Photoproduction of Λ and Σ^0 hyperons using linearly polarized photons

C.A. Paterson, **D.G. Ireland**, K. Livingston, B. McKinnon

CLAS Collaboration Meeting, February 24, 2016

Introduction

Baryon Summary Table

Figure 1: Particle Data Group listing 2014 [1]

p	$1/2^+$	****	$\Delta(1232)$	$3/2^+$	****	Σ^+	$1/2^+$	****	Ξ^0	$1/2^+$	****	Λ_c^+	$1/2^+$	****
n	$1/2^+$	****	$\Delta(1600)$	$3/2^+$	***	Σ^0	$1/2^+$	****	Ξ^-	$1/2^+$	****	$\Lambda_c(2595)^+$	$1/2^-$	***
$N(1440)$	$1/2^+$	****	$\Delta(1620)$	$1/2^-$	****	Σ^-	$1/2^+$	****	$\Xi(1530)$	$3/2^+$	****	$\Lambda_c(2625)^+$	$3/2^-$	***
$N(1520)$	$3/2^-$	****	$\Delta(1700)$	$3/2^-$	****	$\Sigma(1385)$	$3/2^+$	****	$\Xi(1620)$		*	$\Lambda_c(2765)^+$		*
$N(1535)$	$1/2^-$	****	$\Delta(1750)$	$1/2^+$	*	$\Sigma(1480)$		*	$\Xi(1690)$		***	$\Lambda_c(2880)^+$	$5/2^+$	***
$N(1650)$	$1/2^-$	****	$\Delta(1900)$	$1/2^-$	**	$\Sigma(1560)$		**	$\Xi(1820)$	$3/2^-$	***	$\Lambda_c(2940)^+$		***
$N(1675)$	$5/2^-$	****	$\Delta(1905)$	$5/2^+$	****	$\Sigma(1580)$	$3/2^-$	*	$\Xi(1950)$		***	$\Sigma_c(2455)$	$1/2^+$	****
$N(1680)$	$5/2^+$	****	$\Delta(1910)$	$1/2^+$	****	$\Sigma(1620)$	$1/2^-$	*	$\Xi(2030)$	$\geq \frac{5}{2}?$	***	$\Sigma_c(2520)$	$3/2^+$	***
$N(1685)$		*	$\Delta(1920)$	$3/2^+$	***	$\Sigma(1660)$	$1/2^+$	***	$\Xi(2120)$		*	$\Sigma_c(2800)$		***
$N(1700)$	$3/2^-$	***	$\Delta(1930)$	$5/2^-$	***	$\Sigma(1670)$	$3/2^-$	****	$\Xi(2250)$		**	Ξ_c^+	$1/2^+$	***
$N(1710)$	$1/2^+$	***	$\Delta(1940)$	$3/2^-$	**	$\Sigma(1690)$		**	$\Xi(2370)$		**	Ξ_c^0	$1/2^+$	***
$N(1720)$	$3/2^+$	****	$\Delta(1950)$	$7/2^+$	****	$\Sigma(1730)$	$3/2^+$	*	$\Xi(2500)$		*	$\Xi_c'^+$	$1/2^+$	***
$N(1860)$	$5/2^+$	**	$\Delta(2000)$	$5/2^+$	**	$\Sigma(1750)$	$1/2^-$	***				$\Xi_c'^0$	$1/2^+$	***
$N(1875)$	$3/2^-$	***	$\Delta(2150)$	$1/2^-$	*	$\Sigma(1770)$	$1/2^+$	*	Ω^-	$3/2^+$	****	$\Xi_c(2645)$	$3/2^+$	***
$N(1880)$	$1/2^+$	**	$\Delta(2200)$	$7/2^-$	*	$\Sigma(1775)$	$5/2^-$	****	$\Omega(2250)^-$		***	$\Xi_c(2790)$	$1/2^-$	***
$N(1895)$	$1/2^-$	**	$\Delta(2300)$	$9/2^+$	**	$\Sigma(1840)$	$3/2^+$	*	$\Omega(2380)^-$		**	$\Xi_c(2815)$	$3/2^-$	***
$N(1900)$	$3/2^+$	***	$\Delta(2350)$	$5/2^-$	*	$\Sigma(1880)$	$1/2^+$	**	$\Omega(2470)^-$		**	$\Xi_c(2930)$		*
$N(1990)$	$7/2^+$	**	$\Delta(2390)$	$7/2^+$	*	$\Sigma(1900)$	$1/2^-$	*				$\Xi_c(2980)$		***
$N(2000)$	$5/2^+$	**	$\Delta(2400)$	$9/2^-$	**	$\Sigma(1915)$	$5/2^+$	****				$\Xi_c(3055)$		**
$N(2040)$	$3/2^+$	*	$\Delta(2420)$	$11/2^+$	****	$\Sigma(1940)$	$3/2^+$	*				$\Xi_c(3080)$		***
$N(2060)$	$5/2^-$	**	$\Delta(2750)$	$13/2^-$	**	$\Sigma(1940)$	$3/2^-$	***				$\Xi_c(3123)$		*
$N(2100)$	$1/2^+$	*	$\Delta(2950)$	$15/2^+$	**	$\Sigma(2000)$	$1/2^-$	*				Ω_c^0	$1/2^+$	***
$N(2120)$	$3/2^-$	**				$\Sigma(2030)$	$7/2^+$	****				$\Omega_c(2770)^0$	$3/2^+$	***
$N(2190)$	$7/2^-$	****	Λ	$1/2^+$	****	$\Sigma(2070)$	$5/2^+$	*						
$N(2220)$	$9/2^+$	****	$\Lambda(1405)$	$1/2^-$	****	$\Sigma(2080)$	$3/2^+$	**				Ξ_{cc}^+		*
$N(2250)$	$9/2^-$	****	$\Lambda(1520)$	$3/2^-$	****	$\Sigma(2100)$	$7/2^-$	*						
$N(2300)$	$1/2^+$	**	$\Lambda(1600)$	$1/2^+$	***	$\Sigma(2250)$		***				Λ_b^0	$1/2^+$	***
$N(2570)$	$5/2^-$	**	$\Lambda(1670)$	$1/2^-$	****	$\Sigma(2455)$		**				$\Lambda_b(5912)^0$	$1/2^-$	***
$N(2600)$	$11/2^-$	***	$\Lambda(1690)$	$3/2^-$	****	$\Sigma(2620)$		**				$\Lambda_b(5920)^0$	$3/2^-$	***
$N(2700)$	$13/2^+$	**	$\Lambda(1710)$	$1/2^+$	*	$\Sigma(3000)$		*				Σ_b	$1/2^+$	***
			$\Lambda(1800)$	$1/2^-$	***	$\Sigma(3170)$		*				Σ_b^*	$3/2^+$	***

Baryon Spectrum (LQCD)

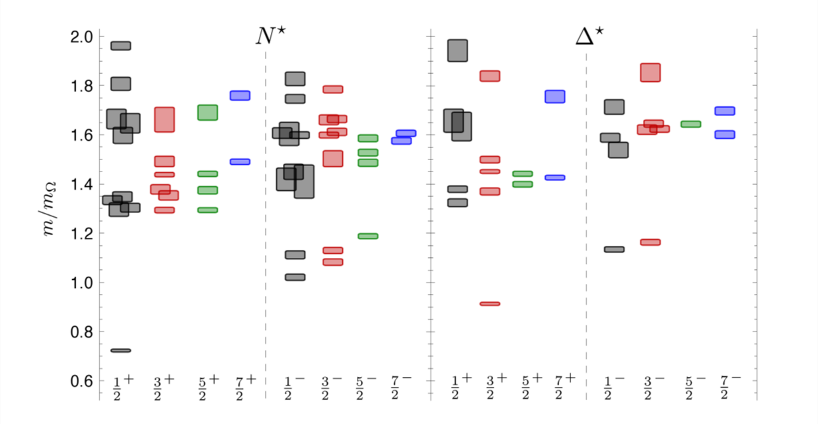


Figure 2: From [2]

Resonance Hunting

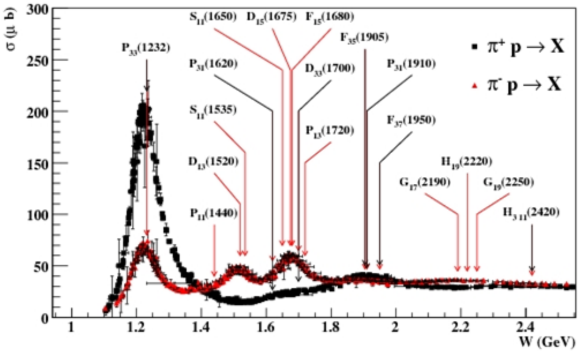


Figure 3: Most resonance information is from πN scattering

Resonance decays to other channels

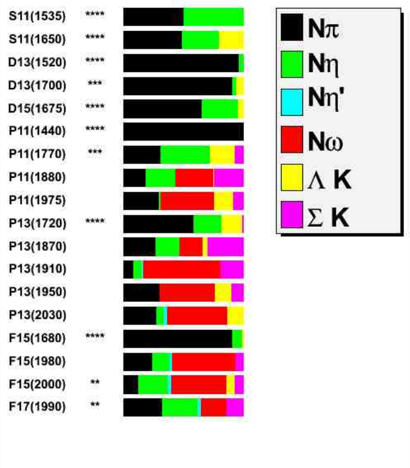


Figure 4: Some resonances predicted to decay into strange channels [3].

Meson Photoproduction

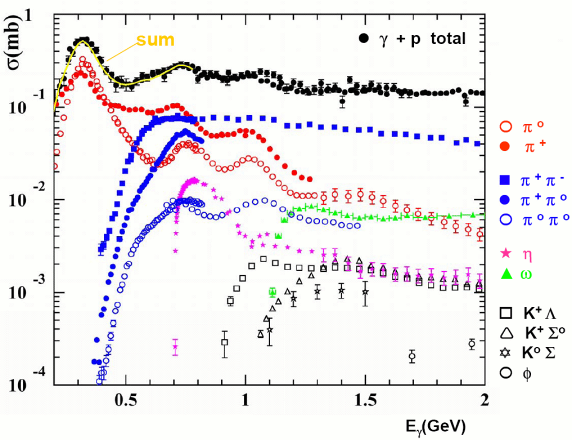


Figure 5: Comparison of photoproduction channels

Kaon Photoproduction

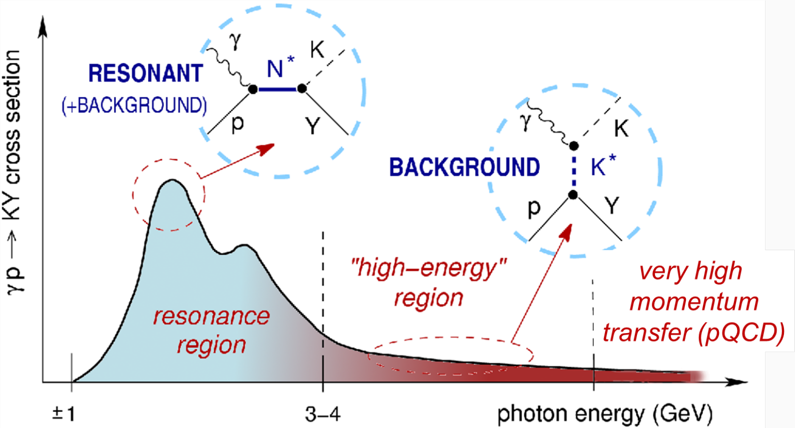


Figure 6: Energy dependence of cross section

Experiment

g8b Run Period

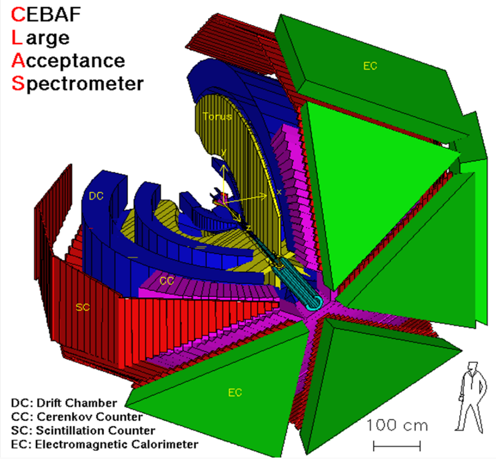


Figure 7: Standard CLAS configuration; 4.5 GeV beam; diamond radiator.

Linear Photon Polarization

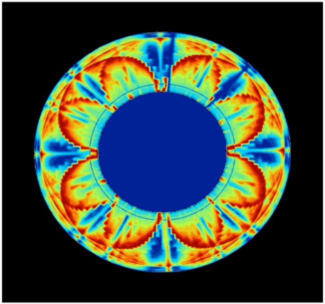


Figure 8: Alignment of diamond radiator

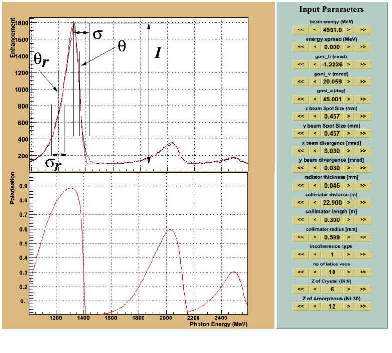


Figure 9: Fitting enhancement spectrum

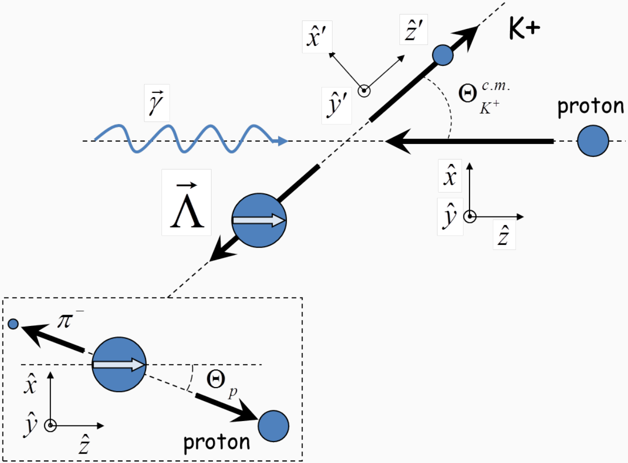


Figure 10: Taken from [4].

Event Selection

Reactions of interest proceed via the branches:

$$\vec{\gamma} p \to K^+ \Lambda \to K^+ p \pi^-$$

and

$$\vec{\gamma} p \to K^+ \Sigma^0 \to K^+ \gamma \Lambda \to K^+ \gamma p \pi^-$$

For this analysis, final state p, K^+ and if possible π^- are identified in CLAS.

Differential cross section reads

$$\begin{aligned} \frac{d\sigma}{d\Omega} &= \left(\frac{d\sigma}{d\Omega}\right)_0 \{1 - P^\gamma \Sigma \cos 2\phi + \alpha \cos \theta_x P^\gamma O_x \sin 2\phi \\ &\quad + \alpha \cos \theta_y P - \alpha \cos \theta_y P^\gamma T \cos 2\phi + \alpha \cos \theta_z P^\gamma O_z \sin 2\phi\} \,. \end{aligned}$$

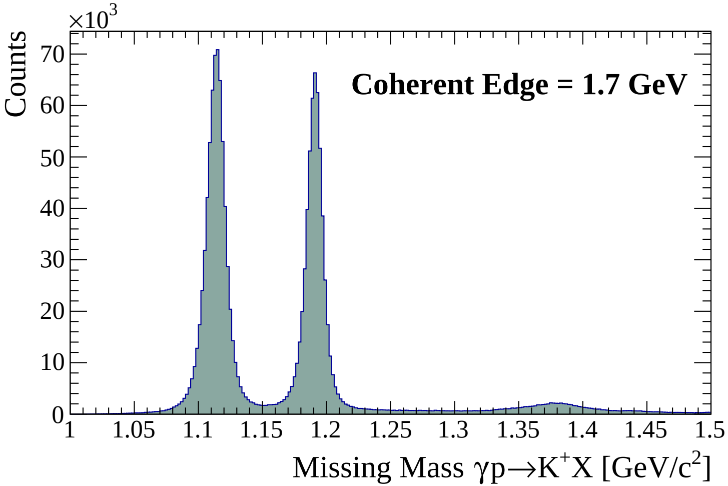
Data Selection and Processing

Event Selection Cuts

Applied Cut	Details	Events
Initial skim	(1 proton) and (1 K^+) and (0 or 1 π^-) and (0 or 1 γ)	6.03×10^7
Vertex cut	$-40 < z < 0$ cm	4.71×10^7
γp and γK^+ vertex timing	Momentum dependent criterion	1.94×10^7
Minimum momentum cut	p_p and $p_{K^+} > 300$ MeV/c	1.59×10^7
Fiducial cut	$> 4°$ in azimuthal angle from the sector edges	1.41×10^7
Pion mis-ID as kaon	Assume $p(\gamma, \pi^+ p)\pi^-$, then missing mass $(\pi^+ p) > 0.17\,\mathrm{GeV/c^2}$	9.36×10^6
Invariant Mass $p\pi^-$	$1.06 < M(p\pi^-) < 1.2\,\mathrm{GeV/c^2}$	7.06×10^6

Table 1: [More details and plots in analysis note]

Selected Events



g8 Event Coverage

Figure 12: $\vec{\gamma}p \to K\vec{\Lambda}$

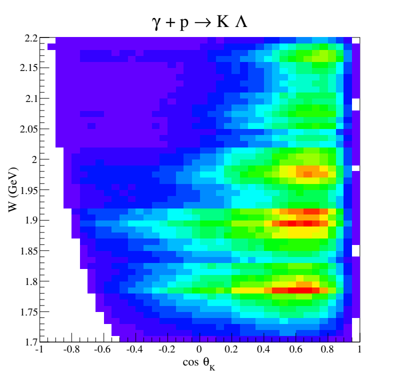
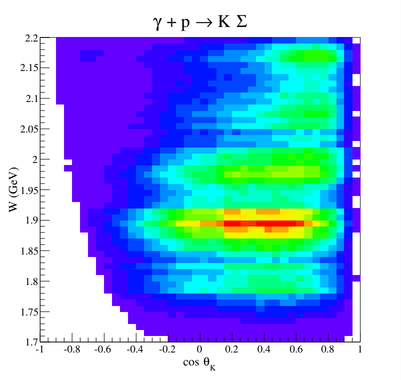


Figure 13: $\vec{\gamma}p \to K\vec{\Sigma}^0$



Linear Photon Polarization

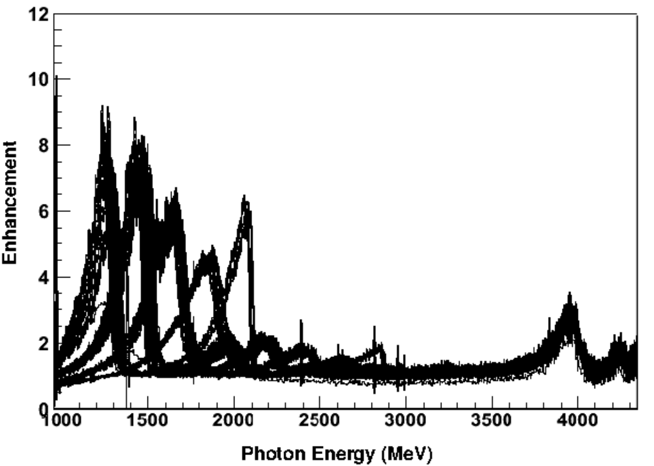


Figure 14: Coherent peak position during g8

Extracting Observables

Measuring Asymmetries

The cross section contains five observables:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \Big\{1 - P^\gamma \, \Sigma \, \cos 2\phi + \alpha \cos\theta_x P^\gamma \, O_x \, \sin 2\phi$$
$$+\alpha \cos\theta_y \, P \, - \alpha \cos\theta_y P^\gamma \, T \, \cos 2\phi + \alpha \cos\theta_z P^\gamma \, O_z \, \sin 2\phi\Big\}.$$

Separate parts dependent and independent of photon linear polarization (each event labelled by i):

$$f_i = 1 + \alpha \cos\theta_{y,i} \, P$$
$$g_i = \left(\Sigma + \alpha \cos\theta_{y,i} \, T\right) \cos 2\varphi_i + \alpha \left(\cos\theta_{x,i} \, O_x + \cos\theta_{z,i} \, O_z\right) \sin 2\varphi_i.$$

Measuring Asymmetries

Define an estimator of asymmetry for a $\{W, \cos\theta_K\}$ bin:

$$\hat{a}_i = \frac{f_i \Delta L + (1-\beta) P^\gamma g_i}{f_i + (1-\beta) P^\gamma g_i \Delta L}.$$

Likelihood is

$$\mathcal{L}_i = \frac{1}{Z} (1 + \hat{a}_i)^{N_\perp = 1(0)} (1 - \hat{a}_i)^{N_\parallel = 0(1)} = \frac{1}{2} (1 \pm \hat{a}_i),$$

Maximize

$$\mathcal{L}_{total} = \prod_i \mathcal{L}_i$$

by varying $\{\Sigma, T, O_x, O_z\} \in [-1, +1]$.

Comparisons

Recoil Polarization

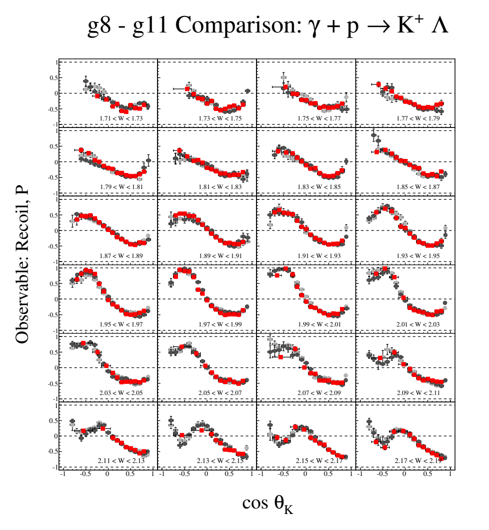
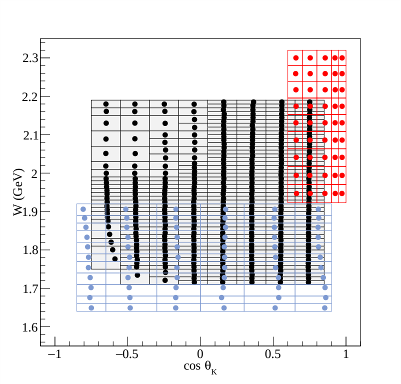


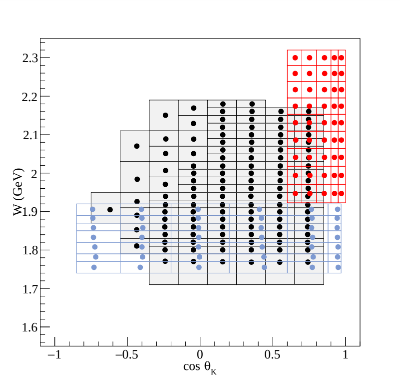
Figure 15: Grey - g11 [5]; Red - g8

g8 Kinematic Coverage

Figure 16: $\vec{\gamma}p \to K\vec{\Lambda}$. Red - LEPS; Blue - GRAAL; Black - CLAS

Figure 17: $\vec{\gamma}p \to K\vec{\Sigma}^0$. Same symbols as in previous plot.





GRAAL Beam Asymmetry

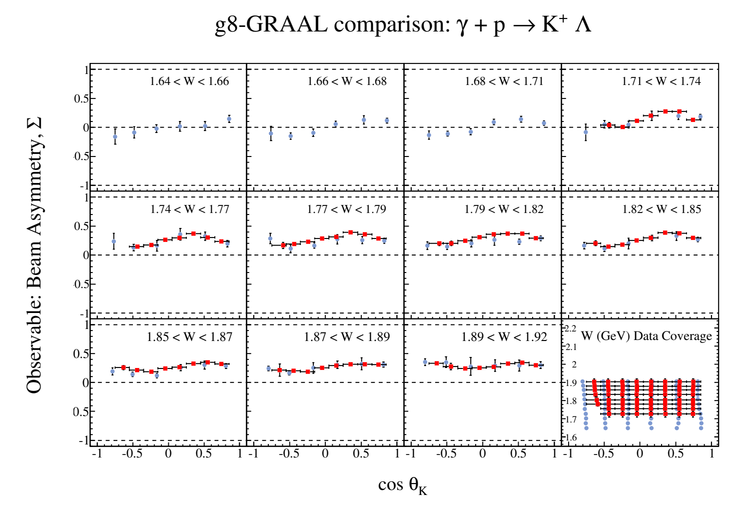


Figure 18: Blue - GRAAL [6]; Red - g8

GRAAL Target Asymmetry

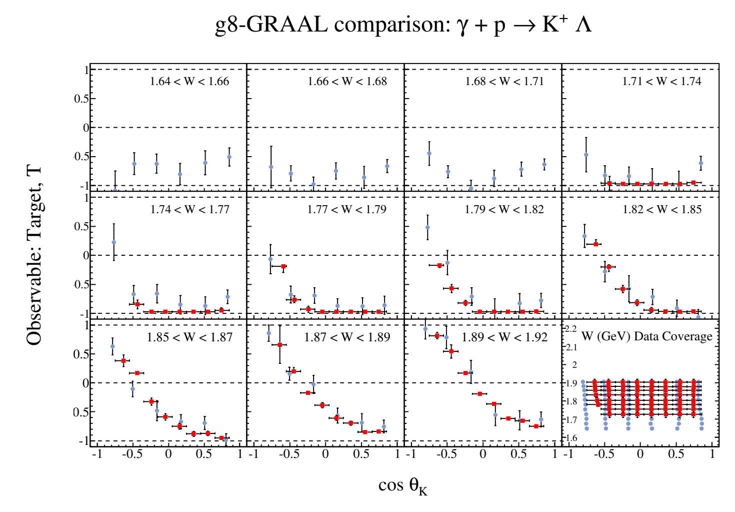


Figure 19: Blue - GRAAL [7]; Red - g8

GRAAL Beam Asymmetry

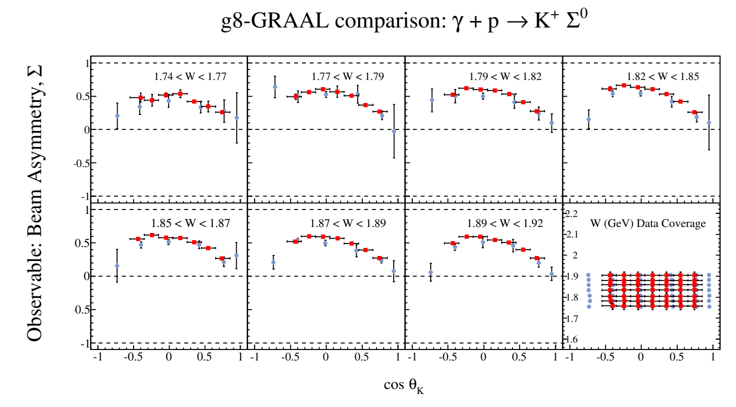


Figure 20: Blue - GRAAL [6]; Red - g8

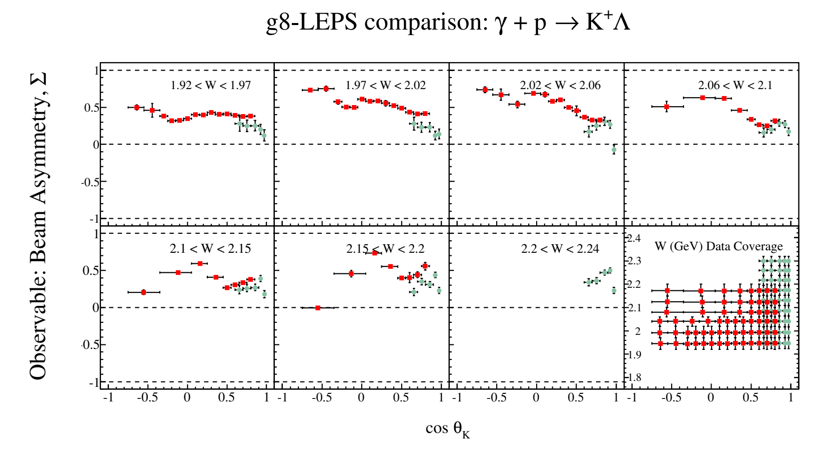


Figure 21: Green - LEPS [8]; Red - g8

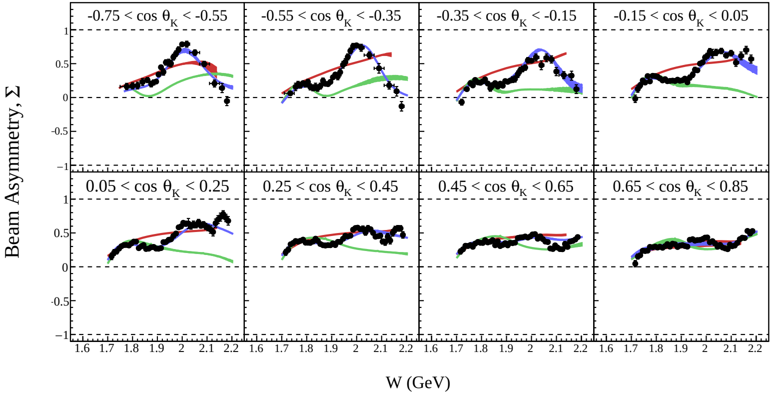
Results

g8 Results

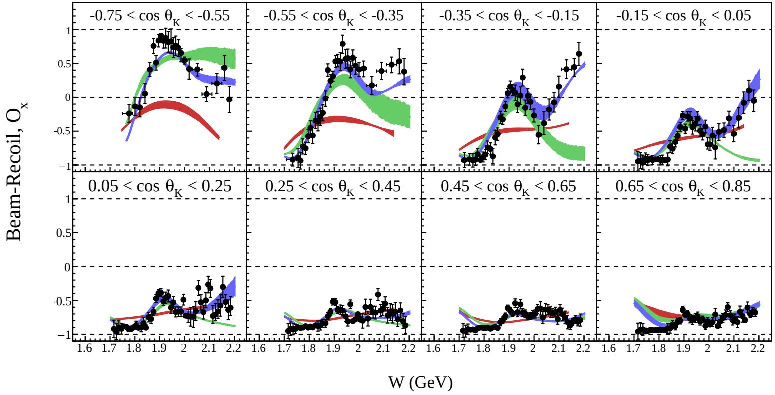
Explanation of symbols and colors:

- Data Points: CLAS g8 results;
- Red: ANL-Osaka calculations [9] (prediction);
- Green: Bonn-Gatchina 2014 fit [10] (BG2014-02, prediction);
- Blue: Bonn-Gatchina full re-fit with CLAS g8 results;
- Calculation bands indicate standard deviation of calculations within angular bin.

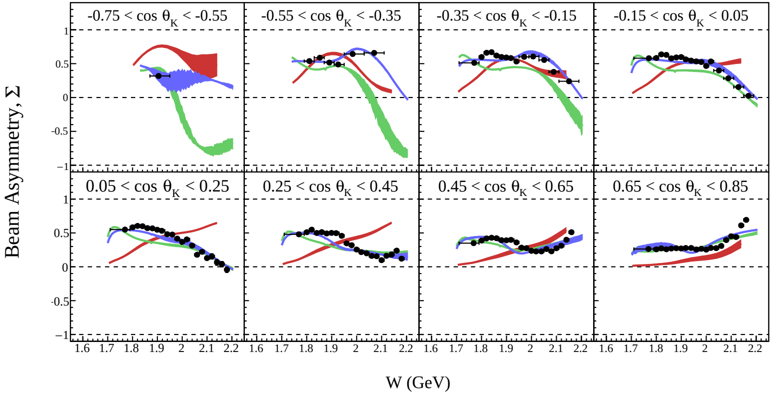
$\vec{\gamma} p \to K^+ \vec{\Lambda}$: Beam Asymmetry



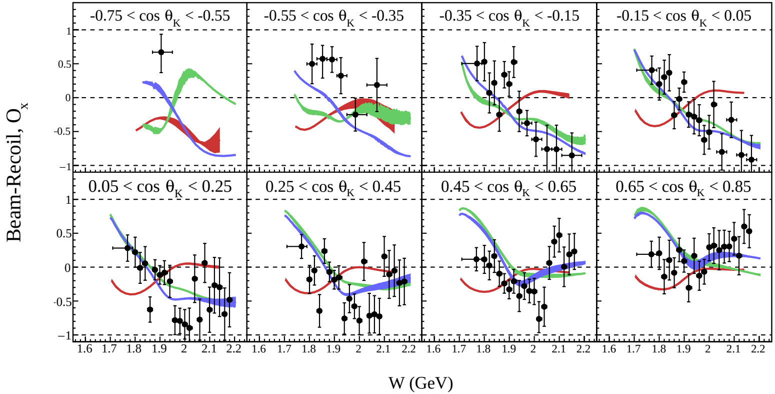
$\vec{\gamma} p \rightarrow K^+ \vec{\Lambda}$: Beam-Recoil, O_x



$\vec{\gamma}p \to K^+\vec{\Sigma}^0$: Beam Asymmetry



$\vec{\gamma} p \to K^+ \vec{\Sigma}^0$: Beam-Recoil, O_x



Bonn-Gatchina PWA

1 Initial fit

We start from the solution BG2014-02. The first fit produced a rather bad description of the new data. Then the rather large weight was introduced for these data and all channels with 2 body final states were refitted. The couplings to the three body final states were fixed while all other parameters were optimized free. In this case we can get a rather good description of the new data except O_z for $\gamma p \to k\Sigma$ (see Fig. 10). The total χ^2 was found to be 55370 (33988 points). However the description of some observables (especially for the $\gamma p \to \pi^+ n$ channel) is notably deteriorated. Then we added one resonance in the region 2.1-2.3 GeV.

	Total	cl09	3200	P	T	Cx	Oz
			$\gamma p \to \pi^+ n$			$\gamma p \to K\Sigma$	
BG2014		1.36	1.30	1.84	3.01	2.58	
Fit	55370	1.78	1.71	2.36	3.78	3.32	2.56
S_{11}	55050	1.92	1.75	2.43	3.79	3.35	2.55
D_{15}	54596	1.58	1.56	2.30	3.61	3.37	2.49
G_{17}	55084	1.90	1.77	2.53	3.76	3.42	2.69
G_{19}	55308	1.78	1.71	2.38	3.78	3.32	2.52
S_{31}	55284	1.82	1.72	2.40	3.81	3.27	2.44
D_{33}	54888	1.66	1.81	2.53	3.76	3.12	2.20
D_{35}	54958	1.85	1.79	2.52	3.73	3.32	2.05
G_{37}	55267	1.72	1.71	2.39	3.80	3.29	2.52
G_{39}	54966	1.57	1.75	2.42	3.58	3.31	2.53
P_{11}	55107	1.63	1.83	2.52	3.62	3.28	2.53
F_{15}	54903	1.80	1.84	2.49	3.73	3.52	2.61
P_{31}	55406	1.77	1.70	2.37	3.75	3.34	2.63
P_{33}	55278	1.72	1.71	2.37	3.81	3.28	2.47
F_{35}	55114	1.81	1.78	2.39	3.76	3.33	2.69
F_{37}	55233	1.75	1.73	2.34	3.66	3.27	2.53
H_{39}	55309	1.78	1.73	2.39	3.75	3.30	2.52
$S_{11}+$							
D_{13}	54821	1.78	1.77	2.46	3.77	3.26	2.39
D_{15}	54539	1.67	1.65	2.34	3.66	3.48	2.59
G_{17}	54953	1.77	1.75	2.40	3.83	3.40	2.51
D_{35}	54732	1.99	1.73	2.53	3.77	3.17	2.26
G_{37}	54852	1.81	1.71	2.51	3.86	3.59	2.45
P_{11}	54933	1.79	1.84	2.52	3.73	3.40	2.52
F_{15}	54760	1.98	1.84	2.42	3.72	3.59	2.64
P_{33}	54865	1.87	1.70	2.55	3.68	3.22	2.51
F_{35}	54526	1.74	1.84	2.63	3.66	3.60	2.65
F_{37}	55049	1.78	1.74	2.24	3.74	3.31	2.47
$D_{13}+$							
D_{15}	54340	1.39	1.59	2.29	3.75	3.34	2.37
S_{31}	54924	1.61	1.74	2.59	3.73	3.40	2.42
D_{35}	54585	1.93	1.88	2.51	3.69	3.15	2.19
G_{37}	54524	1.95	1.82	2.60	3.69	3.24	2.30
P_{11}	54765	1.69	2.06	2.71	3.66	3.19	2.33
F_{15}	54664	1.78	1.78	2.61	3.89	3.29	2.36

	Total	cl09	3200	P	T	Cx	Oz
			$\gamma p \to \pi^+ n$			$\gamma p \to K\Sigma$	
BG2014		1.36	1.30	1.84	3.01	2.58	
Fit	55370	1.78	1.71	2.36	3.78	3.32	2.56
$D_{15}+$							
G_{17}	54441	1.38	1.52	2.37	3.87	3.38	2.57
G_{19}	54436	1.45	1.58	2.37	3.68	3.35	2.54
D_{33}	54285	1.52	1.64	2.55	3.48	3.21	2.22
D_{35}	54190	1.53	1.65	2.39	3.70	3.31	2.16
G_{37}	54224	1.48	1.62	2.39	3.56	3.45	2.51
G_{39}	54304	1.73	1.72	2.52	3.27	3.36	2.56
P_{11}	54427	1.45	1.77	2.59	3.74	3.22	2.41
F_{15}	54056	1.71	1.65	2.45	3.68	3.43	2.57
H_{19}	54505	1.45	1.55	2.29	3.58	3.29	2.49
P_{33}	54493	1.28	1.62	2.31	3.68	3.32	2.55
F_{35}	54144	1.41	1.61	2.21	3.82	3.25	2.42
F_{37}	54365	1.49	1.62	2.27	3.65	3.23	2.47
$G_{17}+$							
G_{19}	54784	1.74	1.75	2.54	3.88	3.41	2.72
S_{31}	55163	1.81	1.72	2.38	3.77	3.27	2.44
D_{33}	54464	1.74	1.86	2.54	3.64	3.07	2.20
D_{35}	54760	2.00	1.77	2.59	3.78	3.08	2.59
G_{37}	54782	1.84	1.71	2.50	3.79	3.50	2.55
G_{39}	54618	1.63	1.78	2.50	3.49	3.43	2.67
P_{11}	54847	1.65	1.87	2.50	3.59	3.29	2.54
F_{15}	54521	1.91	1.69	2.41	3.90	3.45	2.61
H_{19}	54822	1.85	1.73	2.56	3.62	3.27	2.49
P_{33}	54891	1.80	1.75	2.41	3.79	3.27	2.49
F_{35}	54645	1.88	1.79	2.48	3.69	3.44	2.68
F_{37}	54525	1.55	1.84	2.57	3.77	3.33	2.76
H_{39}	54733	1.47	1.79	2.57	3.84	3.39	2.73
$G_{19}+$							
S_{31}	54985	1.84	1.77	2.54	3.84	3.34	2.60
D_{33}	54576	1.67	1.80	2.60	3.56	3.07	2.28
D_{35}	54964	1.83	1.69	2.54	3.68	3.20	2.65
G_{39}	54795	1.55	1.75	2.43	3.48	3.37	2.55
P_{11}	55189	1.66	1.81	2.46	3.73	3.32	2.49
F_{15}	54789	1.91	1.79	2.51	3.86	3.49	2.66
H_{19}	54963	1.90	1.75	2.49	3.56	3.33	2.52
P_{33}	54968	1.51	1.73	2.47	3.86	3.38	2.62
F_{35}	54859	1.74	1.71	2.39	3.78	3.47	2.65
F_{37}	54934	1.76	1.71	2.42	3.67	3.12	2.15
H_{39}	55274	1.83	1.72	2.38	3.71	3.30	2.55
$S_{31}+$							
D_{33}	54870	1.68	1.85	2.54	3.72	3.16	2.25
D_{35}	54957	1.99	1.74	2.53	3.83	3.02	2.44
P_{11}	55047	1.69	1.90	2.51	3.62	3.19	2.42
$D_{33}+$							
D_{35}	54681	1.69	1.72	2.57	3.82	3.07	2.17
G_{37}	54453	1.83	1.83	2.54	3.69	3.03	2.09
G_{39}	54633	1.64	1.79	2.47	3.69	3.20	2.32
P_{11}	54684	1.63	1.97	2.64	3.49	3.09	2.26
F_{15}	54478	1.77	1.91	2.66	3.70	3.31	2.34
H_{19}	54679	1.76	1.81	2.71	3.74	3.14	2.22
P_{33}	54815	1.51	1.85	2.55	3.85	3.09	2.25
F_{35}	54760	1.65	1.81	2.43	3.58	3.15	2.31
F_{37}	54732	1.54	1.86	2.48	3.54	2.99	2.14
H_{39}	54875	1.66	1.80	2.53	3.78	3.12	2.18

	Total	cl09	3200	P	T	Cx	Oz
			$\gamma p \to \pi^+ n$			$\gamma p \to K\Sigma$	
BG2014		1.36	1.30	1.84	3.01	2.58	
Fit	55370	1.78	1.71	2.36	3.78	3.32	2.56
$D_{35}+$							
G_{37}	54476	2.25	1.75	2.70	3.67	2.88	2.16
G_{39}	54352	1.60	1.70	2.56	3.47	2.98	2.53
P_{11}	54398	1.42	1.57	2.20	3.55	3.21	2.49
F_{15}	54525	2.09	1.85	2.59	3.85	2.94	2.40
H_{19}	54682	1.98	1.71	2.73	3.87	2.99	2.47
P_{33}	54398	1.42	1.57	2.20	3.55	3.21	2.49
F_{35}	54543	2.07	1.80	2.54	3.70	3.02	2.47
F_{37}	54685	1.86	1.89	2.48	3.44	2.88	2.53
H_{39}	54790	2.00	1.77	2.54	3.65	3.01	2.47
$P_{11}+$							
H_{19}	54489	1.42	1.82	2.94	3.84	3.23	2.48
P_{31}	54999	1.74	1.91	2.54	3.61	3.21	2.48
P_{33}	54795	1.63	1.97	2.69	3.66	3.22	2.42
F_{35}	54734	1.61	1.93	2.60	3.56	3.19	2.38
$F_{15}+$							
P_{33}	54398	1.42	1.57	2.20	3.55	3.21	2.49
F_{35}	54568	1.75	1.80	2.36	3.85	3.35	2.63
F_{37}	54725	1.75	1.92	2.59	3.51	3.36	2.59
$P_{33}+$							
F_{35}	54588	1.57	1.89	2.48	3.95	3.46	2.66
F_{37}	54985	1.58	1.82	2.43	3.72	3.33	2.63

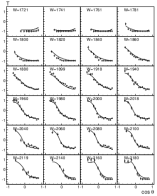


Fig. 2. Description of the target asymmetry on $\gamma p \to K\Lambda$.

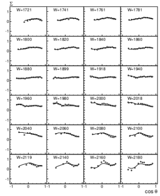


Fig. 1. Description of the beam asymmetry on $\gamma p \to K\Lambda$.

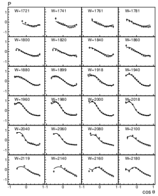


Fig. 3. Description of the recoil asymmetry on $\gamma p \to K\Lambda$.

Bonn-Gatchina PWA

Significant studies carried out [11]:

- *New* fit to data from all two-body final states (33988 points)
- Couplings to three-body final states were kept fixed
- Additional weighting (*sic.*) given to new data
- BG2014-02 fit had total χ^2 of 55370 with new data
- Added one or two new resonances in region 2.1–2.2 GeV
- Many combinations show χ^2 improvement, none significant
- Best combination: $N^\star \left(\frac{3}{2}^+\right)$ and $N^\star \left(\frac{5}{2}^+\right)$ (χ^2 = 54190)

Fierz Identity Comparison

Assuming pseudoscalar meson photoproduction, we have the constraint [12]:

$$O_x^2 + O_z^2 + C_x^2 + C_z^2 + \Sigma^2 - T^2 + P^2 = 1$$

Plot g8 combination:

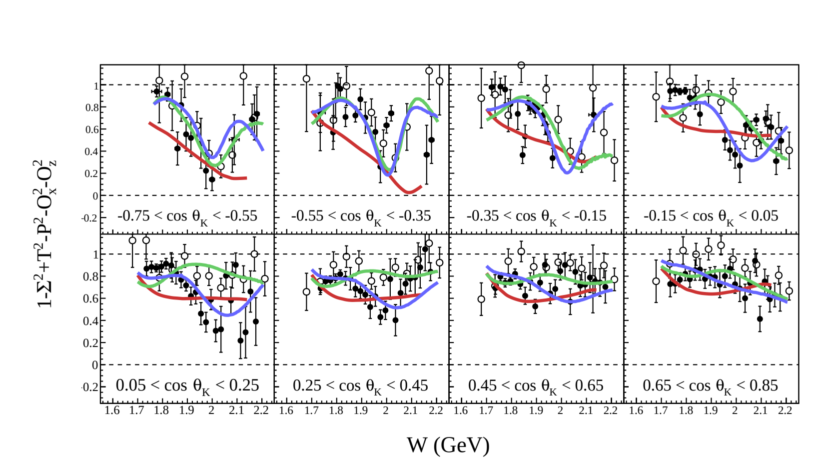
$$1 - O_x^2 - O_z^2 - \Sigma^2 + T^2 - P^2$$

against g1c combination:

$$C_x^2 + C_z^2$$

Fierz Identity Comparison

Figure 22: Open circles - g1c [4]; Filled - g8



Conclusion

Summary

- CLAS g8 run period results
- Measurements of polarization observables for the reactions $\vec{\gamma}p \to K^+\Lambda$ and $\vec{\gamma}p \to K^+\Sigma^0$
- Energy range $1.71\,\mathrm{GeV} < W < 2.19\,\mathrm{GeV}$;
- Angular range $-0.75 < \cos\theta_K < +0.85$.
- Observables extracted: beam asymmetry Σ, target asymmetry T, beam-recoil O_x and O_z.
- Extends kinematic reach and accuracy of $\vec{\gamma}p \to K^+\Lambda$ data
- New data on T, O_x and O_z data for $\vec{\gamma}p \to K^+\Sigma^0$
- Bonn-Gatchina model analysis: some evidence of resonances beyond the 2014 solution

Backup Slides

References I

K. A. Olive and P. D. Group,
Chinese Phys. C 38, 090001 (2014).

R. G. Edwards, J. J. Dudek, D. G. Richards, and S. J. Wallace,
Phys. Rev. D 84, 074508 (2011).

S. Capstick and W. Roberts,
Phys. Rev. D 58, 074011 (1998).

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

M. E. McCracken *et al.*,
Phys. Rev. C 81, 025201 (2010).

A. Lleres *et al.*,
Eur. Phys. J. A 31, 79 (2007).

References II

A. Lleres *et al.*,
Eur. Phys. J. A 39, 149 (2009).

R. G. T. Zegers *et al.*,
Phys. Rev. Lett. 91, 092001 (2003).

H. Kamano, S. X. Nakamura, T.-S. H. Lee, and T. Sato,
Phys. Rev. C 88, 035209 (2013).

E. Gutz *et al.*,
Eur. Phys. J. A 50, 1 (2014).

A. V. Sarantsev and E. Klempt,
Private communication, 2015.

A. M. Sandorfi, S. Hoblit, H. Kamano, and T.-S. H. Lee,
J. Phys. G 38, 053001 (2011).

References III

B. Dey *et al.*,
Phys. Rev. C 82, 025202 (2010).

Linear Photon Polarization

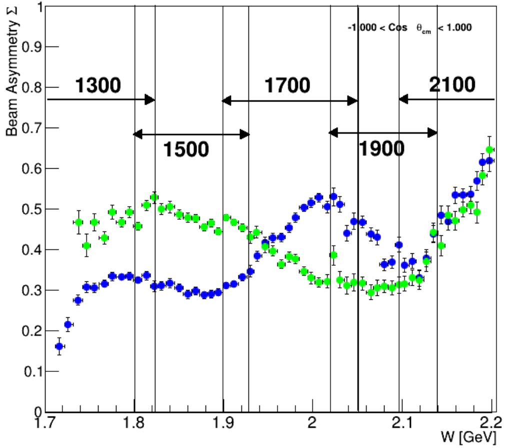


Figure 23: Photon beam asymmetry Σ for $K\Lambda$ (blue) and $K\Sigma^0$ (green)

Background

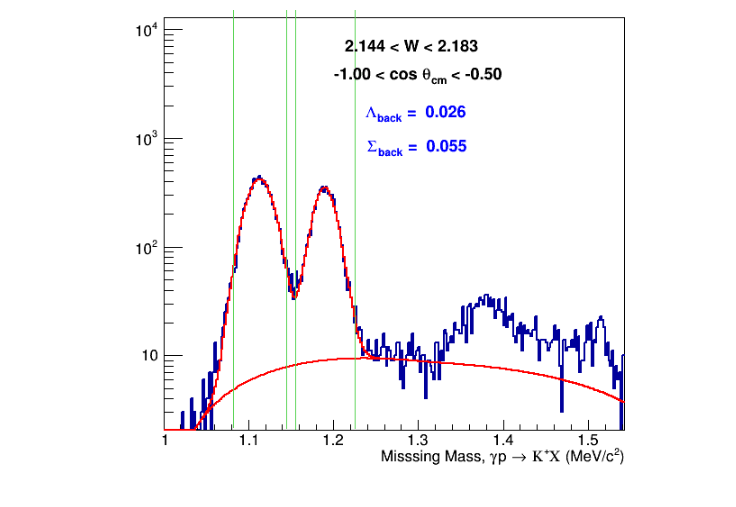


Figure 24: Determining background fraction

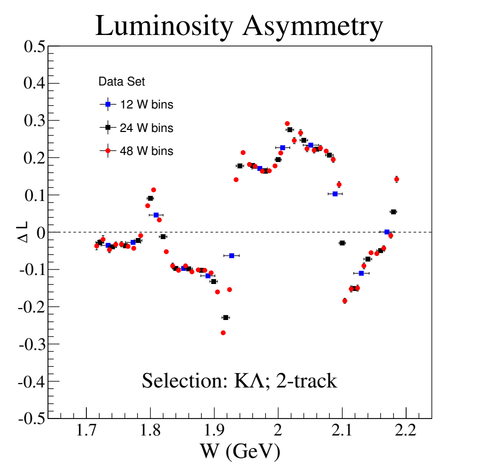


Figure 25: Depends on on W

Definition of luminosity asymmetry:

$$\Delta L = \frac{L_{\perp} - L_{\parallel}}{L_{\perp} + L_{\parallel}}$$

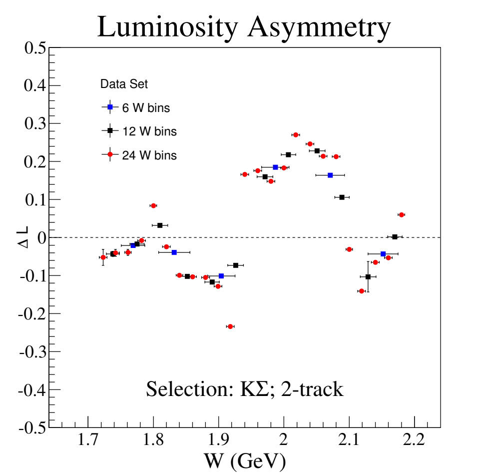


Figure 26: Depends on on W

Measuring Asymmetries

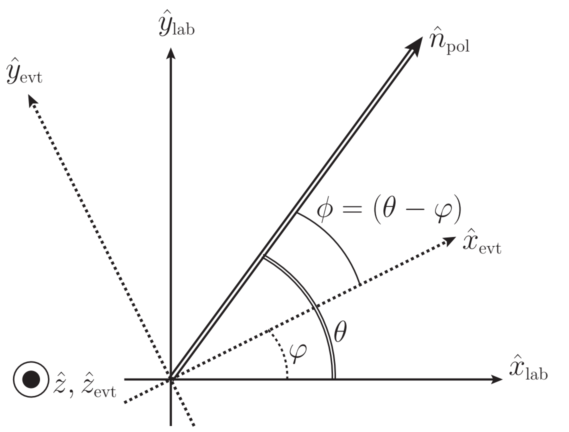


Figure 27: Definitions of angles

Recoil Polarization

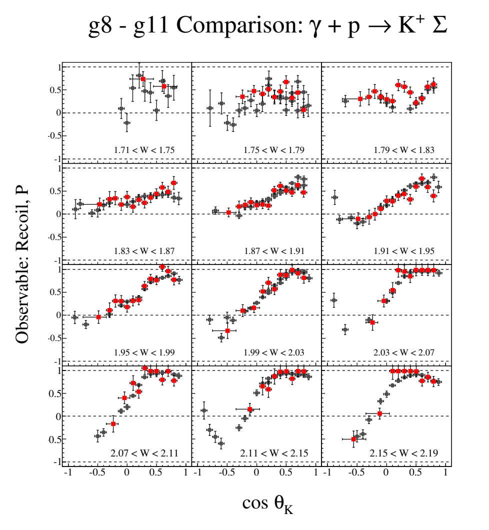


Figure 28: Grey - g11 [13]; Red - g8

GRAAL Beam-Recoil, O_x

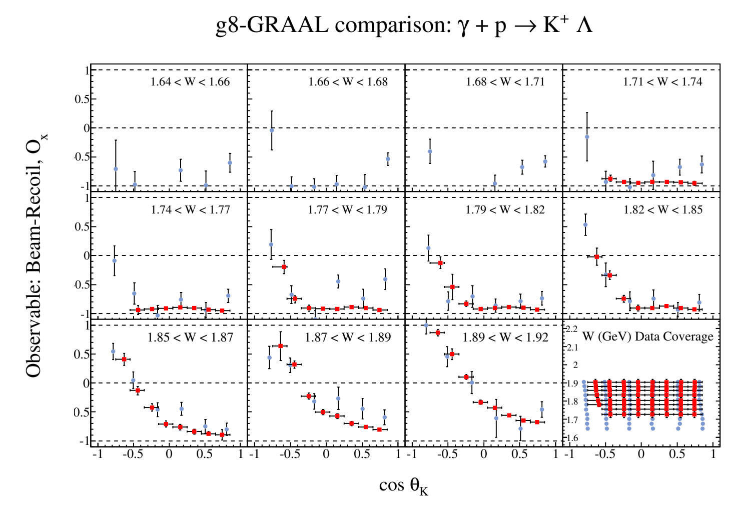


Figure 29: Blue - GRAAL; Red - g8

GRAAL Beam-Recoil, O_z

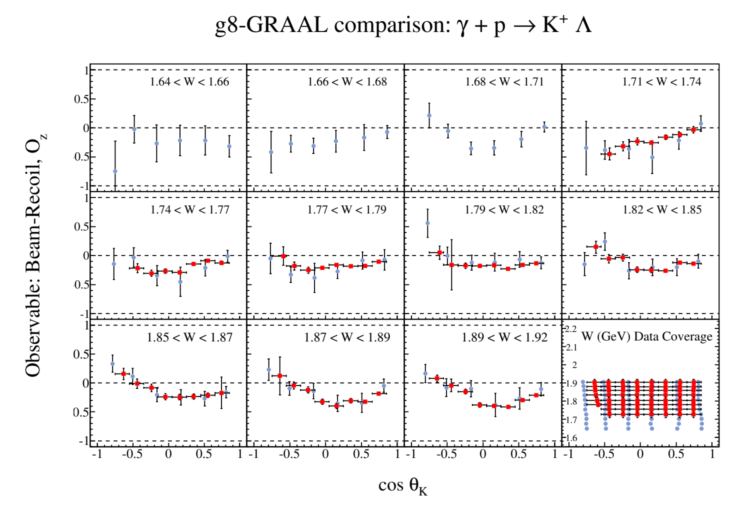


Figure 30: Blue - GRAAL; Red - g8

LEPS Beam Asymmetry

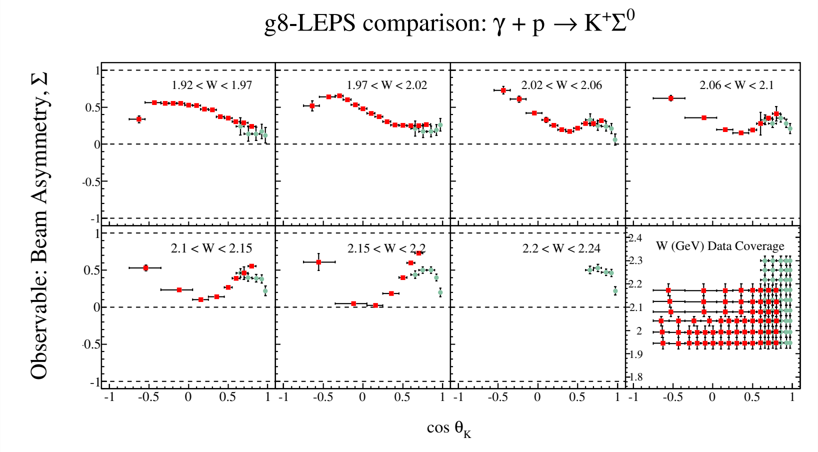
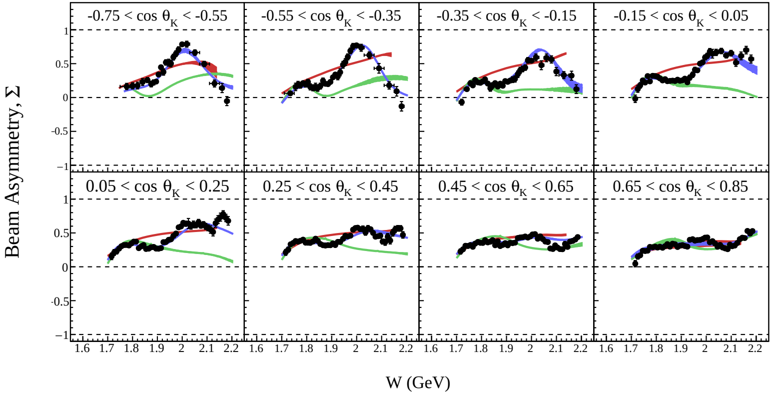
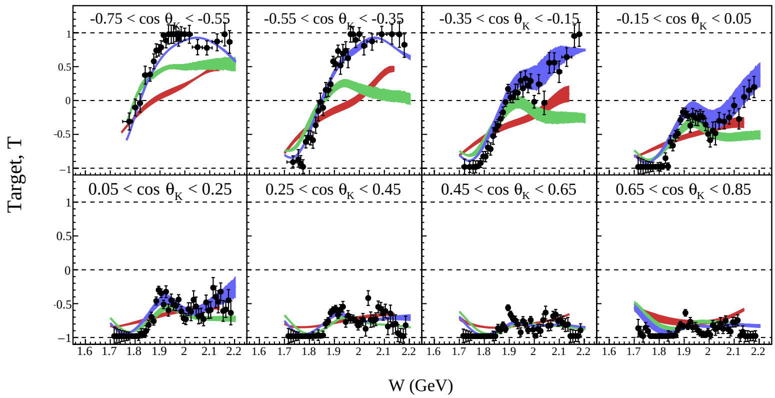


Figure 31: Green - LEPS; Red - g8

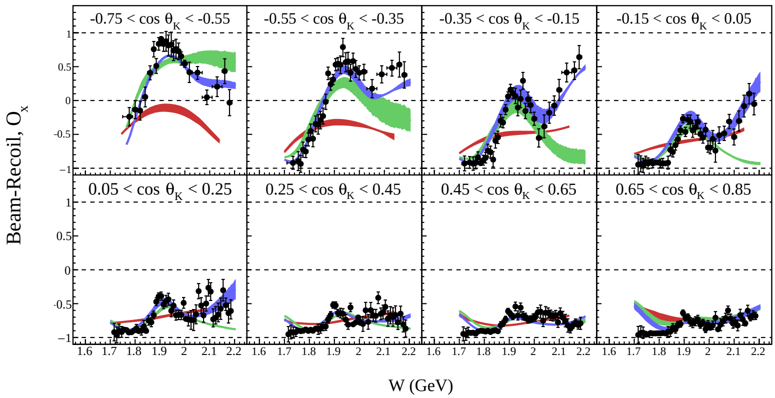
$\vec{\gamma}p \rightarrow K^+\vec{\Lambda}$: Beam Asymmetry



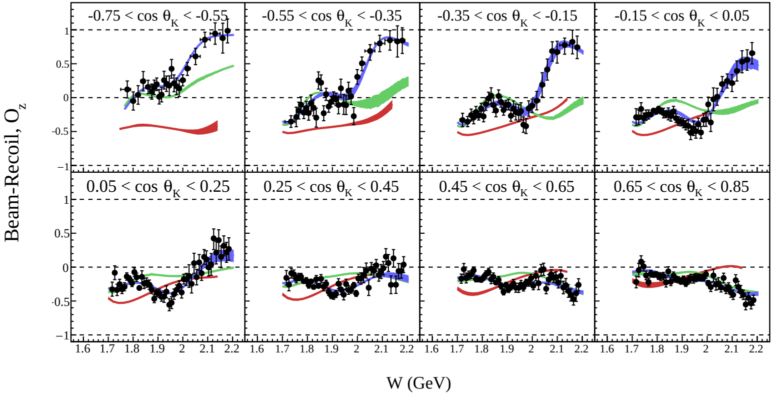
$\vec{\gamma} p \to K^+ \vec{\Lambda}$: Target Asymmetry



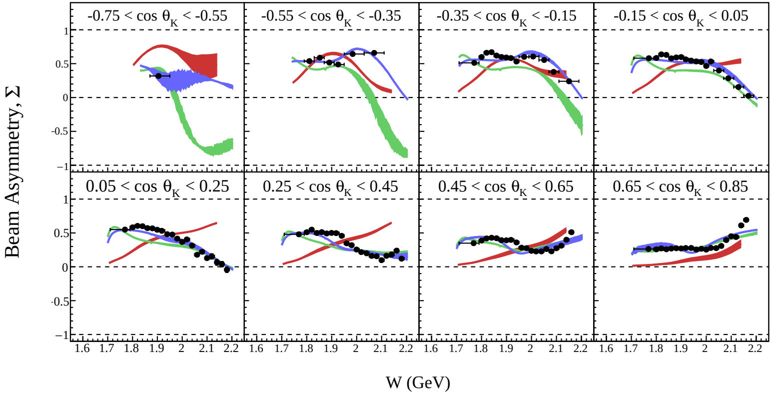
$\vec{\gamma}p \to K^+\vec{\Lambda}$: Beam-Recoil, O_x



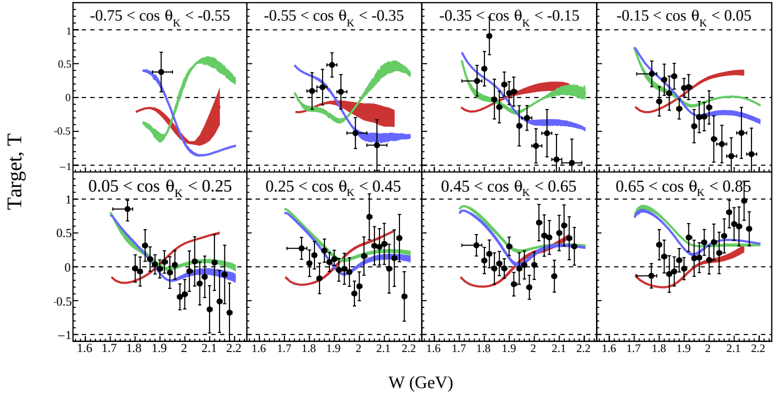
$\vec{\gamma} p \to K^+ \vec{\Lambda}$: Beam-Recoil, O_z



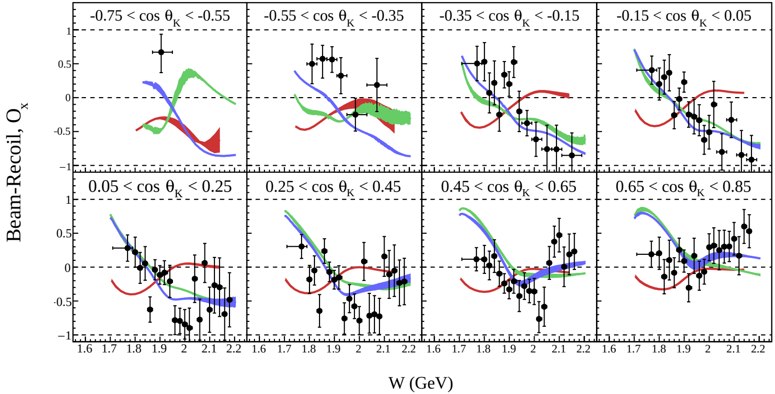
$\vec{\gamma} p \to K^+ \vec{\Sigma}^0$: Beam Asymmetry



$\vec{\gamma} p \to K^+ \vec{\Sigma}^0$: Target Asymmetry



$\vec{\gamma} p \to K^+ \vec{\Sigma}^0$: Beam-Recoil, O_x



$\vec{\gamma} p \rightarrow K^+ \vec{\Sigma}^0$: Beam-Recoil, O_z