η and η' mesons production at COSY-11

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on behalf of the COSY-11 collaboration

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MESON 2006, Ninth International Workshop on Meson Production, Properties and Interactions
Cracow, 9 – 13 June 2006

COSY-11 COLLABORATION

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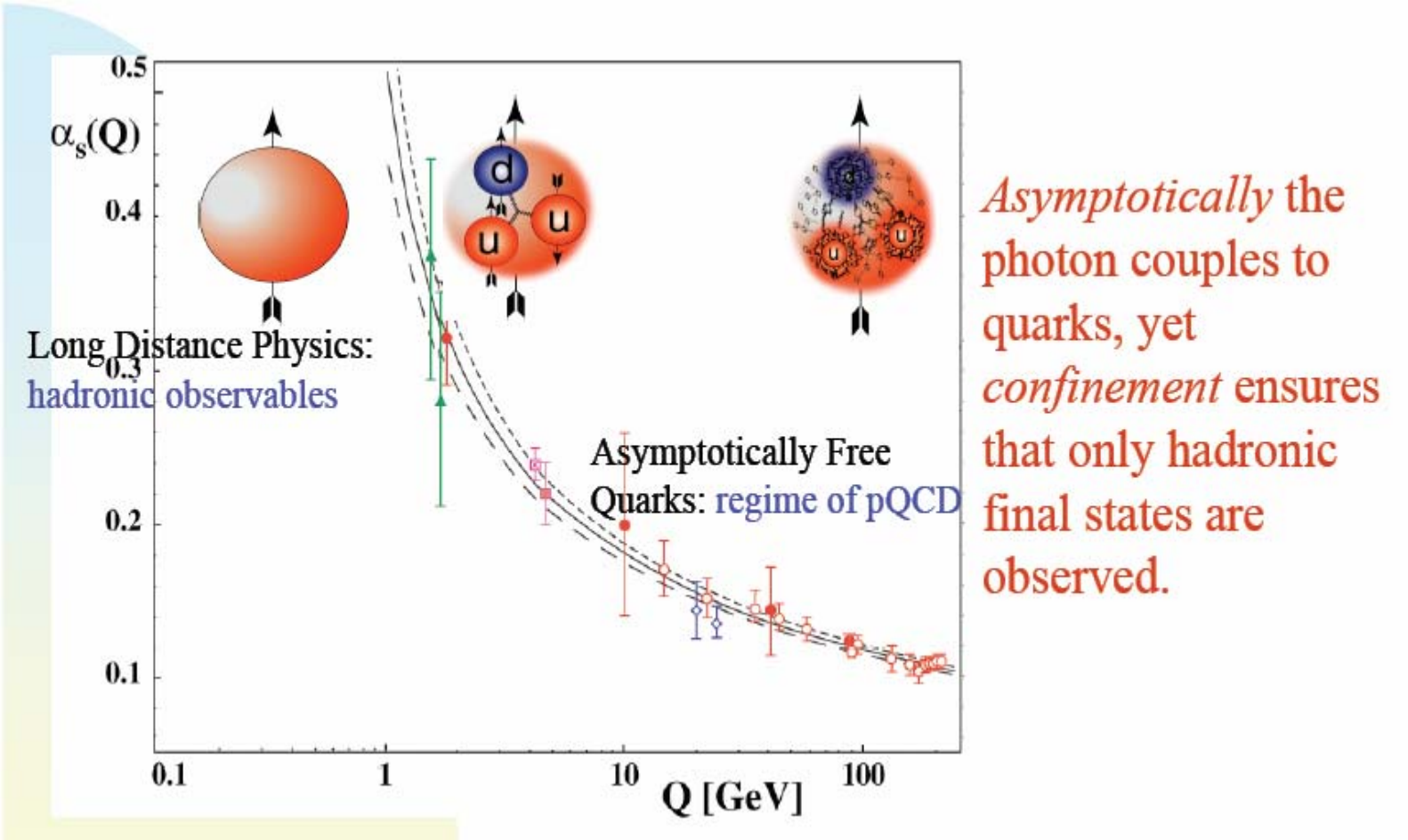
From Quarks to Hadrons



Asymptotically the photon couples to quarks, yet *confinement* ensures that only hadronic final states are observed.

- **Why are quarks confined within hadrons?**
- **How are hadrons constructed from their constituents?**
- **What is the relation of parton degrees of freedom and the low energy structure of hadrons?**
- **Do glueballs (ggg) and hybrids (qqg) exist?**
- **What is the origin of hadron masses ?**
- **How are hadrons modified when embedded in nuclei ?**
- **What is the role of chiral symmetry ?**

What are we trying to learn?

♣ Production mechanism of the η and η' mesons in NN collisions ?

Isovector meson (π, ρ, …) exchange …
Gluonic excitation…
Role of hadronic and quark-gluons degrees of freedom

♣ Nucleon-η' hadronic interaction ?

♣ What is the structure of the η and η' mesons ?

♣ Do the η-mesic nuclei exist ?

hadronic interaction ≡ effective interaction between hadrons caused by the strong interaction between quarks and gluons; constituents of hadrons

mesons η and η' ≡ flavour neutral quark-antiquark objects

$$\eta \sim u\bar{u} + d\bar{d} - 2s\bar{s}$$

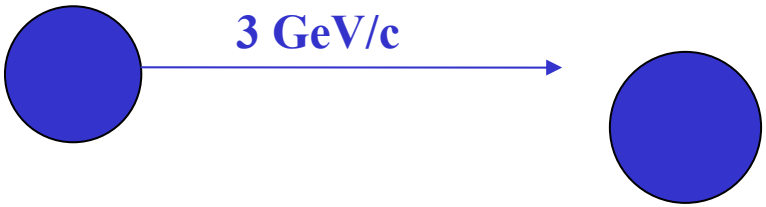
$$\eta' \sim u\bar{u} + d\bar{d} + s\bar{s} + \text{gluons}$$

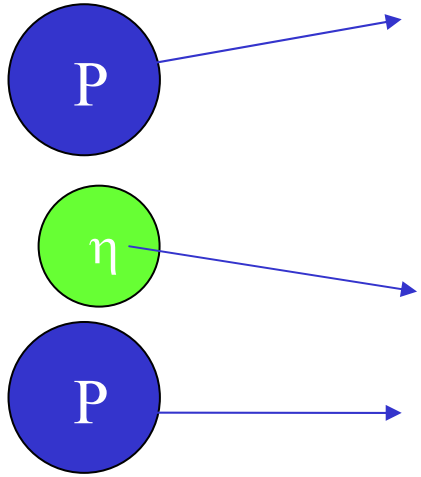
Due to the short life-time these mesons cannot move on the avarge more than few tens of femtometers.

proton - proton proton - deuteron deuteron – deuteron

proton - neutron

in the laboratory

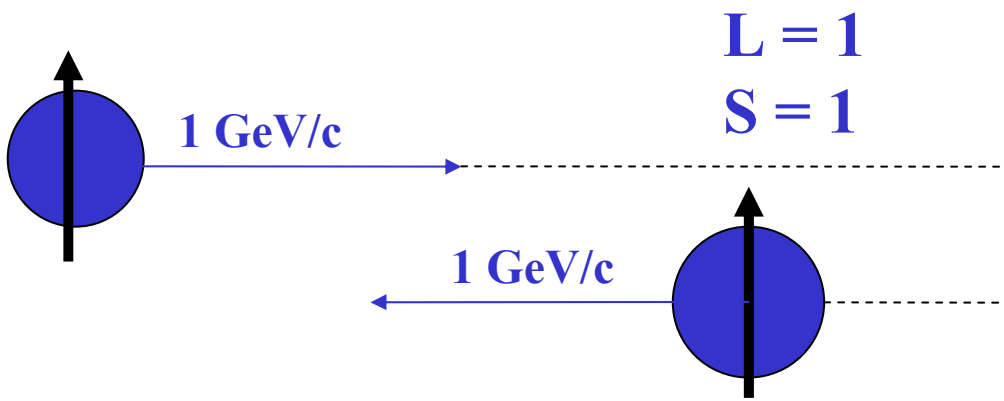


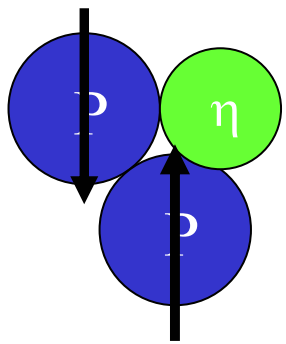


before reaction:

after reaction:

in the centre of mass system

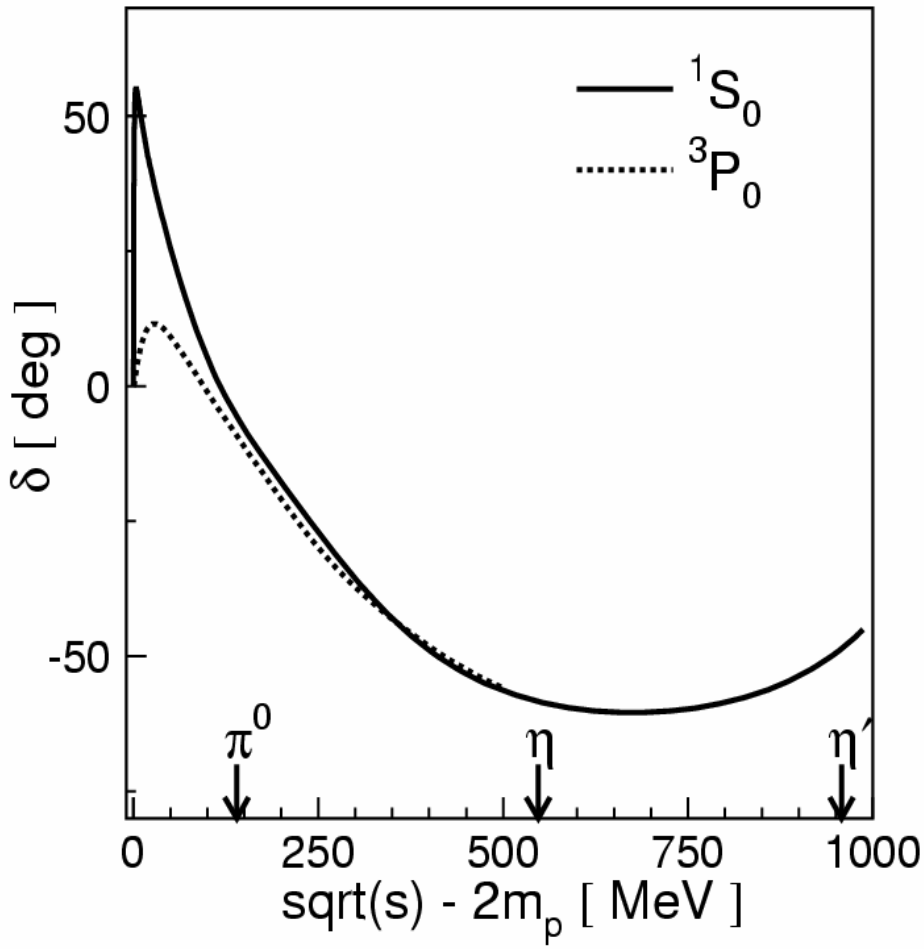




L = 0, l=0

$\Rightarrow$ **Reaction parameter b ~ 0.2 fm**

$^3P_0 \rightarrow {}^1S_0 s$


$^1S_0$
$^3P_0$
50
0
-50
δ [deg]
π⁰
η
η′
0
250
500
750
1000
sqrt(s) - 2m_p [MeV]

OBSERVABLES:

Close-to-threshold excitation function: σ (Q)

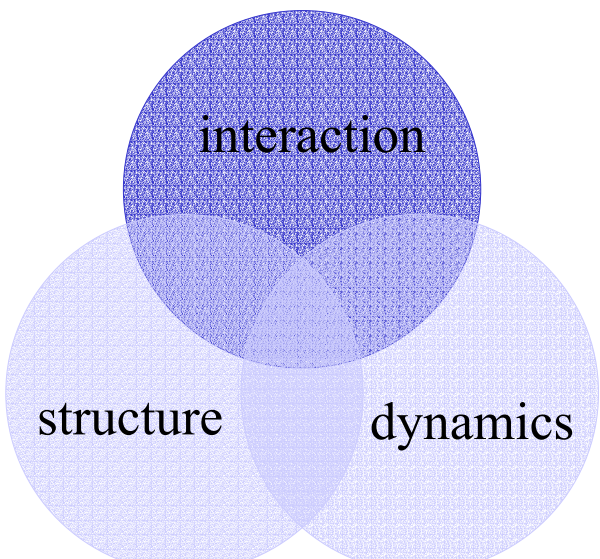
Differential distributions: $\frac{d\sigma}{dm_{pp}}$, $\frac{d\sigma}{d\Omega}$, ...

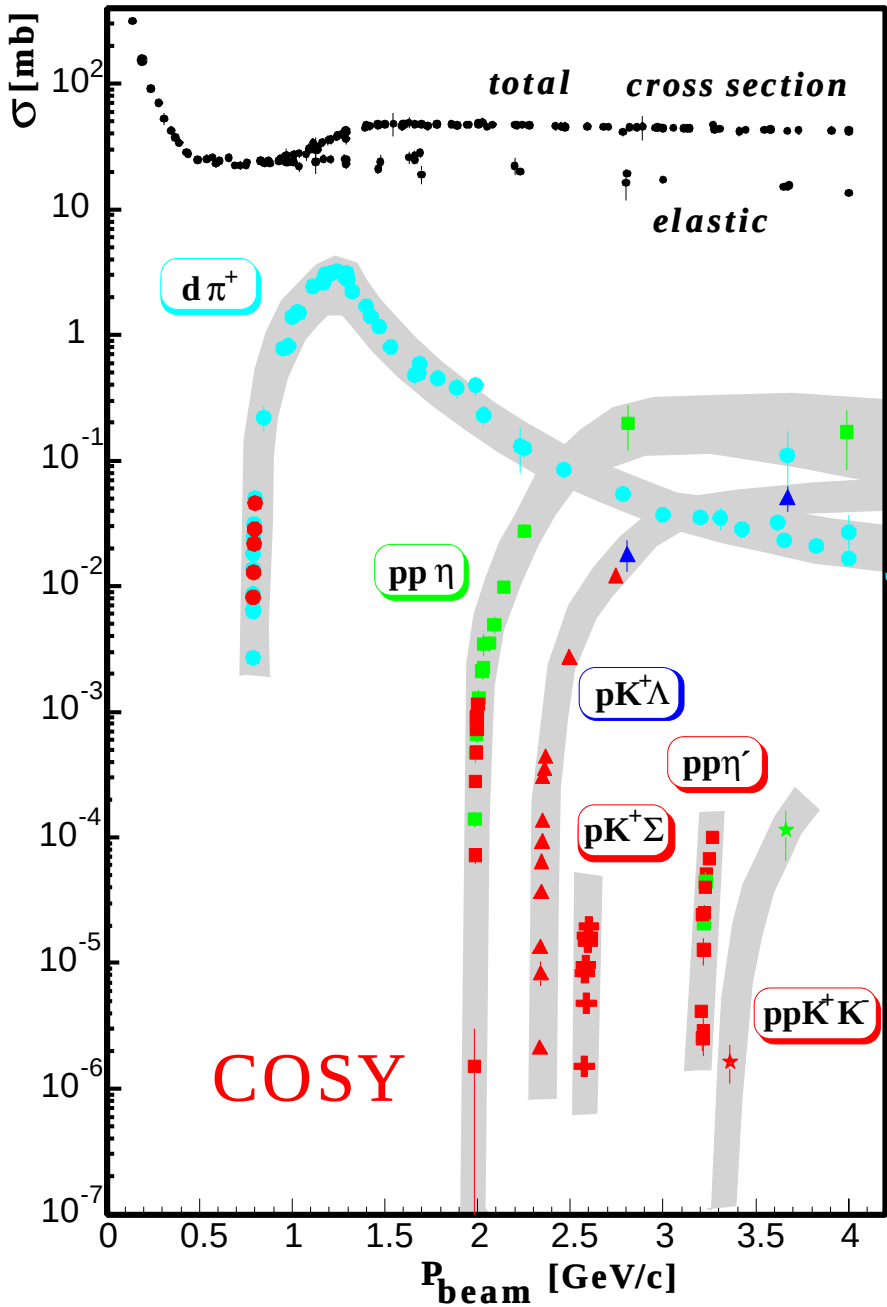
Isospin dependence

Spin observables: A_Y

$NN \rightarrow NN\eta'$

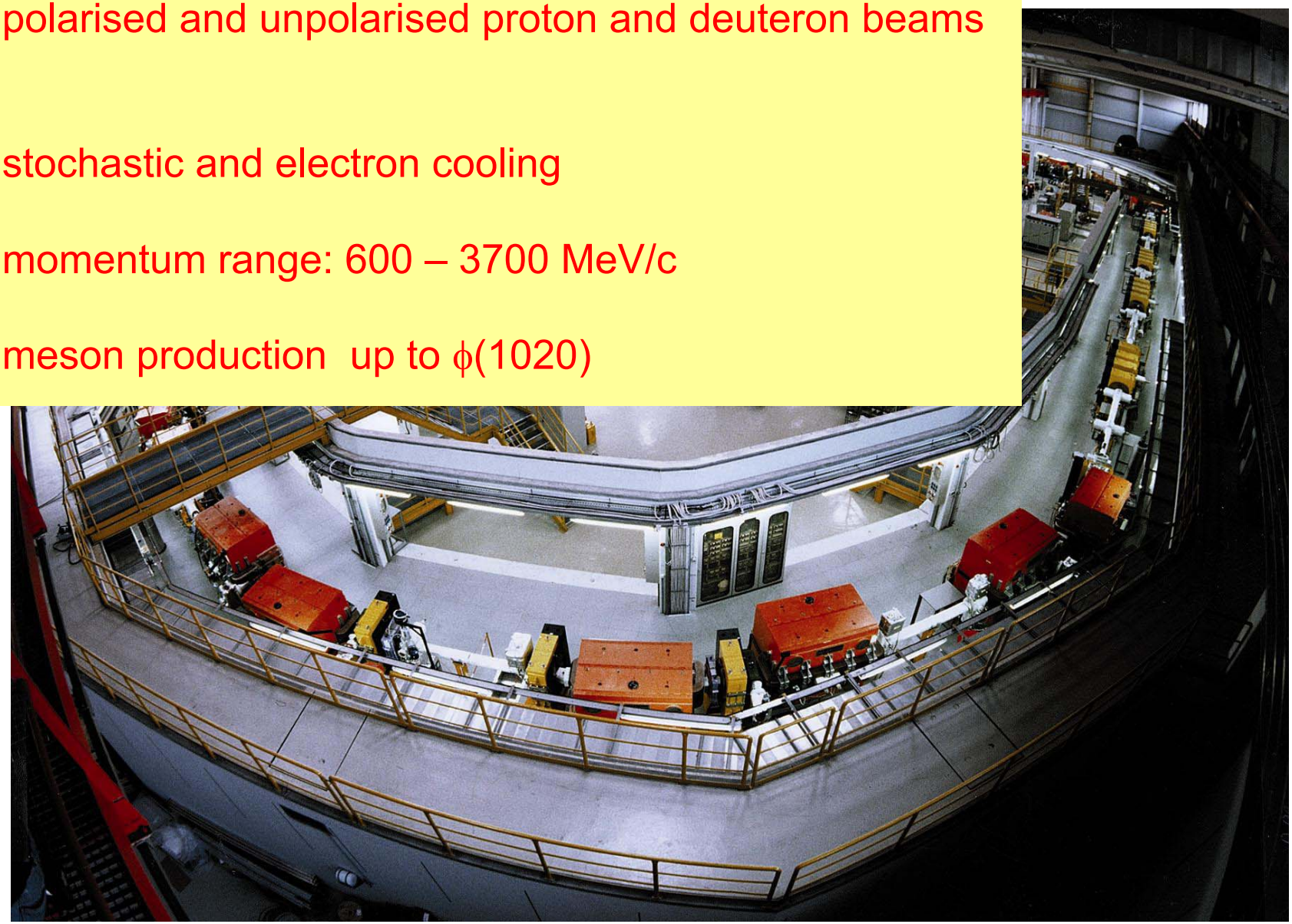
$NN \rightarrow NN\eta$



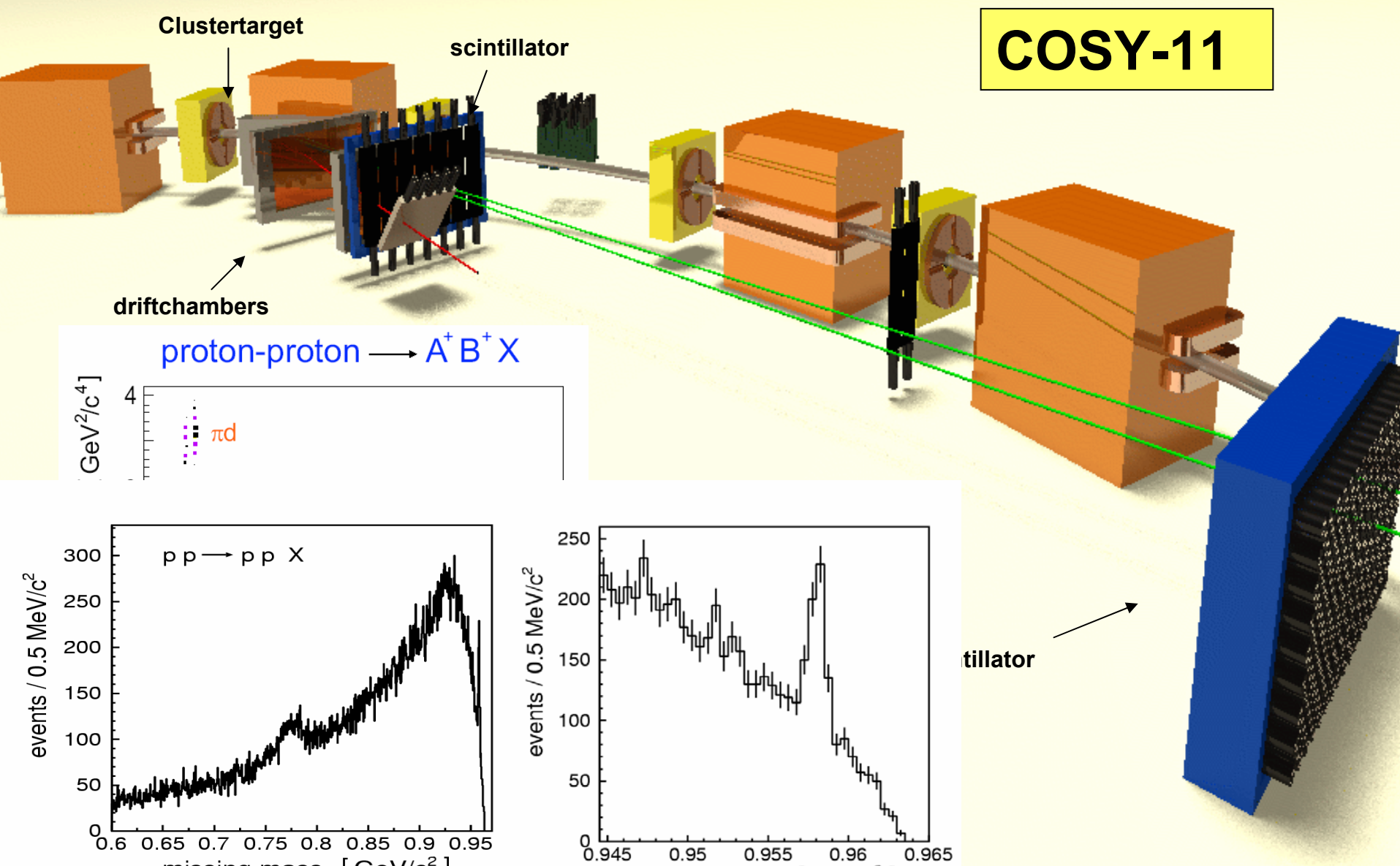


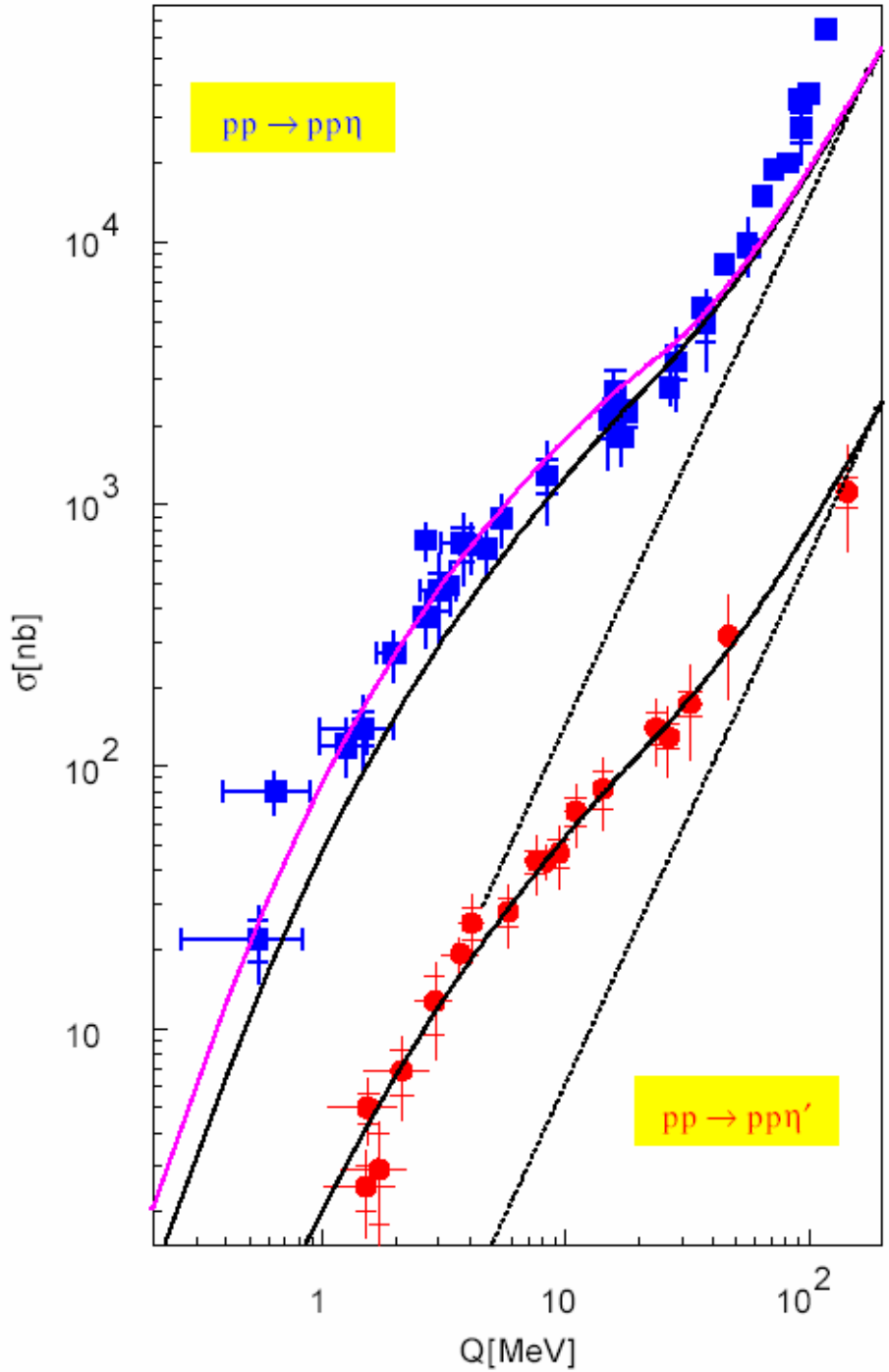
COoler SYnchrotron COSY

- polarised and unpolarised proton and deuteron beams
- stochastic and electron cooling
- momentum range: 600 – 3700 MeV/c
- meson production up to $\phi(1020)$



COSY-11


Clustertarget
scintillator
driftchambers
proton-proton → A⁺ B⁺ X
GeV²/c⁴
4
πd
p p → p p X
events / 0.5 MeV/c²
300
250
200
150
100
50
0
0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
missing mass [GeV/c²]
events / 0.5 MeV/c²
250
200
150
100
50
0
0.945 0.95 0.955 0.96 0.965
missing mass [GeV/c²]
tillator



$$\sigma = \frac{1}{F}\int dV_{ps}\,|M|^2$$

$$|M|^2 \sim |M_0|^2\,|M_{FSI}|^2$$

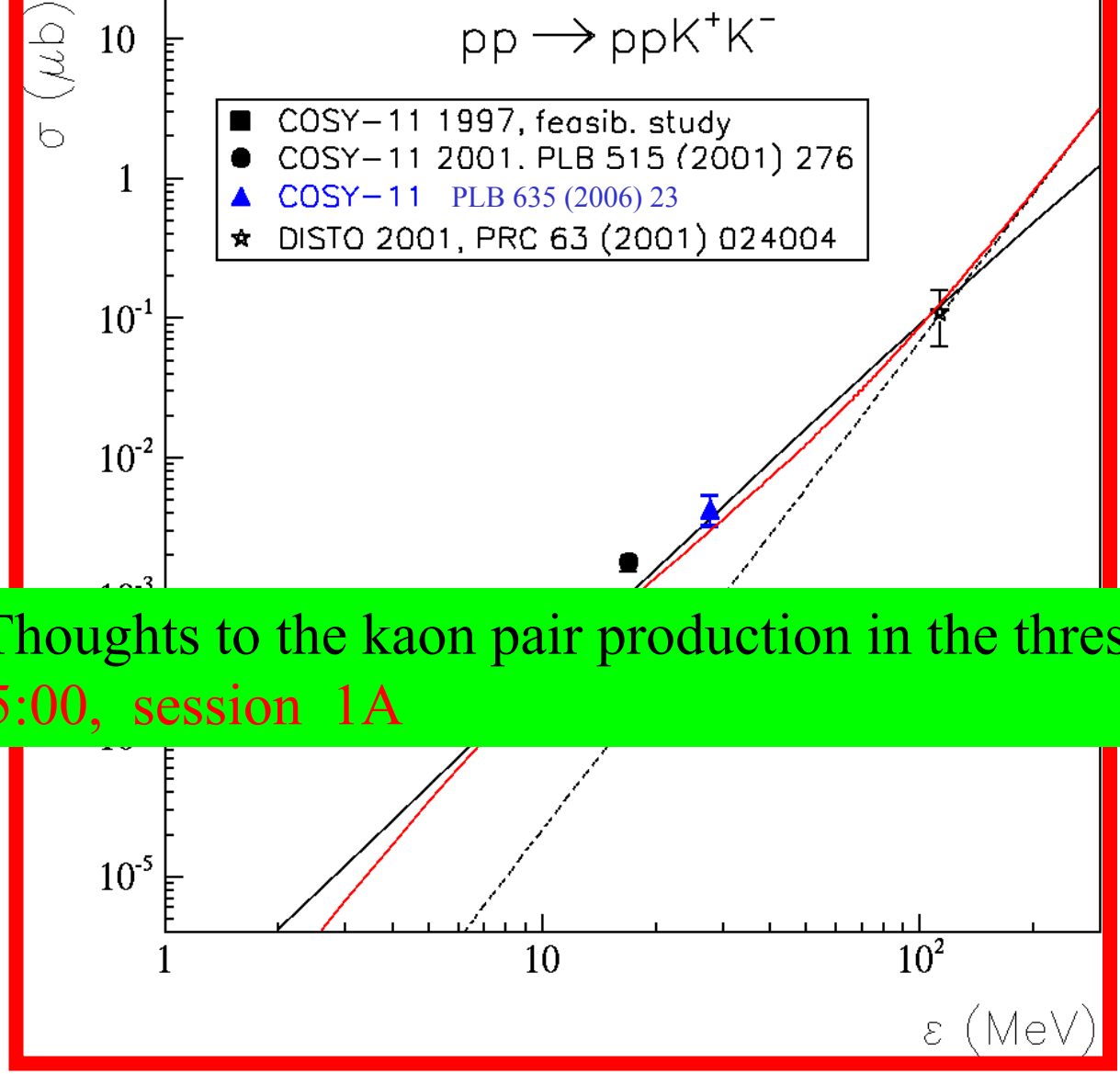
$$|M_{FSI}|^2 \sim |M_{pp}|^2\,|M_{p1\eta}|^2\;|M_{p2\eta}|^2$$

dynamics → $|M_0|^2$

interaction → $\sigma\,(Q)$

COSY-11: A. Khoukaz et al., Eur. Phys. J. **A 20** (2004) 345.
COSY-11: P. M. et al., Phys. Rev. **C 69** (2004) 025203.
COSY-11: P. M. et al., Phys. Lett. **B 482** (2000) 356.
COSY-11: P. M. et al., Phys. Lett. **B 474** (2000) 416.
COSY-11: J. Smyrski et al., Phys. Lett. **B 474** (2000) 182.
COSY-11: P. M. et al., Phys. Rev. Lett. **80** (1998) 3202.
WASA/CELSIUS: H. Calen et al., Phys. Lett. **B 366** (1996) 39.
WASA/CELSIUS: H. Calen et al.., Phys. Rev. Lett. **79** (1997) 2642.
DISTO/SATURNE: F. Balestra et al.., Phys. Lett. **B 491** (2000) 29.

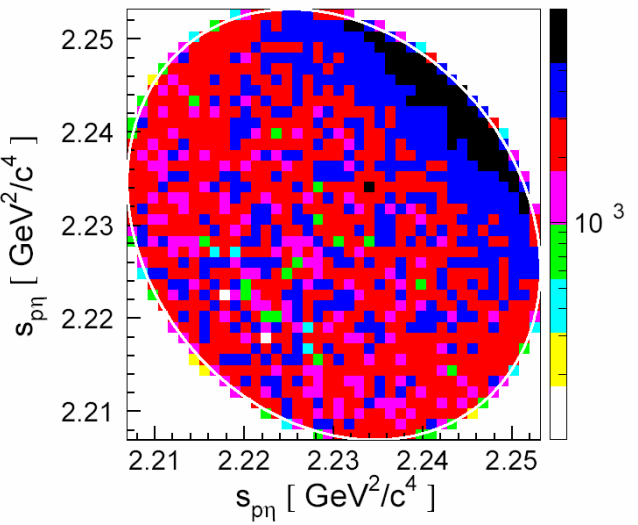
SPES/SATURNE: F. Hibou et al.., Phys Lett. **B 438** (1998) 41.
PINOT/SATURNE: E. Chiavassa et al.., Phys. Lett. **B 322** (1994) 270.
SPES/SATURNE: A. M. Bergdold et al.., Phys. Rev. **D 48** (1993) R2969.
SPES/SATURNE: R. Wurzinger et al.., Phys. Lett. **B 374** (1996) 283.



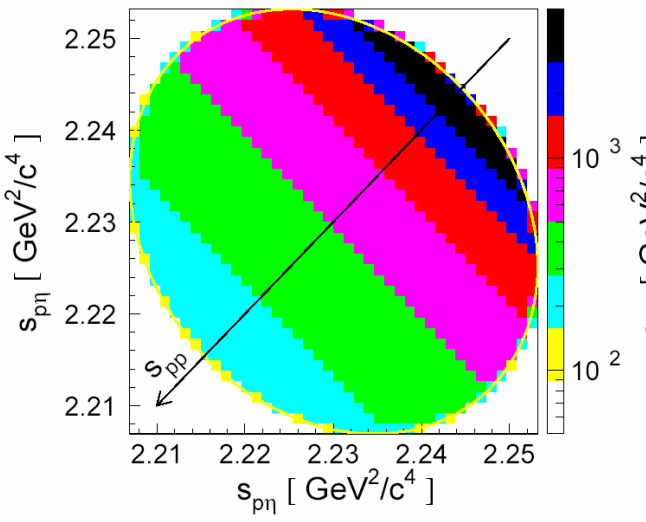
W. Oelert : Thoughts to the kaon pair production in the threshold region
Saturday, 15:00, session 1A

COSY-11: P. Winter et al., Phys. Lett. **B 635** (2006) 23.
COSY-11: C. Quentmeier et al., Phys. Lett. **B 515** (2001) 276.
DISTO: F. Balestra et al., Phys. Rev. **C 63** (2001) 024004.

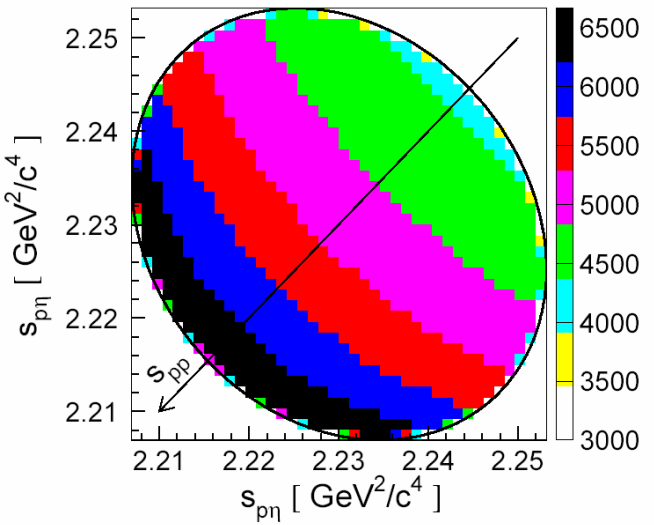
EXPERIMENT Q = 15.5 MeV



SIMULATION

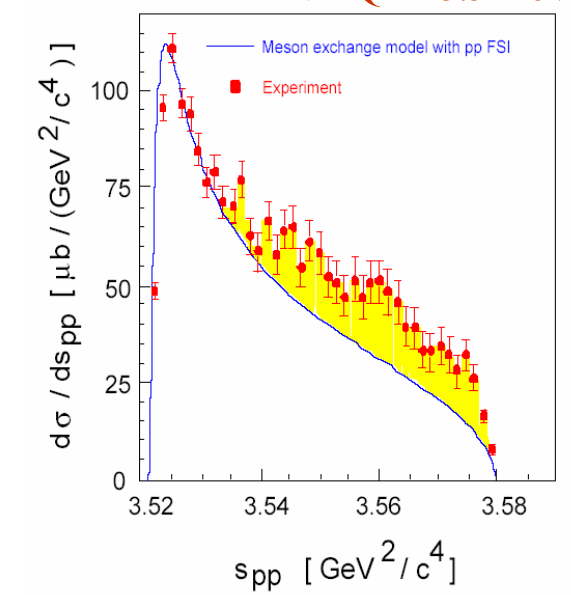


SIMULATION

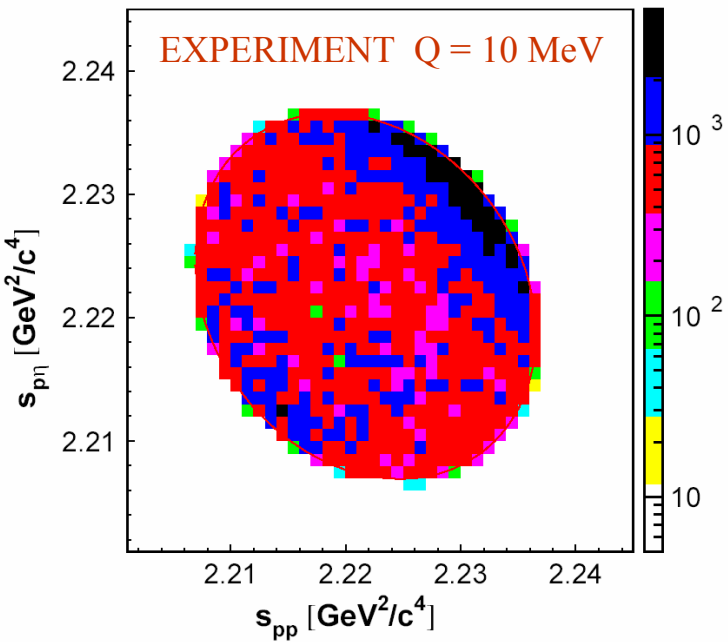


•COSY-11: P. M. et al., Phys. Rev. **C 69** (2004) 025203.

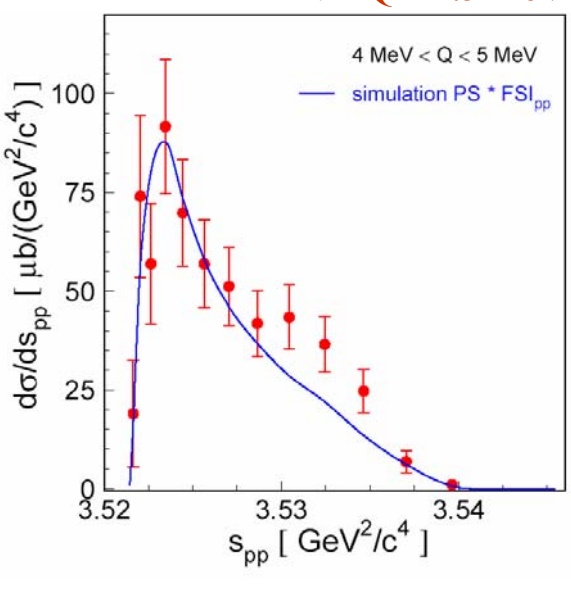
EXPERIMENT Q = 15.5 MeV



EXPERIMENT Q = 10 MeV

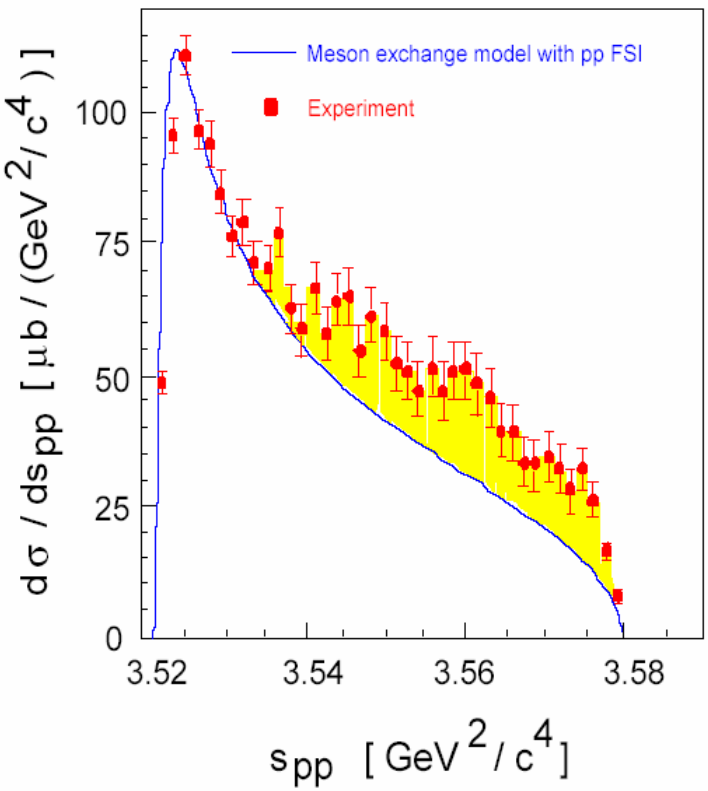


EXPERIMENT Q = 4.5 MeV



pp → ppη

EXPERIMENT Q = 15.5 MeV

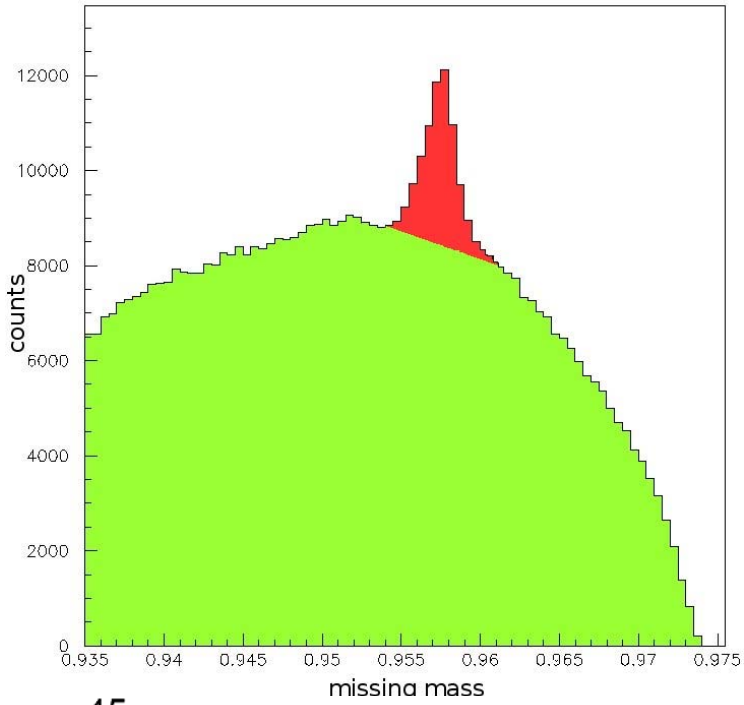


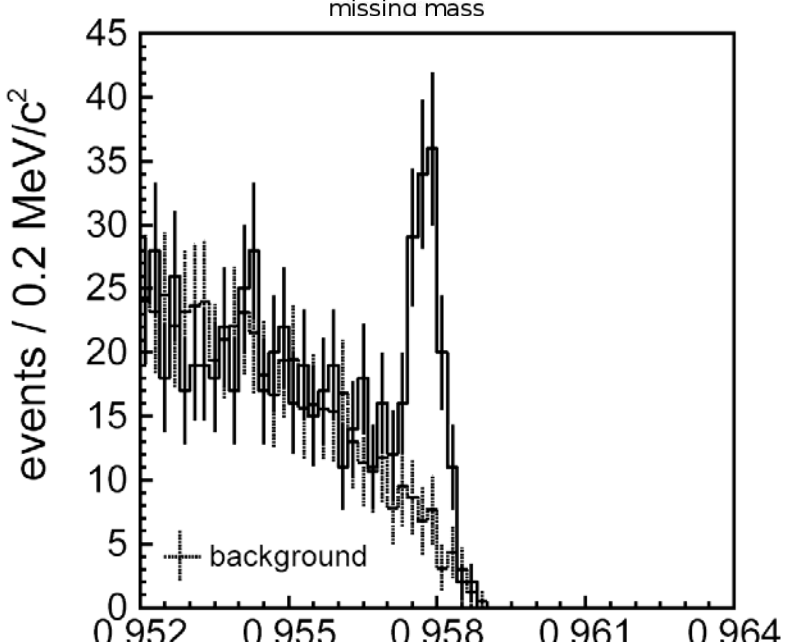
$$m_x^2 = E_x^2 - \vec{P}_x^2 = (E_{beam} + E_{target} - E_1^p - E$$

A precise measurem

pp → ppη'

EXPERIMENT Q = 15.5 MeV





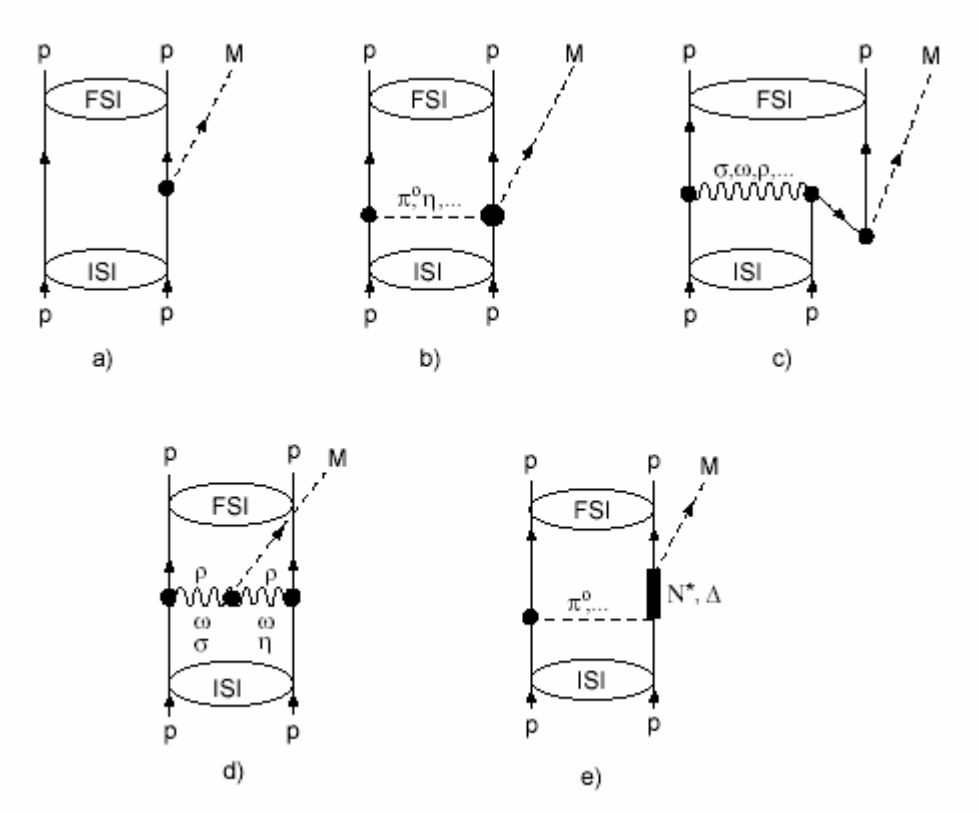
FSI

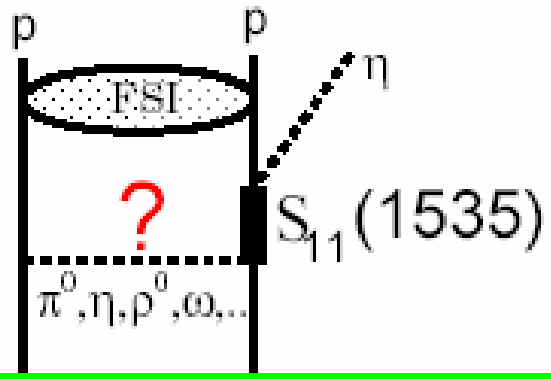
DYNAMICS

SPIN and ISOSPIN observables

Production of the η meson in the few nucleon system

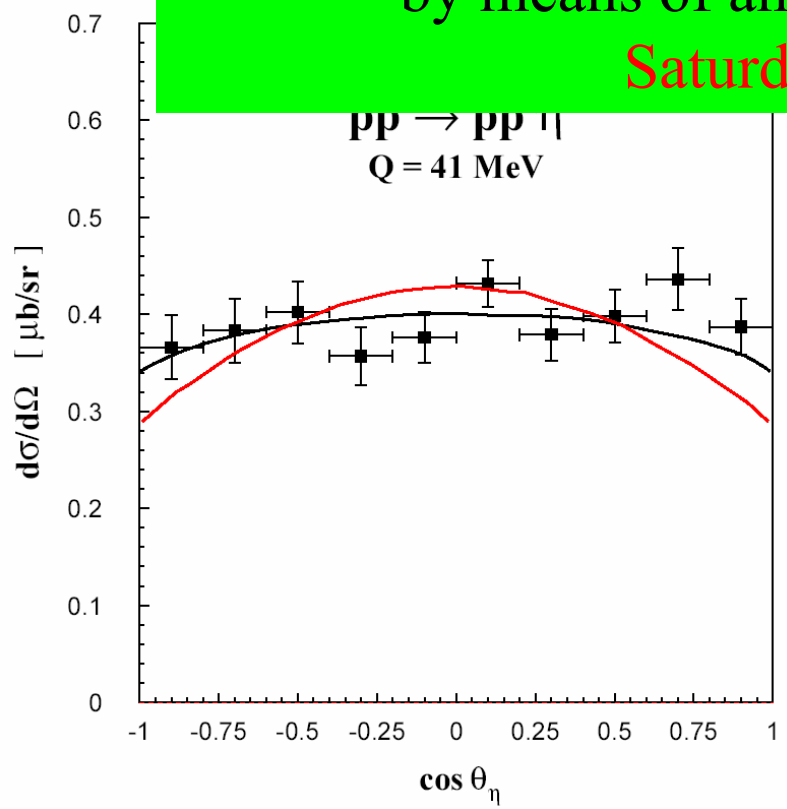
dynamics → $|M_0|^2$

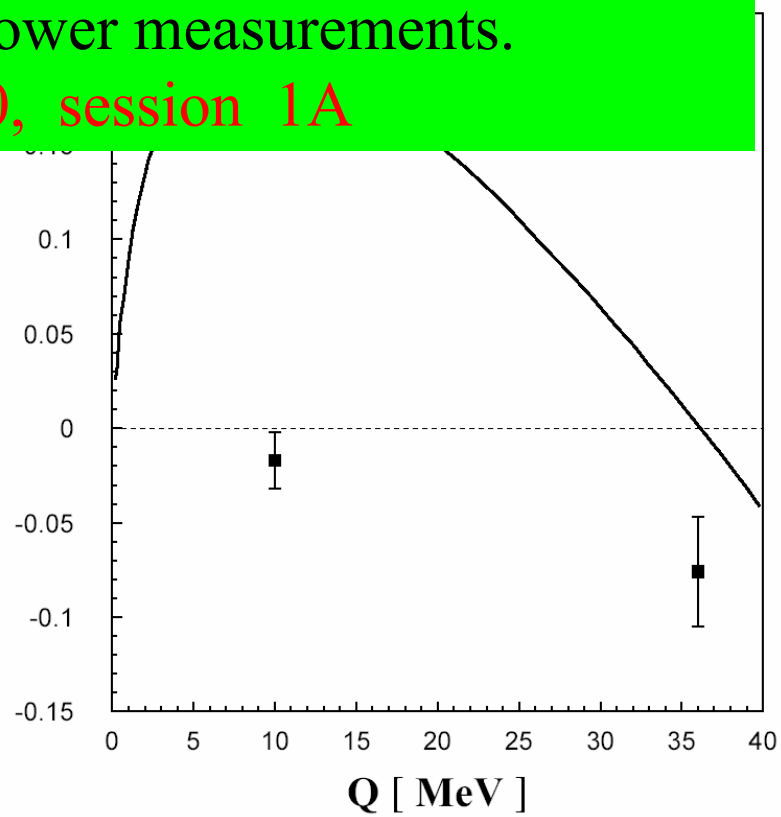


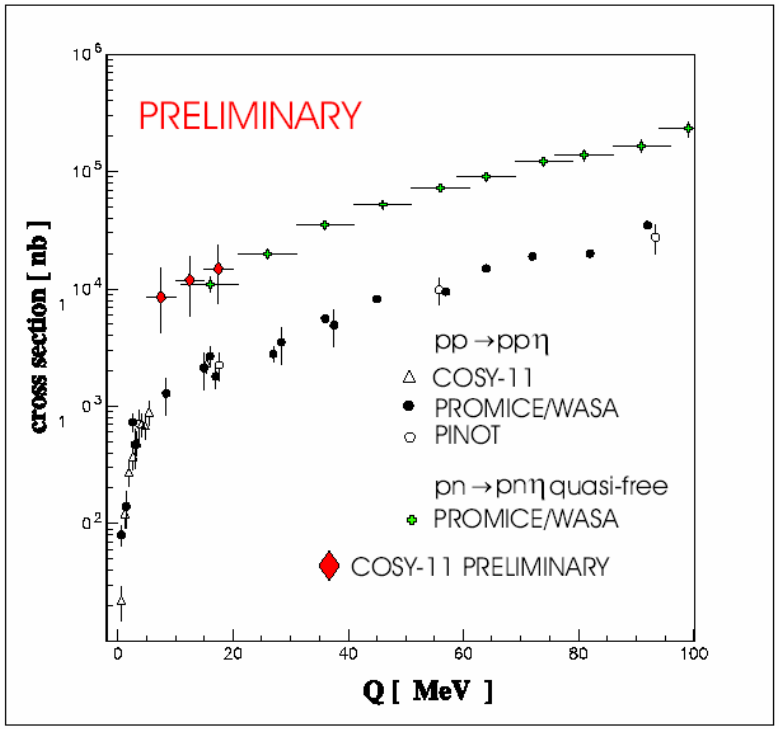


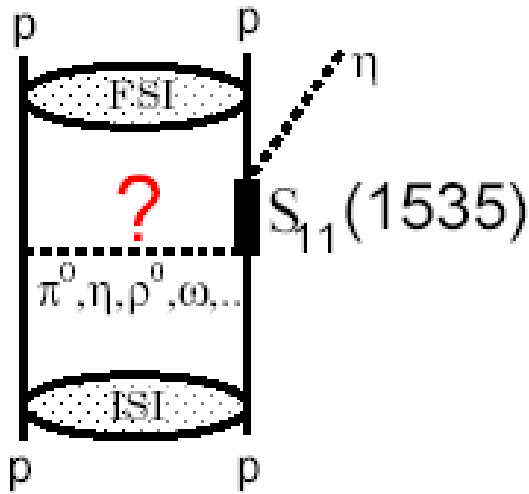
Spin degrees of freedom

Rafał Czyżykiewicz:
Study of the production mechanism of the η meson by means of analyzing power measurements.
Saturday, 16:50, session 1A



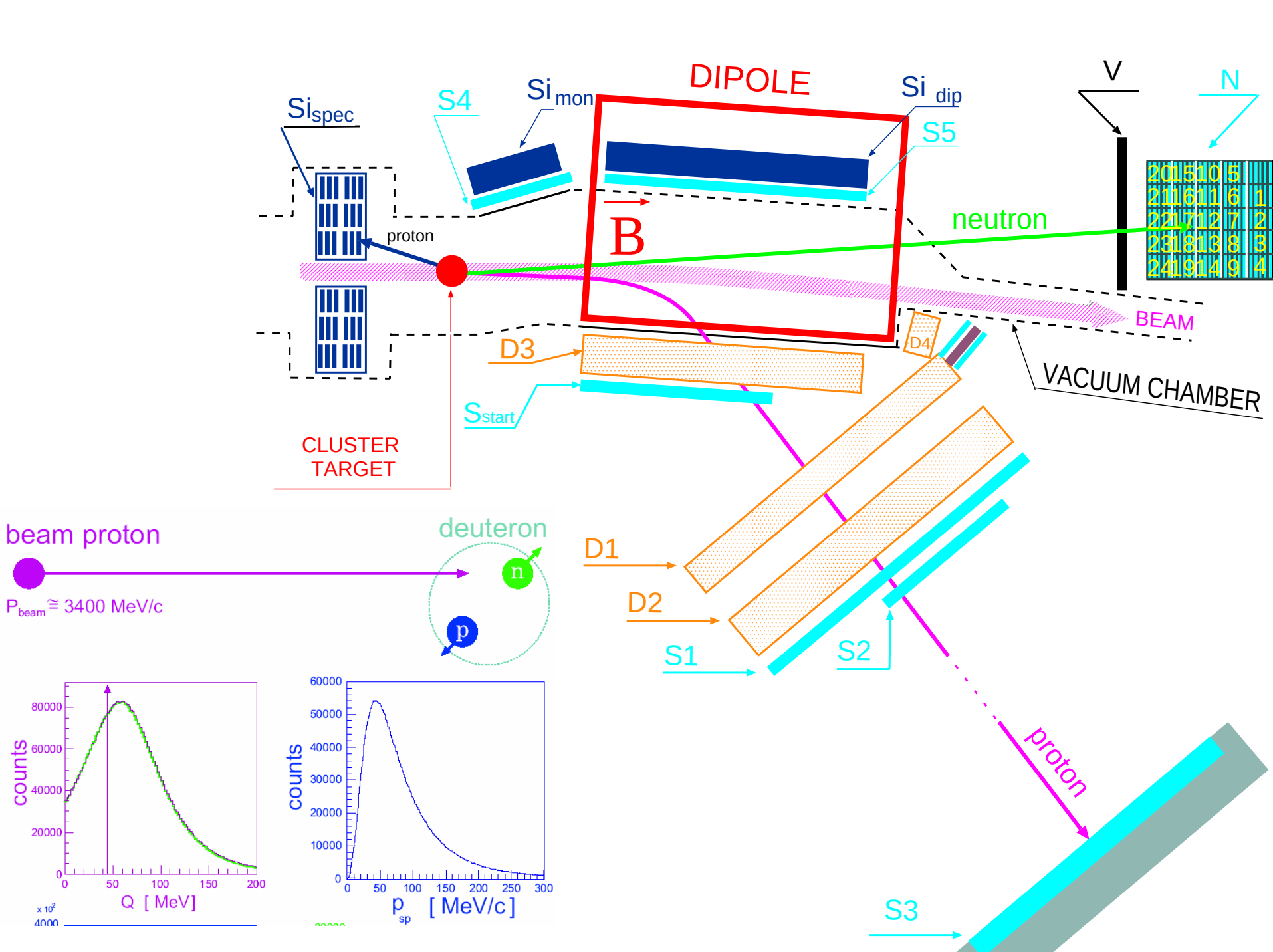


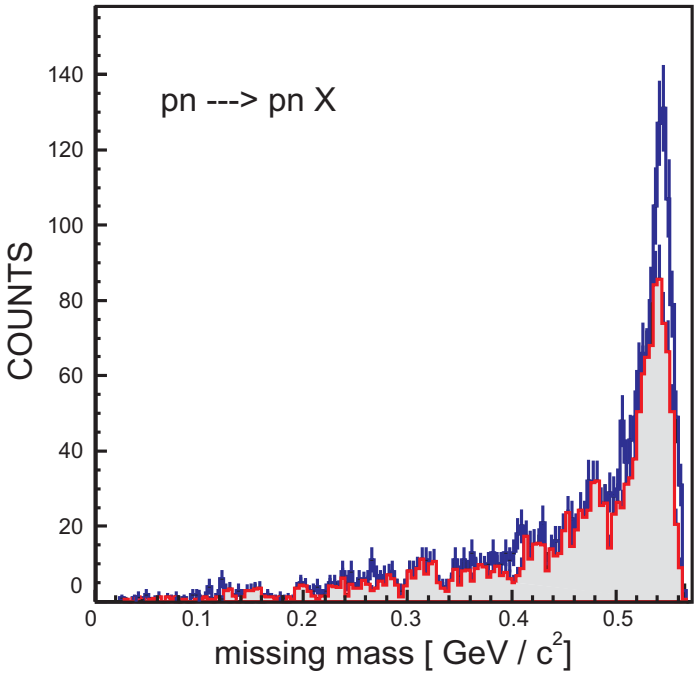


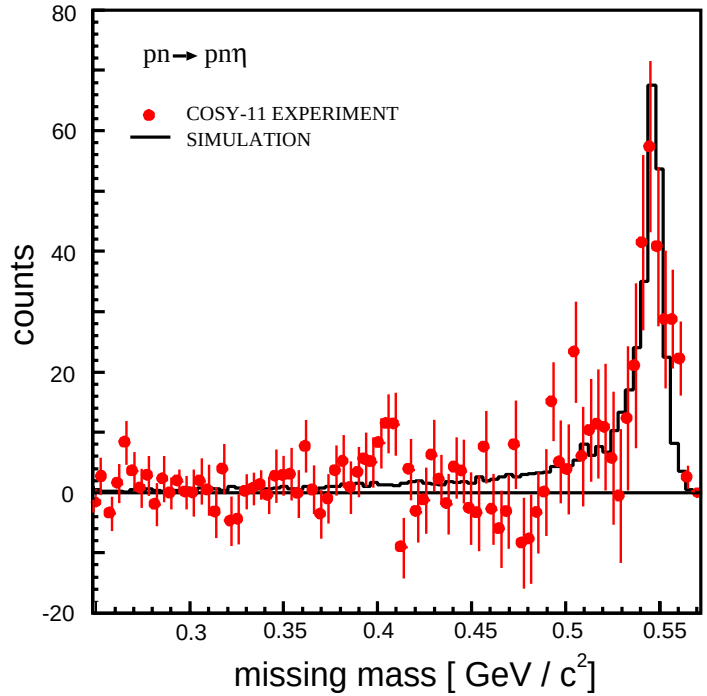


Near constant ratio about 6.5 over measured energy range

Signals strong isovector exchange in production mechanism


DIPOLE
Si spec
S4
Si mon
Si dip
S5
V
N
B
proton
neutron
BEAM
VACUUM CHAMBER
D3
D4
Sstart
CLUSTER
TARGET
beam proton
deuteron
n
p
P beam ≅ 3400 MeV/c
D1
D2
S1
S2
S3
proton
counts
Q [MeV]
p sp [MeV/c]





Test measurement of the p n → p n η

Integrated Luminosity = **$2 \cdot 10^{35}$ cm^{-2}**

•COSY-11: P. M. et al., J. Phys. **G 32** (2006) 629.

p n → p n η'

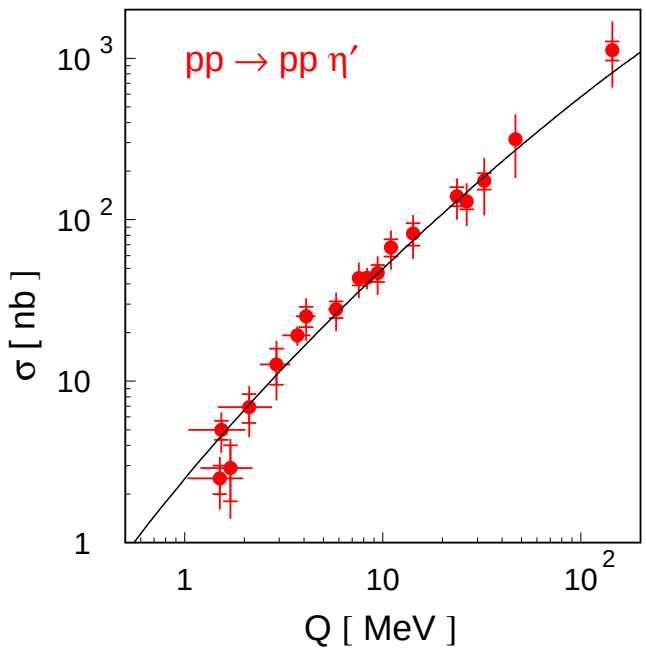
Integrated Lumonosity from runs in 2004/2006 ≈ **$100 \cdot 10^{35}$ cm^{-2}**

Analysis in progress

Isospin dependence of the η' meson production in the nucleon-nucleon collision

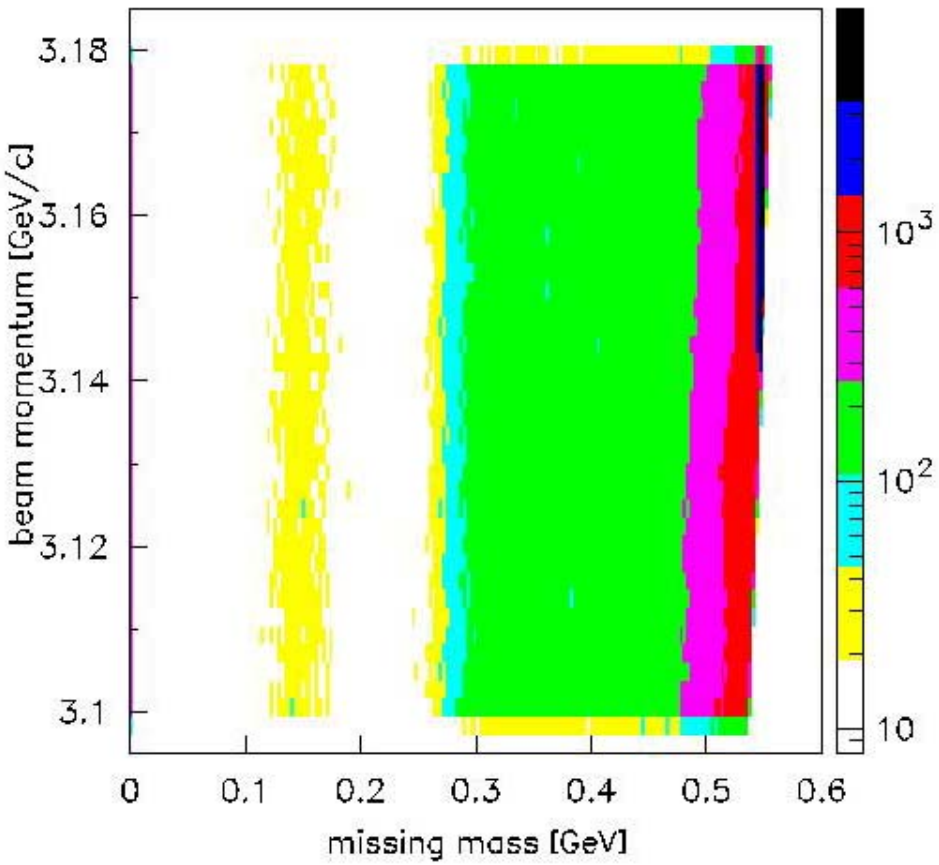
η' production from isospin I = 0 and I = 1

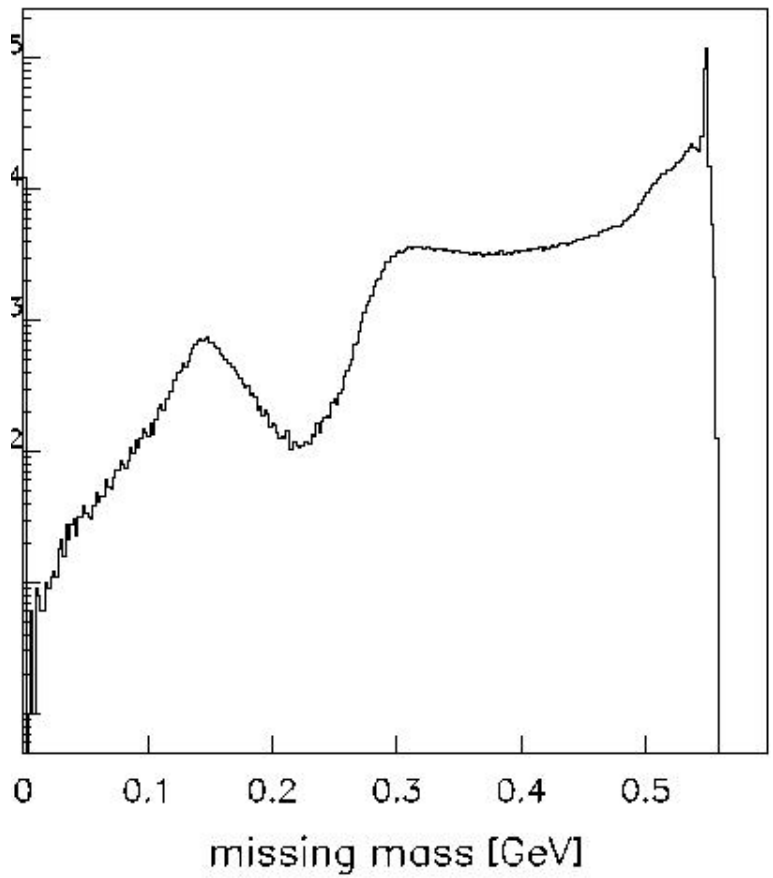
$$R_{\eta'} = \sigma(pn \rightarrow pn\eta')/\sigma(pp \rightarrow pp\eta')$$



Preliminary results from run in 2005

$$dp \rightarrow {}^{3}\mathrm{He}\, X$$

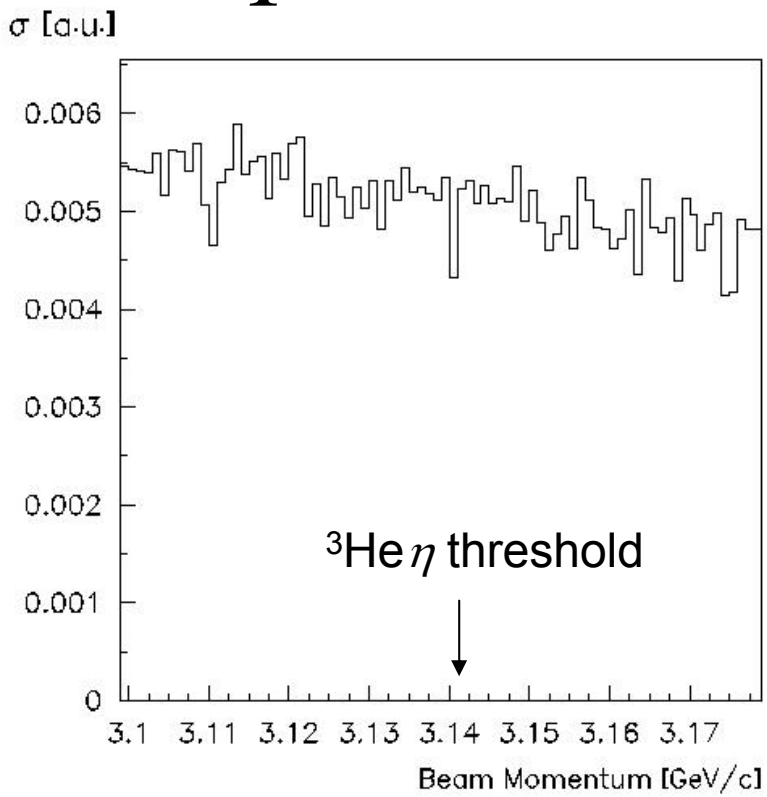




CUSP KILLER !!!!

$$dp \rightarrow {}^3\mathrm{He}\,\pi^o$$

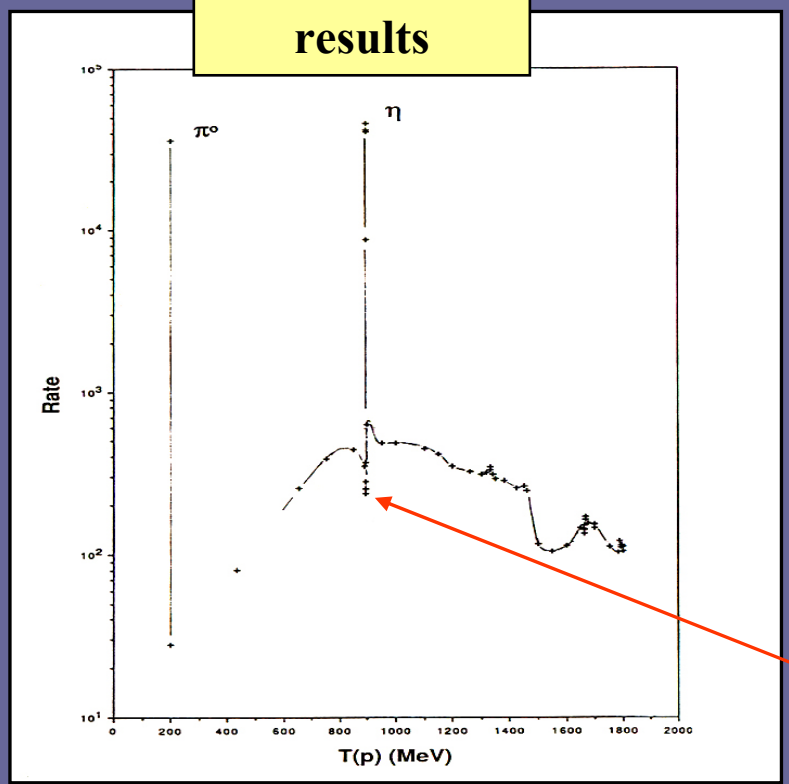
$90^o < \Theta_{p\text{-}\pi} < 180^o$



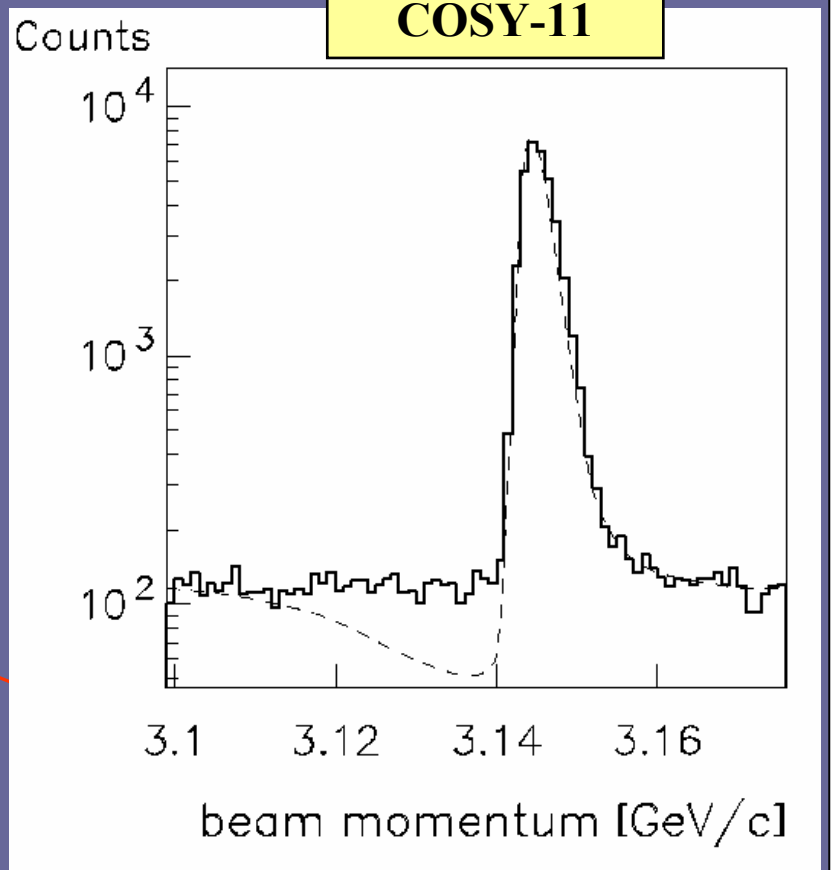
SATURNE $pd \rightarrow {}^3\mathrm{He}\,X$

threshold excitation curve

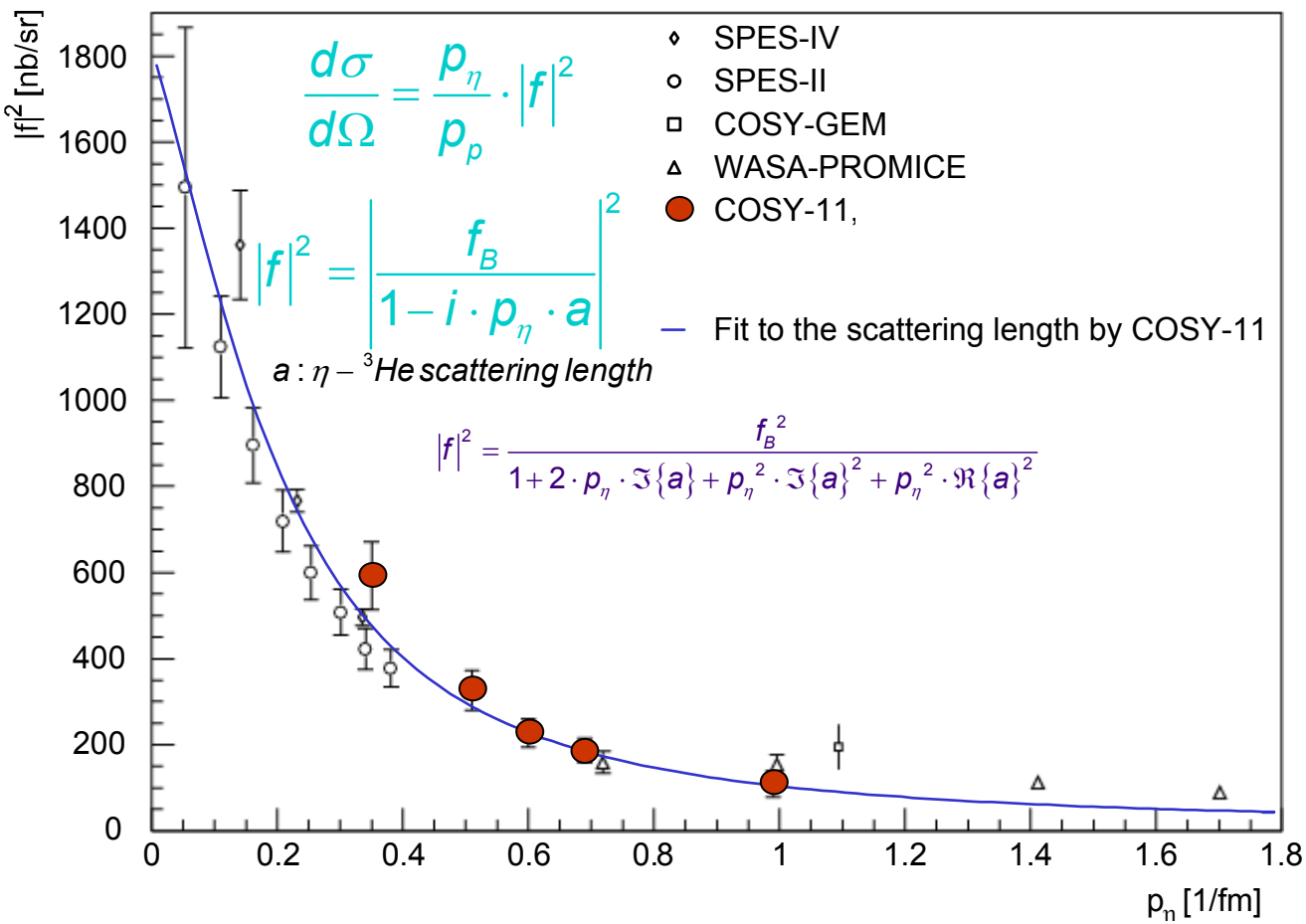
SATURNE results



COSY-11



Production amplitude pd → ^{3}He η



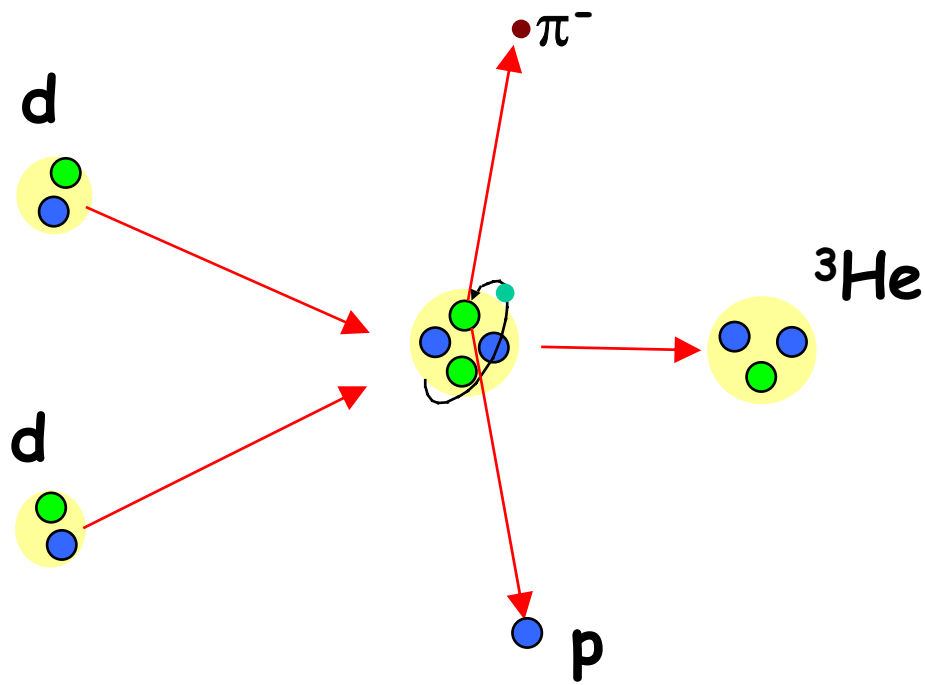
- fit to η-^{3}He scattering length

$f_b = 42.6\,nb/sr$

$|\Re(a)| = 3.8\,fm$

$\Im(a) = 1.3\,fm$

Search for the ^{4}He-η bund state via measurement
of the excitation function of the $d\,d \rightarrow {}^3\mathrm{He}\,p\,\pi^-$ reaction



- p-π back-to-back emission: θ_{cm} ~180°
- ^{3}He is a spectator : p_{cm} ~ 50 MeV/c,
  θ_{lab} ~ 50 / 1500 rad = 1.9°

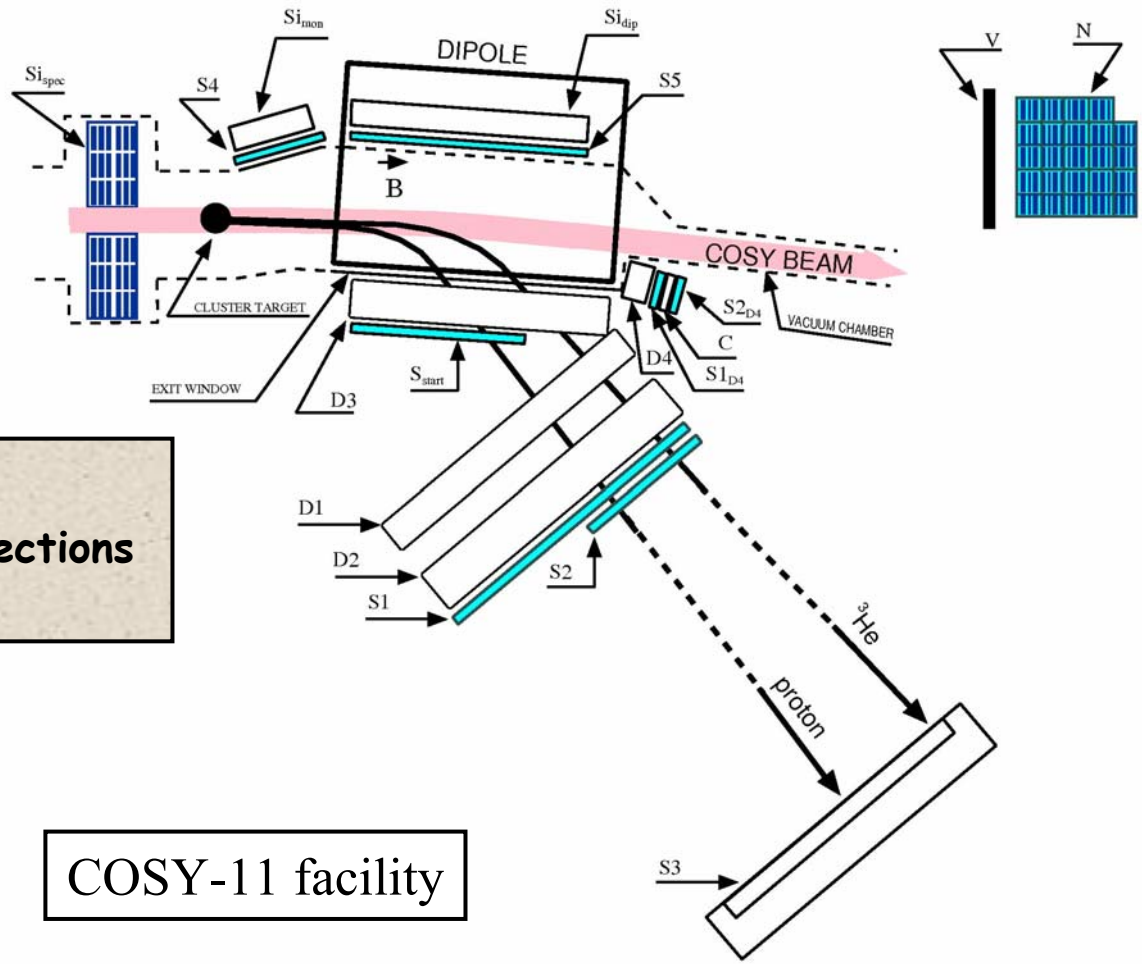
Detection system

deuteron beam ramped
from 2.219 GeV/c
to 2.366 GeV/c

^{3}He and (p or π^-) measured
in coinc.

Luminosity monitored using

- dd $\rightarrow$ ^{4}HeX inclusive cross sections
- p-p quasielastic scattering



COSY-11 facility

Eta bound-states in nuclei

	m (MeV)	z	m^* (MeV)	Rea (fm)
η_8	547.75	3.31	500.0	0.43
η (-10°)	547.75	3.15	474.7	0.64
η (-20°)	547.75	3.00	449.3	0.85
η_0	958	1.46	878.6	0.99
η' (-10°)	958	1.62	899.2	0.74
η' (-20°)	958	1.76	921.3	0.47

SD Bass, AW Thomas, hep-ph/0507024

- Sigma mean field couples to light quarks and not to strange quarks

  → Flavour-singlet component is important !

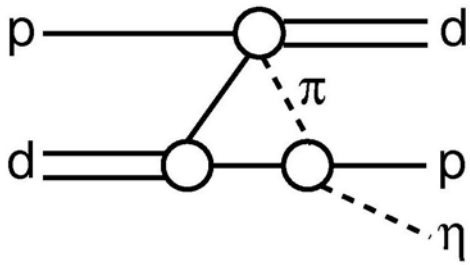
  The bigger the eta-eta´mixing angle, the bigger the singlet component in the eta

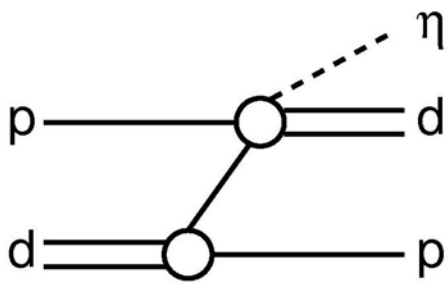
  → greater the attraction

  → more binding

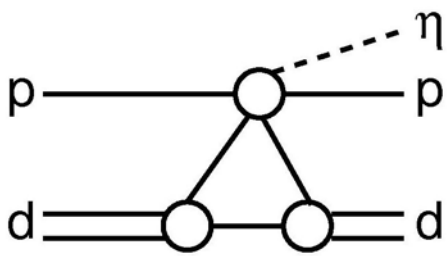
  → bigger eta-N scattering length

Two-step process





Pick-up diagram



Triangle diagram
(impulse approximation)

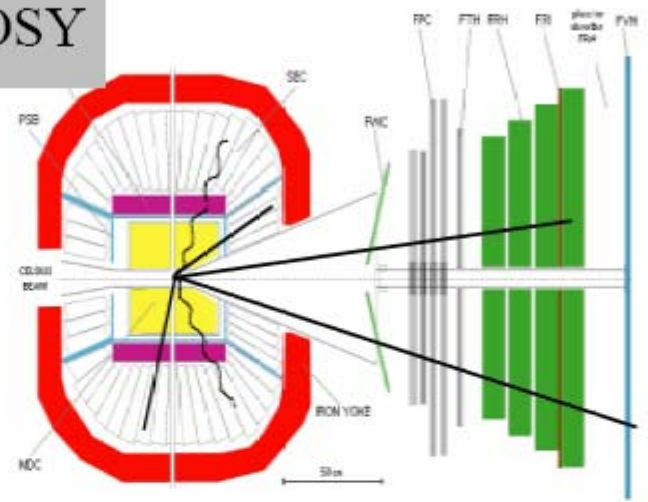
Cezary Piskor-Ignatowicz: Near threshold η meson production in deutron - proton collisions

Saturday, 17:30, session 1A

Decays of η and η′ with WASA at COSY

Luminosity $L = 1 \cdot 10^{32}$

	$pp \to pp\eta$	$pp \to pp\eta'$
T_{beam} [GeV]	1.5	2.54
p_{beam} [GeV/c]	2.25	3.35
Q [MeV]	94	
σ [μb]	25	
production rate [1/s]	2500	30



Charged Particles: ΔE $3° < \theta < 17°$

Kjell Fransson: Status of WASA at COSY
Saturday, 15:00, session 1B