Recoil Polarisation Measurements in Meson Photoproduction

Narrow Nucleon Resonance Workshop

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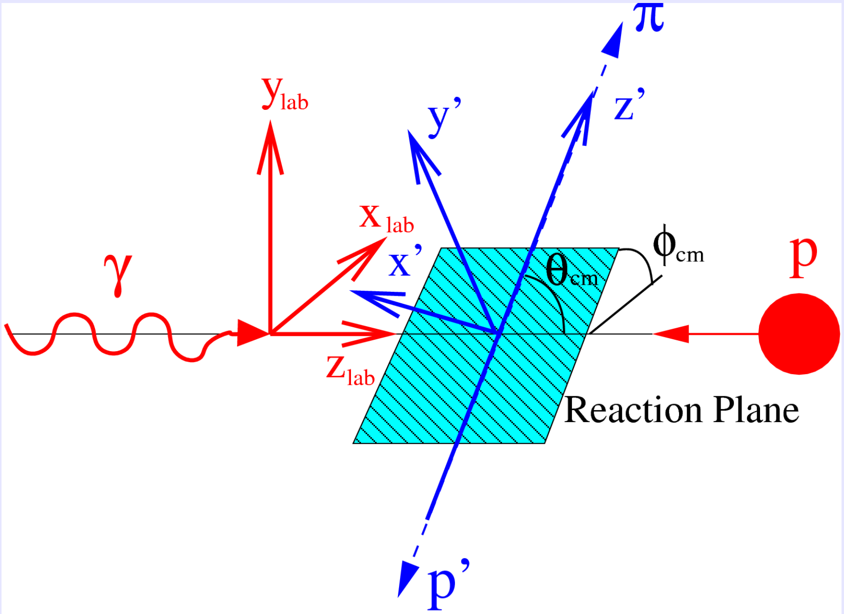
Recoil Polarisation Measurements

- 16 photoproduction observables providing different sensitivities to the reaction amplitudes
- Highly desirable to have recoil observables in addition to beam and target
- Partial Wave Analysis then allows extraction of nucleon resonance characteristics
- Proton and Neutron targets to seperate isospin amplitudes
- Small enough E and θ bins to resolve resonance structure

Beam-Recoil Observables



$$\rho_f \frac{d\sigma}{d\Omega} = \frac{1}{2}\frac{d\sigma}{d\Omega_{un}} \{1 - P_\gamma^T \Sigma \cos 2\phi - \sigma_{x'} \left(P_\gamma^T O_x \sin 2\phi + P_\gamma^C C_x\right)$$
$$+\sigma_{y'} \left(P - P_\gamma^T T \cos 2\phi\right) - \sigma_{z'} \left(P_\gamma^T O_z \sin 2\phi + P_\gamma^C C_z\right)\}$$

Linear P_γ^T and Circular P_γ^C beam polarisation

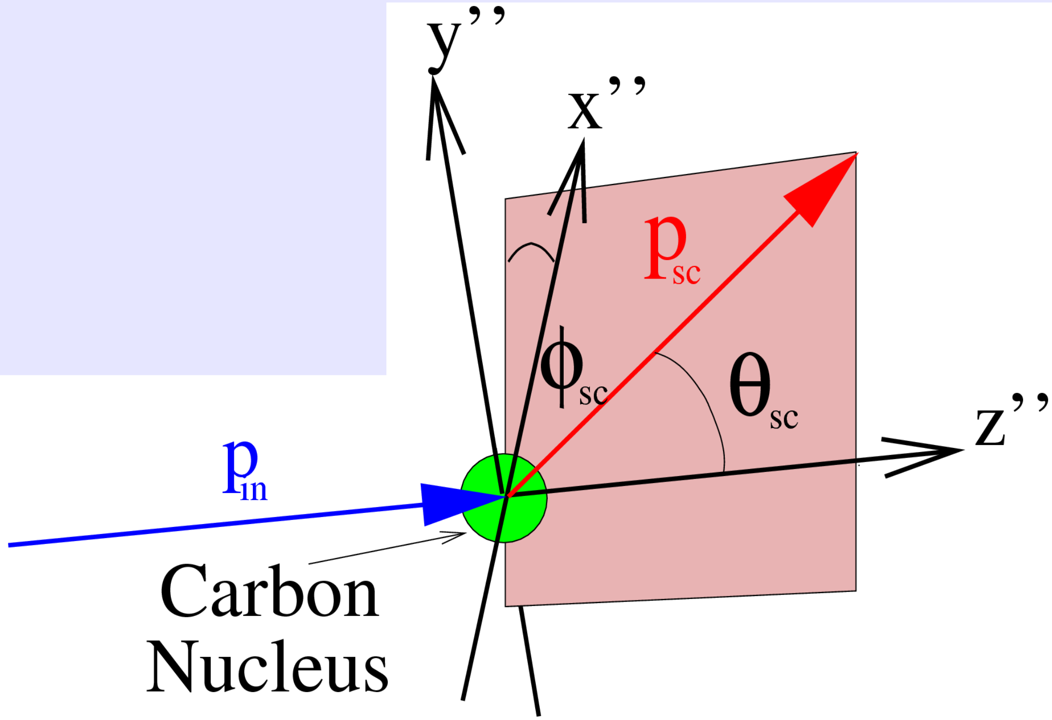
+ **Recoil Polarisation Measurement**

$\Rightarrow$ access to 6 photoproduction observables

No Magnetic Field $\Rightarrow$ Only measure tranverse polarisation

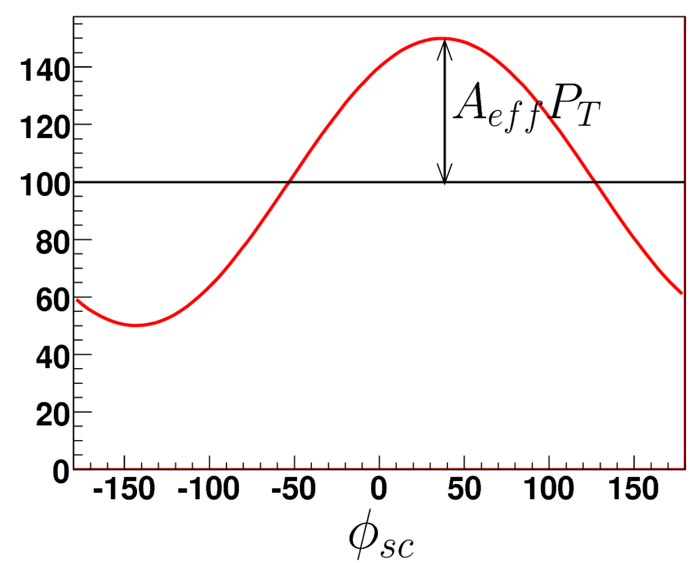
$\therefore$ We can measure $P,\ T,\ O_x,\ C_x$

Measuring Nucleon Polarisation

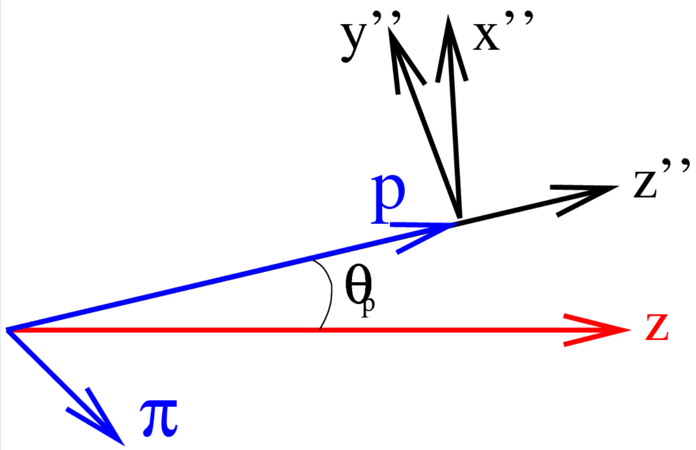


- Use Spin Orbit Interaction
- Azimuthal distribution related to transverse polarisation

$$
\begin{aligned}
n\left(\phi_{sc}\right) &= n_o\left\{1 + A_{eff}\left[P_y\cos\phi_{sc} - P_x\sin\phi_{sc}\right]\right\} \\
&= n_o\left\{1 + A_{eff}P_T\sin\left(\phi_{sc}+\phi_0\right)\right\} \\
\text{with} \quad P_T &= \sqrt{P_x^2+P_y^2} \text{ and } \phi_0 = \arctan\left(-\frac{P_y}{P_x}\right)
\end{aligned}
$$



Polarimeter Reference Frame



Polarisation $P = (P_x, P_y, P_z)$

defined in Lab. frame :

$$\underline{z}'' = \frac{\underline{p}}{|\underline{p}|} \quad \underline{y}'' = \frac{\underline{z} \times \underline{p}}{|\underline{z} \times \underline{p}|} \quad \underline{x}'' = \underline{y}'' \times \underline{z}''$$

The polarisation is Lorentz Rotated from primed CM frame

Effectively rotated around Y-axis
e.g. $C_x \rightarrow C''_x(C_x, C_z)$

- Unpolarised Beam

$P_x = P_z = 0$ and $P_y = -P$

- Circularly Polarised Beam

$P_x = -P^C_\gamma C''_x$, $P_y = -P$ and $P_z = P^C_\gamma C''_z$

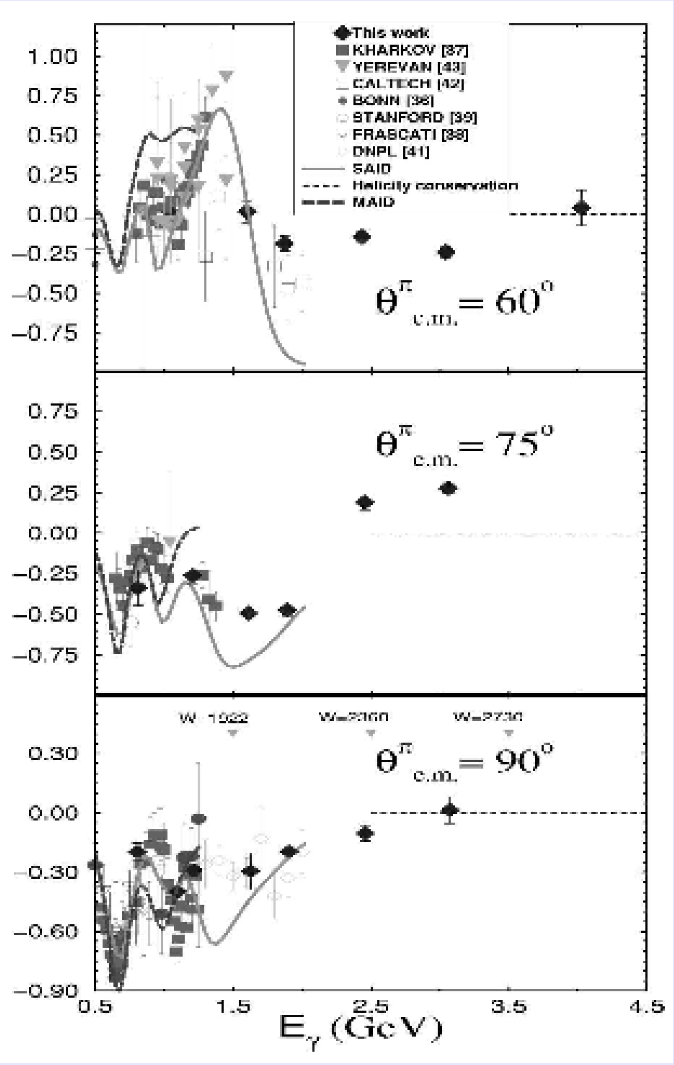
- Linearly Polarised Beam

$$P_x = \frac{-P^T_\gamma O''_x \sin 2\phi}{(1 - P^T_\gamma \Sigma \cos 2\phi)}, \quad P_y = \frac{-P + P^T_\gamma T \cos 2\phi}{(1 - P^T_\gamma \Sigma \cos 2\phi)} \text{ and } P_z = \frac{P^T_\gamma O''_z \sin 2\phi}{(1 - P^T_\gamma \Sigma \cos 2\phi)}$$

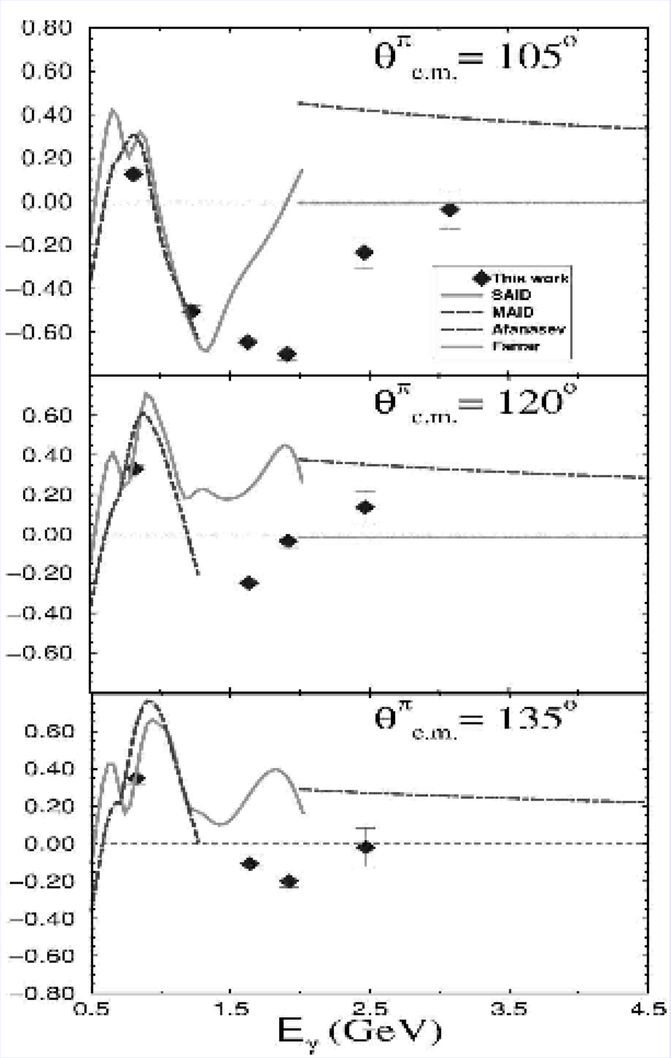
JLab Hall A Results for π^o photoproduction

Phys.Rev. C, 66 034614 (2002)

P



c_x



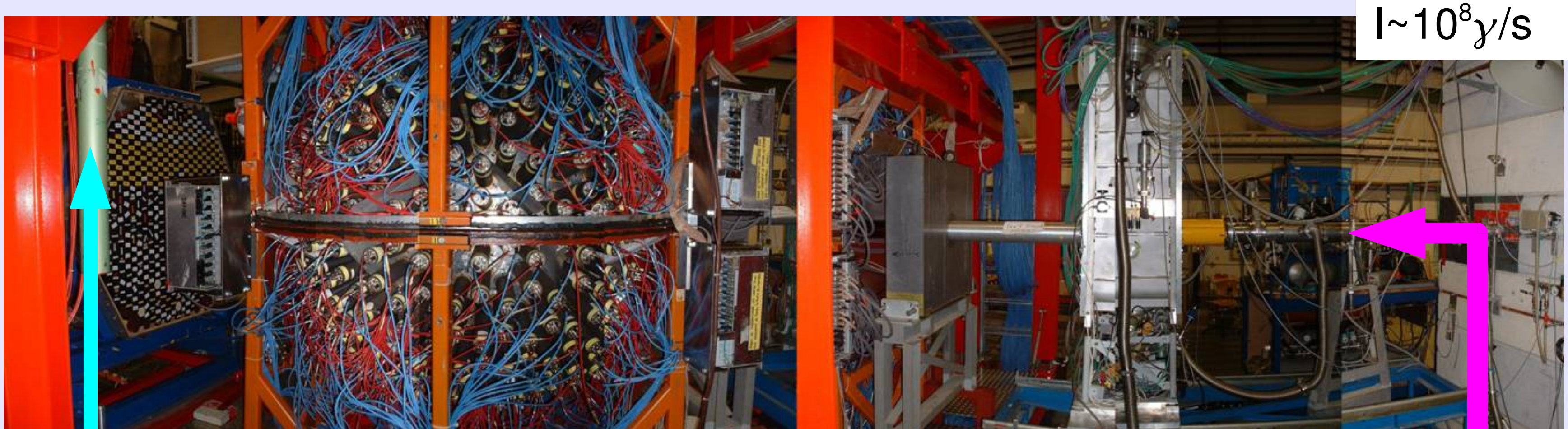
- Used Focal Plane Polarimeter on magnetic spectrometer
  ~30 Data points for P, C_x and C_z
  $0.8<E_\gamma<4.1$GeV, $60<\theta<135$

- Also a reasonable number of previous P measurements below 1.5 GeV

CrystalBall at MAMI

σ_E~2 MeV

I~$10^8\gamma$/s



TAPS

384 BaF2 Crystals

Forward 21°

1.5m upstream

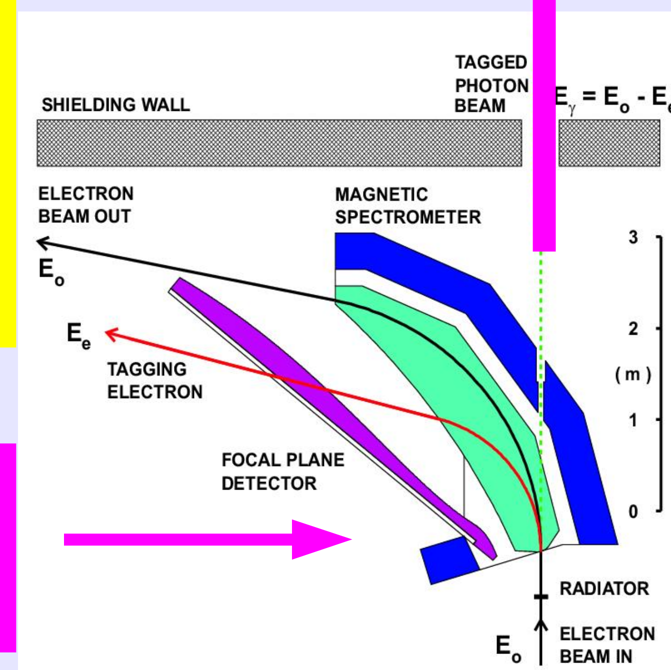
CB 672 NaI(Ti) Crystals

Spherically arranged

around target

93% phase space

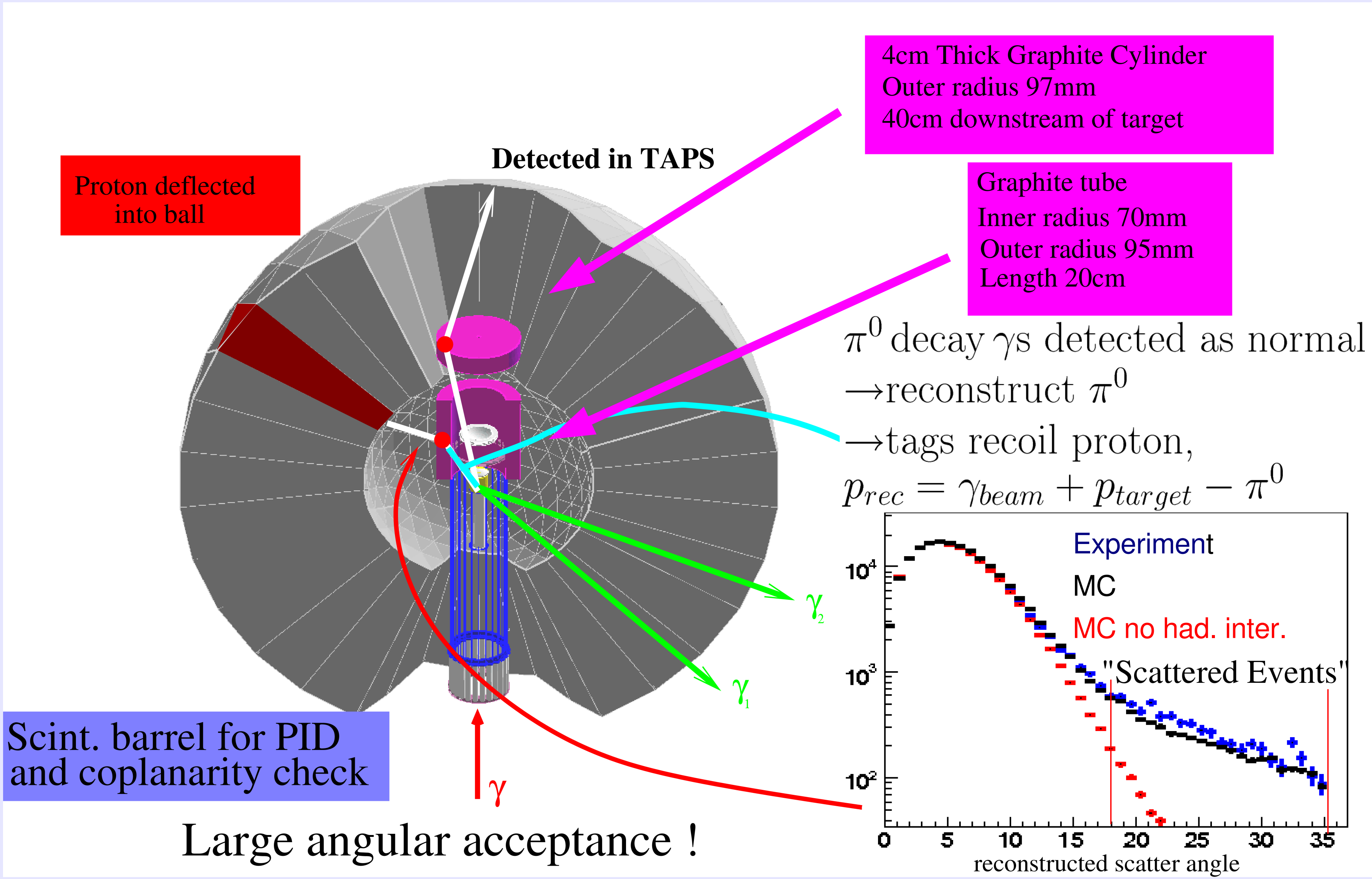
Linear or circular pol.



MAMI-C provides 1.5GeV e-

Tag Brem. Photons to 1.4GeV-

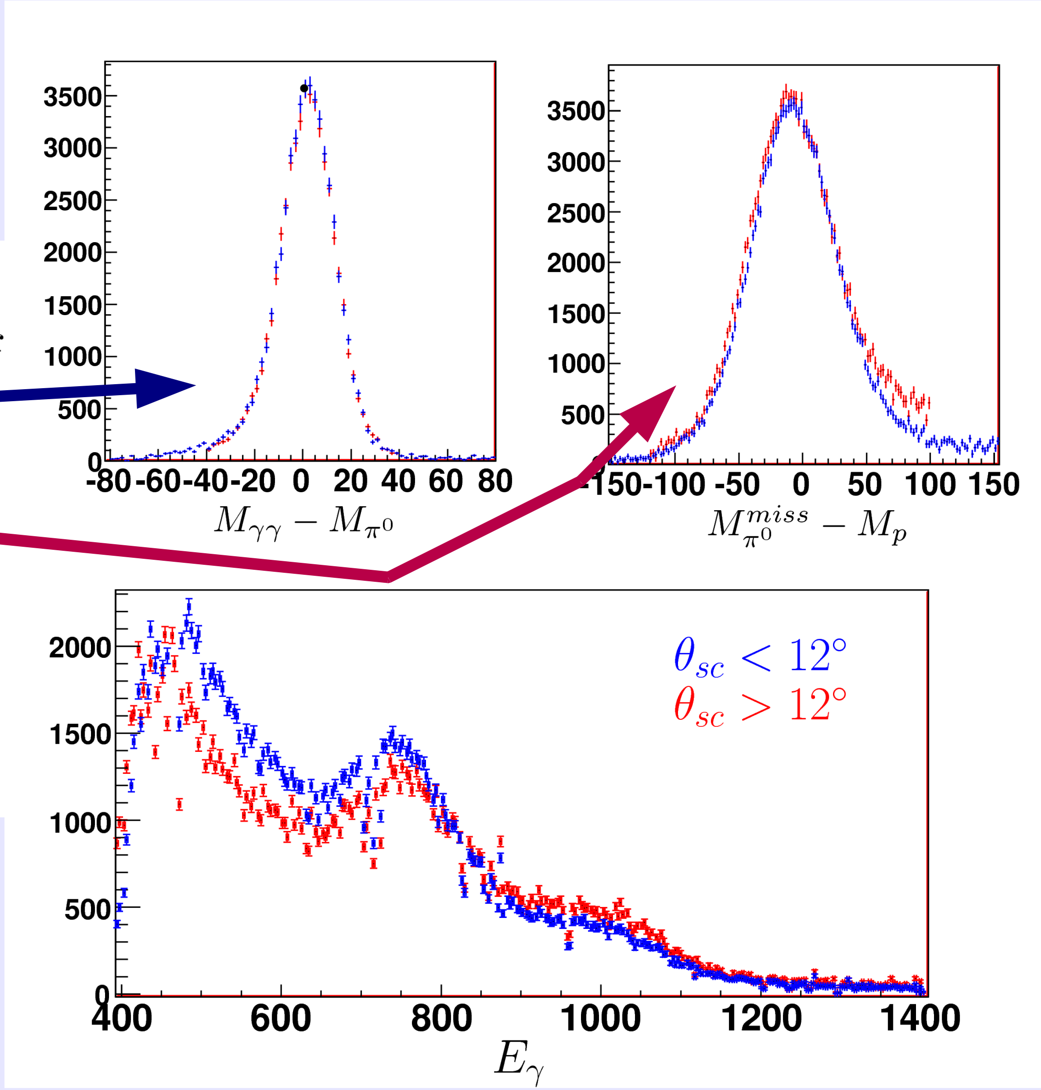
Proton Polarimeter



Polarimeter Data Analysis

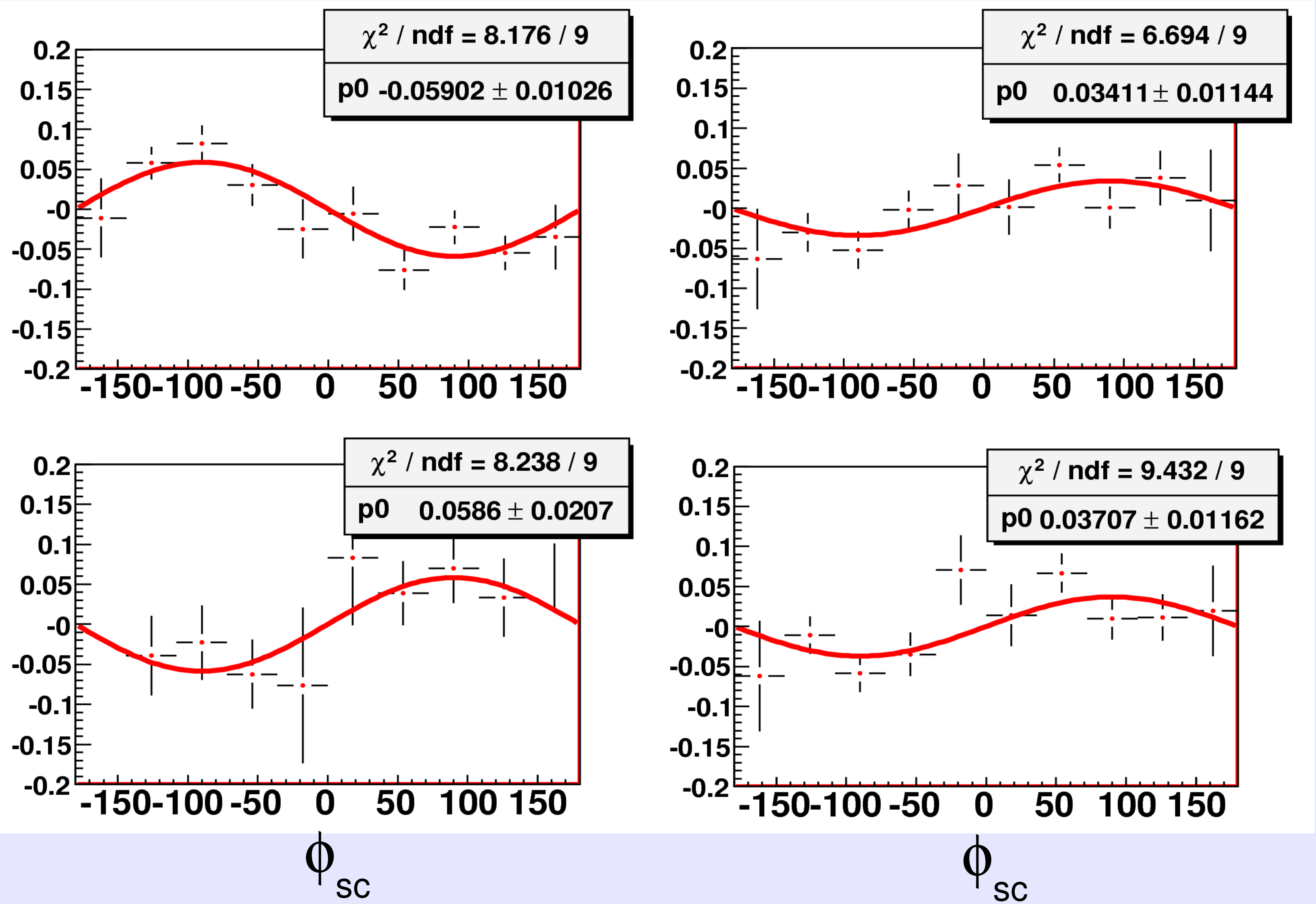
Algorithm

- Look for 3 clusters in ball
- Loop over and find π^0 by invariant mass of 2γ, $M_{\gamma\gamma}$
- Select π^0 events with $M^{miss}_{\pi^0} \simeq M_p$
- Check π^0 in plane with PID scint. hit
- Reconstruct scattering angles
- Select events with large θ_{sc}



Beam Helicity Asymmetries

$$A(\phi_{sc}) = \frac{N^+(\phi_{sc}) - N^-(\phi_{sc})}{N^+(\phi_{sc}) + N^-(\phi_{sc})}$$

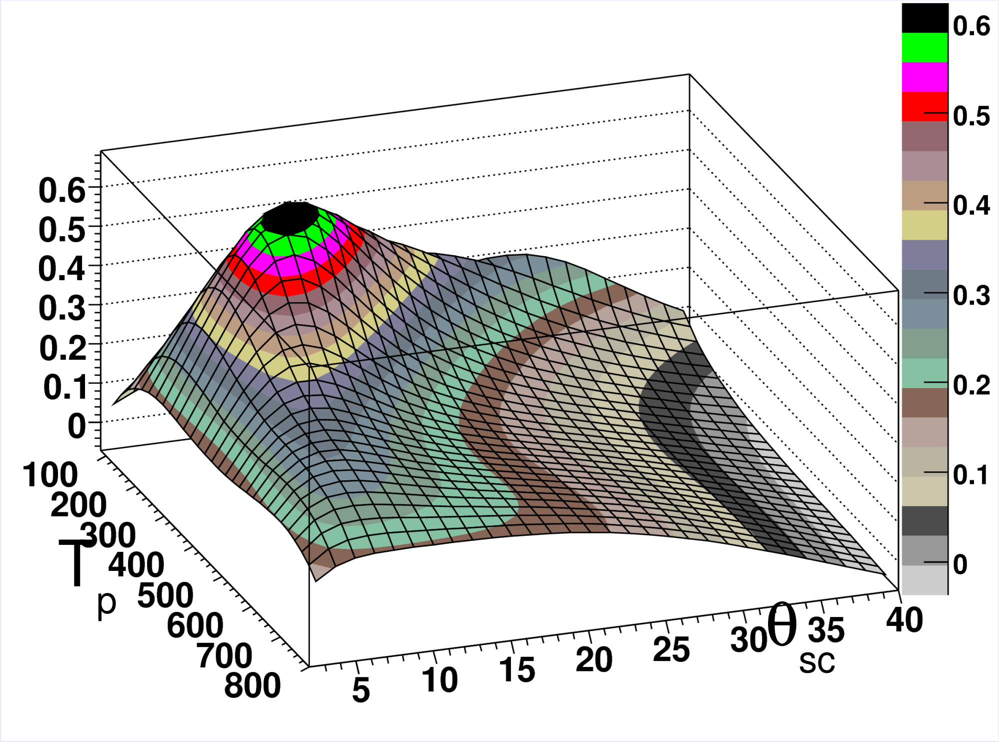


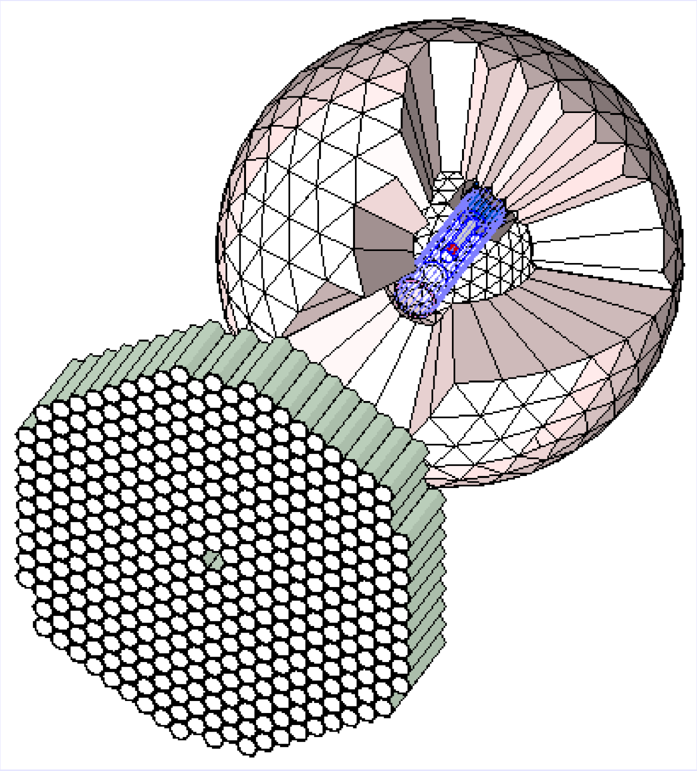
Analysing Power

- Polarised scattering model
- Parameterisation based on world pC scattering data set
- Function of T_p and θ_{sc}

+

- GEANT4 tracking model
- Include all polarimeter
- components
- Track polarisation=+1 and -1



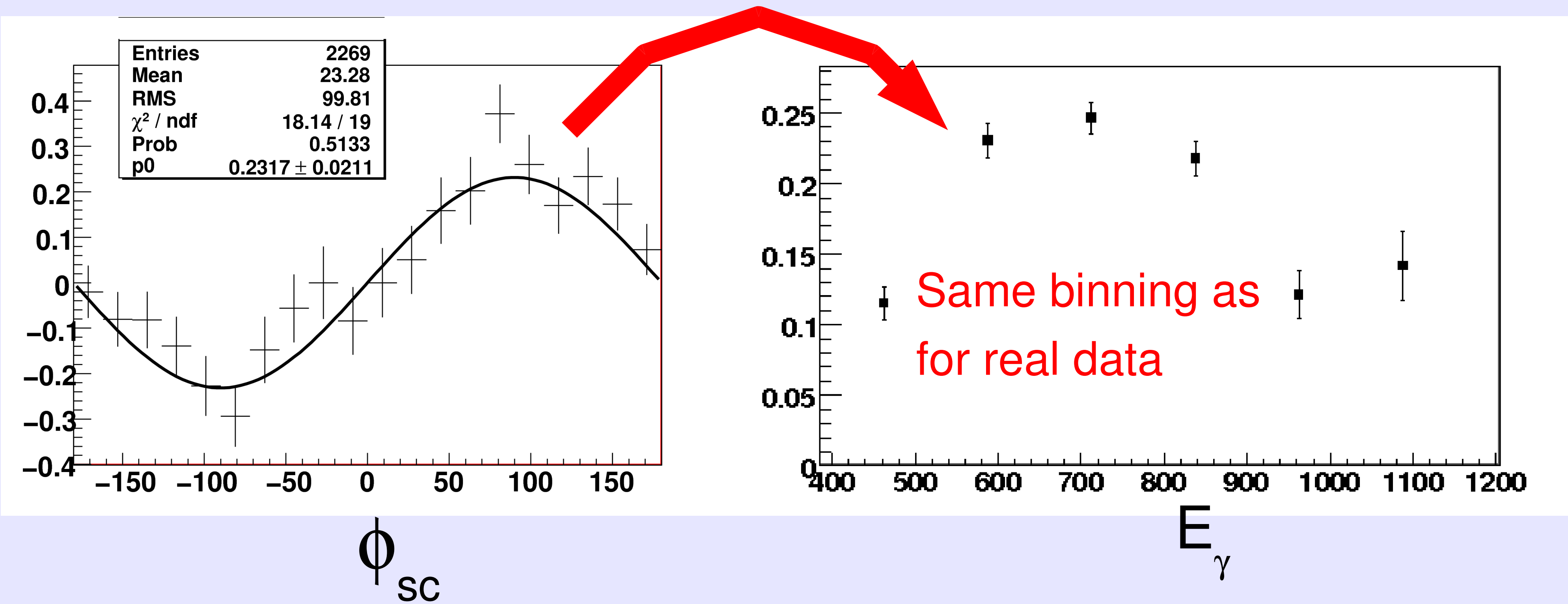


Results of Analysing Power Integration

Perform full data analysis then,

Fit to MC Asymmetries

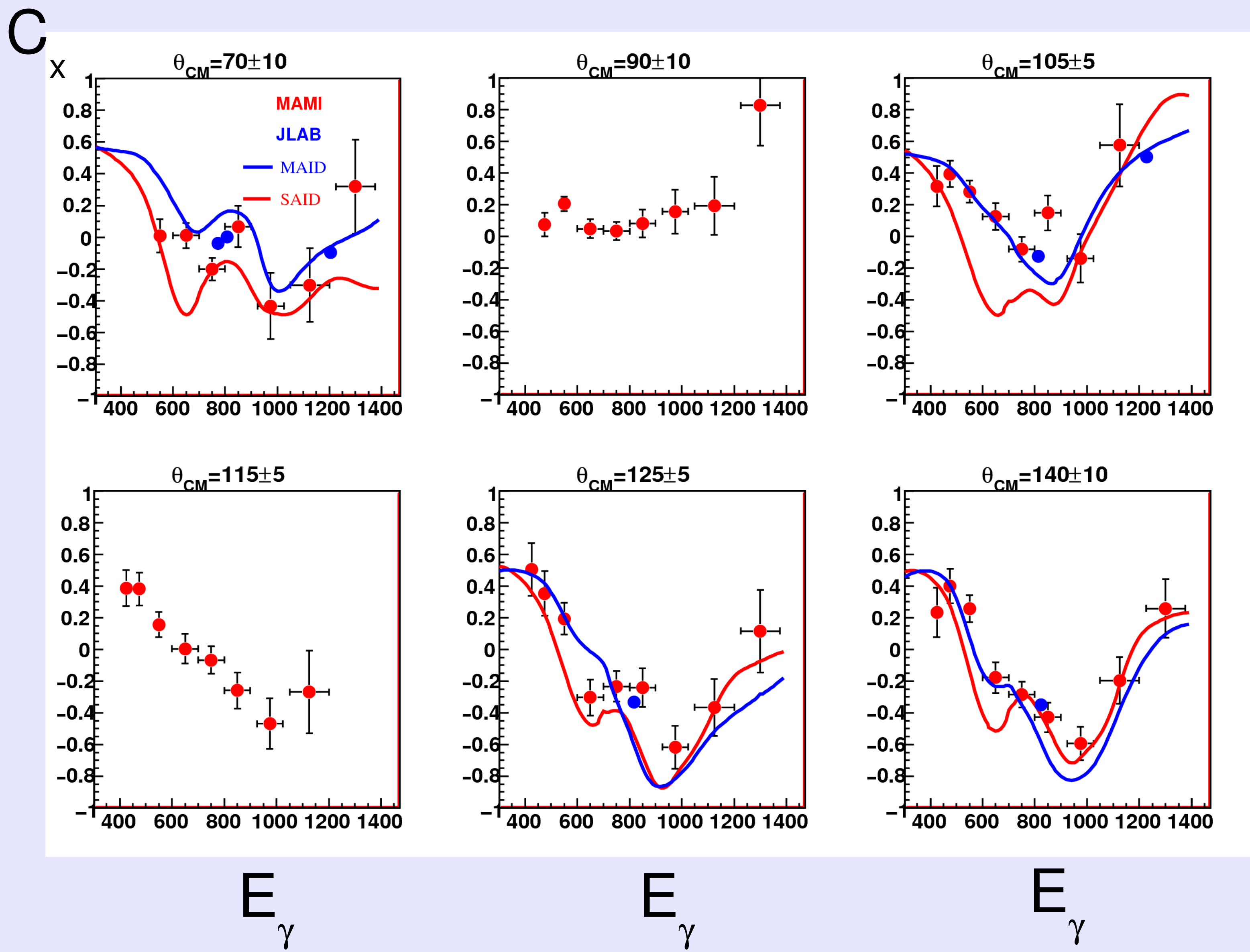
Analysing Power



Overall detection eff. ~2-3%, analysing power~0.2

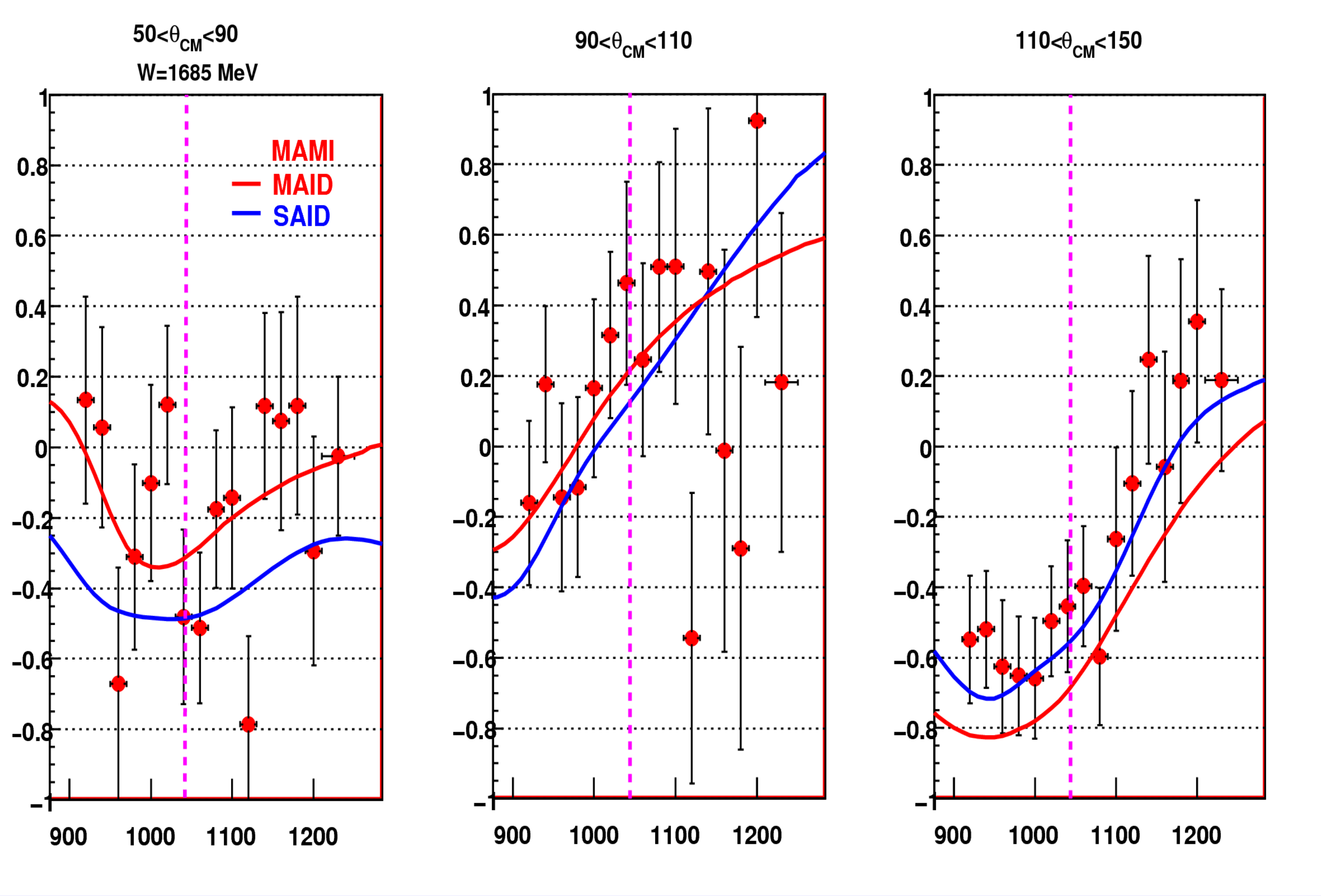
Preliminary π^o C_x Results

- Divide real data asymmetries by MC analysing pow.



Preliminary π^o C_x Results

Do we see any narrow structure around 1685 MeV ?

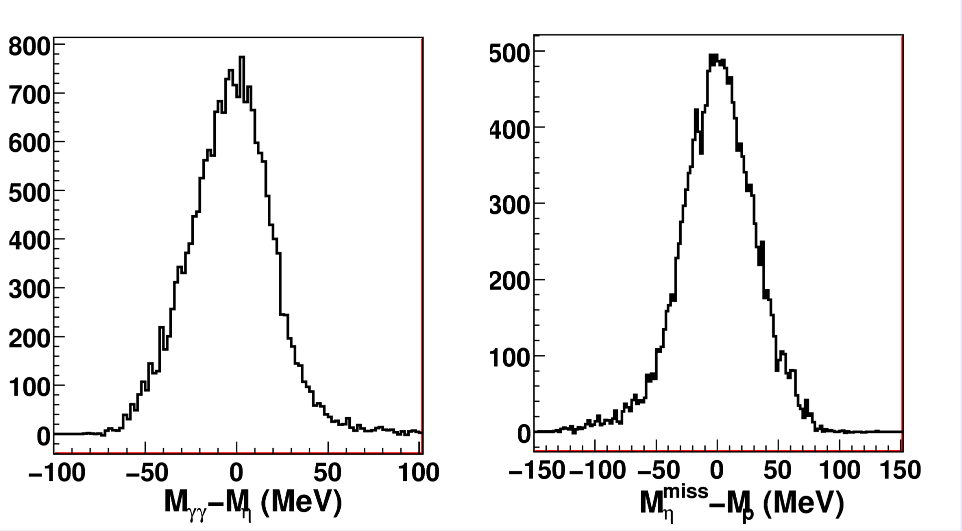


E_γ E_γ E_γ

η photoproduction data analysis

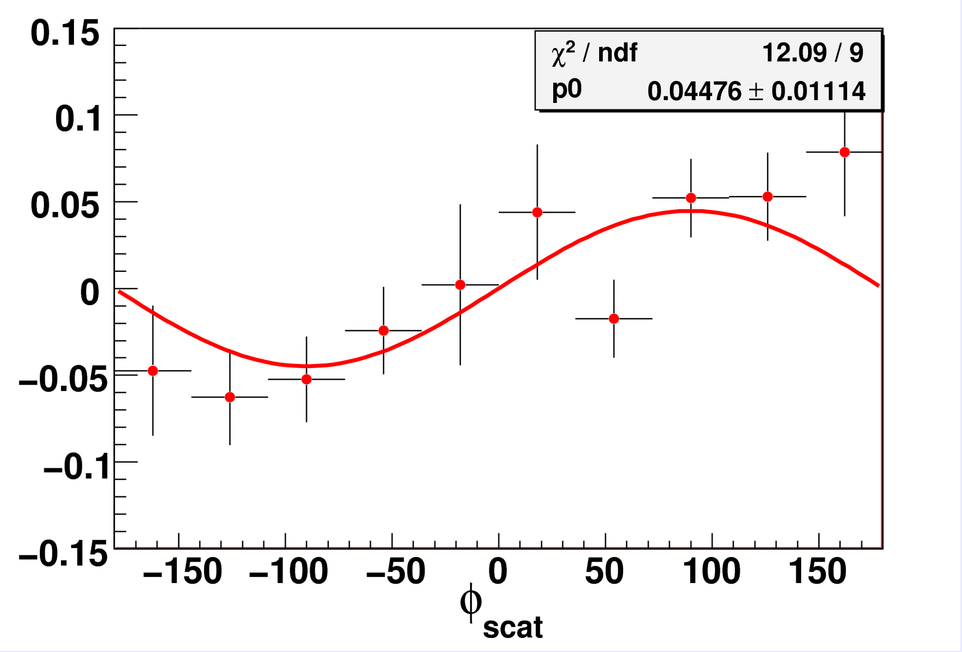
Same algorithm as for π^o analysis

Select on η mass



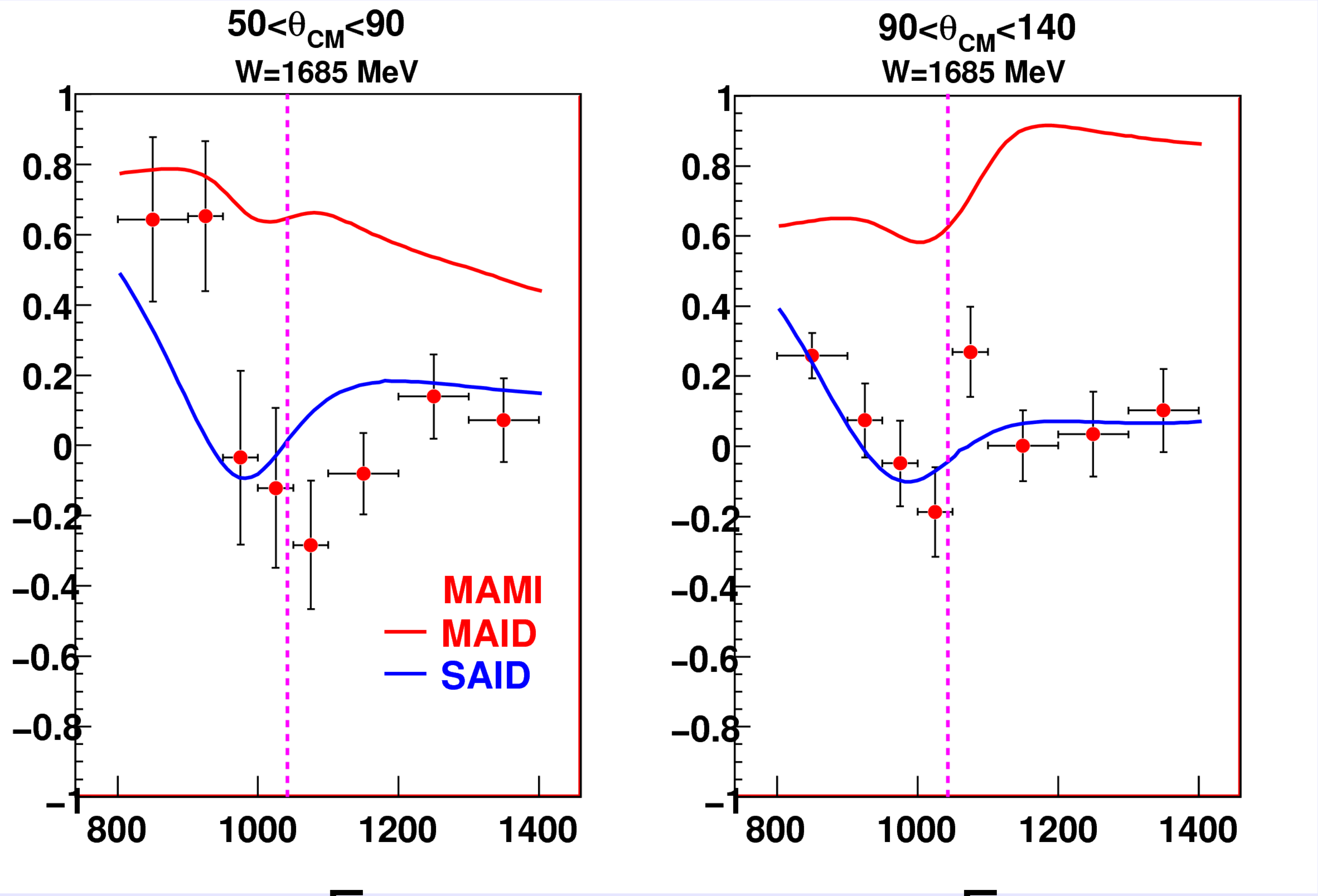
Reconstruct ϕ_{scat} helicity asymmetries

Assume Analysing power =0.3



Very Preliminary η C_x Results

Do we see any narrow structure around 1685 MeV ?



E_γ E_γ

Current Status

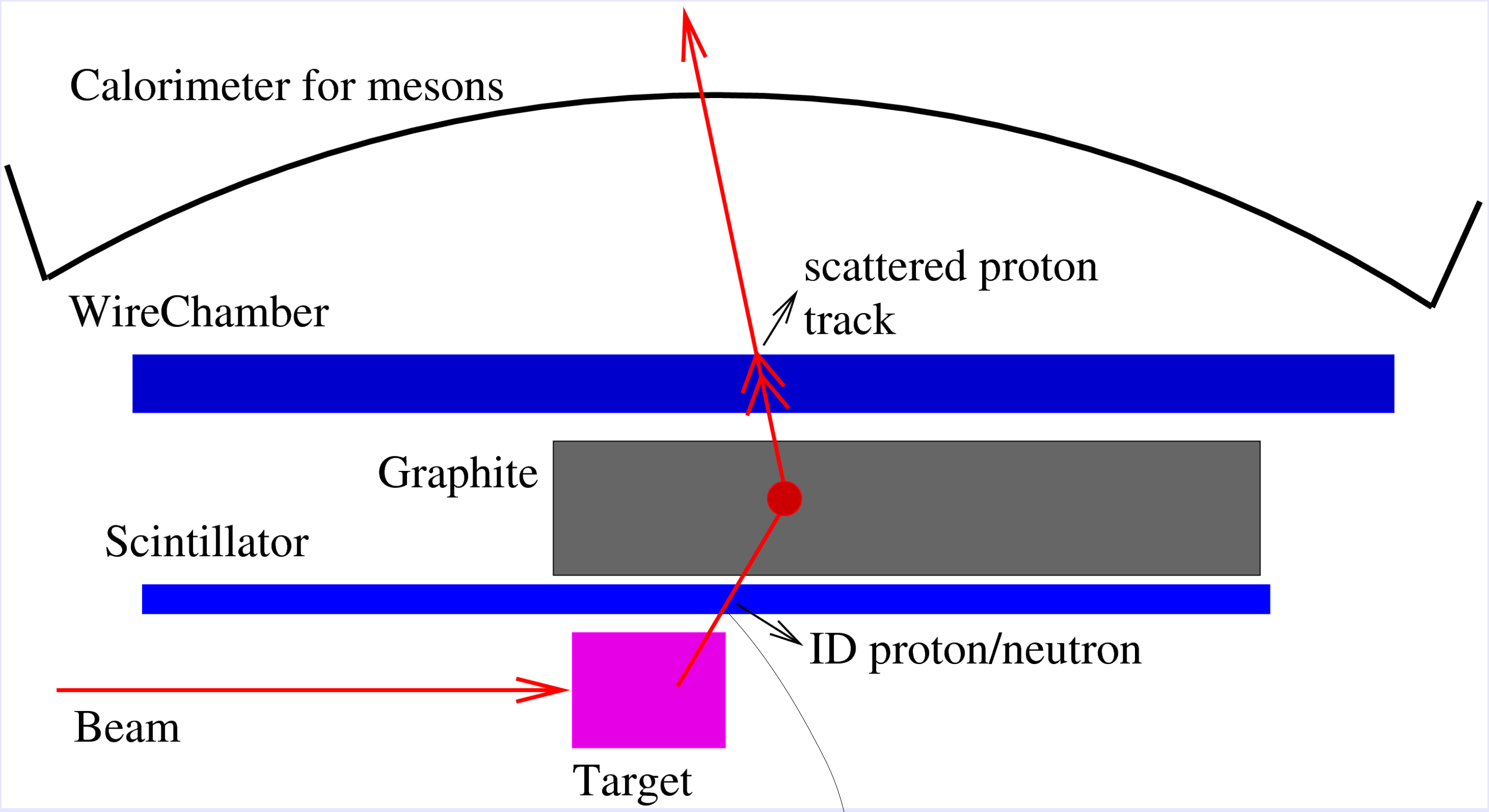
- Preliminary analysis of C_x for π^0 and η photoproduction on the proton completed
- Finalising analysing power calibration
- Monte Carlo acceptance for P
- Linearly polarised photons for $450<E_\gamma<650$ MeV for O_x and T
- Also measure $2\pi^0$ channel

Future plans

Ultimately we would like recoil polarimetry for:

- CHARGED and neutral meson photoproduction
- Protons and NEUTRON targets
- Large acceptance
- New design for MAMI/ELSA PAC

New Central Nucleon Polarimeter Design



Not to scale!

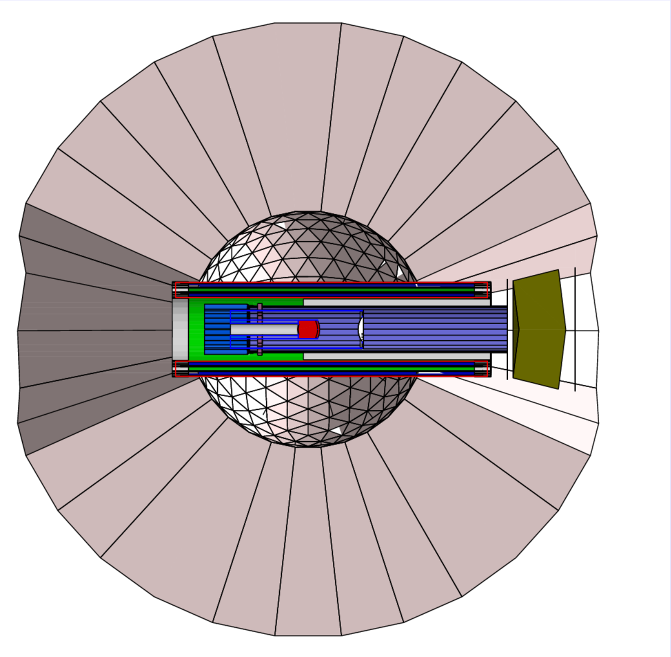
- Scattered vector from wirechambers
  Track back to graphite for incident vector

+ → θ_{sc}, ϕ_{sc} → POLARISATION

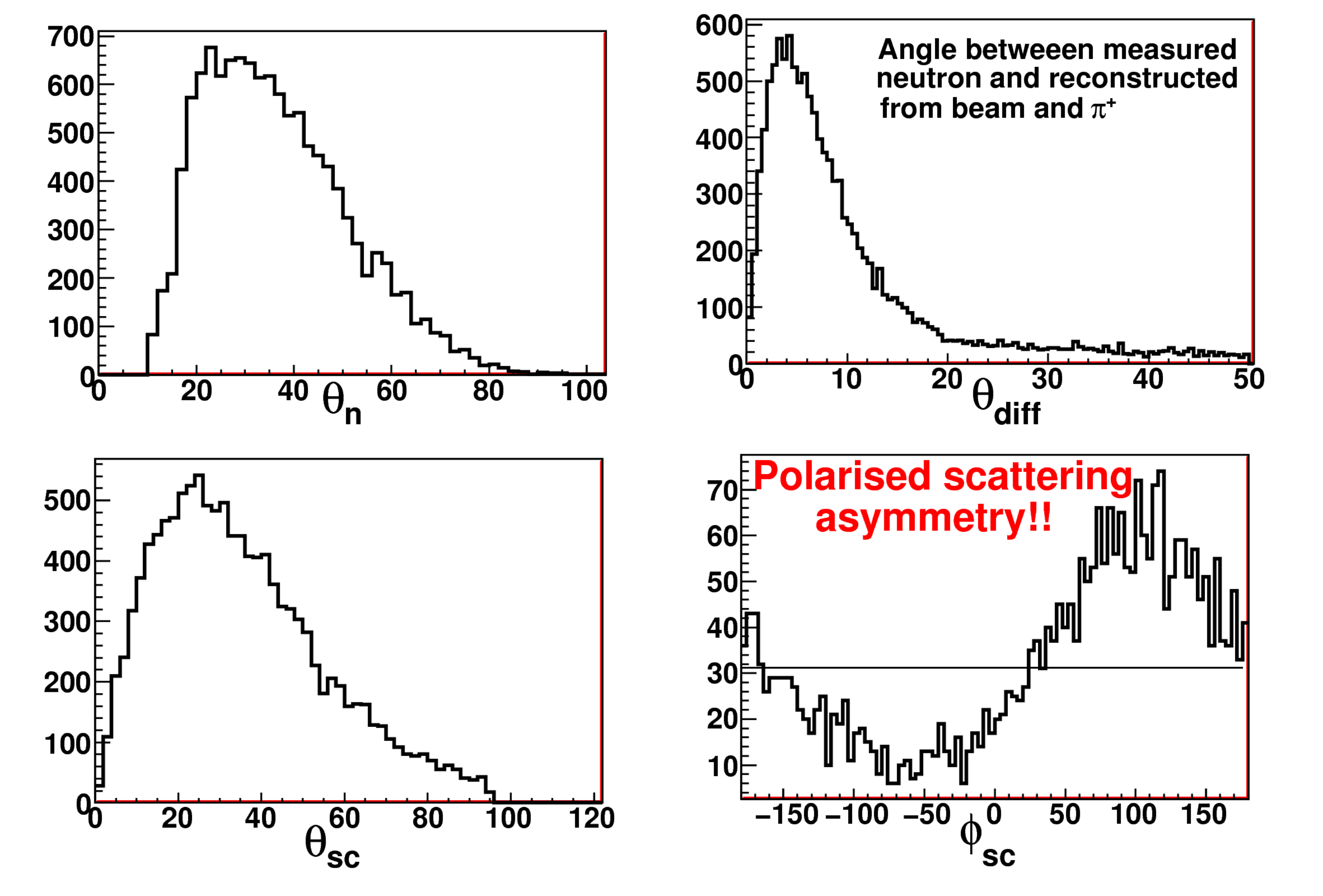
- Use np charge exchange as neutron analyser

Example $\gamma p \longrightarrow \pi^{+} n$

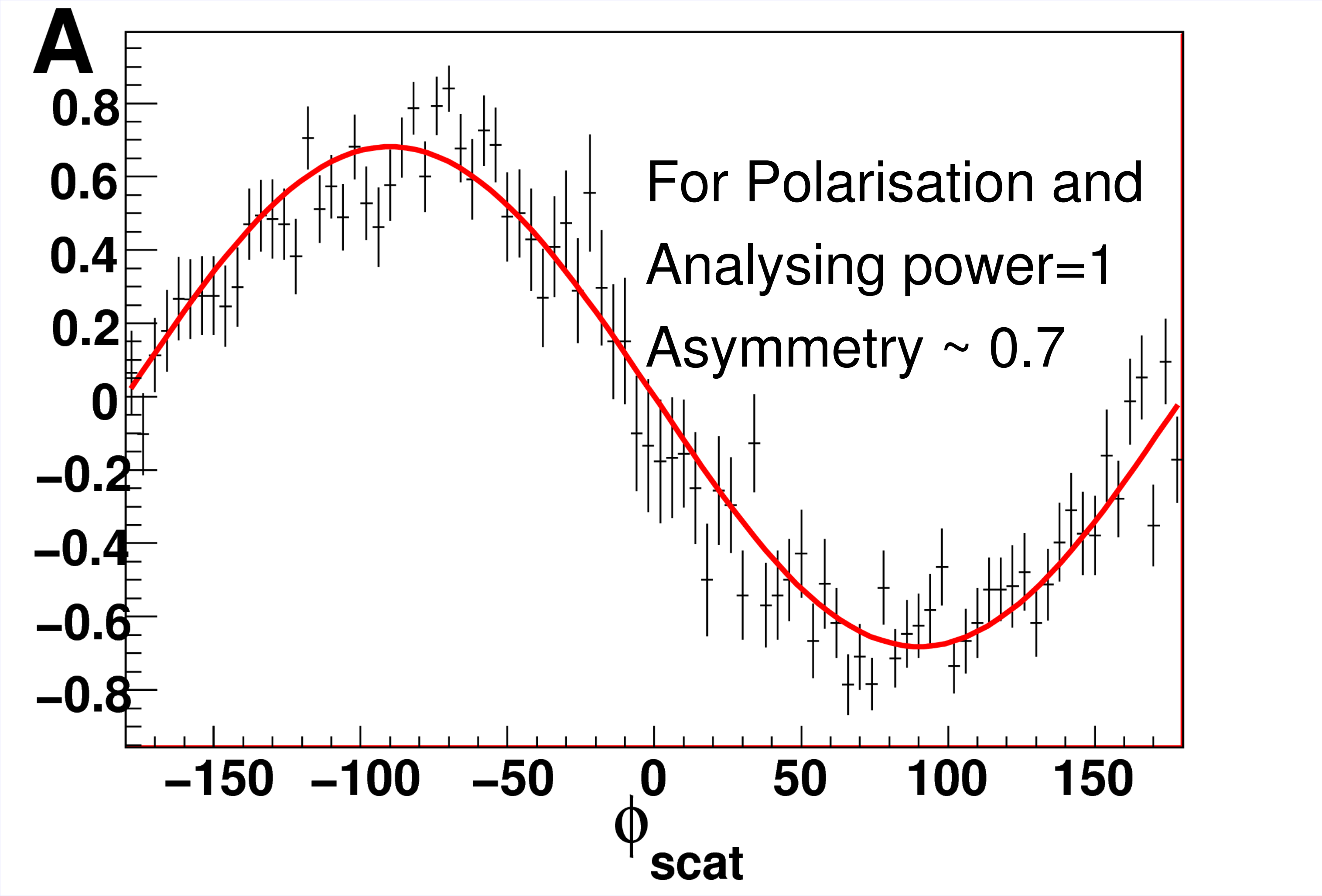
- Implement new design into CrystalBall Monte Carlo model
- Track π^{+} n events and analyse ouput
- π^{+} ID from ΔE-E technique
- n/p charge exchange from wire chamber track with no scintillator hit
- Polarimetry information comes just from track



Simulation Spectra for $\pi^+ n$



Simulation Results for $\pi^+ n$



Detection Efficiency ~1%

We can produce measurable asymmetries!

Comparison of old and new

Relative figure of merit for proton and neutron polarimeter,

$$\frac{F_n}{F_p} = \frac{A^n_{pow}\sqrt{\epsilon^n}}{A^p_{pow}\sqrt{\epsilon^p}} \sim \frac{0.1.\sqrt{1}}{0.2.\sqrt{2.5}} = 0.25$$

Proton beamtime=2.5 weeks,

Therefore 10 weeks required for similar results with neutrons

i.e 6-8 θ bins, 50 MeV E_γ bins, (100 MeV above 1.3GeV) $\sigma \sim 0.05 - 0.1$

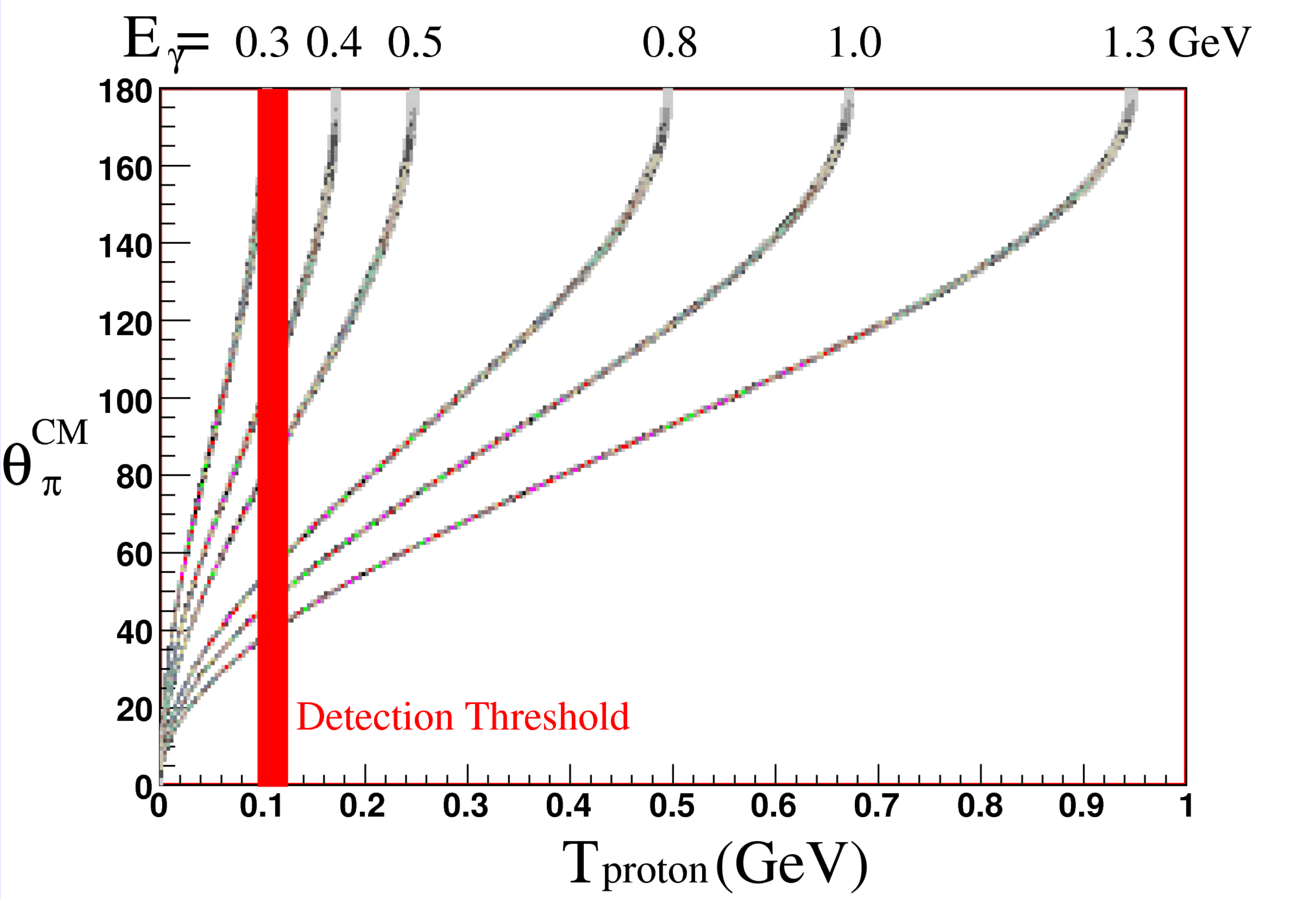
With Deuteron target would simultaneously measure π^0, π^+, π^-, η

4 times as many bins with proton in final state

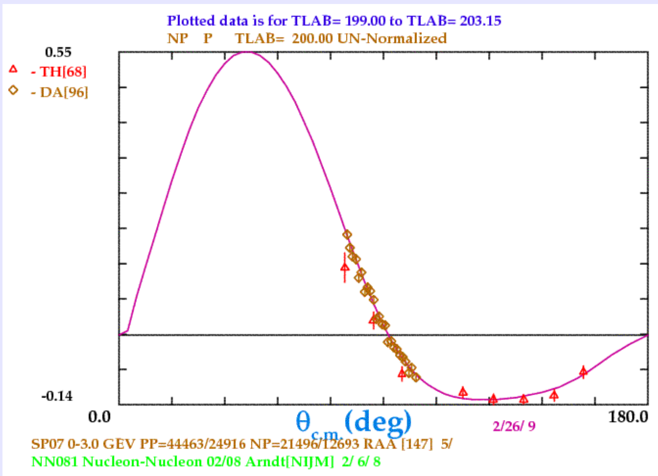
Summary

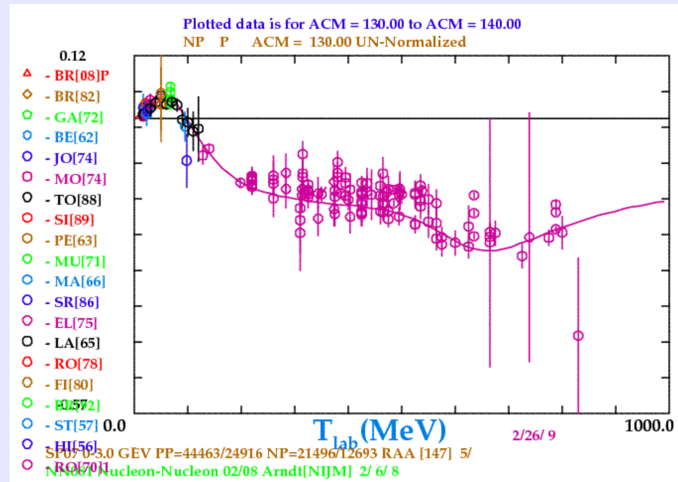
- A novel large acceptance recoil polarimeter has been established with the CrystalBall@MAMI
- Recoil polarisation measurements give new sensitivity to reaction amplitudes and are important for nucleon resonance extraction
- Preliminary π^0 results have qualitative agreement with MAID and SAID predictions
- Hint of some structure at 1685 MeV in very preliminary η, C_x analysis
- What do the models say about this?

Kinematics and Acceptance



Analysing Power for n/p charge exchange



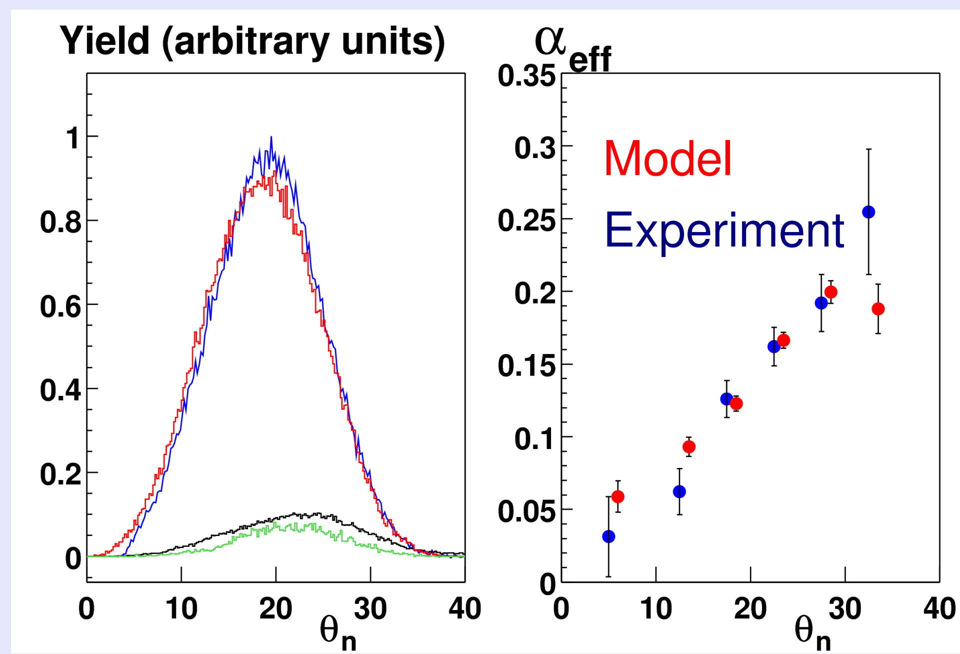


D. Glazier, PhD Thesis,

University of Glasgow, 2003

n/p Charge exchange on CH2 at 400 MeV

well modelled by quaifree model



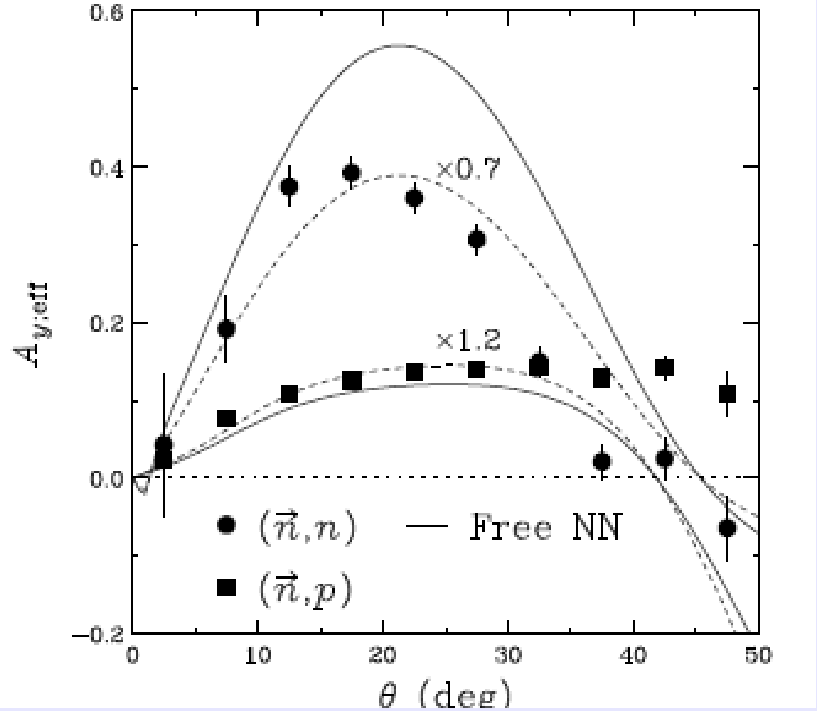
see also NPOL3, NIM A547, (2005) 569

+C(n,p) scattering papers

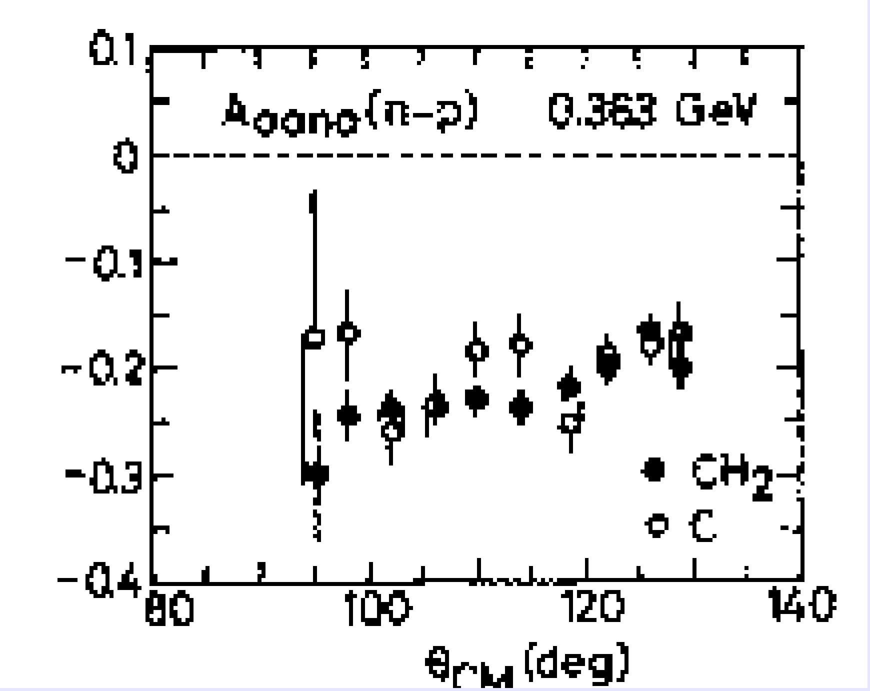
Analysing Power 0.1-0.2 Tn>150 MeV

Analysing powers for $^{12}C(n,p)$ scattering

- Previous polarimeters (e.g. Yerevan) use $^{1}H(n,p)$ analysing powers for $^{12}C(n,p)$.
- Supported by recent RCNP measurements, older Saclay data, A1 at MAMI

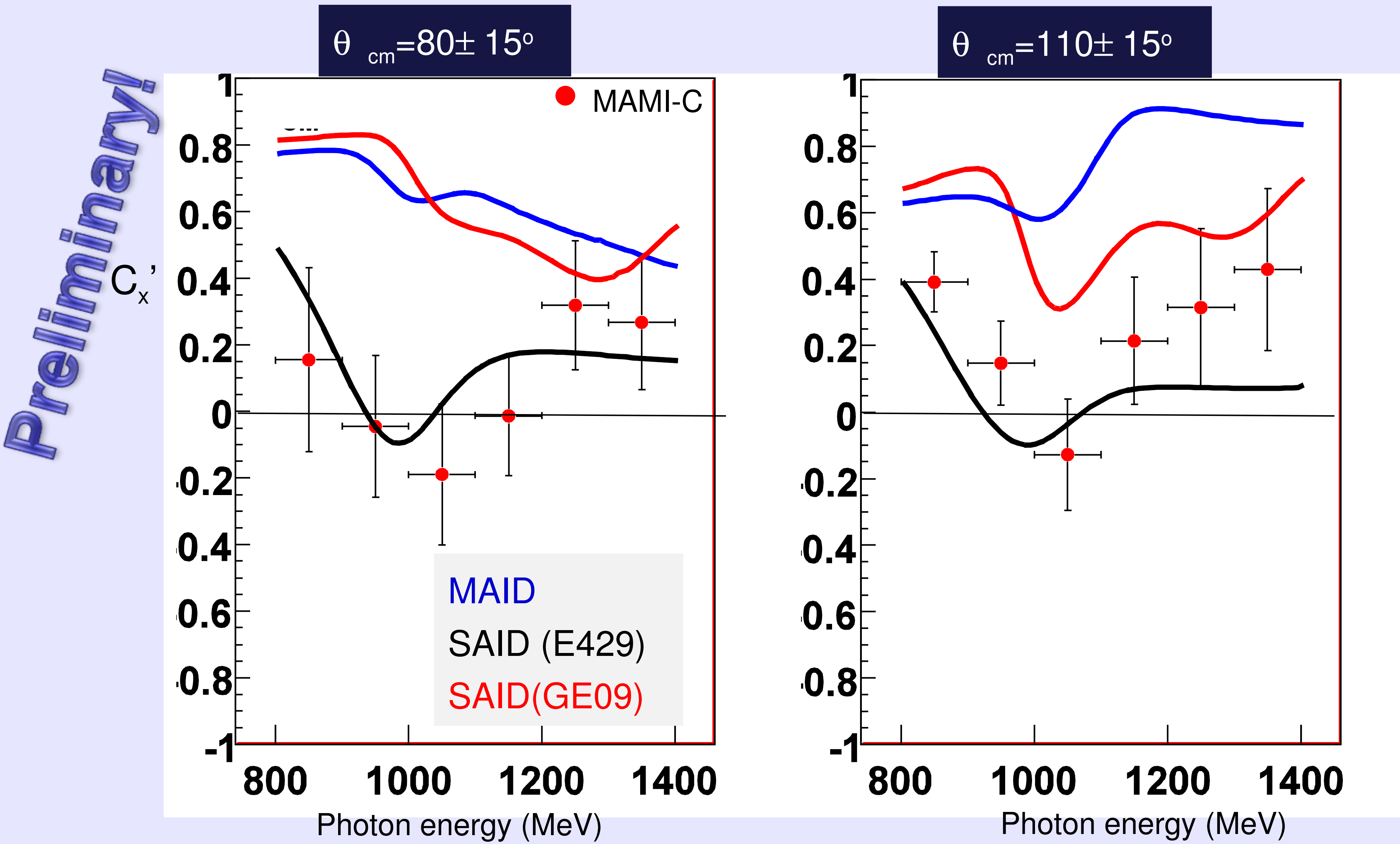


Wakasa et. al. NIM A547 (2005) 269
NPOL3 at RCNP Cyclotron



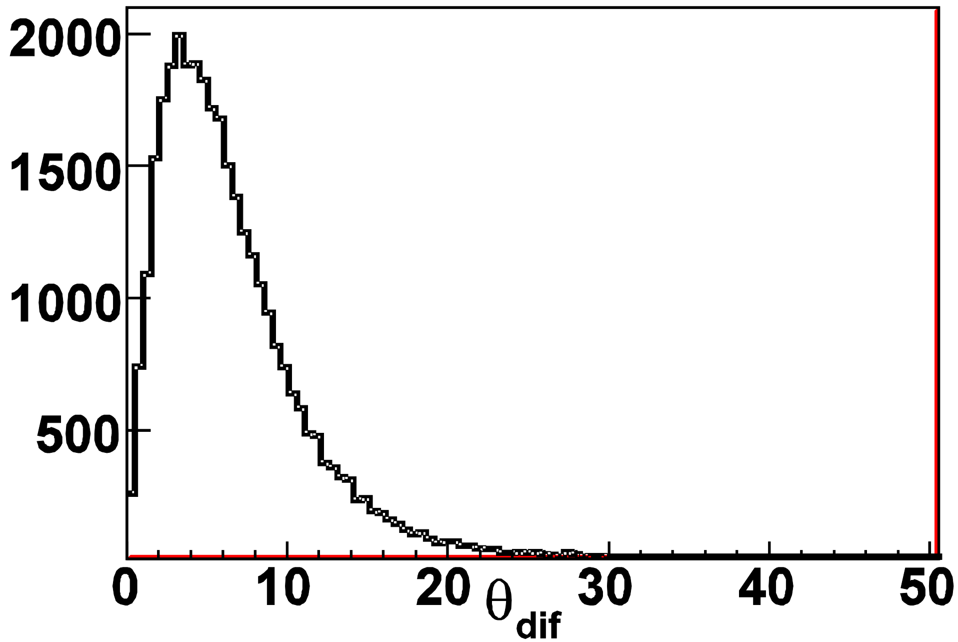
Saclay measurements

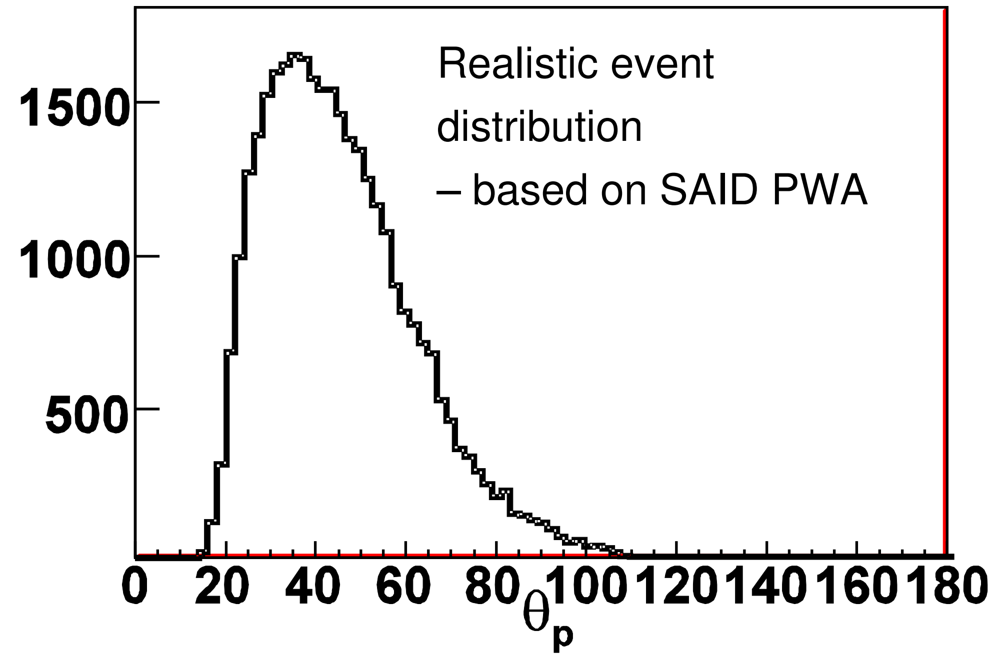
p(γ ,η)p $C_{x'}$

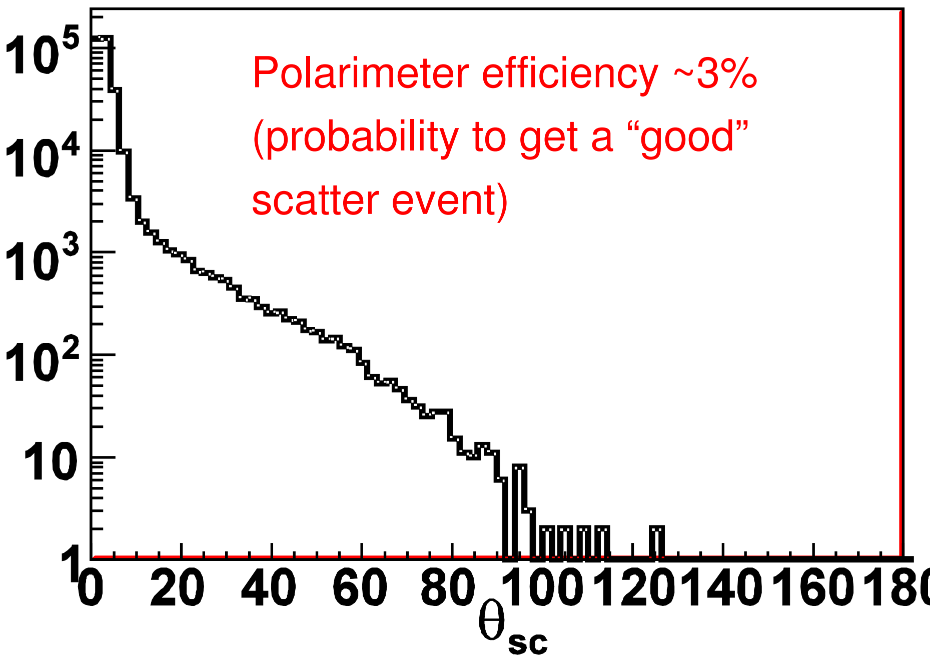


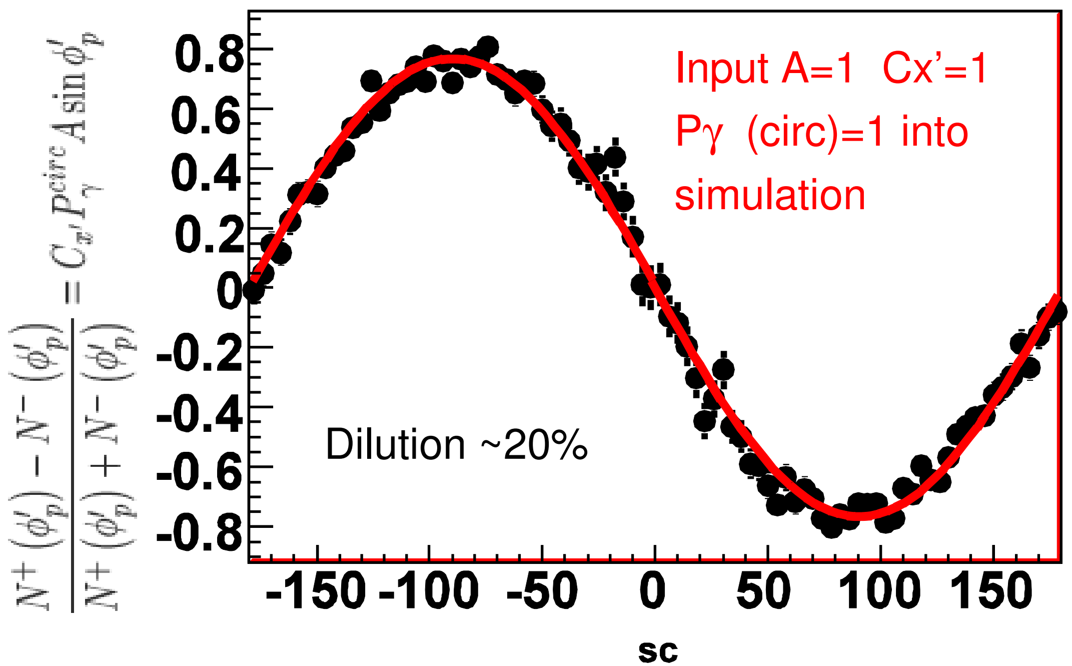
- First measurement of beam-recoil observable in η photoproduction
- Next steps O_x,P, T also p(γ ,2π) and p(γ ,π η) channels

G4 – Stationary proton target: $p(\gamma,\pi^0)p$

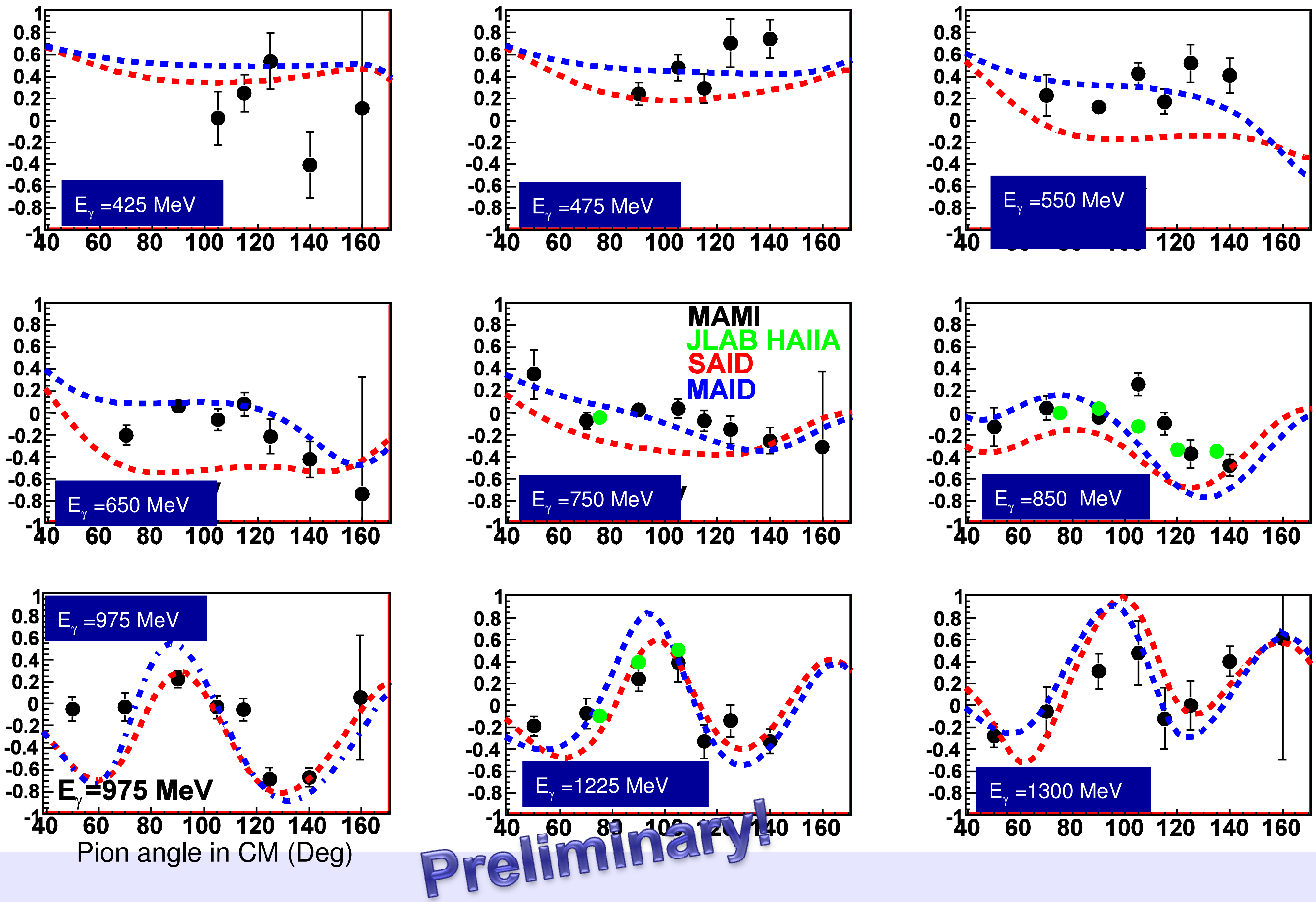


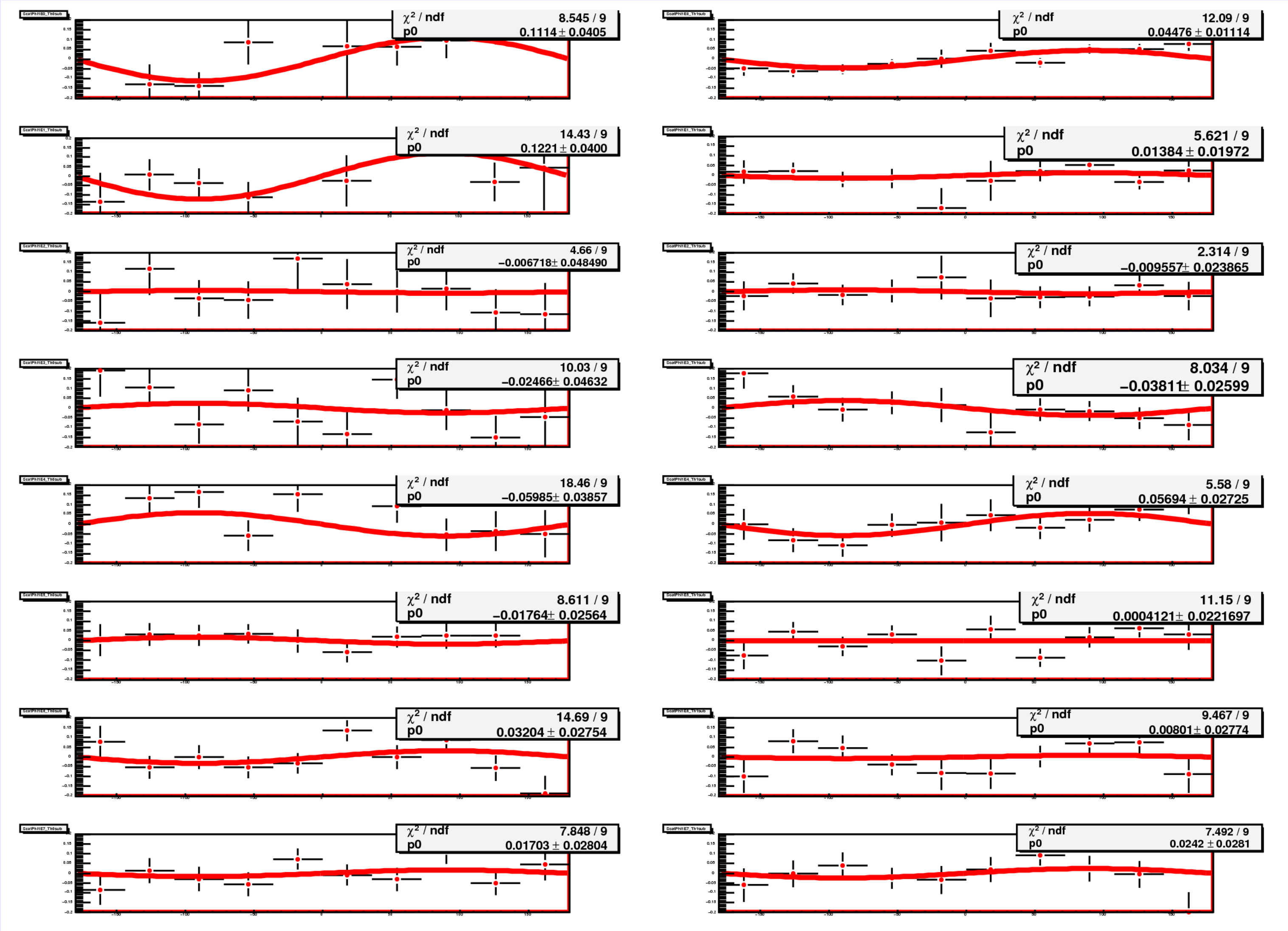






C_x – transferred poln. from circ. pol γ : $p(\gamma,\pi^0)p$




χ2 / ndf 8.545 / 9
p0 0.1114 ± 0.0405
χ2 / ndf 12.09 / 9
p0 0.04476 ± 0.01114
χ2 / ndf 14.43 / 9
p0 0.1221 ± 0.0400
χ2 / ndf 5.621 / 9
p0 0.01384 ± 0.01972
χ2 / ndf 4.66 / 9
p0 −0.006718± 0.048490
χ2 / ndf 2.314 / 9
p0 −0.009557± 0.023865
χ2 / ndf 10.03 / 9
p0 −0.02466± 0.04632
χ2 / ndf 8.034 / 9
p0 −0.03811± 0.02599
χ2 / ndf 18.46 / 9
p0 −0.05985± 0.03857
χ2 / ndf 5.58 / 9
p0 0.05694 ± 0.02725
χ2 / ndf 8.611 / 9
p0 −0.01764± 0.02564
χ2 / ndf 11.15 / 9
p0 0.0004121± 0.0221697
χ2 / ndf 14.69 / 9
p0 0.03204 ± 0.02754
χ2 / ndf 9.467 / 9
p0 0.00801± 0.02774
χ2 / ndf 7.848 / 9
p0 0.01703 ± 0.02804
χ2 / ndf 7.492 / 9
p0 0.0242 ± 0.0281