

# Detection of $K^+$ Mesons in Segmented Electromagnetic Calorimeters

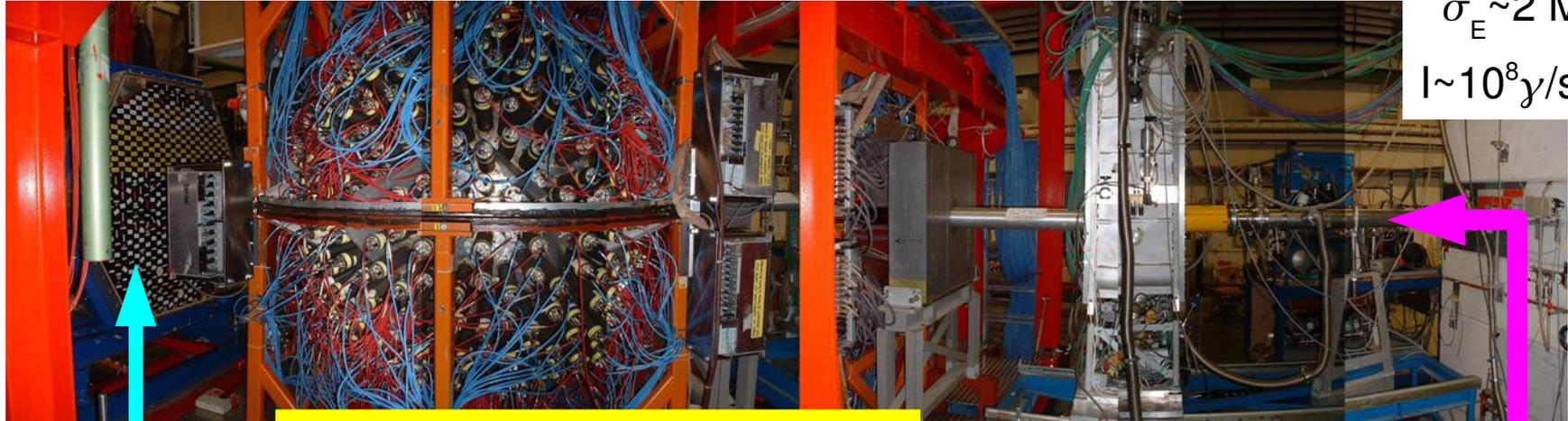
Derek Glazier

University of Edinburgh

for the **CrystalBall@MAMI** collaboration



# Tagged Photon Hall at MAMI



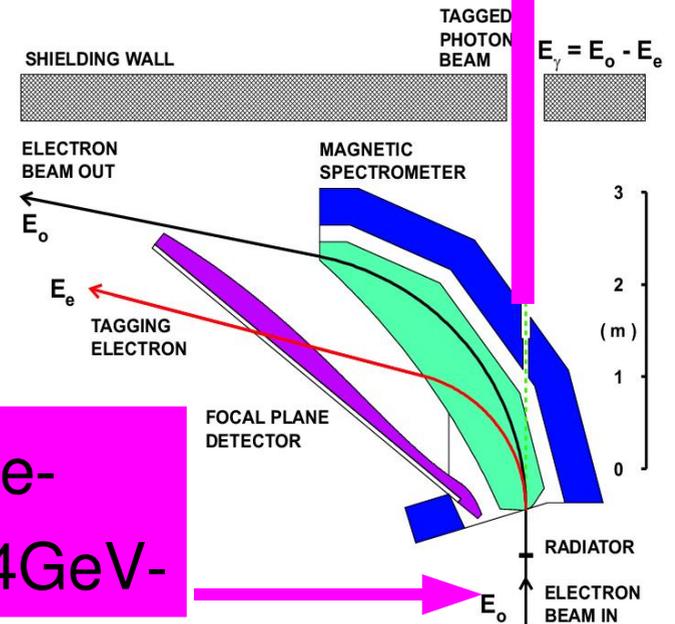
$\sigma_E \sim 2 \text{ MeV}$   
 $I \sim 10^8 \gamma/s$

CB 672 NaI(Tl) Crystals  
 Spherically arranged  
 around target  
 93% phase space

TAPS  
 384 BaF2 Crystals  
 Forward  $21^\circ$   
 1.5m upstream

MAMI-C provides 1.5GeV e-  
 Tag Brem. Photons to 1.4GeV-

Linear or circular pol.



# The CrystalBall and TAPS

## Calorimeters

CB

Truncated triangular pyramid

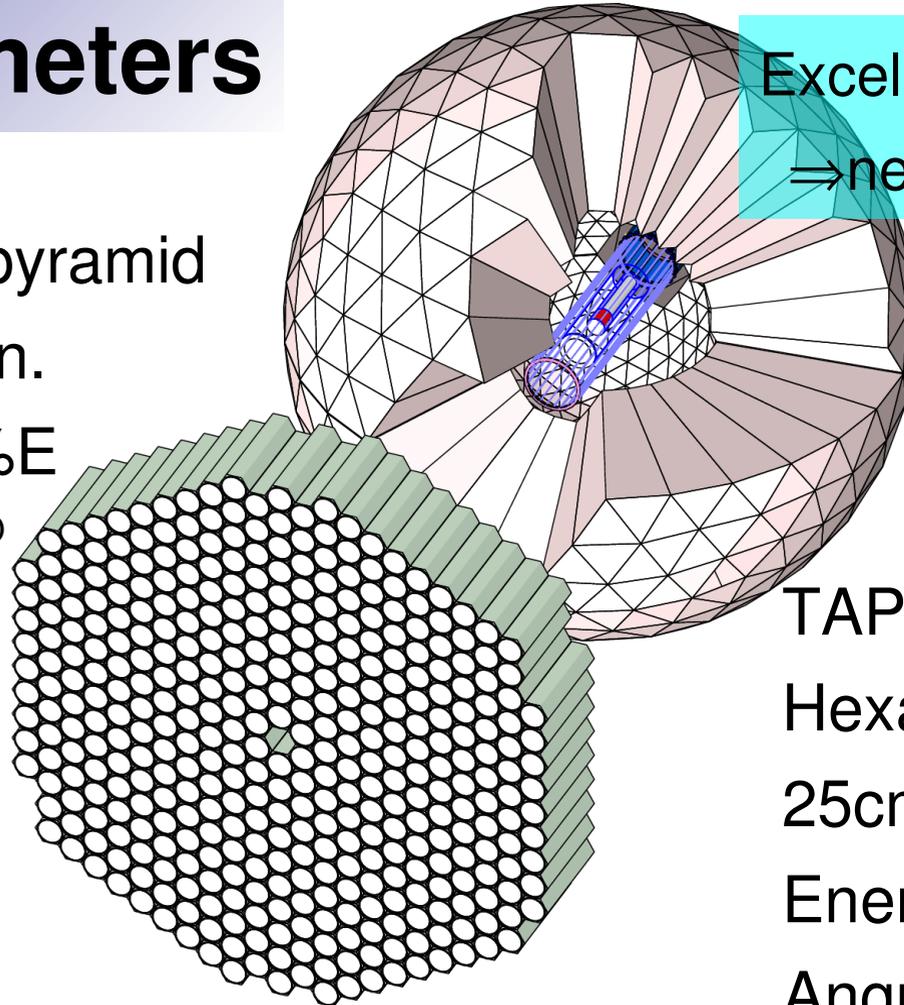
40.6cm or 15.7 rad.len.

Energy resolution  $\sim 2\%E$

Angular resolution  $\sim 3^\circ$

Time resolution  $\sim 4\text{ns}$

See proceedings CALOR04 D.P. Watts



Excellent  $\gamma$  detectors  
 $\Rightarrow$  neutral mesons

TAPS Crystal

Hexagonal Crystal

25cm or 15 rad.len.

Energy Res  $\sim 2.5\%E$

Angular Res  $\sim 1^\circ$

Time Res  $\sim 1\text{ns}$

# Extra Equipment

- Thin scintillator barrel for particle ID ( $\pi^\pm$ , p, D,  $e^-$ )
  - Comprises 24 detectors 4mm thick
- Cylindrical wire chambers for tracking (Pavia)
- Cryogenic Hydrogen, Deuterium targets
- Polarised Targets (H, D, He)
- Solid Targets (C, O, Pb...)

# CB@MAMI Diverse Physics Program

$\eta$  and  $\eta'$  decays - Test of fundamental symmetries (C,CP,CPT...)

“Complete measurement” of meson photoproduction → Baryon spectroscopy

- Polarised beam, target and recoil baryon

$\omega$  production on nuclei - Medium modifications

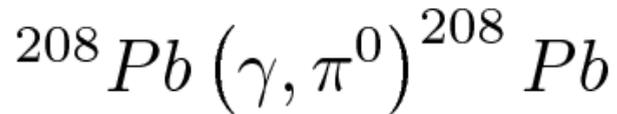
Threshold  $\pi^0$ ,  $K^+$  production – Test of LET/ChPT

Radiative resonance decay - Magnetic moment of  $\Delta$  and  $S_{11}$  resonances

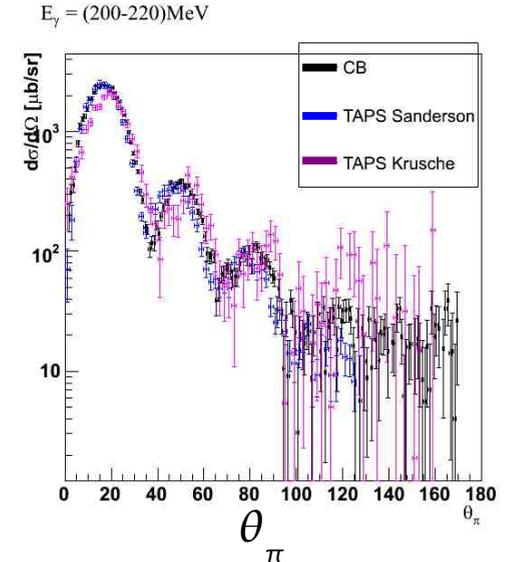
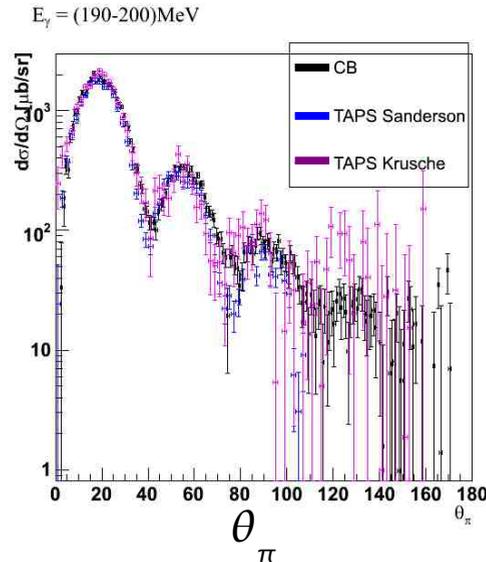
Nucleon Knockout from nuclei – NN interaction

Meson production on nuclei – Nuclear structure

# Coherent $\pi^0$ Photoproduction



Analyse  $\pi^0$  decay  
photons from CB



Characteristic Diffraction Pattern

Minima  $\rightarrow$  Nuclear Mass radius

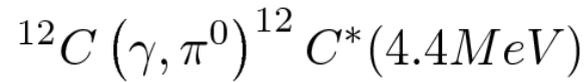
$\rightarrow$  Neutron skin thickness

$\rightarrow$  Neutron stars, atomic parity non-conservation

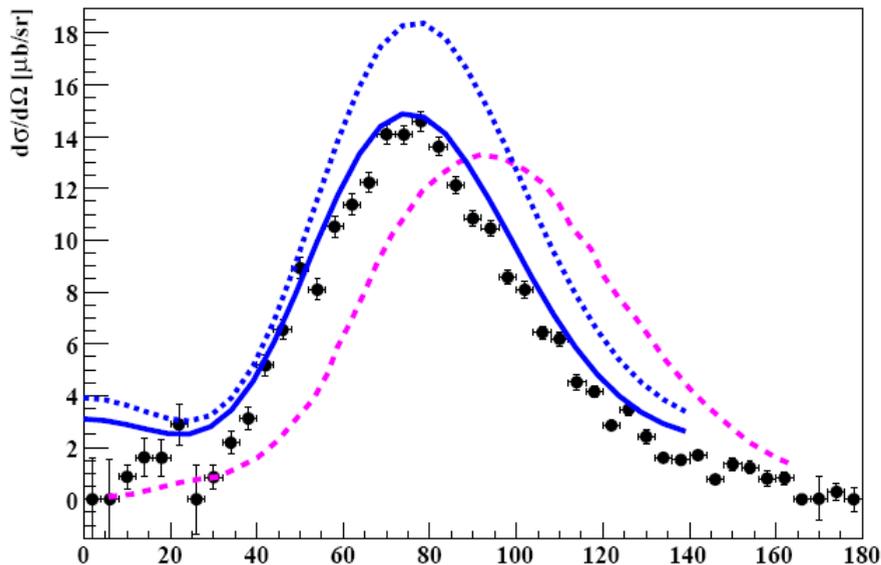
Publication in prep.

# Incoherent $\pi^0$ Photoproduction

Tag Inc. reaction with nuclear decay  $\gamma$

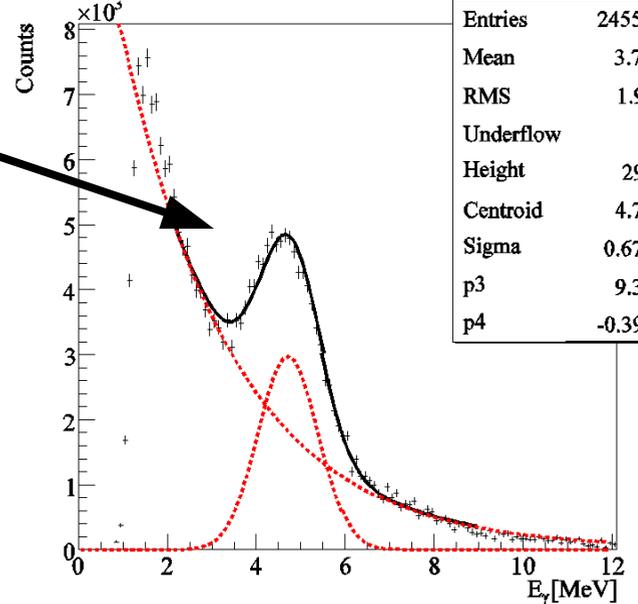


$E_\gamma = (225-245)\text{MeV}$



$\theta$

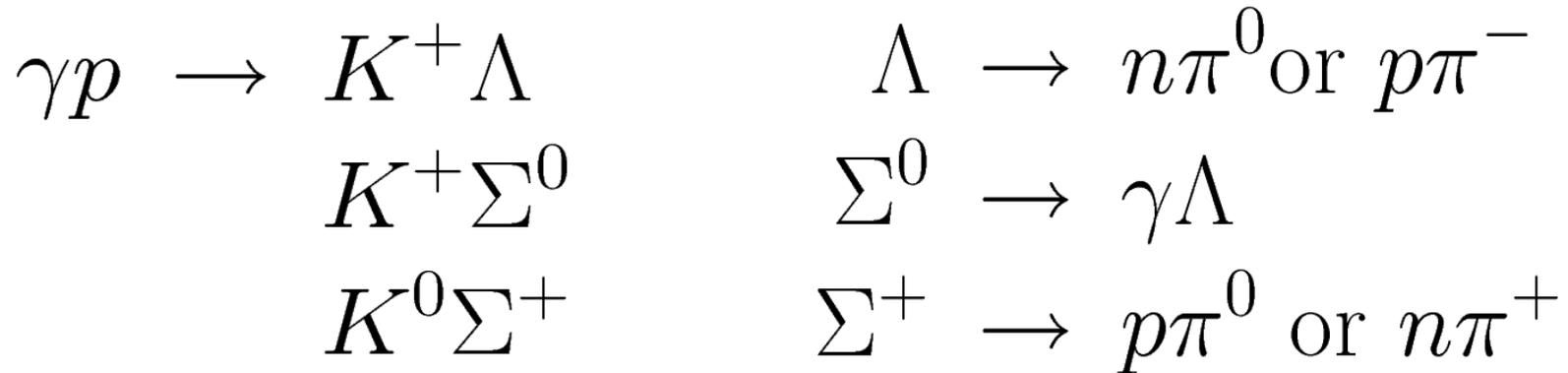
$E_\gamma = (200-220)\text{MeV}$



Measuring transition matter form factors  
Sensitive test of  $\Delta N$  interaction

C.M. Tarbert et al. ([CB@MAMI](#) collab)  
Phys. Rev. Letts. 100, 132301, (2008)

# $K^+$ Photoproduction



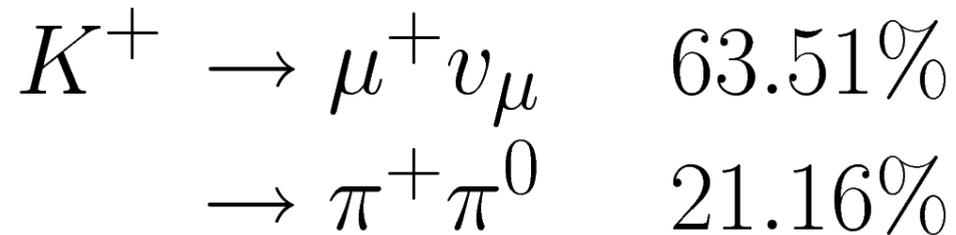
We can measure with polarised beam, target and recoil hyperon  
Measurements are sensitive to intermediate nucleon resonance  
At threshold also an important test of ChPT in SU(3) sector

$K^0$  reconstructed from decay to  $2\pi^0$

How to identify  $K^+$  without a magnetic field.....?

# K<sup>+</sup> Decays

- Mass  $m = 493.667$  MeV



$$T_\mu = 152 \text{ MeV}$$

$$T_\pi = 109 \text{ MeV}$$

- Mean life  $\tau = 12.386$  ns (CB  $\sigma_{\text{time}} = 4$  ns)

$$c\tau = 3.713 \text{ m}$$

# K<sup>+</sup> Tagging

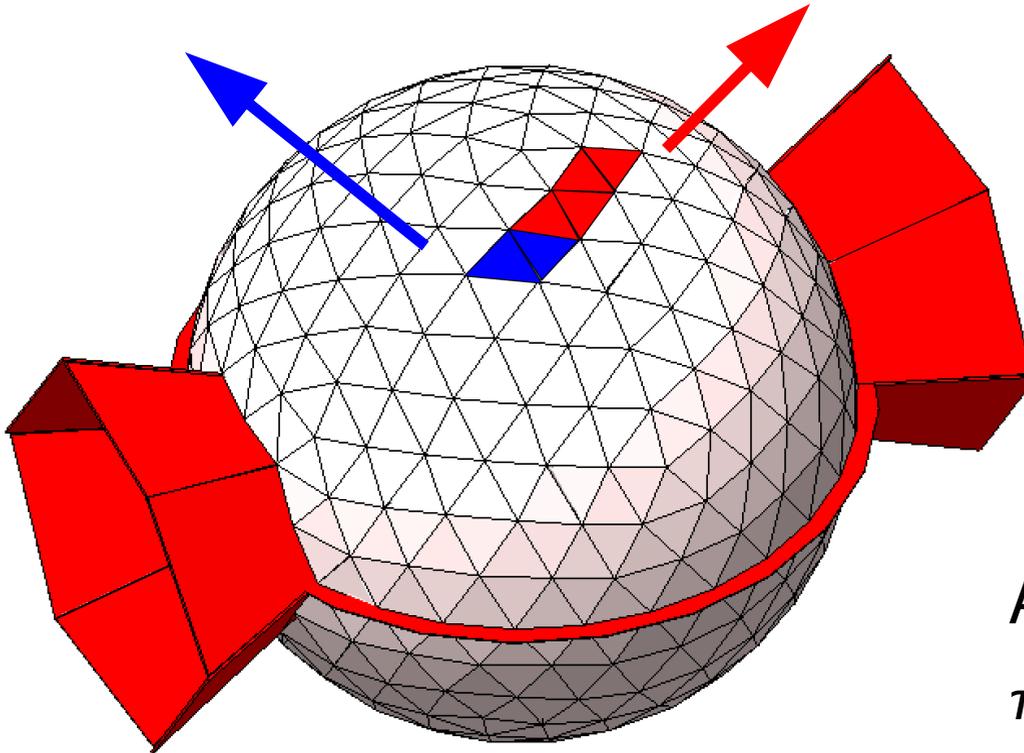
Secondary cluster from decay to  $\mu$

Resolve >10ns later

Up to 8 crystals and 150 MeV

First cluster from K<sup>+</sup>

$t < 1\text{ns}$



Also detect secondary

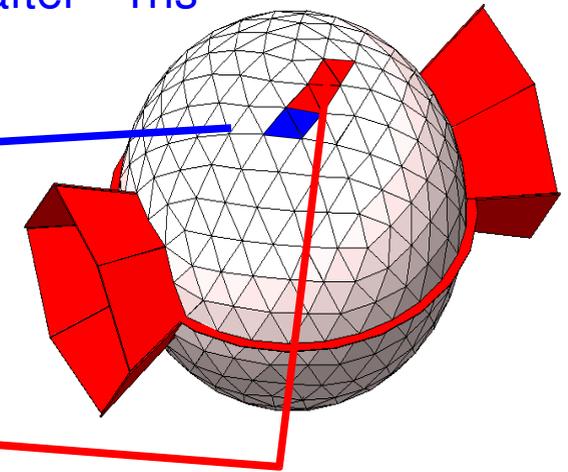
$\pi$  decay cluster

Up to 360 MeV

# K<sup>+</sup> Tag Algorithm

- Construct as large a cluster possible from neighbouring hits
- Split cluster using timing coincidences of crystals ( $\sim 8\text{ns}$ )
- First split cluster is K<sup>+</sup>, second is decay
- Cut on second cluster Energy, Time, Length and Number of crystals
- $\Delta E-E$  of K<sup>+</sup> cluster

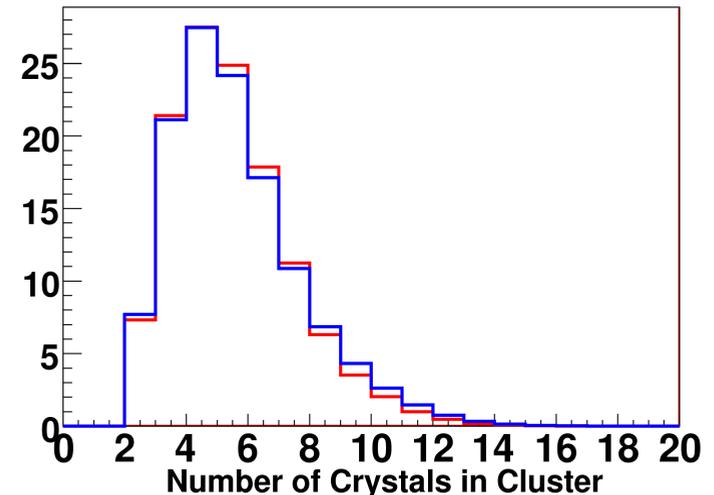
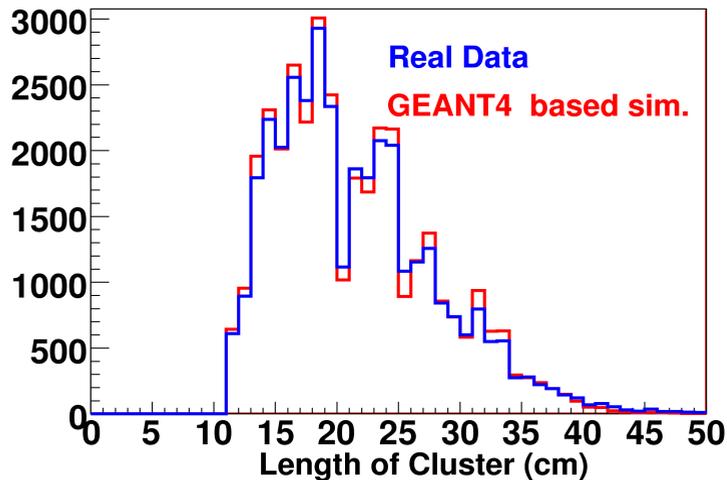
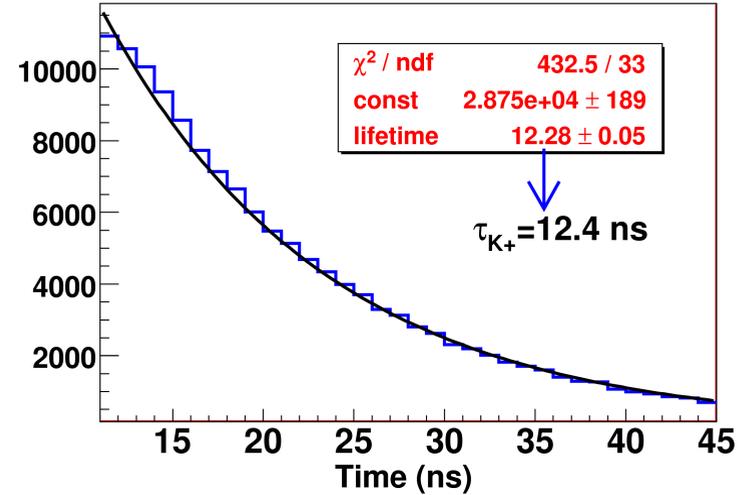
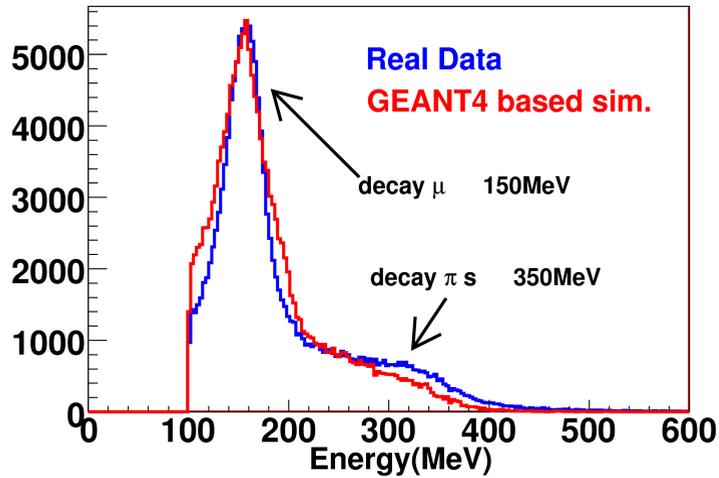
First cluster after  $\sim 1\text{ns}$



Second cluster after  $>10\text{ns}$

# Kaon Tag Cuts

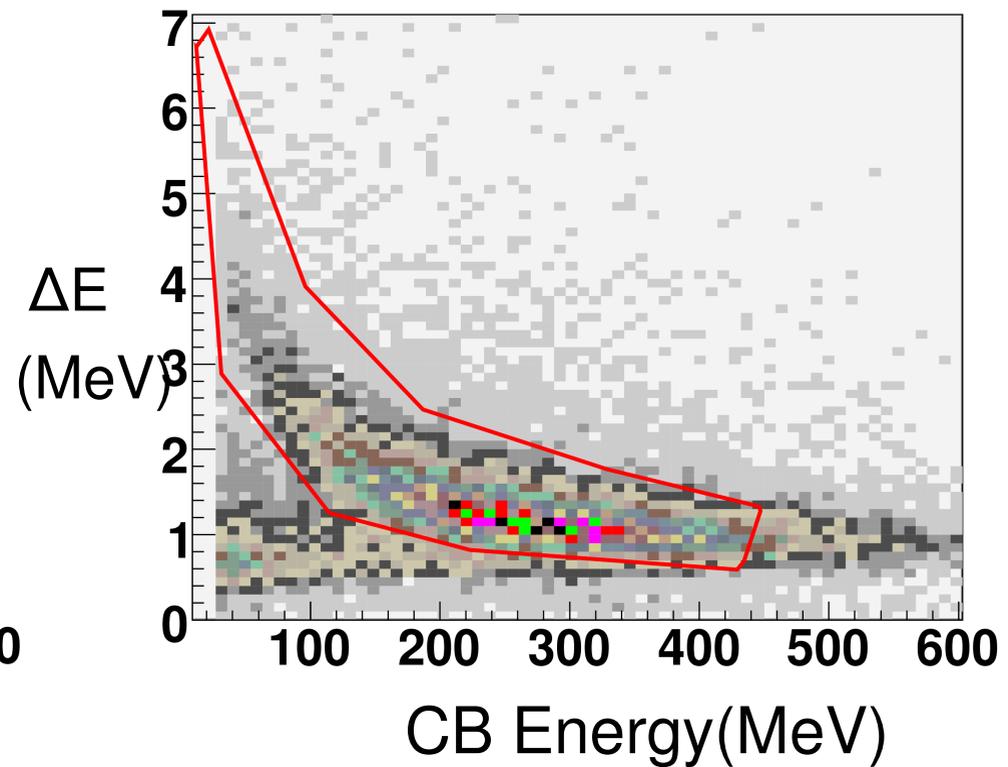
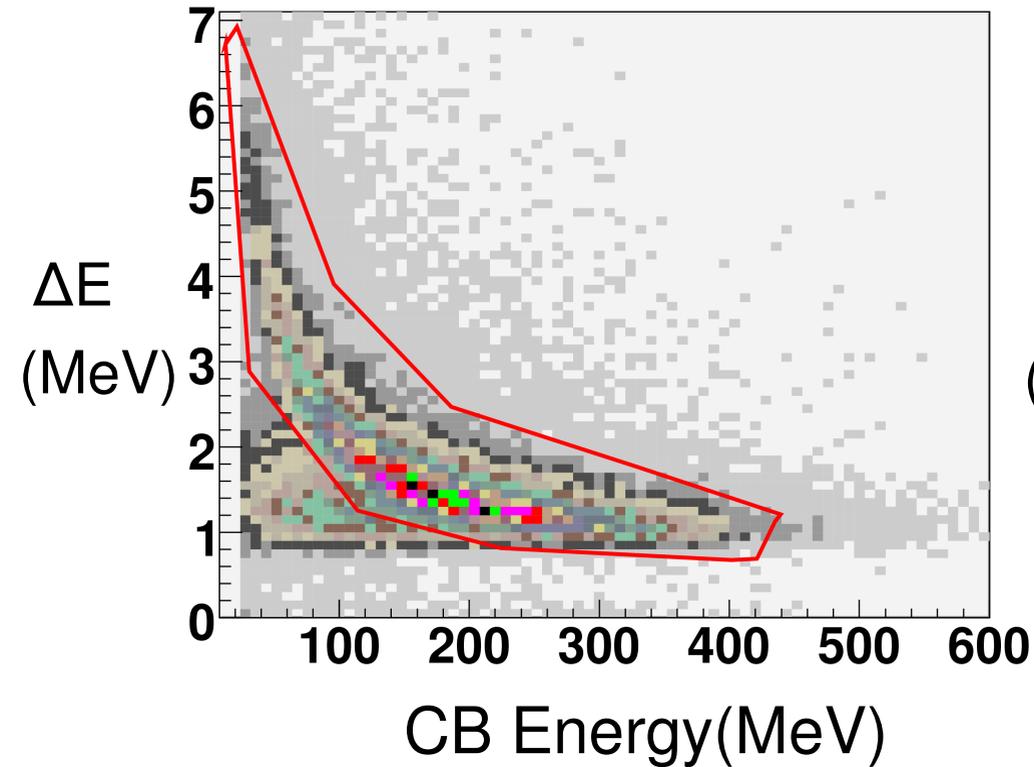
## Characteristics of second cluster



# $\Delta E$ -E Cut

## Simulation

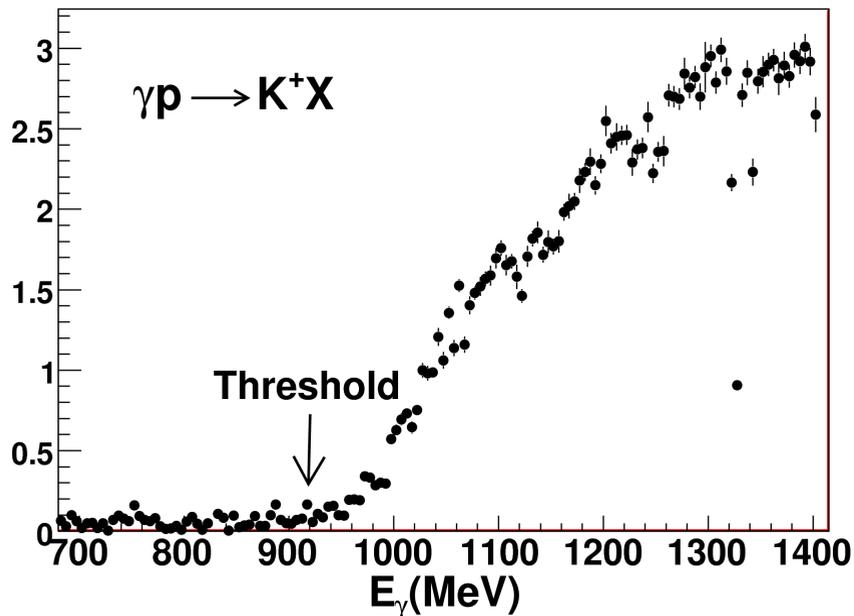
## Real Data



$\Delta E$  from PID scintillator, E from CB

# $K^+(\Lambda\Sigma)$ Photoproduction

Very Raw Excitation Spectra (no accept. cor.)



Detection efficiency  $\sim 10\%$   
Gives  $\sim 2000$   $K^+$ /hour  
CB stops  $K^+$  up to 330 MeV  
or else they pass untagged  
Background from sim.  $\pi^\pm < 10^{-5}$

# $\Lambda$ Polarisation Measurement

!!Preliminary!!

Weak decay of  $\Lambda$  sensitive to its polarisation.

$\Lambda \rightarrow N\pi$

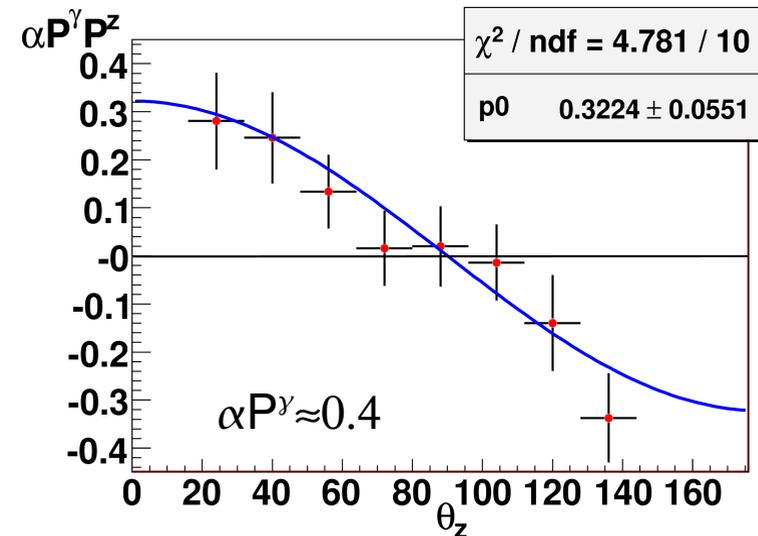
For helicity polarised photons :

$$A(\theta_i) = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P^\gamma P^i \cos \theta_i$$

where  $\theta_i$  is the angle between decay N and axis i

Asymmetry from  $\Lambda \rightarrow n\pi^0$  (T.Jude)

Threshold to  $E_\gamma = 1.2$  GeV



# Summary

- **CB@MAMI** Up and running since 2004
- First paper on Incoherent  $\pi^0$  production published
- Upgrade to MAMI-C gives photon beam energy up to 1.4 GeV
- Allows use of  $K^+$  decay tag in CB and TAPS to investigate strangeness physics
- Polarisation observables in photoproduction
- $K^+$  production on nuclei (incl. Hypernuclei)