Studies of tracking in the transition region between FD and CD

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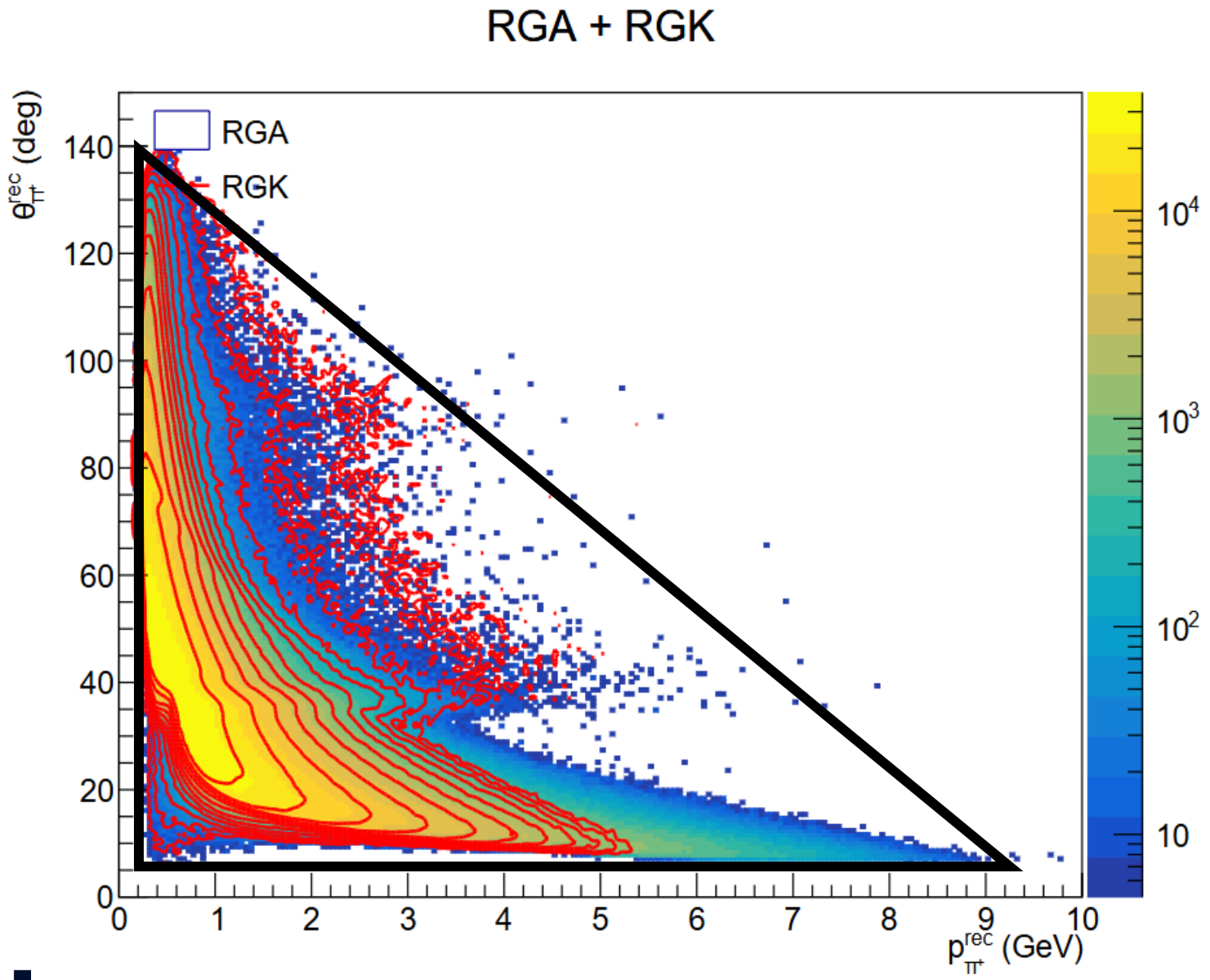
Motivation of my talk

Kinematic Corrections

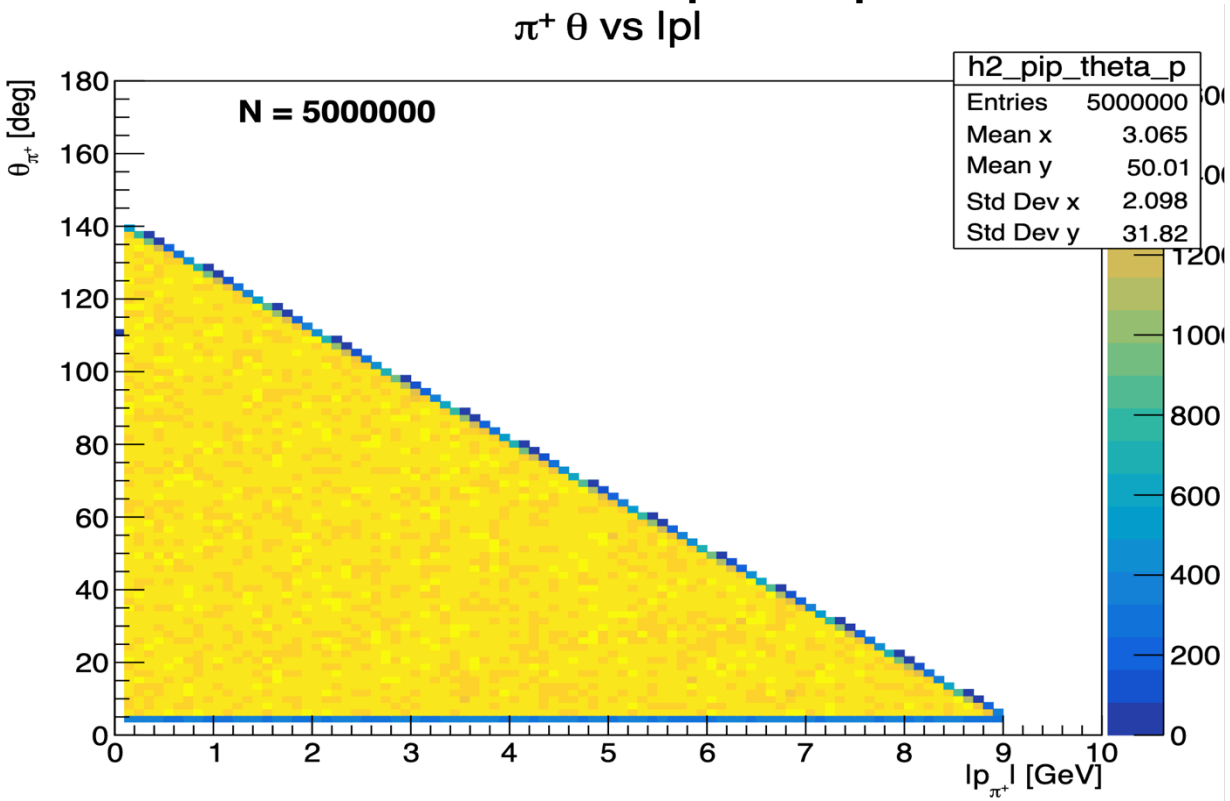
- **Phase 1: Energy-loss corrections**
  - Correct for energy lost by charged particles as they pass through detector material
- **Phase 2: Kinematic corrections**
  - Use exclusive reactions to correct for detector misalignment, magnetic-field mismapping, and related effects
- Done for electrons in FD. Still **needs to be done for hadrons**
- In the **Central Detector**, energy-loss corrections are already applied during reconstruction
- Equivalent corrections are still needed for **Forward Detector tracking**
- This talk will present a part of **hadron energy-loss corrections in the FD**, focusing on the **FD–CD transition region**

Simulation preparation for π^+ in the phase space of RGA+RGK

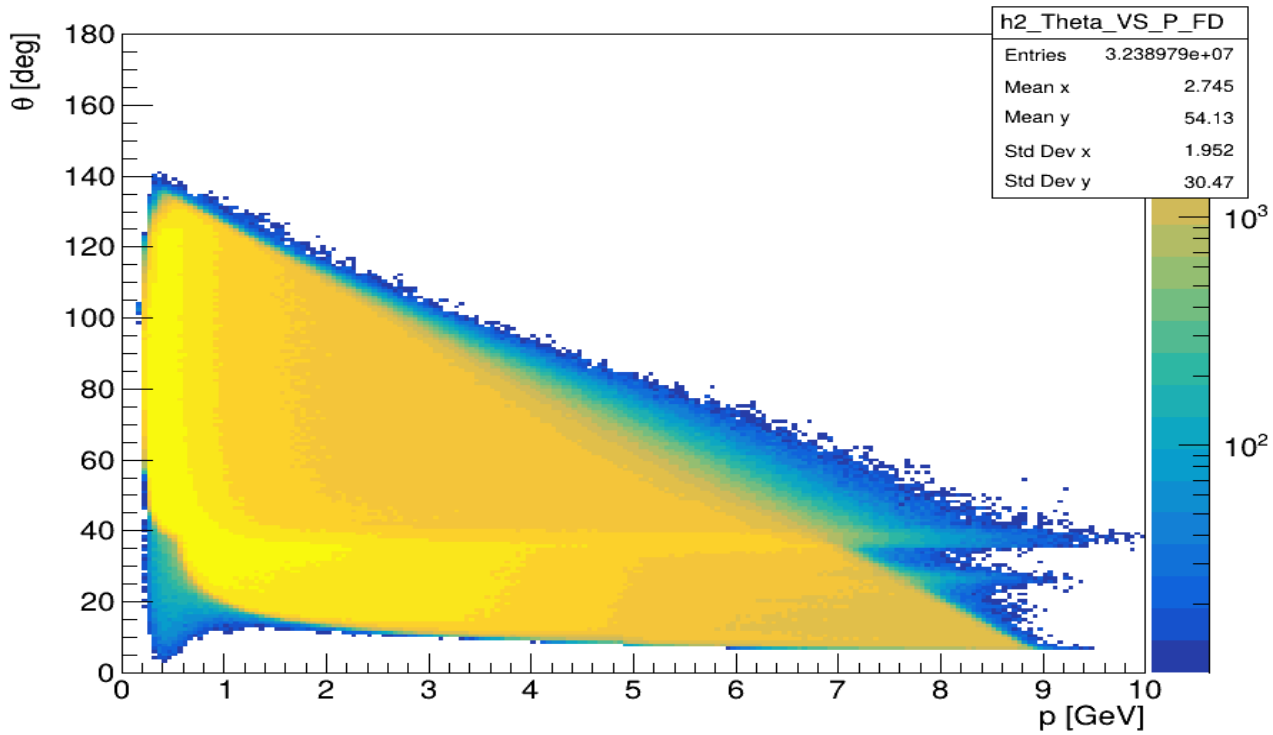


Simulation: one electron and one uncorrelated π^+ per event

Generated π^+ phase space



Reconstructed π^+ phase space



Final state: Generated electron kinematics (trigger particle)

Momentum: $1.5 < p_e < 10.6$ GeV

Polar angle: $5^\circ < \theta_e < 25^\circ$

Generated π^+ kinematics: triangular region

Momentum: $0.1 < p_{\pi^+} < 9.0$ GeV

Polar angle: $5^\circ < \theta_{\pi^+} < 140^\circ$

- **Configuration:** `rga_fall2018`
- **Software versions:** `gemc/5.13`, `coatjava/10.0.7`
- **Magnetic fields:** Torus `+1.00`, Solenoid `−1.00`
- **Negative outbending**

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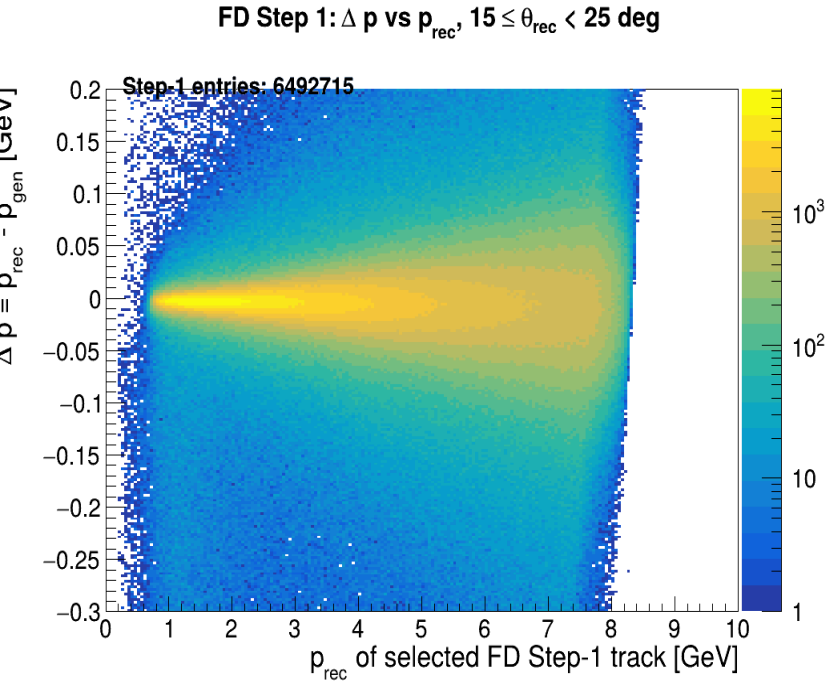
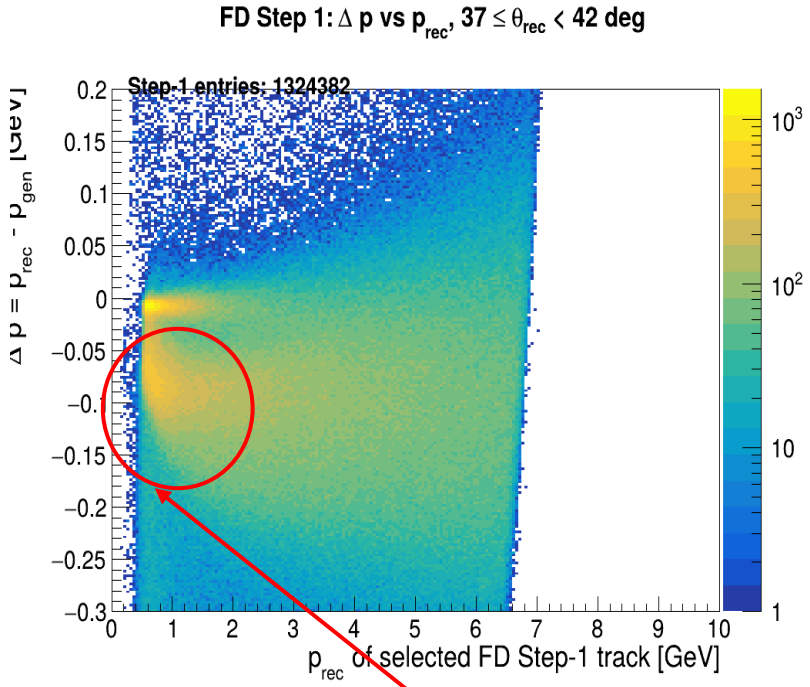
2D distributions in FD

- We select events with at least 1 positive track reconstructed in FD
- Choose the track with momentum closest to the generated one
- $\Delta p = p_{rec} - p_{gen}$
- θ_{rec} – defined at the vertex

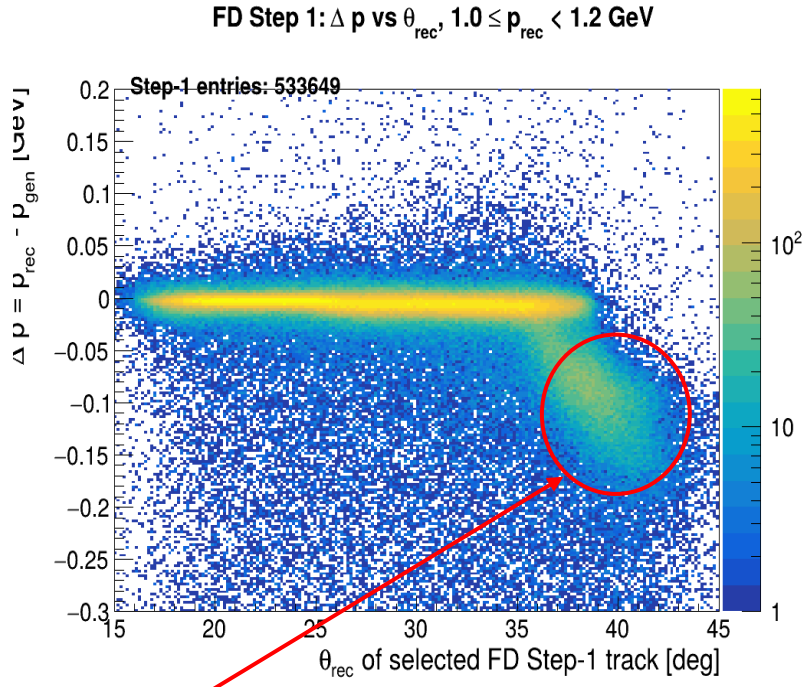
Δp vs p_{rec} in good region



Δp vs p_{rec} in problematic region



Δp vs θ_{rec}

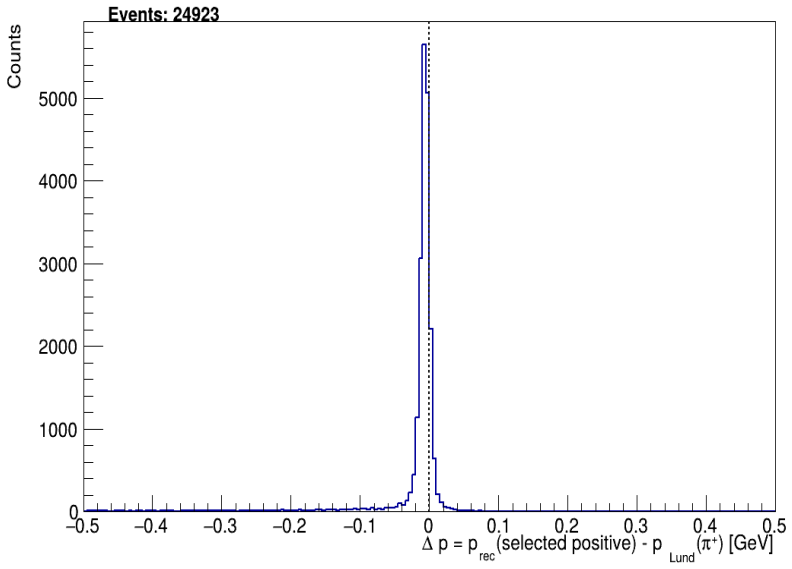


Symptoms of a problem at higher angle

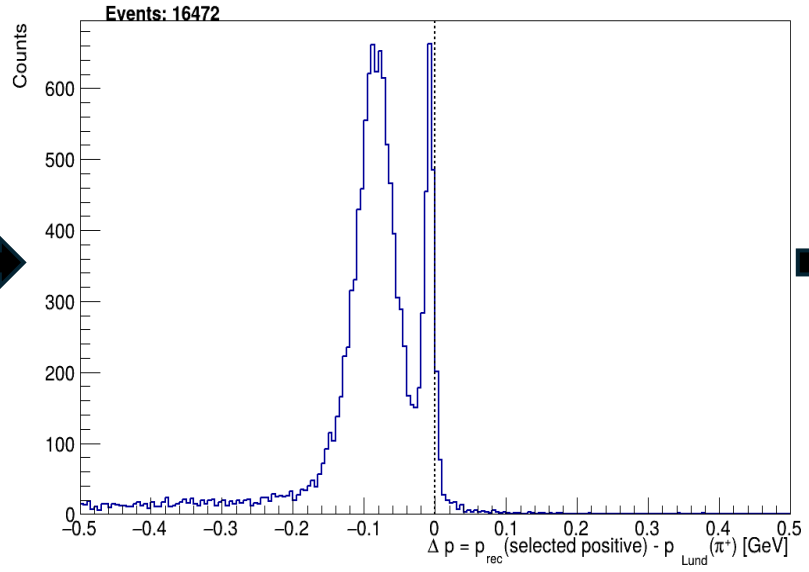
1D Δp distributions in FD

We fix momentum bin: $p_{rec} \in [1,1.2] GeV$

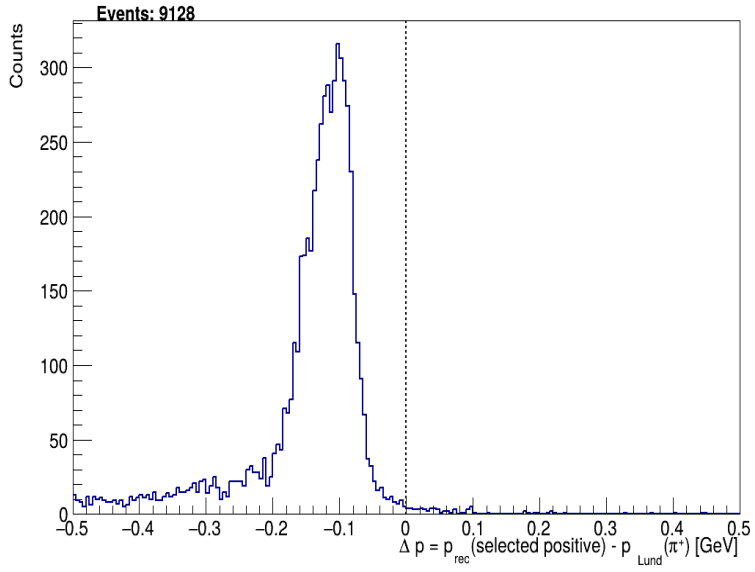
$\theta \in [30,31]^\circ$



$\theta \in [38,39]^\circ$

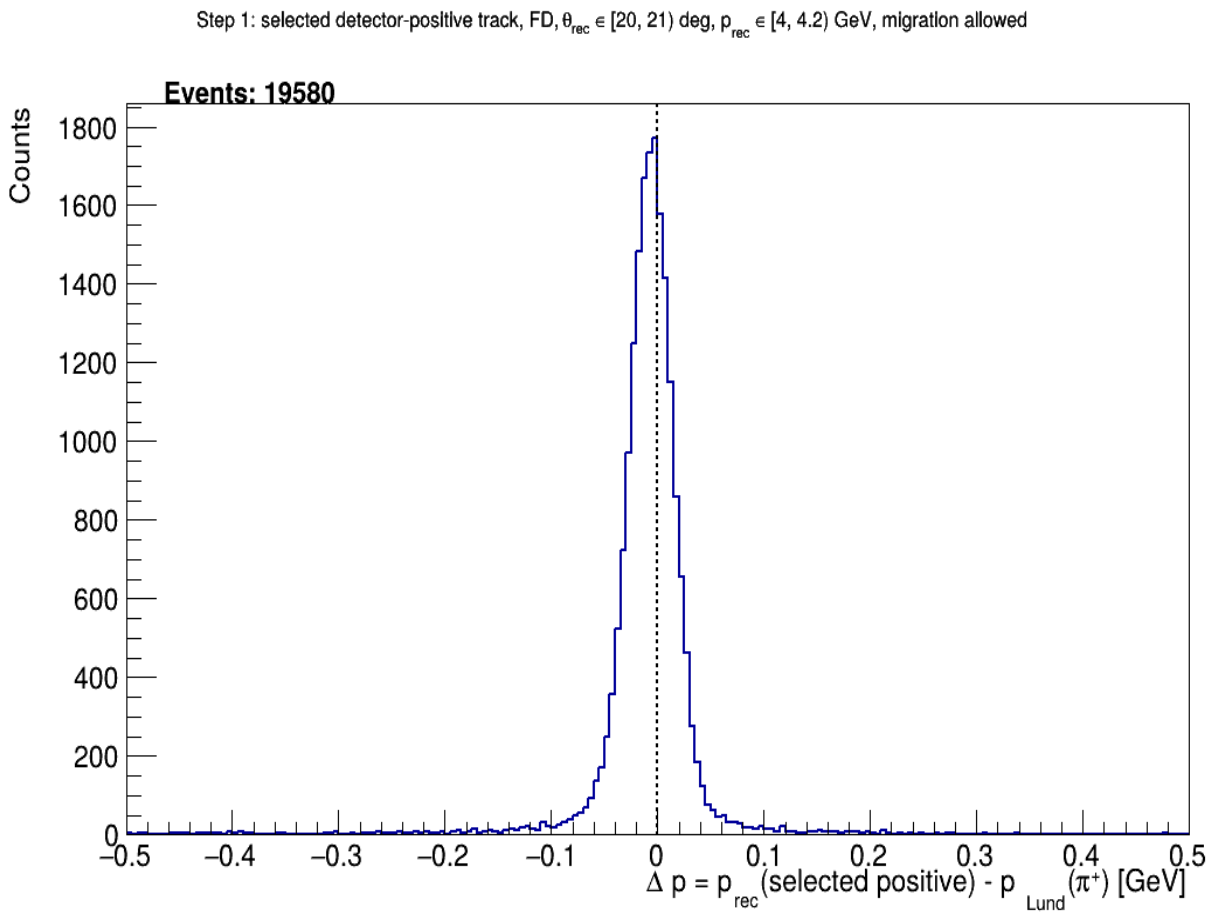


$\theta \in [40,41]^\circ$

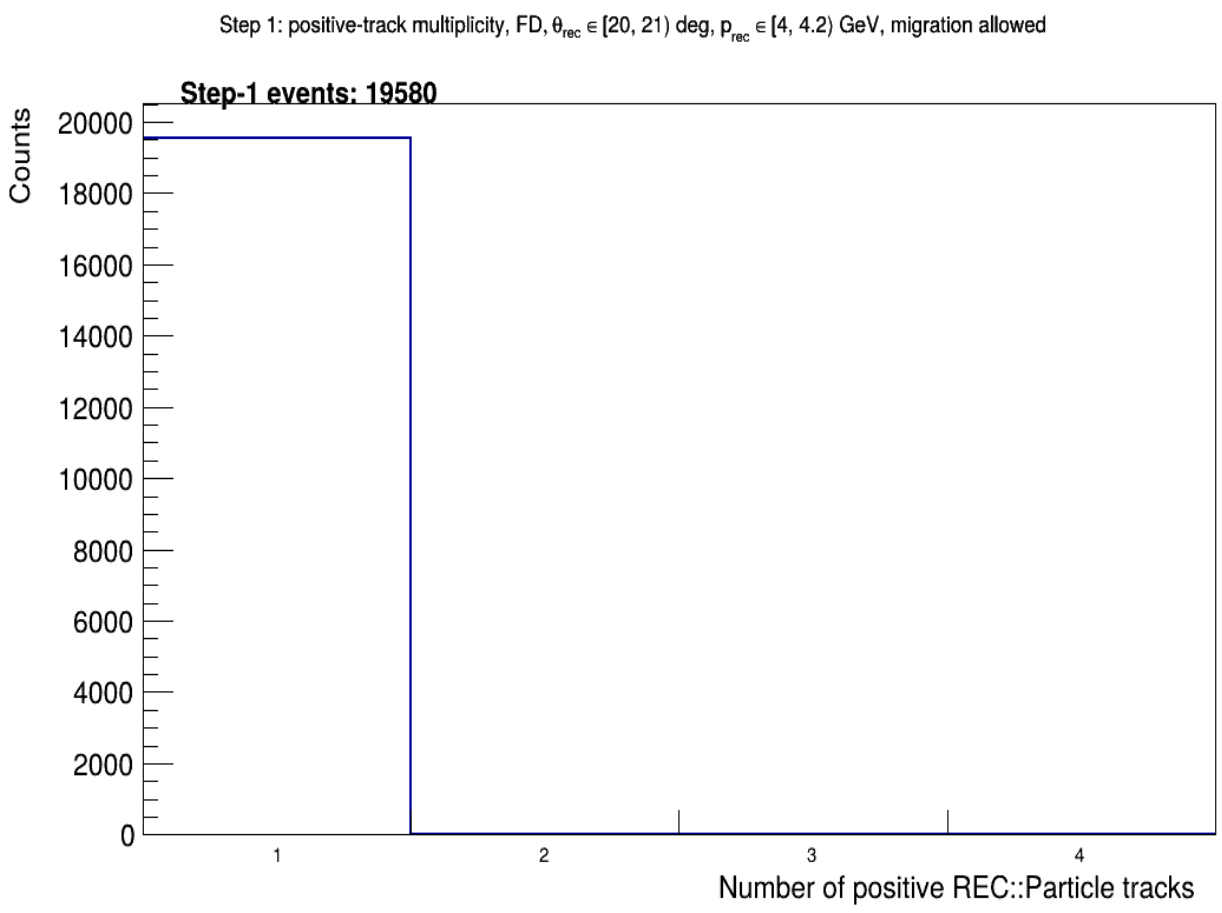


Forward detector. Safe region: $\theta \in [20°, 21°]$, Momentum $\in [4.0, 4.2]$GeV
One narrow peak. Only 1 reconstructed positive track.

Δp distribution

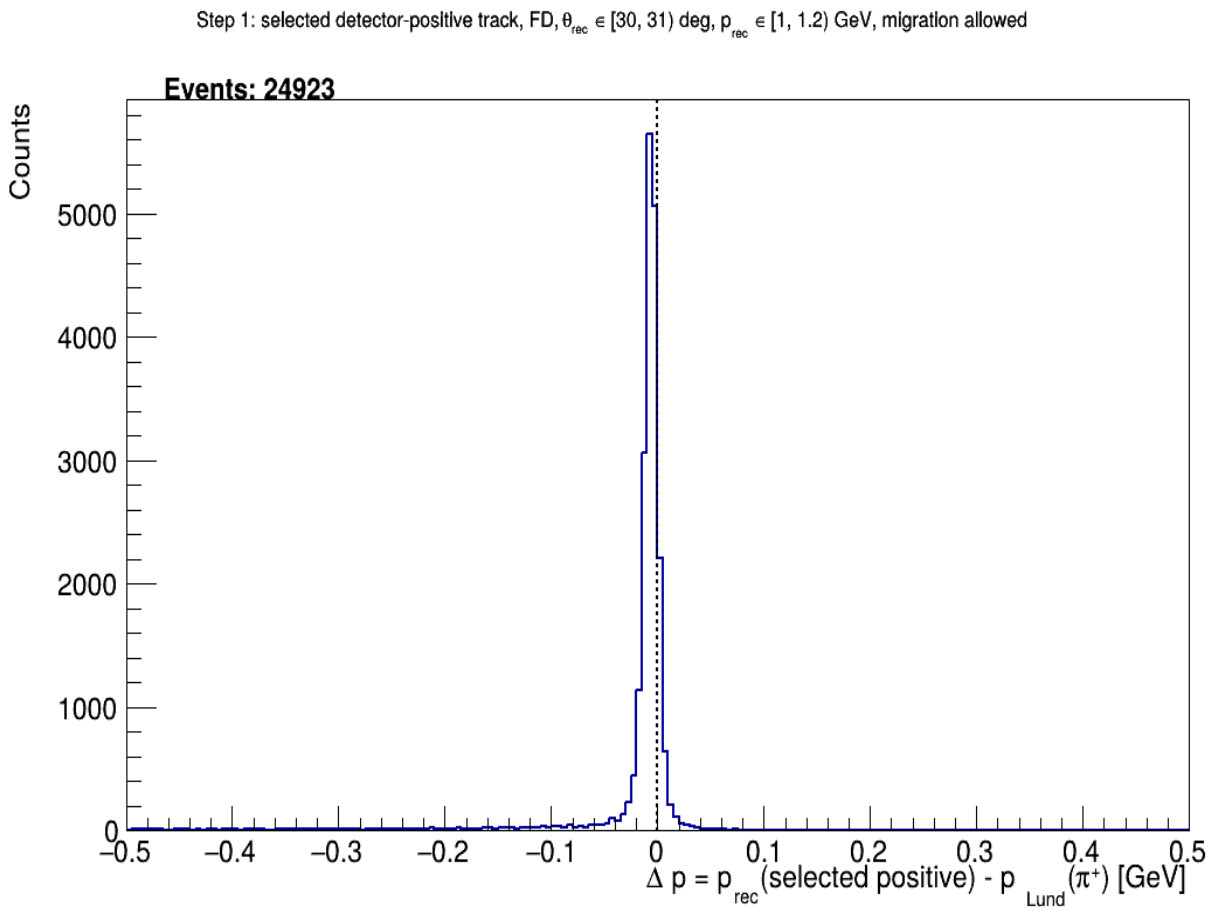


Positive track multiplicity

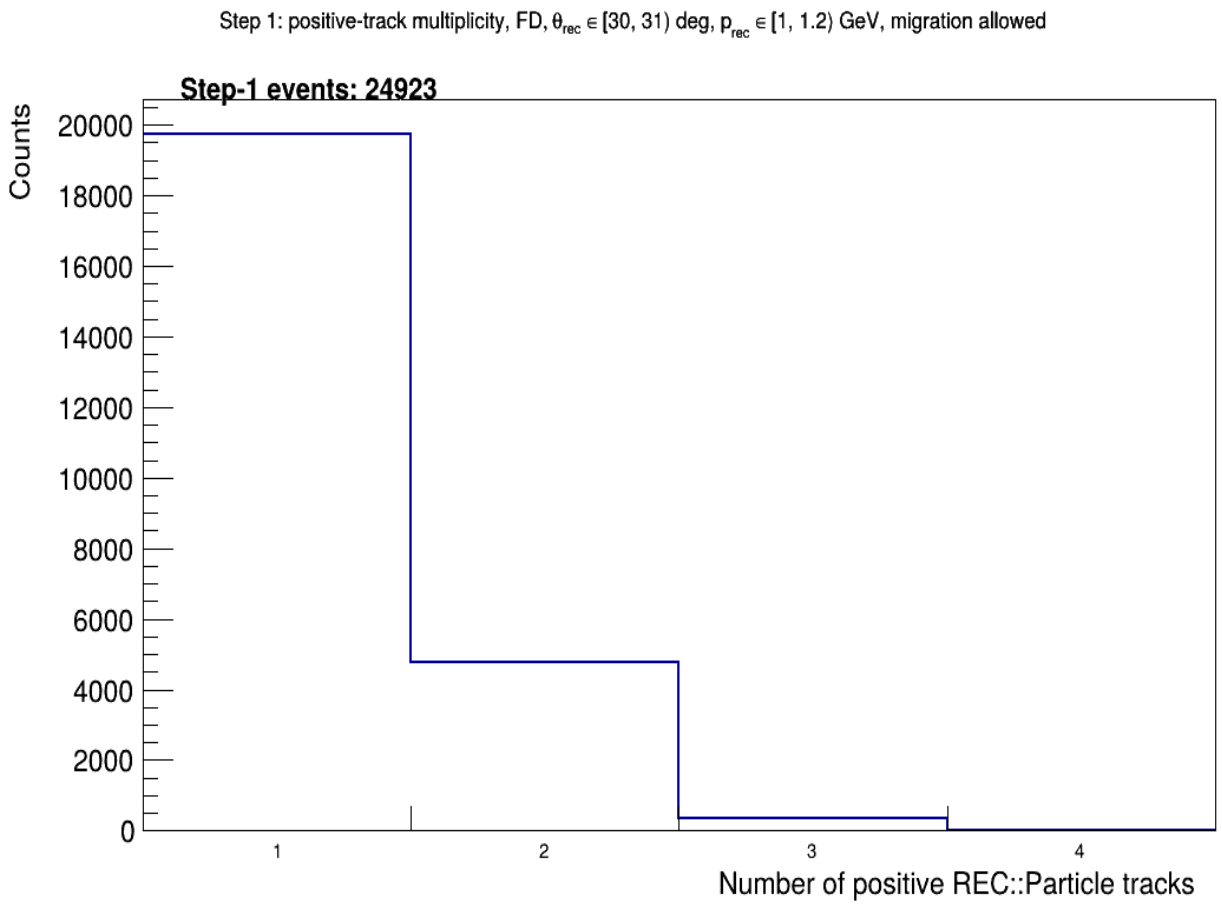


Forward detector. Good region: $\theta \in [30°, 31°]$, Momentum $\in [1.0,1.2]$GeV
One narrow peak. Mostly 1 reconstructed positive track.

Δp distribution

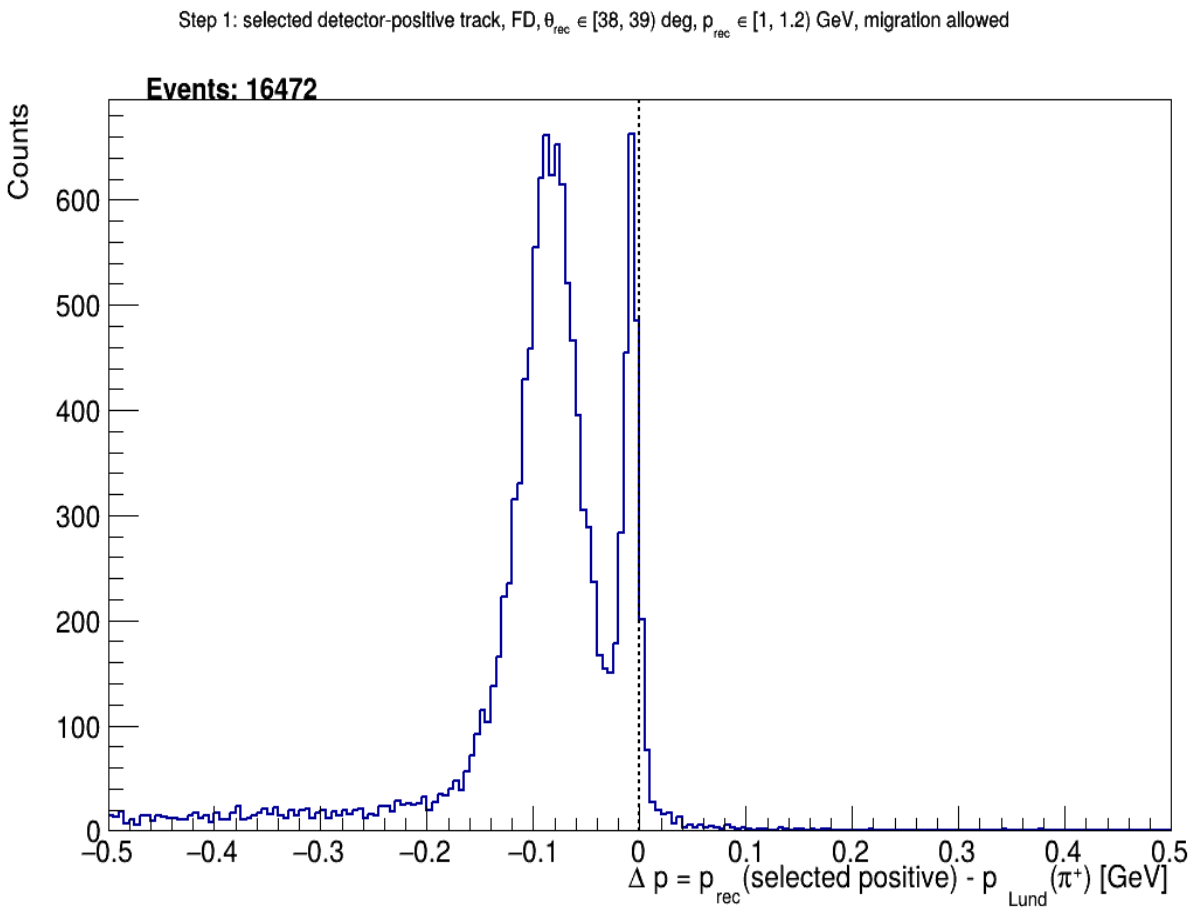


Positive track multiplicity

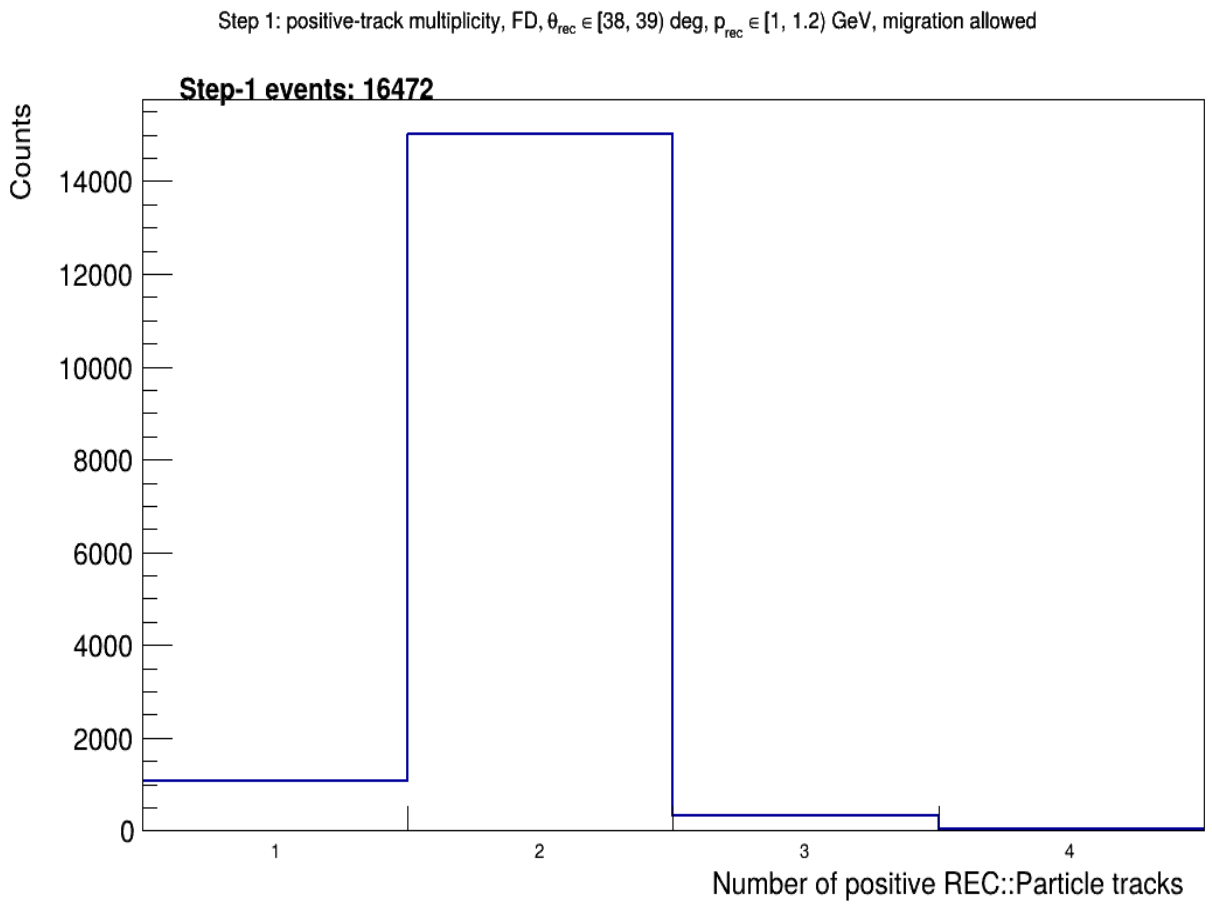


Forward detector. Problematic region: $\theta \in [38°, 39°]$, Momentum $\in [1.0,1.2]$GeV
Narrow peak and wide peak. Mostly 2 reconstructed positive tracks

Δp distribution



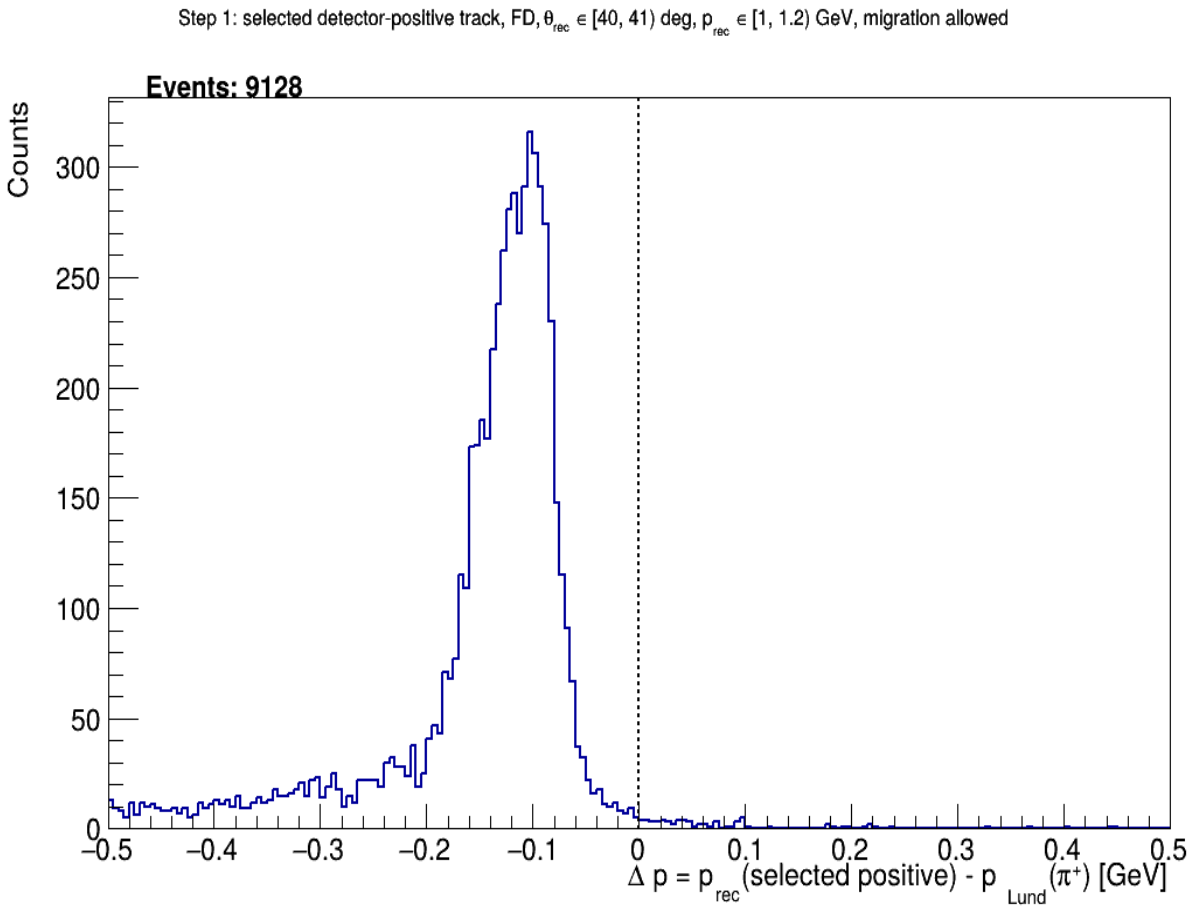
Positive track multiplicity



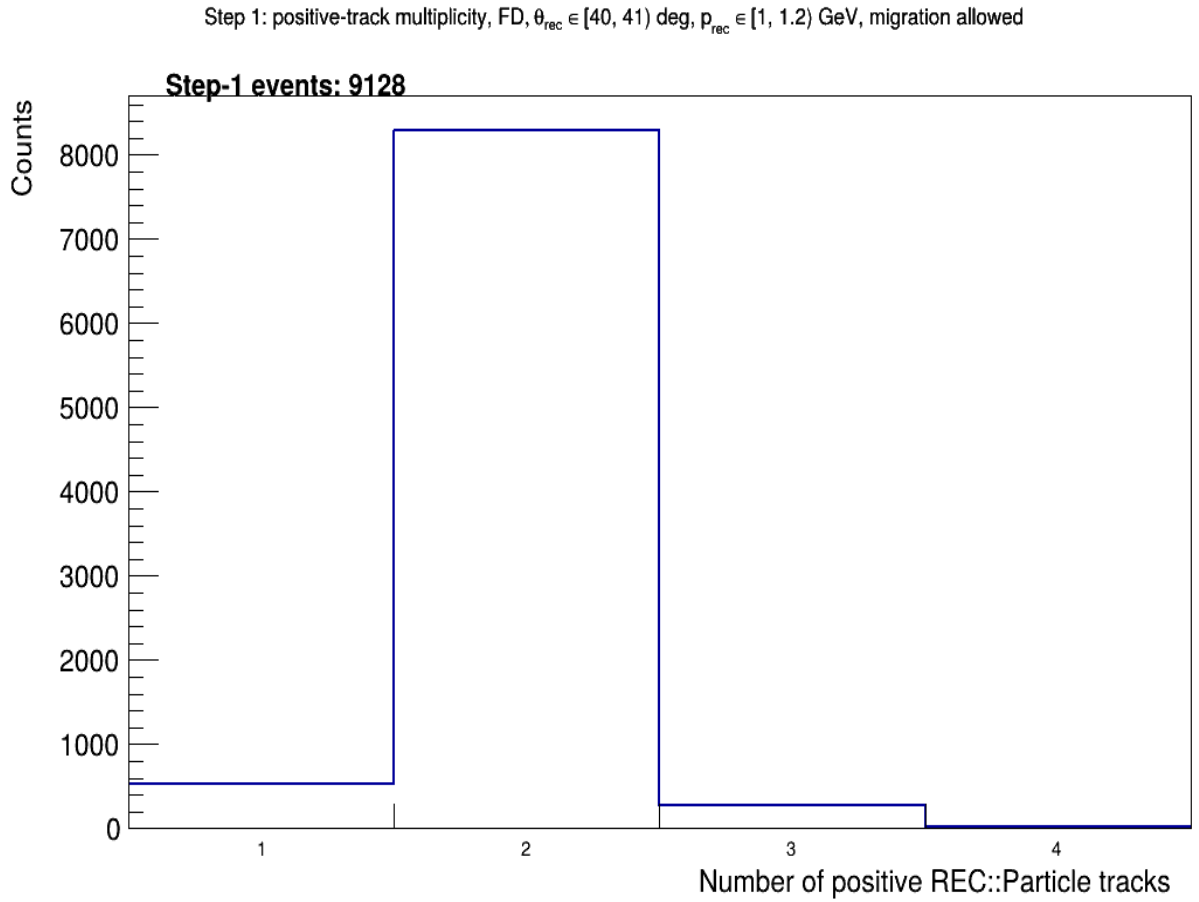
Forward detector. Bad region: $\theta \in [40°, 41°]$, Momentum $\in [1.0,1.2]$GeV

No narrow peak, only wide peak. Mostly 2 reconstructed positive tracks

Δp distribution



Positive track multiplicity

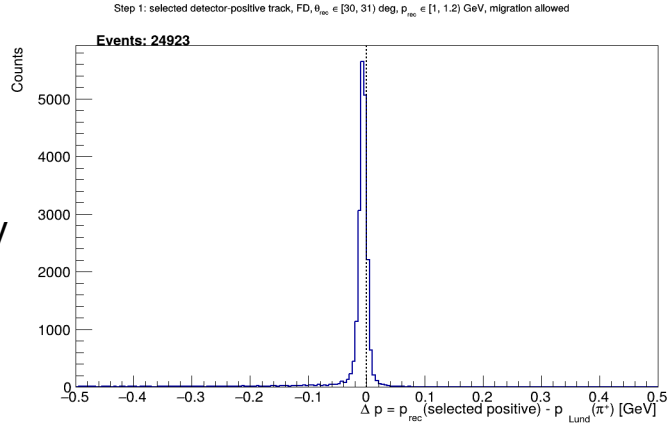


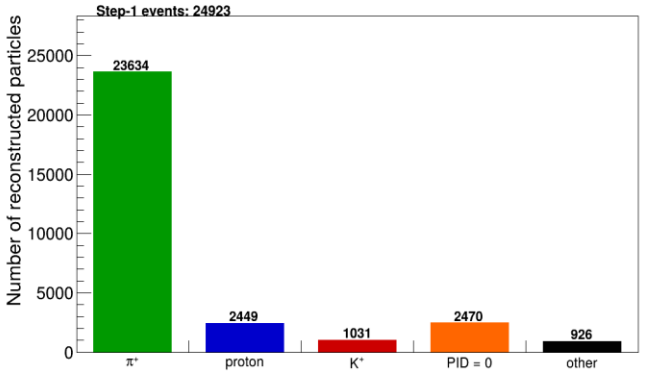
Δp distribution
$\geq$ 1 positive track in the event

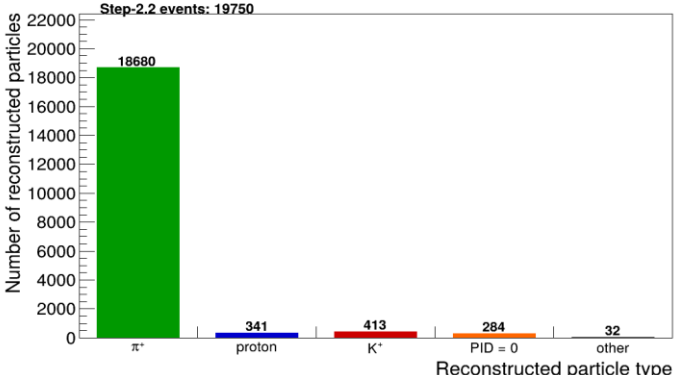
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

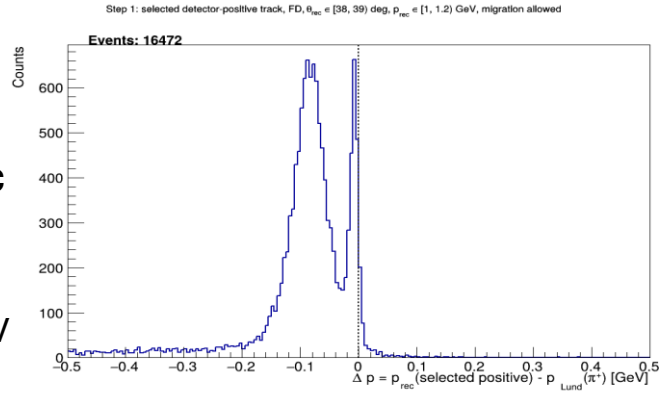
Good region
$\theta \in [30°, 31°]$
P ∈ [1.0,1.2]GeV

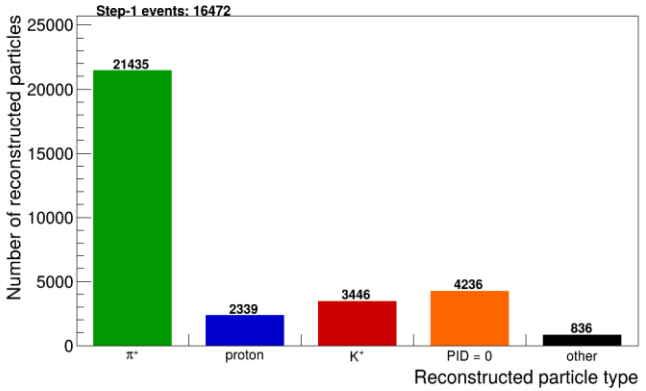


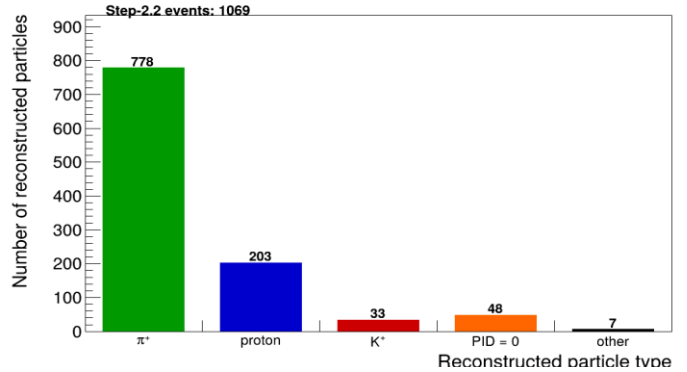




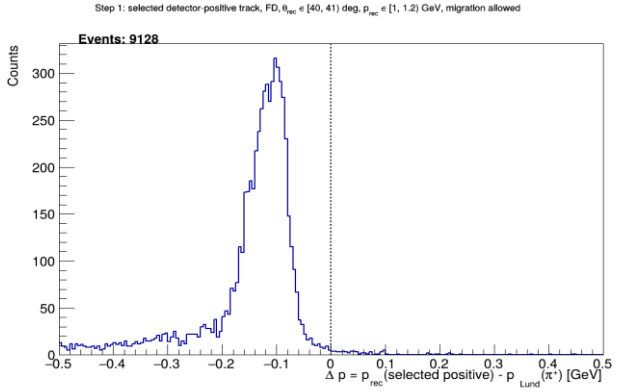
Problematic region
$\theta \in [38°, 39°]$
P ∈ [1.0,1.2]GeV

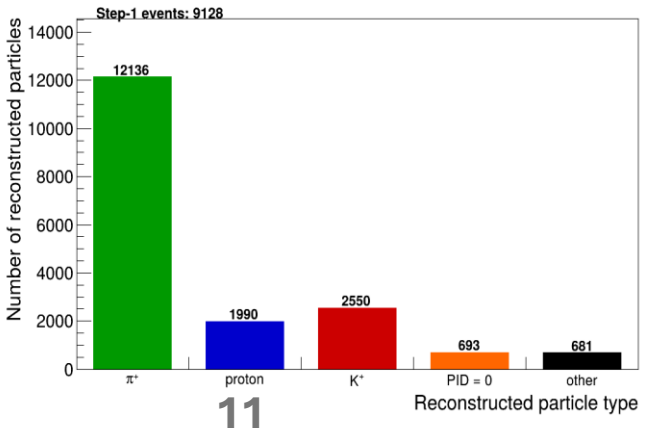


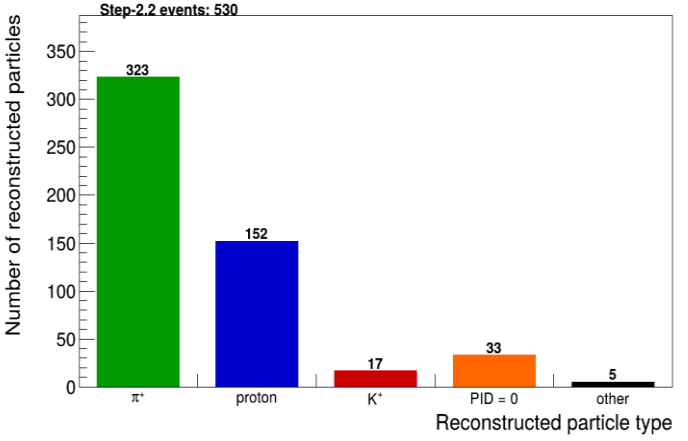




Bad region
$\theta \in [40°, 41°]$
P ∈ [1.0,1.2]GeV







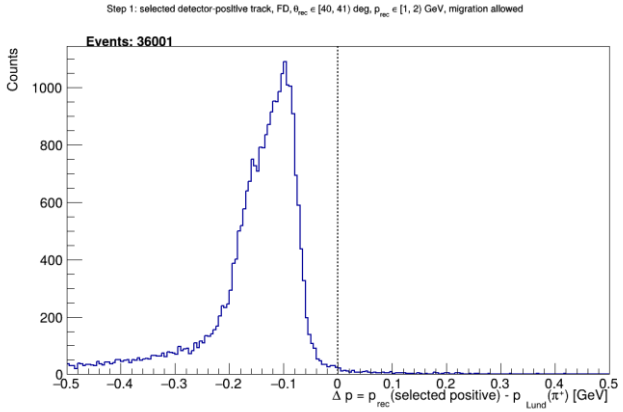
Now we fix polar angle bin $\theta \in [40°, 41°]$ and scan full momentum range in FD

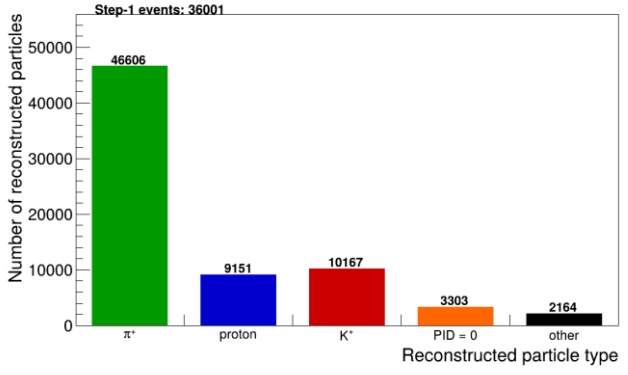
Δp distribution
$\geq$ 1 positive track in the event

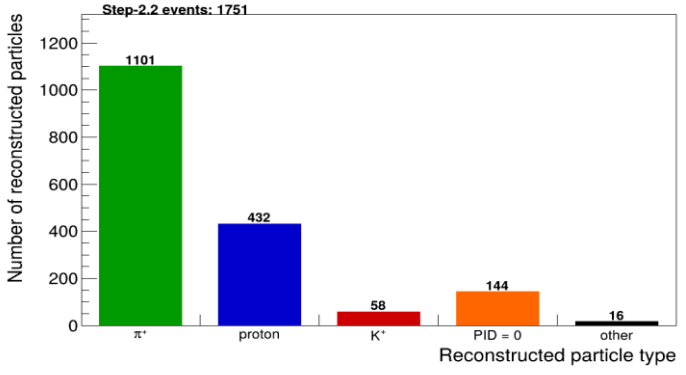
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

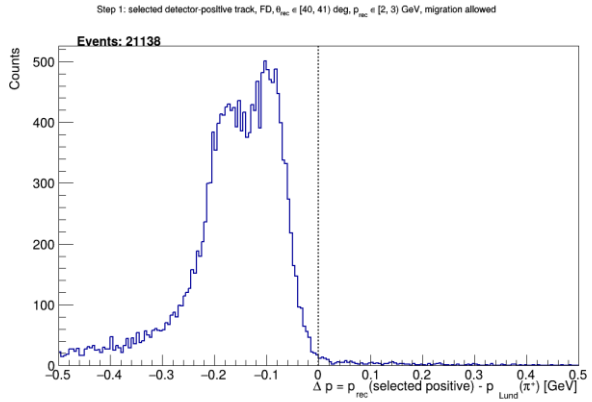
$\theta \in [40°, 41°]$
P $\in$ [1 , 2]GeV

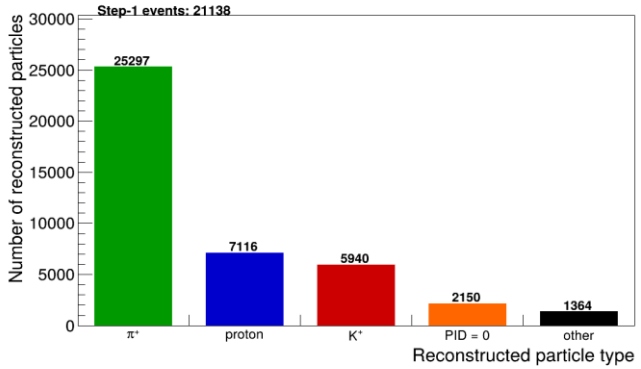


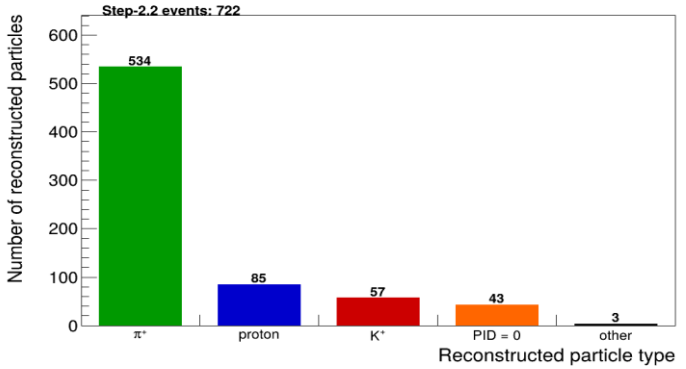




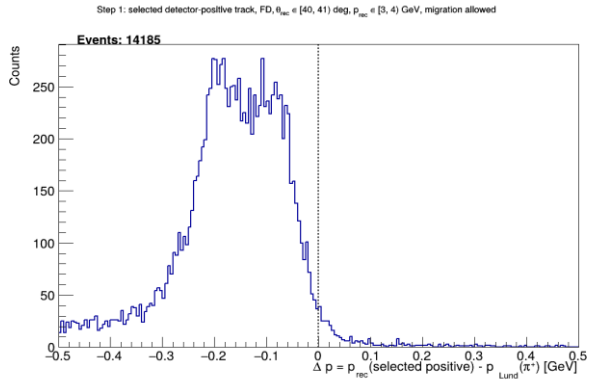
$\theta \in [40°, 41°]$
P $\in$ [2 , 3]GeV

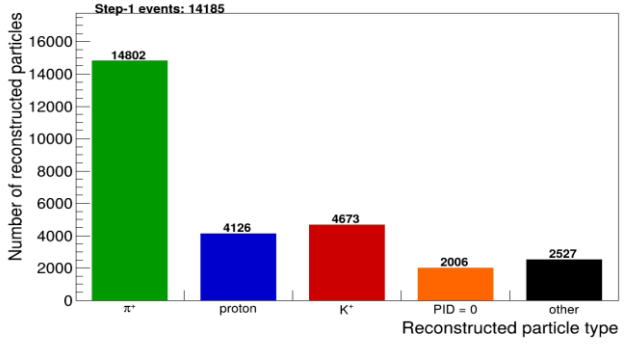


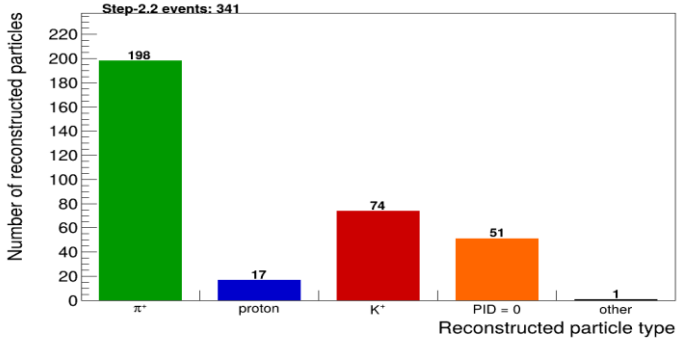




$\theta \in [40°, 41°]$
P $\in$ [3 , 4]GeV





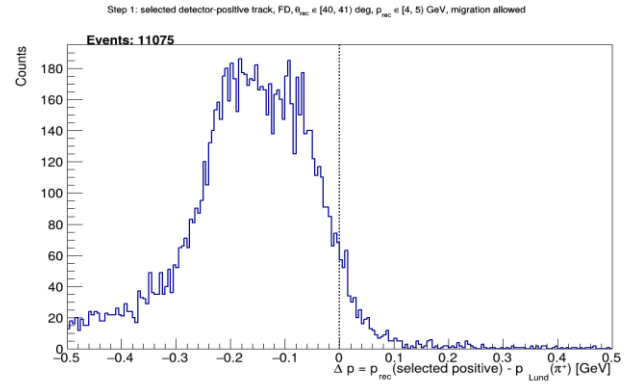


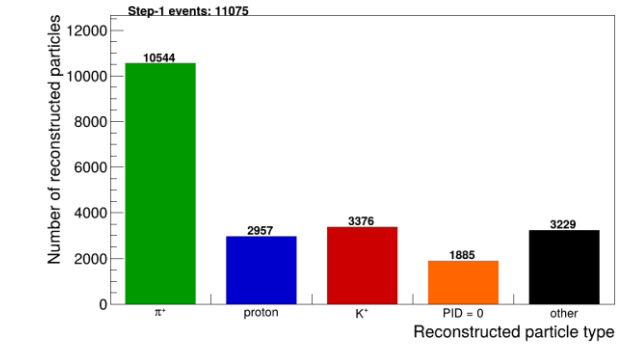
Δp distribution
$\geq$ 1 positive track in the event

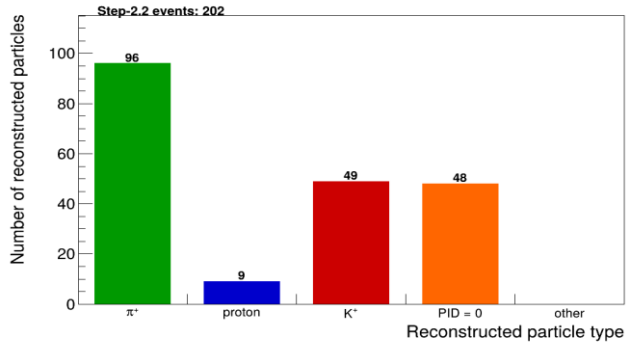
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

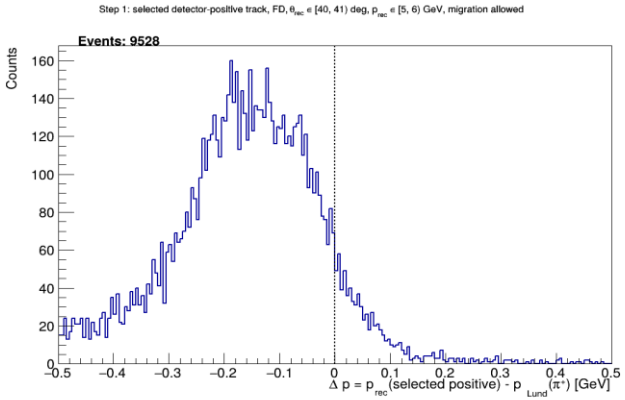
$\theta \in [40°, 41°]$
P $\in$ [4 , 5]GeV

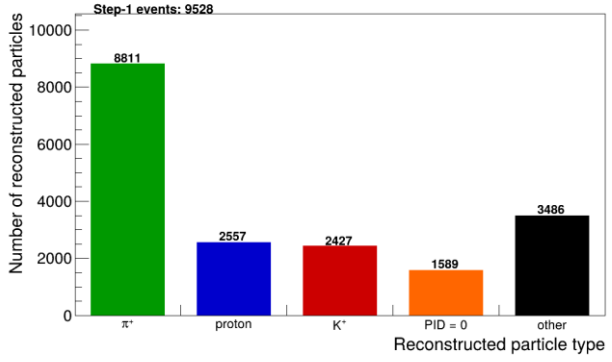


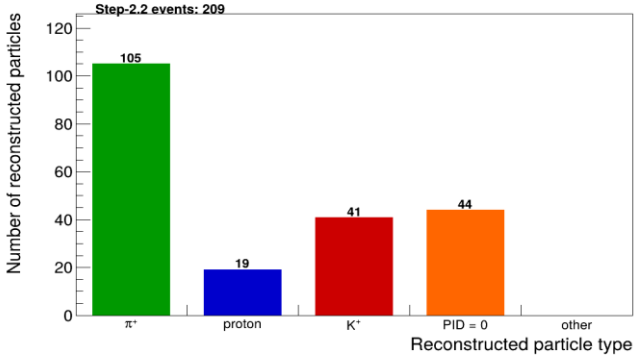




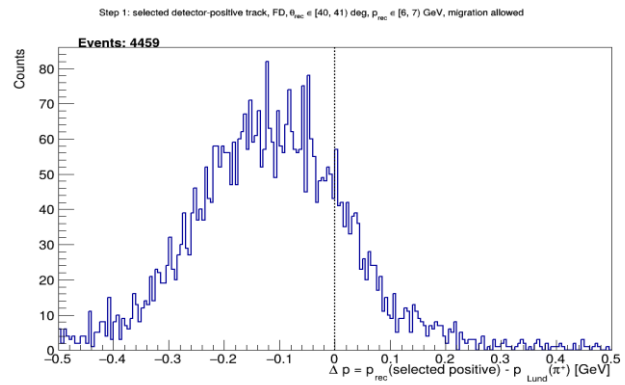
$\theta \in [40°, 41°]$
P $\in$ [5 , 6]GeV

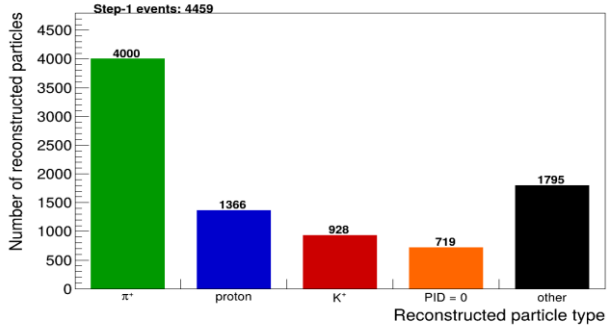


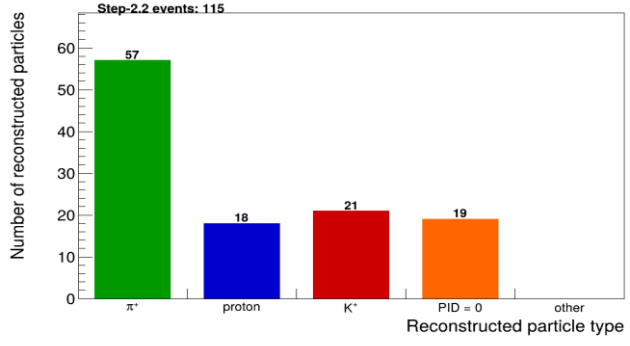




$\theta \in [40°, 41°]$
P $\in$ [6 , 7]GeV







Now let’s change event selection

Before

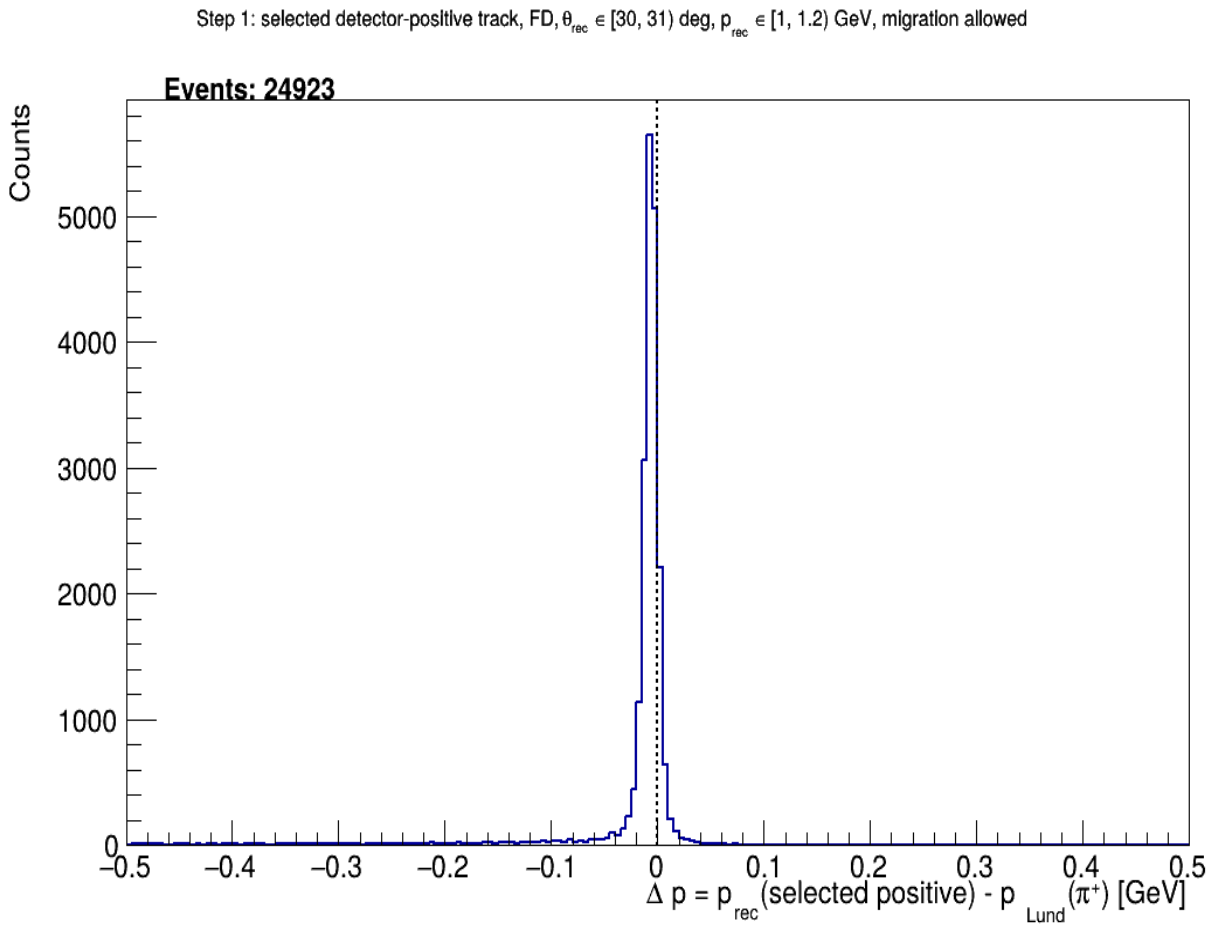
Select events with at least 1 positive track reconstructed in FD.
Choose track with closest momentum to generated pion

After

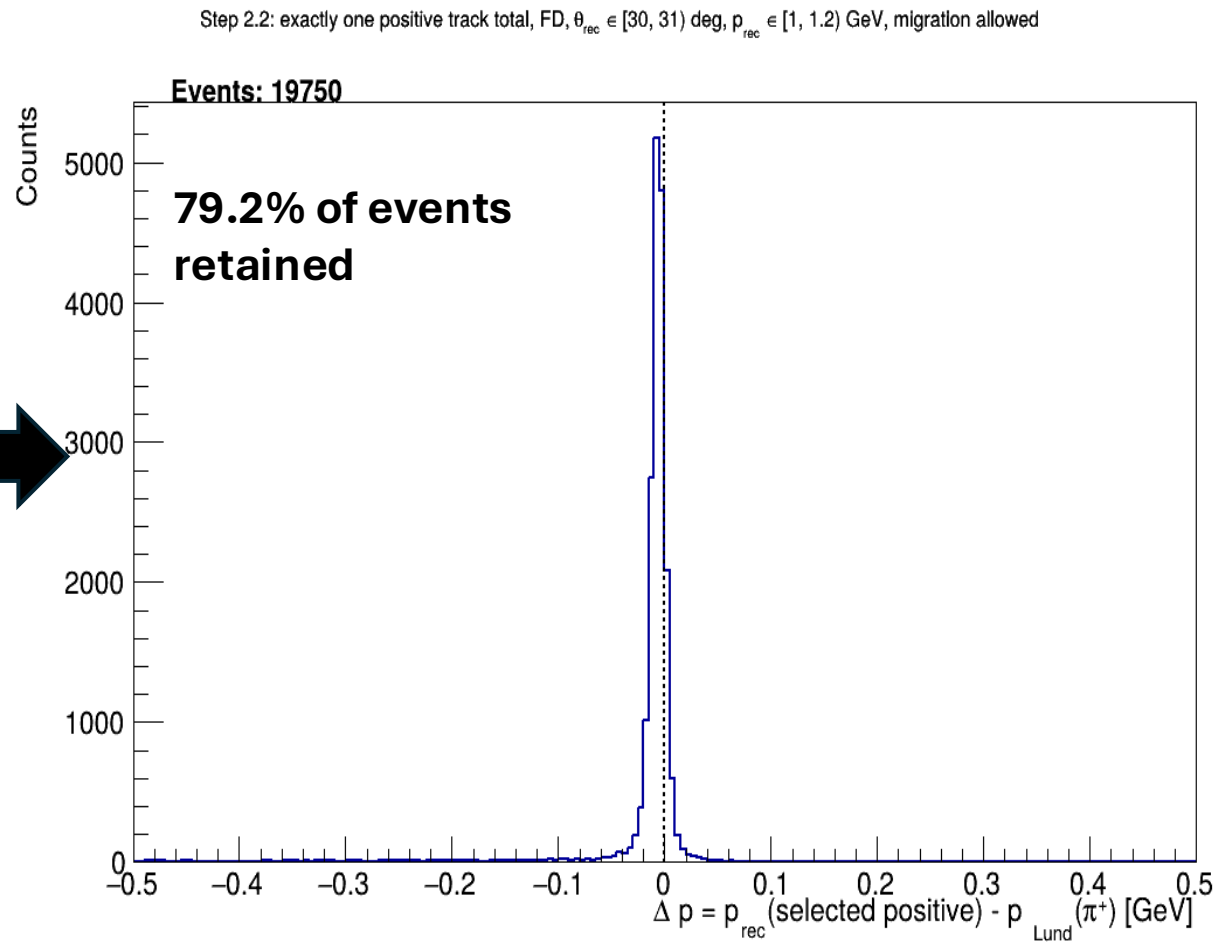
Select events with exactly1 positive track reconstructed in FD.

Forward detector. Good region: $\theta \in [30°, 31°]$, Momentum $\in$ [1.0,1.2]GeV

Before

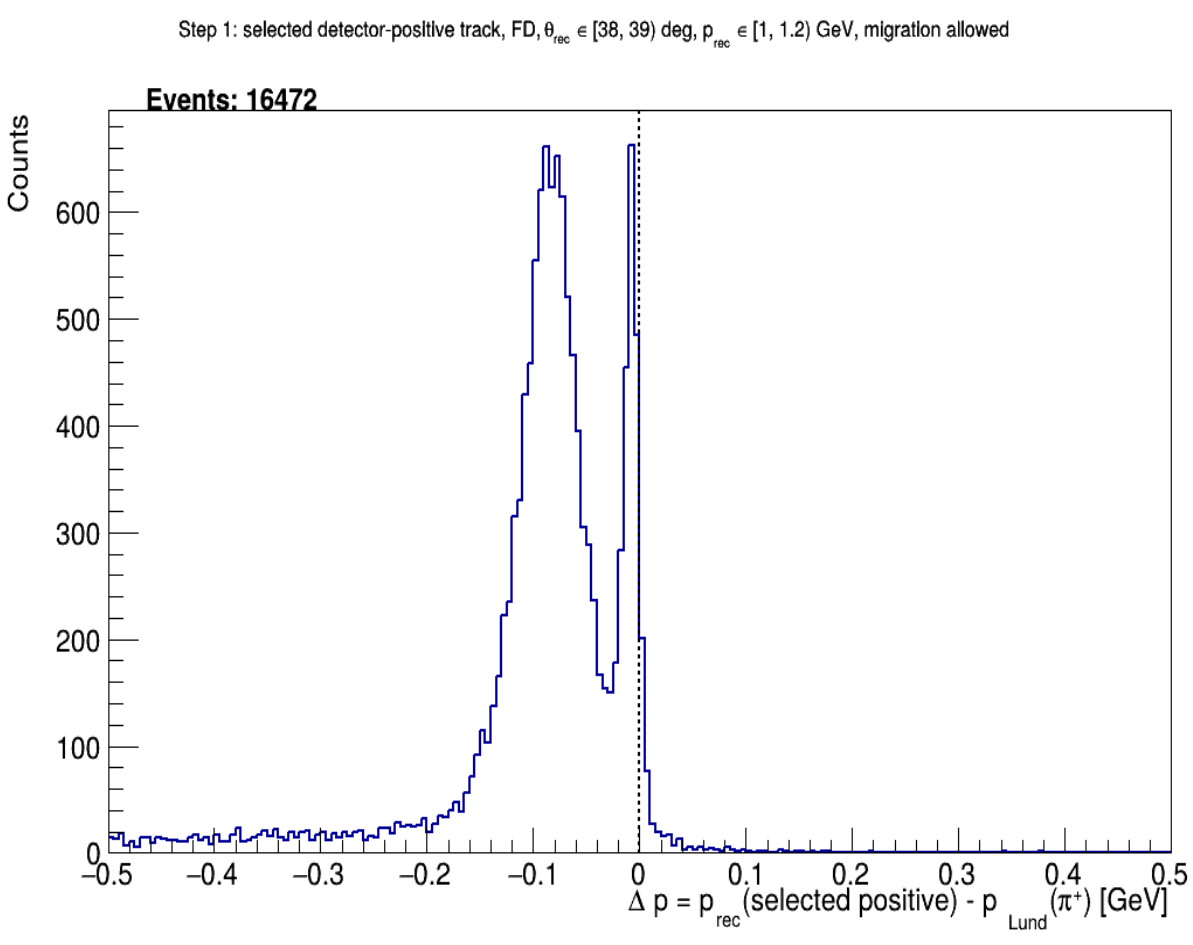


After

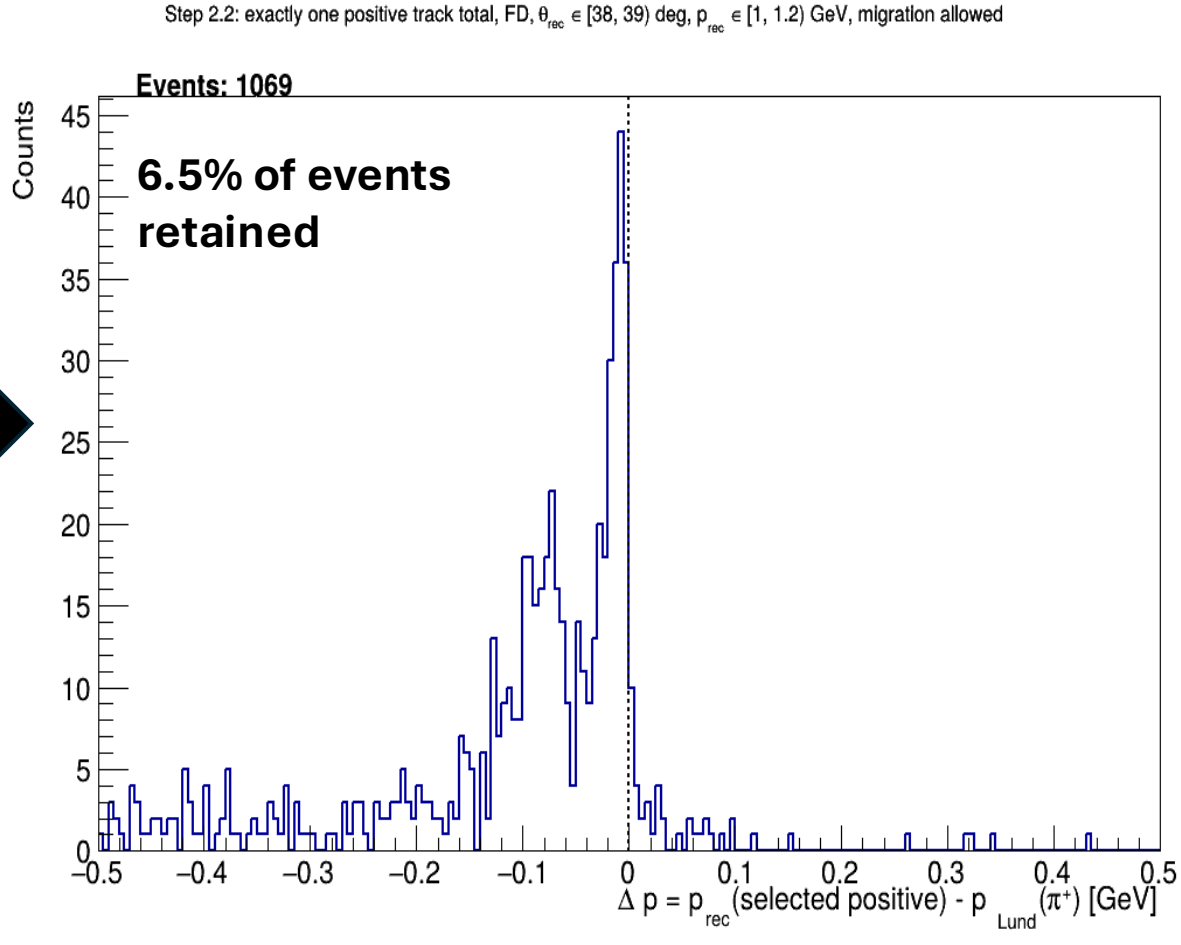


Forward detector. Problematic region: $\theta \in [38°, 39°]$, Momentum $\in [1.0,1.2]$GeV

Before

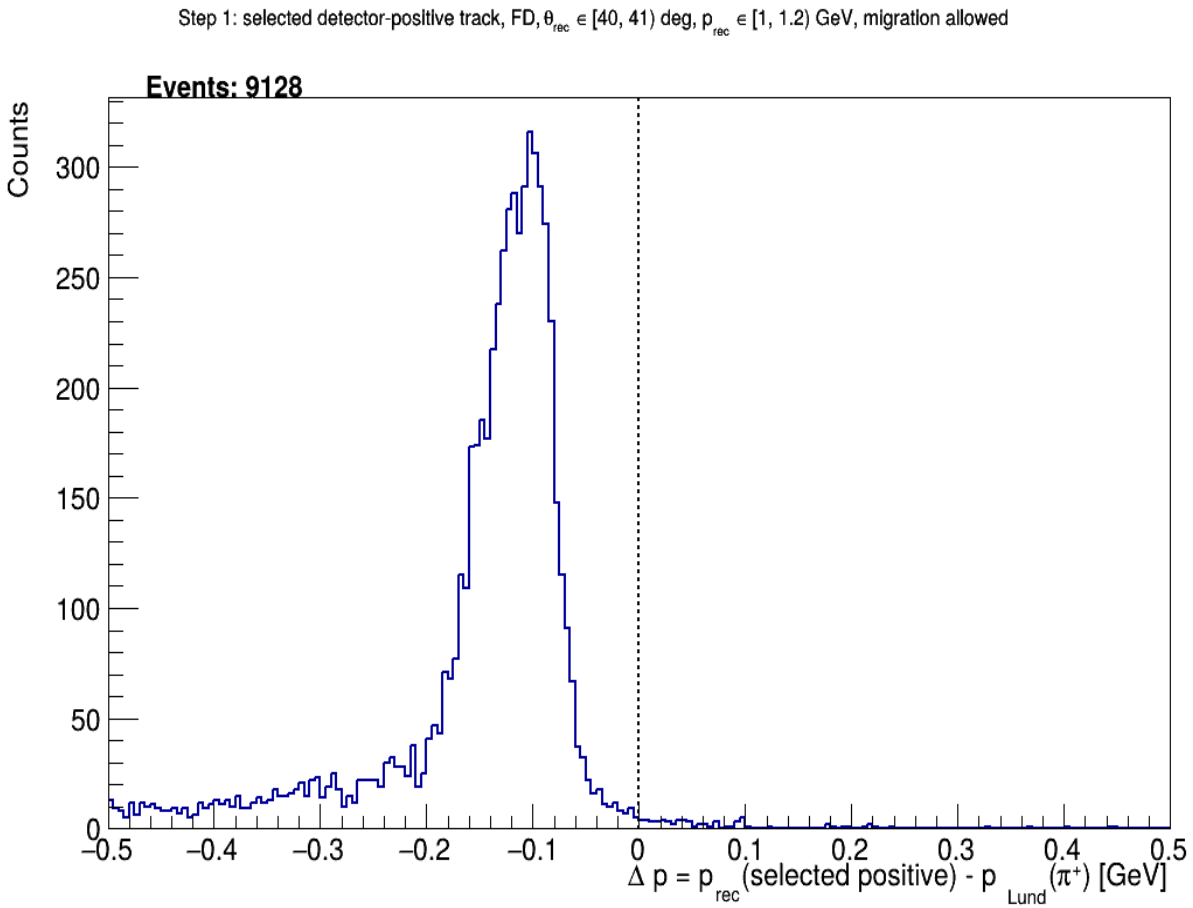


After

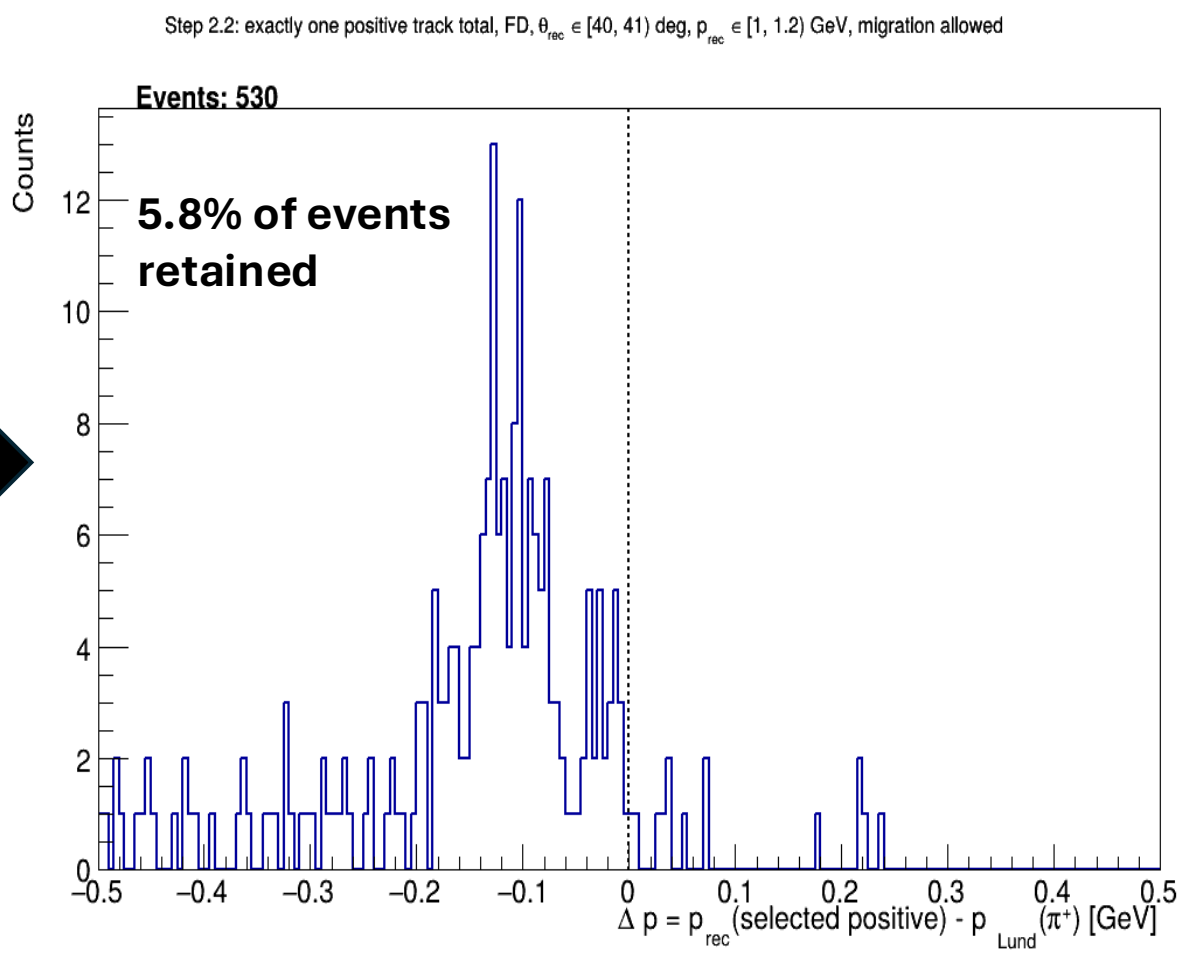


Forward detector. Bad region: $\theta \in [40°, 41°]$, Momentum $\in$ [1.0,1.2]GeV

Before

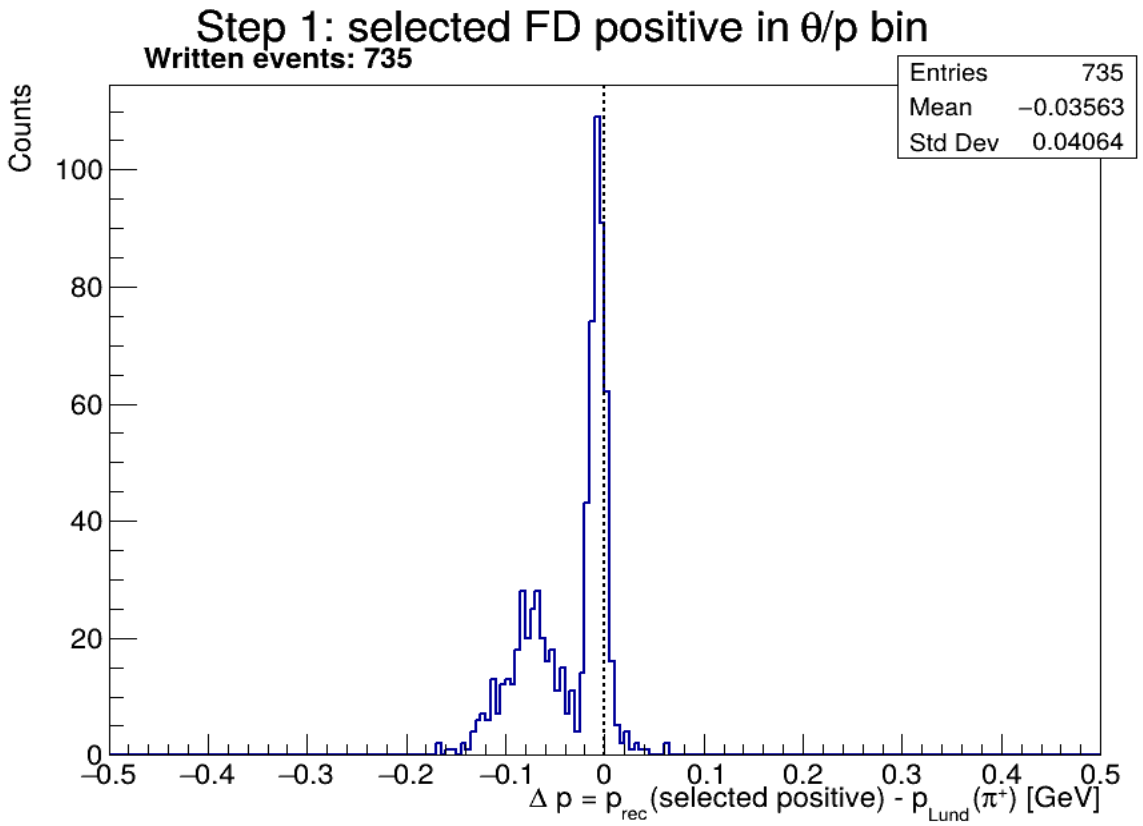


After

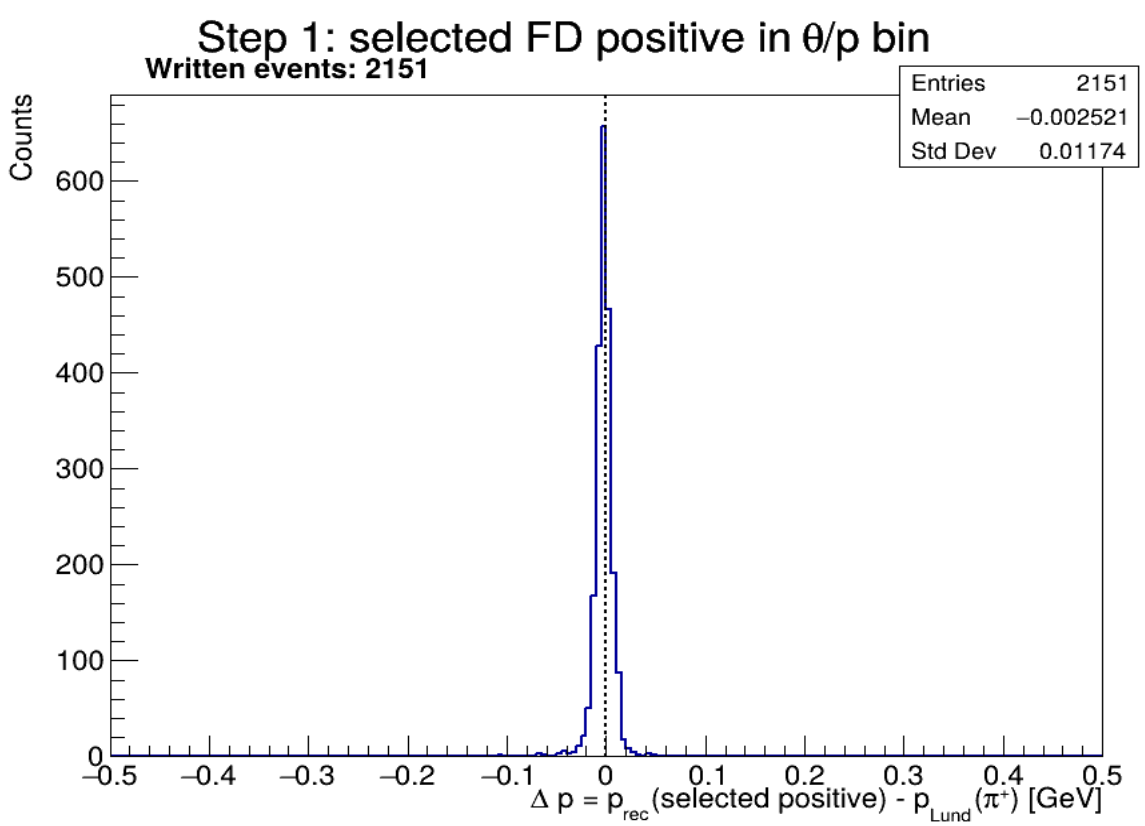


- It is possible to run a custom GEMC simulation, where we can enable/disable CD and see, what effect it will have on the wide peak
- I use small statistics here – only **5000** generated events
- I select events with at least 1 positive track in FD and choose the closest to generated in momentum
- **Problematic region:** $\theta \in [38°, 39°]$, Momentum $\in [1.0,1.2]$GeV
- **Left**: FD and CD turned on; **Right**: FD turned on, CD turned off

CD on



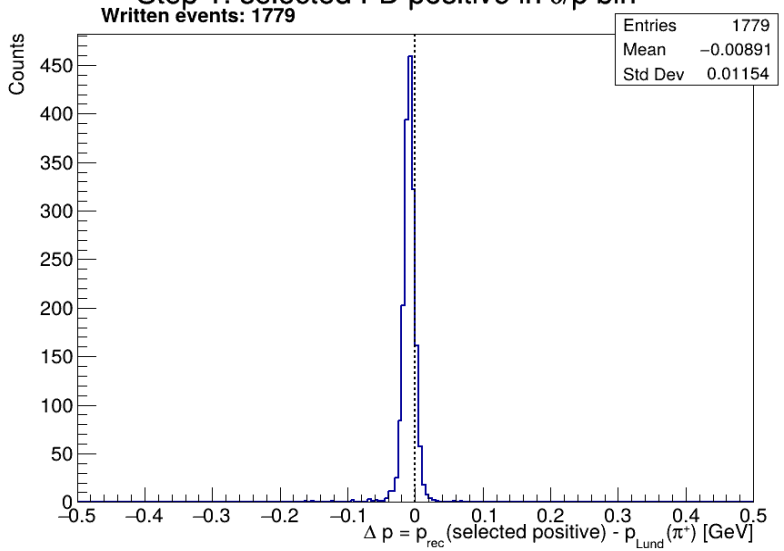
CD off



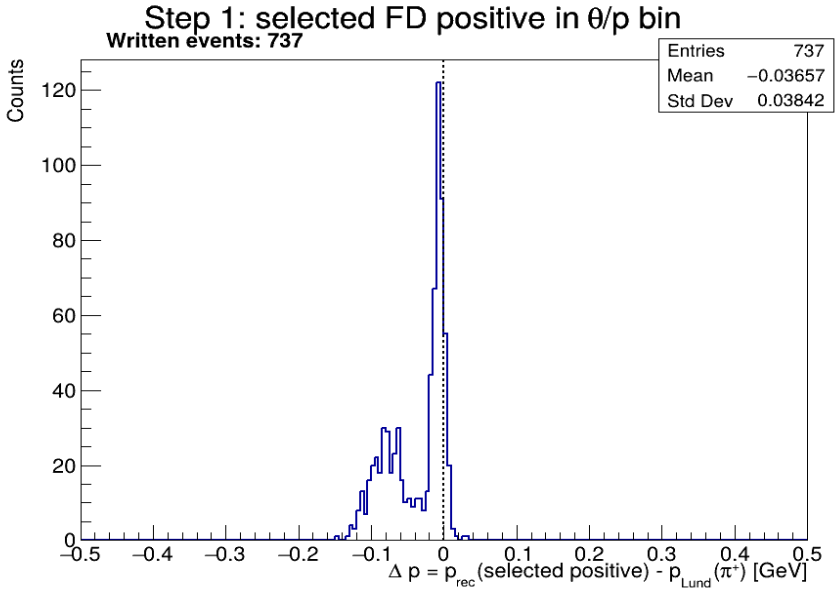
Something in CD is responsible for the wide bump!

- Let's narrow down our search: let's not disable the whole CD, but separate parts of it
- $\theta \in [38°, 39°]$, Momentum $\in [1.0,1.2]$GeV
- We find out that when we turn off **CTOF** the wide peak disappears

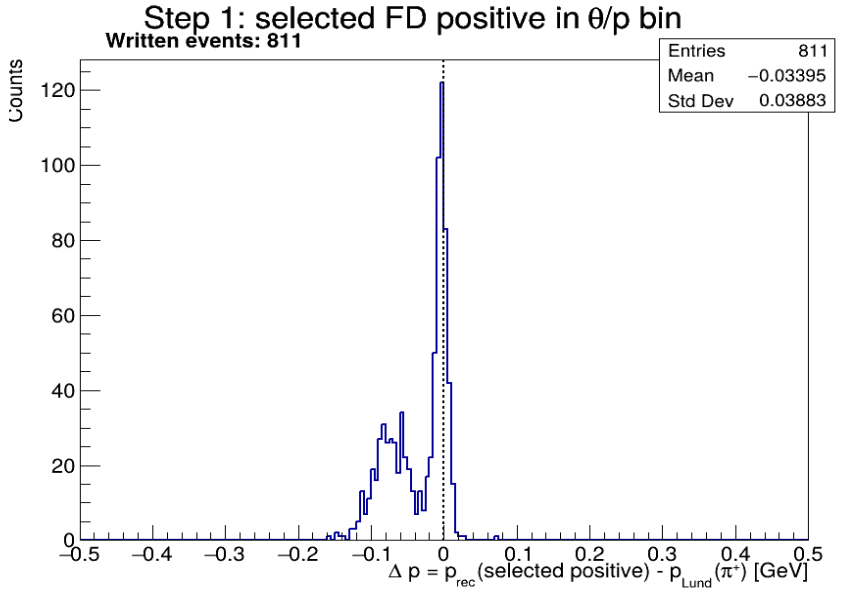
No CTOF



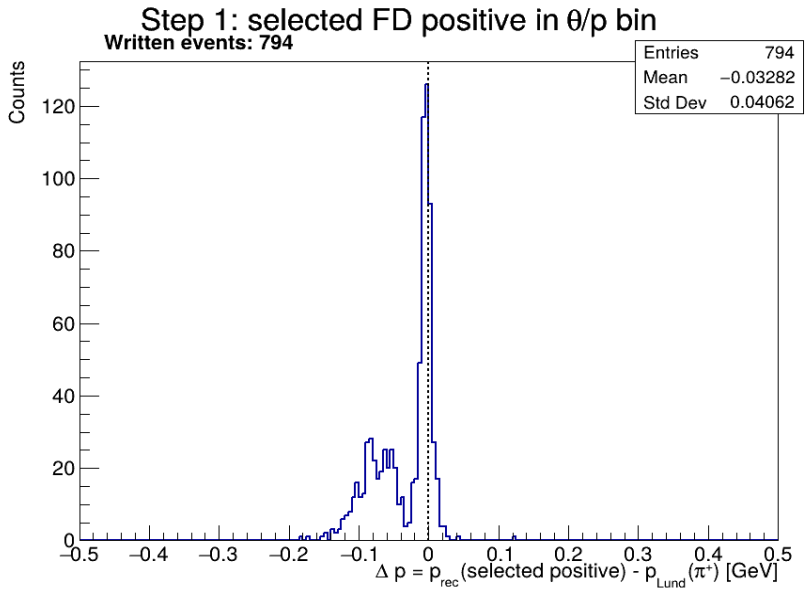
No CND



No Micromegas

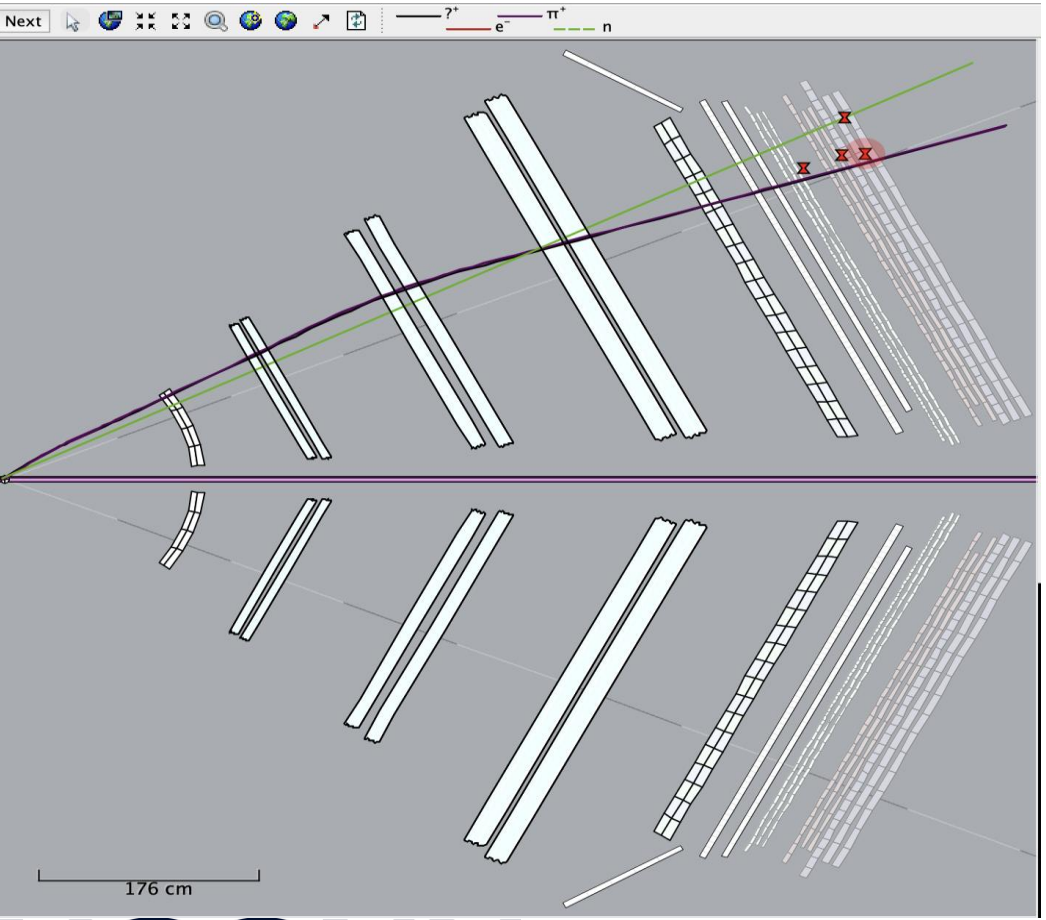


No BST

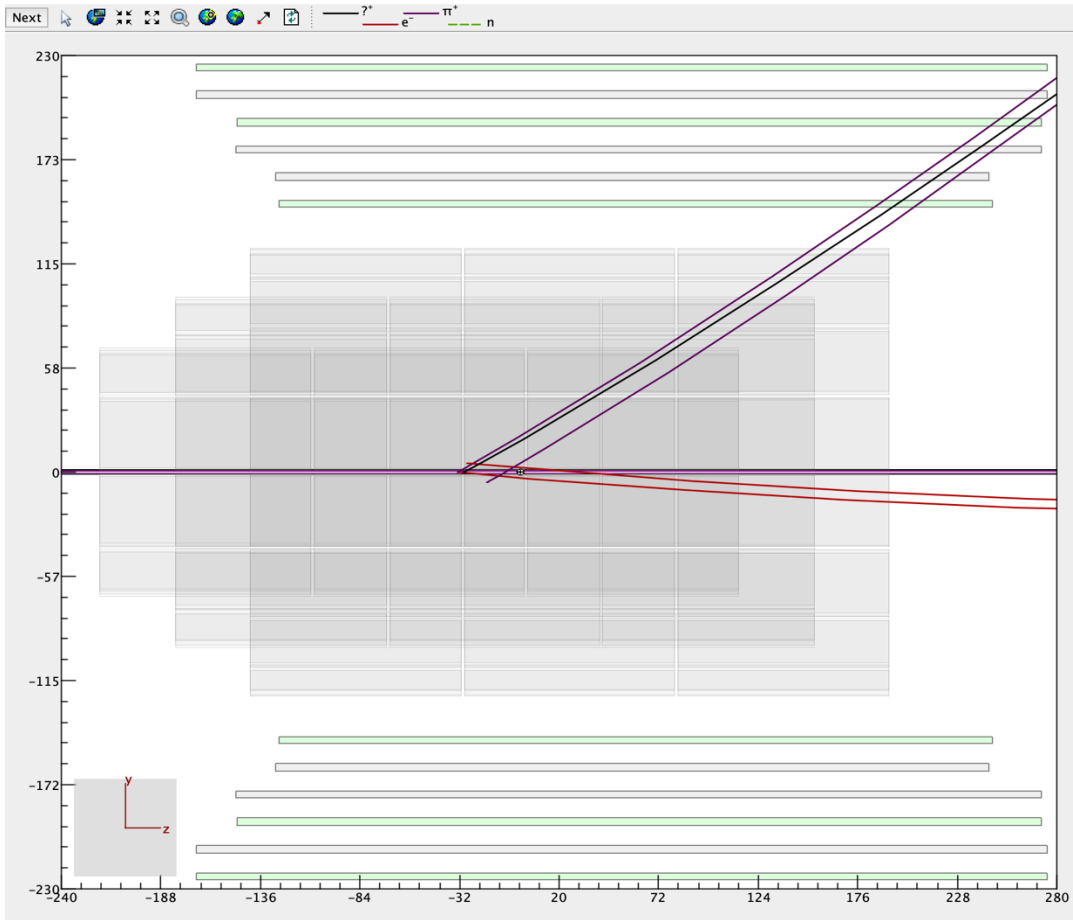


- We sample events from **narrow peak** and visualize them in CED program

FD view

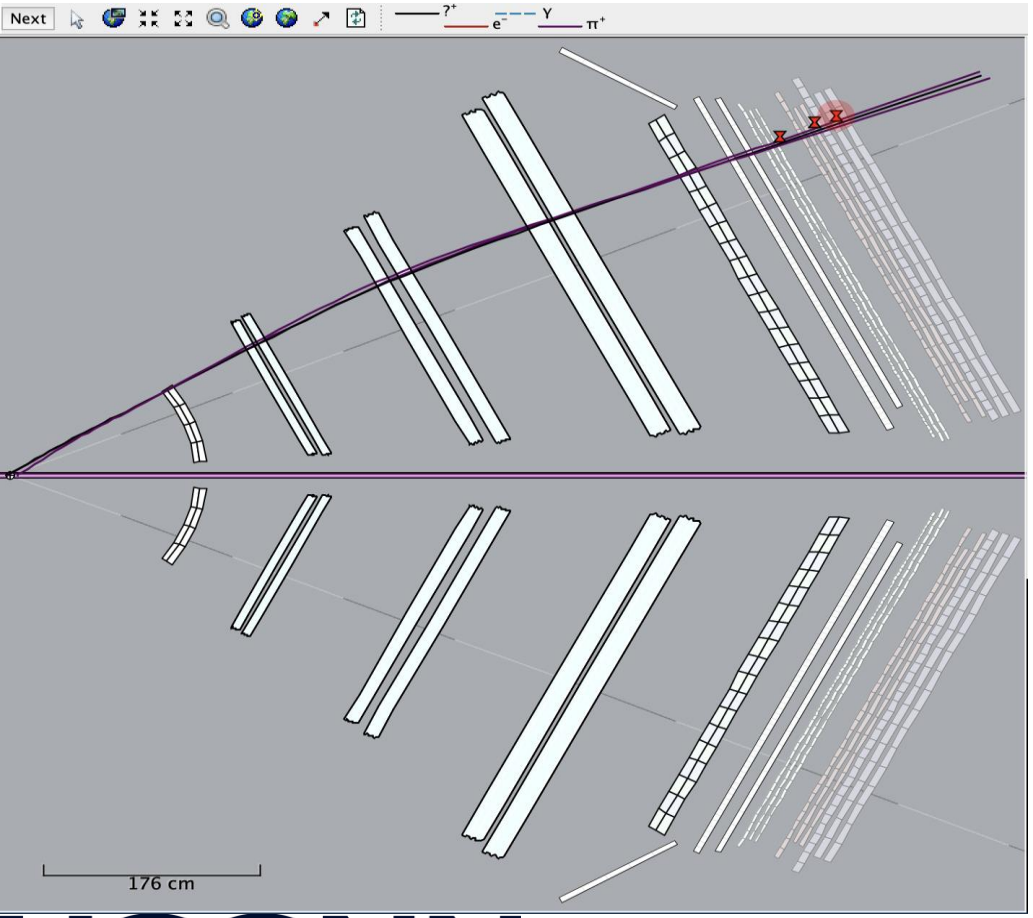


CD view

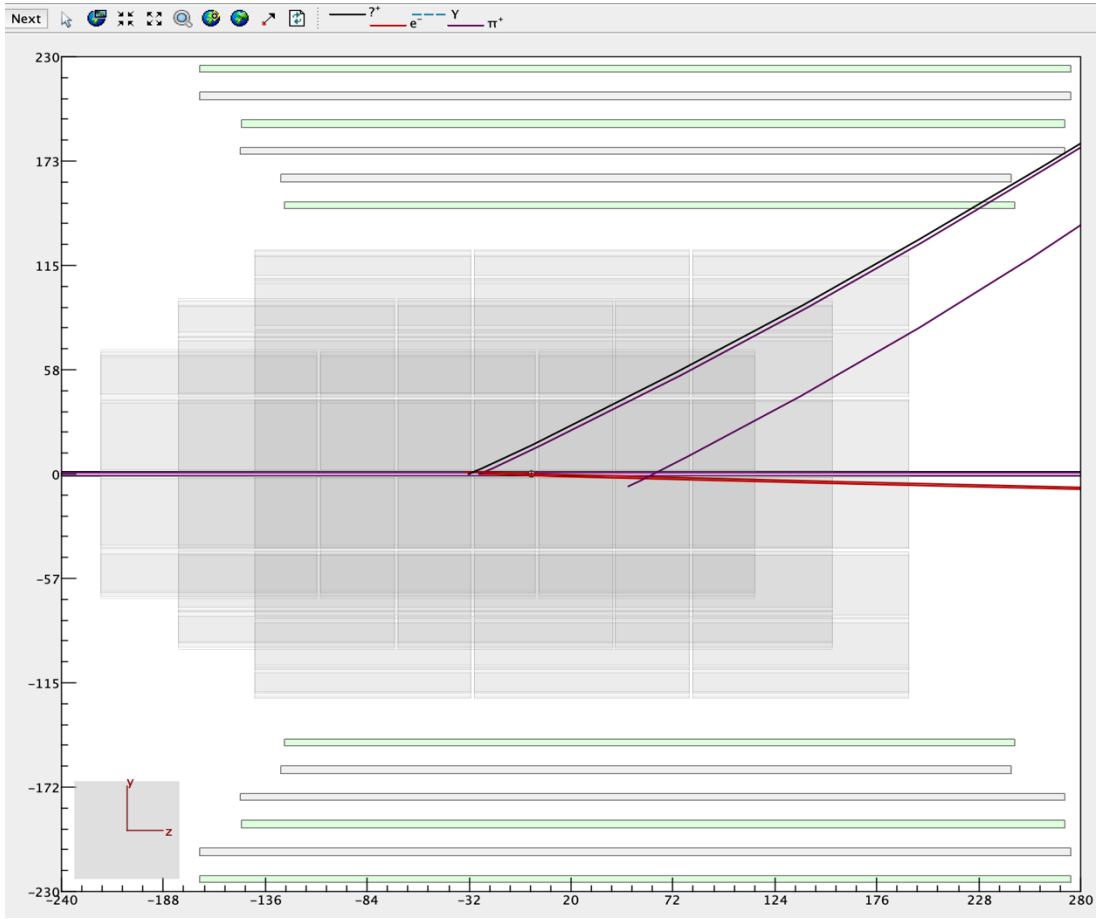


- We sample events from **wide peak** and visualize them in CED program
- Events from wide peak are still reconstructed in FD, even though they touch the CTOF

FD view



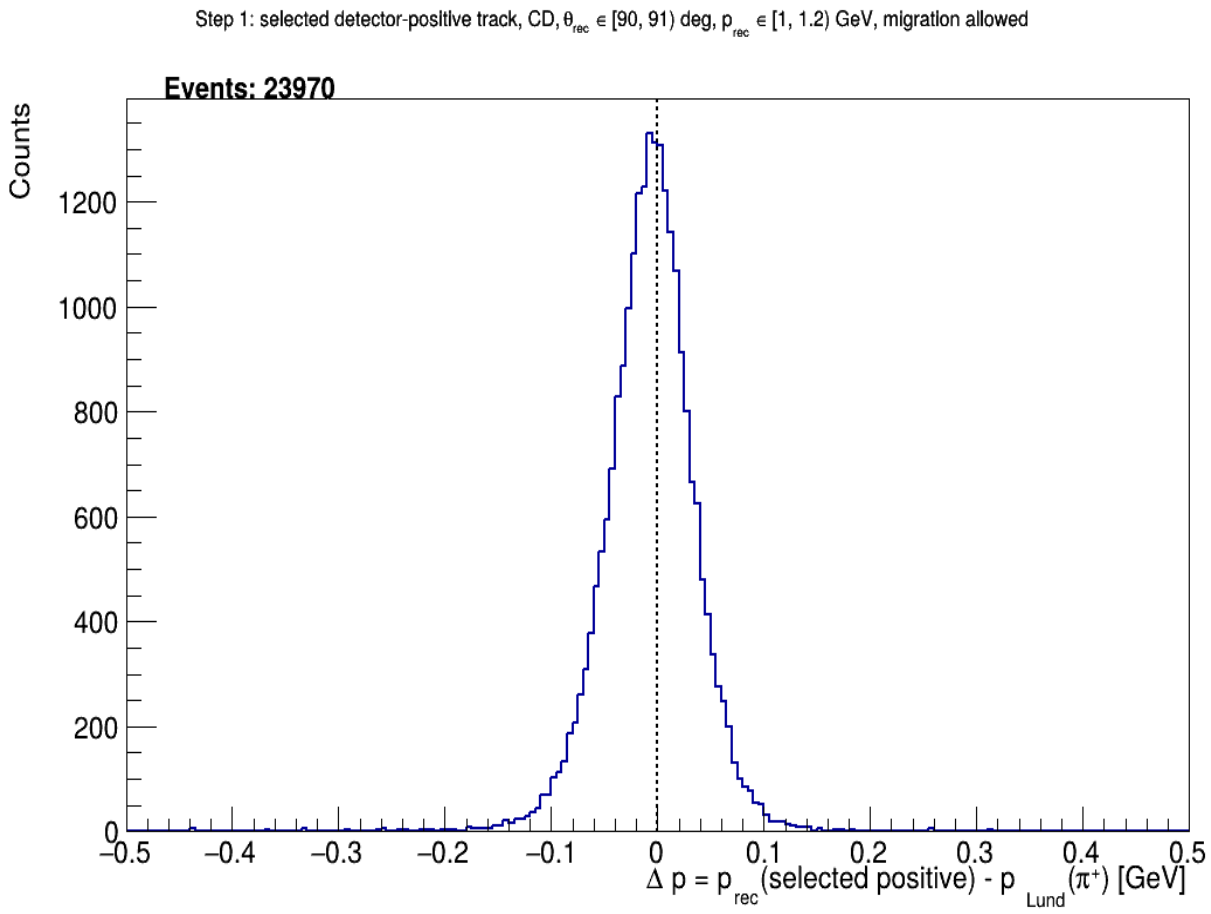
CD view



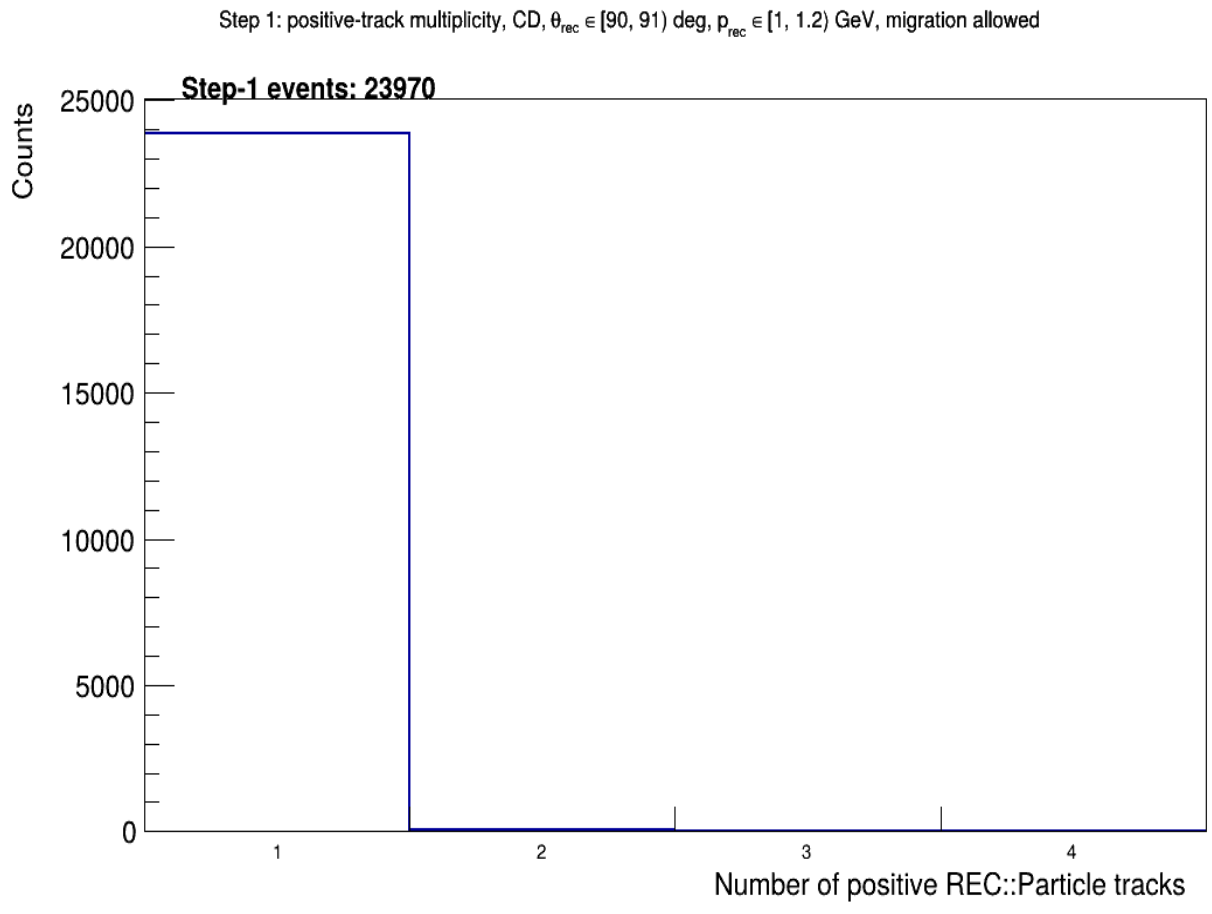
- Let's also look at the Central detector
- Now we select events with at least 1 positive track **in CD** and choose the closest momentum to generated π^+
- We fix momentum bin to be $[1\ ,\ 1.2]$ GeV and decrease theta, starting from "safe" high polar angle and go down to the problematic zone
- On the left side will show Δp histogram, on the right side – positive track multiplicity
- Note that Δp distribution is centered around 0, because energy loss correction is applied at the reconstruction level

- **Central detector.** $\theta \in [90°, 91°]$, Momentum $\in [1\ , 1.2]$GeV
- Mostly single-track events

Δp distribution

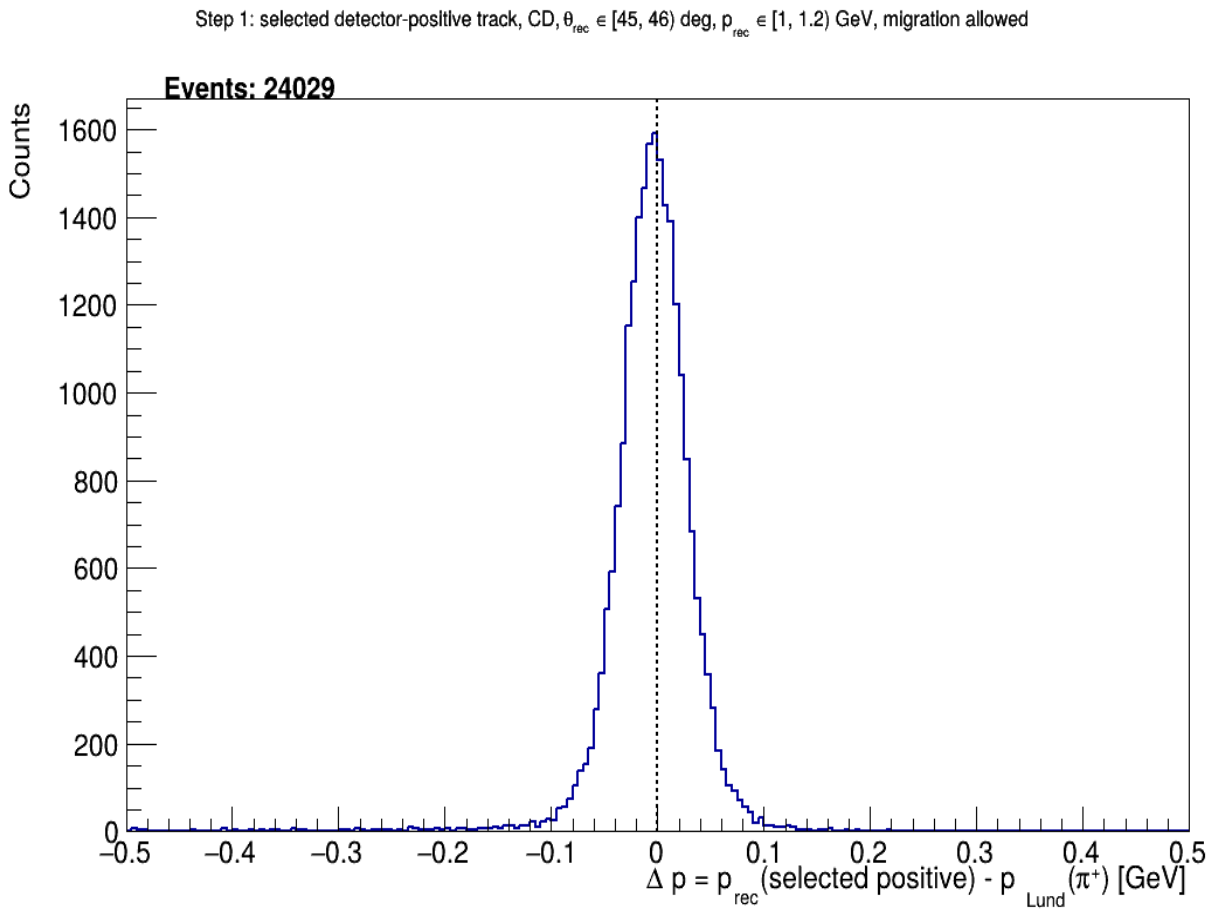


Positive track multiplicity

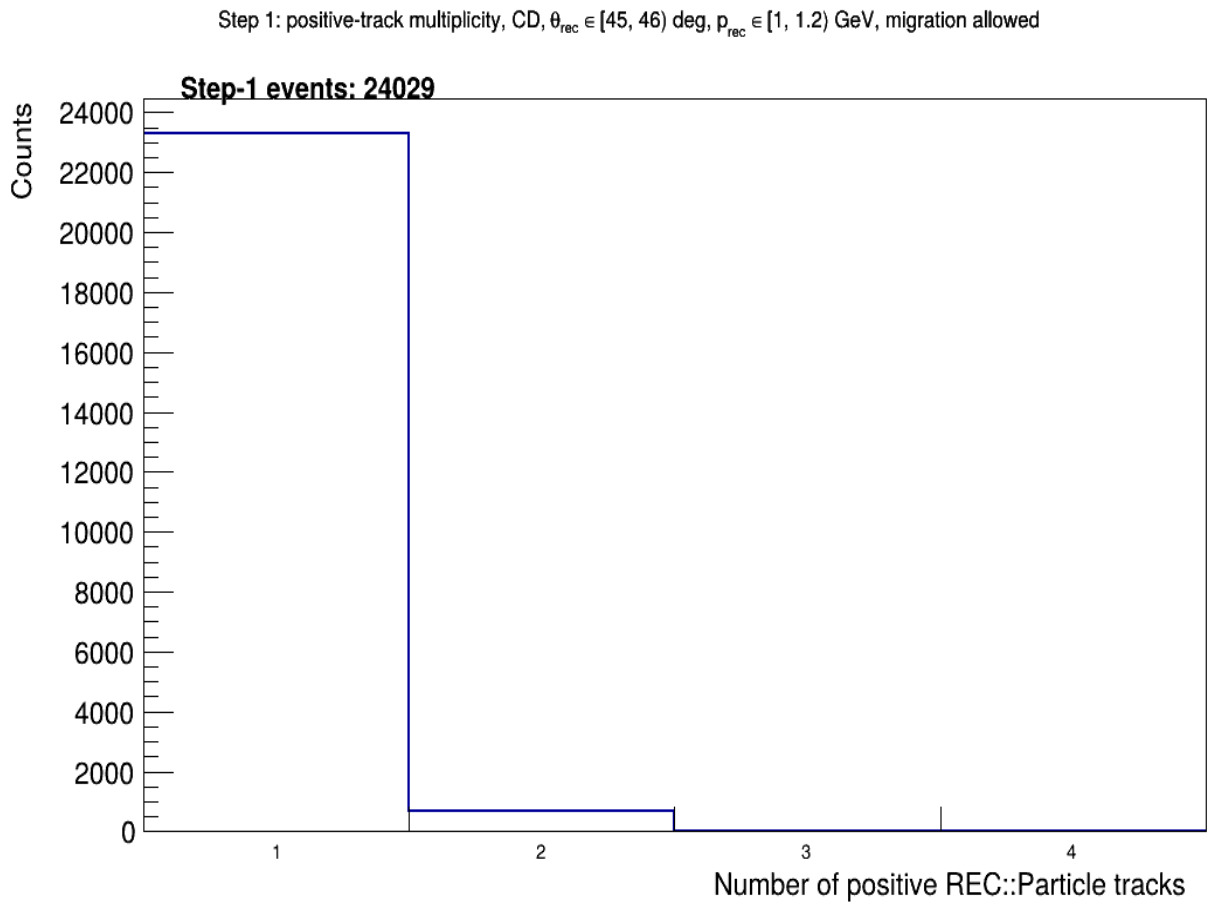


- **Central detector.** $\theta \in [45°, 46°]$, Momentum $\in [1\ , 1.2]$GeV
- Mostly single-track events

Δp distribution

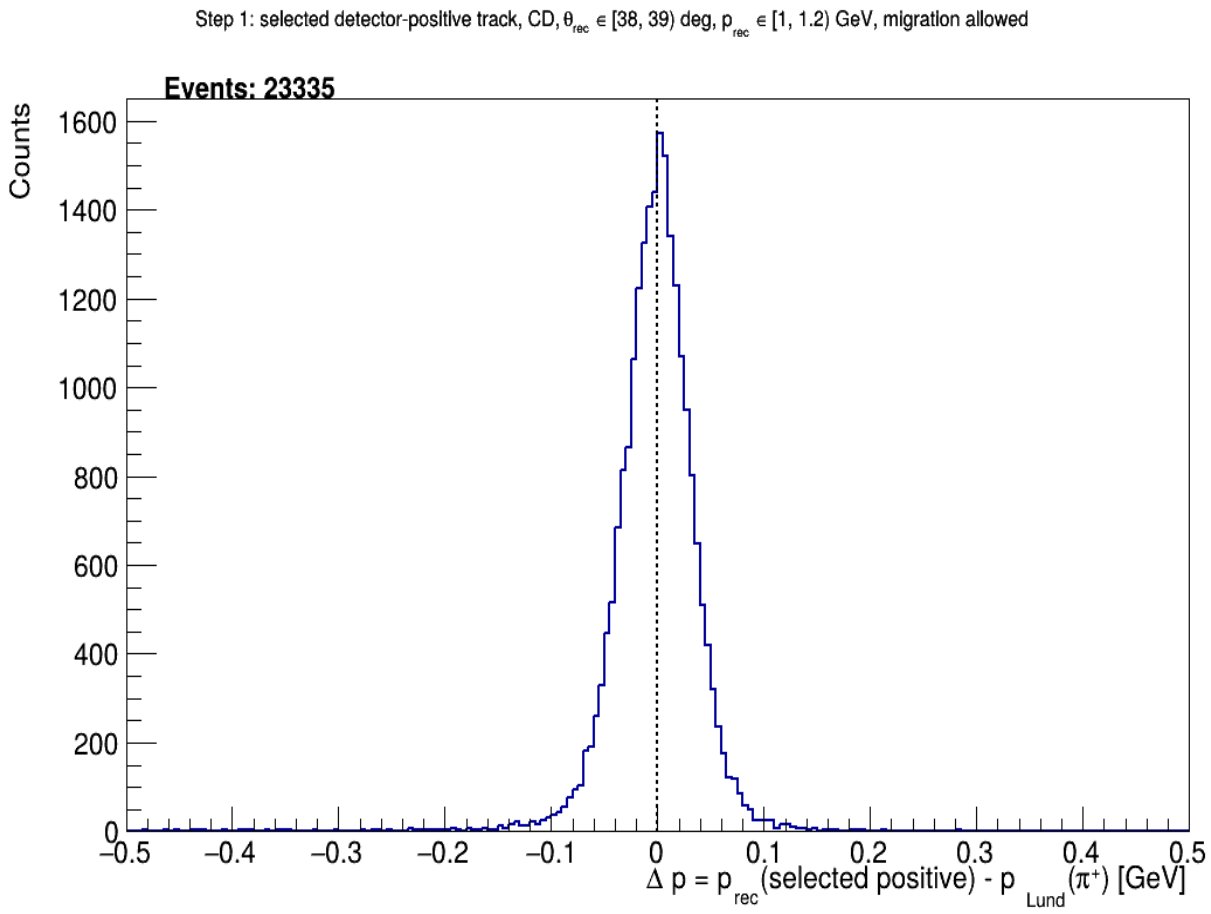


Positive track multiplicity

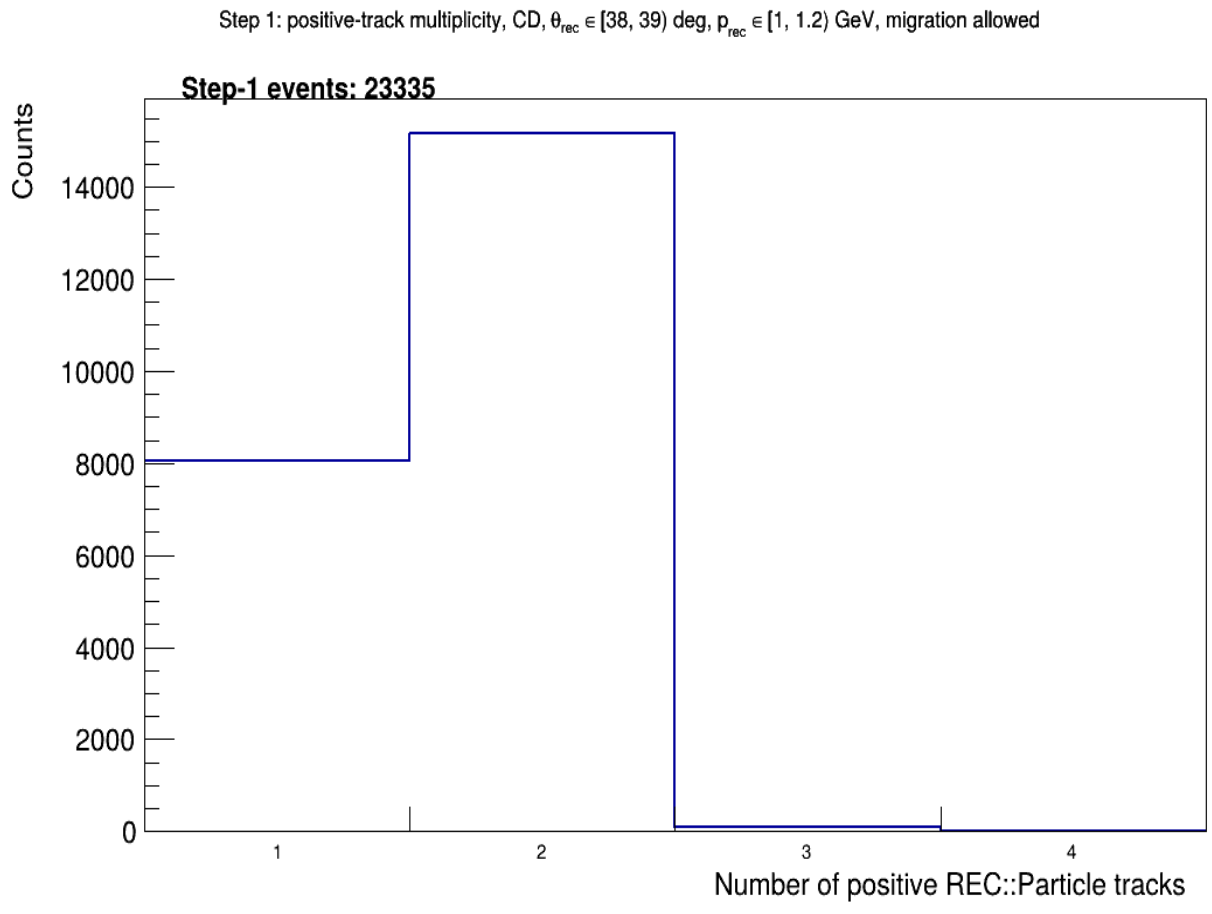


- **Central detector.** $\theta \in [38°, 39°]$, Momentum $\in [1\ , 1.2]$GeV
- Most of events are 2 positive track, but there is a significant fraction of single-track events

Δp distribution

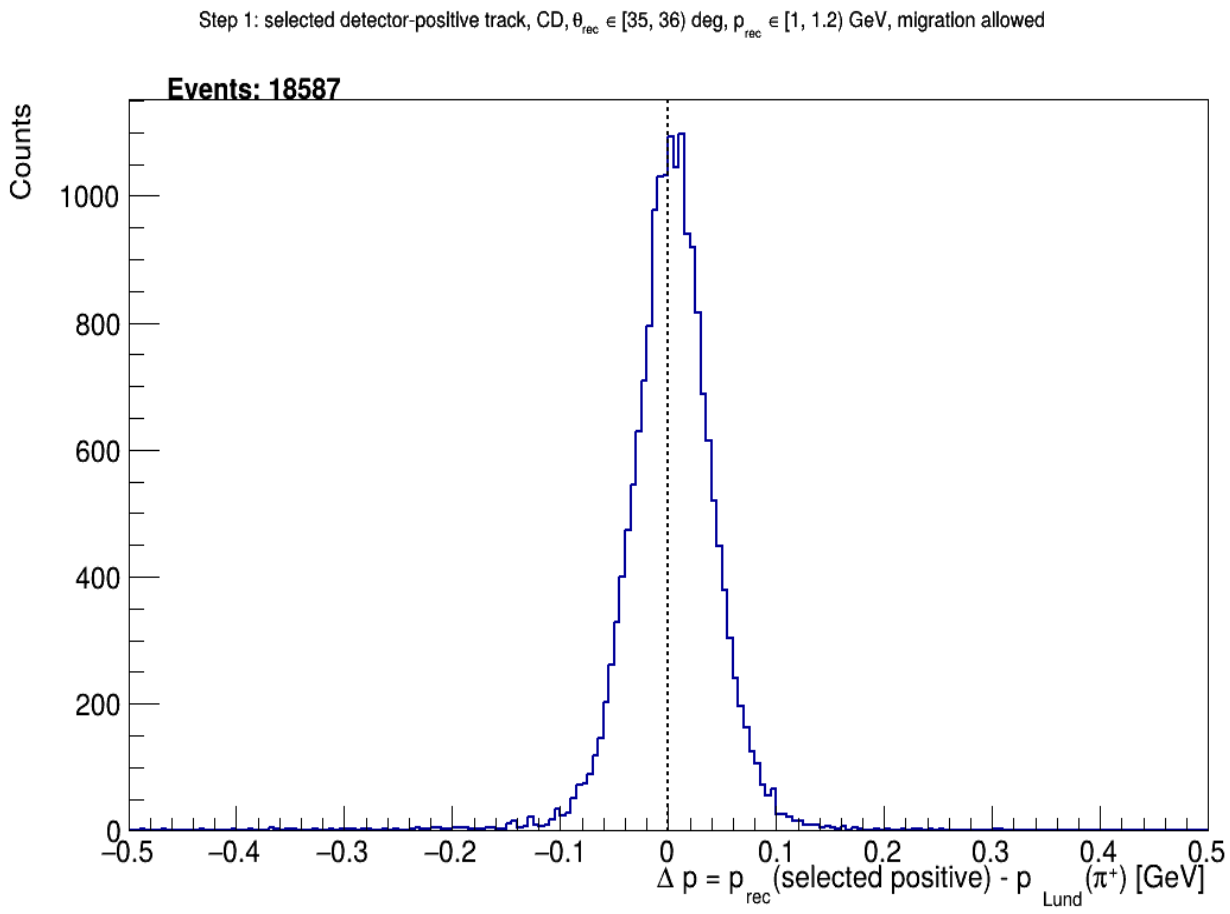


Positive track multiplicity

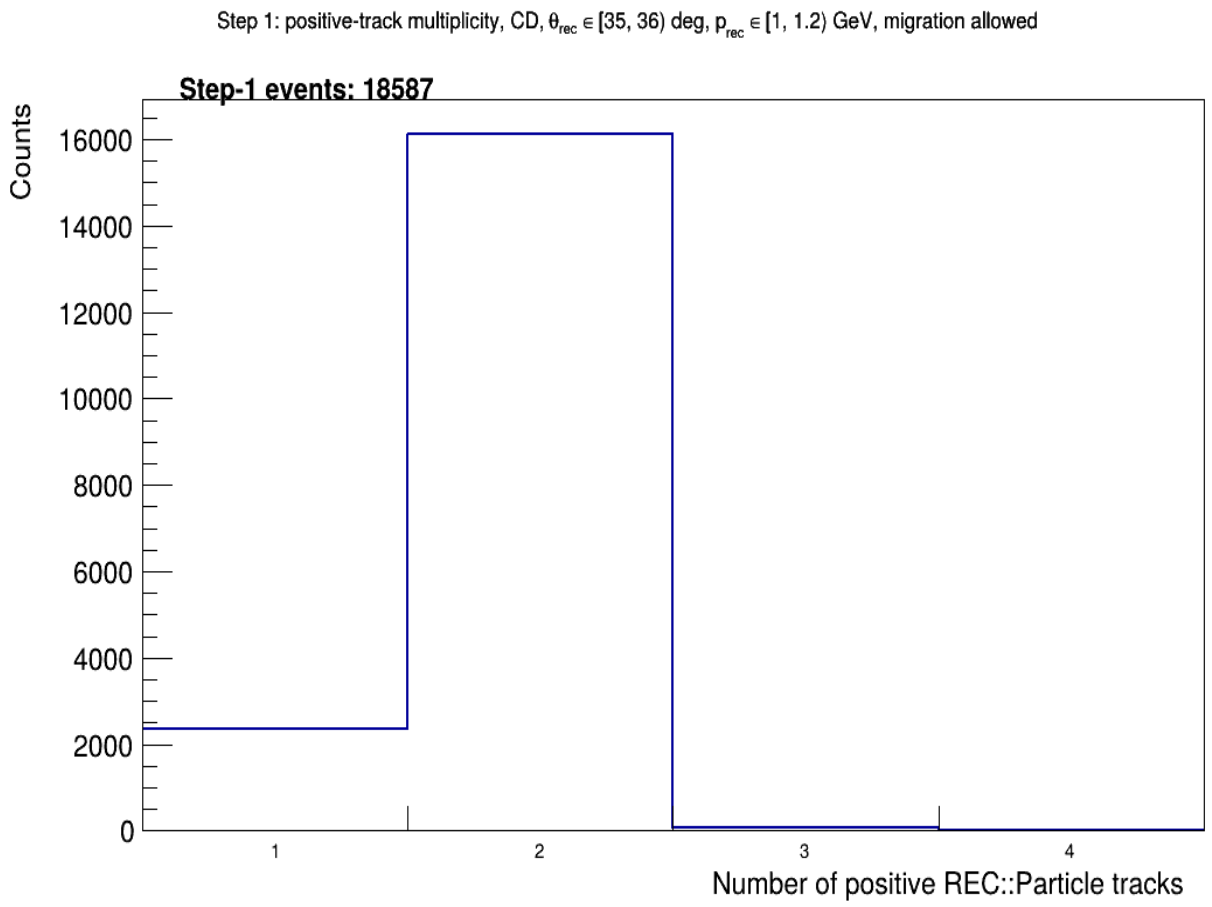


- **Central detector.** $\theta \in [35°, 36°]$, Momentum $\in [1\ , 1.2]$ GeV
- Predominantly 2 positive track events

Δp distribution



Positive track multiplicity

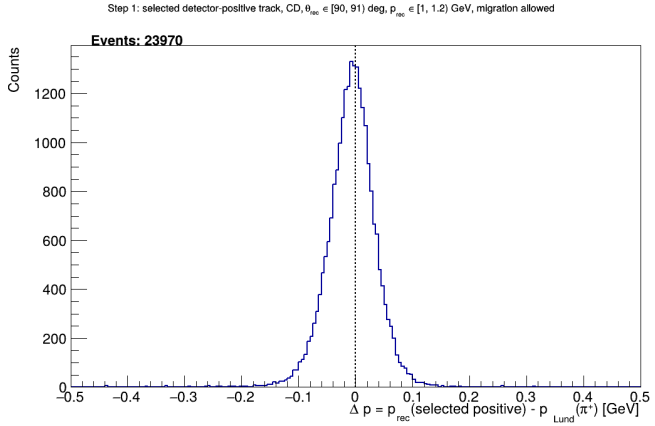


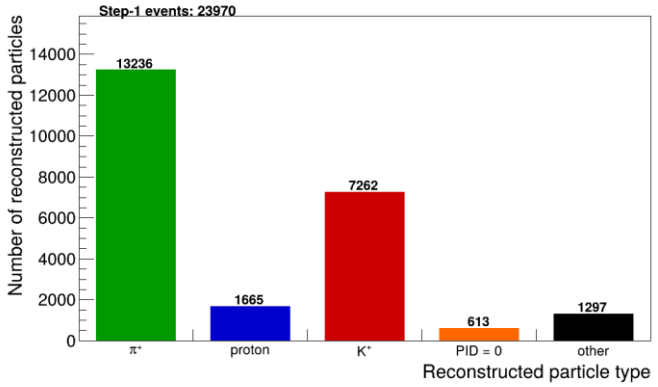
Δp distribution
$\geq$ 1 positive track in the event

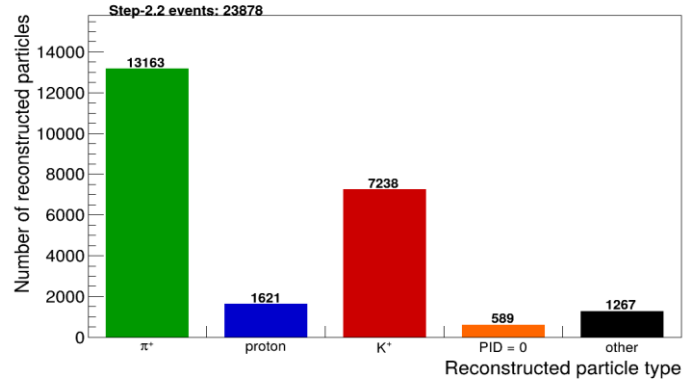
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

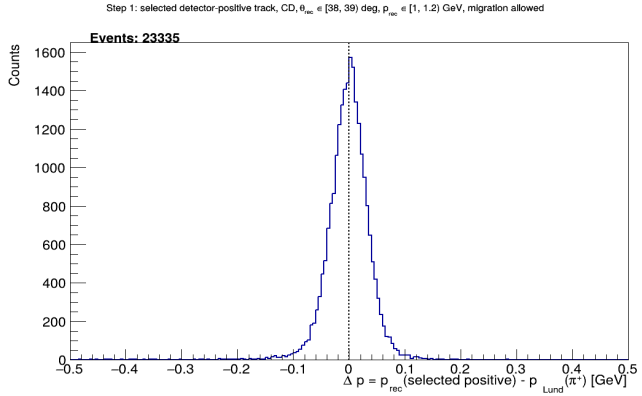
Good region
$\theta \in [90°, 91°]$
P ∈ [1.0,1.2]GeV

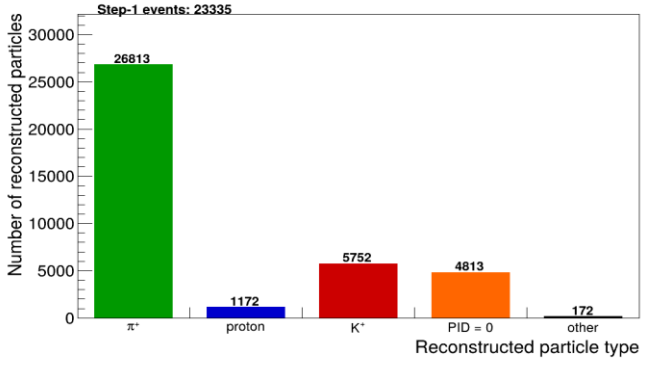


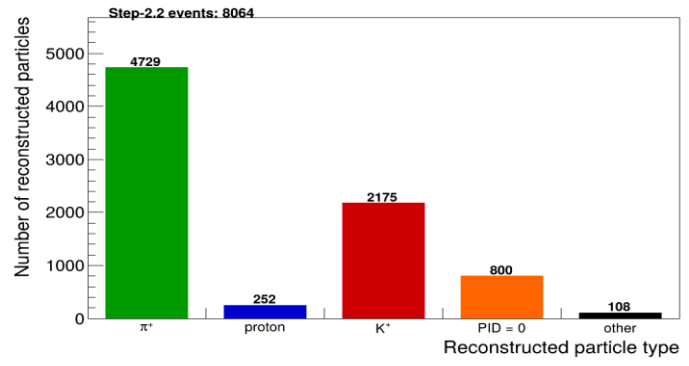




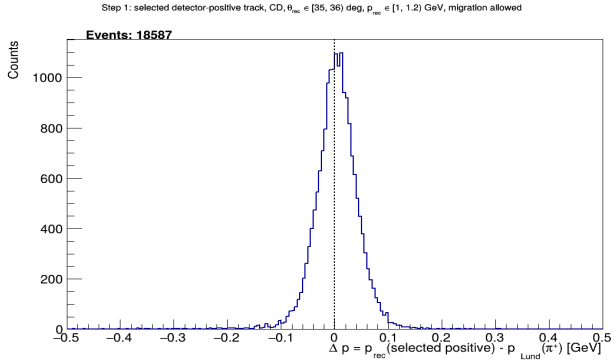
Problematic region
$\theta \in [38°, 39°]$
P ∈ [1.0,1.2]GeV

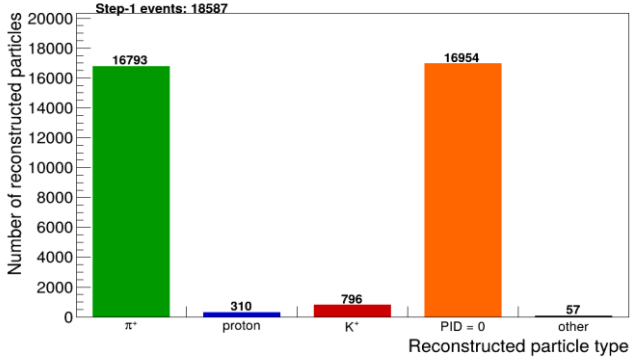


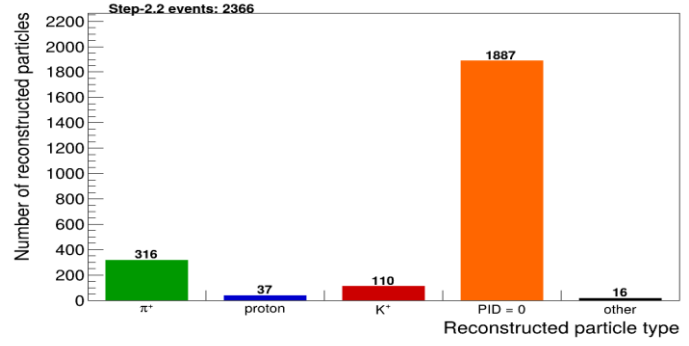




Bad region
$\theta \in [35°, 36°]$
P ∈ [1.0,1.2]GeV







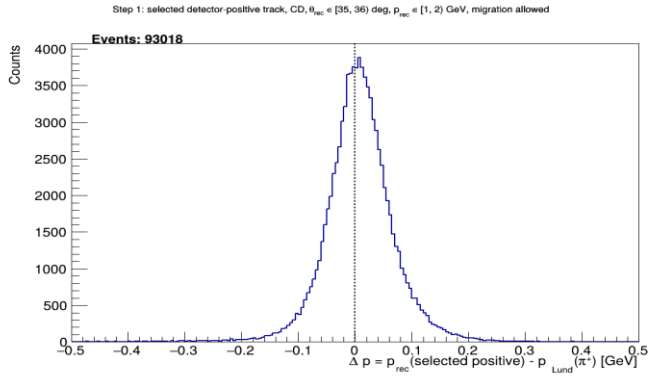
Now we fix polar angle bin $\theta \in [35°, 36°]$ and scan full momentum range in CD

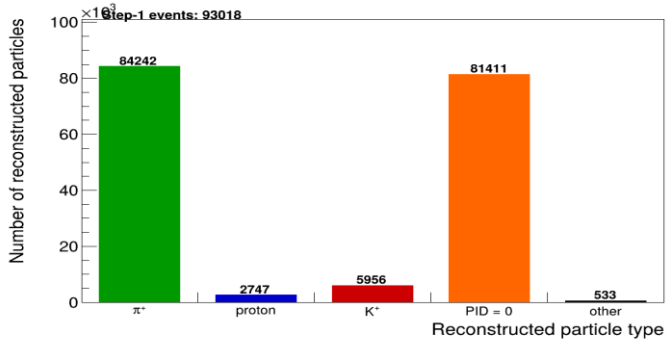
Δp distribution
$\geq$ 1 positive track in the event

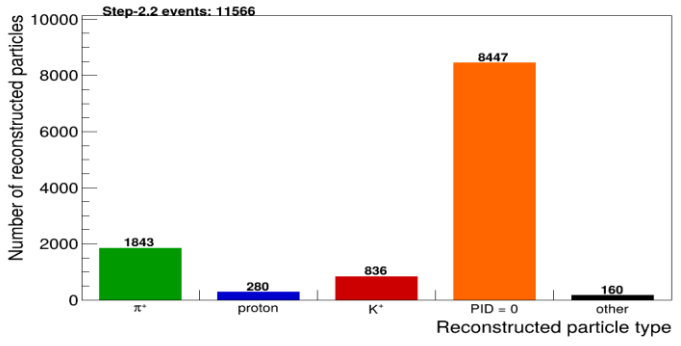
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

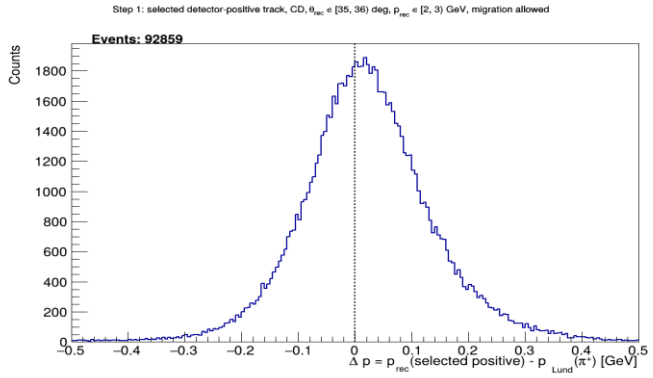
$\theta \in [35°, 36°]$
P $\in$ [1 , 2]GeV

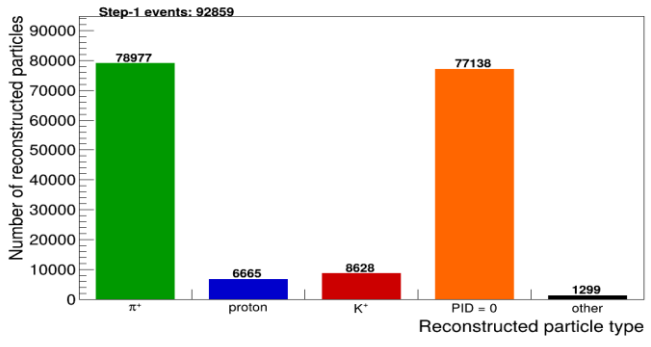


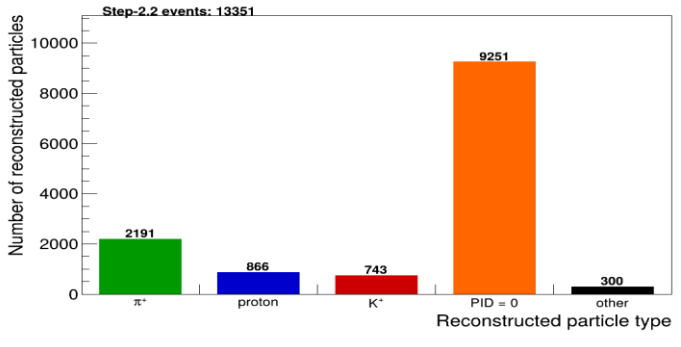




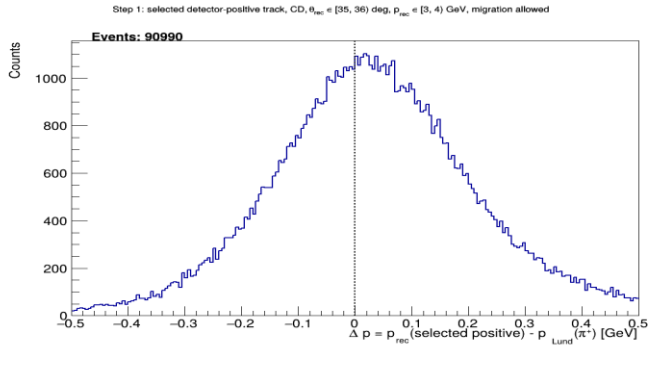
$\theta \in [35°, 36°]$
P $\in$ [2 , 3]GeV

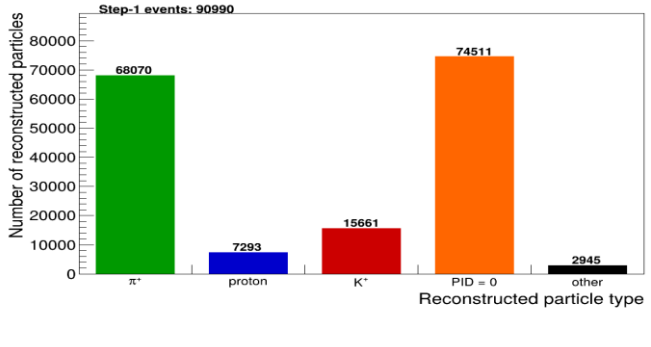


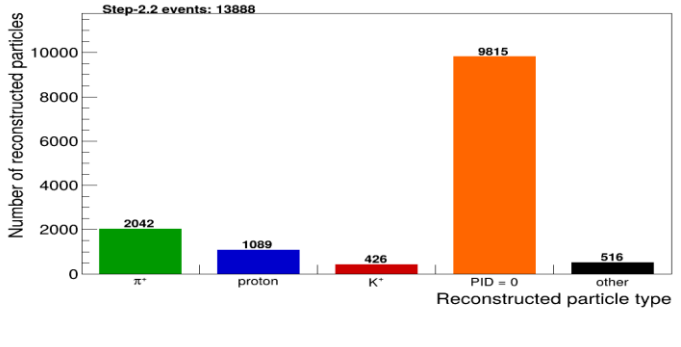




$\theta \in [35°, 36°]$
P $\in$ [3 , 4]GeV





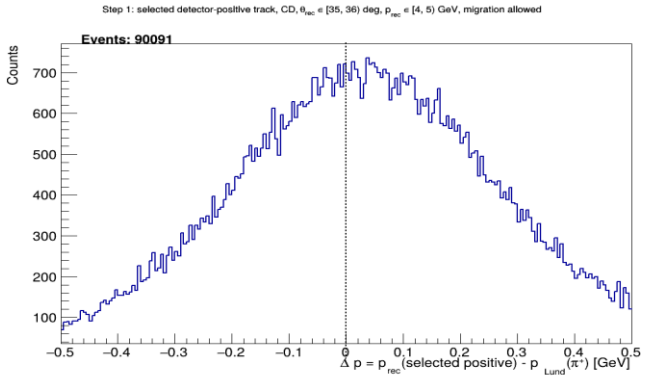


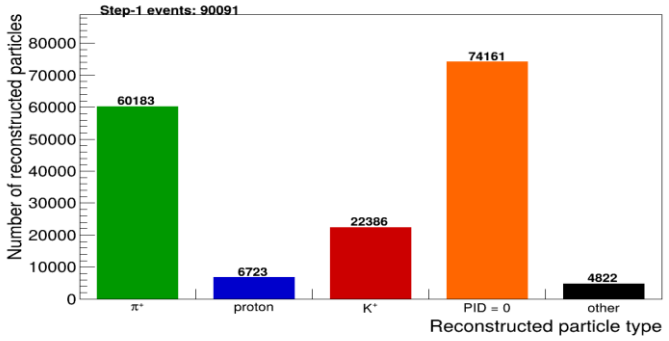
Δp distribution
$\geq$ 1 positive track in the event

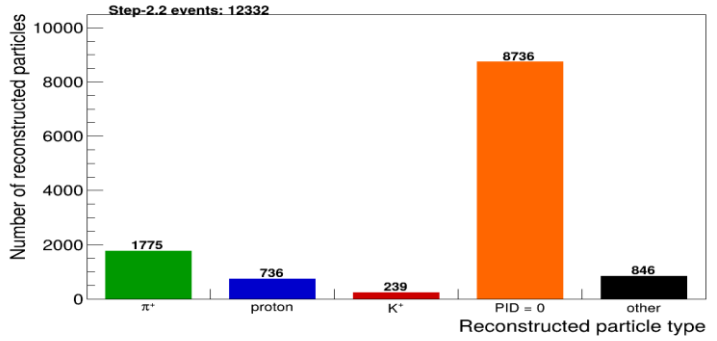
Particle type multiplicity
$\geq$ 1 positive track in the event

Particle type multiplicity
require exactly 1 positive track

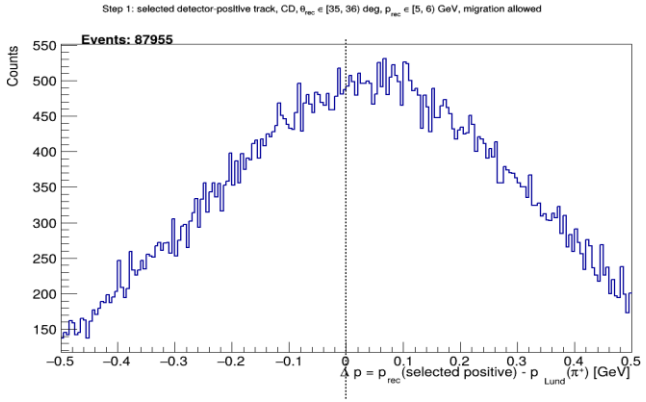
$\theta \in [35°, 36°]$
P $\in$ [4 , 5]GeV

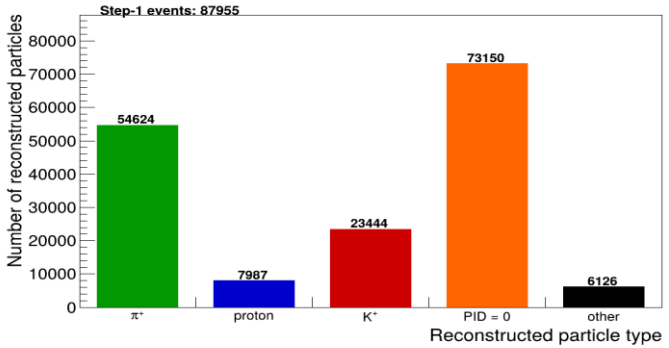


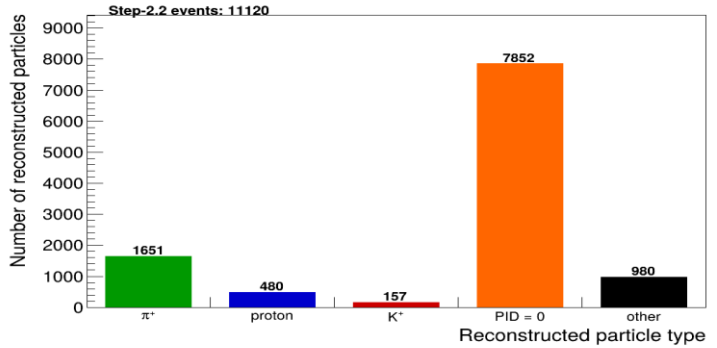




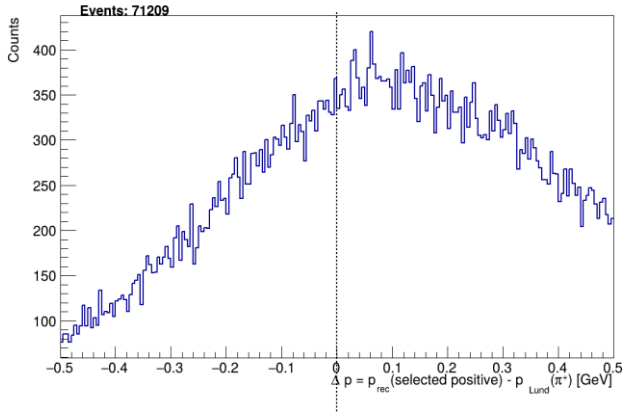
$\theta \in [35°, 36°]$
P $\in$ [5 , 6]GeV

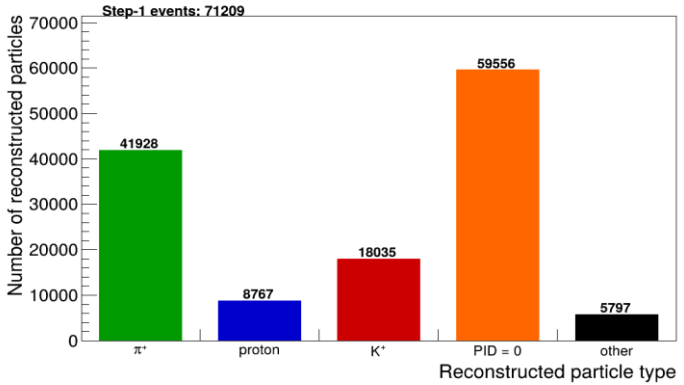


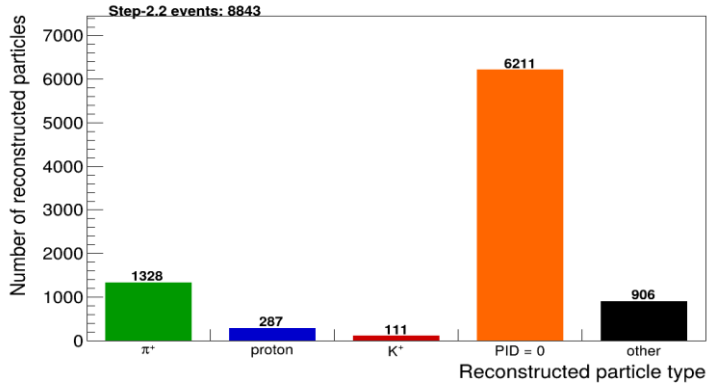




$\theta \in [35°, 36°]$
P $\in$ [6 , 7]GeV

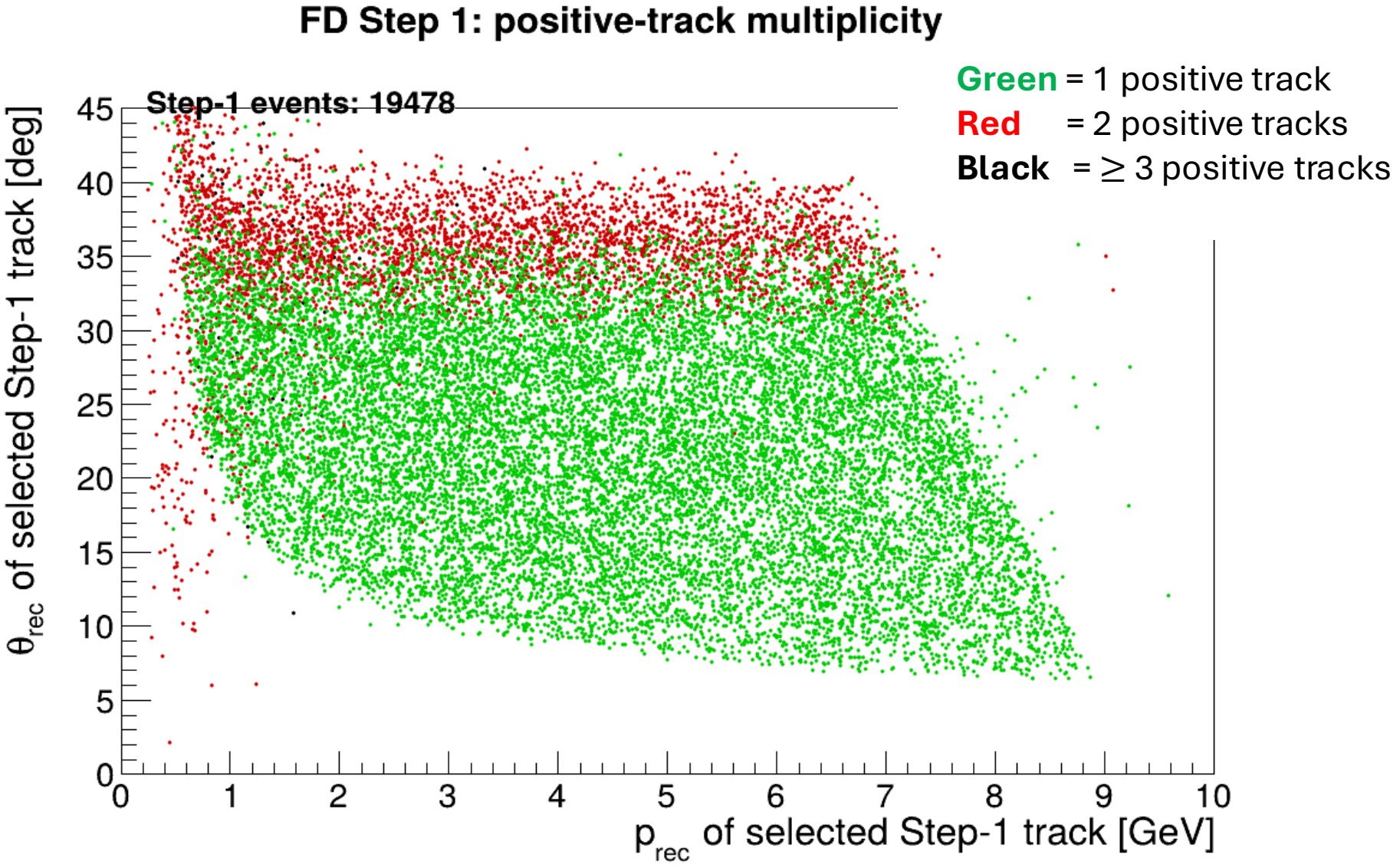






- Now I will show how positive track multiplicity is correlated with theta/momentum on a 2D plot for both FD and CD

Positive track multiplicity map. **Forward detector**



***not full available statistics**

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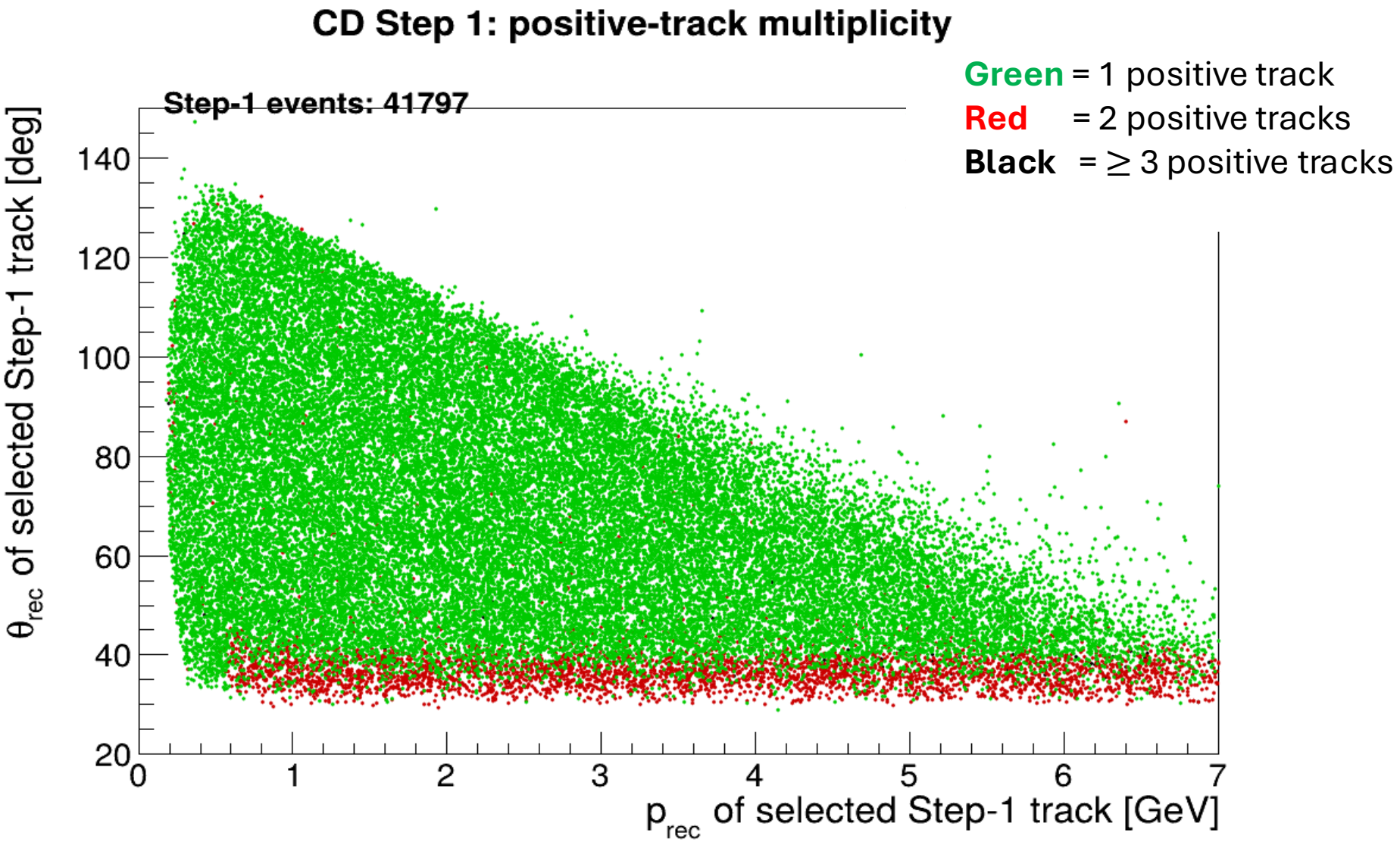
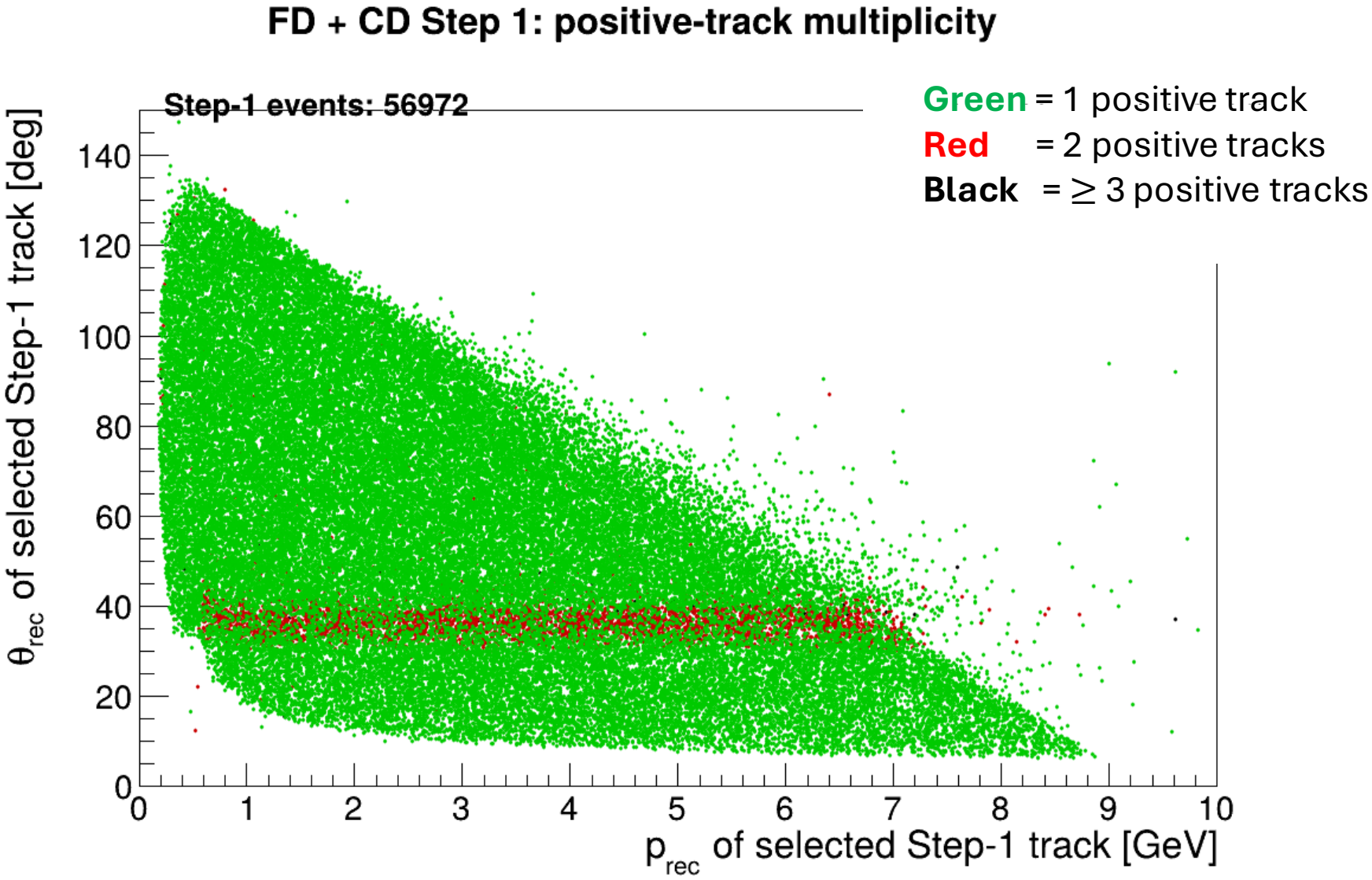
Positive track multiplicity map. **Central detector**



***not full available statistics**

Positive track multiplicity map. **Forward and Central detector together**



***not full available statistics**

- As we can see, the problematic theta/momentum regions are highly correlated with multi-positive reconstructed events

Conclusions

- A broad high-loss Δp structure appears near the **FD–CD transition region**
- It is strongly correlated with **multiple reconstructed positive tracks**
- Tracking multiplicity increases from both the **FD and CD sides** as we move closer to the transition region
- Near the transition region, **pion PID purity decreases**
- Requiring exactly one positive track reduces, but does not eliminate, contamination
- The broad peak disappears when **CTOF is disabled**
- Wide-peak tracks remain reconstructed as **FD tracks**, even when they touch CTOF
- Future analyses should **exclude the unreliable transition region**

Thank you for your attention

Back up slides

Base selection

- Exactly one reconstructed electron per event
- The electron must be the trigger particle (negative status)
- Discard events with reconstructed negative hadrons

Step 1: Select the candidate positive track

- Require at least one positive track in the Forward Detector
- Select the FD track whose momentum is closest to the generated π^+ momentum
- Require the selected track to fall inside reconstructed theta/momentum bin
- Plot $\Delta p = p_{\mathrm{rec}} - p_{\mathrm{gen}}$
- Plot positive track multiplicity histogram

Step 2.1: Apply particle identification first

- Require the selected FD track to be identified as a π^+
- Other positive tracks may still be present
- Plot the Δp distribution

Step 3.1

- Require no additional positive tracks in the event
- Final state contains exactly one positive track
- That track is in the FD and is identified as a π^+
- Plot the Δp distribution

$\Leftrightarrow$

Step 2.2: Apply multiplicity selection first

- Require exactly one positive track in the event
- Because of Step 1, this track is the selected FD track
- Plot the Δp distribution

Step 3.2

- Require the selected track to be identified as a π^+
- Final state is equivalent to Step 3.1
- Plot the Δp distribution

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- Example of corrections. $\theta \in [20,21]$deg