Eta Photoproduction on the Proton

Joe Mancell
University of Glasgow
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Contents

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Introduction – Meson Photoproduction

- Important technique in hadronic physics
- Nucleons excited using photon beam
- Decay products allow extraction of:
  - Nucleon excitation spectrum
  - Resonance properties

- Some resonances predicted by symmetric quark models still missing
- Allows access to specific nucleon resonances via detection of the eta primary decay products

- Eta photoproduction proven useful tool in the search for new narrow nucleon resonances

N^*	Status	$SU(6) \otimes (3)$	Parity	Δ^*	Status	$SU(6) \otimes (3)$
$P_{11}(938)$	****	$(56, 0^+)$	+	$P_{33}(1232)$	****	$(56, 0^+)$
$S_{11}(1535)$	****	$(70, 1^-)$	-			
$S_{11}(1650)$	****	$(70, 1^-)$	-	$S_{31}(1620)$	****	$(70, 1^-)$
$D_{13}(1520)$	****	$(70, 1^-)$	-	$D_{33}(1700)$	****	$(70, 1^-)$
$D_{13}(1700)$	***	$(70, 1^-)$	-			
$D_{15}(1675)$	****	$(70, 1^-)$	-			
$P_{11}(1520)$	****	$(56, 0^+)$	+			
$P_{11}(1710)$	***	$(70, 0^+)$	+	$P_{31}(1875)$	****	$(56, 2^+)$
$P_{11}(1880)$		$(70, 2^+)$	+	$P_{31}(1835)$		$(70, 0^+)$
$P_{11}(1975)$		$(20, 1^+)$	+			
$P_{13}(1720)$	****	$(56, 2^+)$	+			
$P_{13}(1870)$	*	$(70, 0^+)$	+	$P_{33}(1600)$	***	$(56, 0^+)$
$P_{13}(1910)$		$(70, 2^+)$	+	$P_{33}(1985)$		$(70, 2^+)$
$P_{13}(2030)$		$(20, 1^+)$	+			
$F_{15}(1680)$	****	$(56, 2^+)$	+	$F_{35}(1905)$	****	$(56, 2^+)$
$F_{15}(2000)$	**	$(70, 2^+)$	+	$F_{35}(2000)$	**	$(70, 2^+)$
$F_{15}(1995)$		$(70, 2^+)$	+			
$F_{17}(1990)$	**	$(70, 2^+)$	+	$F_{37}(1950)$	****	$(56, 2^+)$

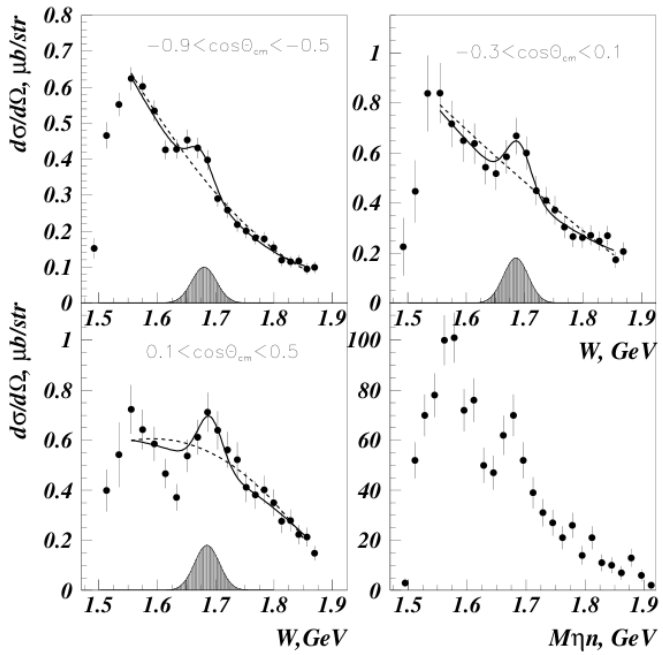
Previous Work & Motivation

- Search for N*(1685) narrow resonance in past decade
- Results published showing structure on the neutron (deuteron target)

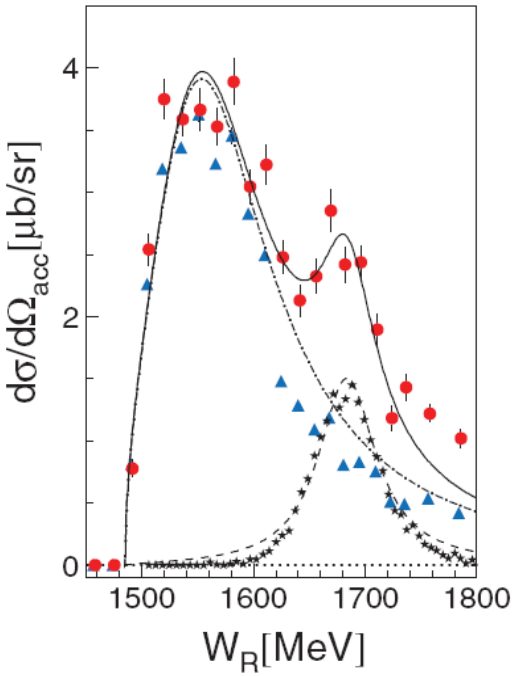
$$\gamma n \longrightarrow \eta n$$

- No structure on the corresponding proton plots, photo-coupling much lower
- Some polarisation observable measurements on the proton channel have shown interesting behaviour around W~1685 MeV

GRAAL (Kuznetsov et al.)



CBELSA/TAPS (Jaegle et al.)

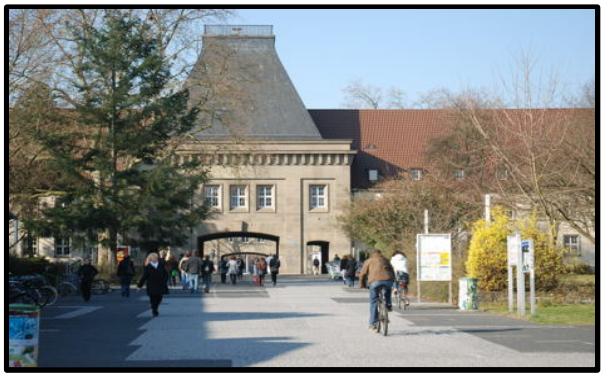


- McNicoll et al, abnormality in Legendre polynomial
- High resolution and statistics needed for proton search
- Use free proton instead of deuteron, no fermi smearing of target or final state interactions

Experimental Run

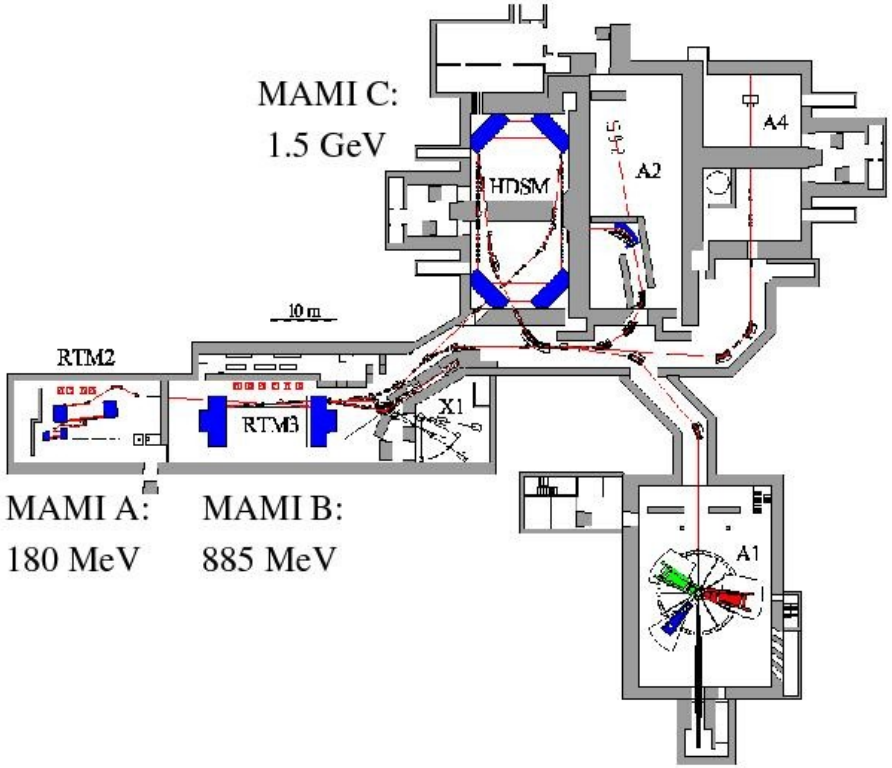
- Experimental run took place in April 2009
- LH_2 Target
- 1557 MeV electron beam
- Channel of interest: $\gamma p \longrightarrow \eta p$

- Aim of experiment was:
  - Detect a final state eta and proton
  - Investigate cross section and invariant mass for signs of narrow structure



The MAMI Accelerator

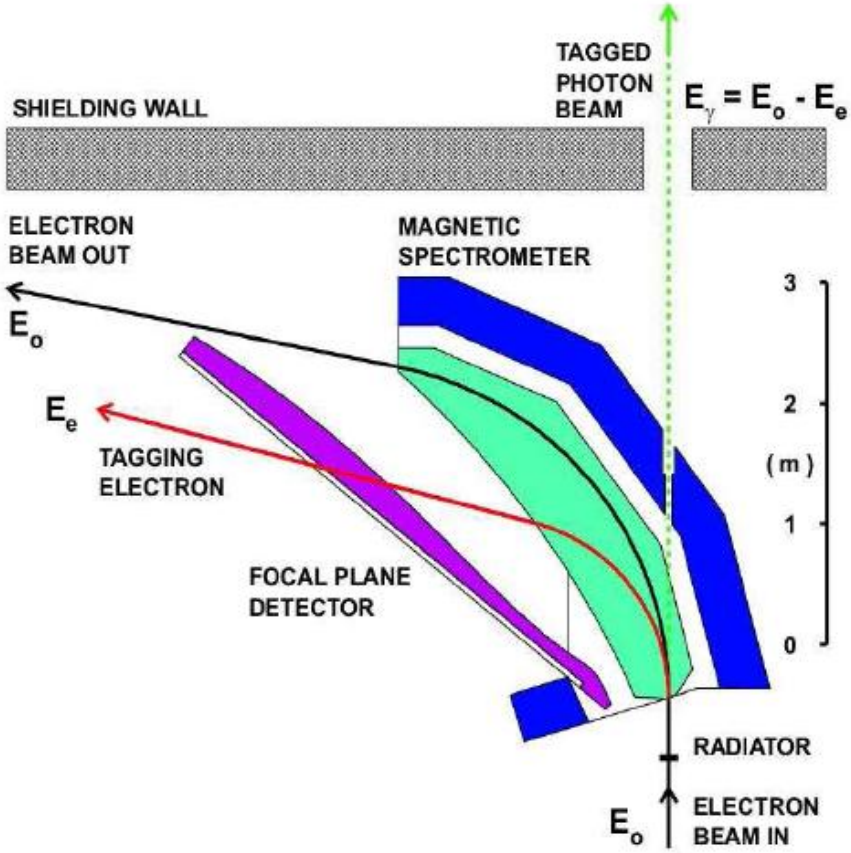
- MAMI based at Institut fur Kernphysik, Mainz University, Germany
- Combination of linear accelerators, race track microtrons and harmonic double sided microtron
- Maximum electron beam energy of ~1.6 GeV
- Three experimental halls, A1, A2 and A4



Glasgow Photon Tagger & Radiator

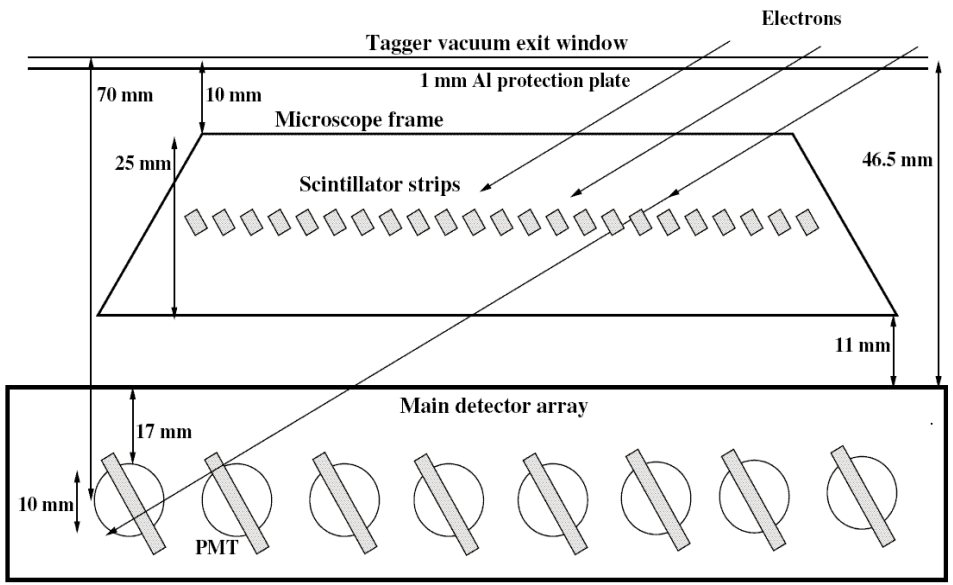
- Electron beam hits Cu radiator
- Bremsstrahlung photons produced
- Electrons bent into tagger
- Photons continue towards target
- Kinematic information of photon calculated from the corresponding electron in focal plane detector (FPD)

- This process is known as “photon tagging”



Microscope Detector

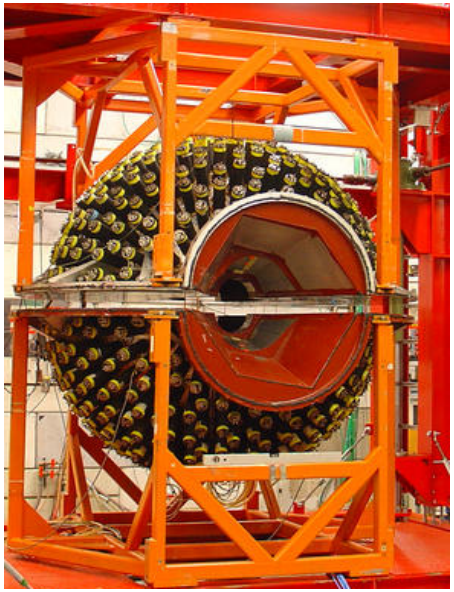
- Used to increase energy resolution of main FPD by a factor of 5
- Covers approx 117 MeV region
- Central point at E_γ ~ 1045 MeV (W ~ 1685 MeV)

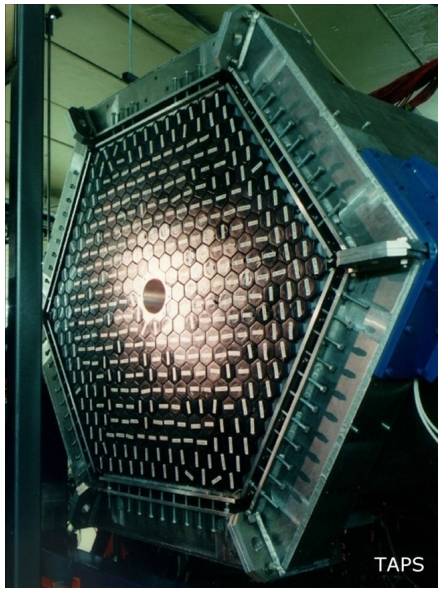


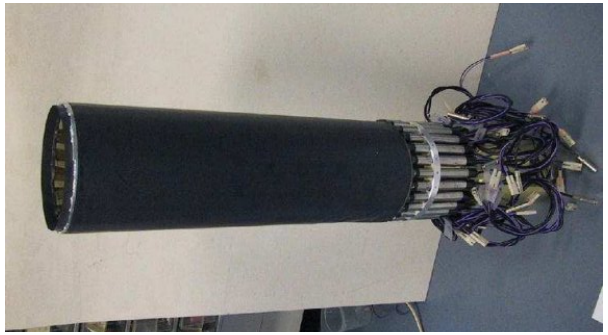
(A. Reiter et al. 2006)

Crystal Ball, PID and TAPS

- Crystal Ball (CB), PID and TAPS responsible for detecting reaction products of photons, protons and mesons
- Crystal Ball highly segmented NaI photon detector
- PID is a barrel of 24 plastic scintillators set inside CB
- PID used in conjunction with CB to detect charged particles
- TAPS is used to plug the CB exit hole
  - 3 methods of proton identification

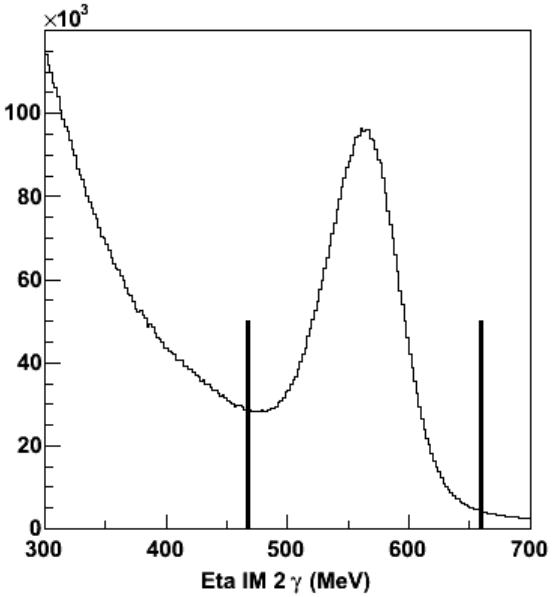


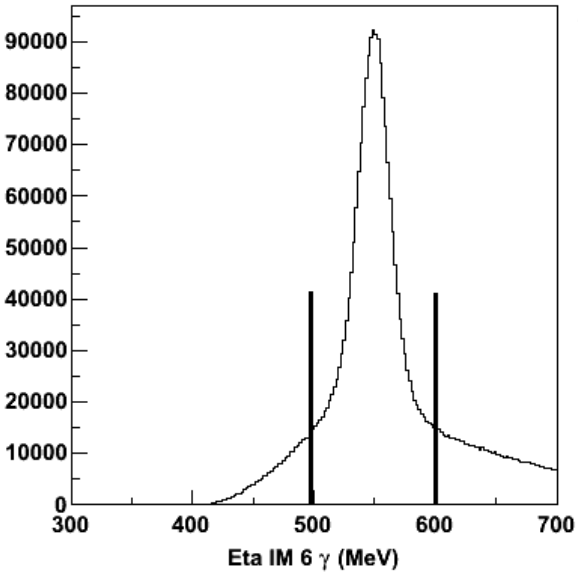




Data Analysis – Eta Flux

- First must identify events with eta final state
- Eta particle decays via 2 photons or 3 pions
  - Each pion decays to 2 photons
- Root based analysis software used to reconstruct kinematic information of particles involved in each reaction

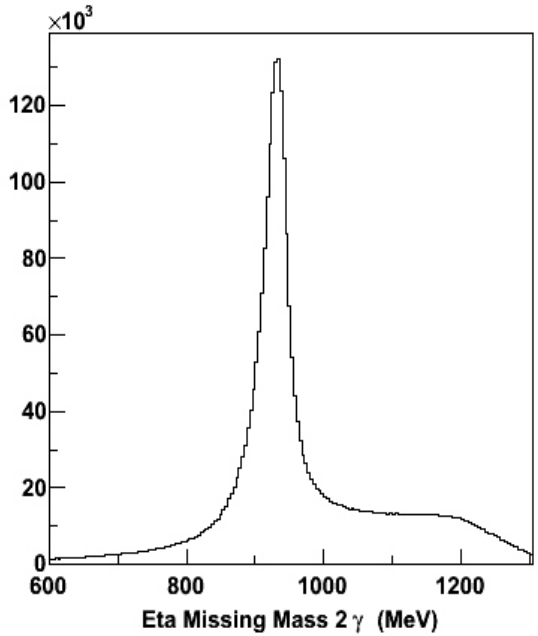


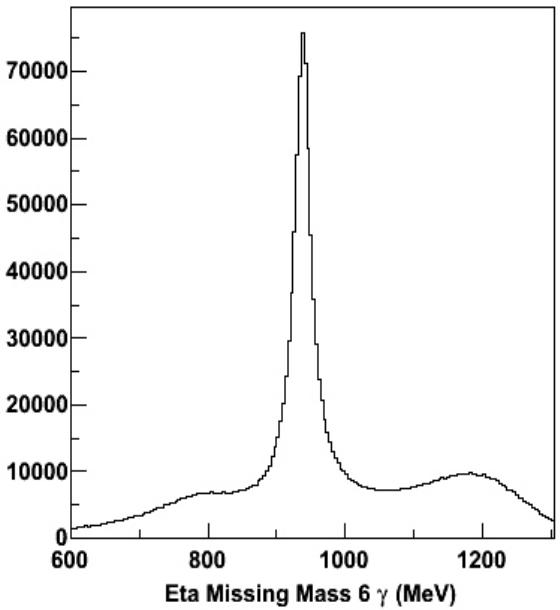


- Invariant Mass of both 2 photon and 6 photon events have been plotted
- Clear peak at eta mass of 548 MeV, 3 sigma cut applied to select final state eta events

Data Analysis – Eta Flux

- Use missing mass technique
- Utilises known kinematic information:
  - Incoming beam photon
  - Target
  - Eta

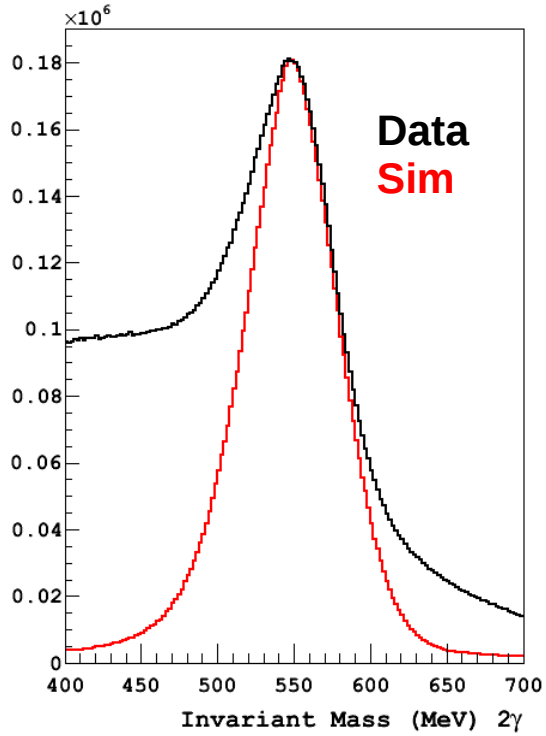


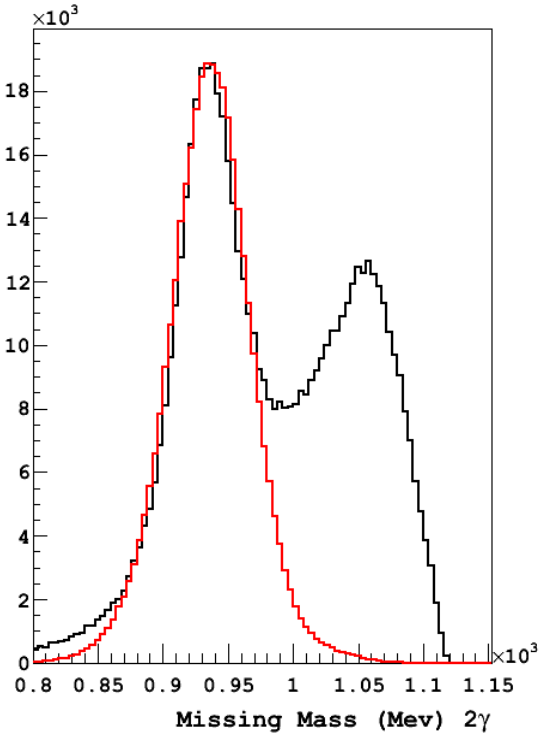


- Random tagger coincidence background subtracted
- Physics background subtracted
- Peak fitted with Gaussian and 3 sigma cut applied

Simulation – Acceptance Correction

- Monte carlo event generator
- Geant4 simulation of A2 hall
- Events ran through analysis code
- Acceptance is ratio of original generated events to events remaining after simulation and analysis

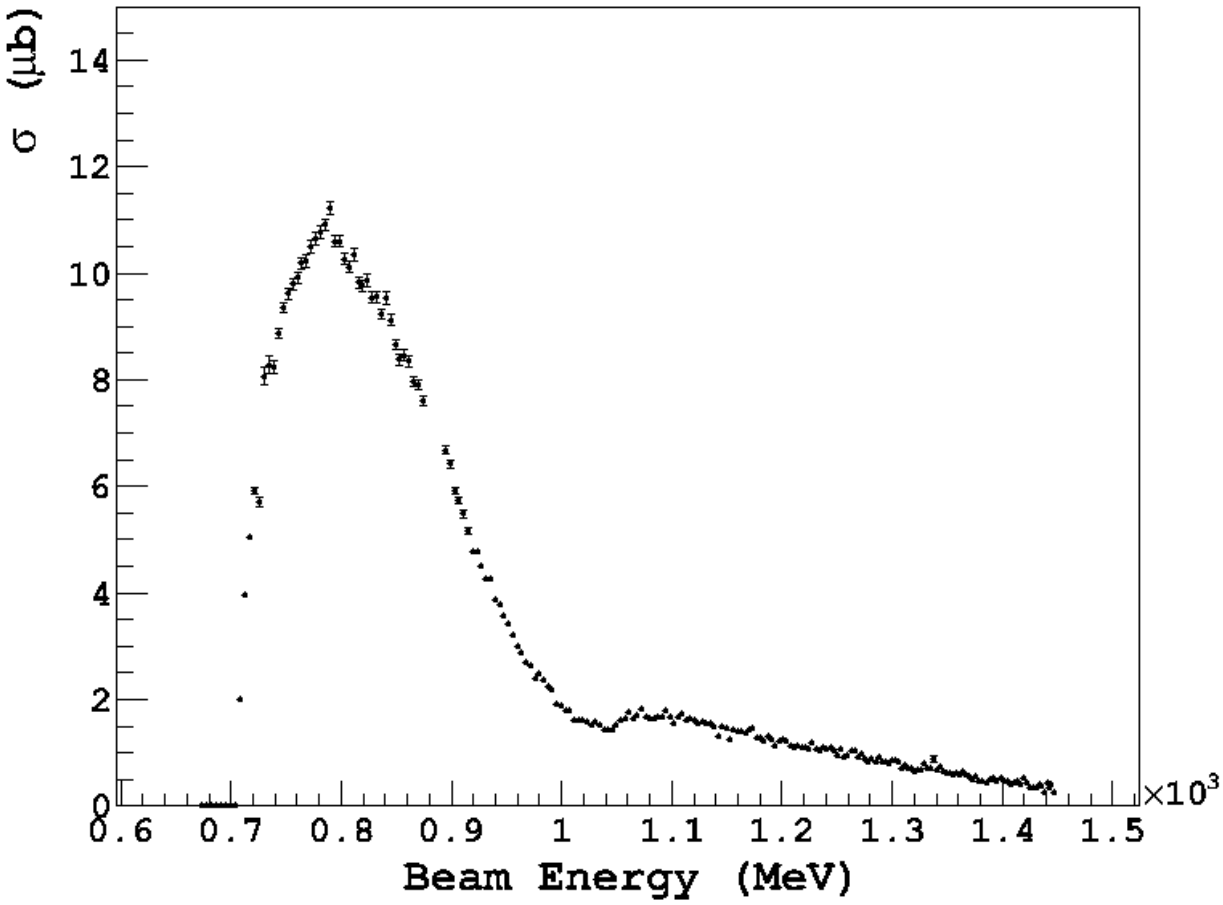




- Single particle energy and angular resolutions adjusted to match IM and MM widths of the data and simulation

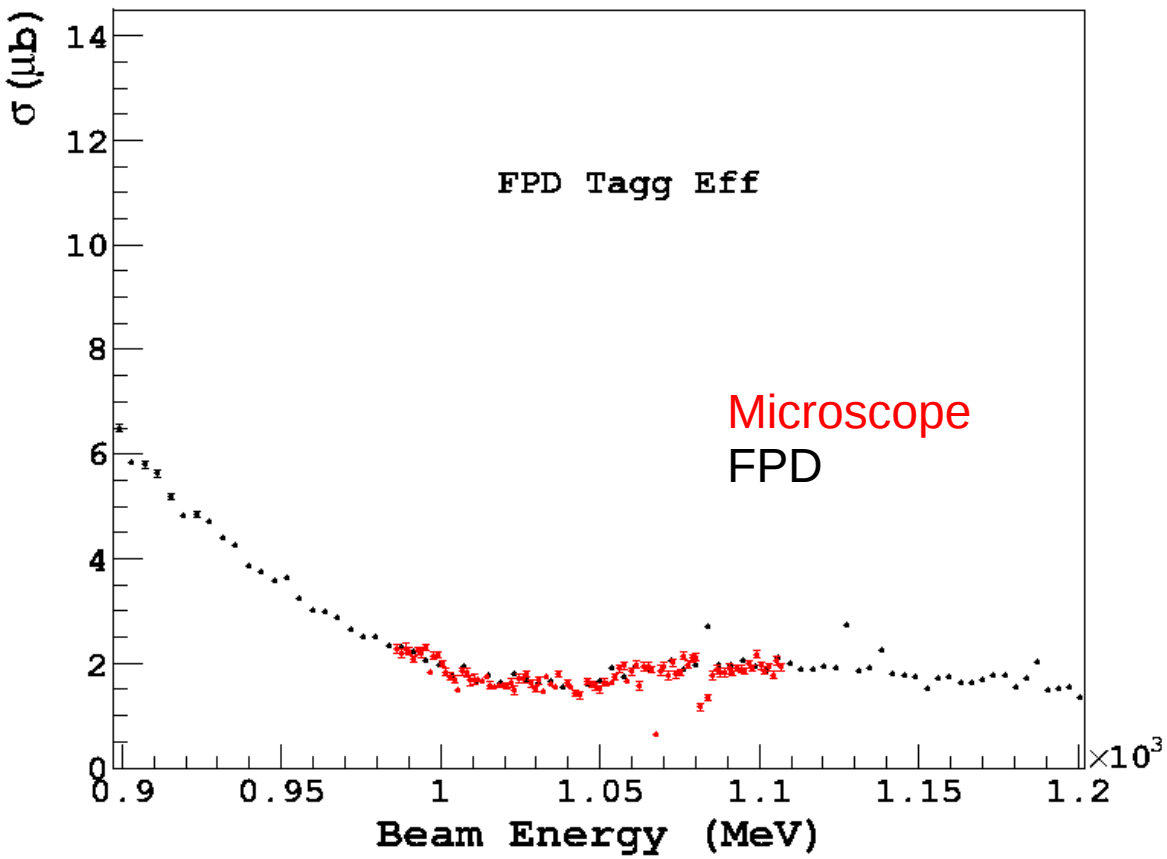
Preliminary Results – Total Cross Section FPD 2g

- No sign of any narrow structure in the region of interest
- Issues still outstanding – cross section too low
- Need to simulate the effects of the experimental trigger



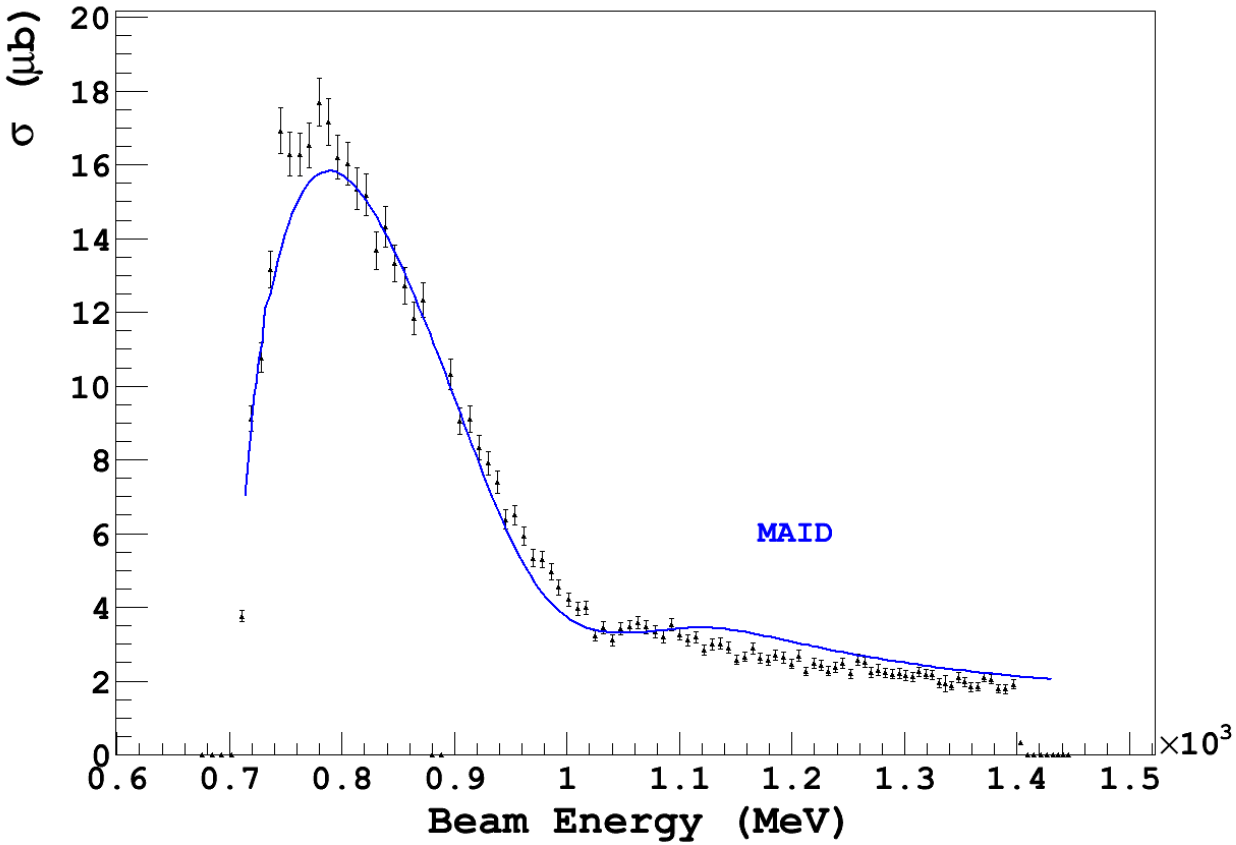
Results – Total Cross Section Microscope 2g

- Cannot use microscope tagging efficiency due to erratic noise in scalers
- Use interpolated tagging efficiency from FPD measurement
- No sign of structure that could be interpreted as a narrow resonance at 1045 MeV region



Preliminary Results – Total Cross Section FPD 6g

- Close to MAID prediction
- Discrepancy around the peak of $S_{11}(1535)$
- No sign of any narrow structure in the region of interest



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Summary

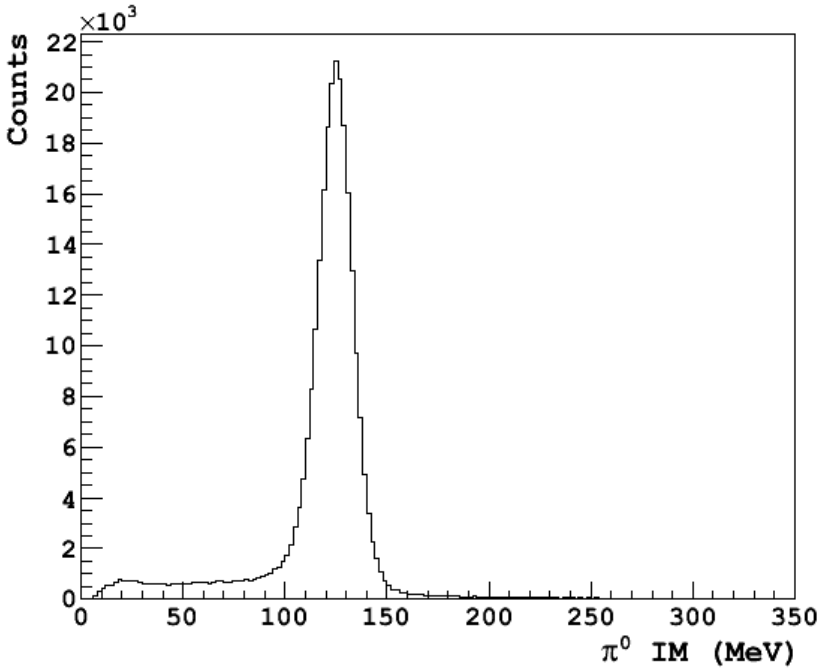
- Experimental run took place in April 2009
- Data analysis underway, event selection completed

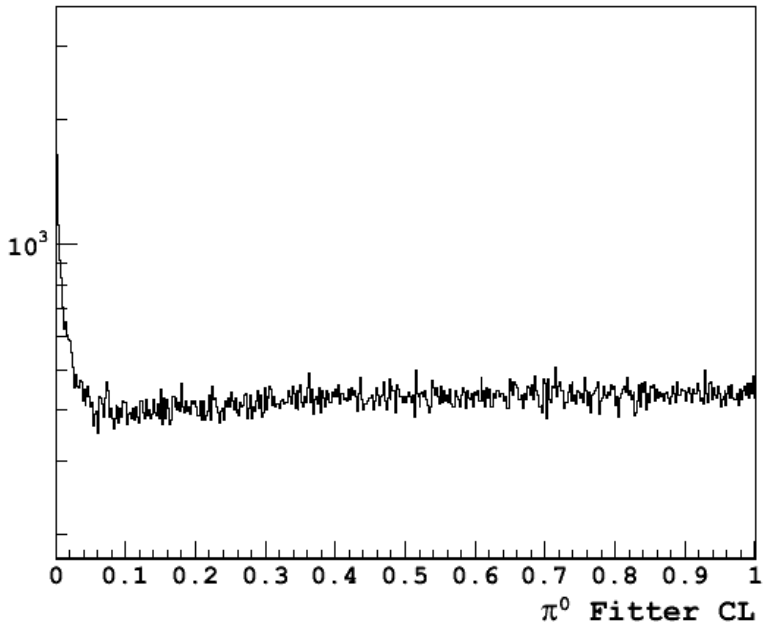
- Preliminary cross sections for both FPD and microscope produced
- Plots do not show any sign of narrow structure

- **Future Work**
  - Produce a final cross section measurement, and place upper limit on the N*(1685) on the proton channel
  - Produce eta-proton invariant mass
  - Use kinematic fitting technique to refine event selection

Preliminary Kinematic Fit Plots - Pions

- A kinematic fit uses the values of the known errors (i.e. resolutions) of a detected particle along with several kinematic constraints to perform a least squares fit on an event by event basis.
- Cut on the Confidence Level of the fit.





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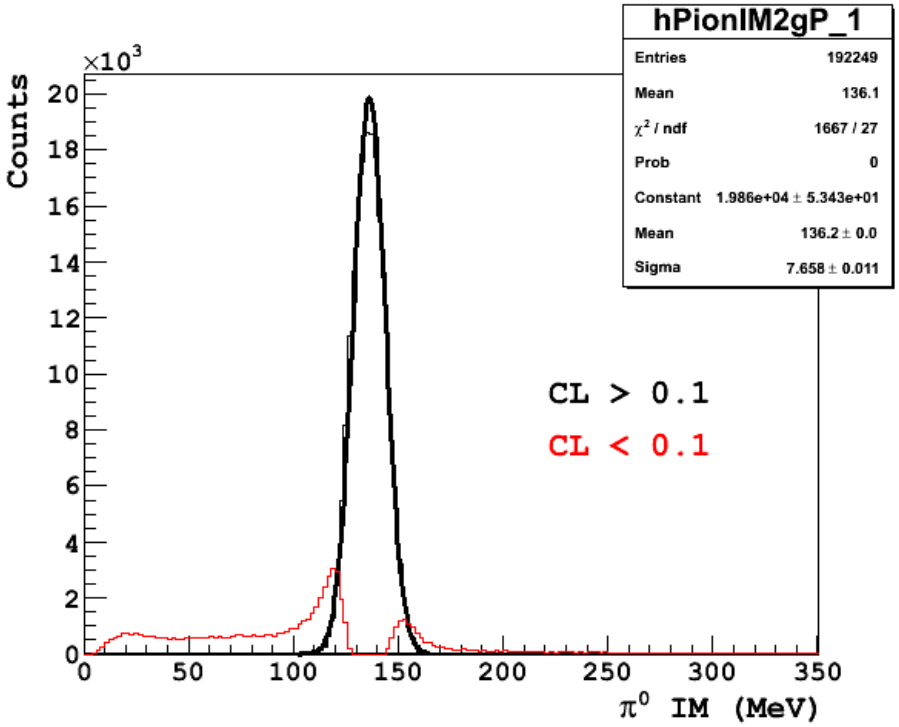
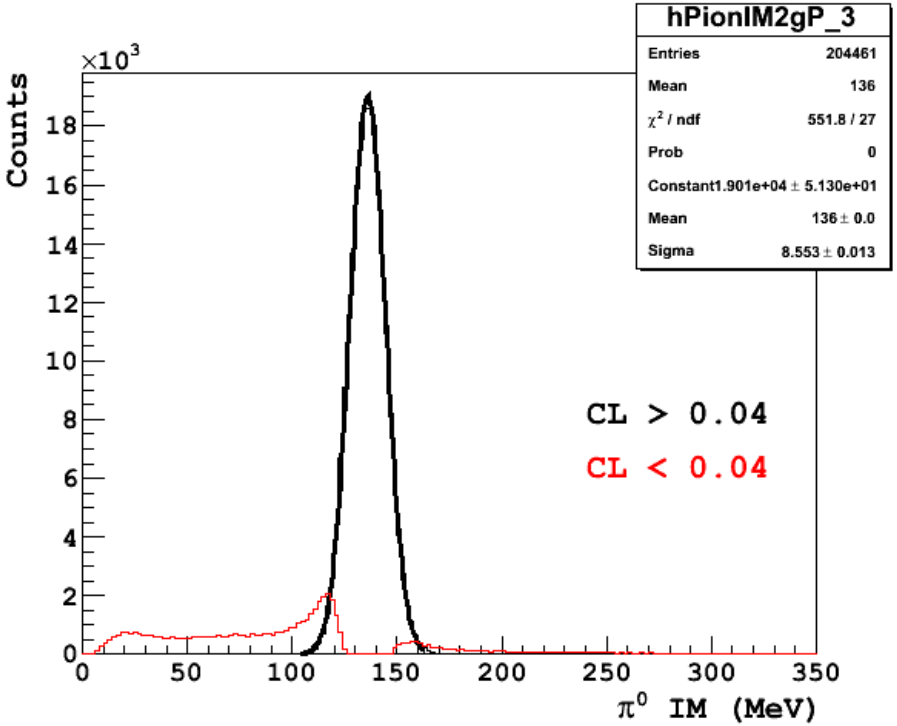
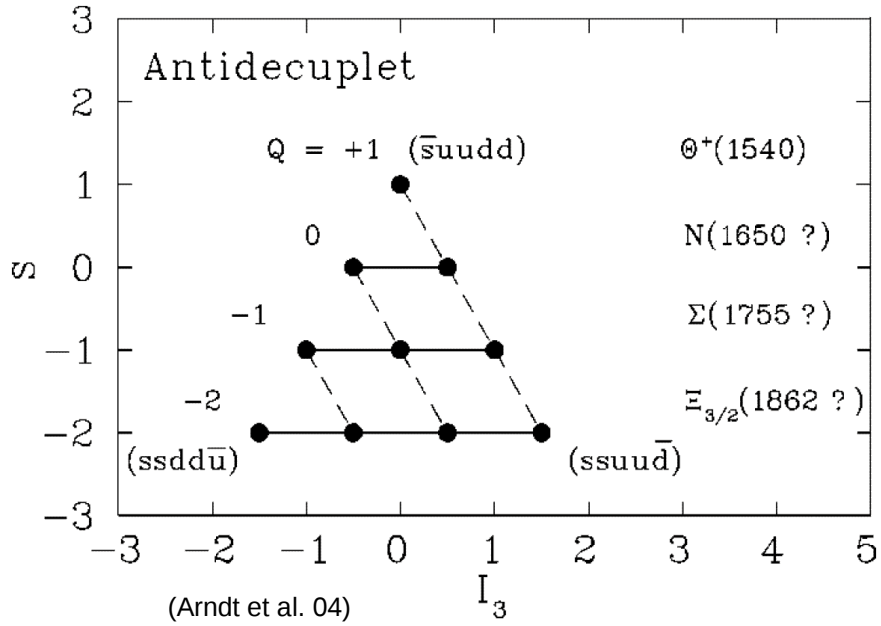




N*(1685) – A narrow nucleon resonance?



(Arndt et al. 04)

- Chiral Soliton model predicts baryon antidecuplet of 5 quark states
- Rotational excitation of solition core of three quarks surrounded by quark anti-quark pair
- N*(1685) is non-strange member of antidecuplet

(See Diakonov & Petrov Phys Rev. D **69** 094011 2004 for indepth explanation)

$$\gamma N \rightarrow N^* \rightarrow \eta N$$

- Eta photoproduction good tool to look for resonance
- Suppressed on proton target due to need to break SU(3) symmetry

Cross Section Analysis

$$\frac{d\sigma}{d\Omega} = \frac{N_{\eta \to n_\gamma \gamma}}{A_{\eta \to n_\gamma \gamma} \cdot N_\gamma \rho_t \cdot \Delta\Omega \cdot \frac{\Gamma_{\eta \to n_\gamma \gamma}}{\Gamma_{total}}}$$

ρ_t = 4.0128 x 10^{-16} m^{-2} : target area density

$N_{\eta \to n_\gamma \gamma}$ = number of reconstructed events in an $(E_\gamma, \cos(\theta_{cm}))$ bin

$A_{\eta \to n_\gamma \gamma}$ = acceptance in an $(E_\gamma, \cos(\theta_{cm}))$ bin

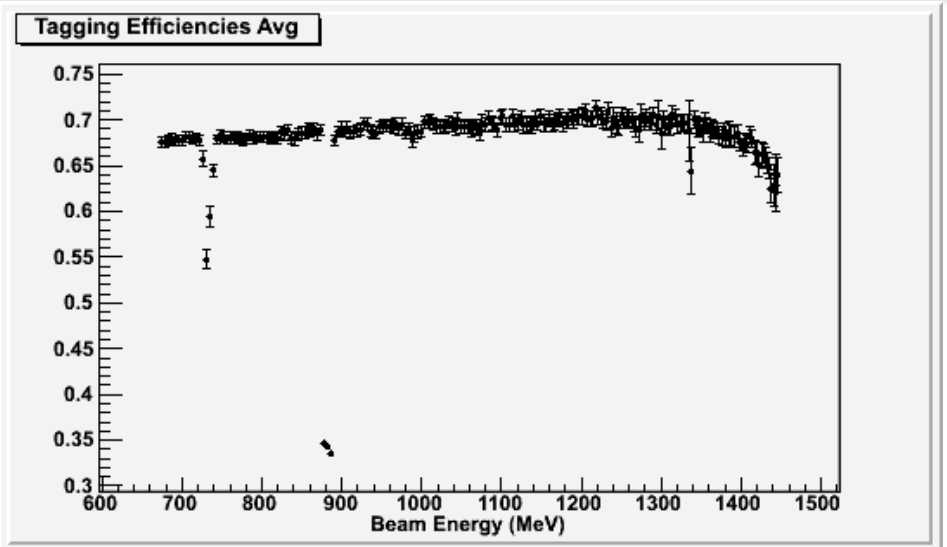
N_γ = number of photons in a E_γ bin

$\Delta\Omega$ = $2\pi\Delta\cos(\theta_{cm})$: solid-angle interval

$\frac{\Gamma_{\eta \to n_\gamma \gamma}}{\Gamma_{total}}$ = decay branching ratio $\eta \to 2\gamma$ $\eta \to 3\pi^0 \to 6\gamma$

Photon Flux

- Tagging Efficiency -
  - Ratio of tagged photons impinging on target



- Scalers -
  - Photons hitting the tagger