

Hadron Generator Comparison

Ye Tian

GENT4

1mm and 40 cm LH target, vacuum

- STD: EM standard.
- [QGSP_BERT_HP](#)
- ✓ The physics list most recommended for [HEP](#)
- ✓ Used by [ATLAS](#)
- ✓ Contains standard EM processs
- ✓ Uses [Bertini cascade](#) for hadrons of energy below $\sim 10\text{GeV}$
- ✓ Uses [QGC](#) model for high energies ($> 20\text{GeV}$)
- ✓ [Used for neutrons below 20MeV](#) (with high precision neutron model)
- ✓ Can be used for radiation protection and shielding applications.

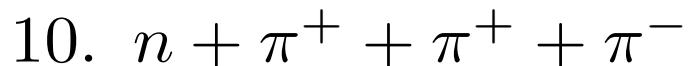
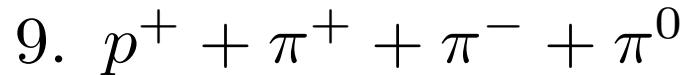
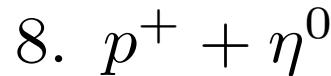
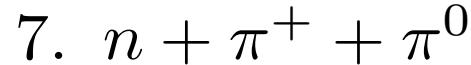
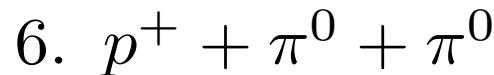
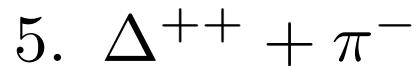
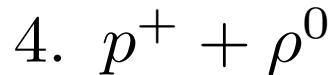
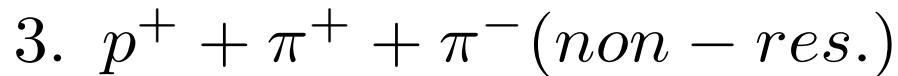
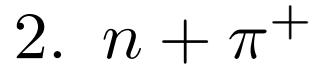
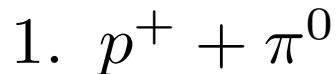
Hadron Generator

1mm and 40cmm LH target

- Hadron Generator ([Bgggen_Version_1.3](#)) modified by Jixie Zhang :
 - E>3 GeV: PYTHIA is used
 - 0.15<E<3 GeV: a mixture of 10 dominating π exclusive processes ($\gamma + p$) is used. For the single pion production differential cross sections, the SAID code is used.
 - Adding Z dependence (loop Z and E_γ).

Hadron Generator

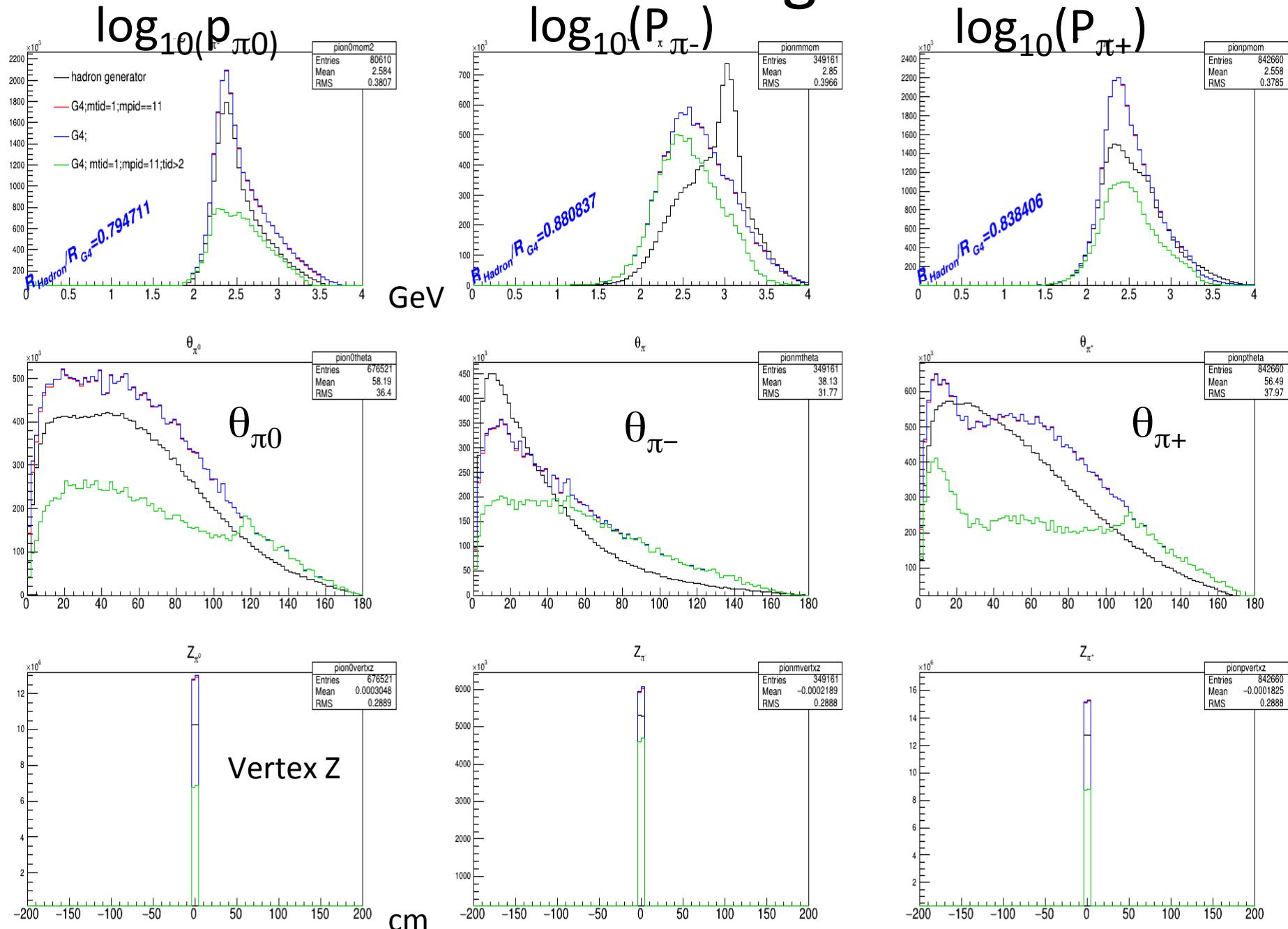
$\gamma + p^+$ reactions



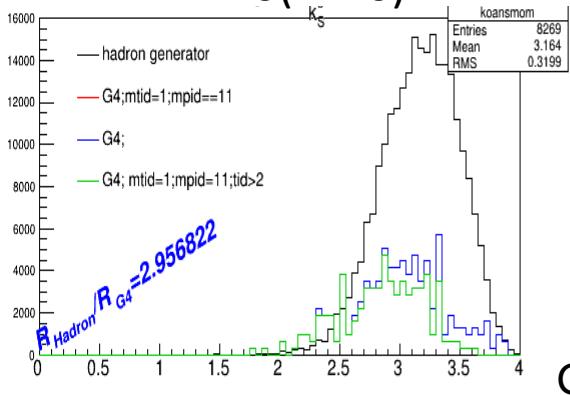
- Rate calculation for A>1: isospin and charge symmetries

$$\sigma_{\pi^-}(A) = \sigma_{\pi^+}(p) * (A - Z) + \sigma_{\pi^-}(p) * Z$$

1mm LH target

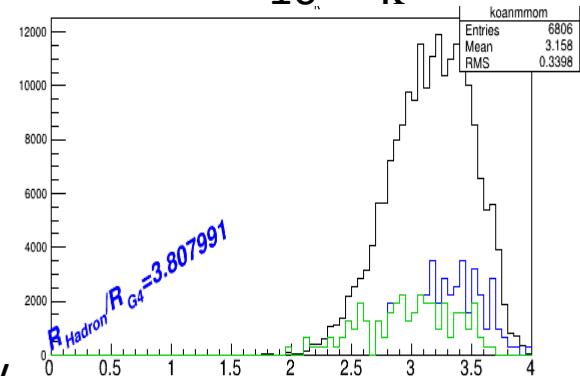


$\log_{10}(p_{kl0})$

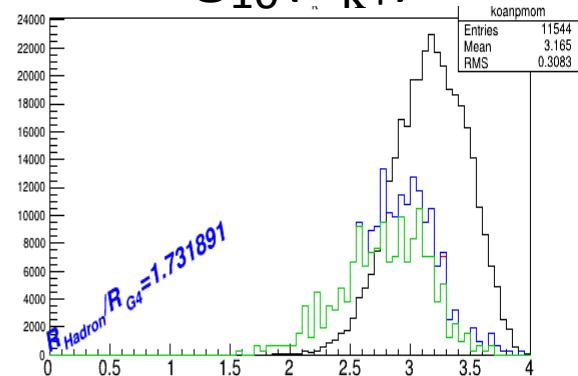


1mm LH target

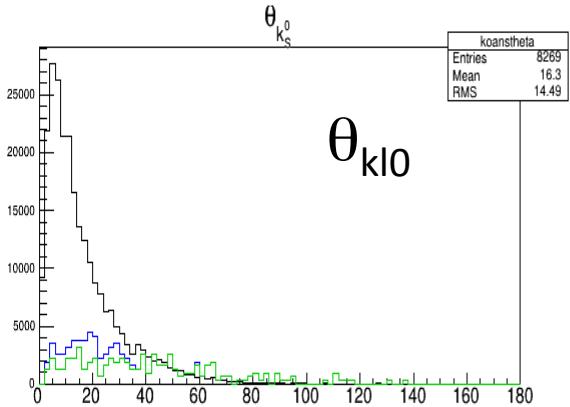
$\log_{10}(P_{K^-})$



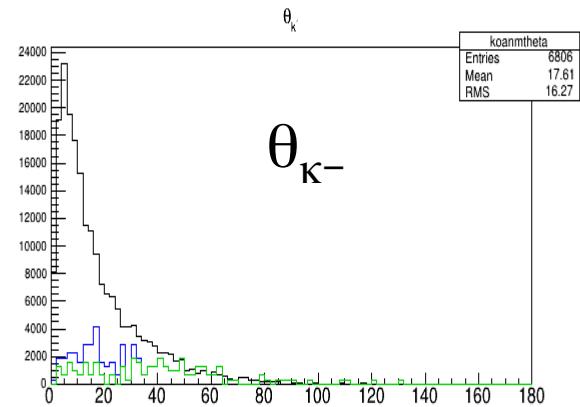
$\log_{10}(P_{K^+})$



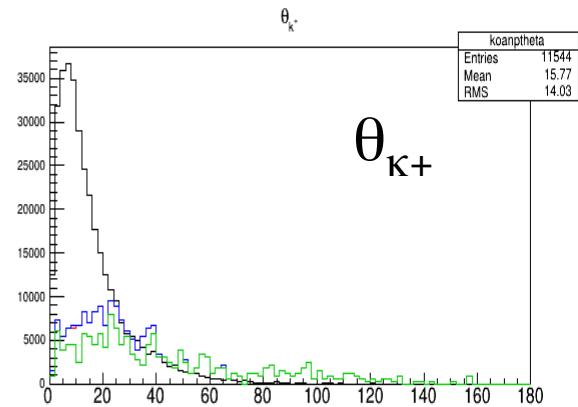
θ_{K^0}



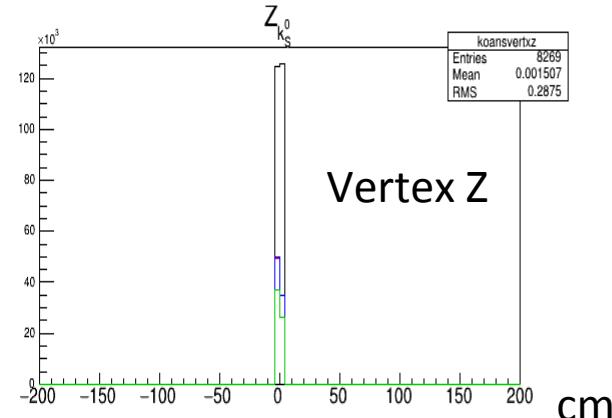
θ_{K^-}



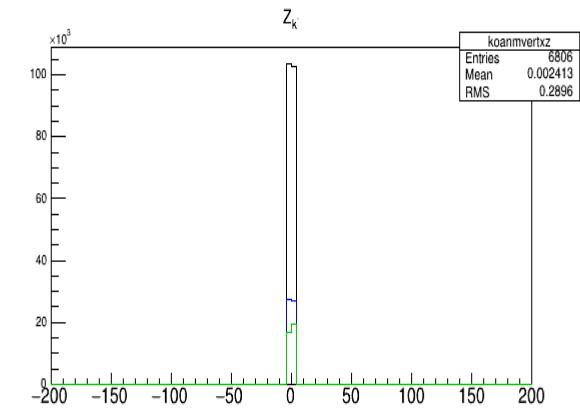
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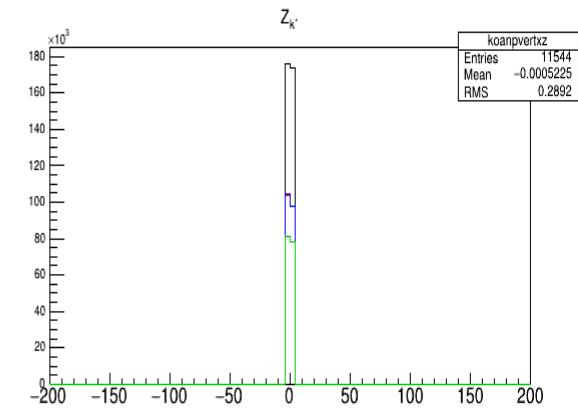
Z_{K^0}



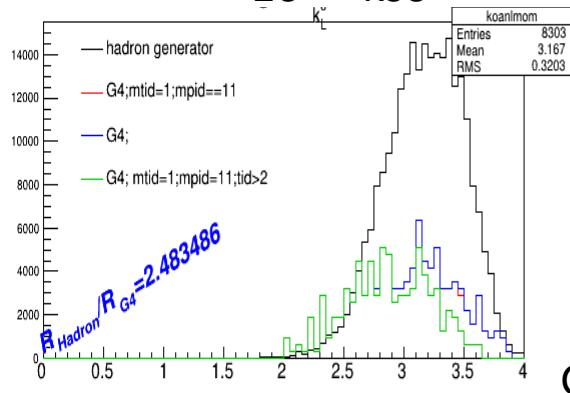
Z_K



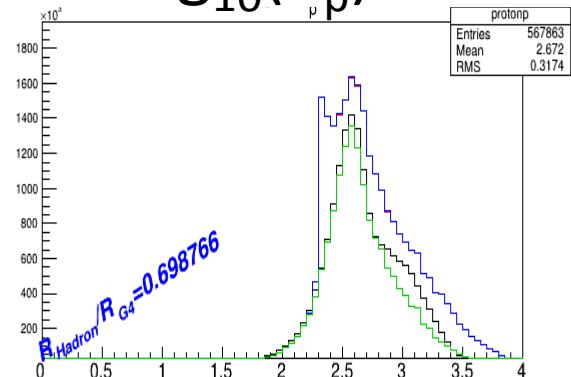
Z_{K^+}



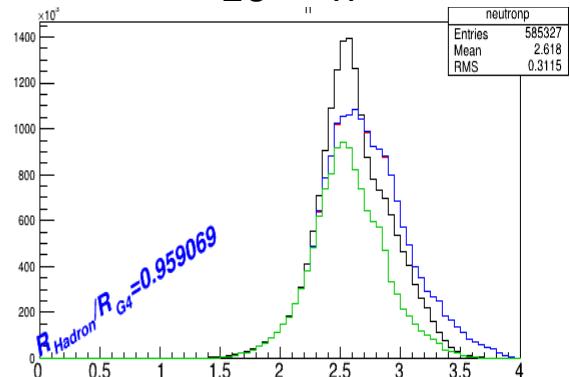
$\log_{10}(P_{ks0})$



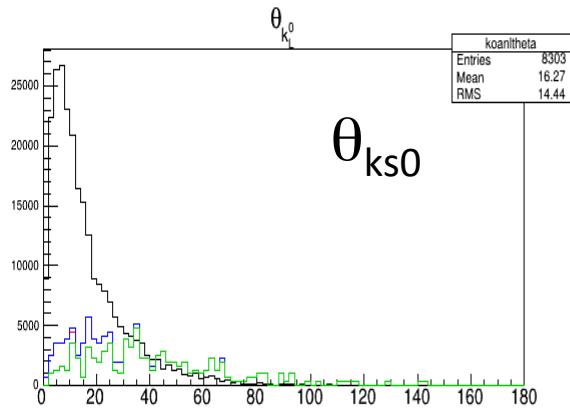
1mm LH target



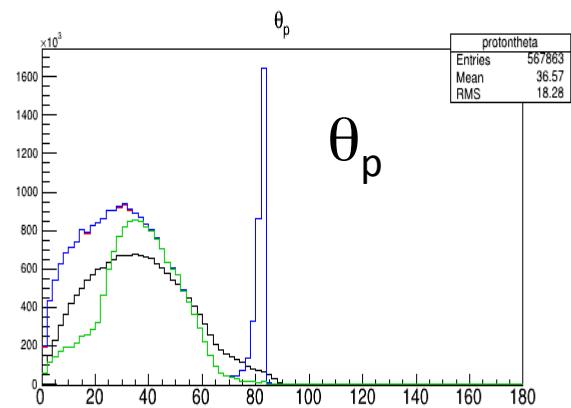
$\log_{10}(P_n)$



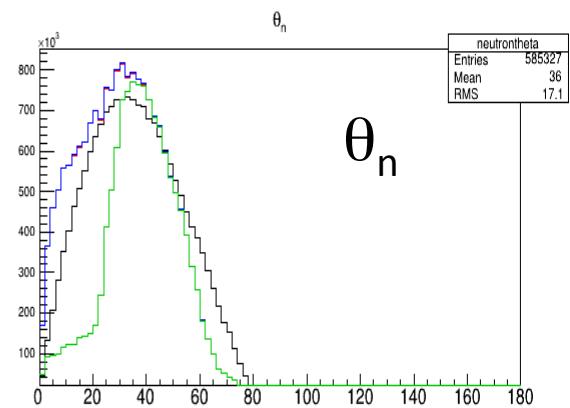
θ_{k_0}



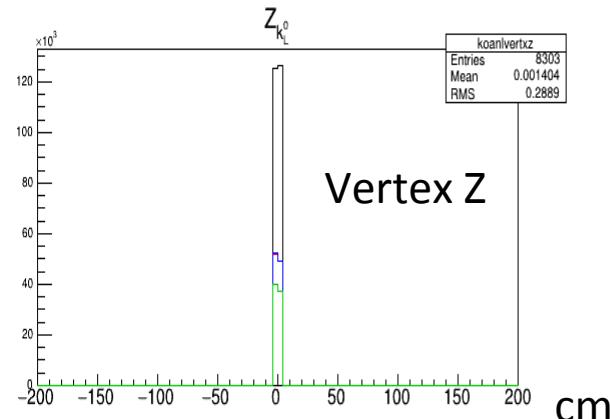
θ_p



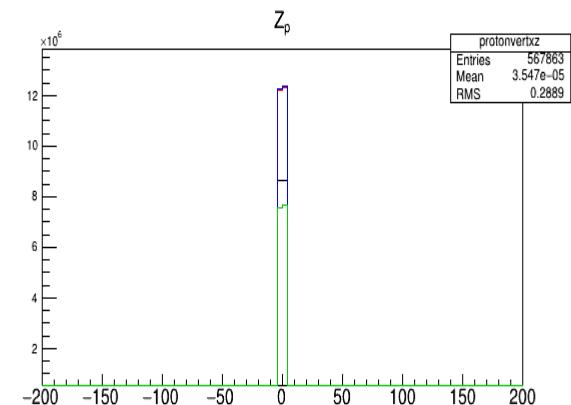
θ_n



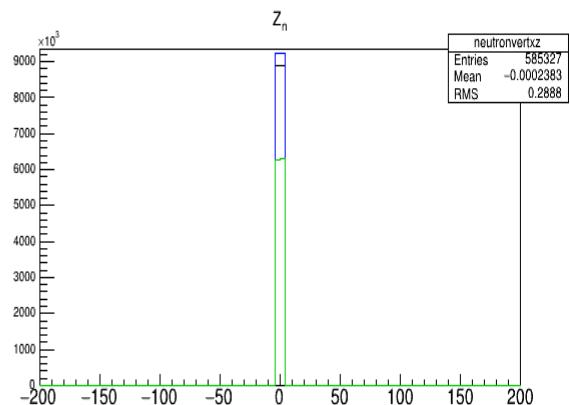
Vertex Z



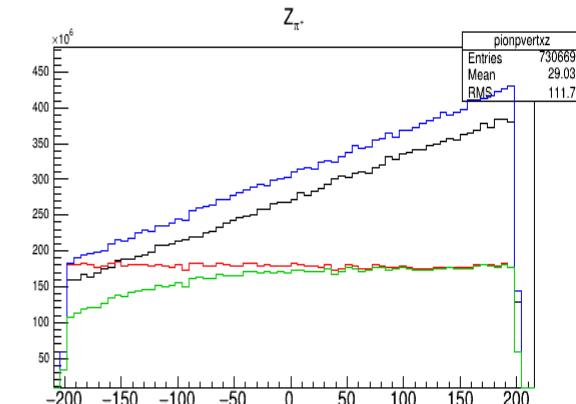
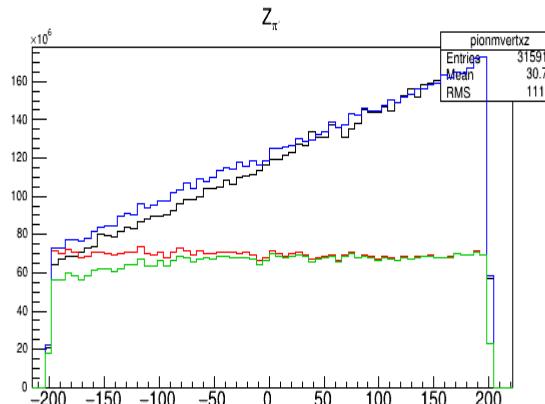
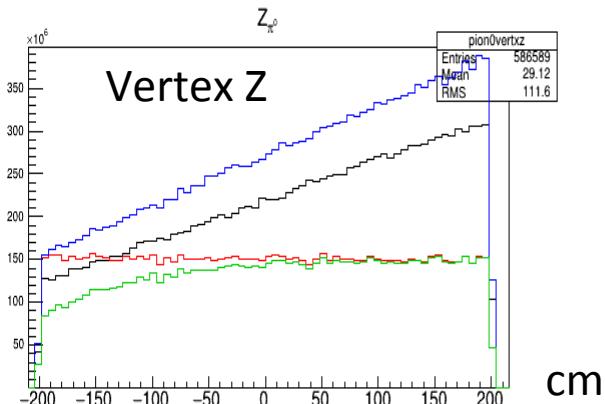
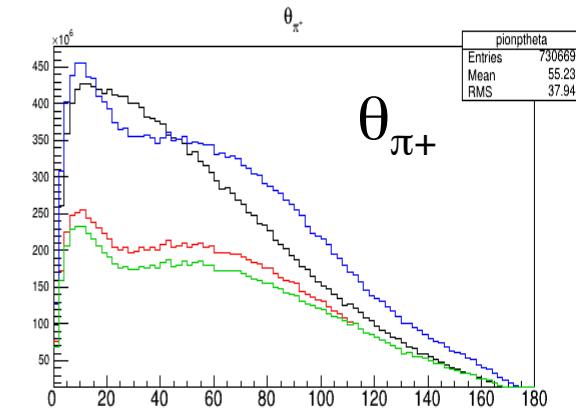
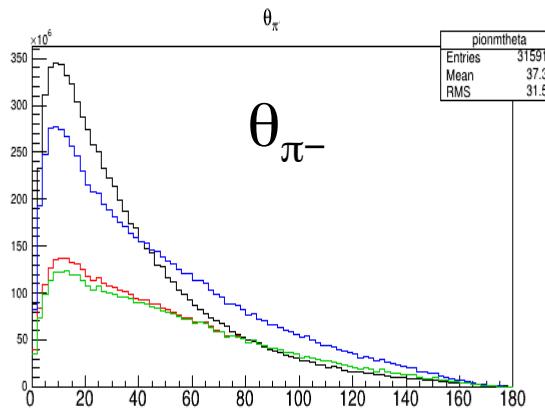
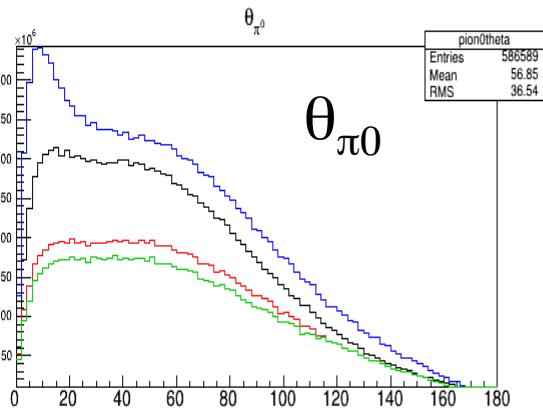
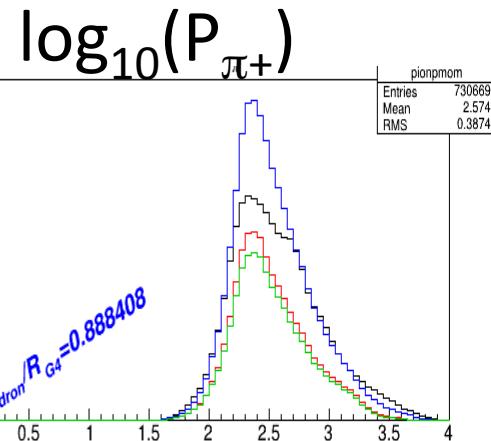
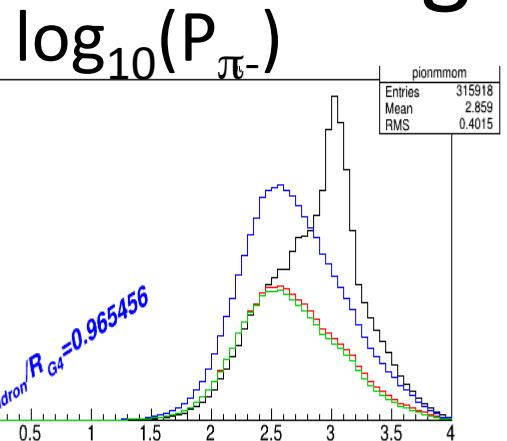
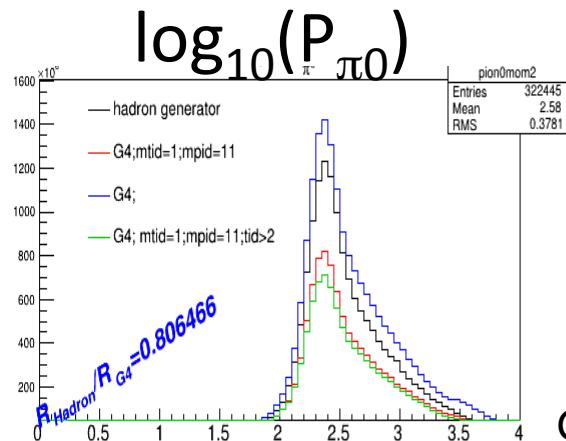
Z_p



Z_n

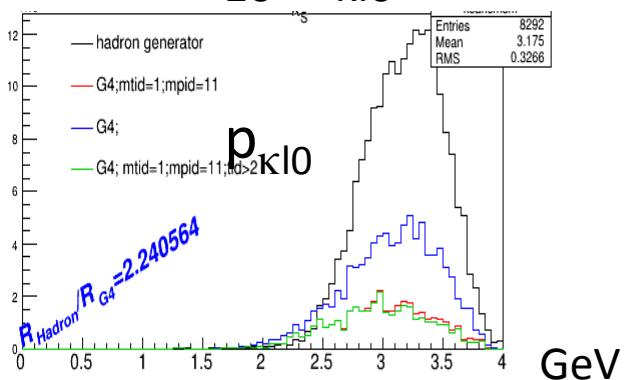


40cm LH target

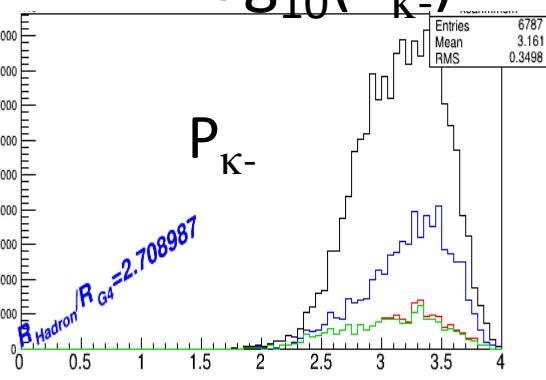


40cm LH target

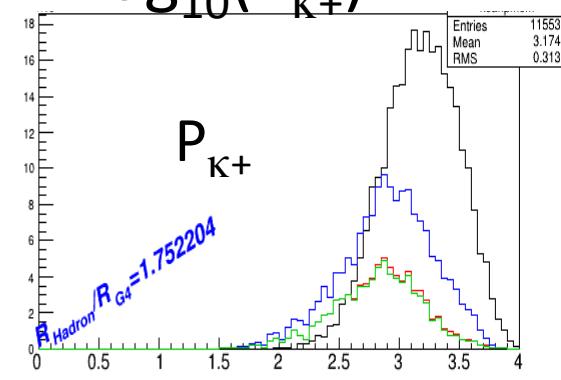
$\log_{10}(P_{\text{k}l0})$



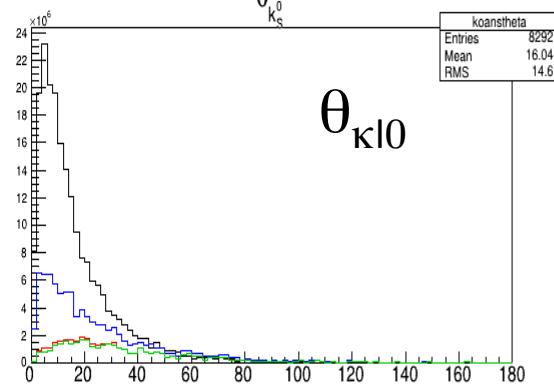
$\log_{10}(P_{\text{k}-})$



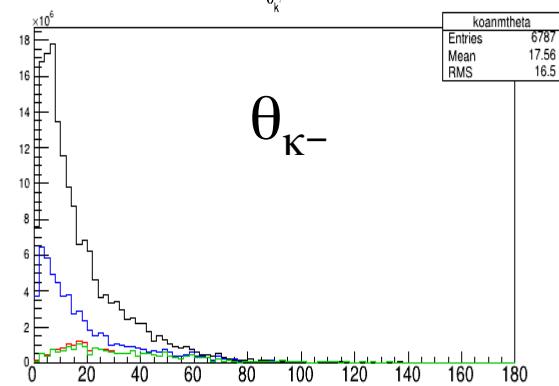
$\log_{10}(P_{\text{k}+})$



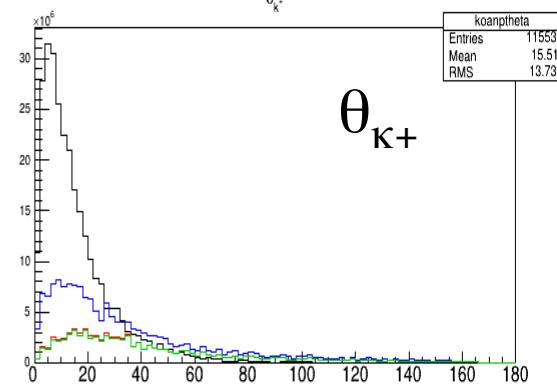
$\theta_{\text{k}_S^0}$



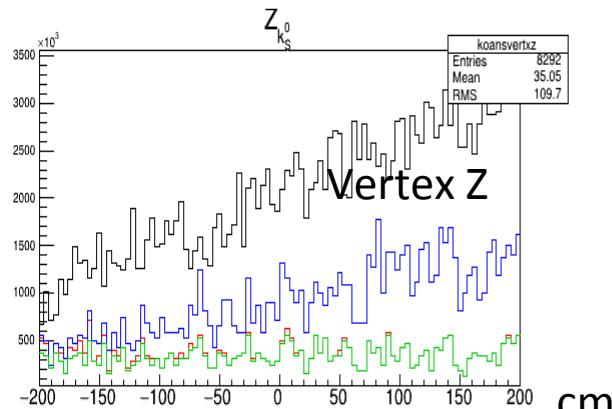
θ_{k}



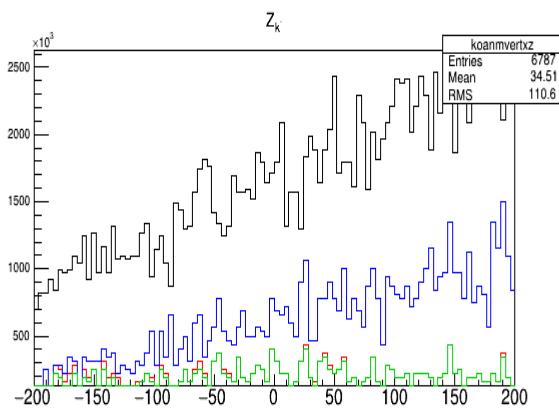
$\theta_{\text{k}+}$



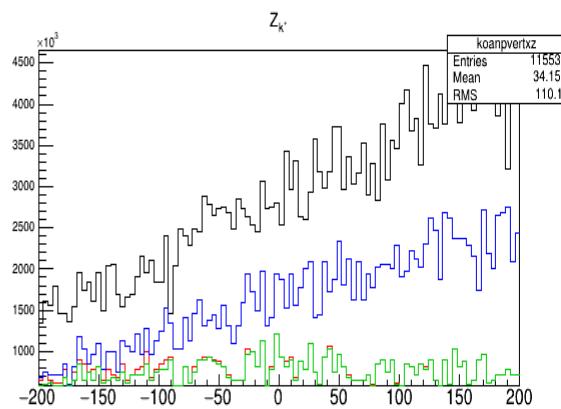
$Z_{\text{k}_S^0}$



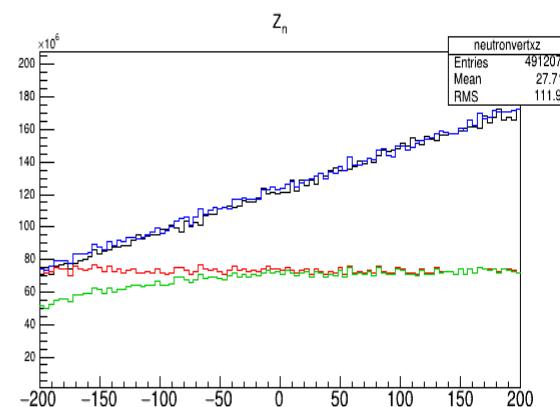
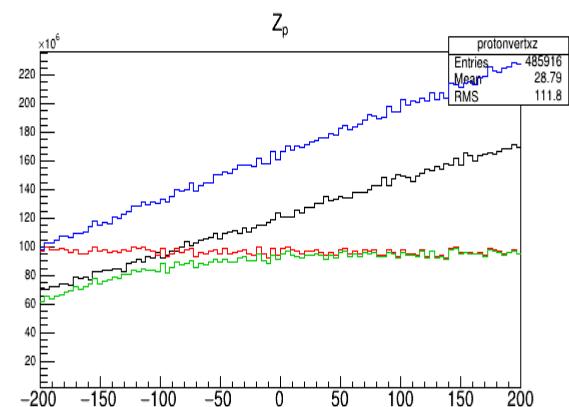
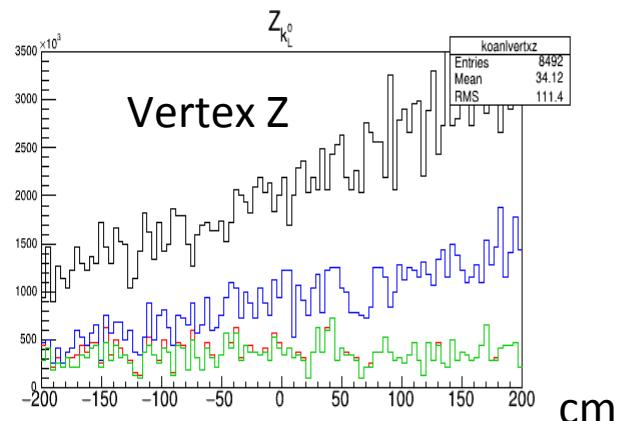
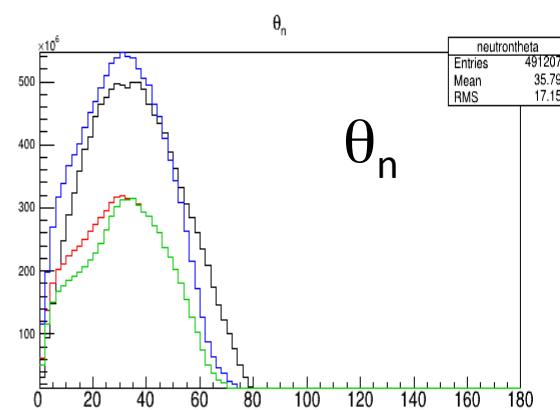
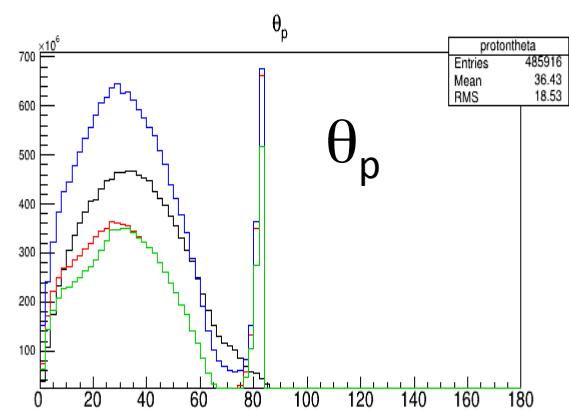
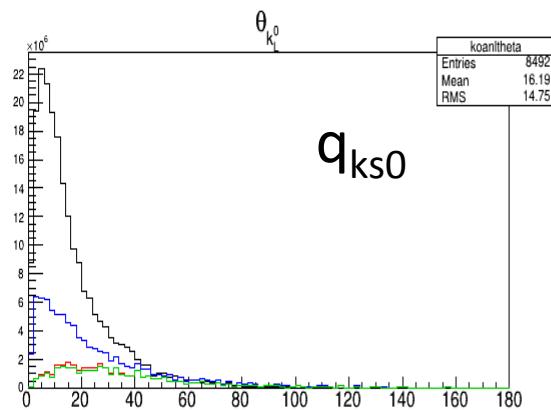
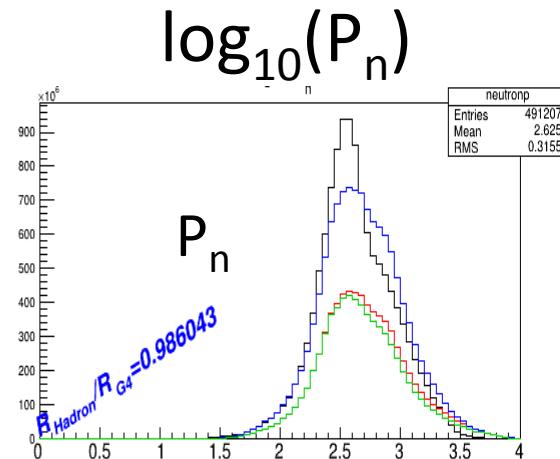
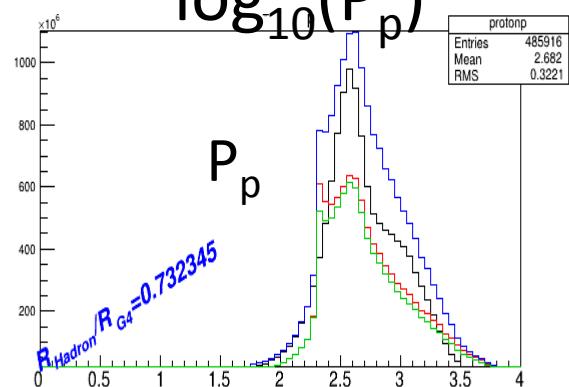
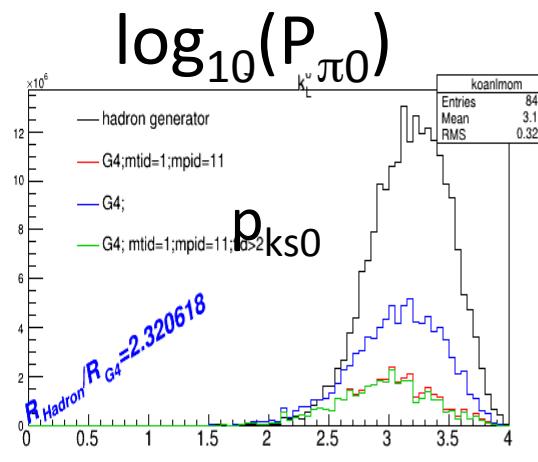
Z_{k}



$Z_{\text{k}+}$



40cm LH target

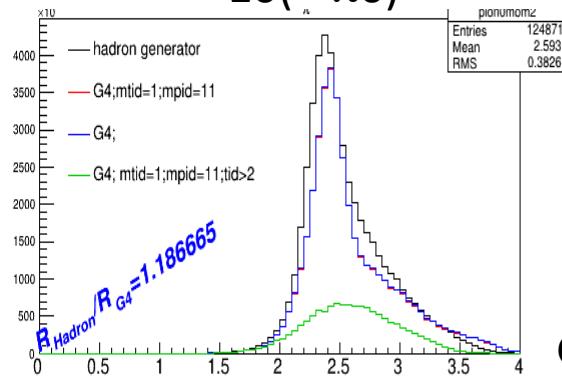


Comparison for LH2 target

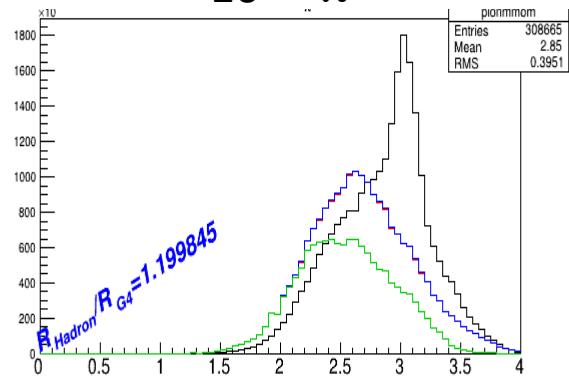
Hadron particles	Ratio (bggen/G4) 1mm target	Ratio (bggen/G4) 40cm target
π^0	0.794	0.806
π^-	0.881	0.965
π^+	0.838	0.888
κ^+	1.732	1.752
κ^-	3.808	2.709
κ^0_L	2.483	2.320
κ^0_s	2.957	2.240
p	0.699	0.732
n	0.960	0.986

1mm LD target

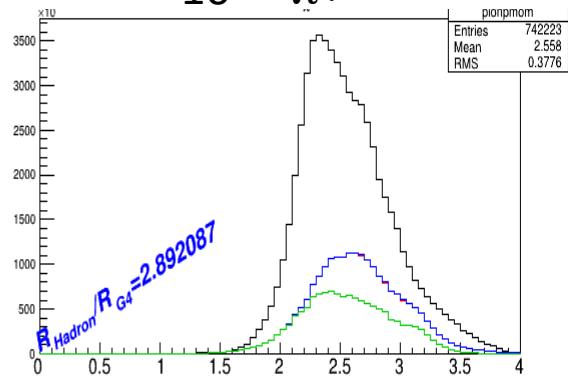
$\log_{10}(p_{\pi^0})$



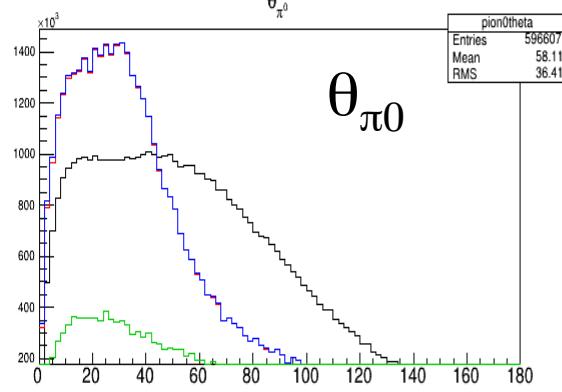
$\log_{10}(P_{\pi^-})$



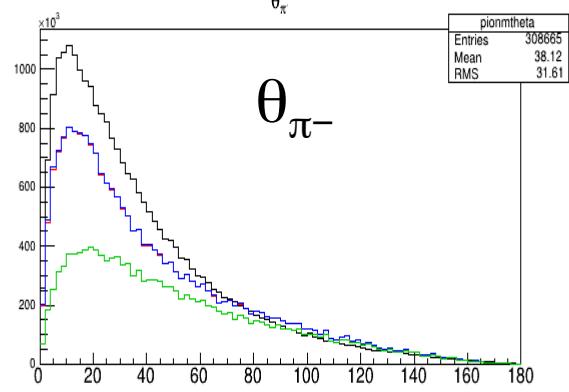
$\log_{10}(P_{\pi^+})$



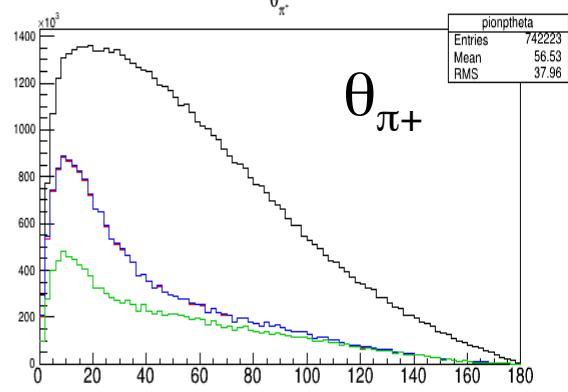
θ_{π^0}



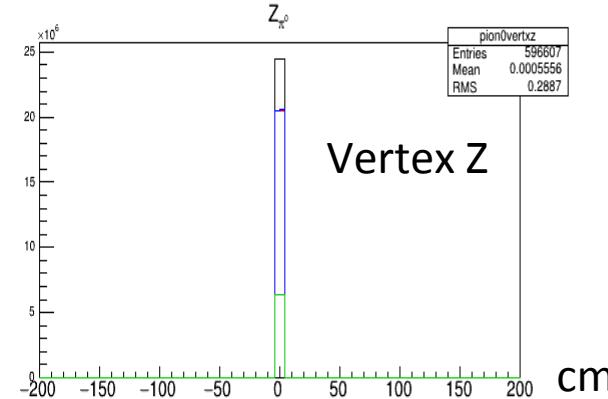
θ_{π^-}



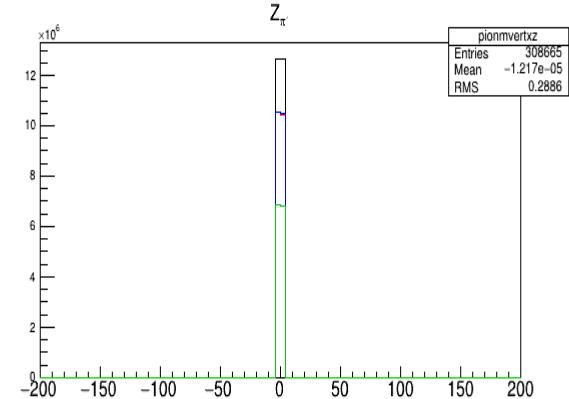
θ_{π^+}



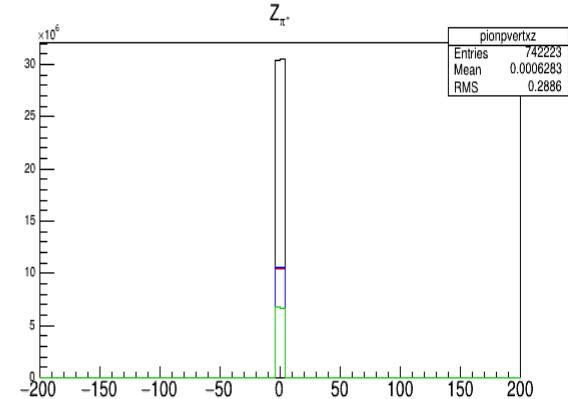
Z_{π^0}



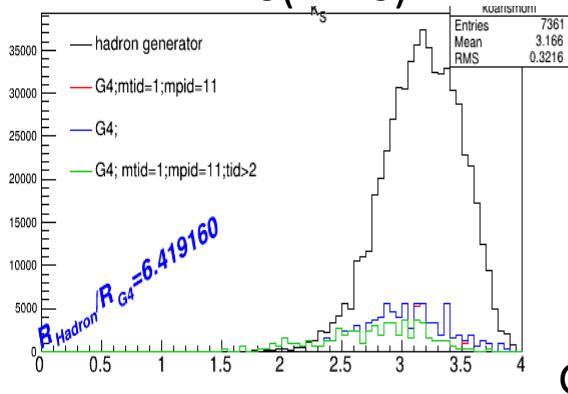
Z_{π^-}



Z_{π^+}

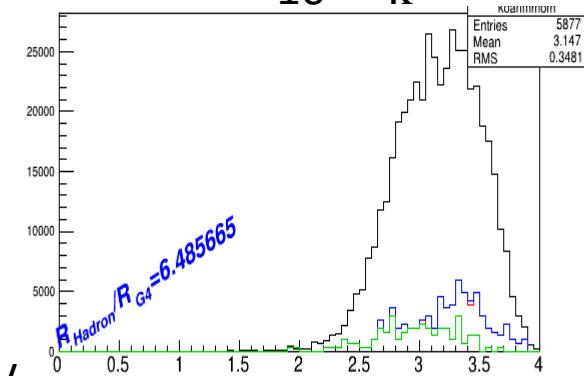


$\log_{10}(p_{kl0})$

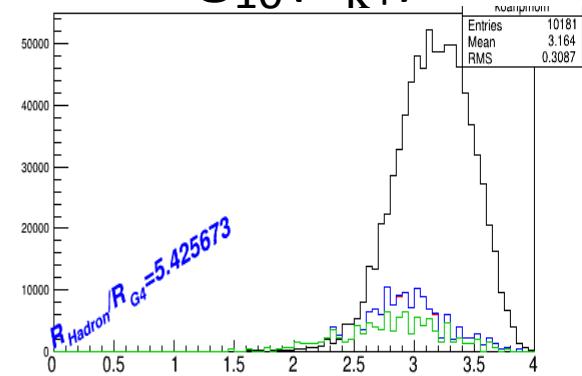
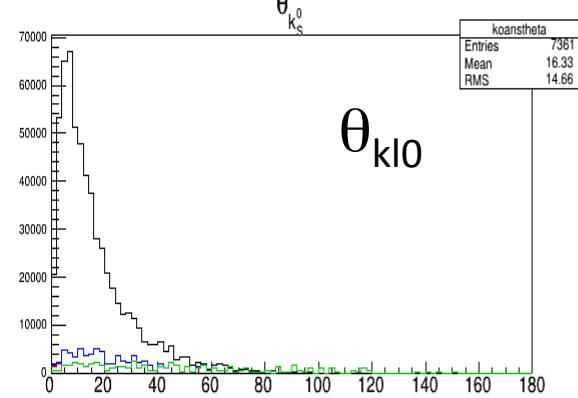
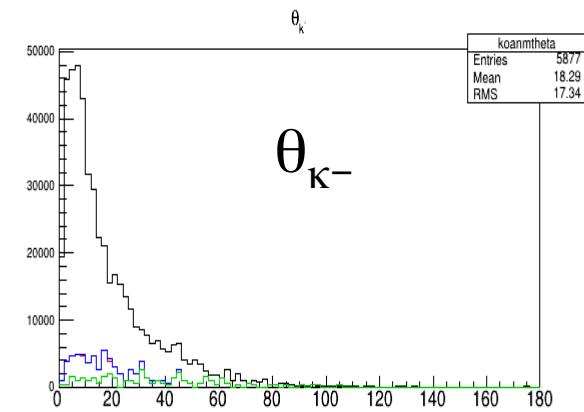
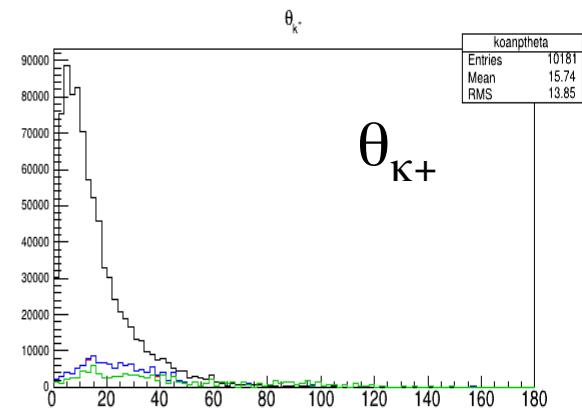


1mm LD target

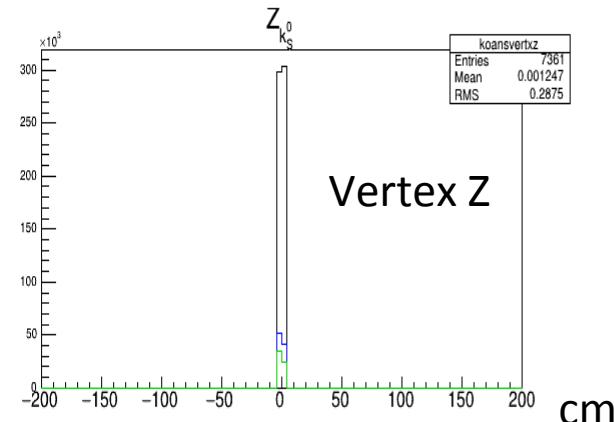
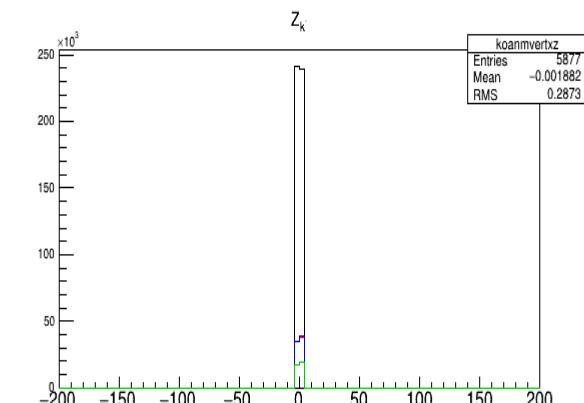
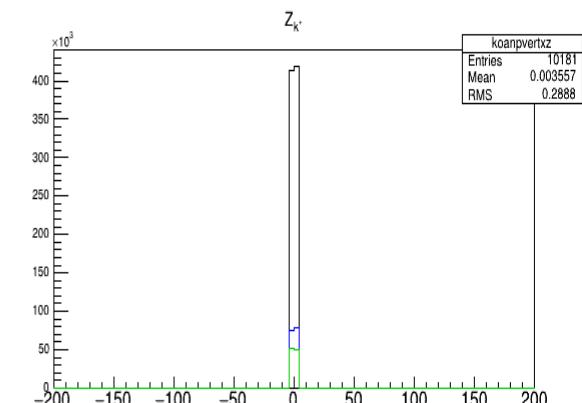
$\log_{10}(P_{K^-})$



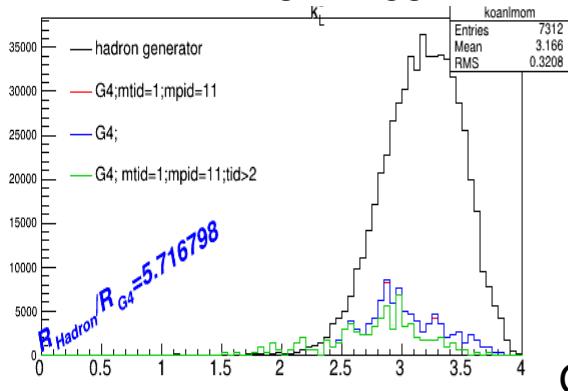
$\log_{10}(P_{K^+})$

 $\theta_{K^0_S}$ θ_{kl0}  θ_K θ_{K^-}  θ_{K^+} θ_{K^+}  $Z_{K^0_S}$

Vertex Z

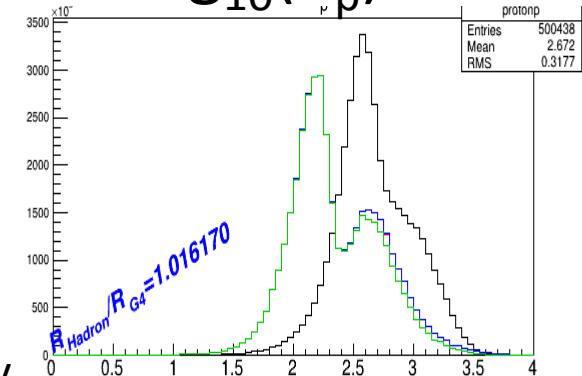
 Z_K  Z_K 

$\log_{10}(P_{ks0})$

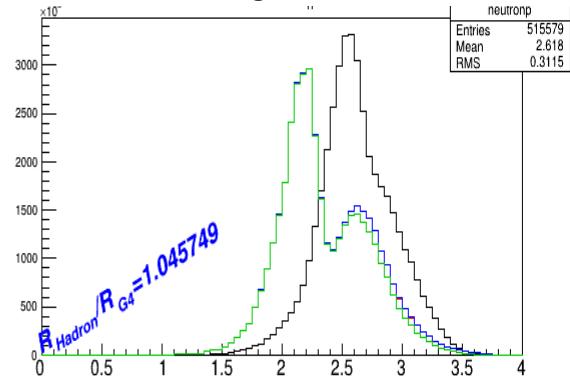


1mm LD target

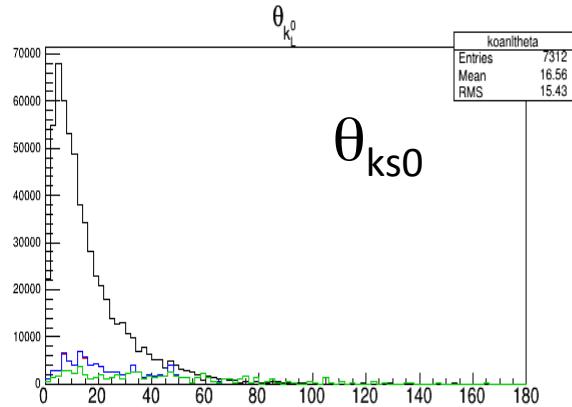
$\log_{10}(P_p)$



$\log_{10}(P_n)$

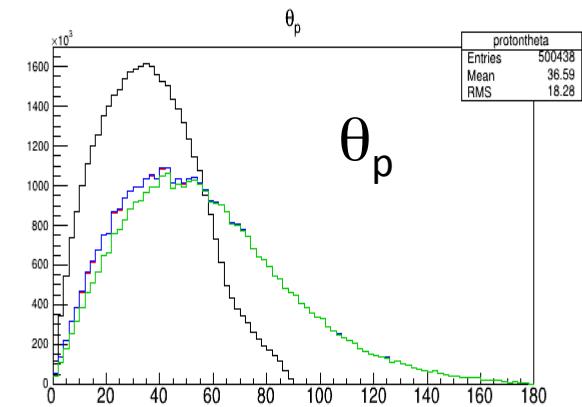


θ_{K^0}

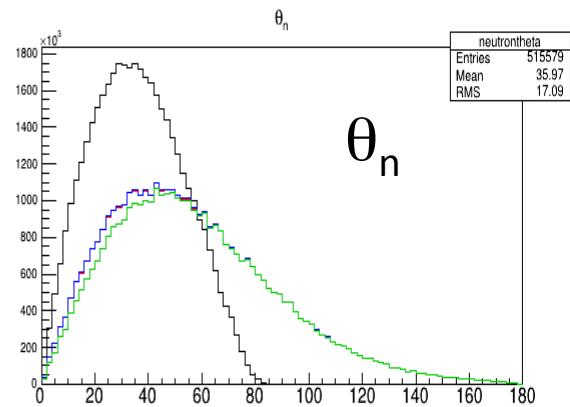


θ_{ks0}

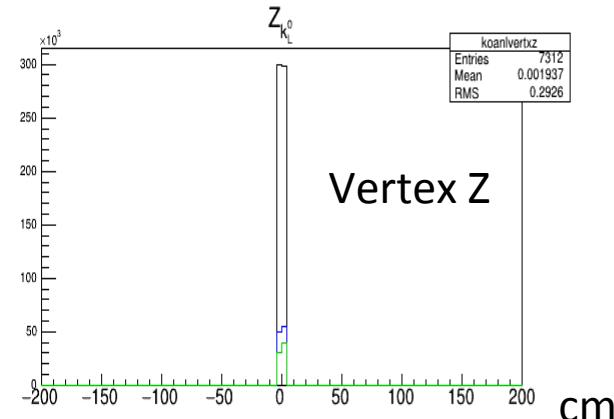
θ_p



θ_n

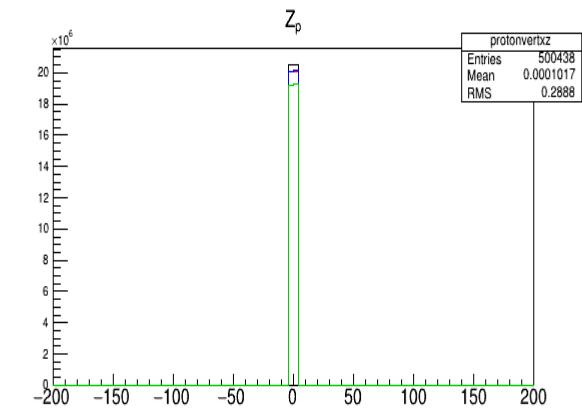


Z_{K^0}

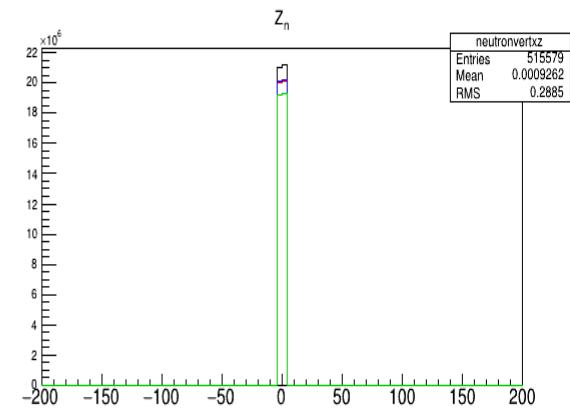


Vertex Z

Z_p

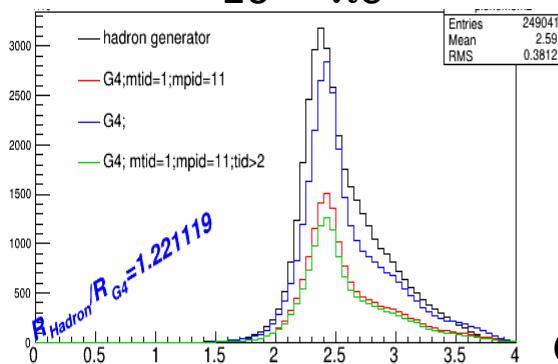


Z_n

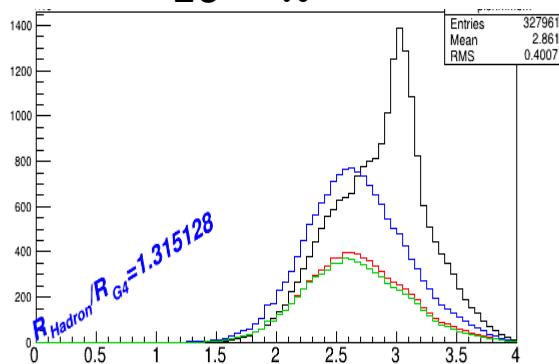


40cm LD target

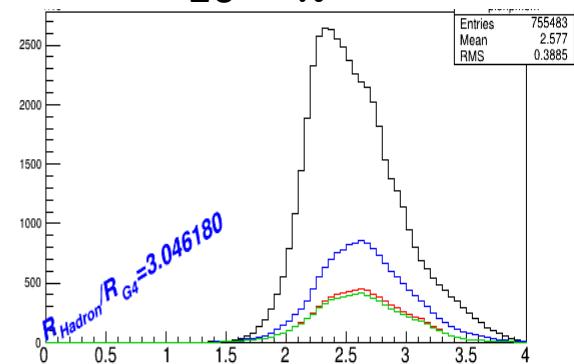
$\log_{10}(P_{\pi^0})$



$\log_{10}(P_{\pi^-})$



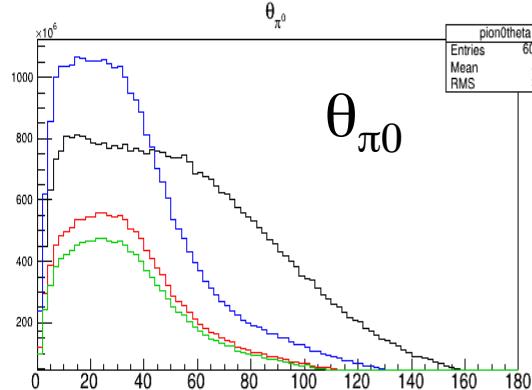
$\log_{10}(P_{\pi^+})$



θ_{π^0}

pion0theta
Entries: 606554
Mean: 56.62
RMS: 36.52

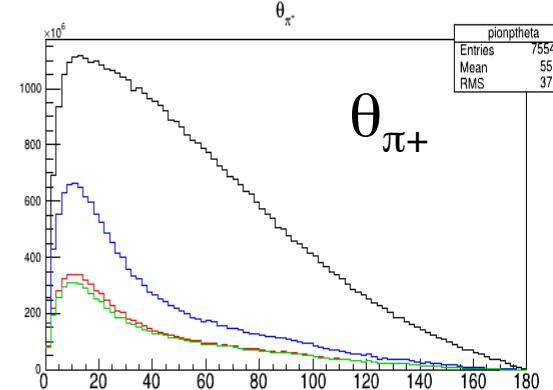
θ_{π^0}



θ_{π^-}

pionmtheta
Entries: 327961
Mean: 37.14
RMS: 31.44

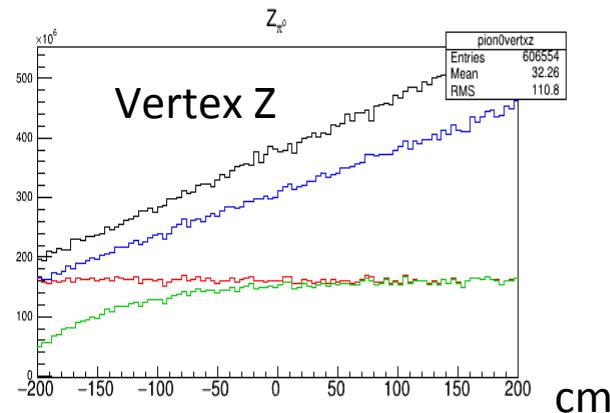
θ_{π^-}



Z_{π^0}

pion0vertxz
Entries: 606554
Mean: 32.26
RMS: 110.8

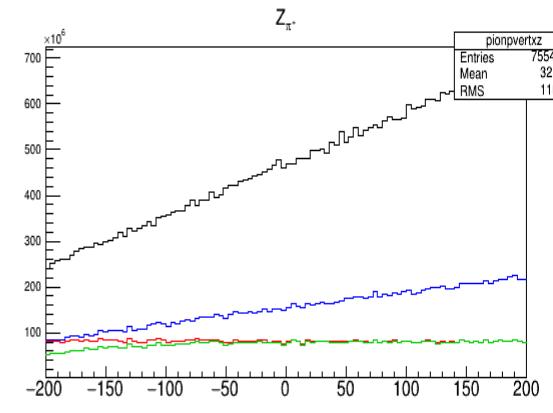
Vertex Z



Z_{π^-}

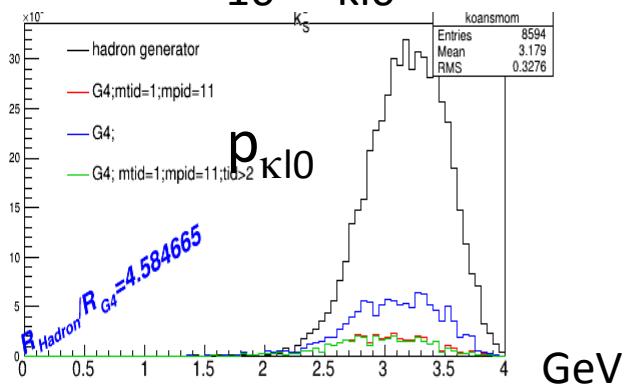
pionmvertxz
Entries: 327961
Mean: 33.8
RMS: 110.4

Z_{π^-}

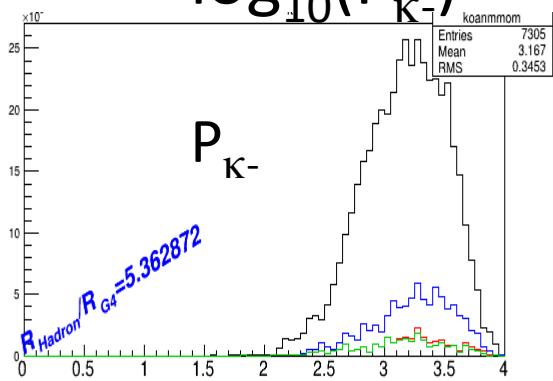


40cm LD target

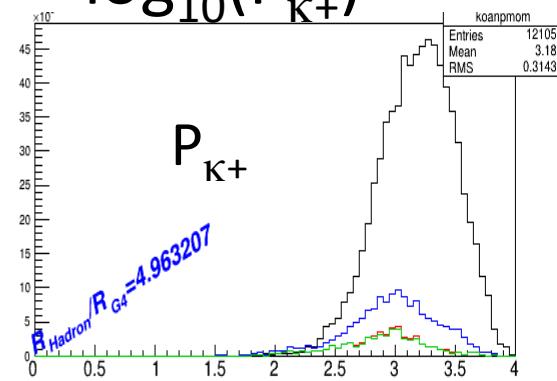
$\log_{10}(P_{\text{kl}0})$



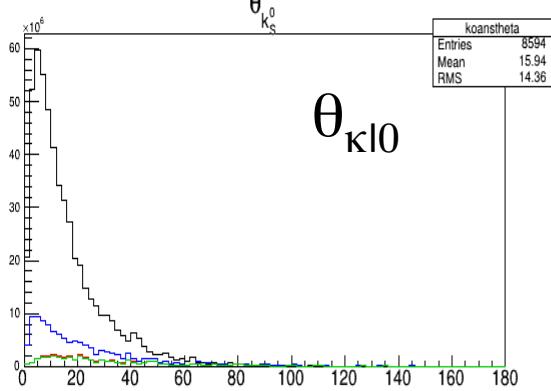
$\log_{10}(P_{K^-})$



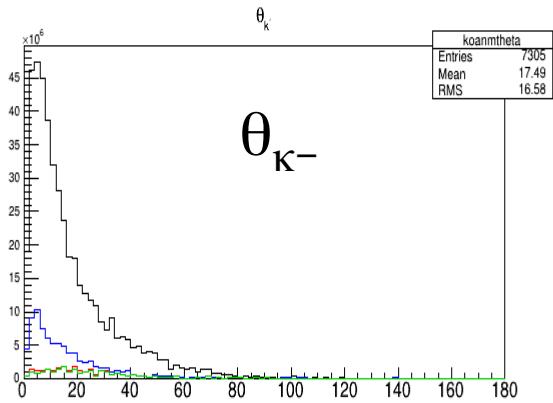
$\log_{10}(P_{K^+})$



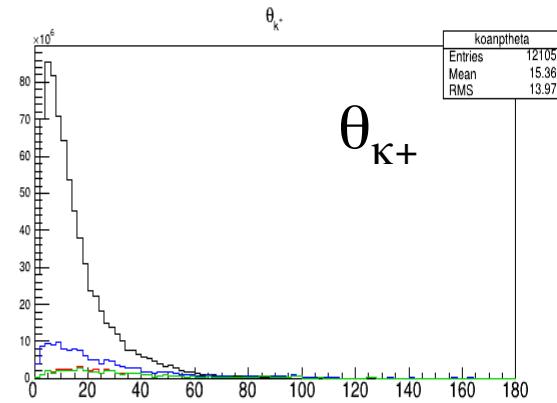
$\theta_{K^0_S}$



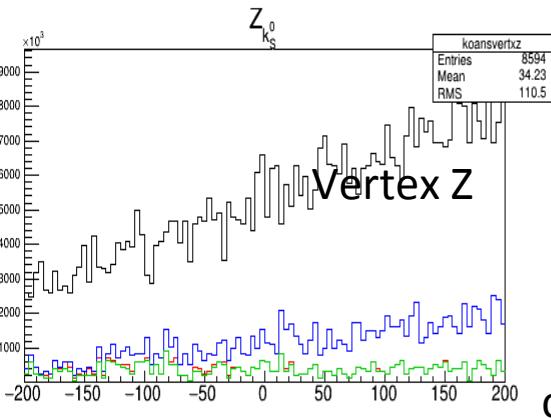
θ_K



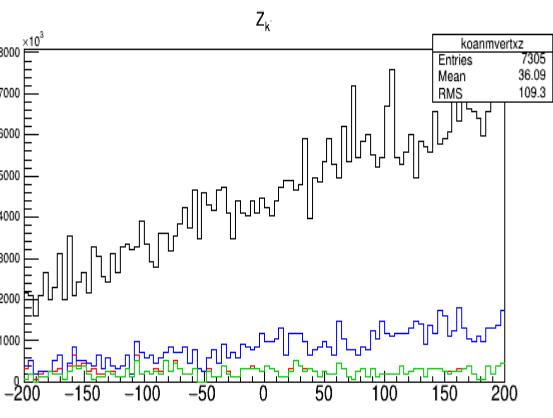
θ_{K^+}



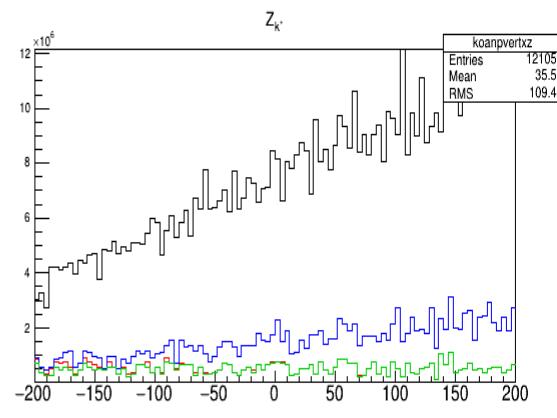
$Z_{K^0_S}$



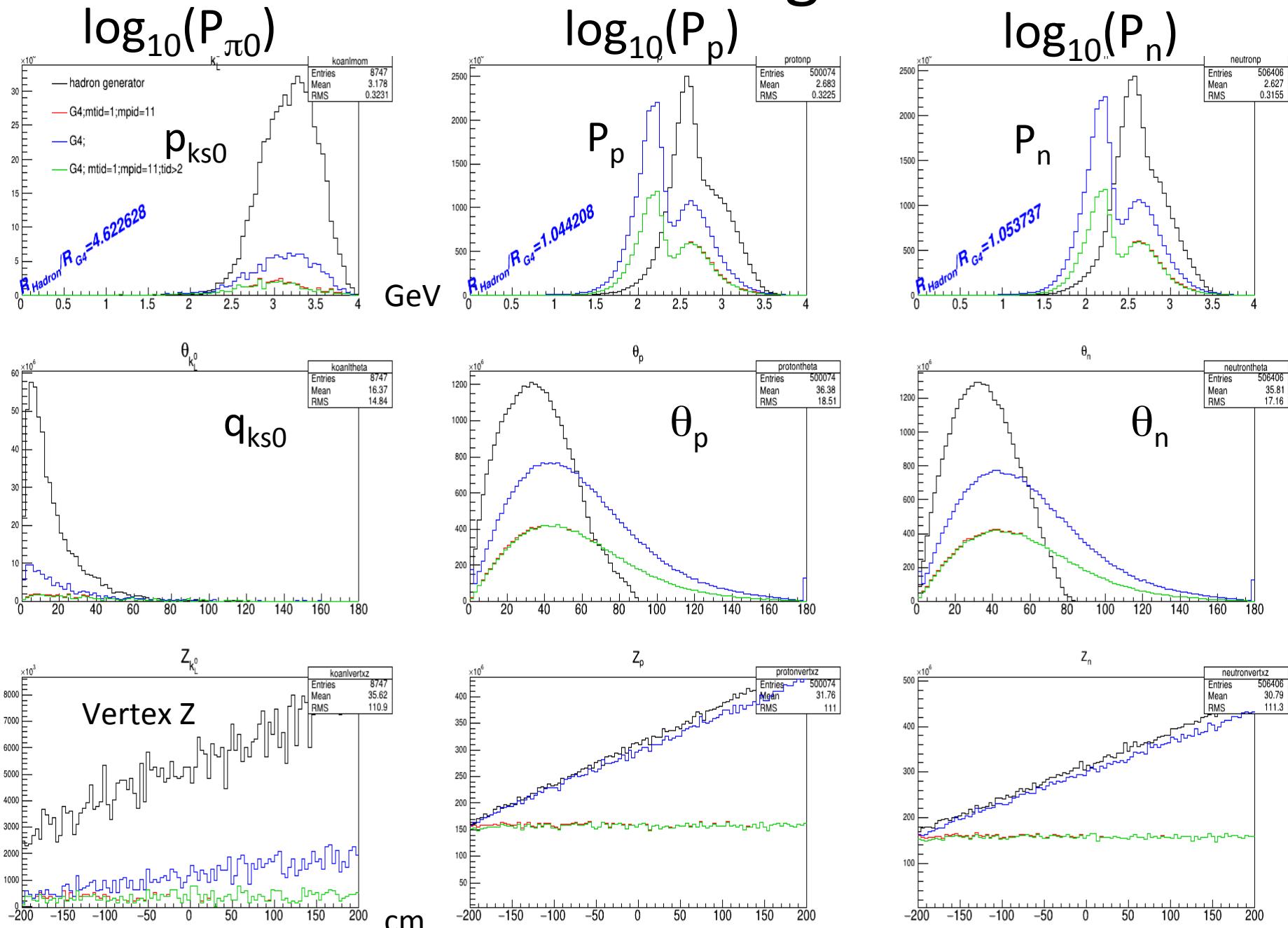
Z_K



Z_{K^+}

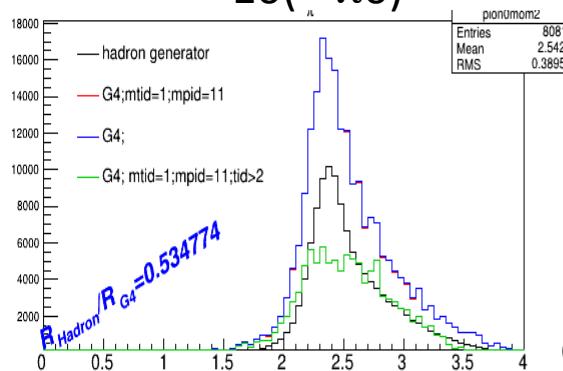


40cm LD target

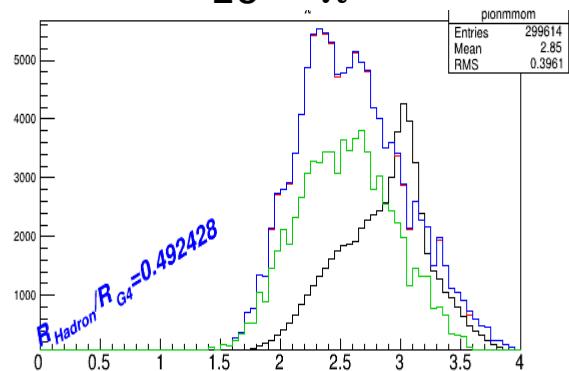


1mm He3 target

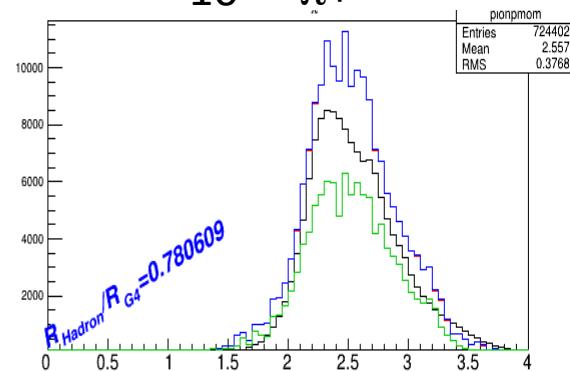
$\log_{10}(p_{\pi^0})$



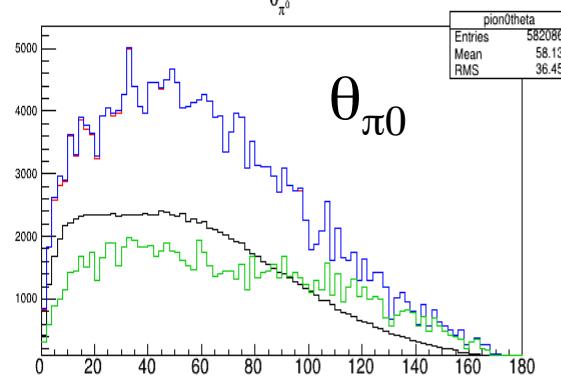
$\log_{10}(P_{\pi^-})$



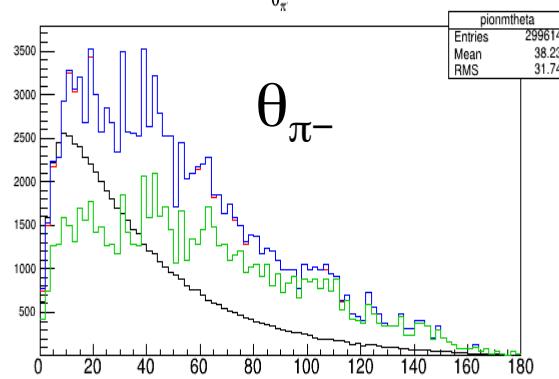
$\log_{10}(P_{\pi^+})$



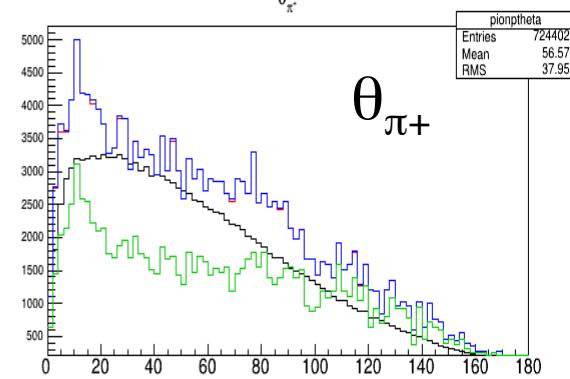
θ_{π^0}



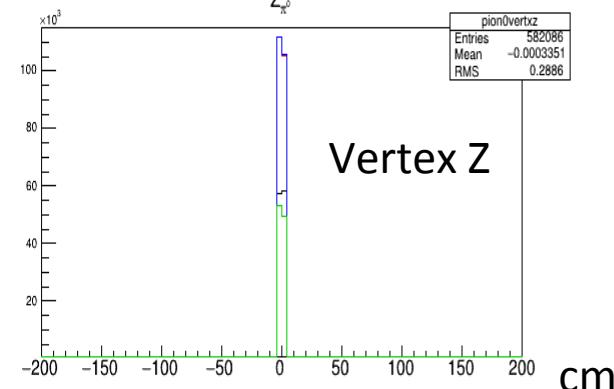
θ_{π^-}



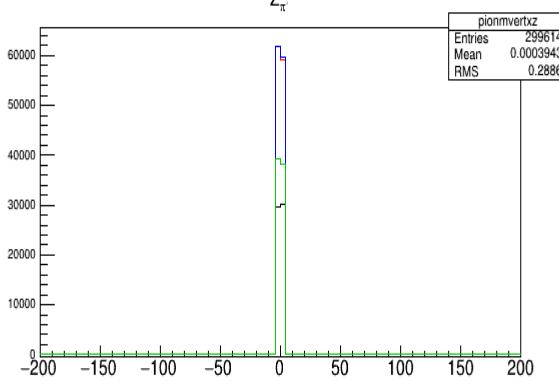
θ_{π^+}



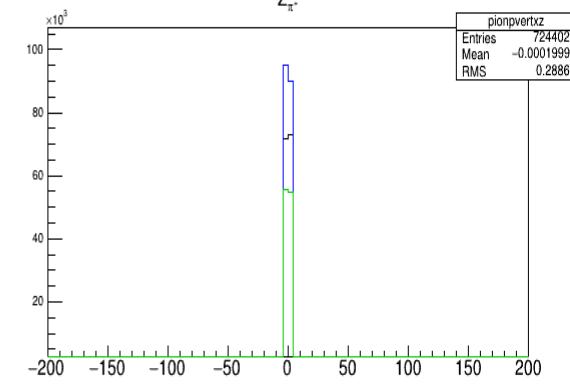
Z_{π^0}



Z_{π^-}

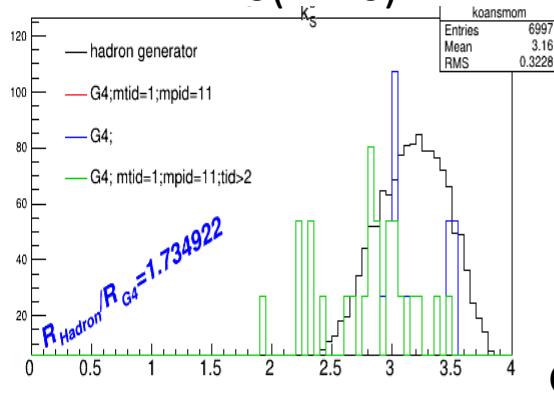


Z_{π^+}

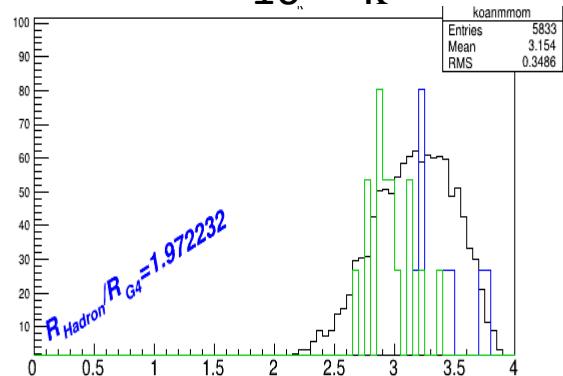


1mm He₃ target

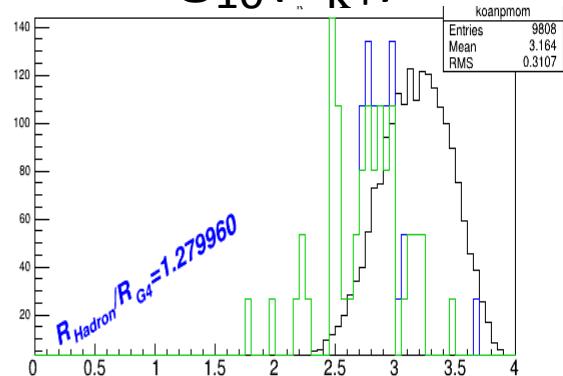
$\log_{10}(p_{kl0})$



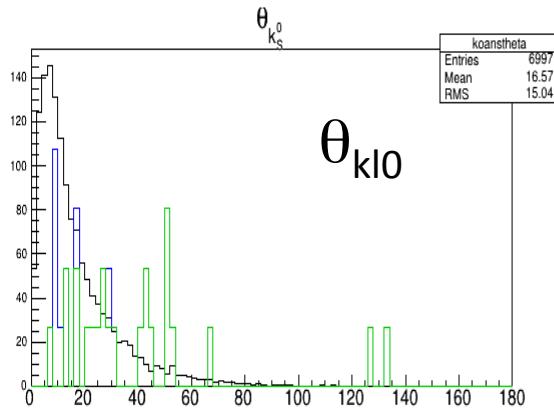
$\log_{10}(P_{K^-})$



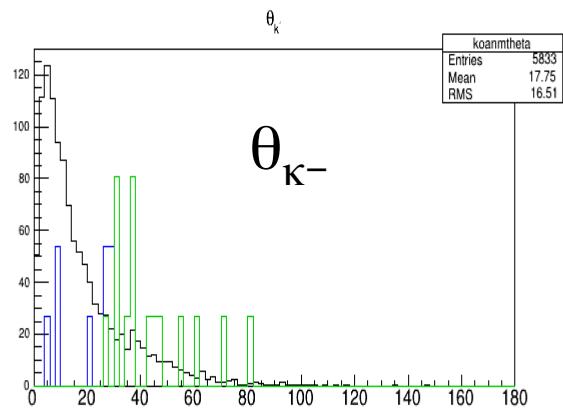
$\log_{10}(P_{K_+})$



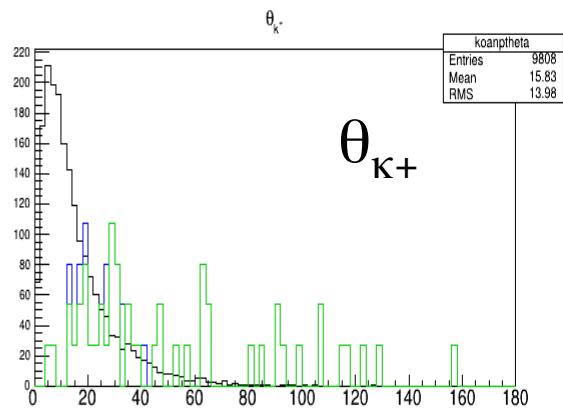
θ_{K^0}



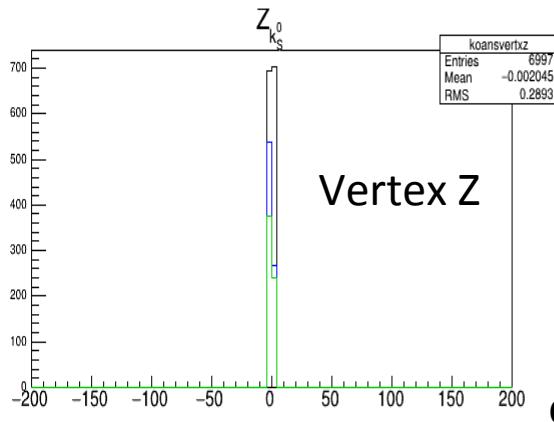
θ_{K^-}



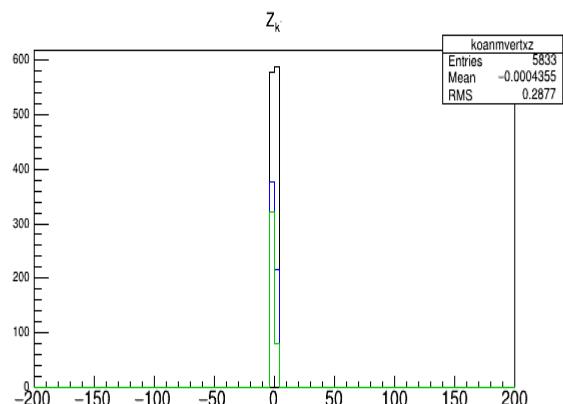
θ_{K^+}



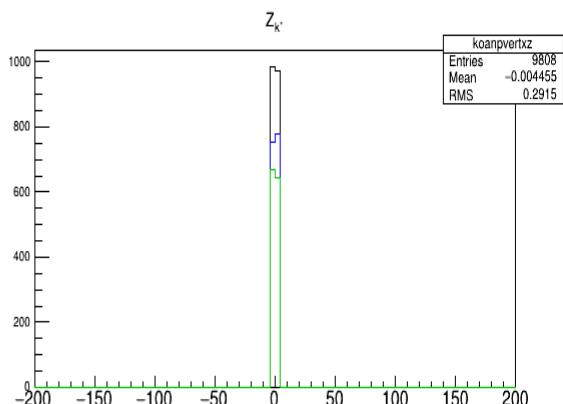
Z_{K^0}



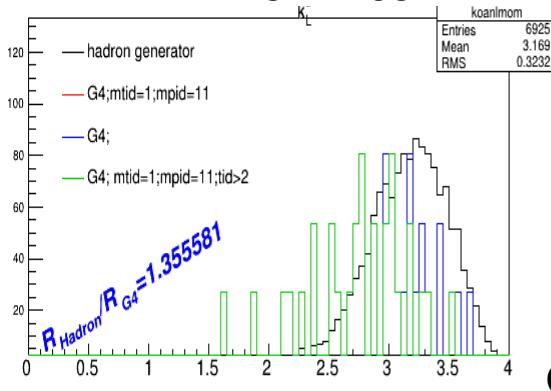
Vertex Z



Z_{K^+}

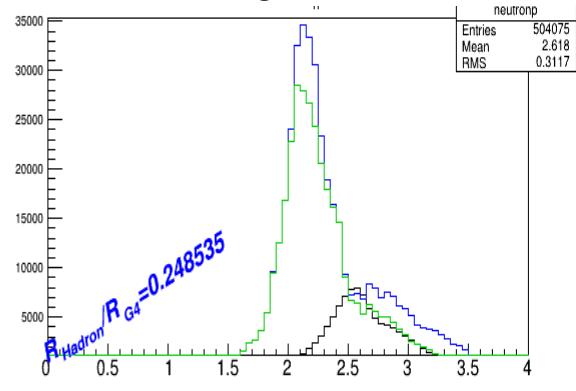


$\log_{10}(P_{ks0})$

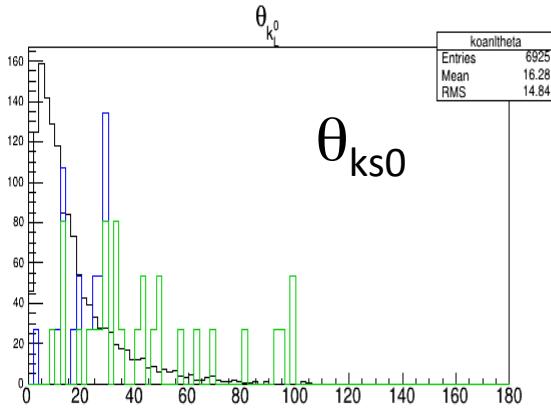


1mm He3 target

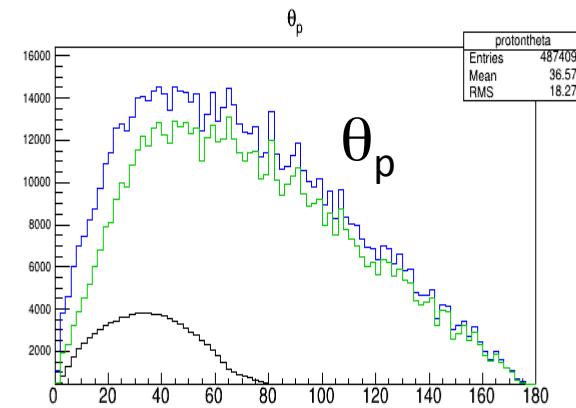
$\log_{10}(P_n)$



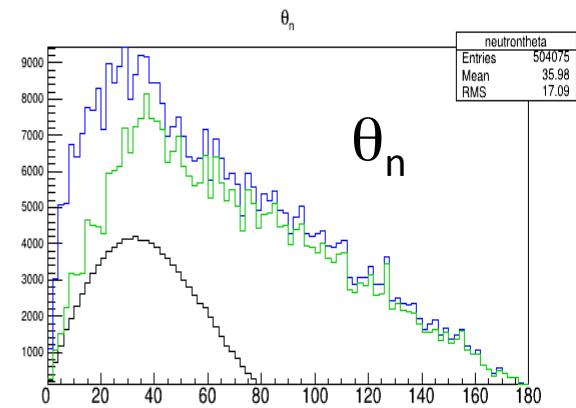
θ_{K^0}



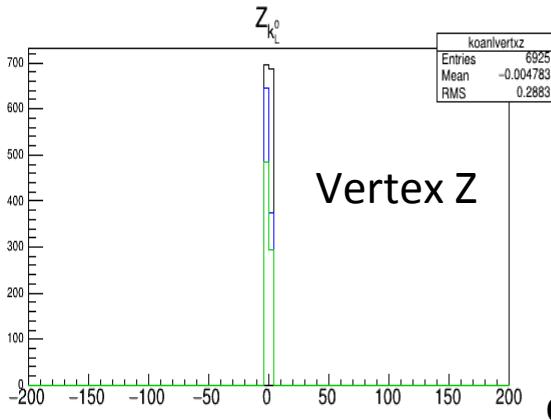
θ_p



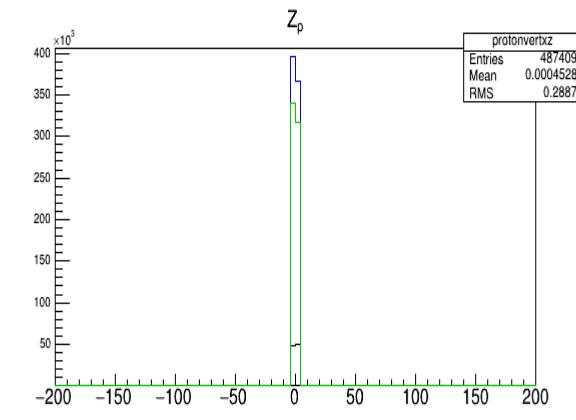
θ_n



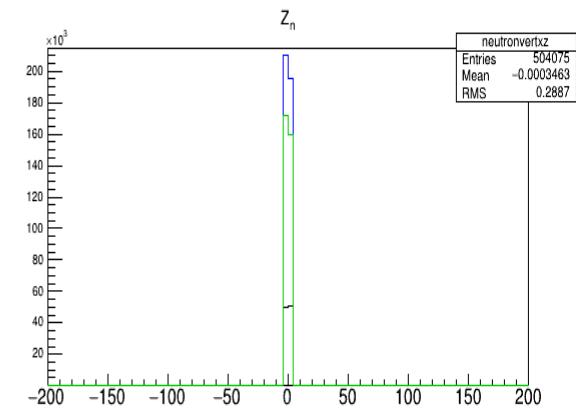
Z_{K^0}



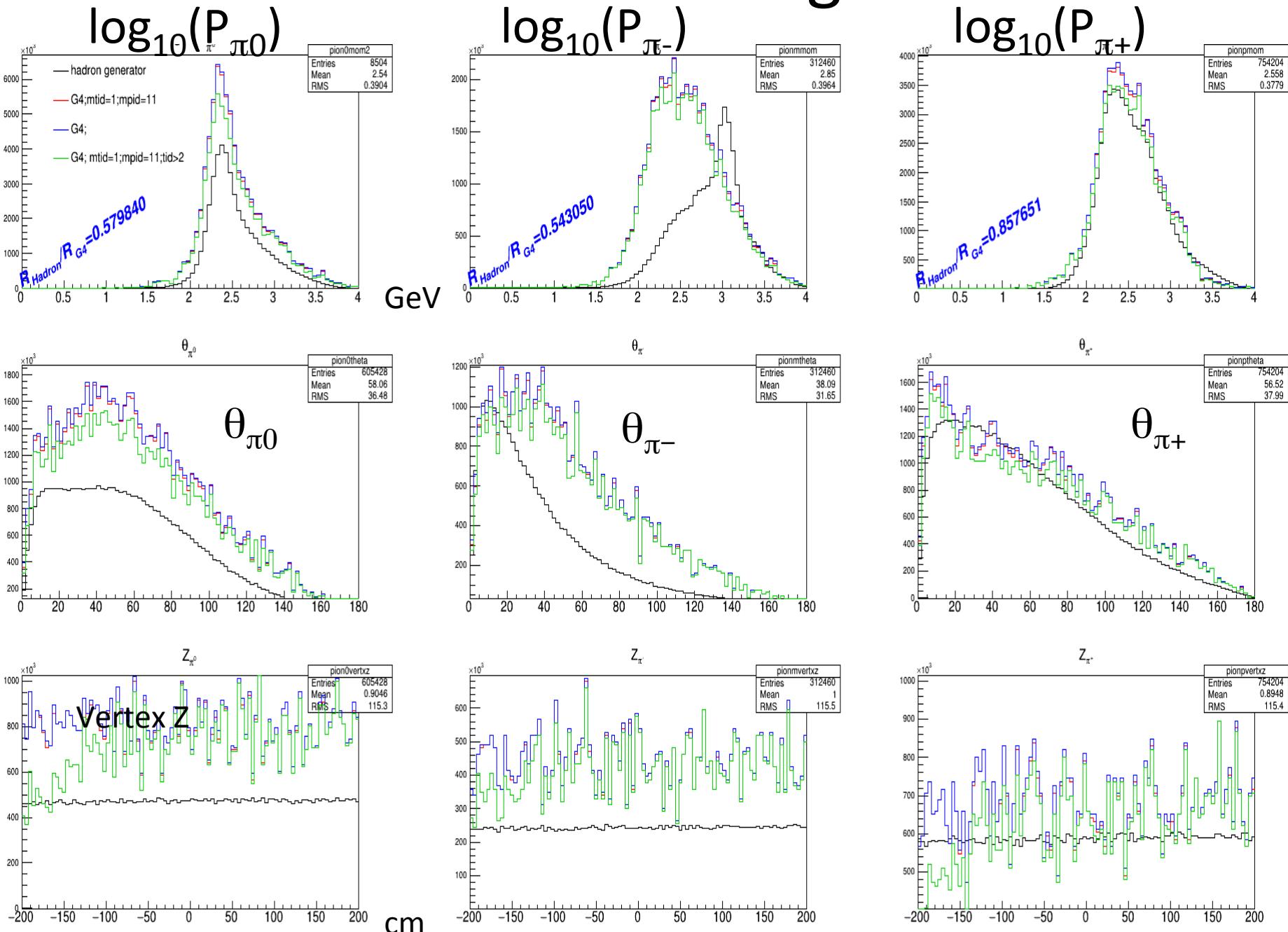
Z_p



Z_n

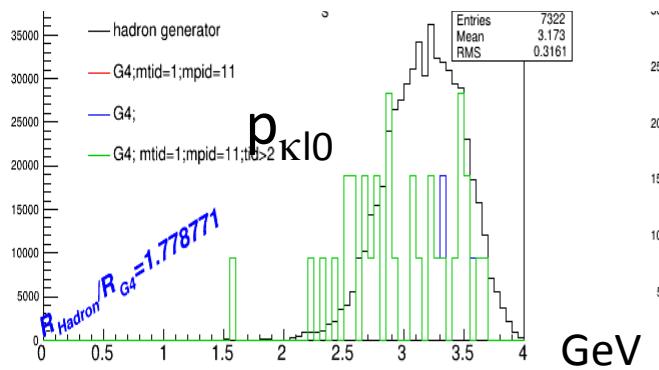


40cm He3 target

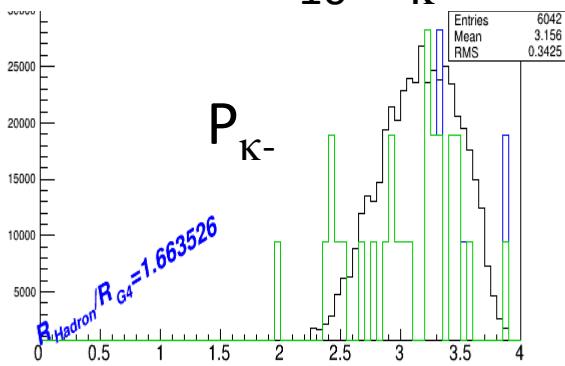


40cm LD target

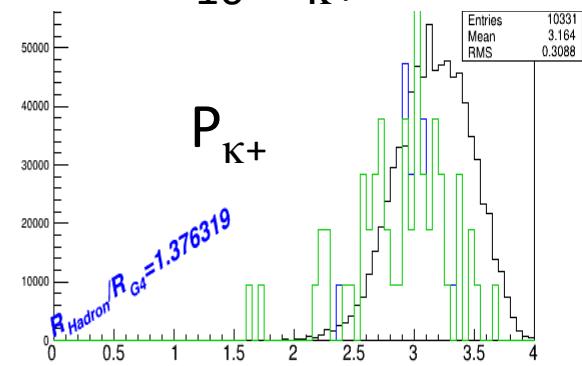
$\log_{10}(P_{\text{kl}0})$



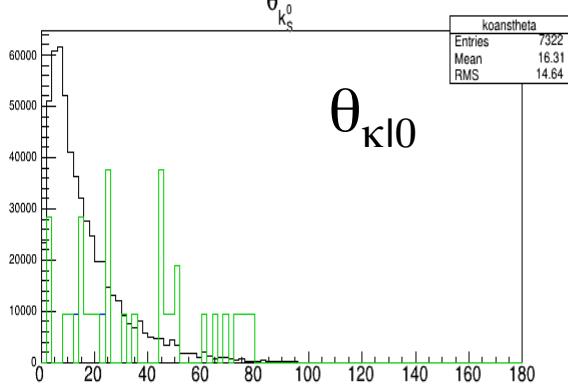
$\log_{10}(P_{\kappa^-})$



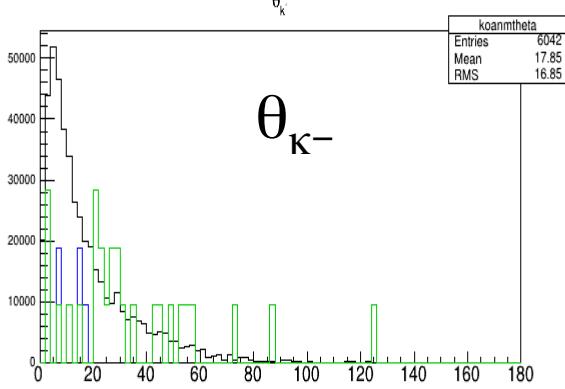
$\log_{10}(P_{\kappa^+})$



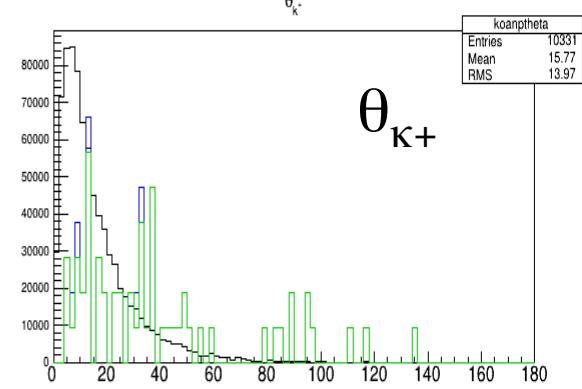
$\theta_{K^0_S}$



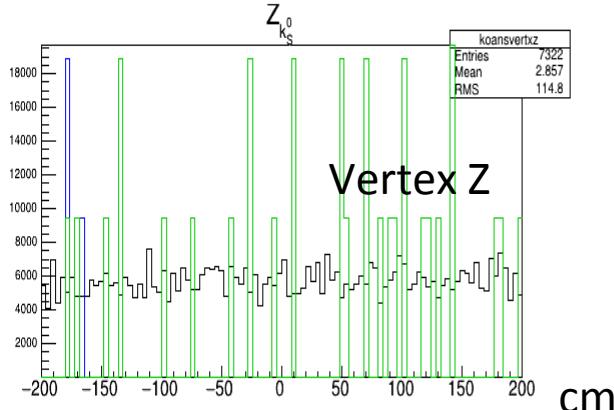
θ_K



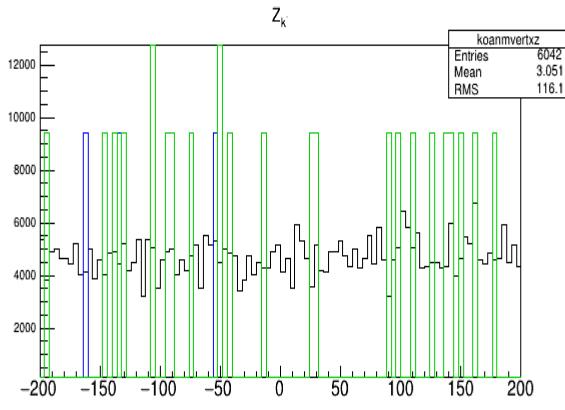
θ_{K^+}



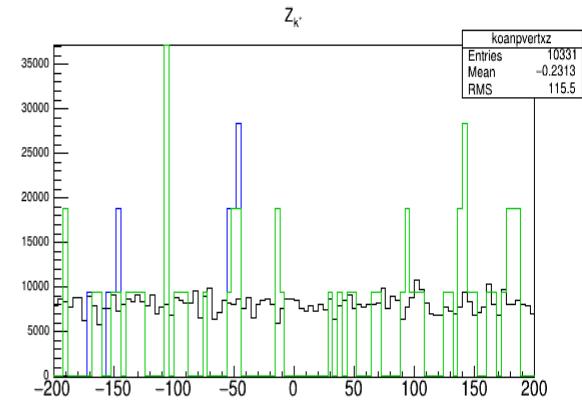
$Z_{K^0_S}$



Z_K



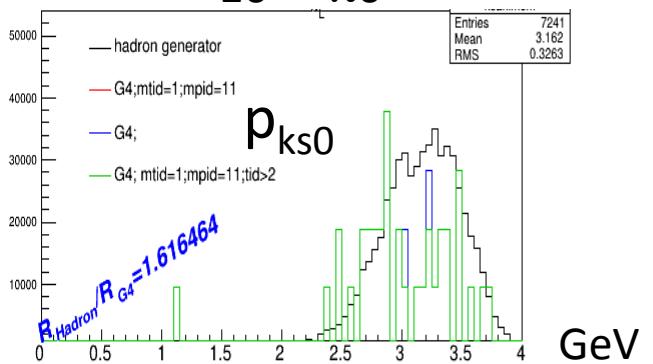
Z_{K^+}



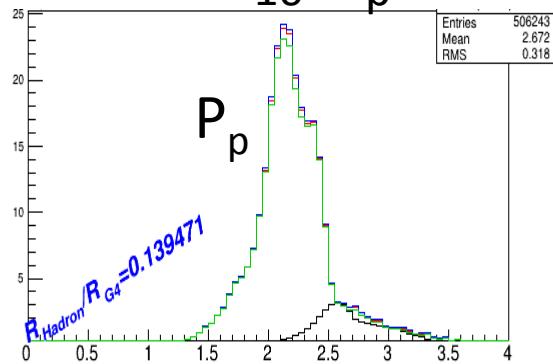
Vertex Z

40cm LD target

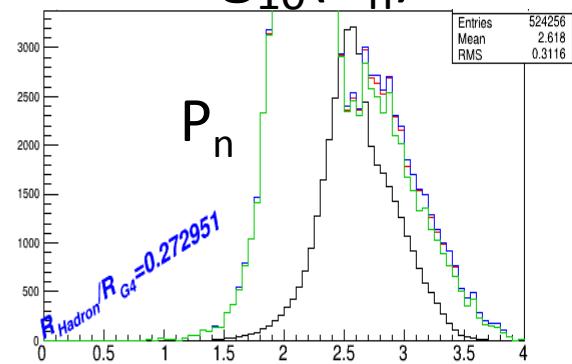
$\log_{10}(P_{\pi^0})$



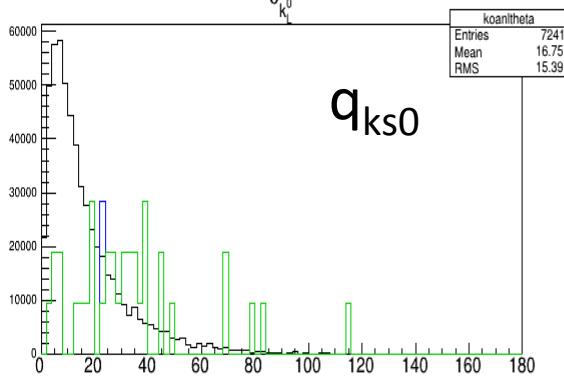
$\log_{10}(P_p)$



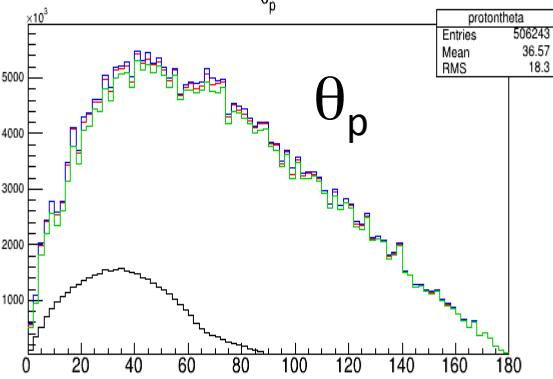
$\log_{10}(P_n)$



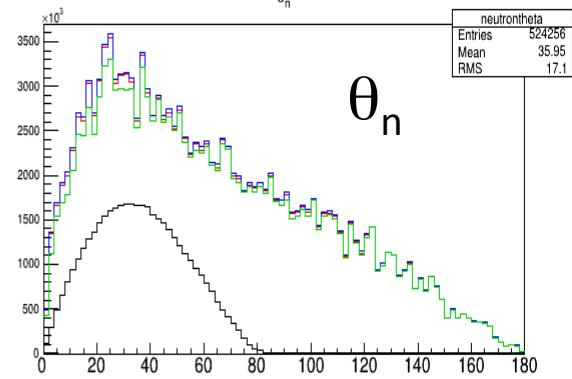
$\theta_{k_L^0}$



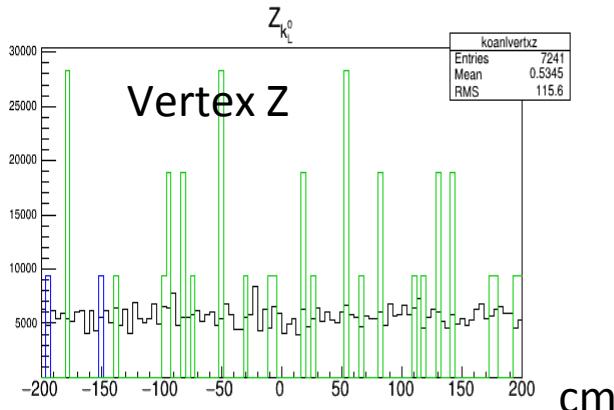
θ_p



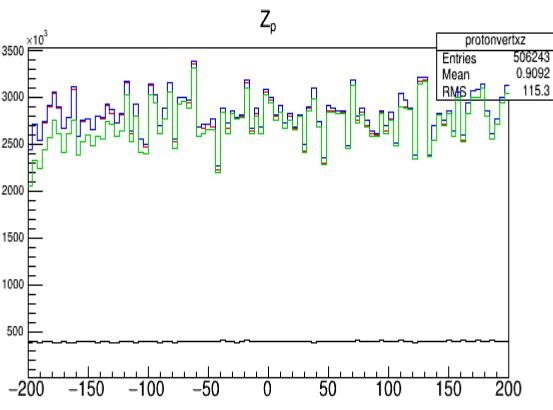
θ_n



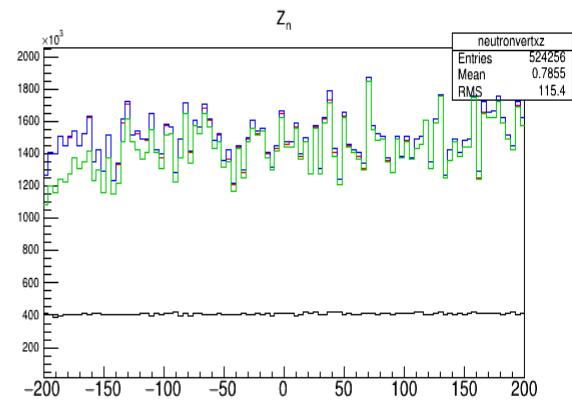
$Z_{k_L^0}$



Z_p



Z_n



Rate Comparison (id=0)

Hadron parti- cles	Ratio (bggen/G4) 1mm LH2	Ratio (bggen/G4) 40cm LH2	Ratio (bggen/G4) 1mm LD	Ratio (bggen/G4) 40cm LD	Ratio (bggen/G4) 1mm He3	Ratio (bggen/G4) 40cm He3
π^0	0.794	0.806	1.186	1.221	0.535	0.580
π^-	0.881	0.965	1.199	1.315	0.492	0.543
π^+	0.838	0.888	2.892	3.046	0.781	0.858
κ^+	1.732	1.752	5.425	4.963	1.280	1.376
κ^-	3.808	2.709	6.485	5.362	1.972	1.663
κ^0_L	2.483	2.320	5.716	4.622	1.355	1.616
κ^0_s	2.957	2.240	6.419	4.584	1.734	1.779
p	0.699	0.732	1.106	1.044	0.128	0.139
n	0.960	0.986	1.045	1.054	0.248	0.273

Back up

- Rate calculation for A>1:

$$\sigma_{\pi^-}(D) = \color{blue}{\sigma_{\pi^-}(n)} + \sigma_{\pi^-}(p) = \color{blue}{\sigma_{\pi^+}(p)} + \sigma_{\pi^-}(p)$$

$$\sigma_{\pi^+}(D) = \color{magenta}{\sigma_{\pi^+}(n)} + \sigma_{\pi^+}(p) = \color{magenta}{\sigma_{\pi^-}(p)} + \sigma_{\pi^+}(p)$$

$$\sigma_{\pi^-}(\text{He}_3) = \color{blue}{\sigma_{\pi^-}(n)} + 2\sigma_{\pi^-}(p) = \color{blue}{\sigma_{\pi^+}(p)} + 2\sigma_{\pi^-}(p)$$

$$\sigma_{\pi^+}(\text{He}_3) = \color{magenta}{\sigma_{\pi^+}(n)} + 2\sigma_{\pi^+}(p) = \color{magenta}{\sigma_{\pi^-}(p)} + 2\sigma_{\pi^+}(p)$$

QGSP_BERT_HP (Geant4 9.4 and later)

- QGS parton-string models for nucleons and mesons at high energies 12 GeV to ~100 TeV
- Precompound model for nuclear de-excitation
- Bertini cascade for nucleons and mesons at medium energies < 10 GeV except for neutrons below 20 MeV
- LEP (parameterized model) for nucleons and mesons for region between 10 GeV and 25 GeV
- HP (high precision neutron) model for neutron elastic, inelastic, capture and fission below 20 MeV
- LEP, HEP (parameterized models) for hyperons, anti-hyperons, anti-nucleons at all energies
- Ions: LEP models for d, t, alpha, all energies
- Stopped negative particle interactions handled by CHIPS model
- e+, e-: G4ElectroNuclearReaction (CHIPS), all energies
- Muon-nuclear: old mu-nuclear model, all energies used in 9.4 new model, G4VDMuonNuclear used in 9.5 and later, and backported to 9.3 p02, all energies
- **Gamma-nuclear: G4GammaNuclearReaction model below 3.5 GeV, QGS model above 3 GeV**
- Elastic: CHIPS and LHEP models for hadrons, with exception of neutrons below 20 MeV, and light ions
- Standard electromagnetic package

Rate Comparison (id=0 and mtid=1)

Hadron parti- cles	Ratio (bggen/G4) 1mm LH2	Ratio (bggen/G4) 40cm LH2	Ratio (bggen/G4) 1mm LD	Ratio (bggen/G4) 40cm LD	Ratio (bggen/G4) 1mm He3	Ratio (bggen/G4) 40cm He3
π^0	0.799	1.448	1.192	2.340	0.536	0.588
π^-	0.885	1.693	1.204	2.479	0.494	0.551
π^+	0.841	1.520	2.904	5.725	0.782	0.868
κ^+	1.737	3.692	5.460	13.53	1.28	1.398
κ^-	3.808	8.070	6.543	16.90	1.972	1.721
κ^0_L	2.491	5.729	5.753	13.83	1.355	1.616
κ^0_s	2.968	5.520	6.464	13.07	1.735	1.778
p	0.701	1.251	1.019	1.961	0.127	0.141
n	0.961	1.667	1.049	1.985	0.249	0.276