Photoproduction of $\pi^0\pi^+$ Pairs off the Free Proton

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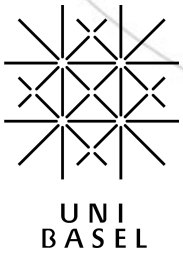
(on behalf of Samuel Abt)
For the A2 Collaboration
Hadron 2017



Outline

- Introduction
- Experimental Setup
- Analysis
- Preliminary Results
- Conclusion

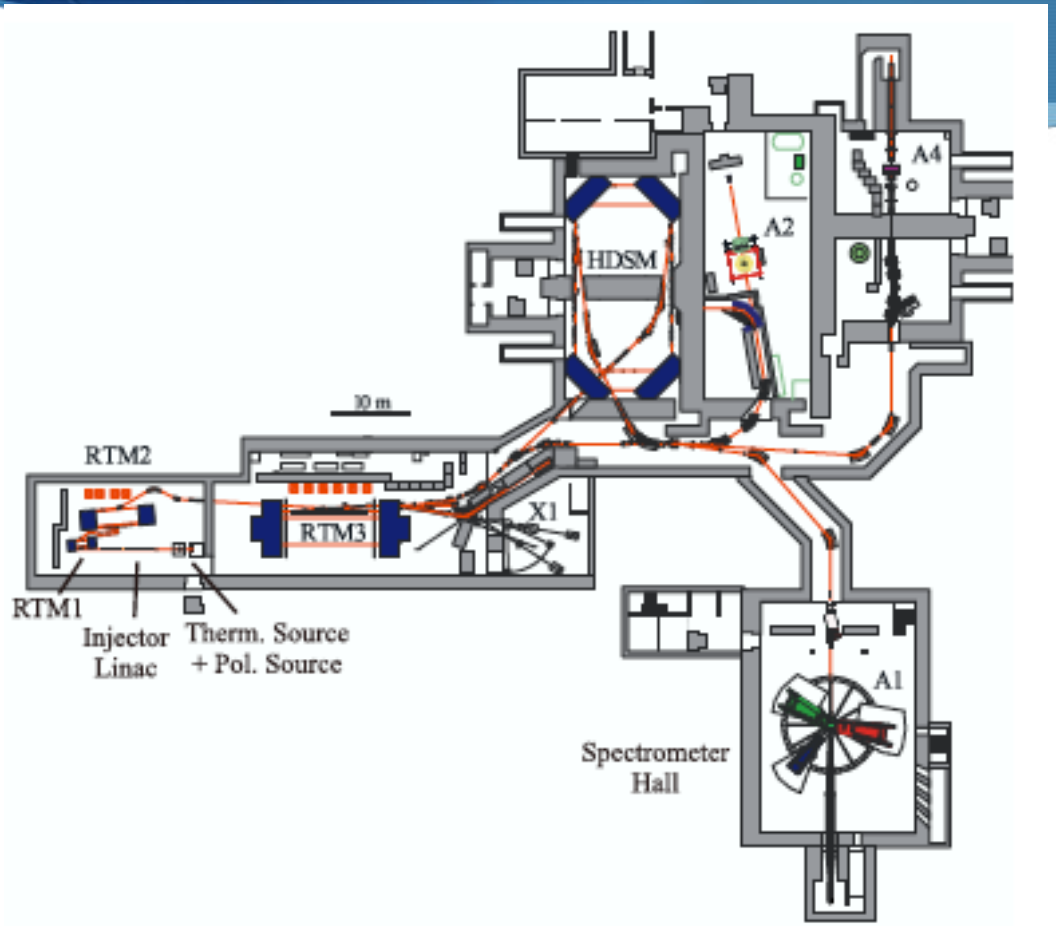
Motivation

- Experiment with pion pairs has many aims:
  - Insight into low energy QCD
  - Study resonances that have no significant decay to ground state
  - Look at elementary decay via ρ emission
  - Due to isospin selectivity, ρ can only contribute to π pairs when two charged pions are present
    - Particularly: intermediate state ρ forbidden for neutral state $\pi^0\pi^0$
  - Study in medium modifications of ρ and those that couple strongly to ρ
    - Specifically, D_{13} couples strongly to ρ
    - Determine Γ of $D_{13,}$ which gives insights into in medium modifications

Channel Analyzed

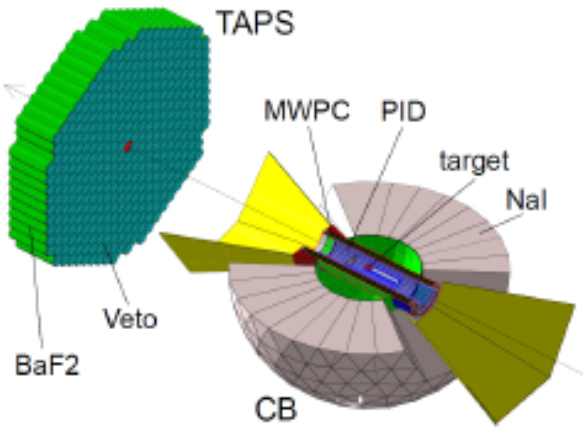
γ p -> π^+ π^0 n
phase space
via Δ^+ -> π^+ π^0 n
via Δ^0 -> π^+ π^0 n
via ρ^+ -> π^+ π^0 n

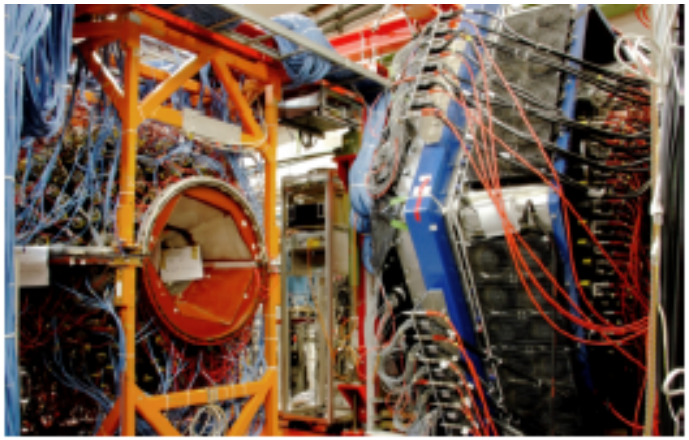
MAinz MIcrotron



- LINAC (3.97 MeV)
- Racetrack microtrons (855 MeV)
- Harmonic double sided microtron (up to 1.6 GeV)
  - Linear beam available
  - Circular beam available

Crystal Ball/TAPS Setup





- Crystal Ball:
  - 672 NaI crystals
    $20° < \theta < 160°$
- TAPS:
  - 366 BaF_2 crystals and 72 $PbWO_4$ crystals
    $2° < \theta < 20°$
- PID done using $\Delta E - E$ with a plastic scintillator barrel
- Charged particles accessible with MWPC, no magnetic field
- Liquid hydrogen target used

Beam Time Parameters

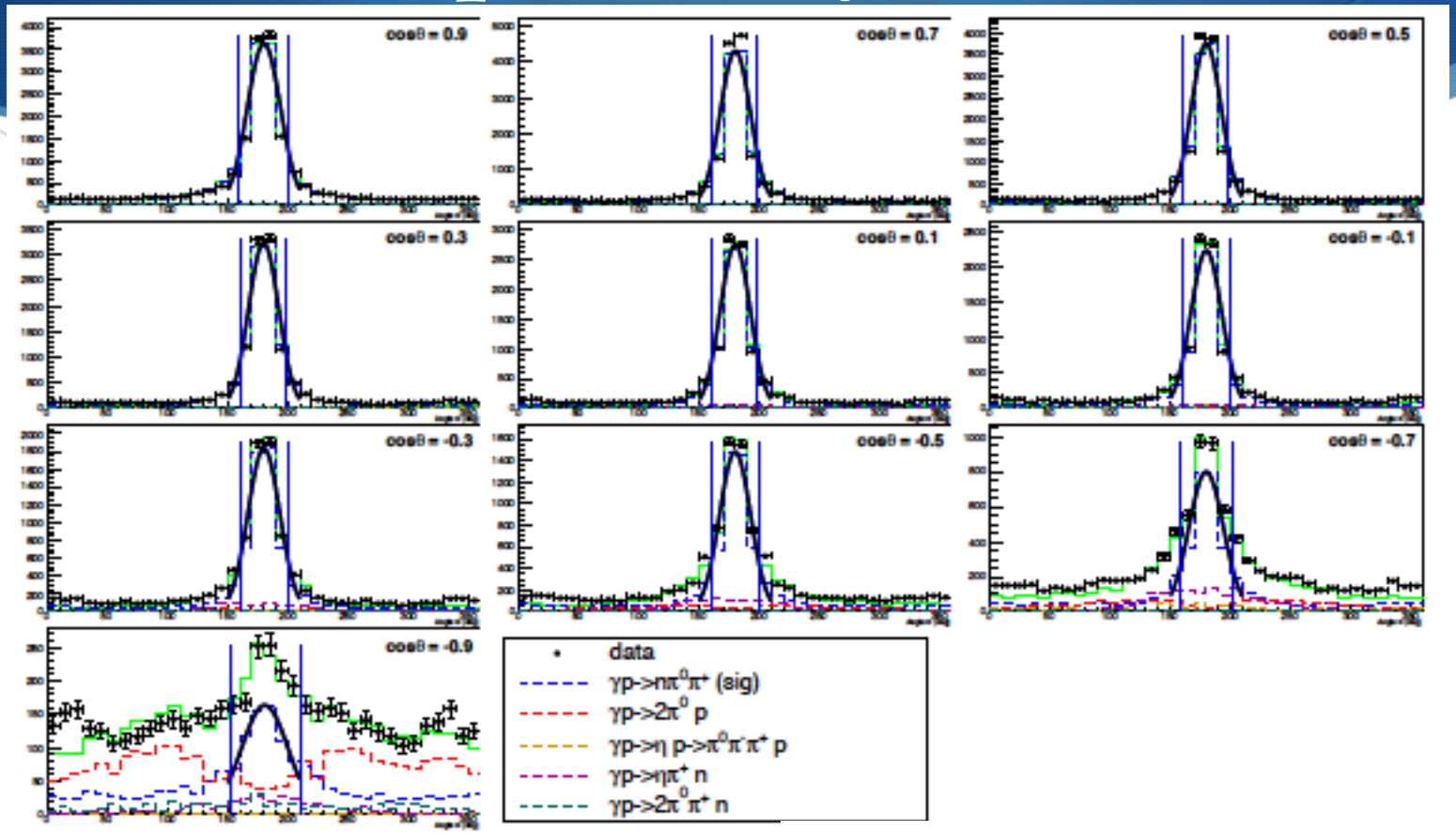
- Density of target: 422 mb^{-1}, length: 10 cm
- Trigger: M3+ (three or more particles in CB)
- CB Energy Sum: 360 MeV
- Electron Beam Energy: 1557.5 MeV
- Photon Tagger Range: 400 to 1400 MeV

Property	Range	Number of Bins	Bin Width
photon energy E_γ	450 – 1450 [MeV]	50	20 [MeV]
$\cos\theta$	-1 – 1 [rad]	10	0.2 [rad]
mass distribution $m(n\pi^0)$	800 – 1840 [MeV]	52	20 [MeV]
mass distribution $m(n\pi^+)$	800 – 1840 [MeV]	52	20 [MeV]
mass distribution $m(\pi^0\pi^+)$	200 – 1240 [MeV]	52	20 [MeV]

Analysis Presort

- Select events: 3 neutral and 1 charged
- Reconstruct π^0 from 2 γ decay with X^2-test and third particle is assumed to be a neutron
- Apply X^2-test for η and when in favor, discard event
- Pulse shape analysis for γ and neutron
- $\Delta E - E$ analysis for π^+

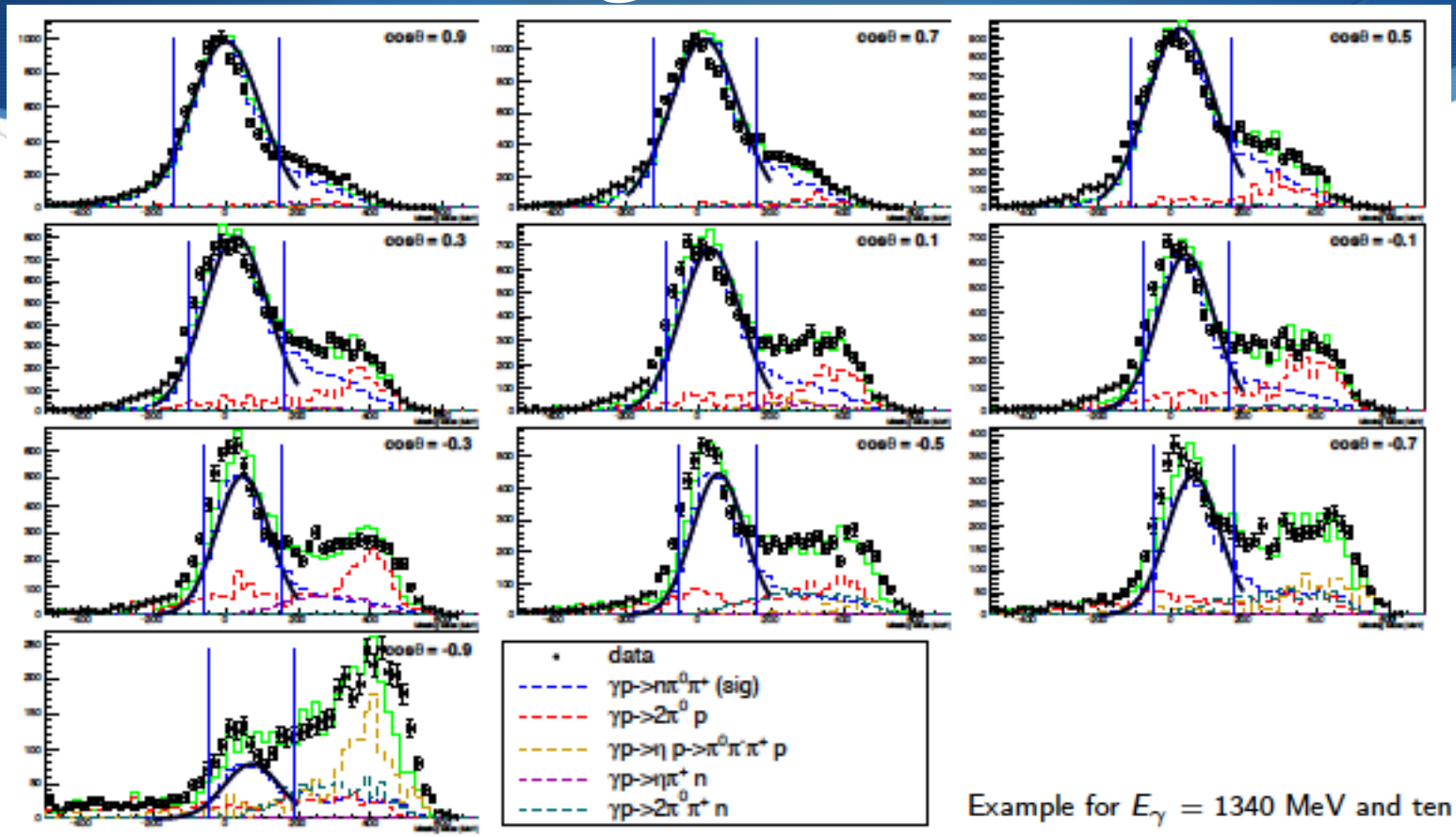
Coplanarity Cuts



Example for $E_\gamma = 1340$ MeV and ten $\cos\theta$ bins

$$\Delta\phi = \begin{cases} \phi - \phi_n, & \text{if } \phi - \phi_n \geq 0 \\ 2\pi - |\phi - \phi_n|, & \text{if } \phi - \phi_n < 0 \end{cases}$$

Missing Mass Cuts



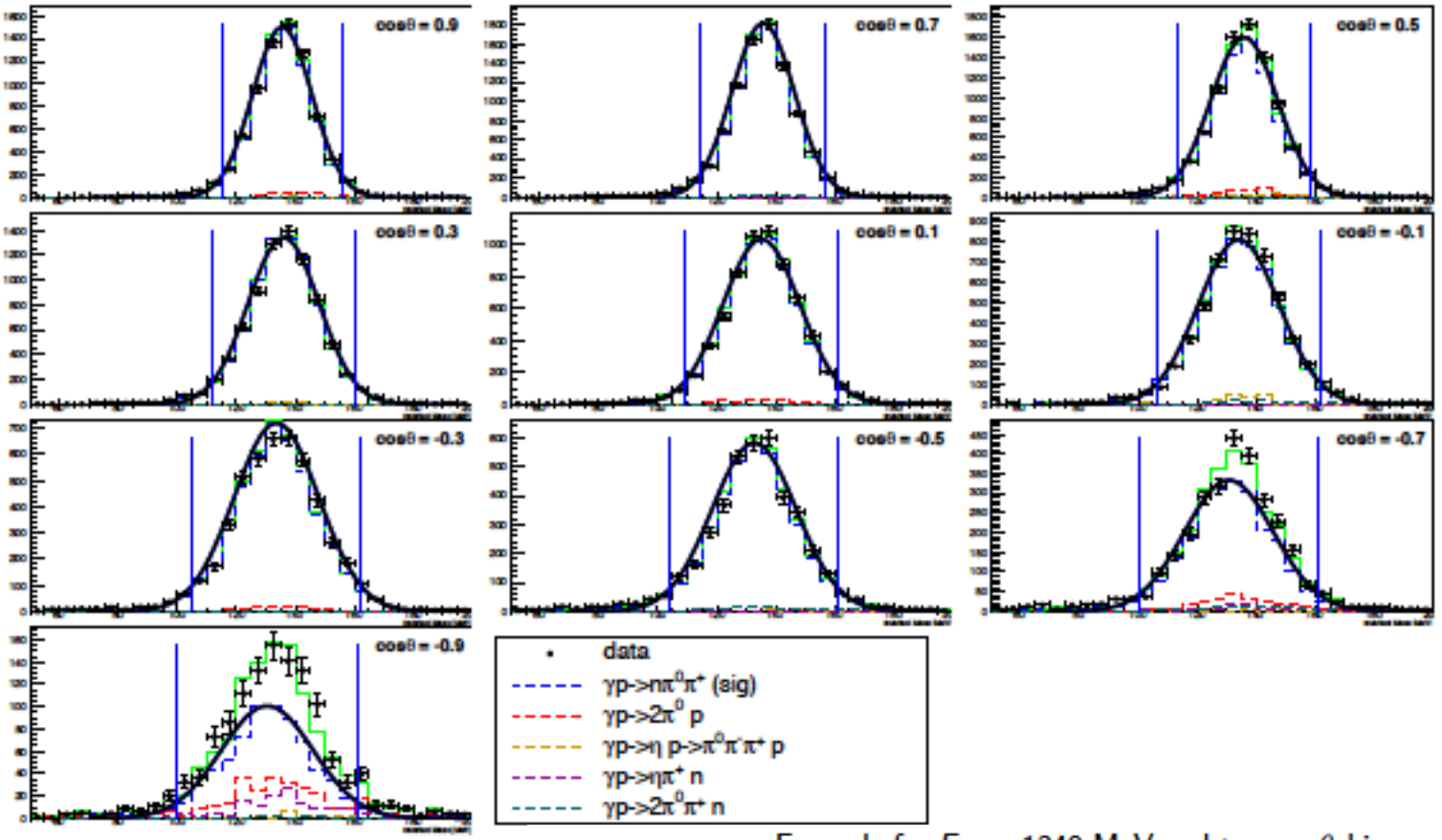
Example for $E_\gamma = 1340$ MeV and ten $\cos\theta$ bins

$$\mathbb{P}_{is} = \mathbb{P}_\gamma + \mathbb{P}_p$$

$$\mathbb{P} = \mathbb{P}_{\pi 0} + \mathbb{P}_{\pi +}$$

$$m_x = |\mathbb{P}_{is} - \mathbb{P}| - m_n$$

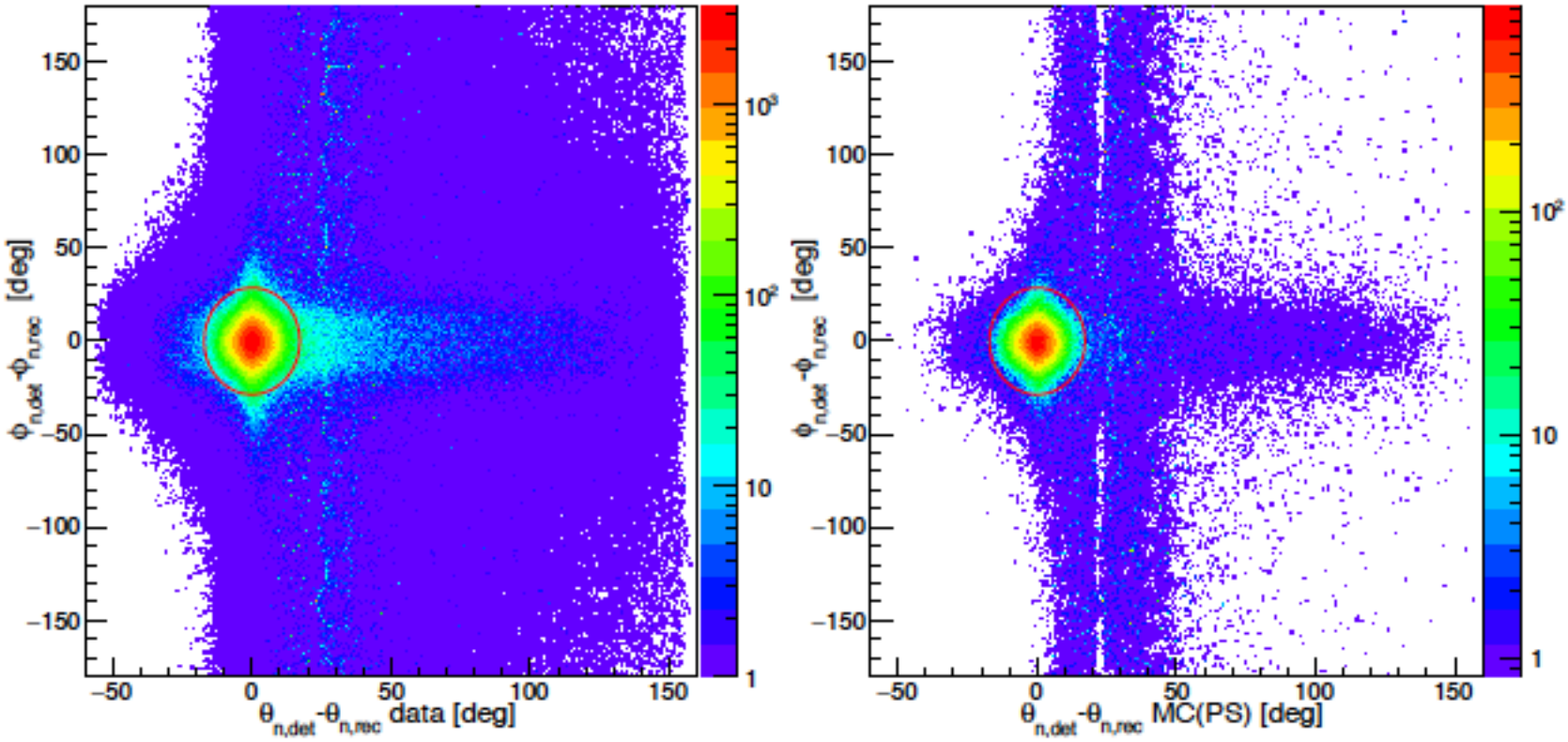
Invariant Mass Cuts



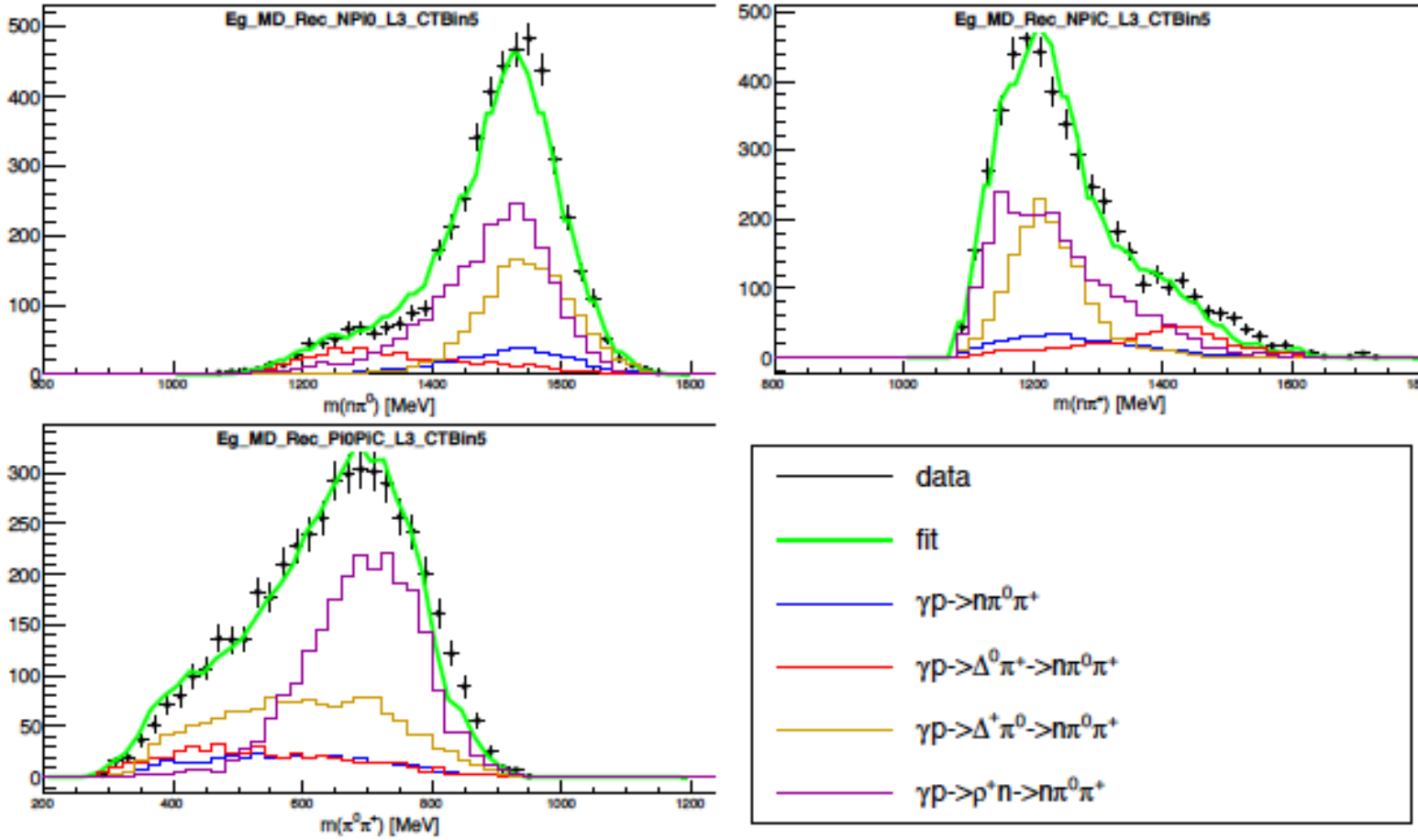
Example for $E_\gamma = 1340$ MeV and ten $\cos\theta$ bins

$$m\left(\pi^0\right) = \sqrt{2\mathbb{P}_{\gamma_1}\mathbb{P}_{\gamma_2}} = \sqrt{2E_{\gamma_1}E_{\gamma_2}\left(1-\cos\phi_{\gamma_1\gamma_2}\right)}$$

Reconstruction Angle Cut of Neutron

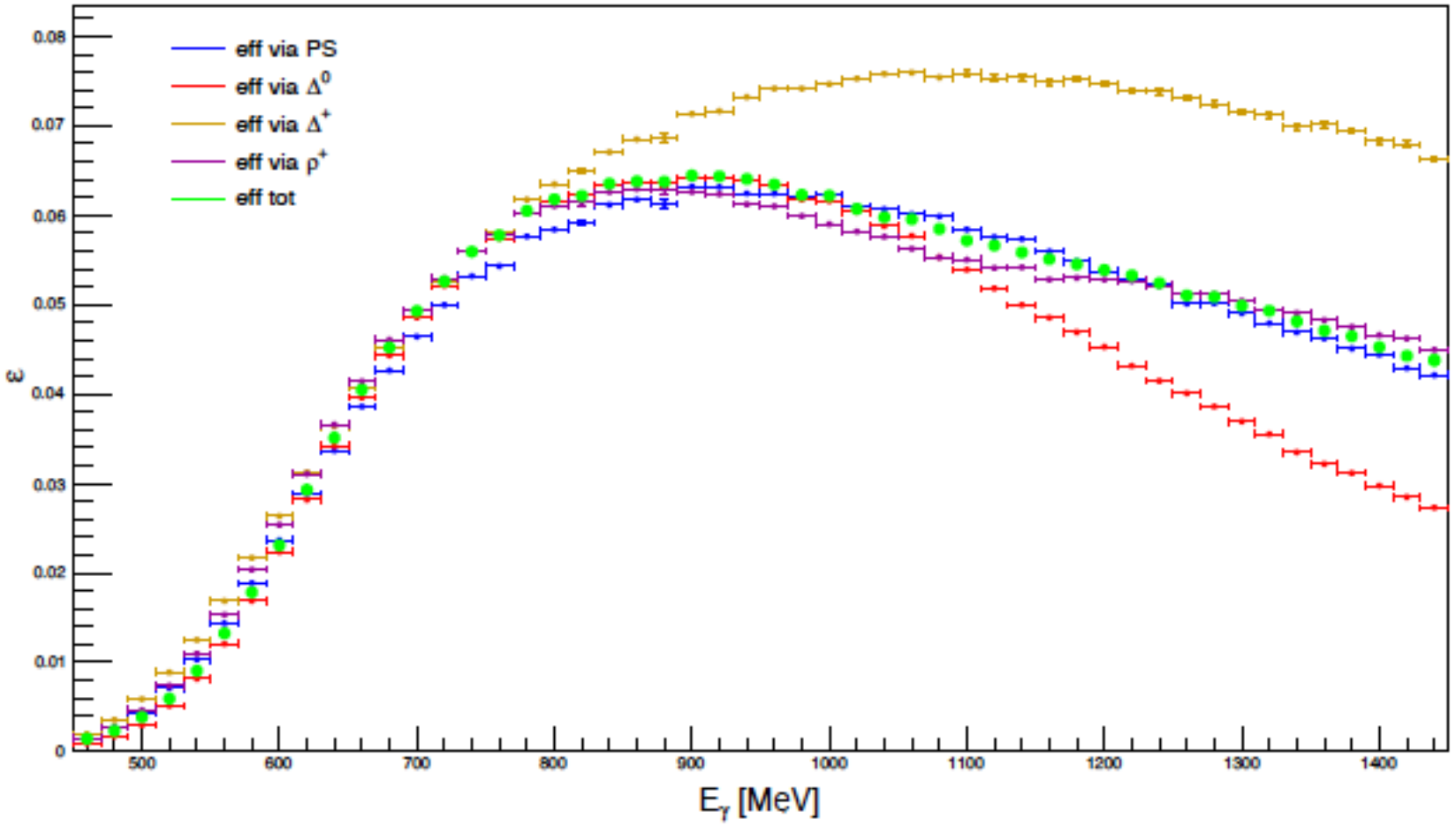


Determination of Fraction Ratios



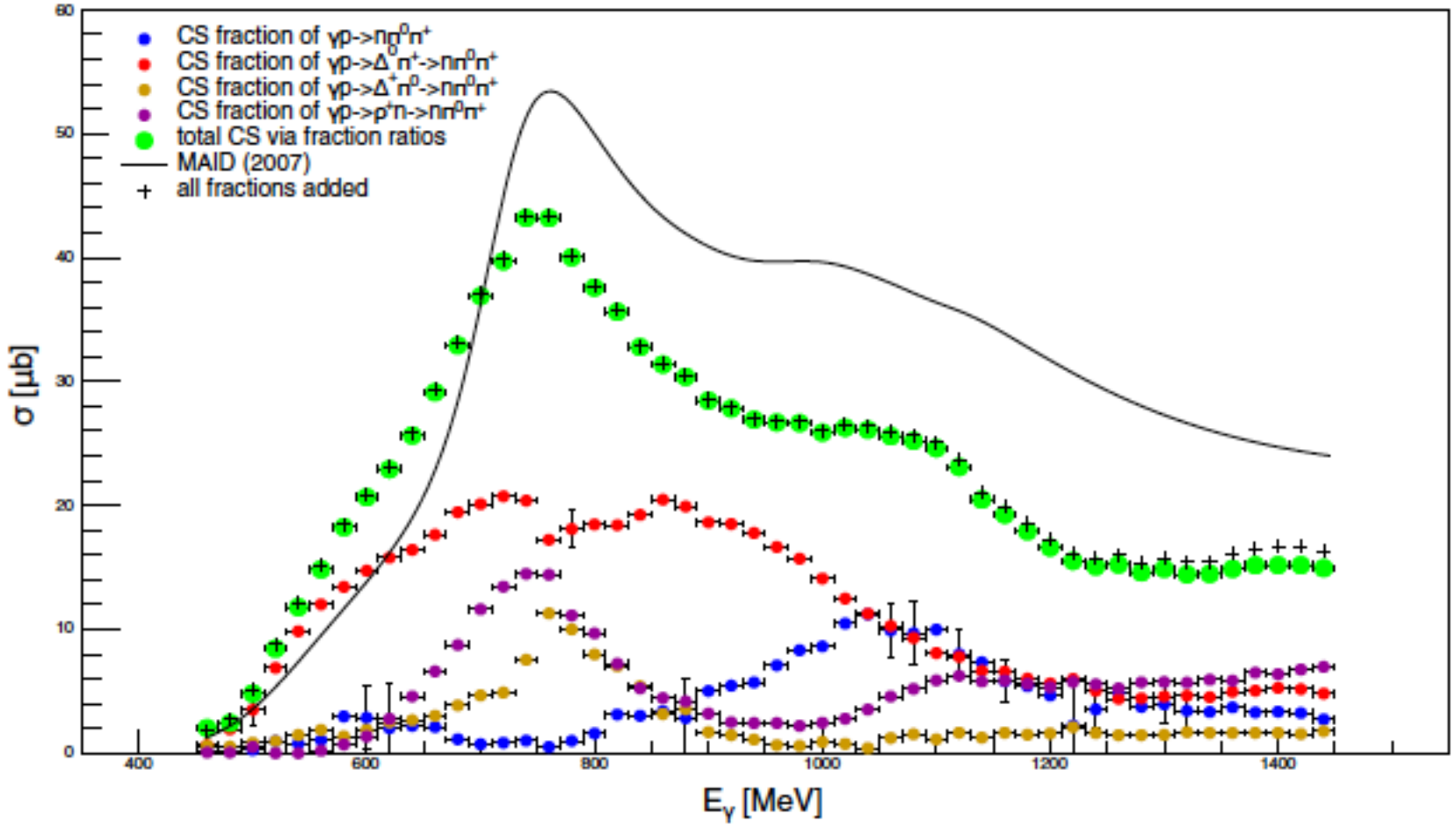
Example for $E_\gamma = 1340$ MeV and $\cos\theta = 0$

Efficiencies

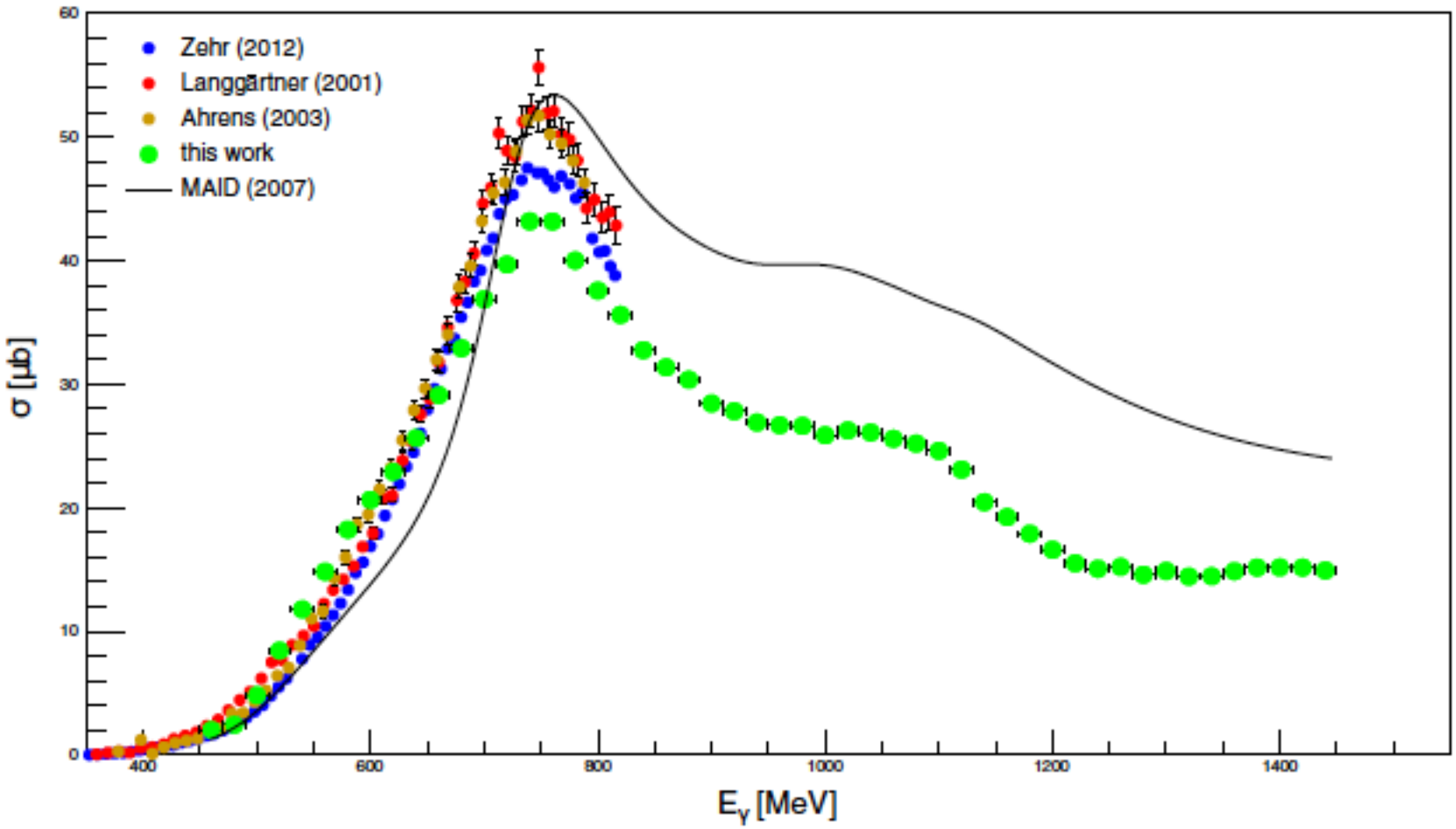


Separate detection efficiencies for all four signal contributions

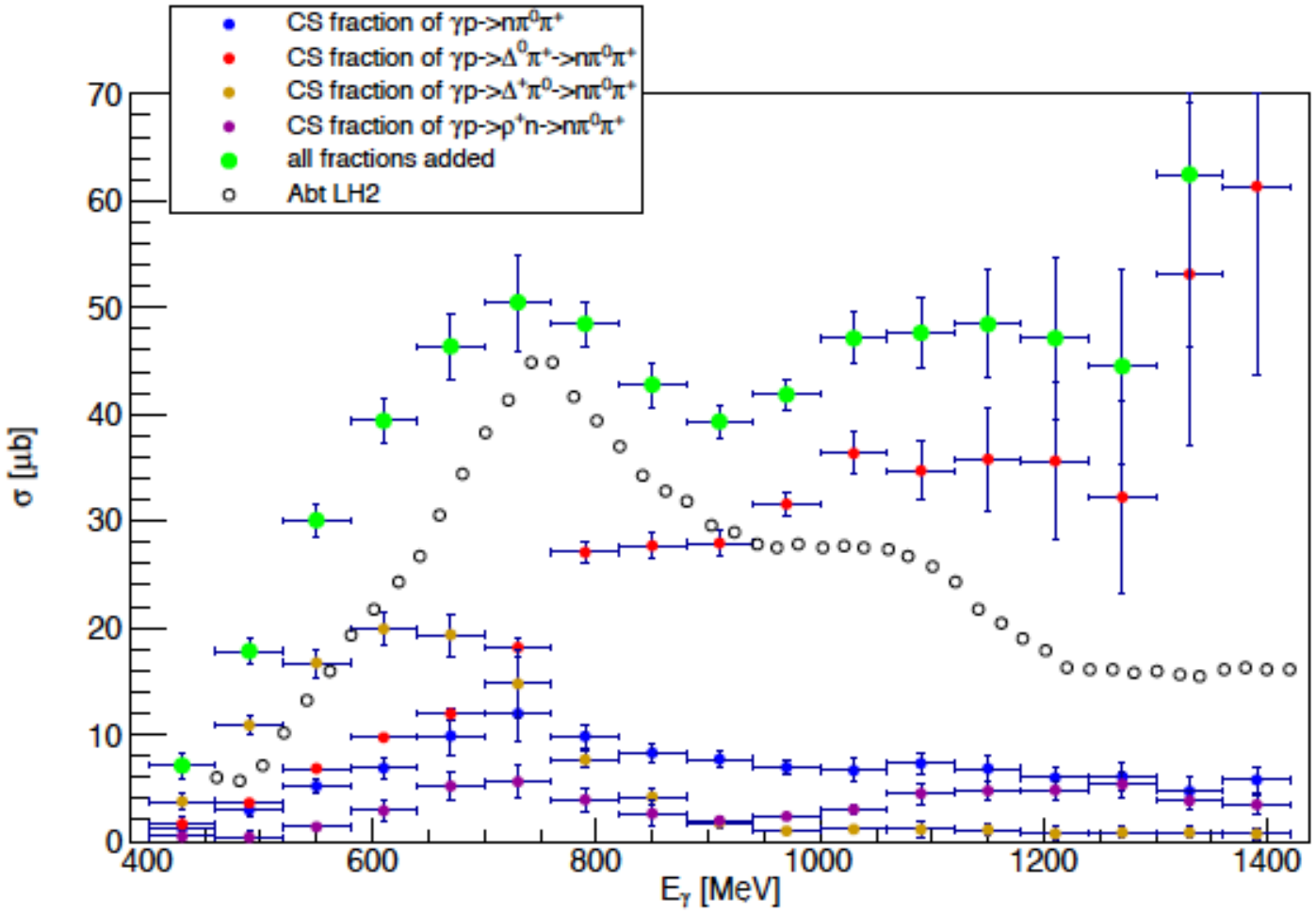
Total Cross Section



Total Cross Section Comparison

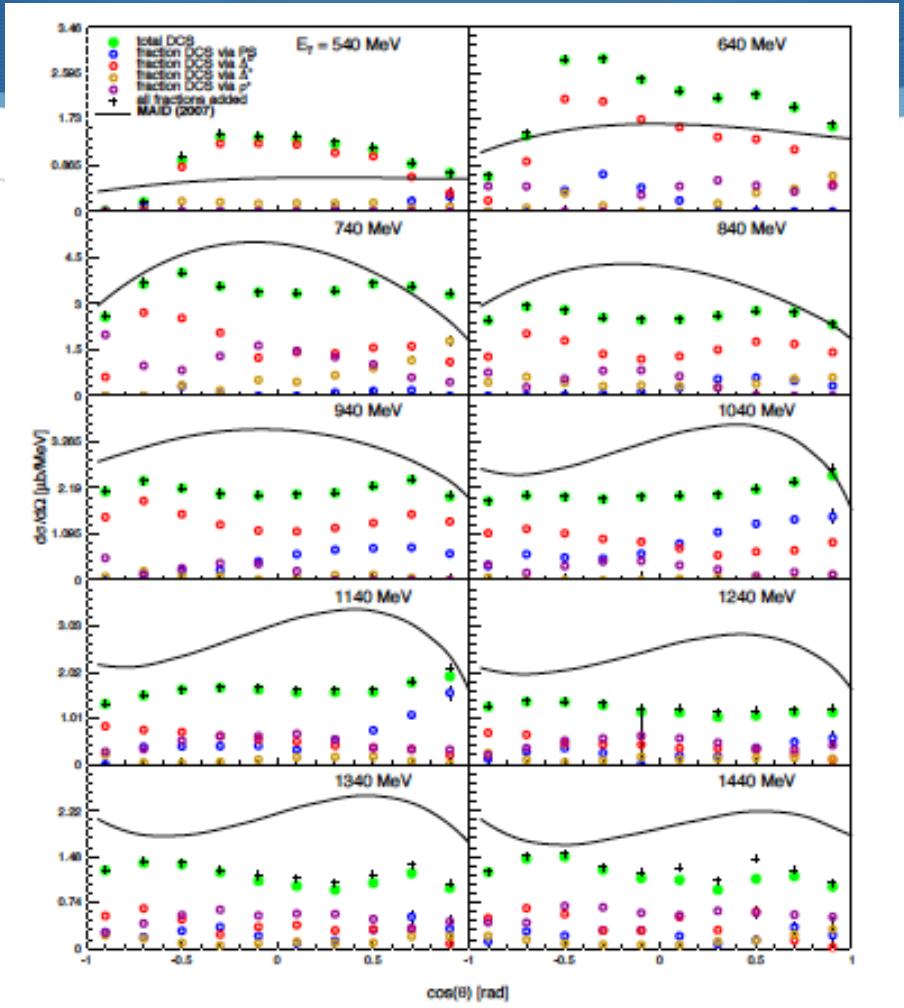


Total Cross Section from Deuteron

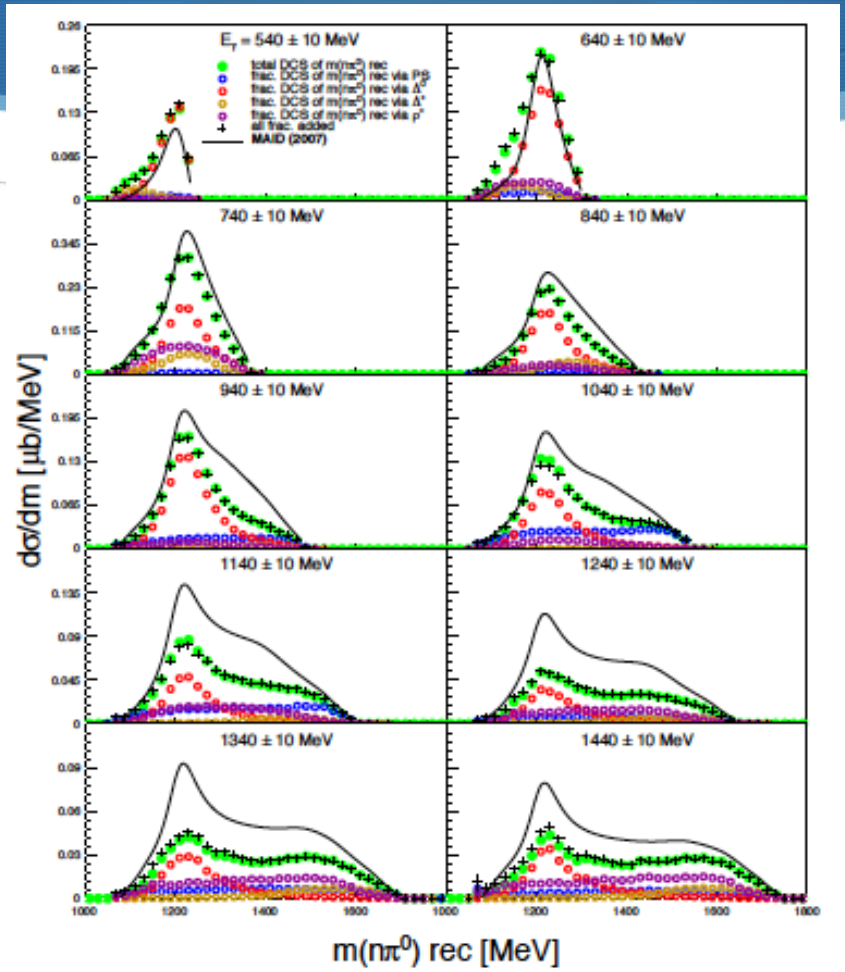


Work by S. Lutterer

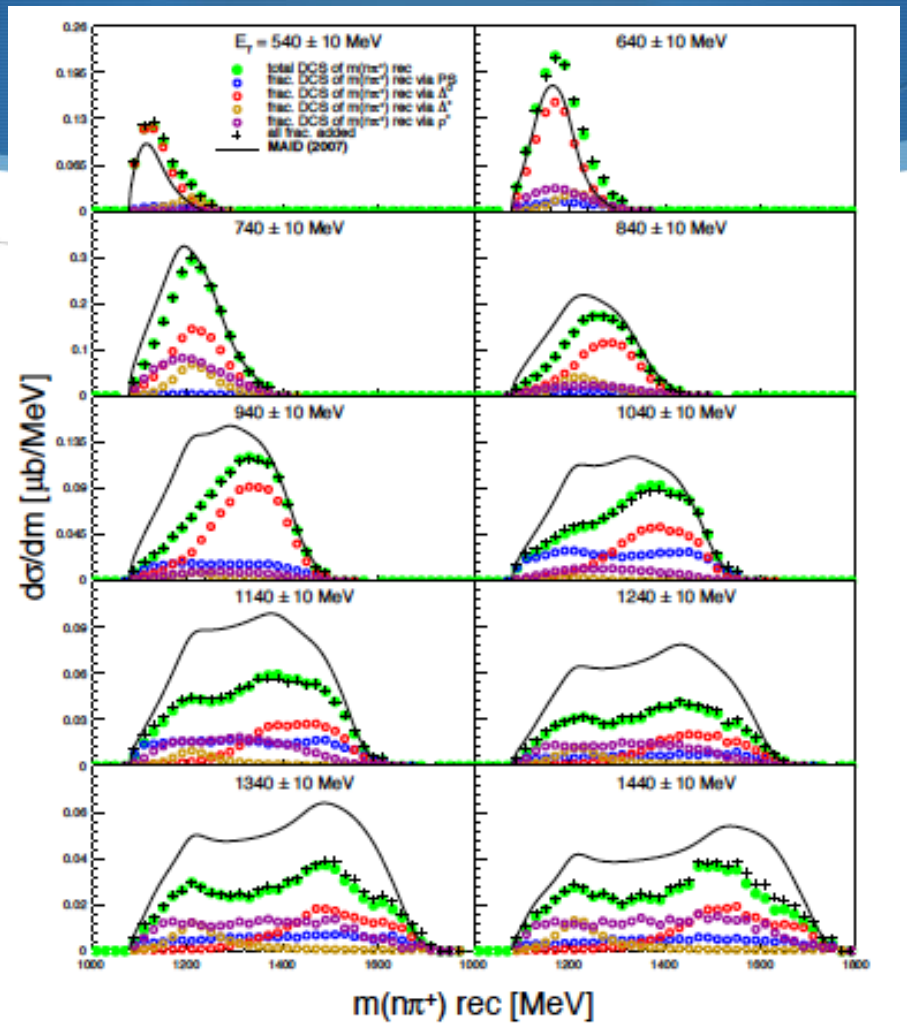
Angular Differential Cross Sections



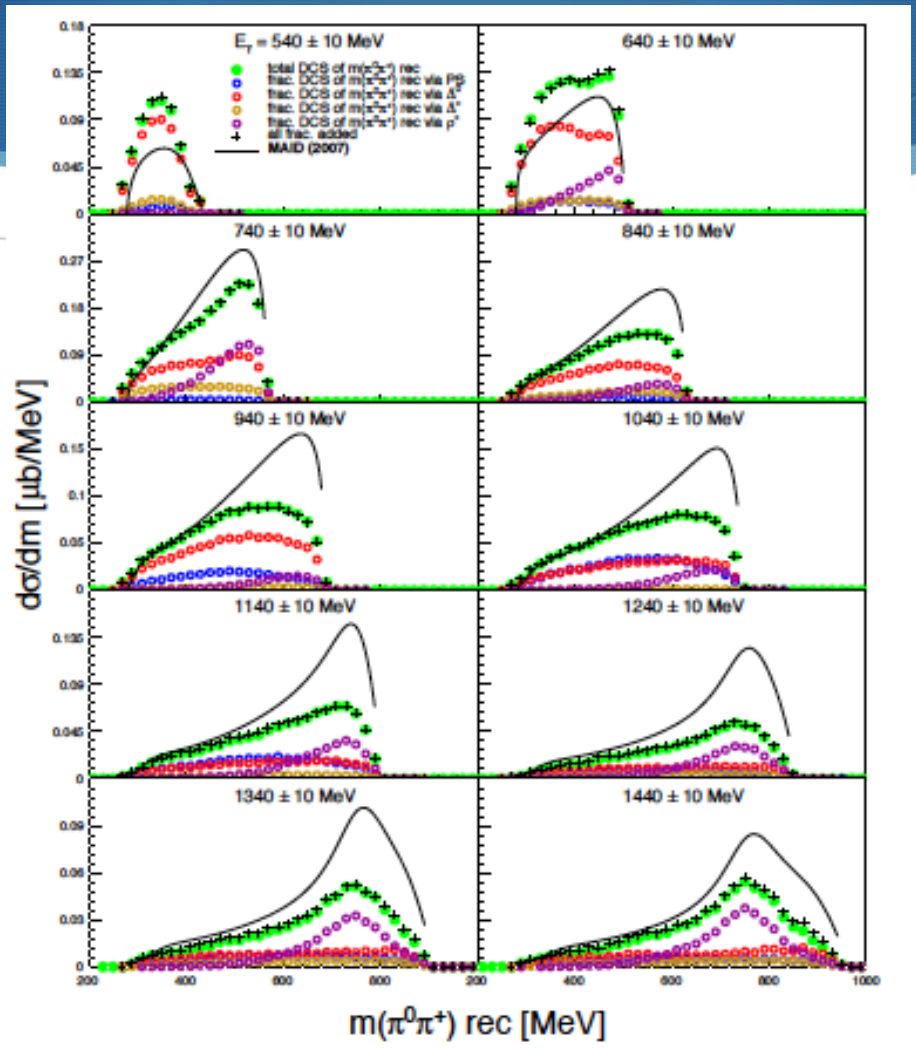
DCS of Mass Distribution m($n\pi^0$)



DCS of Mass Distribution m(nπ⁺)



DCS of Mass Distribution $m(\pi^0\pi^+)$



Conclusion

- The preliminary analysis indicates that the branching ratios are similar
- ρ decay has a different shape than the sequential decays
- Can see from analysis that ρ makes a large contribution in area of D_{13} resonance
- For a full analysis, a partial wave analysis will be required
- A better model is also required
- Will also investigate channel from ^{4}He data taken in A2 earlier this year