



Study of the Λ/Σ^0 electroproduction in the low- Q^2 region at JLab

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Contents

JLab: E12-17-003 (2018) \rightarrow $p(e,e'K^+)\Lambda/\Sigma^0$ reaction (gas H_2 target)

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

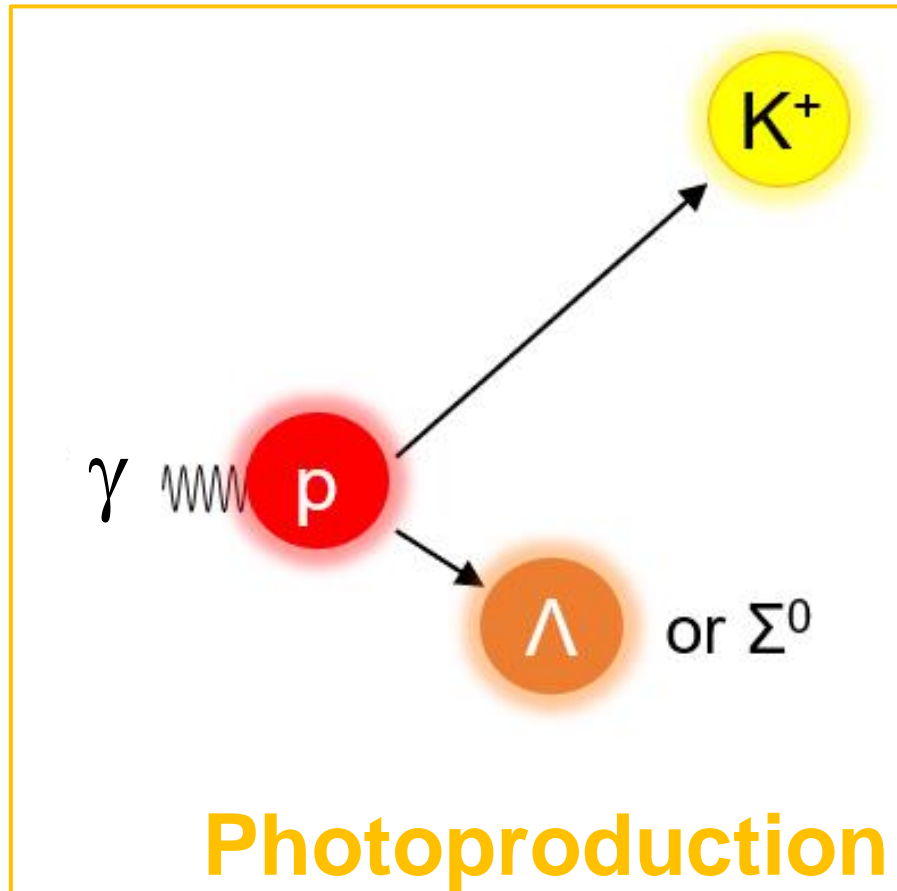
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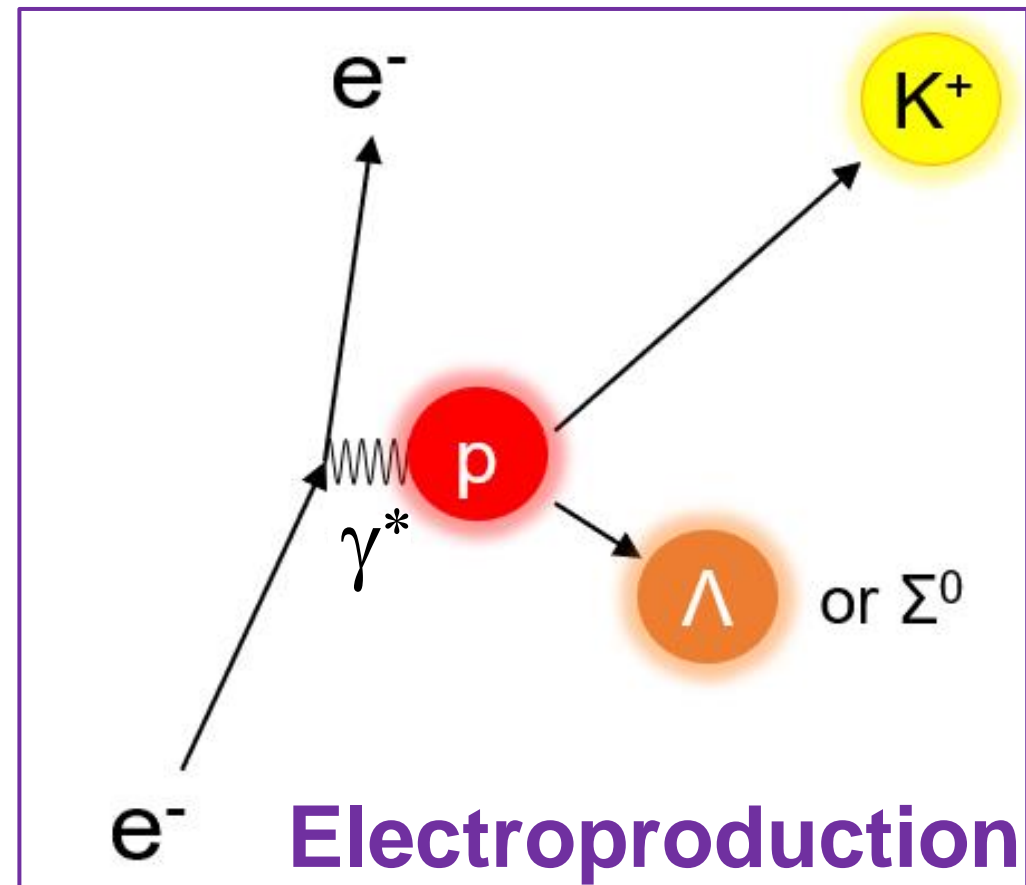
Hyperon **Photo-** and **Electro**production

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



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

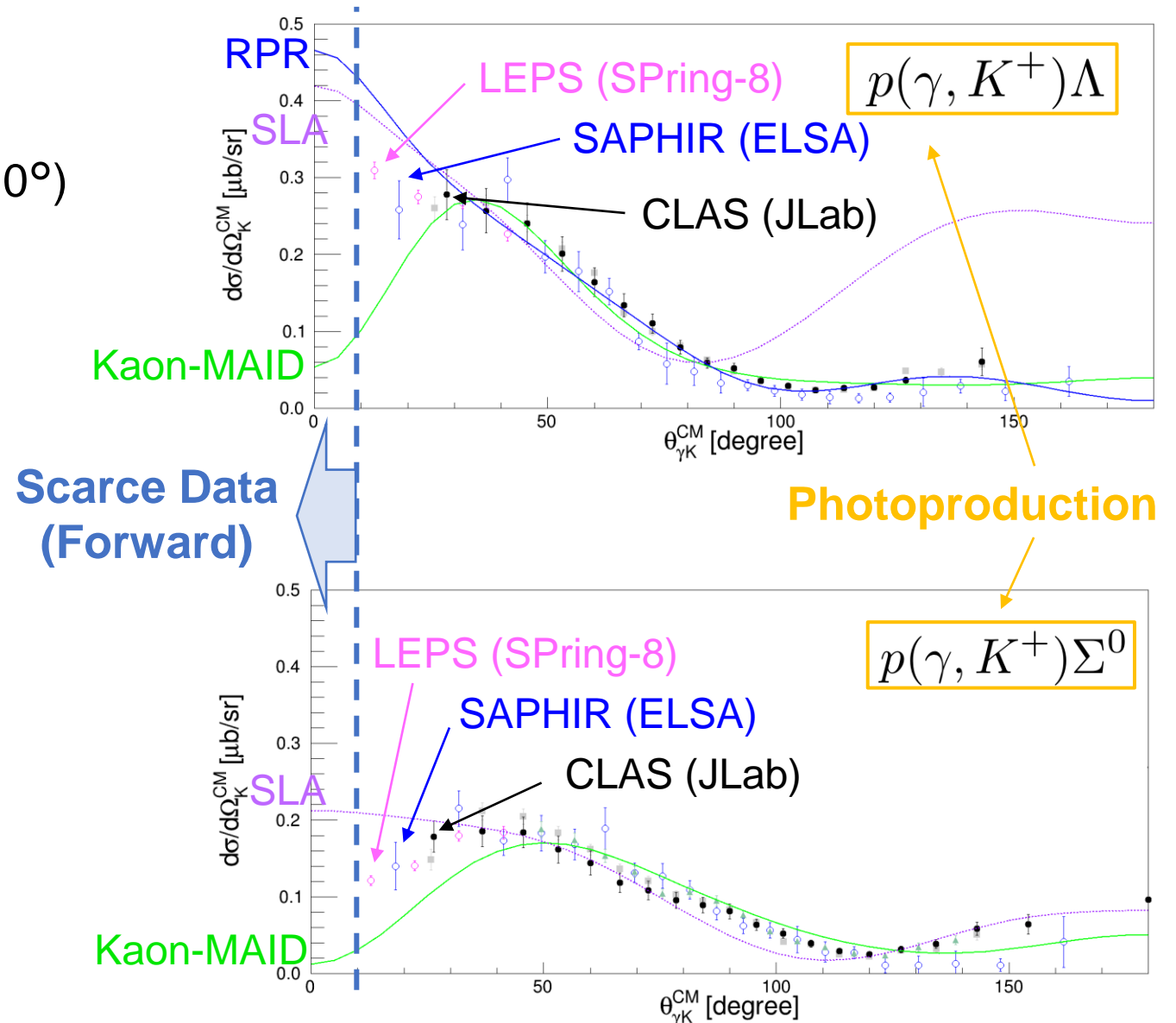
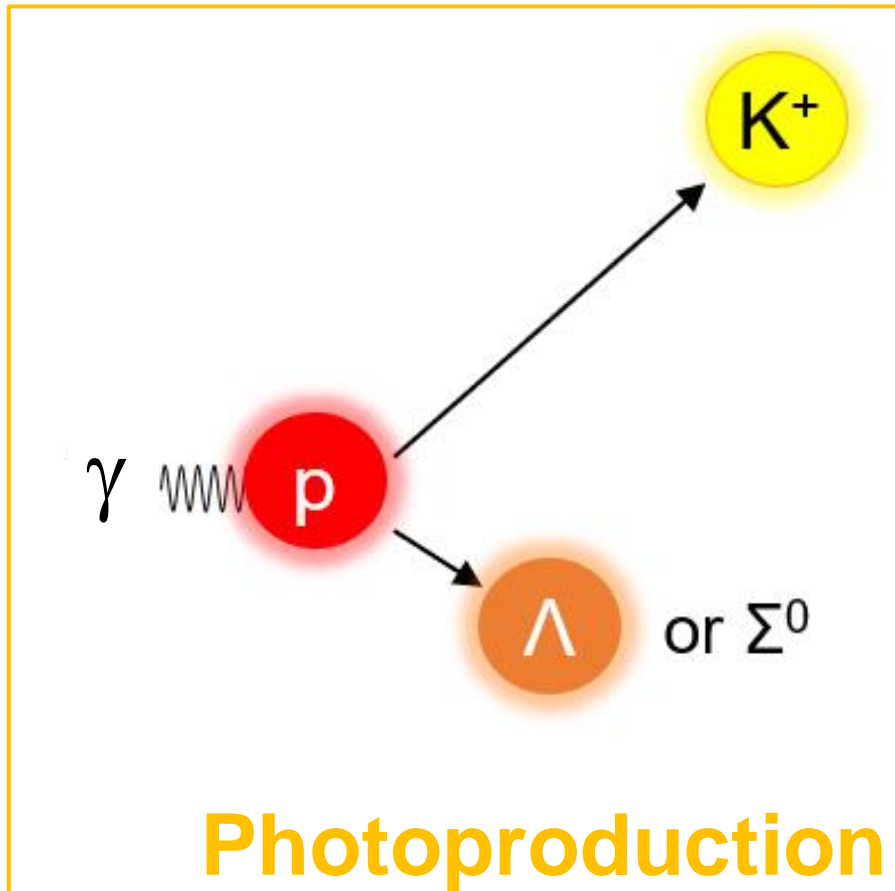
our experiment



Hyperon Photoproduction

W = 2.14 GeV

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



Hyperon Electroproduction

our exp. $\theta_{\gamma K}^{\text{c.m.}} = 8 \text{ deg}$
 E12-17-003 $Q^2 = 0.5 \text{ (GeV/c)}^2$

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

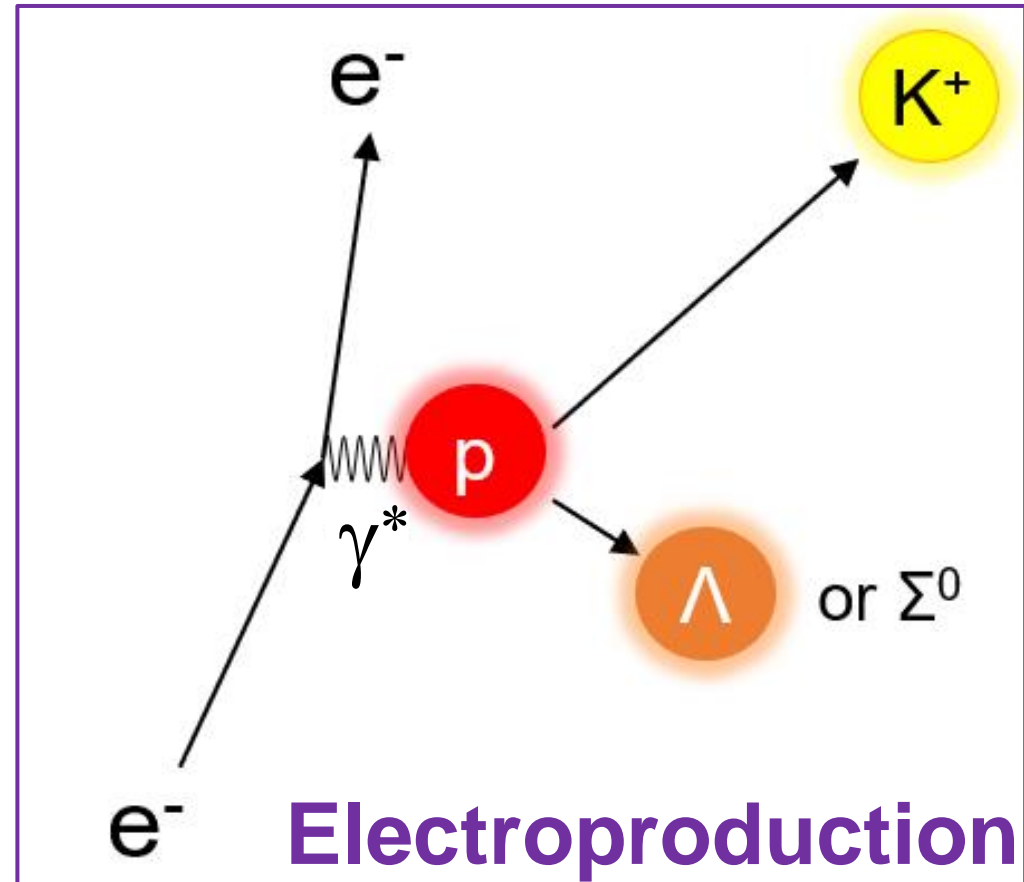
virtual photoproduction

Virtual Photon Flux

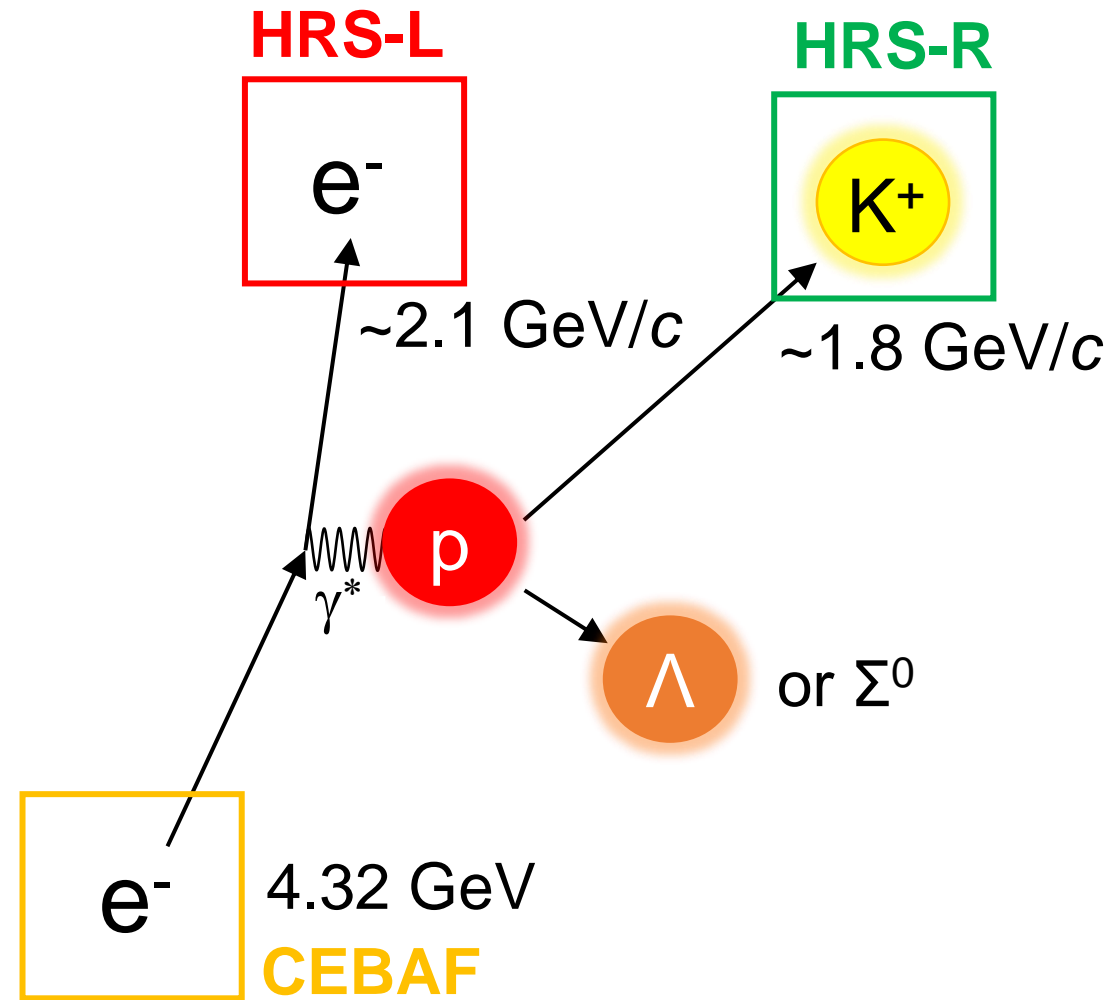
$$\Gamma := \frac{\alpha}{2\pi^2 Q^2} \frac{E_\gamma}{1 - \varepsilon} \frac{E_{e'}}{E_e}$$

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

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



Hyperon Electroproduction at JLab



E12-17-003

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

$Q^2 = 0.5 \text{ (GeV}/c)^2$

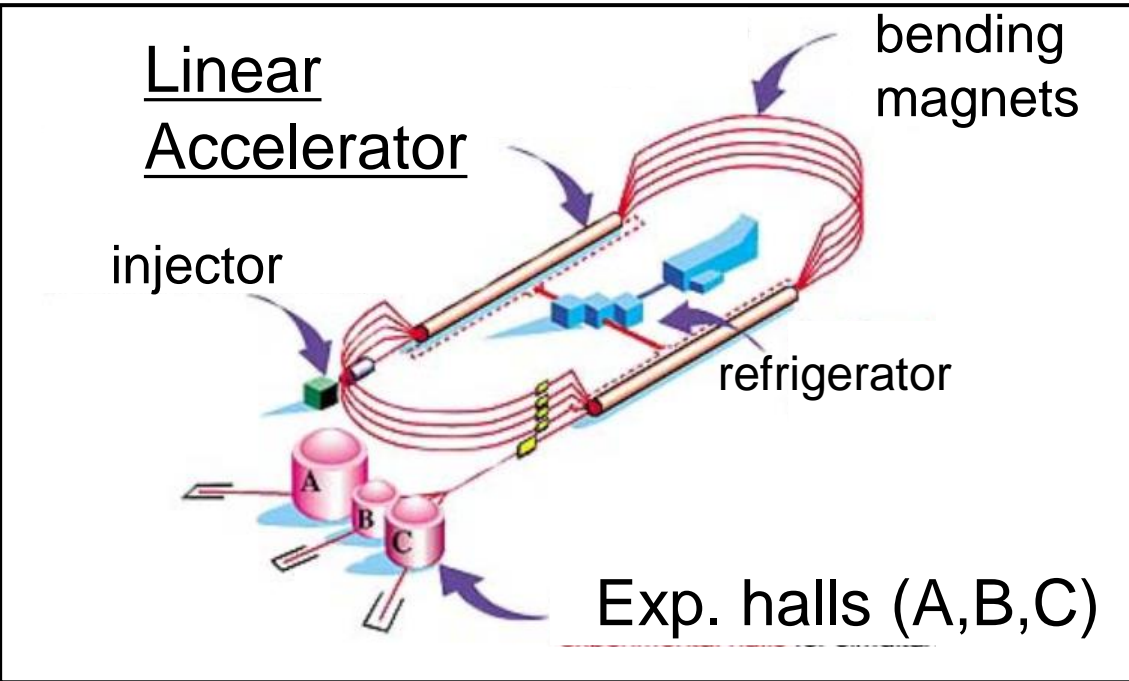
$$\text{Missing Mass} = \sqrt{\{([E_e] - [E_{e'}]) + M_p - [E_K]\}^2 - \{([P_e] - [P_{e'}]) - [P_K]\}^2}$$

Contents

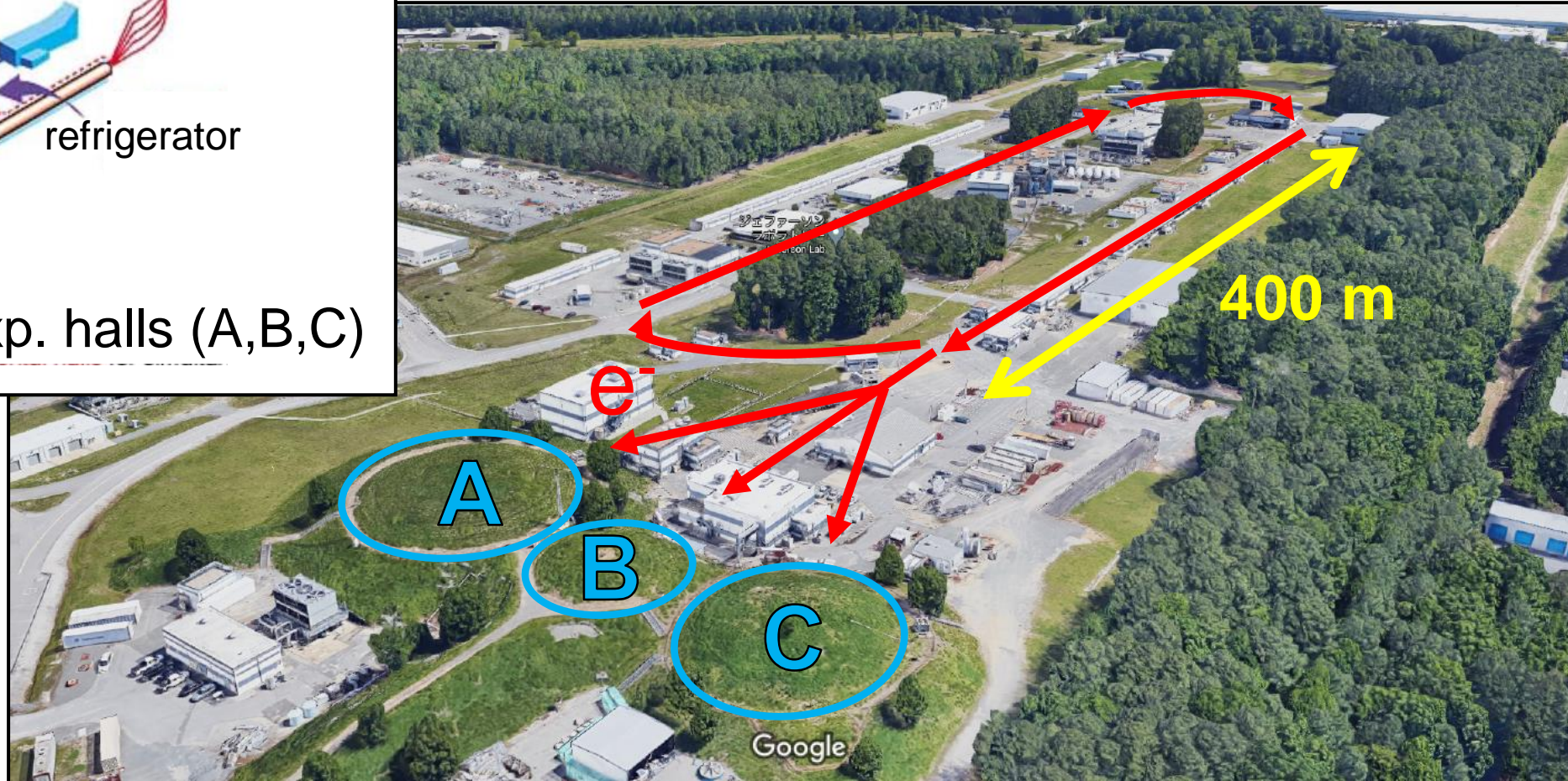
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Jefferson Lab (JLab)



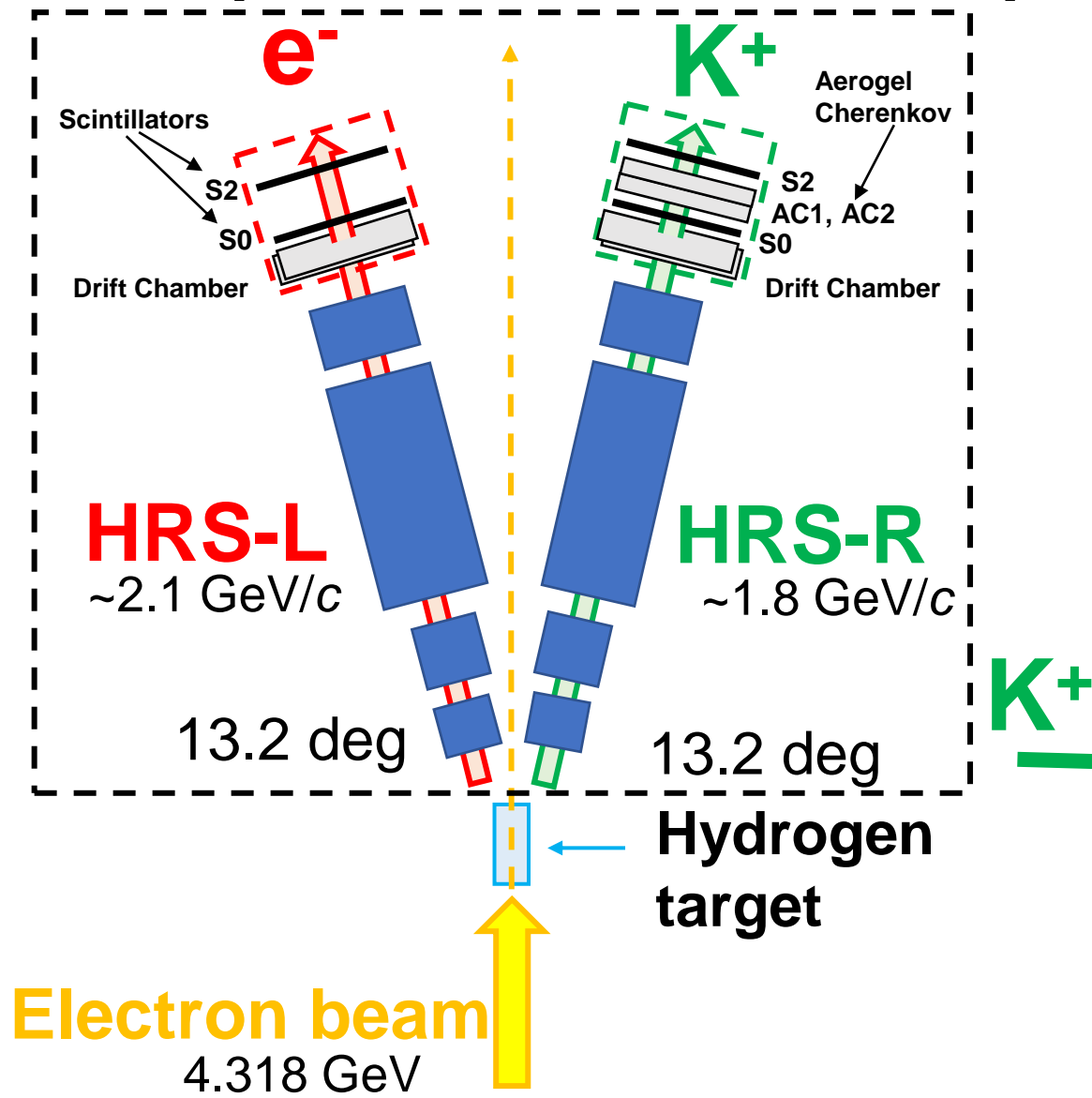
Continuous Electron Beam Accelerator Facility (CEBAF)



E12-17-003 (at Hall-A)

- $E = 4.32 \text{ GeV}$
- $\Delta E/E \sim 10^{-4}$
- $I_e = 22.5 \mu\text{A}$

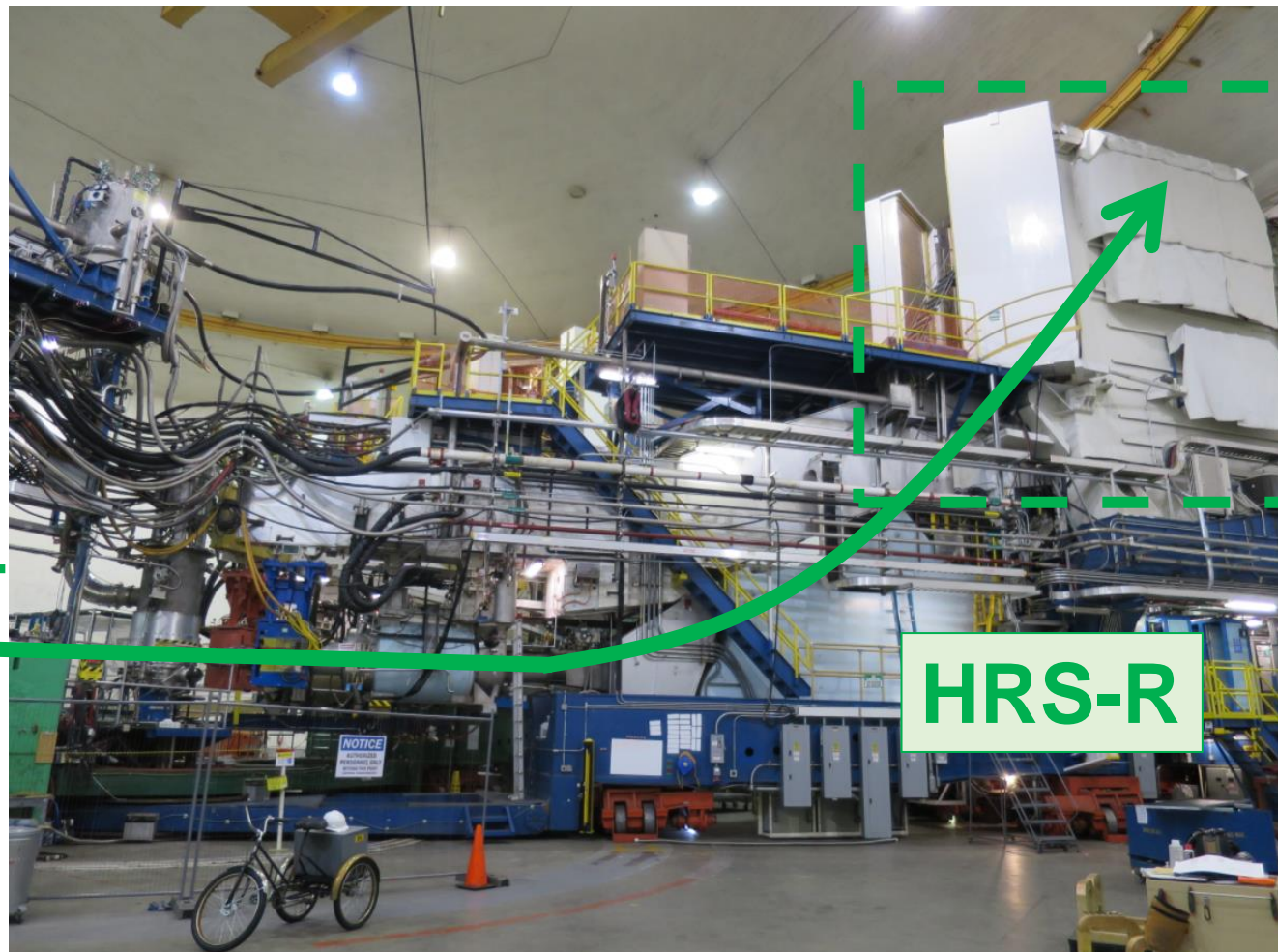
Experimental Setup



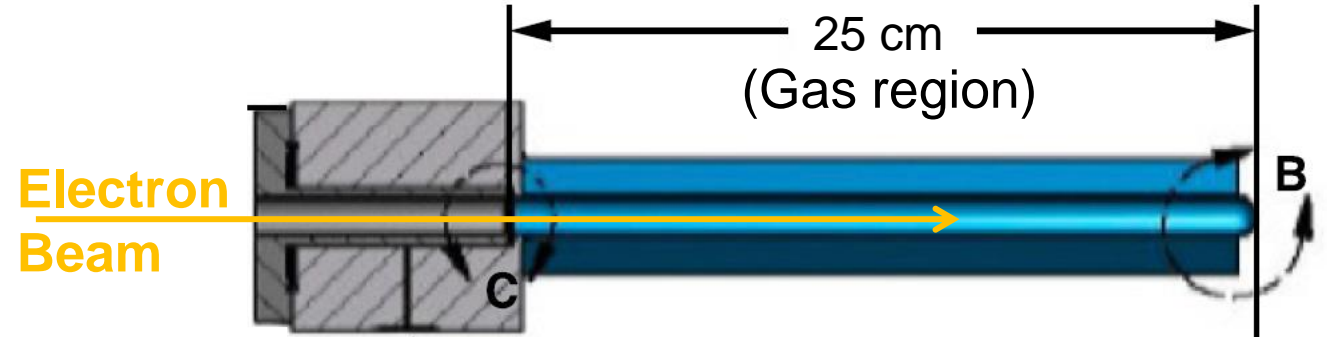
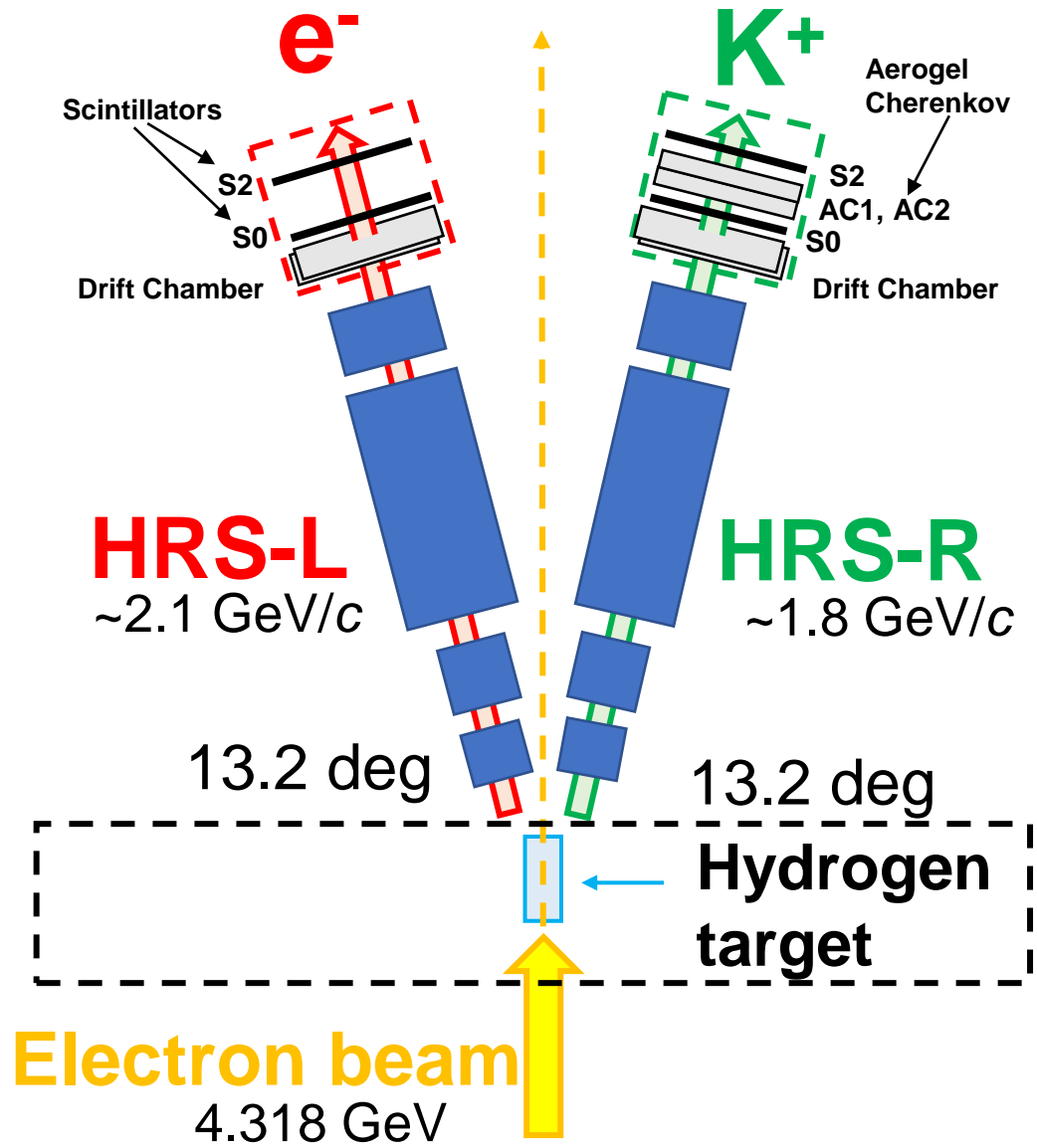
Detectors in HRS

same as
HRS-L

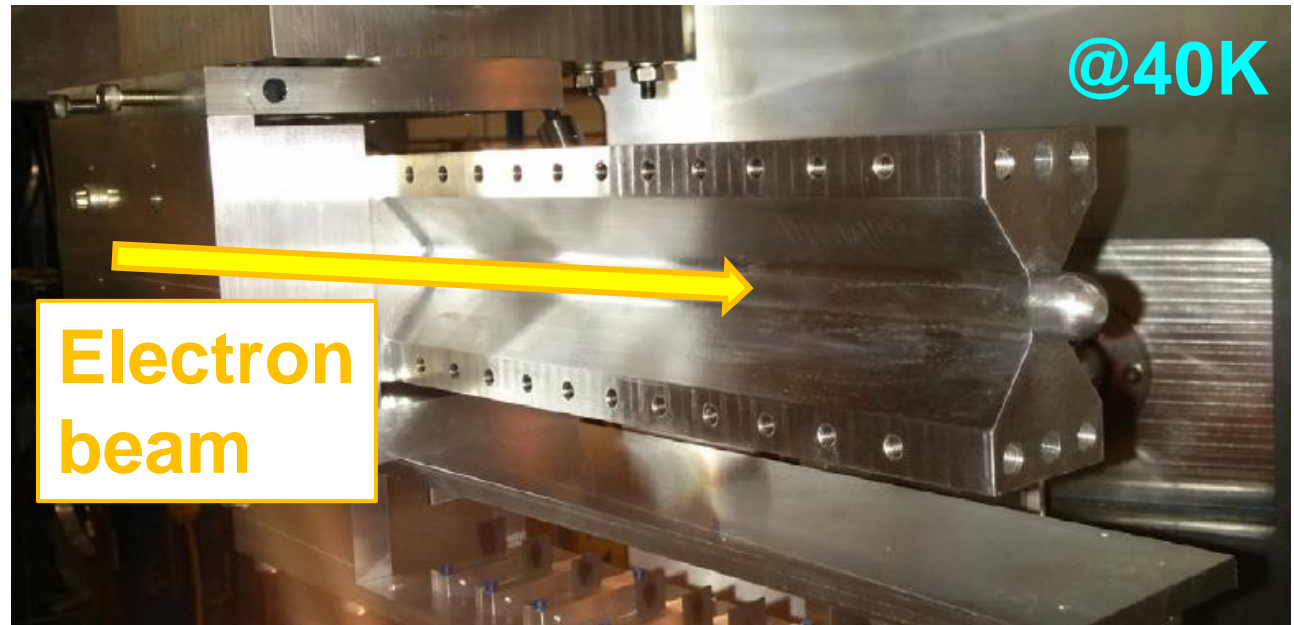
- Drift Chamber (Tracking)
- Scintillators (Timing)
- Aerogel Cherenkov (K^+ identification)



Target Cell



Aluminum Cell thickness: 400 μm



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

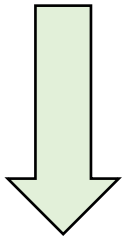
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Analysis flow

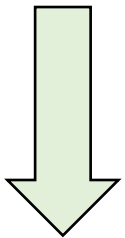
Hydrogen Data



- H₂ 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⁺) Λ/Σ^0 reaction

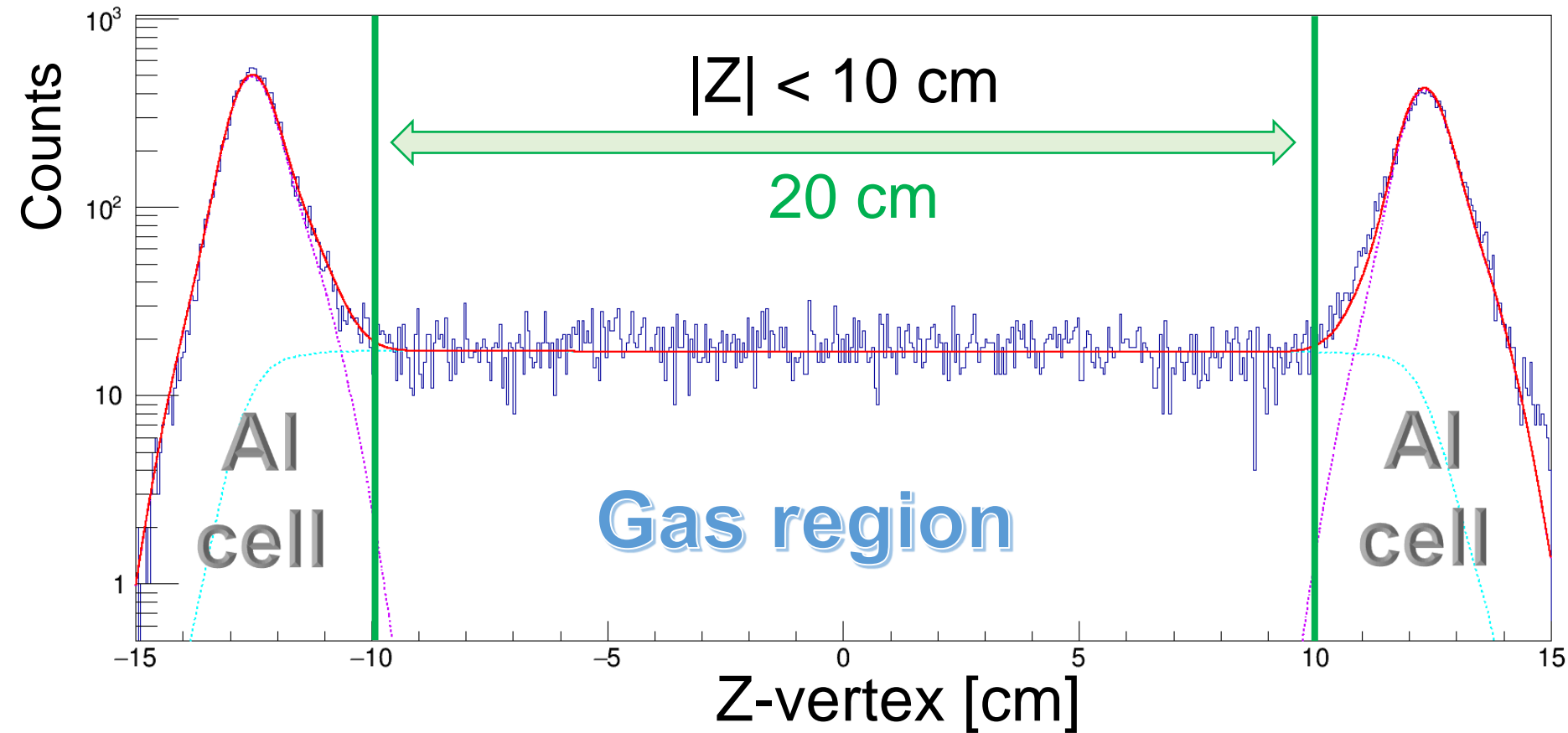
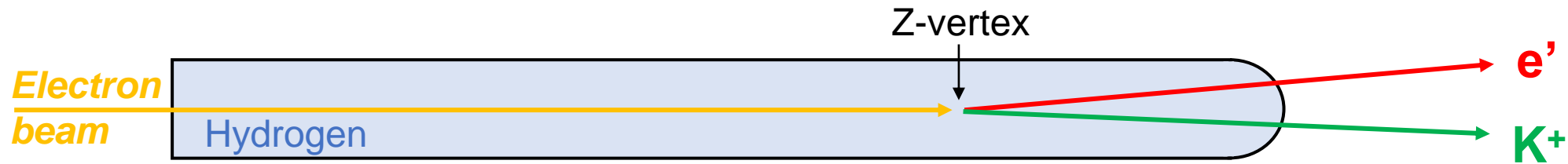


- Efficiency
- Acceptance

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.

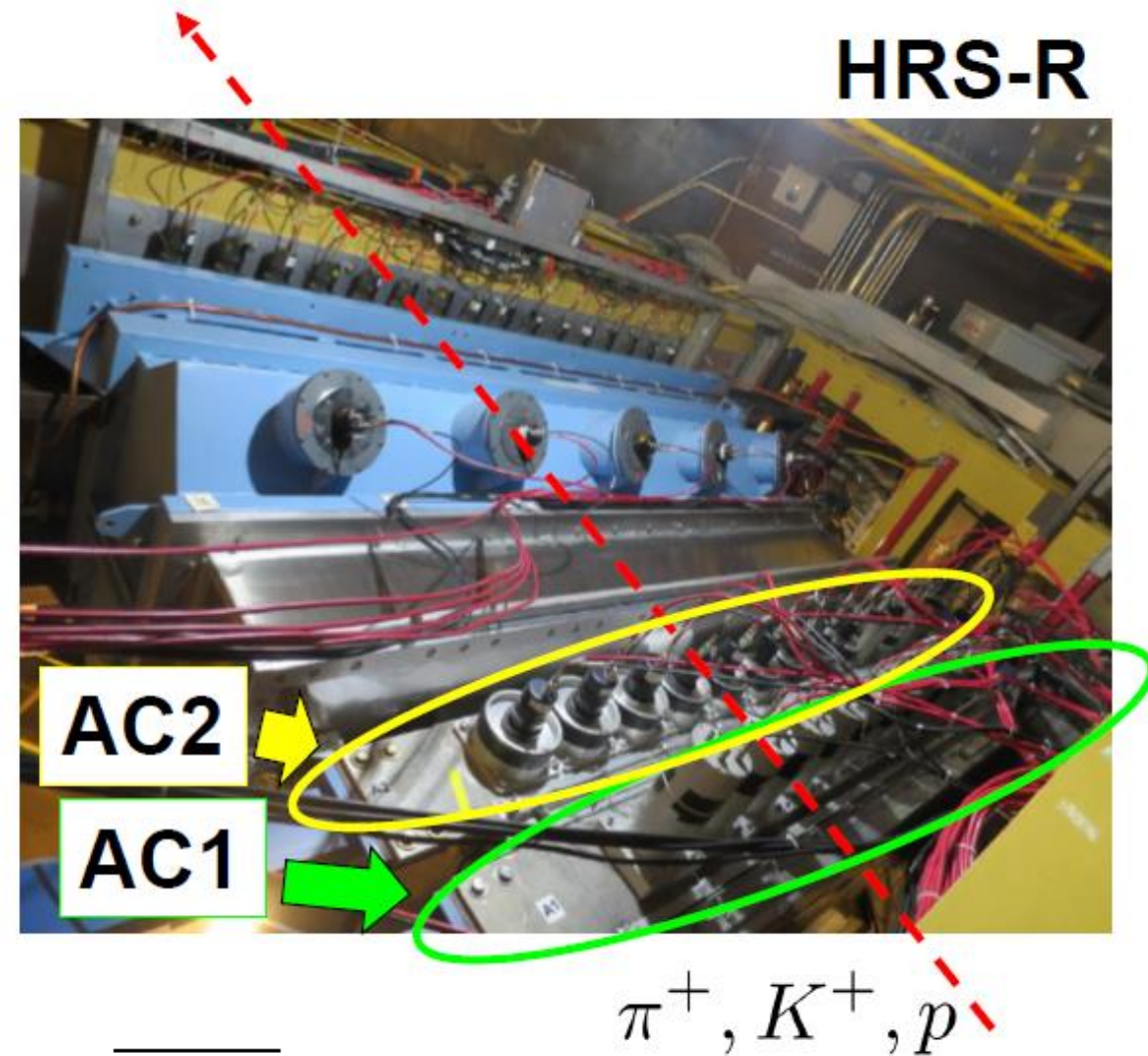
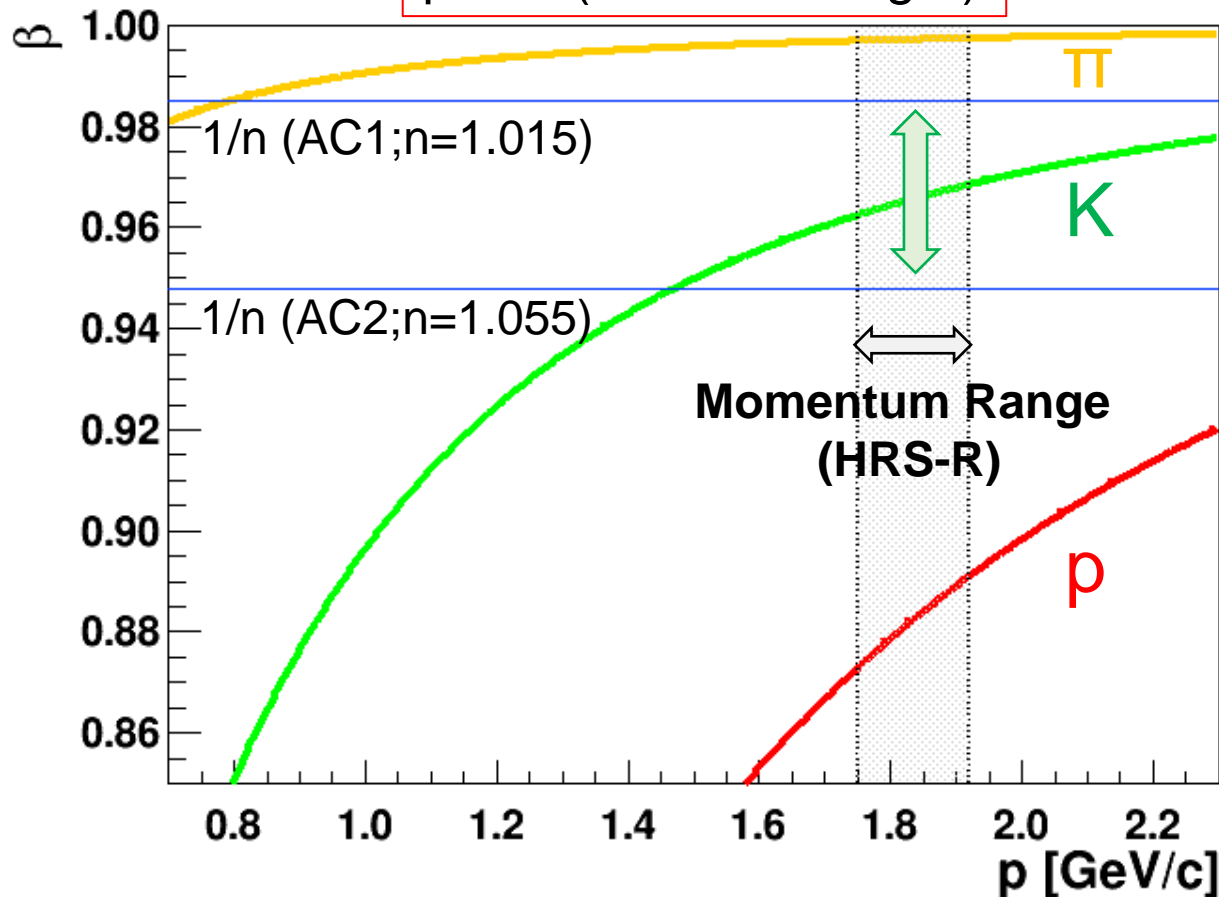
- Gas region: 25 cm
- Used only 20 cm (80% of total)

Aerogel Cherenkov (Kaon identification)

AC1 ($n=1.015$): π^+ , K^+ , p

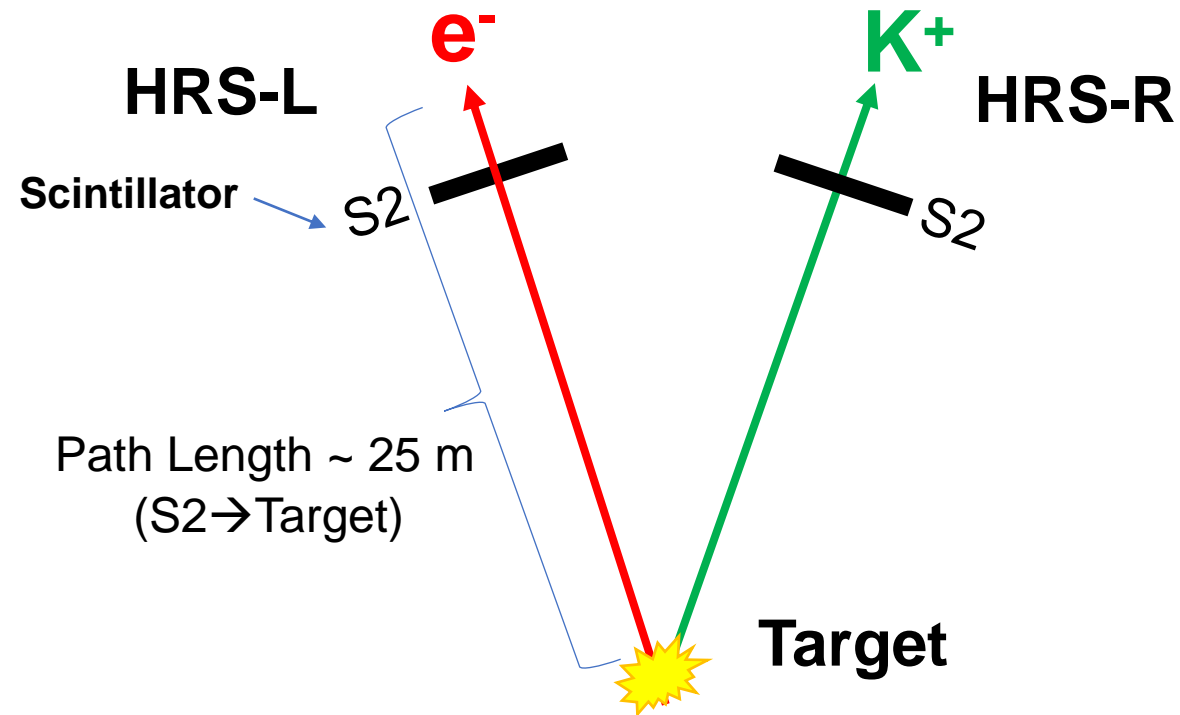
AC2 ($n=1.055$): π^+ , K^+ , p

$\beta > 1/n$ (Cherenkov light)



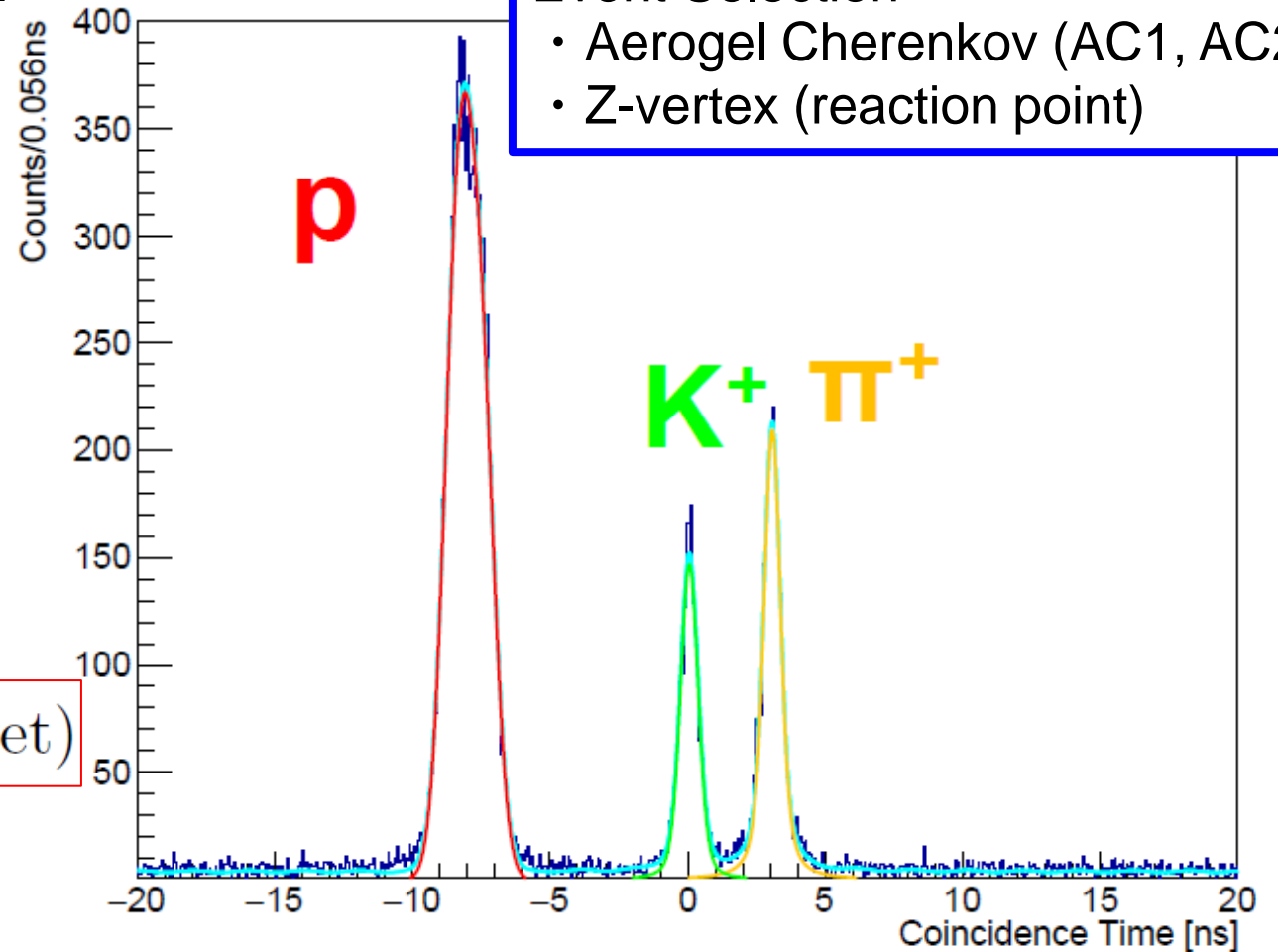
$\overline{AC1} \otimes AC2$

Coincidence Time (Kaon identification)



Event Selection

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



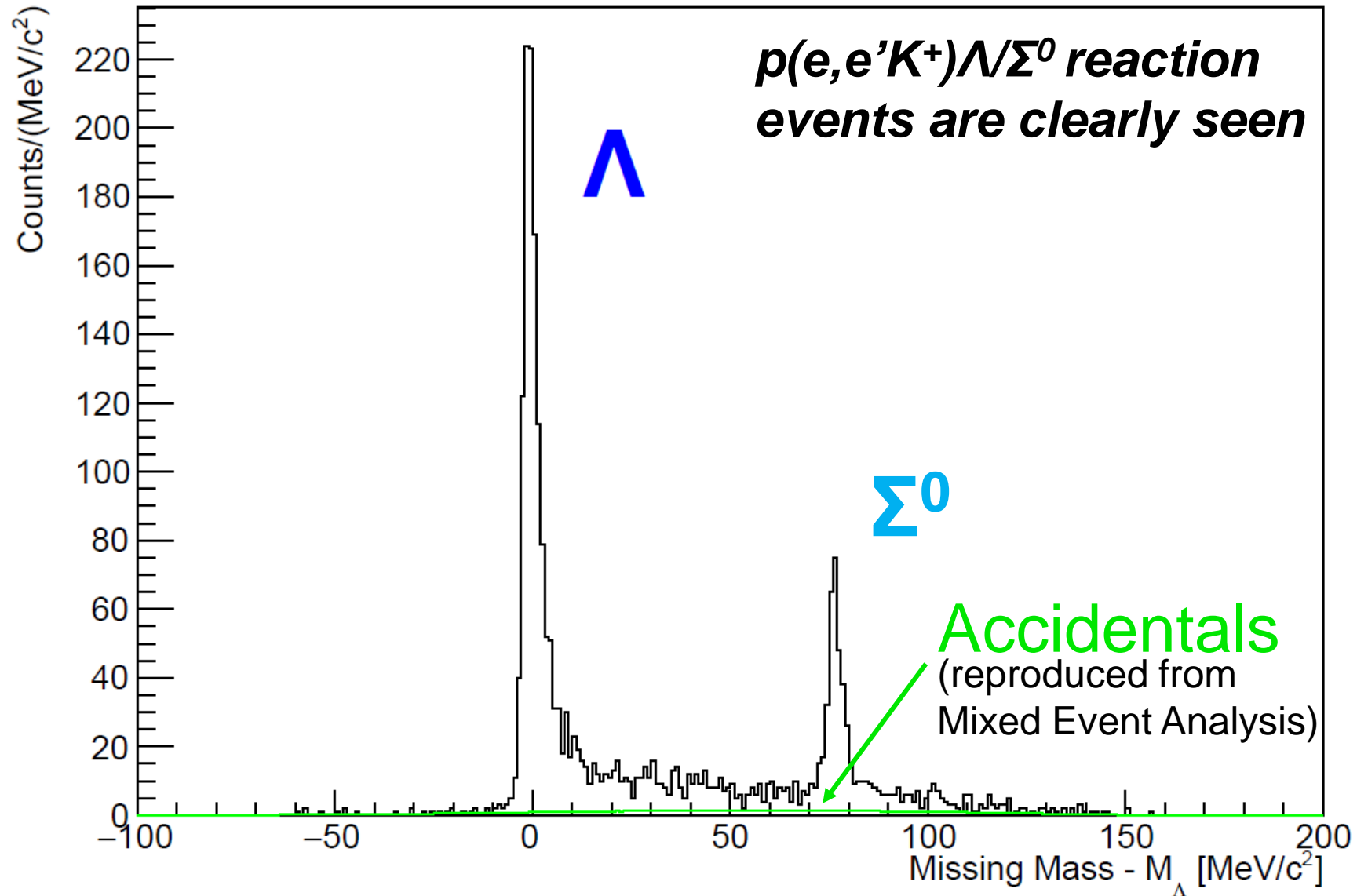
Coincidence Time = Time difference at Target

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

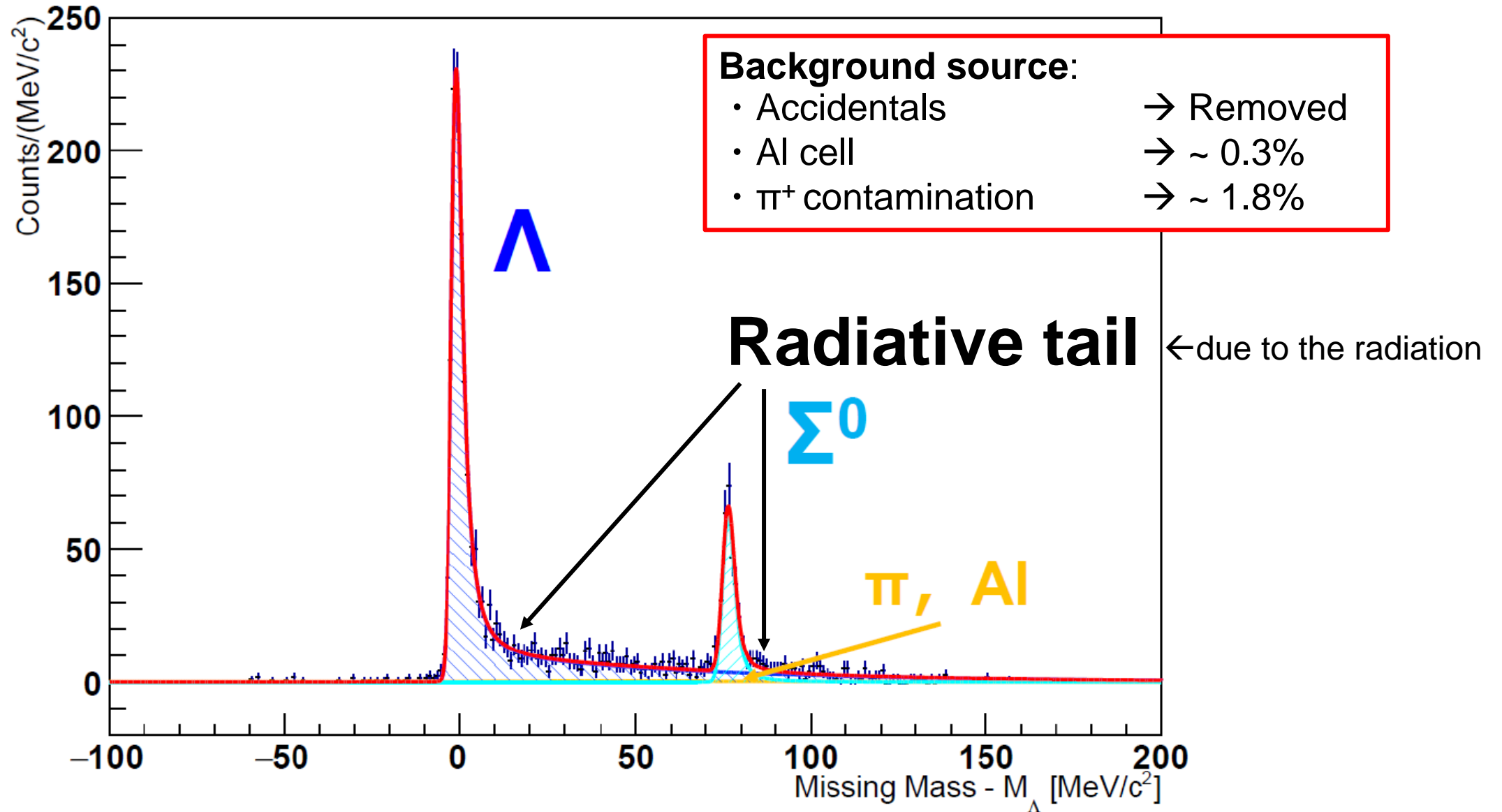
Reaction timing at Target:

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

Missing Mass Spectrum

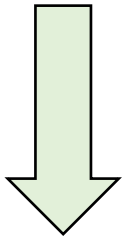


Missing Mass Spectrum



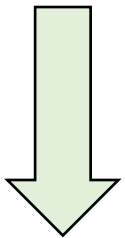
Analysis flow

Hydrogen Data



- H₂ gas region selection (Vertex Position)
- Kaon identification: Part1 (Aerogel Cherenkov)
- Kaon identification: Part2 (Coincidence Time)

Λ/Σ^0 Missing Mass Spectrum



- Efficiency
- Acceptance

Event selection:
p(e,e'K⁺) Λ/Σ^0 reaction

I will briefly explain this part.

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

D.C.S. derivation of the
hyperon electroproduction

Derivation of the differential cross section

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

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

Num. of Target
 0.0375 b⁻¹

Num. of Virtual Photon
 3.53 × 10¹³ (Λ)
 4.95 × 10¹³ (Σ^0)

DAQ efficiency
 ~0.96

Cut efficiency
 0.454 (Λ)
 0.443 (Σ^0)

Solid Angle
 ~5.5 msr

Kaon Survival Ratio
 ~0.14

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Results

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

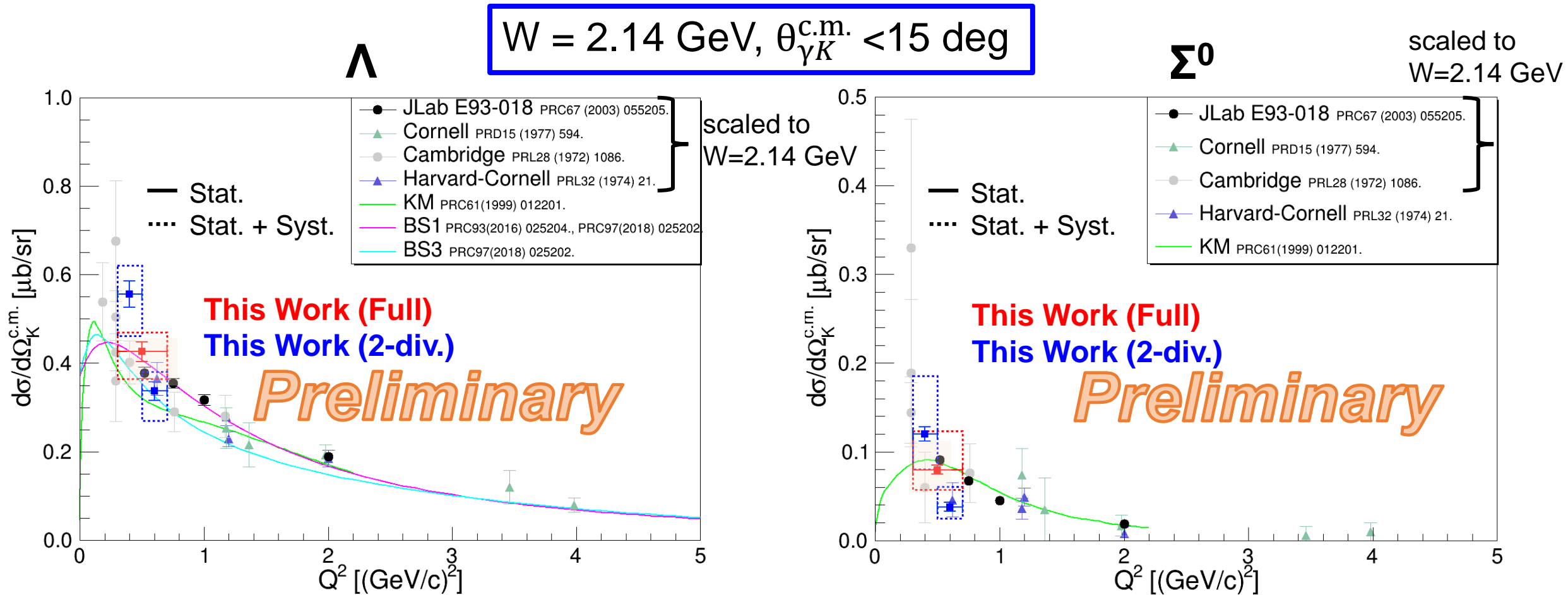
$$\Lambda \quad \overline{\left(\frac{d\sigma_{\gamma^* p \rightarrow K^+ \Lambda}}{d\Omega_{K^+}^{\text{c.m.}}} \right)} = 0.426 \pm 0.022(\text{Stat.})_{-0.040}^{+0.021}(\text{Syst.}) [\mu\text{b/sr}]$$

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

- 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.



Result2: Angle dependence

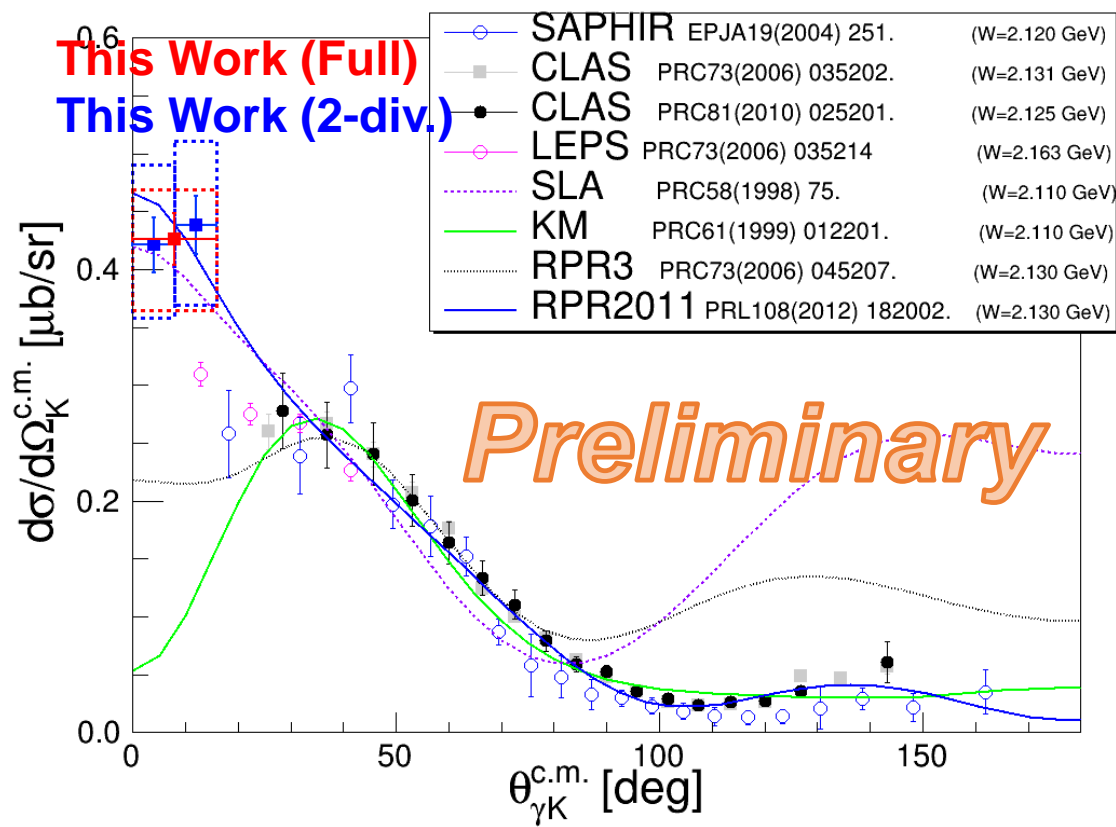
➤ $d\sigma/d\Omega$ tend to decrease as $\theta_{\gamma K}^{c.m.}$ approach to forward angles. (Λ and Σ^0)

Note1: Comparison with photoproduction ($Q^2=0$)

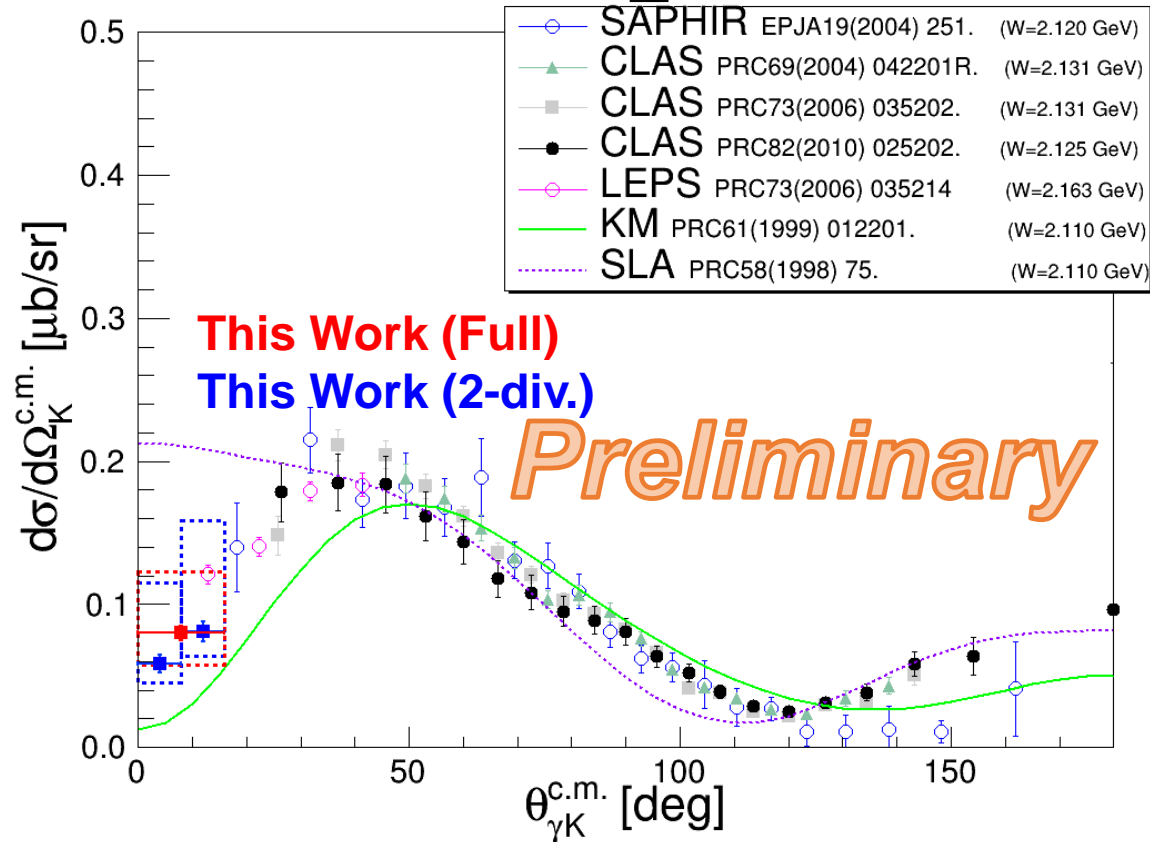
Note2: Our data is $Q^2=0.5$ (GeV/c)²

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

Λ



Σ^0



Summary & Conclusion

- JLab: E12-17-003 experiment in 2018 ($W=2.14$ GeV, $Q^2=0.5$ (GeV/c)², $\theta_{\gamma K}^{\text{c.m.}}=8$ deg)
→ Forward angles data which is scarce in photoproduction

- Identification of the $p(e, e' K^+) \Lambda / \Sigma^0$ reaction using AC, Z-vertex, Coincidence Time

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

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

Preliminary

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

- 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.