Polarization Observables using a Transverse Frozen Polarized Target in CLAS

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Outline

- Motivation
- Polarization Observables
- Experimental Setup of FROST
- Particle Identification
- Preliminary Results
- Conclusion

QCD and Resonances

- QCD is the theory of the strong nuclear force
  - Describes the interactions of quarks and gluons
  - Quarks are confined within hadrons
  - Interactions mediated by gluons
  - Has a color charge (red, green, and blue)
- Since gluons carry a color charge (unlike photons), they mediate AND participate in the interactions
- QCD is extremely hard to solve at low energies
- Nucleon excitations are baryon resonances
- More model states are predicted than observed
- States at M>1600 MeV is difficult to study due to many overlapping resonances
- Cross section data is not enough to do full PWA on $K^+\Lambda$

QCD and Resonances

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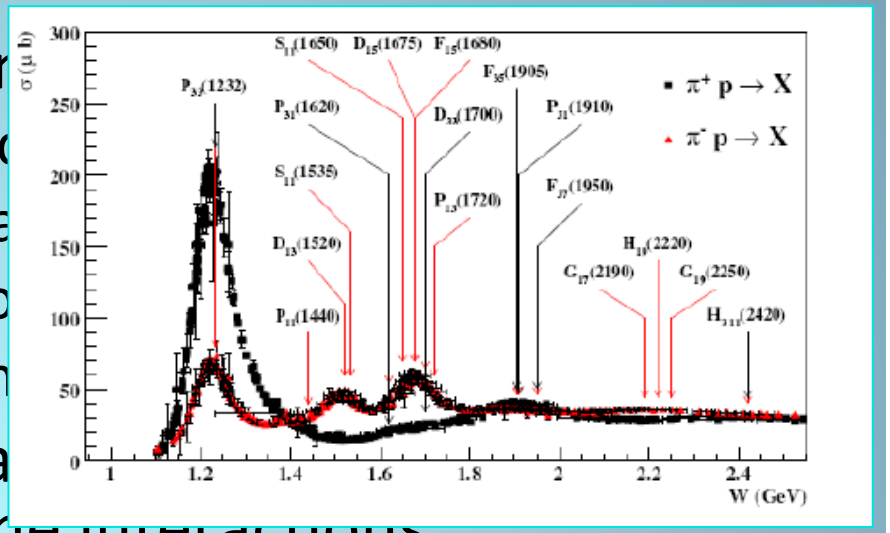

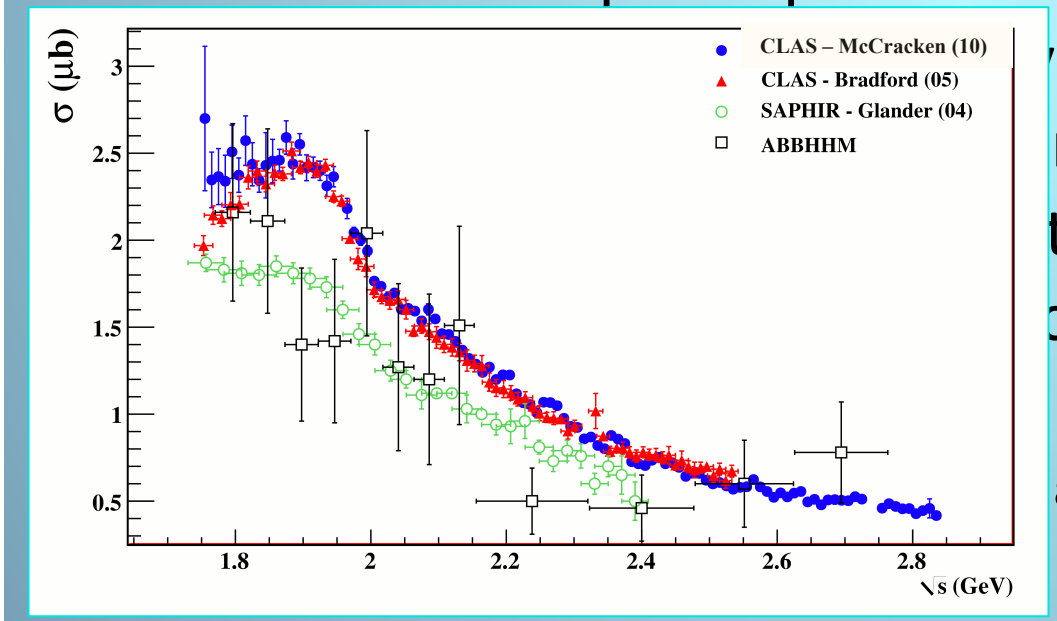

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Polarization Observables

- Photoproduction for K and π production described by four complex helicity amplitudes :
  - Describes spin combinations of incoming and outgoing particles
  - 16 independent measurables calculated
  - Extracted based on target, beam, and recoil polarization
  - Not all independent from each other
- Need observables to disentangle angular momentum to see missing resonances as observables are more sensitive to resonances than cross-section

Photon		Target			Recoil			Target + Recoil			
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

Method to Extract Observables

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_0}\left(1 + P_{XY}^{\text{lab}} P_C F \cos(\beta - \varphi) + P_{XY}^{\text{lab}} T \sin(\beta - \varphi)\right).$$

circular polarization of beam

polarization of target

Cross section is measured within finite bin size of E_γ and $\cos\theta$:
ϕ dependence can be given by density function

$$f^{i,j}(\varphi) \equiv \rho L \int_{E_{i-1}}^{E_i} \int_{\cos\theta_{j-1}}^{\cos\theta_j} \varepsilon(E,\theta,\varphi) \frac{d^3\sigma}{d(\cos\theta)dEd\varphi} d(\cos\theta)dE$$

Expand density function f(ϕ) in Fourier series…

$$f_a^{i,j}(\varphi) = a_0 + \sum_{m=1}^{\infty}\left[a_m \cos(m\varphi) + b_m \sin(m\varphi)\right]$$

$$H_{1,n} = \int_0^{2\pi} f_1^{i,j}(\varphi)\cos(n\varphi)d\varphi$$

Separate cos/sin terms

$$Z_{1,n} = \int_0^{2\pi} f_1^{i,j}(\varphi)\sin(n\varphi)d\varphi$$

using orthogonality of sin($n\phi$), cos($n\phi$), solve for T

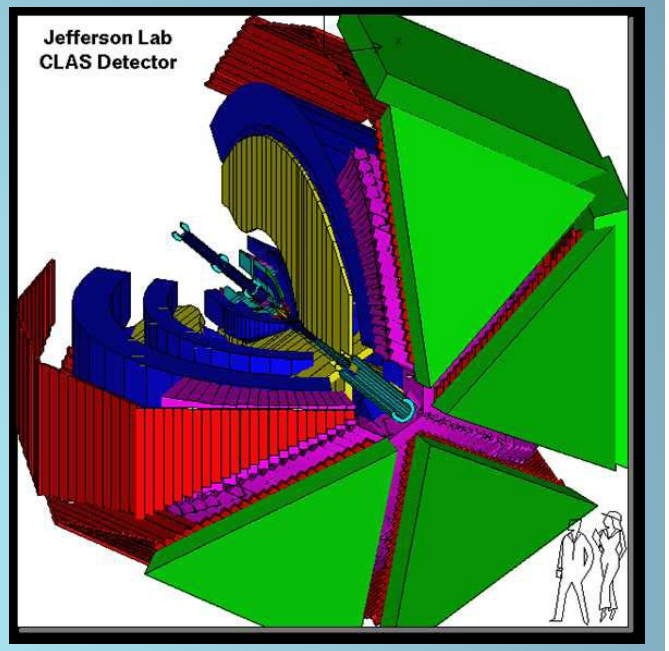
$$T = \left[\frac{\sigma_1 - \sigma_2}{\sigma_1 + \sigma_2}\right]$$

$$T = \frac{2\left(N_2 Z_{1,1} - N_1 Z_{2,1}\right)}{P_2 N_2\left(H_{1,0} - H_{1,2}\right) + P_1 N_1\left(H_{2,0} - H_{1,2}\right)}$$

Can be done similarly for T_x and T_z!!!!

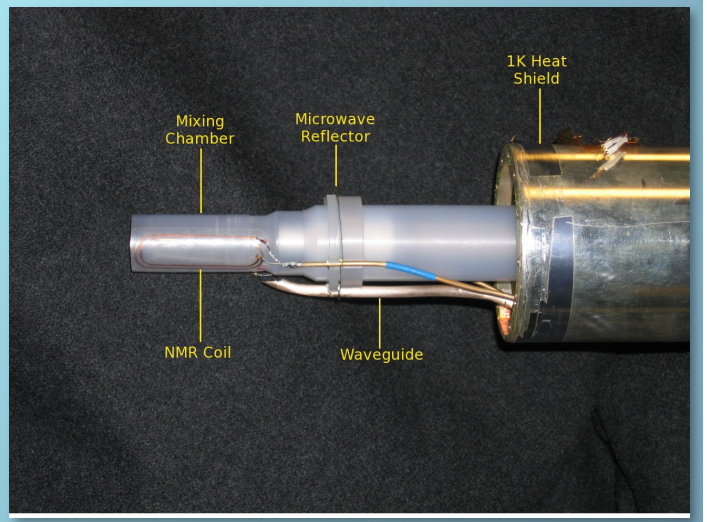
Experimental Setup of g9b (FROST)

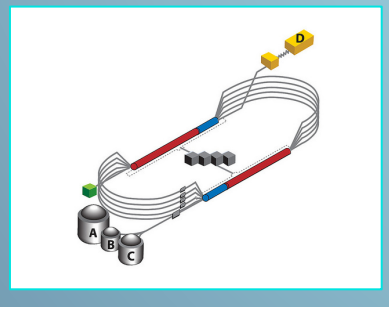
- Transversely polarized target
- Circularly polarized photon beam created by incoherent bremsstrahlung
- FROzen Spin Target
  - L pol g9a
  - T pol g9b



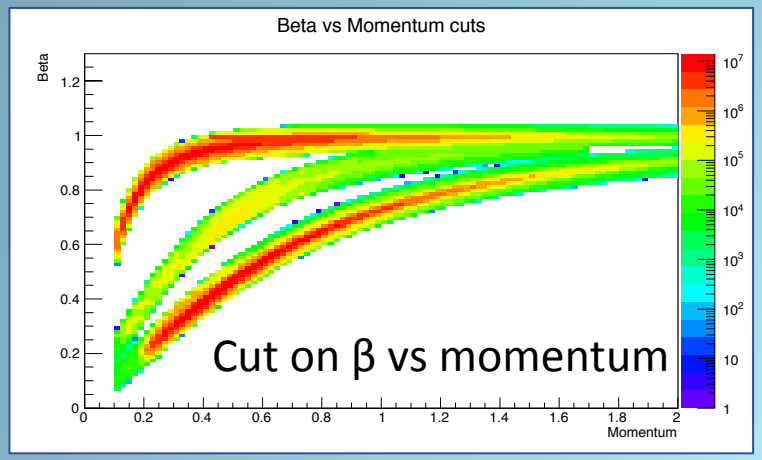
Results:

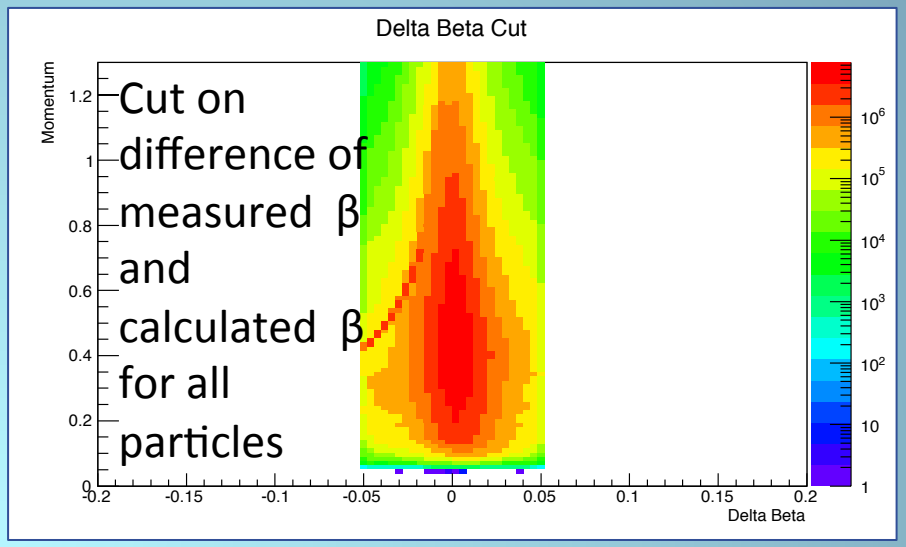
- g9b ran from March 2010 thru August 2010
- Collected ~14B events
- A complete measurement: all beam-target and target-recoil polarization observables for $K^+\Lambda$ and $K^+\Sigma^0$ channels

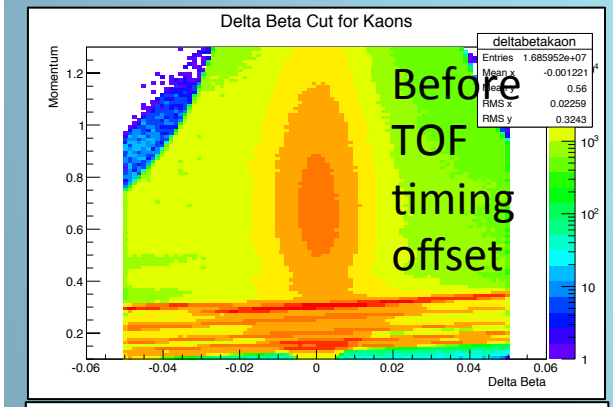


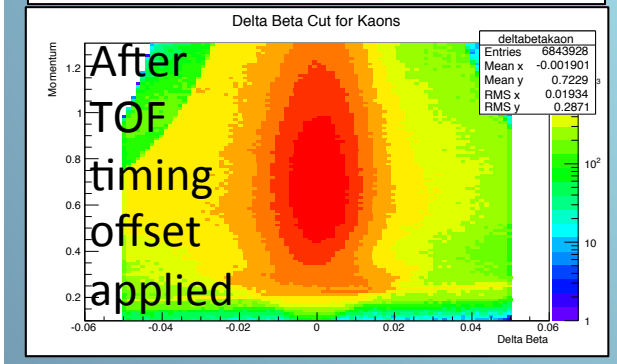


Preliminary Cuts

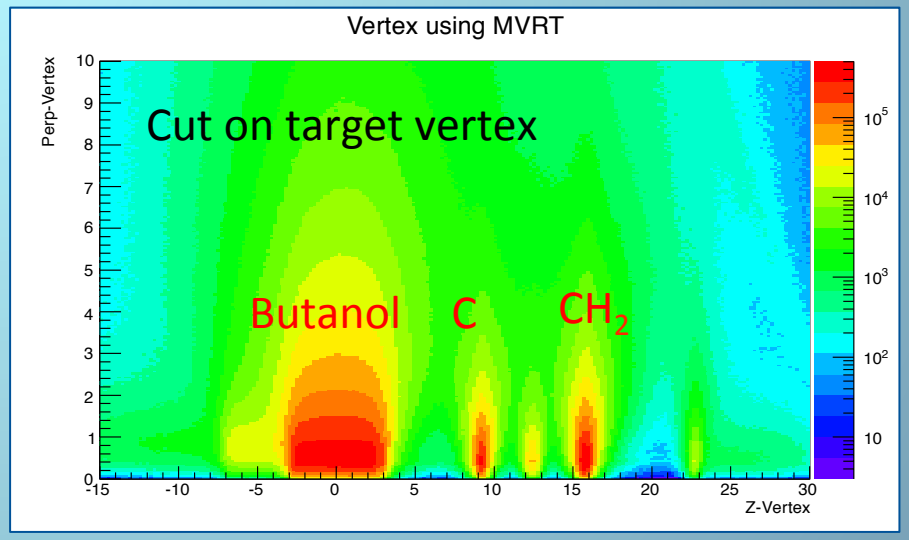








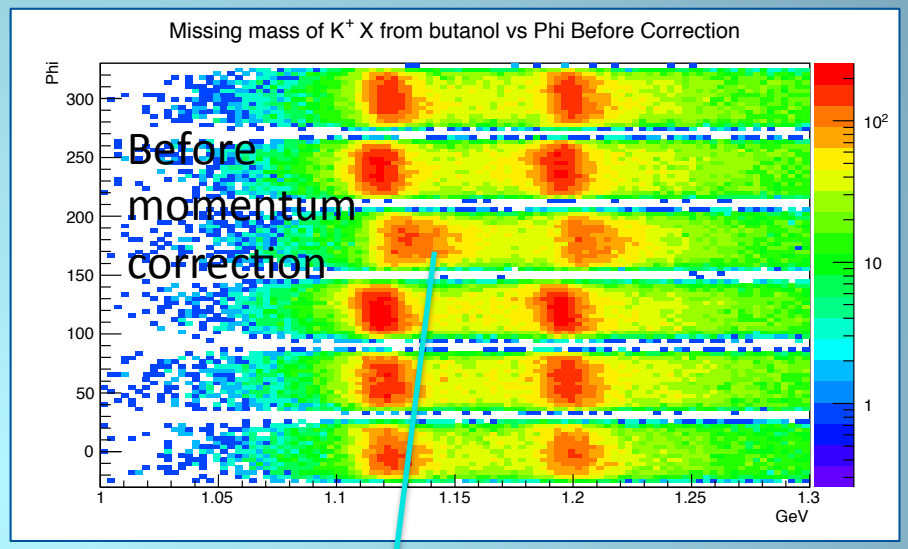
Cut on difference of measured β and calculated β for kaons

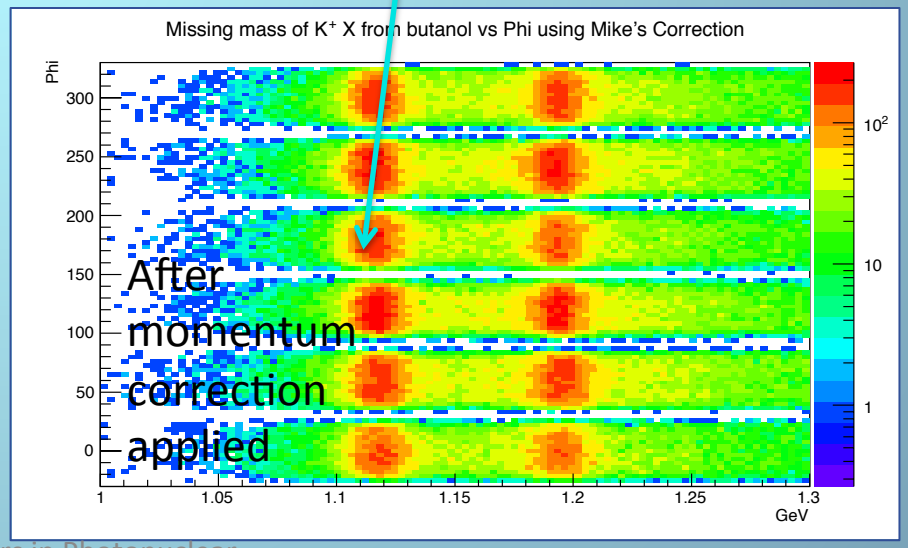


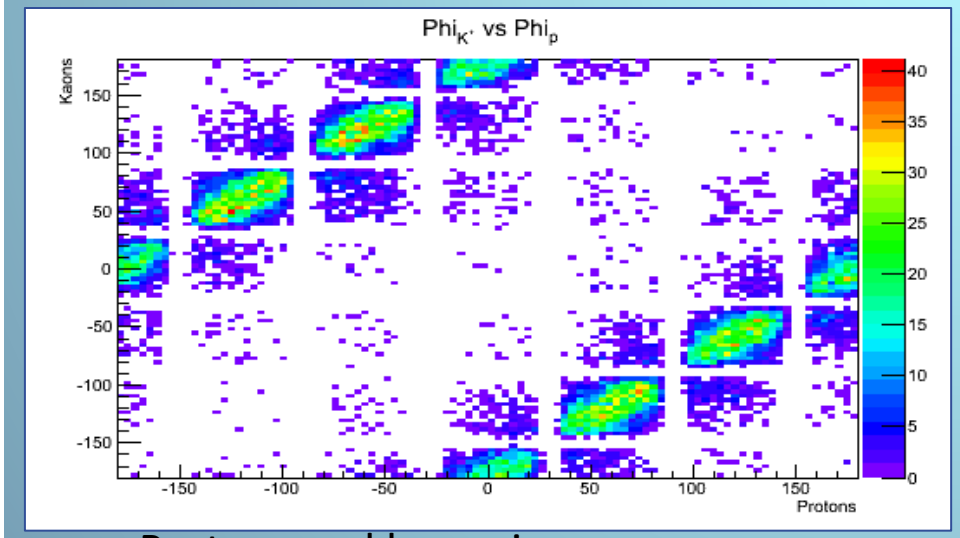
Event Selection Criteria

- Skimmed dataset for K^+ events
  - Event must have 1 identified proton, 1 identified K^+ and only two positively charged particles
- Applied energy loss and momentum corrections
- Timing offset corrected
- Bad TOF paddles cut from analysis
- Cut on coincidence time of ±1 ns

energy loss and momentum corrections

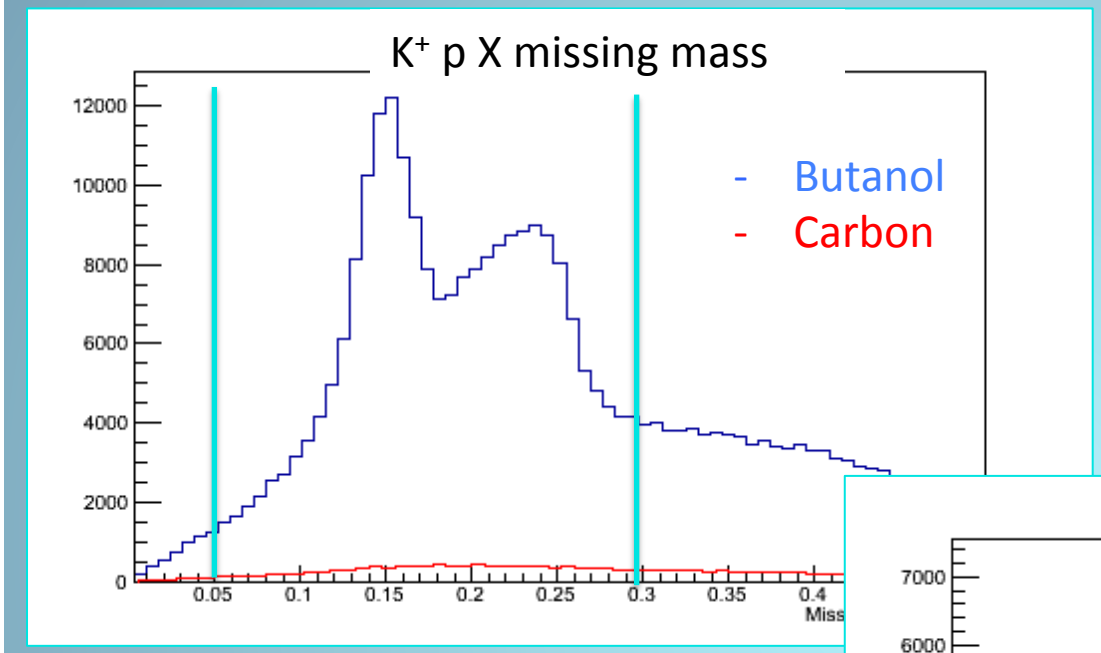


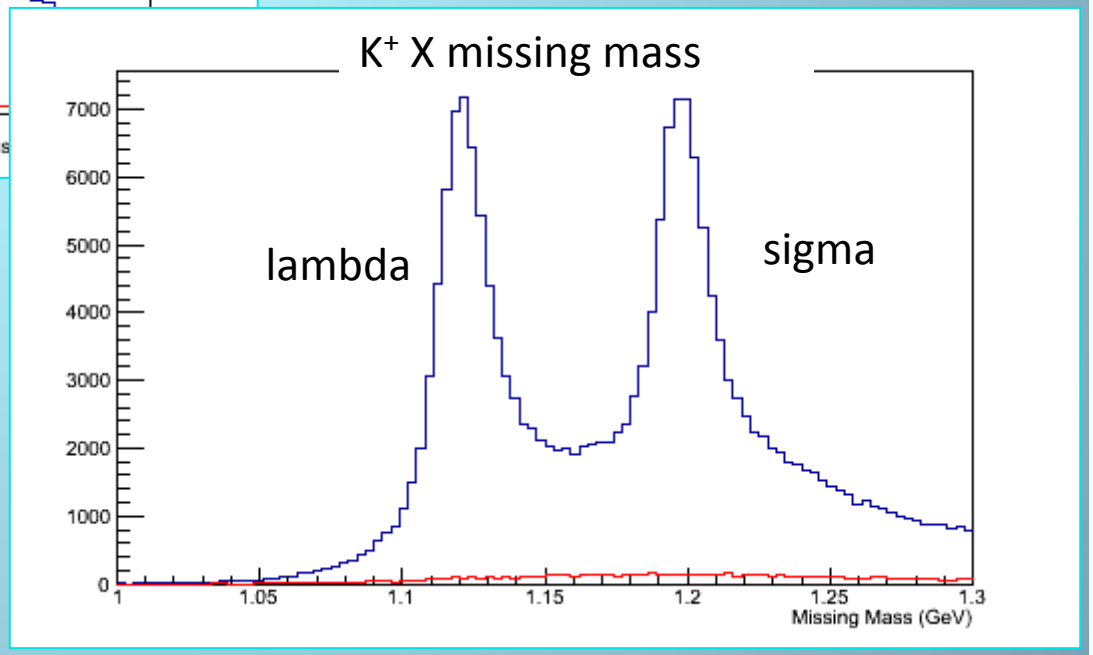




Protons and kaons in opposite sectors

Background Subtraction

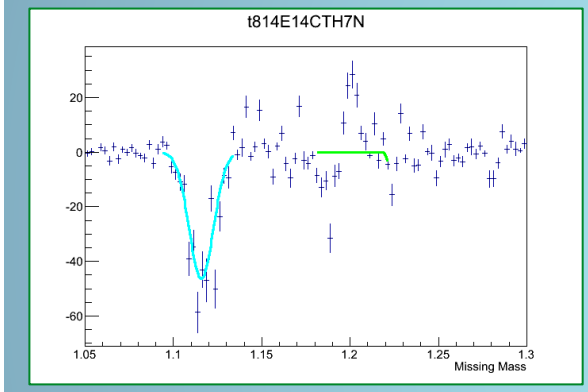


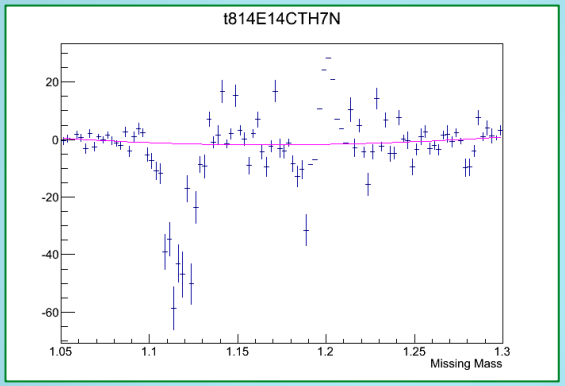


- Remove carbon and signal background from each other
- First make cut on K^+ p X and extract $K^+\Lambda$ and $K^+\Sigma^0$
- Then fit background in $K^+\Lambda$ and $K^+\Sigma^0$ sum and difference spectra

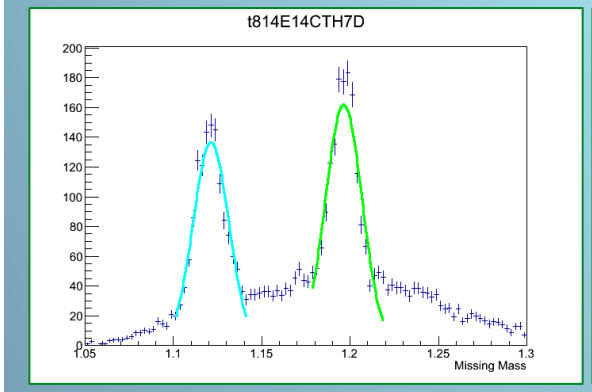
Deciphering the Background

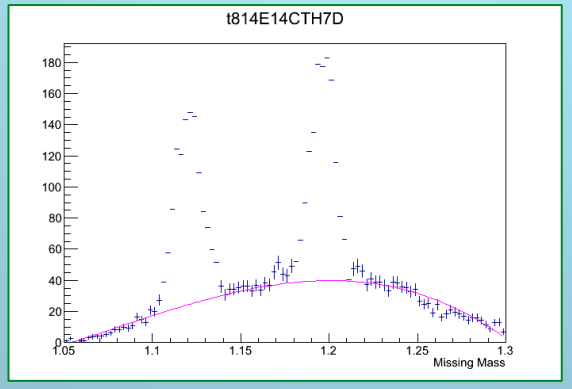
- For pol sum and difference spectra,
  - fit both Λ and Σ^0 with a Gaussian
  - Fit background with a cubic polynomial
- Do for each cosϑ, W bin!



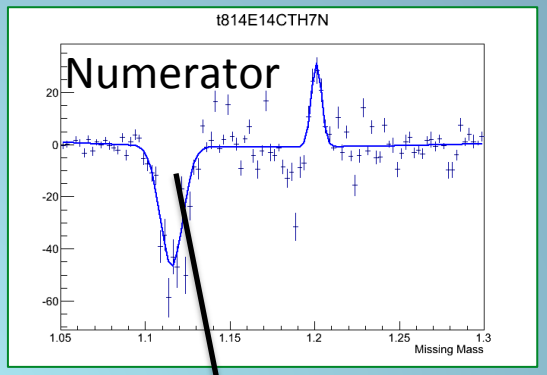


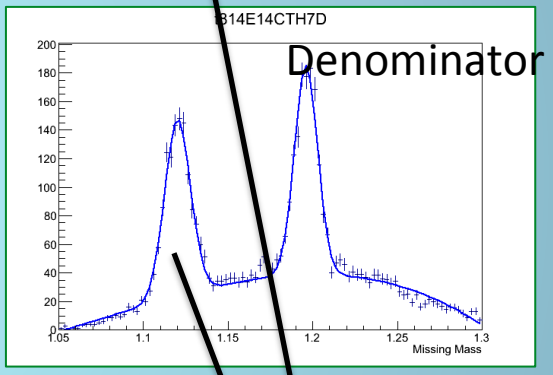
Numerator

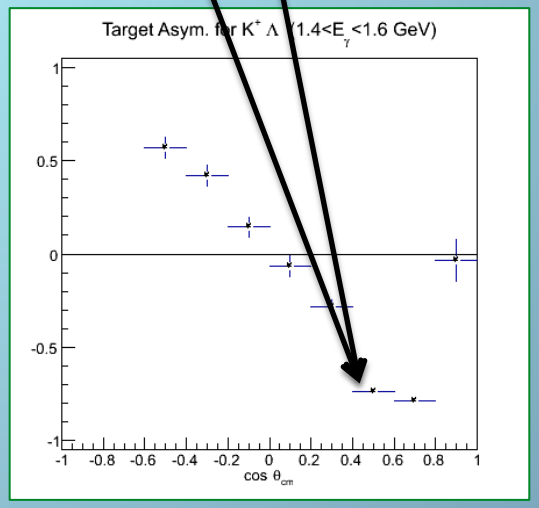




Denominator

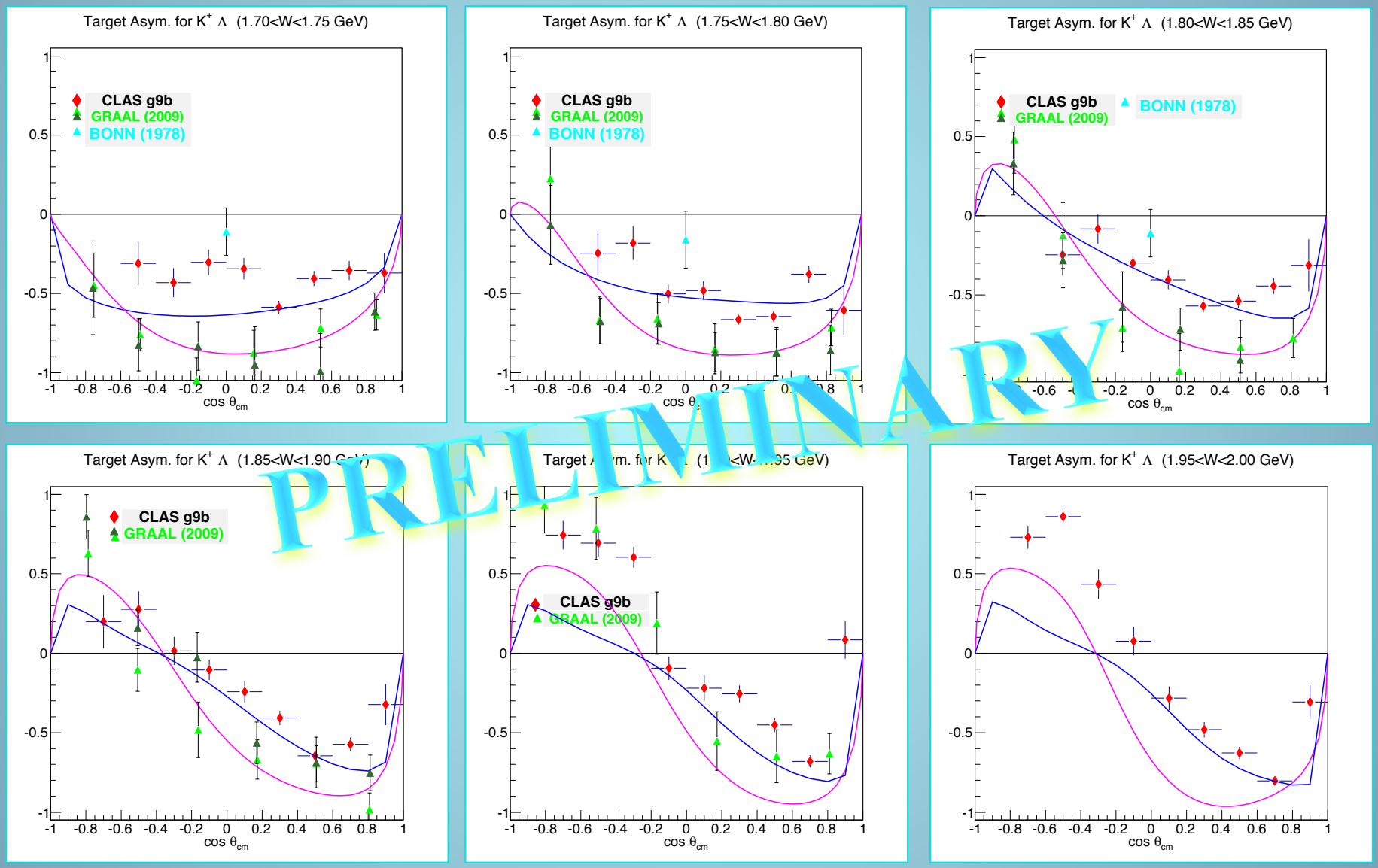






T Asymmetry for $K^+\Lambda$

KAON-MAID
BOGA



T Asymmetry for $K^+\Sigma^0$

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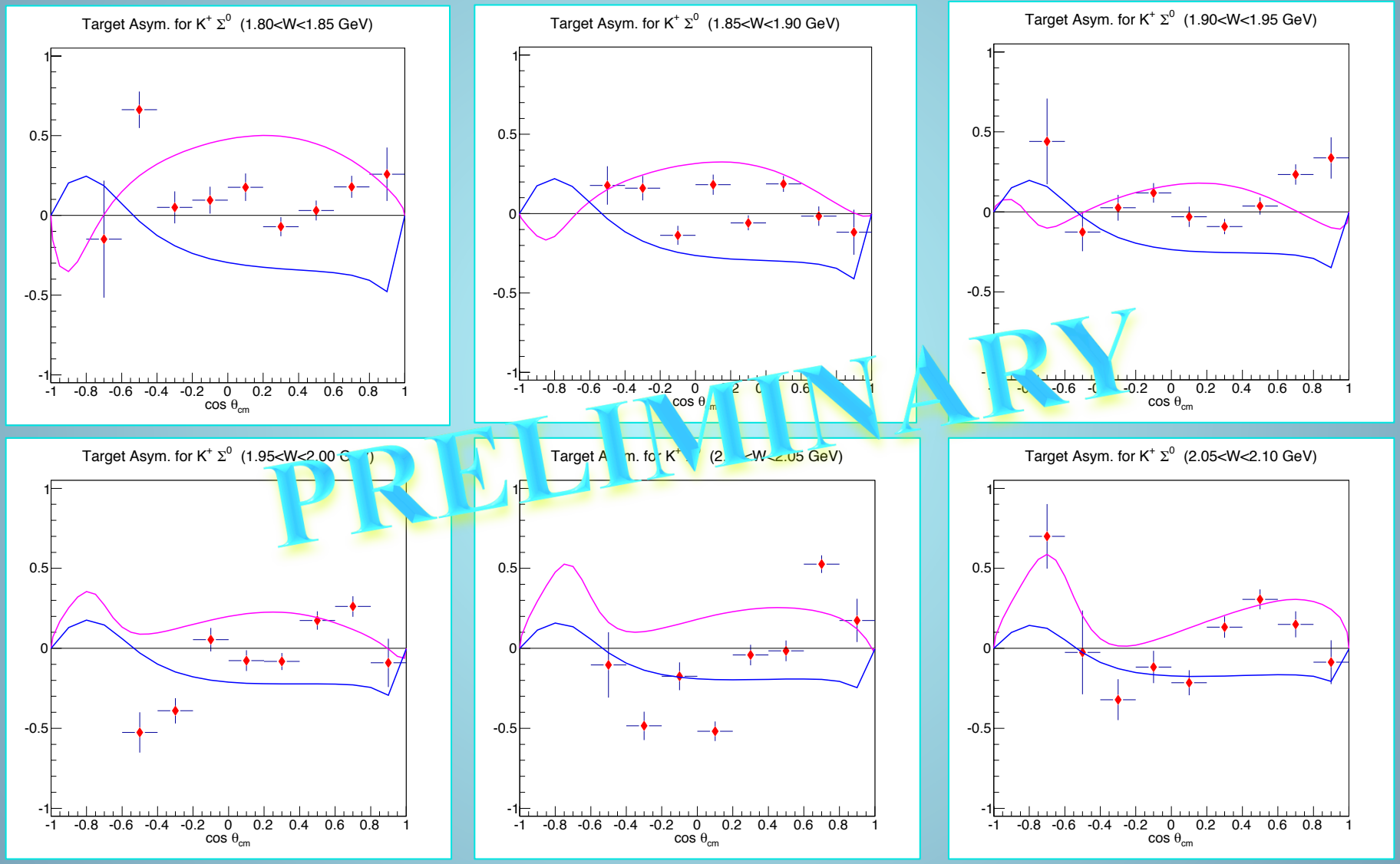

T_x Asymmetry for $K^+\Lambda$ and $K^+\Sigma^0$

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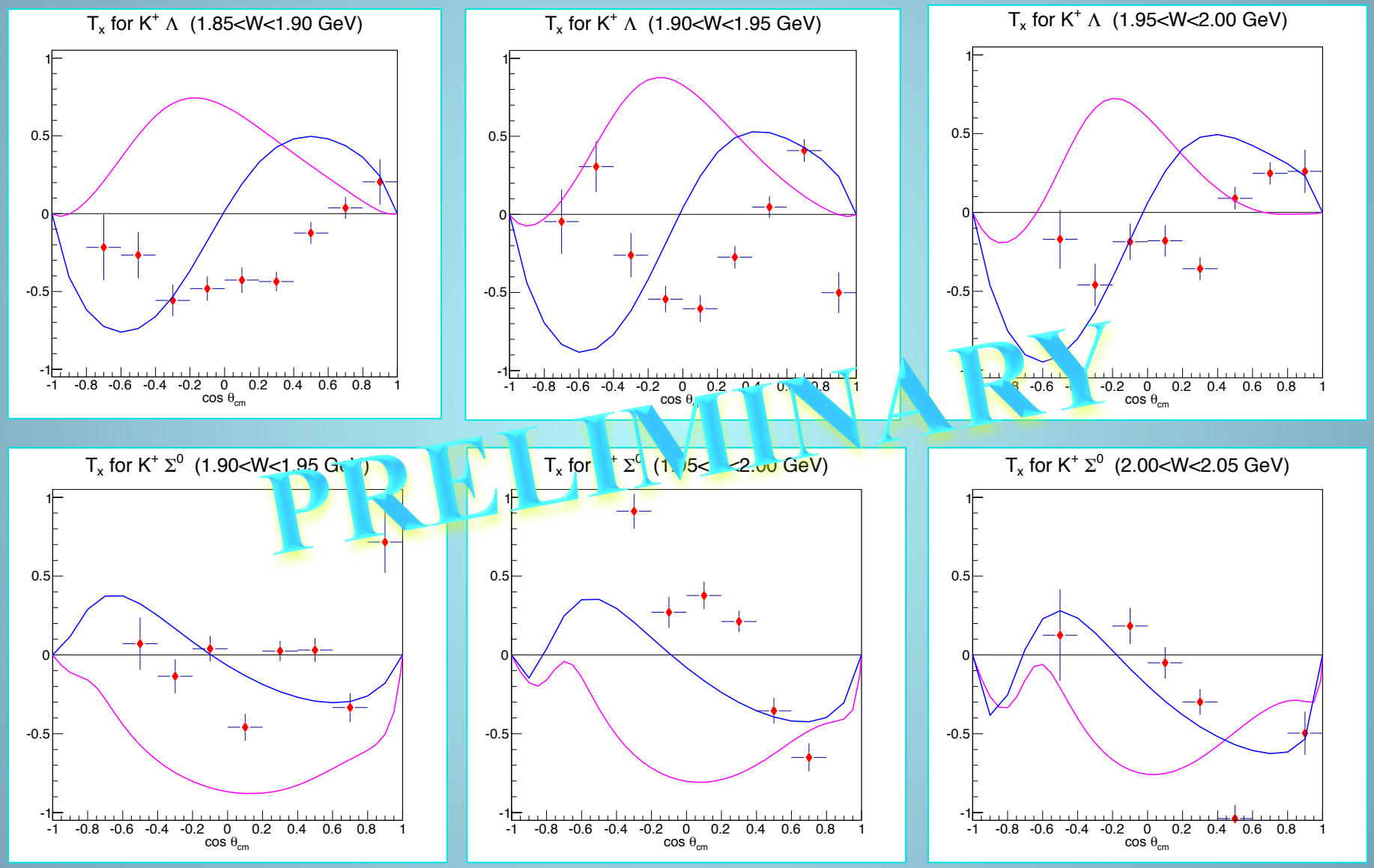

T_z Asymmetry for $K^+\Lambda$ and $K^+\Sigma^0$

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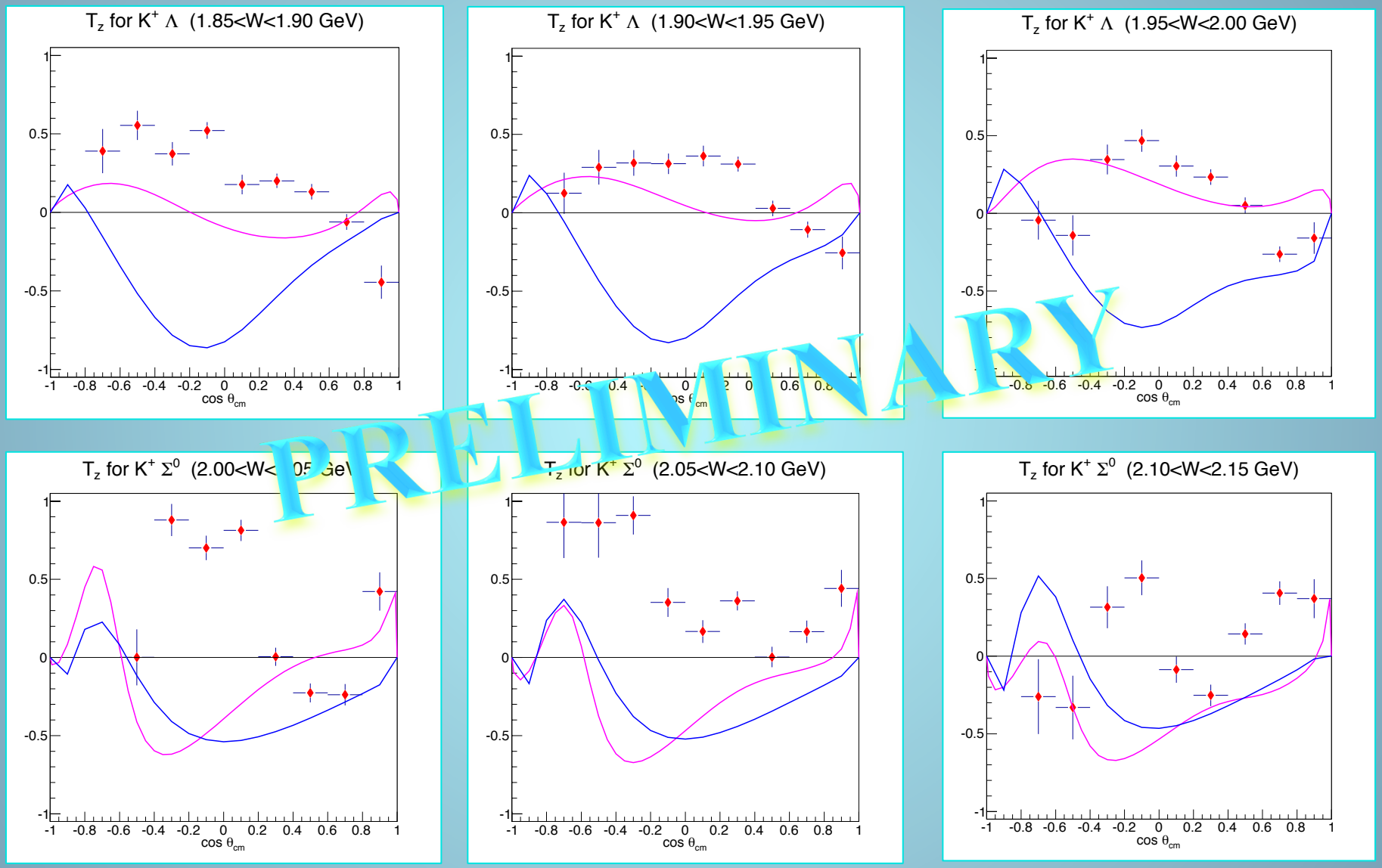
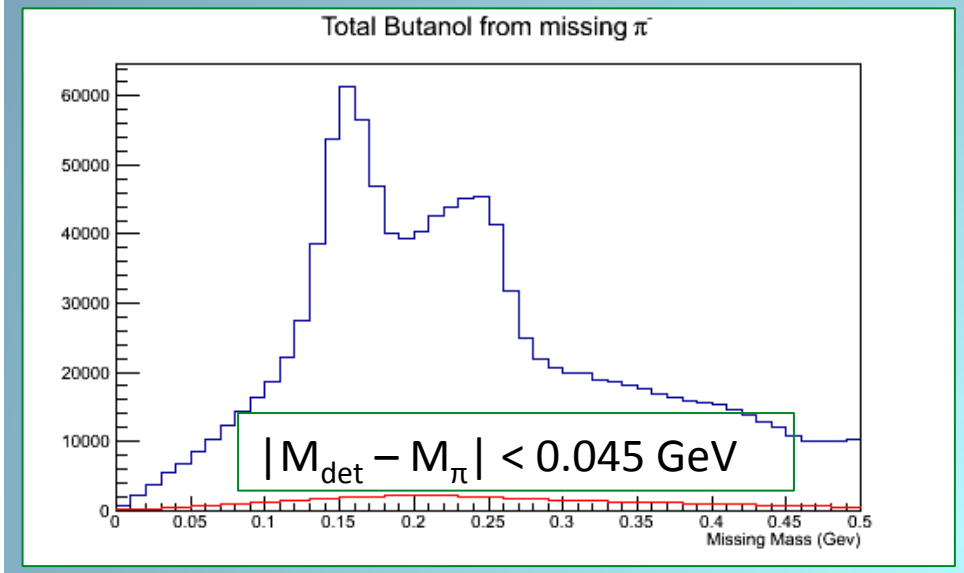


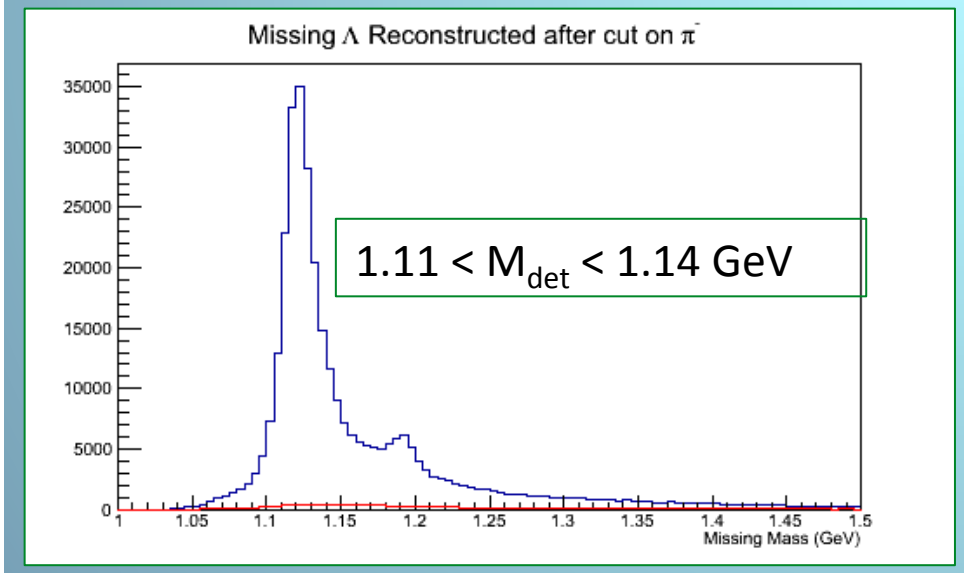
Conclusion

- FROST is the first experiment to measure T_x and T_z
- FROST is the first experiment to DIRECTLY measure T over a wide kinematic range for both $K^+\Lambda$ and $K^+\Sigma^0$
  - largely consistent with previously published data for T for $K^+\Lambda$ (obtained indirectly through double-polarization data together with $O_{x'}$, $O_{z'}$)
- Currently working on systematic studies
- This analysis will significantly add to the world database
- More accurate PWA more be performed using asymmetry data an will give clues regarding missing resonances and resonances that do not have much data

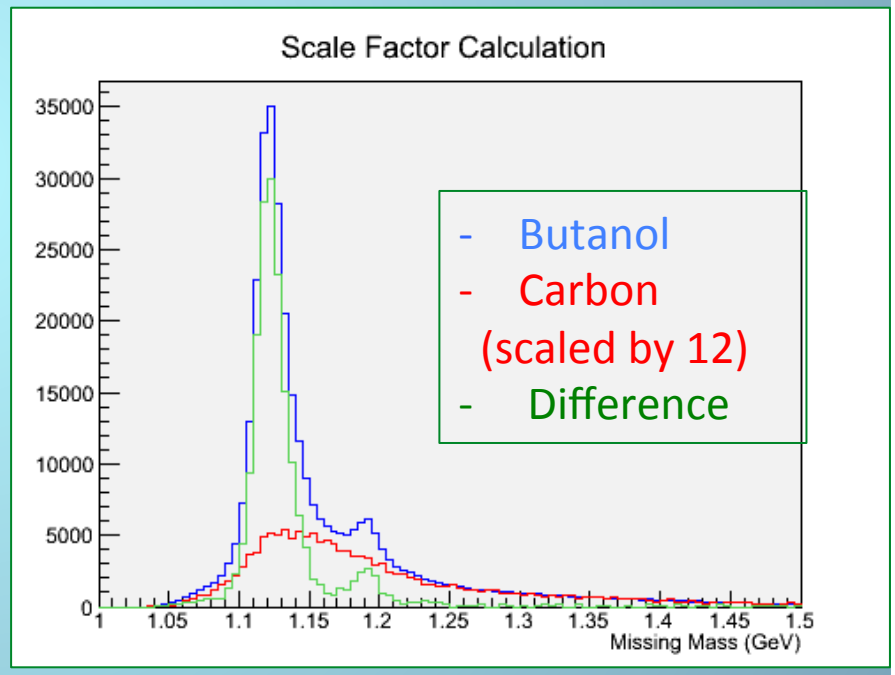
Back up

Fit in Phi Distribution Method





When using "phi-distribution" method, carbon has to be scaled drastically and background subtraction in a given kinematic bin causes large uncertainties due to large fluctuation of the low carbon yield and leakage from remaining Σ^0 signal



64 BOUND protons and ONLY 10 FREE protons in butanol!!

Moment Method Continued…

$$T = \frac{2\left(N_2 Z_{1,1} - N_1 Z_{2,1}\right)}{P_2 N_2\left(H_{1,0} - H_{1,2}\right) + P_1 N_1\left(H_{2,0} - H_{1,2}\right)}$$

H-cos moment terms
Z-sin moment terms
Y-normalization=N2/N1

P1-degree of positive polarization
P2-degree of negative polarization
N1-negative polarization events
N2-positive polarization events

$$T = \frac{2(Ysin1pos - sin1neg)}{P_2 Y(cos0pos - cos2pos) + P_1(cos0neg - cos2neg)}$$

i.e. cos2 = M_{det} ,weighted by cos2ϕ
sin1 = M_{det} ,weighted by sin1ϕ

Moment Method for *F*

Similarly for *F*….

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_0}\left(1 + P_{XY}^{\text{lab}} P_C F \cos(\beta - \varphi) + P_{XY}^{\text{lab}} T \sin(\beta - \varphi)\right).$$

$$\tilde{X}_1 = \tilde{Y}_0(1 + A_1 F \cos(\varphi))$$
$$\tilde{X}_2 = \tilde{Y}_0(1 - A_2 F \cos(\varphi))$$

$$F = 2\left(\frac{\tilde{X}_{1m1} - \tilde{X}_{2m1}}{A_2(\tilde{X}_{1m0} + \tilde{X}_{1m2}) + A_1(\tilde{X}_{2m0} + \tilde{X}_{2m2})}\right)$$

pos-postive target polarization
neg-negative target polarization
A_1-pos targ pol*pos circ beam
A_2-neg targ pol*neg circ beam

$$\tilde{X}_1 \equiv \left(\frac{\tilde{Y}_{11}B_2 + \tilde{Y}_{12}B_1}{B_1 + B_2}\right)$$
$$\tilde{X}_2 \equiv \left(\frac{\tilde{Y}_{21}B_2 + \tilde{Y}_{22}B_1}{B_1 + B_2}\right)$$

Yij ➡

i=moment
j=1=aligned
j=2=antialigned

$$F = 2\frac{\left[cos1\left(\frac{\frac{Y11neg}{N2} + \frac{Y12pos}{N1}}{pos+neg}\right) - cos1\left(\frac{\frac{Y21neg}{N2} + \frac{Y22pos}{N1}}{pos+neg}\right)\right]}{negcirc\left[cos0\left(\frac{\frac{Y11neg}{N2} + \frac{Y12pos}{N1}}{pos+neg}\right) + cos2\left(\frac{\frac{Y21neg}{N2} + \frac{Y22pos}{N1}}{pos+neg}\right)\right] + poscirc\left[cos0\left(\frac{\frac{Y11neg}{N2} + \frac{Y12pos}{N1}}{pos+neg}\right) + cos2\left(\frac{\frac{Y21neg}{N2} + \frac{Y22pos}{N1}}{pos+neg}\right)\right]}$$