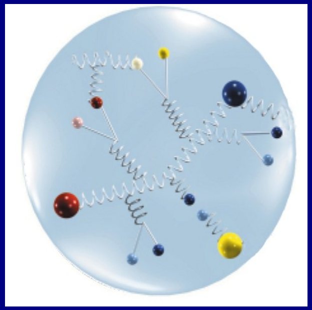
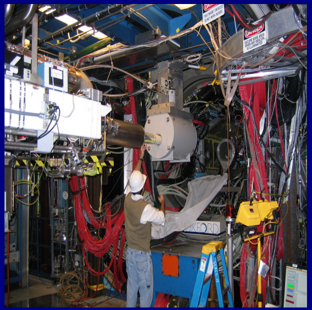
Measurement of the G Double-Polarisation Observable in Pion Photoproduction





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on behalf of
Josephine McAndrew
University of Edinburgh

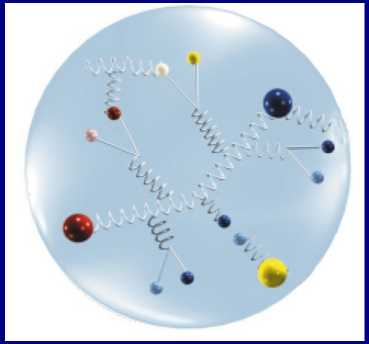
And on behalf of the CLAS Collaboration

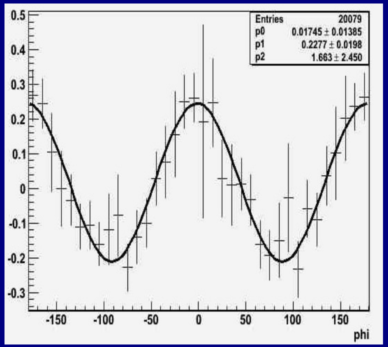
THE UNIVERSITY OF EDINBURGH

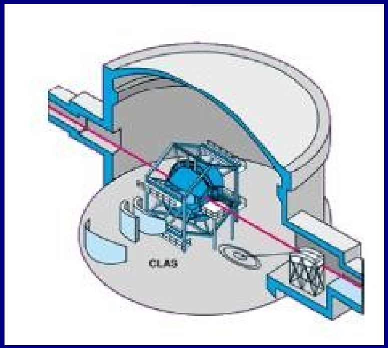
Jefferson Lab

Introduction

- Background and motivation
- Experimental setup
- Analysis procedure: channel selection and observable extraction
- Preliminary Results
- Comments and Conclusions

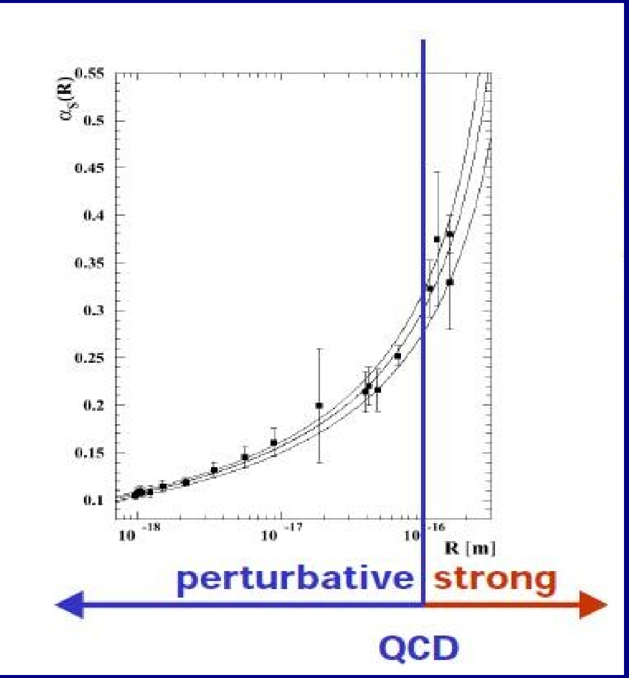


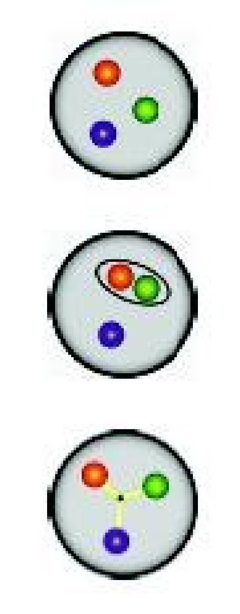




Physics Motivation

- Recent advances in Lattice QCD calculations are closer to predicting nucleon excited states
- Calculations still not performed at realistic quark masses
- Most predictions of nucleon excited states still rely on phenomenological models
- These models predict resonances not yet observed
- Many properties of "known" resonances remain poorly established





Consituent Quark Model

Di-Quark Model

Quark and Flux-Tube Models

Polarisation Observables

Photon			Target			Recoil			Target + Recoil		
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unpol}}\{(1 - p_T \Sigma\cos(2\phi) + p_X\left[-p_T H\sin(2\phi) + p_0 F\right]$$

$$-p_Y\left[T + p_T\cos(2\phi)\right] - p_Z\left[-P_T G\sin(2\phi) + p_0 E\right]\}$$

Polarisation Observables

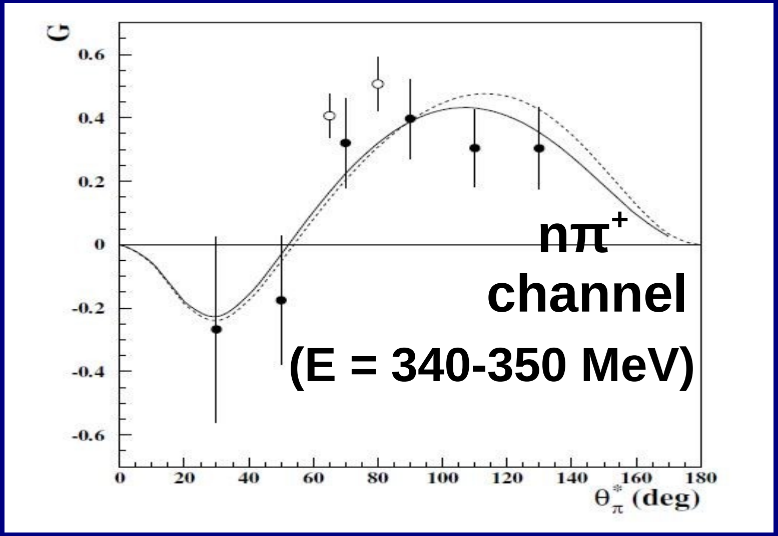
Photon	Target				Recoil			Target + Recoil			
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

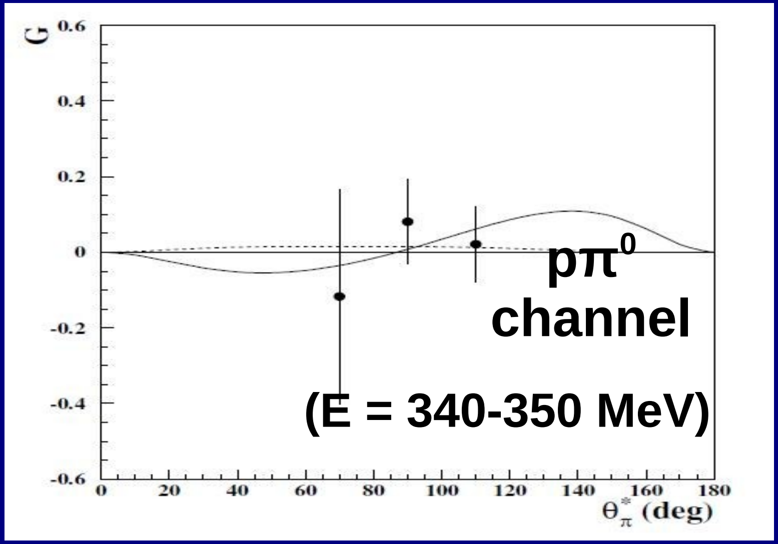
$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unpol}}\{1 - p_T\Sigma\cos(2\phi) + p_X[-p_T H\sin(2\phi) + p_0 F]$$

$$-p_Y[T + p_T\cos(2\phi)] - p_Z[-P_T G\sin(2\phi) + p_0 E]\}$$

Previous Measurements of the G Observable

- First measurement of G from from 600-1875 MeV for the $n\pi^+$ channel by Bussey *et al.*, *Nucl. Phys. B**169*** (1980) 403-414
- Two data points for $n\pi^+$ channel at 350 MeV measured by Belyaev *et al., Sov.J. Nucl. Phys.* **40** 83-86 (1984)
- Six data points measured by Ahrens *et al.* (2005) for the $n\pi^+$ channel and three for the $p\pi^0$ channel at 340 +/- 10 MeV

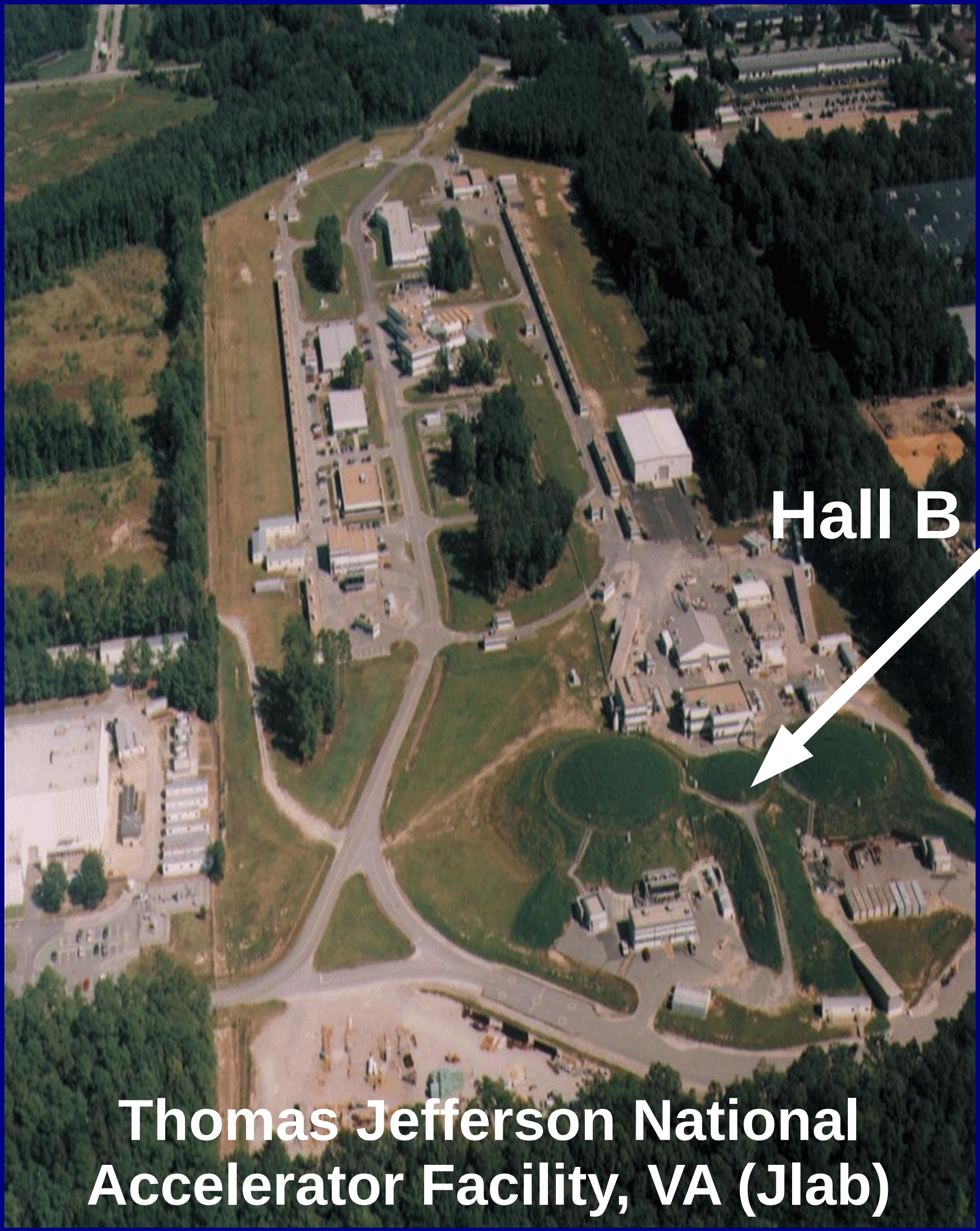




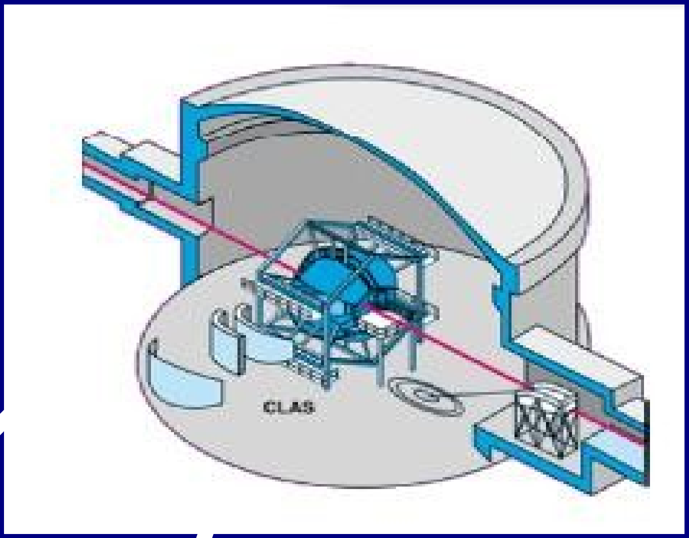
Current data-set for the G Observable (low energies)

J. Ahrens *et al, Eur. Phys. J. A* **26** 135-140 (2005)

Experimental Facility



www.jlab.org



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CLAS

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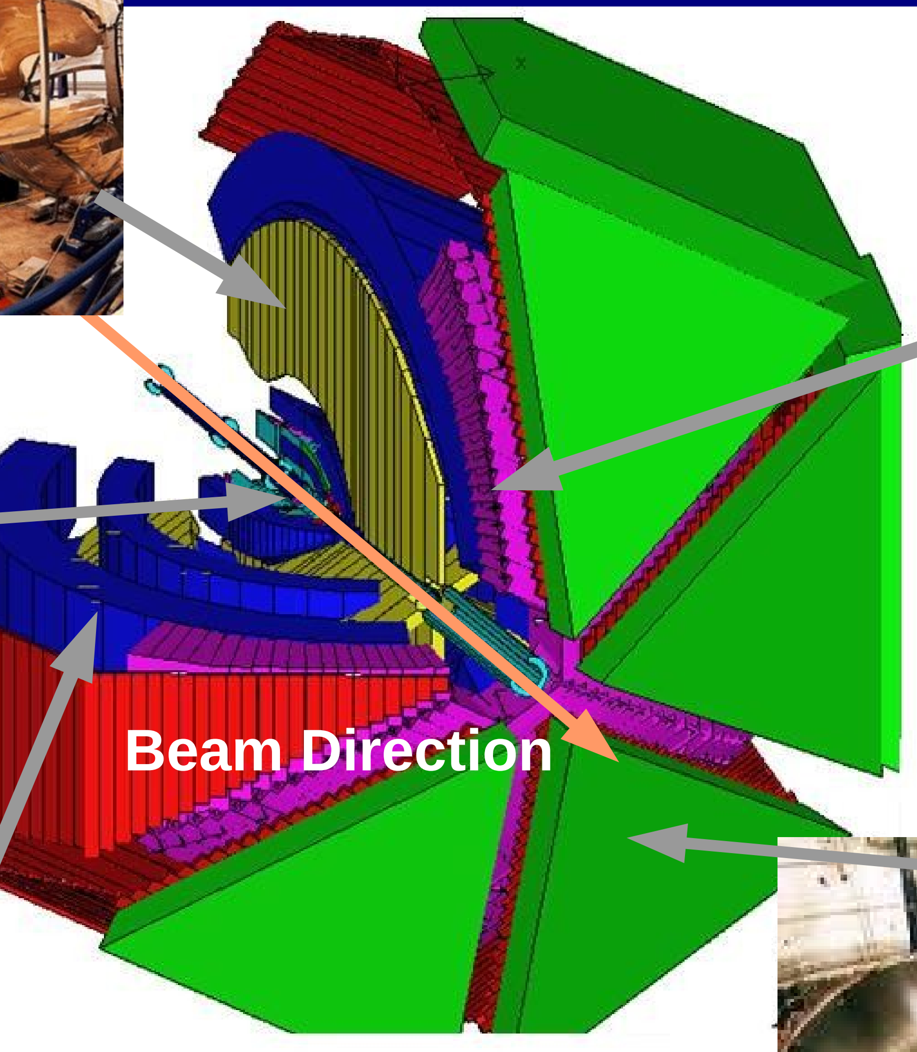
The CLAS Detector

Torus magnet (Divides CLAS into 6 sectors)



Start Counter

Cherenkov Counters

Electromagnetic Calorimeters

Time-of-Flight Scintillation Detector

3 layers of drift chambers

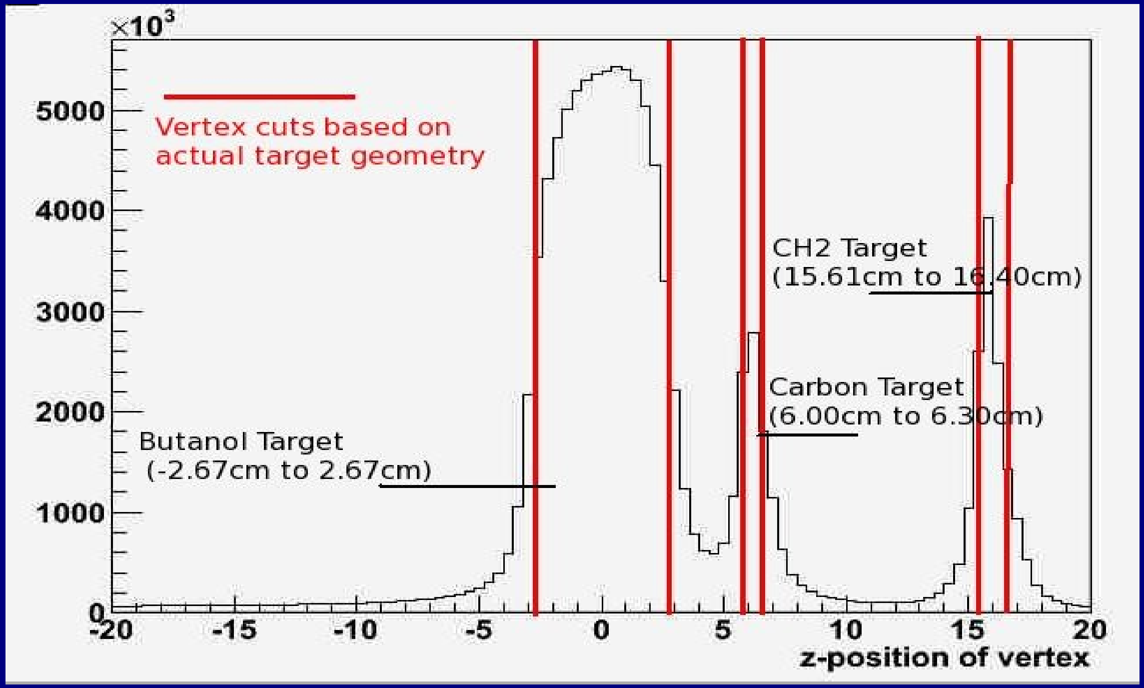
www.jlab.org

Summary of Experimental Setup for g9a

- Experiment performed from October 2007 – February 2008 in Hall B at JLab.
- Used linear and circularly polarised photon beams in the energy range 730-2300 MeV.
- Beam polarisation up to ~80%.
- First experiment with the frozen spin target, FROST.
- Longitudinal target polarisation ~80% to ~90%.
- The G observable requires a linearly polarised photon beam and longitudinally polarised target.

Analysis Procedure

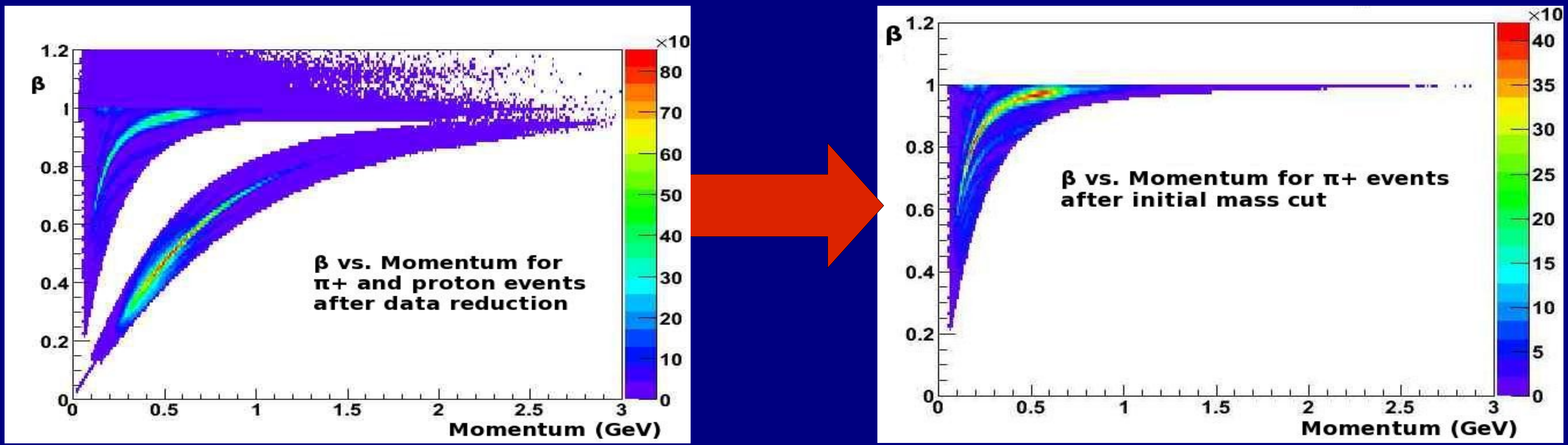
- Reaction studied: **$\gamma(p,n)\pi^+$**
- Analyse data for polarised butanol and unpolarised carbon and CH_2 targets in the beamline:



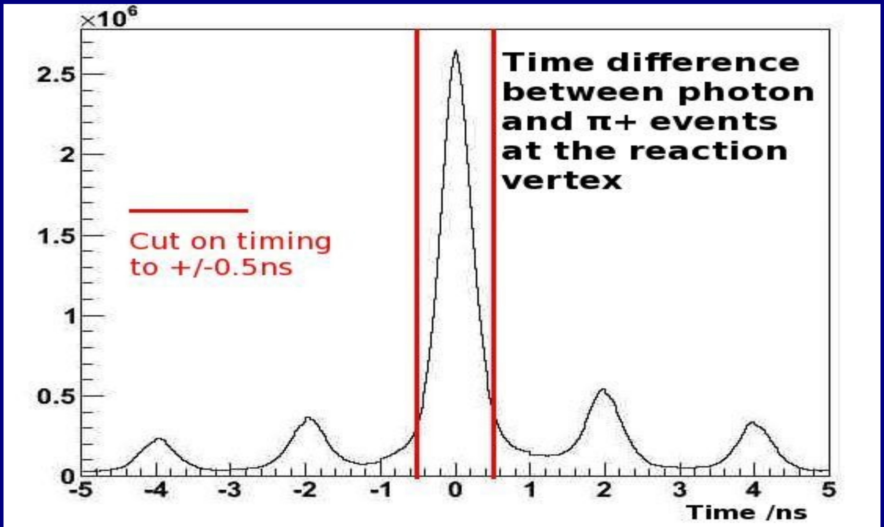
- Channel ID: select π^+ events and reconstruct missing mass of the neutron.

Identifying π+ Events

- Make rough mass cut on π+ mass squared (0-0.4 GeV):

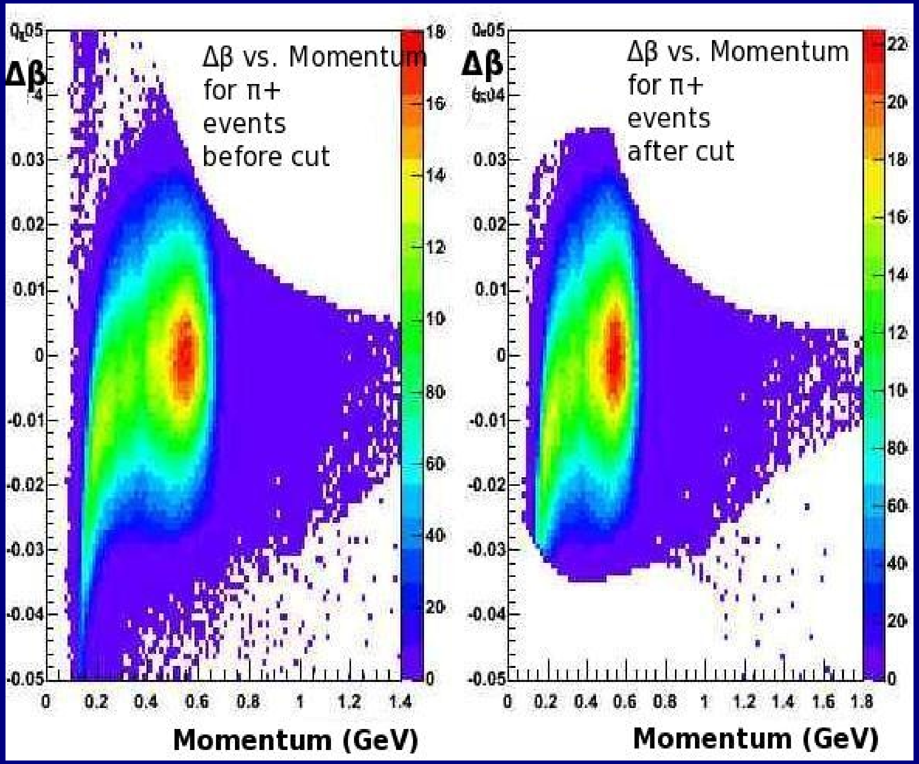


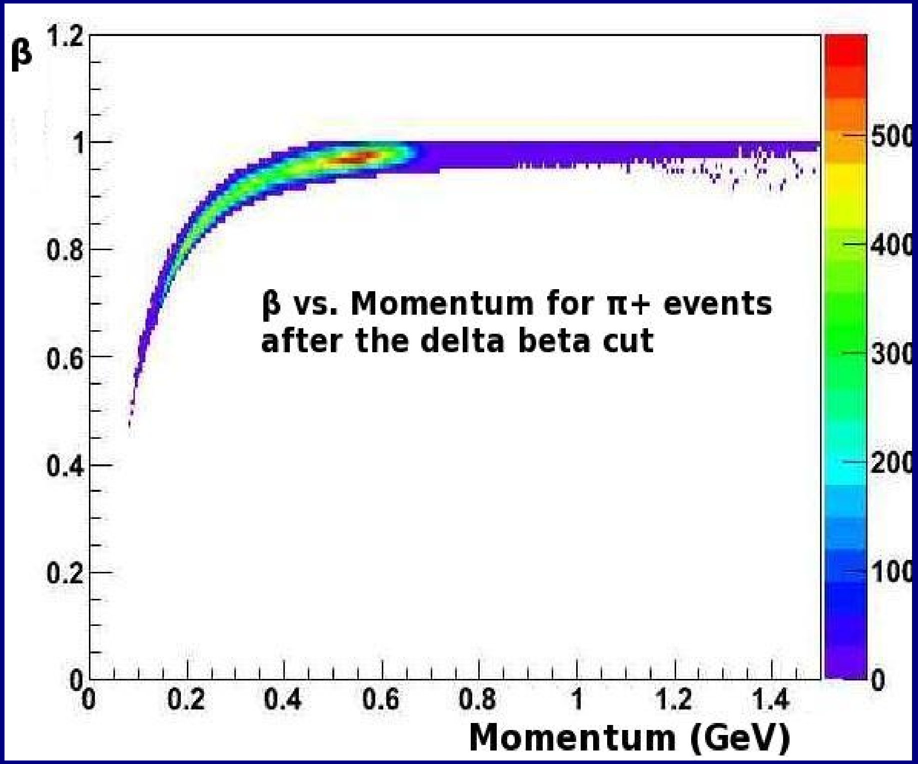
- Timing cuts: find photon responsible for each π+ event.



Identifying π^+ events, continued...

- Correct for π^+ energy loss after photon energy and timing cuts.
- Make better π^+ mass cut using $\Delta\beta$ technique:

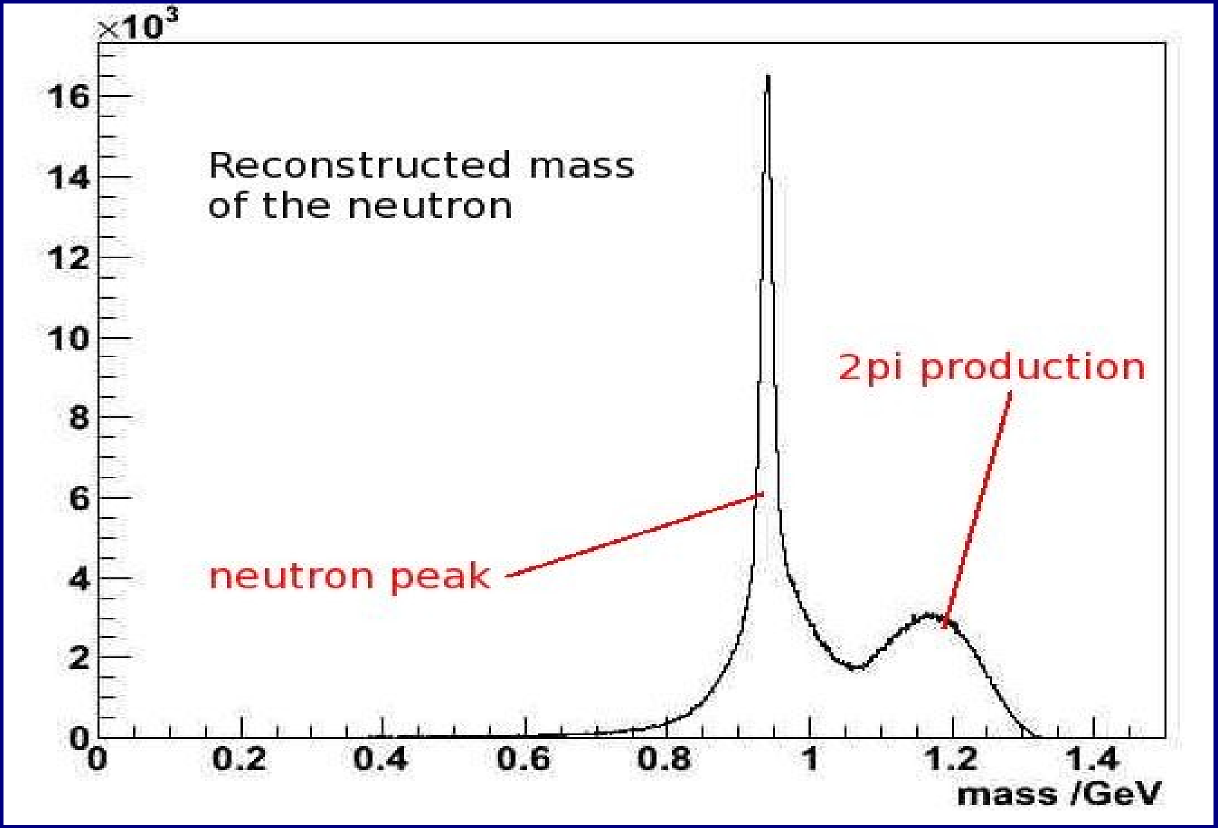




Reconstruction of Missing Mass (Neutron Mass)

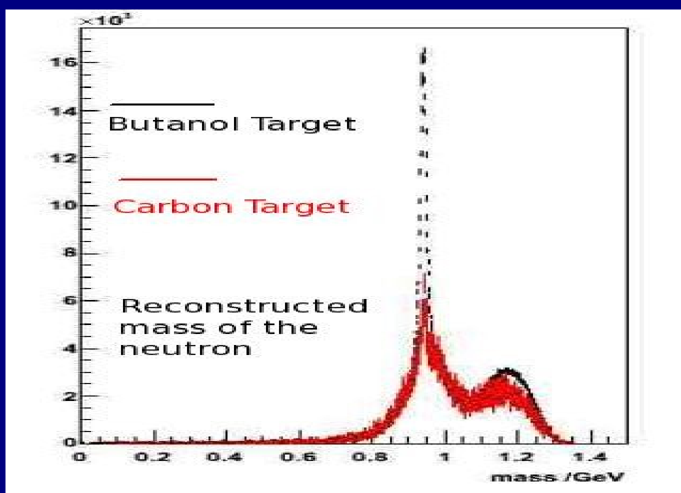
- Use missing mass technique:

$$\gamma + p \rightarrow \pi^+ + X$$



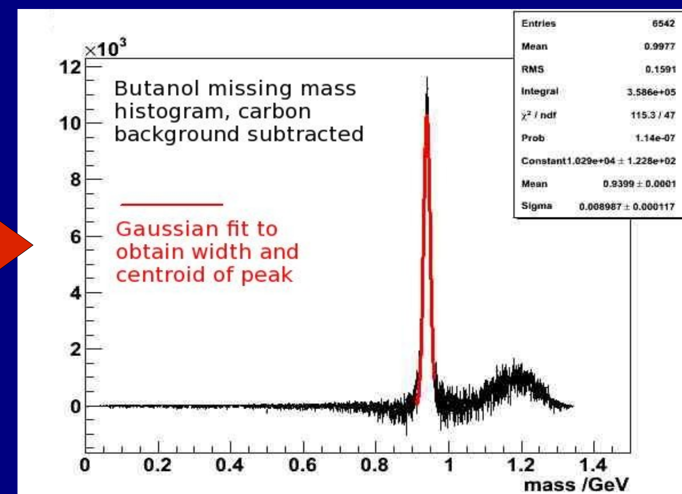
Neutron Mass Cut

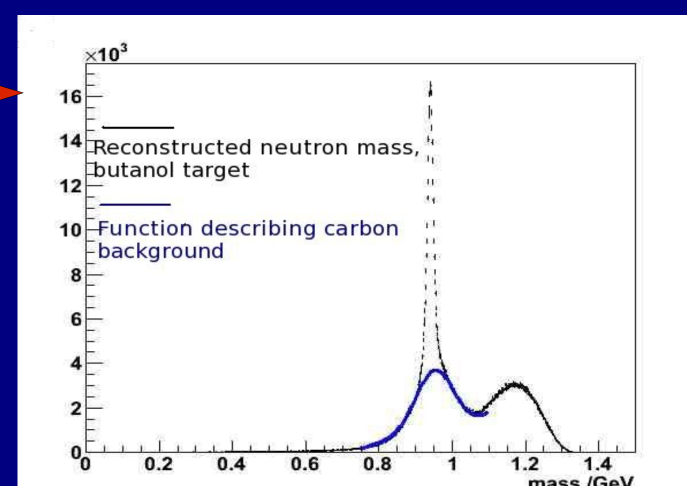
- Butanol is C_4H_9OH, so use carbon target data to assess carbon and oxygen background:



Subtract C missing mass

(To make neutron mass cut only)

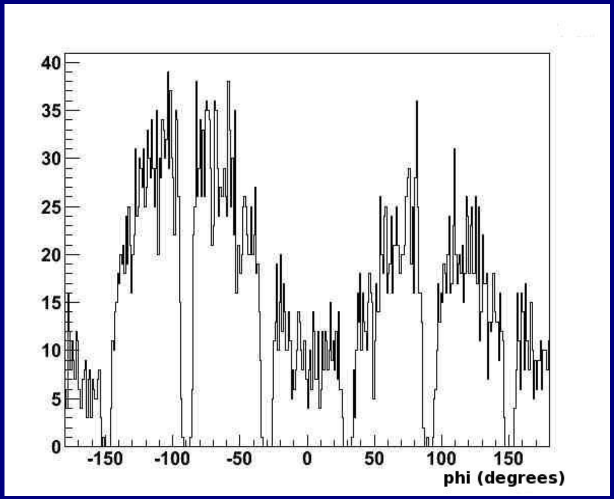




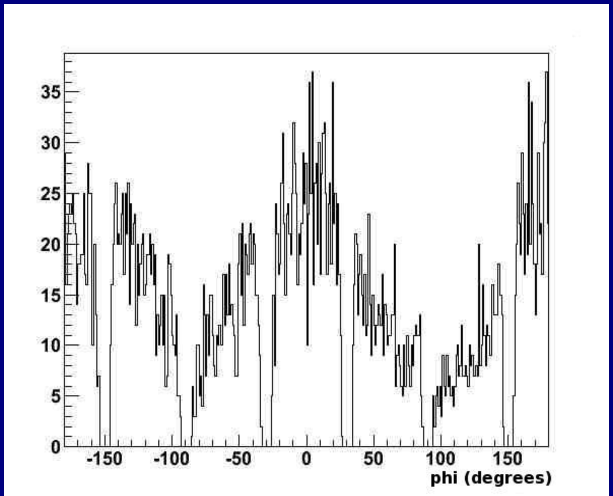
- Can also fit to the missing mass peak in carbon to assess carbon background in butanol:

Asymmetry Production

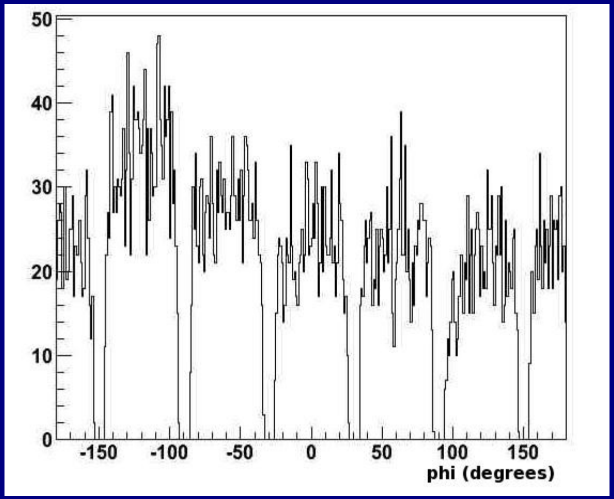
- Plot π^+ azimuthal distribution for each of three beam settings:



PARA beam setting



PERP beam setting



Unpolarised beam setting

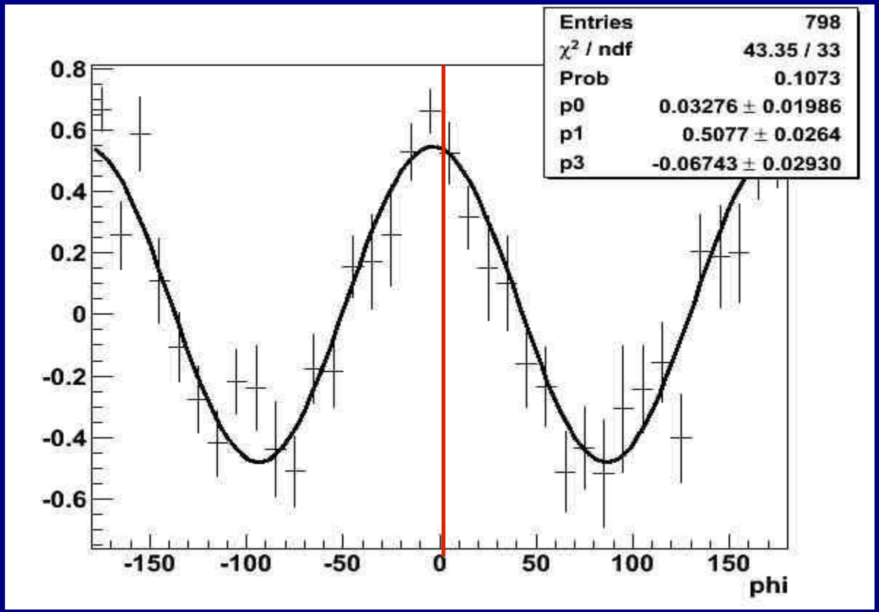
- Use these histograms to produce an asymmetry for each target setting:

$$\frac{N_{||} - N_{\perp}}{N_{||} + N_{\perp}}$$

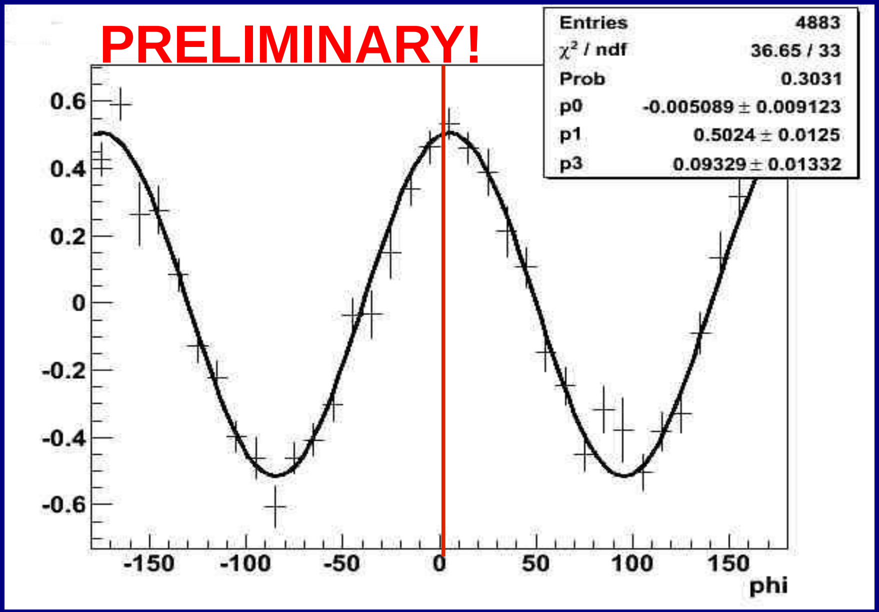
G Observable Extraction

- Create an asymmetry and fit a function to obtain G:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unpol}} \{(1 - p_T \Sigma \cos(2\phi) - p_Z \left[-P_T G \sin(2\phi)\right]\}$$



Asymmetry -ve polarised target



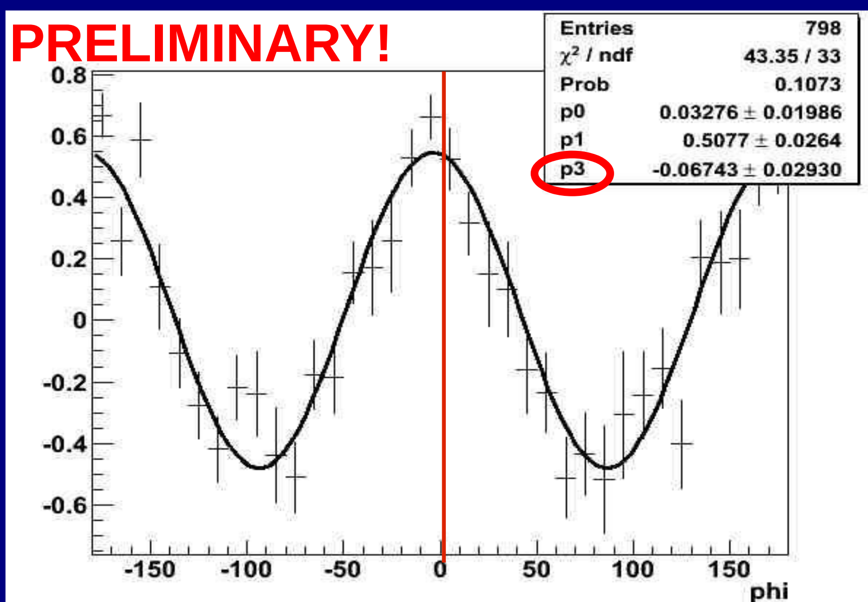
Asymmetry +ve polarised target

G Observable Extraction

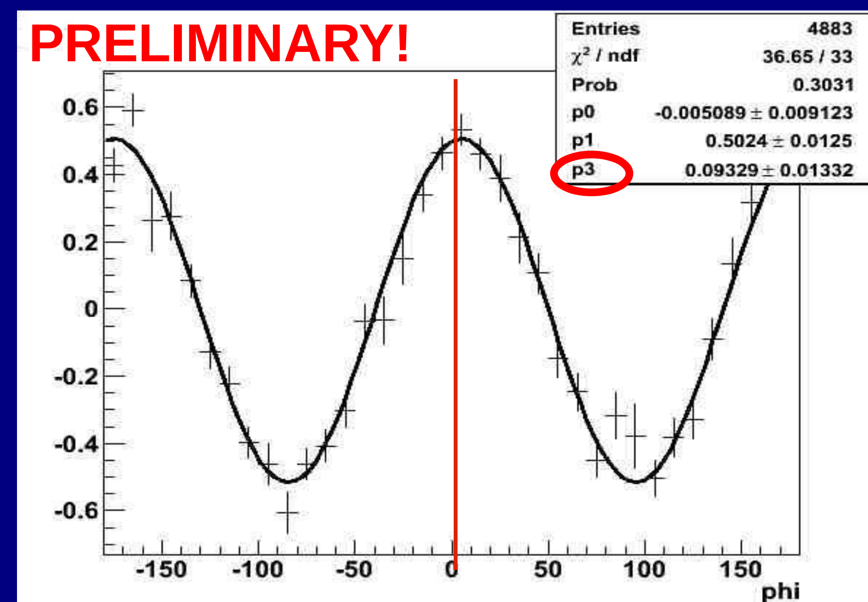
- Create an asymmetry and fit a function to obtain G:

$$f(\phi)_{||\perp} = P0 + P1\cos(2(\phi - P2)) + P3\, sin(2(\phi - P2))$$

$p3 = p_y p_z fG$



Asymmetry -ve polarised target

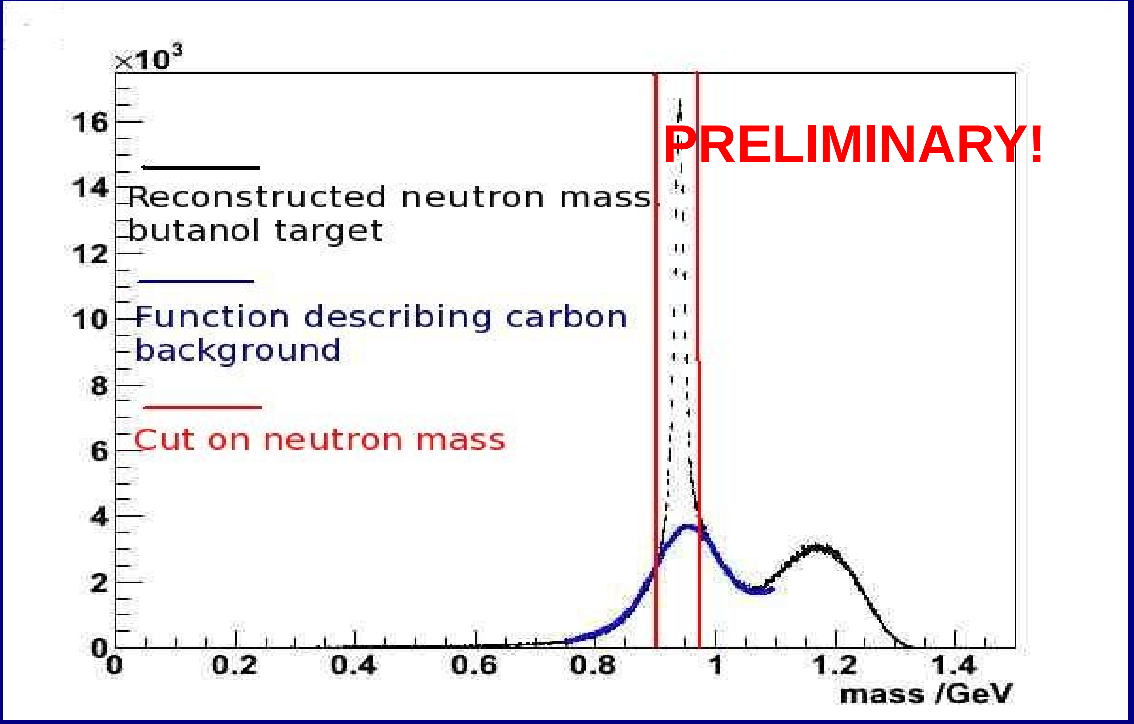


Asymmetry +ve polarised target

Calculating the Dilution Factor f

- This takes into account the ratio of unpolarisable to polarisable protons in butanol:

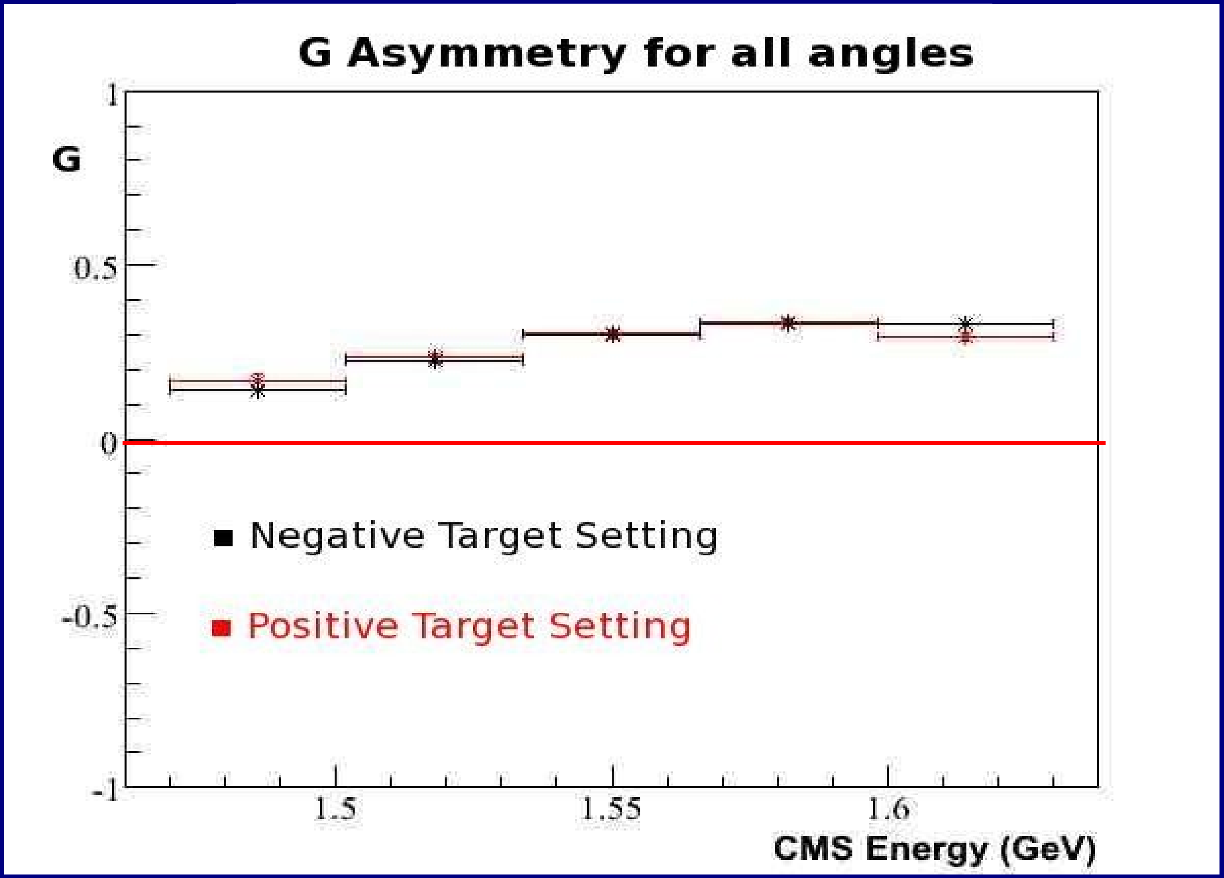
$$f = \frac{N_B - N_C}{N_B} = \frac{N_H}{N_B}$$



- Dilution factor found to be between 0.5 and 0.74 (dependent on photon energy and polar angle, θ) and with ~5%-10% error.

Cross-Checking Results: G Observable

- First step is to check that asymmetries obtained from both target settings (polarised parallel or anti-parallel to the beam direction) are the same:



Cross-Checking Results: Σ Observable

- From fits to butanol asymmetries can also extract Σ:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unpol}}\{(1 - p_T\Sigma\cos(2\phi)) + p_Z\left[-P_T G\sin(2\phi)\right]\}$$

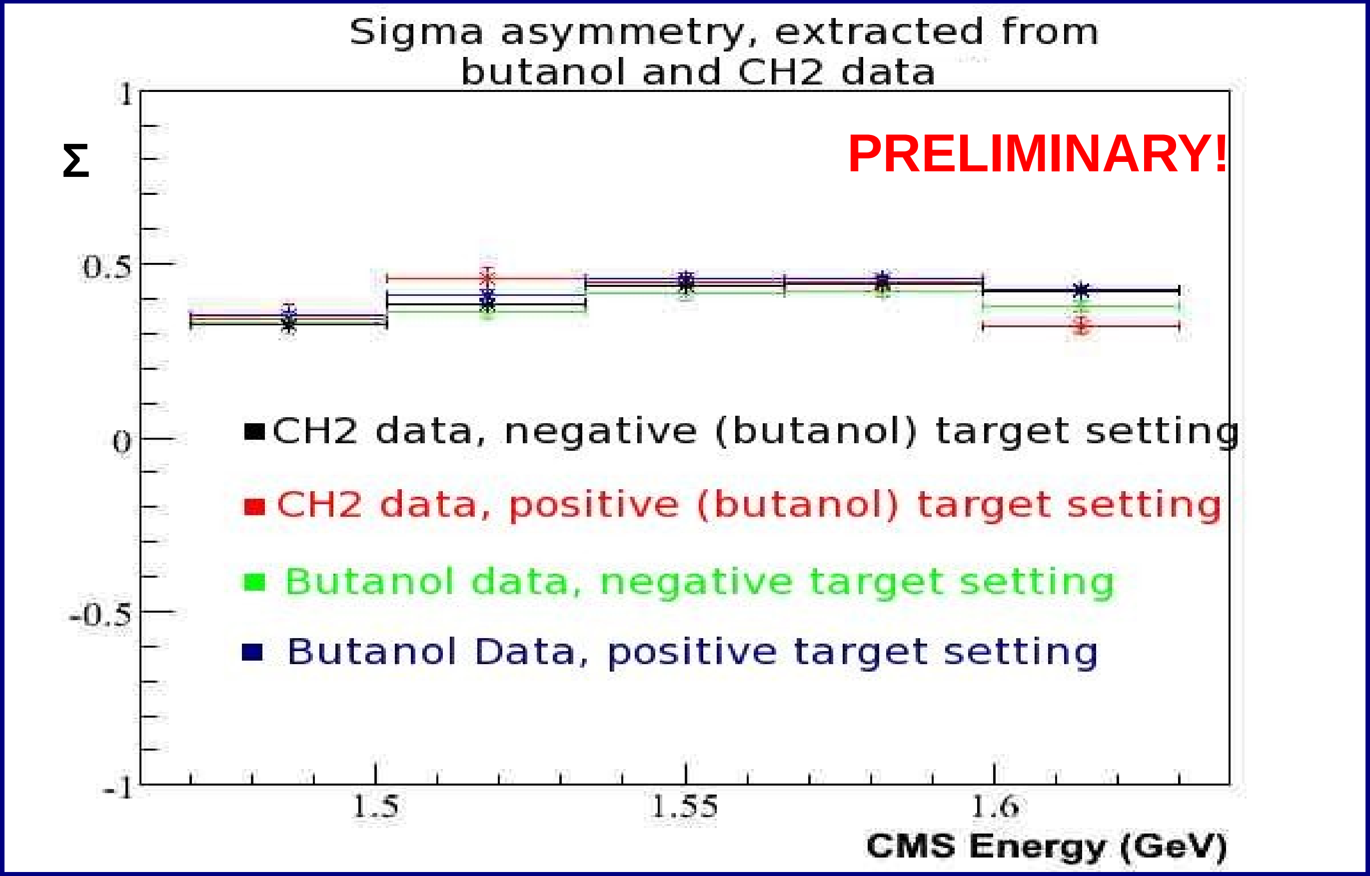
- As CH_2 target unpolarised, asymmetries of the form:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{unpol}}\{(1 - p_T\Sigma\cos(2\phi)\}$$

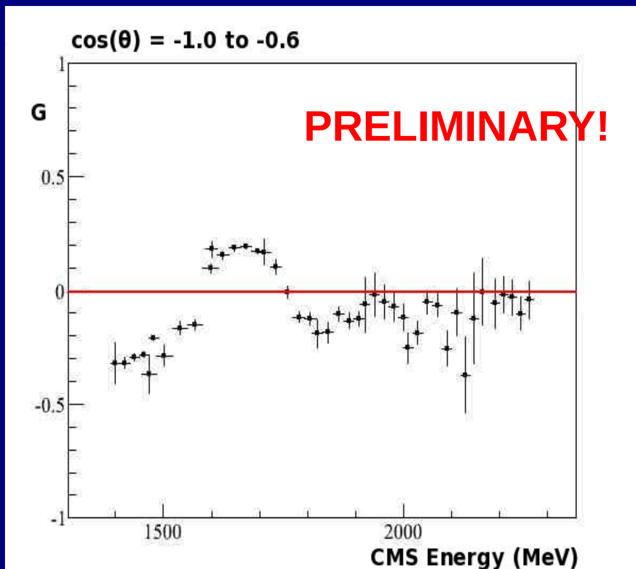
- Compare values of Σ obtained for both targets and for both target settings

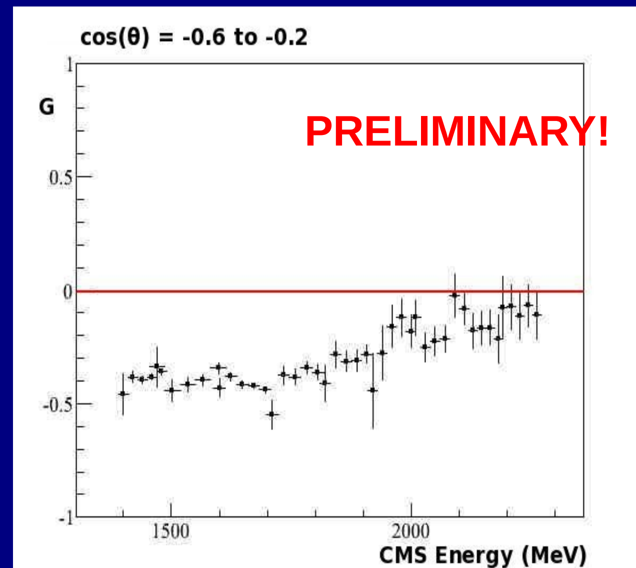
Cross-Checking Results: Σ Observable

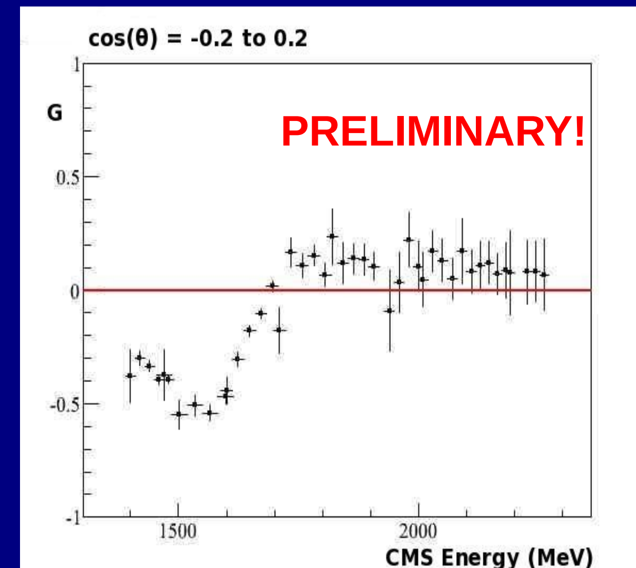
- Consistent values of Σ obtained for both targets and for both target settings:

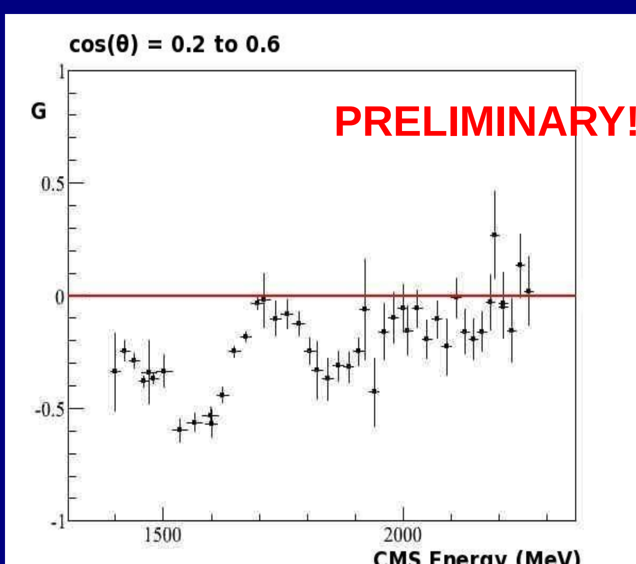


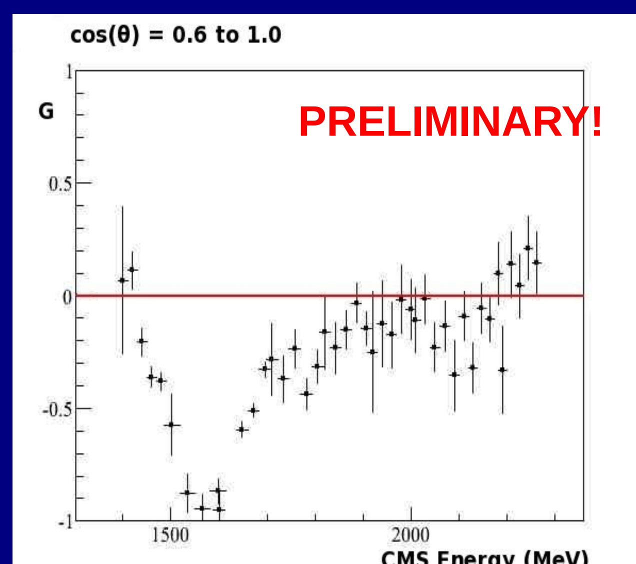
Preliminary Results for G











- g9a data in the energy range 730 – 2300 MeV for fixed angular bins
- Plots shown for **$n\pi^+$ channel**

Comments about Results

- Preliminary values of G have been extracted for the $\gamma(p,n)\pi^+$ channel in the energy range 730-2300 MeV.
- Most comprehensive measurement of G in the 730-2300 MeV energy region to date.
- Some refinement of particle ID cuts and calculation of dilution factor required.

With thanks to the FROST group:

ASU
Arizona State University

The Catholic University of America

Jefferson Lab

The George Washington University
Washington DC

Florida State University
1851

The University of Edinburgh

University of South Carolina

University of Glasgow

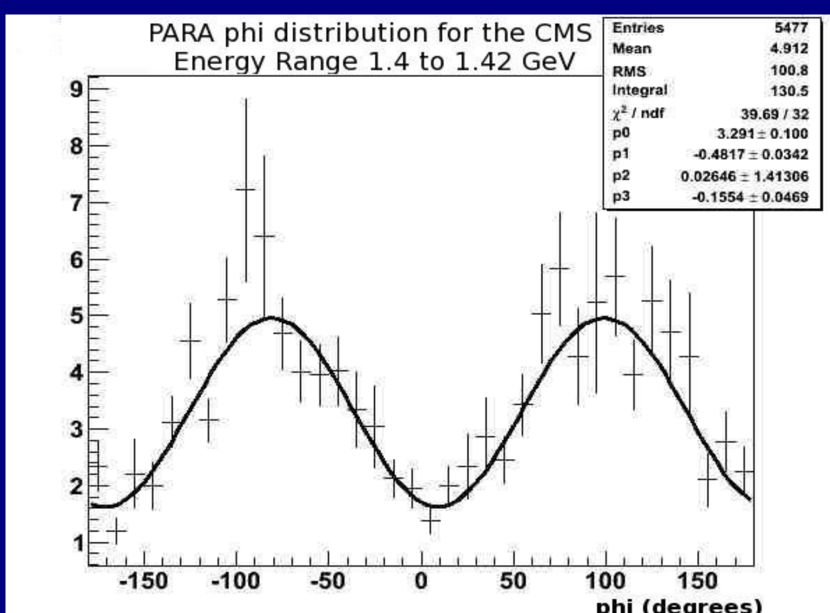
Back-up slides

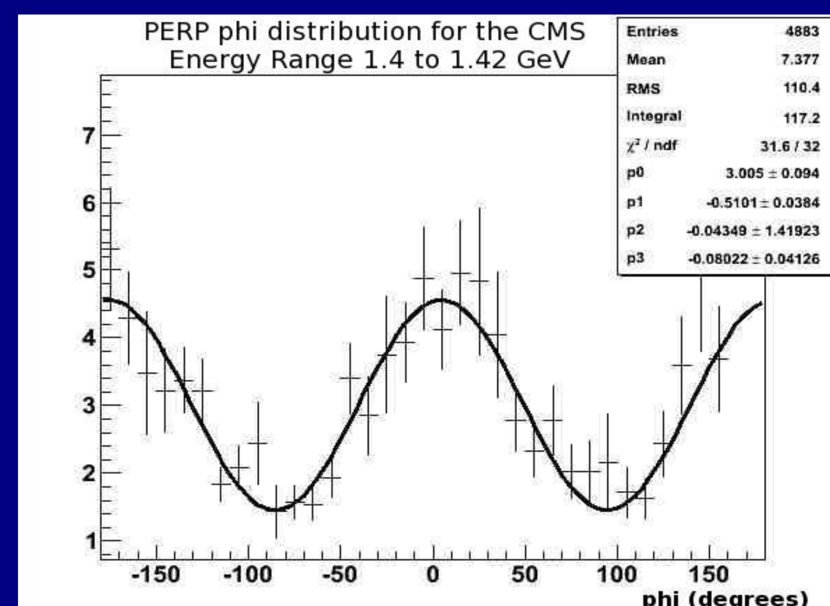
Calculation of Flux Ratio

- Normalise PARA and PERP φ-distributions by dividing through by AMO distribution
- Fit to calculate flux relative to AMO for PARA and PERP data
- Obtain flux ratio for PARA and PERP data sets

$$N(\phi)_{||\perp} = A(\phi)F_{||\perp}(1 \pm p_{||\perp}\Sigma\cos(2(\phi-\phi_0)) \pm p_{||\perp}p_z G\sin(2(\phi-\phi_0)))$$

$$N(\phi)_{AMO} = A(\phi)F_{AMO}$$





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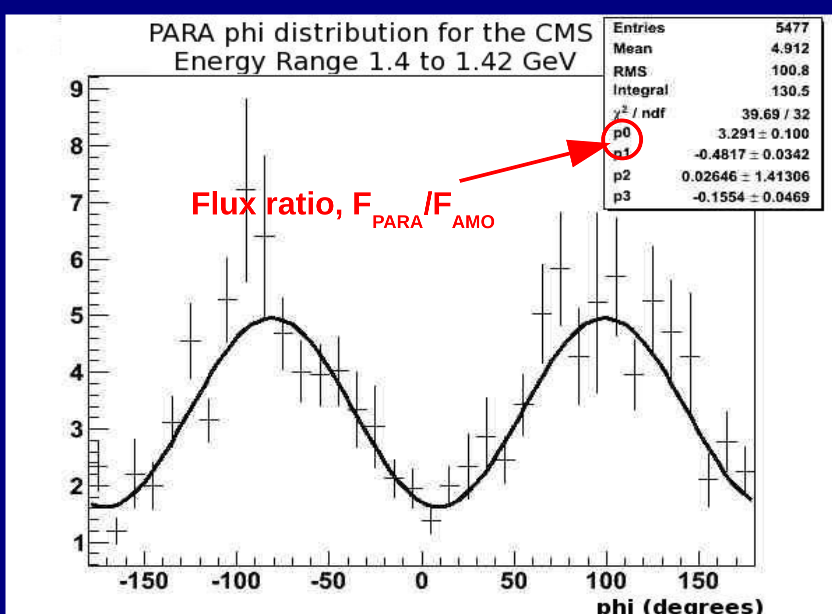
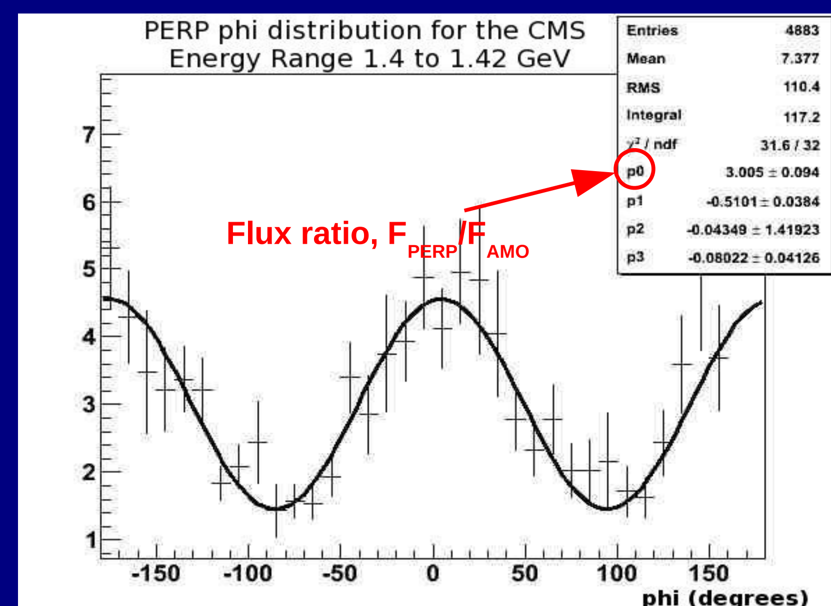
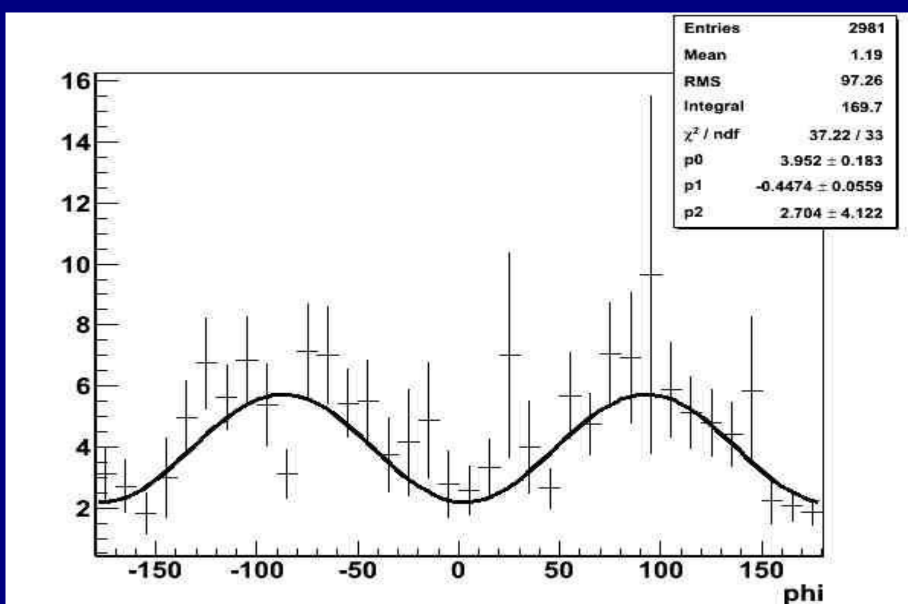


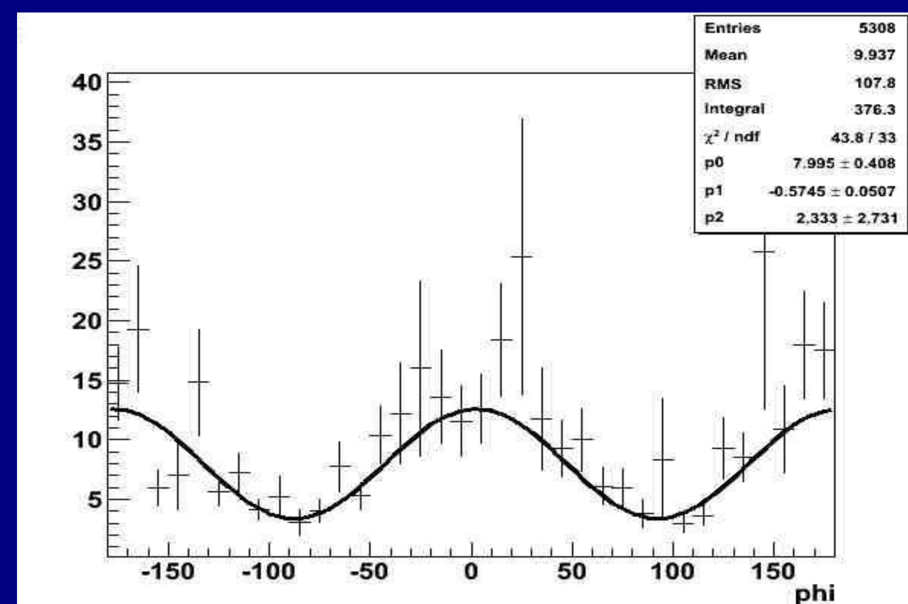


Calculation of φ_0 Offset

- Aim to assess offset of PARA and PERP beam settings
- Extract parameter from fit to normalised π^+ azimuthal distributions (data from unpolarised CH_2) target

$$N(\phi)_{||\perp} = A(\phi)F_{||\perp}(1 \pm p_{||\perp}\Sigma\cos(2(\phi - \phi_0)))$$





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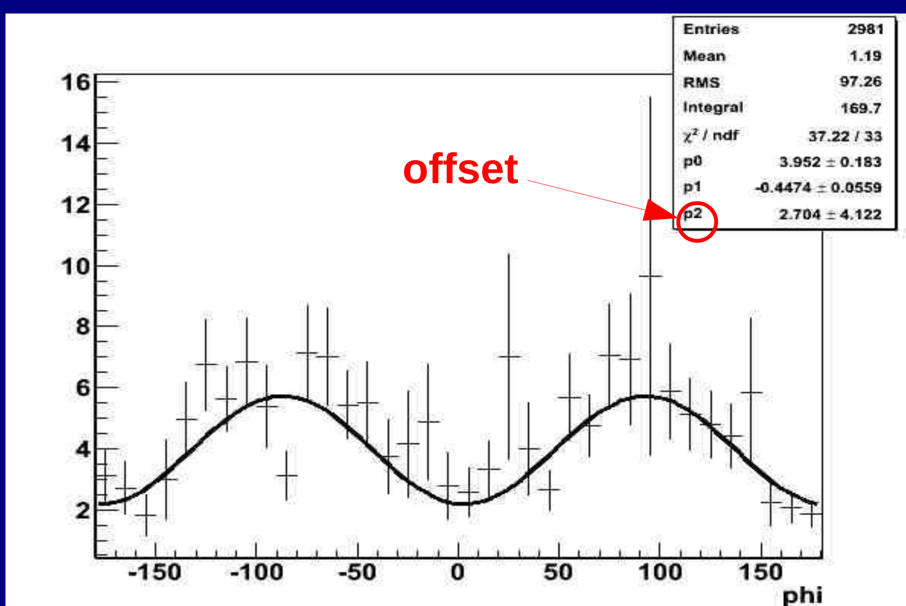

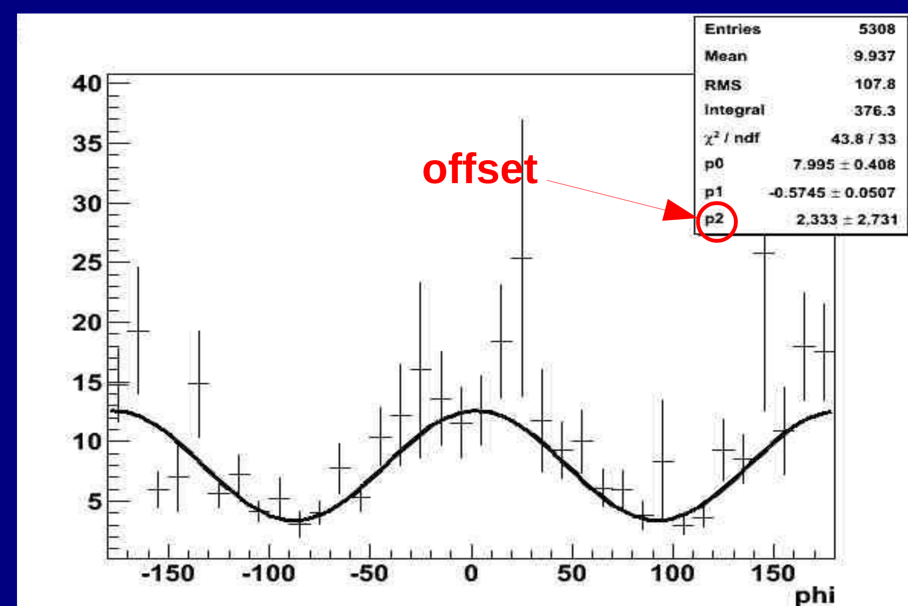

Calculating the scale factor

- Divide butanol missing mass plot by carbon missing mass plot
- Fit to the flat region to the left of the missing mass peaks