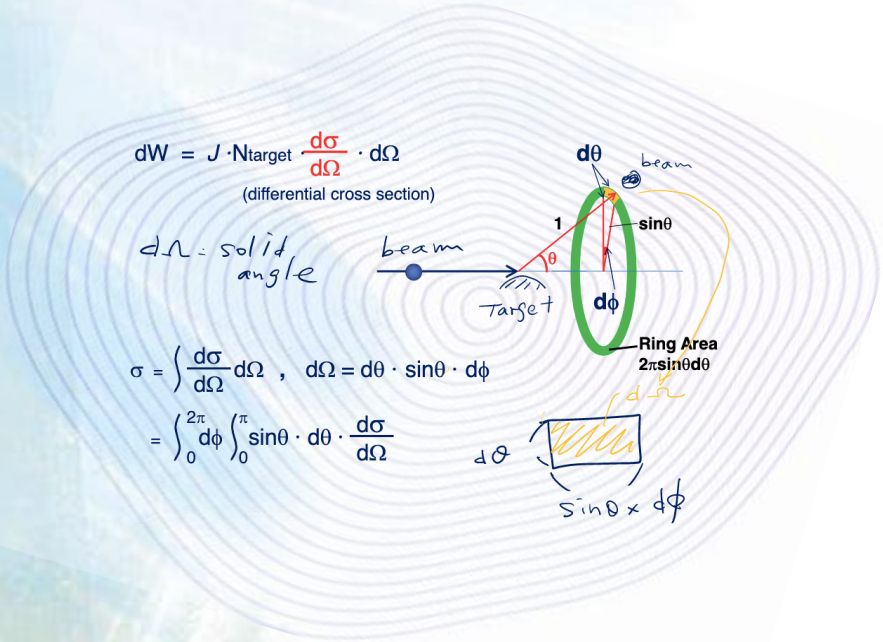
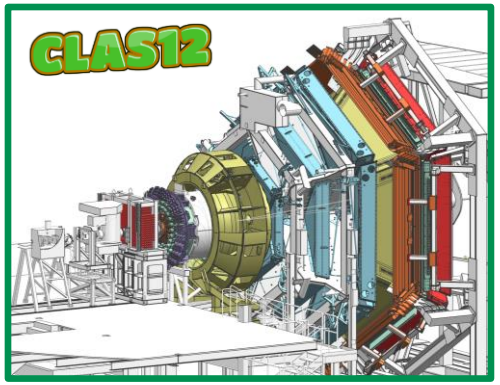
RG-K Spr24 Dataset
Extraction of KY Differential Cross Sections
And Separated Structure Functions





Outline:

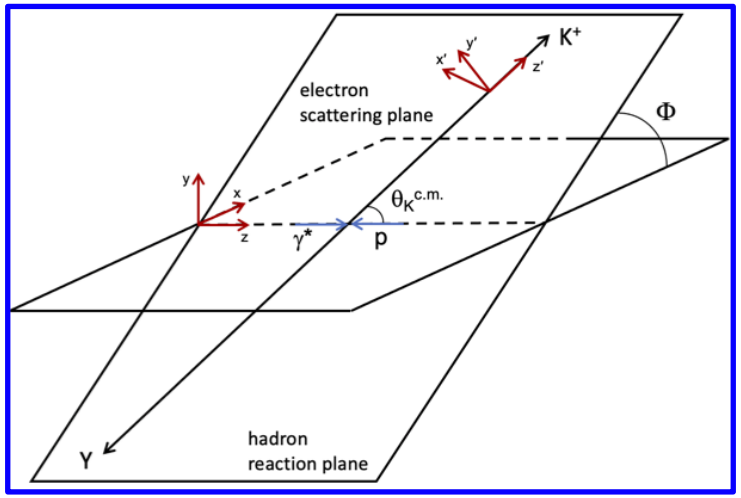
- History – CLAS KY electroproduction
- CLAS12 vs. CLAS datasets
- RG-K analysis details
- Yields & differential cross sections
- Separated structure functions
- Summary & conclusions

Cooking completed on June 7!

Pseudoscalar Meson Production Formalism

$$\frac{d\sigma_v}{d\Omega_K^{c.m.}} = \mathcal{K}\sum_{\alpha,\beta} S_\alpha S_\beta \Big[R_T^{\beta\alpha} + \epsilon R_L^{\beta\alpha} + c_+({}^cR_{LT}^{\beta\alpha}\cos\Phi + {}^sR_{LT}^{\beta\alpha}\sin\Phi)$$
$$+ \quad \epsilon({}^cR_{TT}^{\beta\alpha}\cos 2\Phi + {}^sR_{TT}^{\beta\alpha}\sin 2\Phi) + hc_-({}^cR_{LT'}^{\beta\alpha}\cos\Phi + {}^sR_{LT'}^{\beta\alpha}\sin\Phi) + hc_0 R_{TT'}^{\beta\alpha}\Big]$$

36 independent response function $\Leftrightarrow$ $R_{ij}^{\beta\alpha}(Q^2, W, \cos\theta_K^{c.m.})$



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

$$\frac{d\sigma}{d\Omega_K^{c.m.}} = A + B\cos\Phi + C\cos 2\Phi \equiv \sigma_0$$

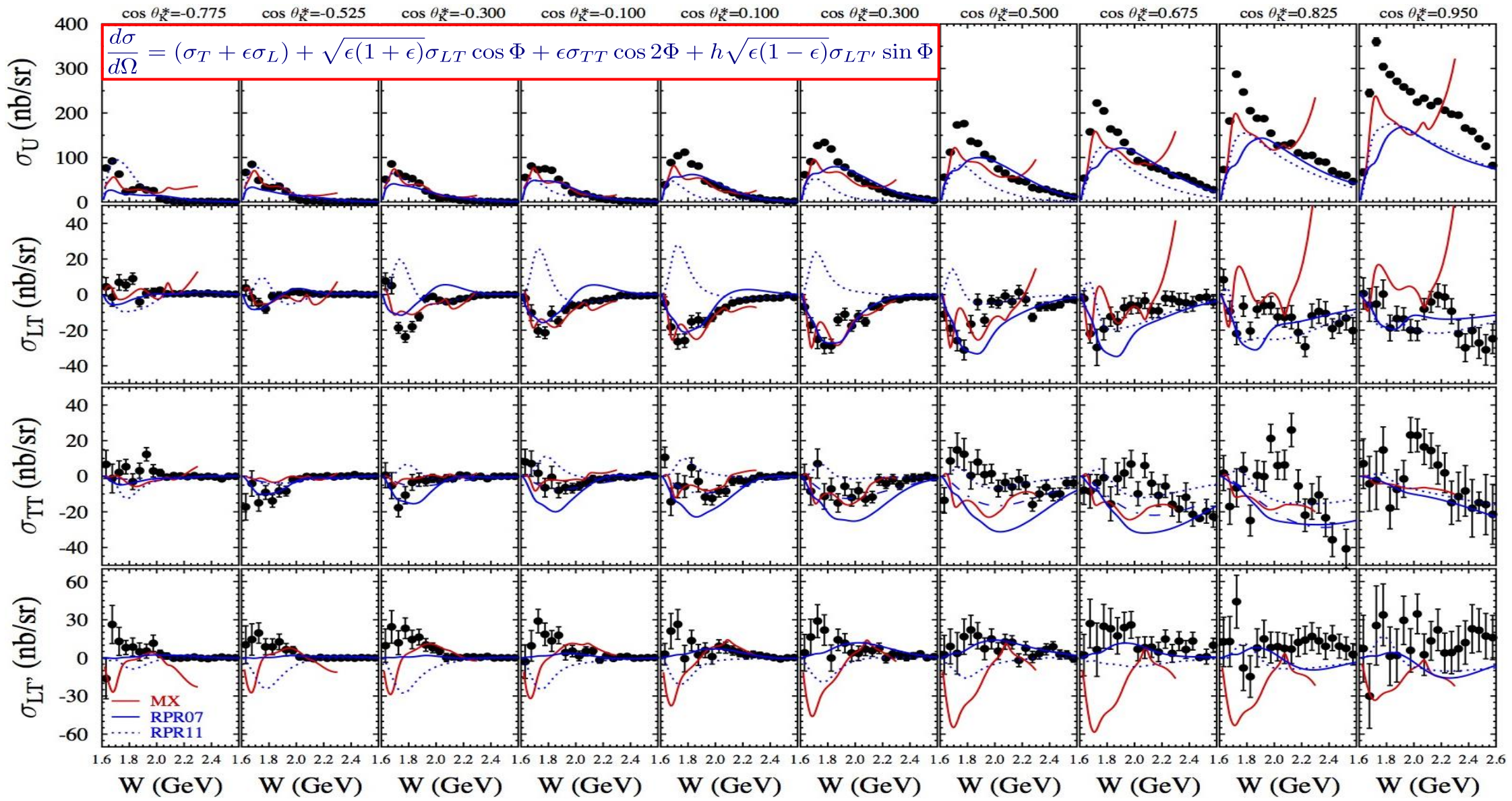
Φ "Moment" analysis

$$A_{LT'} = \frac{1}{P_b}\cdot\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\sqrt{\epsilon(1-\epsilon)}\sigma_{LT'}\sin\Phi}{\sigma_0}$$

Beam spin asymmetry - BSA

CLAS $K^+\Lambda$ Structure Functions

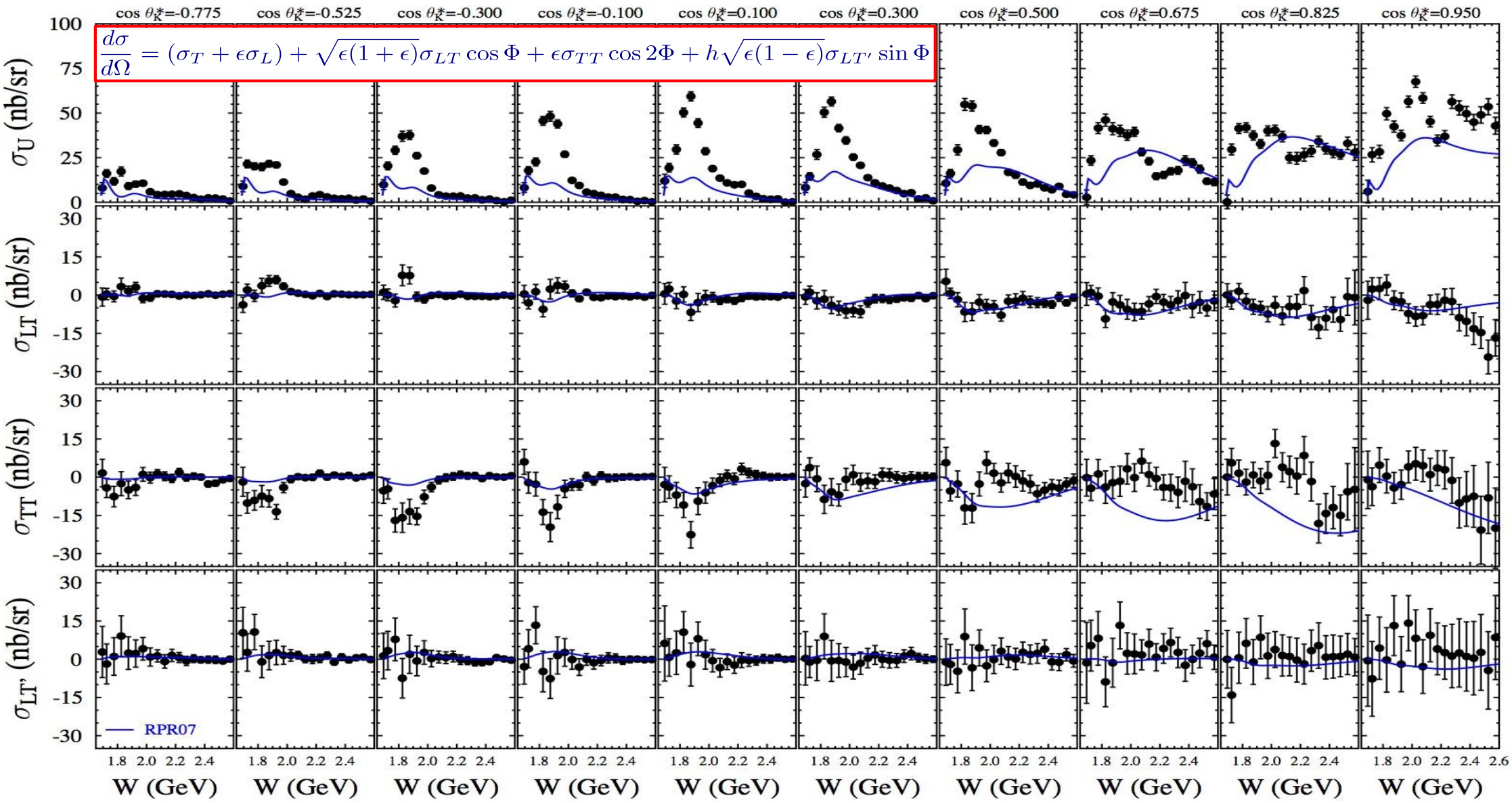
E = 5.5 GeV
W: thr – 2.6 GeV
Q^2 = 1.80, 2.60, 3.45 GeV^2



D.S. Carman et al. (CLAS), PRC 87, 025204 (2013)

CLAS $K^+\Sigma^0$ Structure Functions

E = 5.5 GeV
W: thr – 2.6 GeV
Q^2 = 1.80, 2.60, 3.45 GeV^2

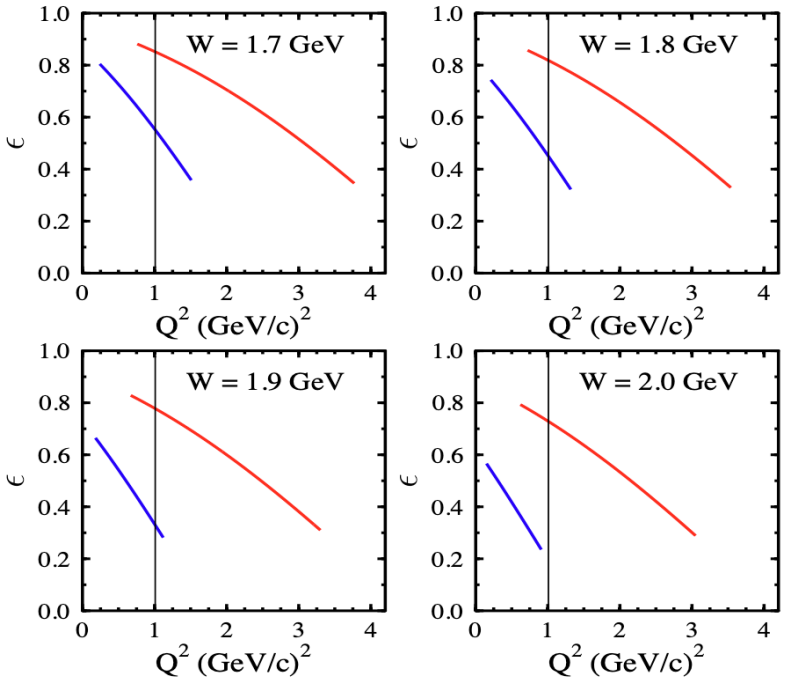


D.S. Carman et al. (CLAS), PRC 87, 025204 (2013)

Rosenbluth Separation

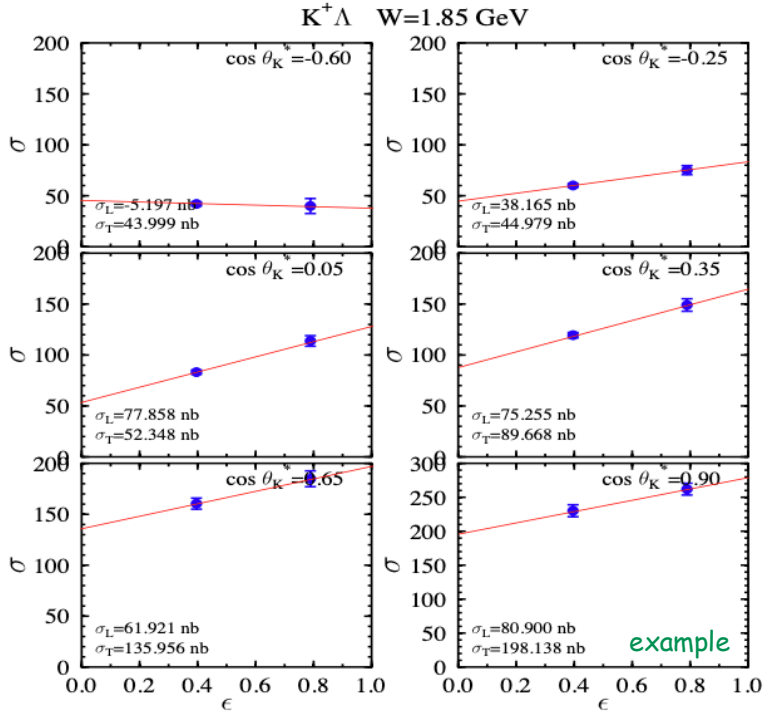
$$\sigma_0 = \sigma_T(Q^2, W, \cos\theta_K^{c.m.}) + \epsilon\sigma_L(Q^2, W, \cos\theta_K^{c.m.})$$

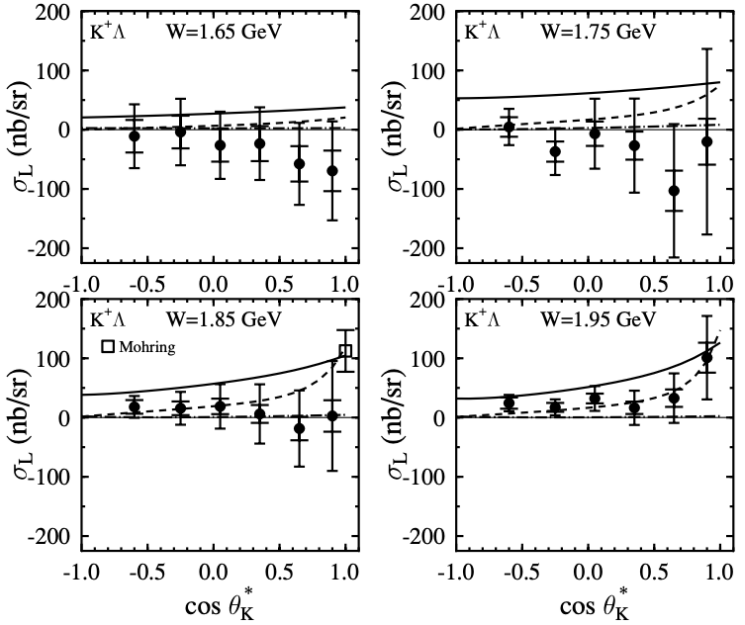
CLAS e1c data @ 2.5 & 4.0 GeV

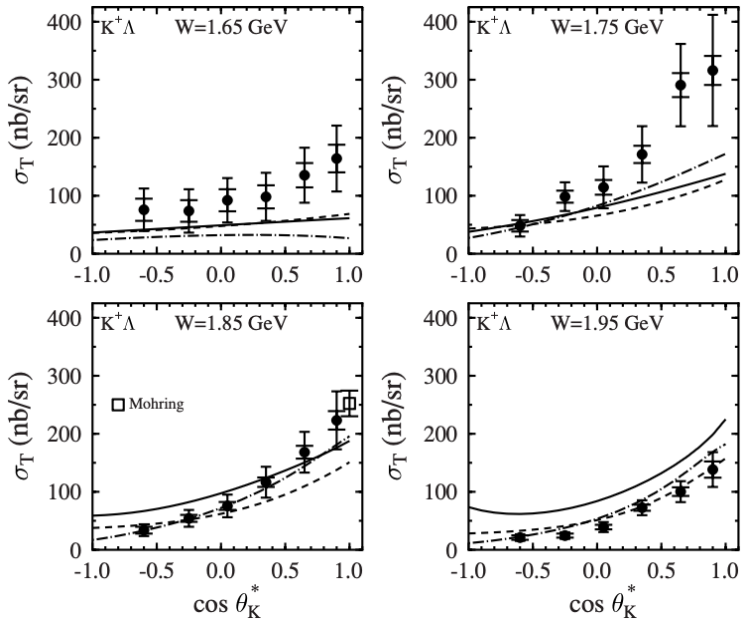


Linear fit to dσ/dΩ vs. ε:

- slope gives σ_L
- y-intercept gives σ_T







The only publication of separated σ_L and σ_T in Hall B to date

P. Ambrozewicz et al. (CLAS), PRC 75, 045203 (2007)

Datasets for KY Electroproduction – CLAS

#	Run	E_b (GeV)	Trig. (M)
1	e1c	2.567	900
2		4.056	370
3		4.247	620
4		4.462	420
5	e1-6	5.754	4500
6	e1f	5.499	5000

Publications (Cross Section):

- $K^+\Lambda$, $K^+\Sigma^0$ cross sections & structure functions
  - $d\sigma/d\Omega$, σ_U, σ_{LT}, σ_{TT}, σ_L, σ_T
    - W=1.6-2.4 GeV, Q^2=0.5-2.8 GeV^2

    P. Ambrozewicz et al. (CLAS), PRC 75, 045203 (2007)
  - $d\sigma/d\Omega$, σ_U, σ_{LT}, σ_{TT}, $\sigma_{LT'}$
    - W=1.6-2.6 GeV, Q^2=1.4-3.9 GeV^2

    D.S. Carman et al. (CLAS), PRC 87, 025204 (2013)
  - $\sigma_{LT'}$
    - W=1.6-2.1 GeV, Q^2=0.65, 1.0 GeV^2

    R. Nasseripour et al. (CLAS), PRC 77, 065208 (2008)
  - $K^+\Lambda$ σ_L/σ_T ratio
    - W=1.72-1.98 GeV, Q^2~0.7 GeV^2

    B.A. Raue & D.S. Carman, PRC 71, 065209 (2005)

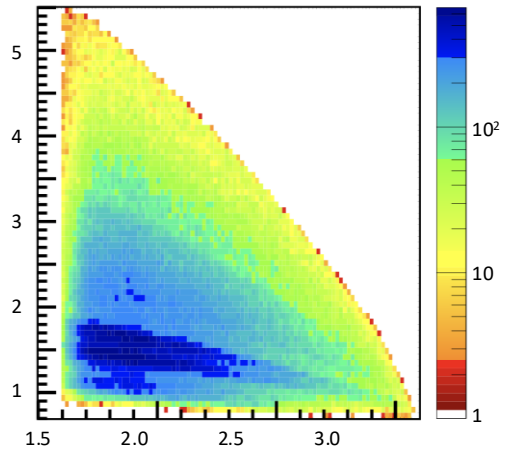
Publications (Polarization):

- $K^+\Lambda$, $K^+\Sigma^0$ beam-recoil polarization transfer
  - W=1.6-2.15 GeV, Q^2=0.3 – 1.5 GeV^2

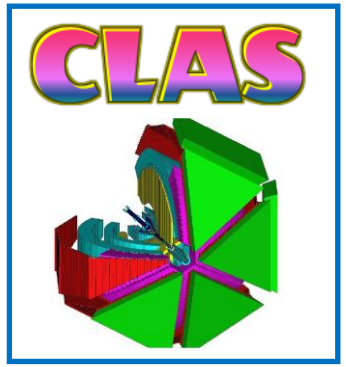
    D.S. Carman et al. (CLAS), PRL 90, 131804 (2003)
  - W=1.6-2.6 GeV, Q^2=0.7-5.4 GeV^2

    D.S. Carman et al. (CLAS), PRC 79, 065205 (2009)
- $K^+\Lambda$ recoil polarization
  - W=1.6-2.7 GeV, $\langle Q^2 \rangle$=1.9 GeV^2

    M. Gabrielyan et al. (CLAS), PRC 90, 035202 (2014)



Q^2 vs. W (GeV)

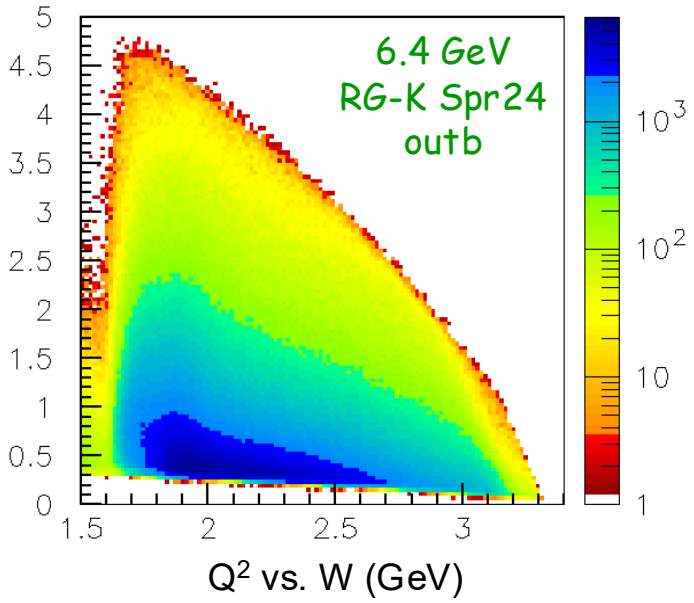


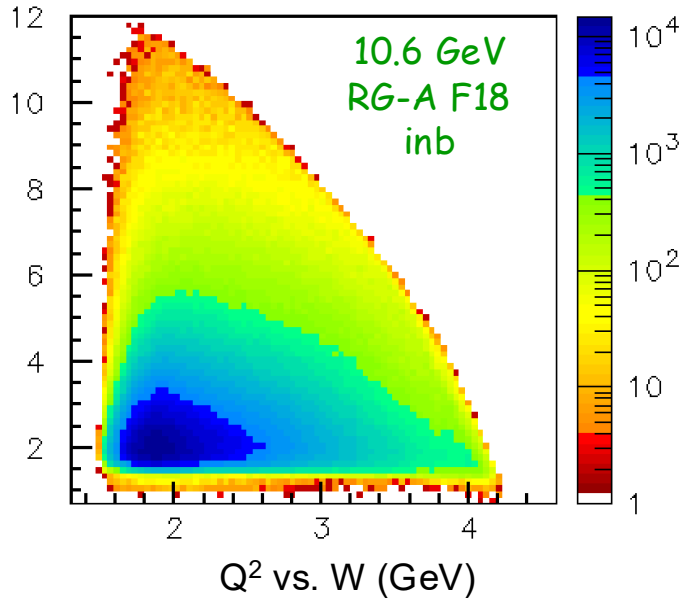
Datasets for KY Electroproduction – CLAS12

#	Run	E_b (GeV)	Trig. (M)
1	RG-A Spr18	10.6	56.0G
2	RG-A F18	10.6	23.7G
3	RG-A Spr19	10.2	12.6G
4	RG-K Win18	6.535	7.8G
5		7.546	7.8G
6	RG-K Spr24	6.394	38.3G
7		8.478	21.7G
8	RG-K 2027	6.6	TBD
9		8.8	TBD

Publications (Polarization):

- $K^+\Lambda$, $K^+\Sigma^0$ beam-recoil polarization transfer
  - W=1.6-2.4 GeV, Q^2=0.3 – 4.5 GeV^2
    D.S. Carman et al. (CLAS), PRC 105, 065201 (2022)
- $K^+\Lambda$, $K^+\Sigma^0$ recoil polarization
  - W=1.6-2.4 GeV, Q^2=0.3 – 4.5 GeV^2
    D.S. Carman et al. (CLAS), PRC 112, 035206 (2025)





Data Analysis

$$e + p \rightarrow e' + K^+ + \Lambda, \quad \Lambda \rightarrow p\pi^- \qquad e + p \rightarrow e' + K^+ + \Sigma^0, \quad \Sigma^0 \rightarrow \Lambda\gamma, \quad \Lambda \rightarrow p\pi^-$$

electrons

Cut	Value
Track Status	$2000 \leq$ abs(STATUS) < 4000
EB PID	11
p_e	$[1.0 : p_{beam}]$ GeV
TOF_e	[21:26] ns
v_z	$[-10:2]$ cm
ECAL S.F.	$\pm 3.5\sigma$
ECAL Fiducial Cut	7 cm edge cut on U, V, W
DC Fiducial Cuts	on

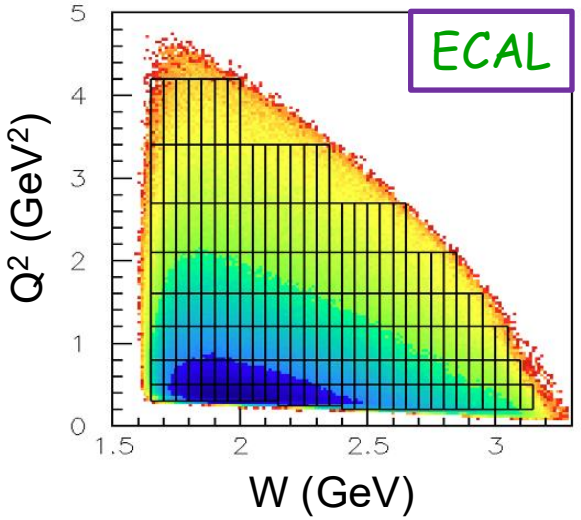
hadrons

Forward Detector

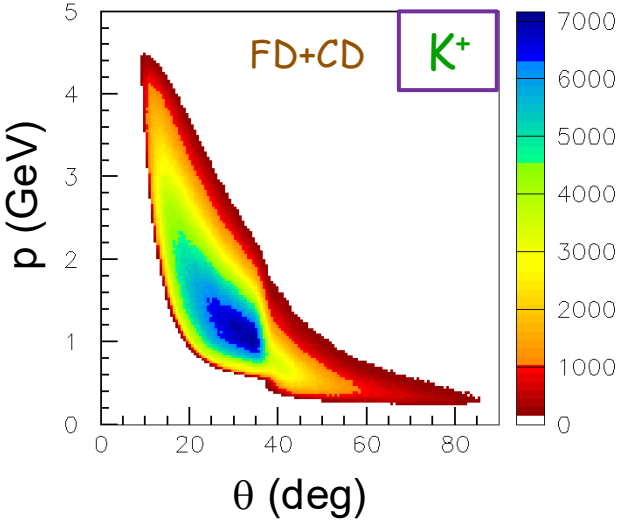
Cut	Value
Track status	$2000 \leq \lvert STATUS \rvert < 4000$
q	$\neq 0$
p_h	$[0.4 : p_{beam}]$ GeV
β_h	[0.4:1.1]
EB PID	± 211, ± 321, or ± 2212
TOF_h	[20:55] ns ($q > 0$), [20:35] ns ($q < 0$)
v_z (K^+)	$[-10:2]$ cm

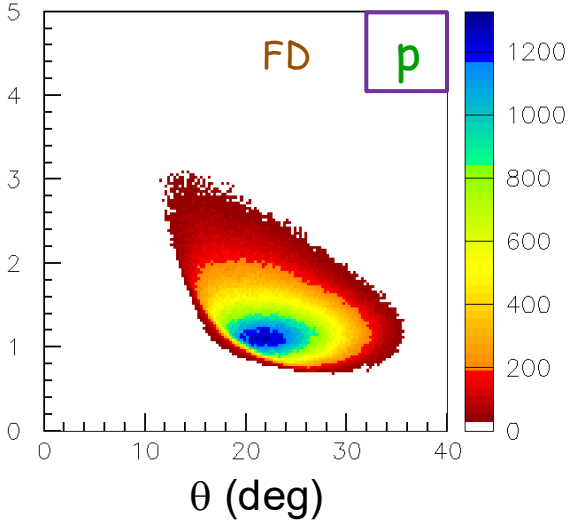
Central Detector

Cut	Value
Track status	$\lvert STATUS \rvert \geq 4000$
q	$\neq 0$
p_h	[0.2:1.5] GeV
β_h	[0.2:1.1]
EB PID	± 211, ± 321, or ± 2212
TOF_h	[0.5:4.0] ns
v_z (K^+)	$[-10:2]$ cm (K^+ candidates)

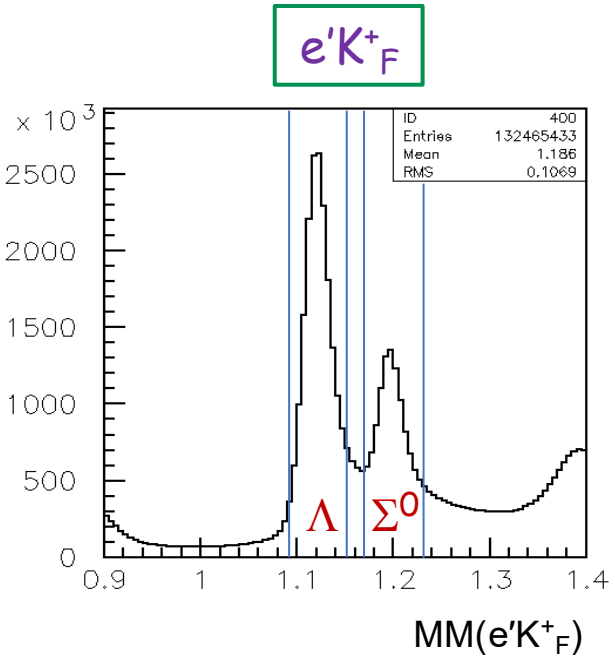


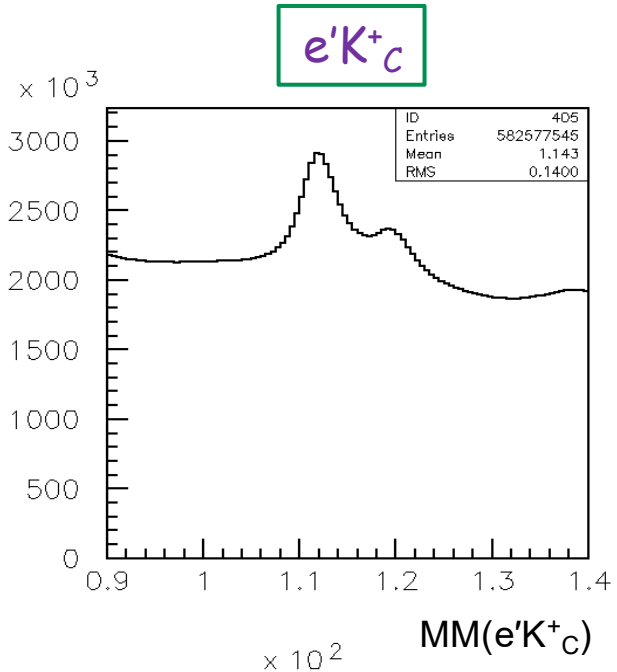
6.398 GeV





Topology Selection





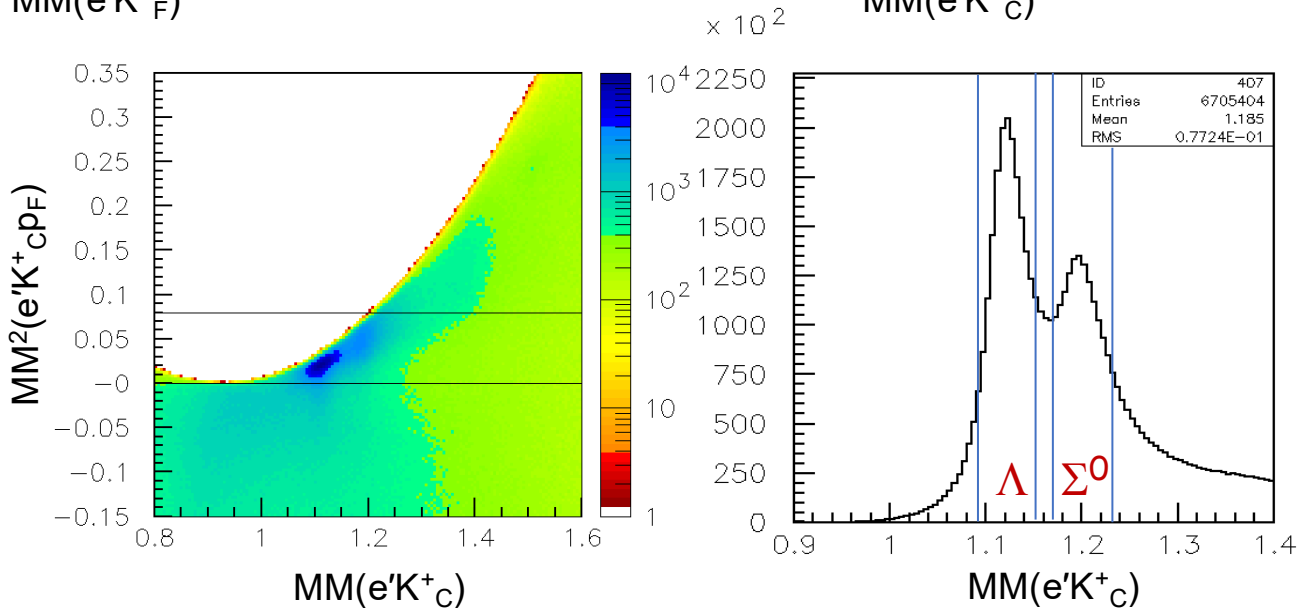
Topology Selection:

1) $e'K^+_F$
2) $e'K^+_C p_F$

Notes:

- Detection of p_F for K^+_C topology necessary to reduce backgrounds in CD
- Account for $\Lambda \rightarrow p\pi^-$ B.R. with weight to $e'K^+_C p_F$ events

"simple" yield extraction



Differential Cross Section Calculation

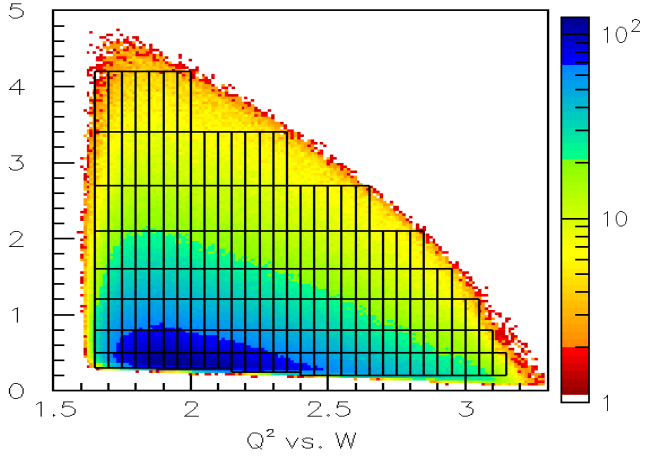
$$\frac{d\sigma_i}{d\Omega_K^*} = \frac{1}{\Gamma_v} \cdot \frac{1}{(\Delta Q^2 \Delta W \Delta \cos\theta_K^* \Delta\Phi)} \cdot \frac{R_i \cdot N_i \cdot BC_i}{\eta_i \cdot N_0} \cdot \frac{1}{(N_A \rho t / M_w)}$$

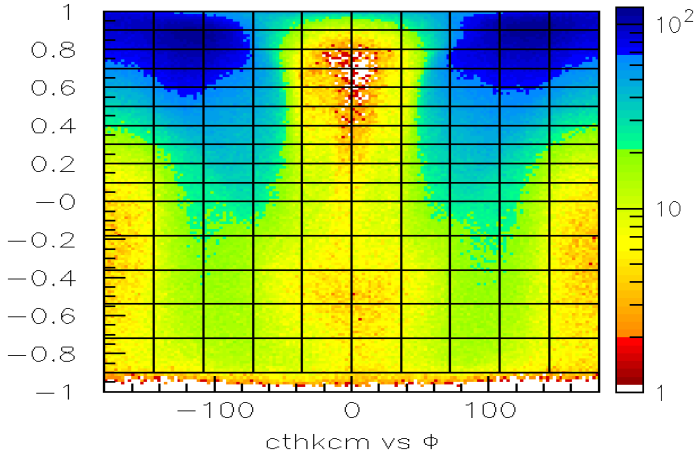
- Γ_v : virtual photon flux factor $\Gamma_v = \frac{\alpha}{4\pi} \cdot \frac{W}{ME_b^2} \cdot \frac{W^2 - M^2}{MQ^2} \cdot \frac{1}{1-\epsilon}$
- $\Delta Q^2 \Delta W \Delta \cos\theta_K^* \Delta\Phi$: kinematic bin volume
- R_i : radiative correction — Set RC =1 for now
- N_i : hyperon yield — Within MM limits
- BC_i : bin centering correction — Set to unity
- η_i : acceptance and efficiency correction — From WIN18 MC
- N_0 : incident electron flux — Q_{tot} = 90/80 mC for 6.398/8.478 GeV
- $N_A \rho t / M_w$ — N_A*0.07151 g/cm^3*5 cm/1.00794 g/mol = 1.079e23/cm^2

RG-K KY Binning and Yields – 6.4 GeV

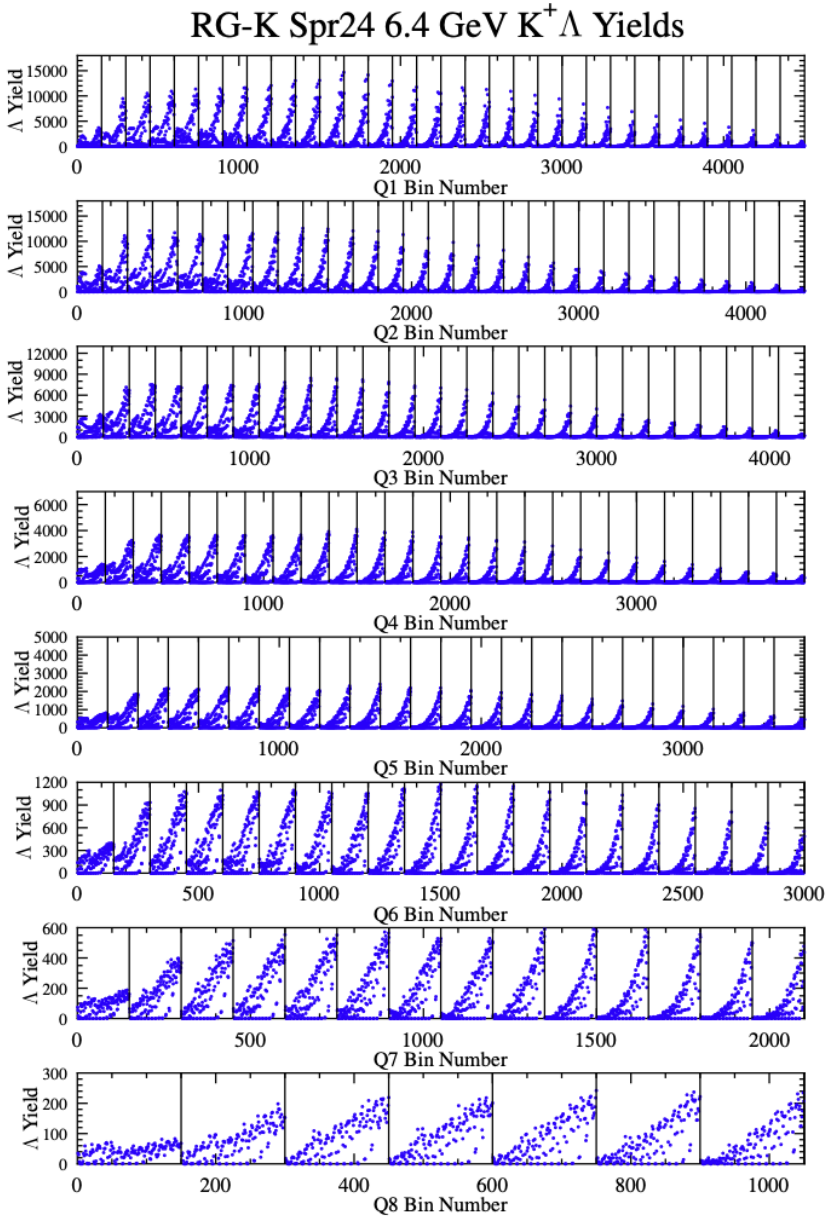
Spr24 datasets allow fine binning in the relevant kinematic variables:

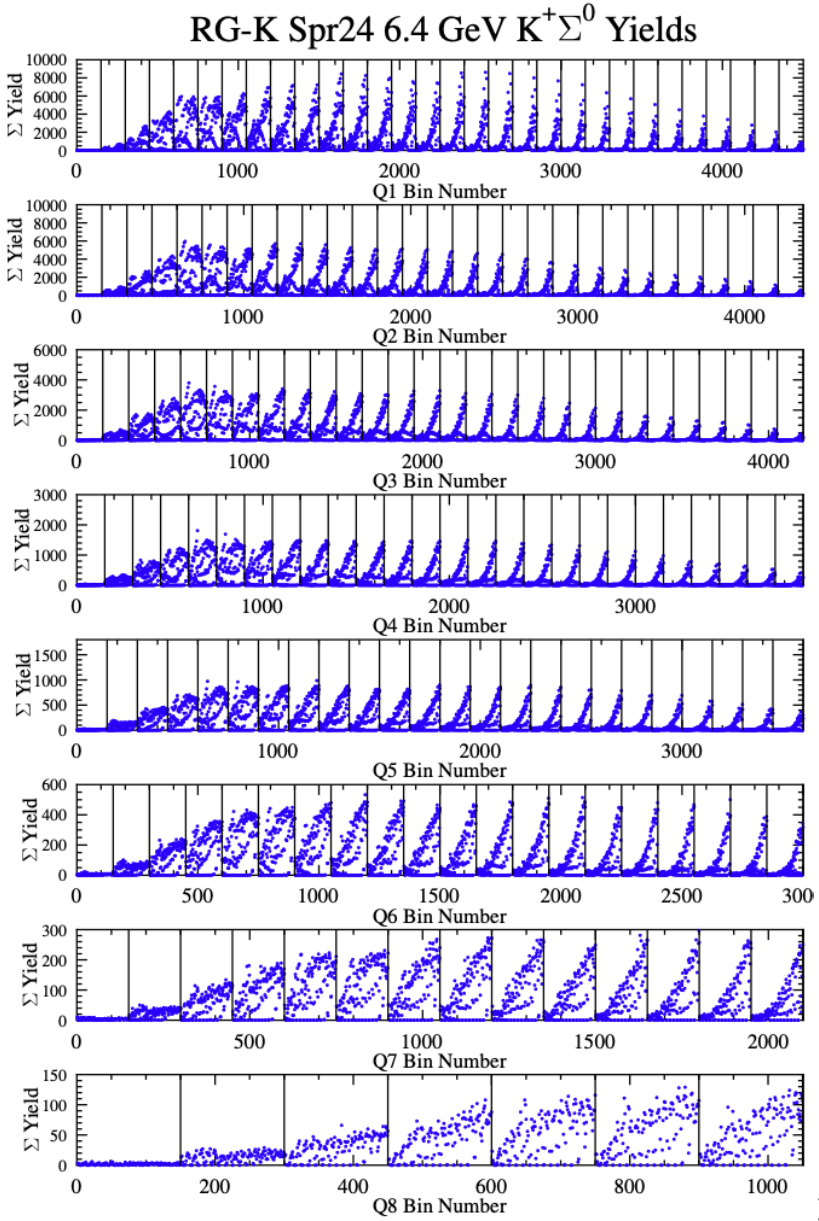
Q^2, W, cos $\theta_K^{c.m.}$, Φ





N_{bins} = 26,700 (x2 for h=±1)

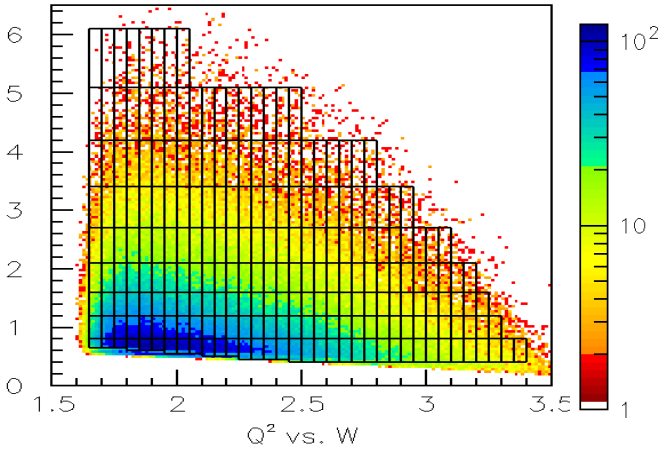


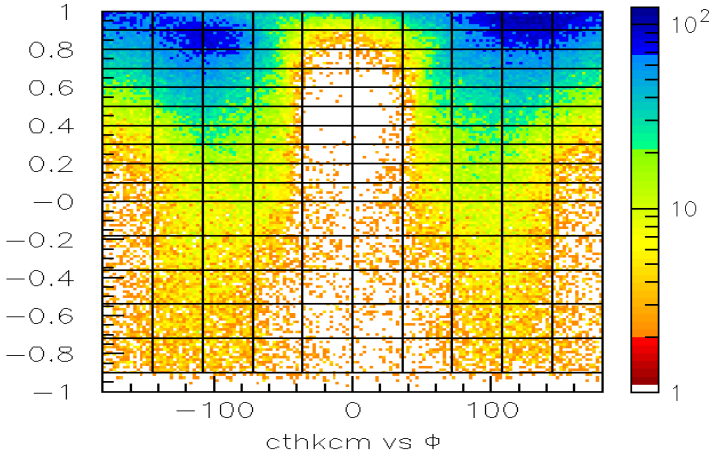


RG-K KY Binning and Yields – 8.5 GeV

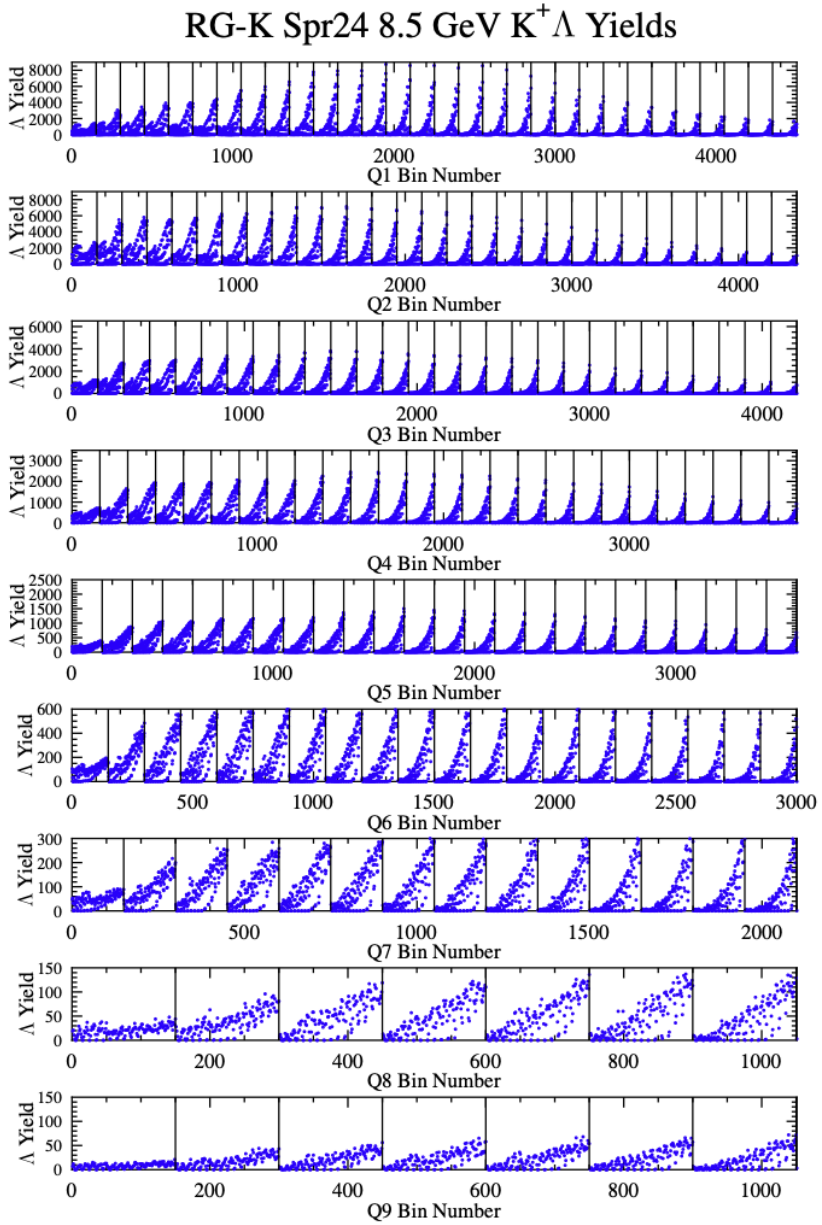
Spr24 datasets allow fine binning in the relevant kinematic variables:

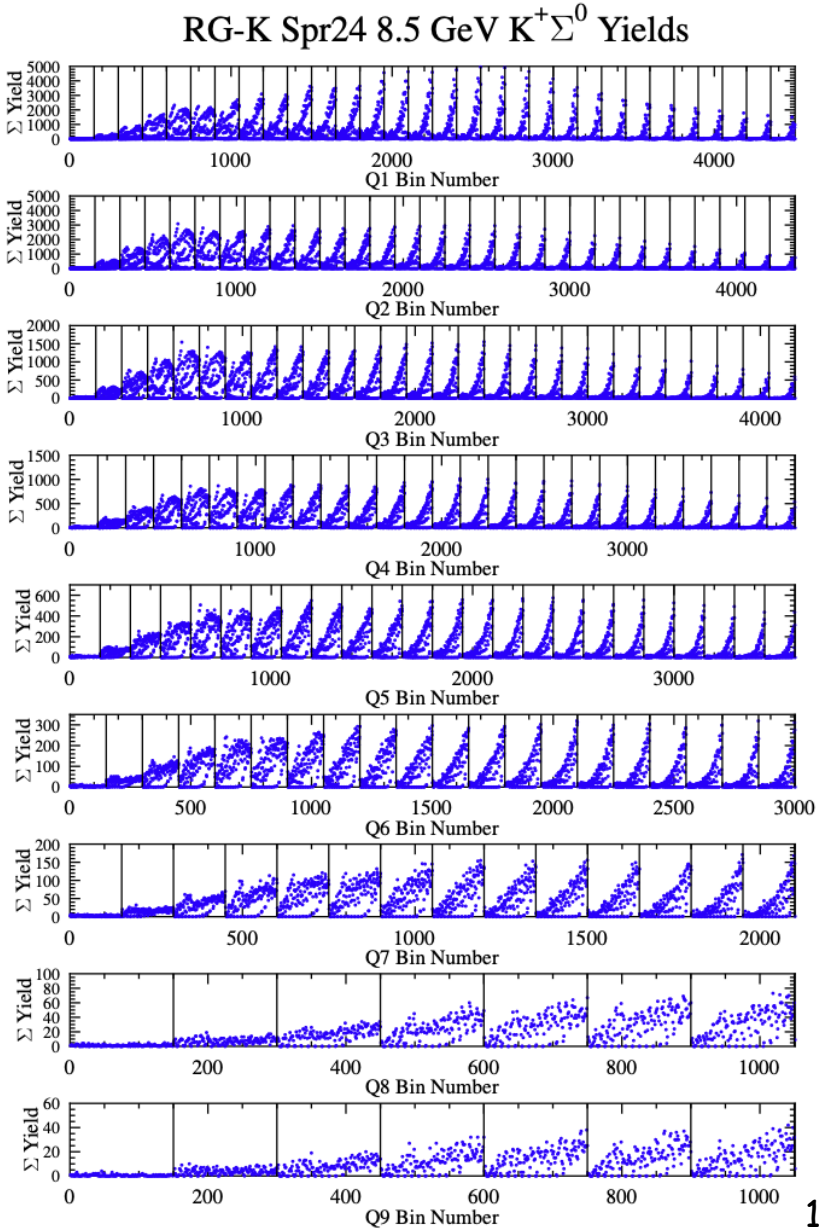
Q^2, W, cos $\theta_K^{c.m.}$, Φ





N_{bins} = 35,100 (x2 for h=±1)

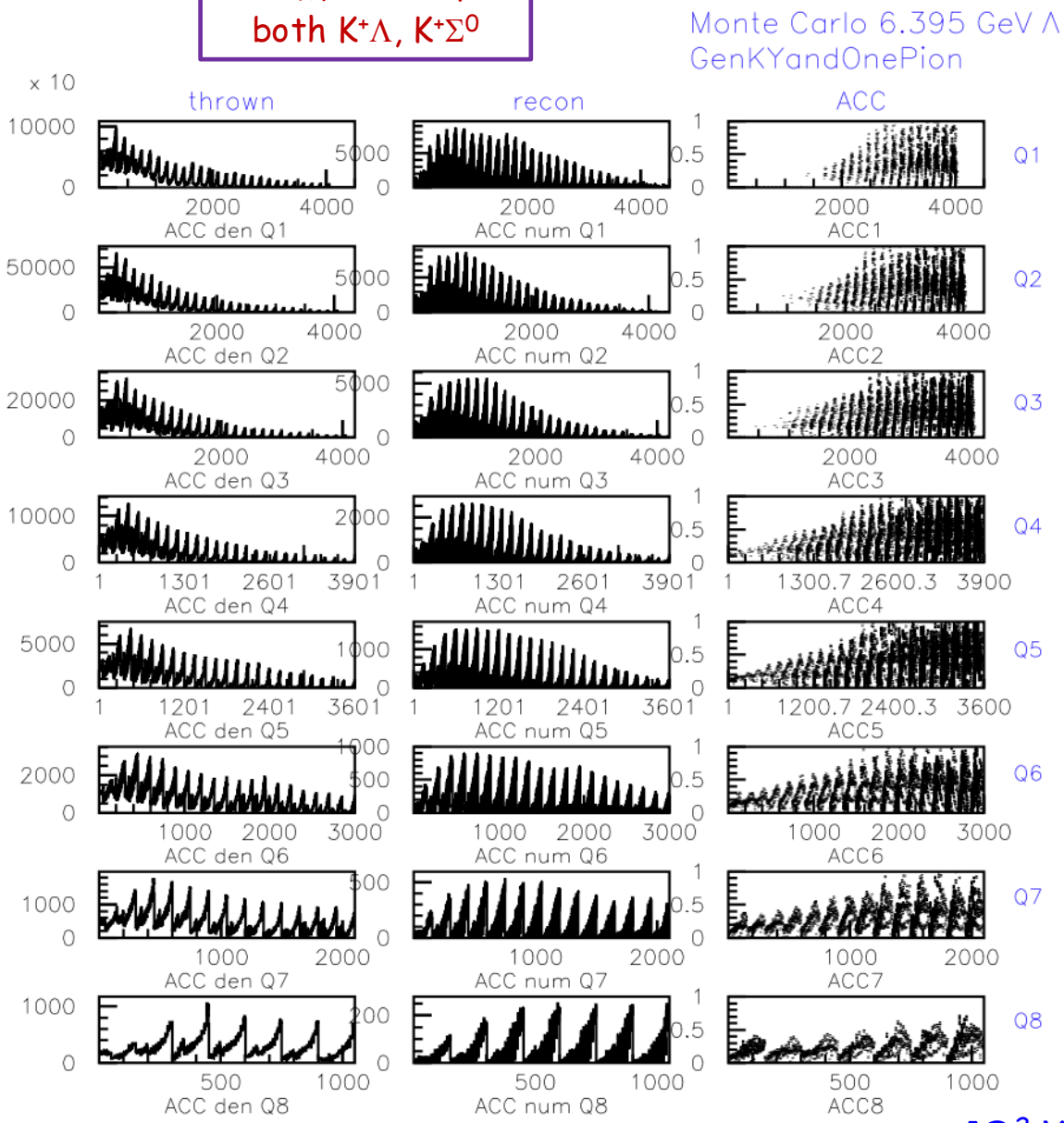


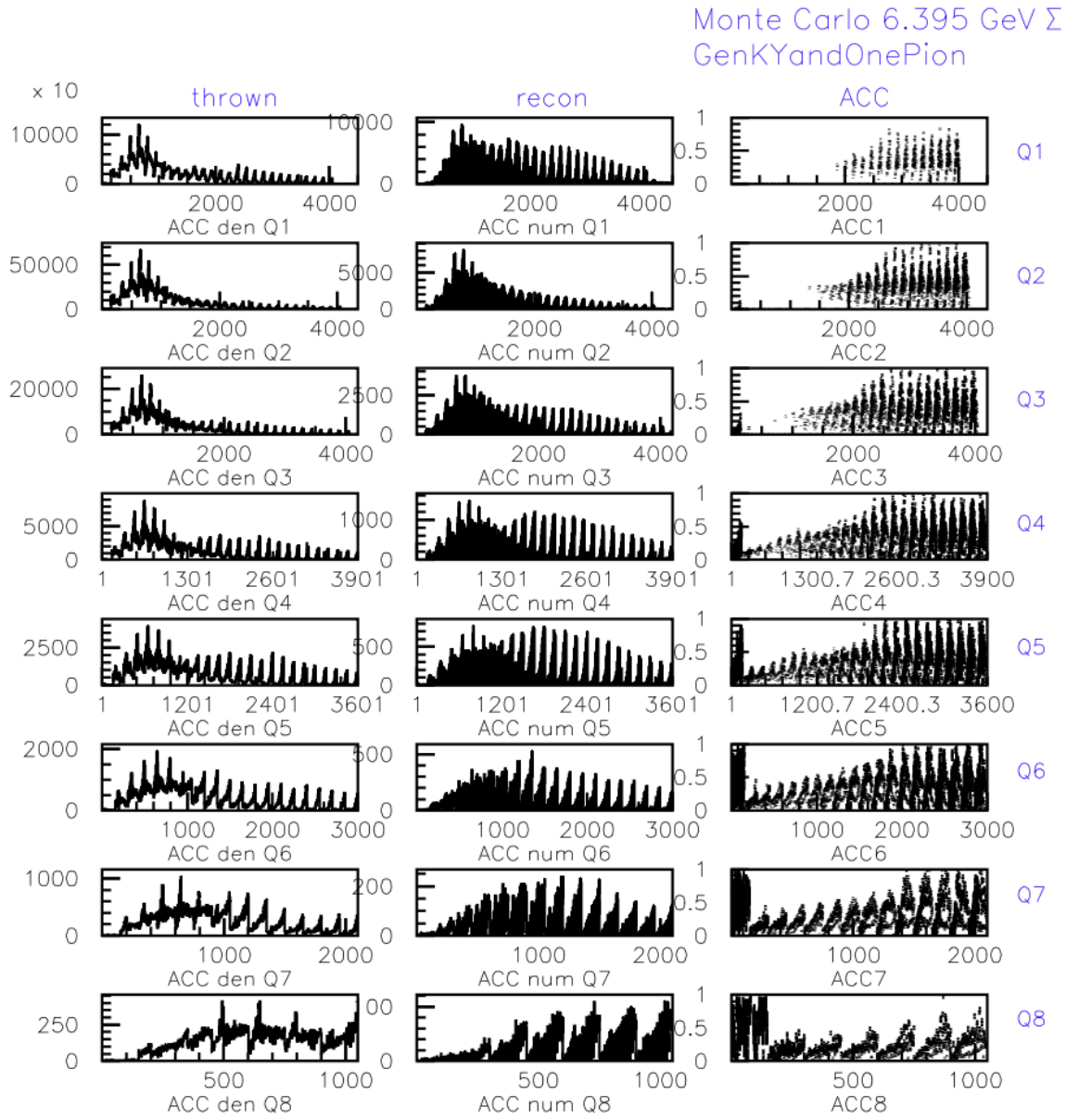


Acceptance Function

200 M events for both $K^+\Lambda$, $K^+\Sigma^0$

*Use RG-K WIN18 MC

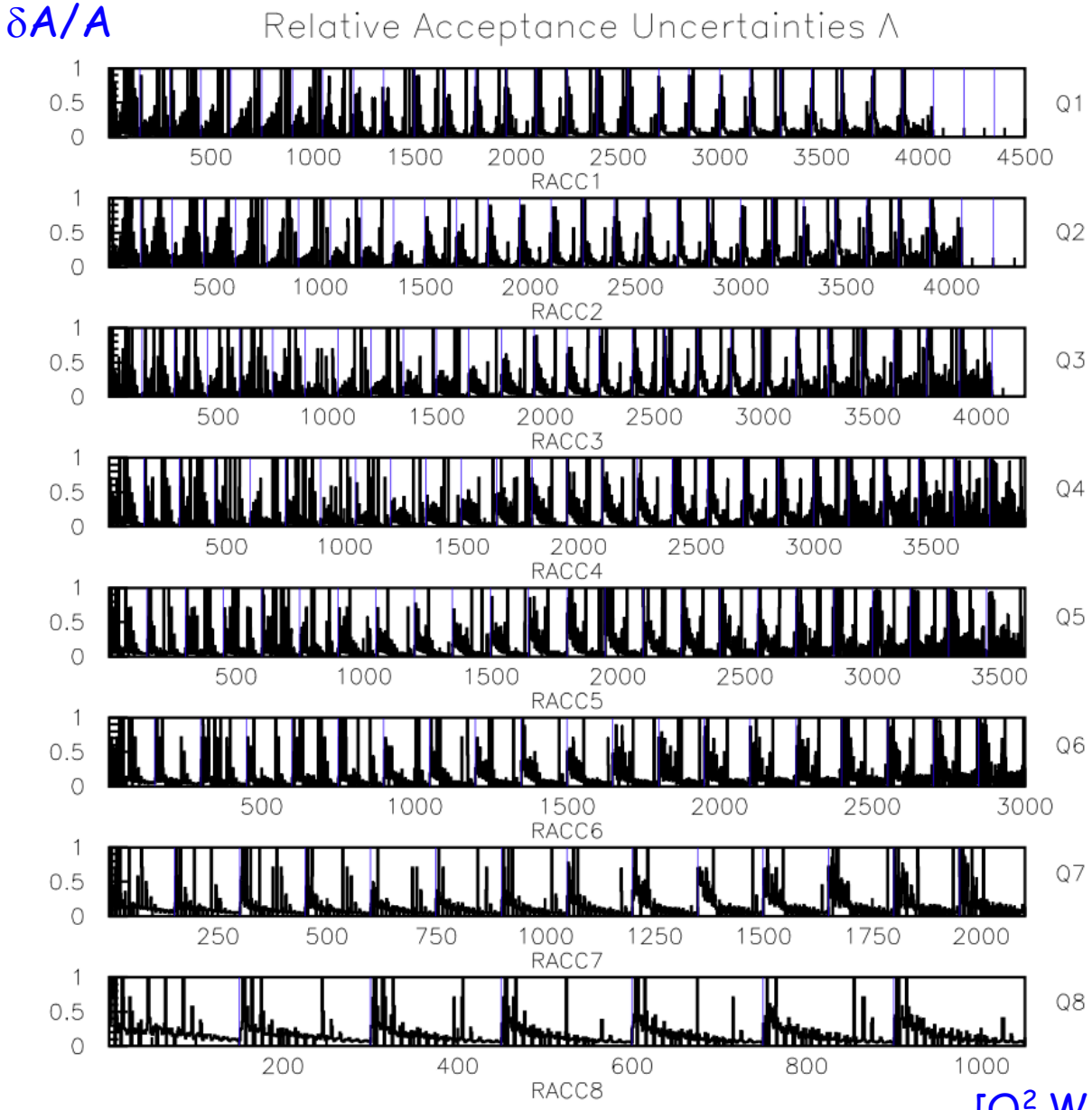


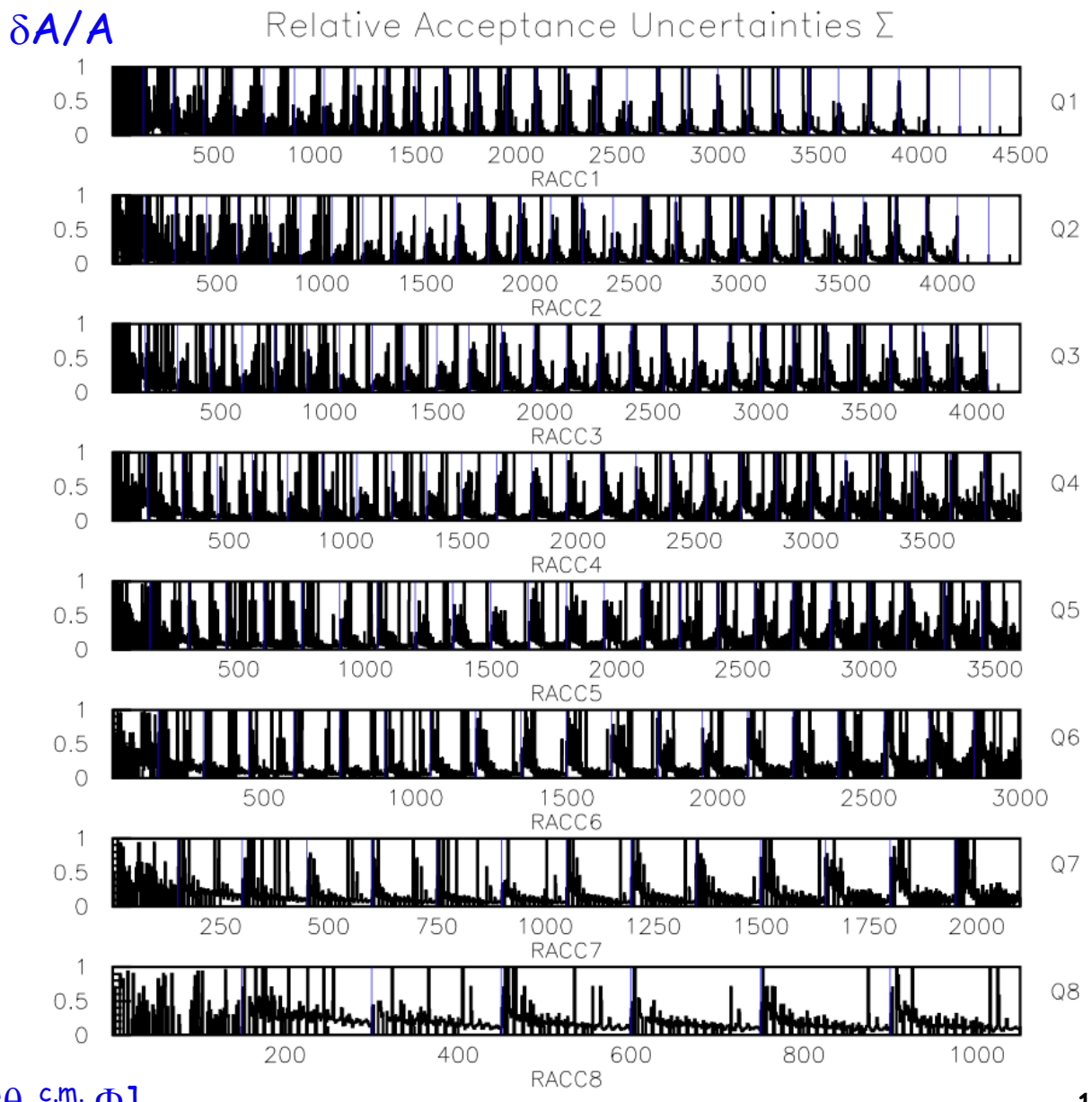


$[Q^2, W, \cos\theta_K^{c.m.}, \Phi]$

Relative Acceptance Uncertainty

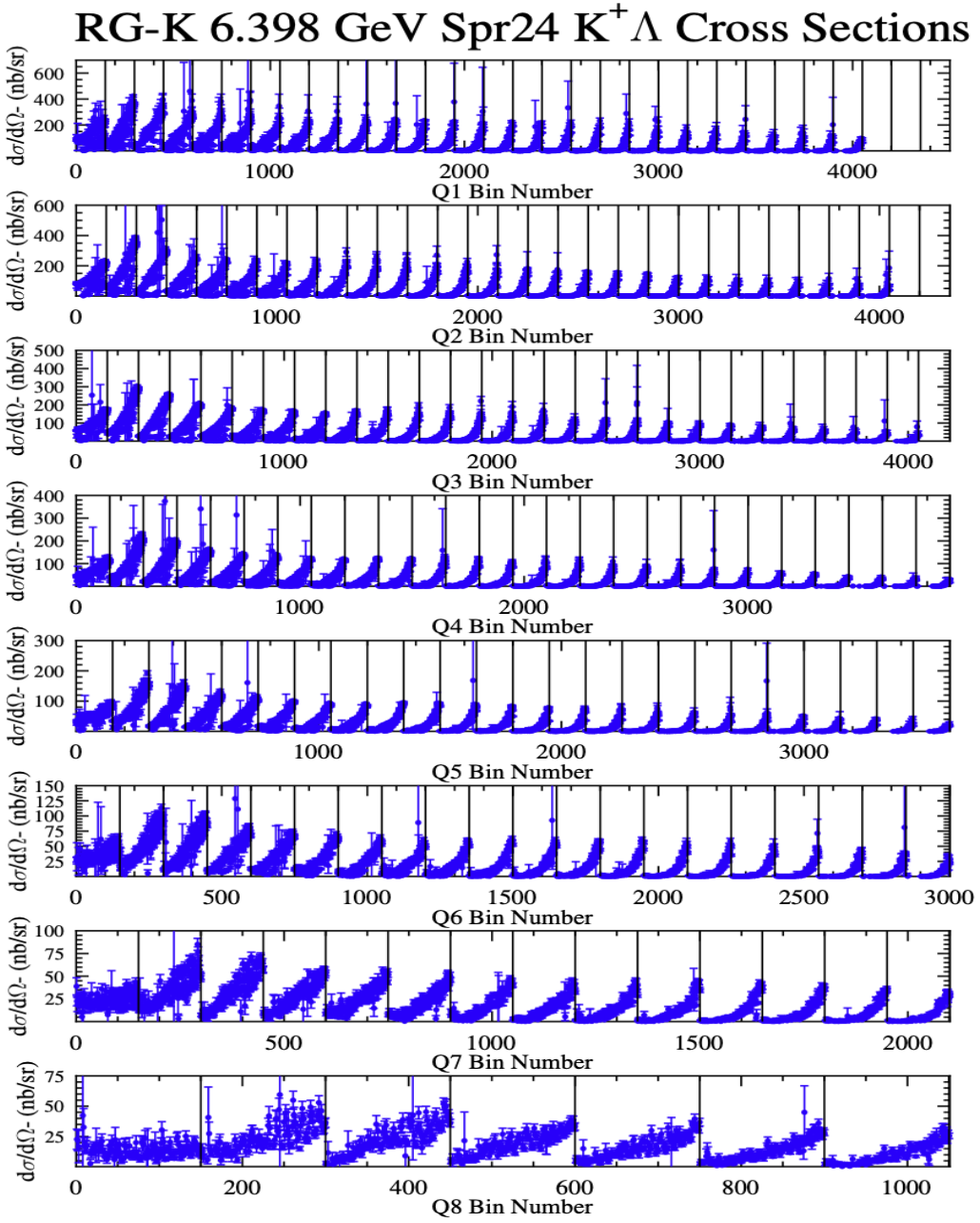
*Use RG-K WIN18 MC

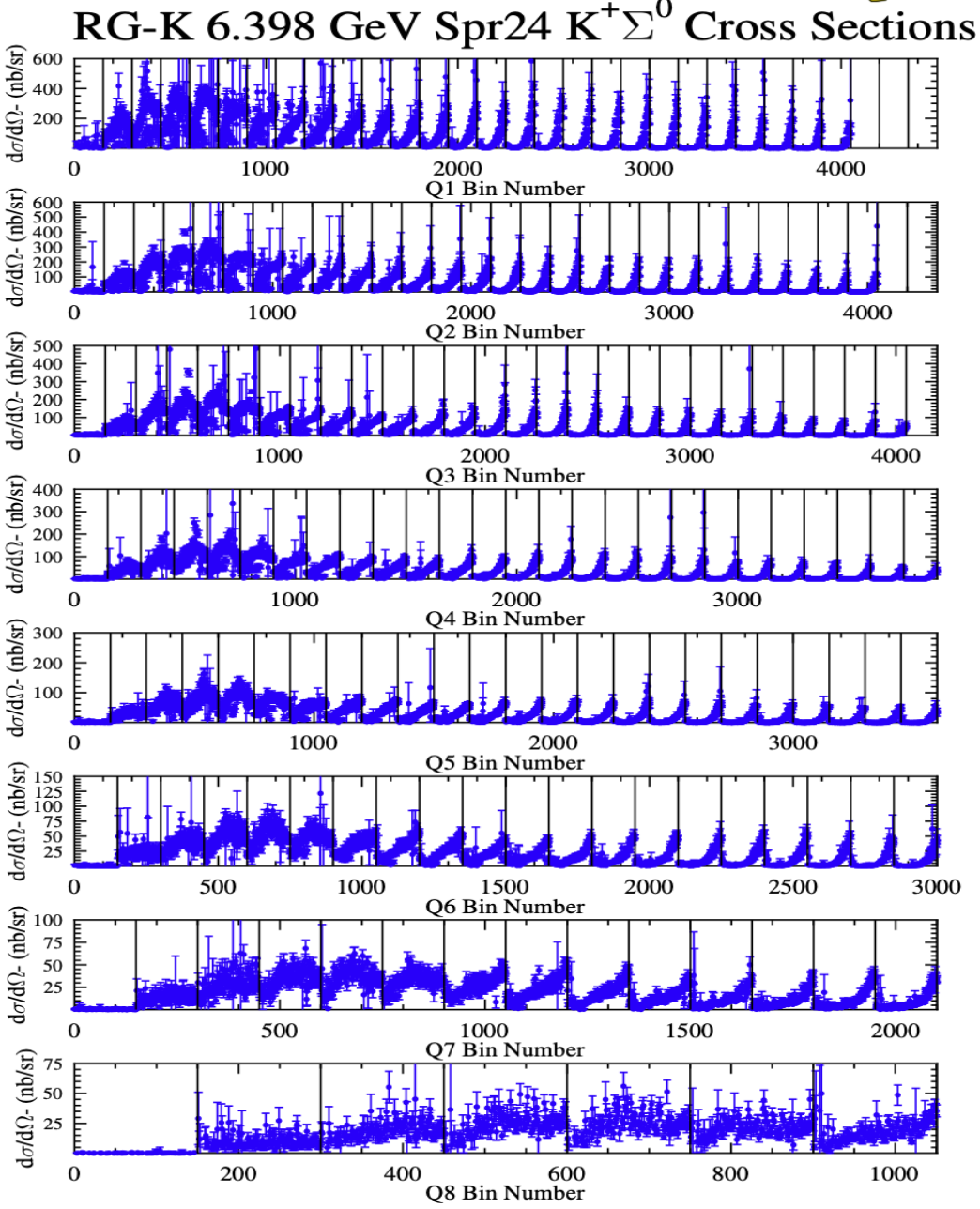




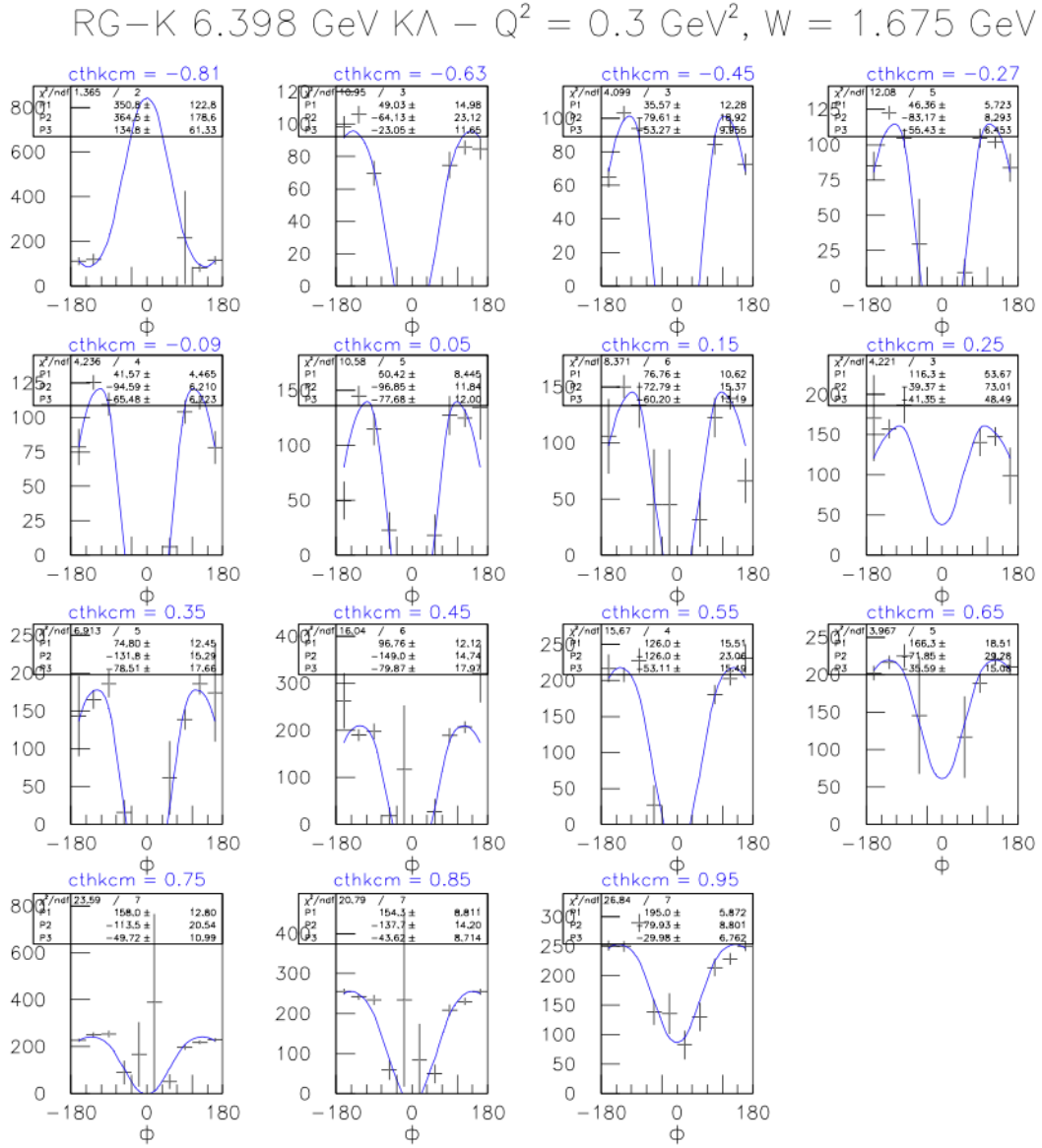
$[Q^2, W, \cos\theta_K^{c.m.}, \Phi]$

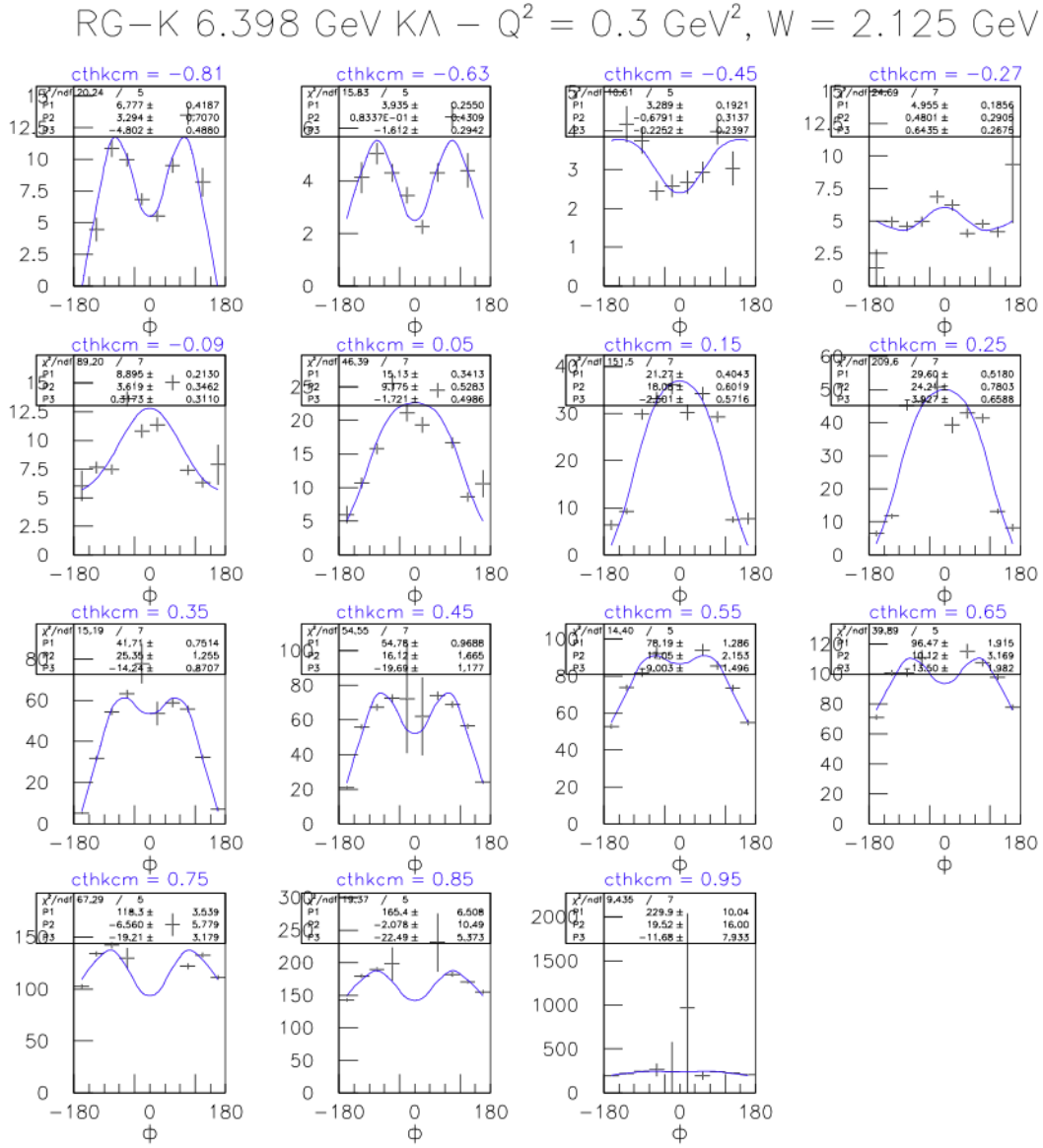
K^+Y Differential Cross Sections





Sample Structure Function Fits

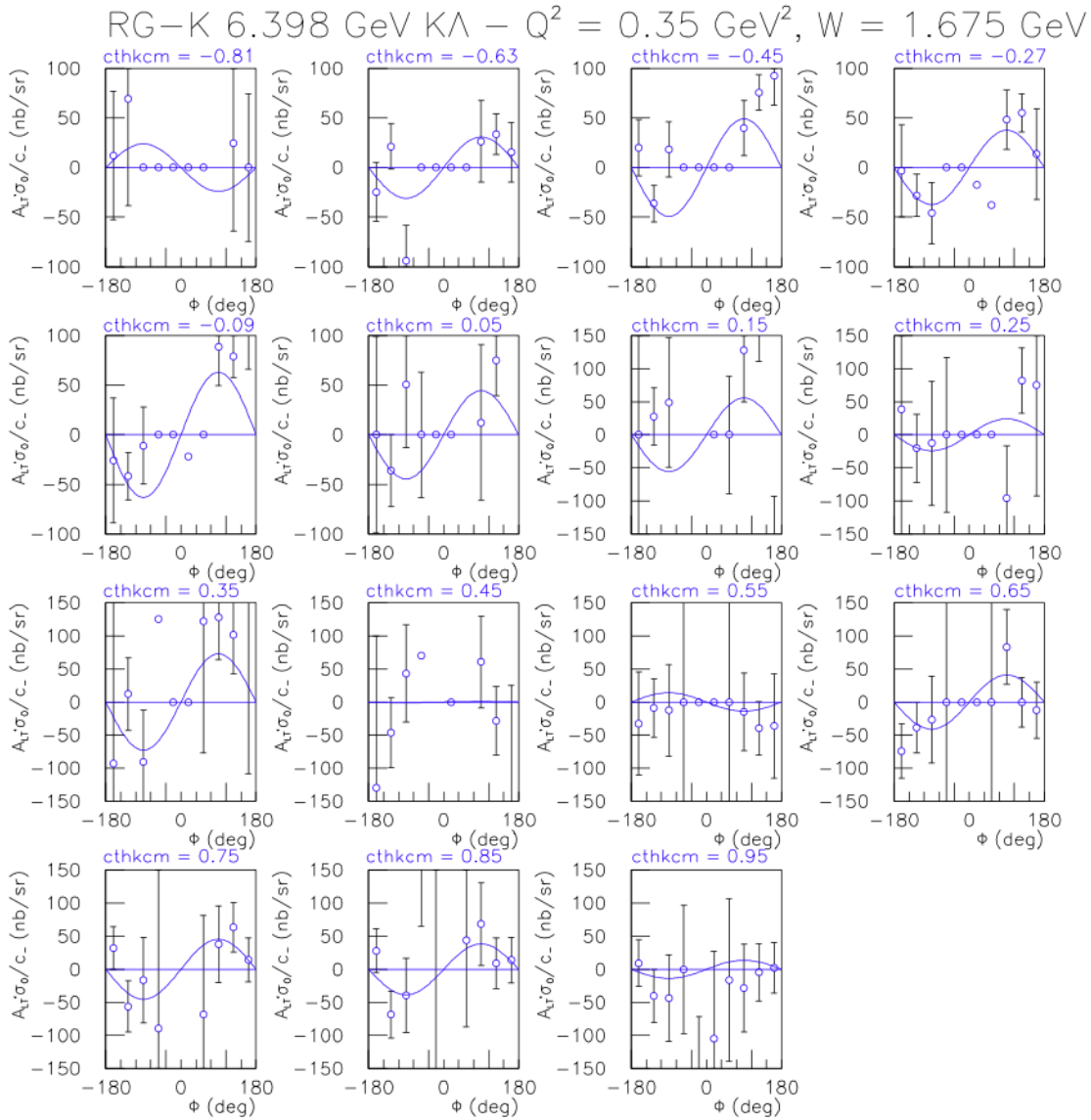


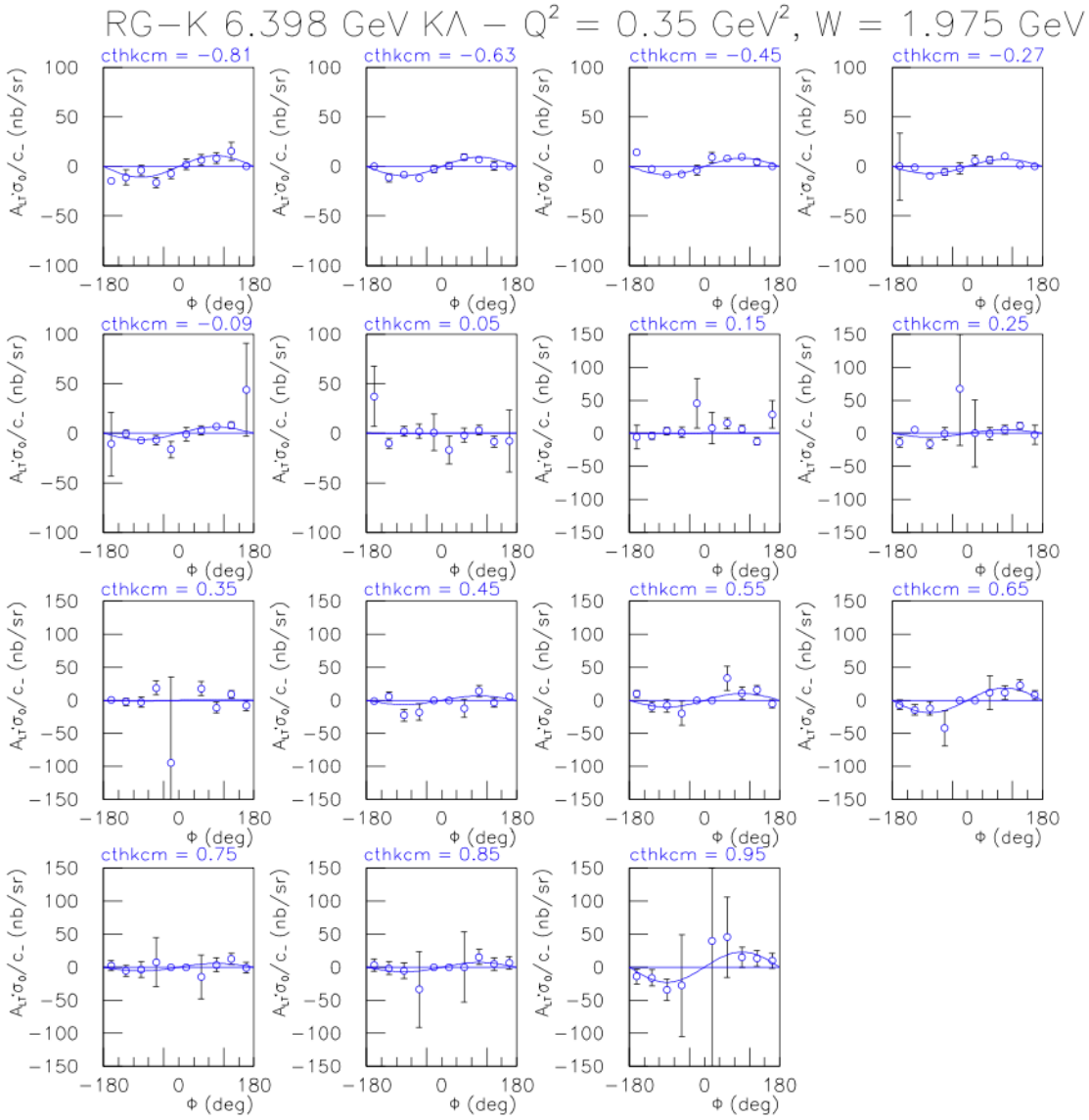


$$\frac{d\sigma}{d\Omega_K^{c.m.}} \equiv \sigma_0 = \sigma_T + \epsilon\sigma_L + \sqrt{\epsilon(1+\epsilon)}\sigma_{LT}\cos\Phi + \epsilon\sigma_{TT}\cos 2\Phi$$

$$\frac{d\sigma}{d\Omega_K^{c.m.}} = A + B\cos\Phi + C\cos 2\Phi$$

Sample Helicity Asymmetry Fits



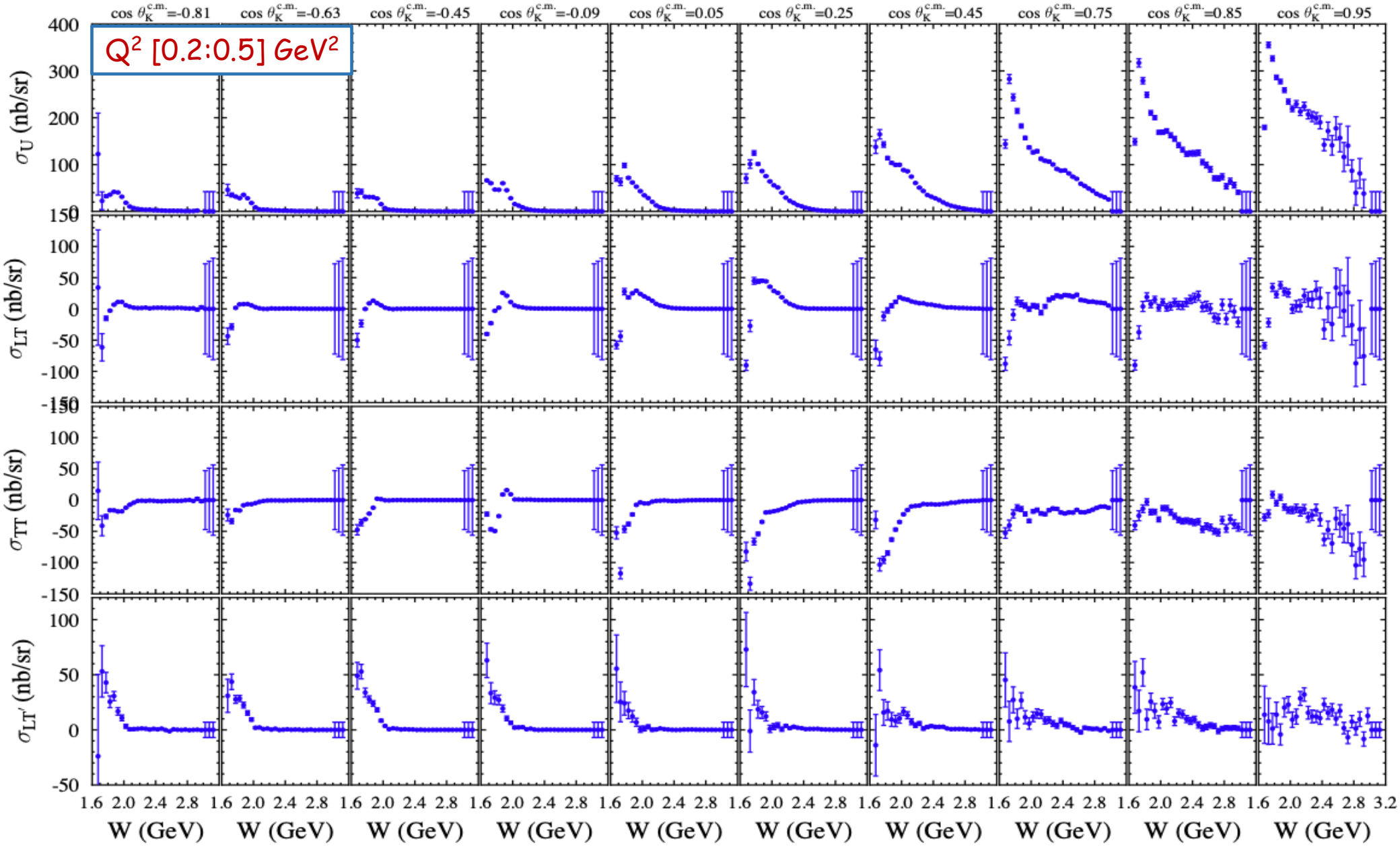


$$A_{LT'} = \frac{1}{P_b} \cdot \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\sqrt{\epsilon(1-\epsilon)}\sigma_{LT'} \sin\Phi}{\sigma_0}$$

RG-K Spr24

6.4 GeV

$K^+\Lambda$ Structure Functions



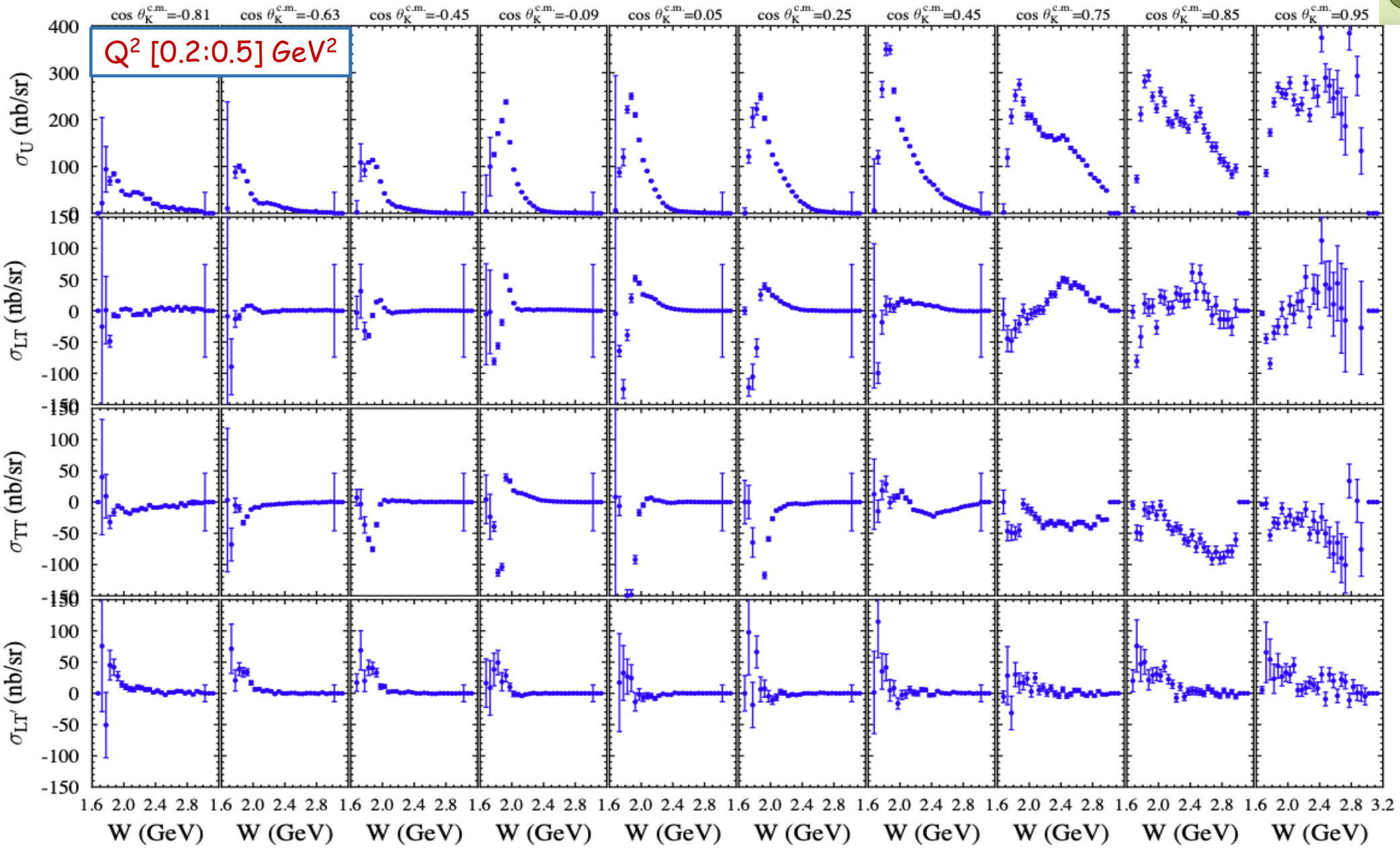
- Huge amount of data compared to CLAS e1f
- Precision/binning at low Q^2 comparable with CLAS γp data
- Peaks from $N^* \rightarrow KY$, interference effects, coupled-channel contributions

$K^+\Sigma^0$ Structure Functions

RG-K Spr24

6.4 GeV

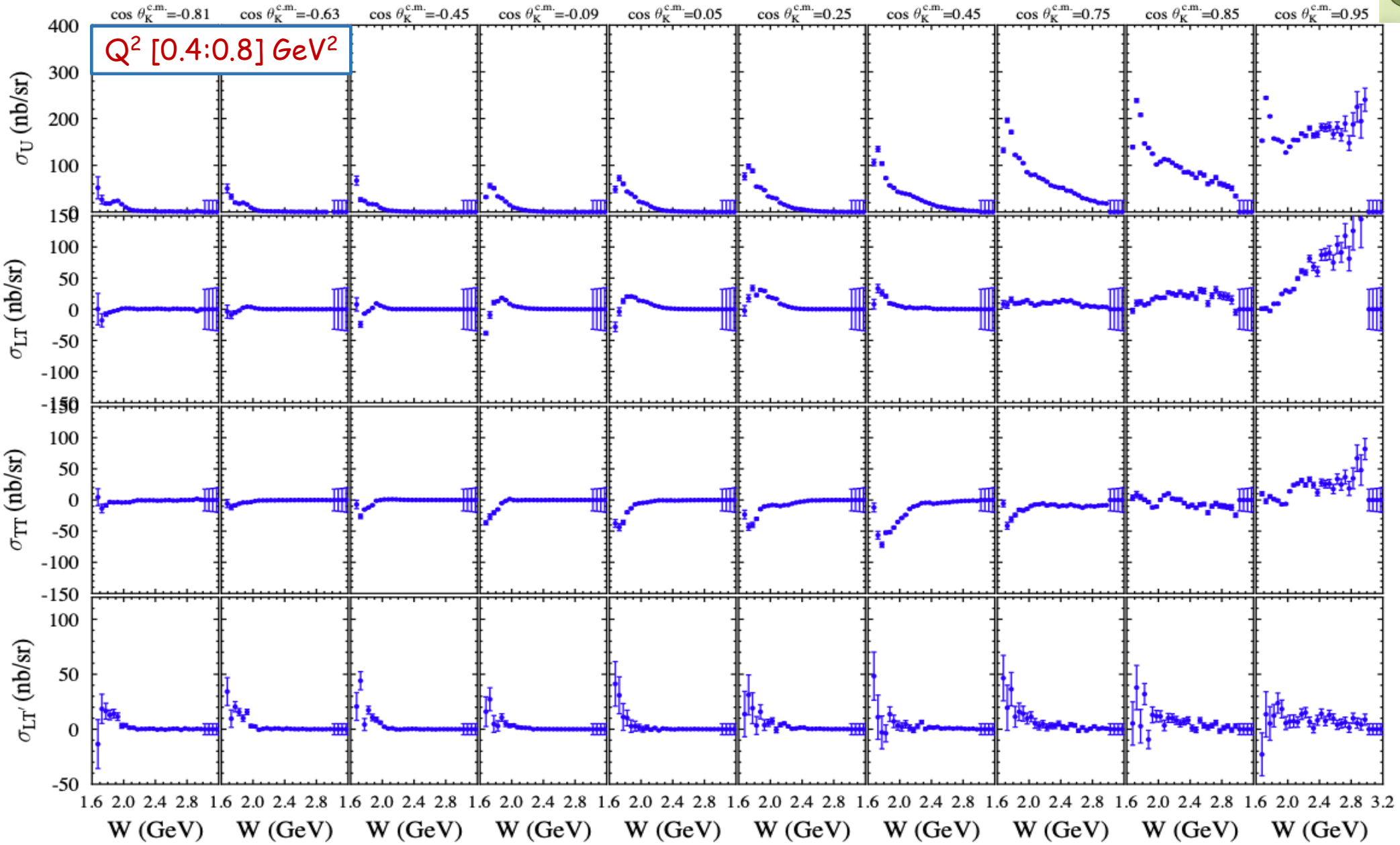
Q^2 [0.2:0.5] GeV^2



$K^+\Lambda$ Structure Functions

RG-K Spr24

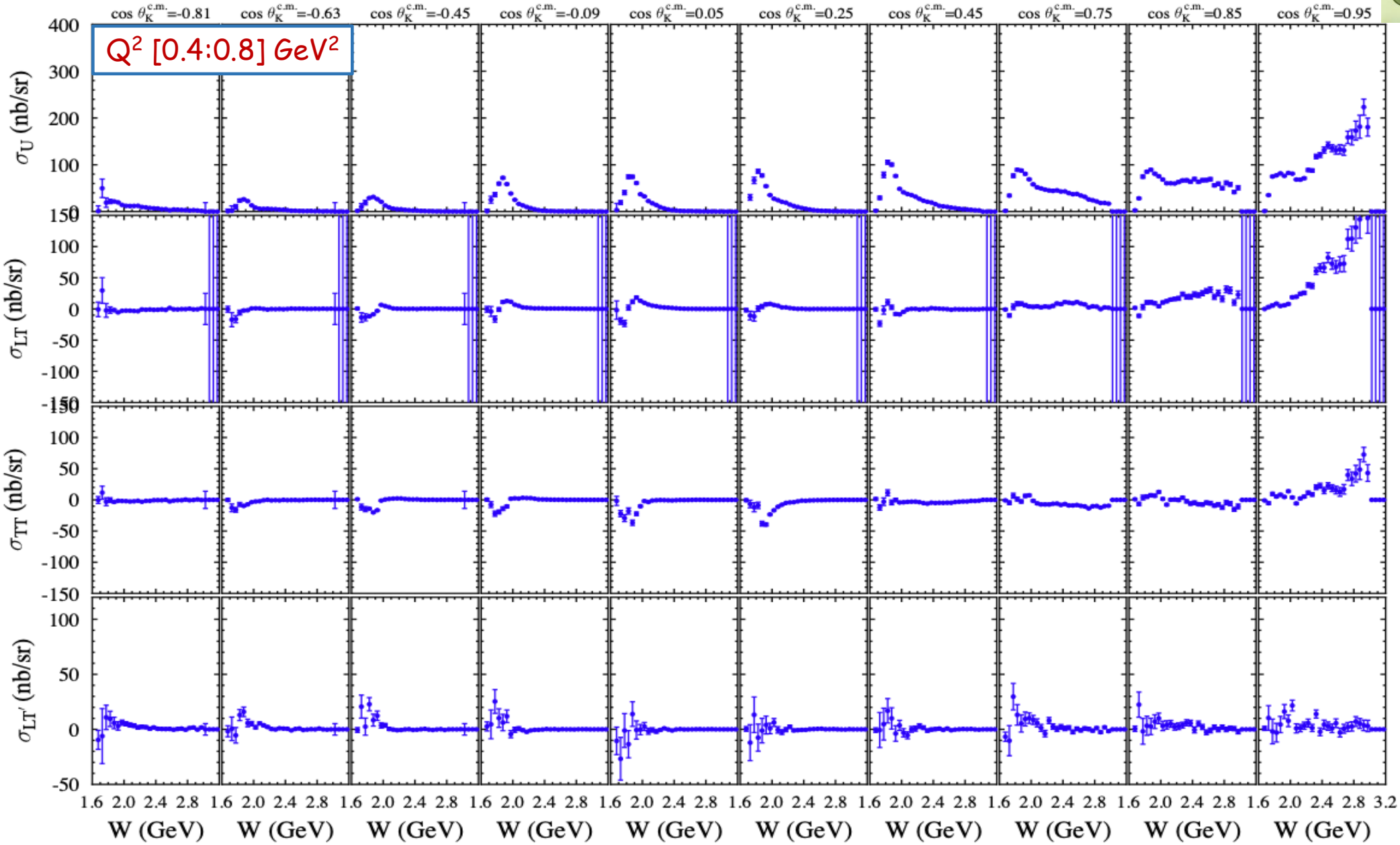
8.5 GeV



$K^+\Sigma^0$ Structure Functions

RG-K Spr24

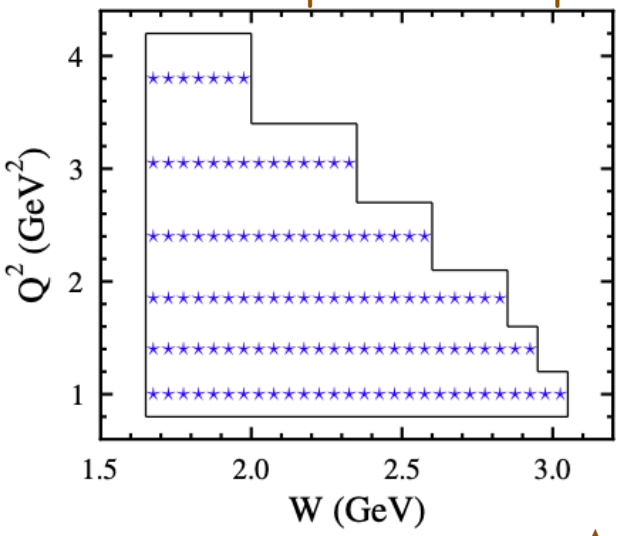
8.5 GeV



RG-K KY Rosenbluth Separation

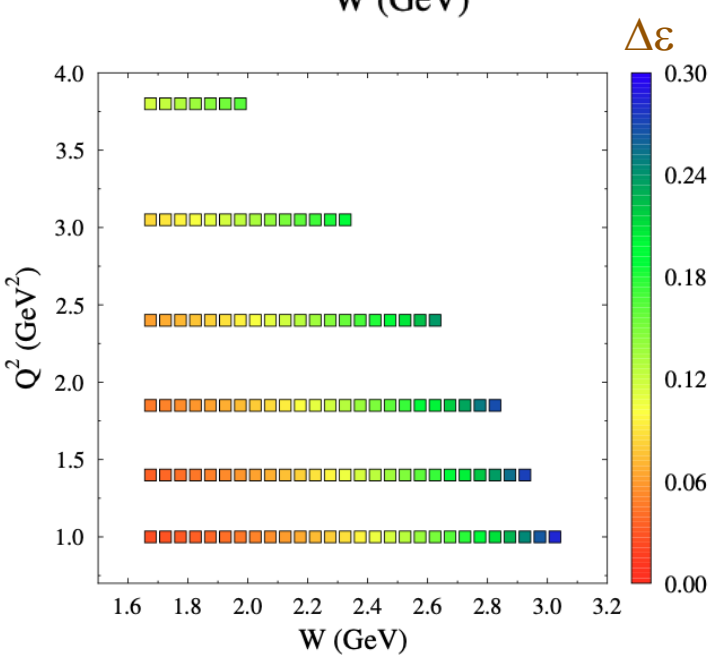
$K^+\Lambda$

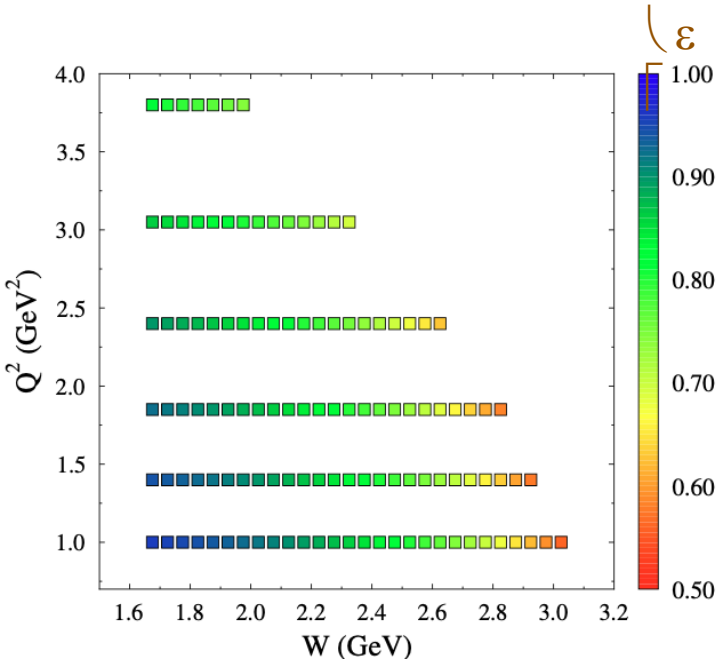
Landscape of Overlap

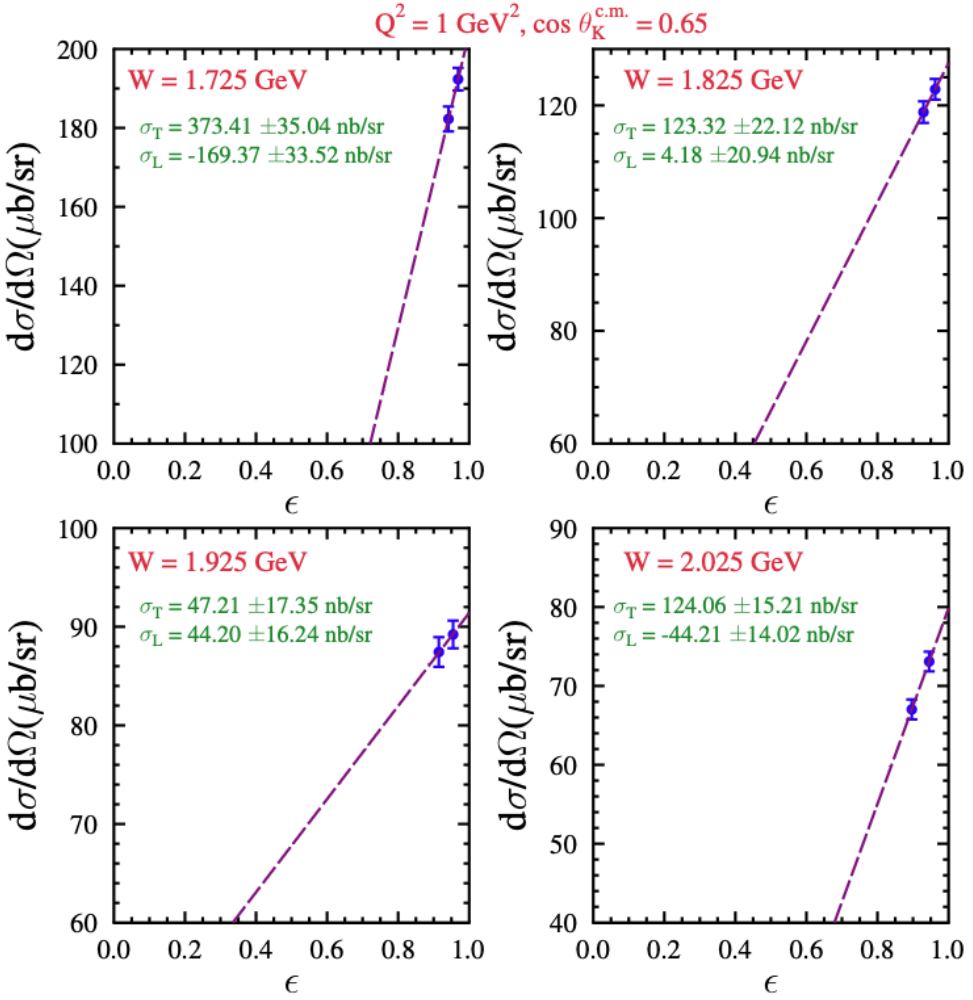


Note:

- Full overlap landscape not practically accessible
- At 6.4 and 8.5 GeV most kinematic points have εH0.8-0.9 with ΔεH0!



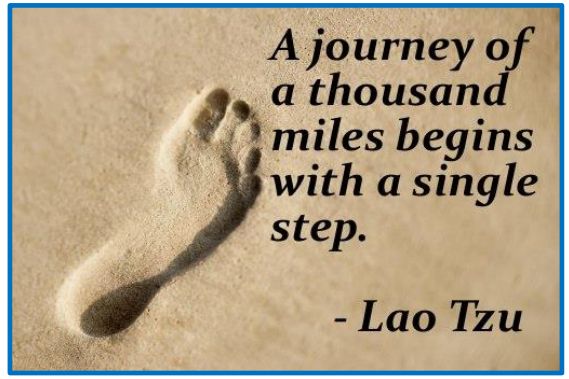




O.K., there is still some work to do …

Summary & Next Steps

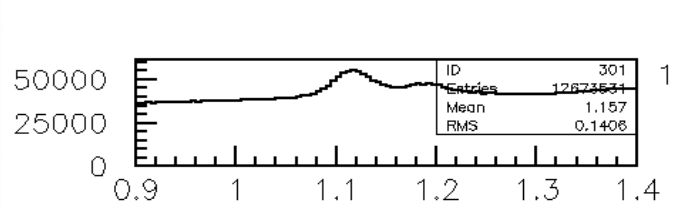
- RG-K Spr24 cooking completed on June 7, 2026 – Huzzah!
- Recent work has focused on developing the cross section extraction code and scripts Claude
- A preliminary extraction of the $K^+\Lambda$ and $K^+\Sigma^0$ differential cross sections has been completed for the 6.395 GeV and 8.478 GeV RG-K Spr24 datasets
  - Two topologies have been combined: $e'K^+_F$ and $e'K^+_C p_F$
  - Note that the proton requirement is necessary in the $e'K^+_C$ topology due to the overwhelming background
- From the differential cross sections, a Φ moment analysis was carried out to the extract the structure functions: σ_U, σ_{LT}, σ_{TT} followed by a BSA analysis to extract $\sigma_{LT'}$
- A first exploration of the landscape for Rosenbluth separations of σ_U into σ_L and σ_T has been performed, but this may not be viable given the kinematics
- Most of the "heavy lifting" is still ahead of me:
  - Optimize analysis cuts, determine electron/hadron momentum corrections
  - Yield fitting to be completed – fitting code has been tuned and optimized
  - Radiative correction model (EXCLURAD) now being integrated into EG
  - Optimization/iteration of EG to match the data
  - Still a long way to go, but a promising start for RG-K Spr24 KY analysis …



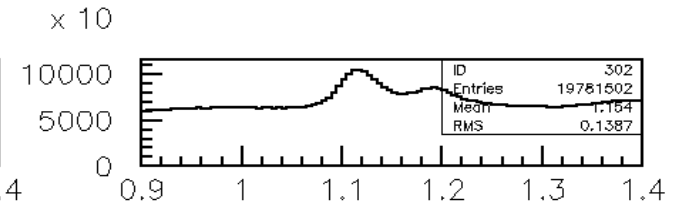
Backup

Central Detector Response

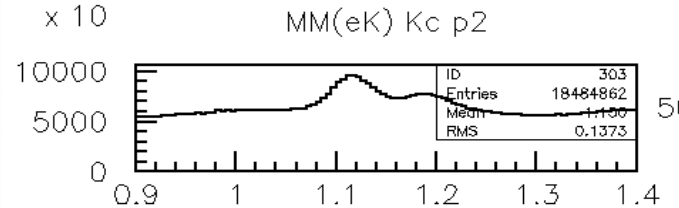
[0.2:0.4] GeV



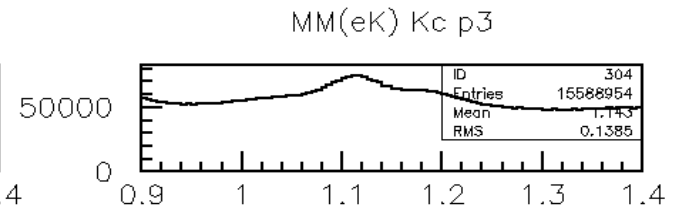
[0.4:0.6] GeV



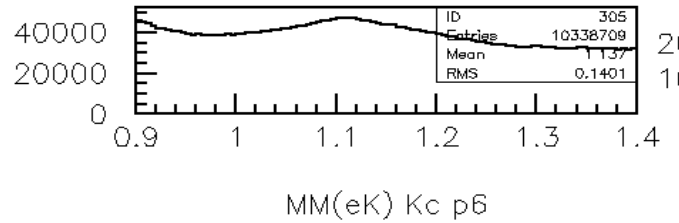
[0.6:0.8] GeV



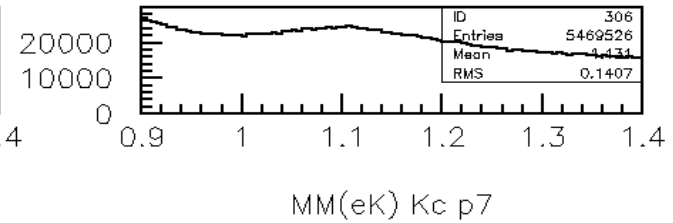
[0.8:1.0] GeV



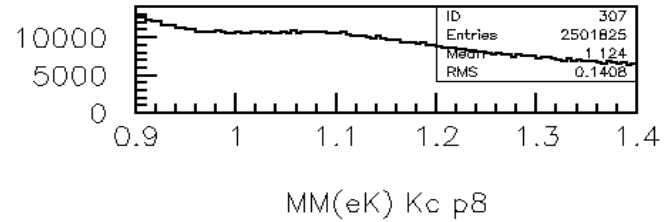
[1.0:1.2] GeV



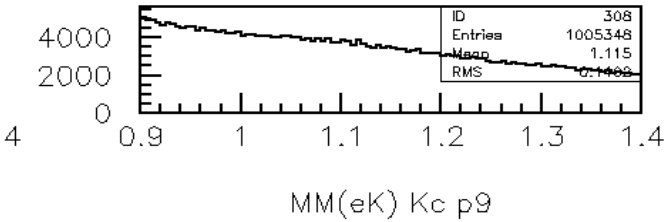
[1.2:1.4] GeV



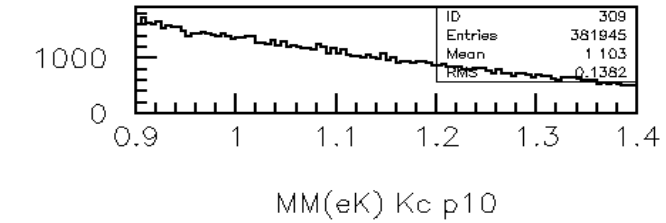
[1.4:1.6] GeV



[1.6:1.8] GeV



[1.8:2.0] GeV



[>2.0] GeV