Polarisation transfer in hyperon photoproduction near threshold

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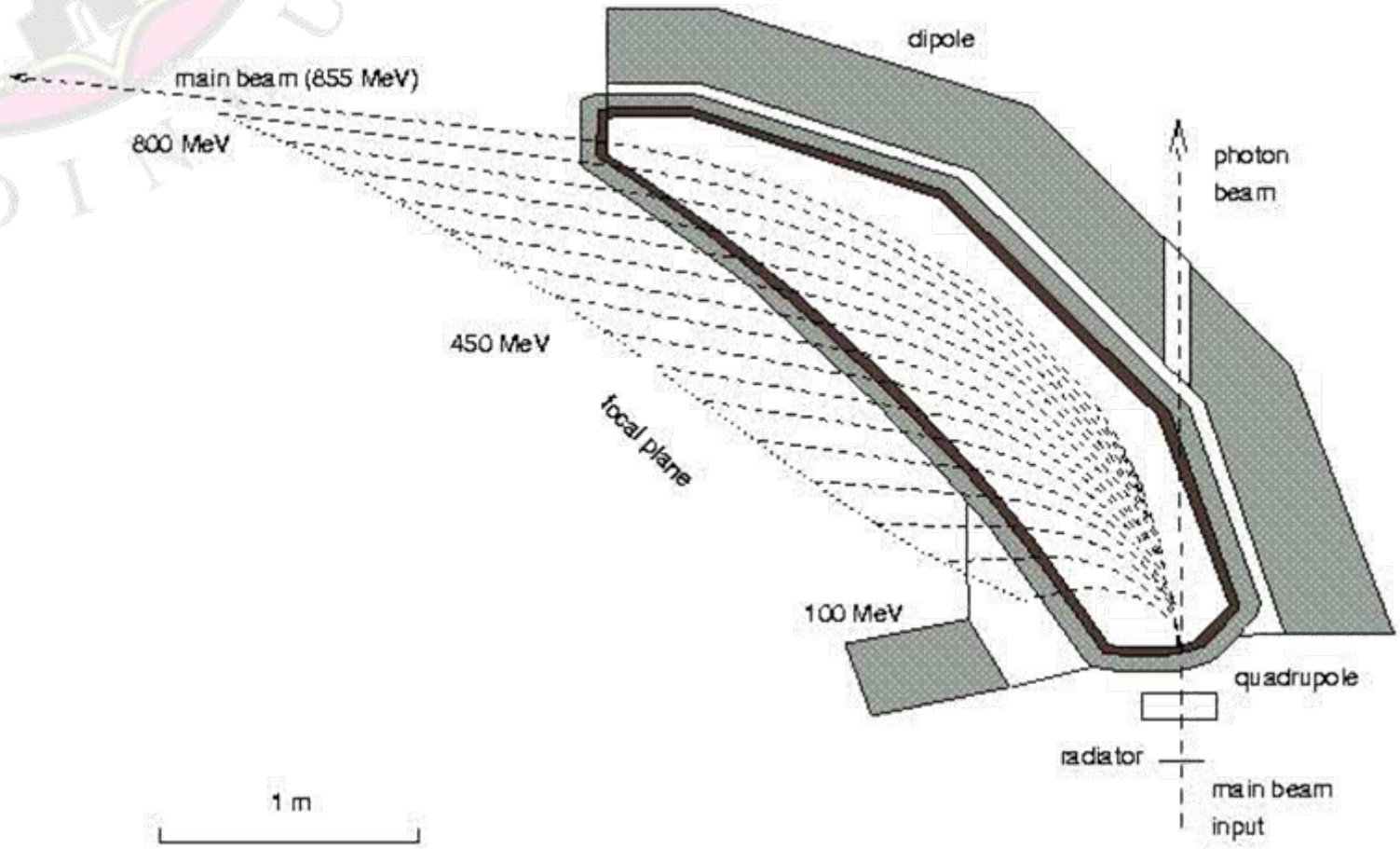
SUPA

Talk Overview

- The Mainz Microtron (MAMI) and the Crystal Ball detector and apparatus
- Hyperon Photoproduction
- Polarisation observables
- Identifying strange decay channels
- Kinematic analysis
- Preliminary asymmetry measurements and extraction of C_X and C_Z

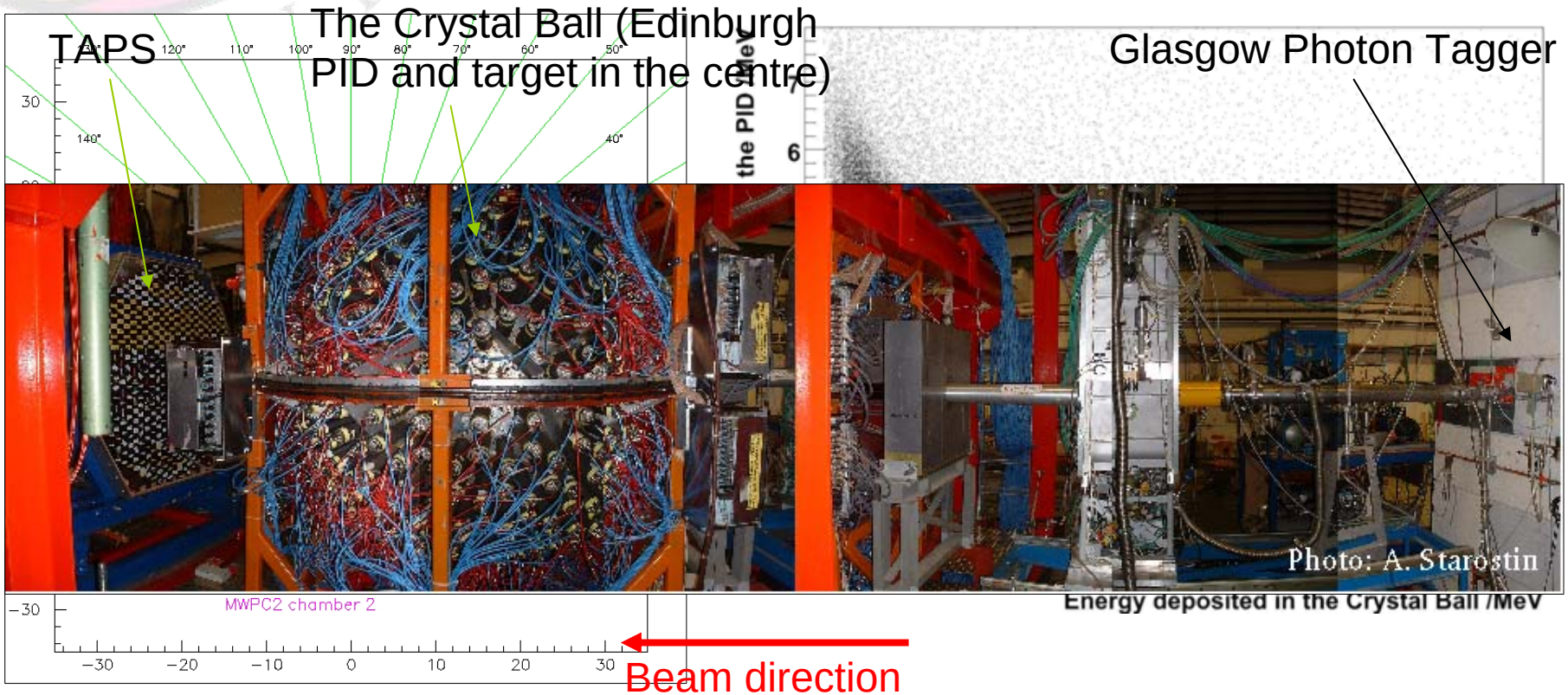
Experimental Apparatus

- MAMI C: Electron accelerator facility with energies up to 1.5 GeV
- Glasgow Photon Tagger:



Experimental Apparatus

- The Crystal Ball detector - 672 NaI crystals covering ~93% of 4π steradians
- Edinburgh PID - 24 Plastic Scintillators parallel to the beam
- TAPS - Segmented BaF2 detector. Used as a forward wall for the Crystal Ball



Hyperon Photoproduction

- Important for investigations of nucleon resonances
- A crucial test of QCD based chiral perturbation theories in the strange quark sector

$$\gamma + p \rightarrow K^+ + \Lambda$$

- $\rightarrow p + \pi^-$ (~ 64%)
- $\rightarrow n + \pi^0$ (~ 36%)
  - $\rightarrow 2\gamma$

$$\gamma + p \rightarrow K^+ + \Sigma^0$$

- $\rightarrow \gamma + \Lambda$

Polarisation observables

• Spin observables – a new constraint for reaction models and baryon resonance structure

• Circularly polarised photons - polarisation transferred to the recoiling hyperon

• Characterised by the observables C_X and C_Z:

$$P_X = -P_\gamma C_X, \quad P_y = P, \quad P_Z = -P_\gamma C_z$$

P_i = polarisation transferred along axis i, P_γ = circular polarisation of photon beam

• Λ decay is a weak decay (parity violating)

• Hyperon polarisation - measured by the distribution of it's decay products

Polarisation observables

• Sixteen different observables in total - beam-target, beam-recoil, target-recoil (all double polarisation), & single polarisation observables

$$\frac{d\sigma}{d\Omega} = \sigma_0\{1 - P_{lin}\sum\cos 2\varphi + P_{x'}(-P_{lin}O_{x'}\sin 2\varphi - P_{\odot}C_{x'}) - P_{y'}(-P + P_{lin}T\cos 2\varphi) - P_{z'}(P_{lin}O_{z'}\sin 2\varphi + P_{\odot}C_{z'})\}$$

Angle between photon polarisation and reaction plane

Polarisations transferred with a circularly pol. beam

Polarisations transferred with a linearly pol. beam

Linear or circular polarisation of the photon beam

Beam-recoil measurements

Axis defined as:

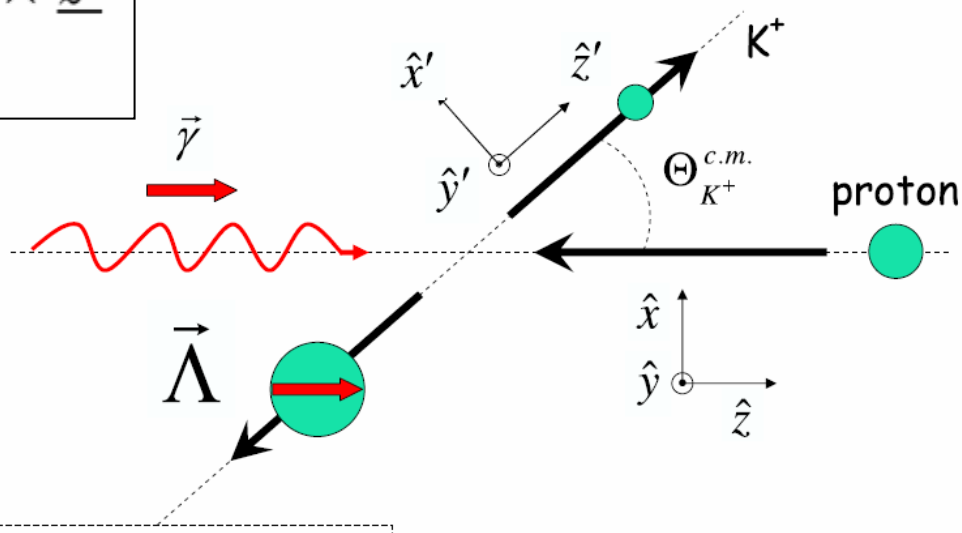
$$\underline{z} = \frac{\underline{k}}{|\underline{k}|} \qquad \underline{y} = \frac{\underline{k}\times\underline{q}}{|\underline{k}\times\underline{q}|} \qquad \underline{x} = \underline{y}\times\underline{z}$$

$$\underline{z'} = \frac{\underline{q}}{|\underline{q}|} \qquad \underline{y'} = \underline{y} \qquad \underline{x'} = \underline{y'}\times\underline{z'}$$

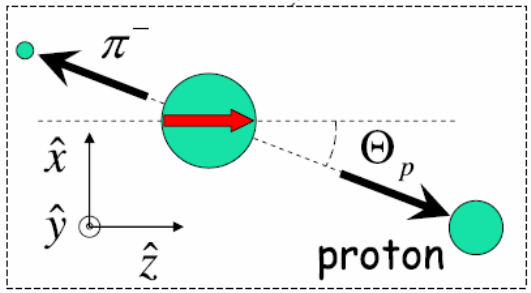
$\underline{k}$ = Photon beam momentum,

$\underline{q}$ = momentum of the recoiling K^+ in CM frame

Centre of mass frame:



Λ rest frame:



R.A. Adelseck and B. Saghai. *Phys Rev C.*, **42**:108, 1990

Beam-recoil measurements

- Measure the polar angle, θ_i, from axis i in the Λ rest frame

- Gives an asymmetry, A, of decay products[1]:

$$A(\cos\theta_i) = \frac{N_+ - N_-}{N_+ + N_-} = \alpha\nu P_\odot C_i \cos\theta_i$$

- $N_{+/-}$ = number of events detected for a +/- beam helicity
- $P_\odot$ = extent of polarisation of the photon beam
- α = weak decay parameter (0.65 +/- 0.04)
- ν = a "dilution factor" in the $K^+\Sigma^0$ channel
- Flipping the polarisation direction cancels acceptance factors in the detector

[1] R. Bradford et al. (The CLAS Collaboration). Phys. Rev. C 75, 035205 (2007)

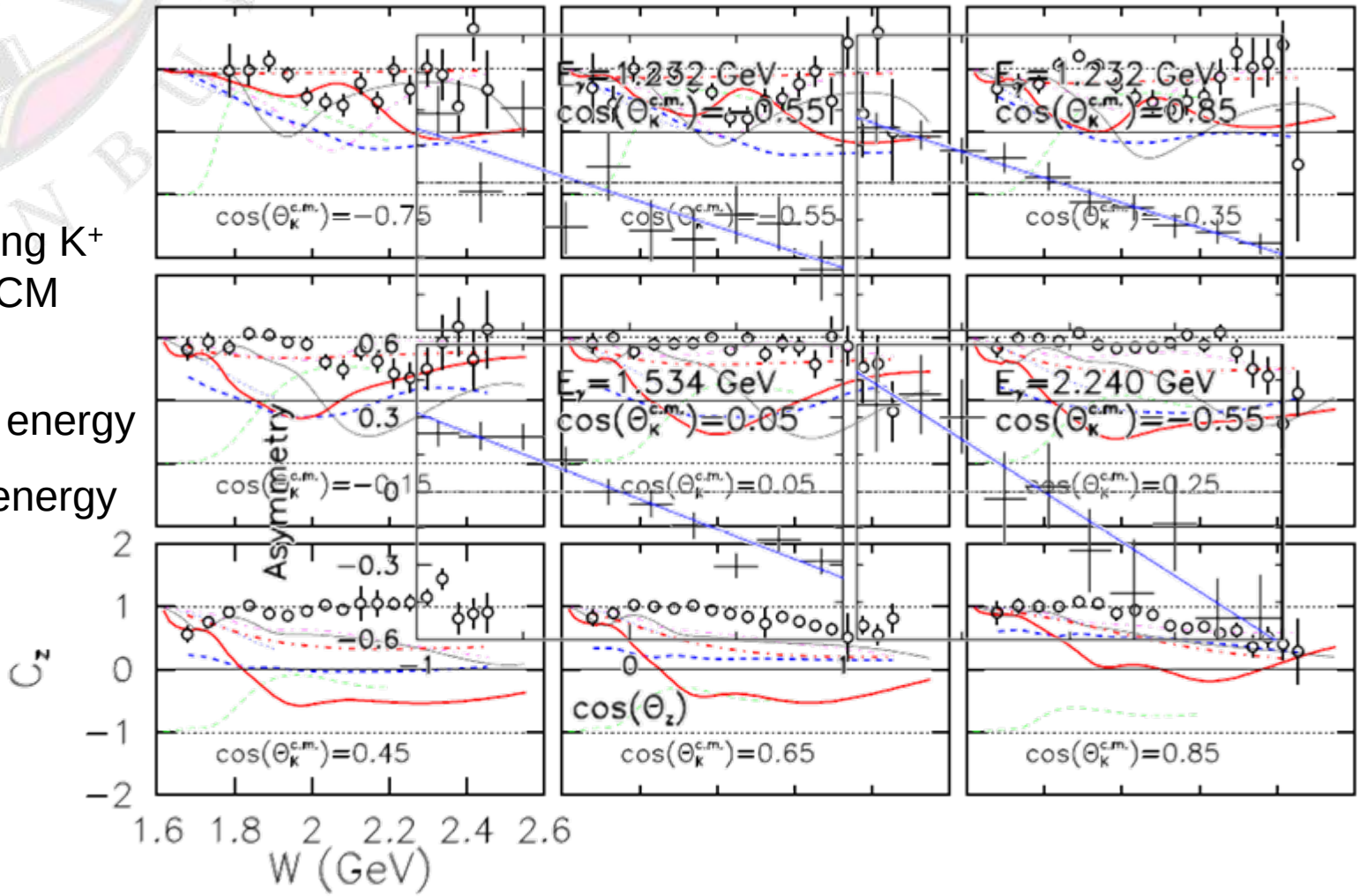
Previous measurements

- Previous measurements of C_x and C_z at the CLAS collaboration at JLab[1]:

θ_K^{cm} = recoiling K^+ angle in the CM frame

E_γ = Photon energy

W = C of M energy



[1] R. Bradford et al. (The CLAS Collaboration). Phys. Rev. C 75, 035205 (2007)

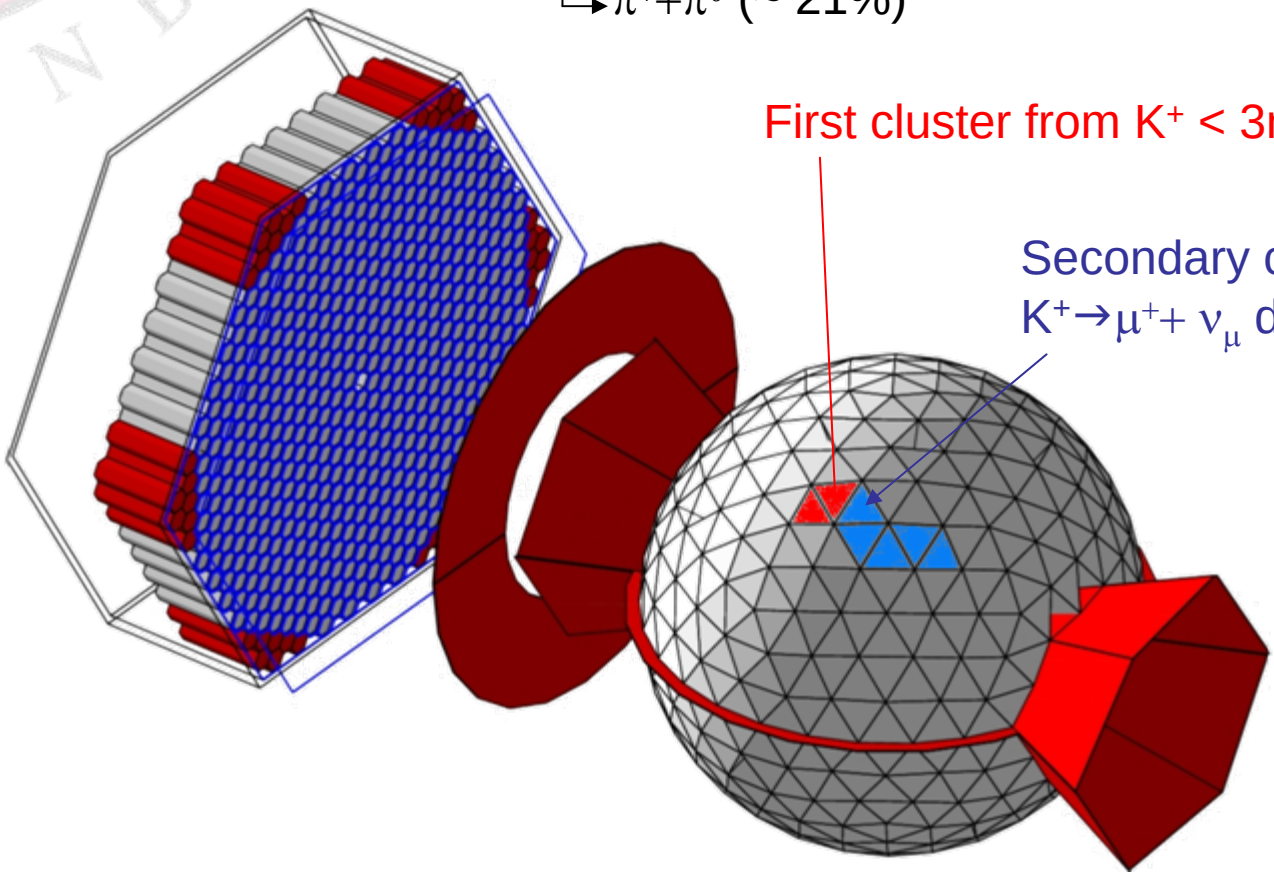
Identifying strange mesons

- A new method of tagging a strange meson reaction channel
- Identify the K^+ decay within the crystals of the Crystal Ball

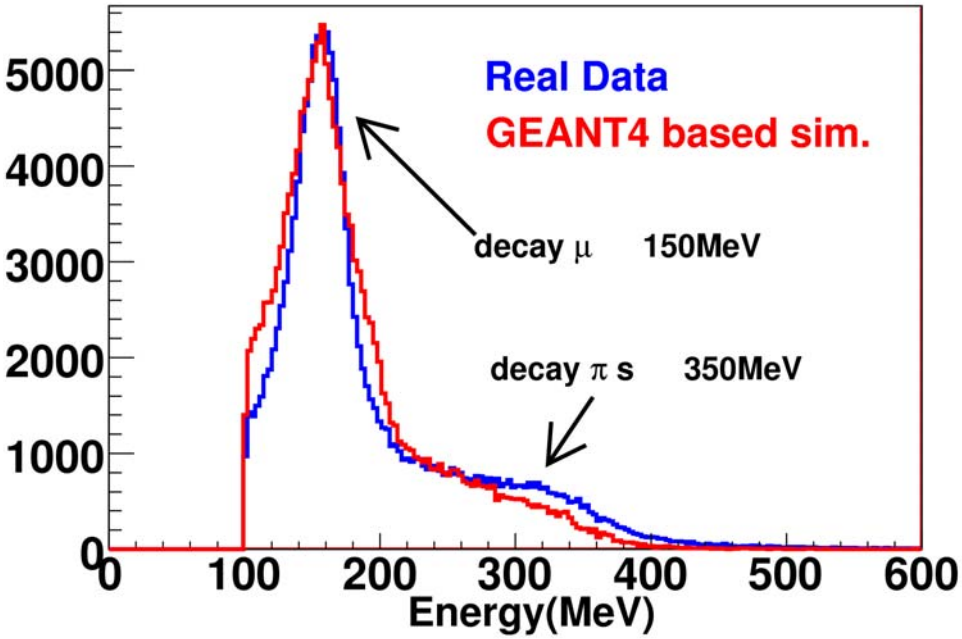
$K^+ \rightarrow \mu^+ + \nu_\mu$ (~ 63%)

$K^+ \rightarrow \pi^+ + \pi^0$ (~ 21%)

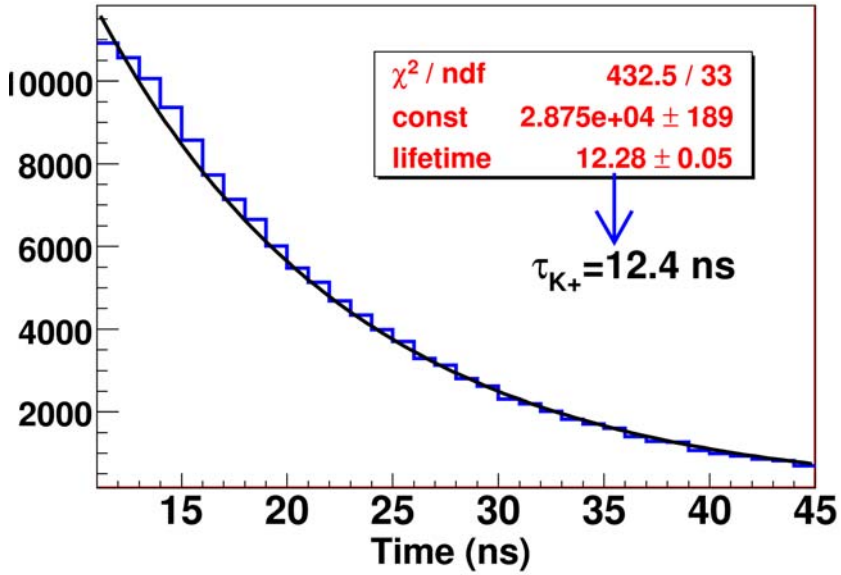
Mean lifetime of K^+ ~ 12 ns

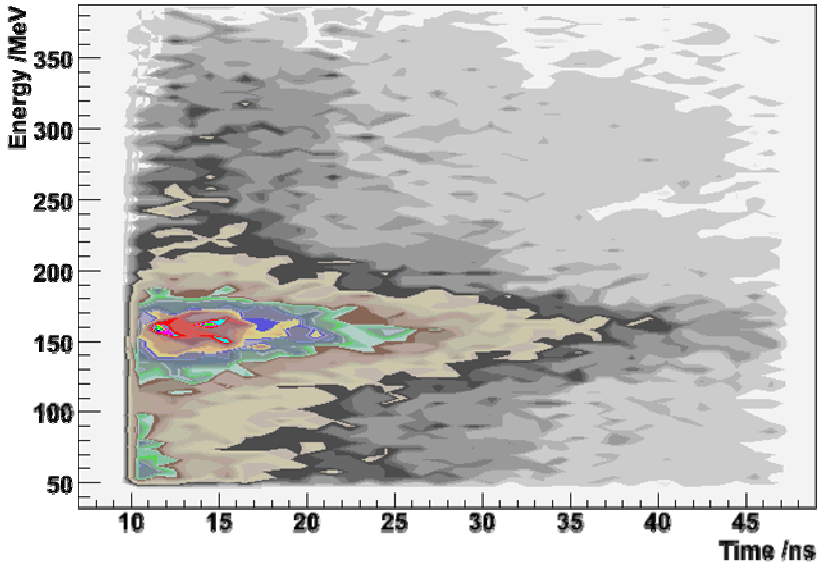


(a) Energy of the Secondary Clusters

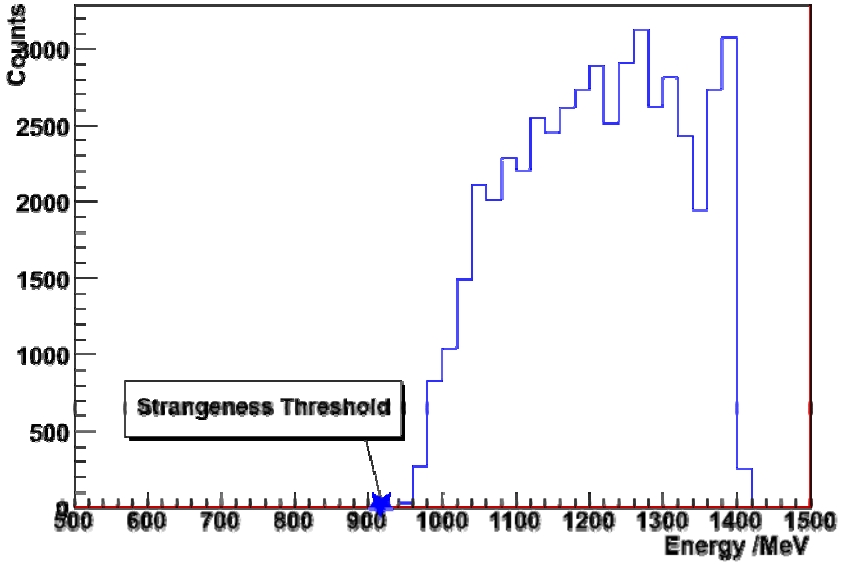


(b) Timing of the Secondary Clusters

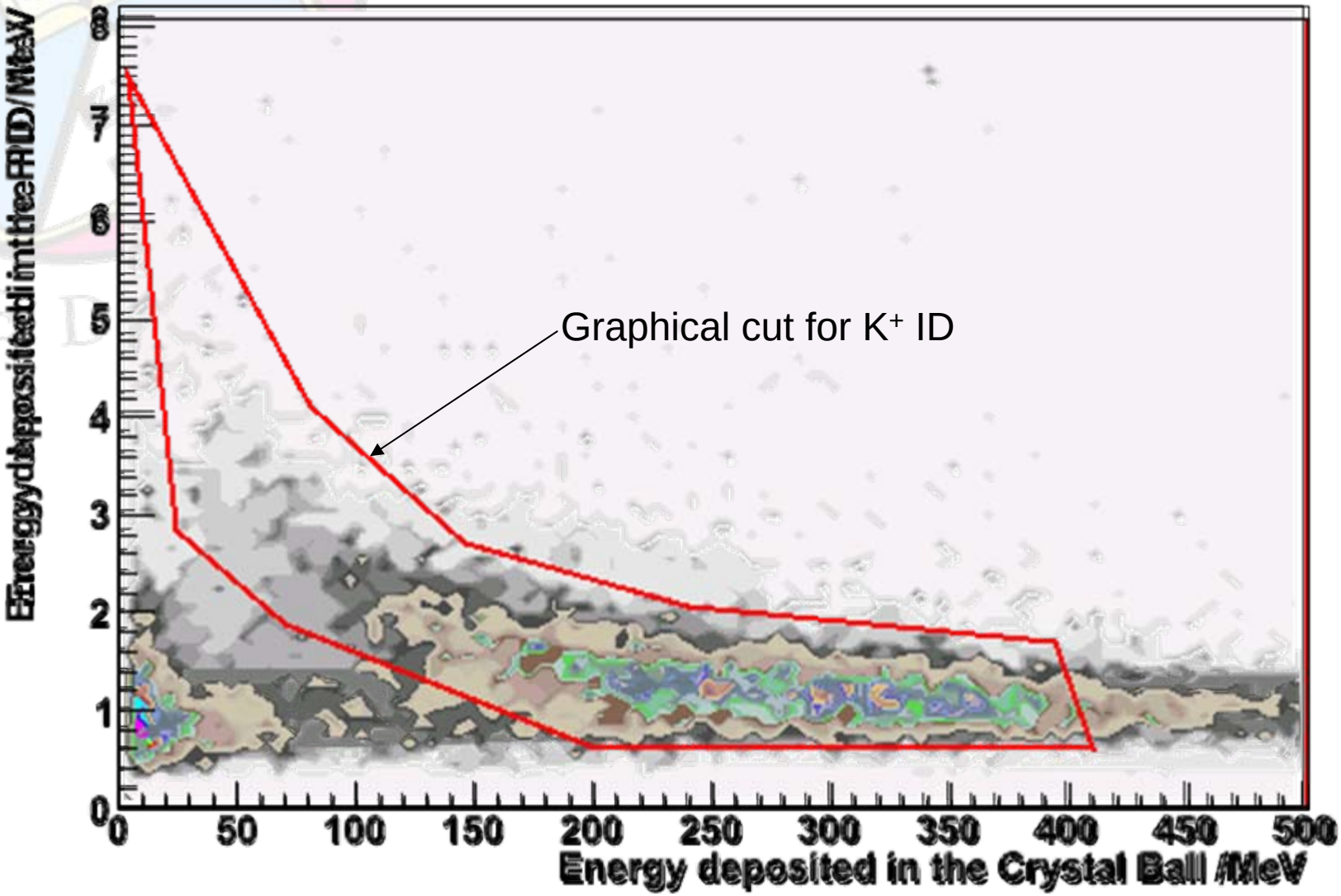




(d) Photon Beam Energy of events with a Secondary Cluster



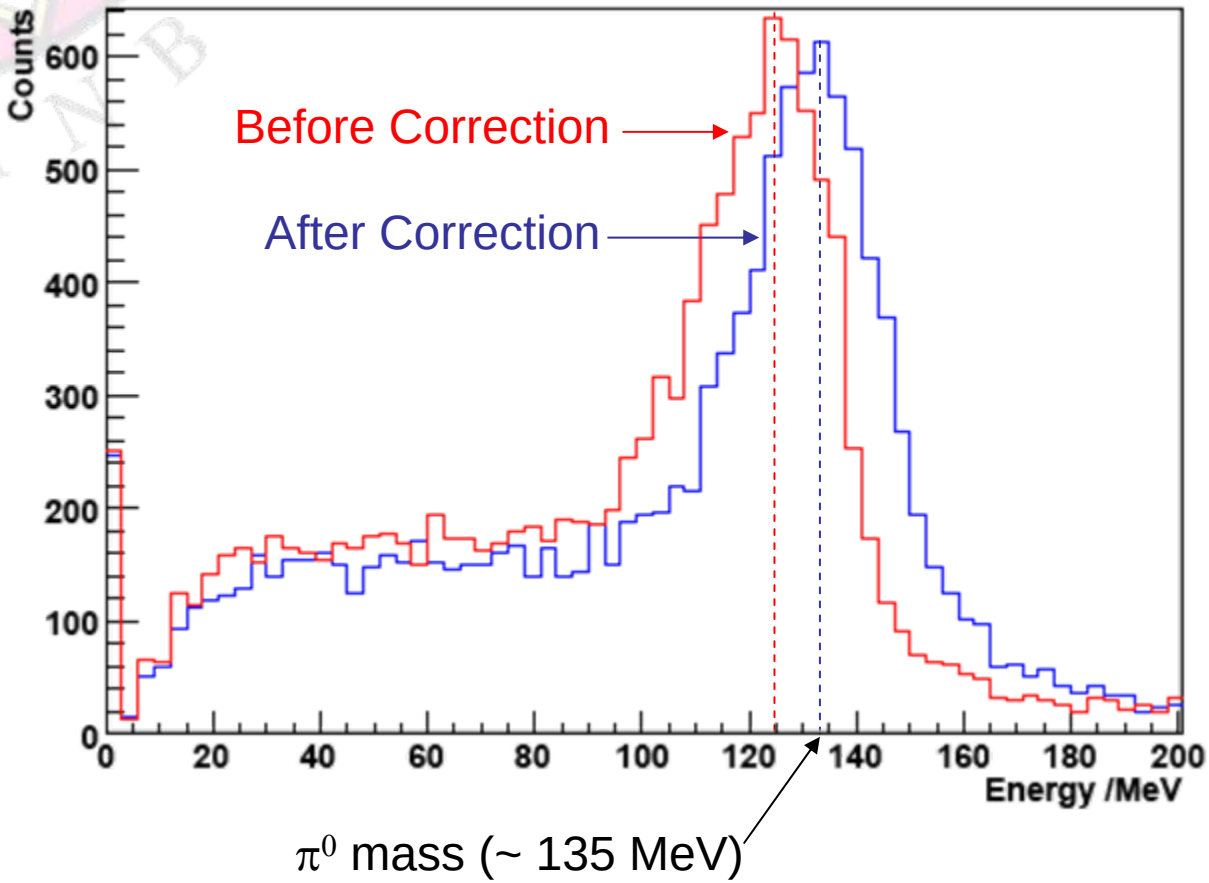
ΔE-E plot for all data with a secondary cluster



Kinematic considerations

- Correcting for the vertex position of the decay: $\Lambda \rightarrow n + \pi^{0:}$

Invariant mass of two photons in coincidence

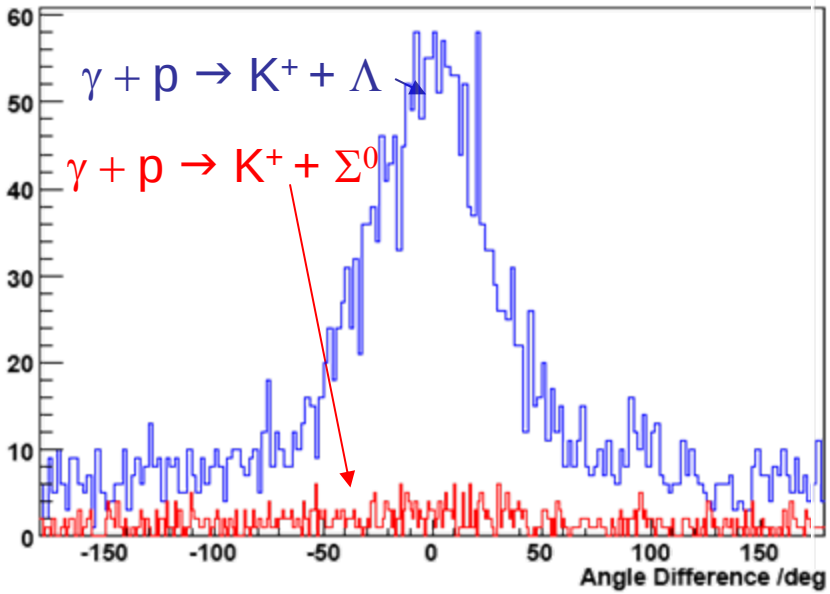


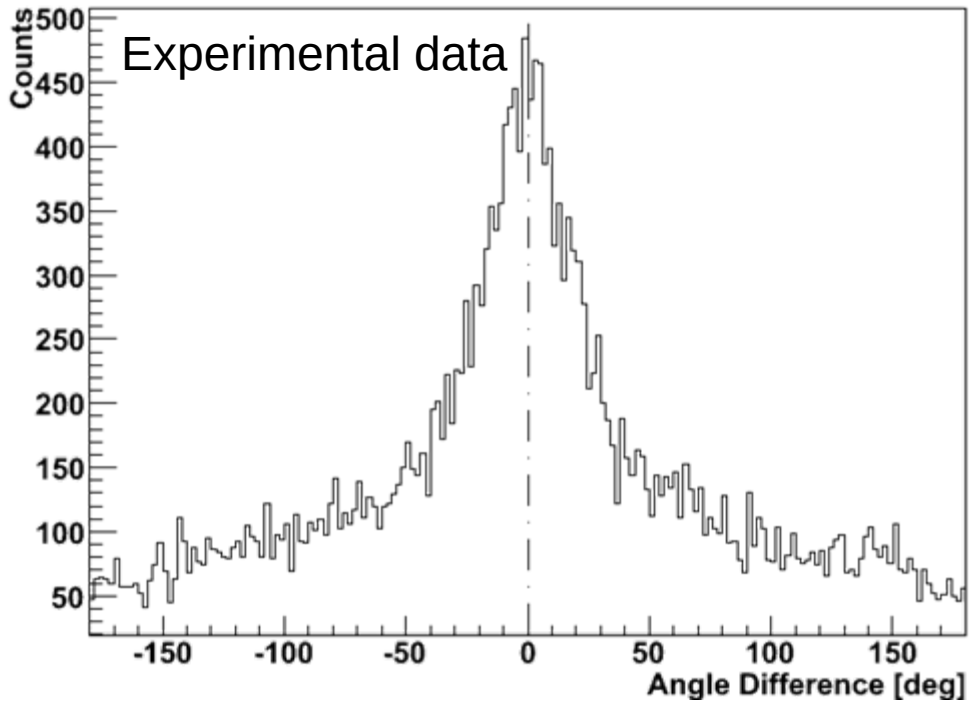
Kinematic considerations

- Neutron detection from Λ decay:
- Calculate neutron momentum from the Λ and π^0 momentum.

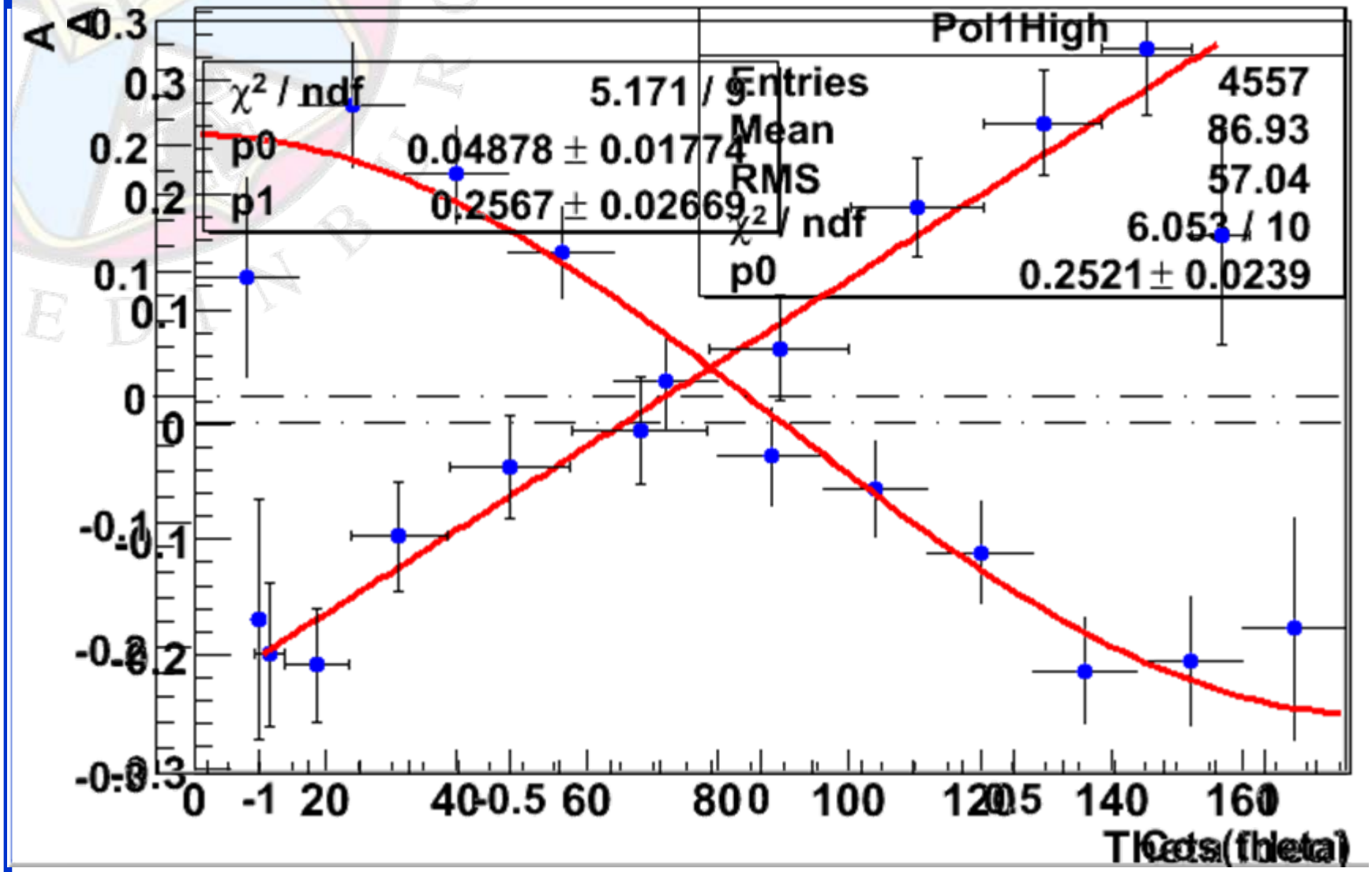
Angle difference between neutron and detected neutral particle:

Simulated data

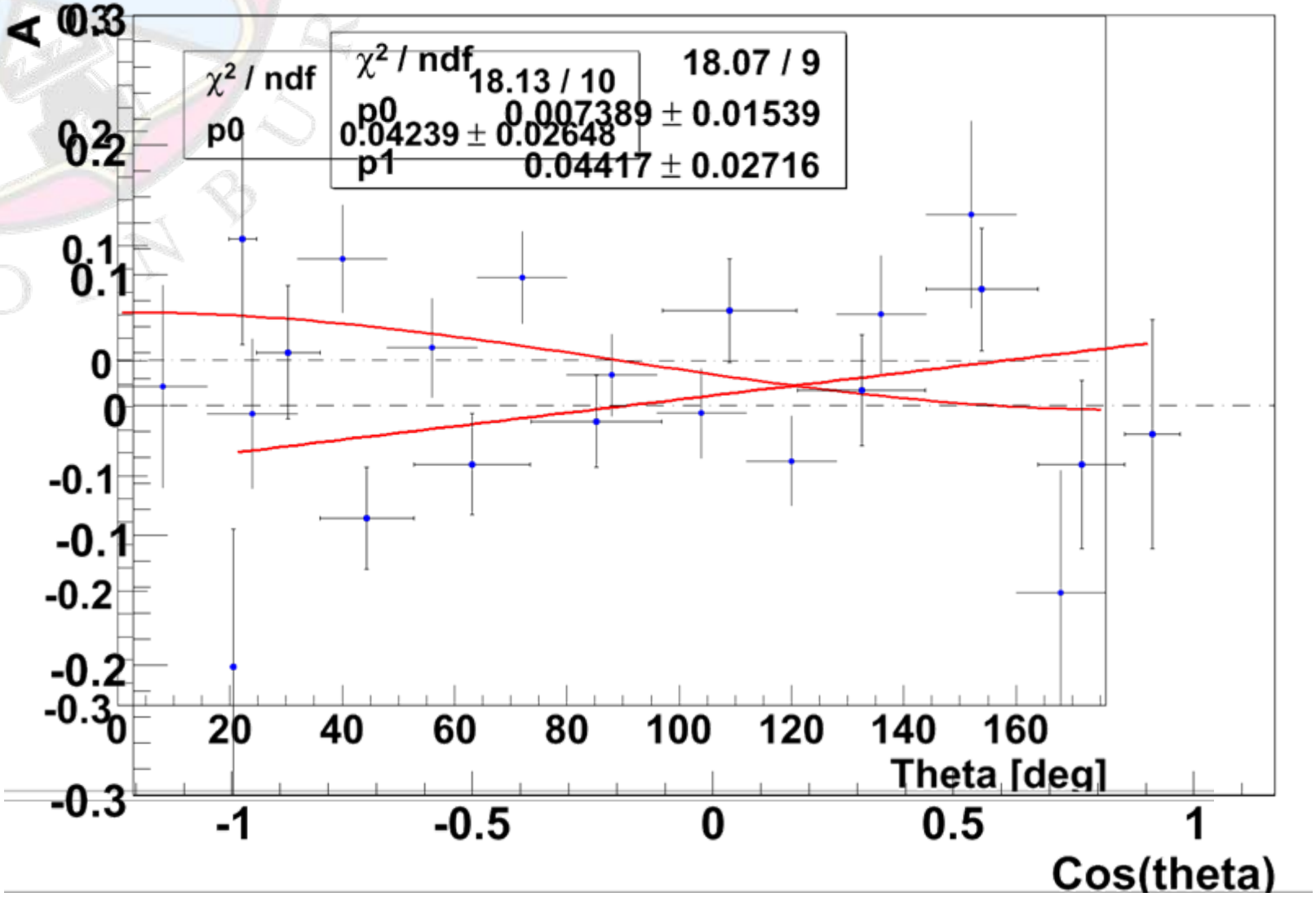




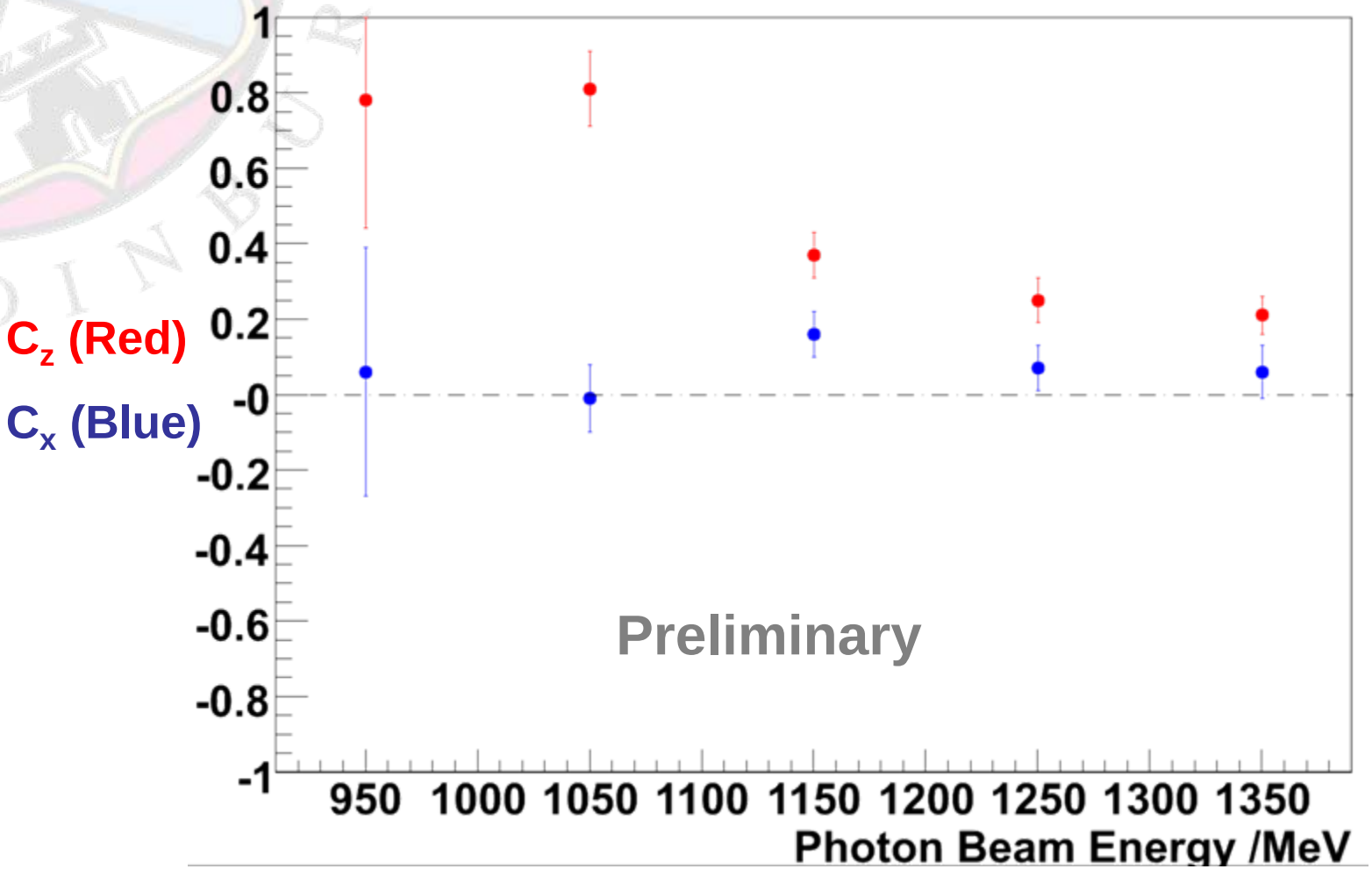
θ_z asymmetry measurements



θ_x asymmetry measurements



Preliminary asymmetry measurements



Future work

- Suppress $K^+\Sigma^0$ channel – identify the gamma decay of the Λ
- K^+ energy loss correction
- Distribution of the decay: $\Lambda \rightarrow p\pi^-$
- Measure absolute cross sections [1]
- Measure P - unpolarised beam and target

[1] Recent discrepancies in cross sections between CLAS and SAPHIR data: T Mart. *arXiv:0803.0601v1 [nucl-th],* 5th March 2008

Summary

- New technique of identifying strange mesons
- The first detection of strangeness photoproduction at MAMI-C
- First preliminary measurements of C_X and C_Z at threshold energies
- Opportunity to measure more polarisation observables with polarised targets and/or beam?
- More data to analyse and more beam time with lower energy thresholds (x20 statistics)