Photon Beam Asymmetry Measurement

from the $\gamma n \to K^+\Sigma^-$ Reaction

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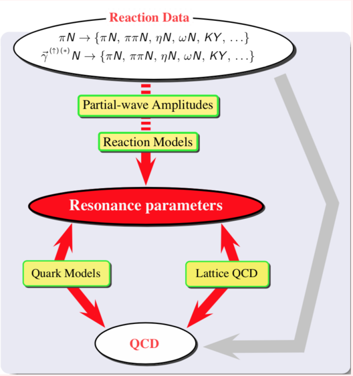
June 8, 2018

Content

Nucleon Excited States



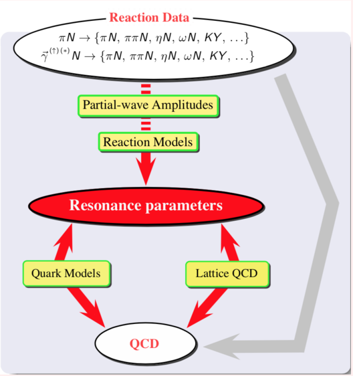
Approximate solutions

- Constituent quark model
- Lattice QCD

Experimentally

- Data
- PWA
- Reaction models
  - Coupled channels

Nucleon Excited States



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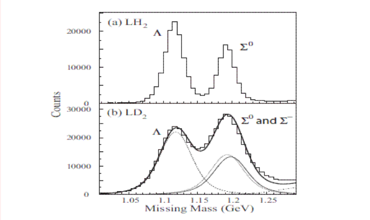
The underlying physics emerges from the comparison between the the spectrum extracted from experimental data and the "approximate" spectra obtained from the QCD approaches

Previous analysis: $\gamma n(p) \to K^+\Sigma^-(p)$

LEPS SPring-8 Data: current existing data for beam asymmetry

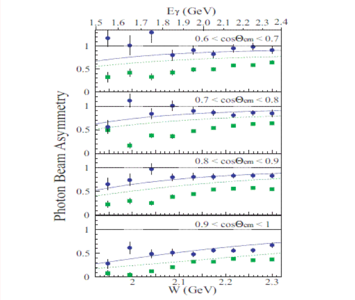
Inclusive analysis: only K^+ detected

$MM(K^+)$ off LH_2 and LD_2



- $M_D = (M_p + M_n)/2$
- $\left.\frac{N(\Sigma^0)}{N(\Lambda)}\right|_{LD_2} = \left.\frac{N(\Sigma^0)}{N(\Lambda)}\right|_{LH_2}$

Beam asymmetry Σ



- E_γ=1.5-2.4 GeV: 9 bins
- $0.6 < \cos\theta_{K^+}^{CM} < 1.0$: 4 bins

JLab: g13 CLAS run period

Polarized photon beam

Circular (g13a) and linear (g13b) polarization

Photon energy range

0.8-2.5 GeV, 1.1-2.3 GeV

Target

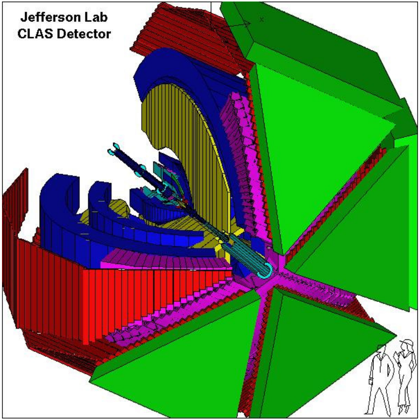
Liquid Deuterium (40-cm length)

Triggers

About a total of 52 billion triggers

JLab: CLAS Detector

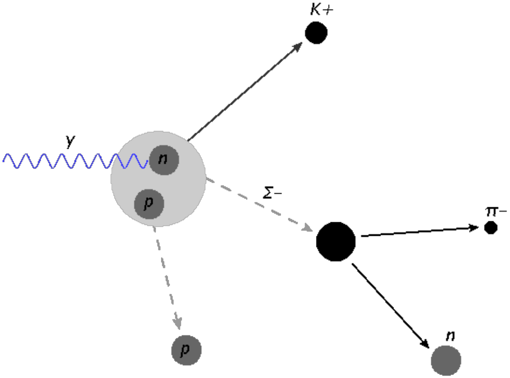
- Six azimuthal spectrometers (5m radius)
- Start Counter (10cm radius)
- Drift Chambers (3 regions)
  - σ_p/p=0.1%
  - σ_θ=0.5 mrad
  - σ_φ=3 mrad
- Superconducting Toroidal Magnet
- Time-of-Flight Scintillators
- Electromagnetic Calorimeter



This analysis: $\gamma n(p) \to K^+\Sigma^-(p)$ $\Sigma^- \to \pi^- n$

CLAS g13b Data: beam asymmetry over a wider angular coverage

Exclusive analysis: K^+, π^-, n detected



This analysis: $\gamma n(p) \rightarrow K^+\Sigma^-(p)$ $\boxed{\Sigma^- \rightarrow \pi^- n}$

Analysis strategy:

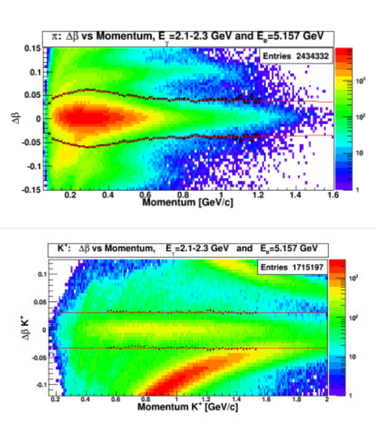
- Particle-ID
- Quasi-free reaction
- Background subtraction
- Beam asymmetry extraction

CORRECTIONS:

- Momentum corrections
- Energy loss corrections
- Σ^- decay vertex correction

Particle-ID: π^- (top) and K^+ (bottom)

$\Delta\beta = \beta_{calc}$ - β_{meas} (3-σ cuts)



$\Delta\beta$ cuts

- $\Delta\beta = \beta_{calc} - \beta_{meas}$

$$\beta_{calc} = \frac{p}{\sqrt{p^2 + m^2}}$$

- p: reconst. momentum
- m: PDG mass

β_{meas} is reconstructed in the CLAS sotfware

Particle-ID: neutron

Neutron detection

Signal in the Calorimeter (EC)

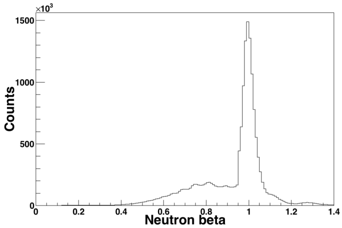
Interaction layer in EC

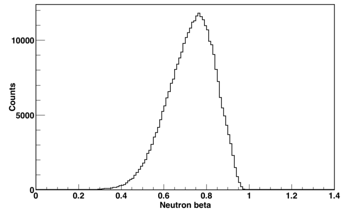
- From $\gamma d \rightarrow \pi^+\pi^- p\ n$

neutron vertex

- $c\tau_{\Sigma^-} \approx 4.4$ cm

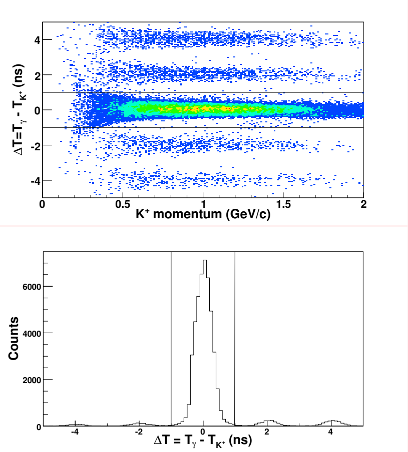
β distribution





Particle-ID: incident photon selection

Best photon: $\Delta T = T_\gamma - T_{K^+}$



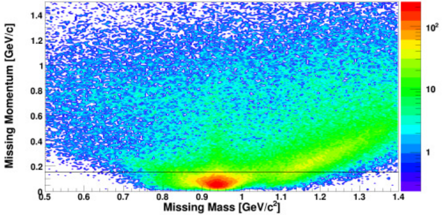
T_γ : Photon arrival time (tagger)

T_{K^+}: Photon arrival time (TOF)

Multiple-good-photon events rejected ($\approx$ 2.85 %)

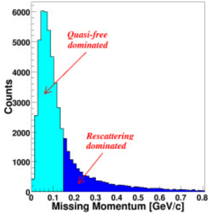
Quasi-free reaction

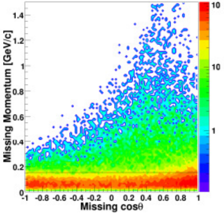
The reaction studied experimentally corresponds to $\gamma d \to K^+\Sigma^- p$ rather than to $\gamma n \to K^+\Sigma^-$



Quasi-free events

$P_{miss} \leq 0.150$ GeV/c

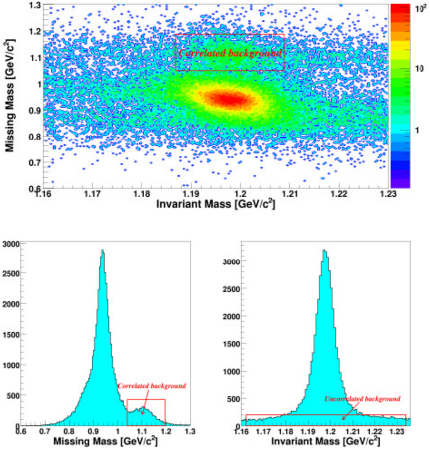




Rescattering events

$P_{miss} > 0.150$ GeV/c

Background Subtraction



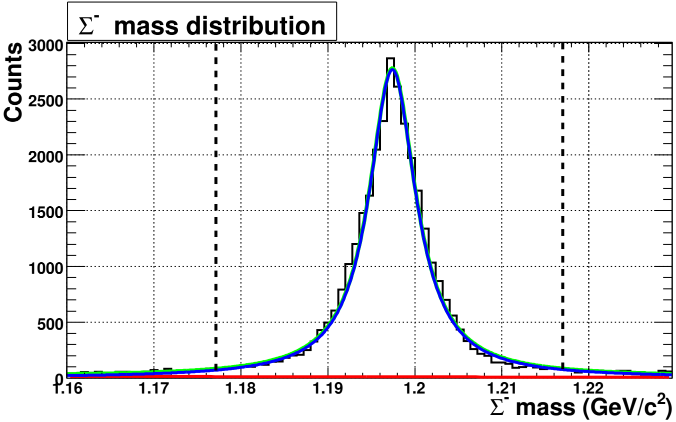
Correlated background
$\gamma d \rightarrow K^+\Sigma^-\pi^0(p)$

- Strategy: cut

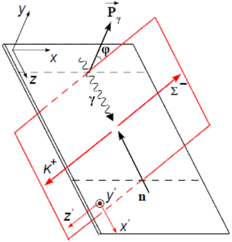
Uncorrelated background
$\gamma d \rightarrow \pi^+\pi^- n p$

- Strategy: fit

Background Subtraction



Beam Asymmetry Extraction Σ



- Two photon polarization planes:
  - Horizontal (PARA)
  - Vertical (PERP)
- Six photon energy settings
- Two methods used to extract Σ:
  - Method of moments
  - ϕ-bin method

Electron energy beam (GeV)	Photon energy beam (GeV)	Mean polarization (%)	
		PARA $P_{\parallel}$	PERP $P_{\perp}$
3.302, 3.914, 4.192	1.1-1.3	0.75	0.71
4.065, 4.475	1.3-1.5	0.70	0.74
4.065, 4.748	1.5-1.7	0.71	0.73
5.057	**1.7-1.9**	0.74	0.78
5.057	**1.9-2.1**	0.70	0.70
5.157	**2.1-2.3**	0.71	0.71

Beam Asymmetry: Method of moments

- Method of moments:

$$\Sigma = \frac{2\left(F_R\, Y_{\perp 2} - Y_{\parallel 2}\right)}{F_R P_{\parallel}\left(Y_{\perp 0} + Y_{\perp 4}\right) + P_{\perp}\left(Y_{\parallel 0} + Y_{\parallel 4}\right)}$$

$F_R = \frac{F_{\parallel}}{F_{\perp}}$: flux ratio; $Y_{\parallel,\perp 0}$, $Y_{\parallel,\perp 2}$, and $Y_{\parallel,\perp 4}$: 0, 2, and 4th moments;

$$Y_{(\perp,\parallel)0} = \sum_{i=1}^{N} 1$$

$$Y_{(\perp,\parallel)m} = \sum_{i=1}^{N} cos(m\phi_i)$$

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Optimal for low-statistics channels: no need to bin in ϕ

Beam Asymmetry: ϕ-bin method

- ϕ-bin method:

$N(\phi)_{\perp,\parallel} \sim A(\phi)F_{\perp,\parallel}(1 \pm P_{\perp,\parallel}\Sigma\cos 2(\phi+\phi_0))$ PERP, PARA distribution

$$\frac{N(\phi)_{\perp} - N(\phi)_{\parallel}}{N(\phi)_{\perp} + N(\phi)_{\parallel}} = \frac{(1-F_R) + \left(\frac{1+F_R P_R}{1+P_R}\right) 2\Sigma\bar{P}\cos 2(\phi+\phi_0)}{(1+F_R) + \left(\frac{1-F_R P_R}{1+P_R}\right) 2\Sigma\bar{P}\cos 2(\phi+\phi_0)}$$

$\bar{P} = \frac{P_{\parallel}+P_{\perp}}{2}$: mean polarization; ϕ_0: offset $P_R = \frac{P_{\parallel}}{P_{\perp}}$: polarization ratio

F_R and ϕ_0 determined from high statistics (*i.e.*single π channels)

Beam Asymmetry: ϕ-bin method

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F_R and ϕ_0 determined from high statistics (*i.e.*single π channels)

Σ is determined from the fit parameter $\Sigma\bar{P}$: need to bin in ϕ

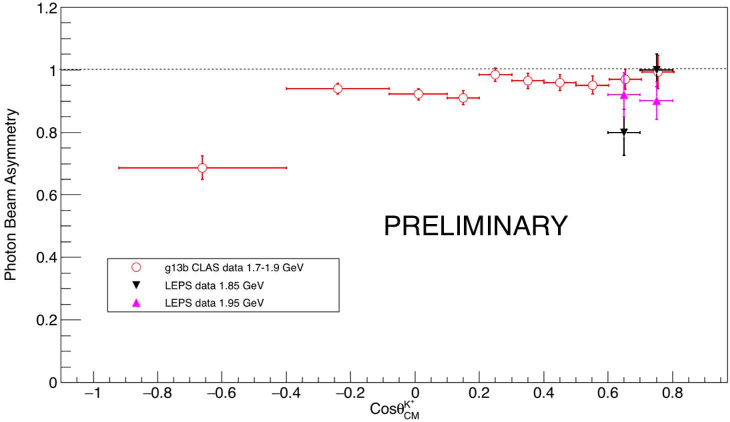
Systematics on the asymmetry

Summary of systematics in Σ

- Polarization: about 5%
- Σ extraction method: about 2%
- $\Delta\beta_{\pi^-}$ cut: $< 1\%$
- $\Delta\beta_{K^+}$ cut: $< 1\%$
- ΔT_γ cut: $< 1\%$
- Correlated background cut: $< 1\%$

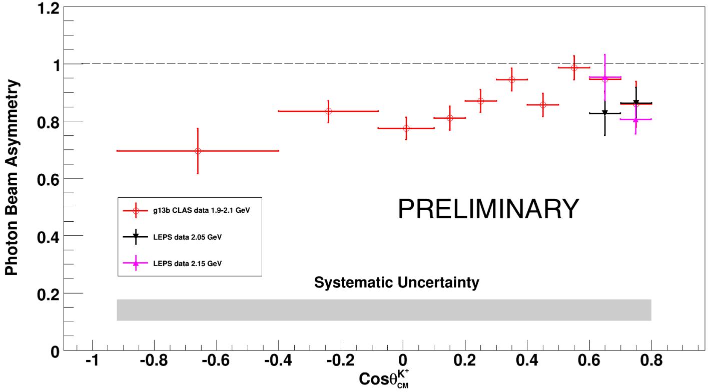
Preliminary beam asymmetry for $\gamma n \rightarrow K^+\Sigma^-$

Photon energy setting: 1.7-1.9 GeV



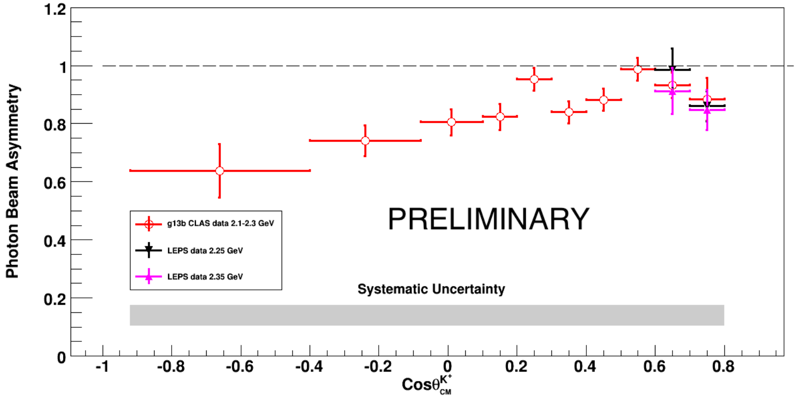
Preliminary beam asymmetry for $\gamma n \rightarrow K^+\Sigma^-$

Photon energy setting: 1.9-2.1 GeV



Preliminary beam asymmetry for $\gamma n \rightarrow K^+\Sigma^-$

Photon energy setting: 2.1-2.3 GeV



Conclusions

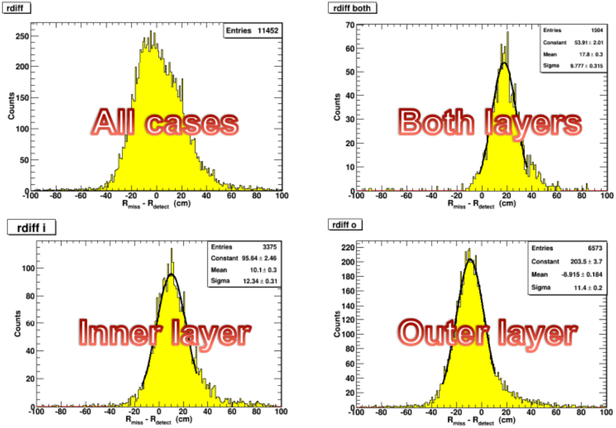
- The preliminary asymmetries indicate CLAS results agree well with LEPS results.
- The results of this work will provide new high-quality beam-asymmetry data for $N^{\star}$ resonances built on the neutron that decay into strange channels.
- These data will be important input for the global fits:
  - For instance, efforts at JLab

Thank you!

BACKUP SLIDES

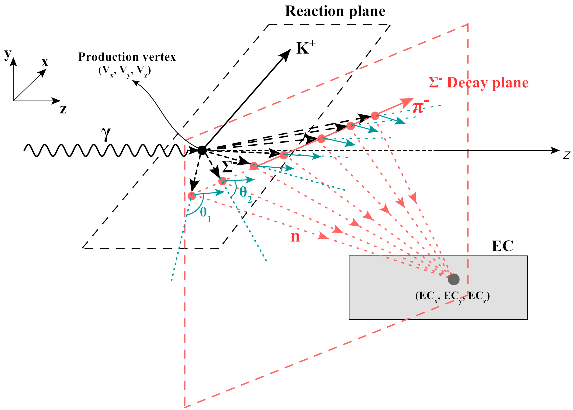
Particle-ID: neutron ($\vec{R}_{EC}$ global correction)

- Neutrons can interact anywhere inside the EC
- Systematic shift can be corrected from $\gamma d \rightarrow \pi^+\pi^- pn$



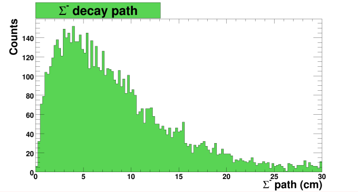
Particle-ID: neutron ($\vec{V}_n$ correction)

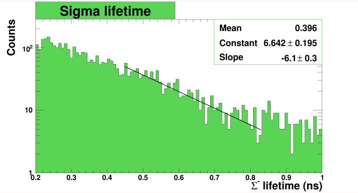
- The non-negligible mean decay path of the Σ^- requires an algorithm to correct for the decay vertex location
- Σ^- should have decayed somewhere along the π^- path



Particle-ID: neutron ($\vec{V}_n$ correction)

Σ^- path and lifetime





Σ^- vertex