Quasi-free photoproduction of η-meson off the neutron

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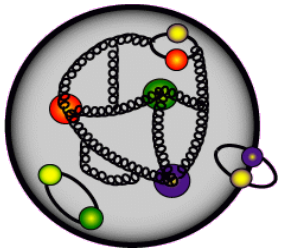
Outline

- Introduction
- Experimental setup
- Results
- Conclusions & Outlook

Nucleon structure

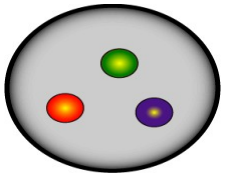
Complex system



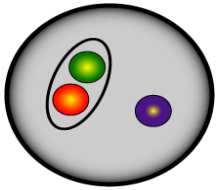
- valence quarks
- sea quarks
- gluons

Degrees of freedom ?

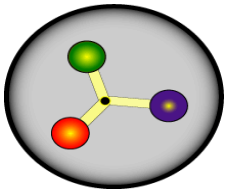
- 3 constituent quarks



- quark-diquark

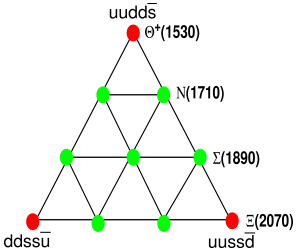


- quark flux - tube



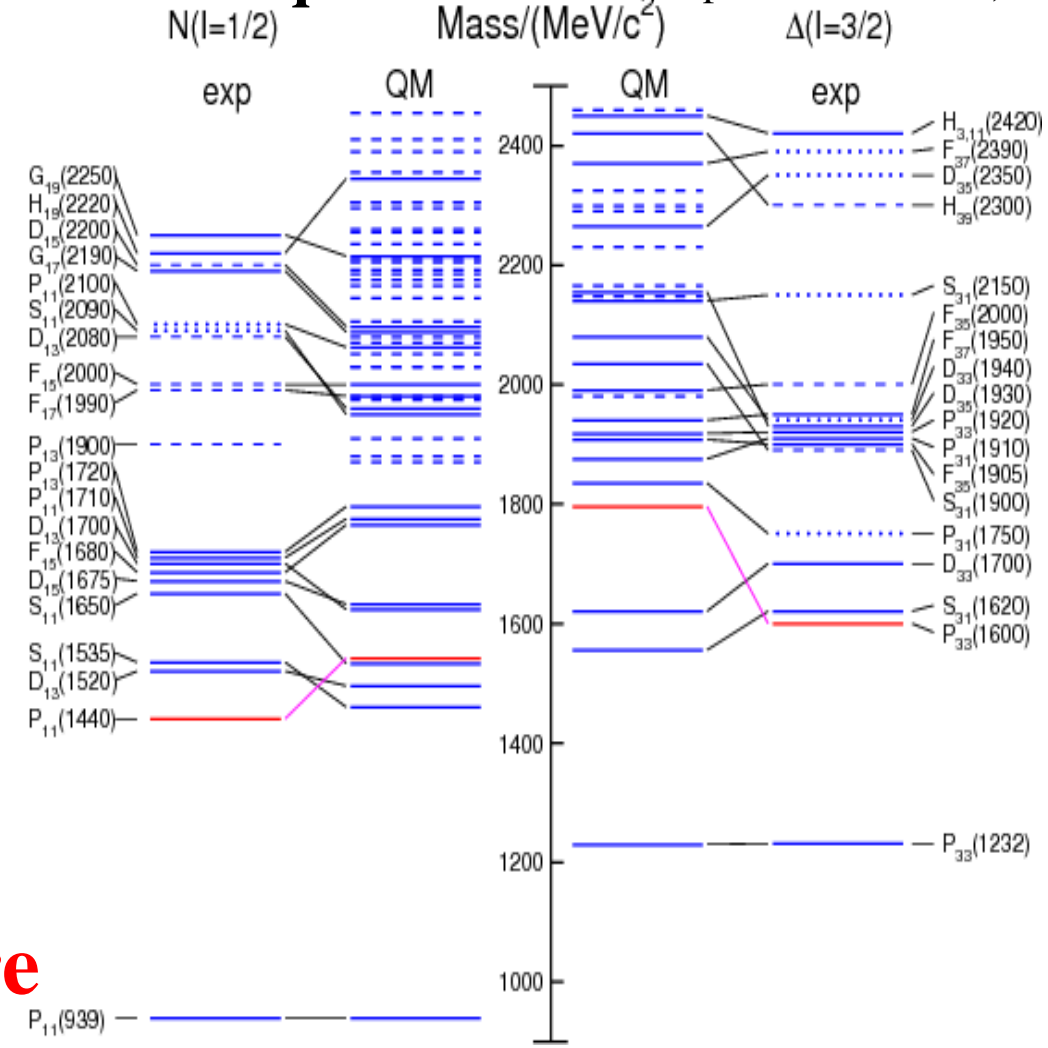
More complicated structure

- coupled channel



- chiral soliton

Comparison : known excited states – constituent quark model (Capstick & Roberts)

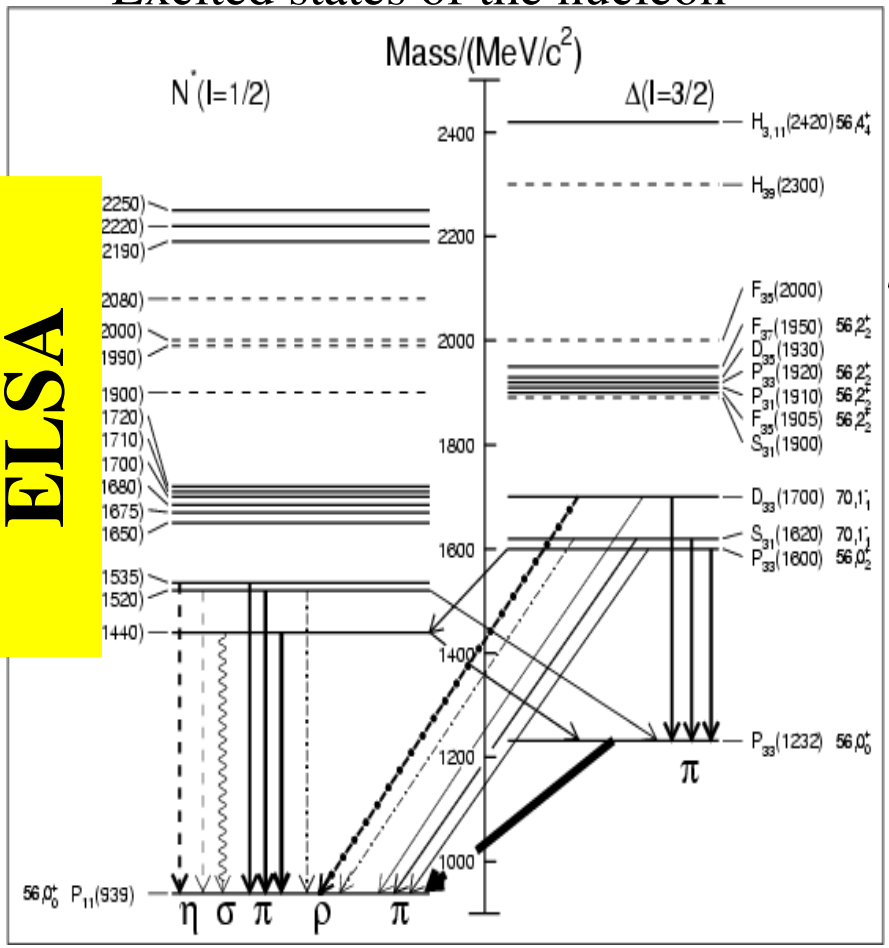


Ordering of low lying states ?

Missing resonances ?

Nature and properties of known resonances

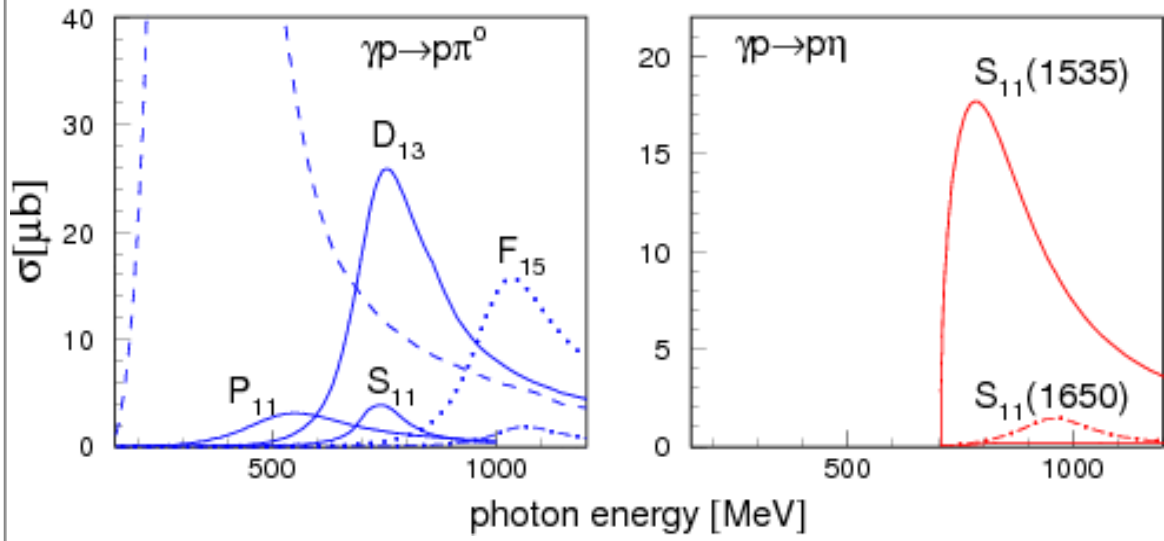
Excited states of the nucleon



ELSA

η isospin filter

broad overlapping resonances



characteristic meson decays can tag specific resonances

e.g. $S_{11}(1535) \rightarrow \eta N$ $b_\eta = 50\%$

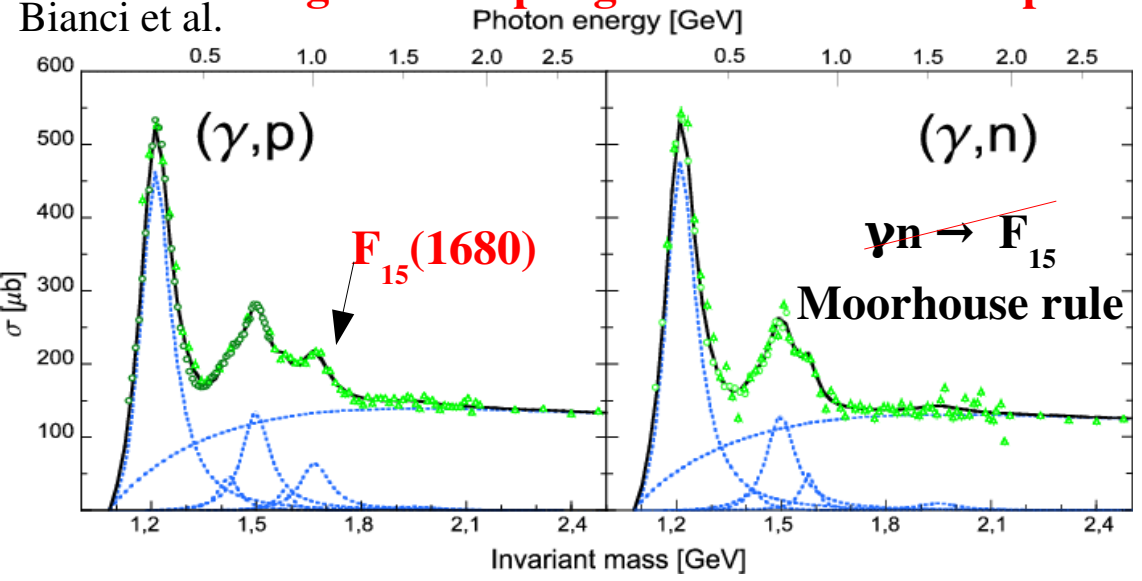
Study of resonances that couple strongly to the neutron

p resonance vs. n resonance

Photoabsorption on the nucleon

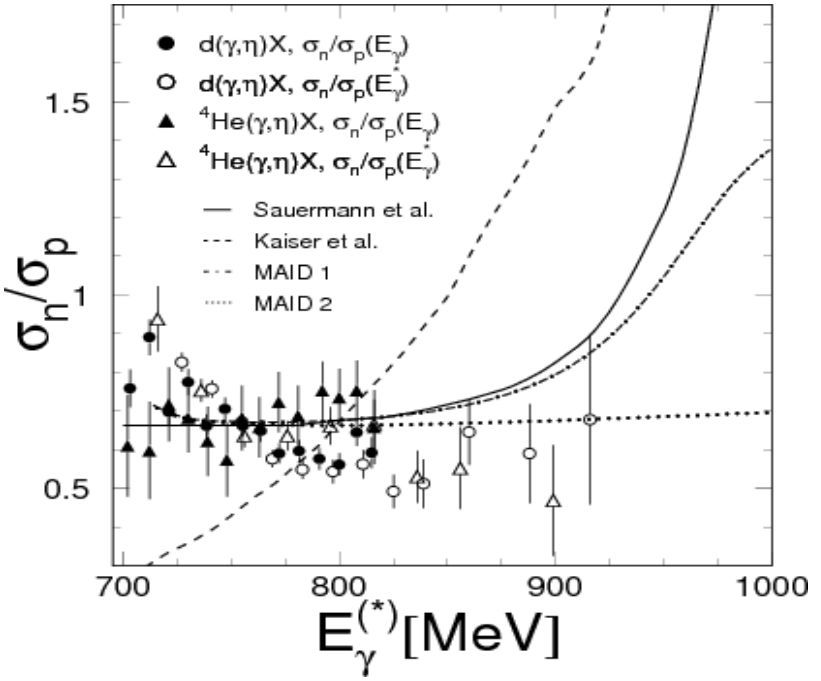
electromagnetic coupling different for n and p

Bianci et al.



Photoproduction of η-meson from light nuclei

(TAPS – MAMI collaboration)



No neutron target

light nuclei : LD_2

$$M_{inc.} = M_p + M_n + M_{coh.}$$

M_n directly

$$M_n = M_{inc.} - M_p$$

($M_{coh.}$ <<1 for η)

$$\sigma_p \approx \left|A^{IS}_{1/2} + A^{IV}_{1/2}\right|^2 = \left|A^{p}_{1/2}\right|^2$$

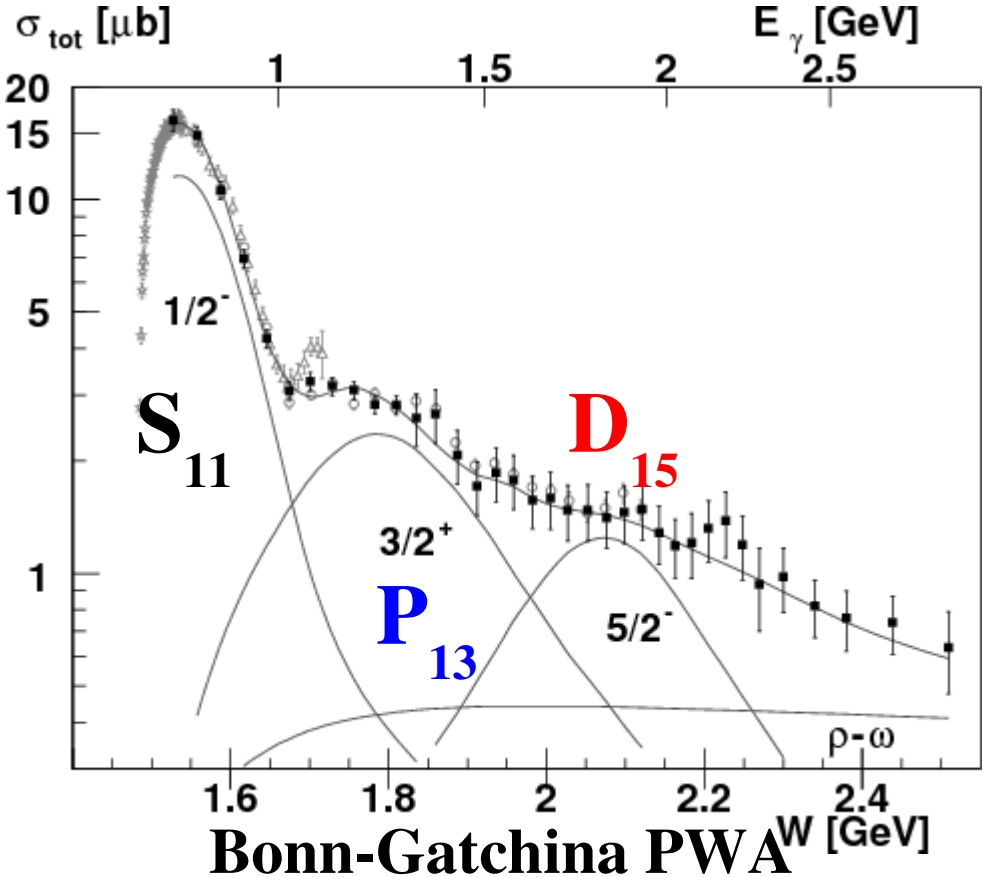
$$\sigma_n \approx \left|A^{IS}_{1/2} - A^{IV}_{1/2}\right|^2 = \left|A^{n}_{1/2}\right|^2$$

$$\sigma_d \approx \left|A^{IS}_{1/2}\right|^2$$

Find the isospin composition of the nucleon resonances

Resonances coupling to η photoproduction

Photoproduction of η-meson off the proton
(TAPS, GRAAL, CLAS and CB–ELSA collaborations)



Bonn-Gatchina PWA
(A.V. Anisovich et al.)

Result : S_{11}, P_{13} and
new resonance $D_{15}(2070)$

Involve less than 12 resonances

$D_{13}(1520)$

$S_{11}(1535)$

$S_{11}(1650)$

$D_{15}(1675)$ **couples strongly to the n**

$F_{15}(1680)$ **couples strongly to the p**

$P_{11}(1710)$

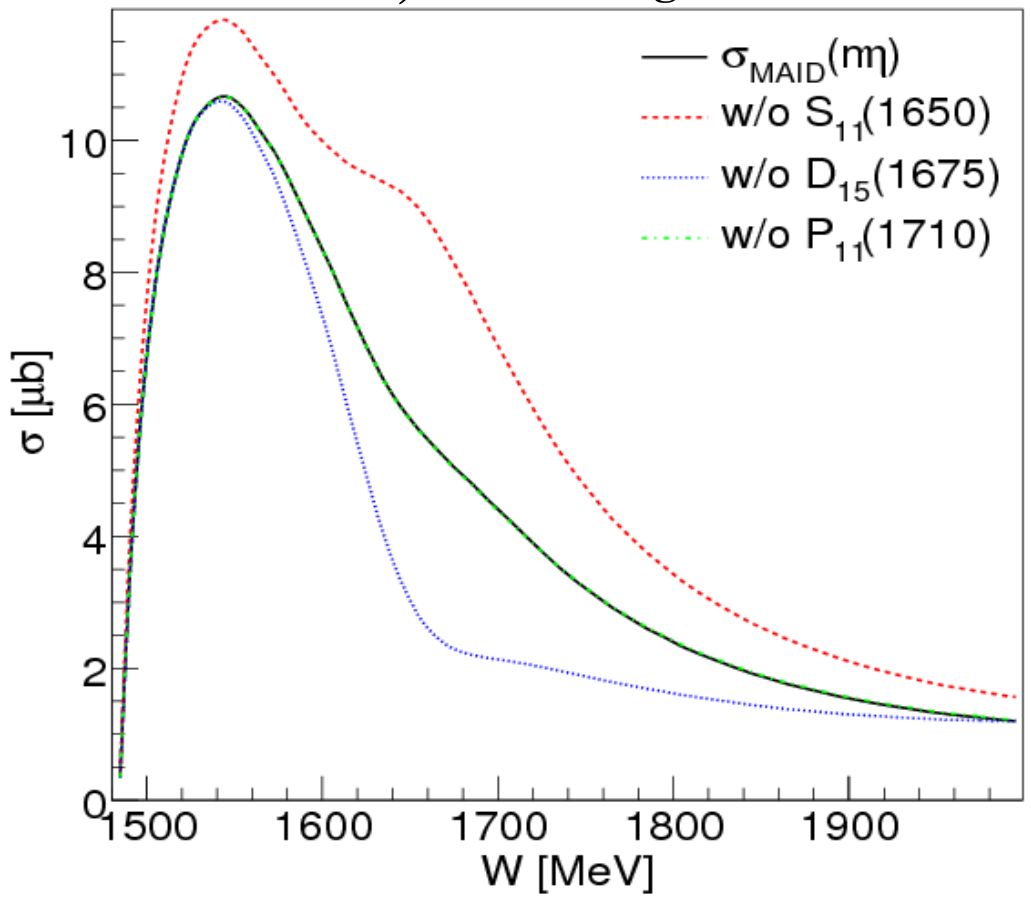
$P_{13}(1720)$ ambiguity

...

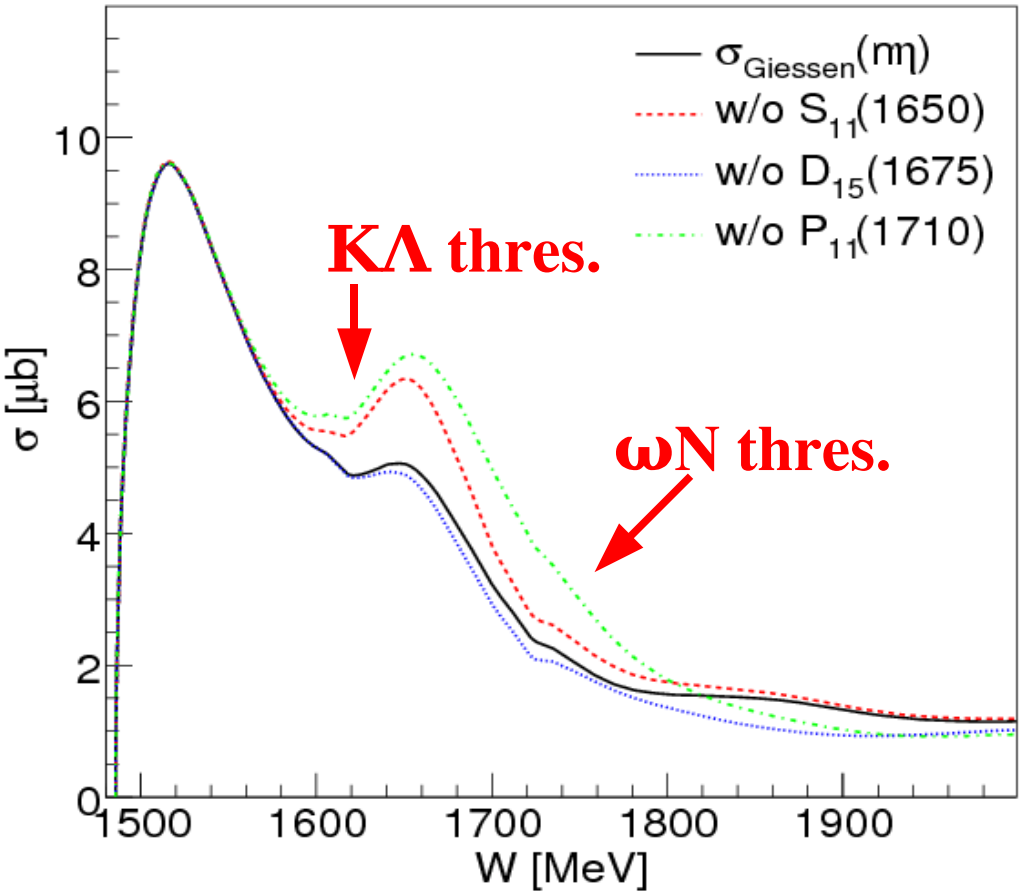
$D_{15}(2070)$ couples strongly to the ?

Prediction for the η photoproduction off the neutron

eta-MAID, W.T. Chiang et al.



Giessen model, V. Shklyar et al.



Role of $D_{15}(1675)$ couples strongly to the neutron. b_η = 15% (for eta-MAID)

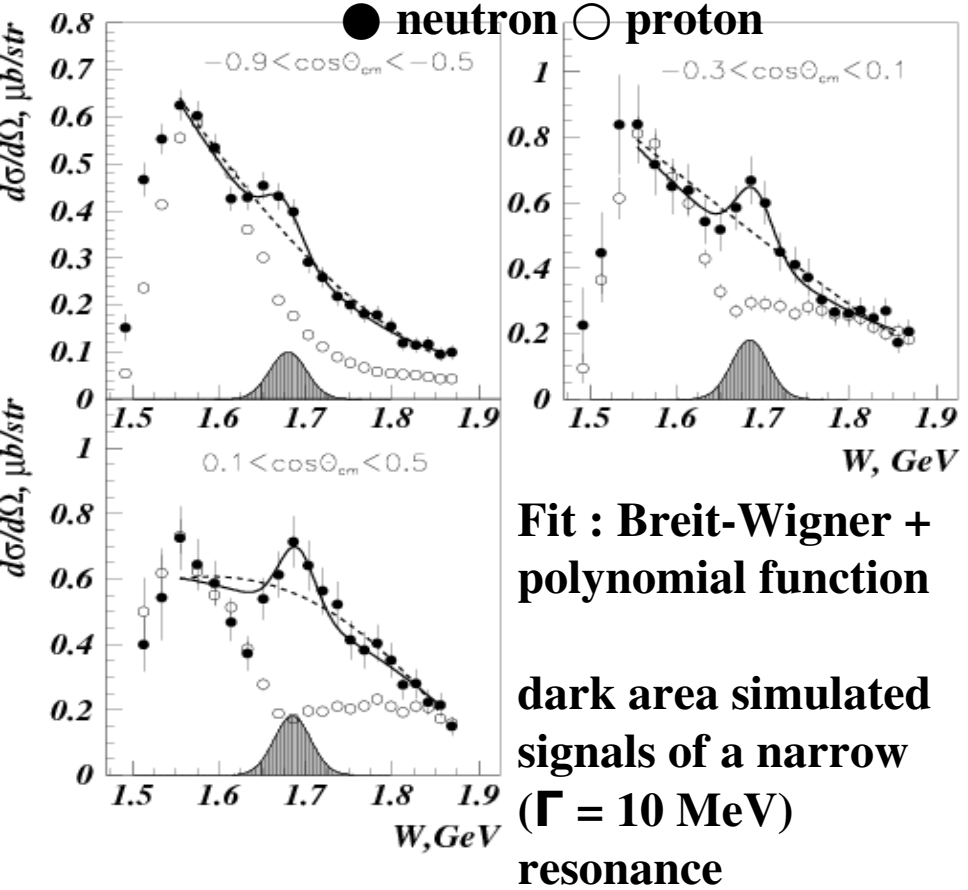
b_η = 0-1% (for PDG)

Combination of photoexcitation, interference of $S_{11}(1650)$ and $P_{11}(1710)$ and cusp effects

Possible evidence of $N(1710)P_{11}$

η photoproduction off the neutron at GRAAL

1st GRAAL analysis (V. Kuznetsov et al.)



Fit : Breit-Wigner + polynomial function

dark area simulated signals of a narrow (Γ = 10 MeV) resonance

A narrow bump is observed on the quasi-free neutron differential cross section

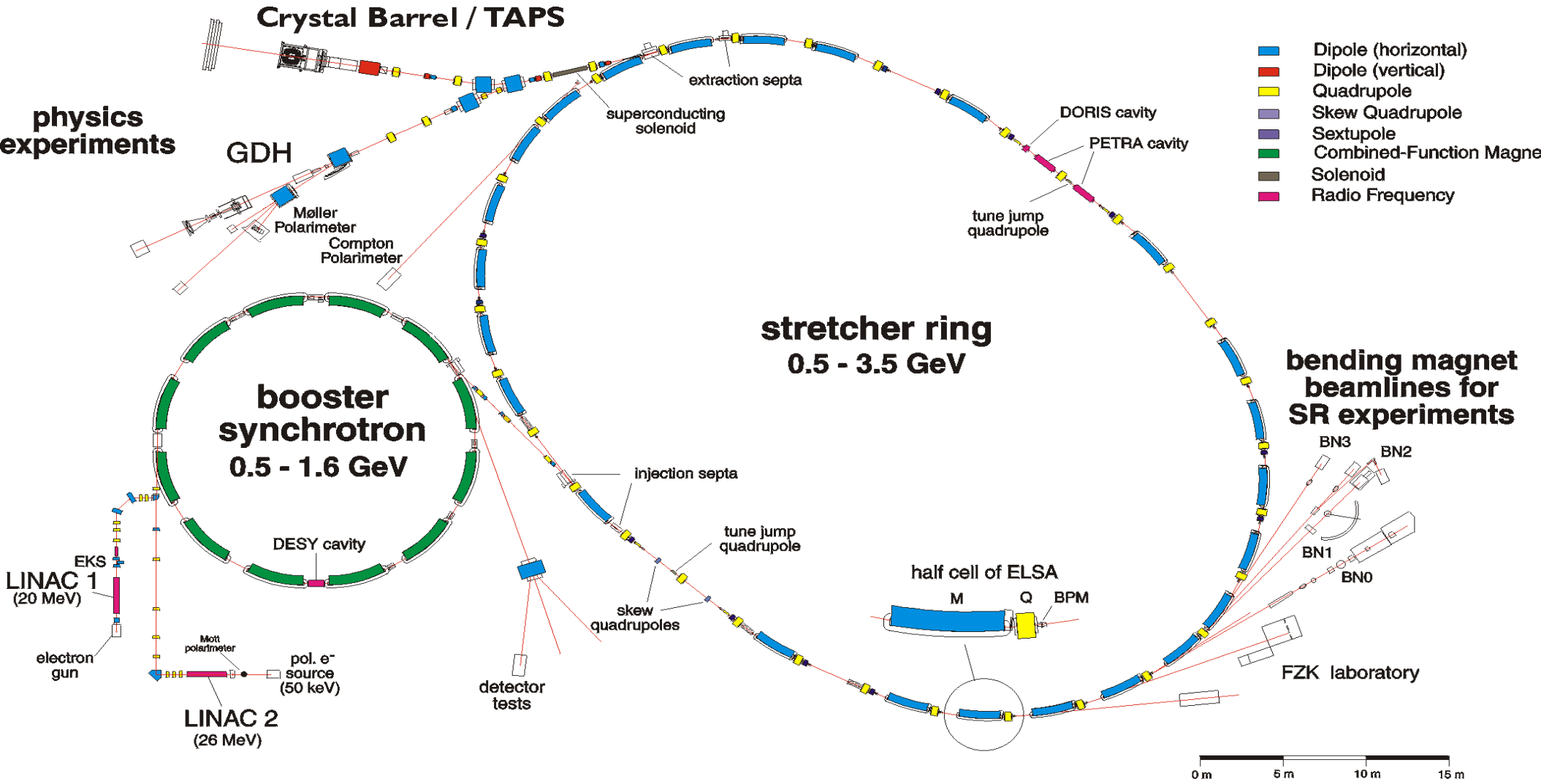
extracted width 50 MeV
experimental resolution 40 MeV

evidence of a narrow resonance Γ< 50 MeV ?

non-strange member of the anti-decuplet ?

No comparison to the results obtained by the TAPS - MAMI collaboration and to the free proton data folded with Fermi motion

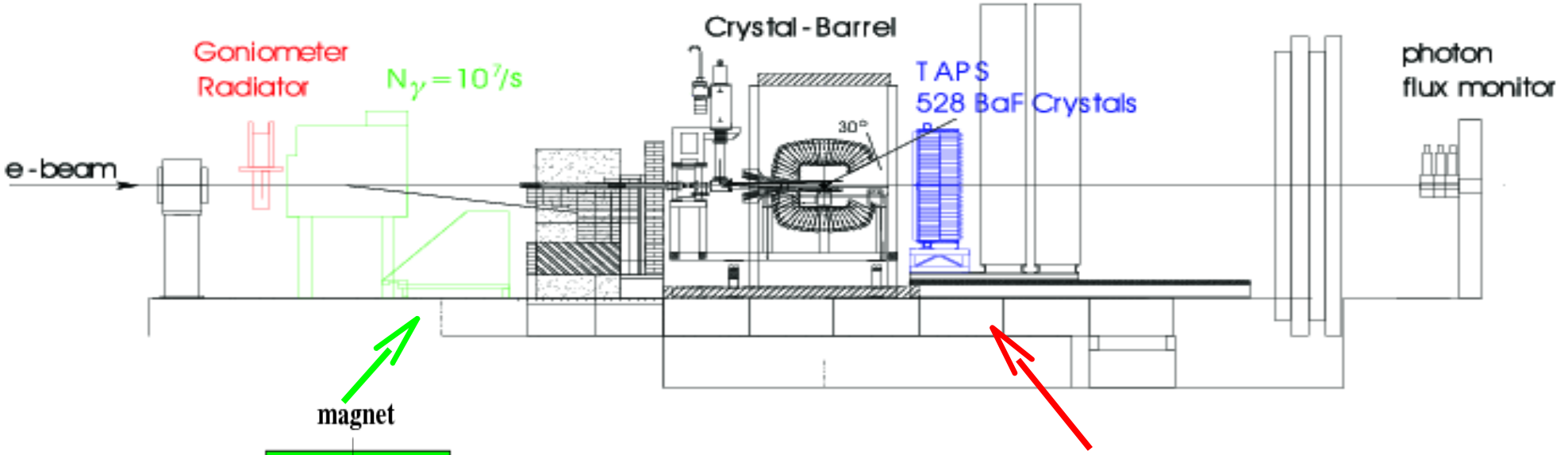
ELSA : electron accelerator

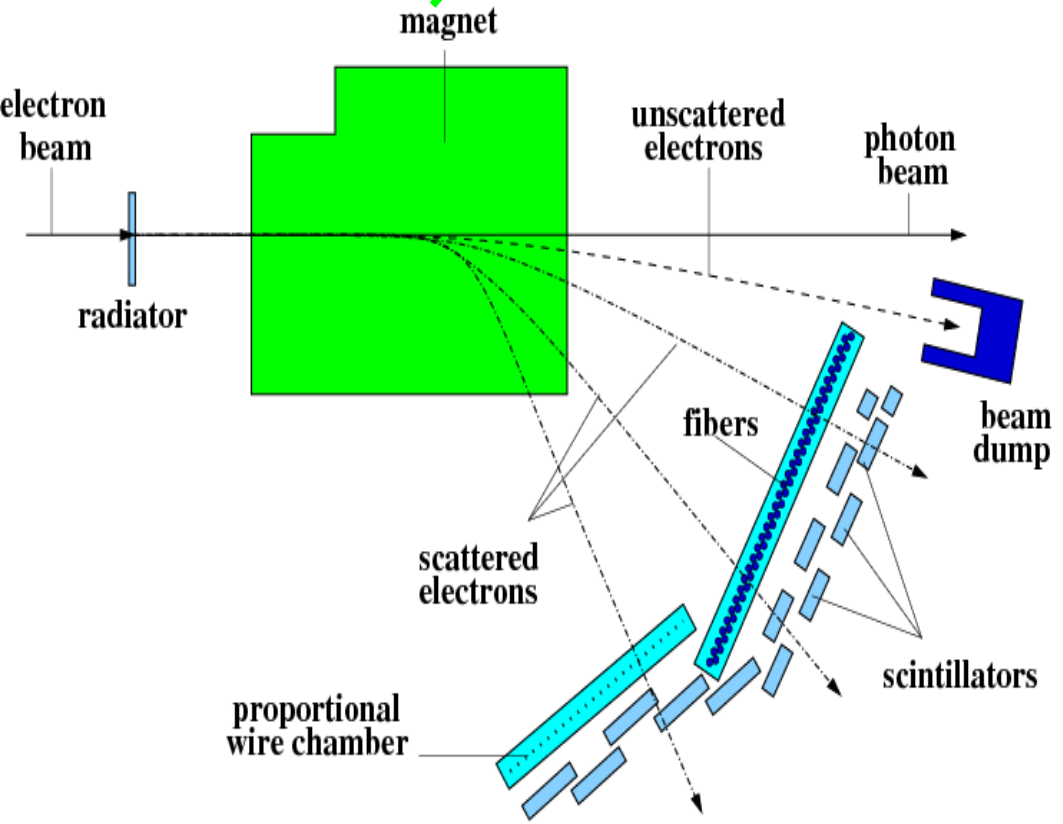


quasi-monochromatic photon beam via bremsstrahlungs tagging

$$0.3\ \text{GeV} \leq E_\gamma \leq 2.6\ \text{GeV}$$

CB-ELSA / TAPS setup





4π detectors :

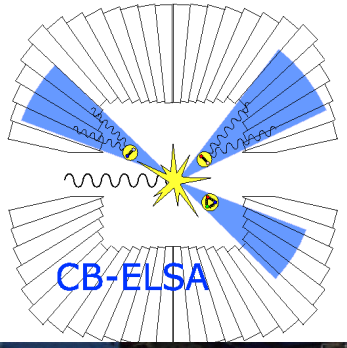
1818 crystals + CPCs

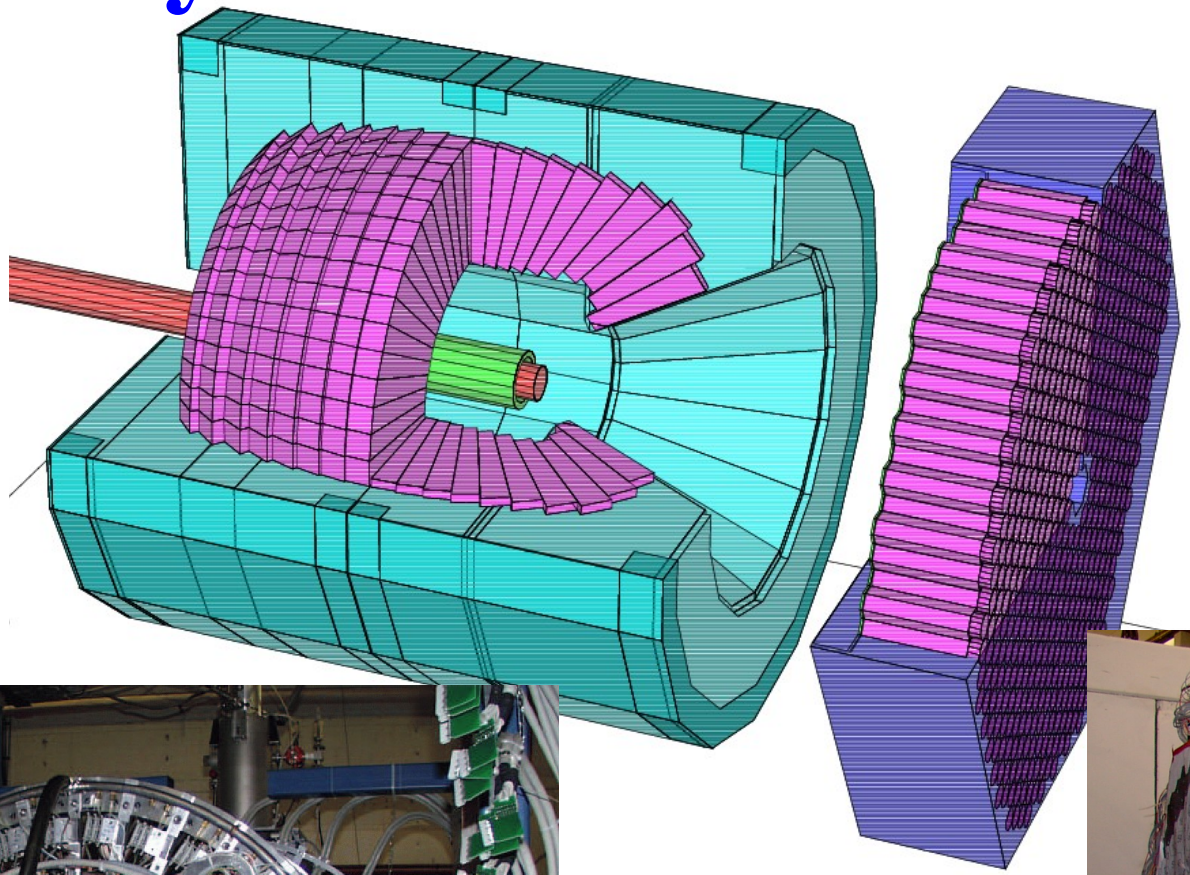
measure:

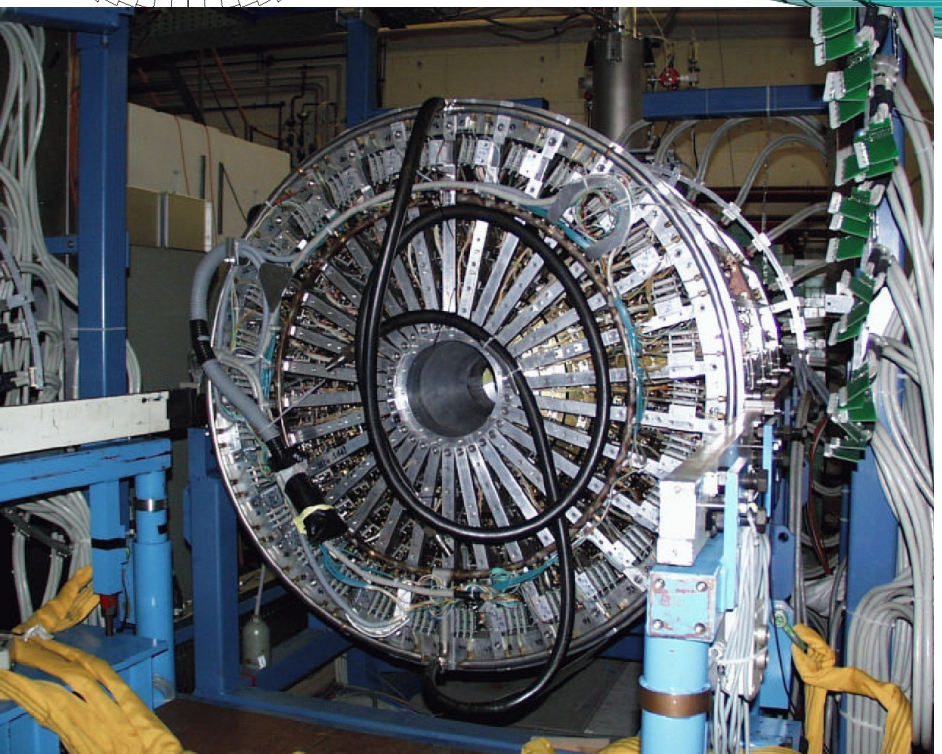
- **incident photon beam**
- **γ**
- **proton**
- **neutron**

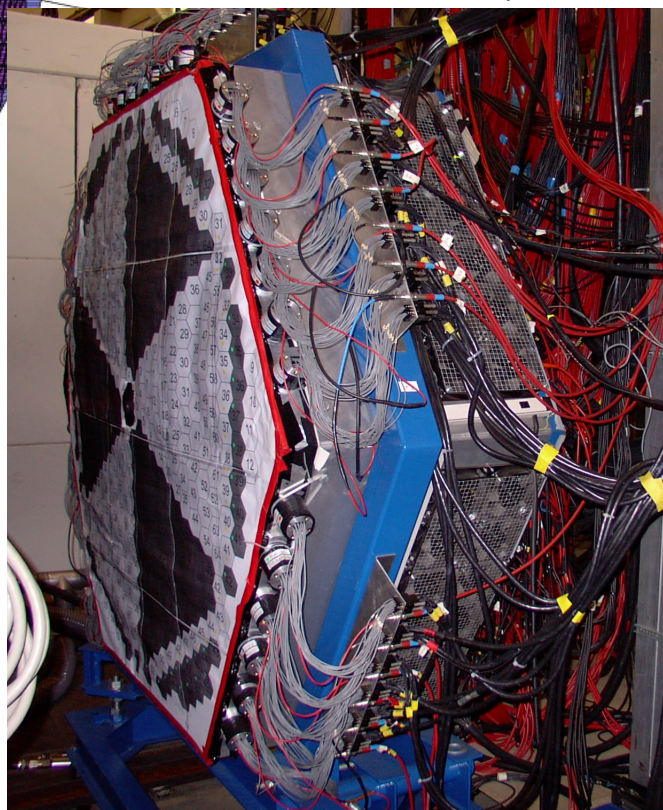
$$E_\gamma = E^0_{e^-} - E_{e^-}$$

Crystal Barrel and TAPS





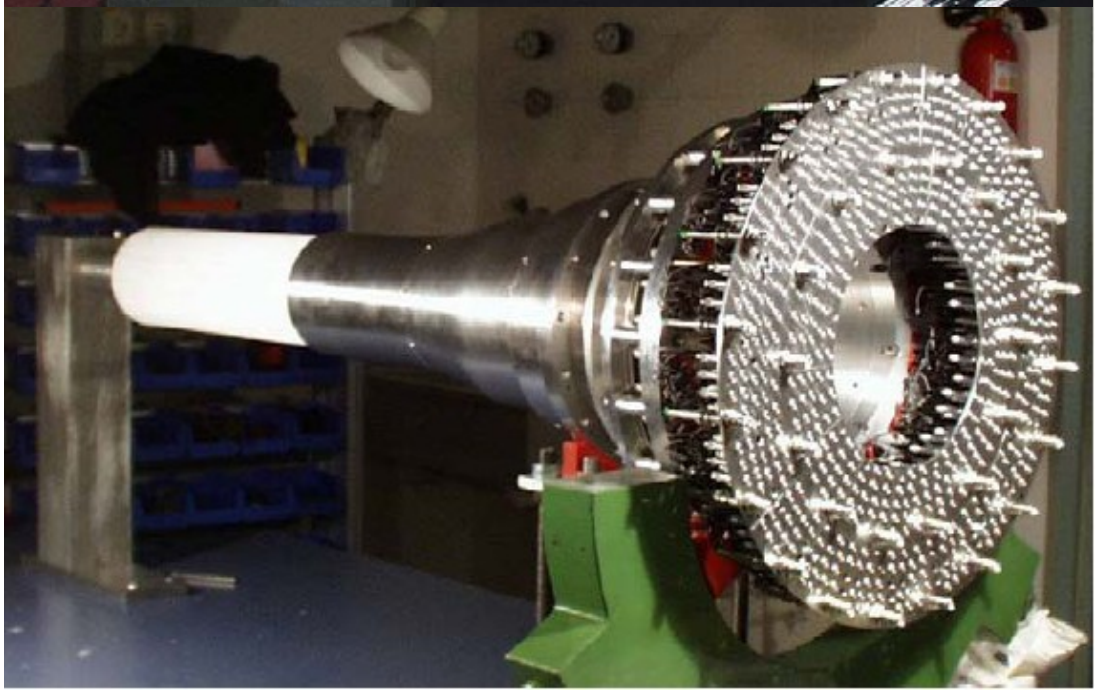




Nucleon Identification CB

inner detector:

- **3 layers of scintillating fibers**
- **cylindrical shape**

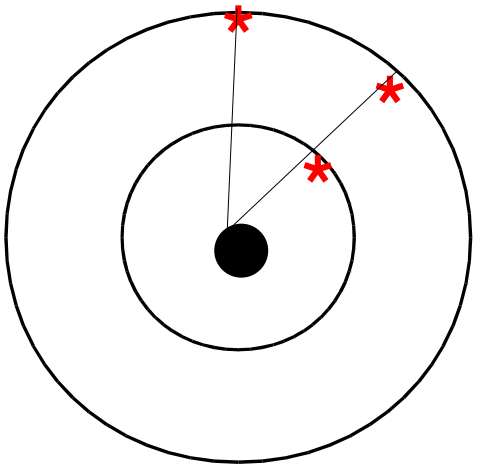


proton:

2 or 3 layers match a hit in the CB

neutron:

no layer has fired



Setup

Nucleon Identification TAPS

taps veto detector:

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

proton:

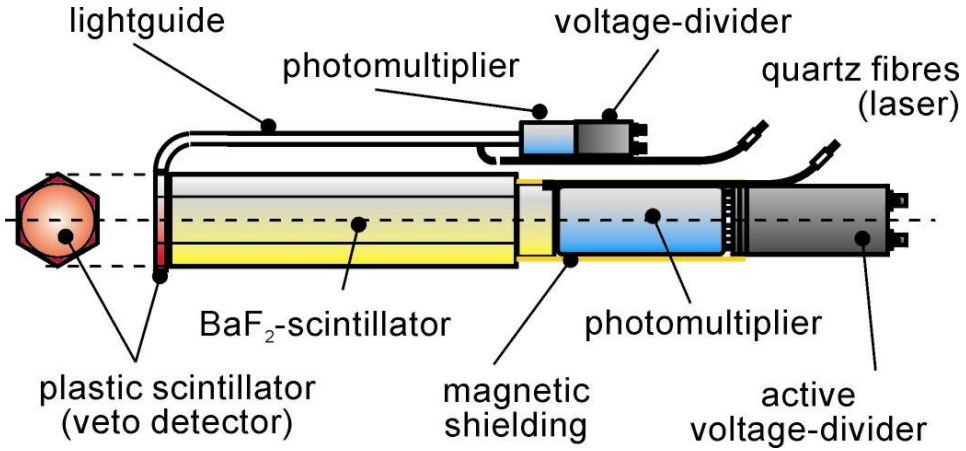
veto hit in front of BaF_2 crystal

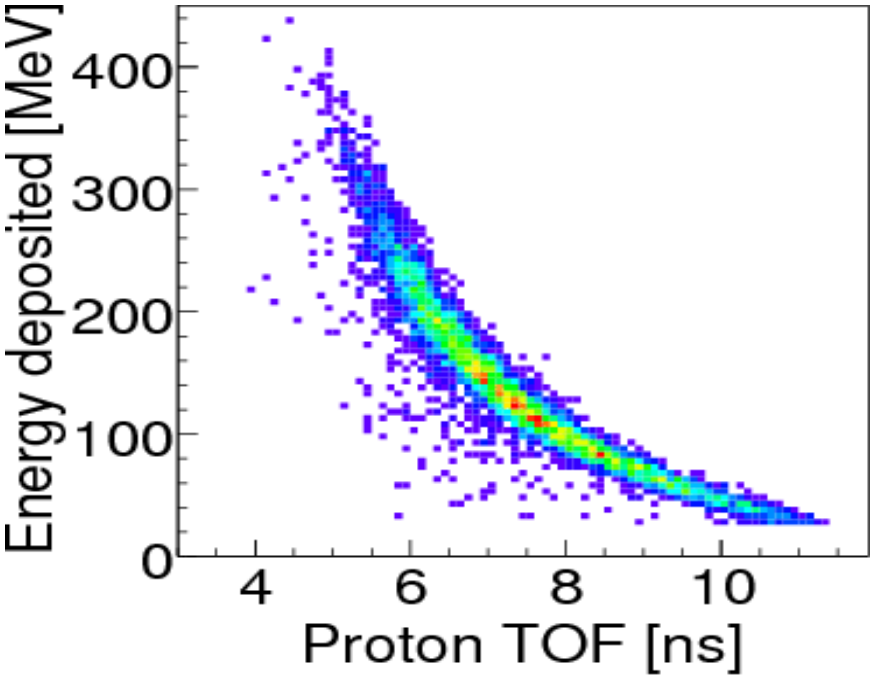
+ E vs TOF

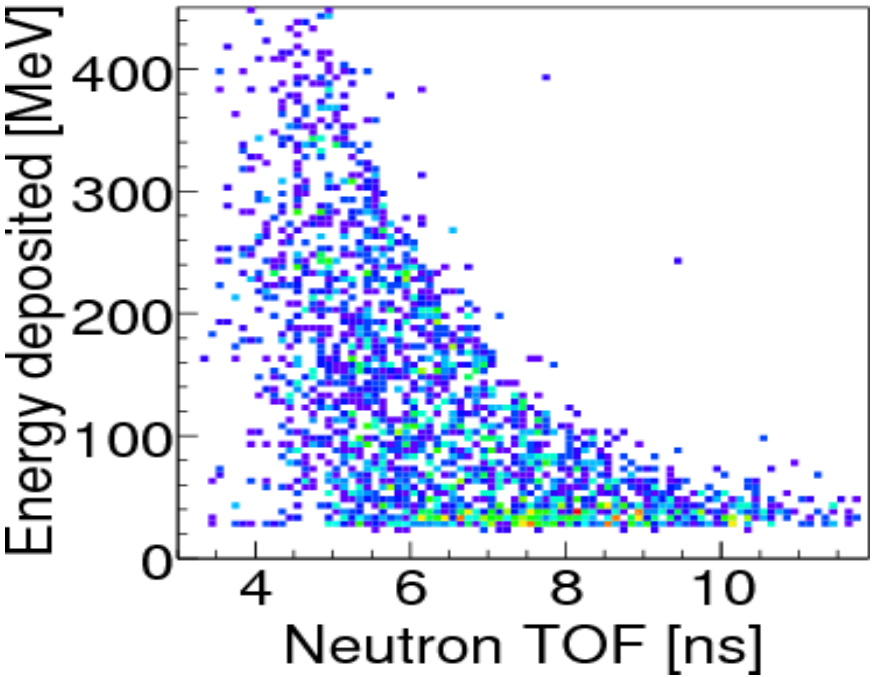
neutron:

no veto hit in front of BaF_2 crystal

+ E vs TOF



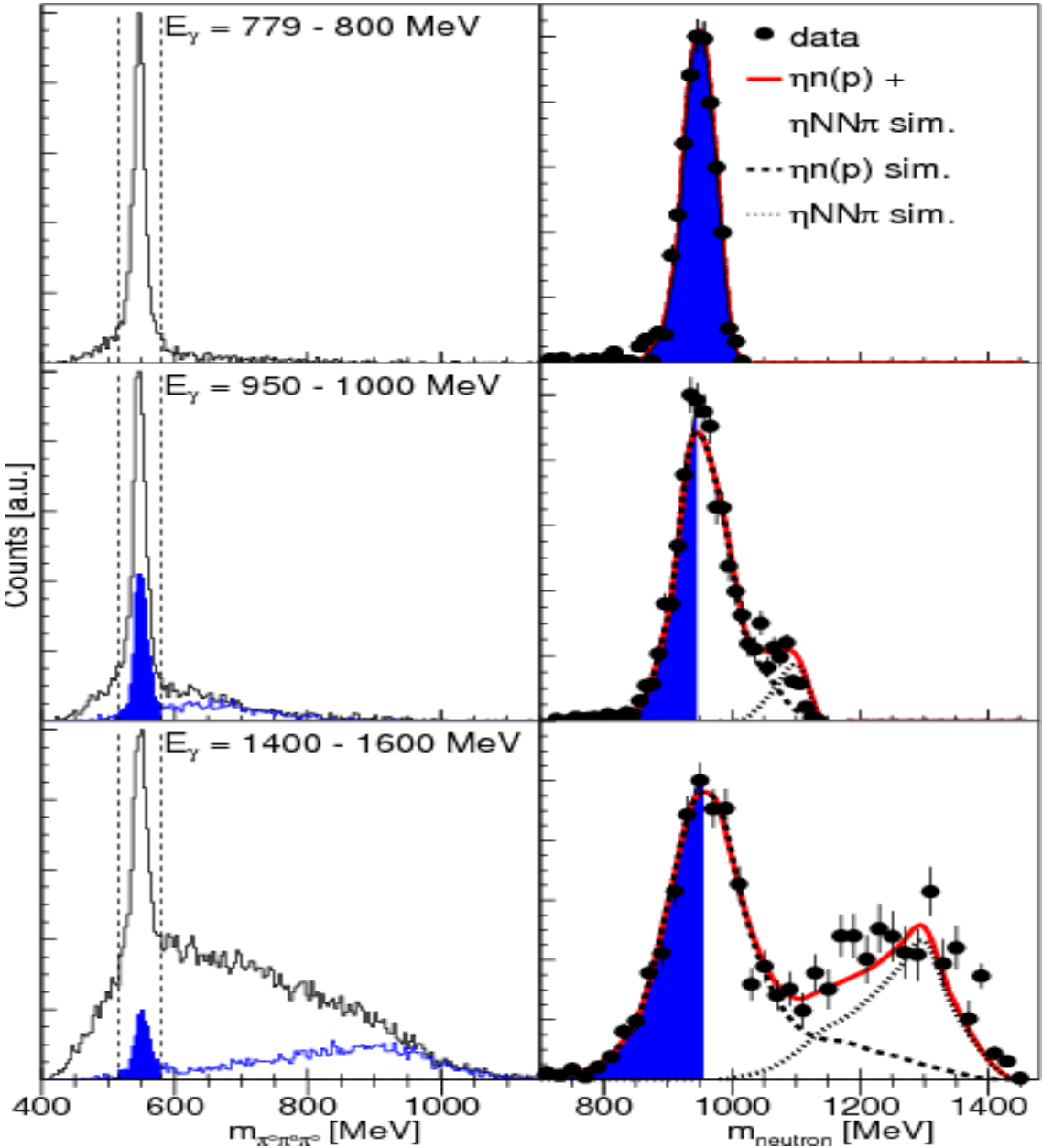




Reaction identification
$\gamma + n(p) \rightarrow \eta + n(p)$

- decay channel $\eta \rightarrow \pi^o\pi^o\pi^o \rightarrow 6\gamma$
- select events with 7 hits
- invariant mass of all photon pairs
- cut on π^o mass
- select best combination of 6γ to $3\pi^o$ by χ^2-test
- use π^o mass as constrain, construct $3\pi^o$ invariant mass
- missing mass analysis to remove $\eta\pi$ final state; treat recoil nucleon as missing particle

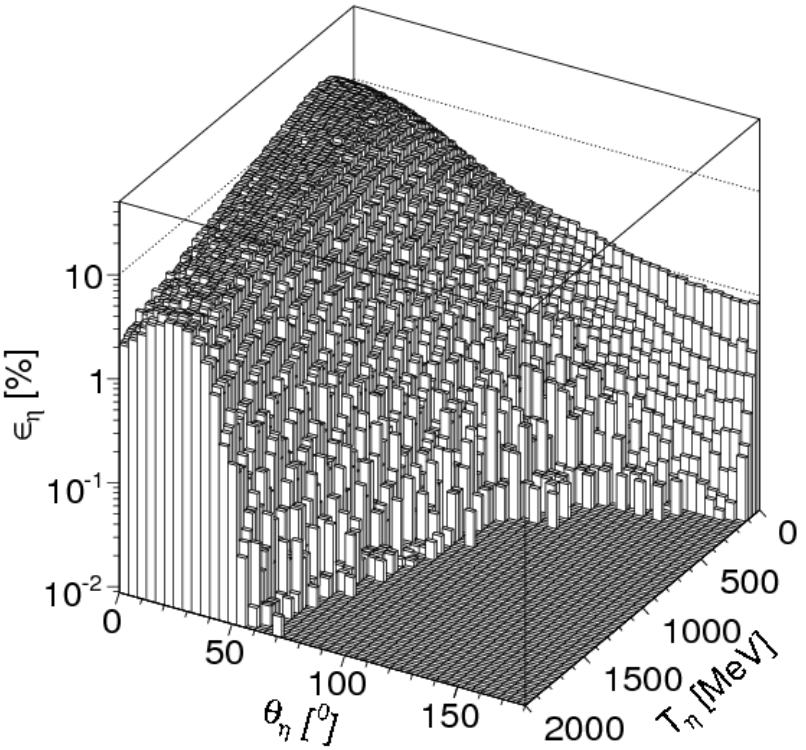
$$m^2 = (P_\gamma + P_N - P_\eta)^2$$

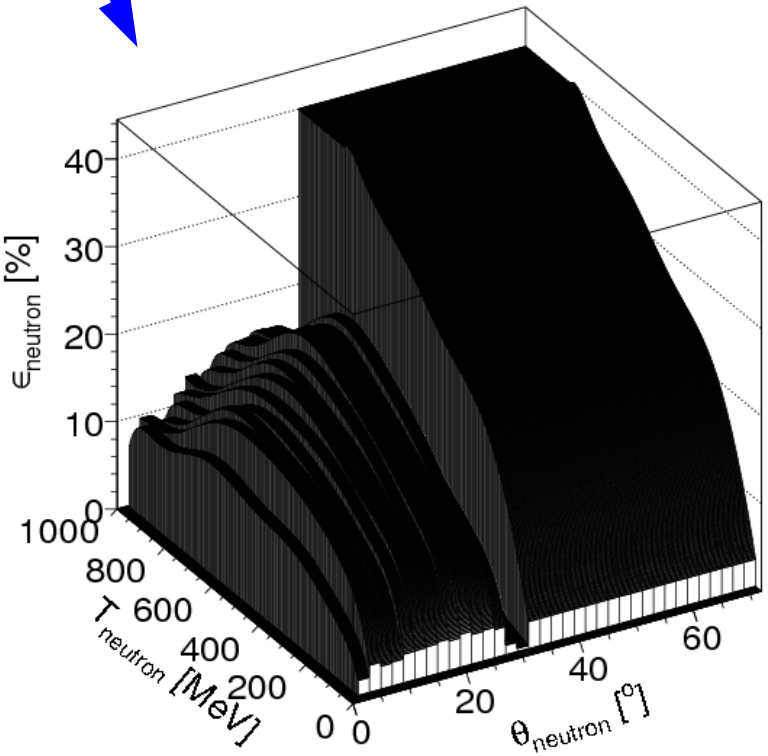


Reaction efficiency

γ+n(p)→η+n(p)

The efficiency is "factorized" : $\varepsilon_r = \varepsilon_\eta \cdot \varepsilon_{neutron} \cdot \varepsilon_{loss}$





- The corrections are applied event-by-event

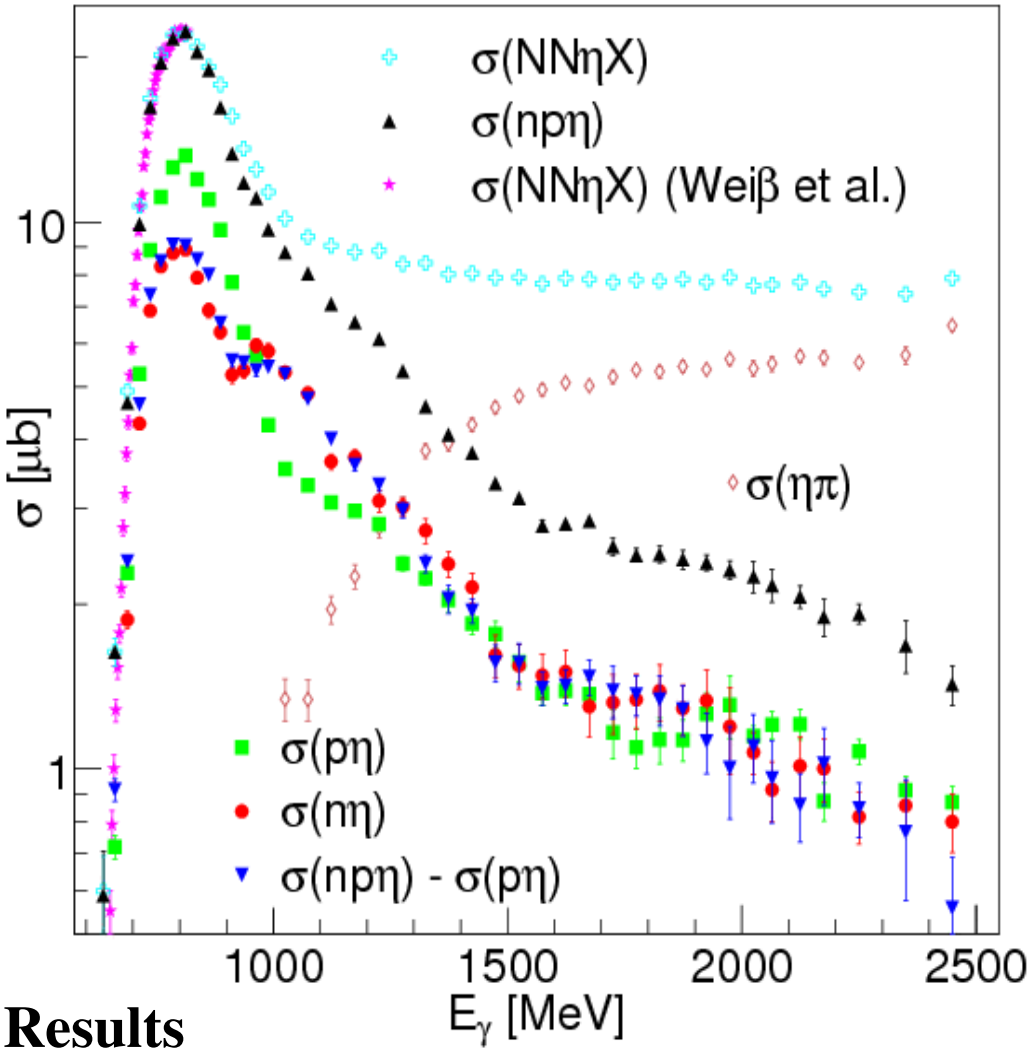
=> no assumption on the reaction kinematics

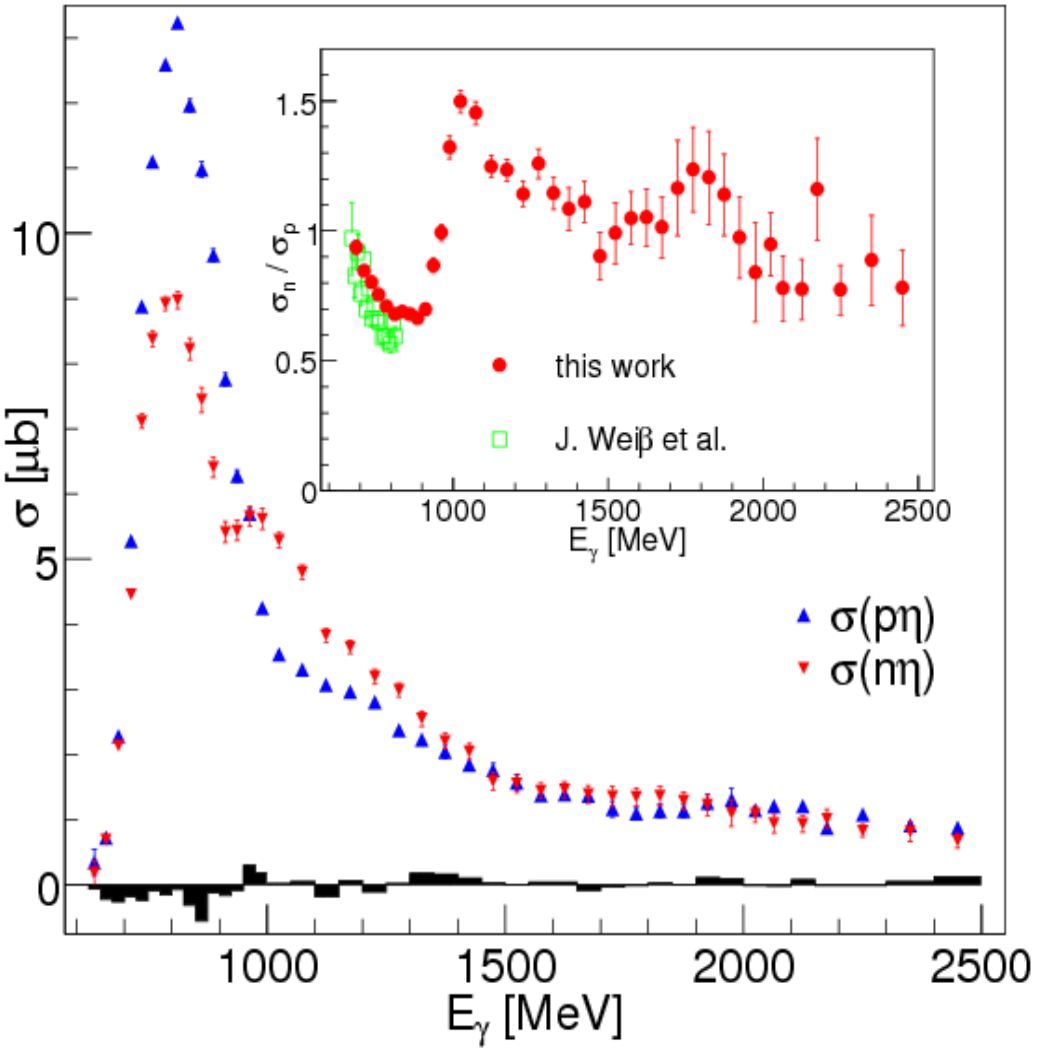
- ε_{loss} : p.s. MC simulation in quasi-free kinematics taking into account the Fermi motion of the nucleons derived from the deuteron wave function

η photoproduction off the deuteron

γn→ηn measured in 2 different ways :

- **η in coincidence with the recoil neutron**
- **difference of inclusive cross section and in coincidence with the recoil proton**





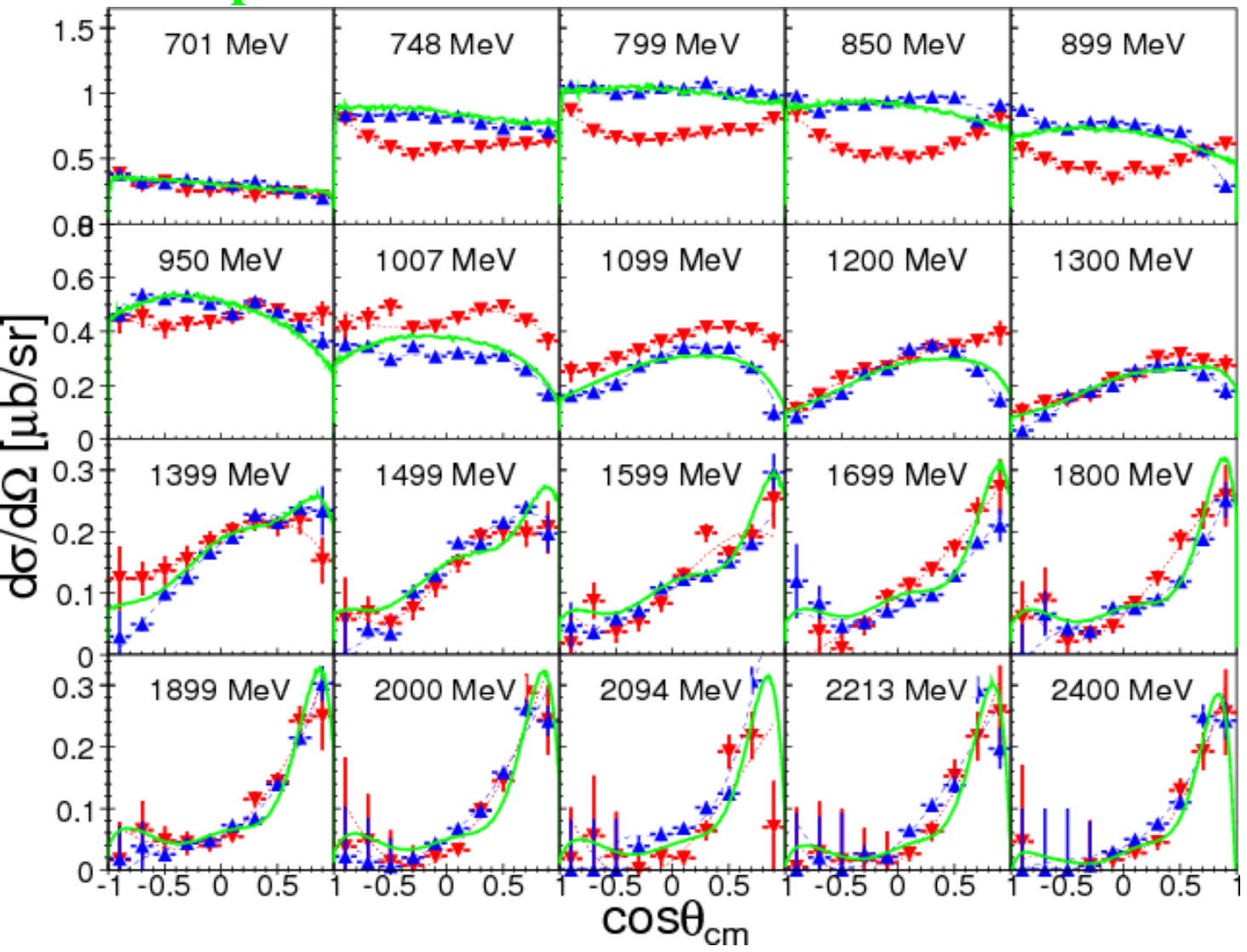
Results

Angular distributions

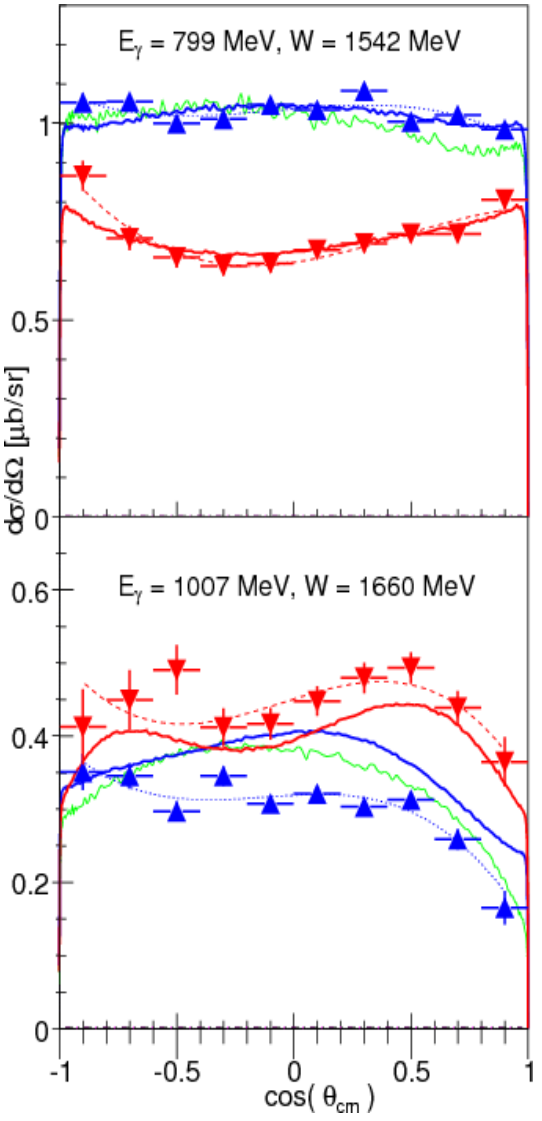
▲ proton

▼ neutron

— free proton folded



Compared to ETA-MAID



Angular distributions fit

- Fit with

$$\frac{d\sigma}{d\Omega} = \sum_{l=0}^{3} A_l P_l^0(\cos(\theta_{cm}))$$

- Result
  - all coefficient similar for proton and neutron above 1.5 GeV
  - A_o coefficient

S_{11} dominance for neutron small shoulder around 1 GeV

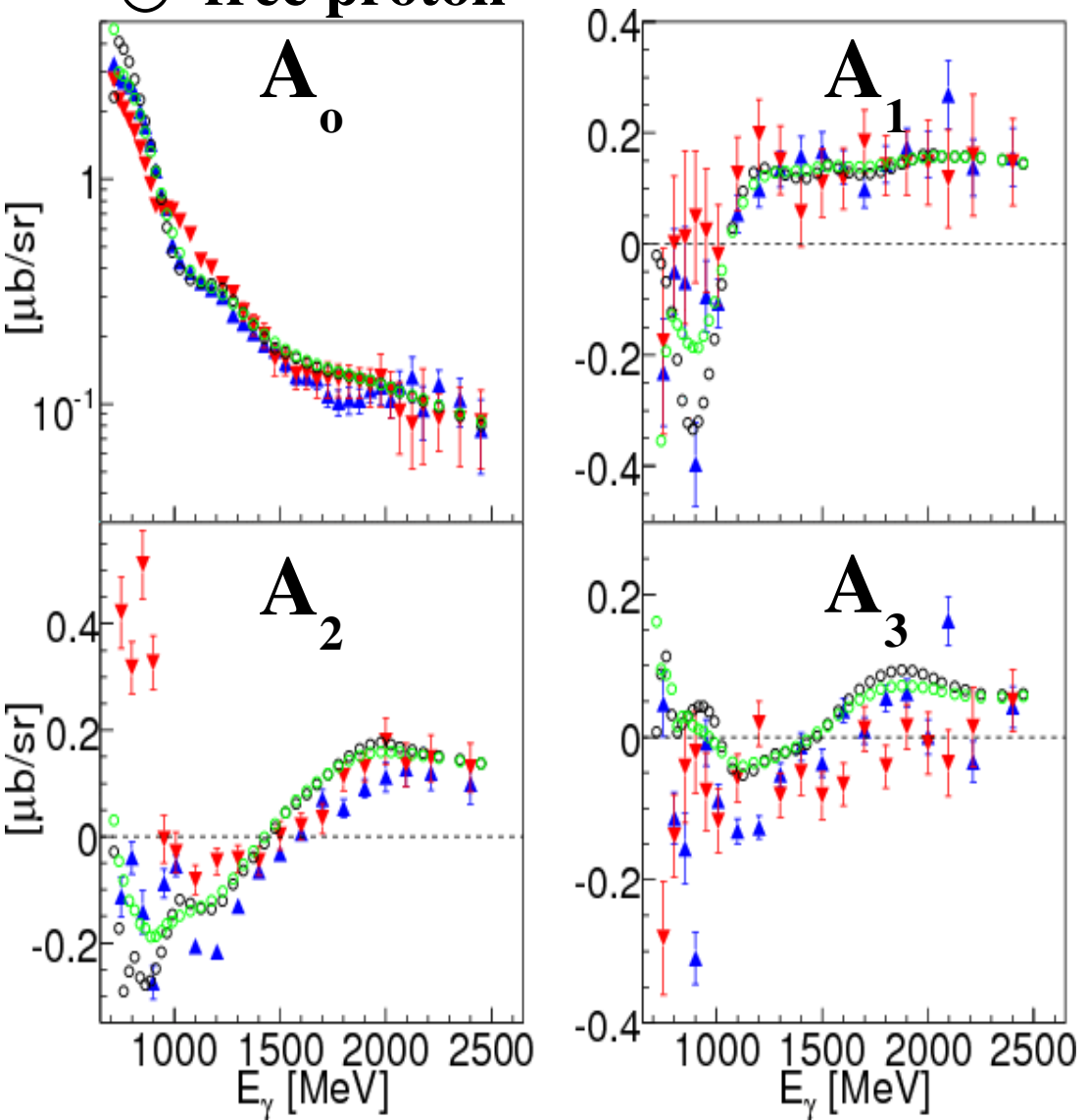
  - A_1 coefficient

at low energies interference between S_{11}-P_{11} / P_{13} resonances ?

  - A_2 coefficient

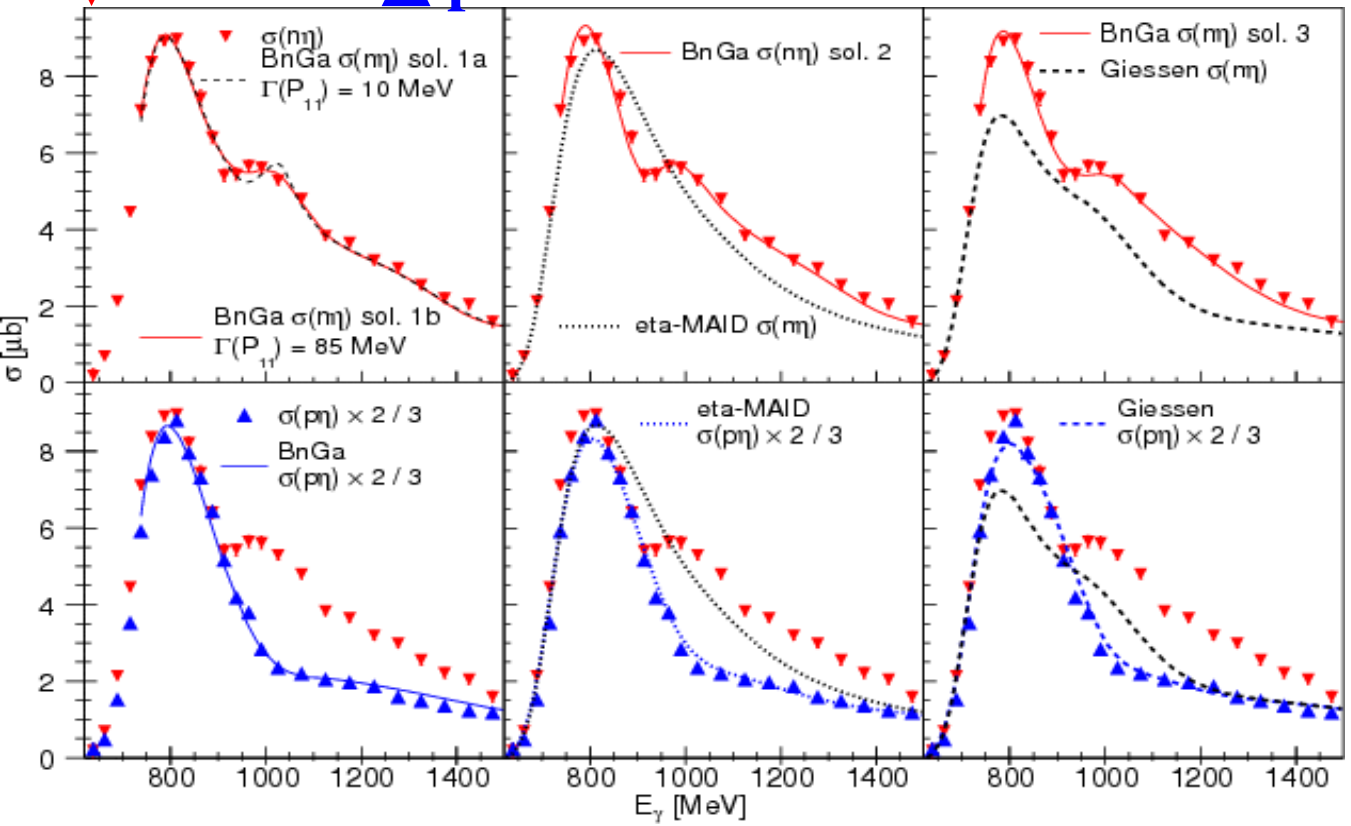
interference between S_{11}-D_{13} resonances

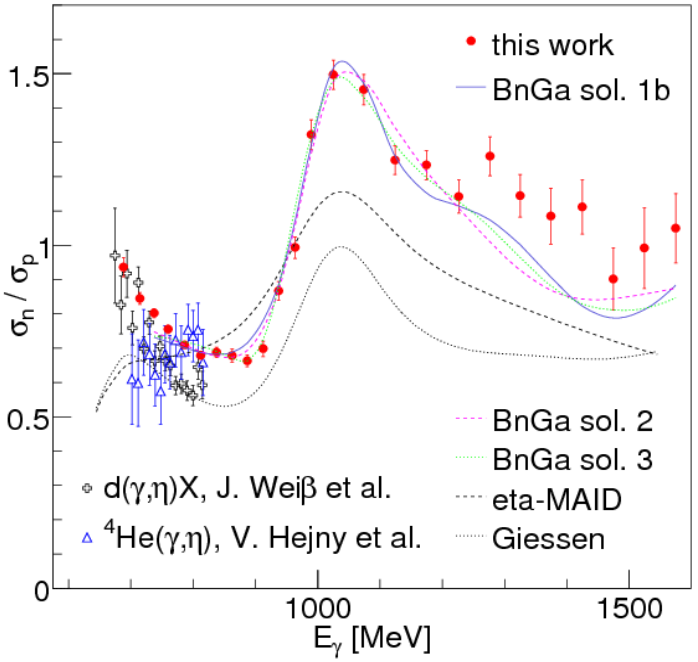
▲ proton
▼ neutron
● free proton folded
○ free proton



Comparison to Models

▼ neutron ▲ proton × 2 / 3





- BnGa solution 1a: narrow P_{11}
- BnGa solution 1b: normal P_{11}
- BnGa solution 2: constructive interference between the two S_{11} and cusp effects
- BnGa solution 3: destructive interference between the two S_{11} and $D_{13}(1720)$
- eta-MAID: $D_{15}(1675)$ is ruled out by GRAAL Σ asymmetry measurement
- Giessen model: $S_{11}(1650)$ and/or $P_{11}(1710)$ and cusp effects

De-folding the fermi motion

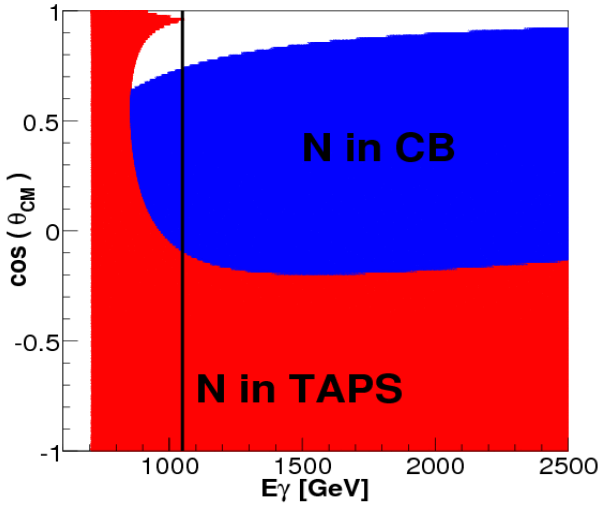
- Find the true total cm energy from

$$W_R = \sqrt{(E_\eta + E_N)^2 - (p_\eta + p_N)^2}$$

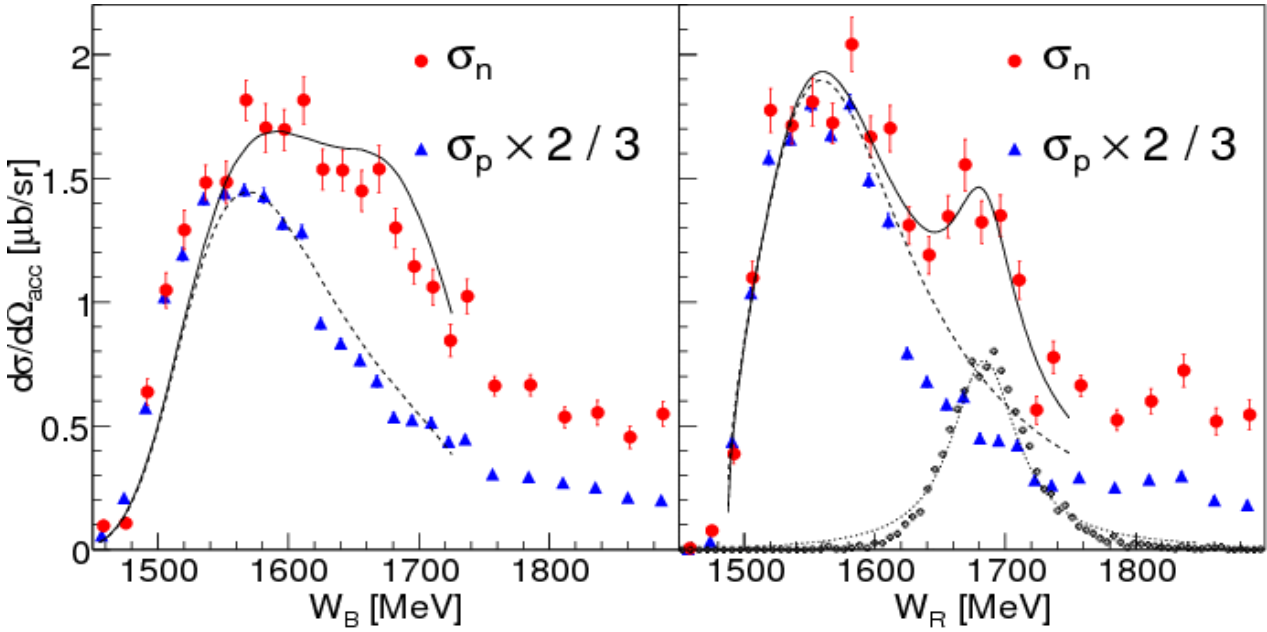
instead of

$$W_B = \sqrt{2E_\gamma m_N + m_N^2}$$

- Possible when the recoil nucleon is going into the TAPS forward wall, use of the time-of-flight ($\cos(\theta_{cm}) < -0.1$)



- Result
  - de-folded proton cross section similar to free proton
  - de-folded neutron cross section shows narrow structure around 1 GeV



W = 1684 MeV ± 2 MeV
Γ = 60 MeV ± 10 MeV
exp. resolution 60 MeV

Conclusions

- **η photoproduction off the deuteron have been analyzed and different observables have been extracted**
  - **previous measurements are reproduced**
  - **quasi-free proton and free proton folded agree within ± 10 %**
  - **the two neutron measurements agree within ± 10 %**

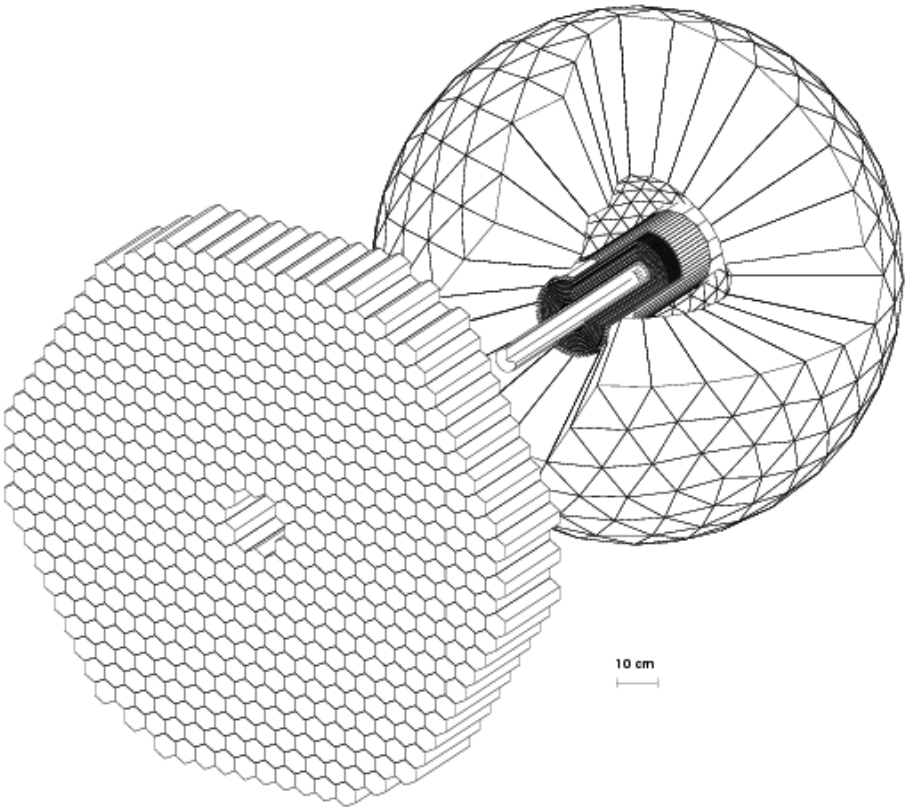
- **γ,η**
  - **a possible narrow resonance is observed at W = 1684 MeV**
  - **a possible new resonance is observed at W = 2080 MeV**
  - **analysis of the measurements under process**

- **published in Phys. Rev. Let.**

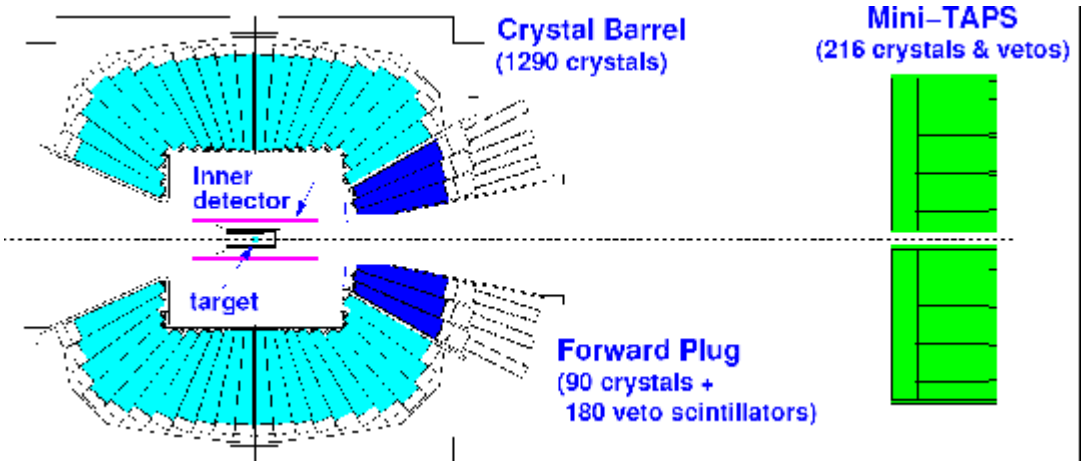
Outlook

η photoproduction off the deuteron with high statistics and double polarization measurements

- **Crystal Ball and TAPS at Mami: high statistics and E**
  E_{e^-}=1.5 GeV, beam intensity 20 nA



- **Crystal Barrel and TAPS at ELSA: Σ and G**
  E_{e^-}=3.5 GeV, beam intensity 5 nA



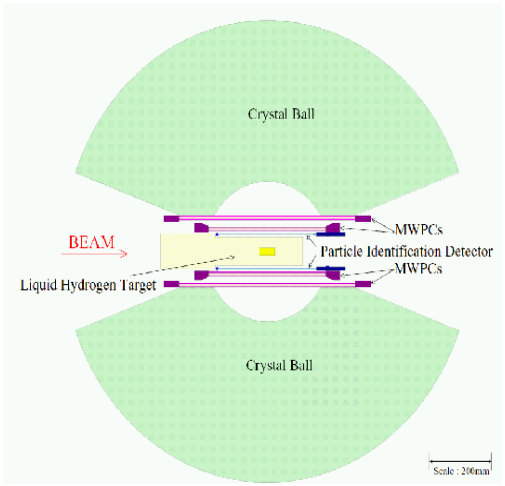
X(1684)→ηn, how narrow could it be ?

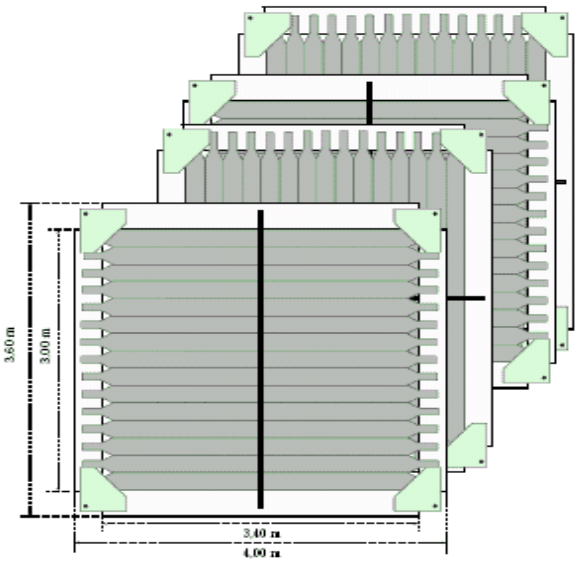
- **Crystal Ball and TAPS at Mami (taken in 12/2007)**

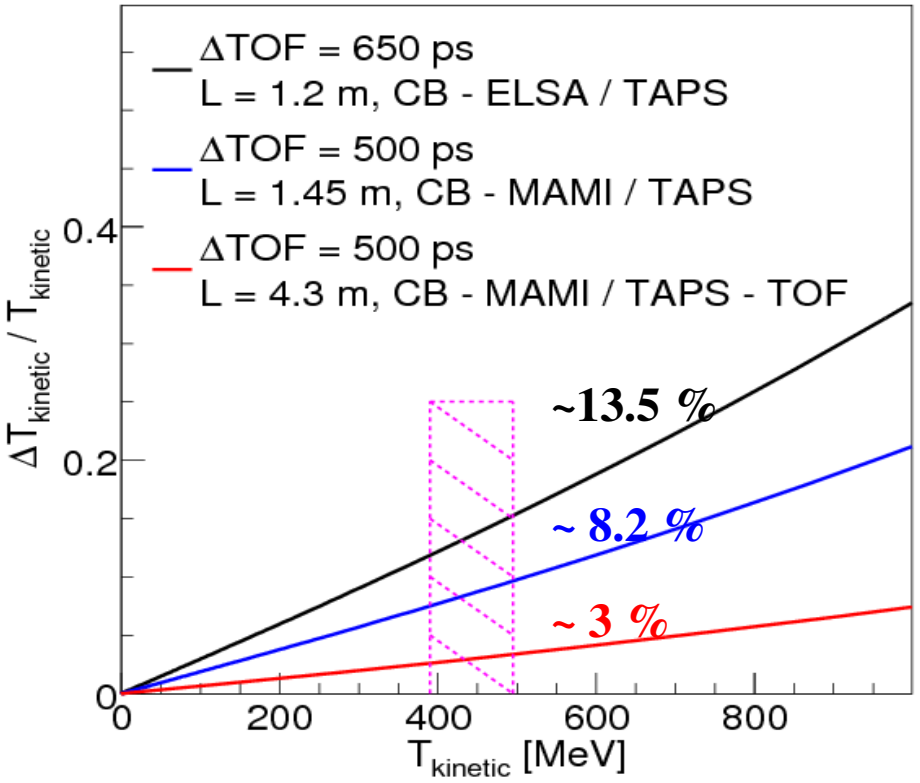
estimated exp. resolution 30 MeV- 40 MeV

Experimental resolution dominated by the ΔTOF improved by moving away the detectors

- **Crystal Ball and TOF - wall configuration at Mami**







Outlook

Thanks for your attention

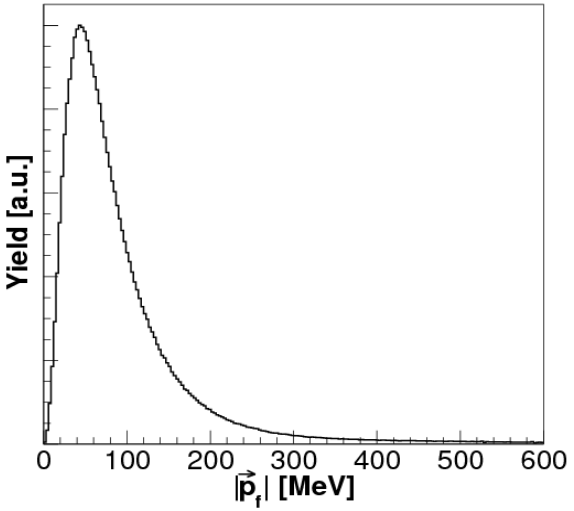
This work was supported by the Swiss National Fund and DFG(TR-16)

Impulse approximation

- calculation made with a nucleon at rest

- with a deuterium target there are "nuclear effects"
  - Fermi motion
  - final state interaction negligible
  - two-nucleon production contributions negligible

- Impulse approximation or spectator – participant approach takes into account the momentum distributions of the bound particles



$p_f \sim 40$ MeV is the most probable energy