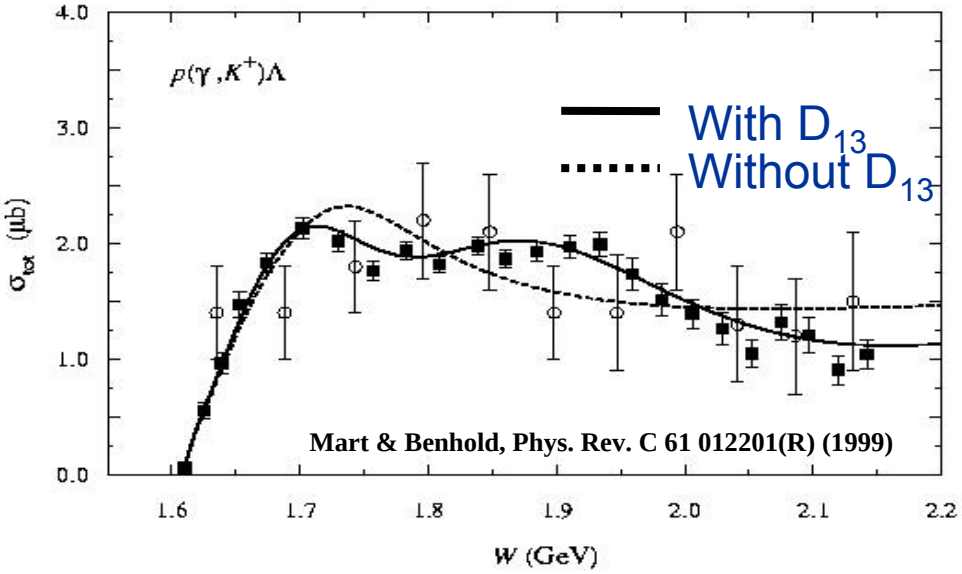
Baryon spectroscopy: recent Kaon photoproduction results from CLAS

Ken Livingston, University of Glasgow

EINN2009, Sep2009, Milos Island, Greece

- Motivation
  - Missing resonances
  - 1st *complete measurement* in pseudoscalar meson production
- Polarization observables at CLAS
  - Progress towards a complete measurement in K^+ photoproduction on p
  - Measurements on the neutron
- Summary

Missing resonances



After Cx, Cz from CLAS, revised as most likely P13.
Eur Phys J A34 (07) 243

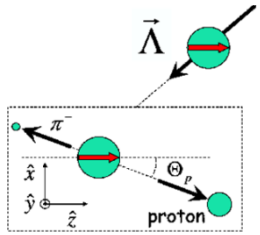
- Clear indication of resonances in γp cross section for many channels
- Constituent quark models predict many resonances, but several missing
  - Mostly from πN scattering and single π photoproduction
  - Really missing or undetected since weak coupling to these channels
  - Try other channels. Eg. K photoproduction
- Eg. Cross sections show some hints of new D_{13}.
  - Better to look at angular distributions and polarization observables.

Polarization observables in pseudoscalar meson production

4 Complex amplitudes: **16** real polarization observables.

Complete measurement from **8** carefully chosen observables.

πN has high statistics but in **KY** recoil is **self-analysing** ☻



πN recoil targ γ

KY γ targ recoil

Symbol	Transversity representation	Experiment required	Type
$d\sigma/dt$	$\lvert b_1\rvert^2+\lvert b_2\rvert^2+\lvert b_3\rvert^2+\lvert b_4\rvert^2$	$\{-;-;-\}$	S
$\Sigma d\sigma/dt$	$\lvert b_1\rvert^2+\lvert b_2\rvert^2-\lvert b_3\rvert^2-\lvert b_4\rvert^2$	$\{L(\frac{1}{2}\pi,0);-;-\}$	
$T d\sigma/dt$	$\lvert b_1\rvert^2-\lvert b_2\rvert^2-\lvert b_3\rvert^2+\lvert b_4\rvert^2$	$\{-;y;-\}$	
$P d\sigma/dt$	$\lvert b_1\rvert^2-\lvert b_2\rvert^2+\lvert b_3\rvert^2-\lvert b_4\rvert^2$	$\{-;-;y\}$	
$G d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_3^* + b_2 b_4^*)$	$\{L(\pm\frac{1}{4}\pi);z;-\}$	BT
$H d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_3^* - b_2 b_4^*)$	$\{L(\pm\frac{1}{4}\pi);x;-\}$	
$E d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_3^* + b_2 b_4^*)$	$\{C;z;-\}$	
$F d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_3^* - b_2 b_4^*)$	$\{C;x;-\}$	
$O_x d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_4^* - b_2 b_3^*)$	$\{L(\pm\frac{1}{4}\pi);-;x'\}$	BR
$O_z d\sigma/dt$	$-2\,\mathrm{Im}(b_1 b_4^* + b_2 b_3^*)$	$\{L(\pm\frac{1}{4}\pi);-;z'\}$	
$C_x d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_4^* - b_2 b_3^*)$	$\{C;-;x'\}$	
$C_z d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_4^* + b_2 b_3^*)$	$\{C;-;z'\}$	
$T_x d\sigma/dt$	$2\,\mathrm{Re}(b_1 b_2^* - b_3 b_4^*)$	$\{-;x;x'\}$	TR
$T_z d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_2^* - b_3 b_4^*)$	$\{-;x;z'\}$	
$L_x d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_2^* + b_3 b_4^*)$	$\{-;z;x'\}$	
$L_x d\sigma/dt$	$2\,\mathrm{Re}(b_1 b_2^* + b_3 b_4^*)$	$\{-;z;z'\}$	

I. S. Barker, A. Donnachie, J. K. Storrow, Nucl. Phys. B95 347 (1975).

circ polarized photons

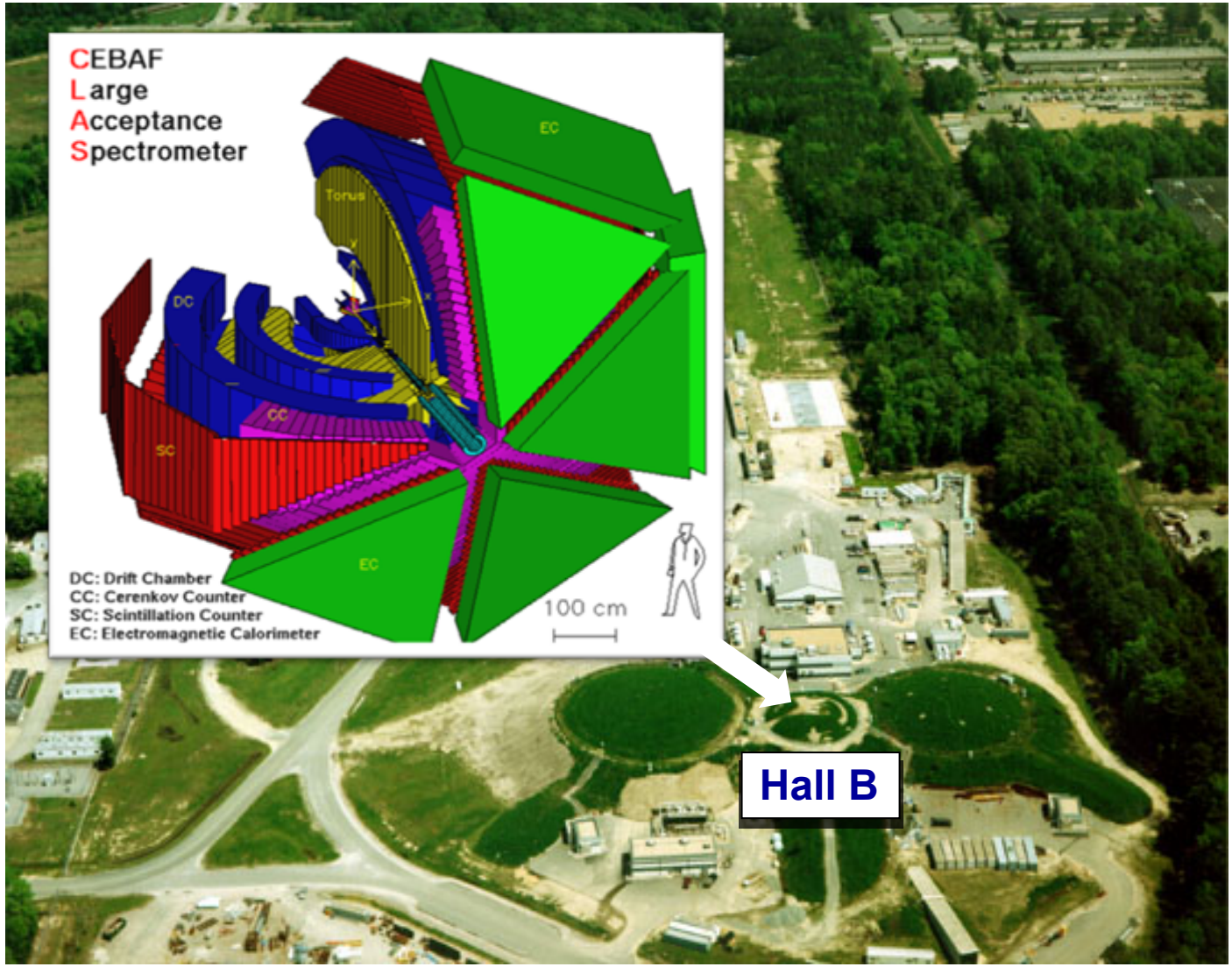
linearly polarized photons

longitudinally polarized target

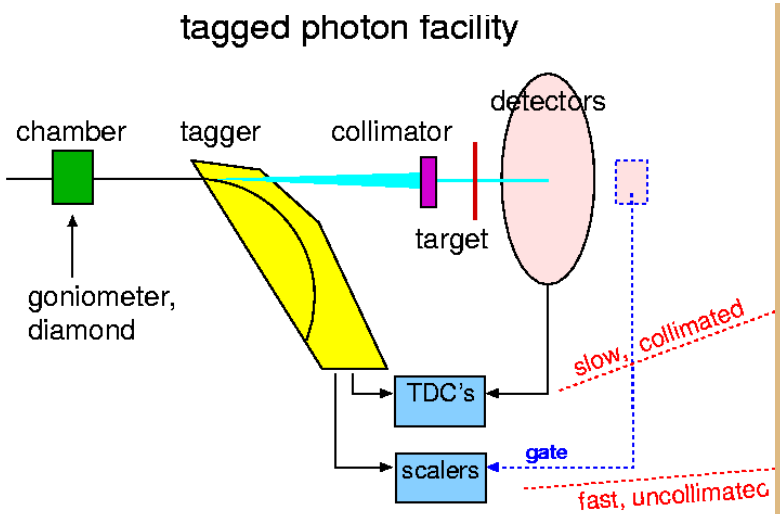
transversely polarized target

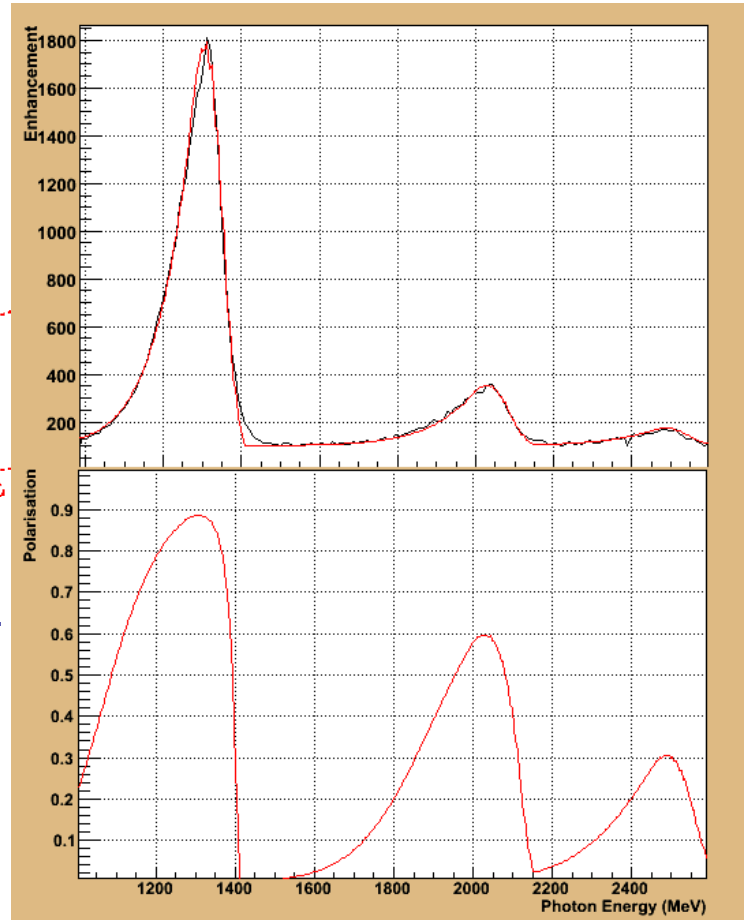
Complete, and over-determined

25 years Jefferson Lab
*Exploring the Nature of Matter



Tagged photons at CLAS

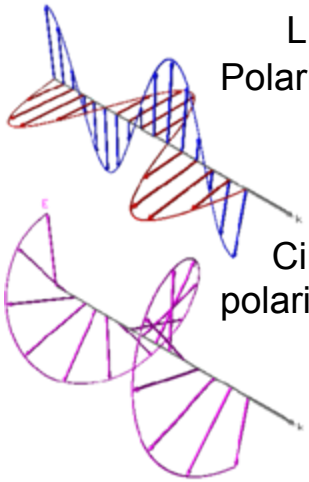




- Tagged bremsstrahlung photons up to 6GeV.
- Timing resolution < 1 beam bucket.
- Circularly polarized
  - up to ~80% now standard

- Linearly polarized
  - coherent bremsstrahlung up to >90%.

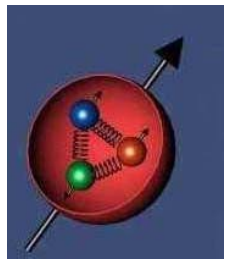
Polarization observables at CLAS



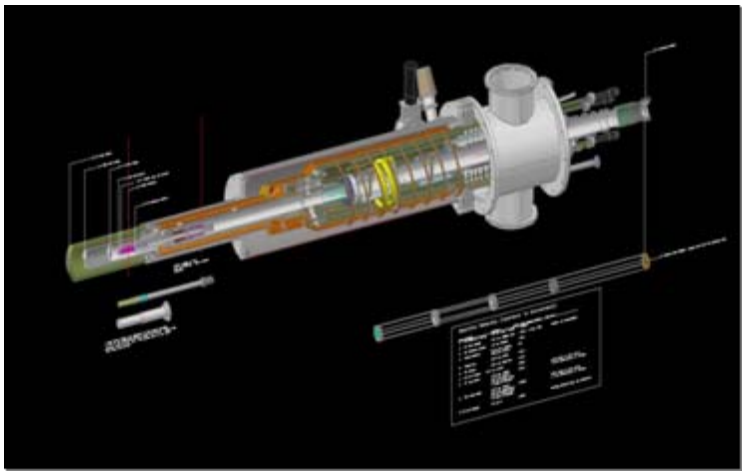
Linear Polarisation ✓

Circular polarisation ✓

$$\gamma + N \rightarrow N + m$$
$$\rightarrow Y + K$$

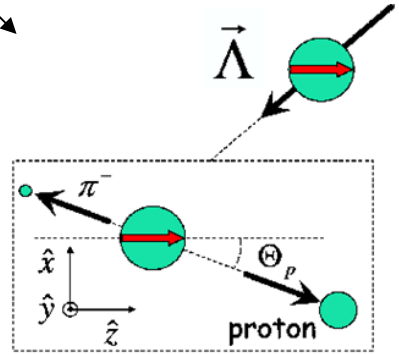


Nucleon recoil polarimiter x



Longitudinally polarized nucleon targets ✓

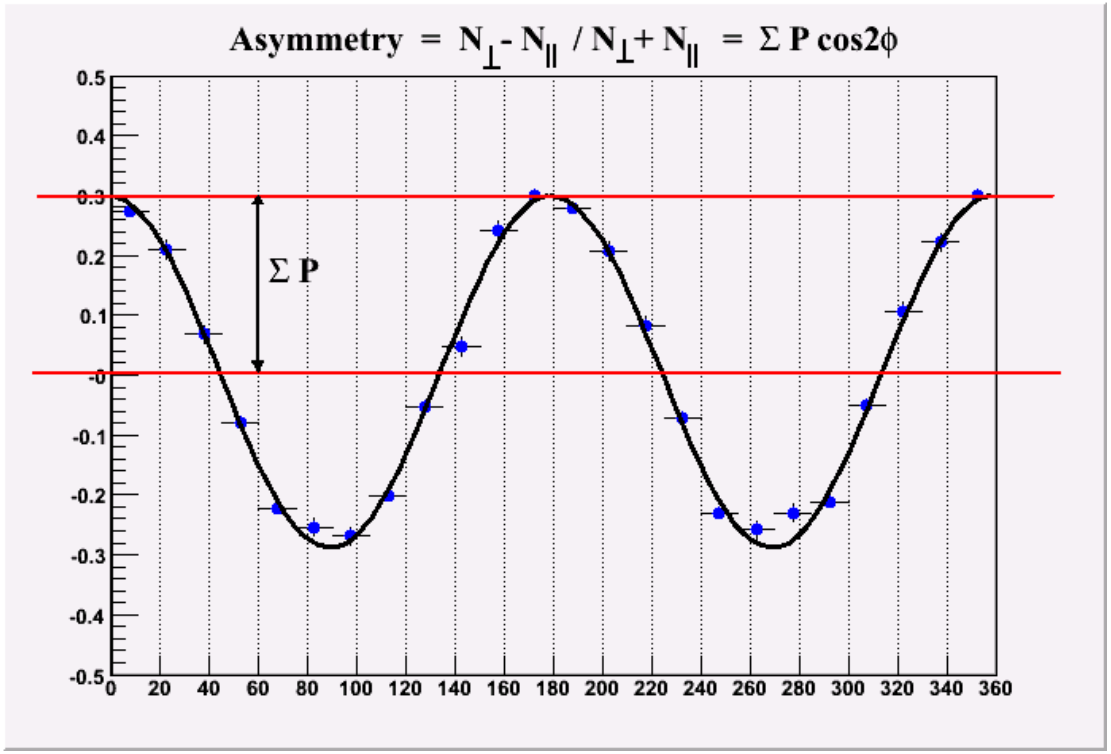
Transverse polarized nucleon targets ✓



Hyperons are “self analysing” ✓

Polarization observables - a simple example, Σ

$$\rho_f \frac{d\sigma}{d\Omega} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_{unpol}\{1 - P_\gamma^{lin}\Sigma\cos 2\phi$$

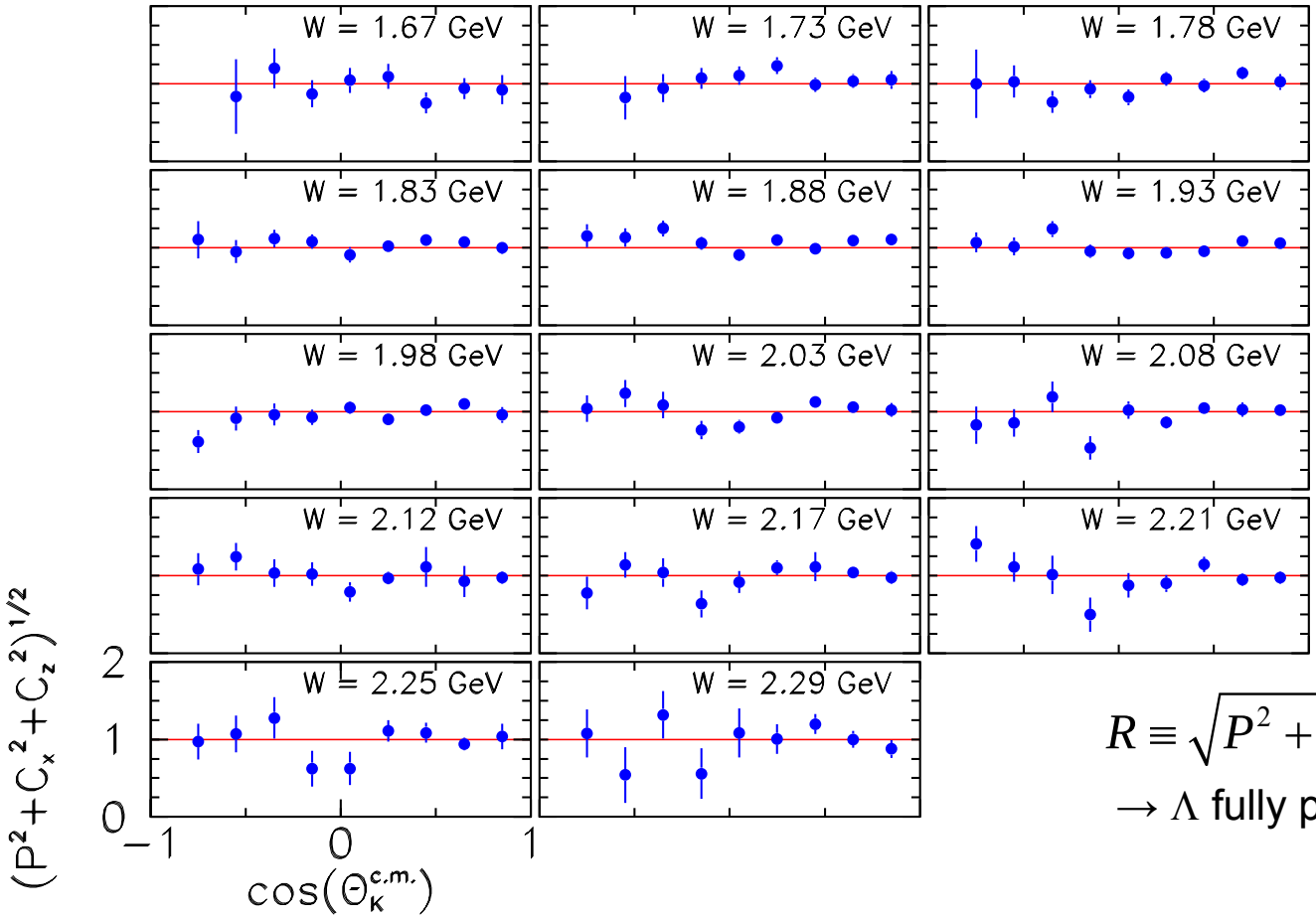


- Systematics of detector acceptance cancel out.
- "Only" need to know P_{lin}, the degree of linear polarization.

1st pol. observables in K photoproduction on p at CLAS.

P, C_x and C_z (Using circularly polarized photons)

R. Bradford *et al.*, Phys. Rev. C **75**, 035205 (2007).



$$R \equiv \sqrt{P^2 + C_x^2 + C_z^2}$$

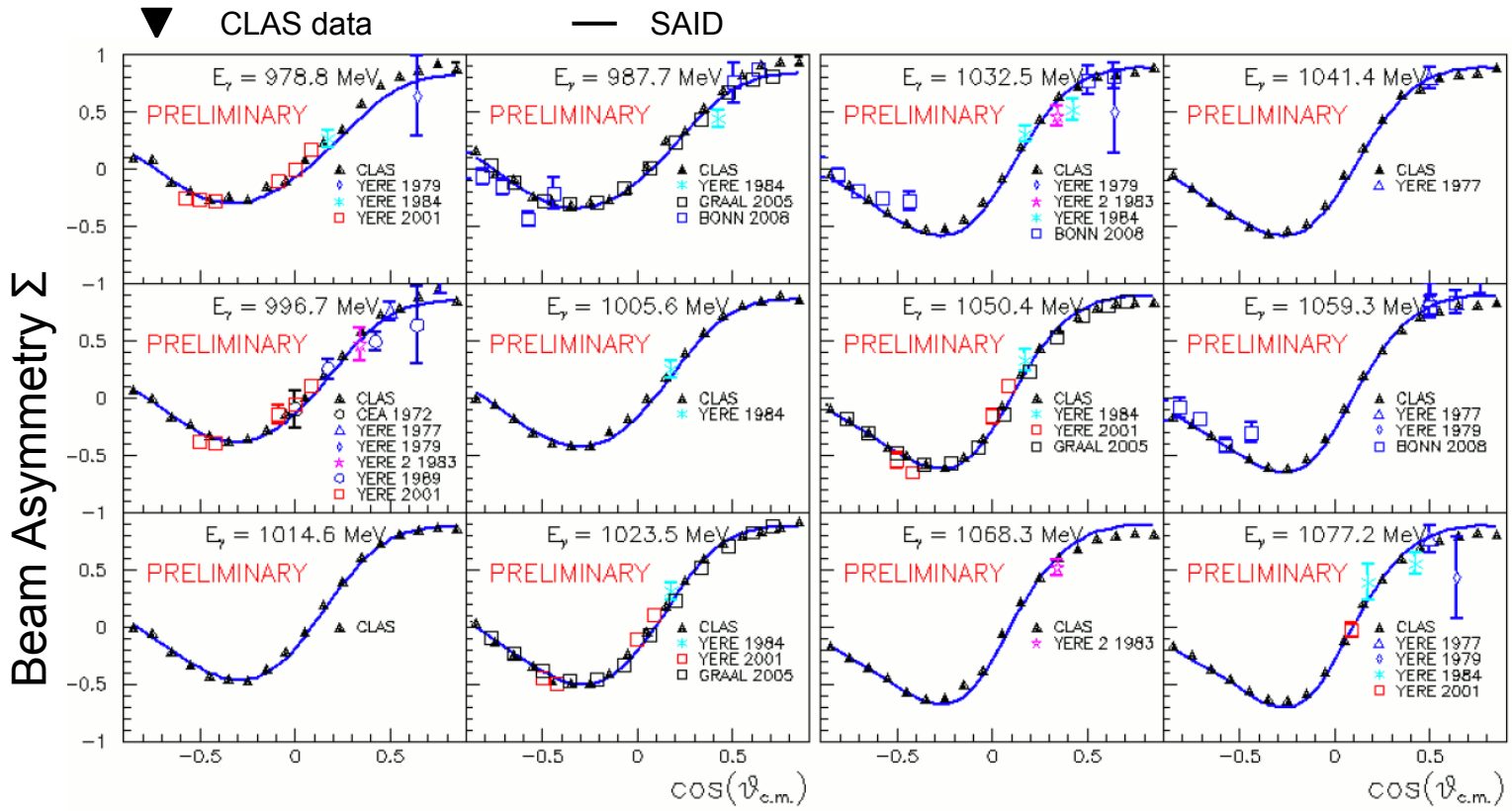
$\rightarrow \Lambda$ fully polarised

Will analagous result hold with the observables from linearly polarized ?

g8b: July 2005

Polarized photon energy range: 1.3 – 2.1 GeV
Events (single charged particle in CLAS): 10 billion

preliminary results: $\pi^0 p$, Mike Dugger, ASU



High statistics. Good agreement with previous measurement. We have P well determined.

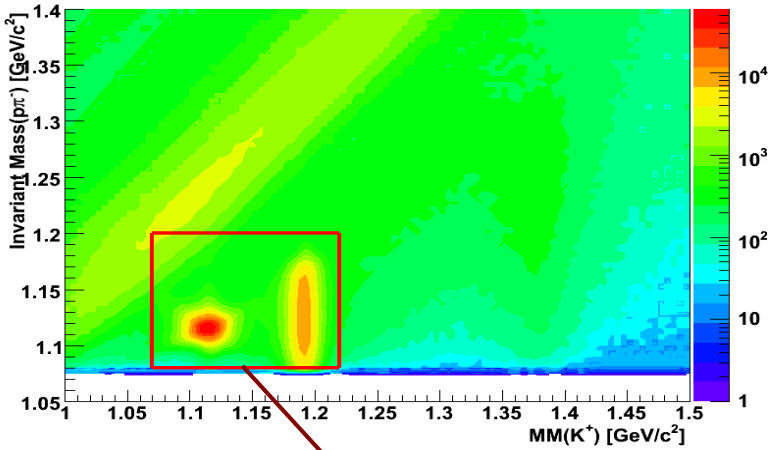
From Brem. Calculation and piN results we expect 3% systematic error in P

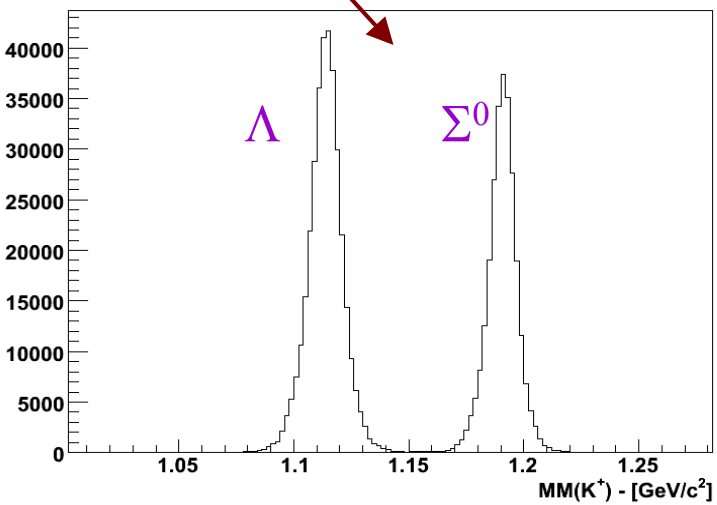
g8b preliminary results - $K^+\Lambda$ and $K^+\Sigma^0$

Craig Paterson, Glasgow

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

$\gamma p \rightarrow K^+\Sigma^0 \rightarrow K^+\Lambda\gamma \rightarrow K^+p\pi^-\gamma$





Single polarization observables

Σ Photon asymmetry

P Recoil polarization (induced pol. along y)

T Target asymmetry

Double polarization observables

O_x Polarization transfer along x

O_z Polarization transfer along z

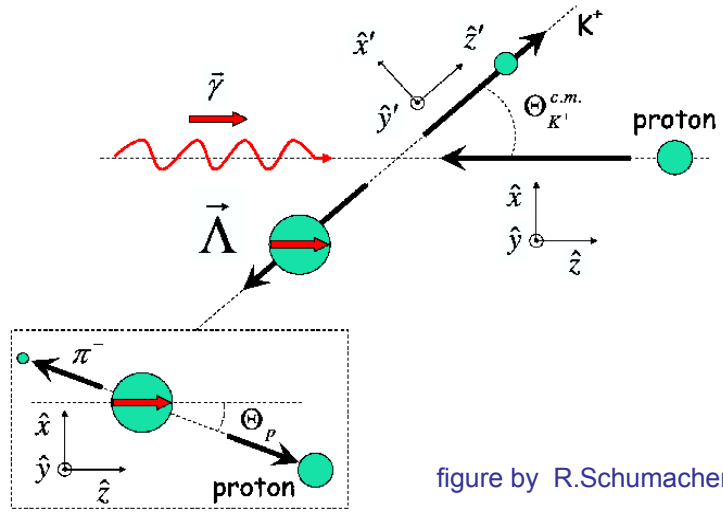
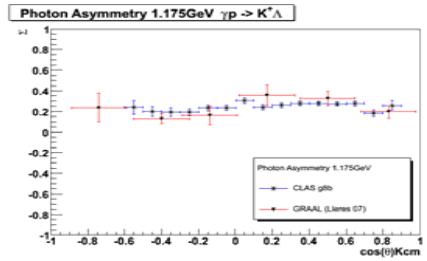
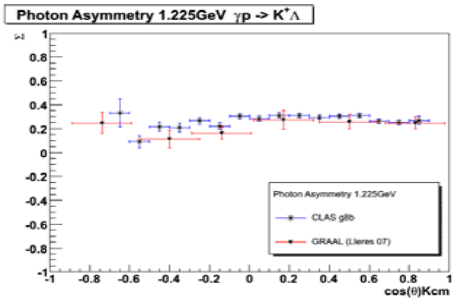


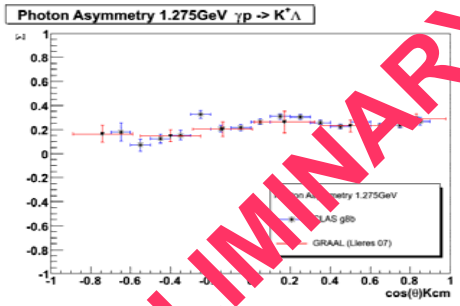
figure by R.Schumacher, CMU

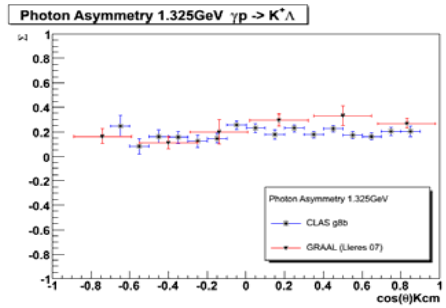
g8b preliminary results - $K^+\Lambda$

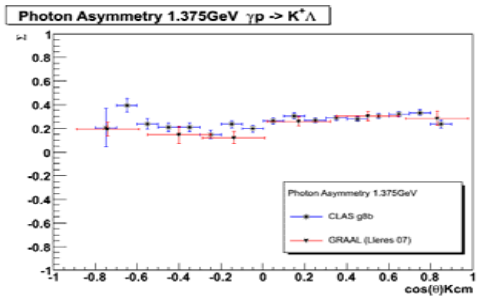
- Results compared with previous results from GRAAL
  - 7, 50MeV Energy bins
  - 1175 -> 1475MeV
  - Good agreement with previous results

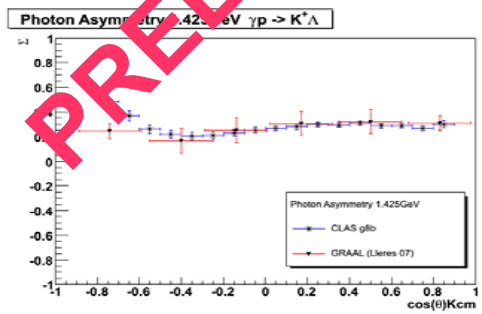


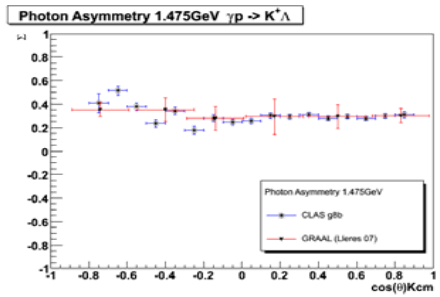












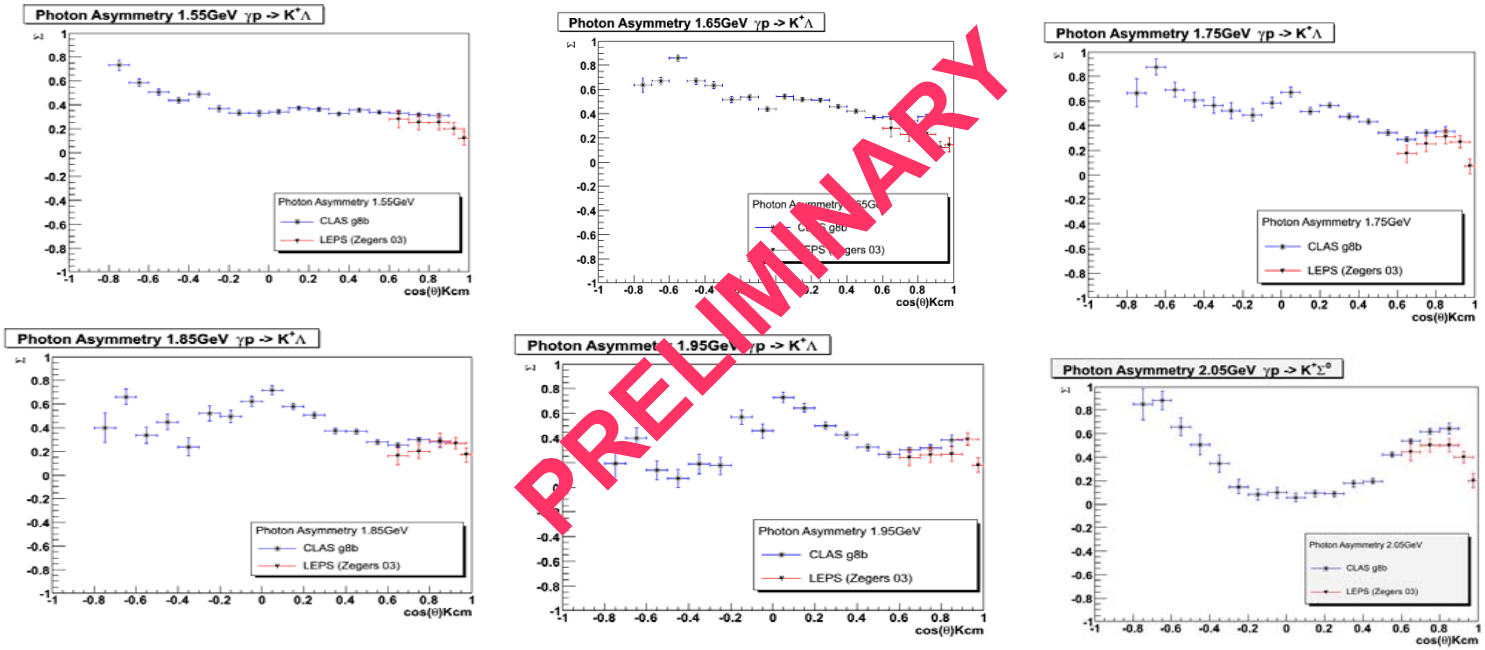
PRELIMINARY

g8b preliminary results - $K^+\Lambda$

- Results compared with previous results from LEPS
  - 6, 100MeV Energy bins
  - 1550 -> 2050MeV
  - More bins for our data

Increase the angular coverage to backward angles

LEPS also recently have some consistent, new points at backward angles.
Hicks et al., PRC 76, 042201(R) (2007).

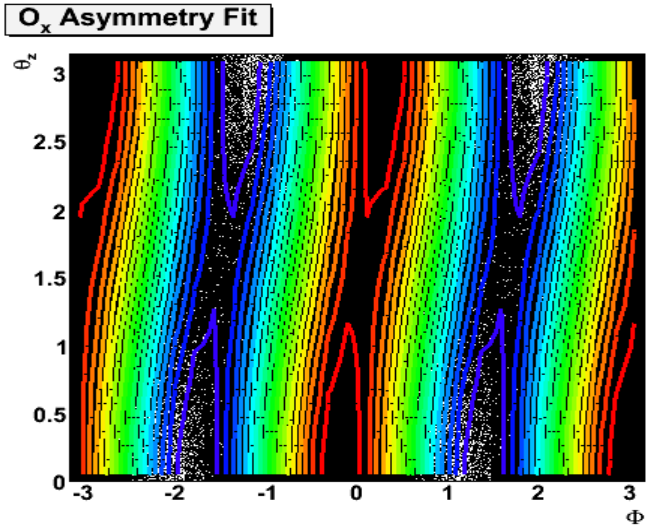


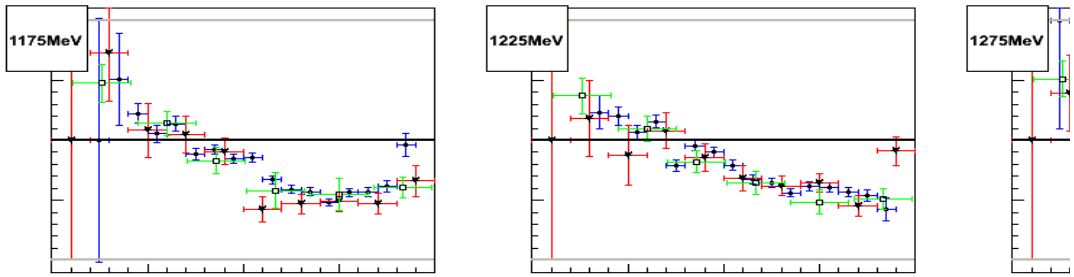
g8b preliminary results - $K^+\Lambda$

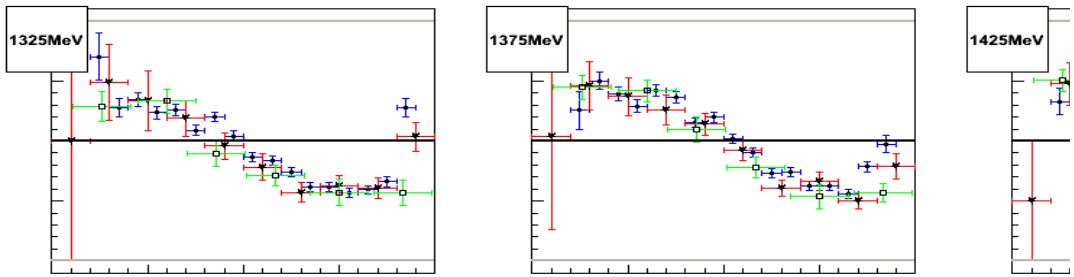
O_x/O_z extracted from fit to 2d asymmetry

T Target asymmetry from 2d asymmetry (not shown)

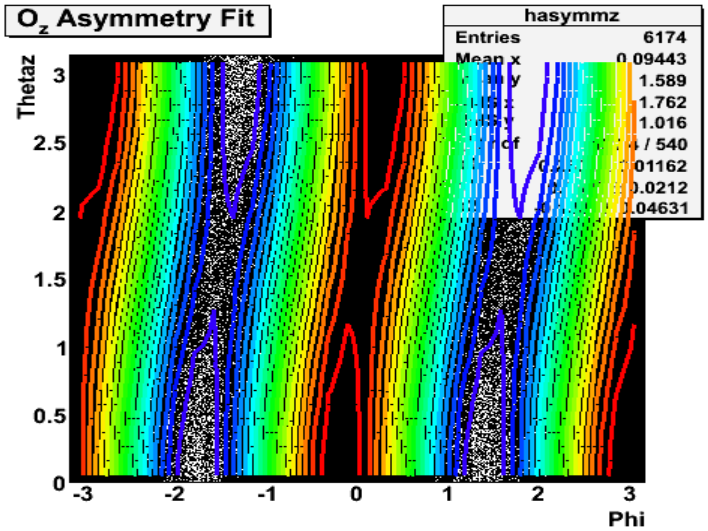
P Recoil pol. from acceptance corrected proton dist.

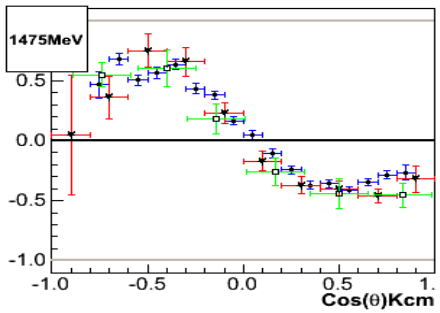






P Recoil pol.



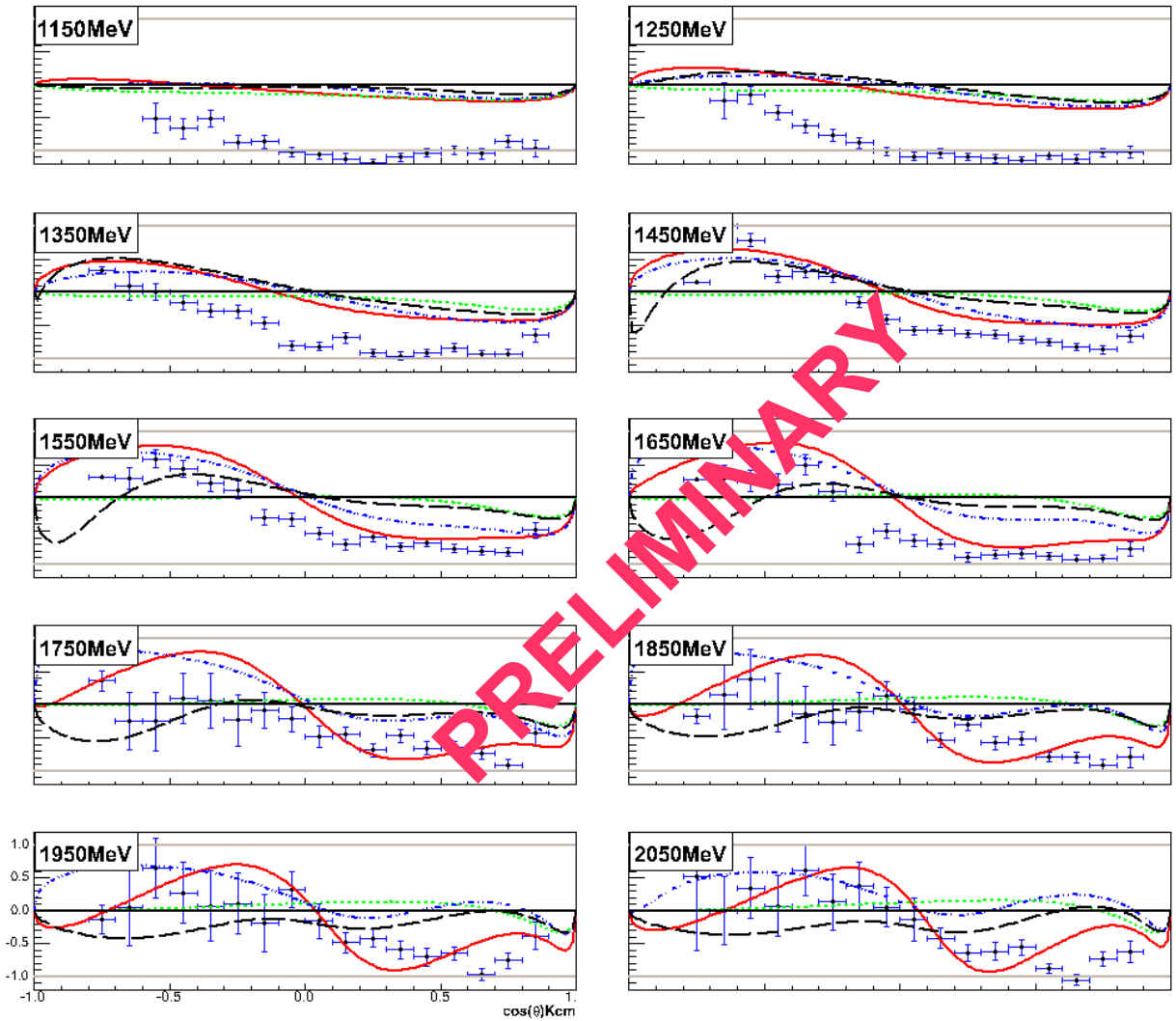


g8b
GRAAL
CLAS J.W.C. McNabb, et al. (CLAS) Phys. Rev. C 69, 042201(R) (2004).

g8b preliminary results - $K^+\Lambda$

Double polarization ovservable O_x

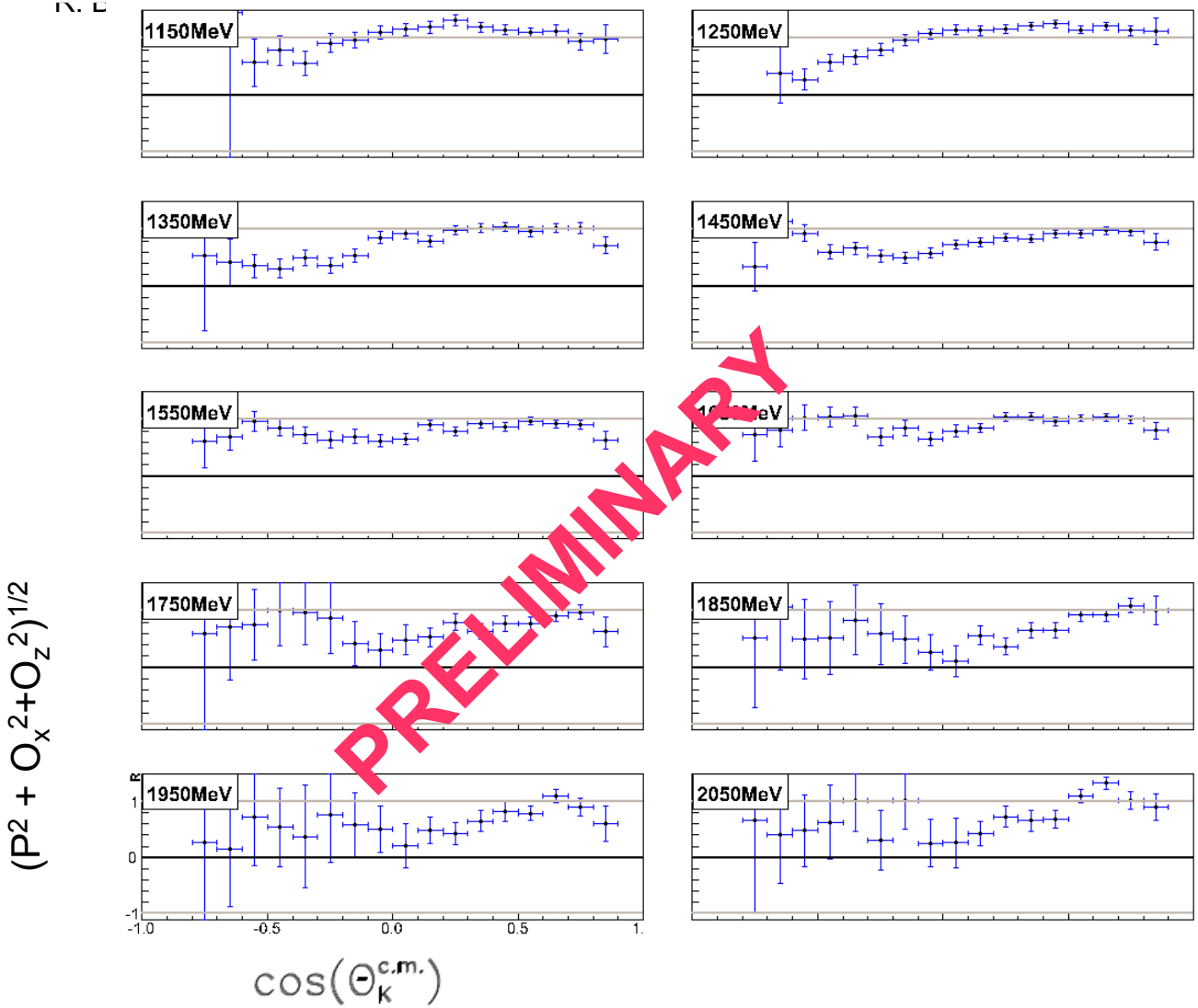
- Results compared with Regge-Plus-Resonance model from Gent group



- Large Polarizations
- Some evidence for an important role for missing $D_{13}(1900)$ state
- Poor agreement at low energy

g8b preliminary results - $K^+\Lambda$

Full lamba polarization ?



- Full polarization at forward angles

- Not repeated over full kinematic range

- More relations can be tested

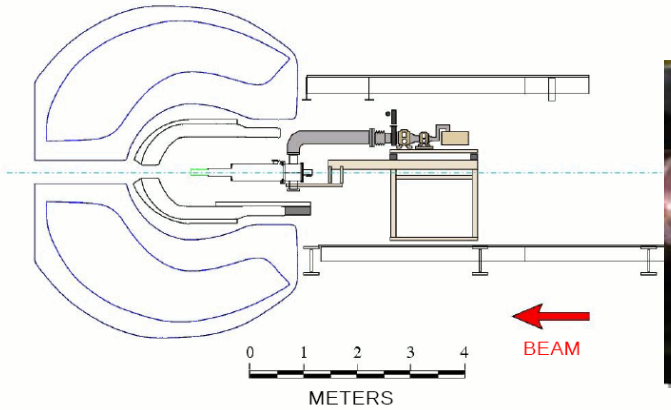
g9 FROST – FROzen Spin Target (butanol = C_4H_9OH)

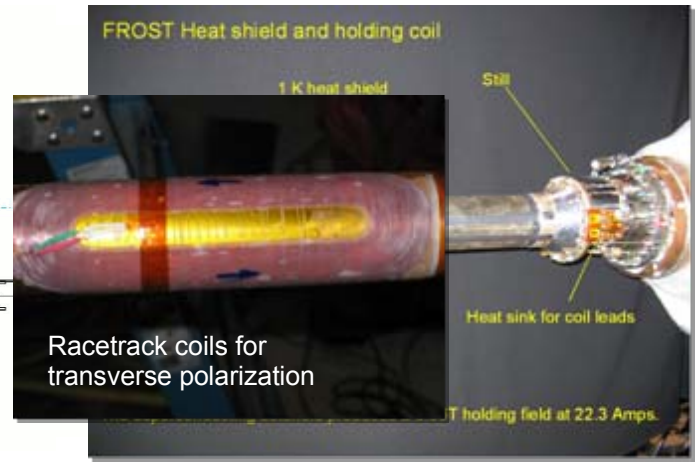
Meson photoproduction with linearly and circularly polarized photons on polarized target

- E02-112: $\gamma p \rightarrow KY$ ($K^+\Lambda$, $K^+\Sigma^0$, $K^0\Sigma^+$)
- E03-105/E04-102: $\gamma p \rightarrow \pi^0 p$, $\pi^+ n$
- E05-012: $\gamma p \rightarrow \eta p$
- E06-013: $\gamma p \rightarrow \pi^+ \pi^- p$

Frozen Spin Mode

- Microwaves OFF
- Polarizing magnet OFF
- Holding magnet ON
- Temperature ≤0.05 K
- Photon beam ON





g9a running conditions

- November 3, 2007– February 12, 2008
- Longitudianally polarized target
- Circularly and linearly polarized photon beam 0.5-2.4 GeV
- Trigger: at least one charged particle in CLAS
- Target Pol > 80%, Relaxation time > 1600hrs – **better that design goals**

g9b

- March – July 2010
- Transversely polarized target

g9aFROST sample analysis of $gp \rightarrow \pi^+ n$

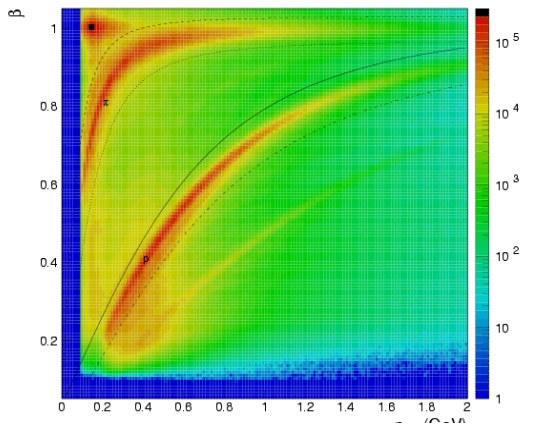
Eugene Pasyuk, ASU. Jo McAndrew, Edinburgh

- Select π^+ applying cut on β vs. p
- Vertex cuts
- Select missing neutron

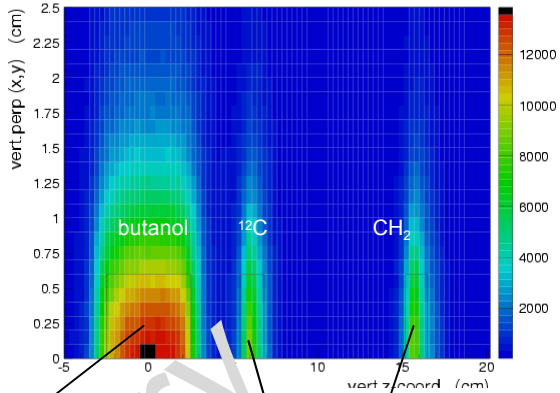
$$Asymmetry = p_\gamma \cos(2\varphi) + P_\gamma p_z G \sin(2\varphi)$$

$$\frac{d\sigma}{} = \sigma_0[1 - P_\odot P_T E] \qquad A = \frac{\rightarrow \quad \leftarrow}{}$$

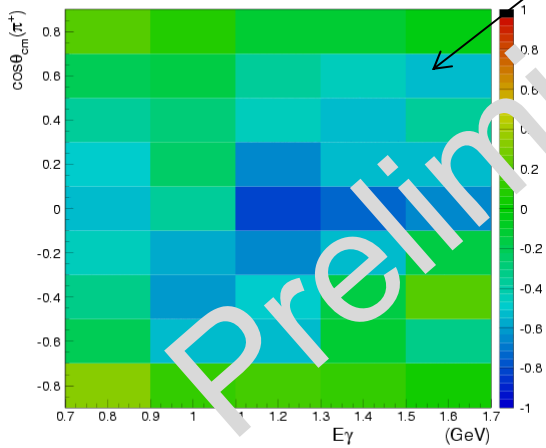
β vs. p cut



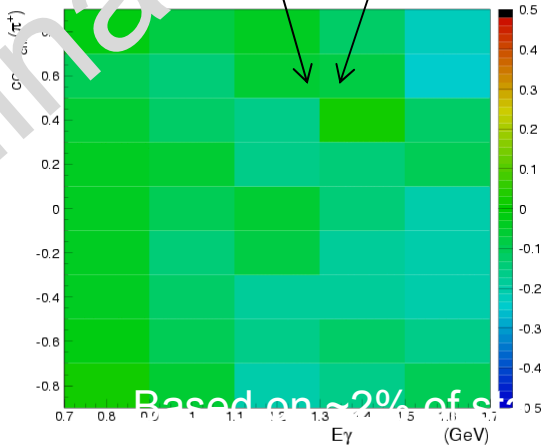
vertex cut

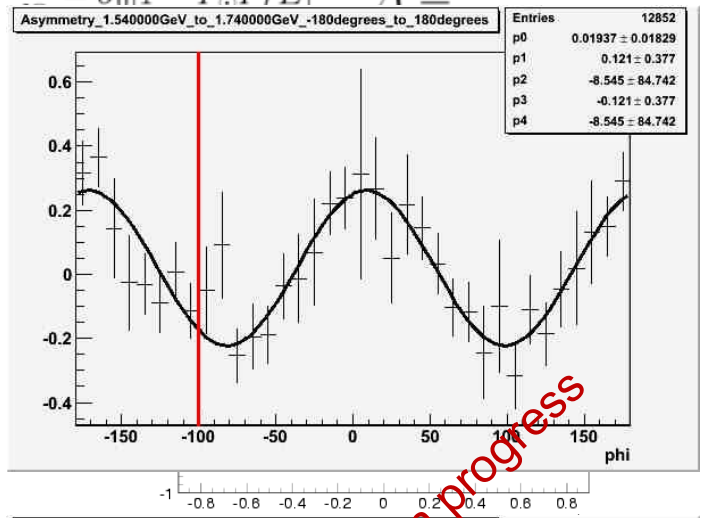


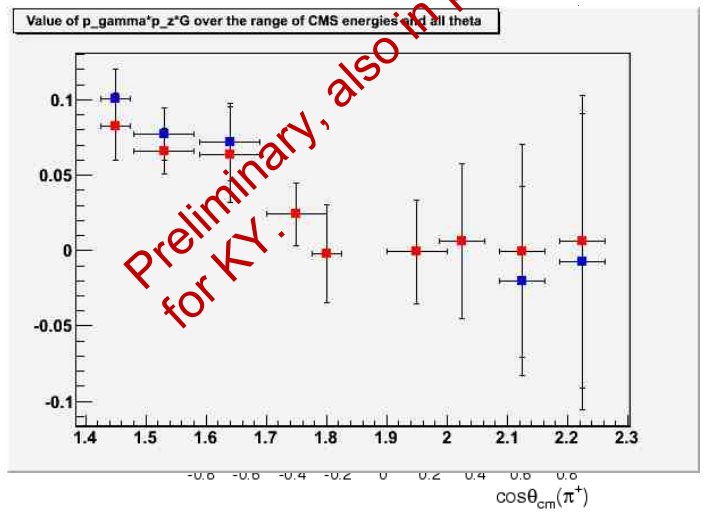
hel.asym.($\pi^+ n$) on target



hel.asym.($\pi^+ n$) on C,CH_2







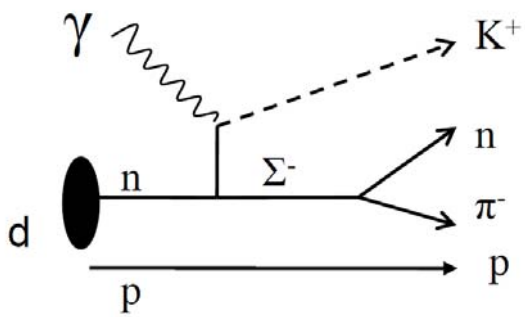
Preliminary

Preliminary, also in progress for KY.

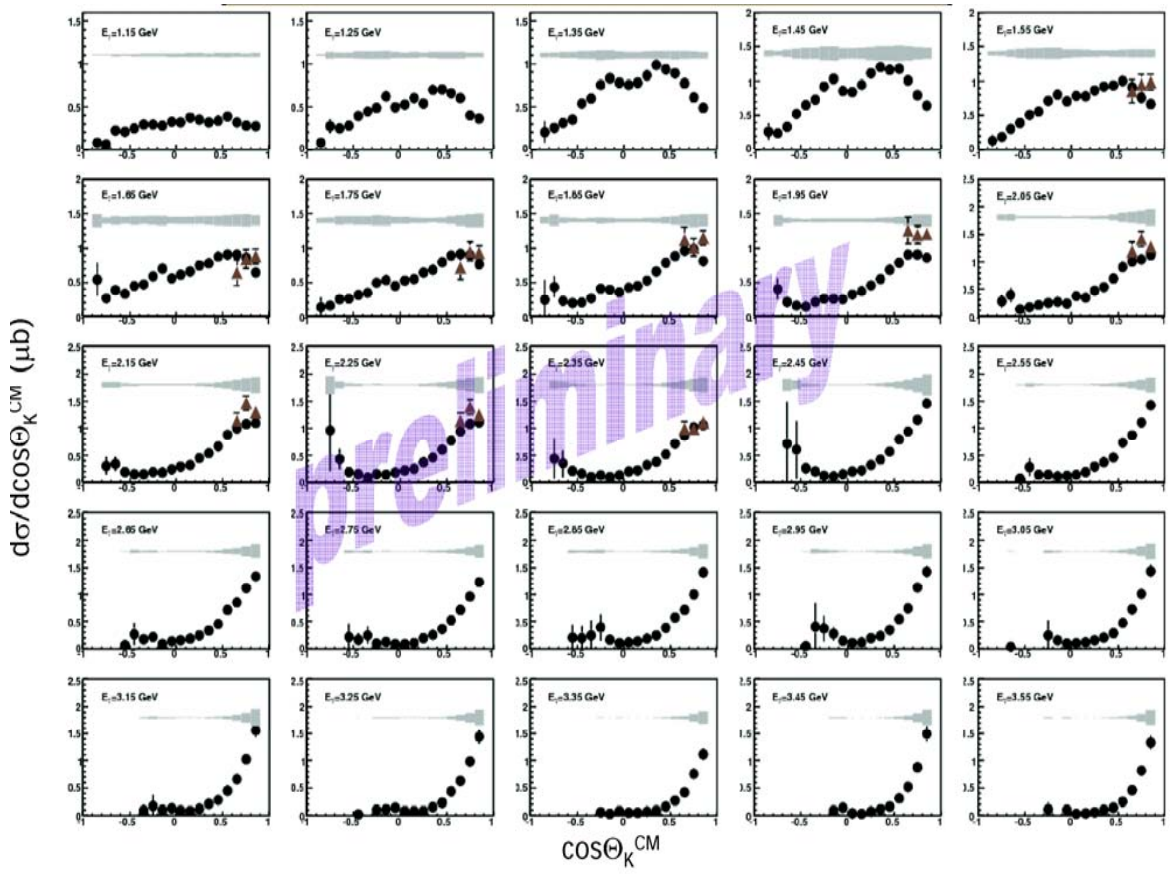
Based on ~2% of s

K production on n. Deuterium target

- G10. Unpolarized photons on Deuterium
- 1st measurement of σ for the γ n → K^+ Σ^- Sergio Anefalos Pereira, INFN.



- Detect π^- n, K^+
- Σ from π^- n inv. mass

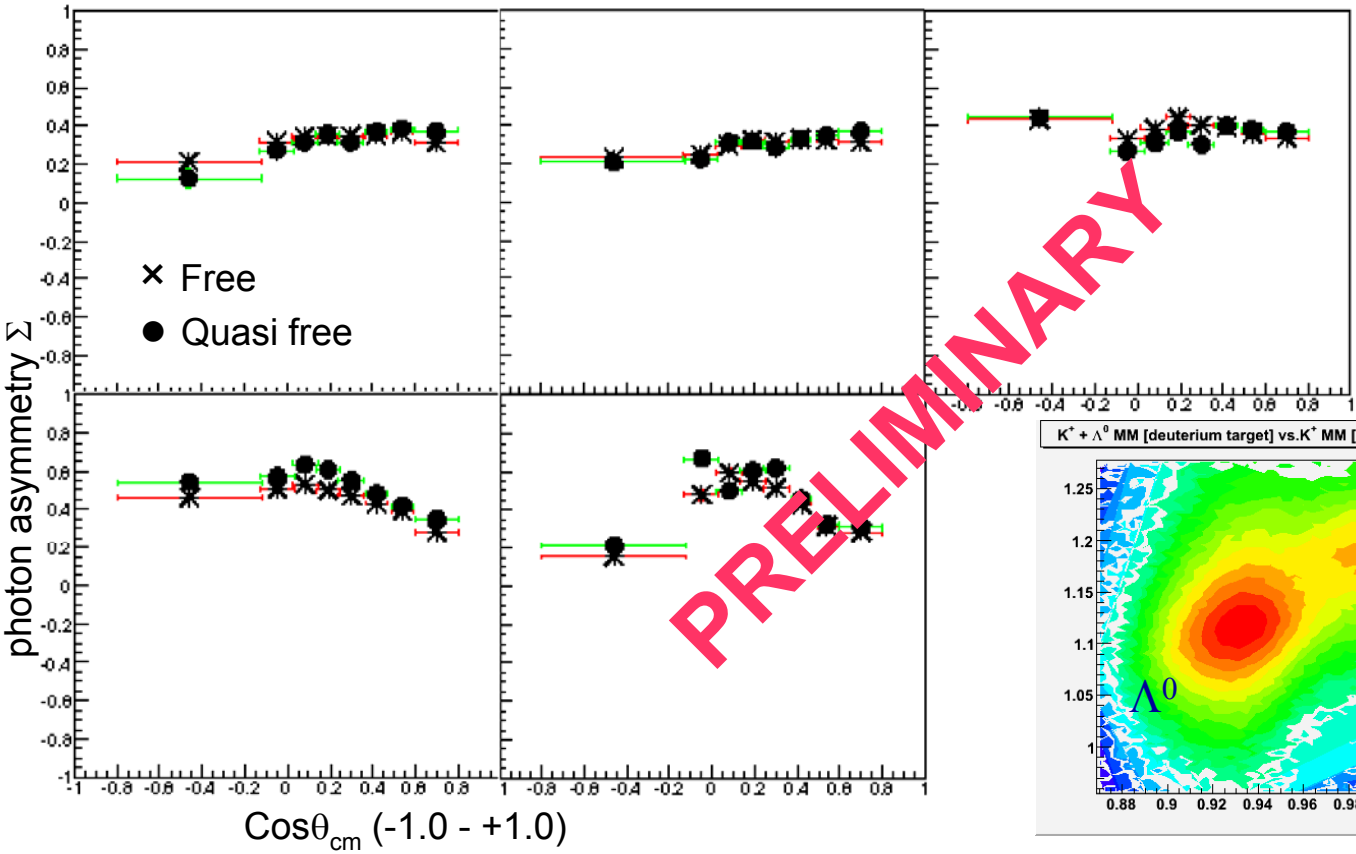


- G13. Circularly and linearly polarized photons on Deuterium
- γ n → K^+ Σ^- analysis for polarization observables underway. Edwin Munevar, GWU

K production on n. Deuterium target

- How good a “free” neutron target is Deuterium ?
- G13. Compare photon asymmetry of $\gamma p\ (n) \rightarrow K^+\Lambda^0\ (n)$ with $\gamma p \rightarrow K^+\Lambda^0$ (free and bound p)

$\gamma p\ (n) \rightarrow K^+\Lambda^0\ (n)$ Russell Johnstone, Glasgow



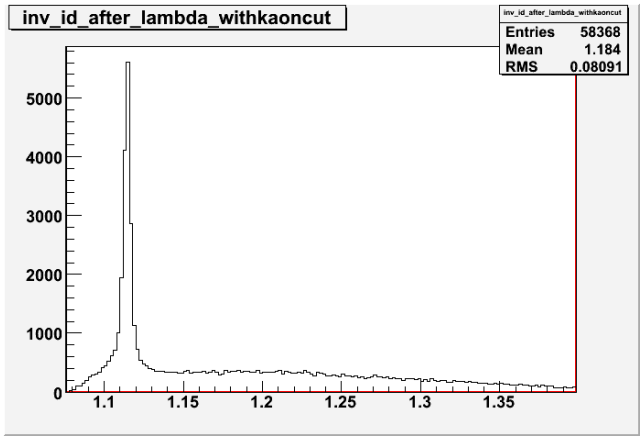
Each plot is 200MeV photon energy bin
1100-2150MeV

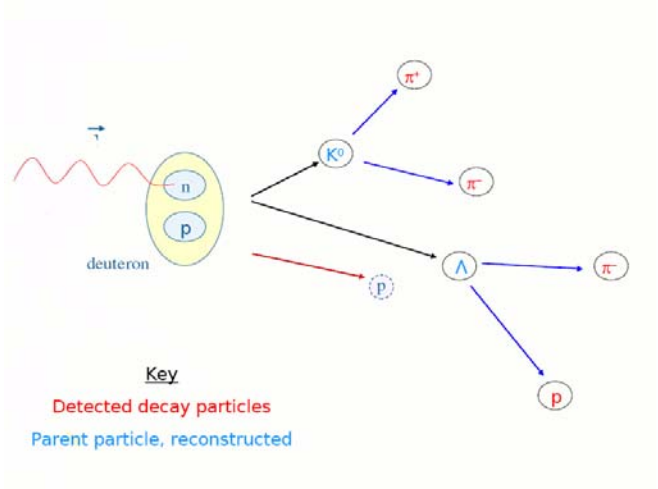
- Free and quasi-free proton
- Quasi free neutron good approx. to free, here.

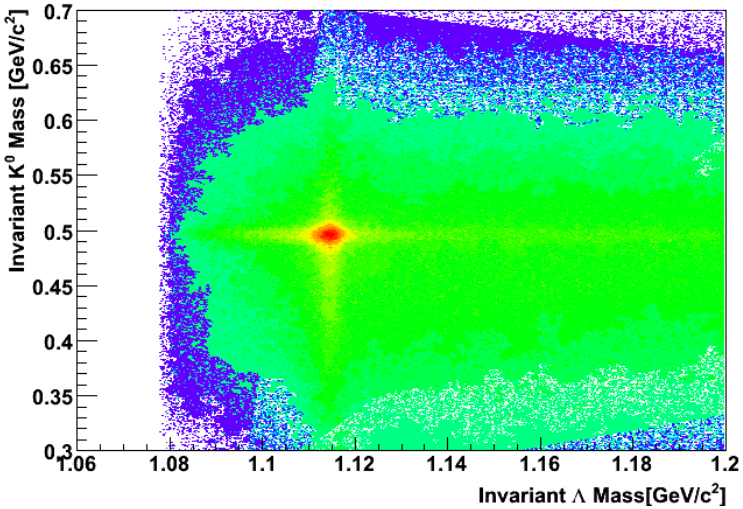
K production on n. Deuterium target

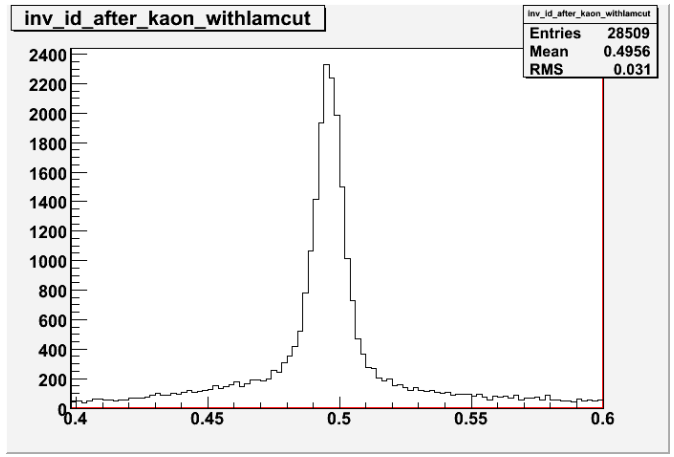
G13 $\gamma n\ (p) \rightarrow K^0_s\ \Lambda^0\ (p)$ $\gamma n\ (p) \rightarrow K^0_s\ \Sigma^0\ (p)$

Neil Hassall, Glasgow





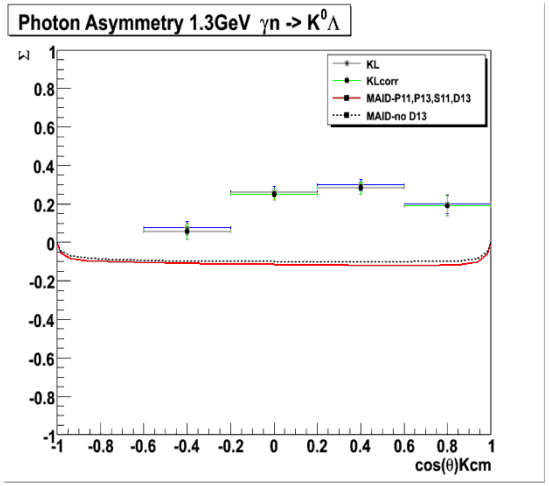


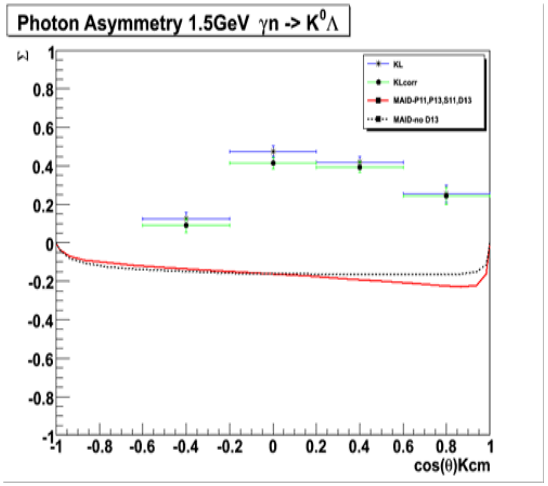


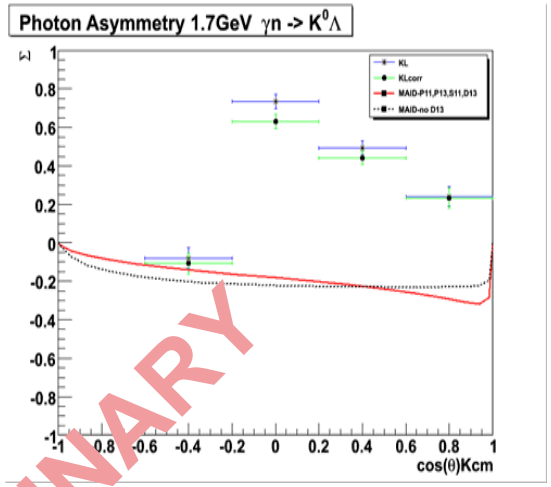
K production on n. Deuterium target

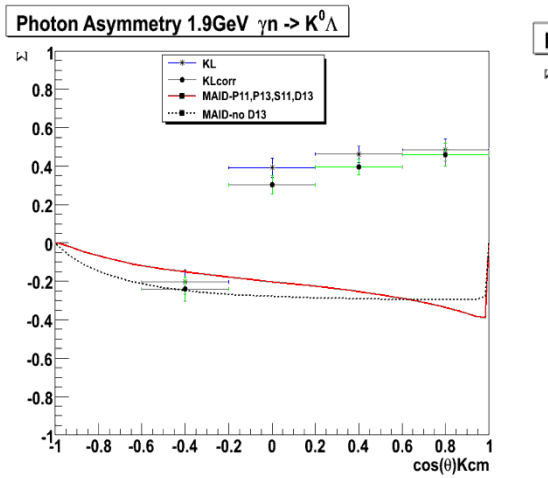
G13 1st measurement of Beam Asymmetry $\gamma n (p) \rightarrow K^0_s \Lambda^0 (p)$

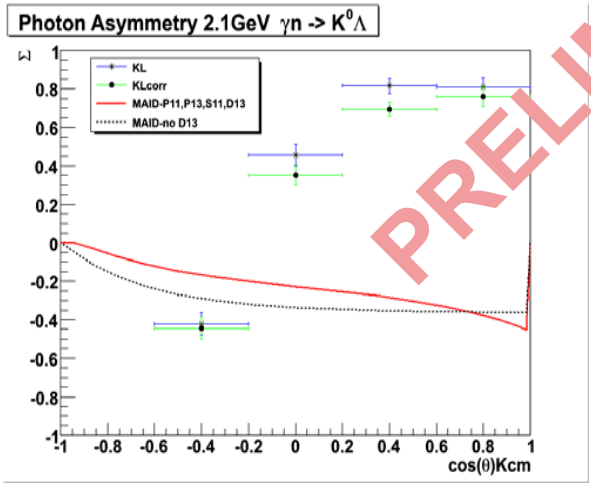
Neil Hassall, Glasgow

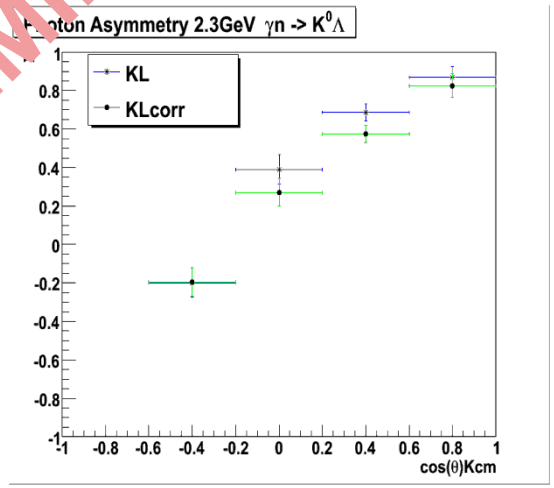










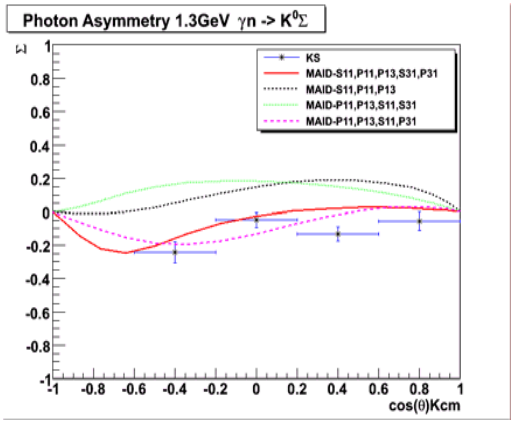


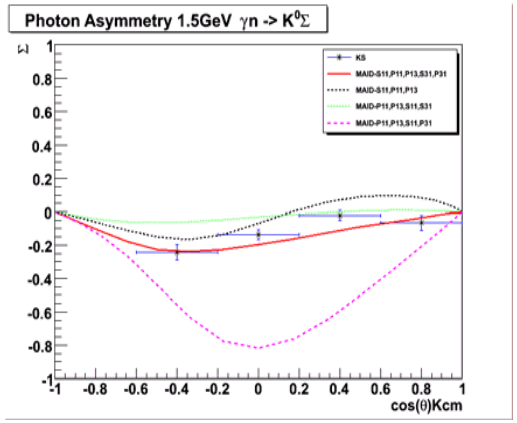
Single, and double polarization observables in progress

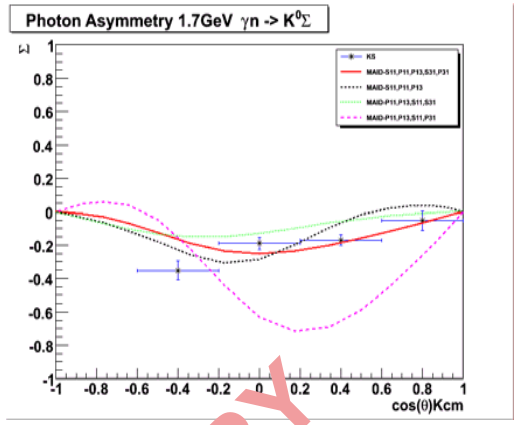
K production on n. Deuterium target

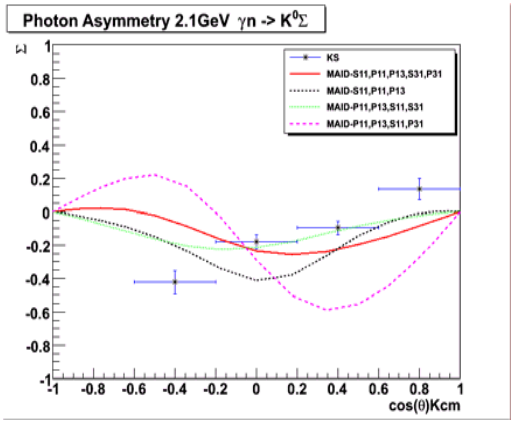
G13 1st measurement of Beam Asymmetry $\gamma n (p) \rightarrow K^0_s \Sigma^0 (p)$

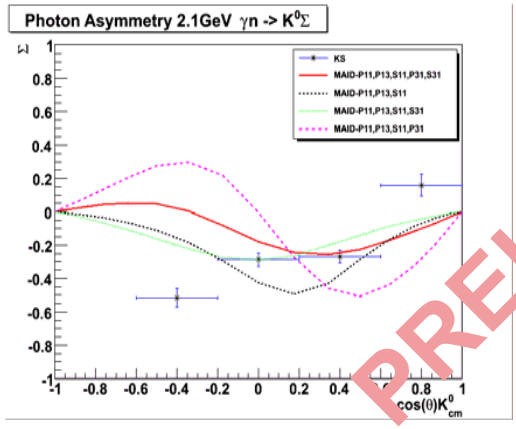
Neil Hassall, Glasgow

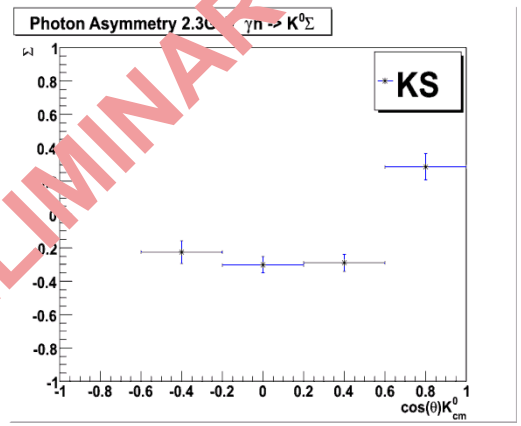








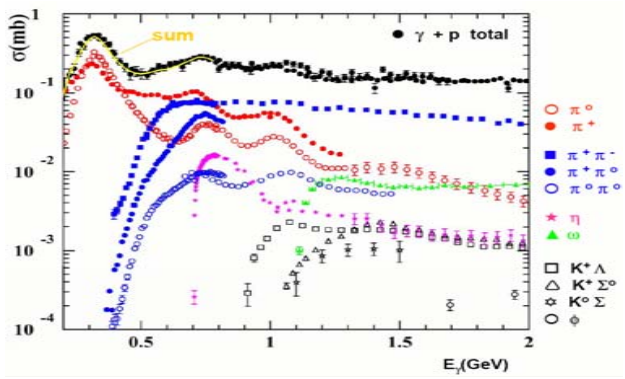




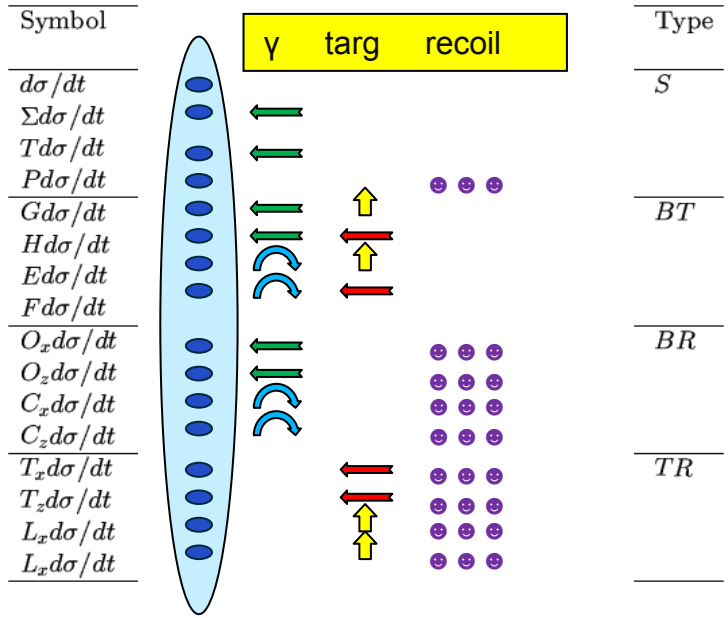
Single, and double polarization observables in progress

Summary

- **Kaon photoproduction at CLAS**
- **Missing resonances**
  - Recent measurements already having impact on resonance predictions
- **Polarization observables**
  - *Explosion* of possibilities at CLAS.
  - **Complete measurement** possible with K Y channels ... and **coming soon**
- **KY on proton**
  - σ, P, C_x, C_z measured (**g1c**)
  - Σ, T, O_x, O_z almost complete (**g8b**)
  - E, G, L_x, L_z data taken, being analysed (**g9a**)
  - F, H, T_x, T_z begins March 2010 (**g9b**)
- **KY on neutron**
  - 1st measurements of σ (g10), P, C_x, C_z , Σ, T, O_x, O_z **(g13)** prelim results, and analysis underway
- **HDIce** A new kind polarized target with H and D scheduled for Autumn 2010 (**g14**)

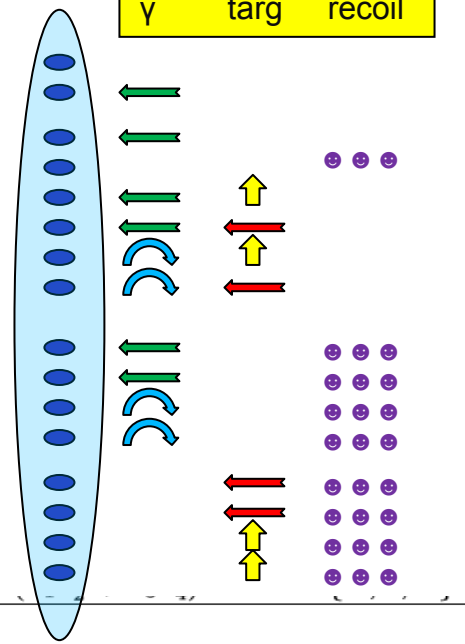


KY



KY

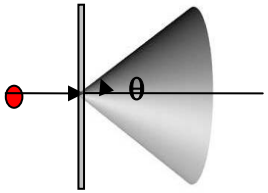
Symbol	Type
$d\sigma/dt$	S
$\Sigma d\sigma/dt$	
$T d\sigma/dt$	
$P d\sigma/dt$	
$G d\sigma/dt$	BT
$H d\sigma/dt$	
$E d\sigma/dt$	
$F d\sigma/dt$	
$O_x d\sigma/dt$	BR
$O_z d\sigma/dt$	
$C_x d\sigma/dt$	
$C_z d\sigma/dt$	
$T_x d\sigma/dt$	TR
$T_z d\sigma/dt$	
$L_x d\sigma/dt$	
$L_x d\sigma/dt$	

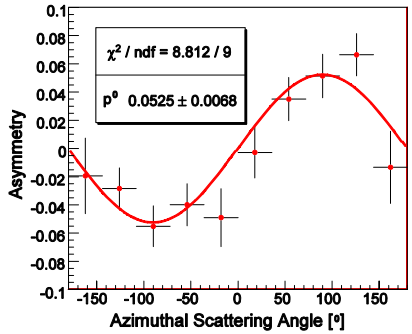


Recoil polarimetry possibilities ?

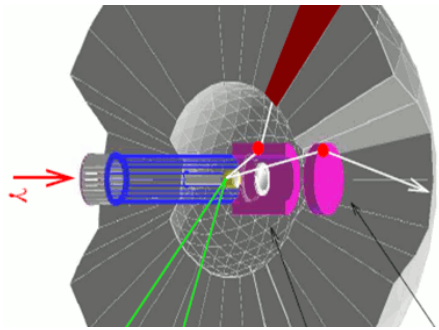
$n(\theta,\phi) = n_o(\theta)\{1 + A(\theta)[P_y \cos(\phi) - P_x \sin(\phi)]$ - How to do this for 4π detector

x and y (transverse) components of nucleon polarisation



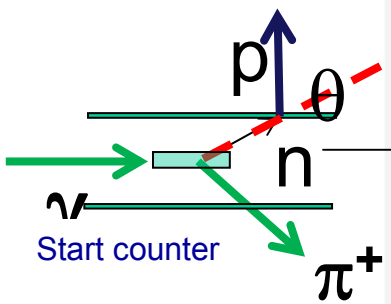


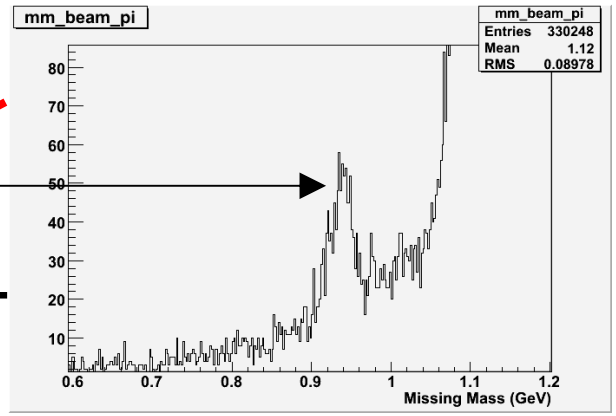
Nucleon polarimeter for CB@MAMI, D. Watts, Edinburgh



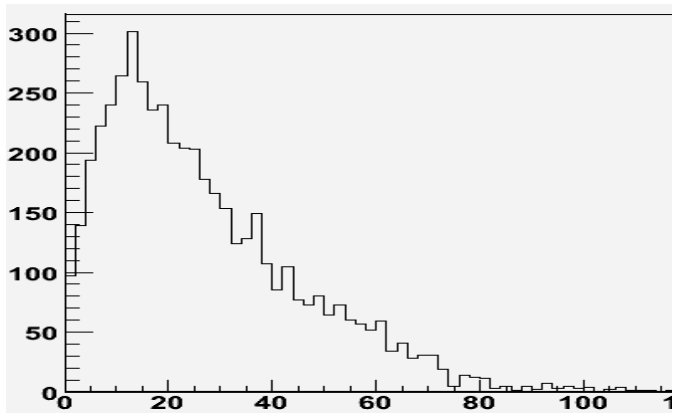
Graphite

g8b data. $\gamma + p \rightarrow \pi^+ n$ with (n,p) scatter (detect $\pi^+ p$)





$M_x(\gamma p \rightarrow \pi^+ X)$

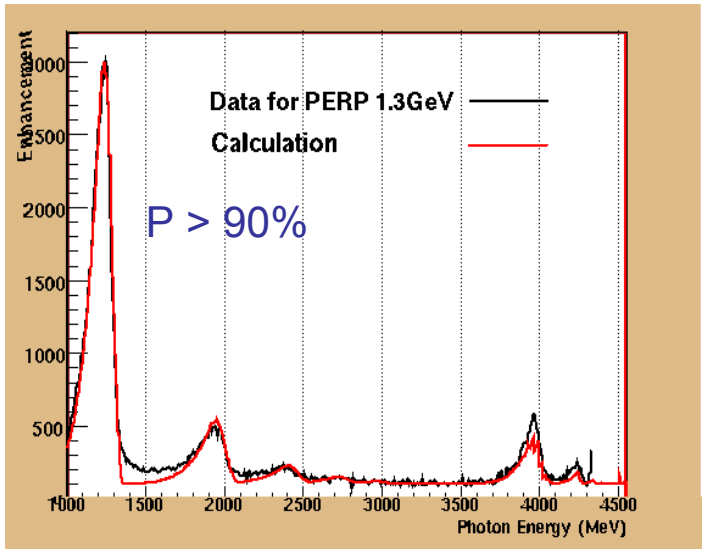


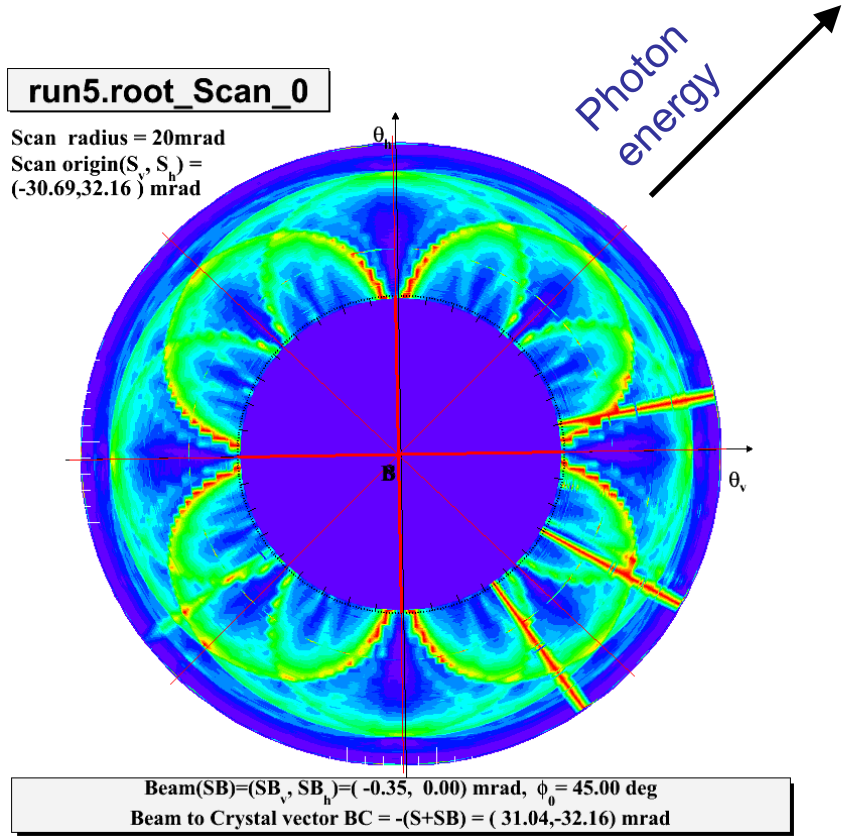
Angle between P_n^{calc} and $P_p^{measured}$

K.Livingston

CLAS coherent bremsstrahlung facility

- Tagging spectrometer with high rate, good energy and timing resolution
- High precision goniometer (GWU)
- High quality, thin diamond (Glasgow)
- Tight photon beam collimation (ISU)
- Polarimetry



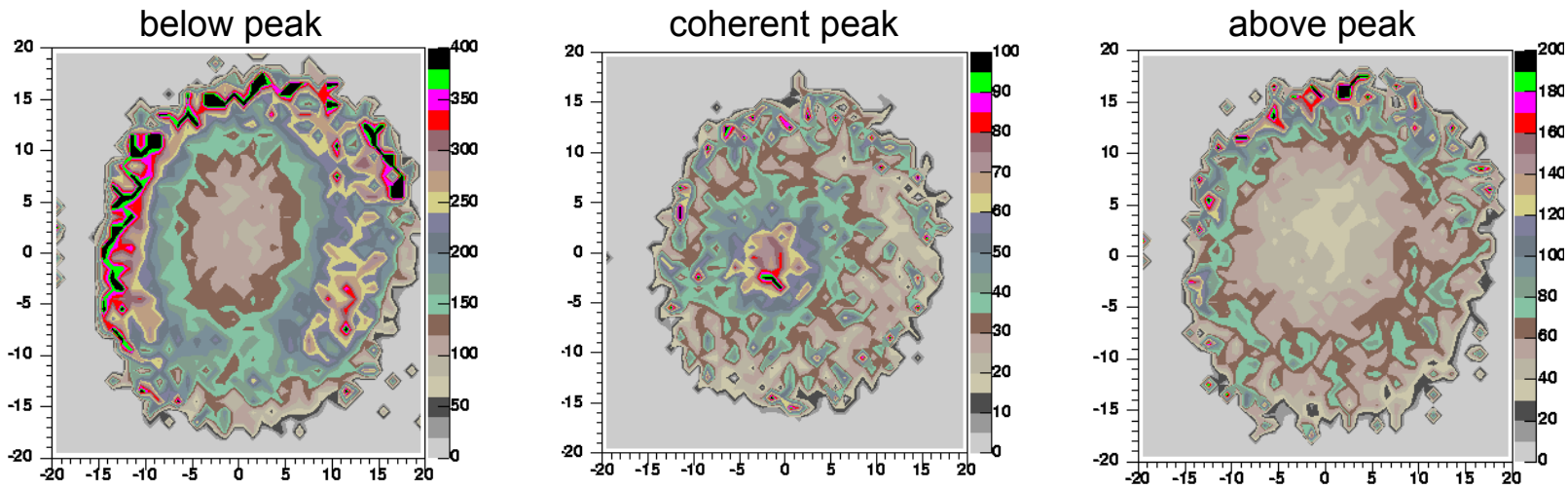


"A device called a goniometer tilts the diamond, much like a lady turning her hand to admire the sparkle of a new ring." - JLAB On Target Magazine

Measurements with photon beam profile detector

D. Glazier, Glasgow

1st Measurement of 2D photon enhancement for coherent bremsstrahlung (MAMI,Mainz)
paper in preparation



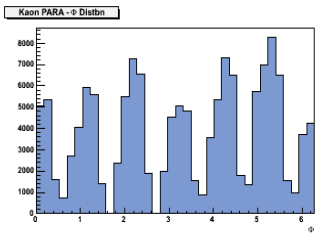
Coherent peak at 300Mev, MAMI electron beam energy 855MeV

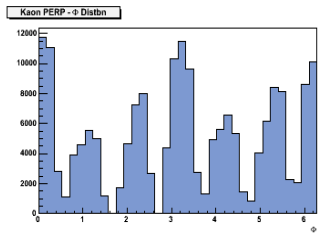
- Good agreement with coherent bremstrahlung calculations
  - Improvements in incoherent component, collimation + multiple scattering.
- No evidence of high energy photons from quasi channeling.
- Investigation of 2D strip detector for polarimetry

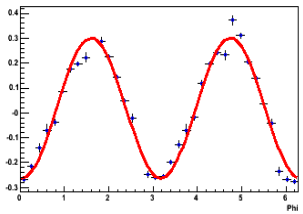
g8b preliminary results - $K^+\Lambda$

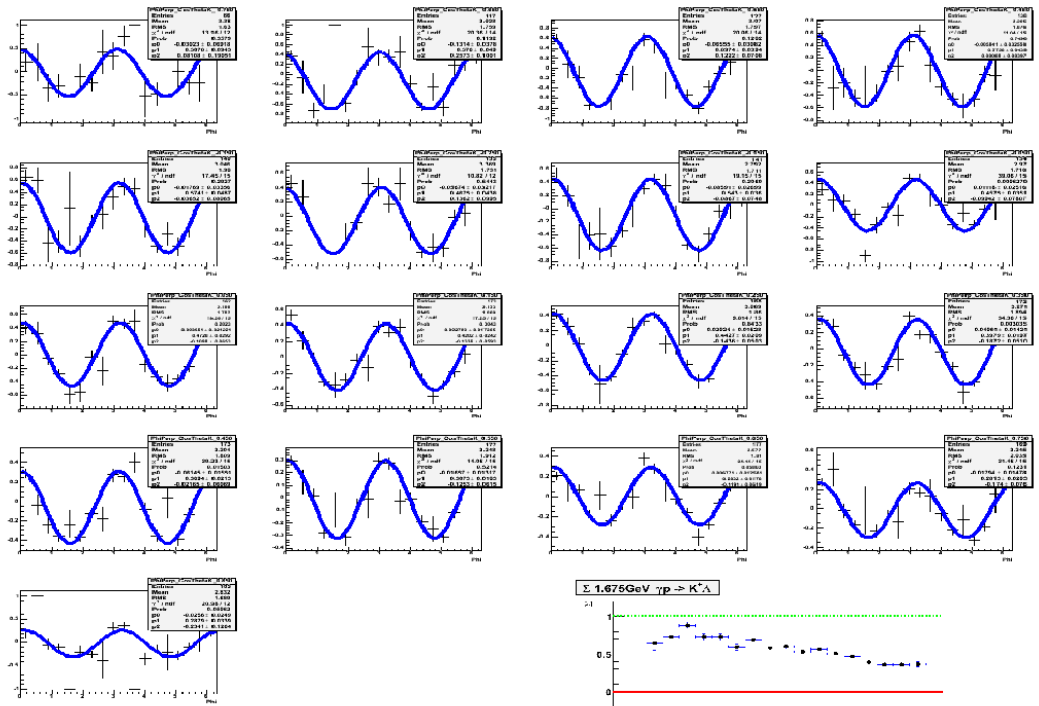
- $K^+\Lambda$ Photon Asymmetry, Σ, extracted from cos(2ϕ) fit to azimuthal kaon distribution
  - Fits shown for 1 energy bin
  - 340 (20E, 17θ) kinematic bins
  - Almost full angular coverage

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{un}}\left\{1 - P_\gamma^T \Sigma cos2\phi\right\}$$



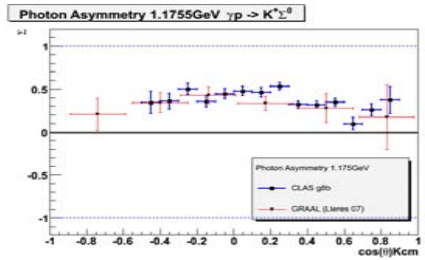


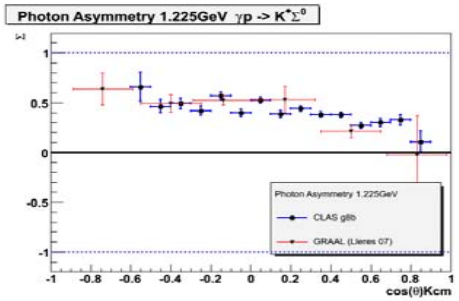


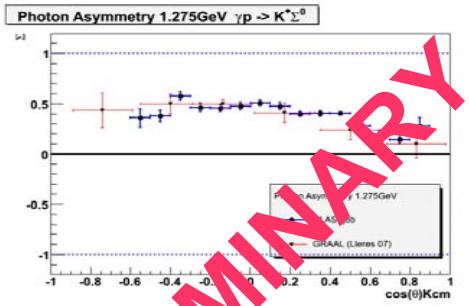


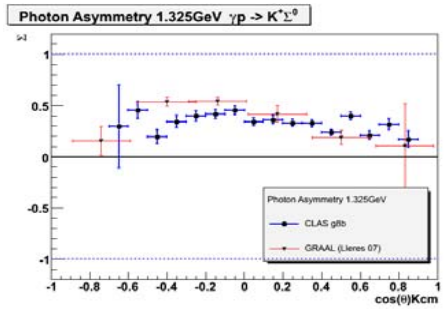
g8b preliminary results - $K^+\Sigma^0$

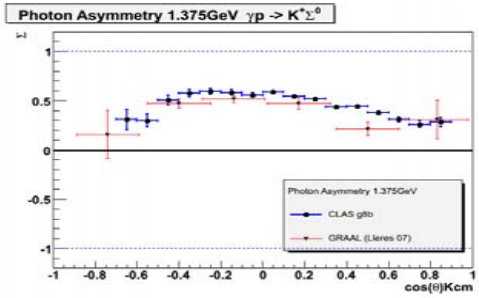
- Results compared with previous results from GRAAL
  - 7, 50MeV Energy bins
  - 1175 -> 1475MeV
  - Good agreement with previous results

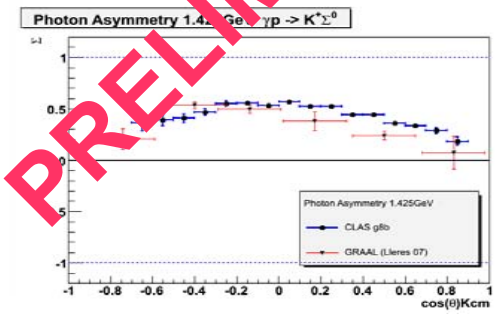


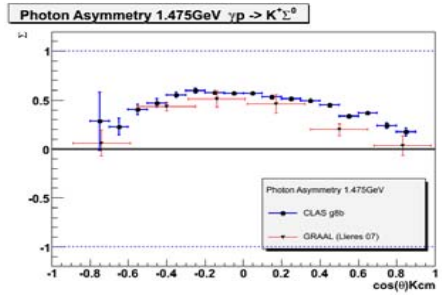










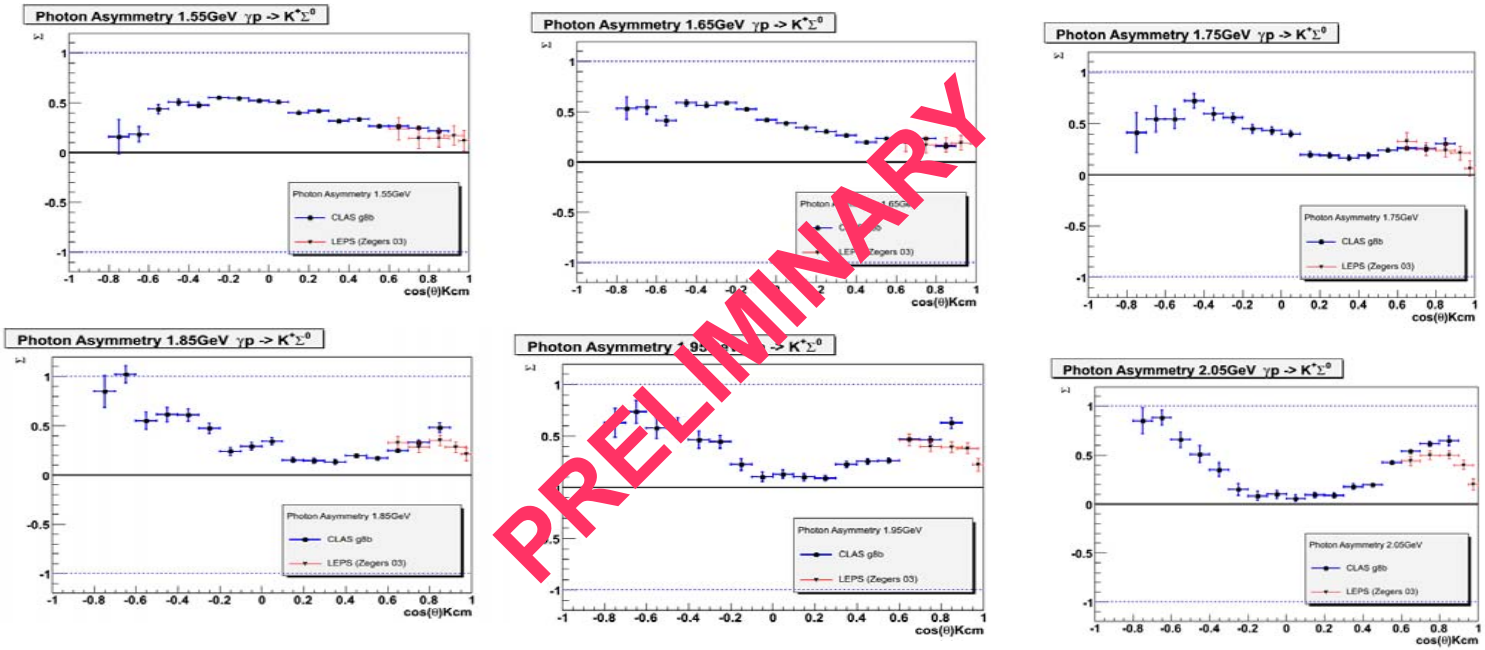


PRELIMINARY

g8b preliminary results - $K^+\Sigma^0$

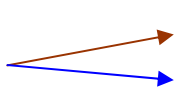
- Results compared with previous results from LEPS
  - 6, 100MeV Energy bins
  - 1550 -> 2050MeV
  - More bins for our data!!!

Increase the angular coverage to backward angles

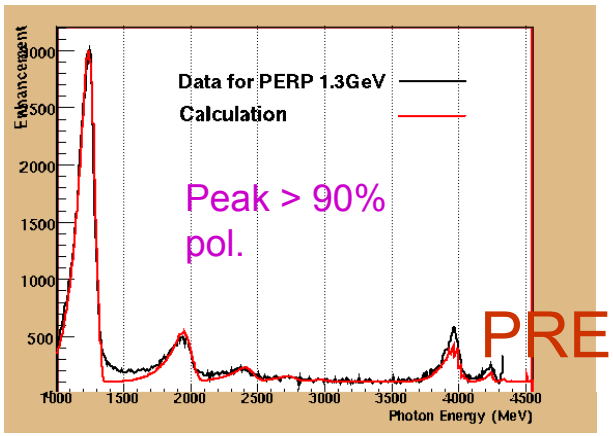


Polarimetry: from pair (e^+,e^-) production

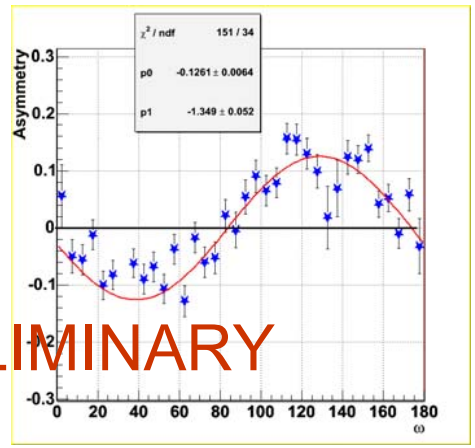
H.Schmieden, Bonn

- Well described by QED, but experimentally difficult – small opening angle
- Pair production 

simulations by Kharkov group
- Polarimeter built and tested at Sping8, recently tested at Jlab



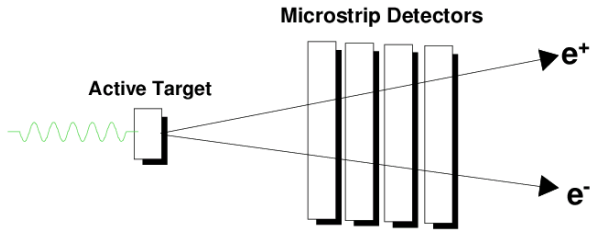
K.Livingston, Glasgow



J.Santoro, CUA

PRELIMINARY

- Polarimeter to be based on Jlab design
- Microstrip detectors, or pixel detectors (Atlas group)
- Bonn student completed 10 months exchange in Glasgow now to be full time in Bonn.



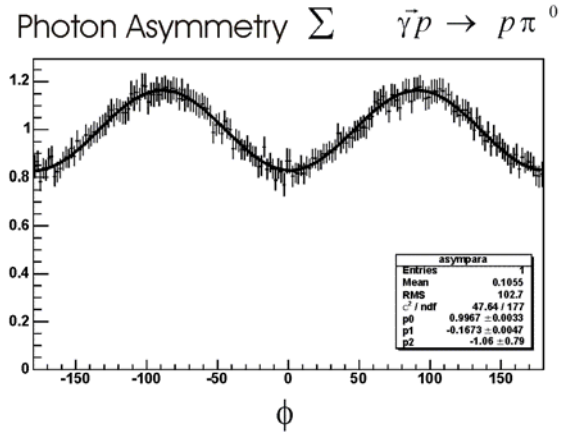
Polarimetry: from hadronic reaction

R. Beck, Mainz -> Bonn

Use reaction with a known photon asymmetry

- Can be high statistics
- Very good relative monitor of polarization
- Combined beam, target polarization.
- Non-indpendent – depends on specific expt
- Need very good systematics or calibration
- Awaiting MAMI polarized target and polarised photon beam in 2nd half of 2007

Crystal Ball Results



Recent preliminary results from JLab (g8b)

- Proton target
- Back to back charge particles in Start Counter
- Atomic or hardonic ?
- Asymmetry from ~20mins DAQ data
- Constant with E from 1.3GeV – 1.9GeV