Peter Pauli

JLab strange baryon physics program

University of Glasgow

QNP2022 - The 9th International Conference on Quarks and Nuclear Physics

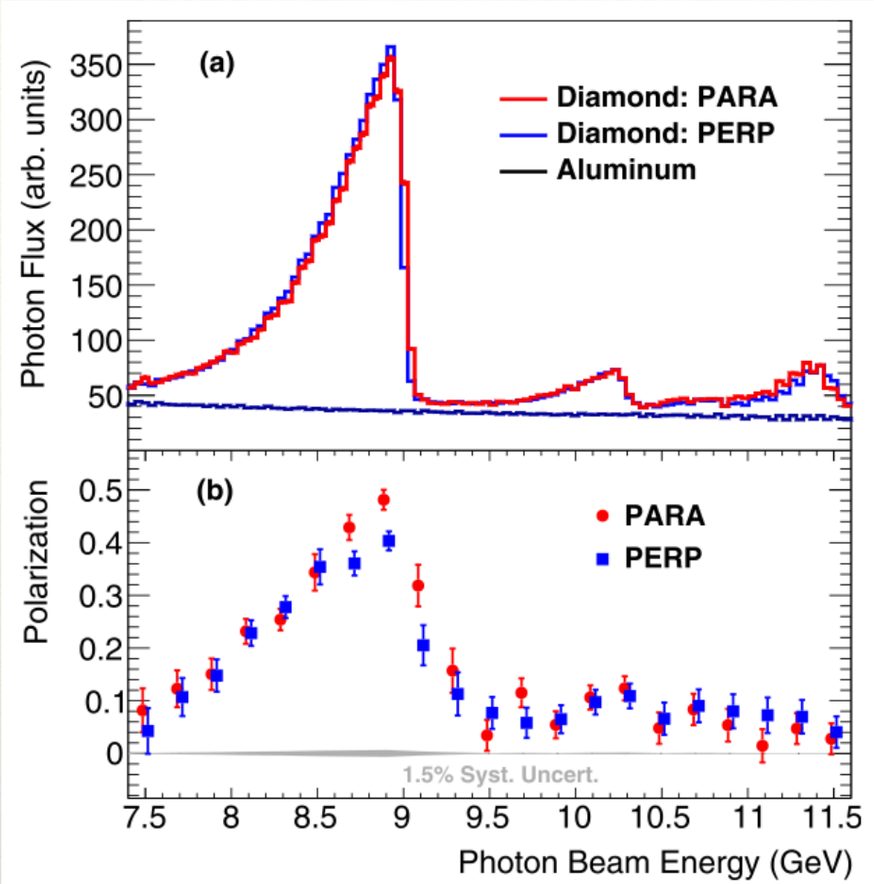
GlueX

Jefferson Lab

CEBAF at Jefferson Lab

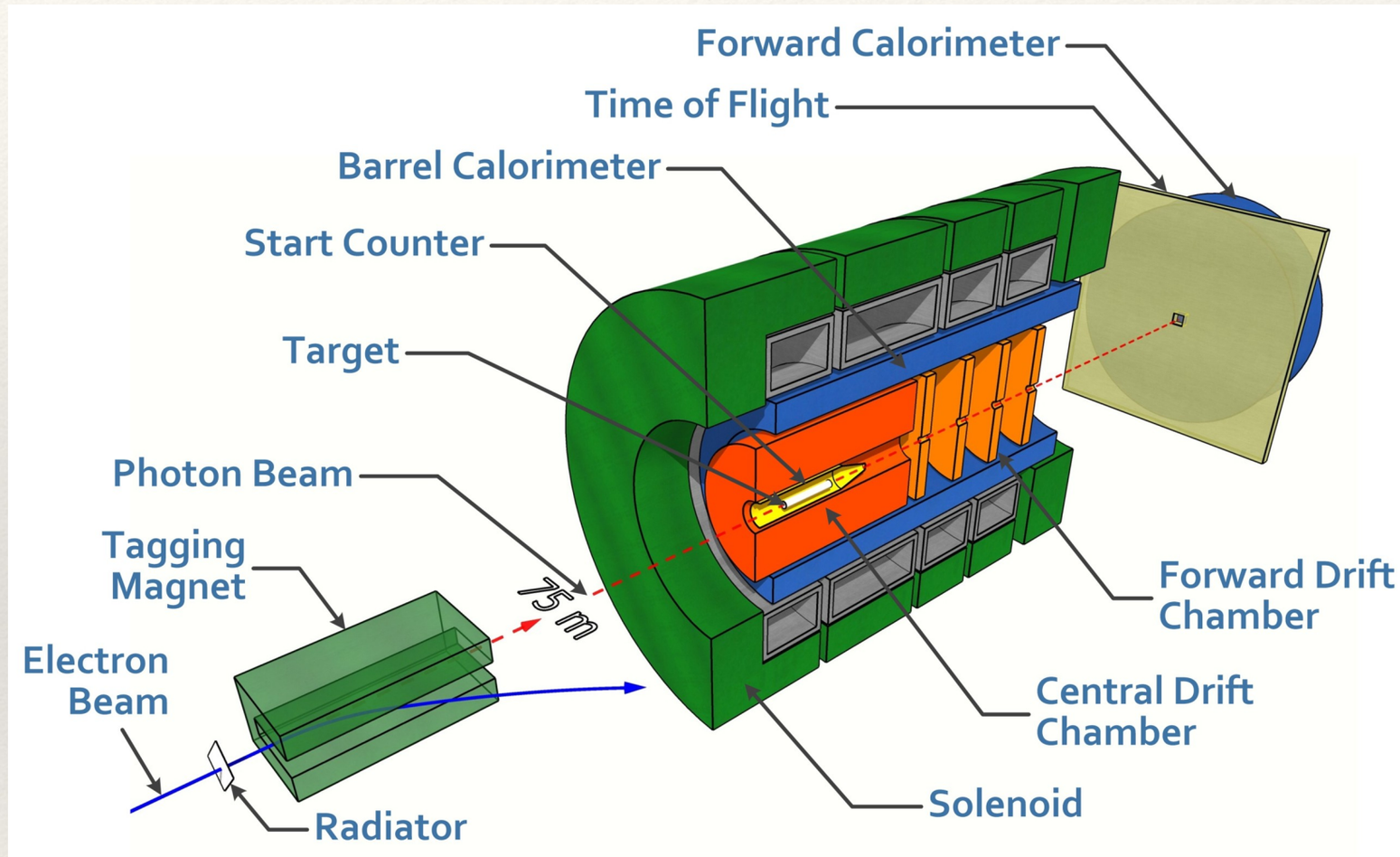
GlueX in Hall D

Nucl. Instrum. & Meth. A**987**, 164807 (2021)



GlueX, Nucl. Instrum. Meth. A 987 (2021) 164807

- produce linearly polarized photon beam via coherent bremsstrahlung on thin diamond



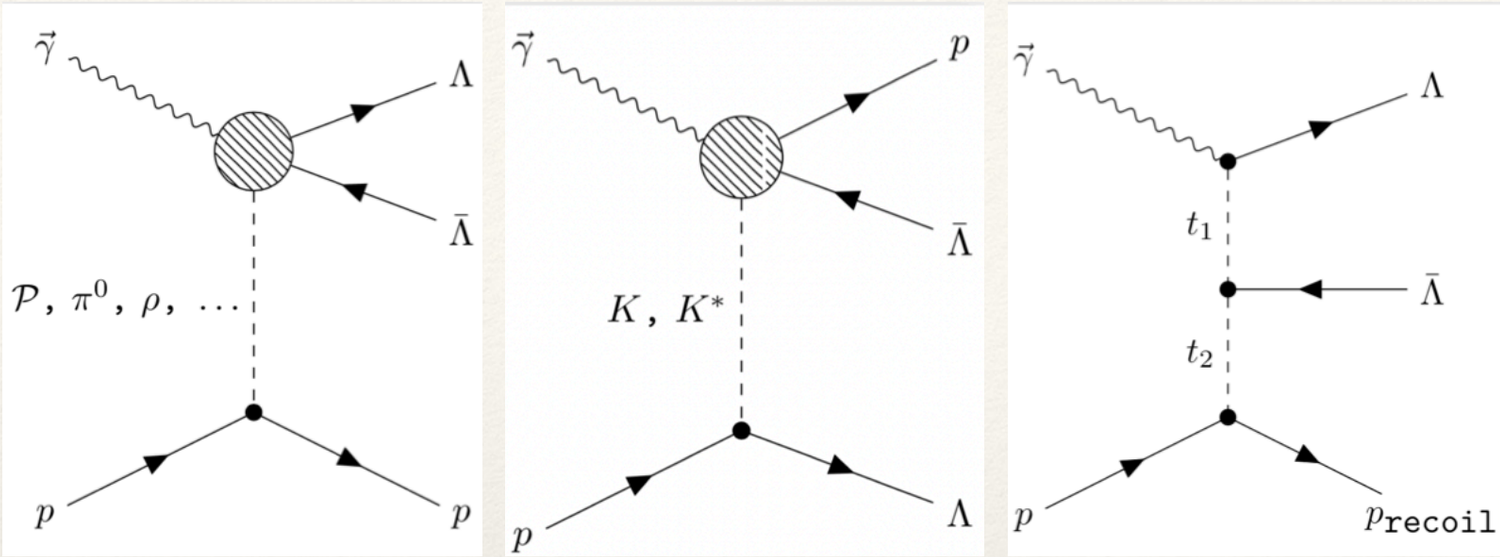
- tag electrons to determine photon energy

- Acceptance: $\theta_{lab} \approx 1^\circ - 120^\circ$
- Charged particles: $\sigma_p/p \approx 1\% - 3\,\%$ ($8\% - 9\,\%$ very-forward high-momentum tracks)
- Photons: $\sigma_E/E = 6\,\%/\sqrt{E} \oplus 2\,\%$

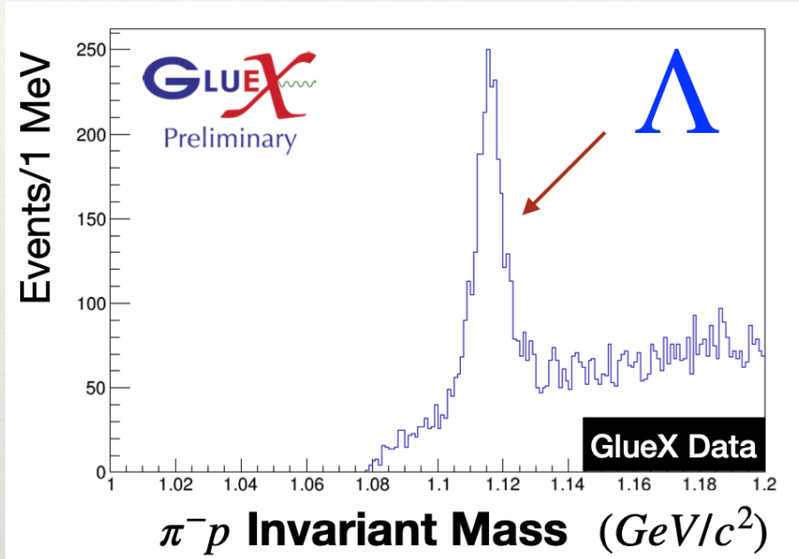
Since 2019: DIRC

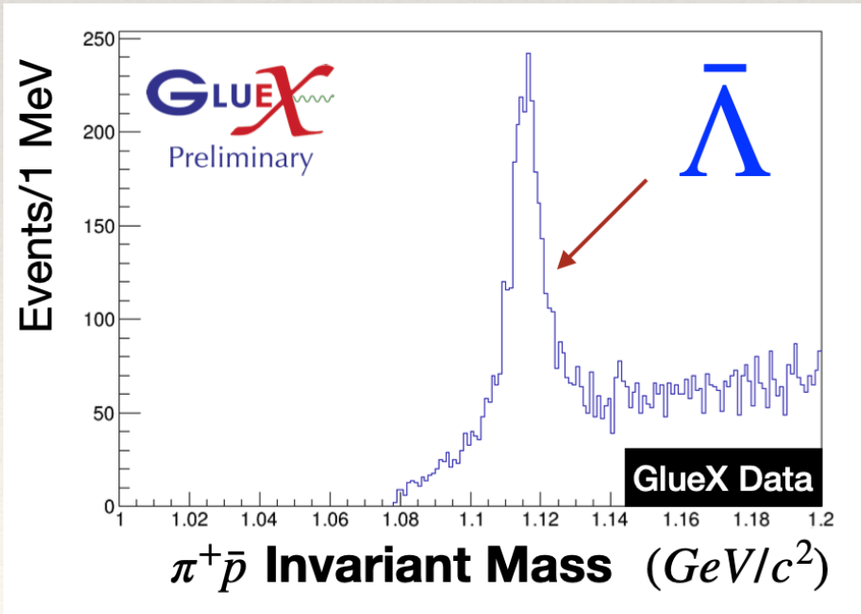
Lambda - anti-Lambda

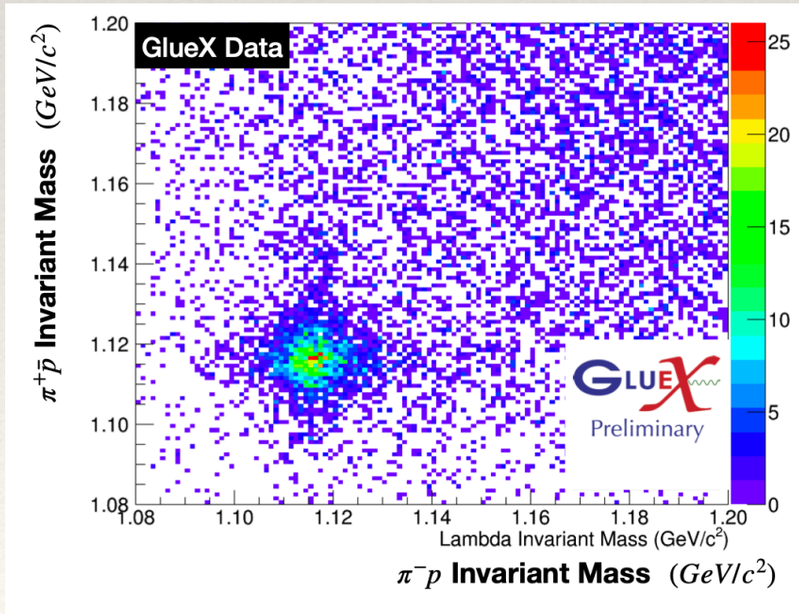
Hao Li (MENU 2019)
Mon 16:15



- BESIII saw interesting threshold enhancement
- $\gamma p \to p\Lambda\bar{\Lambda}\ (\to p\{p\pi^-\}\{\bar{p}\pi^+\})$
- GlueX-I:
  ~400k $\Lambda\bar{\Lambda}$ events
- Cross-section measurements

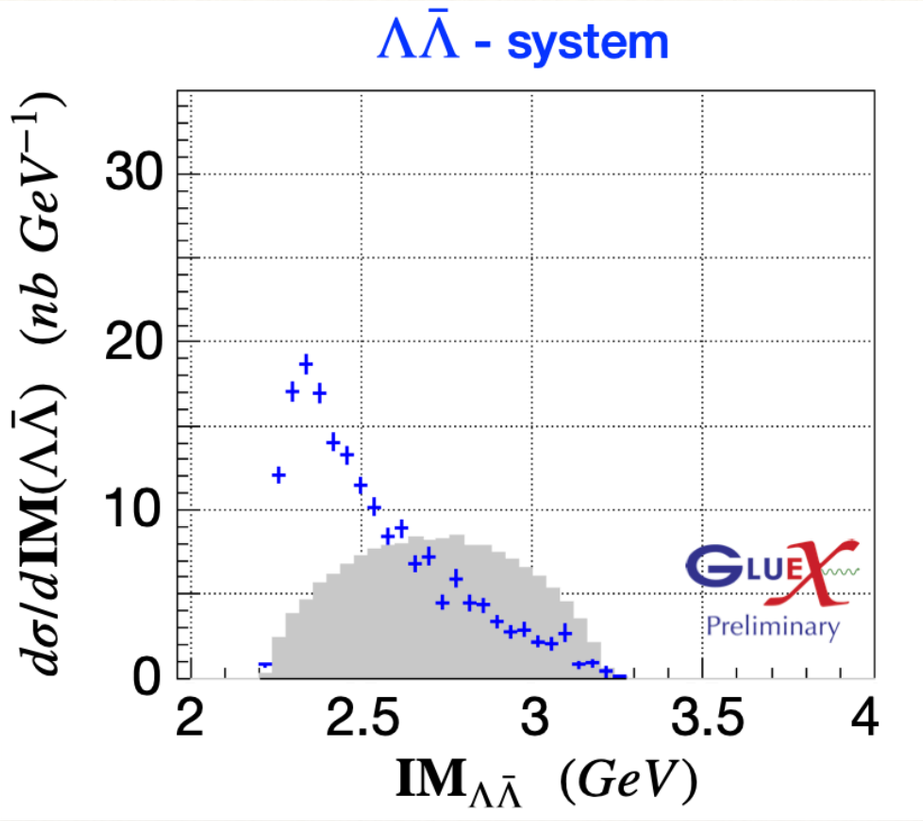


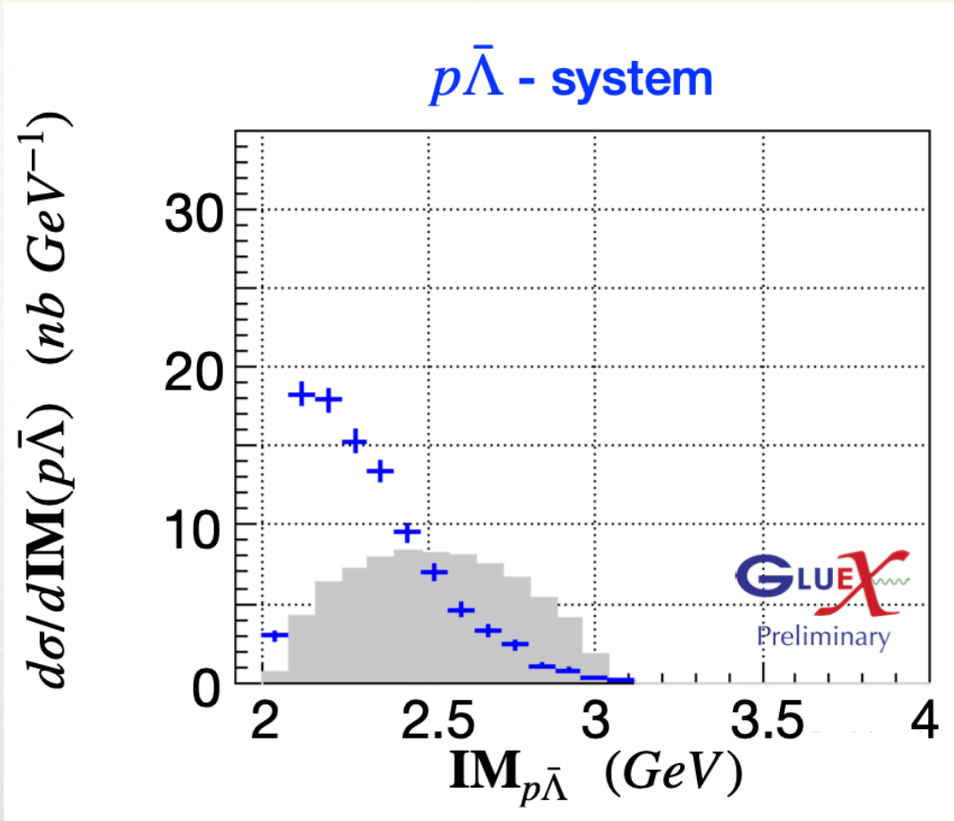


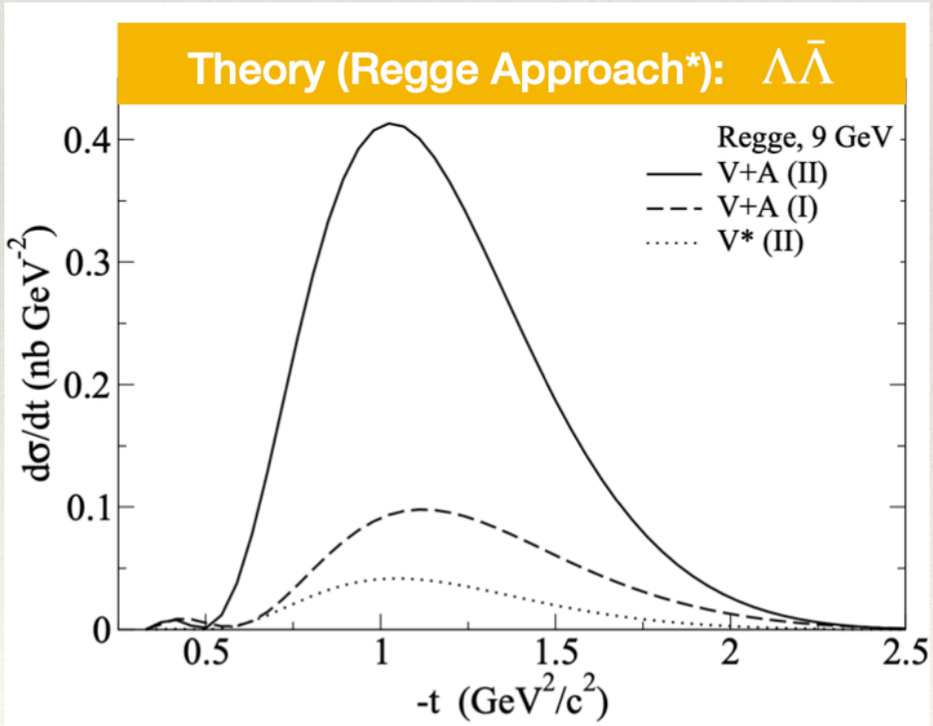


Lambda - anti-Lambda

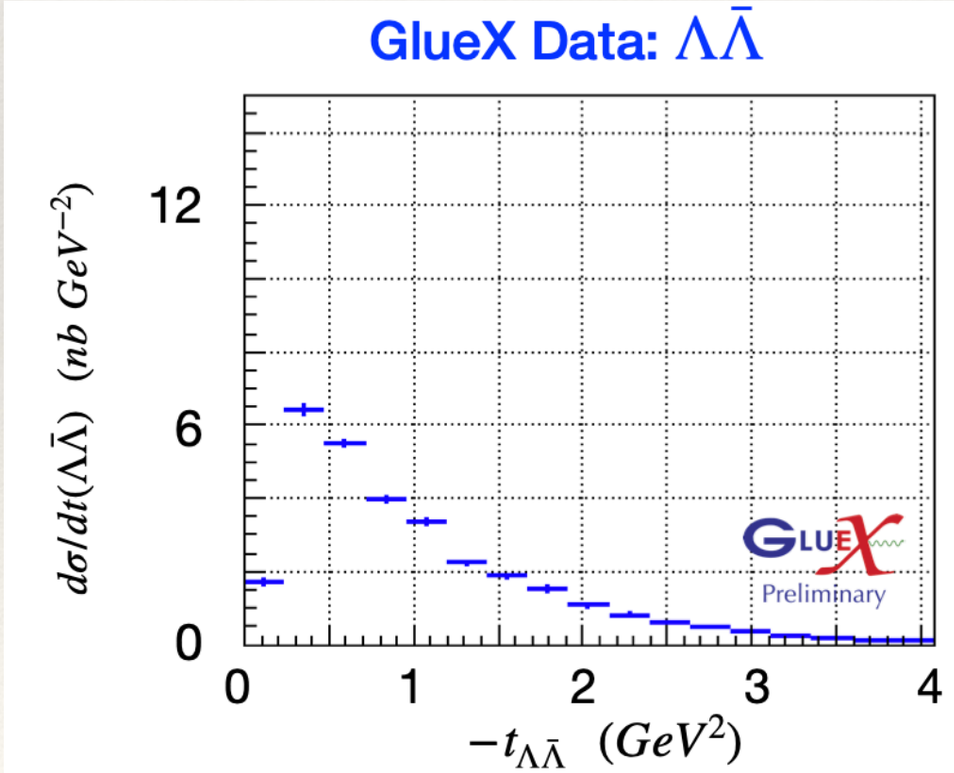
Hao Li (APS DNP 2021)
Mon 16:15







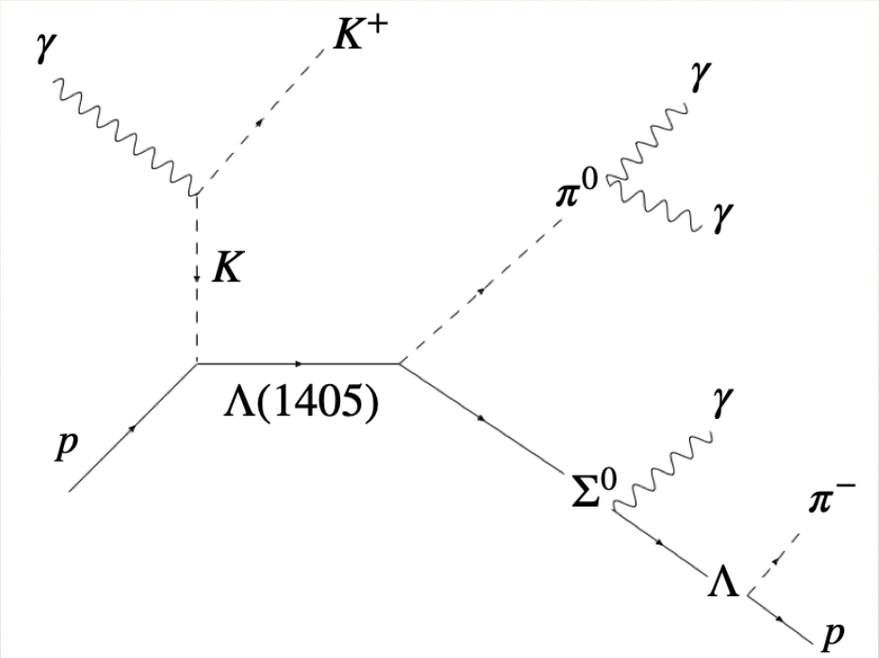
*Gutsche, Thomas, et al. Physical Review D 96(5) (2017) 054024.



- Study production mechanism
- measure beam asymmetry Σ
- Investigate threshold enhancement
- Study Λ polarization

$\Lambda(1405)$ line shape measurement

N. Wickramaarachchi
Wed 15:50

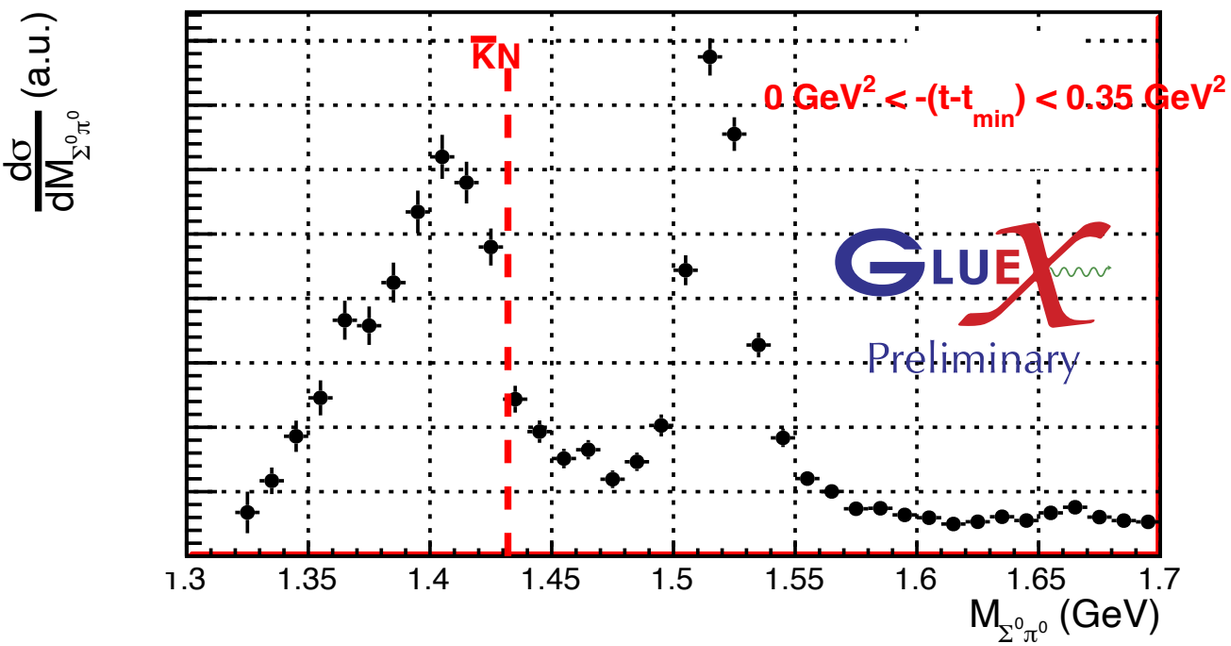


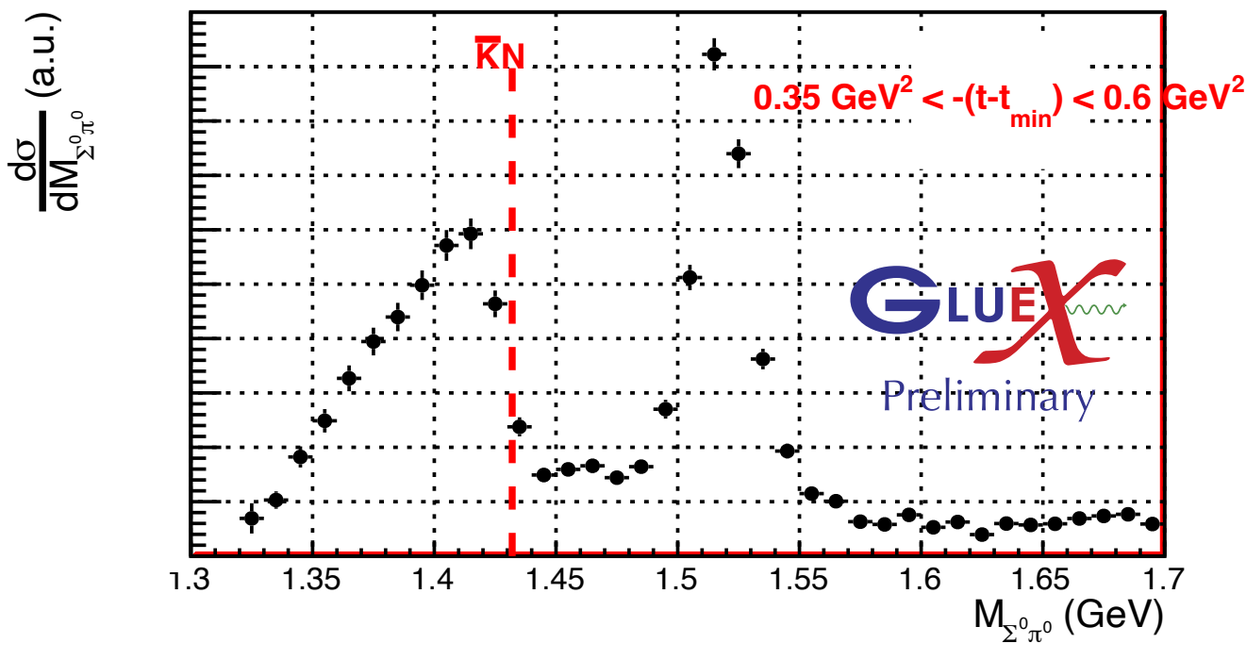
$\Lambda(1405) \to \Sigma^0\pi^0$ $(I = 0)$ is free from $\Sigma(1385)$ background

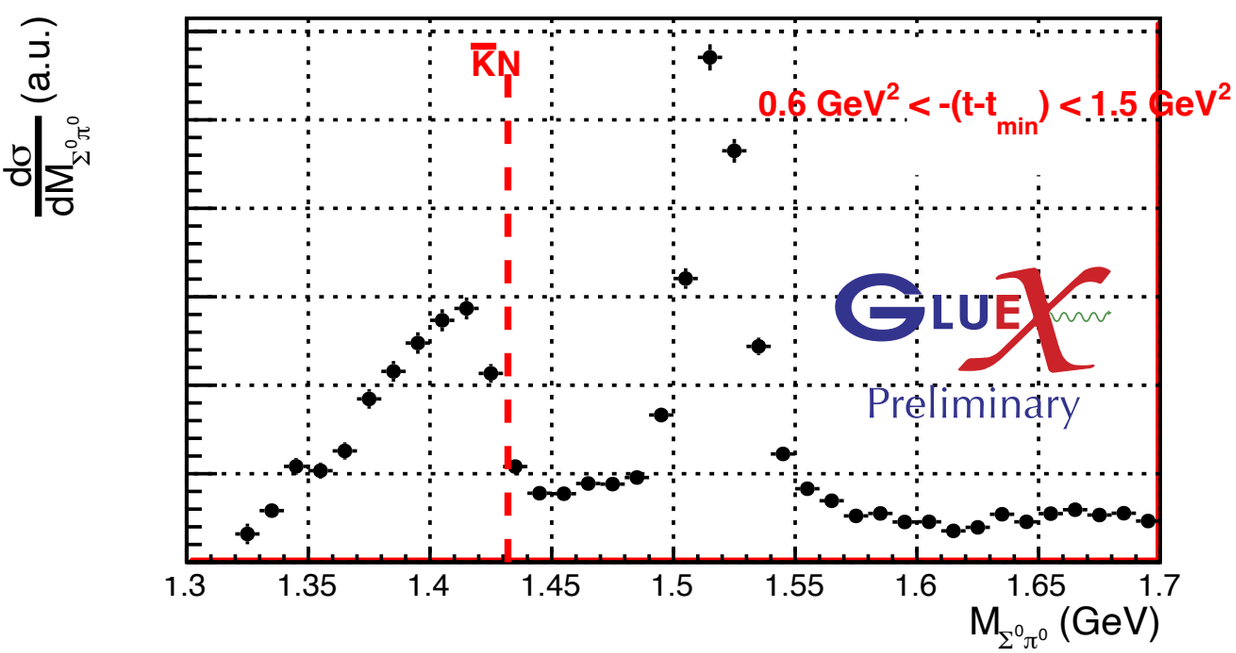
- Excited Λ with $J^P = \frac{1}{2}^-$
- $\Lambda(1405) \to \Sigma\pi$
- Previous measurements (e.g. COSY-Jülich or CLAS) show very clear non-Breit-Wigner line shape
- Interpretation under active investigation
- Many theory models find two-pole structure:
  not just one state
- Recent PDG addition: ** $\Lambda(1380)$

Λ(1405) line shape measurement

N. Wickramaarachchi
(HYP2022) Wed 15:50





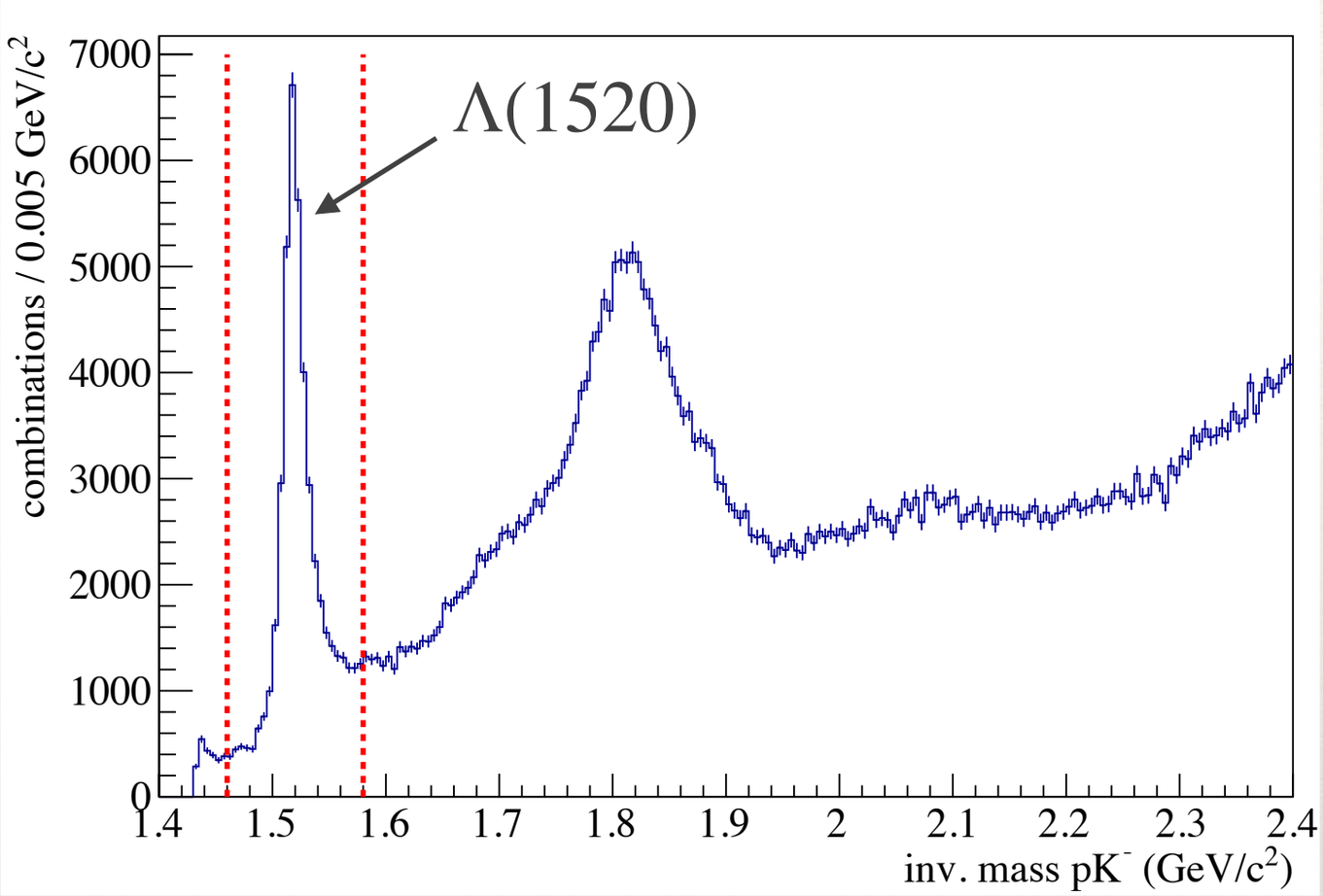


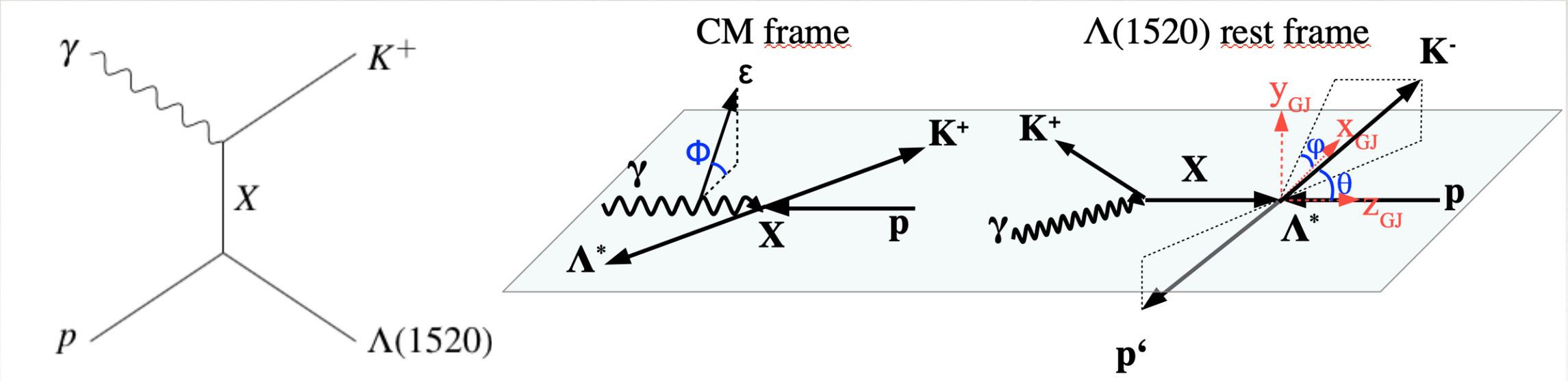
- Λ(1405) t-dependent line shape?
- Could support two-pole structure

Λ(1520) SDMEs

PP (Phys. Rev. C **105**, 035201)

- Excited Λ hyperon with $J^P = \frac{3}{2}^-$
- $\Lambda(1520) \to K^- p$
- different mechanism compared to $\Lambda\bar{\Lambda}$
- Study in Gottfried-Jackson frame

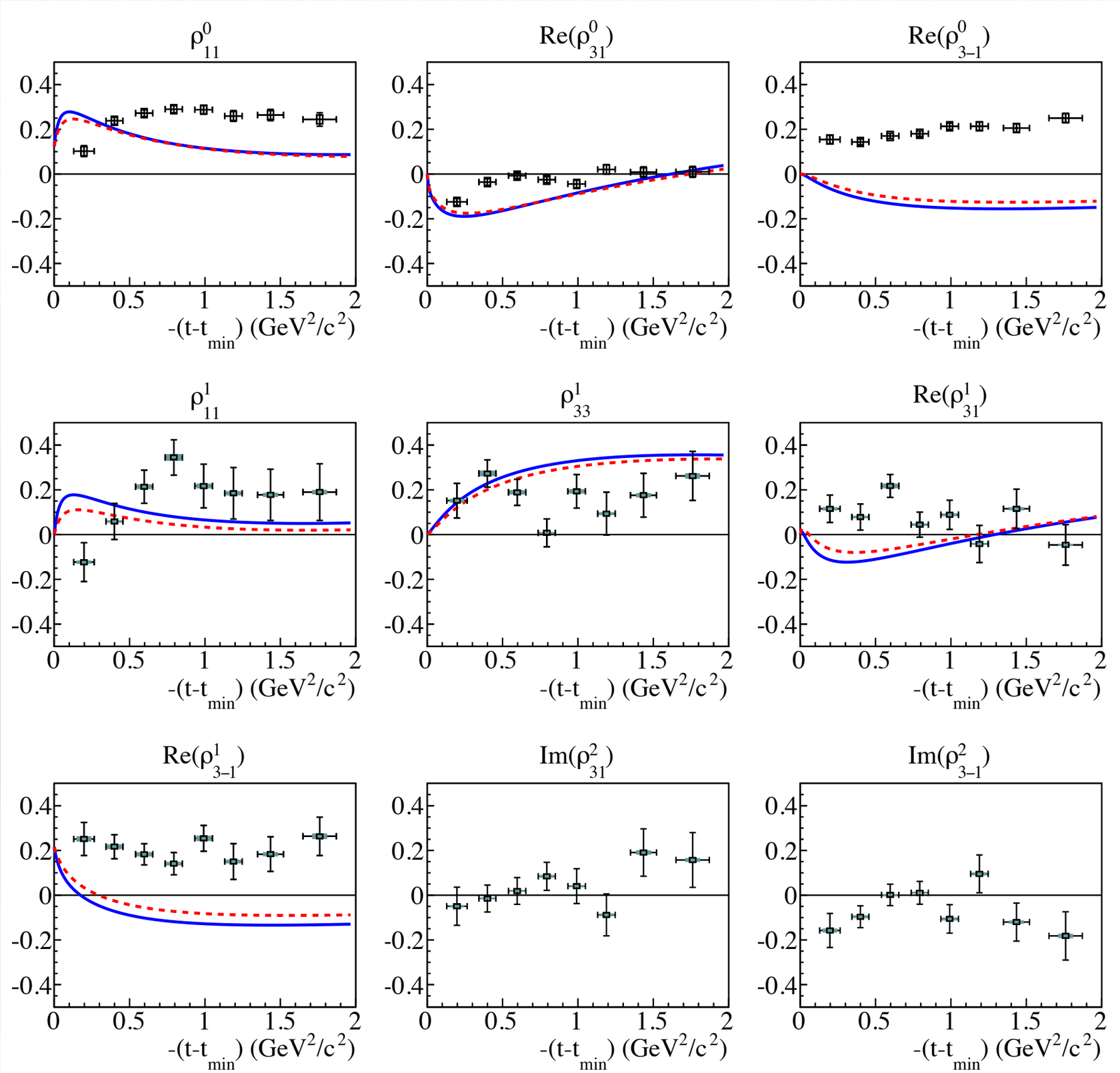




Λ(1520) SDMEs

PP (Phys. Rev. C **105**, 035201)

- So far, sparse data at high energies
- red and blue show model predictions in Reggeized framework (priv. comm. based on [1])
- these measurements constrain models in the future

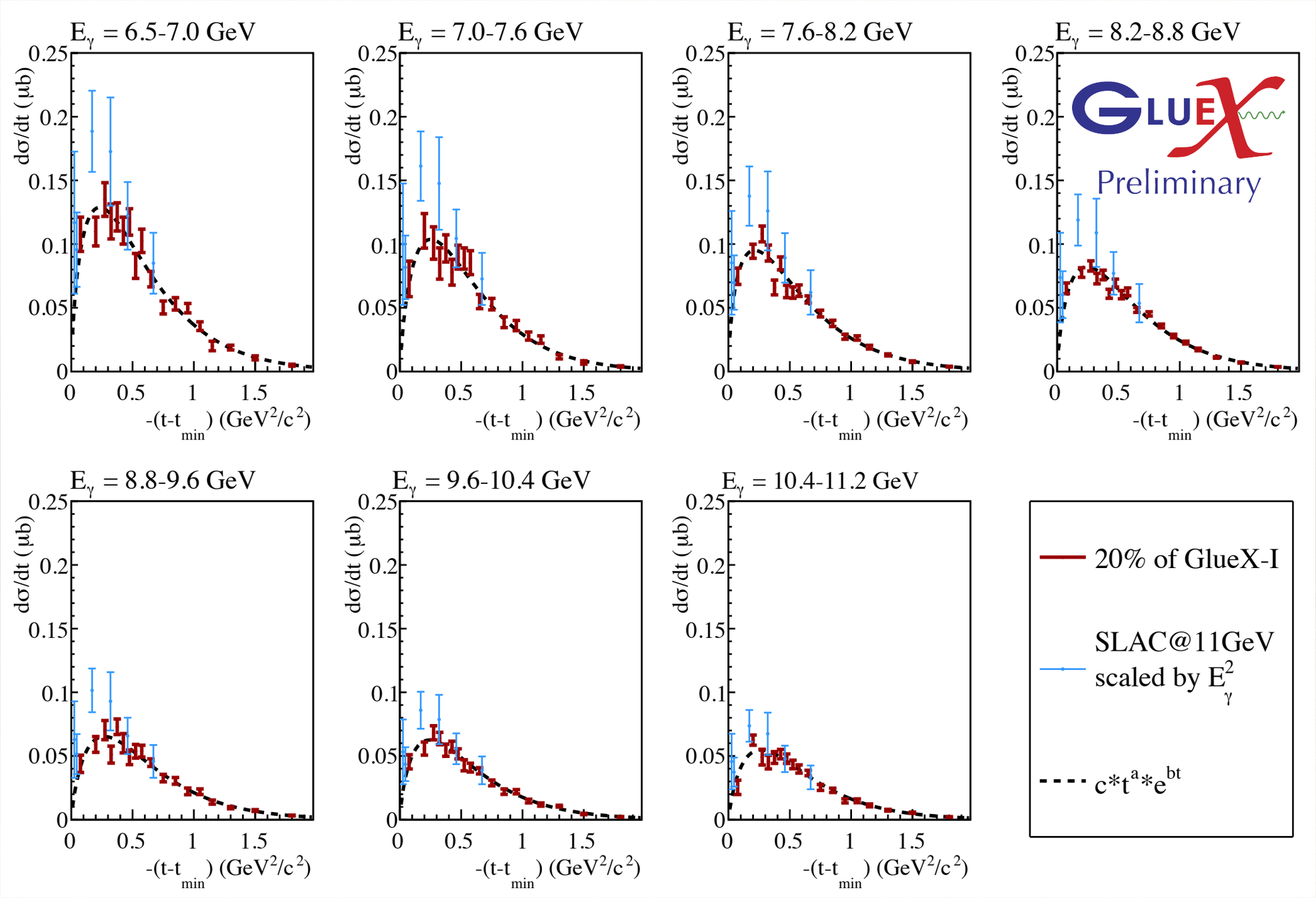


[1] Byung-Geel Yu and Kook-Jin Kong, Phys. Rev. C **96**, 025208 (2017)

Λ(1520) cross-sections

PP (HYP2022)

- To get full picture of production we need couplings: measure cross-sections
- Fit t-distribution and integrate to get "total cross-section"

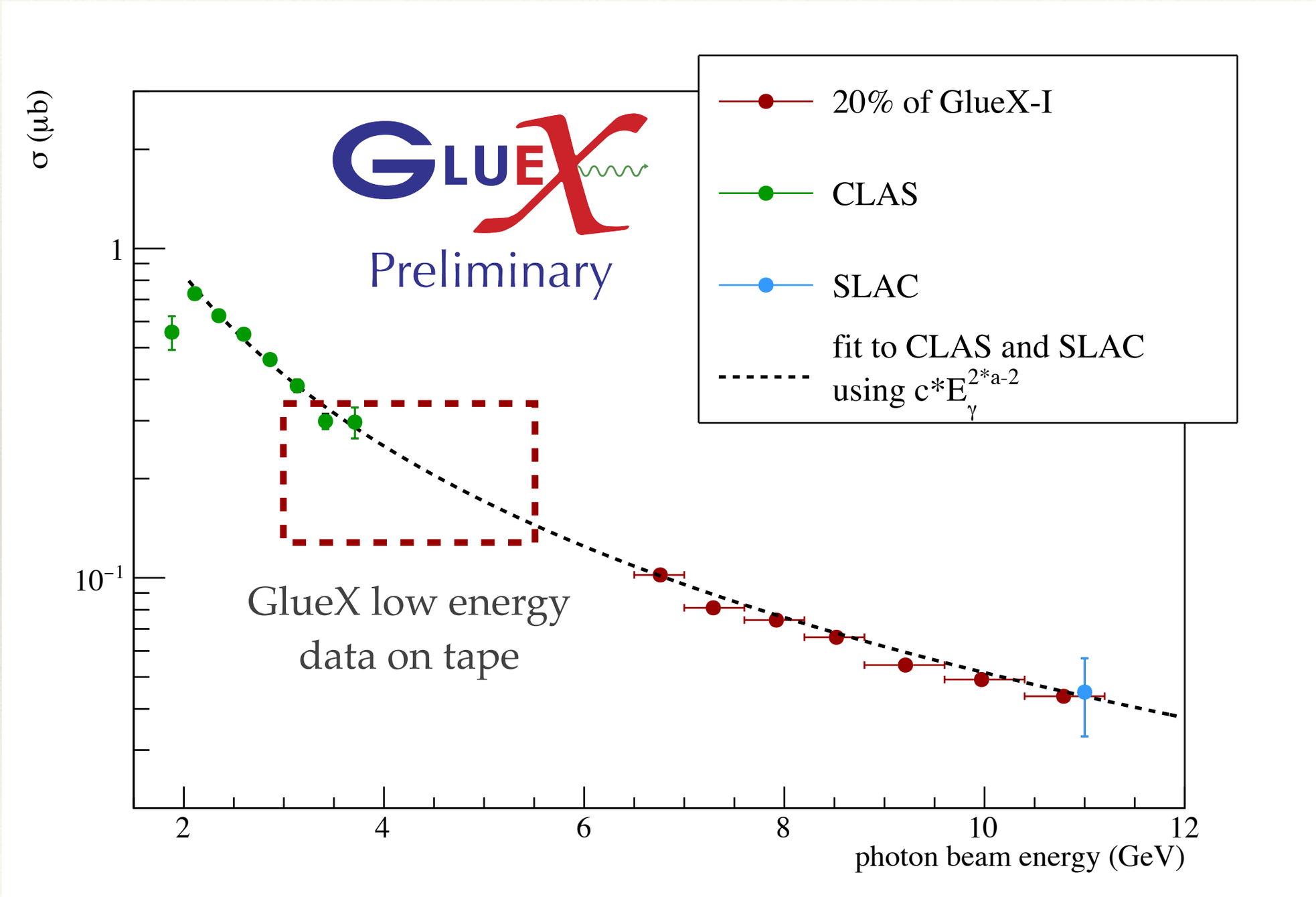


SLAC, *Phys. Lett. B* **34** (1971) 547-550

Λ(1520) cross-sections

PP (HYP2022)

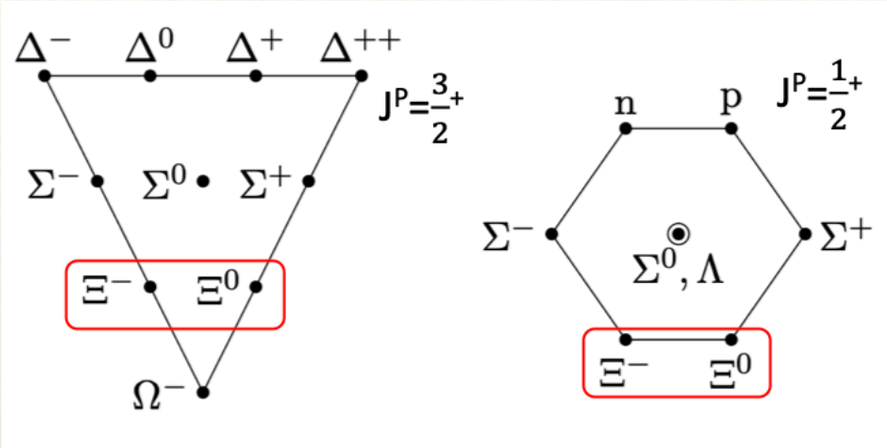
- Good agreement with previous data by SLAC
- More data on tape, including some with lower photon beam energy



CLAS, *Phys. Rev. C* **88** (2013) 045201

SLAC, *Phys. Lett. B* **34** (1971) 547-550

Cascades at GlueX

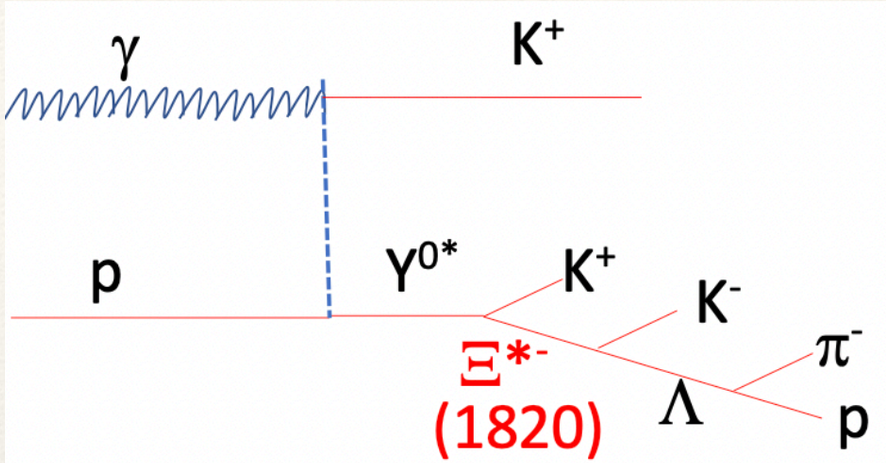


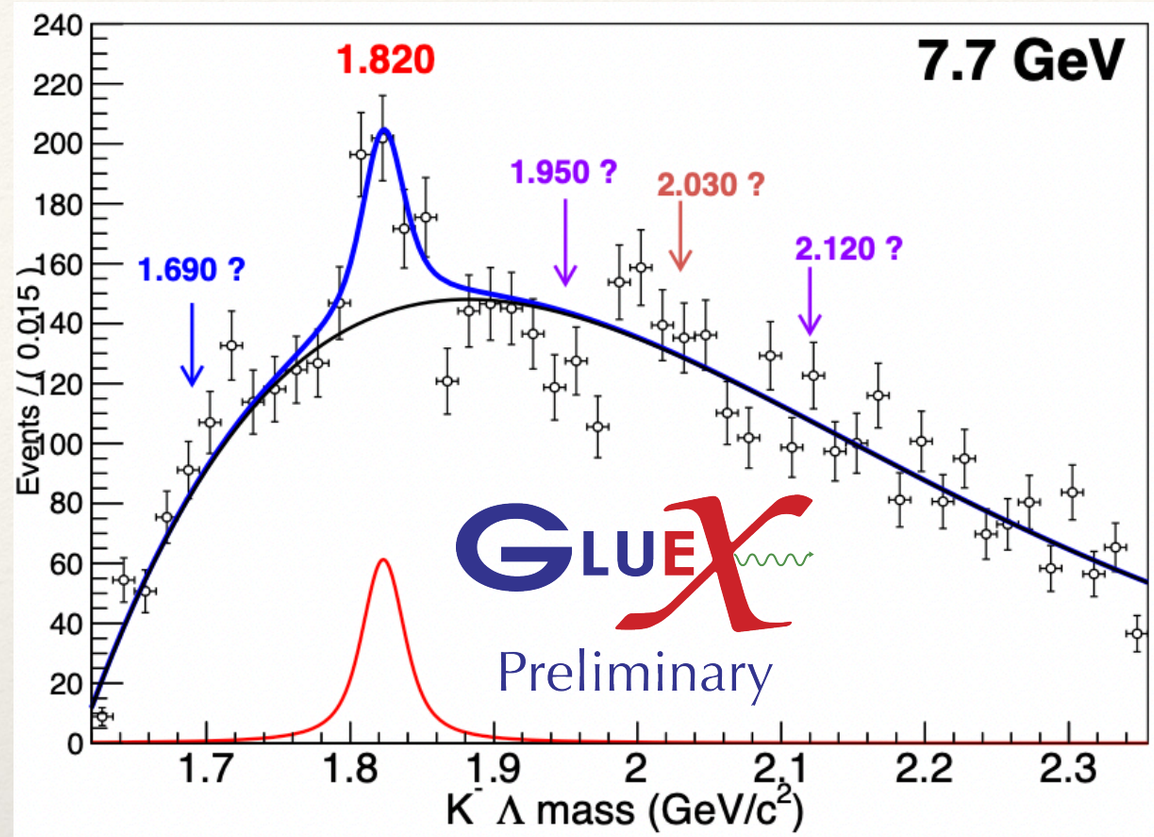
Particle	J^P	Overall Status	– Status as seen in – $\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$
$\Xi(1318)$	$1/2^+$	****				
$\Xi(1530)$	$3/2^+$	****	****			
$\Xi(1620)$		*	*			
$\Xi(1690)$		***		***	**	
$\Xi(1820)$	$3/2^-$	***	**	***	**	**
$\Xi(1950)$		***	**	**		*
$\Xi(2030)$		***		**	***	
$\Xi(2120)$		*		*		
$\Xi(2250)$		**				
$\Xi(2370)$		**				
$\Xi(2500)$		*		*	*	

- Only six well known states (>3***)
- Would expect as many Ξs as N^*s and Δs
- Not many photoproduction experiments have been performed so far ($S = -2$)
- GlueX with its good charged and neutral final state particle coverage could help here
- Difficult analyses due to many final state particles

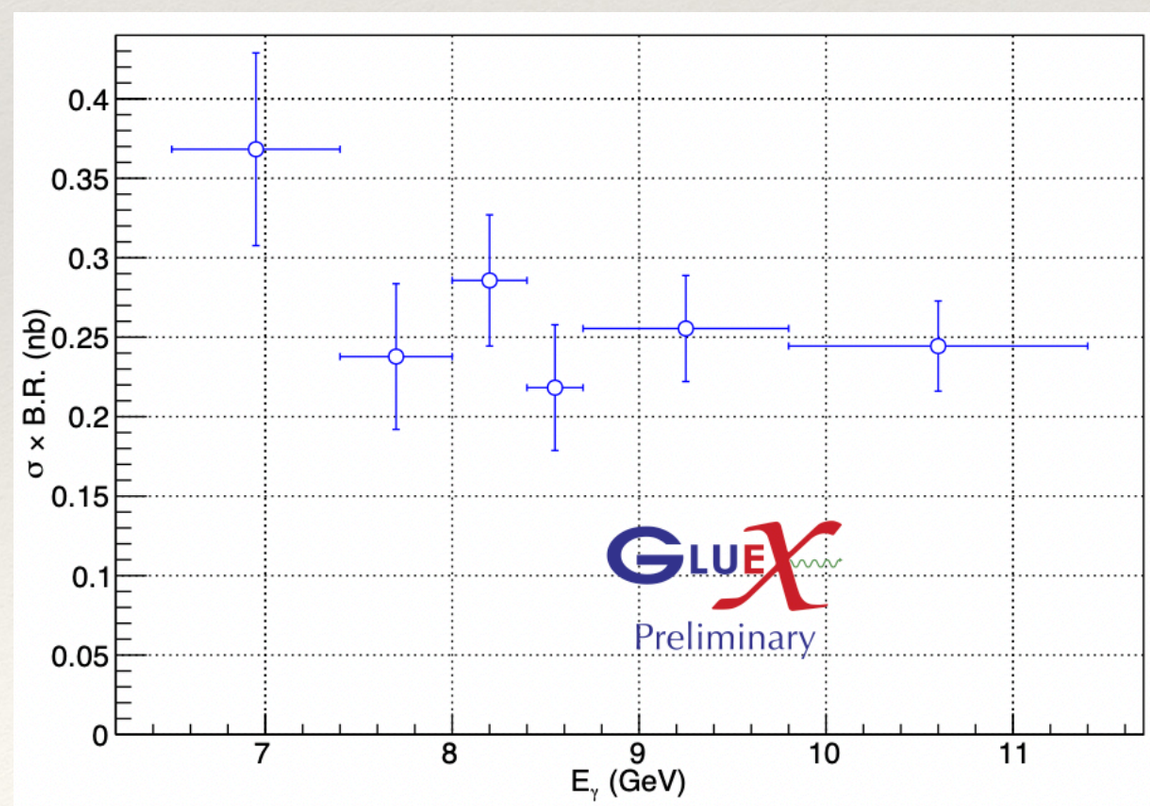
$\Xi^-(1820)$

C. Akondi (HYP2022)



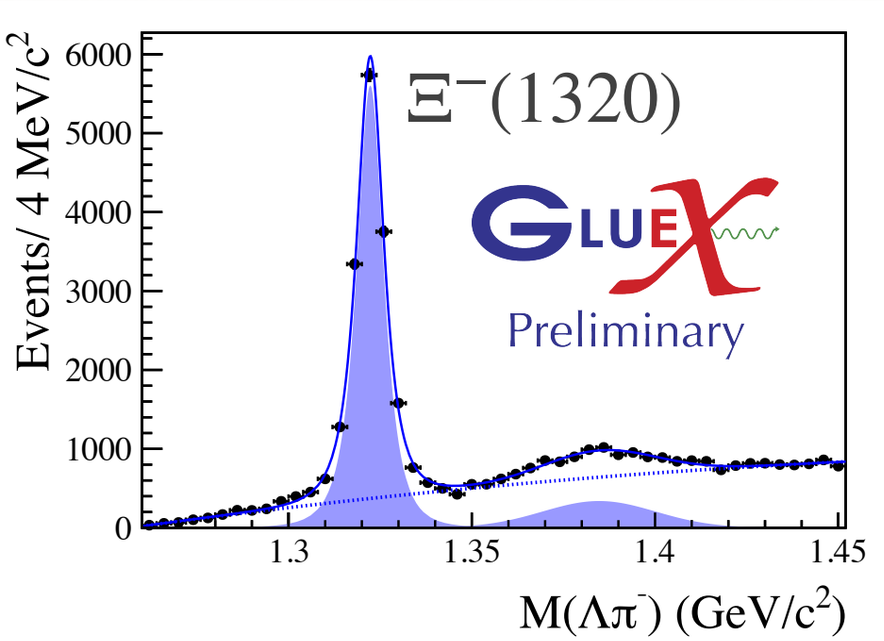


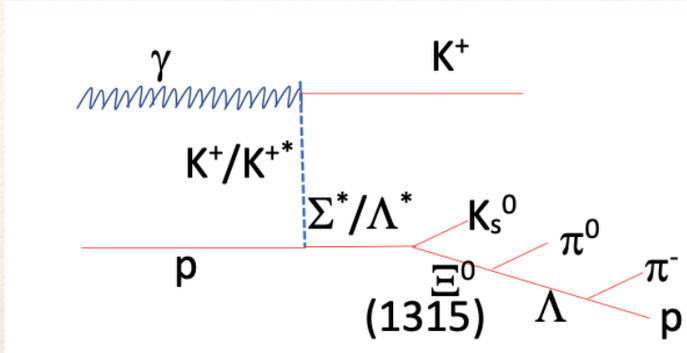
- Excited $\Xi(1820)$ with $J^P = \frac{3}{2}^-$
- *** resonance seen in $K^-\Lambda$ decays
- First measurement of $\Xi(1820)$ in photoproduction
- Only dominating feature in the $K^-\Lambda$ invariant mass

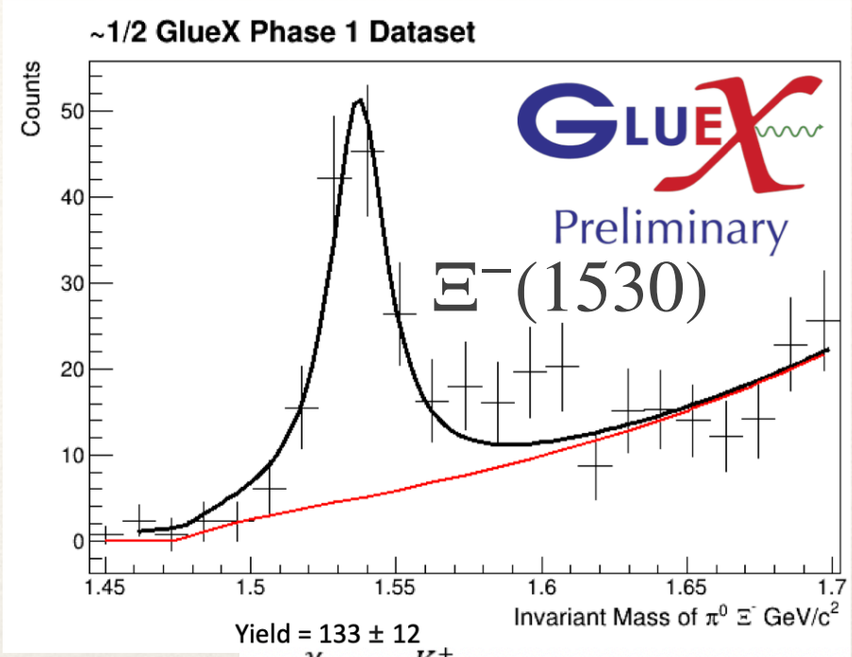


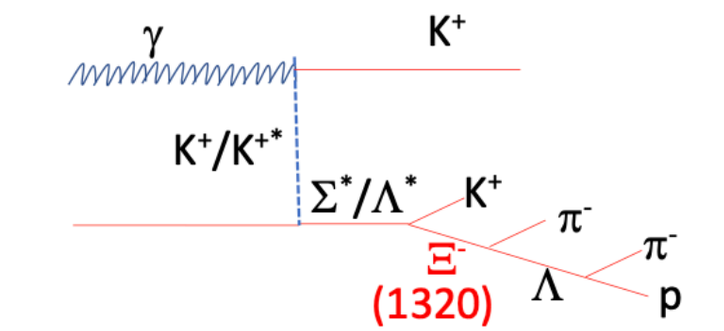
Further Cascades at GlueX

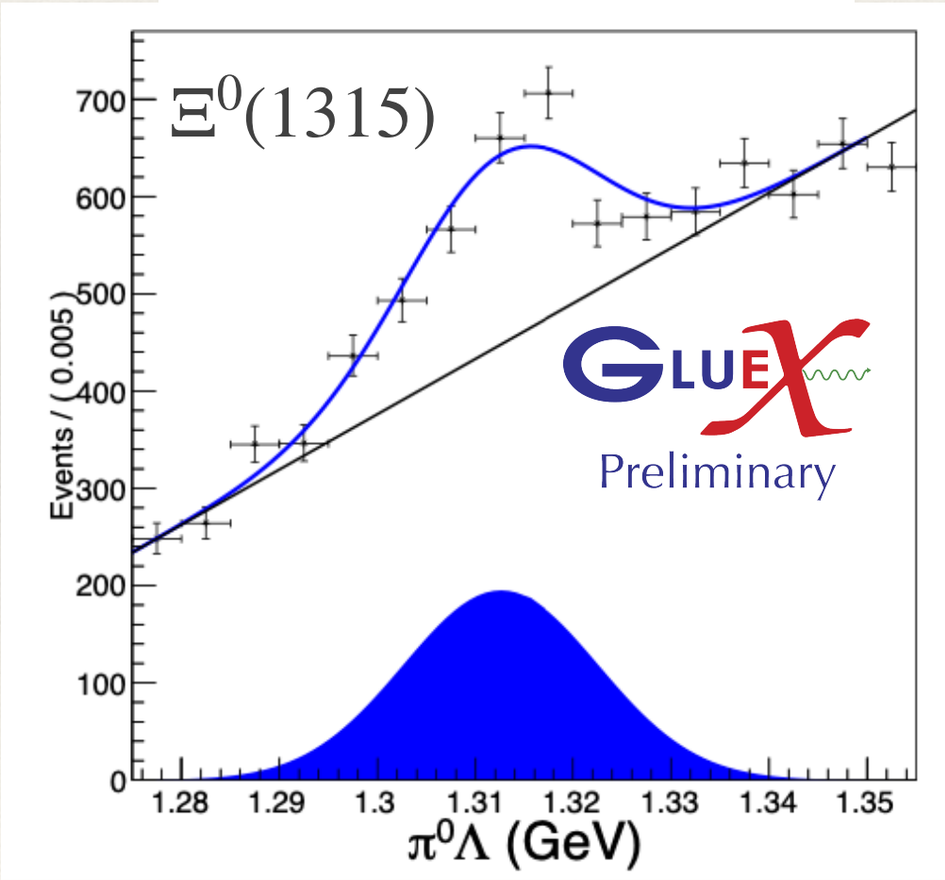
J. Hernandez (SESAPS 2021)
C. Akondi (HYP 2022)
B. Sumner (APS DNP 2021)

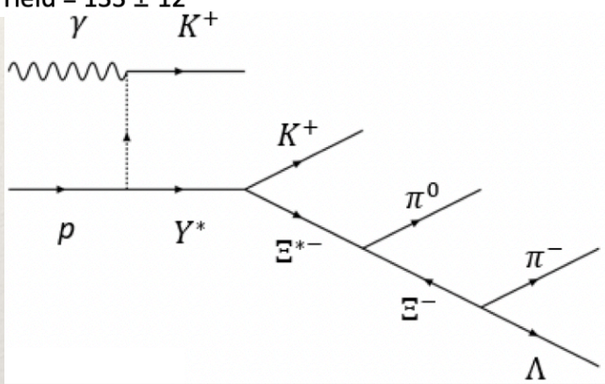








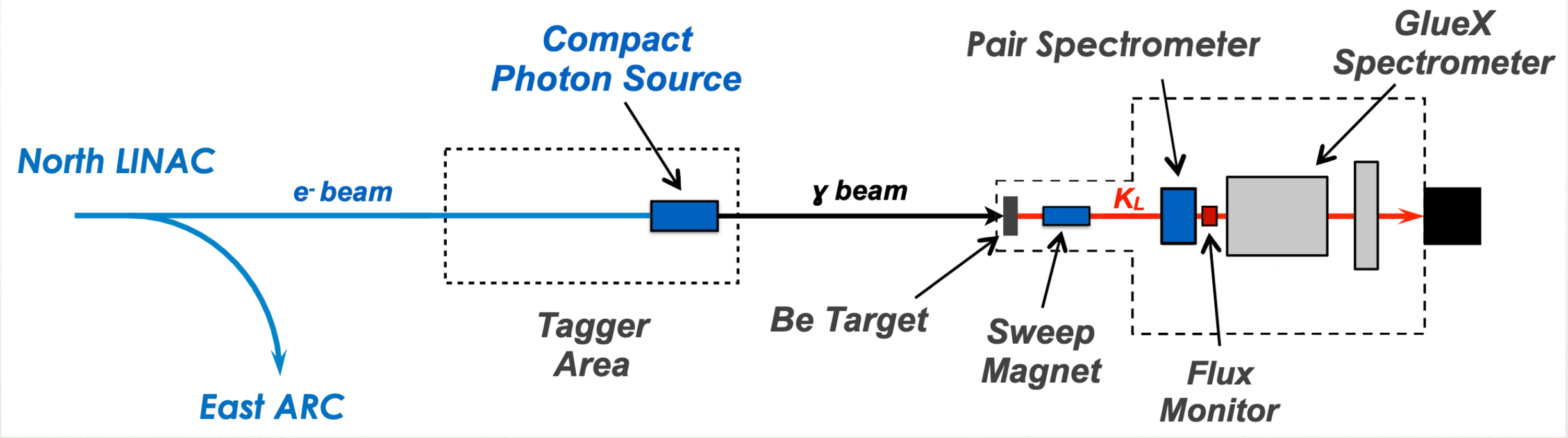




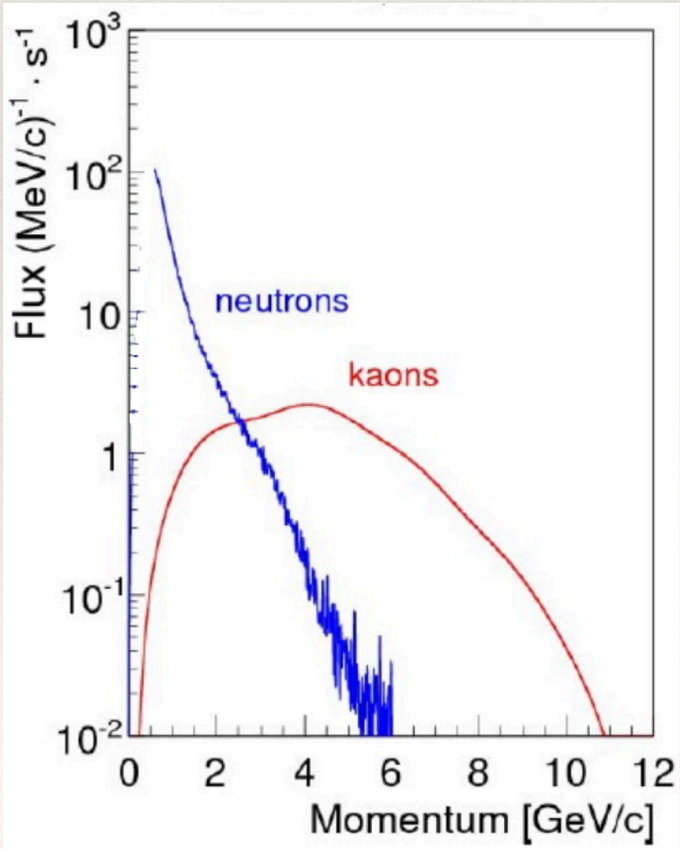
- We see many different cascades in various final states
- Measure differential cross-section $d\sigma/dt$ and total cross-section

KLong facility in Hall D

M. Doering
Wed 12:55

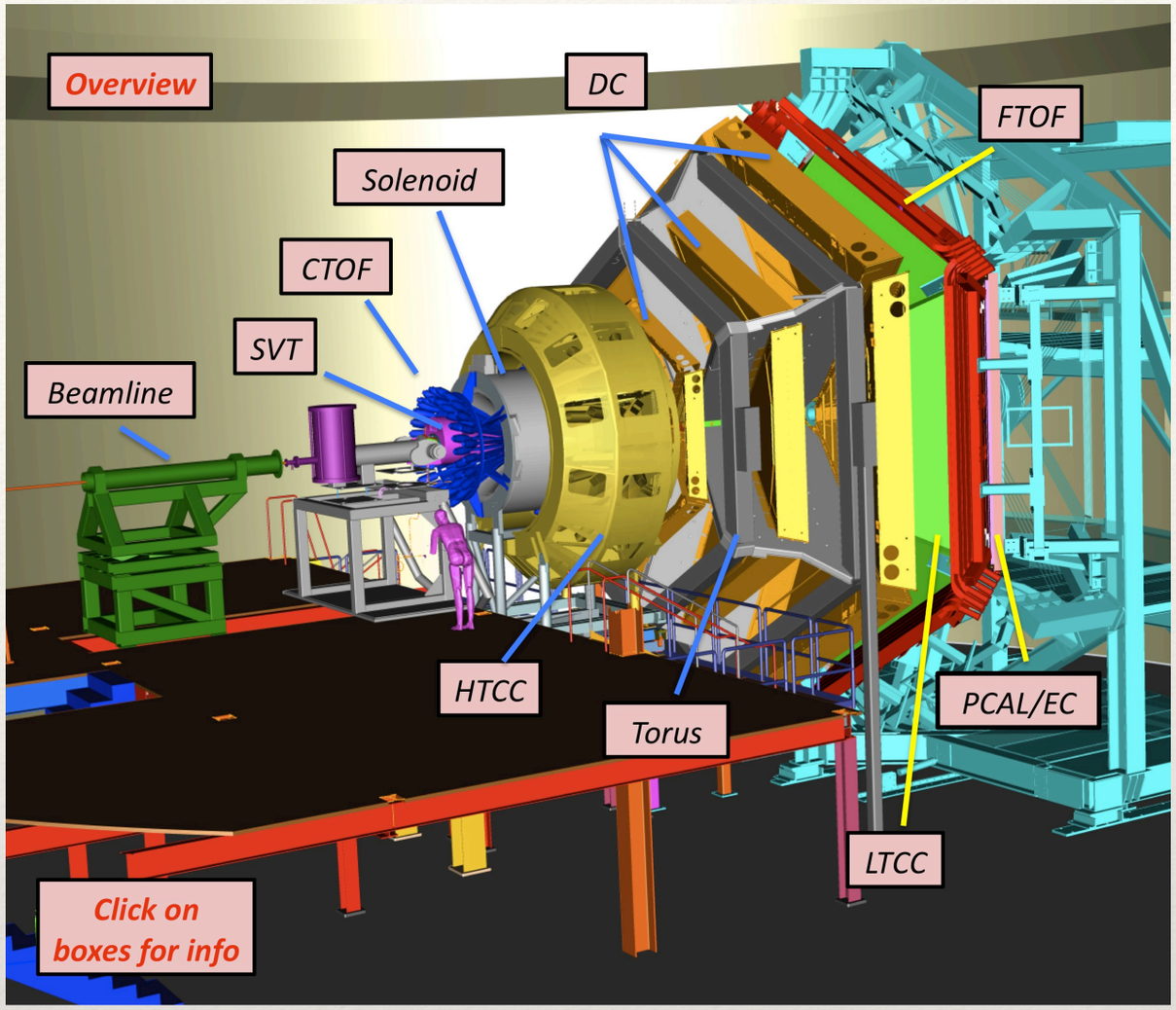


- New kaon beam facility proposed (and accepted by PAC) for Hall D
  - Study of hyperons and kaon spectroscopy
- Produce $\approx 10^4 K_L\ /s$ (1000 times higher than previous experiments)
- Proton and neutron targets
- Use GlueX spectrometer to identify final state
- Might run 2026-2028



CLAS(12) in Hall B

- CEBAF Large Acceptance Spectrometer (1995-2012)
- JLab 12 GeV upgrade completed in 2017 → CLAS12
- Old and new data under analysis
- Very broad science program
- Many experiments and analyses dedicated to strange baryons



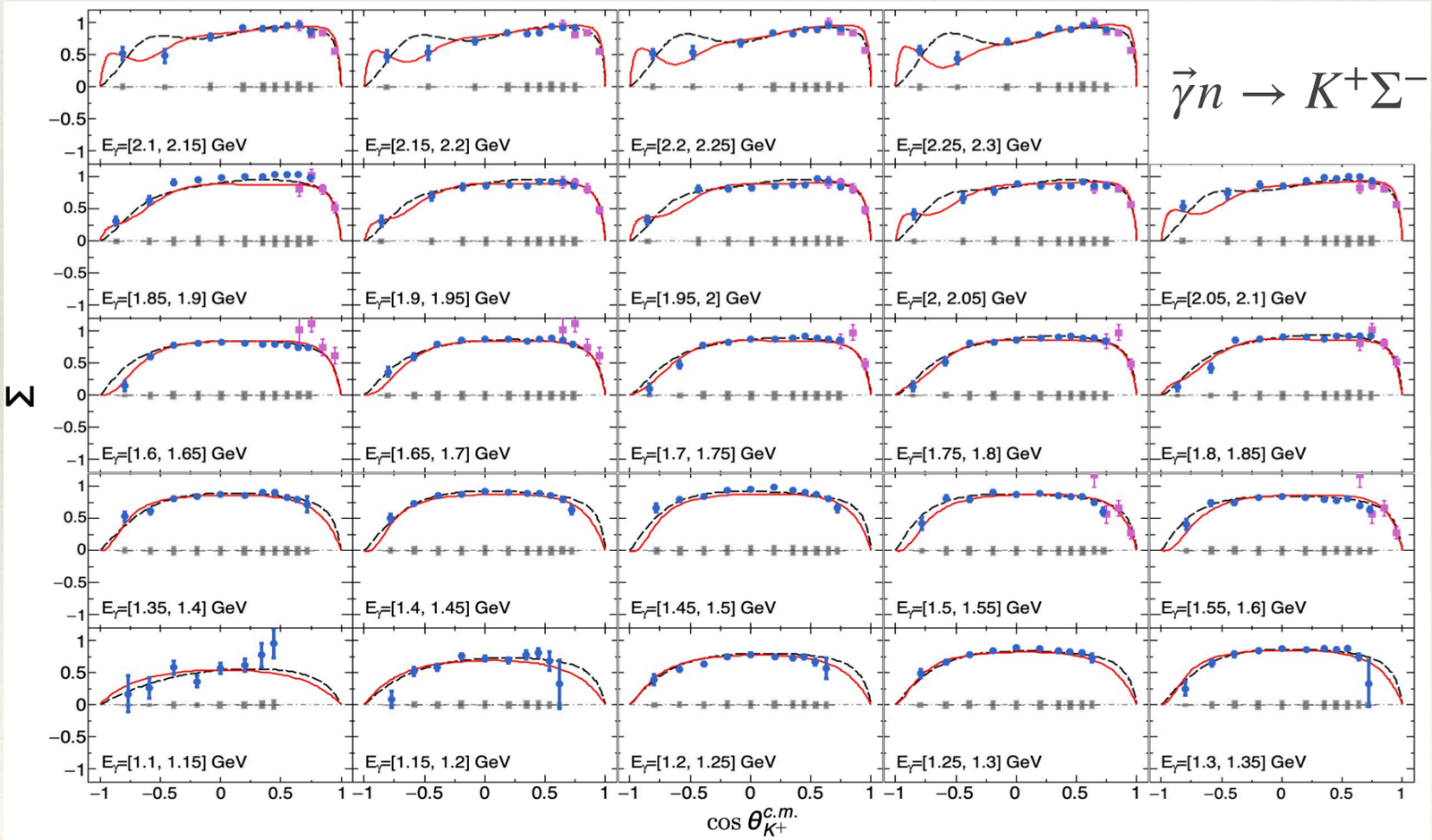
- Providing huge amounts of world data for (double) polarisation experiments (A. D'Angelo, Mon 10:30; S. Fegan, Mon 16:35)
- Very Strange Group, studies excited strange baryons with $S = -2, -3$
- Search for strange Hexaquarks (G. Clash, Wed 16:40)
- Study of hyperon-nucleon interactions

Polarisation observables

Phys.Lett.B 827 (2022) 136985

- "Missing resonances" : There are far more predicted nucleon resonances than have been measured
- Measure (double) polarization observables to provide additional data
- CLAS has many results on $\gamma N \to KY \quad (Y = \Lambda, \Sigma)$
- Adding more and more data over the years
- Used in fits to various models (JuBo, BnGa, MAID, SAID) to extract resonance parameters to get a better picture of nucleon spectrum

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}\Big|_{\text{unpolarised}} \Big[1 - P_\gamma^l \boldsymbol{\Sigma} \cos(2\phi) + P_T^x \left(-P_\gamma^l \boldsymbol{H} \sin(2\phi) + P_\gamma^c \boldsymbol{F}\right) - P_T^y \left(-\boldsymbol{T} + P_\gamma^l \boldsymbol{P} \cos(2\phi)\right) - P_T^z \left(-P_\gamma^l \boldsymbol{G} \sin(2\phi) + P_\gamma^c \boldsymbol{E}\right)\Big]$$



More by S. Fegan, Mon 16:35

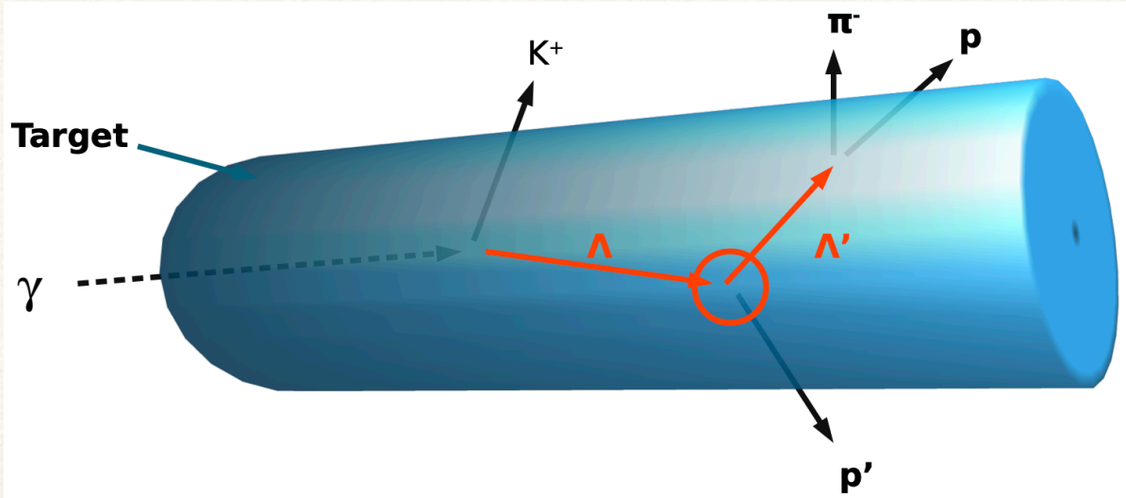
Hyperon scattering

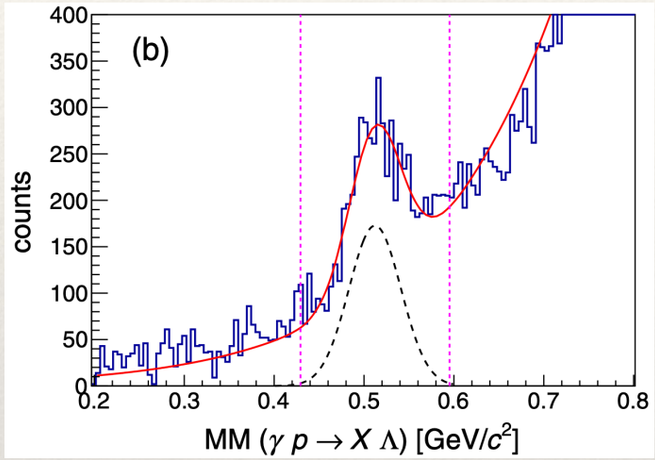
N. Zachariou (HYP2022)
Rowley *et al.*, PRL **127**, 272303 (2021)

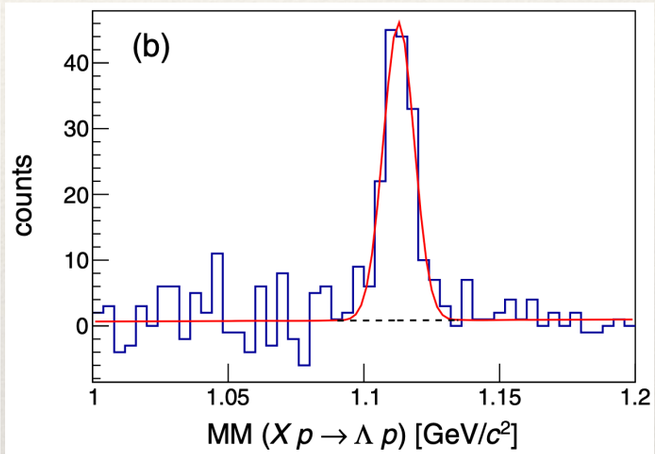
- YN interactions are crucial ingredient in solving the "hyperon puzzle" for neutron stars
  - EOS needs to be stiff but can get softened by existence of hyperons in neutron stars

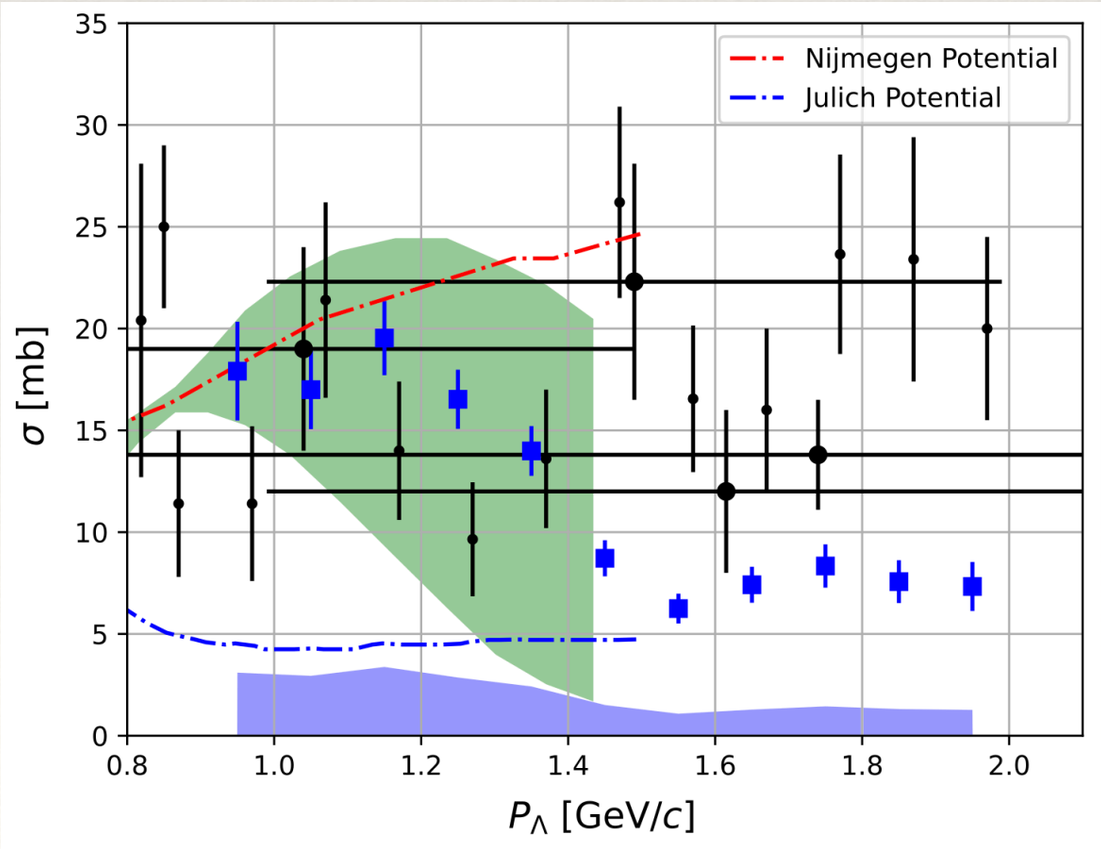
→Two parallel sessions (Tue)

- Measure elastic $\Lambda p \to \Lambda p$ cross-section









$$\sigma(p_\Lambda) = \frac{Y(p_\Lambda)}{A(p_\Lambda) \times \mathcal{L}(p_\Lambda) \times \Gamma}$$

$$\mathcal{L}(p_\Lambda) = \frac{N_A \times \rho_T \times l}{M} N_\Lambda(p_\Lambda)$$

$$\frac{N_\Lambda}{\mathcal{L}_\gamma} = \frac{d\sigma}{d\Omega}(2\pi)[\Delta\cos(\theta)] \qquad P(x) = \exp\left[-\frac{M}{p}\frac{x - x_0}{\tau}\right]$$

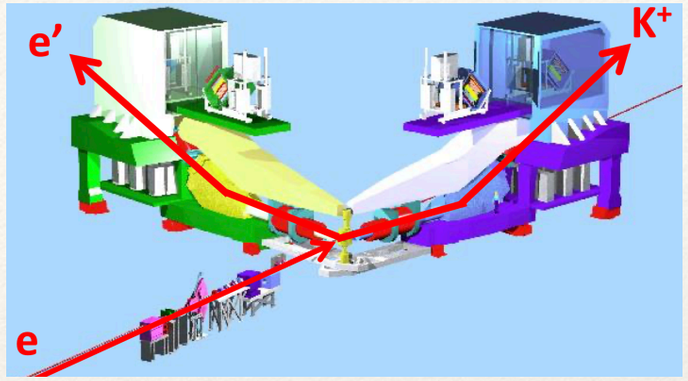
Path length determined from simulations, accounting for beam size and kinematic dependence of photoprod. cs., as well as decay length of hyperons

E12-17-003 in Hall A

L. Tang
Thu 13:45

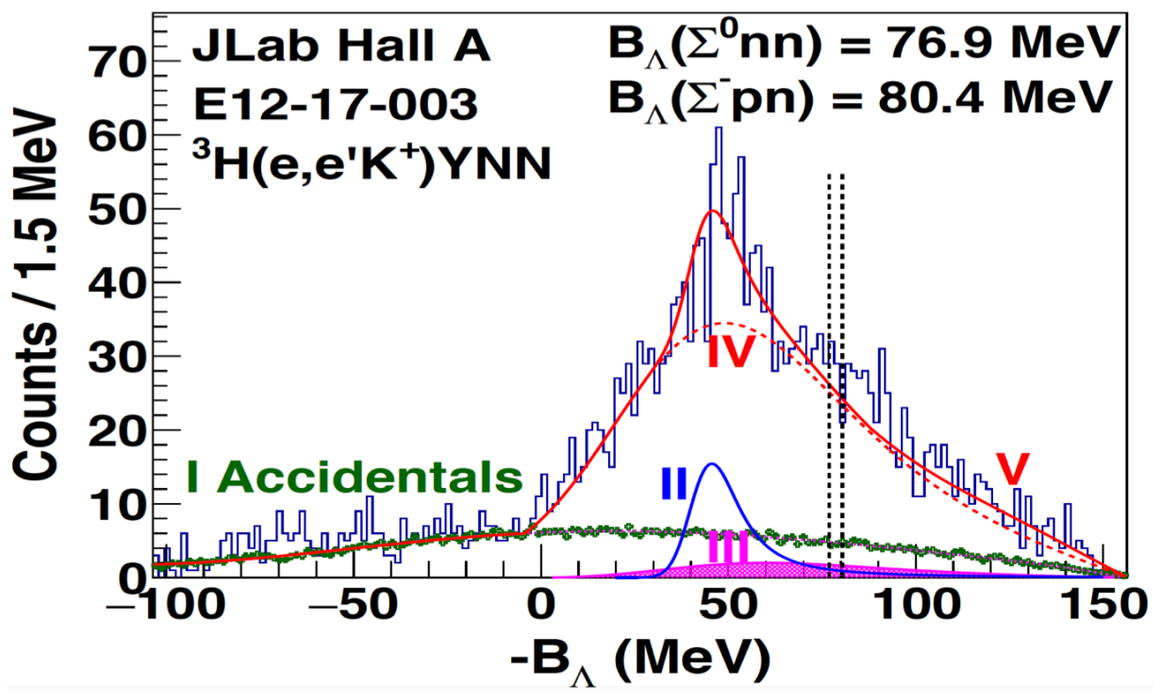
Prog. Theor. Exp. Phys. 2022 013D01
Phys Rev. C 105, L051001 (2022)

- There is limited Λp scattering data but no Λn data
- A previously reported potential Λnn state might be the only way to investigate Λn interaction experimentally
- Study Λnn and Σnn electroproduction on tritium target



HYP2022

ANALYSIS RESULTS – Λnn Spectrum



Although no definite identifications could be made, enhancements at both the Λnn and ΣNN thresholds are highly interesting

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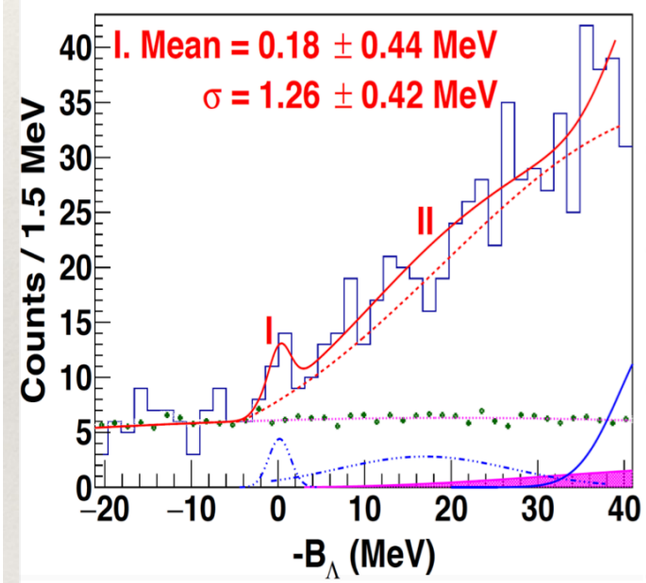
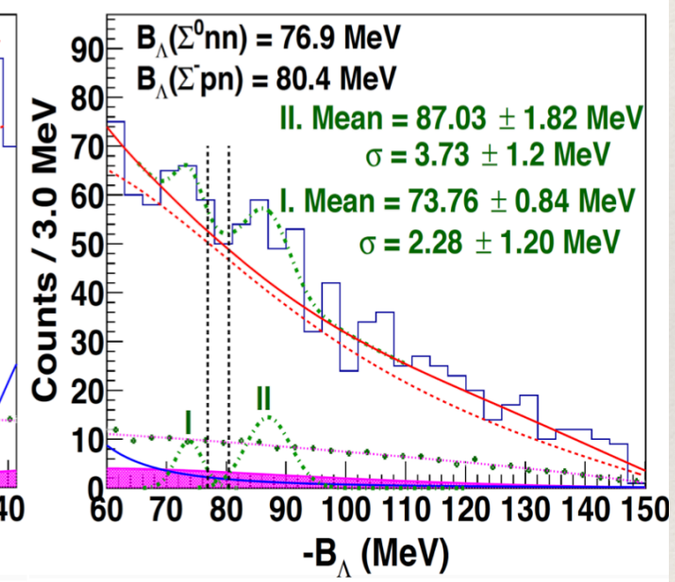
ANALYSIS RESULTS – Possible YNN Resonances





- Possible Λnn resonance:
  $-B_\Lambda$ = 0.18 ± 0.44 (*stat*) ± 0.4 (*sys*)
  $\Gamma/2$ = 0.35 ± 0.42 (*stat*) ± 0.5 (*sys*)
- Significance: ~2.2. If real, cross section ≈ 10 nb/sr)

- Possible bound Σ^0nn state (1st):
  $-B_{\Sigma 0nn}$ = -3.14 ± 0.84 (*stat*) ± 0.4 (*sys*)
- 2nd peak is about 13 MeV away
- Cross sections (1st/2nd) ≈ 20/45 nb/sr

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Statistics too low for definitive statements → new proposal conditionally approved

Summary

- JLab delivers exciting strangeness results
- GlueX provides valuable photoproduction data for many different reactions
  - DIRC upgrade will boost analysis power for strange final states
- KLong will be the next big neutral kaon beam facility
- CLAS still adds to the world data on polarisation observables for strange baryon production
  - But also important data such as YN scattering
- CLAS12 has an ambitious program with many different analyses in the pipeline
- Other experimental halls also perform impressive experiments with strange baryons