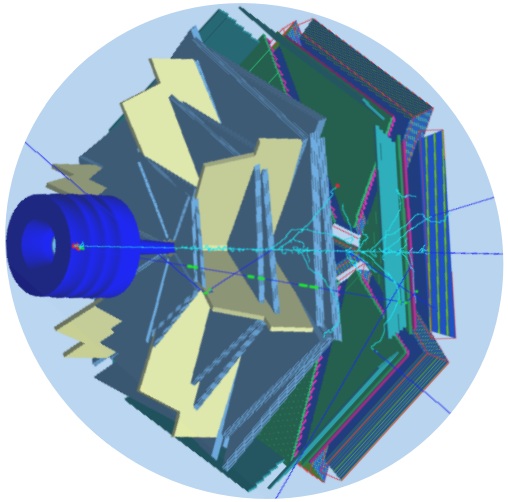
UPDATE ON KY ELECTROPRODUCTION

ANALYSES FROM RG-A AND RG-K DATASETS

Daniel S. Carman – CLAS Collaboration Meeting - July 23, 2020

CLAS/CLAS12 N* Program

The N* program is one of the key physics foundations of Hall B



- CLAS & CLAS12 were designed to measure cross sections and spin observables over a broad kinematic range for exclusive reaction channels:

$$\pi N,\ \omega N,\ \phi N,\ \eta N,\ \eta' N,\ \pi\pi N,\ K\Lambda,\ K^*\Lambda,\ K\Lambda^*$$

- The goal is to probe the *spectrum* of N* states and their *structure*

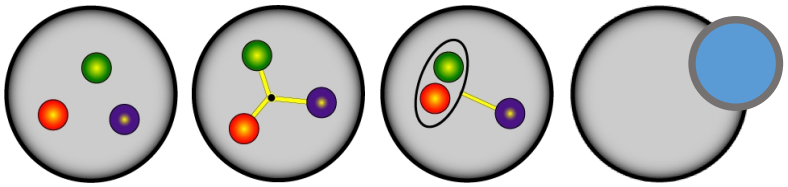
  - Probe underlying degrees of freedom via studies of the Q^2 evolution of the electroproduction amplitudes

    - The N* electrocouplings do not depend on how the states decay but different final states have different hadronic decay parameters and backgrounds

      - Agreement offers model-independent support for findings

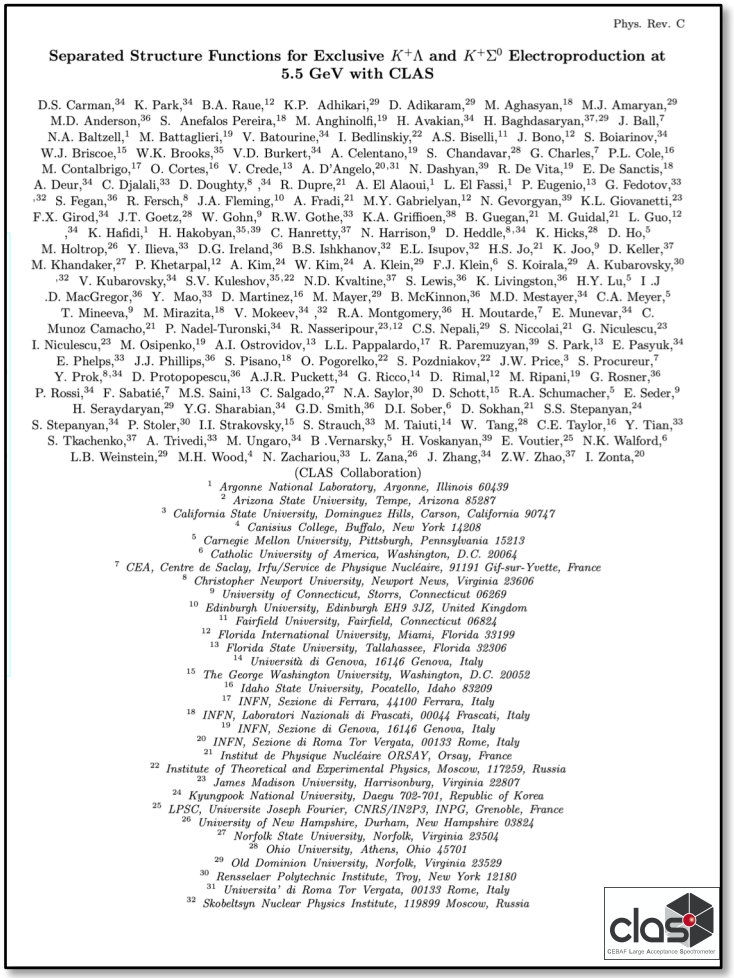
        - Data can unravel the spectrum of contributing states in complementary manner relative to photoproduction

N* degrees of freedom??



K^+Y Exclusive Electroproduction

The dominant part of the world data for K^+Y electroproduction is from the CLAS e1f dataset



Phys. Rev. C

Separated Structure Functions for Exclusive $K^+\Lambda$ and $K^+\Sigma^0$ Electroproduction at 5.5 GeV with CLAS

D.S. Carman,[34] K. Park,[34] B.A. Raue,[12] K.P. Adhikari,[29] D. Adikaram,[29] M. Aghasyan,[18] M.J. Amaryan,[29] M.D. Anderson,[36] S. Anefalos Pereira,[18] M. Anghinolfi,[19] H. Avakian,[34] H. Baghdasaryan,[37,29] J. Ball,[7] N.A. Baltzell,[1] M. Battaglieri,[19] V. Batourine,[34] I. Bedlinskiy,[22] A.S. Biselli,[11] J. Bono,[12] S. Boiarinov,[34] W.J. Briscoe,[15] W.K. Brooks,[35] V.D. Burkert,[34] A. Celentano,[19] S. Chandavar,[28] G. Charles,[7] P.L. Cole,[16] M. Contalbrigo,[17] O. Cortes,[16] V. Crede,[13] A. D'Angelo,[20,31] N. Dashyan,[39] R. De Vita,[19] E. De Sanctis,[18] A. Deur,[34] C. Djalali,[33] D. Doughty,[8,34] R. Dupre,[21] A. El Alaoui,[1] L. El Fassi,[1] P. Eugenio,[13] G. Fedotov,[33,32] S. Fegan,[36] R. Fersch,[8] J.A. Fleming,[10] A. Fradi,[21] M.Y. Gabrielyan,[12] N. Gevorgyan,[39] K.L. Giovanetti,[23] F.X. Girod,[34] J.T. Goetz,[28] W. Gohn,[9] R.W. Gothe,[33] K.A. Griffioen,[38] B. Guegan,[21] M. Guidal,[21] L. Guo,[12,34] K. Hafidi,[1] H. Hakobyan,[35,39] C. Hanretty,[37] N. Harrison,[9] D. Heddle,[8,34] K. Hicks,[28] D. Ho,[5] M. Holtrop,[26] Y. Ilieva,[33] D.G. Ireland,[36] B.S. Ishkhanov,[32] E.L. Isupov,[32] H.S. Jo,[21] K. Joo,[9] D. Keller,[37] M. Khandaker,[27] P. Khetarpal,[12] A. Kim,[24] W. Kim,[24] A. Klein,[29] F.J. Klein,[6] S. Koirala,[29] A. Kubarovsky,[30,32] V. Kubarovsky,[34] S.V. Kuleshov,[35,22] N.D. Kvaltine,[37] S. Lewis,[36] K. Livingston,[36] H.Y. Lu,[5] I .J .D. MacGregor,[36] Y. Mao,[33] D. Martinez,[16] M. Mayer,[29] B. McKinnon,[36] M.D. Mestayer,[34] C.A. Meyer,[5] T. Mineeva,[9] M. Mirazita,[18] V. Mokeev,[34,32] R.A. Montgomery,[36] H. Moutarde,[7] E. Munevar,[34] C. Munoz Camacho,[21] P. Nadel-Turonski,[34] R. Nasseripour,[23,12] C.S. Nepali,[29] S. Niccolai,[21] G. Niculescu,[23] I. Niculescu,[23] M. Osipenko,[19] A.I. Ostrovidov,[13] L.L. Pappalardo,[17] R. Paremuzyan,[39] S. Park,[13] E. Pasyuk,[34] E. Phelps,[33] J.J. Phillips,[36] S. Pisano,[18] O. Pogorelko,[22] S. Pozdniakov,[22] J.W. Price,[3] S. Procureur,[7] Y. Prok,[8,34] D. Protopopescu,[36] A.J.R. Puckett,[34] G. Ricco,[14] D. Rimal,[12] M. Ripani,[19] G. Rosner,[36] P. Rossi,[34] F. Sabatié,[7] M.S. Saini,[13] C. Salgado,[27] N.A. Saylor,[30] D. Schott,[15] R.A. Schumacher,[5] E. Seder,[9] H. Seraydaryan,[29] Y.G. Sharabian,[34] G.D. Smith,[36] D.I. Sober,[6] D. Sokhan,[21] S.S. Stepanyan,[24] S. Stepanyan,[34] P. Stoler,[30] I.I. Strakovsky,[15] S. Strauch,[33] M. Taiuti,[14] W. Tang,[28] C.E. Taylor,[16] Y. Tian,[33] S. Tkachenko,[37] A. Trivedi,[33] M. Ungaro,[34] B .Vernarsky,[5] H. Voskanyan,[39] E. Voutier,[25] N.K. Walford,[6] L.B. Weinstein,[29] M.H. Wood,[4] N. Zachariou,[33] L. Zana,[26] J. Zhang,[34] Z.W. Zhao,[37] I. Zonta,[20]

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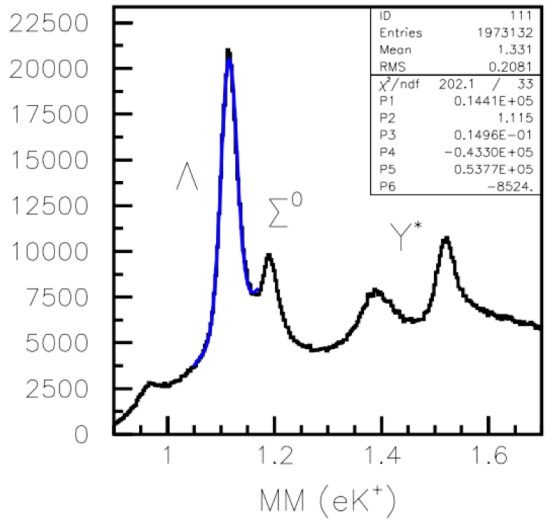
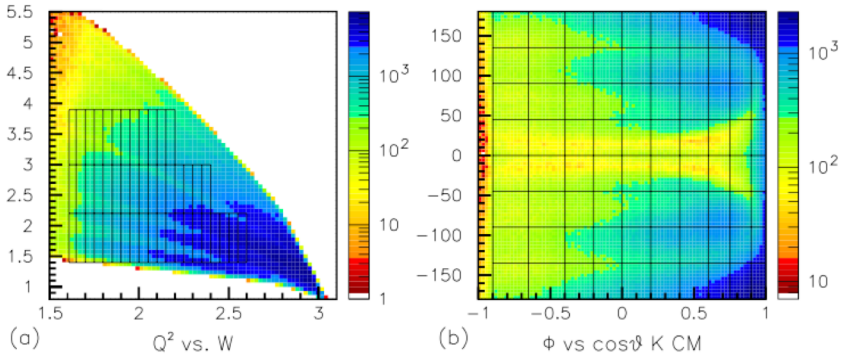
D.S. Carman et al., Phys. Rev. C 87, 025204 (2013)

5.5 GeV



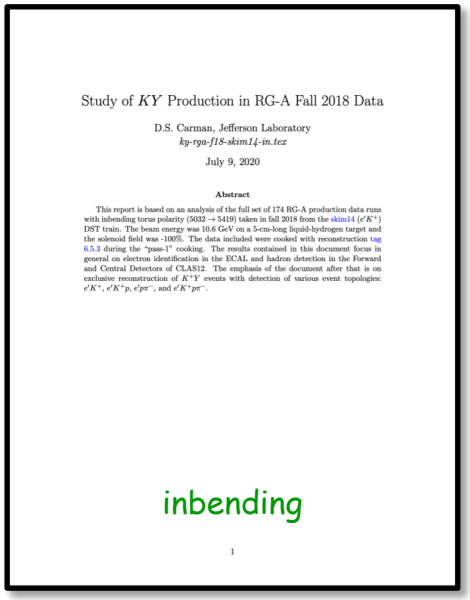


Q^2: [1.4:3.9] GeV^2, W: [1.6:2.6] GeV

e1f data sample ($e'K^+$ topology)

- $K^+\Lambda$: 364k events
- $K^+\Sigma^0$: 156k events

RG-A and RG-K - KY Analysis Notes


Study of KY Production in RG-A Fall 2018 Data

D.S. Carman, Jefferson Laboratory

ky-rga-f18-skim14-in.tex

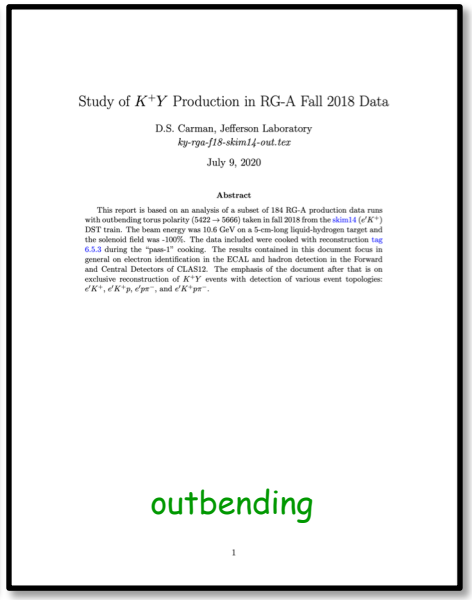
July 9, 2020

Abstract

This report is based on an analysis of the full set of 174 RG-A production data runs with inbending torus polarity (5032 → 5419) taken in fall 2018 from the skim14 ($e'K^+$) DST train. The beam energy was 10.6 GeV on a 5-cm-long liquid-hydrogen target and the solenoid field was -100%. The data included were cooked with reconstruction tag 6.5.3 during the "pass-1" cooking. The results contained in this document focus in general on electron identification in the ECAL and hadron detection in the Forward and Central Detectors of CLAS12. The emphasis of the document after that is on exclusive reconstruction of K^+Y events with detection of various event topologies: $e'K^+$, $e'K^+p$, $e'p\pi^-$, and $e'K^+p\pi^-$.

inbending

1


Study of K^+Y Production in RG-A Fall 2018 Data

D.S. Carman, Jefferson Laboratory

ky-rga-f18-skim14-out.tex

July 9, 2020

Abstract

This report is based on an analysis of a subset of 184 RG-A production data runs with outbending torus polarity (5422 → 5666) taken in fall 2018 from the skim14 ($e'K^+$) DST train. The beam energy was 10.6 GeV on a 5-cm-long liquid-hydrogen target and the solenoid field was -100%. The data included were cooked with reconstruction tag 6.5.3 during the "pass-1" cooking. The results contained in this document focus in general on electron identification in the ECAL and hadron detection in the Forward and Central Detectors of CLAS12. The emphasis of the document after that is on exclusive reconstruction of K^+Y events with detection of various event topologies: $e'K^+$, $e'K^+p$, $e'p\pi^-$, and $e'K^+p\pi^-$.

outbending

1

Hadron Structure Group
Wednesday, 4 p.m.

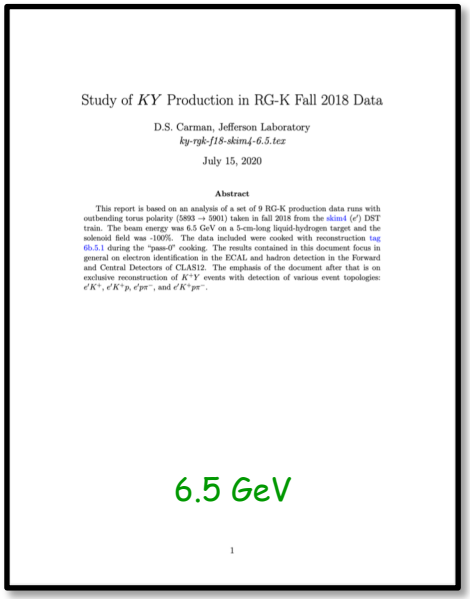
E12-06-108A

https://clasweb.jlab.org/wiki/index.php/First_Experiment_Hadron_Structure_Group

Run Group K Group
Friday, 8 a.m.

E12-16-010A

https://clasweb.jlab.org/wiki/index.php/Run_Group_K


Study of KY Production in RG-K Fall 2018 Data

D.S. Carman, Jefferson Laboratory

ky-rgk-f18-skim4-6.5.tex

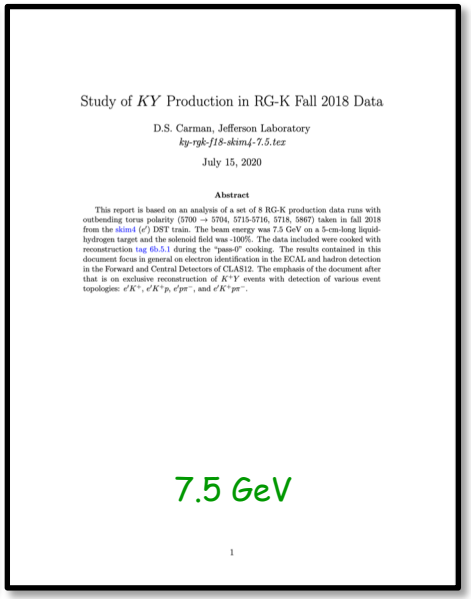
July 15, 2020

Abstract

This report is based on an analysis of a set of 9 RG-K production data runs with outbending torus polarity (5893 → 5901) taken in fall 2018 from the skim4 (e') DST train. The beam energy was 6.5 GeV on a 5-cm-long liquid-hydrogen target and the solenoid field was -100%. The data included were cooked with reconstruction tag 6b.5.1 during the "pass-0" cooking. The results contained in this document focus in general on electron identification in the ECAL and hadron detection in the Forward and Central Detectors of CLAS12. The emphasis of the document after that is on exclusive reconstruction of K^+Y events with detection of various event topologies: $e'K^+$, $e'K^+p$, $e'p\pi^-$, and $e'K^+p\pi^-$.

6.5 GeV

1


Study of KY Production in RG-K Fall 2018 Data

D.S. Carman, Jefferson Laboratory

ky-rgk-f18-skim4-7.5.tex

July 15, 2020

Abstract

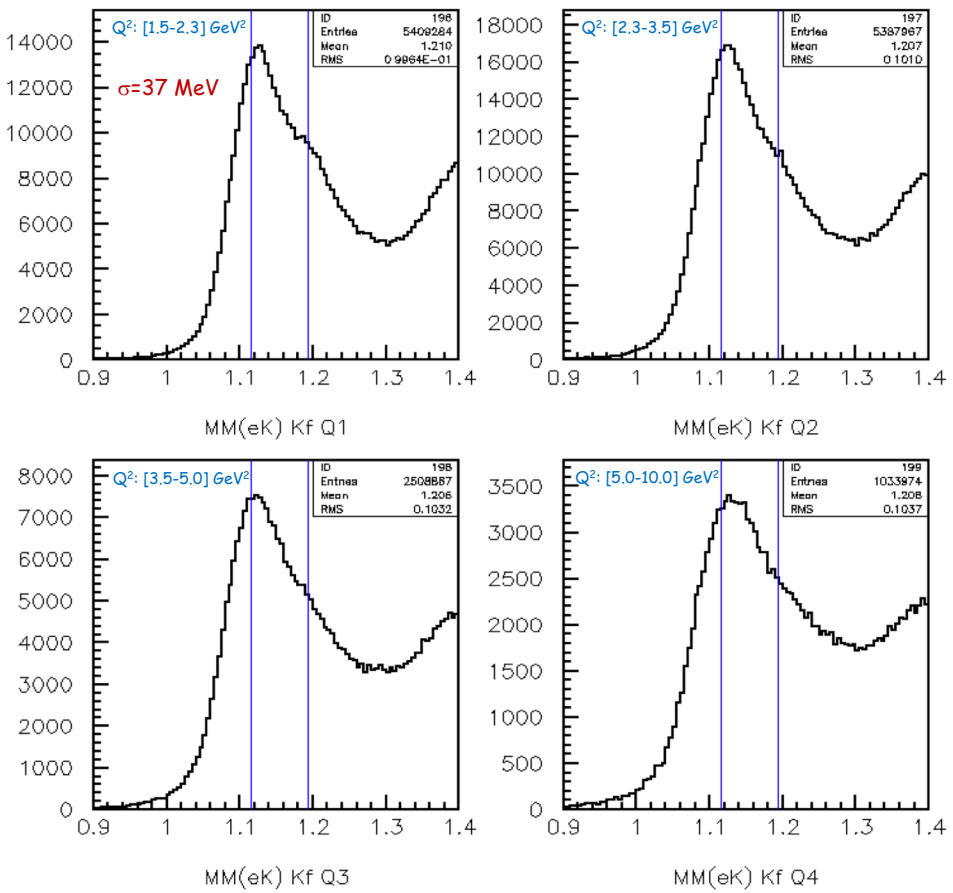
This report is based on an analysis of a set of 8 RG-K production data runs with outbending torus polarity (5700 → 5704, 5715-5716, 5718, 5867) taken in fall 2018 from the skim4 (e') DST train. The beam energy was 7.5 GeV on a 5-cm-long liquid-hydrogen target and the solenoid field was -100%. The data included were cooked with reconstruction tag 6b.5.1 during the "pass-0" cooking. The results contained in this document focus in general on electron identification in the ECAL and hadron detection in the Forward and Central Detectors of CLAS12. The emphasis of the document after that is on exclusive reconstruction of K^+Y events with detection of various event topologies: $e'K^+$, $e'K^+p$, $e'p\pi^-$, and $e'K^+p\pi^-$.

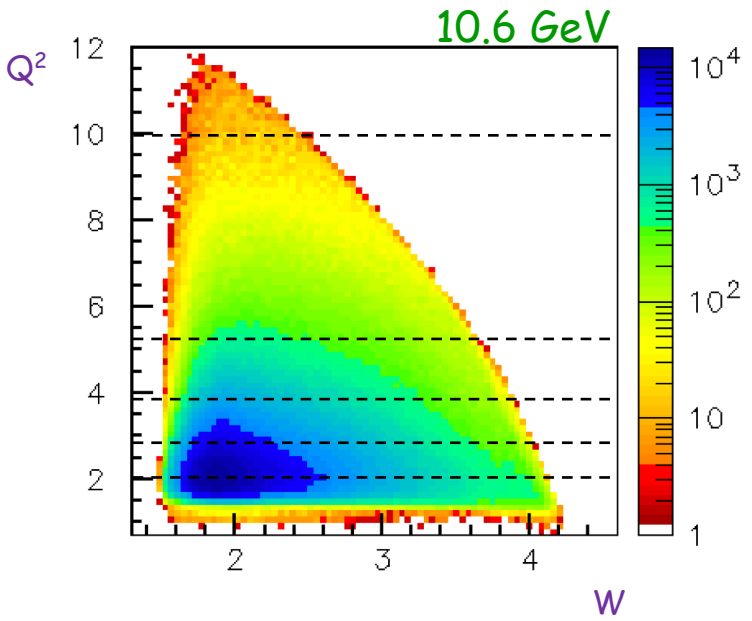
7.5 GeV

1

RG-A Fall 2018 Inbending Dataset

e′ in ECAL, K^+ in FD



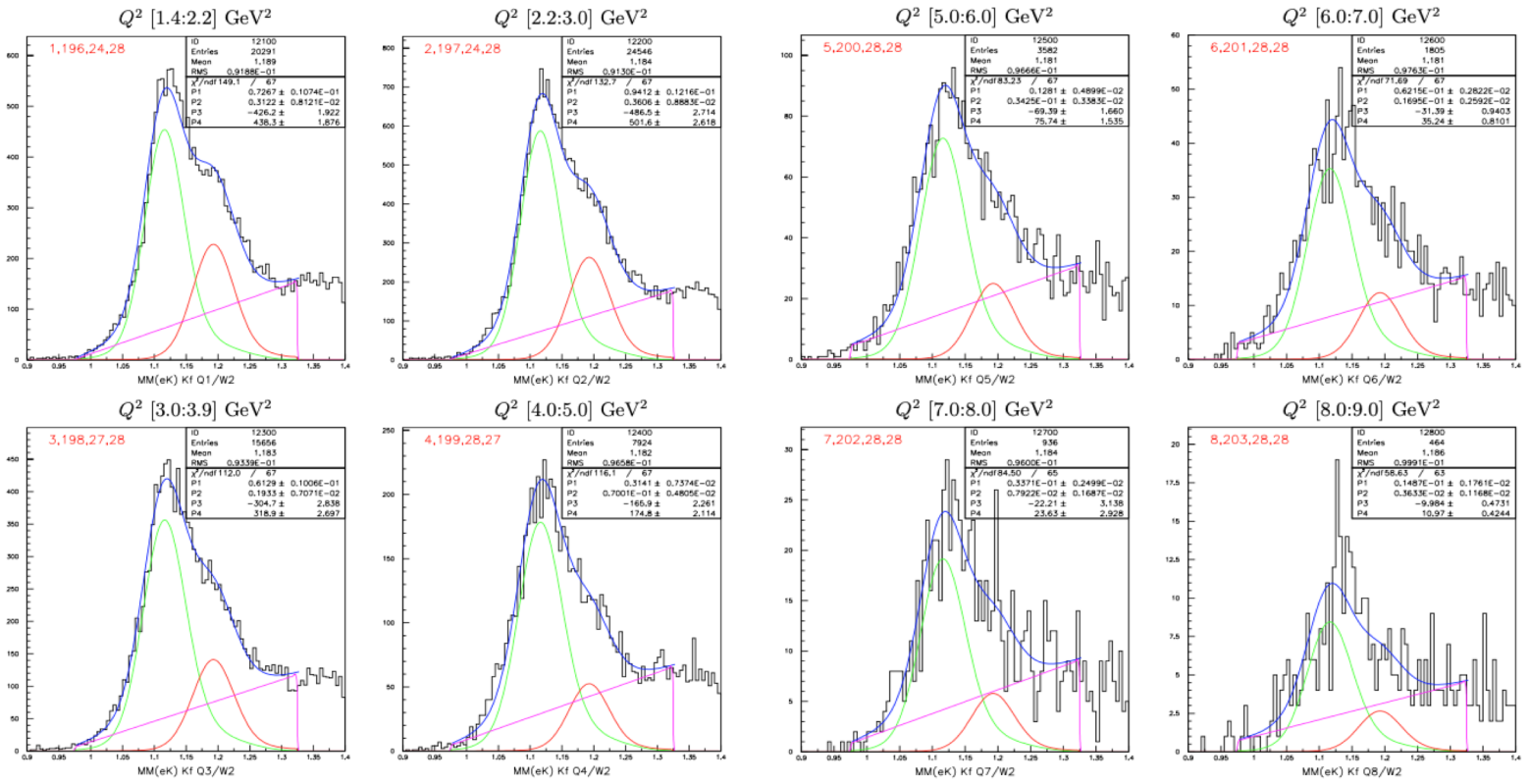


In this (Q^2,W) kinematic range the RG-A f18 data has:

- Comparable statistics to e1f in the CLAS Q^2 range
- Significantly extends Q^2 range up to 10 GeV^2
- Poor MM resolution makes separation of Λ and Σ^0 final states challenging

Working to develop fitting technique using Monte Carlo lineshape templates to extract the event yields

RG-A Inbending Yield Determination



Approach:

1) Generate MC templates for $K^+\Lambda$ and $K^+\Sigma^0$ in bins to match the data
2) Fit data with templates plus background function
3) Convolute templates with Gaussian to minimize χ^2 and match MC to data
4) A critical step is to include momentum corrections to position the Λ and Σ^0 peaks at their PDG masses

RG-A Inbending Yield Estimates

Estimate for full inbending RG-A dataset

Q^2 GeV^2	W GeV	CLAS12 RG-A Yield$_\Lambda$	CLAS12 RG-A Yield$_{\Sigma^0}$
1.4 - 2.2	1.7 - 1.75	49874	11217
2.2 - 3.0	1.7 - 1.75	68241	10555
3.0 - 3.9	1.7 - 1.75	46627	5277
4.0 - 5.0	1.7 - 1.75	24580	1742
5.0 - 6.0	1.7 - 1.75	10605	828
6.0 - 7.0	1.7 - 1.75	5148	302
7.0 - 8.0	1.7 - 1.75	2304	180
8.0 - 9.0	1.7 - 1.75	1217	100
9.0 - 10.0	1.7 - 1.75	525	57
10.0 - 11.0	1.7 - 1.75	208	36
1.4 - 2.2	1.9 - 1.95	56268	28375
2.2 - 3.0	1.9 - 1.95	72871	32774
3.0 - 3.9	1.9 - 1.95	47440	17568
4.0 - 5.0	1.9 - 1.95	24314	6364
5.0 - 6.0	1.9 - 1.95	9914	3110
6.0 - 7.0	1.9 - 1.95	4809	1533
7.0 - 8.0	1.9 - 1.95	2606	720
8.0 - 9.0	1.9 - 1.95	1144	324
9.0 - 10.0	1.9 - 1.95	504	316
10.0 - 11.0	1.9 - 1.75	172	136

E12-06-108A proposal estimated yield in 2 W bins @ 1.7 and 1.9 GeV

Differences between CLAS12 RG-A data and proposal estimates:

1) Ran at lower luminosity:

F_1=75 nA/40 nA = 1.875

2) Lower tracking efficiency

F_2 =1/(0.84*0.84) = 1.42

3) Current analysis has only FD K^+:

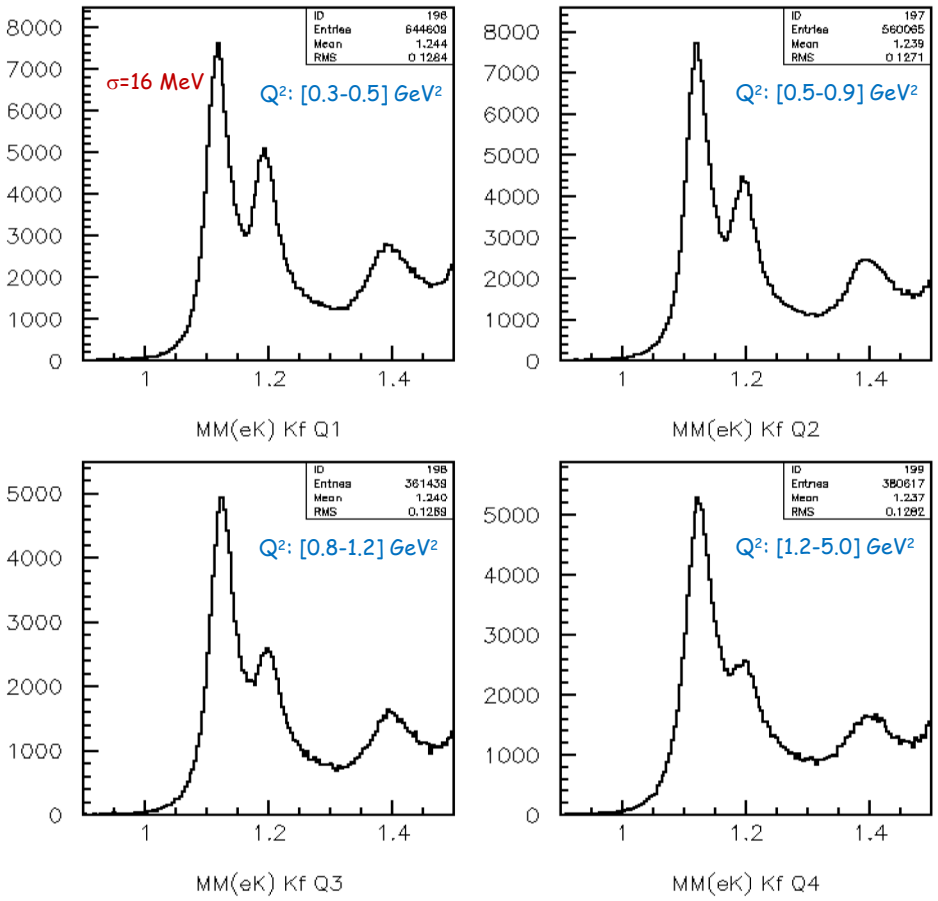
F_3 = 1.25

⇒ Overall reduction F_1*F_2*F_3 = 3.3

Reduction in statistics compared to the proposal estimates will ultimately limit the maximum Q^2 range of the data analysis (10 GeV^2 → 7 GeV^2)

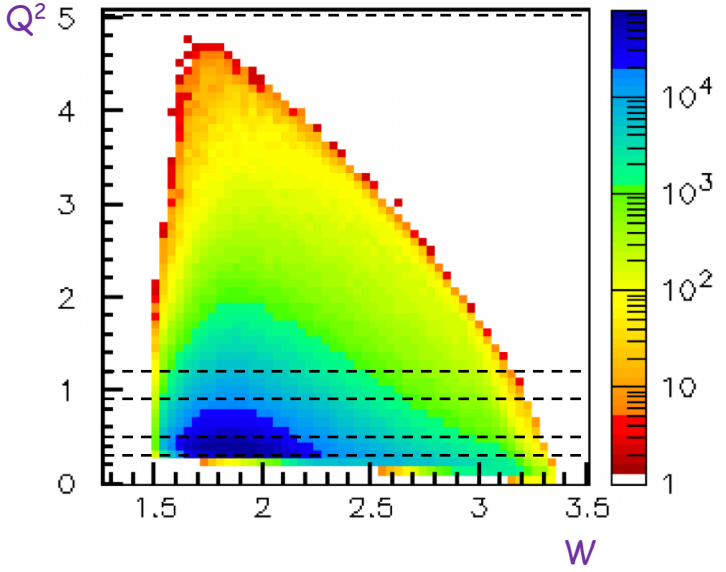
RG-K Fall 2018 6.5 GeV Dataset

e′ in ECAL, K^+ in FD



Working to develop fitting technique using Monte Carlo lineshape templates to extract the event yields

6.5 GeV



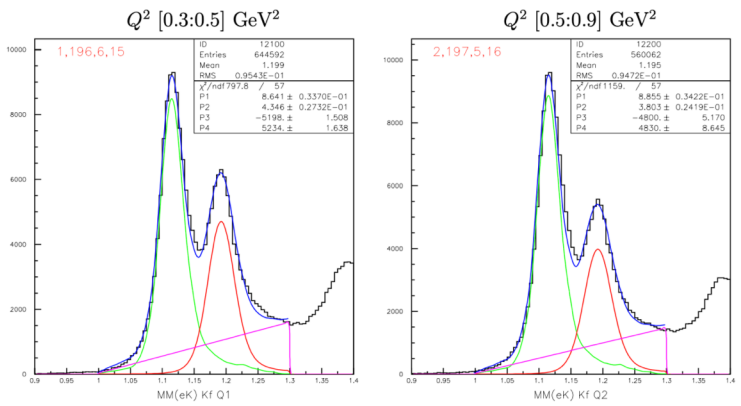
In this (Q^2,W) kinematic range the RG-K f18 data has:

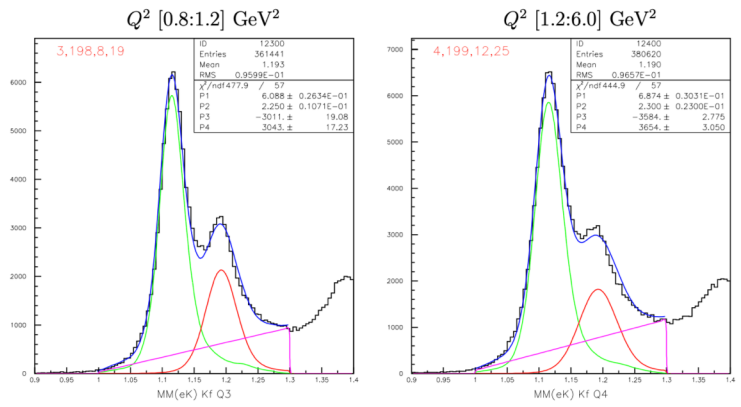
- Allows for connection of the regime of low-energy to high-energy N* structural d.o.f.
- Hyperon final state separation feasible

Data from 10 runs 6b.5.1 cooking

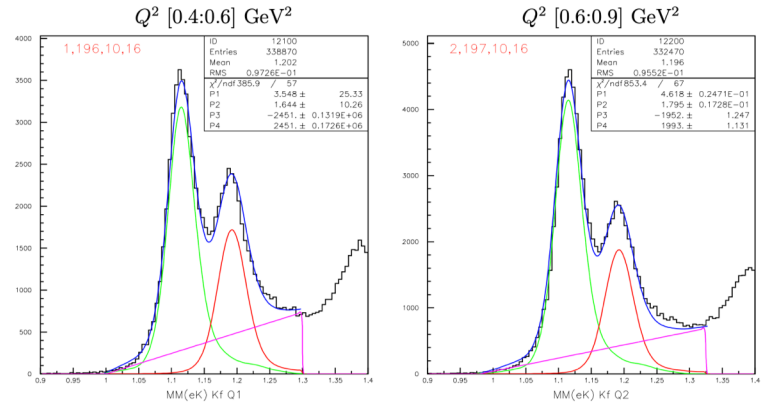
RG-K Yield Determination

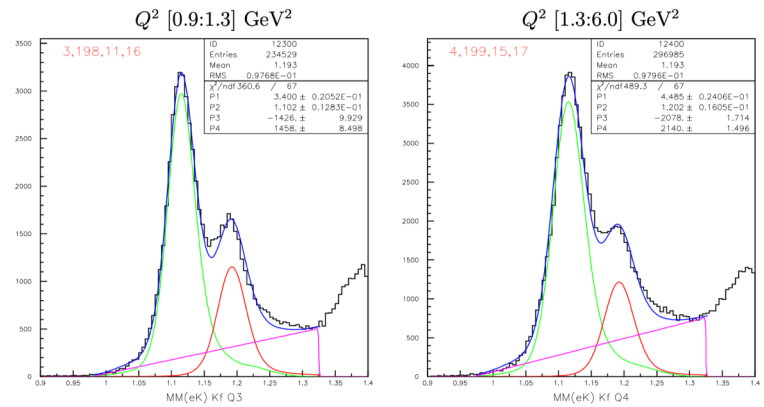
6.5 GeV





7.5 GeV





Approach:

1) Generate MC templates for $K^+\Lambda$ and $K^+\Sigma^0$ in bins to match the data
2) Fit data with ltemplates plus background function
3) Convolute templates with Gaussian to minimize χ^2 and match MC to data
4) A critical step is to include momentum corrections to position the Λ and Σ^0 peaks at their PDG masses

RG-K Yield Estimates

Estimate for full 6.5 RG-K

Q^2 GeV^2	W GeV	CLAS12 RG-K Yield$_\Lambda$	CLAS12 RG-K Yield$_{\Sigma^0}$
0.3 - 0.8	1.7 - 1.75	1076760	163460
0.8 - 1.4	1.7 - 1.75	525190	146980
1.4 - 2.2	1.7 - 1.75	247710	71890
2.2 - 3.0	1.7 - 1.75	91360	14420
3.0 - 3.9	1.7 - 1.75	43560	5760
4.0 - 5.0	1.7 - 1.75	11540	920
0.3 - 0.8	1.9 - 1.95	1344040	870760
0.8 - 1.4	1.9 - 1.95	558050	330730
1.4 - 2.2	1.9 - 1.95	244210	140490
2.2 - 3.0	1.9 - 1.95	93310	40990
3.0 - 3.9	1.9 - 1.95	43360	16680
4.0 - 5.0	1.9 - 1.95	6280	1440

E12-16-010A proposal estimated yield in 2 W bins @ 1.7 and 1.9 GeV

Differences between CLAS12 RG-K data and proposal estimates:

1) Ran at lower luminosity:

F_1=75 nA/60 nA = 1.25

2) Lower tracking efficiency

F_2 =1/(0.76*0.76) = 1.73

3) Current analysis has only FD K^+:

F_3 = 1.33

⇒ Overall reduction F_1*F_2*F_3 = 2.9

Statistics in RG-K will allow for:

- KY electroproduction measurements up to Q^2 = 2 GeV^2 comparable to CLAS photoproduction

RG-A Monte Carlo Studies

OSG Submissions

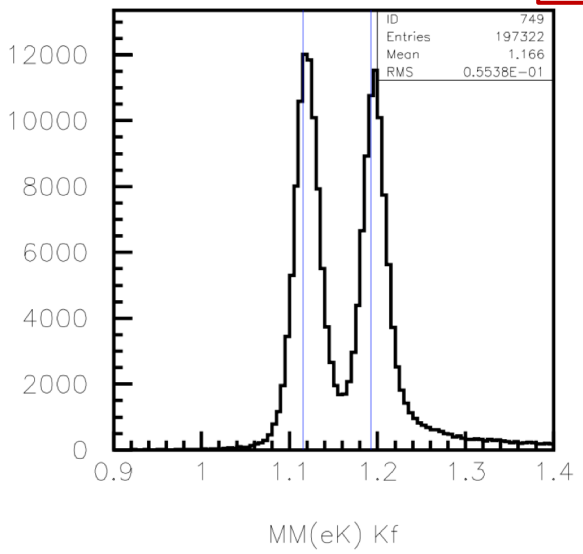
- Generator: genKYandOnePion
- Q^2 range: [1.0:10.0] GeV^2
- W range: [1.5:3.5] GeV
- target z range: [-5.5:-0.5] cm
- Generated events: 2.5M $K^+\Lambda$, 2.5M $K^+\Sigma^0$
- GEMC handles decay of hyperons

EG based on fits to CLAS data up to Q^2=4 GeV^2

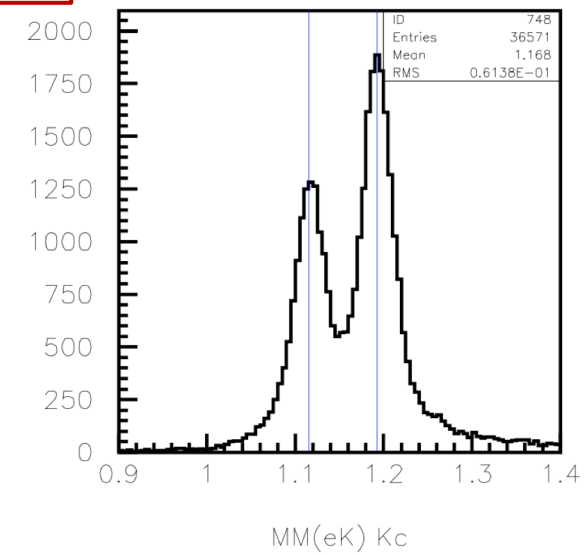
- Current GEMC 4.3.2 simulations have resolutions that do not match the data (15 MeV vs. 40 MeV)
- GEMC 4.4.0 is set for release soon and will have much better energy, position, time smearing

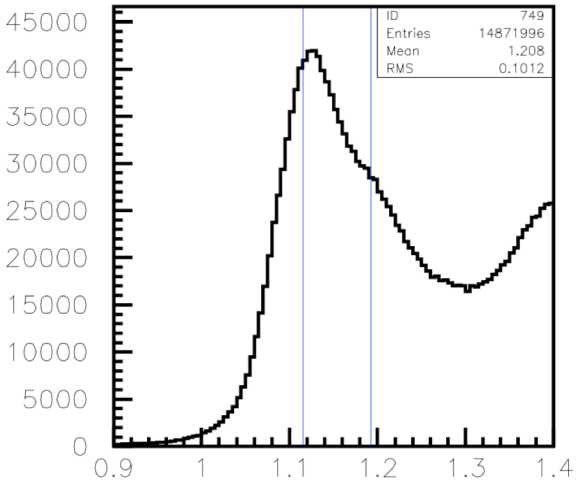
MC

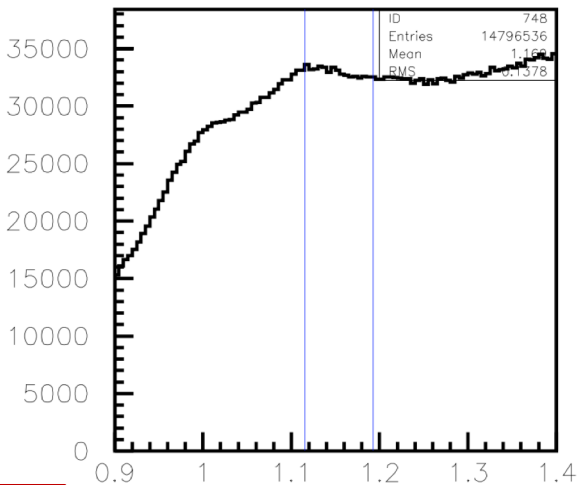
e'K$^+$ FD



e'K$^+$ CD



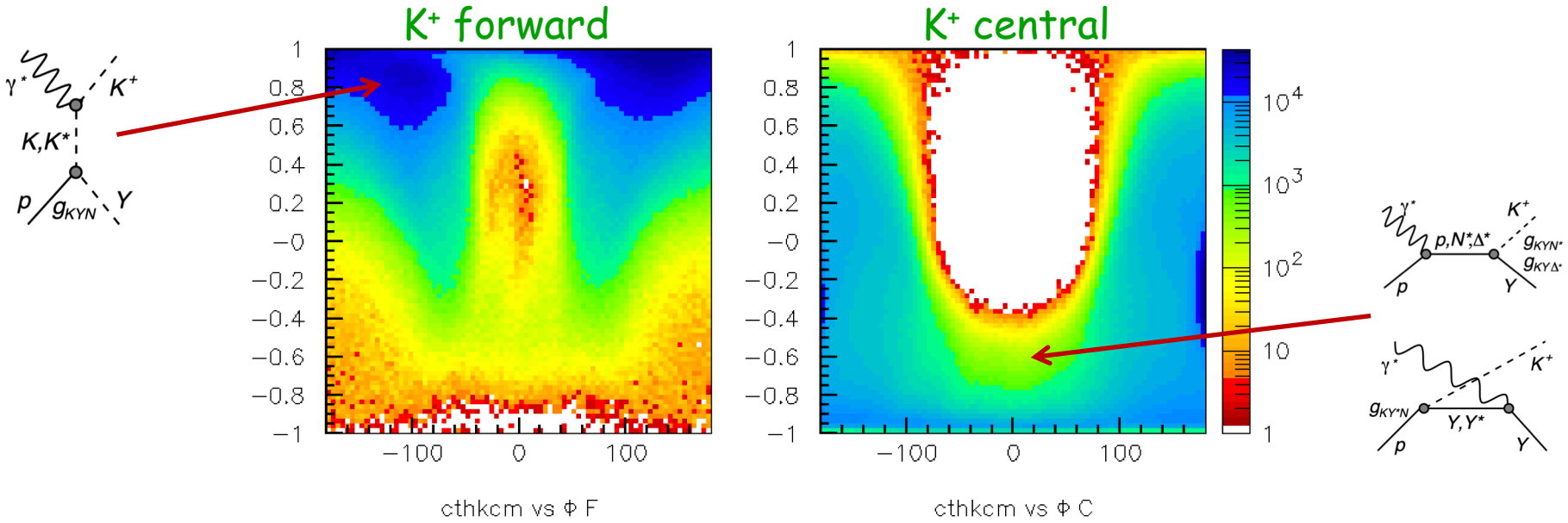




Data

https://clasweb.jlab.org/wiki/images/3/3c/Ky-rga-f18-mc-in.pdf

CLAS12 CM Angular Coverage



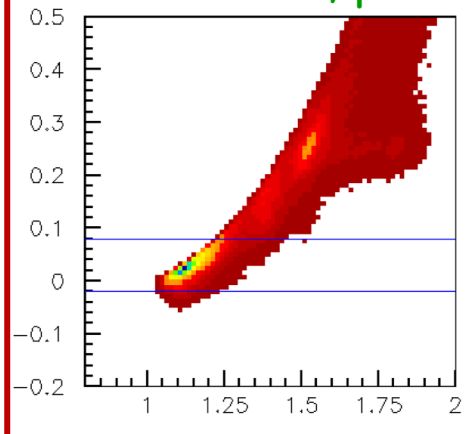
$$\frac{d\sigma}{d\Omega} = (\sigma_T + \epsilon\sigma_L) + \epsilon\sigma_{TT}\cos 2\Phi + \sqrt{\epsilon(1+\epsilon)}\sigma_{LT}\cos\Phi + h\sqrt{\epsilon(1-\epsilon)}\sigma_{LT'}\sin\Phi$$

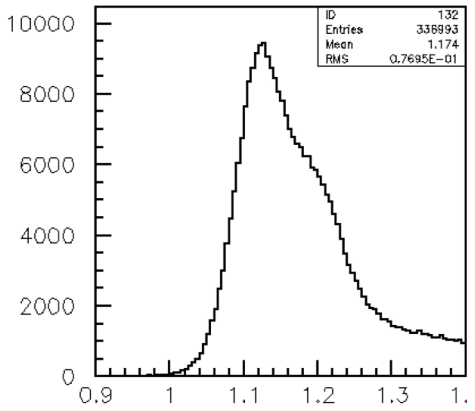
- The first analysis objective is to extract the *separated structure functions* $\sigma_T + \varepsilon\sigma_L$, σ_{TT}, σ_{LT}, $\sigma_{LT'}$ in bins of Q^2, W, cos θ_K^{cm}, Φ
- The physics goals are to ultimately learn about the spectrum and structure of contributing *s-channel* baryon resonances
- The CLAS12 Central Detector covers a *critical* portion of the phase space for this analysis

eK⁺p Topologies – RG-A Data

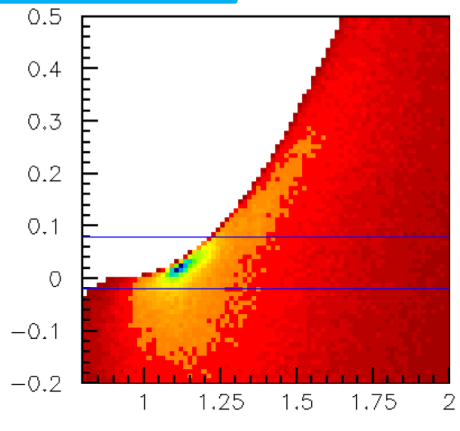
Favored Topologies

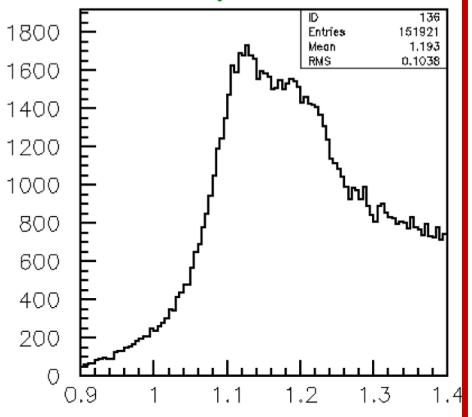
K⁺ forward, p forward



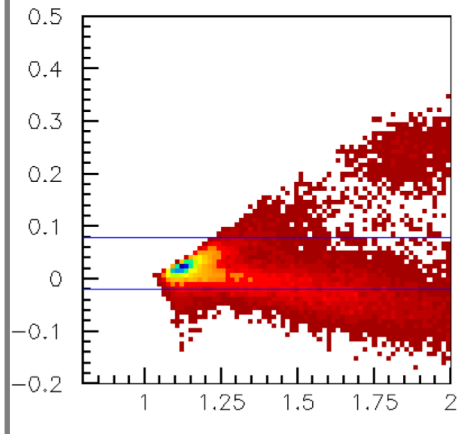


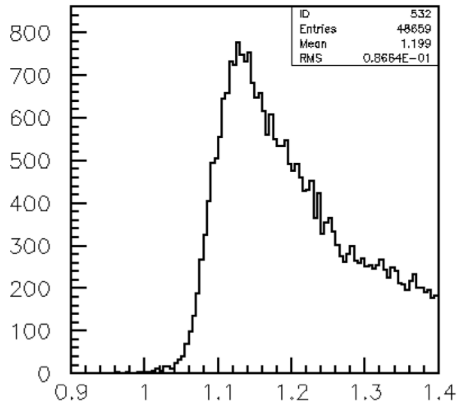
K⁺ central, p forward



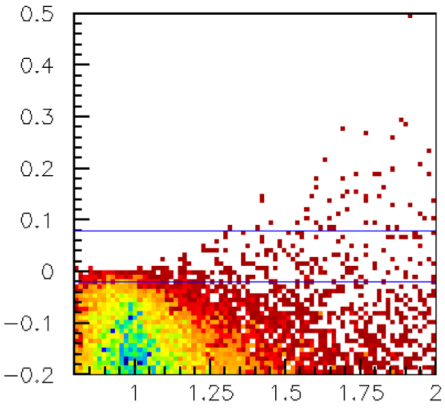


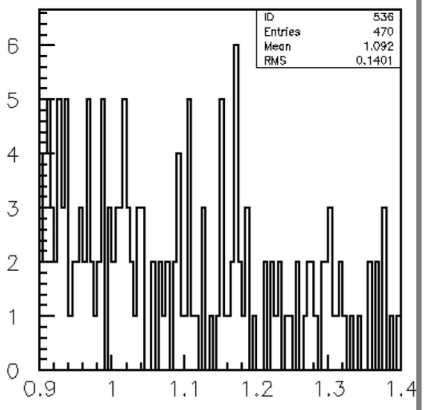
Unfavored Topologies





K⁺ forward, p central





K⁺ central, p central

RG-A Beam-Recoil Λ Transferred Polarization

$$A_\Lambda = \alpha_\Lambda P_b \mathcal{P}'_\Lambda \cos\theta_p^{RF}$$

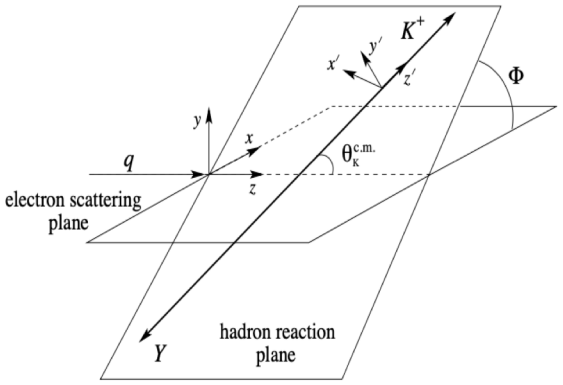
Backgrounds not yet accounted for in A_{meas}

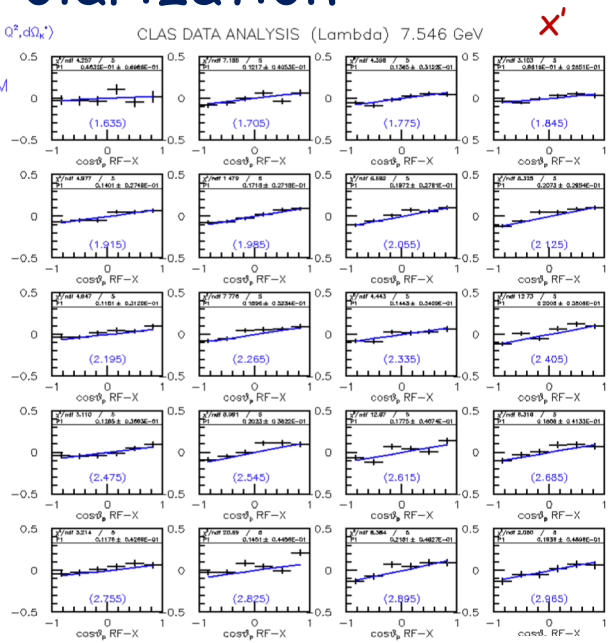
$$A_{meas} = \frac{(N_Y^+ + N_{Y'}^+ + N_{bck}^+) - (N_Y^- + N_{Y'}^- + N_{bck}^-)}{N_Y + N_{Y'} + N_{bck}}$$

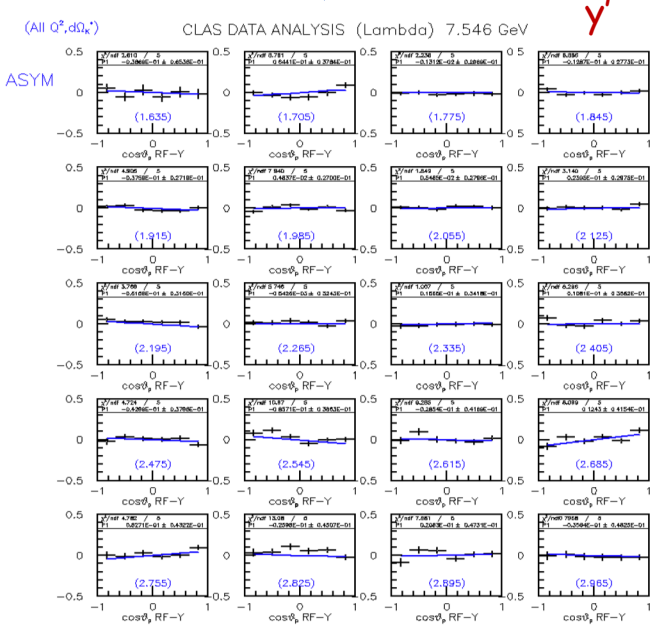
$$\mathcal{P}'_\Lambda = \mathcal{P}'_{meas}(1 + F_{bck})$$

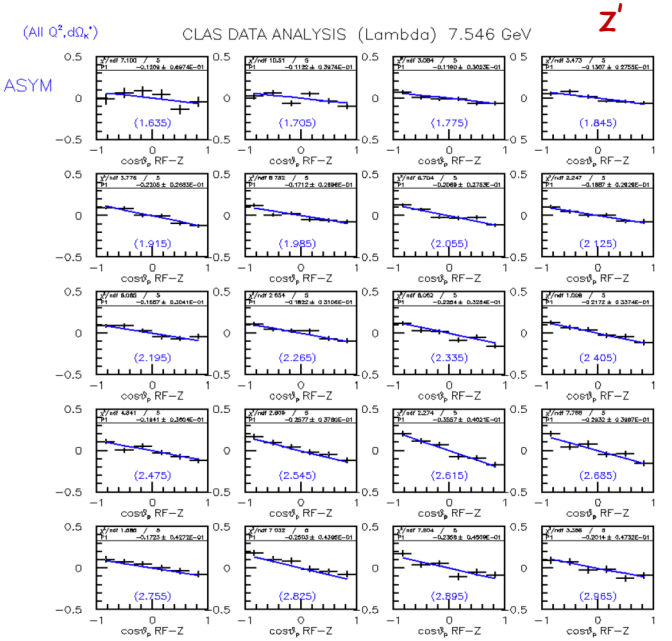
($\alpha_\Lambda = 0.750$)

Asymmetry fits



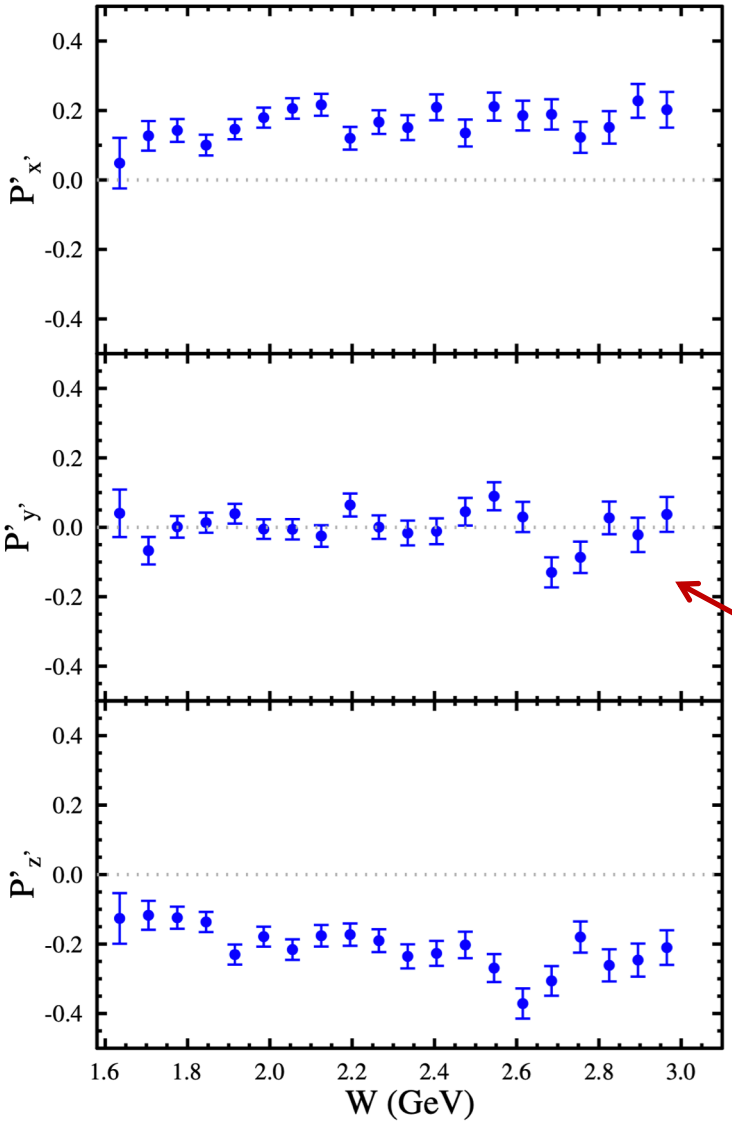






Danie

RG-A Beam-Recoil Λ Transferred Polarization



- Polarization analysis summed over Q^2, cos $\theta_K^{c.m.}$, Φ
- Sign agrees with CLAS e1-6 analysis
- Integration over Φ forces $P'_{y'}$ to be zero; deviations provide a measure of systematics

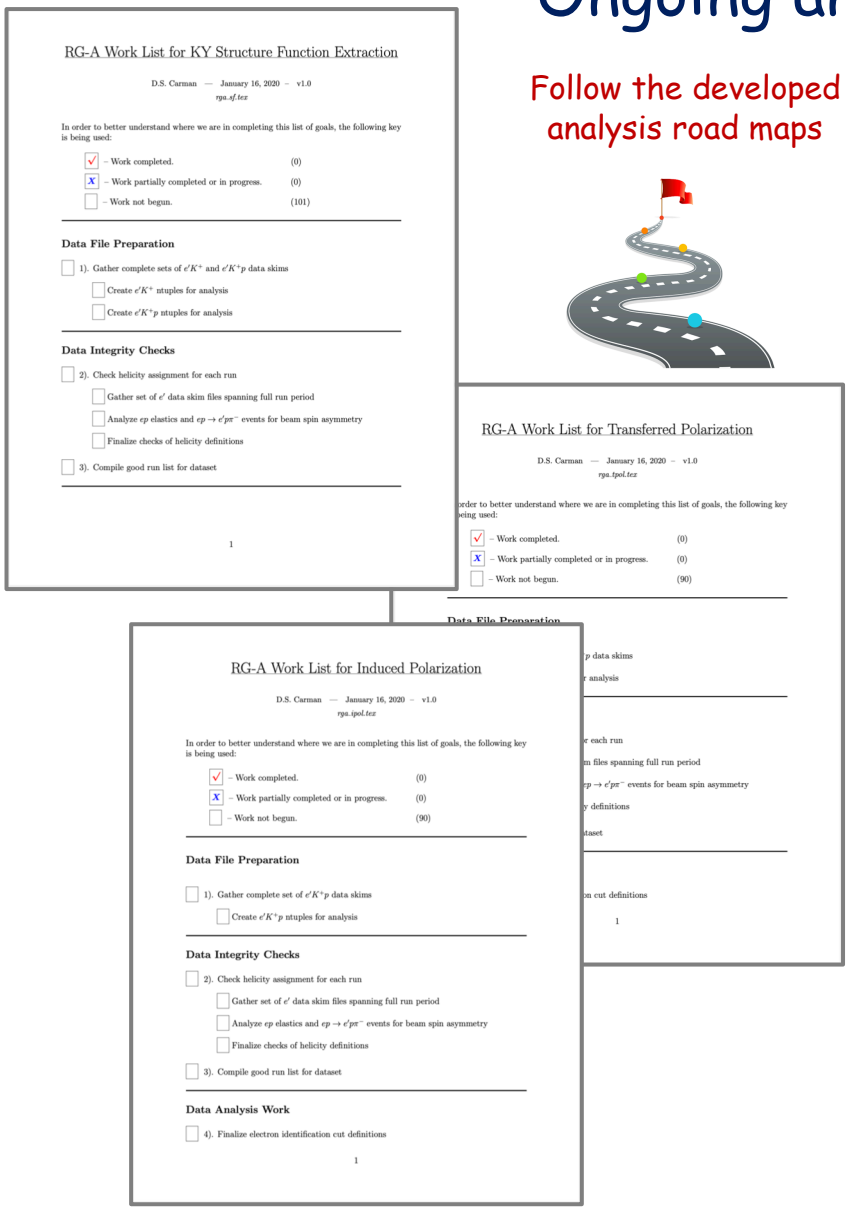
$$\mathcal{P}'_{x'} = \sqrt{1-\epsilon^2} \cdot \frac{R_{TT'}^{x'0}}{R_T^{00} + \epsilon R_L^{00}}$$

$$\mathcal{P}'_{y'} = 0$$

$$\mathcal{P}'_{z'} = \sqrt{1-\epsilon^2} \cdot \frac{R_{TT'}^{z'0}}{R_T^{00} + \epsilon R_L^{00}}$$

Need accurate helicity-gated yield extraction for meaningful results

Ongoing and Future Work



Follow the developed analysis road maps

- Generate Monte Carlo on OSG to test data-developed EG genKYandOnePion
- When GEMC 4.4.0 is available, generate sufficient statistics to evaluate deficiencies of EG compared to the data
- Generate Monte Carlo KY templates to perform reliable yield extractions
- Determine acceptance functions to allow for initial cross section extraction to begin systematic studies and compare to CLAS results
- Extract preliminary beam-recoil transferred polarizations for t-channel dominated FD acceptance
- With Hadron Structure Group include:
  - Momentum corrections
  - Final binning choices
  - Radiative corrections
  - Bin migration studies