GWU, Washington, DC May 23-27, 2011

Meson photoproduction with CLAS

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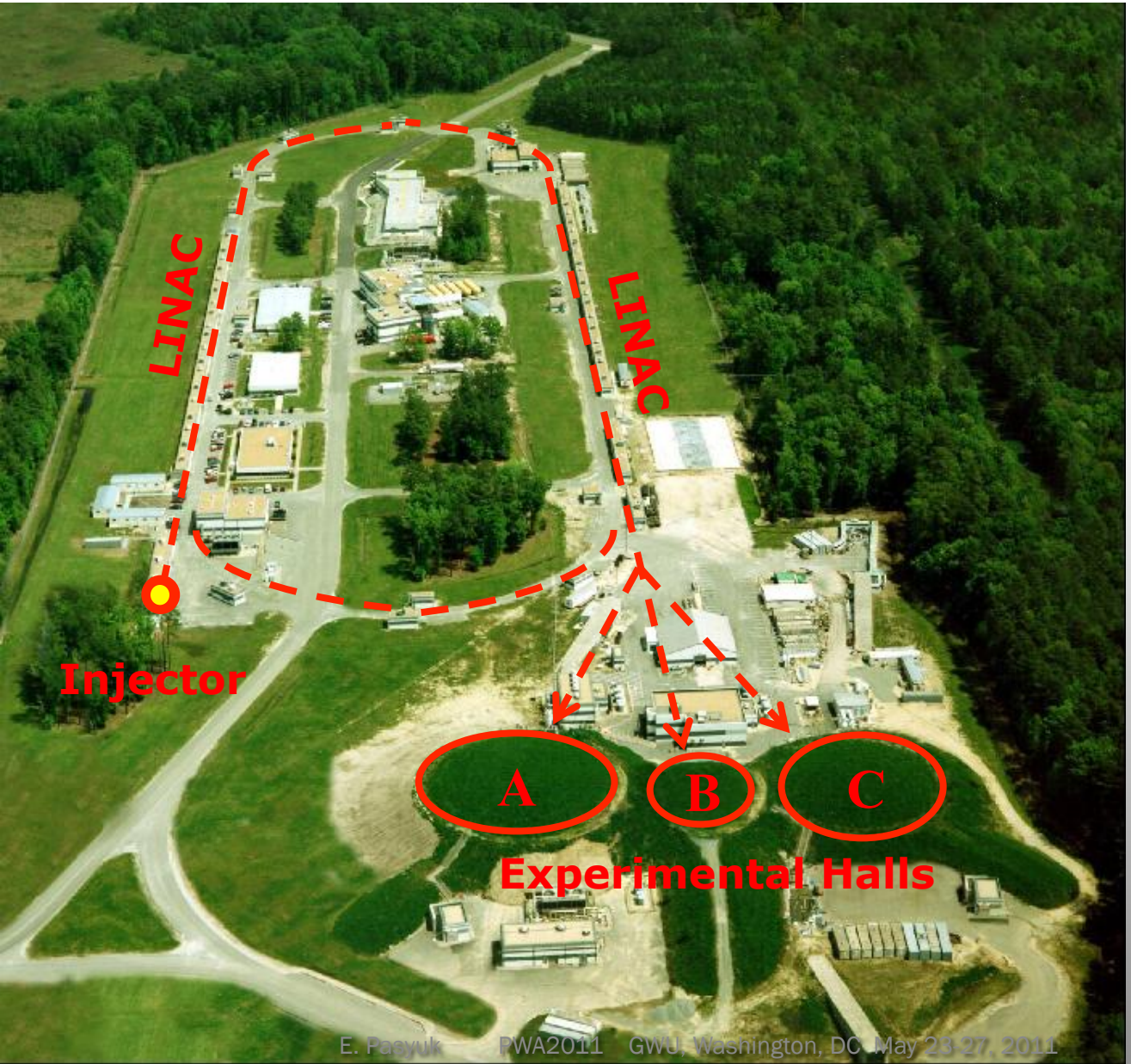
Outline

- Experimental tools in Hall-B
- Selected results
  - single pion production
  - KY
  - two pions
  - Production on deuteron
- Summary

CEBAF



Continuous Electron Beam Accelerator Facility

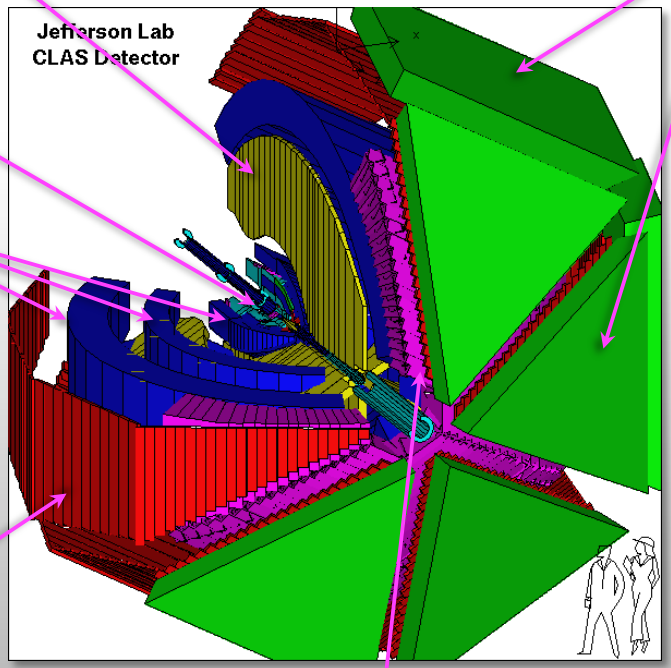
- E: 0.75 –6 GeV
- I_{max}: 200mA
- Duty Cycle: ~ 100%
- s(E)/E: 2.5×10^{-5}
- Polarization: ≥85%
- Simultaneous distribution to 3 experimental Halls

CEBAF Large Acceptance Spectrometer

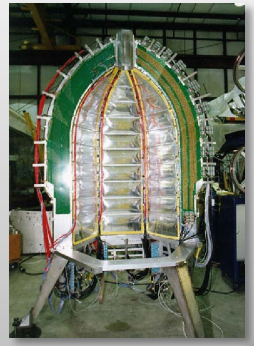
Torus magnet
6 superconducting coils

Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

target + start counter

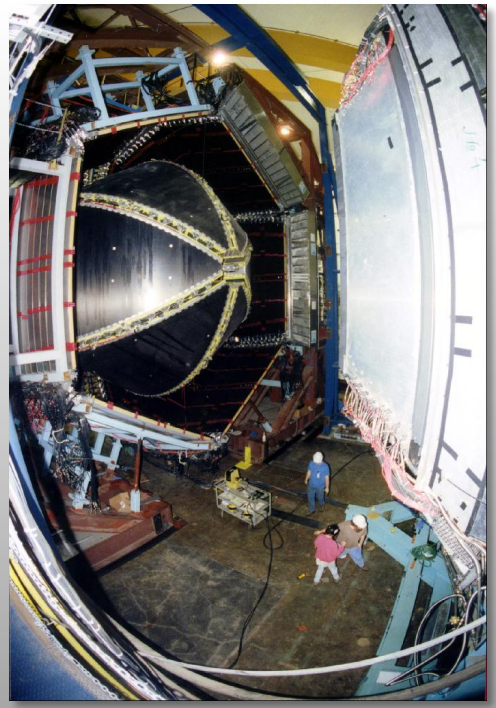


Drift chambers
35,000 cells

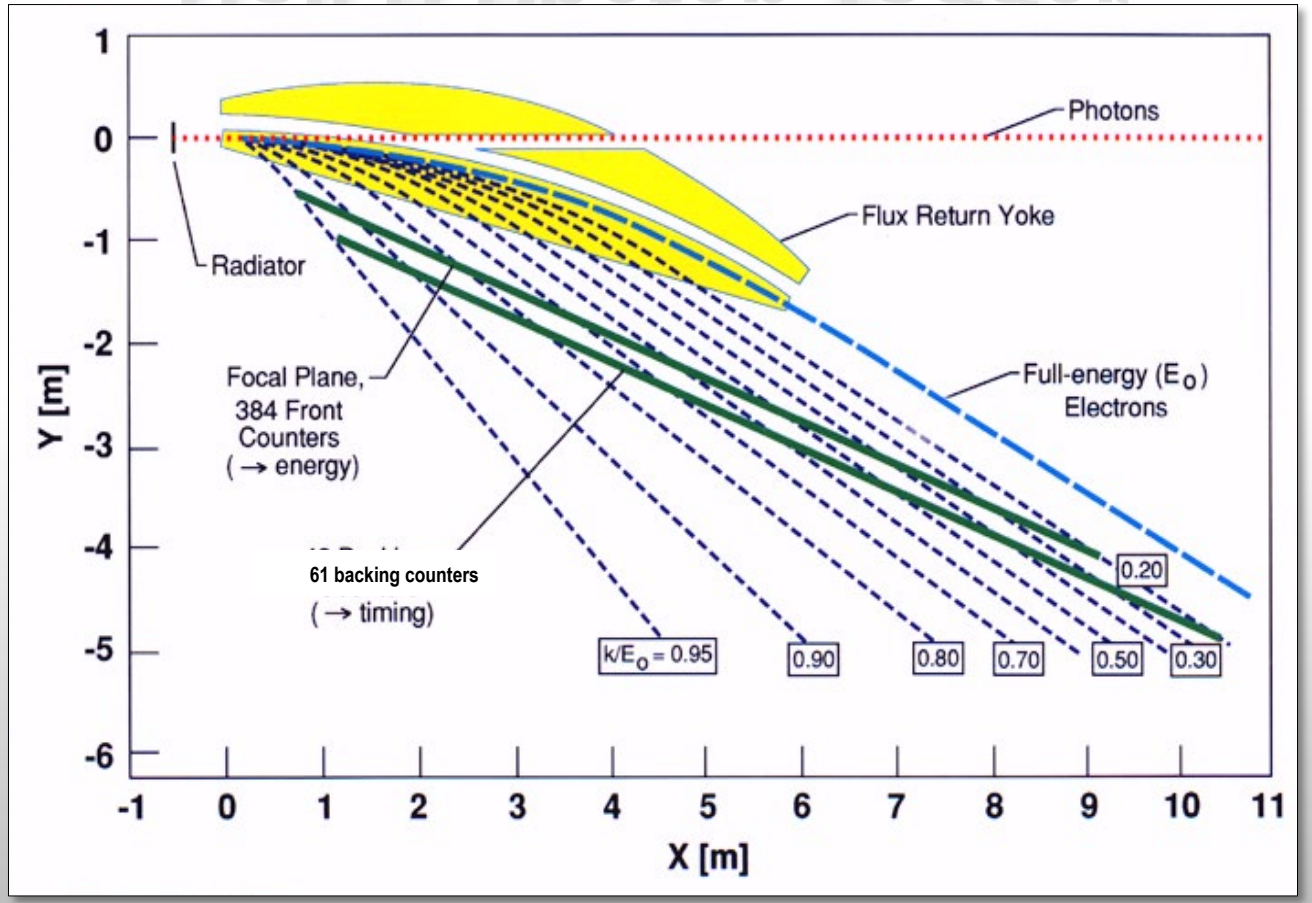


Time-of-flight counters
plastic scintillators, 684 photomultipliers

Gas Cherenkov counters
e/π separation, 256 PMTs

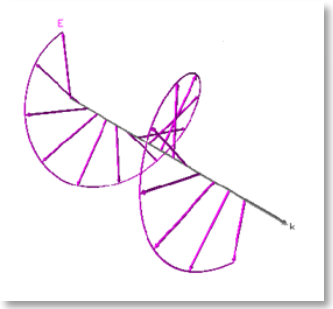


Hall B Photon Tagger

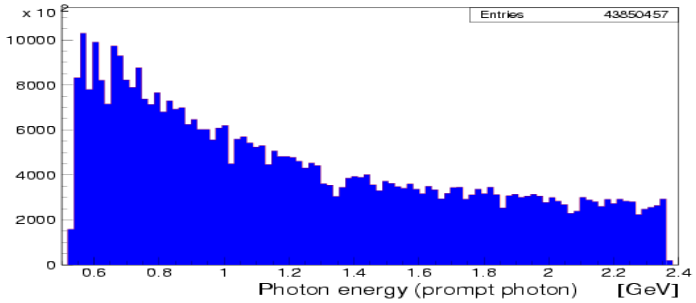


- E_γ = 20-95% of E_0
- E_γ up to ~5.8 GeV
- dE/E ~10^{-3} of E_0

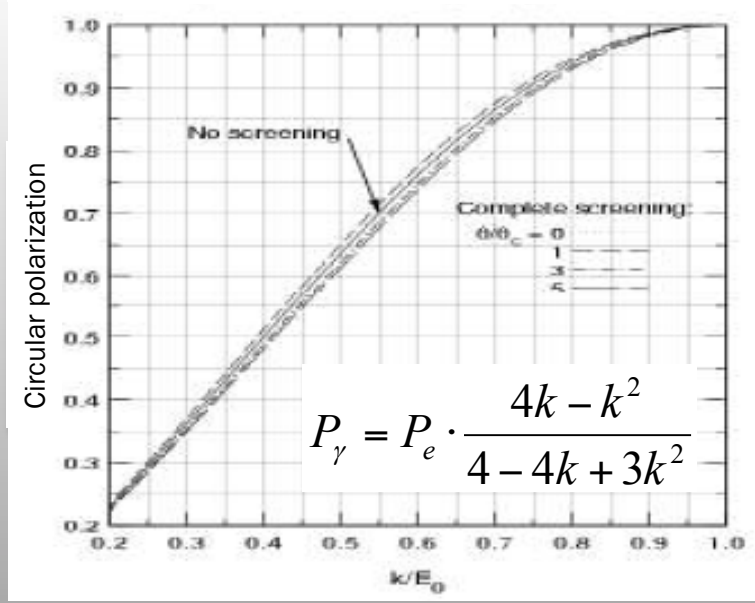
Circularly polarized photons



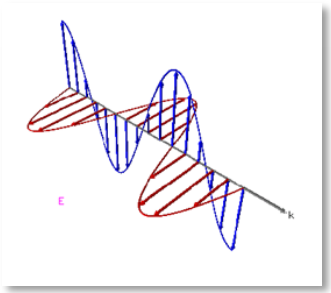
- Circularly polarized beam produced by longitudinally polarized electrons
- CEBAF electron beam polarization >85%
- tagged flux ~ 50 - 100MHz for $k>0.5\ E_0$



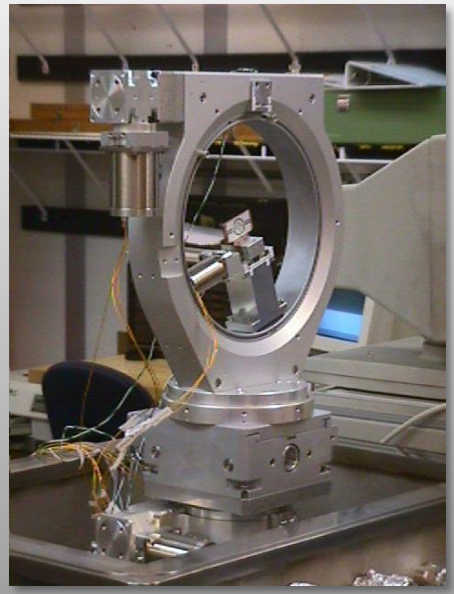
Circular polarization from 100% polarized electron beam

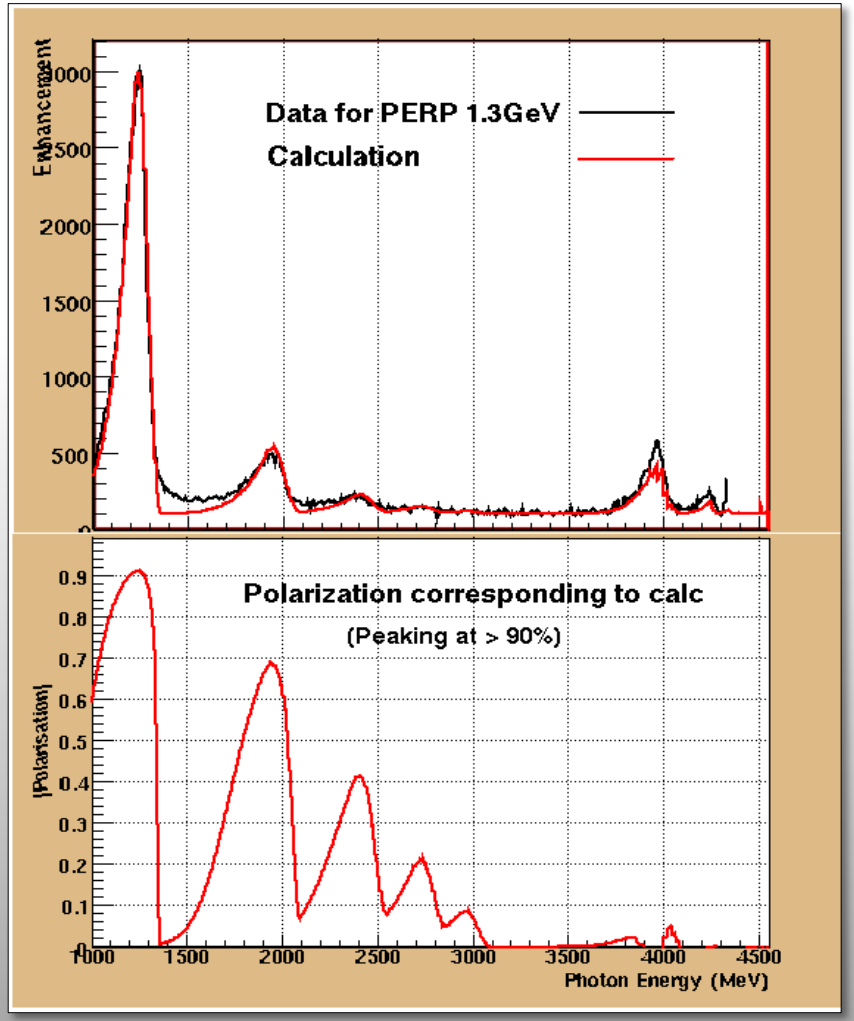


Linearly polarized photons



Linearly polarized photons: coherent bremsstrahlung on oriented diamond crystal

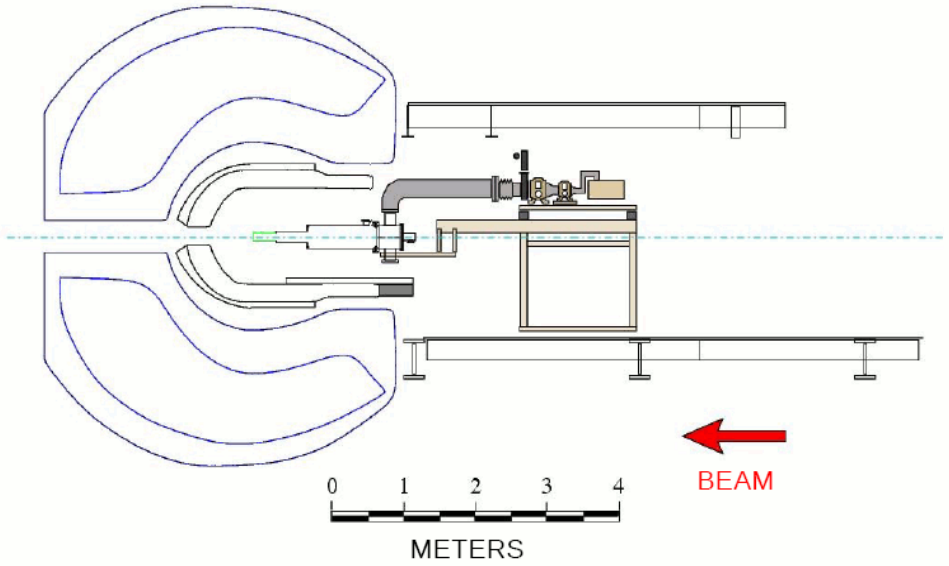


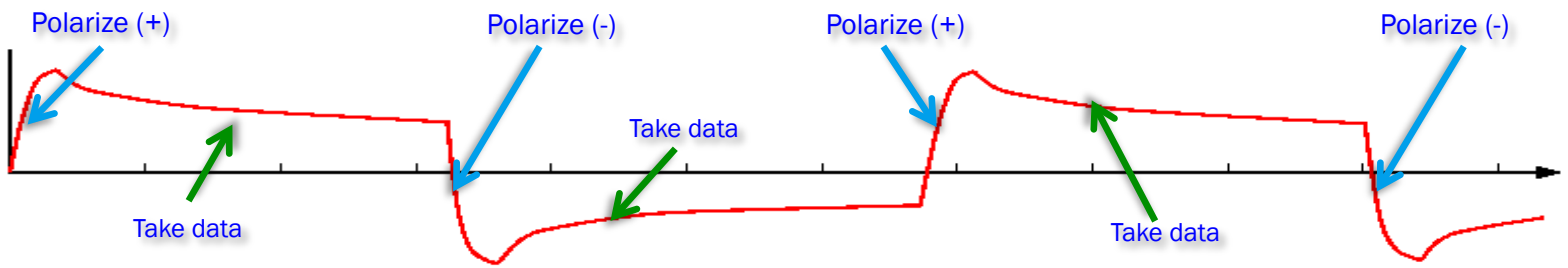


FROzen Spin Target

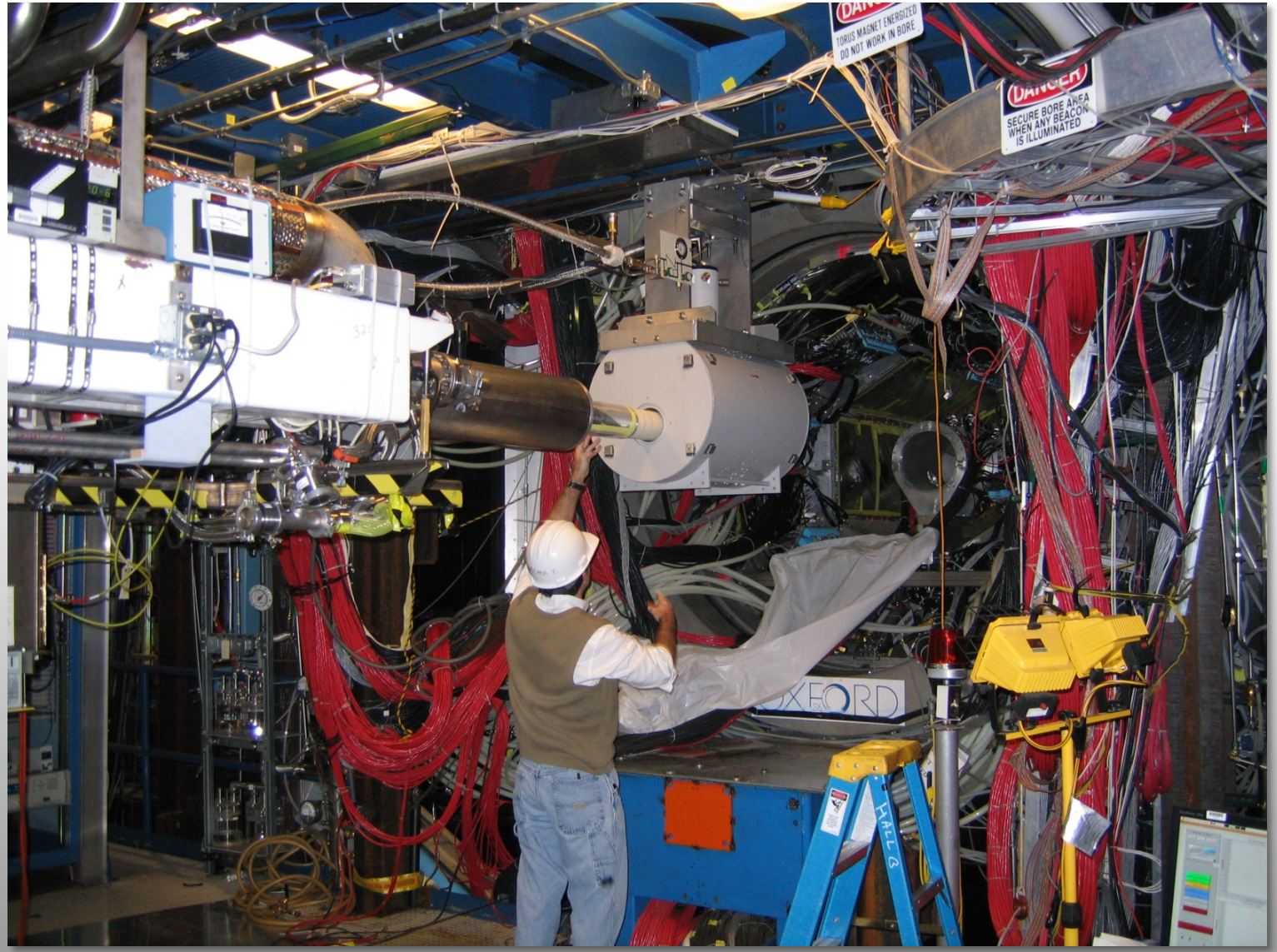
Frozen Spin Mode

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





FROST in Hall B



Performance of FROST during g9 experiment

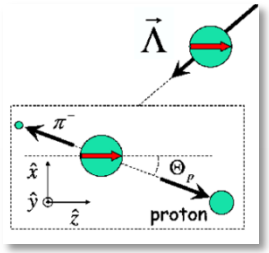
	Design Spec.	g9a (2008)	g9b (2010)
Base Temperature:	50 mK	30 mK	25 mK
Cooling Power, 50 mK: 300 mK:	10 uW 20 mW	800 uW 60 mW	800 uW 75 mW
Polarization:	±85%	+82% - 85%	+85% - 93%
1/e Relaxation Time:	500 h (~5% day^{-1})	2700 h (+) 1400 h (–) (≤ 1.5% day^{-1})	3500 h (+) 1900 h (–) (≤ 1% day^{-1})
On-beam Efficiency:	~80%	~90%	~95%
		longitudinal	transverse

Polarization observables in pseudoscalar meson production

4 Complex amplitudes: 16 real polarization observables.

Complete measurement from 8 carefully chosen observables.

πN has large cross section 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

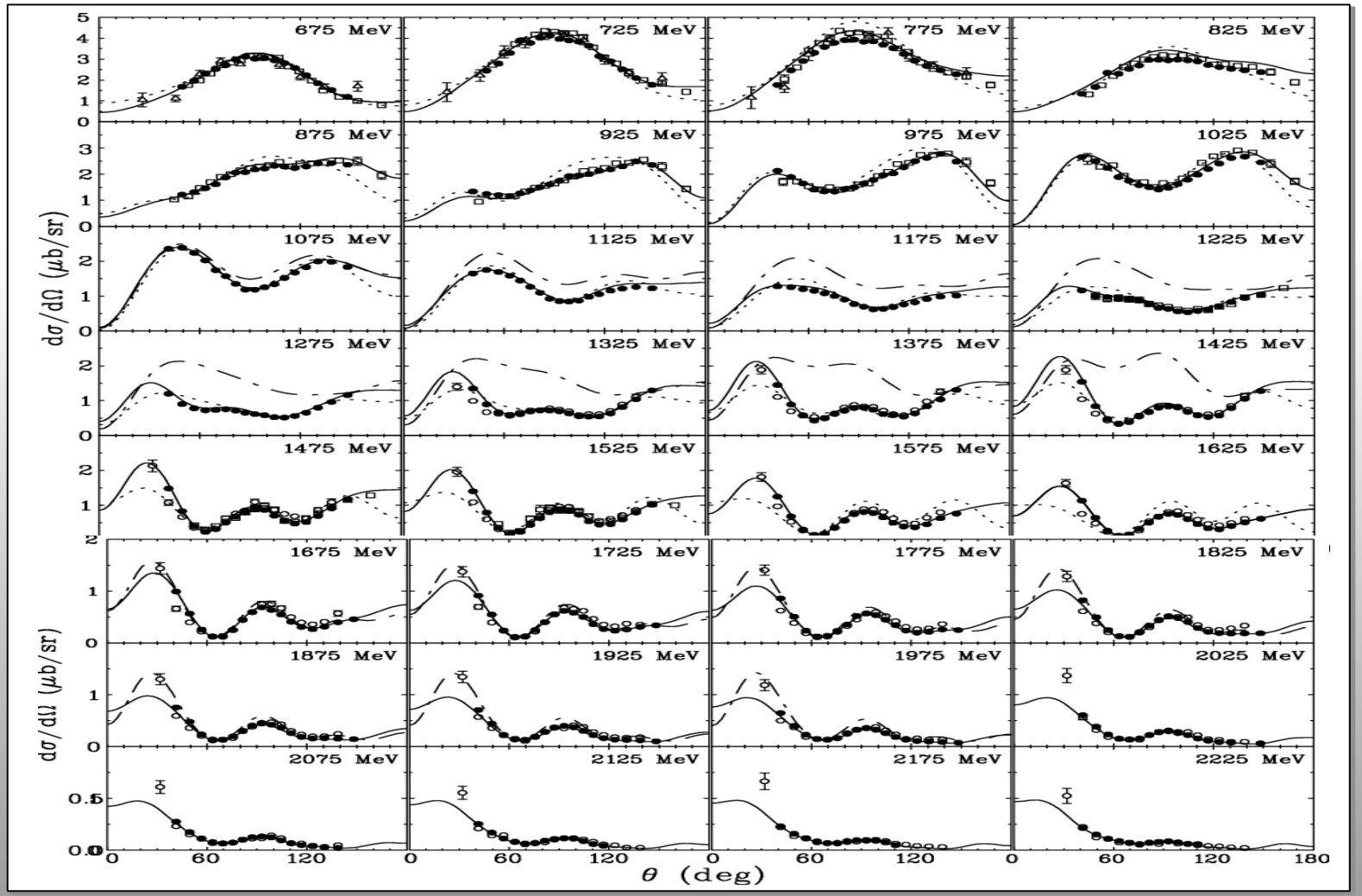
What we measure with CLAS

- $\gamma p \rightarrow \pi^0 p,\ \pi^+ n$
- $\gamma p \rightarrow \eta p$
- $\gamma p \rightarrow \eta' p$
- $\gamma p \rightarrow KY\ (K^+\Lambda,\ K^+\Sigma^0,\ K^0\Sigma^+)$
- $\gamma p \rightarrow \pi^+\pi^- p\ \omega p,\ \rho p,\ \phi p$

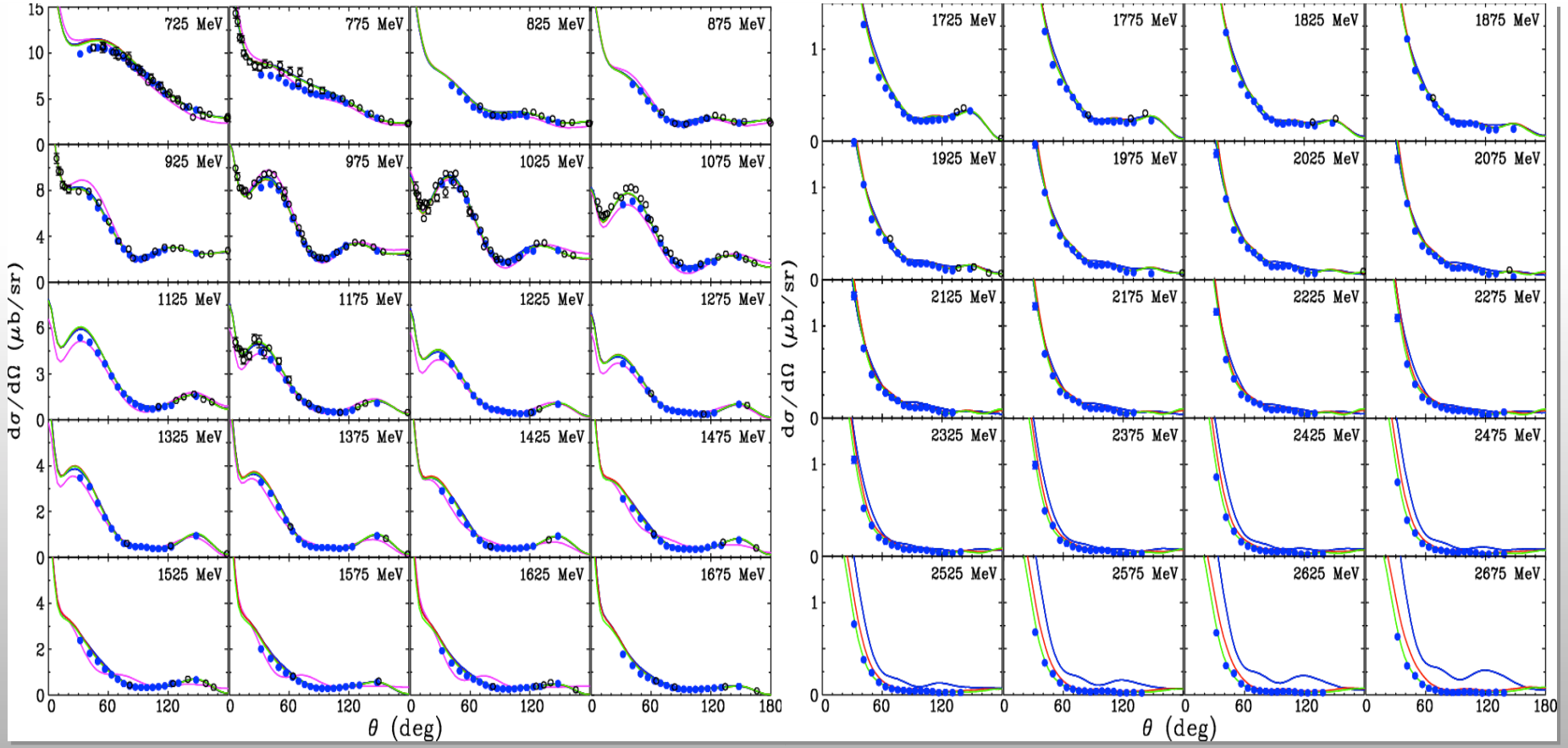
- $\gamma n \rightarrow \pi^- p$
- $\gamma n \rightarrow \pi^+\pi^- n$
- $\gamma n \rightarrow \Sigma^- K^+ ,\ \Lambda K^0$ .....

Single pion production

$\gamma p \rightarrow \pi^0 p$



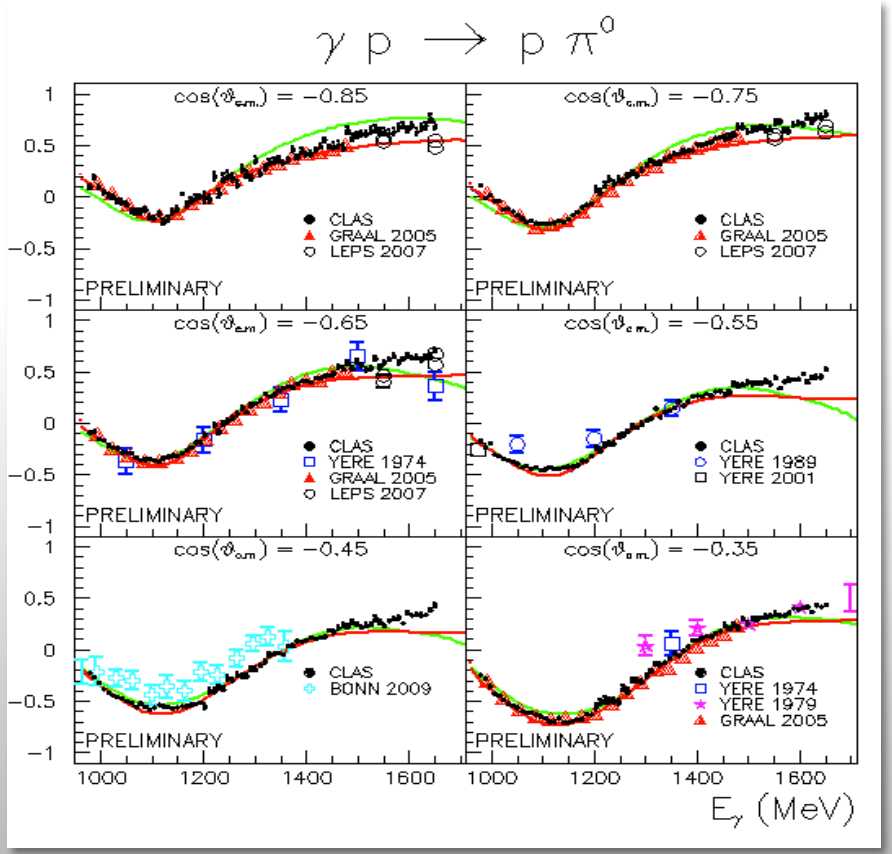
$\gamma p \rightarrow \pi^+ n$

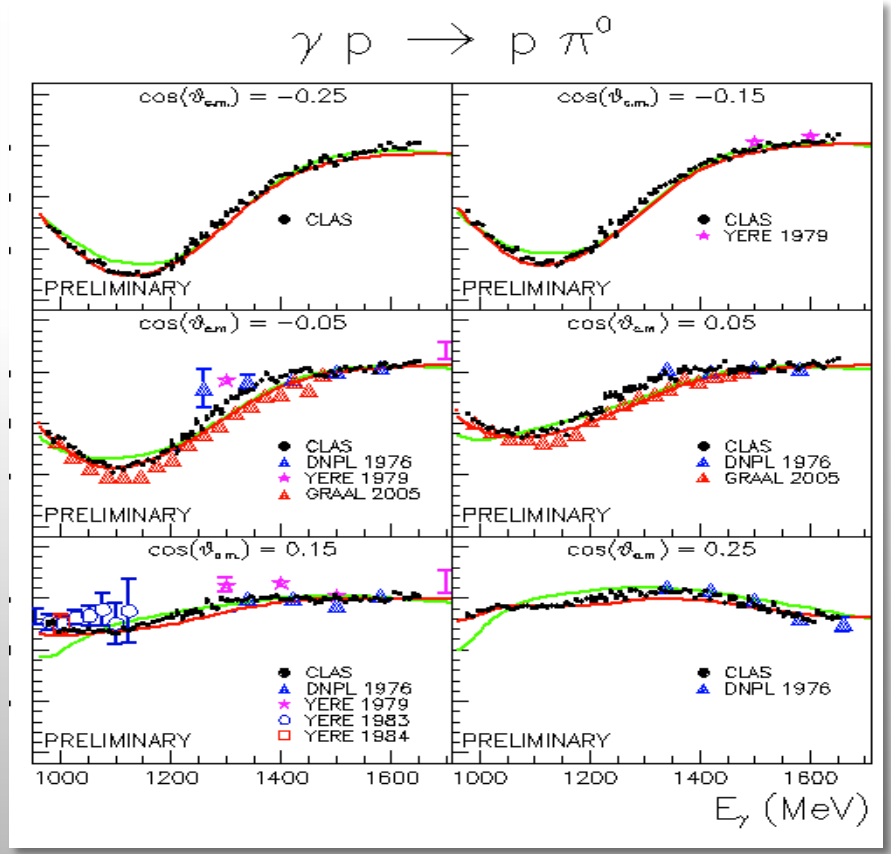


•CLAS SP07 MAID07 SP08 SN08 M. Dugger et al. PRC 79, 065206 (2009)

- Constrained SAID fit at higher energies.
- Does not need any new resonances

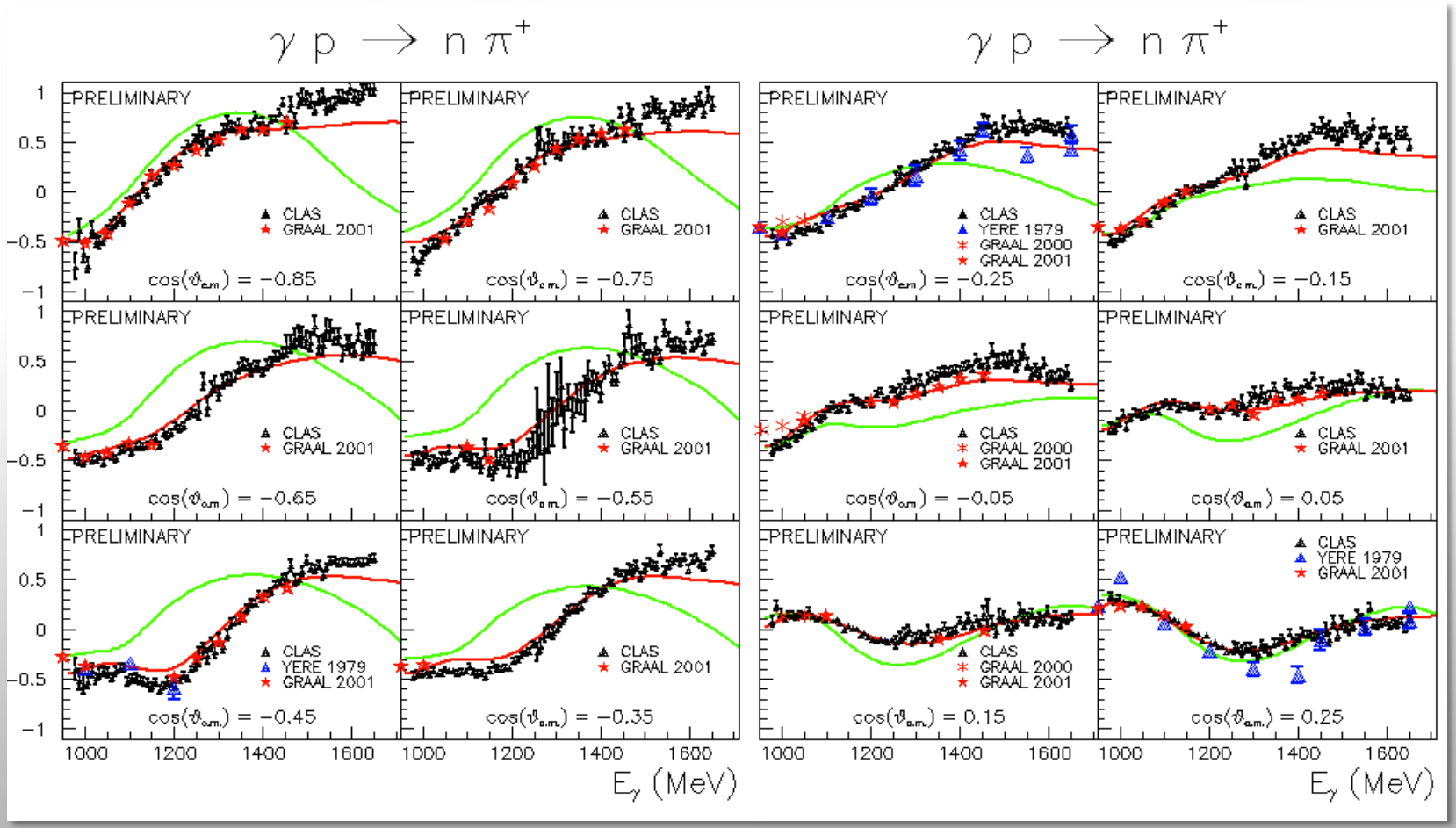
$\gamma p \rightarrow \pi^0 p$ Photon asymmetry Σ





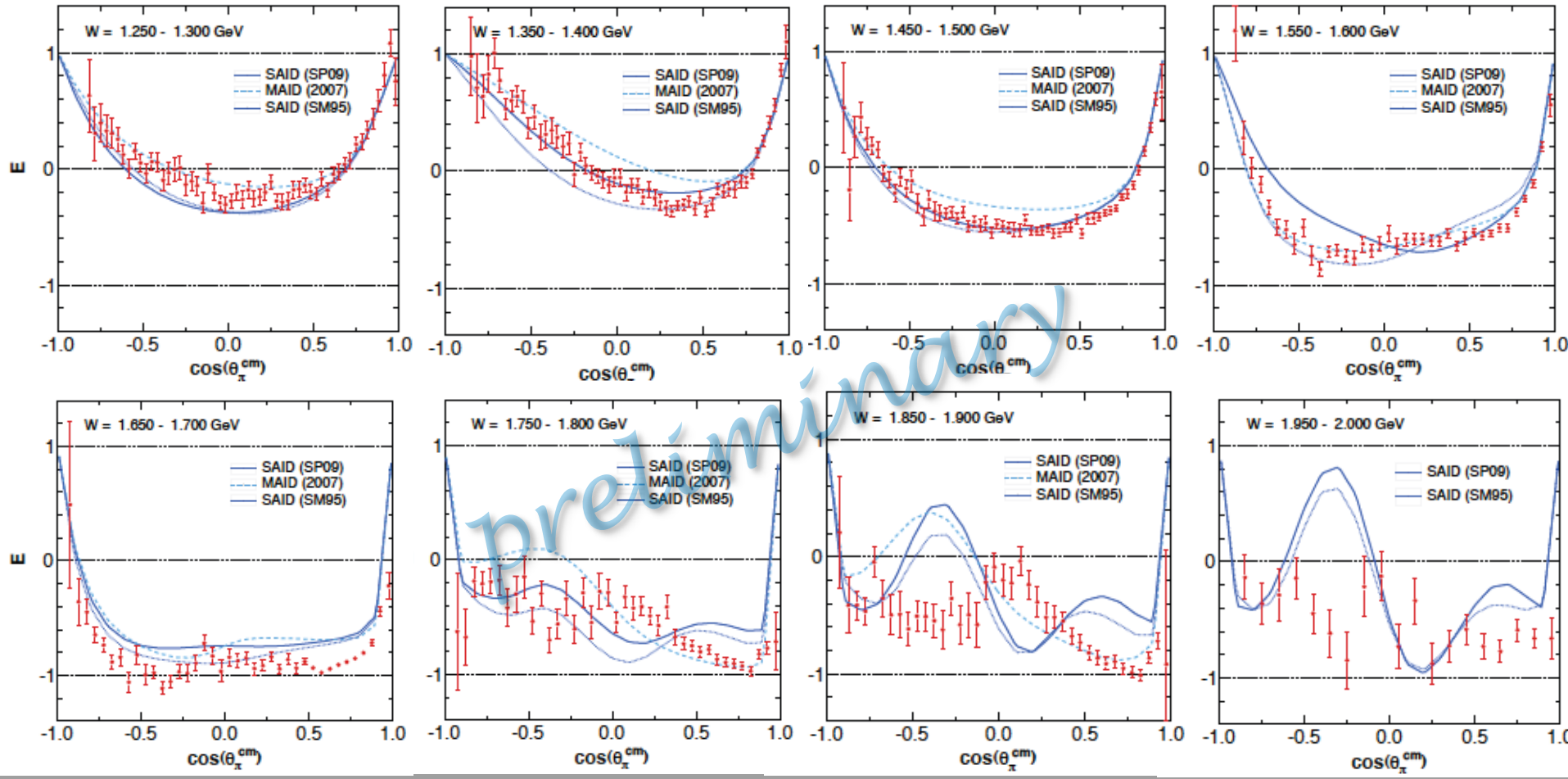
M. Dugger

$\gamma p \rightarrow \pi^+ n$ Photon asymmetry Σ



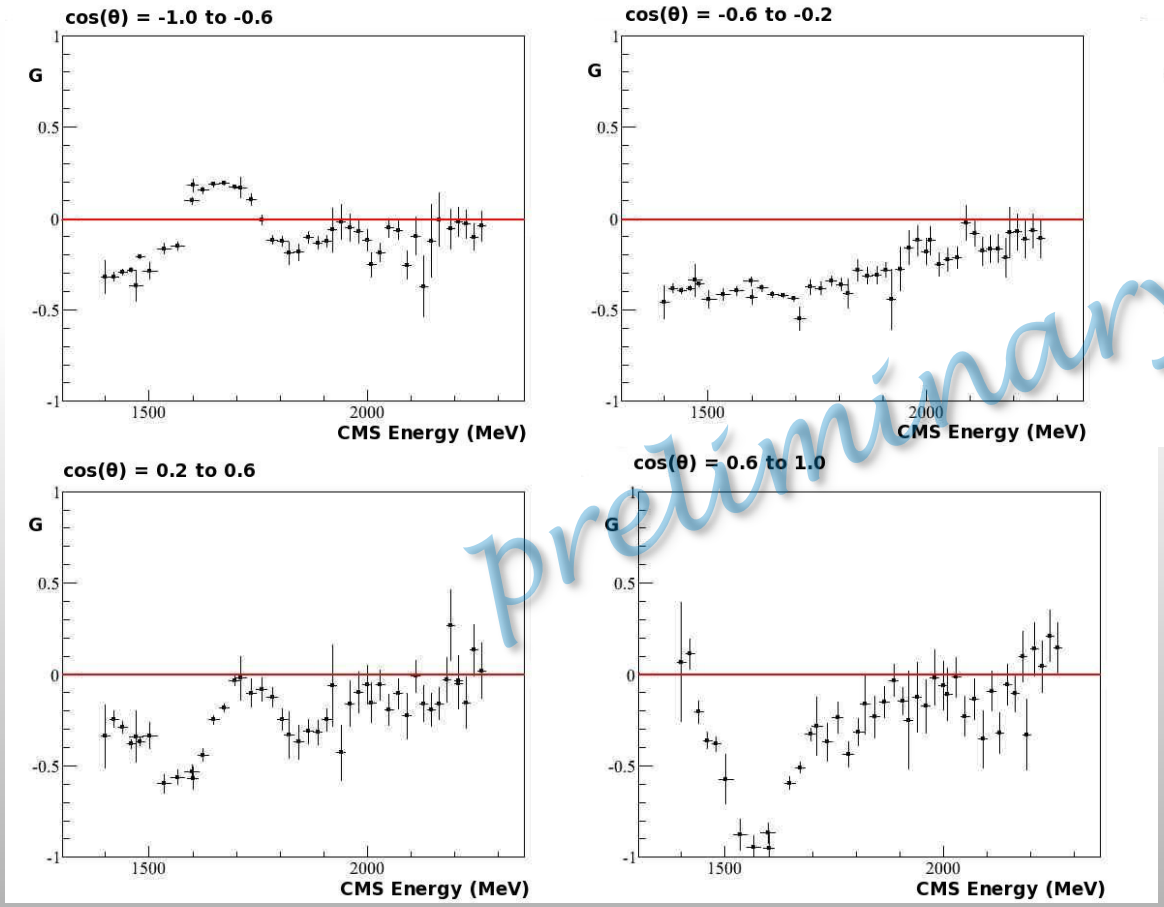
$\gamma p \rightarrow \pi^+ n$ Helicity asymmetry E

circularly pplarized beam – longitudinally polarized target (g9a-FROST)



S. Strauch

$\gamma p \rightarrow \pi^+ n$ Helicity asymmetry G

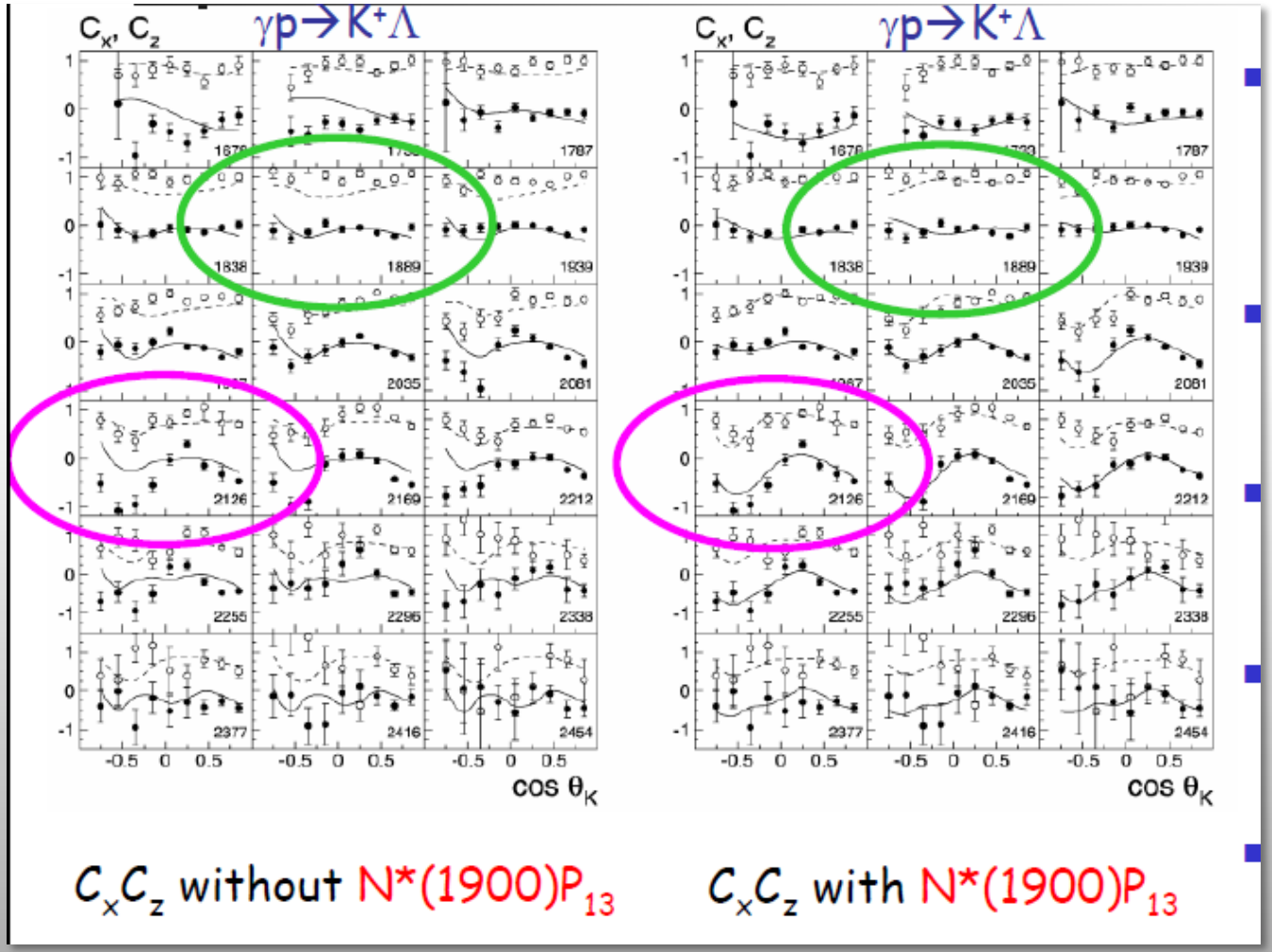


g9a data in the energy range 730 – 2300 MeV for fixed angular bins

J. McAndrew, Edinburgh

KY production

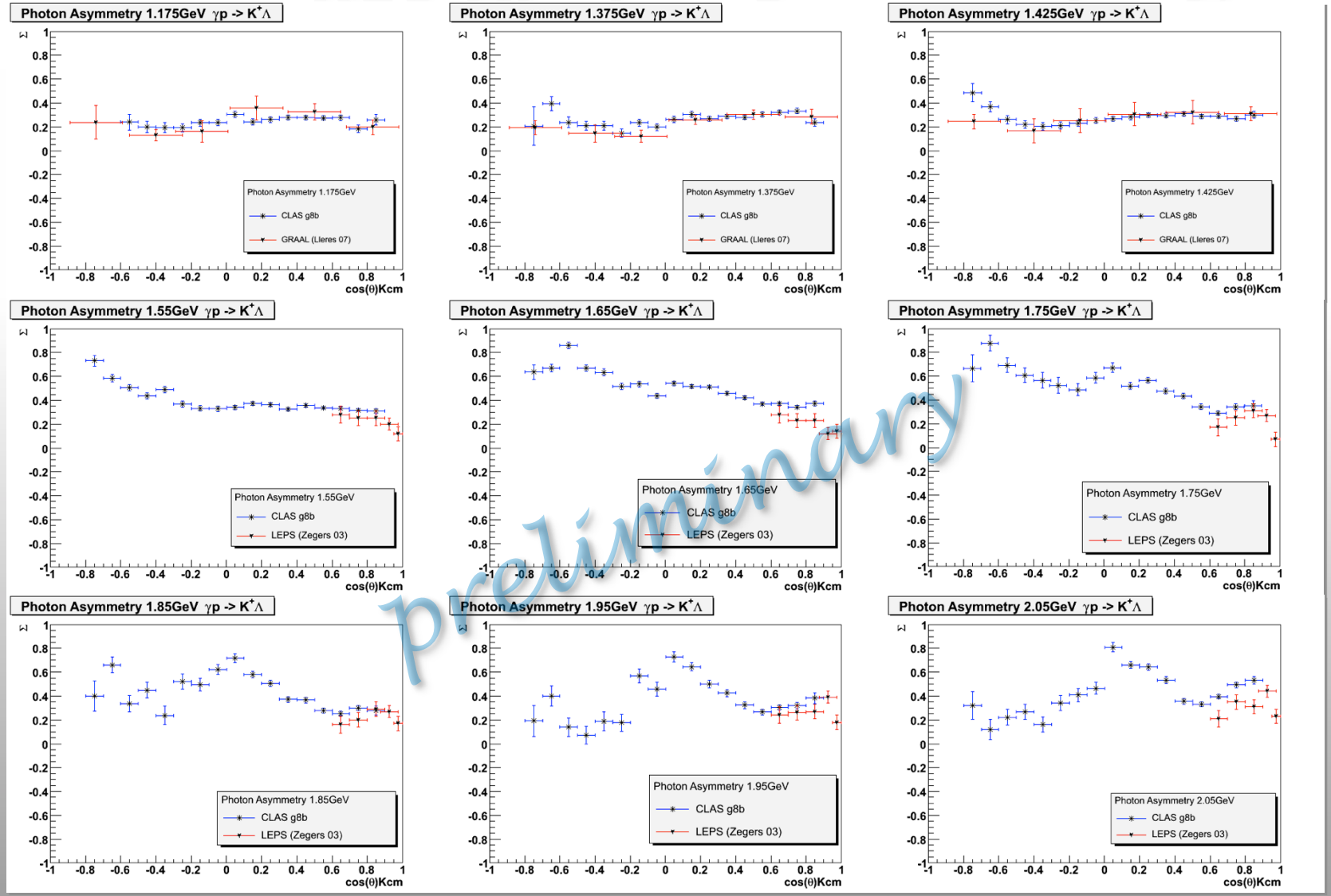
$\gamma p \rightarrow K^+\Lambda$: Cx/Cz



Nikonov *et al*.'s refit of Bonn-Gachina multi-coupled-channel isobar model mix includes:
S11 wave,
P13(1720),
P13(1900),
P11(1840)

Bradford et al.

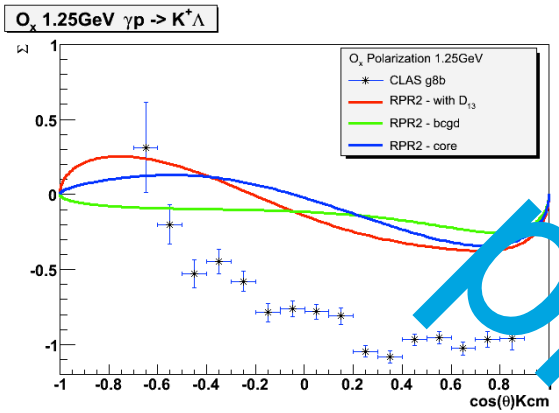
$\gamma p \rightarrow K^+\Lambda$ Photon Asymmetry Σ

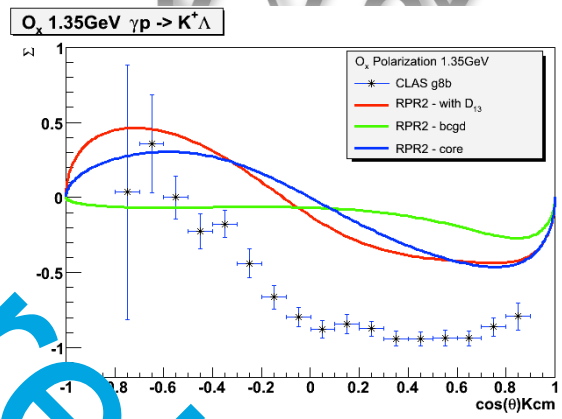


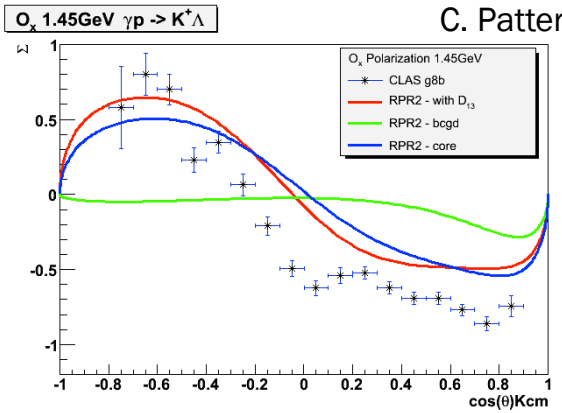
C. Patterson

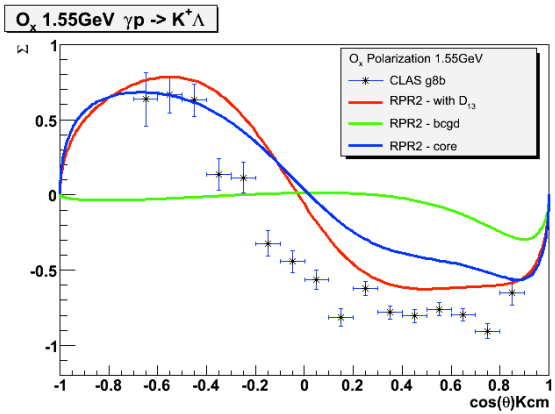
$K^+\Lambda$ Ox

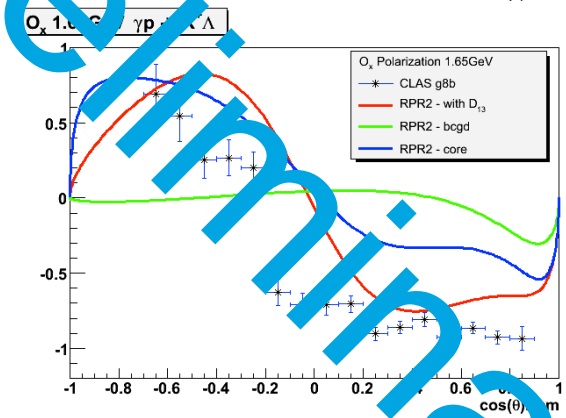
C. Patterson

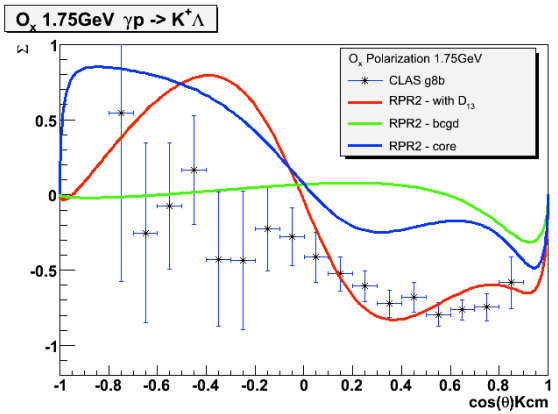


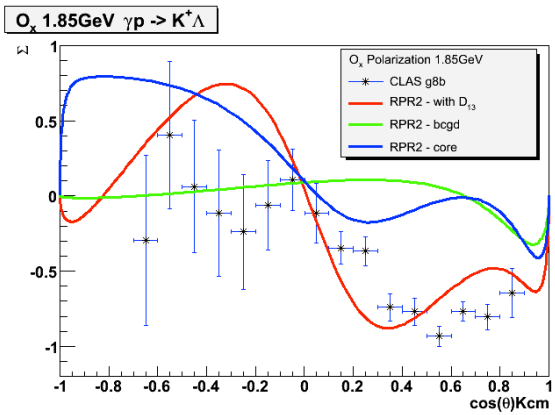


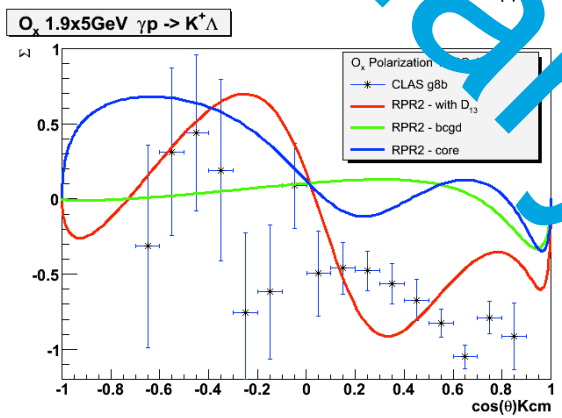


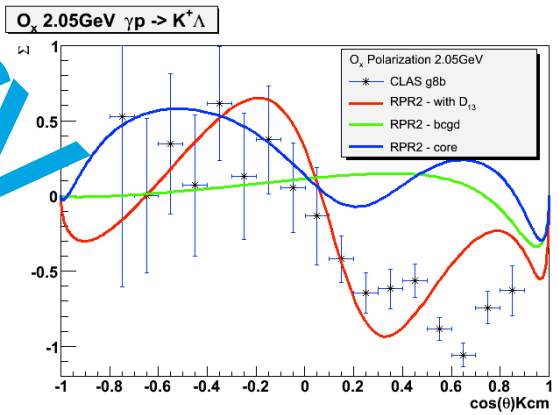






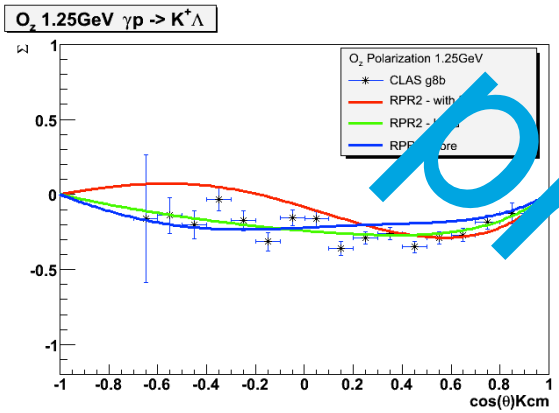


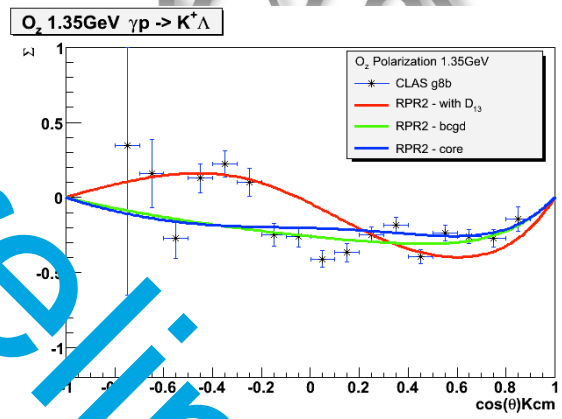


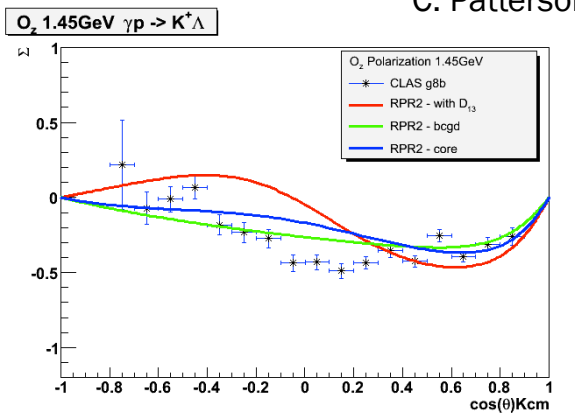


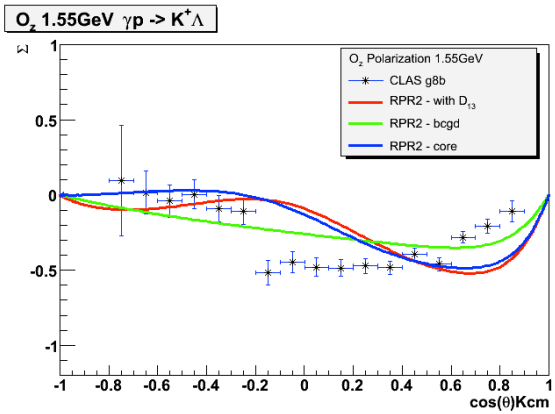
$K^+\Lambda$ Oz

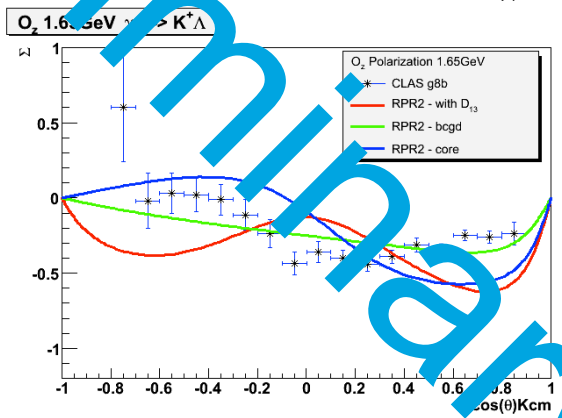
C. Patterson

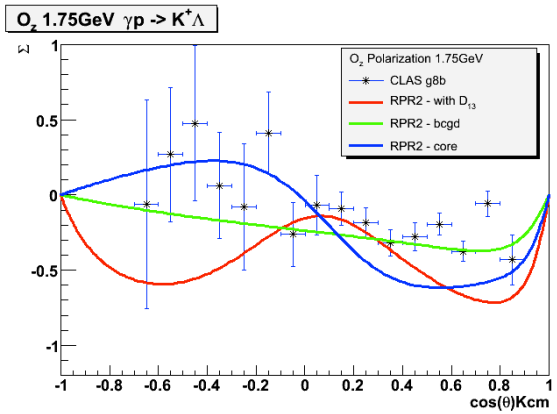


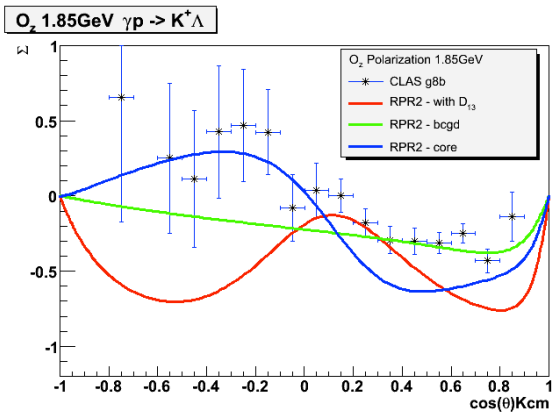


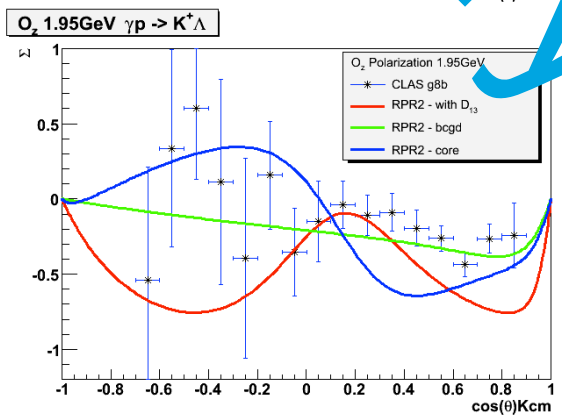


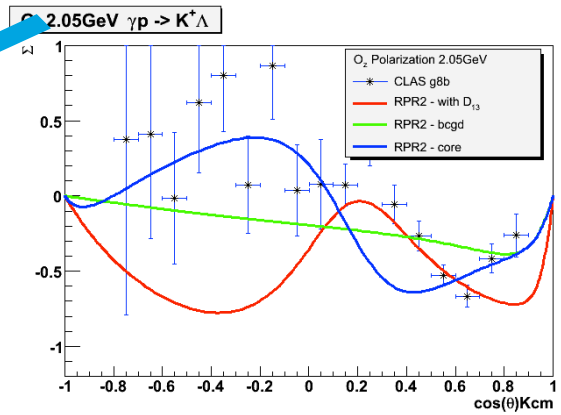






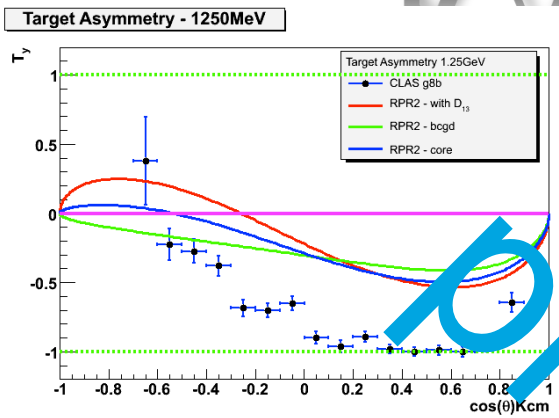


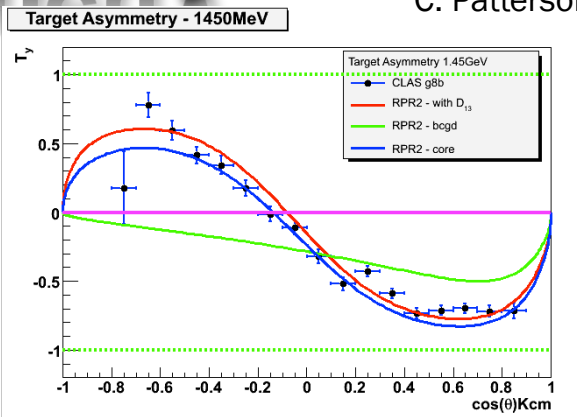


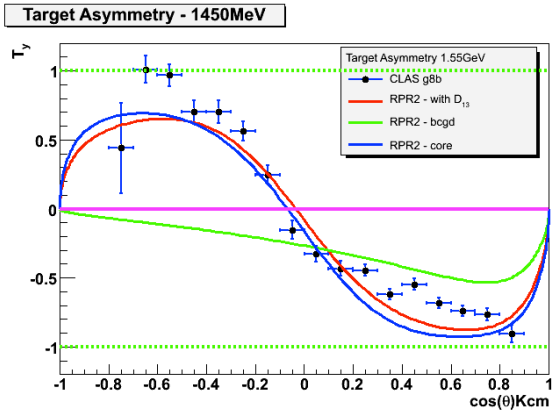


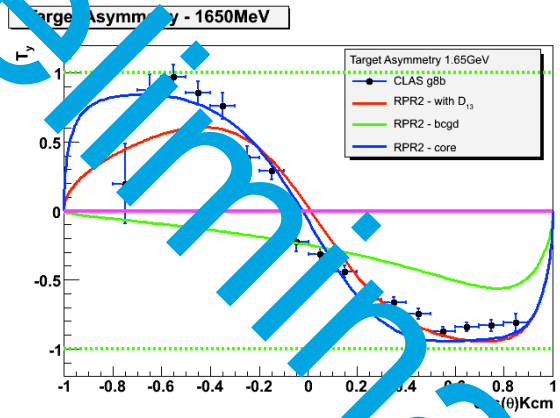
$K^+\Lambda$ Target Asymmetry

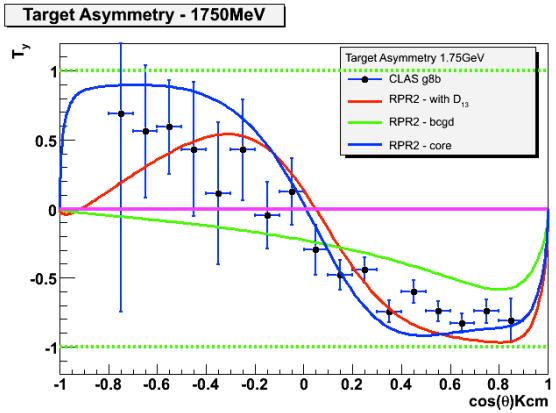
C. Patterson

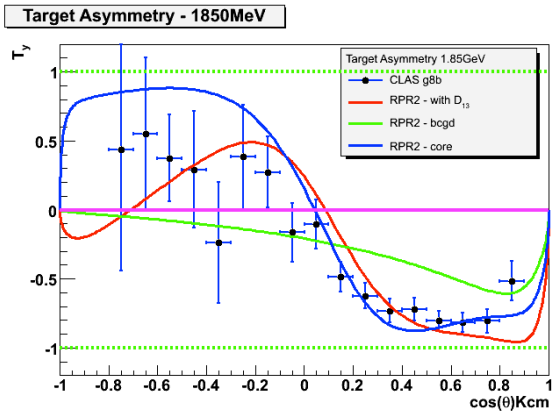


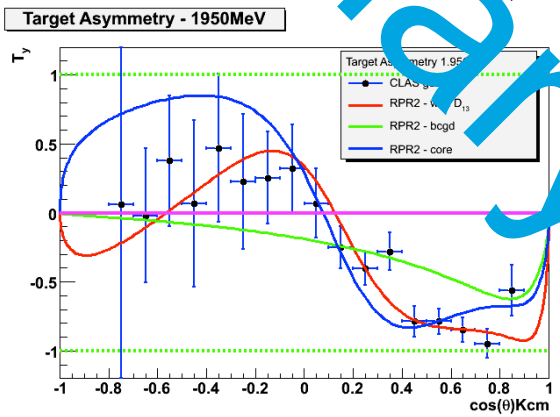


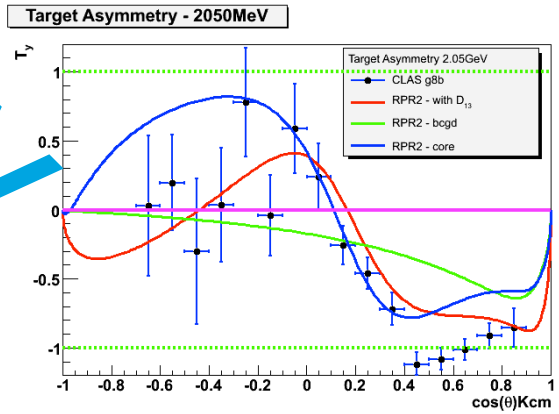






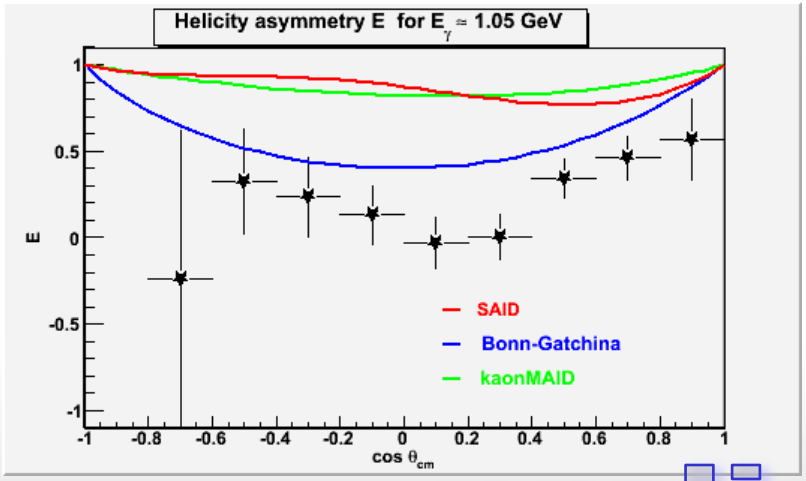


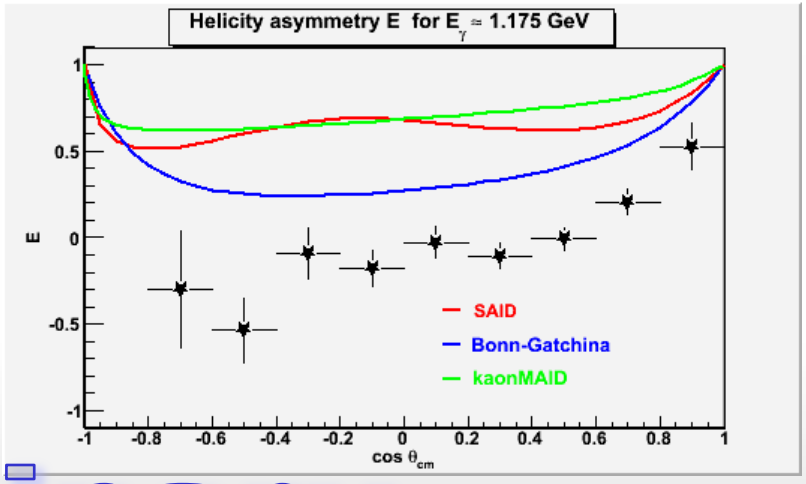




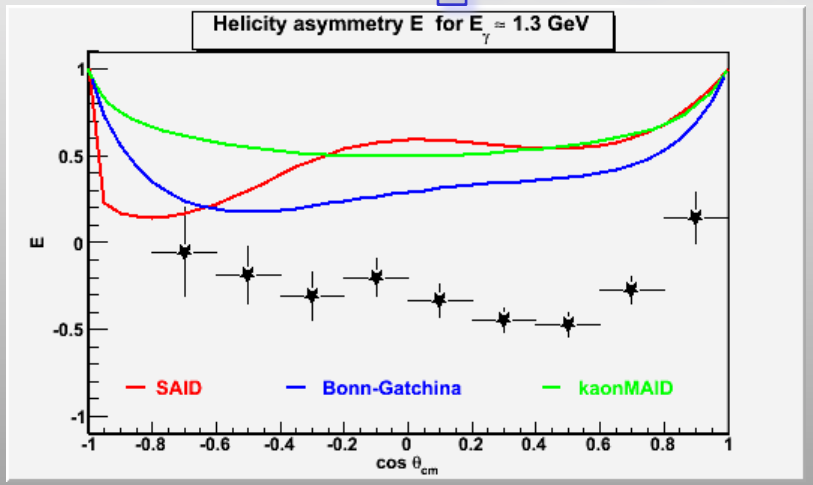
$K^+\Lambda$ helicity asymmetry E

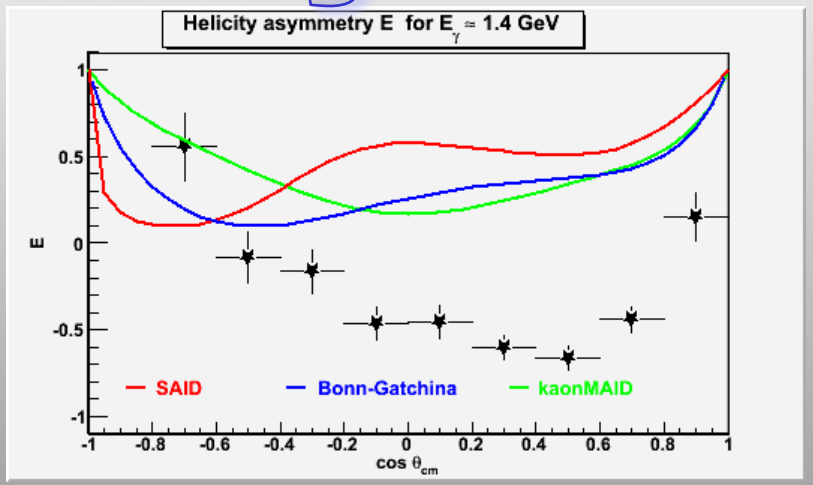
(PhD L. Casey, CUA)





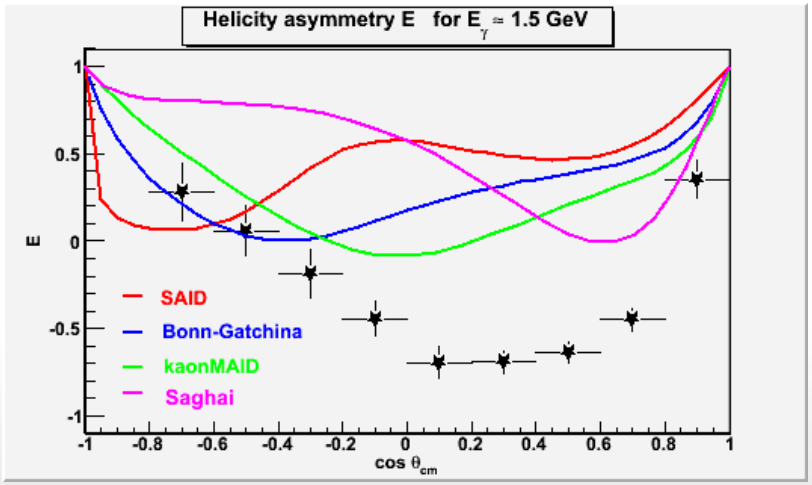
preliminary

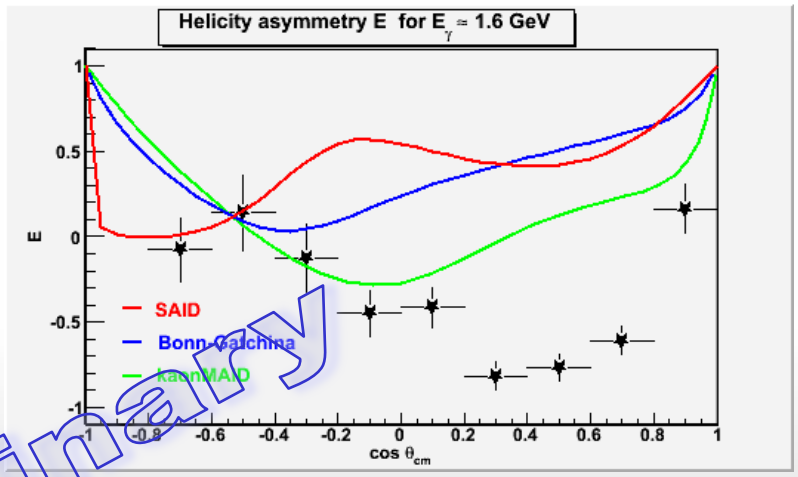


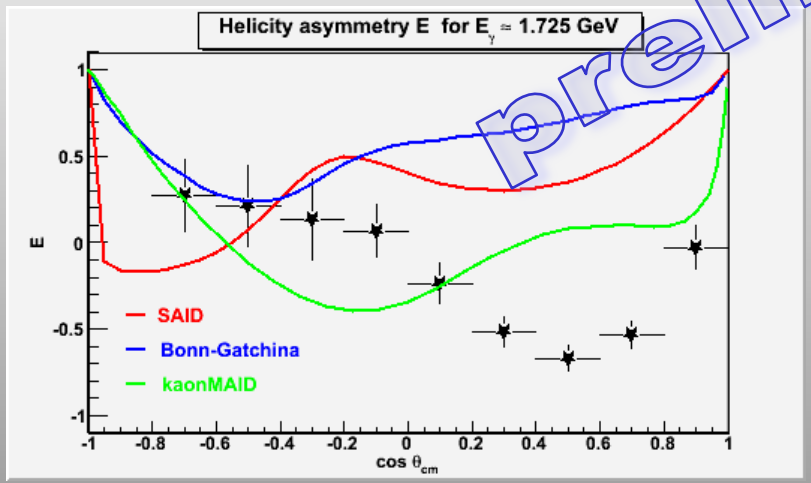


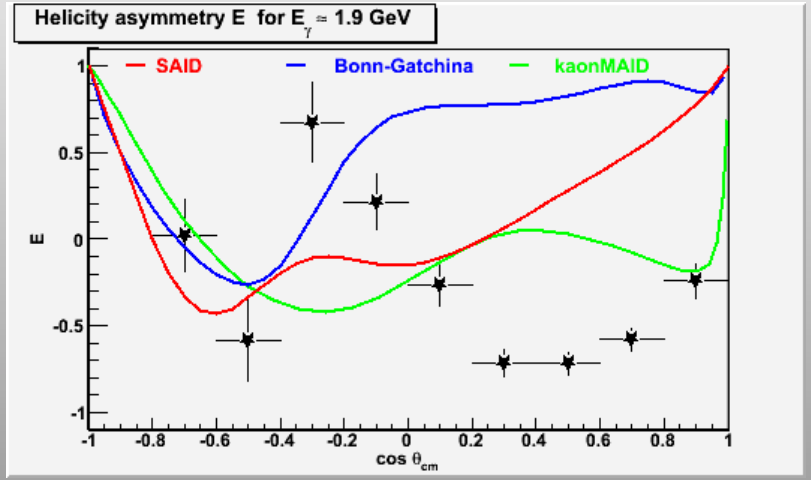
$K^+\Lambda$ helicity asymmetry E

(PhD L. Casey, CUA)





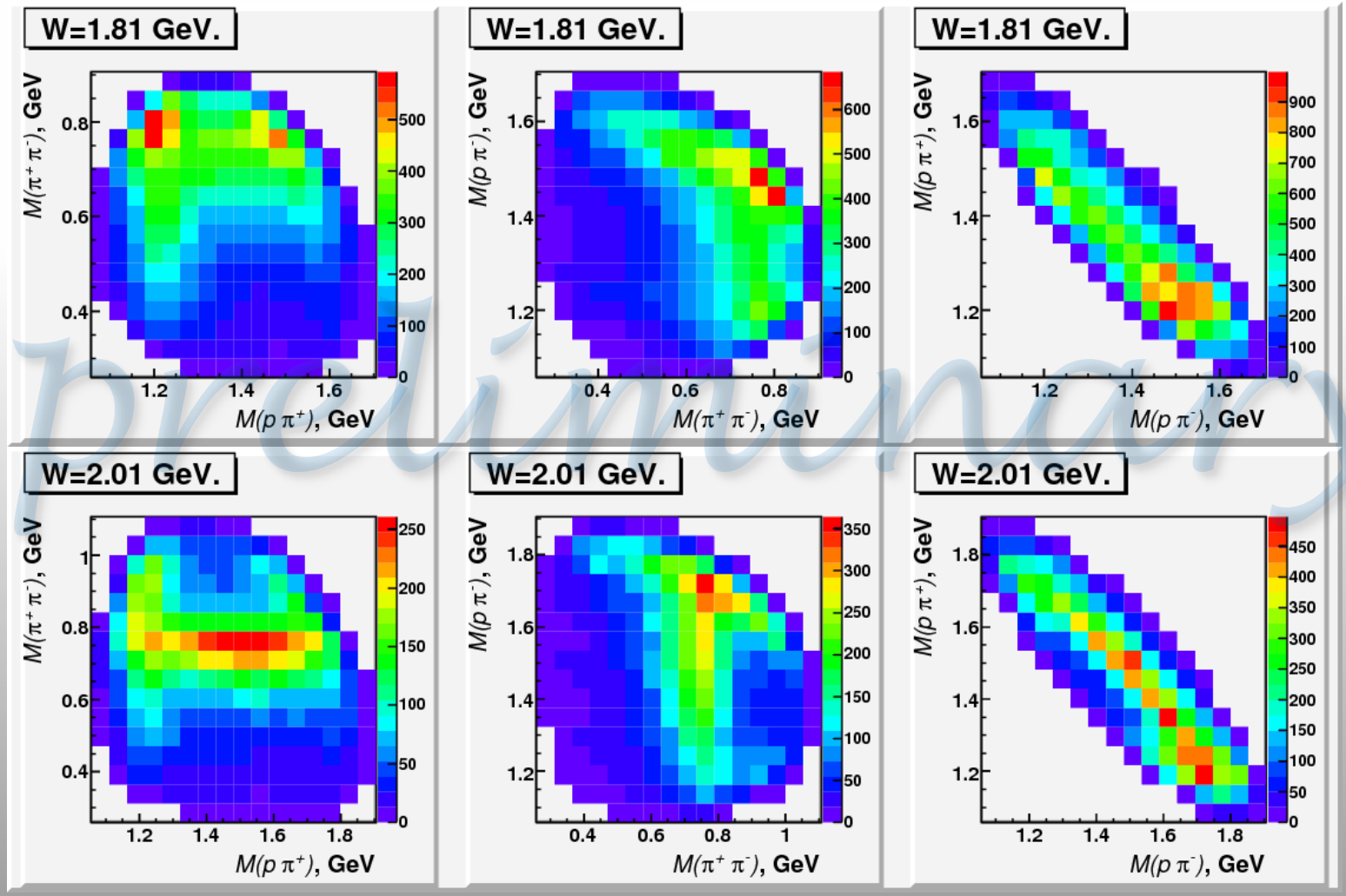




$$\gamma p \rightarrow \pi^+ \pi^- p$$

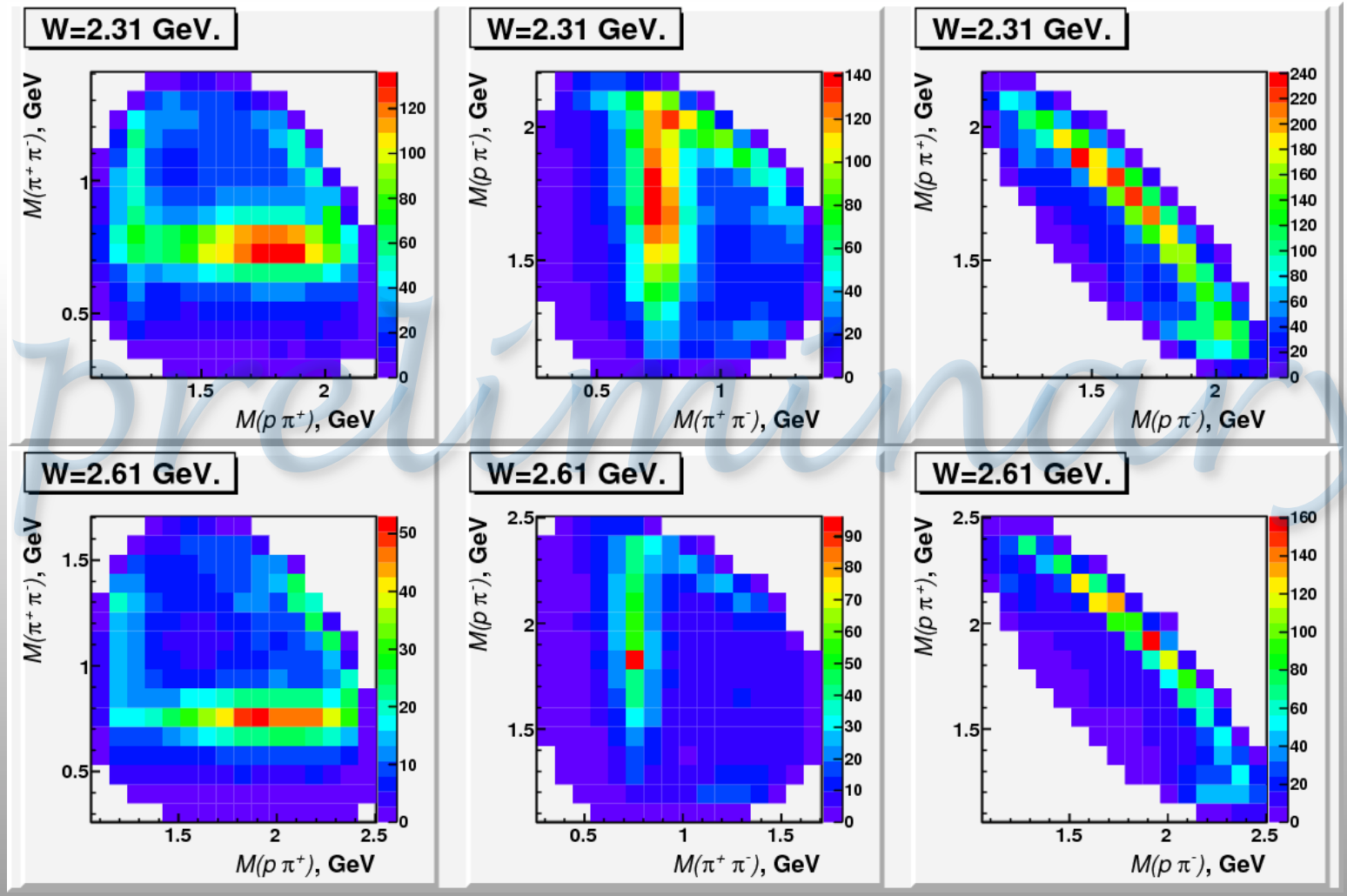
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



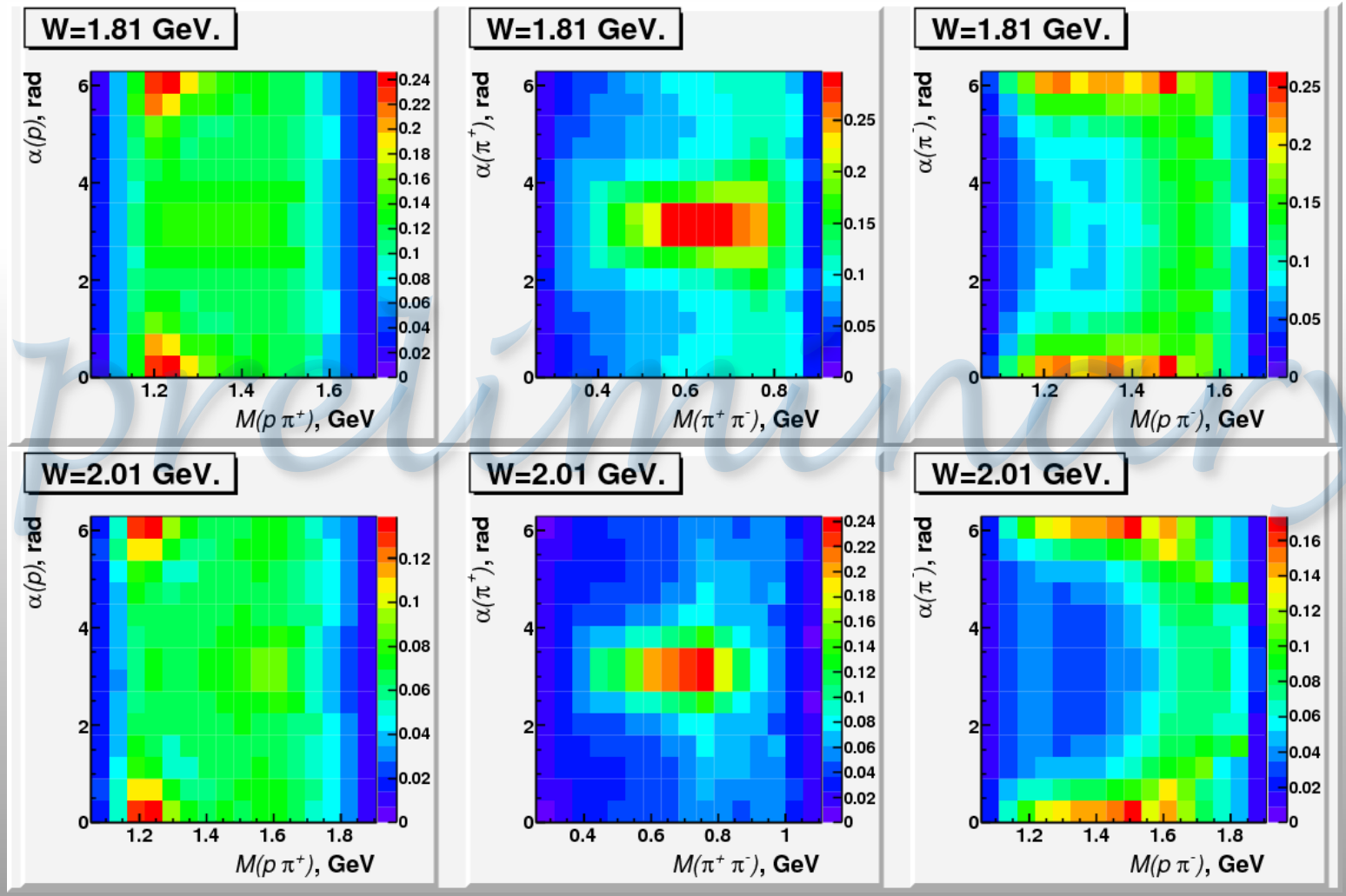
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



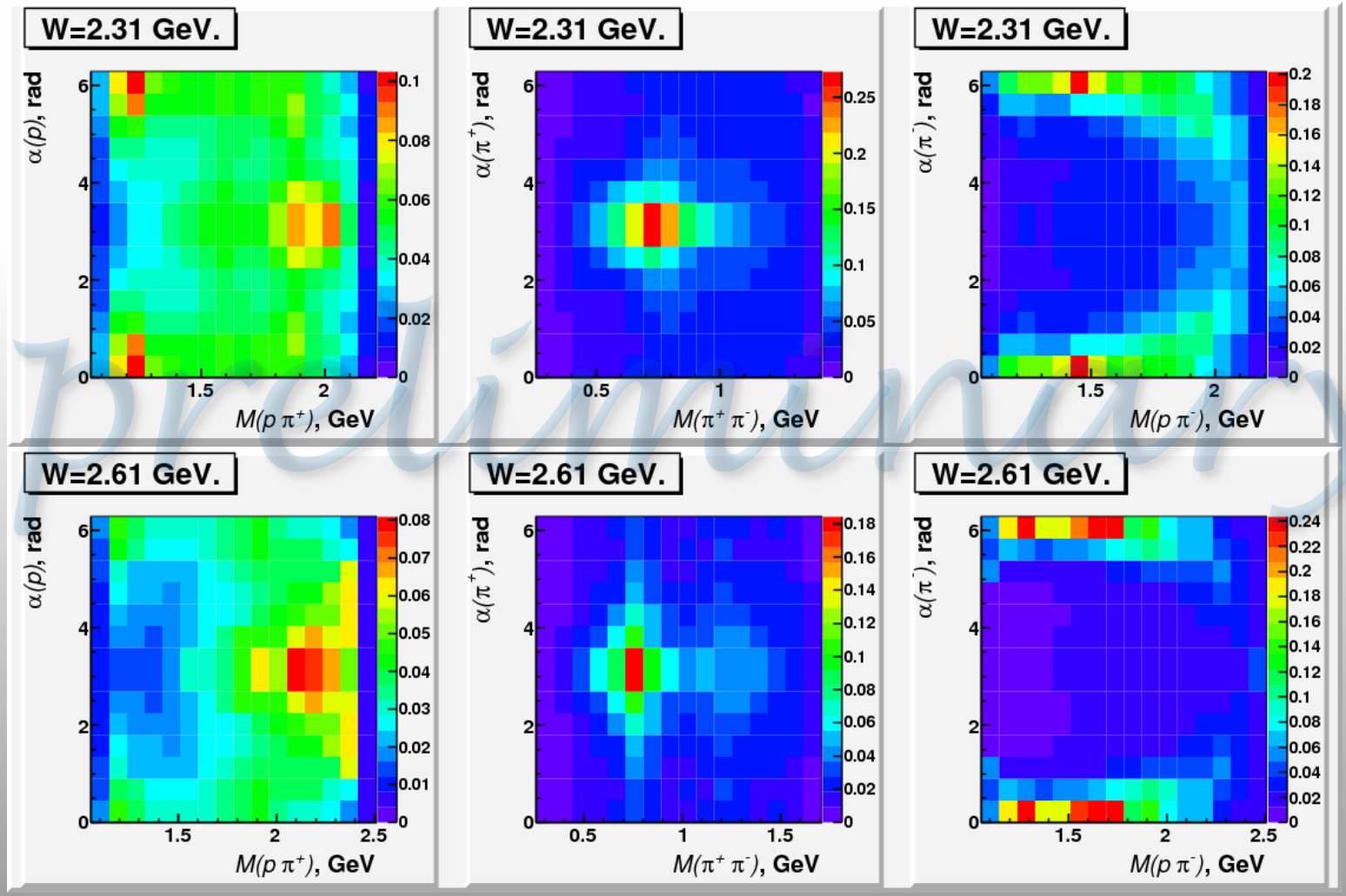
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



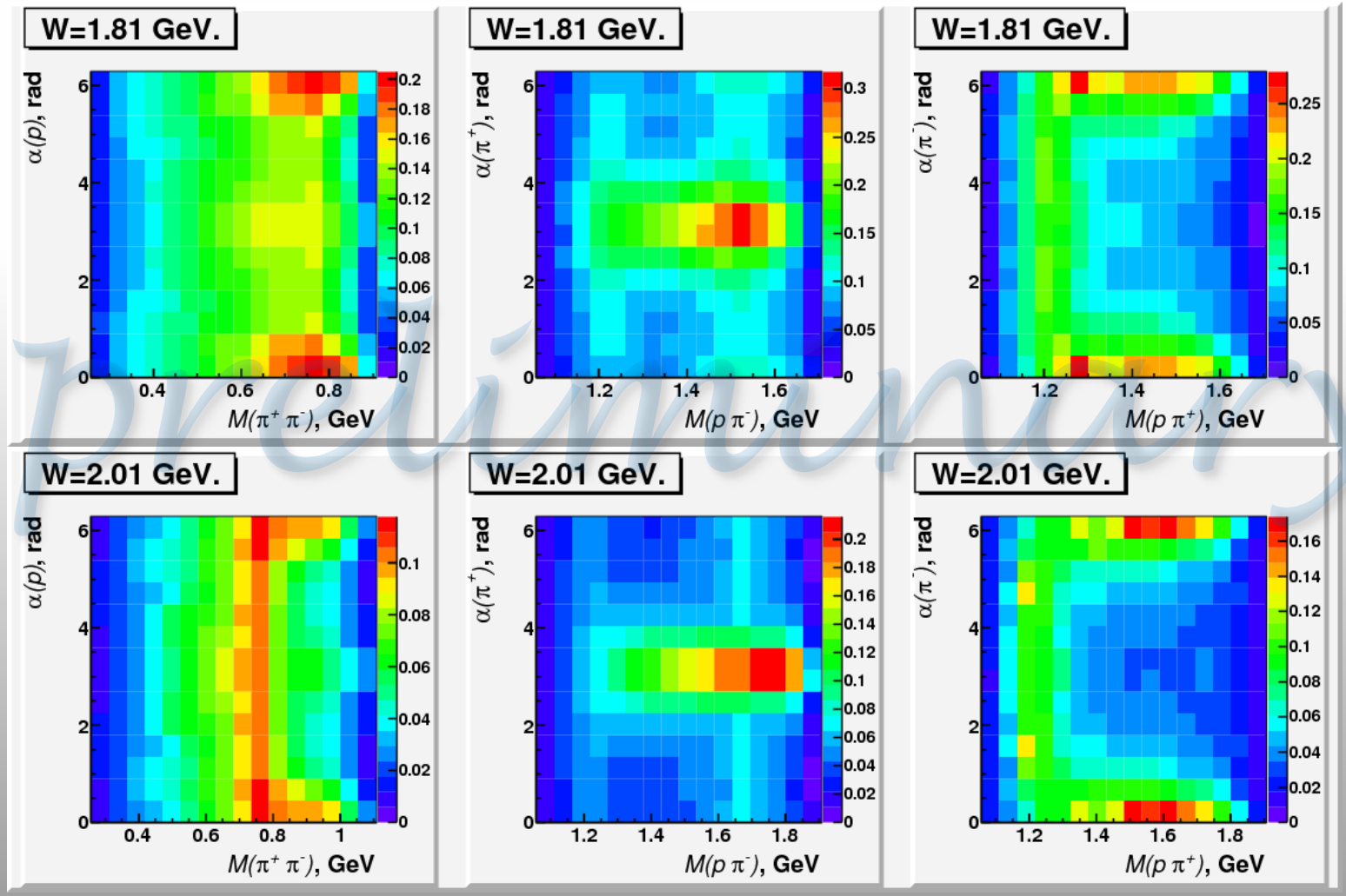
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



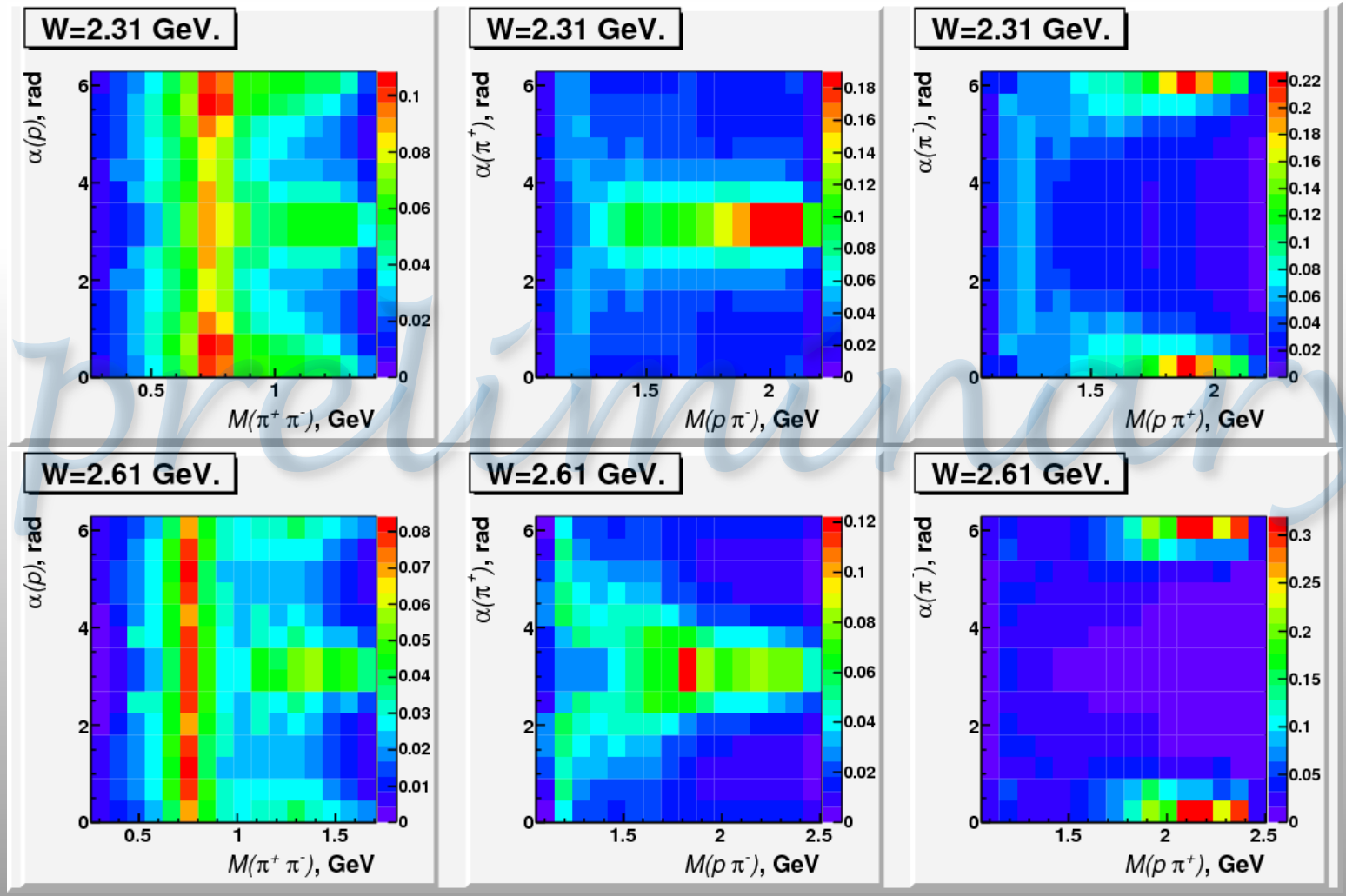
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



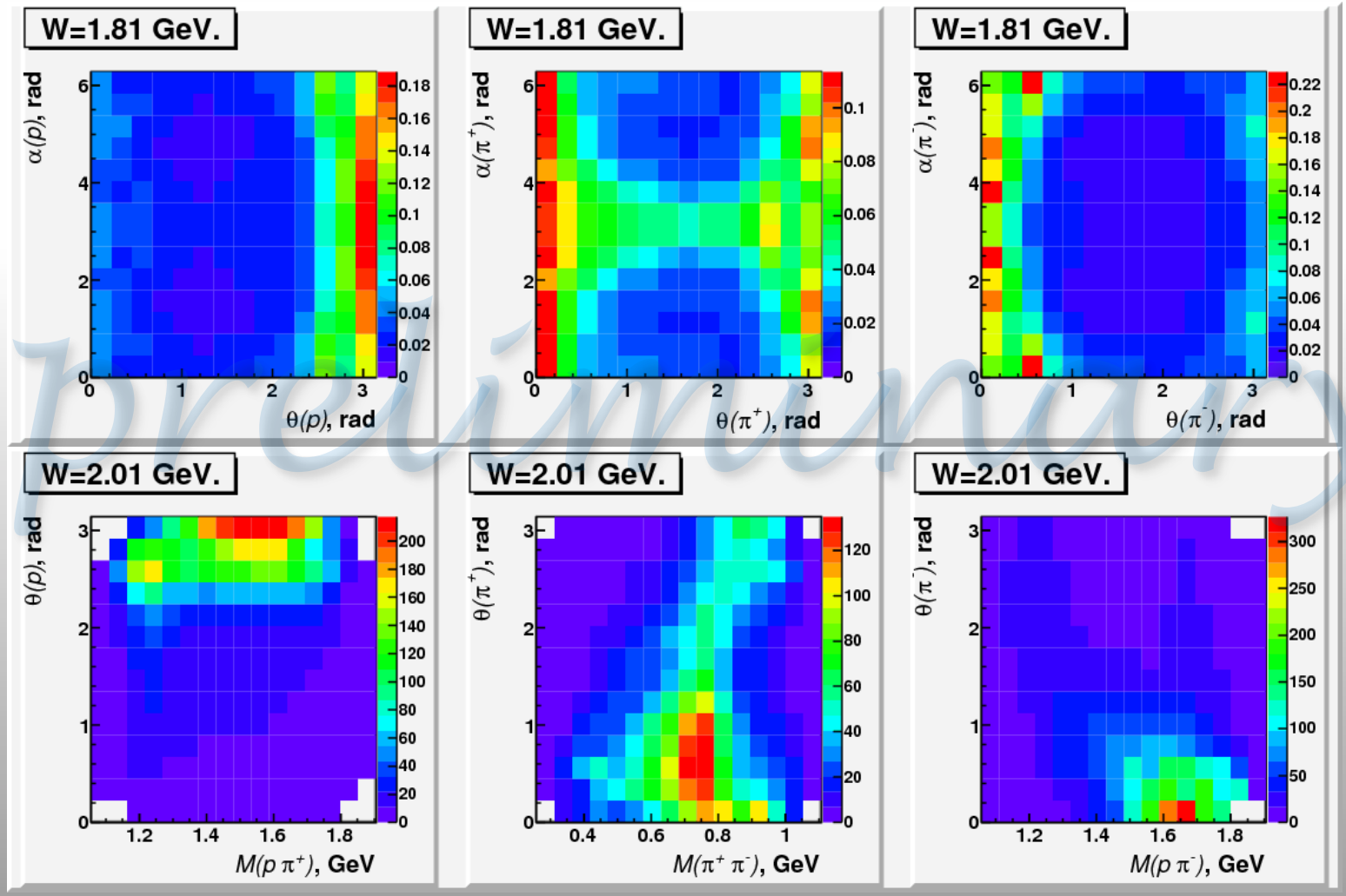
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



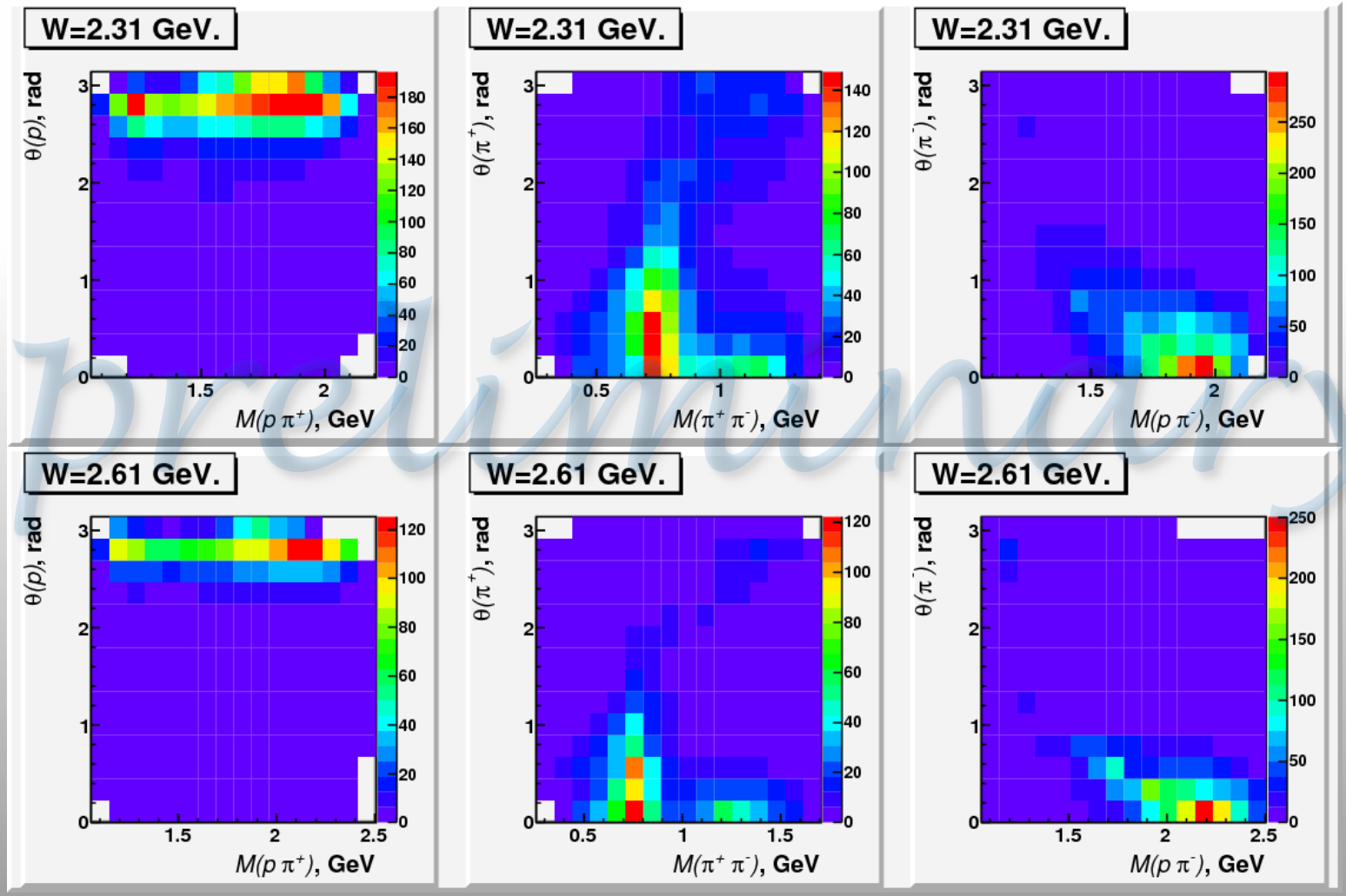
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



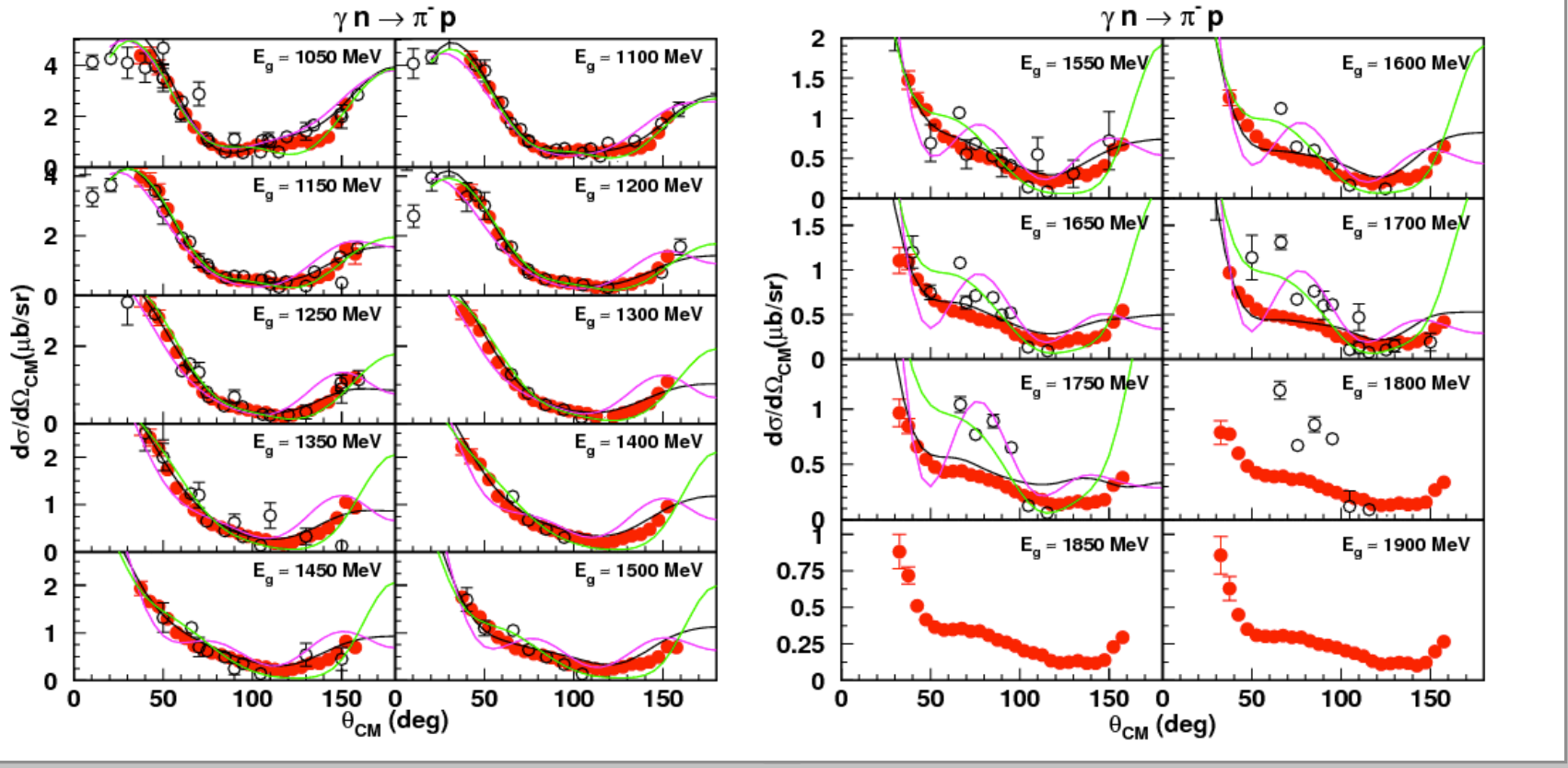
$\gamma p \rightarrow \pi^+ \pi^- p$

E. Golovach, MSU



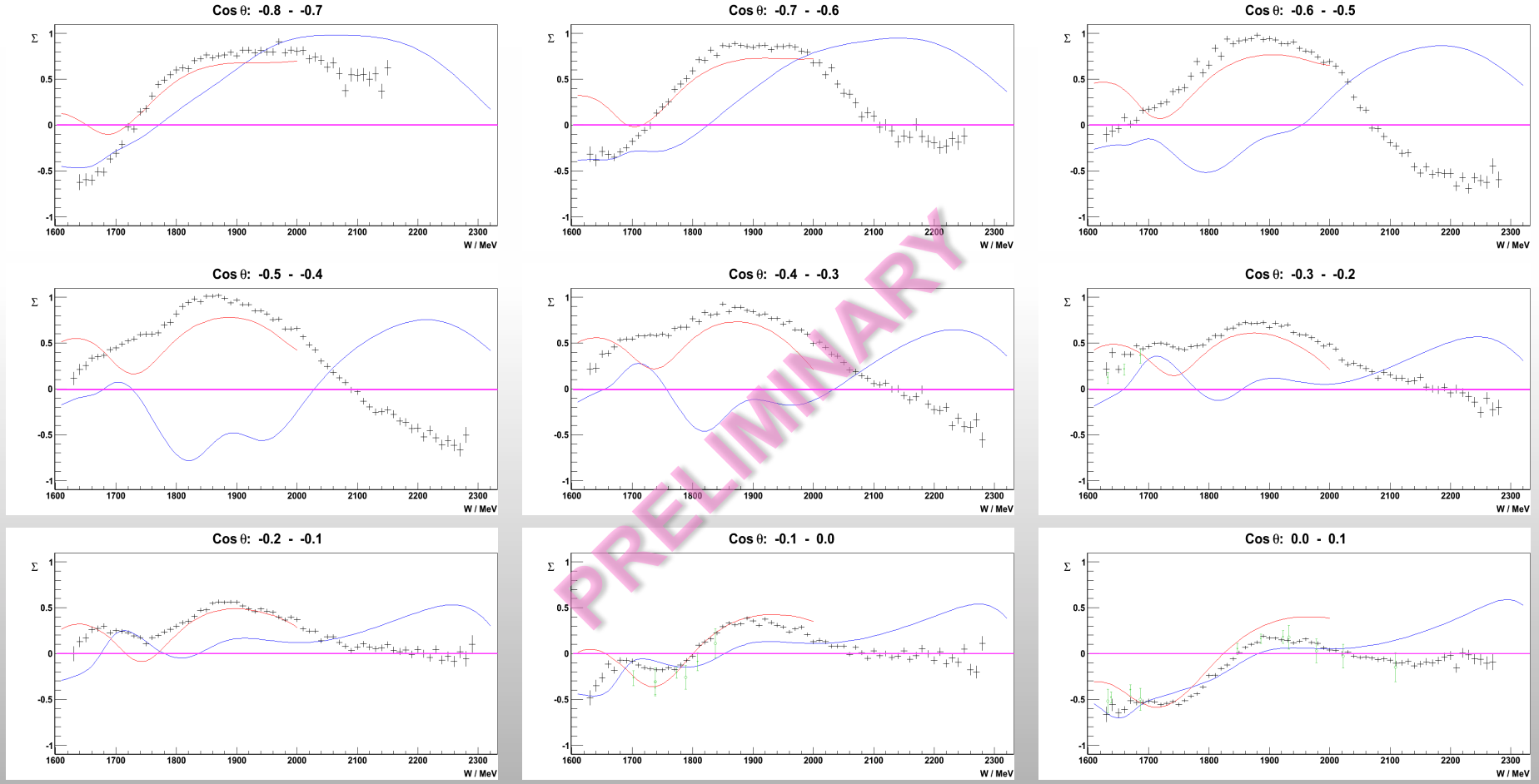
Measurements on deuteron

G10: $\gamma n \rightarrow \pi^- p$



- JLab CLAS g10
- World Data
- FA06
- MAID05
- SM95 2 GeV

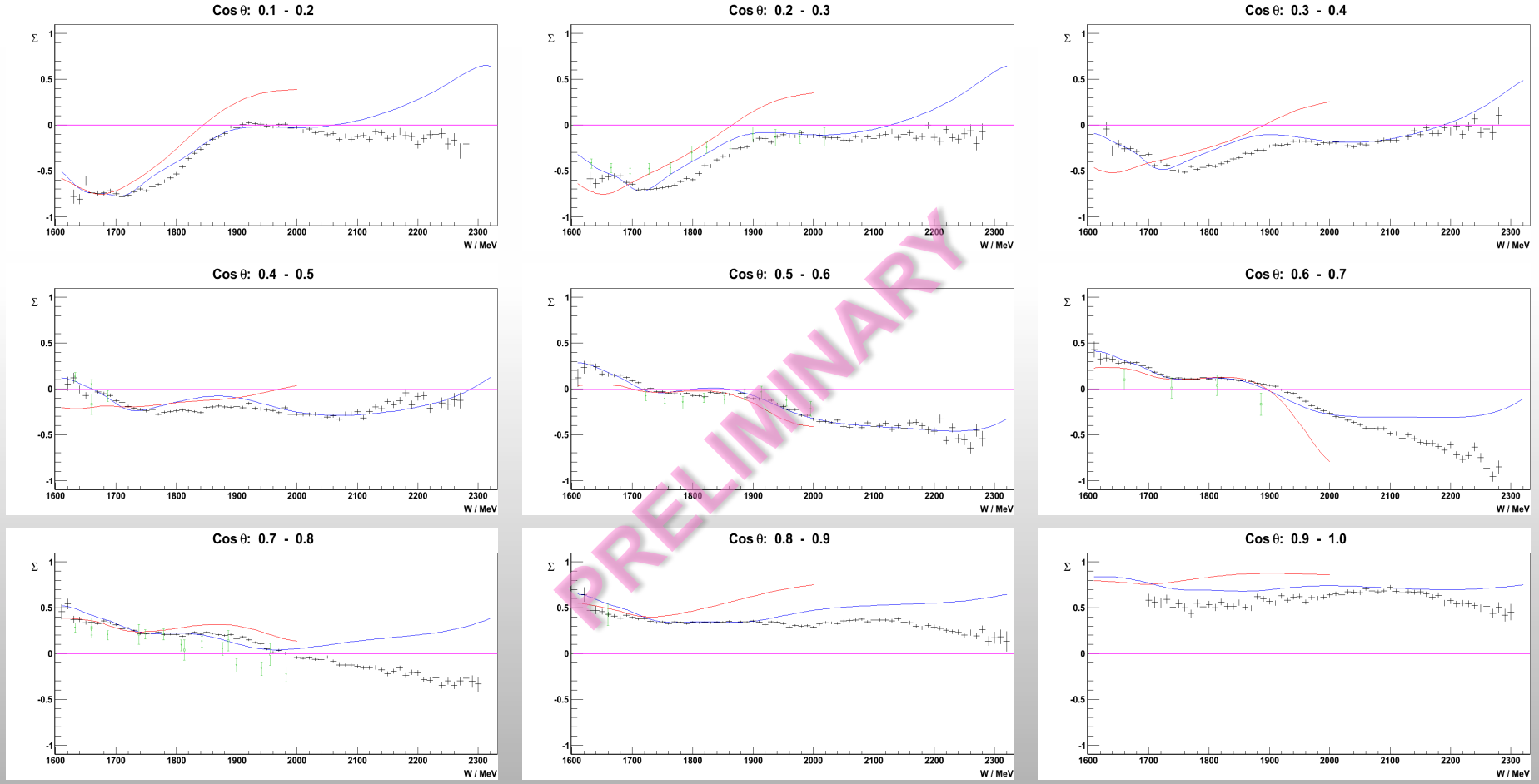
Photon asymmetry Σ $\gamma n \rightarrow \pi^- p$



Daria Sokhan

- Previous data (Alspector, PRL **28**, 1403 ('72), Abrahamian,SJNP 32, 69 ('80), Adamyan, JPG **15,** 1797 ('89)).

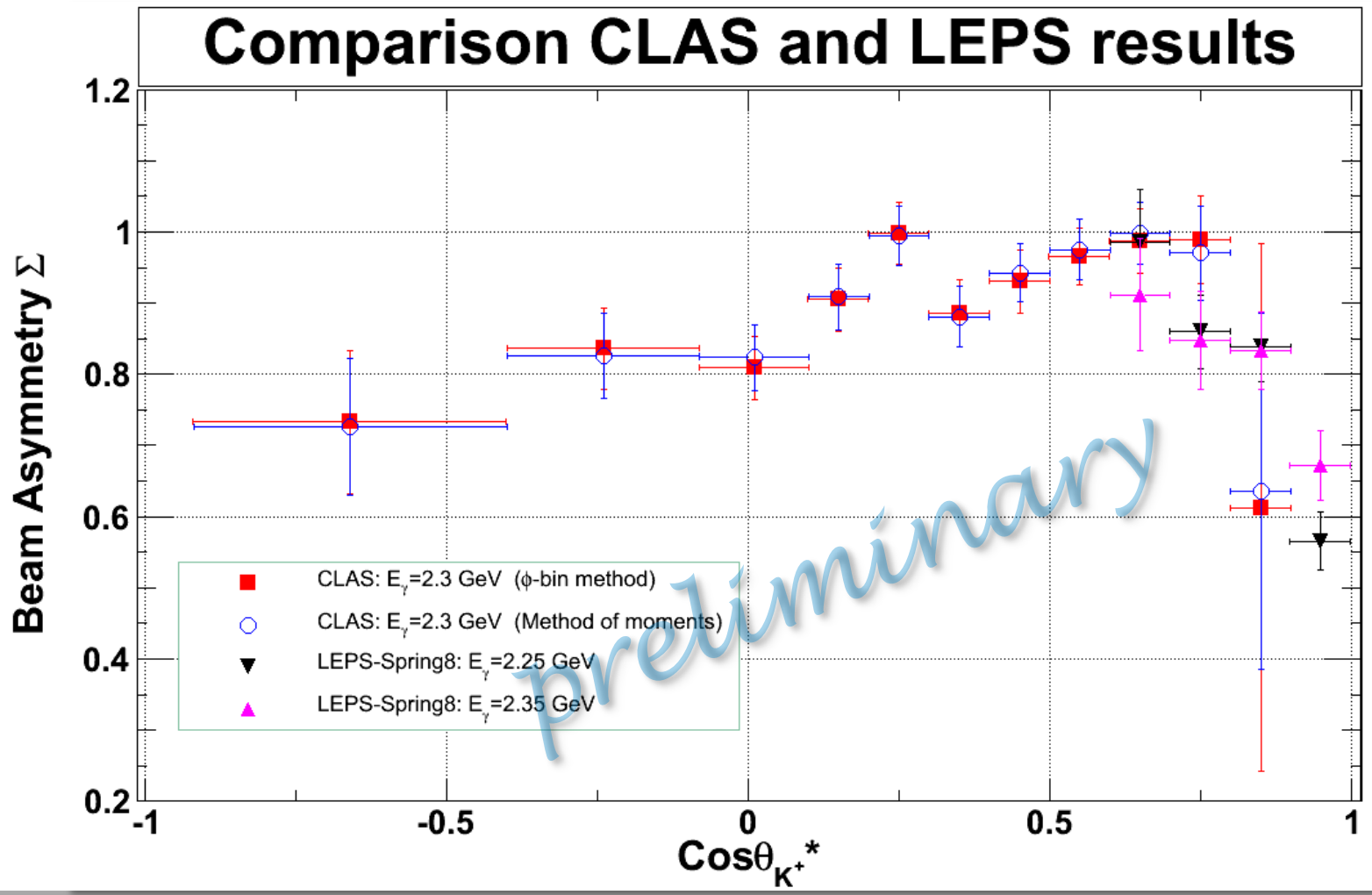
Photon asymmetry $\gamma n \rightarrow \pi^- p$



Daria Sokhan

- Previous data (Alspector, PRL **28**, 1403 ('72), Abrahamian,SJNP 32, 69 ('80), Adamyan, JPG **15,** 1797 ('89)).

$\gamma n \rightarrow \Sigma^- K^+$

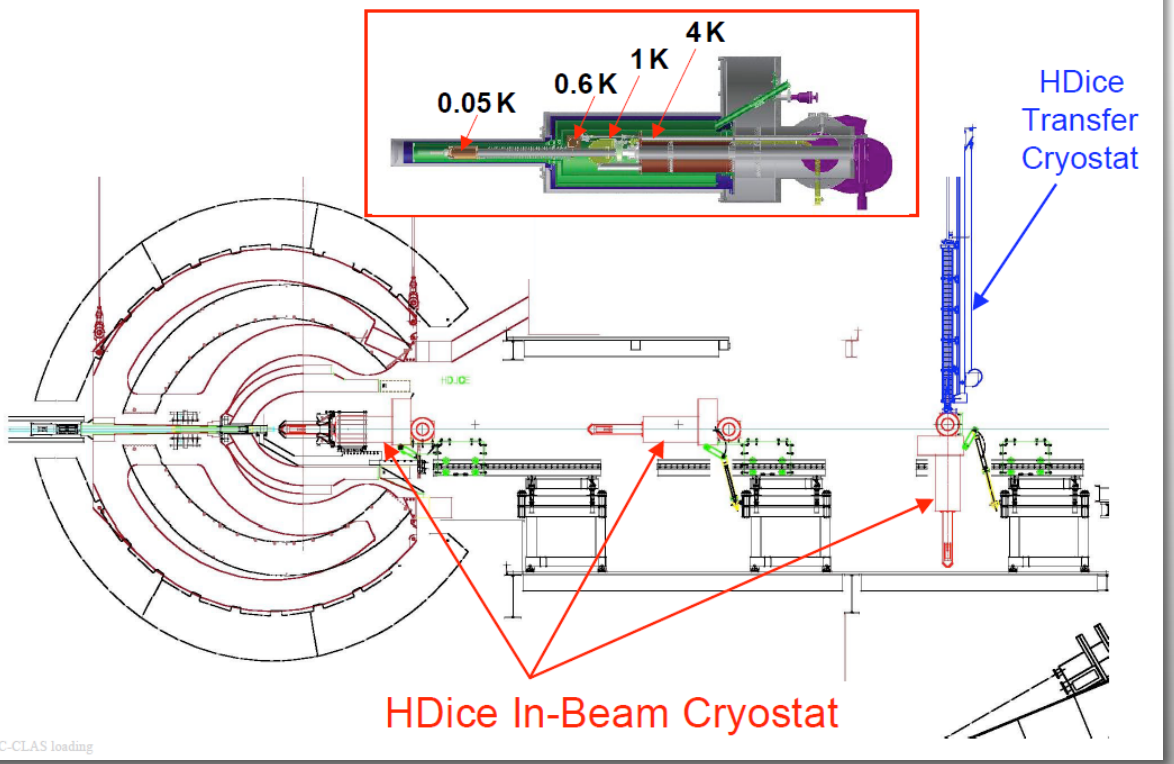


HDIce polarized target

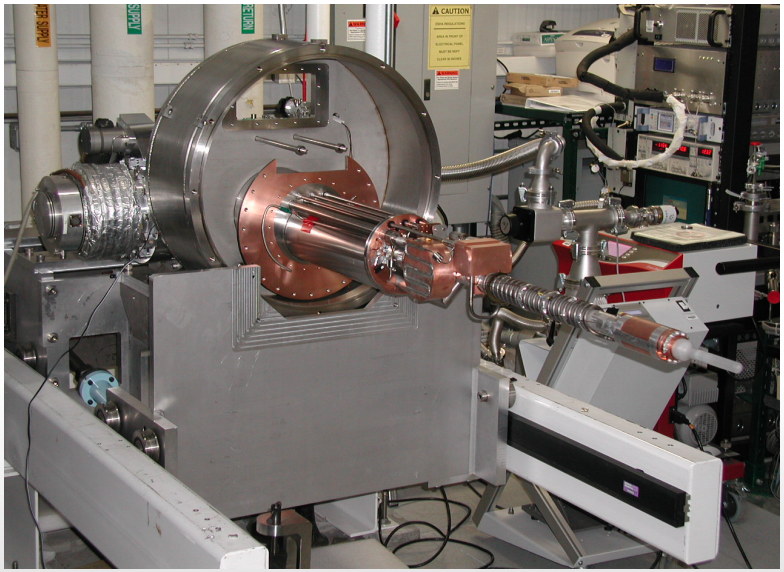
- Spin can be moved between H and D with RF transitions
- All material can be polarized with almost no background

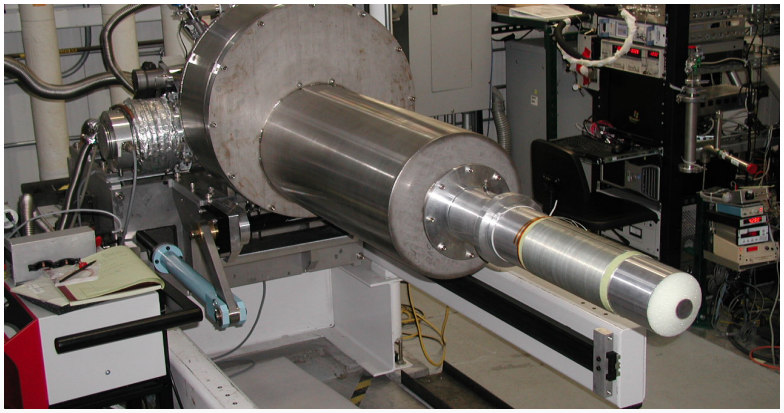
HDIce Solid Deuterium-Hydride (HD) – a new class of polarized target

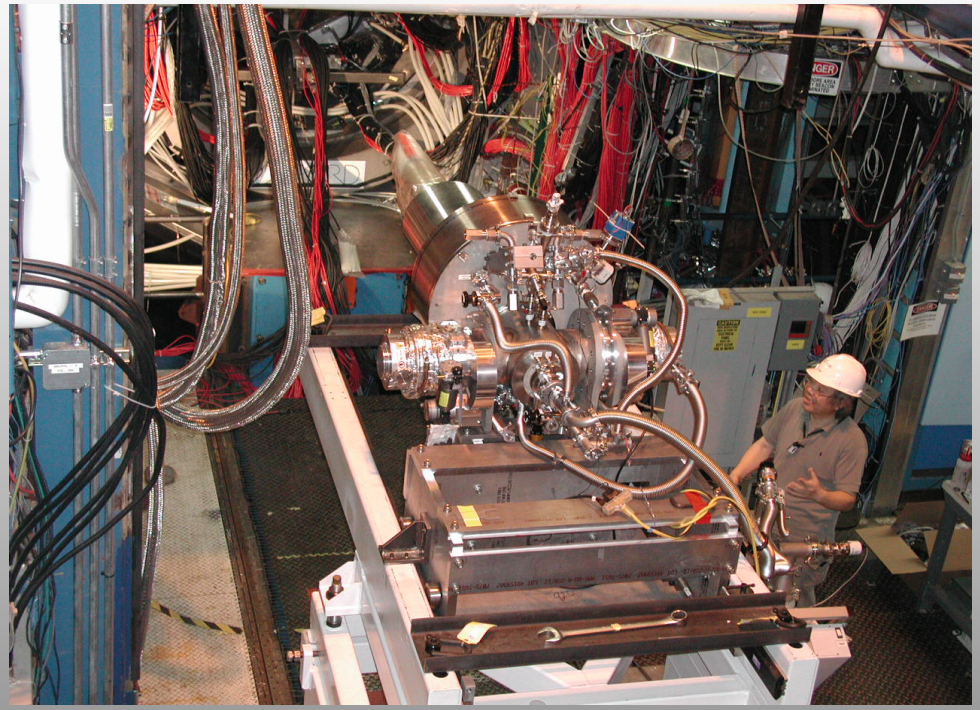
- designed for both γ (w Start Counter) and e⁻ (w mini-Torus) running



HD-Ice







Status of meson photoproduction

	σ	Σ	T	P	E	F	G	H	T_x	T_z	L_x	L_z	O_x	O_z	C_x	C_z
Proton target																
$p\pi^0$	✔	✓	✓	✓	✓	✓	✓	✓								
$n\pi^+$	✔	✓	✓	✓	✓	✓	✓	✓								
$p\eta$	✔	✓	✓	✓	✓	✓	✓	✓								
$p\eta'$	✔	✓	✓	✓	✓	✓	✓	✓								
$p\omega$	✔	✓	✓	✓	✓	✓	✓	✓								
$K^+\Lambda$	✔	✓	✓	✔	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✔	✔
$K^+\Sigma^0$	✔	✓	✓	✔	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✔	✔
$K^{0*}\Sigma^+$	✔	✓									✓	✓				
Neutron target																
$p\pi^-$	✔	✓	✓		✓	✓	✓	✓								
$p\rho^-$	✓	✓	✓		✓	✓	✓	✓								
$K^-\Sigma^+$	✓	✓	✓		✓	✓	✓	✓								
$K^0\Lambda$	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
$K^0\Sigma^0$	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
$K^{0*}\Sigma^0$	✓	✓														

✔ - published, ✓ - acquired, ✔ - planned

Summary

- "compete measurement" in pseudoscalar meson photoproduction becomes reality
- Data collection with proton target is complete
- Data collection on the deuteron is underway