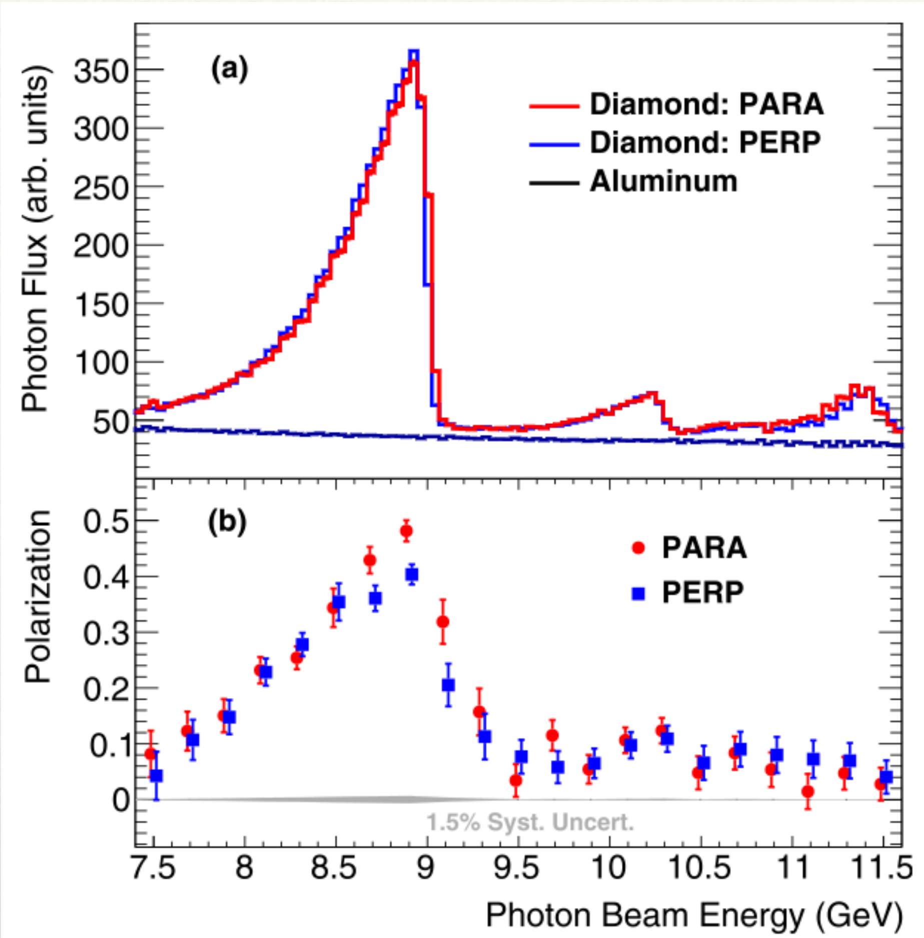
Peter Pauli, on behalf of the GlueX collaboration

The strangeness program at GlueX

University of Glasgow

CEBAF at Jefferson Lab

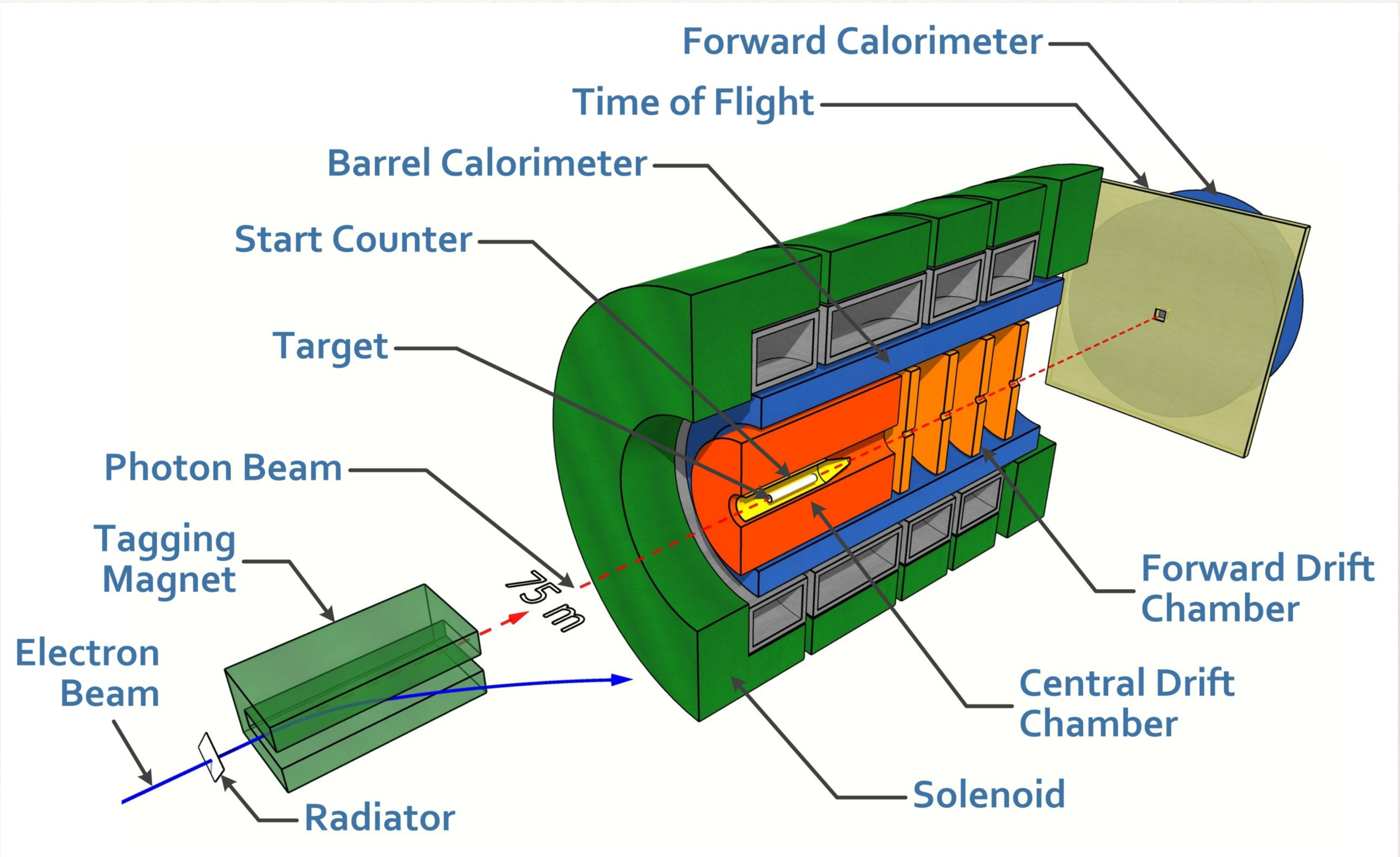
GlueX experiment in Hall D



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

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

- 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: $\sigma_E/E = 6\,\%/\sqrt{E} \oplus 2\,\%$

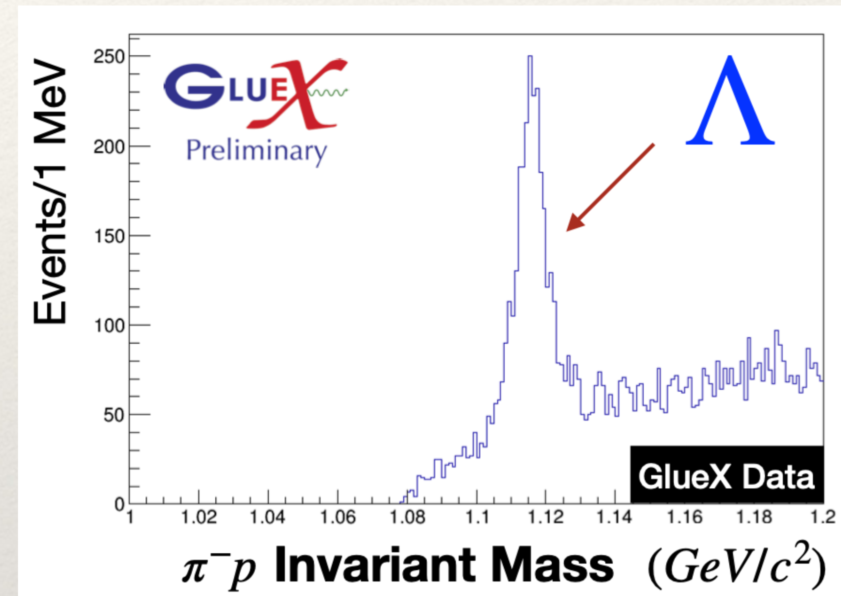
Since 2019: DIRC

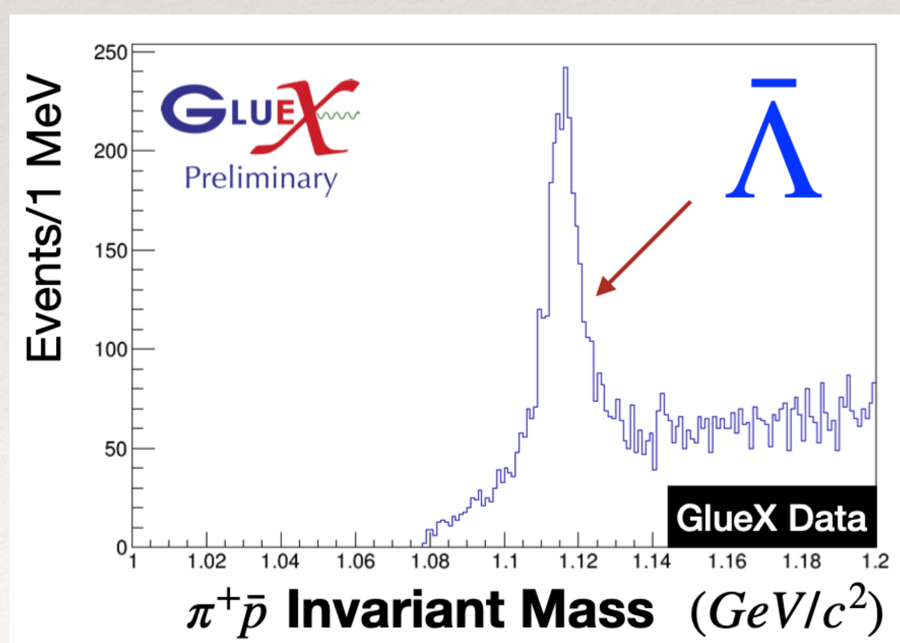
Lambda - anti-Lambda

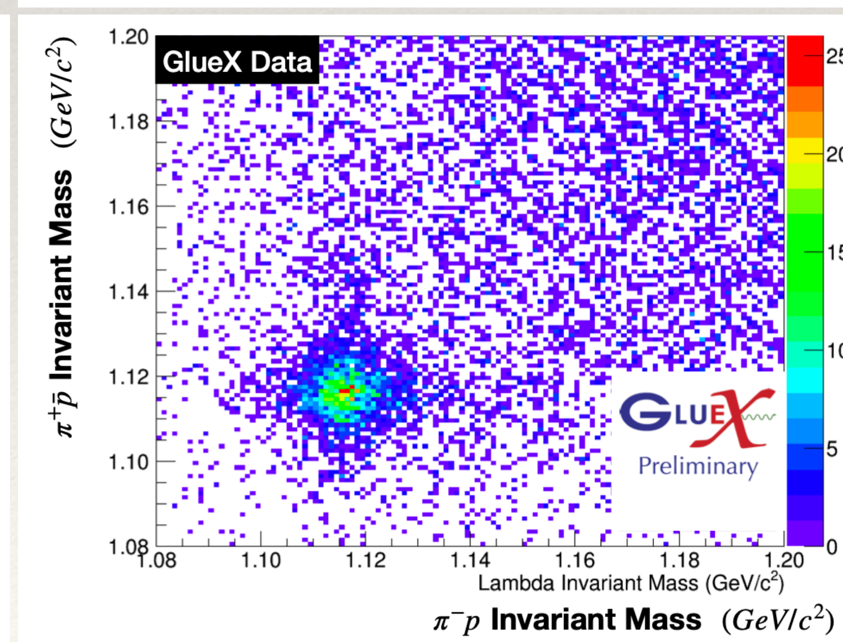
- BESIII saw interesting threshold enhancement

- $\gamma p \rightarrow p\Lambda\bar{\Lambda}\ (\rightarrow p\{p\pi^-\}\{\bar{p}\pi^+\})$
- Study production mechanisms
- Cross-section measurements

- GlueX-I:
  ~400k $\Lambda\bar{\Lambda}$ events

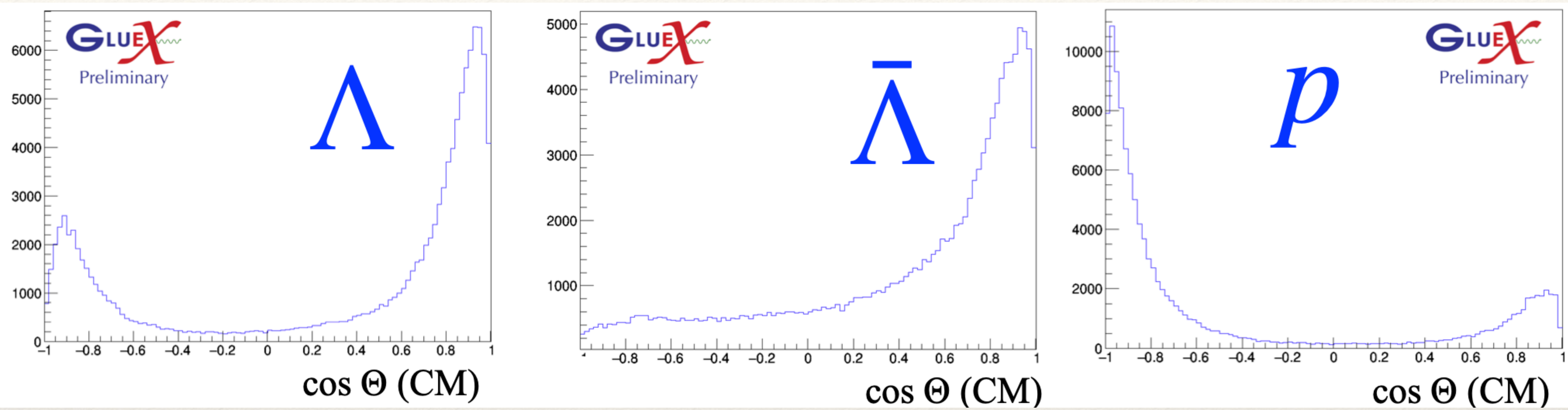


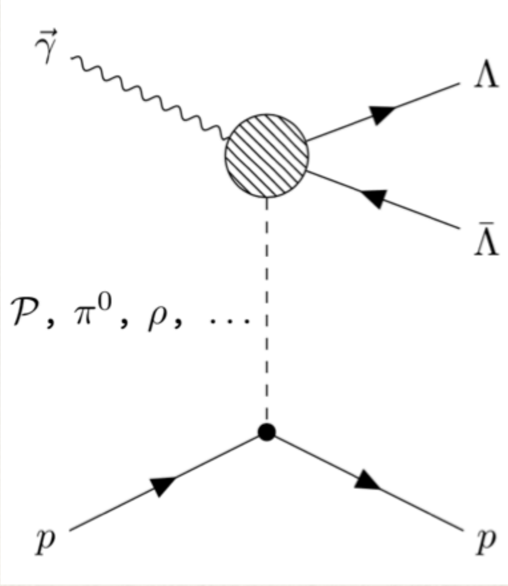




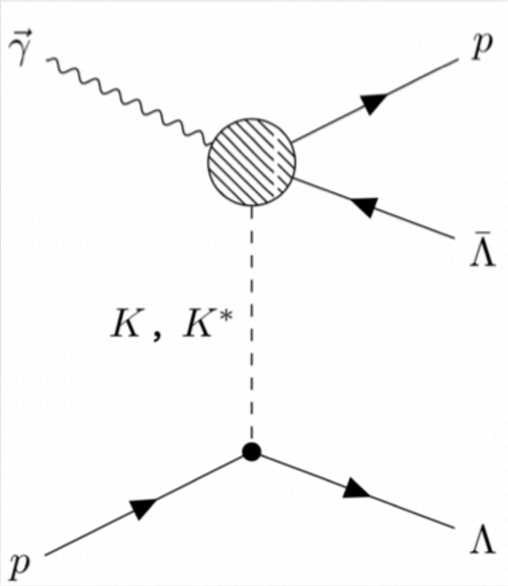
Lambda - anti-Lambda

Hao Li (MENU 2019)

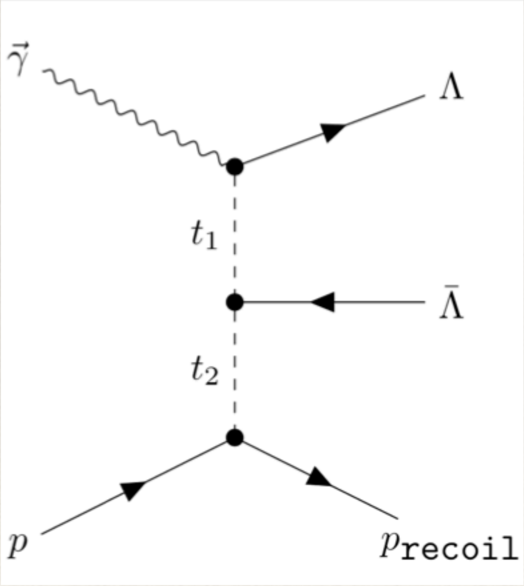




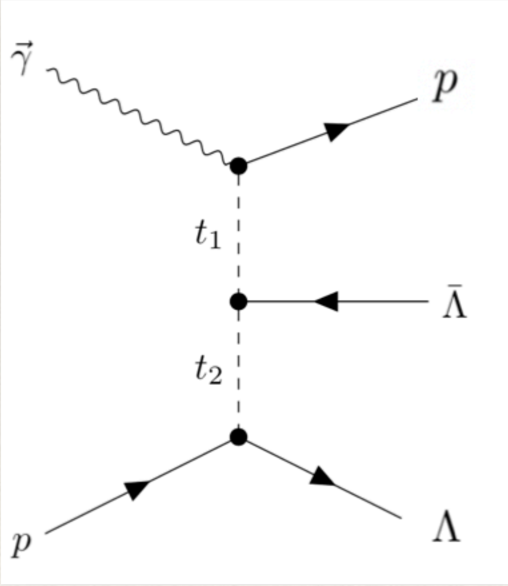
Single Regge I



Single Regge II



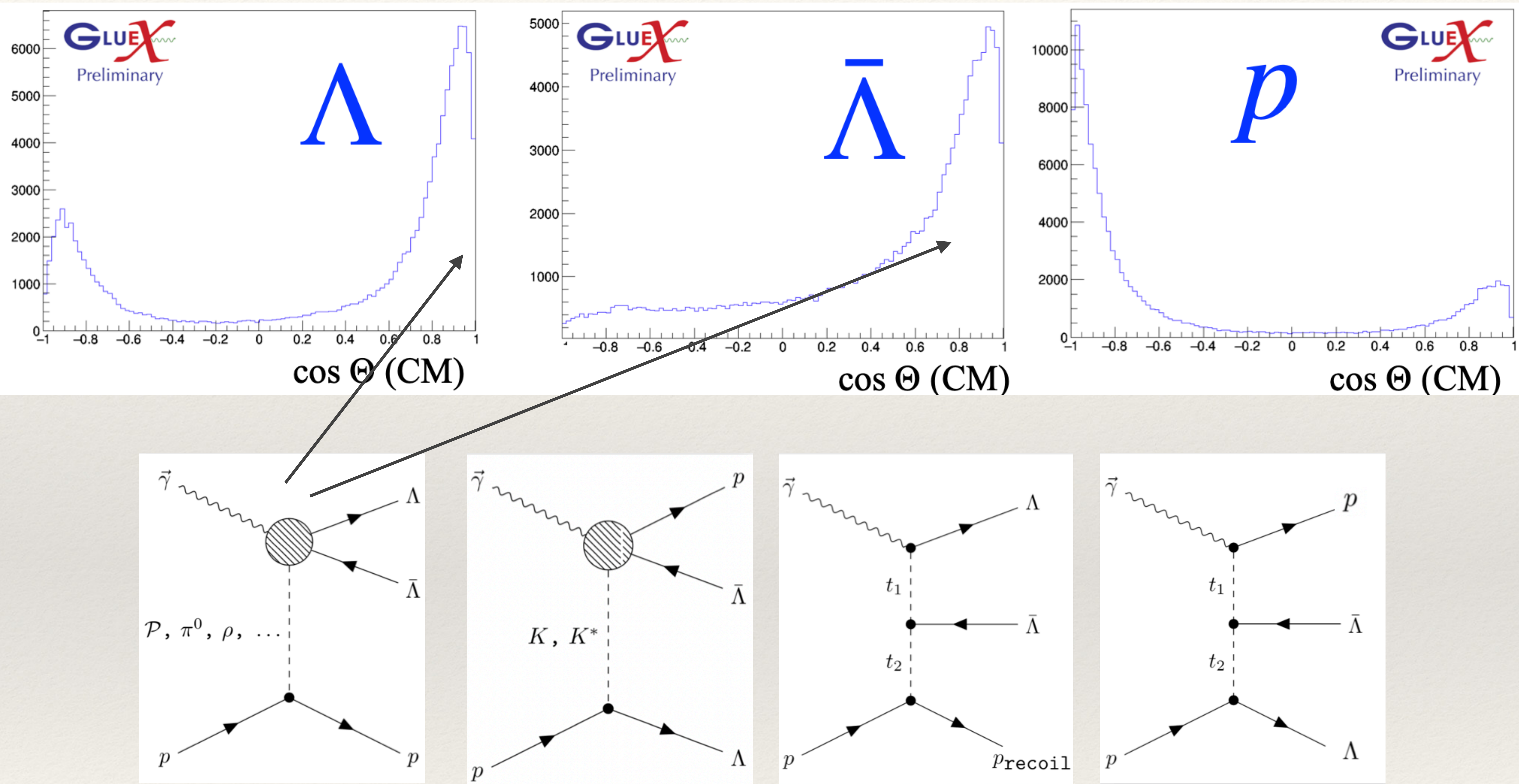
Double Regge I



Double Regge II

Lambda - anti-Lambda

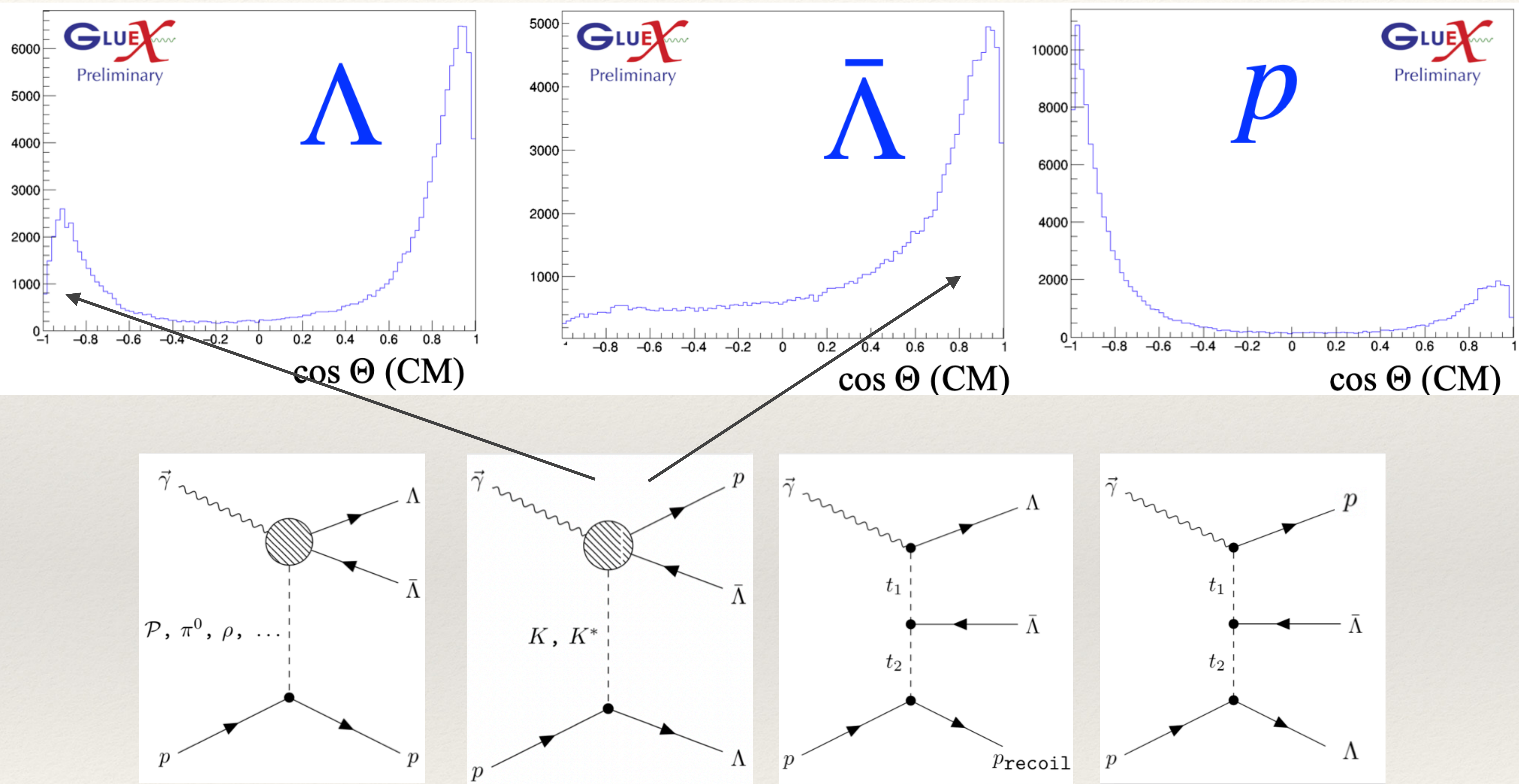
Hao Li (MENU 2019)



Single Regge I   Single Regge II   Double Regge I   Double Regge II

Lambda - anti-Lambda

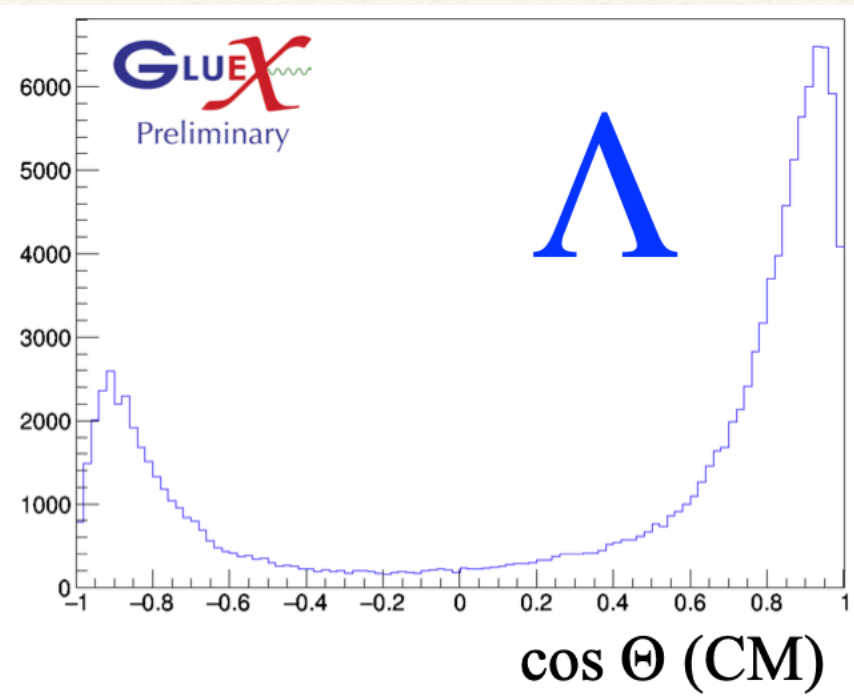
Hao Li (MENU 2019)

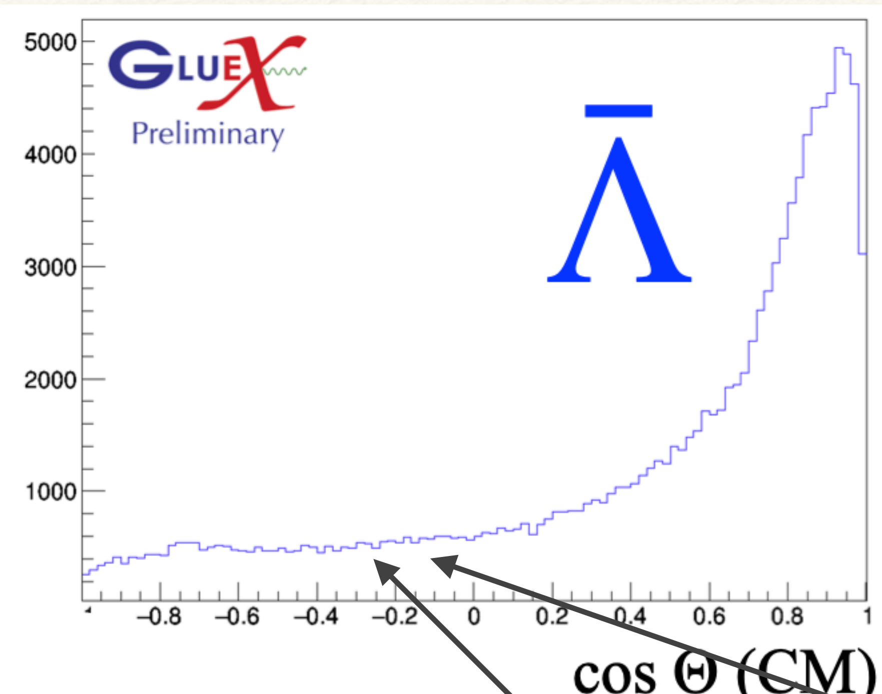


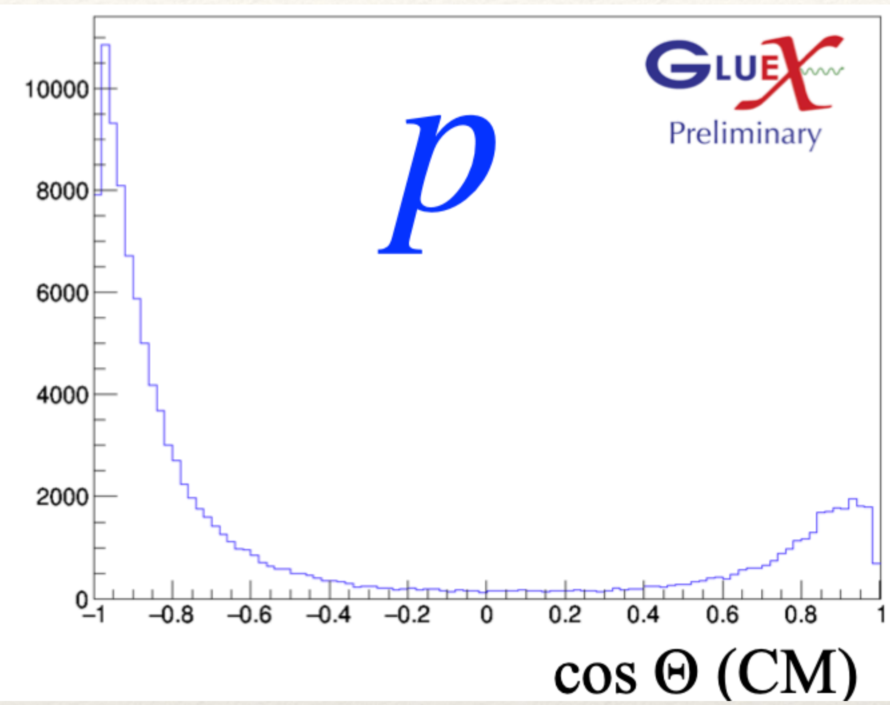
Single Regge I | Single Regge II | Double Regge I | Double Regge II

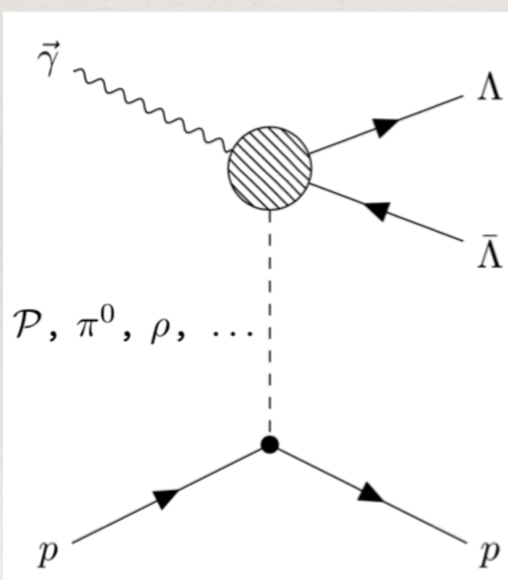
Lambda - anti-Lambda

Hao Li (MENU 2019)

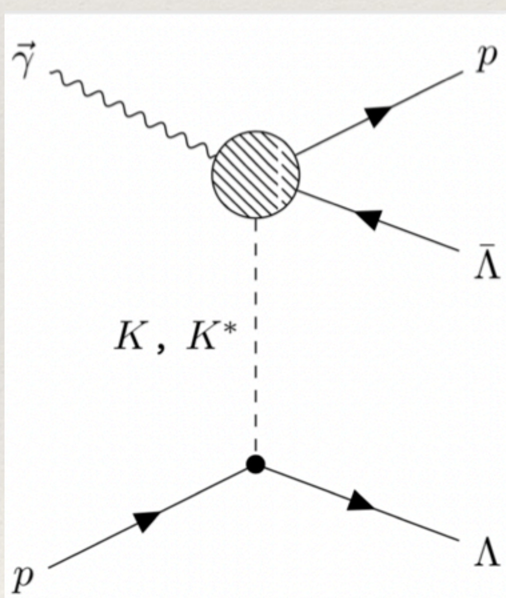




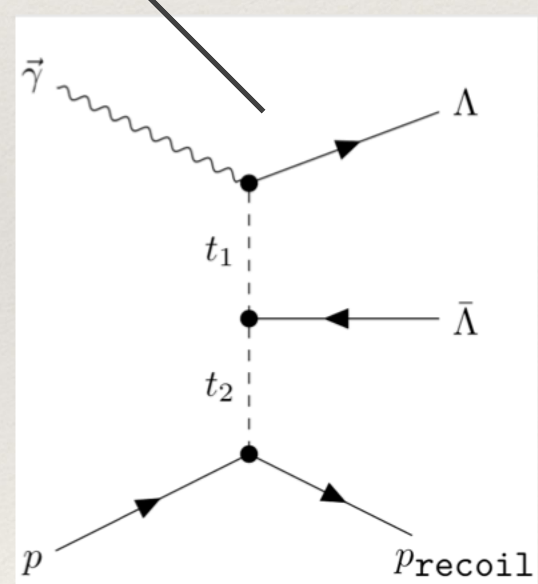




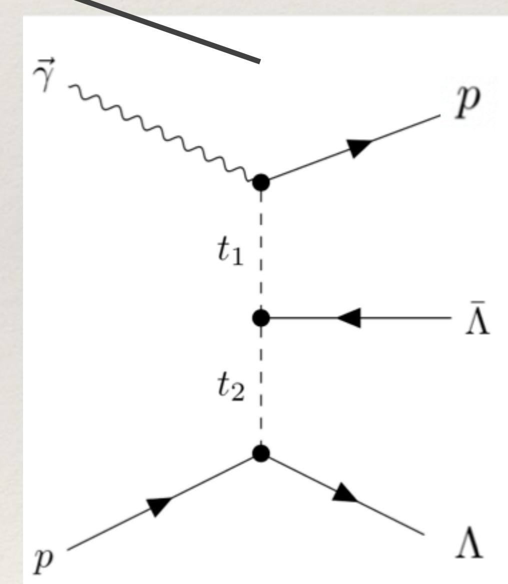
Single Regge I



Single Regge II



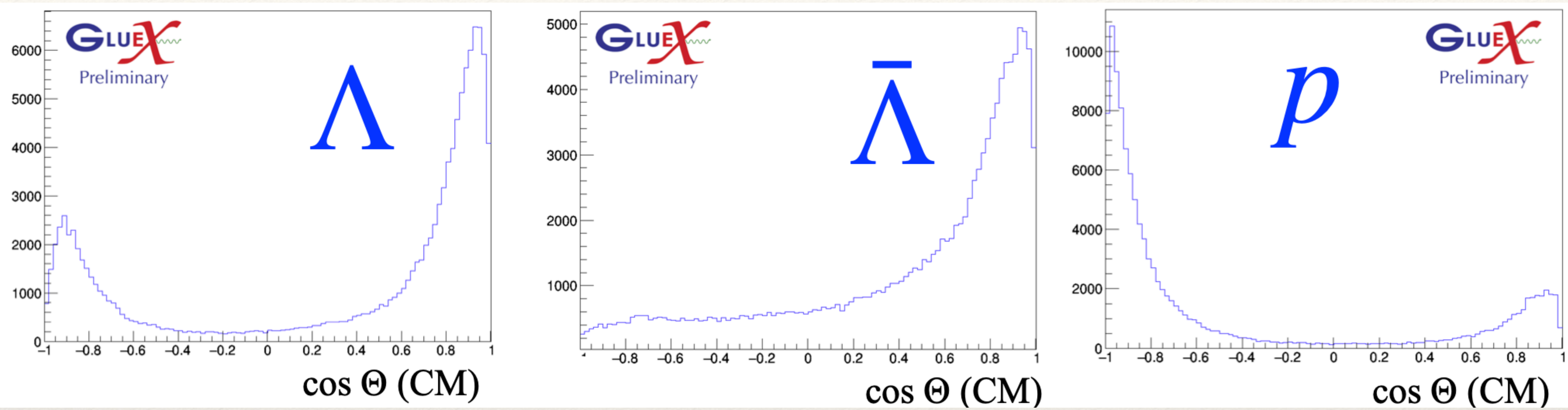
Double Regge I

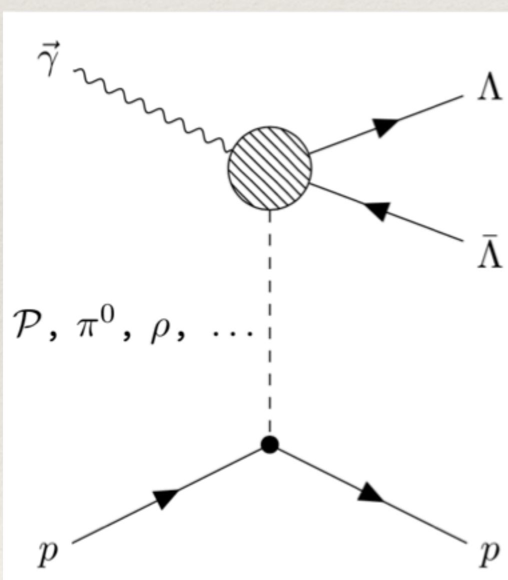


Double Regge II

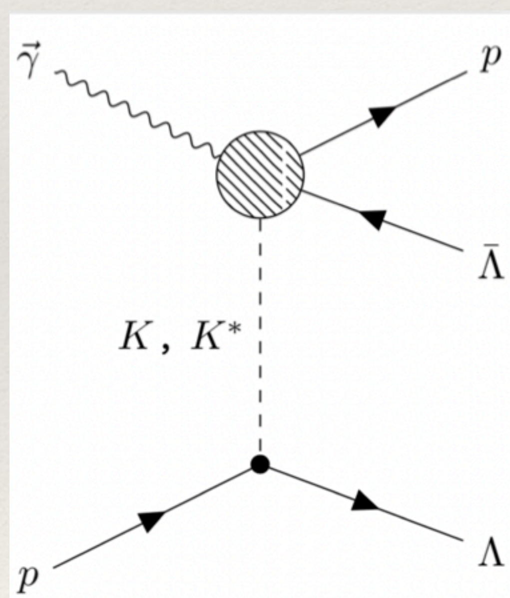
Lambda - anti-Lambda

Hao Li (MENU 2019)

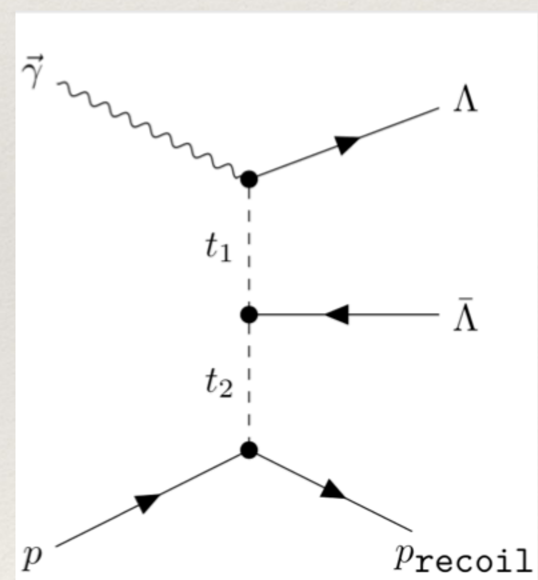




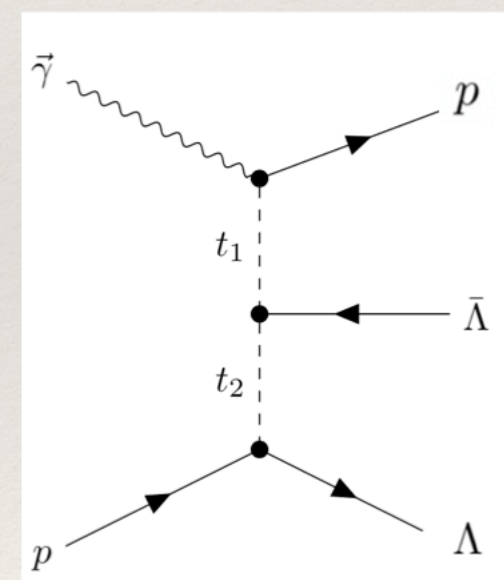
Single Regge I



Single Regge II

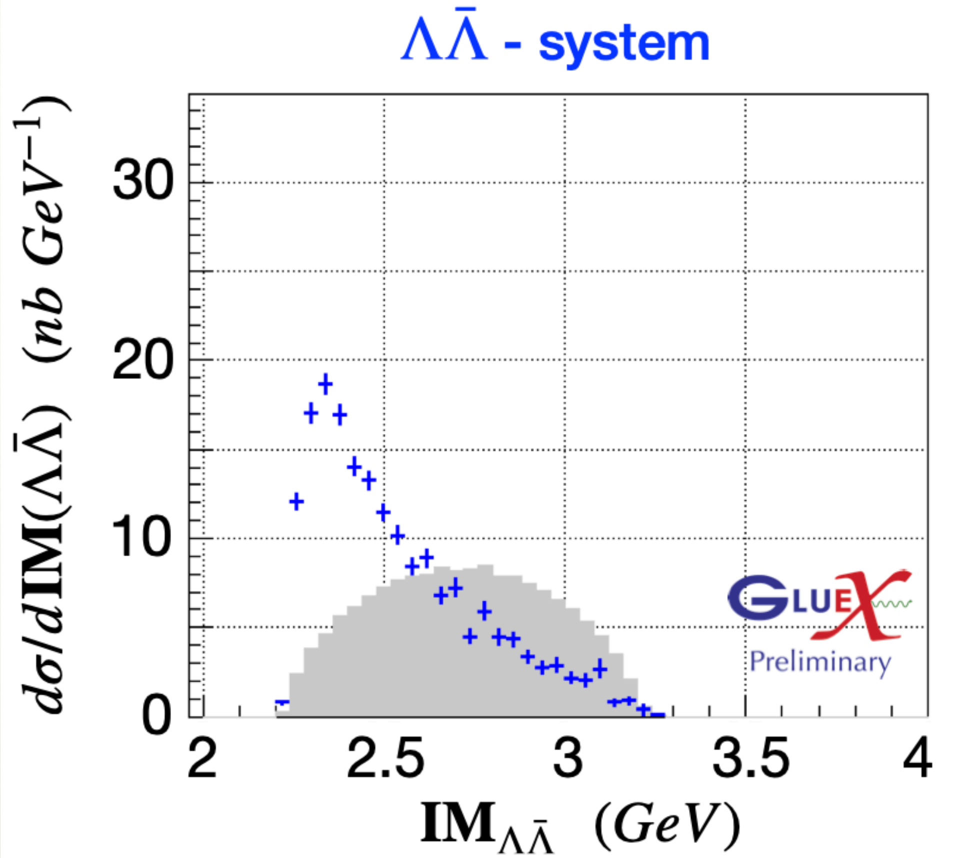


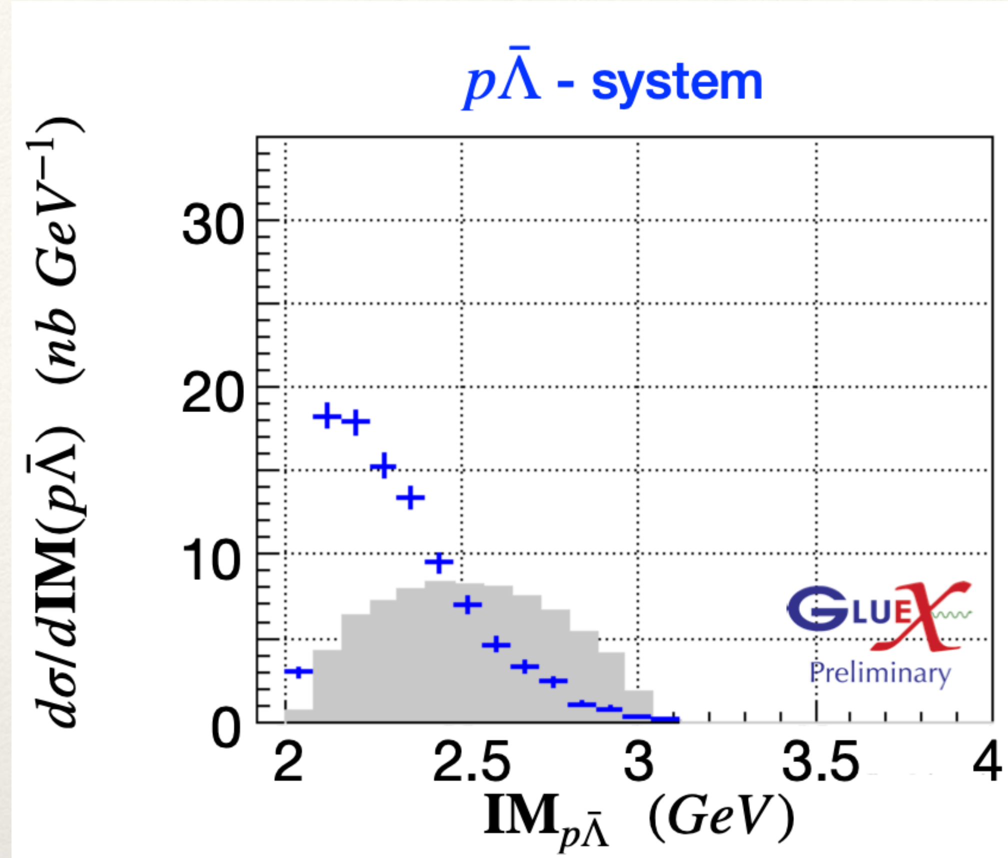
Double Regge I

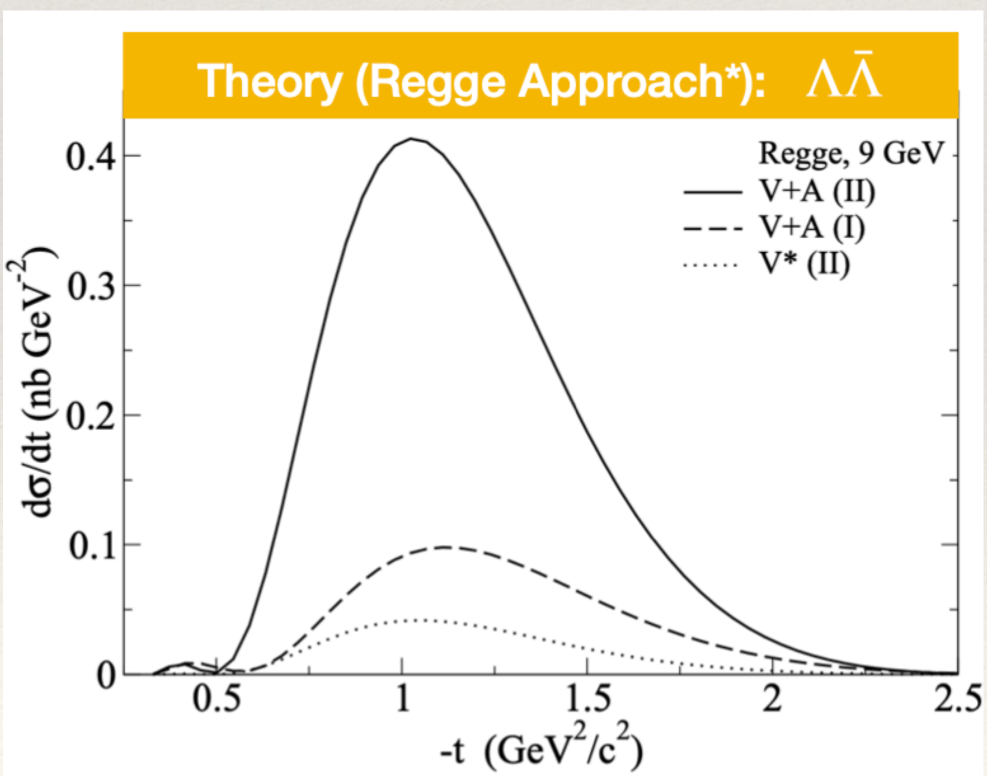


Double Regge II

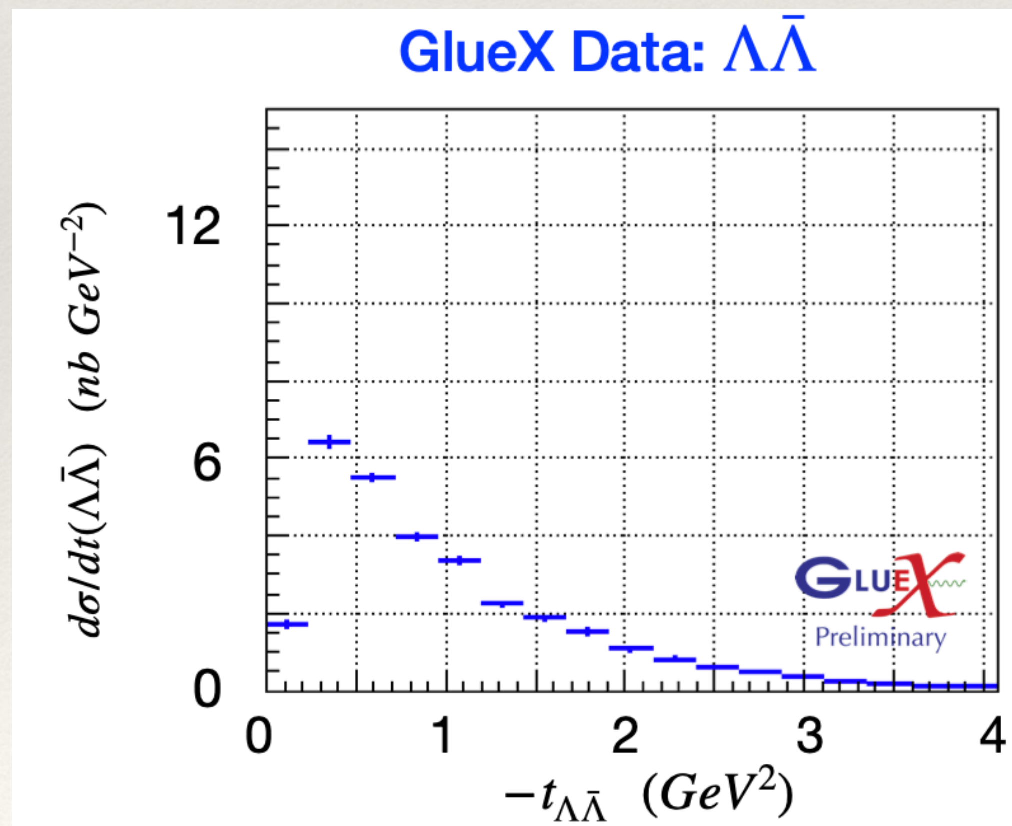
Lambda - anti-Lambda







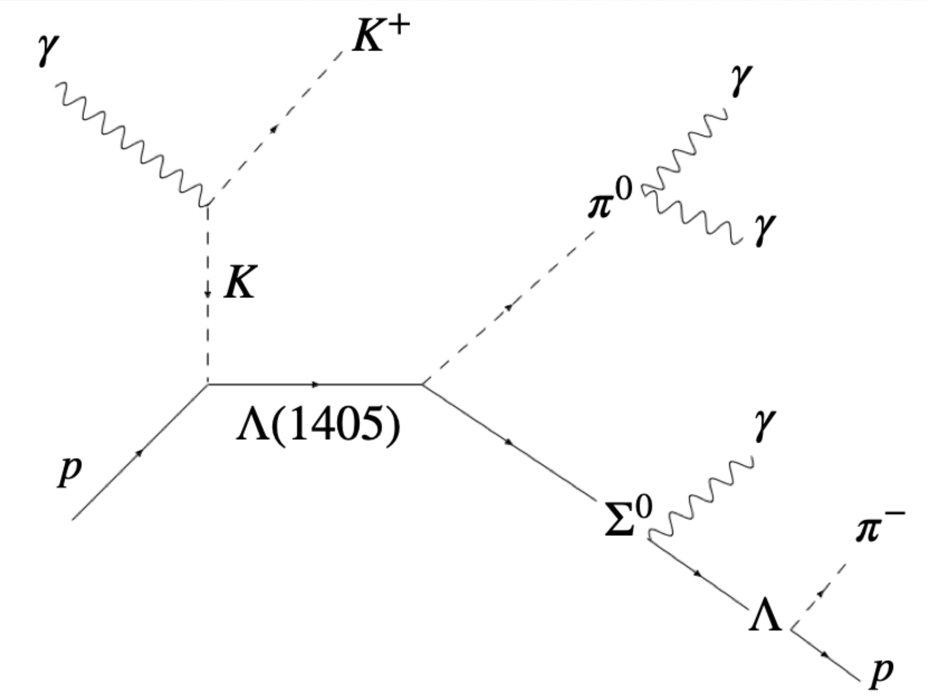
*Gutsche, Thomas, et al. Physical Review D 96(5) (2017) 054024.



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

$\Lambda(1405)$ line shape measurement

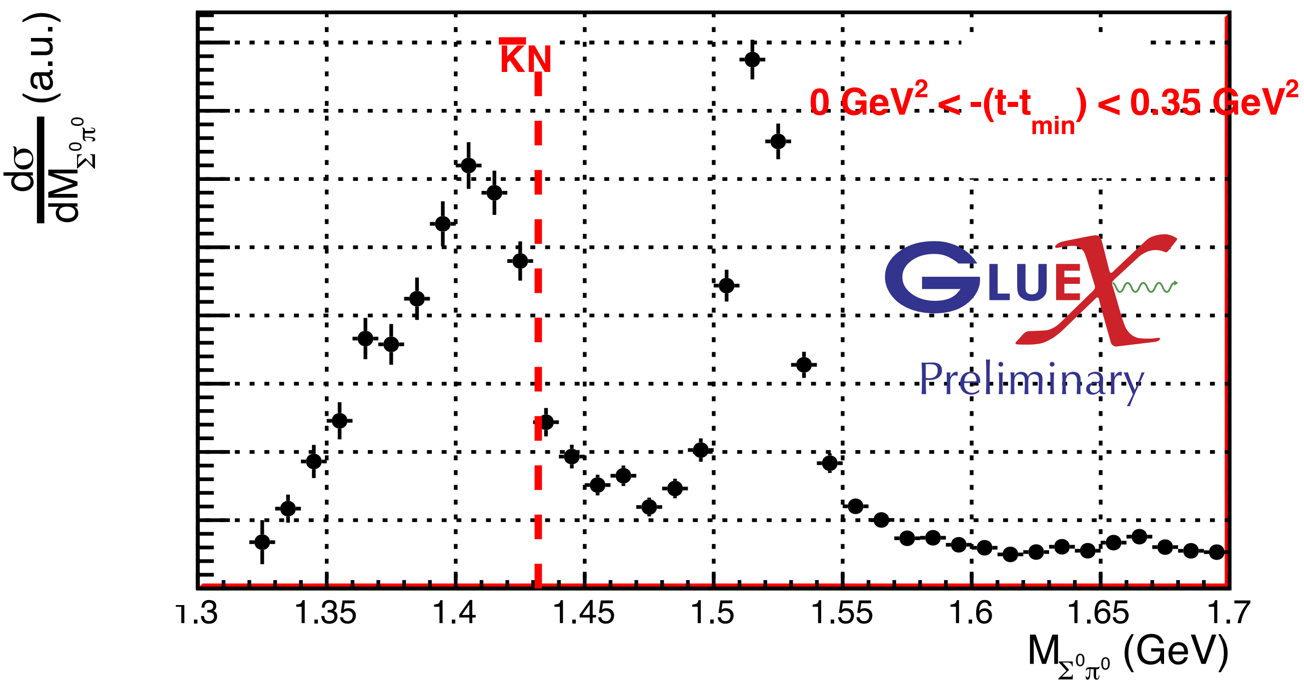
N. Wickramaarachchi (Fri-II)

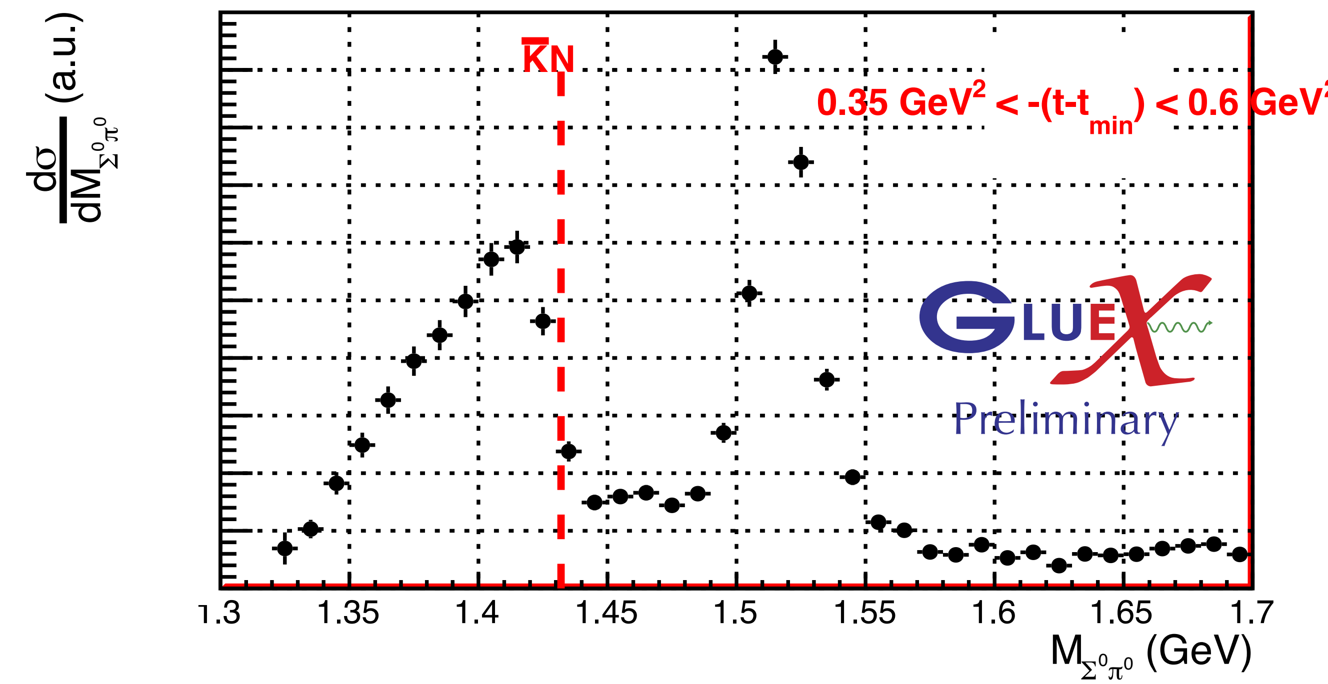


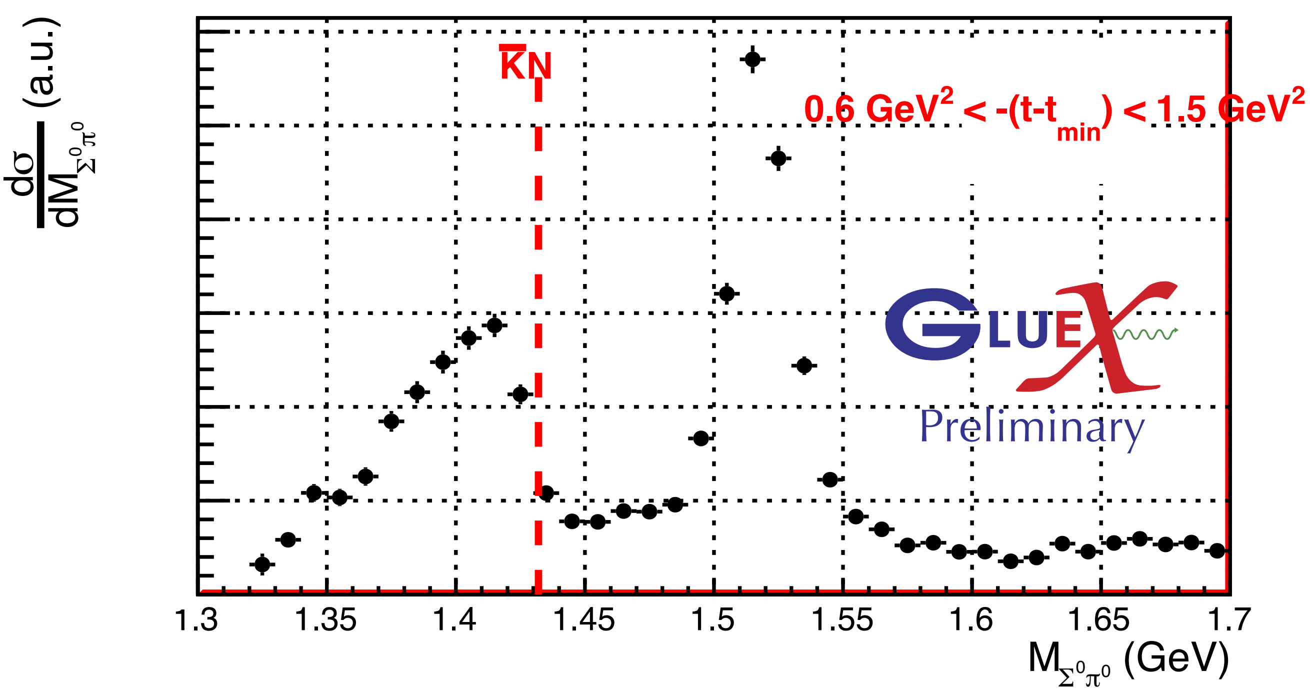
$\Lambda(1405) \to \Sigma^0\pi^0$ $(I = 0)$ is free from $\Sigma(1385)$ background

- 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



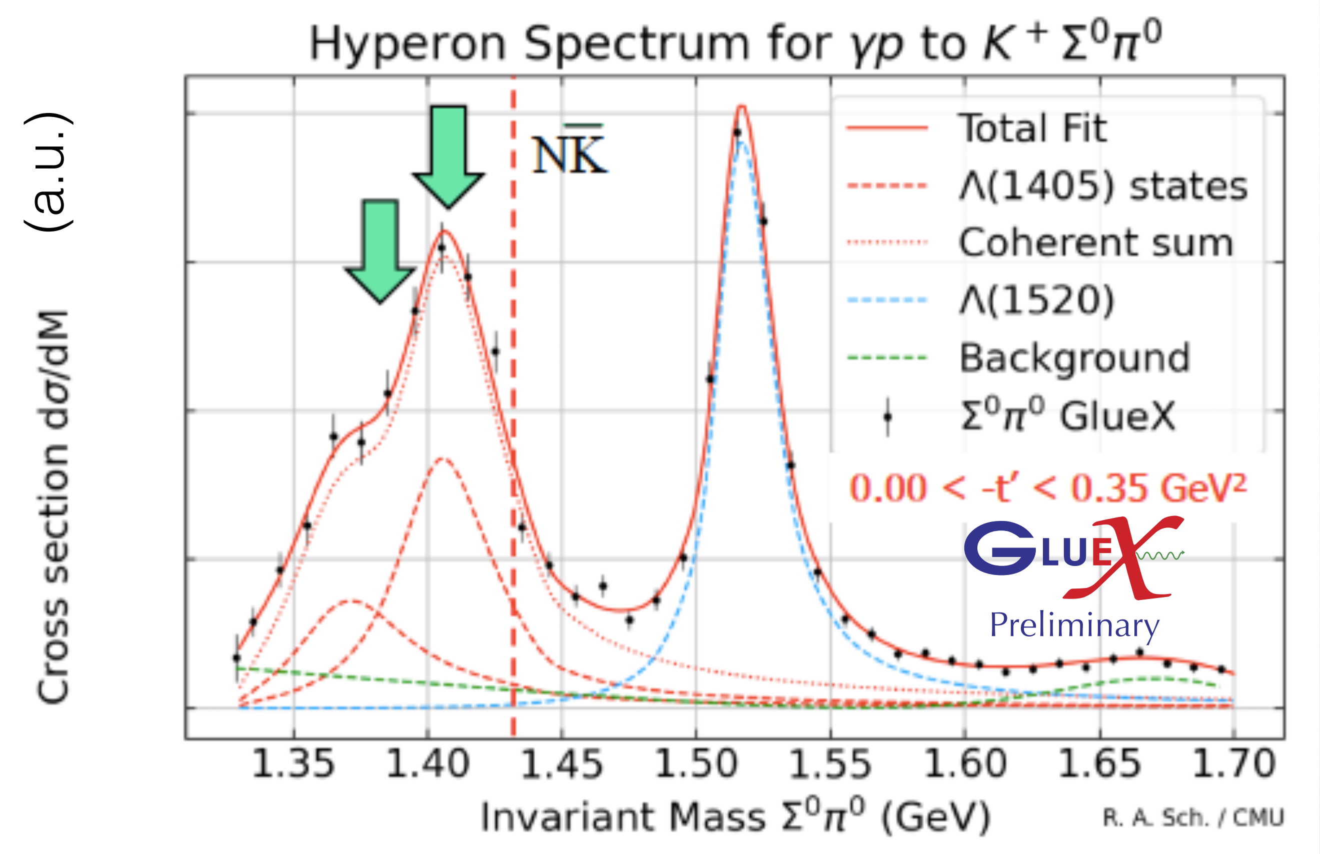


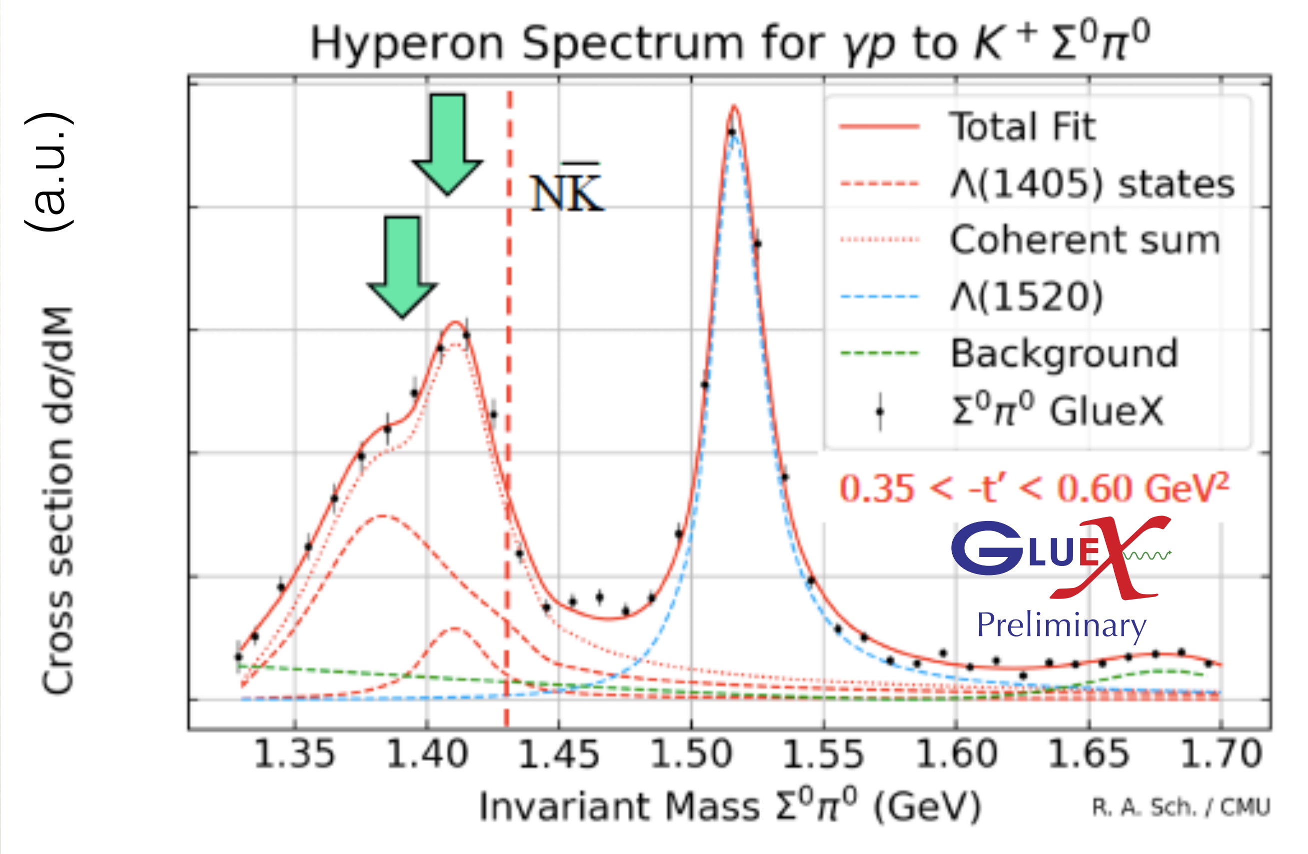


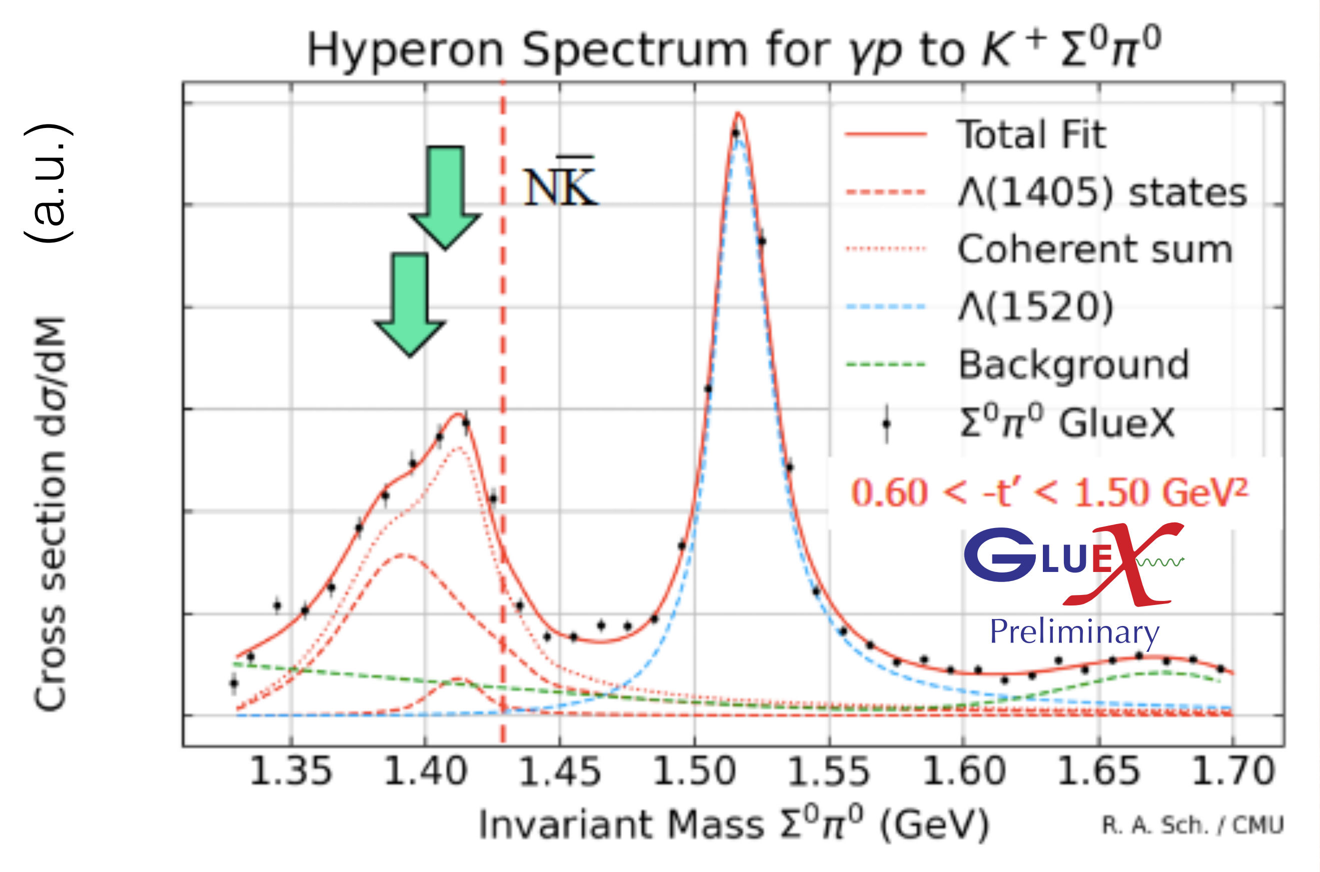
- Λ(1405) t-dependent line shape?
- Could support two-pole structure

Λ(1405) line shape measurement

N. Wickramaarachchi (Fri-II)





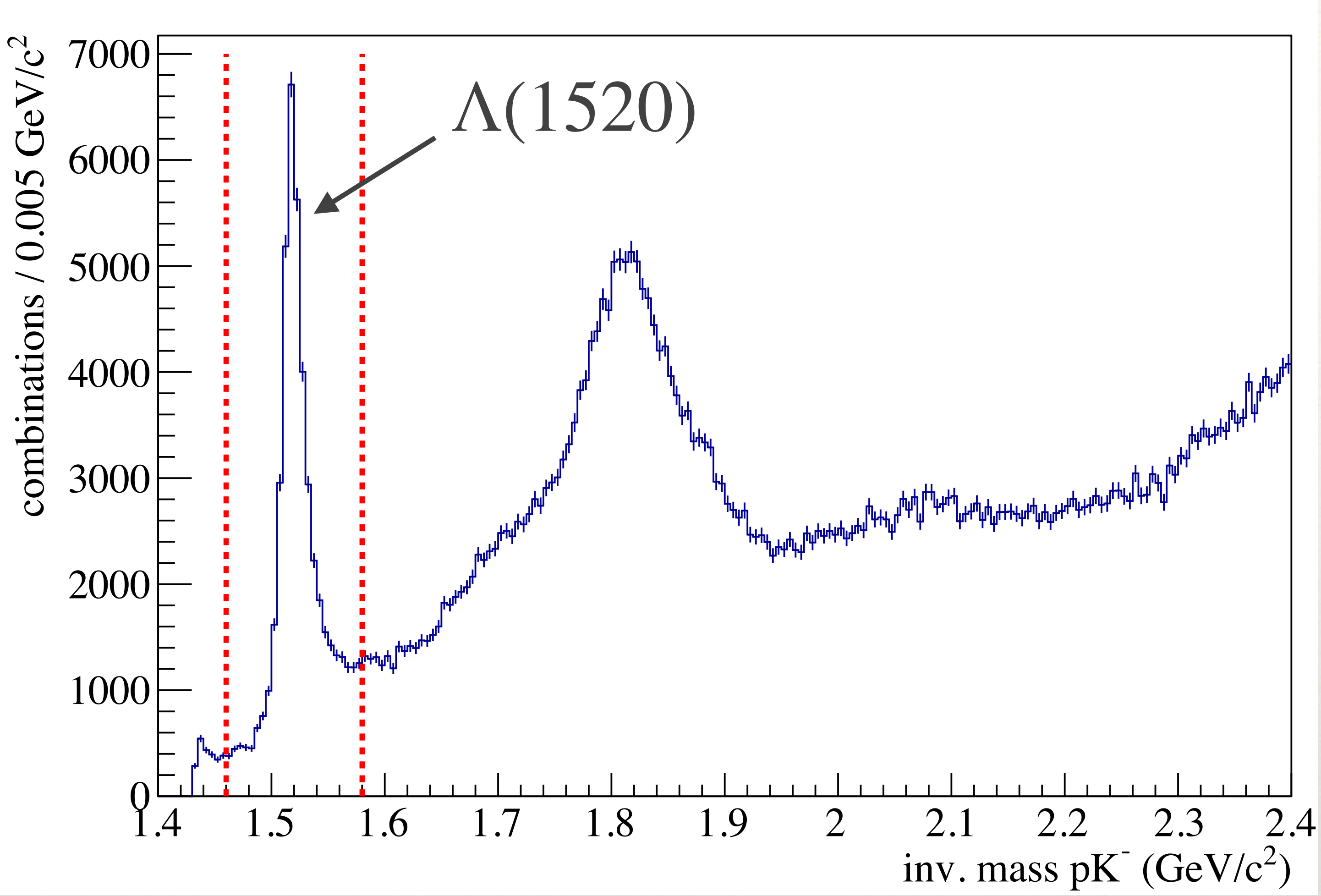


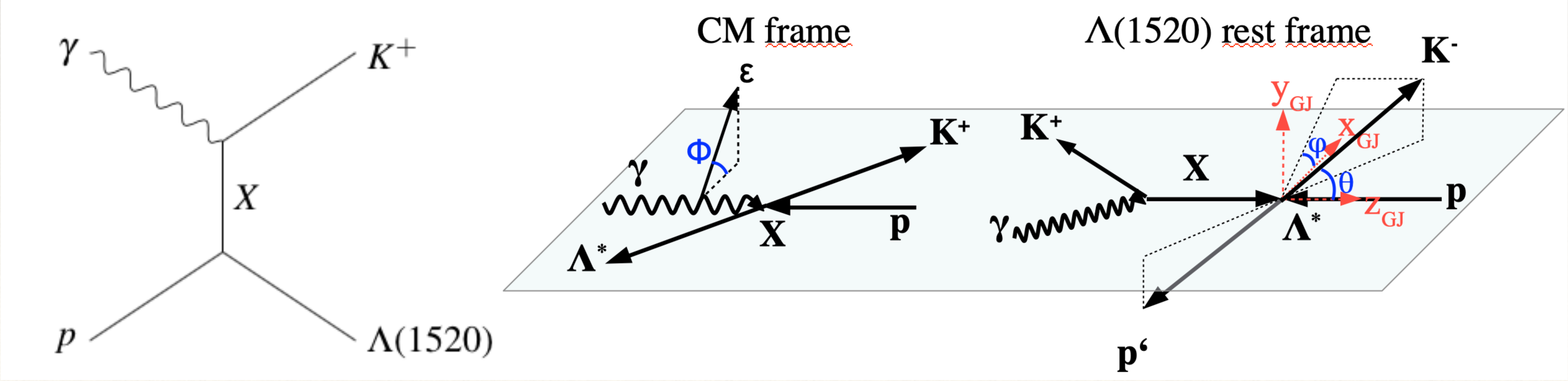
- Fit of two coherent Flatté amplitudes, incoherent Λ(1520) and backgrounds
- Preliminary fit results support two-pole structure

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

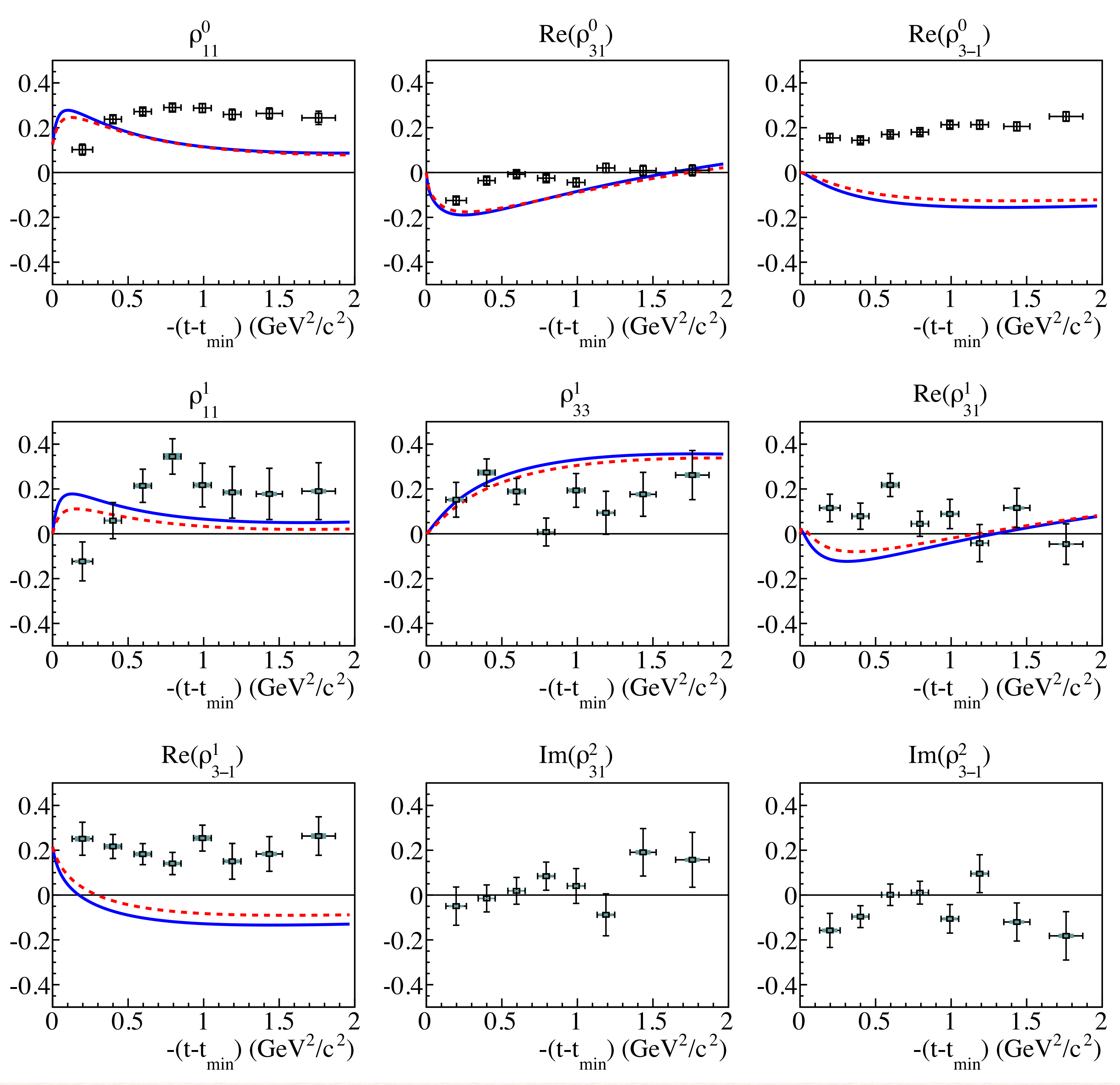




Λ(1520) SDMEs

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

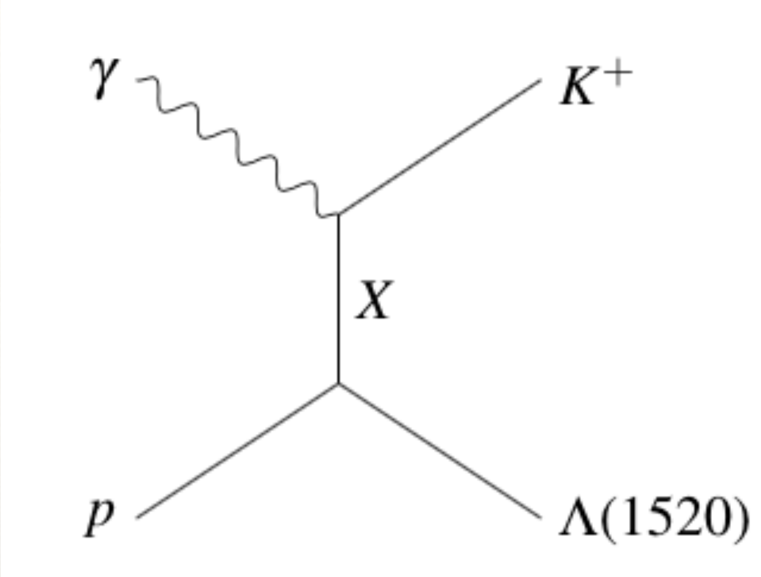


[1] *Byung-Geel Yu and Kook-Jin Kong, Phys. Rev. C* ***96****, 025208 (2017)*

Λ(1520) SDME Interpretation

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

- to help with interpretation form combinations of SDMEs which correspond to purely natural (N) and purely unnatural (U) exchange amplitudes



X is exchange particle with spin-parity quantum number J^P and naturality $\eta = P(-1)^J$

Natural: e.g. $K^*(892)$, $K_2^*(1430)$

Unnatural: e.g. $K(492)$, $K_1(1270)$

$$\rho^0_{11} + \rho^1_{11} = \frac{2}{N}(|N_0|^2 + |N_1|^2) \qquad \mathrm{Re}(\rho^0_{31} + \rho^1_{31}) = \frac{2}{N}(N_{-1}N_0^* - N_2N_1^*)$$

$$\rho^0_{11} - \rho^1_{11} = \frac{2}{N}(|U_0|^2 + |U_1|^2) \qquad \mathrm{Re}(\rho^0_{31} - \rho^1_{31}) = \frac{2}{N}(U_{-1}U_0^* - U_2U_1^*)$$

$$\rho^0_{33} + \rho^1_{33} = \frac{2}{N}(|N_{-1}|^2 + |N_2|^2) \qquad \mathrm{Re}(\rho^0_{3-1} + \rho^1_{3-1}) = \frac{2}{N}(N_{-1}N_1^* + N_2N_0^*)$$

$$\rho^0_{33} - \rho^1_{33} = \frac{2}{N}(|U_{-1}|^2 + |U_2|^2) \qquad \mathrm{Re}(\rho^0_{3-1} - \rho^1_{3-1}) = \frac{2}{N}(U_{-1}U_1^* + U_2U_0^*)$$

$$N = 2(|N_{-1}|^2 + |N_0|^2 + |N_1|^2 + |N_2|^2 + |U_{-1}|^2 + |U_0|^2 + |U_1|^2 + |U_2|^2)$$

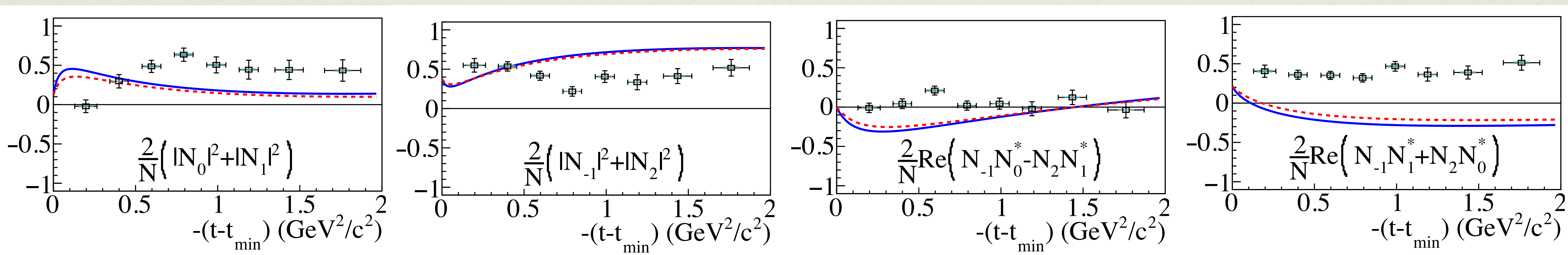
work by V. Mathieu (JPAC)

Λ(1520) SDME Interpretation

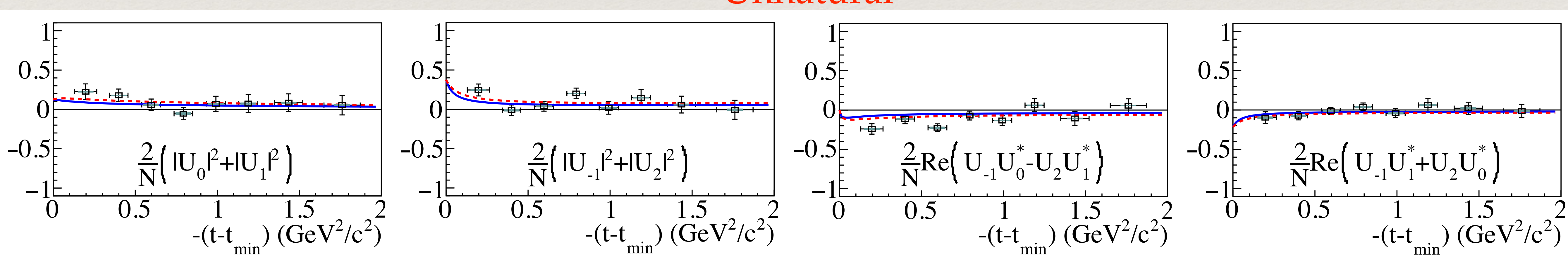
PP (Phys. Rev. C **105**, 035201)

- red and blue show combinations of previous model [1]
- natural amplitudes dominate
- More work needed to model the reaction accurately

Natural



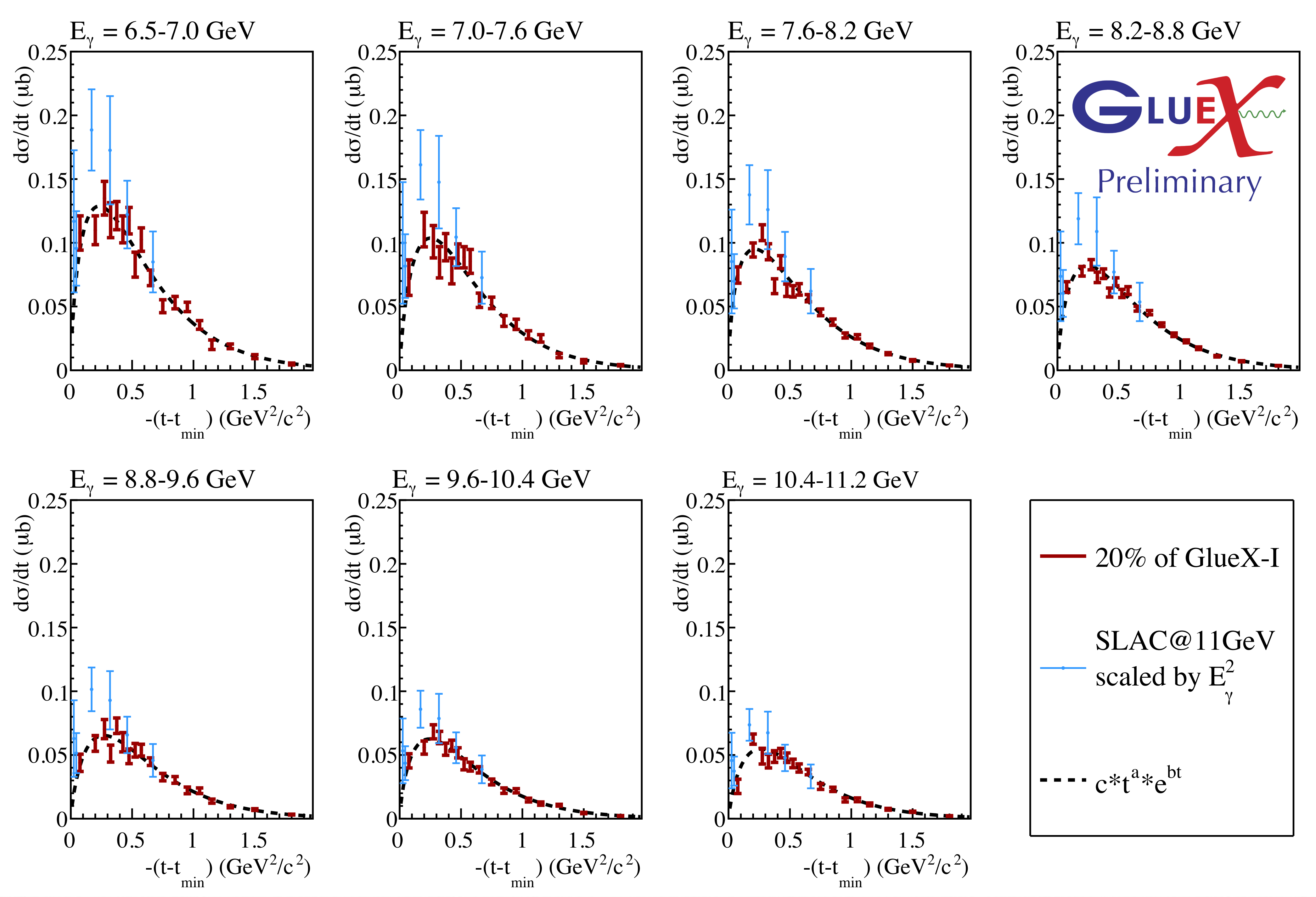
Unnatural



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

Λ(1520) cross-sections

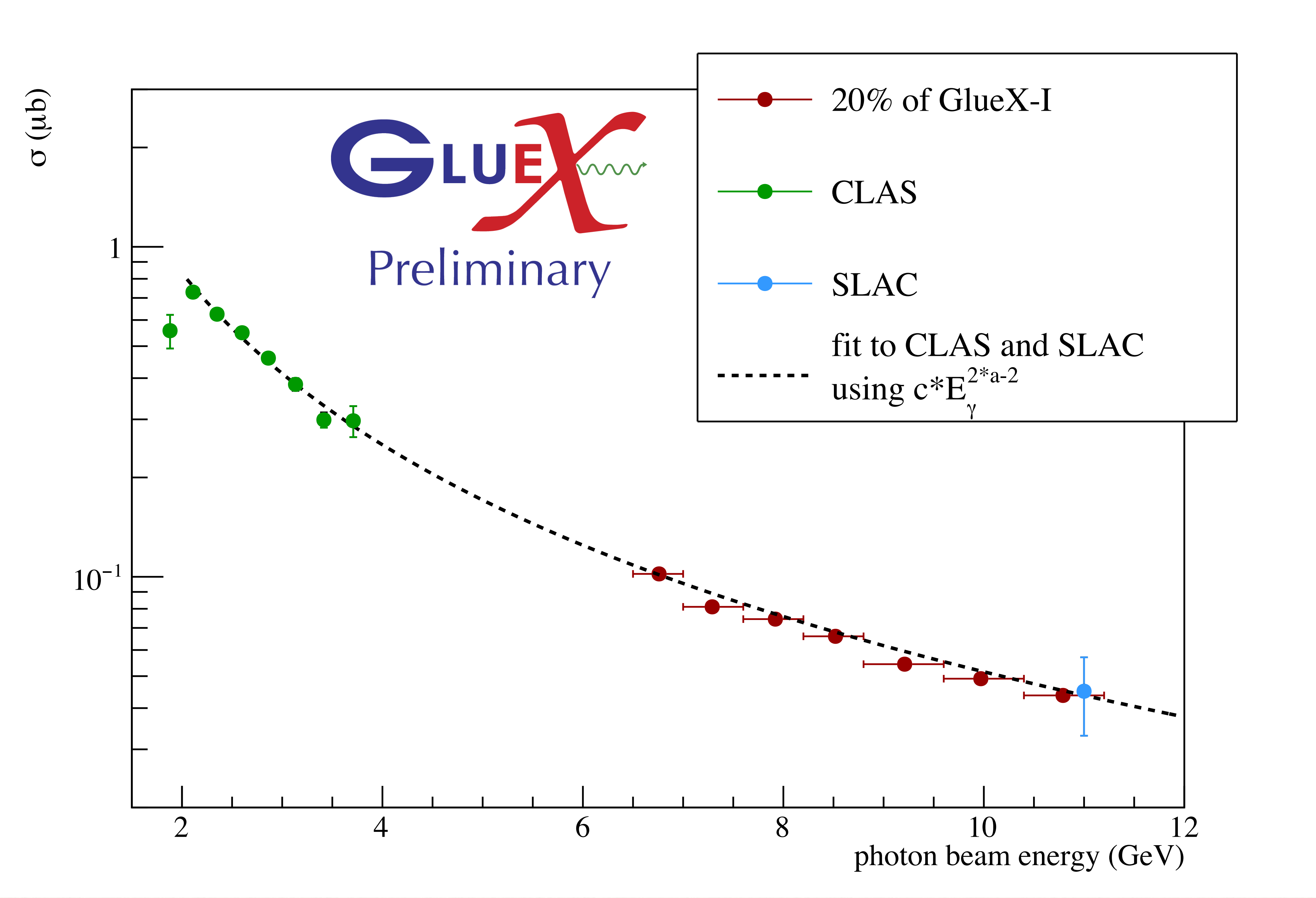
- To get full picture of production we need couplings: measure cross-sections
- Fit t-distribution and integrate to get "total cross-section"



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

Λ(1520) cross-sections

- 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

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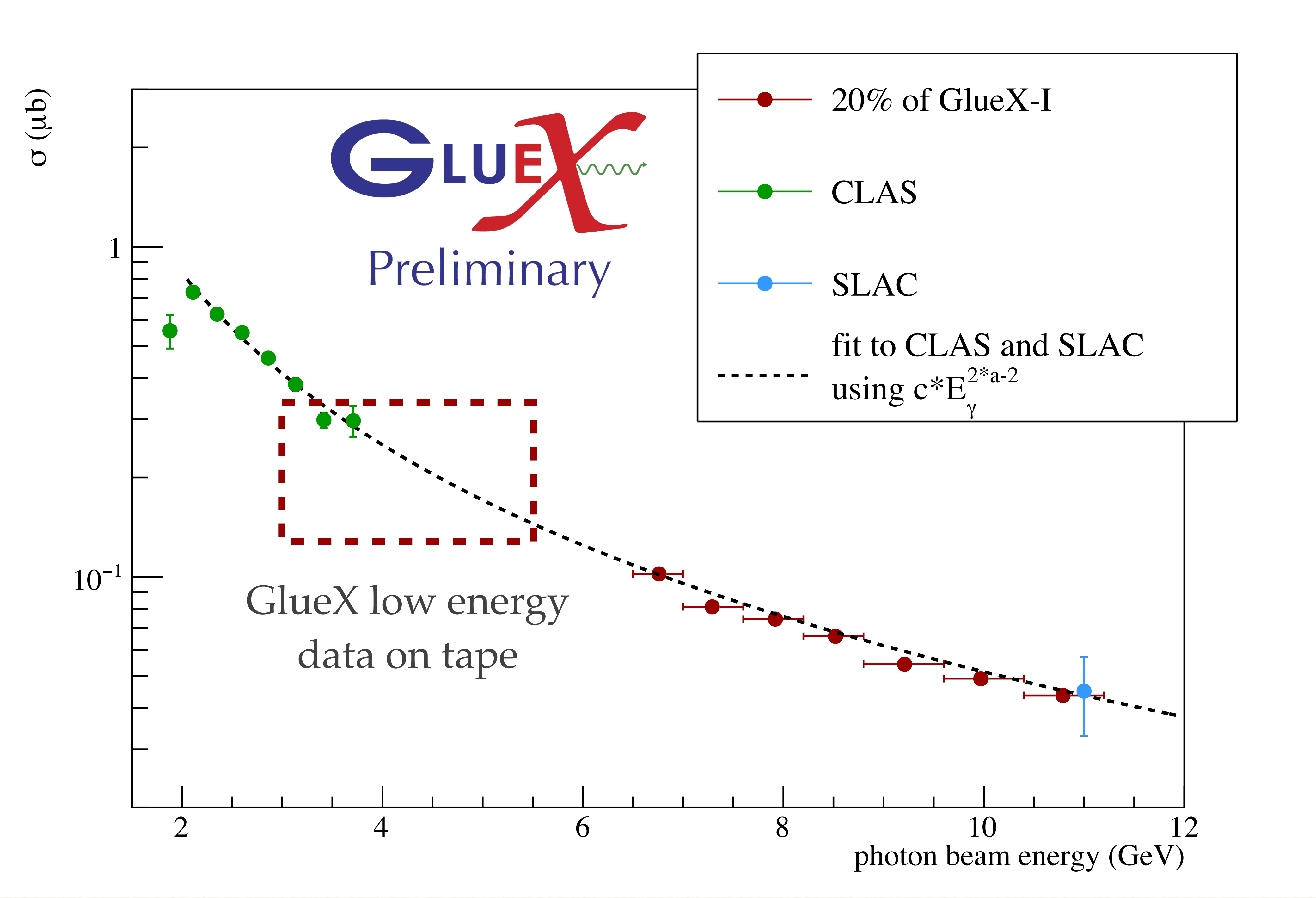


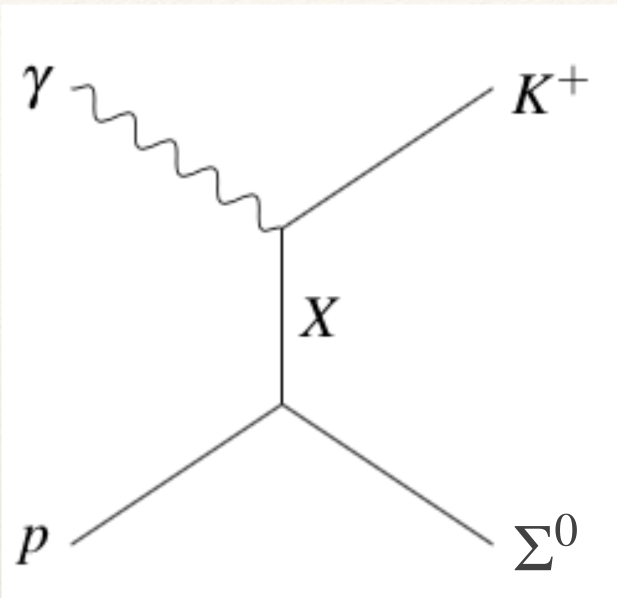
CLAS, *Phys. Rev. C* **88** (2013) 045201

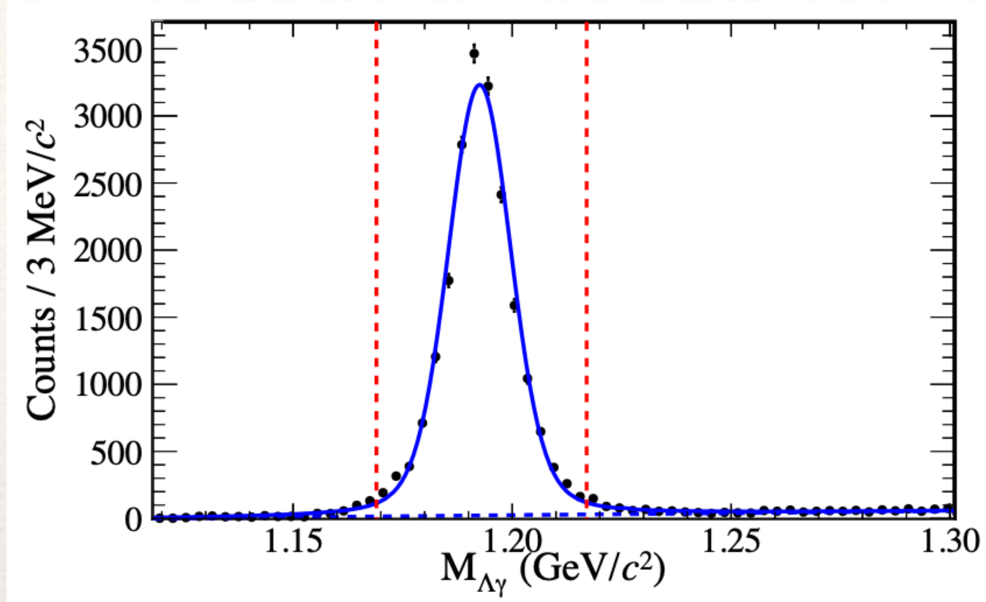
SLAC, *Phys. Lett. B* **34** (1971) 547-550

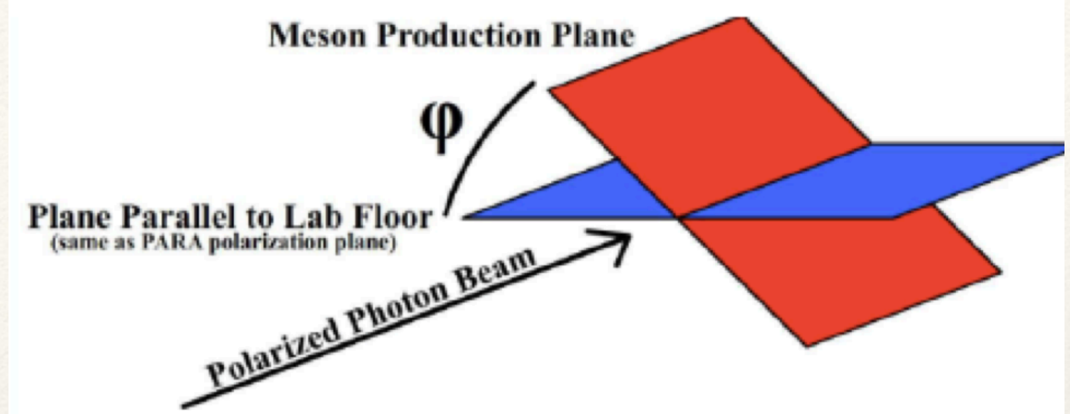
$K^+\Sigma^0$ beam asymmetry

Phys. Rev. C **101**, 065206

$\gamma p \to K^+\Sigma^0 \to K^+\Lambda\gamma \to K^+ p\pi^-\gamma$





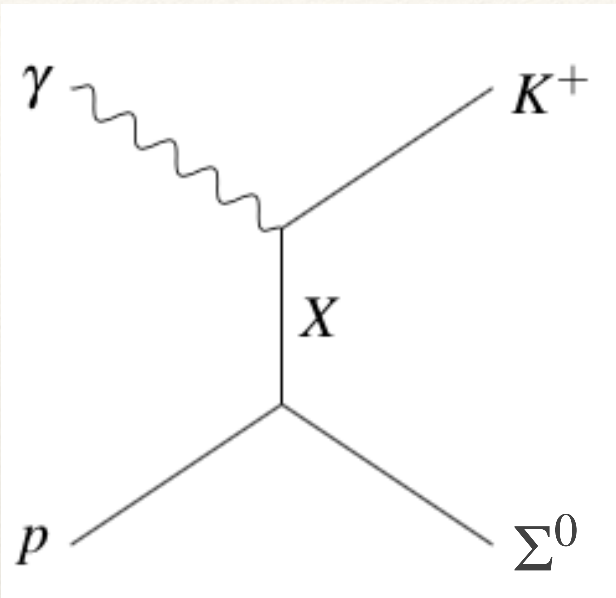


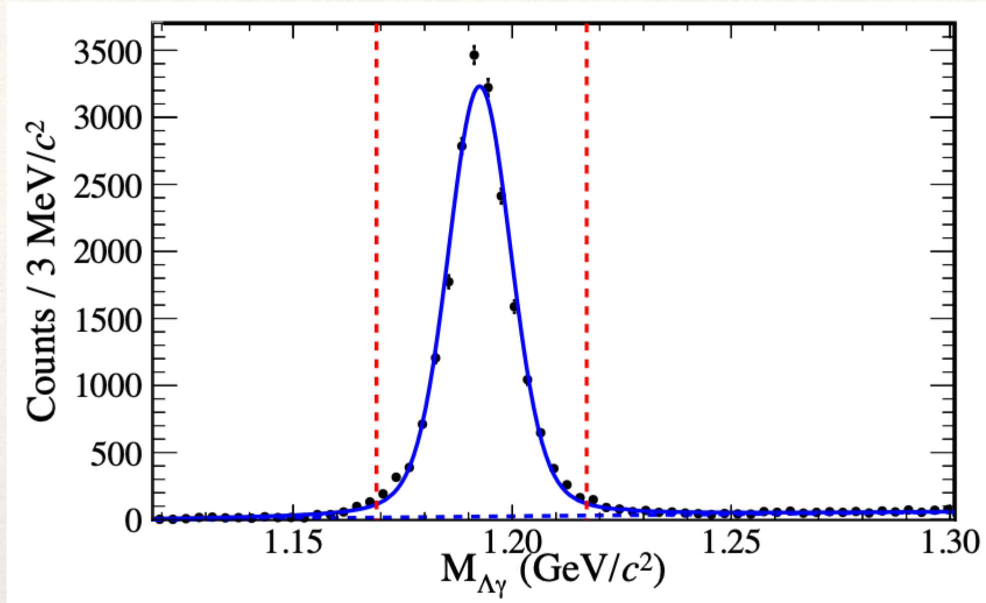
$$\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma\cos 2\phi}{2 + (P_\perp - P_\parallel)\Sigma\cos 2\phi}$$

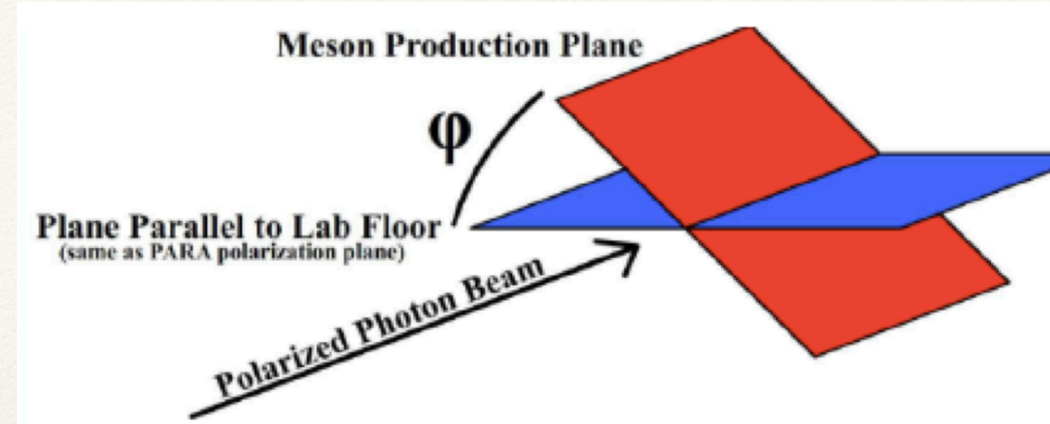
$K^+\Sigma^0$ beam asymmetry

Phys. Rev. C **101**, 065206

$\gamma p \to K^+\Sigma^0 \to K^+\Lambda\gamma \to K^+p\pi^-\gamma$







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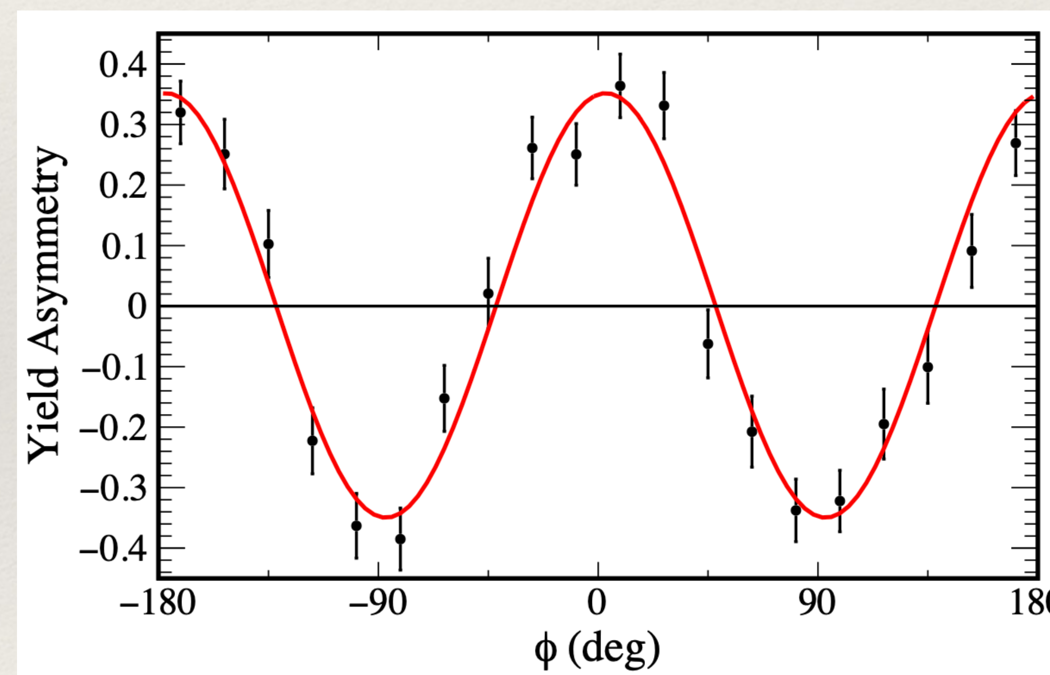
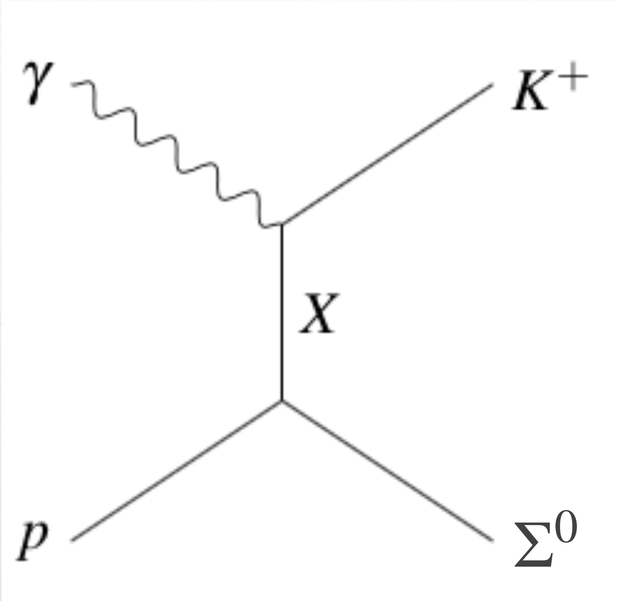
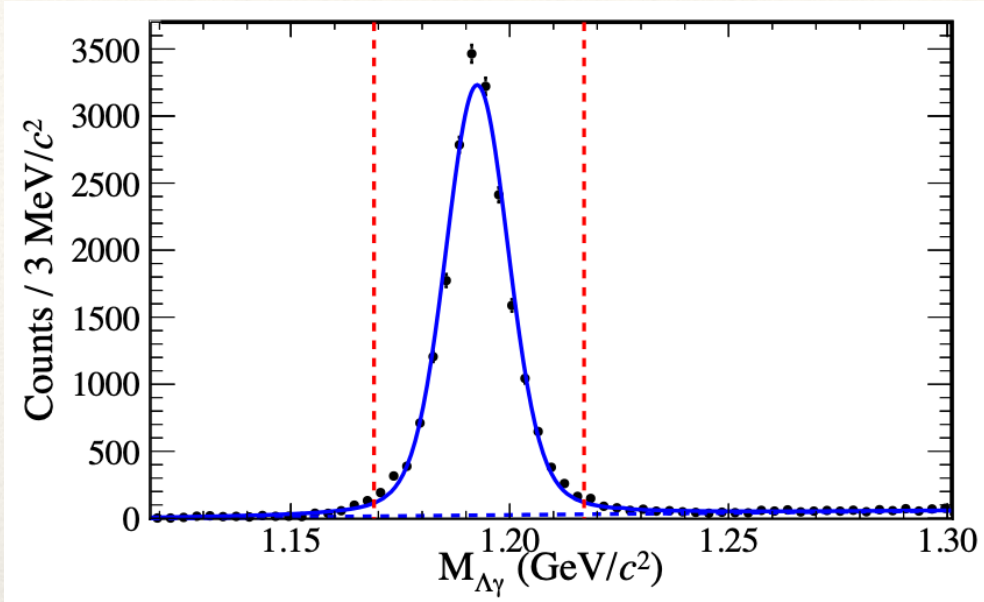


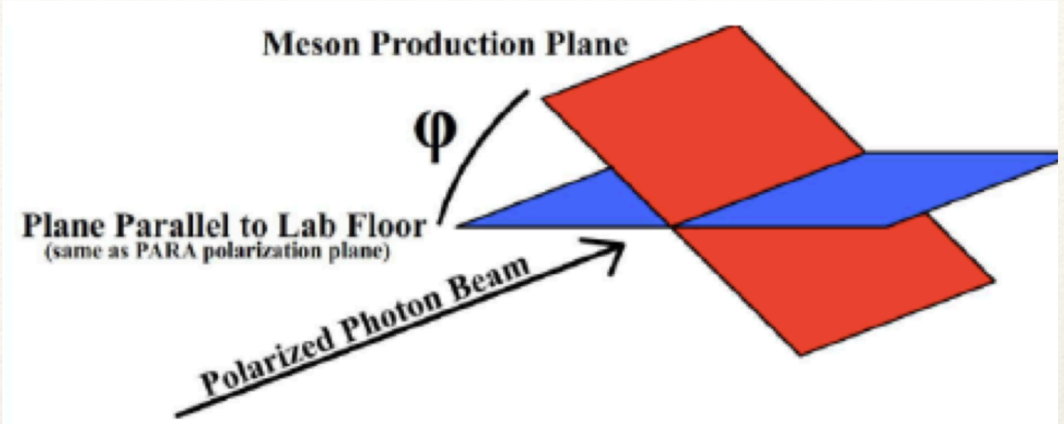
$K^+\Sigma^0$ beam asymmetry

Phys. Rev. C **101**, 065206

$\gamma p \rightarrow K^+\Sigma^0 \rightarrow K^+\Lambda\gamma \rightarrow K^+ p\pi^-\gamma$







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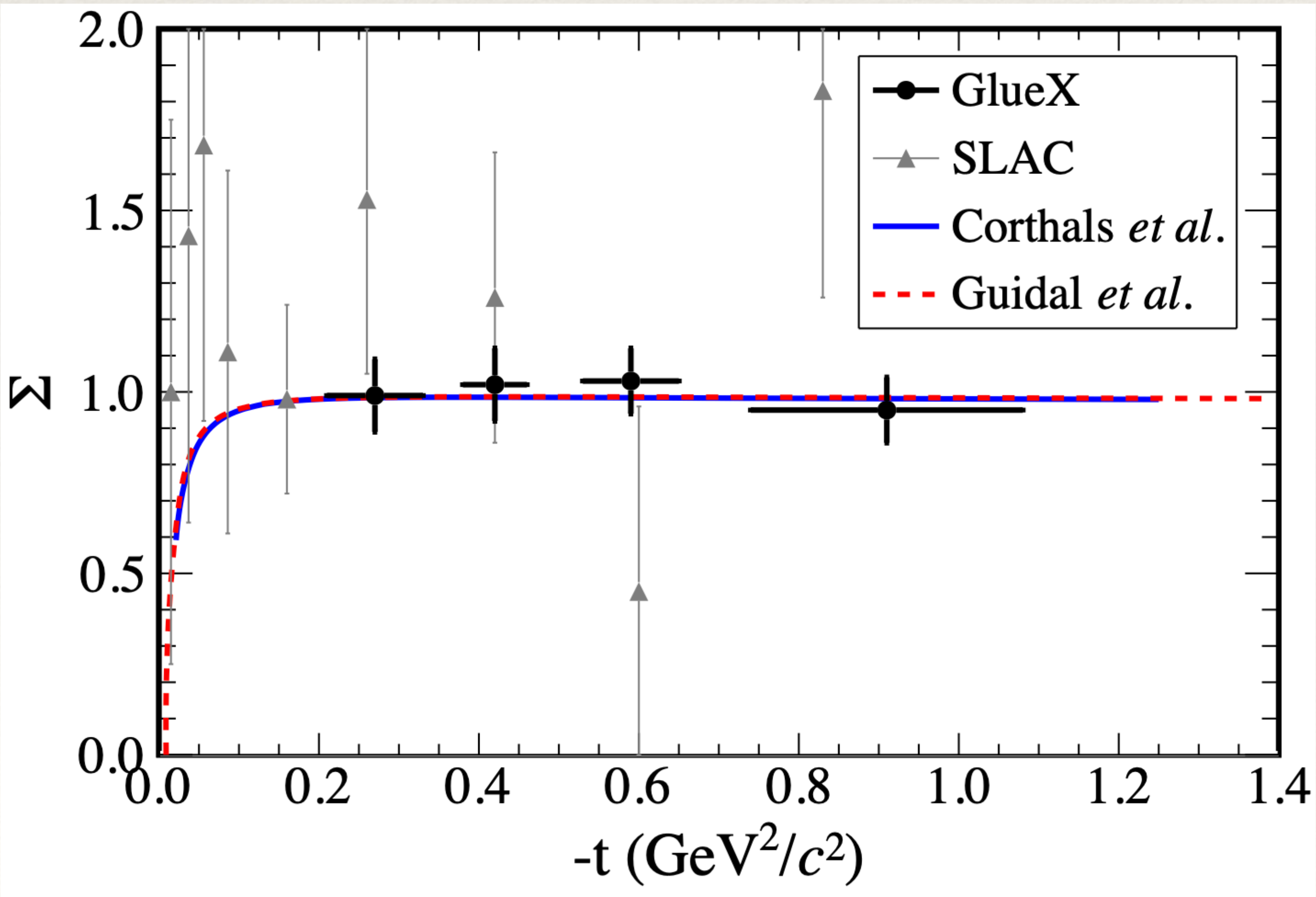
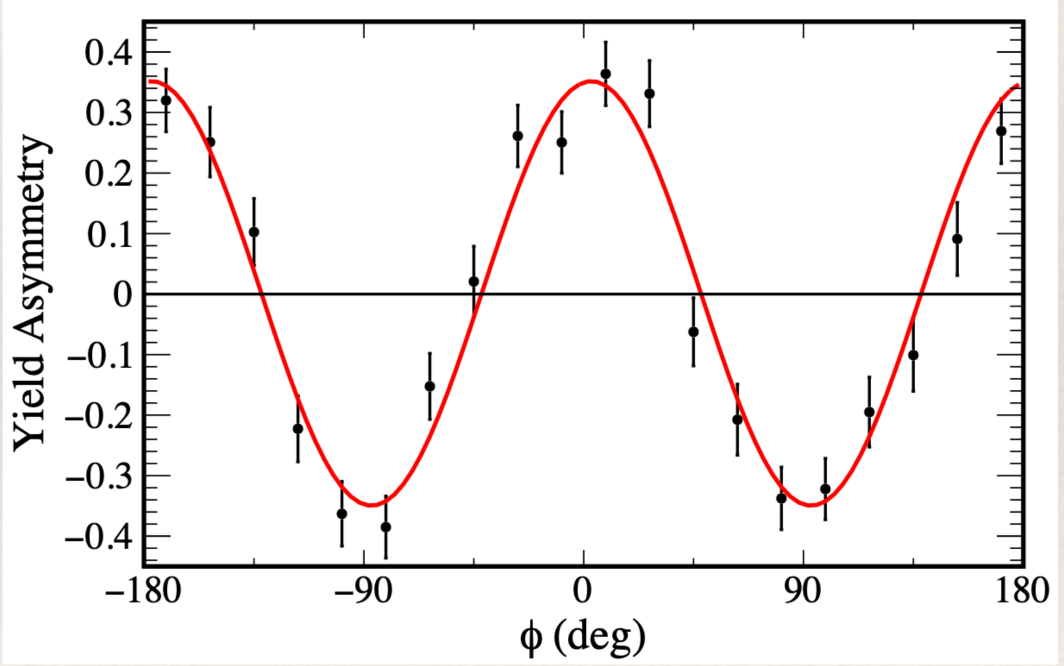
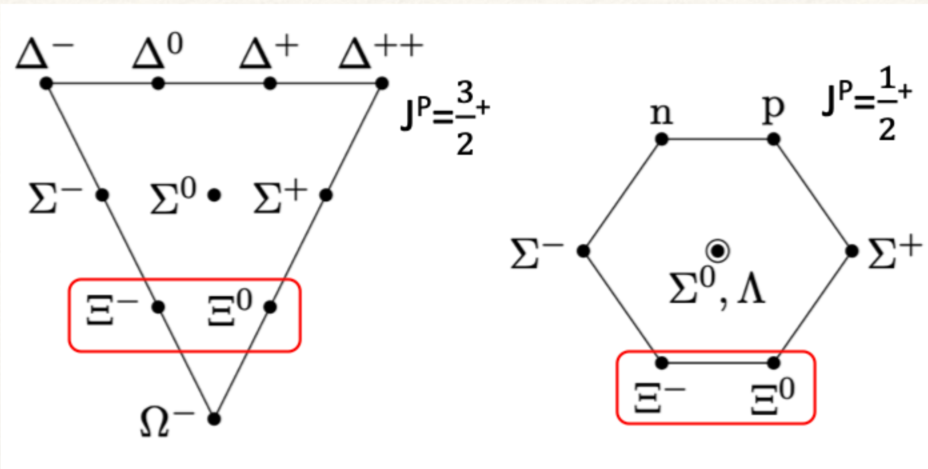




- Natural exchange very dominant
- Sizeable u-channel production

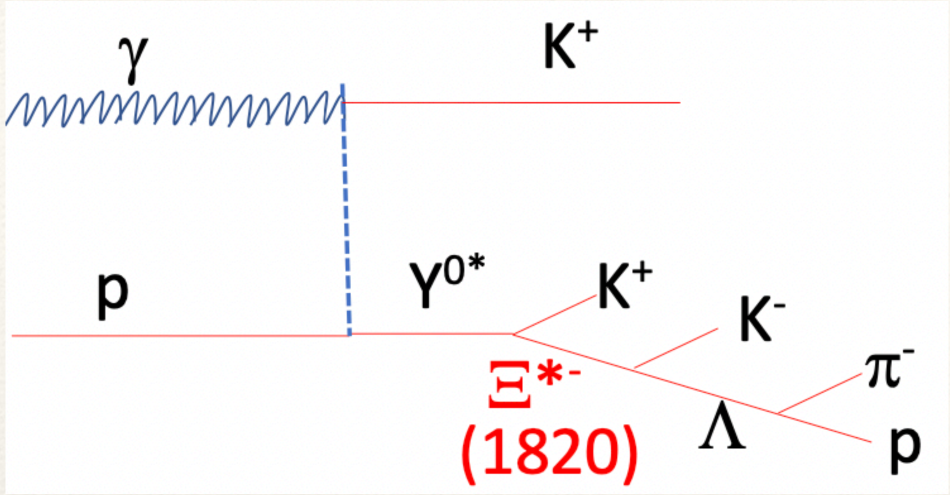
Cascades at GlueX

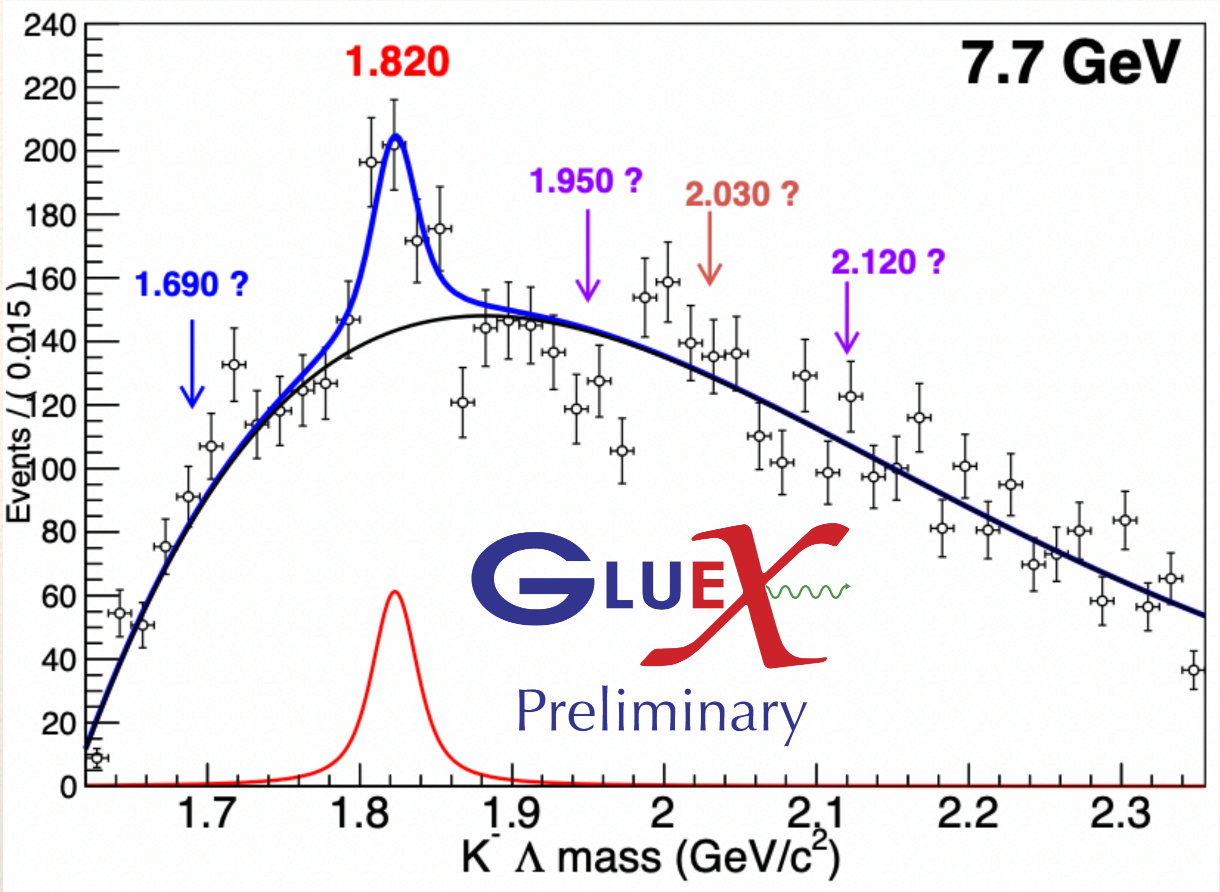


Particle	J^P	Overall Status	– Status as seen in – $\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$
$\Xi(1318)$	$1/2^+$	****				
$\Xi(1530)$	$3/2^+$	****	****			
$\Xi(1620)$		*	*			
$\Xi(1690)$		***		***	**	
$\Xi(1820)$	$3/2^-$	***	**	***	**	**
$\Xi(1950)$		***	**	**		*
$\Xi(2030)$		***		**	***	
$\Xi(2120)$		*		*		
$\Xi(2250)$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

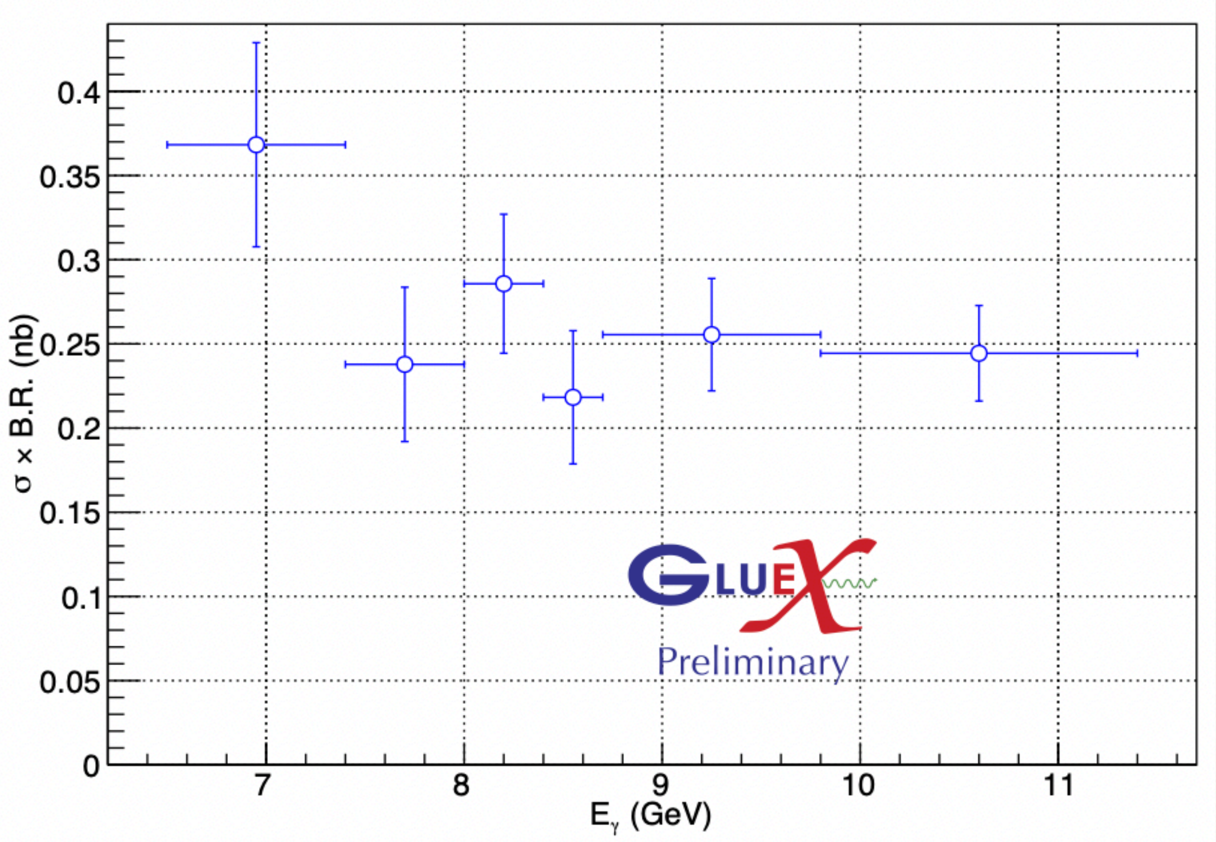
- Only six well known states (>3***)
- Would expect as many Ξs as N^*s and Δs
- Not many photoproduction experiments have been performed so far ($S = -2$)
- GlueX with its good charged and neutral final state particle coverage could help here
- Difficult analyses due to many final state particles

$\Xi^-(1820)$



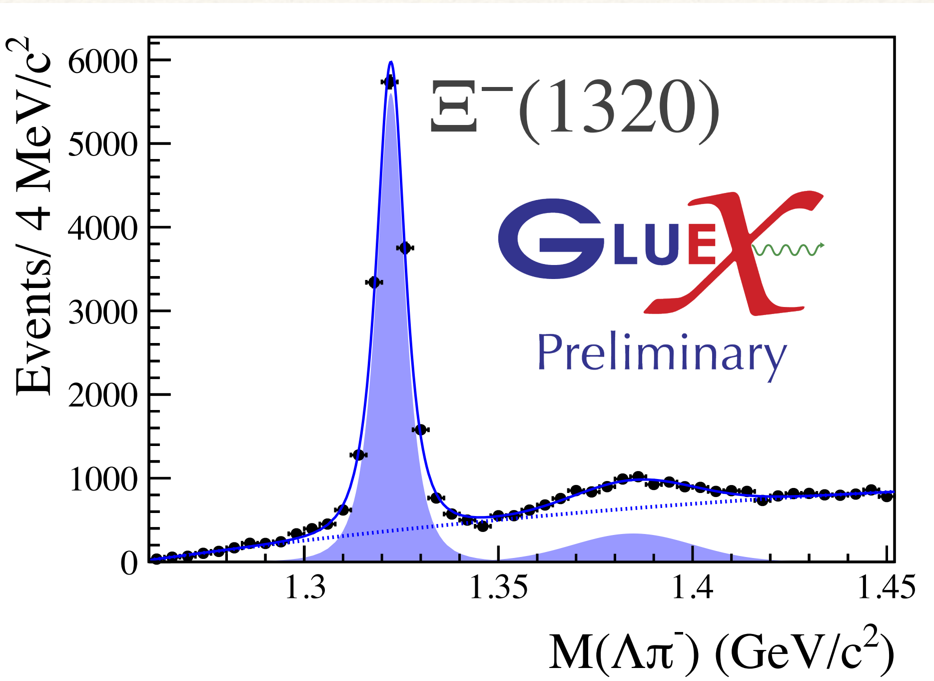


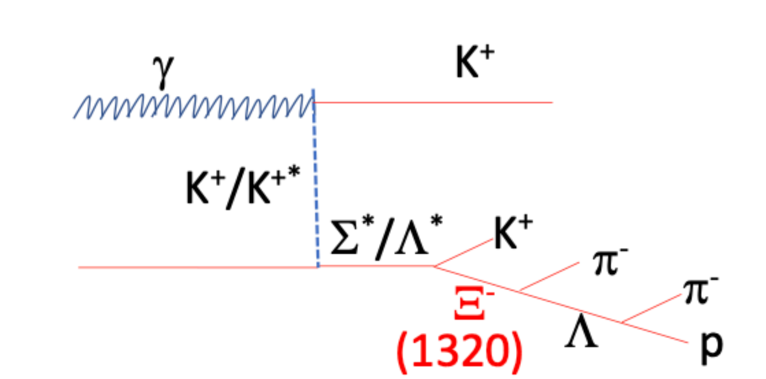
- Excited $\Xi(1820)$ with $J^P = \frac{3}{2}^-$
- *** resonance seen in $K^-\Lambda$ decays
- First measurement of $\Xi(1820)$ in photoproduction
- Only dominating feature in the $K^-\Lambda$ invariant mass

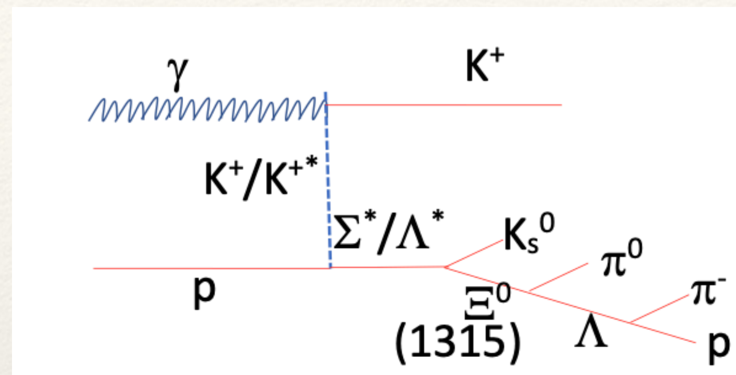


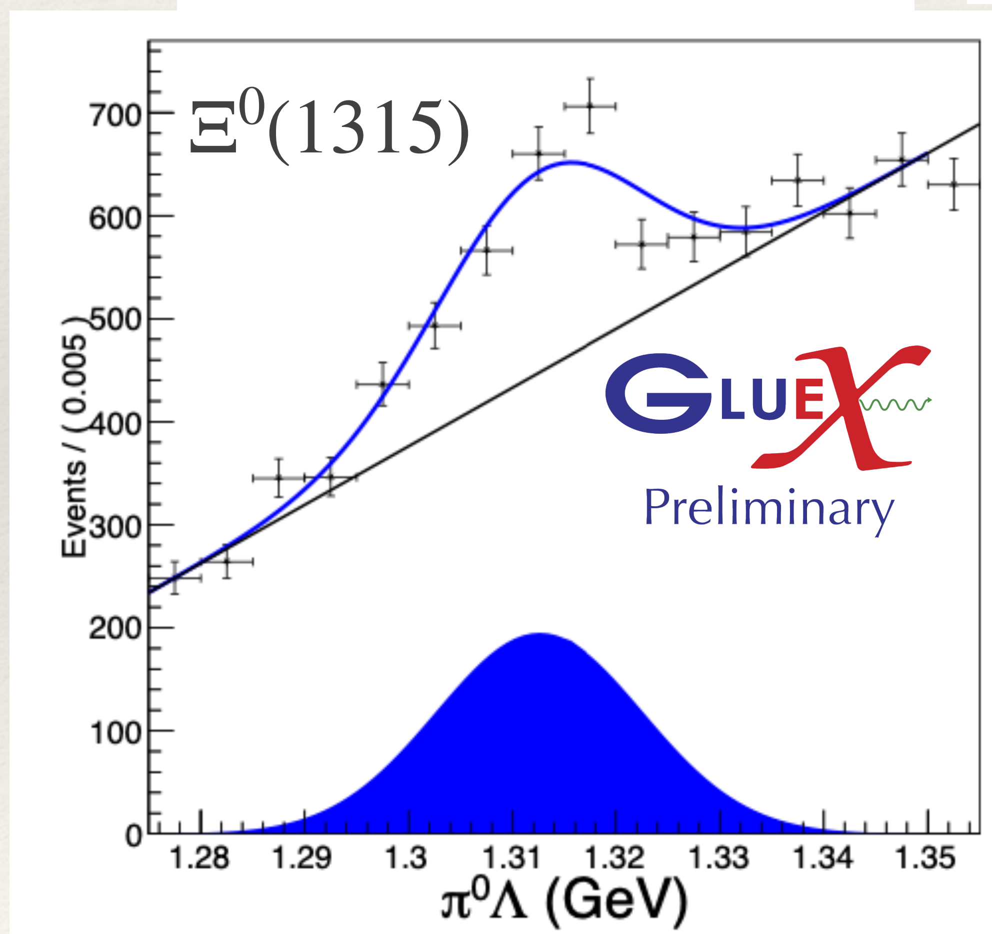
Further Cascades

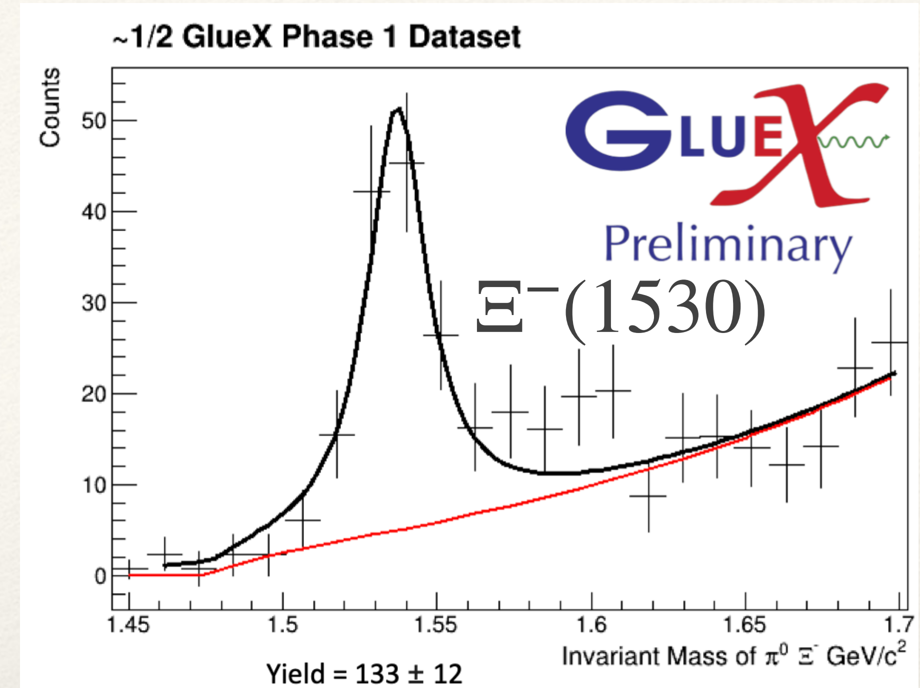
J. Hernandez (SESAPS 2021)
C. Akondi
B. Sumner (APS DNP 2021)

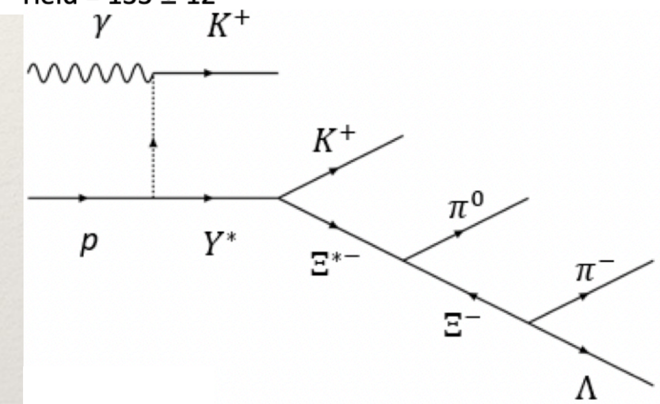








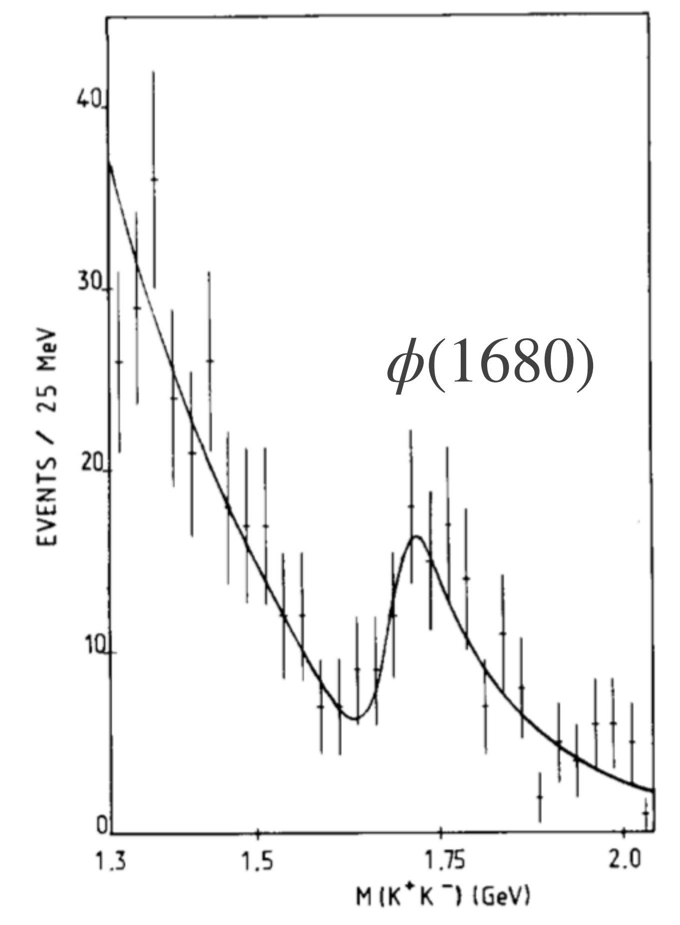


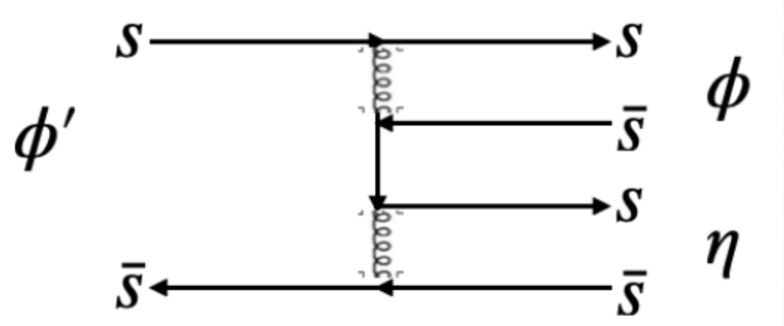


- We see many different cascades in various final states
- Measure differential cross-section $d\sigma/dt$ and total cross-section

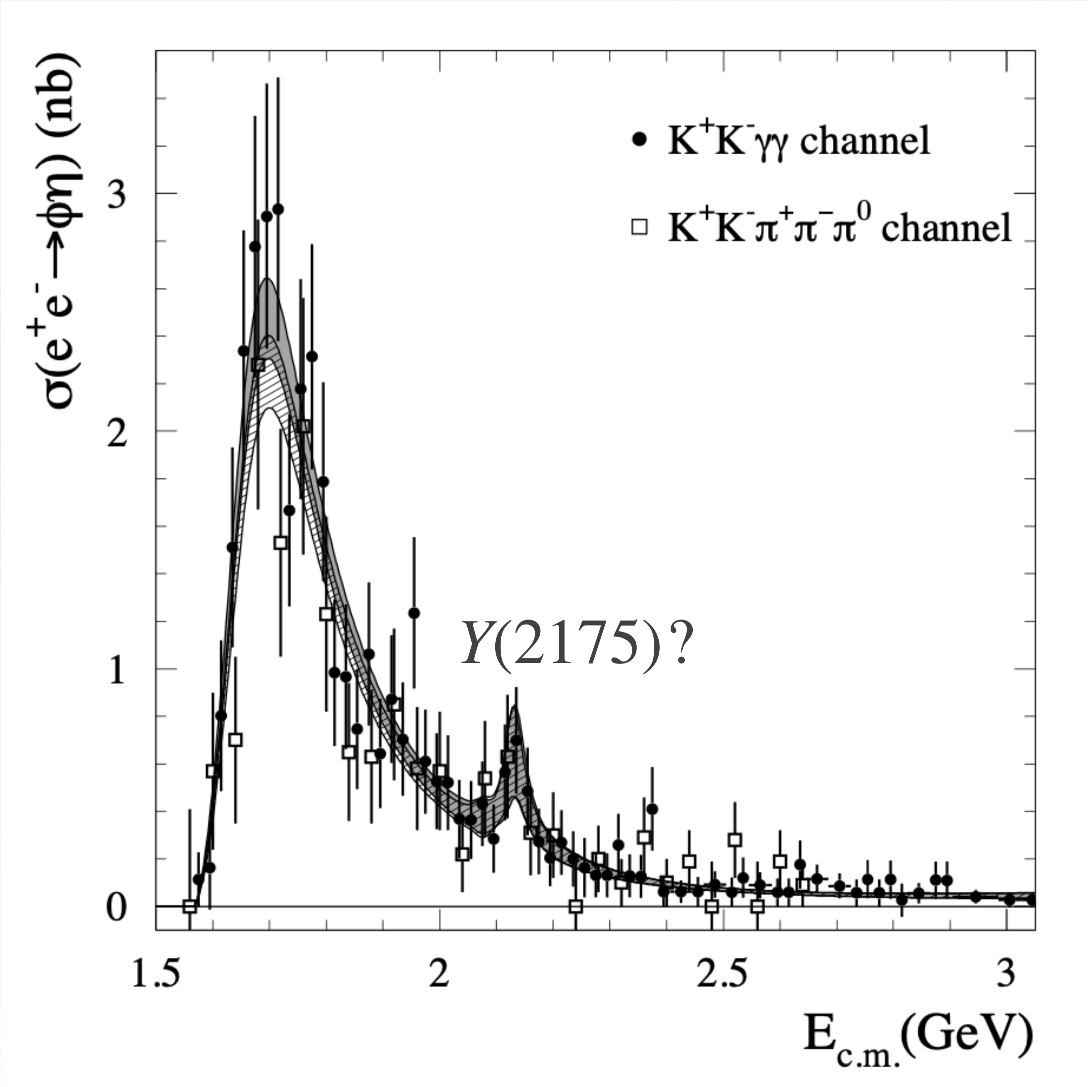
Mesons

D. Aston et al.: Phys. Lett. 104B, 231 (1981)



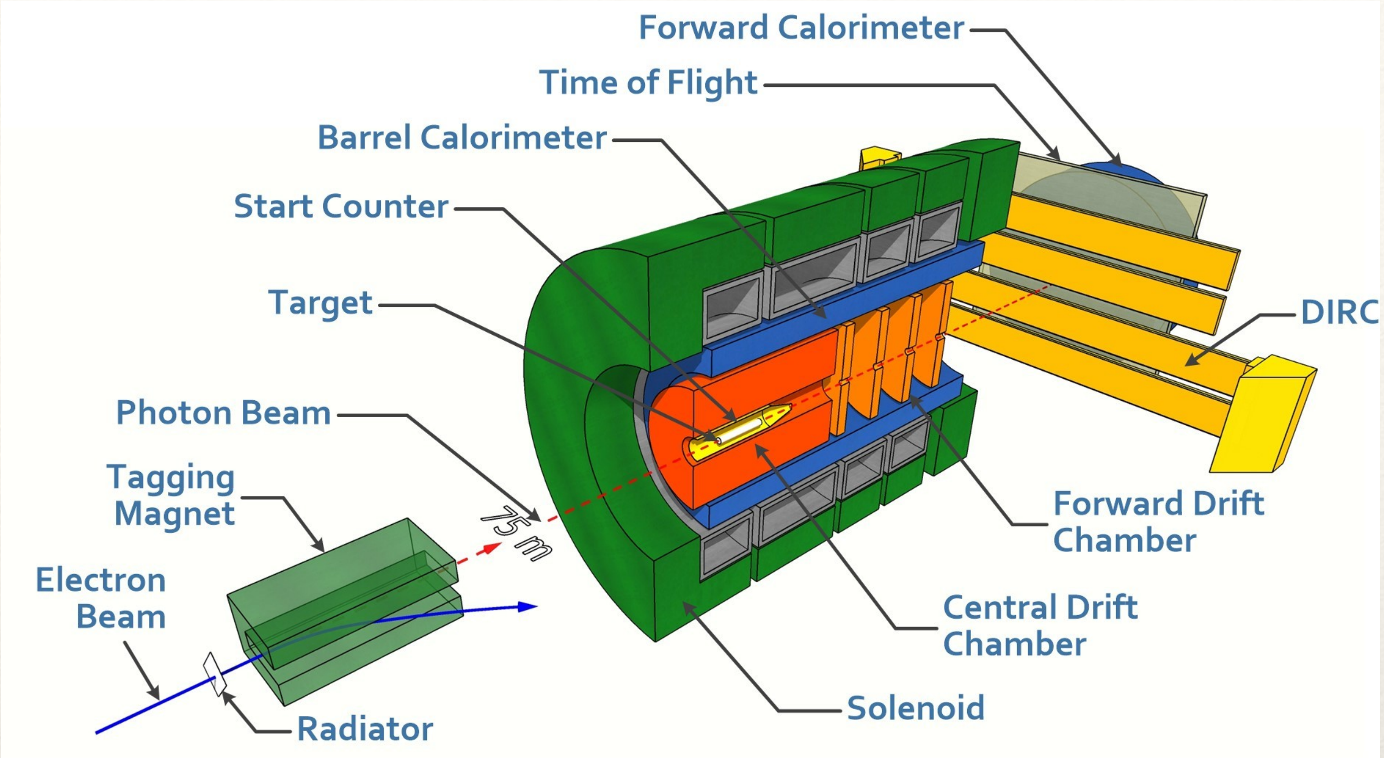


BaBar: Phys. Rev. D 77, 092002 (2008)



- We see many K^*s, analyses are ongoing
- Search for strangeonia ($s\bar{s}$)
- Y(2175)
- With GlueX-II this will expand
  - Search for strangeonium hybrids

Summary

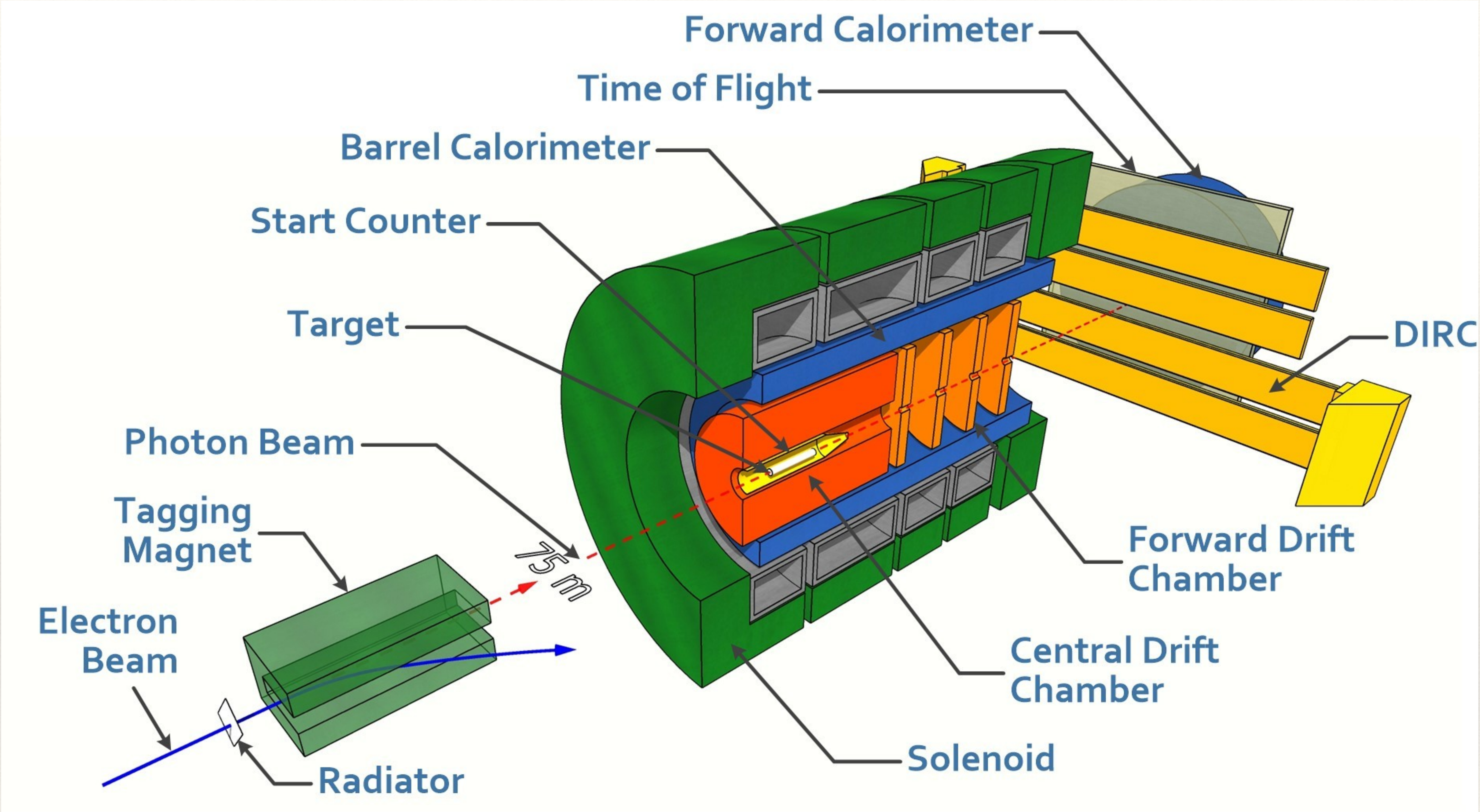


- GlueX has an exciting strangeness program and makes very good progress in many different analyses
- GlueX-II (including the DIRC) will improve our data for final states containing strangeness and will enable us to perform photoproduction measurements with unprecedented statistics
- We are open for ideas and suggestions for interesting measurements

GlueX acknowledges the support of several funding agencies and computing facilities: gluex.org/thanks

Backup

GlueX experiment in Hall D

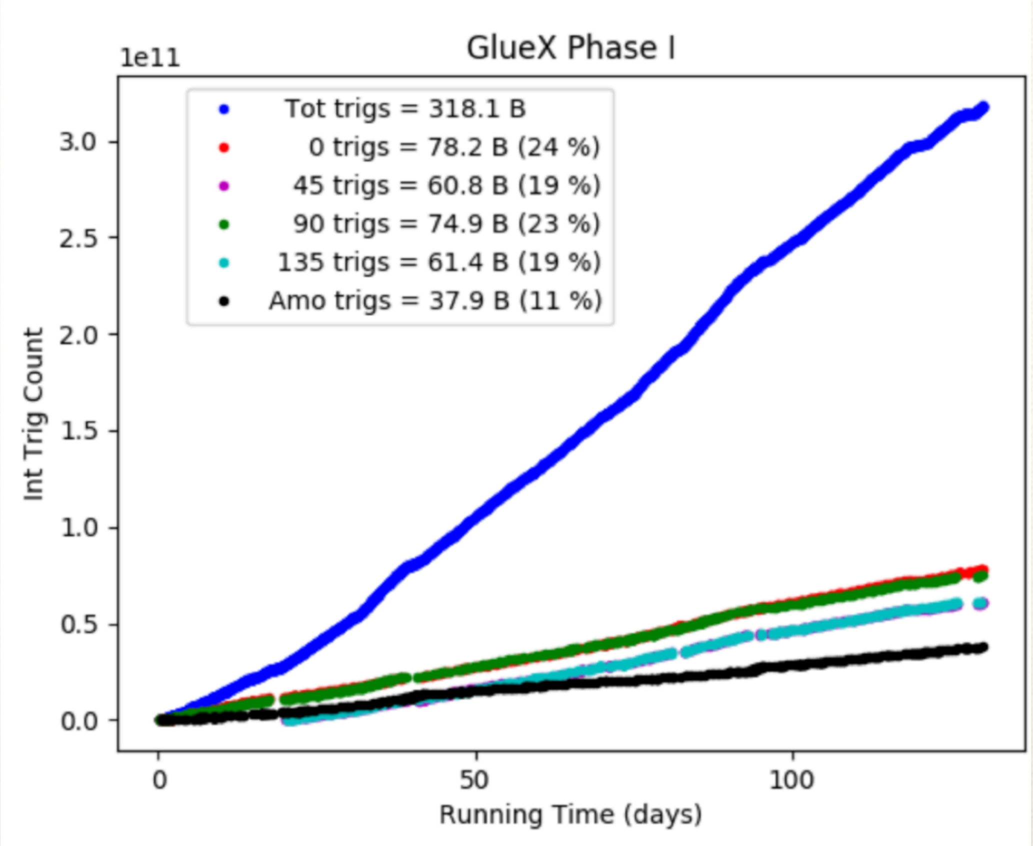


- Acceptance: $\theta_{lab} \approx 1^\circ - 120^\circ$
- Charged particles: $\sigma_p/p \approx 1\% - 3\,\%$ ($8\% - 9\,\%$ very-forward high-momentum tracks)
- Photons: $\sigma_E/E = 6\,\%/\sqrt{E} \oplus 2\,\%$

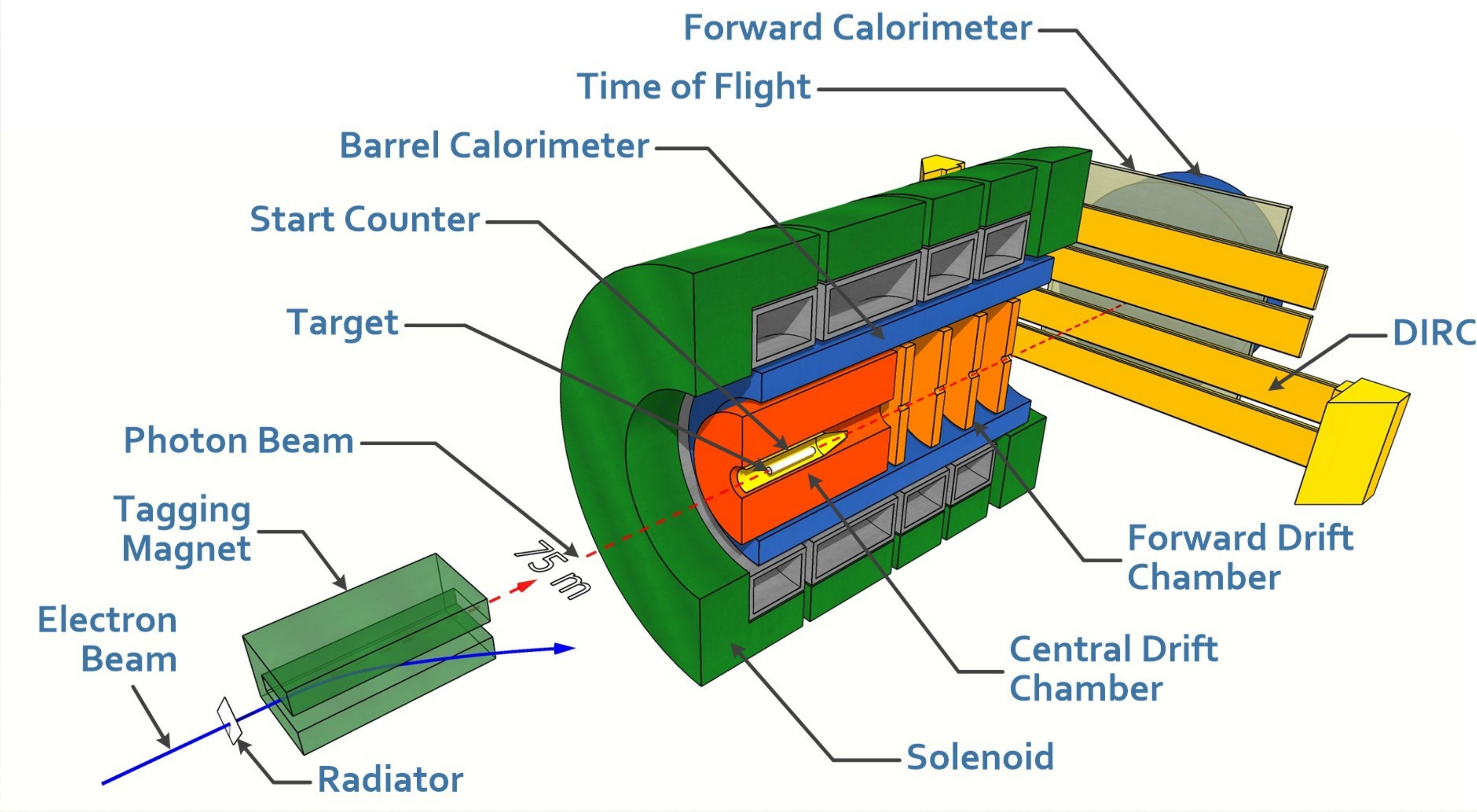
GlueX experiment in Hall D

- Spring 2016
  - Engineering run
- Spring 2017
  - 20% of GlueX-I
- Spring 2018
  - 50% of GlueX-I
- Fall 2018
  - 30% of GlueX-I

121 pb^{-1} in coherent peak

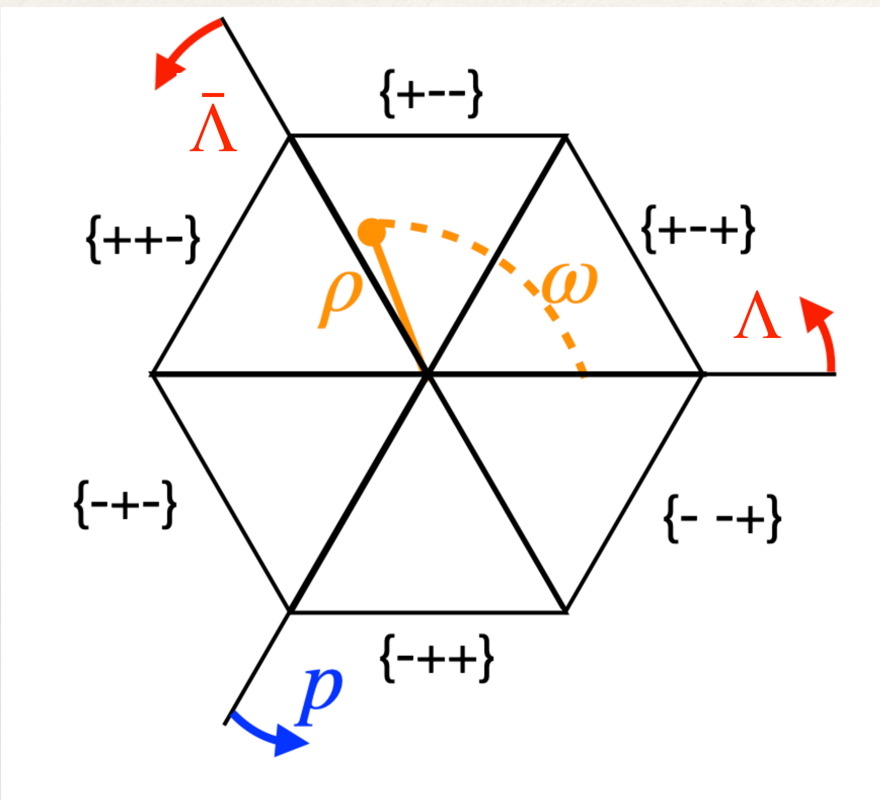


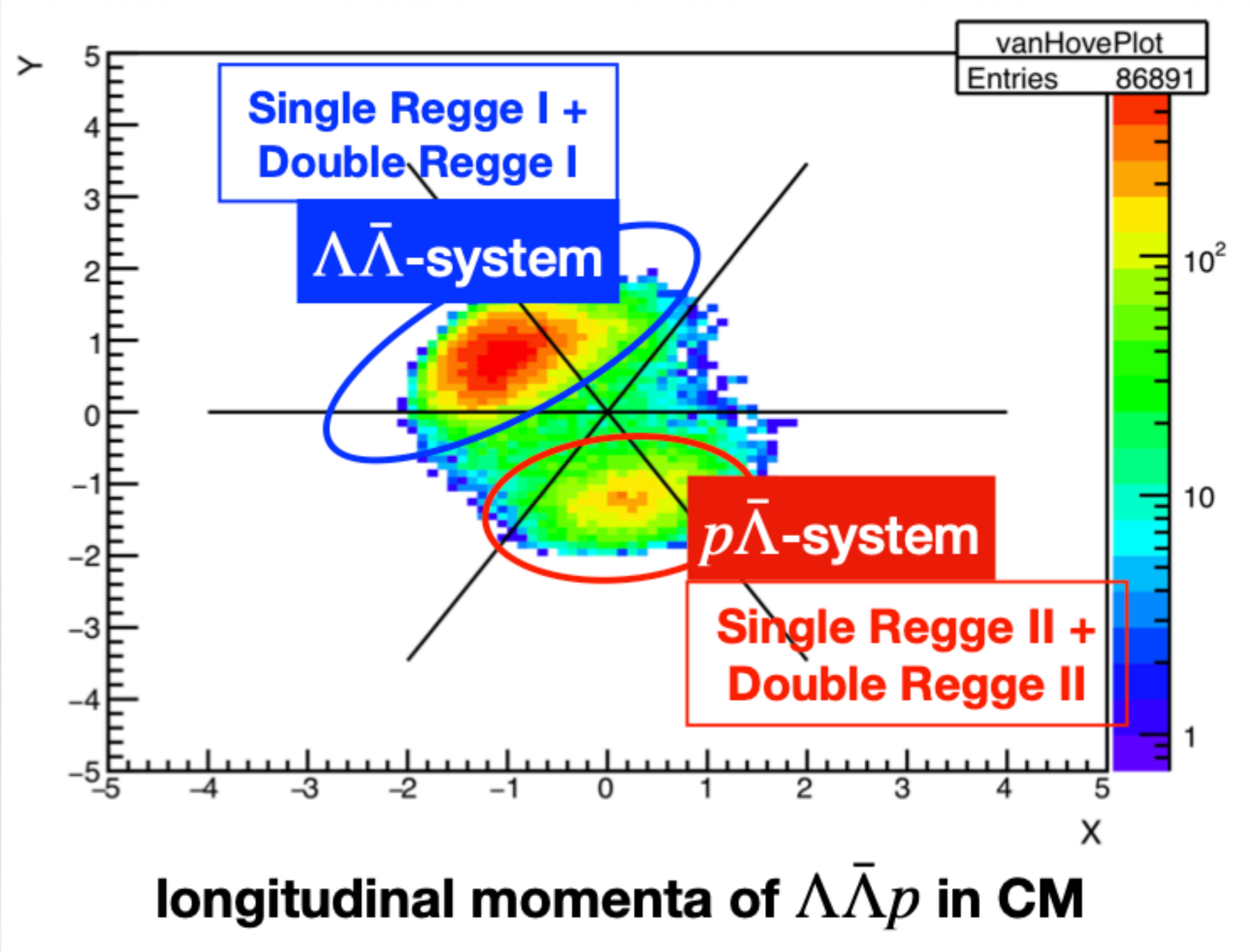
Since 2019:
GlueX-II incl. DIRC



Lambda - anti-Lambda

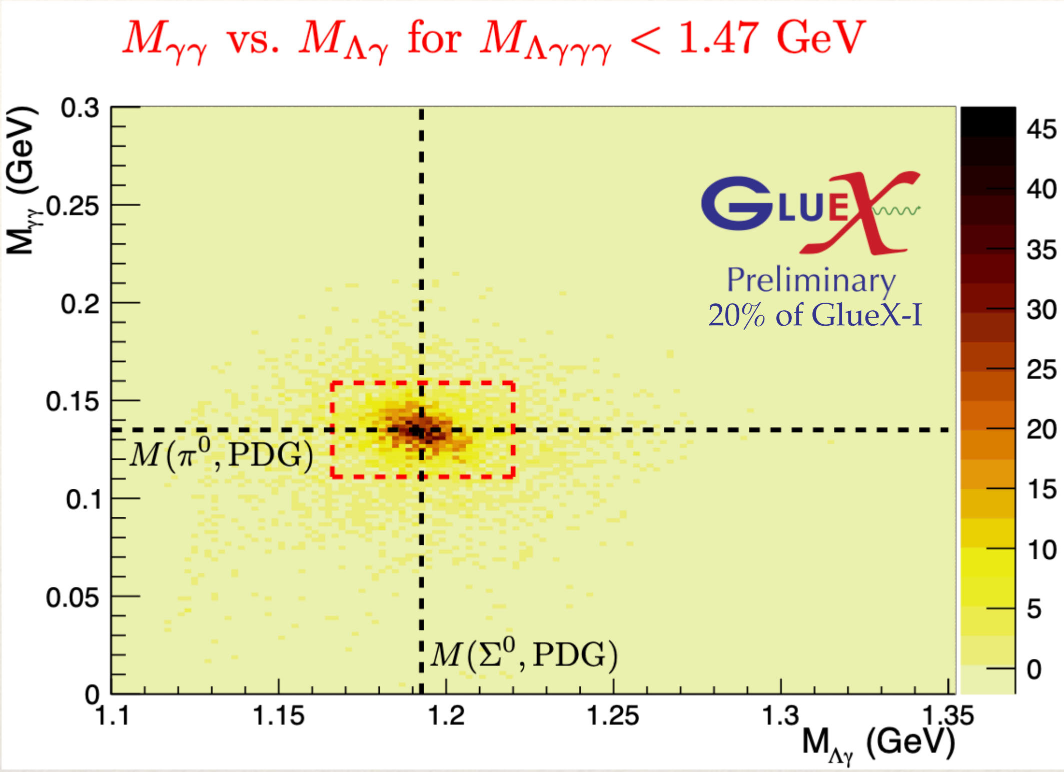
Hao Li (MENU 2019)



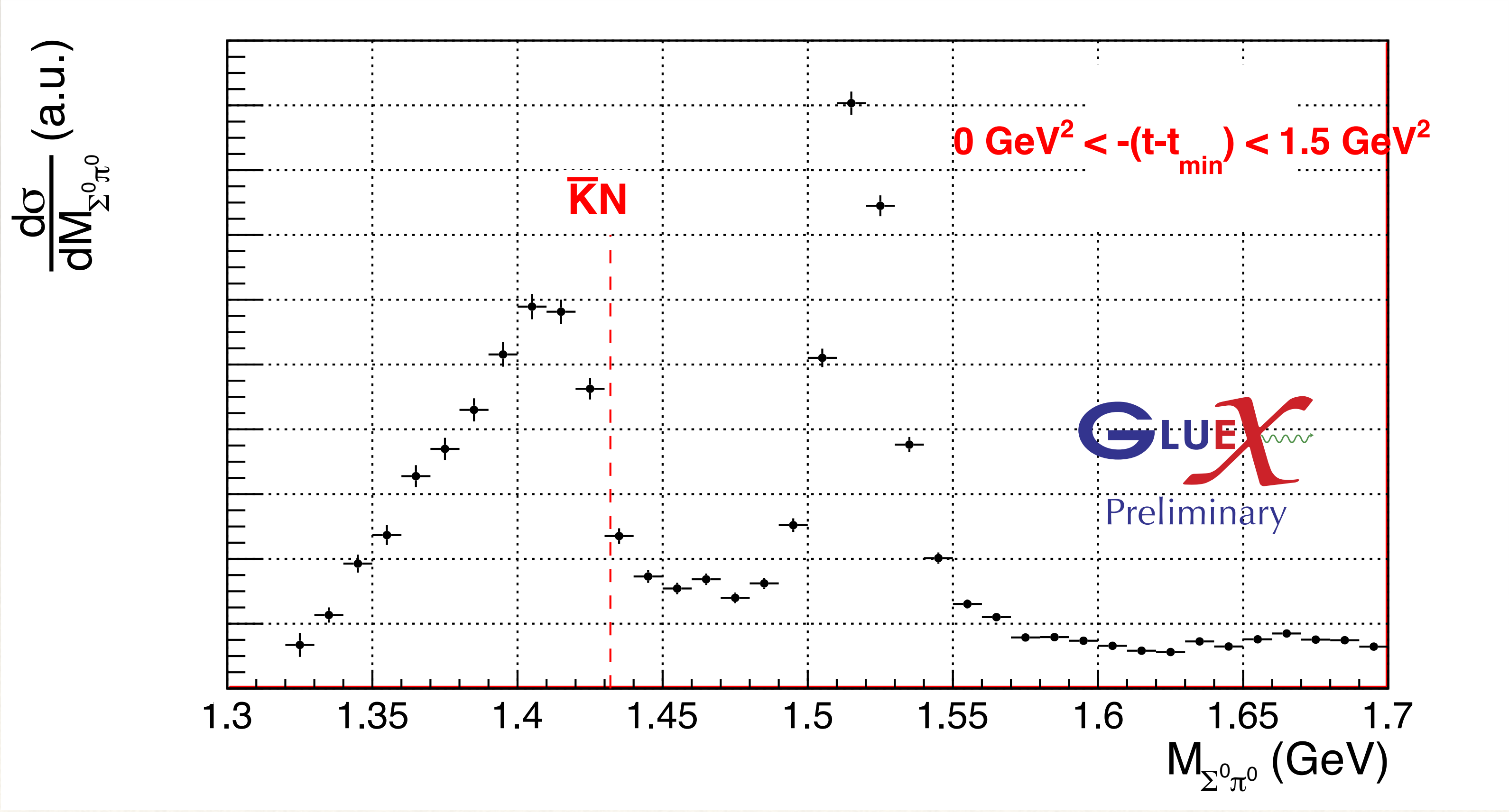


Λ(1405) line shape measurement

N. Wickramaarachchi (Fri-II)

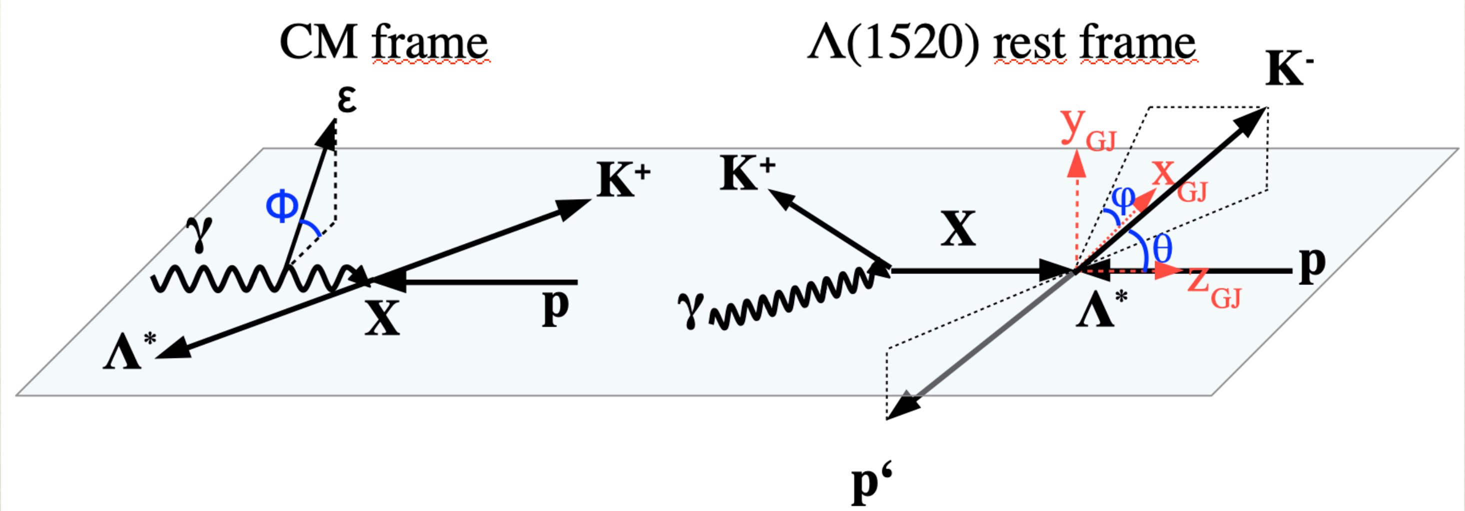


- Very clear $\Sigma^0\pi^0$ signal
- Invariant mass shows Λ(1405) and Λ(1520)
- Λ(1520) has right mass and width
- Λ(1405) clearly non-BW



Λ(1520) Spin-Density Matrix Elements

- parameterise angular distribution of Λ(1520) decay
- 3 variables: two angles of K^- and photon polarisation
- 9 fit parameters: three unpolarised, six polarised
- gives access to production mechanism



For $3/2^- \rightarrow 1/2^+ + 0^-$:

$$W_0 = \frac{1}{4\pi}\left[3\left(\frac{1}{2} - \rho^0_{11}\right)\sin^2(\theta) + \rho^0_{11}\left(1 + 3\cos^2(\theta)\right) - 2\sqrt{3}\left(\mathrm{Re}(\rho^0_{31})\cos(\varphi)\sin(2\theta) + \mathrm{Re}(\rho^0_{3-1})\cos(2\varphi)\sin^2(\theta)\right)\right]$$

$$W_1 = \frac{1}{4\pi}\left[3\rho^1_{33}\sin^2(\theta) + \rho^1_{11}(1 + 3\cos^2(\theta)) - 2\sqrt{3}\left(\mathrm{Re}(\rho^1_{31})\cos(\varphi)\sin(2\theta) + \mathrm{Re}(\rho^1_{3-1})\cos(2\varphi)\sin^2(\theta)\right)\right]$$

$$W_2 = \frac{1}{4\pi}\left[2\sqrt{3}\left(\mathrm{Im}(\rho^2_{31})\sin(\varphi)\sin(2\theta) + \mathrm{Im}(\rho^2_{3-1})\sin(2\varphi)\sin^2(\theta)\right)\right]$$

$$W = W_0 - P_\gamma\cos(2\Phi)W_1 - P_\gamma\sin(2\Phi)W_2$$