η -photoproduction on ^{3}He : Search for η mesic nuclei.

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Uni Basel/A2 Collaboration
Meson 2010

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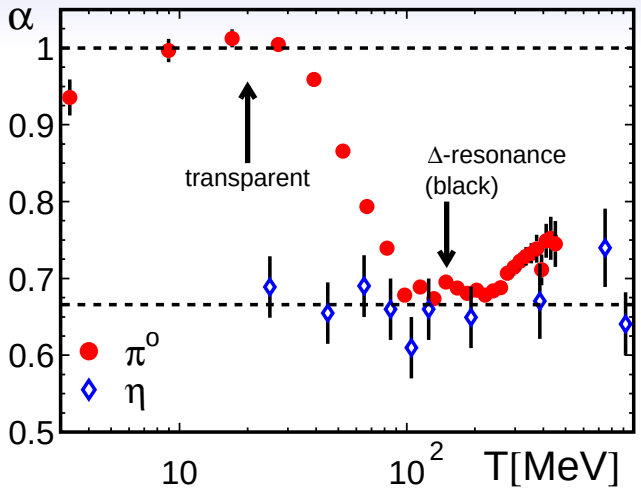
Generalities

Interaction of short-lived mesons with nuclei.



Nucleon absorption properties for η and π^0 .

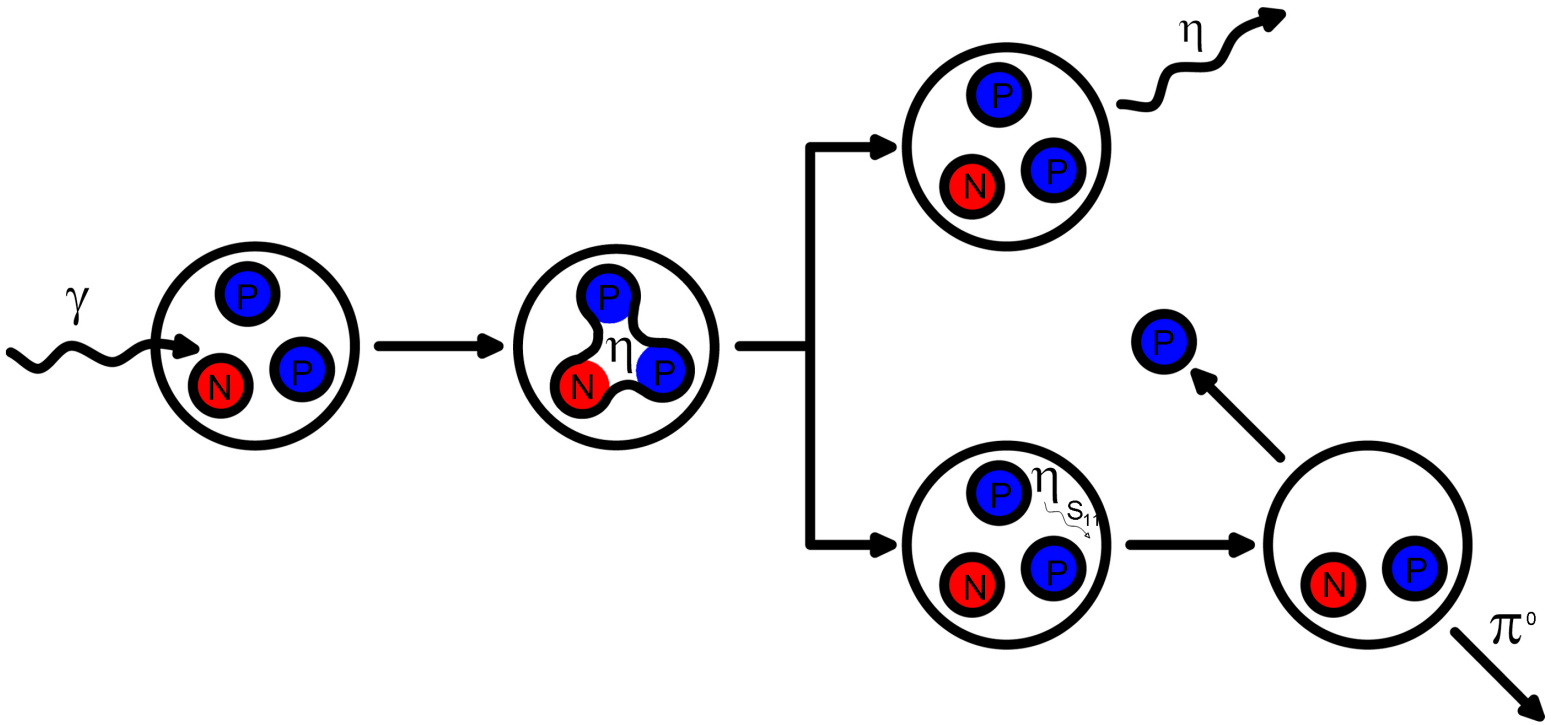
$$\sigma(A) \sim A^{\alpha(T)} \tag{1}$$

Consequences:

- π^0 -nucleus system always unbound
- η -nucleus system might be (quasi)-bound

$\Rightarrow \eta$ might be a good candidate to search for meson bound state

Search for η -mesic nuclei via η -photoproduction: $\gamma + A \rightarrow A + \eta$



Schematic illustration of a possible a signal for the η mesic nuclei via photoproduction.

Strength of the coherent signal

Dependence on A and F(q) :

$$\frac{d\sigma}{d\Omega} \propto \boxed{\mid \Sigma A \mid^2} \times F^2(q^2) \times ..... \quad (2)$$

The amplitude are depending of the spin and the isospin structure

The excitation of $S_{11}(1535)$ resonance is dominating η - photoproduction:

$$\gamma(E1) + N \rightarrow S_{11} \rightarrow \eta + N \quad (3)$$

$$-1 + \frac{1}{2} \rightarrow -\frac{1}{2} \rightarrow 0 - \frac{1}{2} \quad (4)$$

$\Rightarrow$ spin-flip transition

Strength of the coherent signal

S_{11} EM excitation is dominantly isovector

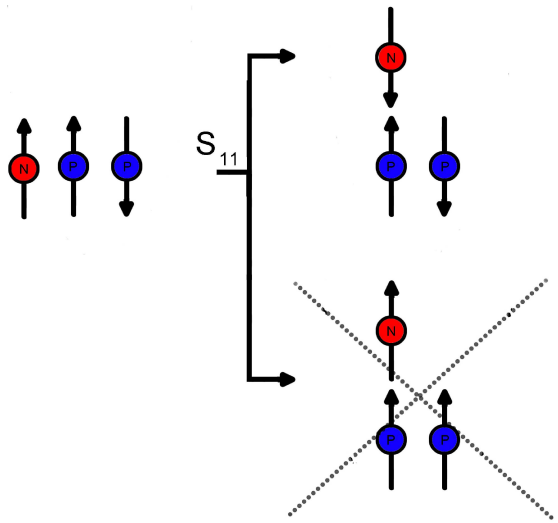
$$\sigma_p \approx | A^{IS}_{1/2} + A^{IV}_{1/2} |^2 = | A^{p}_{1/2} |^2 \qquad A^{p}_{1/2} > 0 \qquad (5)$$

$$\sigma_n \approx | A^{IS}_{1/2} - A^{IV}_{1/2} |^2 = | A^{n}_{1/2} |^2 \qquad A^{n}_{1/2} < 0 \qquad (6)$$

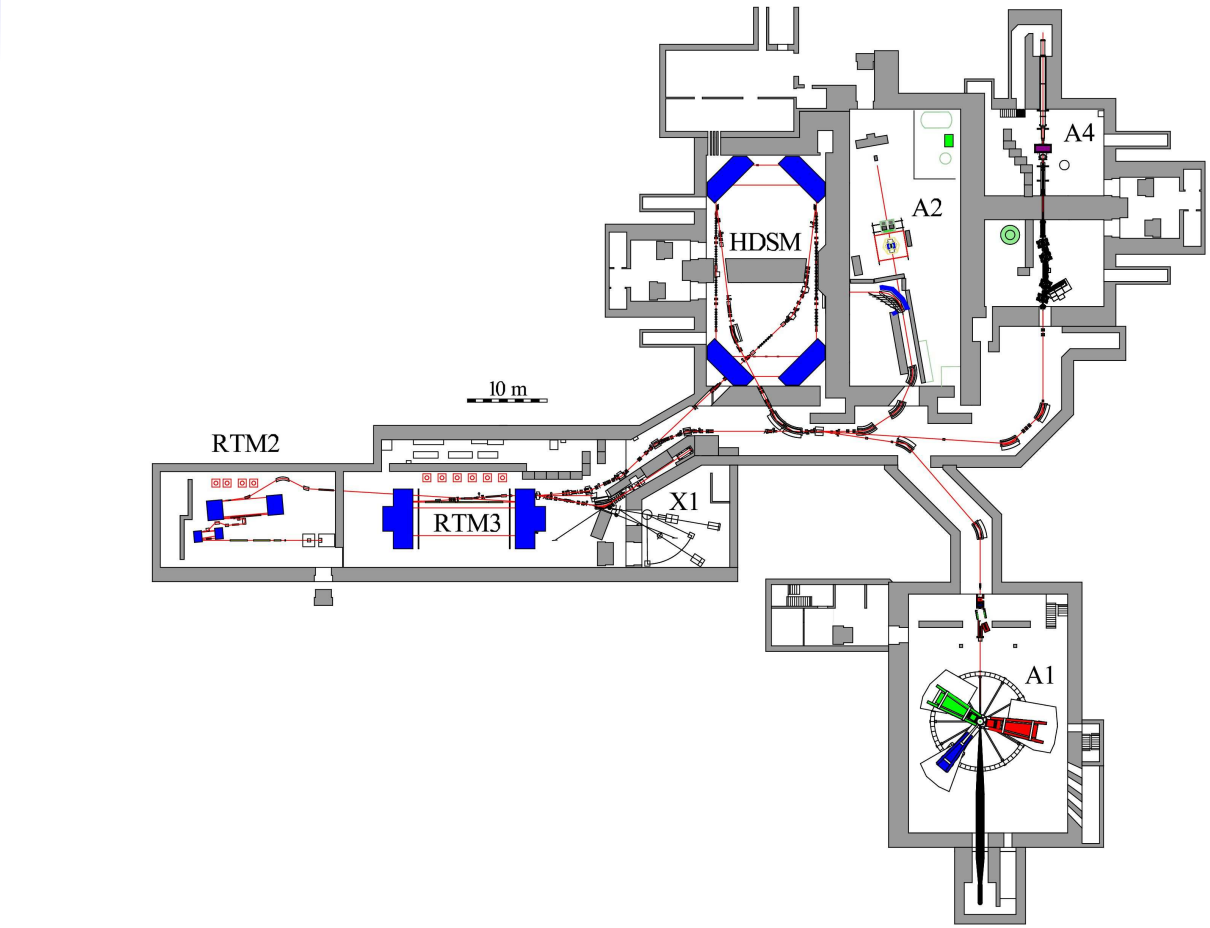
$$\sigma_d \approx | A^{IS}_{1/2} |^2 \qquad A^{n}_{1/2}/A^{p}_{1/2} = -0.845 \pm 0.078 \qquad (7)$$

^{3}He : J = 1/2, I = 1/2, isovector, spin-flip $\Rightarrow$ large signal

^{3}He spin structure

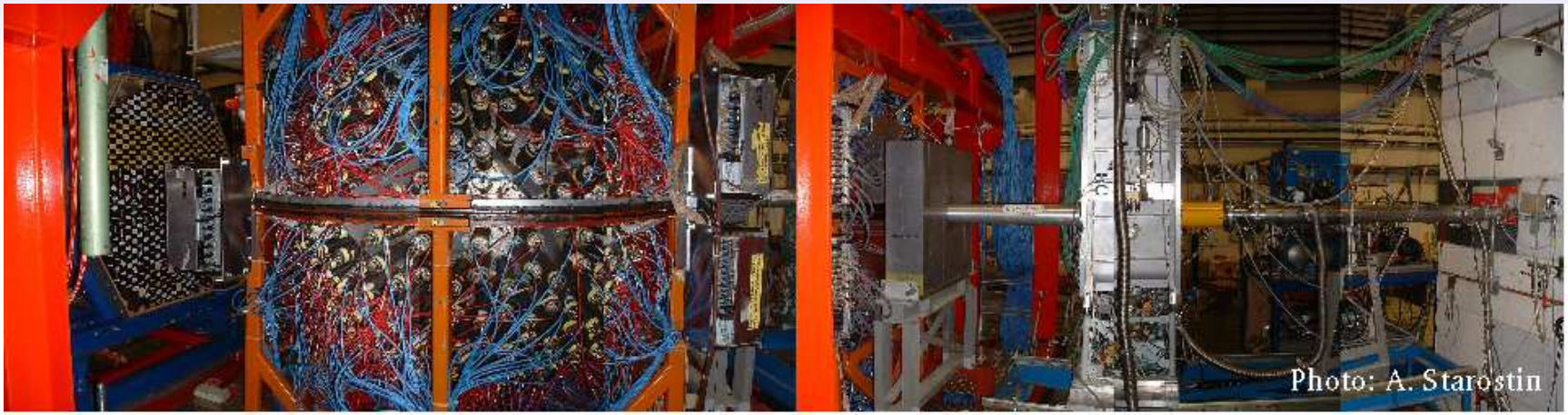


MAinz Microtron



Electron beam: 1400 MeV
Beam current: 8 nA

Setup



Crystal ball system:

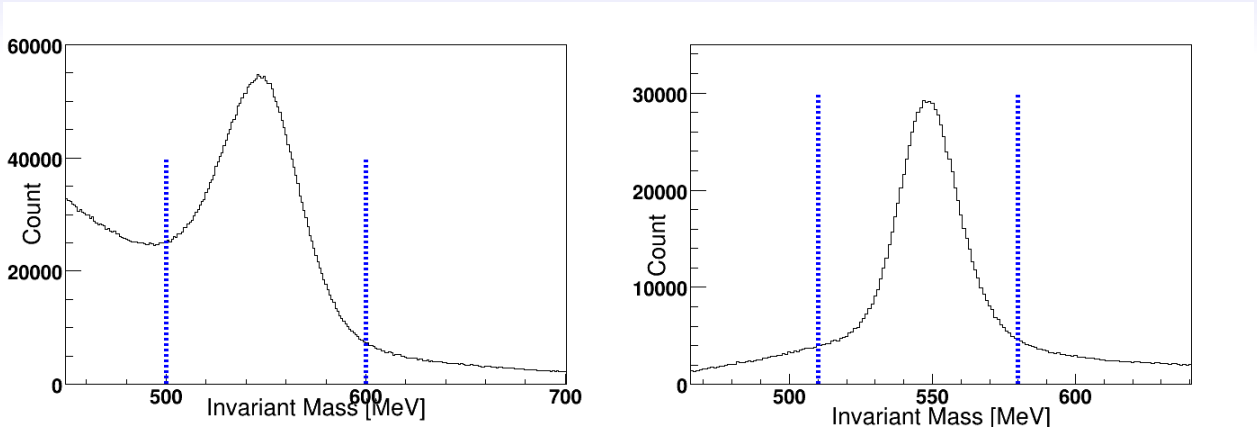
- 4π detector of 672 NaI Crystals
- Inner detector: 24 plastic scintillator

TAPS :

- 380 BaF_2 and 12 $PbWO_4$
- 380 Veto scintillators

Target Cell of 5.6cm lenght: L^3He at 2.5K E_γ tagged between 420 MeV and 1400 MeV with 4 MeV energy resolution

Identification of η



- $\eta \to 2\gamma$

  $M_{inv} = \sqrt{2P_1P_2} = \sqrt{2E_1E_2 \cdot (1 - \cos\Psi_{12})}$

  With E_1, E_2 being the energies of the decay photons and Ψ_{12} the angle between 2 photons.

- $\eta \to 6\gamma$

  Select events with 6 hits
  Invariant mass of $\gamma\gamma$
  Cut on π^0 mass
  Select best combination of 2γ to one π^0 by a χ^2 test.

Missing energy analysis

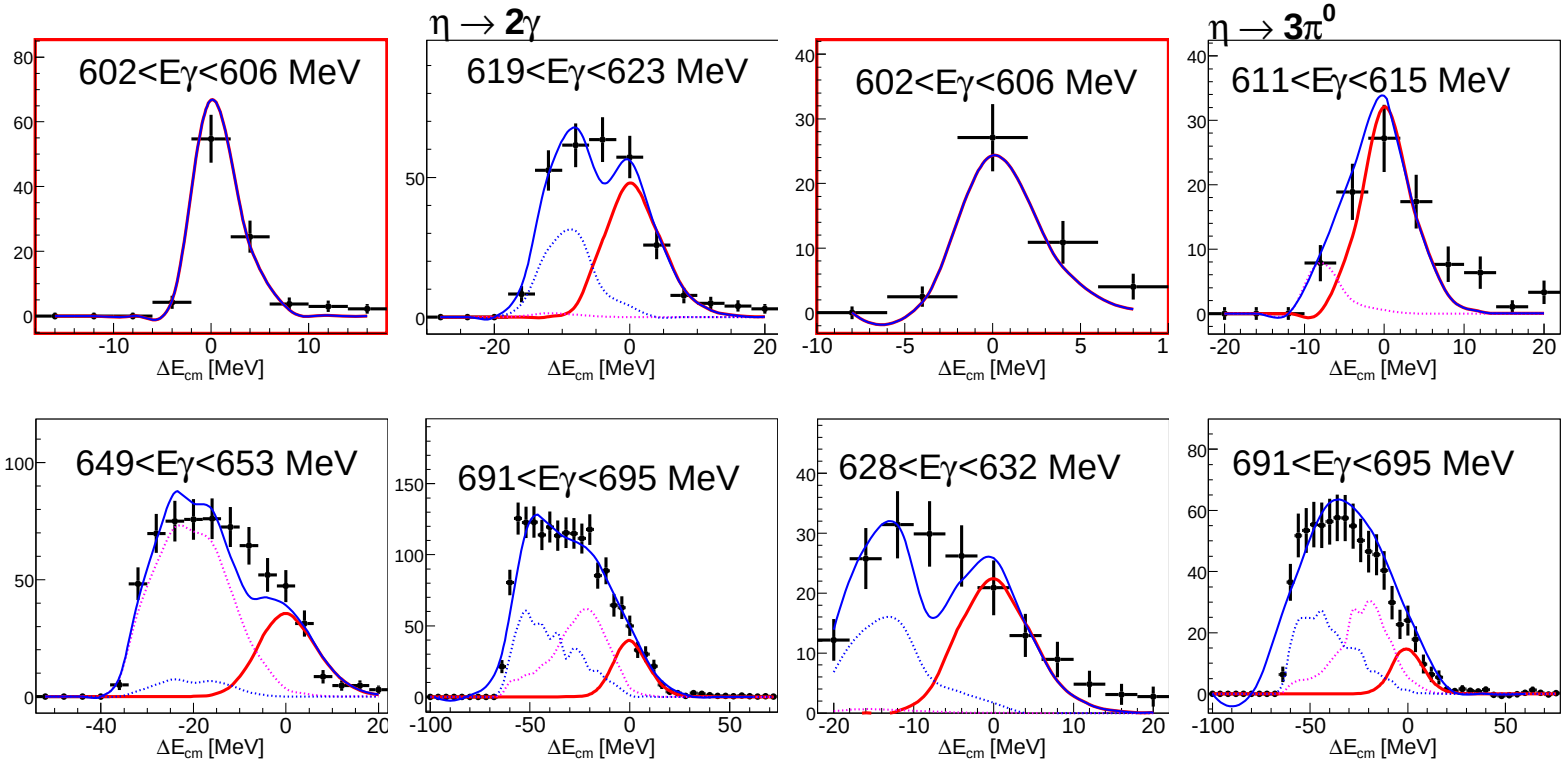
$$E_{miss} = E^*_\eta(P_\eta) - E^*_\eta(E_{\gamma inc}) \quad (8)$$

$E^*_\eta(P_\eta)$: η cm-energy from η 4-vec reconstructed

$E^*_\eta(E_{\gamma inc})$: calculated

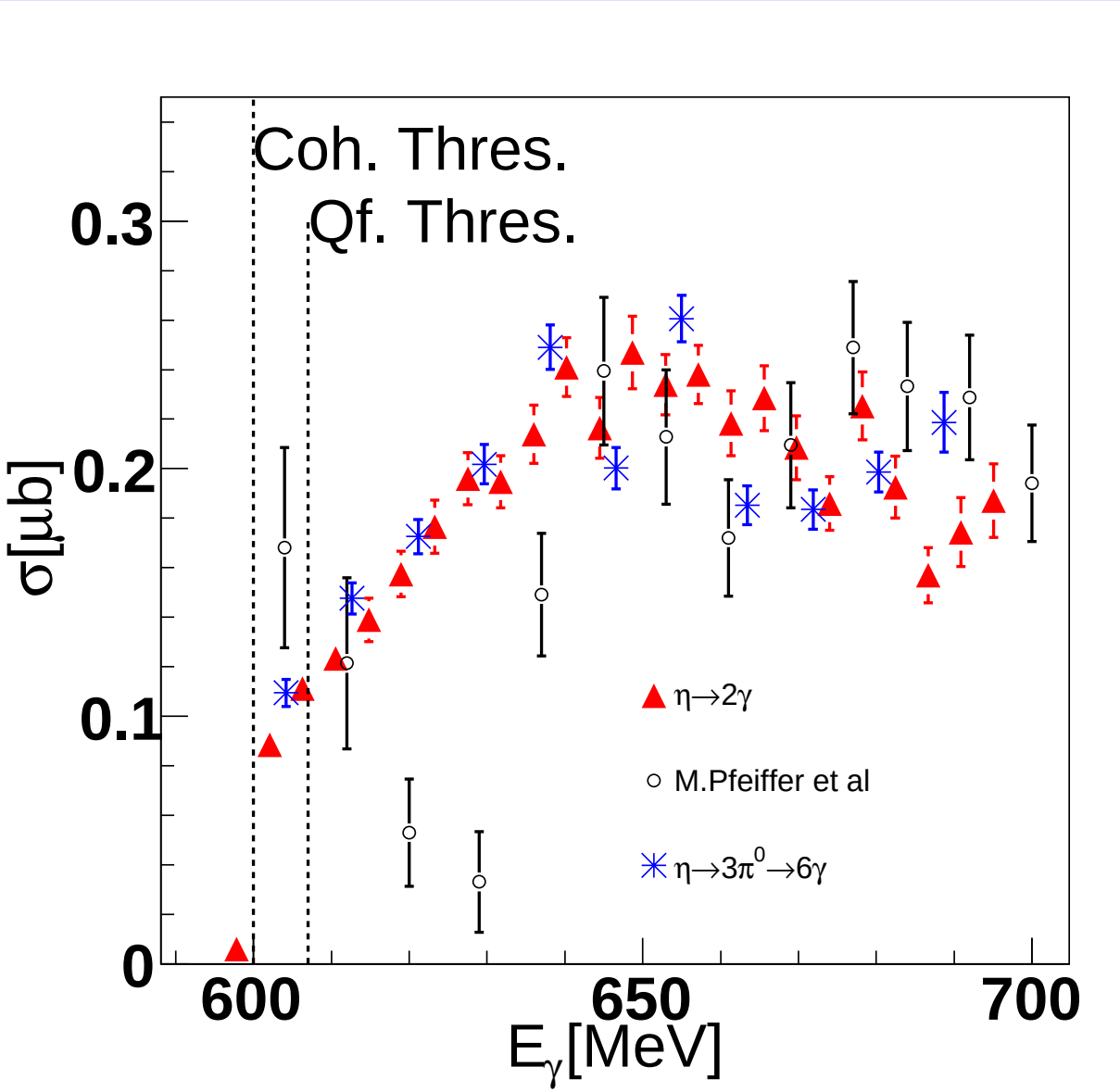
coherent contribution

coherent + breakup contribution

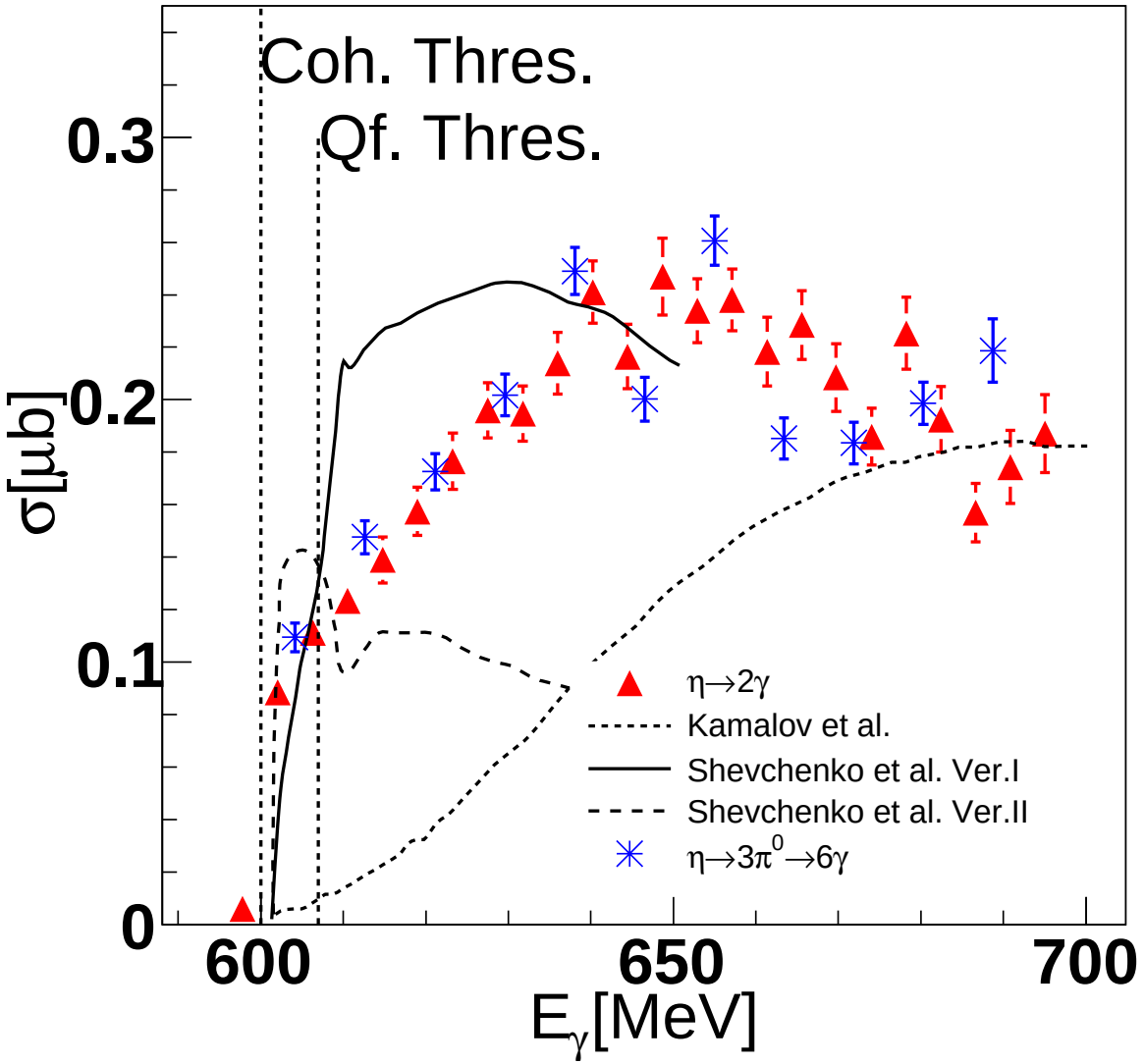


Data lineshape is reproduced by the simulation.

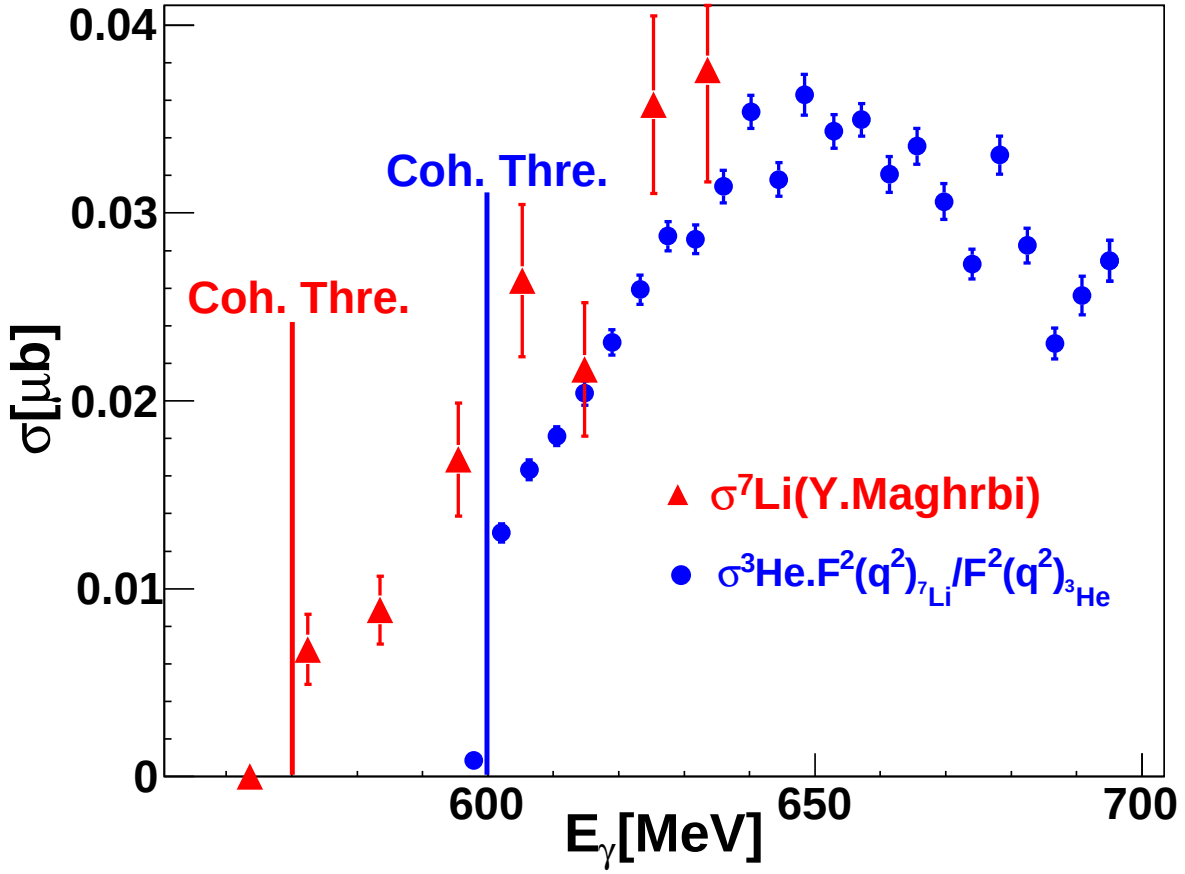
Coherent cross section



Comparison to models

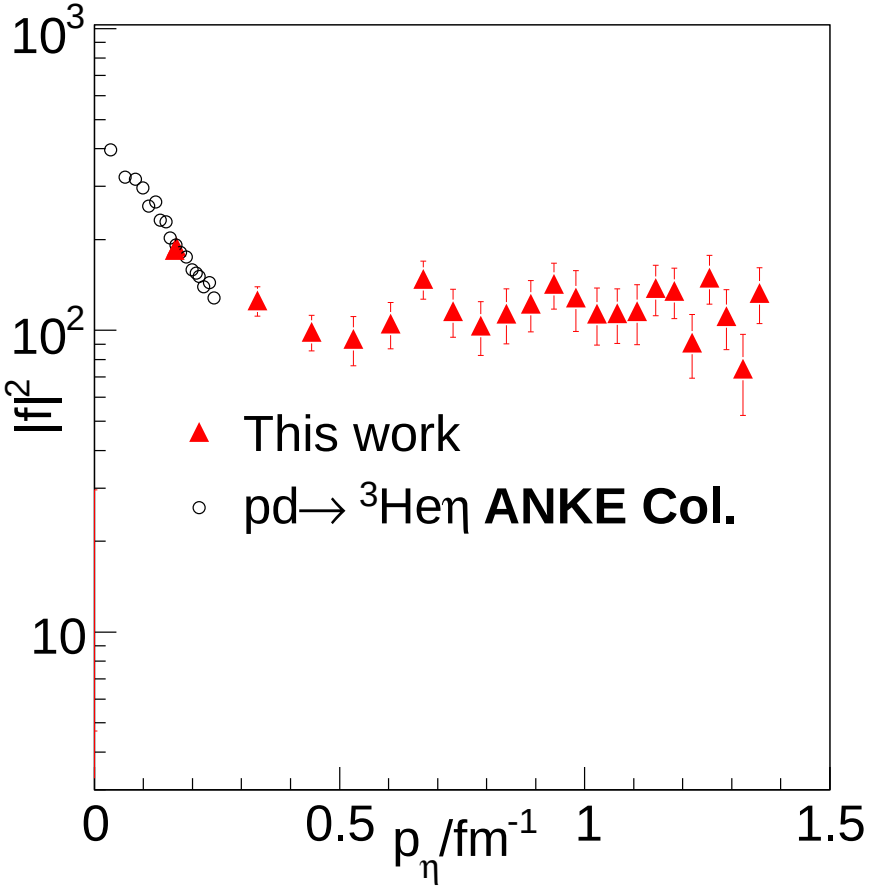


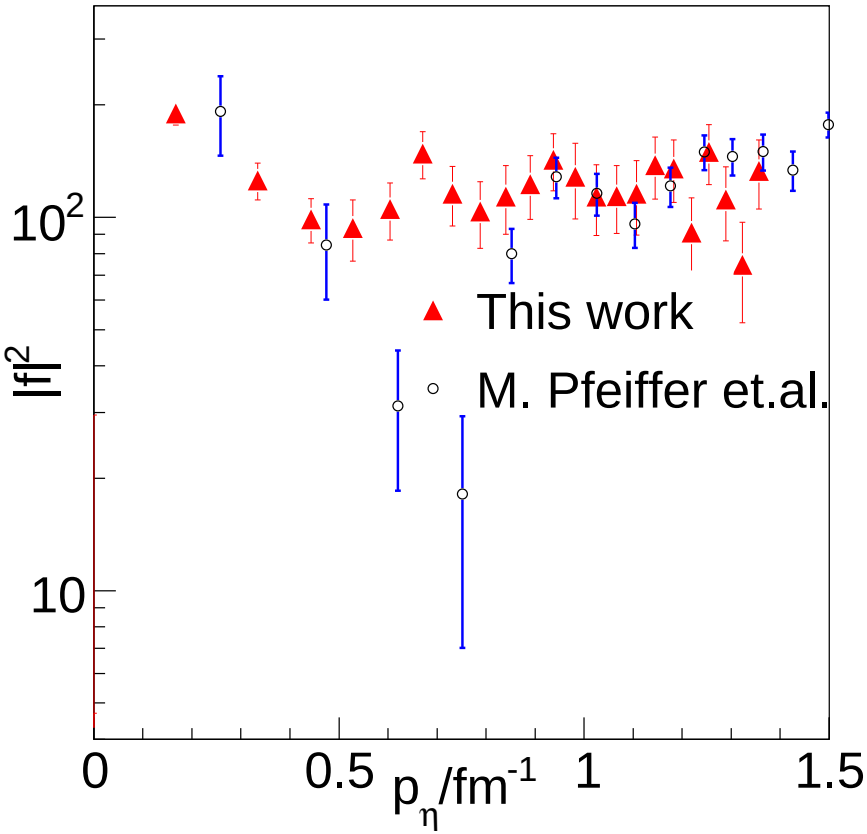
Comparison to ^7Li (next best candidate)



Due to the ratio of the form factor the cross section is smaller by one order of magnitude. Strong rise at threshold is observed (but less pronounced).

Comparison to ANKE/Pfeiffer

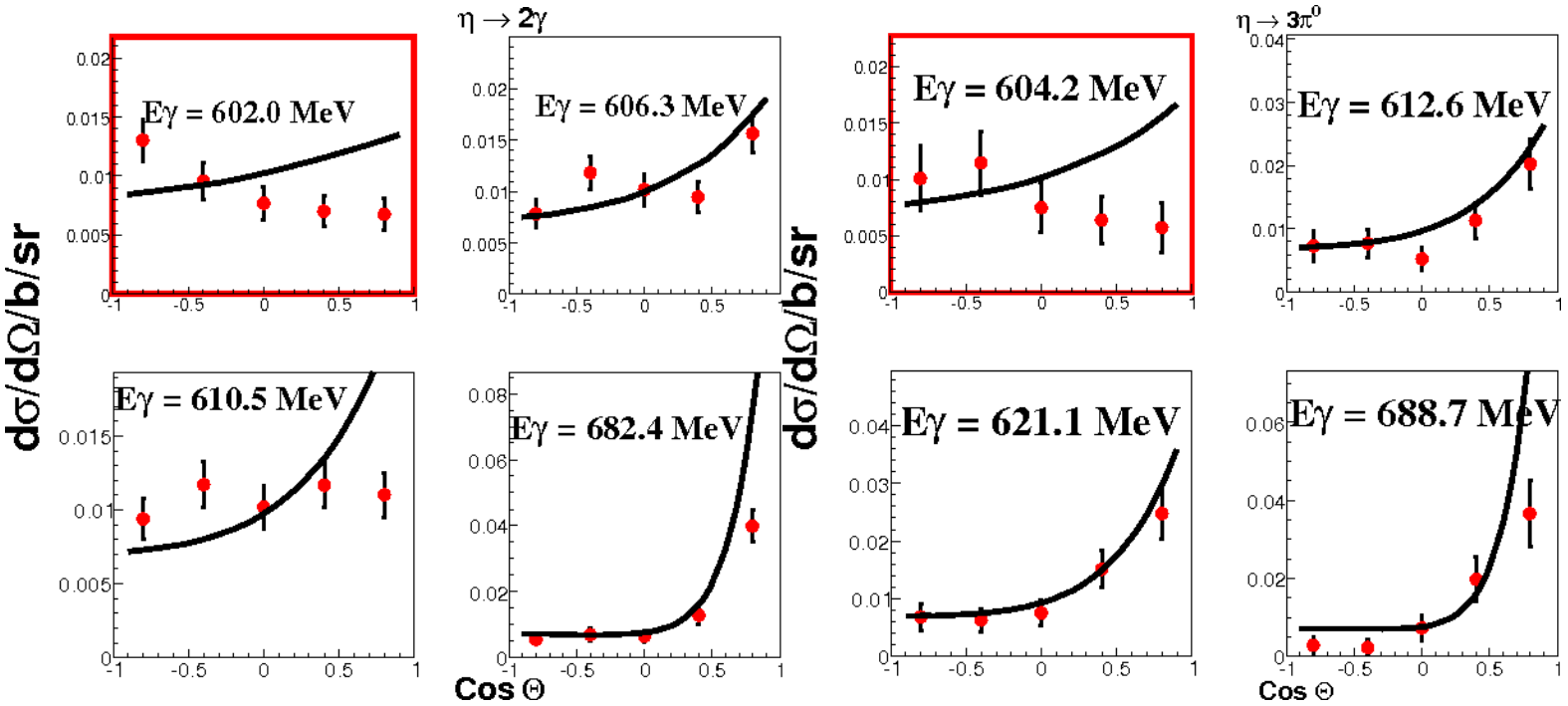




Average amplitude squared as a function of the CM η momentum.
"A nearby pole in the complex Q plane is indeed responsible for the unusual dependance of the cross section" C.Wilkin et al (PLB

Angular distributions

Threshold angular distribution do not behave as expected from form factor dependance



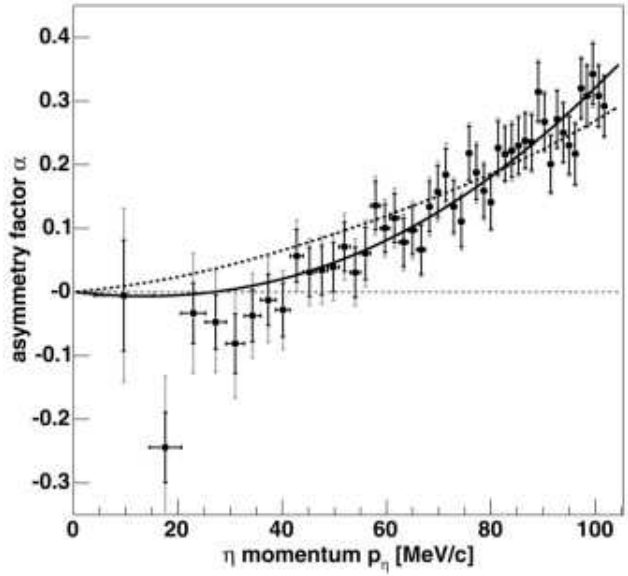
The angular dependence may be summarized in terms of an asymmetry parameter α.

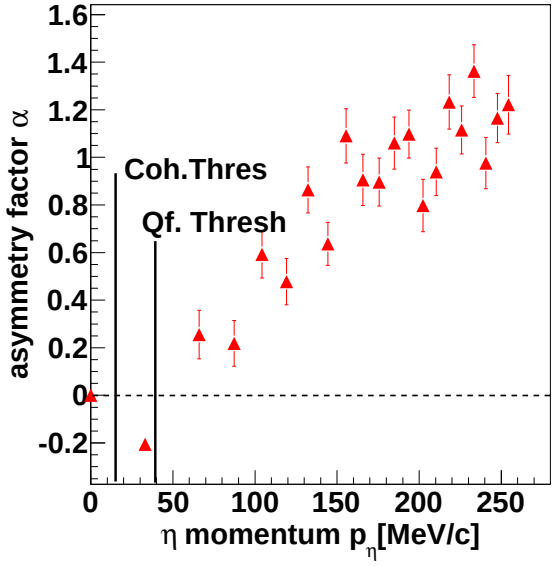
Variation of the asymmetry parameter

$$\alpha = \frac{d}{d(cos\theta_\eta)} ln\left(\frac{d\sigma}{d\omega}\right)\Big|_{cos\theta_\eta=0} \tag{9}$$

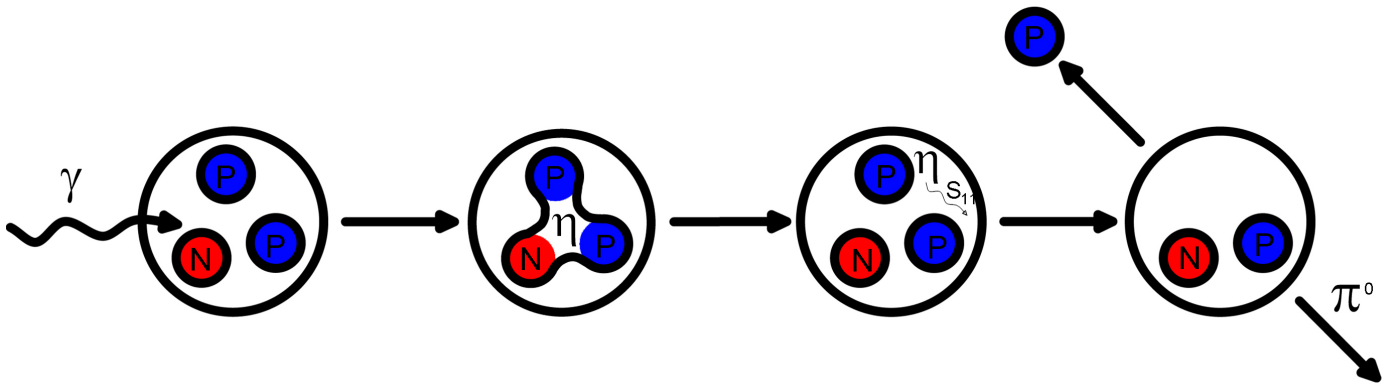
Where $\frac{d\sigma}{d\Omega}$ is defined as:

$$\frac{d\sigma}{d\Omega} = \frac{q}{k}(a + b\cos\theta + c\cos^2\theta) \rightarrow \alpha = \frac{a}{b} \tag{10}$$

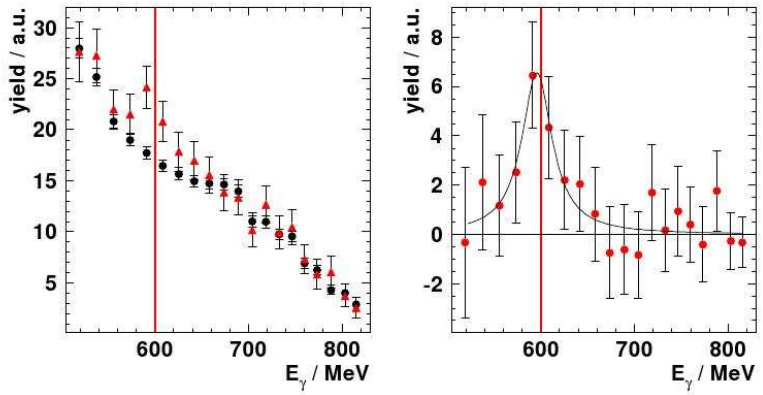




π^0 proton back-to-back

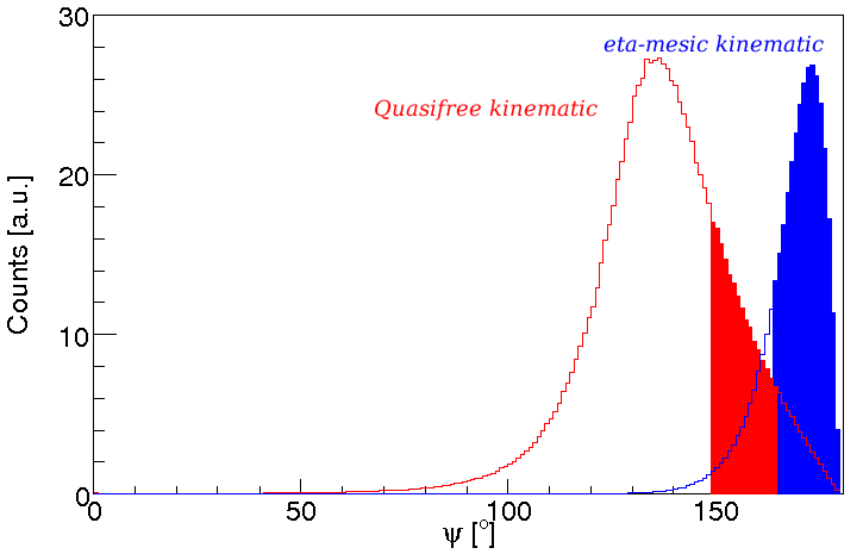


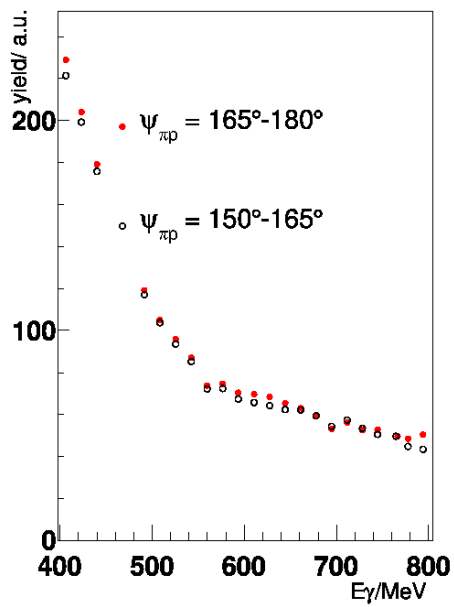
After the formation of a bound state the decay of the S_{11} resonance via the emission of a π^0 -proton back-to-back pair can lead to a peak-like strucure at the coherent η threshold.

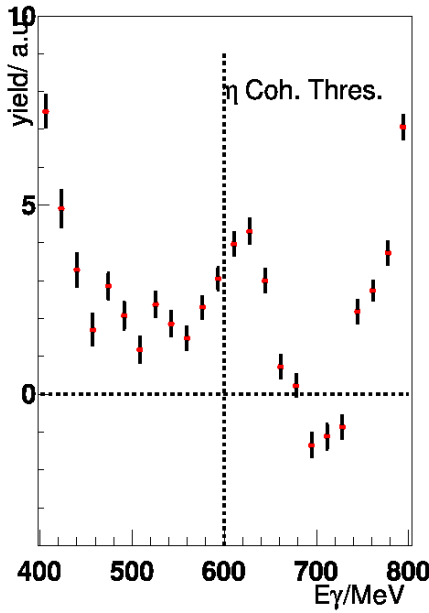


(Pfeiffer et. al.)

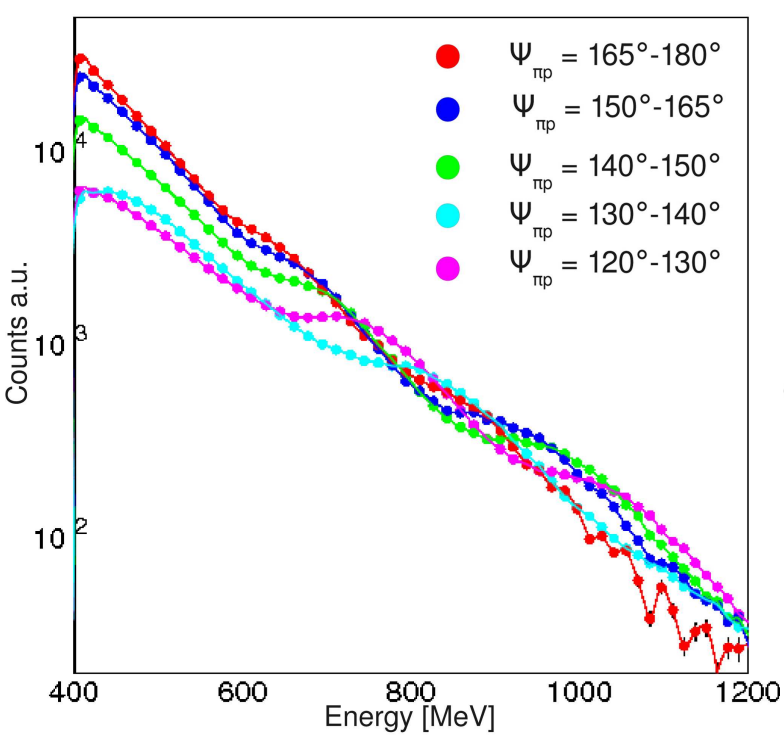
π^0 proton back-to-back

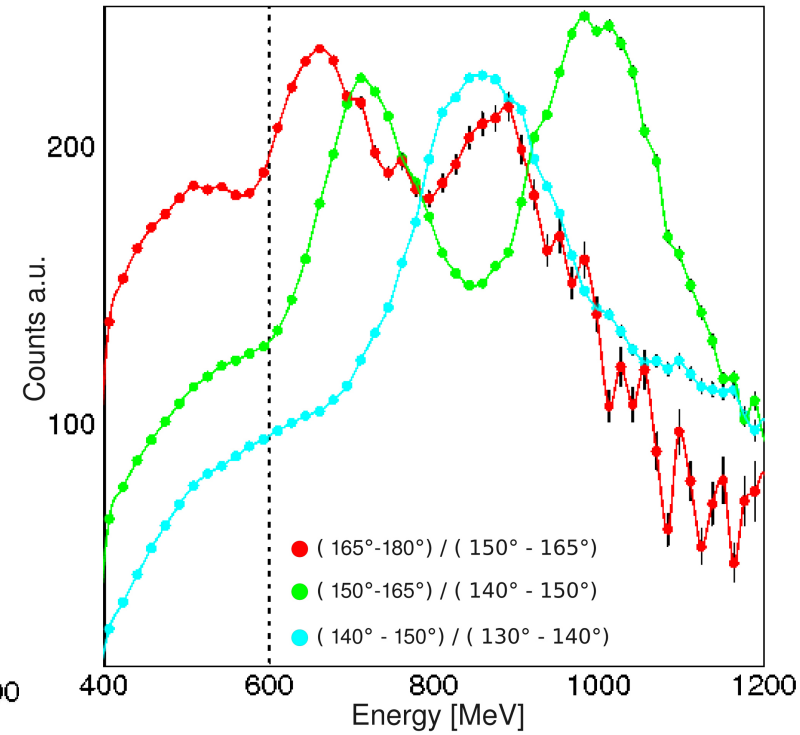






Excitation functions for different opening angles





Conclusion

- The η coherent production was measured with much higher statistical quality and better control of systematic effects than in the previous experiment.
- A strong threshold enhancement of the cross-section was confirmed for $\gamma^3He \rightarrow \eta^3He$ and $\gamma^7Li \rightarrow \eta^7Li$(less pronounced) similar to the observation in the pd$\rightarrow^3$He η reaction at COSY-ANKE.
- Due to the residual contribution from resonances it is impossible to establish a signal of pion-proton back-to-back emission.
- η mesic on ^7Li ? ^4He?

Thanks for your attention
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