

09/09/2026



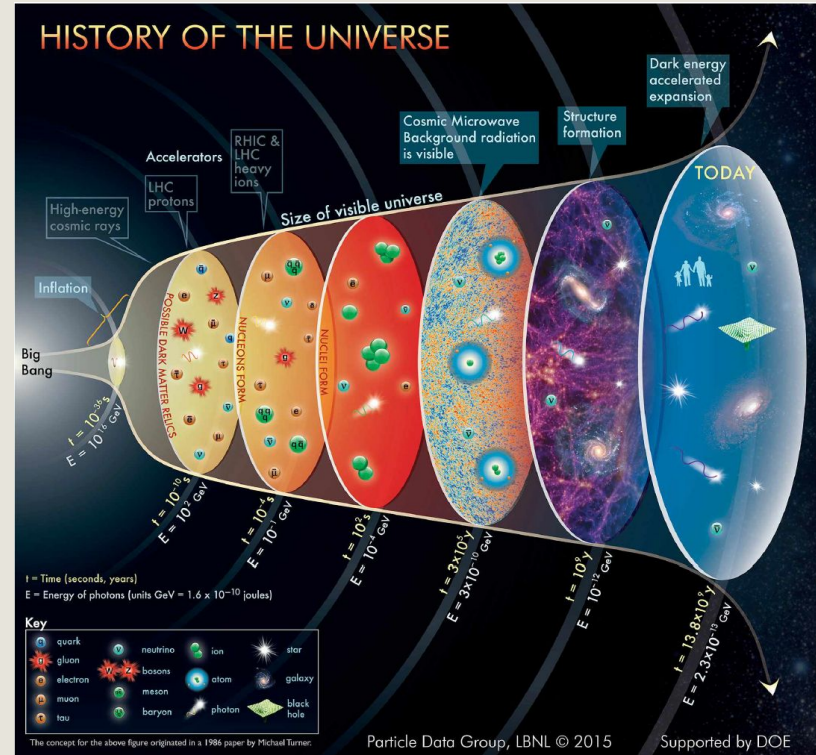
ΣN Interactions at CLAS

Joshua Bryce (joshua.bryce@york.ac.uk), Mikhail Bashkanov

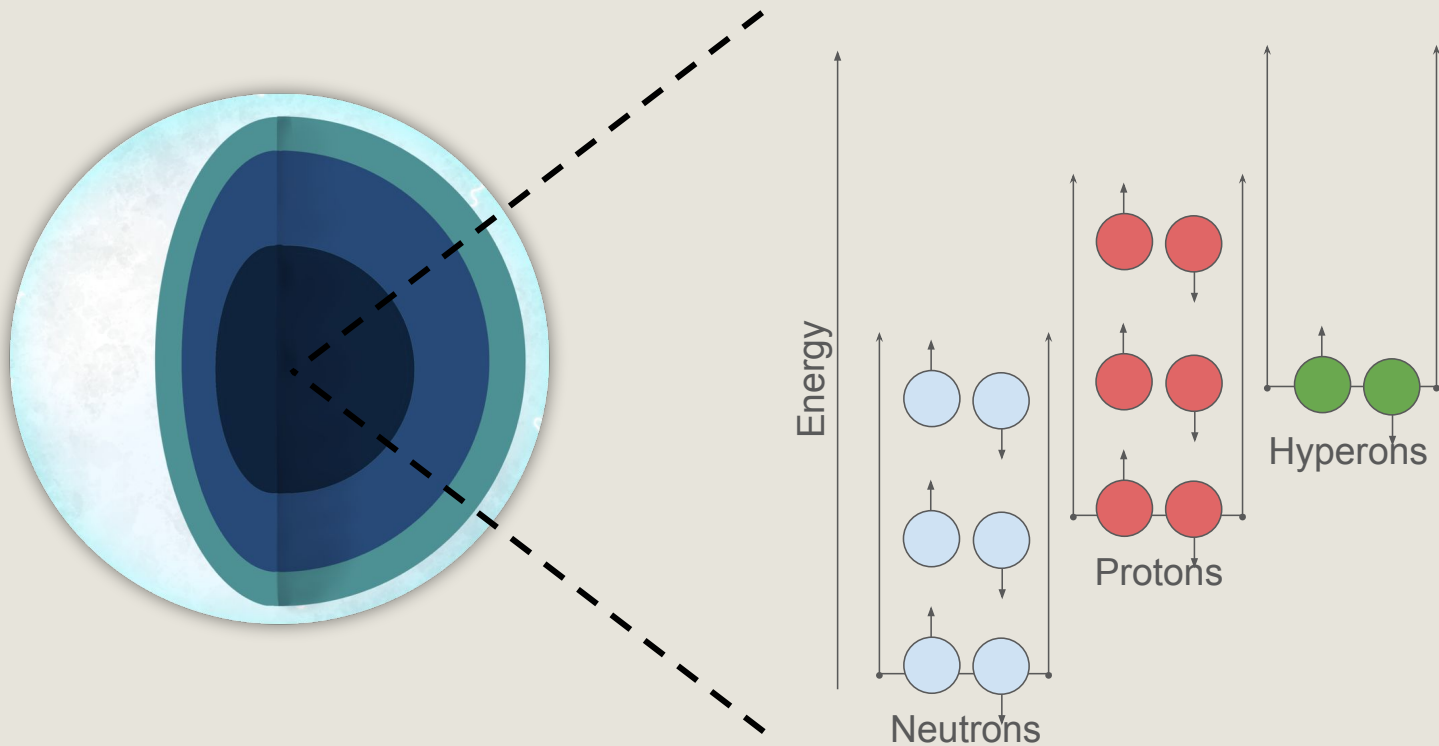


The Early Universe

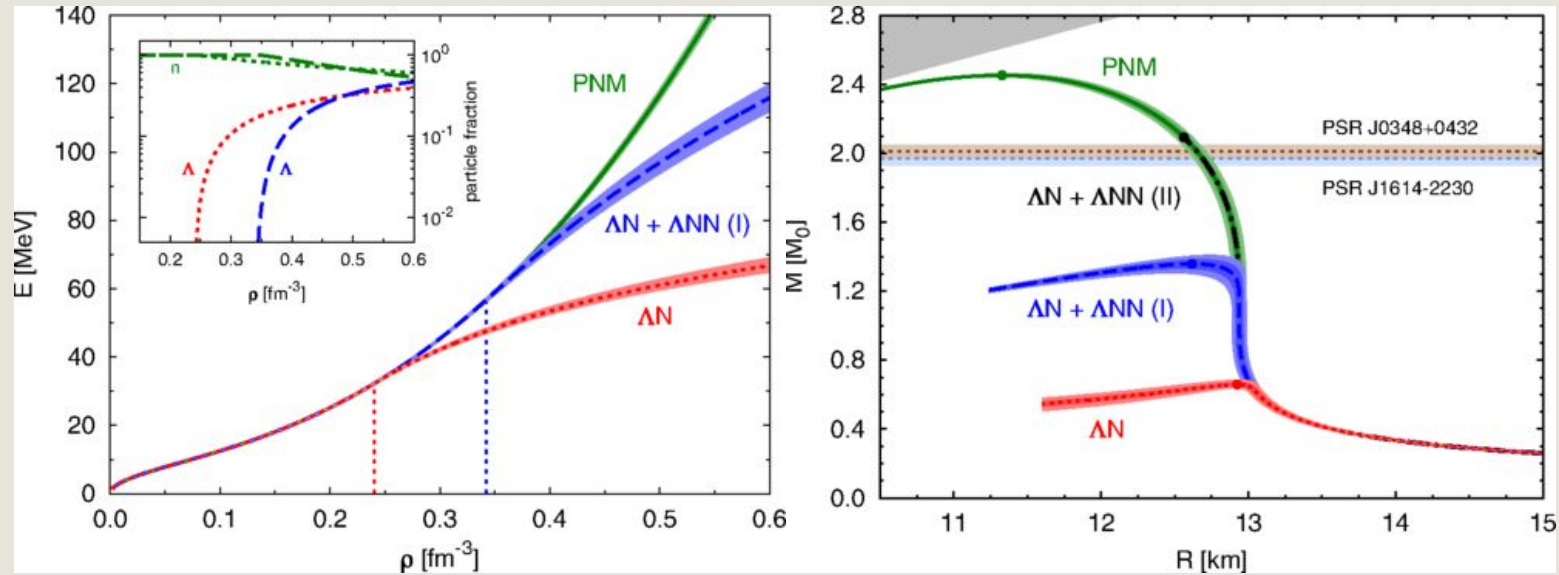
- Early Universe was Strange
 - At Hadronization, $\sim 1/3$ of Quarks were strange.
 - 10^{-10} s Lifetime after Hadronization
- Today's Protons $\leftarrow$ Hyperons
- Effects of Early cooling



The Hyperon Puzzle

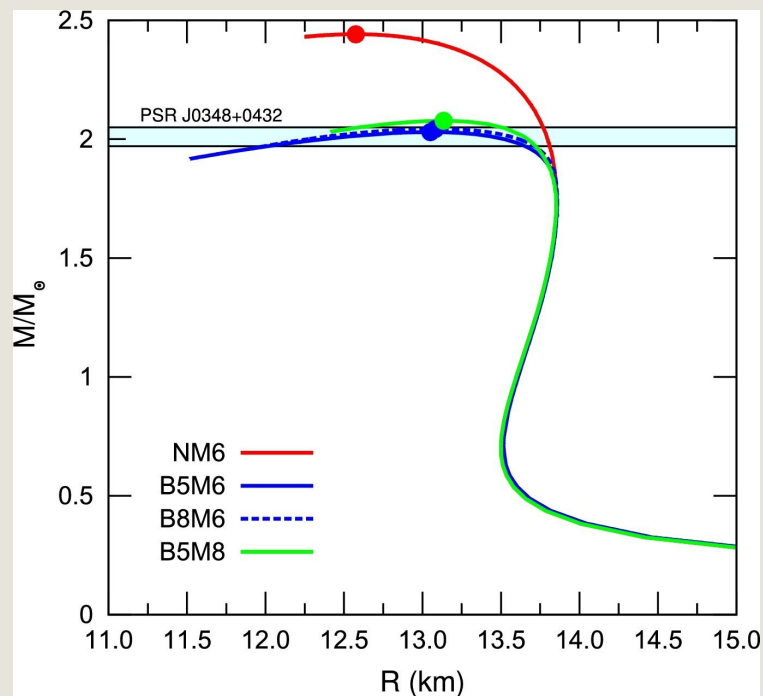
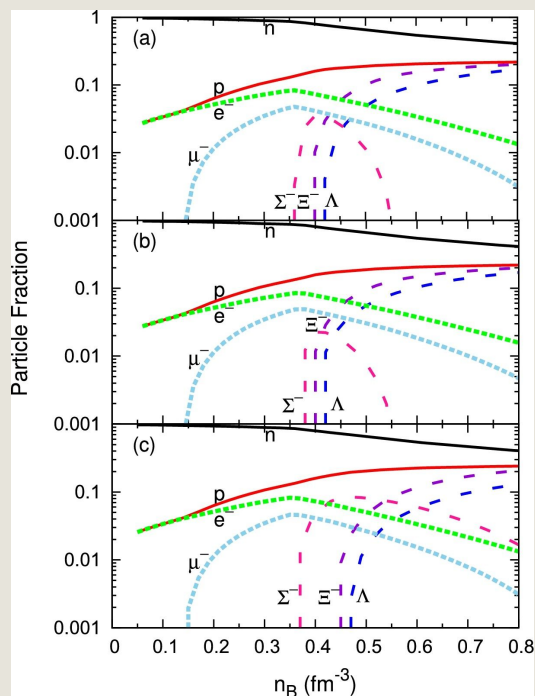


The Hyperon Puzzle - Λ



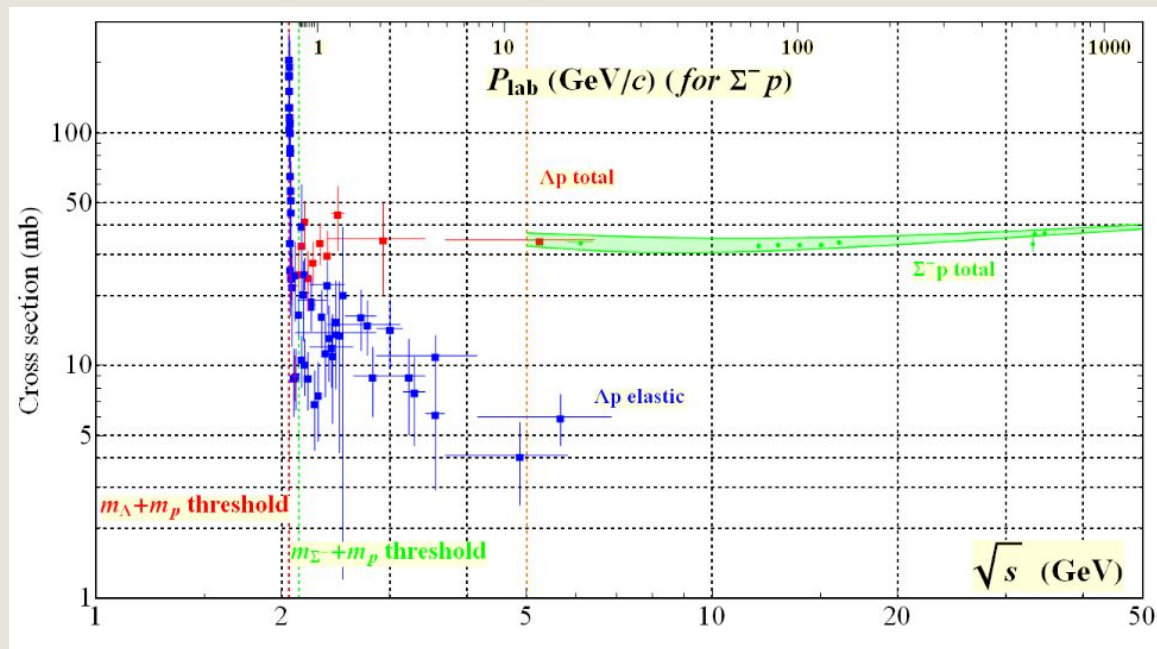
Diego Lonardonì; Alessandro Lovato; Stefano Gandolfi; and Francesco Pederiva, Phys. Rev. Lett. **114**, 092301

The Hyperon Puzzle - Σ and Ξ



Katayama, Tetsuya; Saito, Koichi, PLB, **747**, (2015), 43-47,

What's the World Data?



Particle Data Group

Jefferson Lab

- 6 GeV Electron Beam
 - Bremsstrahlung Photons
- 3 Experimental Halls
 - (A,C) High Intensity
 - (B) High Acceptance
- Typical Beam Currents
 - (A) 1-150 μA
 - (B) 1-100 nA
 - (C) 1-180 μA



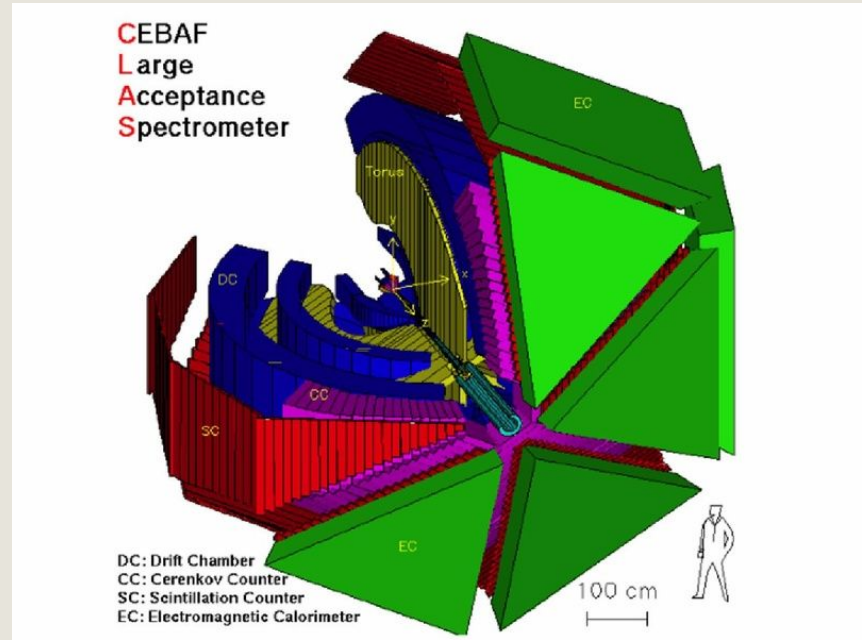
Jefferson Lab - Post Upgrade

- 12 GeV Electron Beam
 - Bremsstrahlung Photons
- 4 Experimental Halls.
 - (A,C) High Intensity
 - (B, D) High Acceptance
- Typical Beam Currents
 - (A) 1-90 μA
 - (B) 1-100 nA
 - (C) 1-90 μA
 - (D) 0.1-5 μA



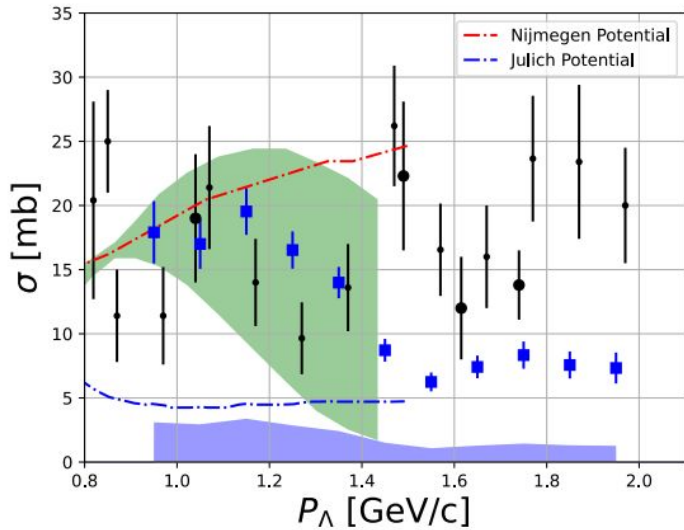
The Experiment: CLAS

- Experiment - Summer 2008
- Bremsstrahlung Photon Beam
 - $E_e \sim 6 \text{ GeV}$
- Liquid Hydrogen Target
 - 40 cm long, 2 cm radius
- 26 Billion Total Events
- $\sim 4\pi$ Acceptance



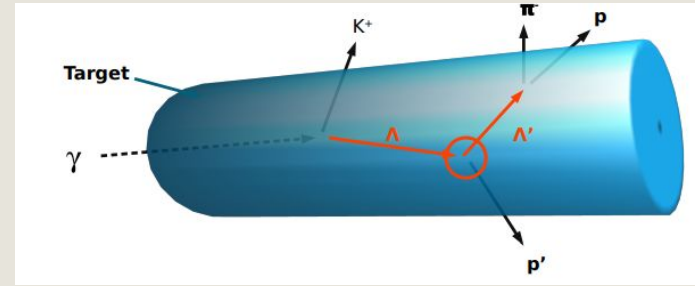
NIM A, **898**, (2018), 90-97

Motivation: Λp Elastic Scattering



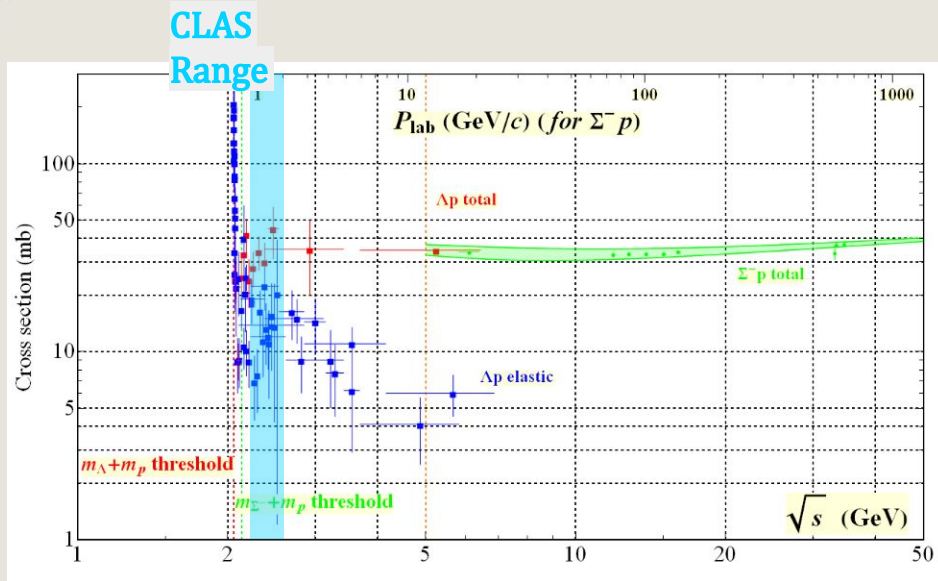
J. Haidenbauer and U.-G. Meißner, Phys. Rev. C 72, 044005 (2005)

T. A. Rijken, V. G. J. Stoks, and Y. Yamamoto, Phys. Rev. C 59, 21 (1999).

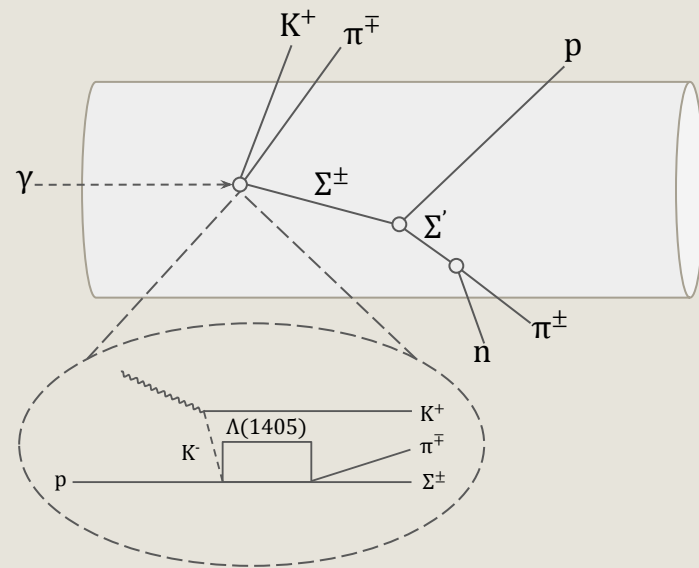


PRL 127.272303 (2021)

Motivation: Σp Scattering Equivalent



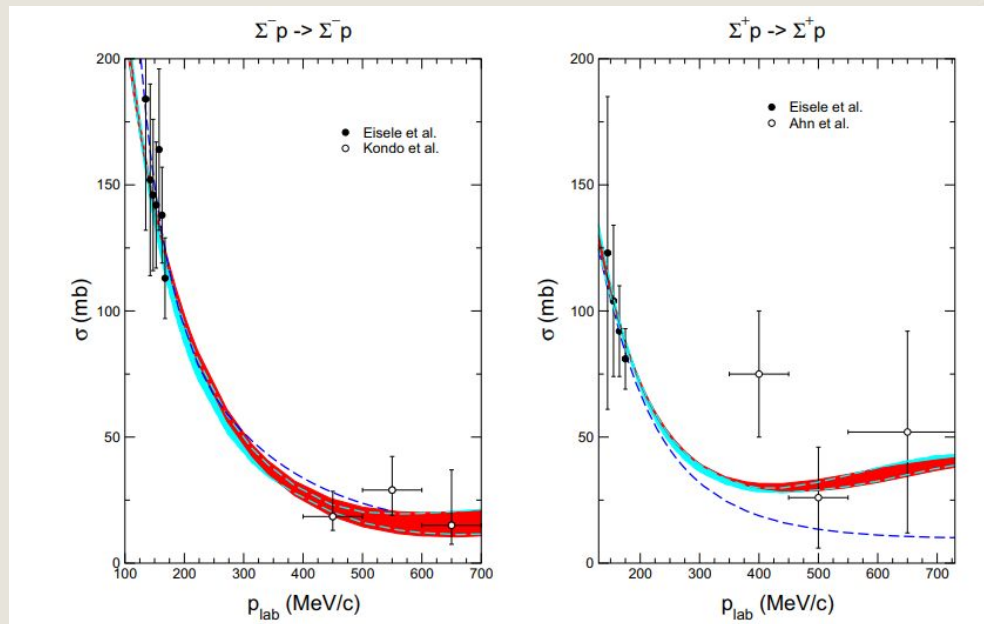
Particle Data Group



- Production through $\Lambda(1405)$
- Equal $\Sigma^\pm$ Flux
- $c\tau = 2.4$ cm (Σ^+) or 4.5 cm (Σ^-)

Theory: Predictions from χ EFT

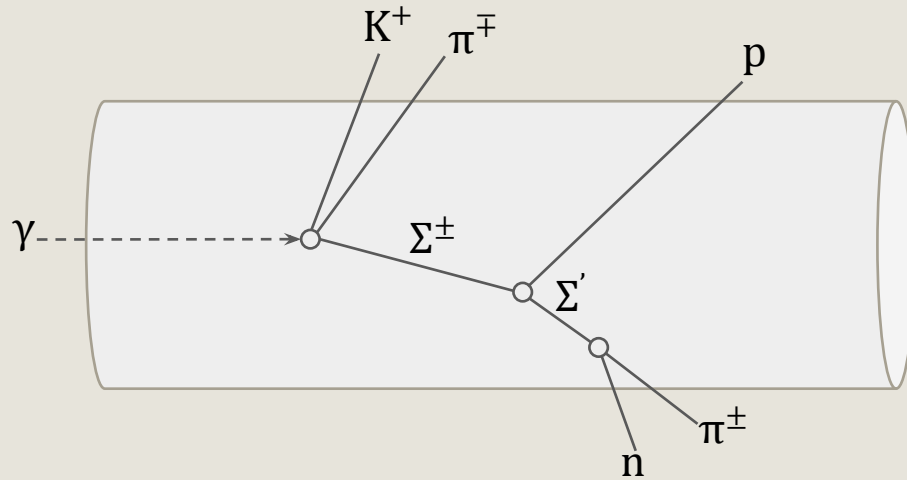
- Haidenbauer & Meißner – YN interaction(χ EFT)
- *Ab initio* Σp cross sections, $p < 700 \text{ MeV}/c$
- Data $p > 700 \text{ MeV}/c$
- Constrain phenomenology



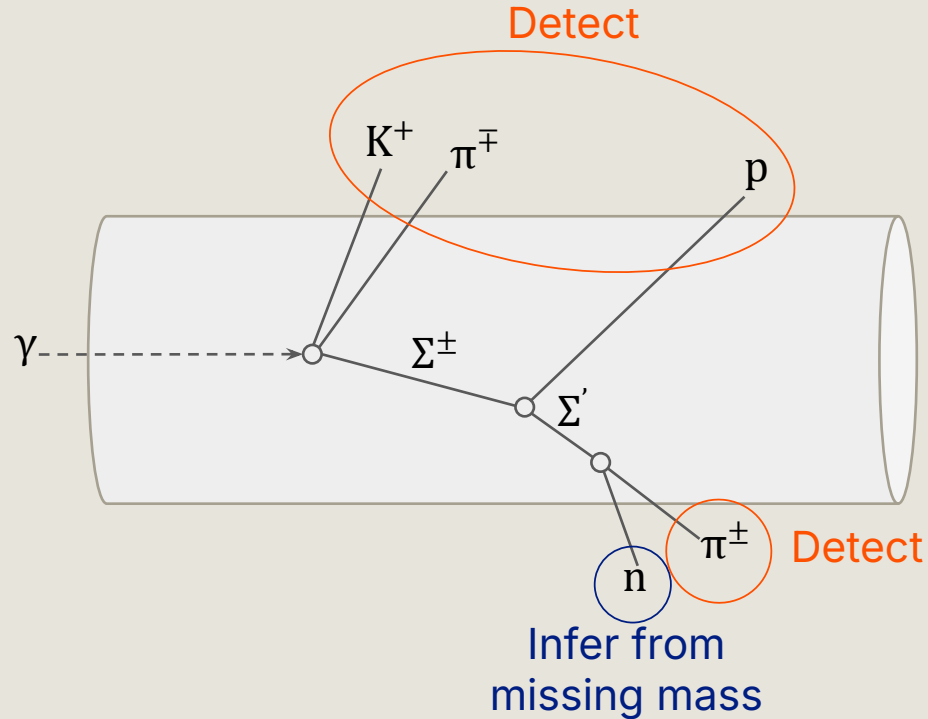
Eur. Phys. J. A **56**, 91 (2020)

Σ^- p Scattering

Event Selection



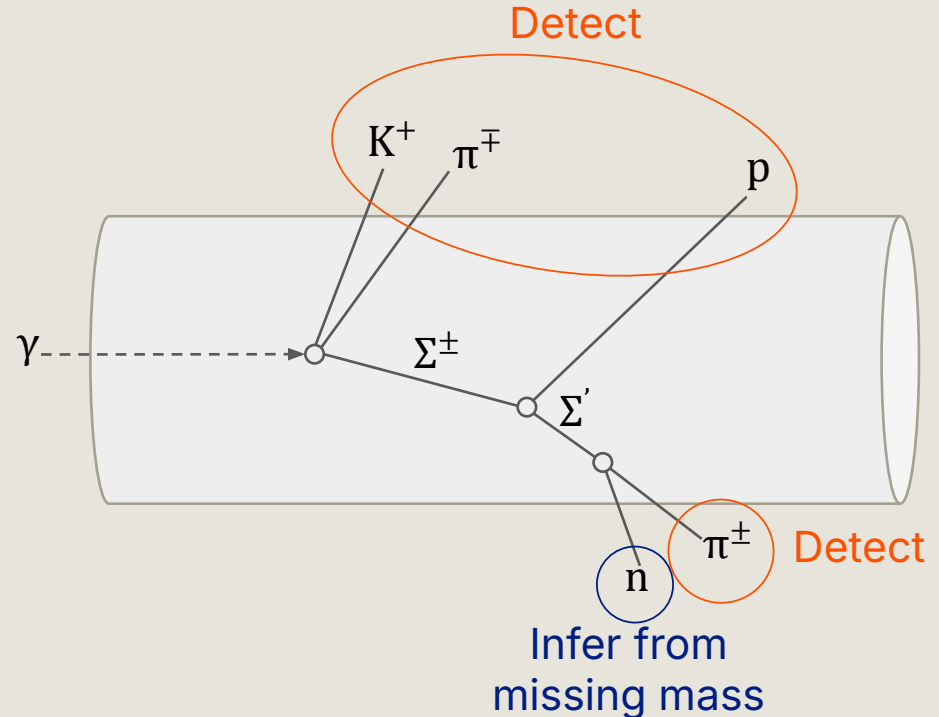
Event Selection



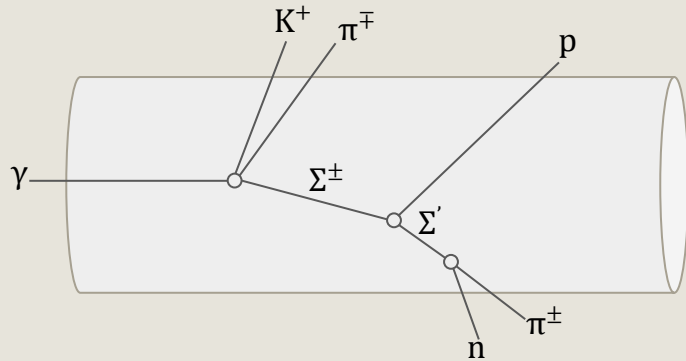
Event Selection

Selection Criteria:

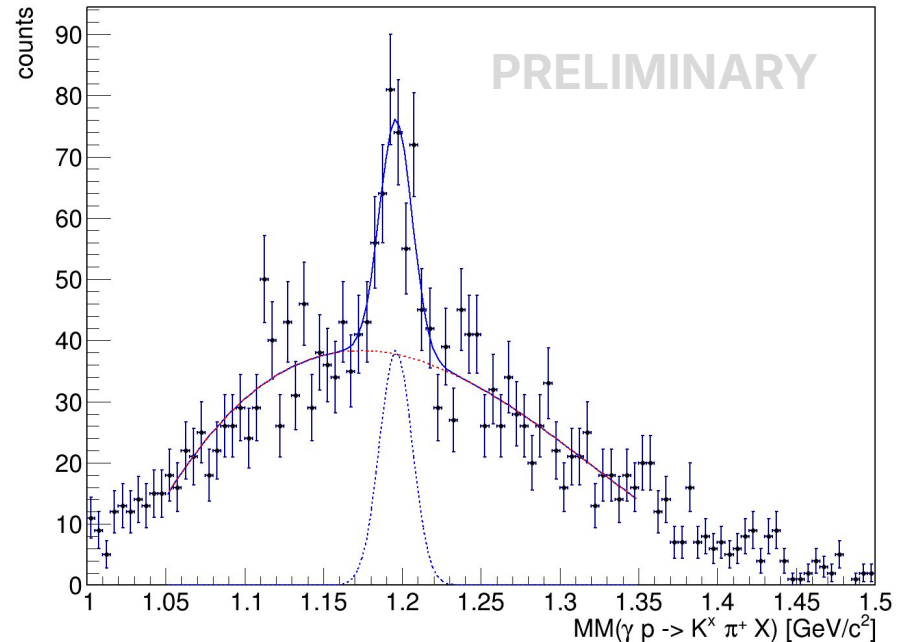
- Final State $K^+\pi^+\pi^-p$
- $MM(K^+\pi^+\pi^-p)$ within 3σ of Neutron
- $MM(K^+\pi^+p)$ within 3σ of Σ^-
 - Or $MM(K^+\pi^-p)$ within 3σ of Σ^+
- Cuts on $IM(\pi^+\pi^-)$, and $IM(\pi^-p)$, reduce K^0 and Δ^0 background



Analysis: Σp Scattering at CLAS

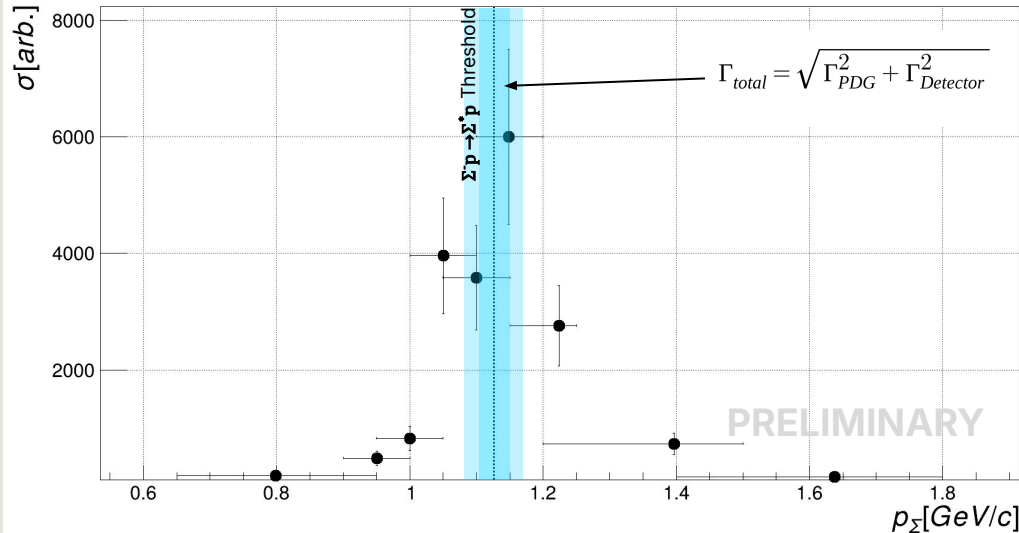


Example Momentum Bin



Analysis: Σp Scattering at CLAS

Momentum Dependent Cross Section of Scattering

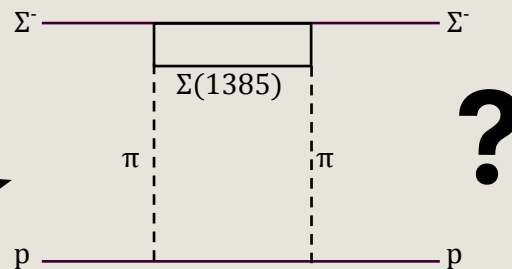
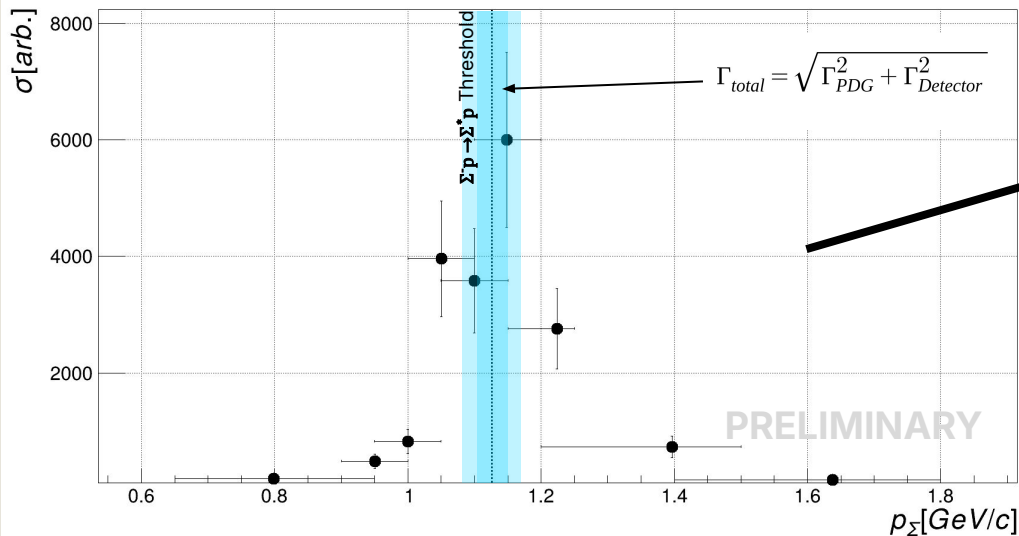


$\Sigma^+ p$, Isospin = 3/2

$\Sigma^- p$, Isospin = 3/2 and 1/2

Analysis: Σp Scattering at CLAS

Momentum Dependent Cross Section of Scattering

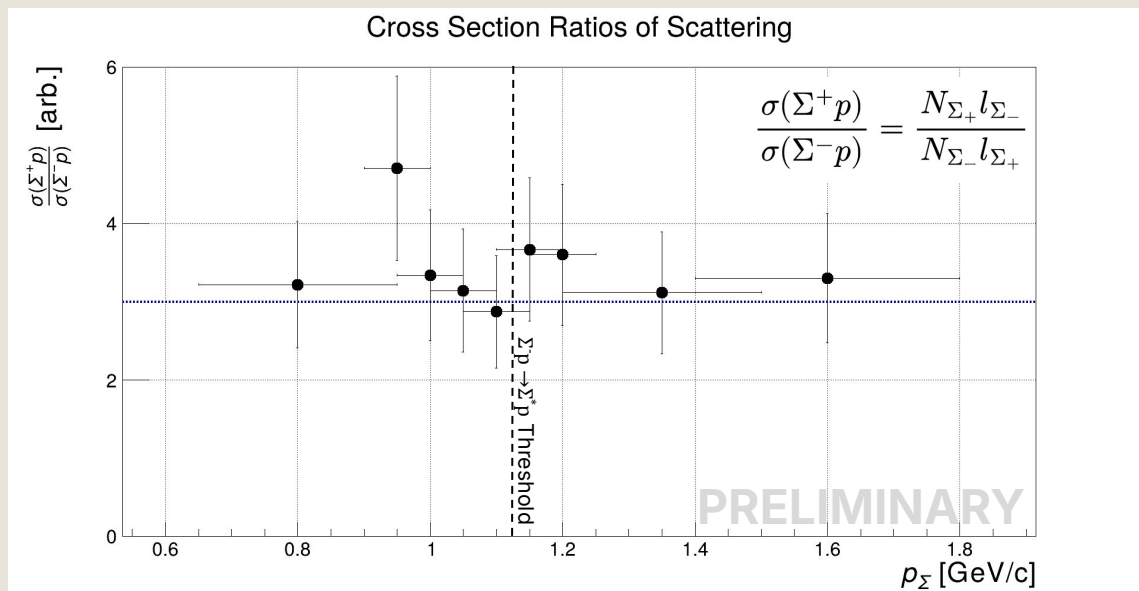


$\Sigma^+ p$, Isospin = 3/2

$\Sigma^- p$, Isospin = 3/2 and 1/2

Analysis: Σp Scattering at CLAS

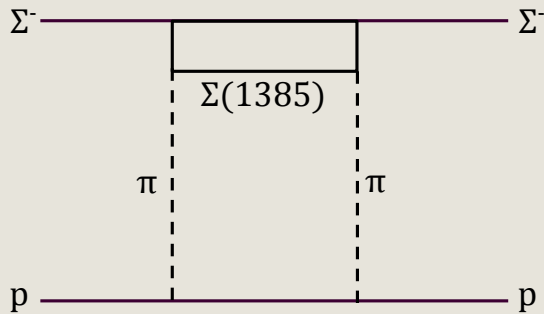
- High Statistics
- Good Systematics
- Exaggerated Error Bars



CLAS -> CLAS12

Where we stand

- Interesting Structure around $\Sigma(1385)p$ threshold
- Consistent with diagrams such as:



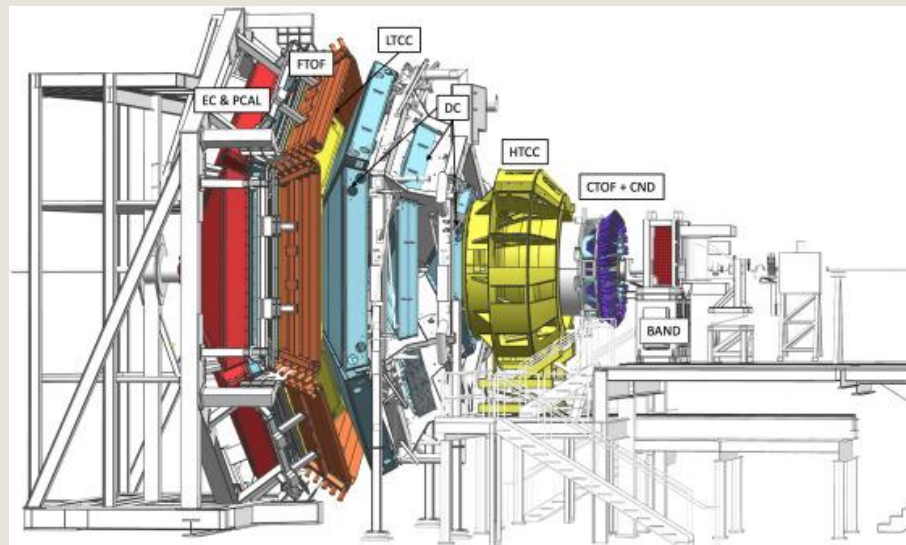
Moving to CLAS12

- Very high stats
- Deuterium Target:
 - In medium modifications
 - Simplest nuclear medium
 - Analogous channel in a much smaller target

Σ^* Quasi-Real Photoproduction

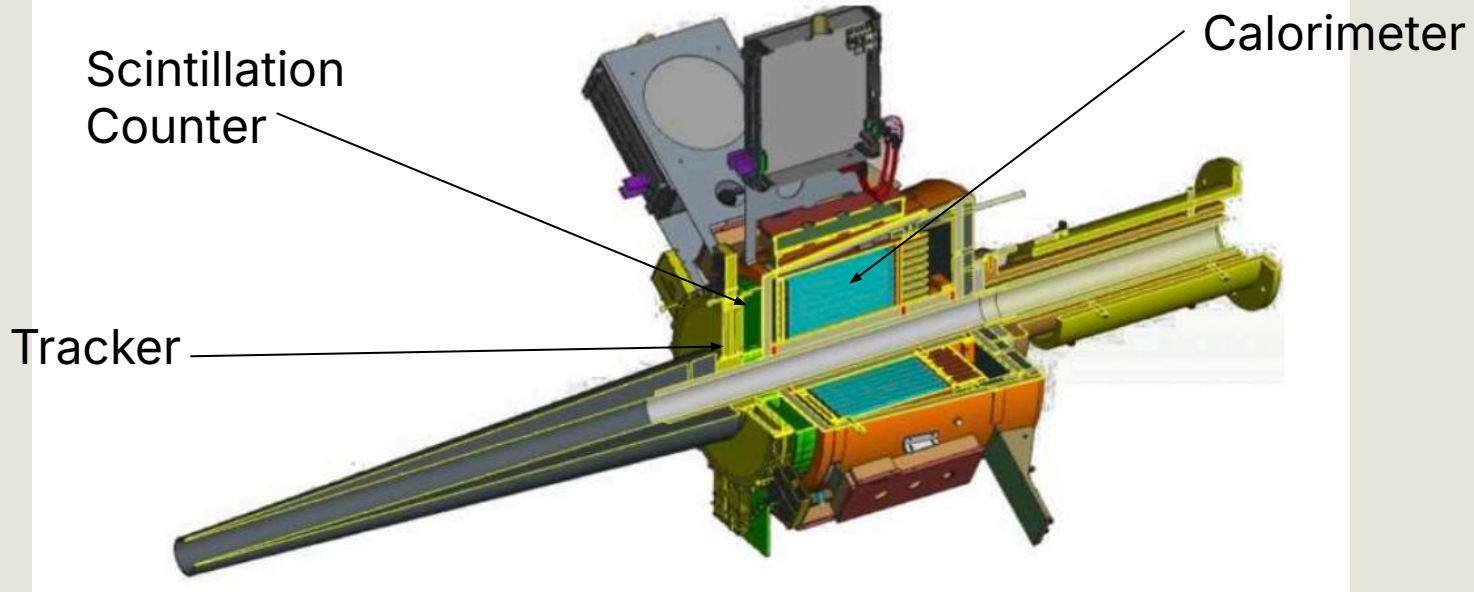
The Experiments: CLAS12

- Three running periods
 - Total of 54 Days, in 2019/20
- Electron Beam ($E_e \sim 10.6$ GeV)
 - 35-50 nA Beam Current
- Liquid Deuterium Target
 - 5 cm long, 1.25 cm radius
- $\sim 4\pi$ Acceptance
- 42.5 Billion Total Events



NIM A, 163419.

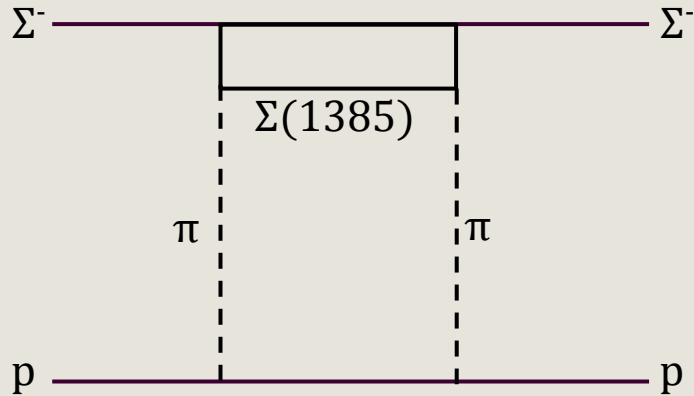
The CLAS12 Forward Tagger



NIM A, 163475.

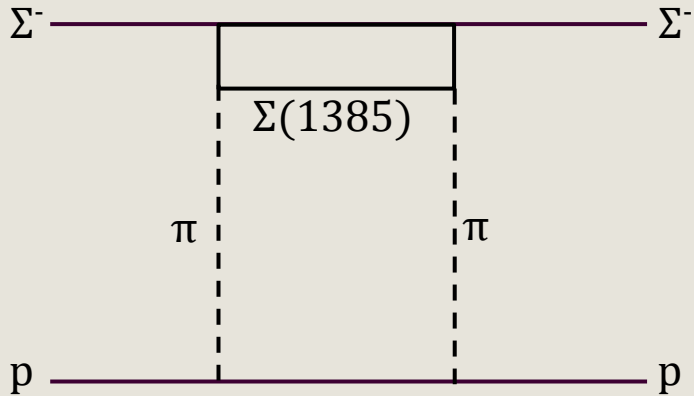
From Scattering to Production

CLAS

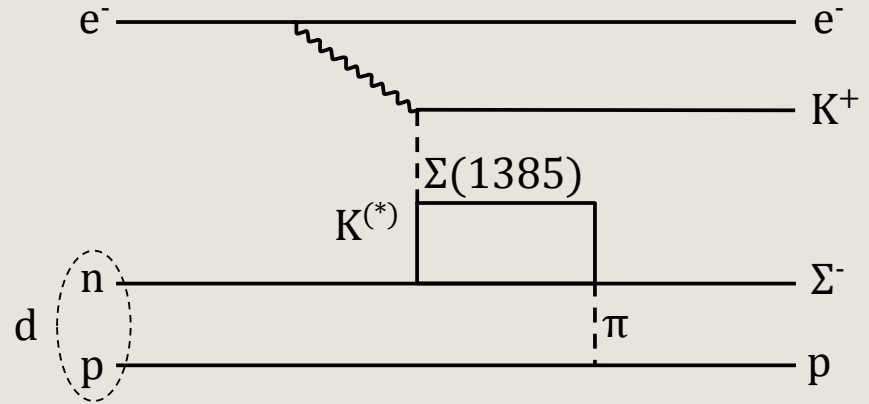


From Scattering to Production

CLAS

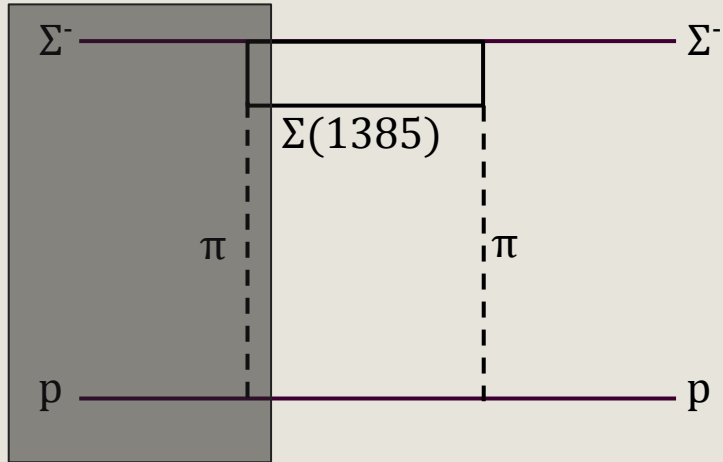


CLAS12

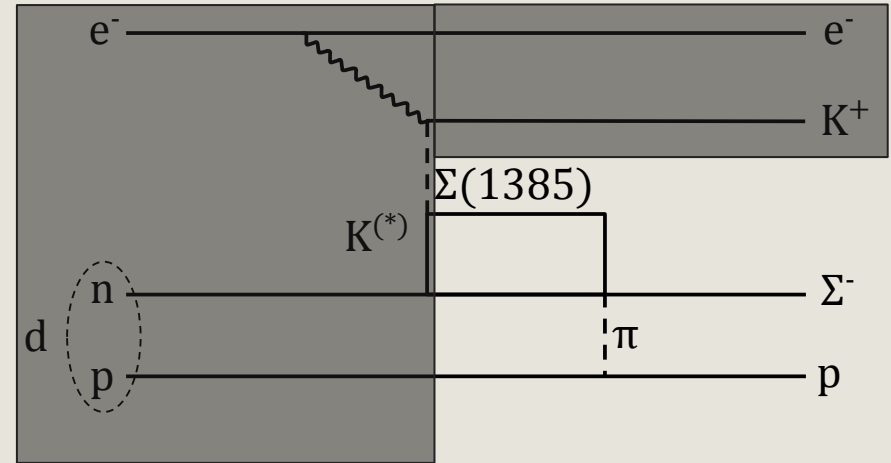


From Scattering to Production

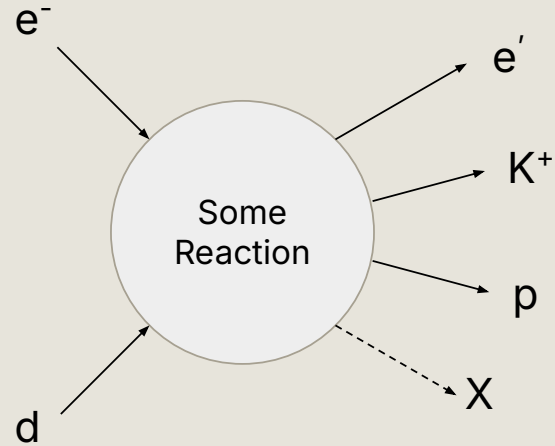
CLAS



CLAS12

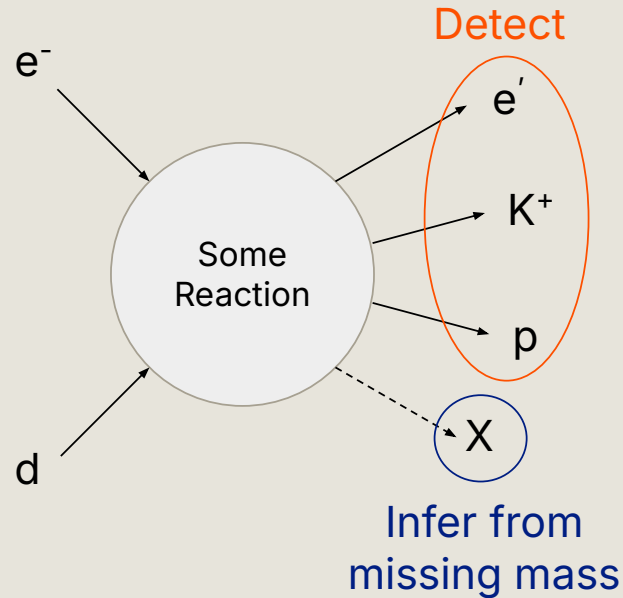


Σ Missing Mass



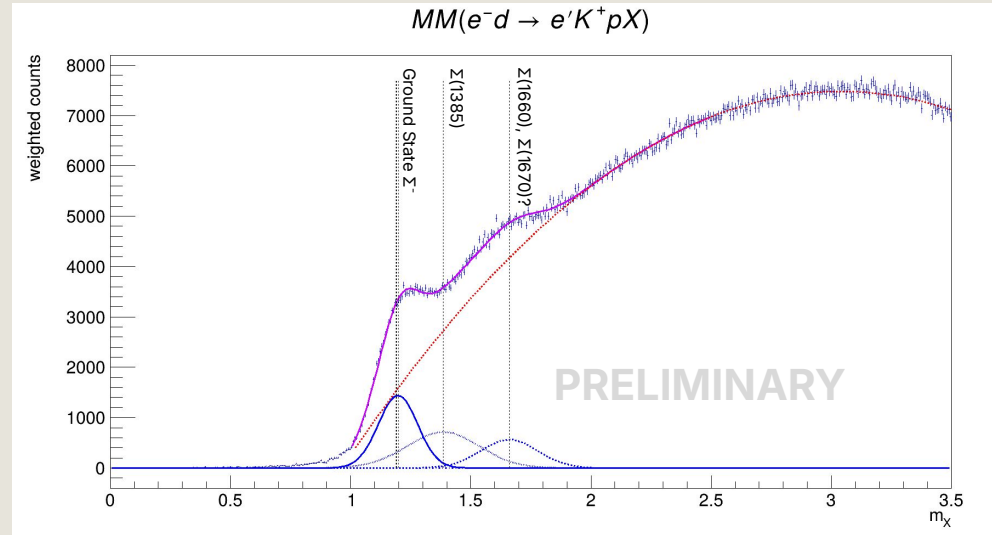
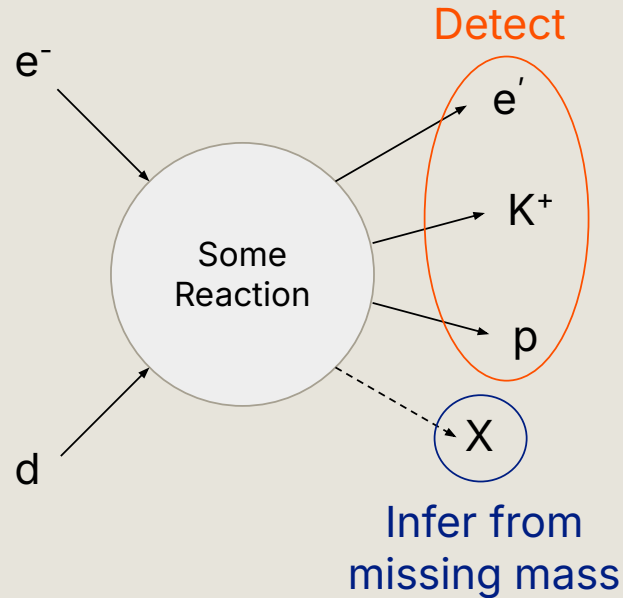
- High proton momentum, $p > 500 \text{ MeV}/c$

Σ Missing Mass



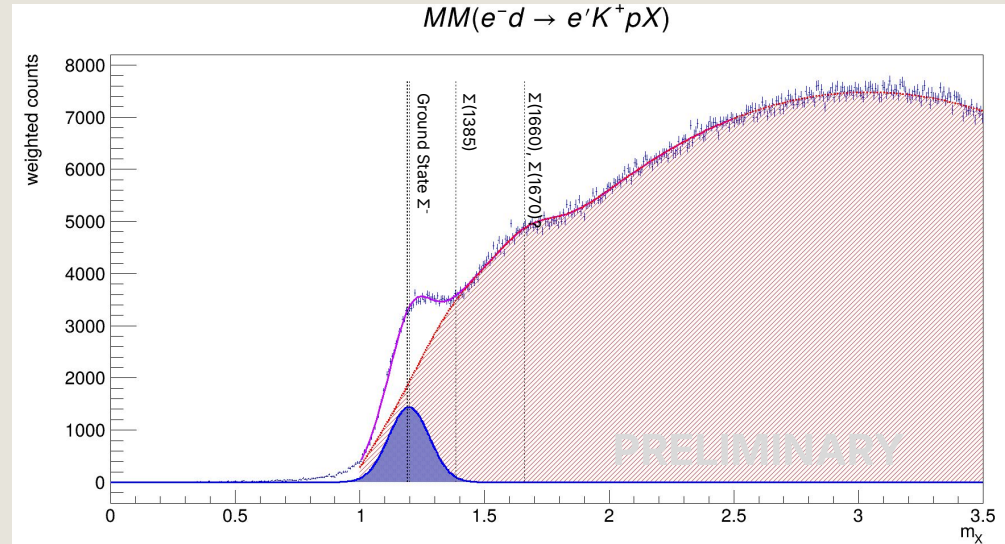
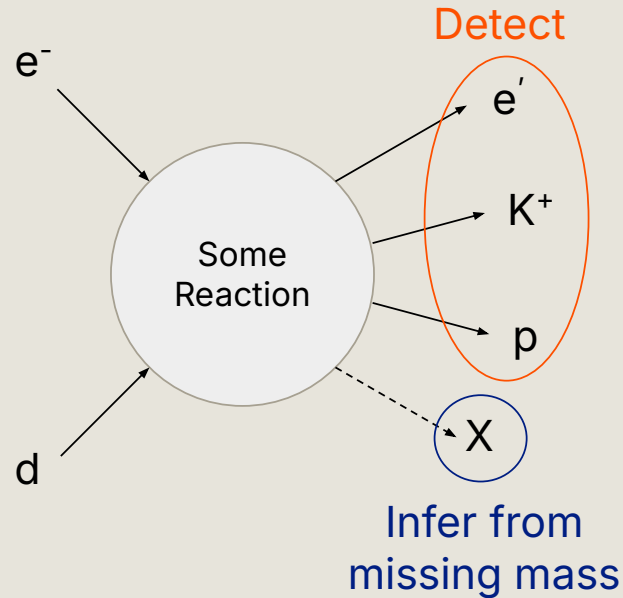
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Σ Missing Mass



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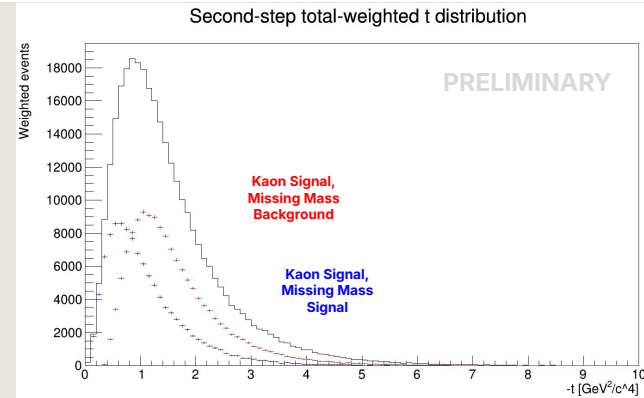
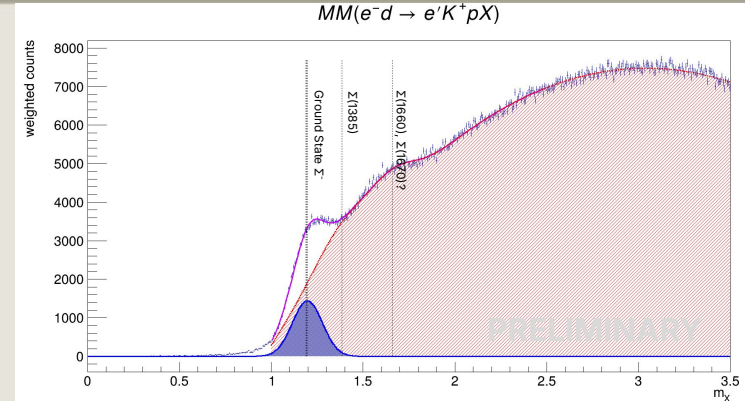
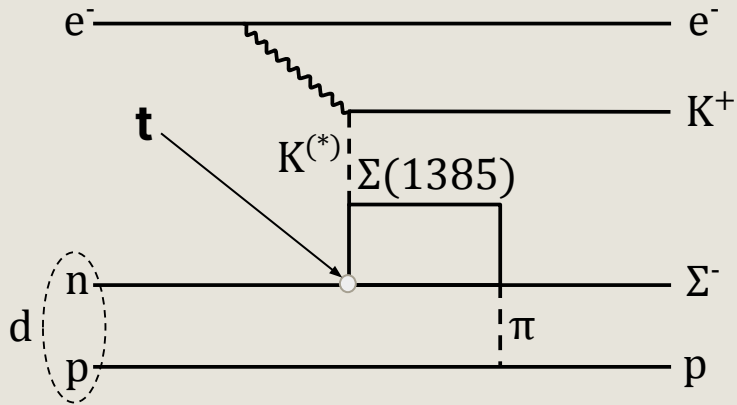
Σ Missing Mass



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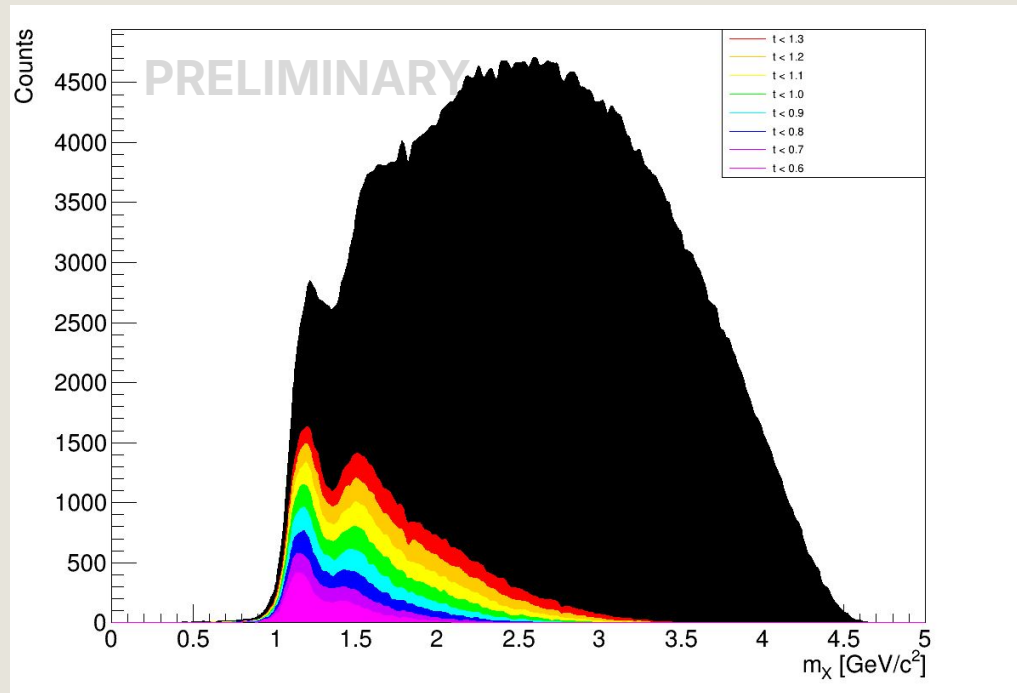
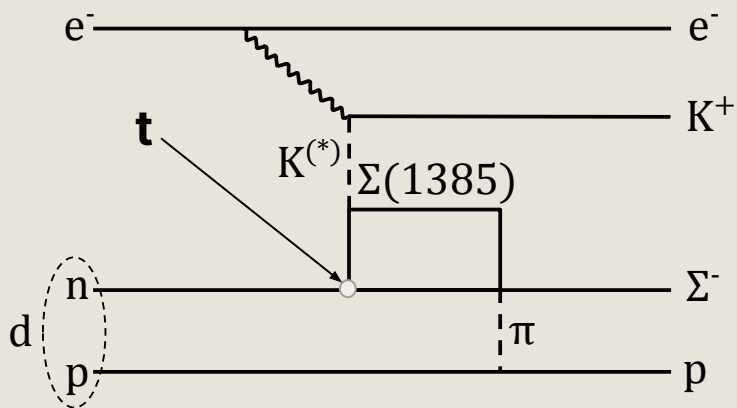
Reaction t-dependance

$$t = (P_{\text{beam}} - P_{e'} - P_K)^2$$

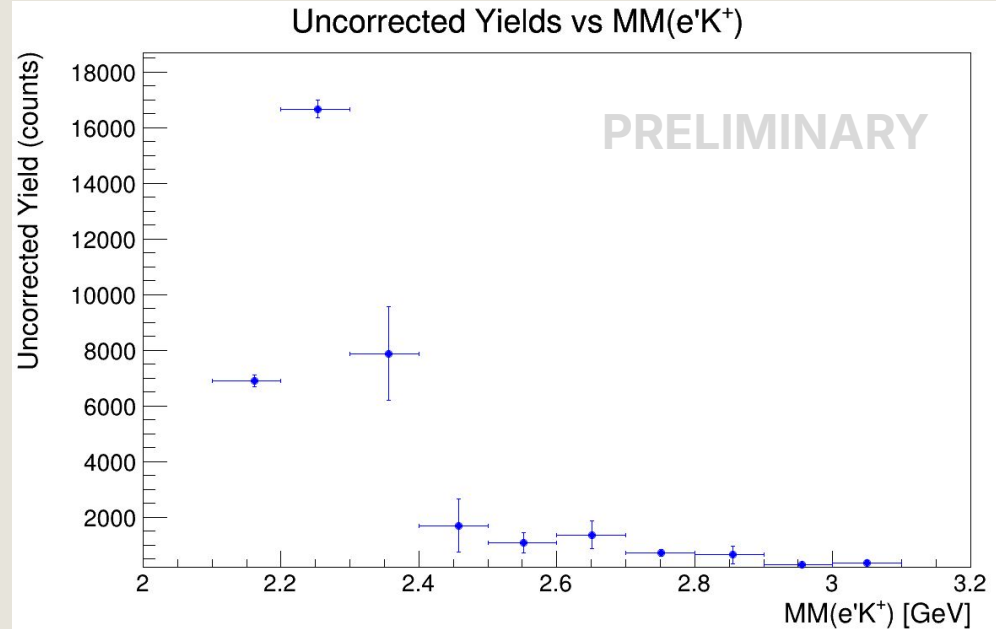
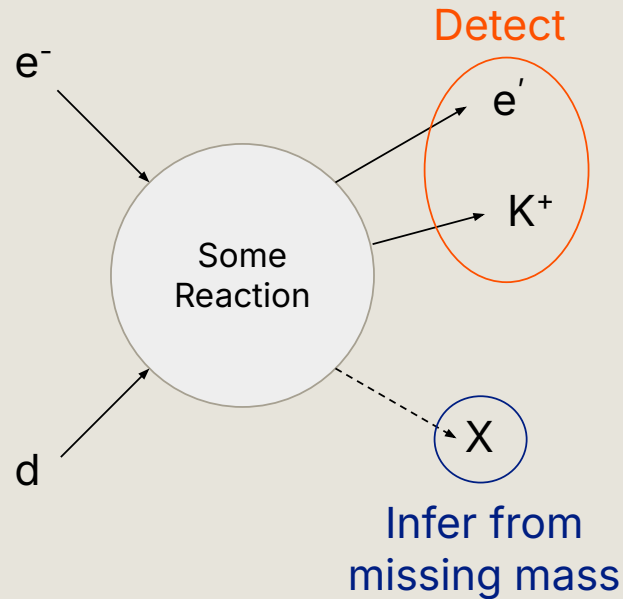


Reaction t-dependance

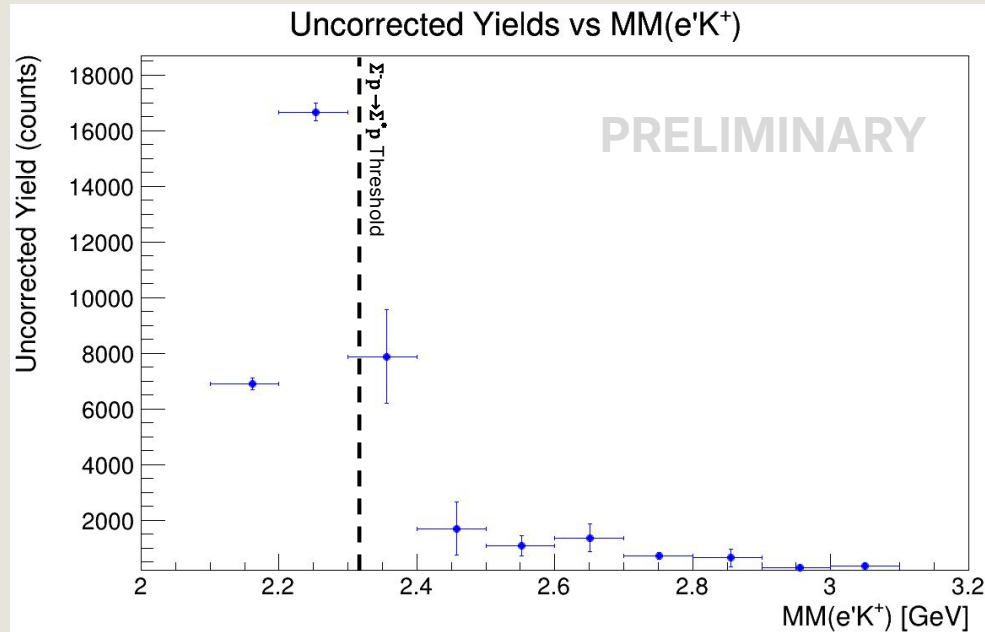
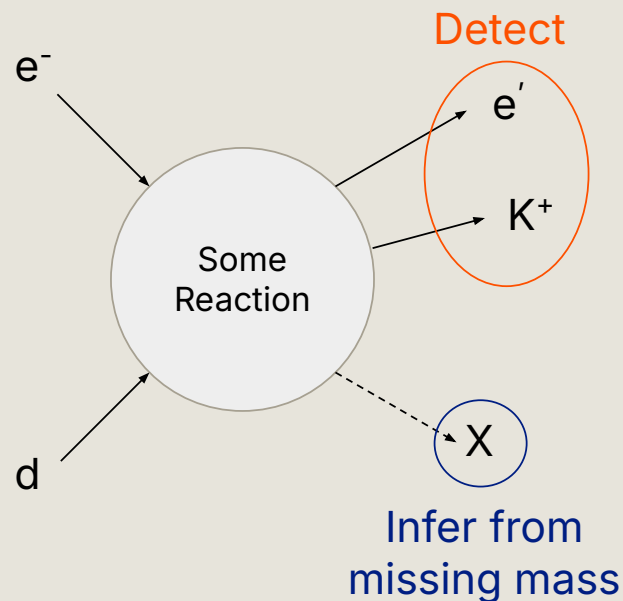
$$t = (P_{\text{beam}} - P_{e'} - P_K)^2$$



Yields in MM($e'K^+$)



Yields in MM($e'K^+$)



- Σ^-p and Σ^+p Scattering
 - High Precision
- Reconstructed Σ^- Produced off Deuteron
- Next Steps:
 - Yield Extraction
 - Characterising production mechanism
 - Resonances in the Deuteron

Summary & Conclusion

- Hyperons play key roles in Cosmology and Astrophysics.
- The YN Interaction
- At CLAS and CLAS12 we can explore these interactions.
- Σ^-p & Σ^+p Scattering Cross Sections – Coupled Channel Effects?
- Σ^+p/Σ^-p Scattering cross section ratios, High Sensitivity to physics
- $\Sigma(1385)$ Produced in Medium?



Thank you for listening, any Questions?