Photoproduction of Λ^* Resonances at CLAS

CLAS Collaboration Meeting
March 07, 2019

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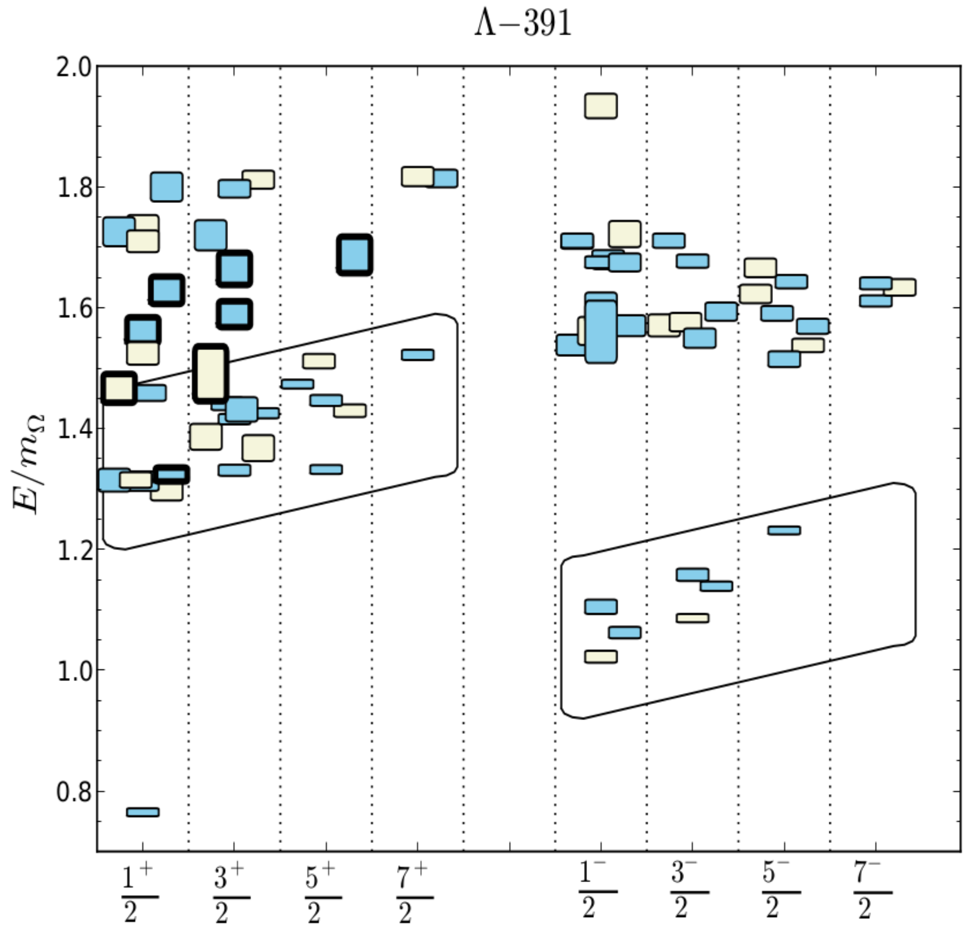
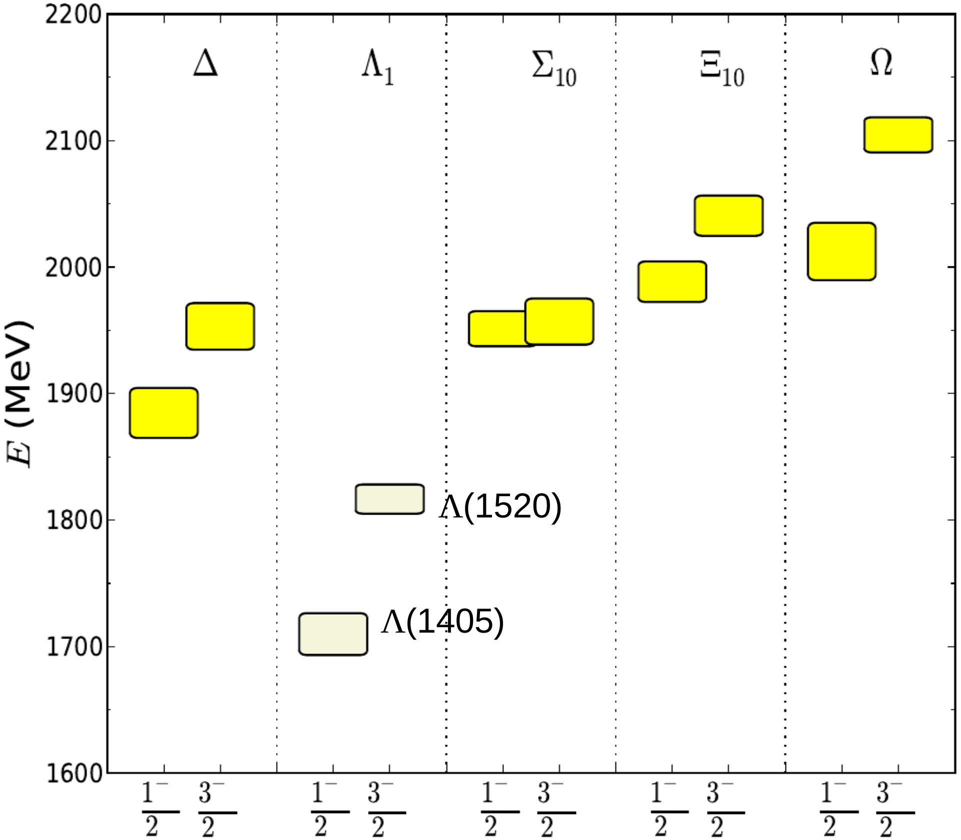
Λ*

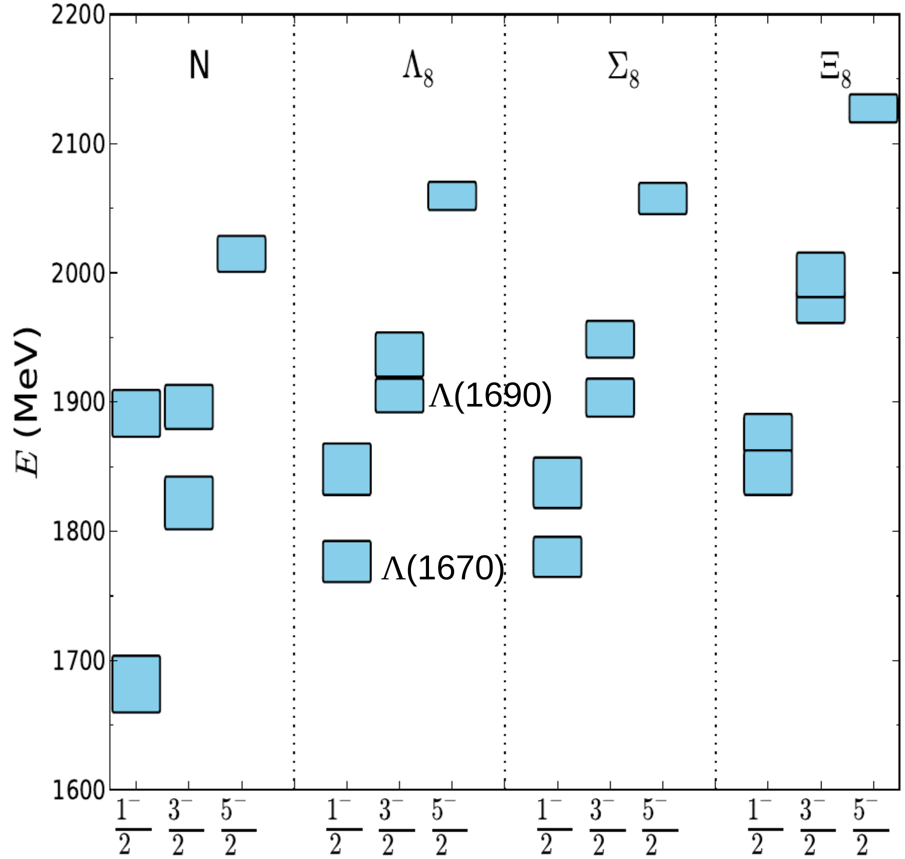
J^P	$(D, L^P_N)\,S$		Octet members				Singlets
$1/2^+$	$(56,0^+_0)$	$1/2$	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56,0^+_2)$	$1/2$	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(1690)^\dagger$	
$1/2^-$	$(70,1^-_1)$	$1/2$	$N(1535)$	$\Lambda(1670)$	$\Sigma(1620)$	$\Xi(?)$	$\Lambda(1405)$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



- 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.

Λ*

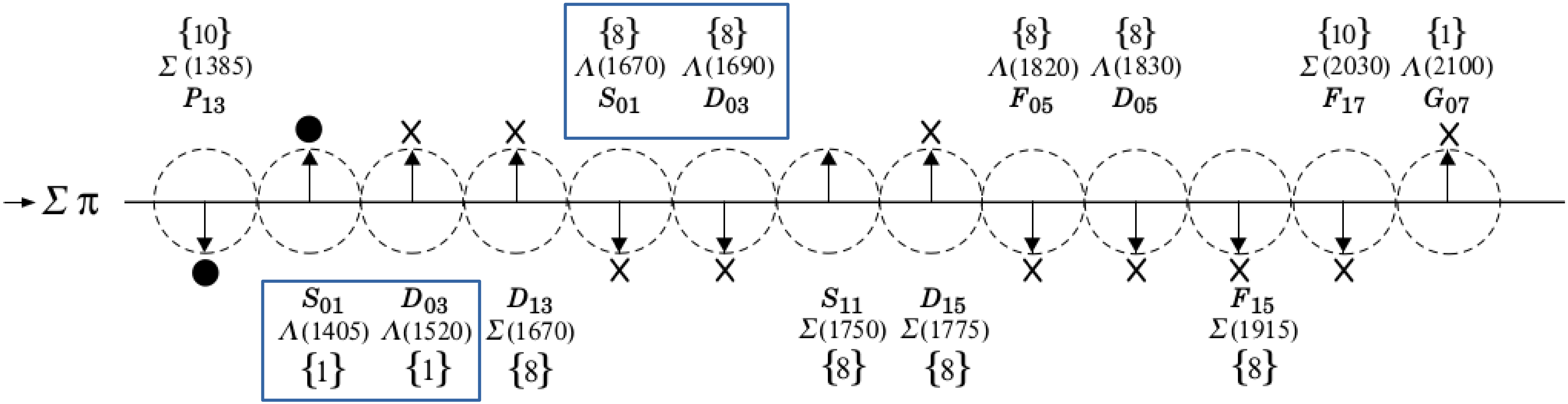




Edwards *et al.*

- 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	****	$\Lambda\pi\pi, \Sigma\pi\pi$

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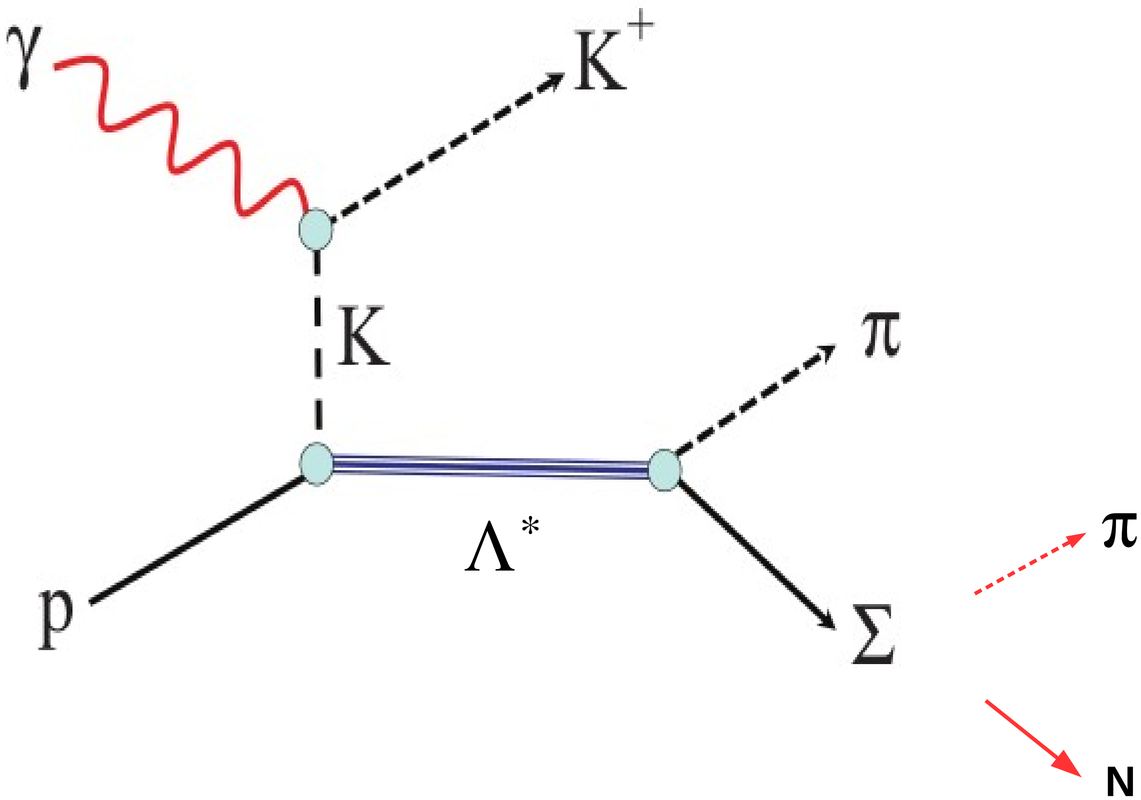
Reaction



$$\gamma + p \rightarrow K^{+} + \Lambda^{*}$$

$$\Lambda^{*} \rightarrow \Sigma^{+} + \pi^{-}$$

$$\Lambda^{*} \rightarrow \Sigma^{-} + \pi^{+}$$

Photo-prodution off a proton creates a Λ^*, which can decay by $\Sigma\pi$ channel. With Σ giving n & π, the final particles detected are K^+, π^+ & π^-.

PID

$\gamma + p \rightarrow K^+ + \Lambda(1520)$

~14% $\quad \Sigma^+ + \pi^-$

~14% $\quad \Sigma^- + \pi^+$

$\Sigma^+ + \pi^-$: ~48% $\quad n + \pi^+$

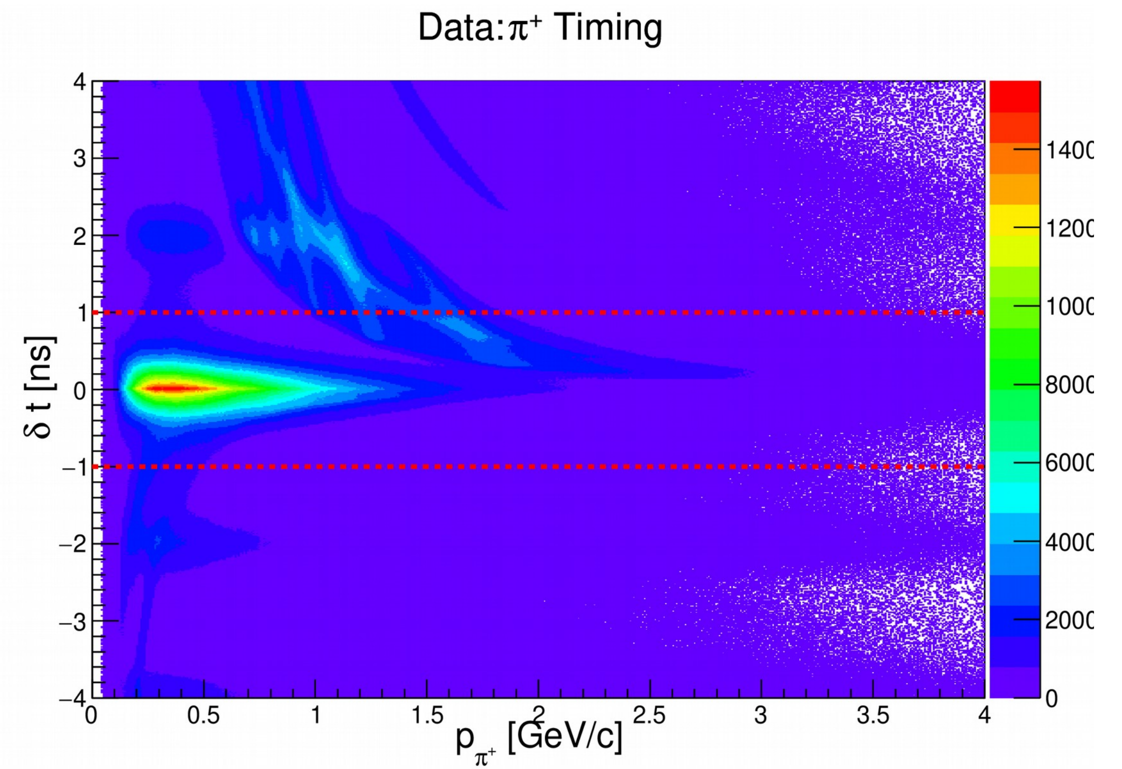
$\Sigma^- + \pi^+$: ~100% $\quad n + \pi^-$

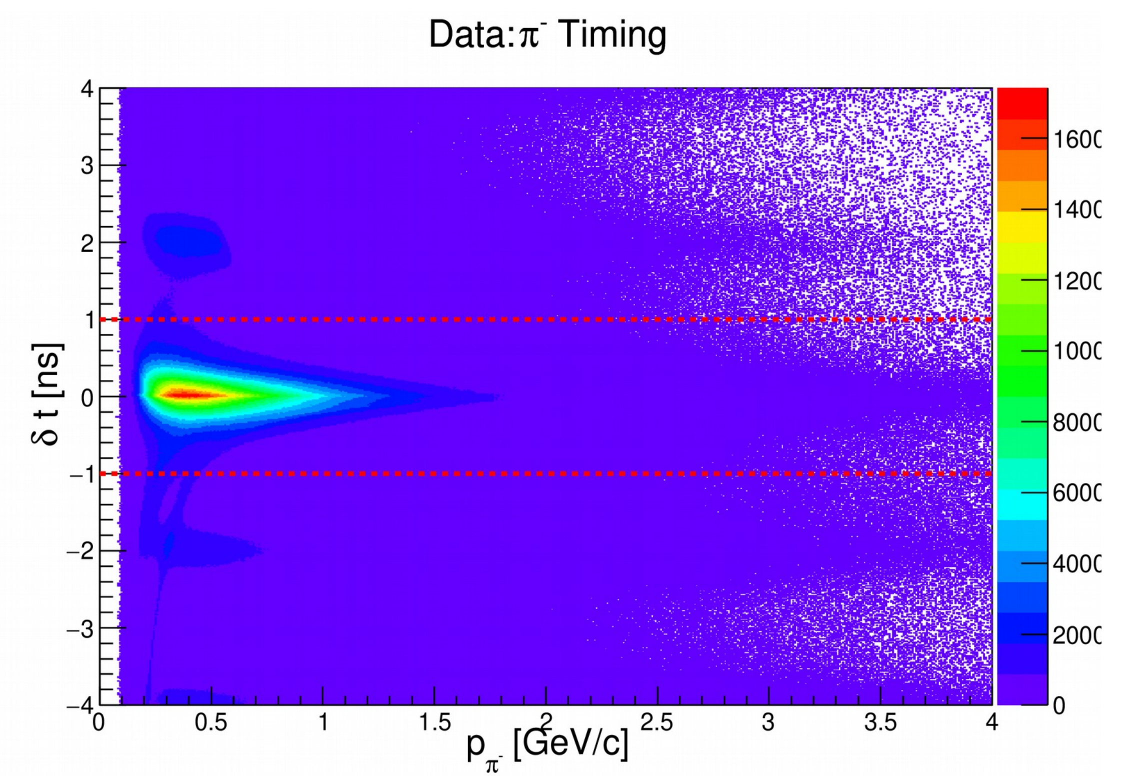
$$\delta t = t_{meas} - t_{calc}$$

$$t_{meas} = t_{SC} - t_{\gamma}$$

$$t_{calc} = \frac{d_{path}}{c}\frac{E_i}{p_i}$$

Similar |δt| < 1 [ns] for K^+ was done





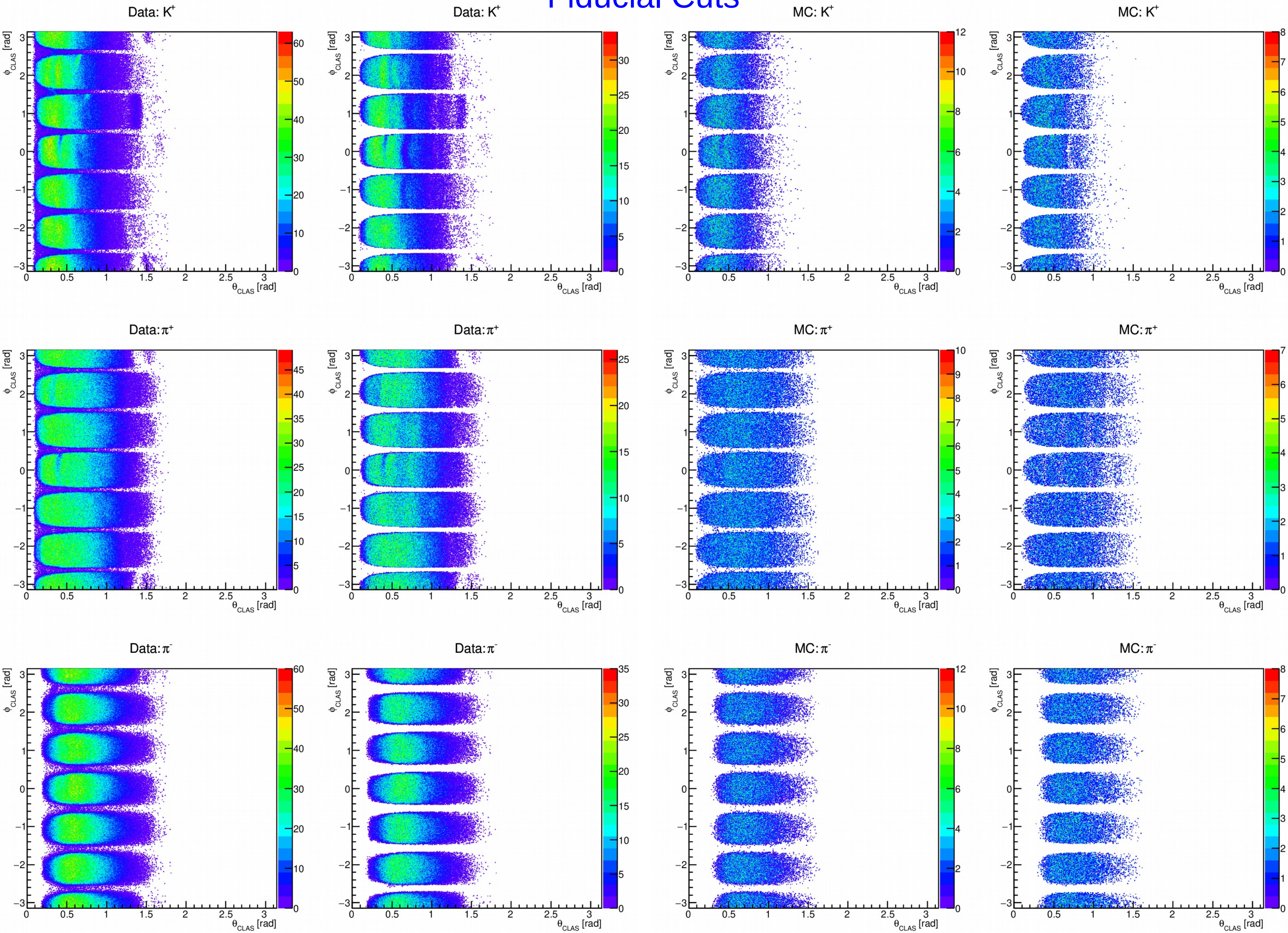
Outline (Cuts)

Trigger	$\Sigma^+\pi^-$	$\Sigma^-\pi^+$
Data	~78 %	~78 %
MC	~74 %	~77 %

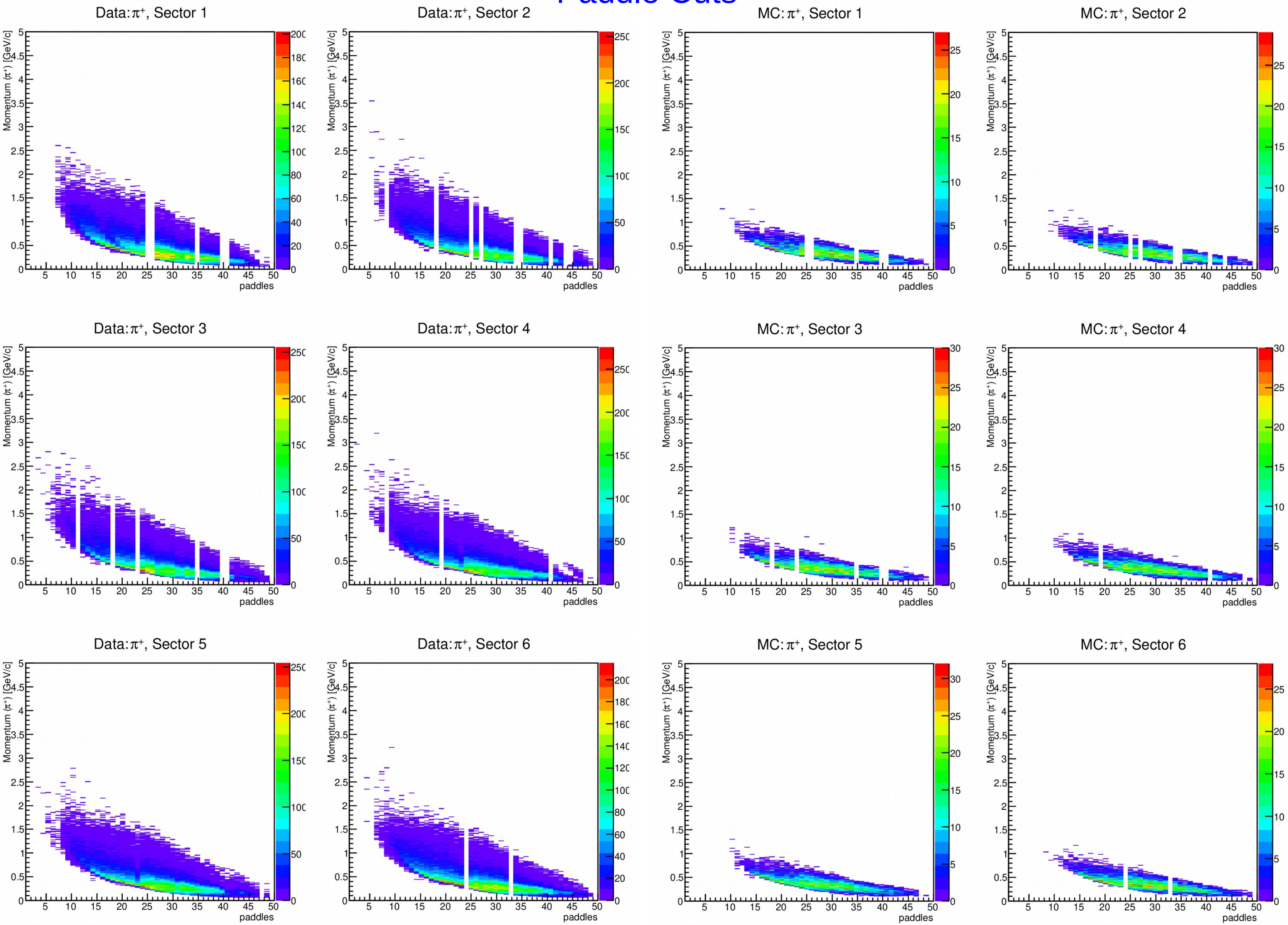
- Photon selection → 1 and 2 photon case (Photon Multiplicity)
- The g12 trigger: all three particles detected in three different sectors.
- PID → K^+, π^+, π^-. Straight cuts of 1 ns on Momentum Vs Timing plots were made for particle identification.
- Fiducial and Paddle Cuts for the g12 requirements were carried out.
- 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
$1.44 \leq MM(K^+) \leq 1.6$	Fitting Range
$2.15 \leq W \leq 2.45$ GeV $-0.9 \leq \cos\theta^{K+}_{cm} \leq 0.9$	Kinematic Ranges

Fiducial Cuts



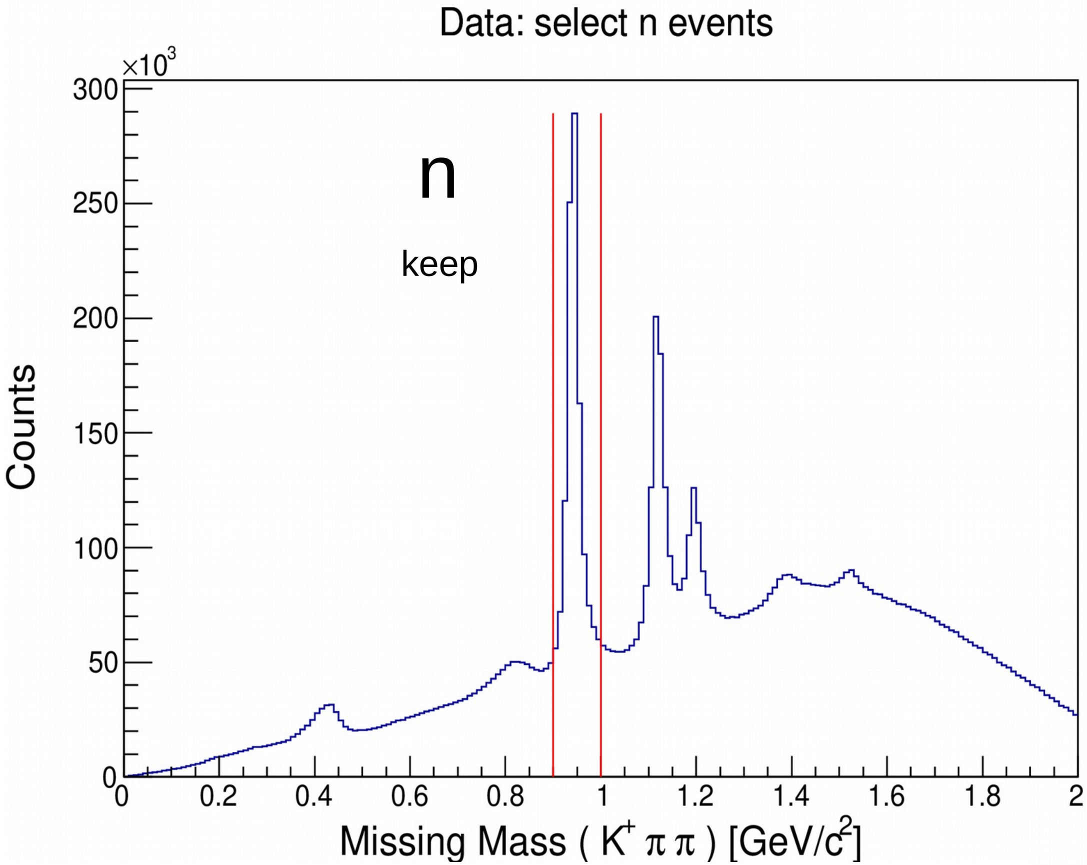
Paddle Cuts



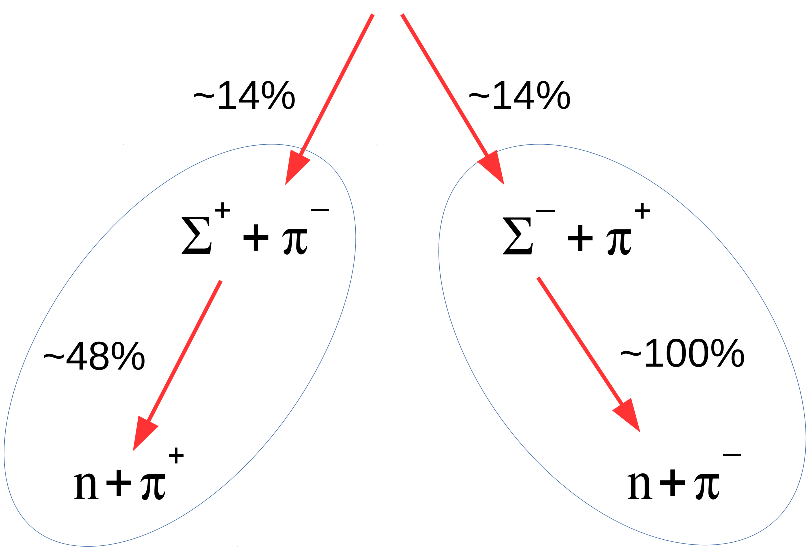
Data: π⁺, Sector 1
Data: π⁺, Sector 2
MC: π⁺, Sector 1
MC: π⁺, Sector 2
Data: π⁺, Sector 3
Data: π⁺, Sector 4
MC: π⁺, Sector 3
MC: π⁺, Sector 4
Data: π⁺, Sector 5
Data: π⁺, Sector 6
MC: π⁺, Sector 5
MC: π⁺, Sector 6
Momentum (π⁺) [GeV/c]
paddles

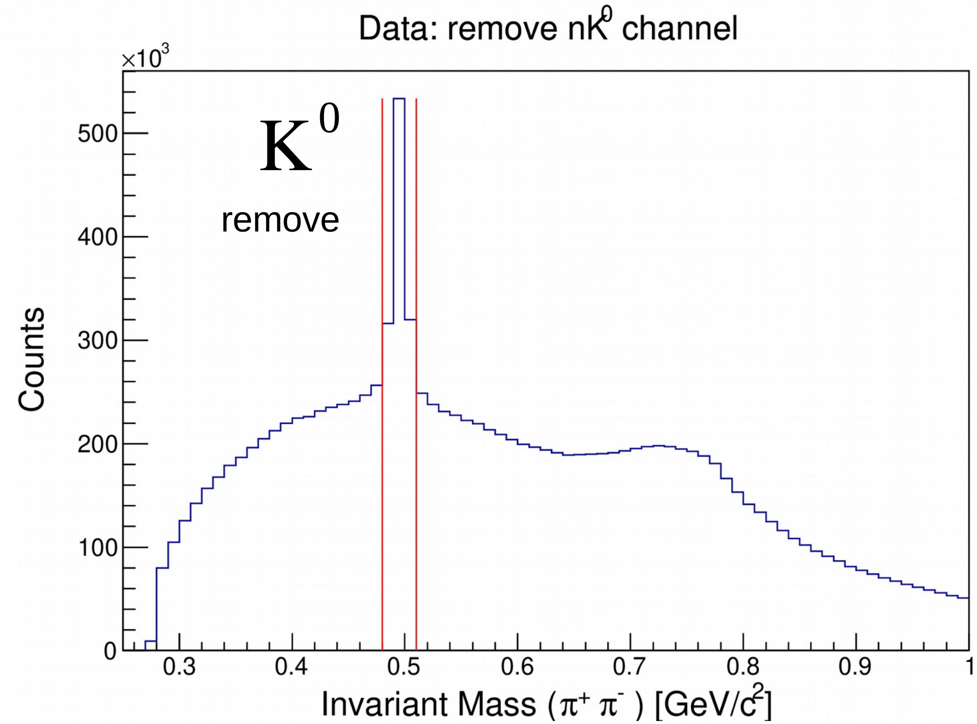
Cuts

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



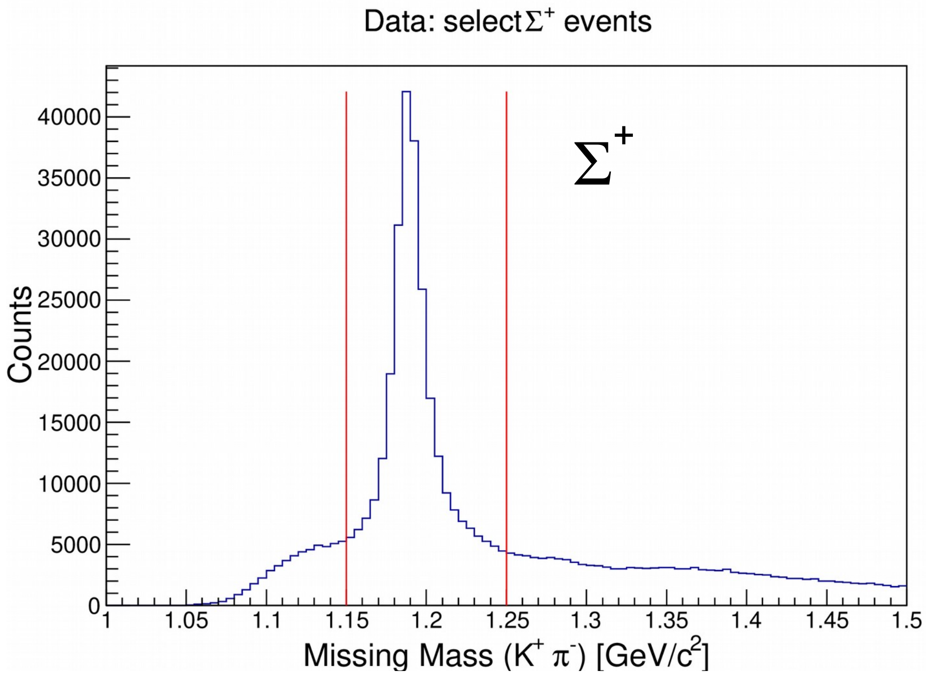
$$\gamma + p \rightarrow K^{+} + \Lambda(1520)$$

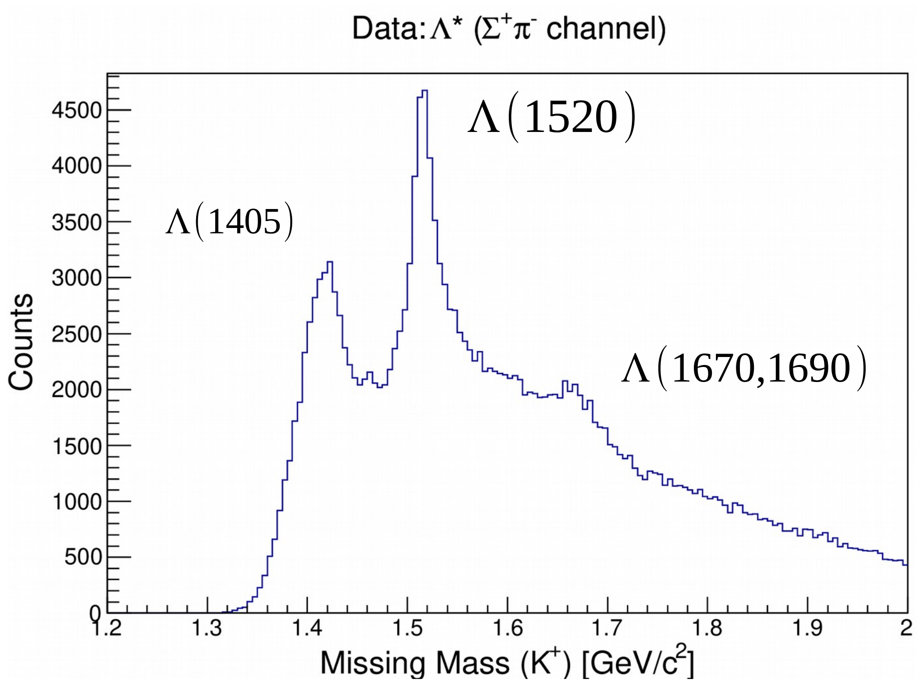




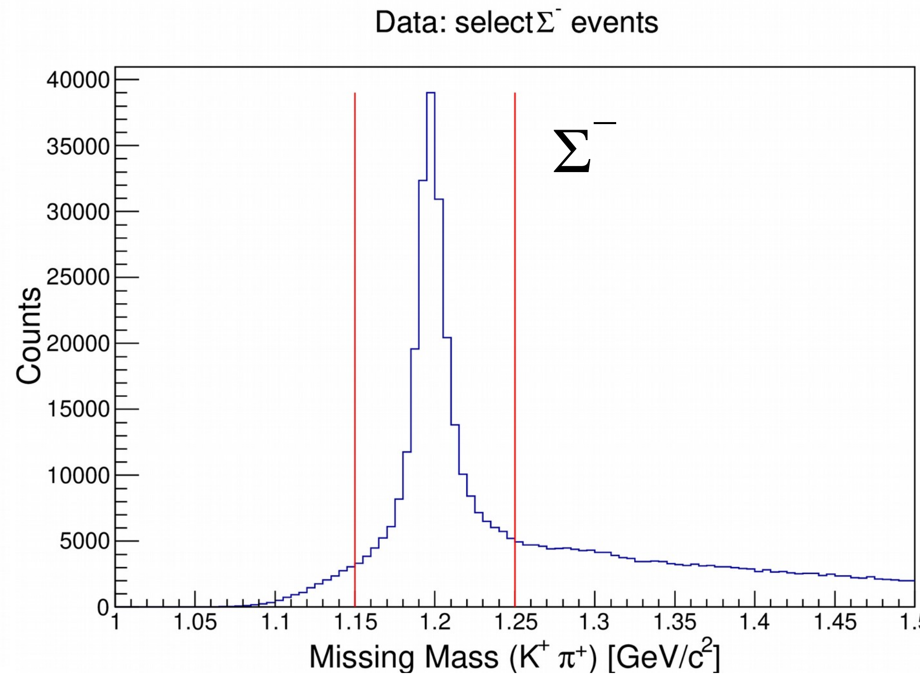
Cuts

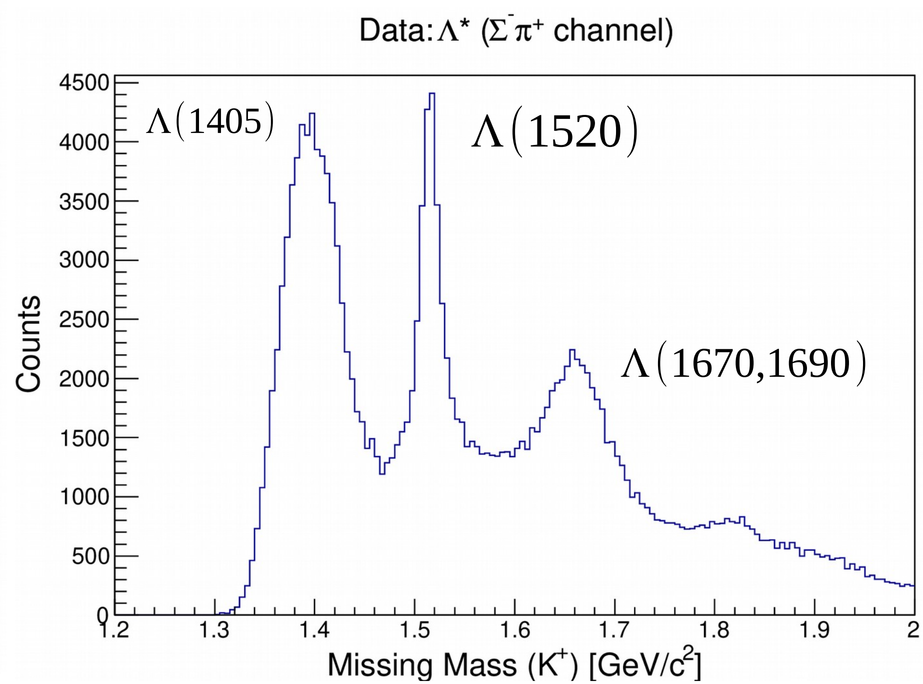
$\Lambda(1520) \rightarrow \Sigma^{+} + \pi^{-}$





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

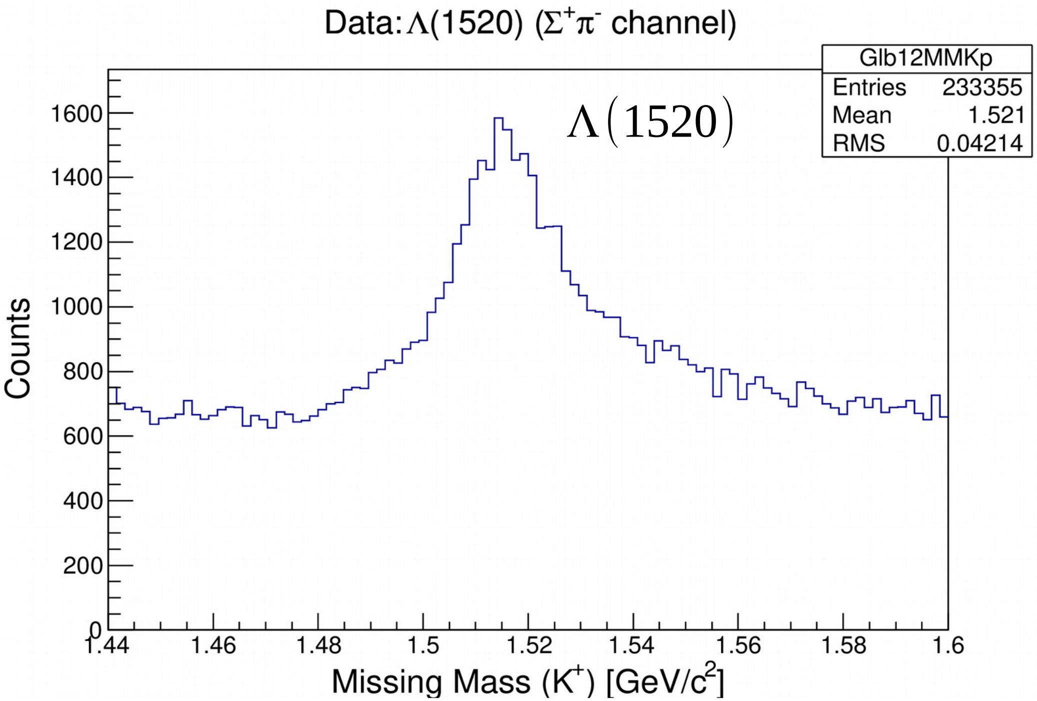


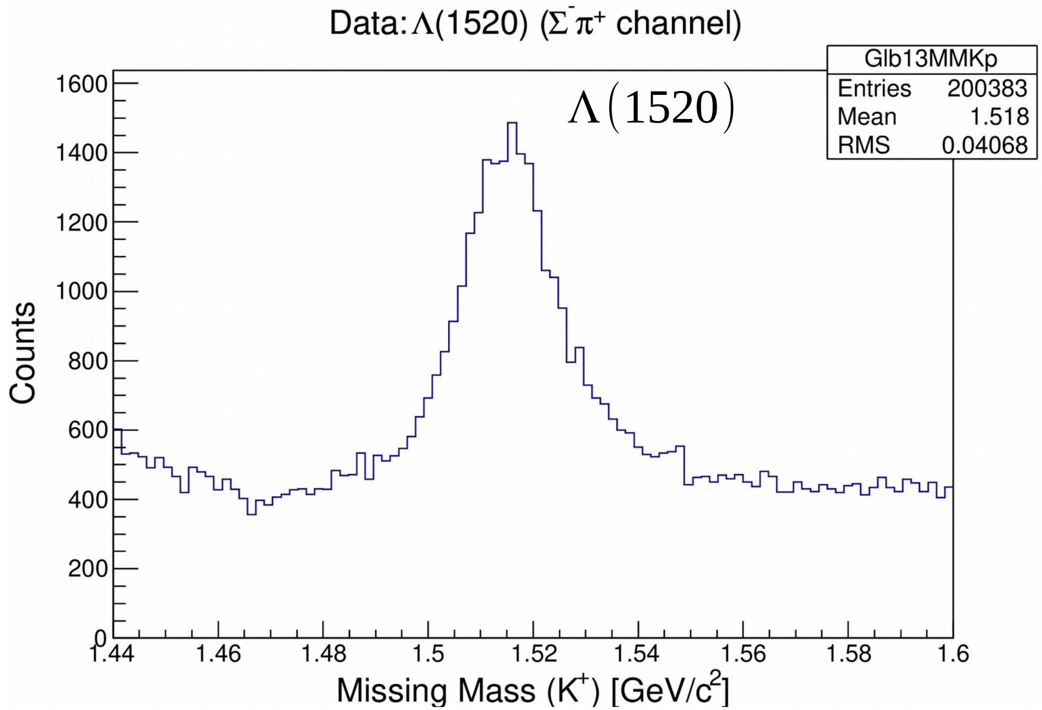


Global Spectrum

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

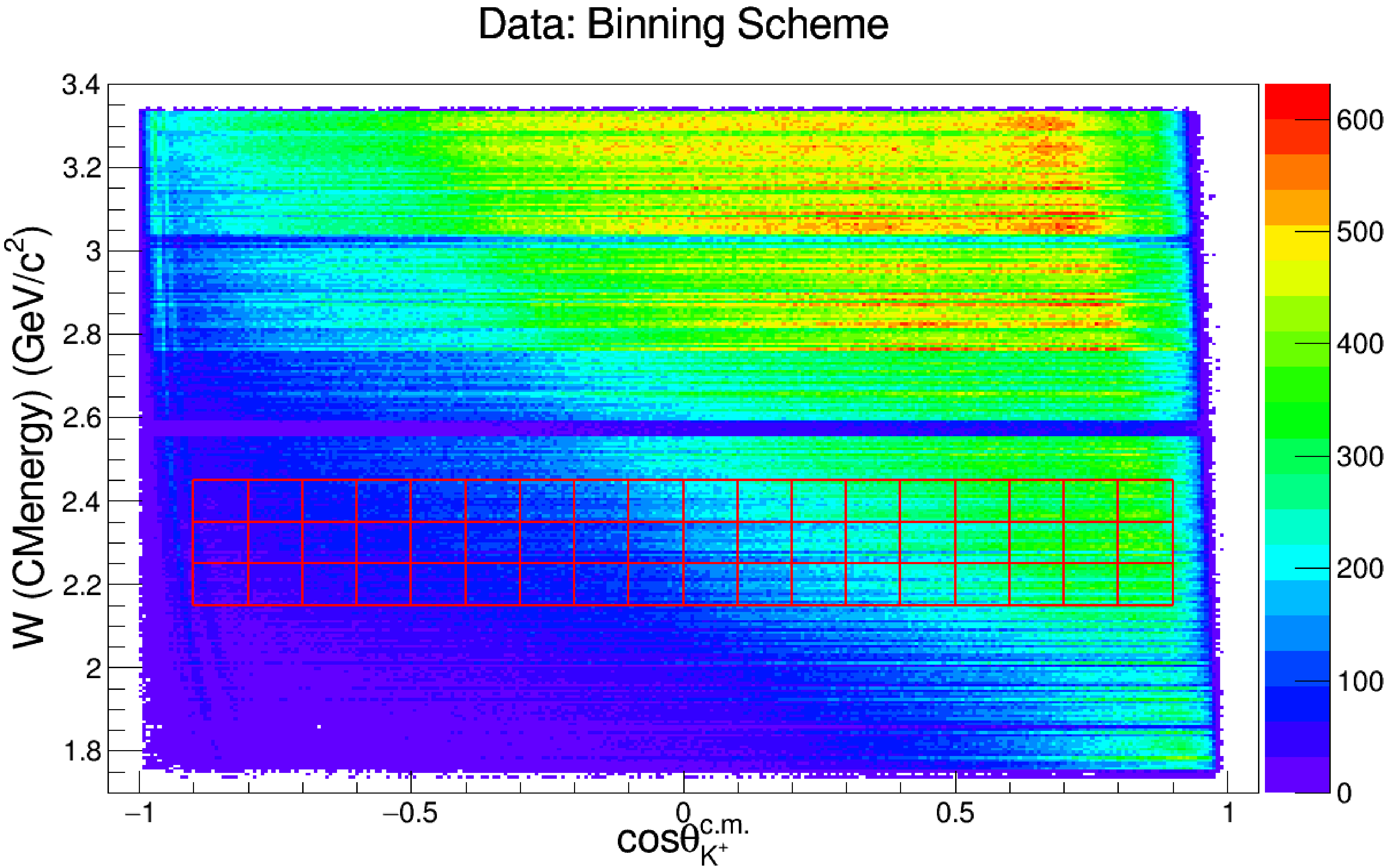
$\Lambda(1520) \rightarrow \Sigma^{-} + \pi^{+}$



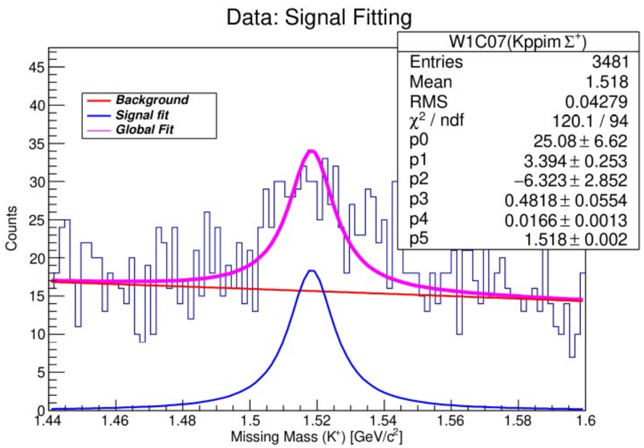


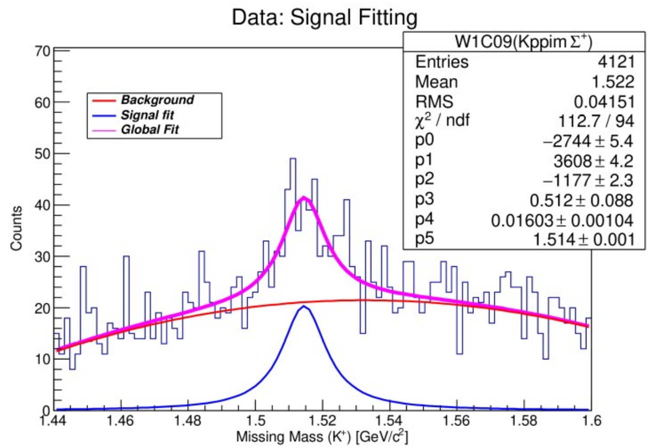
Global spectrum integrated over all angles leads towards fitting the $\Lambda(1520)$ peak with a Lorentzian function that rests on a smooth quadratic background.

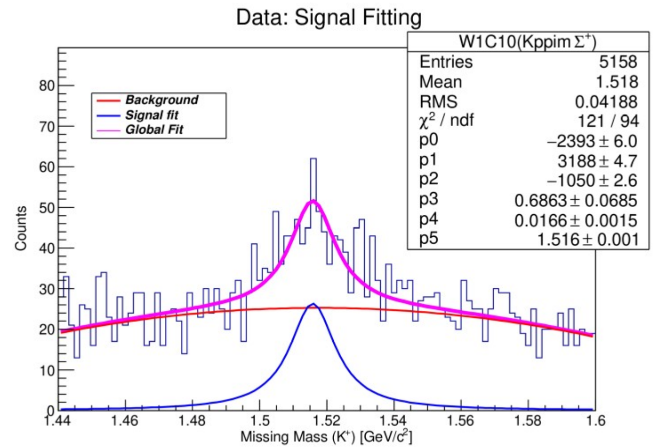
Bin Scheme

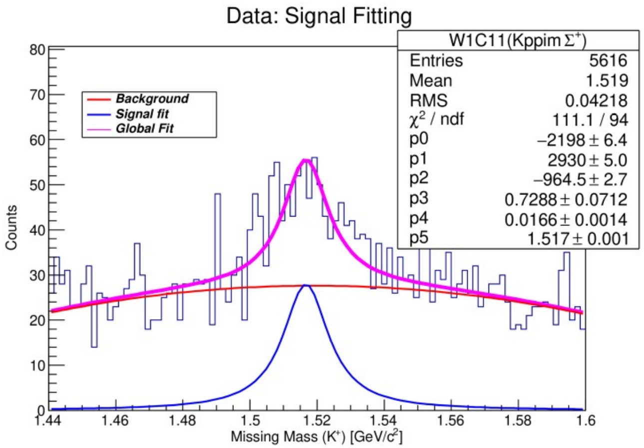

Data: Binning Scheme
W (CMenergy) (GeV/c^2)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
−1
−0.5
0
0.5
1
$\cos\theta_{K^+}^{c.m.}$
600
500
400
300
200
100
0

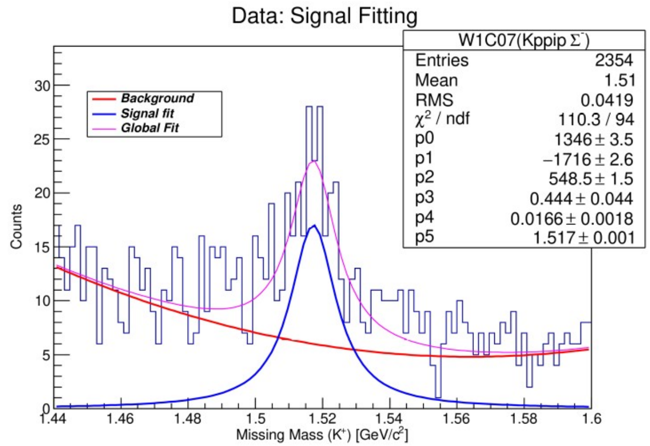
Fitting

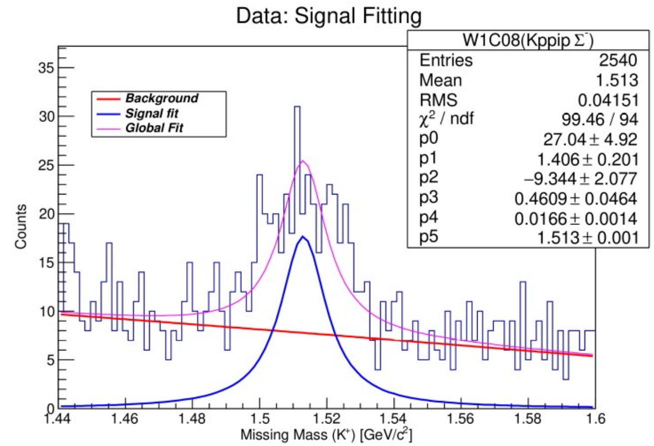

Data: Signal Fitting
W1C07(Kppim Σ+)
Entries 3481
Mean 1.518
RMS 0.04279
χ2 / ndf 120.1 / 94
p0 25.08 ± 6.62
p1 3.394 ± 0.253
p2 −6.323 ± 2.852
p3 0.4818 ± 0.0554
p4 0.0166 ± 0.0013
p5 1.518 ± 0.002
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

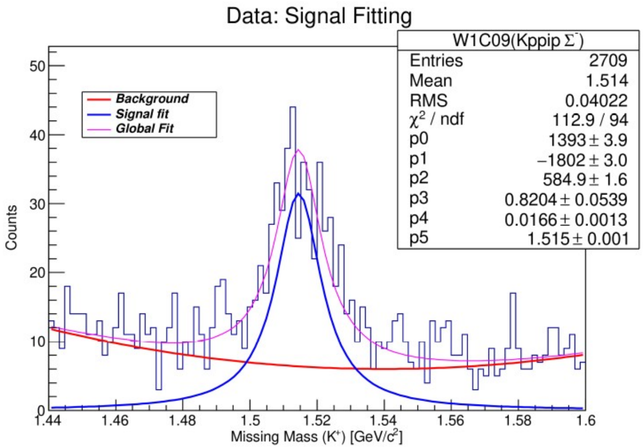

Data: Signal Fitting
W1C09(Kppim Σ+)
Entries 4121
Mean 1.522
RMS 0.04151
χ2 / ndf 112.7 / 94
p0 −2744 ± 5.4
p1 3608 ± 4.2
p2 −1177 ± 2.3
p3 0.512 ± 0.088
p4 0.01603 ± 0.00104
p5 1.514 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

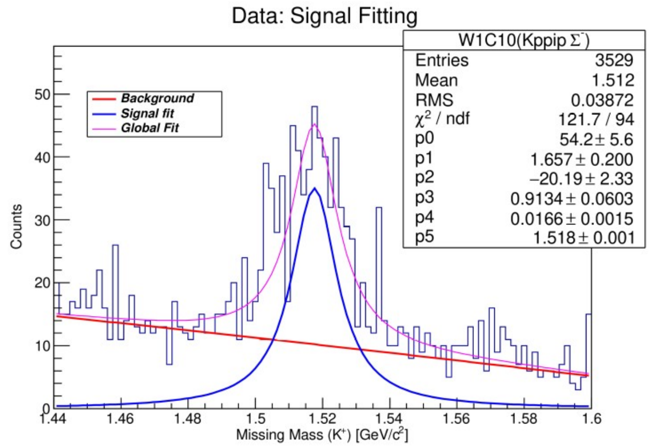

Data: Signal Fitting
W1C10(Kppim Σ+)
Entries 5158
Mean 1.518
RMS 0.04188
χ2 / ndf 121 / 94
p0 −2393 ± 6.0
p1 3188 ± 4.7
p2 −1050 ± 2.6
p3 0.6863 ± 0.0685
p4 0.0166 ± 0.0015
p5 1.516 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

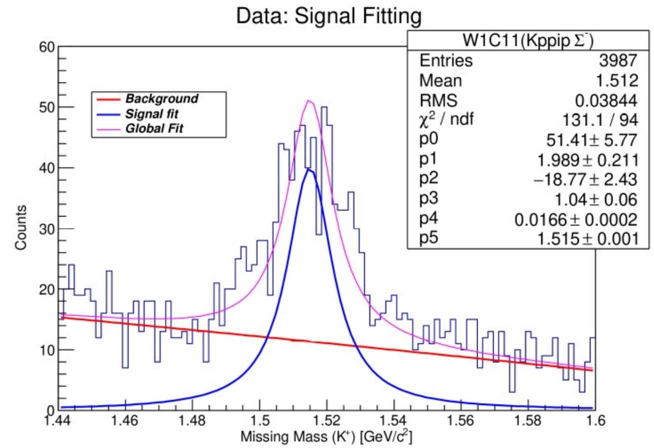

Data: Signal Fitting
W1C11(Kppim Σ+)
Entries 5616
Mean 1.519
RMS 0.04218
χ2 / ndf 111.1 / 94
p0 −2198 ± 6.4
p1 2930 ± 5.0
p2 −964.5 ± 2.7
p3 0.7288 ± 0.0712
p4 0.0166 ± 0.0014
p5 1.517 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]


Data: Signal Fitting
W1C07(Kppip Σ-)
Entries 2354
Mean 1.51
RMS 0.0419
χ2 / ndf 110.3 / 94
p0 1346 ± 3.5
p1 −1716 ± 2.6
p2 548.5 ± 1.5
p3 0.444 ± 0.044
p4 0.0166 ± 0.0018
p5 1.517 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

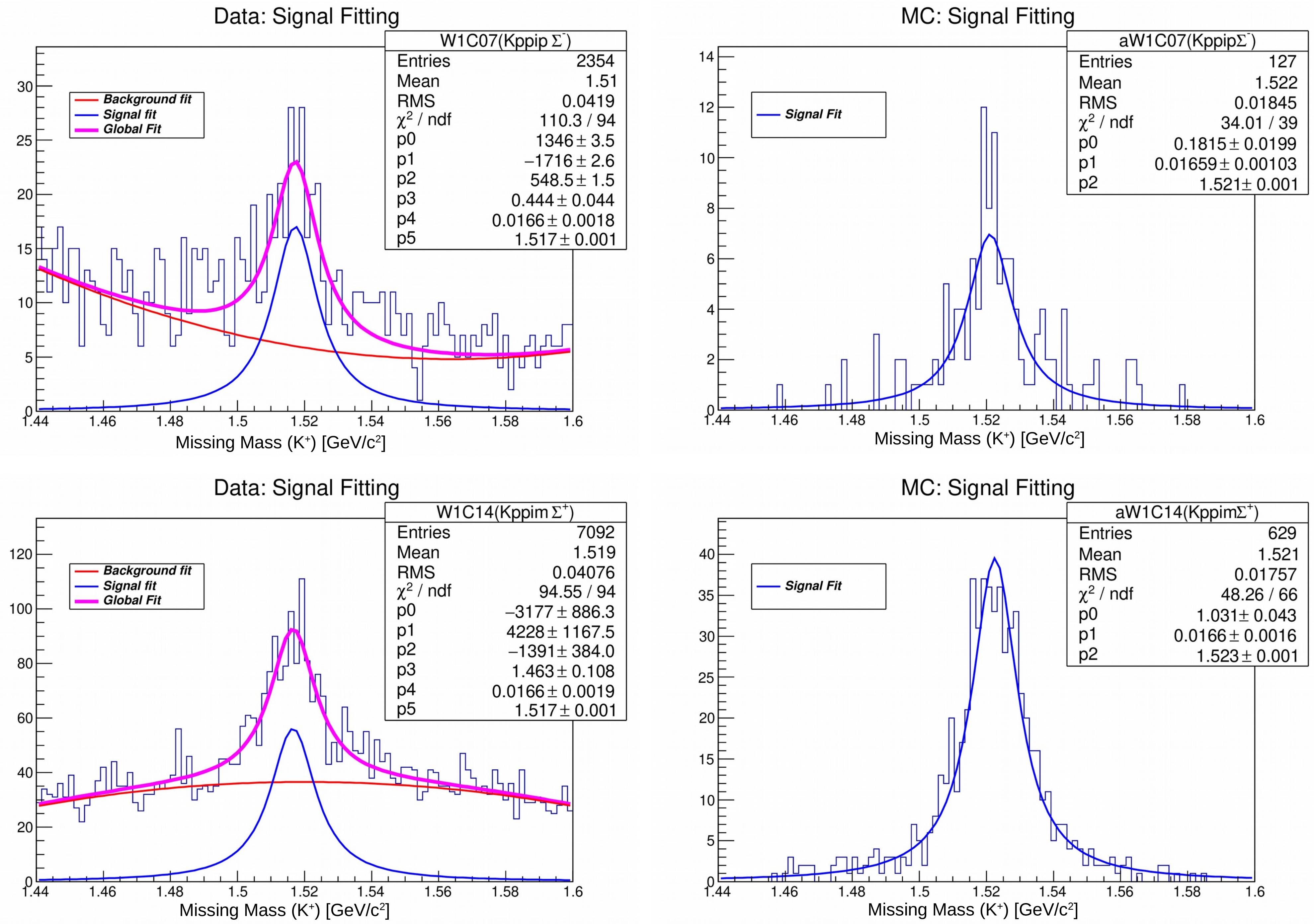

Data: Signal Fitting
W1C08(Kppip Σ-)
Entries 2540
Mean 1.513
RMS 0.04151
χ2 / ndf 99.46 / 94
p0 27.04 ± 4.92
p1 1.406 ± 0.201
p2 −9.344 ± 2.077
p3 0.4609 ± 0.0464
p4 0.0166 ± 0.0014
p5 1.513 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]


Data: Signal Fitting
W1C09(Kppip Σ-)
Entries 2709
Mean 1.514
RMS 0.04022
χ2 / ndf 112.9 / 94
p0 1393 ± 3.9
p1 −1802 ± 3.0
p2 584.9 ± 1.6
p3 0.8204 ± 0.0539
p4 0.0166 ± 0.0013
p5 1.515 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]


Data: Signal Fitting
W1C10(Kppip Σ-)
Entries 3529
Mean 1.512
RMS 0.03872
χ2 / ndf 121.7 / 94
p0 54.2 ± 5.6
p1 1.657 ± 0.200
p2 −20.19 ± 2.33
p3 0.9134 ± 0.0603
p4 0.0166 ± 0.0015
p5 1.518 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

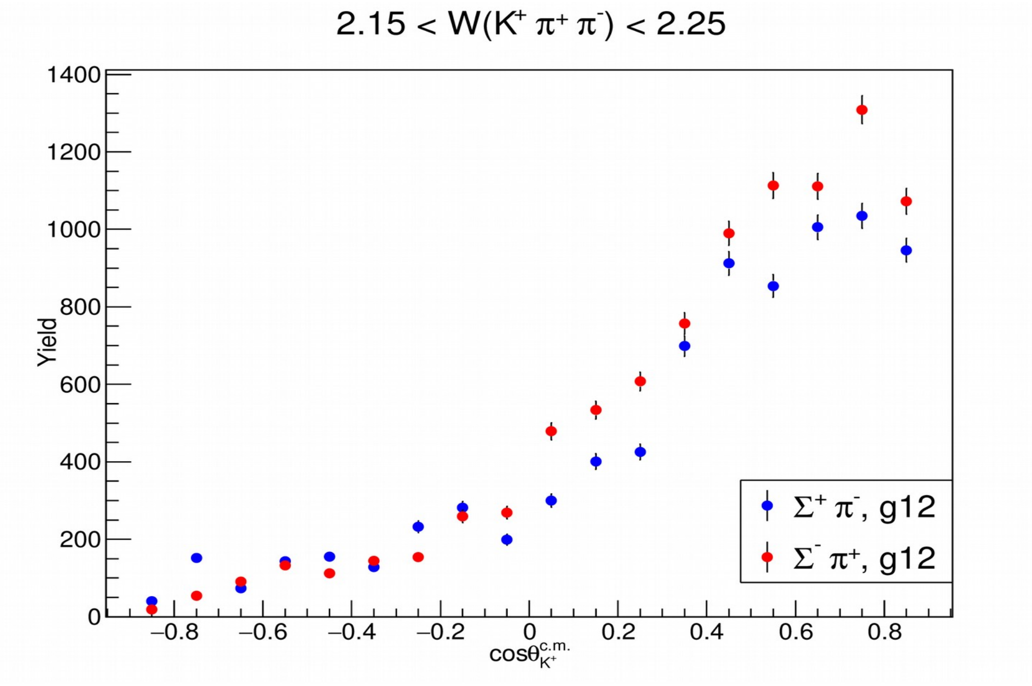

Data: Signal Fitting
W1C11(Kppip Σ-)
Entries 3987
Mean 1.512
RMS 0.03844
χ2 / ndf 131.1 / 94
p0 51.41 ± 5.77
p1 1.989 ± 0.211
p2 −18.77 ± 2.43
p3 1.04 ± 0.06
p4 0.0166 ± 0.0002
p5 1.515 ± 0.001
Background
Signal fit
Global Fit
Counts
Missing Mass (K+) [GeV/c2]

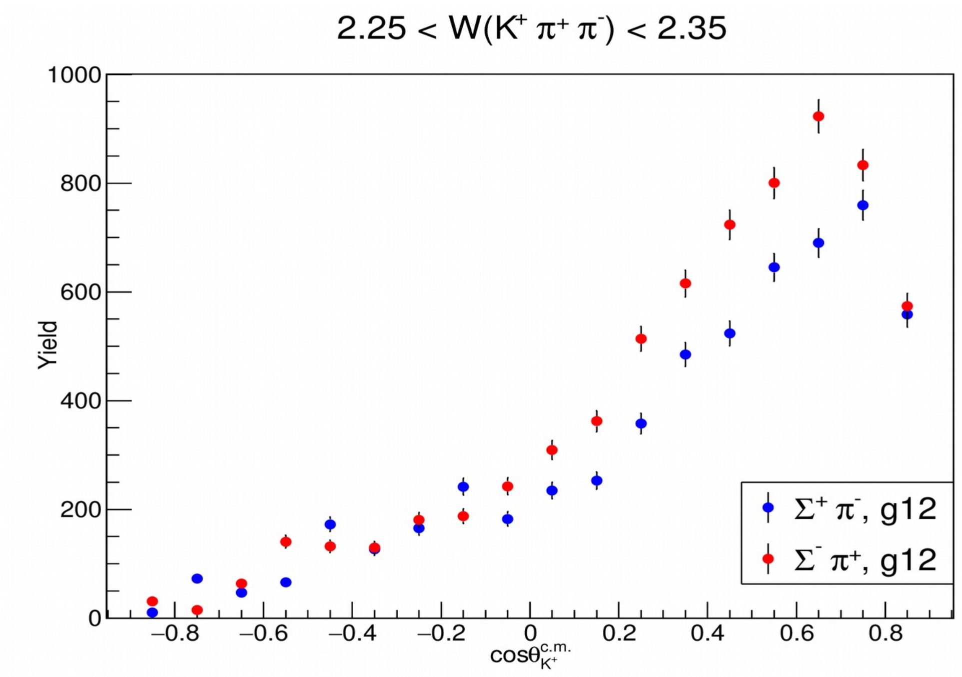
Yield & Acceptance

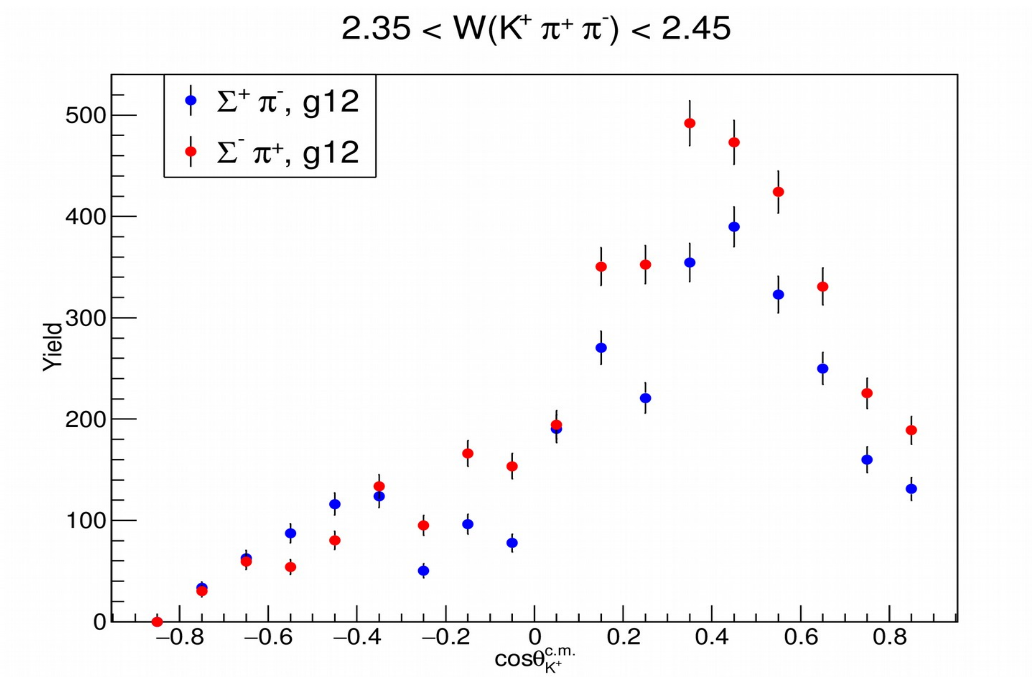


Yield

Lorentzian Signal Fit



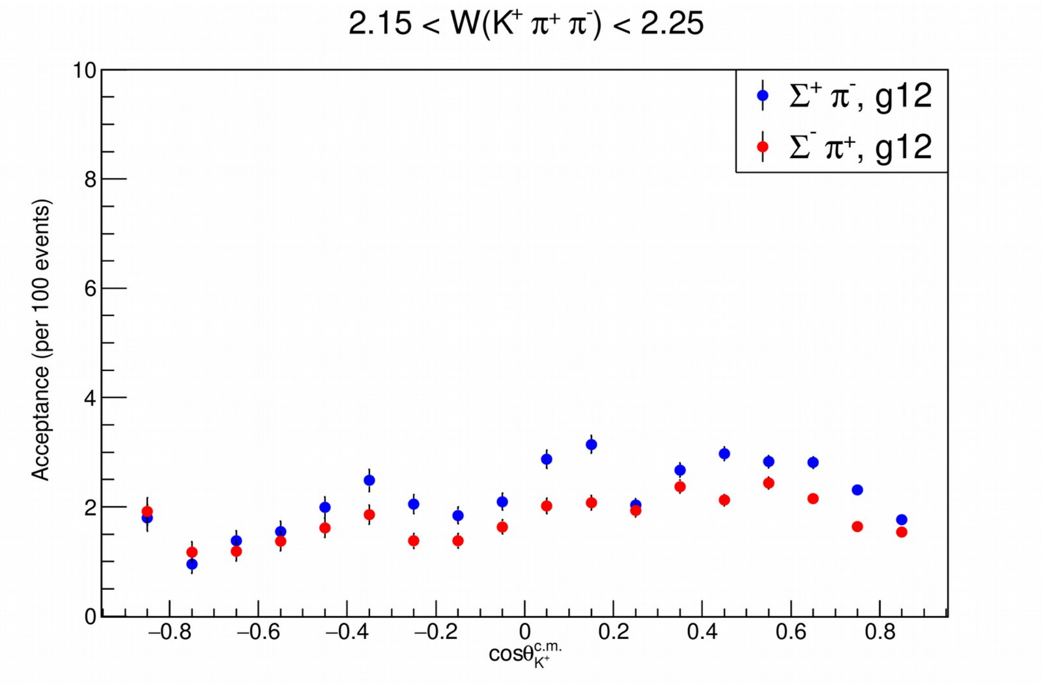


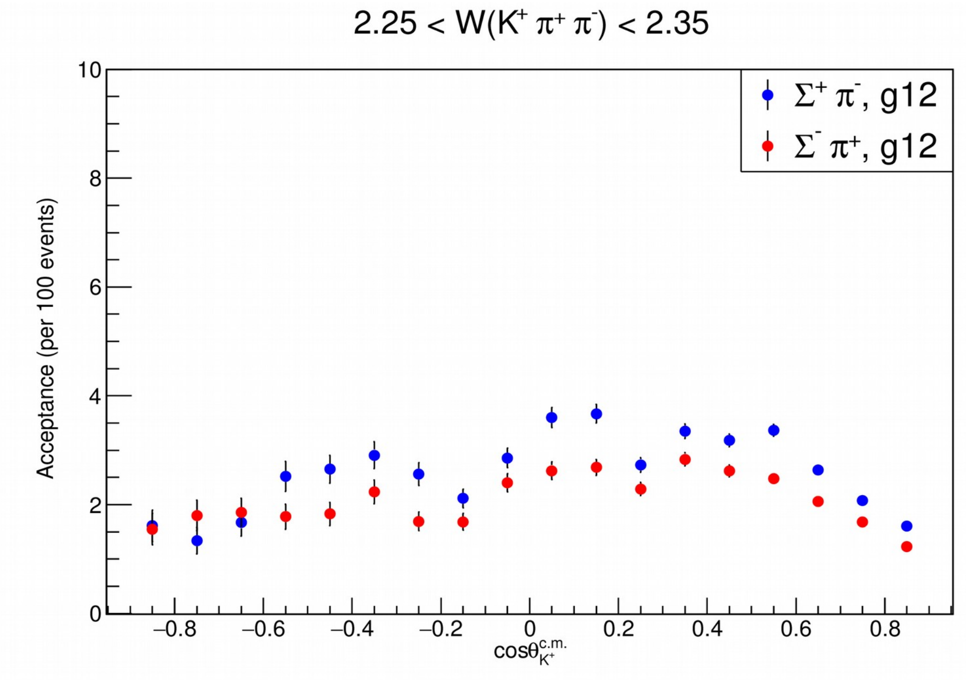


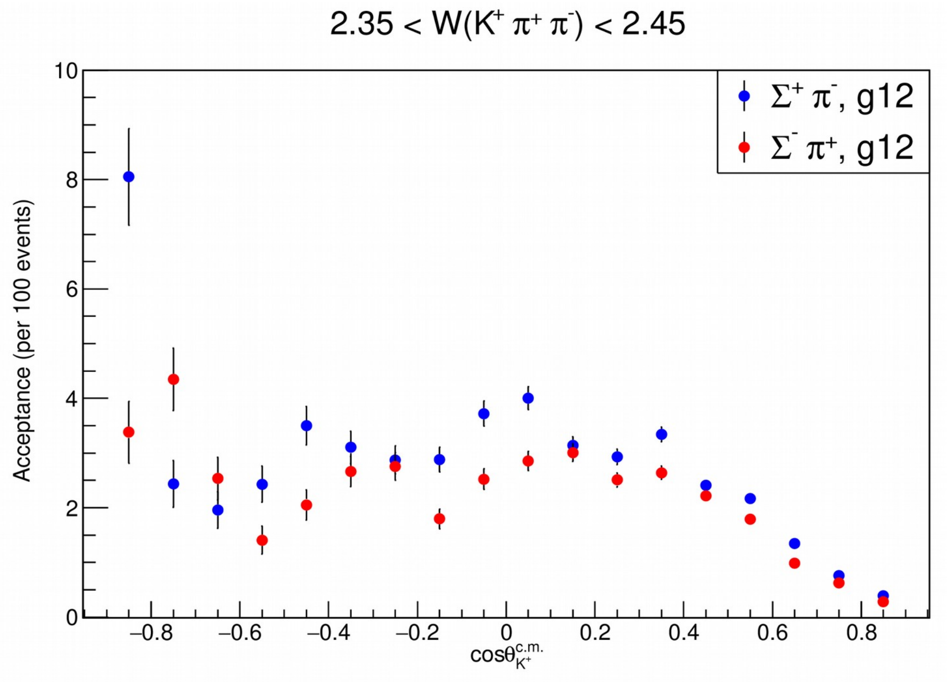
Acceptance

$$Acceptance = \frac{Accepted\ Events}{Generated\ Events}$$

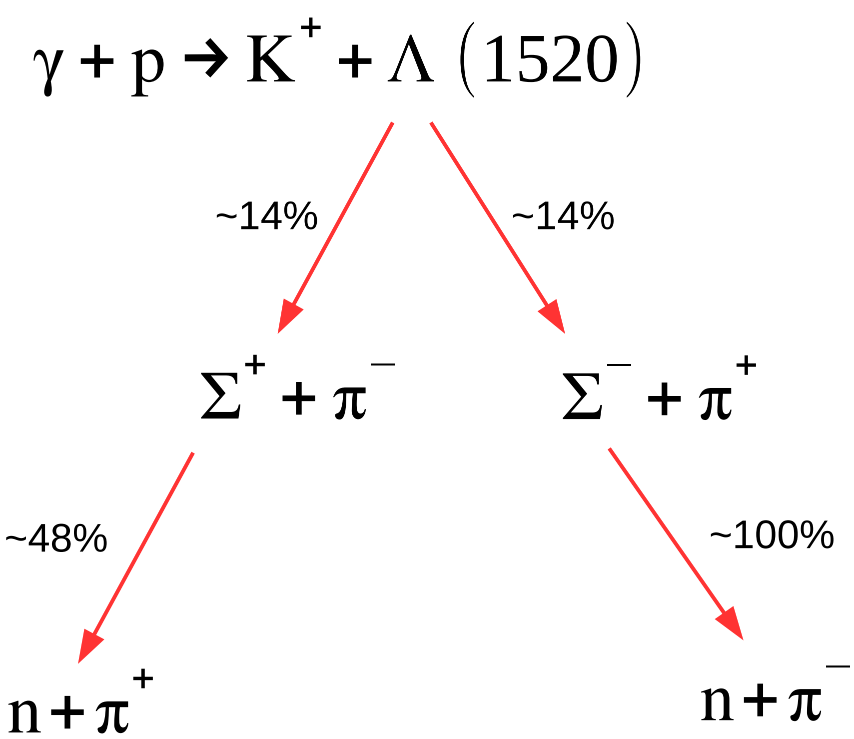
GEANT Based MC Simulation







Differential Cross-section

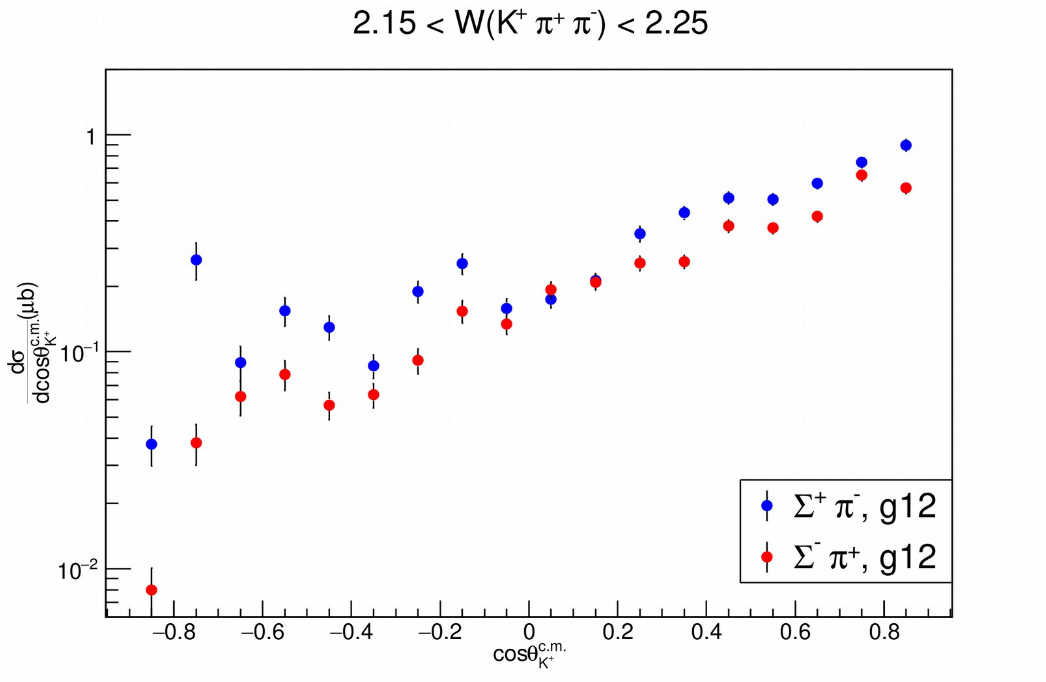


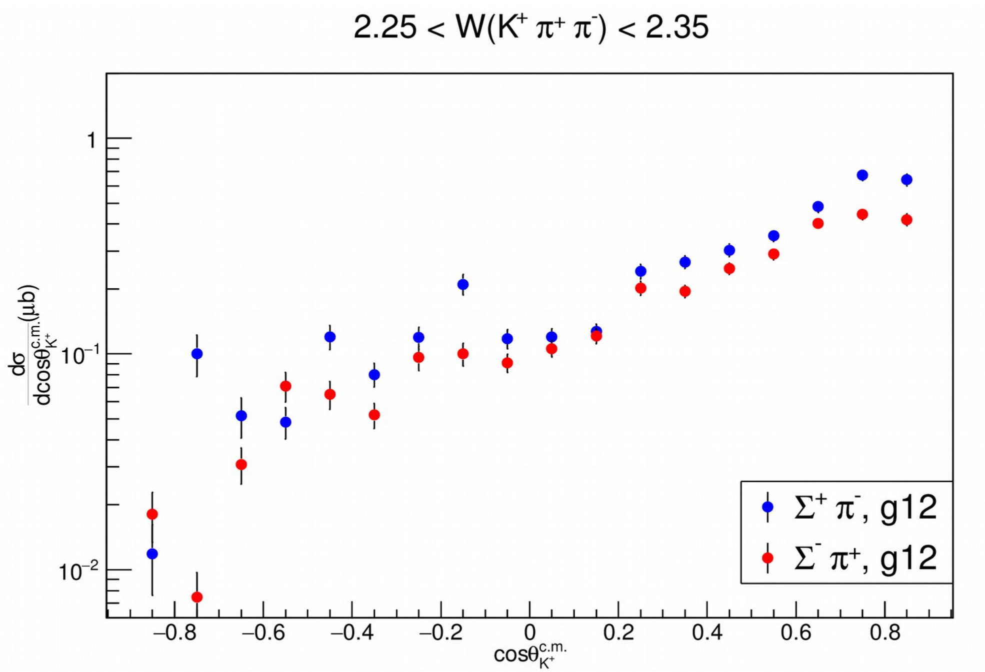
Differential Cross-section

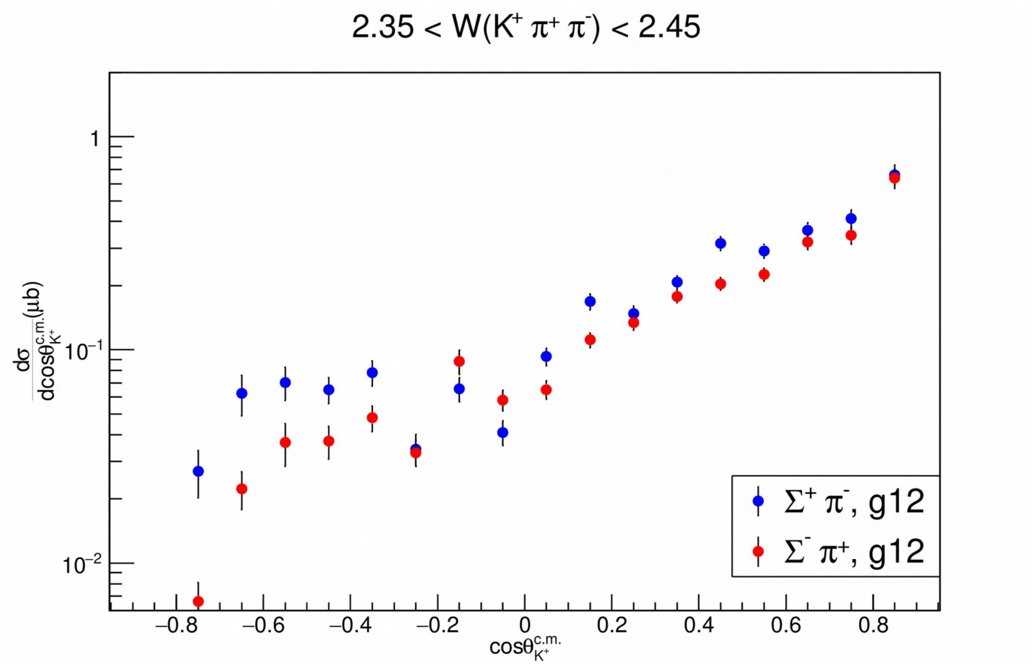
$$\frac{d\sigma}{dCos\theta_{K^+}^{c.m.}} = \frac{Y_d}{\tau\,\Delta\cos\theta_{K^+}^{c.m.}\,A\,L(W)}$$

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

Differential Cross-section



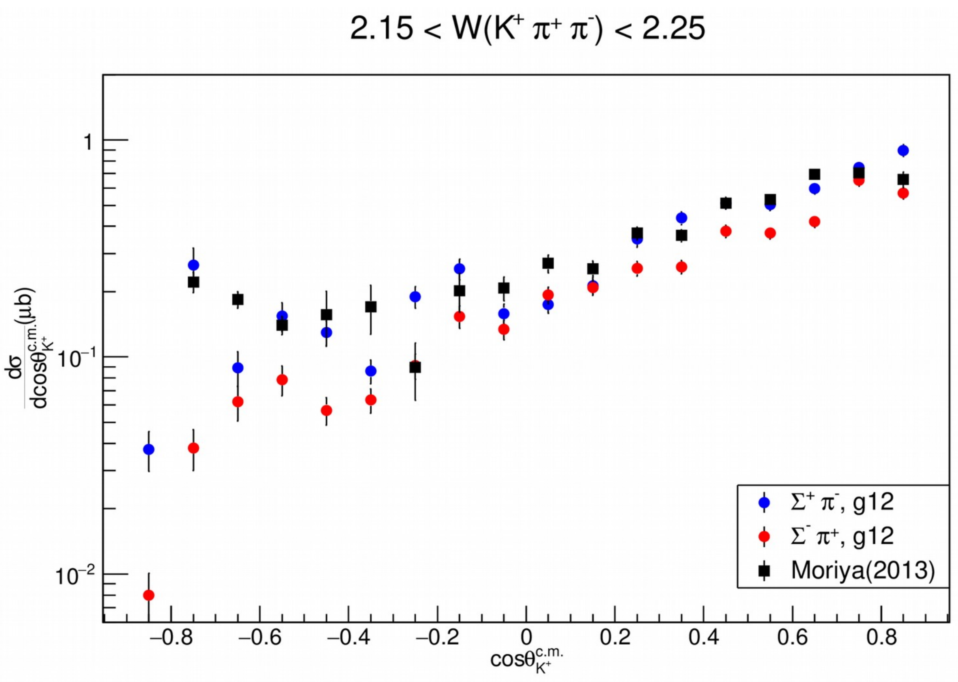


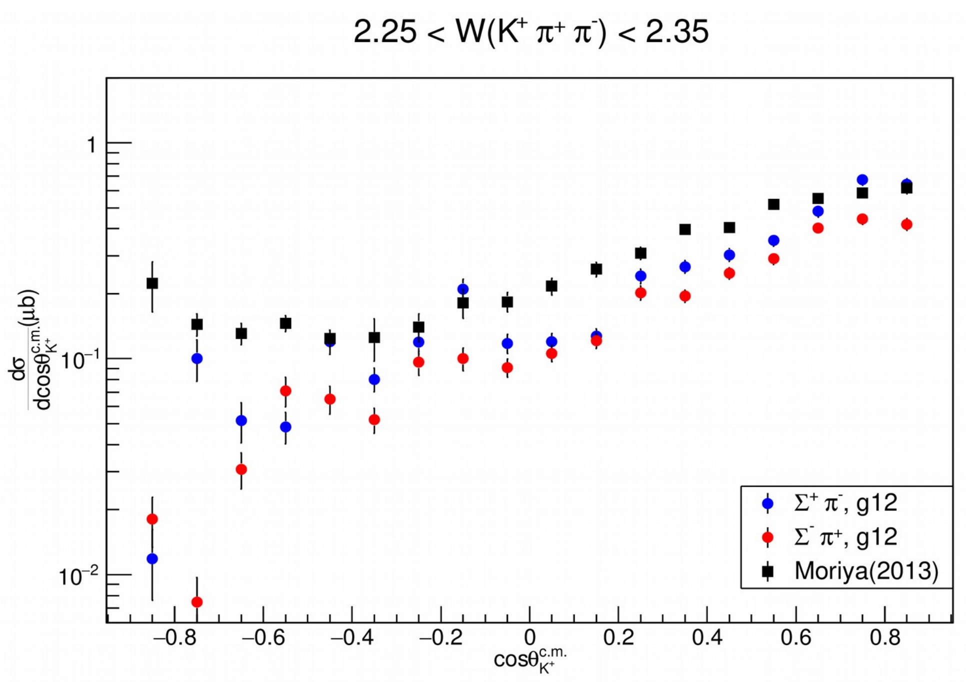


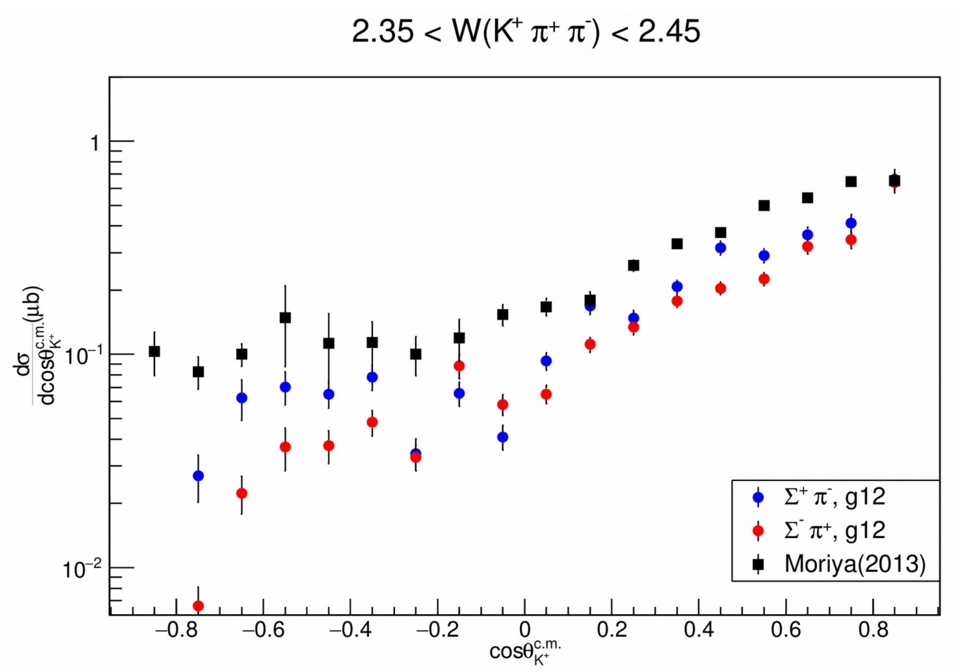
Preliminary!!!

Differential Cross-section

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





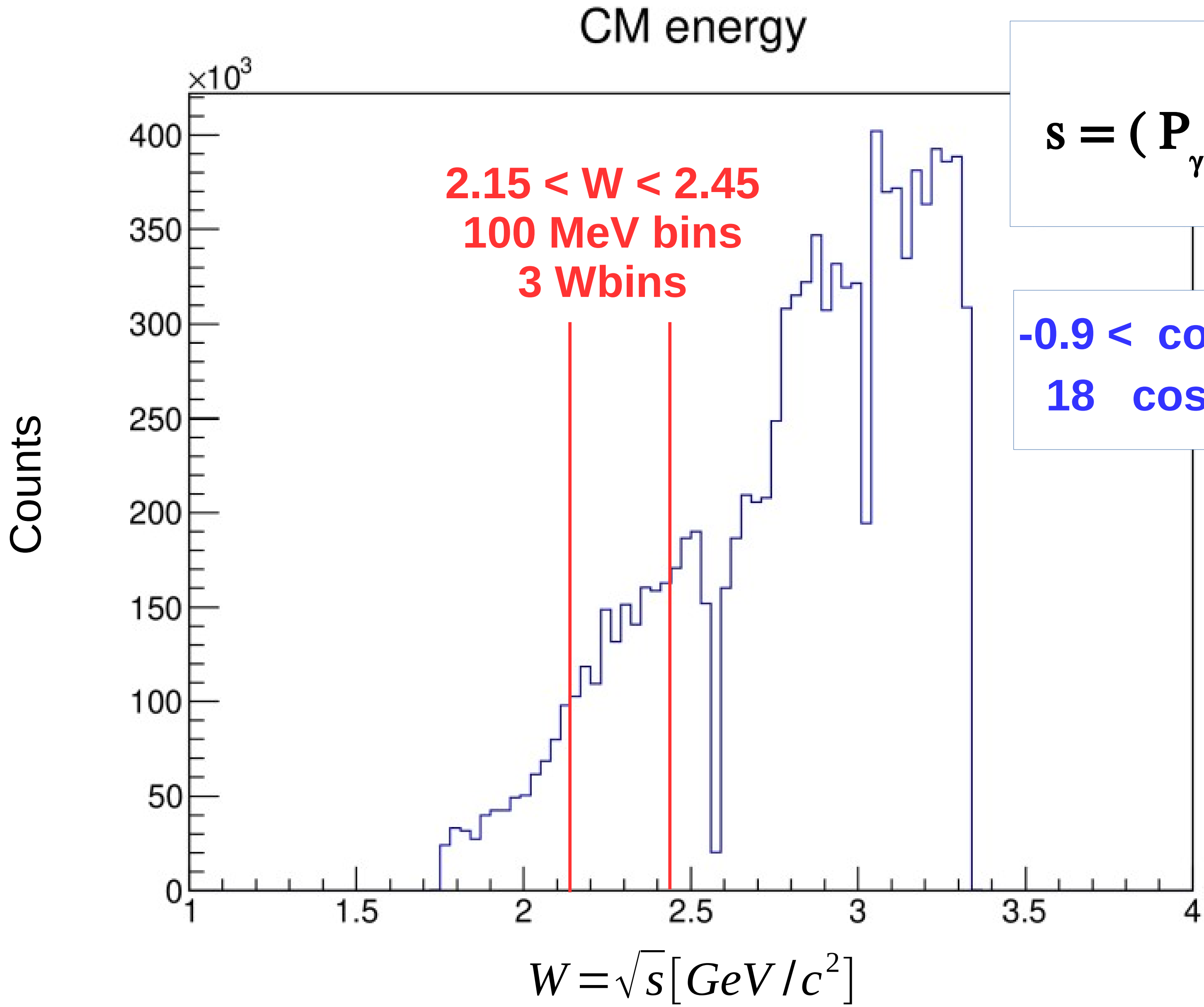


Preliminary!!!

Next

- The Λ(1520) cross section using CLAS g12 data set show consistent shape.
- Screening the run list to select only good runs from the inclusive good run list as provided by the g12 analysis procedures.
- Beam energy corrections and z-vertex cut will also be employed.
- More stringent cuts are to be applied to the particle identification procedure. A momentum dependent timing cuts will be employed.
- Momentum distribution for all three final state particles in all six sectors will be studied for MC and compared with that for the data.
- Proper modeling of the backgound and use of other fit funciton for background estimation are important. A bin-by-bin analysis of the yield values will follow for samples with poor fitting result.
- The Binning Scheme will be extended to higher W-ranges.
- Analysis of higher mass resonances, ie, Λ(1670) & Λ(1690), using partial wave analysis can be studied.

Analysis W



$$s = (P_\gamma + P_p)^2$$

$-0.9 < \cos\theta_{k+}^{c.m.} < 0.9$

18 $\cos\theta_{k+}^{c.m.}$ bins

Extras

Used PART bank reconstruction for the analysis. EVNT was NOT used	N/A ☐ Yes ☐ No ☐
Momentum corrections as described in the g12 note	N/A ☐ Yes ☐ No ☐
Beam energy correction as described in the g12 note	N/A ☐ Yes ☐ No ☐
Inclusive Good run list as described in table 7. Individual analysis may use a subset of it	N/A ☐ Yes ☐ No ☐
Target density and its uncertainty as described in the g12 note	N/A ☐ Yes ☐ No ☐
Photon flux calculation procedure as described in the g12 note	N/A ☐ Yes ☐ No ☐
Lower limit for the systematic uncertainty of normalized yield is 5.7%	N/A ☐ Yes ☐ No ☐
Photon polarization calculation procedure as described in the g12 note	N/A ☐ Yes ☐ No ☐
Systematic uncertainty of the photon polarization as described in the g12 note	N/A ☐ Yes ☐ No ☐
gsim parameters	N/A ☐ Yes ☐ No ☐
gpp smearing parameters	N/A ☐ Yes ☐ No ☐
DC efficiency map	N/A ☐ Yes ☐ No ☐
EC knockout	N/A ☐ Yes ☐ No ☐