Hyperon Production Simulation Updates ($K^+\Sigma^0$, $K^+\Lambda^0$, $K^0\Sigma^+$ rates)

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Major Concern

- Background effects:

The weak decays of the hyperons preferentially emit pions along the direction of the hyperon spin, inducing a helicity dependent background. The LGC is the device potentially most sensitive to this false asymmetry. (LGC threshold ~50MeV)

- The background asymmetry: The measured asymmetries are at 5×10^{-3} level. We would like asymmetry in the LGC singles rate to be at the 10^{-4} level (arises from the dead time caused by the accidental singles rate in the LGC).

Hyperon Event Generator

- Electroproduction (available from HallB hyperon group and the generator are checked with data.) with Ebeam=11GeV, 3.4 GeV<Q^2<12 GeV, and threshold (GeV) <W< 2.835 GeV . (https://userweb.jlab.org/~golovach/ev_gen/piN_KY/)

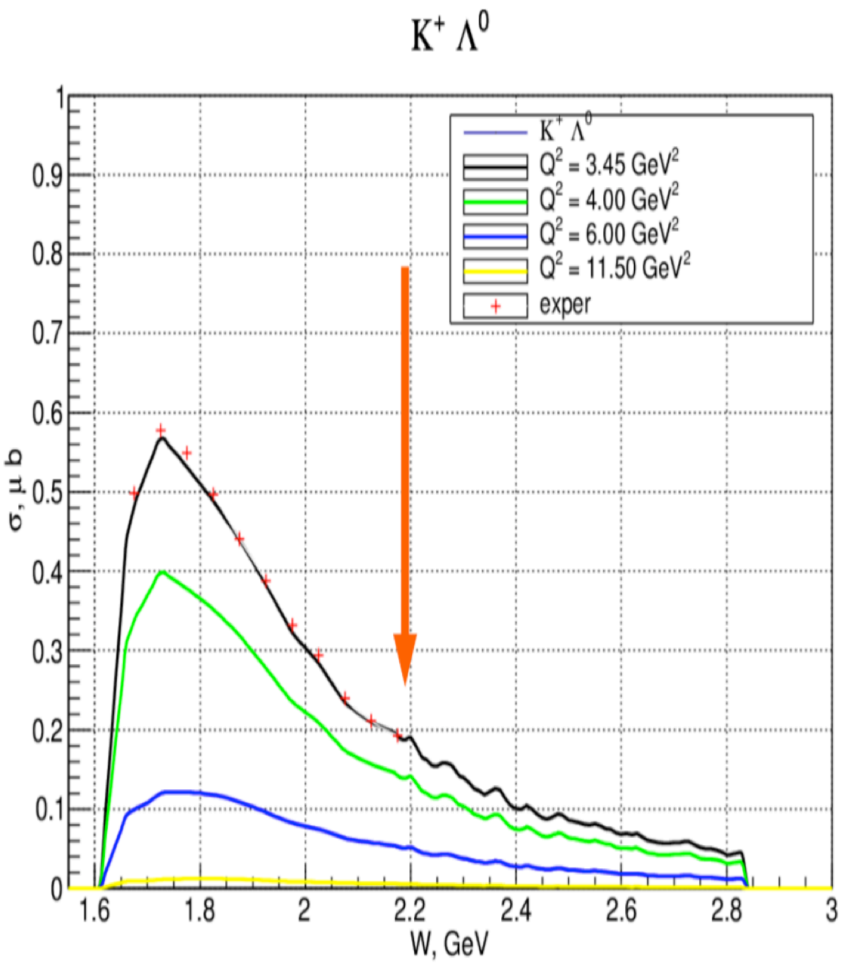
- Bremsstrahlung photoproduction event generator that is based on the Ugent model: *Phys. Rev. C73,045207(2006)* ~~*and*~~ *Phys. Rev. C75,045204(2007)* (http://rprmodel.ugent.be/calc/ cross section tables) with Ebeam=11GeV and 1.61(9)GeV<W<4.65 GeV.

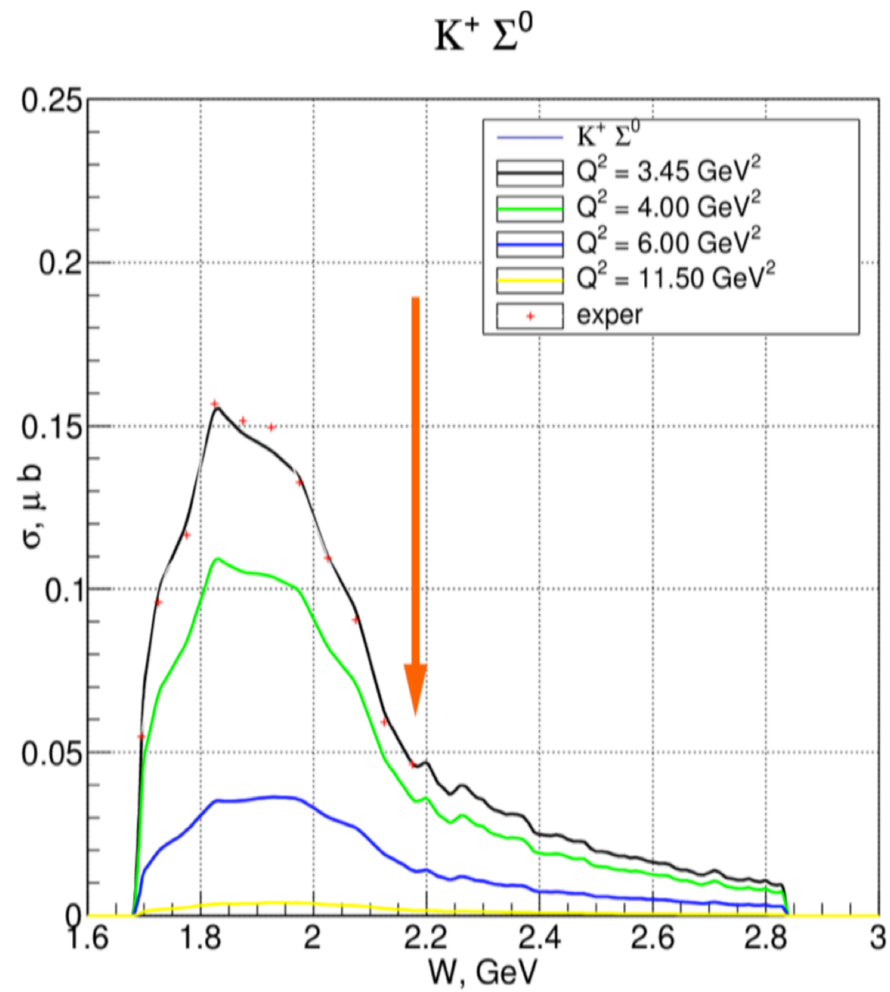
  Two versions are available:

  RPR-2007 version for channels: $\gamma p \to K^+ \Lambda^0$, $K^+ \Sigma^0$ and $K^0 \Sigma^+$

  RPR-2011 version only for channels: $\gamma p \to K^+ \Lambda^0$

Electroproduction Extrapolation of the cross section into larger W region (from W-dependence of the photoproduction data)





V. Klimenko, E. Golovach, and V. Mokeev (Mocow State University and JLab

RPR-2007 Version model and data comparison

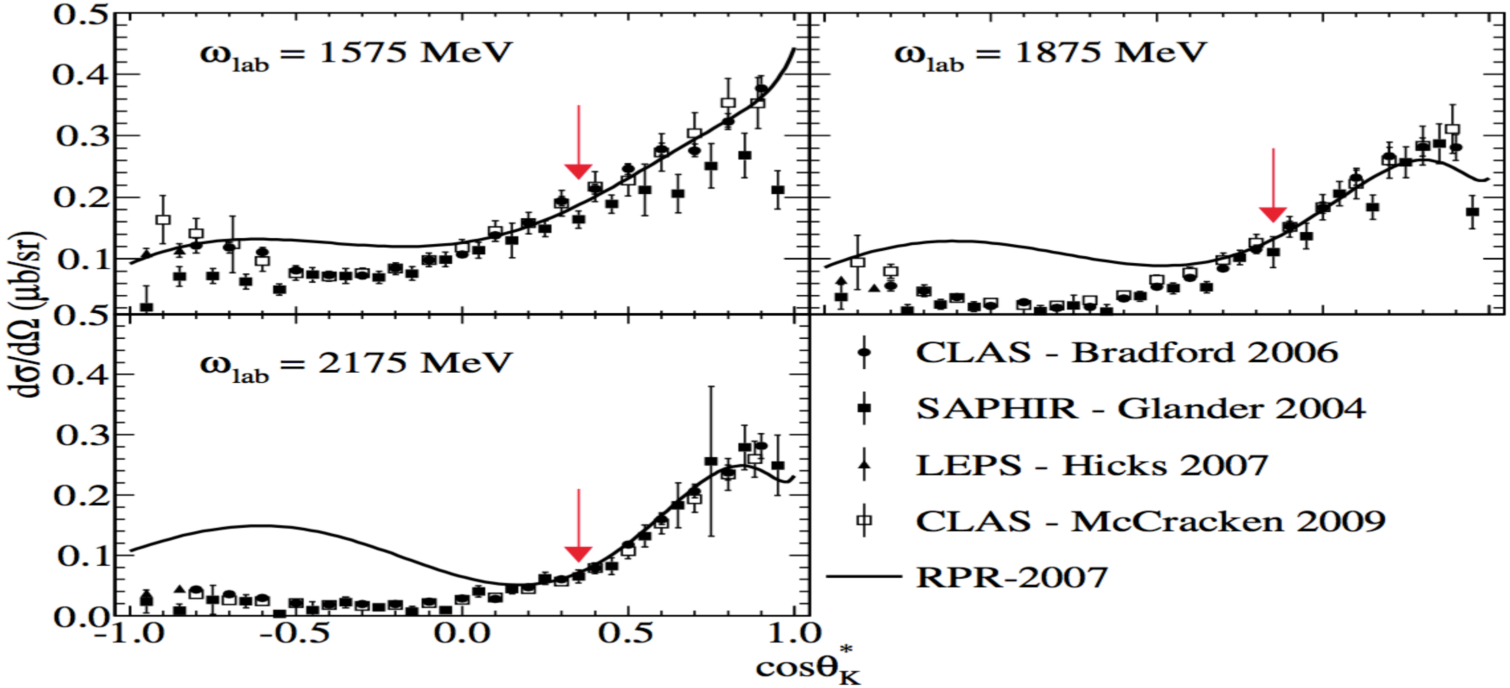


Figure 1: (color online). The $p(\gamma, K^+)\Lambda$ differential cross section as a function of $\cos\theta_K^*$ for the laboratory photon-energy bins ω_{lab} = 1575 MeV, 1875 MeV and 2175 MeV. The line denotes the RPR-2007 result and the data are from references [32–35]. The RPR-2007 model is optimized against the $\cos\theta_K^* > 0.35$ data (indicated with the arrow).

https://arxiv.org/abs/1205.2195v3

It turns out that RPR-2007 version is constrained to forward angle ($\cos\theta^*_k$ >0.35).

RPR-2011 Version model and data comparison

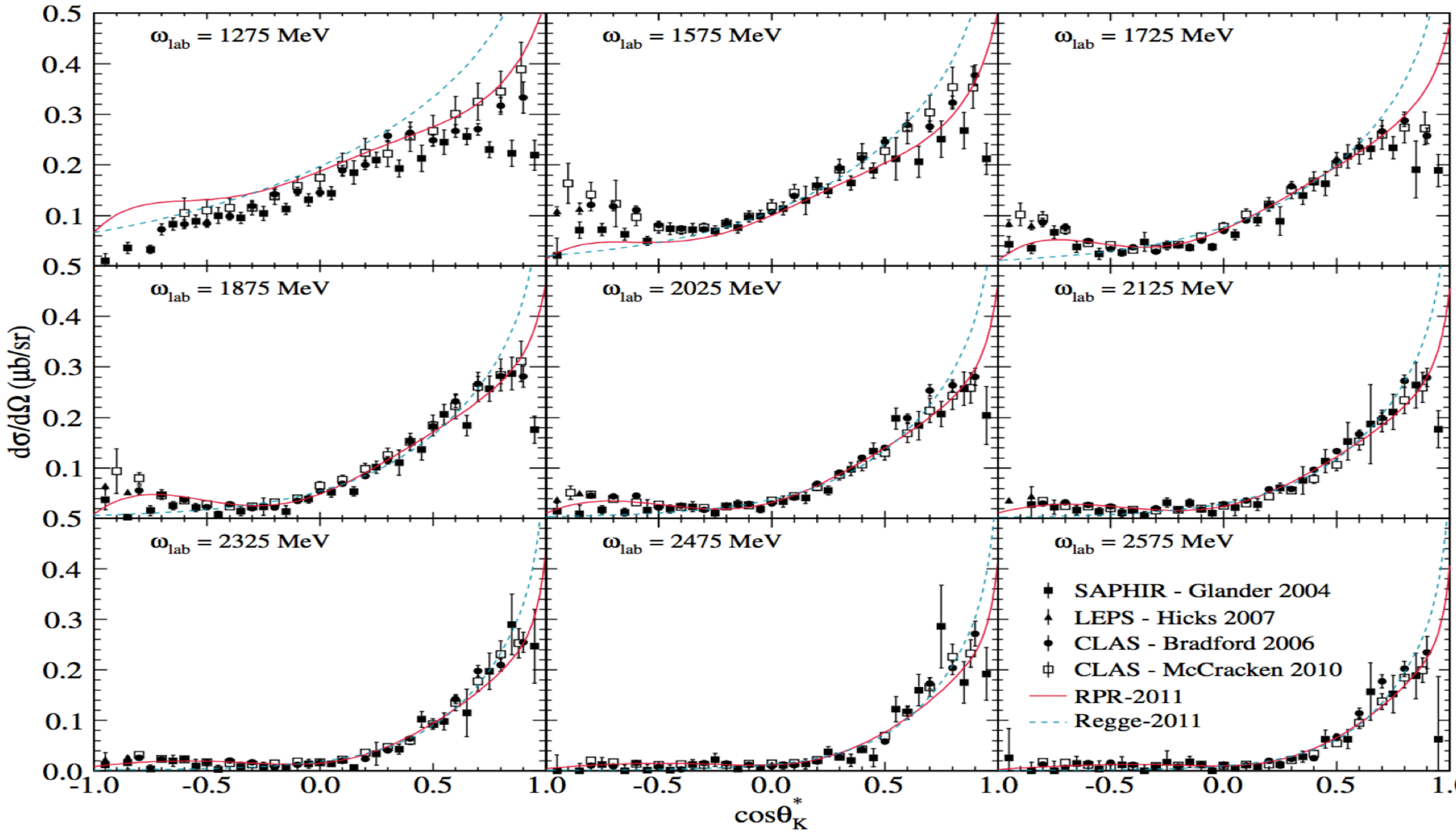


Figure 11: (color online). Angular dependence of the differential cross section at various incident photon energies $\omega_{\rm lab}$. The full red line represents the RPR-2011 model, the blue dashed line corresponds with Regge-2011. Data are from Refs. [32–35].

https://arxiv.org/abs/1205.2195v3

It turns out that RPR-2011 version is consistent with data, but it is only available for $\gamma p \to K^+ \Lambda^0$ channel now.

Part I

$K^{+}\Lambda^{0}$

Electro-and photon-production simulation comparison

$K^{+}\Lambda^{0}$ simulation

◆ The electroproduction simulation condition: e^{-} beam

E_{beam}=11 GeV, 3.4GeV^2<Q<12GeV^2, and 1.61 GeV<W<2.835 GeV

◆ The photonproduction simulation condition:

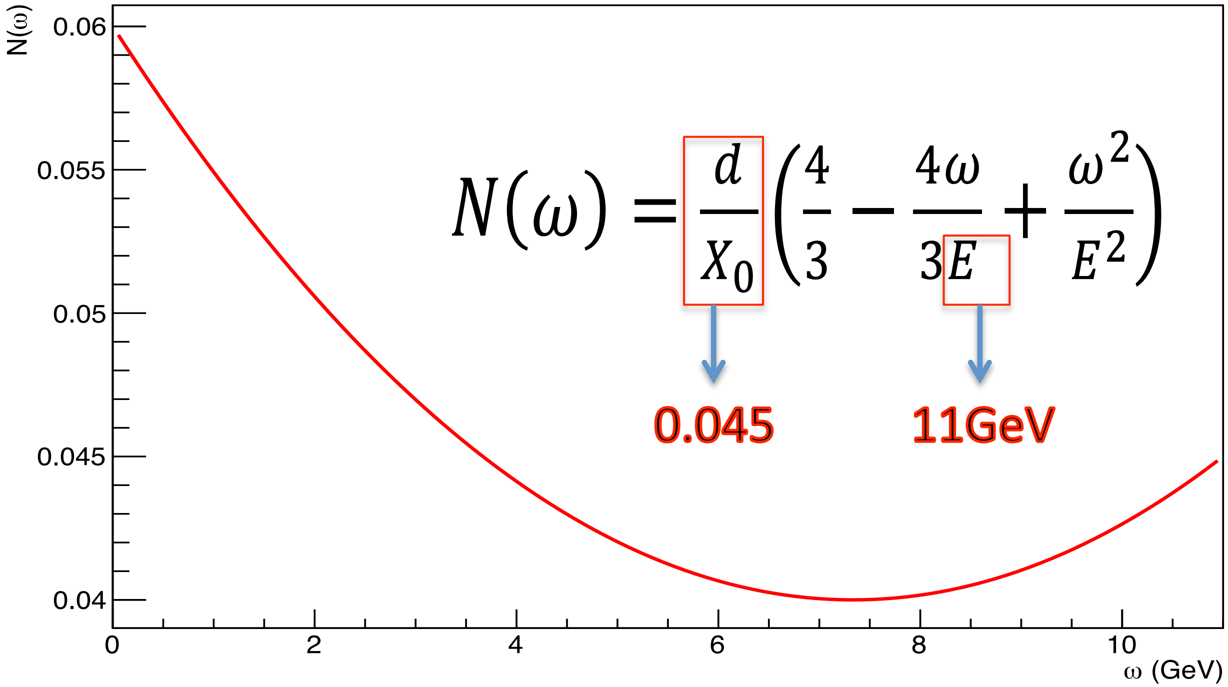
The number of bremsstrahlung photons with energy between ω_{max} and ω_{min}

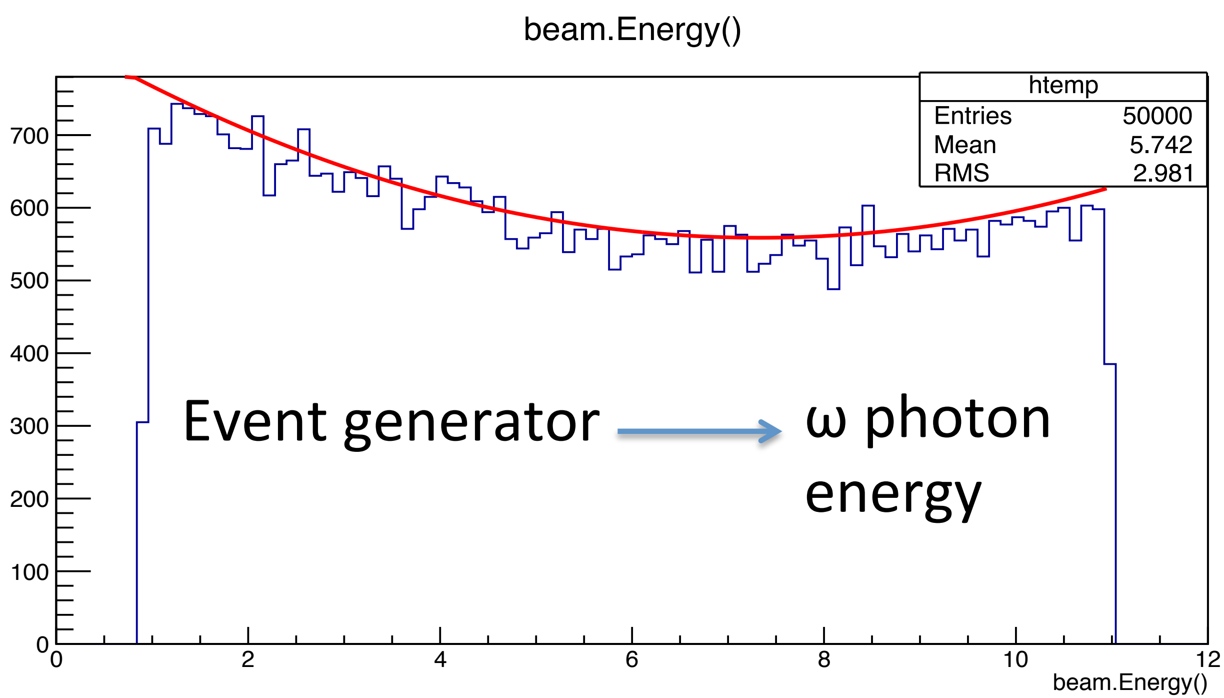
$$n_r = \frac{4d}{3X_0}\left[ln\frac{\omega_{max}}{\omega_{min}} - \frac{\omega_{max}-\omega_{min}}{E} + \frac{3\left(\omega_{max}^2-\omega_{min}^2\right)}{8E^2}\right]$$

$$\frac{dn}{d\omega} = \frac{N(\omega)}{\omega} = \frac{4d}{3X_0\omega}\left(1-\frac{\omega}{E}+\frac{3\omega^2}{4E^2}\right)$$

$$N(\omega) = \frac{d}{X_0}\left(\frac{4}{3}-\frac{4\omega}{3E}+\frac{\omega^2}{E^2}\right)$$

d = ρ · t where ρ is target density and t is target thickness



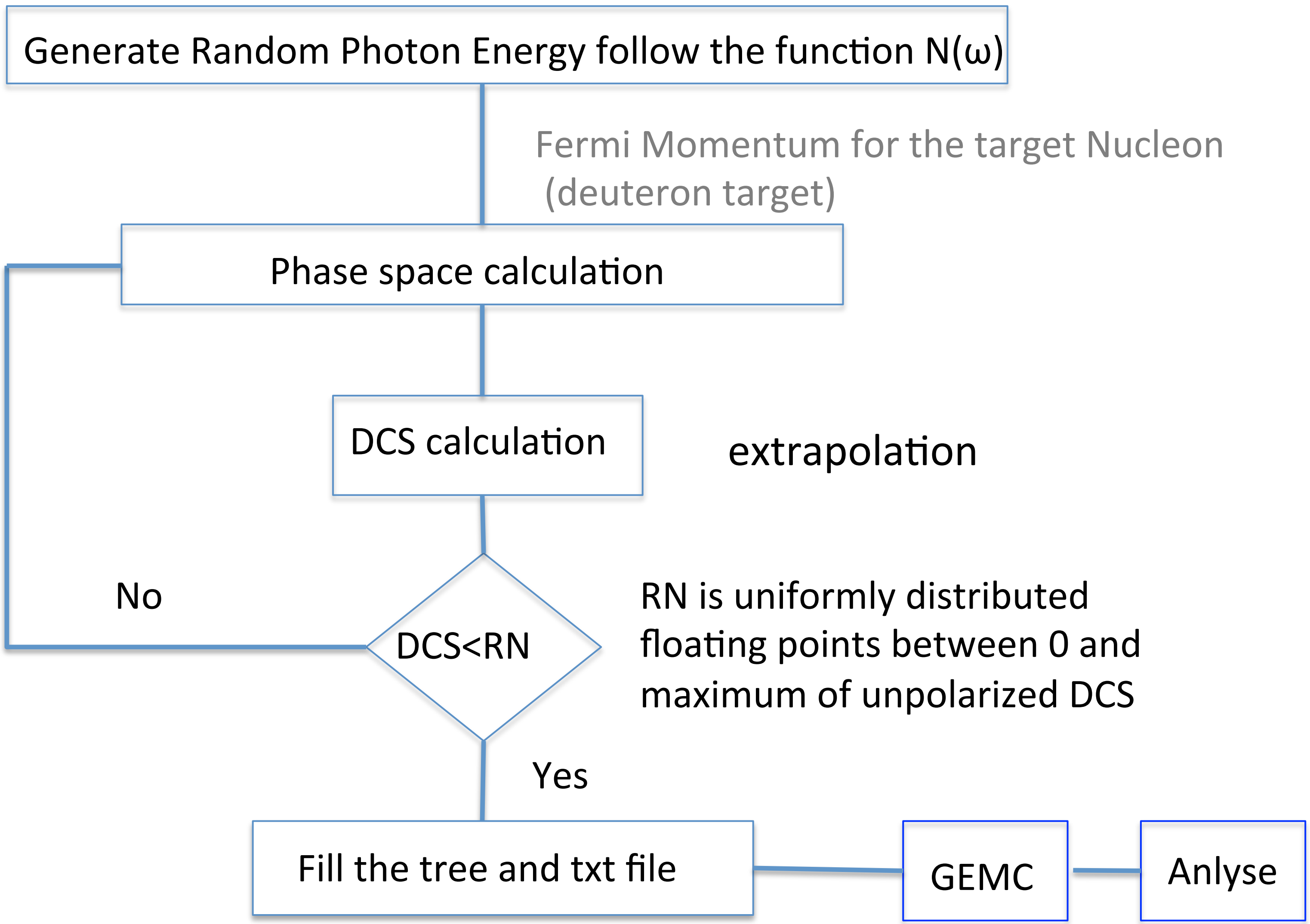


$\gamma p \rightarrow K^+Y$

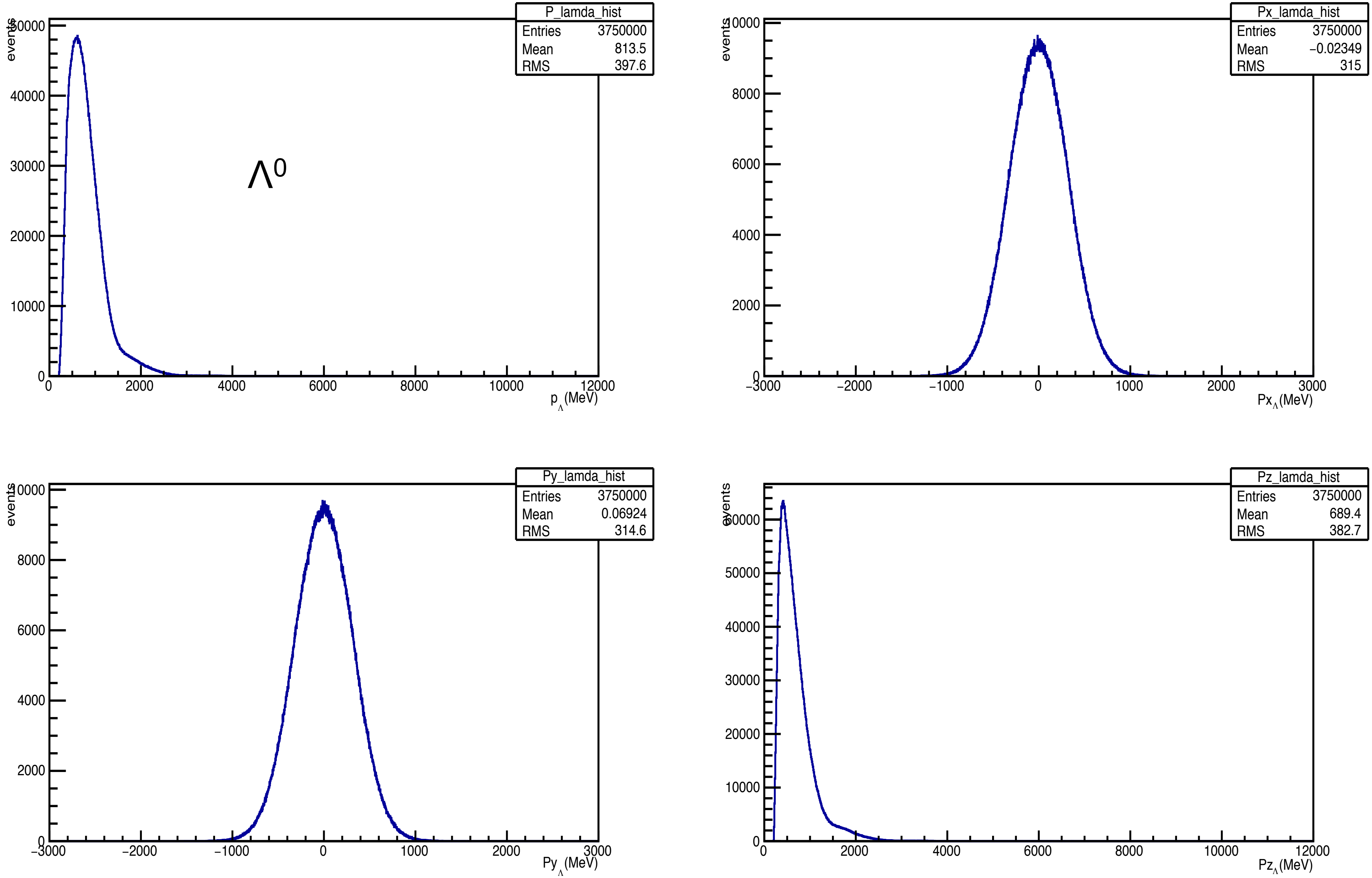
Λ^0or Σ^0

Event Generator Scheme

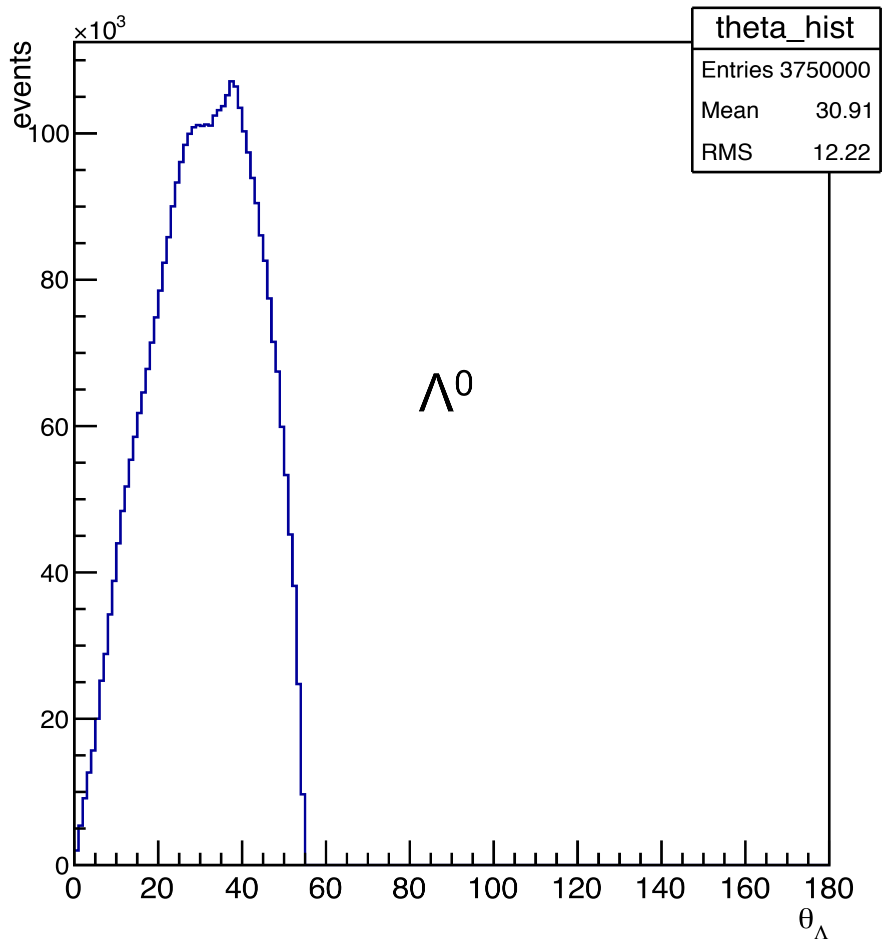
Model table: W, $\cos\theta_k$, σ, $d\sigma/d\Omega$

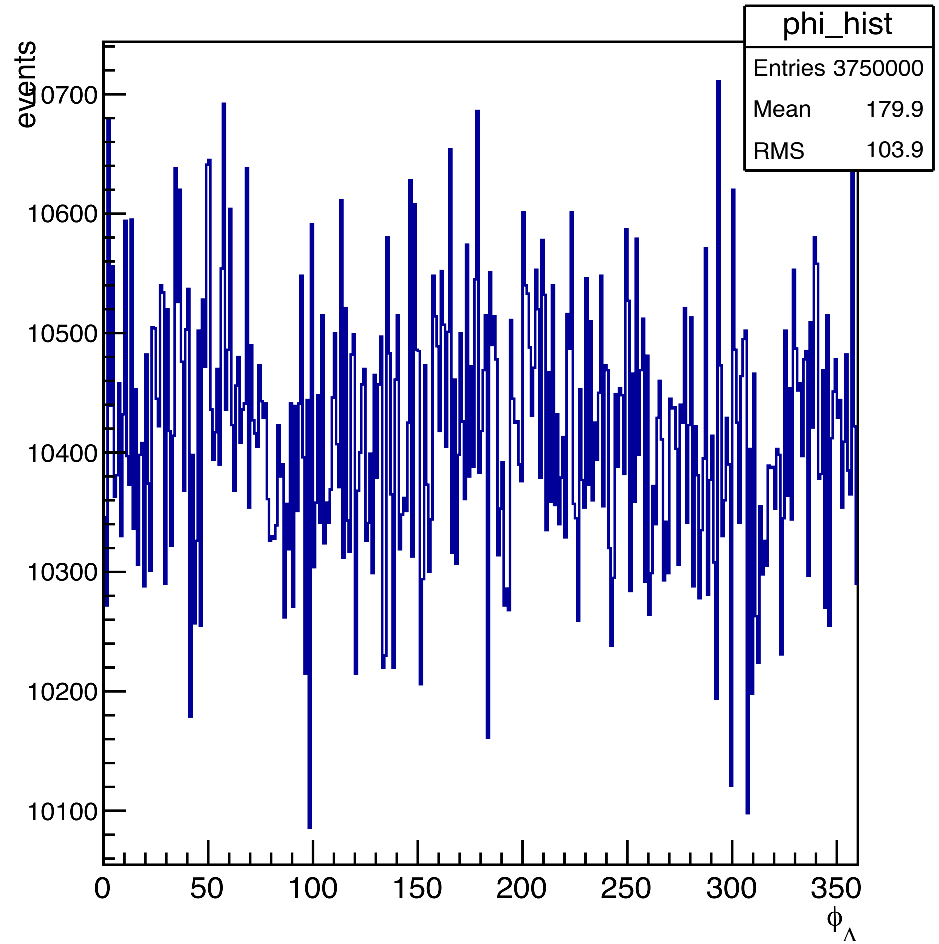


$\Upsilon P \longrightarrow K^+\Lambda^0$ Simulation Results

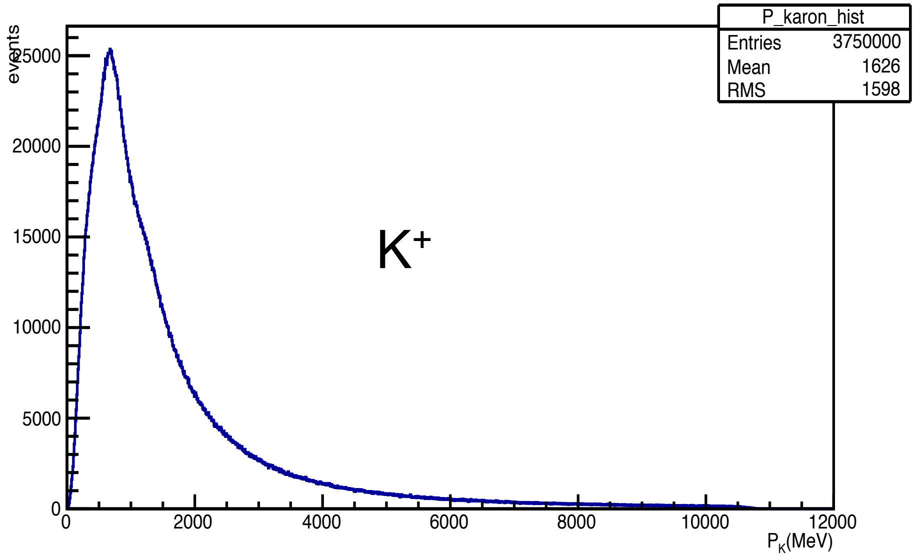


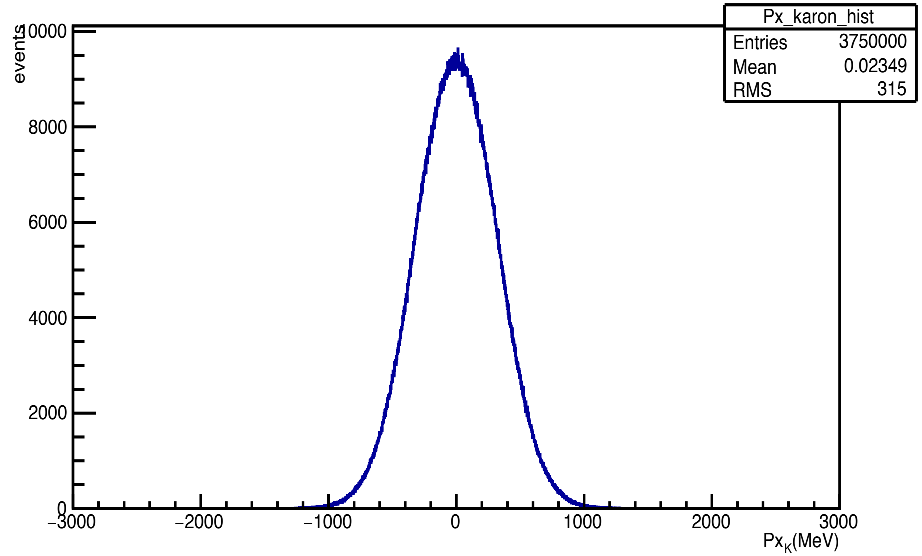
$\Upsilon P \longrightarrow K^+\Lambda^0$ Simulation Results

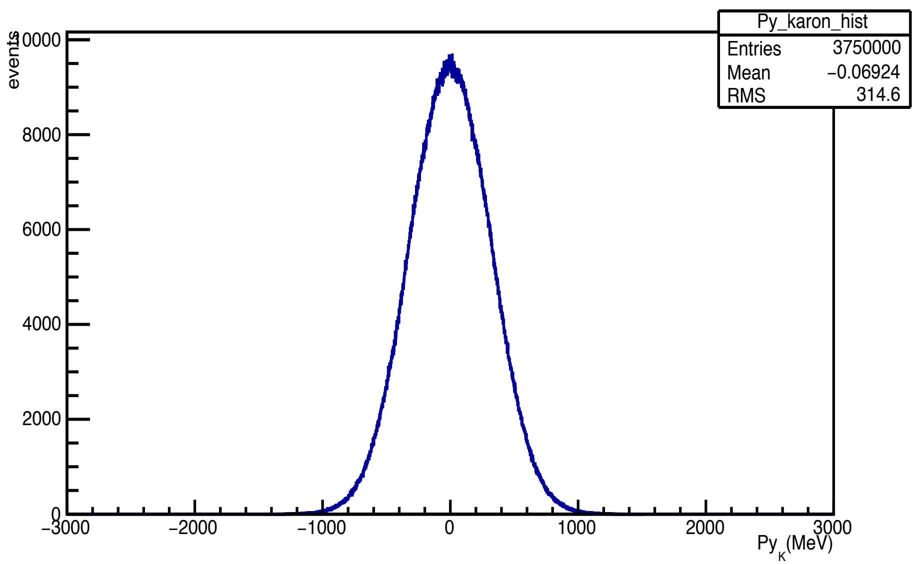


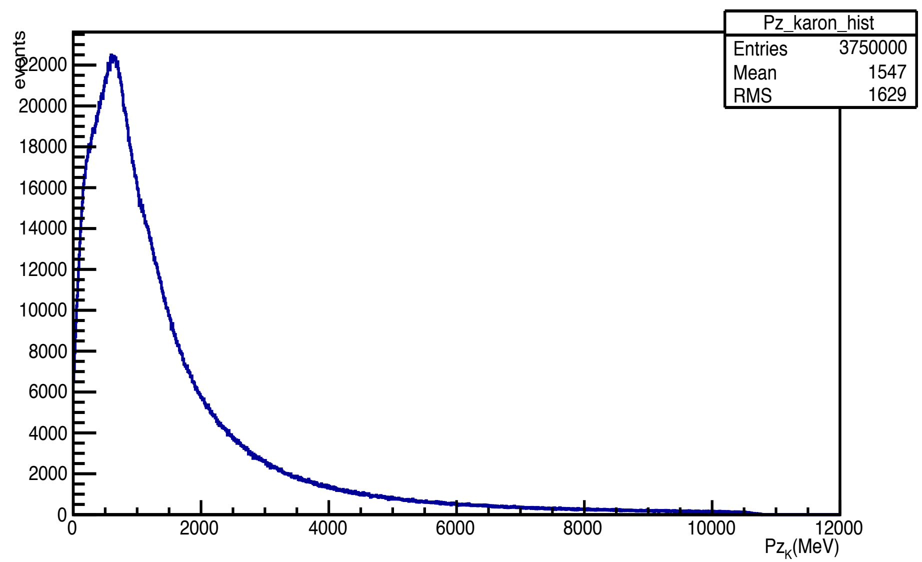


$\Upsilon P \longrightarrow K^+\Lambda^0$ Simulation Results

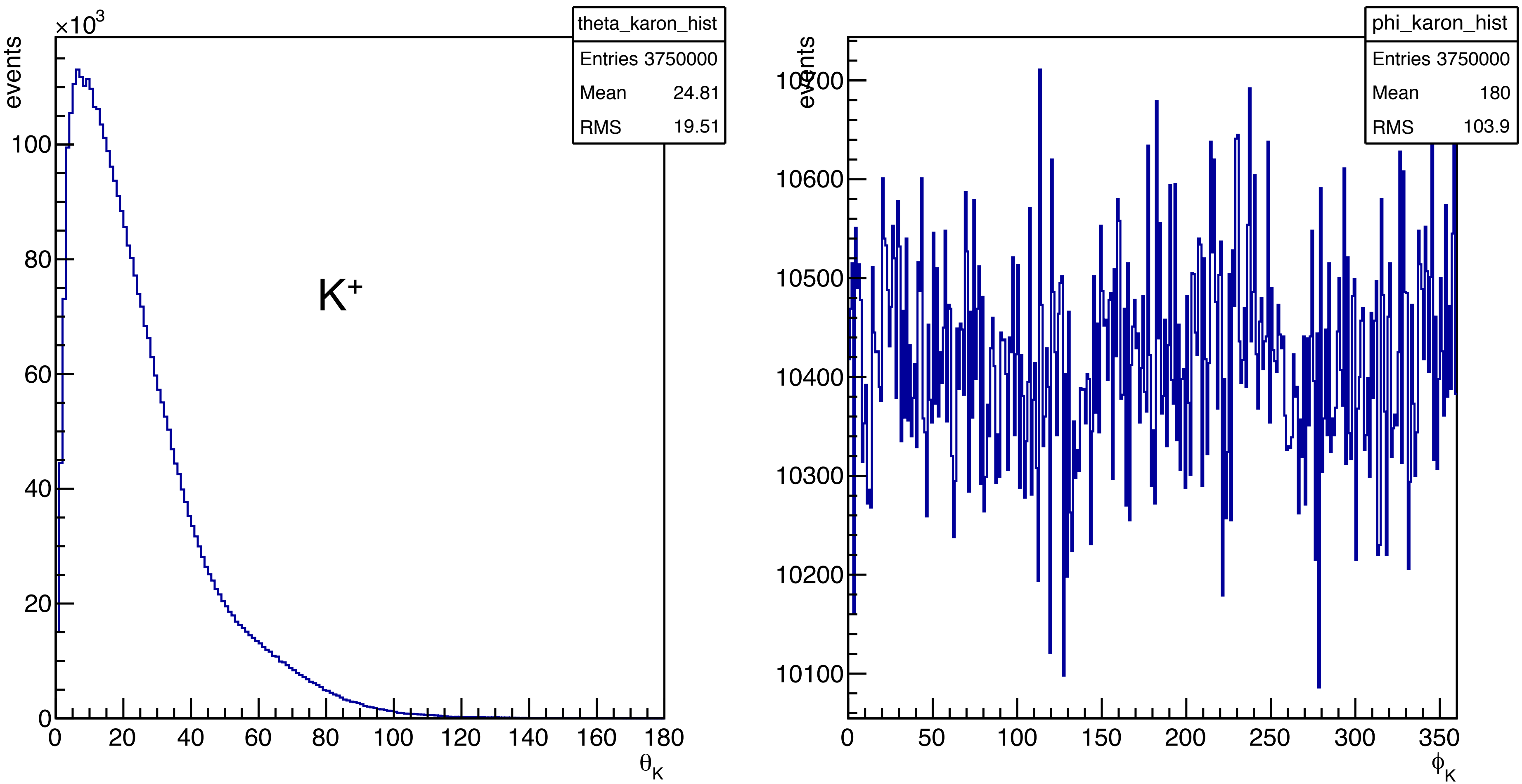








$\Upsilon P \longrightarrow K^+\Lambda^0$ Simulation Results



Reconstruct π^0 Analysis

- $\Upsilon\, p \longrightarrow \overset{1}{K^+}\ \overset{2}{\Lambda^0}$

  $\Lambda^0 \rightarrow \overset{4}{\boxed{n}}\ \overset{3}{\pi^0}$

  $\pi^0 \rightarrow \overset{5}{\boxed{\Upsilon}}\ \overset{6}{\Upsilon}$

  $\Upsilon \rightarrow e^- e^+$

mtid,
mpid, tid, and pid

$2\text{x}10^6$ events

$$\boxed{\pi_0^\mu = \Lambda_0^\mu - n^\mu}$$

in the same event

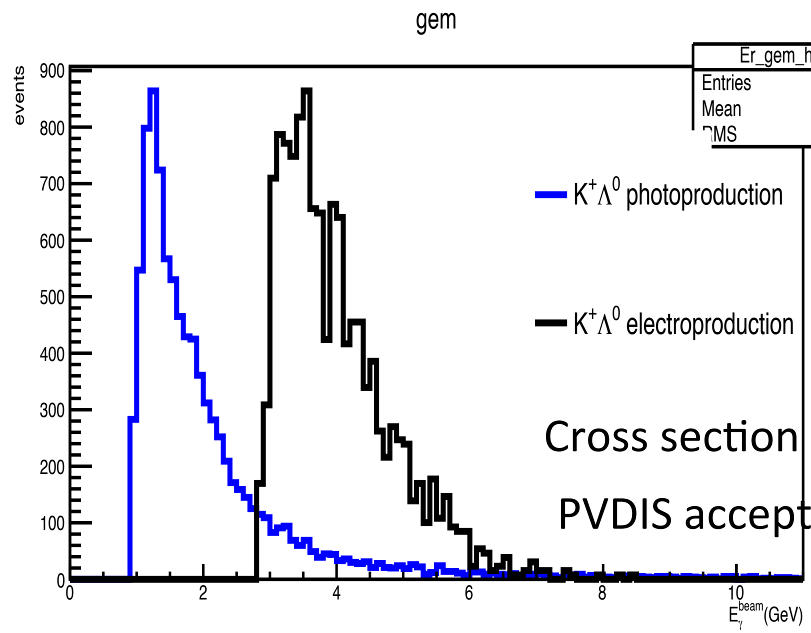
Reconstruct π^0

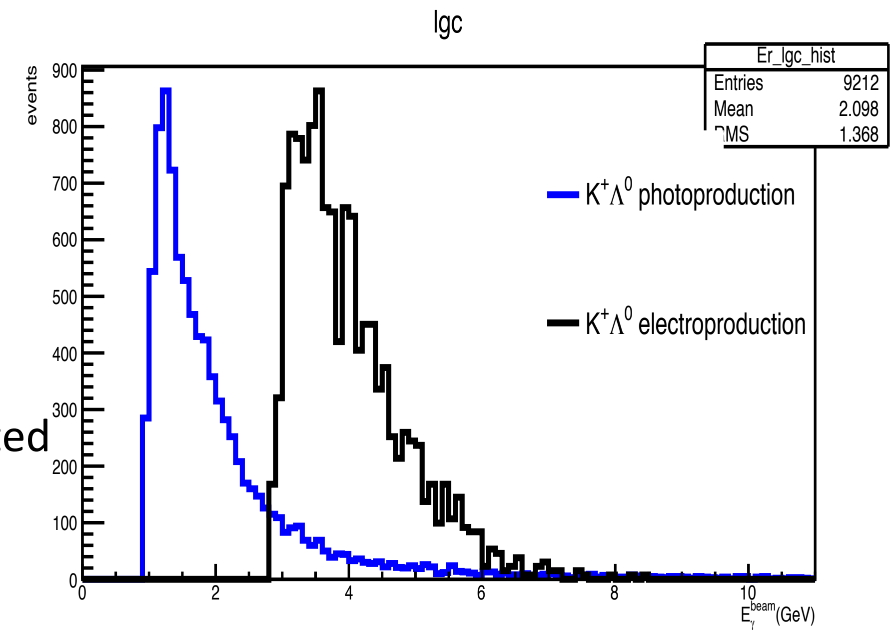
◆ Gem: flux hit detector ID = 1, sub-detector ID=1, 2, 3, 4, 5,
subsubdetector=1

◆ Lgc: flux hit detector ID = 2, sub-detector ID=1, 2.
subsubdetector=1

◆ Ecal: flux hit detector ID = 3, sub-detector ID =1, and
subsubdetector=1

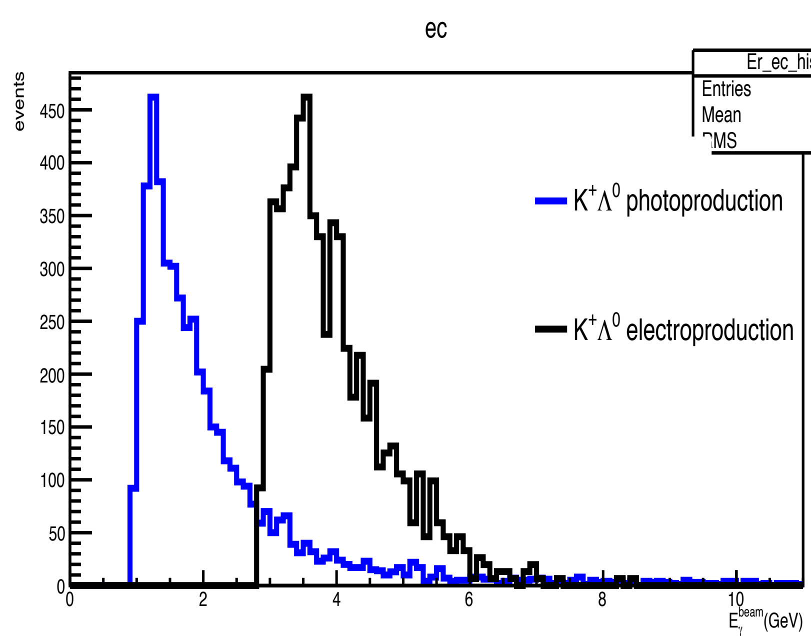
$\Upsilon P \to K^+\Lambda^0$





Cross section weighted

PVDIS acceptance



RPR-2011 version: photoproduction

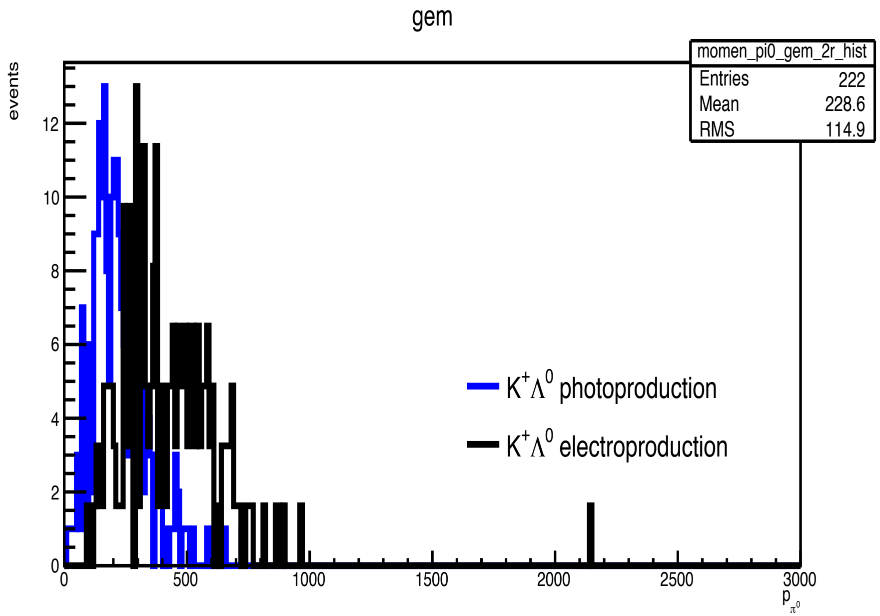
E_γ : bremsstrahlung photon energy

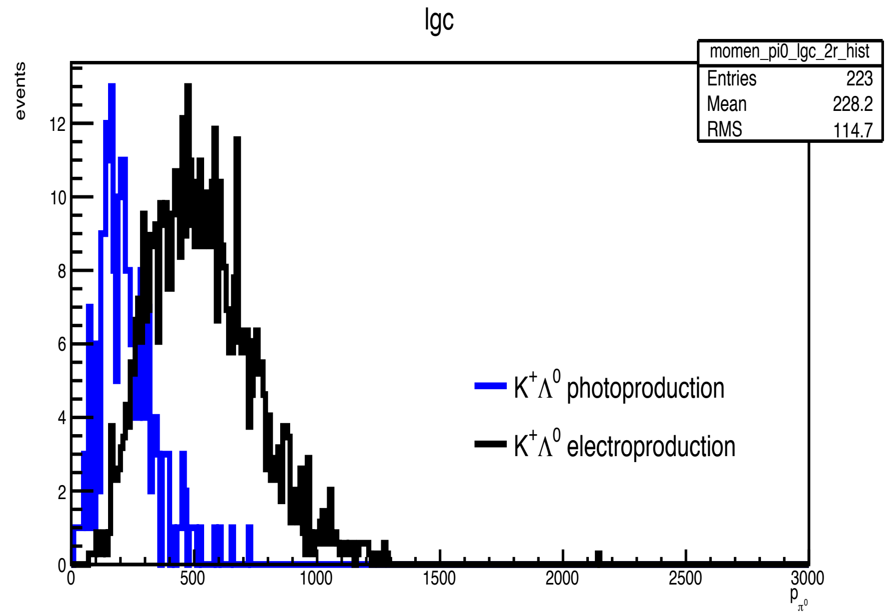
$Er = (W^2 - m_p^2)/2m_p$

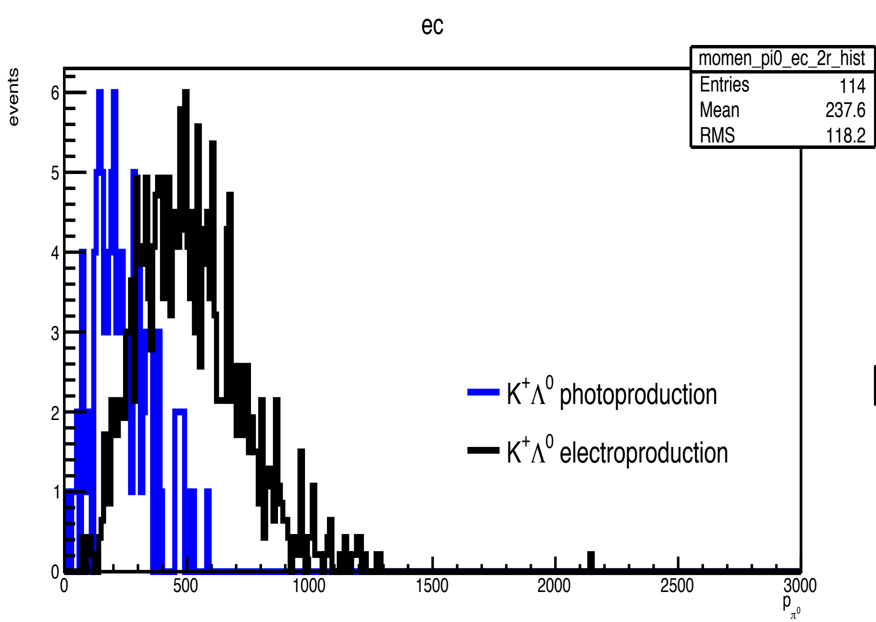
Hall B Hyperon event generator (EG): electroproduction

virtual photon energy $E\gamma^* = E_e - E_e'$

π^0 Momentum Distribution in the Lab Frame







RPR-2011 version: photoproduction

Hall B Hyperon event generator (EG): electroproduction

$K^+\Lambda^0$ Rate Comparison

Bremsstrahlung photoproduction

(MHz)	Rate	Trigger rate PMT>=2; Nphe>=2
Gem (3)	$\overset{\gamma}{0.1896}+\overset{e^-}{0.0207}+\overset{e^+}{0.0107}=0.22$	
Lgc	$0.1893+0.0205+0.0112=0.22$	4.69×10^{-3}
Ecal	$0.1084+0.0057+0.0033=0.12$	

Electroproduction

(MHz)	Rate	Trigger rate
Gem (3)	8.02×10^{-4}	
Lgc	8.08×10^{-4}	1.24×10^{-5}
Ecal	4.45×10^{-4}	

$$\text{Rate} = \frac{\int \mathcal{L}\frac{d\sigma}{d\Omega}d\Omega}{N_{total}^{gen}N_{file}}\ ,\ \mathcal{L} = \frac{50\times10^{-6}\times40\times0.169\times6.02\times10^{23}}{1.6\times10^{-19}\ \times2.014\ cm^2 s}$$

comparison

(MHz)	Rate	Trigger rate
Gem (3)	0.1896+0.0207+0.0107=0.22	
Lgc	0.1893+0.0205+0.0112=0.22	$4.69\text{x}10^{-3}$
Ecal	0.1084+0.0057+0.0033=0.12	

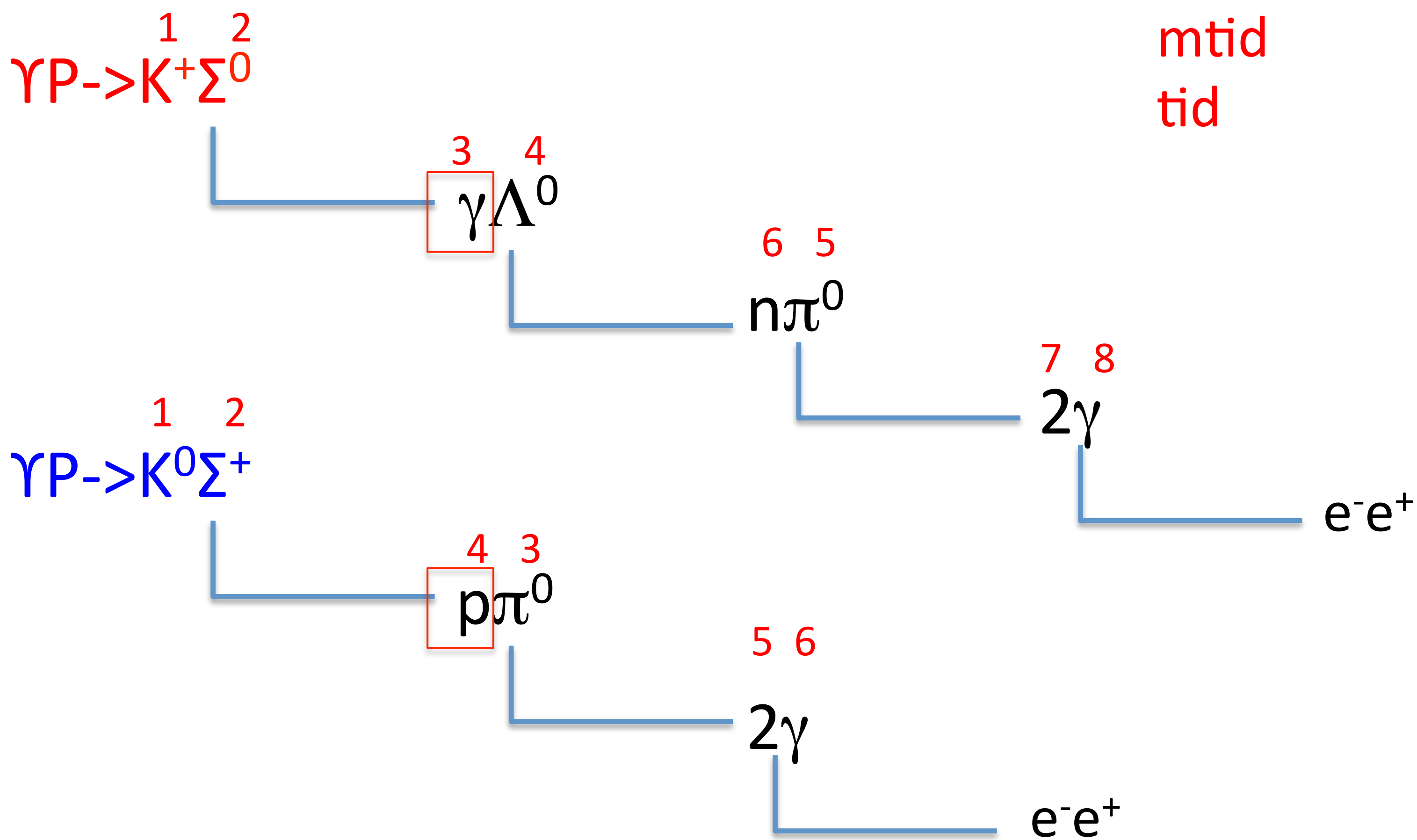
PVDIS ECAL Trigger Rates

- Only 1 GeV or larger momentum tracks can initiate a trigger
- Low energy (less than 1 GeV) tracks contribute to trigger as pile up to high momentum tracks by increasing energy deposit in trigger windows
  - When only background tracks < 1 *GeV* incident on ECAL the total trigger rate is about 0.06 MHz (or 0.002 MHz per sector)
  - Only 2 out of 35070 windows triggered by low momentum pile up at higher radii (very low statistics)
  - Low momentum pions at higher radii are very rare
- Total (background+DIS) trigger rate is 5.1 MHz (or 0.17 MHz per sector)
- From Wiser based backgrounds : Total (background+DIS) trigger rate is 8.7 MHz (or 0.29 MHz per sector)
  - This includes 3.1 MHz background trigger due to pileups from tracks < 1 *GeV*

PID	Total Rate (MHz)	Trigger Rate (MHz)
π^-	280	4.5
π^+	150	0.3
DIS	0.44	0.26
Total ECAL Trigger		5.127

Part II

Other Hyperon Production Channel Study



RPR-2007 version: ϒP->K$^+$Σ^0 and ϒP->K^{0}Σ$^+$

RPR-2011 version: ϒP->K$^+$Λ^0

comparison

$\Upsilon P \rightarrow K^+\Sigma^0$

(MHz)	Rate	Trigger rate
Gem (3)	0.292	
lgc	0.292	6.11×10^{-3}
ec	0.141	

$\Upsilon P \rightarrow K^0\Sigma^+$

(MHz)	Rate	Trigger rate
Gem (3)	0.077	
lgc	0.077	1.289×10^{-3}
ec	0.026	

Summary

(MHz)	ϒP->$K^+\Sigma^0$	ϒP->$K^+\Lambda^0$	ϒP->$K^0\Sigma^+$
lgc Trigger rate	6.11×10^{-3}	4.69×10^{-3}	1.289×10^{-3}

Based on your note: Hyperon Production and Asymmetries

9 Decay of the Σ^0

The Σ^0 decays to the Λ via a M1 transition [3]. According to Ref [4], the P_z of the Λ is -1/3 of the P_z of the parent Σ^0. Since the Σ^0 has the same production asymmetry near threshold, then the direct Λ and the Λ's from Σ^0 decay have opposite polarization directions and there is cancellation. The Σ^+ has the same sigh production asymmetry but the opposite analyzing power for π^0 decay, so this reduces the asymmetry.

The asymmetry in the background is determined by decay asymmetry parameters a^0 and by the $\cos\theta$ of the decay π^0

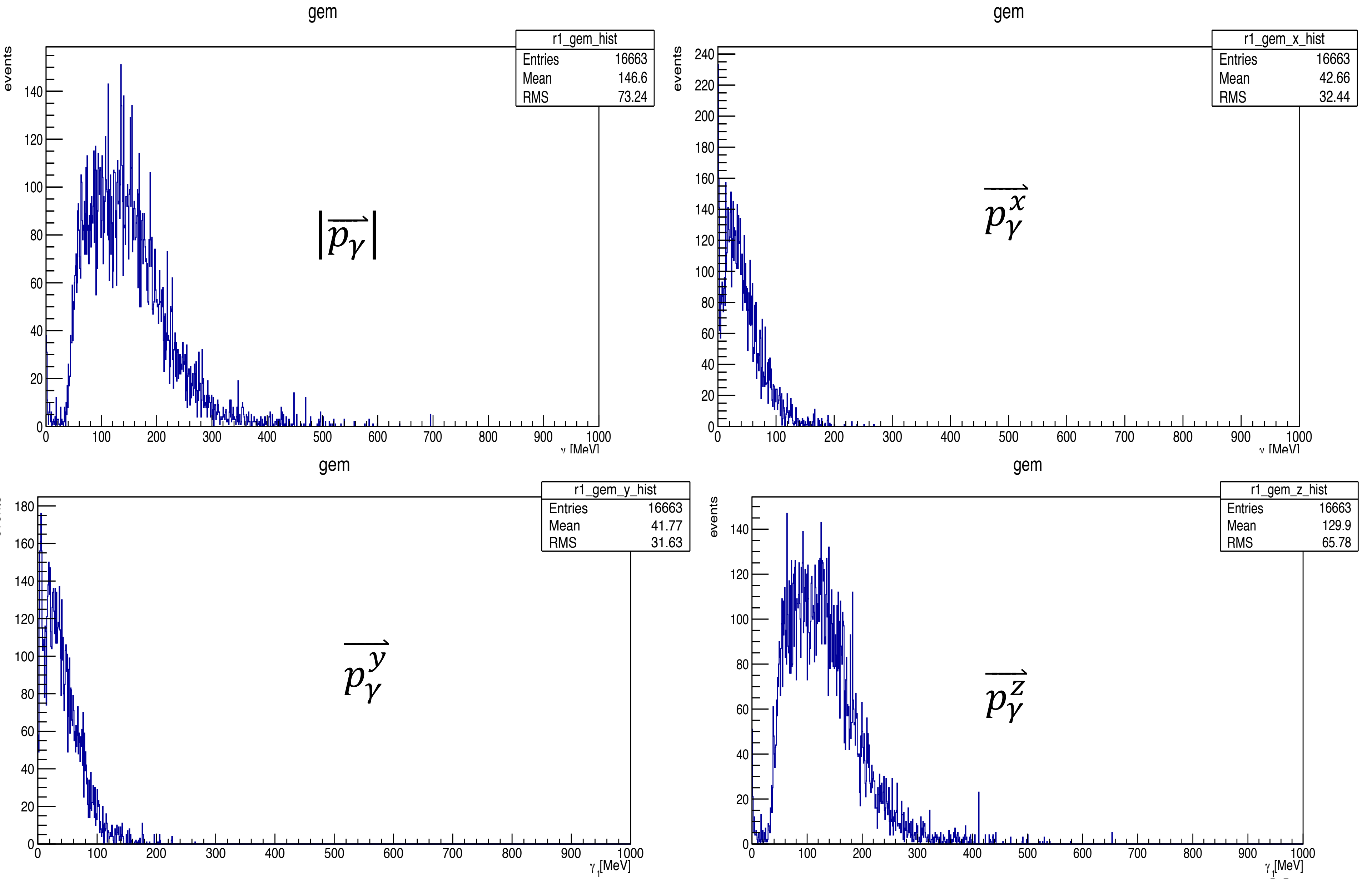
Hyperon	Mass	$c\tau$	F_0	a^0	p_0	$a^{\pm}$	$p_{\pm}$
Λ	1115.6	8 cm	0.357	0.65	101	0.64	104
Σ^+	1189.4	2.4 cm	0.515	-0.98	189	0.068	185
Σ^0	1192.5	$\to \gamma\Lambda$					
Σ^-	1197.4	4.4 cm	0	-	-	-0.068	193
Δ	11232	0	0	-	227	-	227

Need the $\cos\theta_\pi$ information to study the cancellation effect.

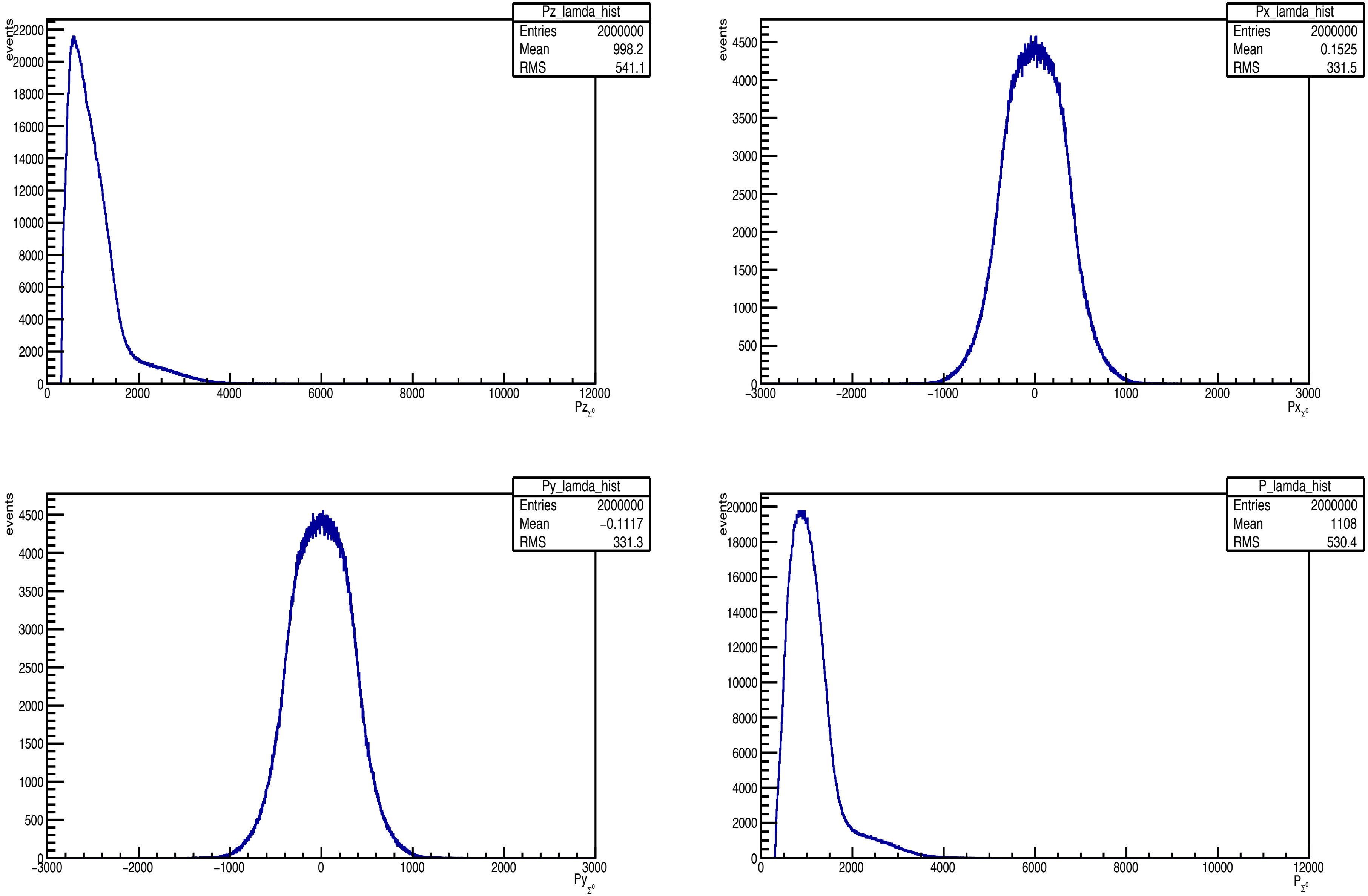
Any comments and suggestions ?

Backup

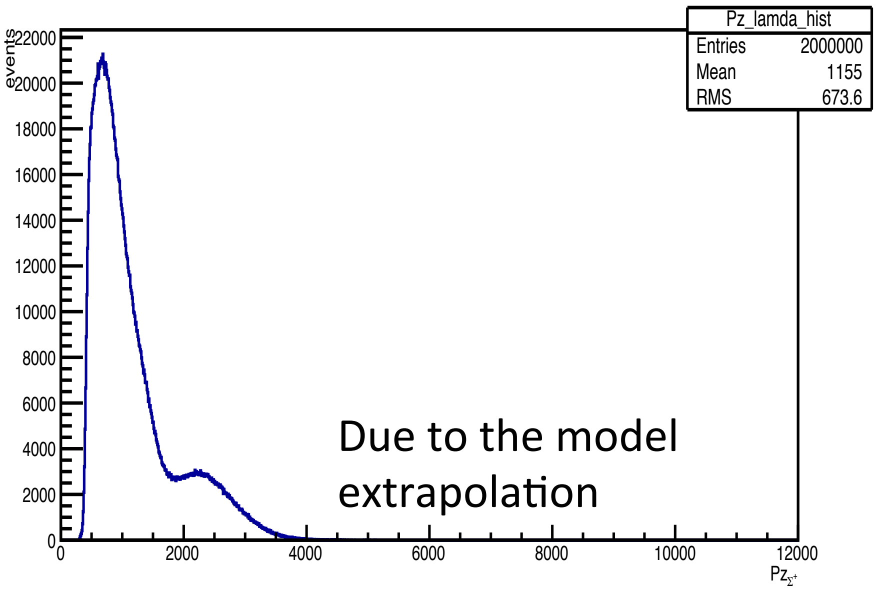
γ_1 Momentum for $\Lambda 0$ production

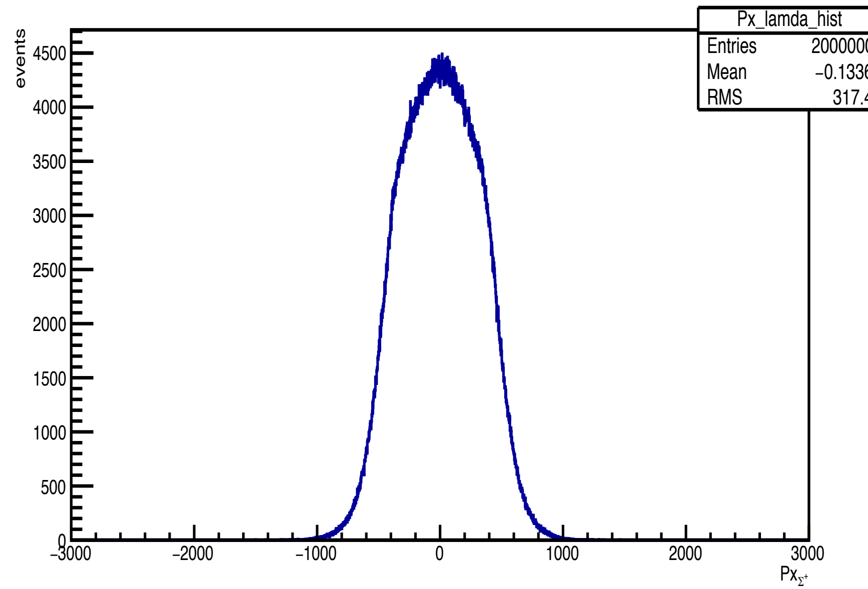


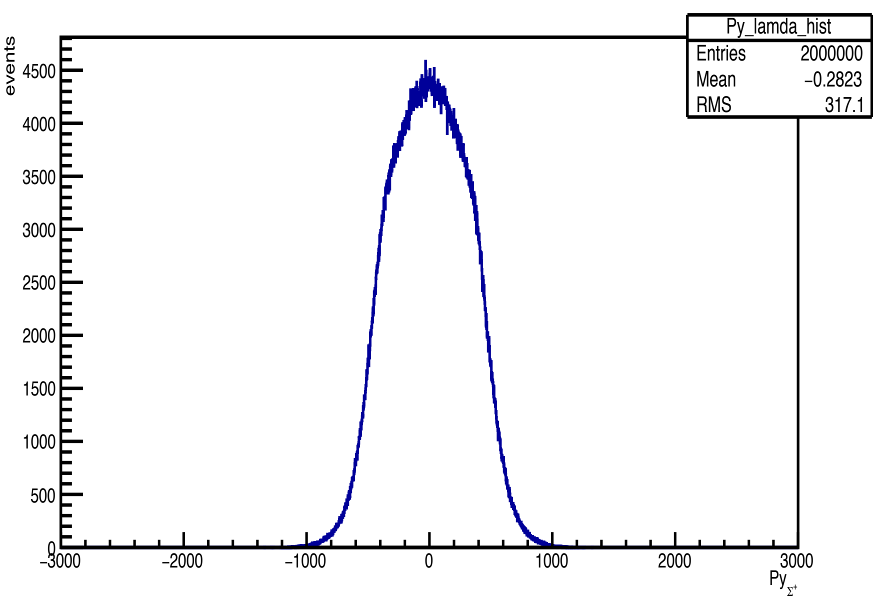
The Generated Σ^0 Momentum Distributions

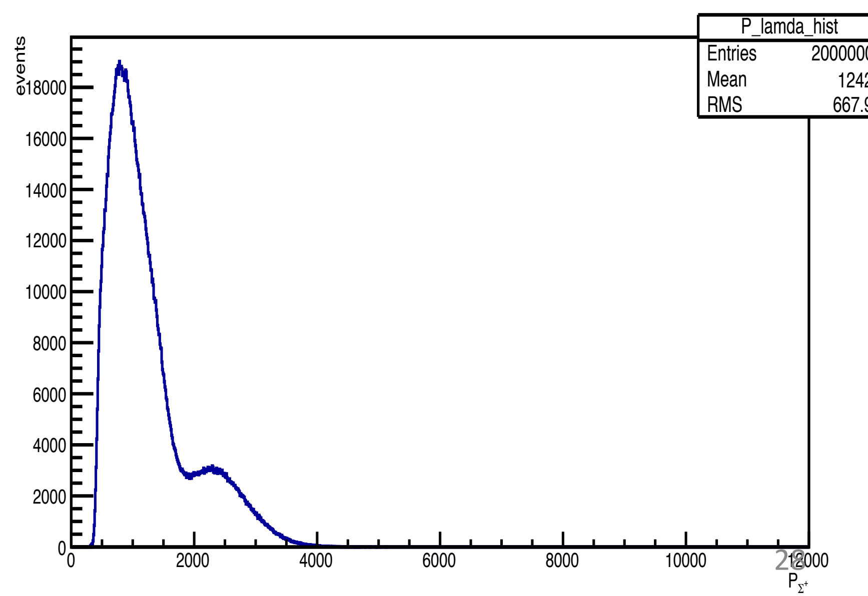


The Generated Σ^+ Momentum Distributions









2ϒ event rate per sector

$K^+\Lambda^0 \rightarrow \pi^0 n \rightarrow \boxed{2\Upsilon}$	**Rate (MHz)** mtid=5 and 6	**Trigger rate (MHz)** PMT>=2; Nphe>=2
Gem (3)	0.1896	
lgc	0.1893	$3.946\text{x}10^{-4}$
ec	0.1084	0

$$\text{Rate} = \frac{\int \mathcal{L}\frac{d\sigma}{d\Omega}d\Omega}{N_{total}^{gen} N_{file}} \; , \; \mathcal{L} = \frac{50\times10^{-6}\times40\times0.169\times6.02\times10^{23}}{1.6\times10^{-19}\times2.014\ cm^2 s}$$

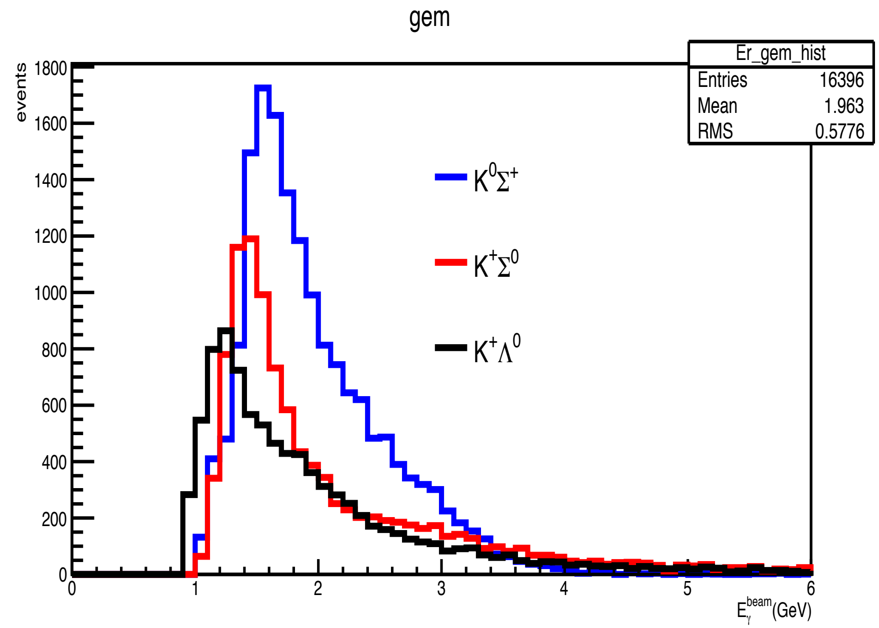
e^- event rate per sector

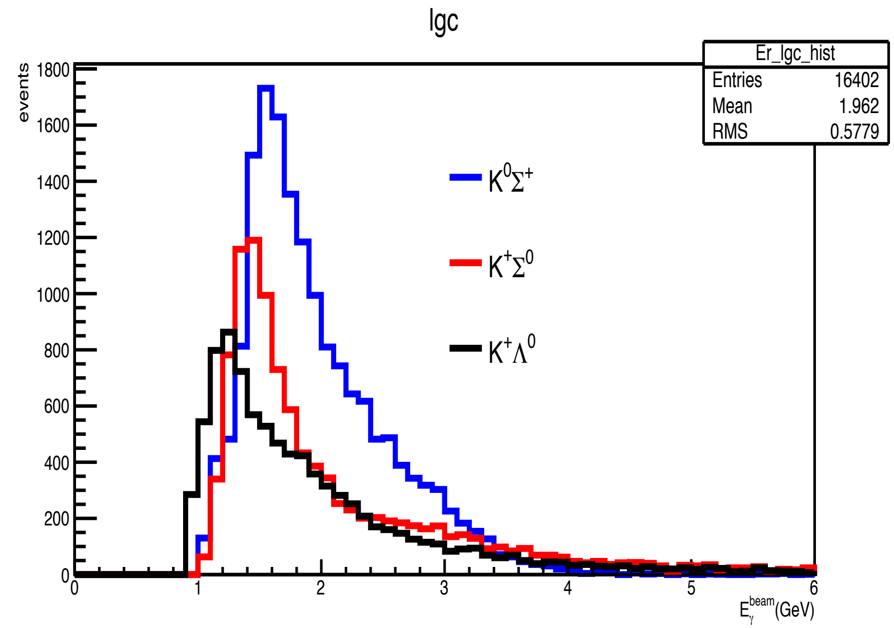
$K^+\Lambda^0$ → $\pi^0 n$ → 2Υ → e^-e^+	**Rate (MHz)** mtid=5/6	**Trigger rate (MHz)**
Gem (3)	0.0207	
lgc	0.0205	2.420×10^{-3}
ec	0.00567	0

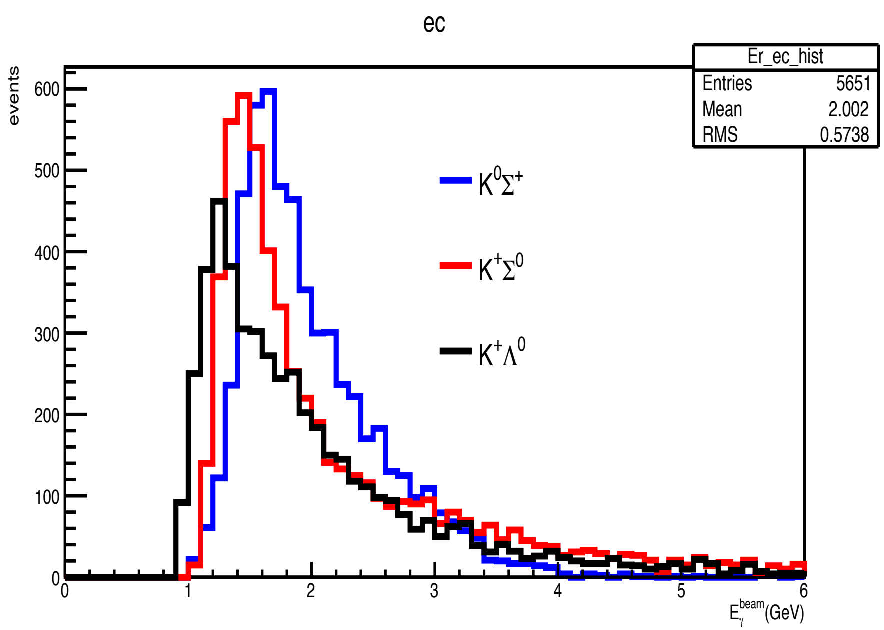
e^+ event rate per sector

$K^+\Lambda^0$ → $\pi^0 n$ → 2Υ → e^-e^+	Rate (MHz) mtid=5/6	Trigger rate (MHz)
Gem (3)	0.01073	
lgc	0.01116	$1.877\text{x}10^{-3}$
ec	0.003313	0 (trigger for p>1GeV)

Bremsstrahlung Photon Energy







PVDIS acceptance

Cross section weighted

RPR-2007 version: $\Upsilon P\text{->}K^+\Sigma^0$ and $\Upsilon P\text{->}K^0\Sigma^+$

RPR-2011 version: $\Upsilon P\text{->}K^+\Lambda^0$