Search for mesic nuclei in the photoproduction of η and η' mesons off light nuclei

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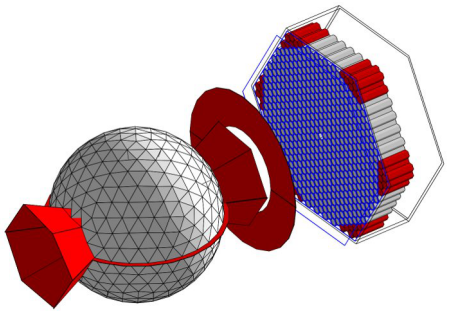
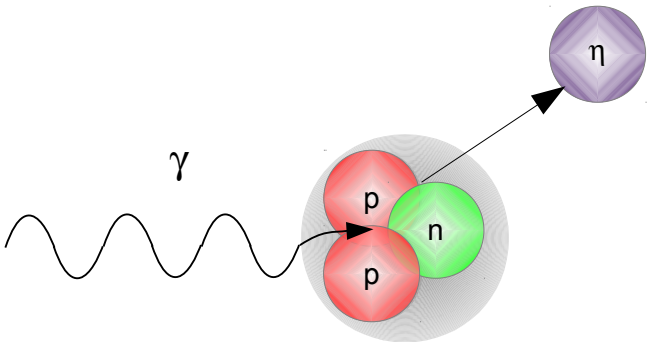
Outline

- ✔ Introduction
- ✔ Experimental Setup
- ✔ Data Analysis
- ✔ Results
- ✔ Conclusion





Basel group EMC @ PANDA, PreAmp & HV

Low Noise/Low Power (**LNP**) preamplifier for APD and VPTT

W. Erni, M. Steinacher, I. Keshelashvili, **B. Krusche**

Material: $PbW0_4$ - 22 X_0

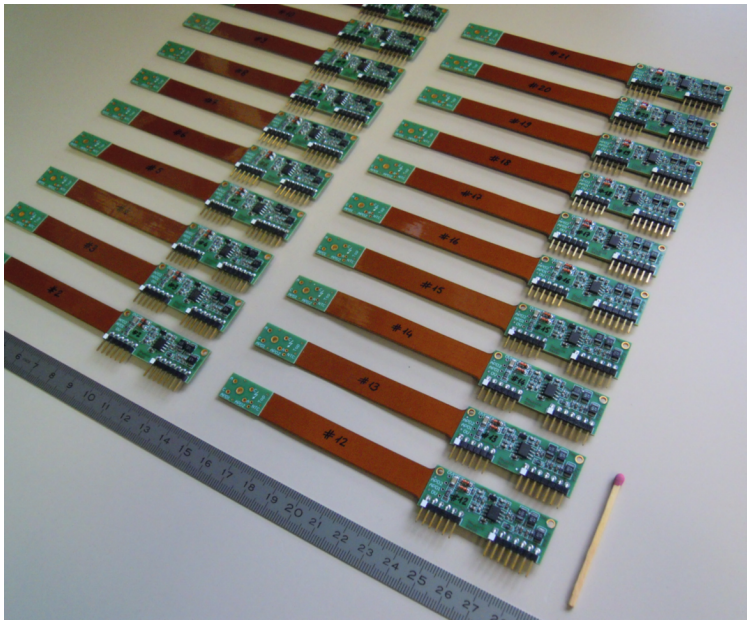
Crystal size: 2 cm x 2 cm x 20 cm

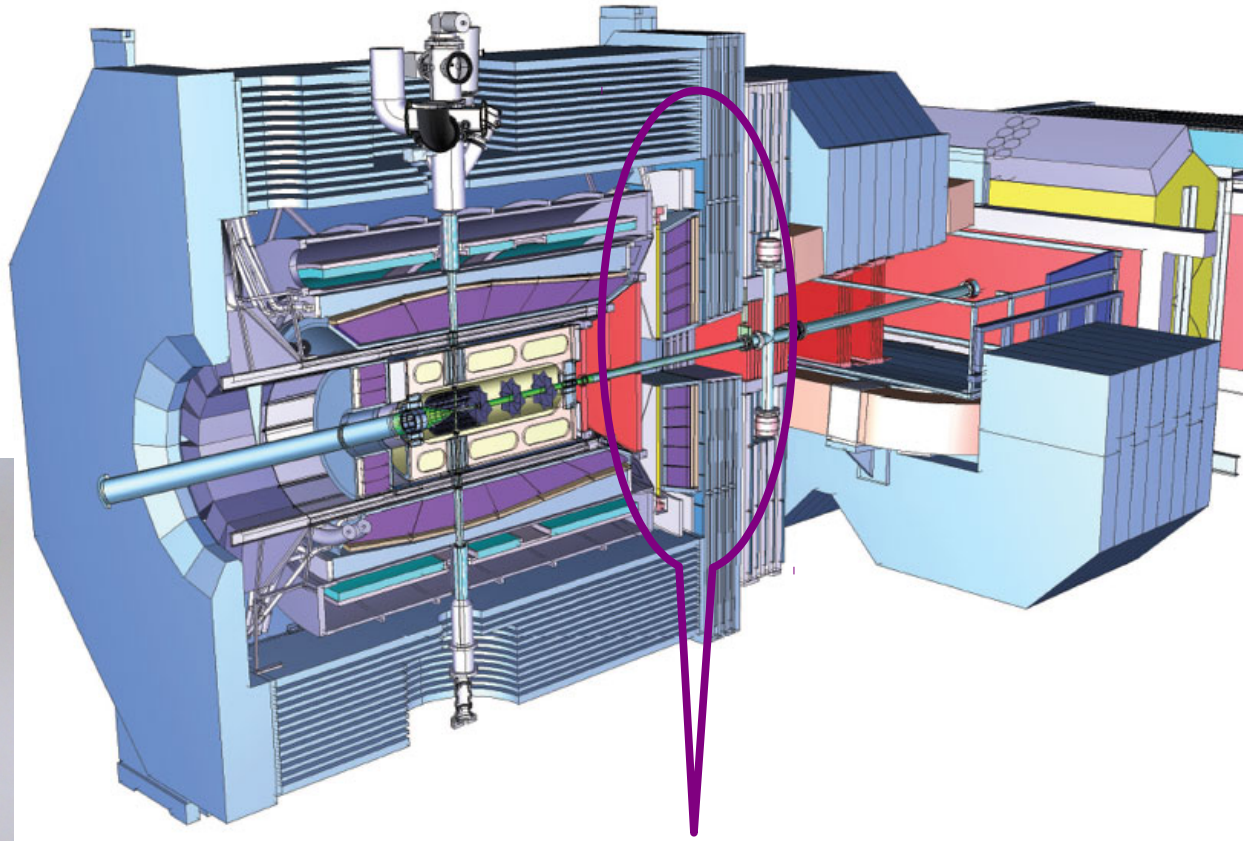
Energy resolution: 1.54% / √E/[GeV]+0.3%

Number of crystals: 15552

Forward EMC: 3600 – Basel LNP

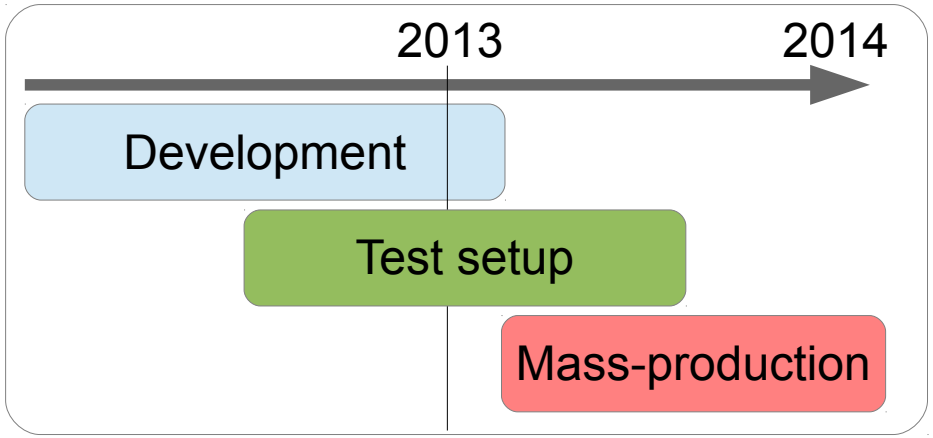
Per crystal 2xAPD or VPTT

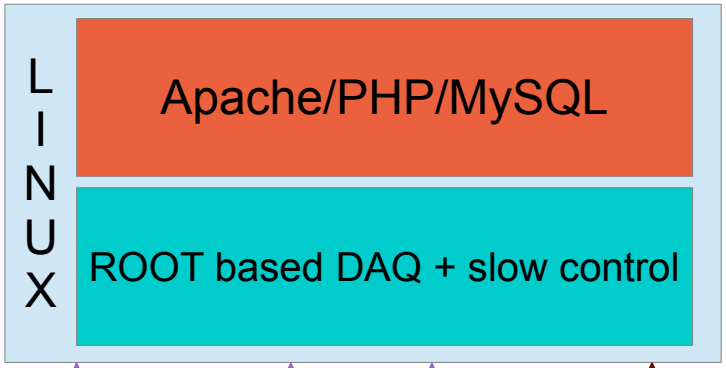


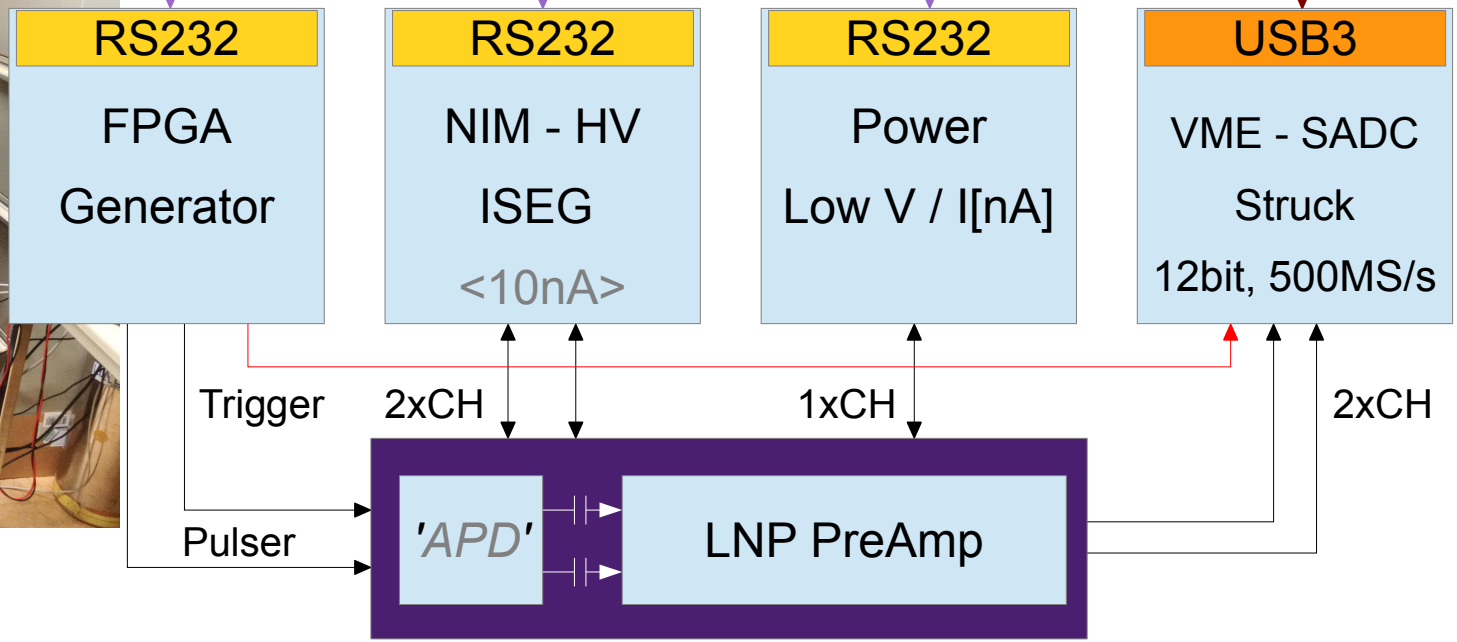


Cooled down to -25 °C

Basel group EMC @ PANDA, PreAmp & HV

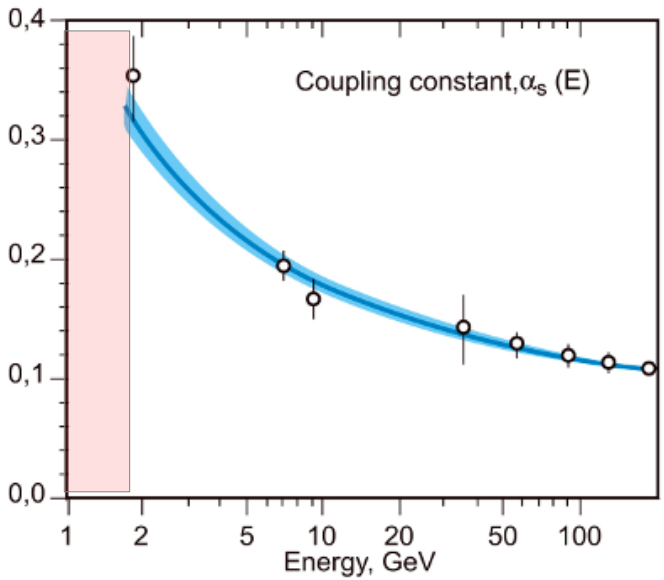


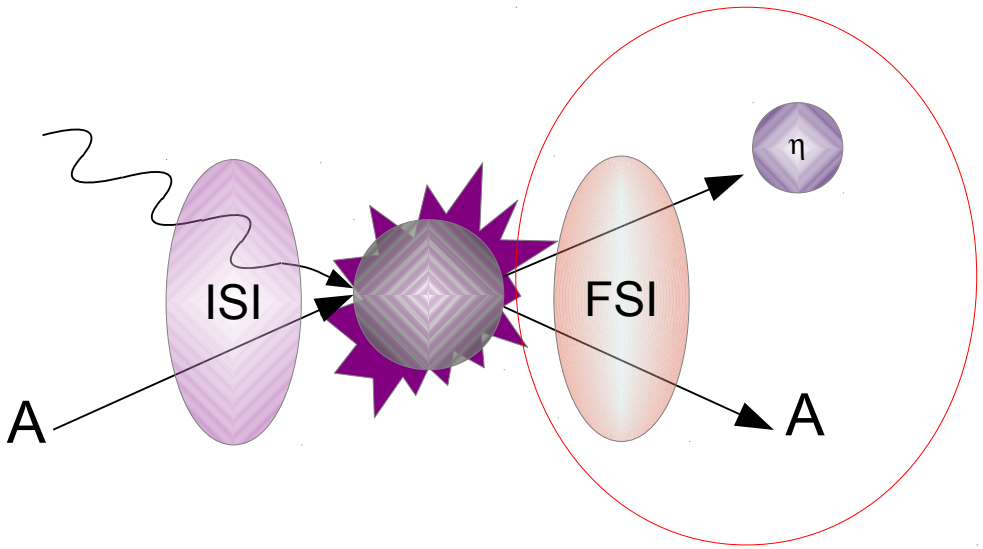




Introduction

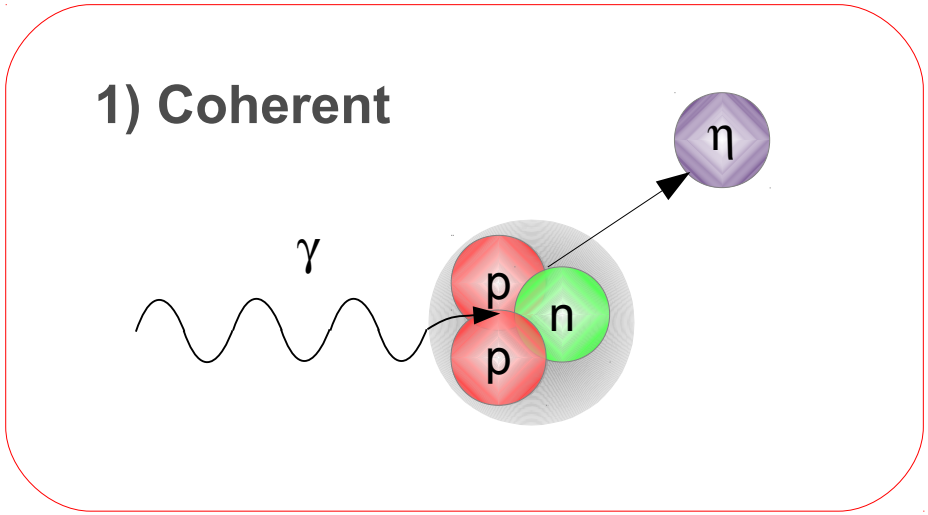
Strong Interaction

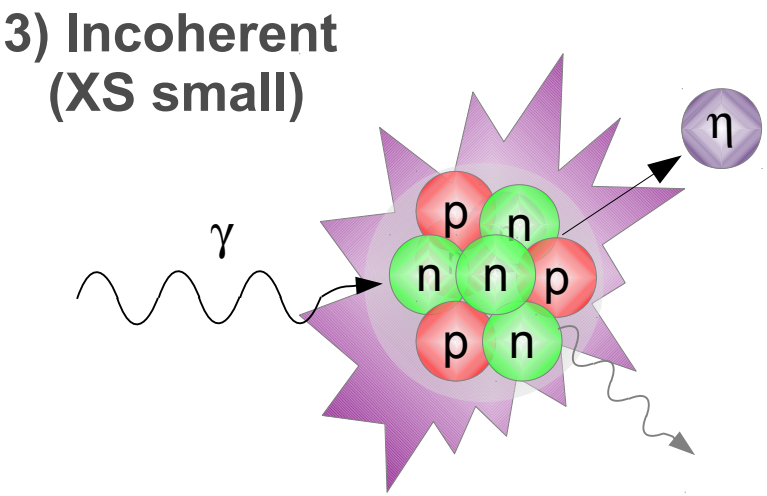


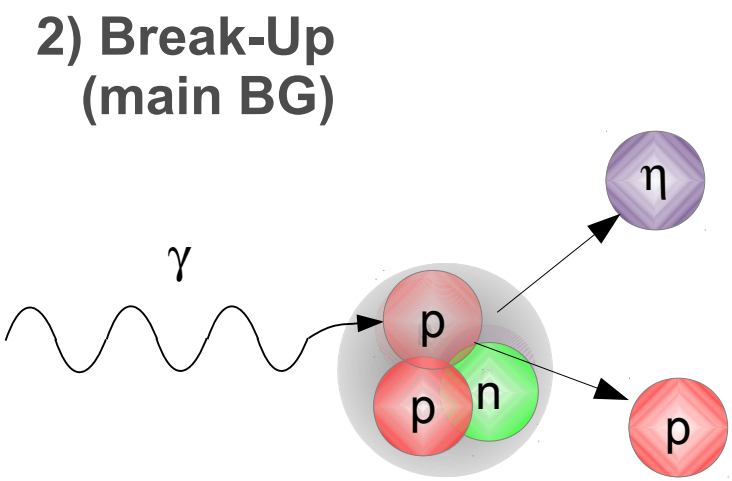


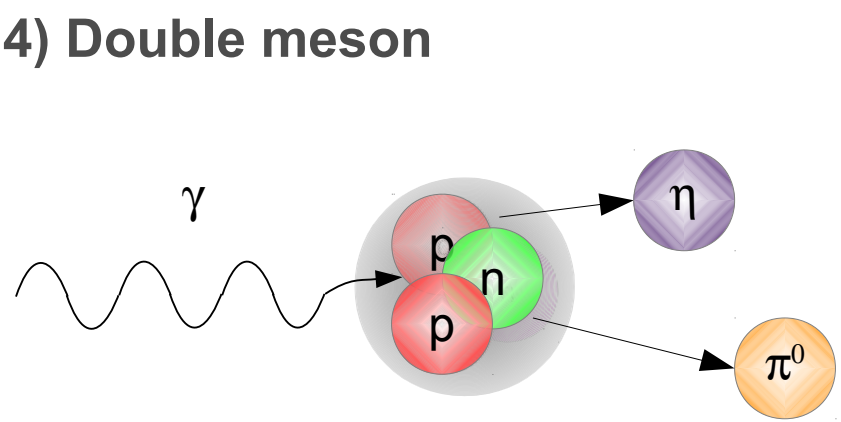
hadron	$c\tau$	mass (GeV)	flavor content	detection channel
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	$\gamma\gamma$
π^+	7.8 m	0.14	$u\bar{d}$	direct
π^-	7.8 m	0.14	$d\bar{u}$	direct
η	0.17 nm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	$\gamma\gamma$
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\pi^0$
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	$\pi^+\pi^-\eta$
K^+	3.7 m	0.49	$u\bar{s}$	direct
K^-	3.7 m	0.49	$\bar{u}s$	direct
K^0	27 mm	0.50	$d\bar{s}$	$\pi^+\pi^-$

Why coherent production?









History

1985: Bhalerao & Liu: coupled-channel analysis
attractive s-wave η-A ; π–induced for A≥12
scatt. lengths: Re: 0.27-0.28 fm Im: 0.19-0.22 fm;

1986: Liu & Haider:
suggestion of η-nucleus bound states for A>10

experiments: inconclusive evidence:
Chrien et al. (1988): $\pi^+ + {}^{16}O \rightarrow p + \eta\, {}^{15}O$

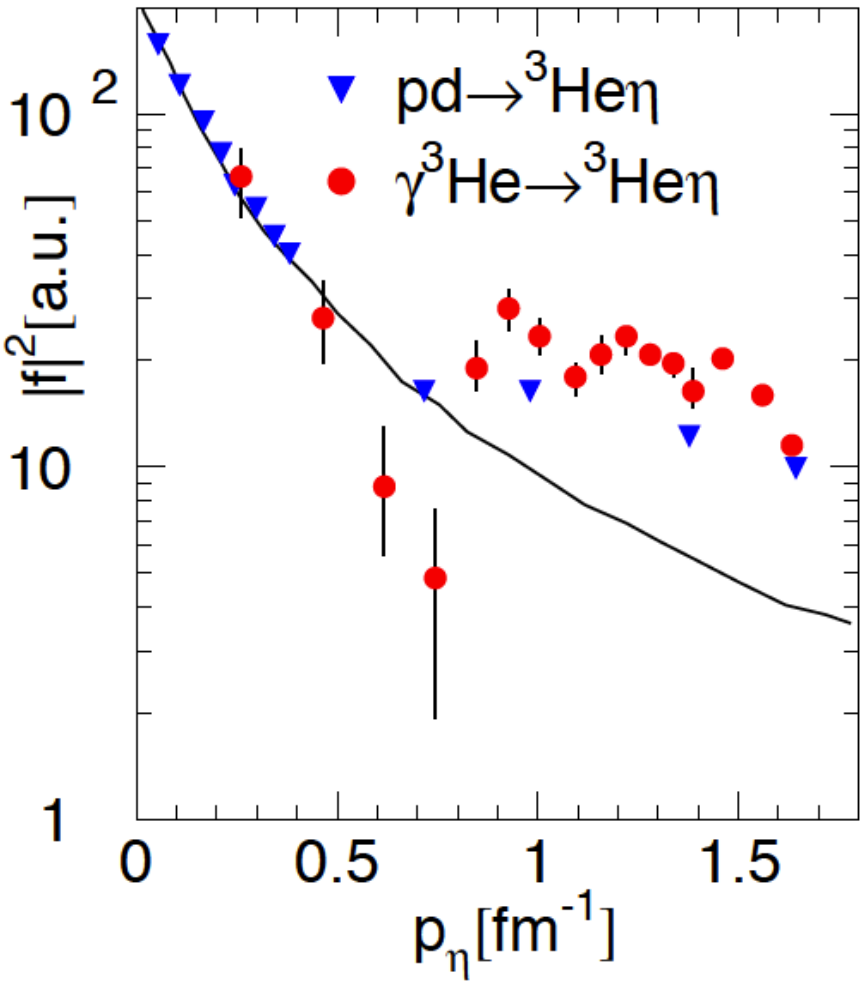
Johnson et al. (1993): $\pi^+ + {}^{18}O \rightarrow \pi^- + \eta\, {}^{18}Ne$

Sokol et al. (99): $\gamma + {}^{12}C \rightarrow p(n) + \eta\, {}^{11}B(C) \rightarrow \pi^+ + n + X$

1993 - 2002: analysis of new
η-production data from the proton:
larger ηN-scattering lengths

1991 - 2002: T. Ueda, C. Wilkin,
S.A. Rakityanski and others:
suggestions of bound
${}^2H$-, ${}^3H$-, ${}^3He$-, ${}^4He$-η states

experiments:
threshold behavior
of η-production



Why is the η-meson case special?

- **η-photoproduction dominated by excitation of $S_{11}(1535)$**

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

$$J_z: \quad -1 \qquad +1/2 \quad -1/2 \qquad -1/2 \quad 0$$

→ spin-flip transition

- **Expectation for light nuclei:**

I) ^{4}He: J=0, I=0, isoscalar, non spin-flip **→ very small signal**
(not seen, only upper bounds, V. Hejny et al.)

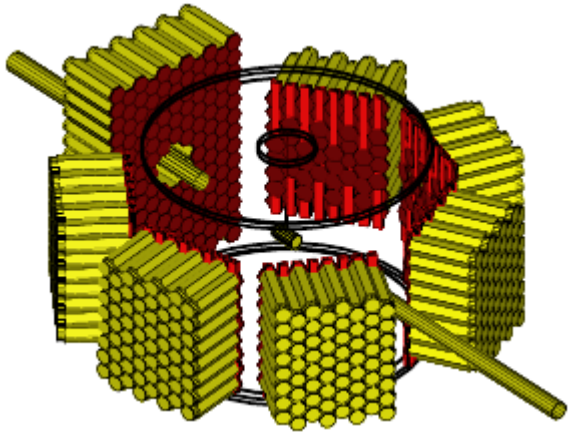
II) ^{2}H: J=1, I=0, isoscalar, spin-flip **→ small signal**
(seen, almost in agreement with expectations)

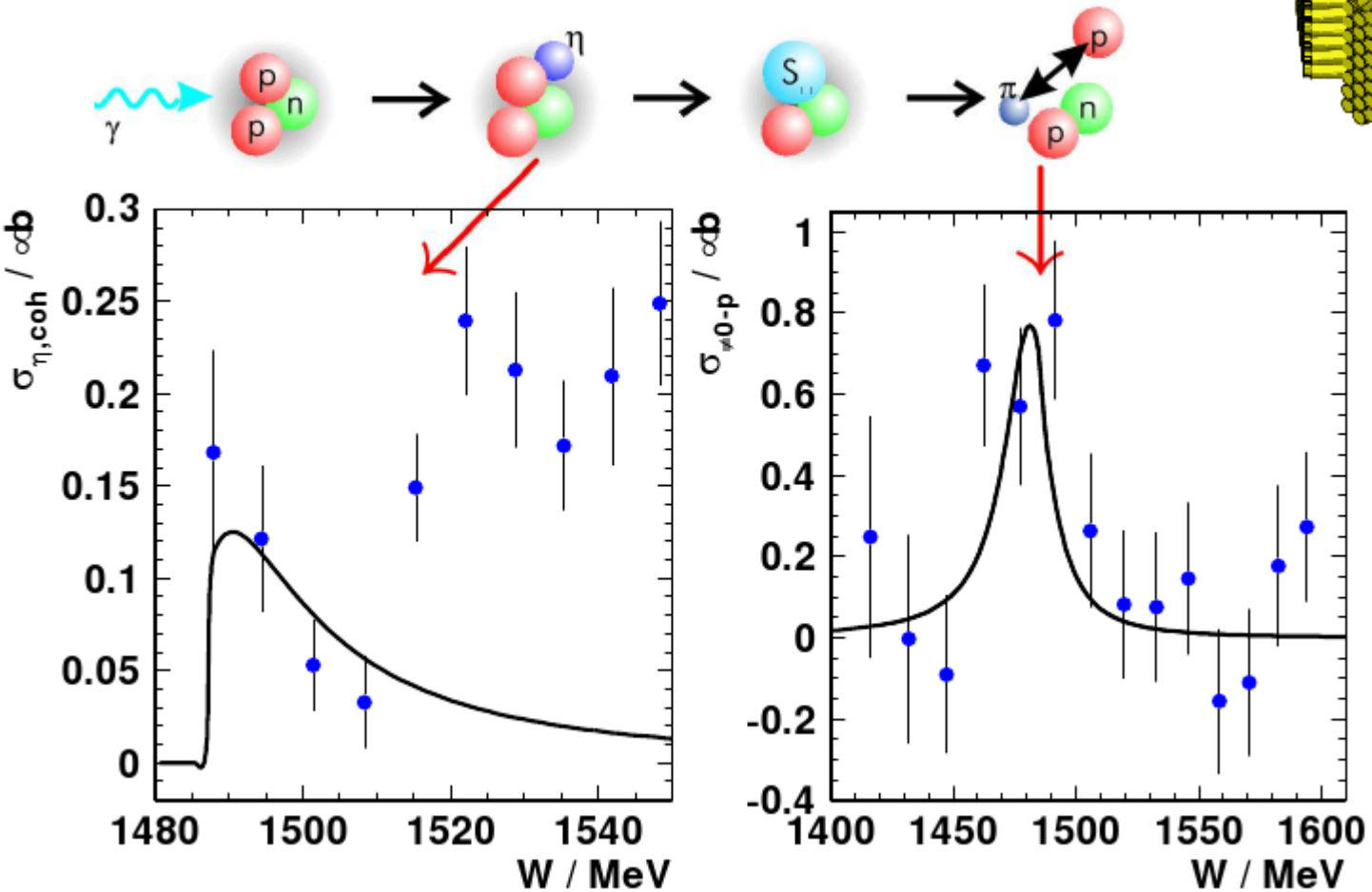
III) ^{3}He: J=1/2, I=1/2, isovector, spin-flip **→ 'large' signal**

TAPS - Photoproduction of η – mesic ^{3}He

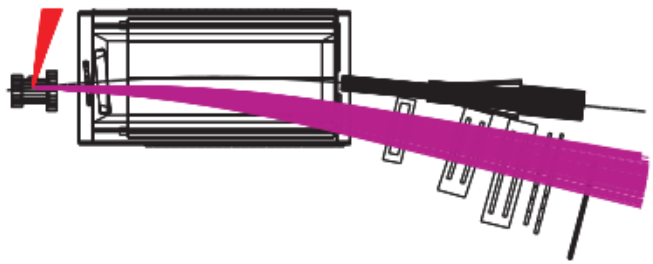
Photoproduction of eta-mesic ^{3}He

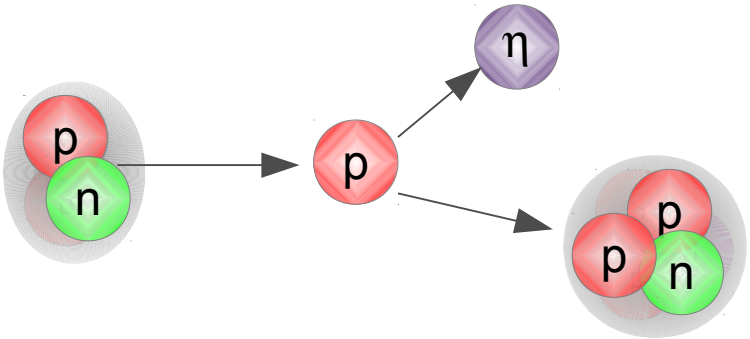
M. Pfeiffer at al. Phys. Rev. Lett. 92 (2004) 252001

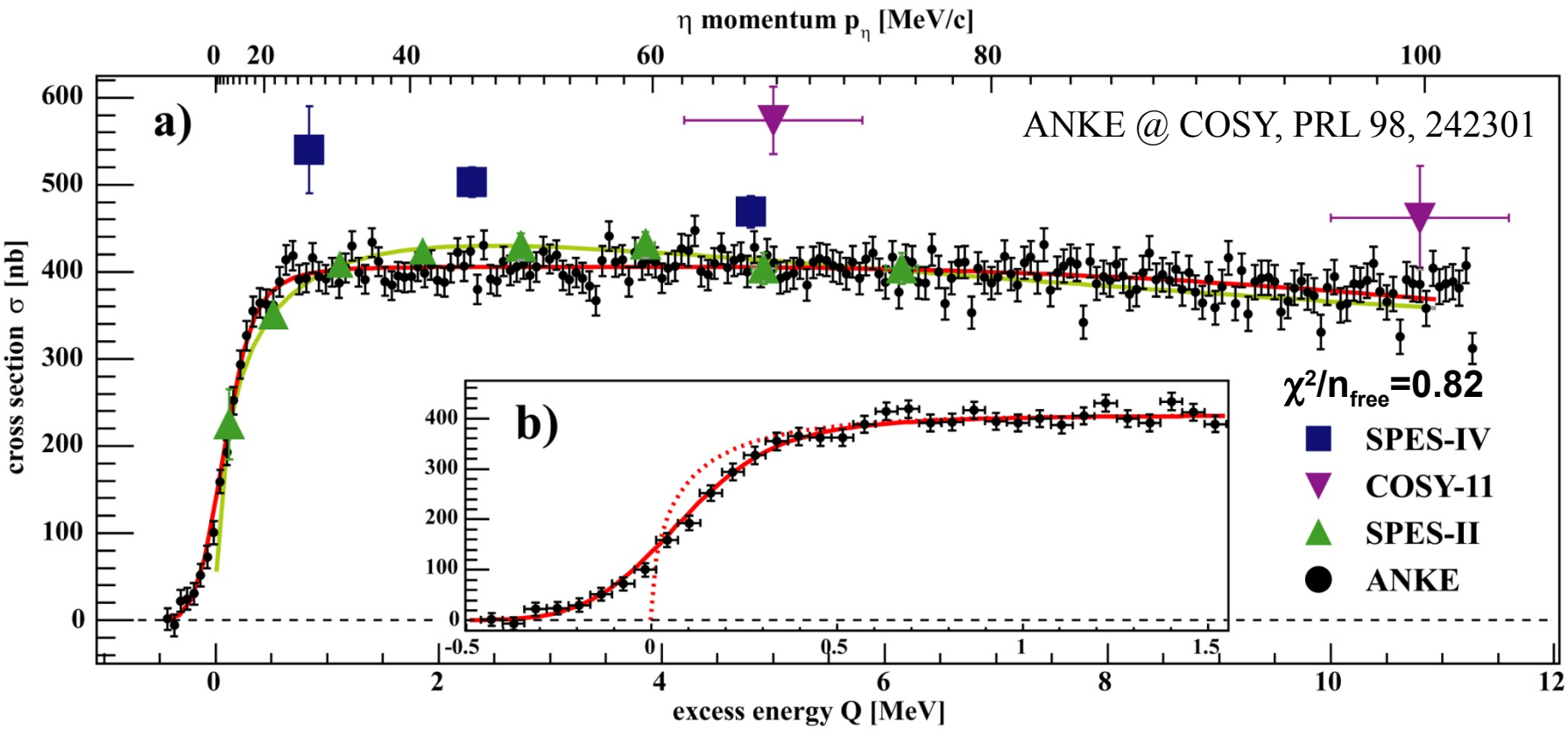




ANKE - Excitation function: dp→^{3}Heη

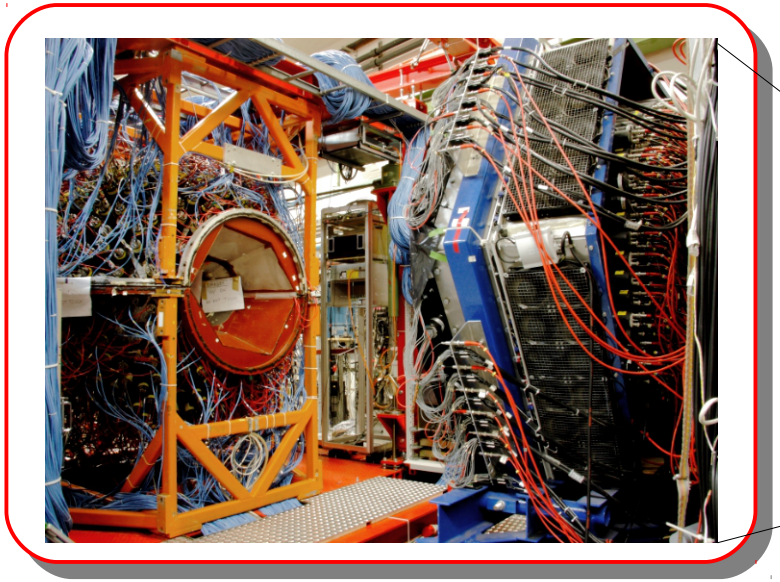




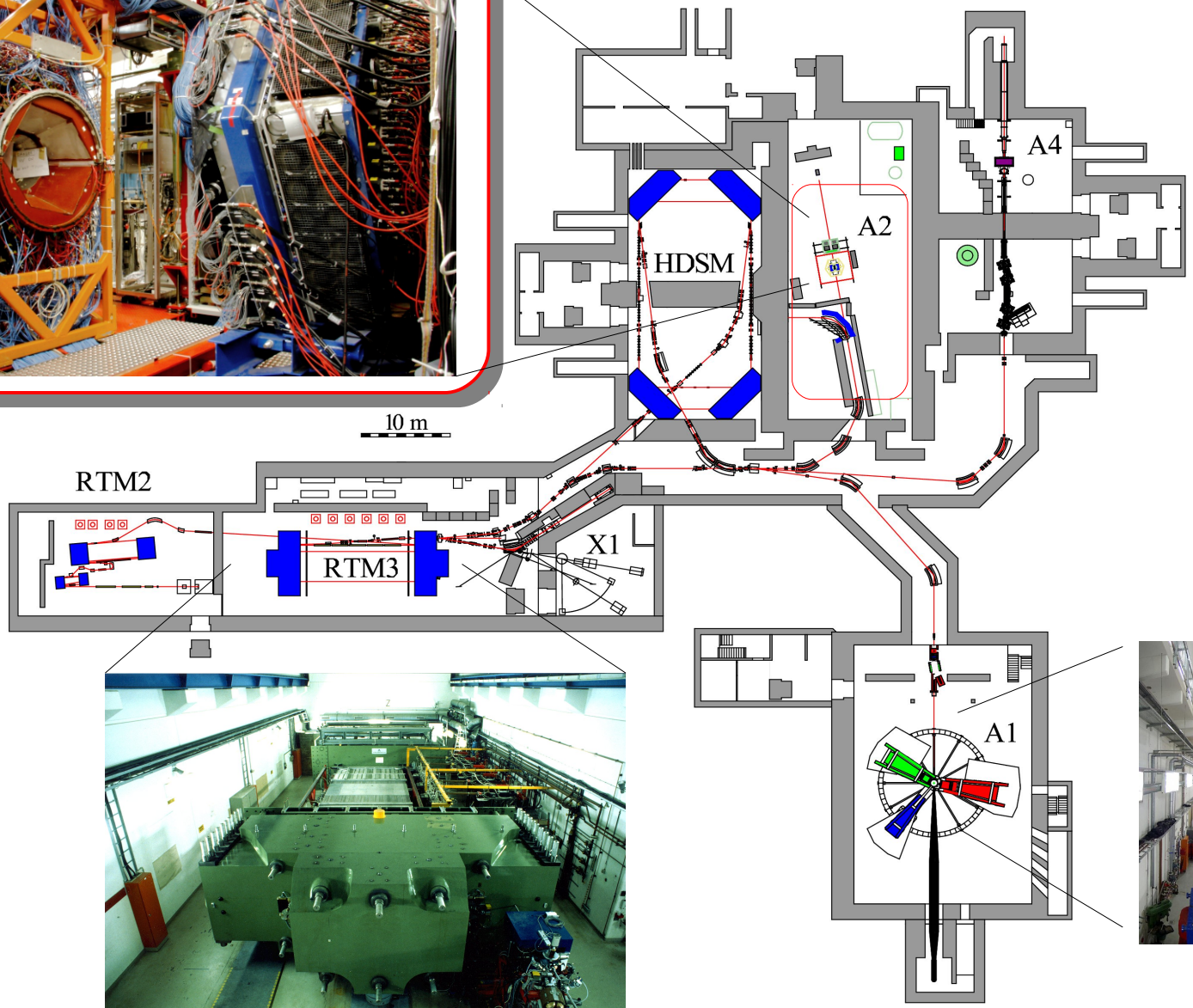


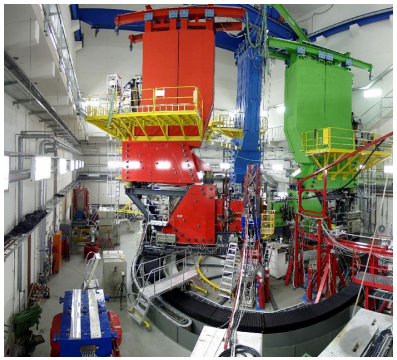
Experiment

MAMI (Mainzer Mikrotron)

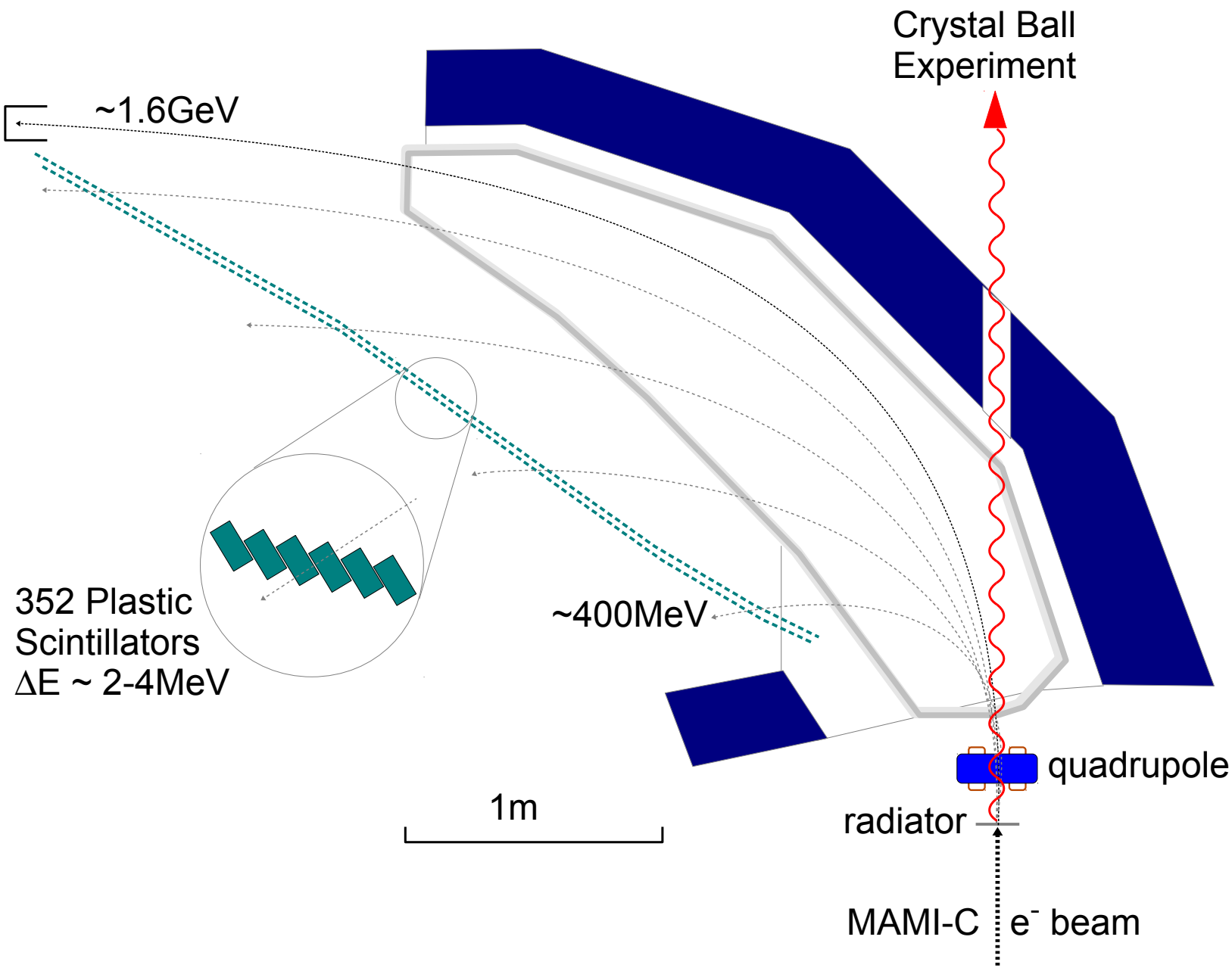


continuous wave



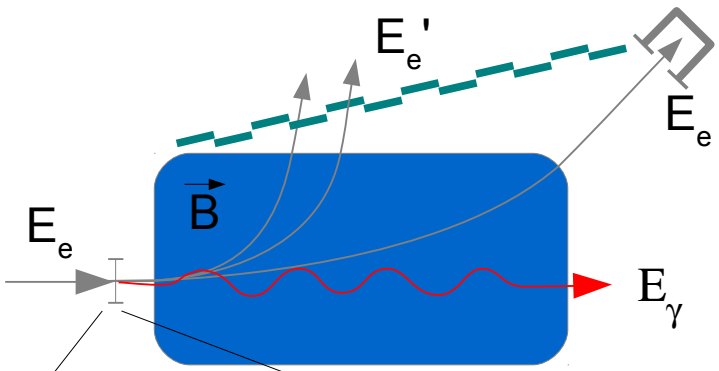


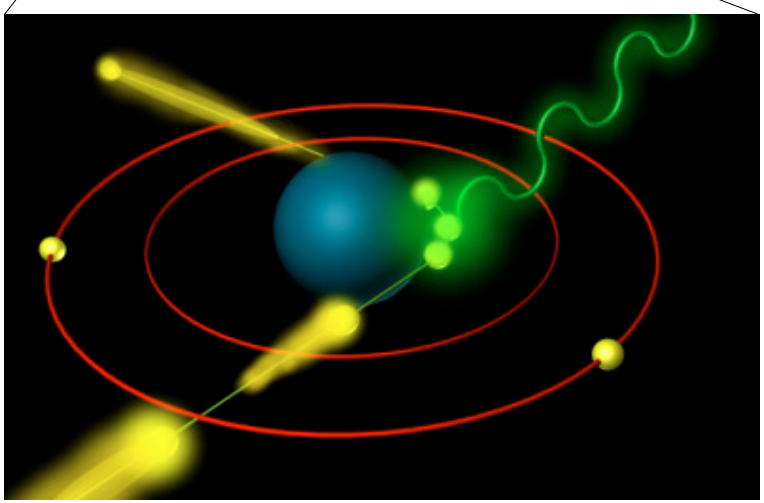
Glasgow Tagger

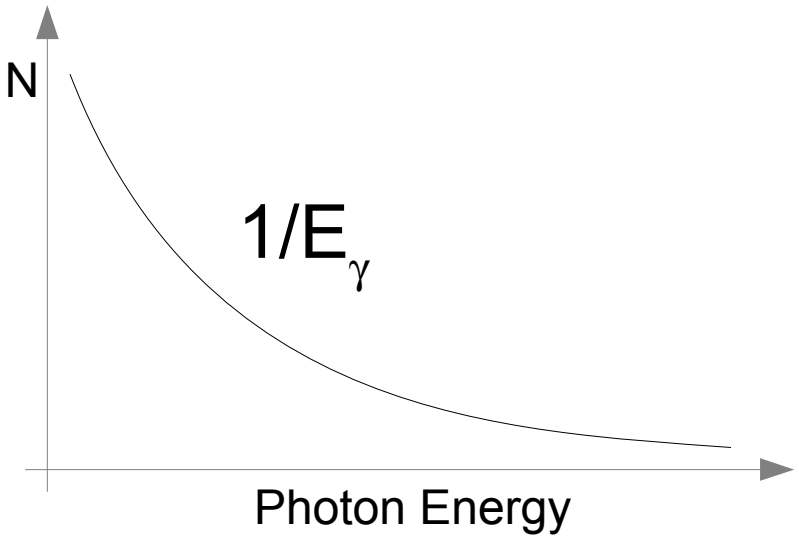


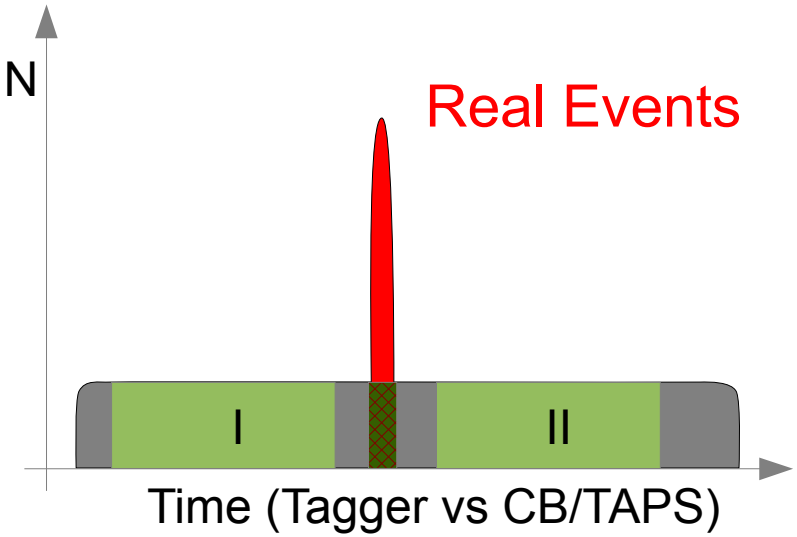
How to get the photon energy?

$$E_\gamma = E_e - E_e'$$









Crystal Ball / TAPS Detector

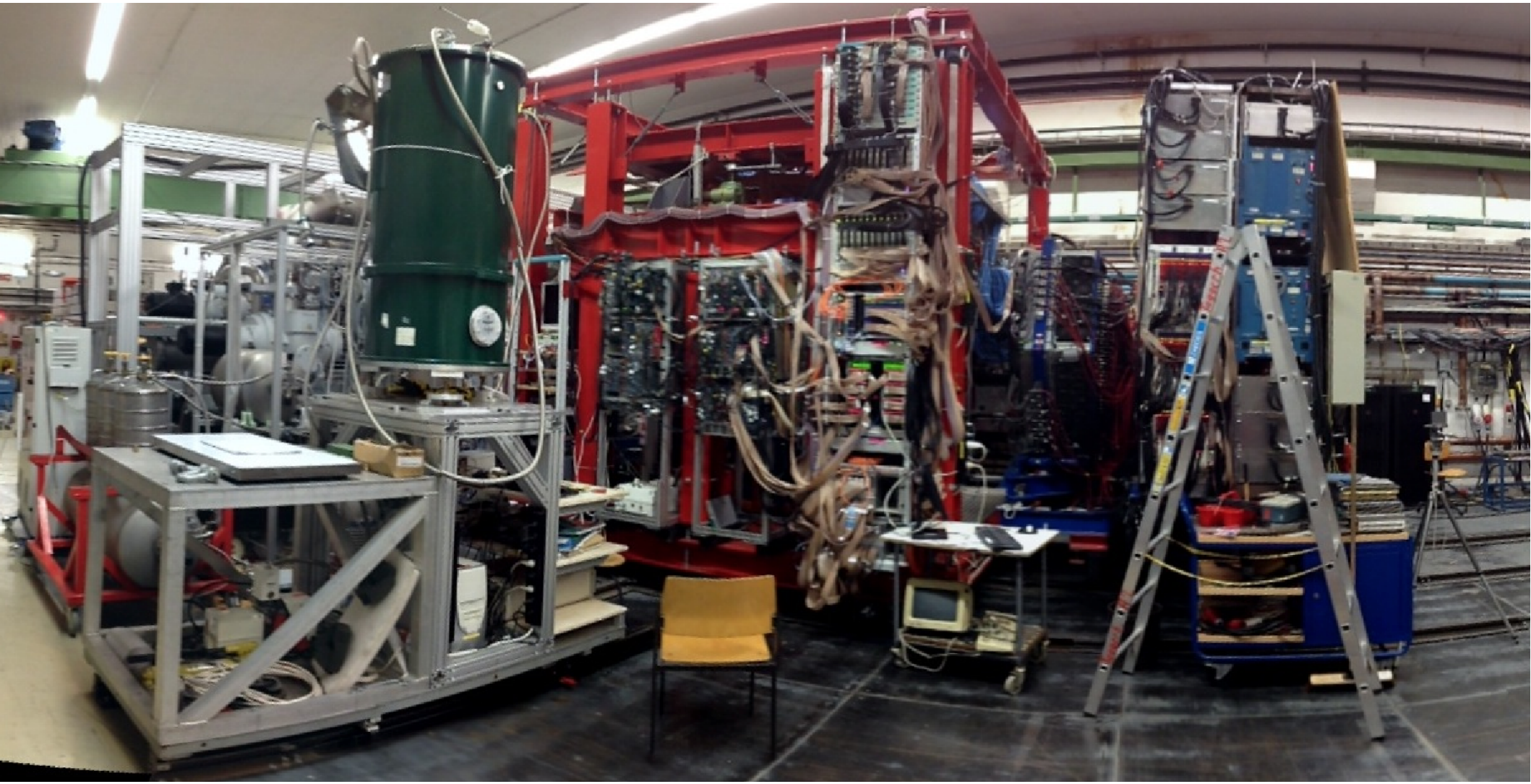
Polarized Target

Crystal Ball
672 NaI(Tl)

PID 24 Pl.Sci.

TAPS
BaF_2 + PWO

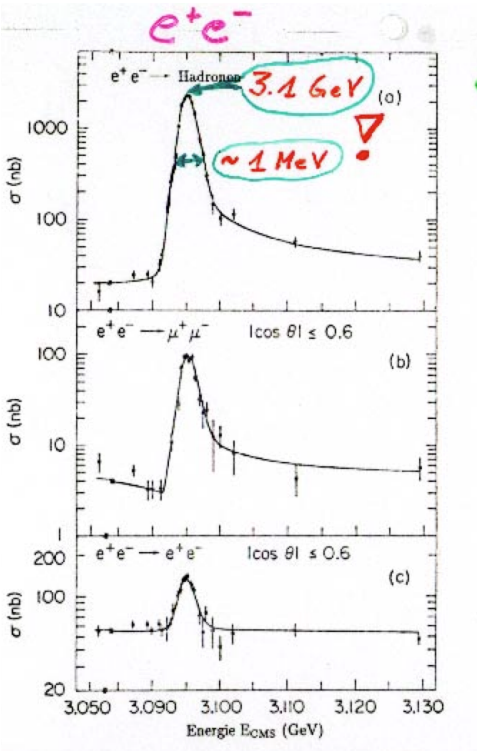
VETO 384 Pl.Sci.

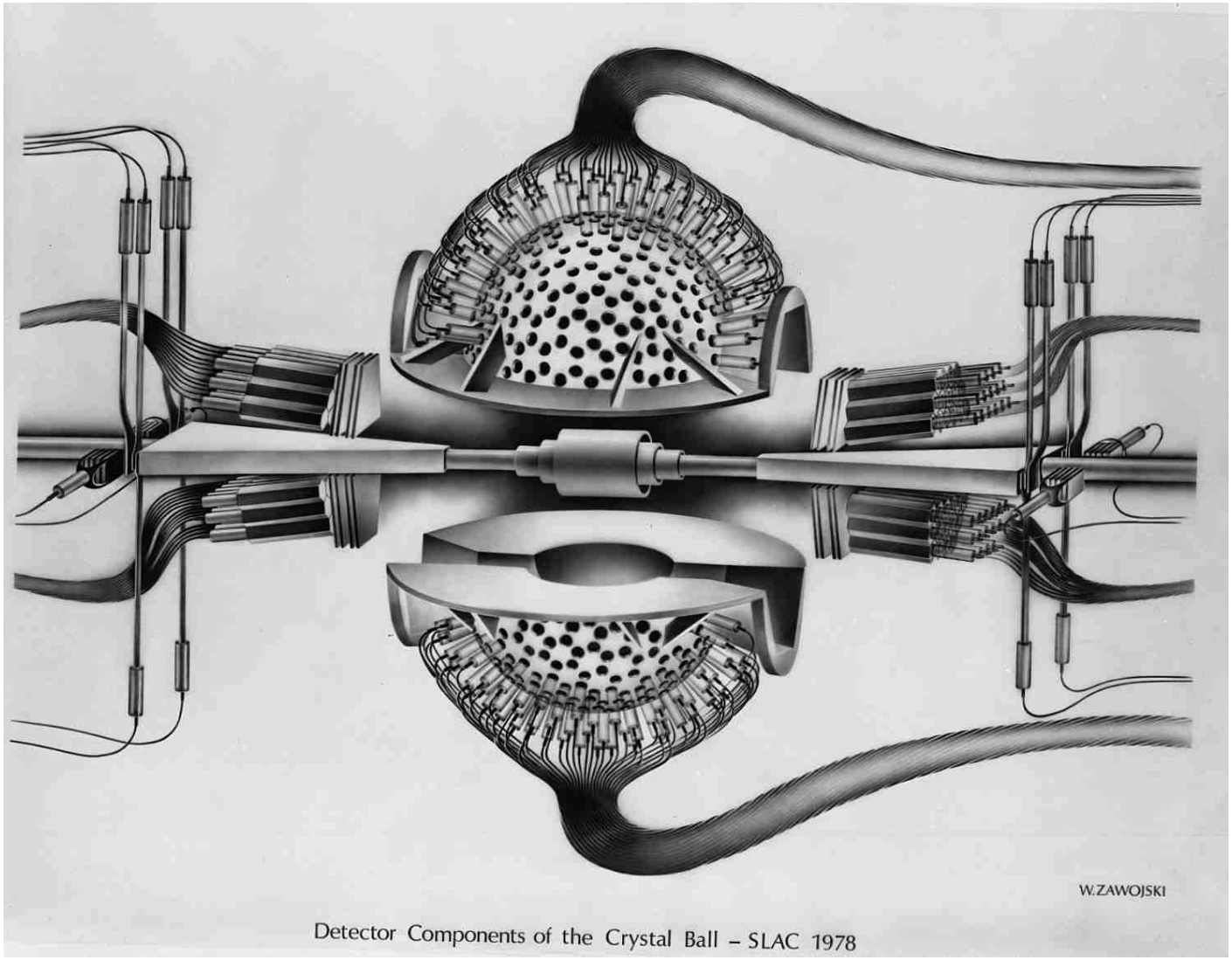


Crystal Ball detector at SPEAR @ SLAC

- SPEAR began 1972
- $e^- e^+$ @ 3GeV
- J/ψ meson

  Nobel price 1976
- +many charmonium states
- SLAC, DASY, BNL, MAMI





Detector Components of the Crystal Ball – SLAC 1978

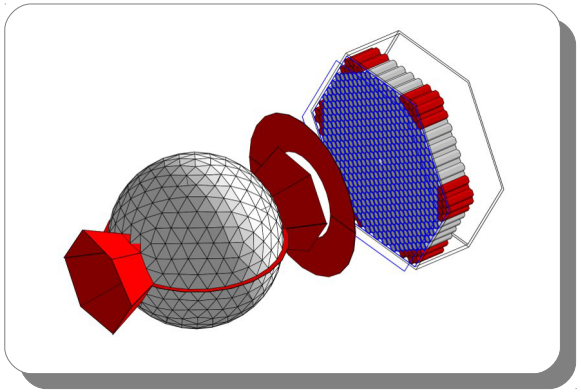
Crystal Ball / TAPS Detector

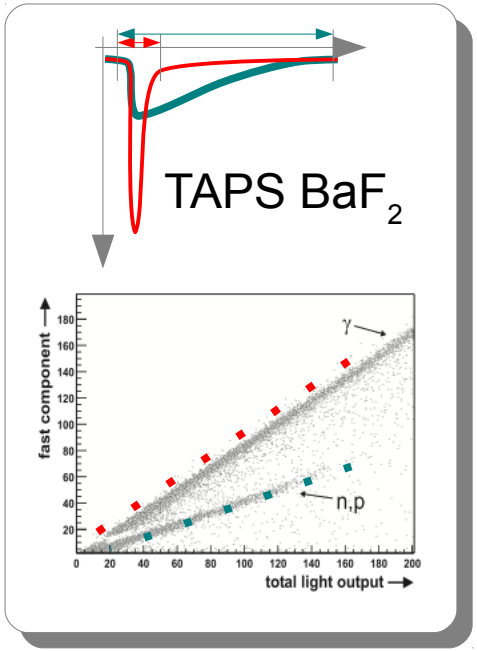
Invariant Mass

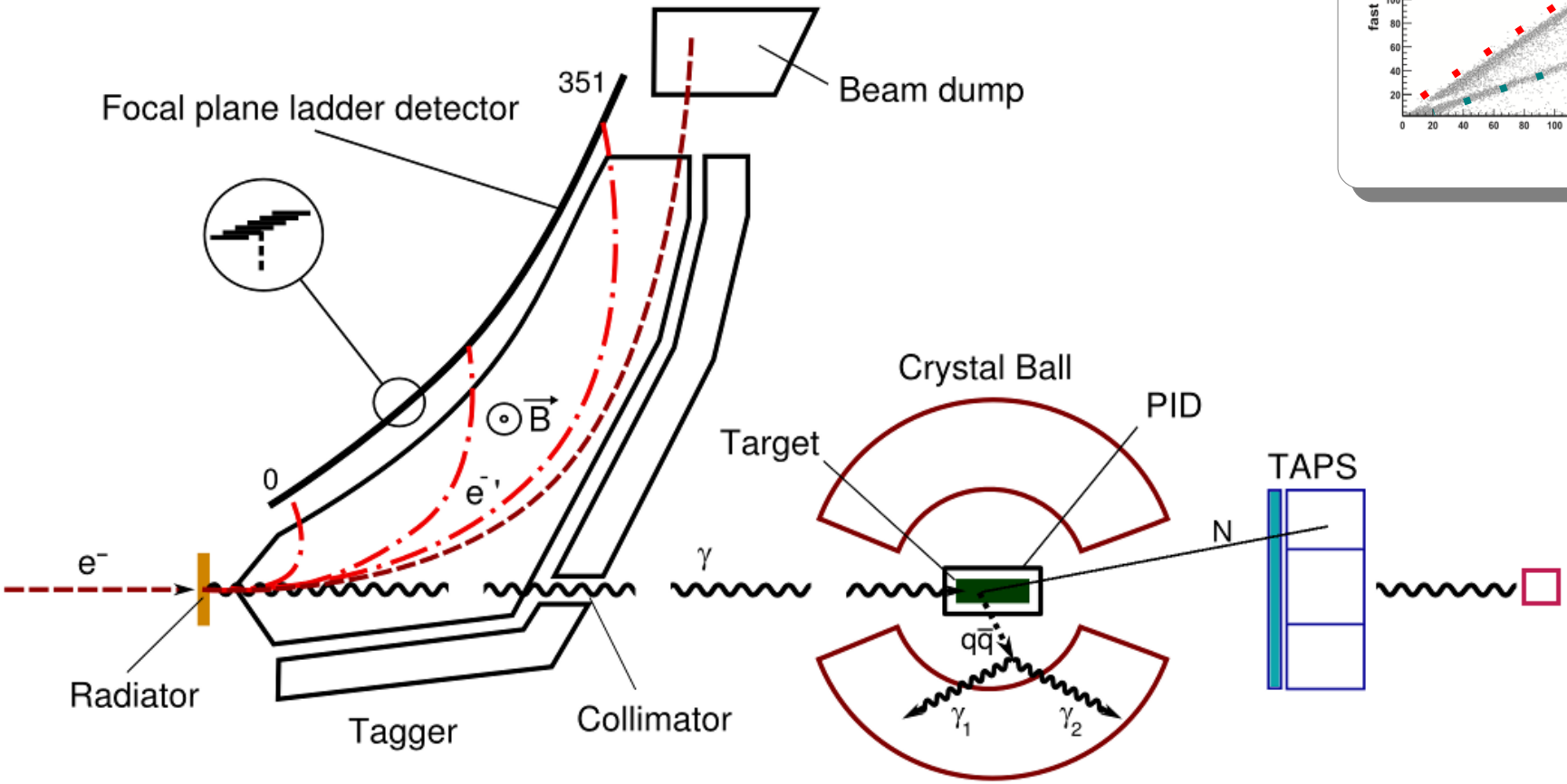
Missing Energy or Mass

Pulse Shape

TOF – Time-Of-Flight

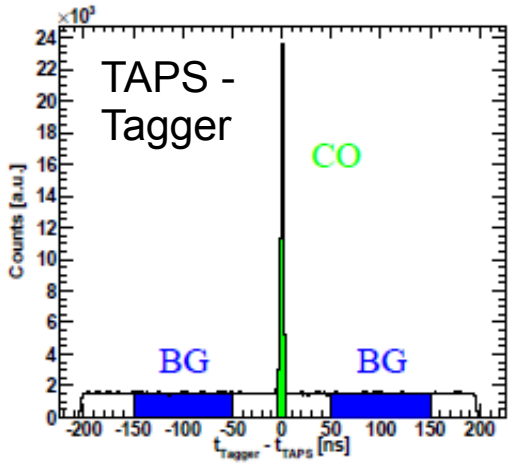


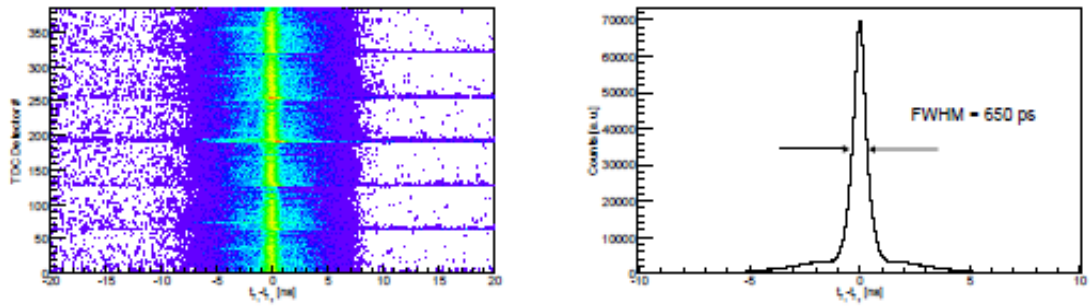




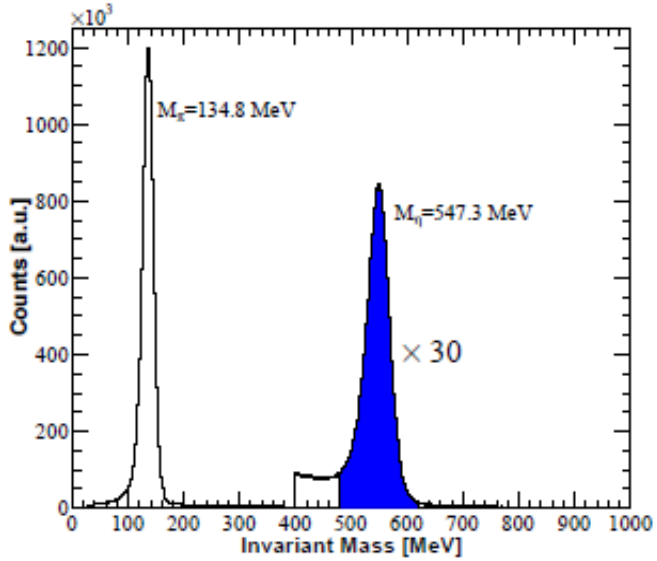
Analysis

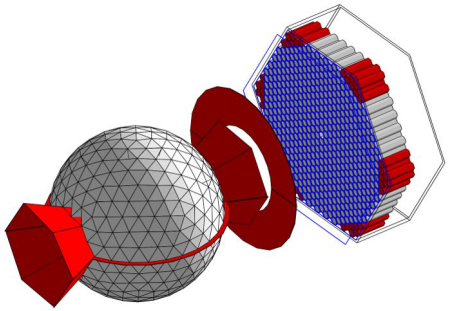
Data Analysis

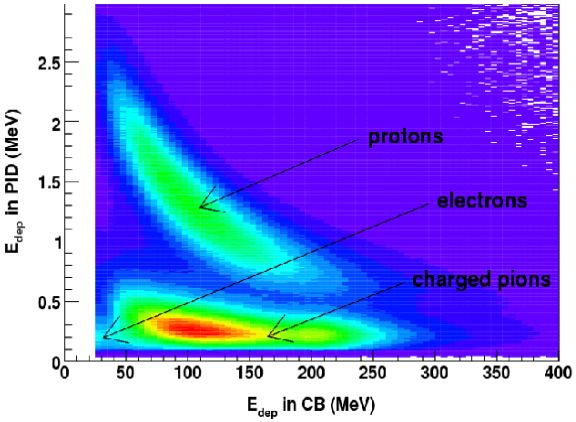




$$M_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma 2}(1-\cos\phi_{12})}$$







$$\frac{d\sigma}{d\Omega}(E_\gamma,\theta) = \frac{N_{event}(E_\gamma,\theta)}{\epsilon_{event}(E_\gamma,\theta)\cdot\Gamma_{BR}\cdot N_{target}\cdot N_{scaler}(E_\gamma)\cdot\epsilon_\gamma(E_\gamma)\cdot\Omega}$$

Results

$$\gamma + {}^3He \rightarrow {}^3He + \eta$$

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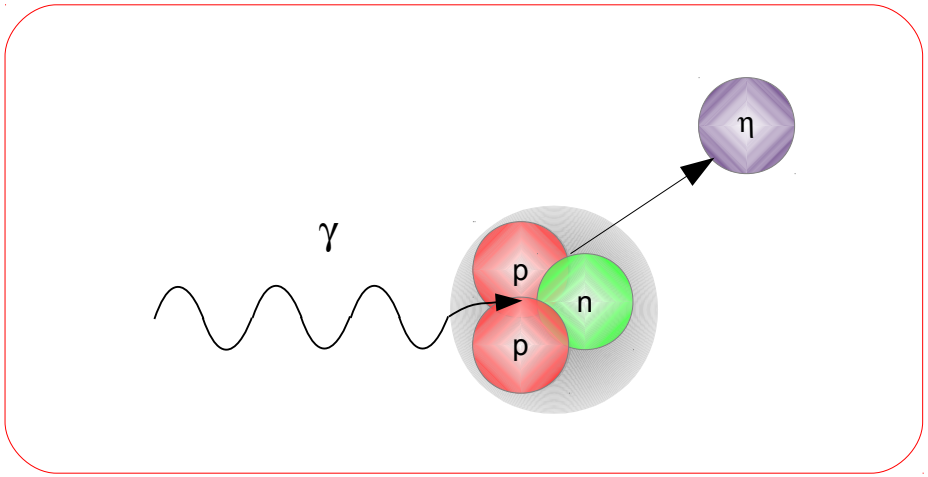
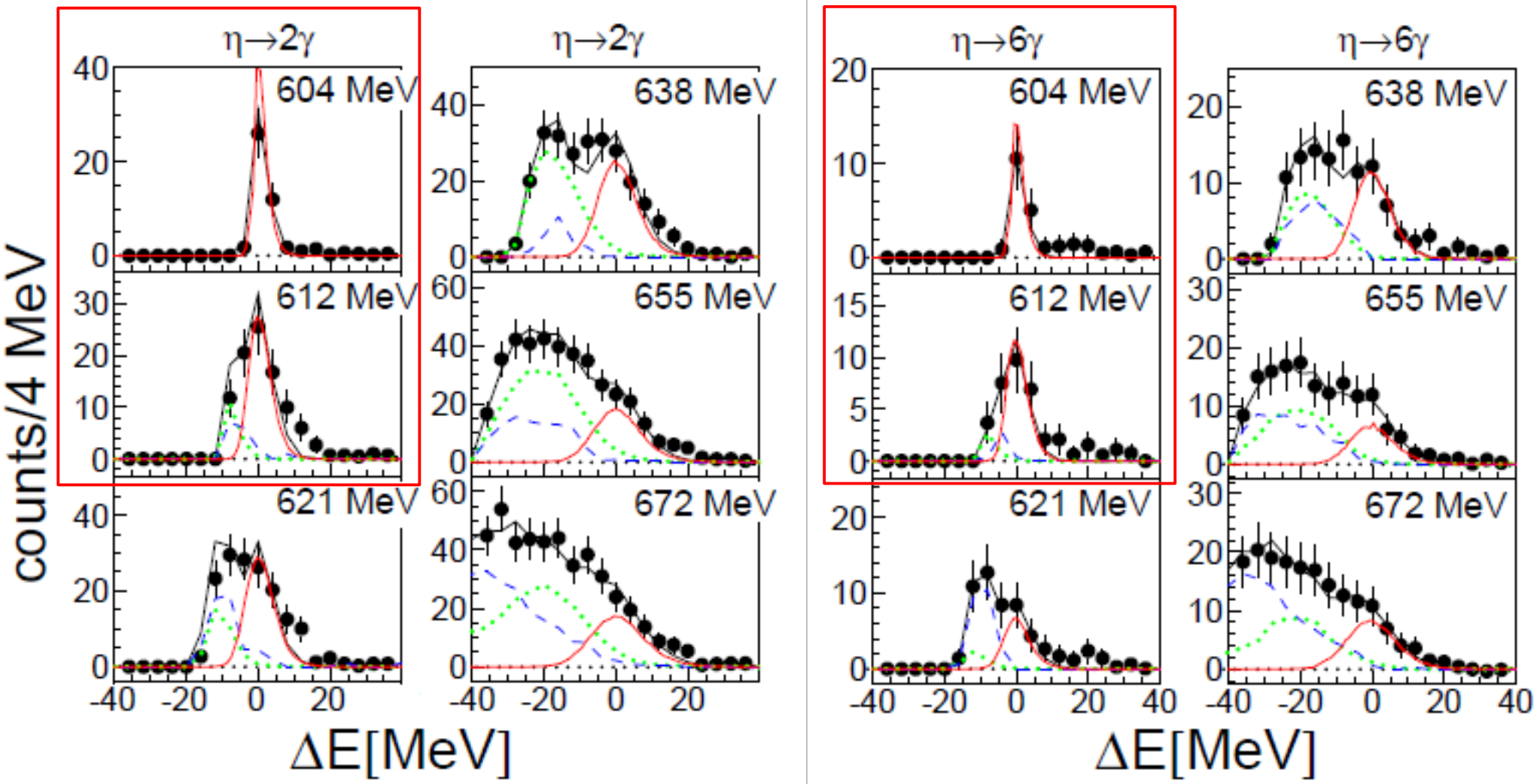
Coherent photoproduction of η-mesons off ^{3}He – search for η-mesic nuclei

F. Pheron [a], J. Ahrens [b], J.R.M. Annand [c], H.J. Arends [b], K. Bantawa [d], P.A. Bartolome [b], R. Beck [e], V. Bekrenev [f], H. Berghäuser [g], B. Boillat [a], A. Braghieri [h], D. Branford [i], W.J. Briscoe [j], J. Brudvik [k], S. Cherepnya [l], B. Demissie [j], M. Dieterle [a], E.J. Downie [b,c,j], P. Drexler [g], D.I. Glazier [i], E. Heid [b], L.V. Fil'kov [l], D. Hornidge [m], D. Howdle [c], O. Jahn [b], I. Jaegle [a], T.C. Jude [i], V.L. Kashevarov [l,b], I. Keshelashvili [a], R. Kondratiev [n], M. Korolija [o], M. Kotulla [a,g], A. Kulbardis [f], S.P. Kruglov [f], B. Krusche [a,*], V. Lisin [n], K. Livingston [c], I.J.D. MacGregor [c], Y. Maghrbi [a], J. Mancell [c], D.M. Manley [d], Z. Marinides [j], M. Martinez [b], J.C. McGeorge [c], E. McNicoll [c], D. Mekterovic [o], V. Metag [g], S. Micanovic [o], D.G. Middleton [m], A. Mushkarenkov [h], B.M.K. Nefkens [k], A. Nikolaev [e], R. Novotny [g], M. Oberle [a], M. Ostrick [b], B. Oussena [b,j], P. Pedroni [h], A. Polonski [n], S.N. Prakhov [k], J. Robinson [c], G. Rosner [c], T. Rostomyan [a,h], S. Schumann [b], M.H. Sikora [i], D.I. Sober [p], A. Starostin [k], I. Supek [o], M. Thiel [g], A. Thomas [b], M. Unverzagt [b], D.P. Watts [i], D. Werthmüller [a], L. Witthauer [a], F. Zehr [a]

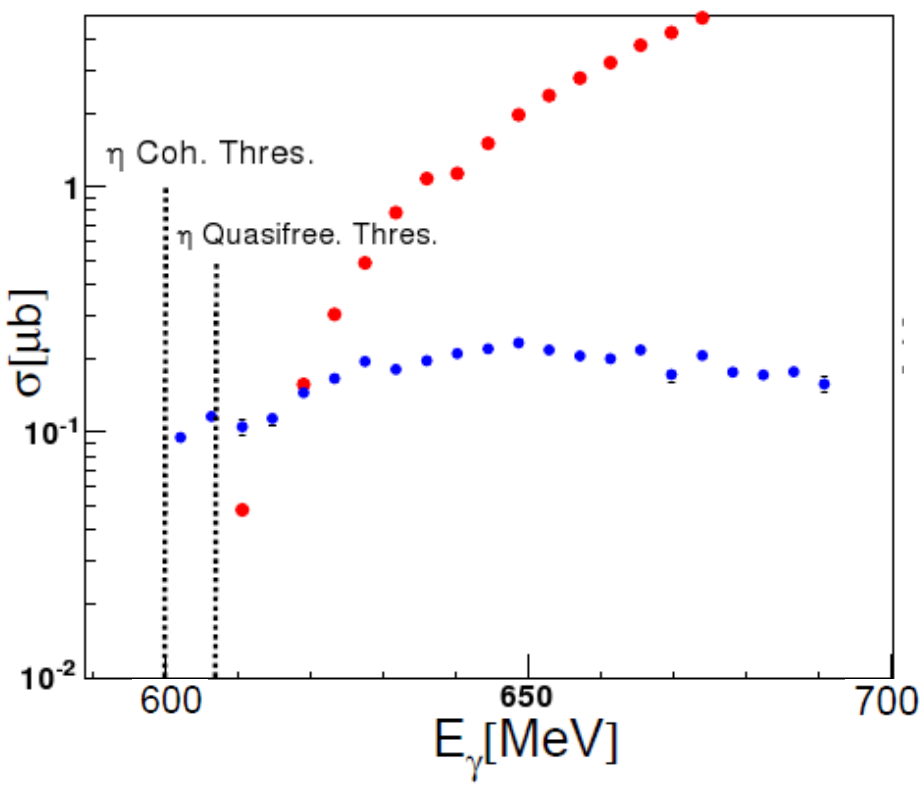


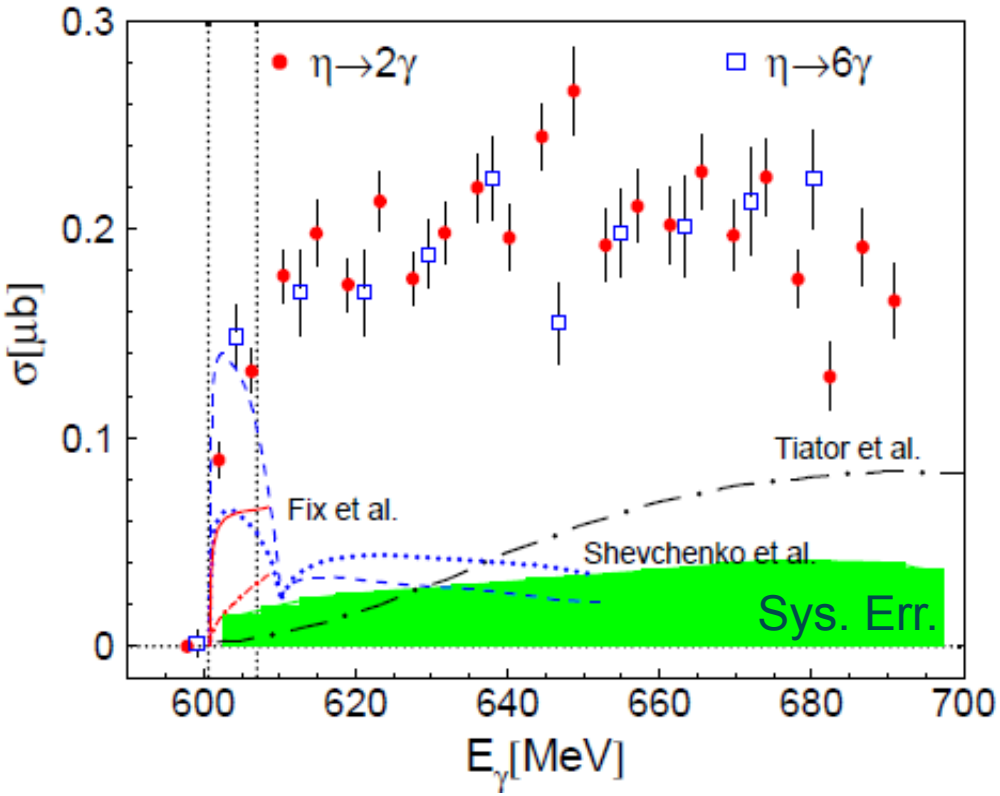
Coherent η photoproduction off ^{3}He

ME coherent η off ^{3}He - 2γ (left) and $3\pi^0/6\gamma$ (right)



Coherent η photoproduction off ^{3}He





Shevchenko et al. 3N system in a microscopic few-body description.
Strong dependence on the elastic *ηN* rescattering. Strong threshold effects, bad reproduction above the breakup threshold

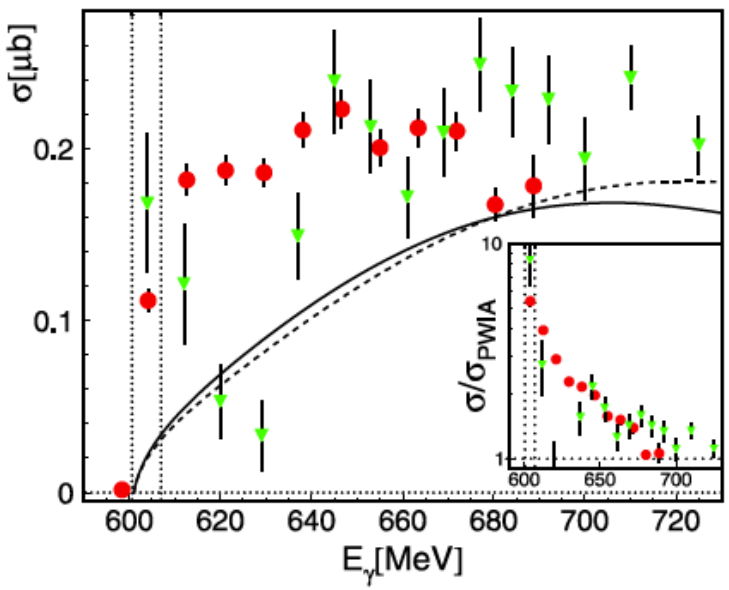
Fix et al. ^{3}He and ^{3}H in PWIA, in a distorted-wave impulse approximation (DWIA) using optical potential. Strong FSI effects. Underestimates XS.

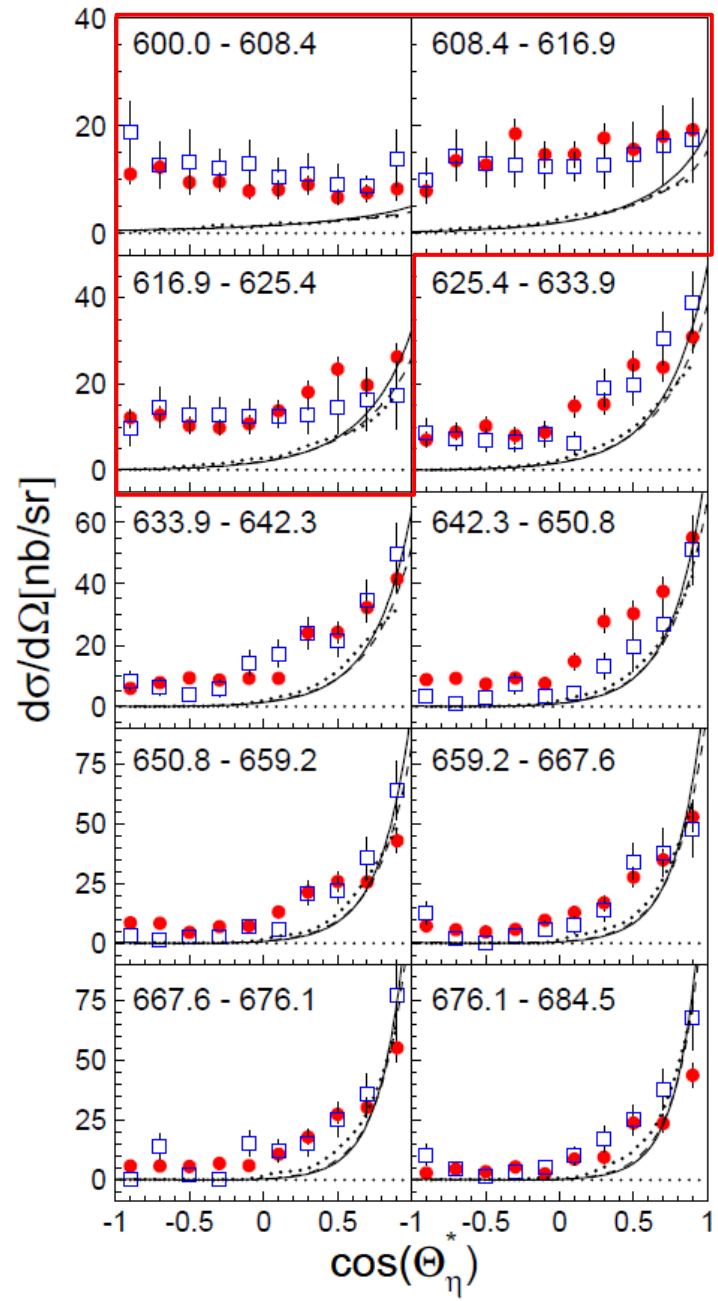
Tiator et al. model was based on the PWIA. Strongly underestimates measured XS and does not reproduce the energy dependence.

Coherent η photoproduction off ^{3}He

(Red) $\eta \rightarrow 2\gamma$ decay (Blue) $\eta \rightarrow 6\gamma$ decay

The behavior of the angular distributions of the PWIA is dominated by the nuclear form factor, which is responsible for the strong forward peaking.

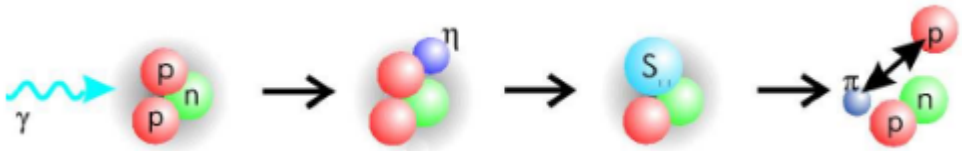


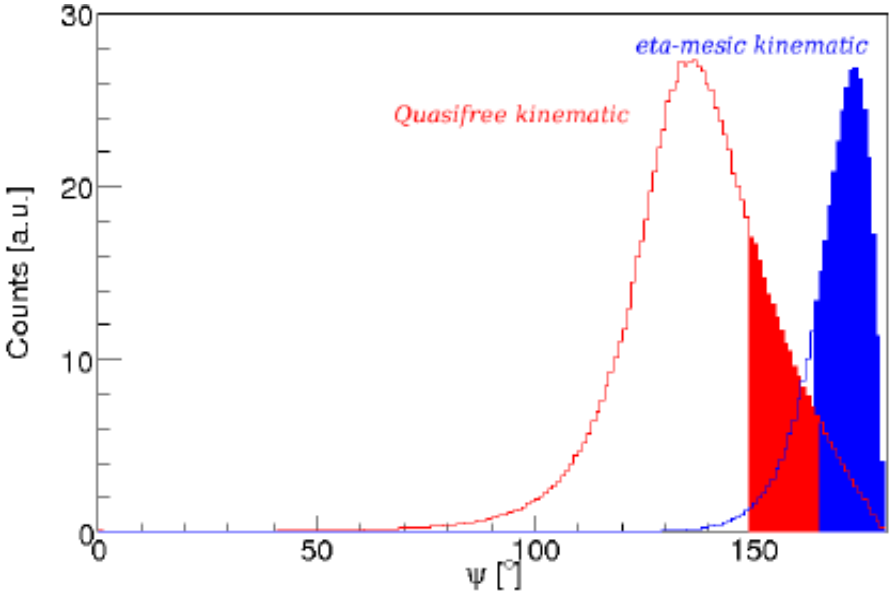


Solid (dashed) curves: PWIA with realistic (isotropic) angular distribution for $\gamma n \rightarrow n\eta$

Photoproduction of η – mesic ^{3}He

simulation of opening angle behavior for quasi-free π^0 production and η-mesic state



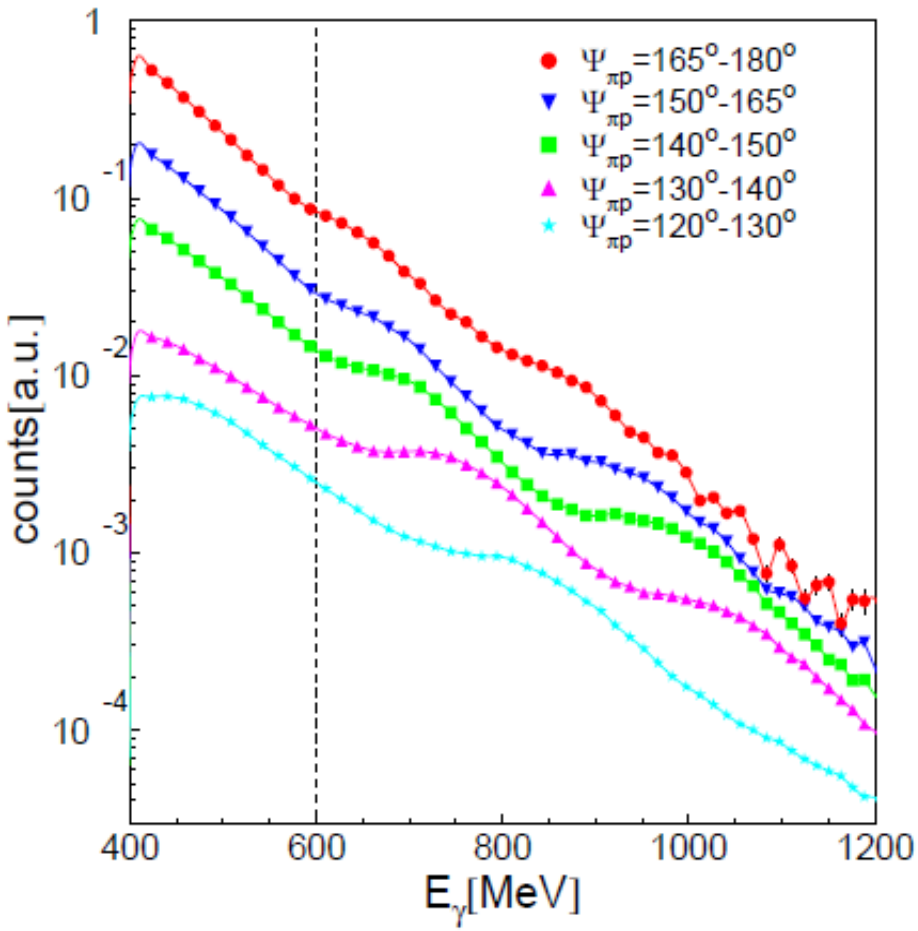


- nucleon resonances produce opening angle dependent structures in excitation functions
- subtraction of excitation functions for different opening angles can produce artificial structures almost everywhere
- basically no hope to isolate tiny structure from η-mesic state in this complicated landscape!

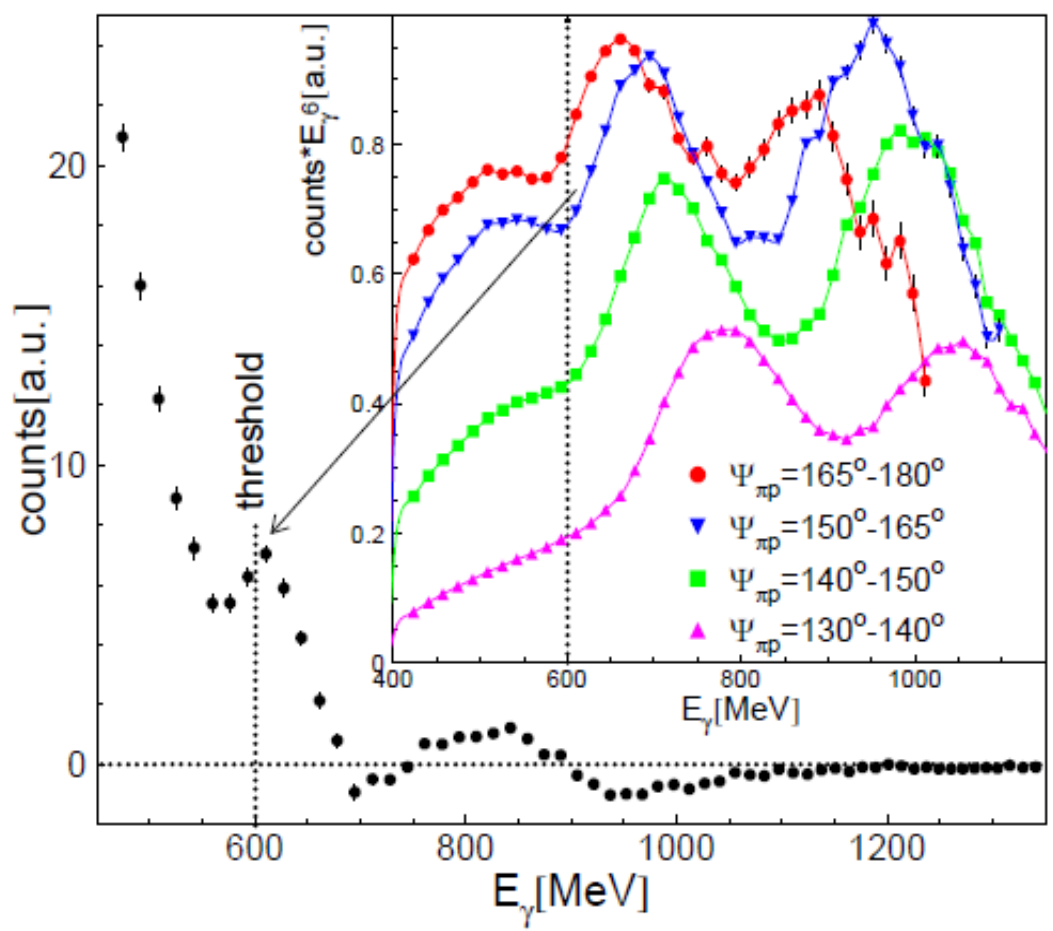
Photoproduction of η – mesic ^{3}He

$$\gamma + {}^3He \rightarrow (\eta\, {}^3He) \rightarrow p + \pi^0 + X$$

Excitation functions



Excitation functions x E_γ^6



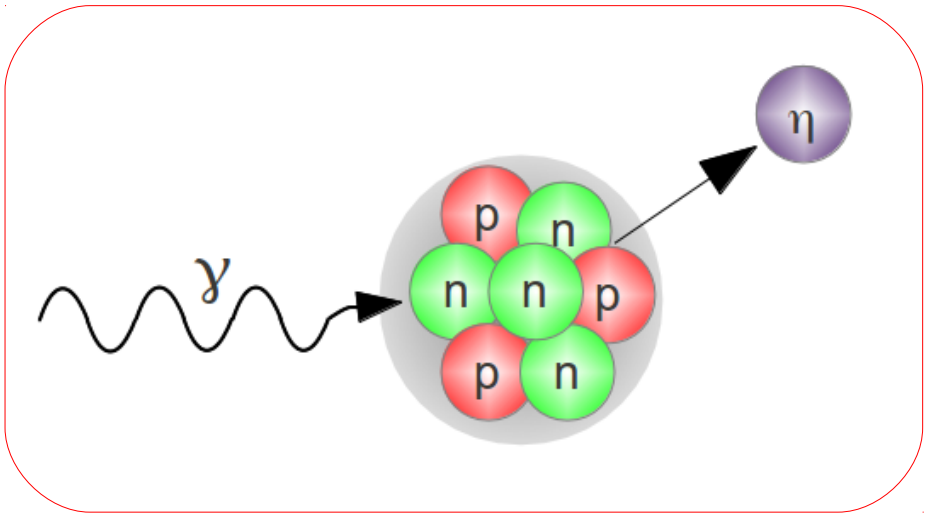
Summary I

$$\gamma + {}^3He \rightarrow {}^3He + \eta$$

- ✗ Strong threshold enhancement and shape of angular distributions confirmed
- ✗ Evidence for very strong FSI effects
- ✗ Alternative decay channel π^0-p back-to back suffers from complicated background structure, signal not confirmed

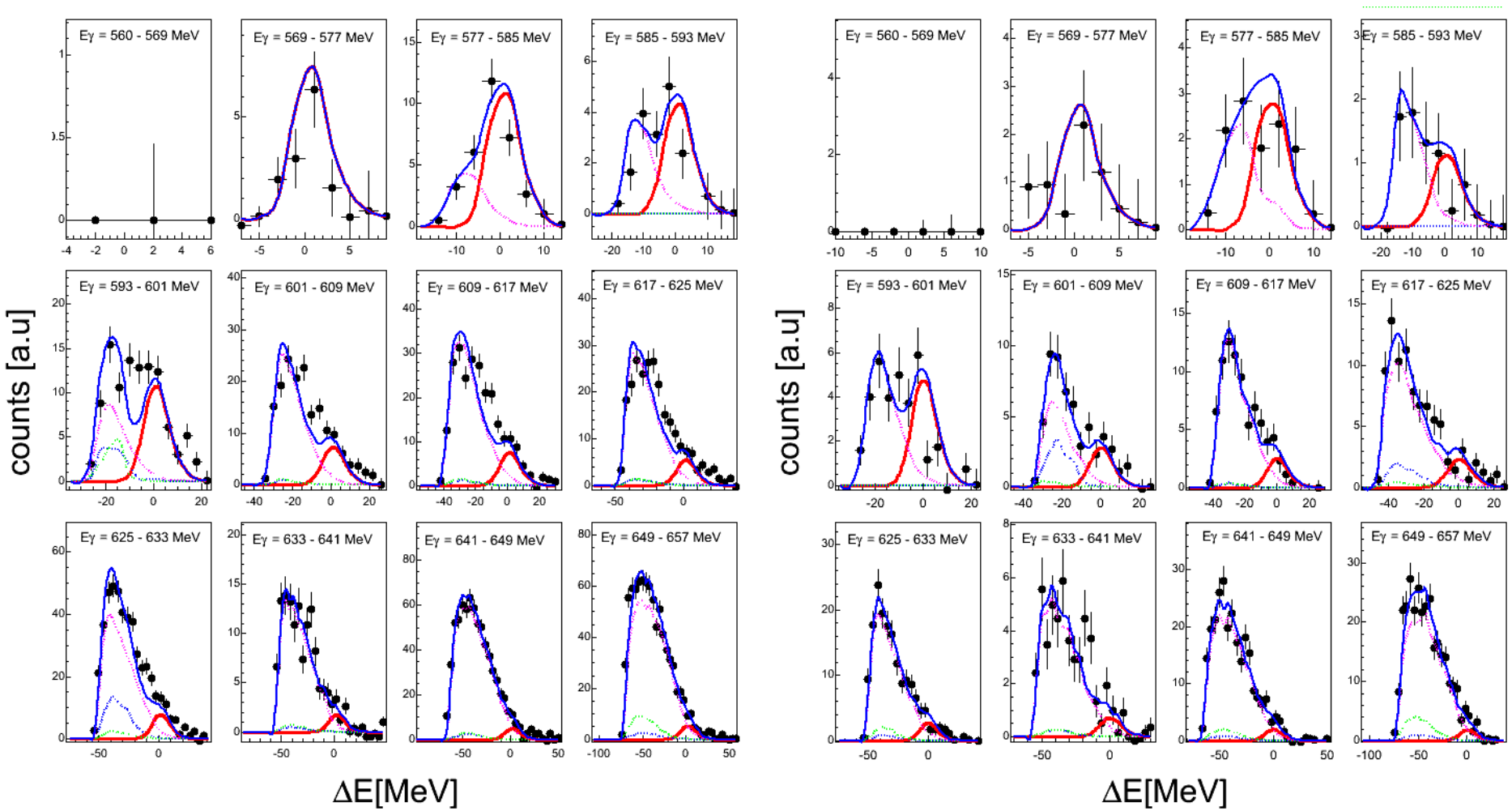
Coherent η -photoproduction off ^{7}Li nuclei

(Ph.D. work of Yasser Maghrbi)

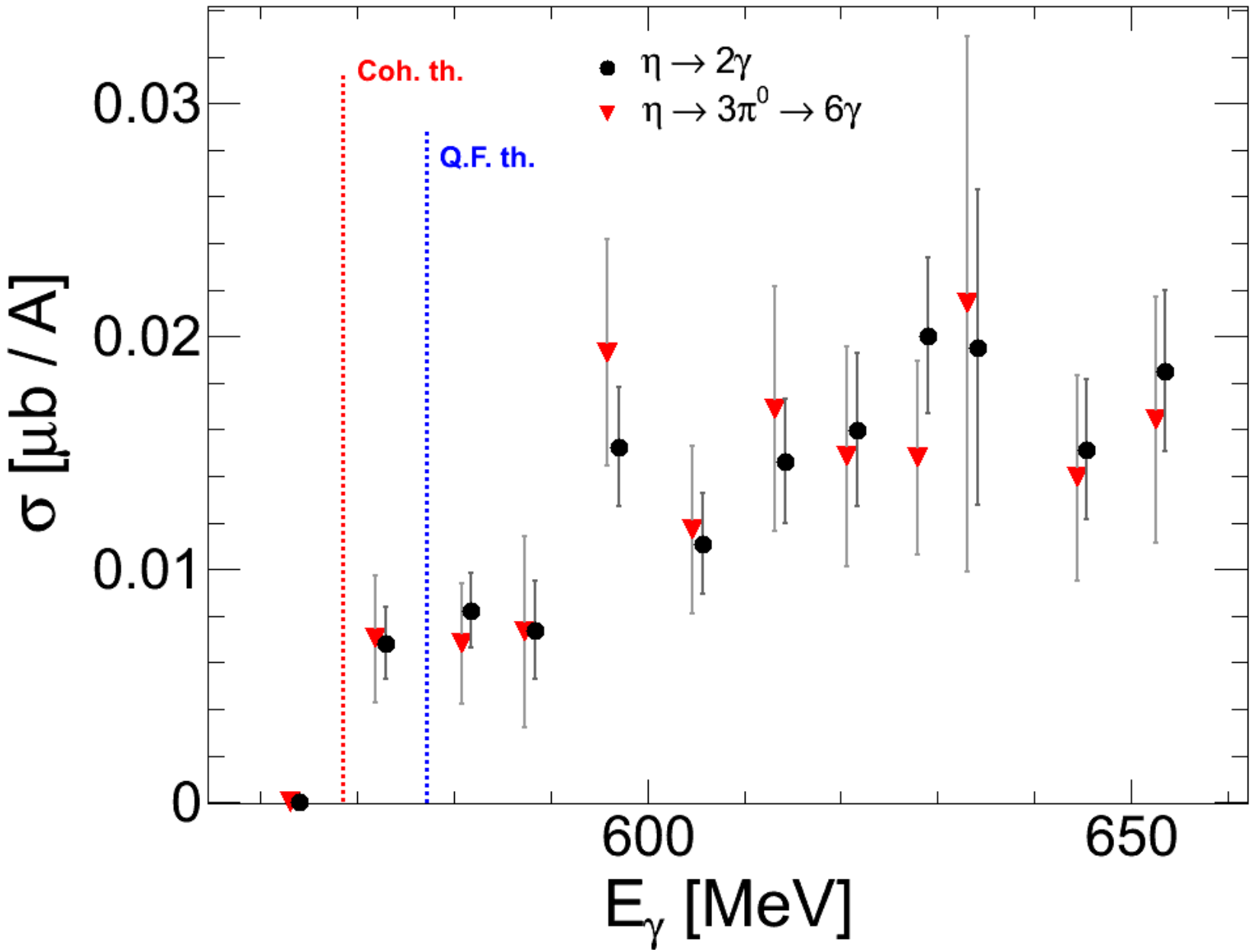


Coherent η- photoproduction off ^{7}Li

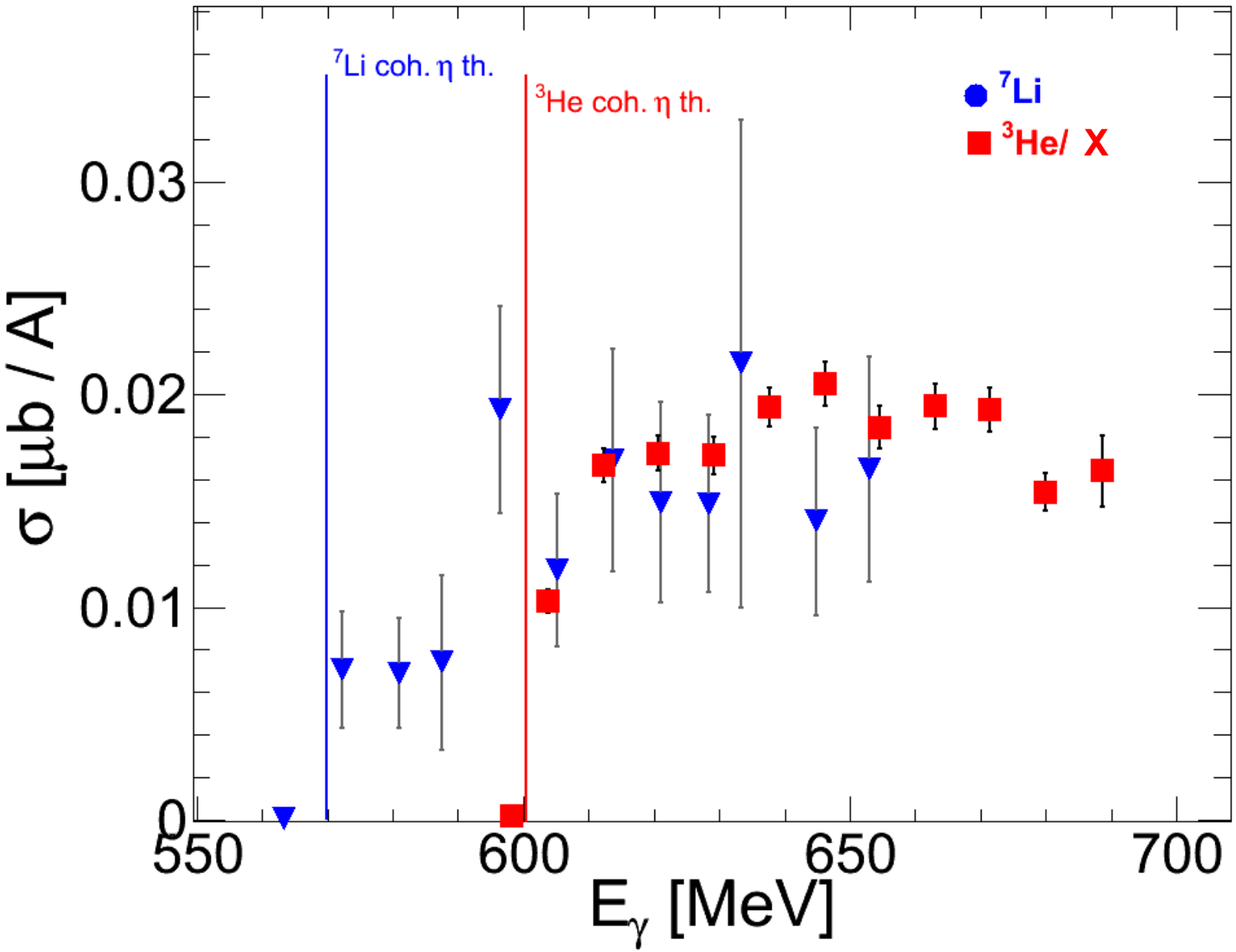
ME coherent η off ^{7}Li - 2γ (left) and $3\pi^0/6\gamma$ (right)



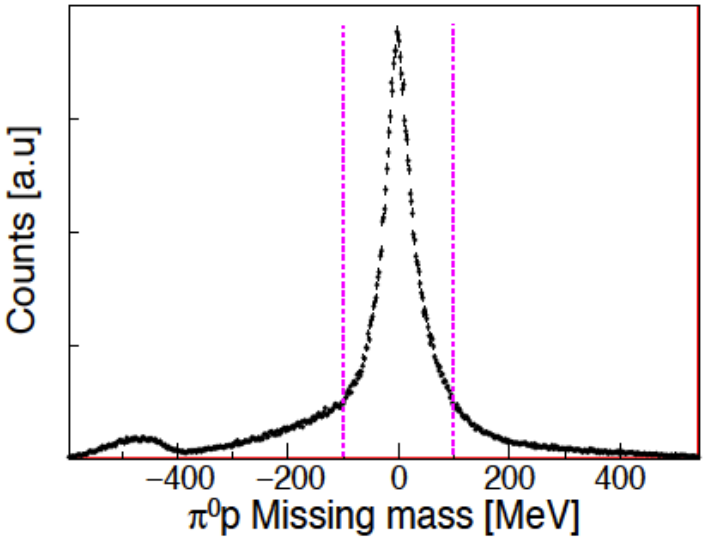
Coherent η- photoproduction off ^{7}Li

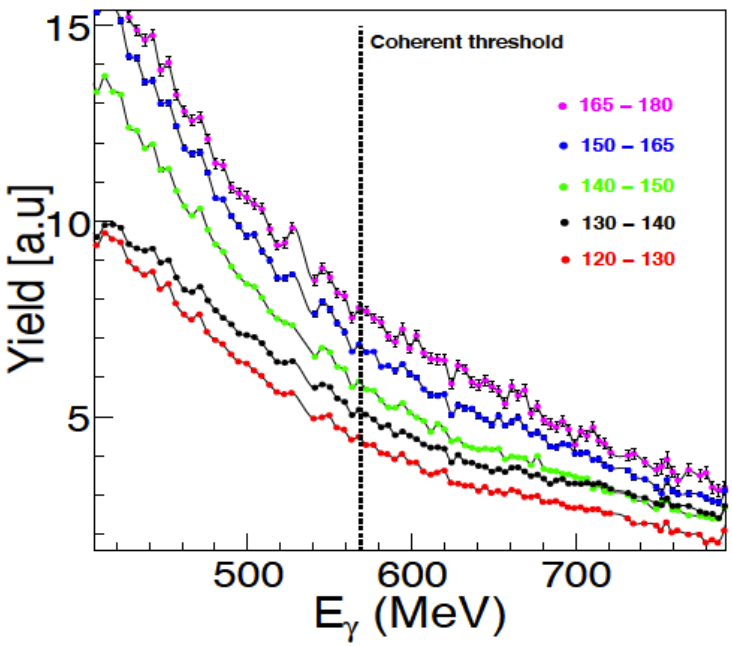


Coherent η- photoproduction off ^{7}Li

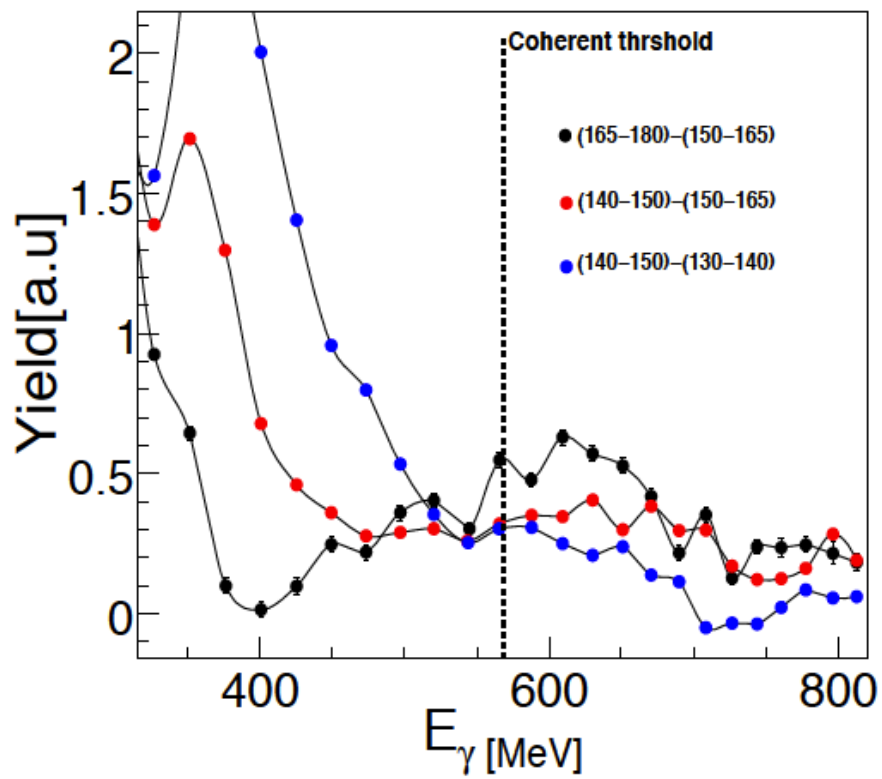


Photoproduction of η – mesic ^{7}Li

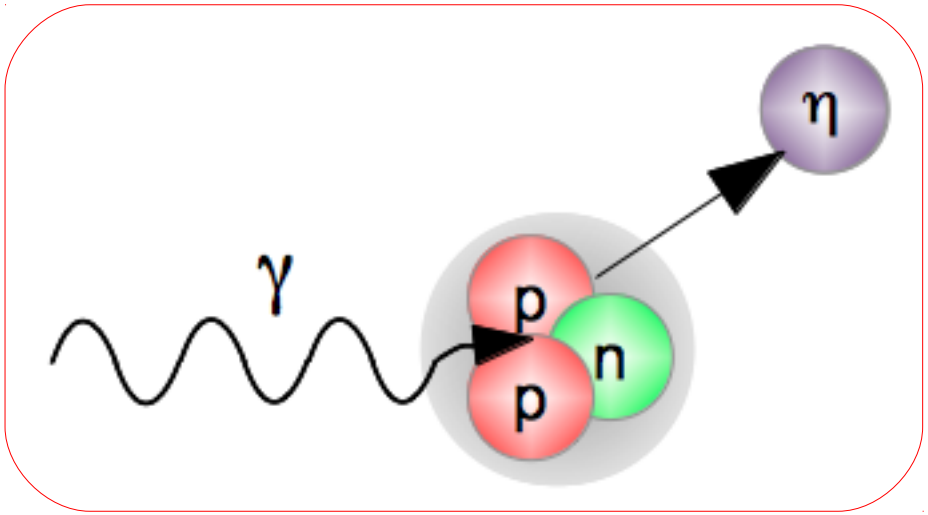




$$\gamma + {}^7\mathrm{Li} \rightarrow (\eta\, {}^7\mathrm{Li}) \rightarrow p + \pi^0 + X$$

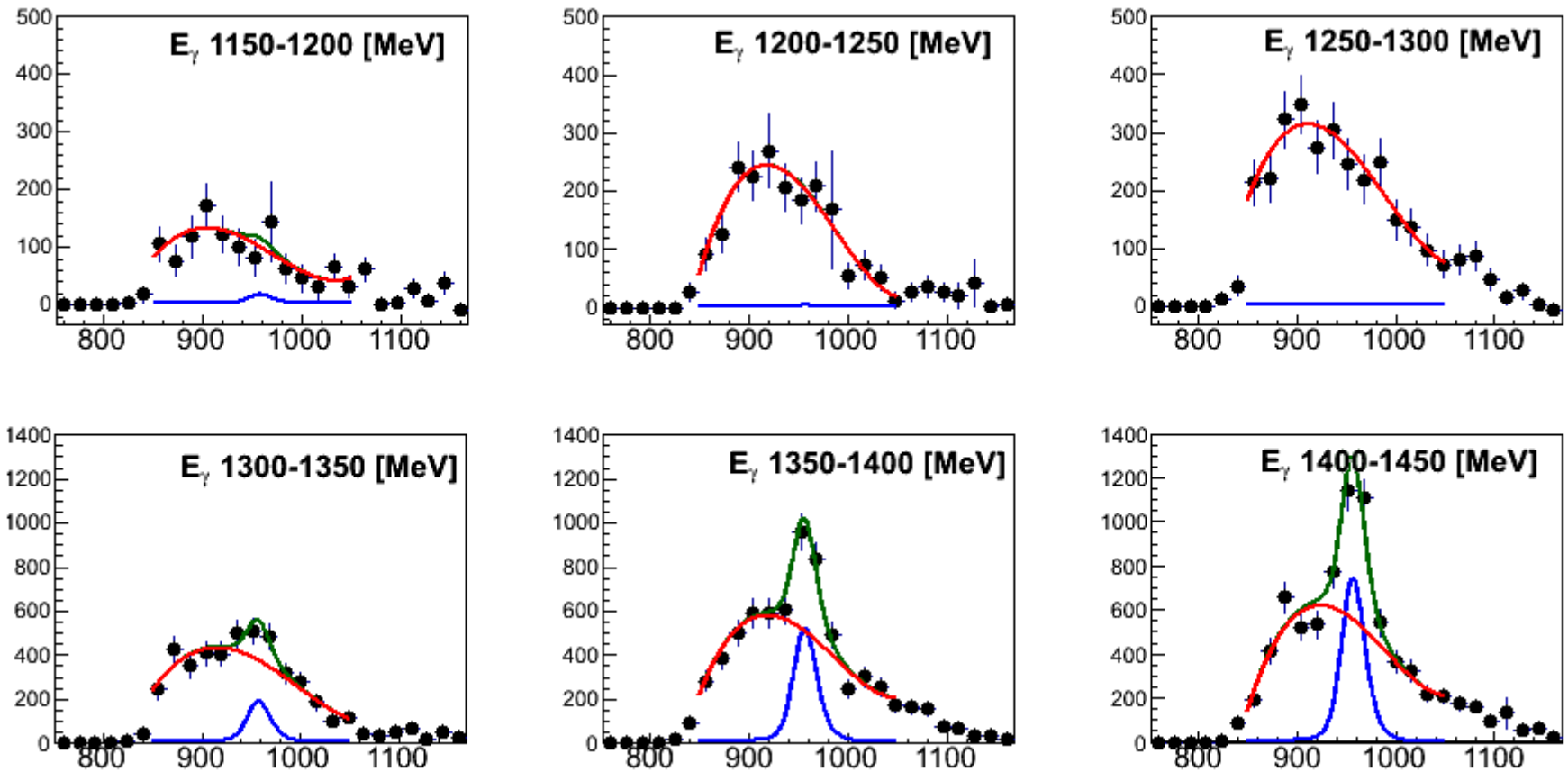


Coherent η′ -photoproduction off LD and ^{3}He nuclei (Ph.D. work of Roman Trojer)



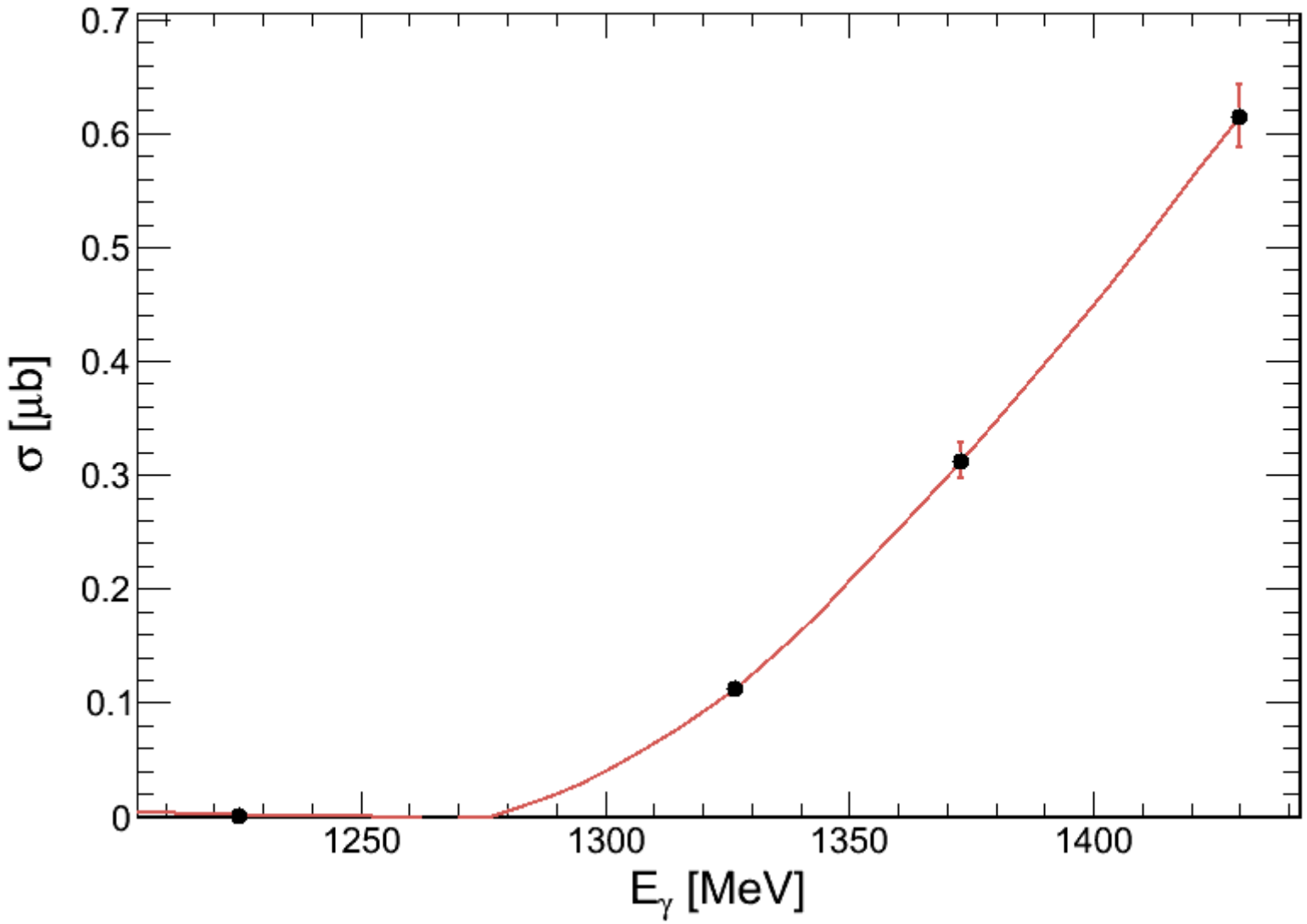
Coherent η′- photoproduction off LD

$$\gamma + d \rightarrow X + \eta' \rightarrow X + \eta(\gamma\gamma)\pi^0(\gamma\gamma)\pi^0(\gamma\gamma)$$



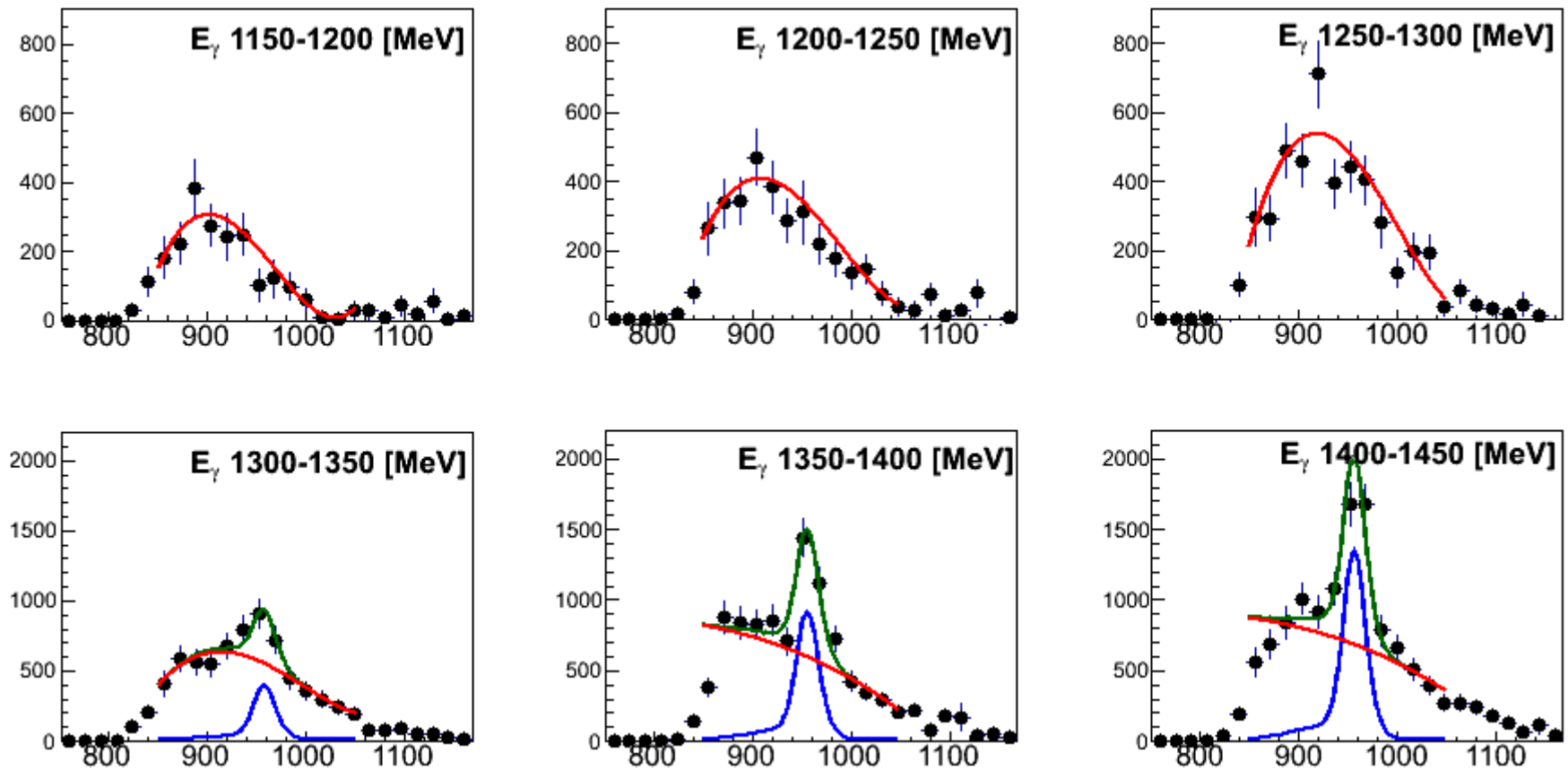
Coherent η′- photoproduction off LD

$\gamma + d \rightarrow X + \eta' \rightarrow X + \eta(\gamma\gamma)\pi^0(\gamma\gamma)\pi^0(\gamma\gamma)$



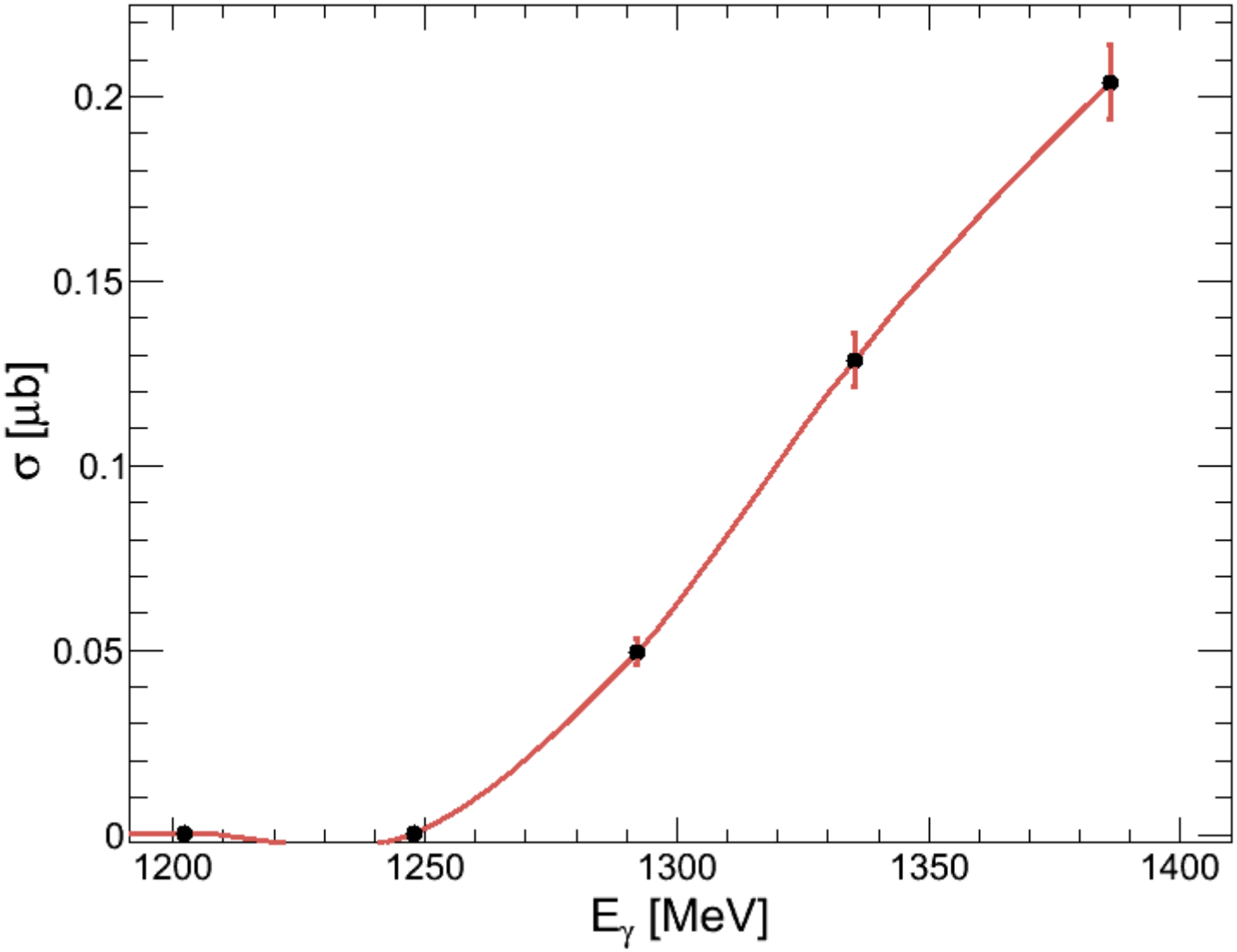
Coherent η′- photoproduction off ^{3}He

$$\gamma + {}^3He \rightarrow X + \eta' \rightarrow X + \eta(\gamma\gamma)\pi^0(\gamma\gamma)\pi^0(\gamma\gamma)$$



Coherent η′- photoproduction off ^{3}He

$$\gamma + {}^3He \rightarrow X + \eta' \rightarrow X + \eta(\gamma\gamma)\pi^0(\gamma\gamma)\pi^0(\gamma\gamma)$$



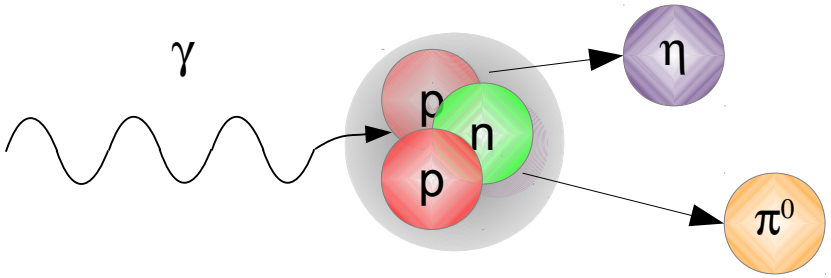
Summary II

- ✗ Similarities between ^{3}He and ^{7}Li cross section shows strong threshold enhancement
- ✗ ^{7}Li decay channel π^{0}-p back-to-back suffers from complicated background structure, signal not confirmed
- ✗ η' show also very rapid rise of the total cross section

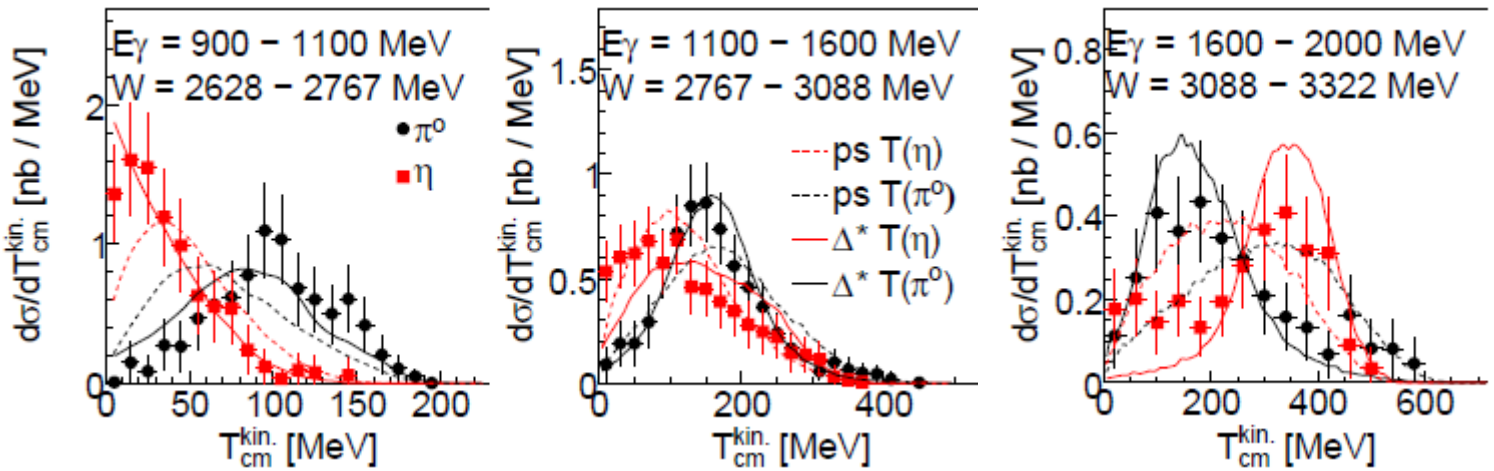
Outlook

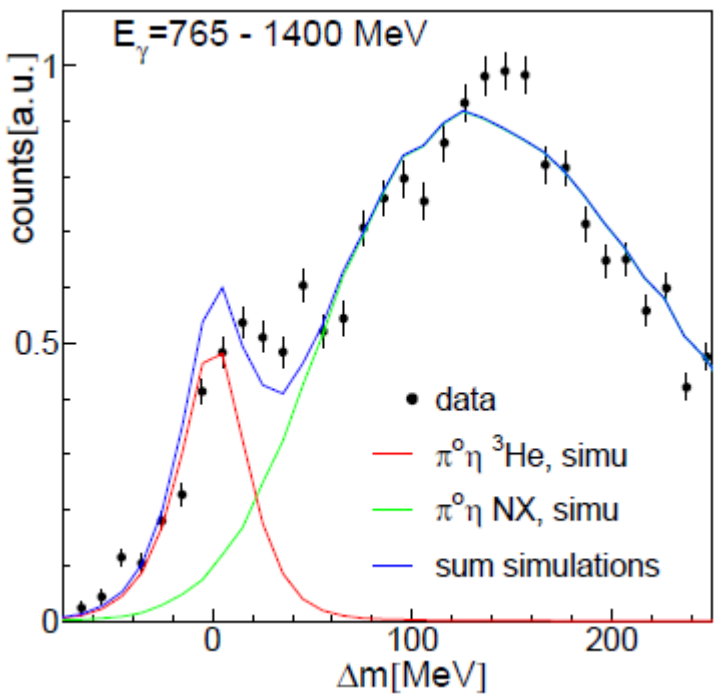
✗ We have accepted proposal by the PAC

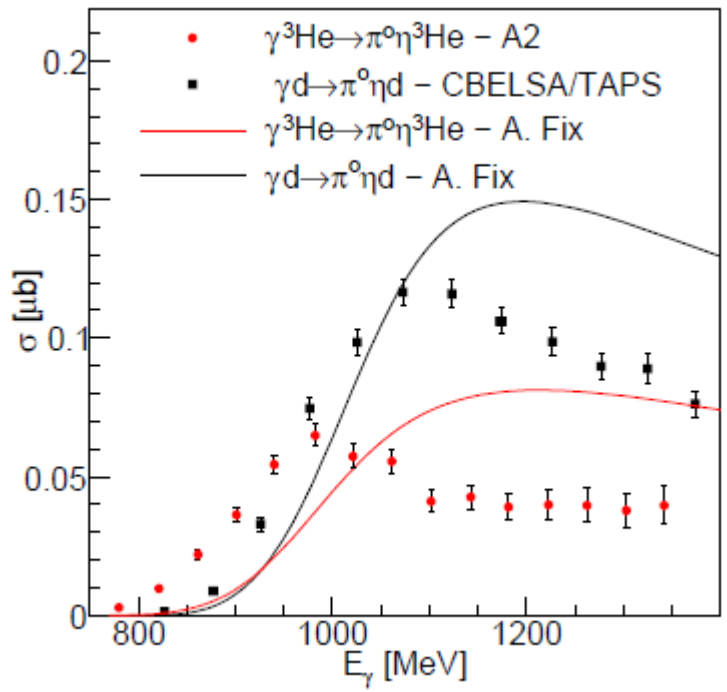
A2-16/09	Coherent production of $\pi^0\eta$ pairs off ^4He
Spokespersons	I.Jaegle, I.Keshelashvili, B.Krusche (Basel)
Beam	1558MeV, circularly polarized
Target	liquid ^4He
Beam Time	**700h**



$\eta\pi^0$- photoproduction off deuteron

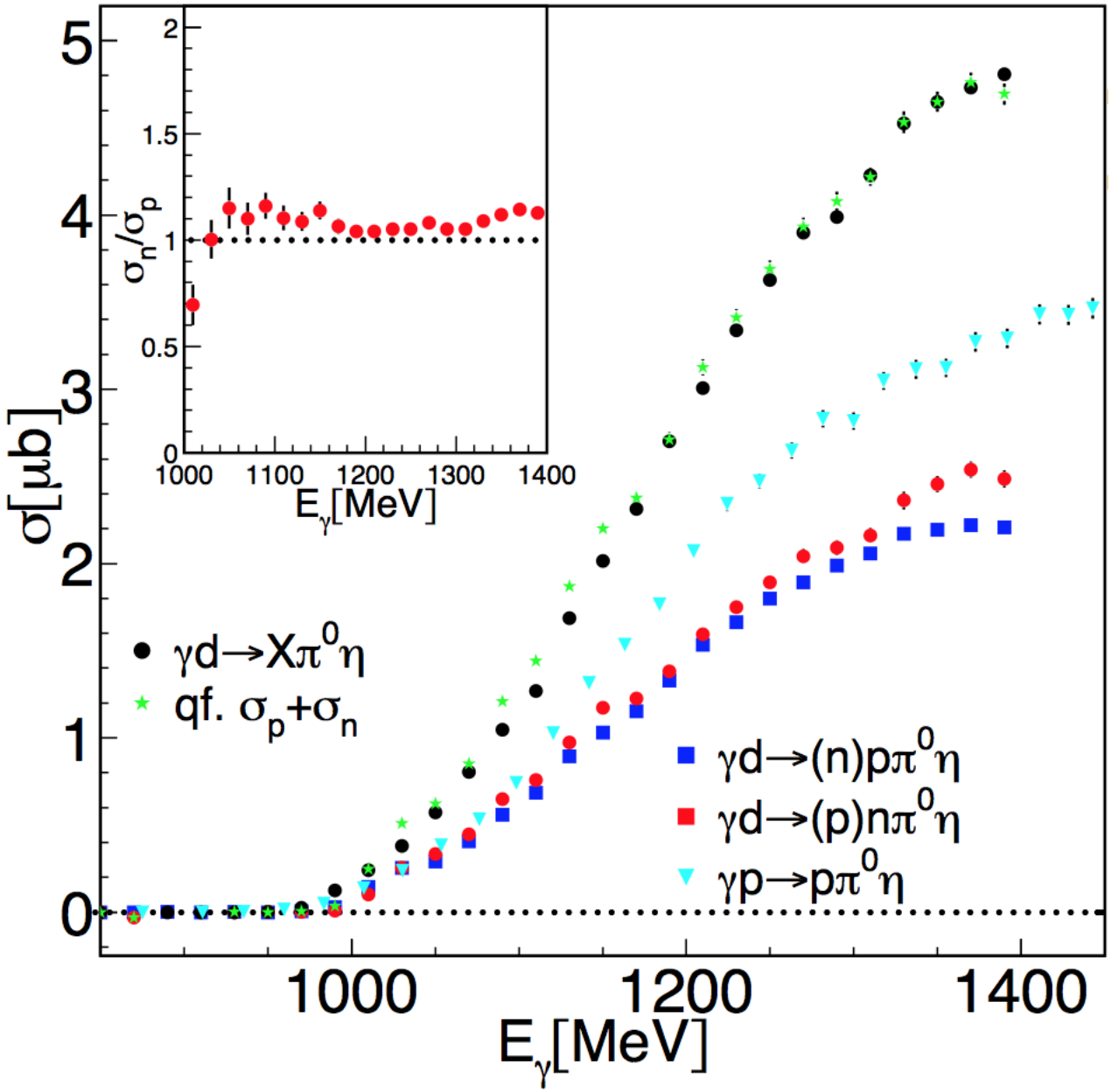






$\eta\pi^0$- photoproduction off deuteron

Preliminary results: Ph.D. Work of A. Käser



Thank you
for your Attention

University of Basel

Group of Prof. Bernd Krusche

Group members

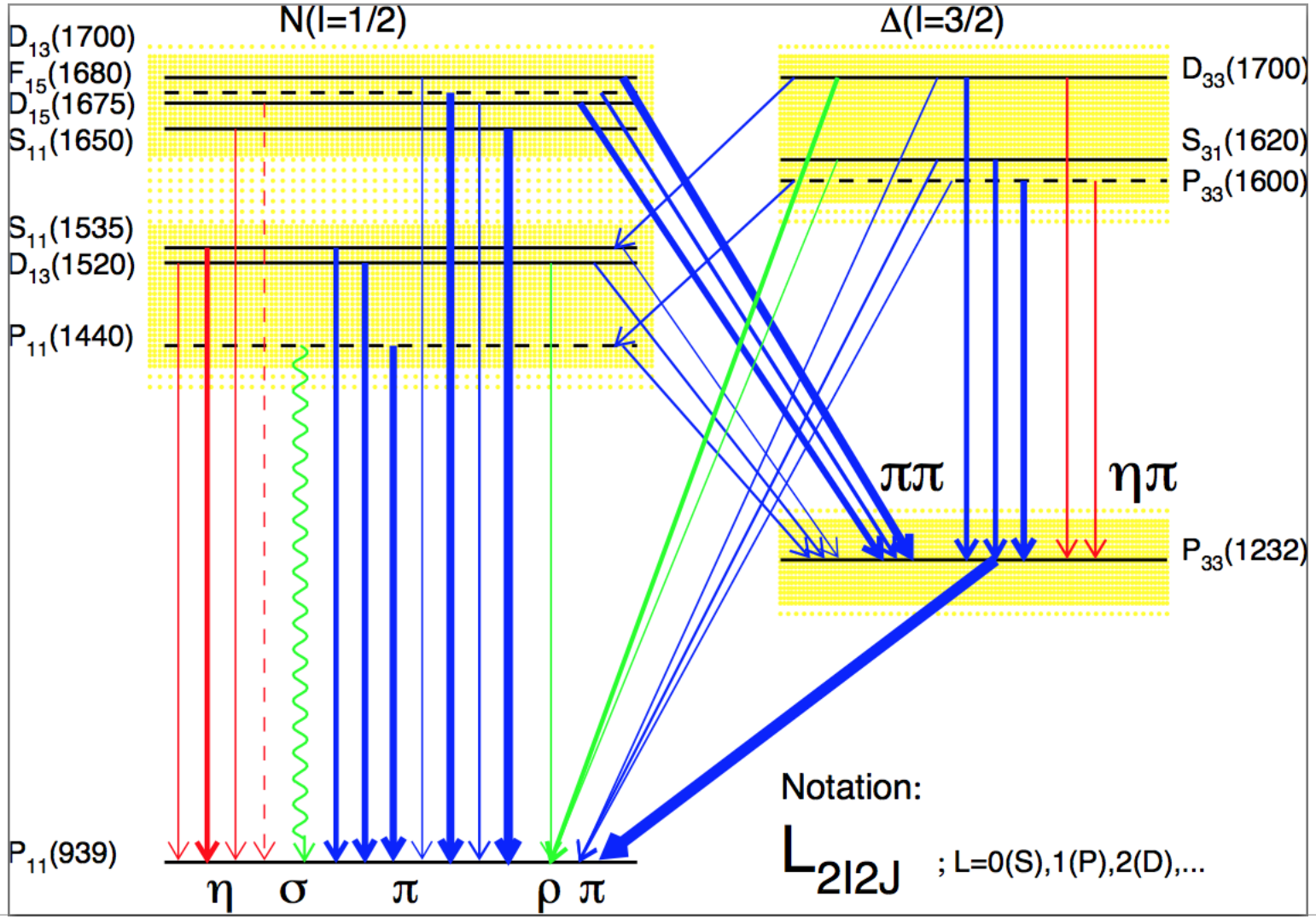
Manuel Dieterle | Stefanie Garni | Alexander Käser

Irakli Keshelashvili | Markus Oberle | Tigran Rostomyan | Thomas Strub

Dominik Werthmüller | Lilian Witthauer

$\eta\pi^0$- photoproduction off deuteron

- allows to investigate sequential decays
- η works as isospin filter: Due to isospin conservation, only higher energetic $N^*(\Delta^*)$ resonances can can decay into a $\eta N^*(\Delta^*)$ intermediate state



$\eta\pi^0$- photoproduction off deuteron