Central Exclusive Production of $\pi^+\pi^$ pairs in pp collisions at $\sqrt{s} = 200$ GeV

Jacek Turnau for the STAR Collaboration

Outline:

- Central Exclusive Production studies : physics motivation
- STAR detector at RHIC
- forward proton tagging at STAR
- selection of Central Exclusive Production events
- results
- summary and outlook



Central Exclusive Production (CEP)



□ our measurement : $p + p \rightarrow p + X + p \quad X : \pi^+ \pi^-$

□ colliding particles emerge intact

produced state X is fully measured

□ particular case : large rapidity gaps $\Delta y \approx \Delta \eta > 3 \rightarrow$ for hadronic processes, CEP = Double Pomeron Exchange (DPE), Pomeron : Regge trajectory with vacuum quantum numbers

 \Box DPE is a spin-parity-isospin filter I^GJ^{PC} for system X : 0⁺0⁺⁺,0⁺2⁺⁺...

□Diffractive photoproduction (γ +P) of vector particles (J/ Ψ , ρ ...)



Colliders : ISR, TEVATRON, RHIC, LHC, $M_{\chi} \sim \sqrt{s}$

□ LHC (> 2015) H, WW, ...

□ TEVATRON: high mass region < 100 GeV : heavy mesons production, perturbative QCD (Maria Żurek at Meson 2012)

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□ ISR, RHIC : low mass region :
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spectroscopy, glueball search

non-perturbative aspects of meson production



Physics motivation of CEP studies

Spectroscopy :

• understanding of scalar meson spectrum. CEP advantage : spin and isospin filter simplifies PWA

• general agreement that lightest glueball should be a scalar with mass in the range 1 - 2 GeV. In DPE its formation might be enhanced

Non-perturbative aspects of meson production:

L.A. Harland-Lang et al., The phenomenology of CEP at hadron colliders arXiv:1204.4803

➢ P.Lebiedowicz et al., Exclusive pp→ppπ⁺π⁻ reaction: From the threshold to LHC, Phys. Rev. D81(2010)036003

> R. Staszewski et al. Exclusive $\pi^+\pi^-$ Production at the LHC with Forward Proton Tagging, Acta Phys. Polon. B42(2011)1861)

P.Lebiedowicz, talk at Meson2012 CEP at STAR Meson2012





The STAR experiment at RHIC



Large acceptance detector running since 2000

- > high resolution tracking device : TPC -1 < $|\eta|$ < 1
- > particle identification capability : TPC dE/dx; TOF (not for data presented here)

Forward proton tagging



- roman pots with silicon strip detector for forward proton tagging
- staged implementation to cover wide kinematic range:
 - ➢ phase I (present data, 200 GeV, low momentum transfer ~0.003 < -t < ~0.03)</p>

> phase II (500 GeV, larger t coverage ~0.1 < -t < ~1.5, standard optics, large data samples)

RP Phase I (2009) at STAR detector



Horizontal and vertical RP for full φ coverage CEP at STAR Meson2012

Data selection

Data : polarized pp 100 + 100 GeV, run 9 (2009)

≻RP trigger

- two forward (diffractive) protons
- ✓ On each side of IP (East and West) ~ 100 GeV proton registered in RP
- ✓ non-collinear tracks : $\Delta \theta = \sqrt{(\theta_x^W \theta_x^E)^2 + (\theta_y^W \theta_y^E)^2} > 0.15$ mrad

two oppositely charged tracks in TPC

- **√** | η | <1
- ✓ > 14 hits/track
- ✓ p_T > 150 MeV

✓ From primary vertex

transverse momentum balance

$$p_T^{miss} = \left| (\overrightarrow{p_E} + \overrightarrow{p_W} + \overrightarrow{\pi^+} + \overrightarrow{\pi^-})_T \right| < 0.02 \text{ GeV} \quad \left| \overrightarrow{p_E} \right| \cong \left| \overrightarrow{p_W} \right| \cong 100 \text{ GeV}$$

Data selection

• partially selected sample: pp + two charged tracks (no $\Delta \theta > 0.15$ mrad)

• contains elastic pp→pp events with TPC track not belonging to the same interaction vertex, characterized by large fraction of 'like-sign' tracks (red curve)

 these 'overlap' events can be removed by requirement of TOF signal within bunch for central tracks at cost of statistics

transverse momentum balance cut very efficient in reduction of the 'overlap' events as well as the nonexclusive backgroud

• $\Delta \theta > 0.15$ mrad cut still needed to remove cosmics



Invariant mass of centrally produced $\pi^+\pi^-$

- p_T^{miss} < 0.02 GeV
- Δθ > 0.15 mrad
- $\left| dE/dx (dE/dx)_{\pi} \right| < 3\sigma$

Spectrum similar to the one published by AFS at ISR (1985):

- almost no like-sign background
- dominated by low invariant mass pairs < 1 GeV
- characteristic cross section drop ~1 GeV due to $f_0(980)$ in final state interaction



Summary and outlook

 \Box measurement of the central exclusive production of π + π - pairs in proton-proton collisions at 200 GeV using Roman Pot tagging of the diffractively scattered protons at very small momentum transfers has been shown

□ very small non-exclusive background, estimated by like-sign content of the two-pion sample, has been demonstrated

□ further studies of the 200 GeV CEP sample (cross section, interpratation of the measured spectrum) in progress

□ preparation for the analogous measurement at 500 GeV in 2013 in progress (30-40 times larger statistics, PWA possible)

□ plans for Phase II of the measurement (standard beam optics, very large statistics, various studies of non-perturbative QCD e.g. instanton search)

Backup slides

Acceptance for $pp \rightarrow pp\pi^+\pi^-$











- acceptance for small p_T diffractive protons (unlike ISR AFM experiment)
- acceptance (TPC+protton tagger) is
 ~flat in two-pion invariant mass

Acceptance studies for $pp \rightarrow pp\pi\pi$



AFS ISR 62 GeV CEP $\pi^+\pi^-$ inv. mass



AABCDHW ISR 62 GeV CEP $\pi^+\pi^-$ inv. mass



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ALICE LHC 7.0 TeV CEP $\pi^+\pi^-$ inv. mass





Fig. 1. Modulus of the pion scalar form factor Γ_1^n (solid line), obtained in our fit using the NLO a_i^p with $\kappa = 2$ GeV and for which the fitted parameter $c = (19.5 \pm 4.2)$ GeV⁻⁴, compared to that calculated in Ref. [37] using the Muskhelishvili-Omnès equations (double-dash dot line). The dash-dot line (for c = 15.3 GeV⁻⁴) and the dashed one (for c = 23.7 GeV⁻⁴) represent the variation of the Γ_1^n modulus when c varies within its error band.