Photoproduction of Λ^* Resonances at CLAS

DNP Meeting
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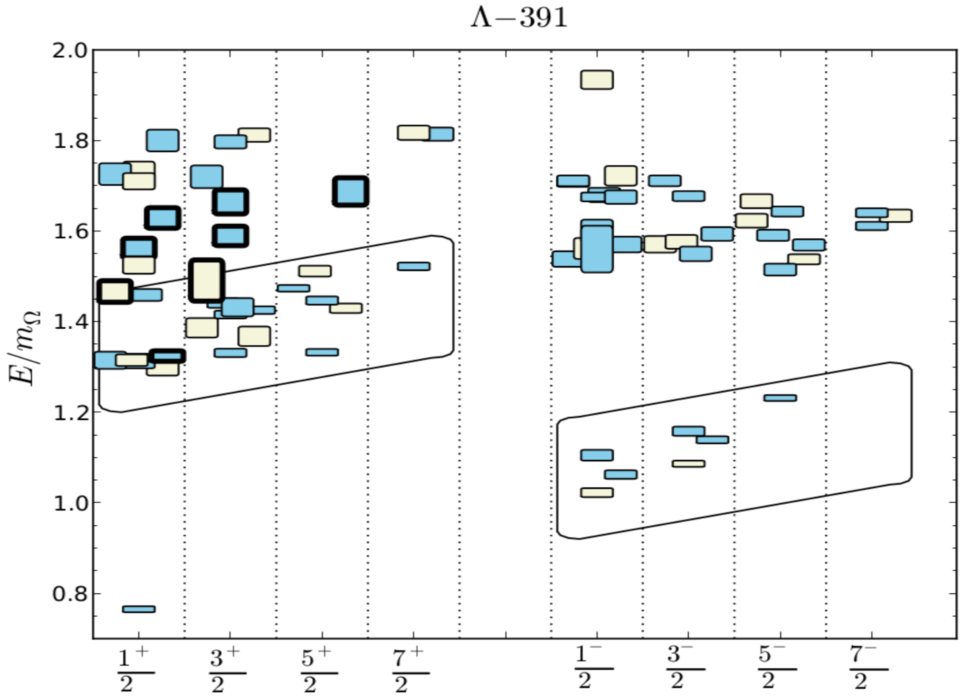
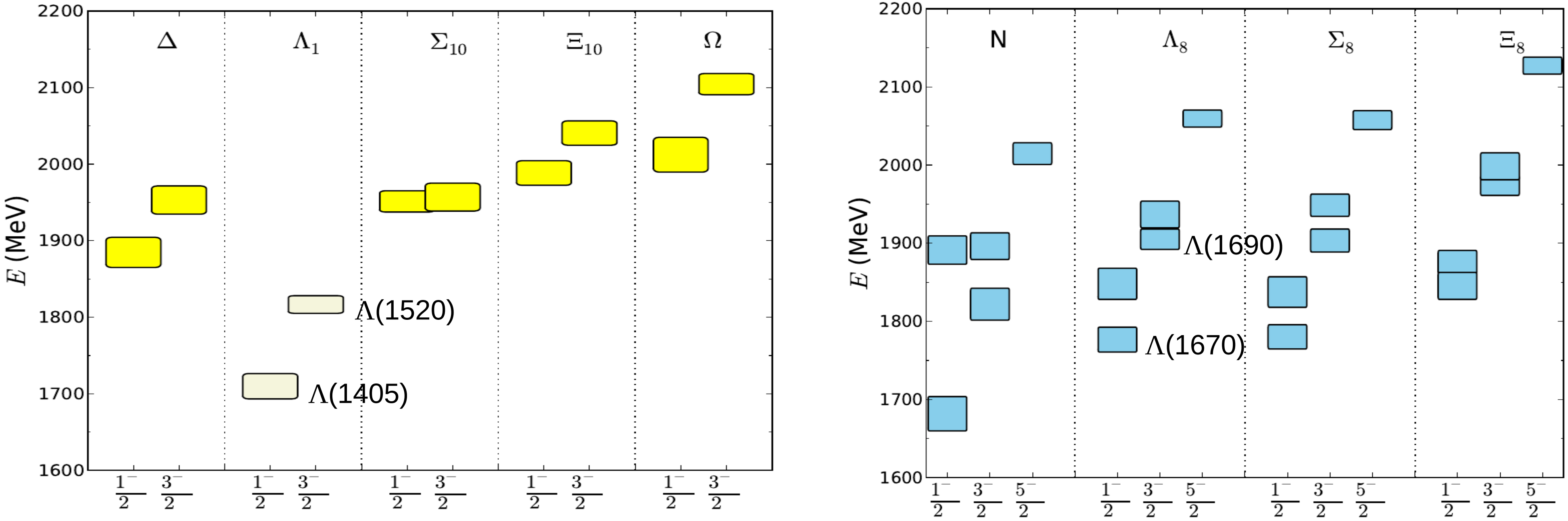
Λ^*

J^P	(D, L_N^P)	S	Octet members				Singlets
$1/2^+$	$(56,0_0^+)$	$1/2$	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56,0_2^+)$	$1/2$	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(1690)^\dagger$	
$1/2^-$	$(70,1_1^-)$	$1/2$	$N(1535)$	$\boxed{\Lambda(1670)}$	$\Sigma(1620)$	$\Xi(?)$	$\boxed{\Lambda(1405)}$
					$\Sigma(1560)^\dagger$		
$3/2^-$	$(70,1_1^-)$	$1/2$	$N(1520)$	$\boxed{\Lambda(1690)}$	$\Sigma(1670)$	$\Xi(1820)$	$\boxed{\Lambda(1520)}$
$1/2^-$	$(70,1_1^-)$	$3/2$	$N(1650)$	$\Lambda(1800)$	$\Sigma(1750)$	$\Xi(?)$	
					$\Sigma(1620)^\dagger$		
$3/2^-$	$(70,1_1^-)$	$3/2$	$N(1700)$	$\Lambda(?)$	$\Sigma(1940)^\dagger$	$\Xi(?)$	
$5/2^-$	$(70,1_1^-)$	$3/2$	$N(1675)$	$\Lambda(1830)$	$\Sigma(1775)$	$\Xi(1950)^\dagger$	
$1/2^+$	$(70,0_2^+)$	$1/2$	$N(1710)$	$\Lambda(1810)$	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(1810)^\dagger$
$3/2^+$	$(56,2_2^+)$	$1/2$	$N(1720)$	$\Lambda(1890)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^+$	$(56,2_2^+)$	$1/2$	$N(1680)$	$\Lambda(1820)$	$\Sigma(1915)$	$\Xi(2030)$	
$7/2^-$	$(70,3_3^-)$	$1/2$	$N(2190)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^-$	$(70,3_3^-)$	$3/2$	$N(2250)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$9/2^+$	$(56,4_4^+)$	$1/2$	$N(2220)$	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	



- Missing baryon resonances play important role to explore the fundamental degrees of freedom inside hadrons.
- Study of quark dynamics to determine properties of hadrons that are responsible for spectrum of hadrons.

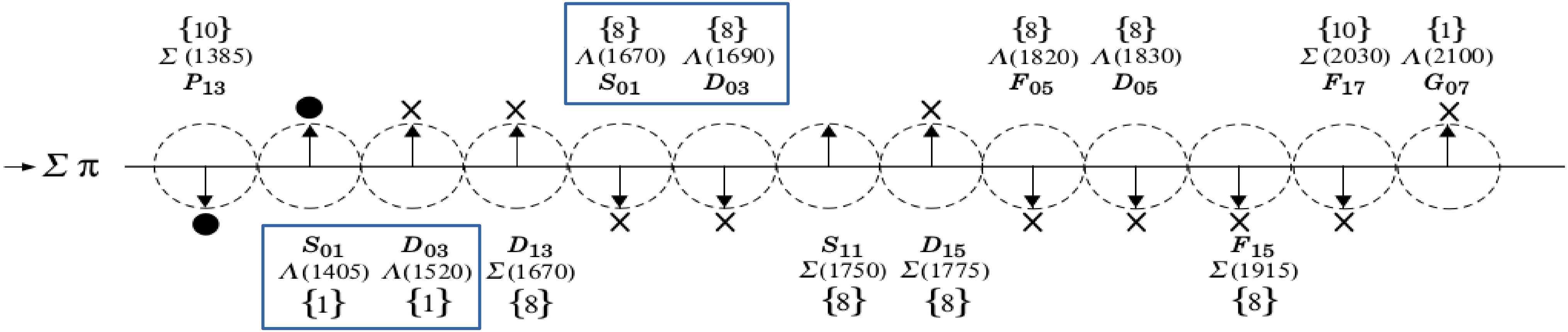
Baryon Spectra from Lattice QCD



Robert G. Edwards, Nilmani Mathur, David G. Richards, and Stephen J. Wallace. Flavor structure of the excited baryon spectra from lattice qcd. *Phys. Rev. D*, 87:054506, Mar 2013.

- Missing baryon resonances play important role to explore the fundamental degrees of freedom inside hadrons.
- Study of quark dynamics to determine properties of hadrons that are responsible for spectrum of hadrons.

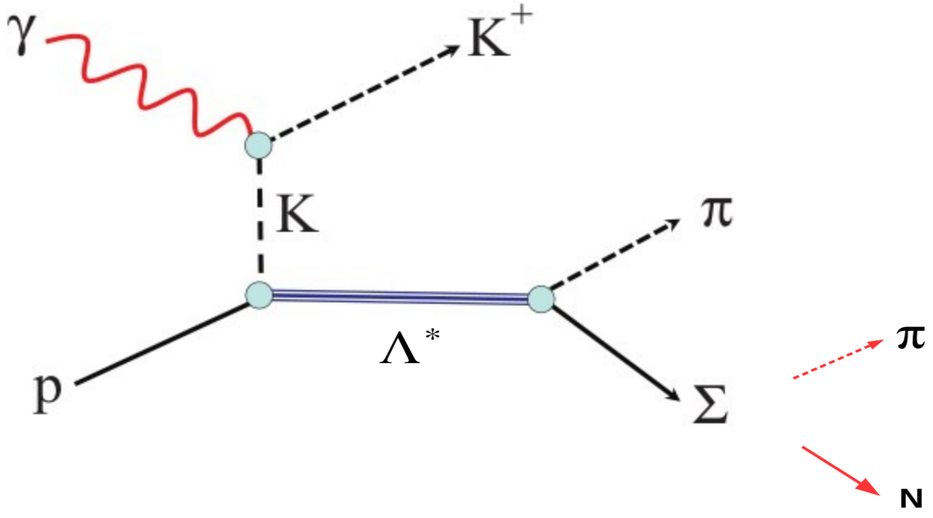
Motivation

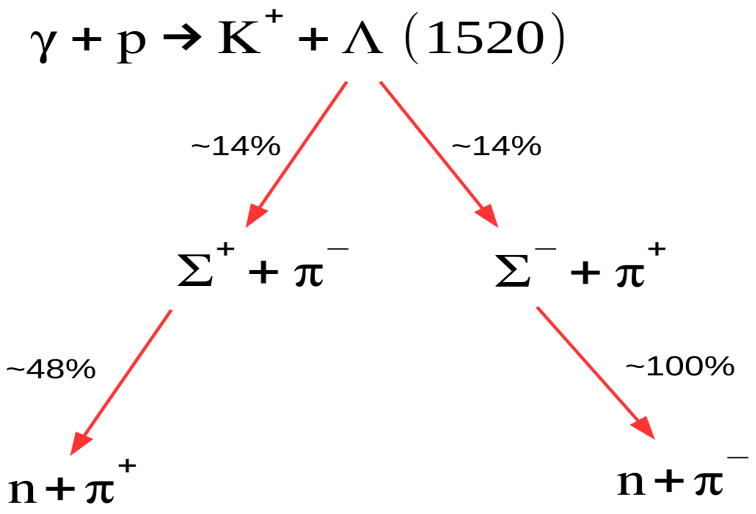


Particle	J^P	Overall status	$N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
$\Lambda(1116)$	$1/2+$	****		F		$N\pi$(weakly)
$\Lambda(1405)$	$1/2-$	****	****	o	****	
$\Lambda(1520)$	$3/2-$	****	****	r	****	$\Lambda\pi\pi, \Lambda\gamma$
$\Lambda(1600)$	$1/2+$	***	***	b	**	
$\Lambda(1670)$	$1/2-$	****	****	i	****	$\Lambda\eta$
$\Lambda(1690)$	$3/2-$	****	****	d	****	$\Lambda\pi\pi, \Sigma\pi\pi$

pdg.lbl.gov

Λ^* Photoproduction

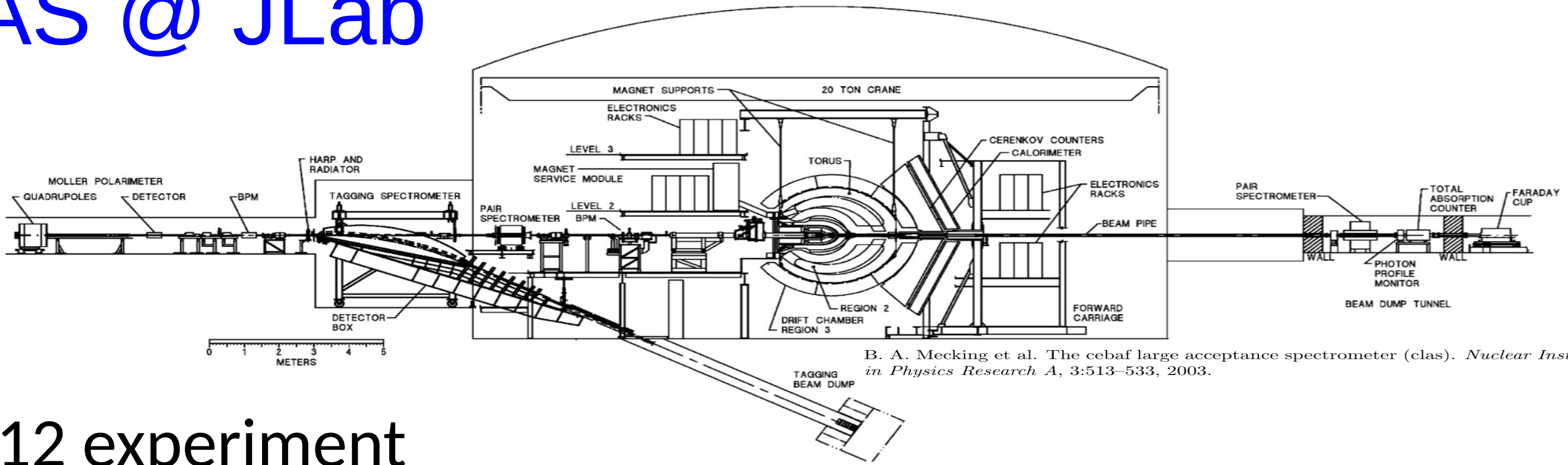




$$\gamma + p \rightarrow K^+ + \Lambda^* \qquad \Lambda^* \rightarrow \Sigma^+ + \pi^- \qquad \Lambda^* \rightarrow \Sigma^- + \pi^+$$

- Photo-prodution off a proton creates a K^+-meson and a Λ^*.
- Λ^* decays by $\Sigma\pi$ channel. Σ^+ gives off a n & π^+, Σ- gives off a n & π^-.
- The final particles detected are K^+, π^+ & π^-.

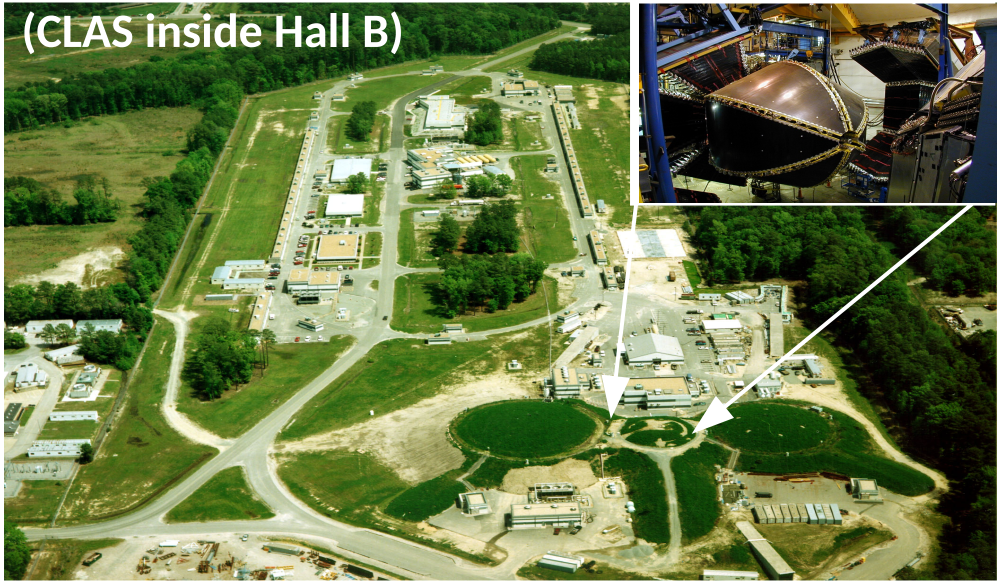
CLAS @ JLab



B. A. Mecking et al. The cebaf large acceptance spectrometer (clas). *Nuclear Instruments and Methods in Physics Research A*, 3:513–533, 2003.

The g12 experiment

E_{beam} of photon	5.715 GeV
Beam Polarization	Circular
e^- Current	60–65 nA
Tagger Range	5% - 95% of e^- energy
Tagger Trigger Range	3.6–5.441 GeV
Torus Magnet	$\frac{1}{2}B_{\text{max}}$ (1930 A)
Target Length	40 cm
Target Center (z location)	−90 cm
Target Material	ℓH_2
Target Polarization	None
Start Counter Offset	0 cm
Radiator Thickness	10^{-4} radiation lengths
Collimator Radius	6.4 mm



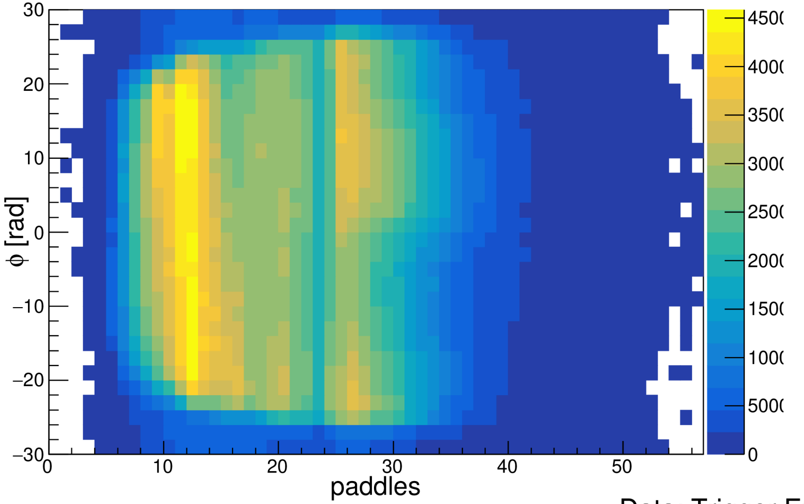
Outline (Cuts)

- Photon selection → 1 and 2 photon case (Photon Multiplicity)
- PID → K^+, π^+, π^-. Straight cuts of 1 ns on Momentum Vs Timing plots were made for particle identification.
- Trigger Correction was applied creating trigger efficiency map using the g12 trigger configuration.
- The g12 standard data analysis procedure was followed for Vertex, Fiducial & Paddle Cuts.
- A series of Missing Mass cut was followed to obtain the nature of Λ^* resonances.
- Further analysis includes an appropriate binning and fitting scheme to obtain yield and acceptances for differential cross-section.

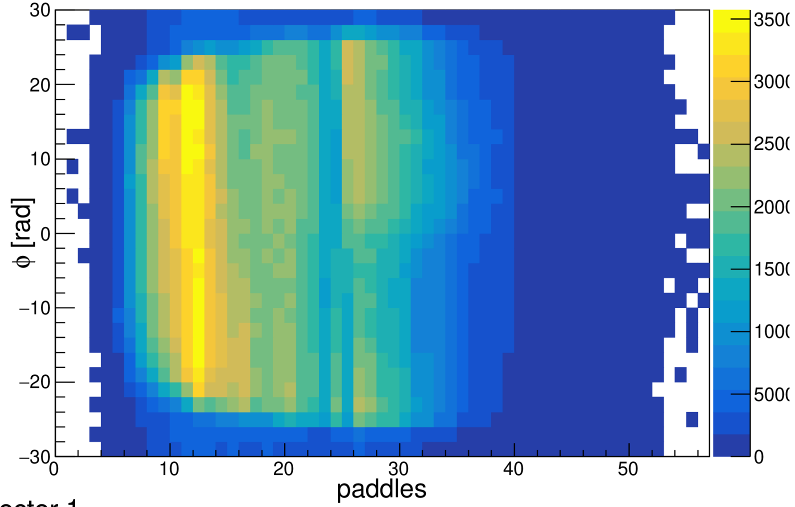
$0.9 \leq MM(K^+\pi\pi) \leq 1$	Select neutron events
$0.48 \leq IM(\pi^+\pi^-) \leq 0.51$	Remove nK^0 channel
$1.15 \leq MM(K^+\pi^-) \leq 1.25$ $1.15 \leq MM(K^+\pi^+) \leq 1.25$	Select Σ^+ and Σ^- events for exclusive $\Sigma\pi$ channels
$1.44 \leq MM(K^+) \leq 1.6$ $1.62 \leq MM(K^+) \leq 1.76$	Fitting Range $\Lambda(1520)$ Fitting Range $\Lambda(1670)$ & $\Lambda(1690)$
$2.15 \leq W \leq 2.95$ GeV $-0.9 \leq \cos\theta^{K+}_{cm} \leq 0.9$	Kinematic Ranges

Trigger Correction “new”

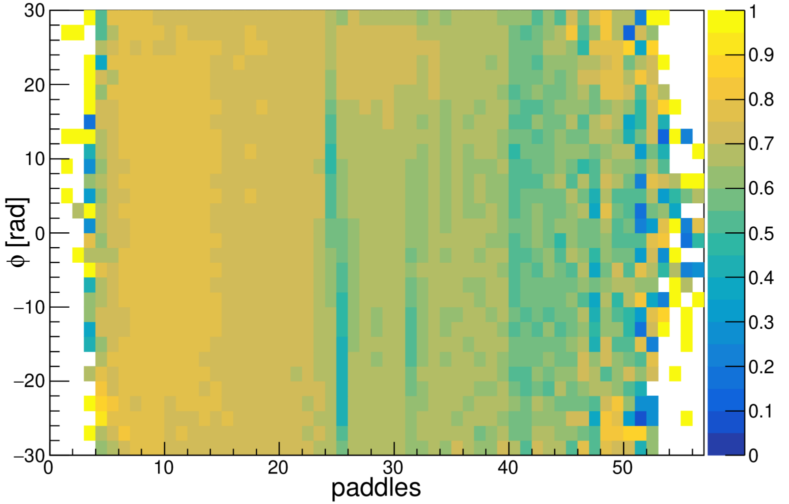
Data: Total (3-sector) events, K^+ Sector 1



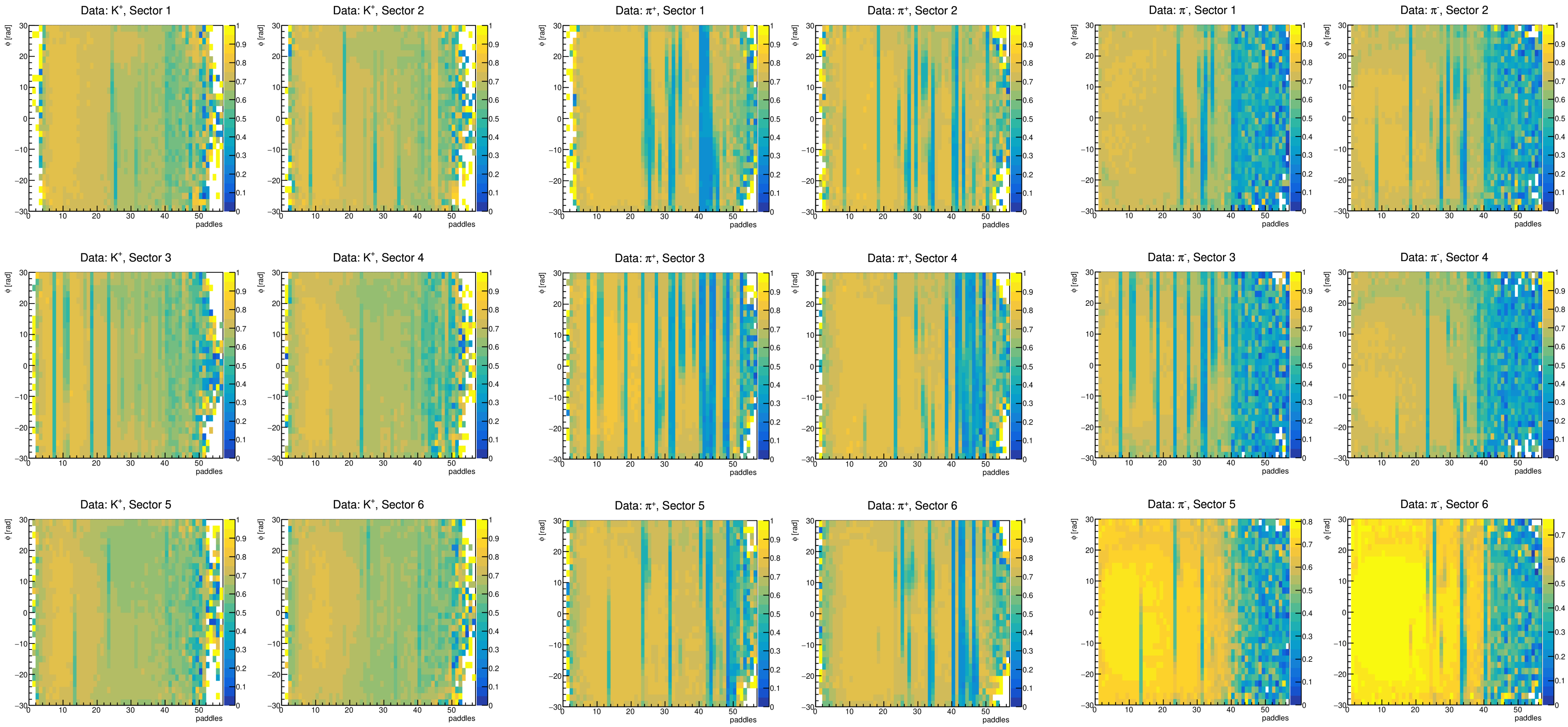
Data: Hit (2-sector) events, K^+ Sector 1



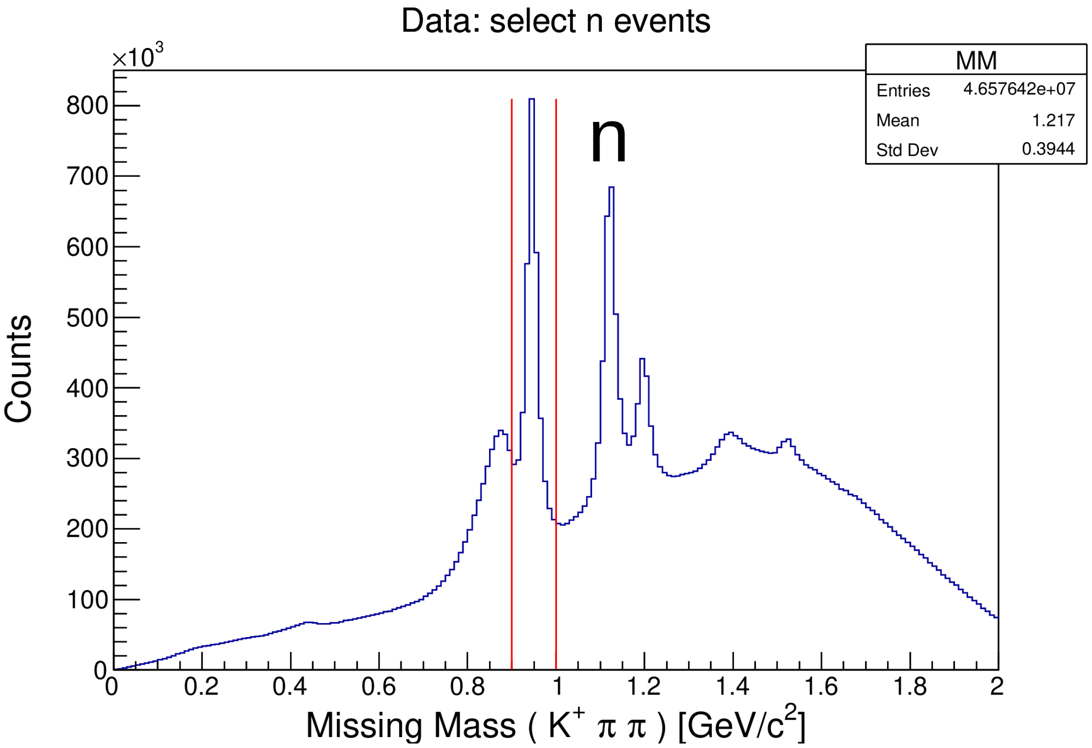
Data: Trigger Efficiency Map, K^+ Sector 1



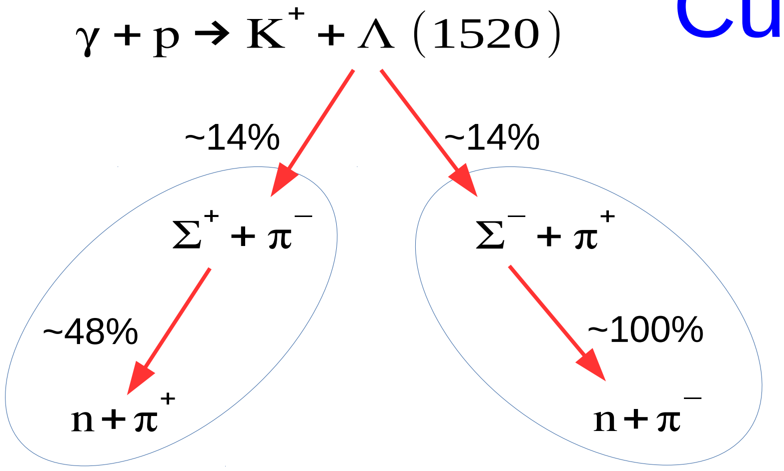
Trigger Efficiency Map

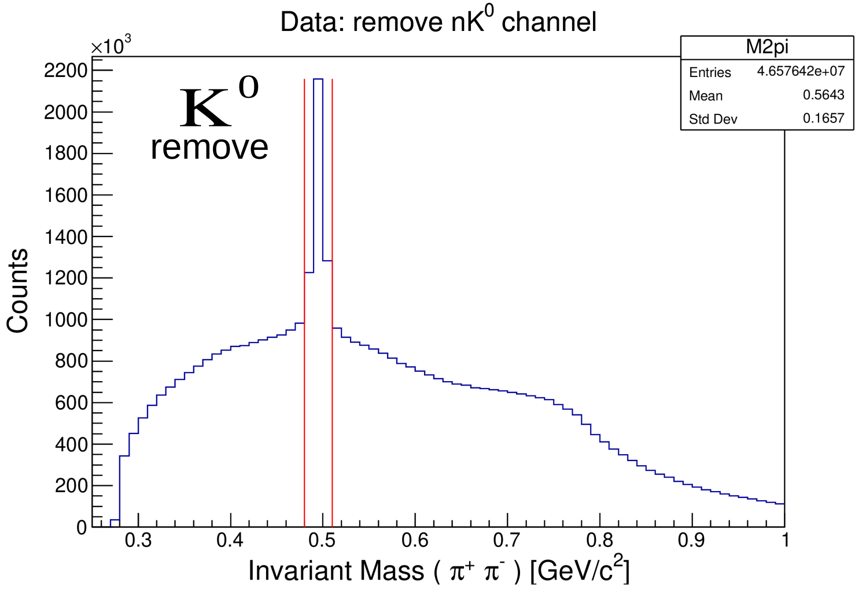


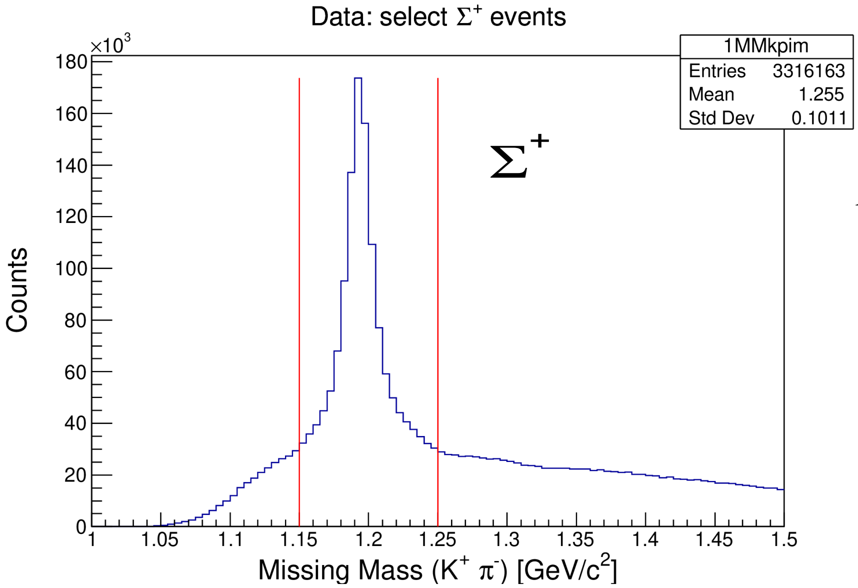
Cuts



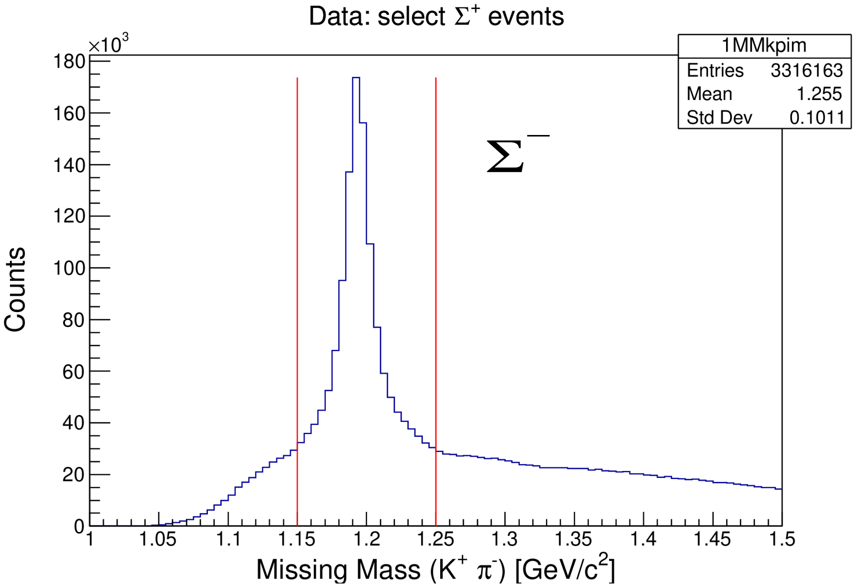
$$0.9 < MM(K^{+}\pi\pi) < 1.0 \ \ [GeV]$$



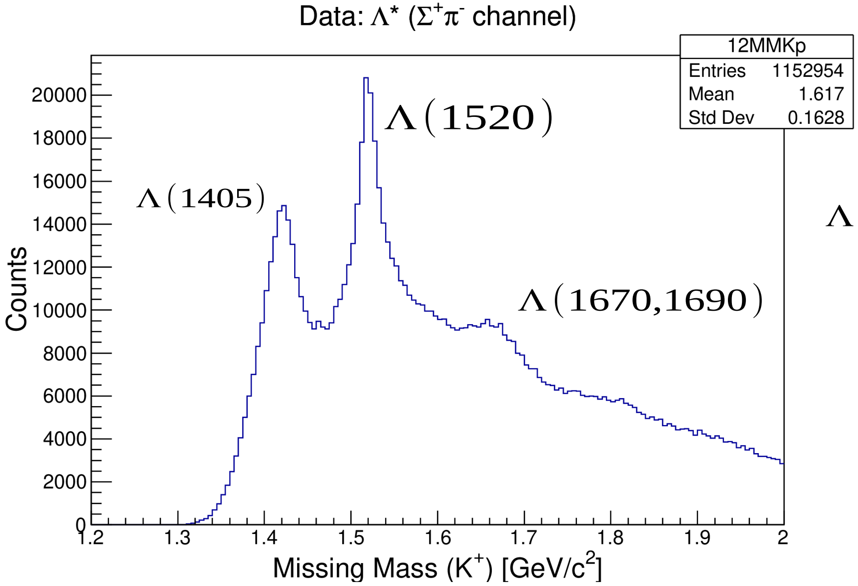




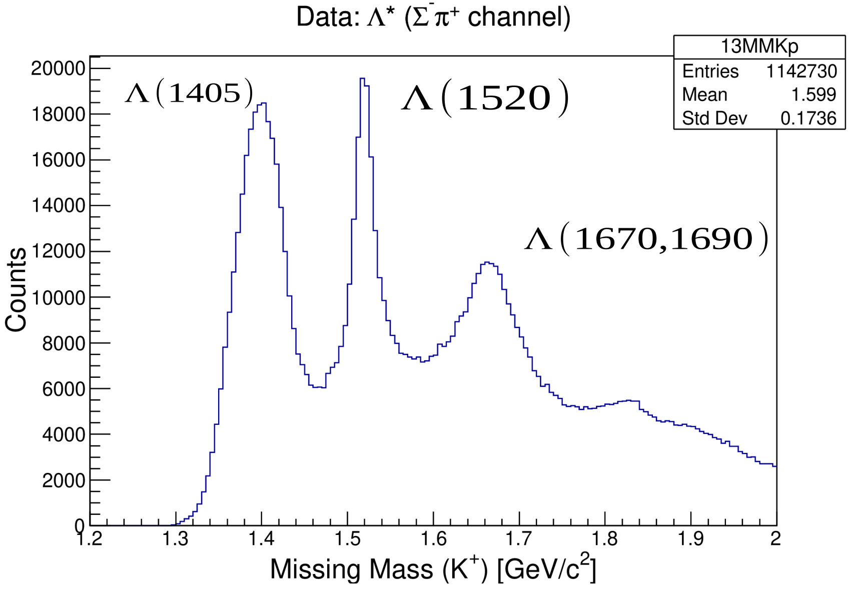
$$\Lambda(1520) \rightarrow \Sigma^{+} + \pi^{-}$$



Cuts

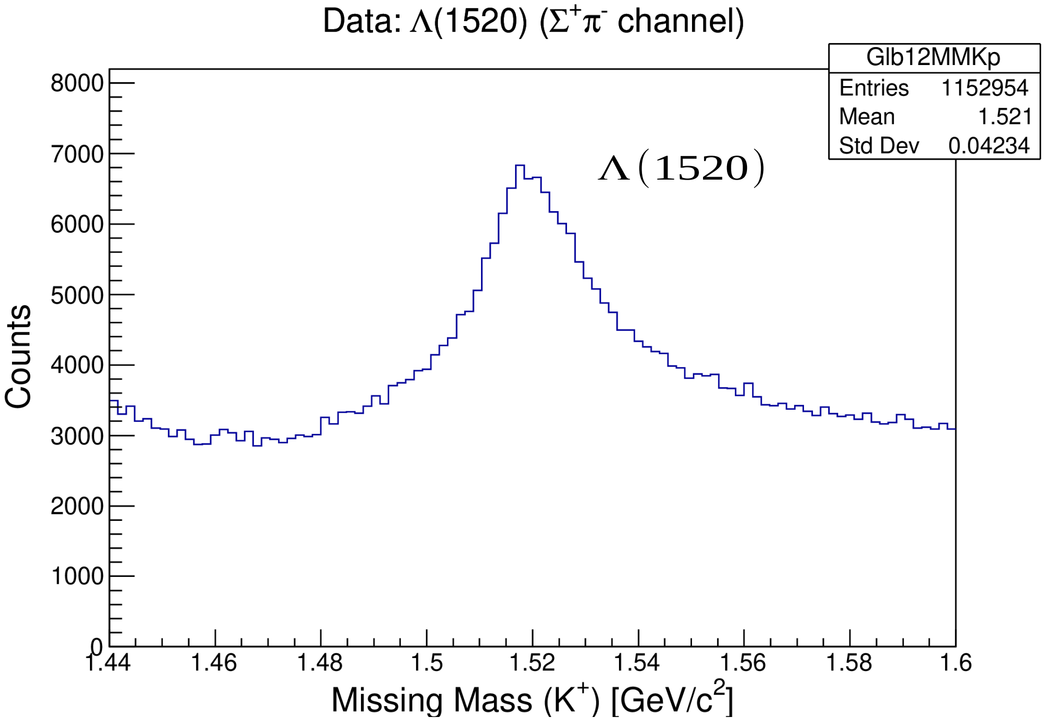


$$\Lambda(1520) \rightarrow \Sigma^{-} + \pi^{+}$$

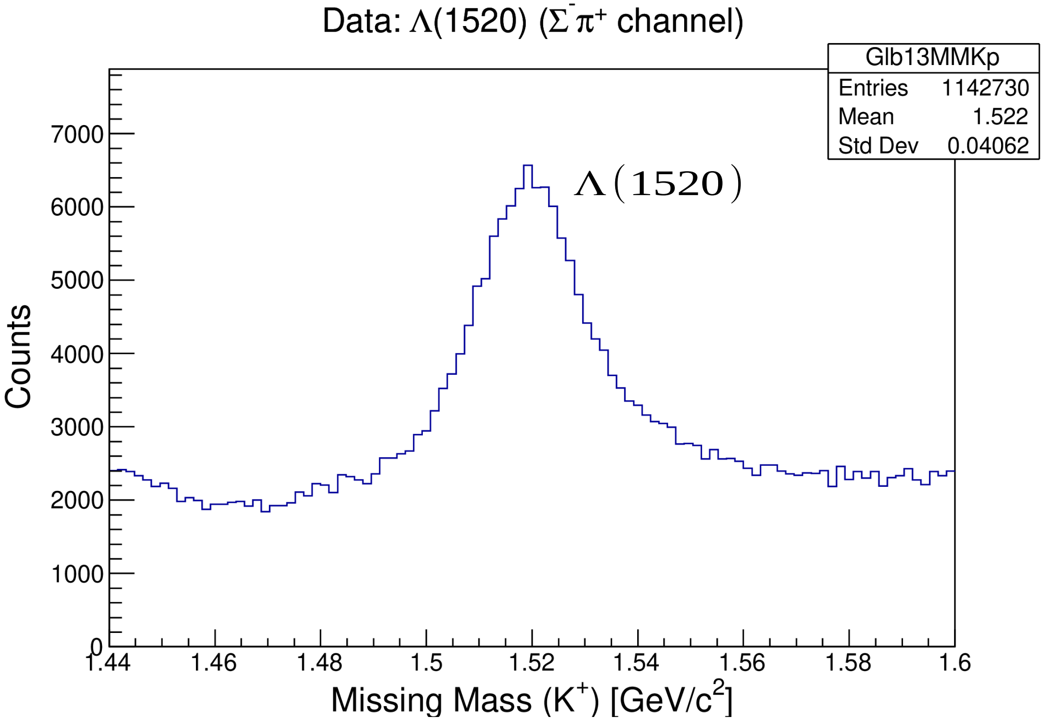


Global Spectrum

$\Lambda(1520) \rightarrow \Sigma^{+} + \pi^{-}$

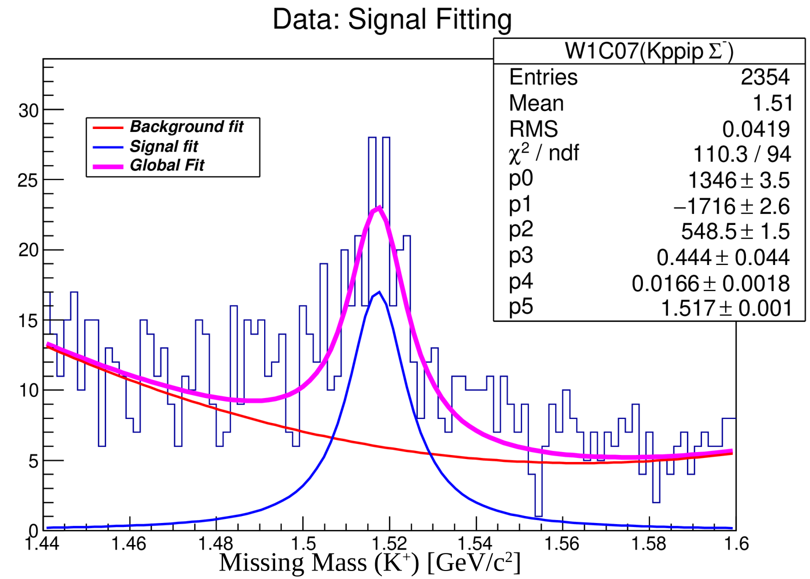


$\Lambda(1520) \rightarrow \Sigma^{-} + \pi^{+}$

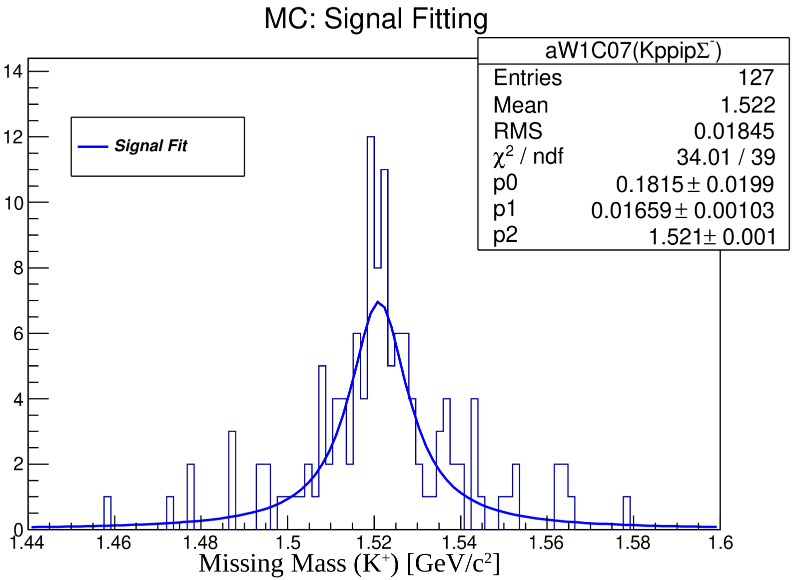


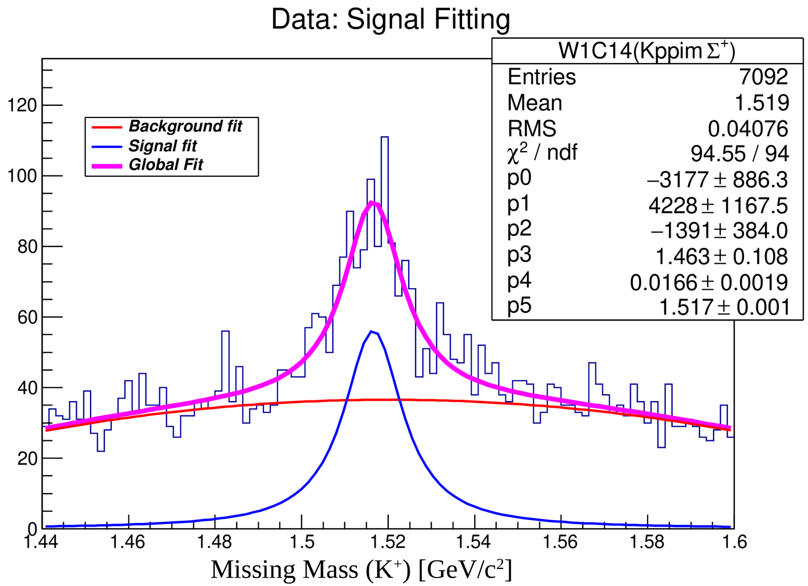
Global spectrum integrated over all angles leads towards fitting the $\Lambda(1520)$ peak with a Lorentzian function that rests on a smooth quadratic background.

Λ(1520): Yield & Acceptance

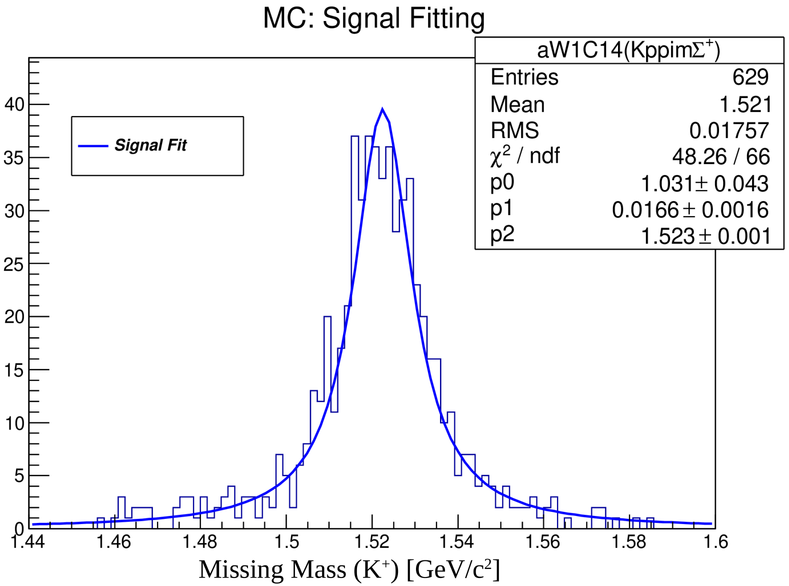


$\Lambda(1520) \rightarrow \Sigma^- + \pi^+$





$\Lambda(1520) \rightarrow \Sigma^+ + \pi^-$



Differential Cross-section: Λ(1520)

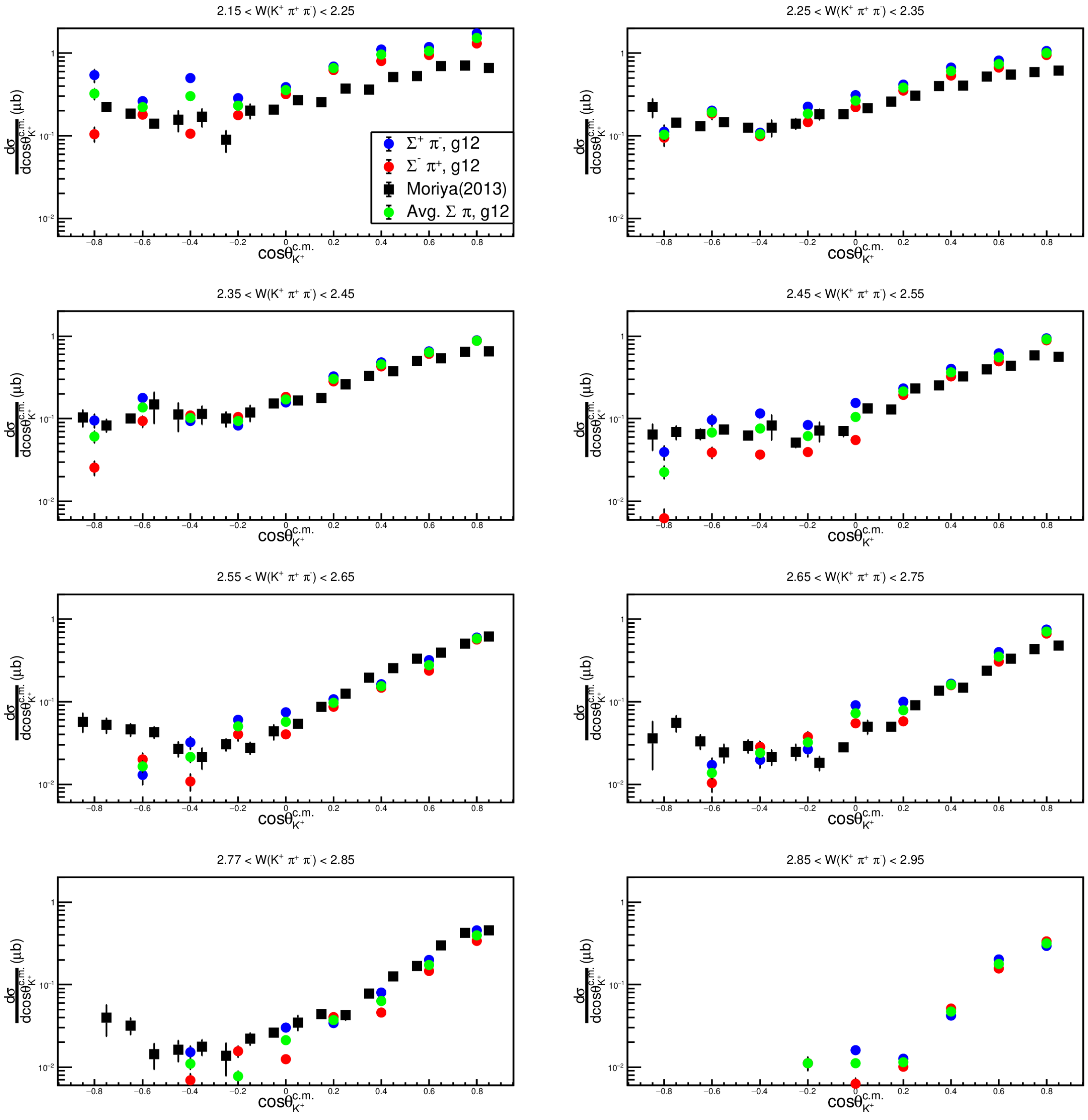
$$\frac{d\sigma}{dCos\theta^{c.m.}_{K^+}} = \frac{Y_d}{\tau\, \Delta\, cos\theta^{c.m.}_{K^+}\, A\, L(W)}$$

$\tau = Branching\ ratio$
$Y_d = Signal\ Yield$
$A = Acceptance$
$\Delta\ cos\theta^{c.m.}_{K^+} = Width\ of\ cos\theta\ bin$
$L(W) = Luminosity$

$$L(E_W) = \frac{\rho_p N_A l_t}{A_p} N_\gamma(W)$$

$l_t = 40$ cm
$\rho_p = 0.07114\ \mathrm{g/cm^3}$
$A_p = 1.00794$ g/mol
N_A is Avogadro's number

Λ(1520) dcs for $\Sigma^+\pi^-$ & $\Sigma^-\pi^+$ channels with g11 CLAS results



K. Moriya et al. Differential photoproduction cross sections of the $\Sigma^0(1385)$, $\Lambda(1405)$, and $\Lambda(1520)$ *Phys. Rev. C*, 88:045201, Oct 2013.

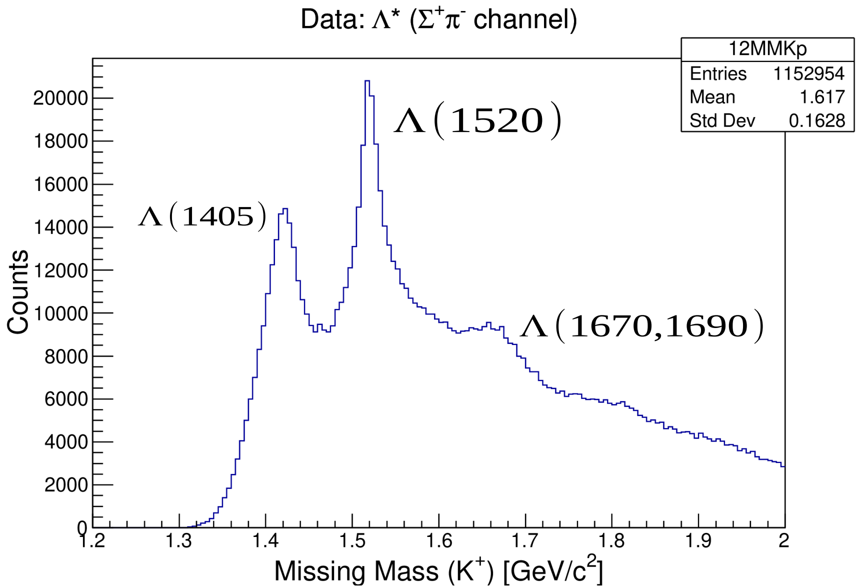
$\Lambda(1670)$ & $\Lambda(1690)$

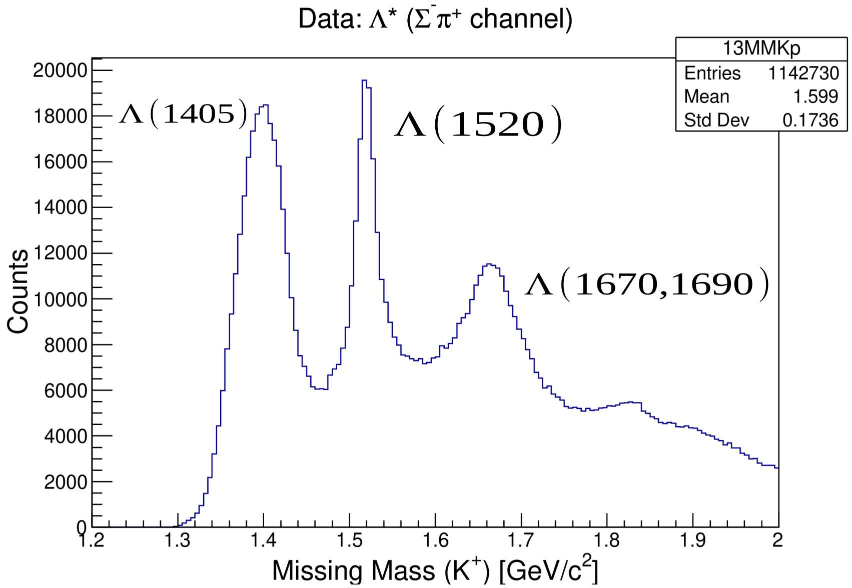
Particle	J^P	PDG rating	Status as seen in $N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other Channels
$\Lambda(1405)$	1/2-	****	****	Forbidden	****	
$\Lambda(1520)$	3/2-	****	****	Forbidden	****	$\Lambda\pi\pi$, $\Lambda\gamma$
$\Lambda(1670)$	1/2-	****	****	Forbidden	****	$\Lambda\eta$
$\Lambda(1690)$	3/2-	****	****	Forbidden	****	$\Lambda\pi\pi$, $\Sigma\pi\pi$

Not well investigated using photoproduction data.

Same final state particles: K^+, π^+, π^-

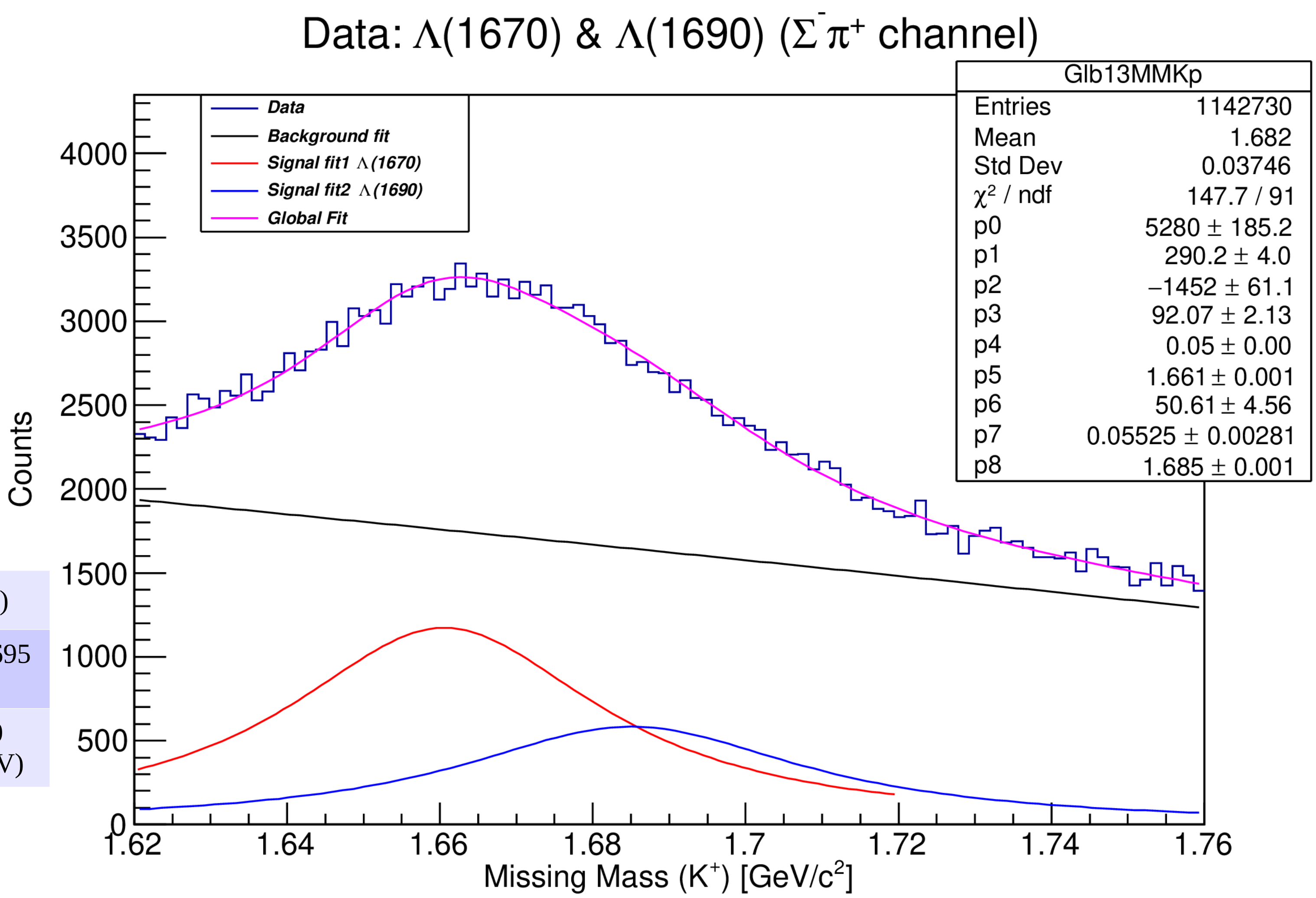
Partial Wave Analysis will be employed.



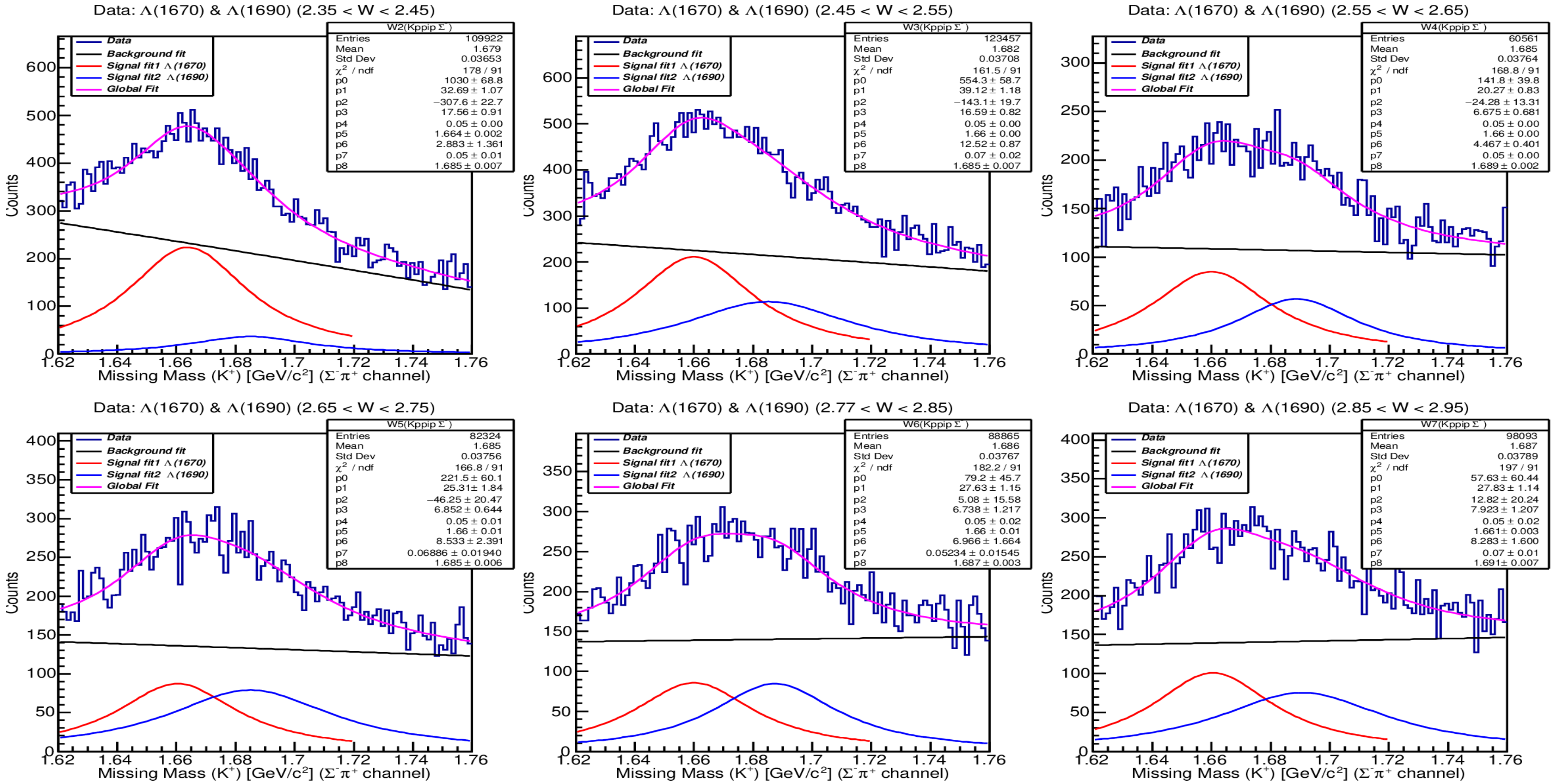


Signal Fitting: Λ(1670) & Λ(1690)

Parameter	Λ(1670)	Λ(1690)
Peak	1660 – 1680 (MeV)	1685 – 1695 (MeV)
Width	25 – 50 (~35 MeV)	50 – 70 (~60 MeV)



Signal Fitting: $\Lambda(1670)$ & $\Lambda(1670)$ $\Sigma^{-}\pi^{+}$ channel (W bins)



Next

- The $\Lambda(1520)$ cross section matched with the CLAS g11 data.
- $\Lambda(1520)$ cross sections for higher W value will be obtained.
- First attempt at $\Lambda(1670)$ & $\Lambda(1690)$ peaks show need for better understanding of the background function.
- Simulation are ongoing to study the nature of the peaks.
- Further Analysis of higher mass resonances, ie, $\Lambda(1670)$ & $\Lambda(1690)$, using partial wave analysis will be done.