# Photon Asymmetry Measurements of $^{12}$C($\vec{\gamma}$,pp) with CB@MAMI

## Abstract

Photonuclear cross section (σ) measurements average the parallel and perpendicular responses of nuclei. In contrast measurements of the photon asymmetry (defined as $\Sigma = (\sigma_{\parallel} - \sigma_{\perp})/(\sigma_{\parallel} + \sigma_{\perp})$ ), using linearly polarised photons, allow the difference between parallel and perpendicular responses to be measured, allowing unique access to observables which are sensitive to details of the reaction process. For two-nucleon knockout reactions, this sensitivity provides us with a means to study the interaction between nucleons in the nucleus. This work is primarily concerned with (γ pp) reactions in Carbon nuclei where Δ-currents and central Short Range Correlations (SRC) are thought to be the major contributors.

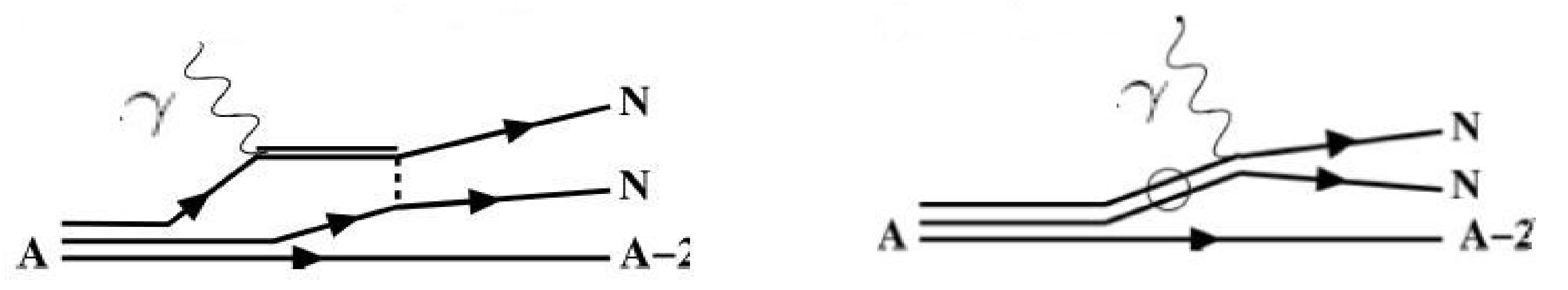


*Fig.2*: Δ-current and SRC reaction mechanisms largely responsible for two proton knockout reactions

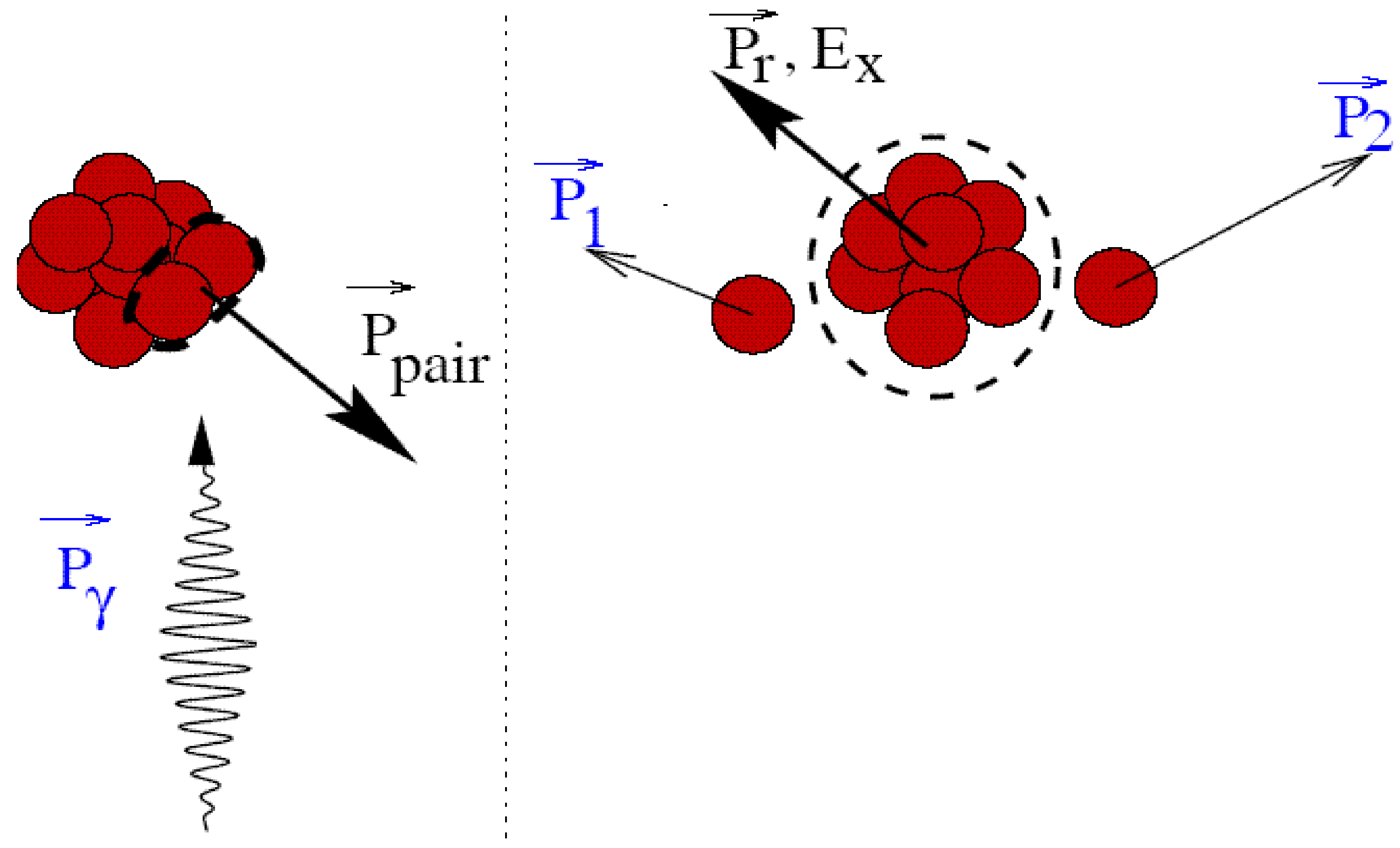


*Fig.1*: Photoinduced two proton knockout reaction

## Previous Measurements

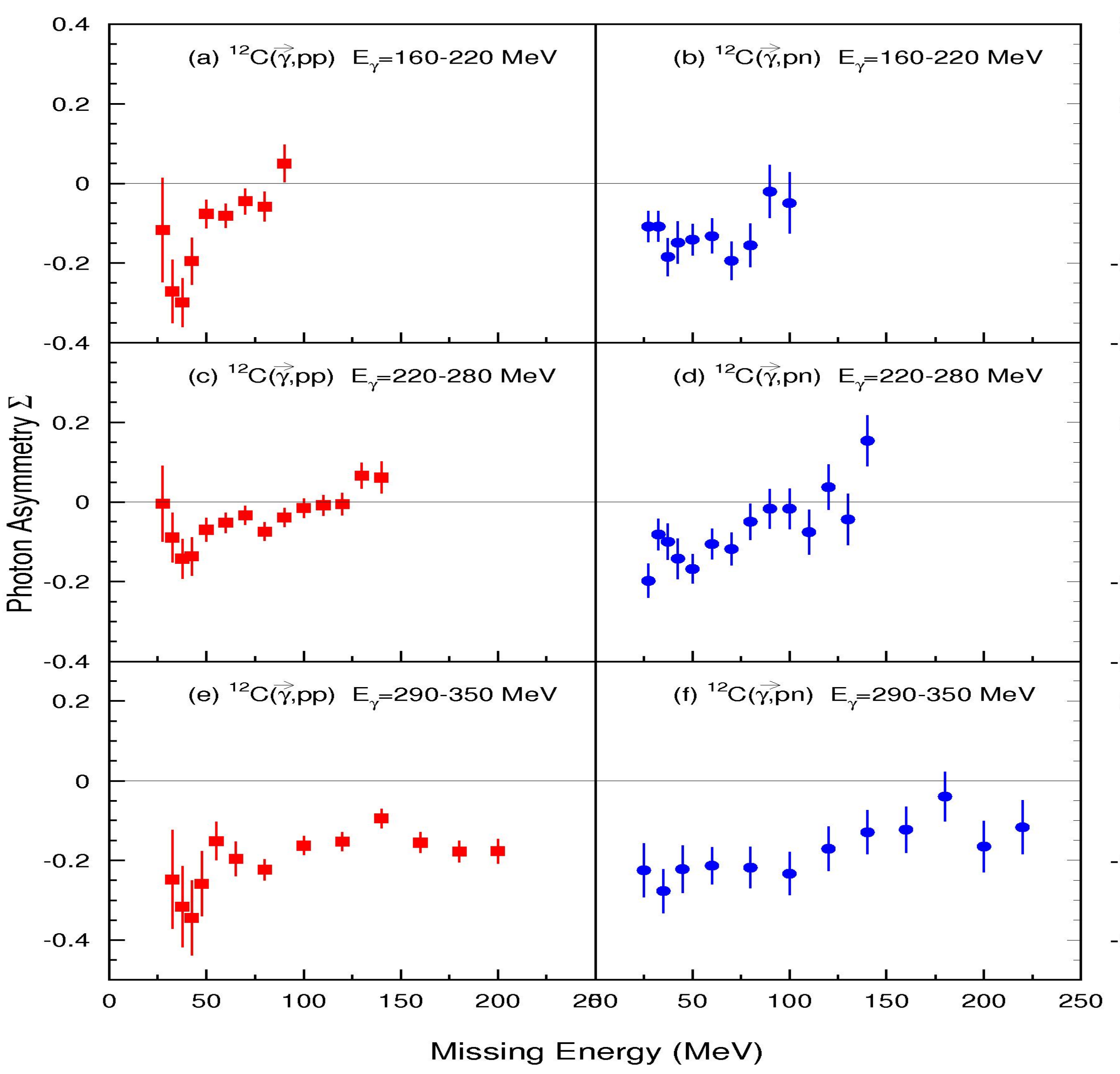


*Fig.3*: Previous measurements of $^{12}$C(γ,pp) and $^{12}$C(γ,pn), PIP TOF
Setup using the MAM I-B electron accelerator and Glasgow Photon Tagger

Previous measurements carried out in Mainz show a negative photon asymmetry for both reaction channels for photon energies $E_\gamma$ = 160 -350 MeV. At low missing energies, $E_m$ <70 MeV, there is a strong peak in Σ with a particularly prominent structure in the (γ,pp) channel. There are distinct differences between $\Sigma_{(\gamma,pp)}$ and $\Sigma_{(\gamma,pn)}$ . At low $E_m$, Σ is larger in (γ,pp) than (γ,pn) suggesting that direct two-nucleon knockout is the dominant reaction mechanism and not charge exchange final state interactions.

Comparison of this data with theoretical calculations fails to account for dominant Δ-current parallel and perpendicular contributions. However, this data suffered from poor statistical accuracy, particularly limited in angular coverage ($50^o$-$130^o$) and Eγ (180-340 MeV).

This experiment intends to improve the statistical accuracy of the (γ,pp) data set using the 1.5 GeV MAMI-C electron beam with the Glasgow Photon Tagger. A thin diamond radiator is used to provide linearly polarised photons which impinge on a $^{12}$C target housed in the, near 4π, Crystal Ball (CB)detector. The CB, aided by a particle identification detector (PID), a barrel composed of 24 plastic scintillators were used to detect protons.

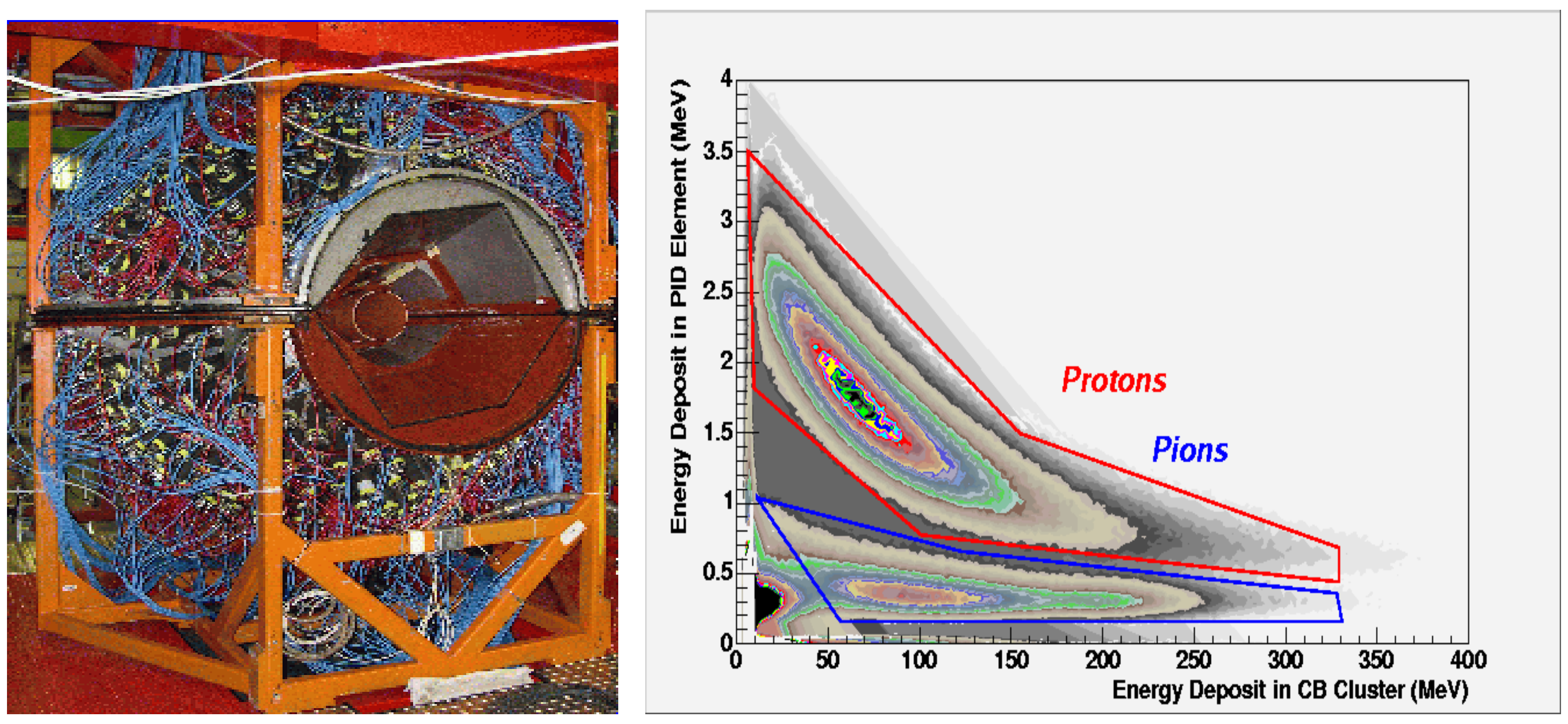


*Fig.4*: a) Crystal Ball positioned in the A2 Hall Mainz. b) PID 'banana' plot, the red region depicts the band of protons

## Linearly Polarised Photons

In order to extract a photon asymmetry, one must first produce polarised photons. In the A2 Hall in Mainz, the primary 1.5GeV electron beam from MAMI-C undergoes a process known as Coherent Bremsstrahlung, producing a secondary beam of polarised photons. The energy of these photons are measured by the Glasgow Photon Tagger (Fig. 5)

In the Coherent Bremsstrahlung process high energy electrons scatter off a diamond crystal, to produce photons at discrete fractional energies, corresponding to specific momentum transfers from the electrons to the crystal nuclei. When the diamond radiator is aligned correctly with respect to the electron beam photons can be produced coherently, with a high degree of polarisation, if the momentum transfer from the electron to the nuclei matches a reciprocal lattice vector of the crystal (Fig. 6). This process is analogous to Bragg scattering.

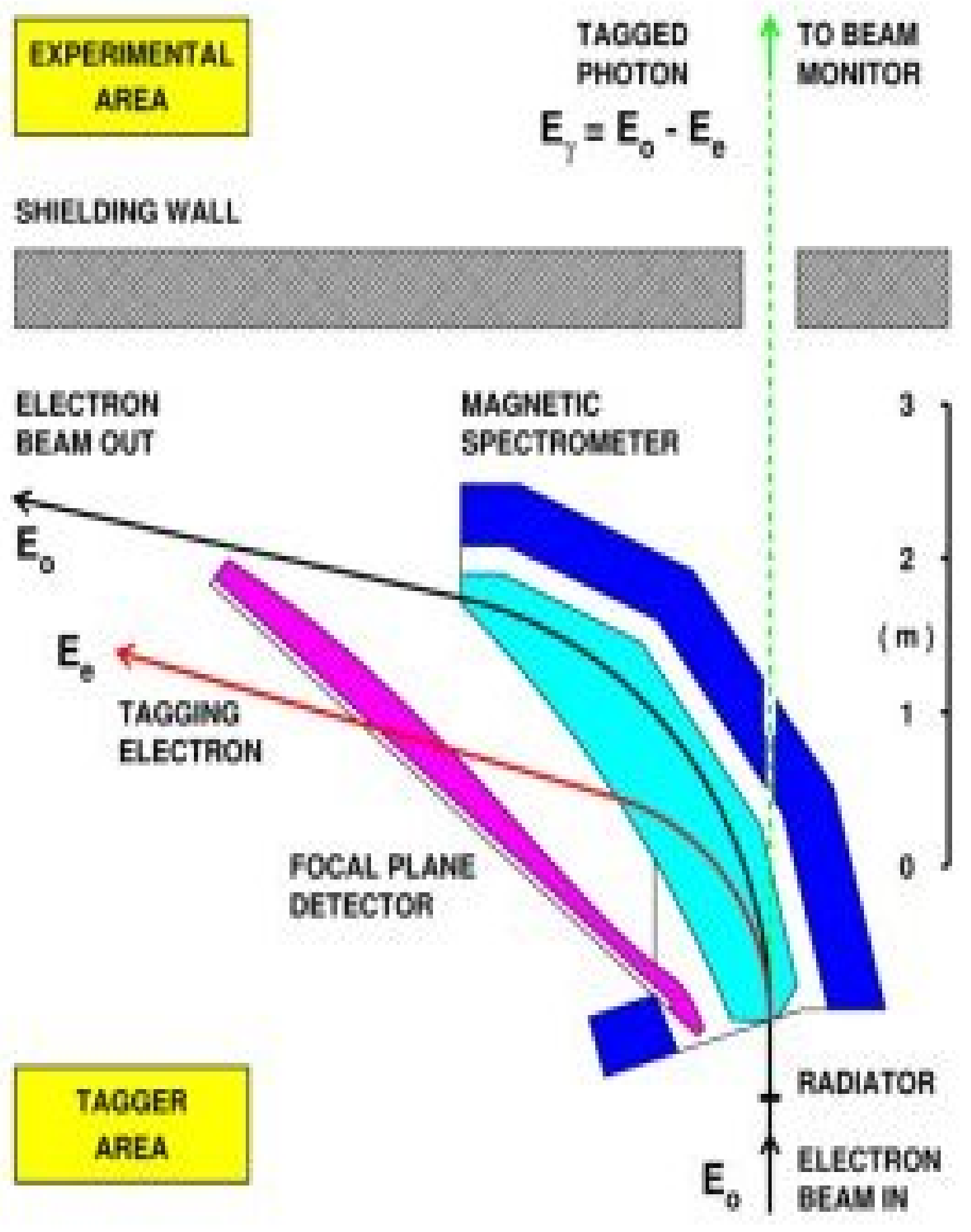


Fig5: Glasgow Photon Tagger. Scattered electrons are directed onto a focal plane detector by a magnetic spectrometer where they are momentum analysed from which $E_\gamma$ is deduced.

## Measurement of Photon Polarisation

The expression for the polarised cross section (reduced in terms of photon asymmetry only) for this reaction is given below and shows the relationship between the observables and the degree of linear polarisation, P.

$$\frac{d\sigma}{d\Omega}(\theta,\phi) = \frac{d\sigma}{d\Omega}(\theta)\left[1 + P\Sigma\cos(2\phi)\right]$$

A good measurement of photon polarisation is therefore essential for accurate extraction of Σ and coherent $\pi^0$ photoproduction from $^{12}$C is an excellent tool to achieve this. Σ for coherent $\pi^0$ production from spin-0 nuclei such as $^{12}$C is known to equal 1. Extraction of PΣ for clean $^{12}$C(γ,$\pi^0$) signal is therefore a direct measurement of the photon polarisation.

Separate coherent events from background (quasifree and incoherent) via missing energy selection using tagging spectrometer

$$E_m = E_\pi^{cm}(E_\gamma,\theta_\pi) - E_\pi^{cm}(\gamma_1\gamma_2)$$

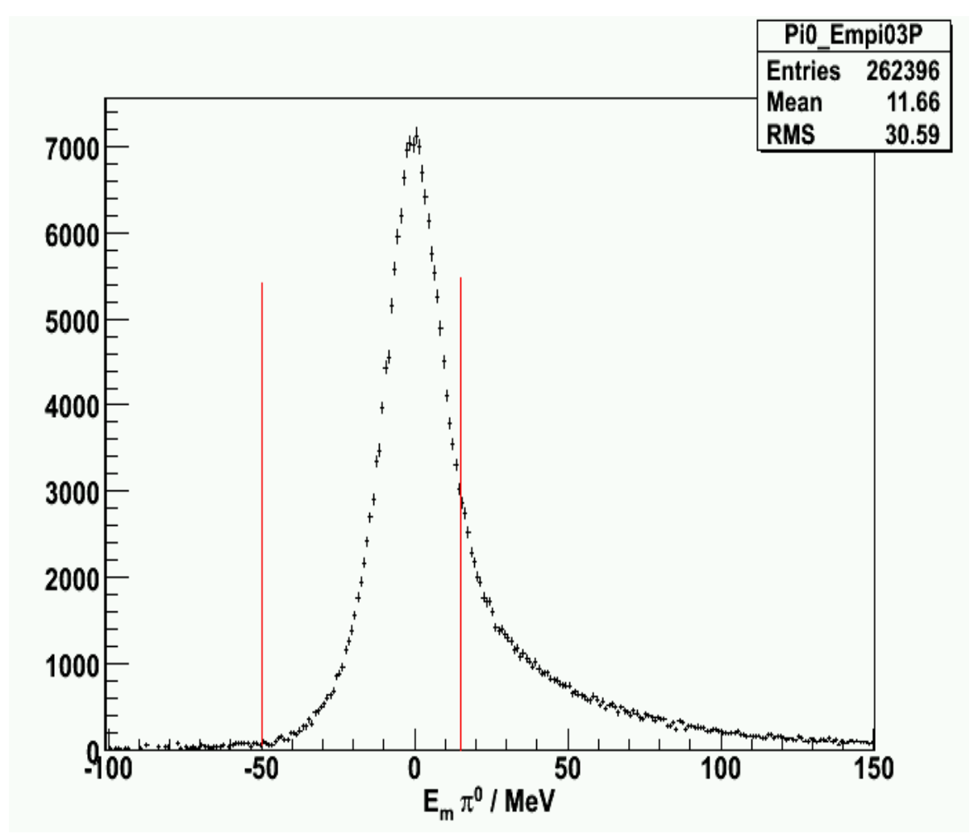


Fig6: Selection of coherent events via missing energy. Coherent events about 0 MeV with background at higher missing energies

Fig 7a. shows the azimuthal asymmetry for coherent pion events averaged over the full coherent peak. The magnitude of the fit gives the average polarisation over the coherent peak. Furthermore, analysis of this asymmetry as a function of photon energy allows measurement of photon polarisation as a function of $E_\gamma$, shown in fig 7b.

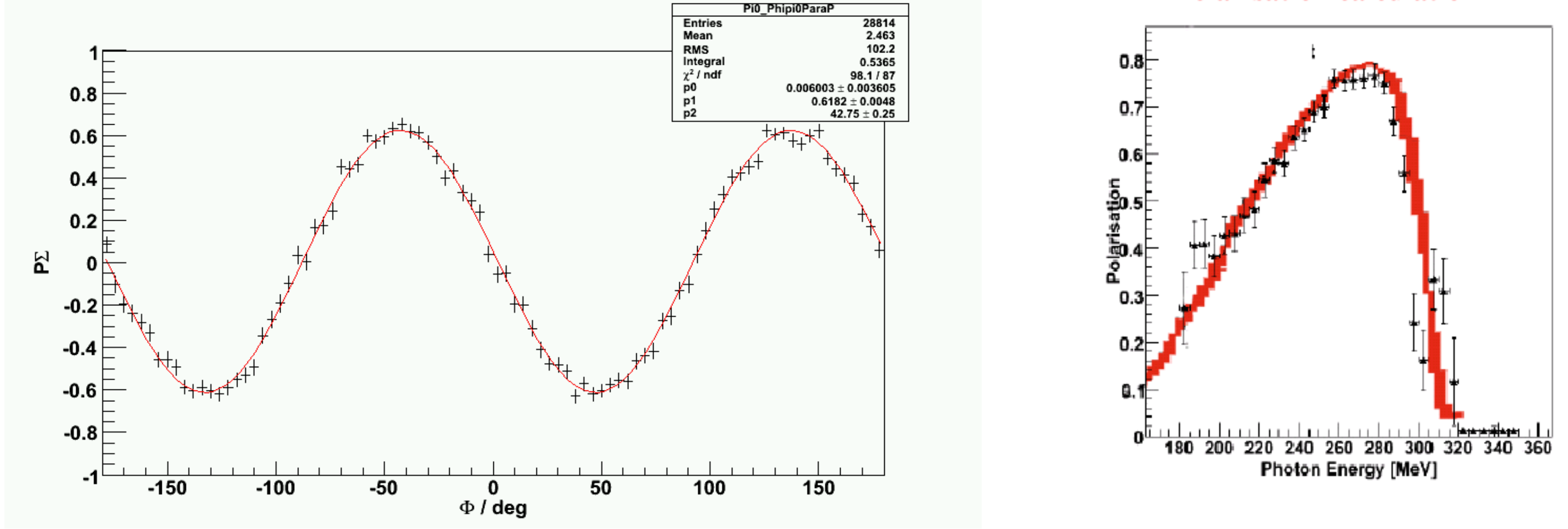
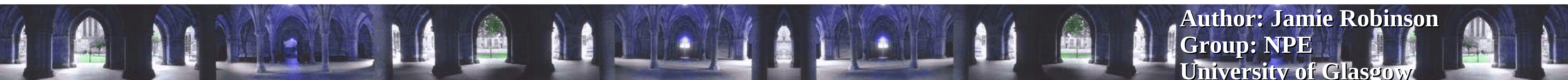


*Fig.7*: a) Azimuthal asymmetry for coherent pions b) Polarisation measurement using coherent pion photoproduction form $^{12}$C compared with anb polarisation calculation



**Author: Jamie Robinson**
**Group: NPE**
**University of Glasgow**