Study of the Λ and Σ^0 production (E12-17-003)

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- Motivation & Experiment
- Data Analysis: $p(e,e'K^+)\Lambda/\Sigma^0$ reaction
- Results & Summary

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- **Motivation & Experiment**
- Data Analysis: p(e,e'K$^+$)Λ/Σ^0 reaction
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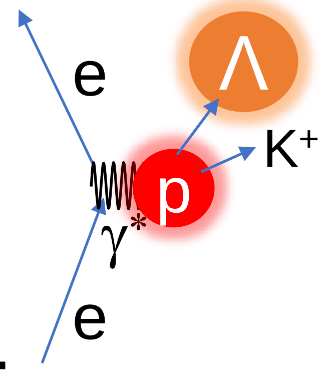
Motivation: Hyperon Electroproduction



Hyperon electroproduction
as an <u>elementary process</u> of Hypernucleus electroproduction

Experimentally;

Cross section is necessary because of … yield estimation, realistic energy spectrum
- based on photoproduction: γ (real) → γ^* (virtual, Q^2=0.5 (GeV/*c*)^2)
- abundant data <u>except</u> forward angles ⇔ our Exp. ($\theta_{\gamma K}$<10)

Theoretically;

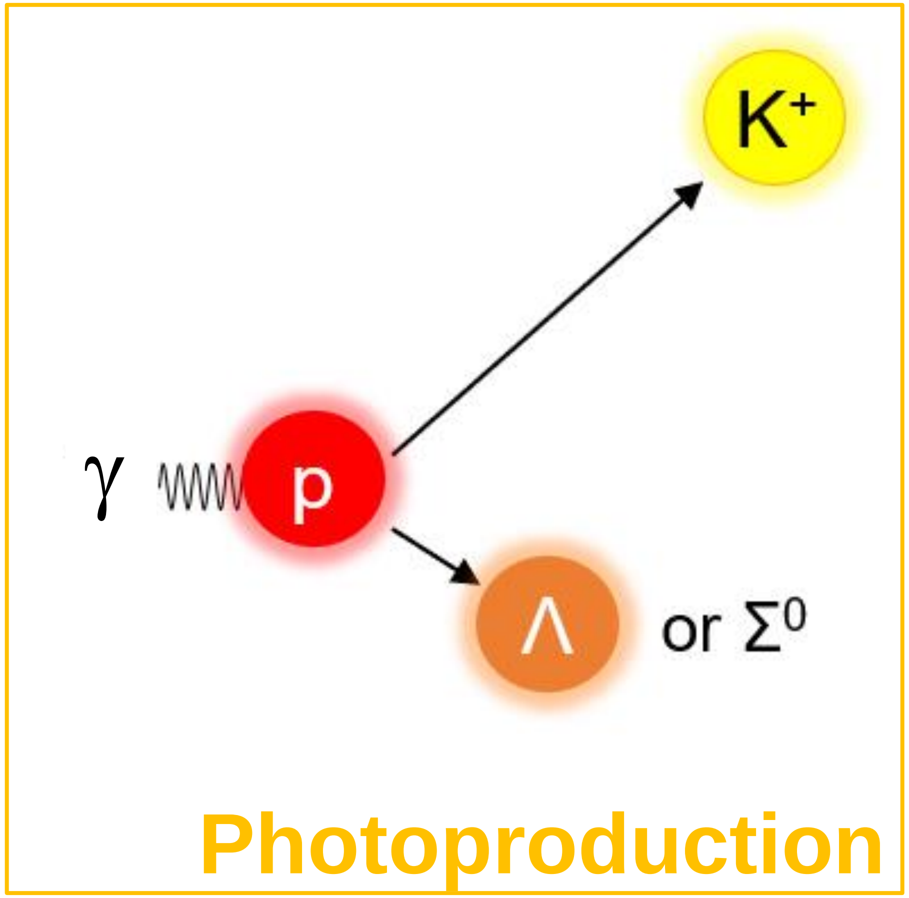
Isobaric model and RPR model were well established
- based on Exp. data (Photo-: ~3500 data >> Electro-: ~200 data)
- Missing resonance may couple to KΛ, KΣ channels

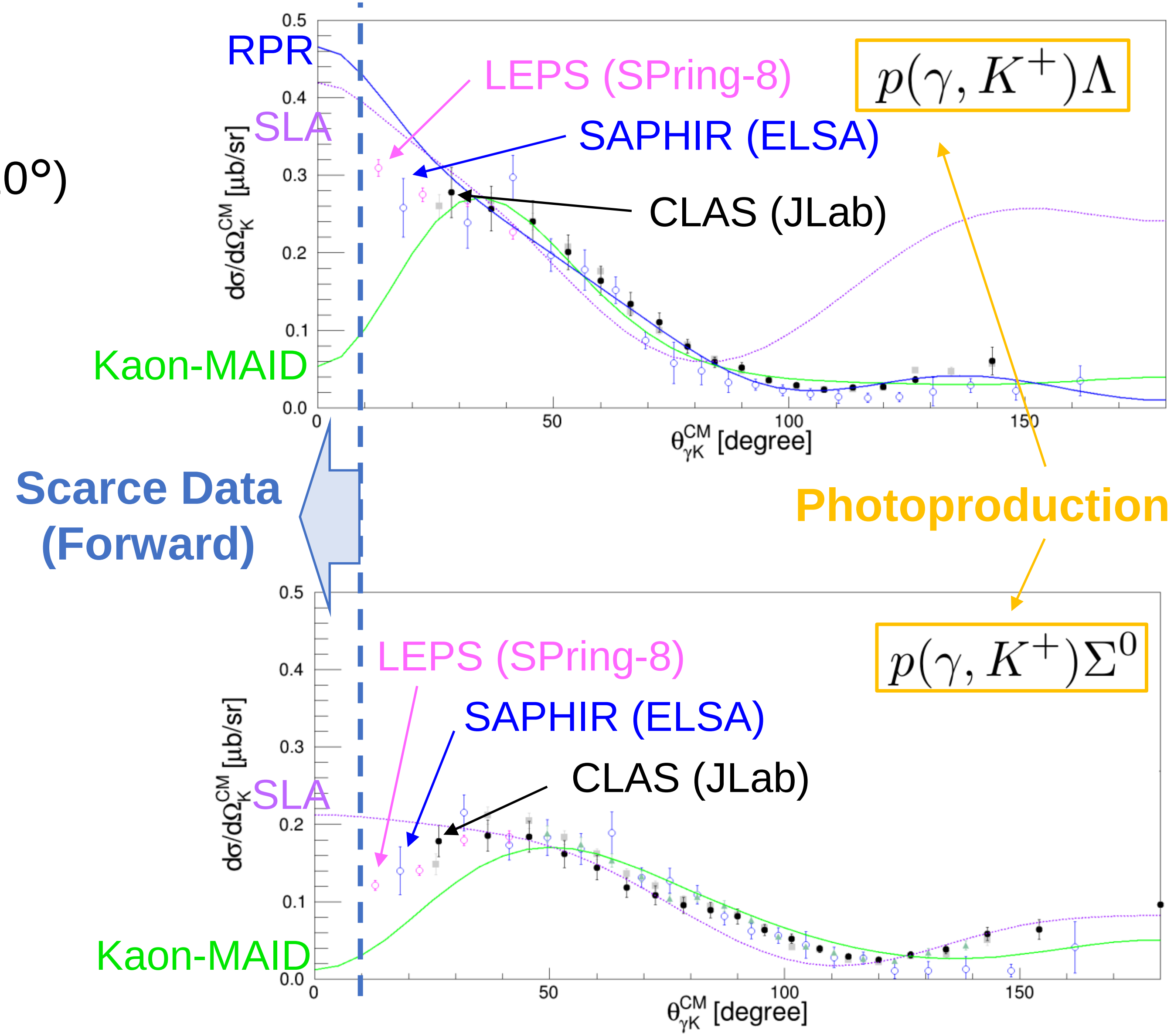
Accumulating the hyperon electroproduction data is necessary!

Hyperon Photoproduction

W = 2.14 GeV

- **Photoproduction (Q^2=0)**
  →Rich experimental data
  →but NO data in forward angles ($\theta_{\gamma K}^{CM}$<10°)





Hyperon **Electroproduction**

our exp.
E12-17-003

$\theta_{\gamma K}^{\text{c.m.}}$=8 deg
Q^2=0.5 (GeV/c)^2

$$\frac{d^3\sigma}{d\omega d\Omega_{e'} d\Omega_K^{\text{c.m.}}} = \Gamma \frac{d\sigma_{\gamma^*}}{d\Omega_K^{\text{c.m.}}}$$

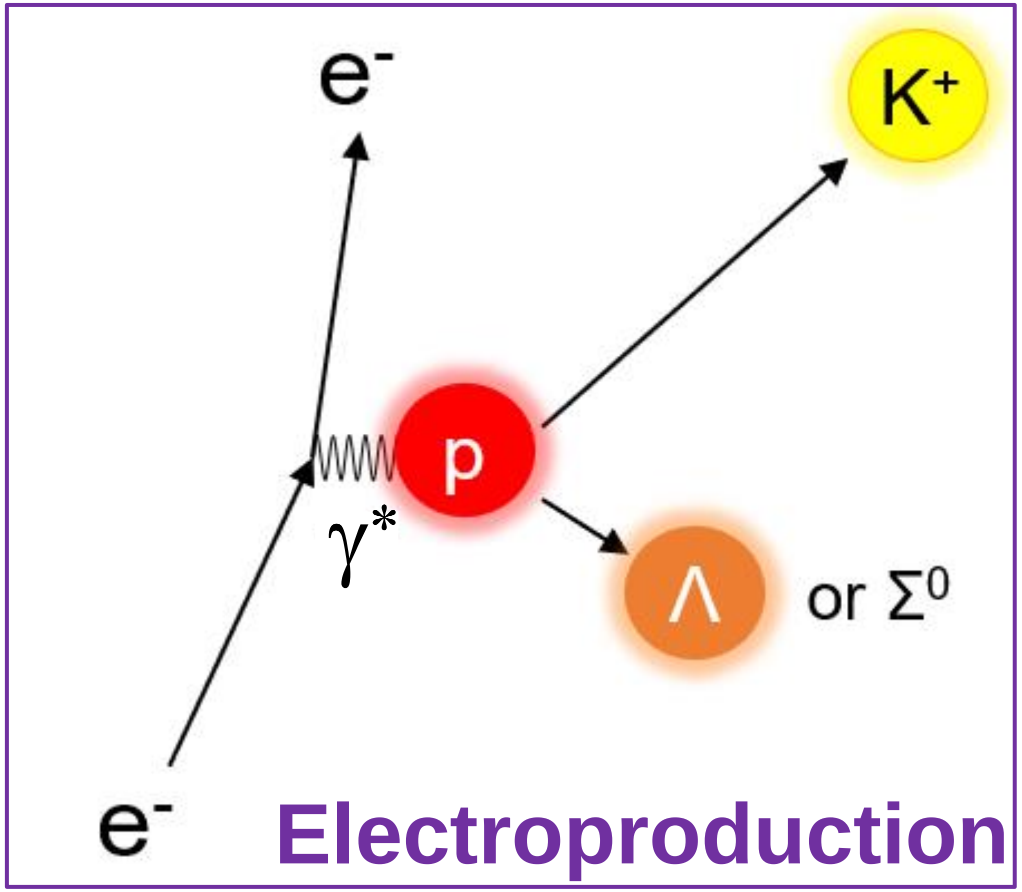
virtual photoproduction

Virtual Photon Flux

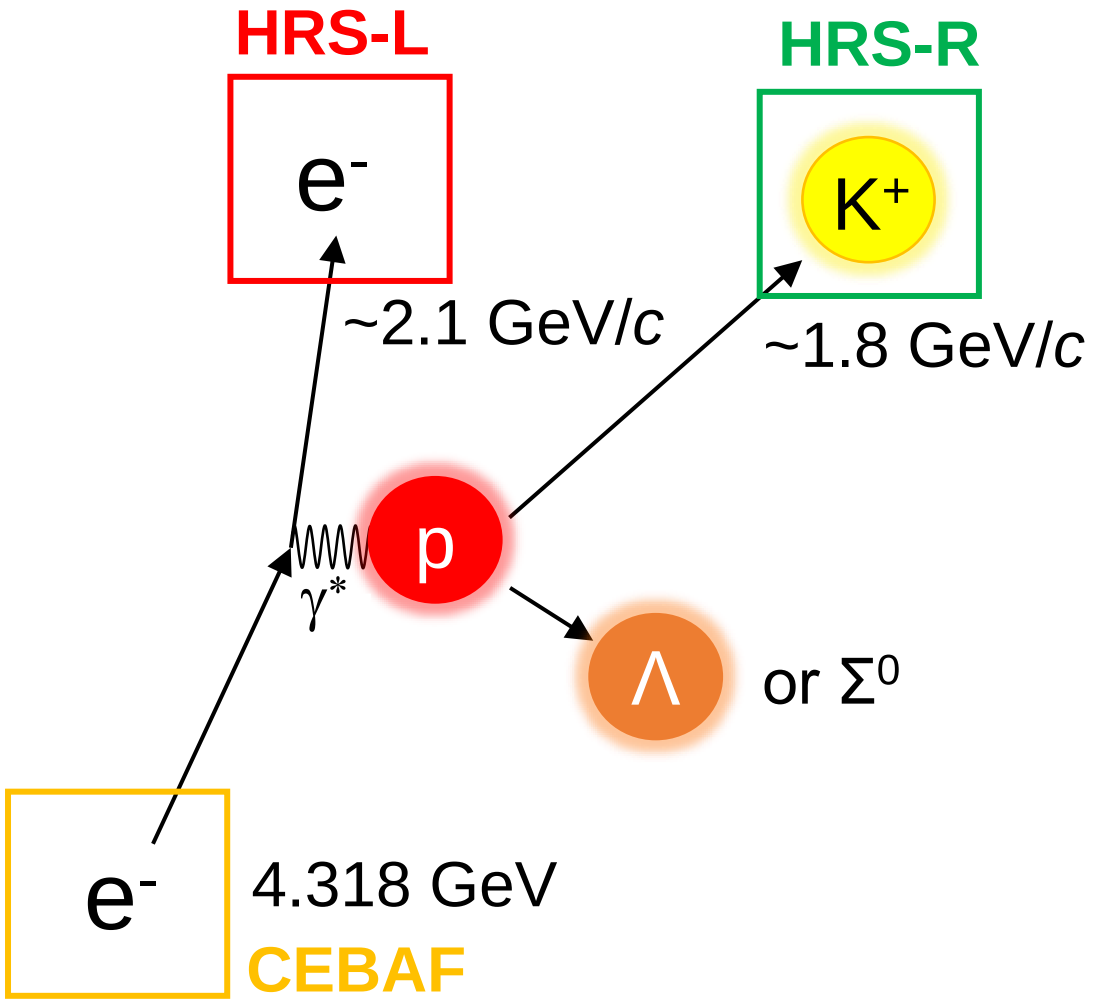
$$\Gamma := \frac{\alpha}{2\pi^2 Q^2} \frac{E_\gamma}{1-\varepsilon} \frac{E_{e'}}{E_e}$$

$$\varepsilon := \left[1 + 2\frac{|\boldsymbol{q}|^2}{Q^2} \tan^2\left(\frac{\theta_{ee'}}{2}\right)\right]^{-1}$$

- **Electroproduction** **(Q^2>0)**
  →accessible in forward angles
  →Q^2 dependence appears



Hyperon **Electroproduction** at JLab



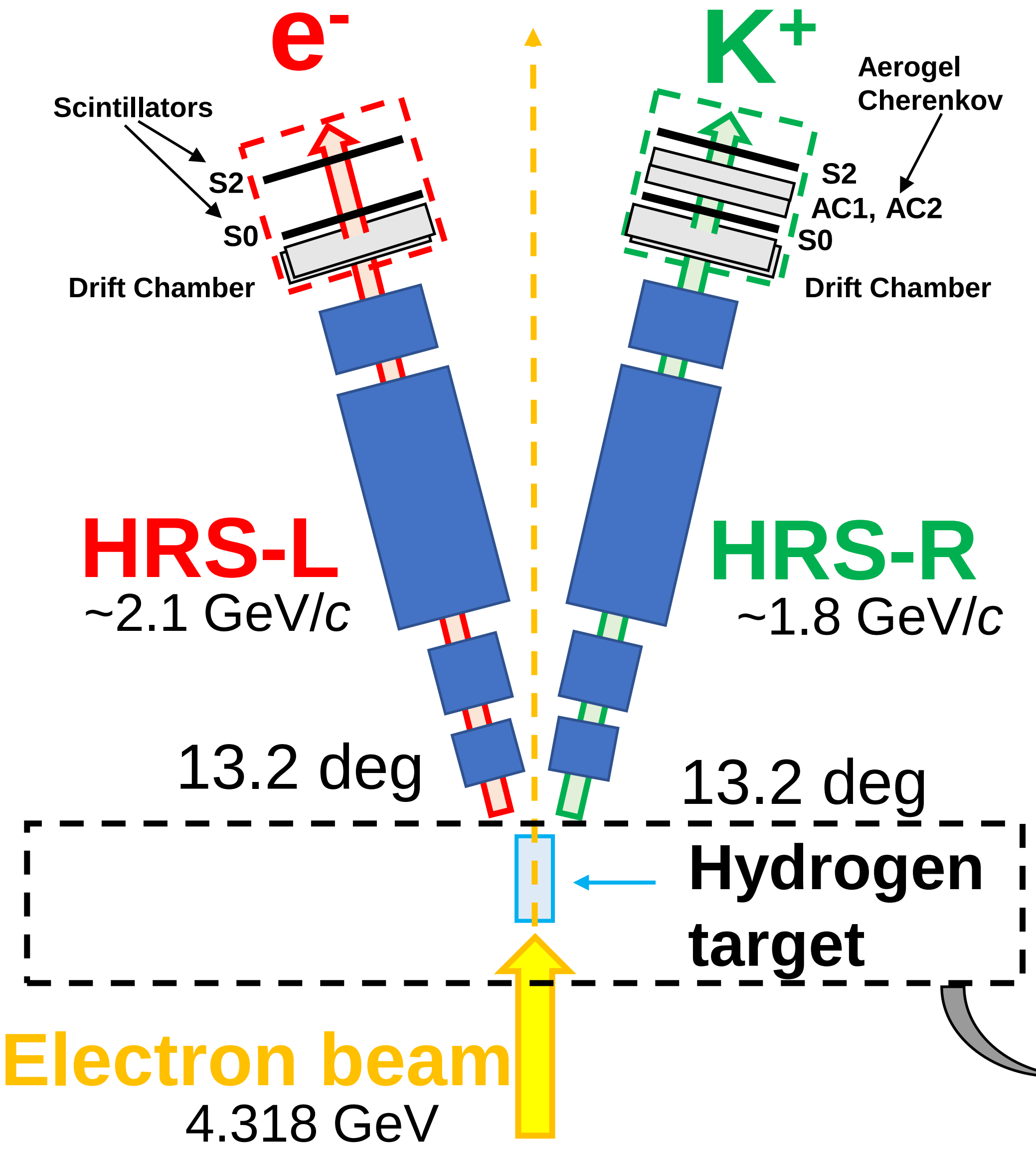
E12-17-003

$\theta_{\gamma K}^{c.m.}$=8 deg

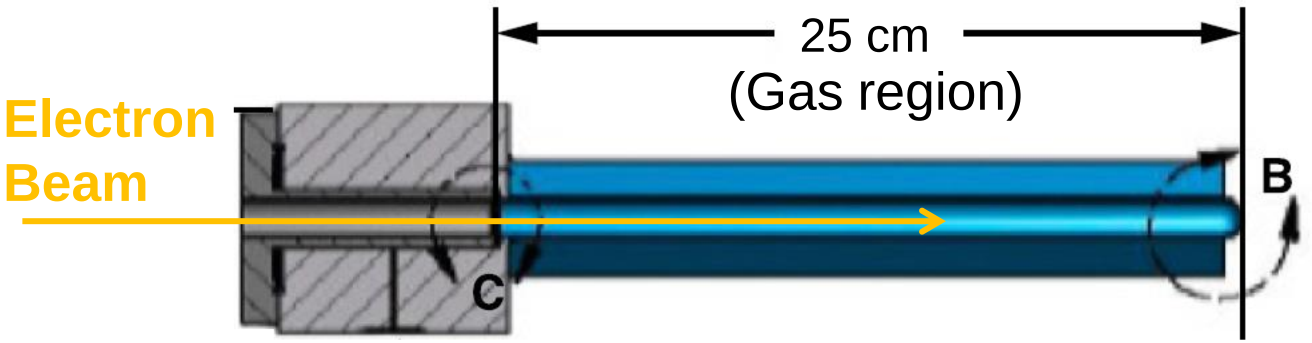
Q^2=0.5 (GeV/c)^2

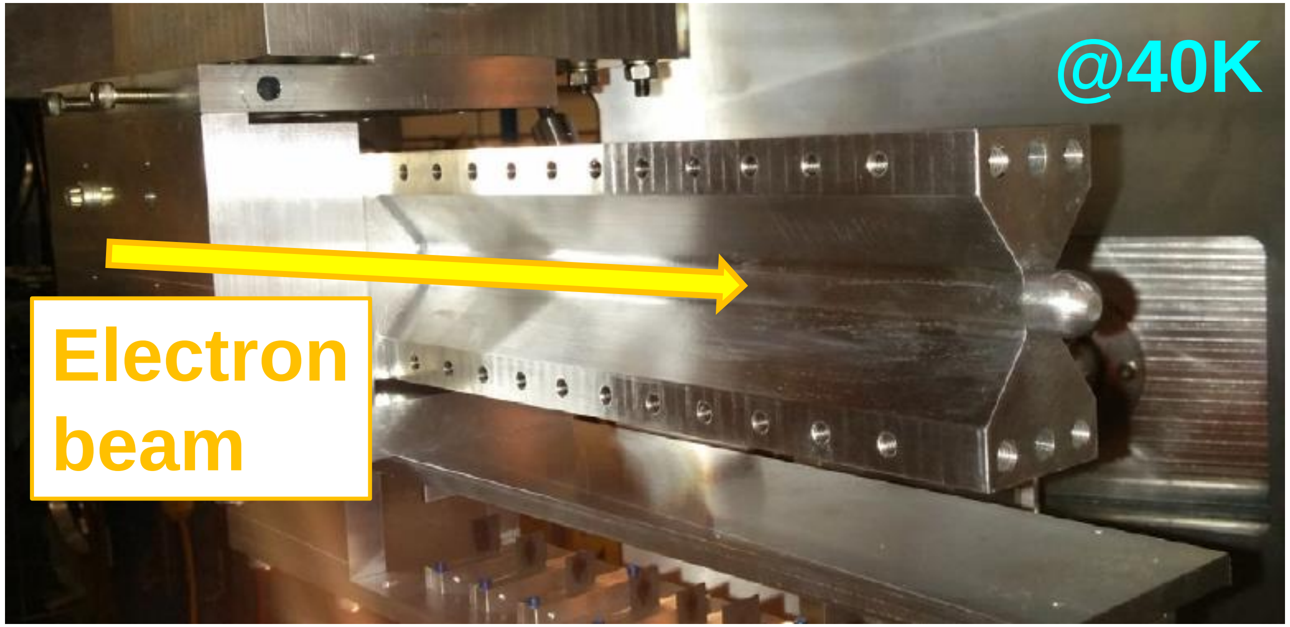
$$\text{Missing Mass} = \sqrt{\{(E_e - E_{e'}) + M_p - E_K\}^2 - \{(\boldsymbol{P}_e - \boldsymbol{P}_{e'}) - \boldsymbol{P}_K\}^2}$$

Experimental Setup



Target Cell made of Al-alloy





S.N. Santiesteban *et al.*, Nucl. Inst. and Meth. A **940**, 351 (2019).

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- Motivation & Experiment
- **Data Analysis: p(e,e'K$^+$)Λ/Σ^0 reaction**
- Results & Summary

Analysis flow

Hydrogen Data

- H_2 gas region selection (Vertex Position)
- Kaon identification: Part1 (Aerogel Cherenkov)
- Kaon identification: Part2 (Coincidence Time)

Λ/Σ^0 Missing Mass Spectrum

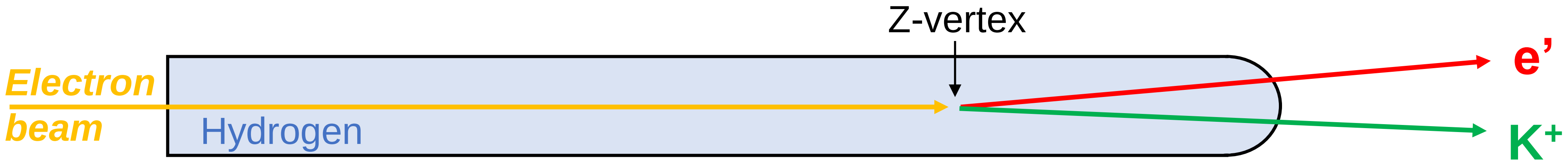
Event selection:
$p(e,e'K^+)\Lambda/\Sigma^0$ reaction

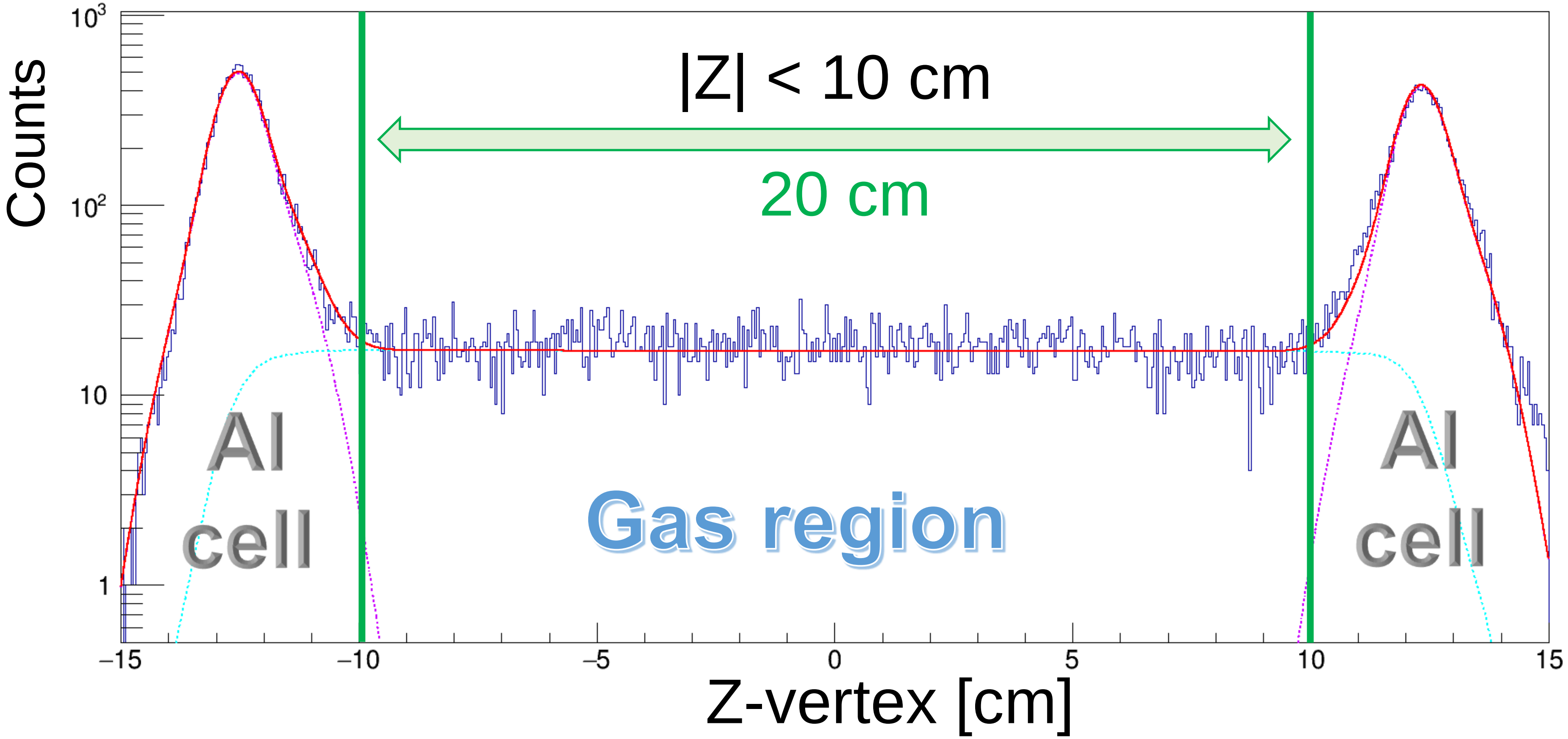
- Efficiency
- Acceptance

The Differential Cross Sections (D.C.S.)

D.C.S. derivation of the hyperon electroproduction

Z-vertex (Target selection)



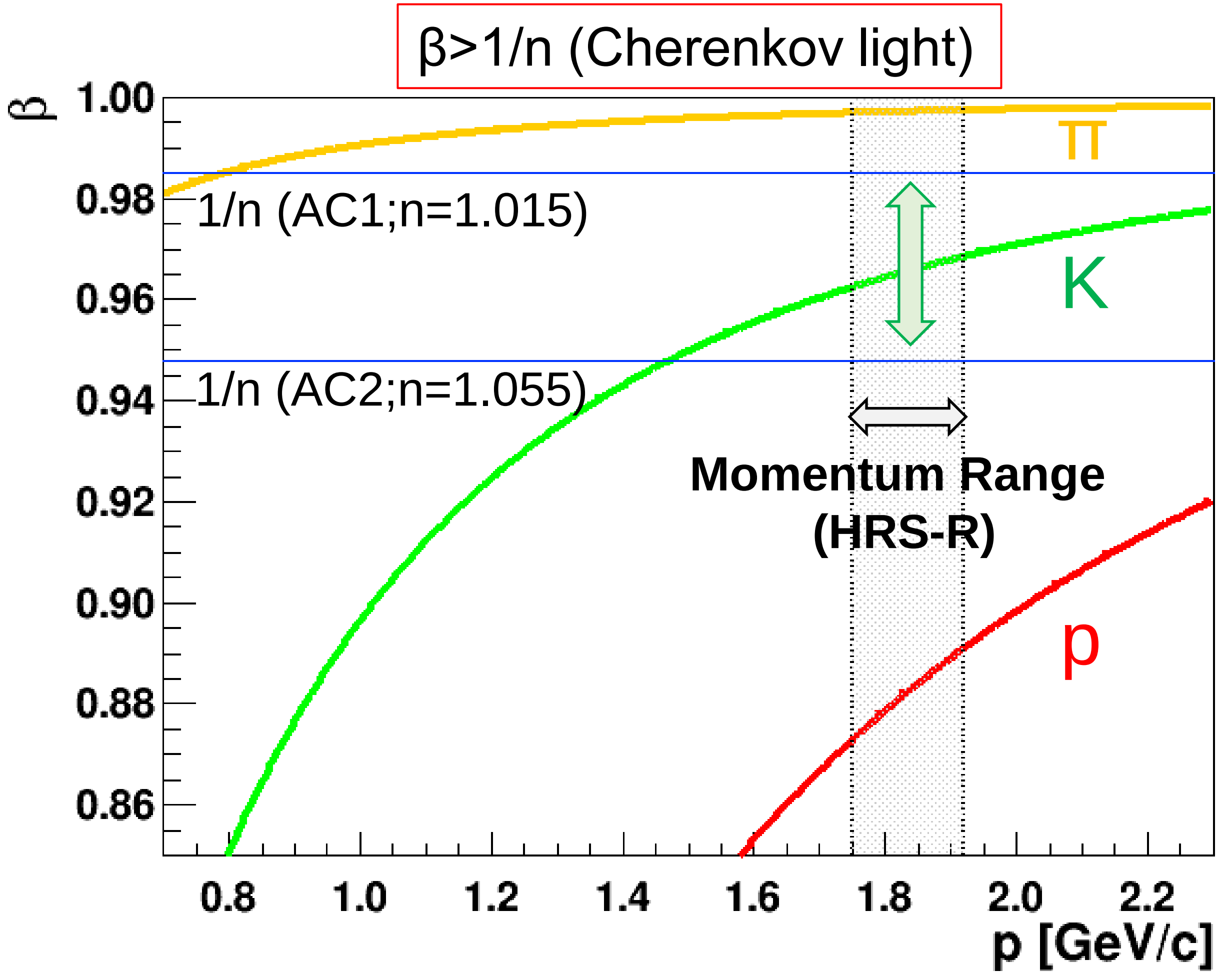


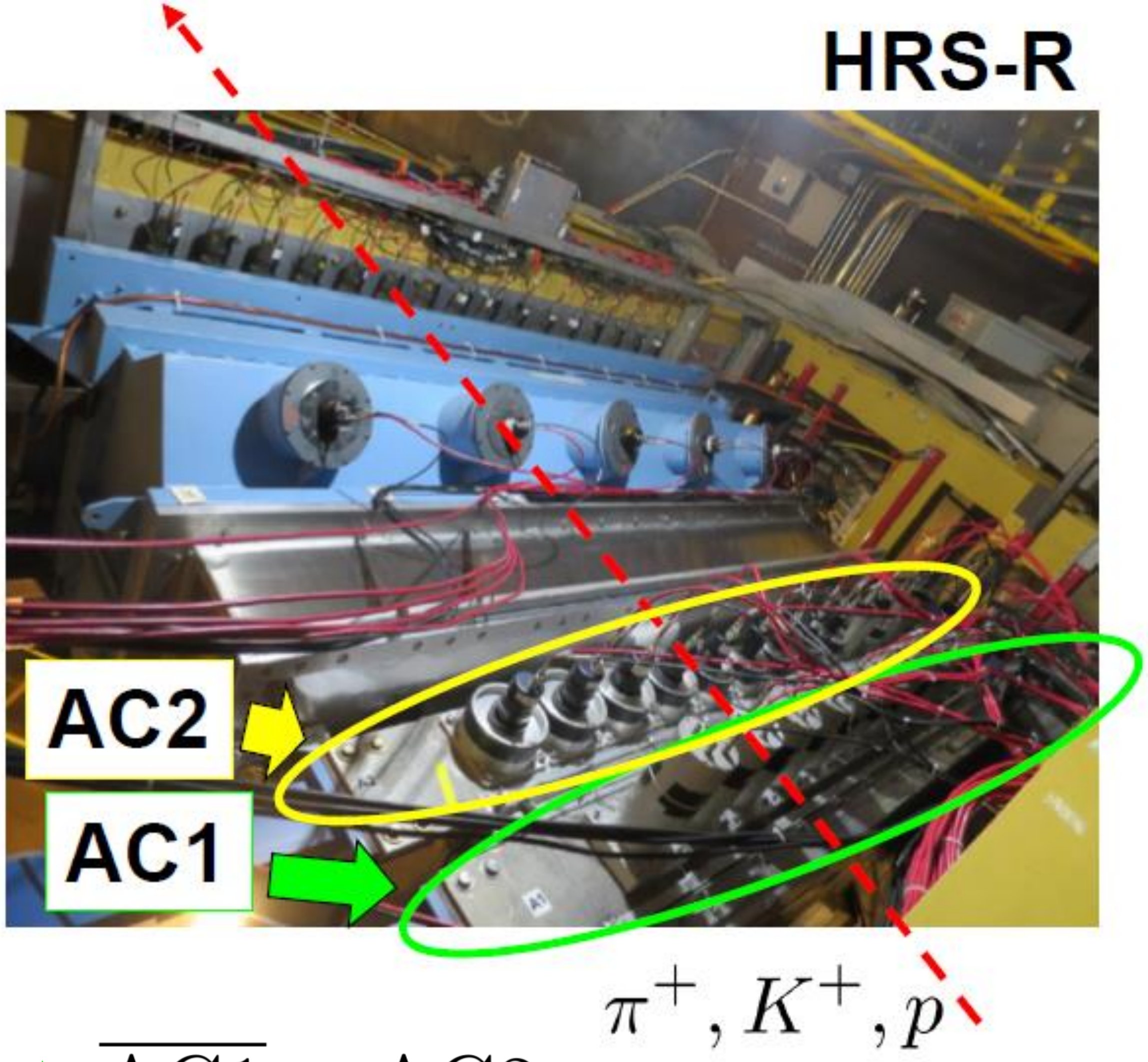
Z-vertex is derived from the tracking information.

- Gas region: 25 cm
- Used only 20 cm (80% of total)

Aerogel Cherenkov (Kaon identification)

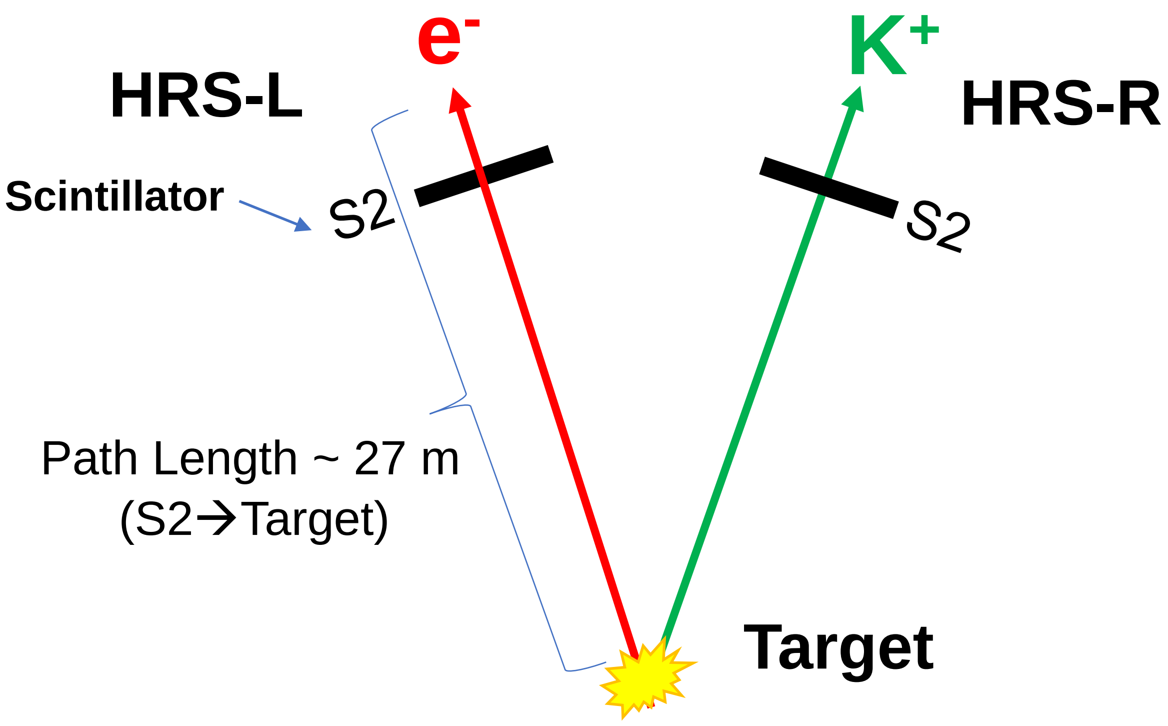
AC1 (n=1.015): π^+, K^+, p
AC2 (n=1.055): π^+, K^+, p





$\Rightarrow \overline{AC1} \otimes AC2$

Coincidence Time (Kaon identification)



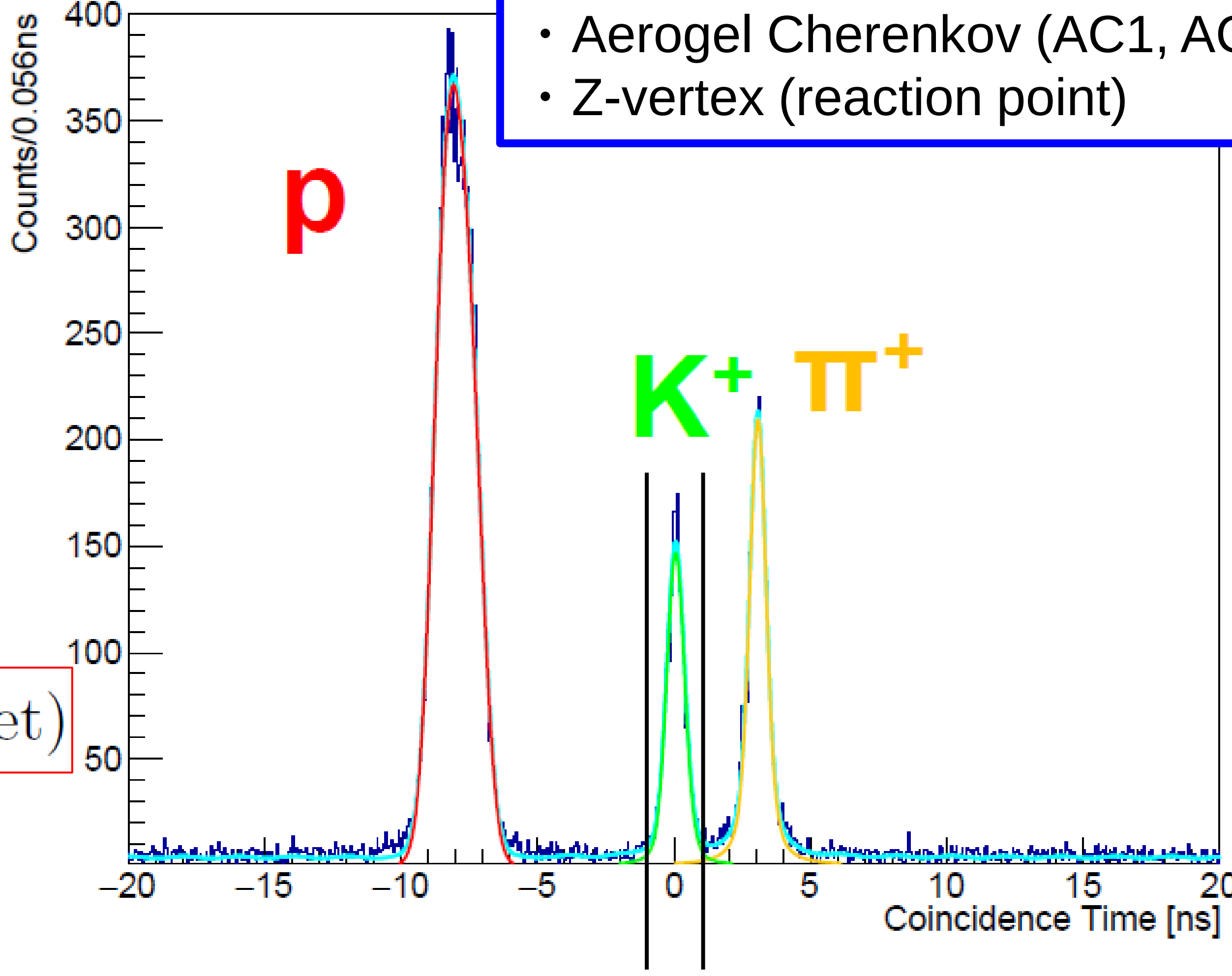
Coincidence Time = Time difference at Target

$$t_{\text{Coin.}} := t_{\text{HRS-L}}(\text{Target}) - t_{\text{HRS-R}}(\text{Target})$$

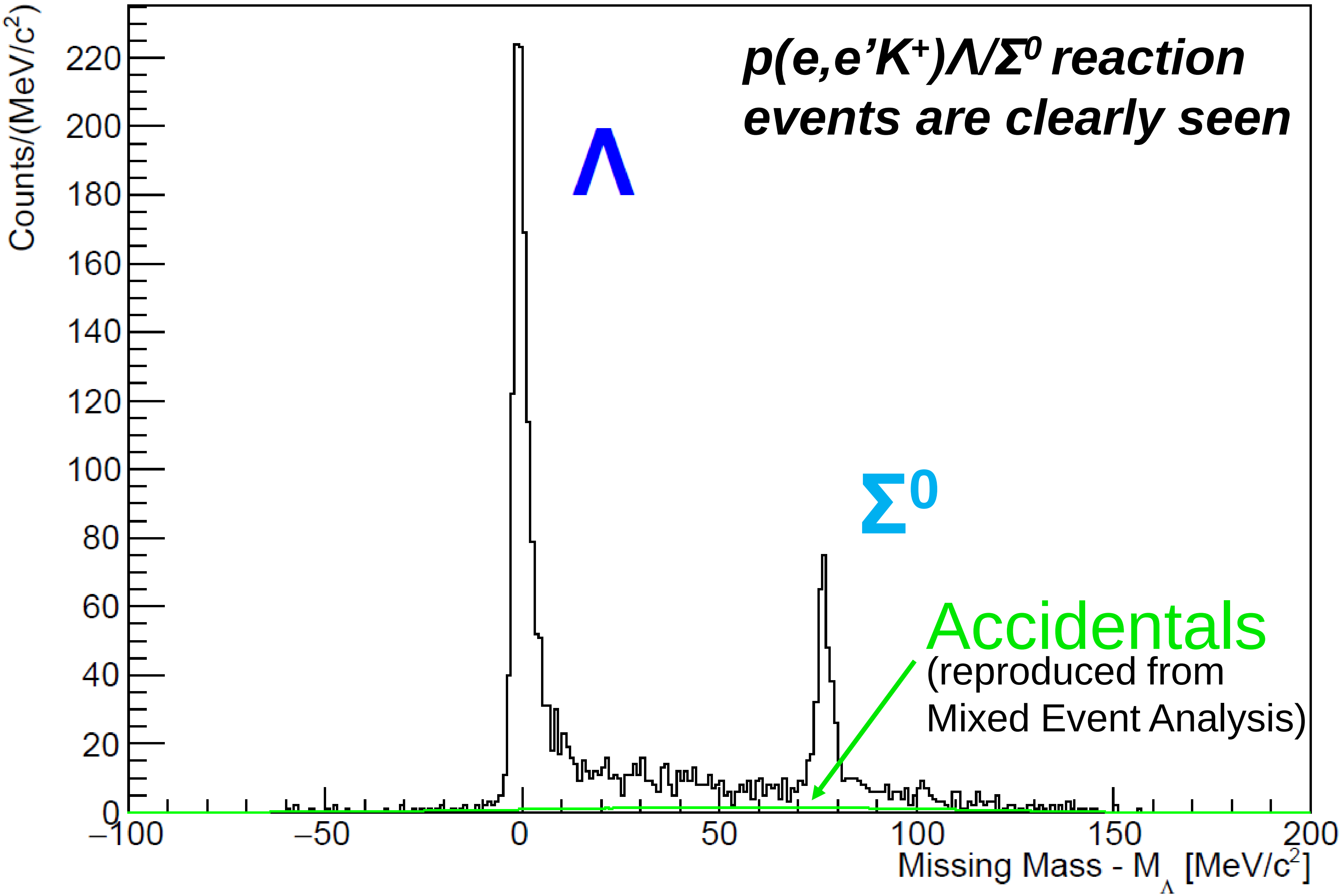
Reaction timing at Target:

$$t(\text{Target}) := t(\text{S2}) - \frac{\text{Path Length}}{\beta c}$$

Event Selection
- Aerogel Cherenkov (AC1, AC2)
- Z-vertex (reaction point)



Missing Mass Spectrum

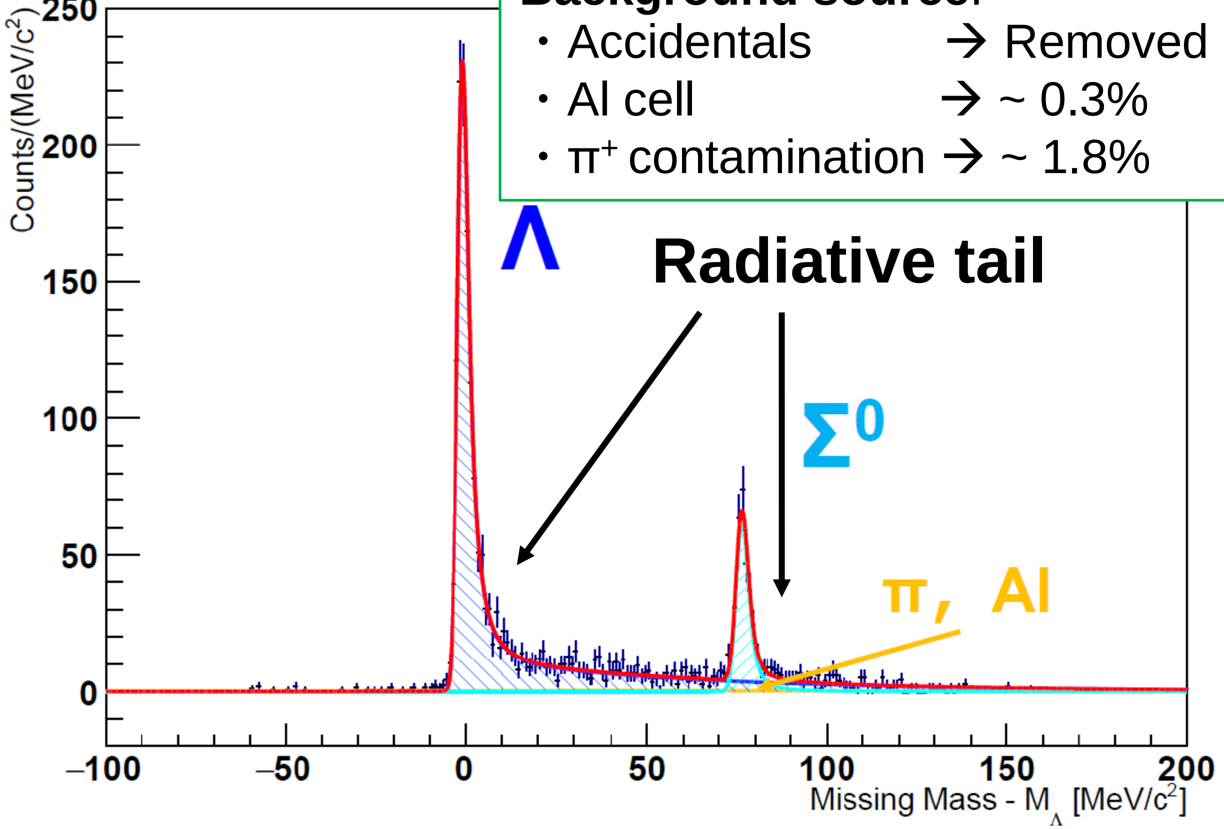


Estimation of Radiative Tail

Data Fitting

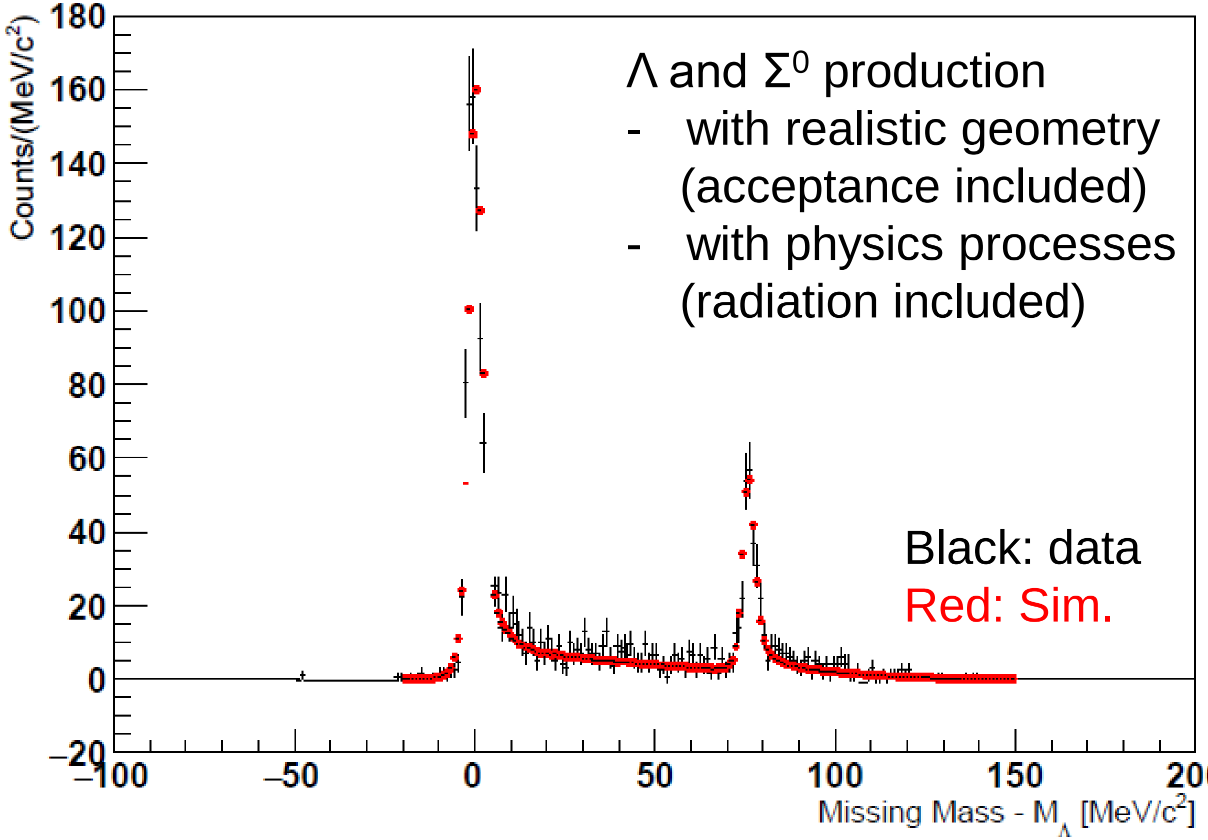
(Landau+Exp) ∗ Gaus

Background source:
- Accidentals → Removed
- Al cell → ~ 0.3%
- π^+ contamination → ~ 1.8%



Monte Carlo Simulation

SIMC



Analysis flow

Hydrogen Data

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- Kaon identification: Part2 (Coincidence Time)

Λ/Σ^0 Missing Mass Spectrum

Event selection:
$p(e,e'K^+)\Lambda/\Sigma^0$ reaction

I will briefly explain this part.

- Efficiency
- Acceptance

The Differential Cross Sections (D.C.S.)

D.C.S. derivation of the hyperon electroproduction

Derivation of the differential cross section

$$\left(\frac{\mathrm{d}\sigma_{\gamma^* p \to K^+ \Lambda(\Sigma^0)}}{\mathrm{d}\Omega_{\mathrm{K}^+}}\right)_{\text{HRS-R}} = \frac{1}{N_{\mathrm{T}}} \cdot \frac{1}{N_{\gamma^*}} \cdot \frac{1}{\bar{\varepsilon}} \cdot \sum_{i=1}^{N_{\Lambda(\Sigma^0)}} \frac{1}{\varepsilon_i^{\mathrm{DAQ}} \cdot \varepsilon_i^{\mathrm{Decay}} \cdot \Delta\Omega_{\text{HRS-R}}}$$

~1360 (Λ), ~370 (Σ^0)
Num. of Hyperons

Num. of Target
0.0375 b^{-1}

Num. of Virtual Photon
3.53×10^{13} (Λ)
4.95×10^{13} (Σ^0)

Cut efficiency
0.454 (Λ)
0.443 (Σ^0)

DAQ efficiency
~0.96

Kaon Survival Ratio
~0.14

Solid Angle
~5.5 msr

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Results

Kinematics (E12-17-003): W=2.14 GeV, Q^2=0.5 (GeV/*c*)^2, $\theta_{\gamma K}^{\mathrm{c.m.}}$ =8 deg

Λ	$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p \to K^+ \Lambda}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)} = 0.426 \pm 0.022(\mathrm{Stat.})^{+0.021}_{-0.040}(\mathrm{Syst.})\ [\mu\mathrm{b/sr}]$$
Σ^0	$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p \to K^+ \Sigma^0}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)} = 0.080 \pm 0.005(\mathrm{Stat.})^{+0.038}_{-0.017}(\mathrm{Syst.})\ [\mu\mathrm{b/sr}]$$

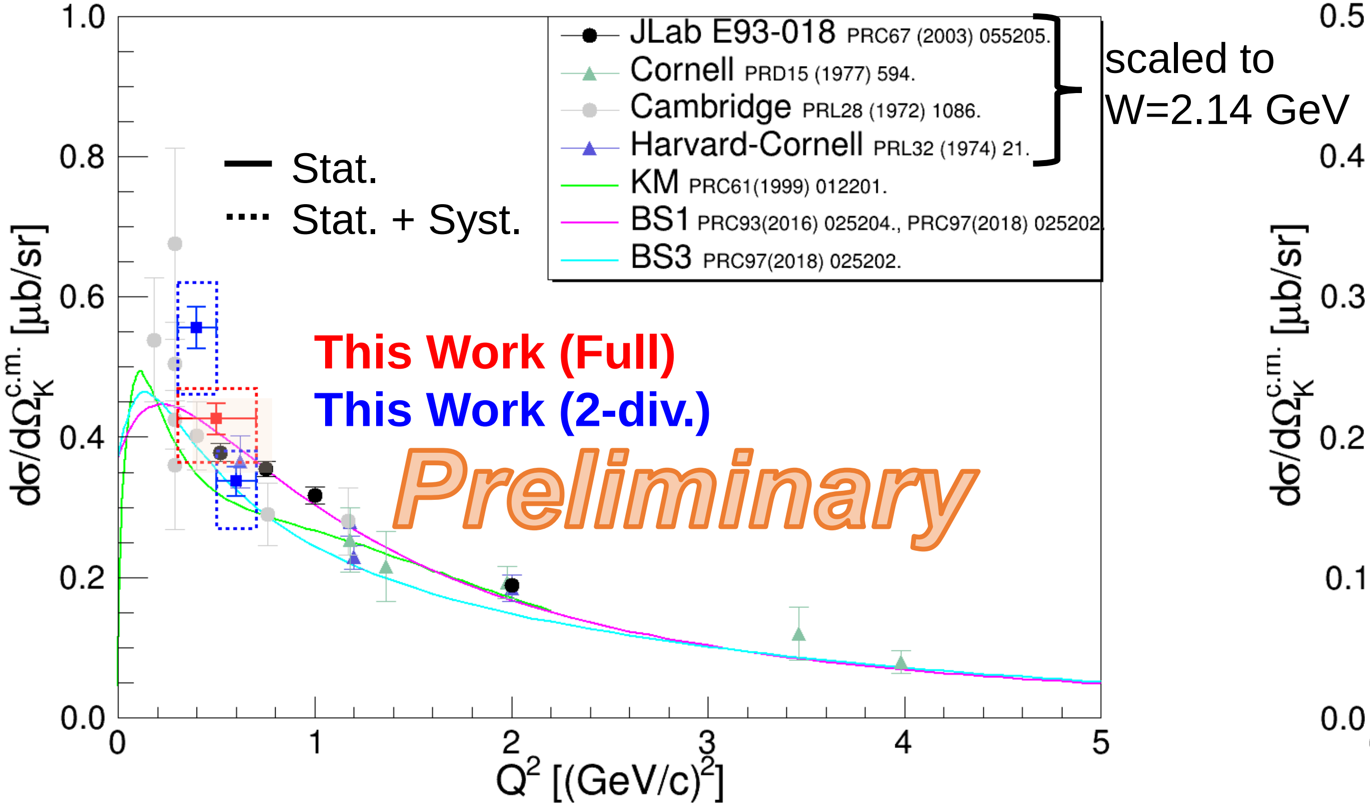
- Result1: Q^2 dependence
- Result2: Angle dependence

Result1: Q^2 dependence

- **We deduced the differential cross sections at $Q^2 \sim 0.5$ (GeV/*c*)^2.**
- **$d\sigma/d\Omega$ (Λ and Σ^0) tend to increase as Q^2 decrease, and so do our results.**

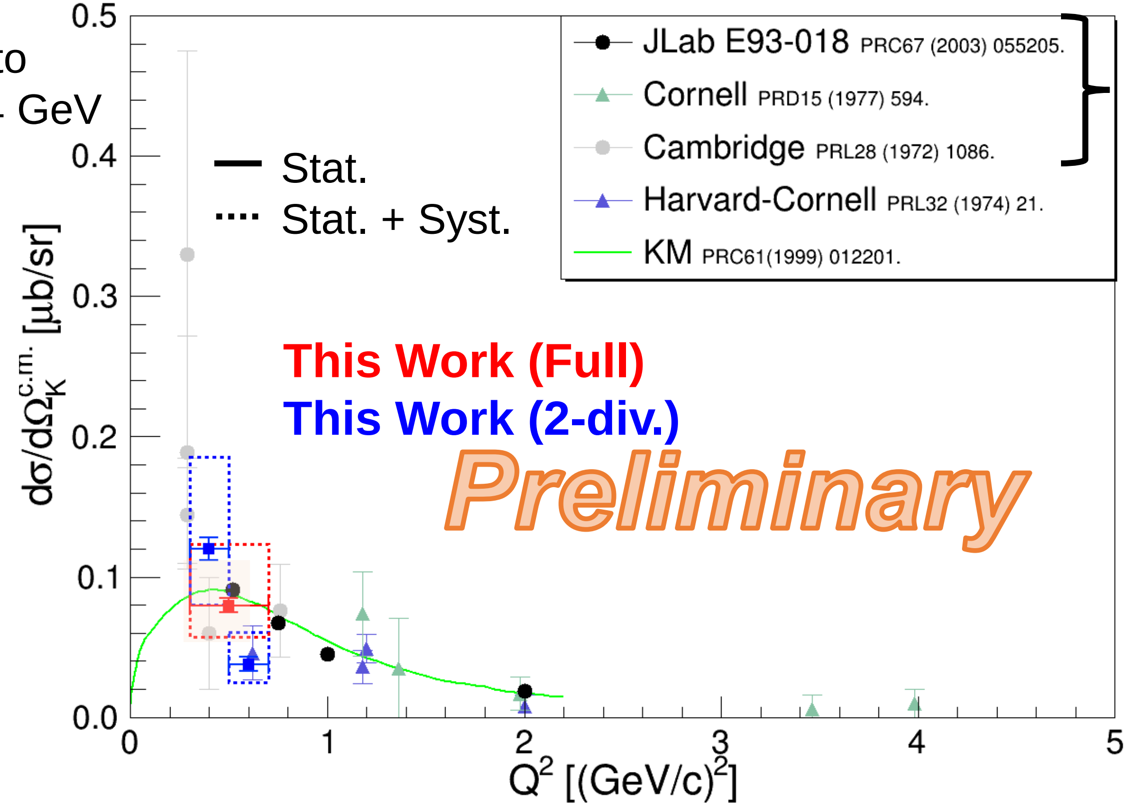
W = 2.14 GeV, $\theta_{\gamma K}^{c.m.}$ <15 deg

Λ



Σ^0

scaled to W=2.14 GeV

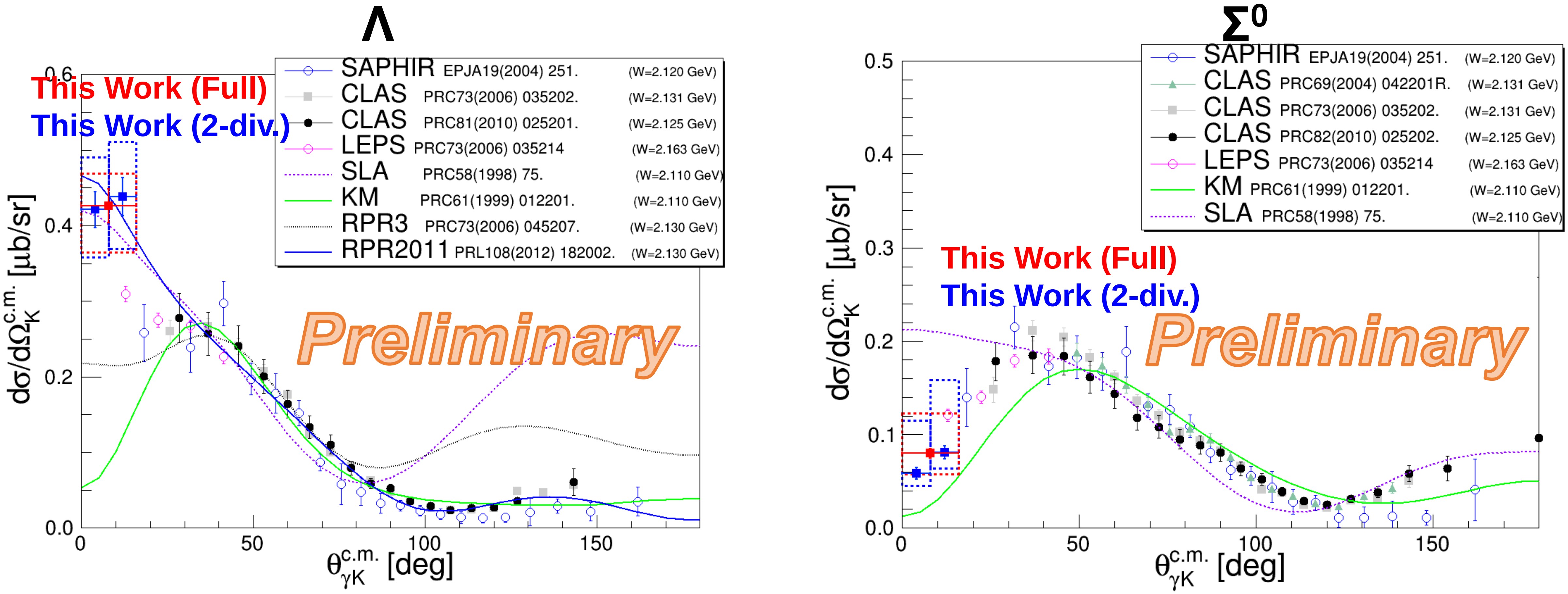


Result2: Angle dependence

- **Comparison with photoproduction (Q^2=0)**←well known except for forward angles

Note1: Plotted with photoproduction w/o corr.
Note2: Our data is Q^2=0.5 (GeV/c)^2

$$\frac{d^3\sigma}{d\omega d\Omega_{e'} d\Omega_K^{c.m.}} = \Gamma \frac{d\sigma_{\gamma^*}}{d\Omega_K^{c.m.}}$$



Summary & Conclusion

- JLab: E12-17-003 experiment in 2018 (W=2.14 GeV, Q^2=0.5 (GeV/*c*)^2, $\theta_{\gamma K}^{\mathrm{c.m.}}$ =8 deg)

→Forward angles data which is scarce in photoproduction

- We deduced the differential cross section of the Λ/Σ^0 electroproduction;

$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p \to K^+\Lambda}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)} = 0.426 \pm 0.022(\mathrm{Stat.})^{+0.021}_{-0.040}(\mathrm{Syst.})\ [\mu\mathrm{b/sr}]$$

$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p \to K^+\Sigma^0}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)} = 0.080 \pm 0.005(\mathrm{Stat.})^{+0.038}_{-0.017}(\mathrm{Syst.})\ [\mu\mathrm{b/sr}]$$

- We obtained the differential cross section of the hyperon electroproduction in the low-Q^2 region. I hope this work help understanding hyperon photo- and electroproduction in the same framework.

- I am going to write Ph.D Thesis with this topic. (~ March, 2024)