MAMI C - Results and Perspectives

Michael Ostrick

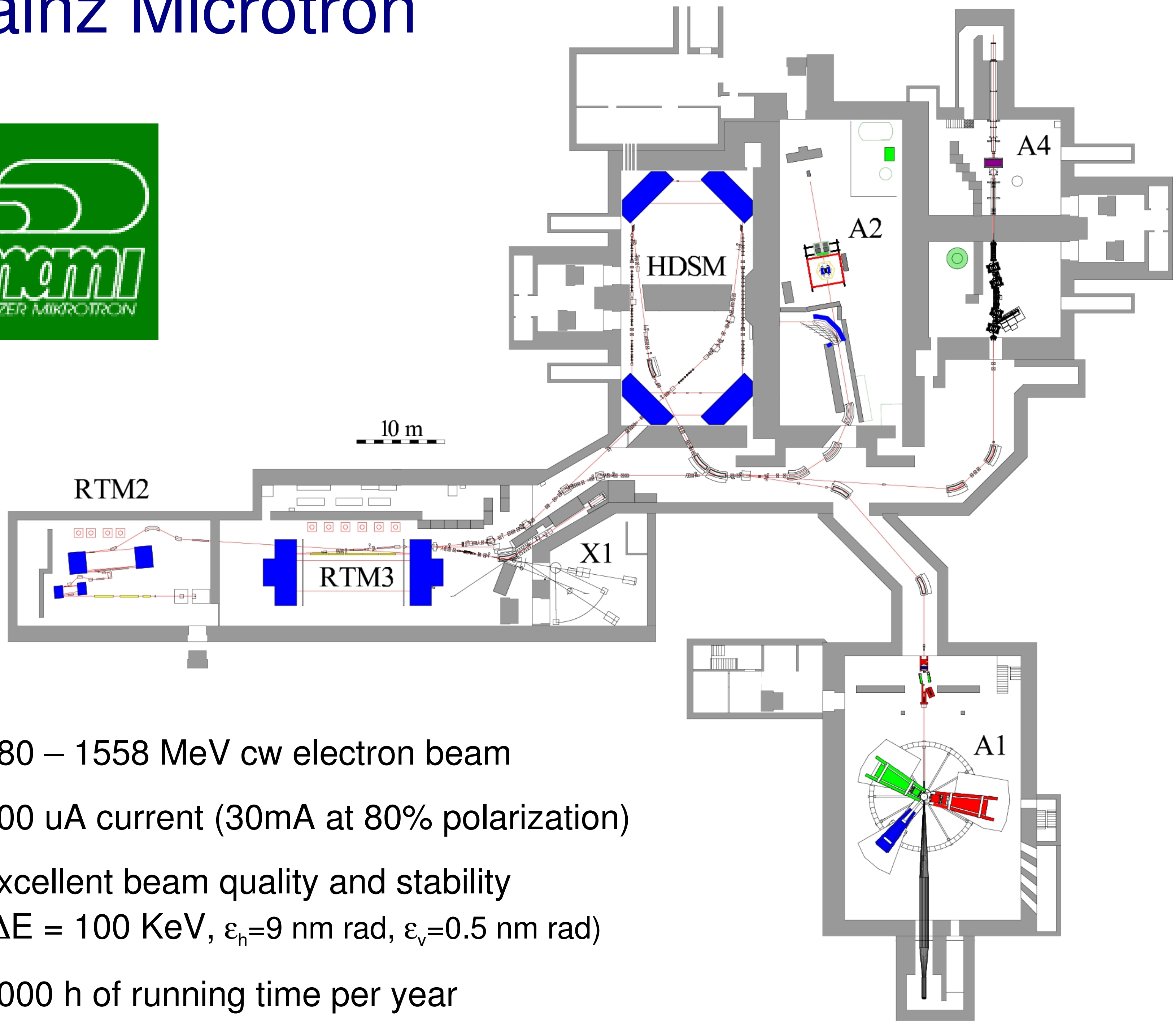
Edinburgh, June 8 - 10 2009

SFB 443

Outline

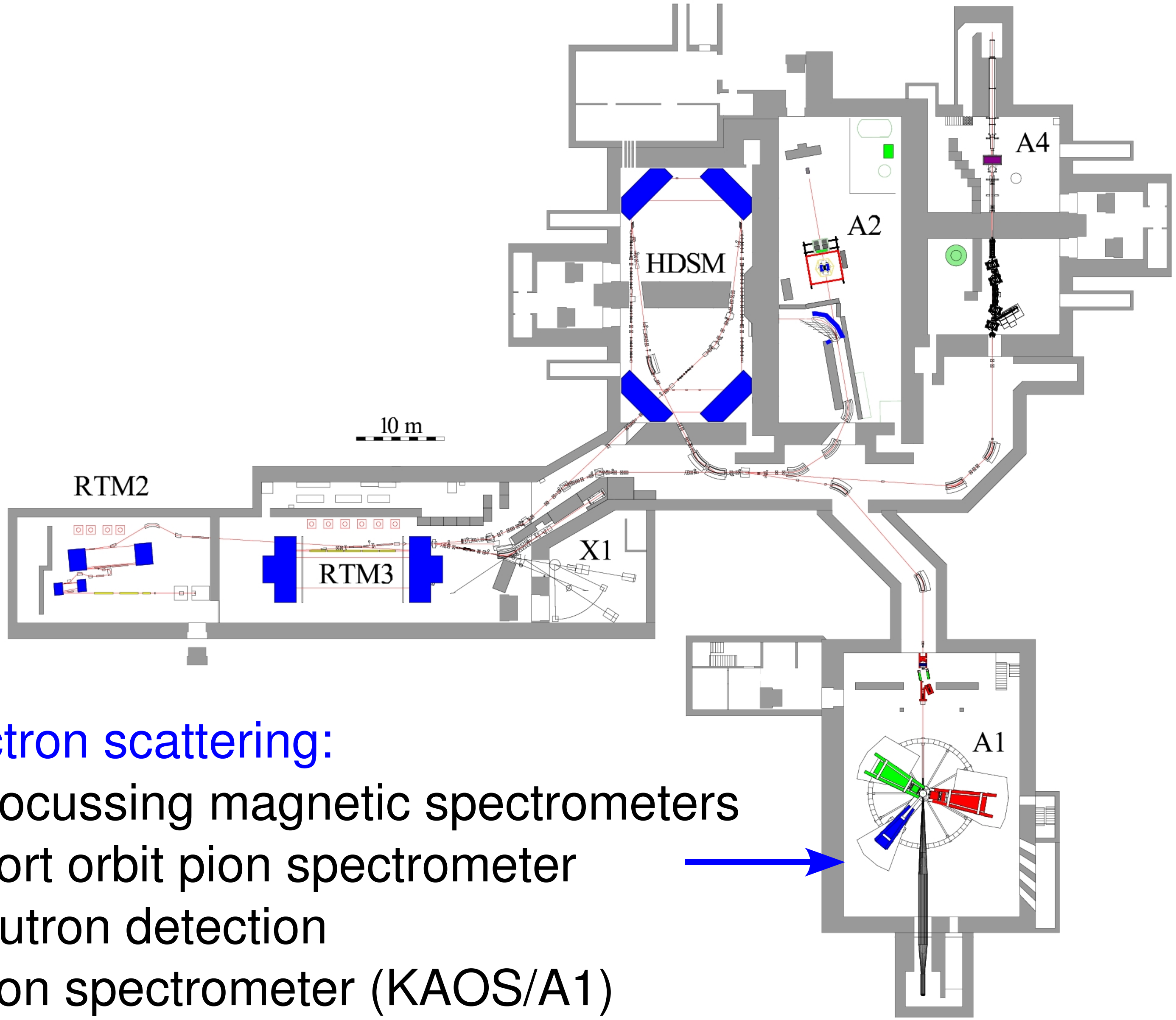
- Mainz Microtron MAMI
  - beam and detectors
- Nucleon Spectroscopy at MAMI
  - selected topics
- Outlook

Mainz Microtron



- 180 – 1558 MeV cw electron beam
- 100 uA current (30mA at 80% polarization)
- excellent beam quality and stability
  (ΔE = 100 KeV, ε_h=9 nm rad, ε_v=0.5 nm rad)
- 7000 h of running time per year

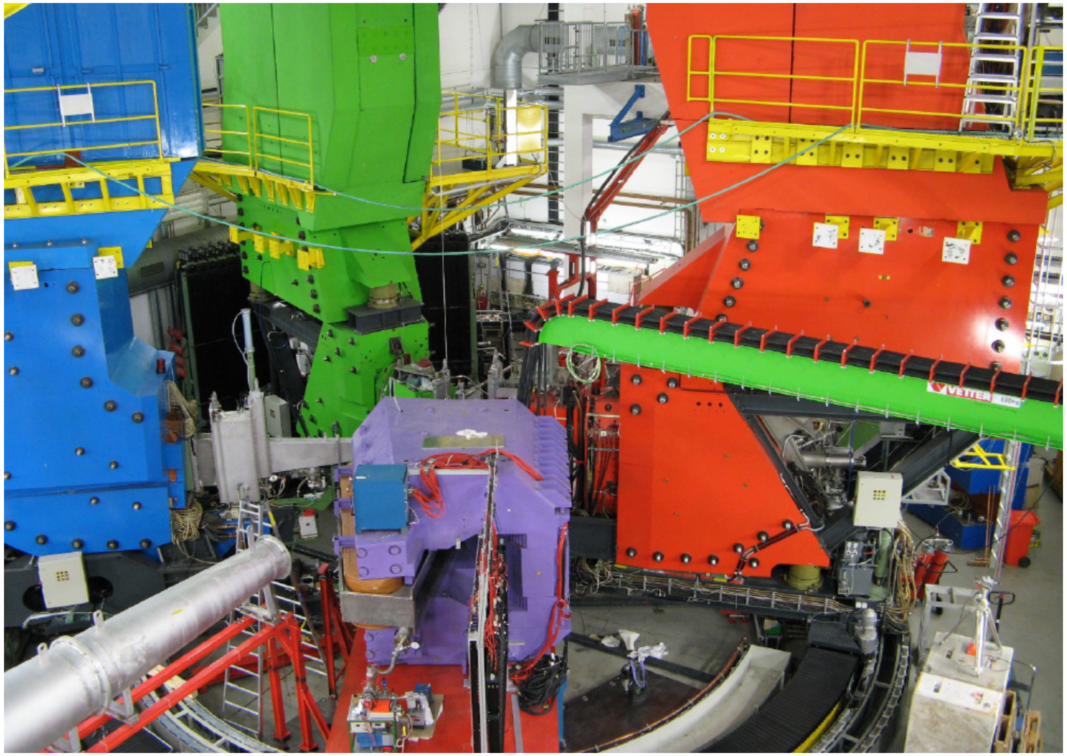
Experimental equipment



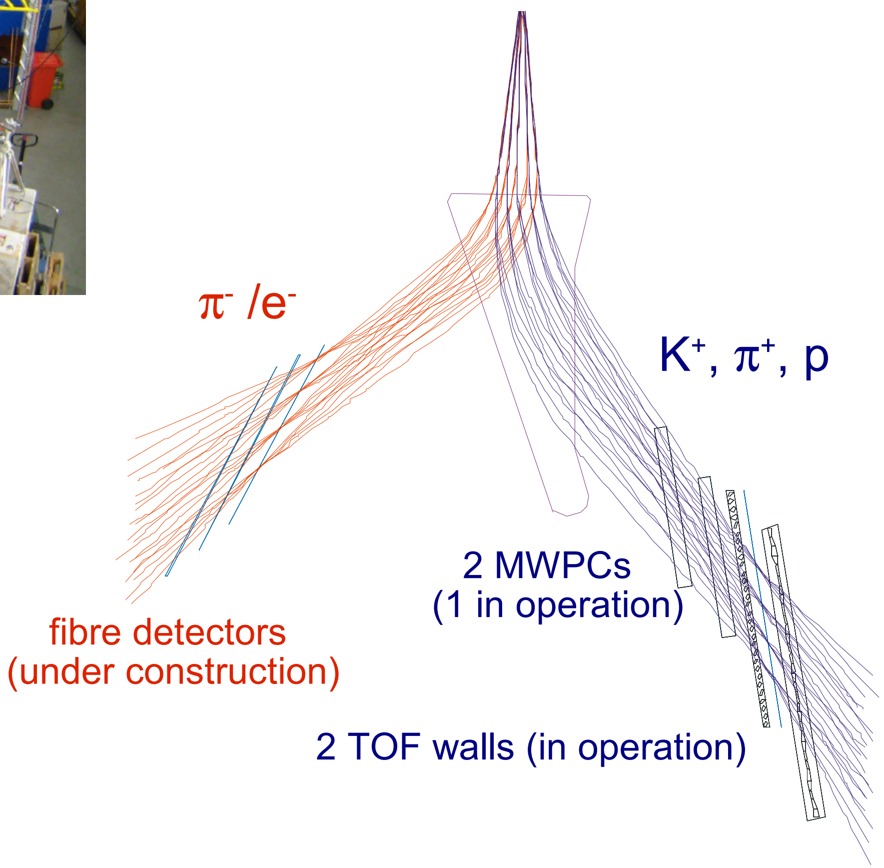
electron scattering:

- 3 focussing magnetic spectrometers
- short orbit pion spectrometer
- neutron detection
- kaon spectrometer (KAOS/A1)

High resolution electron scattering



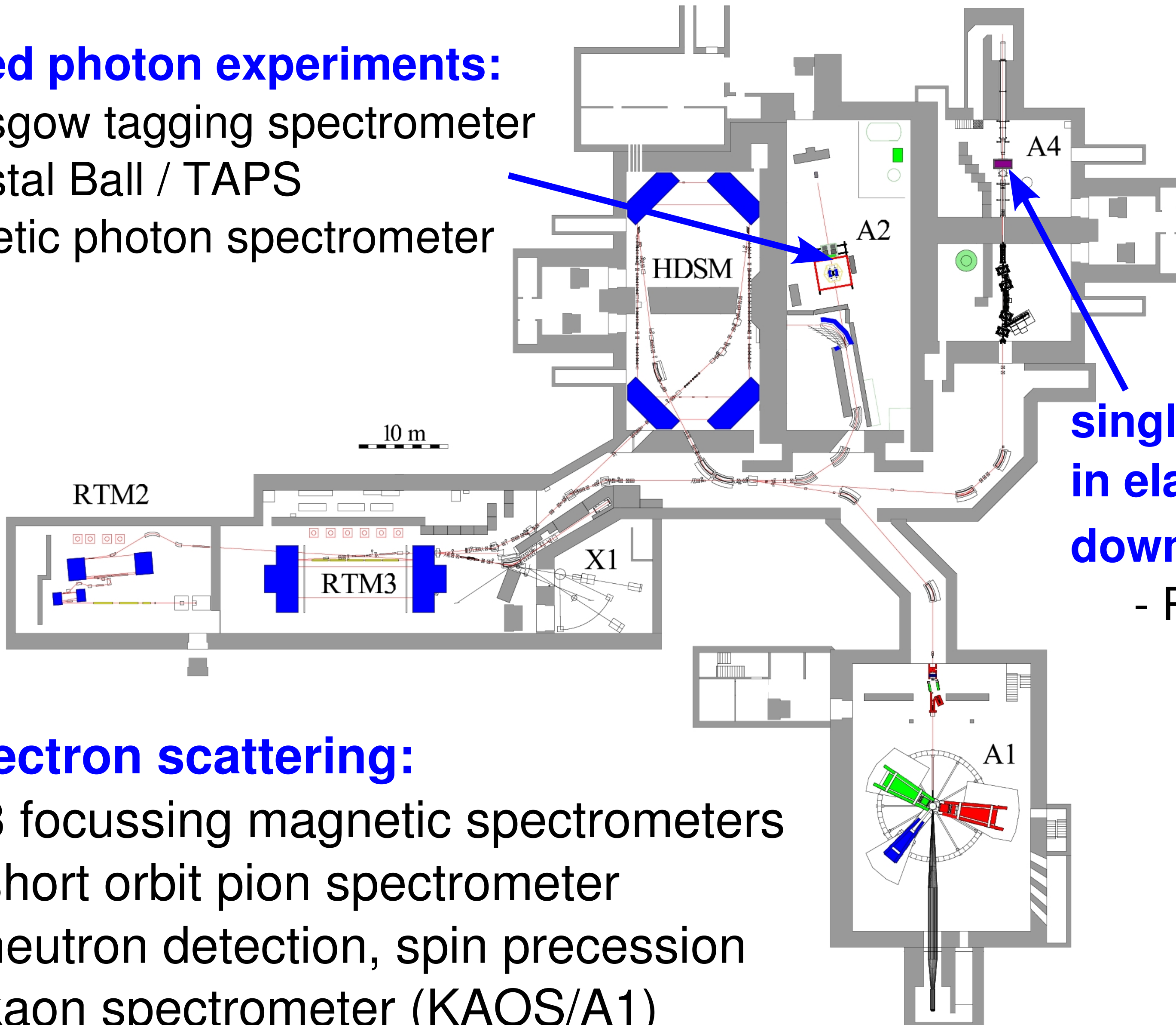
3-spectrometer setup
- momentum resolution $\delta p/p < 10^{-4}$
- momentum acceptance $\Delta p/p = 20\%$
- $\Delta\Omega$ = 28msr
- recoil proton polarimeter



KAOS/A1 spectrometer
- efficient kaon detection
- 2 focal planes
- acceptance in forward direction
- p(e,e' K$^+$)Λ/Σ in 2009

Experimental equipment

tagged photon experiments:
- Glasgow tagging spectrometer
- Crystal Ball / TAPS
hermetic photon spectrometer

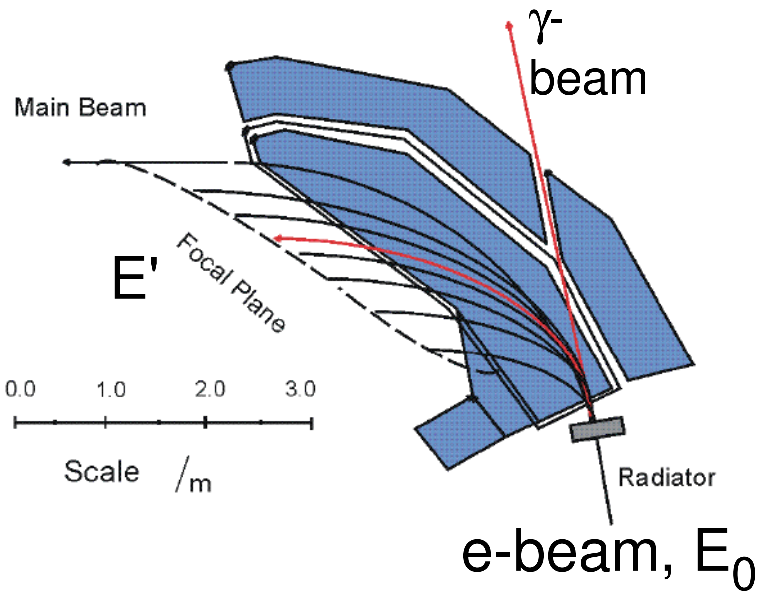


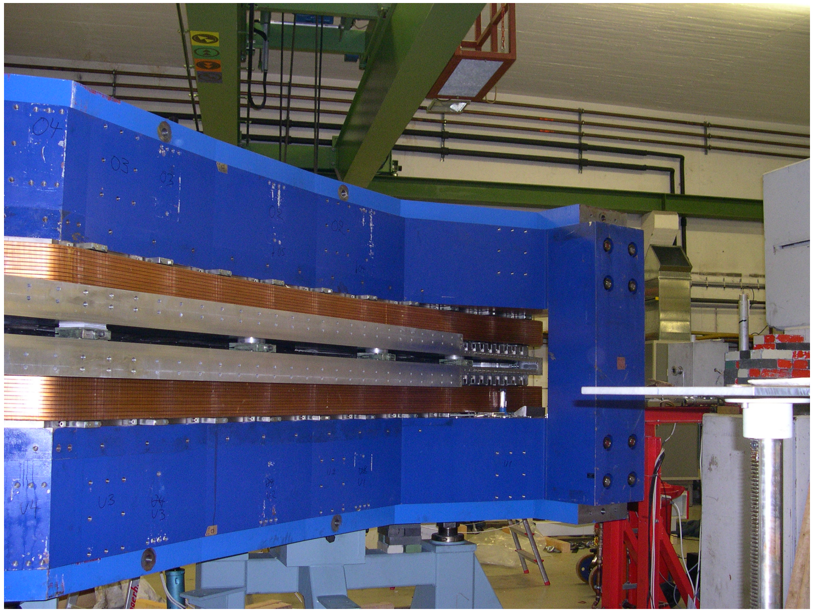
single spin asymmetries in elastic ep scattering down to 10^{-6}
- PbF2 calorimeter

electron scattering:
- 3 focussing magnetic spectrometers
- short orbit pion spectrometer
- neutron detection, spin precession
- kaon spectrometer (KAOS/A1)

Real photon experiments

Energy tagging of Bremsstrahlung:





Glasgow Tagging Spectrometer
EPJ A 37, 129 (2008)

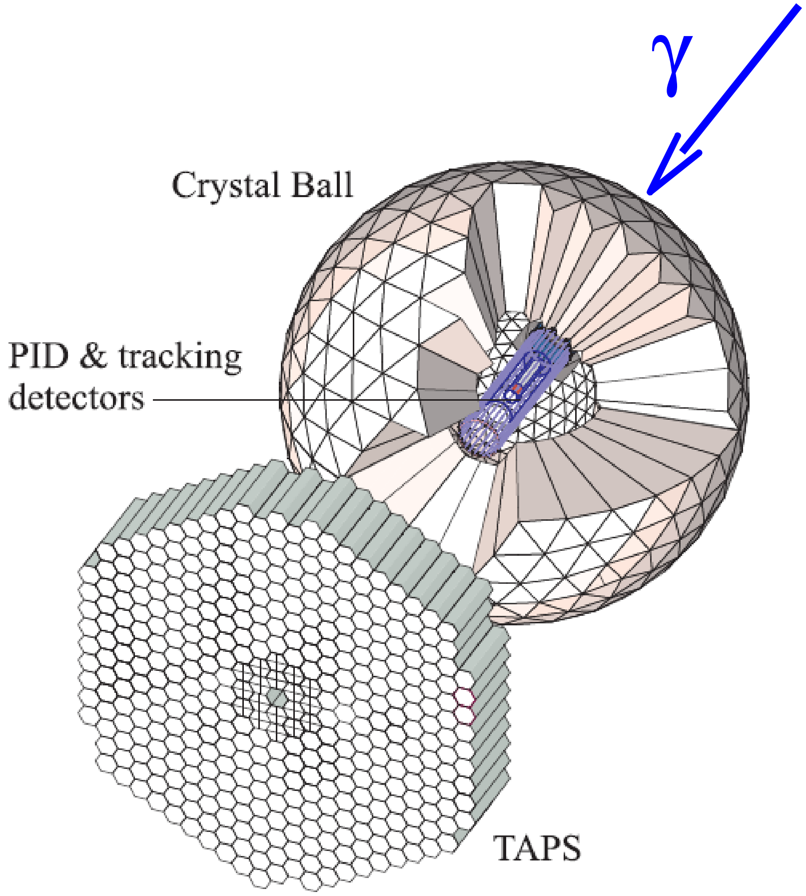
$E_\gamma = E_0 - E'$

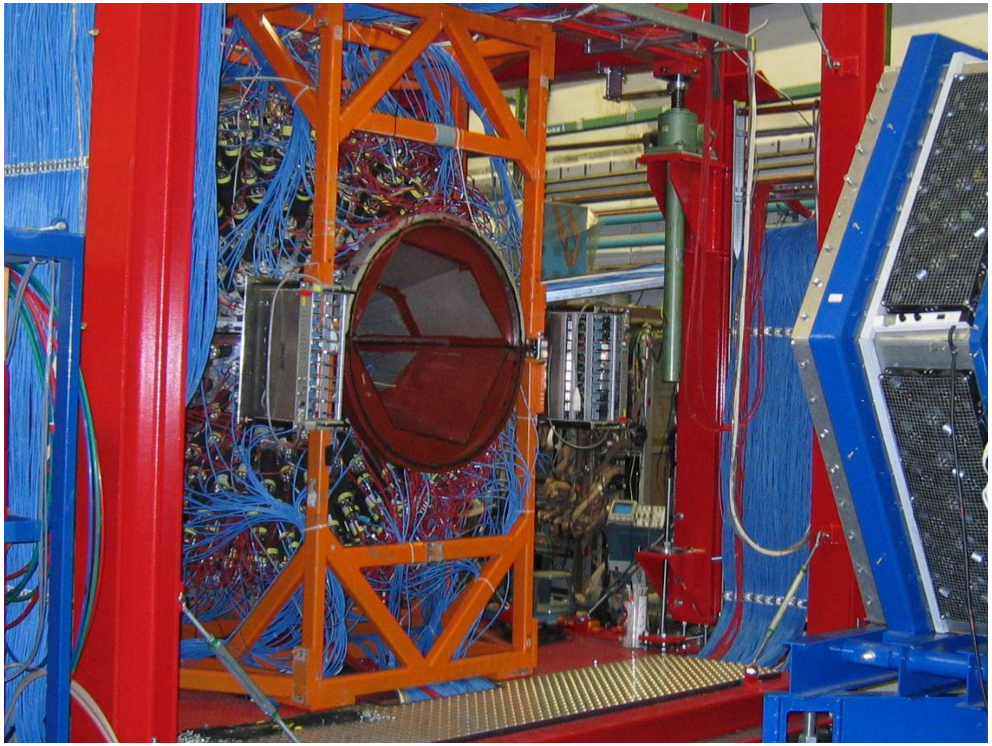
$\Delta E_\gamma / E_0 \sim 2 \cdot 10^{-3}$

linear and circular polarisation
up to 80%

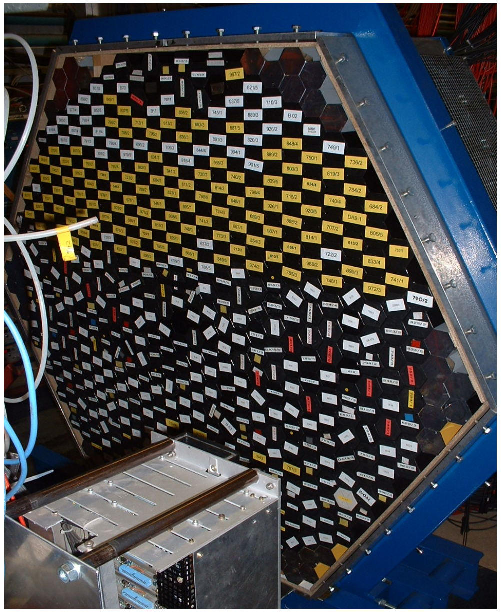
Crystal Ball/TAPS Detector

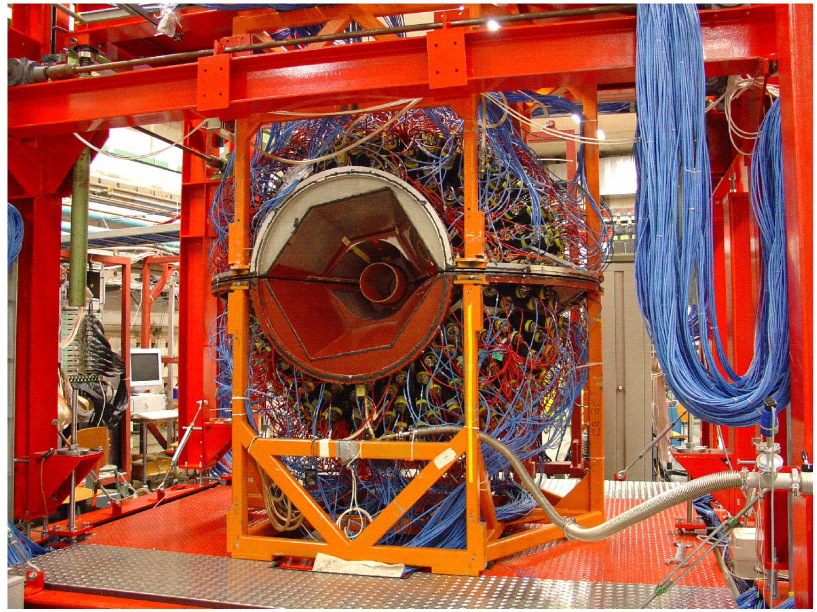
self-triggering hermetic photon spectrometer

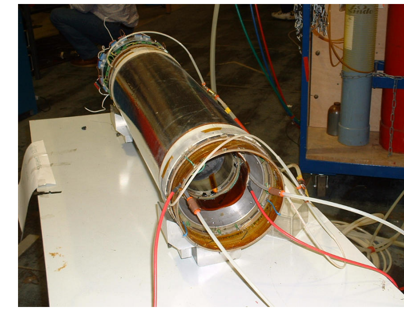


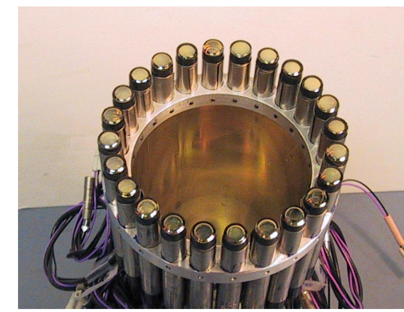


Crystal Ball/TAPS Detector









TAPS:

- 384 BaF_2 crystals (1-20^{o})
- individual charged particle vetos

Crystal Ball:

672 NaI Scintillators

(20-160^{o})

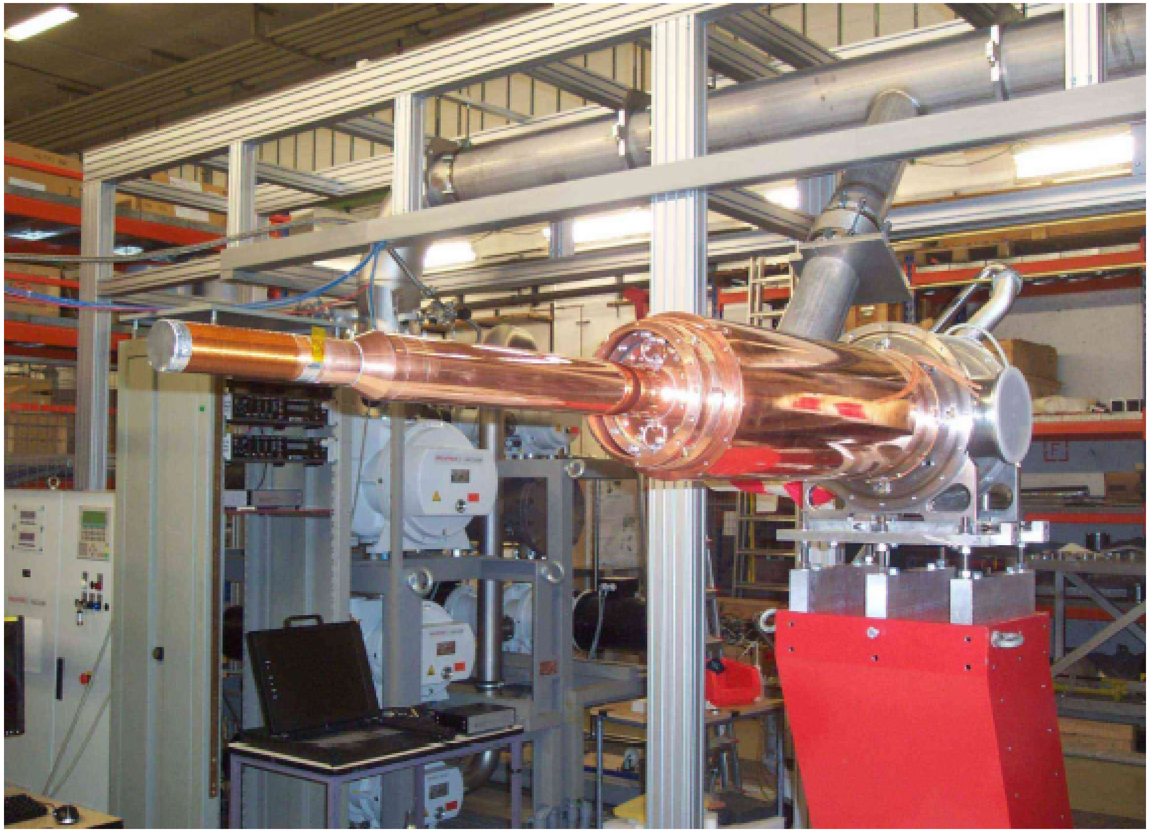
PID and tracking:

- barrel of 24 plastic scintillators (Edinburgh)
- MWPC (Pavia)
- carbon analyser for nucleon recoil polarimetry

D. Glaziers talk !

Polarized frozen spin target for Crystal Ball

New $^3He^4He$-Dilution refrigerator (Mainz/JINR Dubna)



P_{proton} ~ 95%
$P_{deuteron}$~70%

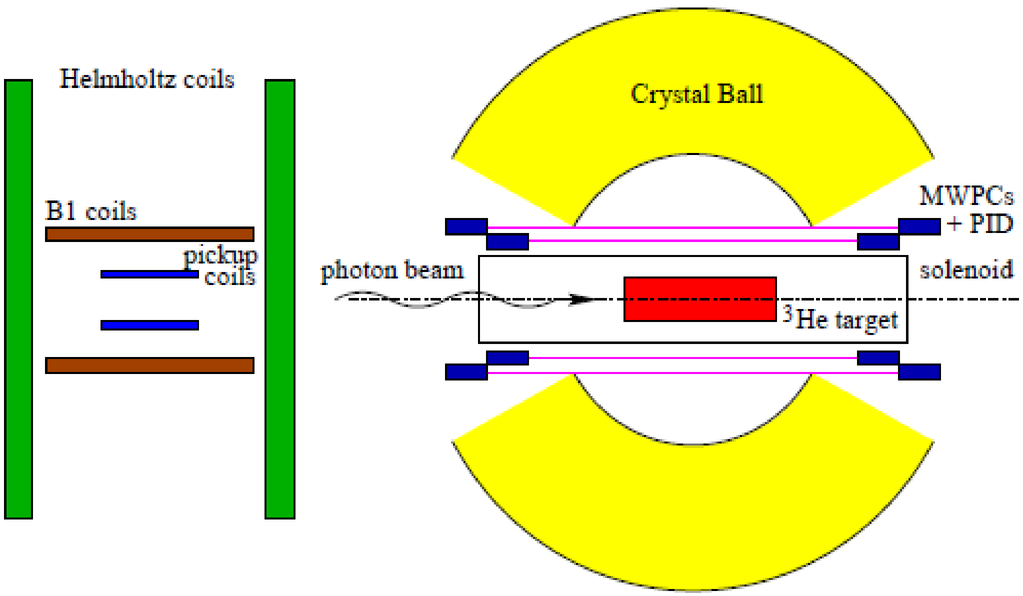
Transverse and Longitudinal

Internal Holding coil →

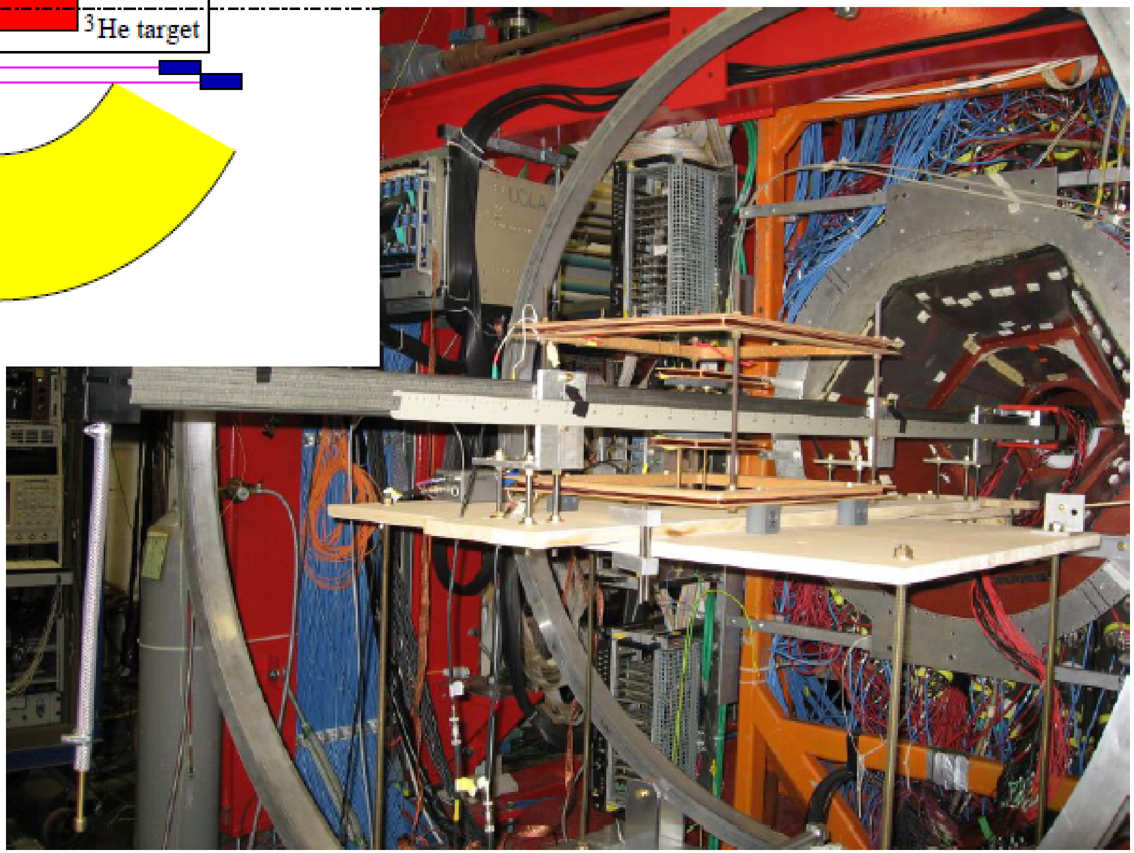
polarisation in all directions

First runs before end of this year

Polarized ^{3}He gas target



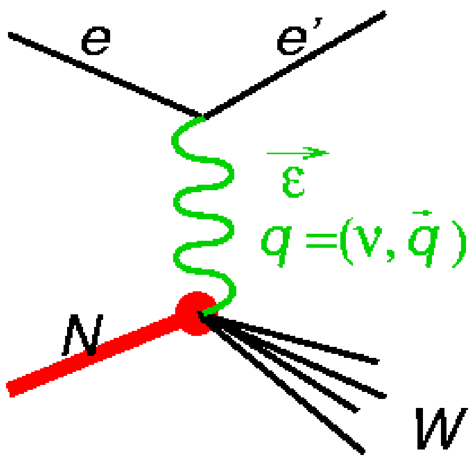
20cm, 6 bar
70% polarisation

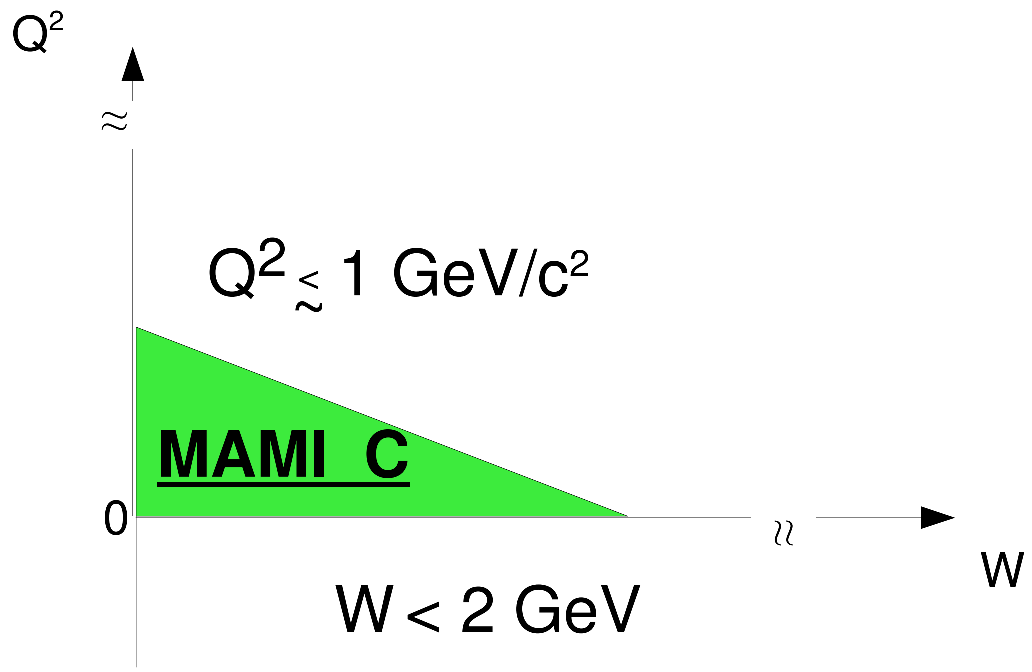


data taking in July 2009

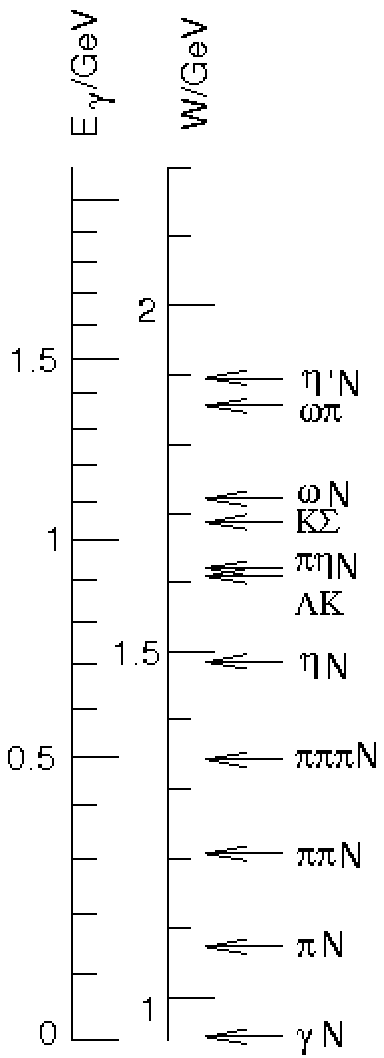
Nucleon Structure and Spectrum with MAMI

e N→ e' Hadrons



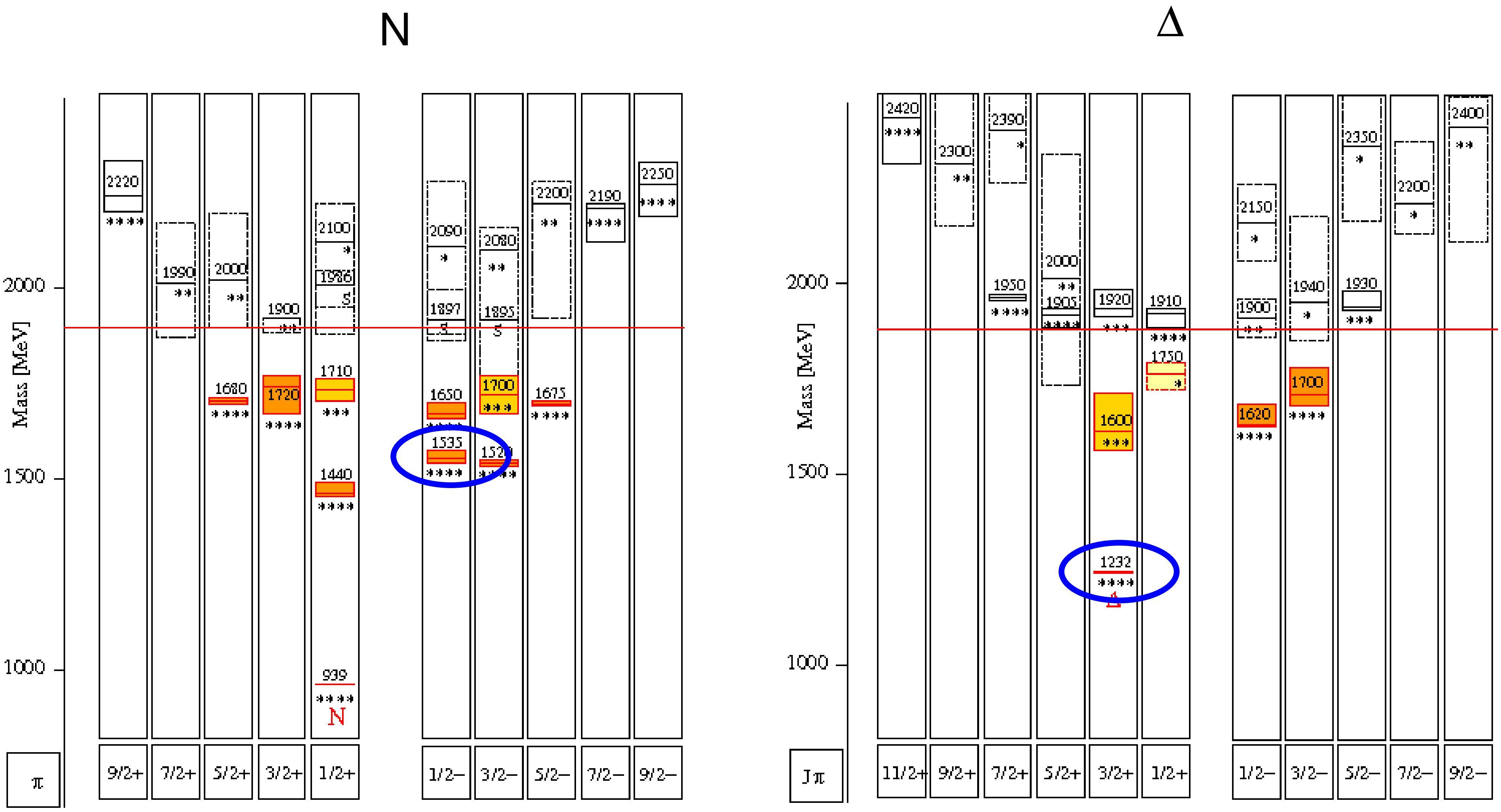


Research program at MAMI



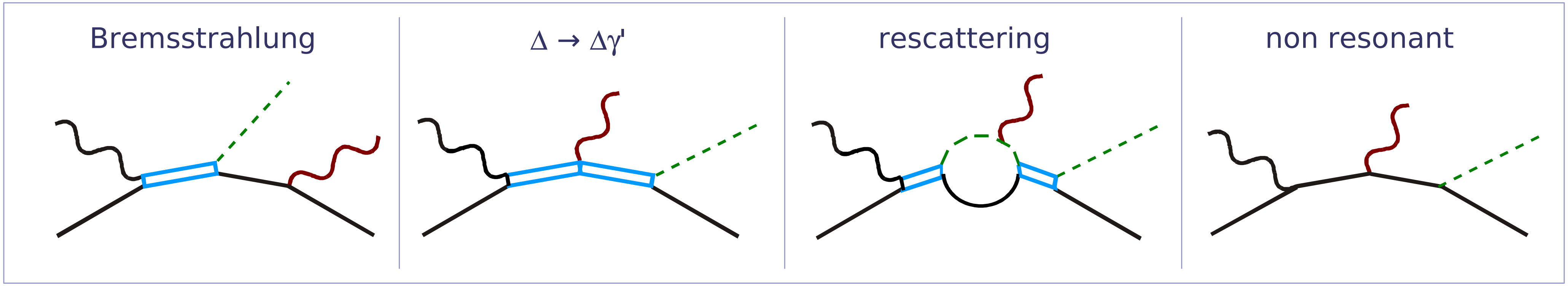
- real and virtual Compton Scattering
  ⇒ spin- and generalised polarisabilities of nucleons
- spin observables in threshold meson production
  ⇒ chiral and resonance dynamics
- towards complete experiments in π and η photoproduction with high precision
  ⇒ first N and Δ excitations in each PWA
  ⇒ Lattice QCD
- form factors (elastic and inelastic) at low Q^2
- η and η' factory
  ⇒ symmetry breaking in hadronic decays, tests of fundamental symmetries

Baryon Spectroscopy at MAMI C



Radiative pion production

$$\gamma\, p \rightarrow \pi^0\, p\, \gamma\,'$$



$\Delta\Delta\gamma$ vertex $\rightarrow$ magnetic moment of the $\Delta^+(1232)$ resonance

Calculations:

Machavariani, et al., NPA (1999)
Drechsel et al, PLB (2000)

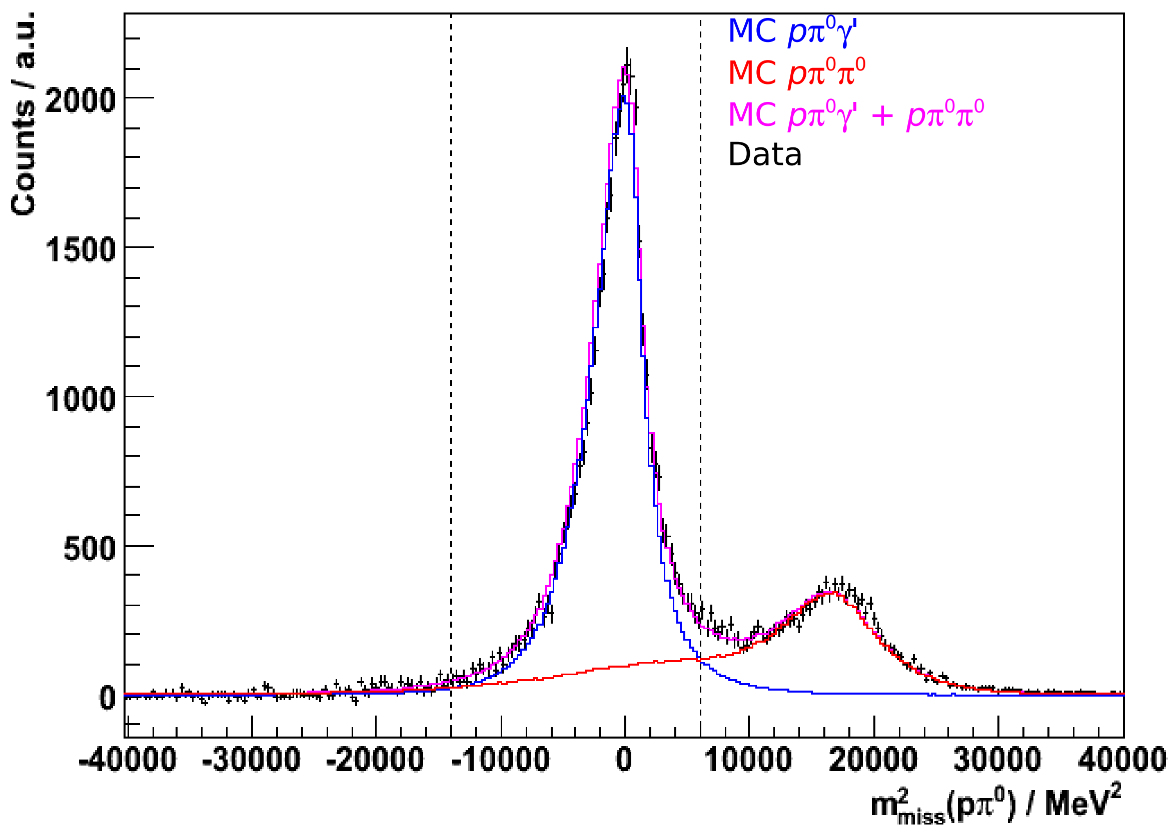
Drechsel & Vanderhaeghen, PRC (2001)
Chiang et al., PRC (2005)

EFT: Pascalutsa, Vanderhaeghen,
PRL 94 (2005)
PRD 77 (2008)

Radiative pion production

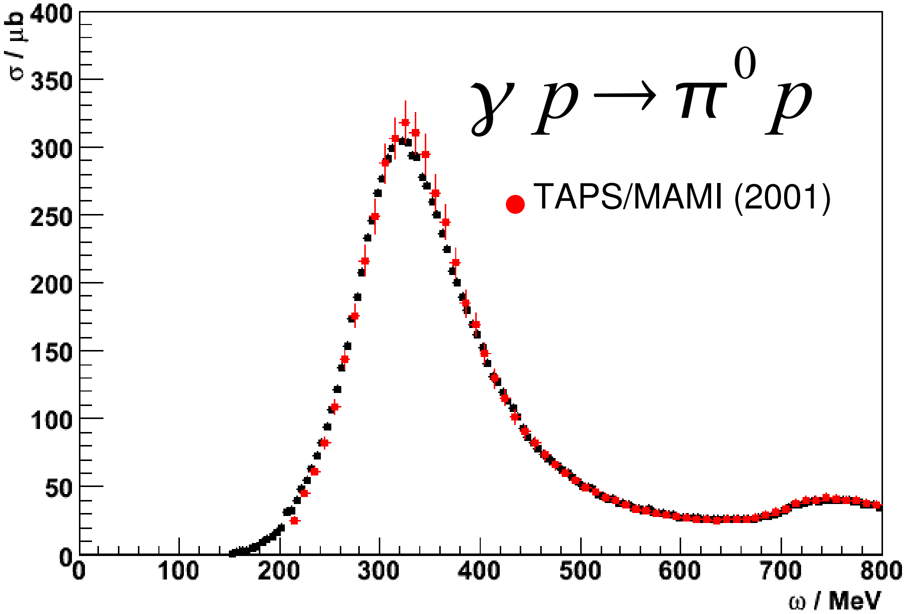
- identify $p\,\pi^0\,\gamma' \rightarrow p\,\gamma\,\gamma\,\gamma'$ final state
- all particles detected

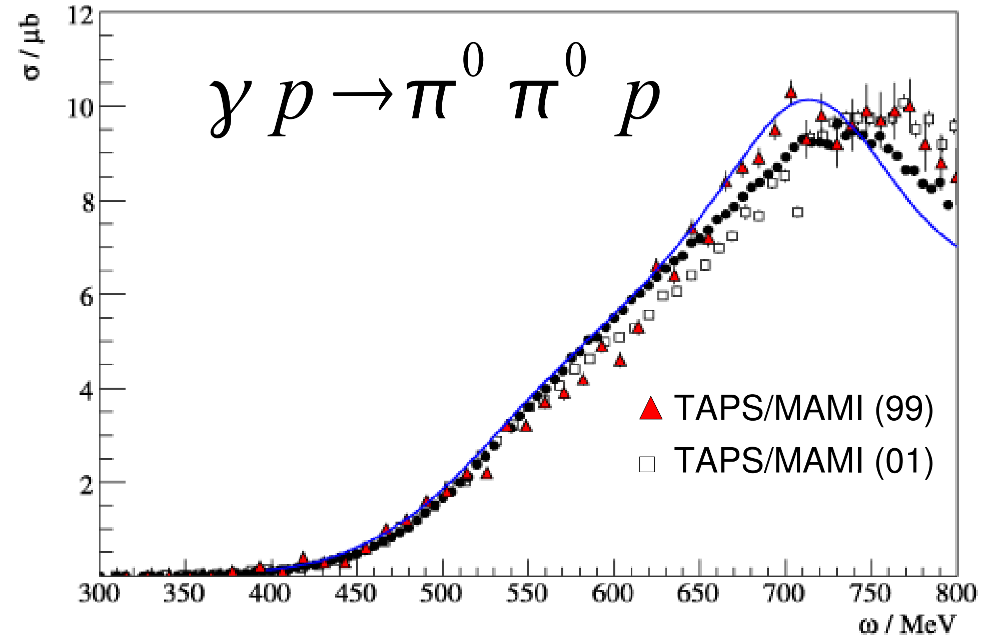
$\rightarrow$ missing mass, missing energy to reject background from $p\,\pi^0$ and $p\,\pi^0\,\pi^0$

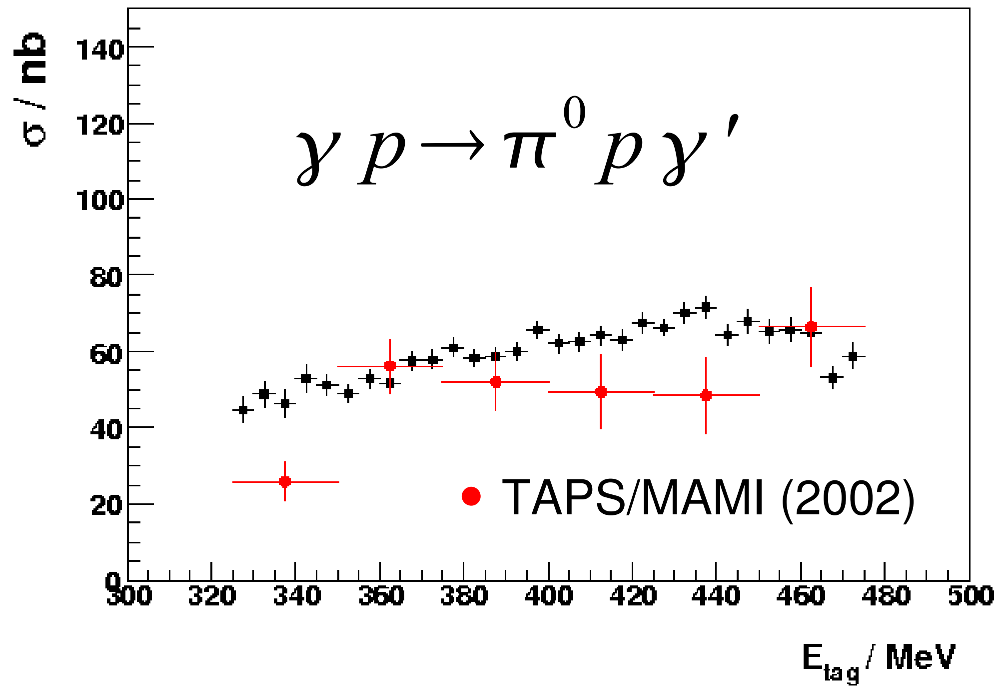


B.Boillat,
E.Downie
S.Schuman

Radiative pion production

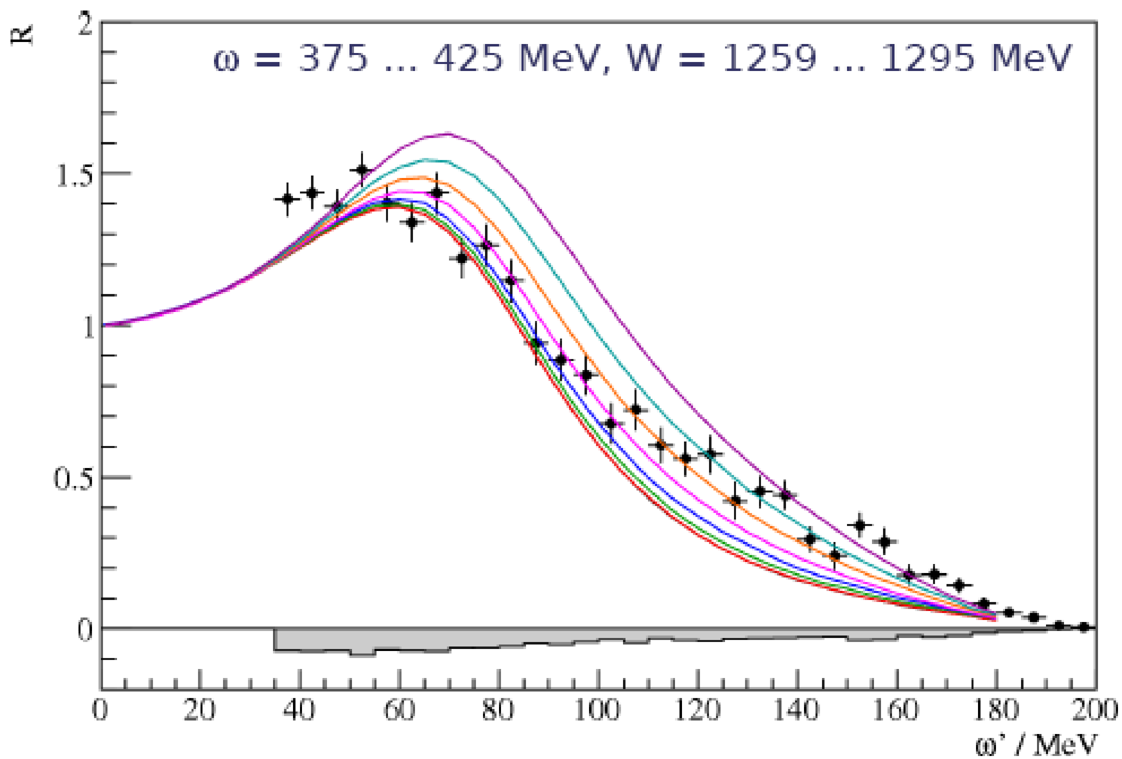






Radiative pion production

$$R = \frac{1}{\sigma_{\pi 0}} \cdot E_{\gamma'} \cdot \frac{d\sigma}{dE_{\gamma'}}$$

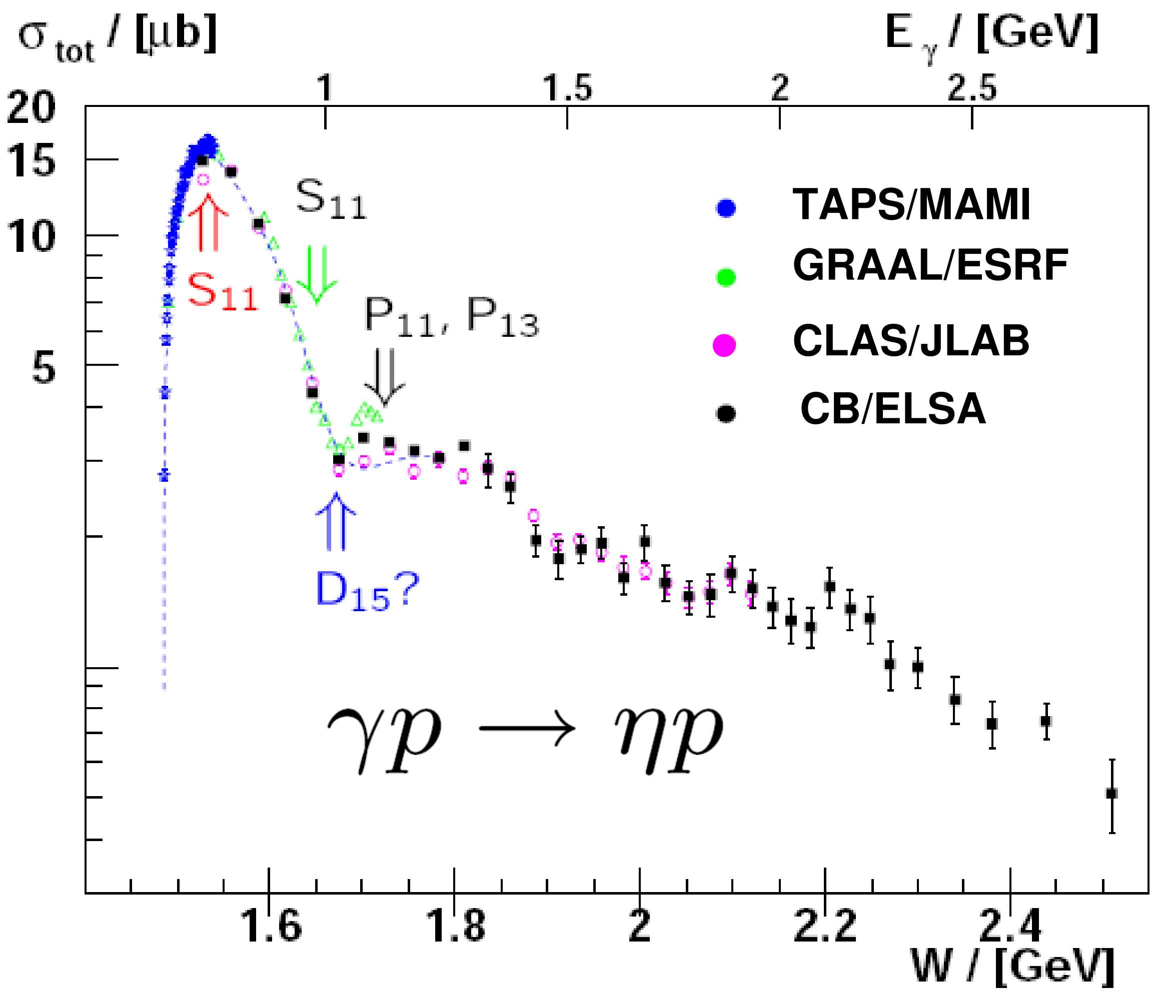


κ = 0
κ = 1
κ = 2
κ = 3
κ = 4
κ = 5
κ = 6
κ = 7

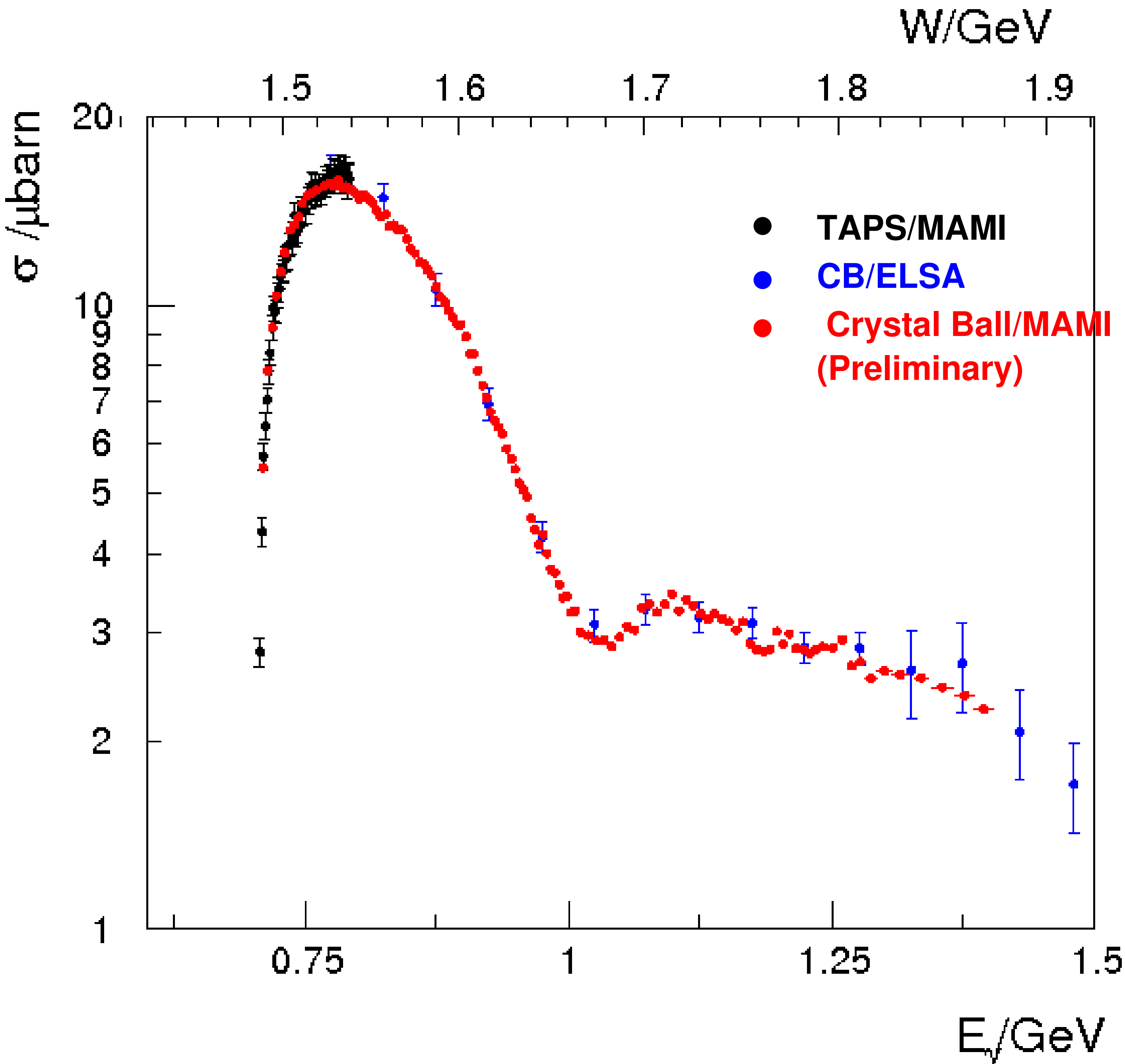
calculations:
V. Pascalutsa, M. Vanderhaeghen,
PRD 77 (2008) 014027

→ Helicity asymmetries!

η photoproduction: $\gamma\, p \rightarrow \eta\, p$

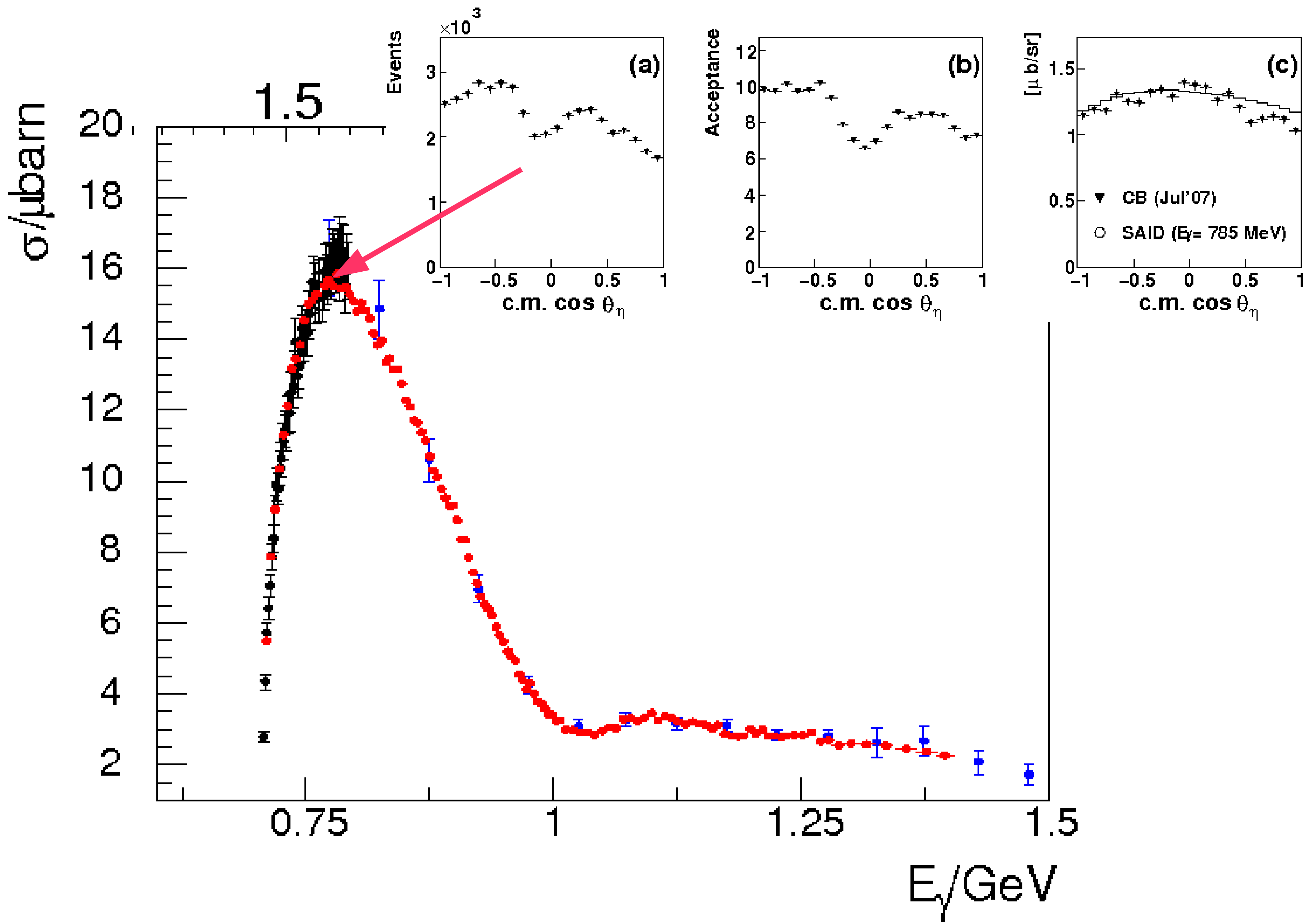


η photoproduction: $\gamma\, p \to \eta\, p$



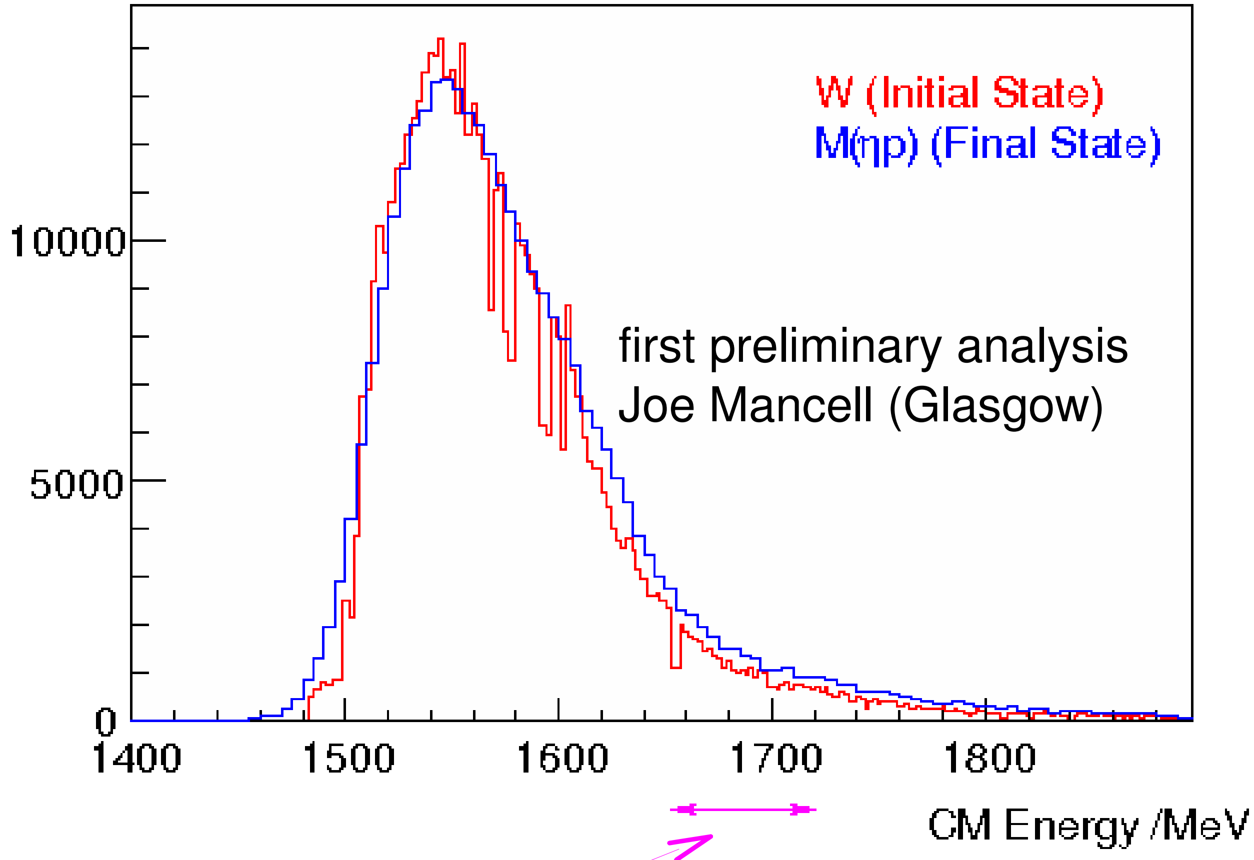
S.Prakhov

η photoproduction: γ p→ η p



η photoproduction: γ p→ η p

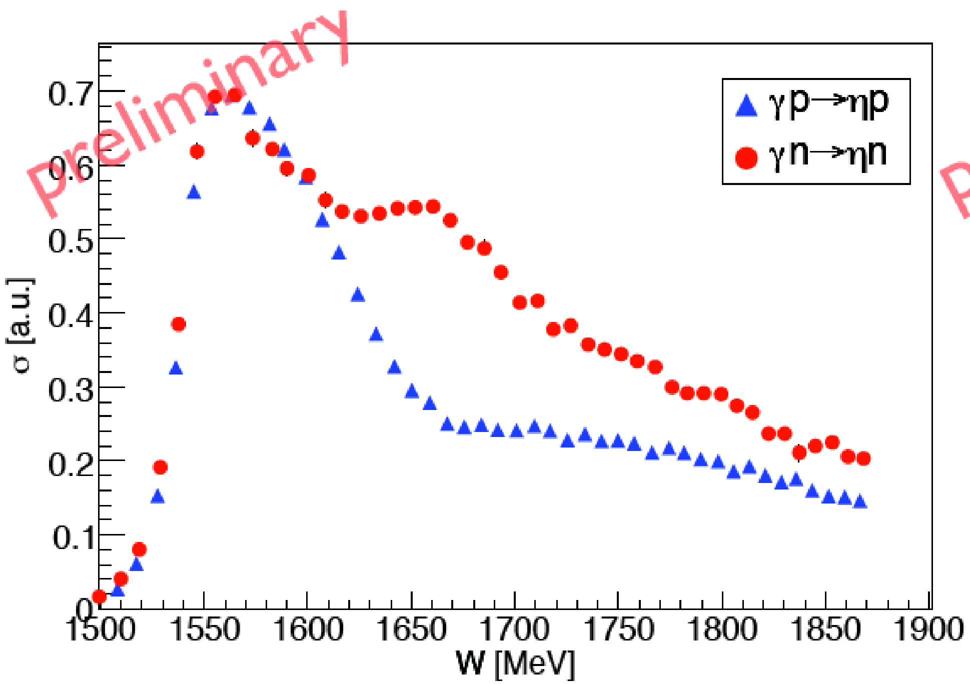
New Data from April 2009

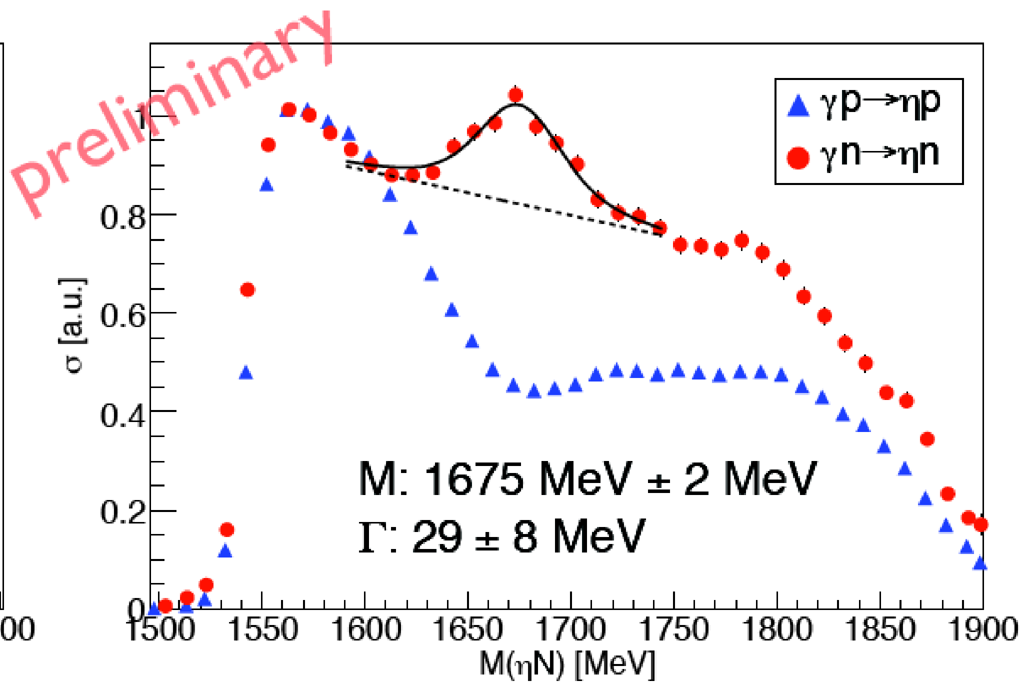


Covered by high resolution microscope ΔE ~ 1MeV

$\gamma D \to \eta p n$

B.Krusche's talk on Tuesday

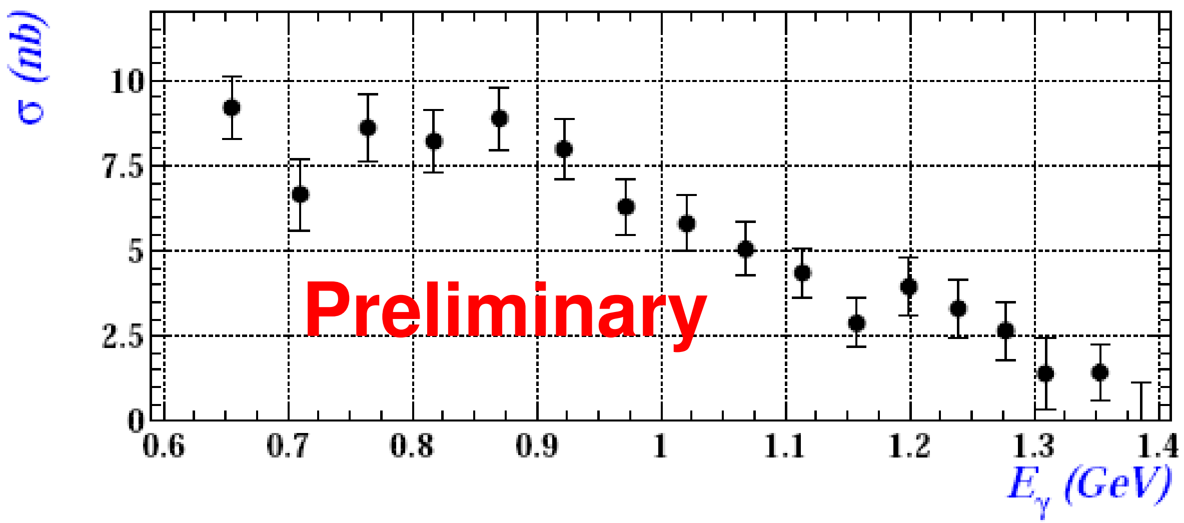


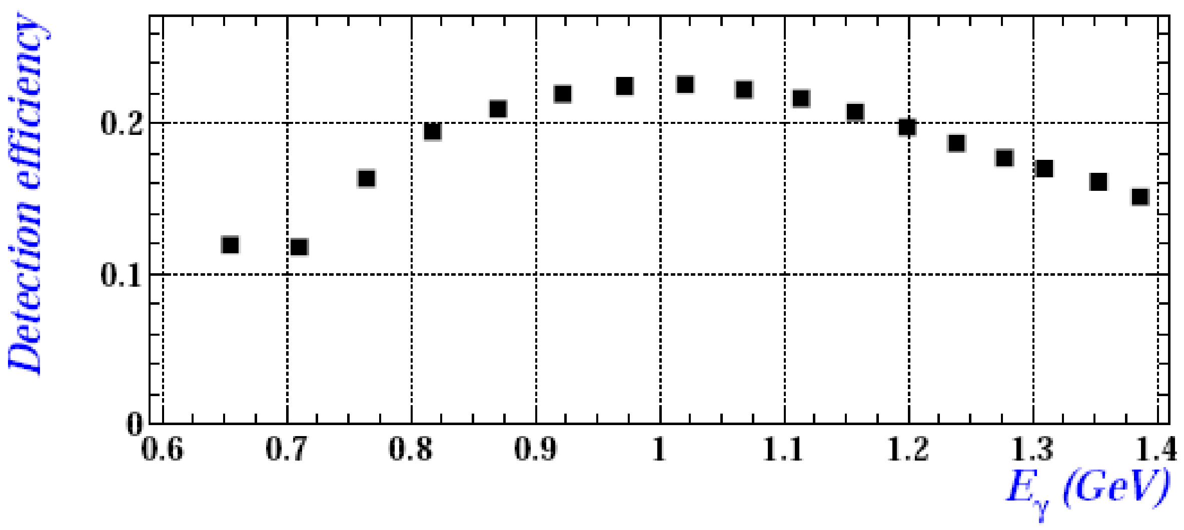


D.Werthmüller

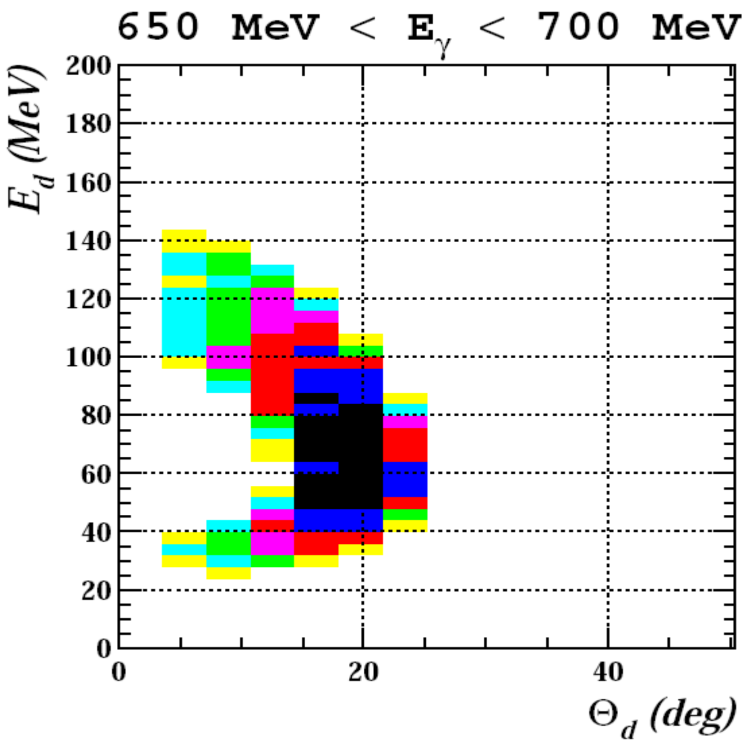
$\gamma D \rightarrow \eta D$ coherent photoproduction

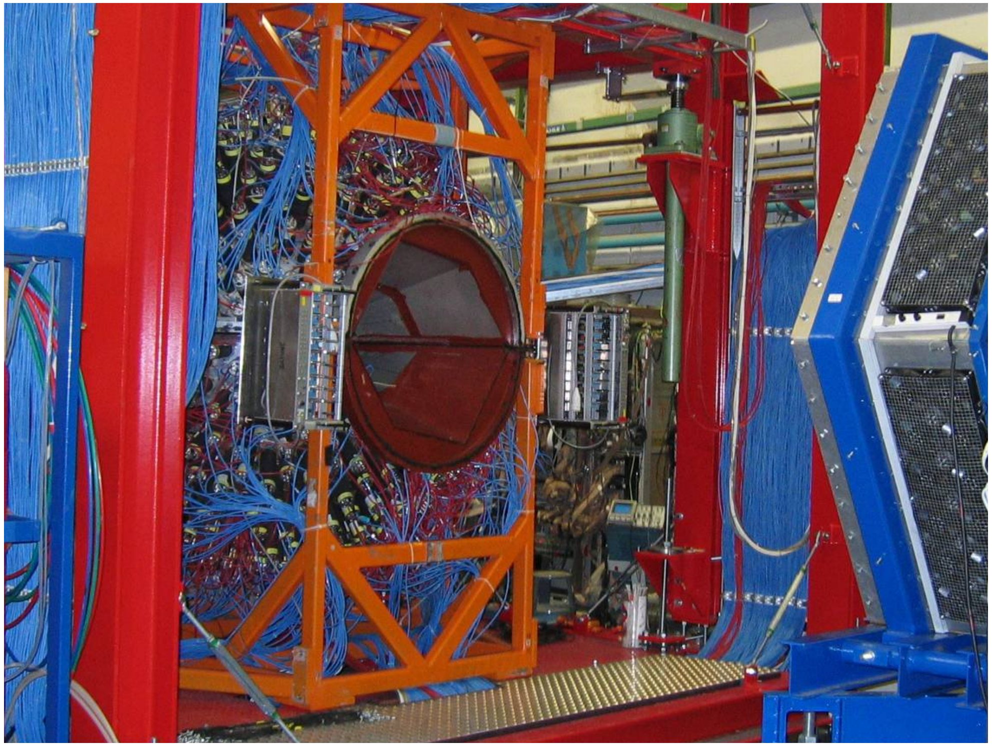
V.Kashevarov



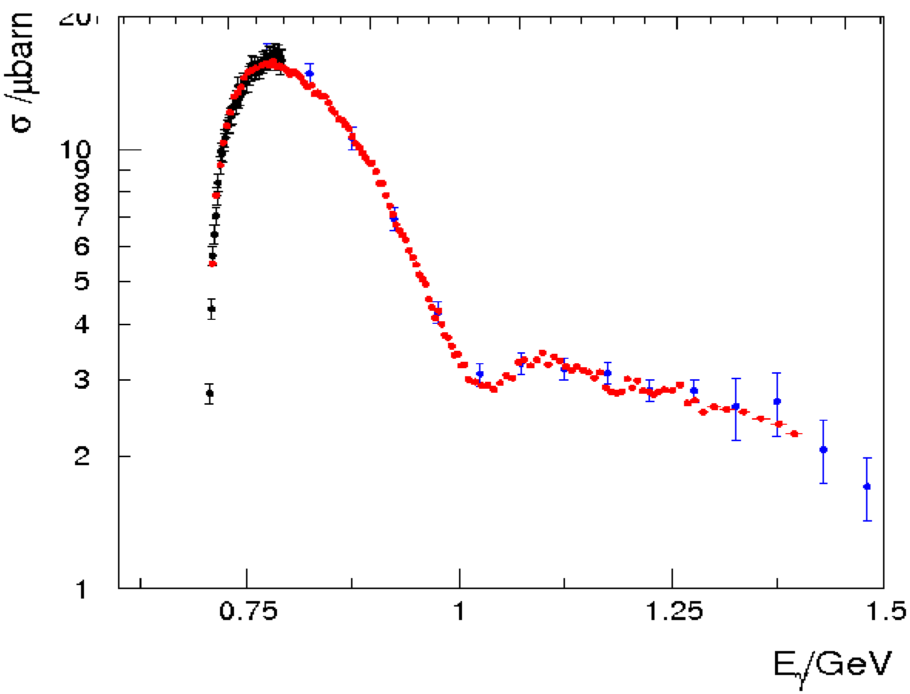


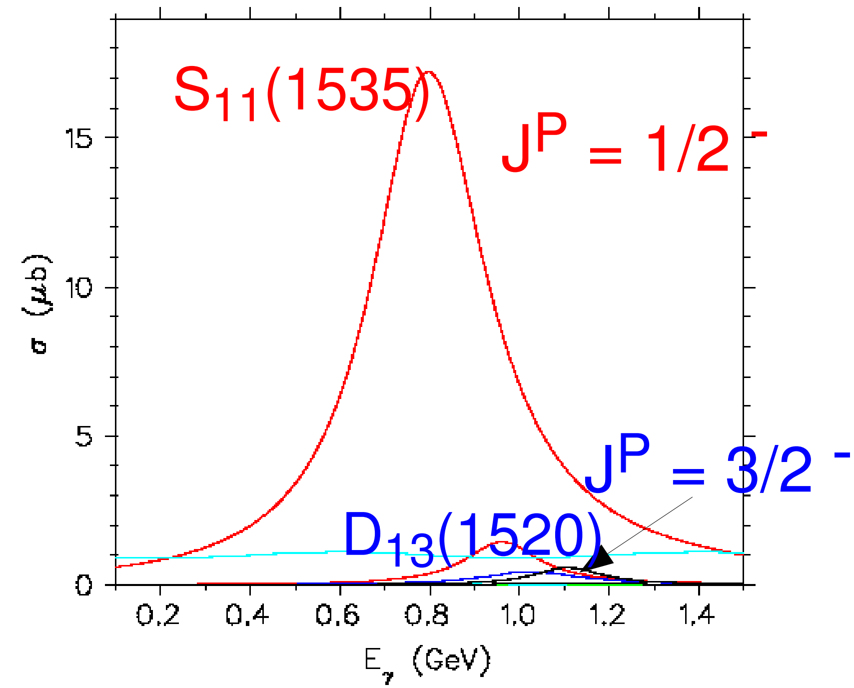
$\gamma D \rightarrow \eta D$ coherent photoproduction





Transverse asymmetries in $\gamma p \rightarrow \eta p$



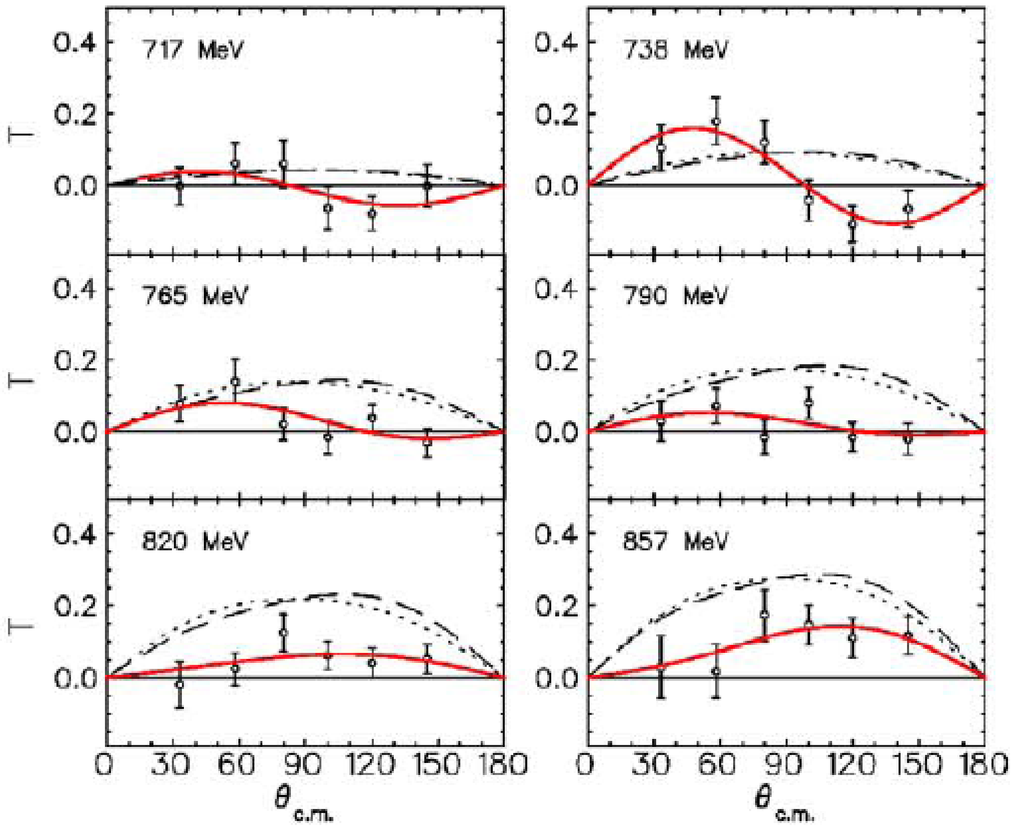


asymmetry with transvesly polarised target: T ~ Im (E_{0+}^* (E_{2-} + M_{2-}))

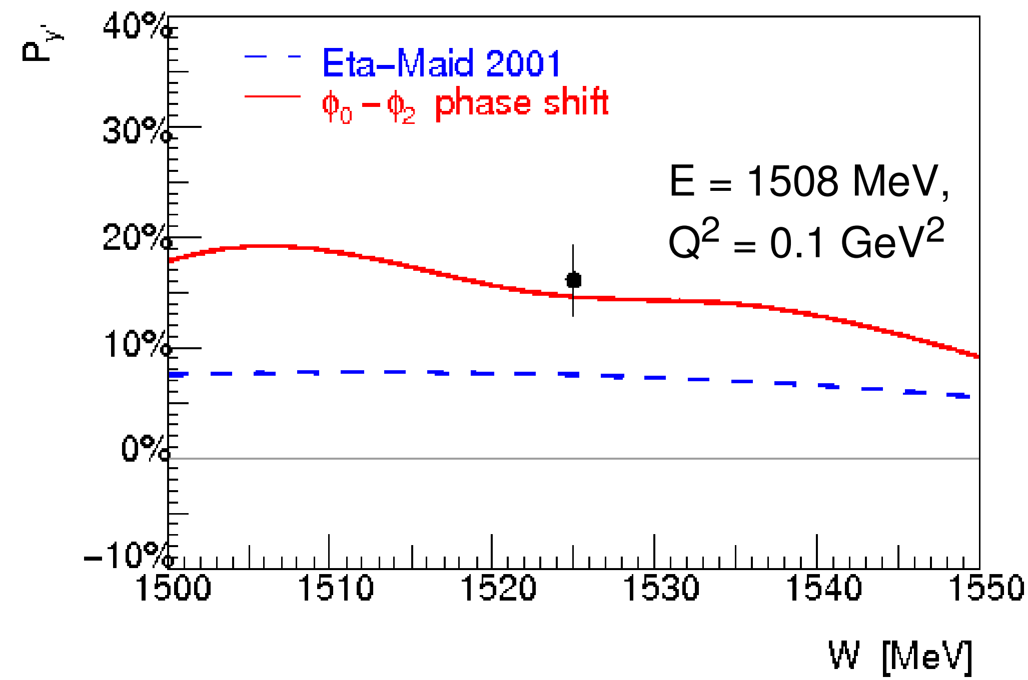
polarisation of recoiling proton: P_y ~ Im (E_{0+}^* (E_{2-} + M_{2-}))

Transverse asymmetries in $\gamma\, p \rightarrow \eta\, p$

Phoenix/Bonn (PRL81(1998))



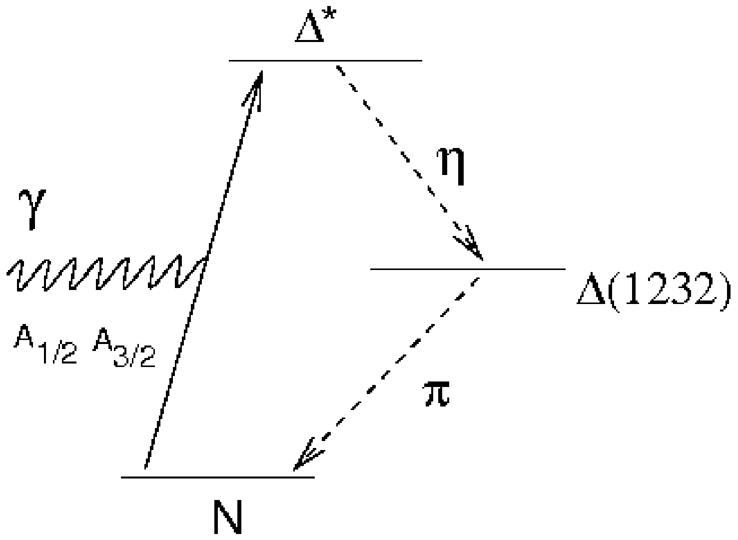
Merkel et al., PRL 99:132301,2007



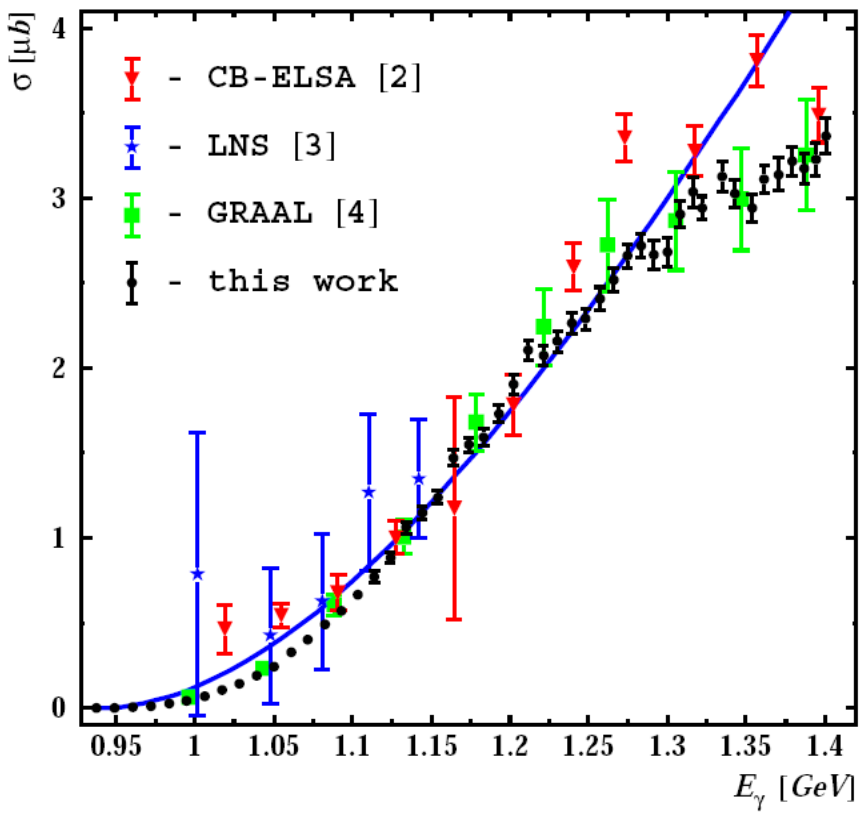
Breit-Wigner resonances
N*(1535) and N*(1520)

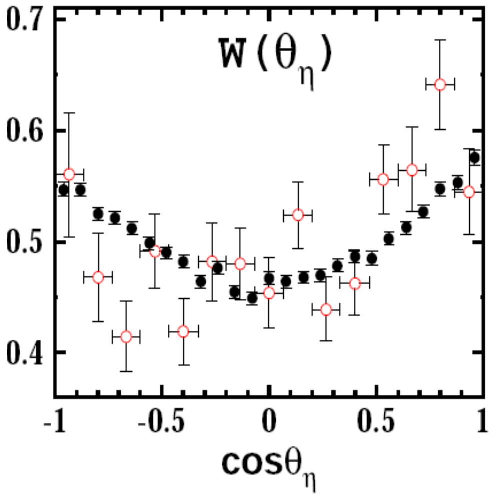
energy dependent phase shift
between $J^P = 1/2^-$ und $2/3^+$
partial wave amplitudes

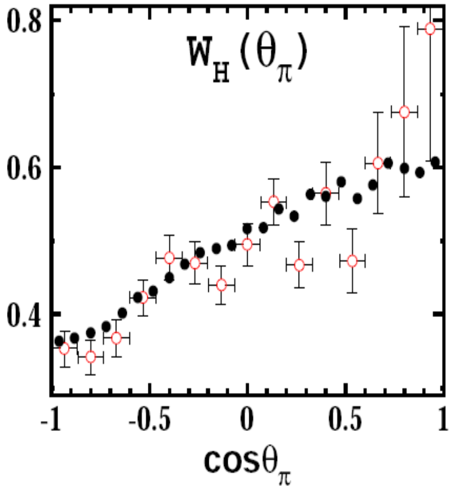
$\gamma\, p \rightarrow p\, \pi^0\, \eta$



$\gamma p \to p \pi^0 \eta$ with CB@MAMI C



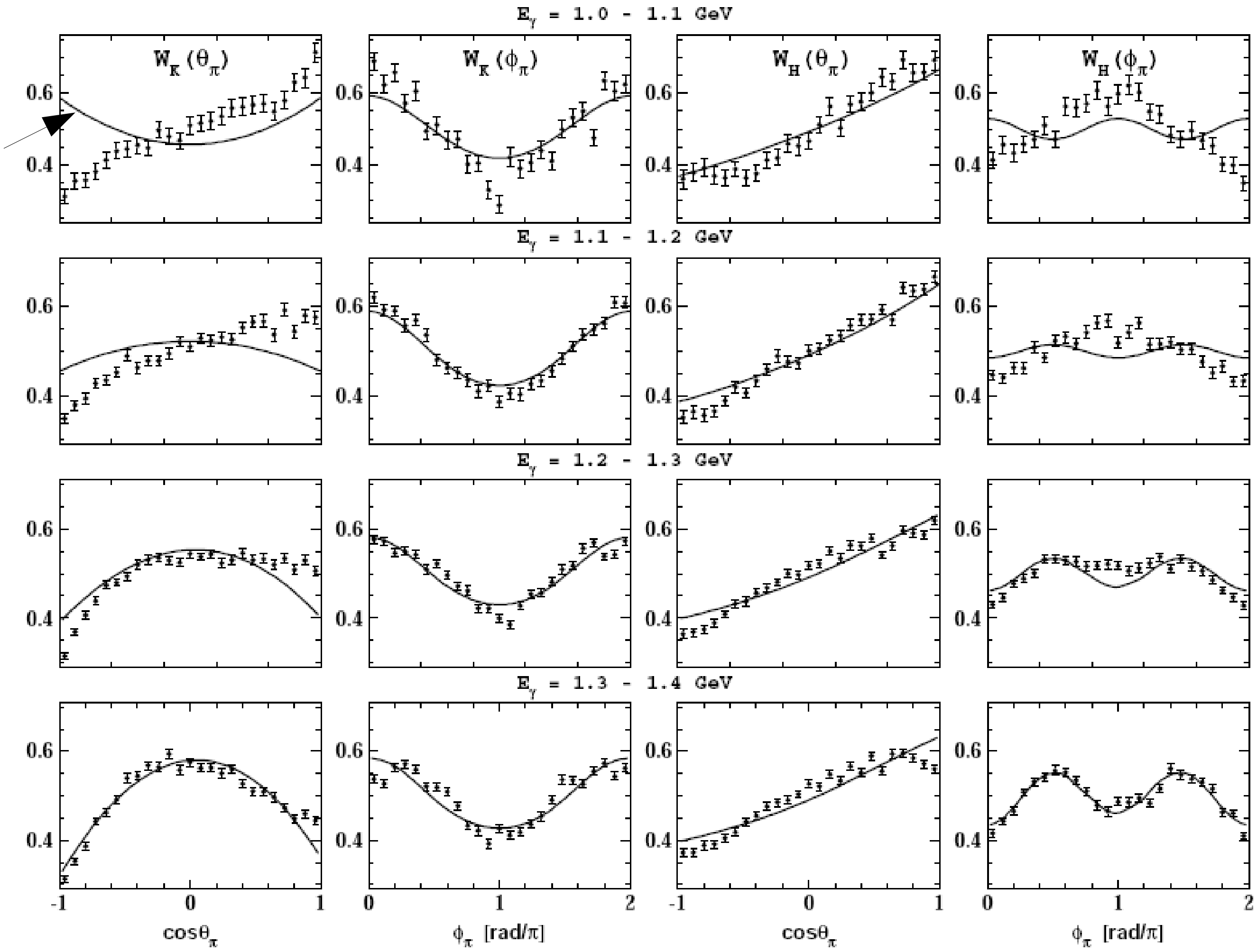




$\gamma\, p \to p\, \pi^0 \eta$ with CB@MAMI C

D$_{33}$(1700)

Fix et al.,
EPJA 36, 61 (2008)



$$\left.\frac{\Gamma^{(\pi S_{11})}_{\pi\eta N}}{\Gamma^{(\eta\Delta)}_{\pi\eta N}}\right|_{M_R} = \frac{2}{3}$$

$$\left(\frac{A_{3/2}(W)}{A_{1/2}(W)}\right)^2 = 0.7 - 2.0$$

Properties of the $\Delta(1700)D_{33}$

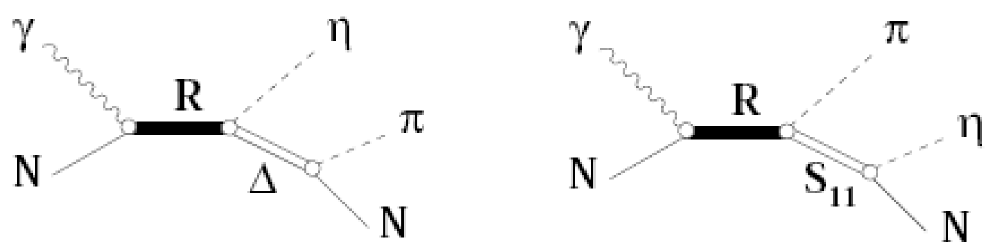
- $J^P=3/2^-$
- PDG : $\Delta(1700) \rightarrow N\pi$ 10-20%
  $\rightarrow N\pi\pi$ 80-90%
- Photocouplings in $10^{-3}\ \mathrm{GeV}^{-1/2}$

	PDG	GW06	2003	2007
$A_{1/2}$	104 ± 15	125.4 ± 3.0	135	226
$A_{3/2}$	85 ± 22	105.0 ± 3.2	213	210

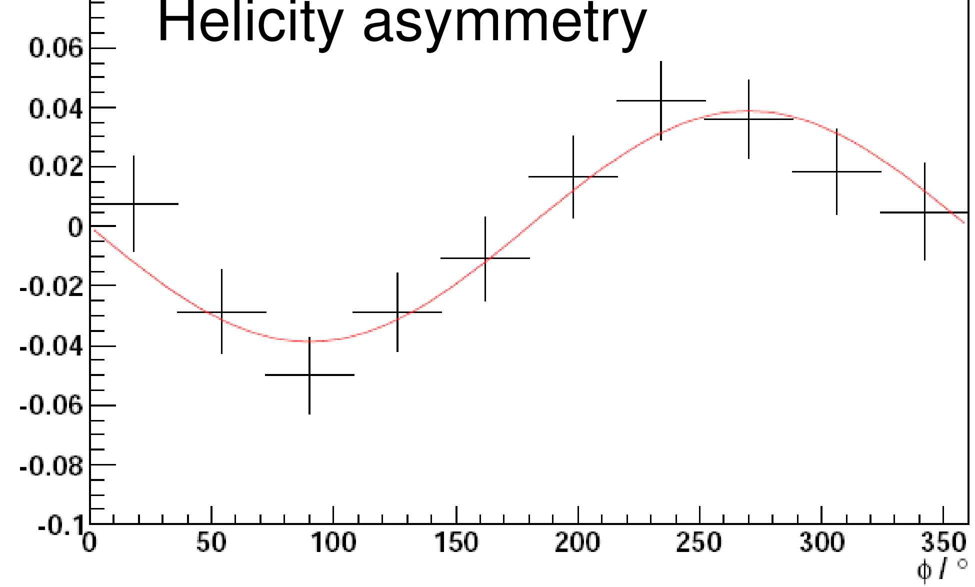
- emergence from strong baryon - meson dynamics?

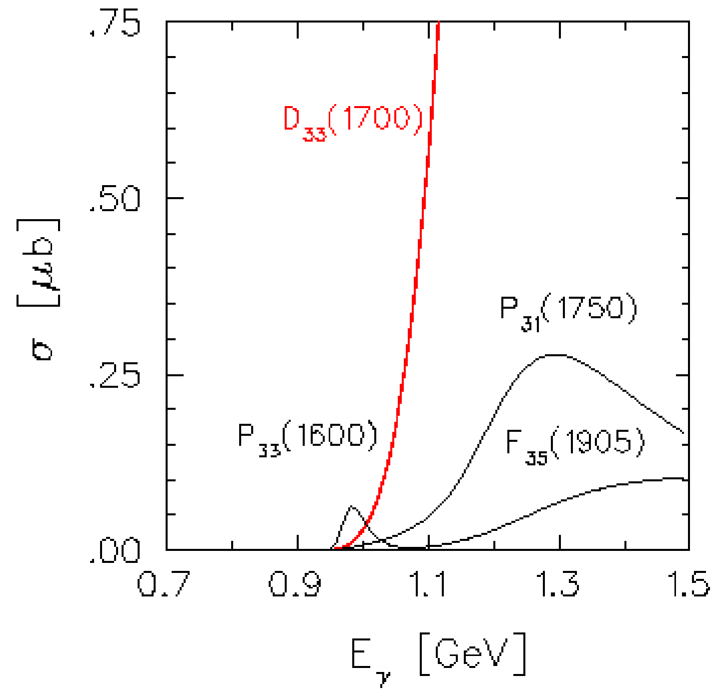
(M. Döring, et al.)

$\gamma p \rightarrow p \pi^0 \eta$ at threshold



Spin Observables





$\gamma p \rightarrow p \pi^0 \eta$: open questions

- Spin/Isospin structure of the production amplitude
  - $\gamma p \rightarrow n \pi^+ \eta$
  - quasi free and coherent processes on deuteron targets

$$R_1 = \frac{\gamma p \rightarrow p \pi^0 \eta}{\gamma p \rightarrow n \pi^+ \eta} = 2 \qquad \text{(for pure isovector)}$$

$$R_2 = \frac{\gamma d \rightarrow p \pi^0 \eta (n_s)}{\gamma d \rightarrow n \pi^+ \eta (p_s)} = 1 \qquad \text{(for pure isovector)}$$

- Systematic analysis of contributions from p-wave amplitudes
  - spin observables (E, T, F)

Summary

- MAMI
  ⇒ E = 1.5 GeV (1.6 GeV)
  high intensity and polarization
  excellent beam quality and stability

- high performance detector systems
  ⇒ broard range of topics in nuclear and hadron physics

- Resonances
  ⇒ spin observables with high precission
  and radiative processes
  ⇒ carefully chose significant observables