Track fitting performance for soft particles in SpdRoot

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Motivation

- Problems often arise when dealing with soft tracks in the analysis.
- Reconstructed values of track parameters (momentum, etc.) can be very inaccurate.
  Applying track fit quality cuts give cleaner sample but can highly reduce statistics.
- It is unclear which track fit quality cuts should be used.
  Ideally, a set of recommendations should be developed.
- In this study I investigate how track fitting works for different momenta and angles.

Event samples

- 4 samples: π^+, K^+, p, d (400 000 primary particles in each sample)
- Kinematics:
  - Momentum magnitude p_0 of primary particles changes from 0.005 to 0.995 GeV/c with step = 0.01 GeV/c.
  - Isotropically distributed (i.e. uniformly in cos(θ) and φ).
- Primary vertex:
  - Gaussian smearing with σ_z = 30 cm, $\sigma_x = \sigma_y$ = 0.1 cm.
- SpdRoot commit from master branch 16.03.2023.
- Geometry:
  - ITS: DSSD option is used (3 layers, endcaps present).
  - TS: 62 layers in the barrel, 16 layers in each of the end-caps (default).
  - Other parts of the setup also in default configuration.

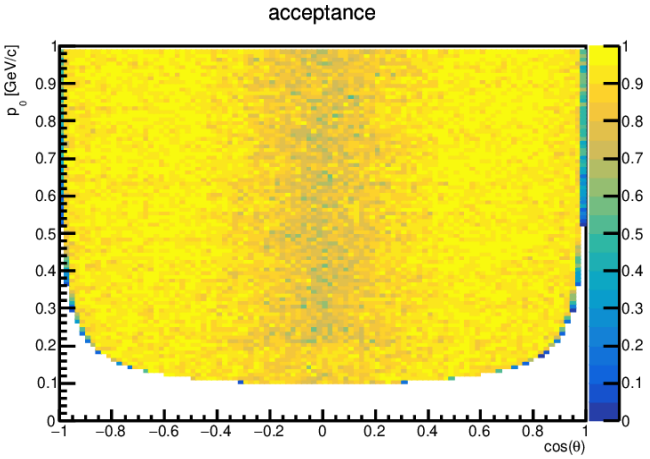
Tracks

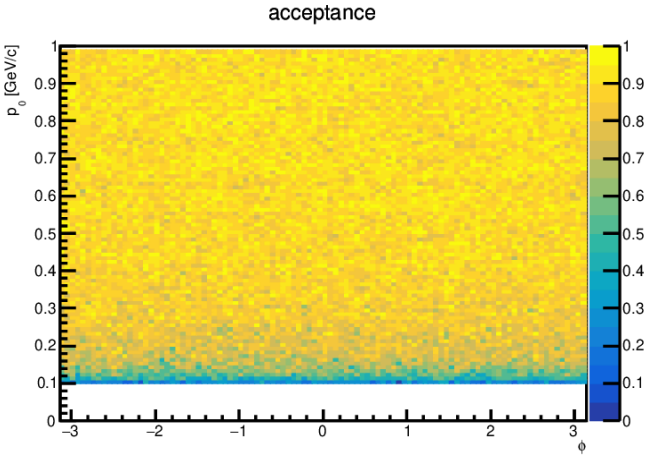
- Several classes representing tracks (`SpdTrackMC, SpdTrackRC`) exist in SpdRoot.
- `SpdTrackMC:`
  - As a set of track points are taken all hits produced by a particle (MC-truth is used.)
  - Then a fitting procedure using GenFit2 is performed to reconstruct momentum.
- `SpdMCTrackFinder,` which makes tracks (`SpdTrackMC`) from particles (`SpdMCParticle`) applies the following cuts:

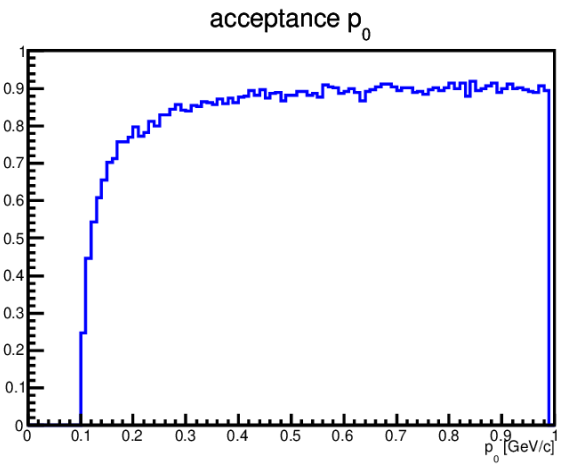
Variable	**Min. value**	**Comment**
Transverse momentum p_T	0.1 GeV/c	
Momentum p	0.004 GeV/c	GF requirement
$\beta\gamma$	0.05	GF requirement
Hits in ITS	**1**	
Hits in ITS + TS	**3**	

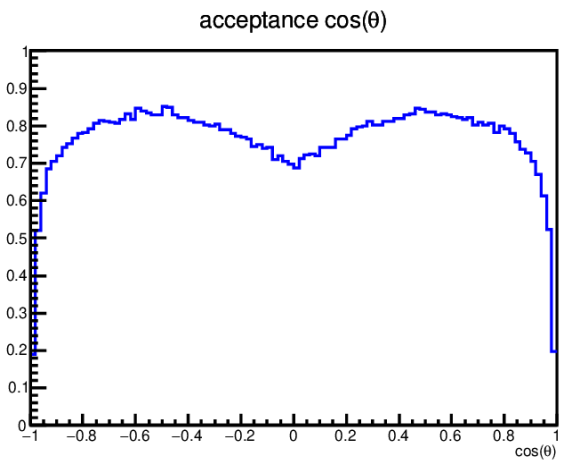
Pions: acceptance as a function of p_0, cos θ, ϕ

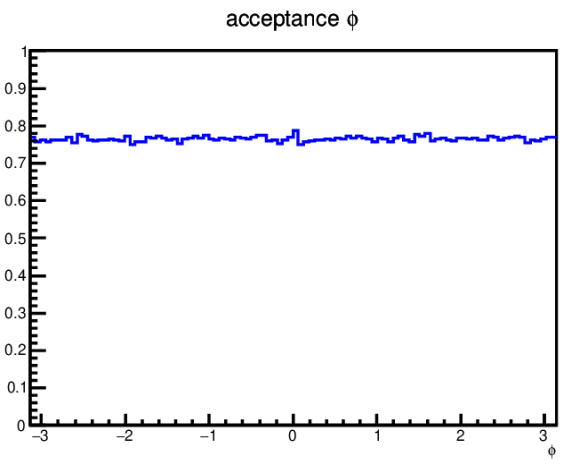
$$\text{acceptance} = \frac{\text{N of tracks}}{\text{N of primary particles}}$$







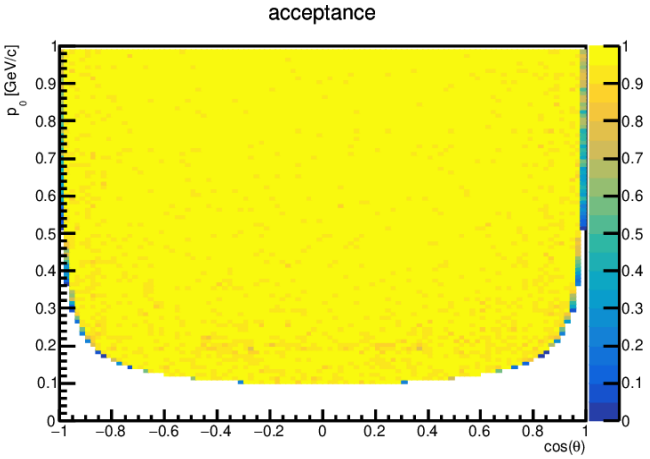


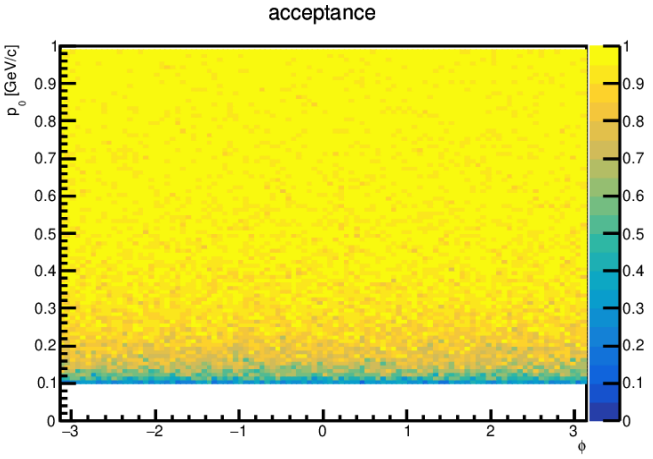


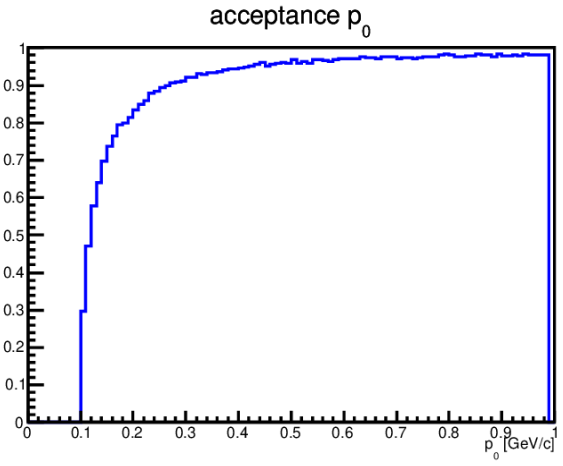
Pions: acceptance as a function of p_0, cos θ, ϕ

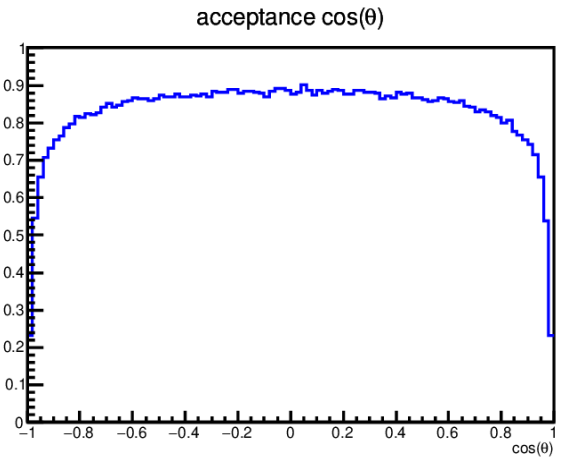
$$\text{acceptance} = \frac{\text{N of tracks}}{\text{N of primary particles}}$$

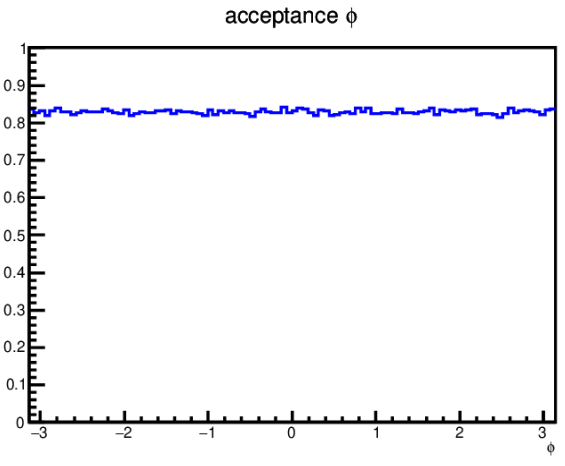
$Z_{vertex} = 0$





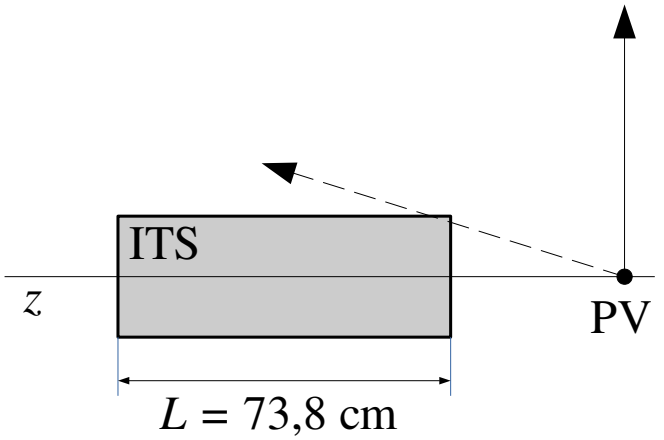






Tracks from the primary vertices outside of the ITS region

- For σ_z = 30 cm 12% of primary vertices are outside of the region covered by ITS.
- Particles going out of these vertices at large angles to the z axis will not have any hits in the ITS.
- `SpdRCTrackFinder` (implementation of a track finding procedure) uses as a track seed a combination of hits in the ITS
  → all such tracks also will be missing.
- **We need a track finding procedure for tracks without ITS hits!**
- For σ_z = 80 cm 64% of primary vertices will be outside of the region covered by ITS !



Track fit characteristics

SpdTrackFitPar

- fErrorFlag (always 0)
- fErrorMesg
- fNFailedHits
- fConvergencyGF
  (0 — not converged,
  -1 — partially converged,
  1 — fully converged)

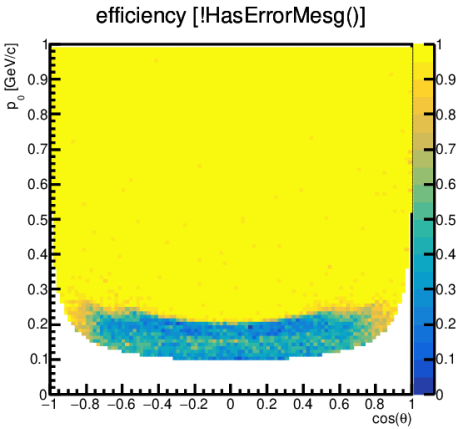
- fChi2
- fNDF
- fDChi2

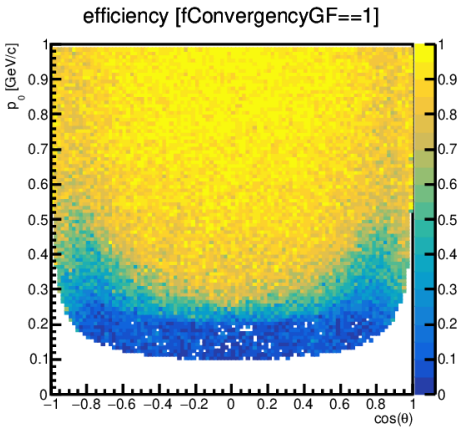
χ^2/ndf

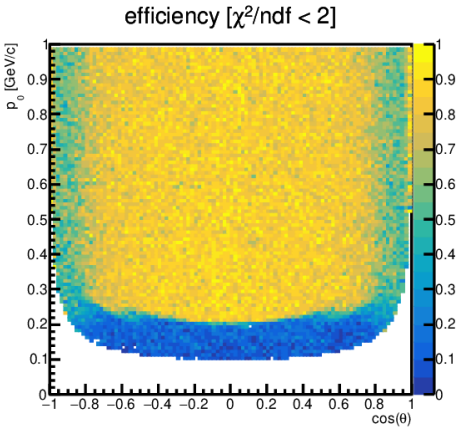
```
//-----------------------------------------------------------
inline Bool_t SpdTrackFitPar::GetIsGood() const
{
    if (fErrorFlag != 0) return false;
    if (HasErrorMesg()) return false;
    //if (fNFailedHits > 0) return false;
    if (fConvergencyGF != 1) return false;
    return true;
}

//-----------------------------------------------------------
inline Bool_t SpdTrackFitPar::GetIsAcceptable() const
{
    if (fErrorFlag != 0) return false;
    if (HasErrorMesg()) return false;
    //if (fNFailedHits > 0) return false;
    if (fNDF < 3) return false;
    if (GetChi2overNDF() < 2) return true;
    return false;
}
```

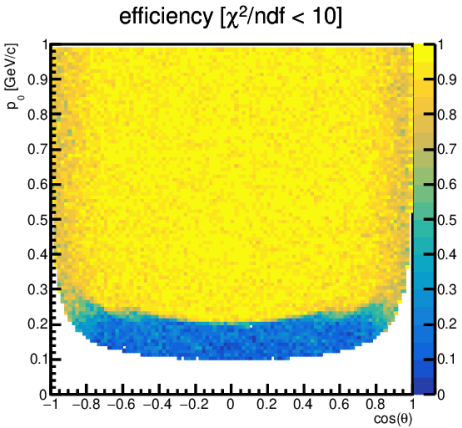
Pions: Track fitting efficiency for different quality cuts

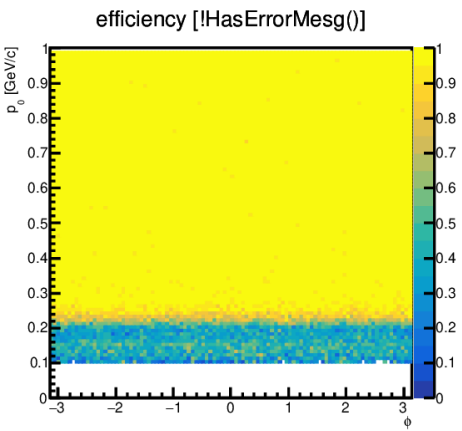
$$\text{efficiency} = \frac{\text{N of tracks with cut}}{\text{N of tracks without cut}}$$

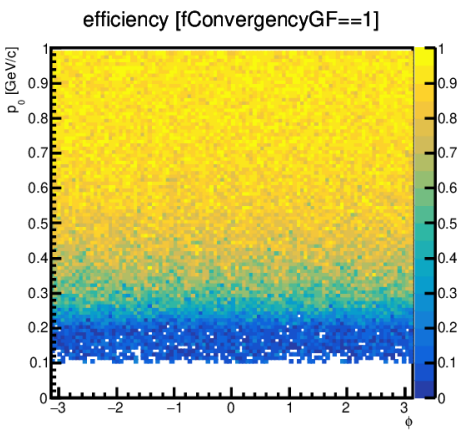


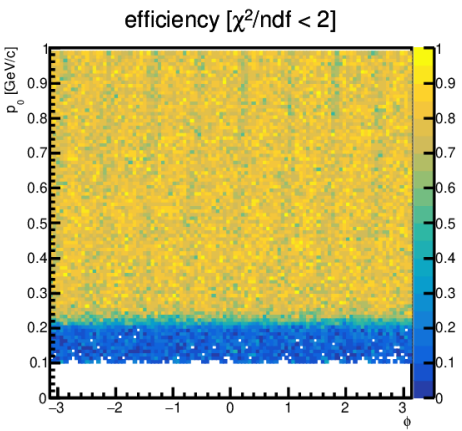


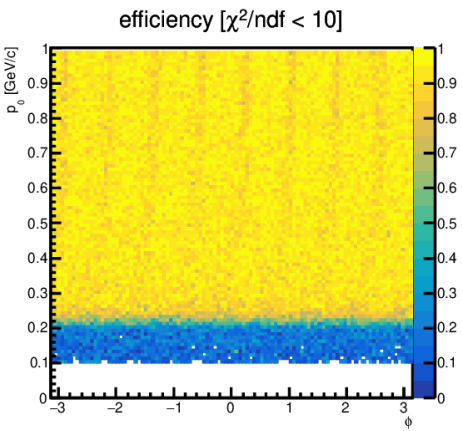








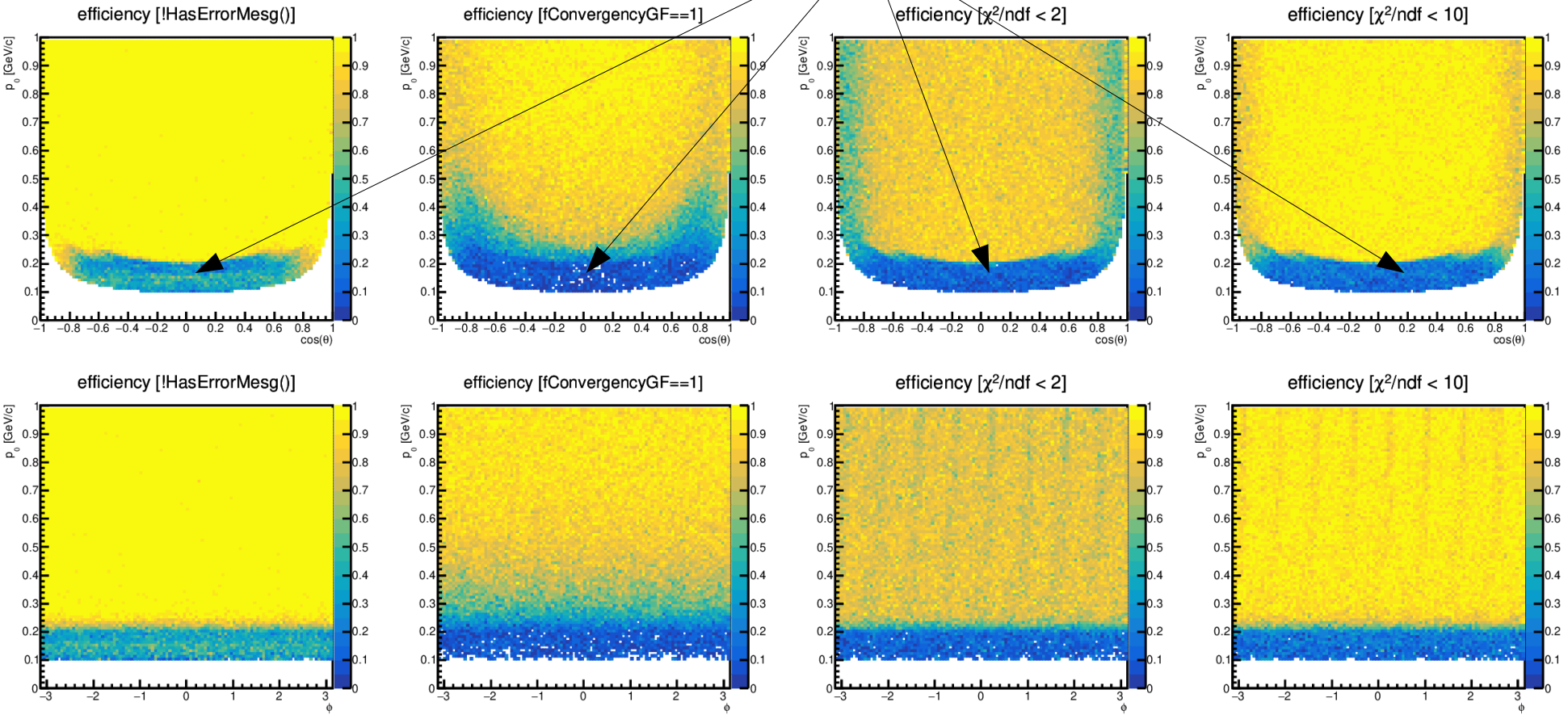




Pions: Track fitting efficiency for different quality cuts

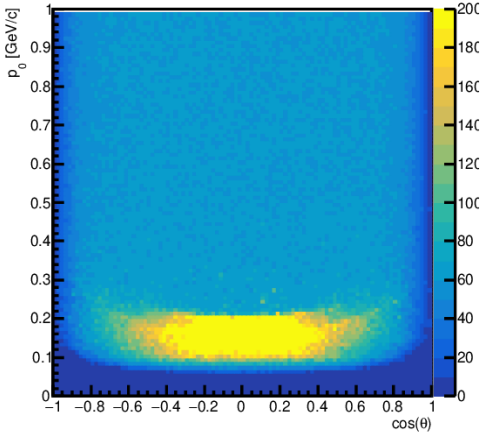
$$\text{efficiency} = \frac{\text{N of tracks with cut}}{\text{N of tracks without cut}}$$

Particles with $p \lesssim 0.2$ GeV are mostly rejected by the fit quality cuts.
They have trajectories inside the straw tracker region.

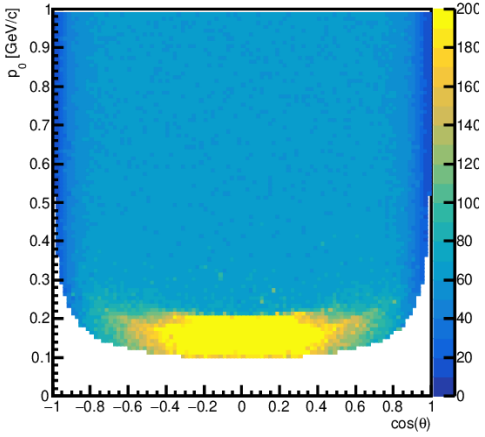


Pions: Mean number of hits (p_0 : cos θ)

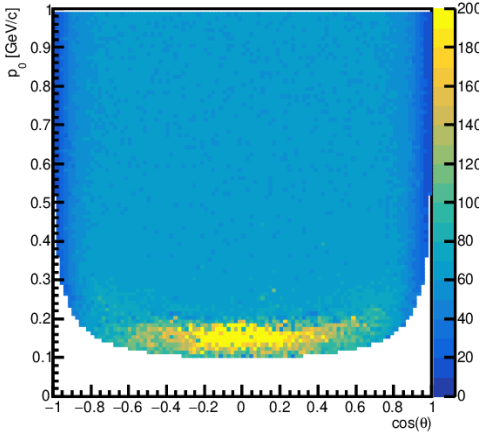
<N hits> (all primary particles)



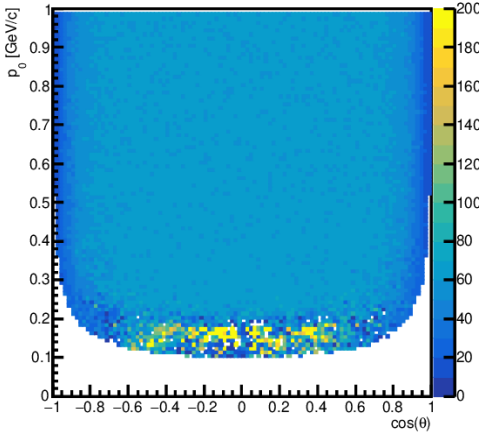
<N hits> (tracks, no quality cut)



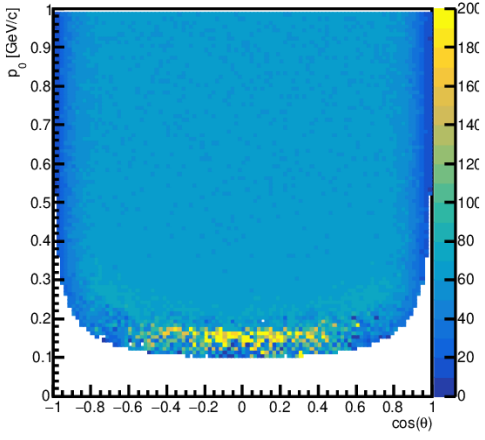
<N hits> [!HasErrorMesg()]



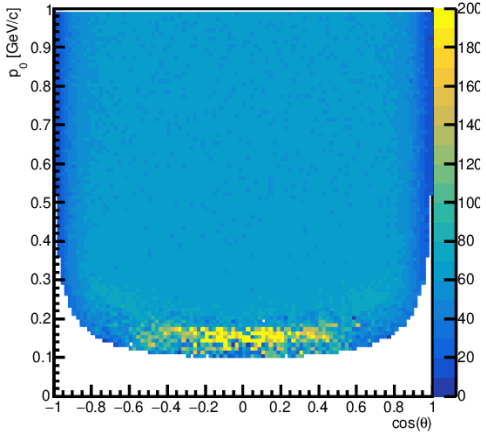
<N hits> [fConvergencyGF==1]



<N hits> [χ^2/ndf < 2]



<N hits> [χ^2/ndf < 10]



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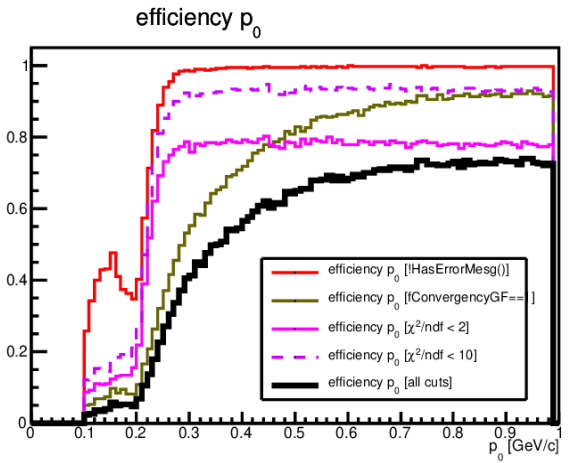
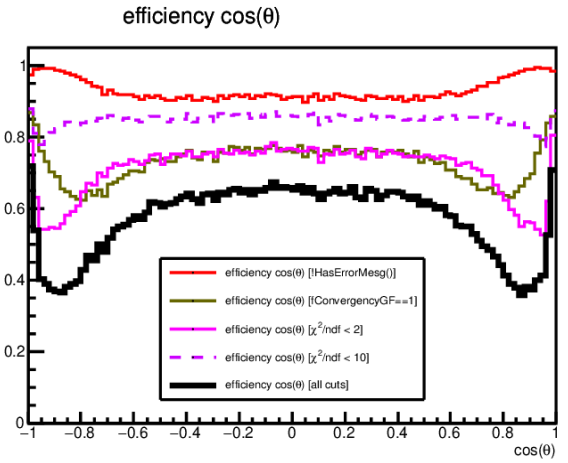
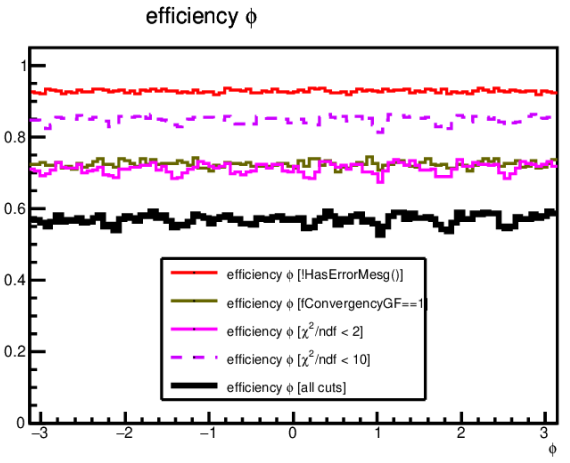
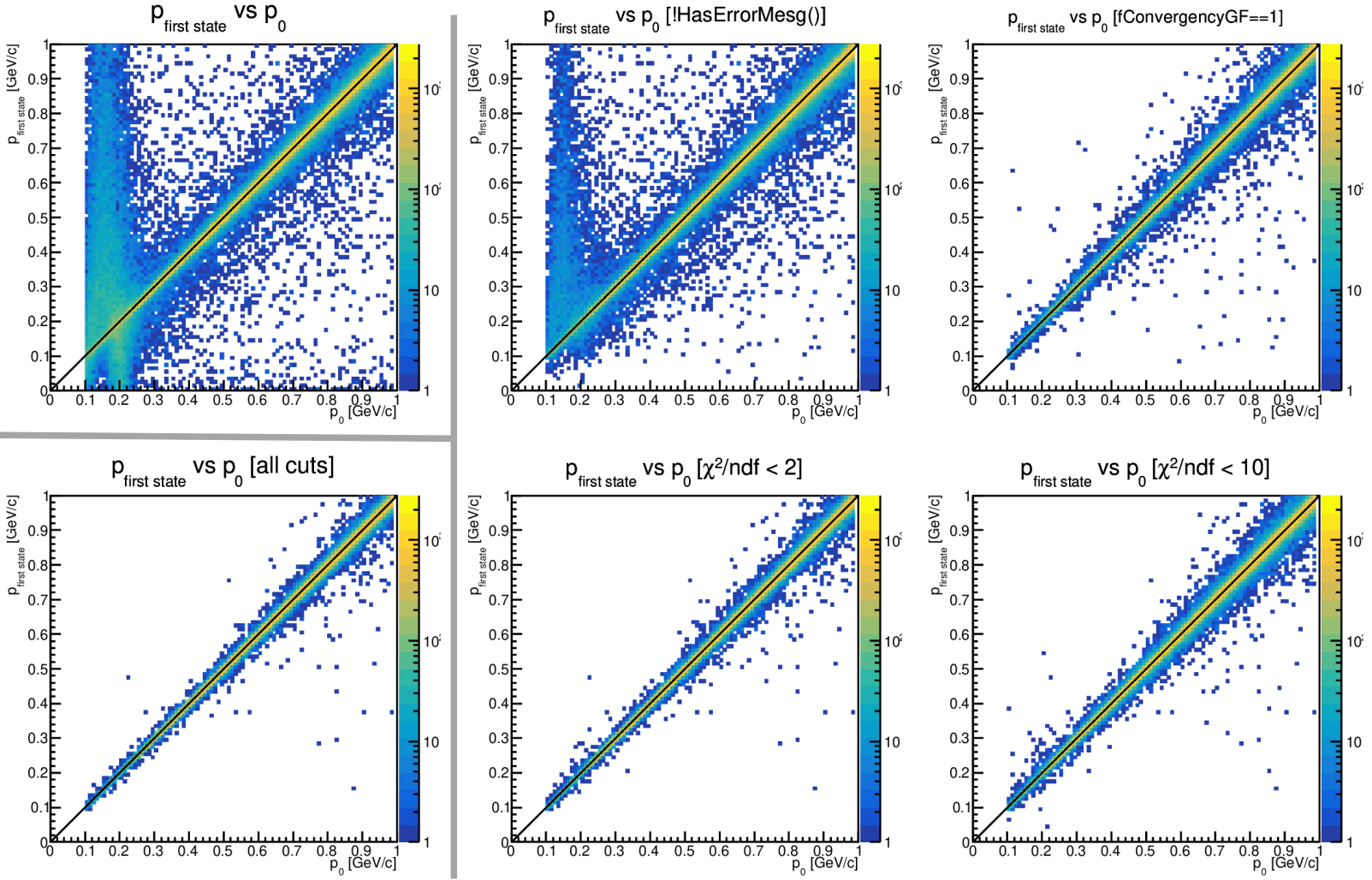


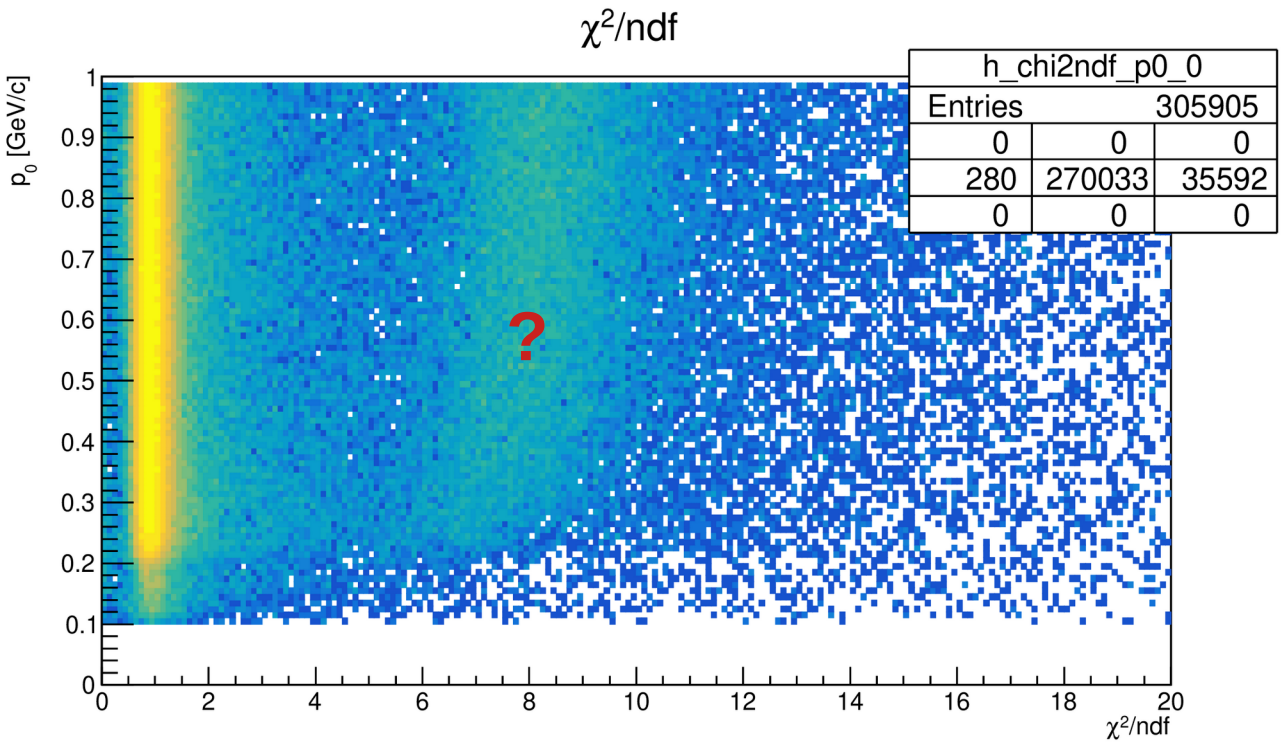


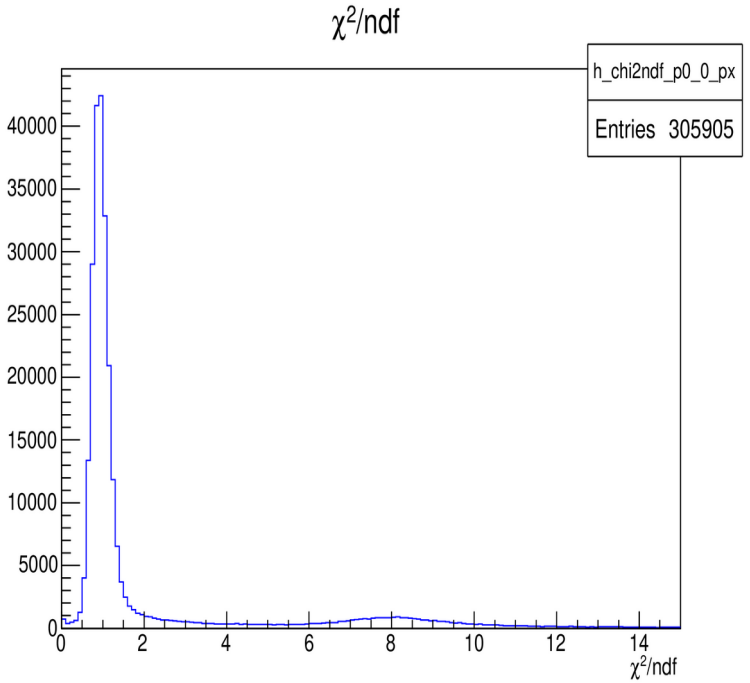


Pions: Reconstructed momentum in the first track point vs p_0

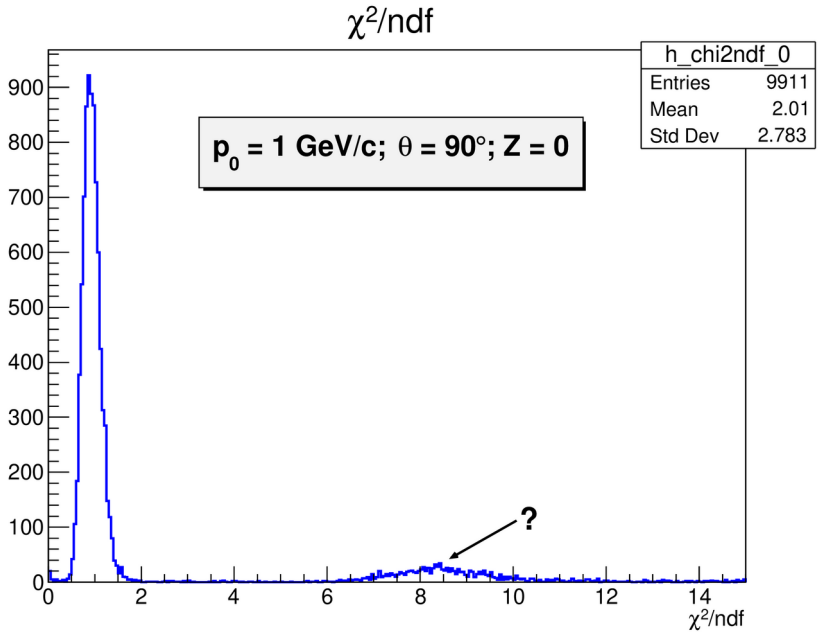


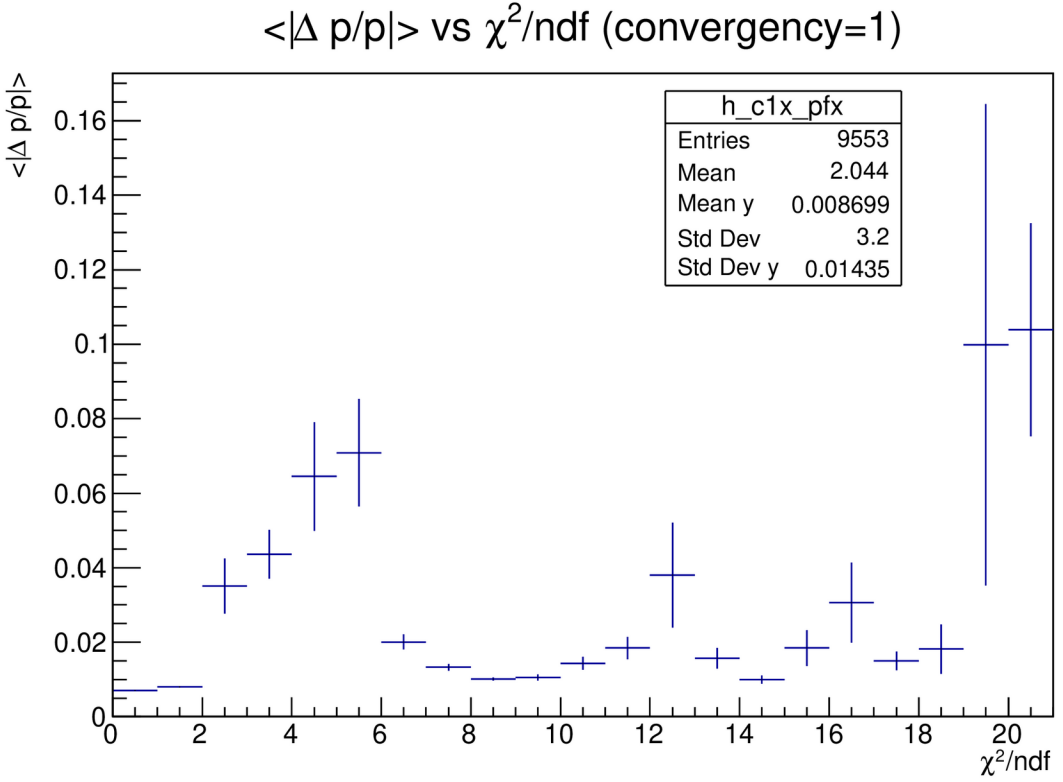
Pions: χ^2/ndf distribution





Pions: χ^2/ndf distribution [p_0=1 GeV, θ=90°, Z=0]

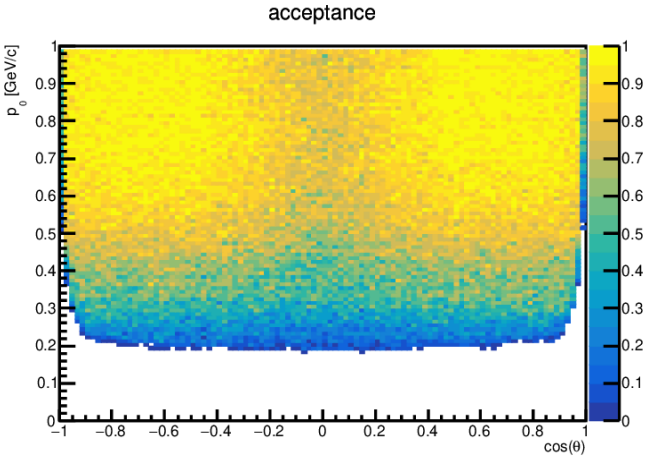


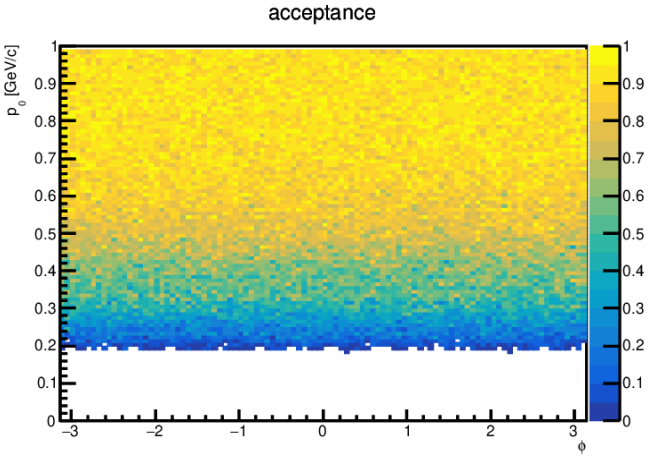


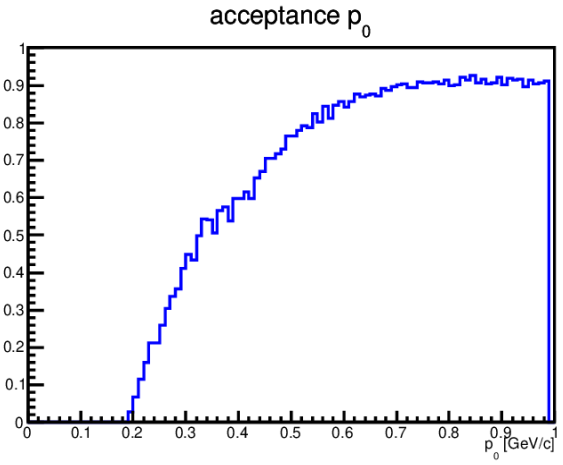
Protons

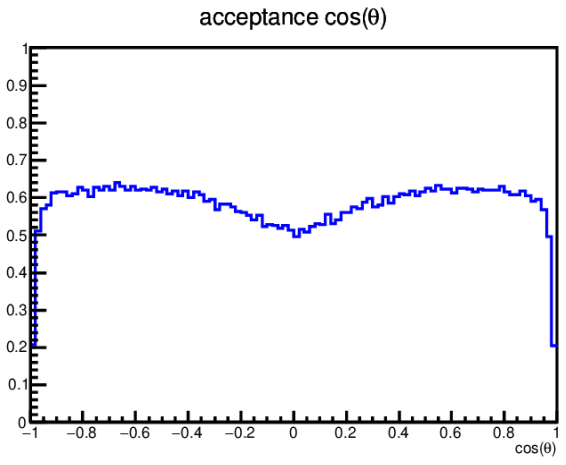
Protons: Acceptance as a function of p_0, cos θ, ϕ

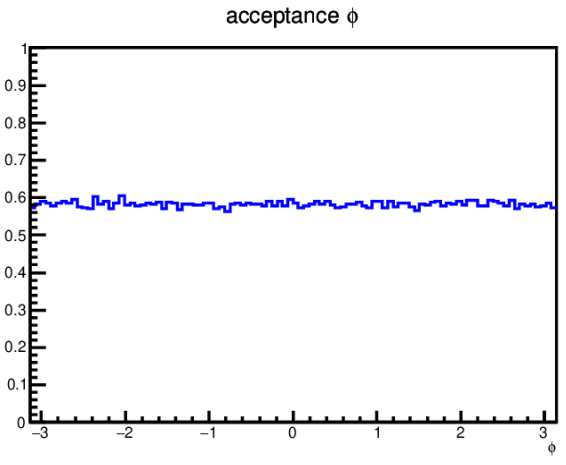
$$\text{acceptance} = \frac{\text{N of tracks}}{\text{N of primary particles}}$$





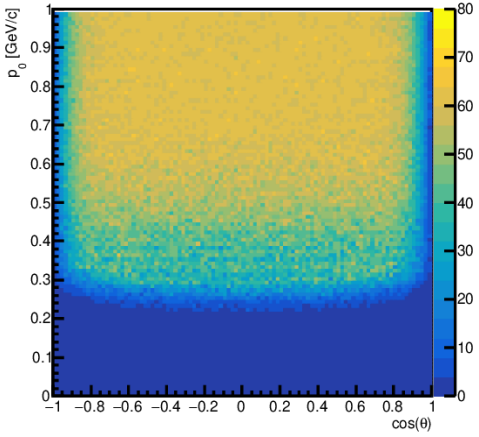




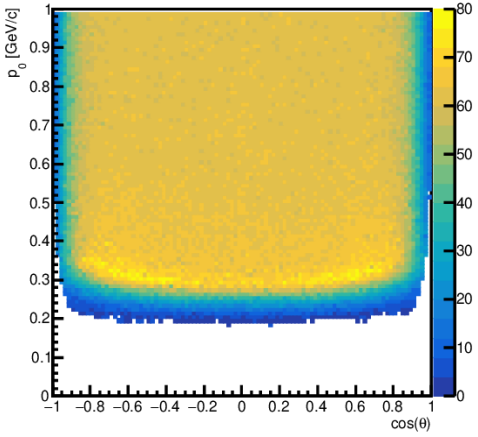


Protons: Mean number of hits (p_0 : cos θ)

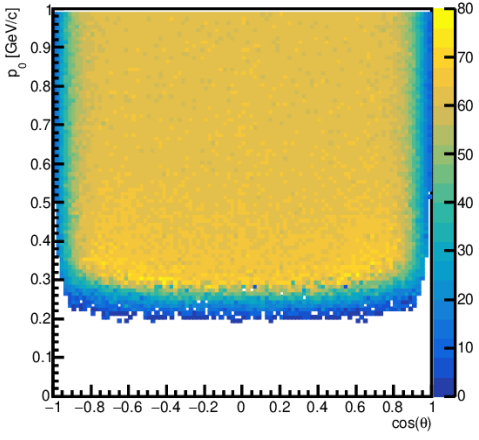
<N hits> (all primary particles)



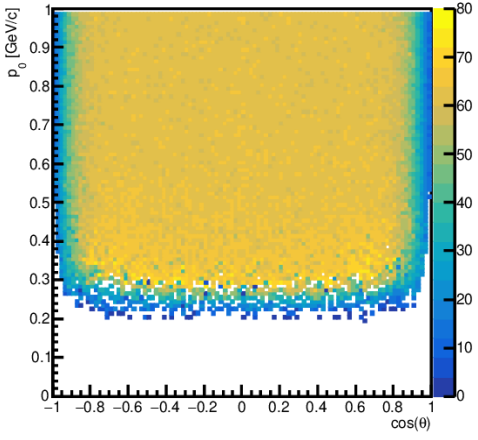
<N hits> (tracks, no quality cut)



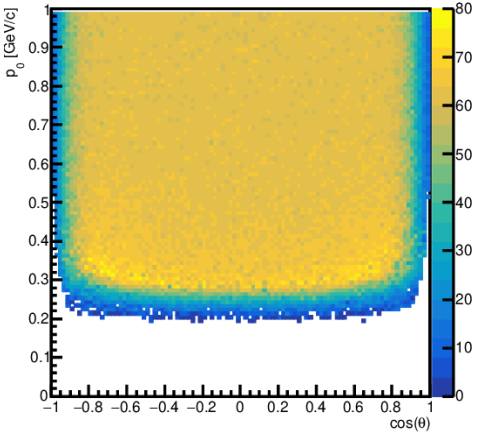
<N hits> [!HasErrorMesg()]



<N hits> [fConvergencyGF==1]



<N hits> [χ^2/ndf < 2]



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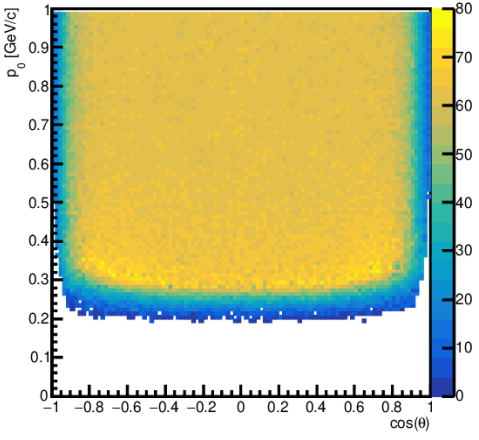
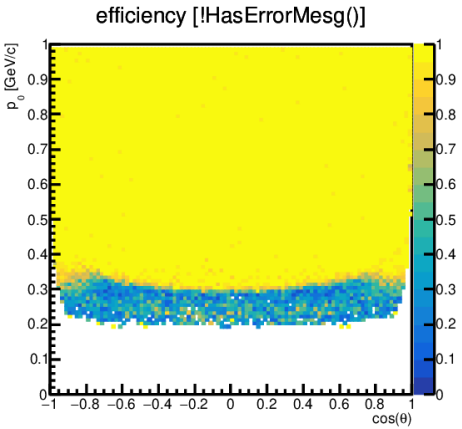
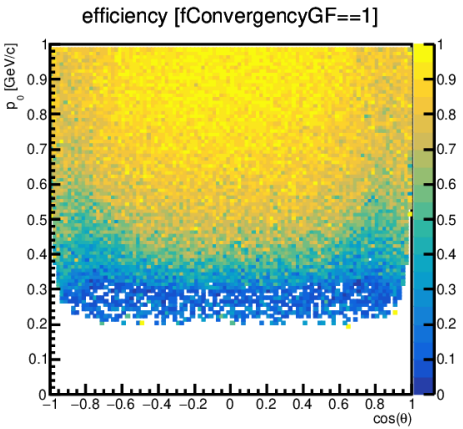
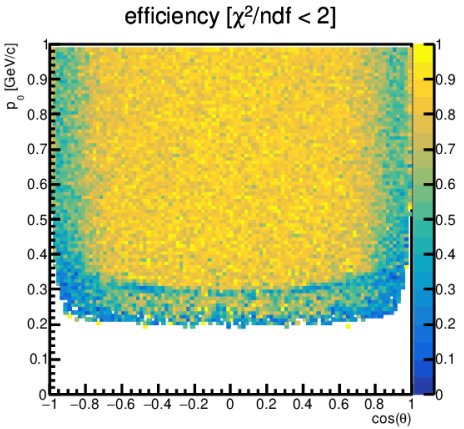


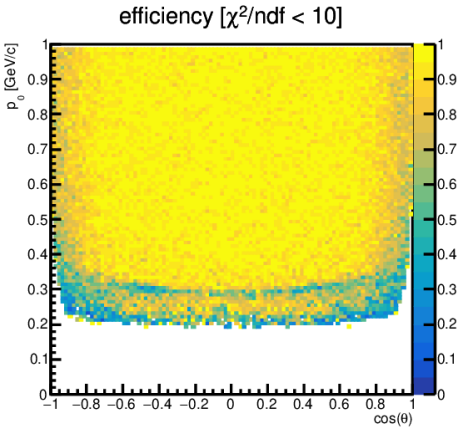
Protons: Track fitting efficiency for different quality cuts

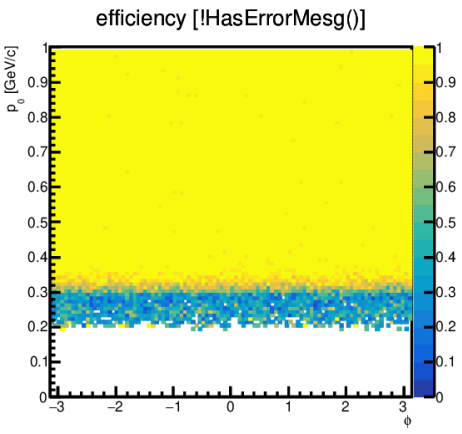
$$\text{efficiency} = \frac{\text{N of tracks after cut}}{\text{N of tracks before cut}}$$

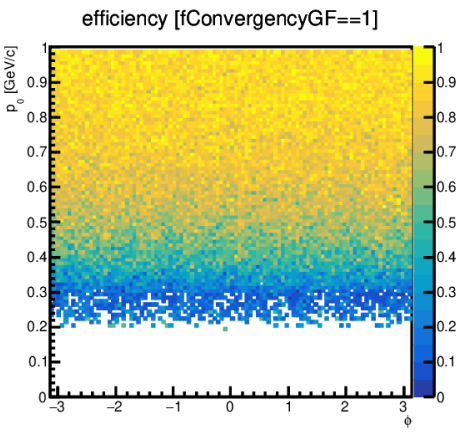


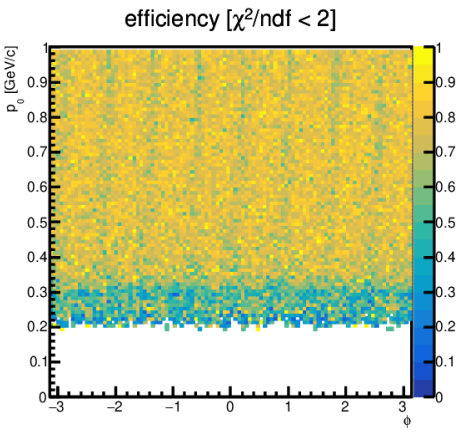


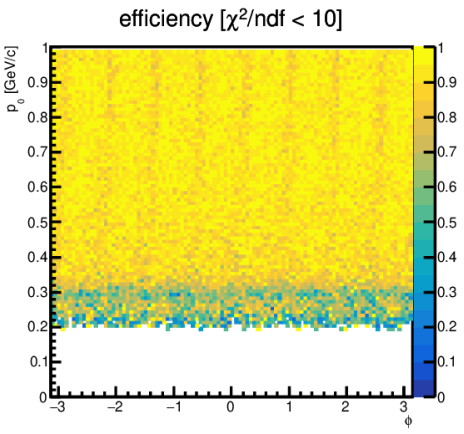




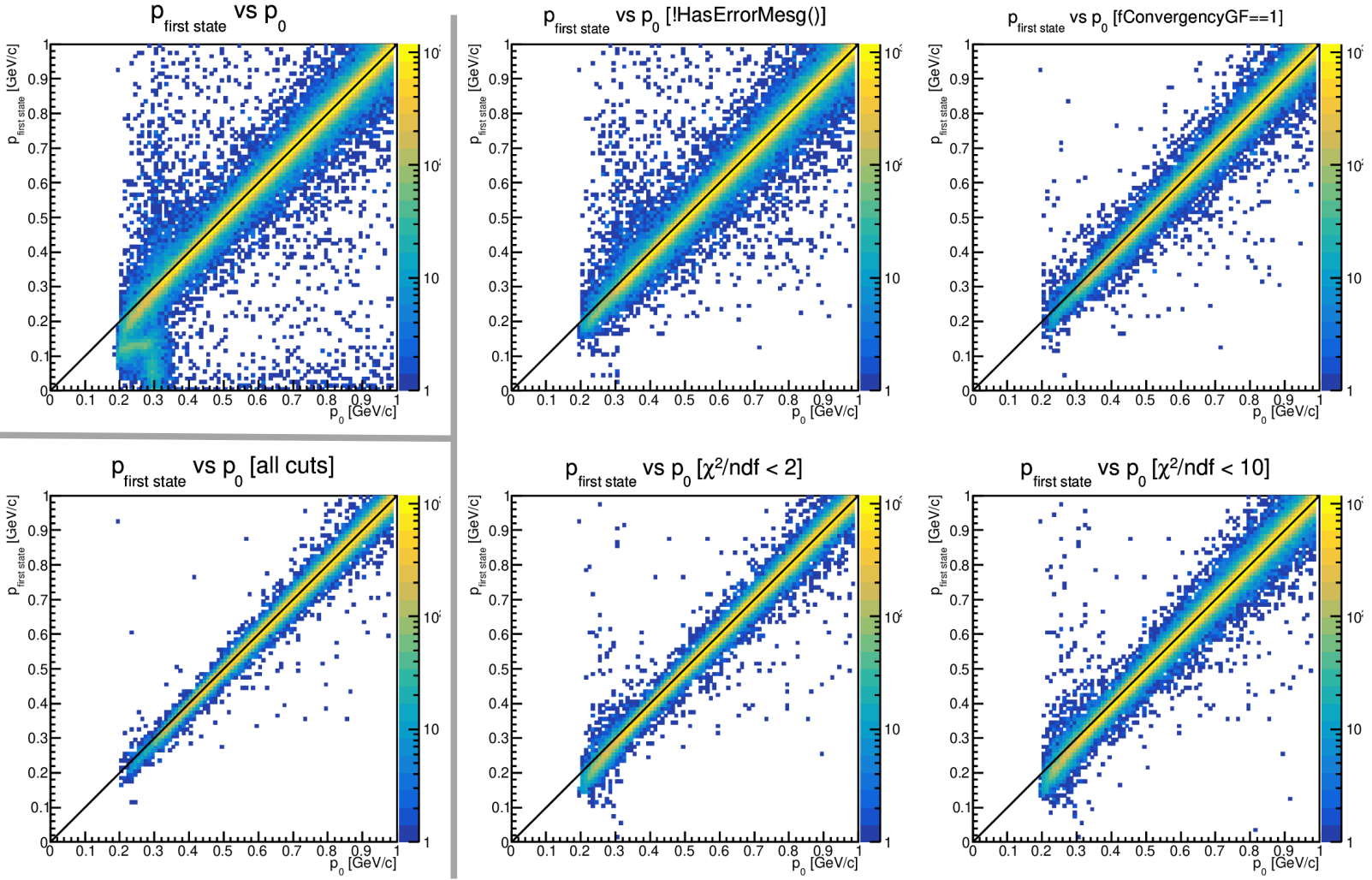






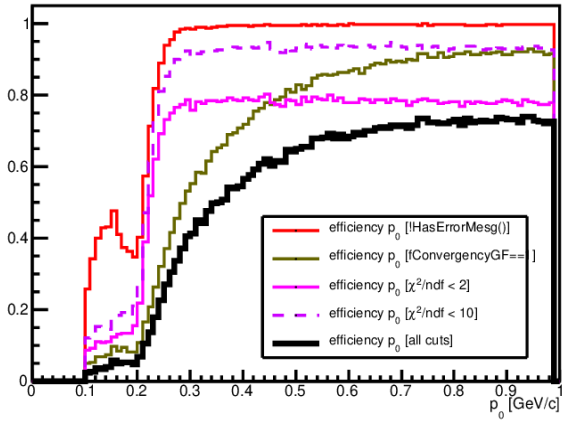


Protons: Reconstructed momentum in the first track point vs p_0

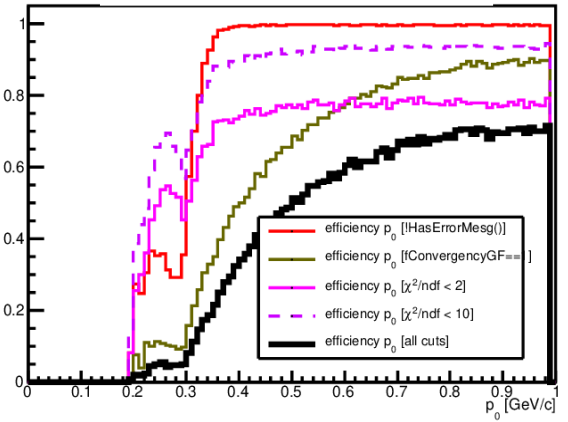


Track fitting efficiency for different quality cuts

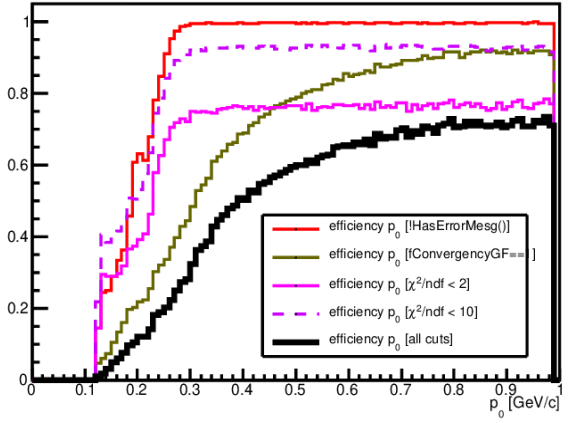
pions



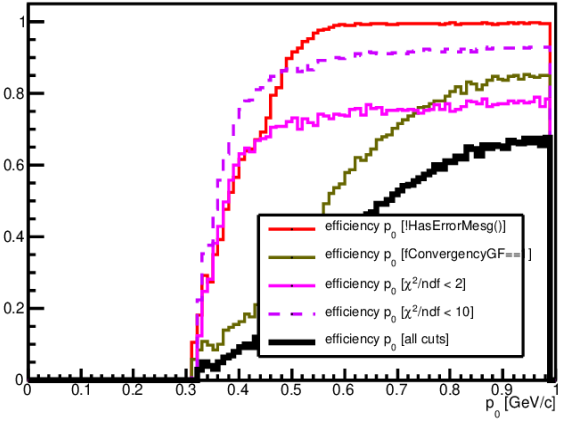
protons



kaons



deuterons



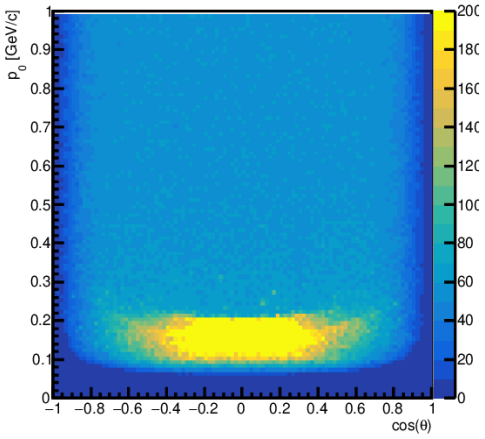
Summary

- Study of track fitting performance is SpdRoot was made.
- How tracking works is partially understood.
- We need tracking for tracks without ITS hits.
- χ^2/ndf distribution is puzzling.

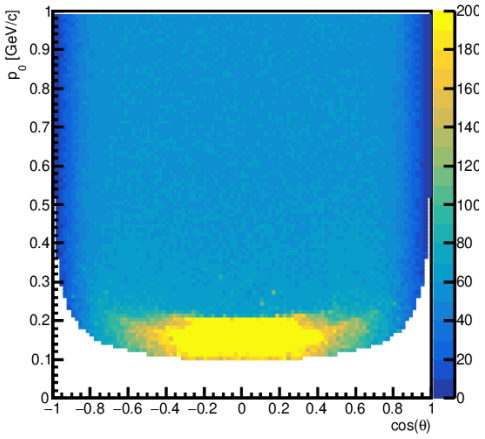
backup slides

Pions: Mean number of hits in TS barrel (p_0 : cos θ)

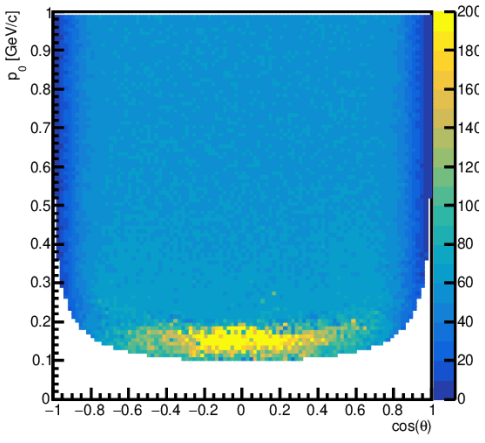
<N hits TS-B> (all primary particles)



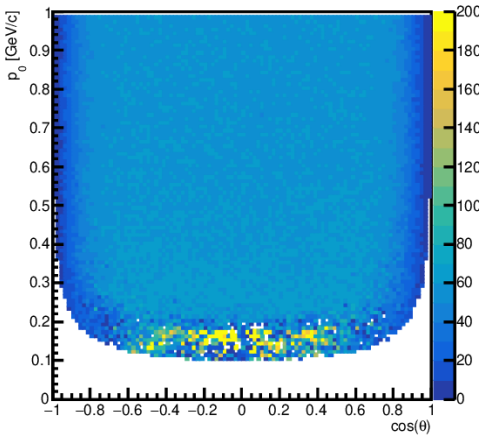
<N hits TS-B> (tracks, no quality cut)



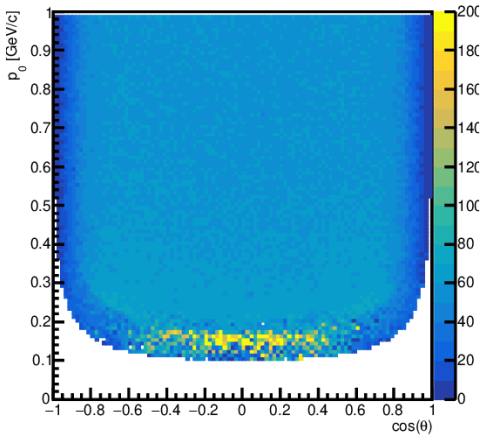
<N hits TS-B> [!HasErrorMesg()]



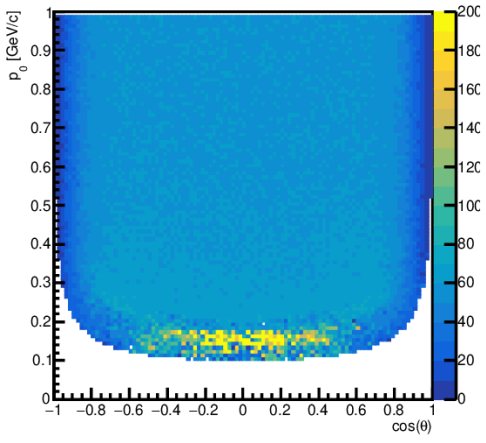
<N hits TS-B> [fConvergencyGF==1]



<N hits TS-B> [χ^2/ndf < 2]

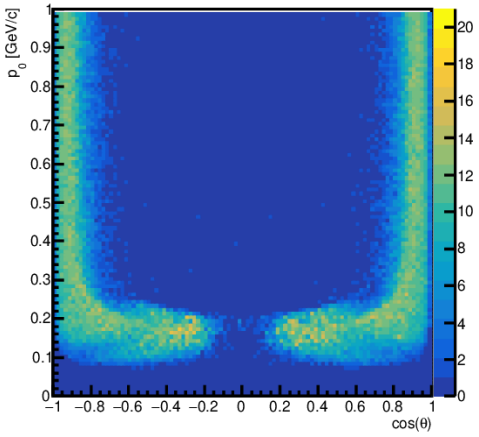


<N hits TS-B> [χ^2/ndf < 10]

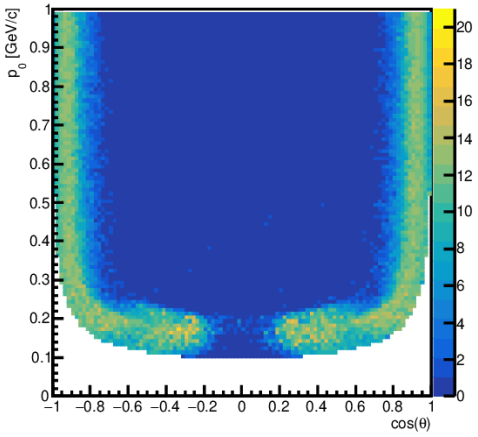


Pions: Mean number of hits in TS end-caps (p_0 : cos θ)

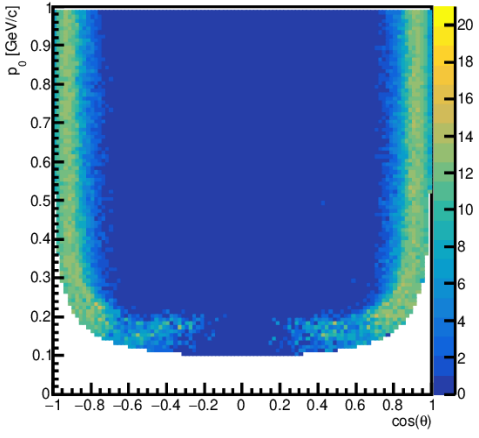
<N hits TS-EC> (all primary particles)



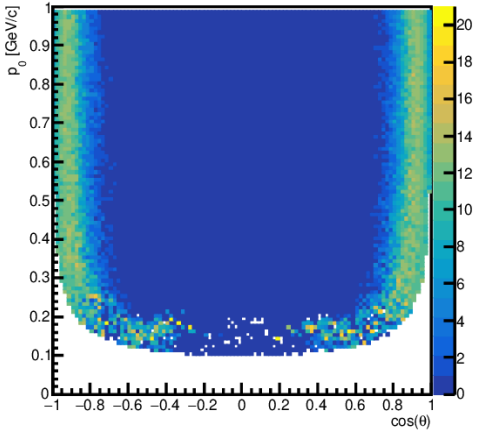
<N hits TS-EC> (tracks, no quality cut)



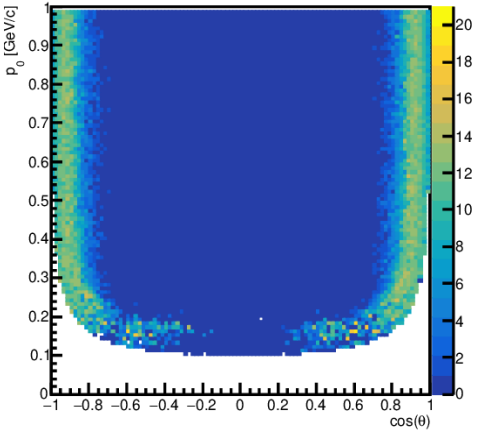
<N hits TS-EC> [!HasErrorMesg()]



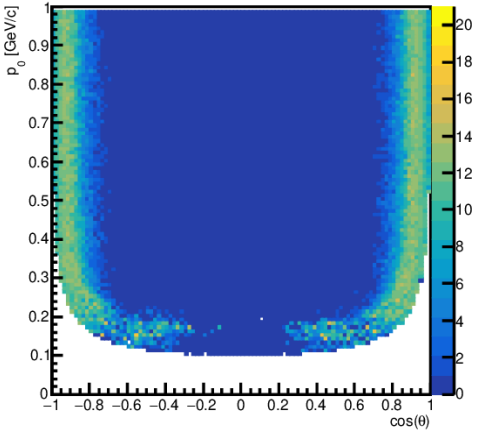
<N hits TS-EC> [fConvergencyGF==1]



<N hits TS-EC> [χ^2/ndf < 2]

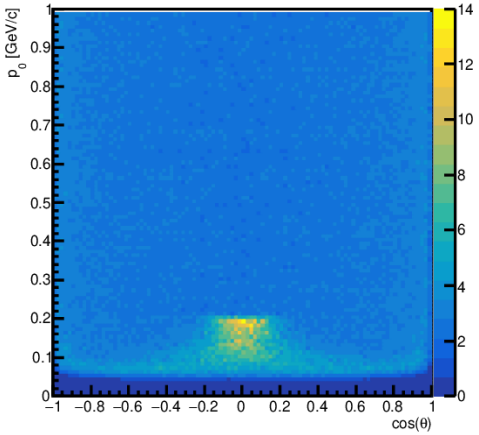


<N hits TS-EC> [χ^2/ndf < 10]

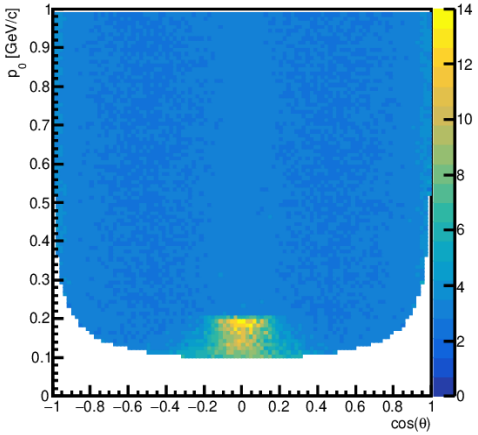


Pions: Mean number of hits in ITS (p_0 : cos θ)

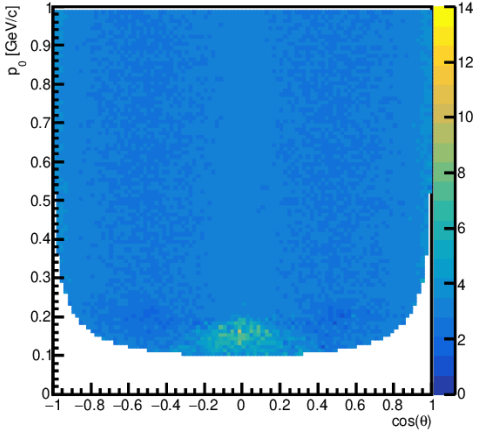
<N hits ITS> (all primary particles)



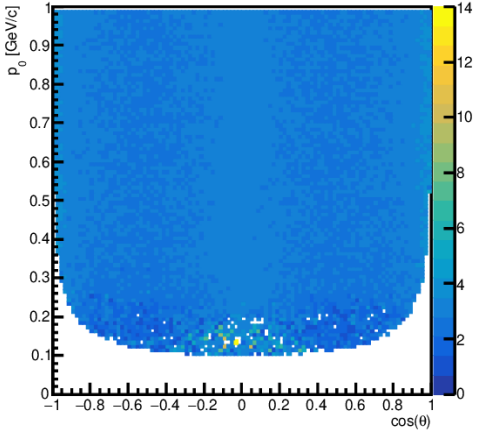
<N hits ITS> (tracks, no quality cut)



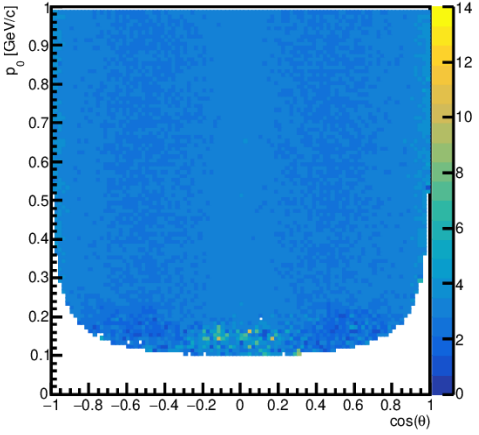
<N hits ITS> [!HasErrorMesg()]



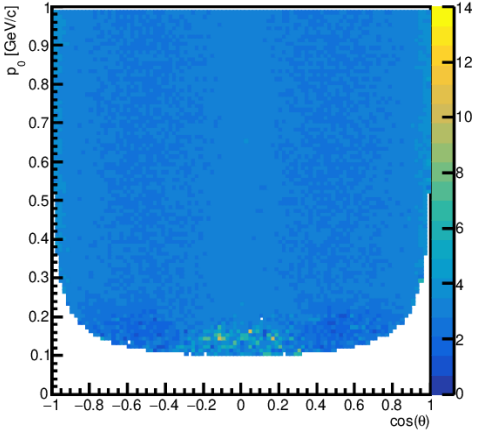
<N hits ITS> [fConvergencyGF==1]



<N hits ITS> [χ^2/ndf < 2]

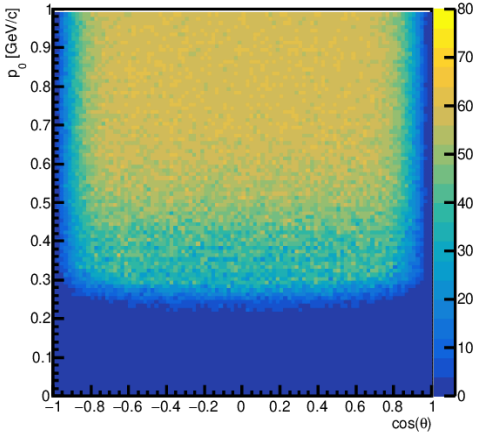


<N hits ITS> [χ^2/ndf < 10]

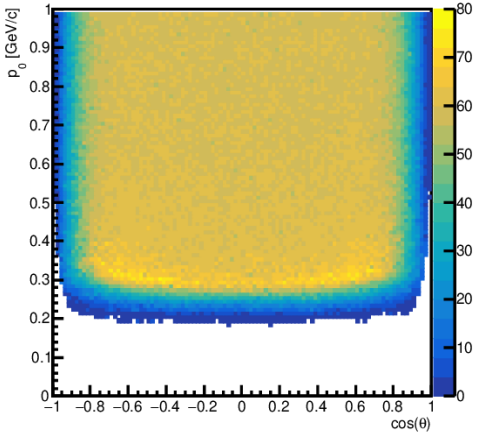


Protons: Mean number of hits in TS barrel (p_0 : cos θ)

<N hits TS-B> (all primary particles)



<N hits TS-B> (tracks, no quality cut)



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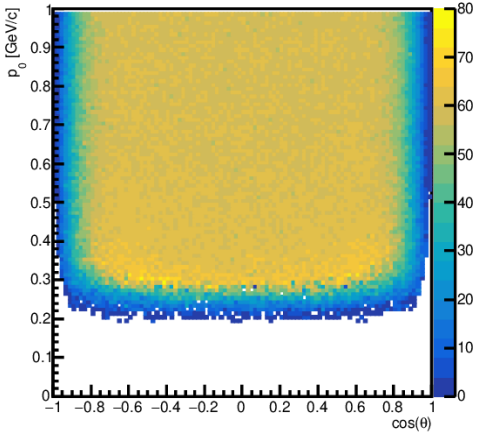
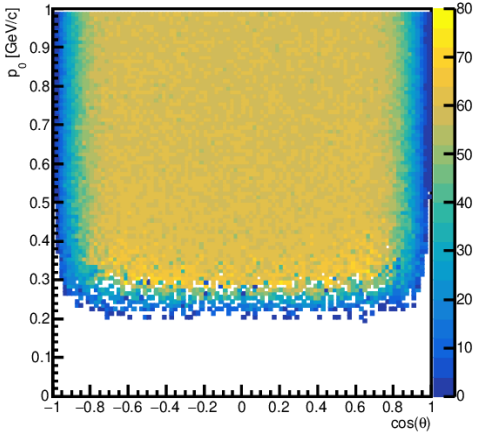
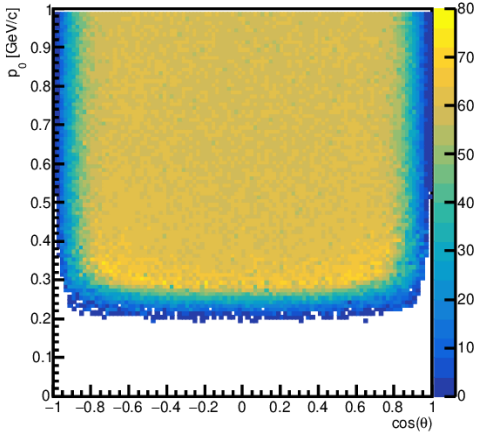


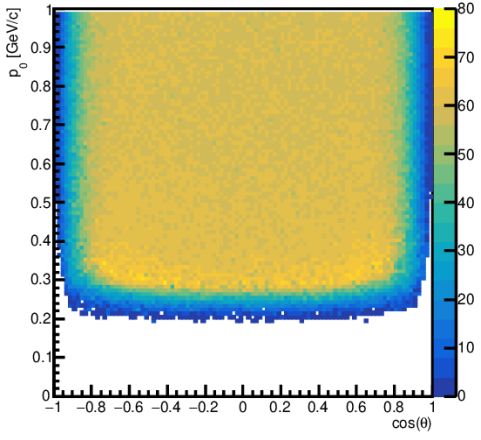
<N hits TS-B> [fConvergencyGF==1]



<N hits TS-B> [χ^2/ndf < 2]

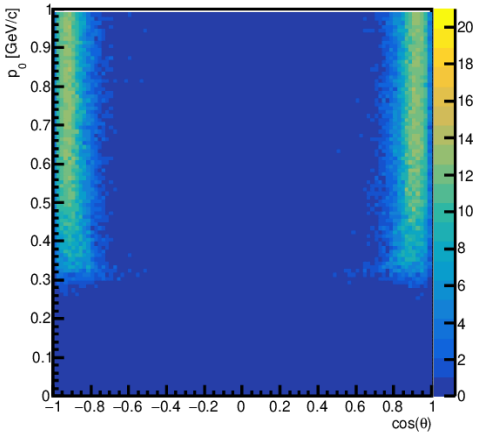


<N hits TS-B> [χ^2/ndf < 10]

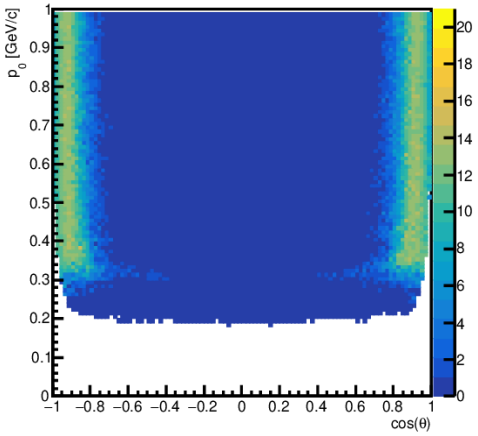


Protons: Mean number of hits in TS end-caps (p_0 : cos θ)

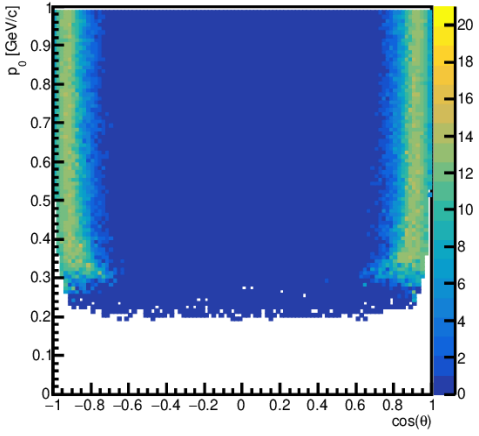
<N hits TS-EC> (all primary particles)



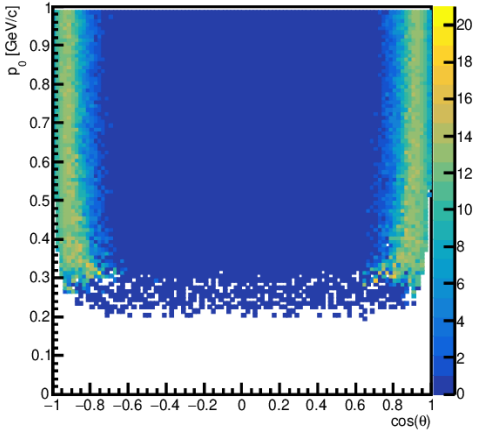
<N hits TS-EC> (tracks, no quality cut)



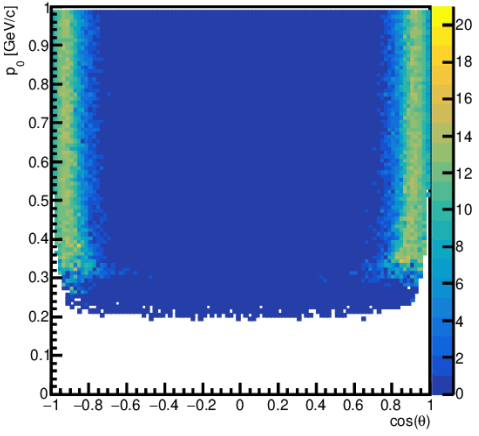
<N hits TS-EC> [!HasErrorMesg()]



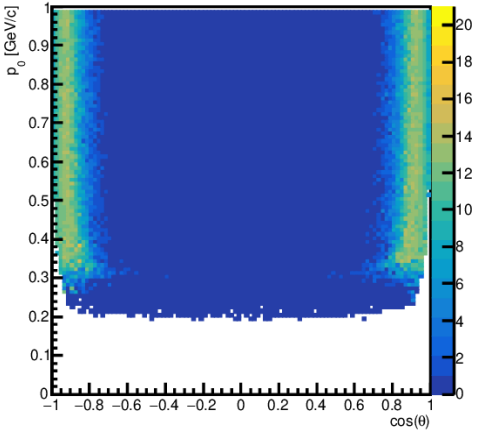
<N hits TS-EC> [fConvergencyGF==1]



<N hits TS-EC> [χ^2/ndf < 2]



<N hits TS-EC> [χ^2/ndf < 10]



Protons: Mean number of hits in ITS (p_0 : cos θ)