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Analysis of 1.5 GeV/c $\bar{p}p \rightarrow \phi\phi$

Sep 03, 2019 | Albrecht Gillitzer

PANDA 1st Online Physics Analysis Meeting

$\bar{p}p \rightarrow \phi\phi$: Important Channel in Meson Spectroscopy

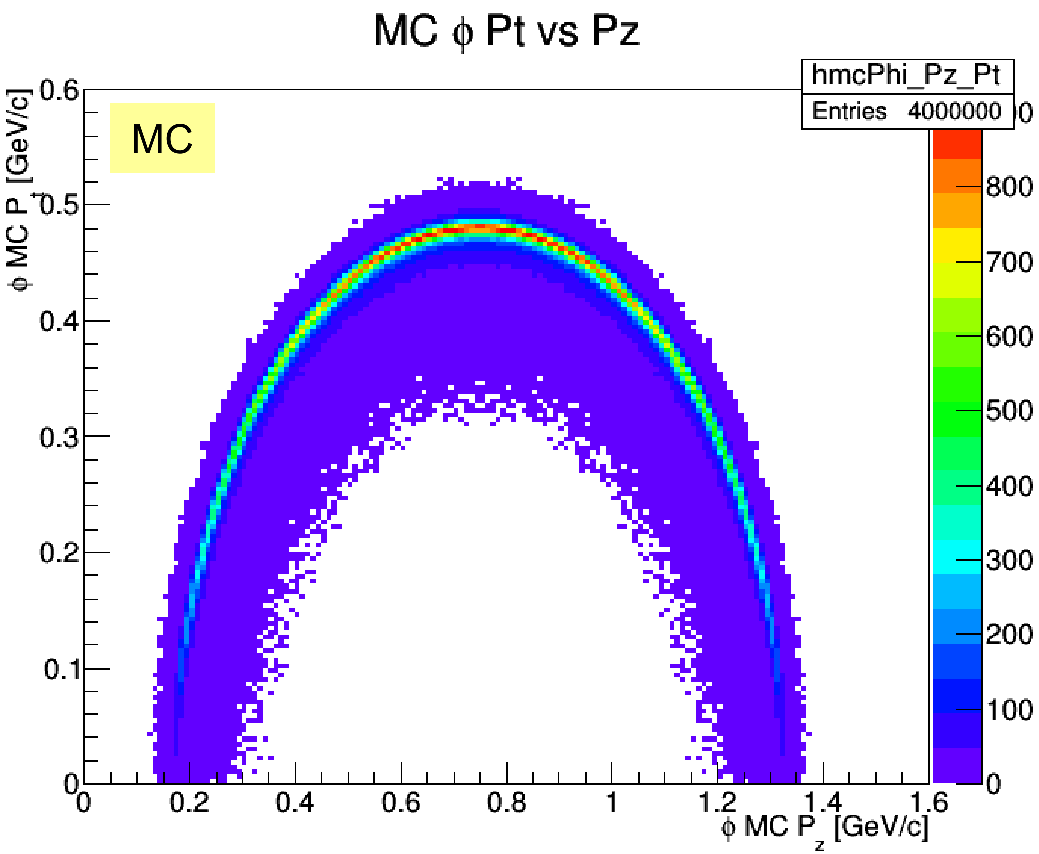
- One of the benchmark channels in the design of PANDA
- Sensitivity to tensor glueball state predicted by lattice QCD around 2.4 GeV/c^2
- $\bar{p}p \rightarrow \phi\phi$ cross section much above OZI rule estimate
- See talk at PANDA CM June 2019 by Iman Keshk:
  - very low reconstruction efficiencies for kaons at small angles
  - no proper PWA possible

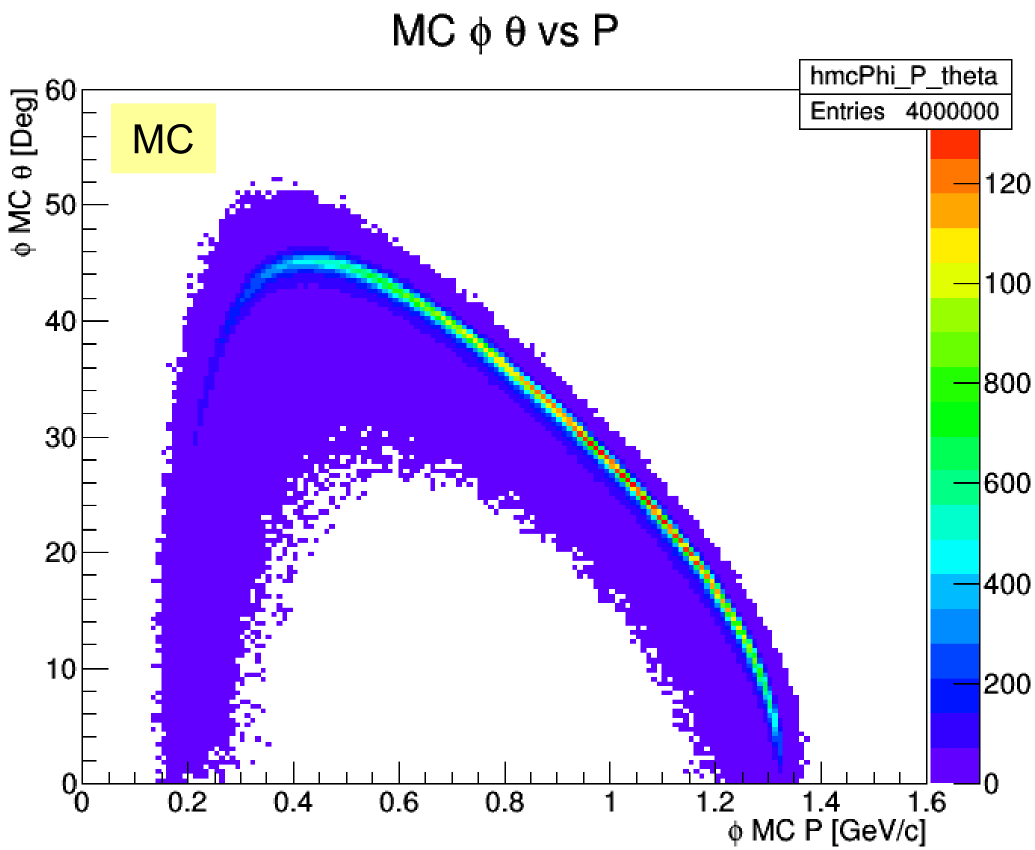
➢ Further investigations, e.g. independent simulation studies, needed

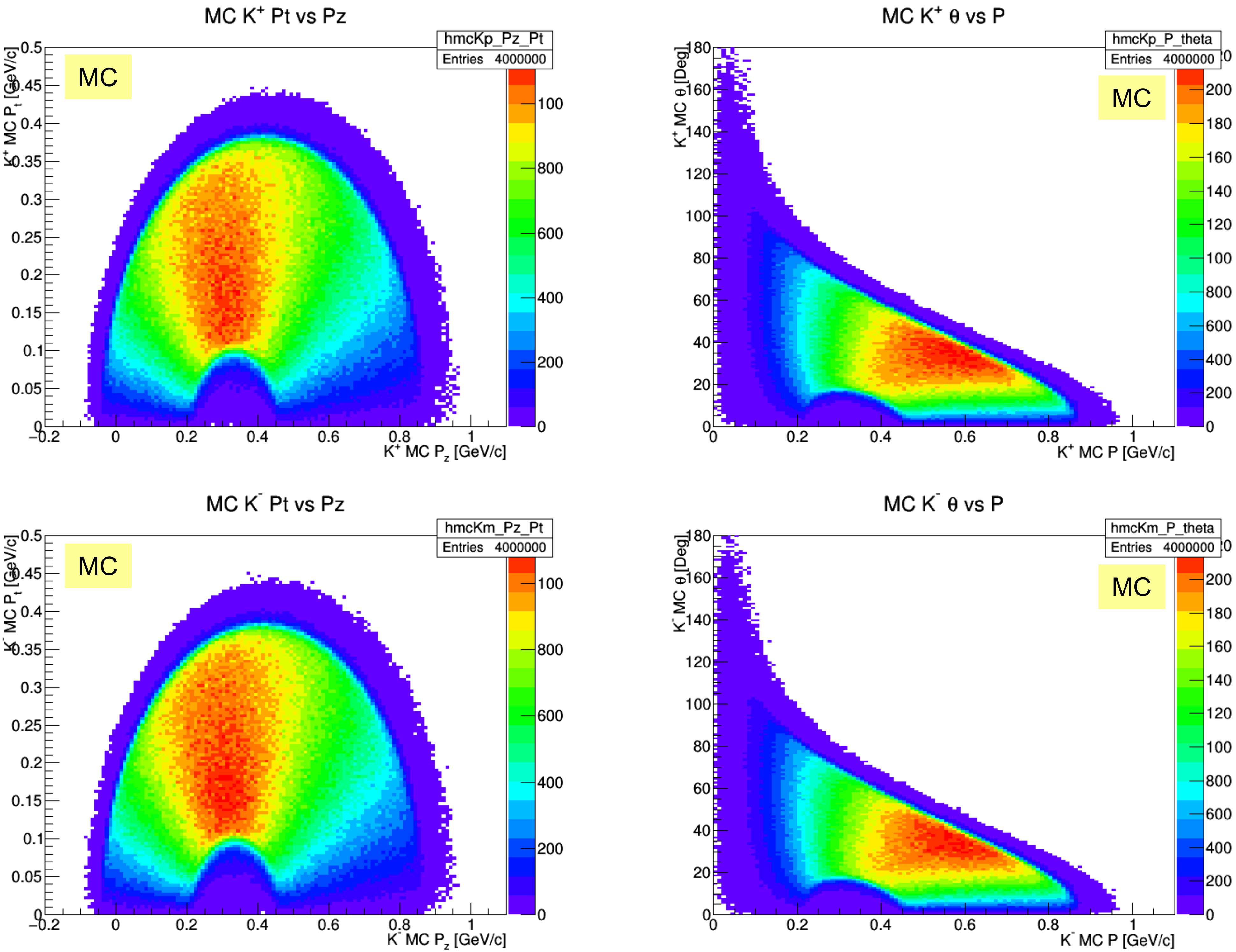
$\bar{p}p \to \phi\phi$ PandaRoot Simulation Parameters

- $p_{\bar{p}} = 1.5\ \mathrm{GeV}/c$
- 2 M events
- PHSP in $\bar{p}p \to \phi\phi$, VSS in $\phi \to K^+K^-$
- 100% decay branch for $\phi \to K^+K^-$
- Standard PANDA setup
- Standard reconstruction
- Decay tree fitter
- Open PID (no MC info on particle species used)
- PandaRoot: trunk 30122 & 30127

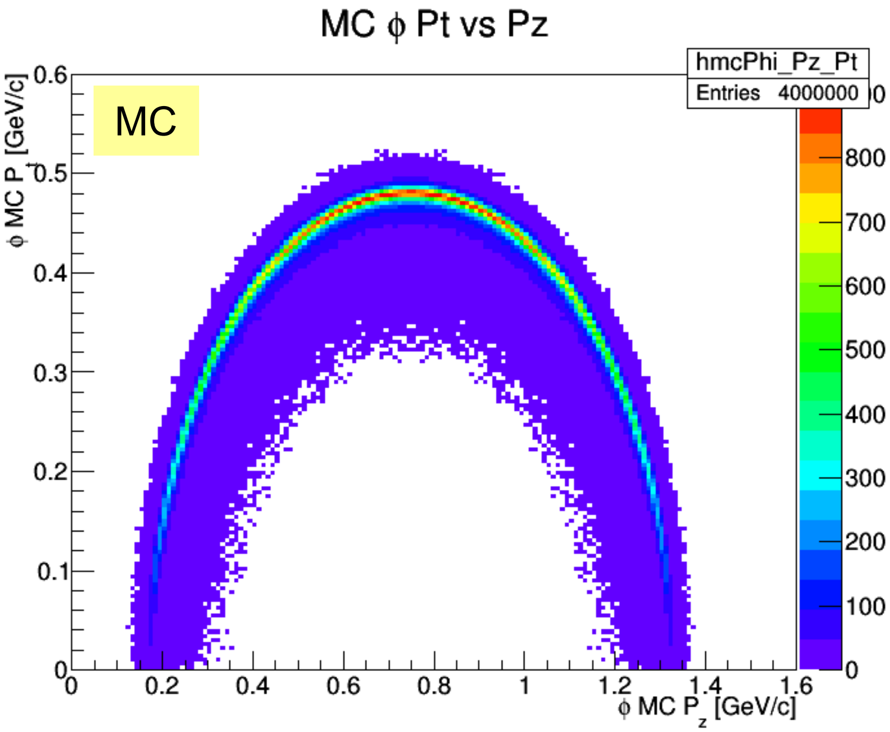
Generated MC ϕ spectra





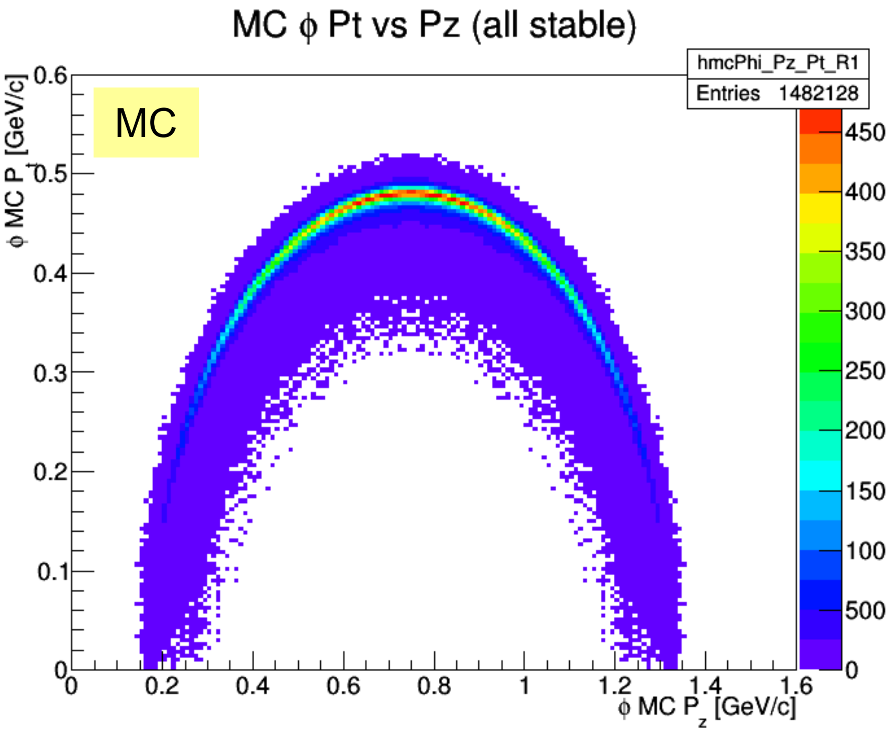


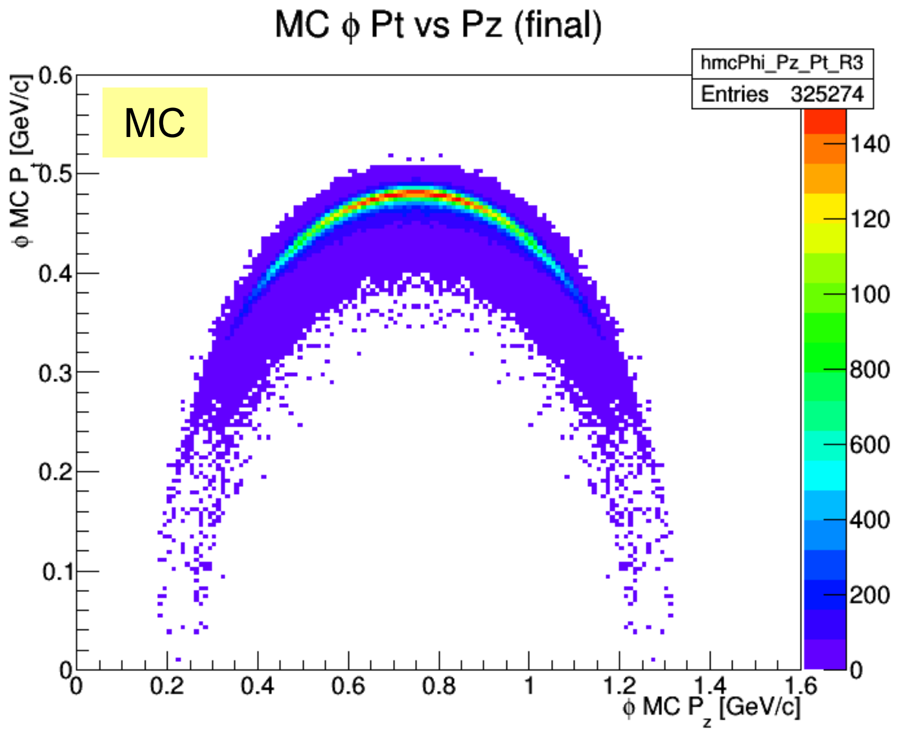
MC K+ Pt vs Pz
hmcKp_Pz_Pt
Entries 4000000
MC
K+ MC Pt [GeV/c]
K+ MC Pz [GeV/c]
MC K+ θ vs P
hmcKp_P_theta
Entries 4000000
MC
K+ MC θ [Deg]
K+ MC P [GeV/c]
MC K- Pt vs Pz
hmcKm_Pz_Pt
Entries 4000000
MC
K- MC Pt [GeV/c]
K- MC Pz [GeV/c]
MC K- θ vs P
hmcKm_P_theta
Entries 4000000
MC
K- MC θ [Deg]
K- MC P [GeV/c]

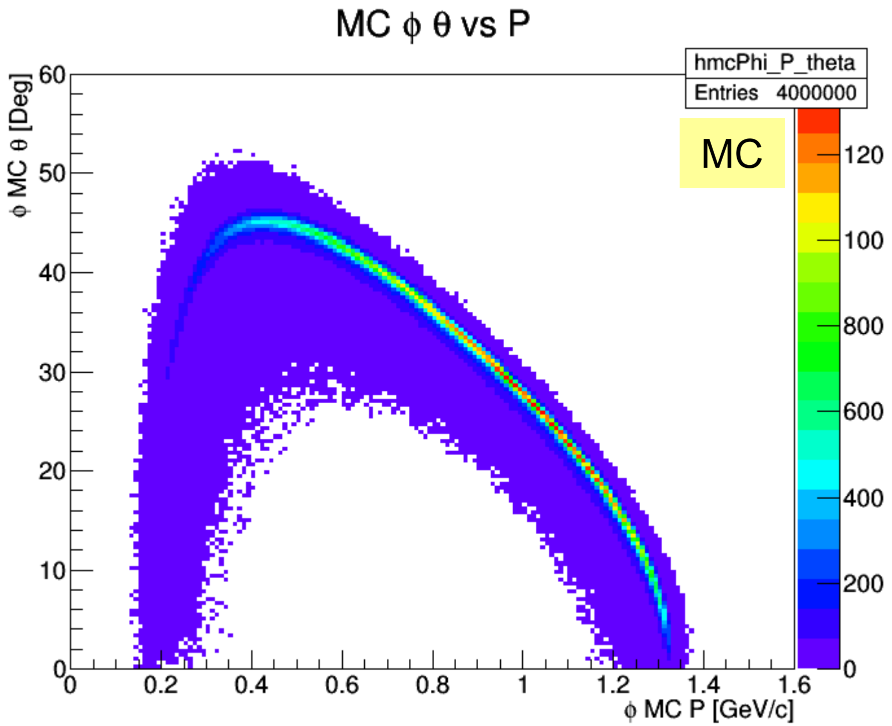


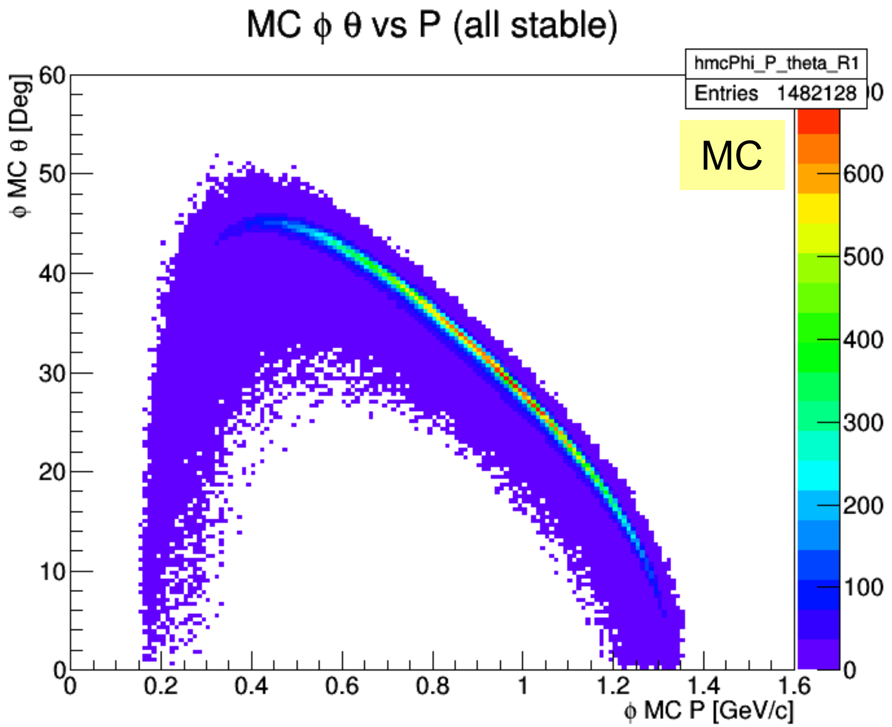
MC truth partners of finally selected events:

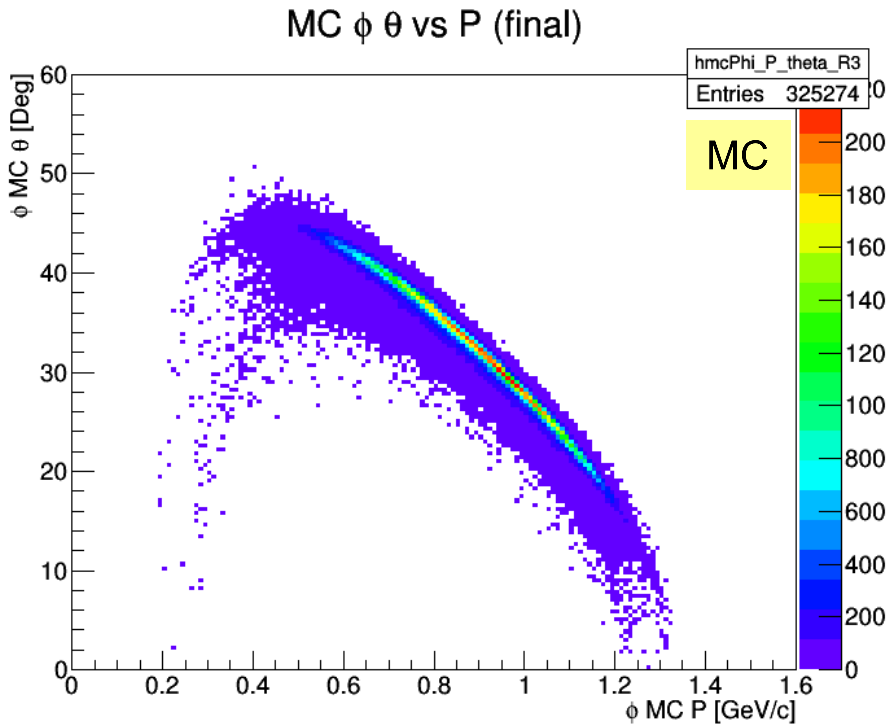
ϕ with small transverse momenta i.e. emitted at forward/backward cm angles poorly or not reconstructed

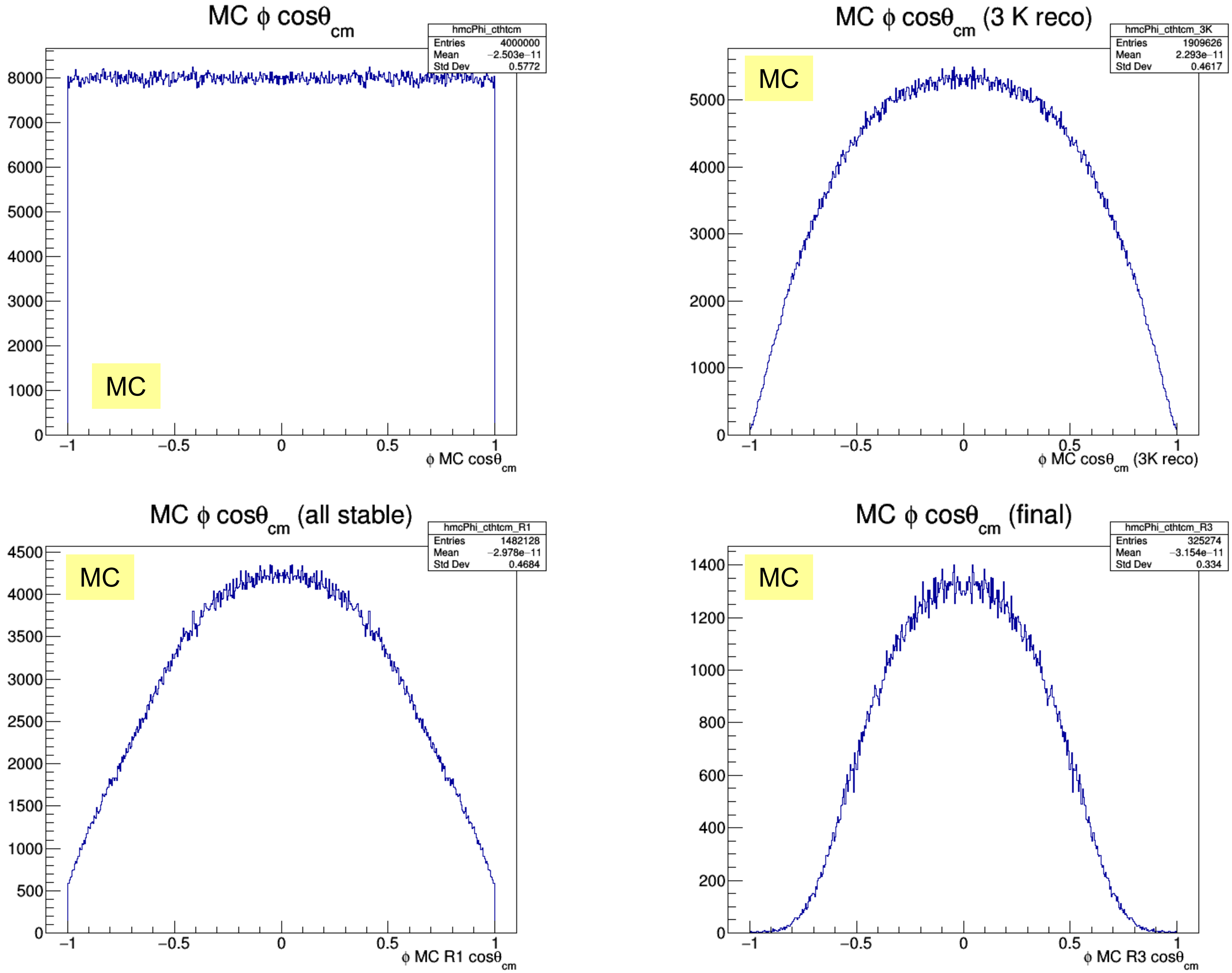





MC ϕ θ vs P
hmcPhi_P_theta
Entries 4000000
MC
ϕ MC θ [Deg]
ϕ MC P [GeV/c]

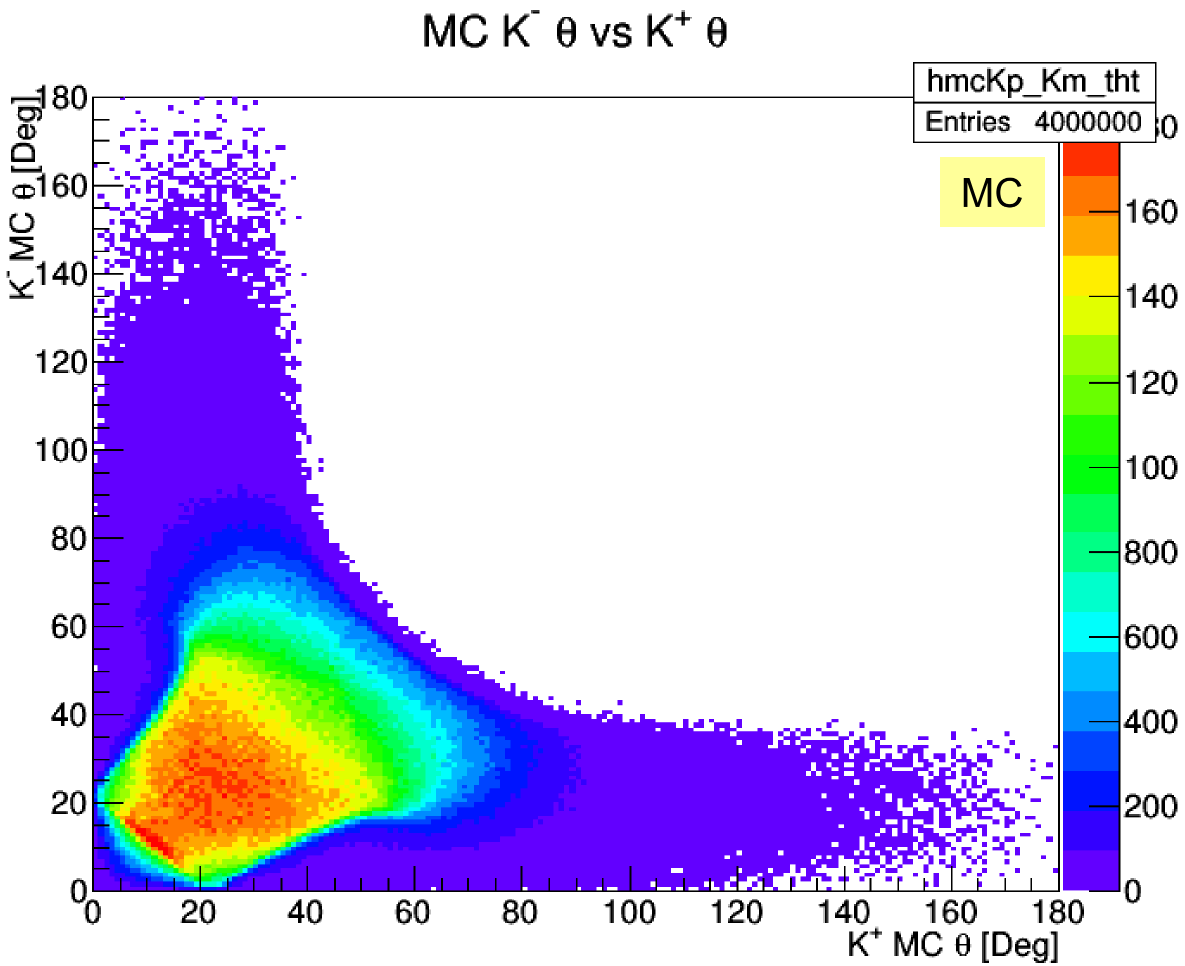

MC ϕ θ vs P (all stable)
hmcPhi_P_theta_R1
Entries 1482128
MC
ϕ MC θ [Deg]
ϕ MC P [GeV/c]


MC ϕ θ vs P (final)
hmcPhi_P_theta_R3
Entries 325274
MC
ϕ MC θ [Deg]
ϕ MC P [GeV/c]

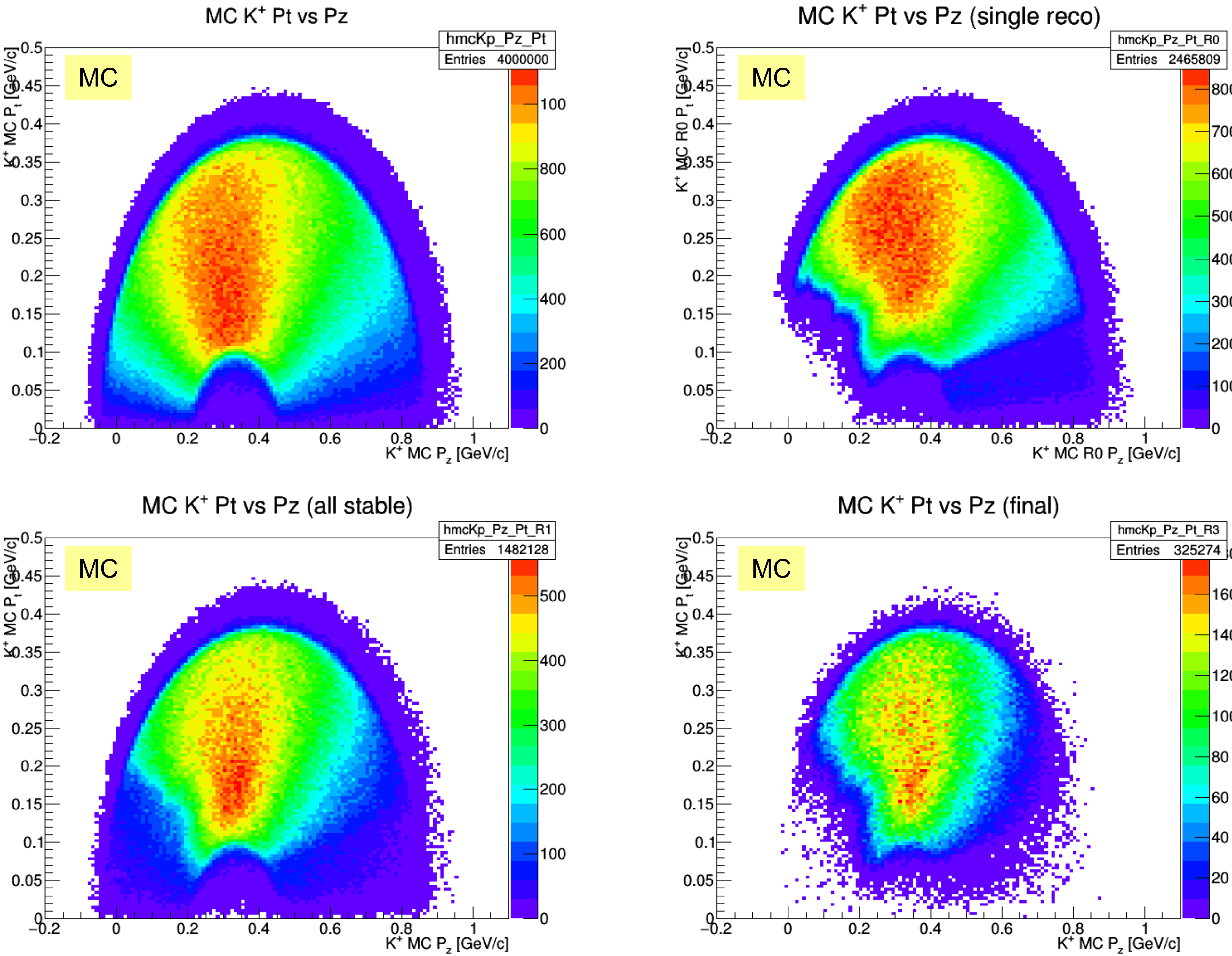


MC ϕ cosθ_cm
hmcPhi_cthtcm
Entries 4000000
Mean −2.503e−11
Std Dev 0.5772
MC
ϕ MC cosθ_cm
MC ϕ cosθ_cm (3 K reco)
hmcPhi_cthtcm_3K
Entries 1909626
Mean 2.293e−11
Std Dev 0.4617
MC
ϕ MC cosθ_cm (3K reco)
MC ϕ cosθ_cm (all stable)
hmcPhi_cthtcm_R1
Entries 1482128
Mean −2.978e−11
Std Dev 0.4684
MC
ϕ MC R1 cosθ_cm
MC ϕ cosθ_cm (final)
hmcPhi_cthtcm_R3
Entries 325274
Mean −3.154e−11
Std Dev 0.334
MC
ϕ MC R3 cosθ_cm

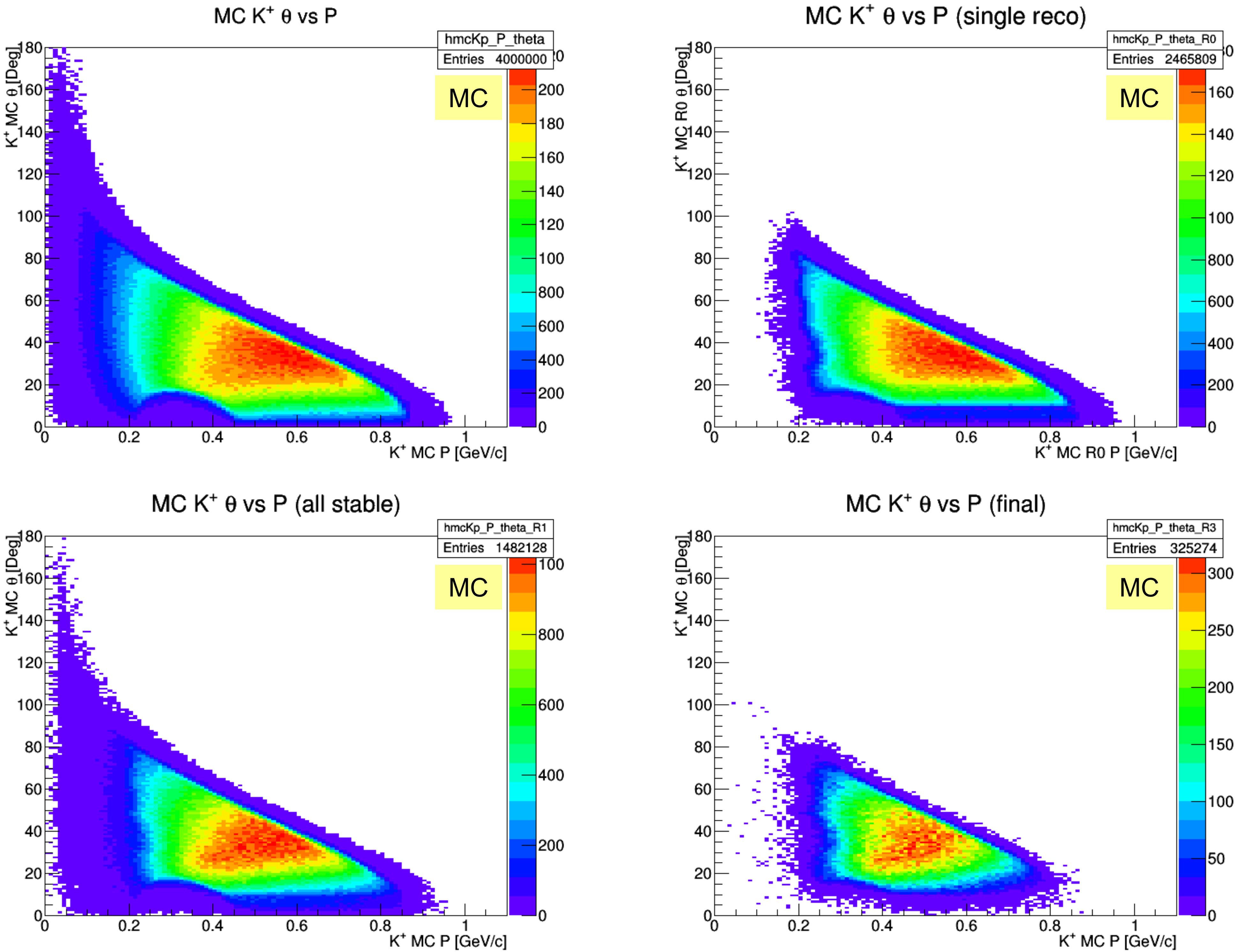
$K^+ K^-$ Pairs at Small Angles

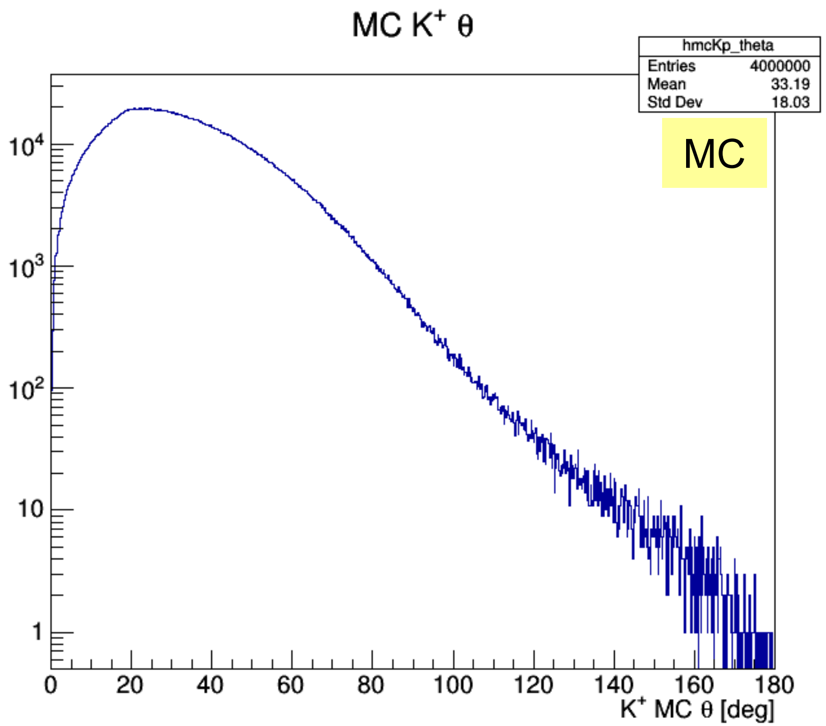


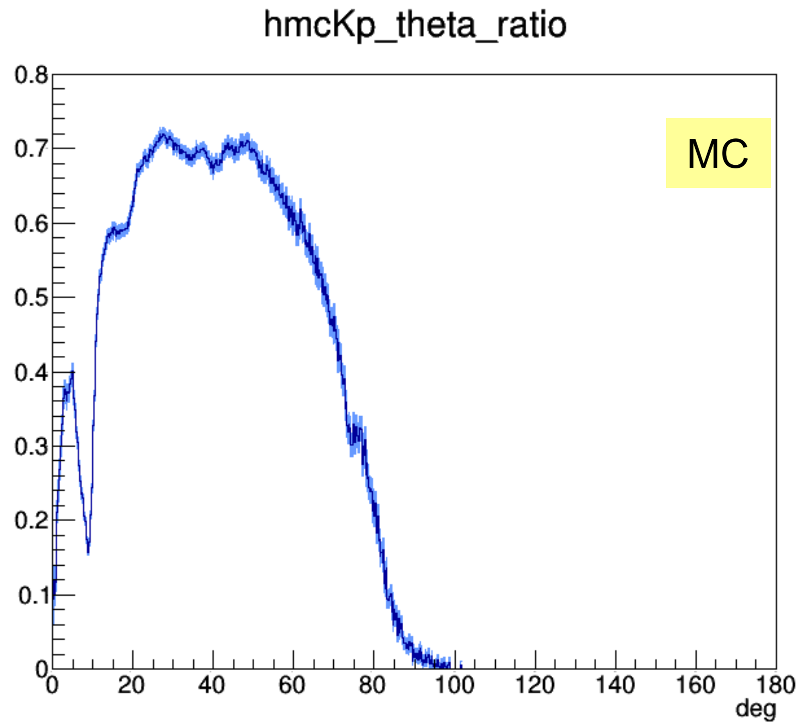
- Few events with both K^+ and K^- at $\theta < 10^o$
- Many events with both K^+ and K^- at $\theta < 20^o$

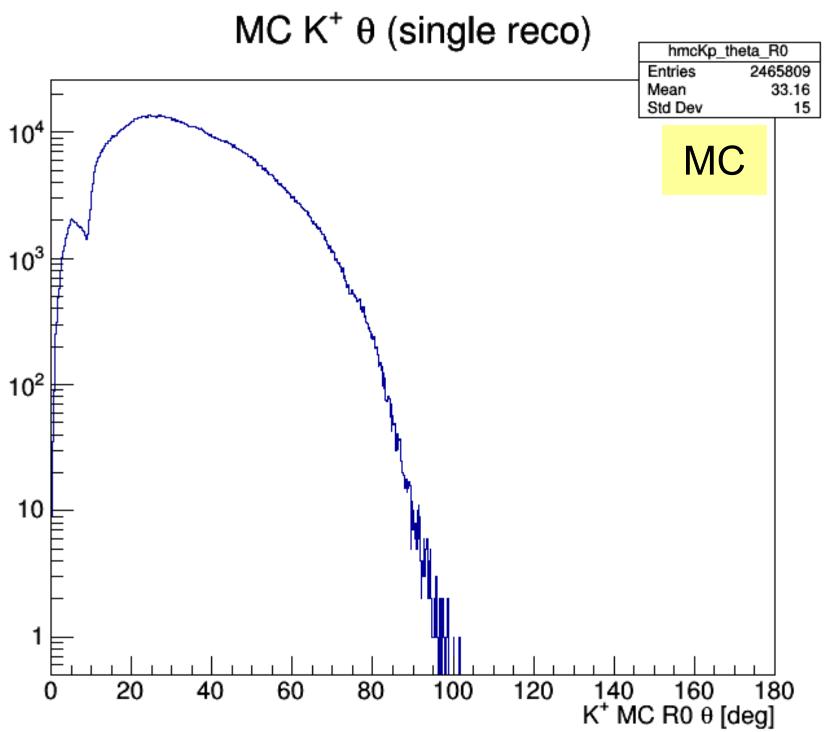


MC K+ Pt vs Pz
hmcKp_Pz_Pt
Entries 4000000
MC
K+ MC Pt [GeV/c]
K+ MC Pz [GeV/c]
MC K+ Pt vs Pz (single reco)
hmcKp_Pz_Pt_R0
Entries 2465809
MC
K+ MC R0 Pt [GeV/c]
K+ MC R0 Pz [GeV/c]
MC K+ Pt vs Pz (all stable)
hmcKp_Pz_Pt_R1
Entries 1482128
MC
K+ MC Pt [GeV/c]
K+ MC Pz [GeV/c]
MC K+ Pt vs Pz (final)
hmcKp_Pz_Pt_R3
Entries 325274
MC
K+ MC Pt [GeV/c]
K+ MC Pz [GeV/c]

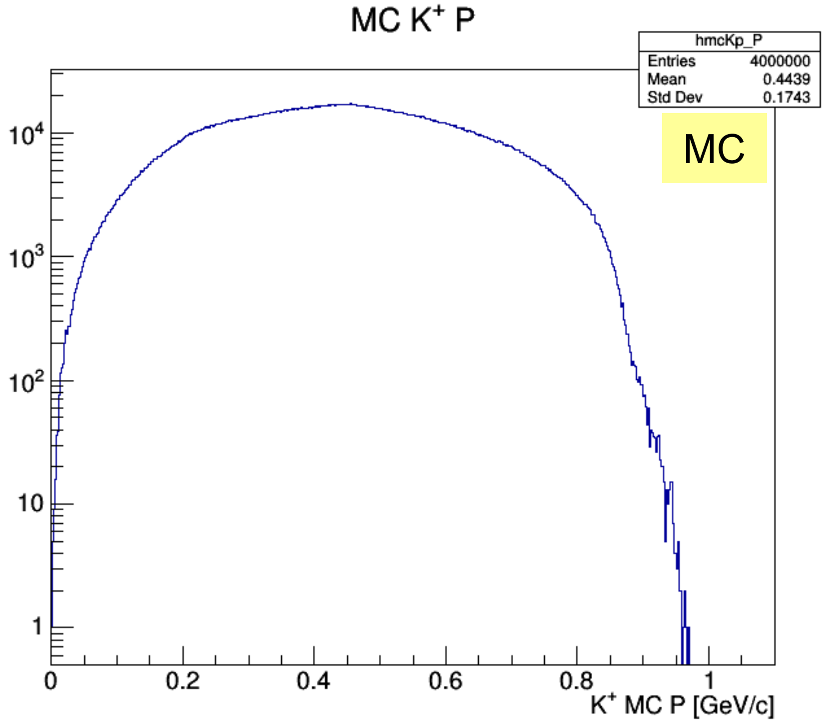

MC K+ θ vs P
hmcKp_P_theta
Entries 4000000
MC
K+ MC θ [Deg]
K+ MC P [GeV/c]
MC K+ θ vs P (single reco)
hmcKp_P_theta_R0
Entries 2465809
MC
K+ MC R0 θ [Deg]
K+ MC R0 P [GeV/c]
MC K+ θ vs P (all stable)
hmcKp_P_theta_R1
Entries 1482128
MC
K+ MC θ [Deg]
K+ MC P [GeV/c]
MC K+ θ vs P (final)
hmcKp_P_theta_R3
Entries 325274
MC
K+ MC θ [Deg]
K+ MC P [GeV/c]

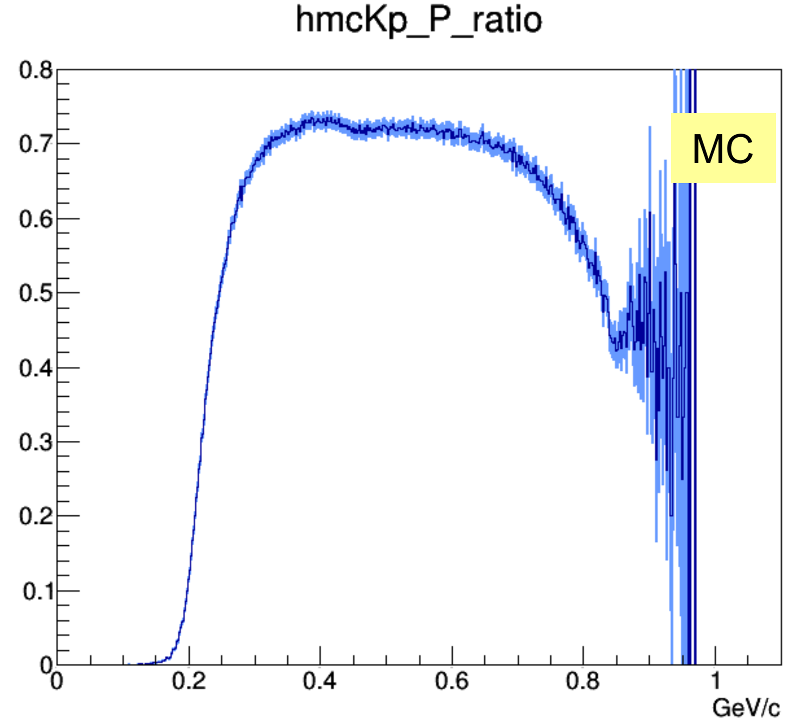


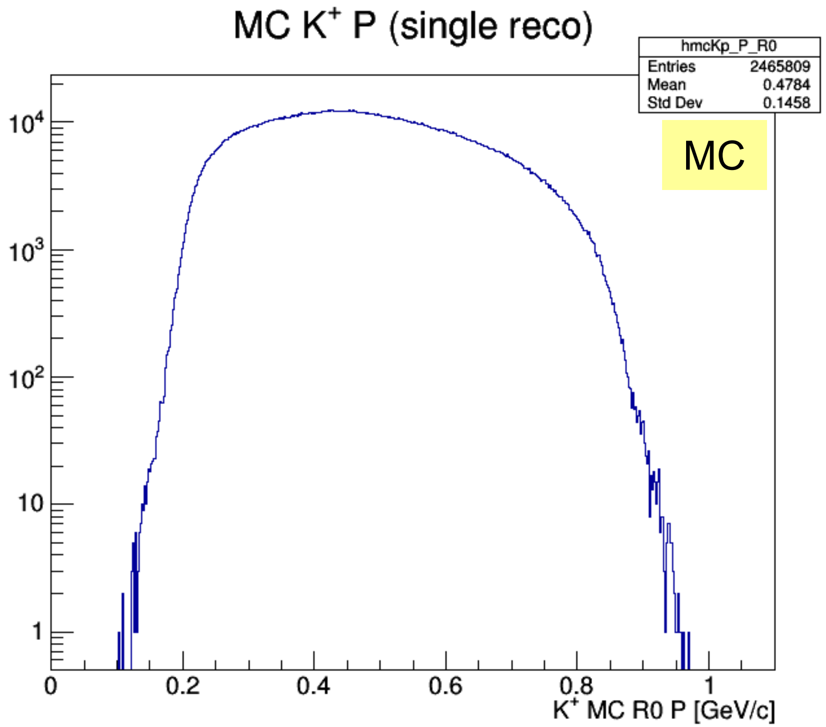




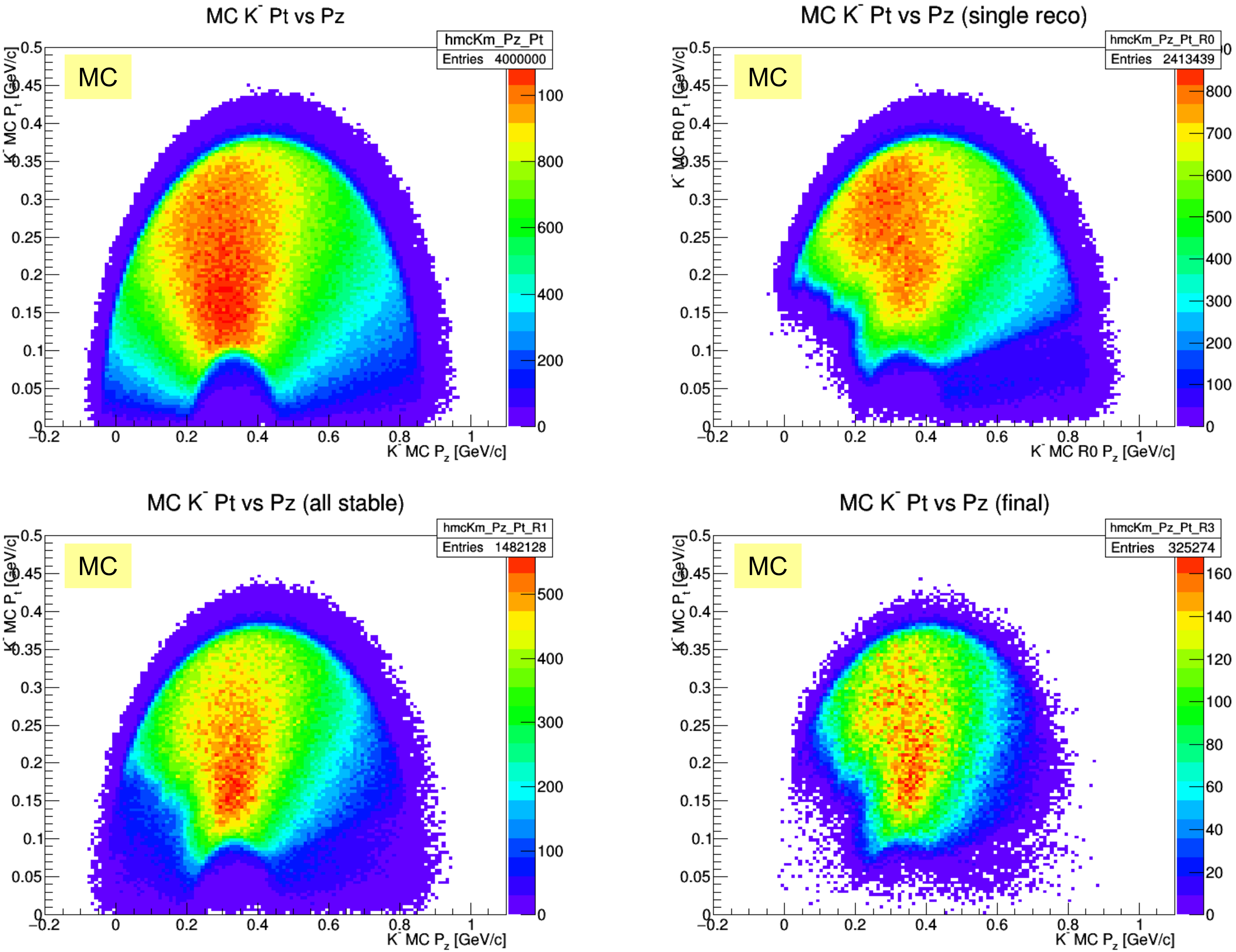
No detection efficiency at polar angles above ~90^o



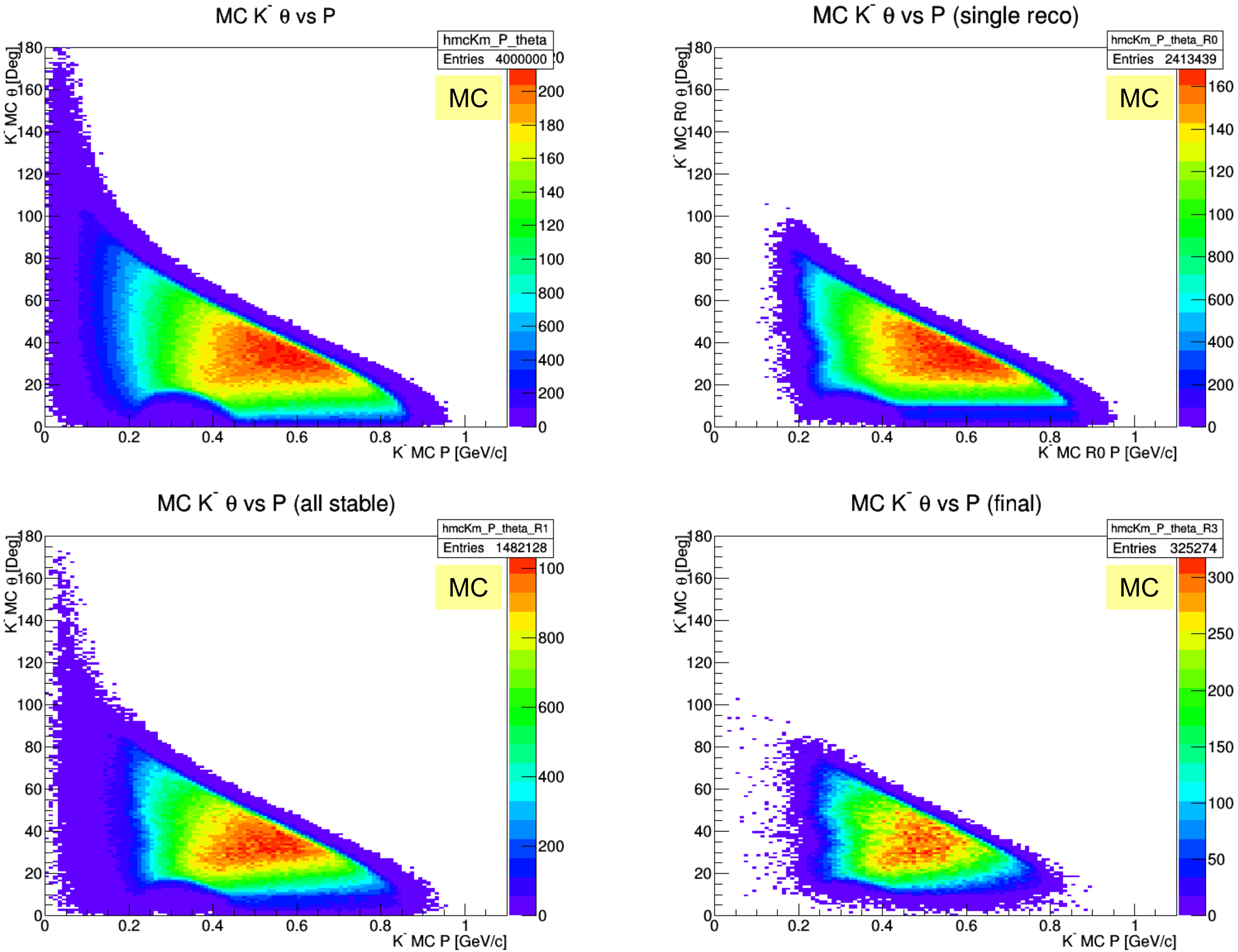




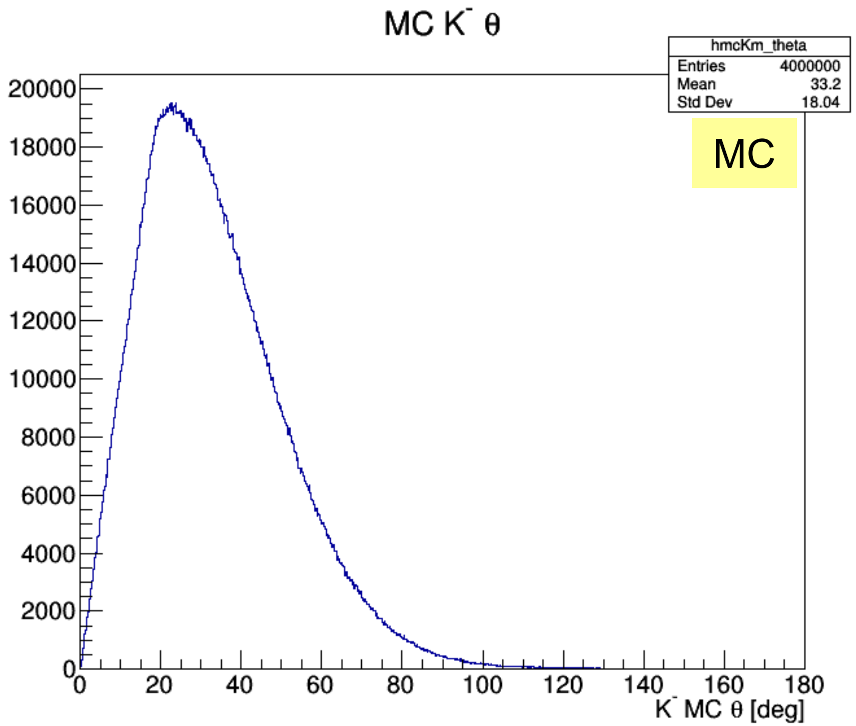
No detection efficiency at momenta below ~0.2 GeV/c

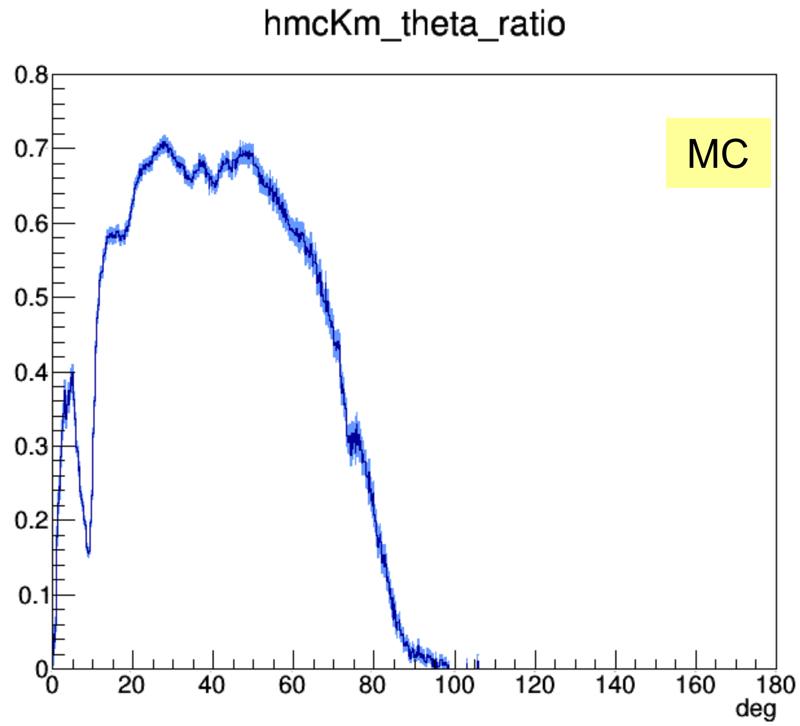


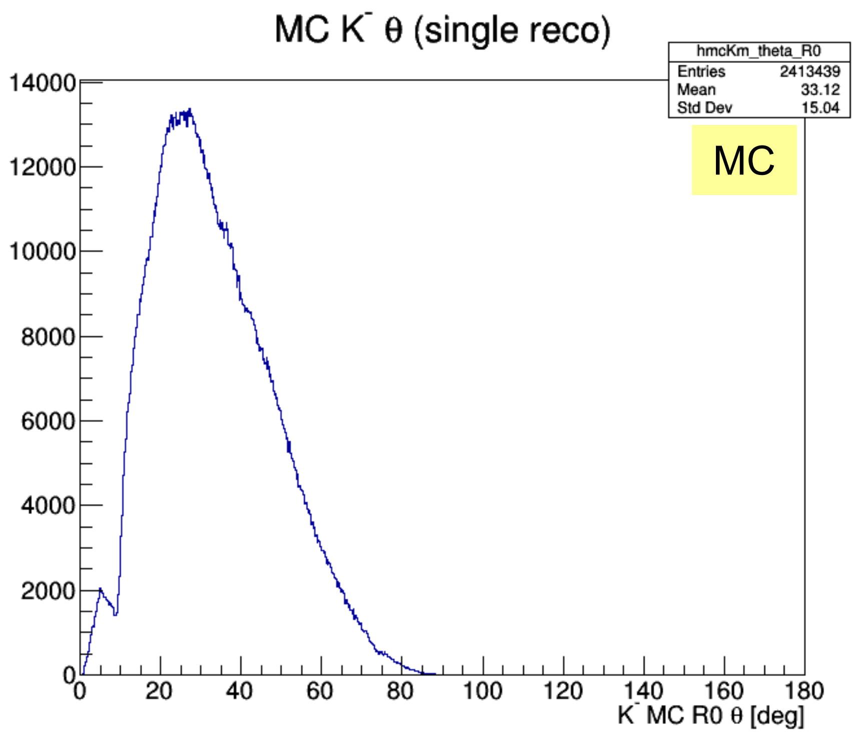
MC K⁻ Pt vs Pz
hmcKm_Pz_Pt
Entries 4000000
MC
K⁻ MC P_t [GeV/c]
K⁻ MC P_z [GeV/c]
MC K⁻ Pt vs Pz (single reco)
hmcKm_Pz_Pt_R0
Entries 2413439
MC
K⁻ MC R0 P_t [GeV/c]
K⁻ MC R0 P_z [GeV/c]
MC K⁻ Pt vs Pz (all stable)
hmcKm_Pz_Pt_R1
Entries 1482128
MC
K⁻ MC P_t [GeV/c]
K⁻ MC P_z [GeV/c]
MC K⁻ Pt vs Pz (final)
hmcKm_Pz_Pt_R3
Entries 325274
MC
K⁻ MC P_t [GeV/c]
K⁻ MC P_z [GeV/c]



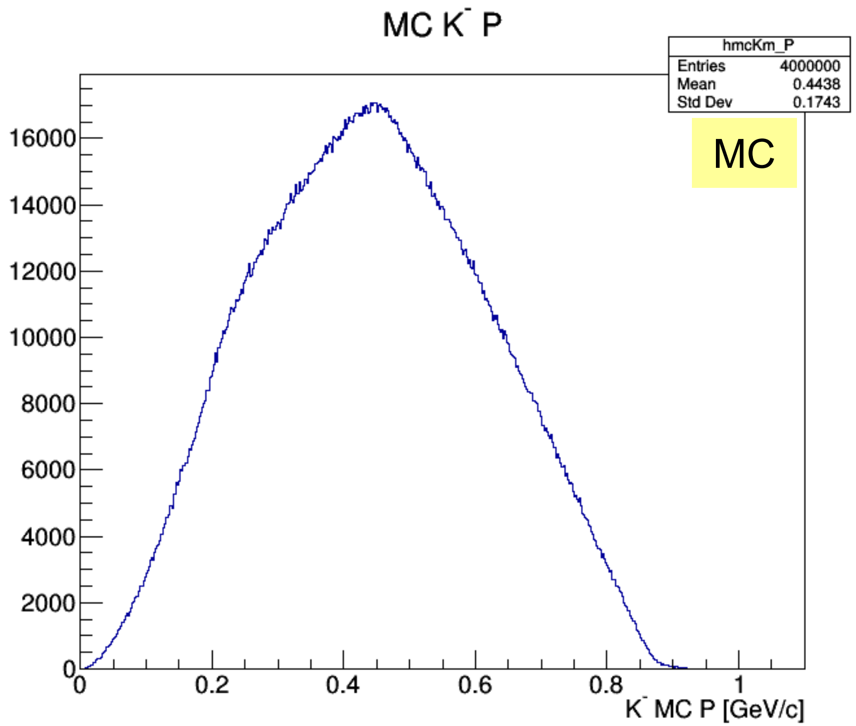
MC K⁻ θ vs P
hmcKm_P_theta
Entries 4000000
MC
K⁻ MC θ [Deg]
K⁻ MC P [GeV/c]
MC K⁻ θ vs P (single reco)
hmcKm_P_theta_R0
Entries 2413439
MC
K⁻ MC R0 θ [Deg]
K⁻ MC R0 P [GeV/c]
MC K⁻ θ vs P (all stable)
hmcKm_P_theta_R1
Entries 1482128
MC
K⁻ MC θ [Deg]
K⁻ MC P [GeV/c]
MC K⁻ θ vs P (final)
hmcKm_P_theta_R3
Entries 325274
MC
K⁻ MC θ [Deg]
K⁻ MC P [GeV/c]

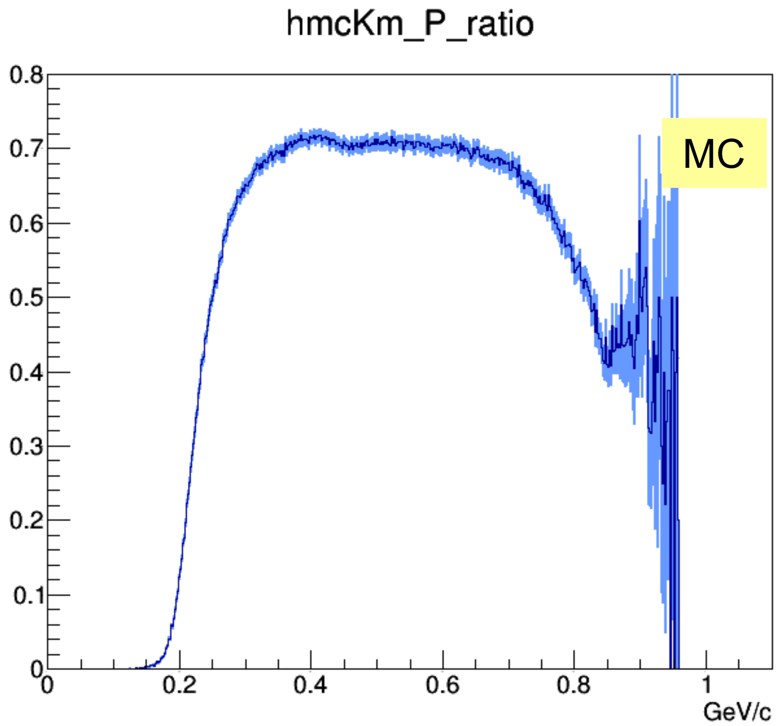


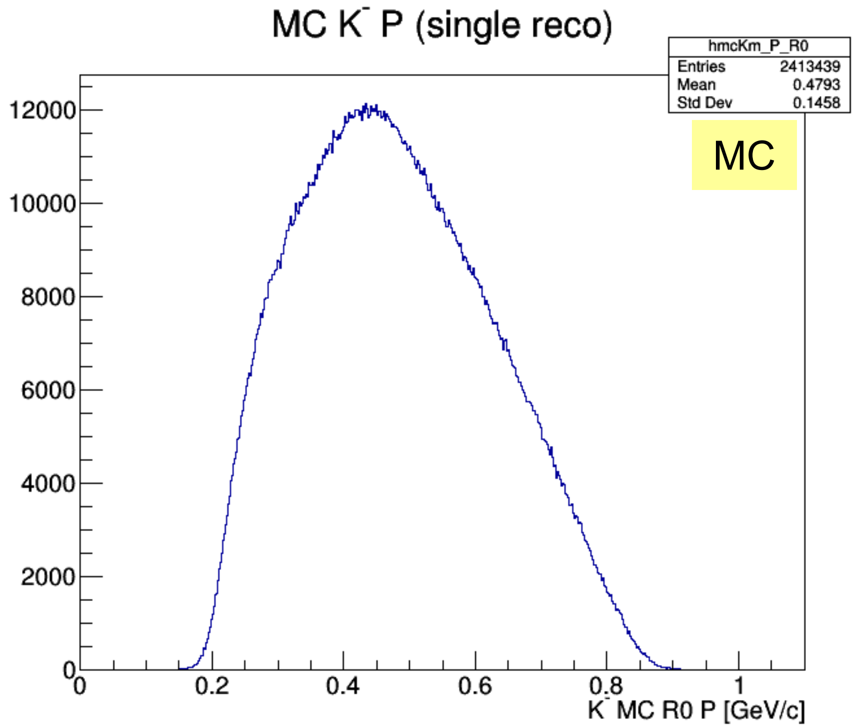




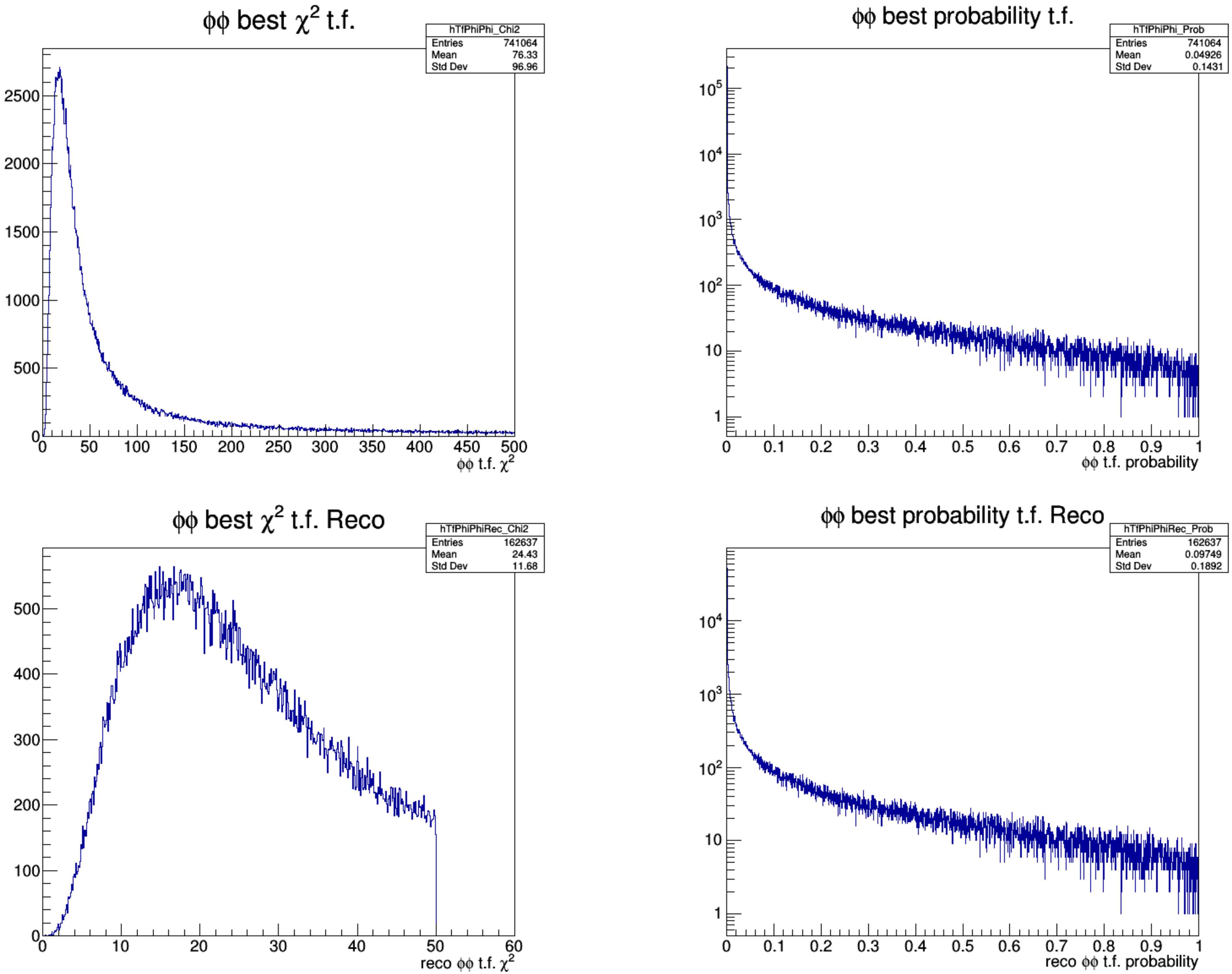
No detection efficiency at polar angles above ~90^o

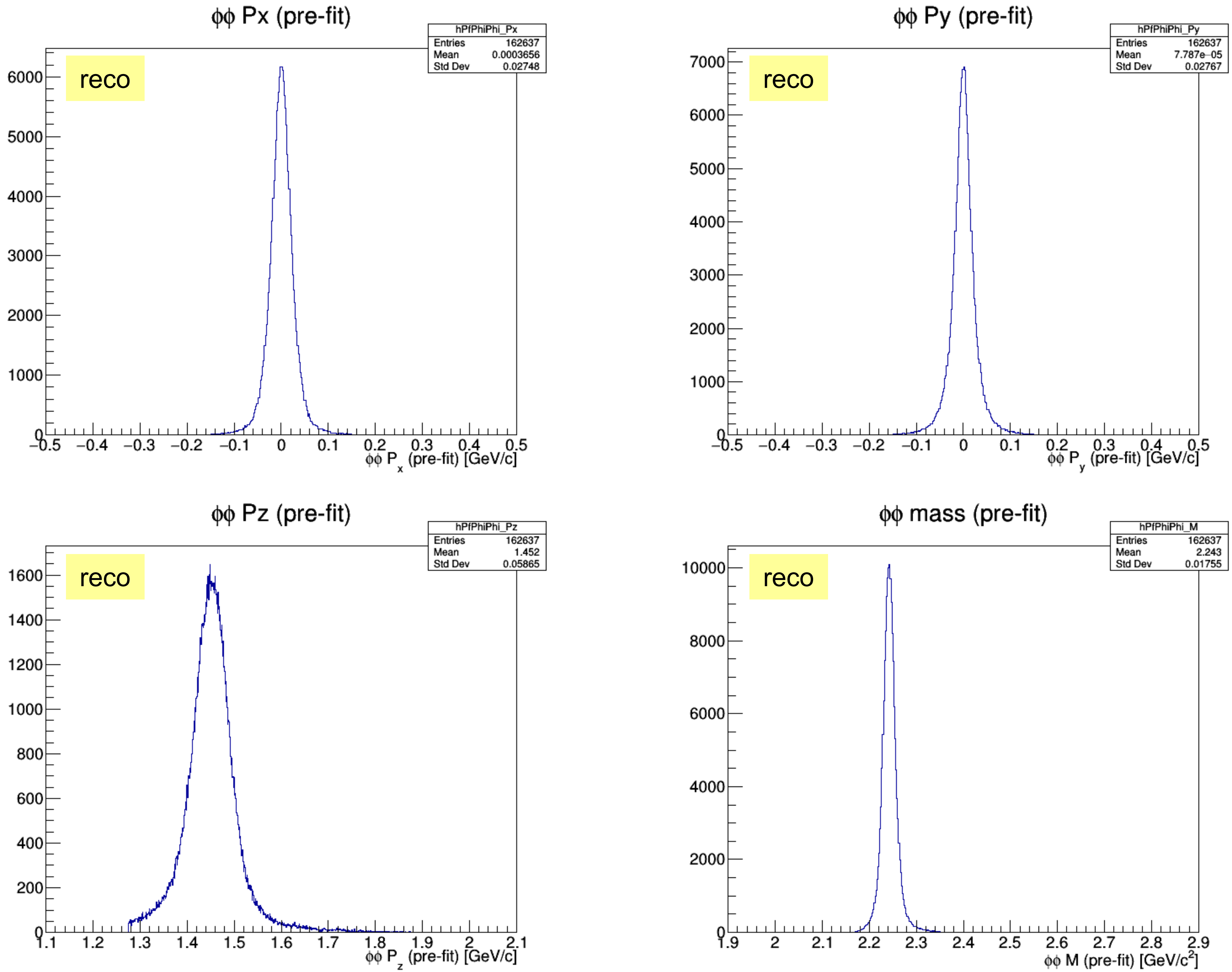




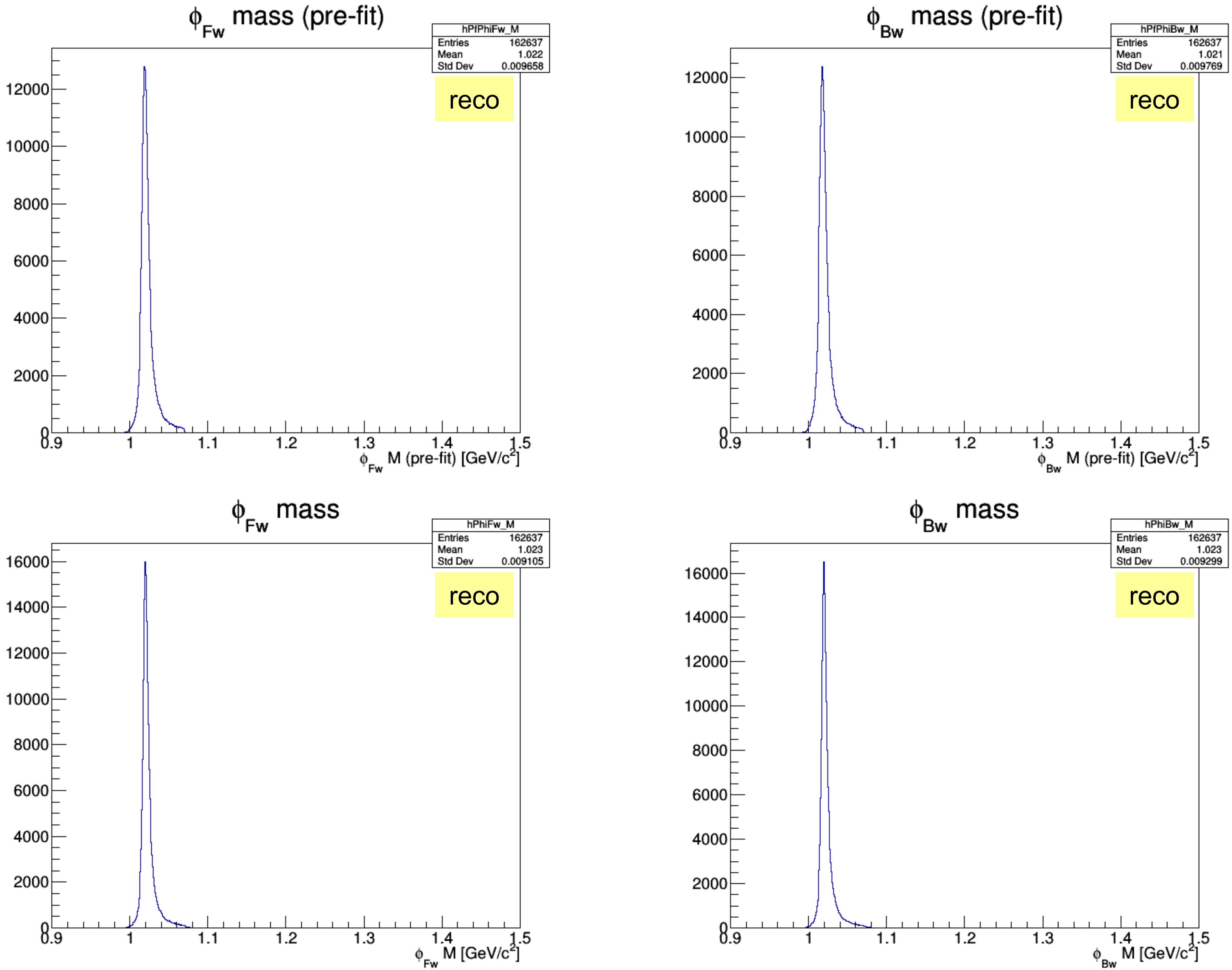


No detection efficiency at momenta below ~0.2 GeV/c


φφ best χ2 t.f.
hTfPhiPhi_Chi2
Entries 741064
Mean 76.33
Std Dev 96.96
φφ t.f. χ2
φφ best probability t.f.
hTfPhiPhi_Prob
Entries 741064
Mean 0.04926
Std Dev 0.1431
φφ t.f. probability
φφ best χ2 t.f. Reco
hTfPhiPhiRec_Chi2
Entries 162637
Mean 24.43
Std Dev 11.68
reco φφ t.f. χ2
φφ best probability t.f. Reco
hTfPhiPhiRec_Prob
Entries 162637
Mean 0.09749
Std Dev 0.1892
reco φφ t.f. probability

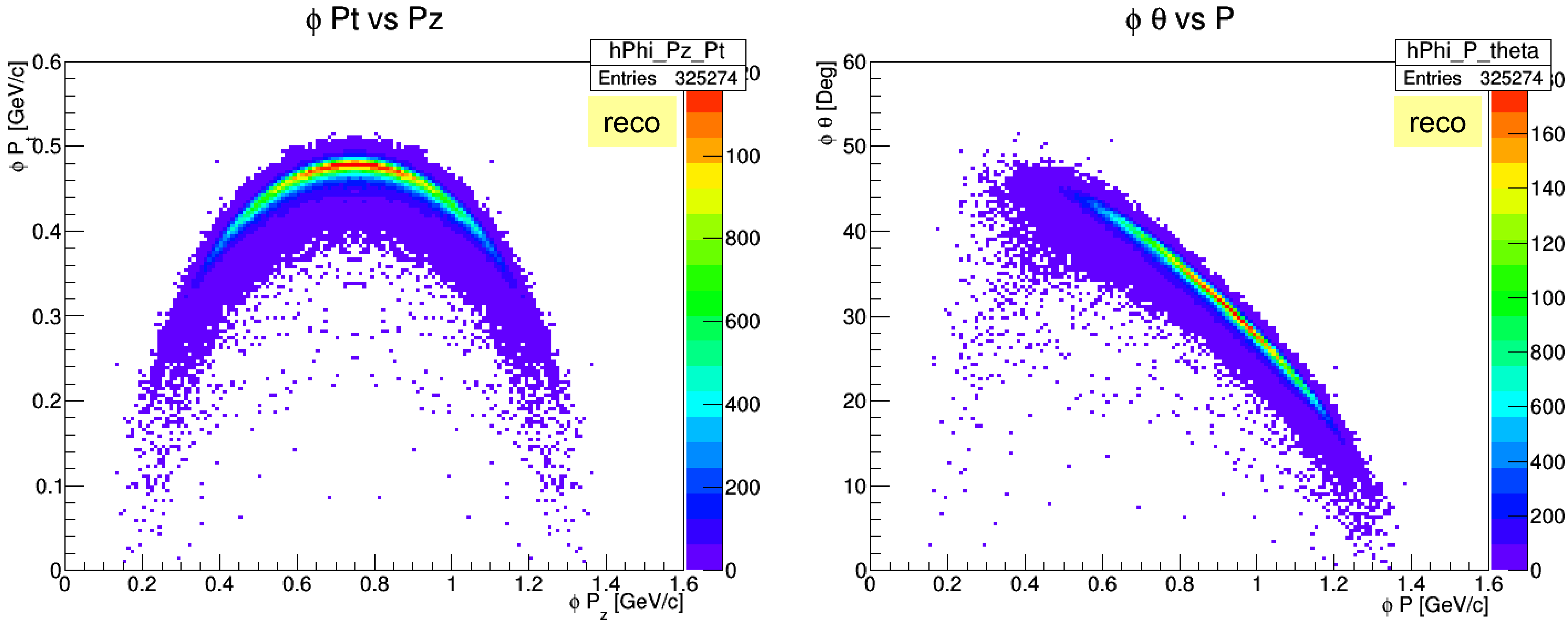


ϕϕ Px (pre-fit)
hPfPhiPhi_Px
Entries 162637
Mean 0.0003656
Std Dev 0.02748
reco
ϕϕ P_x (pre-fit) [GeV/c]
ϕϕ Py (pre-fit)
hPfPhiPhi_Py
Entries 162637
Mean 7.787e−05
Std Dev 0.02767
reco
ϕϕ P_y (pre-fit) [GeV/c]
ϕϕ Pz (pre-fit)
hPfPhiPhi_Pz
Entries 162637
Mean 1.452
Std Dev 0.05865
reco
ϕϕ P_z (pre-fit) [GeV/c]
ϕϕ mass (pre-fit)
hPfPhiPhi_M
Entries 162637
Mean 2.243
Std Dev 0.01755
reco
ϕϕ M (pre-fit) [GeV/c^2]

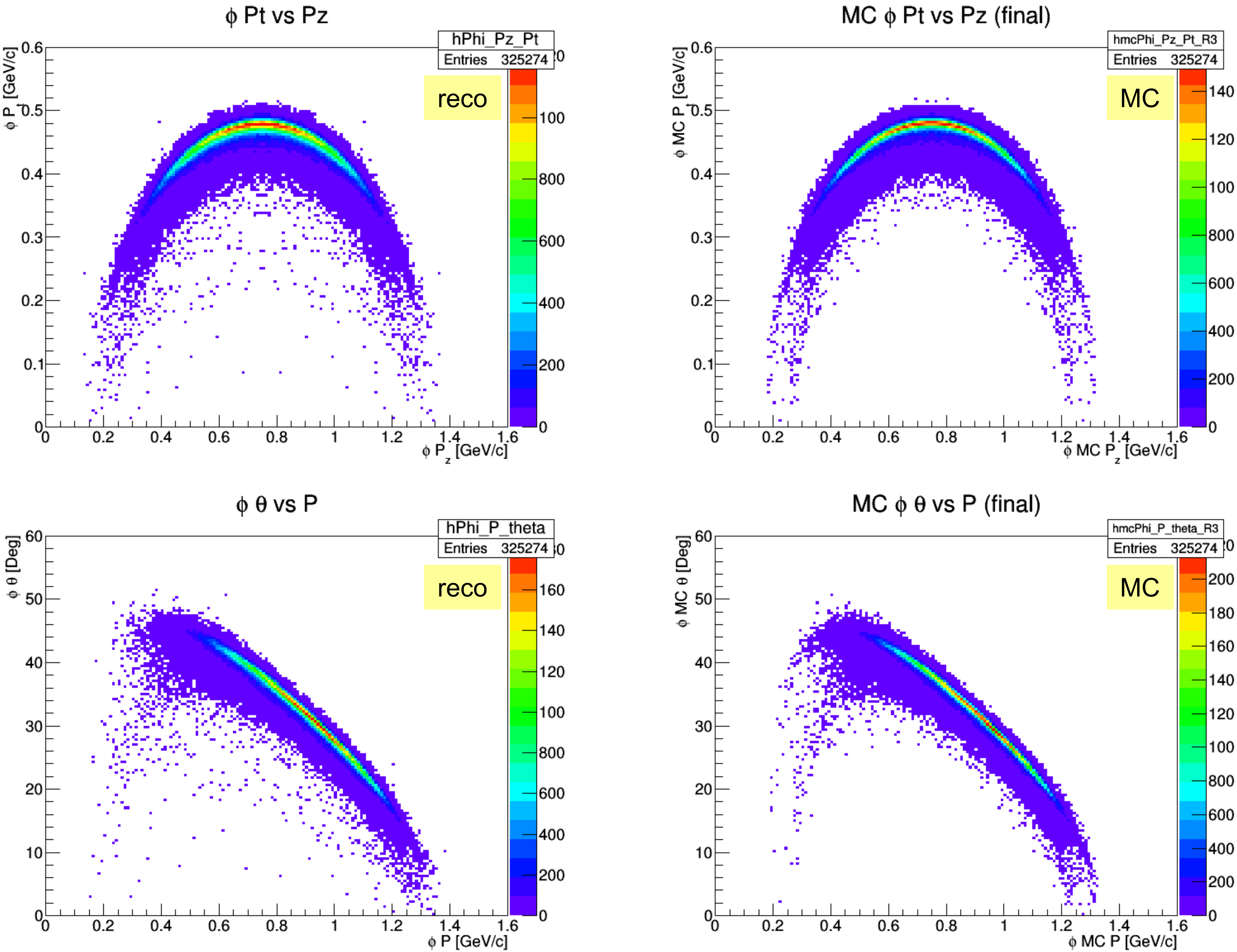


ϕ Fw mass (pre-fit)
hPfPhiFw_M
Entries 162637
Mean 1.022
Std Dev 0.009658
reco
ϕ Fw M (pre-fit) [GeV/c2]
ϕ Bw mass (pre-fit)
hPfPhiBw_M
Entries 162637
Mean 1.021
Std Dev 0.009769
reco
ϕ Bw M (pre-fit) [GeV/c2]
ϕ Fw mass
hPhiFw_M
Entries 162637
Mean 1.023
Std Dev 0.009105
reco
ϕ Fw M [GeV/c2]
ϕ Bw mass
hPhiBw_M
Entries 162637
Mean 1.023
Std Dev 0.009299
reco
ϕ Bw M [GeV/c2]

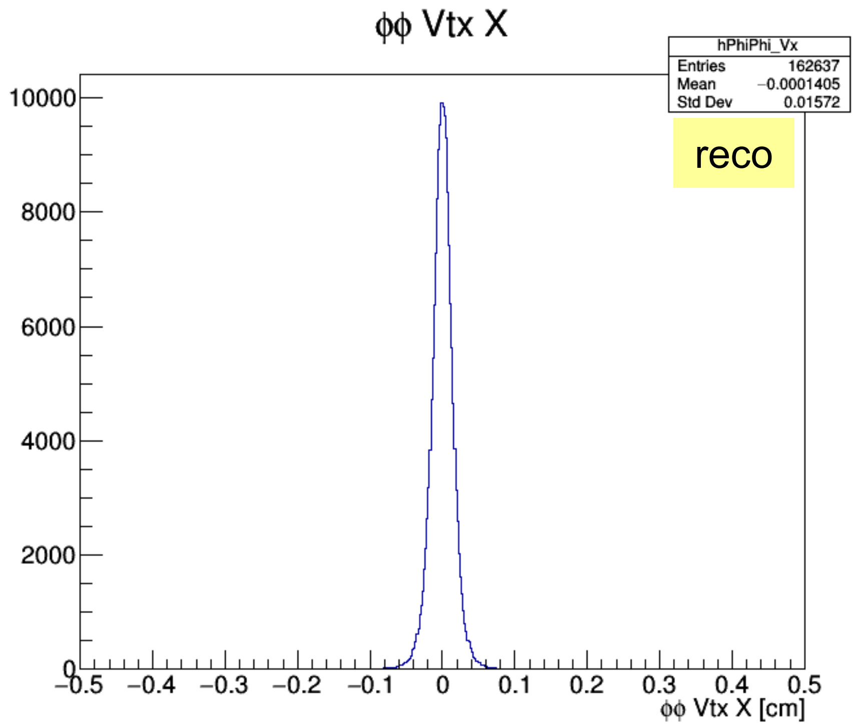
Reconstructed ϕ



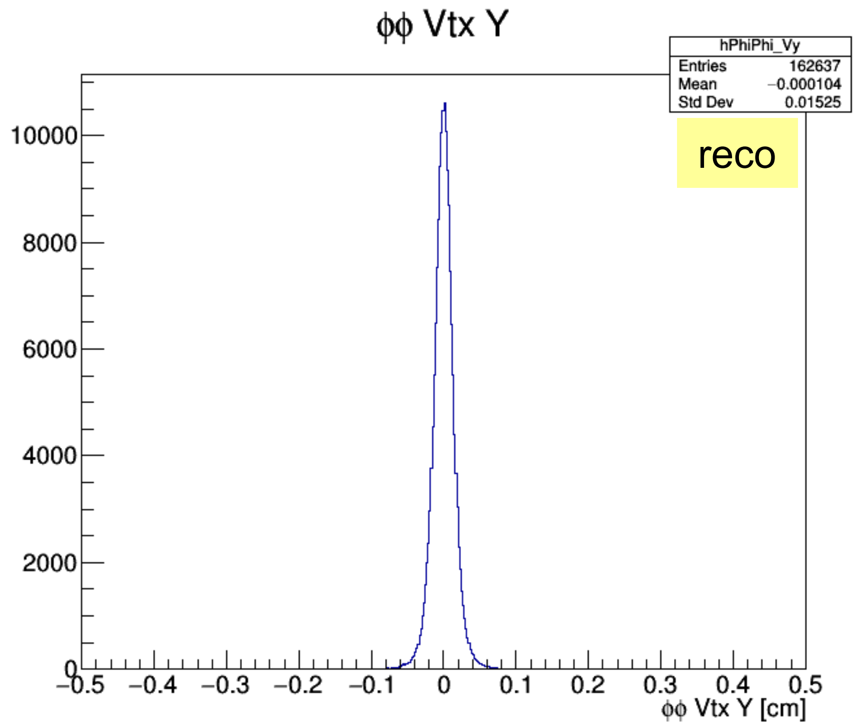
- ϕ emitted at forward and backward cm angles suppressed



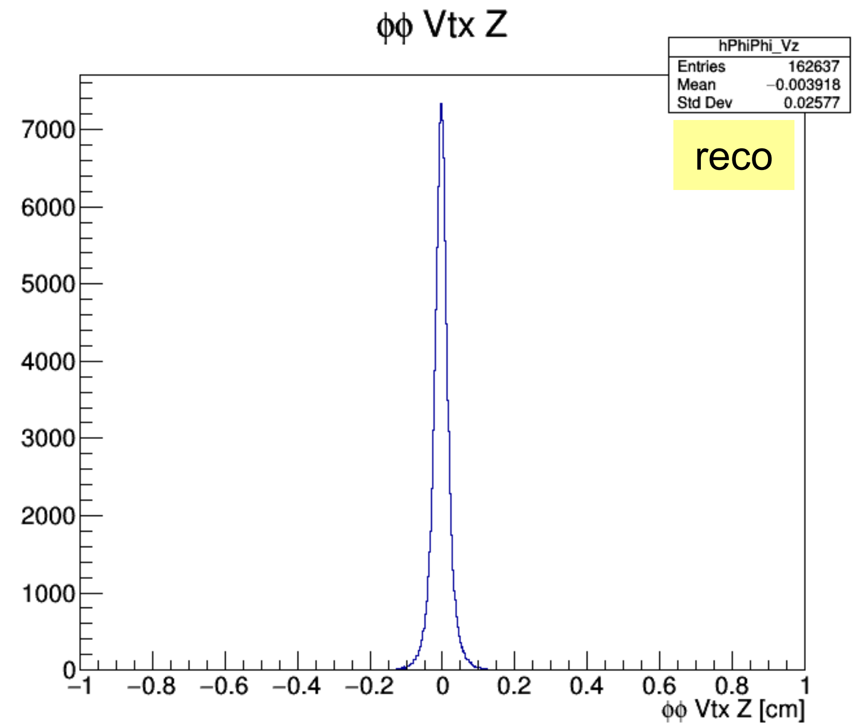
ϕ Pt vs Pz
hPhi_Pz_Pt
Entries 325274
reco
ϕ P_t [GeV/c]
ϕ P_z [GeV/c]
MC ϕ Pt vs Pz (final)
hmcPhi_Pz_Pt_R3
Entries 325274
MC
ϕ MC P_t [GeV/c]
ϕ MC P_z [GeV/c]
ϕ θ vs P
hPhi_P_theta
Entries 325274
reco
ϕ θ [Deg]
ϕ P [GeV/c]
MC ϕ θ vs P (final)
hmcPhi_P_theta_R3
Entries 325274
MC
ϕ MC θ [Deg]
ϕ MC P [GeV/c]



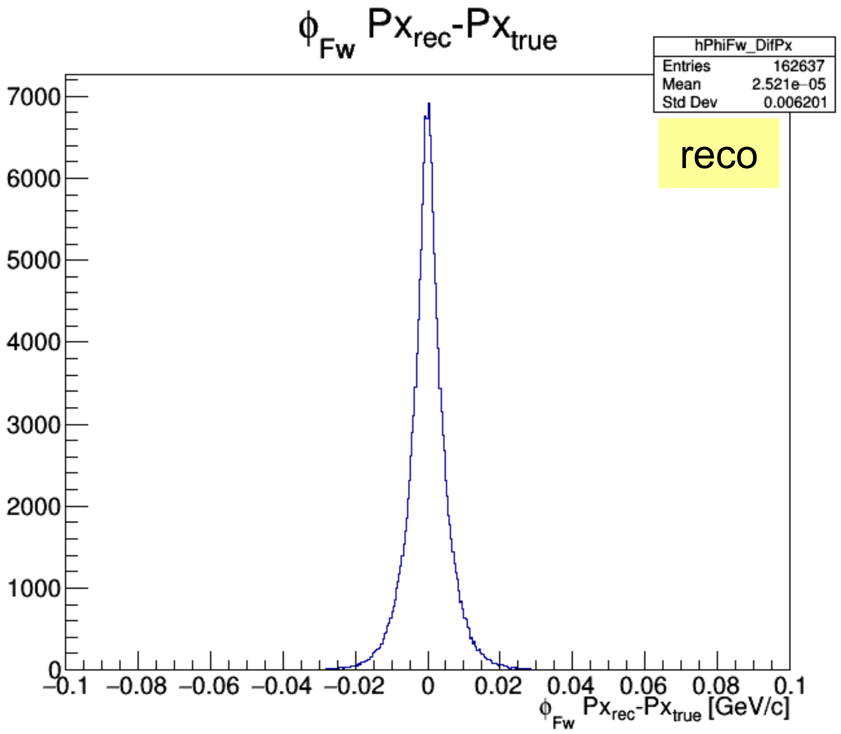
ϕϕ Vtx X
hPhiPhi_Vx
Entries 162637
Mean −0.0001405
Std Dev 0.01572
reco
ϕϕ Vtx X [cm]



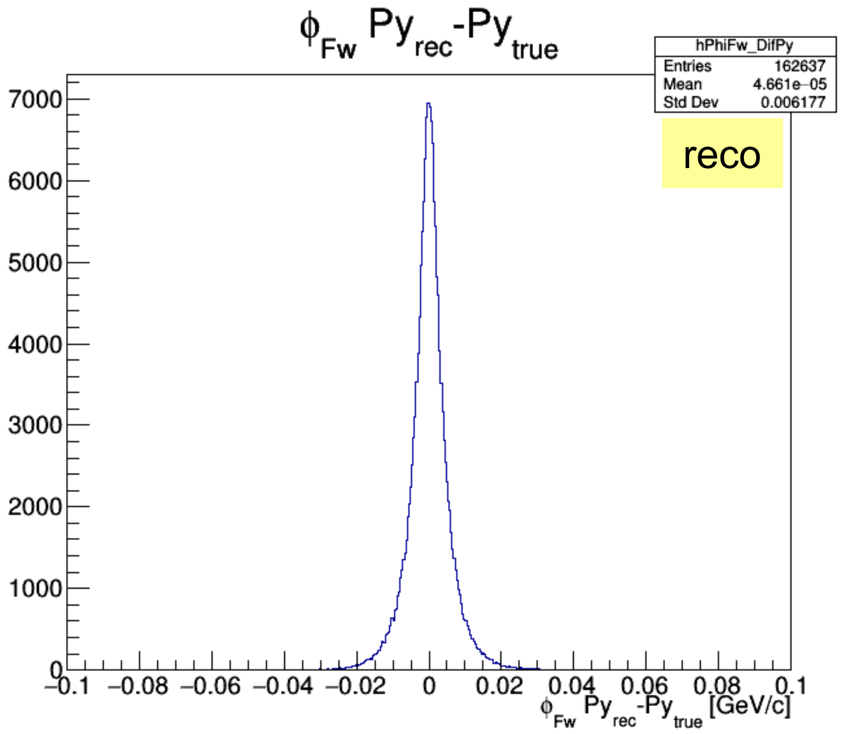
ϕϕ Vtx Y
hPhiPhi_Vy
Entries 162637
Mean −0.000104
Std Dev 0.01525
reco
ϕϕ Vtx Y [cm]



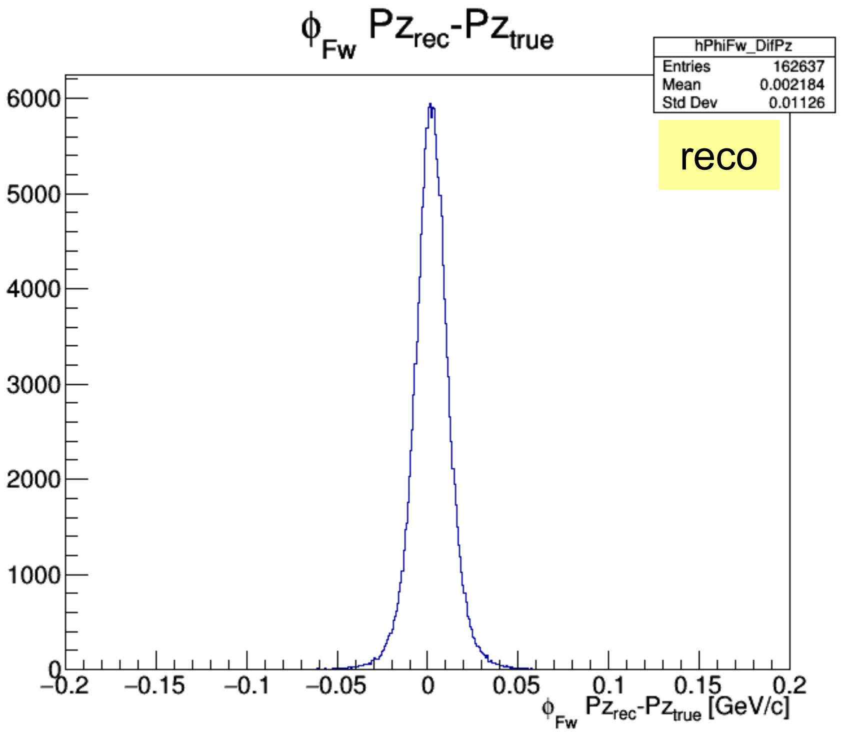
ϕϕ Vtx Z
hPhiPhi_Vz
Entries 162637
Mean −0.003918
Std Dev 0.02577
reco
ϕϕ Vtx Z [cm]



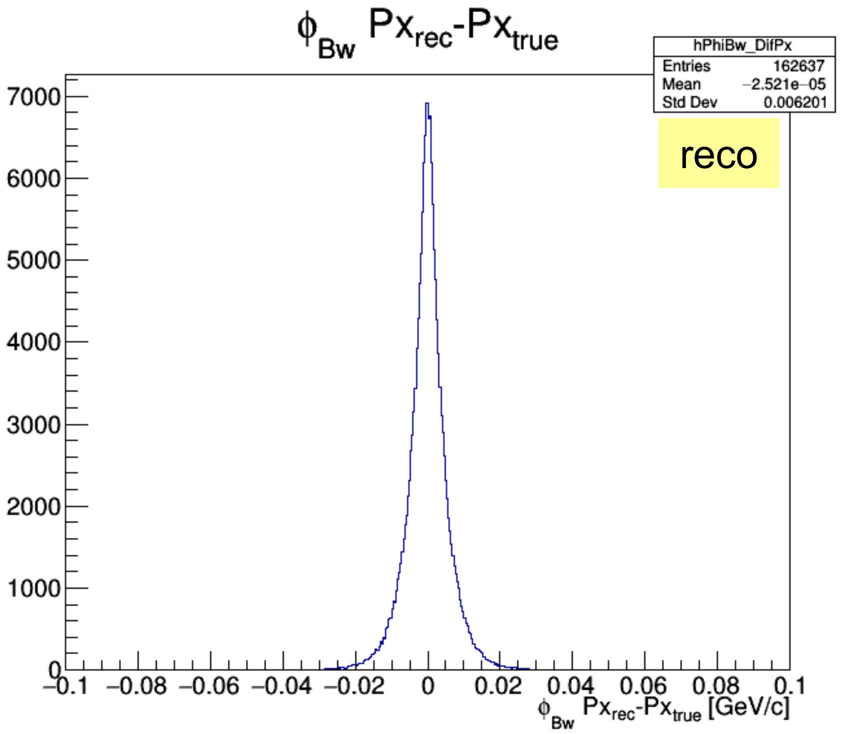
ϕFw Pxrec-Pxtrue
hPhiFw_DifPx
Entries 162637
Mean 2.521e−05
Std Dev 0.006201
reco
ϕFw Pxrec-Pxtrue [GeV/c]



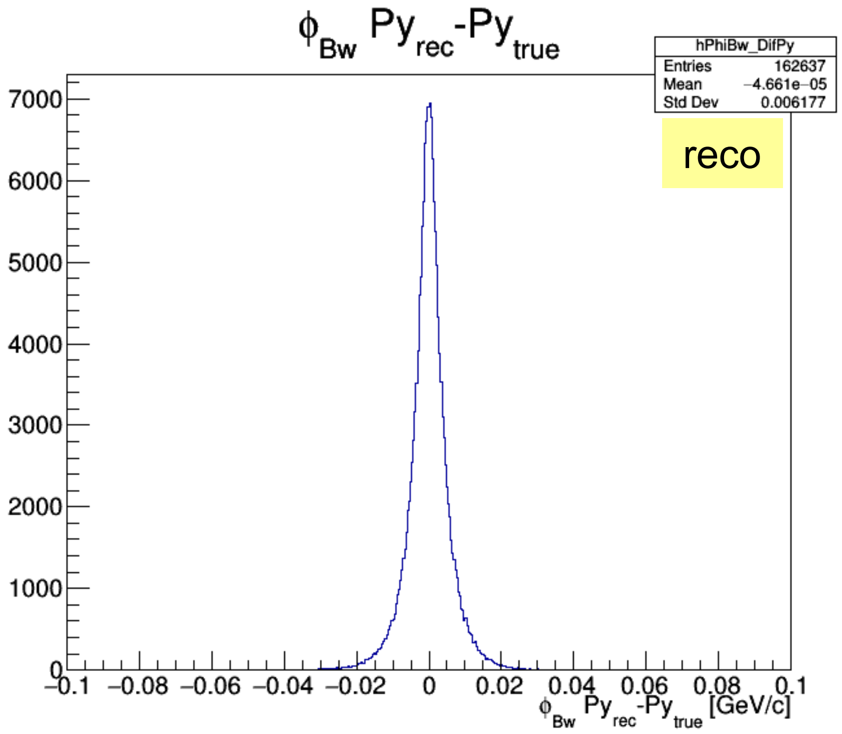
ϕFw Pyrec-Pytrue
hPhiFw_DifPy
Entries 162637
Mean 4.661e−05
Std Dev 0.006177
reco
ϕFw Pyrec-Pytrue [GeV/c]



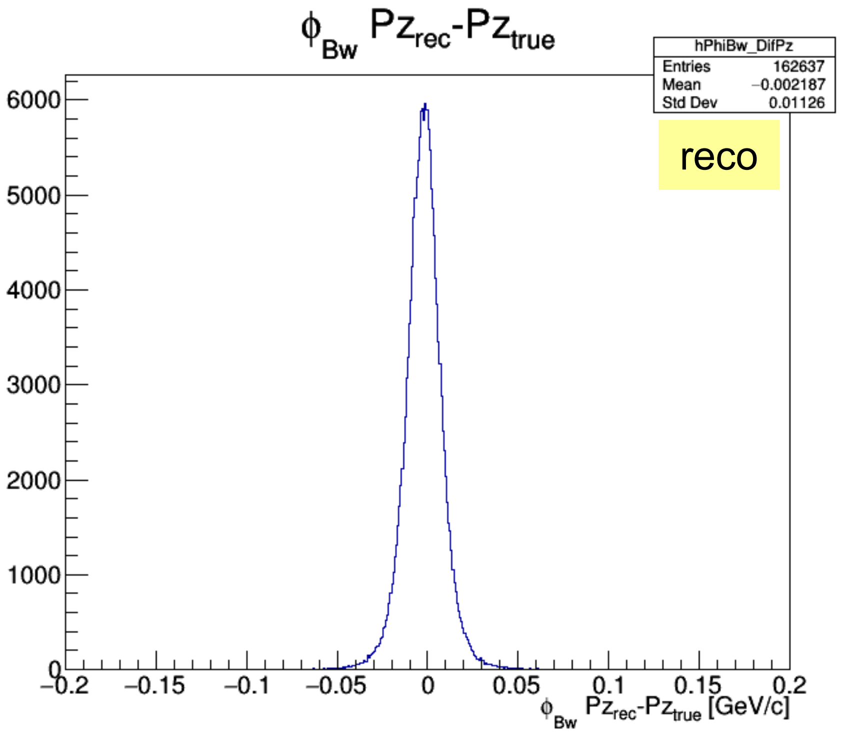
ϕFw Pzrec-Pztrue
hPhiFw_DifPz
Entries 162637
Mean 0.002184
Std Dev 0.01126
reco
ϕFw Pzrec-Pztrue [GeV/c]



ϕBw Pxrec-Pxtrue
hPhiBw_DifPx
Entries 162637
Mean −2.521e−05
Std Dev 0.006201
reco
0
1000
2000
3000
4000
5000
6000
7000
−0.1 −0.08 −0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.08 0.1
ϕBw Pxrec-Pxtrue [GeV/c]



ϕBw Pyrec-Pytrue
hPhiBw_DifPy
Entries 162637
Mean −4.661e−05
Std Dev 0.006177
reco
0
1000
2000
3000
4000
5000
6000
7000
−0.1 −0.08 −0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.08 0.1
ϕBw Pyrec-Pytrue [GeV/c]



ϕBw Pzrec-Pztrue
hPhiBw_DifPz
Entries 162637
Mean −0.002187
Std Dev 0.01126
reco
0
1000
2000
3000
4000
5000
6000
−0.2 −0.15 −0.1 −0.05 0 0.05 0.1 0.15 0.2
ϕBw Pzrec-Pztrue [GeV/c]

Reconstruction Efficiencies & Purities

Reco Cond.	# Entries / Events	n / n_{MC}
K^+ single rec.	2 465 809	0.616
K^- single rec.	2 413 439	0.603
R1: all stable cands.	741 064	0.371
3K: 3 kaons rec.	954 813	0.477
R3: final sample	162 637	0.0813
True $\phi\phi$ rec.	150 627	0.0753

- Single kaon reconstruction efficiency ~ 60 %
- True $\phi\phi$ reconstruction efficiency ~ 7.5 %
- Reconstructed signal purity ~ 92.6 %

Conclusion & Outlook

- 7.5 % reco efficiency, 92.6 % purity w.r.t. combinatorial background
- full cm angular distribution not accessible in exclusive reconstruction
- further steps:
  - kaon hypothesis for track reconstruction
  - semi-inclusive reconstruction with 3 out of 4 kaons
  - neutral decay $\phi \rightarrow K_S K_L$ for backward ϕ ?
  - 2.5 GeV/c momentum