JÜLICH
FORSCHUNGSZENTRUM

p̄anda

Simulation of $X(3872) \rightarrow Z^{\pm}(3730)\pi^{\mp}$ Transitions

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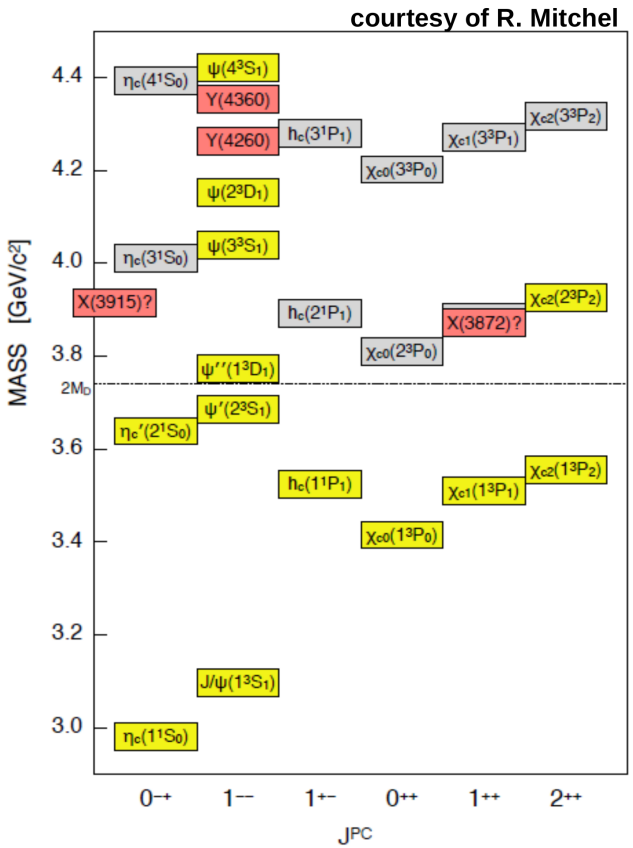
Introduction

Exotic States

Exotic states: observed c $\bar{c}$-like resonances that do not “fit” within the charmonium model



- X(3872)
  - Narrow state close to DD* threshold
  - Quantum numbers measured (LHCb): $J^{PC} = 1^{++}$
  - Nature still unknown $\Longrightarrow$ measure width with high precision: $\bar{\text{P}}$ANDA’s flagship measurement
- Z states
  - Observed at Belle, BESIII
  - Charged, possible isospin multiplets

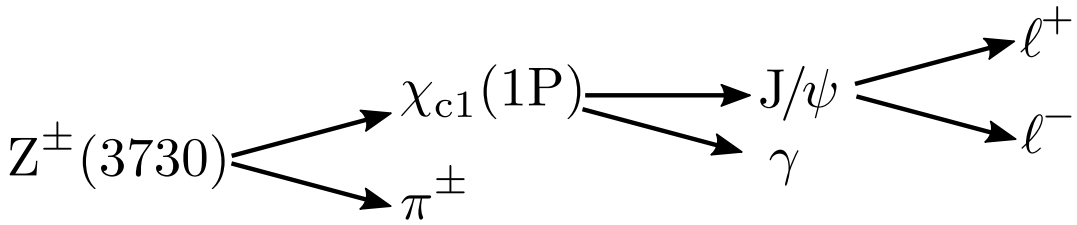
Motivation

- Strong theoretical motivations for Z state at the DD threshold
  - Z near DD* threshold: Z(3900) (observed, BESIII)
  - Z near D*D* threshold: Z(4020) (observed, BESIII)
  - Z near DD threshold: never observed
    - Quantum numbers incompatible with $e^+ e^-$ production
- Transitions between exotic states
  - Y(4260) $\rightarrow$ Z(3900)$^- \pi^+$ (observed, BESIII)
  - Y(4260) $\rightarrow$ X(3872) γ (observed, BESIII)
  - $X \rightarrow Z$ or $Z \rightarrow X$ still unobserved
- $\bar{\text{P}}$ANDA is a X(3872) factory
  - Belle 2: 7500 X(3872) in $\sim$10 years
  - BESIII: $\sim$250 X(3872)/year
  - $\bar{\text{P}}$ANDA: [57000 $\div$ 146000] X(3872)/day ($\mathcal{L} = 0.864$ pb^{-1}/day)

$\Longrightarrow$ $\bar{\text{P}}$ANDA: unique capabilities for studying rare/suppressed processes involving X(3872)

Strategy

- Main idea: study $X \to Z$ transitions using data from the X(3872) mass scan run
- Two possible simulations:
  - $\bar{p}p \to Z(3730)\pi$
  - $\bar{p}p \to X(3872) \to Z(3730)\pi$
- Z(3730) decay channel:



  - Channel with J/ψ: $\sim 10^4$ background suppression
  - Complement search for neutral Z(3730)
  - Test performance of $\chi_{c1}(1P)$ reconstruction

Strategy

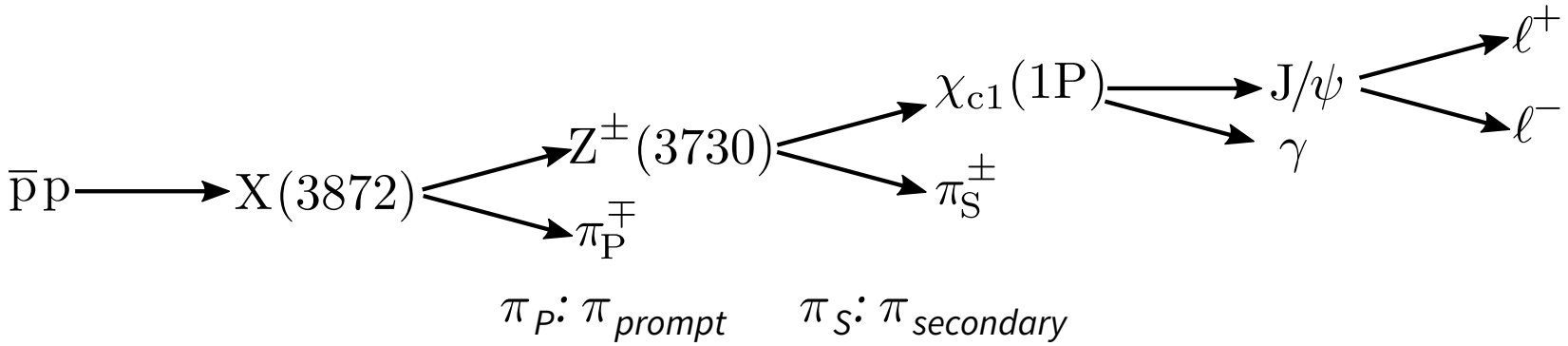
Branching Ratio

$$N_{evt}/\text{day} = N_X/\text{day} \times \mathcal{B}(X \to Z\pi) \times \mathcal{B}(Z \to \chi_{c1}\pi) \times \mathcal{B}(\chi_{c1} \to J/\psi\gamma) \times \mathcal{B}(J/\psi \to \ell^+\ell^-)$$

- $\mathcal{B}(\chi_{c1} \to J/\psi\gamma) = (33.9 \pm 1.2)\%$ (PDG)
- $\mathcal{B}(J/\psi \to \ell^+\ell^-) = 11.52\%$ (PDG)
- $\mathcal{B}(X \to Z\pi) \times \mathcal{B}(Z \to \chi_{c1}\pi) = \mathcal{B}_{\text{unknown}}$
- $N_{evt}/\text{day} = [2200 \div 5700] \times \mathcal{B}_{\text{unknown}}$

- Perform analysis
- Calculate minimum $\mathcal{B}_{\text{unknown}}$ for which we can get 5σ during data-taking period

Simulation

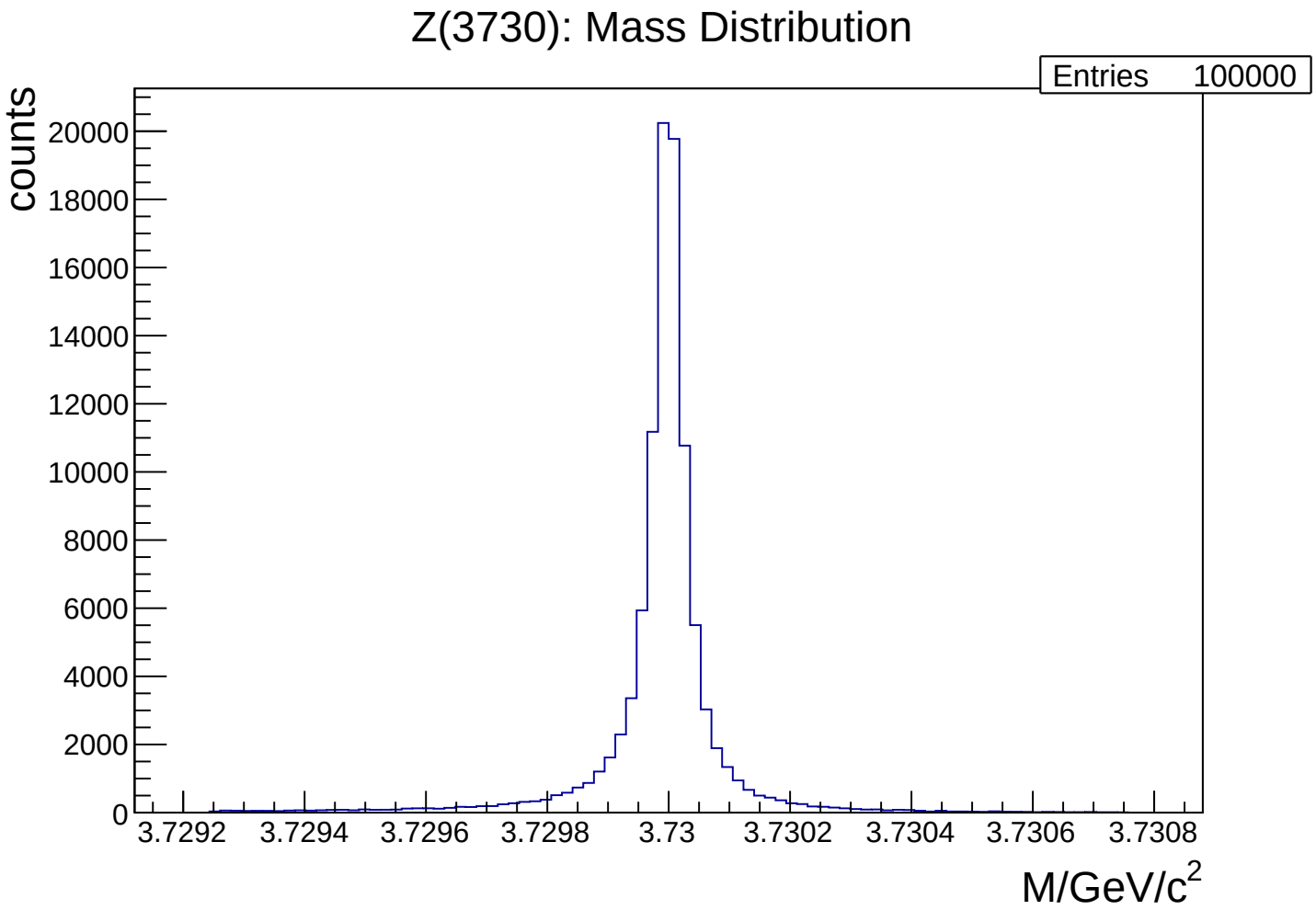


- 100k events, using `SimpleEvtGenRO`
- Using `pbarpSystem1` ($S = 1$) with $p_{\text{beam}} = 6.99102$ GeV/c
- `PHSP` decays
- All BR 1.0

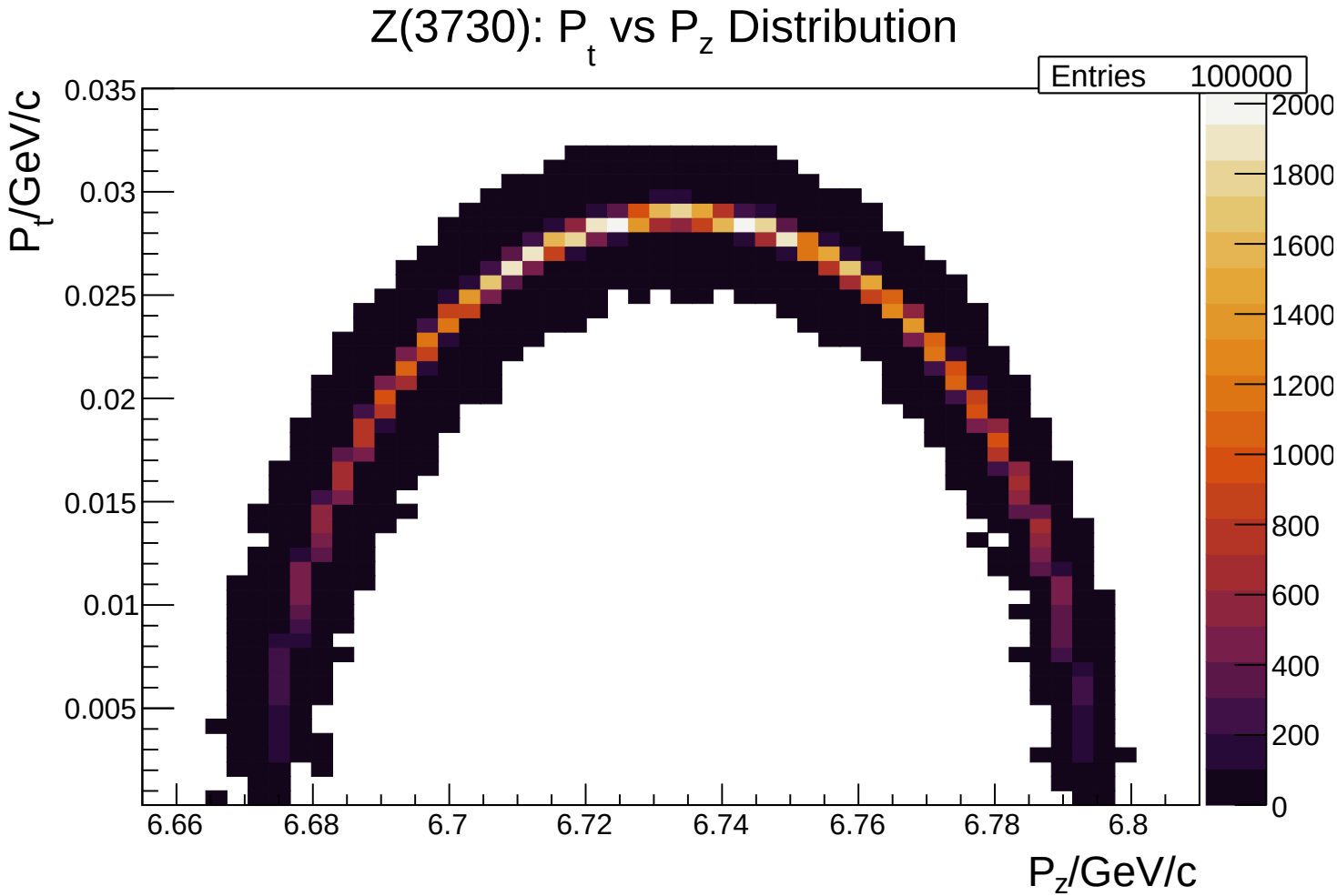
- $Z^{\pm}(3730)$ model in EvtGen:

```
add p Particle Z(3730)- 99663302 3.73000e+00
5.0e-05 0 -3 0 0.0000000e+00 0
```

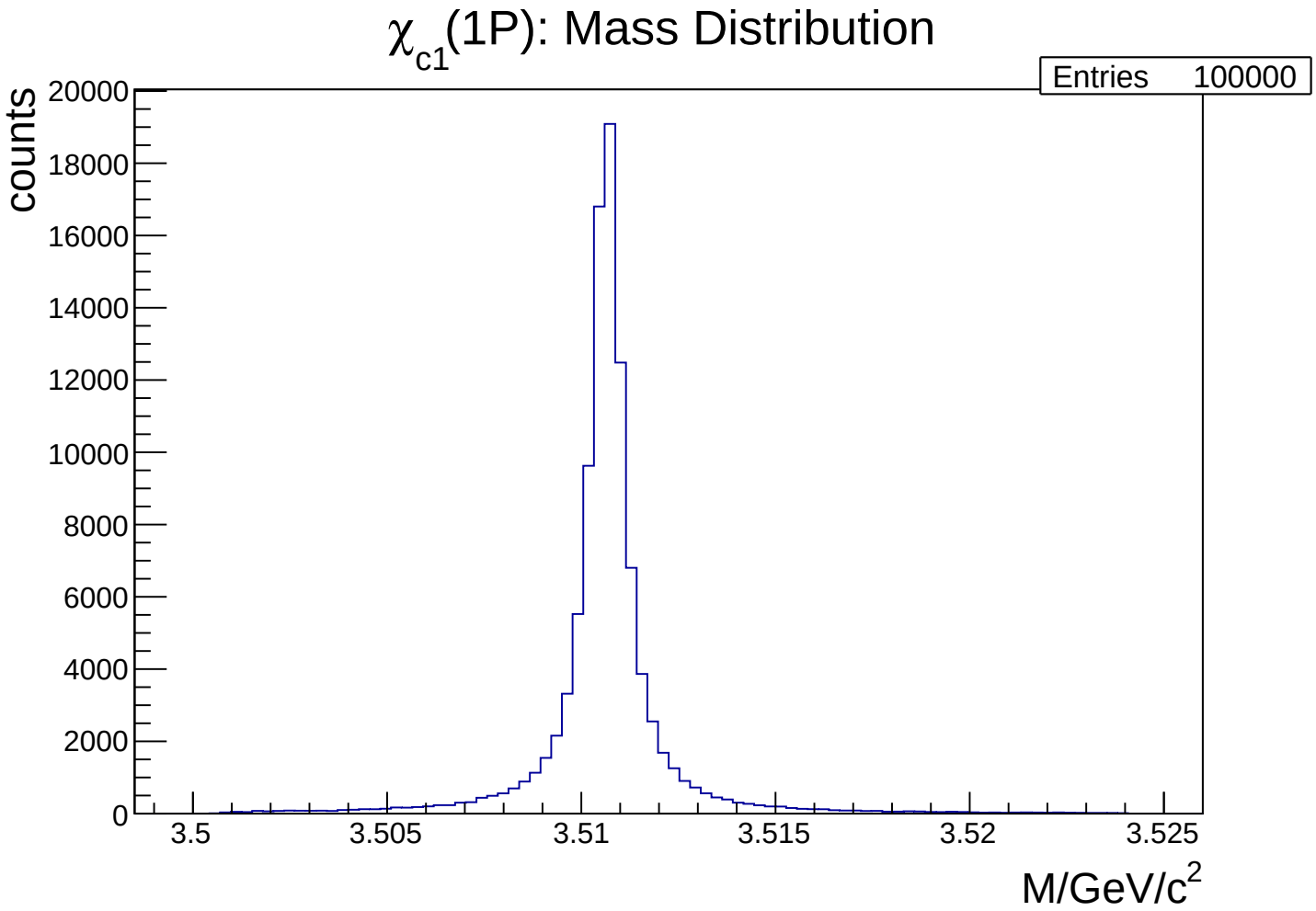
Plots



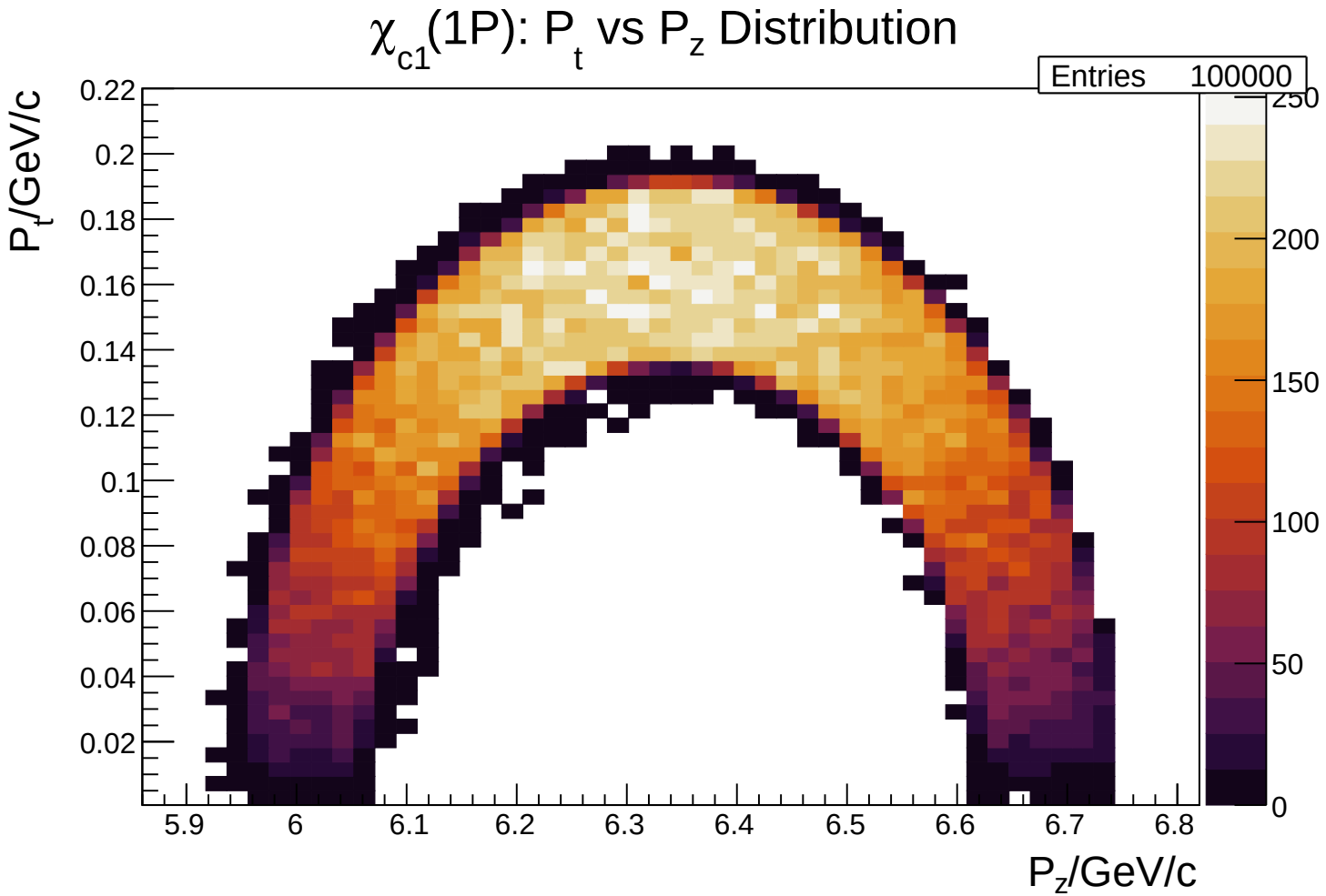
Plots



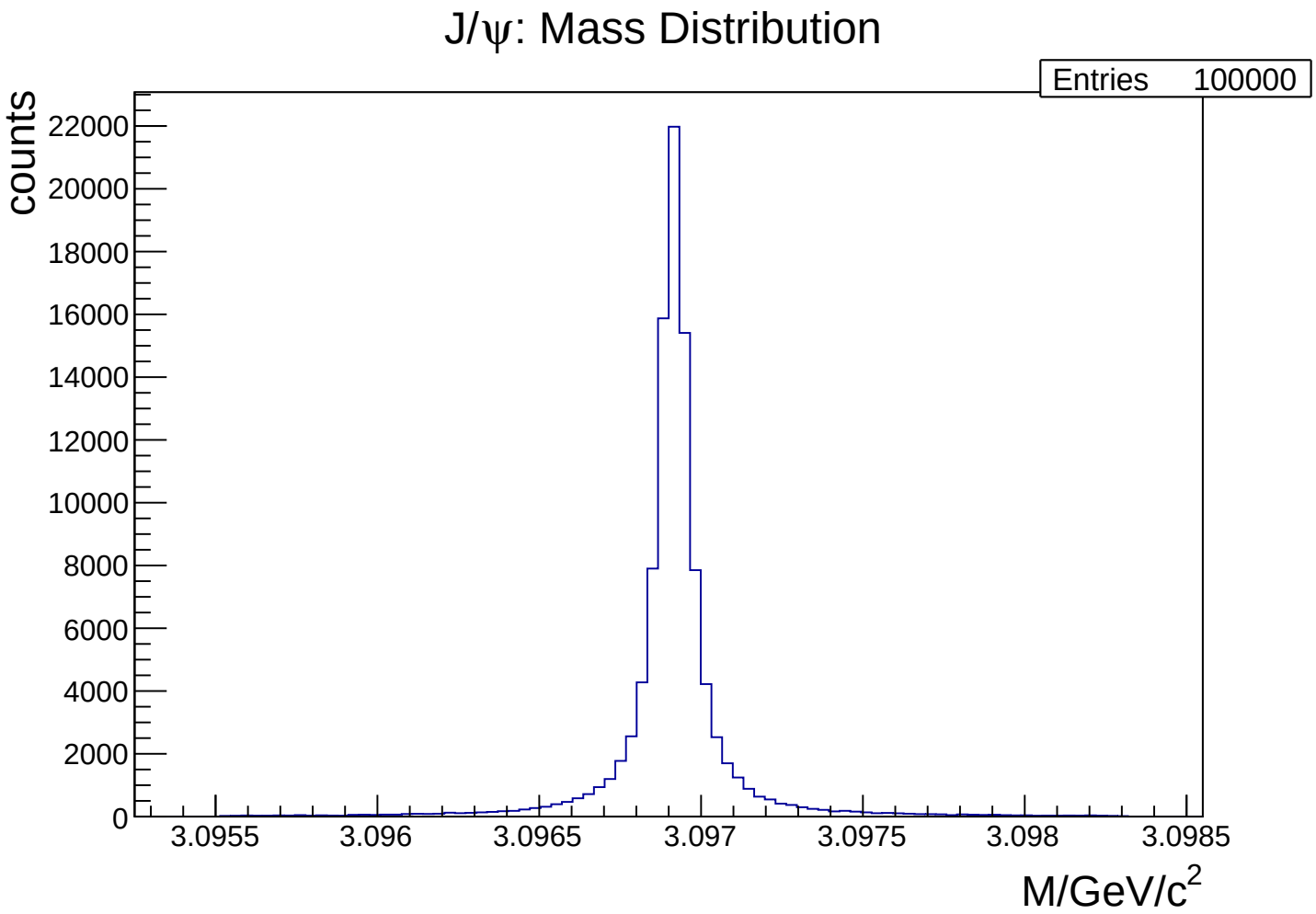
Plots



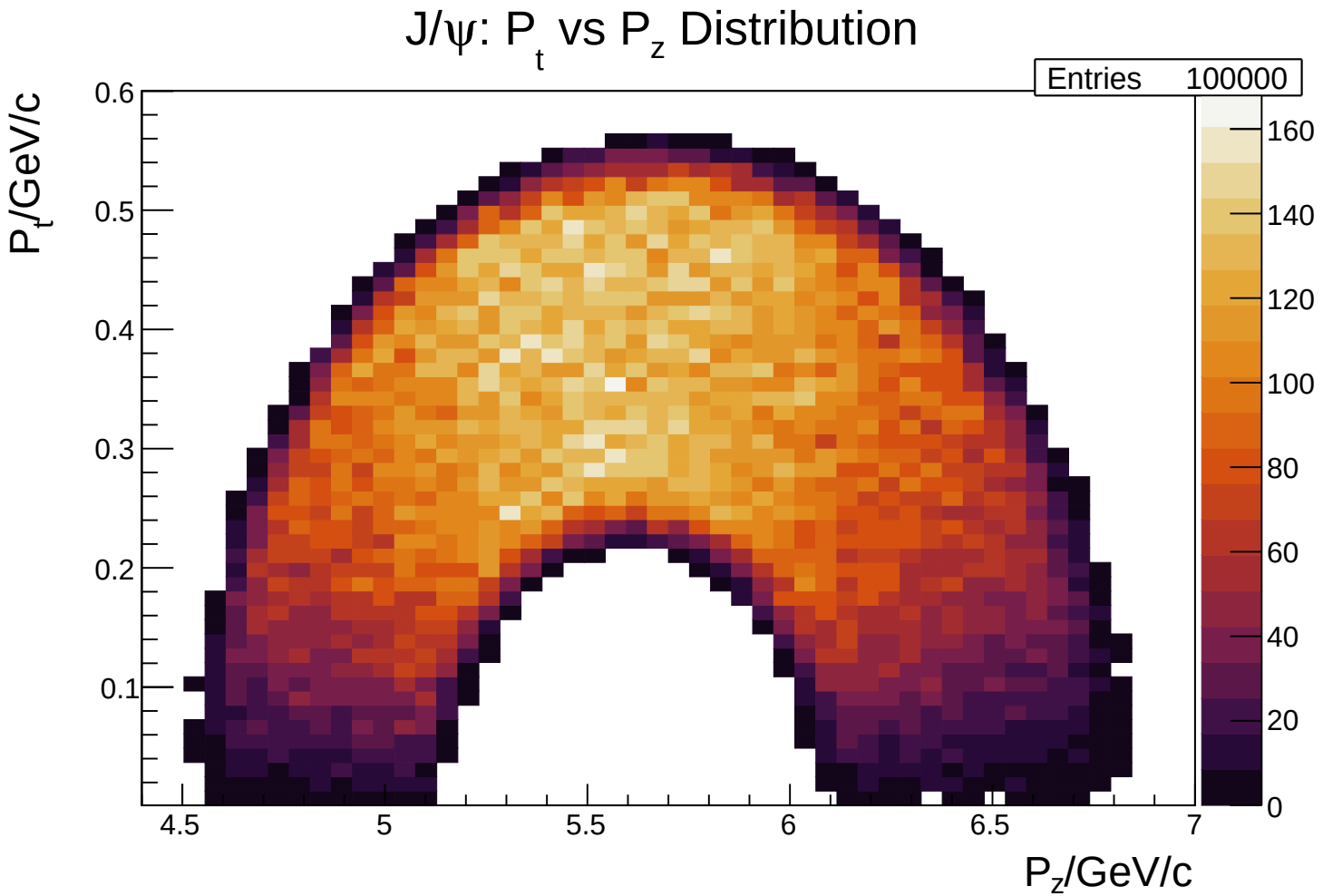
Plots



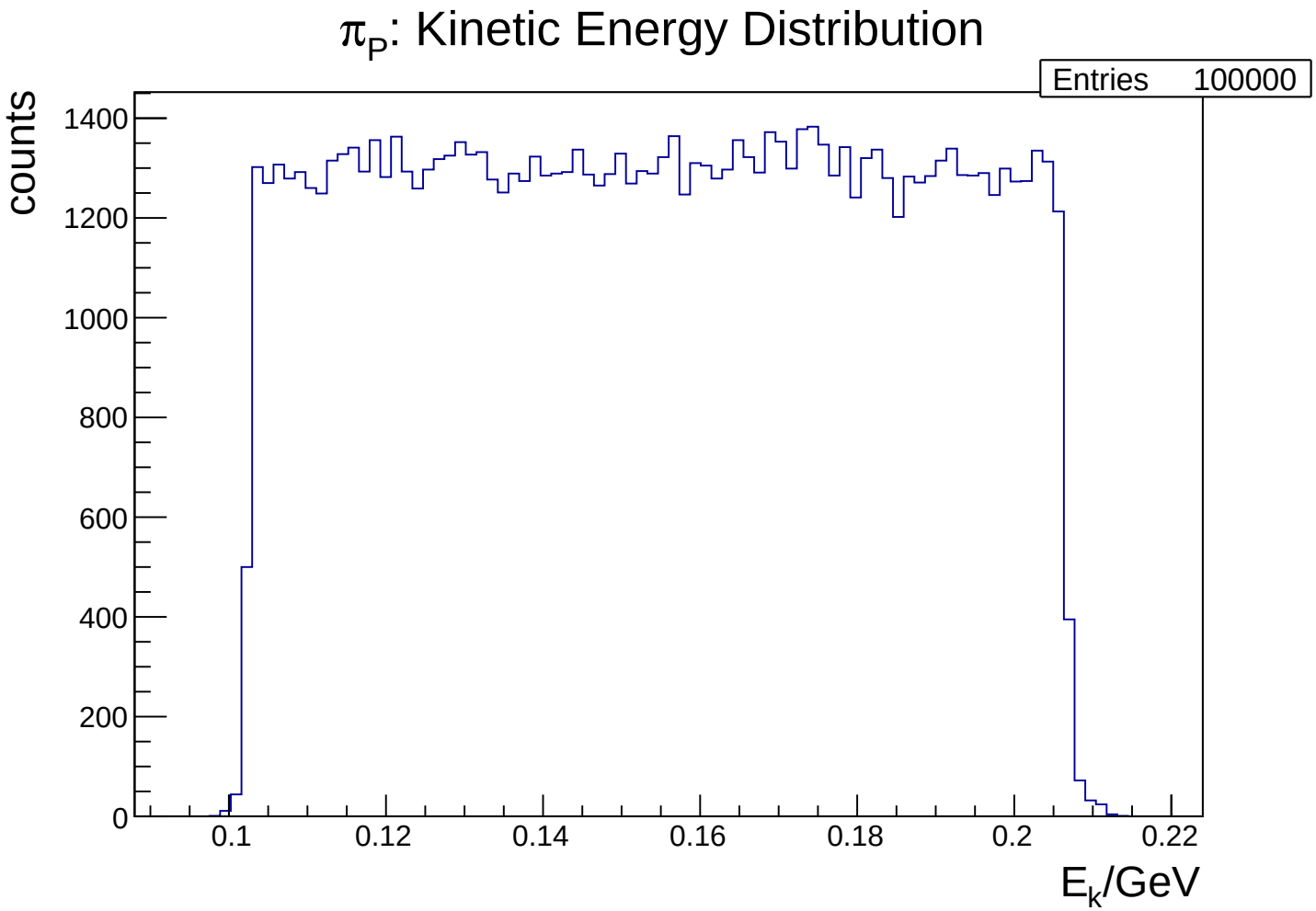
Plots


J/ψ: Mass Distribution
Entries 100000
counts
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
3.0955
3.096
3.0965
3.097
3.0975
3.098
3.0985
M/GeV/c²

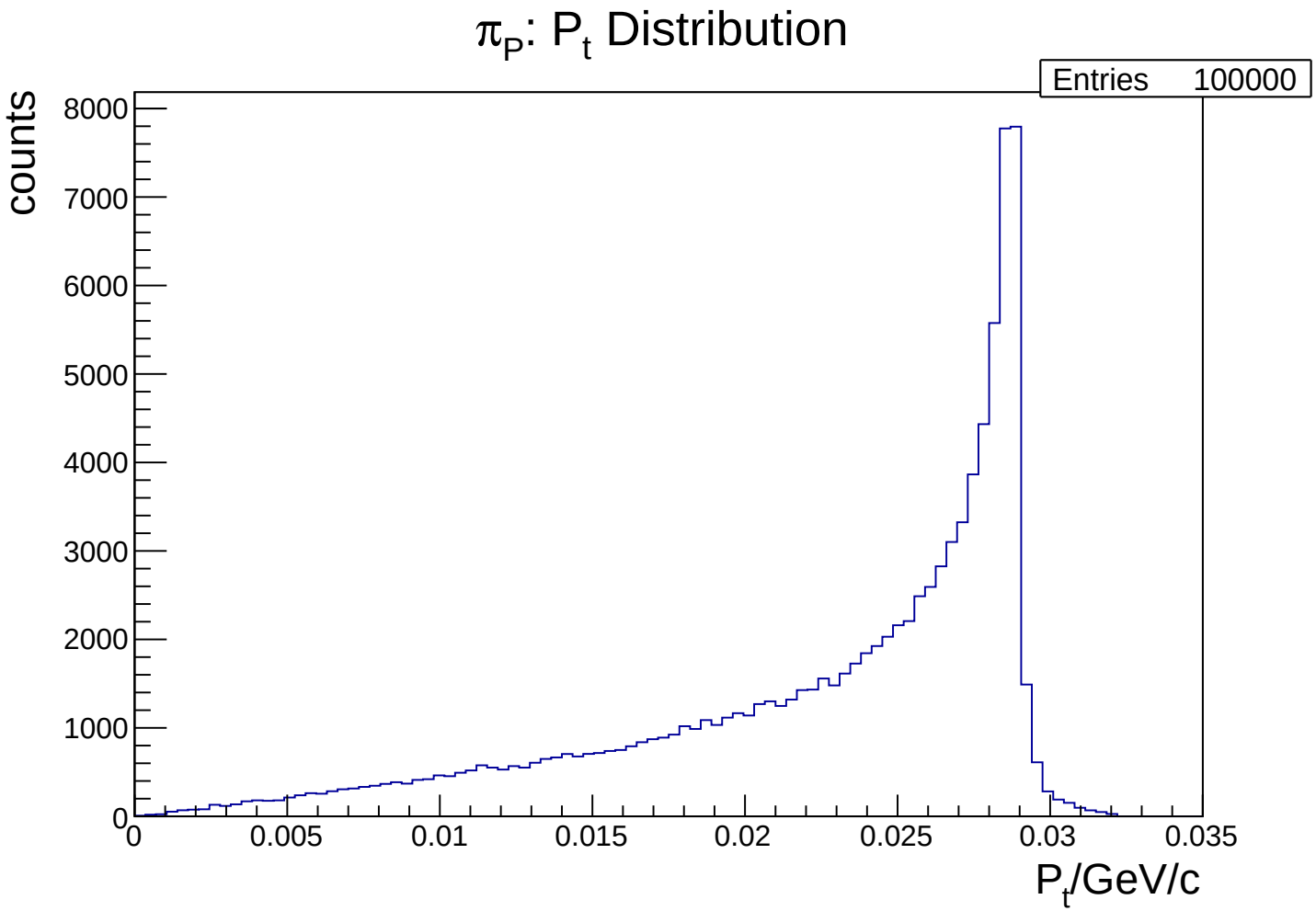
Plots



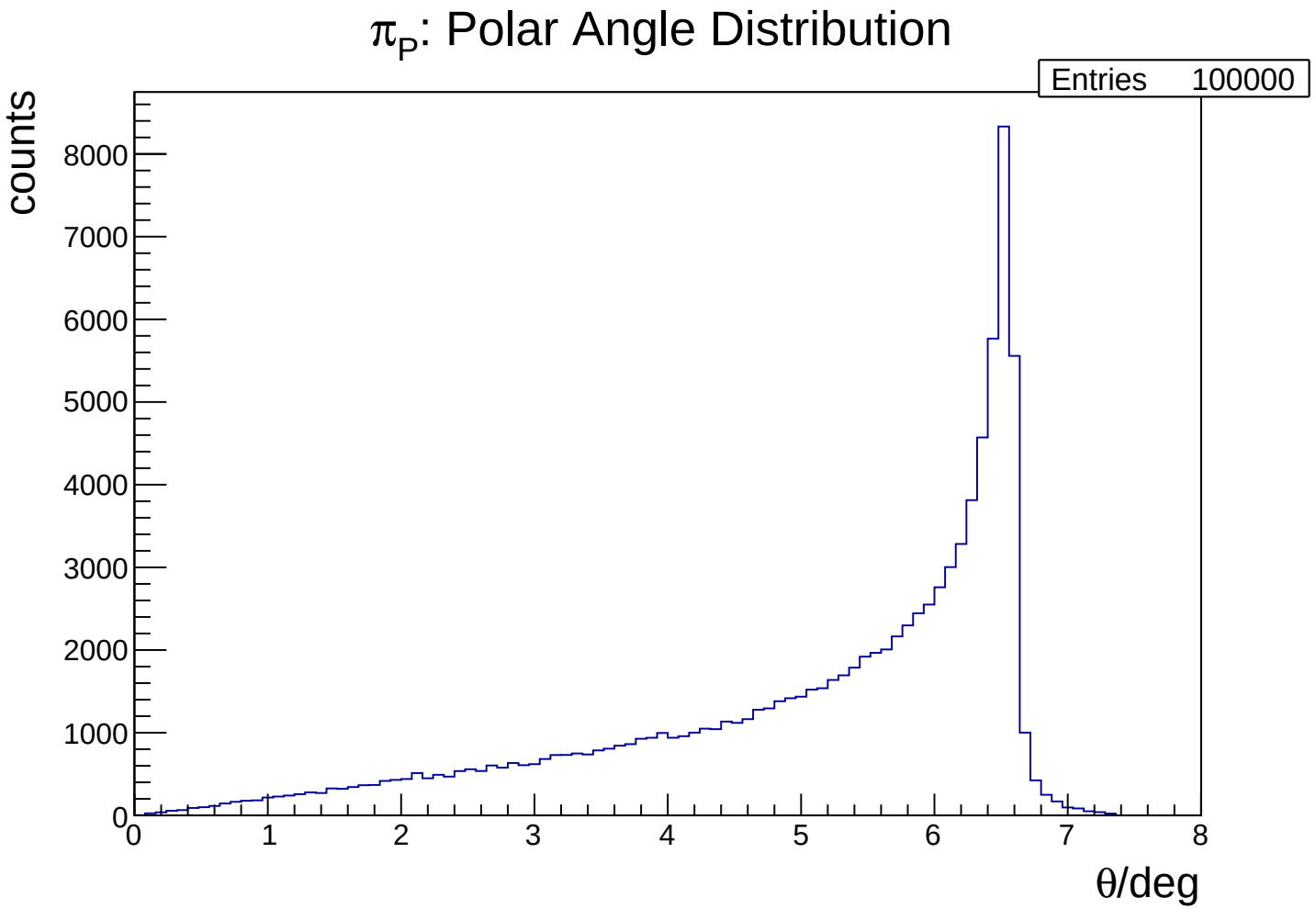
Plots



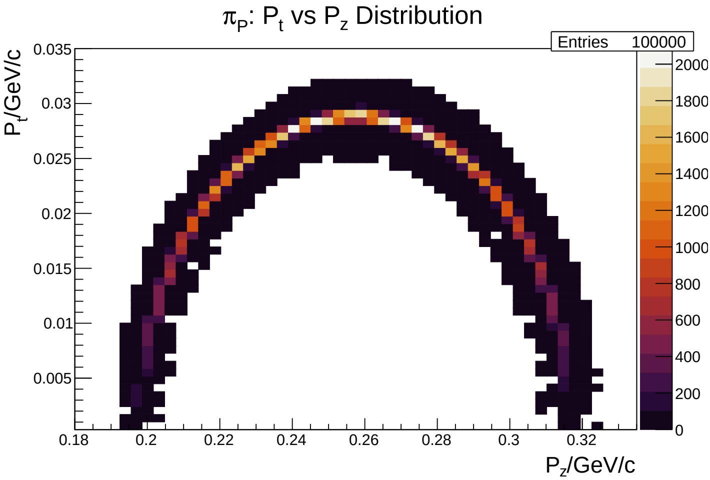
Plots



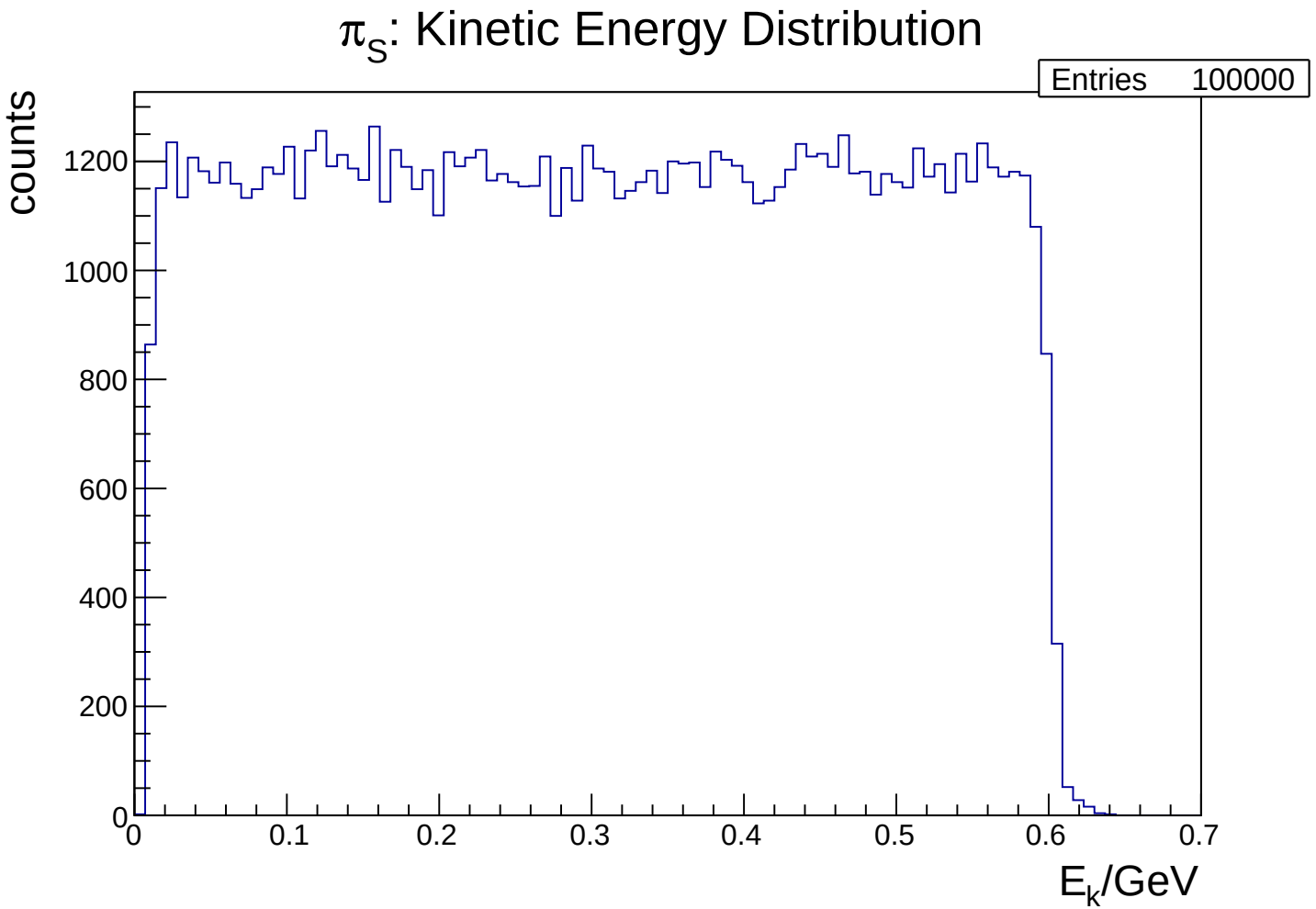
Plots



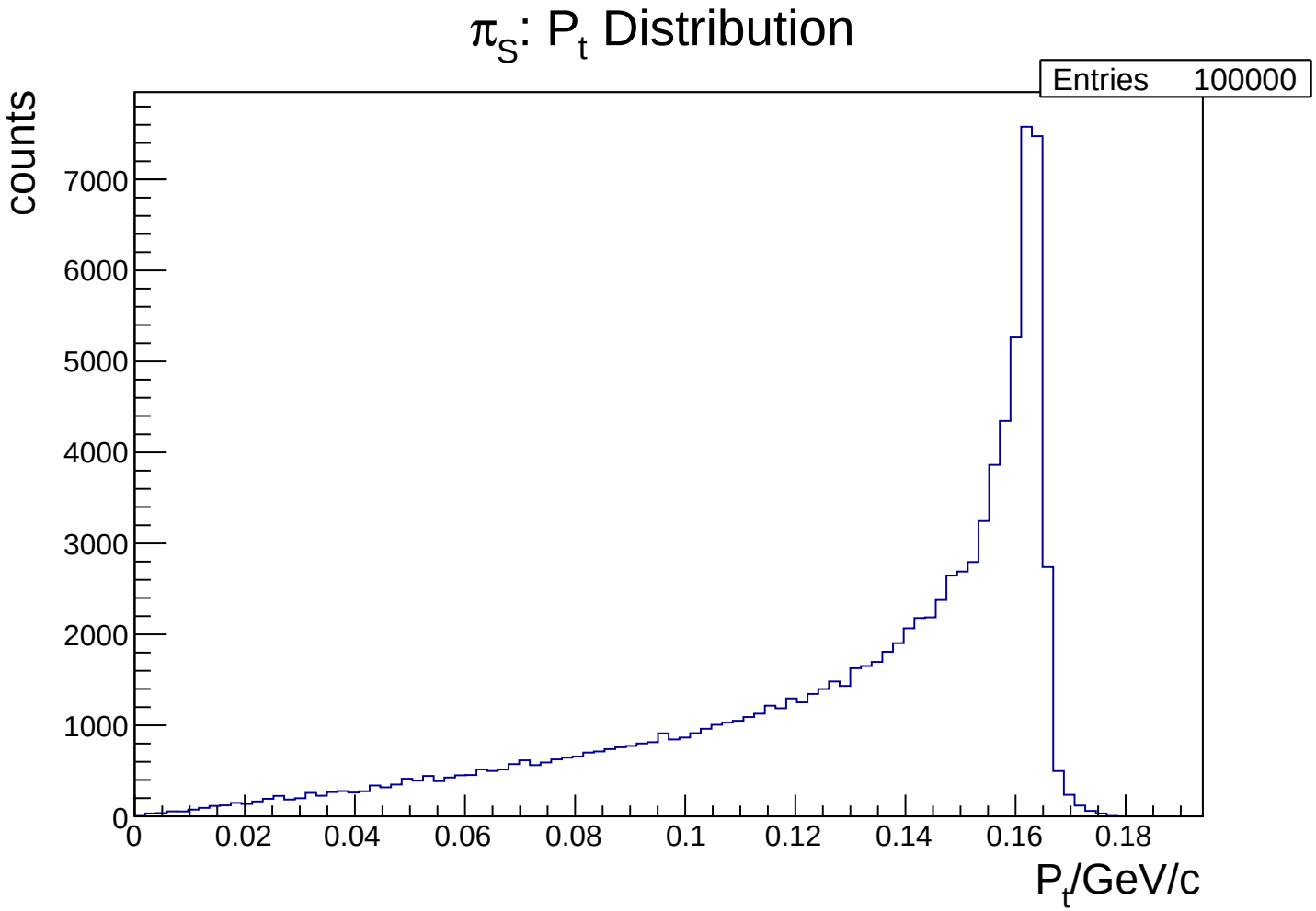
Plots



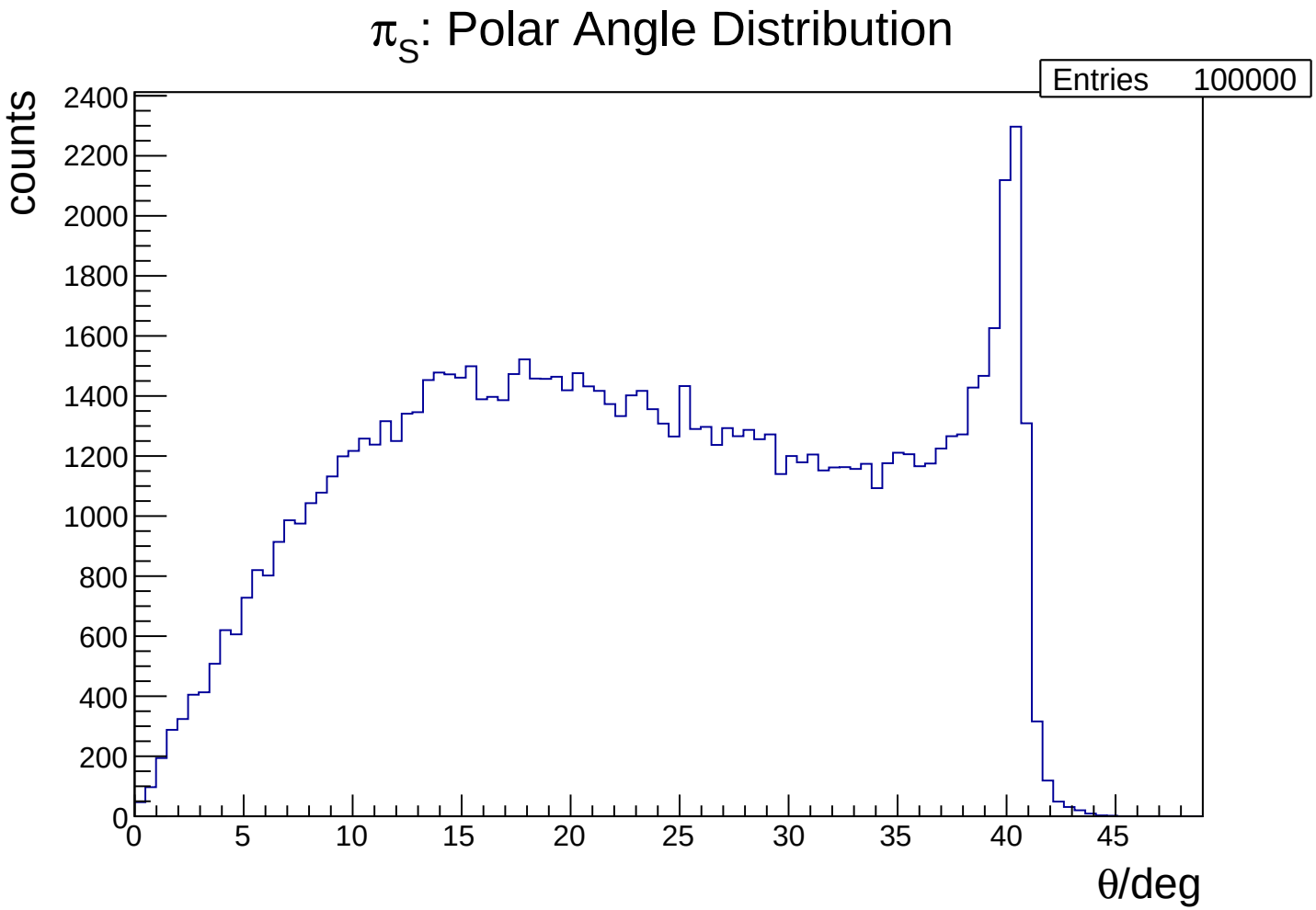
Plots



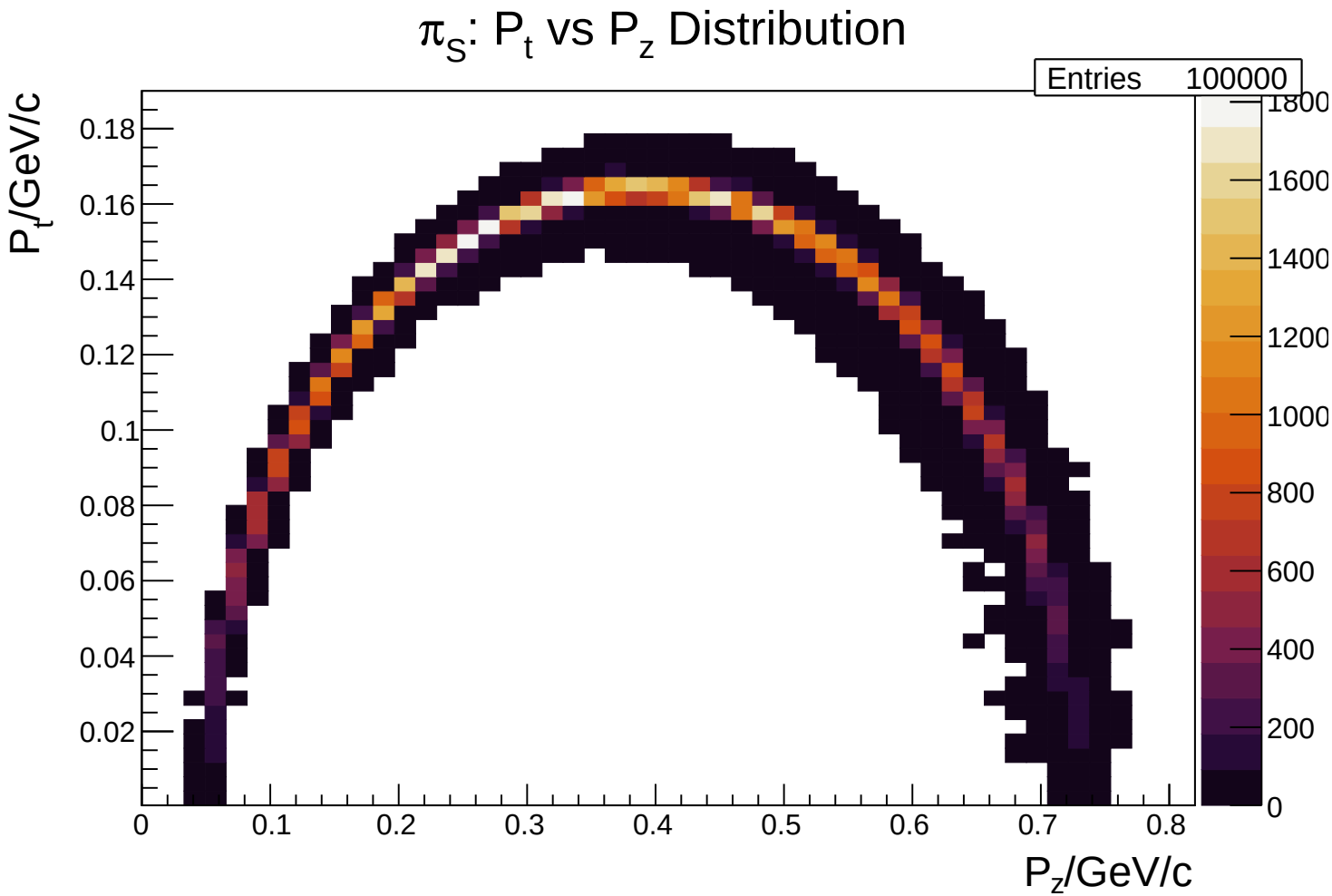
Plots



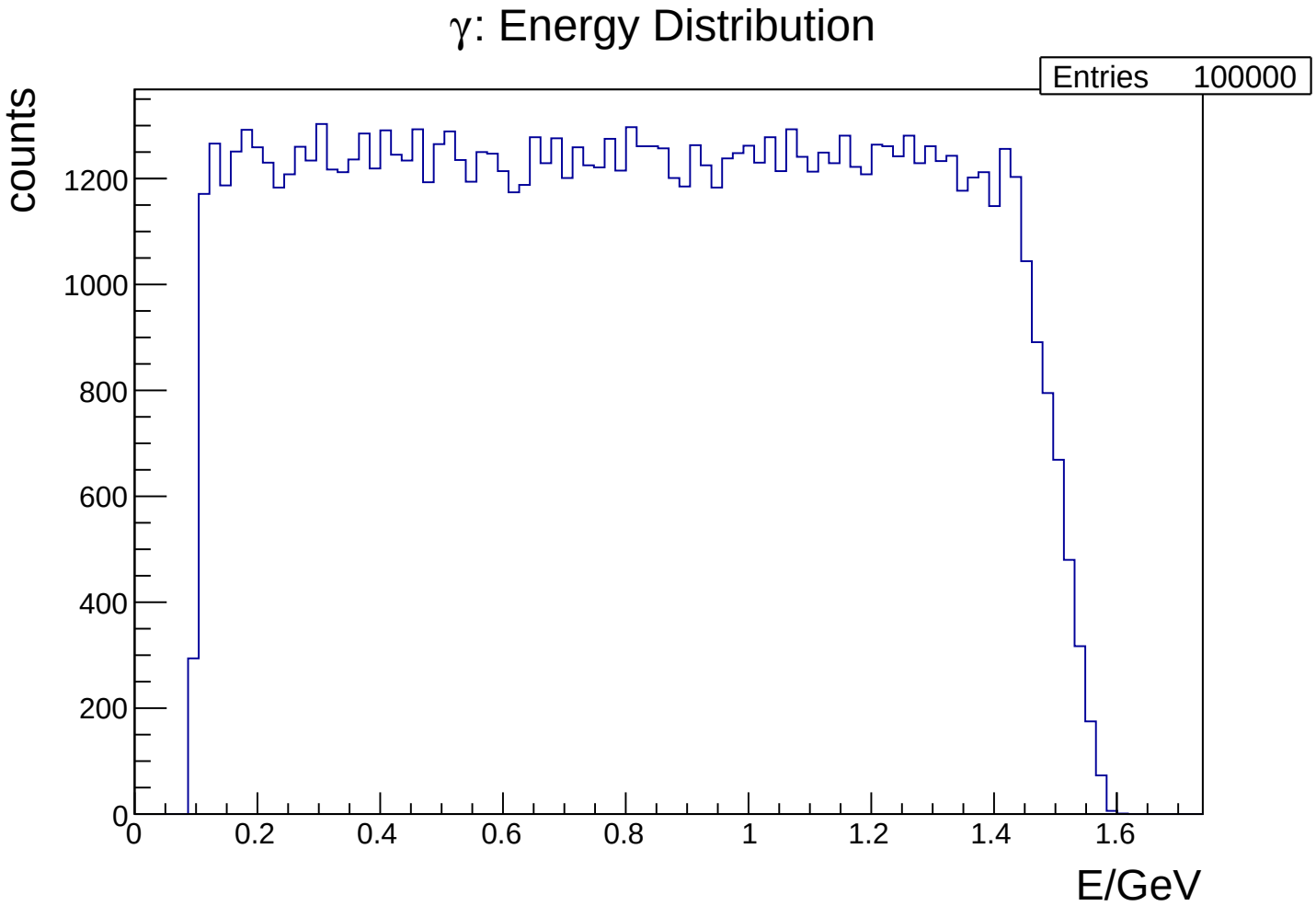
Plots



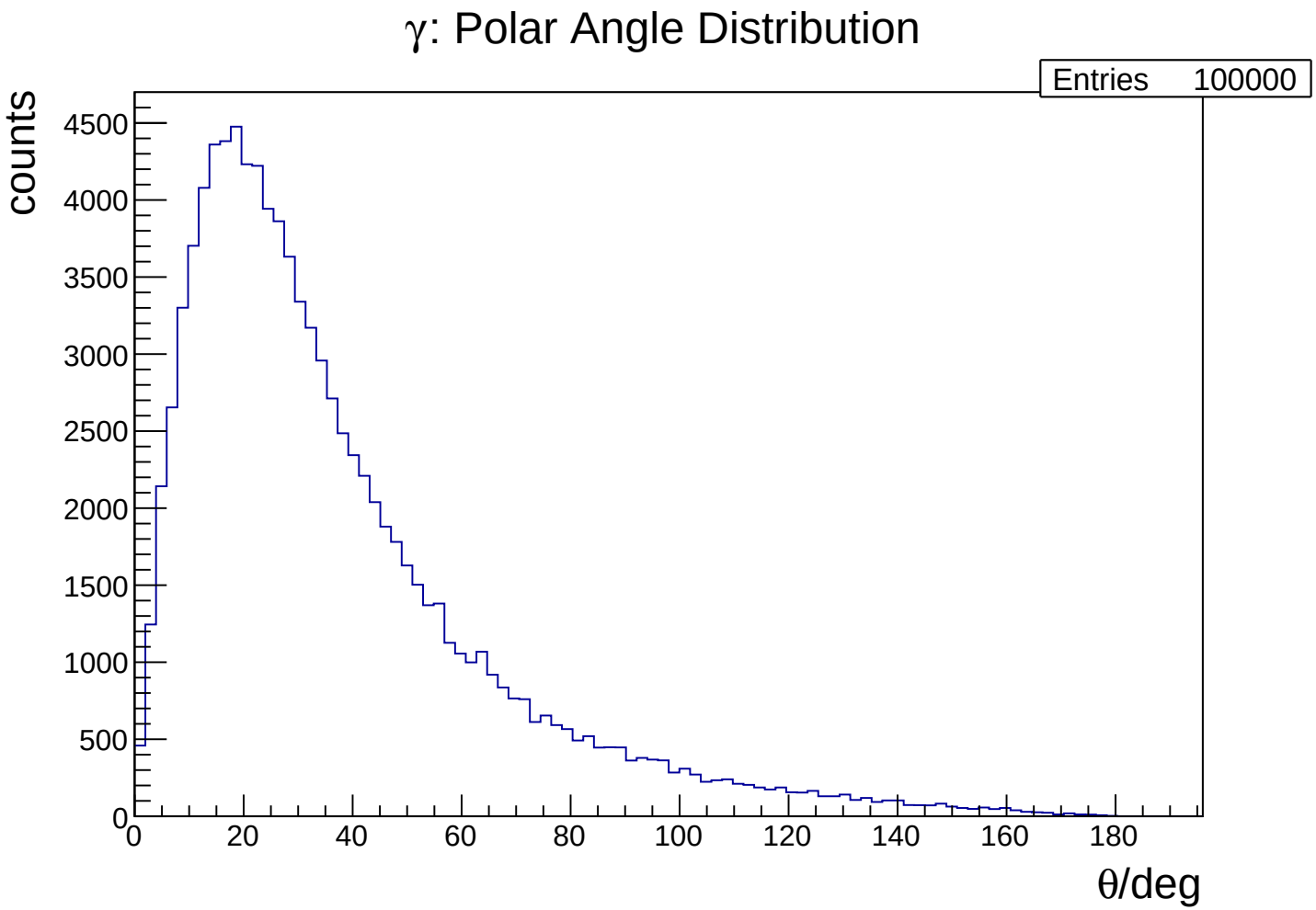
Plots



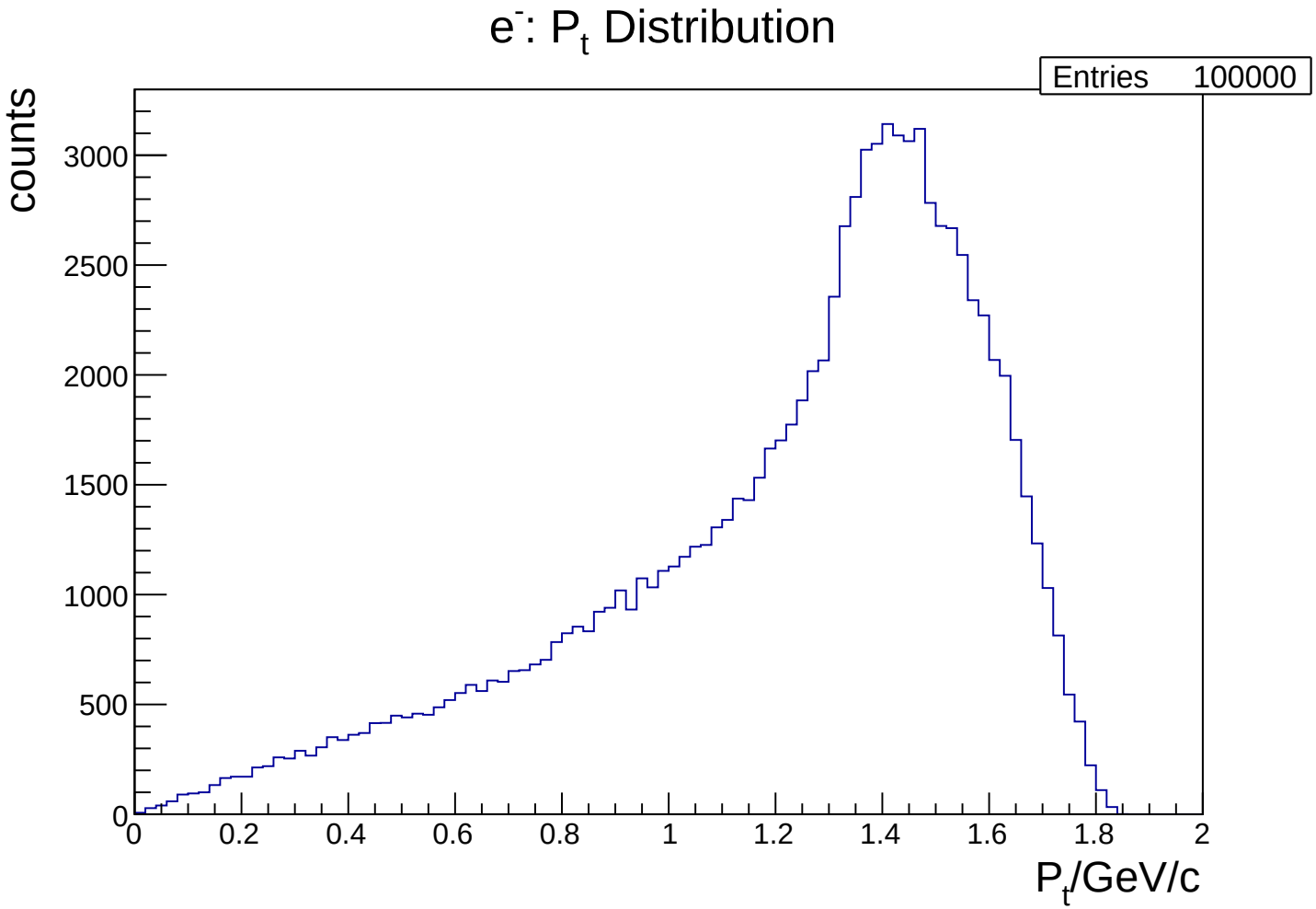
Plots



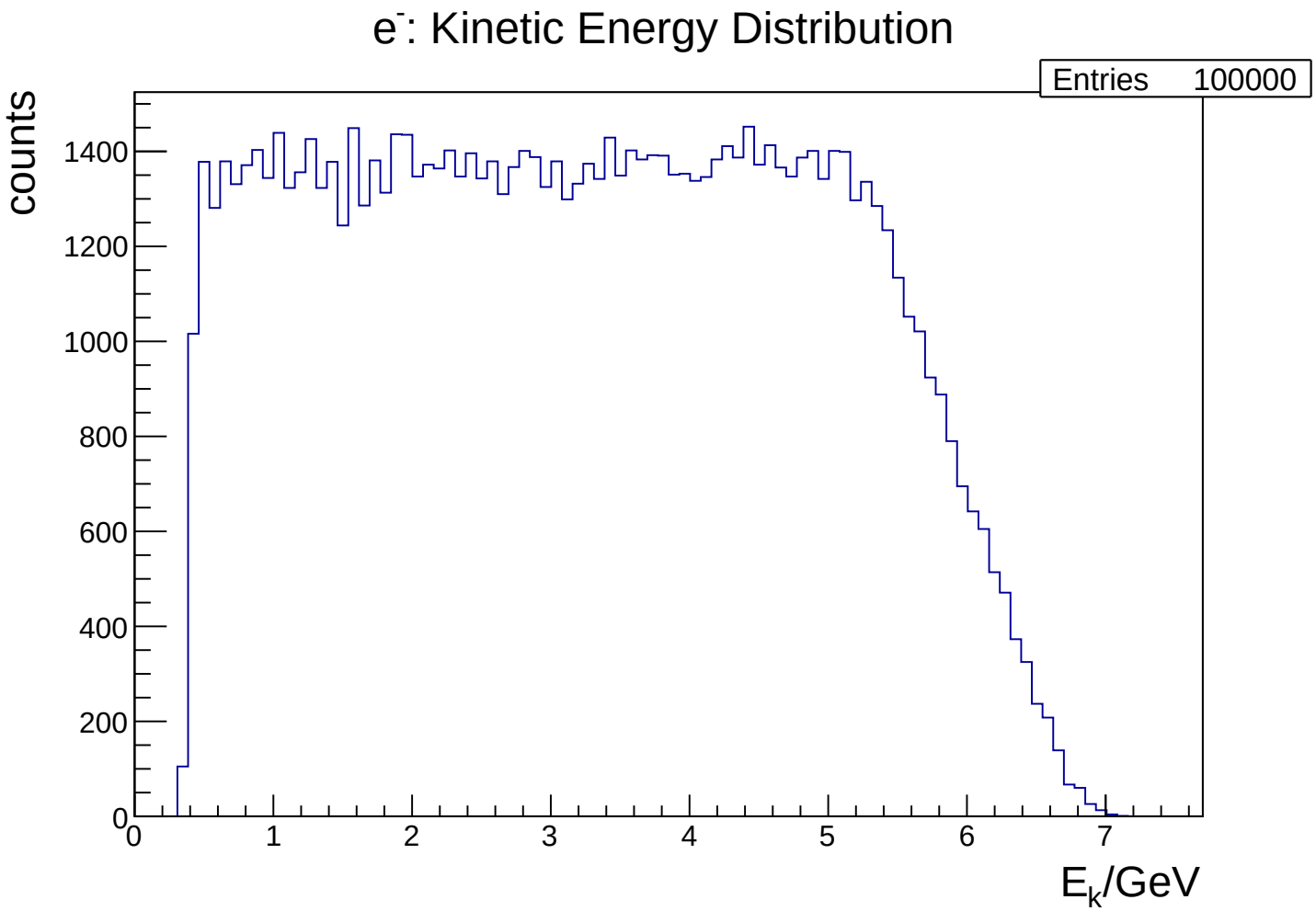
Plots



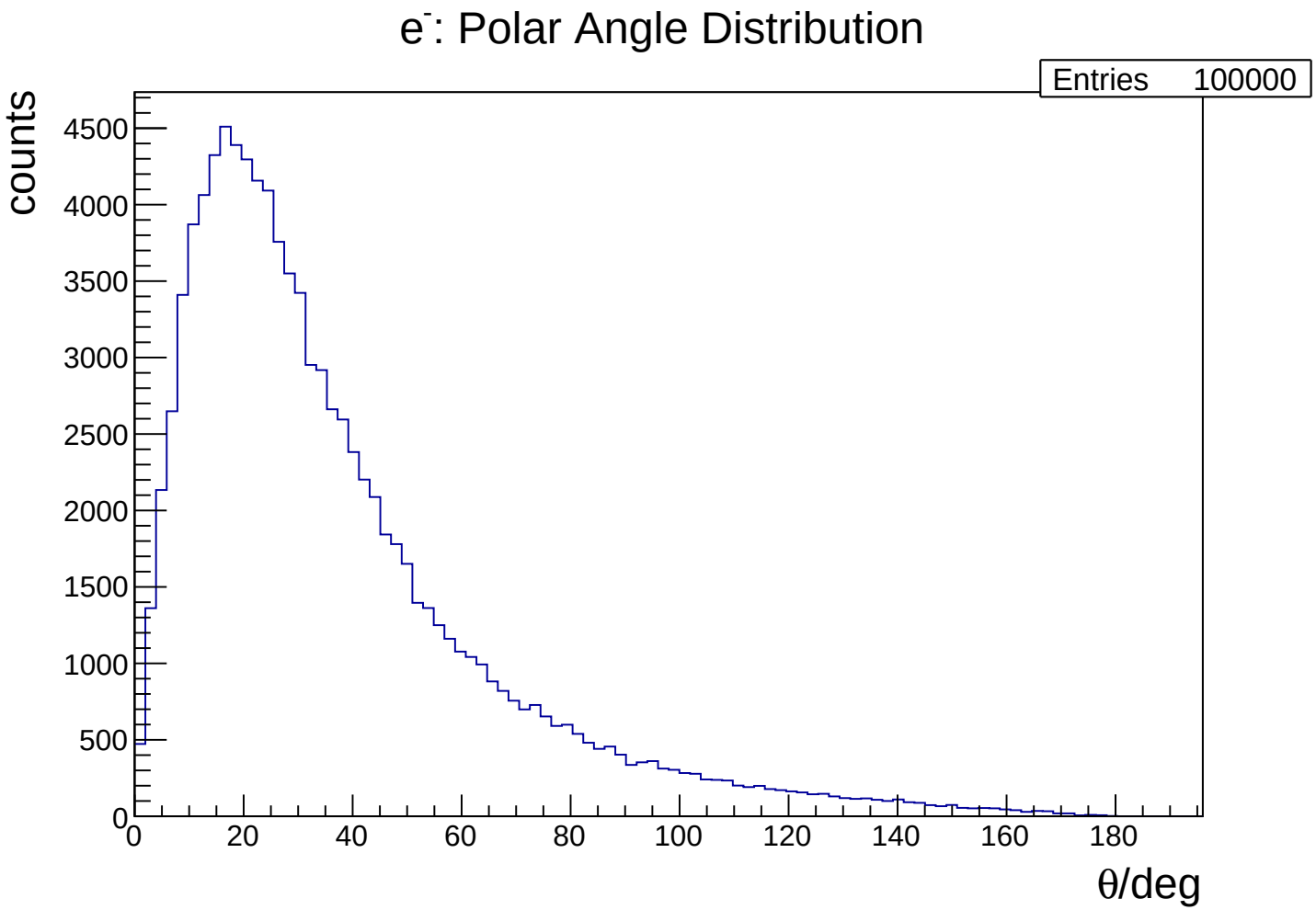
Plots



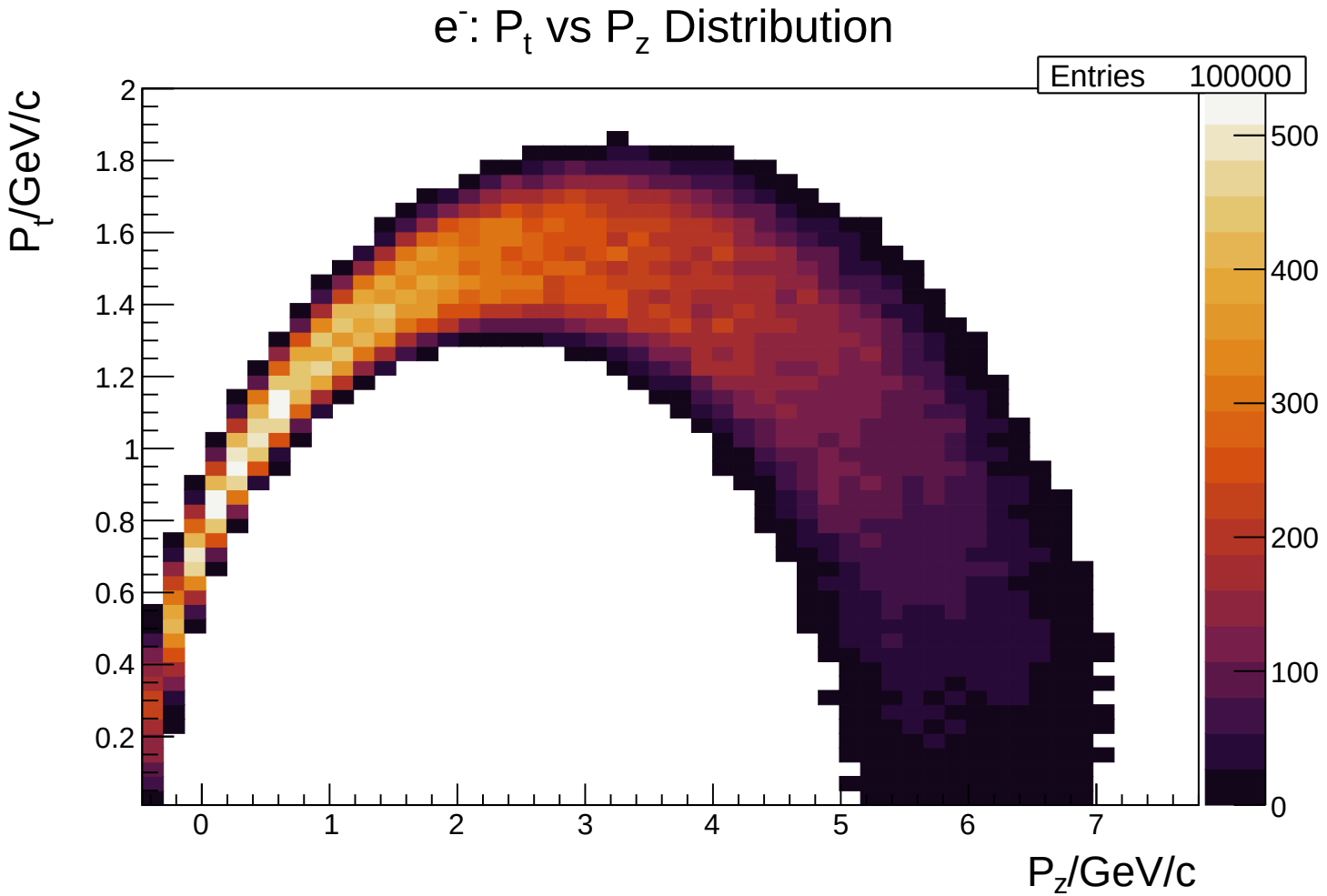
Plots



Plots


e⁻: Polar Angle Distribution
Entries 100000
counts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
180
θ/deg

Plots



Summary & Outlook

- Study X to Z transitions in the X(3872) mass scan dataset
- First look at generator-level information with EvtGen
- Next step: simulation $\bar{p}p \rightarrow Z(3730)$ in PandaRoot
  - Release: `mar15` (improved MC matching of photons)
  - Re-use existing MC samples (and disk space!)
- Additional information:
  - Internal note IN-PRP-2015-004
  - Sören's talk at CM Uppsala: Slides