Preliminary Lambda-Nucleon Scattering with g12 at Jefferson Lab

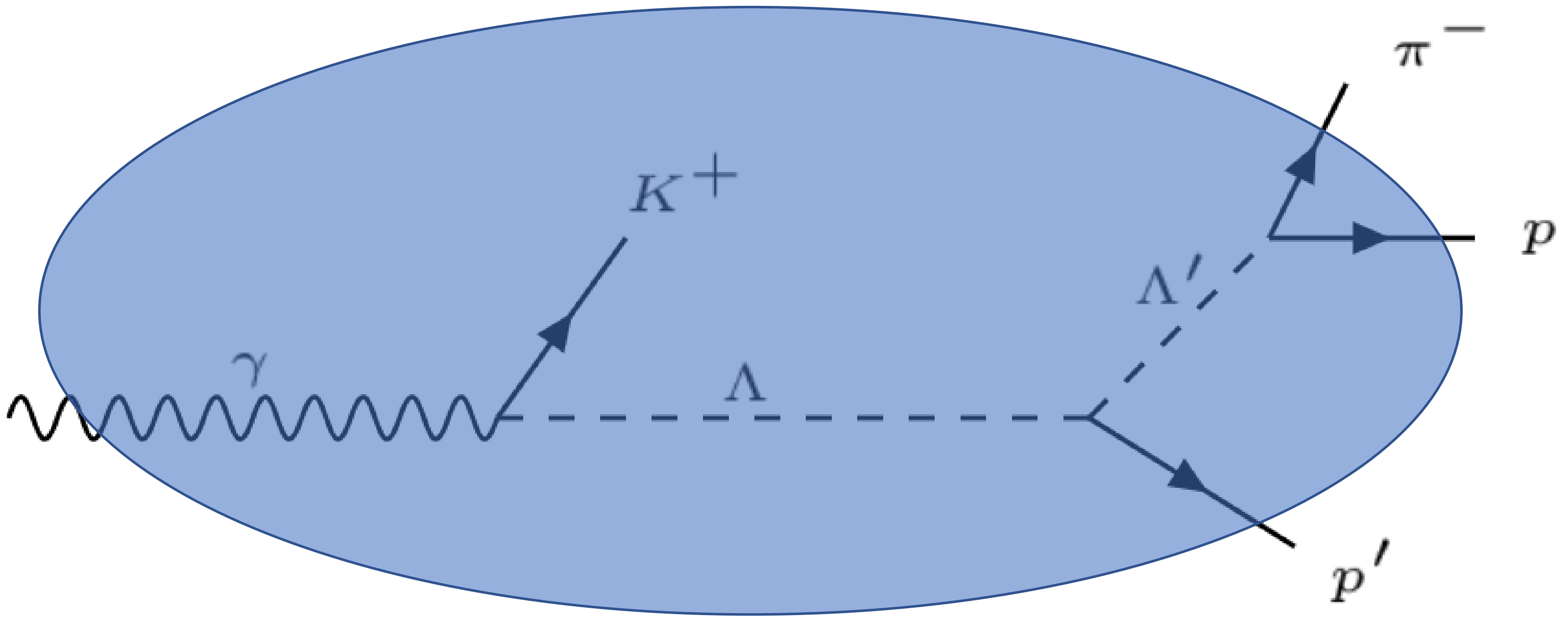
Joey Rowley, Kenneth Hicks (Ohio University)

John Price (Cal State Univ Dominguez Hills)

CEBAF Large Acceptance Spectrometer

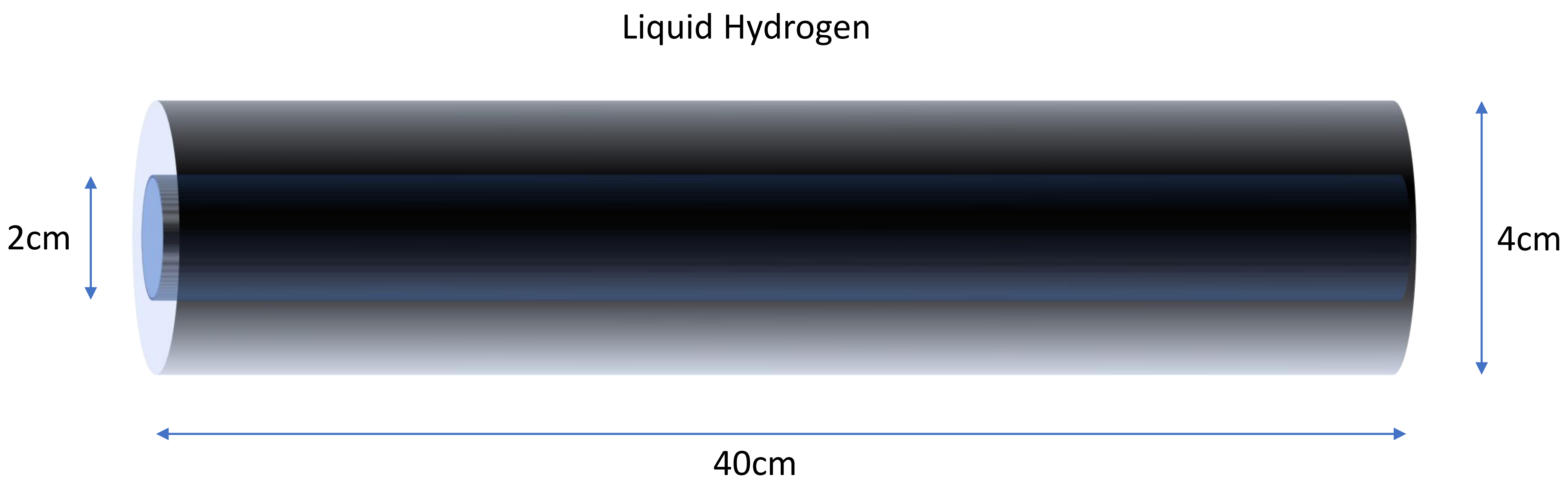
Department of physics + astronomy OHIO UNIVERSITY

Reaction



- p, p', π^- detected
- $\Lambda p'$ scatter elastically

Target



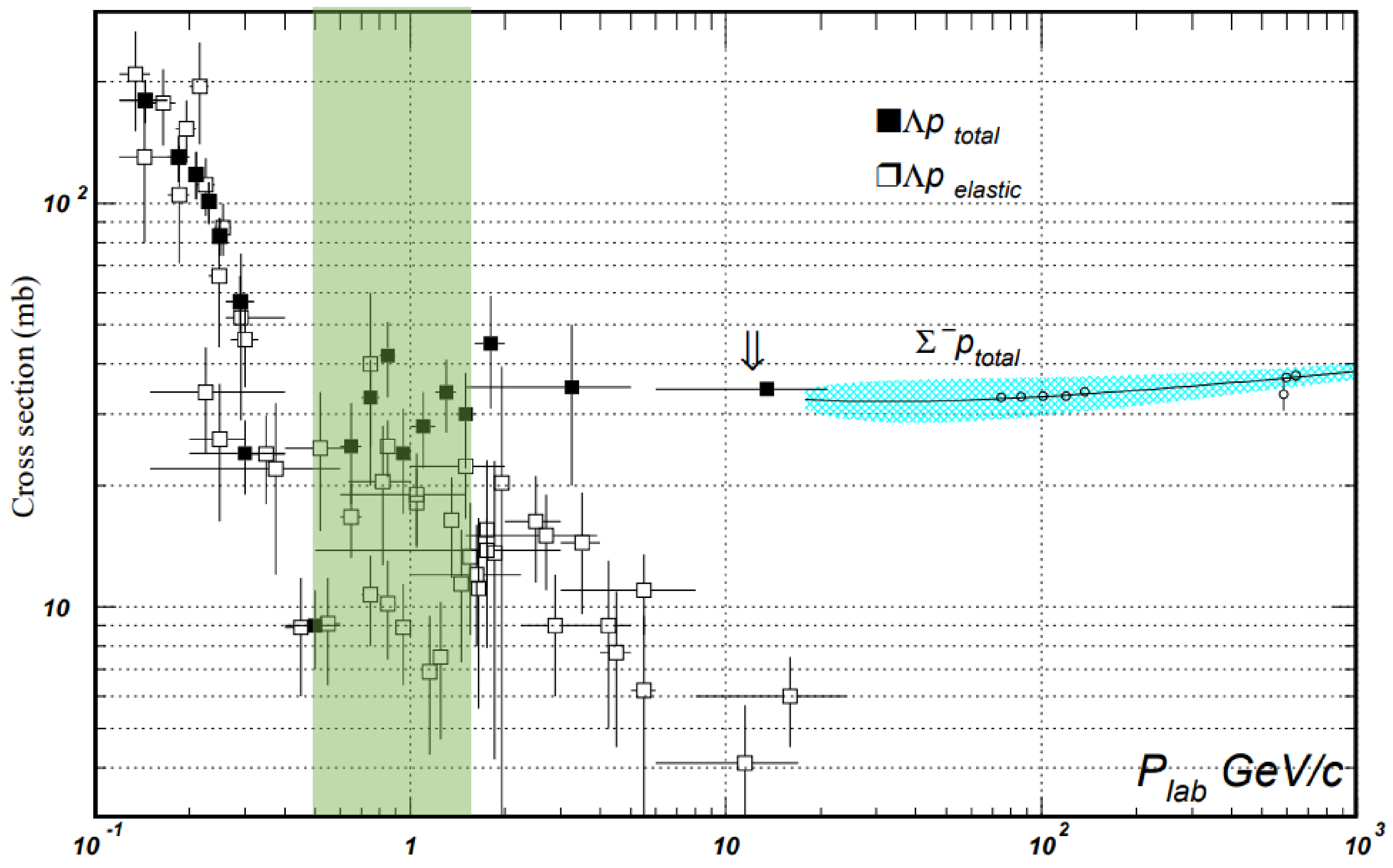
Length: 40cm
Width: 4cm
2cm diameter collimator

Motivation

- ΛN scattering is important to understand the interior of neutron stars. (Haidenbauer and Meissner, PRC 72, 044005 (2005).)

- Currently very little data for ΛN scattering compared to other elastic scattering processes (NN, KN or πN)

- With a high flux of Λ we can measure the Λp elastic scattering cross section.



C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C, **40**, 100001 (2016) and 2017 update.

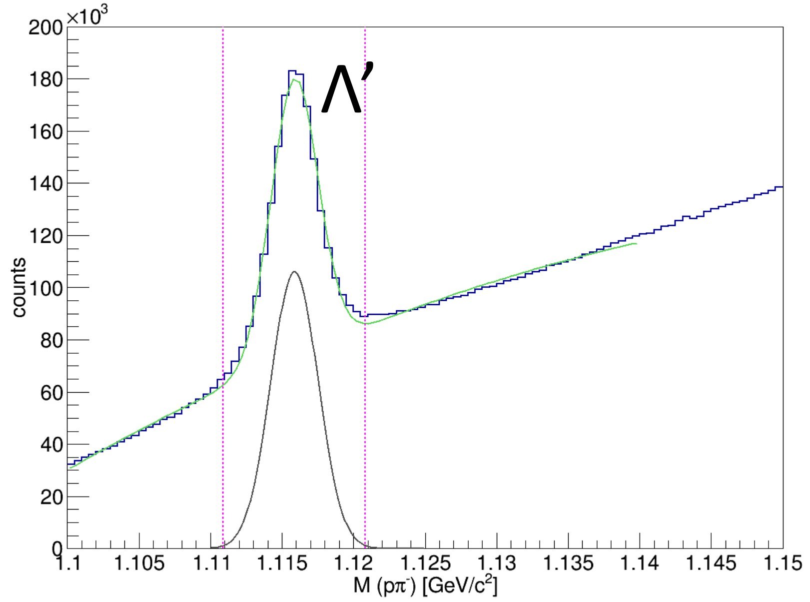
Procedure Analysis

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

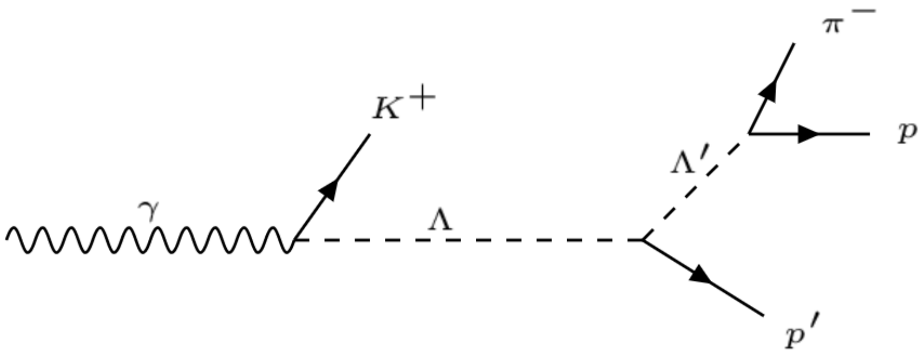
$$\hookrightarrow \Lambda \mathrm{p} \rightarrow \Lambda' p' \rightarrow p' p \pi^{-}$$

- Data from g12
- Reconstruct Λ' mass: $M(\Lambda') = M(p\pi^{-})$
- Reconstruct incident Λ
- Identify K^{+} by missing mass
- Use known $K^{+}\Lambda$ cross section to get flux

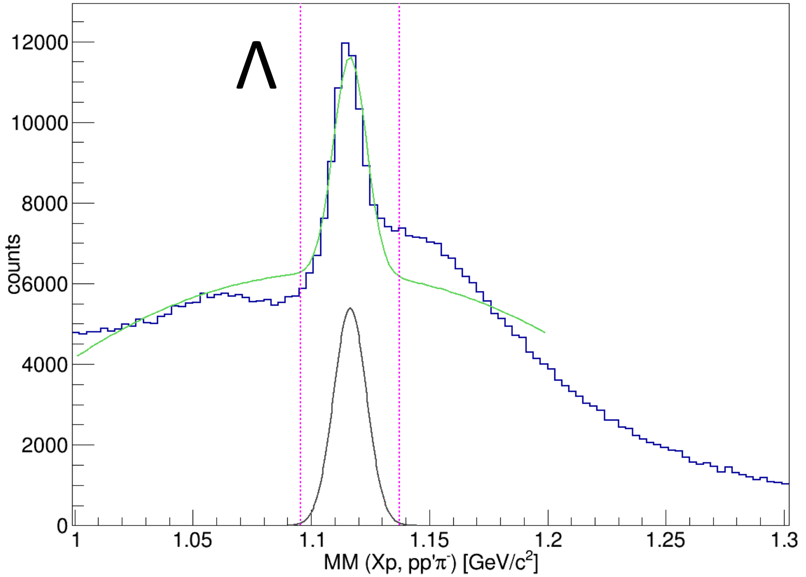
Cuts



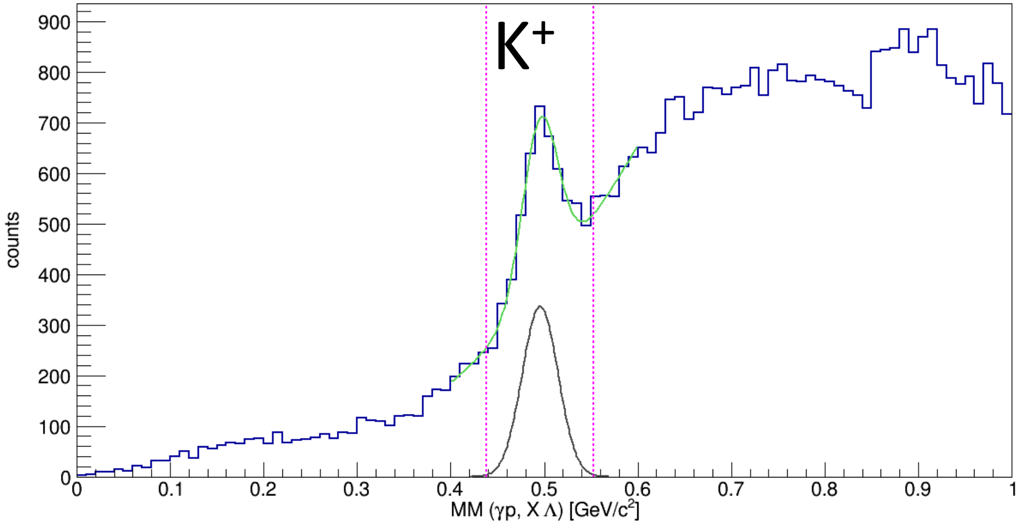
Λ’
counts
M (pπ⁻) [GeV/c²]



γ
K+
Λ
Λ′
π−
p
p′

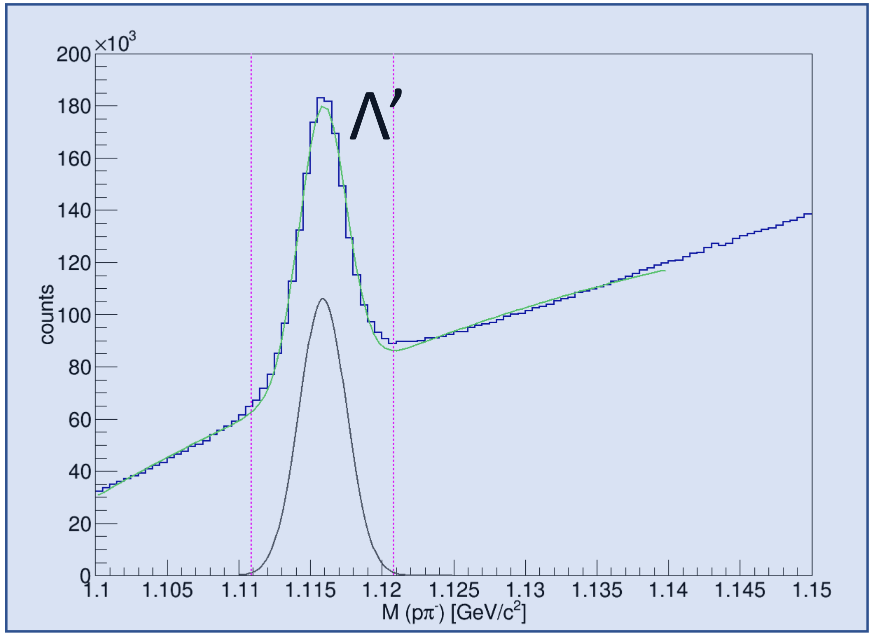


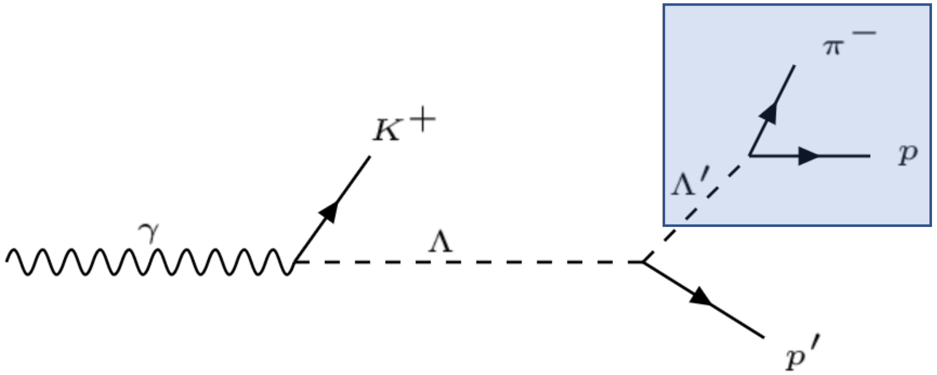
Λ
counts
MM (Xp, pp'π⁻) [GeV/c²]

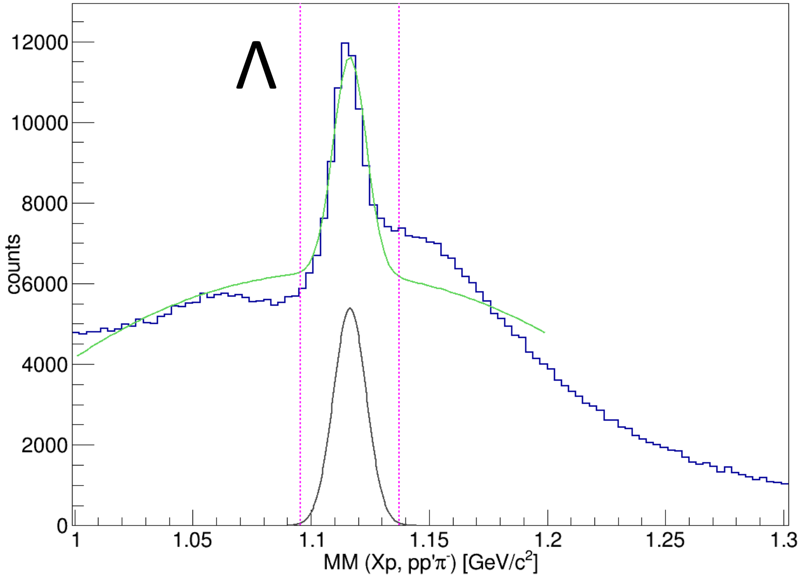


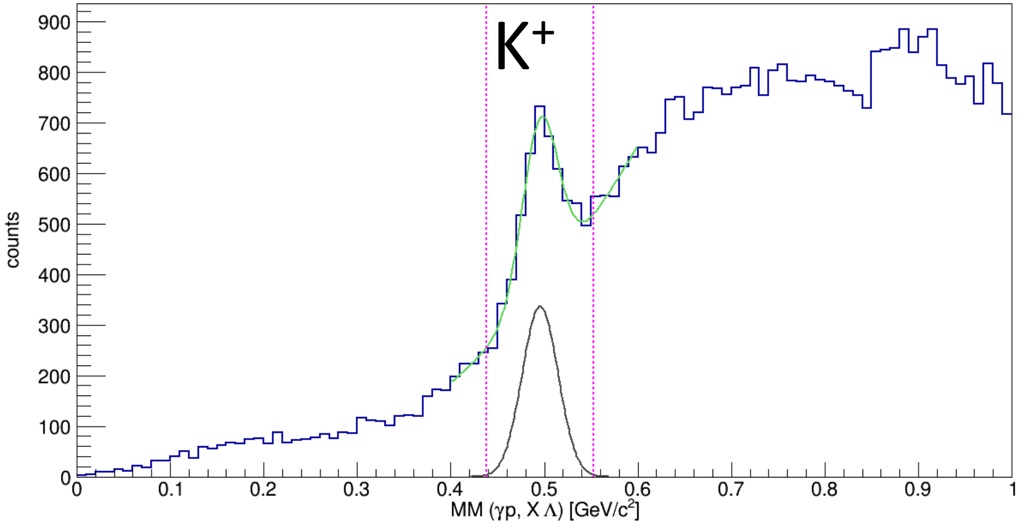
K+
counts
MM (γp, X Λ) [GeV/c²]

Cuts

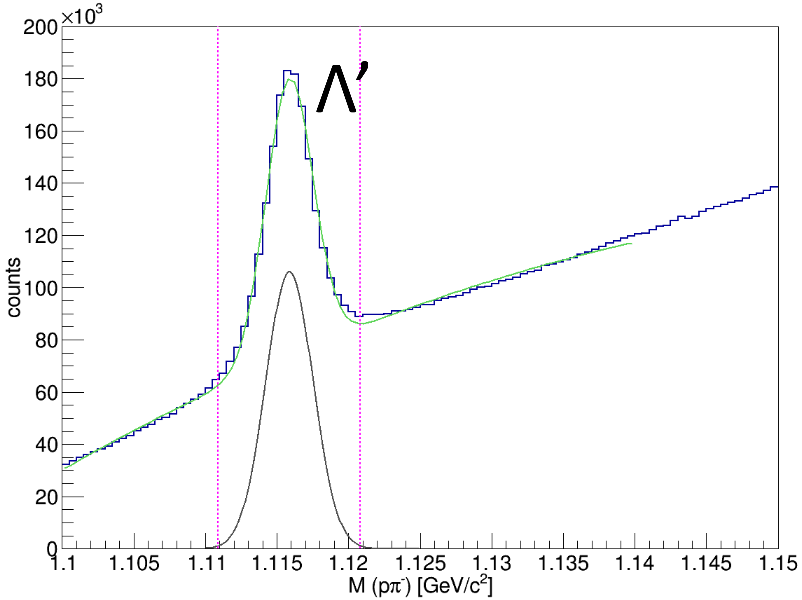

Λ'
counts
M (pπ⁻) [GeV/c²]

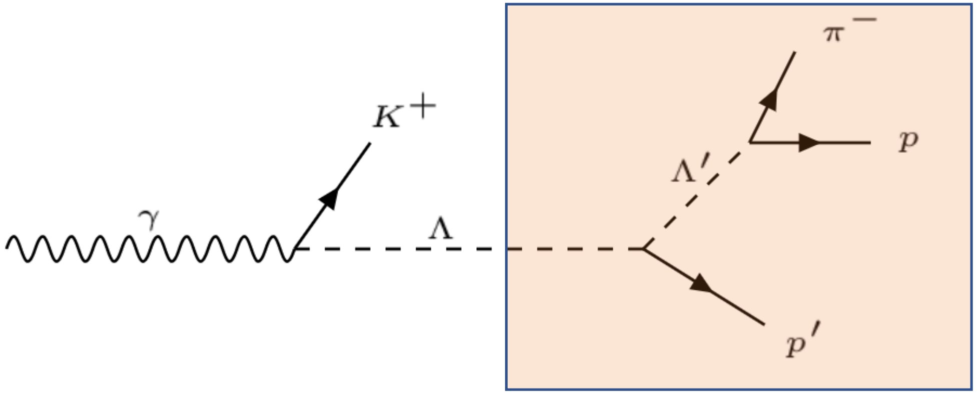

γ
K+
Λ
Λ'
π−
p
p'

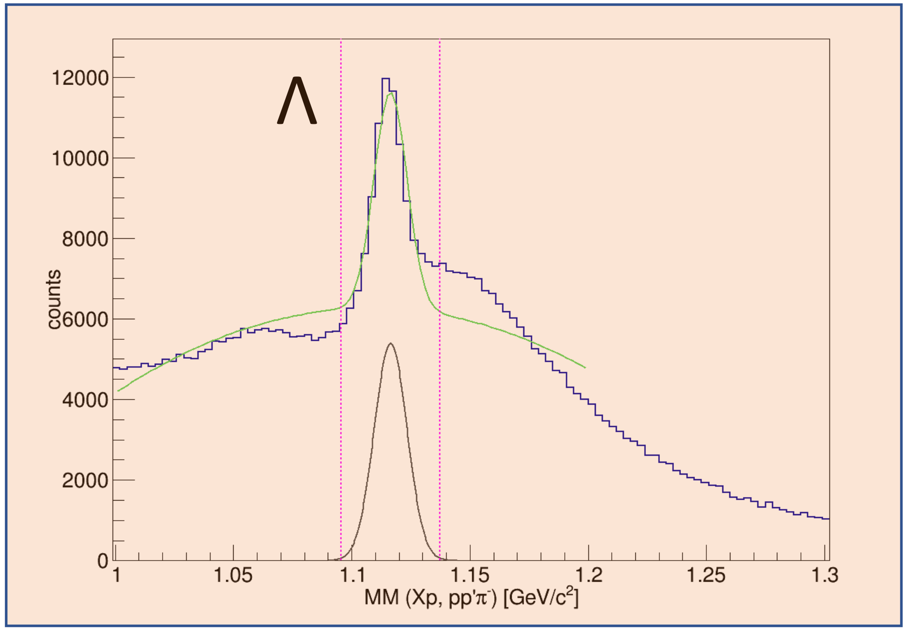

Λ
counts
MM (Xp, pp'π⁻) [GeV/c²]

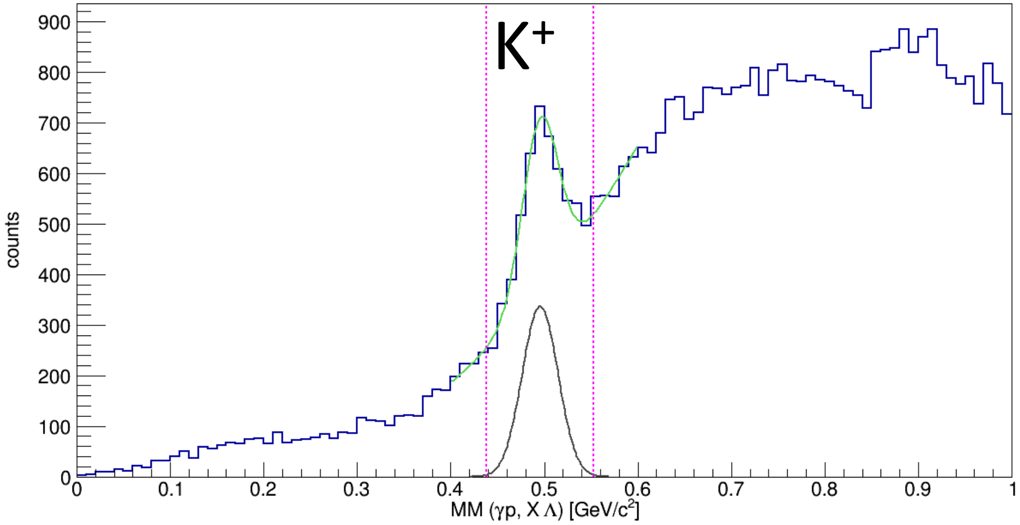

K+
counts
MM (γp, X Λ) [GeV/c²]

Cuts

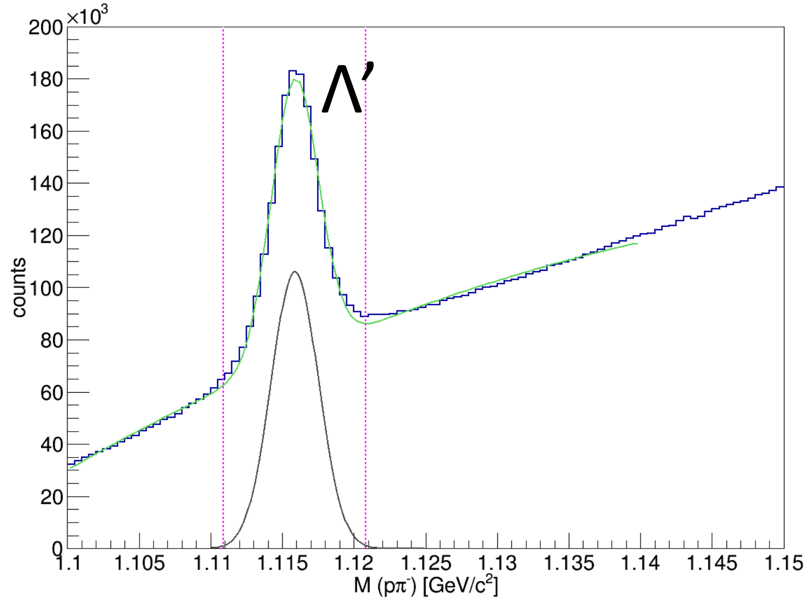

Λ’
counts
M (pπ⁻) [GeV/c²]

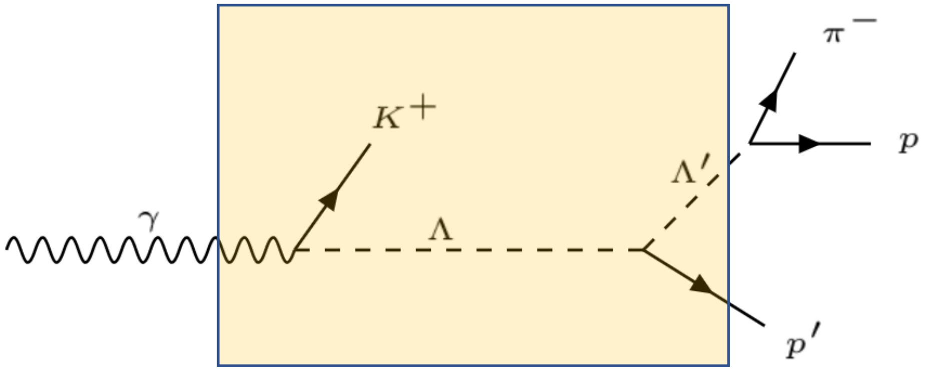

K+
γ
Λ
Λ′
π−
p
p′

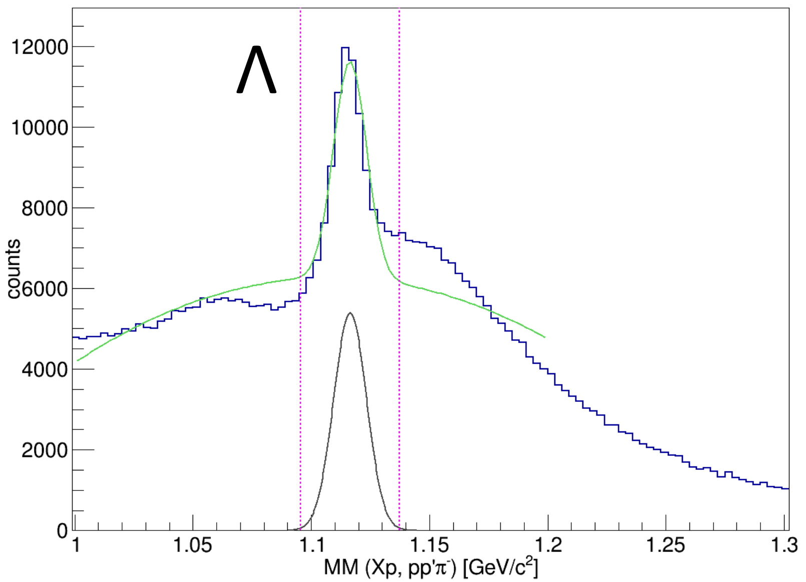

Λ
counts
MM (Xp, pp'π⁻) [GeV/c²]

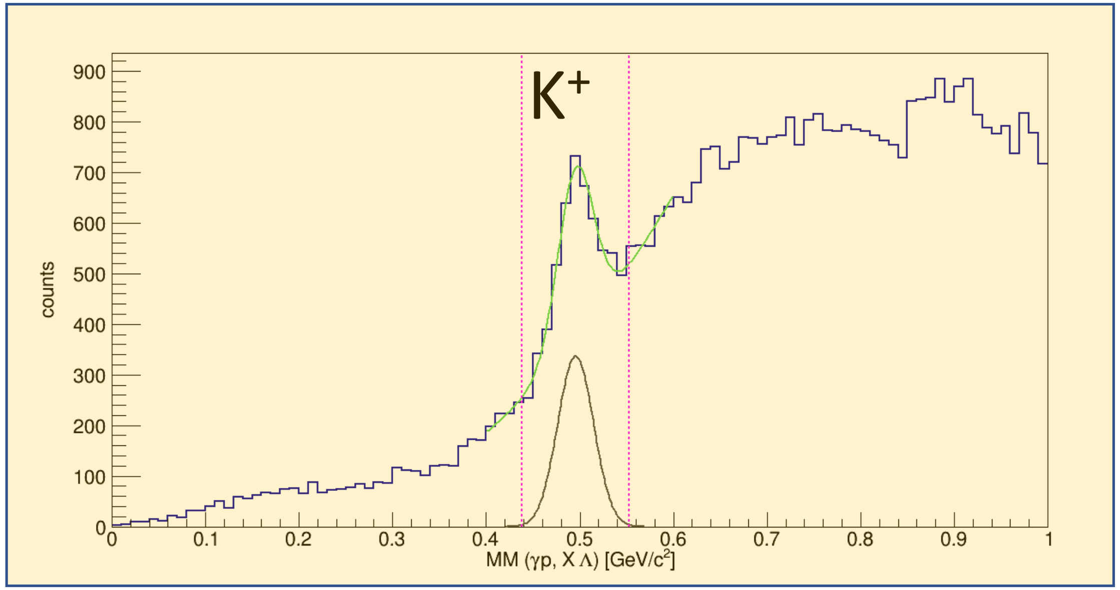

K+
counts
MM (γp, X Λ) [GeV/c²]

Cuts

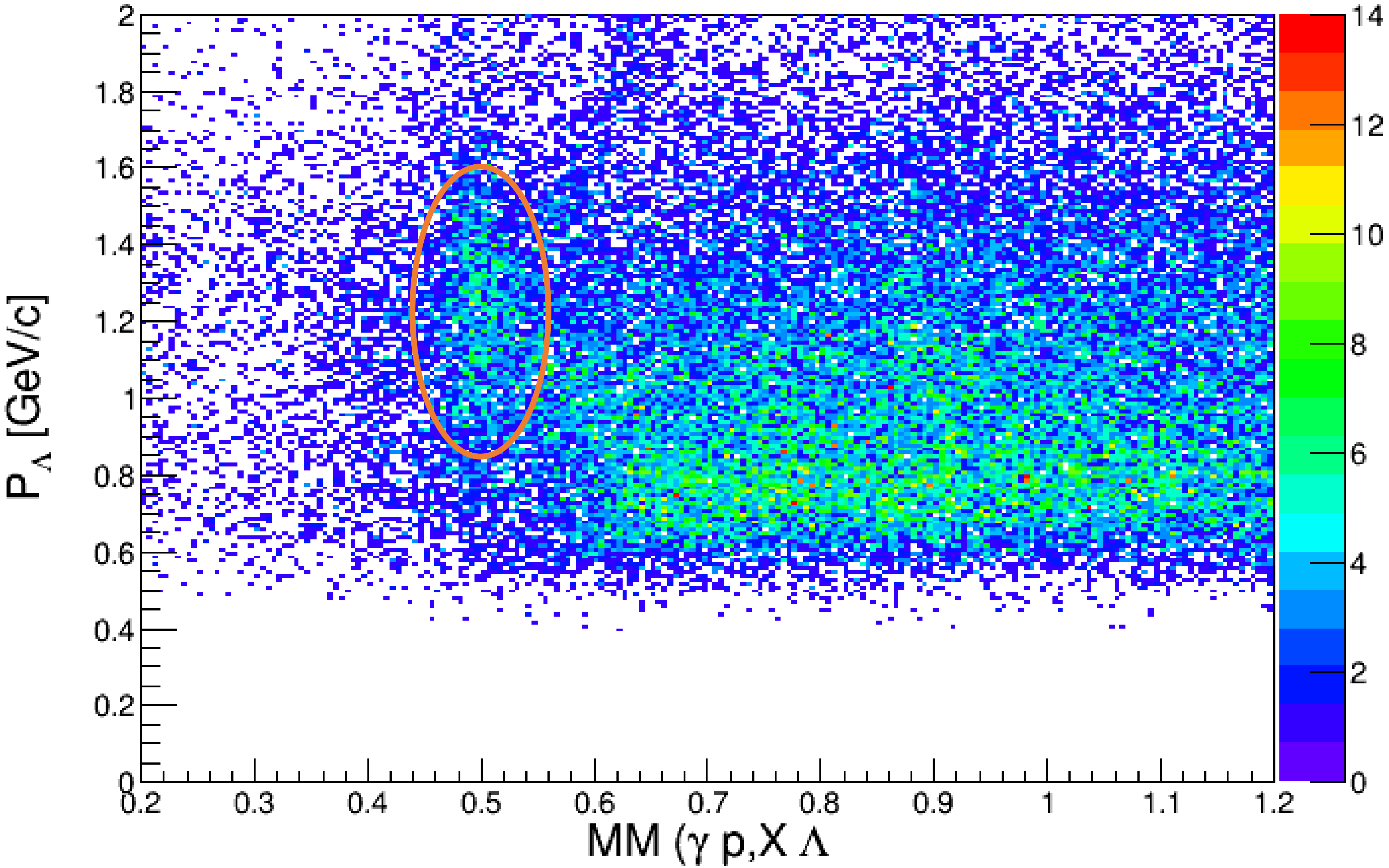

Λ’
counts
M (pπ⁻) [GeV/c²]


γ
K+
Λ
Λ′
π−
p
p′


Λ
counts
MM (Xp, pp'π⁻) [GeV/c²]


K+
counts
MM (γp, X Λ) [GeV/c²]

Cuts



P_Λ [GeV/c]
MM (γ p,X Λ
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.4
1.6
1.8
2
4
6
8
10
12
14

Cross Section

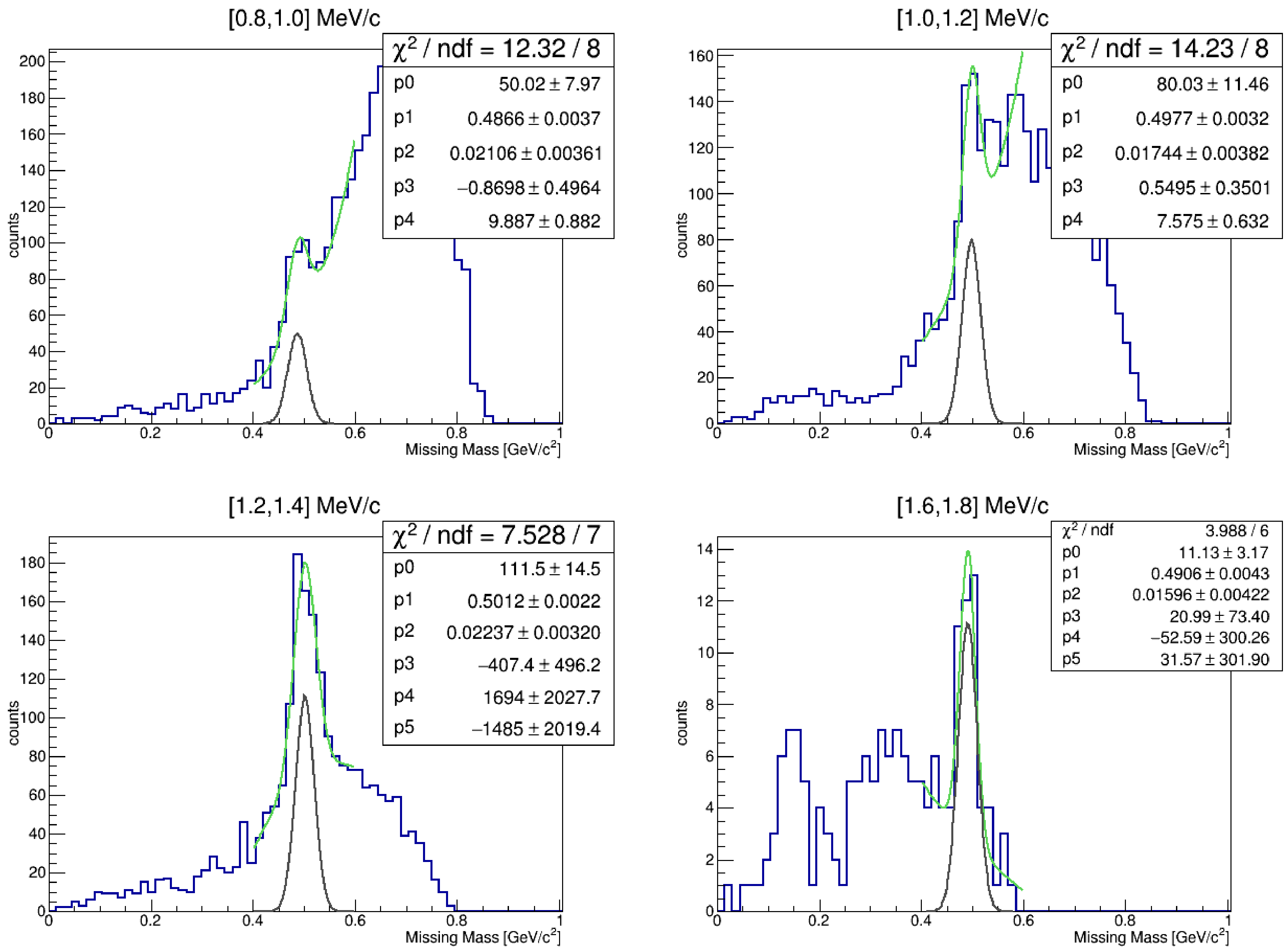
$$\frac{d\sigma}{d\cos(\theta)}(E) = \frac{Y}{A * \mathcal{L} * \mathrm{b.r.} * \Delta\cos(\theta)}$$

Y: Yield
A: Acceptance
$\mathcal{L}$: Luminosity
b.r: Branching ratio (for $p\pi^-$)

$\frac{d\sigma}{d\cos(\theta)}(E)$: Energy dependent cross section

Yields

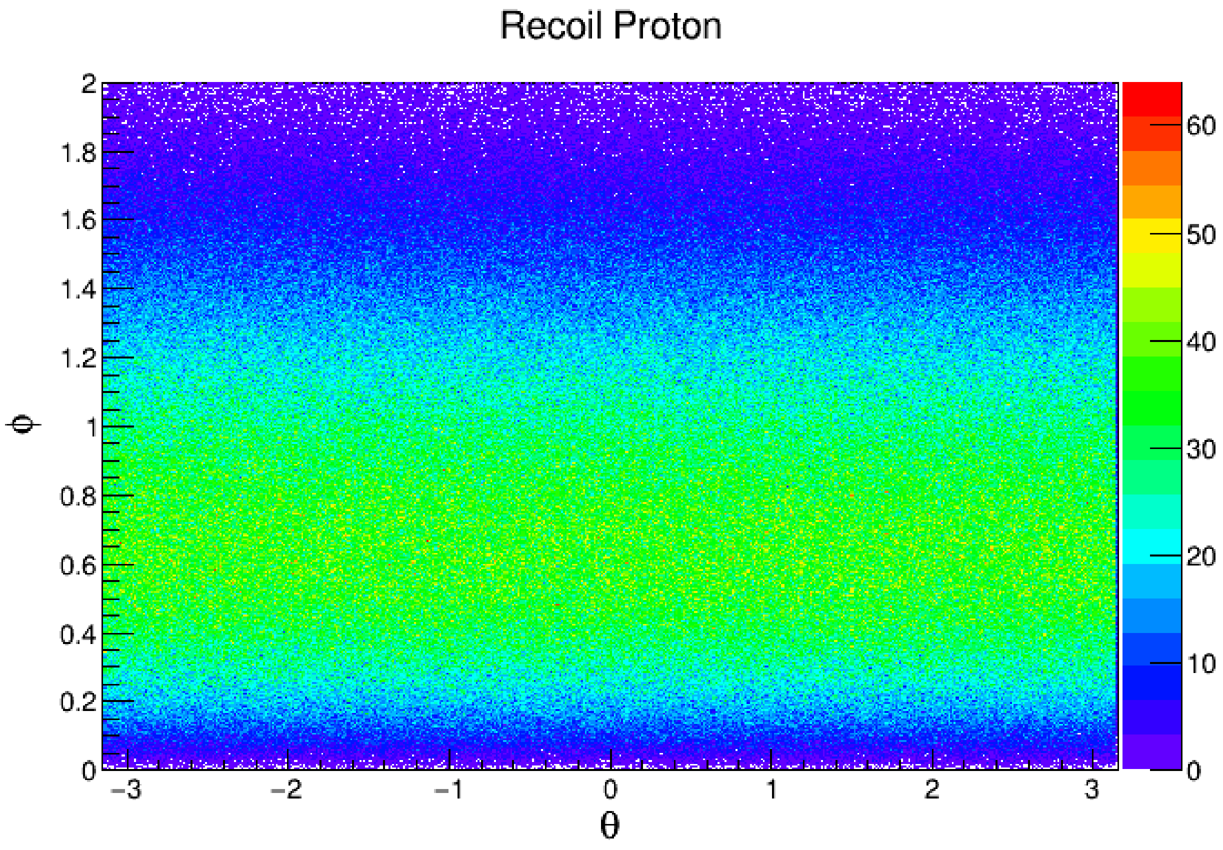
Binned in Incident Λ Momentum
for Eγ = [1.2,1.6]



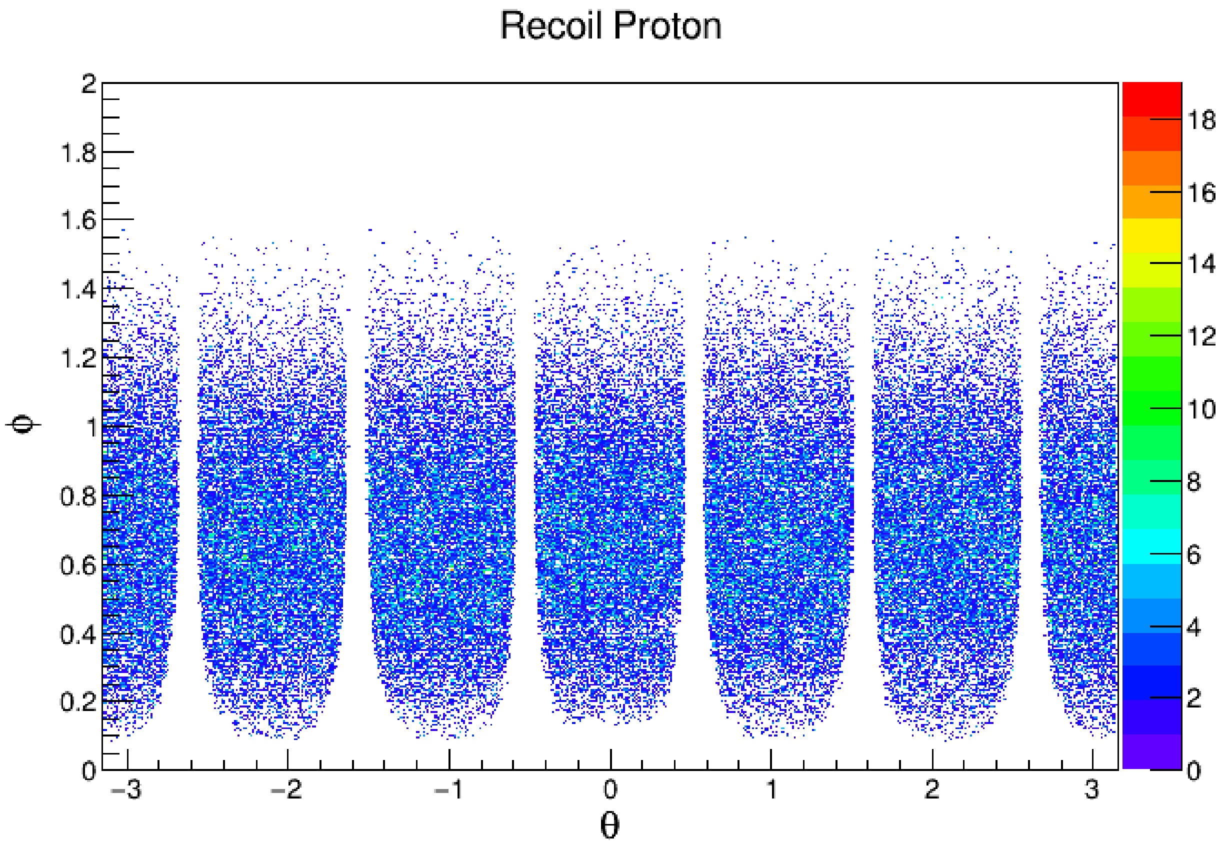
Acceptance

$$Acceptance = \frac{Accepted\ pp\pi^-}{Generated\ \Lambda p\ scattering}$$

Using g12 standard
software for simulations.

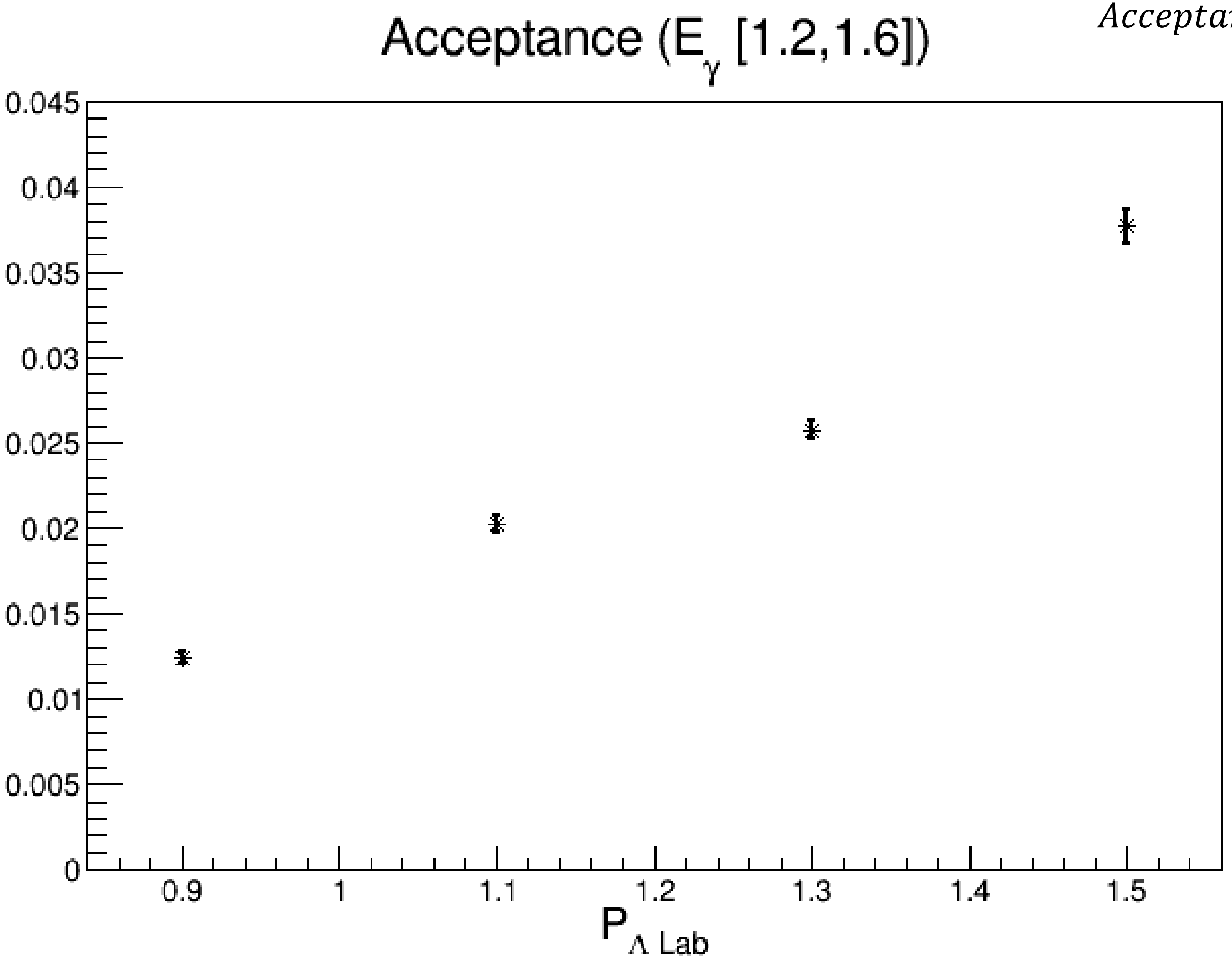


Generated



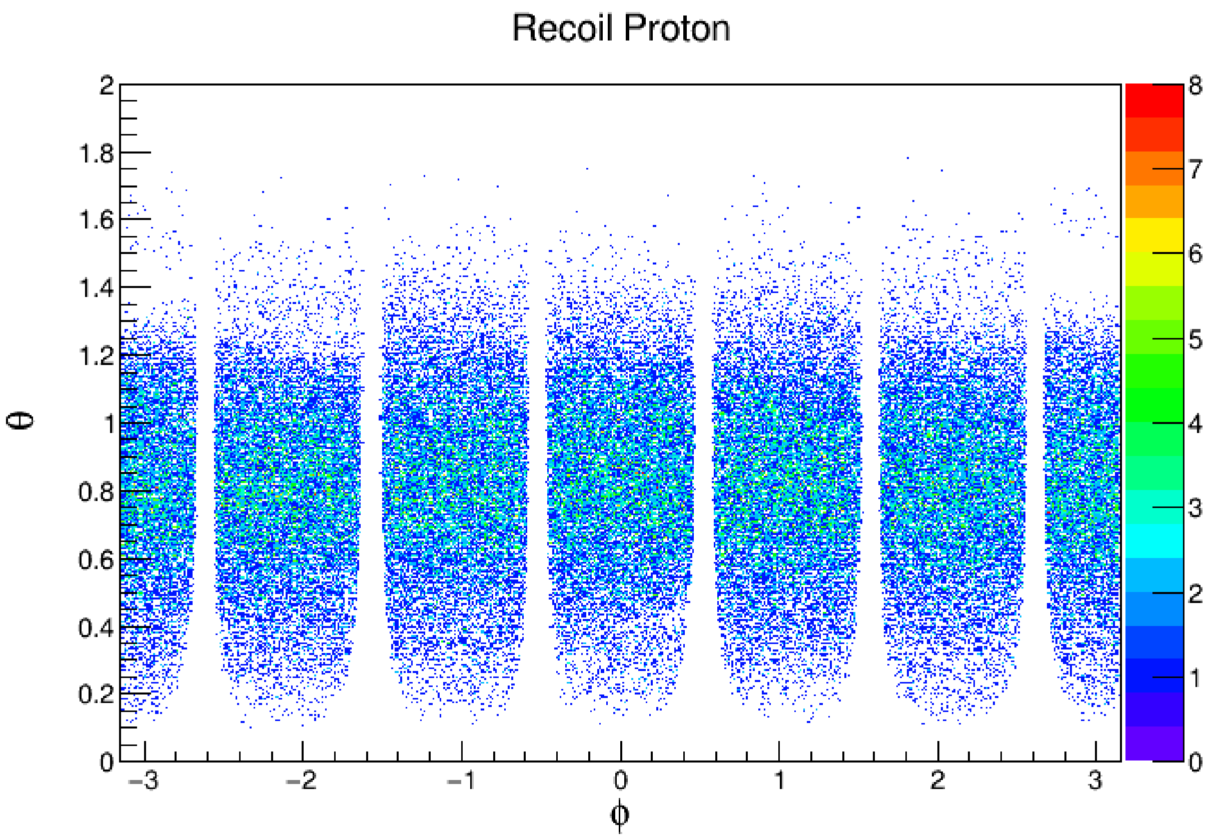
Accepted

$$Acceptance = \frac{Accepted\ pp\pi^-}{Generated\ \Lambda p\ scattering}$$

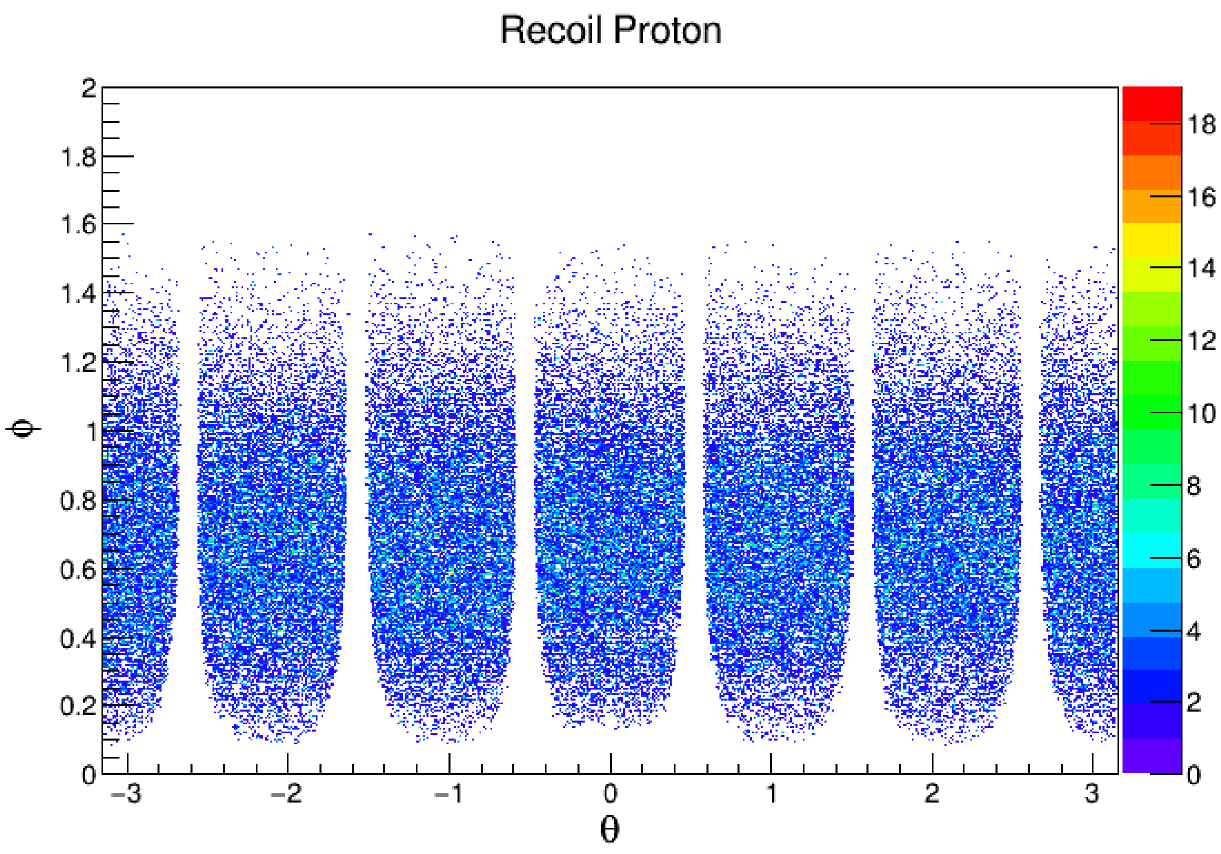


Acceptance

$$Acceptance = \frac{Accepted\ pp\pi^-}{Generated\ \Lambda p\ scattering}$$



Data



Accepted

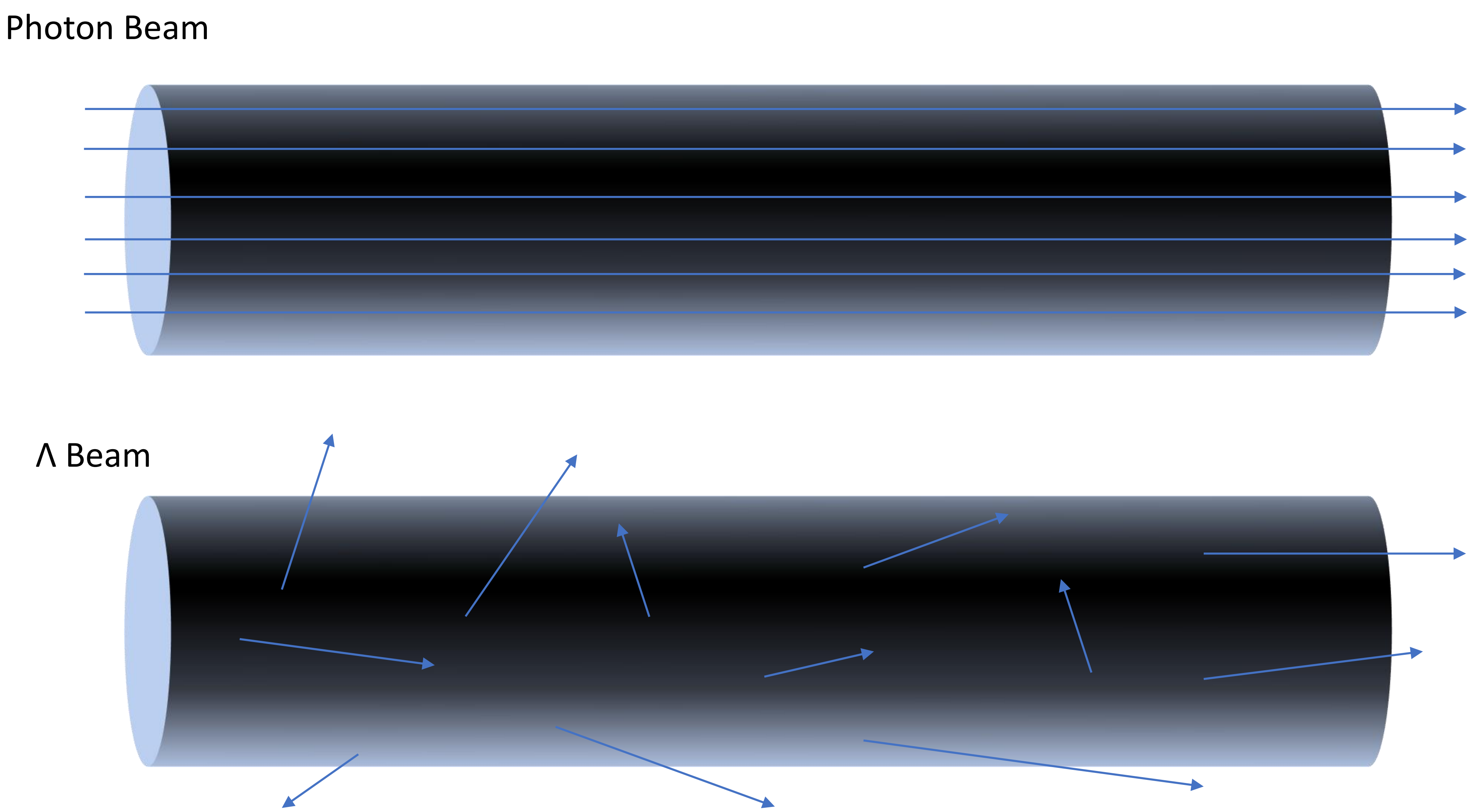
Luminosity

$$L_\Lambda(E_\Lambda) = \frac{\rho_T * N_A * l}{M} * N_\Lambda(E_\Lambda)$$

- ρ_T: density of the target
- N_A: Avogadro's number
- M: molar mass of Hydrogen
- l: travel distance of Λ
- $N_\Lambda(E_\Lambda)$: yield in a certain energy range

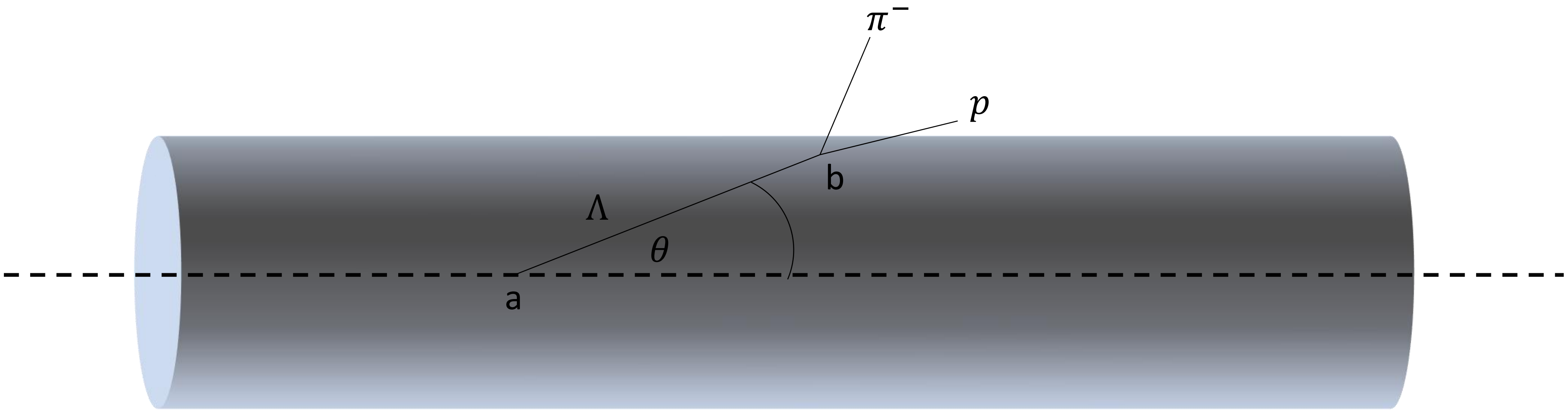
Problem: How do we find l and $N_\Lambda(E_\Lambda)$?

Luminosity



Λ Decay Length (l)

Assume Simplest case: Lambda along z-axis



Distance between a and b is the Λ decay length

Λ Decay Length (*l*)

$$P(z) = e^{-\left(\frac{M}{p}\right)\left(\frac{z-z0}{c\tau}\right)}$$

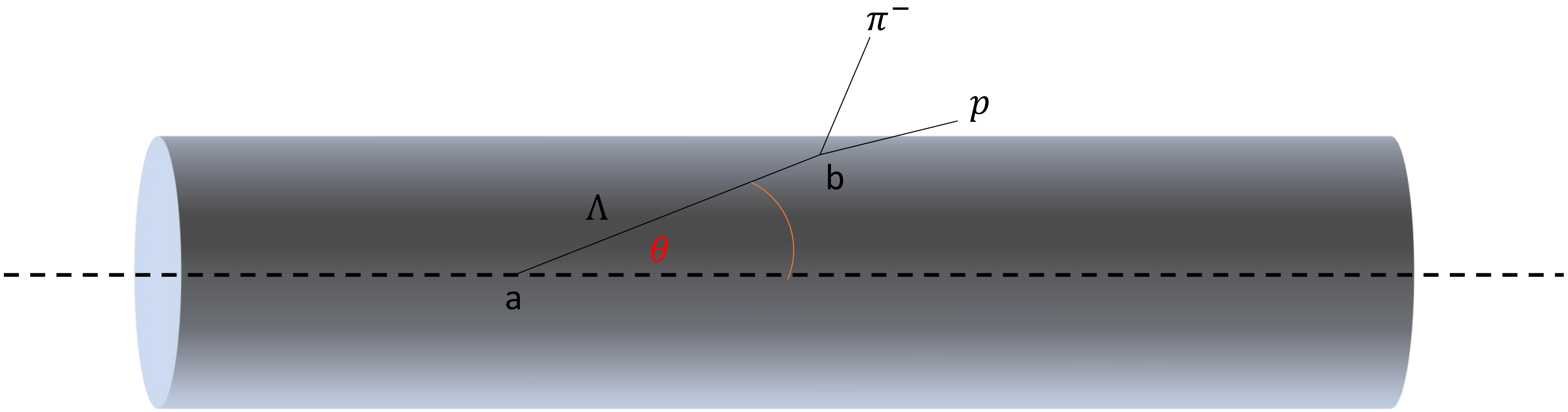
- P(z): probability of Λ decay
- M: mass of Λ (1.115 GeV/c^2)
- p: momentum of Λ
- z0: starting position
- $c\tau$: mean proper life (7.89cm)

Λ Decay Length (l)

- 10,000 generated Λ
- Step size: 1mm
- p_Λ = 1115 MeV/c (can do this for any p_Λ)

Z Vertex (cm)	Cos(Θ)	Avg. Pathlength (cm)
0.0	1.0	7.5
20	1.0	7.2
20	.707	2.4
Random	Random	2.2

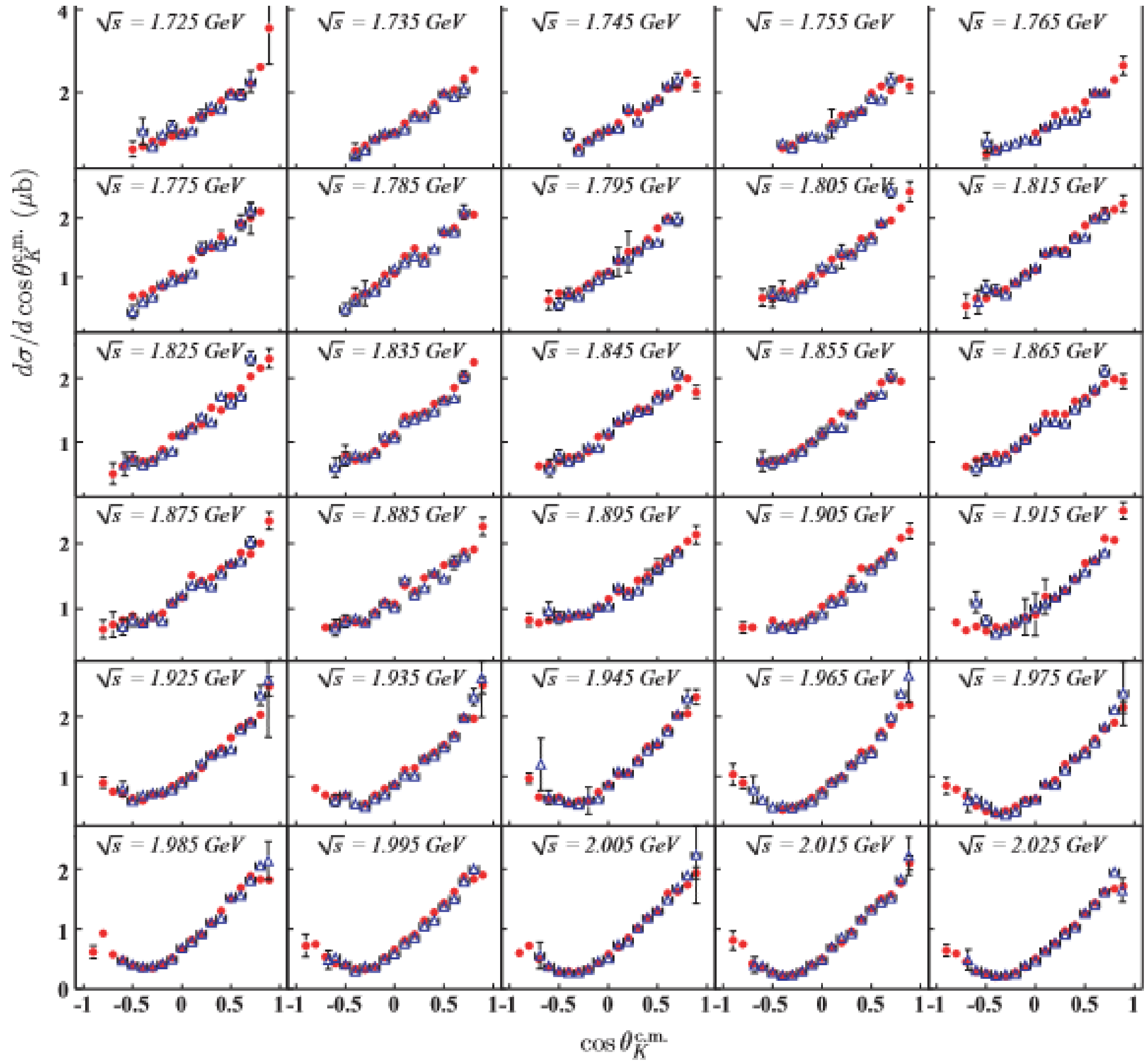
Scattering Angle



$$\theta = ?$$

$N_\Lambda(E_\Lambda)$

$$\frac{d\sigma}{d\Omega} = \frac{N_\Lambda}{2\pi * L_\gamma * \Delta\cos(\theta)}$$



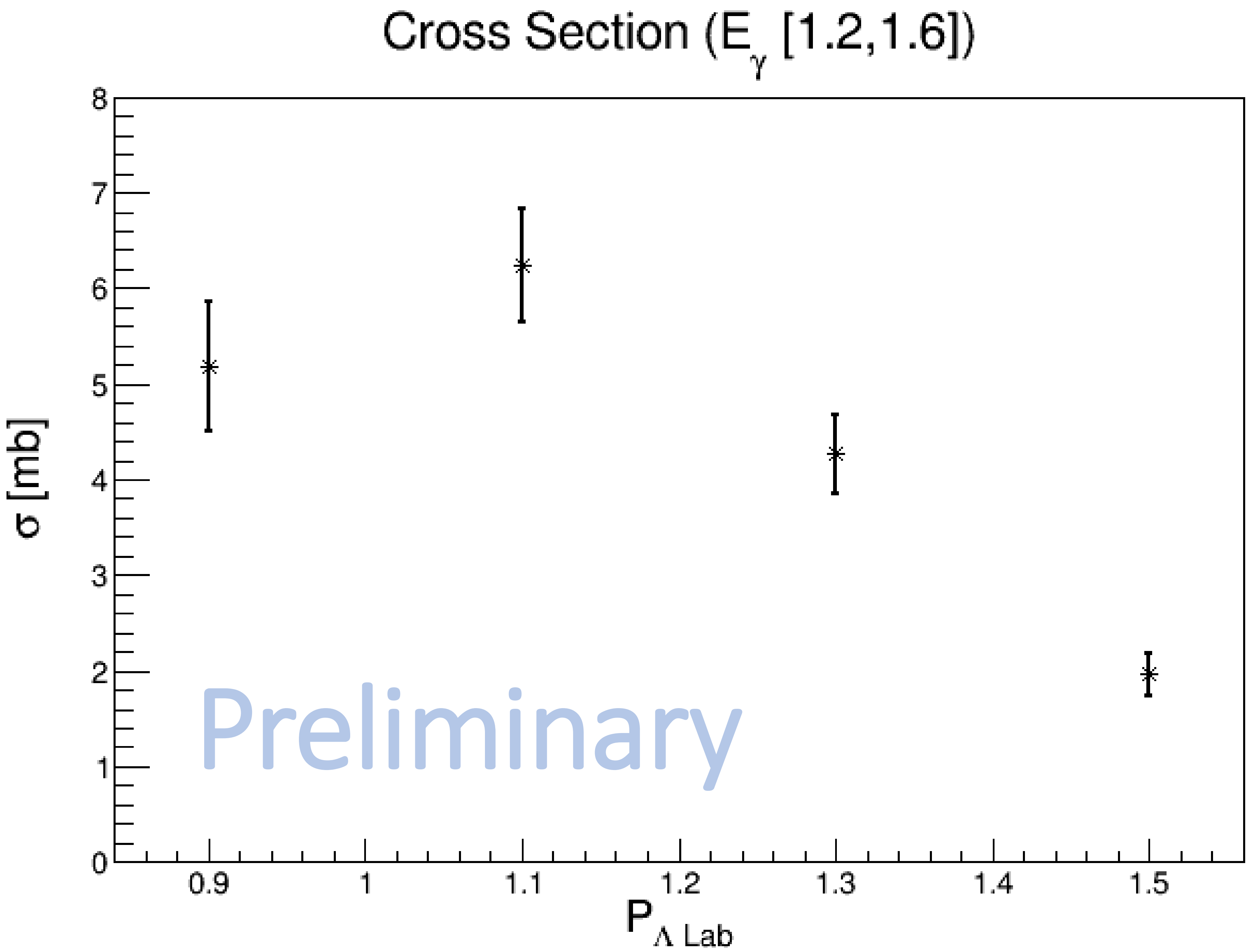
M. E. McCracken *et al.* PHYSICAL REVIEW C 81, 025201 (2010)

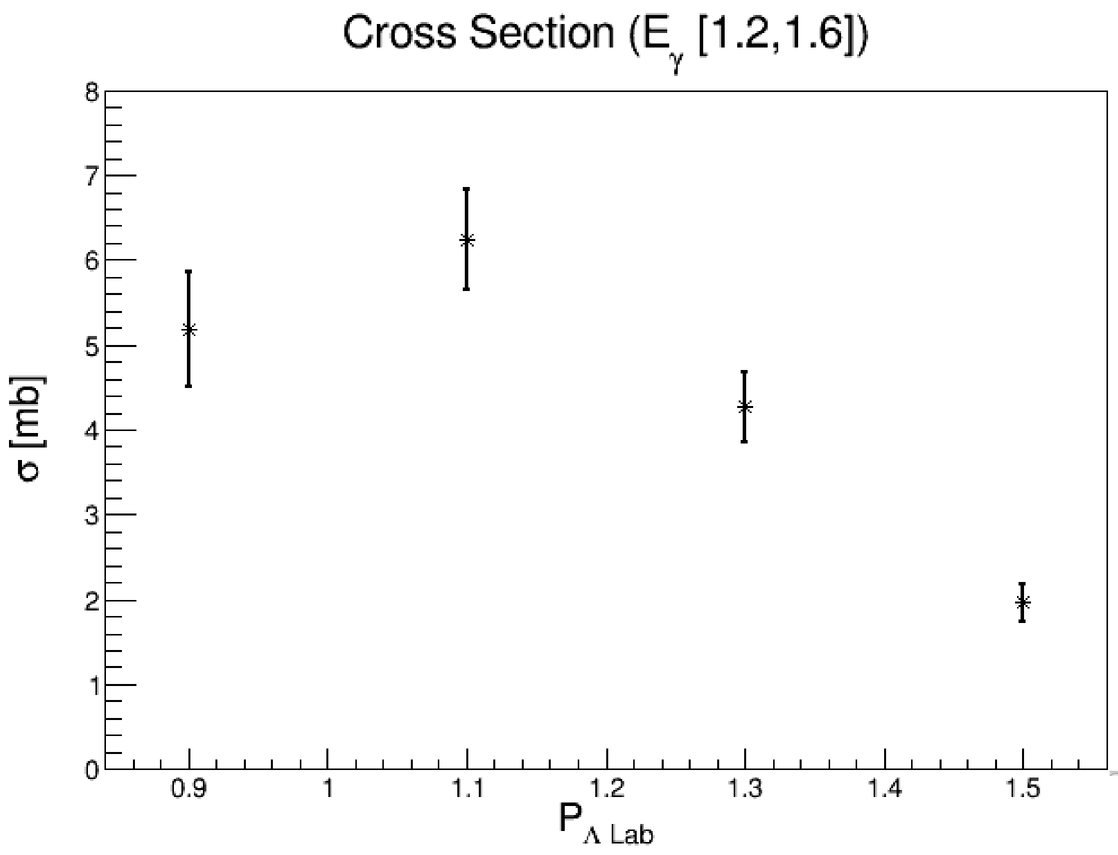
Luminosity

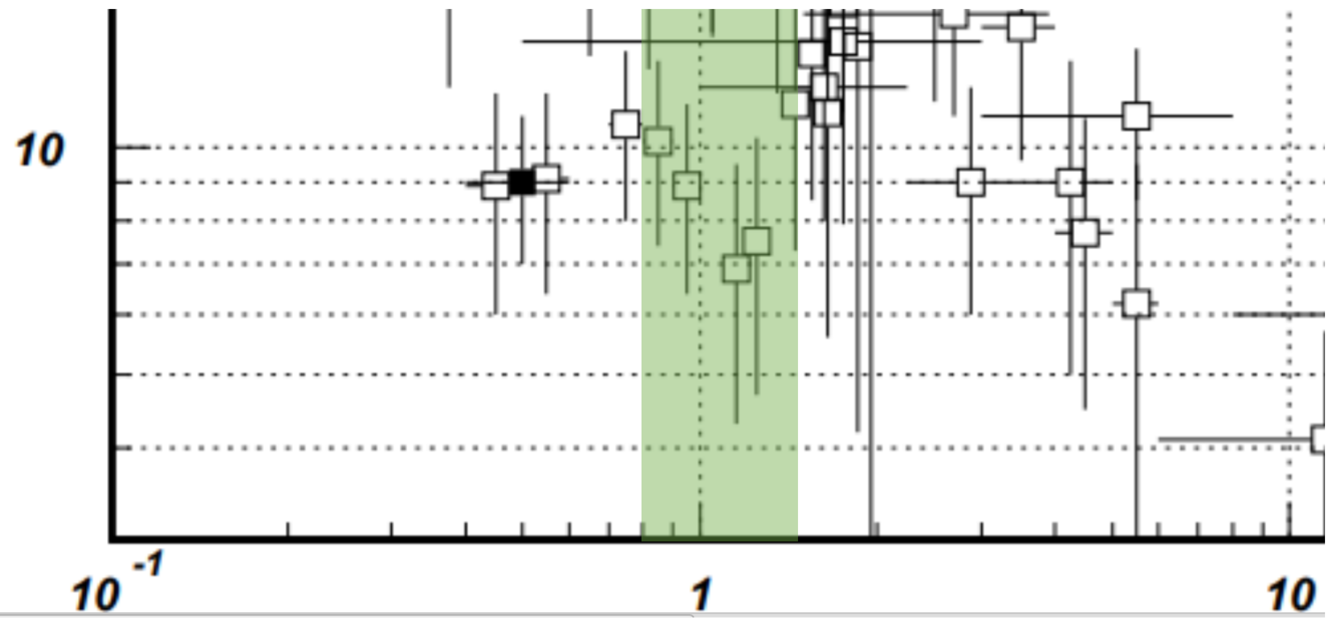
Z Vertex (cm)	Cos(ϴ)	Avg. Pathlength (cm)
0.0	1.0	7.5
20	1.0	7.2
20	.707	2.4
Random	Random	2.2

$$\frac{d\sigma}{d\Omega} = \frac{N_\Lambda}{2\pi * L_\gamma * \Delta\cos(\theta)}$$

$$L_\Lambda(E_\Lambda) = \frac{\rho_T * N_A * l}{M} * N_\Lambda(E_\Lambda)$$


Cross Section (E$_\gamma$ [1.2,1.6])
σ [mb]
0
1
2
3
4
5
6
7
8
0.9
1
1.1
1.2
1.3
1.4
1.5
P$_{\Lambda\ Lab}$
Preliminary



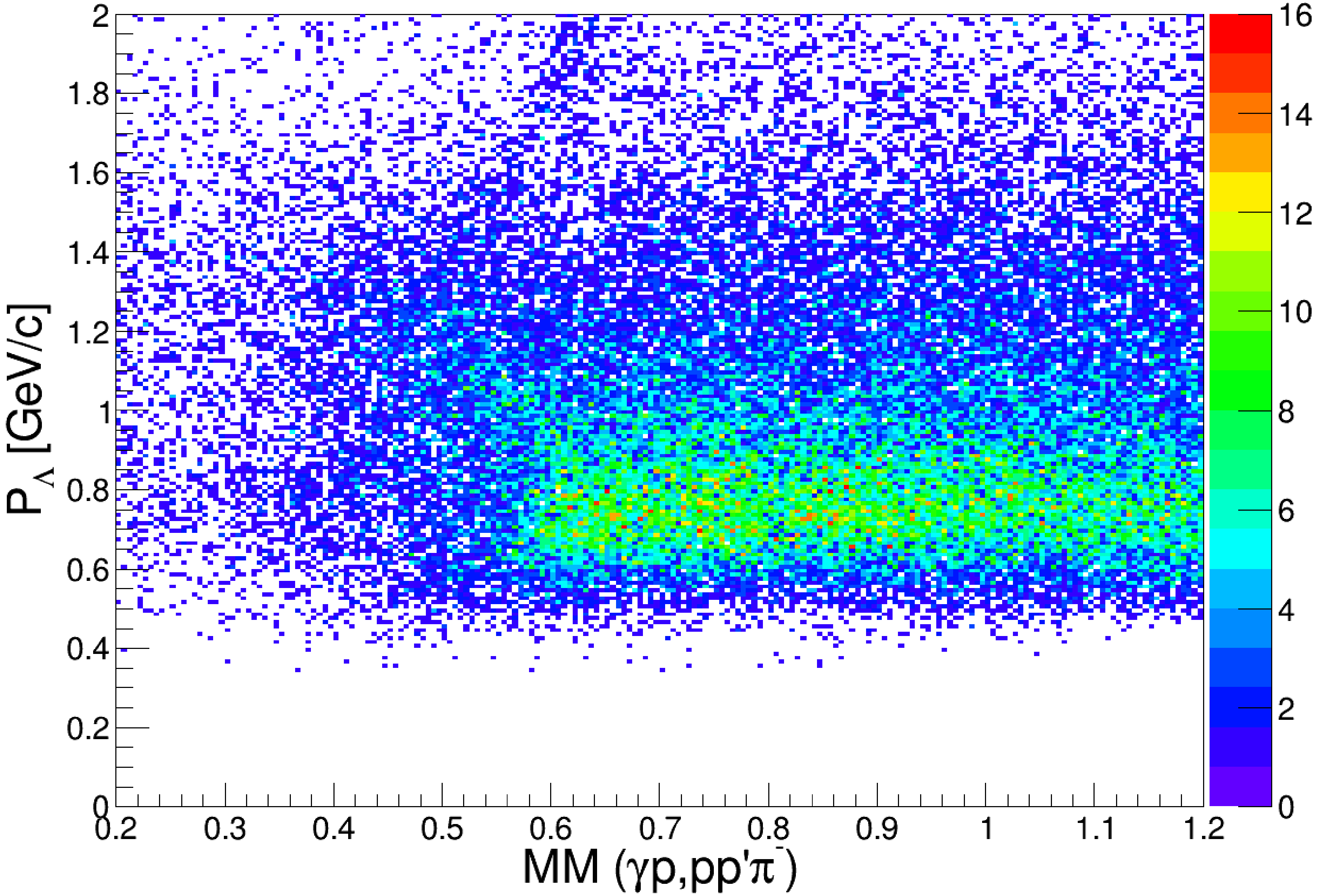


C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C, **40**, 100001 (2016) and 2017 update.

Summary/Future Work

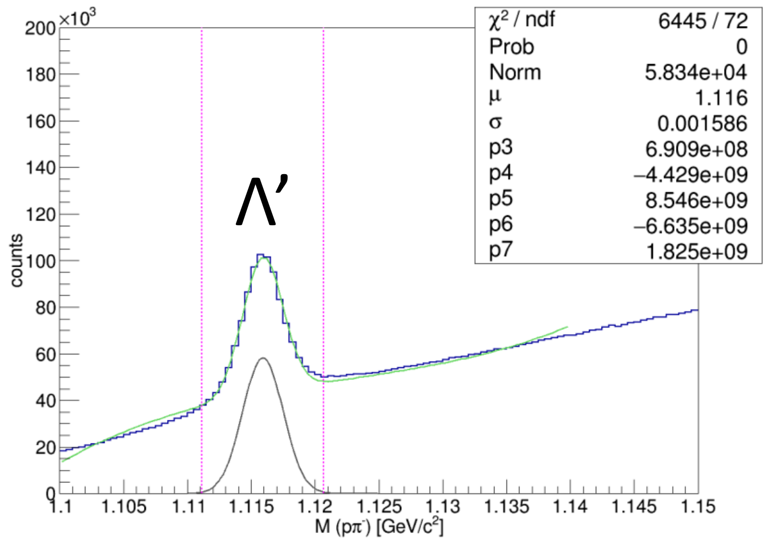
- There are many Λp events in the g12 data
- Various corrections still need to be made but all the mechanisms are in place.
- Helicity dependent cross sections are also possible

Side Band

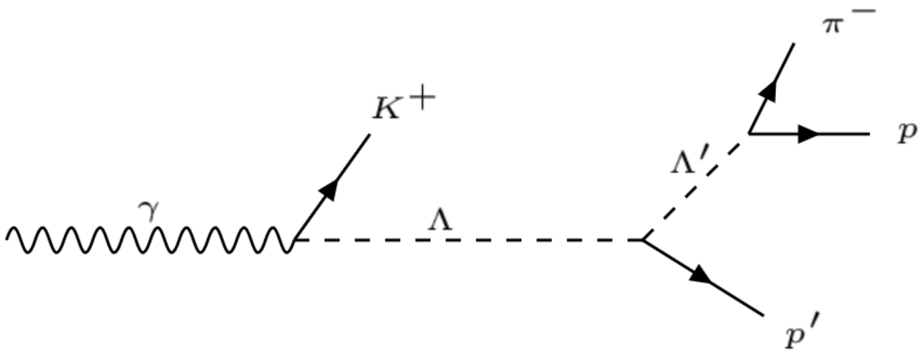


P_Λ [GeV/c]
MM (γp,pp'π^-)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8
10
12
14
16

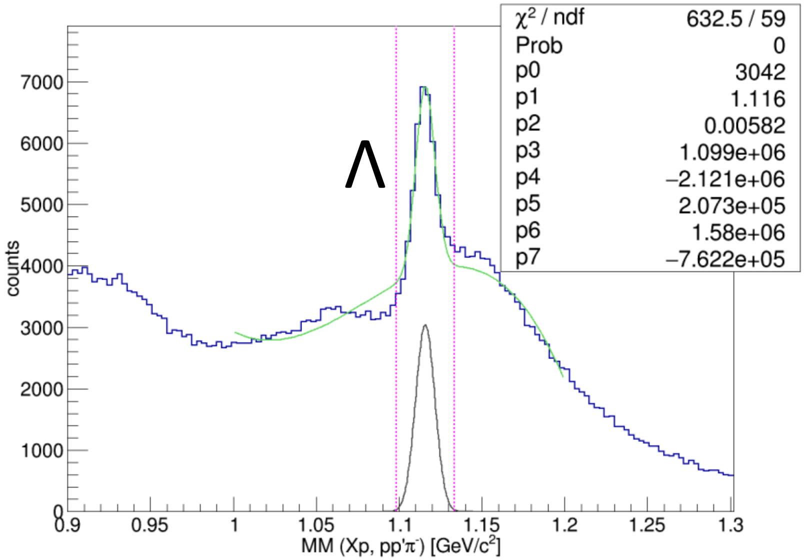
Cuts



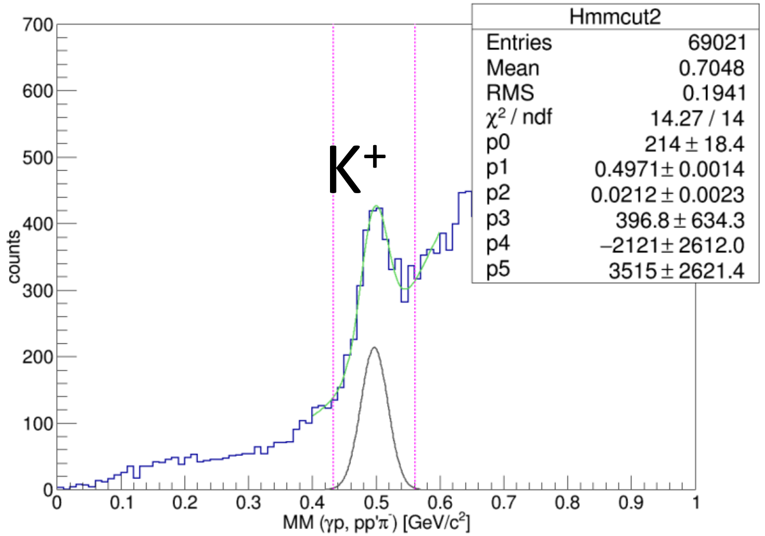
Λ’
χ² / ndf 6445 / 72
Prob 0
Norm 5.834e+04
μ 1.116
σ 0.001586
p3 6.909e+08
p4 −4.429e+09
p5 8.546e+09
p6 −6.635e+09
p7 1.825e+09
counts
M (pπ⁻) [GeV/c²]



γ
K⁺
Λ
Λ′
π⁻
p
p′



Λ
χ² / ndf 632.5 / 59
Prob 0
p0 3042
p1 1.116
p2 0.00582
p3 1.099e+06
p4 −2.121e+06
p5 2.073e+05
p6 1.58e+06
p7 −7.622e+05
counts
MM (Xp, pp'π⁻) [GeV/c²]



K⁺
Hmmcut2
Entries 69021
Mean 0.7048
RMS 0.1941
χ² / ndf 14.27 / 14
p0 214 ± 18.4
p1 0.4971 ± 0.0014
p2 0.0212 ± 0.0023
p3 396.8 ± 634.3
p4 −2121 ± 2612.0
p5 3515 ± 2621.4
counts
MM (γp, pp'π⁻) [GeV/c²]

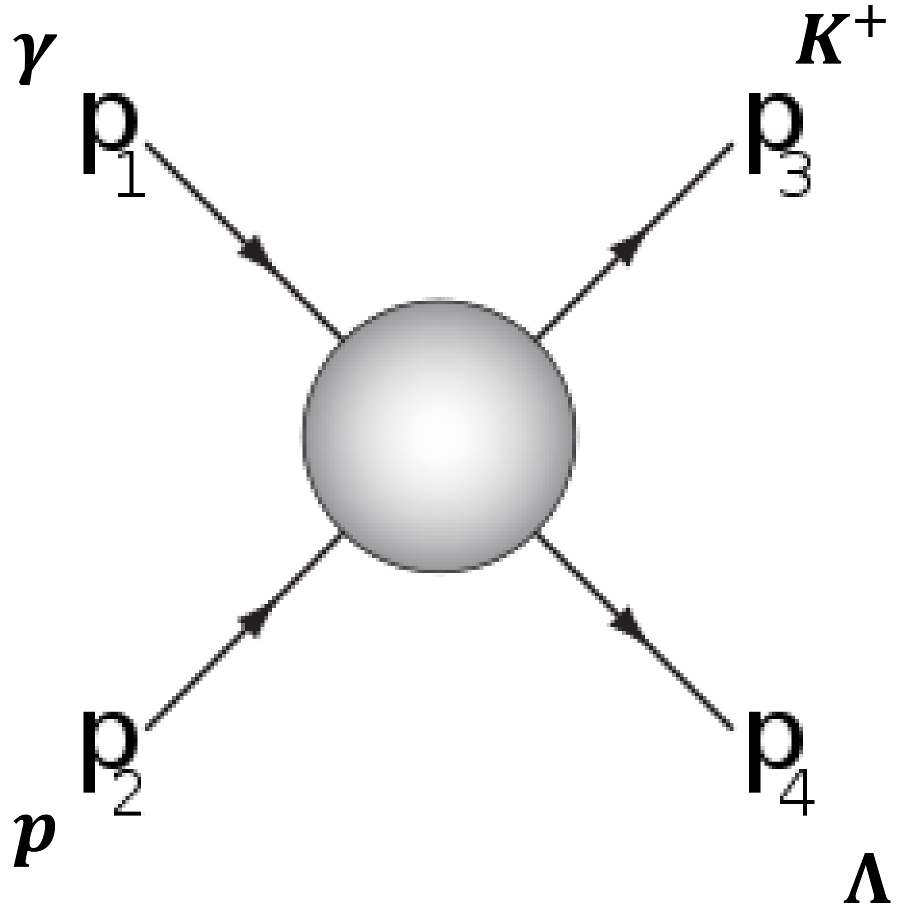
Extra (Mandelstam Variables)

$$\boldsymbol{t = (p_1 - p_3)^2 = (p_4 - p_2)^2}$$

$$\cos(\theta)_{K^+} = \frac{t + 2E_\gamma E_{K^+} - m_{K^+}^2}{2E_\gamma \sqrt{E_{K^+}^2 - m_{K^+}^2}}$$

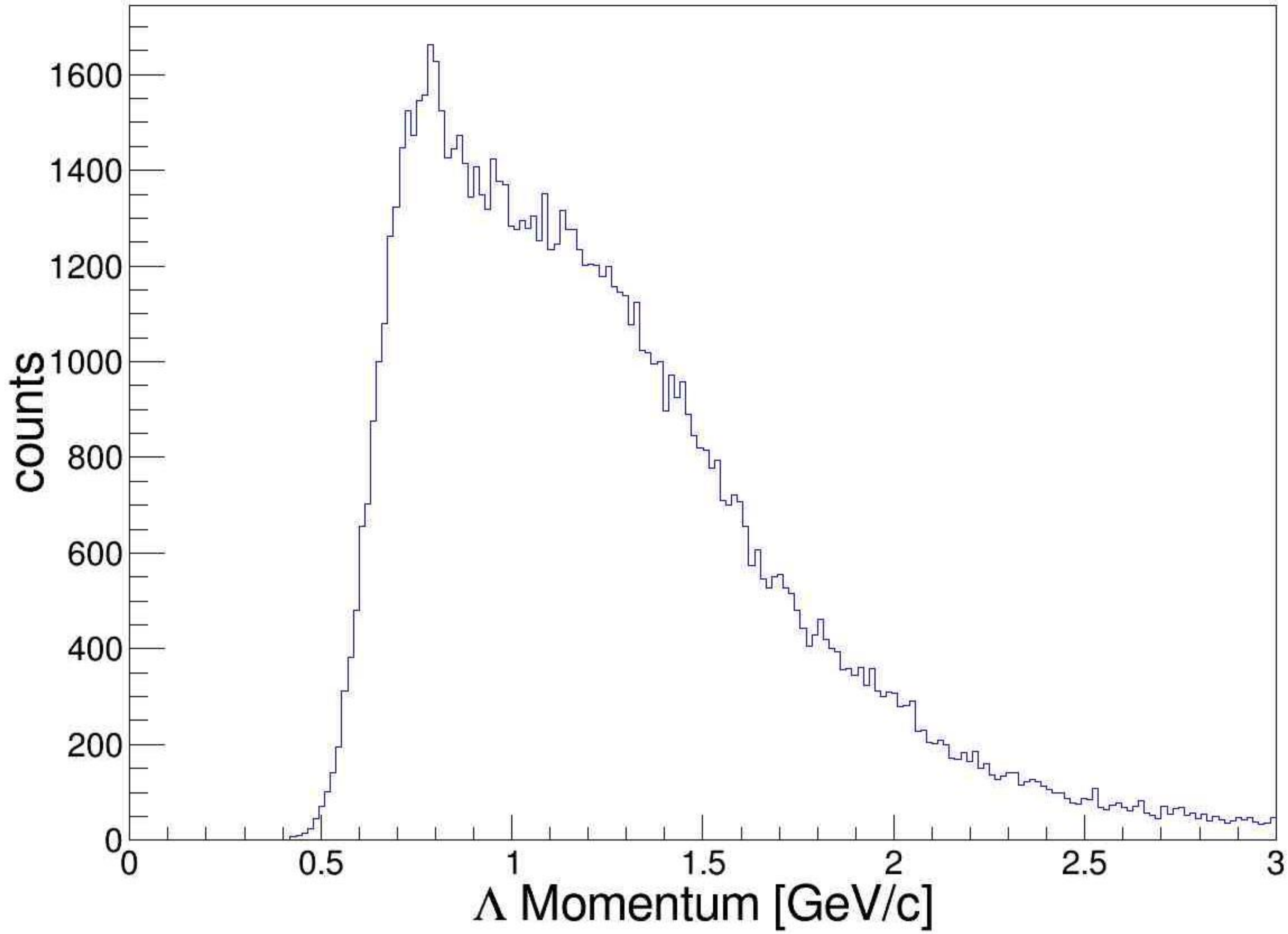
$$E_{K^+} = E_\gamma + m_p - E_\Lambda$$

$$E_\Lambda = -\frac{t - m_p^2 - m_\Lambda^2}{2m_p}$$

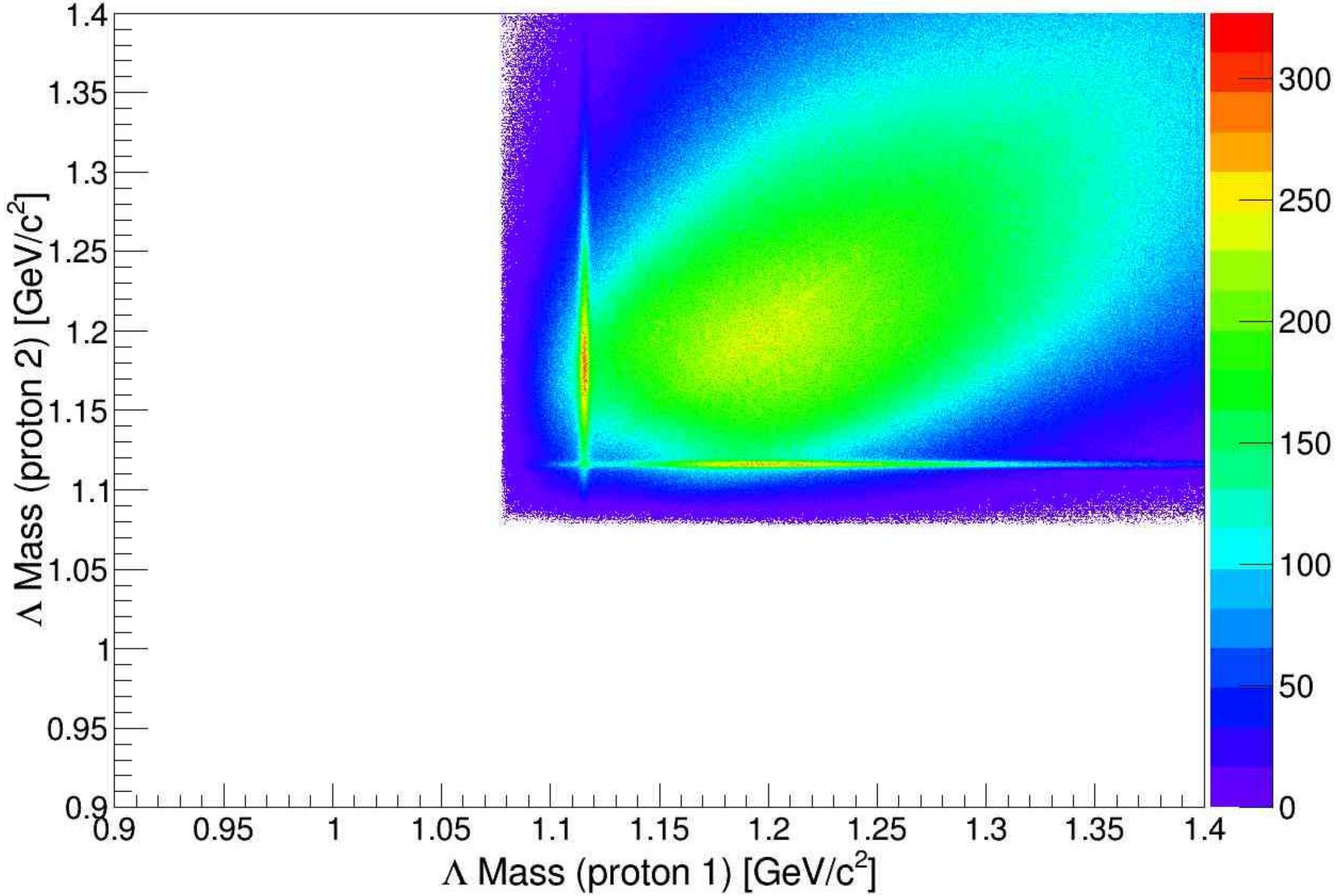


$$\cos(\theta)_{K^+\,CM} \rightarrow \cos(\theta)_{\Lambda\,LAB}$$

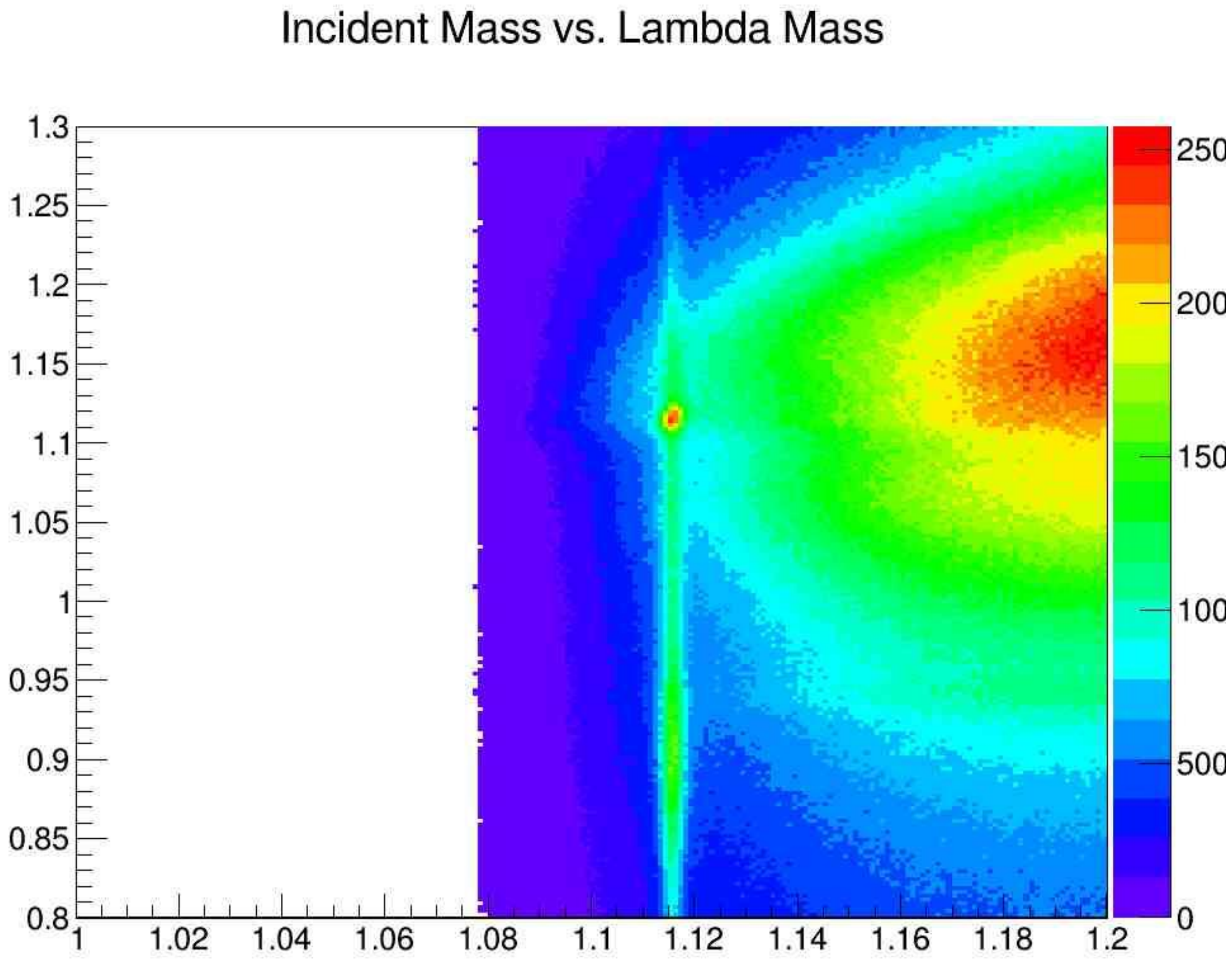
Extra (Global Λ Momentum)



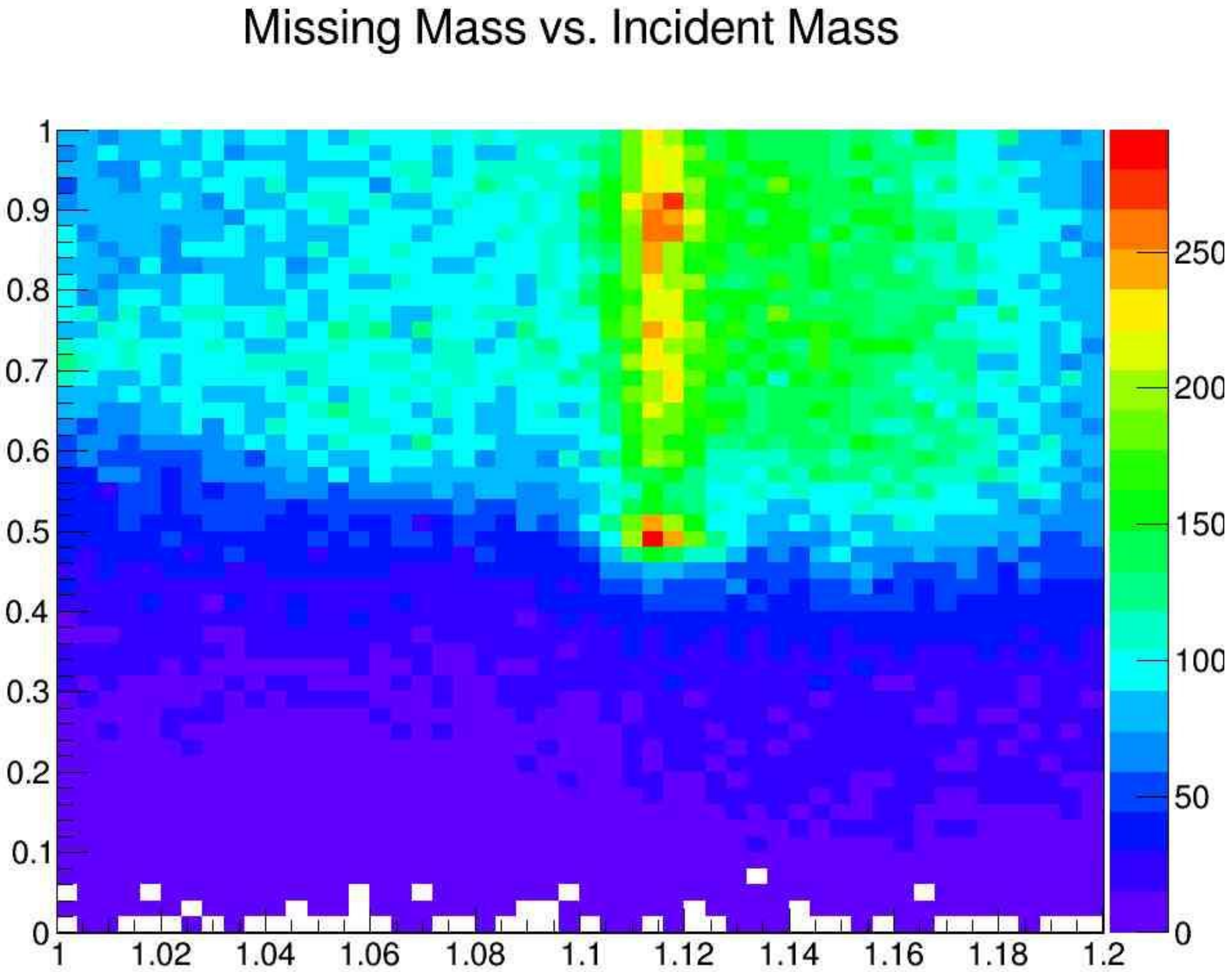
Extra (Invariant Mass)



Extra


Incident Mass vs. Lambda Mass
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
250
200
150
100
500
0

Extra


Missing Mass vs. Incident Mass
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
50
100
150
200
250

Extra (Global Energy Spectrum)