Λ polarization in $ep \rightarrow eK^{+}\Lambda$ with RGC

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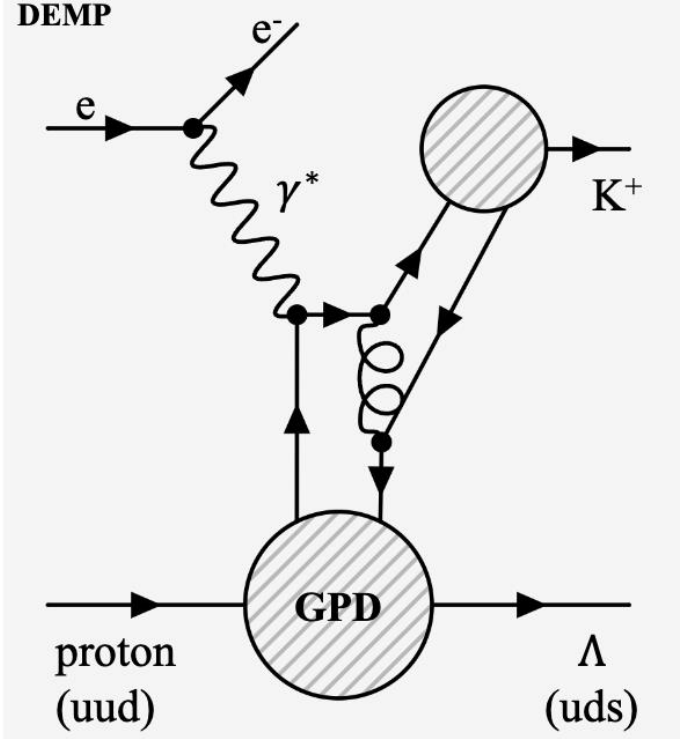
Jun 30th, 2026

Outline

- Introduction
- Data and MC samples
- Event selection
- Λ signal extraction
- Next to do

Introduction

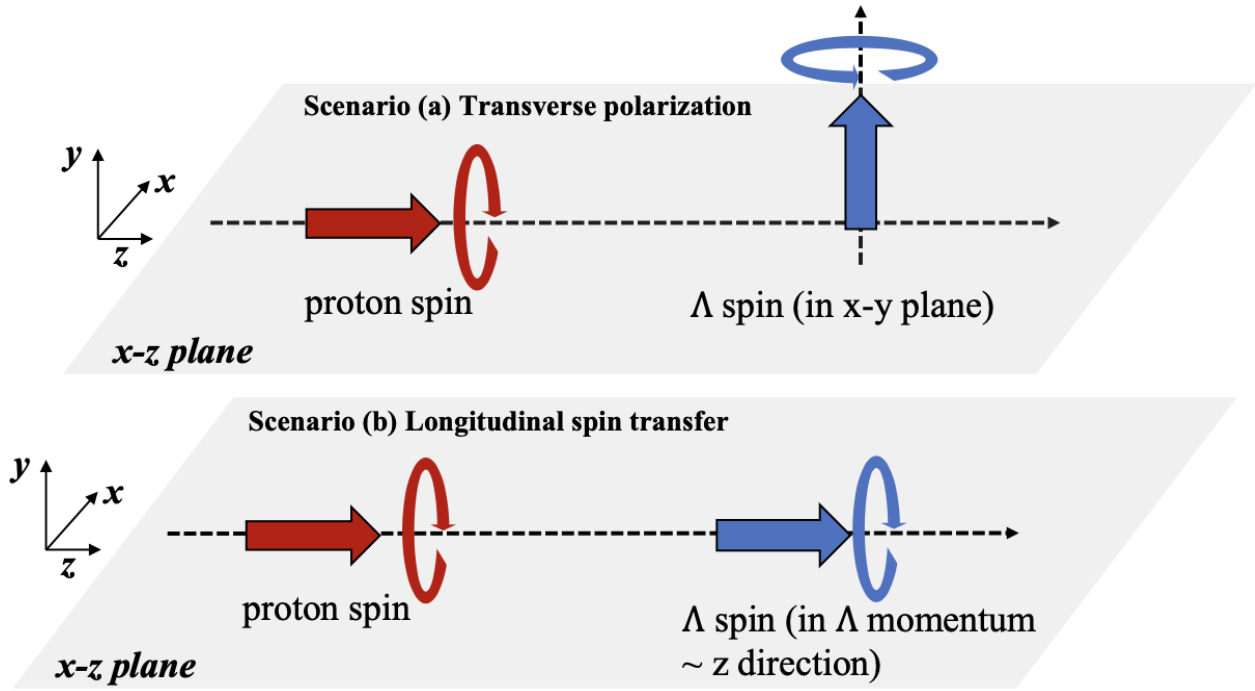
- Motivation
  - Probe chiral-odd GPD
    - Difficult to access (helicity flip processes are suppressed)
    - Λ polarization is a sensitive probe for the chiral-odd GPD
  - Probe the origin of Λ transverse polarization
    - Λ polarization puzzle: unexpected transverse Λ polarization in unpolarized collisions (pp, ep, etc.)
    - Key question: the underlying mechanism of Λ polarization
- Approach
  - $ep \rightarrow eK^{+}\Lambda$ with longitudinally polarized NH_3 target
    - $\Lambda \rightarrow p\pi^{-}$: Self-analyzing weak decay
    - Exclusive process: Simplify the picture
      - No fragmentation, no feed-down
    - Polarized target: Study the spin transfer



PhysRevC.109.055205

Introduction

- Analysis goal: Find out which direction the Λ is polarized
  - Scenario (a): Transverse polarization with respect to the production plane
  - Scenario (b): Large longitudinal spin transfer from proton to Λ



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Data and MC samples

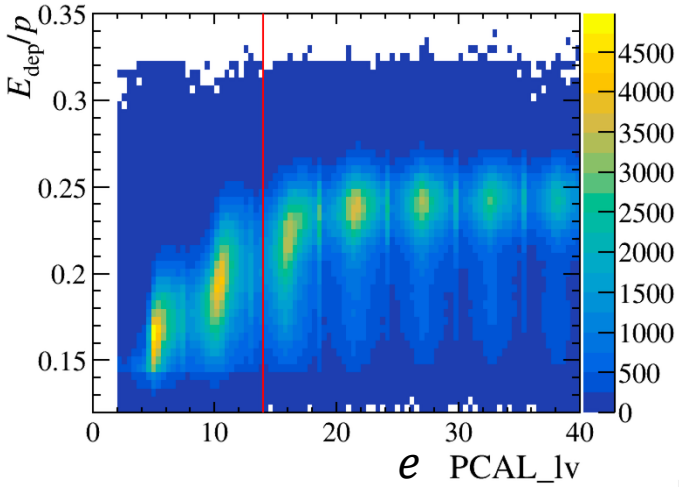
- Data sample
  - RGC data collected in summer 2022, fall 2022 and spring 2023 (inbending)
  - Beam: 10.5 GeV highly polarized electron beam
  - Target: Longitudinally polarized NH3 + background targets
- MC sample
  - $ep \rightarrow eK^{+}\Lambda(\rightarrow p\pi^{-})$ sample (5M events)
    - Generator: genKYandOnePion
    - Fall22 configuration (Solenoid -1 & Torus -1)
    - Proton target
  - MC samples for background study
    - $ep \rightarrow eK^{+}\Sigma^{0}(\rightarrow \Lambda\gamma)$ sample (Generator: genKYandOnePion)
    - $ep \rightarrow ep\pi^{+}\pi^{-}$ sample (Generator: deep-pipi-gen)

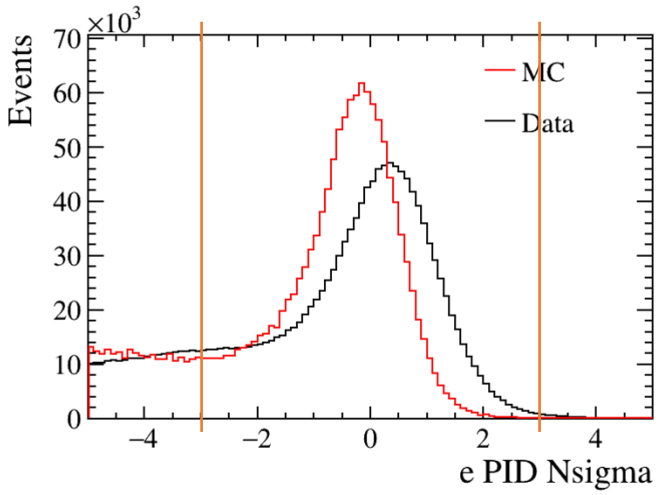
Event selection

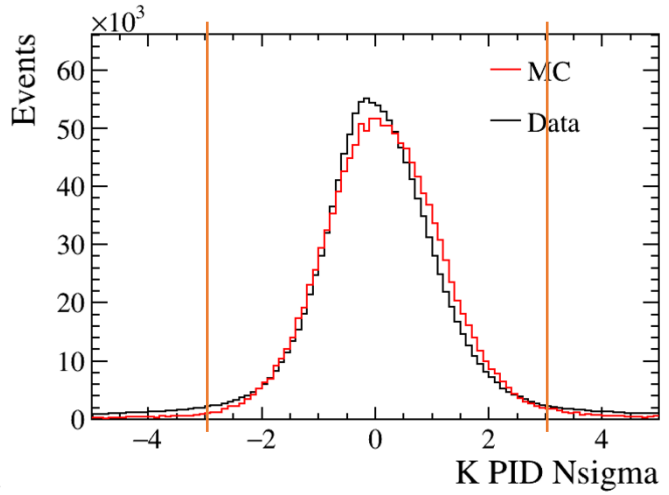
- Select $ep \to eK^+\Lambda(\to p\pi^-)$ data
  - Final states: eK^+p (π^- not required)
    - Limited detection efficiency for low momentum π^-
  - $p_e > 1\ \mathrm{GeV}$, $p_K > 0.3\ \mathrm{GeV}$, $p_p > 0.3\ \mathrm{GeV}$
  - For events with more than one combination (19%), select the one with the smallest χ^2-like quantity
    - $\left(m^2_{\mathrm{miss}\,\Lambda} - M^2_\Lambda\right)^2 + \left(m^2_{\mathrm{miss}\,\pi} - M^2_\pi\right)^2$
  - Kinematic coverage: $Q^2 > 1\ \mathrm{GeV}^2$, $W > 2\ \mathrm{GeV}$
    - Avoid the resonance-dominated region

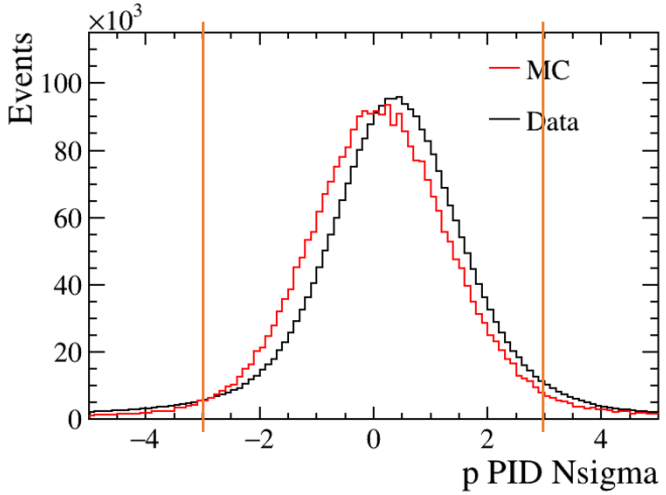
Event selection

- PID cuts
  - e, K^+, p: |chi2pid| < 3
- Fiducial cuts
  - e, K^+, p are all reconstructed in FD
  - e: PCAL lv(lw) > 14
  - e, K^+, p: DC edge > 6

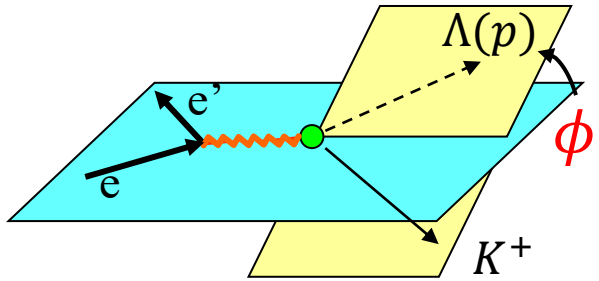






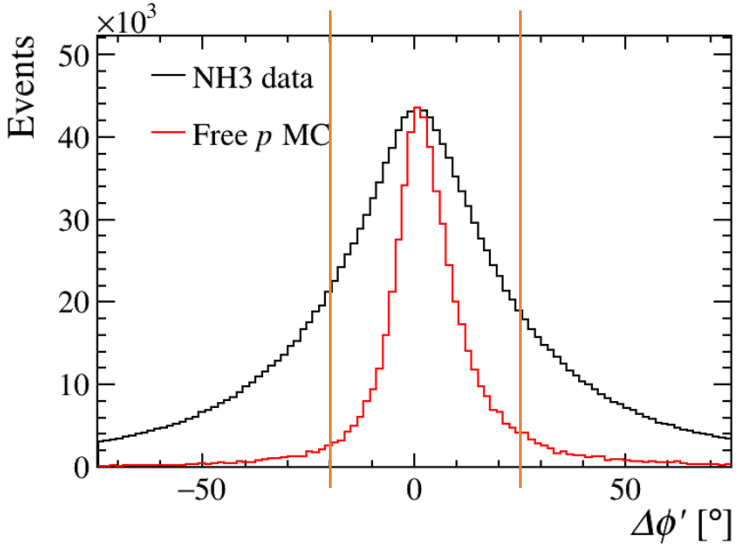


Exclusivity cuts

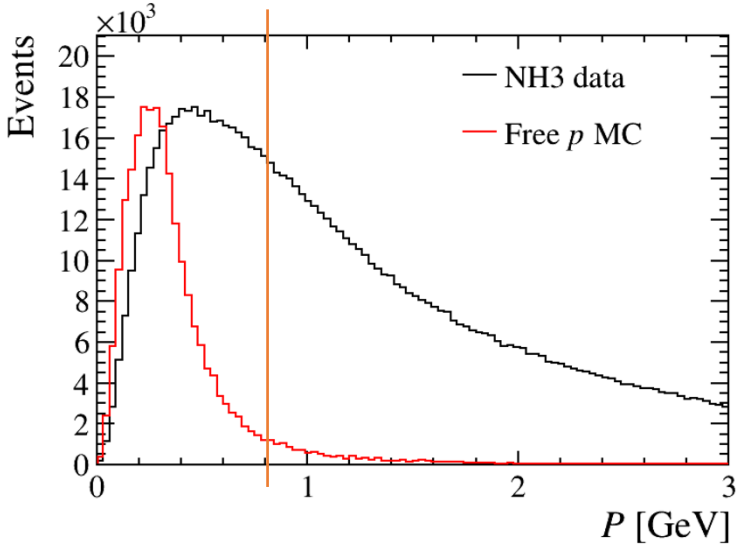


ϕ: angle between leptonic plane and hadronic plane

- $\Delta\phi$: difference in ϕ between
  - hadronic plane formed by K^+ and γ^*
  - hadronic plane formed by K^+ and Λ
- $\Delta\phi'$: use the p momentum as an approximation for the Λ momentum

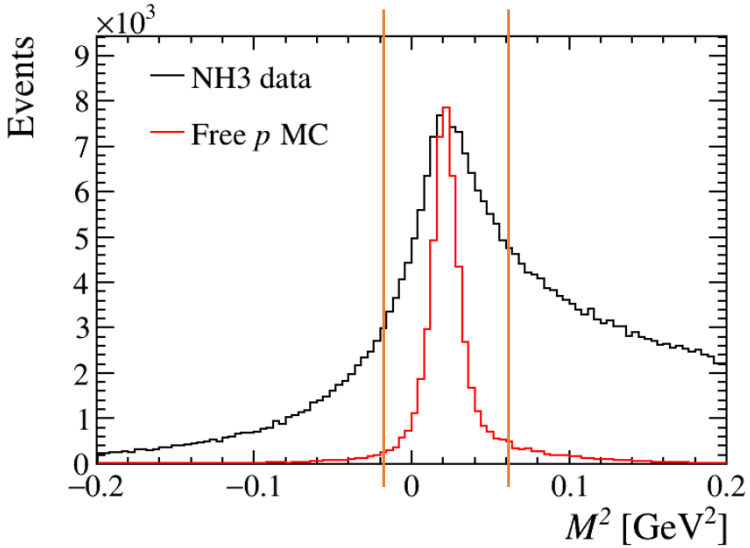


$-20° < \Delta\phi' < 25°$



$P_X < 0.8$ GeV

for $ep \to eK^+pX$

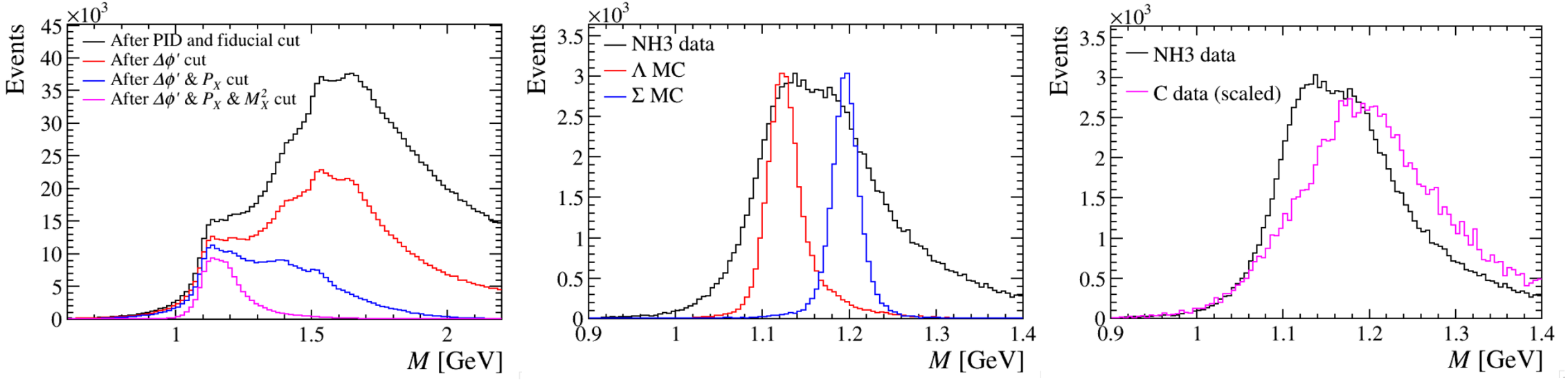


$-0.02 < m_X^2 < 0.06$ GeV^2

for $ep \to eK^+pX$

Distribution of missing Λ mass

- The exclusivity cuts effectively suppress backgrounds from other channels
- Λ signal peak in the distribution of missing mass m_X for $ep \to eK^+X$
- Remaining backgrounds
  - $K^+\Sigma^0$ channel
  - Target background: mostly from N in the NH_3 target (modeled with C data)

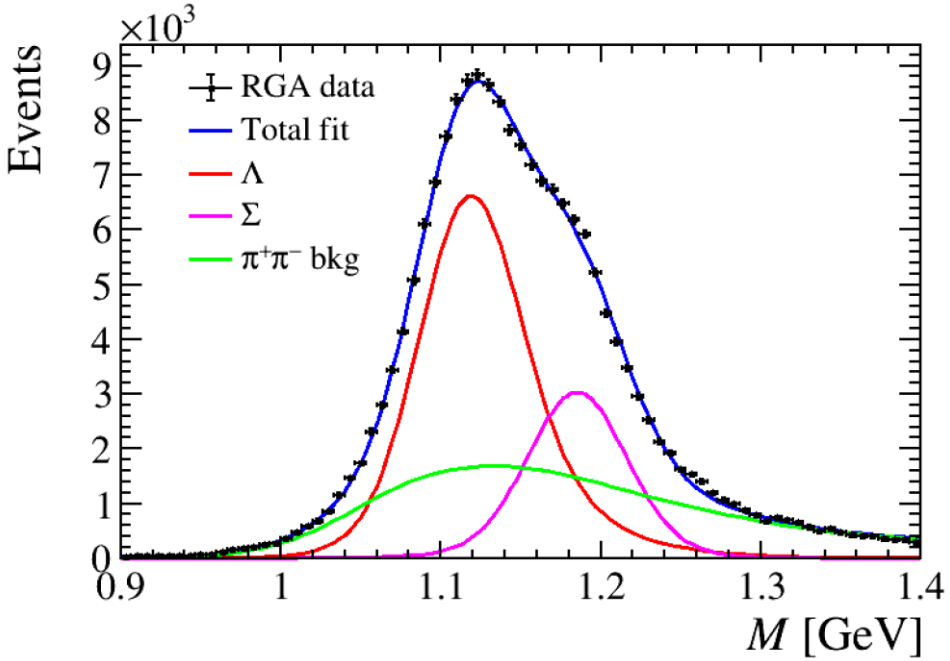


m_X for missing Λ $(ep \to eK^+X)$

$\pi^+\pi^-$ background

- Background
  - $ep \to ep\pi^+\pi^-$ but π^+ is misidentified as K^+
  - Contribute to a wide distribution to the missing Λ mass
- Missing Λ mass fit to the RGA data
  - Λ shape: Kernel Density Estimation (KDE) from MC
  - Σ^0 shape: KDE from MC
  - $\pi^+\pi^-$ bkg: KDE from MC, set the π^+ mass as the K^+ mass
  - All the MC shapes are convolved with a Gaussian function to correct the resolution difference between data and MC
  - Good description of RGA data with $\pi^+\pi^-$ bkg included

- Fit result:
  - $N_\Lambda = 89.8 \pm 0.9$ k
  - $N_\Sigma = 36.7 \pm 0.5$ k
  - $N_{\pi\pi} = 61.8 \pm 0.7$ k

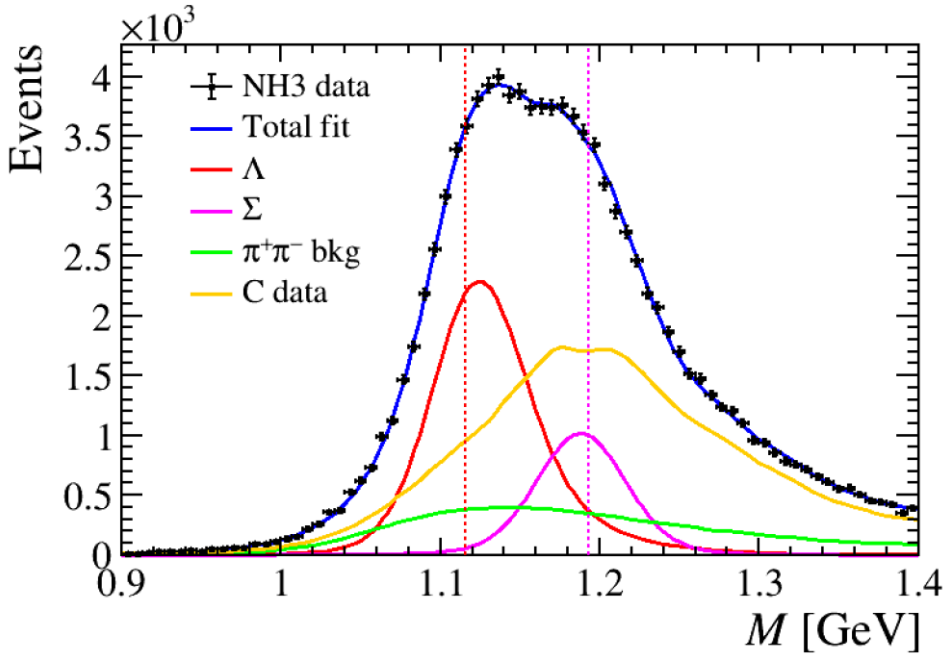


m_X for missing Λ $(ep \to eK^+X)$

Λ signal extraction

- Missing Λ mass fit to the RGC data (NH_3)
  - Λ shape: KDE from MC
  - Σ^0 shape: KDE from MC
  - $\pi^+\pi^-$ bkg: KDE from MC, set the π^+ mass as the K^+ mass
  - Target background: KDE from C data
  - All MC shapes are convolved with a Gaussian function to correct the resolution difference between data and MC
  - The positions of Λ and Σ^0 peaks are free parameters in the fit
    - Peak shift is seen: maybe need momentum corrections

- Fit result:
  - $N_\Lambda = 28.4 \pm 0.6$ k
  - $N_\Sigma = 11.1 \pm 0.4$ k
  - $N_{\pi\pi} = 14.3 \pm 1.4$ k
  - $N_C = 52.0 \pm 1.3$ k



m_X for missing Λ $(ep \to eK^+X)$

Next to do

- Study the momentum corrections
- Perform the missing mass fit separately for different data periods to verify the signal extraction method
- Extract the Λ yield in each kinematic bin
- Determine the acceptance correction
- Extract the Λ polarization

Thank you!