Study of ppη dynamics in the pp → ppη reaction using WASA- at-COSY

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Outline

Motivation

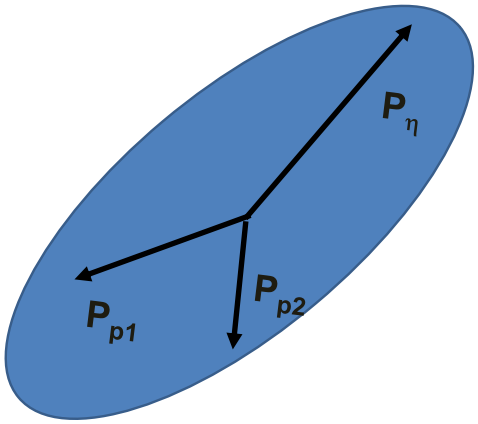
Experimental set-up

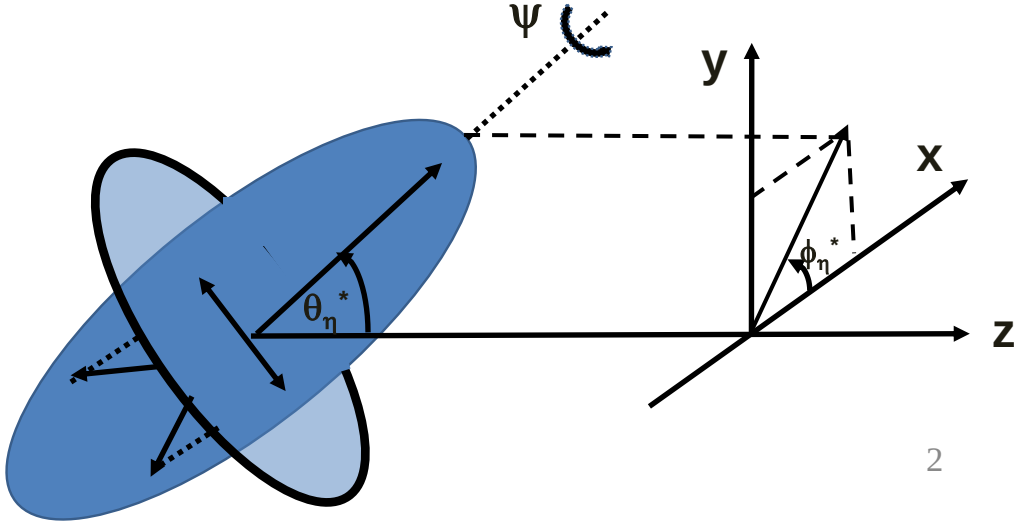
Analysis for ppη dynamics

Conclusions & outlook

Motivation

- Production of η-meson in NN collision is not well understood.
- Interaction of eta with nucleons using direct scattering experiments difficult.
- Study interaction by production near kinematical threshold
- Mutual interaction will show up in differential cross-sections.
- ppη system can be described by 12 variables, 7 are fixed by E-P conservation and particle masses
- Invariant mass distribution of pp and p-η system
- Orientation of the emission plane (θ_η^* ,ϕ_η^* ,ψ_η^*)





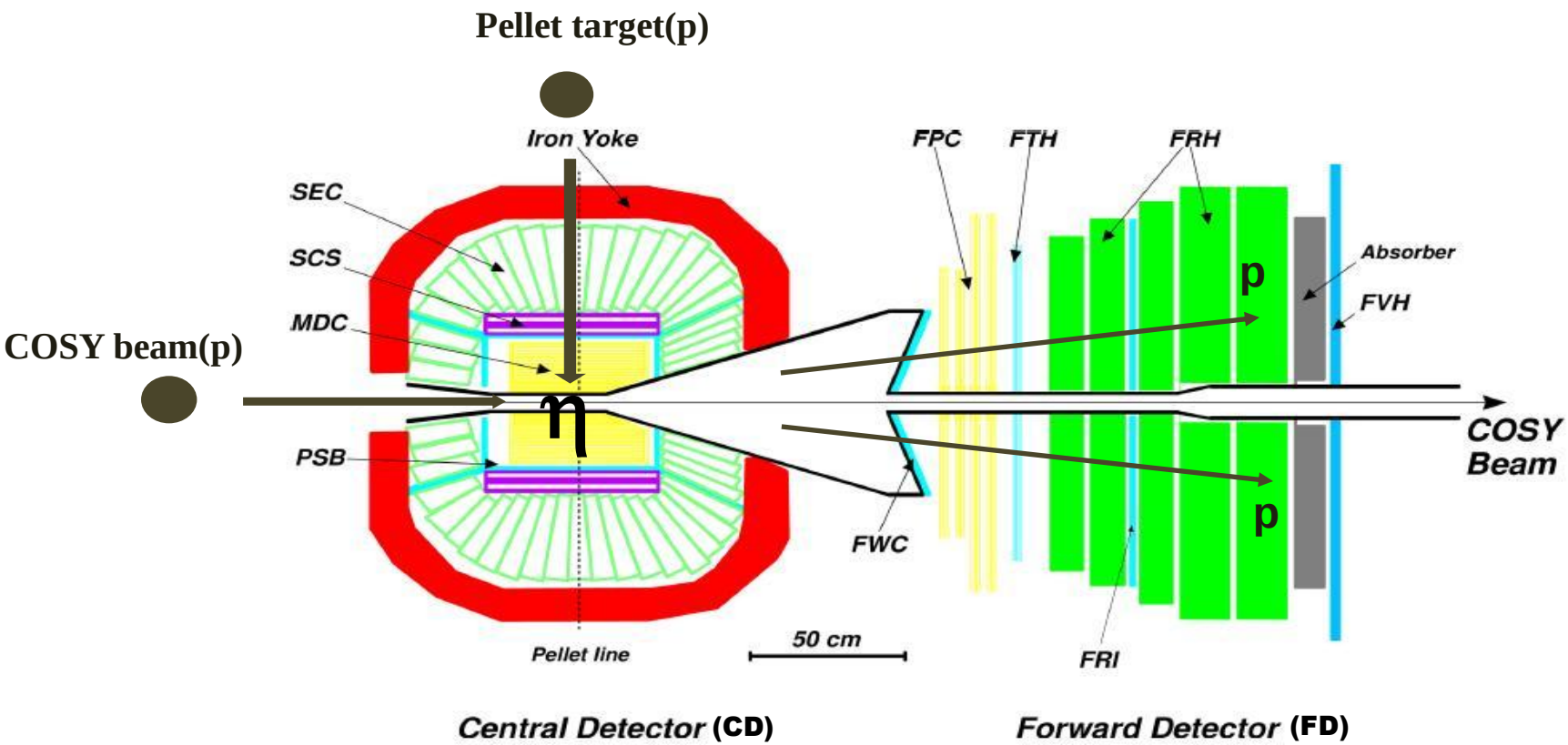
Previous measurements for pp→ppη

Excess Energy	Detector	Conclusions
10, 15.5 MeV	COSY-11[1,2]	•Angular distributions→isotropic •m^2_{pp}, $m^2_{p\eta}$→show deviation from phase space •Explanation - pp FSI but enhancement at $m^2_{p\eta}$ could not be explained
16, 37 MeV	PROMICE/WASA[3]	•Angular distribution of η→anisotropic •Explanation - Ss/Sd interference
16, 41 MeV	COSY-TOF[4]	•Angular distributions→isotropic •m^2_{pp}, $m^2_{p\eta}$→show deviation from phase space •Can not be explained by pp FSI alone
40, 72 MeV	CELSIUS/WASA[5]	• Angular distributions→isotropic •m^2_{pp}, $m^2_{p\eta}$→show deviation from phase space •Explanation – contribution from higher partial waves
324, 412, 554 MeV	DISTO[6]	•Angular distribution of η→anisotropy at lowest energy •anisotropy disappears as the energy increases •Explanation - N(1535) resonance and no need of higher partial waves

No consistent explanation yet available!

1 P Moskal et al., Phys. Rev. C 69, 025203(2004)
2 R. Czyzyjuewicz et al., Phys. Rev. Lett. 98, 122003 (2007)
3. H. Calen et al., Phys Lett. B 458, 190 (1999)
4 M. Abdel-Bary et al., Eur. Phys. J. A 16, 127(2003)
5 H Petren,Thesis 2009
6 F. Balestra et al., Phys. Rev. C 69, 064003 (2004)

WASA-at-COSY Detector

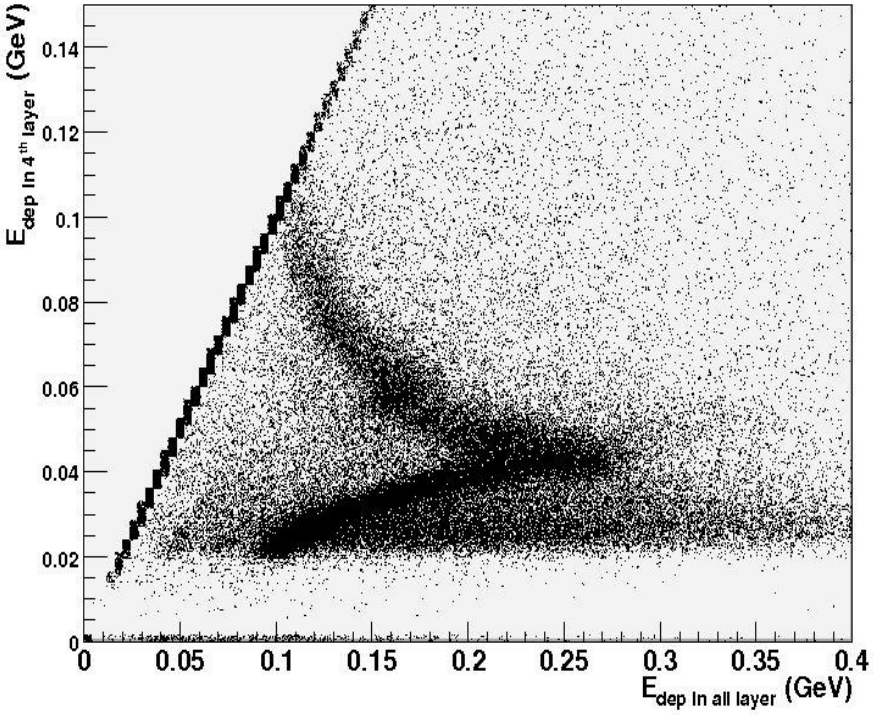


- For ppη dynamic study pp→pp ($\eta \rightarrow 3\pi^0$) is chosen
- Data taken at beam energy 1.4 GeV (Q = 56 MeV)
- Two charged track in the forward detector
- Six neutral clusters in central detector

Identification in forward detector

- Identification of protons by using ΔE-E technique
- Calibration: Deposited energy → Kinetic energy
- Theta and phi from Tracks
- Reconstruct four vectors of each proton

Proton identification



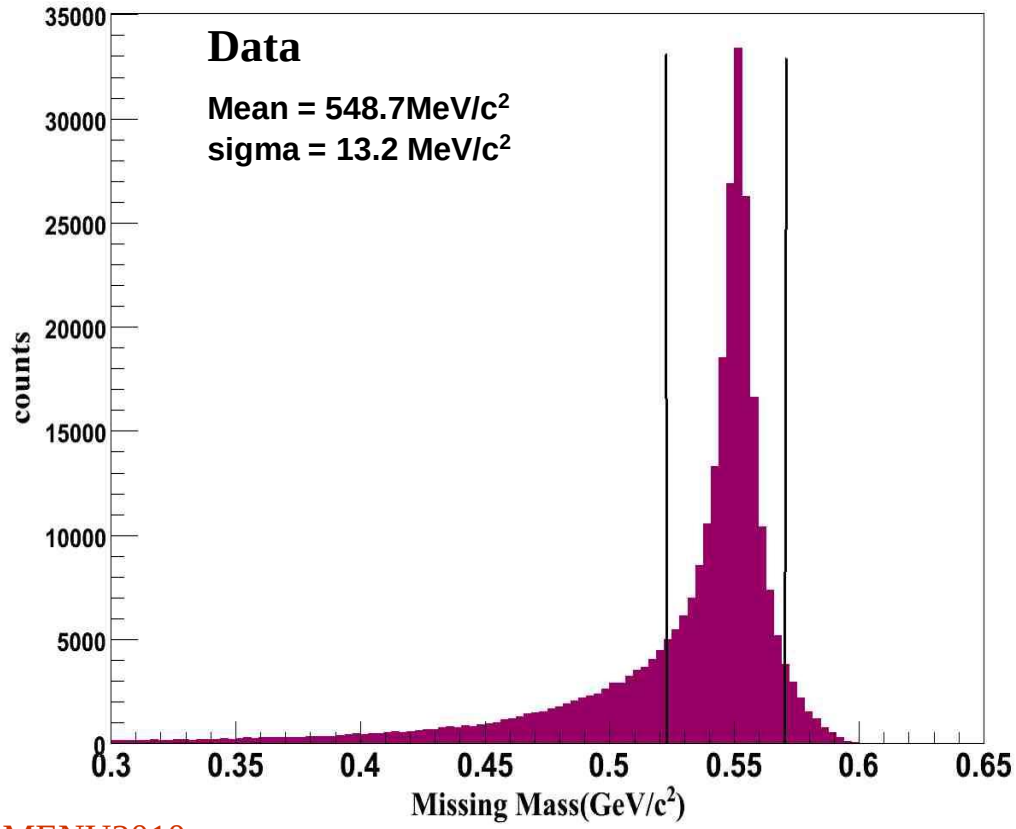
Missing mass of pp

- Missing mass of two protons

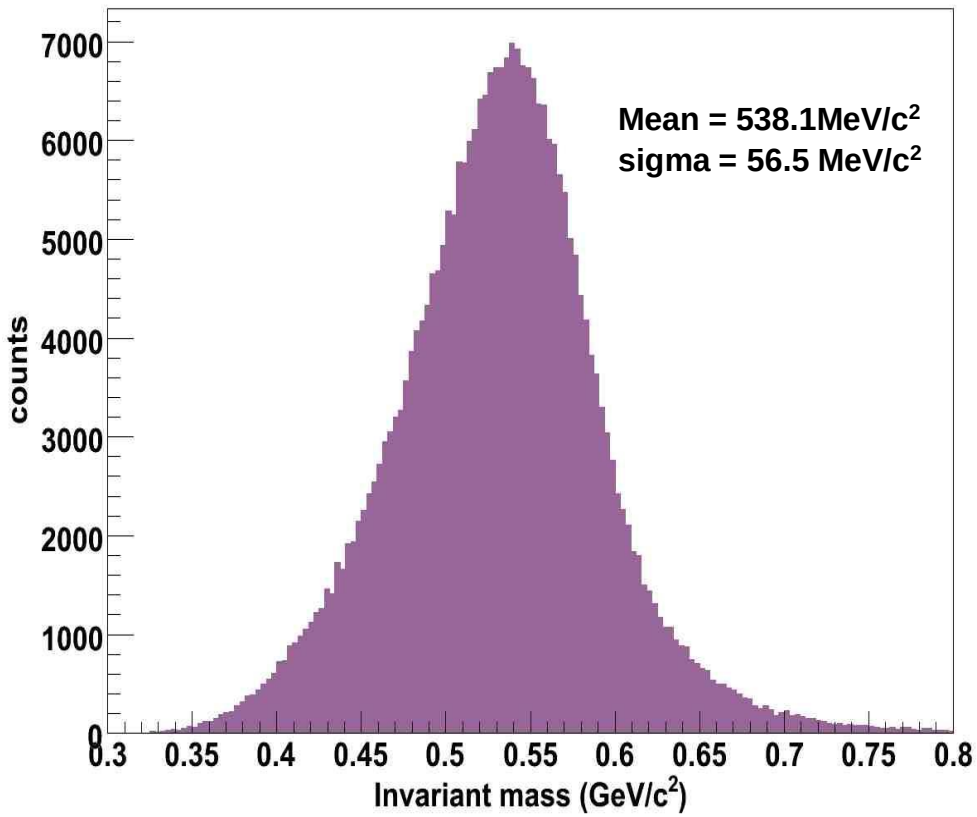
$$MM^2 = (E_{beam} - E_{p1} - E_{p2})^2 - (P_{beam} - P_{p1} - P_{p2})^2$$

Good mass resolution in forward detector helps in η tagging

Missing Mass of pp data



Invariant Mass of η-data



Kinematic fit

- Kinematic fit is used to improve measured quantities by fitting known values and constraints.

- The measured variables are adjusted within experimental errors so that the constraint equations are satisfied with minimum error.

- **Confidence level :** $CL(\chi^2) = 1 - \int P(\chi^2, n) d\chi^2$

Probability distribution

$$P(\chi^2, n) = \frac{2^{-n/2}}{\Gamma(n/2)} \chi^{n-2} e^{-\chi^2/2}$$

Kinematic fit

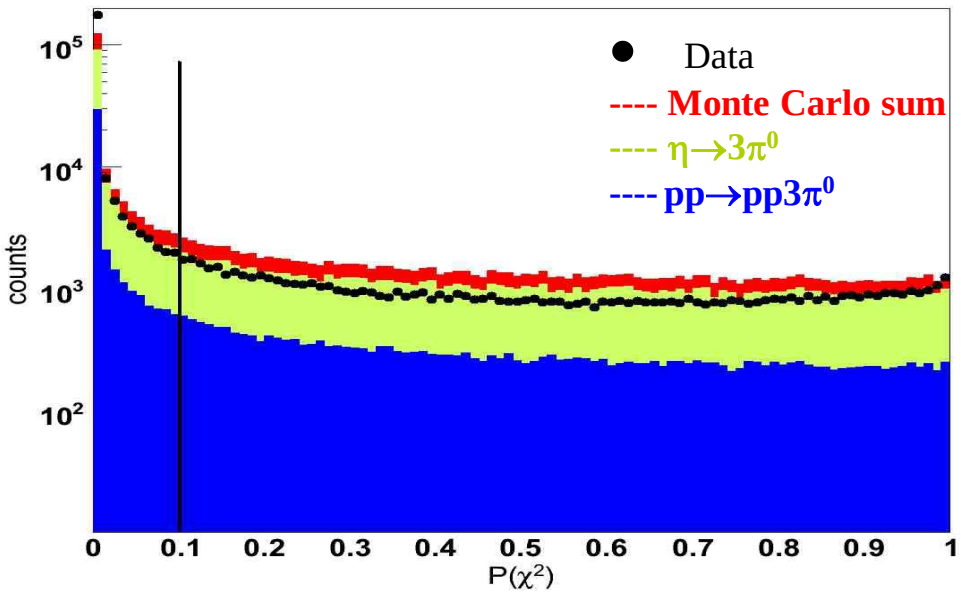
- **Constraints :**

Energy-momentum balance → **4**

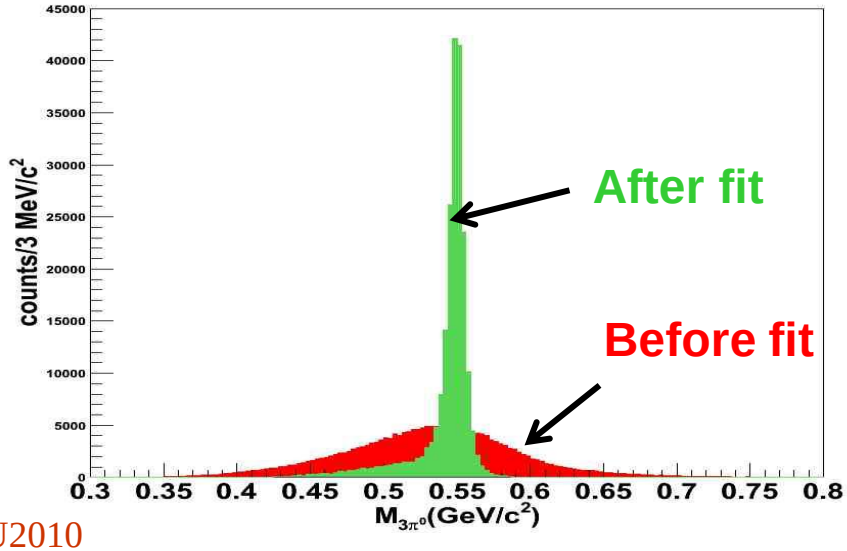
π^0 invariant mass → **3**

No constraint over η mass

Confidence level:



Invariant mass:



Mass widths:
Before kinematic fit σ = 56.5 MeV/c²
After kinematic fit σ = 5.6 MeV/c²

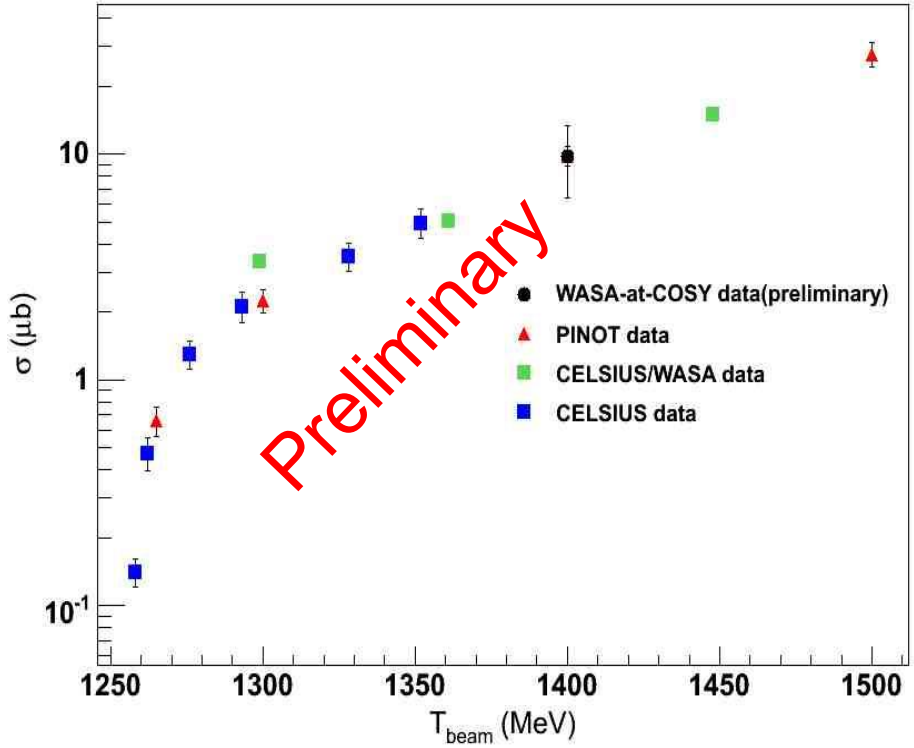
Total cross-section

- Total 9.7×10^6 events of $\eta\rightarrow3\pi^0$ from April-2007 data

- we have production cross-section of η,

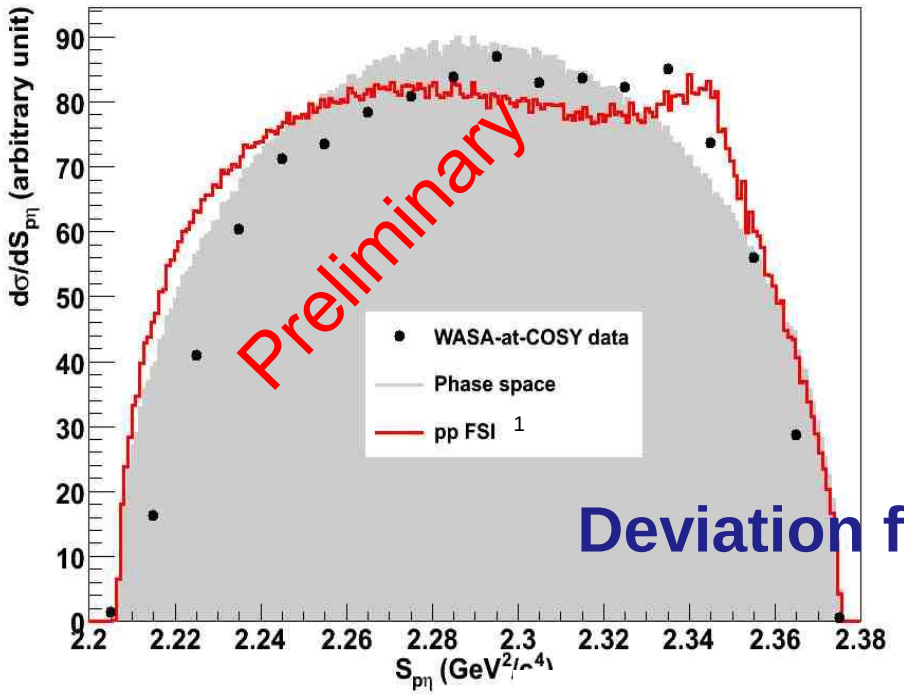
$$\sigma = (9.83\pm 0.03_{stat}+3.47_{sys})\ \mu b$$

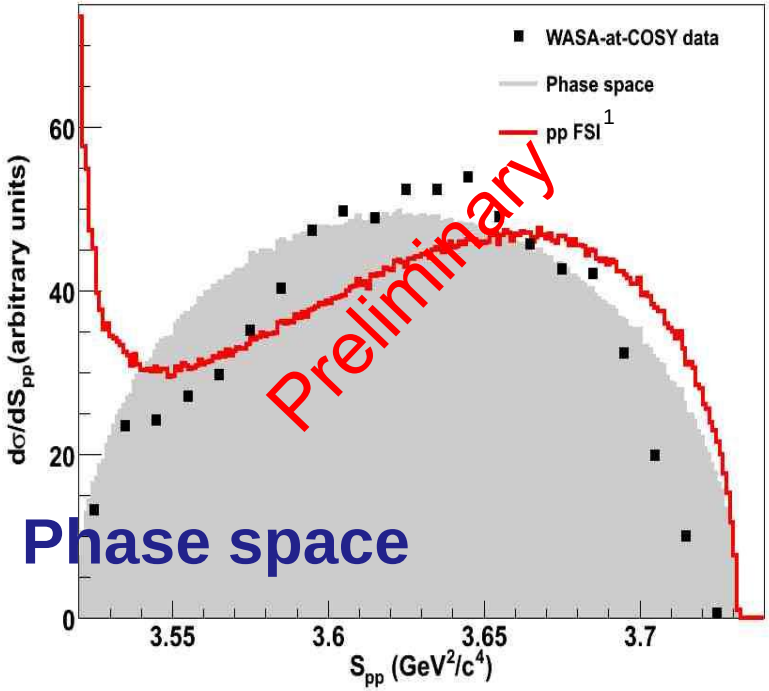
Normalization is the major source of error.



Total cross-section as a function of beam KE

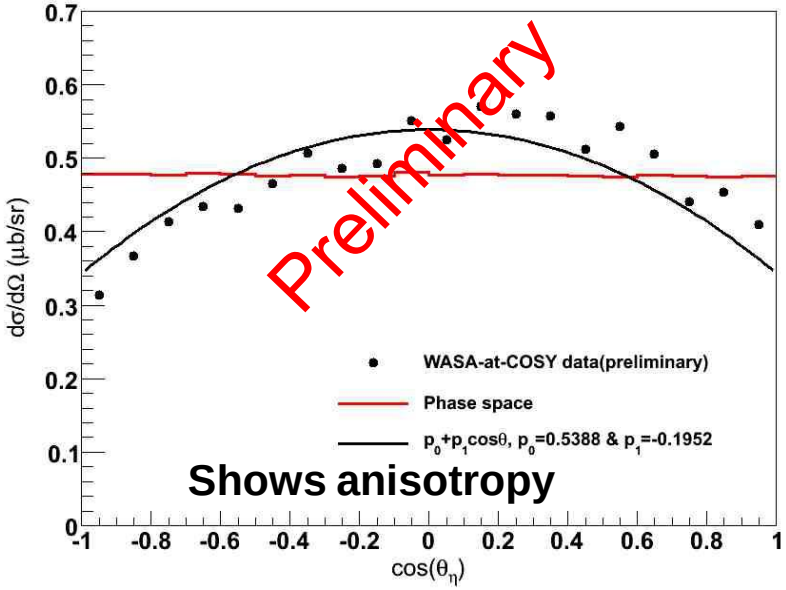
Observables for ppη dynamics





Deviation from Phase space

1. Phys. Lett. B 458 (1990) 190



Shows anisotropy

Conclusions

- Total cross-section for η production in pp has been measured.
- The invariant mass squared distributions for pp and pη show deviation from phase space.
- Inclusion of pp FSI could not explain the data.

Outlook

- The collaboration is planning to do measurements with polarised beam.

Partial waves

The low energy pp→ppη amplitude,

$$M = \tilde{A}_{Ss}\,\phi_f^\dagger\,(\hat{p}\cdot\boldsymbol{\varepsilon}_i) + A_{Sd}\,\phi_f^\dagger\,(\hat{p}\cdot\boldsymbol{k})(\boldsymbol{k}\cdot\boldsymbol{\varepsilon}_i) \quad + \quad A_{Ps}\,\phi_i\left(\boldsymbol{q}\cdot\boldsymbol{\varepsilon}_f^\dagger\right) + A_{Ds}\,\phi_f^\dagger\,(\hat{p}\cdot\boldsymbol{q})(\boldsymbol{q}\cdot\boldsymbol{\varepsilon}_i)\,.$$

p momentum of initial proton
K momentum of final η
2q relative momentum in the final two proton system
ε_I (ε_f) spin-one polarization vector of the initial(final) pp pair
ϕ_I (ϕ_f) spin-zero functions

The spin averaged matrix element square,

$$\overline{|M|^2} = \tfrac{1}{4}\Big[\,|\tilde{A}_{Ss}|^2 + 2\,k^2\,\mathrm{Re}\{\tilde{A}_{Ss}^*\,A_{Sd}\}\cos^2\theta_\eta$$
$$+ 2\,q^2\,\mathrm{Re}\{\tilde{A}_{Ss}^*\,A_{Ds}\}\cos^2\theta_{pp} + q^2\,|A_{Ps}|^2\Big]\,,$$

The enhancement factors for $(Ss)^2$, Ss-Sd and Ss-Ds terms,

$$F_{SS}(q) = 0.440 + \frac{151.7}{1 + q^2/\alpha^2}\,,$$

$$F_{SD}(q) = 0.968 + \frac{11.5}{1 + q^2/\alpha^2}\,,$$

The differential cross-section,

$$d\sigma = \frac{N}{p}\left(F_{SS}(q) + a\,\frac{k^2}{\mu m_p}\,F_{SS}(q)\cos^2\theta_\eta \quad + b\,\frac{q^2}{\mu m_p}\,F_{SD}(q)\cos^2\theta_{pp}\right)\mathrm{dLips}\,,$$

(H. Calen et al, Phy. Lett. B 458 (1999) 190)