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on Meson Production, Properties and Interaction
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BOOK OF ABSTRACTS

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1 Thursday

Testing the Standard Model at the precision frontier: the anomalous magnetic moment of the muon

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The anomalous magnetic moment of the muon $(g-2)_\mu$ is one of the most precisely measured quantities in particle physics (0.54 ppm). There is a long-standing discrepancy of 3-4 standard deviations between the direct measurement of $(g-2)_\mu$ and its theoretical evaluation. This theoretical prediction is subdivided into three contributions: QED, weak and hadronic. The QED and weak parts can be determined in perturbative approaches with very high precision. Thus, the hadronic uncertainty dominates the total theoretical uncertainty. Within the hadronic uncertainty, the largest contribution stems from the vacuum polarization term, which can be evaluated with the measurement of the inclusive hadronic cross section in e^+e^- annihilation. The second largest contribution to the hadronic uncertainty stems from the so-called Light-by-Light amplitudes. They have to be evaluated via theoretical models. These models require transition form factor measurements as input. Existing and future measurements of the relevant hadronic cross sections and transition form factors are presented.

Electric Dipole Moment searches

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Since the 1950's people search for permanent Electric Dipole Moments (EDM) of fundamental systems, as a non-zero EDM would be an unambiguous manifestation of parity (P) and time reversal symmetry (T) violation. Assuming conservation of CPT, T violation in a fundamental system also means CP violation. EDMs are considered promising candidate systems, as this turns out to be a natural consequence of many theories beyond the SM. Different systems used to search for EDMs are the neutron, atomic and molecular systems, as well as charged particles. They all provide complementary information on beyond the SM physics. In the recent years, various new ideas have been developed and also existing concepts have undergone significant technical improvements. An overview of different strategies and their implications, as well as recent developments and results will be discussed in this talk.

Baryon spectroscopy: recent results and impact

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The nucleon excitation scheme has been under intensive investigation with meson photoproduction experiments during the last few years world wide. Currently, a lot of new experimental results are coming out from the CLAS experiment at Jlab, the Crystal Barrel experiment at the ELSA accelerator in Bonn and the Crystal Ball experiment at the MAMI accelerator in Mainz. These experiments focus on the investigation of single and double polarization observables for different meson production reactions using longitudinally and transversely polarized targets, linearly and circularly polarized photon beams as well as the polarization of the recoil protons. The new data sets provide stringent constraints for partial wave analyses of meson photoproduction off the nucleon and will lead to an unique determination of the contributing resonances. The new experimental results will be presented and the impact of the new results to the nucleon excitation spectrum will be discussed.

Photoproduction of mesons from quasi-free nucleons

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The investigation of the baryon states is important to understand the underling nature/symmetries of hadronic matter. Historically, the first nucleon excitation experiments have been done using charged pion and kaon secondary beams. Later the antiproton-proton scattering have also been involved. However, since the beginning of the 90's meson photoproduction reactions have been considered as a powerful tool in baryon spectroscopy. Despite the great efforts the physical parameters of many well established states remain uncertain. Moreover, the existence of strong isospin dependence of the electromagnetic transition amplitudes can only be studied with meson photoproduction off the neutron. The final goal of this activities is to collect (almost) complete data sets, allowing PWA and the extraction of nucleon resonance properties without model dependent ambiguities.
The experiments worldwide, are using virtual or real photon beams and measuring neutral or charged ejectiles. The large solid-angle EM calorimeters, Crystal Barrel/TAPS at ELSA (Bonn) and Crystal Ball/TAPS at MAMI (Mainz) are using real/tagged photon beams, whereas CLAS at CEBAF(JLab) and A1 at MAMI are utilizing high energy electron beams for virtual photon scattering experiments. "Unfortunately", the nonexistence of free neutrons requires the use of quasi free neutrons as targets(bound in the deuteron or the other light nuclei). The scientific programs of this experiments also include single and double polarization measurements. We will review the current status of these programs.

HADES results in elementary reactions

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The High Acceptance Di-Electron Spectrometer (HADES) installed at GSI in Darmstadt is a second generation experiment designed to measure e+e- pairs (dielectrons) in the 1-3.5 GeV/nucleon energy regime. The main goal of the experiment is to measure dielectron emission from a compressed baryonic matter formed in heavy ion collisions and ultimately learn about in-medium hadron properties. In addition, the excellent particle identification capabilities of the detector allow for strangeness production measurements, hence providing an additional probe of the dense medium.
A dedicated program focusing on systematic investigations of dielectron and strangeness production in nucleon-nucleon, proton-nucleus and heavy ion reactions is ongoing and will be soon extended to measurements with the GSI pion beam.

The data obtained by HADES in elementary reactions give an indispensable reference to isolate true medium effects. Using both pp and quasi-free 'n'p reaction, isospin effects were studied. Inclusive as well as exclusive production cross-sections of π, η , ω and ρ mesons could be measured in both hadronic and dielectron channels in an energy range where previous data were very scarce. In addition, a contribution to the dielectron yield due to the coupling of the ρ meson to light baryonic resonances can be clearly identified. This is of particular interest, due to the link to the electromagnetic structure of the involved baryons and to the role of such couplings in the expected in-medium modifications of vector mesons.
Along this line, the precise differential spectra measured for the production of K^0_S and Λ in elementary reactions are used to constrain the investigations on the kaon-nuclear potential. Complementary information is provided by the reconstruction of other strange particles, e.g. $\Lambda(1405)$ and $\Sigma(1385)$.
In this talk, I will present recent HADES results obtained in elementary reactions. The main focus will be on dilepton production, but I will also show selected results obtained in the strangeness sector and will discuss as well the upcoming measurements with the HADES setup and the GSI pion beam.

CLAS results on meson spectroscopy

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The study of the structure and properties of mesons in an important part in understanding QCD. Searching for states described by the Quark Model and more complex states such as hybrids or glue balls is needed to understand the confinement of quarks and the behavior of gluons. CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab (JLab) offers a unique set of opportunities in meson spectroscopy using photo and electro production. This talk will give an update on the experimental results as well as describe the latest theoretical developments from JPAC (JLab Physics Analysis Center) to help understand how the data can provide insights into the fundamental theory of strong interactions.

The COMPASS hadron program

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COMPASS is a multi-purpose fixed-target experiment at the CERN Super Proton Synchrotron aimed at studying the structure and spectrum of hadrons. One main goal is the search for new hadronic states, in particular hybrid mesons and glueballs. Its large acceptance, high resolution, and high-rate capability make the COMPASS experiment an excellent device to study the spectrum of light-quark mesons in diffractive and central production up to masses of about 2.5 GeV/c^2. COMPASS is able to measure final states with charged as well as neutral particles, so that resonances can be studied in different reactions and decay channels. During 2008 and 2009, COMPASS took a large data sample using 190 GeV negative and positive hadron beams on various targets.
We present new results from the analyses of this data set. One focus lies on the search for new mesons in diffractively produced multi-particle final states. Here novel analysis methods are applied to study the dependence of partial waves on the squared four-momentum transfer t' from the beam to the target. This also leads to a better separation of resonant and non-resonant contributions. In addition a new

analysis scheme was developed that permits to extract information about the $\pi^+\pi^-$ subsystem in the $\pi^-\pi^+\pi^-$ final state with only inimal model bias. In addition central-production reactions are studied in order to search for glueball candidates in the scalar sector. Finally an update will be given on the recent analysis of the pion polarizability, well suited to test chiral dynamics.

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Diffractive production of mesons

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I will give a short introduction of diffractive meson production. I will review the data situation from the COMPASS experiment, CDF at the TEVATRON, the RHIC experiments and the ALICE and LHCb experiments at the LHC.

EM formfactors and OLYMPUS

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The elastic form factors characterize the distributions of charge and magnetization in momentum space and are important input for calculations of strong interaction phenomena and nuclear structure. The dramatic discrepancy in the observed ratio of elastic proton form factors between the Rosenbluth separation and polarization transfer methods has invoked numerous theoretical and experimental investigations. The previously neglected effect from two-photon exchange has become the favored explanation for the discrepancy. While the effect can not be calculated from first principles, it can be verified experimentally in several ways, most stringently by comparing the positron-proton and electron-proton elastic cross sections. The OLYMPUS experiment at DESY has been carried out to quantify the effect of two-photon exchange using intense stored positron and electron beams along with an internal unpolarized hydrogen target and a large acceptance detector to measure the ratio of the positron-proton and electron-proton elastic scattering cross sections. I will present the status of form factor measurements and of the experimental efforts to verify the effect of two-photon exchange, with some emphasis on the OLYMPUS experiment.

National Instruments off-the-shelf (COTS) products: Example system architecture. Case studies.

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Engineers, scientists, and physicists around the world are working on high-energy physics with particle accelerators, energy from fusion, and astrophysics with advanced telescopes. It is common for these domain experts to need hardware and software that meet their measurement, diagnostic, control, interlock, and safety system requirements. From programming multicore embedded real-time systems that contain FPGAs to working with high-speed data acquisition systems that require timing and

synchronization, NI offers commercial off-the-shelf (COTS) software and hardware to help meet these needs. Moreover, our team provides Linux and Experimental Physics and Industrial Control System (EPICS) drivers and performs radiation and magnetic field testing.

First results from the commissioning of the BGO-OD experiment at ELSA

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The BGO-OD experiment, set up at the ELSA accelerator facility in Bonn, combines the highly segmented BGO calorimeter with a particle tracking magnetic spectrometer at forward angles. In this configuration the BGO-OD experiment is uniquely suited for a systematic study of meson photoproducion. It is capable of detecting final states of mixed charge with nearly 4π acceptance and with very high precision at forward angles for charged particles, complementary to other existing setups.
An extensive physics programme using an energy tagged bremsstrahlung photon beam is planned. This includes measurements of associated strangeness, vector meson and pseudoscaler meson photoproduction. The commissioning phase of the experiment is recently complete, enhancements for the BGO-OD experiment are nevertheless in development. This talk will provide an overview of the BGO-OD setup and recent results from the analysis of the commissioning data, which includes particle track reconstruction in the forward spectrometer and momentum reconstruction with the BGO calorimeter.

Systematic studies of isospin-violating transitions in charmonium with BESIII

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Isospin symmetry, to a good approximation, is preserved by the strong interaction due to the small mass difference between up and down quarks with respect to the mass of hadrons. Therefore, isospin-breaking decays are believed to be sensitive probes that can be used to access, for example, the up- and down-quark mass differences. Moreover, isospin breaking effects are considered as a signature for identifying exotic states of matter, such as the $X(3872)$.
Charmonium is an excellent system to study pure hadronic effects that lead to isospin breaking, since the contribution of electromagnetic processes is shown to be small compared to the quark-mass difference. We will report on systematic studies of isospin-suppressed transitions in charmonium performed by the BESIII collaboration. Measurements of the branching fractions of transitions $\psi(2S) \to \pi^0 J/\psi(h_c)$ and $\chi_{c0,2} \to \pi^0 \eta_c$, will be presented and interpreted using different theoretical approaches.

Charge Symmetry Breaking in $dd \to {}^4\mathrm{He}\pi^0$ with WASA-at-COSY

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Symmetries and symmetry breaking patterns in the non-purtubative regime of QCD is a key issue of the physics program of WASA-at-COSY. One objective is the determination of possible p-wave contributions to the charge symmetry breaking amplitude in the reaction $dd \rightarrow {}^4\mathrm{He}\pi^0$ at 1.2 GeV/c beam momentum (corresponding to an excess energy of $Q = 60\,\mathrm{MeV}$).
Charge symmetry is a subgroup of isospin symmetry being broken by the different masses of the up and down quarks as well as electromagnetic interaction [1]. In order to get access to quark mass effects on hadron level it is favorable to look at charge symmetry breaking (CSB) observables as the relative pion mass difference, which is of electromagnetic origin, does not contribute. The reaction $dd \rightarrow {}^4\mathrm{He}\pi^0$ is forbidden by charge symmetry and, thus, the cross section is directly proportional to the square of the CSB amplitude. While the reaction has been measured close to threshold at IUCF [2] resulting in a cross section compatible with s-wave, data at higher excess energies sensitive to higher partial waves are missing. Such data are, however, crucial for ChPT calculations currently under way. These calculations are a major theoretical effort and recent developments in this direction are reported in Ref. [3,4].
This presentation will discuss the results of the initial measurements completed in 2007 and 2008 as well as the status of the recent high statistics run in spring 2014.

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Complete next-to-next-to-leading order calculation of $NN \rightarrow NN\pi$ in chiral EFT

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Understanding of near-threshold pion production is of significant importance since it allows a direct test of chiral EFT, probes NN dynamics at intermediate energies and provides access to isospin violation in few-nucleon processes [1].
It has been known since years that neutral pion production in $pp \rightarrow pp\pi^0$ is the most challenging process since the experimental cross-section in this channel is suppressed by more than an order of magnitude, as compared to the charged channels near threshold. The experimental evidence is fully in line with the chiral suppression of the leading production operators in this channel and the important role of higher order effects, especially chiral loops.
We present the results of the full pion production operator near threshold calculated up-to-and-including next-to-next-to-leading order (NNLO) in chiral effective field theory [2,3]. We include explicit Delta degrees of freedom and demonstrate that they provide essential contribution required to understand neutral pion production data. Analysis of chiral loops at NNLO reveals new mechanisms which are important, but have not been considered in phenomenological studies so far. The methods developed in this work can be helpful in the study of charge symmetry breaking in $pn \rightarrow d\pi^0$ and $dd \rightarrow \alpha\pi^0$.

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Recent results from NA61/SHINE at the CERN SPS

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The main part of this contribution is devoted to looking at the NA61/SHINE experiment [1] through the prism of the needs of neutrino oscillation experiments. An overview is shown of the results on hadron production measurements from $p + C$ interactions at 31 GeV/c registered during 2007. In addition, the new preliminary results from 2009 data are presented. These results are crucial for the precise determination of background contamination in the neutrino flux of the Tokai to Kamioka (T2K) experiment at J-PARC [2]. The presented results, i.e. inclusive production cross-sections for charged pions, kaons, and protons, are used in the T2K beam simulation program to reweight hadron yields obtained from models. Knowledge of neutral kaon production is also required for the accurate calculation of the ν_e and $\bar{\nu}_e$ fluxes from $K^0_L \to \pi e \nu_e$ decays. Therefore this contribution also discusses the analysis of the K^0_S and Λ particles. New results on production cross-sections of strange particles K^0_S, Λ, and K^+ are shown as well as the relative multiplicities of these particles. All measured spectra are compared to the predictions of hadron production models – Venus, UrQMD.
Beyond the neutrino program a brief overview is given of the other main physics goals, inter alia the efforts to discover the critical point of strongly interacting matter and to study properties of the onset of deconfinement. These aims will be pursued by measurements of hadron production properties in nucleus-nucleus, proton-proton, and proton-nucleus interactions. Preliminary results from proton-proton interactions at 20, 31, 40, 80, and 158 GeV/c will be shown and compared to the corresponding data on central Pb+Pb collisions from NA49 [3].

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Coherent photo-production of ρ^0 mesons in ultra-peripheral Pb+Pb collisions at the LHC, measured by ALICE

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Ultra-peripheral collisions are characterized by an impact parameter exceeding the sum of the two nuclear radii. The photon flux of heavy ions such as Pb is enhanced by the nucleus charge squared. This allows to study gamma-nucleus processes, such as the production of ρ^0 vector mesons decaying into two pions, as well as gamma-gamma processes, e.g., the continuum production of electron pairs. Coherent processes are characterized by the emission of low pt photons ($p_t \leq 200$ MeV) coupling to almost all the nucleons. As a consequence, the produced vector meson has low pair-transverse momentum which can be used to separate coherent production from non-coherent processes.
The ALICE experiment at the LHC is well-suited for measuring ultra-peripheral processes at low

invariant masses at mid-rapidity since its acceptance extends down to very low track momenta. The ALICE collaboration implemented a dedicated trigger, requiring
activity at mid-rapidity and using the forward detectors as a veto. Neutrons, generated by nuclear breakup, can be detected in the two zero-degree calorimeters (ZDC), situated at about ± 100 m from the interaction point. Due to the excellent energy resolution of the ZDCs, single neutrons can be detected.
We will present the differential ρ^0 cross section at mid-rapidity ($-0.5 < y < 0.5$) measured by the ALICE experiment in Pb-Pb collisions, as well as the total ρ^0 cross section obtained by model-based extrapolation to all rapidities. The measured cross sections are compared to various model predictions, as well as to earlier measurements at RHIC. In addition, nuclear breakup probabilities will be shown for different breakup modes and compared to models.

QCD sum rules for D and B mesons in a strongly interacting medium

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Mesons with open charm or bottom, such as D or B mesons, represent the "hydrogen problem" of QCD. QCD sum rules provide a tool to get access to the $\bar{Q}q$ and $\bar{q}Q$ bound states, where $q = u, d$ and $Q = c, b$. Medium modifications of such states are of particular interest since they offer an opportunity to study the change of the complex QCD ground state. Within QCD sum rules, there is a direct impact of QCD condensates on the spectral properties of mesons. Most notable are changes of the chiral condensate and the gluon condensate which are related to chiral symmetry breaking and scale invariance breaking, respectively. The operator product expansion of qQ mesons in a medium up to mass dimension 5 is extended here to four-quark condensate contributions of mass dimension 6. A complete catalogue of four-quark condensates in the qQ sector is presented. Four-quark condensates on the one hand proofed to be of utmost numerical importance in other meson sum rules, in particular for the ρ meson, and on the other hand they contain chirally odd contributions providing insight into the breaking patterns of chiral symmetry, which we are going to investigated by means of Weinberg-type sum rules. The calculation of associated Wilson coefficients from tree-level diagrams is performed for interpolating currents of chiral partner mesons, i.e. scalar, pseudo-scalar and vector, axial-vector mesons. Numerical results showing the impact of four-quark condensate contributions are presented. Medium modifications of qQ meson properties are of relevance for RHIC and LHC heavy-ion collisions as well as for the envisaged experiments at FAIR.

New results on Coulomb effects in meson production in relativistic heavy ion collisions

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We propose a new method of investigating the space-time evolution of meson production in heavy ion collisions, by making use of spectator-induced Coulomb effects. The presence of two nuclear remnants ("spectator systems") in the non-central collision generates a strong Coulomb field, which modifies the trajectories of charged final state hadrons. This results in - large distortions of charged meson spectra and ratios (π^+/π^-, K^+/K^-), - azimuthal anisotropies in charged meson production. In our approach, these effects can be computed numerically by means of a high-statistics Monte Carlo simulation, using the distance between the meson formation zone and the spectator system as (unique) free parameter.

Our simulation correctly describes: - the very sizeable distortion of π^+/π^- ratios in peripheral Pb+Pb collisions at top SPS energy, known from NA52 [1] and NA49 [2] experiments; - the Coulomb effect on azimuthal anisotropies observed for π^+ and π^- mesons in Au+Au collisions at lower RHIC energy, known from data recently reported by the STAR Collaboration [3]. We also predict large azimuthal anisotropies for positive pions at target and beam rapidities, in agreement with data from the WA98 experiment [4], and a very large Coulomb distortion of K^+/K^- ratios at high values of x_F [5]. In all the cases studied above we find that spectator-induced Coulomb effects offer sensitivity to the position of the meson formation zone with respect to the spectator system. Therefore, we conclude that these effects can serve as a new tool to investigate the space-time evolution of meson production, and the dynamics of the heavy ion collision. More details on this work can be found in [6,7].

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Hidden charm meson production in antiproton-induced reactions on nuclei

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The production of charmonia $J/\psi(1S)$ and $\psi'(2S)$ in the antiproton-nucleus reactions at $p_{lab} = 3 - 10$ GeV/c is studied on the basis of the Glauber model taking into account nuclear Fermi motion effects [1,2]. The main reaction channel is charmonium formation in an antiproton-proton collision. We show that the target mass dependence of the charmonium transparency ratio allows to determine the genuine charmonium-nucleon dissociation cross section. This is contrasted to the J/ψ photoproduction at high energies ($E_\gamma = 20$ and 120 GeV), where charmonium formation length is large which blurs the sensitivity of the transparency ratio to the charmonium-nucleon dissociation cross section. Furthermore, the polarization effects in the production of $\chi_{c2}(1P)$ states are evaluated within the generalized eikonal approximation [3]. Finally, the new opportunities for the studies of the X, Y, Z noncharmonium candidates at PANDA experiment are discussed.

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2 Friday

Single and double charmed meson production at the LHC

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We discuss production of charmed mesons in proton-proton collisions at the LHC. The cross section for inclusive production of $c\bar{c}$ pairs is calculated in the framework of the $k_\perp$-factorization approach, i.e. effectively includes next-to-leading order corrections. Taking wide range of x values necessary for the calculation we use and test several unintegrated gluon distributions from the literature. Some of them include effect of small-x saturation and fullfil Balitsky-Kovchegov evolution equation. Theoretical uncertainties of the model related to the choice of renormalization and factorization scales as well as due to the quark mass are also discussed. Results of the $k_\perp$-factorization approach are compared to NLO parton model and FONLL predictions.

The hadronization of charm quarks is included with the help of different fragmentation functions found for the production of charm in e^+e^- collisions. Sensitivity of our predictions to the choice of the model of fragmentation is also shown. Inclusive differential distributions in transverse momentum and (pseudo)rapidity of several charmed mesons (D^0, $D^\pm$, $D^{*\pm}$, $D_S^\pm$) will be presented and compared to recent results of the ALICE, ATLAS and LHCb collaborations. Furthermore, we also consider production of different charmed meson-antimeson pairs ($D^0\overline{D}^0$, D^0D^-, $D^+D_S^-$ etc.) in unique kinematics of forward rapidities of the LHCb experiment. Kinematical correlations in azimuthal angle $\varphi_{D\overline{D}}$, invariant mass $M_{D\overline{D}}$ and rapidity difference $Y_{D\overline{D}}$ distributions are presented and compared to LHCb data [1].

Moreover we discuss production of two pairs of $c\bar{c}$ within a simple formalism of double-parton scattering (DPS). Surprisingly large cross sections, comparable to single-parton scattering (SPS) contribution, are predicted for LHC energies. We compare results of exact calculations of single-parton scattering (SPS) and double-parton scattering (DPS) for production of $c\bar{c}c\bar{c}$ and for $D-D$ meson-meson correlations [2,3]. Each step of DPS is also calculated within k_t-factorization approach. The SPS calculations are performed in collinear approximation with exact matrix element for $gg \to c\bar{c}c\bar{c}$ subprocess as well as with approximate matrix elements in high-energy approximation. We compare our predictions for double charm production (DD meson-meson pairs) with recent results of the LHCb collaboration for azimuthal angle φ_{DD}, dimeson invariant mass M_{DD} and rapidity distance between mesons Y_{DD}. The predicted shapes are similar to the measured ones, however, some strength seems to be still lacking. Possible missing contribution within the framework of DPS mechanism is suggested. Our new calculations clearly confirm the dominance of DPS in the production of events with double charm. Finally, we emphasize possible significant contribution of DPS mechanism to inclusive charmed meson spectra measured recently by ALICE, ATLAS and LHCb.

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Latest XYZ Results from e^+e^- colliders

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We report on new results in the field of charmonium and charmonium-like spectroscopy from the B factory experiments BABAR and BELLE as well as the BESIII experiment in Beijing. While the B-factory experiments have not been capable of running at center-of-mass energies in the vicinity of 4 GeV, BESIII has very recently analyzed a major data set taken at energies up to 4.6 GeV. Several charged states have been observed, which must contain at least four quarks. Furthermore, for the first time interrelations between XYZ states have been discovered.

LHCb physics and prospects

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The LHCb detector is a single-arm forward spectrometer optimized to study hadrons containing charm and beauty quarks. The detector has recorded about 3 fb^{-1} of data during 2011 and 2012 operations of the Large Hadron Collider. In the talk, we present a description of the detector, a selection of latest and most important physics results, and we discuss as well the future and upgrade plans for the detector.

BaBar studies of conventional and exotic quarkonium states

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for the BaBar Collaboration

The B factories provide a unique playground for studying the properties of conventional and exotic quarkonium states.
We report on a variety of recent results obtained using the full data set collected with the BaBar detector at the PEP-II e^+e^- collider. Among the others, we present measurements of the double charmonium production, searches for charmonium-like states, as well as studies of radiative transitions between bottomonium states.

Puzzling out the proton radius puzzle

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The discrepancy between the proton charge radius extracted from the muonic hydrogen Lamb shift measurement and the best present value obtained from the elastic scattering experiments, remains unexplained and represents a burning problem of today's nuclear physics. After more than 50 years of research the radius of a basic constituent of matter is still not understood. This discrepancy created a

great excitement in the physics community, because it rigorously tests the theory of quantum electrodynamics and our understanding of nuclear physics. Since the observation of the discrepancy in 2010, various explanations for the problem have been offered, ranging from trivial experimental mistakes to those that suggest the need for physics beyond the Standard Model. Some of the explanations have already been rejected, while the intriguing ideas, like the introduction of a new mediator particle, still need to be tested. Therefore, several new experiments have been proposed that will provide new constraints to the existing interpretations.
High-precision electron scattering experiments are scheduled at the Thomas Jefferson National Accelerator Facility and the Mainz Microtron accelerator at the Johannes Gutenberg University Mainz. As a complement to these measurements, a muon-proton scattering experiment is envisioned at the Paul Scherrer Institute. This will be the first experiment of its kind and will provide information on proton radius from a perspective yet unexplored. Together with the nuclear scattering experiments, new atomic experiments are also foreseen. Very precise measurements of Lamb shift in both hydrogen and deuterium will be performed in order to provide further insight into the proton radius puzzle.
In this presentation a summary of the existing proton radius measurements will be presented, followed by an overview of the possible explanations for the observed inconsistency between the hydrogen and the muonic-hydrogen data. In the last part the upcoming experiments, dedicated to remeasuring the proton radius, will be described.

The Qweak experiment: first determination of the weak charge of the proton

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The primary focus of the Qweak experiment at Jefferson Lab is to perform a precision measurement of the proton's neutral weak charge. The Standard Model gives a firm prediction for the weak charge; any deviation from that can be interpreted as evidence for new physics beyond the Standard Model. The experiment measures the parity-violating asymmetry in the elastic scattering of 1.1 GeV longitudinally polarized electrons on the proton at low momentum transfer (Q^2 .025$(\mathrm{GeV}/c)^2$). A description of the technical challenges and achievements of the experiment and the procedure for obtaining the weak charge from the asymmetry will be provided. Results and implications from the recently published first determination of the proton's weak charge, based on about 1/25 of the overall dataset, will be presented. The status of the analysis effort leading to the final precision result based on the full dataset will also be discussed.

Encounters with dibaryons - have they finally become true?

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The long history of dibaryon searches dating back to the fifties has been a very changeful one - with many ups and downs. After Gell-Mann's famous paper on the quark model Dyson and Xuong were the first to correlate this topic with SU(6) and six quark systems – still in the year 1964. But it was not until Jaffe's note in 1977 about a bound $\Lambda\Lambda$ system, the H-dibaryon, when a real rush for dibaryons started – both theoretically and experimentally. As a result there were predictions of a vast number of dibaryon states and endless experimental claims, but finally none survived careful experimental

investigations.
Despite their long painful history dibaryon searches have recently received renewed interest, in particular by the recognition that there are more complex quark configurations than just the familiar $q\bar{q}$ and qqq systems. Recently two groups announced that lattice QCD calculations provide evidence for a bound H-dibaryon - though any experimental evidence is still pending. However, recently the WASA-at-COSY collaboration has found that the double-pionic fusion reaction $pn \to d\pi^0\pi^0$ proceeds dominantly via a resonance structure observed in the total cross section at $\sqrt{s} = 2.37$ GeV with $\Gamma \approx$ 70 MeV and $I(J^P) = 0(3^+)$. Meanwhile nearly all possible decay channels have been investigated, in particular also the one into the elastic np channel. And, indeed, new data on polarized np scattering in the region of interest produce a resonance pole in the coupled ${}^3D_3 - {}^3G_3$ partial waves in accordance with the resonance hypothesis. This is the first solid evidence that dibaryons really exist. Since this resonance is observed to decay predominantly via an intermediate $\Delta\Delta$ system, it constitutes asymptotically a $\Delta\Delta$ system bound by nearly 100 MeV - as predicted by Dyson and lateron also by Goldman et al., who called it the "inevitable dibaryon". Most recent relativistic three-body calculations based on hadron dynamics as well as quark model calculations succeeded to predict properly important characteristics of this resonance. In addition they predict a number of further dibaryon states. Is it just a matter of time, until those are discovered, too?

Supported by COSY-FFE (FZ Juelich).

Experimental support for a new h1 resonance around 1830 MeV and theoretical backing from the vector-vector interaction; Prediction of I=1 molecular states of $D\bar{D}^*$ and $D^*\bar{D}^*$ and relationship to the $Z_c(3900)$ and the claimed $Z_c(4025)$.

OSET, Eulogio[1]

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for the E. Oset, Ju-Jun Xie, M. Albaladejo, F. Aceti, M. Bayar, A. Martinez Torres, K. P. Khemchandani, F. S. Navarra, M. Nielsen, J. M. Dias Collaboration

The BES data on the $J/\psi \to \eta K*^0 \bar{K}*^0$ reaction show a clear enhancement in the $K*^0 \bar{K}*^0$ mass distribution close to the threshold of this channel. Such an enhancement is usually a signature of a L=0 resonance around threshold, which in this case would correspond to an h1 state with quantum numbers $I^G(J^{PC}) = 0^-(1^{+-})$. A state around 1800 MeV results from the interaction of the $K*\bar{K}*$ using the local hidden gauge approach. We show that the peak observed in $J/\psi \to \eta K*^0 \bar{K}*^0$ naturally comes from the creation of this h1 state with mass and width around 1830 MeV and 110 MeV, respectively. A second analysis, model independent, corroborates the first result, confirming the relationship of the enhancement in the invariant mass spectrum with the h1 resonance. After discussing the OZI suppression of one light meson exchange in the interaction of $D^*\bar{D}^*$ with isospin I=1, we study the contribution of two pion exchange to the interaction and the exchange of a heavy vector J/ψ. We find this latter mechanism weak but enough to barely bind the system in J=2 with a mass around 4000 MeV, while the effect of the two pion exchange is a net attraction but weaker than that from J/ψ exchange. We discuss this state and try to relate it to the $Z_c(4025)$ state, above the $D^*\bar{D}^*$ threshold, claimed in an experiment at BES from and enhancement of the $D^*\bar{D}^*$ distribution close to threshold. Together with the results from a recent reanalysis of the BES experiment showing that it is compatible with a J=2 state below threshold around 3990 MeV, we conclude that the BES experiment could be showing the existence of the state that we find in our approach. At the same time we study the interaction of $D\bar{D}^*$ in the isospin I=1 channel in the light of recent theoretical advances that allow to combine elements of the local hidden gauge approach with heavy quark spin symmetry. We find that the exchange of

light qqbar is OZI suppressed and, thus, we concentrate on the exchange of heavy vectors and of two pion exchange. The latter is found to be small compared to the exchange of heavy vectors, which then determines the strength of the interaction. A barely $D\bar{D}^*$ bound state decaying into $\eta_c\rho$ and $\pi J/\psi$ is found. At the same time we reanalyze the data of the BESIII experiment on $e^+e^- \to \pi^\pm(D\bar{D}^*)^\pm$, from where a $Z_c(3885)$ state was claimed, associated to a peak in the $(D\bar{D}^*)^\pm$ invariant mass distribution close to threshold, and we find the data compatible with a resonance with mass around 3875 MeV and width around 30 MeV. We discuss the possibility that this and the $Z_c(3900)$ state found at BESIII, reconfirmed at 3896 MeV at Belle, or 3885 MeV at CLEO, could all be the same state and correspond to the one that we find theoretically.

New high precision data on the differential cross sections of the pion-proton elastic scattering

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The EPECUR collaboration presents new high precision data on the pion-proton elastic scattering in the second resonance region. The experiment EPECUR is placed on the universal beam channel of the accelerator ITEP. The setup features 0.1% beam pion momentum tagging system; 25 cm long liquid hydrogen target, placed in mylar container and beryllium outer shell; low material wire drift chambers and high performance DAQ. More than 3 billions of triggers collected. The data covers pion beam momentum range 0.8 - 1.3 GeV/c and 40-120 degrees center-of-mass scattering angle range for both positive and negative pions. The measured differential cross section has 1% statistical accuracy in 2 degrees angle and 5 MeV/c momentum intervals.

SAID nucleon-nucleon analysis

WORKMAN, Ron[1]

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The SAID approach to partial-wave analysis of nucleon-nucleon scattering data is reviewed. This has been applied to recent COSY *np* scattering data. The appearance of poles (dibaryons) is discussed in light of these new fits.

Single pion production in proton-proton collisions at 1.25 GeV measured with HADES and the Bonn-Gatchina PWA description

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for the HADES Collaboration

HADES is a versatile magnetic spectrometer installed at GSI Darmstadt at SIS18 [1]. Thanks to its high acceptance, powerful particle ($p/K/\pi/e$) identification and very good mass resolution ($2-3\%$ for dielectrons in the light vector meson mass range) it allows to study both hadron and rare dilepton production in $N+N$, $p+A$, $A+A$ collisions at a few AGeV beam energy range. In collisions $p+p$ @ 1.25 GeV, the intermediate $\Delta(1232)$ resonance is expected to play a dominant role in the pion

production, but it is known to be not sufficient to describe fully the data. The resonance cross section was determined from exclusive $pp\pi^0$ and $np\pi^+$ channels [2] in the framework of a OPE model with accuracy of $20-30\%$. Investigation of these reaction channels by means of the PWA (Partial Wave Analysis) was also done [3] by the Bonn-Gatchina group at a smaller beam energy [4]. It revealed a dominant contribution of $\Delta(1232)p$ intermediate state but also sizeable non-resonant terms and interference effects.
In this work we report on the PWA of the single-pion production in proton-proton collisions (as in [2]) measured with HADES. The pp is a pure isospin $I = 1$ state and, at this beam energy the following initial pp-states contribute: (J=0) $^1S_0$, $^3P_0$, (J=1) $^3P_1$, (J=2) $^1D_2$, $^3P_2$, $^3F_2$, (J=3) $^3F_3$ and (J=4) $^1G_4$, $^3H_4$. Unlike in proton-proton collisions at lower energies, higher partial waves are necessary for a proper data description. The final states are limited to $S-$, $P-$, $D-$, $F-$, $G-$ and $H-$ wave states with the two possible intermediate resonance states $P_{33}(1232)$ and $P_{11}(1440)$. The data samples (for both channels, $pp\pi^0$ and $pn\pi^+$) were analysed with the event-by-event background estimation (Q factors). The analysis was preformed together with other available data (see [5], 11 measurements for $pp\pi^0$ and only two for $pn\pi^+$ channel) covering mostly lower beam energies. The stability of solutions was investigated based on a few parametrisations of the transition amplitude A_{tr} (with total energy dependence) and various descriptions of resonance states (Δ and N^*). The obtained solutions generally describe the HADES data very well in various projection observables (CM angular distributions, invariant masses, angular distributions in the helicity and the Gottfried-Jackson frames). The analysis shows the dominant $P_{33}(1232)$ contribution in $np\pi^+$ at the level of 95% and in $pp\pi^0$ (80%) which is an important message for the dilepton analysis, where the branching of Δ Dalitz decays can be identified (in the pe^+e^- channel).

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[2] G. Agakishiev et al., Eur. Phys. J. A48 (2012) 74
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The PWA of $\pi^-\pi^0$ system with subtraction of the known background

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The ρ-(770) production density matrix is studied with the VES setup in $\pi^-N \to N'\pi^-\pi^0$ with statistics three orders of magnitude bigger than in previous studies. A significant background to the $\pi^-\pi^0$ sample is leakage from previously studied $\pi^-\pi^0\pi^0$ system. The estimation of the background contribution is implemented in the Partial Wave Analysis procedure.

Meson production in initial-state radiation of e^+e^- events at BABAR

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for the BaBar Collaboration

The BaBar Collaboration has an intensive program studying the hadronic cross section at low-energy e^+e^- collisions, accessible at BaBar via initial-state radiation (ISR). These measurements allow significant improvements in the accuracy of the predicted value of the muon anomalous magnetic moment,

which is necessary for shedding light on the current 3.5 sigma difference between prediction and experiment. A number of processes with two to six hadrons in final states have been published by BaBar. We report the results of recent studies on the reactions $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$, K_SK_L, $K_SK_L\pi^+\pi^-$, $K_SK_S\pi^+\pi^-$, and K^+K^- obtained via ISR. Number of intermediate states have been studied for the multi-hadron states as well as measurements of J/ψ branching fractions to these channels.

Exclusive photoproduction of J/ψ and ψ' mesons in proton-proton collisions

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We present results based on our new paper [1]. The amplitude for $\gamma p \to Vp$ is calculated in a pQCD k_T-factorization approach. The coresponding total cross section for different unintegrated gluon distributions is calculated and compared with new HERA data for photon-proton collisions. We also compare the total cross section for $\gamma p \to Vp$ reaction with recent data extracted by of the LHCb collaboration. The amplitude for $\gamma p \to Vp$ is used to predict cross section for exclusive photoproduction of J/ψ and ψ' mesons in proton-proton collisions. Both Dirac and Pauli electromagnetic form factors are included in the calculation and results are compared with old results (only Dirac form factor). The effect of Pauli form factor is quantified. Absorption effects are included and their uncertainties are discussed. Different differential distributions e.g. in J/ψ (ψ') rapidity and transverse momentum are presented and compared with existing experimental data for Tevatron and LHC energy.

[1] A.Cisek, W. Schäfer and A. Szczurek, a paper in preparation.

Exotic meson studies at LHCb

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The latest years have seen a resurrection of interest in searches for exotic states motivated by tantalising observations by Belle and CDF. Using the data collected at pp collisions at 7 and 8 TeV by the LHCb experiment we present studies of the $X(3872)$ properties including its decay rate to $\psi(2S)\gamma$, as well as recent studies of putative states such as the $Z(4430)^+$.

First measurement of associated vector boson plus prompt charmonium production at the ATLAS experiment

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for the ATLAS Collaboration

We present evidence of associated vector boson+prompt J/ψ production and measure its production rate. This is a key observable to further the understanding of quarkonium production mechanisms. We estimate the relative contributions to the signal from single and double parton scattering and discuss possible implications of this novel final state for study of multiple parton interactions. Single parton scattering cross-sections are compared to cutting-edge theoretical calculations in the colour singlet and colour octet formalisms.

Search for baryonium and the physics of FAIR

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The attempts to detect exotic states in nucleon-antinucleon system have a long unsuccessful history. However, several recently performed experiments allow to isolate specific partial waves and see certain structures. These experiments include anti-protonic atoms, J/ψ decays and nuclear absorption of antiprotons. One has a consistent evidence for a weakly bound and fairly broad S-wave quasi-bound state. We [1] argue that this state is seen in the J/ψ decays into a state named $X(1835)$ [2], and in the threshold enhancement in radiative decays to proton-antiproton system [3].
In this contribution we concentrate on a model for $J/\psi \to p\bar{p}, meson(\gamma)$. The assumption that mesons are formed in the final state emission from the baryons offer a consistent description of the rate and the spectra in cases of : π, ω, ϕ. It fails in the case of the radiative decay. One has to assume that the photon is emitted by quarks in the early stage of the decay. Next, the final state interactions of the nucleon and anti-nucleon pair generate two peaks observed by BES in the proton-antiproton invariant mass. One peak is due to a quasi-bound state (baryonium) while the other is due to shape resonance in this system. These decays are of interest for the FAIR project at GSI as they offer a doorway to the J/ψ formation in nuclei. Our model allows quantitative predictions.

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[2] M. Ablikim for BES Collaboration, Phys.Rev.Lett. 95, 262001 (2005)
[3] J.Z.Bai for BES Collaboration, Phys.Rev.Lett. 91, 022001 (2003)

Analysis of anti-Kaon-induced Cascade baryon production

JACKSON, Benjamin[1], NAKAYAMA, Kanzo[1], HABERZETTL, Helmut[2], OH, Yongsoek[3]

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In preparation for the forthcoming experiments on multi-strangeness baryon production at JLab and JPARC, we analyze the general features of Cascade production in both the anti-kaon- and photon-induced reactions. Particular attention is paid to the spin structure of the reaction amplitude for producing Cascade resonances with the emphasis on identifying the spin observables required to determine the production amplitude as well as the spin-parity of the resonance. For the production of Cascade resonances with spin higher than 1/2, the spin-density-matrix formalism is proven to be particularly useful. The $\gamma N \to KK\Xi$ and $\bar{K}N \to K\Xi$ reactions are investigated within a simple model. Emphasis will be placed on the results of the model calculations.

The Cascade production in antikaon reactions with protons

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The chiral SU(3) Lagrangian extended to next-to-leading order (NLO) has been used to study the meson-baryon interaction in S-wave in the strangeness $S = -1$ sector. Consequently our model has 7 new parameters which have to do with NLO terms in the chiral Lagrangian, and which are of prime interest for us. A large set of experimental data available for different two-body channels has been used in the fit of the model. We pay particular attention to the $K^- p \to K\Xi$ reactions, where the effect of the NLO terms in the Lagrangian is sufficiently large to restrict the NLO parameters. In order to improve our model in these particular channels, we take into account phenomenologically the effects

of the high spin hyperonic resonances, namely $\Sigma(2030)$ $\left(\frac{7}{2}^+\right)$ and $\Sigma(2250)$ $\left(\frac{5}{2}^-\right)$. Some preliminary results can be found in Refs. [1].

[1] V.K. Magas, A. Feijoo Aliau, A. Ramos, arXiv:1311.5025 [hep-ph]; arXiv:1402.3971 [hep-ph].

The meson spectroscopy program using the Forward Tagger with CLAS12 at Jefferson Lab

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for the CLAS Collaboration

The 12 GeV upgrade to the Continuous Electron Beam Accelerator Facility (CEBAF) will enable a new generation of experiments in hadronic nuclear physics at Jefferson Lab, seeking to address fundamental questions in QCD. For example, confirming the existence of exotic states, suggested by both quark models and lattice calculations, would allow gluonic degrees of freedom to be explored, and may help explain the role played by gluons in the QCD interaction.In Experimental Hall B, meson spectroscopy (the MesonEx experiment) will be performed using low Q^2 electron scattering to produce quasi-real photons. The scattered electron is detected at small angles by the Forward Tagger device, determining the properties of the photon on an event-by-event basis. This technique has notable advantages over real photon beams, and over hadronic beam experiments, where most experimental data exists. The development of the Forward Tagger by the INFN Genova group, and the proposed MesonEx experiment, will be the focus of the work presented.

The importance of vector meson-baryon dynamics on meson production reactions around 2 GeV

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The theoretical description of meson photoproduction reactions off the proton at energies around 2 GeV requires the consideration of channels involving vector mesons and baryons together with a proper implementation of unitarization. A clear example is provided by the $\gamma p \to K^0\Sigma^+$ reaction in the energy region around the $K^*\Lambda$ and $K^*\Sigma$ thresholds, where the CBELSA/TAPS cross section shows a sudden drop [1]. We have developed a unitarized coupled channel model [2] that incorporates the dynamics of the vector meson-baryon interaction, which is obtained from the hidden gauge formalism. We find that the cross section in this energy region results from a delicate interference between amplitudes having $K^*\Lambda$ and $K^*\Sigma$ intermediate states. The sharp downfall is dictated by the presence of a nearby N^* resonance produced by our model, a feature that we have employed to predict its properties. We also show predictions for the complementary $\gamma n \to K^0\Sigma^0$ reaction.
Another manifestation of the importance of the vector meson-baryon dynamics may be found on the in-medium properties of the vector mesons. We have analyzed the contributions to the vector meson self-energies in nuclear matter coming from various sources [3,4]. We find that the width of the K^* meson at normal nuclear matter density is about Γ_{K^*}=260 MeV while that of the ω meson is Γ_ω=121 MeV, both substantially larger than their free space values.

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[3] A. Ramos, L. Tolos, R. Molina, E. Oset, Eur. Phys. J. A (2013) 49: 148.
[4] L. Tolos, R. Molina, E. Oset, A. Ramos, Phys. Rev. C82 (2010) 045210

Polarization observables T and F in single π^0 and η-photoproduction off quasi-free nucleons

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for the A2 Collaboration

Meson photoproduction has developed into a powerful tool to study the nucleons excitation spectrum and test effective quark models which operate in the non-perturbative regime of QCD. An insight into the J^P configurations and isospin decompositions of the contributing resonances is gained by measuring a minimal set of polarization observables on both the proton and the neutron. Single π^0 and η-photoproduction off a transversally polarized D-butanol target has been measured with circularly polarized bremsstrahlung photons generated by the MAMI-C electron microtron. With the nearly 4π acceptance of the combined Crystal Ball/TAPS setup the double polarization observable F and the target asymmetry T can be extracted for the first time for polarized, quasi-free neutrons over a wide energy and angular range.

Measurement of the quasi free $np \to np\pi^+\pi^-$ and $np \to pp\pi^-\pi^0$ reactions at 1.25 GeV with HADES

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We present the results of two-pion production in tagged quasi-free np collisions at a proton incident beam energy of 1.25 GeV measured with the High-Acceptance Di-Electron Spectrometer (HADES) installed at GSI. The specific acceptance of HADES allowed for the first time to obtain high-precision data on $\pi^+\pi^-$ and $\pi^-\pi^0$ production in np collisions in a region corresponding to large transverse momenta of the secondary particles. The obtained differential cross section data provide strong constraints on the production mechanisms and on the various baryon resonance contributions ($\Delta\Delta$, $N(1440)$, $N(1520)$, $\Delta(1600)$). The invariant mass and angular distributions from the $np \to np\pi^+\pi^-$ and $np \to pp\pi^-\pi^0$ reactions are compared with different theoretical model predictions.

Measurement of the transition form factor in $\phi \to \eta e^+e^-$ and $\phi \to \pi^0 e^+e^-$ decays at KLOE

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for the KLOE-2 Collaboration

The KLOE experiment has collected 2.5 fb^{-1} at the peak of the phi resonance at the e^+e^- collider DAPHNE in Frascati. A new beam crossing scheme, allowing for a reduced beam size and increased luminosity, is operating at DAPHNE. The upgraded KLOE-2 detector is successfully rolled in inside this new interaction region and is ready to acquire collision data.
The V→Pgamma Dalitz decays, associated to internal conversion of the photon into a lepton pair, are not well described by the Vector Meson Dominance (VMD) models, as in the case of the process $\omega \to \pi^0\mu^+\mu^-$, measured by the NA60 collaboration. The only existing data on $\phi \to \eta e^+e^-$ come from

the SND experiment, which has measured the Mee invariant mass distribution on the basis of 213 events. At KLOE, a detailed study of this decay has been performed using both $\eta \to \pi\pi\pi$ final states. Simple analysis cuts provide clean signal events, with a residual background contamination of 2-3%. With the fully neutral η decay channel, we obtain a preliminary measurement of the branching fraction for the process $\phi \to \eta e^+ e^-$, with an accuracy improved by a factor of five with respect to the previous most precise measurement, and of the slope of the transition form factor, which is in agreement with VMD expectations.
We have also studied the decay $\phi \to \pi^0 e^+ e^-$, where no data are available on transition form factor. Dedicated analysis cuts strongly reduce the main background component of Bhabha events to 20%, leading to 4000 signal events in the whole KLOE data set.

Close to threshold η' meson production in proton-proton collisions at COSY-11

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for the COSY-11 Collaboration

We present a new result from close to threshold measurement of excitation function for $pp \to pp\eta'$ reaction with the accuracy better for cross section and excess energy determination with respect to previous measurements. The cross sections determined at five excess energy values down to 0.76 MeV enabled an extraction of the scattering length of the η'-proton interaction in the vacuum.

Results on quarkonium production and polarization in pp collisions with the CMS detector

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for the CMS Collaboration

Explaining the production dynamics of conventional quarkonium has been a challenge for nearly 20 years. The state-of-the-art theoretical framework, Non-Relativistic QCD (NRQCD), nowadays explains relatively well the observed production cross-sections, but it also predicts transverse polarization of the $q\bar{q}$ states at high tranverse momentum, which is not observed. This talk presents the CMS quarkonium production results, in pp collisions, placing emphasis on the most recent measurements, which include the cross-sections and polarizations of all five S-wave states. We will also present new results on P-wave quarkonium production in the bottomonium family.

Highlights of charm physics at BESIII

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[1]Shandong University

for the BESIII Collaboration

In this talk, the latest BESIII results on charm physics will be presented, such as the strong phases in $D \to K_s\pi^+\pi^-$ and $D \to K^-\pi^+$, the y_{cp} mixing parameters, D purely leptonic decays and D semi-leptonic decays. Many of these results are the most precise to date.

Meson spectroscopy at LHCb

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[1]AGH Cracow

The 7 and 8 TeV pp collision data collected by the LHCb experiment during 2011 and 2012 provide a rich sample of heavy flavour production and decays in which to study hadron properties. We present a summary of the recent experimental results from LHCb including studies of D_J mesons, B^{**}. We also report a search for the doubly charmed baryon Ξ_{cc}.

Heavy meson production at HERA

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for the H1 and ZEUS Collaboration

The copious production of charm mesons at HERA has allowed QCD to be probed in open charm and charm vector meson production. Elastic and proton-dissociatve photoproduction of J/ψ mesons have been measured at HERA. The data are compared to other measurements and the W and t dependences are parametrised using phenomonological fits. The $\psi(2S)$ state has also been measured exclusively and the ratio of its production rate to J/ψ mesons presented as a function of the kinematic variables. Inelastic production of J/ψ and $\psi(2S)$ mesons gives insight into non-relativistic QCD and final results are presented here. Open charm production has been measured in order to better understand the fragmentation process of charm mesons as well as giving insight into the structure of the proton.

Study of rare and suppressed processes in B meson decays with ATLAS

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for the ATLAS Collaboration

The large amount of Heavy Flavor data collected by the ATLAS experiment is potentially sensitive to New Physics, which could be evident in processes that are naturally suppressed in the Standard Model. The most recent results on the search for the rare decay B_s (B_0) $\rightarrow \mu^+\mu^-$ are presented. Recent results are also presented on the angular distribution parameters AFB and FL describing the decay $B_d \rightarrow K^*\mu^+\mu^- \rightarrow K^+\pi^-\mu^+\mu^-$. The accuracy obtained from data collected in 2011 is comparable to the best previous measurement in the region $q^2(\mu^+\mu^-)>16$ GeV^2.

Low-energy structure of the nucleon from chiral effective field theory

ALARCON SORIANO, Jose Manuel[1]

[1]University of Mainz

In this talk I will show how chiral effective field theory (chiral EFT) provides a deep insight into the structure of the nucleon in term of the low-energy symmetries of QCD. Later, I will present some of the more recent progresses in the determination of the scalar and electromagnetic structure of the nucleon from the relativistic formulation of chiral EFT. Finally, I will comment the impact of these result on precision experiments and searches for new physics.

Effects of (axial)vector mesons on the chiral phase transition: initial results

WOLF, Gyorgy[1], KOVACS, Peter[1], GIACOSA, Francesco[2], RISCHKE, Dirk[2]

[1]Wigner Research Centre for Physics, [2]Goethe University Frankfurt

We investigate the effects of (axial)vector mesons on the chiral phase transition in the framework of an SU(3), (axial)vector meson extended linear sigma model with additional constituent quarks and Polyakov loops. We determine the parameters of the Lagrangian at zero temperature in a hybrid approach, where we treat the mesons at tree-level, while the constituent quarks at 1-loop level. We assume two nonzero scalar condensates and determine their temperature and baryochemical potential dependence according to the 1-loop level equations of states. We also investigate the changes of the tree-level scalar/vector meson masses in the hot and dense medium.

ChPT tests at NA48 and NA62

GONNELLA, Francesco[1]

[1]INFN Frascati

for the NA48 and NA62 Collaboration

New final results from an analysis of about 400 $K^{\pm} \to \pi^{\pm}\gamma\gamma$ rare decay candidates collected by the NA48/2 and NA62 experiments at CERN during low intensity runs with minimum bias trigger configurations are presented. The results include a model-independent decay rate measurement and fits to Chiral Perturbation Theory (ChPT) description. The data support the ChPT prediction for a cusp in the di-photon invariant mass spectrum at the two pion threshold.
The NA48/2 Collaboration at CERN has accumulated unprecedented statistics of rare kaon decays in the Ke4 modes Ke4(+-) to $\pi^+\pi^- e\nu$ and Ke4(00) to $\pi^0\pi^0 e\nu$ with one percent background contamination. The detailed study of form factors is sensitive to small isospin symmetry breaking effects. This brings new inputs to low energy QCD description and crucial tests of predictions from Chiral Perturbation Theory and lattice QCD calculations.

Dispersive approach to hadronic light-by-light scattering and the muon $g-2$

STOFFER, Peter[1], COLANGELO, Gilberto[1], HOFERICHTER, Martin[1], PROCURA, Massimiliano[1]

[1]University of Bern

The anomalous magnetic moment of the muon has been measured and computed to very high precision of about 0.5 ppm. For more than a decade, a discrepancy has persisted between the experiment and the Standard Model prediction, now of more than 3 sigma. Forthcoming experiments at FNAL and J-PARC aim at reducing the experimental error by a factor of 4.
The main uncertainty of the theory prediction is due to strong interaction effects. At present, the largest uncertainty comes from hadronic vacuum polarisation, which, however, is expected to be reduced significantly with help of new data from e^+e^- experiments. In a few years, the subleading hadronic light-by-light (HLbL) contribution will become the dominating error.
So far, only model calculations of the HLbL contribution exist. Recently, we have published a first dispersive approach to HLbL scattering (arXiv:1402.7081). This new, model-independent approach is based on the fundamental principles of unitarity, analyticity, crossing and gauge invariance. I will

explain the ideas of our approach and highlight the advantages of a data-driven determination of the hadronic light-by-light contribution to the muon $g-2$.

Interactions of light mesons with photons

LEUPOLD, Stefan[1]

[1]Uppsala University

It is pointed out why a good understanding of the electromagnetic properties of light mesons is mandatory to explore the structure of hadrons, but also to improve the Standard Model predictions for quantities like $g-2$ of the muon or the rare decay of pseudoscalars to a dilepton [1]. Recent results for meson transition form factors, two-photon reactions and related quantities are shown [2,3,4].

[1] E. Czerwinski et al., MesonNet Workshop on Meson Transition Form Factors, e-Print: arXiv:1207.6556 [hep-ph]
[2] C. Terschluesen, B. Strandberg, S. Leupold, F. Eichstaedt, Eur.Phys.J. A49 (2013) 116
[3] I.V. Danilkin, M.F.M. Lutz, S. Leupold, C. Terschluesen, Eur.Phys.J. C73 (2013) 2358
[4] C. Terschluesen, S. Leupold, Phys.Lett. B691 (2010) 191

3 Saturday

Can strong quantum correlations of entangled K-mesons be experimentally tested?

HIESMAYR, Beatrix C.[1]

[1]University of Vienna

This talk will present a proposal for a first conclusive experimental test of revealing correlations that are stronger than those allowed by classical physics [1]. Surprisingly, in a certain setup the tiny difference between a world of matter and a world of antimatter, the famous violation of the CP symmetry (C – charge conjugation; P – parity), becomes responsible for the possibility of revealing these strong quantum correlations. Hence, a relation between entanglement and symmetry violations in Particle Physics is established that is even more puzzling since the symmetry violation in weak interactions links to the unsolved problem of why we live in a universe dominated by matter.
Neutral mesons are naturally oscillating systems as are neutrinos or chiral molecules. Therefore, they qualify for studying precisely the quantum superposition, i.e. via decoherence models or collapse models. Collapse models provide a concise mathematical framework for modelling how a classical world emerges from quantum mechanics. Its dynamics preserves (practically) quantum linearity for microscopic systems whereas when moving towards macroscopic scales it becomes strongly nonlinear and provides new physical predictions for the region in between. Are collapse models testable with mesons, neutrinos or chiral molecules? [2]

[1] Hiesmayr et al., European Physical Journal C 72, 1856 (2012).
[2] Bahrami et al., Nature: Scientific Reports 3, 1952 (2013).

Images of Dynamical Chiral Symmetry Breaking

CLOET, Ian[1]

[1]Argonne National Laboratory

The pion occupies a special place in nuclear physics: to many it is the "simplest hadron", however this is a misnomer. The pion encapsulates the myriad complexities of Quantum Chromodynamics (QCD), e.g., it is both a bound-state of a dressed-quark and a dressed-antiquark in quantum field theory and the Goldstone mode associated with dynamical chiral symmetry breaking in QCD. Using QCDs Dyson-Schwinger equations we will discuss properties of the pion, as expressed by aspects of its light-front wavefunction, and connect this to dynamical chiral symmetry breaking (DCSB) in QCD. The role of DCSB in the momentum transfer evolution of the pion and nucleon form factors will also be discussed.

Latest results from KLOE-2

BLOISE, Caterina[1]

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for the KLOE-2 Collaboration Collaboration

The KLOE experiment in year 2013-14 obtained several results on i) CPT symmetry test with neutral kaons, ii) charged kaon branching fraction to 3 charged pions, iii) γ–γ physics; iv) on the isospin-violating decay $\eta \to \pi^+\pi^-\pi^0$, sensitive to the light-quark mass ratio, v) on the form factors (TFF) in $\Phi \to \eta e^+e^-$ and $\Phi \to \pi^0 e^+e^-$ transitions, and on vi) searches for the U–boson.
We present these results and give a status report on the experiment that successfully completed the detector upgrade a) to improve vertex reconstruction near the beam interaction region with a cylindrical tracking chamber (IT) based on GEM technology, b) to increase the acceptance for low polar angle photons with two stations of LYSO calorimeters (CCALT), and c) to reconstruct particles passing through the DAFNE final focusing region with two sampling calorimeters (QCALT) of tungsten/scintillator–tiles.

Exotic and conventional mesons from lattice

PRELOVSEK, Sasa[1]

[1]Jožef Stefan Institute

I will present lattice results on meson spectroscopy. The emphasis will be on interesting states near thresholds, like the recently discovered charged Z_c. I will also review the pioneering attempts to extract the strong decay widths of various mesonic resonances from lattice.

Topics in low-energy QCD with strange quarks

WEISE, Wolfram[1]

[1]ECT* and TU München

Recent developments and phenomena related to low-energy antikaon interactions with baryonic systems are summarized. Expectations for kaonic deuterium and for the $\bar{K}$-deuteron scattering length are outlined in view of planned experiments. Updated information is provided concerning the structure of the $\Lambda(1405)$. The quest for kaon condensation and the role of strangeness in dense baryonic matter is discussed with focus on the core of neutron stars.

K^-pp search experiments at J-PARC

NAGAE, Tomofumi[1]

[1]Kyoto University

for the E27 and E15 Collaborations

Whether a Kaonic bound system, K^-pp, exists or not is one of important issues in Strangeness nuclear physics at J-PARC. Based on low-energy KN scattering data and kaonic-atom X-ray data, it is well known that the KN interaction near threshold has a strong attraction in the isospin 0 channel. It can be a driving force to form the Kaonic bound state, K^-pp. The FINUDA and DISTO collaborations reported possible signatures of the K^-pp decaying into a Λp pair. In order to establish the existence,

it would be crucial to confirm it in different reactions.
At J-PARC, there are two experiments searching for the K^-pp: E27 and E15.
In E27, the $d(\pi^+, K^+)X$ reaction at 1.7 GeV/c is used to produce the K^-pp. The inclusive (π^+, K^+) spectrum is measured with the SKS spectrometer in a good energy resolution. To suppress large backgrounds coming from quasi-free hyperon(Ys and Y*s) productions, coincidence of high-momentum protons emitted in the target area (39 – 122 degrees) is further required. A pilot data taking was already performed in 2012, and the analysis results on the inclusive and coincidence spectra will be presented in the conference.
In E15, the ^{3}He$(K^-, n)X$ reaction at 1.0 GeV/c is used to produce the K^-pp. The forward neutron is detected by a neutron hodoscope with 15-m time-of-flight. The (K^-, p) spectrum can be also obtained. At the same time, the decay products from the K^-pp are detected with a cylindrical detector system with an acceptance coverage of 66Some preliminary results will be reported.

Current theoretical topics on K^-pp quasi-bound state

AKAISHI, Yoshinori[1]

[1]RIKEN Nishina Center

The Λ^*=$\Lambda(1405)$ plays an essential role in forming anti-kaonic nuclear clusters, the simplest one of which is $K^-pp = (K^-p) - p = \Lambda^* - p$. In relation to this clustering structure we have examined the reaction processes, ^{3}He$(K^-, n)K^-pp$ and D$(\pi^+, K^+)K^-pp$, of the recent E15 and E27 J-PARC experiments. The $\Lambda^* - p$ structure interacting with "super-strong force" due to $\bar{K}$ migration between two nucleons provides a possible explanation of both the recent data on K^-pp. The structure is extended to K^-K^-pp system, which is of more fundamental importance in deeply bound anti-kaonic nuclei.

Investigation of the low-energy kaons hadronic interactions in light nuclei by AMADEUS

PISCICCHIA, Kristian[1]

[1]Laboratori Nazionali di Frascati INFN, Centro Fermi

The AMADEUS experiment deals with the investigation of the low-energy kaon-nuclei hadronic interaction at the DAΦNE collider at LNF-INFN, which is fundamental to solve longstanding questions in the non-perturbative strangeness QCD sector. AMADEUS step 0 consisted in the analysis of 2004/2005 KLOE data, exploiting K^- absorptions in H, ^4He, ^9Be and ^{12}C, leading to the first invariant mass spectroscopy study with in-flight negative kaons. With AMADEUS step 1 a dedicated pure Carbon target was implemented in the central region of the KLOE detector, providing a high statistic sample of pure at-rest K^- nuclear interaction.
We will show the results obtained in the analysis of the $\Sigma^+\pi^-$ and $\Sigma^0\pi^0$ (pure isospin 0) channels, intended to shed light on the controversial nature of the $\Lambda(1405)$ state. The analysis of the $\Lambda(\Sigma^0)\pi^-$ channel, from which the measurement of the module of the isospin 1, S-wave non resonant transition amplitude ca be extracted for the first time, will be presented. The investigation of single versus multi nucleon absorption in correlated Λp pairs production, and internal conversion processes will be shown, together with preliminary results on correlated Λd and Λt production.

Charmed mesons in the extended Linear Sigma Model

ESHRAIM, Walaa[1], GIACOSA, Francesco[1], RISCHKE, Dirk[1]

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We enlarge the so-called Extended Linear Sigma Model (eLSM) by including the charm quark according to the global U(4)rxU(4)l global chiral symmetry. In the eLSM, besides scalar and pseudoscalar mesons, also vector and axial-vector mesons are present. Almost all the parameters of the model were fixed in a previous study of mesons below 2 GeV. In the extension to the four-flavor case, only three additional parameters (all of them related to the bare mass of the charm quark) appear. We then compute the masses, weak decay constants and (OZI dominant) strong decays of open and hidden charmed mesons. The results are in good agreement with the experimental data.

Improvement of $\pi\pi$ amplitudes and correct position of the σ pole

NAZARI, Vahabeddin[1], KAMIŃSKI, Robert[1], BYDZOVSKI, Petr[2]

[1]Institute of Nuclear Physics PAS, [2]Nuclear Physics Institute ASCR

Recently a big progress in understanding and description of the $\pi\pi$ interactions has been made due to dispersive analyses with imposed crossing symmetry [1]. This has led to significant changes in the information on these interactions, (mostly below 1 GeV), presented in the Particle Data Tables 2012 [2]. Nevertheless old parameterizations of the $\pi\pi$ amplitudes with e.g. wide and heavy $f_0(500)$ pole are still used in many calculations. The reason is that theoretical approach presented in those dispersive analyses can sometimes be unconvincing and size of those changes difficult to accept especially in experimental analyses.
To solve this problem we apply dispersion relations with imposed crossing symmetry to chosen S and P-wave amplitudes with wide and heavy $f_0(500)$ pole and with not correctly parameterized near threshold region. In our work, these amplitudes are modified in the low-energy region and then fitted to experimental data and to the dispersion relations. Very good agreement with data is achieved for both amplitudes from the threshold up to 1.8 GeV and with dispersion relations up to 1.1 GeV. Consequences of the applied modifications, e.g. changes of the S-wave lowest-pole positions, are presented.
Presented results of our analysis should show the way the practical application of the results of the dispersive analysis for the $\pi\pi$interactions, or at least make this application significantly easier.

[1] R. Garcia-Martin et al., Phys. Rev. D83, 074004 (2011)
[2] "2013 Review of Particle Physics" J. Beringer et al.(Particle Data Group), Phys. Rev. D86, 010001 (2012)

Simple trigonometric proof for the new parameters of the σ meson

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[1]Institute of Nuclear Physics PAS

The recent precise determination of the σ meson parameters ($f_0(500)$ meson) was done in analysis of new dispersion relations with imposed crossing symmetry condition [1,2]. Although results of this analysis are widely accepted, one can still find studies which use previous, significantly different values of the mass and the width of that resonance. Although results of that dispersive analysis have already changed significantly parameters of the σ meson in the Particle Data Tables [3], it is still necessary to present a simpler and more intuitive proof of correctness of these results.
Here, the simple proof based on a purely mathematical relations and properties of analytic functions is

presented. It is shown that the mere analysis of amplitudes presented as trigonometric functions and derivatives of these functions clearly define the area in which σ mass and the width must be. Achieving these results requires also a simple analysis of the signs of integral over the physical region.
One can expect that this simple proof will be sufficiently convincing and will eliminate still existing doubts about the parameters of σ meson.

[1] R. Garcia-Martin et al., Phys. Rev. D83, 074004 (2011)
[2] R. Garcia-Martin et al. Phys. Rev. Lett. 107 (2011) 072001
[3] "2013 Review of Particle Physics", J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)

Study of the process $e^+e^- \to 2(\pi^+\pi^-\pi^0)$ in $E_{cm} = 1.5 - 2.0$ GeV energy range with CMD-3 detector at VEPP-2000 collider

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for the CMD-3 Collaboration

The analysis of the process $e^+e^- \to 2(\pi^+\pi^-\pi^0)$ is described. The measurement of the process cross section in $E_{cm} = 1.5 - 2.0$ GeV energy range was based on 22 pb^{-1} of integrated luminosity collected with the CMD-3 detector at the VEPP-2000 e^+e^- collider. The preliminary study of the process dynamics will be also discussed in the talk.

Meson exchange currents in muon capture on the deuteron and ^{3}He

ELMESHNEB, Alaa Eldeen[1]

[1]Jagiellonian University

We will investigate the role of meson exchange currents in the description of the μ^-+d $\to \nu_\mu$+n+n and $\mu^-+{}^3$He $\to \nu_\mu+{}^3$H reactions. They both are treated as the decay of the corresponding muonic atoms, with the muon initially on the lowest K shell. The muon binding energy in these atoms can be safely neglected and in the initial state we deal essentially with the deuteron (or ^{3}He) and muon at rest.
These two reactions are interesting for several reasons. First of all, they offer a testing ground for the nuclear wave functions, which for any nucleon-nucleon (NN) and three-nucleon (3N) forces can be constructed for such light systems with great accuracy.
In these reactions few-nucleon weak current operators are an important dynamical ingredient. In the current operators apart from the relatively well known single nucleon contributions, two-nucleon parts (generated by various meson exchanges) play an important role. Their details are not well known and several models should be considered [1].
We will present our formalism for dealing with these reactions and a simple method for partial wave decomposition of the two-nucleon operators. The crucial nuclear matrix elements of the corresponding weak current operators will be calculated in the momentum space and using partial wave decomposition. The effect of meson exchanges will be investigated in the energy spectrum of the emitted neutrinos (in the deuteron case) and in the total decay rates for the two reactions.
We will employ various models of NN and 3N forces, such as the Bonn B [2] or chiral NNLO potentials [3]. Our results with the single nucleon currents look already very promising and we hope for the improvement in the description of the experimental data, when dominant two-nucleon current operators are included in our framework.

1. L. Marcucci et al., Phys. Rev. C83, 014002 (2011).
2. R. Machleidt, Adv. Nucl. Phys. 19 (1989) 189.
3. E. Epelbaum, Prog. Part. Nucl. Phys. 57, 654 (2006).

Muon induced deuteron disintegration in three-dimensions

TOPOLNICKI, Kacper[1], GOLAK, Jacek[1], SKIBIŃSKI, Roman[1], MARCUCCI, Laura Elisa[2], ELMESHNEB, Alaa Eldeen[1]

[2]University of Pisa, [1]Jagiellonian University

We will present a three-dimensional (3D) description of muon induced deuteron disintegration. This reaction is treated as the decay of the muonic atom with the muon initially on the lowest K shell. Our aim is to calculate the total and differential decay rates. We work in momentum space and use 3D momentum eigenstates directly. This approach allowed us to calculate the appropriate nuclear matrix elements, necessary building blocks for the differential decay rate, in a single step. For contrast - in classical calculations many partial-waves have to be taken into account. We achieved a very good agreement between the 3D and partial-wave methods for calculations that involve single-nucleon currents. Our result for the total decay rate is also in agreement with experimental values, though these are not very precise. This success motivates us to also include two-nucleon current contributions that include the meson exchange currents. Additionally, our formalism can also be applied to other, so far poorly described, processes like: μ+^{3}He $\rightarrow$ ν+n+d or μ+^{3}He $\rightarrow$ ν+n+n+p.

The Muon Scattering Experiment (MUSE) at PSI and the proton radius puzzle

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[1]Hampton University

for the MUSE Collaboration

The unexplained large discrepancy of the proton charge radius measurements with muonic hydrogen Lamb shift and determinations from elastic electron scattering and Lamb shift in regular hydrogen of seven standard deviations is known as the proton radius puzzle. Suggested solutions of the puzzle range from possible errors in the experiments through unexpectedly large hadronic physics effects to new physics beyond the Standard Model.
A new approach to verify the radius discrepancy in a systematic manner will be pursued with the Muon Scattering Experiment (MUSE) at PSI. The experiment aims to compare elastic cross sections, the proton elastic form factors and the extracted proton charge radius with scattering of electrons and muons of either charge and under identical conditions. The difference in the observed radius will be probed with a similar precision as has been established with hydrogen spectroscopy and electron scattering.
An overview of the experiment and the current status will be presented.

Experimental and simulated dp breakup reaction data at 300, 400 and 500 MeV

JANEK, Marian[1], PIYADIN, Semen[2], LADYGIN, Vladimir[2], GURCHIN, Yuriy[2], ISUPOV, Alexandr[2], KARACHUK, Julia[3], KURILKIN, Aleksey[2], KURILKIN, Pavel[2], LIVANOV, Alexei[2], MARTINSKA, Gabriela[4], REZNIKOV, Sergey[2], TEREKHIN, Arkadiy[2], TARJANYIOVA, Gabriela[1]

[3]Advanced Research Institute for Electrical Engineering, [4]University of Pavol Jozef Šafárik, [2]Joint Institute for Nuclear Research, [1]Zilina University

for the DSS Collaboration

Dp breakup reaction occupied large phase space. Two and three nucleon forces and relativistic effects can be investigated under various detector configuration. The results of simulation of dp breakup reaction in energy region from 300 to 500 MeV are presented. Preliminary results obtained at 300, 400 and 500 MeV of deuteron energy at some detector configurations at Nuclotron such as future plans in investigation of relativistic effects are discussed.

Studies of three-nucleon force effects via deuteron-proton breakup at 160 MeV

PAROL, Wiktor[1], CIEPAŁ, Izabela[1], KISTRYN, Stanisław[1], KŁOS, Barbara[2], KOZELA, Adam[3], STEPHAN, Elżbieta[2]

[2]University of Silesia, [1]Jagiellonian University, [3]Institute of Nuclear Physics PAS

for the Few Body Experiment Group Collaboration

Investigation of three-nucleon system provides basis for understanding details of interaction between nucleons, going also beyond simple pairwise forces. Modern realistic nucleon-nucleon (NN) interaction models describe well systems composed of the two nucleons. They are able to predict observables of the deuteron-proton breakup reaction only if combined with additional component of the dynamics - the three nucleon force (3NF). Studies of this effect can be done quantitatively by comparing observables calculated with the use of Faddeev equations with results of precise measurements. The two- and three-nucleon interactions can also be modeled within the coupled-channel (CC) framework by an explicit treatment of the Δ-isobar excitation. Alternatively, contribution of NN and 3NF to the dynamics may come from Chiral Perturbation Theory. All the approaches describing the system of at least 3 nucleons should include not only 3NF model but also the Coulomb interactions or the relativistic component. All the effects reveal in different parts of the phase space with different magnitude what can be noticed in the observables.
Experiments devoted to study such subtle ingredients of the nuclear dynamics in the 3-nucleon systems were carried out at KVI Groningen and FZ-Juelich with the use of the $^1H(d,pp)n$ breakup reaction at intermediate energy deuteron beams. Present studies are continuation of a wide research program aimed at investigations of the few-nucleon system dynamics and focuses on measurement done with unpolarised deuteron beam at 80 MeV/nucleon energy impinging on liquid hydrogen target. Goal of the work presented here is to determine the breakup differential cross-sections and verify the currently developed theoretical predictions. Current status of the data analysis of the deuteron-proton reaction at 160 MeV will be presented, including preliminary results of the cross-sections for the breakup channel.

Experimental investigation of few-nucleon dynamics in deuteron-deuteron collision at 160 MeV

KHATRI, Ghanshyam[1], CIEPAŁ, Izabela[1], KISTRYN, Stanisław[1], KOZELA, Adam[2], STEPHAN, Elżbieta[3]

[3]University of Silesia, [1]Jagiellonian University, [2]Institute of Nuclear Physics PAS

Few-nucleon systems are basic laboratories to study nuclear forces. Among them, the system composed of three nucleons (3N) is the simplest and non-trivial environment, in which models of nuclear interaction can be tested. Nucleon-nucleon (NN) interaction is here dominant; there are, however, reasons to

assume existence of additional dynamics, referred to as the three-nucleon force (3NF) [1]. Nowadays, there are many theoretical predictions based on rigorous solutions of Faddeev equations. Besides the realistic potentials, combined with models of 3N forces (e.g. TM99 and Urbana IX), the 3N system dynamics can also be modelled with the coupled-channels (CC) method [2]. In parallel, the theoretical approach based on dynamics generated via Chiral Perturbation Theory (ChPT) [3] is being gradually developed. These approaches are able to predict different components of few-nucleon interaction, not only 3NF but also even more subtle four nucleon force (4NF) effects (rigorous predictions are limited to a domain below breakup threshold), Coulomb interaction [2] and relativistic effects. Thus, for verification and further development of the models, possibly large basis of precise data is necessary. The d+d breakup reaction offers unique environment to study all the mentioned effects with further advantages of enhanced 3NF effects in the 4N system.
We have performed an experiment at KVI laboratory (The Netherlands) with use of the BINA detector and 160 MeV deuteron beam impinging on deuteron target. Aim of the measurement was to determine the differential cross-sections for three-(dd→dpn) and four-body breakup (dd→ppnn) reactions. The experiment appears even more important due to the fact that the experimental database for d+d breakup is scarce. Our experiment is a continuation of previous very successful measurements at other medium energies [4-8]. The apparatus is a new-generation construction which offers access to almost full phase-space of the studied breakup process, well suited for such experiments at intermediate energies.
The preliminary results covering test of data consistency, geometry cross-check, calibration, identification of the reaction channels and precision of kinematical reconstructions, as well as sample distributions of differential cross section will be presented.

[1] H. Witała et al., Phys. Lett. B 634 (2006) 374
[2] A. Deltuva et al., Phys. Rev. C 73 (2006) 057001
[3] E. Epelbaum, Prog. Part. Nucl. Phys. 57 (2006) 654
[4] N. Kalantar-Nayestanaki et al., Rep. Progr. Phys. 75 (2012) 016301
[5] I. Ciepał et al. Few-Body Systems, Springer Link, Jan-2013
[6] B. Kłos et al. Acta Physica Polonica B ,Vol. 44, No. 3, March 2013, p-345
[7] St. Kistryn et al., Phys. Rev. C 72 (2005) 044006
[8] St. Kistryn et al., Phys. Lett. B 641 (2006) 23

The effect of three nucleon force in theoretical calculations

SKWIRA-CHALOT, Izabela[1]

[1]University of Warsaw

The basic way to understanding the mechanism of reactions involving nucleons and nuclei is creating a model of nuclear forces which with a very good agreement describes the data from experiments. For systems of three nucleons one can do an exact calculations using one of three types of theory, which are used for comparisons with experimental data. The first theory (calculations of Witała group [1]) is based on realistic nucleon-nucleon potentials (such as charge-dependent (CD) Bonn, AV18, Nijm I and Nijm II) which could be combined with the models of three nucleon force (TM99 or Urbana IX). The second one is based on coupled-channel potential (CCP) with Δ-isobar excitation [2]. In these calculations the potential is given by the realistic CD Bonn potential, but in addition includes the excitation of single nucleon to Δ-isobar. The third calculations [3] based on the Chiral Perturbation theory (ChPT).
In order to observe the scale of effect of three nucleon force in dp breakup reactions at different beam energies we compared the results of two types of calculations (CDB+TM99, AV18+UIX) of the Witała group. Such analysis of theoretical results it is very important from the experimental point of view, because it provides information about the phase space of such effect.

[1] H. Witała, et al., Phys. Rev. Lett. 81 (1998) 1183
[2] A. Deltuva, et al., Phys. Rev. C 68 (2003) 024005
[3] E. Epelbaum, et al., Eur. Phys. J. A 19 (2004) 125; ibid. A 19 (2004) 405

Recent results on B and D decays from LHCb

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[1]AGH University of Science and Technology

The LHCb experiment has collected more than 3/fb of integrated luminosity in 2011 and 2012 and is producing a large amount of excellent results in beauty and charmed meson physics. An overview of the most recent results on rare B decays, CP violation, and charm physics will be given along with an outlook to the physics perspectives and to the LHCb upgrade.

Recent progress and prospectives on hadron physics study from the Lanzhou Research Group

YUAN, Xiao-Hua[1], LIN, Qing-Yong[1], LIU, Xiang[2], XU, Hu-Shan[1], RONG, Xin-Juan[1], LI, Zhan-Kui[1]

[1]Institute of Modern Physics CAS, [2]Lanzhou University

Charmed baryons are expected to exhibit a rich spectrum of states. However, only a few of these states have been confirmed and there must be many more excited states need to be found. Being one of them, the charmed baryon $\Lambda_c(2880)^+$ was observed by CLEO collaboration, BaBar collaboration and Belle collaboration, respectively. Now, more studies should still be required to enrich our understanding of $\Lambda_c(2880)$.
Exploring the production of $\Lambda_c(2880)$ is helpful to reveal the inner structure of $\Lambda_c(2880)$ as well as studying the decay behavior of $\Lambda_c(2880)$. Therefore, we calculate the total and differential cross sections of $p\bar{p} \to \Lambda_c^- \Lambda_c(2880)^+$ by the effective Lagrangian approach under a D meson exchanged mechanism. The numerical results indicate that $p\bar{p} \to \Lambda_c^- \Lambda_c(2880)^+$ is a suitable process to explore the $\Lambda_c(2880)^+$ production at $\overline{P}$ANDA. Considering the designed luminosity of $\overline{P}$ANDA (2×10^{32} cm^{-2}s^{-1}) and an overall efficiency of 10Based on the theoretical caculation, we suggest future $\overline{P}$ANDA experiment to perform the search for the charmed baryon $\Lambda_c(2880)^+$. This experimental study can not only further confirm $\Lambda_c(2880)^+$ by different processes, but also provide more abundant information to $\Lambda_c(2880)^+$, which will be valuable to reveal the underlying structure of $\Lambda_c(2880)^+$.
As a new scientific project HIAF(*H*igh *I*ntensity Heavy-Ion *A*ccelerator *F*acility) is being planned to be built in the near future, the proton beam with intensity of 3.0×10^{12} and energy of 12 GeV/c will be achieved. The possibilities for more hadron physics research will be also discussed in the talk.

Modification of meson properties in the vicinity of nuclei

FILIP, Peter[1]

[1]Institute of Physics SAS

We shall discuss to what extent the properties of pseudoscalar and vector mesons (e.g. η, ω) bound in mesoatomic systems can become modified due to very strong static electromagnetic fields present in the close vicinity of the nucleus surface. Using the analogy with the behavior of ortho-positronium decaying in the magnetic field, we suggest that quantum superposition of spin-singlet and m_z=0 triplet states of the quark-antiquark pair becomes the meson ground state in strong magnetic field. Consequently,

conservation of quantum numbers (e.g. C-parity) may become affected in decays of mesons, if bound to specific nuclei.

Hadronic resonance production measured with ALICE at the LHC

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Short-lived hadronic resonances constitute a sensitive probe of the dynamical evolution of the fireball created in heavy-ion collisions, since a significant fraction of them decay in the time span (of the order of few fm/c) between chemical and kinetic freeze-out. Competing processes, such as regeneration and re-scattering, may alter the ratio of the resonance to non-resonance yields. The study of resonance production in collision systems such as pp and p-Pb provides a necessary baseline to disentangle initial-state effects from genuine medium-induced effects. ALICE has measured the production of both meson and baryon resonances in different collision systems at LHC energies. A review will be presented in comparison with the measurements at RHIC energies and to the predictions from models. In particular, recent results on $K(892)^0$ and $\phi(1020)$ production in p-Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV will be discussed. Ratios of resonance to long-lived hadron production in Pb-Pb are compared with the same quantities measured in pp and p-Pb collisions, in order to investigate re-scattering effects. The nuclear modification factors ($\rm R_{AA}$, $\rm R_{pPb}$), recently measured up to high $p_{\rm T}$ for resonances, are compared to the same measurement for long-lived hadrons.

The contribution of multi-channel pion-pion scattering in the final states of Υ-meson family decays

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In the analysis of data on decays of the Υ-meson family - $\Upsilon(2S) \to \Upsilon(1S)\pi\pi$, $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ and $\Upsilon(3S) \to \Upsilon(2S)\pi\pi$ - the contribution of multi-channel $\pi\pi$ scattering in the final-state interactions is considered. The analysis, which is aimed at studying the scalar mesons, is performed jointly considering the isoscalar S-wave processes $\pi\pi \to \pi\pi, K\overline{K}, \eta\eta$, which are described in our model-independent approach based on analyticity and unitarity and using an uniformization procedure, and the charmonium decay processes $J/\psi \to \phi(\pi\pi, K\overline{K})$, $\psi(2S) \to J/\psi(\pi\pi)$. Results of the analysis confirm all our earlier conclusions on the scalar mesons. It is also shown that in the final states of the Υ-meson family decays (except for the $\pi\pi$ scattering) the contribution of the coupled processes, e.g., $K\overline{K} \to \pi\pi$, is important even if these processes are energetically forbidden. This is in accordance with our previous conclusions on the wide resonances: If a wide resonance cannot decay into a channel which opens above its mass but the resonance is strongly connected with this channel (e.g. the $f_0(500)$ and the $K\overline{K}$ channel), one should consider this resonance as a multi-channel state with allowing for the indicated channel taking into account the Riemann-surface sheets related to the threshold branch-point of this channel and performing the combined analysis of the considered and coupled channels.

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Status of measurement of $K_S \to \pi e \nu$ branching ratio and lepton charge asymmetry with the KLOE detector

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We present the current status of the analysis of about 1.7 billion K_S K_L pair events collected at DAFNE with the KLOE detector to determine the branching ratio of $K_S \to \pi e \nu$ decay and the lepton charge asymmetry. This sample is 4 times larger in statistics than the one used in a previous KLOE analysis, allowing us to improve the accuracy of the measurement and of the related tests of CPT symmetry and $\Delta S = \Delta Q$ rule.

A direct test of T symmetry in the neutral K meson system with $K_S K_L \to \pi^{\pm} l^{\mp} \nu_l 3\pi^0$ at the KLOE-2 experiment

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Quantum entanglement of K and B mesons allows for a direct experimental test of time-reversal symmetry independent of CP violation. The T symmetry can be probed by exchange of initial and final states in the reversible transitions between flavor and CP-definite states of the mesons which are only connected by the T conjugation. While such a test was successfully performed by the BaBar experiment with neutral B mesons, the KLOE-2 detector can probe T-violation in the neutral kaons system by investigating the process with $K_S \to \pi^{\pm} l^{\mp} \nu_l$ and $K_L \to 3\pi^0$ decays. Analysis of the latter is facilitated by a novel reconstruction method for the vertex of $K_L \to 3\pi^0$ decay which only involves neutral particles. Details of this new vertex reconstruction technique will be presented as well as prospects for conducting the direct T symmetry test at the KLOE-2 experiment.

Theoretical investigation of $\Lambda(1405)$ formation in $K^- p$ reactions comparing to Hemingway data

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In this work, the differential cross section of $\Lambda(1405)$ formation in $K^- p \to \Sigma^+(1660)$, $\Sigma^+(1660) \to \Lambda(1405)\pi^+$ and finally $\Lambda(1405) \to (\Sigma\pi)^0$ have been calculated theoretically. Calculation and investigation of the invariant mass of this reaction give an opportunity to find out the structure of this resonance state. We use Hemingway experimental data and χ^2 (chi square) fitting method to compare our theoretical calculation to data. Fitting by χ^2 method showed the peak of $\Lambda(1405)$ around M=1405 MeV/c^2 which confirms the deeply bound state of $\bar{K}N$ interaction.

A dispersive treatment of $K_{\ell 4}$ decays

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$K_{\ell 4}$ decays are interesting for several reasons: they allow an accurate measurement of a combination of S-wave $\pi\pi$ scattering lengths, one form factor is connected to the chiral anomaly and the decay is the best source for the determination of some low-energy constants of ChPT.
We present a dispersive approach to $K_{\ell 4}$ decays, which takes rescattering effects fully into account. The dispersion relation treats both experimentally accessible form factors simultaneously and also describes the dependence on the dilepton invariant mass. We apply isospin breaking corrections before fitting the data of NA48/2 and E865 measurements and extract the values of low-energy constants from a matching to two-loop ChPT.

Dibaryons – a new state of matter?

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Despite their long painful history dibaryon searches (where dibaryon means a baryon number $B = 2$ state independently on the internal structure: genuine six-quark state/baryonic-molecule) have recently received new interest, in particular by the recognition that there are more complex quark configurations than just the familiar $q\bar{q}$ and qqq systems. The "hidden color" aspect makes dibaryons a particularly interesting object in QCD.
A resonance like structure recently observed in double-pionic fusion to deuteron, at $M = 2.38GeV$ with $\Gamma = 70MeV$ and $I(J^p) = 0(3^+)$ meanwhile proved to be the so called “inevitable dibaryon” d^*. To investigate its structure we have measured its decay branches into the $d\pi^0\pi^0$, $d\pi^+\pi^-$, $pp\pi^-\pi^0$, $pn\pi^0\pi^0$ and pn channels by pd and dp collisions in the quasi-free reaction mode, utilizing the WASA detector setup at COSY.
The pn decay channel was measured by use of polarized deuterons in inverse kinematics. These new np analyzing power data exhibit a pronounced resonance effect in their energy dependence. The SAID partial-wave analysis with inclusion of these data reveals a pole in the complex plane of the $^3D_3$ partial wave at $(2380 \pm 10)MeV - i(40 \pm 5)MeV$ in accordance with the d^* resonance hypothesis.
Since in the double-pionic fusion reactions to ^3He and ^4He the signature of this resonance is observed too, it obviously is robust enough to survive even in a nuclear surrounding, which may have interesting consequences for the nuclear matter under extreme conditions.
In addition to the Wasa-at-Cosy results also the latest results in this field as well as the influence of dibaryons on other areas of physics, including heavy ion collisions, will be discussed.
The enhancement in the dilepton spectrum observed in heavy-ion collisions for invariant electron-positron masses in the range 0.15 GeV $< M_{e^+e^-} <$ 0.6 GeV has recently been traced back to a corresponding enhancement in proton-neutron (pn) collisions relative to pp collisions. Whereas the dilepton spectra from pp collisions are understood quantitatively, theoretical descriptions fail to account for the much higher dilepton rate in pn collisions - in particular regarding the region $M_{e^+e^-} >$ 0.3 GeV at beam energies below 2 GeV ("DLS Puzzle").
We show that the missing strength can be attributed to ρ^0-channel $\pi^+\pi^-$-production, which is dominated by t-channel $\Delta\Delta$ excitation and the recently found isoscalar dibaryonic resonance d^* at $M \approx$ 2.37 GeV.

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Direct vs. final state tensor meson photoproduction - amplitude analysis

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Understanding the mechanism of the non-strange tensor meson photoproduction is essential for description of the light meson spectrum. This is because the $f_2(1270)$ photoproduction amplitude is prominent in partial wave analyses where two pions or two kaons in the final state are involved. Description of this sector is complicated, however, by possible existence of scalar and tensor glueballs which mix with conventional mesons. Contribution of the D-wave resonances is also important for the hybrid and exotic meson searches where it makes the essential part of the non-exotic background. So far the experimental data on the tensor meson photoproduction were very scarce and the situation changed only recently with the advent of abundant CLAS data [1] and is to further improve with CLAS12 and GlueX experiments at JLab where data are to be taken in 2015. Thus our study of the tensor meson photoproduction is timely and opportune.
We analyze two mechanisms of $f_2(1270)$ resonance photoproduction, namely the direct photoproduction with t-channel vector meson exchange and the mechanism where tensor meson is created due to final state interactions of pion pairs. The first (direct) photoproduction mechanism is justified by the common belief that $f_2(1270)$ is conventional $q\overline{q}$ state. So it is a kind of surprise that the strengths of the partial waves corresponding to different tensor meson helicities are very well described with the final state interaction model which we described in [2]. Another advantage of the final state interaction model is that it respects two particle unitarity of the amplitude and properly accounts for its analytical structure [3].
In the talk we will discuss predictions of these two models with respect to basic polarization observables and confront them with the CLAS data.

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Electromagnetic structure of vector mesons

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Electromagnetic structure of the complete nonet of vector mesons is investigated in the framework of the Unitary and Analytic model and insufficient experimental information on it is discussed.

Hadronic decays of the ω meson measured with WASA-at-COSY

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Decay studies of the ω, a light vector meson, covers a span of interesting physics including 3π decay dynamics, the $\rho-\omega$ mixing and the $\omega-\pi^0$ transition form factor. The ongoing study presented by this poster covers the first two mentioned topics through measurements of the $\omega \to \pi^+\pi^-\pi^0$ and $\omega \to \pi^+\pi^-$ channels where the ω was produced in the $p + d \to {}^3He + \omega$ reaction and measured with the

experimental setup of WASA-at-COSY.
A high statistics study of the $\omega \to \pi^+\pi^-\pi^0$ dynamics can provide quantitative experimental verification of the predicted onset of the ρ in the decay process as well as the impact of $\pi-\pi$ interactions. This study has the goal of providing experimental values of a parametrisation of the Dalitz plot for a comparison with current theoretical predictions, [1,2].
The isospin breaking $\omega \to \pi^+\pi^-$ decay can give insight into the behaviour of the $\rho - \omega$ mixing. This channel has already been widely studied in e^+e^- collisions where the interference has been conclusively shown as destructive [3]. Only a few measurements with limited statistics have been performed for hadronic production of the ω meson with hints of a possible constructive interference 4]. The aim of this study is to investigate the structure of the $\omega \to \pi^+\pi^-$ signal in proton on deuteron collisions.

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On the precise determination of the differences of ρ-meson family parameters

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The mass and decay width differences of charge and neutral members of the known ρ-meson families are determined by exploiting experimental data on $e^+e^- \to \pi^+\pi^-$ and $\tau^- \to \pi^-\pi^0\nu_\tau$ processes and by the Unitary and Analytic models of the corresponding electromagnetic a weak π form factors.

Studies on implementation of pellet tracking in hadron physics experiments

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Pellets are microscopic spheres of frozen hydrogen (approx. 25 micrometers in diameter), used as the target in hadron physics experiments such as WASA (Forschungszentrum Juelich, Germany) and the future PANDA experiment (GSI, Darmstadt, Germany). Because the space between the pellet generator and the interaction region is occupied by the particle detector system, pellets are produced approx. 2-3 m above the interaction region and travel towards it inside thin pipes. Because of the non uniform velocity of pellets in the stream, their time distribution is stochastic with the average distance between pellets of the order of a few millimeters. The average pellet velocity is approx. 70 m/s which means, that the generated pellet needs approx. 30 microseconds to reach the accelerator beam region and traverses it during approx. 70 microseconds.
The aim of the pellet tracking system is to optically detect pellets, measuring their positions and times at a few measurement levels installed in two sections located below the pellet generator and above the pellet dump. The measured information will be used to reconstruct pellet tracks and consequently, to be able to know their position at a time of hadronic interaction. The tracking system will operate in synchronization with the main experimental DAQ, but at the same time it will operate in much longer time scale than the main DAQ.

One of the advantages given by the pellet tracking is suppression of events not coming from pellets, but from a background - from the rest-gas (a product of pellet evaporation remaining in the scattering chamber) or from other non-pellet sources. This functionality may be demonstrated using another system. Such a system can be operated at the moment, before the prototypes of the full scale pellet tracking are built and used in accelerator facilities. This kind of study has been performed with the use of WASA detector.
It is known from previous studies that pellets are present in the beam region only for some fraction of time. The events from rest-gas happen all the time. However, it is more probable that when a pellet is in the beam region, the recorded event originated in the pellet. Bearing this in mind, one can exploit an alternative method of checking when pellets are in the beam region, based on the integrated event rate of interactions and the knowledge that when a pellet passes through the beam, there are more interactions.
The described method makes use of so called Long Range TDC - a device continuously recording times of input signals. In our case these signals are WASA elastic triggers - coincidence conditions between different detector parts activating the data acquisition and designed to be especially sensitive to elastic scattering events. Usage of these triggers in the study has been also proven to favor events occurring close to the nominal interaction point, providing even better separation between "good" events and non-pellet background.
The study proved, that it is possible to distinguish between the events originating in pellets and the non-pellet background. Moreover, because of many technical similarities to the full scale pellet tracking system, the described method gives an experience in working with such system. This includes the hardware part of the project, as well as the further data processing and using the obtained information in the analysis of hadronic reactions.

Electromagnetic calorimeter for HADES experiment

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Electromagnetic calorimeter (ECAL) is being developed to complement dilepton spectrometer HADES currently operating on the beam of the SIS18 heavy-ion synchrotron at GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany. ECAL will enable the HADES@FAIR experiment to measure data on neutral meson production in heavy ion collisions at the energy range of 2-10 A GeV on the beam of future accelerator SIS100@FAIR.
Calorimeter will consist of 978 modules divided into 6 sectors and it will cover forward angles $12° \theta < 45°$ and almost full azimuthal angle. Each module consists of a lead glass Cherenkov counter, photomultiplier, HV divider and optical fiber.
We will report results of the last beam test in MAMI facility at Johannes Gutenberg Universität Mainz. Detector response of the setup consisting of several modules were studied using secondary photon beam with energies ranging from 81 MeV up to 1399 MeV (eight different triggers were used). The photon beam hitted the setup at three different positions (-4cm, -2cm, center of the module = 0cm, +2cm) and under three inclinations (angles 0°, 6° and 12° with respect to the module's longitudinal axe). Various prototypes of front-end boards ("Cracow" and PaDiWa AMPS) were tested as well.

Energy calibration for the forward detector at WASA-at-COSY

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One of the main aspects of the WASA-at-COSY physics program are studies on rare and forbidden decays of light mesons. In this context a large data set of η mesons has been produced in proton proton scattering in order to investigate the decay properties of this meson. This high statistic measurement allows, e.g., for the search for the C parity violating reaction $\eta \to \pi^0 + e^+ + e^-$, for which only an upper limit for the branching ratio could be measured so far. The analysis of this forbidden decay channel relies on an effective separation of the physical background which is mainly caused by the direct π production.
To handle this background a missing mass analysis and kinematic fitting will be applied. Since both methods rely on a high energy resolution the forward detector, which measures the proton energies, has to be calibrated very carefully. In this contribution, a new calibration software is presented which has been developed especially for proton-proton measurements, and which allows for a precise determination of the calibration parameters by the mean of a graphical user interface and a dedicated fitting algorithm.

Supported by COSY-FFE grants.

J-PET: a novel detector system for tests of discrete symmetries and for the medical diagnostics

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The Jagiellonian Positron Emission Tomography (J-PET) based on polymer scintillators is currently under development at the Jagiellonian University [1,2,3]. The novelty of the concept lies in employing strips of polymer scintillators instead of crystals as detectors of annihilation quanta, and in using (for the hit position reconstruction) the timing of signals instead of their amplitudes.
J-PET detector will be used as a prototype for the whole body PET modality and as a detector system for studies of discrete symmetries violations in the decays of positronium. The detector will allow to investigate symmetries such as parity (P), time reversal (T), charge conjugation (C) and their combinations in the purely leptonic system in which e.g. the CP violation has not yet been observed.
To take fully advantage of the fast signals of plastic scintillators a novel front-end electronics allowing for sampling in a voltage domain was developed [4], and new methods for the reconstruction of hit position of the gamma quantum based e.g. on the Compressing Sensing theory are elaborated [5].
The talk will include presentation of the detector system and discussion of novel sampling electronics.

The project is supported by the Foundation for Polish Science and the Polish National Center for Development and Research

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Time and hit position reconstruction method for Positron Emission Tomography based on a library of model events

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Positron Emission Tomography is a very successful medical imaging system. However, the current PET modalities do not allow for simultaneous whole body imaging because the number of crystals, photomultipliers and electronics modules increase linearly with increasing longitudinal field of view (FOV). Therefore, building a PET detector for covering the whole human body is economically unrealistic when applying the current technologies. The J-PET collaboration is developing a new concept which will allow to built a PET detector with large FOV based on the long strips of polymer scintillators. At present, it is in its early stage of development and requires elaborations of new time and hit-position reconstruction methods which would allow to make use of the potential it offers.
In this poster, we will present a novel reconstruction method based on a library of model signals. The proposed method allows to determine time and hit position of the gamma quanta along the large diagnostic chamber with time and spatial resolution. The results are comparable with presently used tomography systems. The characteristics and application of the elaborated method will be presented and discussed.

4 Monday

Kaonic atoms – experiments on the strong interaction with strangeness

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The strong interaction of antikaons ($\bar{K}$) with nucleons and nuclei in the low-energy regime is a fascinating topic because of the strong attraction, which is related to the question about kaonic nuclear bound states. A rather direct experimental access to the antikaon-nucleon interaction is provided by precision x-ray spectroscopy of transitions to low-lying states in light kaonic atoms like kaonic hydrogen and helium isotopes. After the successful completion of precision measurements on kaonic hydrogen and helium isotopes by SIDDHARTA at DAFNE/LNF, new X-ray studies with the focus on kaonic deuterium are in preparation (SIDDHARTA-2). With the kaonic deuterium data the antikaon-nucleon isospin-dependent scattering lengths can be extracted for the first time. The talk will give an overview of the experimental results of SIDDHARTA, the implications for the theory of low-energy strong interaction with strangeness and will provide an outlook to future perspectives in this frontier research field.

Antikaons in dense matter: from atoms to K^-pp and other beasts

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Recent studies of kaonic atoms, few-body kaonic quasibound states and kaonic nuclei based on s-wave $\bar{K}N$ chiral interaction models that are consistent with the SIDDHARTA K^- hydrogen data are reviewed, focusing on the K^-pp dibaryon. Remarks are made on low-lying dibaryons other than $\Lambda(1405)N$, particularly those involving p-wave interactions of pions with octet baryons.

First πK atom lifetime measurement and recent results from the DIRAC experiment

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Low-energy QCD and specifically Chiral Perturbation Theory (ChPT) calculated $\pi\pi$ and πK scattering lengths with per cent precision. For processes involving u- and d-quarks theoretical predictions

have been experimentally checked by $\pi^+\pi^-$ atom lifetime measurement [1] and by analysis of K-decays [2,3]. Detection and lifetime measurement of πK atom cast a look into processes which involve s-quark as well.
We report evidence for πK atoms production, using 24 GeV/c proton beam from CERN PS interacting with a thin Ni target. We have identified (178 ± 49) πK pairs, which were produced and were subsequently broken-up (ionized) in the Ni target. Analysis yields a first measurement of the πK atom lifetime $\left(2.5^{+3.0}_{-1.8}\right)$ fs [4]. This lifetime is connected in a model-independent way to the S-wave isospin-odd πK scattering lengths difference $|a_0^-| = \frac{1}{3}|a_{1/2} - a_{3/2}| = \left(0.11^{+0.09}_{-0.04}\right) M_\pi^{-1}$ (a_I for isospin I).
Through the measurement of the $\pi^+\pi^-$ atom (pionium) lifetime, the experiment obtained the S-wave $\pi^+\pi^-$ scattering lengths difference $|a_0 - a_2|$ with 4% precision [1]. In 2011-2012 DIRAC collaboration collected data towards observation of long-lived (metastable) states of pionium. The observation of long-lived states opens the possibility to measure the energy difference between ns and np states and to determine the value of the combination $(2a_0 + a_2)$ of S-wave $\pi\pi$ scattering lengths. The experiment used two targets method: after production in the beryllium foil, atoms flied through a permanent magnetic field to reach the platinum ionization foil. The distance between foils is large enough for ns-states to vanish due to annihilation. Only $\pi^+\pi^-$ atoms in states with non-zero angular momentum can get into the second Pt target. We report unambiguous observation of long-lived (metastable) states of $\pi^+\pi^-$ atoms.

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Strange meson production near threshold in nucleus-nucleus collisions

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Strange mesons are the rare probes of the nucleus-nucleus collisions investigated by the FOPI collaboration at the beam kinetic energy range of 1-2A GeV. This energy falls below (K^-, $\phi(1020)$) or near (K^+, K^0) thresholds in the free nucleon-nucleon collision, therefore a considerable contribution to the production of these particles is expected to proceed via the secondary channels, involving mesons (π, ρ) and/or intermediate resonances (Δ, N^*, Σ^*, Λ^*) [1,2].
A particularly interesting case is the K^- meson. Its production in medium is predicted to proceed via the creation of the $\Sigma^*(1385)$ resonance [3]. However, K^- is also produced in vacuum from the decays of ϕ mesons. Both these sources have been investigated by the FOPI Collaboration [4-6].
Strange mesons propagate through the hot and dense collision zone, where their properties like effective mass, and production cross section are modified [3].
These modifications are also studied by the FOPI collaboration in AA and πA systems by means of comparing the flow observables and ratios of kinematic distributions to the predictions of transport calculations [7,8,9]. In this talk I will present the overview of the abovementioned findings.

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Dark photon searches with accelerators

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The cosmological standard model assumes that a large fraction of the universe is made of dark matter while only a small fraction of matter is made of ordinary baryonic matter. Up to now, the nature of dark matter is unknown, and this is certainly one of the most pressing puzzles of today's physics. Dark matter interacts in cosmology only via gravitation with ordinary matter. In particle physics, however, one assumes that for a possible particle candidate at least a very weak interaction with ordinary matter remains, calling such a candidate a "weakly interacting massive particle" (WIMP).
A particle physics candidate would appear naturally e.g. if one demands R-parity in Super-symmetry. Most experiments therefor concentrate on the direct detection of the so called "lightest super-symmetric particle'" as the WIMP. A more general approach however was suggested by different authors (e.g. Arkani-Hamed et al.), explaining a series of puzzling phenomena like e.g. the DAMA/LIBRA modulation and the positron excess recently confirmed by the newest AMS results by a U(1) gauge boson of the dark matter sector which mixes with the photon. Besides Super-symmetry, nearly all well motivated extensions of the standard model, e.g. string theories, introduce an additional gauge boson, since large symmetries have to be broken and U(1) bosons provide the lowest-rank local symmetries. Such gauge bosons would have naturally a mass in the range of 1 GeV, making this accessible to existing accelerators, however with very small coupling.
In this talk an overview of the existing and planed experimental searches for dark photons at accelerators will be presented.

Particle physics at the Pierre Auger Observatory

EBR, Jan[1]

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for the Pierre Auger Collaboration

The Pierre Auger Observatory is the largest detector of ultra-high energy cosmic rays (UHECR) in the world. These particles, presumably protons or heavier nuclei of energies up to 10^{20} eV initiate extensive air showers which can be detected by sampling the particles that arrive at ground level or observing the fluorescence light generated during the passage of showers through the atmosphere - the Pierre Auger Observatory employs both these techniques. As the center-of-mass energies of the first interactions in the showers can be several orders of magnitude beyond the reach of the LHC, the UHECR provide an unique opportunity to study hadronic interactions. While the uncertainty in modeling these interactions is somewhat degenerate with the unknown composition of the primary beam, interaction models can be tested using data such as the depths of the maxima of the longitudinal development of the showers or their muon content. Particular sensitivity to interaction models is achieved when several observables are combined. Moreover, using careful data selection, proton-air cross section at the c.m.s. energy of 57 TeV per nucleon-nucleon pair can be obtained.

Recent results from Belle

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for the Belle Collaboration

Recent results from the Belle experiment will be presented, using the full data sample of Belle, corresponding to 772 million $B\bar{B}$ pairs. Special emphasis is given to precise measurements on CP violation and tests of CPT invariance. The presentation will also include new data on T violation and complementary measurements from other world data.

Generalized Beth–Uhlenbeck approach to mesons and diquarks in hot, dense quark matter

BLASCHKE, David[1], DUBININ, Aleksandr[1], BUBALLA, Michael[2]

[2]TU Darmstadt, [1]University of Wrocław

An important first step in the program of hadronization of chiral quark models is the bosonization in meson and diquark channels. This procedure is presented at finite temperatures and chemical potentials for the SU(2) flavor case of the NJL model. The thermodynamic potential is obtained in the gaussian approximation for the meson and diquark fields and it is given the Beth-Uhlenbeck form. This allows a detailed discussion of bound state dissociation in hot, dense matter (Mott effect) in terms of the in-medium scattering phase shift of two-particle correlations. It is shown for the case without meson-diquark mixing that the phase shift can be separated into a continuum and a resonance part. In the latter, the Mott transition manifests itself by a change of the phase shift at threshold by π in accordance with Levinson's theorem, when a bound state transforms to a resonance in the scattering continuum The consequences for the contribution of pionic correlations to the pressure are discussed by evaluating the Beth-Uhlenbeck equation of state in differen approximations. An outlook to the next step in the hadronization program is given: the introduction of baryons and "integrating out" the diquark fields.

Search for the ^{4}He-η bound state in $dd \to (^4\text{He-}\eta)_{bound} \to {}^3\text{He}n\pi^0$ and $dd \to (^4\text{He-}\eta)_{bound} \to {}^3\text{He}p\pi^-$ reactions with the WASA-at-COSY facility

SKURZOK, Magdalena[1], KRZEMIEŃ, Wojciech[1], MOSKAL, Paweł[1]

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for the WASA-at-COSY Collaboration

In 1986 Haider and Liu postulated a new kind of exotic nuclear matter - η-mesic nuclei in which the η meson is bound in a nucleus by means of the strong interaction [1]. However, till now there is no clear experimental evidence confirmed empirically its existence. In November 2010, the search for the ^{4}He-η bound state was performed with high statistics and high acceptance with the WASA-at-COSY detector [2].
The experimental method is based on the measurement of the excitation functions for the two reaction channels: $dd \to {}^3\text{He}n\pi^0$ and $dd \to {}^3\text{He}p\pi^-$ near the η production threshold. The measurement was carried out using a ramped beam technique. The beam momentum was varying continuously from

2.127 GeV/c to 2.422 GeV/c corresponding to the excess energy range $Q \in (-70, 30)$ MeV. The presentation will include description of the experimental method and next steps leading to determination of preliminary excitation functions from the 2010 data.

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Investigation of the structure of the few body Kaonic Nuclei using the method of hyperspherical functions in momentum space

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Kaonic three-body K^-NN, and of four-body K^-NNN and K^-K^-NN nuclei are studied within the method of hyperspherical functions in momentum representation, using realistic local and separable potential models for the nucleon-nucleon and kaon-nucleon interactions as well as for the kaon-kaon interaction. We solve nonrelativistic three- and four-body Schrodinger equation in momentum representation in the framework of the method of hyperspherical harmonics to find a ground state binding energy and corresponding wave function. The following ground-state binding energies were obtained: 48.3 MeV (K^-pp), 28.2 MeV (K^-K^-p), 67.2 MeV (K^-ppn), and 89.3 MeV (K^-K^-pp), which are in good agreement with previous results obtained for the same potentials using Faddeev equations and variational method. There are severe theoretical discrepancies relating to the binding energy of kaonic nuclei, coming from the different KN and KK interactions. For Argonne V18 potential NN separable and one channel (N. Shevchenko, Phys. Rev. C 85, 034001 (2012) separable potentials gives the binding energy 23.4 MeV (KNN). Using realistic AV4 NN (Wiringa, Pieper, Phys. Rev. Lett. 89, 182501, 2002) potential and energy dependent chiral KN and KK local potentials (Barnea et al, Phys. Lett. B 712, 132, 2012) we received the following results of the binding energies 13.9 MeV $(KNN)_{\frac{1}{2},0}$, 27.3 MeV $(KNNN)_{I=0}$ and 30.4 MeV $(K^-KNN)_{I=0}$. The results of our calculations are in agreement with results of Shevchenko and Barnea et al. The experimental evidences to support theoretical predictions are discussed.

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Search for the K^-pp bound state via the in-flight $^3\mathrm{He}(\mathrm{K}^-, \mathrm{n})$ reaction

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for the J-PARC E15 Collaboration

Over the last decade, kaonic nuclear states have been studied extensively. In particular, the simplest state, K^-pp, is widely discussed in terms of its binding energy and width, since such simplest state is quite sensitive to the $\bar{K}N$ interaction. There are various theoretical predictions of the K^-pp state at present, thus it is quite important to compare the theoretical calculations with experimental studies. However, the experimental situation is also controversial; the DISTO and FINUDA collaborations have claimed observations of the deeply-bound K^-pp state, while the HADES and LEPS groups recently reported null results of the K^-pp searches. Therefore, we need to investigate the K^-pp state in different reactions and to understand background process, such as multi-nucleon absorption processes of K^-.
In the J-PARC E15 experiment, the K^-pp search is performed via the $^3\mathrm{He}(K^-, n)$ reaction at 1.0 GeV/c. A forward-going neutron is detected by a neutron counter with 15 m flight length, and decay

particles from K^-pp are simultaneously measured by a cylindrical detector system that surrounds a liquid ^{3}He target system. In March and May, 2013, we carried out the first physics data-taking with 5x10^9 incident kaons on the ^{3}He target, and we have obtained the missing-mass spectrum of $^3\mathrm{He}(K^-, n)$ and the exclusive analysis result of $^3\mathrm{He}(K^-, \Lambda p)n$ reaction. We have also examined not only the expected $K^-pp \to \Lambda p$ decay but also multi-nucleon absorption processes of in-flight K^- by reconstructing the exclusive $^3\mathrm{He}(K^-, \Lambda p)n$ channel. In this talk, we present the latest analysis results of the first physics data of J-PARC E15.

New boundaries for the ppK^- production in $p+p$ collisions

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for the HADES Collaboration

The ppK^-, a well established state in theory, is a hot candidate for a new kind of hadronic matter. A type of matter where kaons are bound to nucleons. The HADES spectrometer at GSI provides ideal conditions to test the existence of this cluster of particles. HADES has recorded $p+p$ collisions at a beam energy of 3.5 GeV that we have analysed for events where a p, K^+ and Λ were produced in the final state. I will discuss how these three particles are connected to the ppK^- and how we tested the p, K^+, Λ events for the fingerprints of a possible ppK^- production.
In this talk, I will present how a partial wave analysis lead to the establishment of an upper limit of the production cross section of this cluster. We cannot confirm the findings of the DISTO collaboration at a lower beam energy of 2.8 GeV.

B_c mesons in the deconfined phase

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[1]Institute of Nuclear Physics PAS

Heavy charmonia and bottomonia in a deconfined quark-gluon plasma are studied by considering the B_c family of mesons. With the introduction of this bound state of a charm and a beauty quark at finite temperature the behavior of the quarkonium is investigated in an energy region between the ψ and the Υ states. Calculations are performed within a potential model.

Weak decays of $\bar{B}_s$ mesons

ALBERTUS-TORRES, Conrado[1]

[1]University of Granada

In this work we study the semileptonic decays of $\bar{B}_s$ mesons in the context of nonrelativistic constituent quark models. We estimate the uncertainties of our calculation using different interquark potentials to obtain the meson wave functions. We check the results from our model against the predictions of Heavy Quark Symmetry, in the limit of infinite heavy quark mass. We also study the nonleptonic decays of $\bar{B}_s$ mesons within the factorization approximation.

Dalitz-plot analysis of the $D^0 \to K^0_S\pi^+\pi^-$ decays in a factorization approach

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[1]Institute of Nuclear Physics PAS, [2]Laboratoire de Physique Nucleaire et de Hautes Energies

A quasi two-body QCD factorization is used to study the $D^0 \to K^0_S\pi^+\pi^-$ decay channel. Starting from the weak effective Hamiltonian, 28 tree and annihilation (W-exchange) amplitudes build up the full $D^0 \to K^0_S\pi^+\pi^-$ amplitude [1]. The meson-meson final state interactions are described by the kaon-pion and pion scalar and vector form factors for the S and P waves and by Breit-Wigner formulae for the D waves. Unitarity, analyticity and chiral symmetry are used to constrain functional forms of form factors and to group several resonances in a given partial wave. This, together with charge symmetry, allows to reduce the 27 non-zero amplitudes into 10 effective amplitudes depending on 33 free parameters. The presently available high-statistics Dalitz plot data of the $D^0 \to K^0_S\pi^+\pi^-$ process measured by the Belle and BABAR Collaborations are analyzed together with the $\tau^- \to K^0_S\pi^-\nu_\tau$ decay data. The total experimental branching fraction is also included in the fit which shows a very good overall agreement with the Dalitz plot density distribution. The branching fractions of the dominant channels compare well with those of the isobar Belle or BABAR models. We show that the lower-limit values of the branching fractions of the annihilation amplitudes are significant. Our $D^0 \to K^0_S\pi^+\pi^-$ decay amplitude could be a useful input for determinations of $D^0 - \bar{D}^0$ mixing parameters and of the Cabibbo-Kobayashi-Maskawa angle γ (or ϕ_3). Upon request, we can provide numerical values for our amplitudes.

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Exclusive production in CMS

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for the CMS Collaboration

Exclusive production has been proposed as a unique environment in which to study vector meson photoproduction, as well as light meson production via Double-Pomeron exchange. In this talk we present CMS measurements of photon-induced and Central Exclusive Production from Run 1 of the LHC. The results, based on up to 5 fb^{-1} of pp collisions collected at $\sqrt{s} = 7$ TeV, are compared to theoretical predictions and other experimental measurements.

Pseudoscalar transition form factors from rational approximants

SANCHEZ PUERTAS, Pablo[1]

[1]University of Mainz

Pseudoscalar Transition Form Factors are analyzed in the space-like region at the low- and intermediate-energy regions with rational approximants in a model-independent way. Low-energy parameters are, then, extracted from a fit to such data. The feasibility of the form factors to determine the η and η' mixing is analyzed as well as their implications into the light-by-light contribution to the anomalous magnetic moment and the pseudoscalar decays into a lepton pair.

Study of η meson production with polarized proton beam

OZERIANSKA, Iryna[1], MOSKAL, Paweł[1], ZIELIŃSKI, Marcin[1]

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for the WASA-at-COSY Collaboration

The dynamics of η meson production and the interaction of η mesons with nucleons can be studied using the $\vec{p}p \to pp\eta$ reaction via measurements of the analyzing power A_y. Previous experiments measuring A_y suffer from low statistics [1,2,3] and large uncertainities, therefore further studies are desirable. To this end, we have performed a measurement of the $\vec{p}p \to pp\eta$ reaction using the large acceptance and φ symmetric WASA-at-COSY detector, for beam momenta of 2026 MeV/c and 2188 MeV/c. Protons ejectiles were registered in the forward part of the WASA detector, while the η meson decay products (e.g. $\eta \to \gamma\gamma$) were detected in the central Electromagnetic Calorimeter. The polarization for each beam momentum has been determined using pp elastic scattering. Furthermore, in order to control systematic effects caused by potential asymmetries in the detector setup, the spin of the proton beam has been flipped for every accelerator cycle.
Systematic studies have been performed calculating the degree of polarization, which is different for spin up and spin down modes. The results of these studies show that the polarization is sensitive to the $x-$ and $y-$coordinate of the vertex position [4,5]. Moreover, it seems now possible to control the polarization determined from the $\vec{p}p \to pp$ reaction with a systematic error of about 1%.
In this talk we would like to present preliminary results of determination of the polarization for the $\vec{p}p \to pp$ reaction, and the status of the ongoing analysis of the $\vec{p}p \to pp\eta$ reaction.

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Non-perturbative pion dynamics for the $X(3872)$

BARU, Vadim[1], EPELBAUM, Evgeny[1], FILIN, Arseniy[1], HANHART, Christoph[2], MEIßNER, Ulf G.[3], NEFEDIEV, Alexey[4]

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We discuss the role of the non-perturbative pion dynamics on the near-threshold resonance X(3872) charmonium state, which is assumed to be an S-wave $D\bar{D}^*$ bound system [1,2]. The calculations are performed within the framework of coupled-channels Faddeev-type three-body equations for the $D\bar{D}\pi$ system in the $J^{PC} = 1^{++}$ channel. The πD interaction is parameterised via a D^* pole, and a three-body contact interaction is included to render the equations well defined. The strength of the contact term is adjusted such that the $X(3872)$ appears as a $D\bar{D}^*$ bound state 0.5 MeV below the neutral threshold. We discuss the contribution to the width of the $X(3872)$ from the $D\bar{D}\pi$ intermediate state treated non-perturbatively and compare it with different approximate treatments. Moreover, we explore the quark-mass dependence of the pole position of the $X(3872)$ state. We find that the trajectory of the $X(3872)$ depends strongly on the assumed quark-mass dependence of the short-range interactions which can be determined in lattice QCD calculations, see e.g. [3] for the first results.

[1] V. Baru et al., Phys. Rev. D 84, 074029 (2011)
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[3] S. Prelovsek and L. Leskovec, Phys. Rev. Lett. 111, 192001 (2013).

Analysis of the pion scalar form factor provides model independent values of $f_0(500)$ and $f_0(980)$ meson parameters

DUBNICKA, Stanislav[1], DUBNICKOVA, Anna Zuzana[2], LIPTAJ, Andrej[1]

[2]Comenius University, [1]Institute of Physics SAS

Starting from general considerations of the pion scalar form factor in elastic region, the parametrization of tangens of the S-wave isoscalar $\pi - \pi$ scattering phase shift is found to be rational function in the pion c.m. three-momentum variable q with real coefficients. As a result, this phase shift can achieve asymptotically either the value $\pi/2$ or 0, depending on the fact, if degree of the numerator is larger, or lower, than the degree of the denominator. An optimal description of the data on the S-wave isoscalar $\pi - \pi$ scattering phase shift reveals that asymptotically the phase shift achieves the value $\pi/2$. Taking into account this fact the phase representation of the pion scalar form factor with one subtraction is derived in the framework of the unitary and analytic approach. Substituting explicite form of the S-wave isoscalar $\pi - \pi$ scattering phase shift into the pion scalar form factor phase representation and calculating the corresponding integral by theory of residua, [1/4] Pade-type approximation of the pion scalar form factor in the pion c.m. three-momentum variable q is found, from which the $f_0(500)$ and $f_0(980)$ scalar meson parameters are determined in a model independent way.

Study of the processes $e^+e^- \to K^+K^-\pi^+\pi^-$, $K^+K^-\eta$ with the CMD-3 detector at e^+e^- collider VEPP-2000

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for the CMD-3 Collaboration

Since December 2010 the CMD-3 detector has taken data at the electron-positron collider VEPP-2000 at Novosibirsk. The collected data sample corresponds about 60 inverse picobarn of the integrated luminosity in the c.m. energy range from 0.32 up to 2 GeV. The preliminary results for the processes $e^+e^- \to K^+K^-\pi^+\pi^-$ and $e^+e^- \to K^+K^-\eta$ are presented. The cross sections of these processes are in agreement with BaBar results, but have better accuracy. It is shown that the several intermediate states give the contribution to the cross sections.

Light hadron production in experiments with the SND detector at the e^+e^- collider VEPP-2000

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for the SND-VEPP-2000 Collaboration

The experiments have been carried out with the SND detector at the VEPP-2000 e^+e^- collider in the energy range from 0.3 to 2 GeV. The cross sections for the processes $e^+e^- \to 3\pi$, 4π, $\omega\pi^0$, K^+K^-, $\eta\pi^+\pi^-$, ηK^+K^-, $\eta 3\pi$, $p\bar{p}$, $n\bar{n}$ have been measured. The measured cross sections are fitted in extended vector meson dominance model, giving parameters of excited vector meson states.

Measurement of the polarised Drell-Yan process at COMPASS

QUARESMA, Márcia[1]

[1]LIP

for the COMPASS Collaboration

The COMPASS experiment at CERN has been playing an important role in the studies of the spin content of the nucleon. The Semi-Inclusive Deep Inelastic Scattering (SIDIS) process gives access to the transverse momentum dependent parton distribution functions (TMDs) by the measurement of azimuthal asymmetries that have been studied in COMPASS and published in recent years. TMDs are also accessible by the transversely polarised Drell-Yan (DY) process which will be measured in COMPASS. This will be the first ever polarised DY measurement. The valence quarks region will be dominant due to the use of a negative pion beam at 190 GeV/c momentum impinging on a transversely polarised ammonia target. The QCD prediction that Sivers and Boer-Mulders TMDs change sign when accessed by SIDIS or by DY will be checked by the COMPASS measurement. The data taking is scheduled to start in the fall of this year. After one year of data collection, a statistical error below 2% in the azimuthal asymmetry related to the u quark Sivers function is expected. Details of the final experimental setup will be presented.

Central exclusive $\pi^+\pi^-$ production in $p\bar{p}$ collisions at $\sqrt{s} = 0.9$ and 1.96 TeV at the Tevatron

ŻUREK, Maria[1], ALBROW, Michael[2], ŚWIĘCH, Artur[3]

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for the CDF Collaboration

Exclusive central hadronic systems from hadron collisions result primarily from double pomeron exchange, and these have very restrictive quantum numbers: $I^G J^{PC} = 0^+(\text{even})^{++}$. This "quantum number filter" is a powerful tool for meson spectroscopy in the isoscalar sector, especially for glue-rich states. In addition it provides information on the nature of the pomeron.
We have measured exclusive $\pi^+\pi^-$ production in proton-antiproton collisions at $\sqrt{s} = 0.9$ and 1.96 TeV in the Collider Detector at Fermilab. We selected events with exactly two oppositely charged particles, assumed to be pions, in $|\eta| < 1.3$ with no other particles detected in $|\eta| < 5.9$. The central $\pi^+\pi^-$ was required to have rapidity $|y| < 1$. By requiring no other charged particles, these events are dominated by double pomeron exchange, which constrains the quantum numbers of the central state. The data extend up to $M(\pi^+\pi^-) = 5$ GeV/c^2, and show resonance structures attributed to the f_0 and f_2 mesons. We place upper limits on exclusive $\chi_{c0} \to \pi^+\pi^-$ and $\chi_{c0} \to K^+K^-$.
The data is valuable for light hadron spectroscopy, and understanding the pomeron in a region of transition between non-perturbative and perturbative QCD.

Exclusive central diffractive production of scalar, pseudoscalar and vector mesons

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We discuss exclusive central diffractive production of scalar ($f_0(980)$, $f_0(1370)$, $f_0(1500)$), pseudoscalar ($\eta, \eta'(958)$), and vector (ρ^0) mesons in proton-proton collisions. The amplitudes are formulated in terms

of effective vertices required to respect standard rules of Quantum Field Theory and propagators for the exchanged pomeron and reggeons [1]. Different pomeron-pomeron-meson tensorial (vectorial) coupling structures are possible in general. In most cases two lowest orbital angular momentum - spin couplings are necessary to describe experimental differential distributions [2]. We discuss differences between results of the "tensorial pomeron" and "vectorial pomeron" models. For the $f_0(980)$ and η production the reggeon-pomeron, pomeron-reggeon, and reggeon-reggeon exchanges are included in addition, which seems to be necessary at relatively low energies. The theoretical results are compared with the WA102 experimental data, in order to determine the model parameters. Correlations in azimuthal angle between outgoing protons, distributions in rapidities and transverse momenta of outgoing protons and mesons in a special "glueball filter variable", as well as some two-dimensional distributions are presented. For the ρ^0 production the photon-pomeron and pomeron-photon exchanges are considered. The coupling parameters of tensor pomeron and/or reggeon are fixed from the H1 and ZEUS experimental data of the $\gamma p \to \rho^0 p$ reaction. We present first predictions of this mechanism for $pp \to pp\pi^+\pi^-$ reaction being studied at COMPASS, RHIC, Tevatron, and LHC [3]. We analyse influence of the experimental cuts on integrated cross section and various differential distributions for pions. We compare the ρ^0 contribution with two-pion continuum [4]. We show that high-energy central production, in particular of pseudoscalar mesons, could provide crucial information on the spin structure of the soft pomeron. This is particularly clear for the coupling of the pomeron to particles carrying non-zeroth spin as ρ^0 meson for example.

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Constraints from leptoproduction of vector meson within different frameworks

BESSE, Adrien[1]

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Exclusive electroproduction of mesons have been the subject of many studies in the last years. I will focus on results obtained within kT-factorization where one can use models of dipole cross-sections and within the modified perturbative approach where one can test and constrain GPD models. I will present comparison of the different predictions obtained within these models with available data.

Description of hadrons with covariant quark model

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The covariant quark model is a successful tools for a unified description of the multiquark states (mesons, baryons, tetraquarks, ...) which is based on an effective quantum field approach to hadronic interactions. It is well suited to provide a theoretical framework in connection with existing or expected results from heavy quark factories. The model, its basic features and chosen results will be presented.

Feasibility studies for nucleon structure measurements with $\bar{P}$ANDA

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for the PANDA Collaboration

The $\bar{P}$ANDA detector is a multi-purpose experiment to be installed at the Facility for Antiproton and Ion Research (FAIR). It is currently under active development and will exploit the possibilities offered by the antiproton beam of 1.5 to 15 GeV/c that will be available at the High Energy Storage Ring (HESR) of FAIR. One of the many physics goals of $\bar{P}$ANDA is to explore the structure of nucleons by measuring, among other observables, the time-like electric $G_E\left(q^2\right)$ and magnetic $G_M\left(q^2\right)$ form factors of protons in $\bar{p}p \rightarrow\ e^+e^-$ reactions and the π-nucleon Transition Distribution Amplitudes (TDAs) in $\bar{p}p \rightarrow\ \pi^0 J/\psi,\ J/\psi \rightarrow\ e^+e^-$ reactions. The interpretation of the TDAs in terms of the pionic content of the nucleon wave functions will be discussed. The low cross section of these processes combined with much higher background cross section from multi-pion events impose an excellent electron identification with the ability to reject charged pions by up to a factor of 10^4 as a major design requirement for $\bar{P}$ANDA.
Simulation studies in the PANDAROOT framework to explore the level of rejection that is achievable on the $\pi^0\pi^+\pi^-$ as a background to the $\pi^0 J/\psi$ channel, will be presented. Since the main electron identification technique in the relevant momentum range is energy-momentum matching, not only does this imply the need for high acceptance high resolution calorimetery, but also the highest possible precision of momentum reconstruction. A special algorithm for the momentum reconstruction reducing the degrading effect of Bremsstrahlung in the detector material will be presented. In addition the simulations used to study the feasibility of these reactions need to be accurate to within the tolerance allowed for pion rejection. A systematic check of GEANT hadronic physics models to investigate the sensitivity of the background rejection studies to the choice of models will also be covered.

Extracting excited mesons from the finite volume

DORING, Michael[1]

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As quark masses come closer to their physical values in lattice simulations, finite volume effects dominate the level spectrum. Methods to extract excited mesons from the finite volume will be discussed, like moving frames in the presence of coupled channels. Effective field theory can be used to stabilize the determination of the resonance spectrum.

Different approaches to calculate the $K^\pm \rightarrow \pi^\pm\ \pi^0\ e^+e^-$ decay width

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[1]Joint Institute for Nuclear Research

The rare $K^\pm \rightarrow \pi^\pm\pi^0 e^+e^-$ decay, currently under analysis by the NA62 Collaboration, is considered. We have performed two theoretical approaches to calculate the differential decay width - in the kaon rest frame, where we use Cabibbo-Maksimovicz variables, and in the center-of-mass system of the lepton pair. The latter essentially simplifies the computations. A comparison between the two approaches has been performed. We have also found the dependencies of the differential decay rate as a function of the virtual photon and dipion system masses.

Searching a dark photon with HADES

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for the HADES Collaboration

The existence of a photon-like massive particle, the γ' or dark photon, is postulated in several extensions of the Standard Model. These models are often advocated to explain some recent puzzling astrophysical observations, as well as to solve the sofar unexplained deviation between the measured and calculated values of the muon anomaly. The dark photon, unlike conventional photon, would have mass and would be detectable via its mixing with the latter.
We present a search for the e^+e^- decay of such a hypothetical dark photon, also named U vector boson, in inclusive dielectron spectra measured by HADES in the p (3.5 GeV) $+p$, Nb reactions, as well as the Ar (1.756 GeV/u) + KCl reaction. An upper limit on the kinetic mixing parameter squared ϵ^2 at 90% CL has been obtained for the mass range M(U) = 0.02 - 0.55 GeV/c^2 and is compared with the present world data set. For masses 0.03 - 0.1 GeV/c^2, the limit has been lowered with respect to previous results, allowing to exclude a large part of the parameter region favored by the muon $g-2$ anomaly. Furthermore, an improved upper limit of $2.3 \cdot 10^{-6}$ at 90 % CL on the branching ratio has been set on the branching ratio of the helicity-suppressed direct decay of the η meson, $\eta \to e^+e^-$.

B decays with leptons: powerful probes of New Physics with BaBar data

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B decays with leptons in the final states are in general affected by small theoretical uncertainties and have quite clean experimental signatures. These makes the semileptonic $B \to Xl\nu$ and $B \to Xll$ channels extremely interesting to search for physics beyond the Standard Model directly through the effect that new particles can give to some of these channels or indirectly through the clean measurements of the magnitude of the CKM matrix elements V_{cb} and V_{ub} that are crucial constraints in all the existing CKM fitters. We present results obtained with the full data set of about 470 millions B meson pairs recorded by the BABAR experiment at the PEP-II e^+e^- storage ring. In particular we report on studies of B-meson decays in inclusive and exclusive penguin decays $B \to Xl^+l^-$, that are sensitive to new heavy particles in the loops. We also cover the most recent semileptonic B decays $B \to Xl\nu$ that allow to extract the magnitude of the V_{ub} and V_{cb} CKM parameters. We will also present new results on the SM forbidden $B \to Xl^+l^+$ that put strong constrain on the presence of heavy Majorana neutrinos. Last but not least the leptonic and semileptonic decays with taus allow to put constraint on the charged Higgs masses and couplings that are competitive with the direct search at the LHC experiments. We will review the most recent results.

Testing fundamental physical principles with entangled neutral K mesons

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The neutral kaon doublet is one of the most intriguing systems in nature. Entangled pairs of neutral K mesons produced in ϕ decays offers a unique possibility to perform very precise tests of fundamental

discrete symmetries in nature, as well as of basic principles of quantum mechanics. The most recent results will be reviewed and perspectives in the field will be discussed.

Search for a new light boson in η meson decays

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Present low energy experiments do not exclude the existence of a new light ($M < 1$ GeV) particle with a small coupling to leptons. It can manifest in the decays of mesons with electron-positron pair(s) in the final state. We present here some results from the search for the very rare $\eta \to e^+e^-$ decay obtained using the WASA detector at COSY as well as a feasibility study for $\eta \to \pi^0 + A' \to \pi^0 + e^+e^-$ based on the data collected in the same experiment. The present status of the experimental search for the new light boson will be presented.

Mixing and CP violation in the B_s system with ATLAS

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The different amplitudes contributing to the decay of B_s into $J/\psi\ \phi(\mu^+\mu^-K^+K^-)$ can be studied with a combined analysis of decay time and angular correlations. An analysis based on data collected in 2011 and with inital B-meson flavour tagging is presented, improving the accuracy in the CP-violating phase ϕ_s compared to the untagged analysis.

5 Tuesday

Overview of ALICE results

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ALICE is a dedicated experiment for measurements of heavy-ion collisions at the Large Hadron Collider (LHC). A wealth of experimental data recorded in 2010, 2011 and 2012 suggests that a strongly interacting de-confined medium is created in collisions of lead ions at a centre-of-mass energy $\sqrt{s_{\rm NN}}$ = 2.76 TeV. In order to quantify the properties of this hot and dense matter, measurements were performed in smaller systems, such as proton-proton and proton-lead, where effects related to the medium are expected to be negligible. We present an overview of recent measurements of particle production and particle correlations in proton-proton, Pb–Pb and p–Pb collisions at the LHC by ALICE Collaboration.

Heavy meson production and spectroscopy at CMS

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CMS experiment accumulated 20 fb^{-1} and 5 fb^{-1} of proton-proton collision data at $\sqrt{s} = 8$ TeV and $\sqrt{s} = 7$ TeV in Run I. We have analyzed these data and produced fruitful results on heavy meson production and conventional and exotic meson spectroscopy. This talk will present new results from CMS covering J/Ψ, Υ cross section and polarization measurements, B_c branching fraction measurement, $X(3872)$ cross section measurement, observation of $Y(4140)$, search for $X_b \to \Upsilon(1S)\pi\pi$, as well as other new results to date.

Hadron production and bottomia suppression at the LHC

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Hadron production in heavy-ion collisions at the LHC through gluon-gluon and gluon-valence quark collisions can be described in various microscopic and macroscopic models. Here I use a phenomenological three-sources approach that allows to precisely account for the charged-hadron pseudorapidity distributions measured by the ALICE collaboration in Pb-Pb collisions as function of centrality at the current c.m. energy of 2.76 TeV, and make predictions at the design energy of 5.52 TeV. The

three-sources model also describes the asymmetric charged-particle distributions recently measured in proton-lead collisions at 5 TeV [1] where it provides a prediction [2] at large pseudorapidities $|\eta| > 2$. As a sensitive probe for the quark-gluon plasma that is likely created in heavy-ion collisions at RHIC and LHC energies, heavy quarkonia and in particular, the Υ meson as observed by CMS [3] have proven to be a very useful tool. Here it is suggested that the combined effect of gluon-induced dissociation, collisional damping, screening, and reduced feed-down explains [4] most of the suppression of Upsilon states that has been observed [3] in Pb-Pb relative to pp collisions at $\sqrt(s_{NN}) = 2.76$ TeV at the CERN LHC. The suppression is thus a clear, albeit indirect, indication for the presence of a Quark-Gluon Plasma.

[1] B. Abelev et al., ALICE Collab., Phys. Rev. Lett. 110, 032301 (2013).
[2] G. Wolschin, J. Phys. G 40, 045104 (2013).
[3] S. Chatrchyan et al., CMS Collab., Phys. Rev. Lett. 107, 052302 (2011); 109, 222301 (2012).
[4] F. Nendzig and G. Wolschin, Phys. Rev. C87, 024911 (2013), and submitted to J. Phys. G.

Recent ATLAS results in the field of meson physics

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for the ATLAS Collaboration

Recent results on flavor physics are presented, using data from the ATLAS detector. The $\Upsilon(nS)$ and charmonium inclusive production cross-sections are discussed. J/Ψ production associated with a W vector boson is presented. An inclusive analysis of the $B(u)$ meson production is shown. Results on the production of heavy quarkonia are complemented by the measurement of inclusive phi meson production. The latest information on heavy flavor spectroscopy and searches for new physics using B-meson rare decays is also covered. These results are based on data samples collected during the 2011 and 2012 LHC running periods.

η meson production in proton-deuteron collisions

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Since many years the strong final state interaction between eta mesons and light nuclei and the discussed possibility for the formation of η-mesic nuclei has attracted broad experimental and theoretical investigations. Prominent examples are production experiments on the ^{3}He$-\eta$ final state which present an unexpected strong total cross section enhancement at threshold, indicating the presence of a pole very close to threshold. Stimulated by these results new proton-deuteron collision experiments on the eta meson production have been performed in the near-threshold region and at higher excess energies using both polarized and unpolarized beams. Recent results will be presented and discussed in this talk.

Meson properties from mesic atoms and mesic nuclei

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Meson properties are believed to have close connection to the fundamental theory, QCD, and have been studied for a long time both theoretically and experimentally. In this talk, we study the recent research activities in this field and consider mainly the deeply bound pionic atoms and the $eta(958)$ mesic nuclei.
We report the new possibilities of the spectroscopic study of the pionic atoms using the (d,^{3}He) reactions. We consider the (d,^{3}He) reaction at finite angles to produce the atomic states with different angular momenta and on the odd-neutron nuclear target to produce the pionic states in the even-even nucleus which has a well-known neutron distribution. As for the $\eta(958)$ mesic nuclei, we summarize the recent research activities on the $\eta(958)$ meson property in nucleus and report the possible formation of the $\eta(958)$ mesic nuclei by the (p,d) reactions in detail.

Systematic studies of deeply-bound pionic atoms at the RIKEN RIBF facility

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[1]University of Tokyo

Spectroscopy of deeply-bound pionic atoms using the (d,^{3}He) reaction has been shown to be a powerful tool to study the pion in-medium modification. The 1s binding energies of medium-heavy pionic atoms can be related to the "partial restoration" of chiral condensate with the Tomozawa-Weinberg and the Gell-Mann-Oakes-Renner relations, as was demonstrated in our previous experiment carried out at GSI [1].
There remain however systematic errors in determining the magnitude of chiral condensate due to the uncertainties in the neutron-to-proton density difference near the nuclear surface.
At the RIKEN RIBF facility, systematic studies of deeply-bound pionic atoms are underway; we plan to explore a wider range of isotopes and isotones around the Sn region, so as to disentangle the QCD effect from the nuclear effect. Results of recent "pilot" experiment and near-future plans are presented.

[1] K. Suzuki, et al., Physical Review Letters 92, 072302 (2004); T. Yamazaki, et al., Physics Reports 514, 1 - 87 (2012).

Recent results and progress from LEPS and LEPS2 at SPring-8

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for the LEPS and LEPS2 Collaboration

We have been studying hadron physics by using a linearly polarized photon beam with energies up to 3 GeV at the Laser Electron Photon beamline at SPring-8 (LEPS). The photon beam is produced by the backward Compton scattering of laser photons off the 8-GeV electrons stored in the synchrotron radiation ring. In this talk, the recent results from the LEPS experiment are reported. We constructed a new beamline, LEPS2 and the first experiment was started in December, 2013. The recent status and future prospects at LEPS and LEPS2 are reported.