Λ and Σ^0 electroproductions in JLab E12-17-003

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Contents

JLab: E12-17-003 (2018) → p(e,e'K^+)Λ/$Σ^0$ reaction (gas H_2 target)

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

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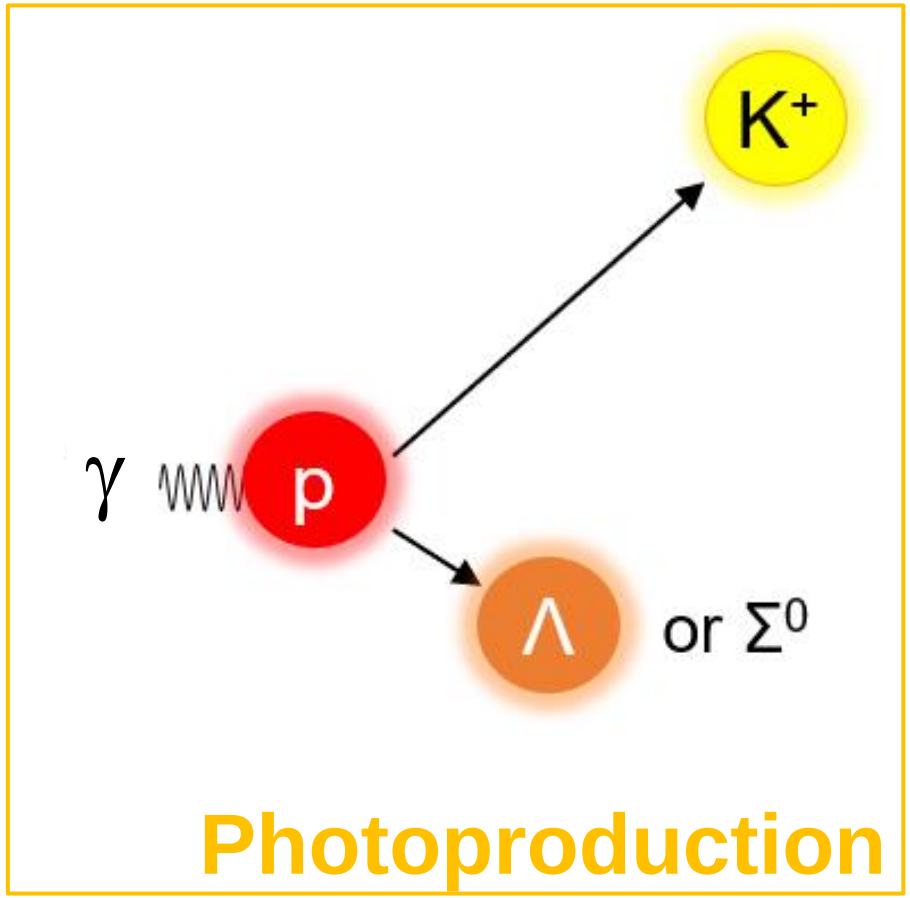
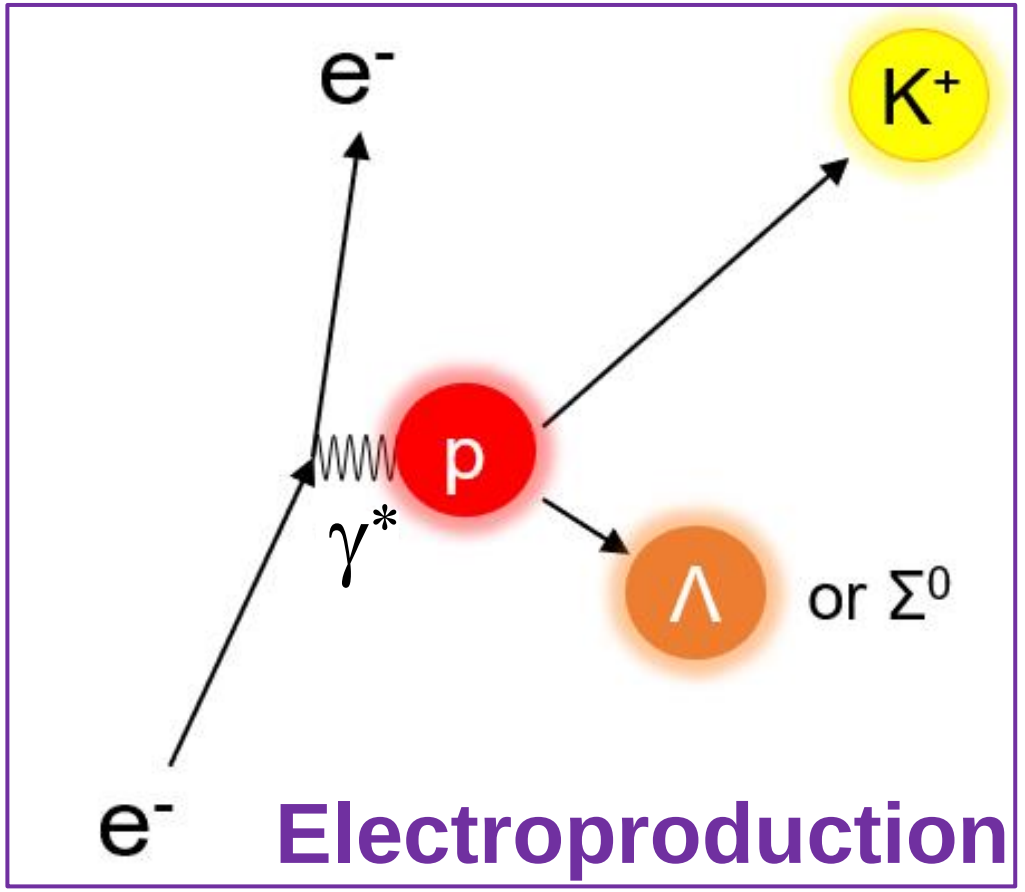
Hyperon Photo- and Electroproduction

our experiment

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



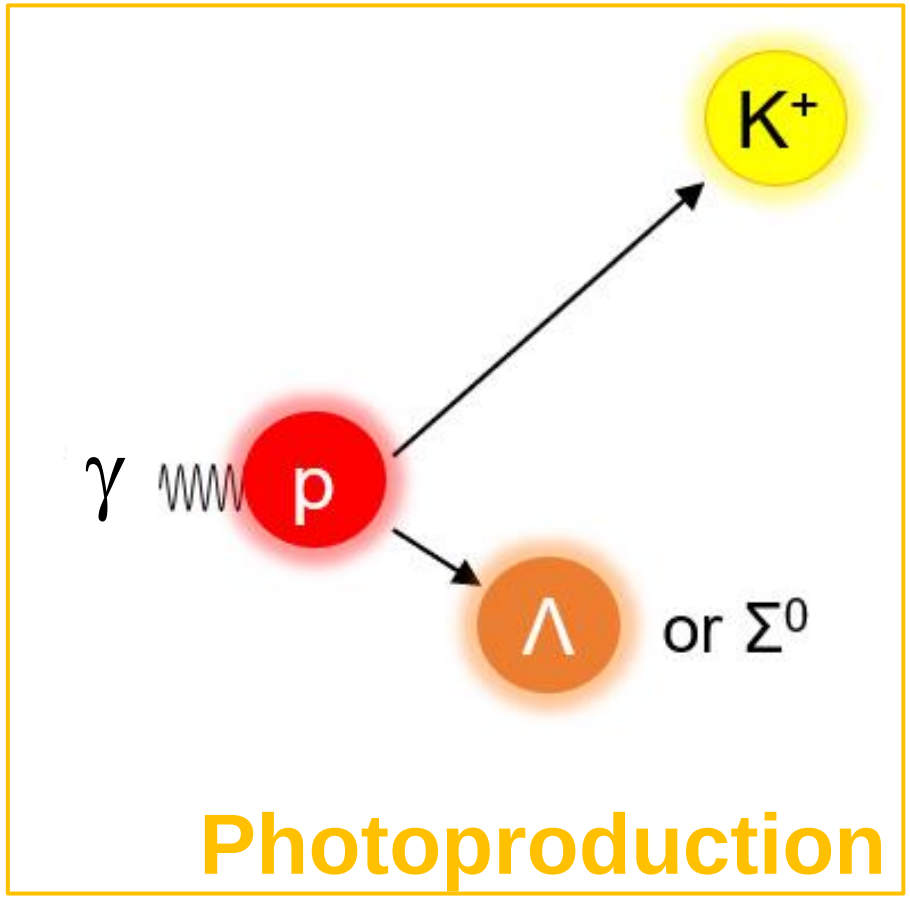
- **Electroproduction ($Q^2>0$)**
  - →accessible in forward angles
  - →Q^2 dependence appears

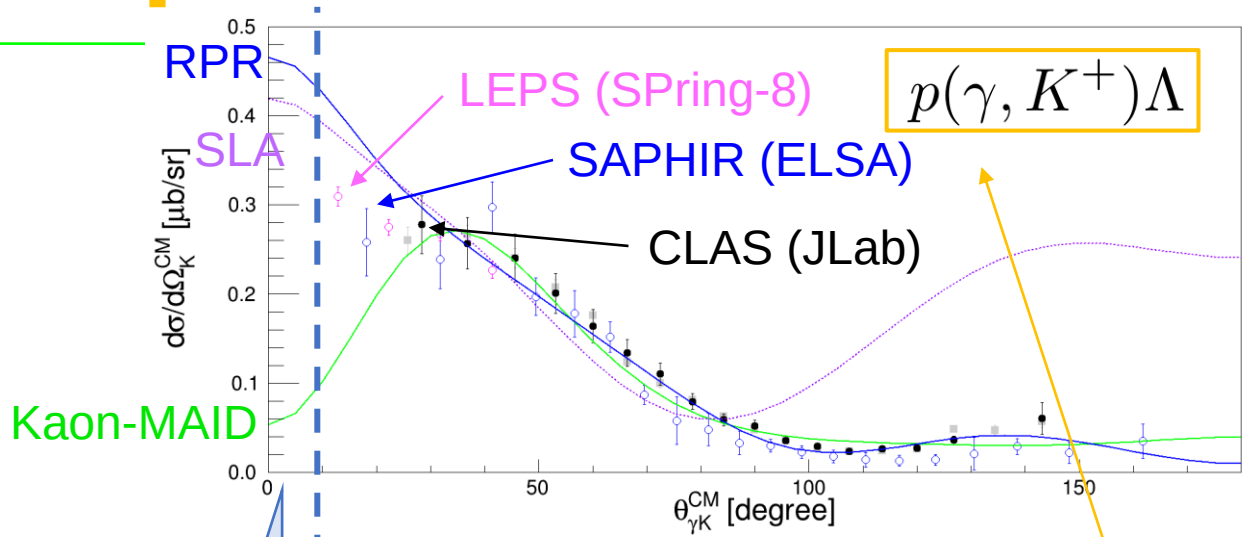


Hyperon Photoproduction

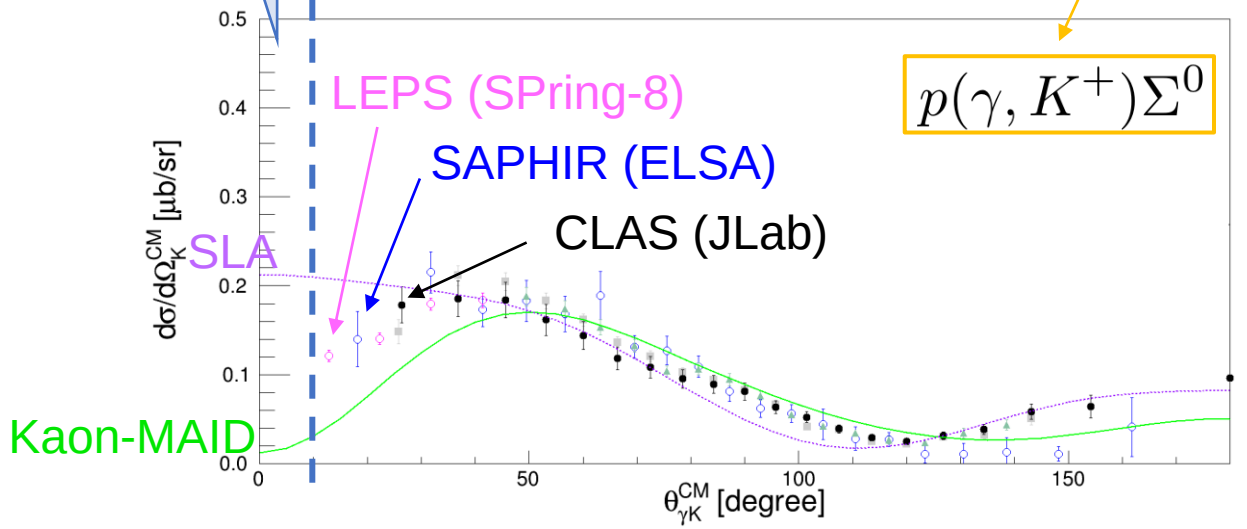
W = 2.14 GeV

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





Scarce Data (Forward)



Hyperon Electroproduction

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

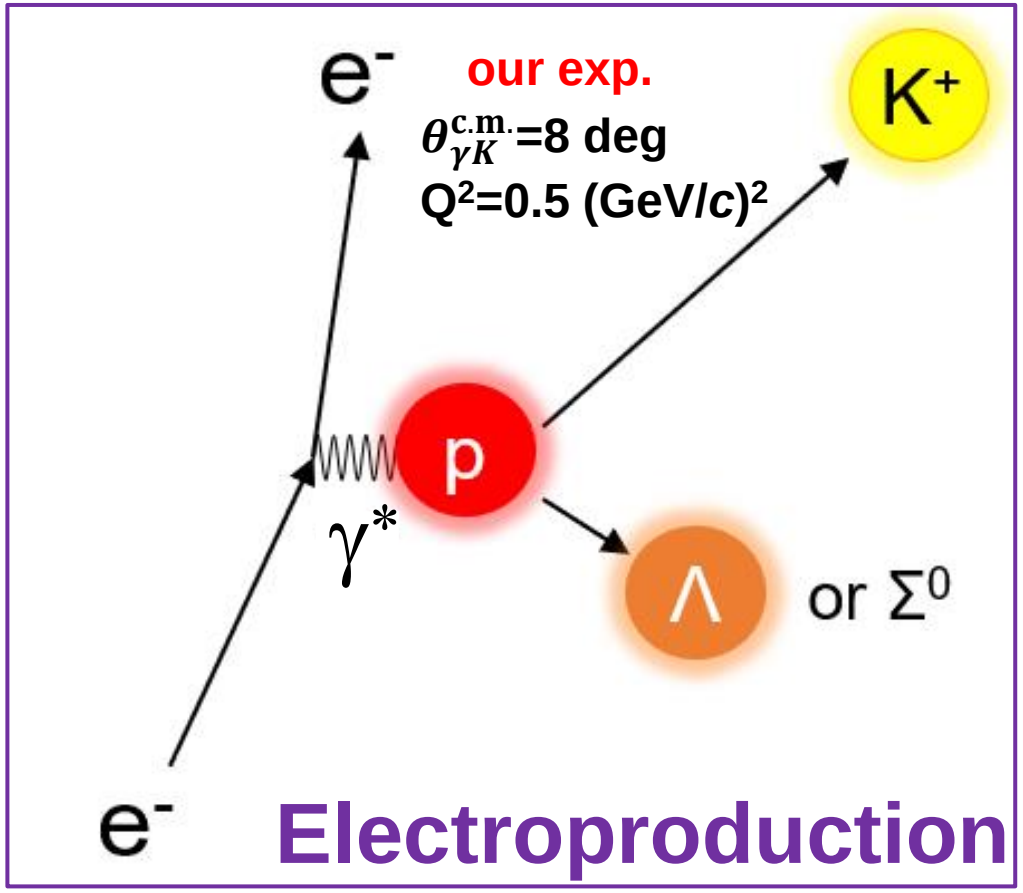
virtual photoproduction

Virtual Photon Flux

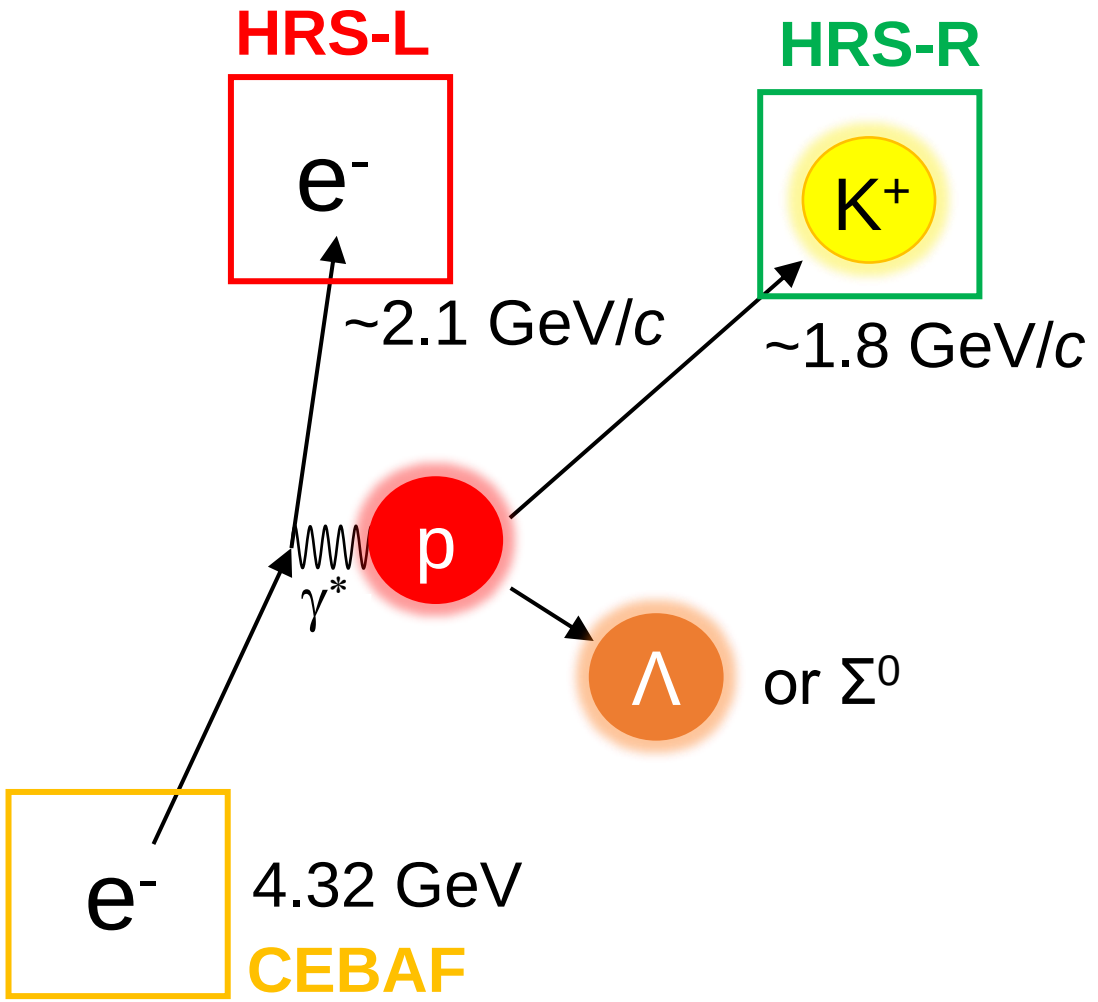
$$\Gamma := \frac{\alpha}{2\pi^2 Q^2}\frac{E_\gamma}{1-\varepsilon}\frac{E_{e'}}{E_e}$$

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

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



Hyperon **Electroproduction** at JLab



E12-17-003

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

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

$$\text{Missing Mass} = \sqrt{\{(E_{\mathrm{e}} - E_{\mathrm{e}'}) + M_{\mathrm{p}} - E_{\mathrm{K}}\}^2 - \{(\boldsymbol{P}_{\mathrm{e}} - \boldsymbol{P}_{\mathrm{e}'}) - \boldsymbol{P}_{\mathrm{K}}\}^2}$$

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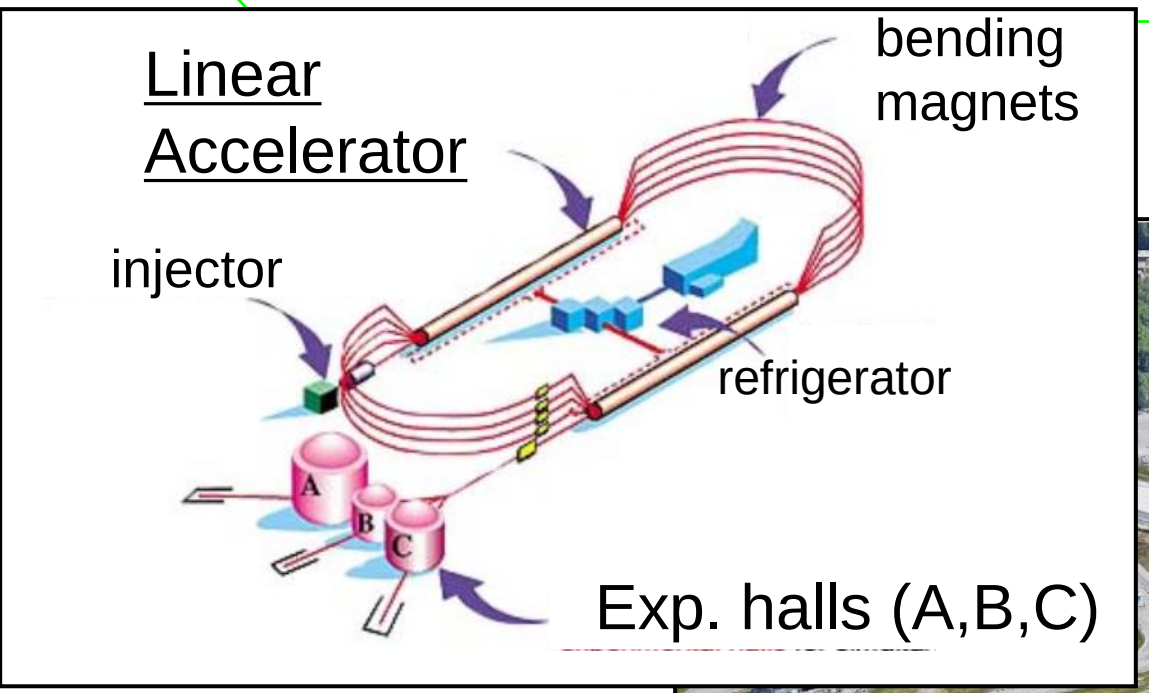
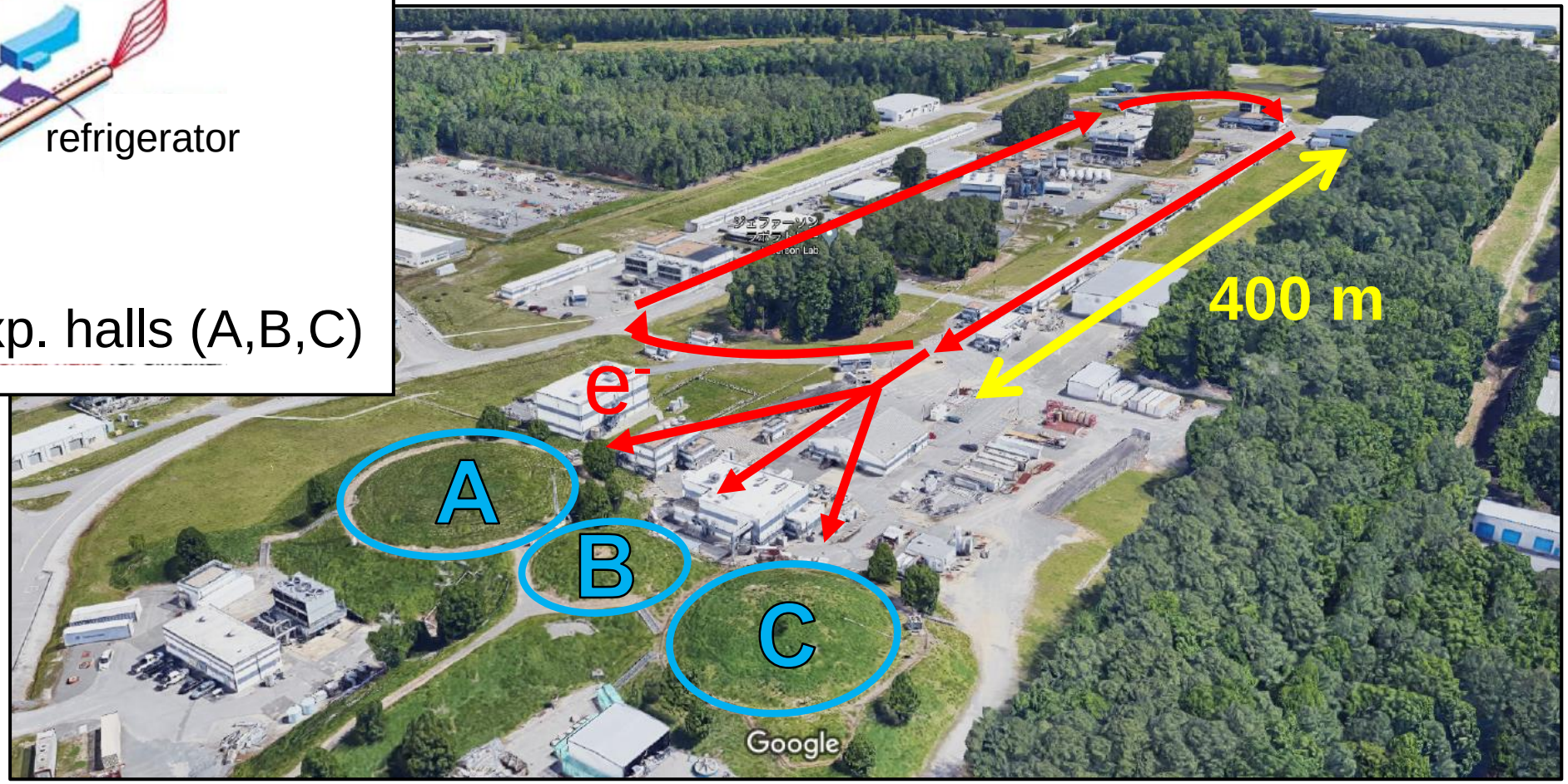
Jefferson Lab (JLab)



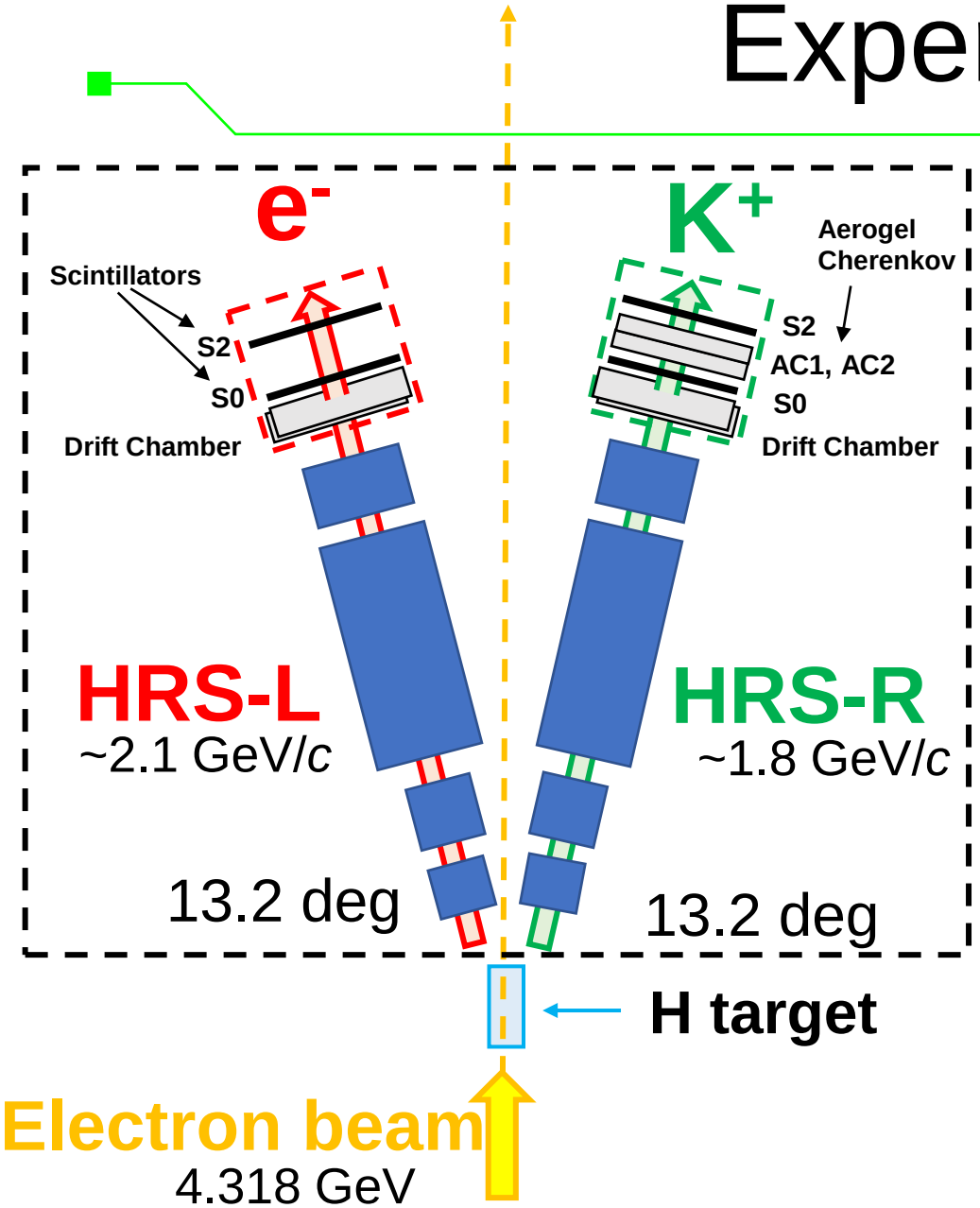
Continuous Electron Beam Accelerator Facility (CEBAF)

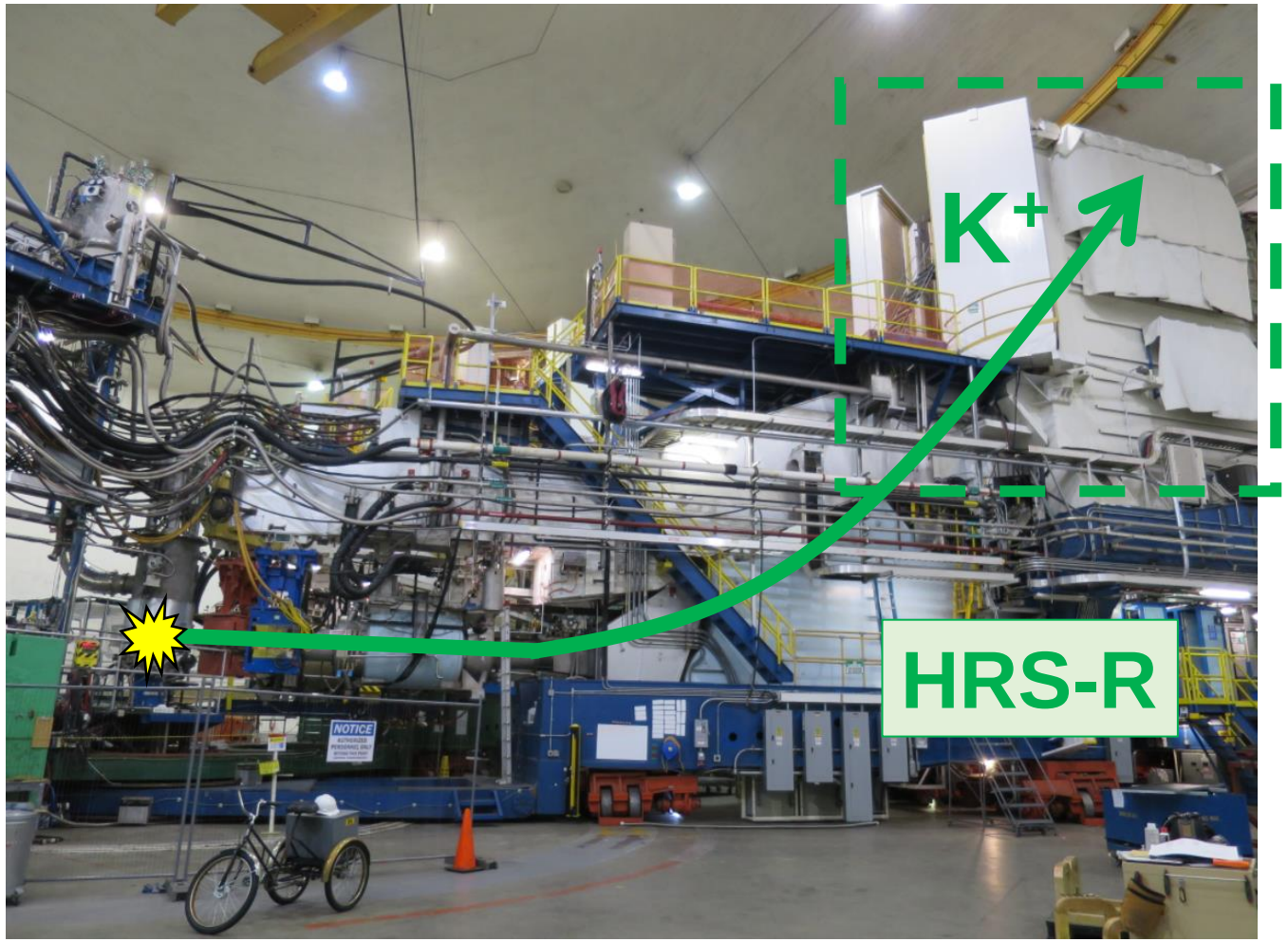


E12-17-003 (at Hall-A)

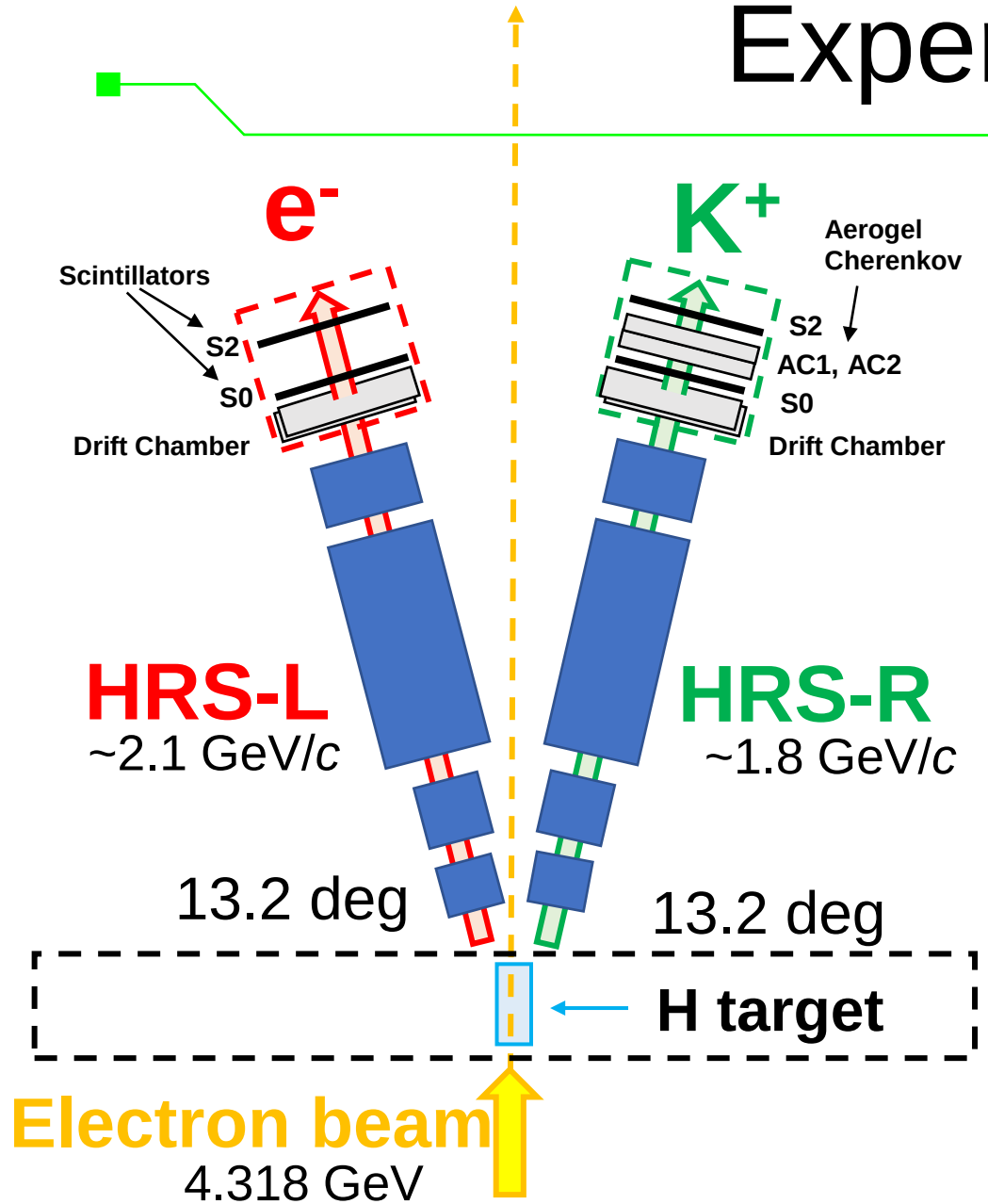
- E = 4.32 GeV
- $\Delta E/E \sim 10^{-4}$
- I_e = 22.5 μA

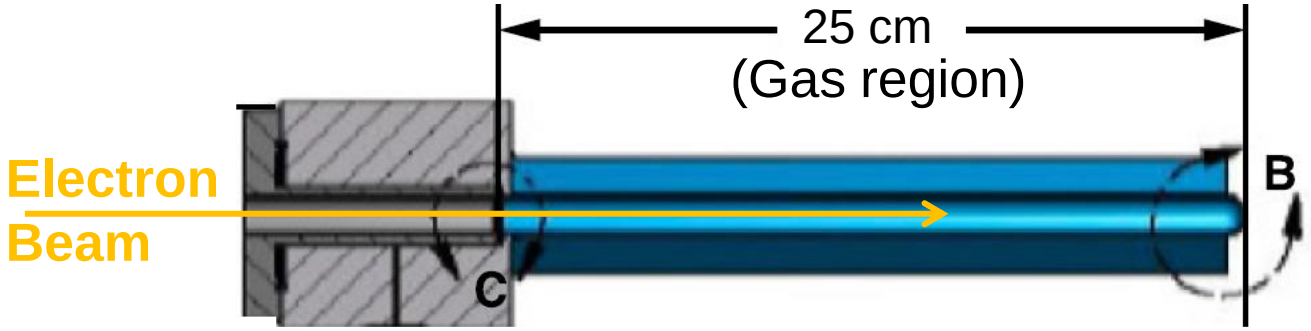
Experimental Setup



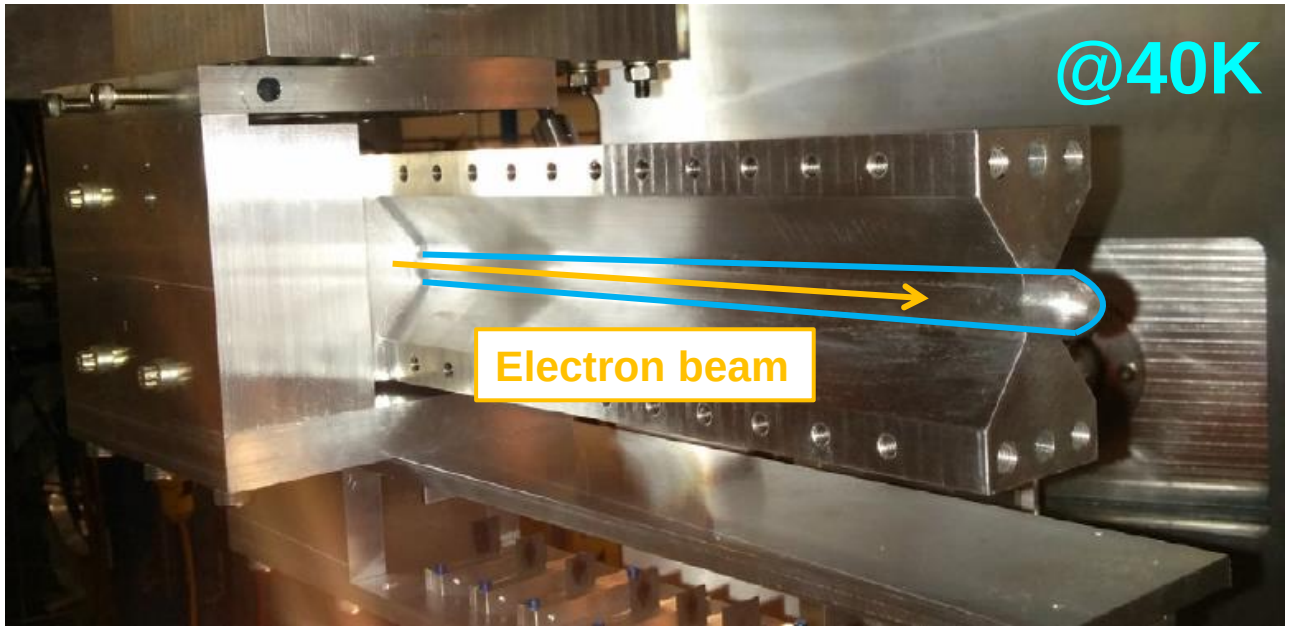


Experimental Setup





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

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

Λ/Σ^0 Missing Mass Spectrum

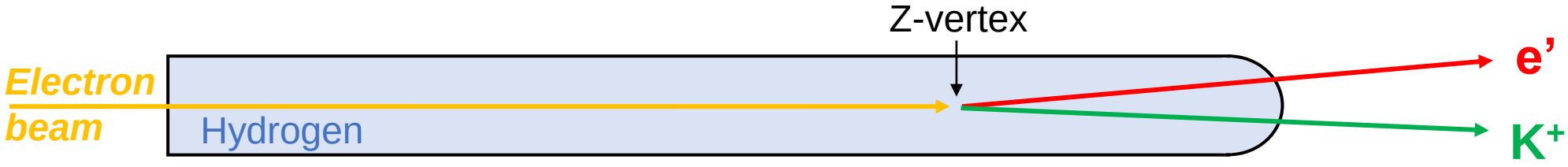
Event selection:
$p(e,e'K^+)\Lambda/\Sigma^0$ reaction

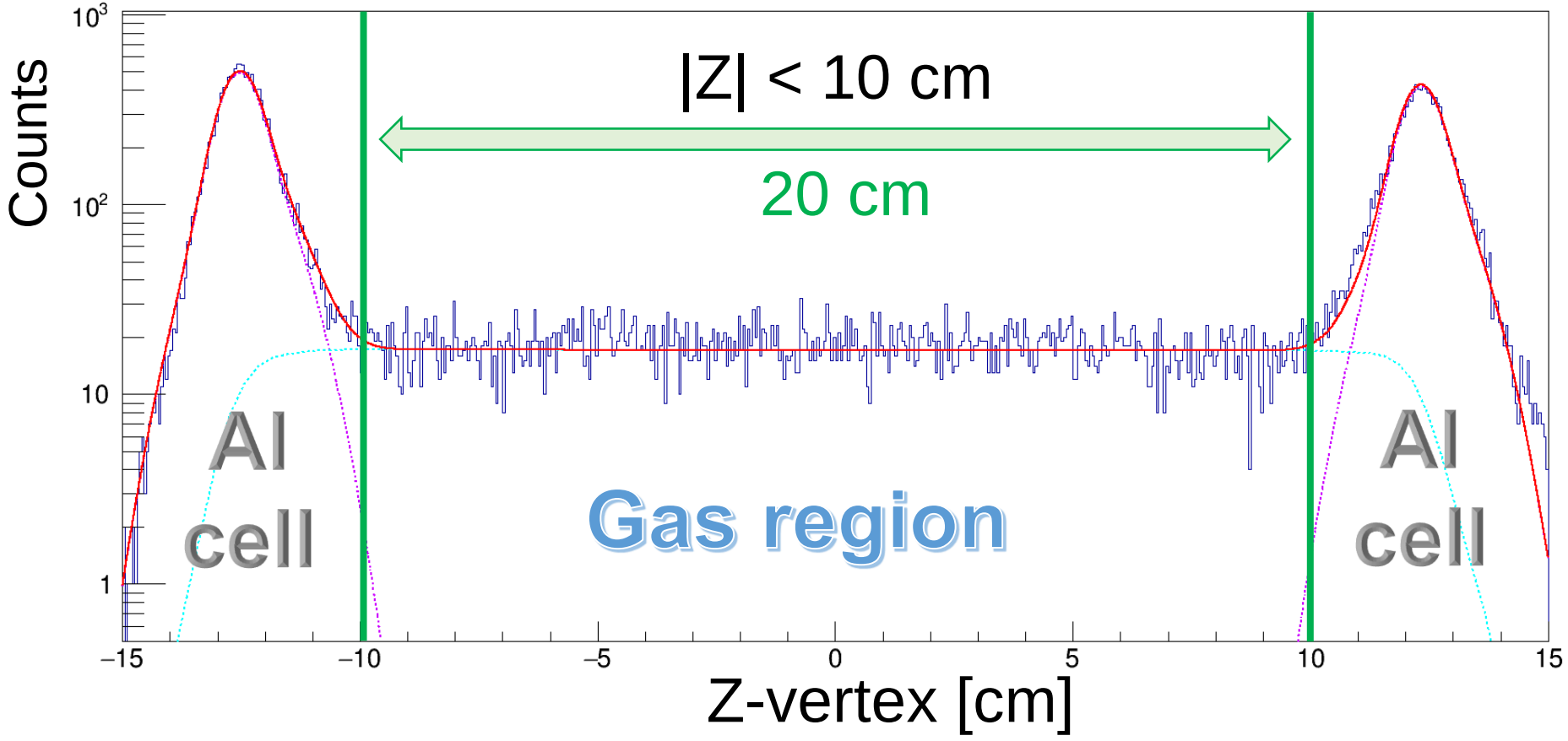
- Efficiency
- Acceptance

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.

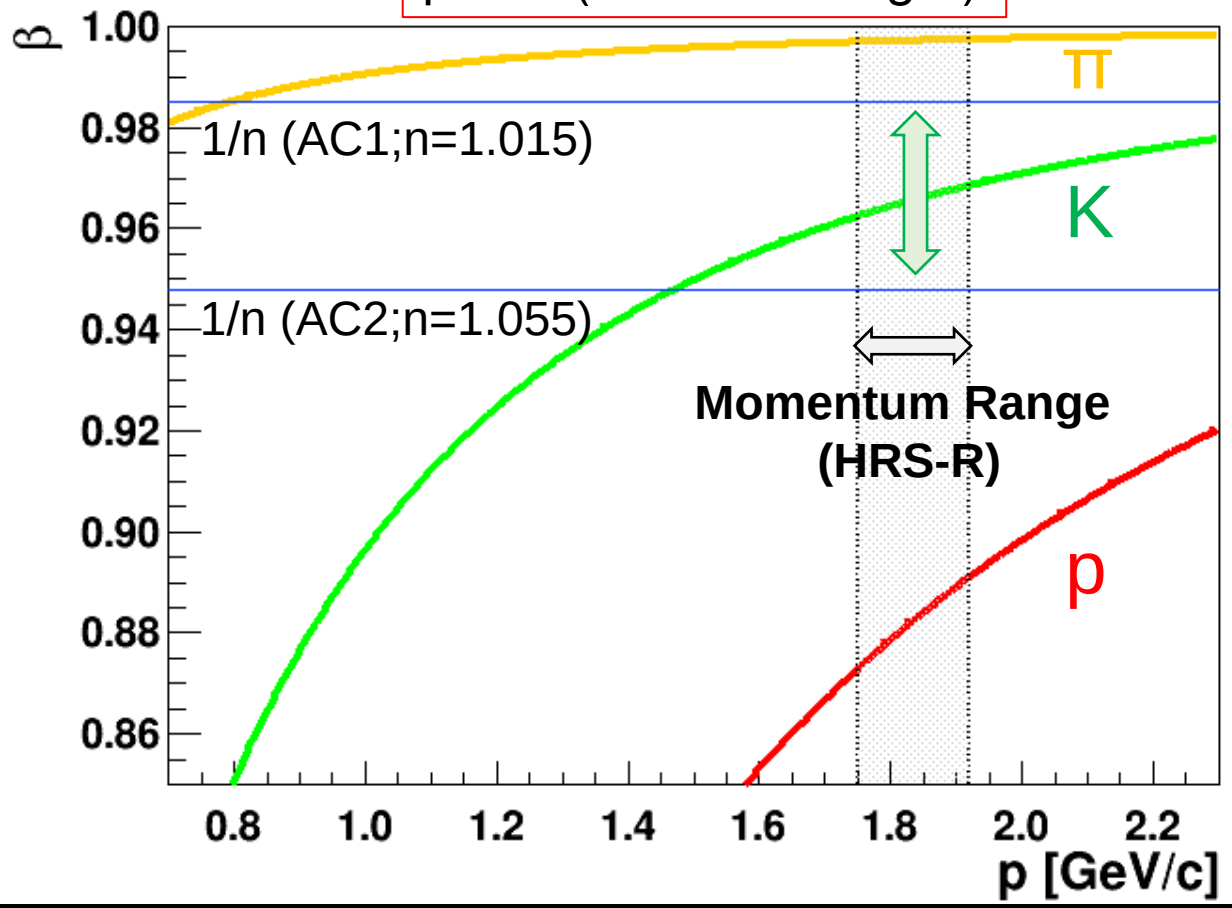
- Gas region: 25 cm
- Used only 20 cm (80% of total)

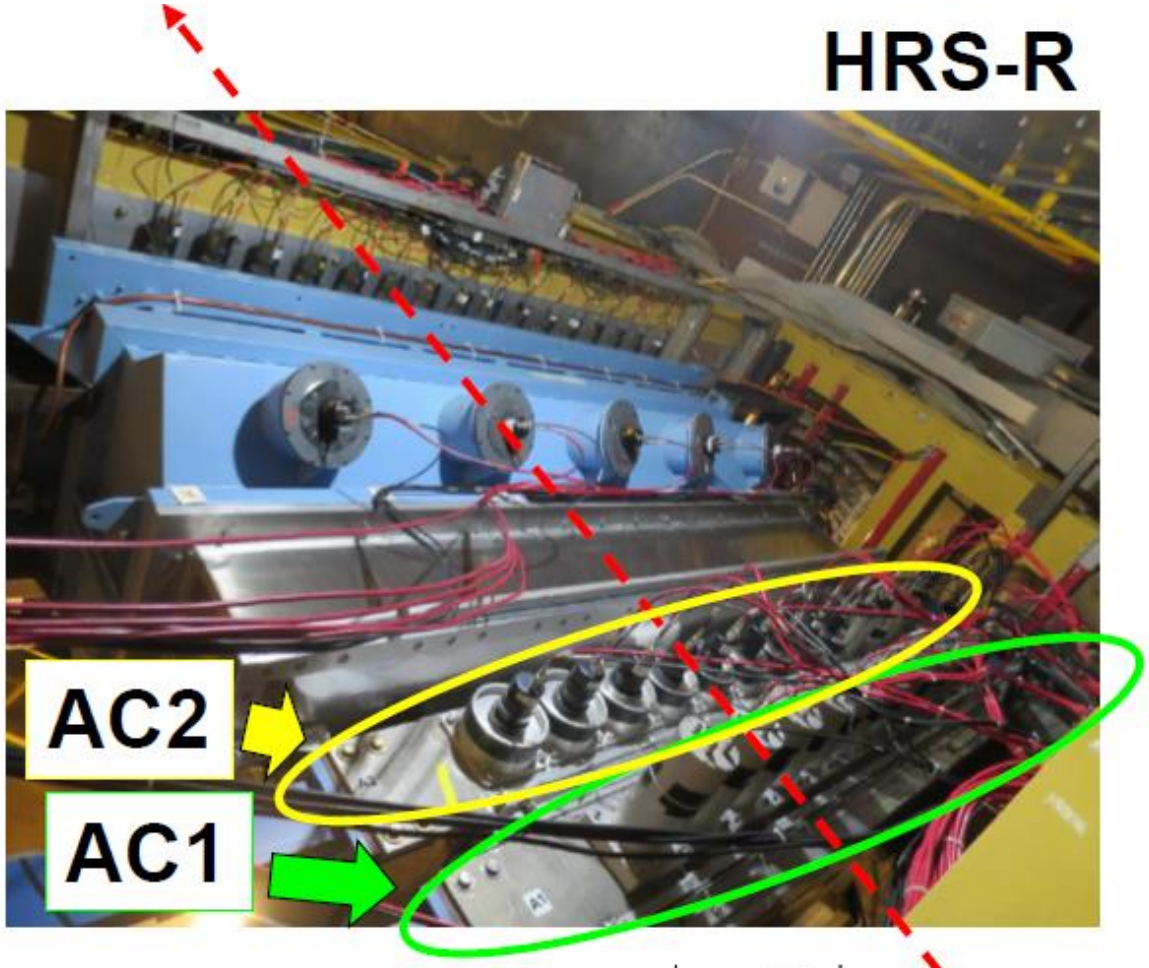
Aerogel Cherenkov (Kaon Identification)

AC1 (n=1.015): π^+, K^+, p

AC2 (n=1.055): π^+, K^+, p

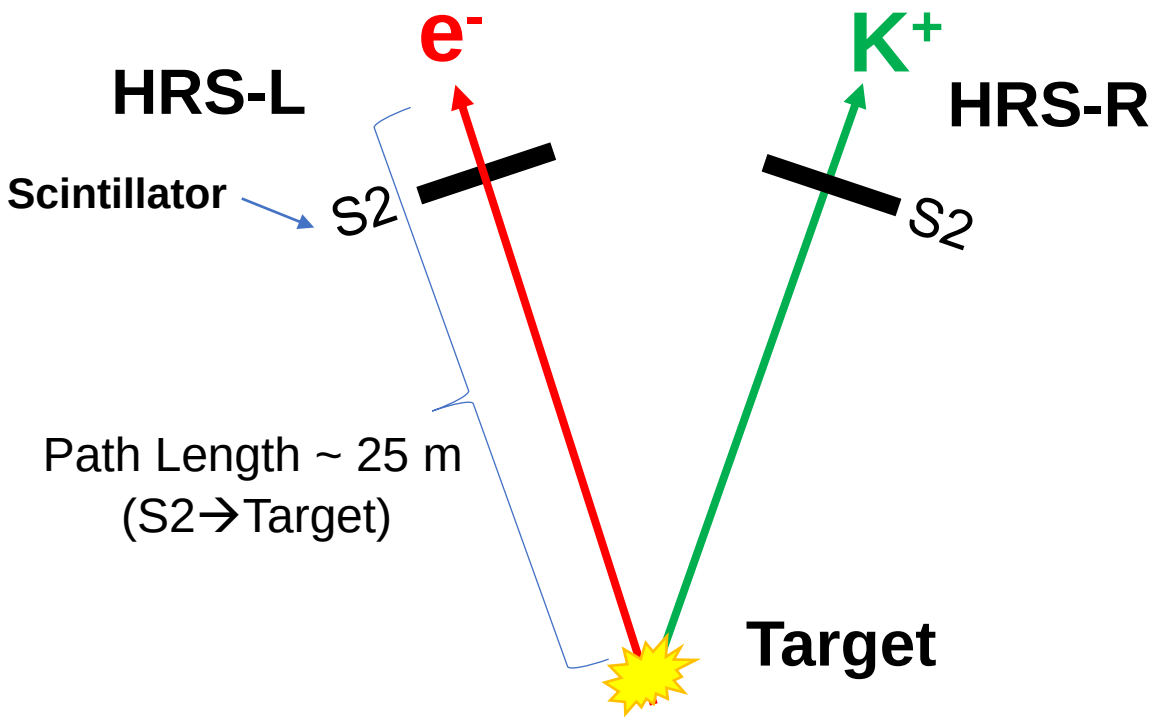
β>1/n (Cherenkov light)





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

Coincidence Time (Kaon Identification)



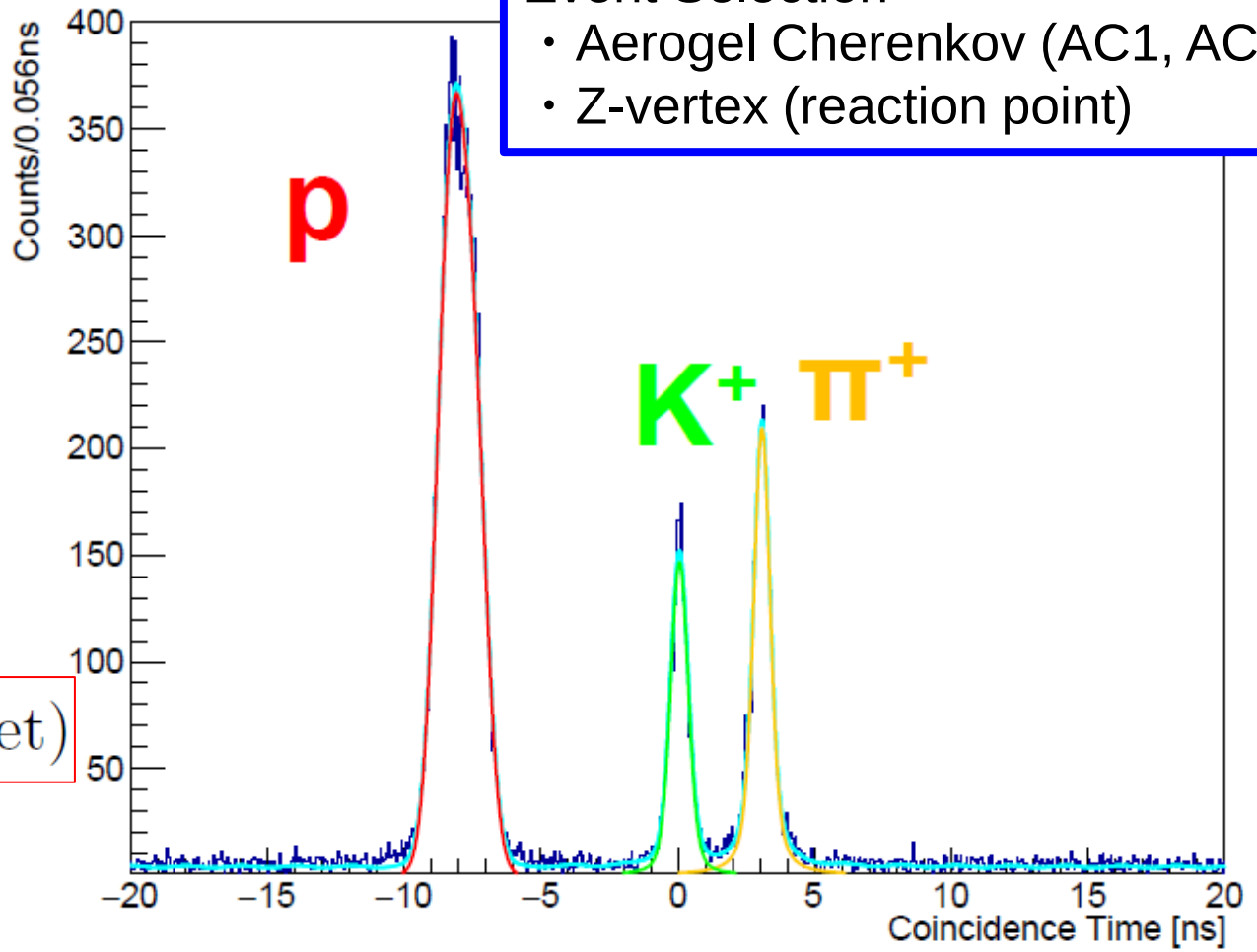
Coincidence Time = Time difference at Target

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

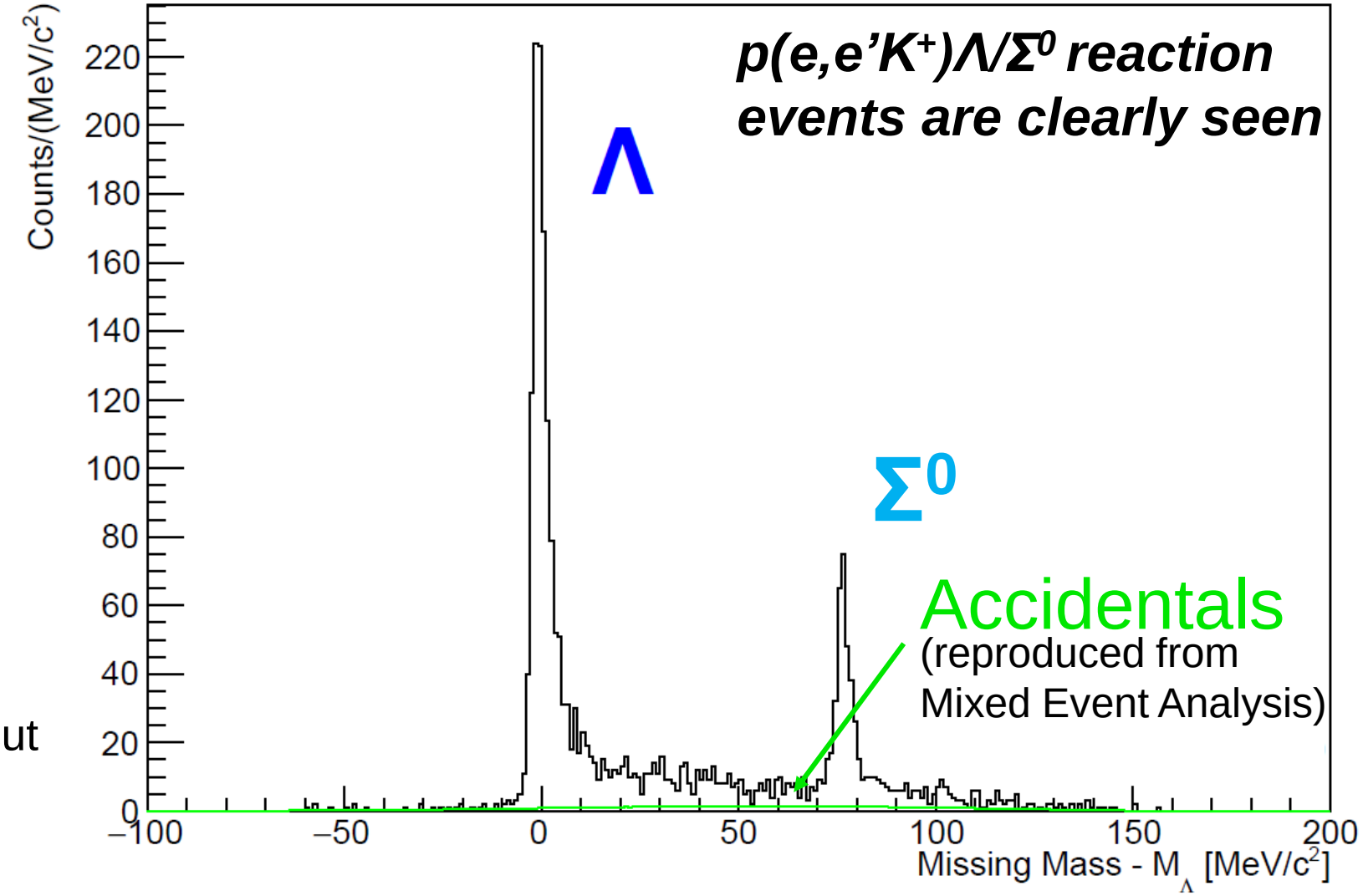
Reaction timing at Target:

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

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

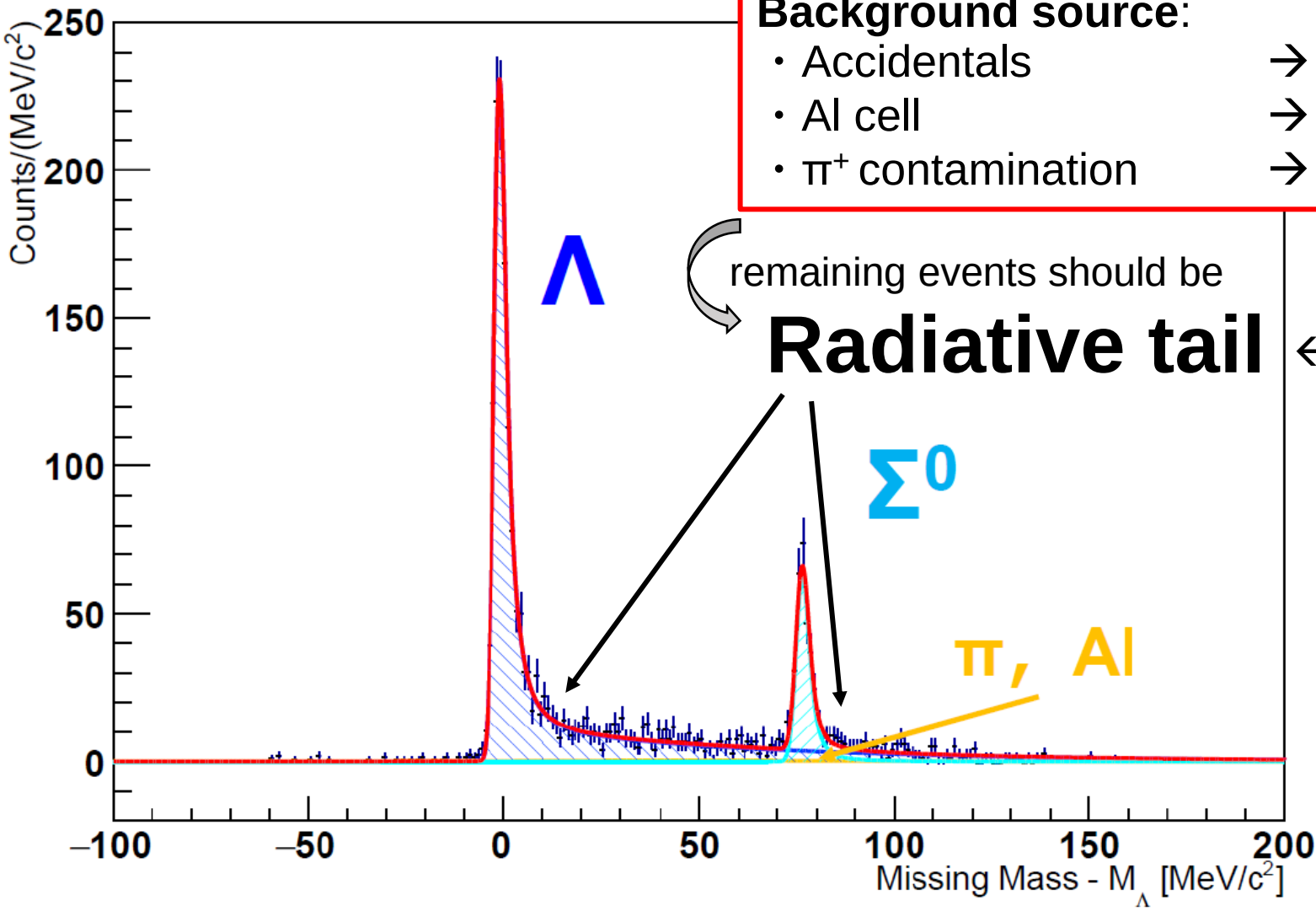


Missing Mass Spectrum



- Z-vertex cut
- AC cut
- Coin. Time cut
- other cuts…

Missing Mass Spectrum



Background source:

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

Analysis Flow

Hydrogen Data

- H_2 gas region selection (Vertex Position)
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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

Differential Cross Section

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

$N_{\Lambda(\Sigma^0)}$: Number of detected $\Lambda(\Sigma^0)$

N_{T} : Number of proton targets [b^{-1}]

N_{γ^*} : Number of virtual photons

ε_i : Event cut efficiency for i-th event

$\varepsilon_i^{\mathrm{DAQ}}$: DAQ efficiency when taking i-th event

$\varepsilon_i^{\mathrm{Decay}}$: Survival ratio of K^+ against decay

$\Delta\Omega_{\text{HRS-R},i}$: Solid angle with HRS-R for i-th event [sr]

	Λ	Σ^0
N_{T}	0.0375 ± 0.0013 b^{-1}	
$N_{\gamma^*}/10^{13}$	3.53 ± 0.01	4.95 ± 0.01
$\bar{\varepsilon}$	$44.9 \pm 1.5\%$	$40.0^{+3.0}_{-3.2}\%$
$N_{\text{Hyperon}}/10^3$	1.36 ± 0.04	0.37 ± 0.02
$\varepsilon^{\mathrm{Decay}}$	$\sim 14\%$	$\sim 14\%$
$\varepsilon^{\mathrm{DAQ}}$	$\sim 96\%$	$\sim 96\%$
$\Delta\Omega^{\mathrm{Lab}}_{\text{HRS-R}}$	~ 5.5 msr	

Differential Cross Section

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$N_{\Lambda(\Sigma^0)}$: Number of detected $\Lambda(\Sigma^0)$

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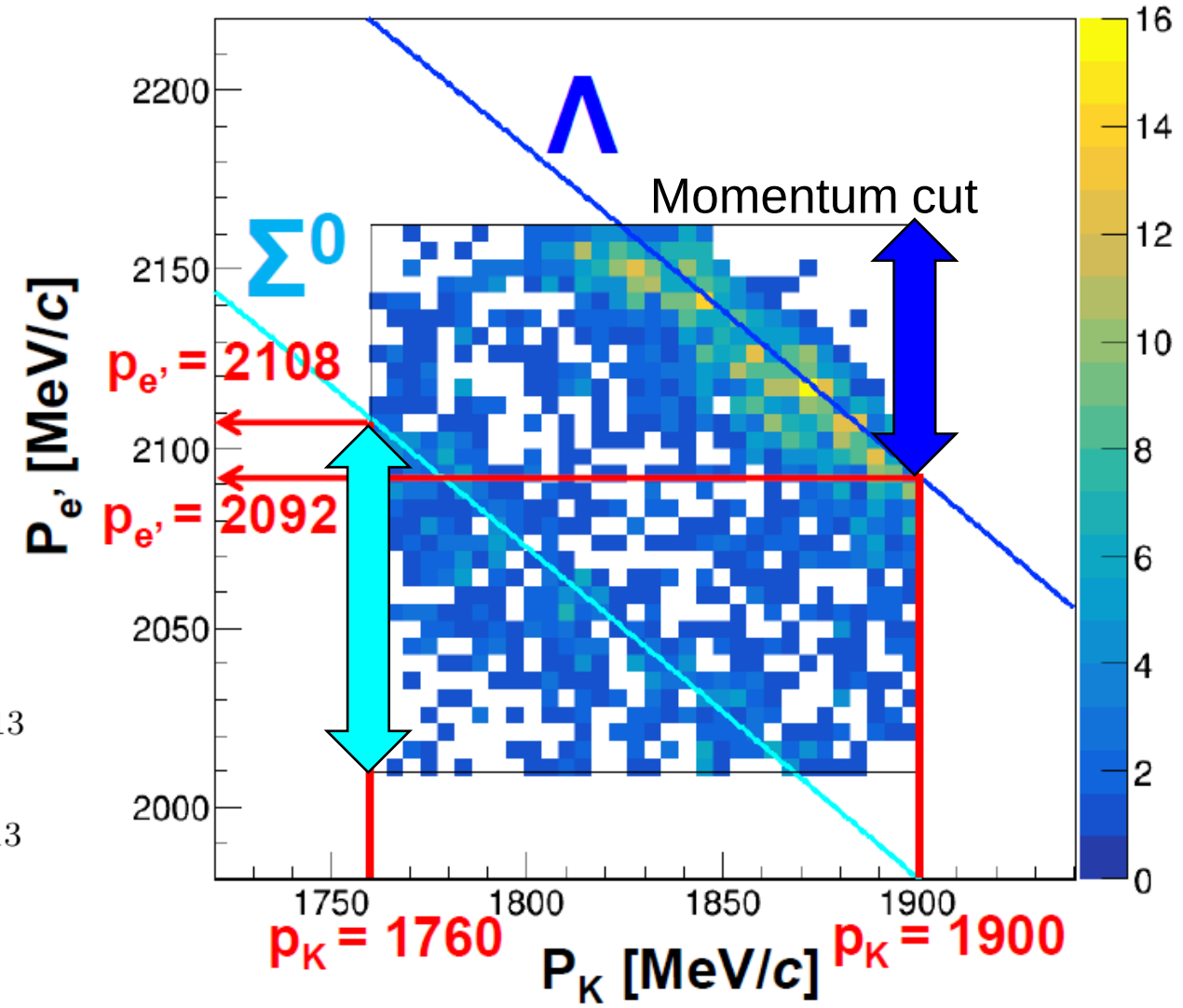
Virtual Photon Flux Integral

$$N_{\gamma^*} = N_{\mathrm{e}} \int_{E_{\mathrm{e}'}} \int_{\Omega_{\mathrm{e}'}} \Gamma \mathrm{d}E_{\mathrm{e}'} \mathrm{d}\Omega_{\mathrm{e}'}$$

When determining the integral range, momentum correlations between scattered electrons (detected at HRS-L) and kaons (detected at HRS-R) should be considered.

$$N_{\gamma^*(\Lambda)} = \left(3.53 \pm 0.01(\mathrm{Stat.})^{+0.05}_{-0.08}(\mathrm{Syst.})\right) \times 10^{13}$$

$$N_{\gamma^*(\Sigma^0)} = \left(4.95 \pm 0.01(\mathrm{Stat.})^{+0.09}_{-0.06}(\mathrm{Syst.})\right) \times 10^{13}$$



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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

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

Λ
$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p\to K^+\Lambda}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)}_{\mathrm{HRS\text{-}R}} = 0.431 \pm 0.024(\mathrm{Stat.})^{+0.027}_{-0.043}(\mathrm{Syst.}) \quad \mu\mathrm{b/sr}$$

Σ^0
$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p\to K^+\Sigma^0}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)}_{\mathrm{HRS\text{-}R}} = 0.088 \pm 0.009(\mathrm{Stat.})^{+0.042}_{-0.019}(\mathrm{Syst.}) \quad \mu\mathrm{b/sr}$$

Preliminary

Next…

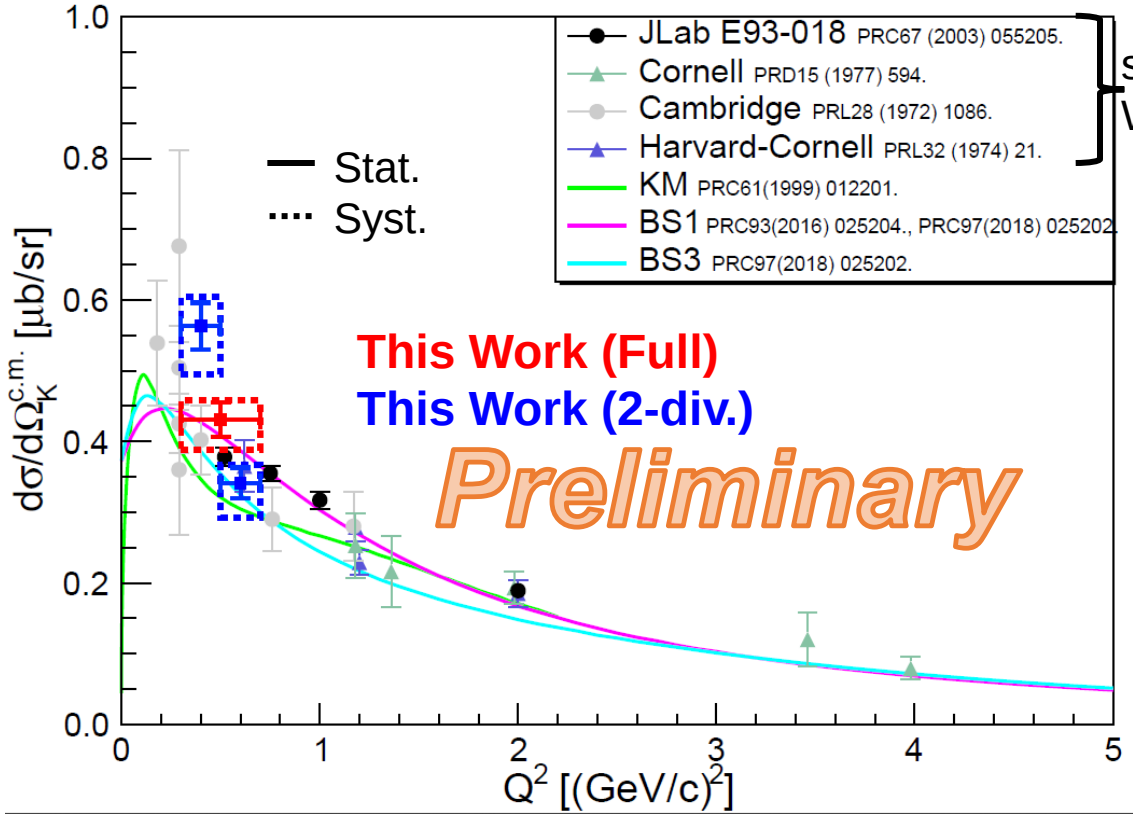
- Result1: Q^2 dependence
- Result2: Angle dependence

Result 1: Q^2 dependence

- **We deduced the differential cross sections at Q^2~0.5 (GeV/*c*)^2.**
- **dσ/dΩ (Λ and Σ^0) tend to increase as Q^2 decrease, and so do our results.**

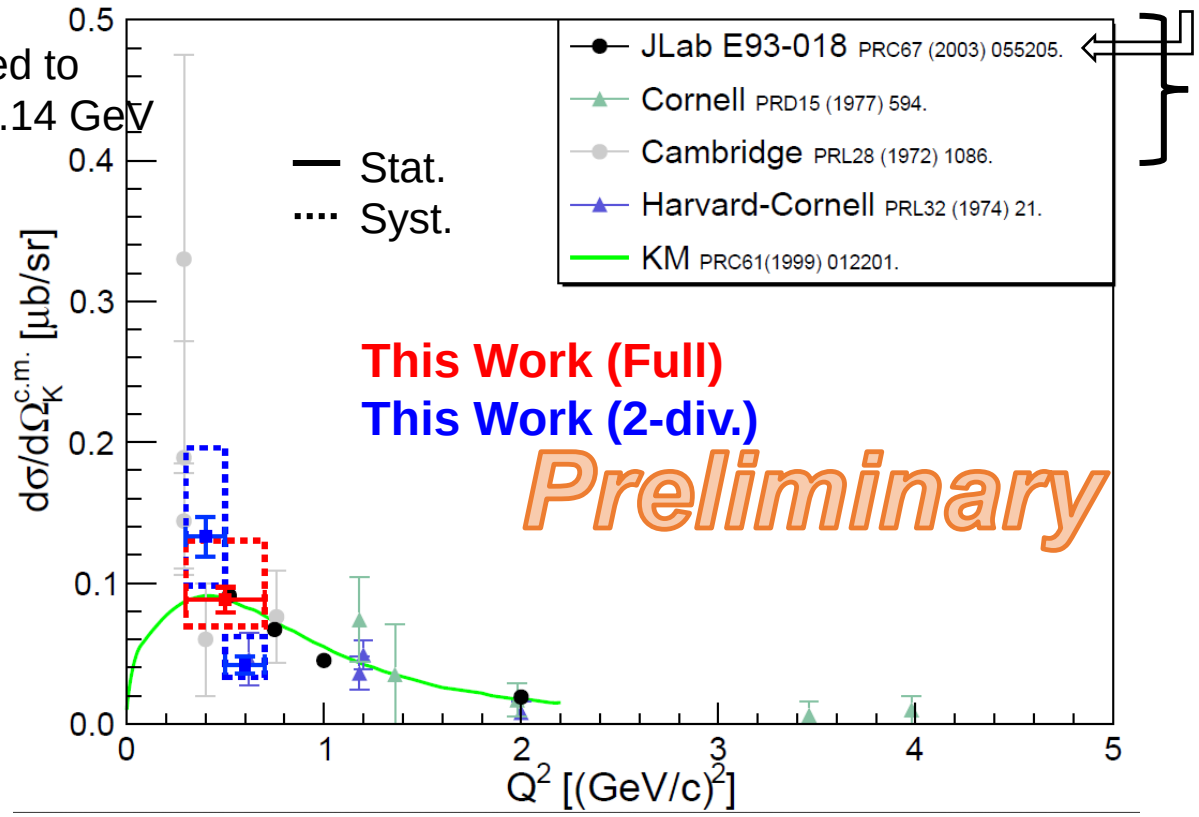
$W = 2.14$ GeV, $\theta_{\gamma K}^{c.m.} < 15$ deg

Λ



Σ^0

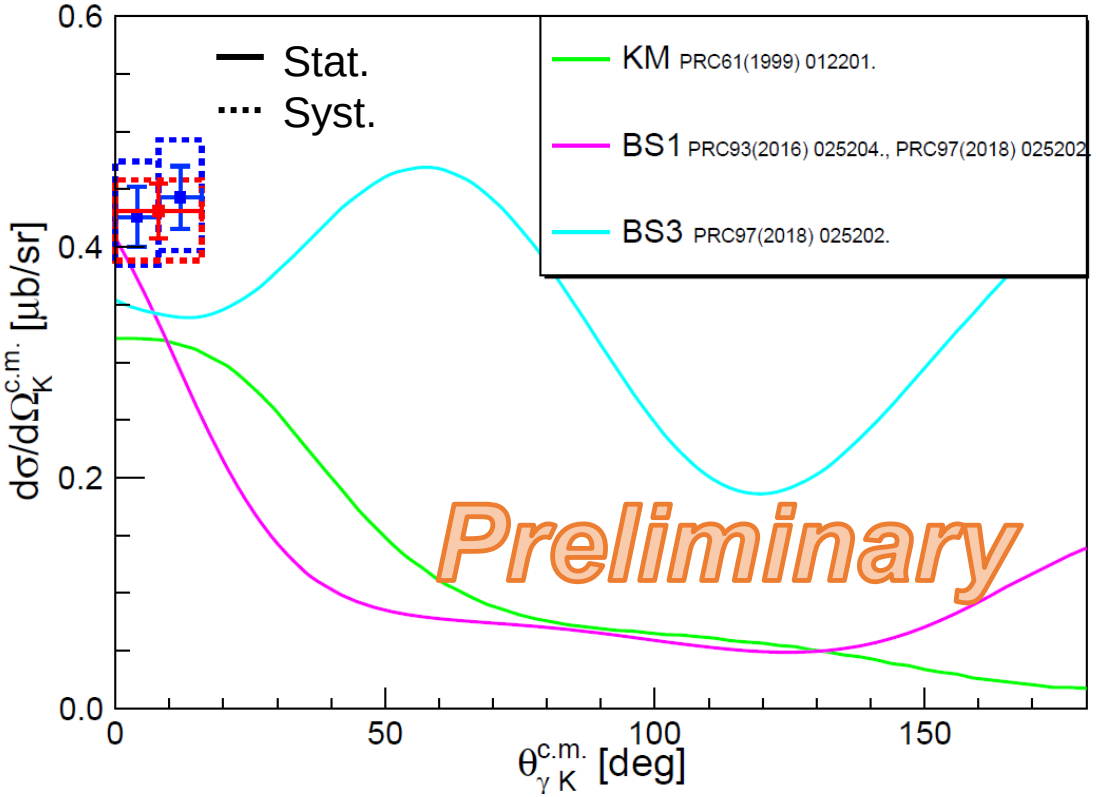
scaled to W=2.14 GeV based on

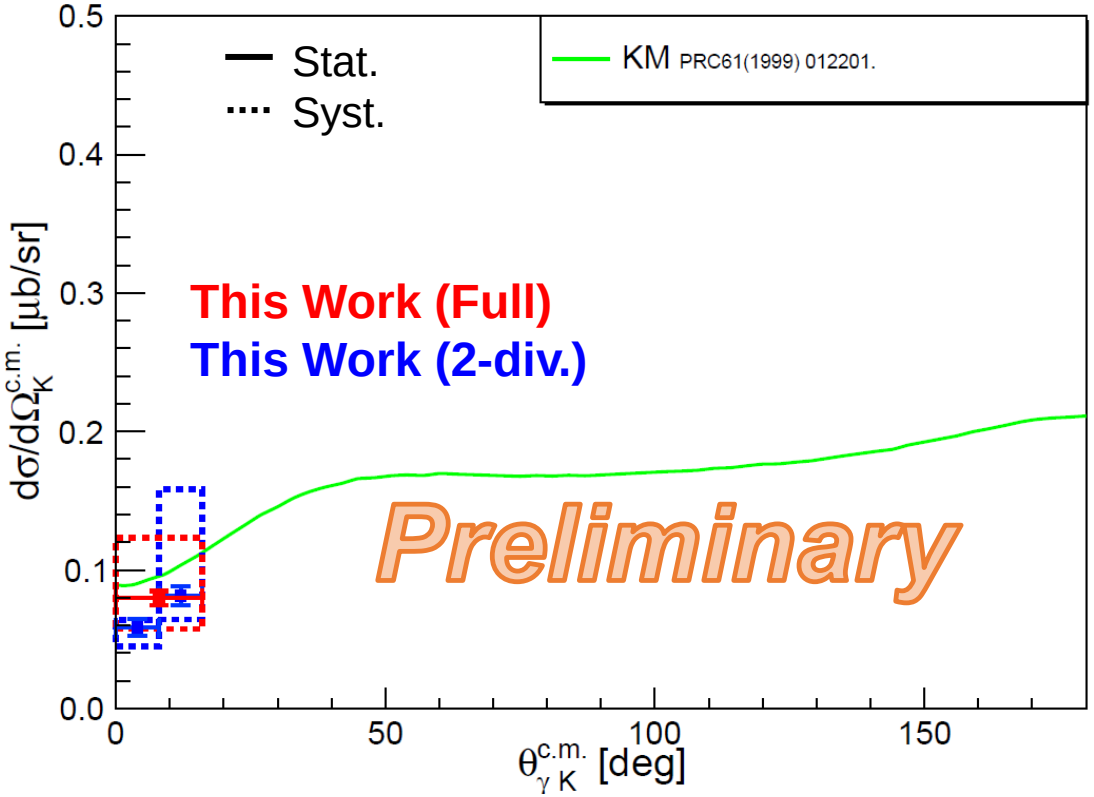


Result 2: Angle dependence

- **dσ/dΩ tend to decrease as $\theta_{\gamma K}^{\mathrm{c.m.}}$ approach to forward angles. (Λ and Σ^0)**
- **but, obvious angle dependence were not visible because of the errors**

Λ W = 2.14 GeV, Q^2=0.5 $(\mathrm{GeV}/c)^2$ **Σ^0**





Summary & Conclusion

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

→Forward angles data which is scarce in photoproduction

- Identification of the p(e,e'K^+)Λ/Σ^0 reaction using AC, Z-vertex, Coincidence Time

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

$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p\to K^+\Lambda}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)}_{\text{HRS-R}} = 0.431 \pm 0.024(\mathrm{Stat.})^{+0.027}_{-0.043}(\mathrm{Syst.}) \quad \mu\mathrm{b/sr}$$

Preliminary

$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p\to K^+\Sigma^0}}{\mathrm{d}\Omega_{K^+}^{\mathrm{c.m.}}}\right)}_{\text{HRS-R}} = 0.088 \pm 0.009(\mathrm{Stat.})^{+0.042}_{-0.019}(\mathrm{Syst.}) \quad \mu\mathrm{b/sr}$$

- We obtained the differential cross sections of the hyperon electroproduction at forward angles. I hope this work help understanding hyperon photo- and electroproduction in the same framework.