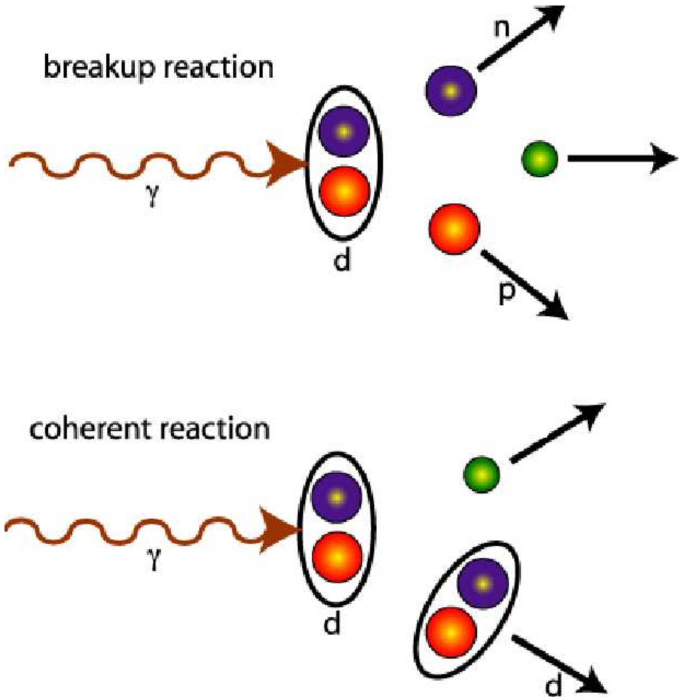
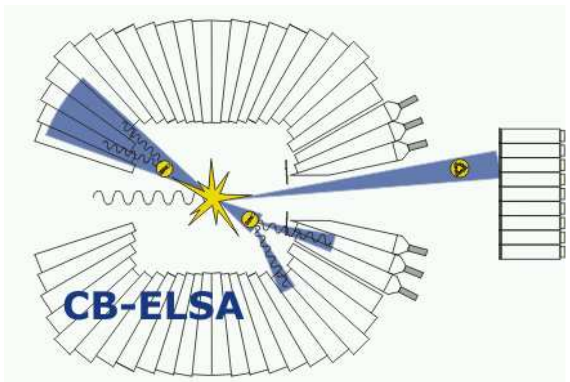
Photoproduction of η-mesons off the deuteron

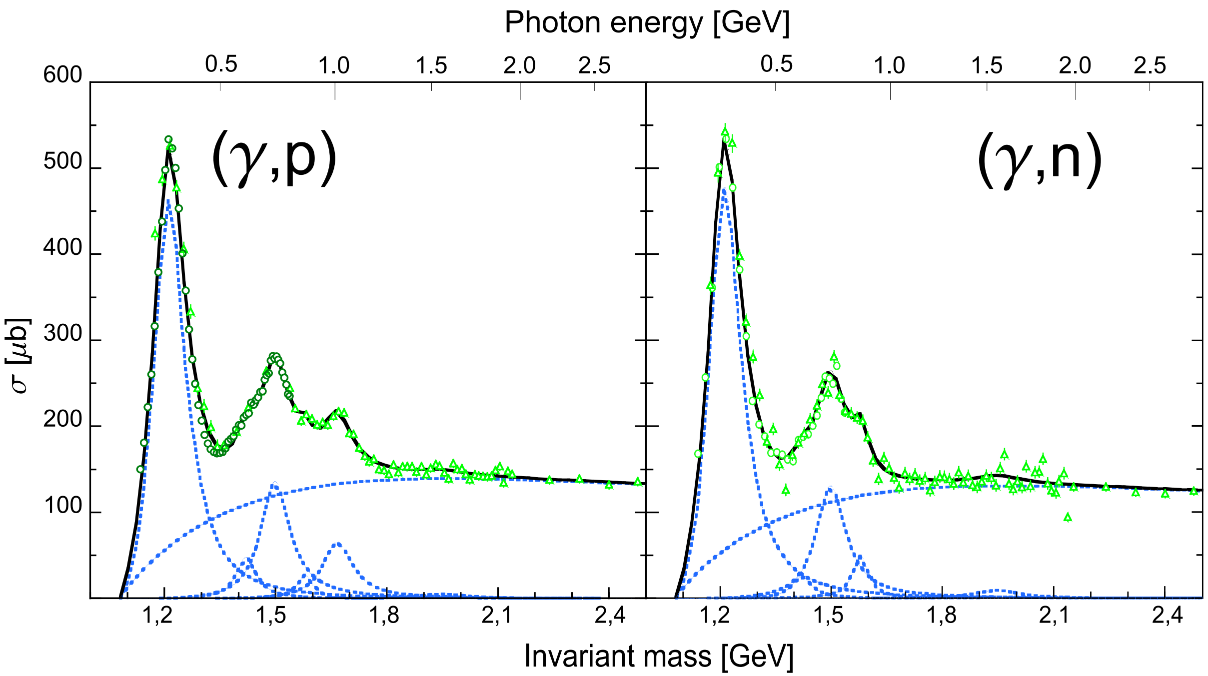
- Introduction
- Photoproduction of η-mesons
- Some other channels
- Conclusions





electromagnetic excitation off the neutron

- **importance of measurements off the neutron:**
  - different resonance contributions
  - needed for extraction of iso-spin composition of elm. couplings

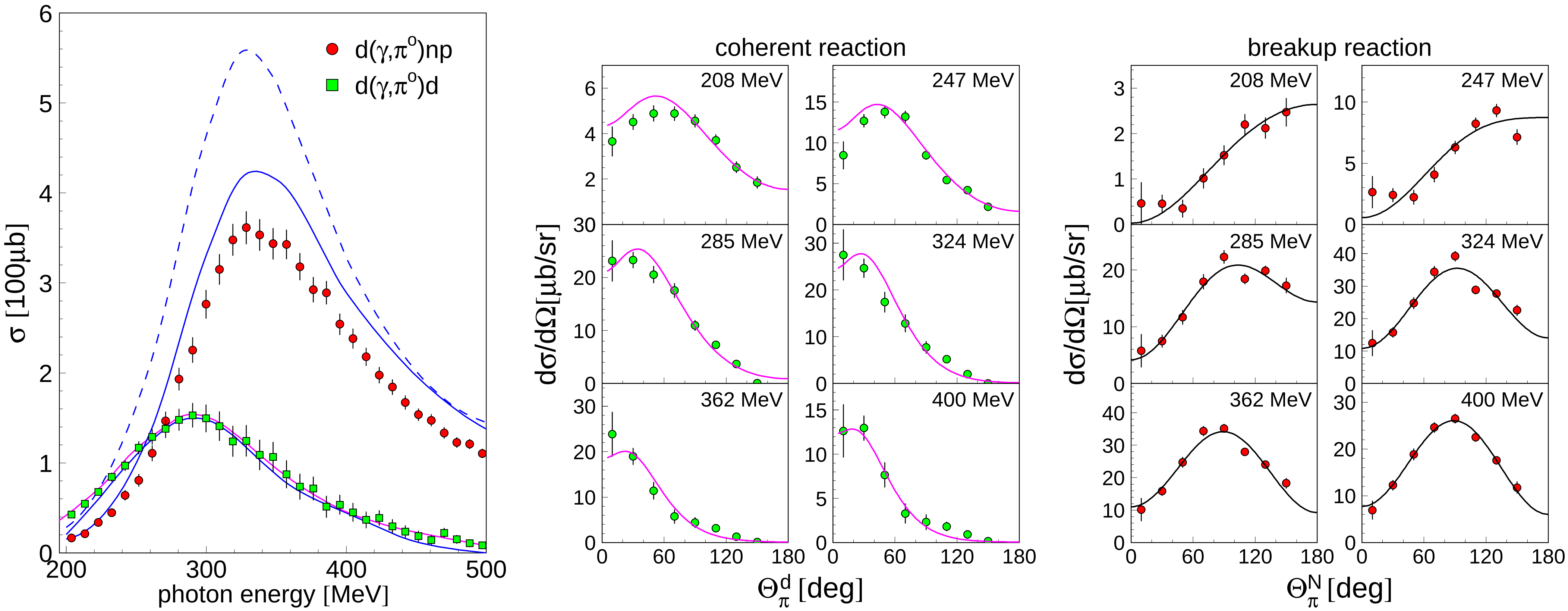


- **complications due to use of nuclear targets (deuteron):**
  - Fermi motion
  - nuclear effects like FSI, re-scattering, coherent contributions

TAPS

π^o-mesons in the Δ-resonance: coherent - breakup - FSI

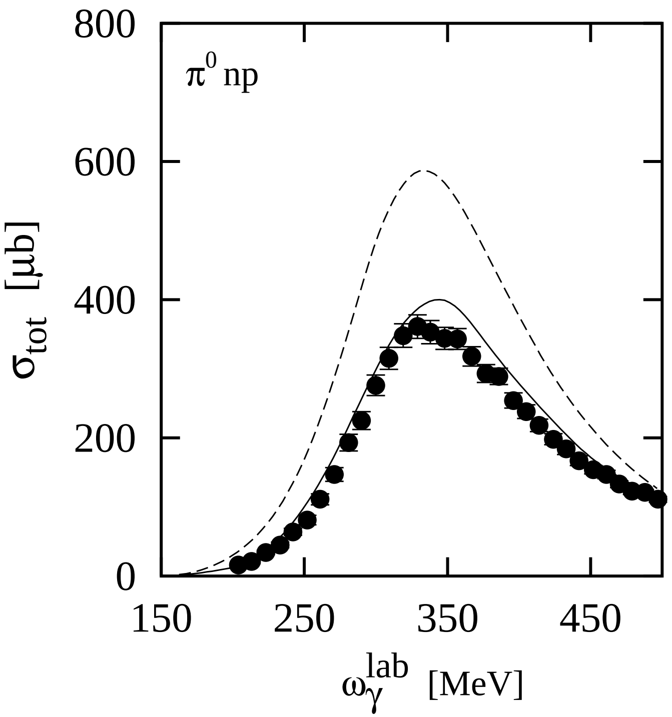
- **large coherent cross section, strong FSI**

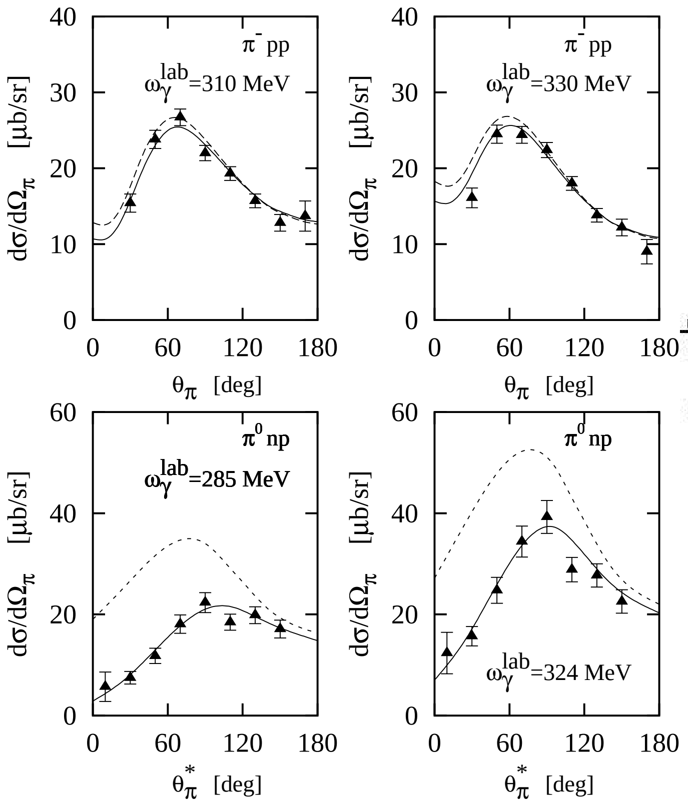


- **coherent part in good agreement with models (Kamalov et al. ’97, Laget ’81)**
- **large FSI effects for breakup part**
- **agreement with model predictions reasonable**

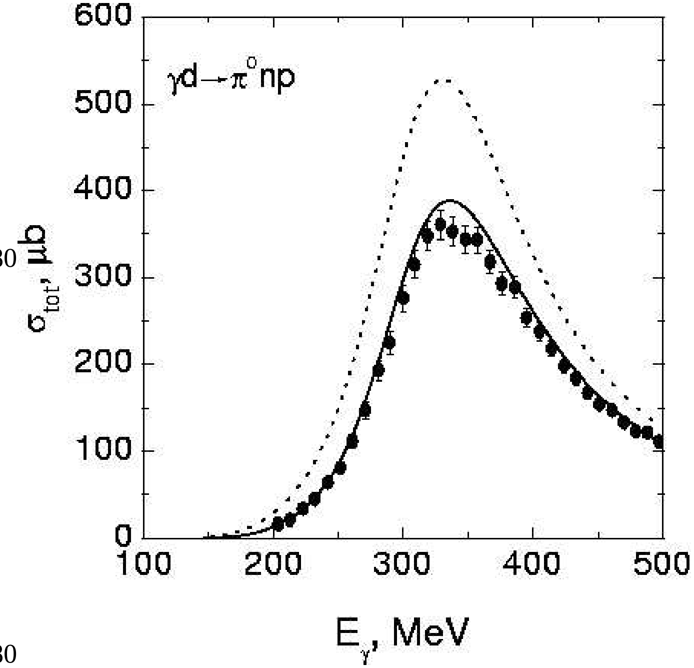
more recent models: better

- Darwish et al.'03;





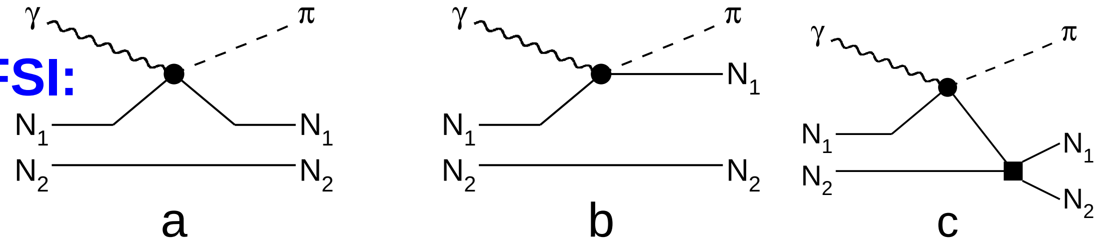
- Levchuk et al. '00

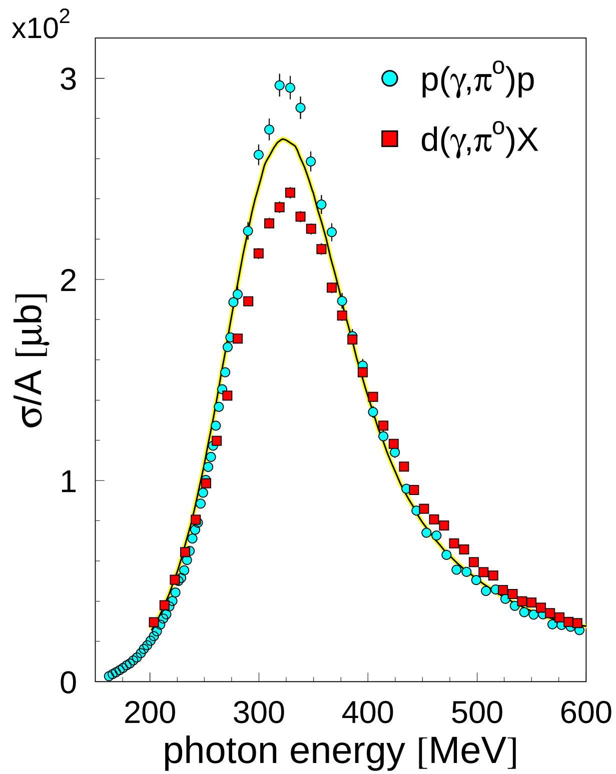


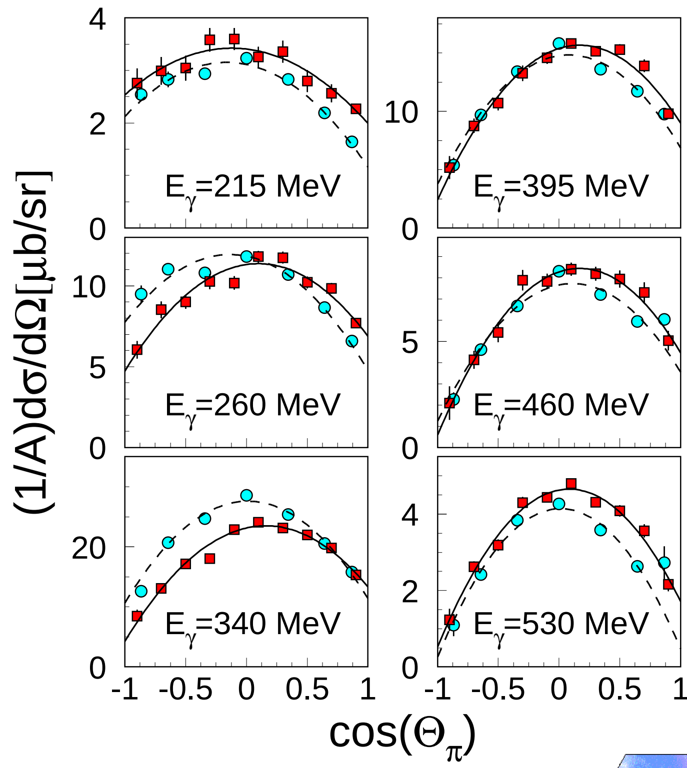
- **better control of FSI (most important: NN-FSI)**
- **large FSI for neutral pions at forward angles**

most simple qualitative interpretation: completeness relations

- **systems with strong FSI: breakup cross sections no good estimate for free nucleon cross sections**
- **coherent and breakup related via FSI:**
- **breakup + coherent ≈ quasi-free without FSI**

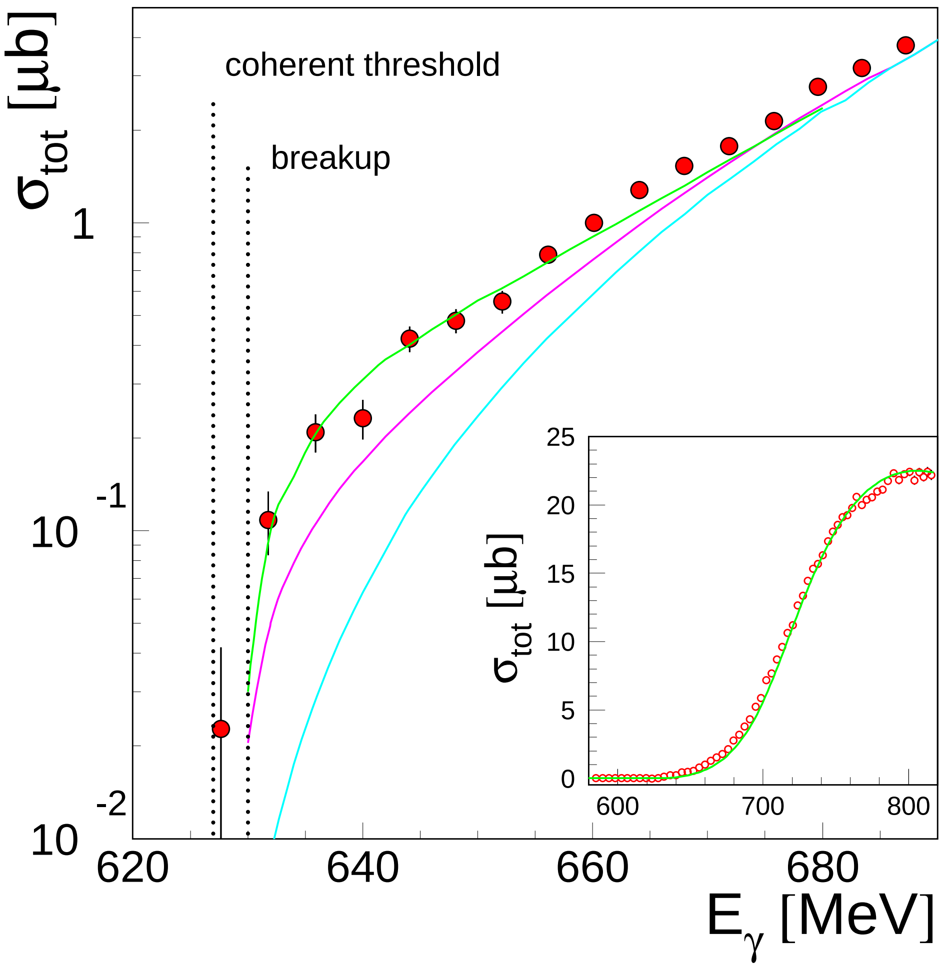


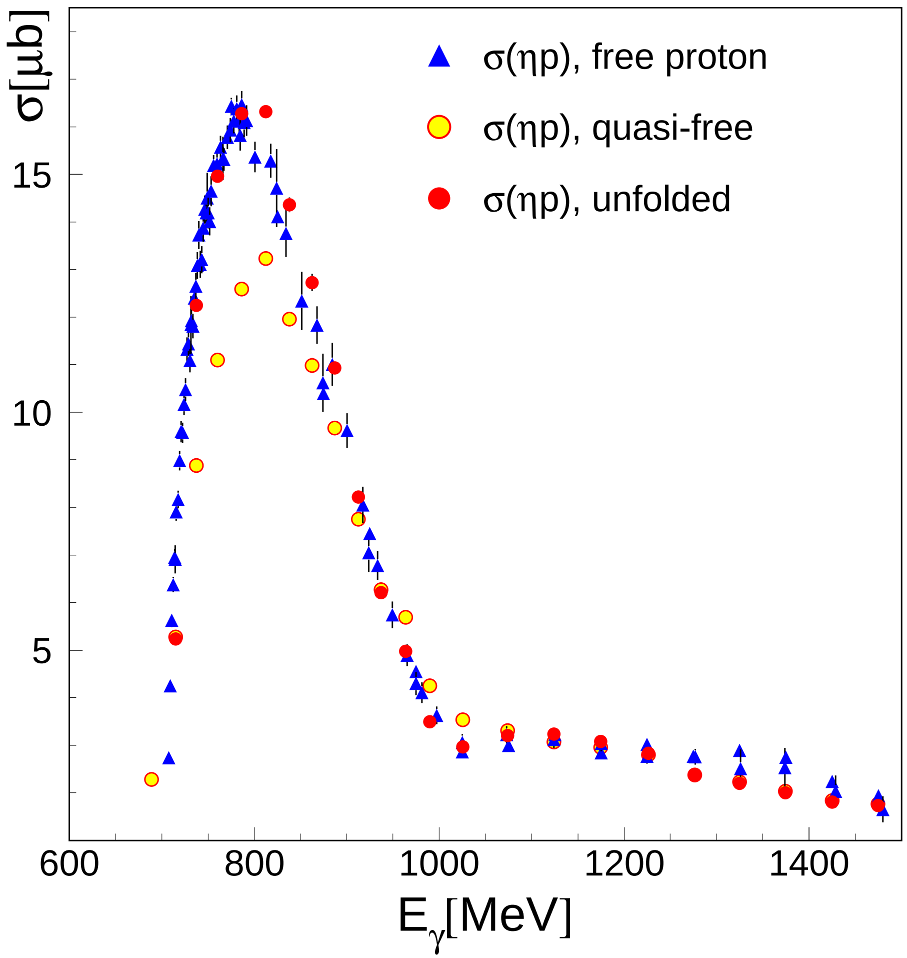




the (much simpler) η case

- **no complication from coherent process, no significant FSI efffects, more or less controllable Fermi motion effects**

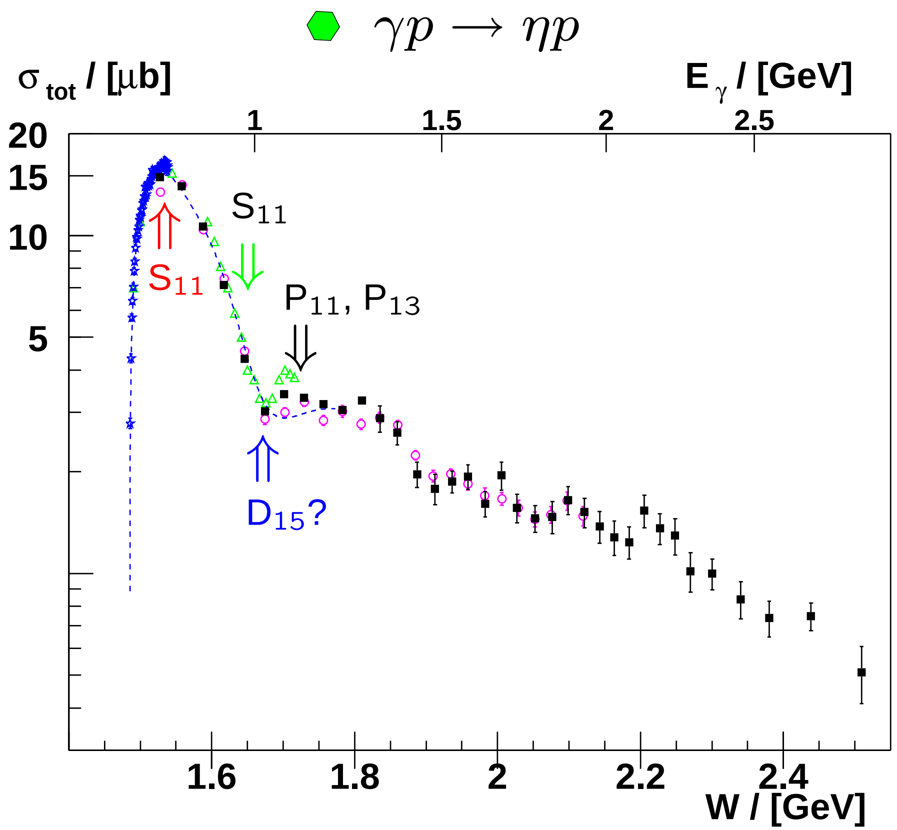




resonances coupling to η photoproduction

branching ratios and elm. couplings (PDG):

state	b_η [%]	$A^p_{1/2}$	$A^p_{3/2}$	$A^n_{1/2}$	$A^n_{3/2}$
• $D_{13}(1520)$:	0.23 ± 0.04	-24	166	59	139
• $S_{11}(1535)$:	30 - 55	90		-46	
• $S_{11}(1650)$:	3 - 10	53		-15	
• $D_{15}(1675)$:	0 ± 1	19	15	-43	-58
• $F_{15}(1680)$:	0 ± 1	-15	133	29	-33
• $D_{13}(1700)$:	0 ± 1				
• $P_{11}(1710)$:	6.2 ± 1.0				
• $P_{13}(1720)$:	4 ± 1				



- $D_{15}(1675)$ has stronger electromagnetic coupling to the neutron than to the proton

but parameters quite uncertain:

$A^p_{1/2}$=6 - 34,$A^p_{3/2}$=3-30, $A^n_{1/2}$=-(21-57),$A^n_{3/2}$=-(30-77)

b_η=$0-1\%$ (PDG), b_η=17% (ETA-MAID, Chiang et al.)

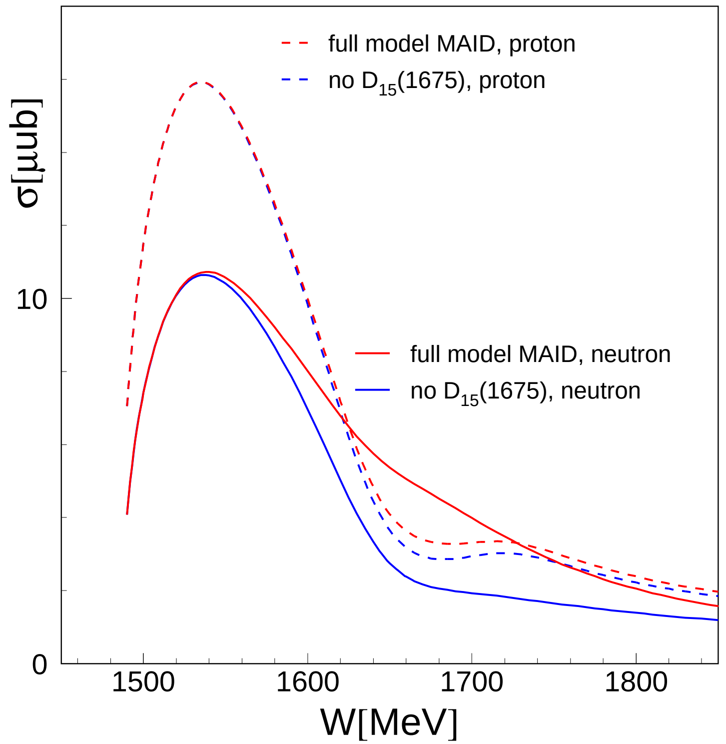
- interference structure in S_{11}-sector?

Data:

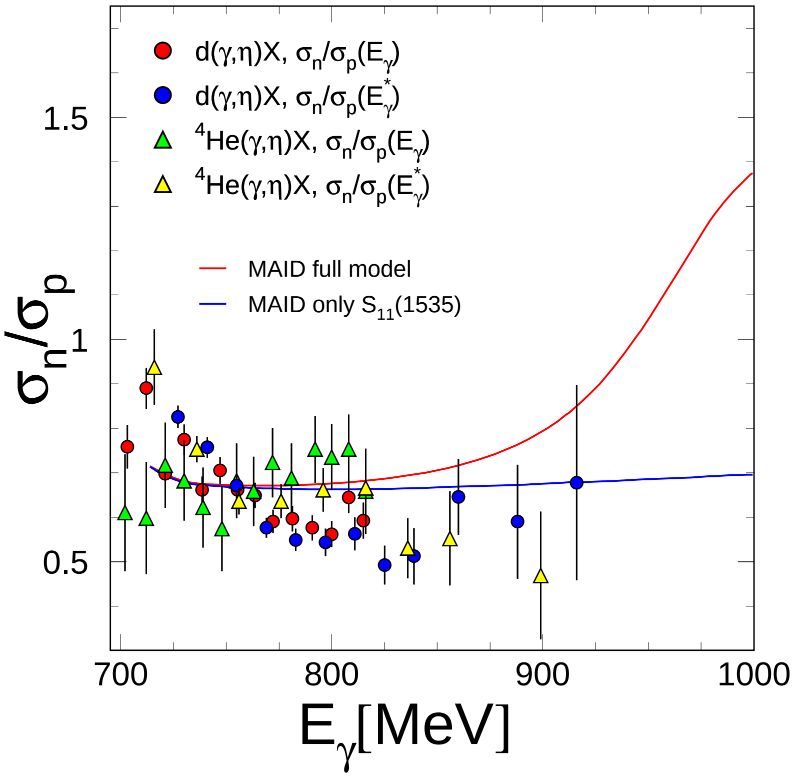
- TAPS: B. Krusche et al., PRL74 (1995) 3736
- GRAAL: F. Renard et al., PLB528 (2002) 215
- CLAS: M. Dugger et al., PRL89 (2002) 222002
- Crystal Barrel: V. Crede et al., PRL94 (2005) 012004

what is expected for $n(\gamma,\eta)n$ - why is it interesting?

- total cross sections for proton and neutron from MAID model with and without $D_{15}(1675)$ (Eta-MAID, W.T. Chiang et al., NPA 700 (2002) 429)



- previous data from MAMI only at lower incident photon energies



- predictions from chiral soliton models: P_{11}-like state of the anti-decuplet has strong photon-coupling to the neutron and large ηN decay branching ratio

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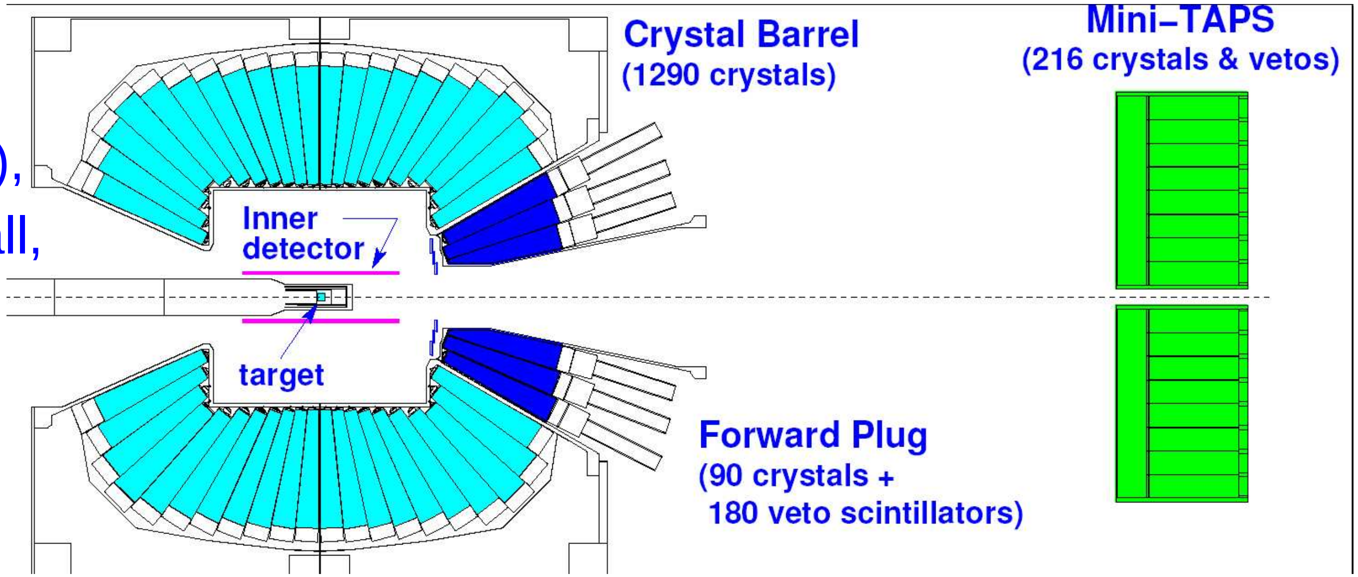
experimental setups - Ball, Barrel and TAPS and ...

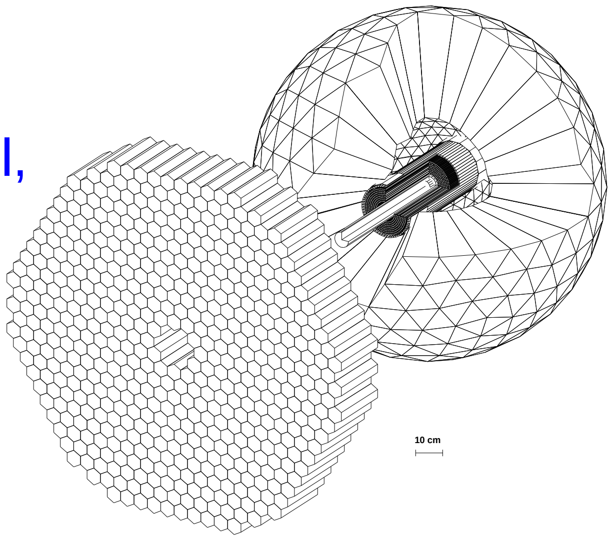
- Bonn ELSA accelerator:
  Crystal Barrel (1380 CsI),
  TAPS (BaF_2) forward wall,
  inner detectors

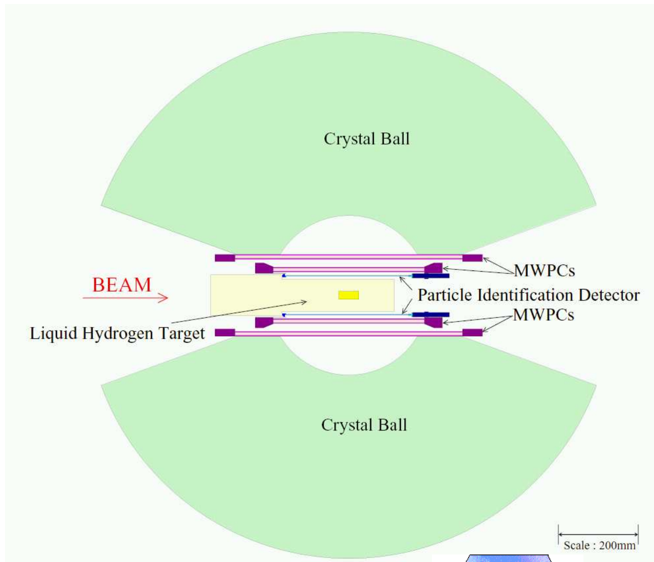
  $E_\gamma \leq$ 3.5 GeV,
  lin. pol.: available,
  circ. pol.: available



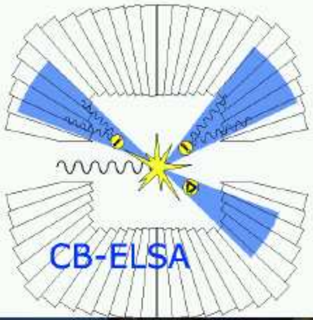
- Mainz MAMI accelerator:
  Crystal Ball (672 NaJ),
  TAPS (BaF_2) forward wall,
  inner detectors

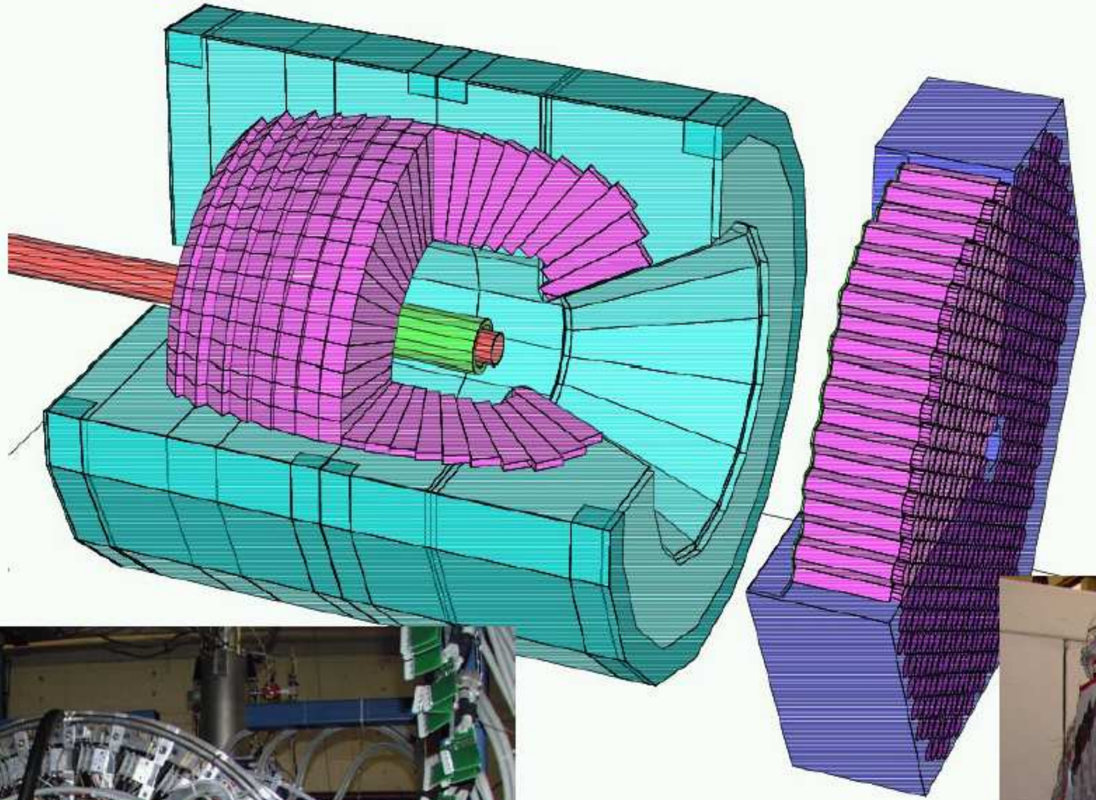
  $E_\gamma \leq$ 1.5 GeV,
  lin. pol.: available,
  circ. pol.: available

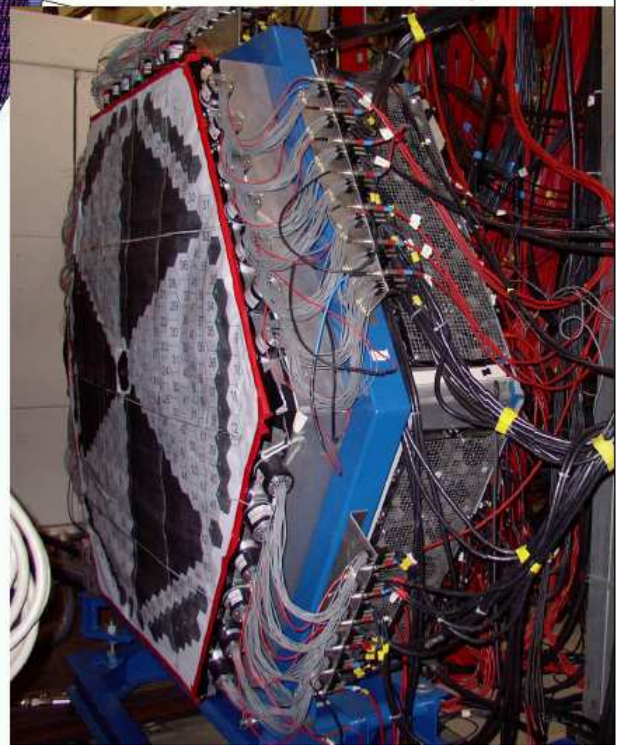




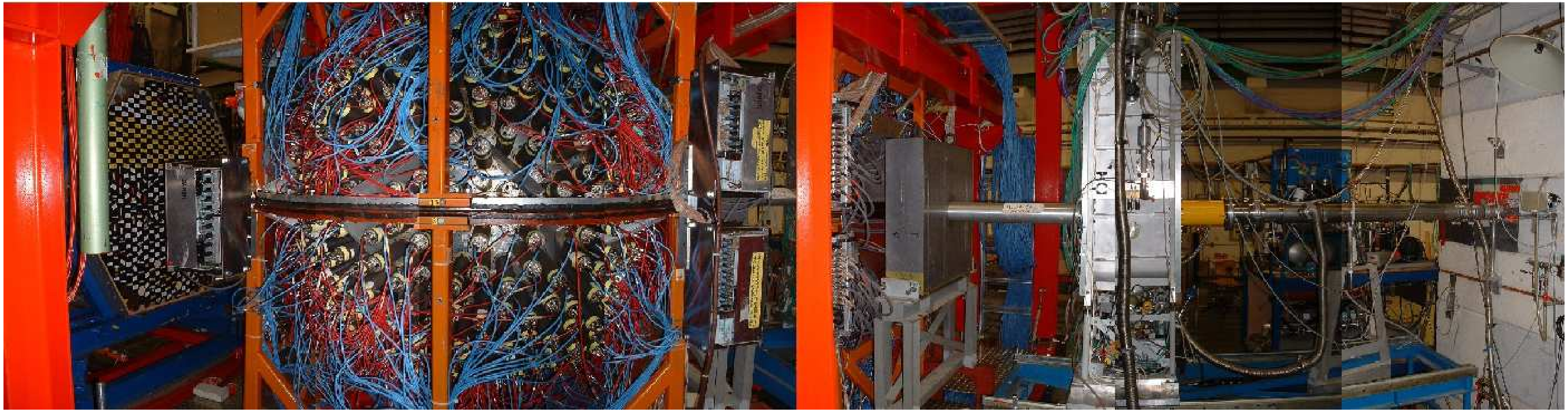
Crystal Barrel and TAPS





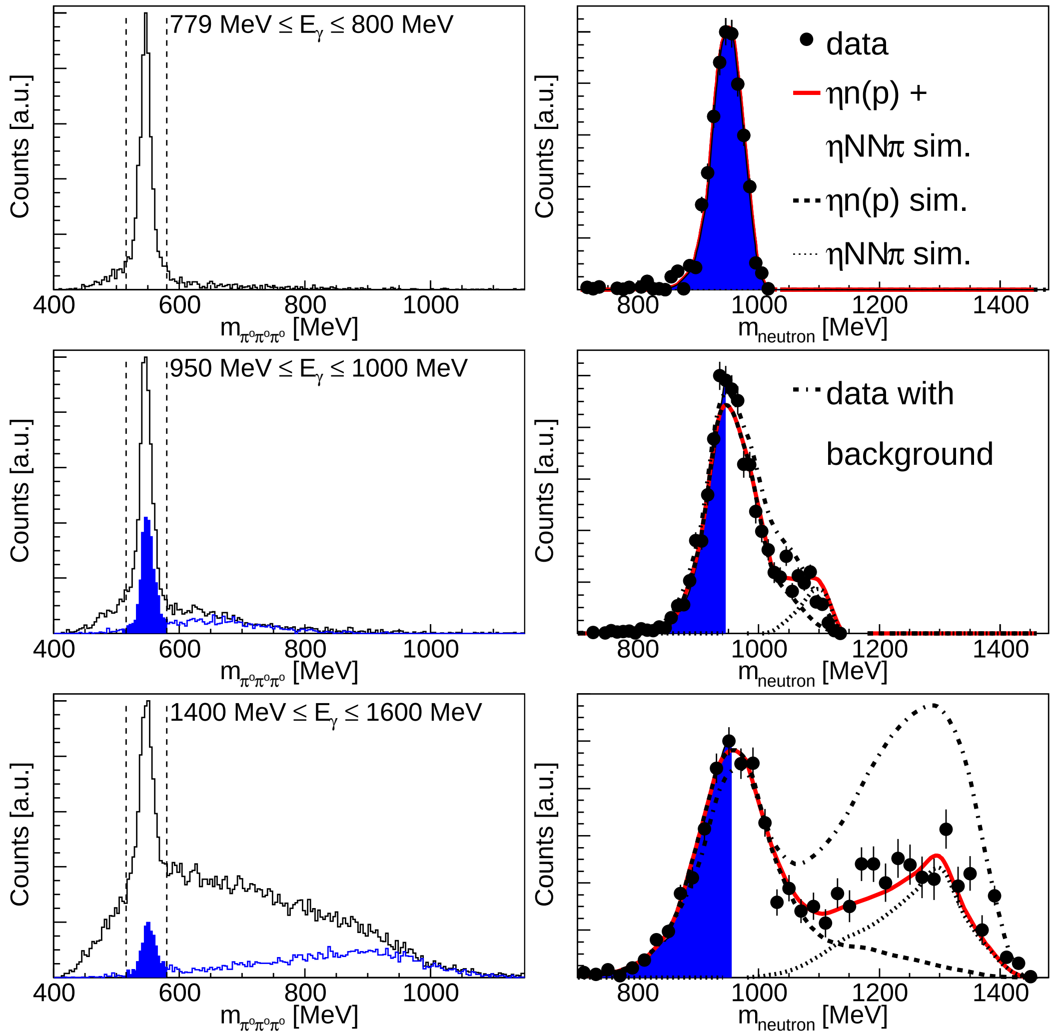


TAPS Crystal Ball - at MAMI



Identification of η-meson production (exclusive)

- decay channel: $\eta \rightarrow 3\pi^o \rightarrow 6\gamma$
- select events with 7 hits
- invariant mass off all photon pairs
- cut on π^o invariant mass
- select best combination of 6γ to $3\pi^o$ by χ^2-test
- use π^o mass as constraint, construct $3\pi^o$ invariant mass
- cut on $3\pi^o$ invariant mass
- missing mass analysis to remove $\eta\pi$ final states etc. treat recoil nucleon as missing particle: $m^2 = (\mathbf{P}_\gamma + \mathbf{P}_N - \mathbf{P}_\eta)^2$,



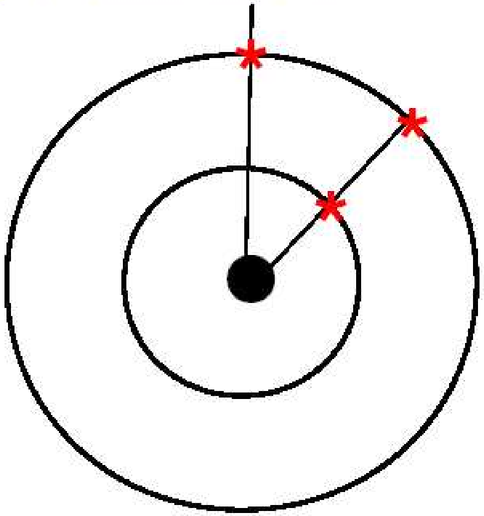
Nucleon Identification CB

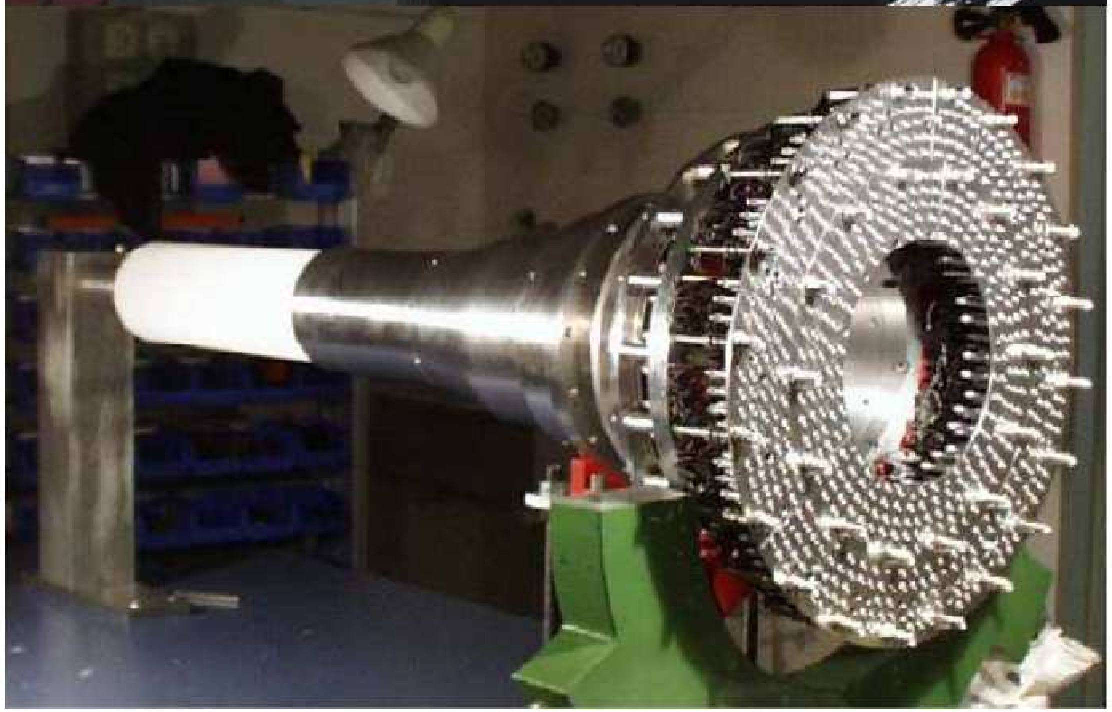
inner detector:

- 3 layers of scintillating fibers
- cylindrical shape
- proton:
2 or 3 layers match a hit in the CB

-neutron:

no layer has fired





Nucleon Identification TAPS

taps veto detector:

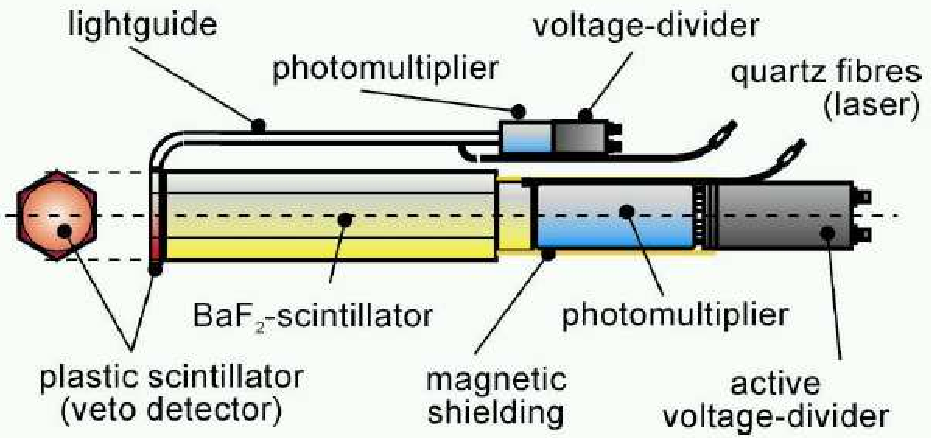
- **5 mm plastic scintillator**
- **individual for each BaF_2 crystal**

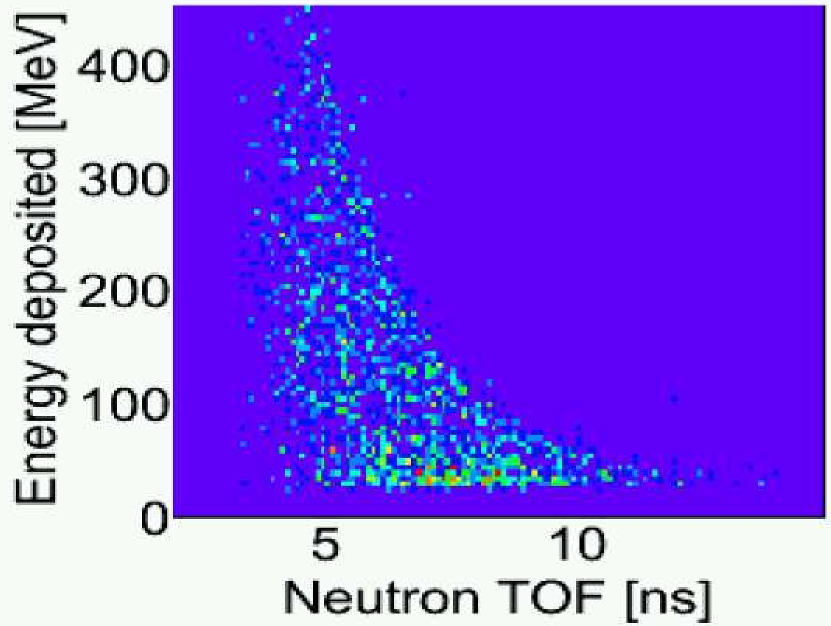
proton:

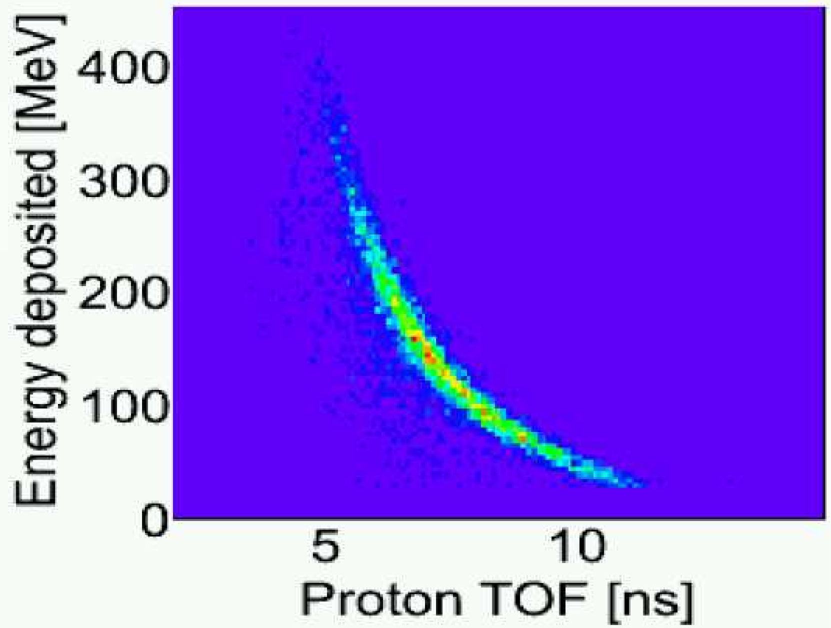
veto hit in front of BaF_2 crystal
+ E vs TOF

neutron:

no veto hit in front of BaF_2 crystal
+ E vs TOF

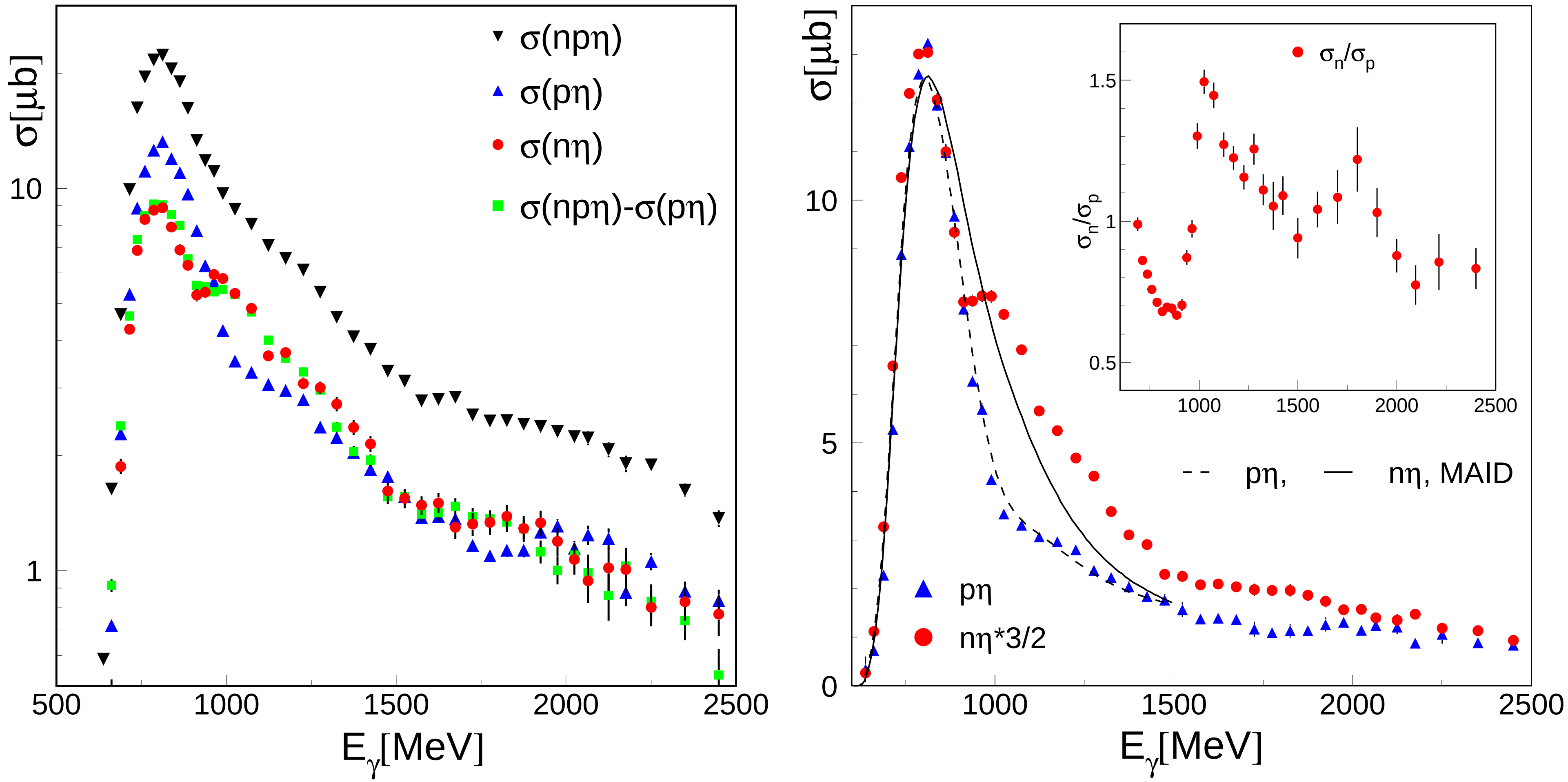






quasifree η-photoproduction off the deuteron (PhD thesis I.Jaegle)

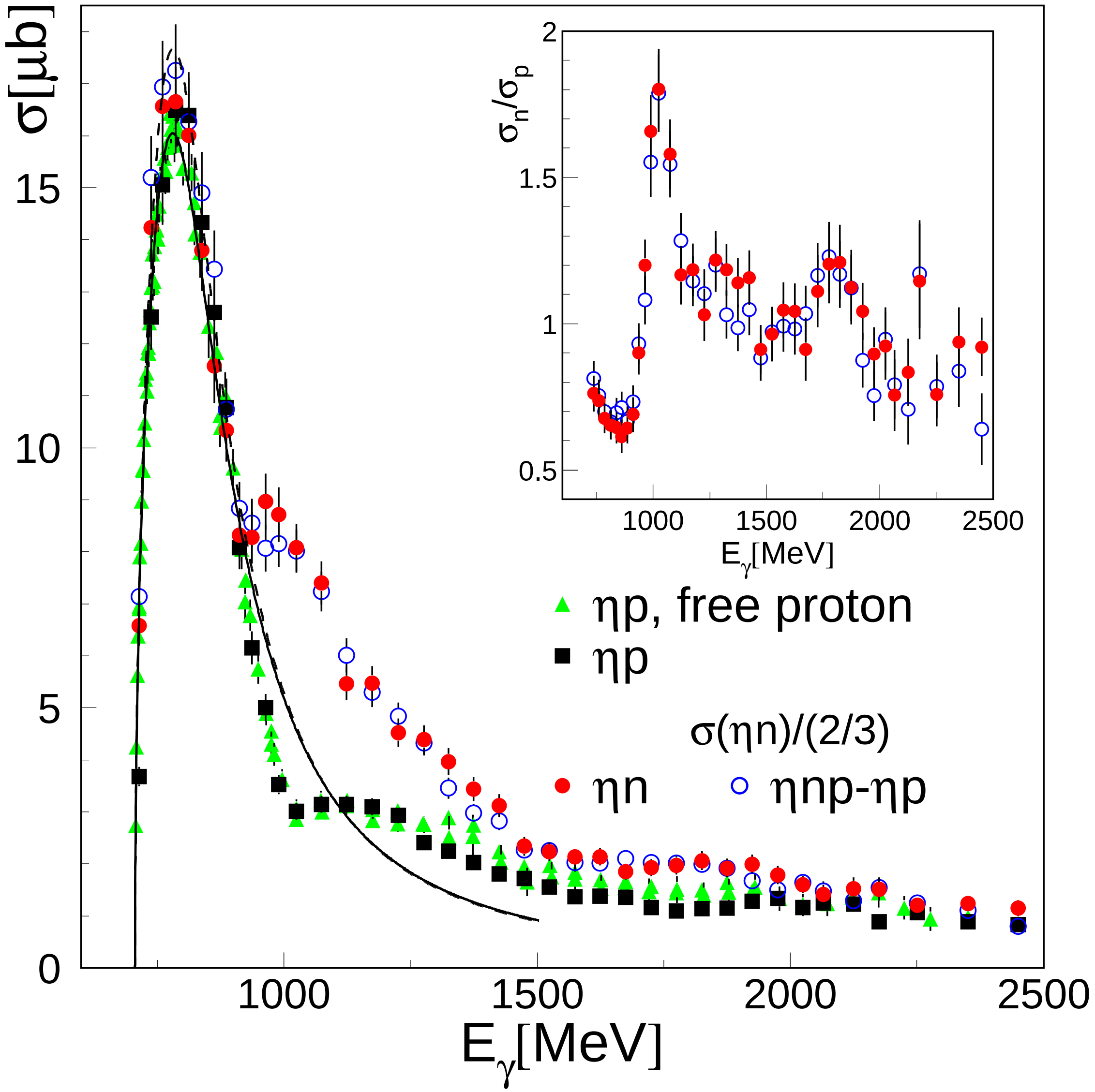
- cross section for $\gamma n \rightarrow \eta n$ from two analyses with very different systematics:
  (1) η in coincidence with recoil neutrons
  (2) difference of inclusive cross section and η in coincidence with recoil protons



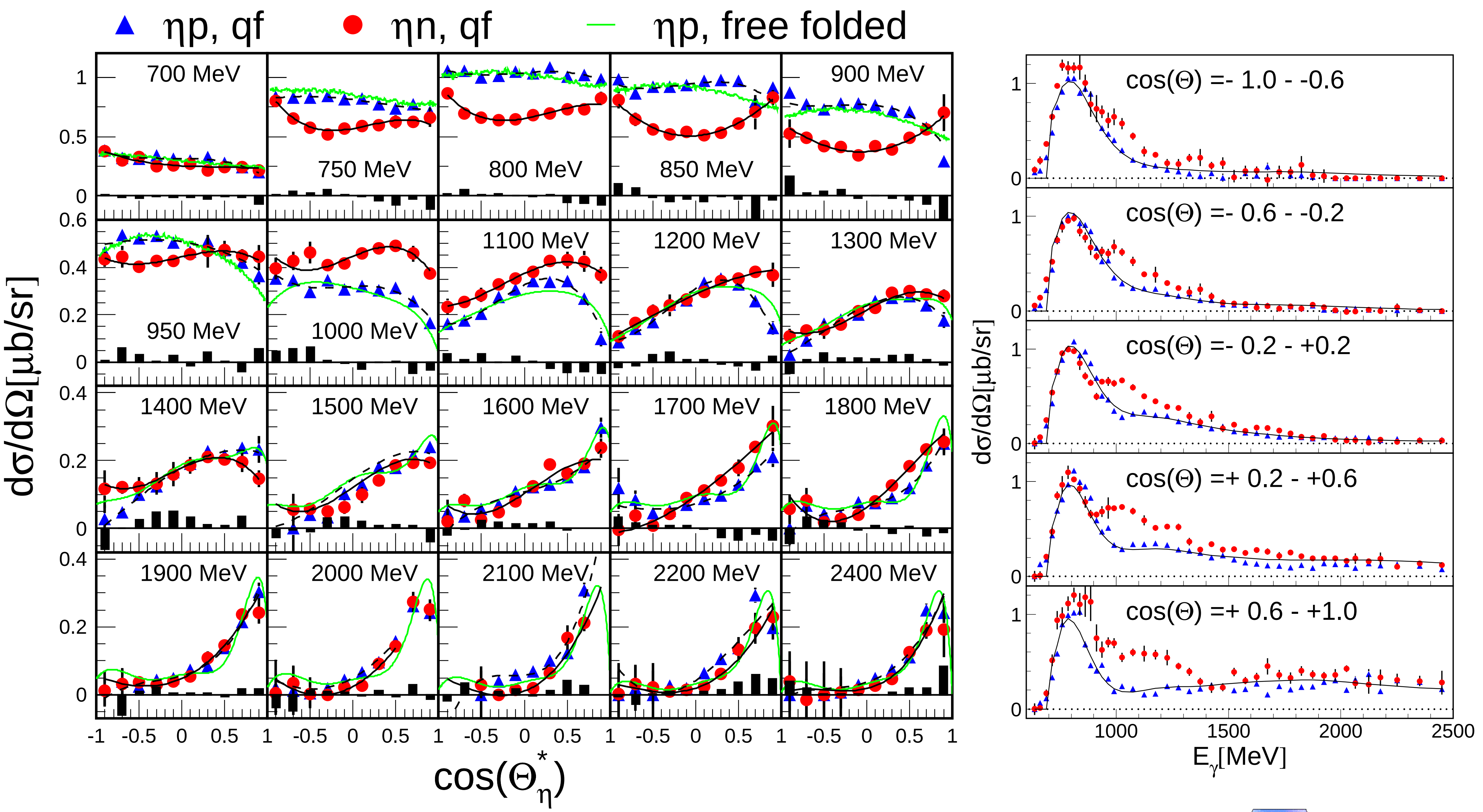
comparison of free and quasi-free cross sections

- quasi-free total cross sections corrected for Fermi smearing with correction factors calculated by folding known free proton cross section, respectively ETA-MAID prediction with momentum distribution of bound nucleons.

- result:
  - in S_{11}(1535) peak below 0.9 GeV perfect agreement between free and quasi-free proton data and quasi-free neutron data scaled by 2/3.
    Fit parameters for S_{11} Breit-Wigner:
    proton:
    W=1538 MeV, Γ=157 MeV, $A^p_{1/2}$=103
    neutron:
    W=1538 MeV, Γ=148 MeV, $A^n_{1/2}$=85
  - narrow structure around 1 GeV in neutron/proton ratio,
    width is only upper bound



angular distributions



fit of angular distributions

- fit with:

$$\frac{d\sigma}{d\omega} = \frac{q^\star}{k^\star} \sum A_i P_i(cos(\Theta^\star))$$

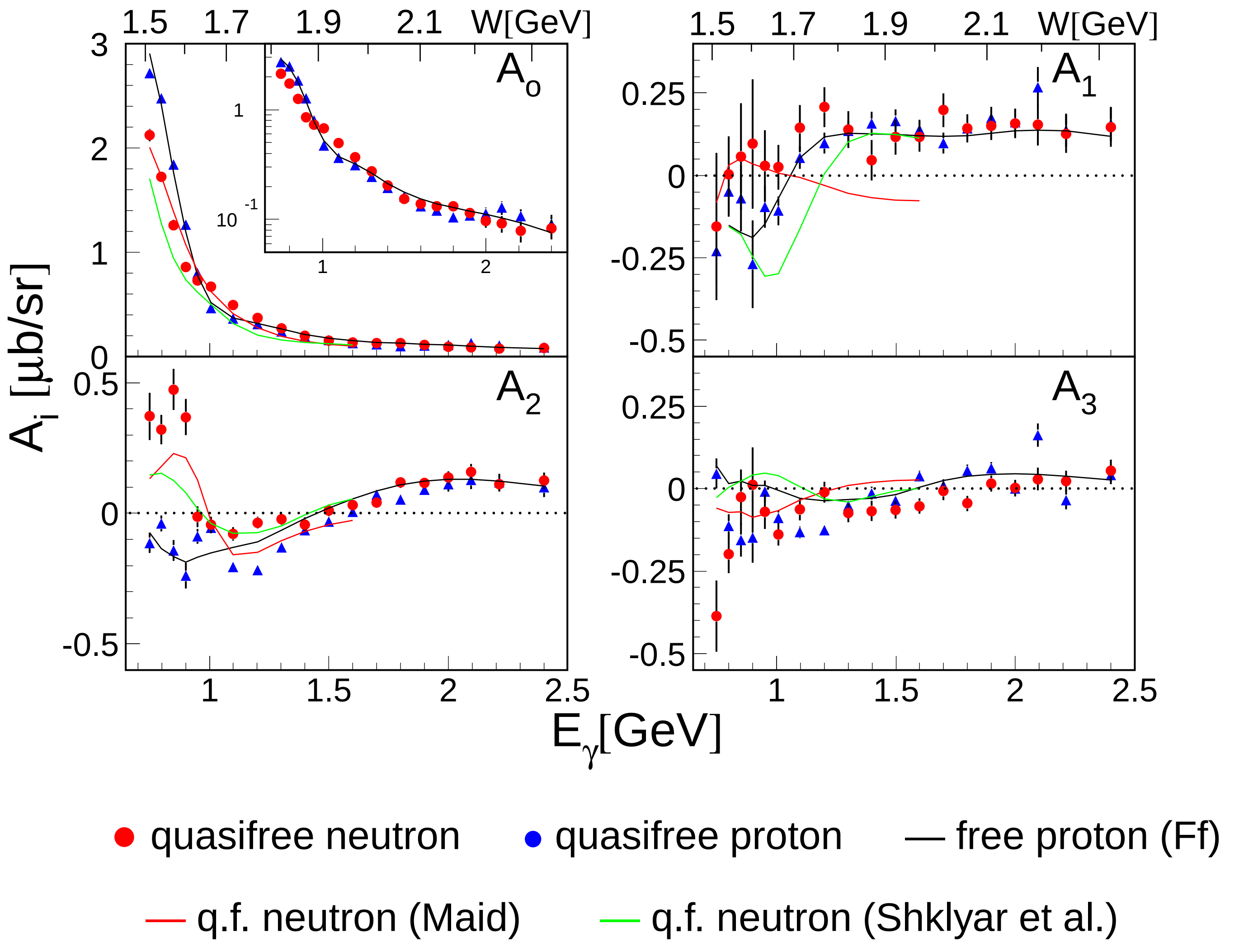
- result:

- all coeffi cients similar for proton and neutron above 1.25 GeV

- A_o coeffi cient:
  dominance of S_{11} resonances,
  for neutron small shoulder around 1 GeV

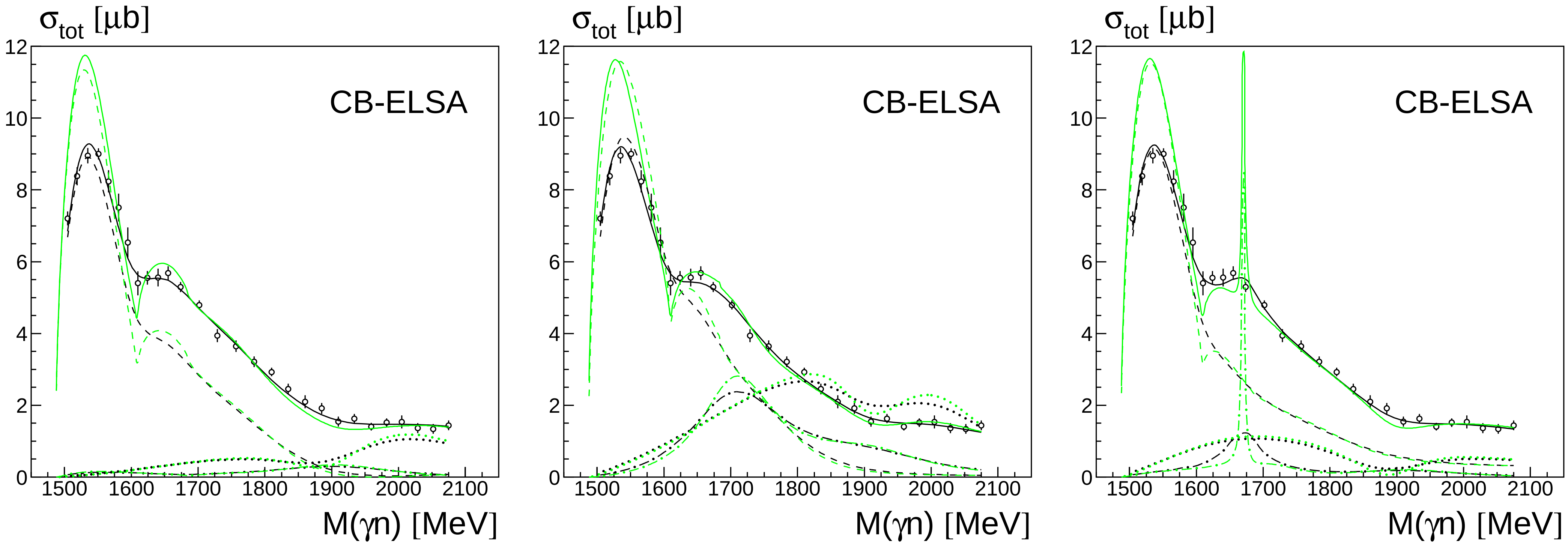
- A_1 coeffi cient:
  interference S_{11}, P_{11}?

- A_2 coeffi cient:
  interference S_{11} - D_{13} resonance



Bonn-Gatchina model analysis

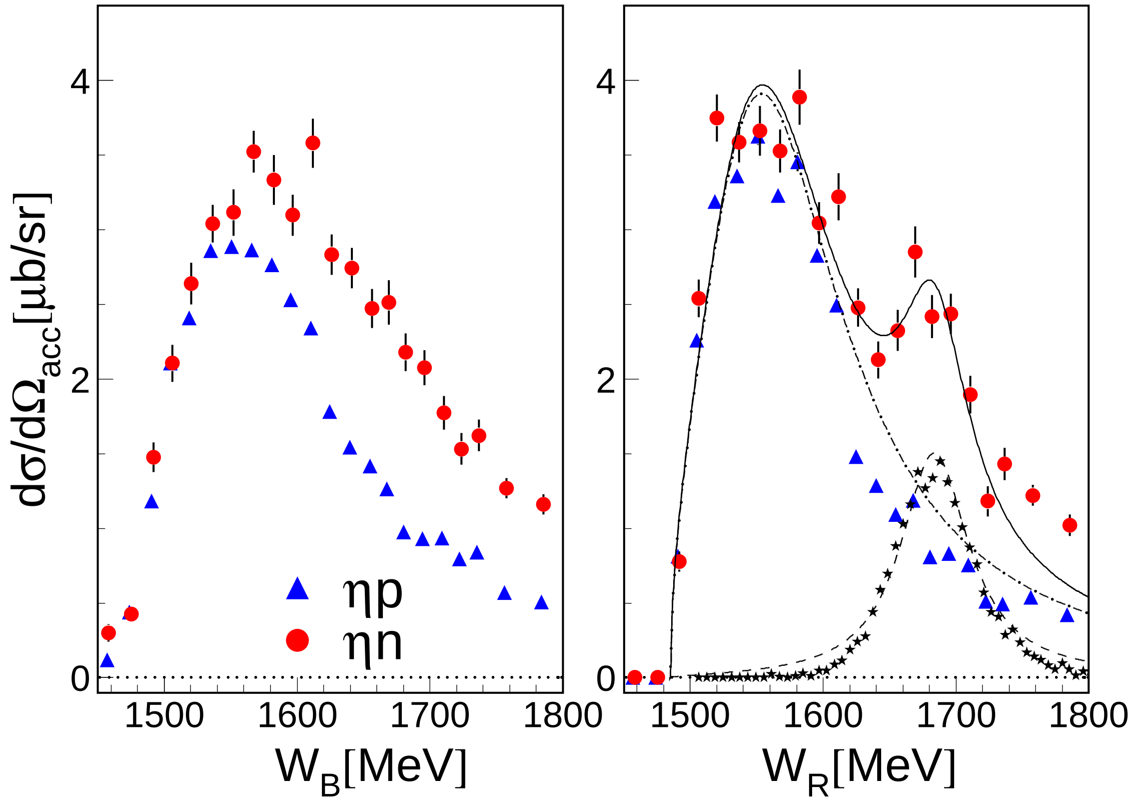
- basis: coupled channel isobar analysis with background terms



- different scenarios to reproduce 'bump' structure:
  - left: interference in S_{11}-sector: adjusting phases etc.
  - middle: introduction of conventional (broad) P_{11} resonance
  - right: introduction of very narrow P_{11} resonance

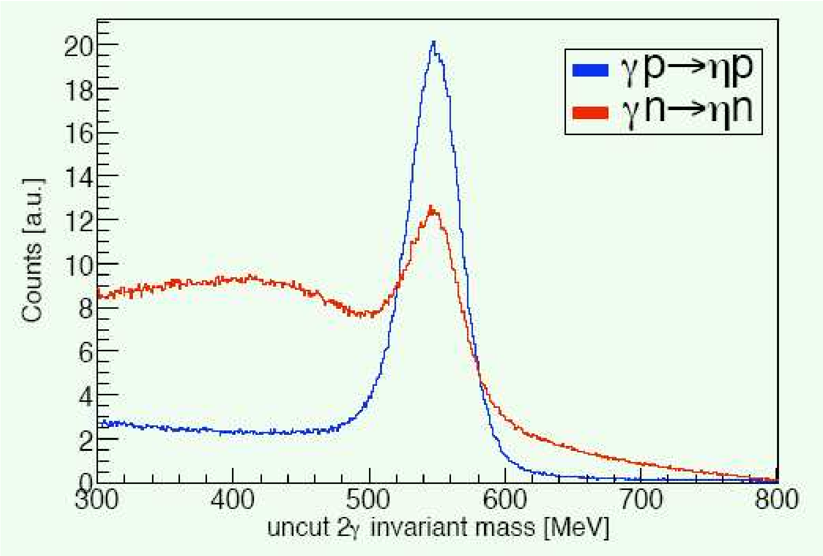
de-folding of Fermi smearing

- for events with neutron in TAPS
  $(cos(\Theta_\eta^\star) < -0.1)$
  neutron energy from time-of-flight
- comparsion: W from photon energy (Fermi smeared) - W from nucleon - meson 4-vectors (resolution smeared)
- de-folded proton cross section similar to free proton,
  de-folded neutron cross section shows structure around 1.7 GeV:
  - position: W=1683 MeV
  - width: Γ=60$\pm$10 MeV
  - (resolution dominated)

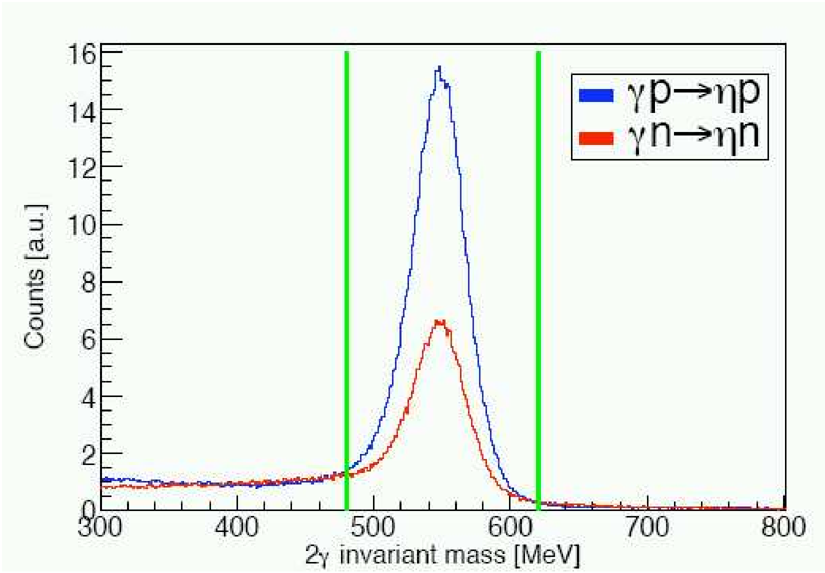


new preliminary results from MAMI C: reaction identification

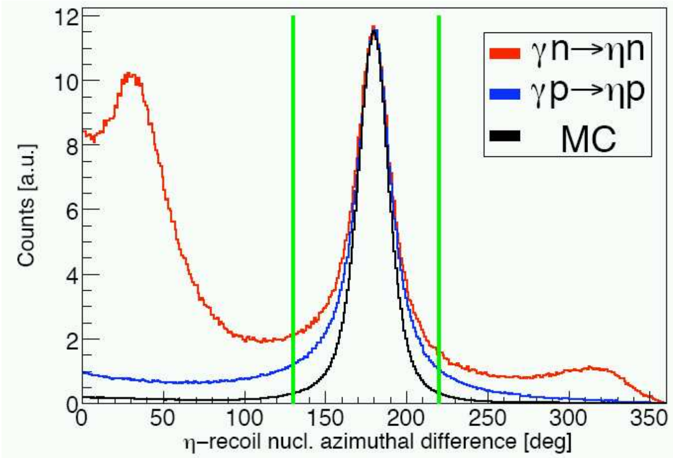
- **raw invariant mass**



- **cut on co-planarity**

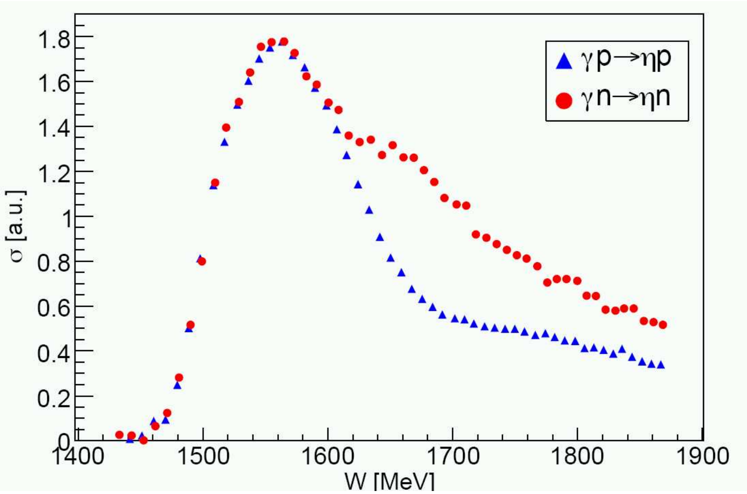


- **co-planarity**

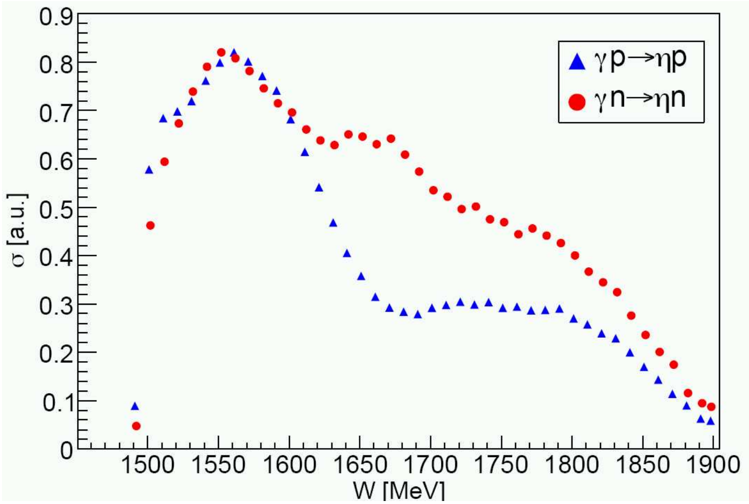


preliminary excitation functions (PhD thesis D. Werthmüller)

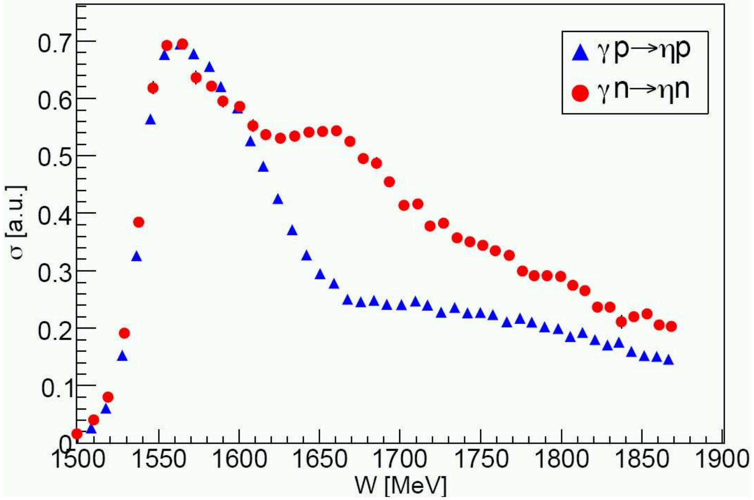
- $W = f(E_\gamma)$, $130 < \Delta\Phi < 220$



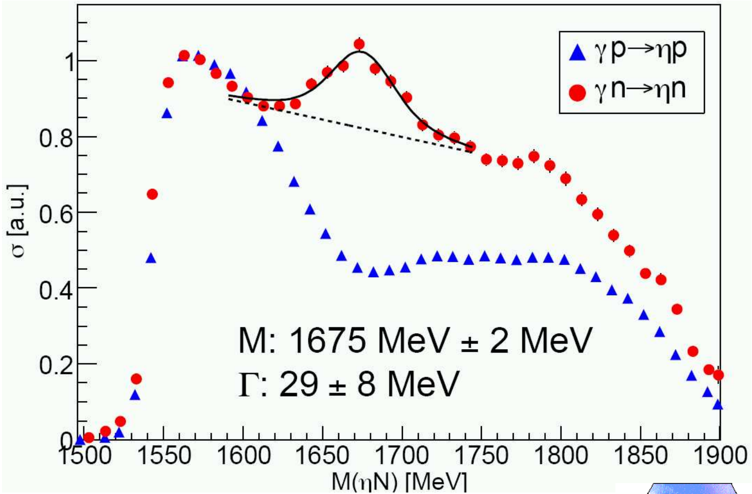
- $W = f(n, \eta)$, $130 < \Delta\Phi < 220$



- $W = f(E_\gamma)$, $170 < \Delta\Phi < 190$



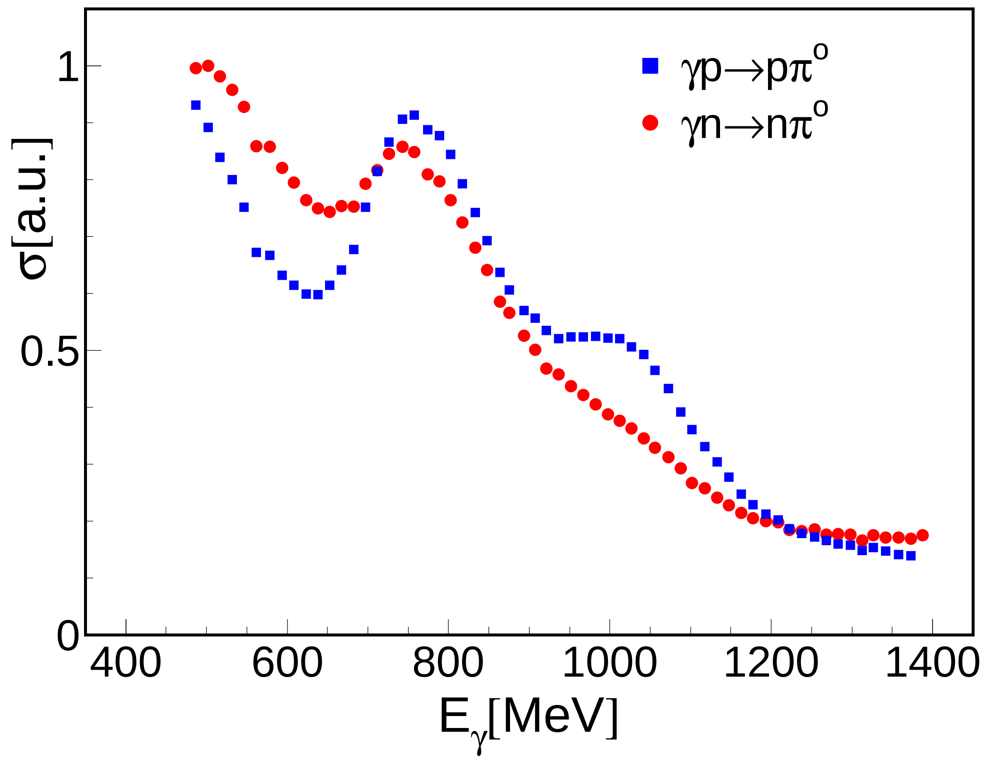
- $W = f(n, \eta)$, $170 < \Delta\Phi < 190$

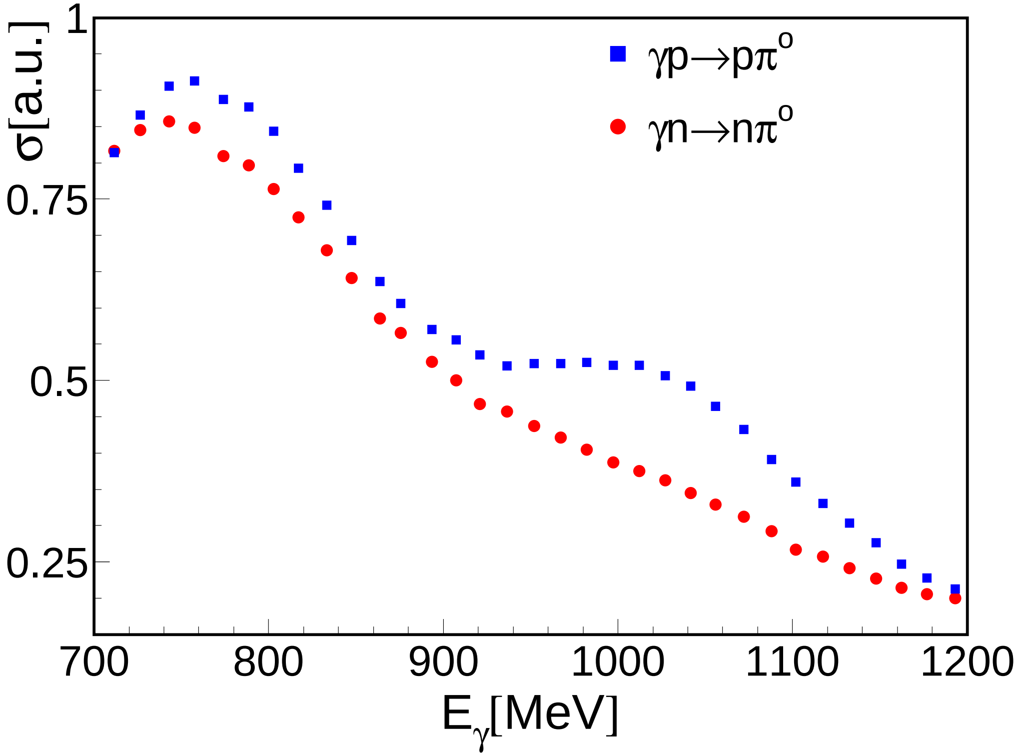


other channels: photoproduction of π^o mesons (MAMI-C)

(master thesis M. Dieterle)

- very preliminary (no normalization, no efficiency corrections)
- no structure in neutron excitation function around 1 GeV ?





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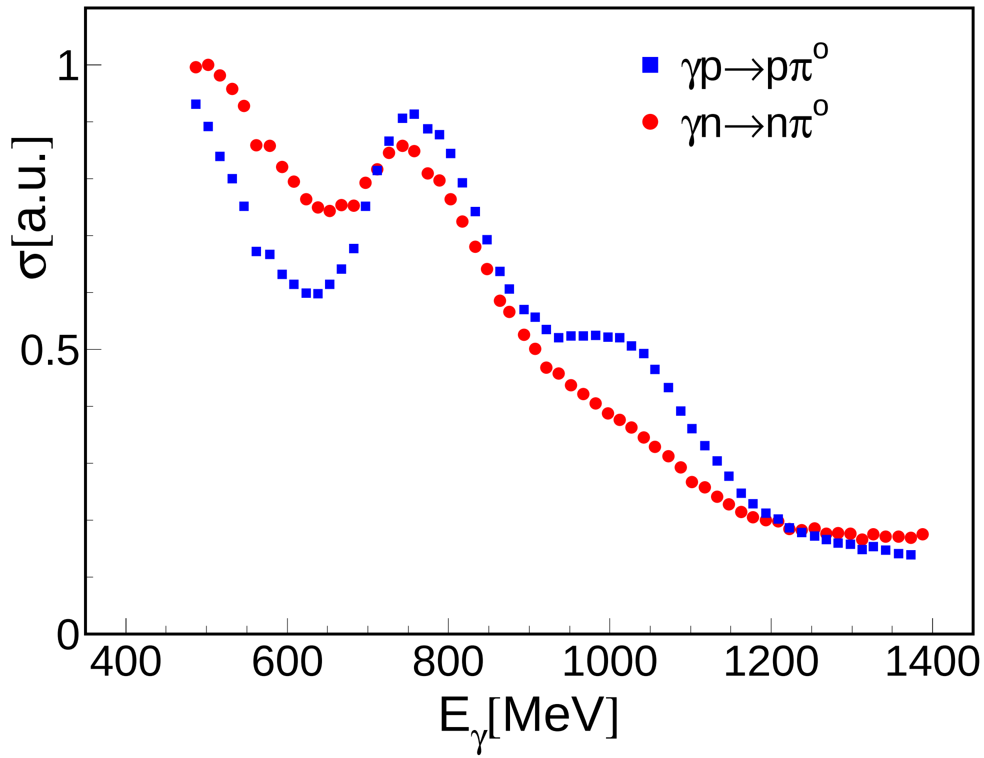
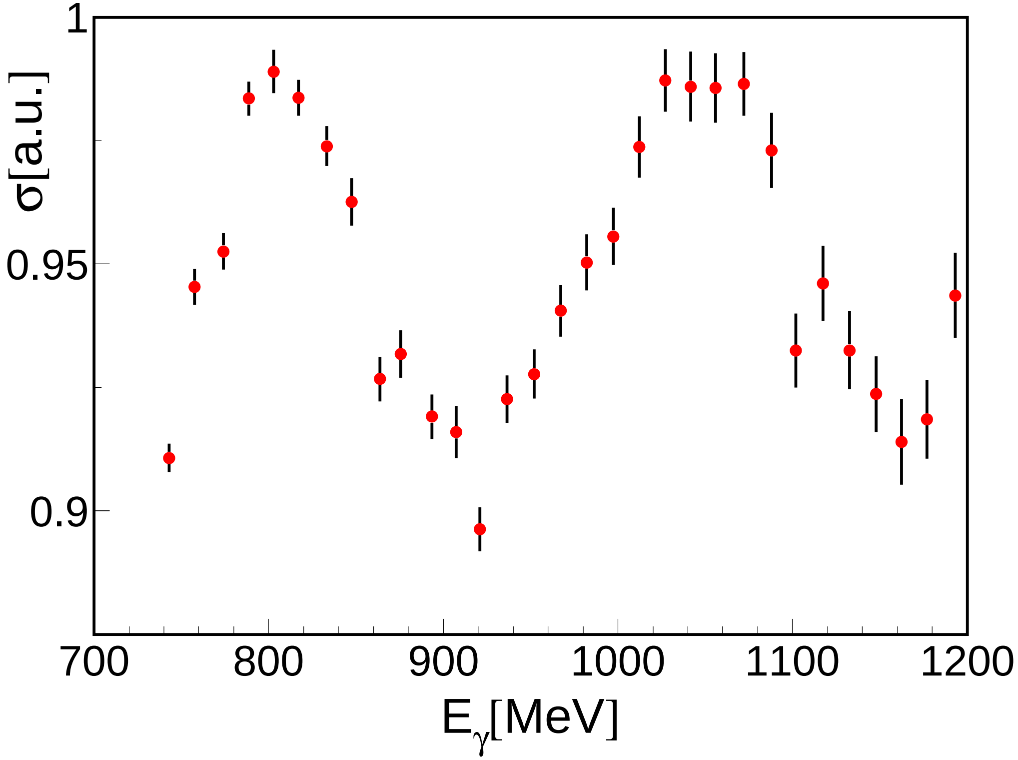
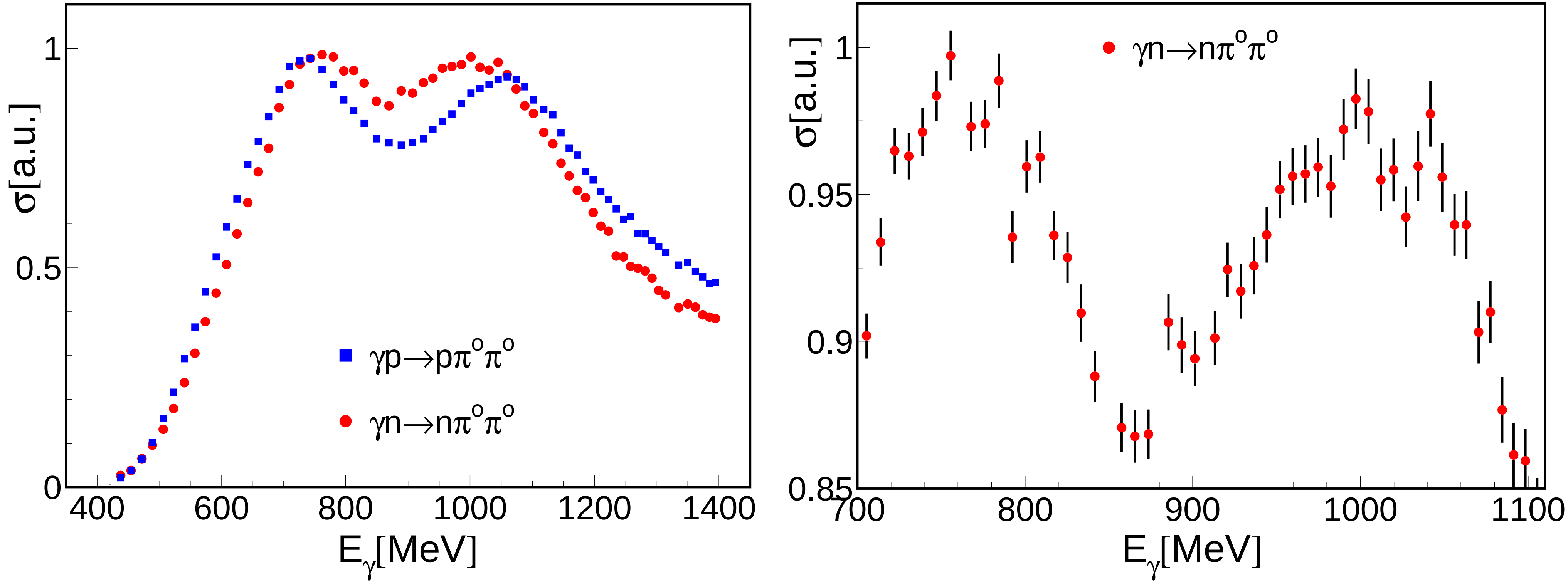




other channels: photoproduction of π^o-pairs (MAMI-C)

(master thesis M. Oberle)

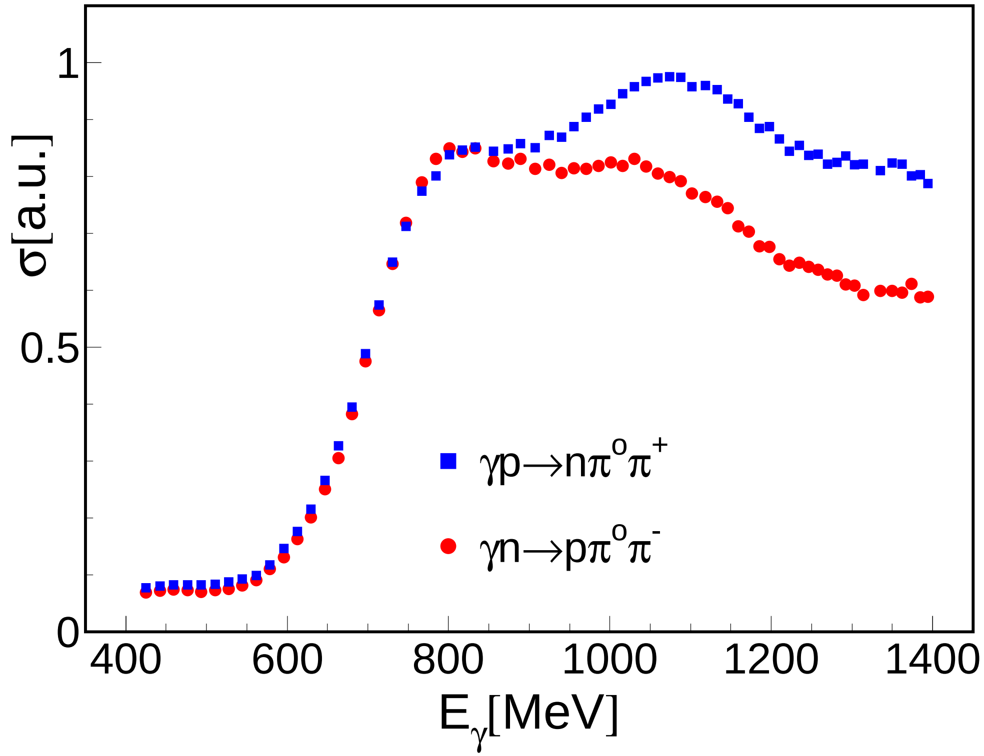
- very preliminary (no normalization, no efficiency corrections)
- more statistics needed (already measured but not yet analyzed)

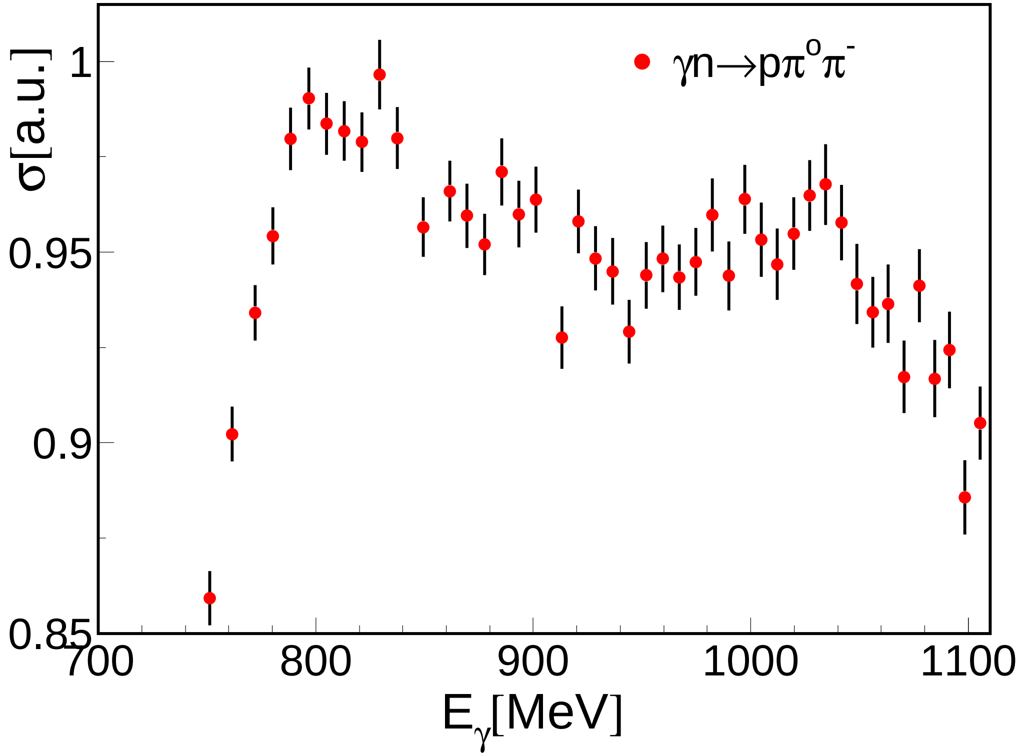


other channels: photoproduction of $\pi^o\pi^{\pm}$-pairs (MAMI-C)

(master thesis M. Oberle)

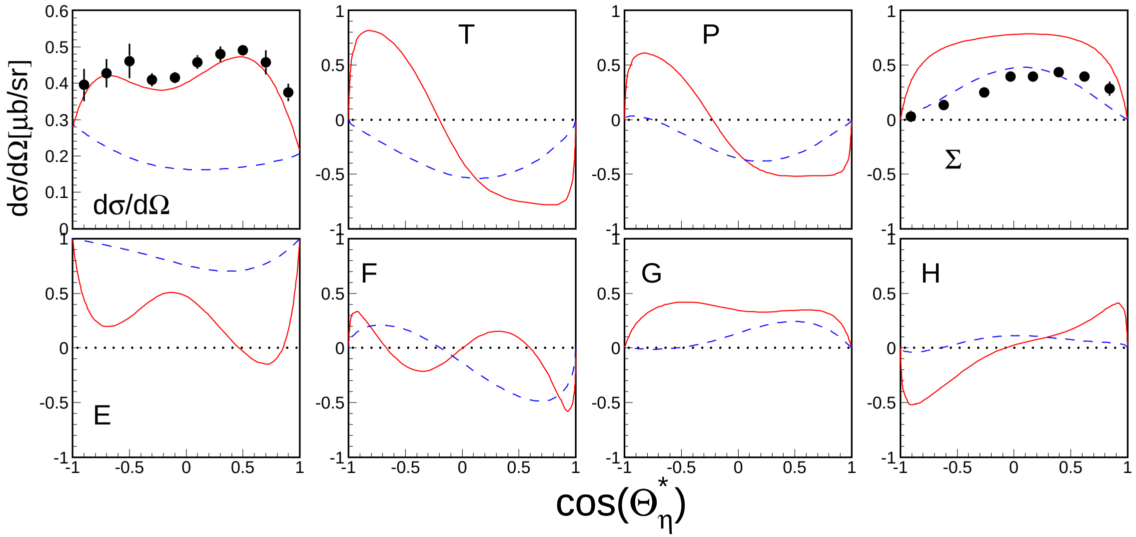
- very preliminary (no normalization, no efficiency corrections)
- more statistics needed (already measured but not yet analyzed)



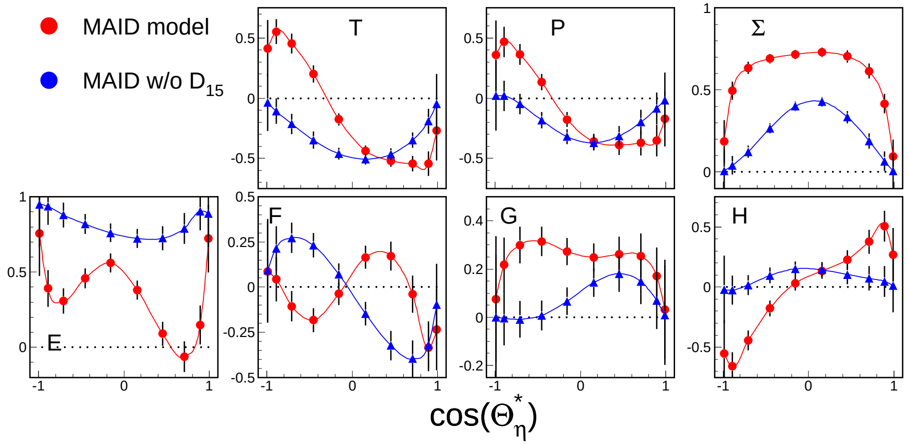


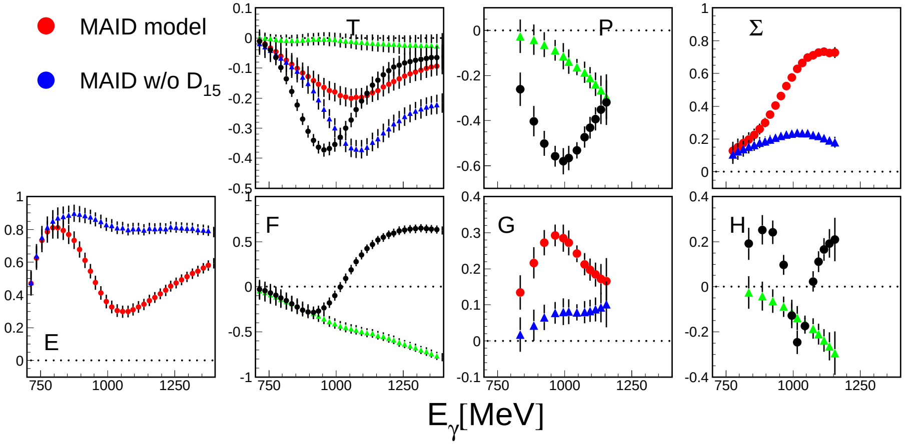
future: polarization observables

- **MAID predictions for E_γ=1 GeV with and w/o D_{15} (data: xs: ELSA, Σ: GRAAL)**



- **expected sensitivity (MAMI: E, T, F; ELSA: Σ, G, H, P)**





Summary

systematic investigation of meson photoproduction off the deuteron:

- photoproduction of η-mesons:
  - narrow structure in excitation function off neutron (width $\approx$ 30 MeV)
  - also seen at GRAAL/Grenoble and LNS/Tohoku
  - almost certainly not a nuclear effect
  - at MAMI-C also seen in photoproduction off ^{3}He
  - nature not yet determined
  - measuements of polarization observables upcoming
- other channels:
  - analysis off $\gamma n \rightarrow n\eta'$ finished
  - analysis off $\gamma n \rightarrow n\pi^o, \rightarrow n\pi^o\pi^o, \rightarrow p\pi^o\pi^-, \rightarrow n\pi^o\eta$ under way

main contributions from:

I. Jaegle

D. Werthmüller

M. Oberle

M. Dieterle