Update on the K_S^0 Rescue System / 6-Layer Online Tracking for the Belle II Pixel Detector

Leonard Koch, Wolfgang Kühn, Sören Lange, and David Münchow

II. Physikalisches Institut
Justus-Liebig-Universität Gießen

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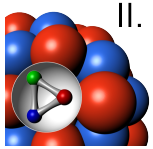

II. Physikalisches Institut

Bundesministerium für Bildung und Forschung

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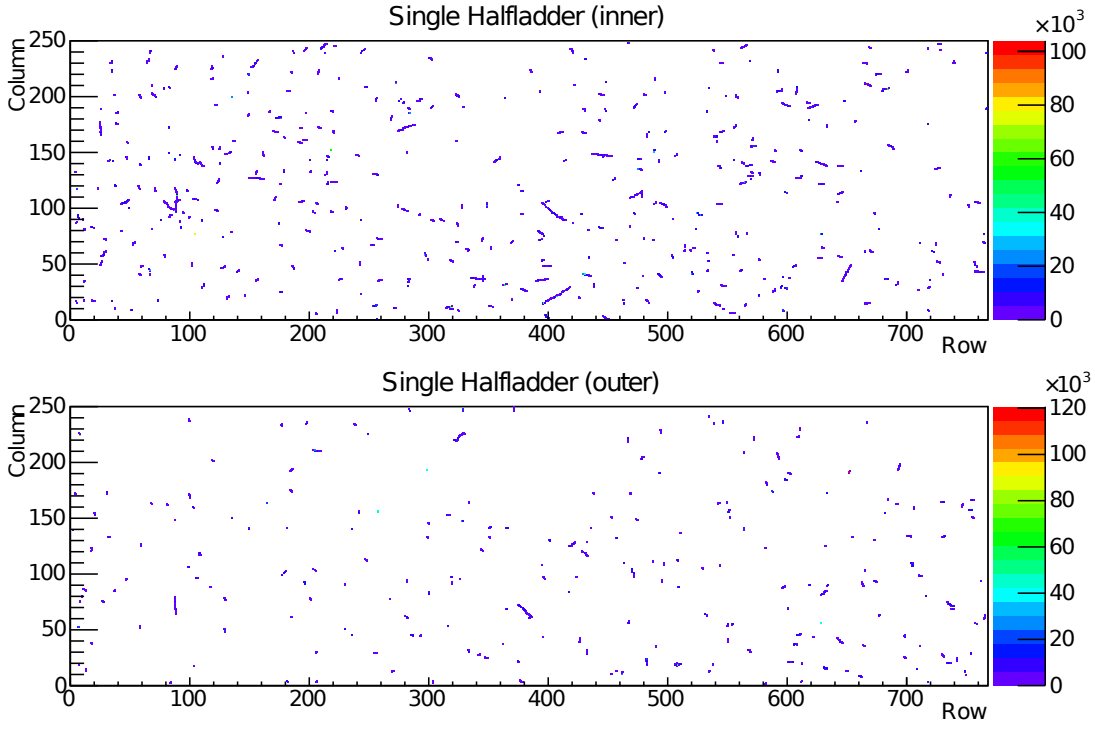
PXD background



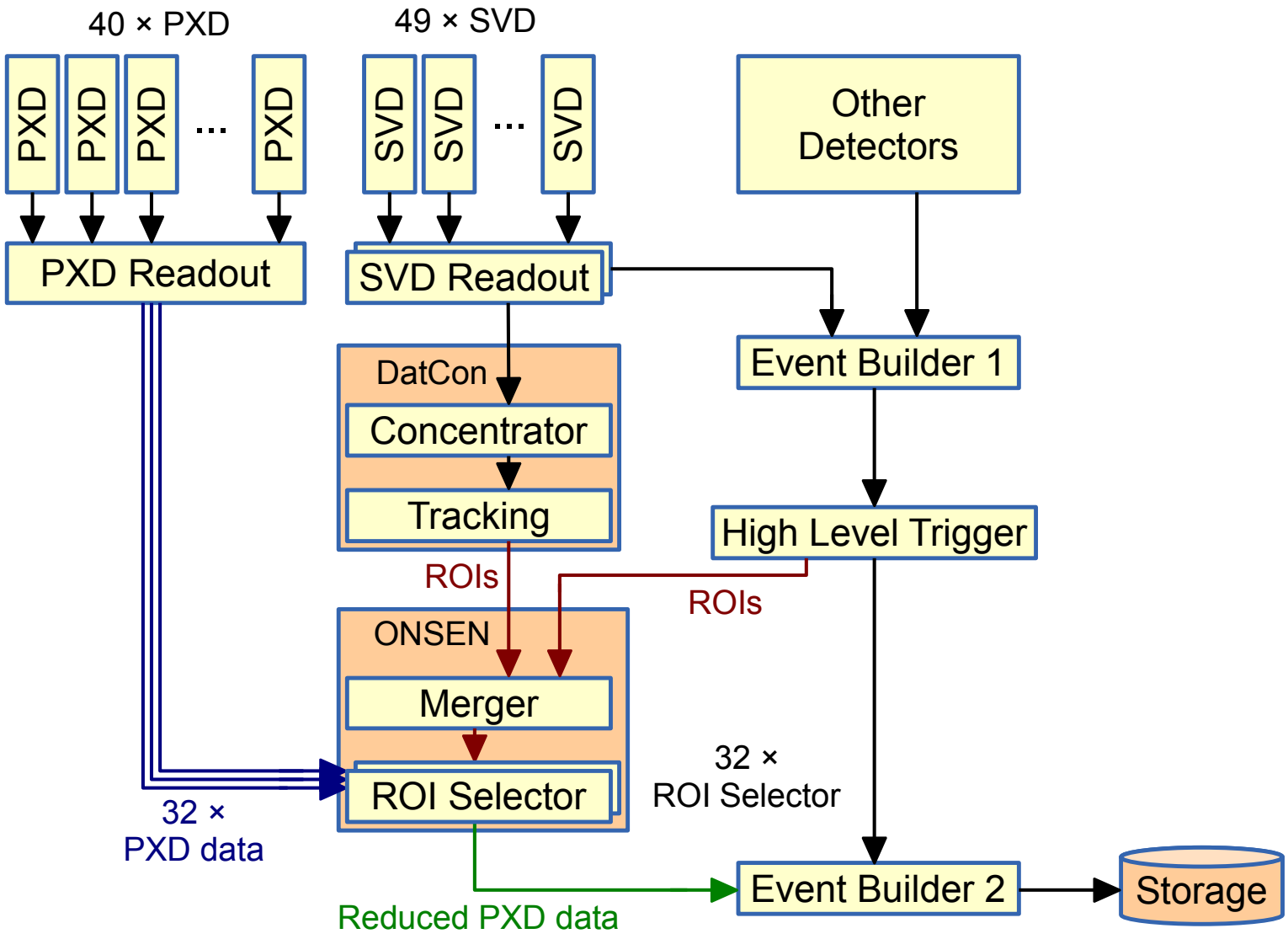
background sources

- Beam - gas scattering
- Synchrotron radiation
- Touschek effect
- Radiative Bhabha
- Two photon QED

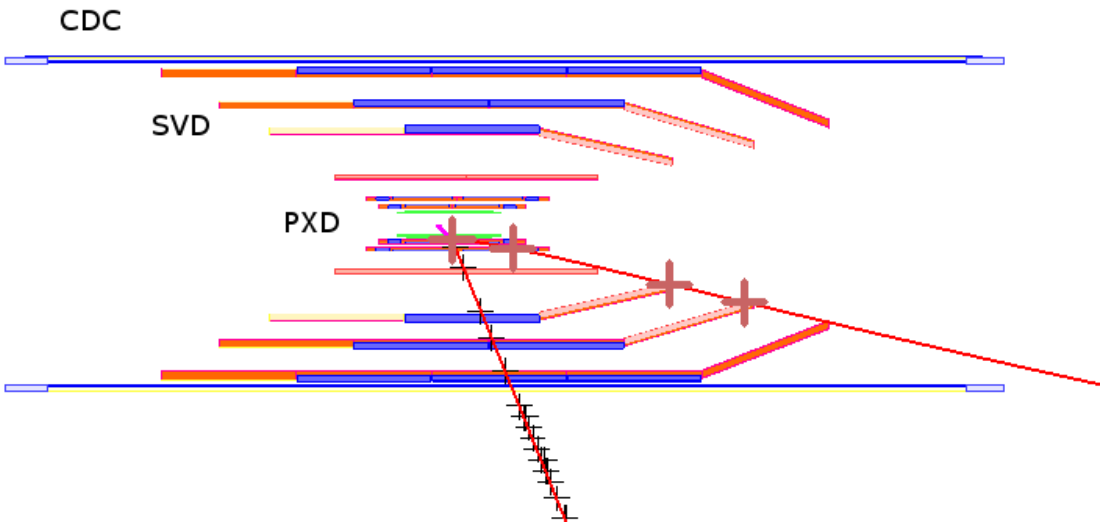
$\Rightarrow \leq 3\%$ occupancy

$\Rightarrow \sim 20\,\mathrm{GB/s}$ PXD data output ($\sim 10\times$ output from rest of detector)

PXD Readout


40 × PXD
49 × SVD
PXD
PXD
PXD
...
PXD
SVD
SVD
...
SVD
Other Detectors
PXD Readout
SVD Readout
DatCon
Concentrator
Tracking
Event Builder 1
High Level Trigger
ROIs
ROIs
ONSEN
Merger
ROI Selector
32 × ROI Selector
32 × PXD data
Reduced PXD data
Event Builder 2
Storage

The Problem



- Only two hits in SVD
- $\Rightarrow$ no ROI $\Rightarrow$ PXD hits not stored
- Enough VXD hits for tracking

The Idea

6-Layer tracking for hit recovery

6-Layer tracking

Platform:

FPGA

Track finding:

1. Filter out the backgound-like VXD hits
2. Choose hits in 3rd VXD layer as reference point for conformal transformation (secondary vertices)
3. fast hough transformation only with hits “fitting” the reference hit

Properties used to distinguish signal and background

PXD

- Coordinates of SpacePoint
- Layer
- Charge
- SeedCharge
- Size
- USize
- VSize

SVD

- Coordinates of SpacePoint
- Layer
- UCharge, VCharge
- USeedCharge, VSeedCharge
- USize, VSize

10^4 $b\bar{b}$ events

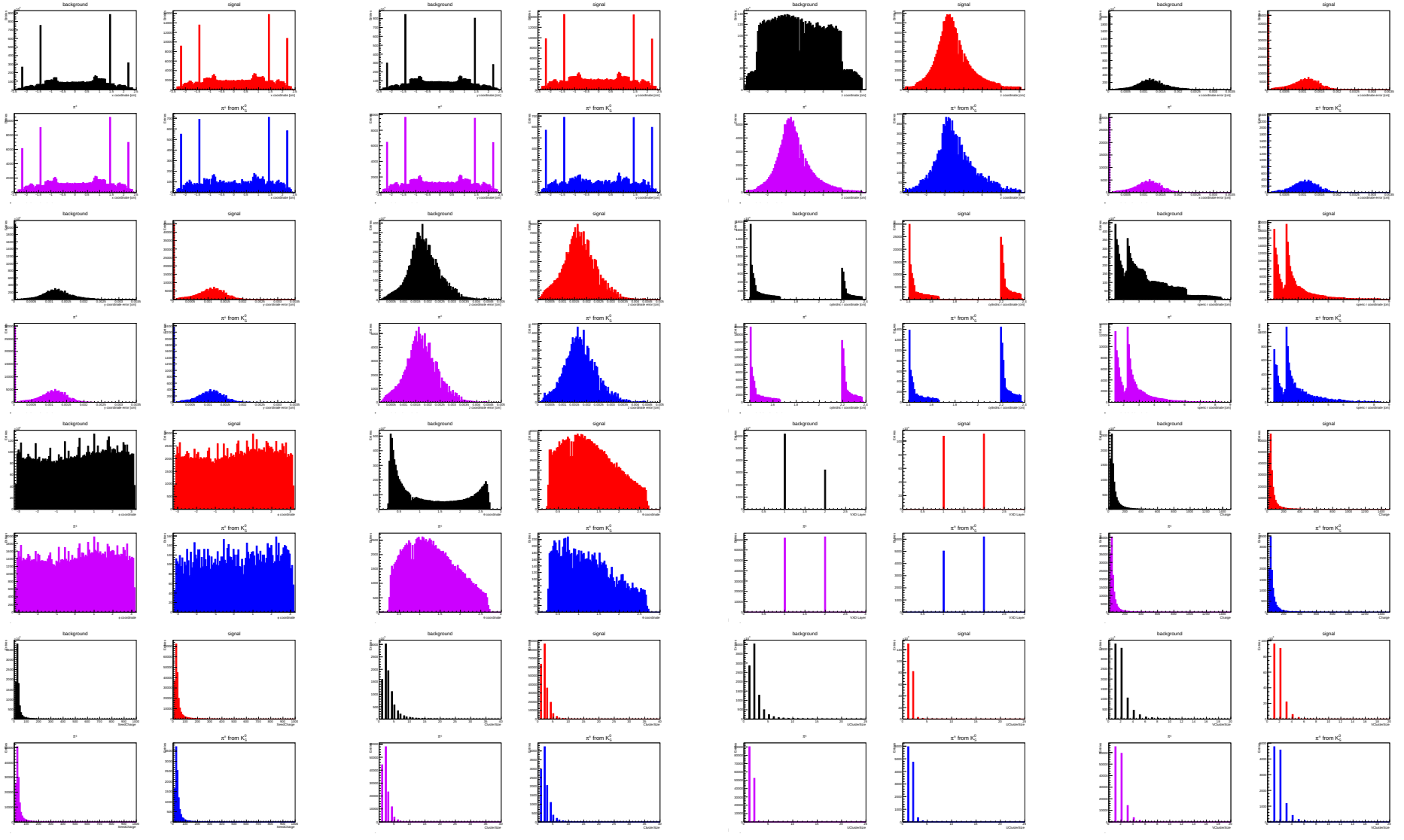
PXD

9344156	background hits (934 per event) (realistic?)
217236	signal hits (22 per event)
144068	hits from pions (14 per event)
11218	hits from pions from K_S^0 (1.1 per event)

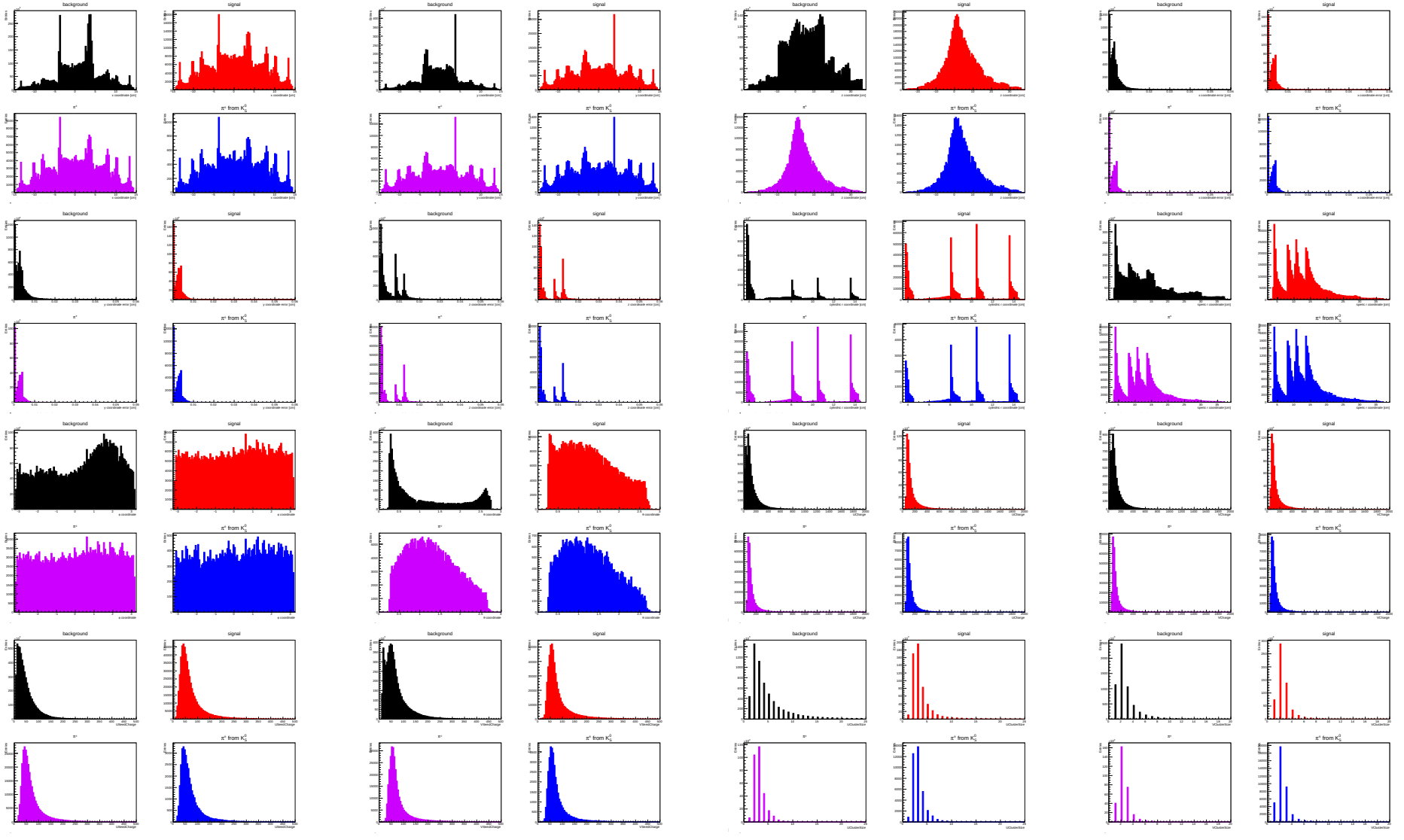
SVD

5754490	background hits (575 per event) (realistic?)
566582	signal hits (57 per event)
305592	hits from pions (31 per event)
37318	hits from pions from K_S^0 (3.7 per event)

PXD hit properties



SVD hit properties



2 hit filtering

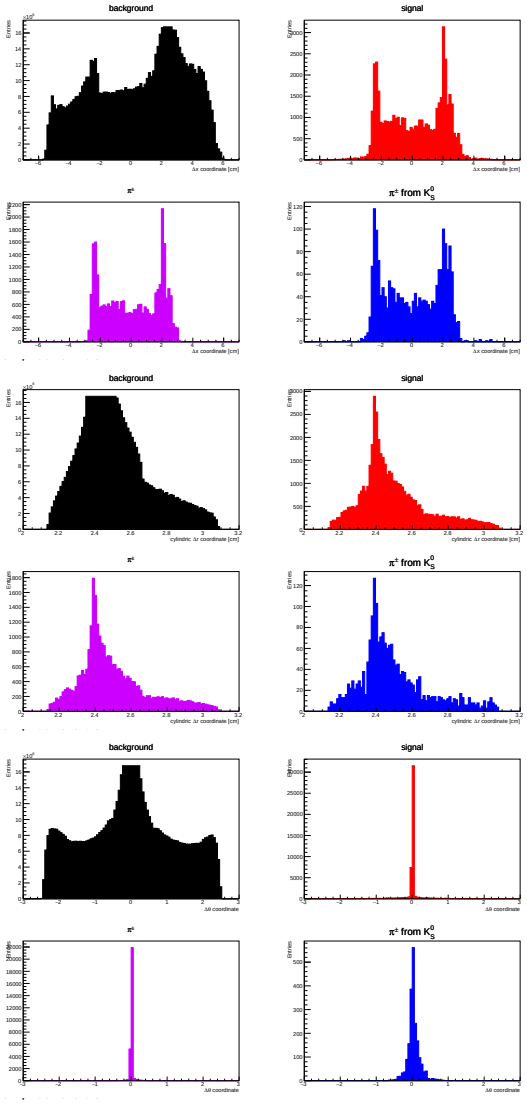
Properties used to distinguish between signal and background

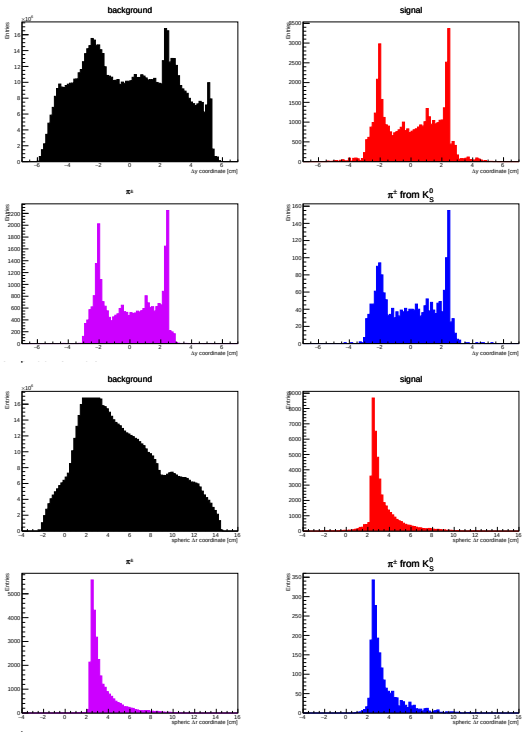
- same as for single hit filtering
- $\Delta\text{coordinate}_{ij} = \text{coordinate}_{\text{Layer } i}$ - $\text{coordinate}_{\text{Layer } j}$

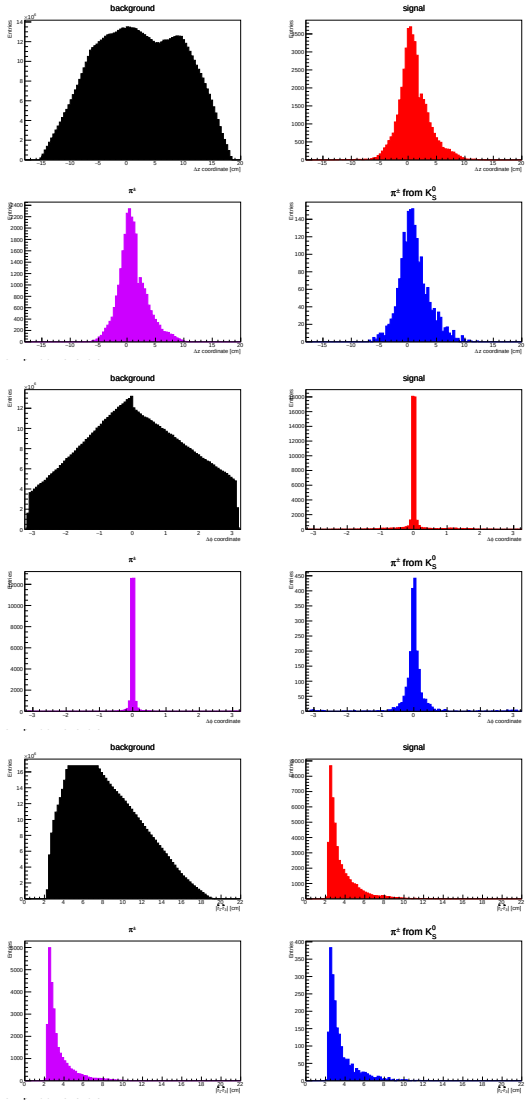
4000 $b\bar{b}$ events: hit-hit combinations per event

i - j	background	signal	pion	pion from K_S^0
1 - 3	202258	12	7.2	0.51
1 - 4	67075	11	7.4	0.52
2 - 3	108884	14	7.4	0.63
2 - 4	36179	12	7.6	0.65

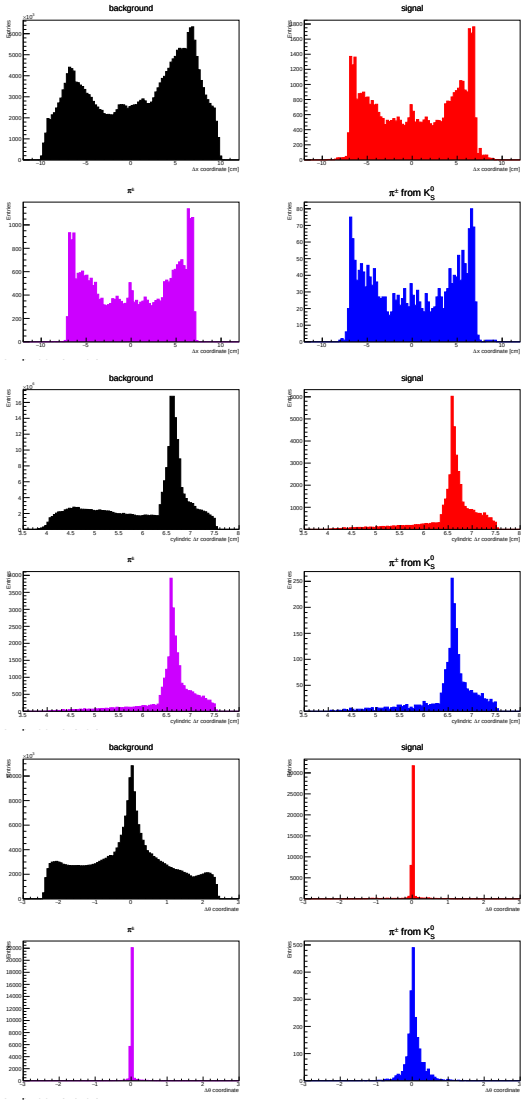
1 - 3 properties

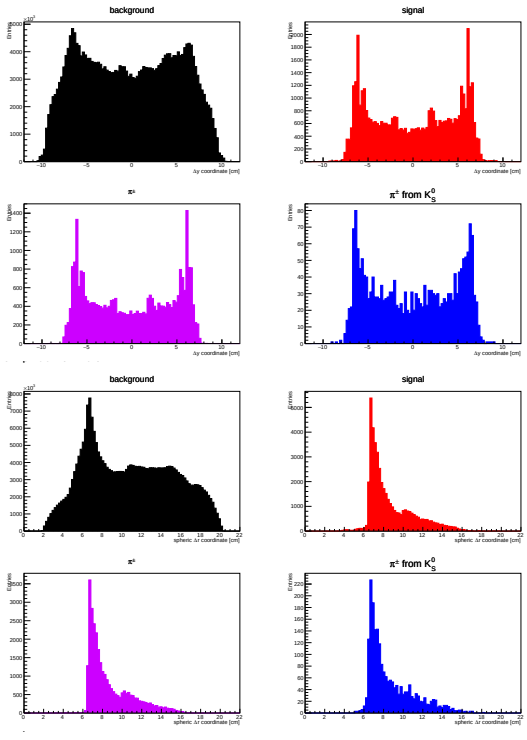


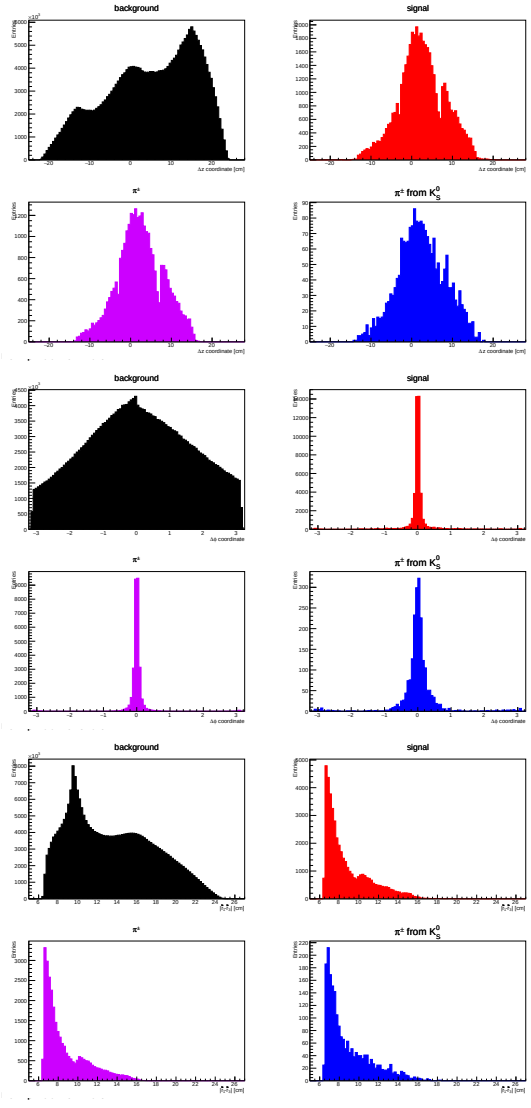




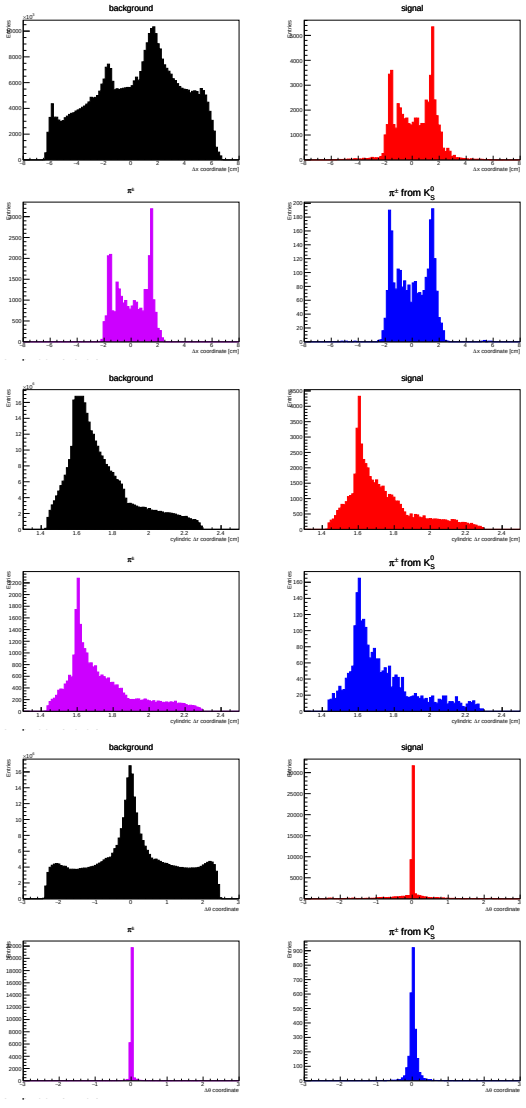
1 - 4 properties

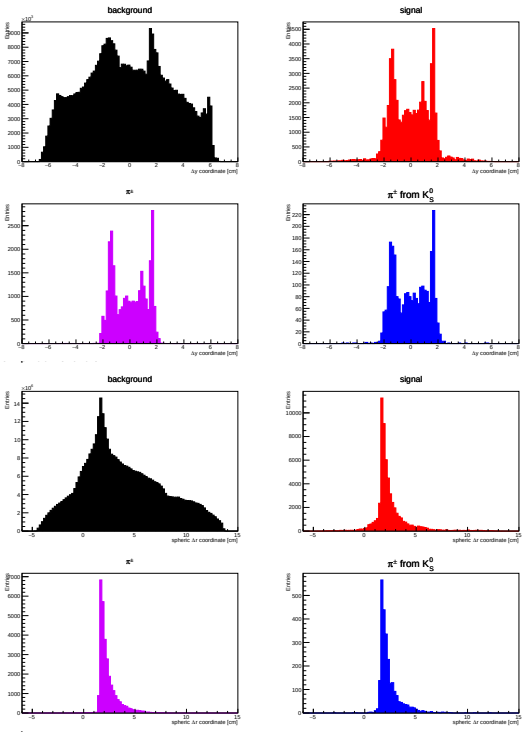


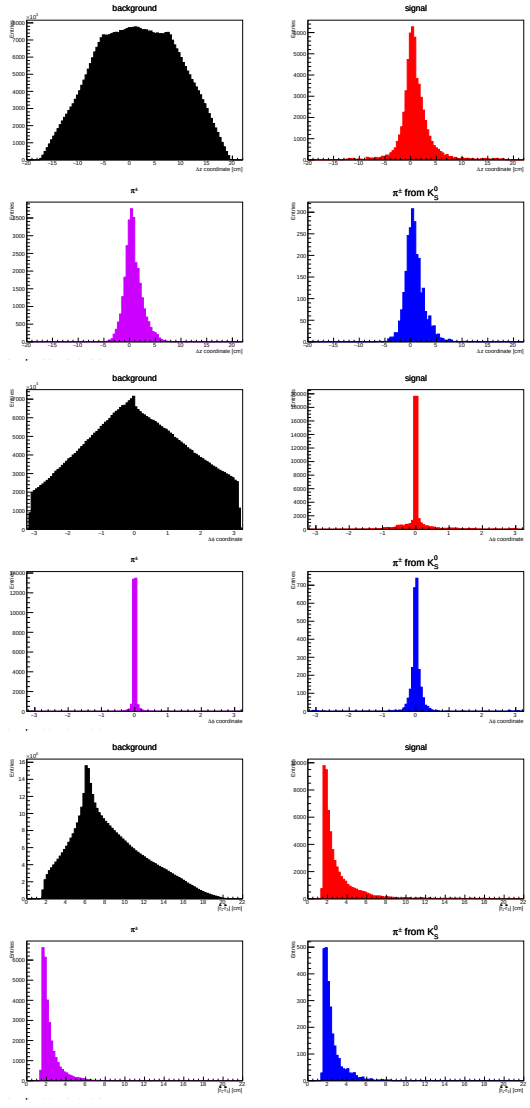




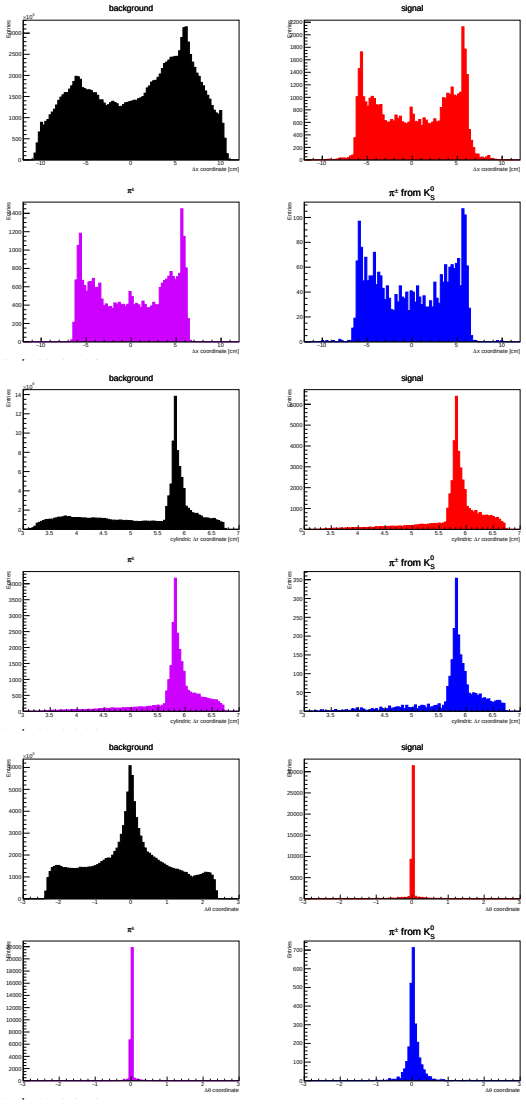
2 - 3 properties

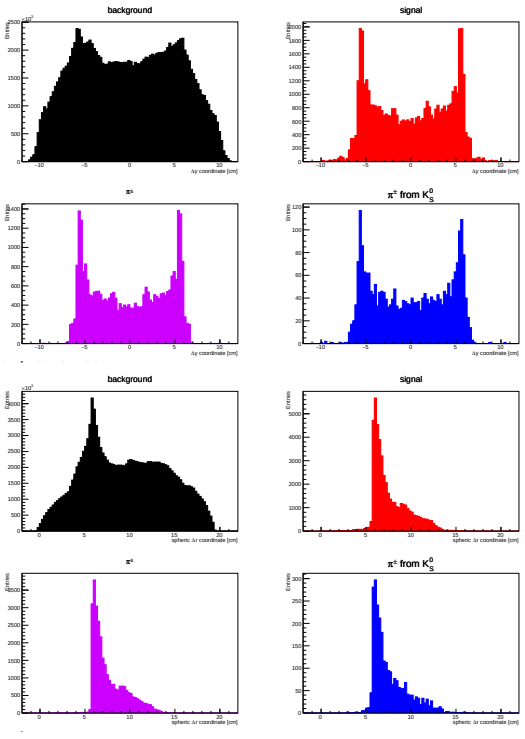


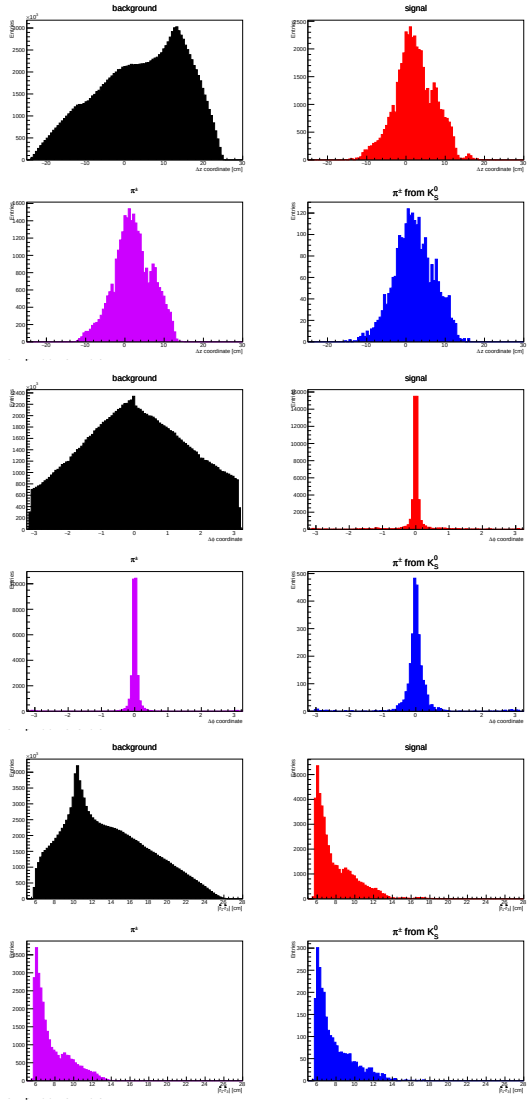




2 - 4 properties

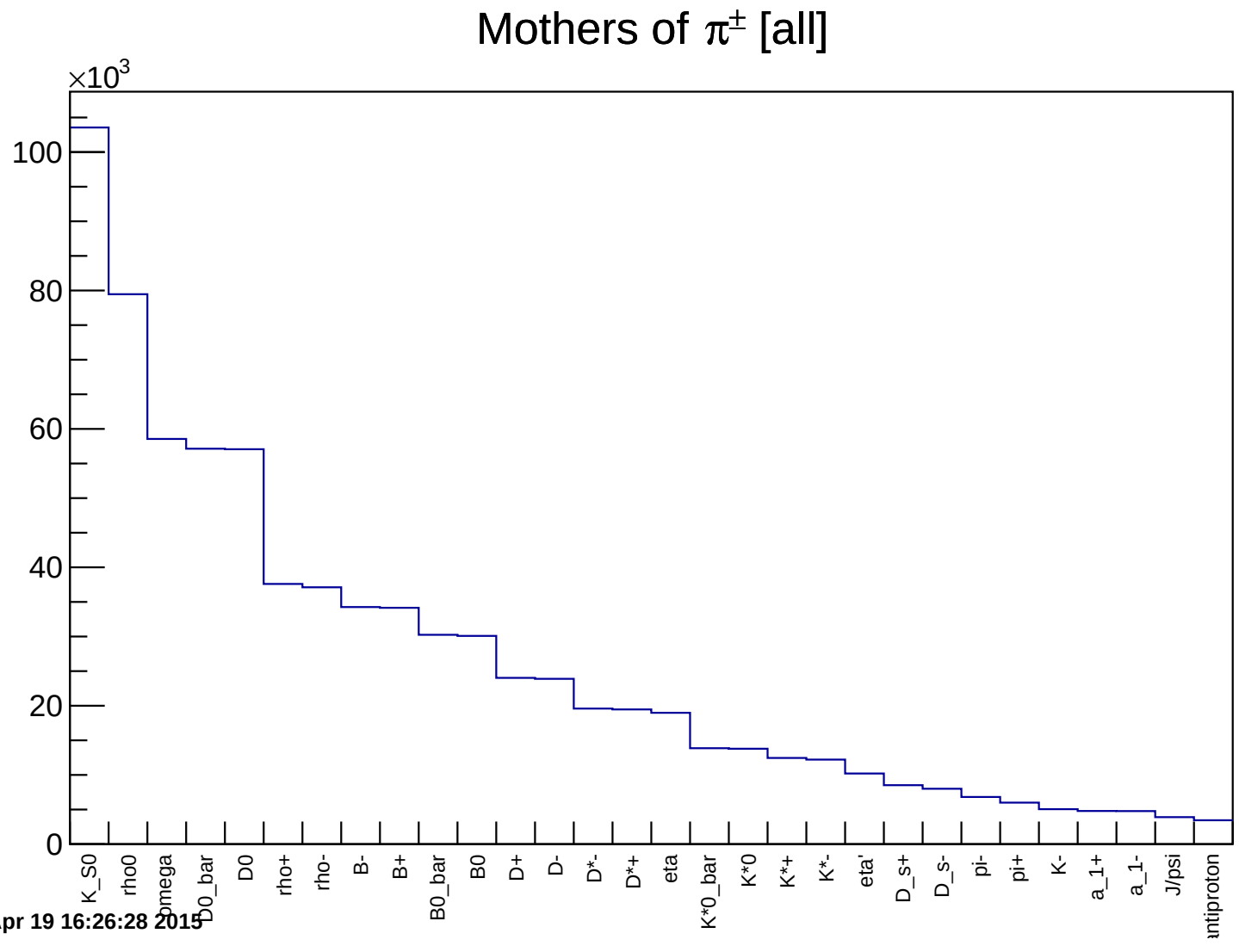






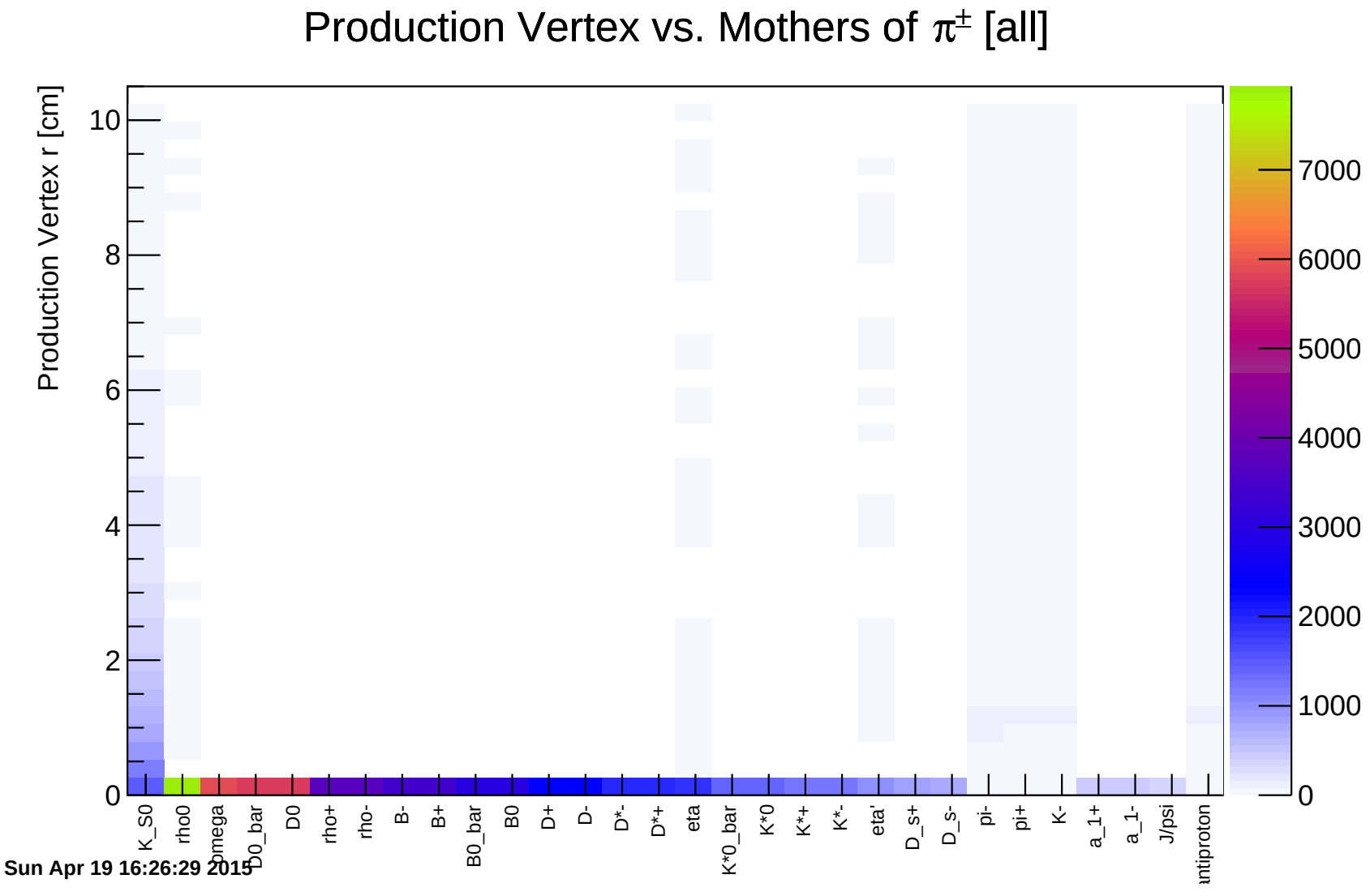
10^5 $b\bar{b}$-events

Origin of $\pi^{\pm}$s



10^5 $b\bar{b}$-events

Origin of $\pi^{\pm}$s



Performance estimation

Definitions

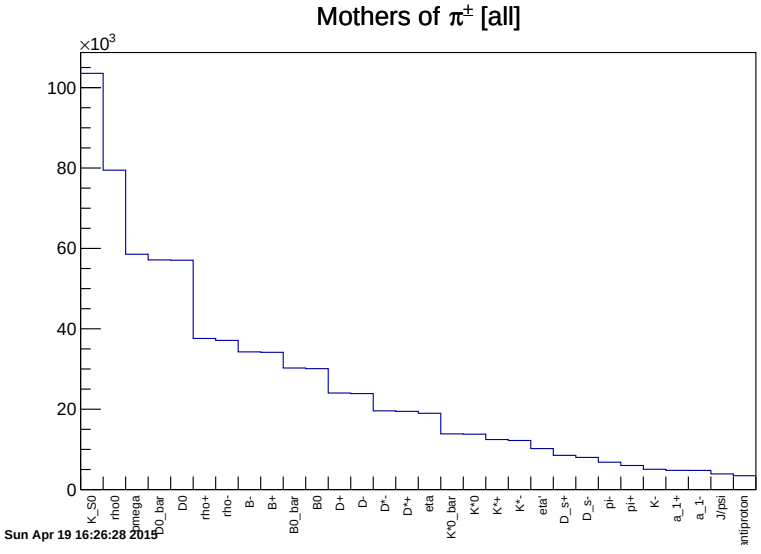
- trackable $\hat{=} \geq 3$ SVD hits
- lost $\hat{=} < 3$ SVD hits
- only 6-layer trackable $\hat{=} < 3$ SVD hits & $\text{SeedCharge}_{\text{PXDhits}} < 45$ & $\geq 3\,(4)$ VXD hits

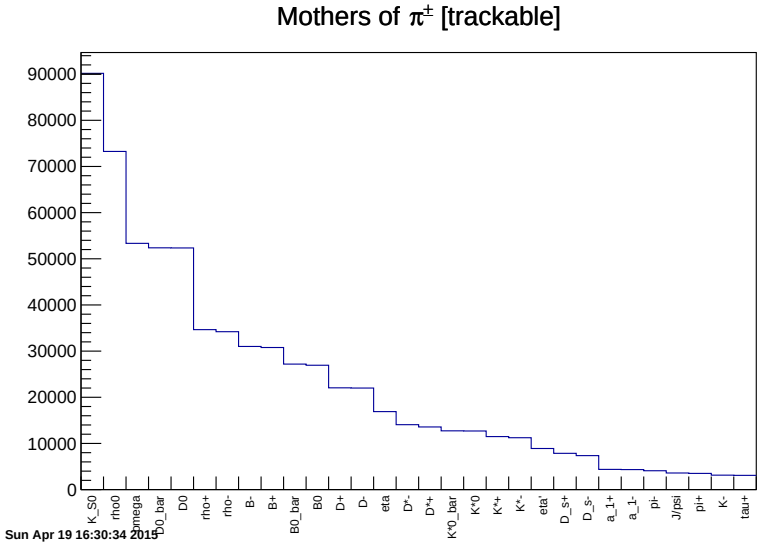
830372 $\pi^{\pm}$s

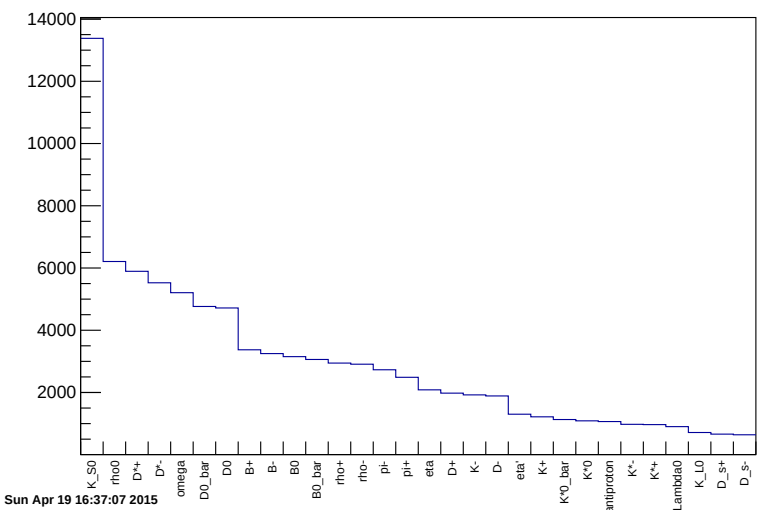
- 736315 trackable (89%)
- 94057 lost (11%)
- 5363 only 6-layer trackable (3 hits) (0.65%)
- 2286 only 6-layer trackable (4 hits) (0.28%)

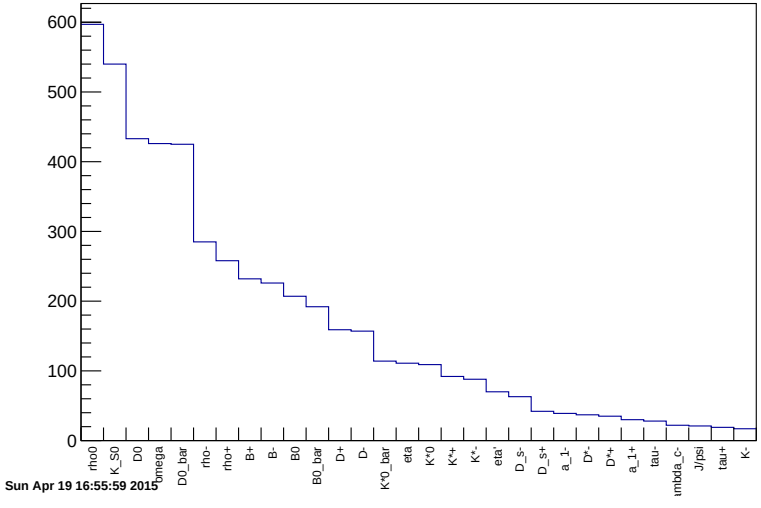
10^5 $b\bar{b}$-events

Origin of $\pi^{\pm}$s



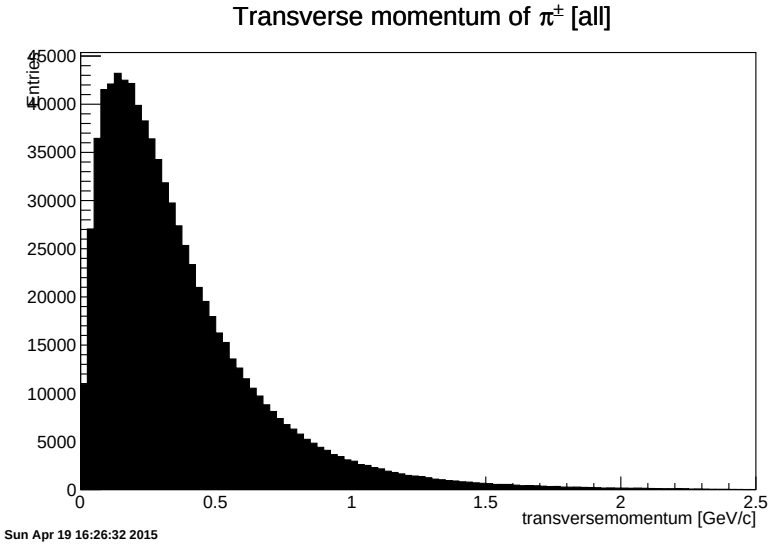


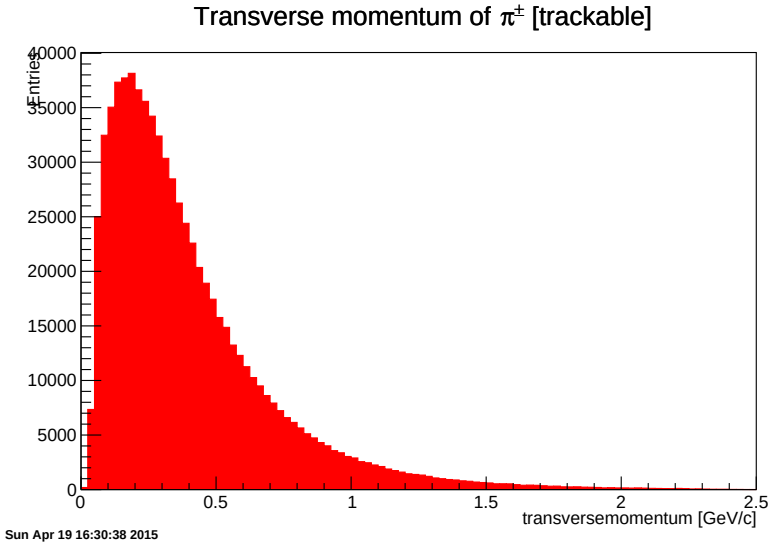


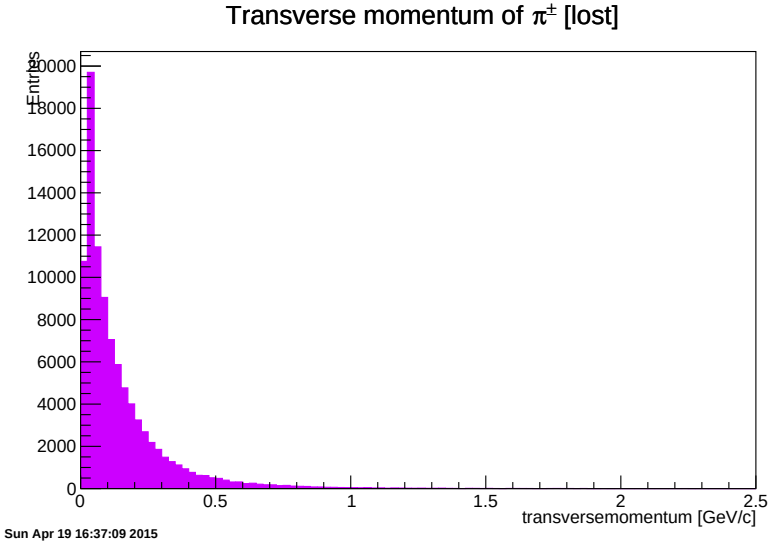


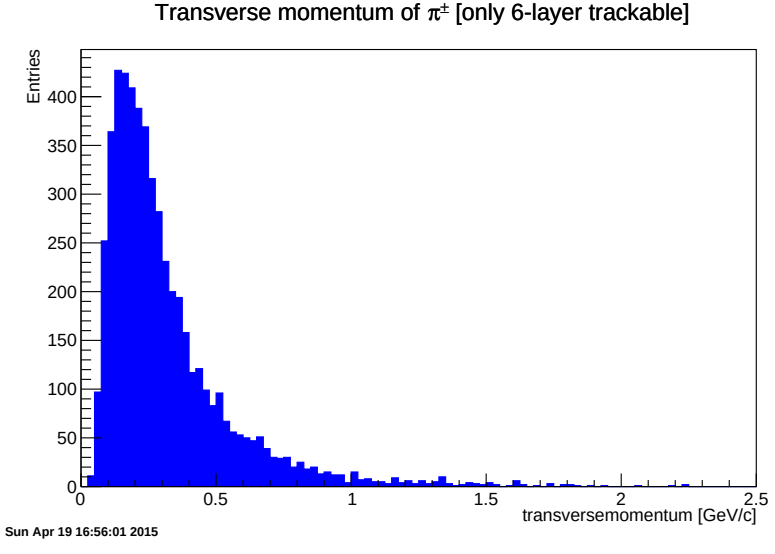
10^5 $b\bar{b}$-events

Transverse momentum

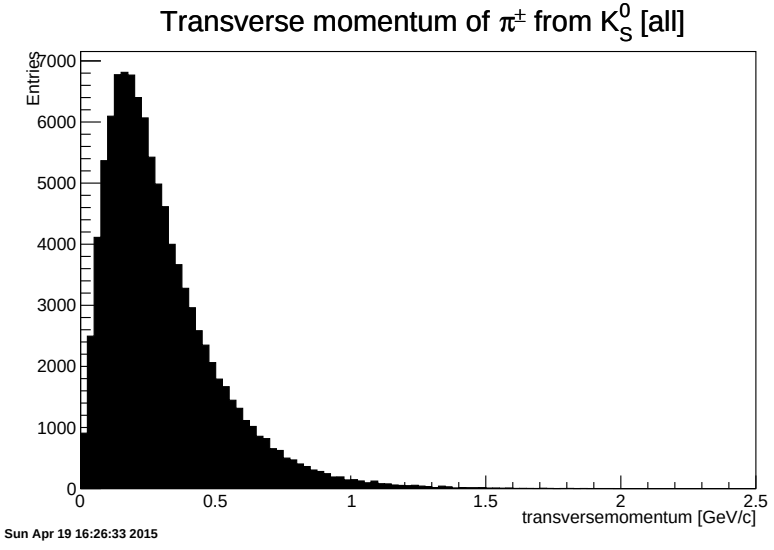


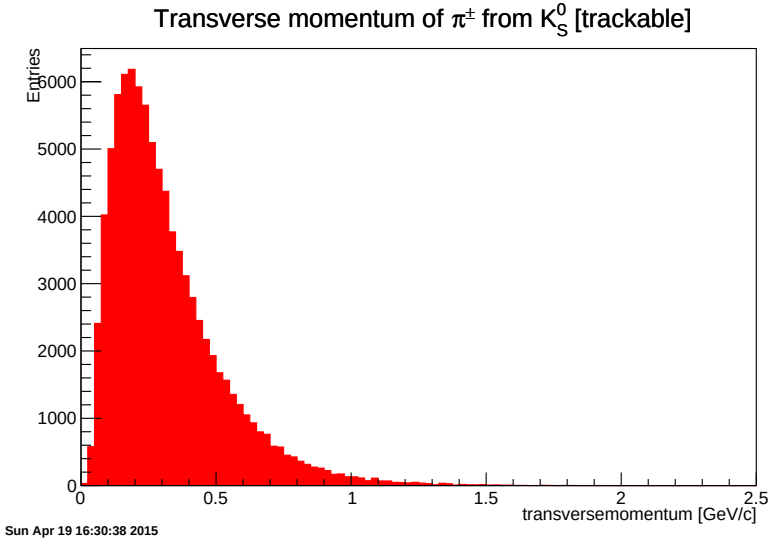


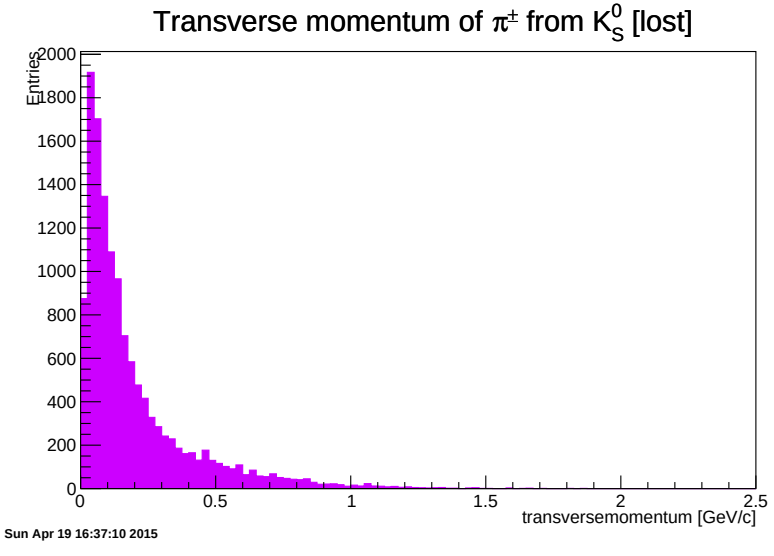


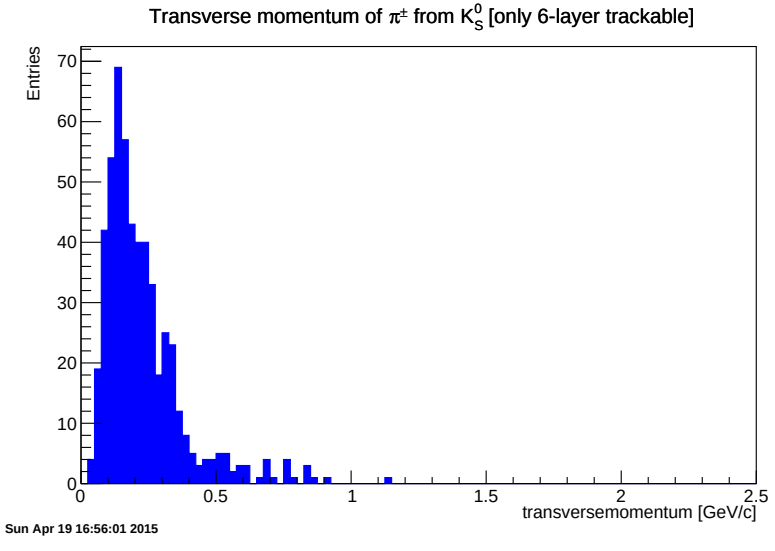


Transverse momentum





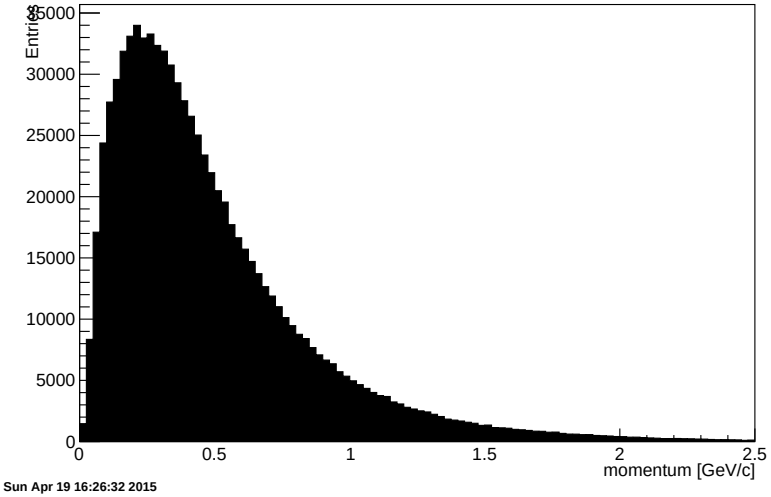




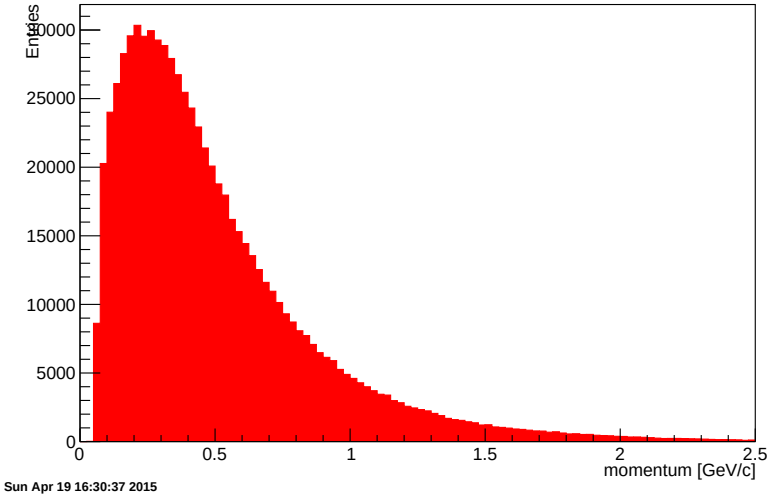
10^5 $b\bar{b}$-events

Momentum

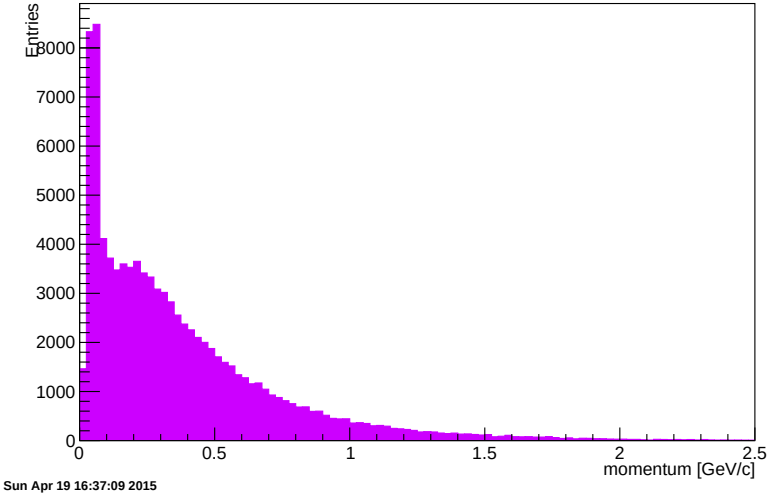
Momentum of $\pi^{\pm}$ [all]



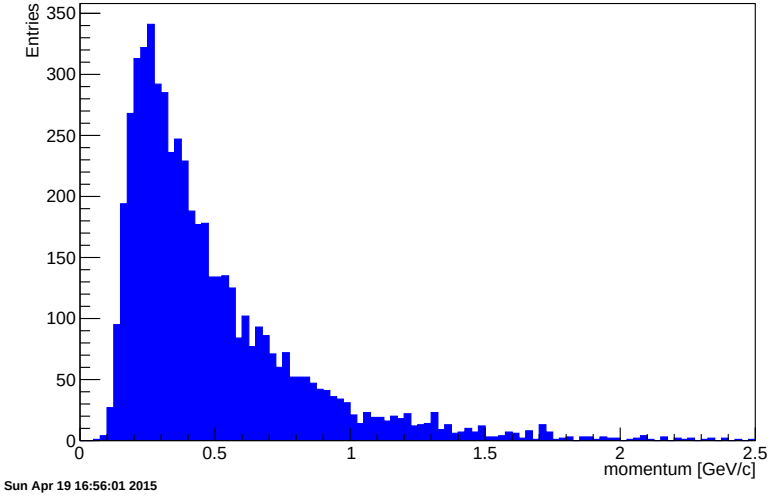
Momentum of $\pi^{\pm}$ [trackable]



Momentum of $\pi^{\pm}$ [lost]

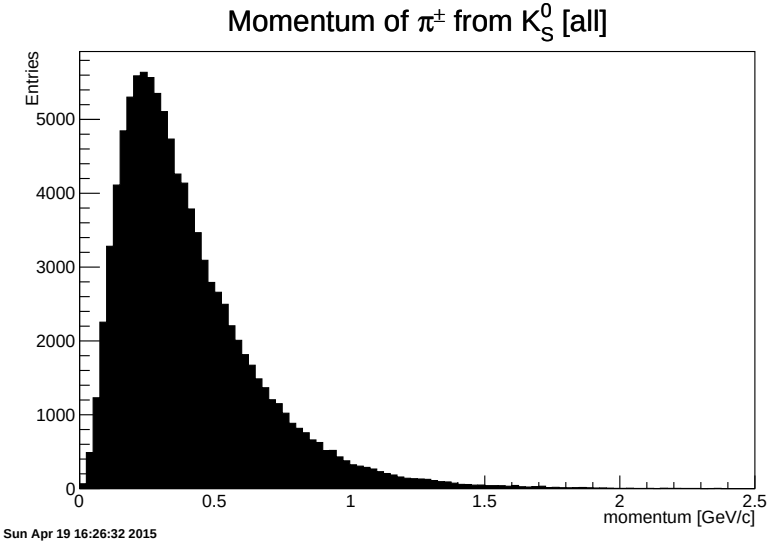


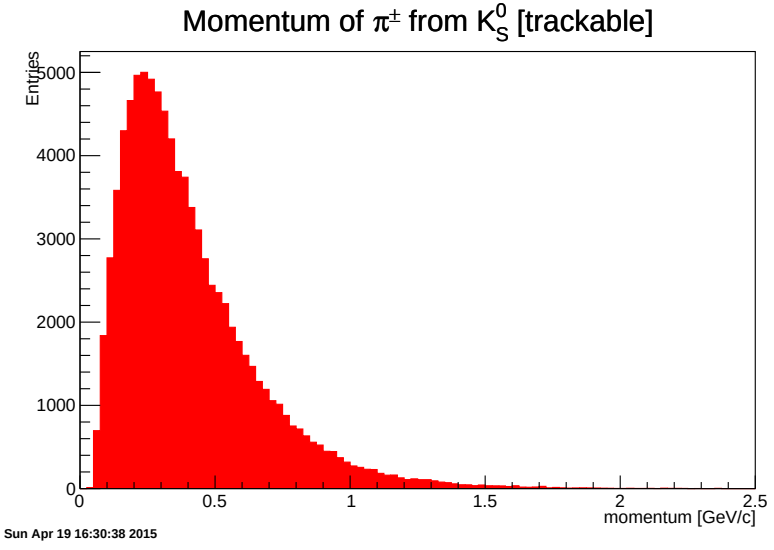
Momentum of $\pi^{\pm}$ [only 6-layer trackable]

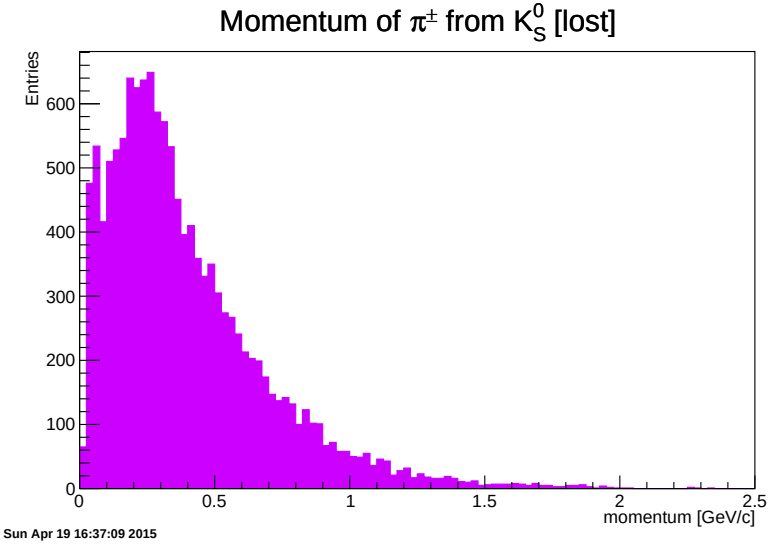


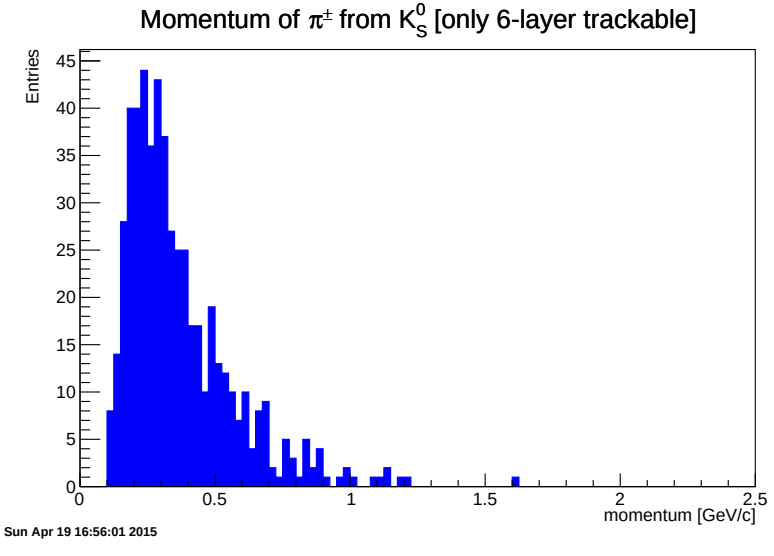
10^5 $b\bar{b}$-events

Momentum



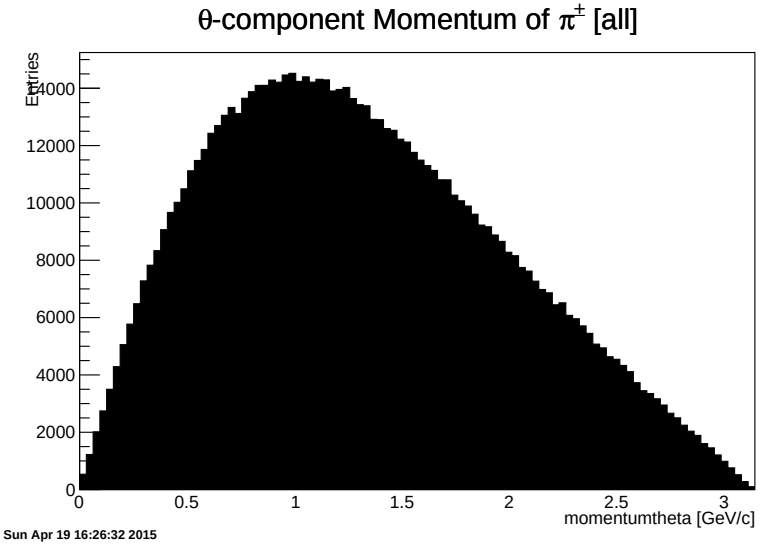


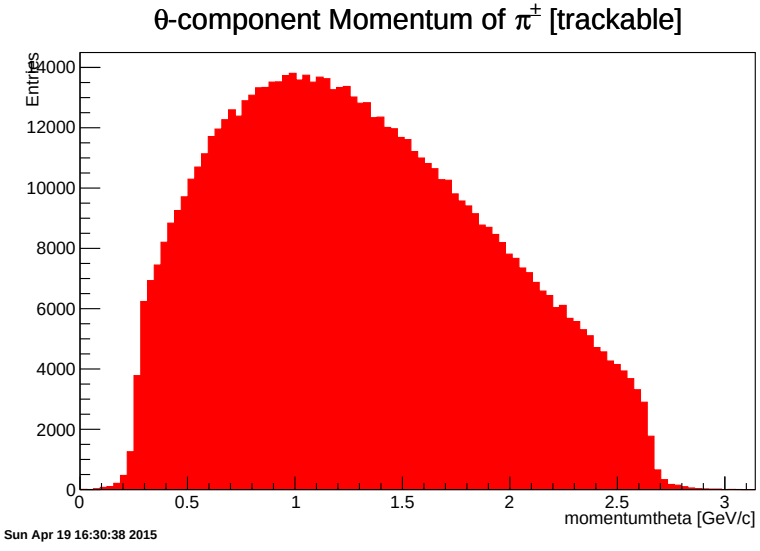


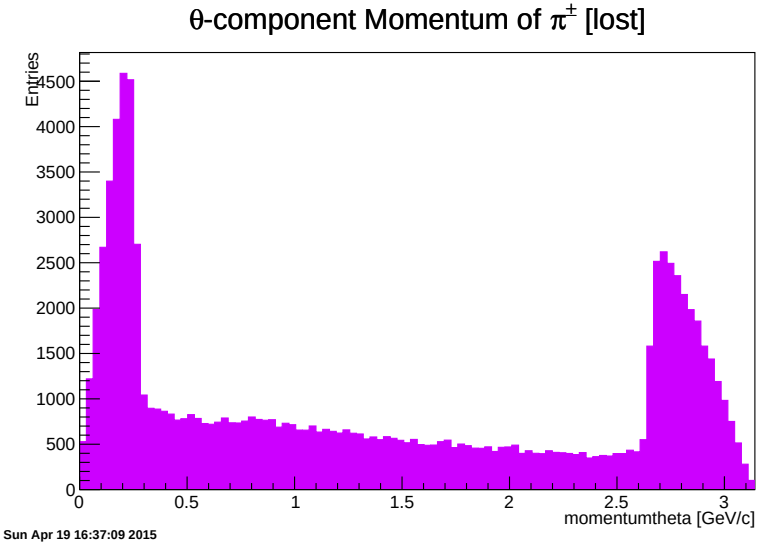


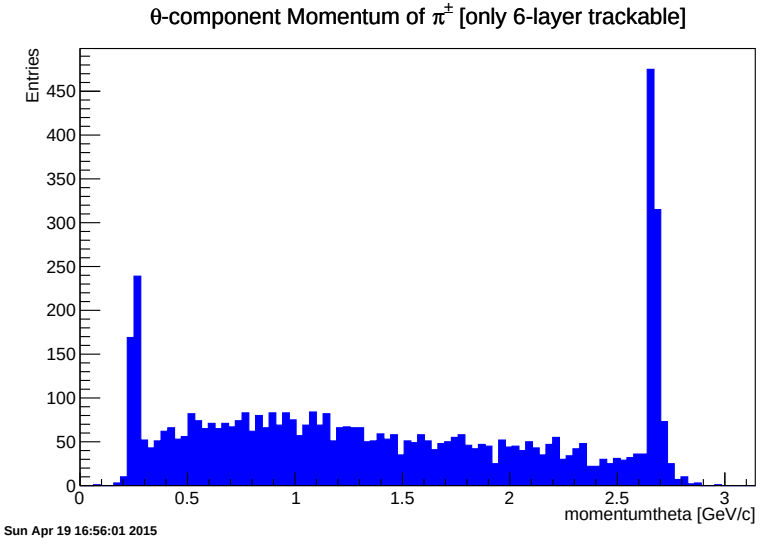
10^5 $b\bar{b}$-events

θ-component of momentum



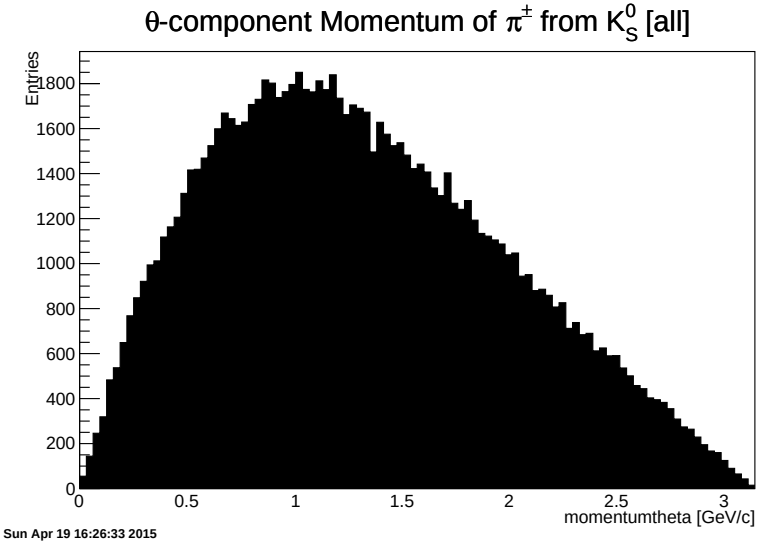


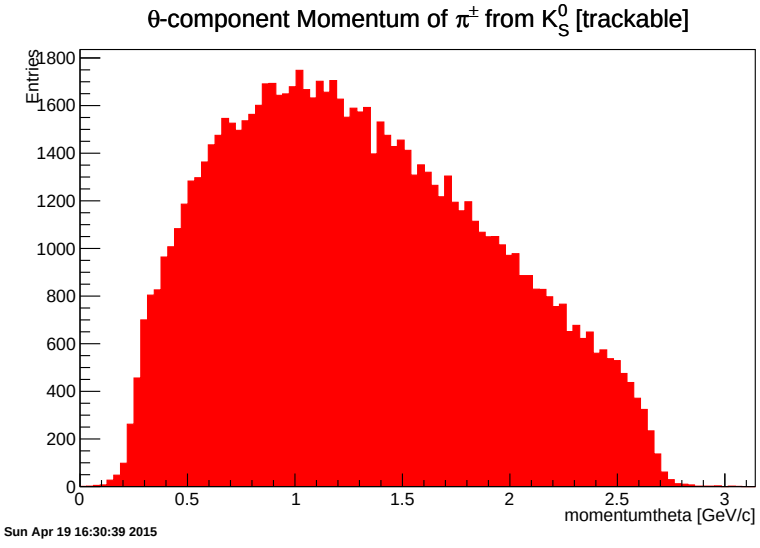


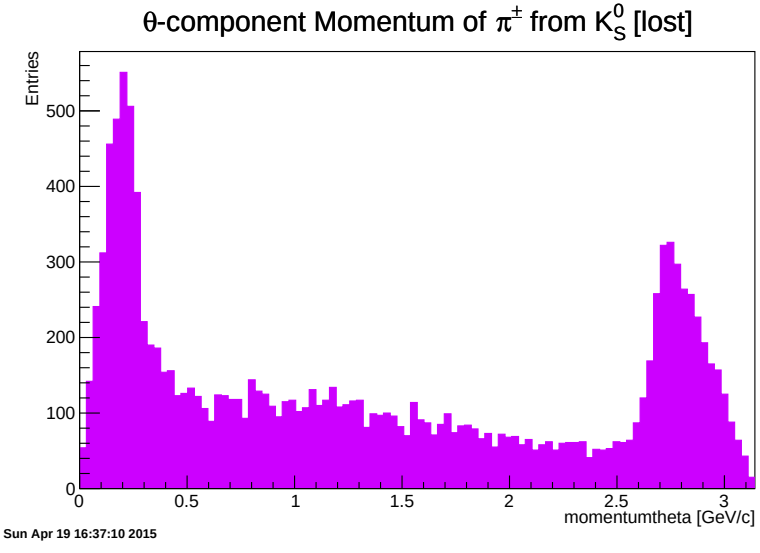


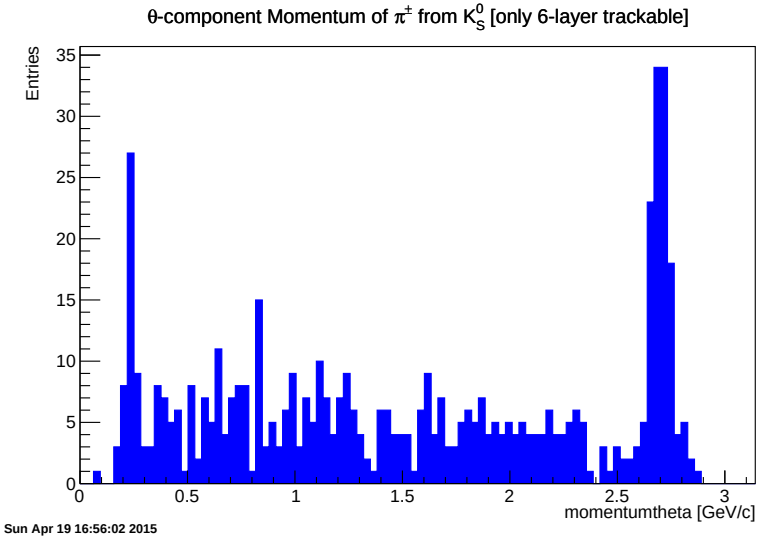
10^5 $b\bar{b}$-events

θ-component of momentum





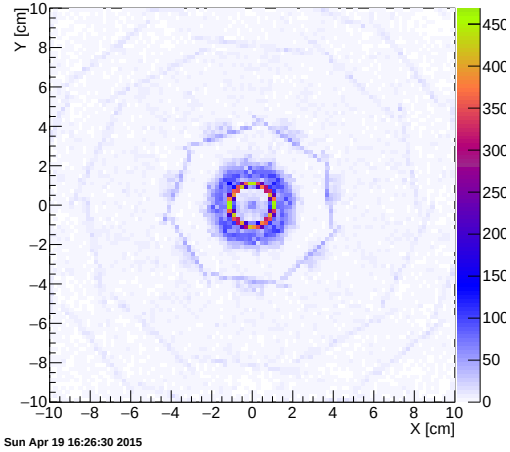




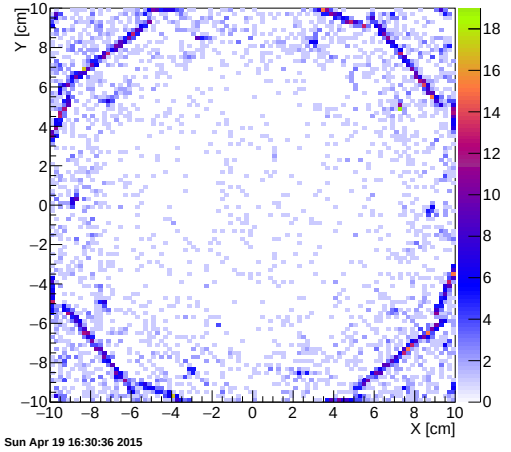
10^5 $b\bar{b}$-events

Decay vertex

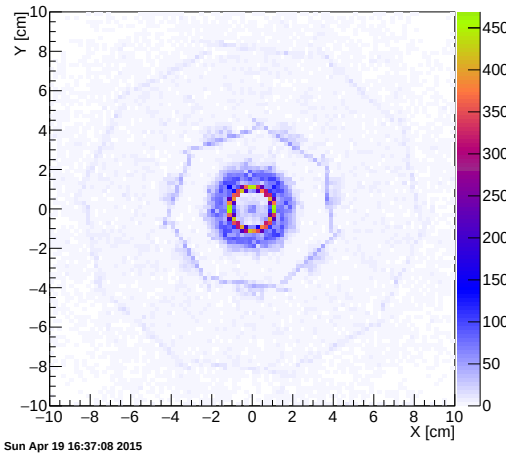
DecayVertex of $\pi^{\pm}$ [all]



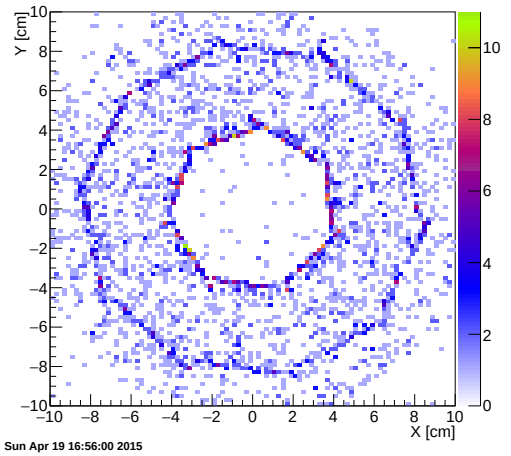
DecayVertex of $\pi^{\pm}$ [trackable]



DecayVertex of $\pi^{\pm}$ [lost]



DecayVertex of $\pi^{\pm}$ [only 6-layer trackable]



Other decays

5×10^4 $B \to K^*(\to K^0_S(\to \pi^+\pi^-)\pi^0)\gamma$ events: 284285 $\pi^\pm$s

- 245499 trackable (86%)
- 38786 lost (14%)
- 1494 only 6-layer trackable (3 hits) (0.53%)
- 624 only 6-layer trackable (4 hits) (0.22%)

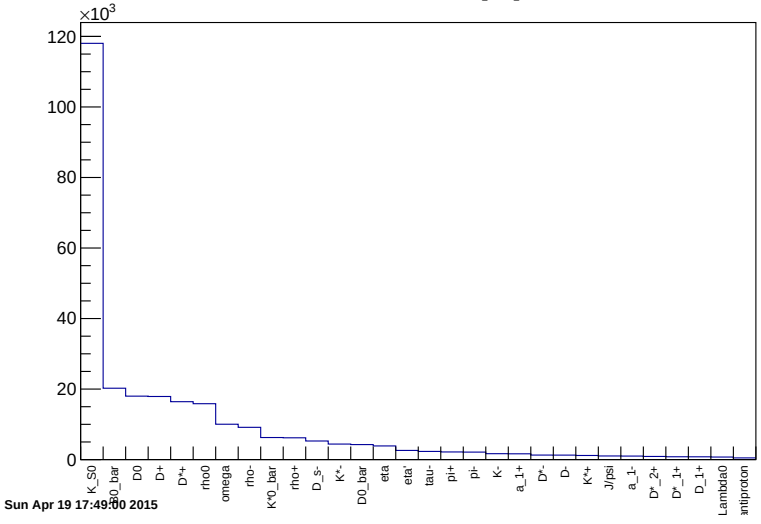
5×10^4 direct $e^+e^- \to D\bar{D}$ events: 159949 $\pi^\pm$s

- 150691 trackable (94%)
- 9258 lost (5.8%)
- 732 only 6-layer trackable (3 hits) (0.46%)
- 322 only 6-layer trackable (4 hits) (0.20%)

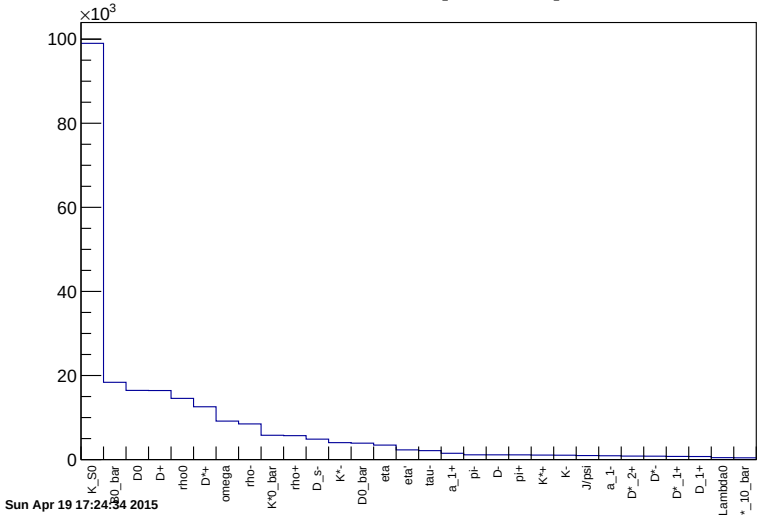
Other decays

$B \to K^*(\to K^0_S(\to \pi^+\pi^-)\pi^0)\gamma$

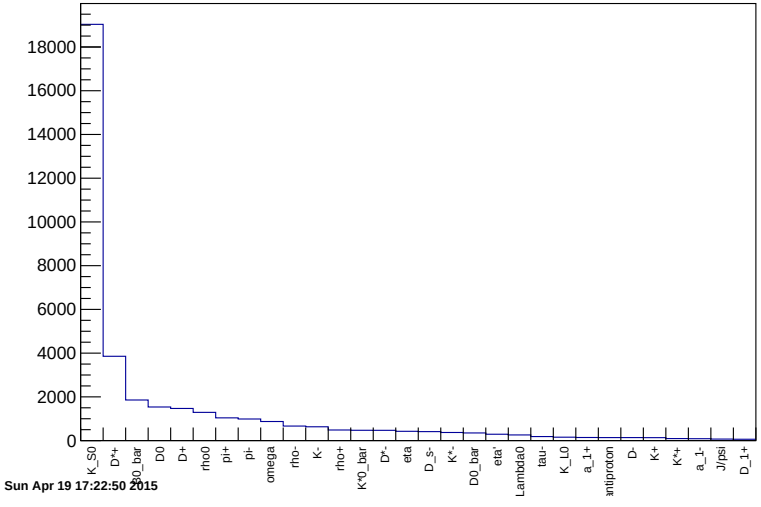
Mothers of $\pi^\pm$ [all]



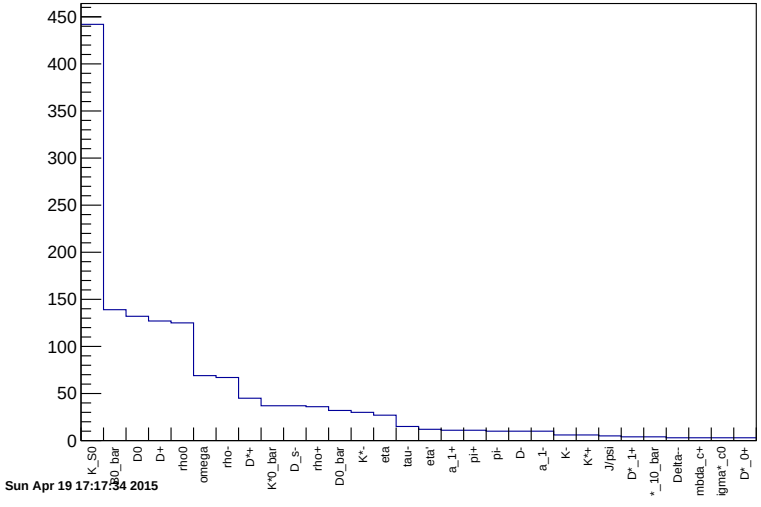
Mothers of $\pi^\pm$ [trackable]



Mothers of $\pi^\pm$ [lost]



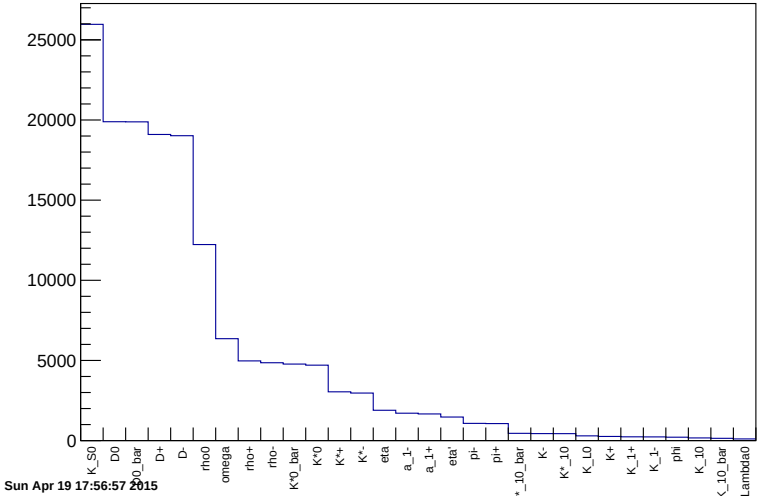
Mothers of $\pi^\pm$ [only 6-layer trackable]



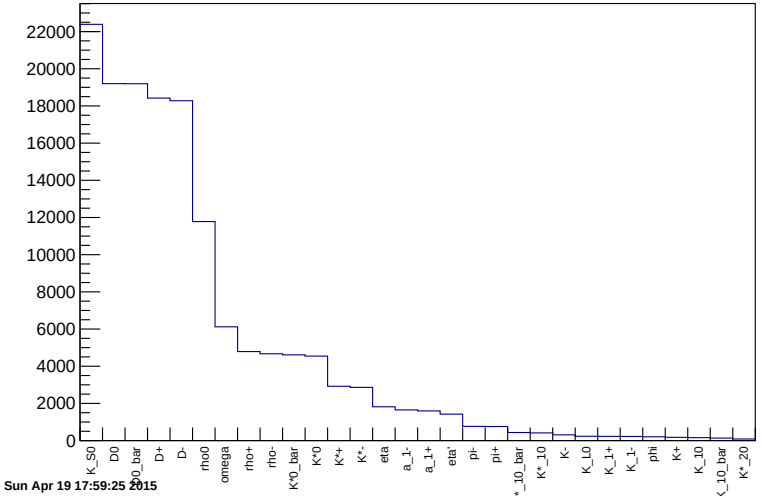
Other decays

$e^+e^- \to D\bar{D}$

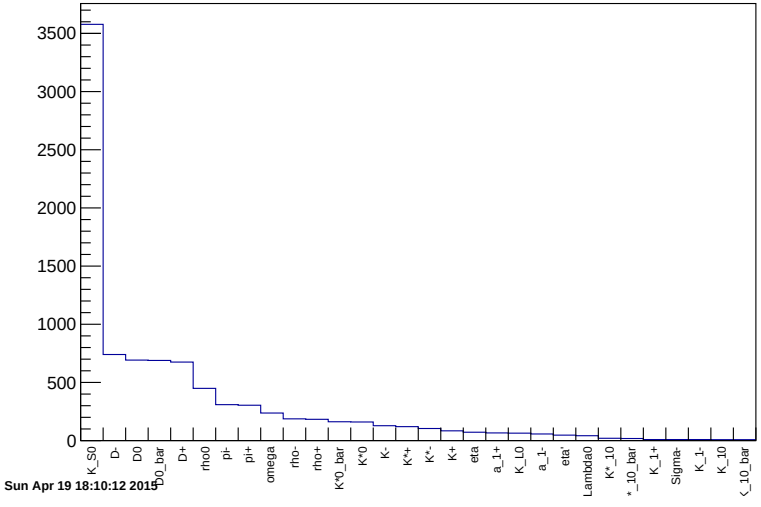
Mothers of $\pi^{\pm}$ [all]



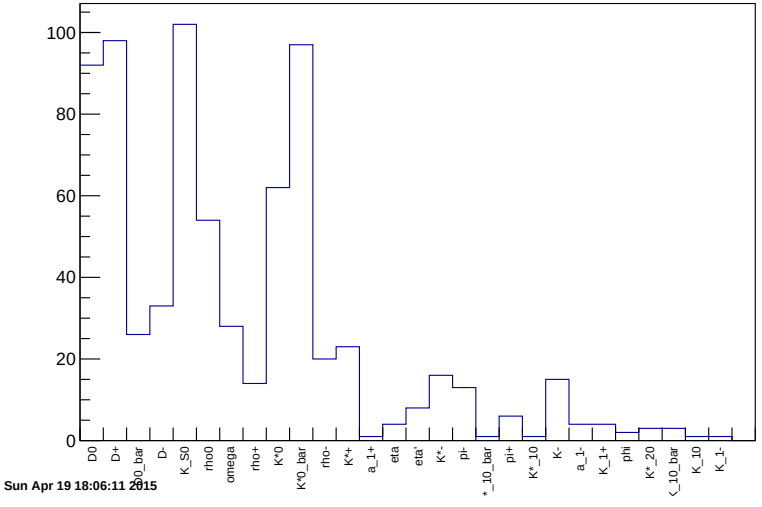
Mothers of $\pi^{\pm}$ [trackable]



Mothers of $\pi^{\pm}$ [lost]



Mothers of $\pi^{\pm}$ [only 6-layer trackable]



Summary

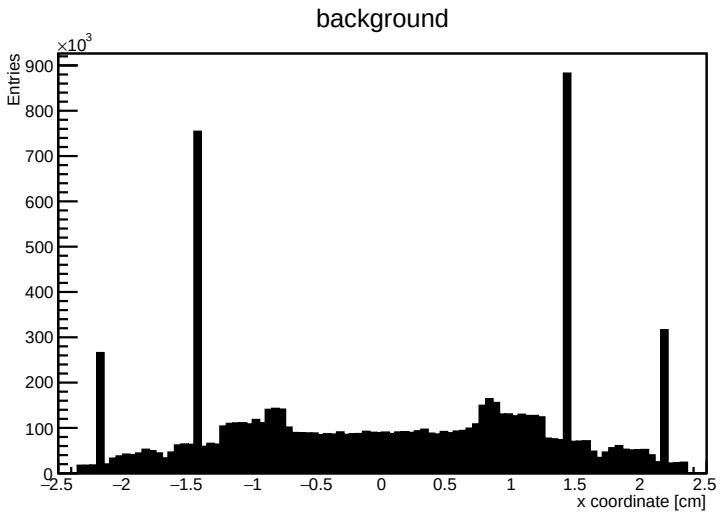
- PXD data reduction via ROIs
- Tracks with too few hits in SVD + CDC $\rightarrow$ no ROI
- Solution: Tracking with PXD + SVD
- Reduction of combinatorics using MVA methods
- expected gain in efficiency < 1%

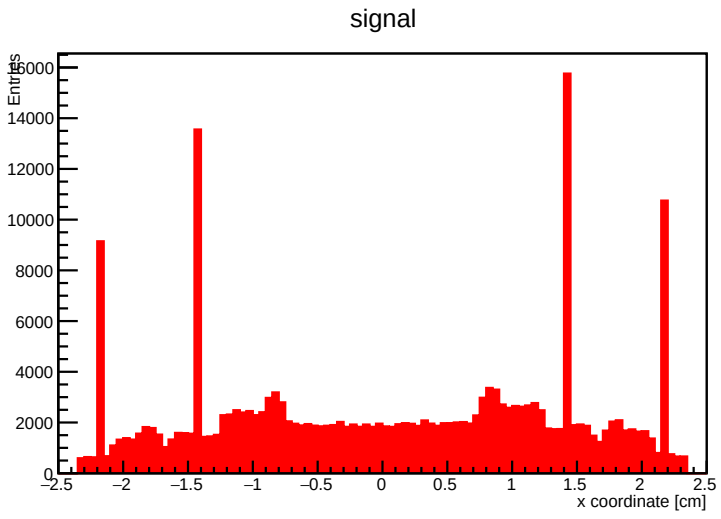
To do:

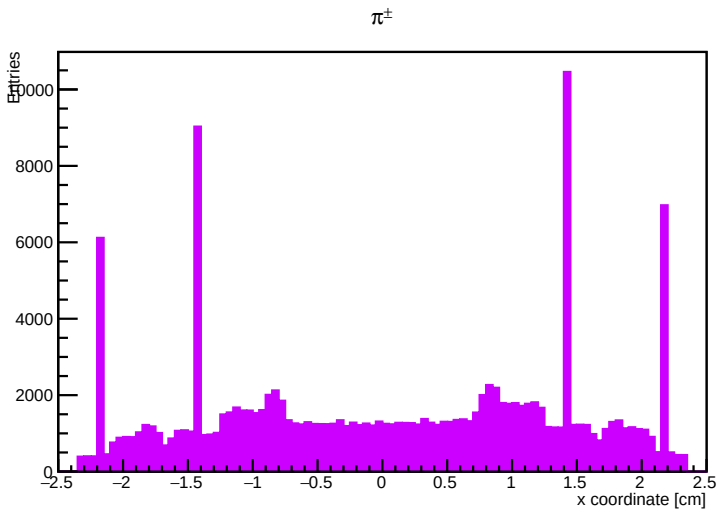
- Do the TMVA
- More realistic trackable/lost criteria
- Do the tracking

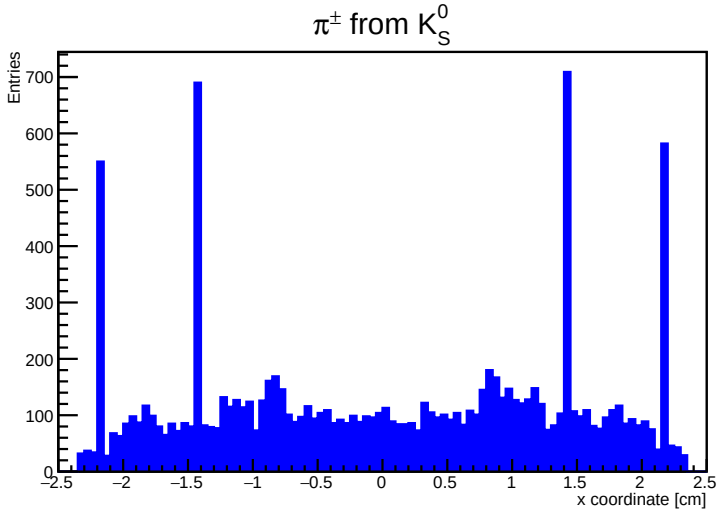
Thanks for your attention!

PXD hit properties

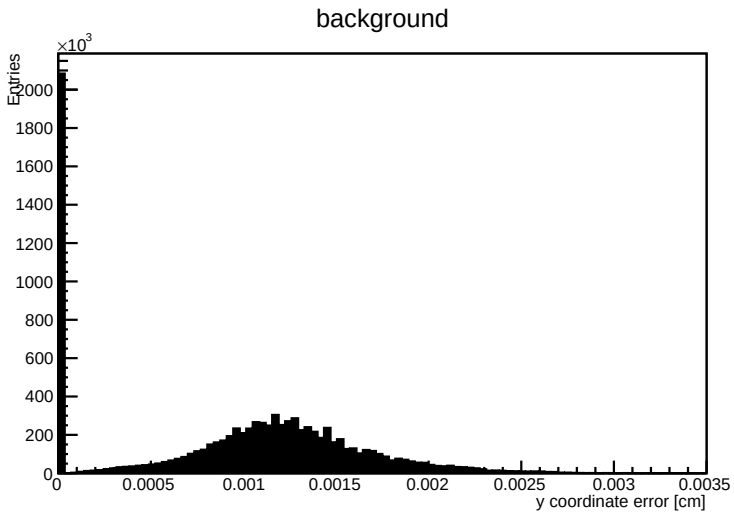


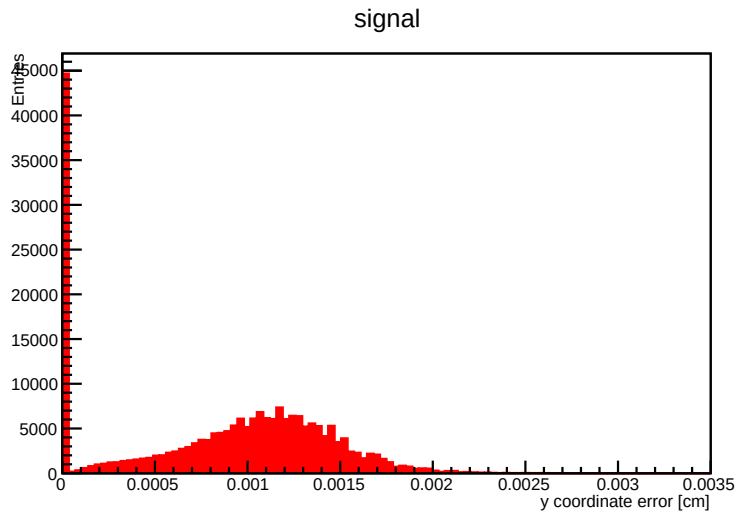


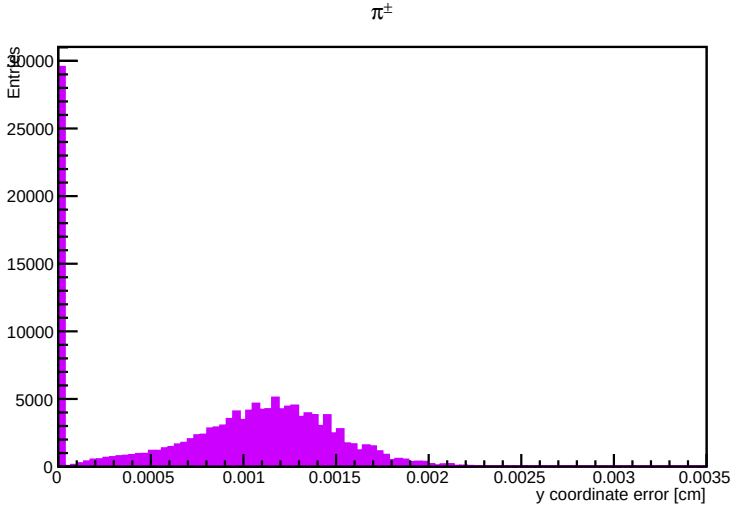


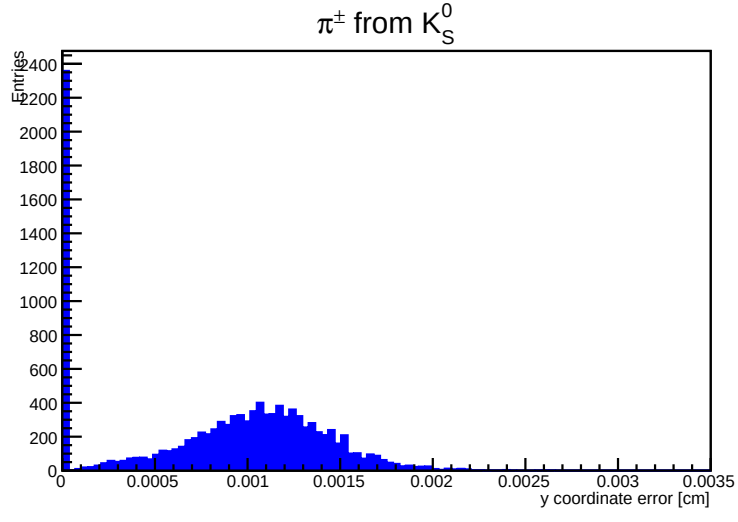


PXD hit properties









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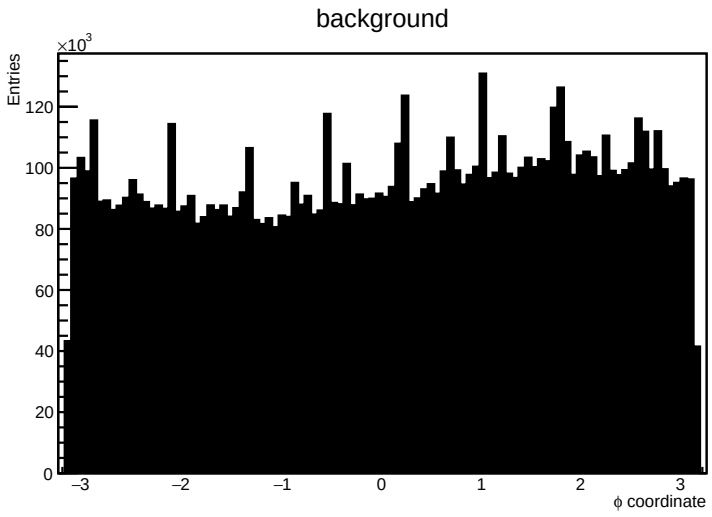

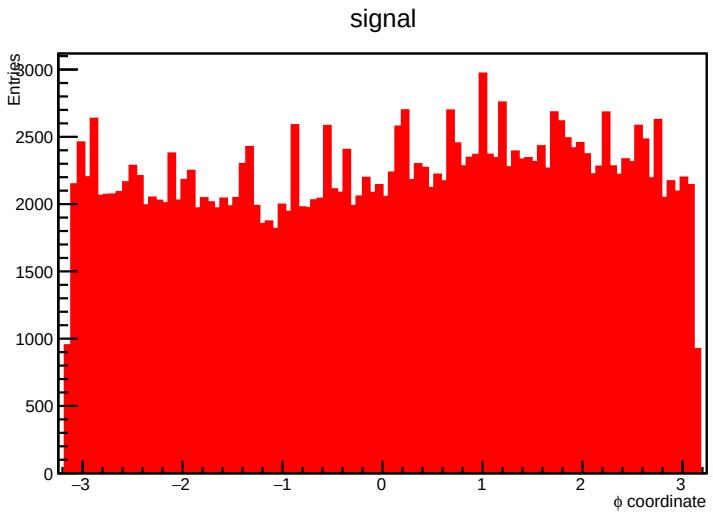

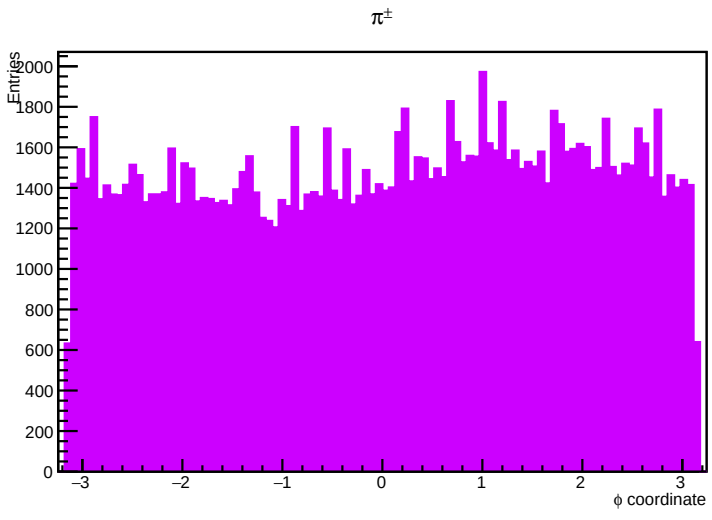

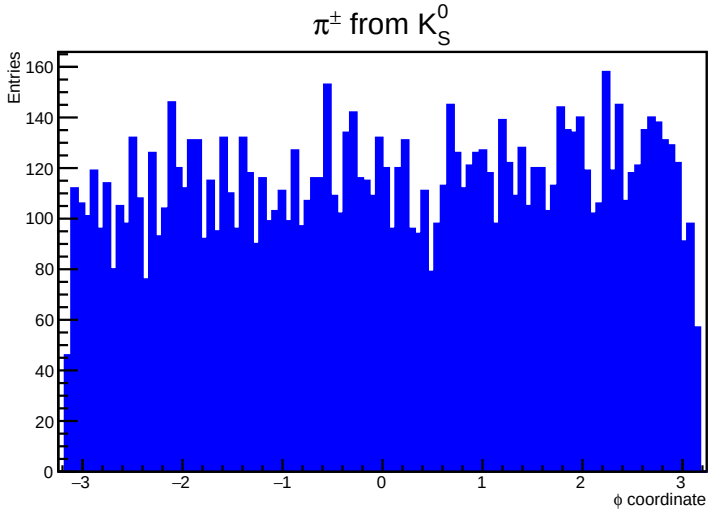

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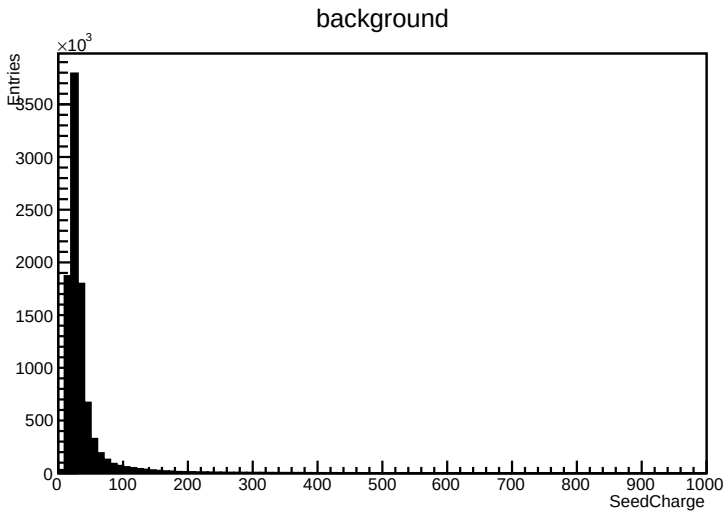

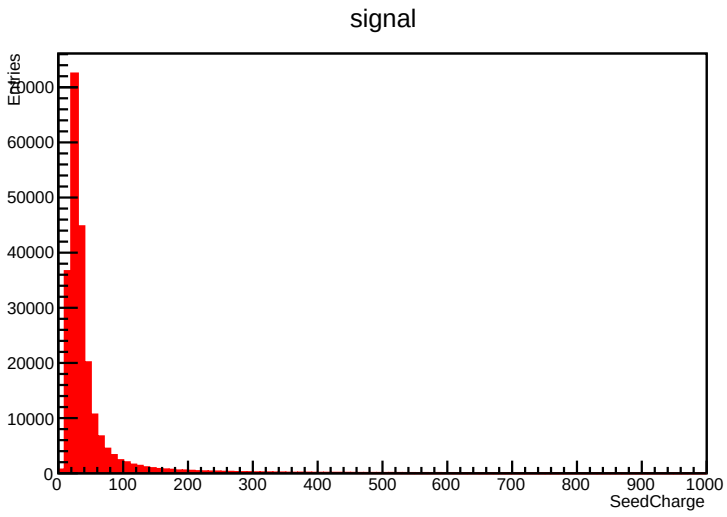

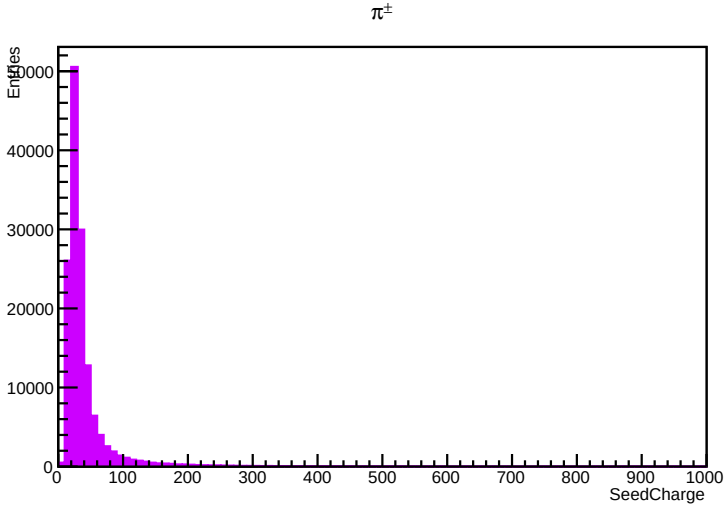

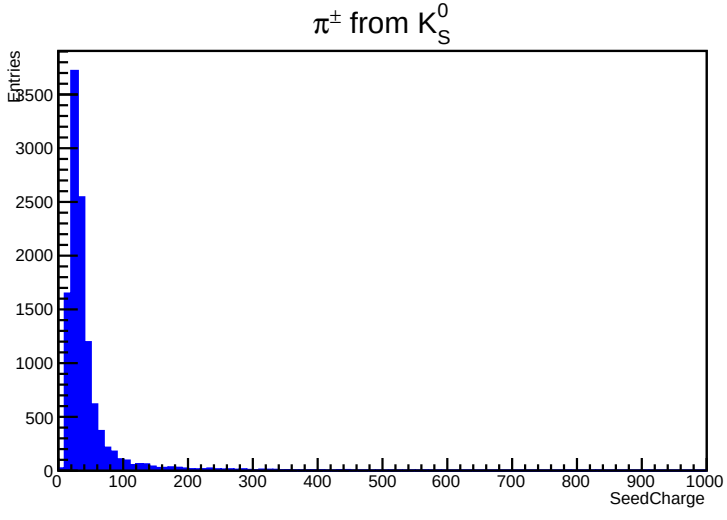

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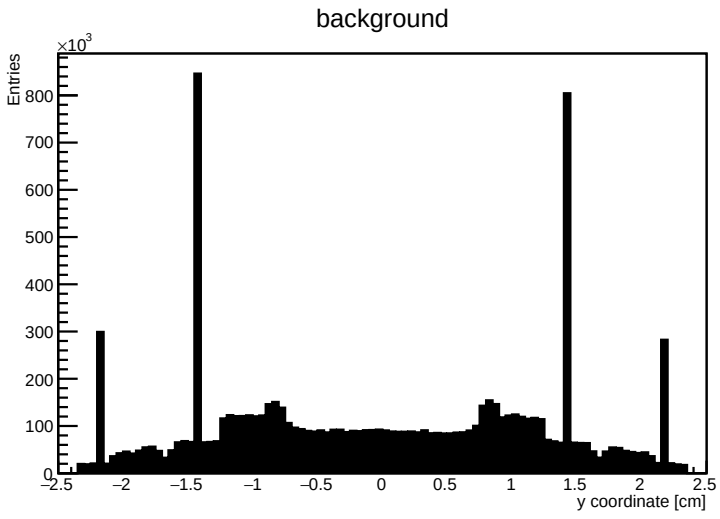

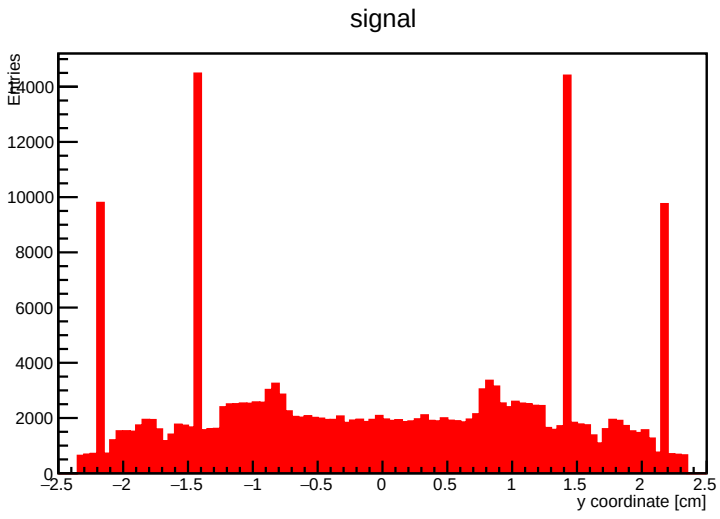

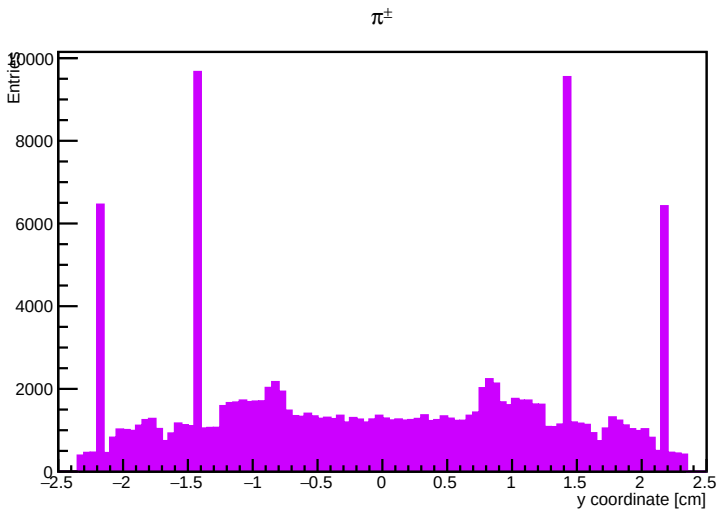

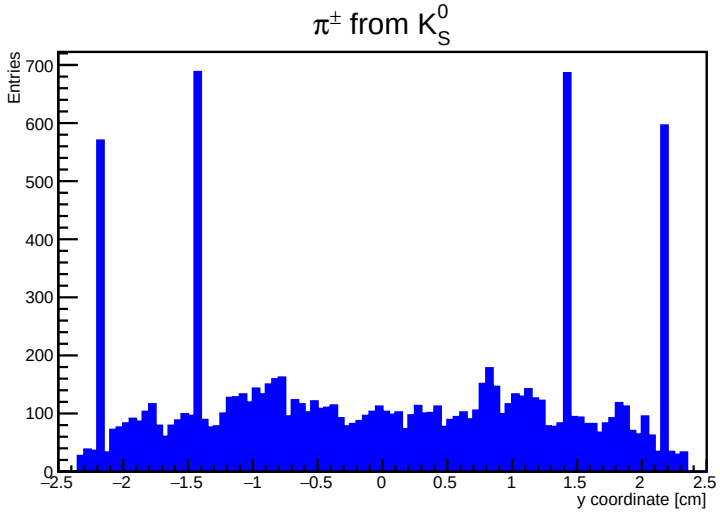

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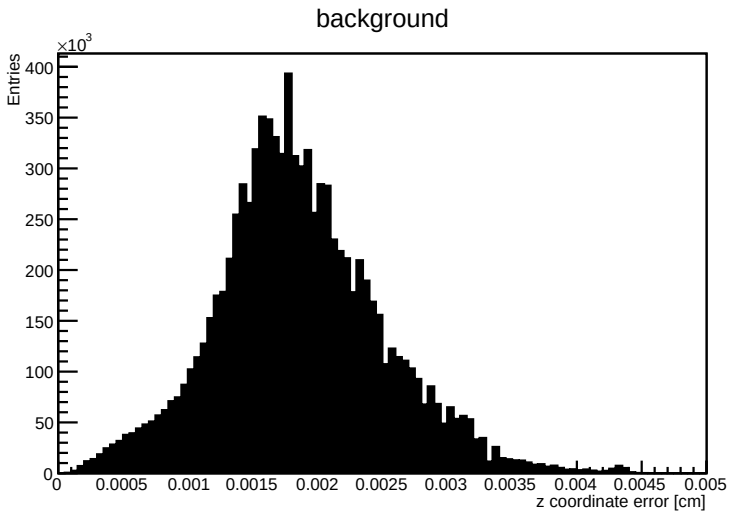

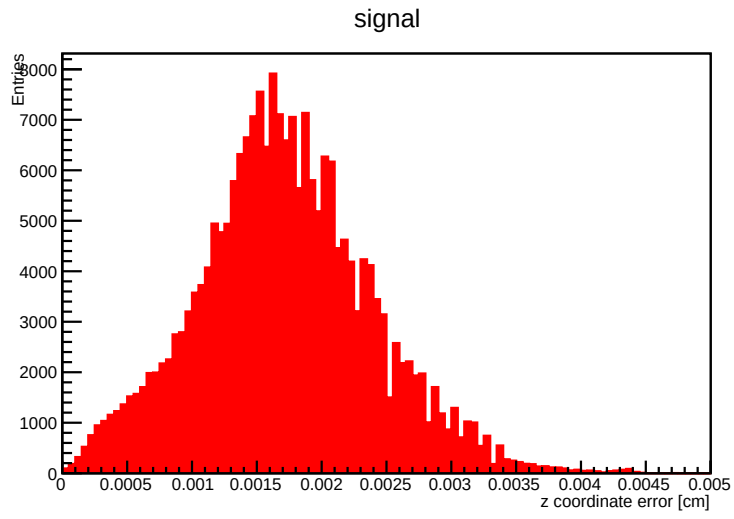

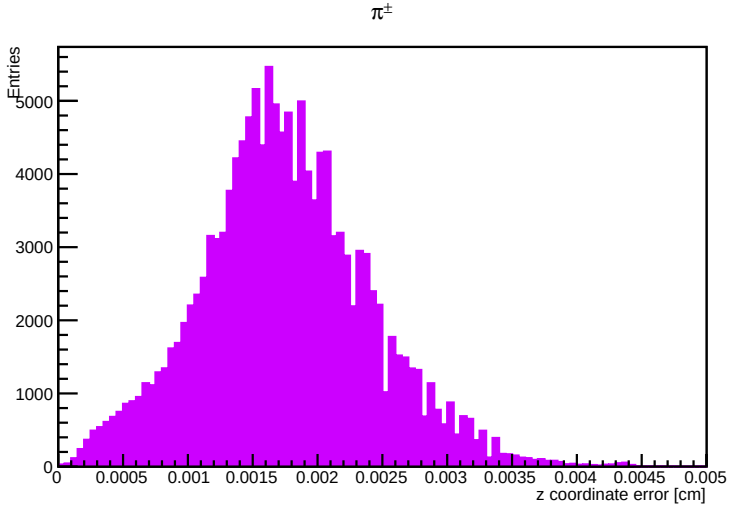

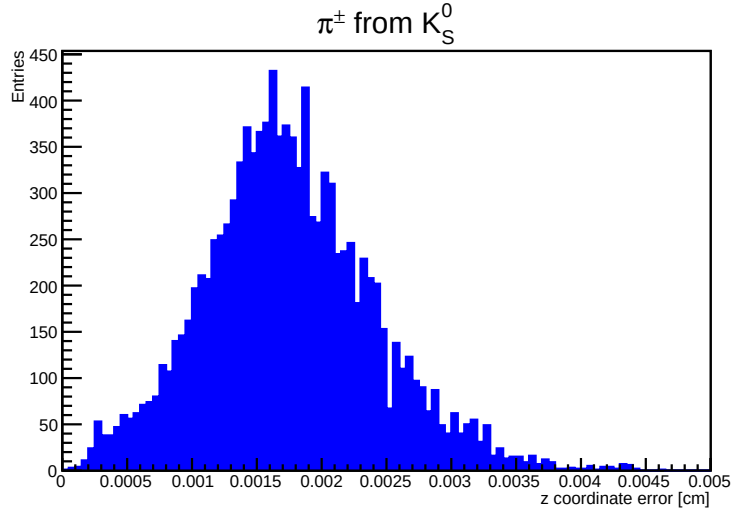

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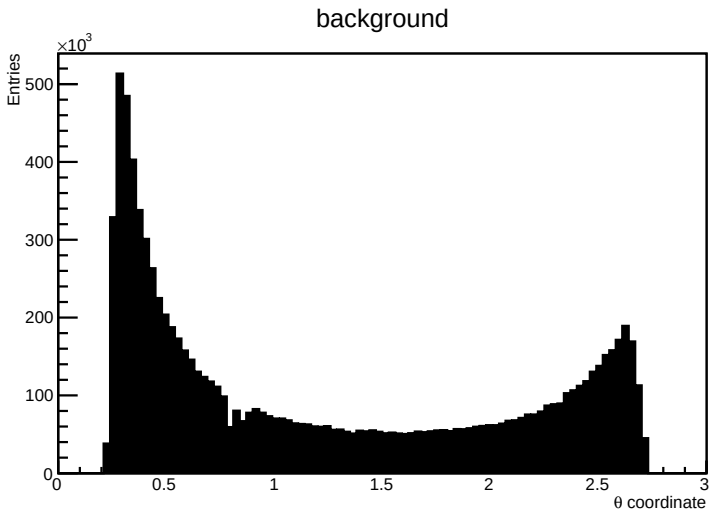

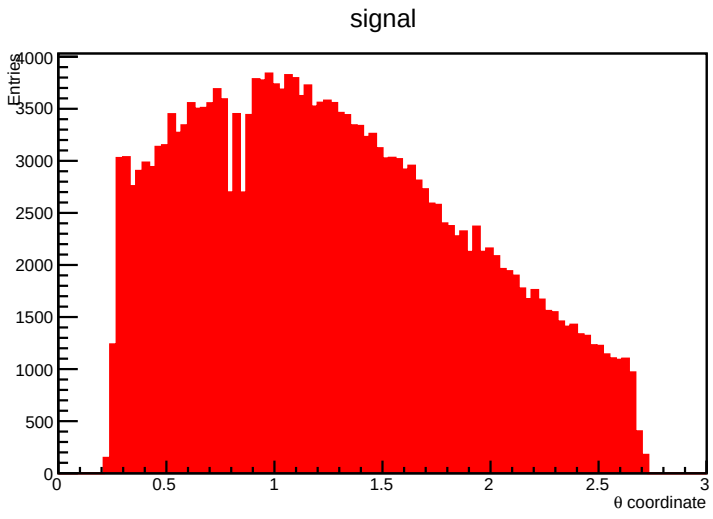

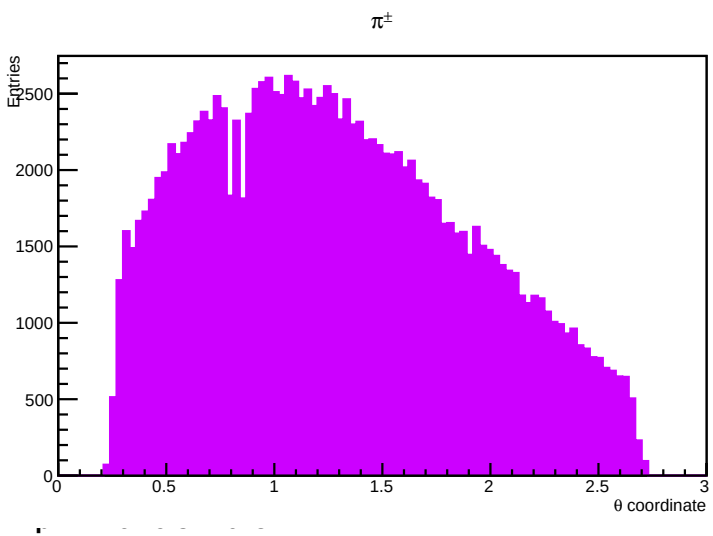

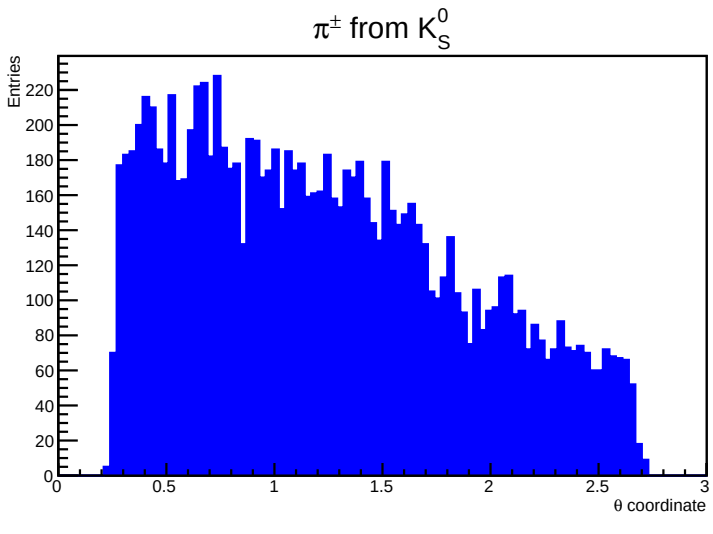

PXD hit properties

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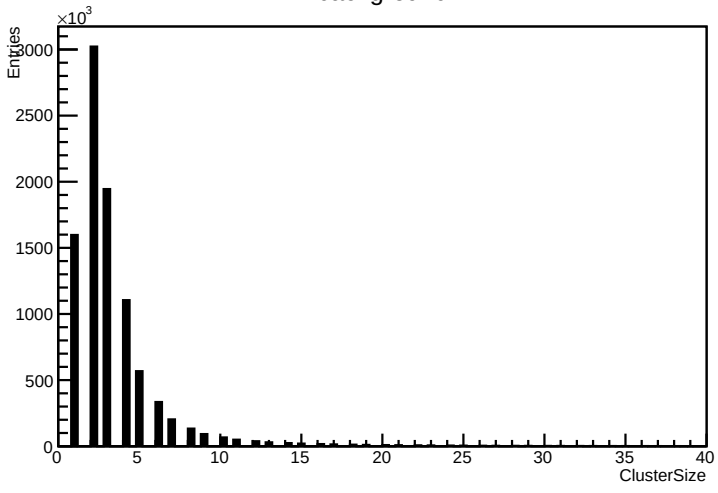
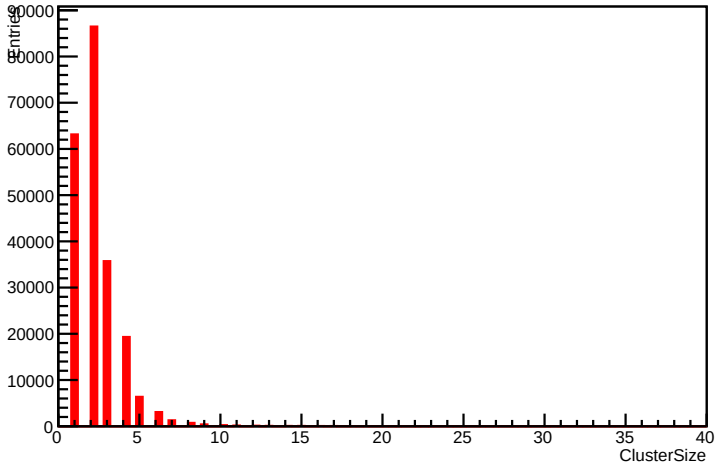
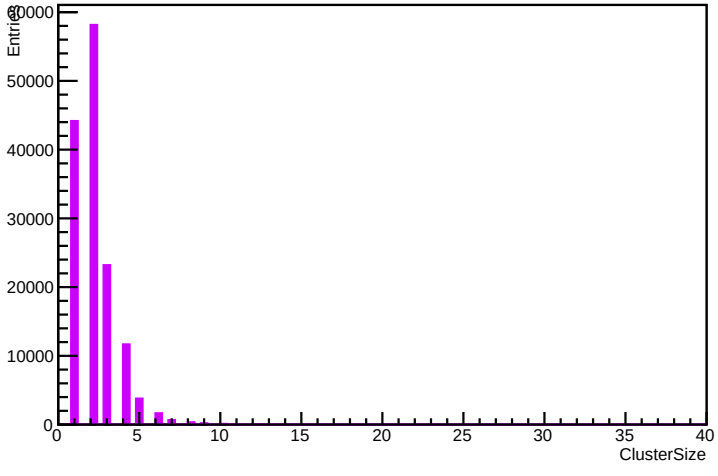


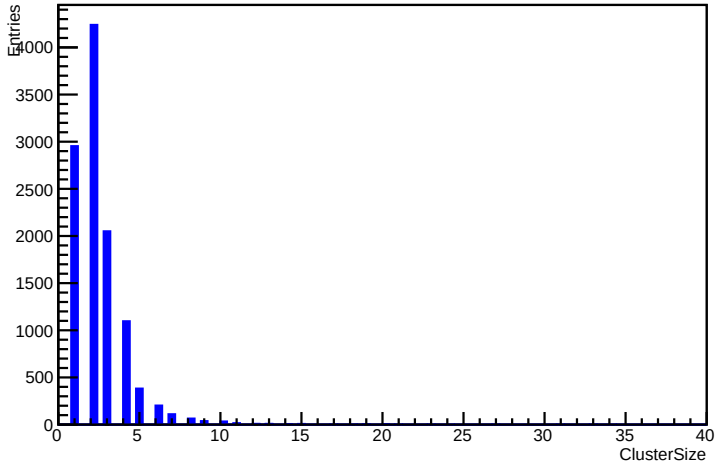
signal



$\pi^{\pm}$



$\pi^{\pm}$ from K^0_S



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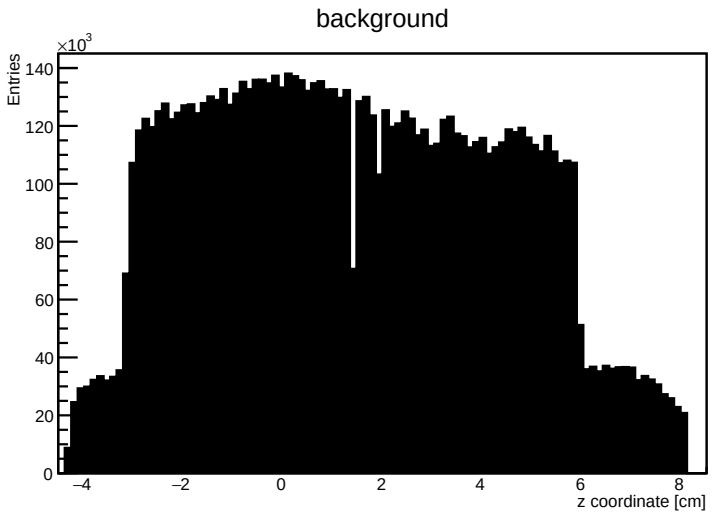
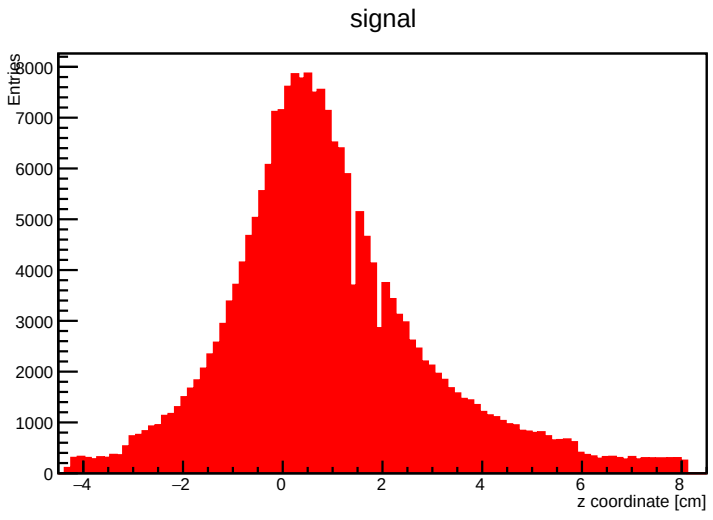
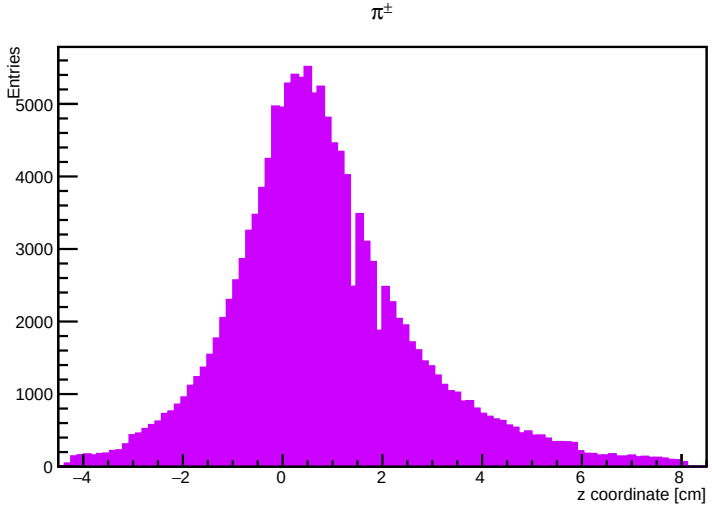
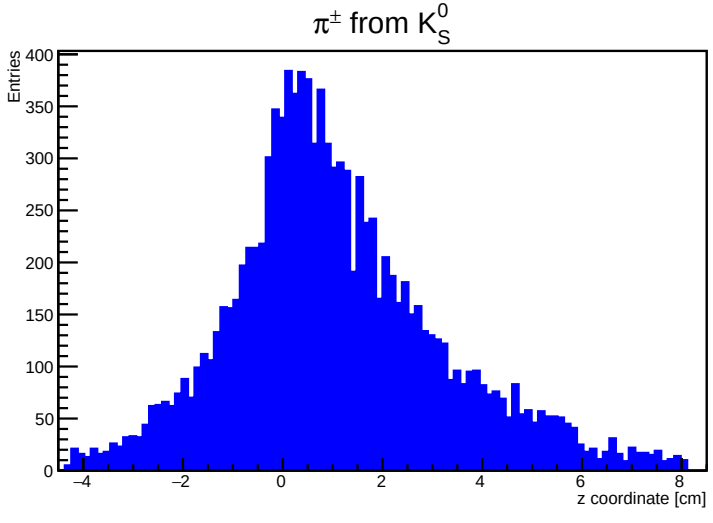
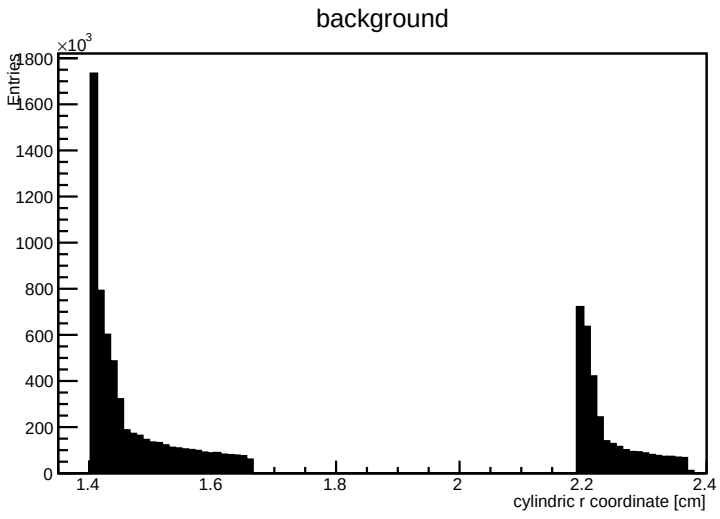


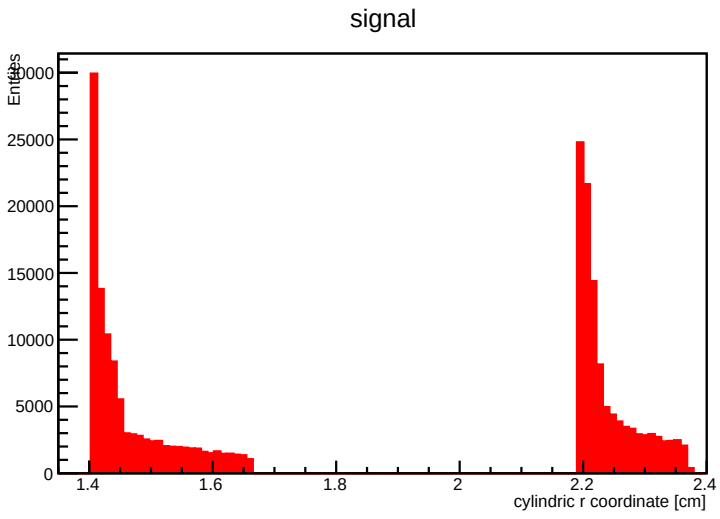


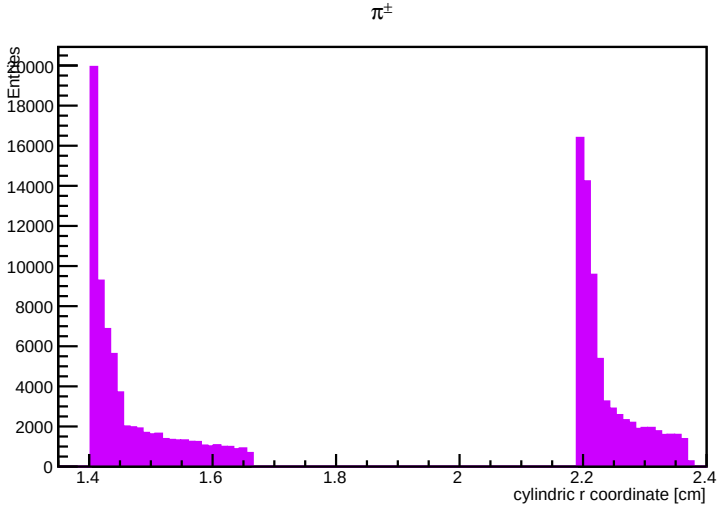


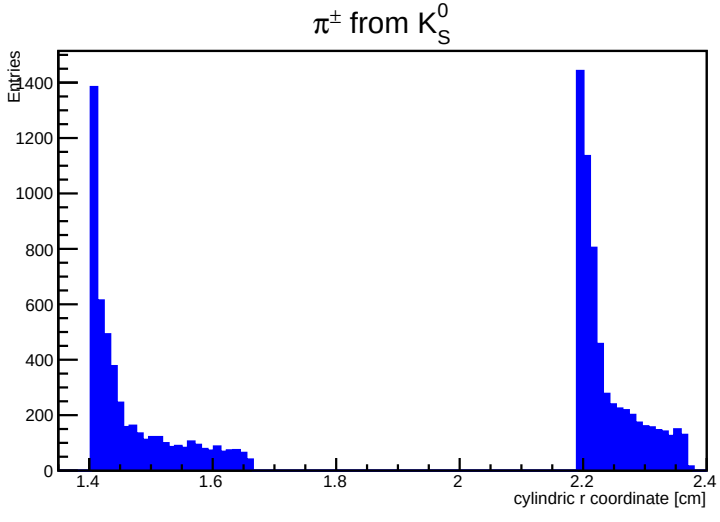


PXD hit properties









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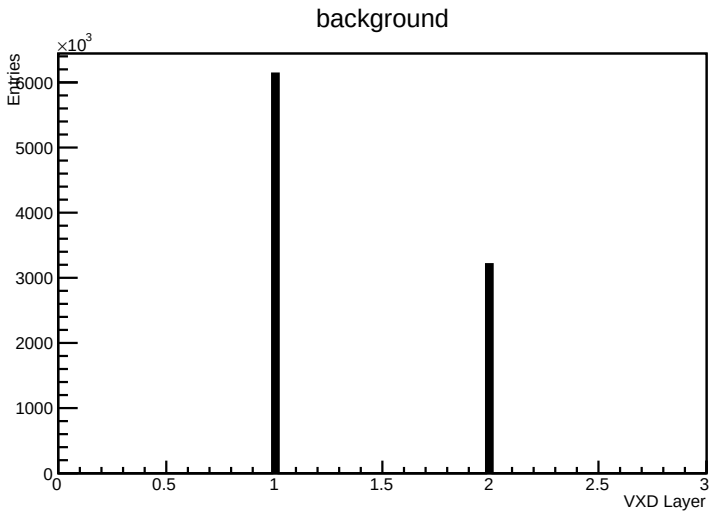
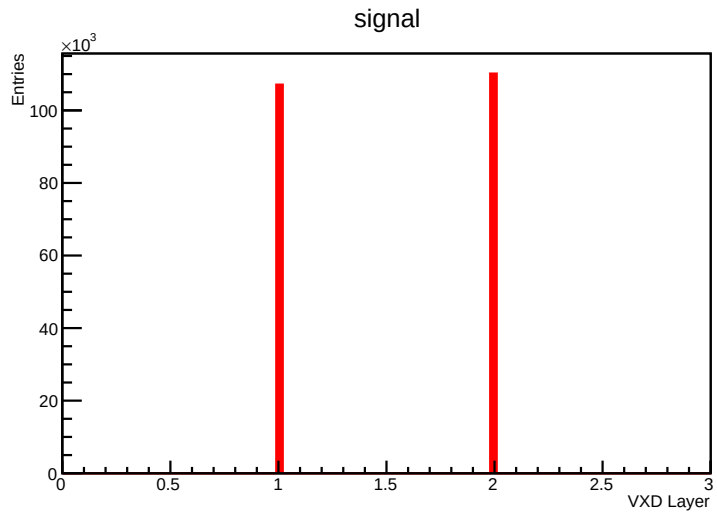
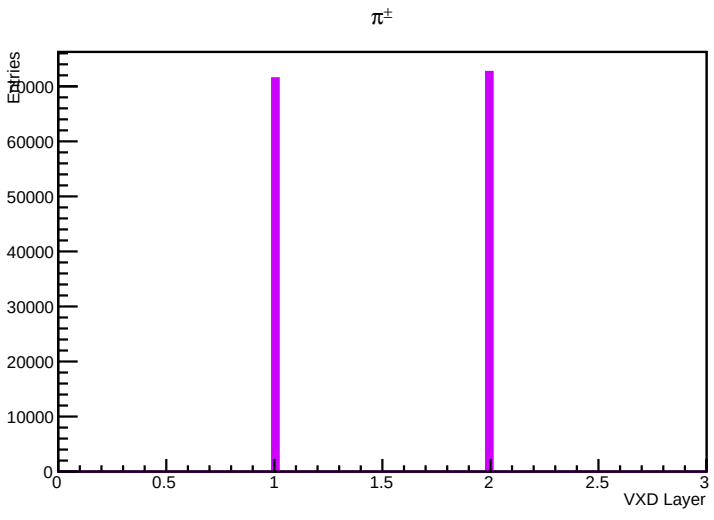
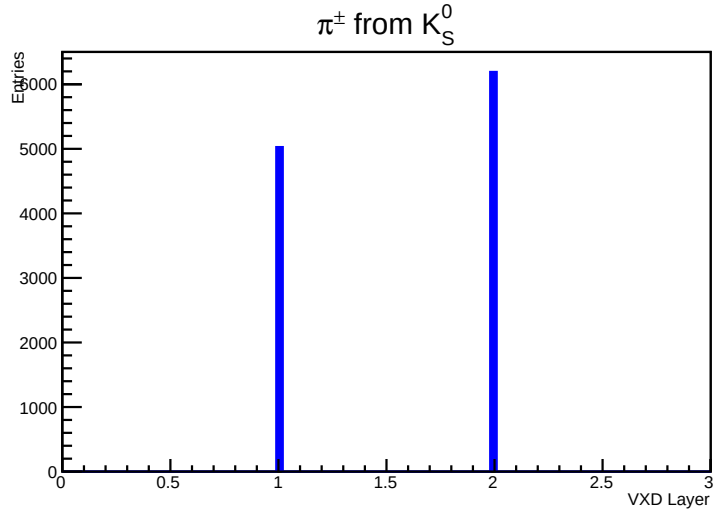
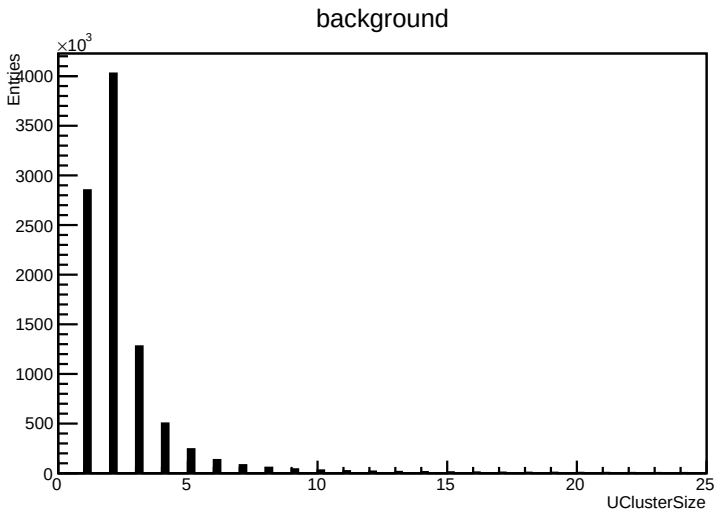


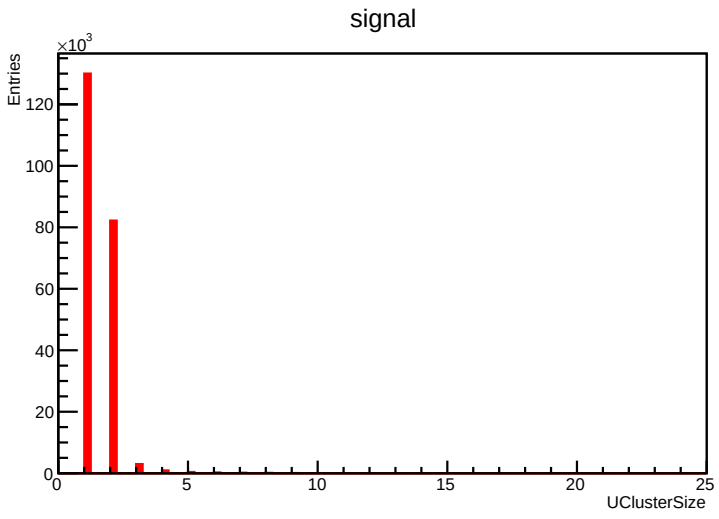


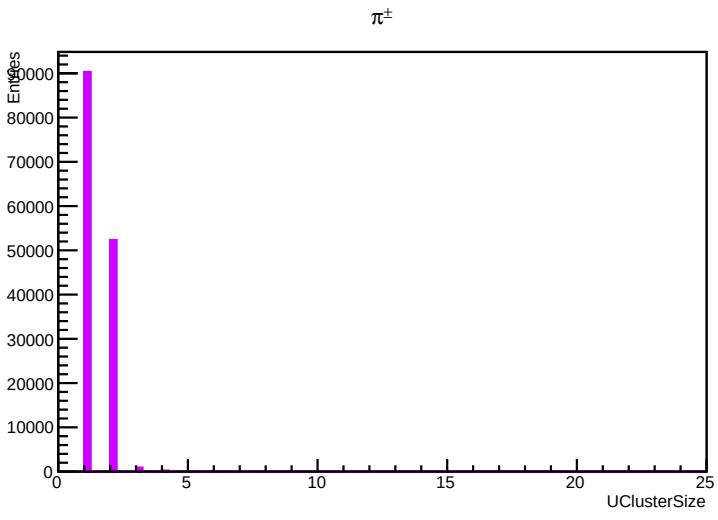


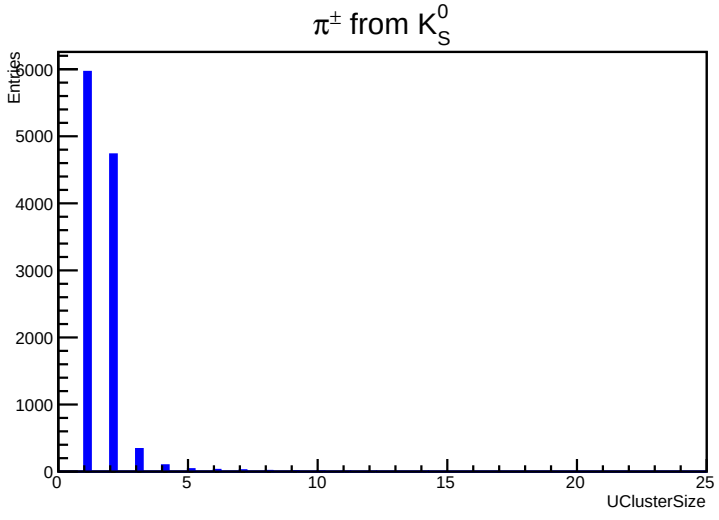


PXD hit properties









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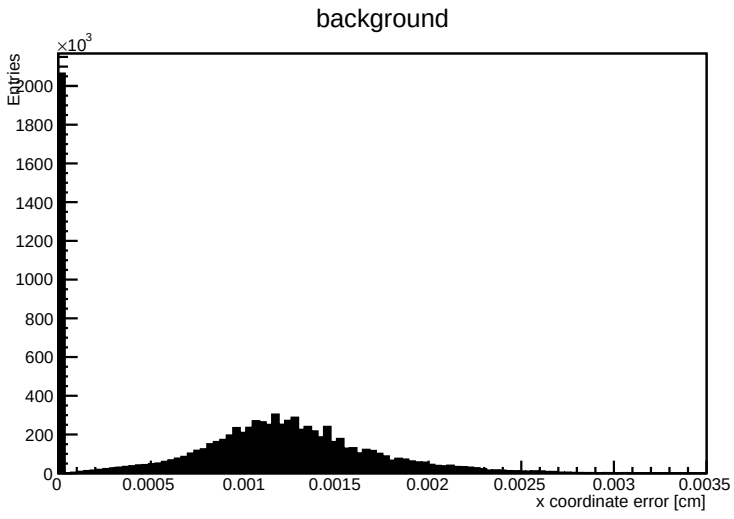

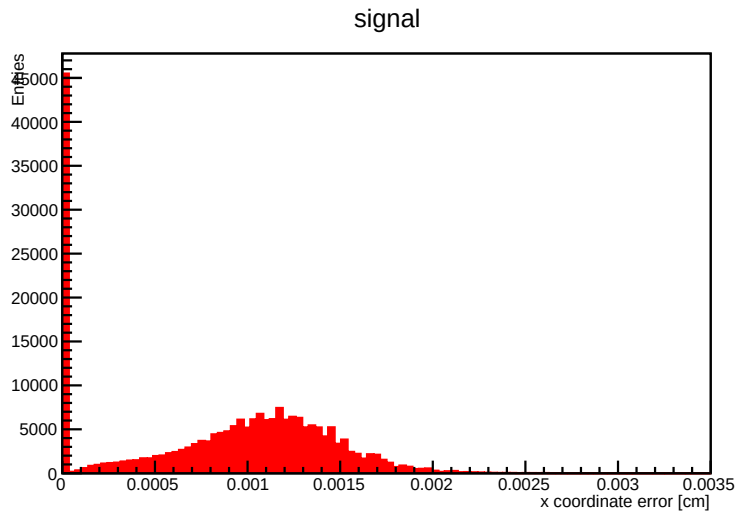

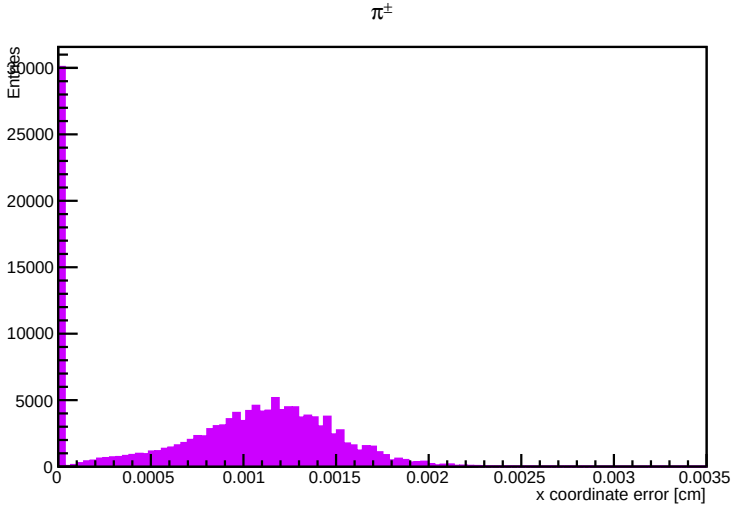

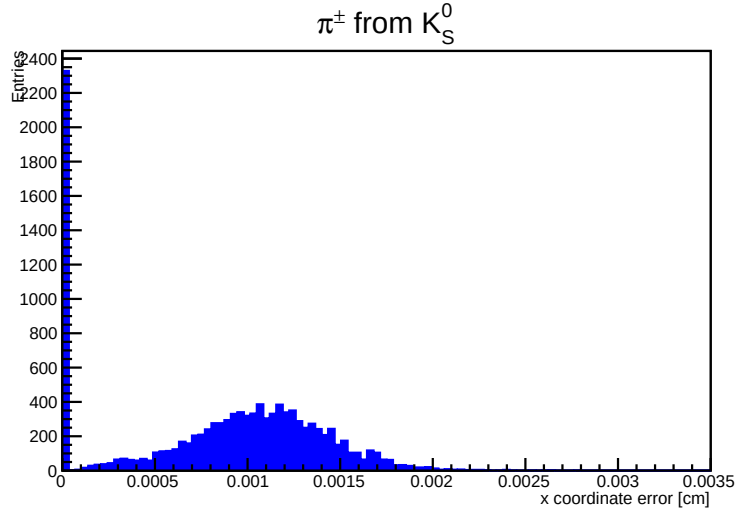

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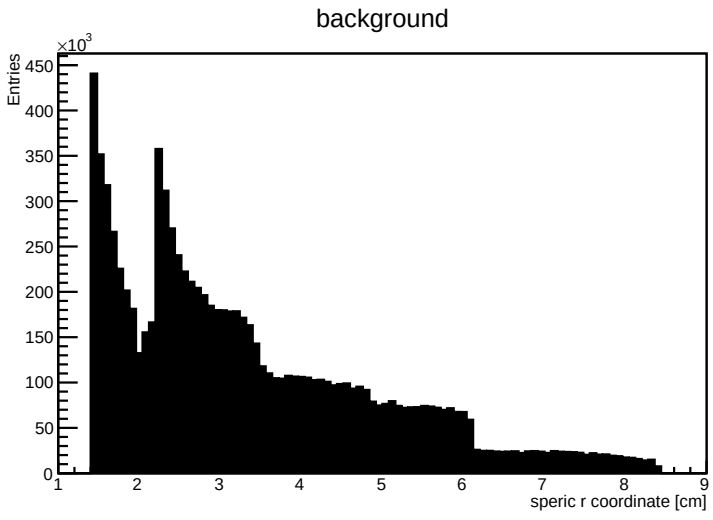

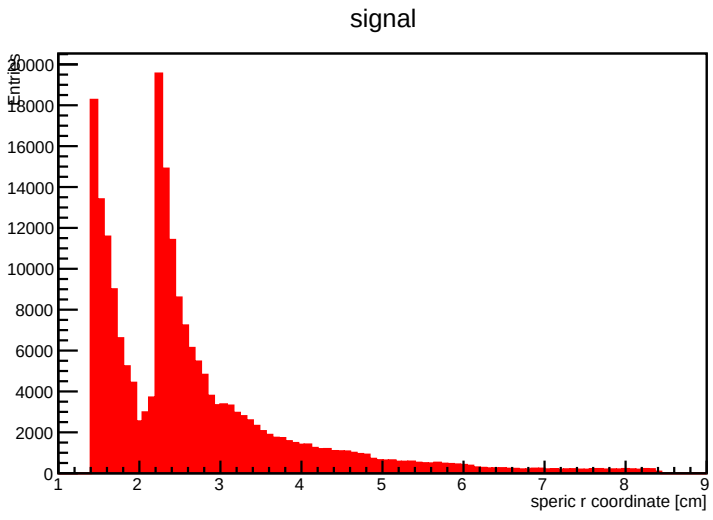

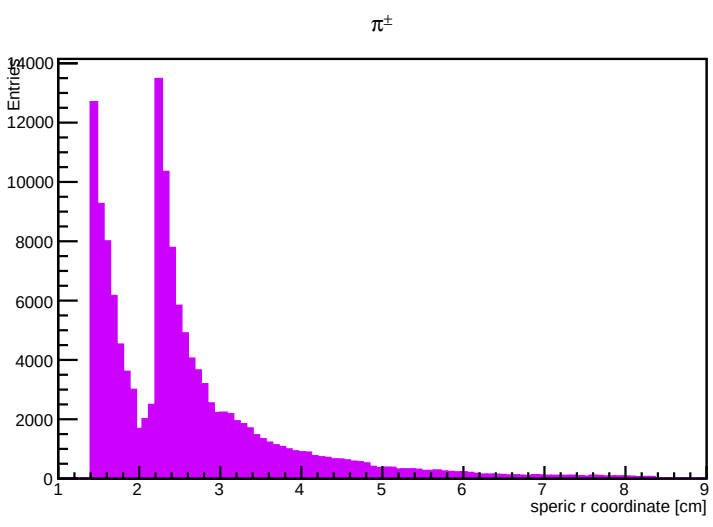

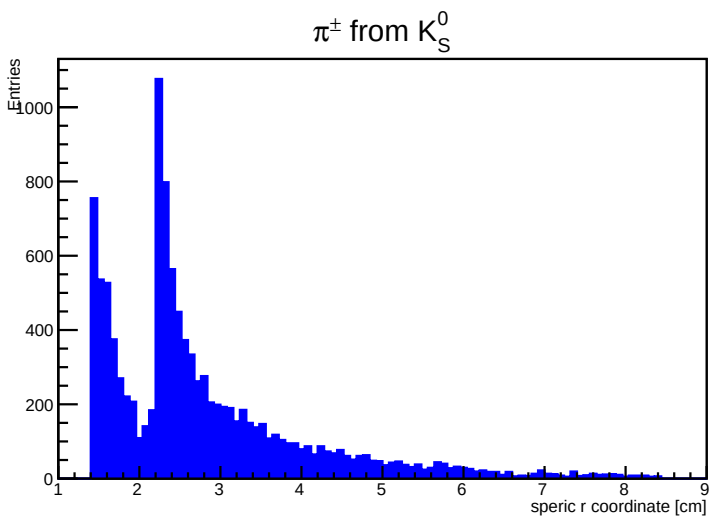

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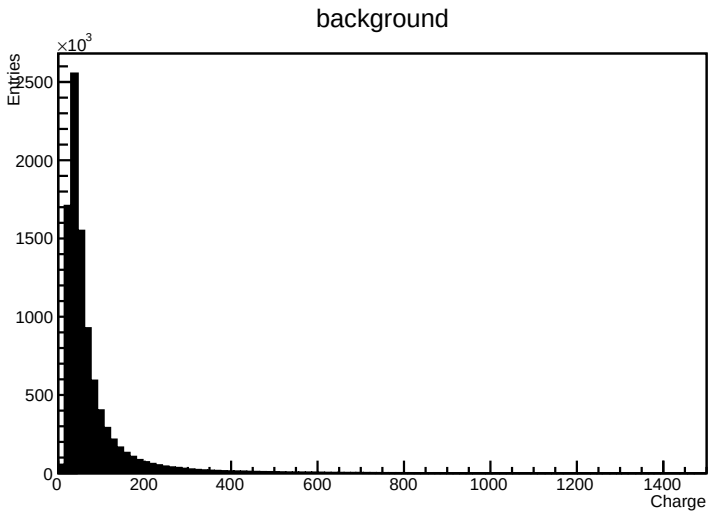

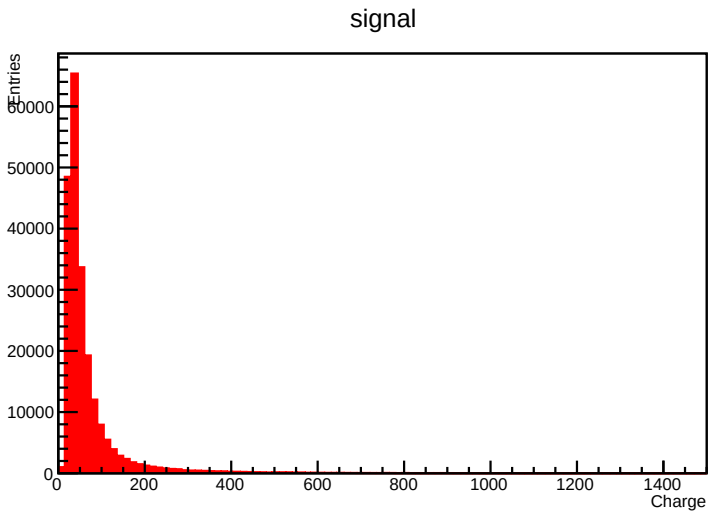

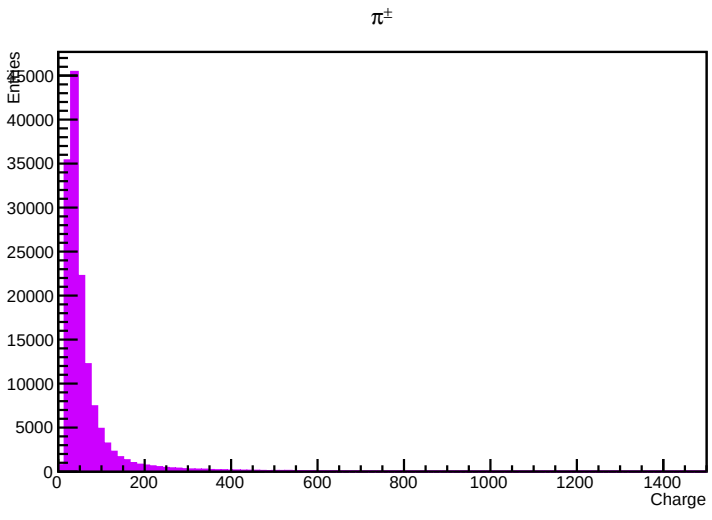

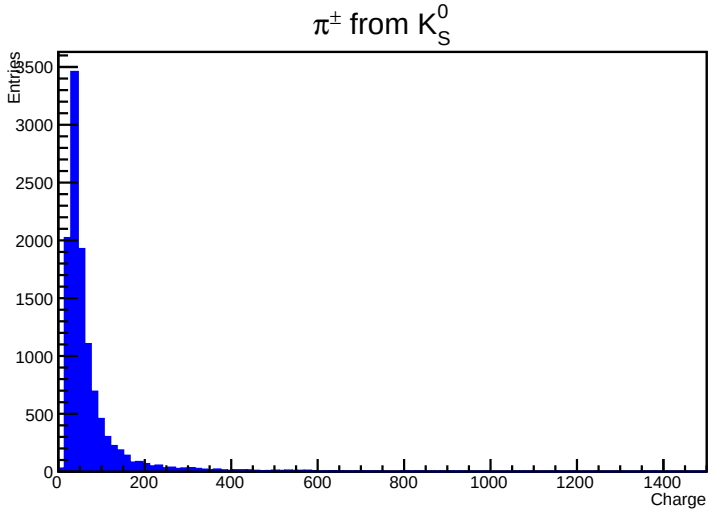

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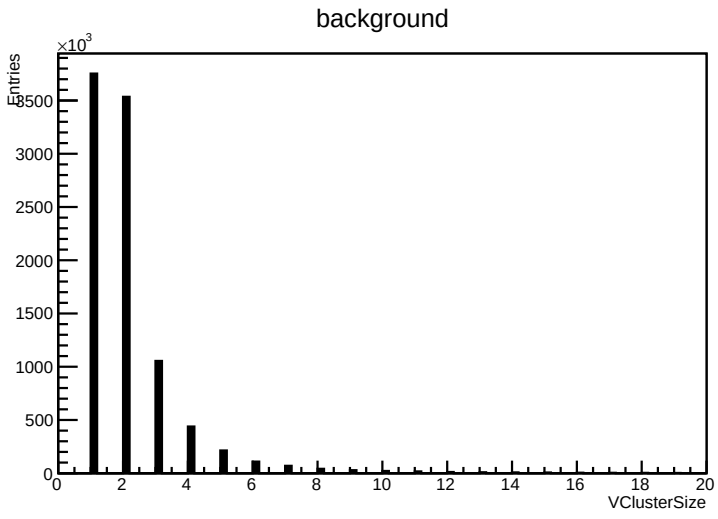

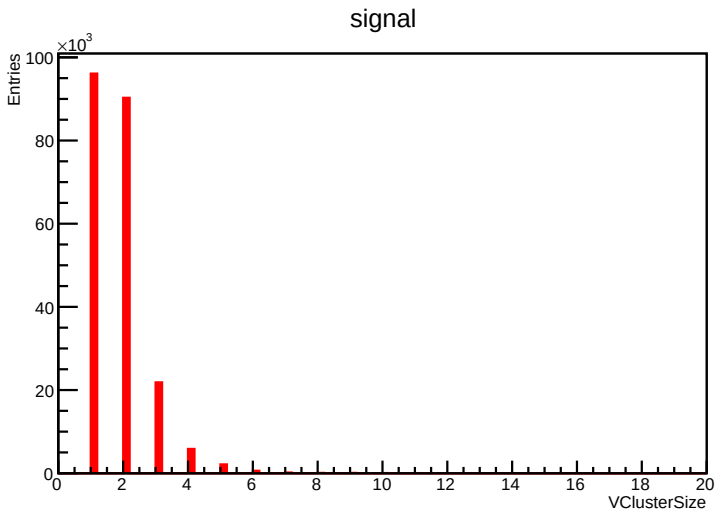

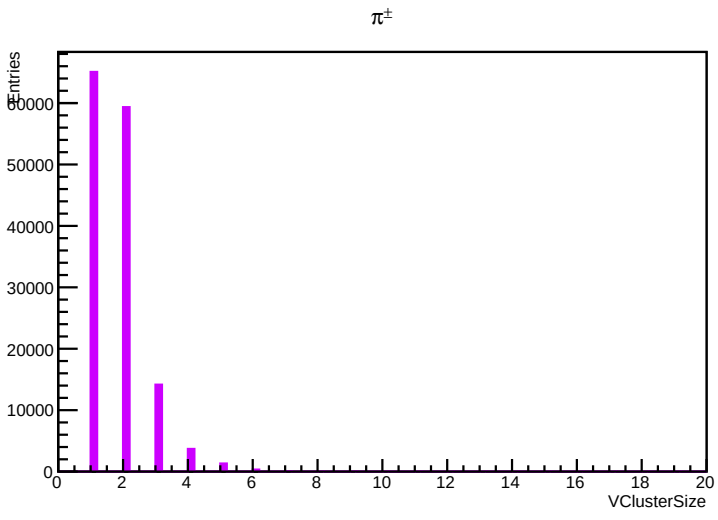

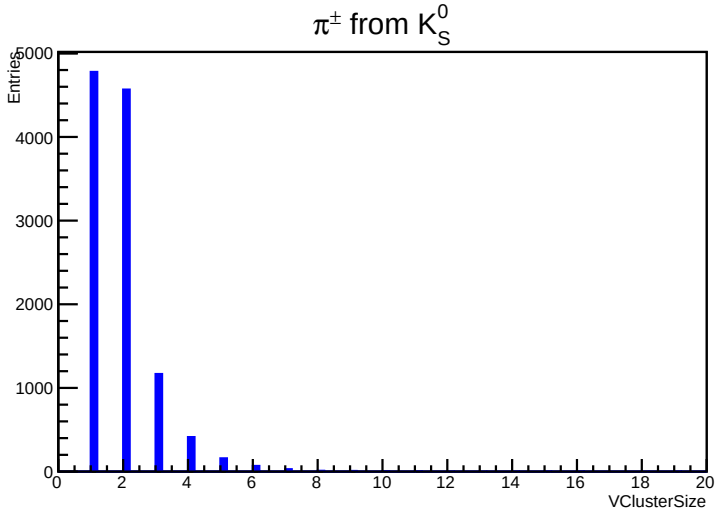

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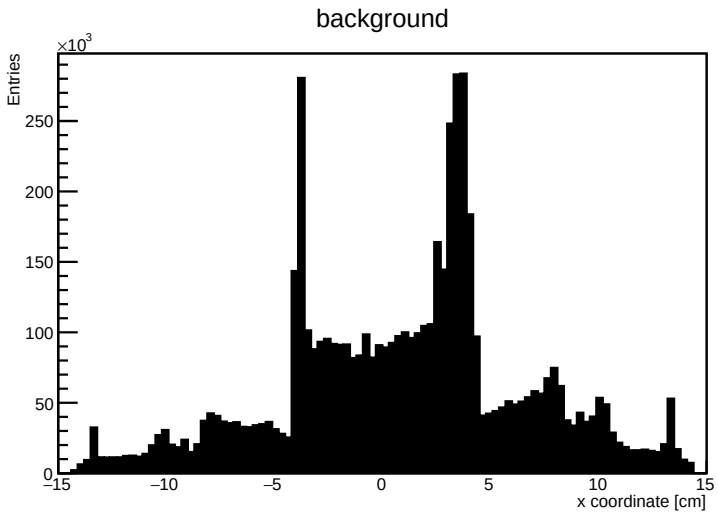

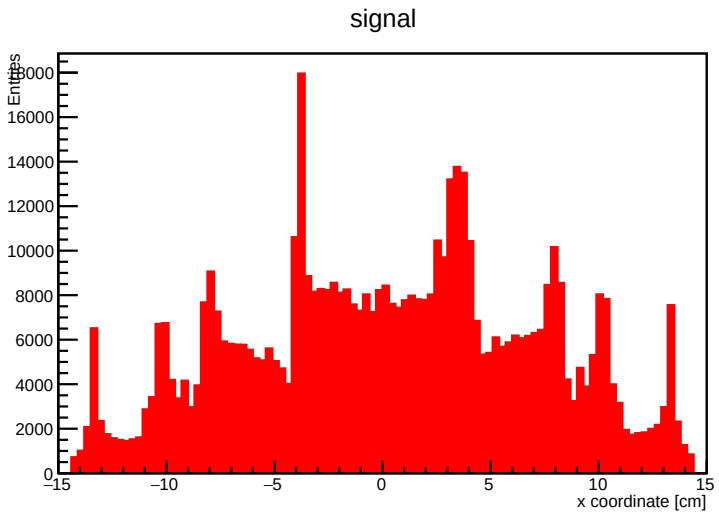

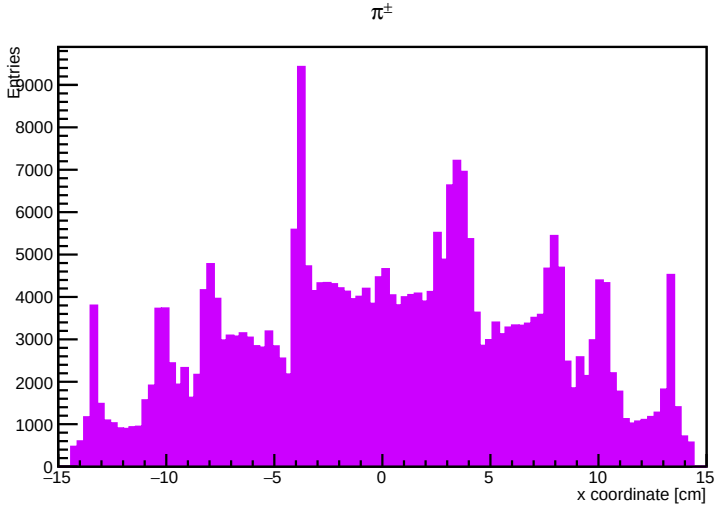

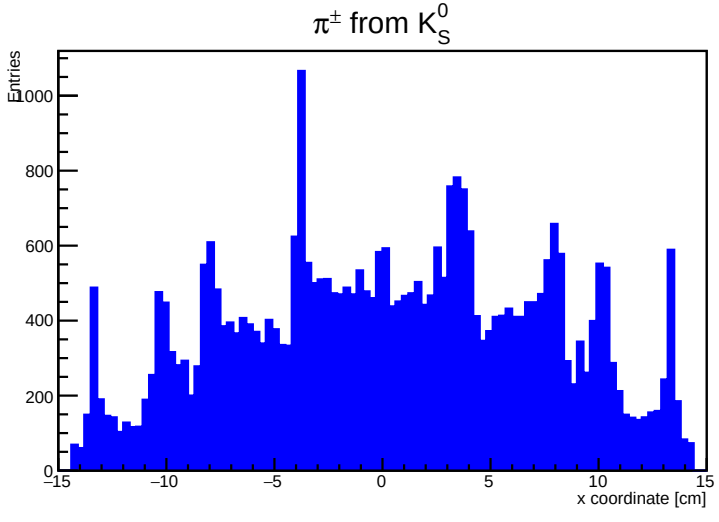

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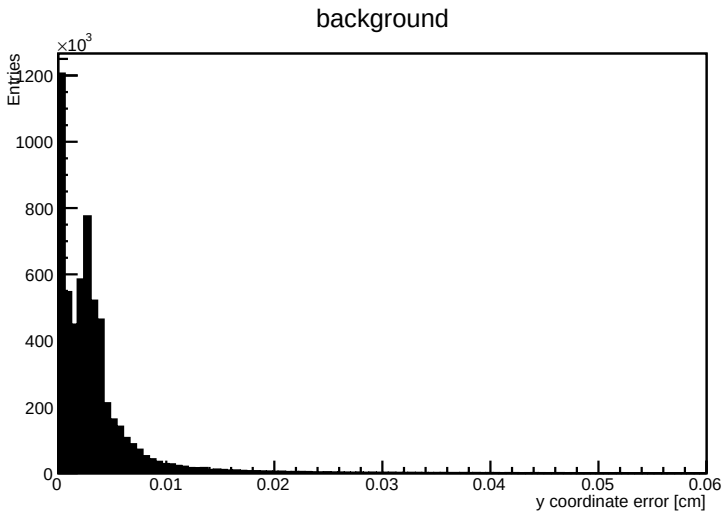

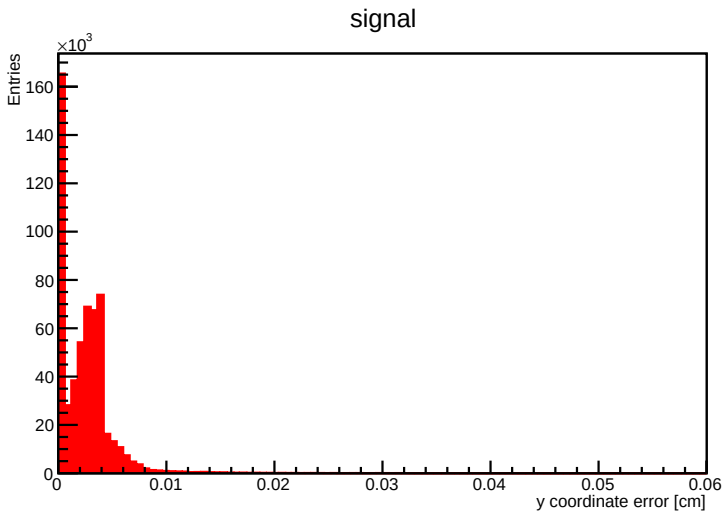

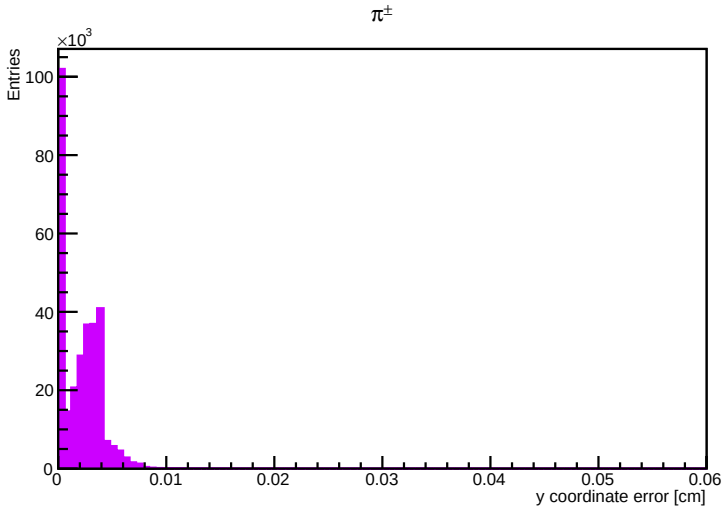

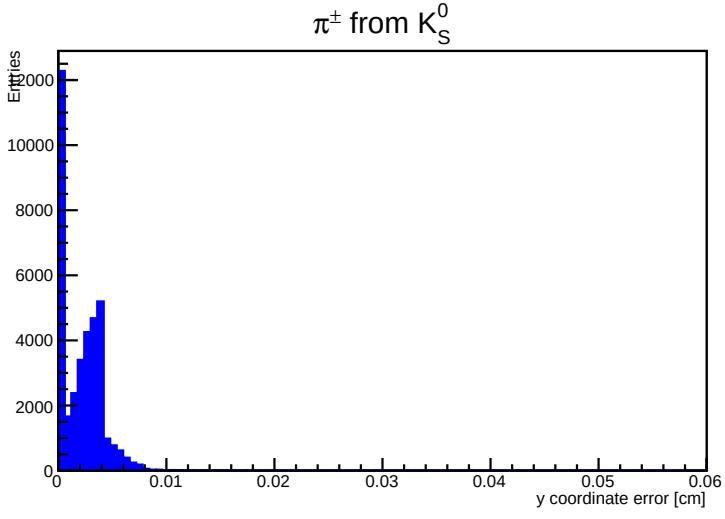

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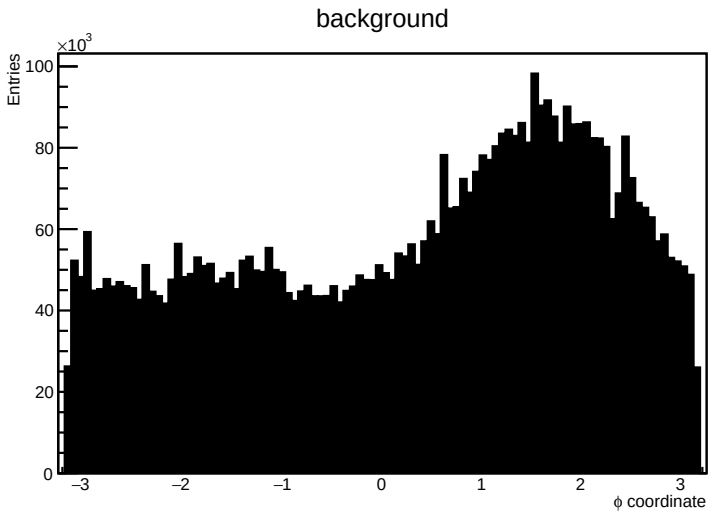

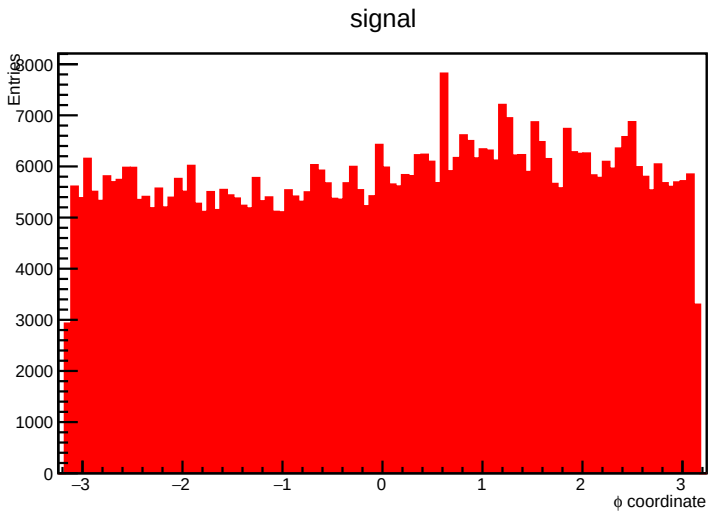

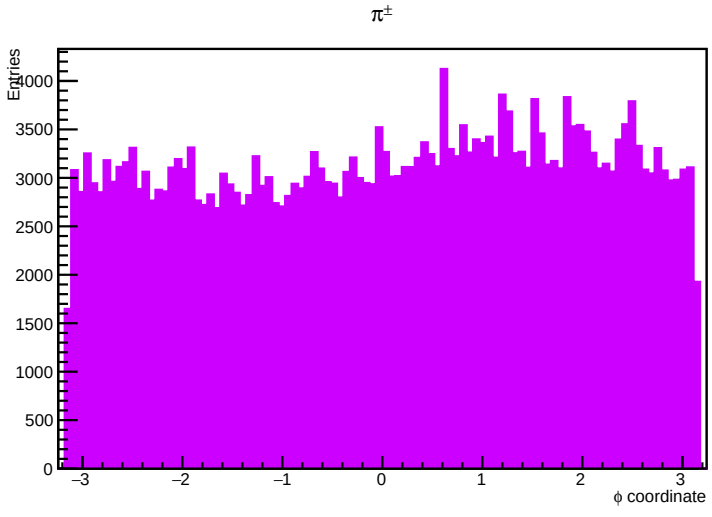

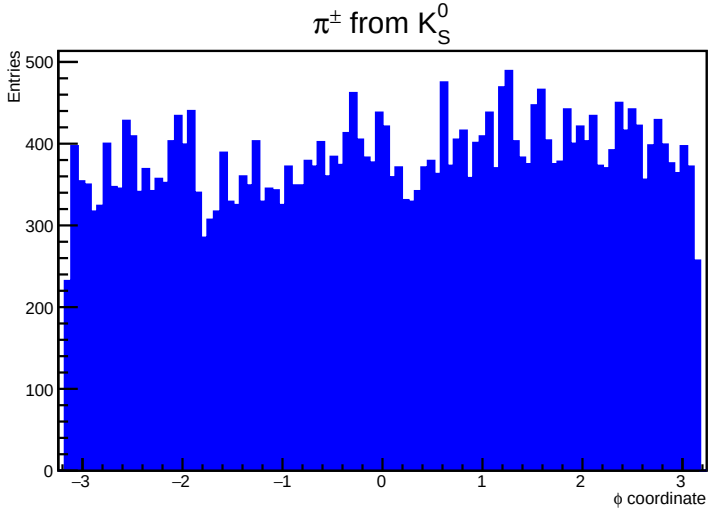

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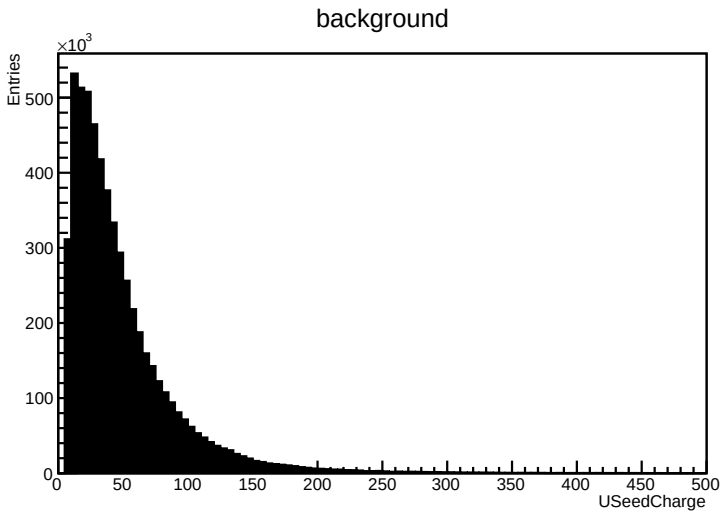

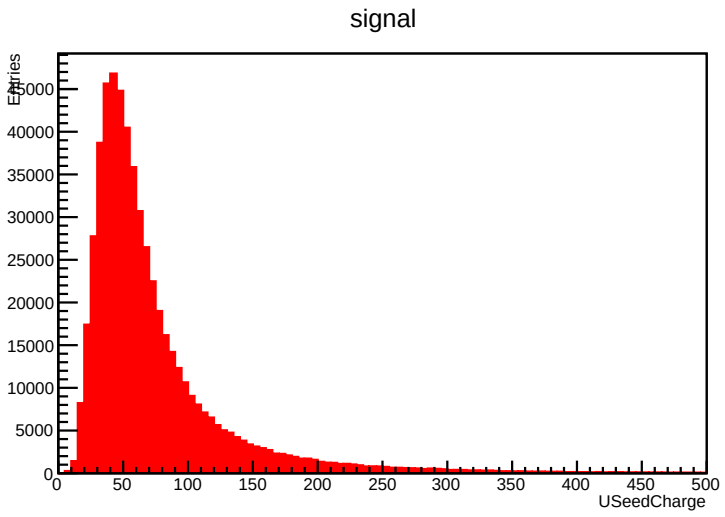

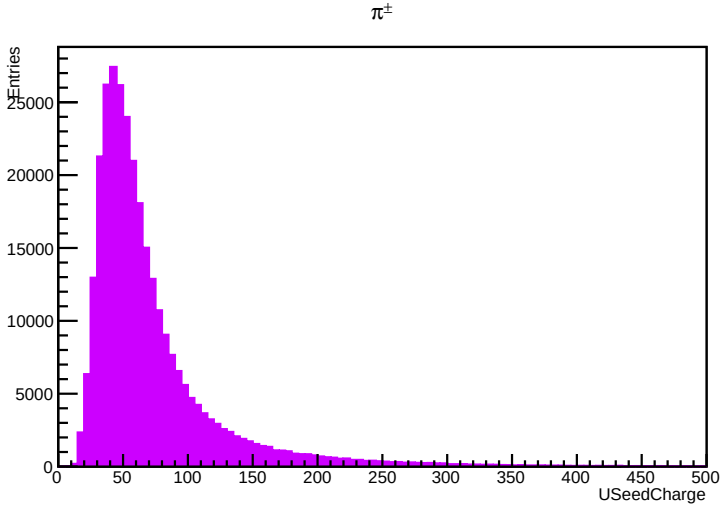

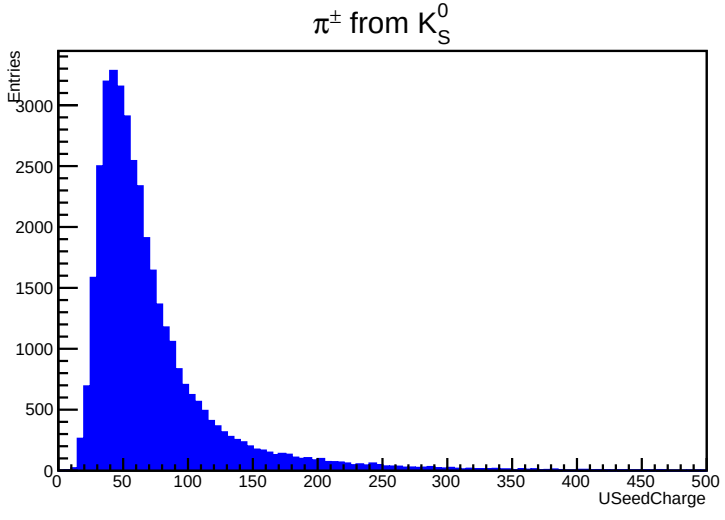

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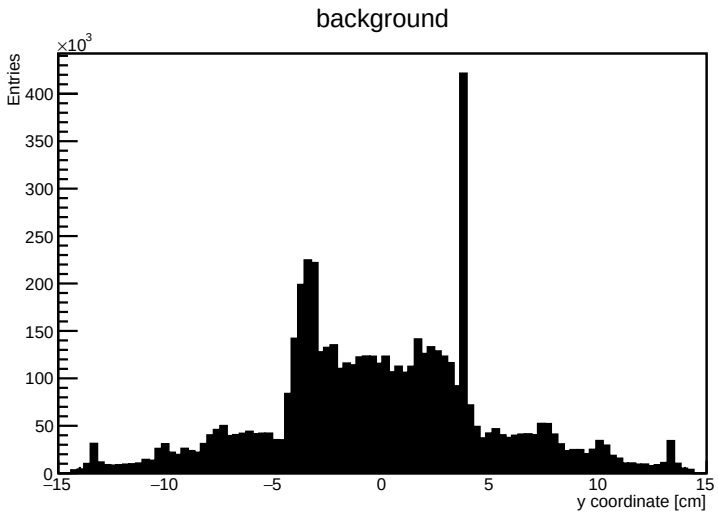

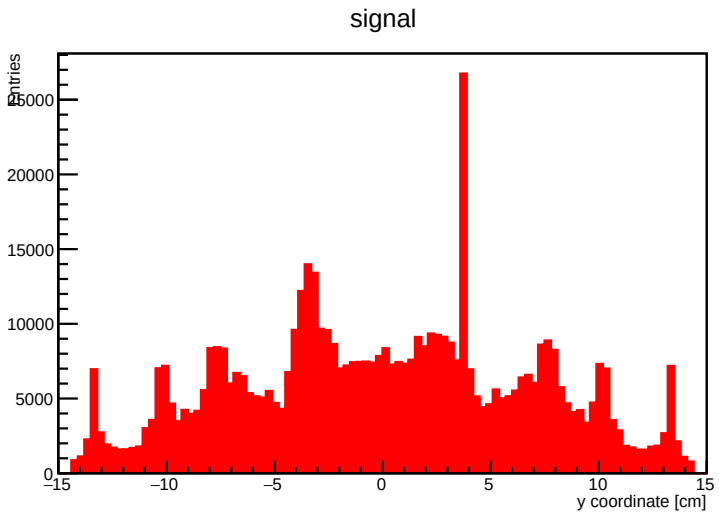

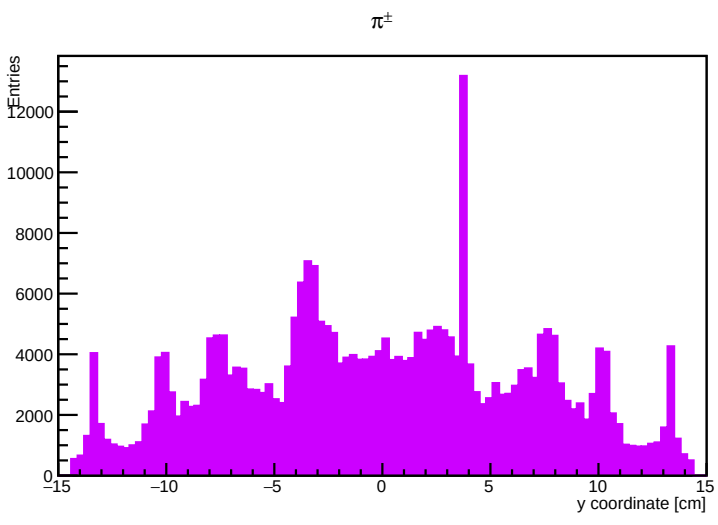

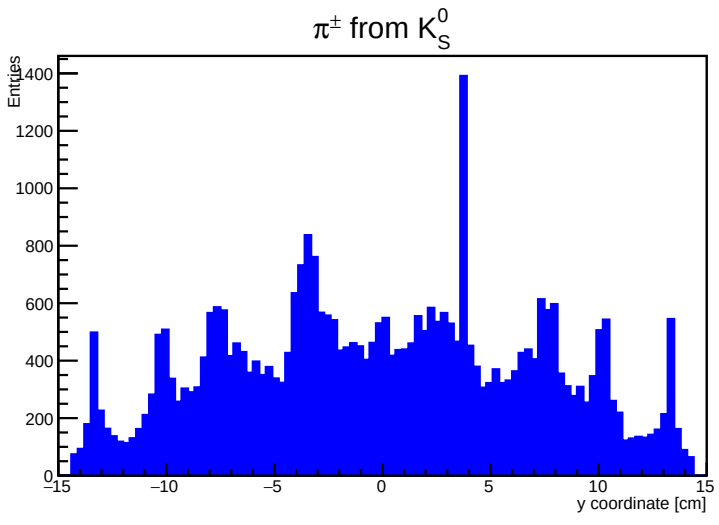

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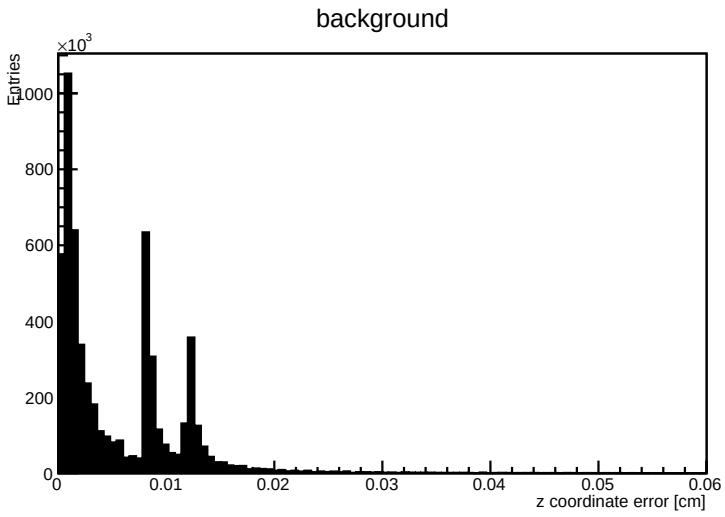

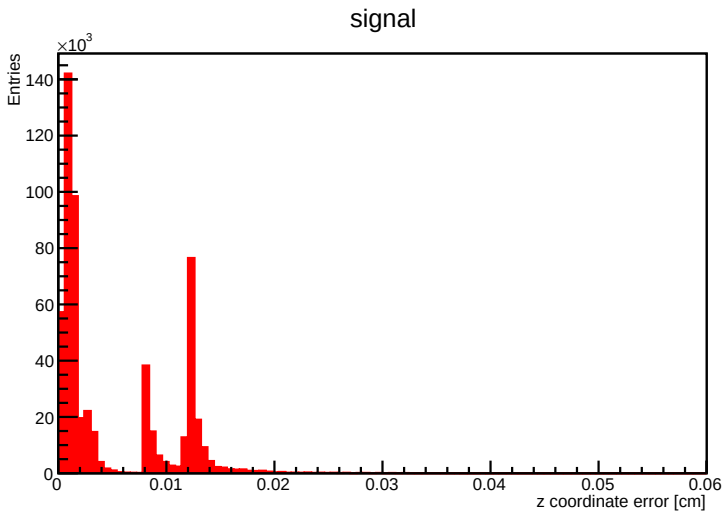

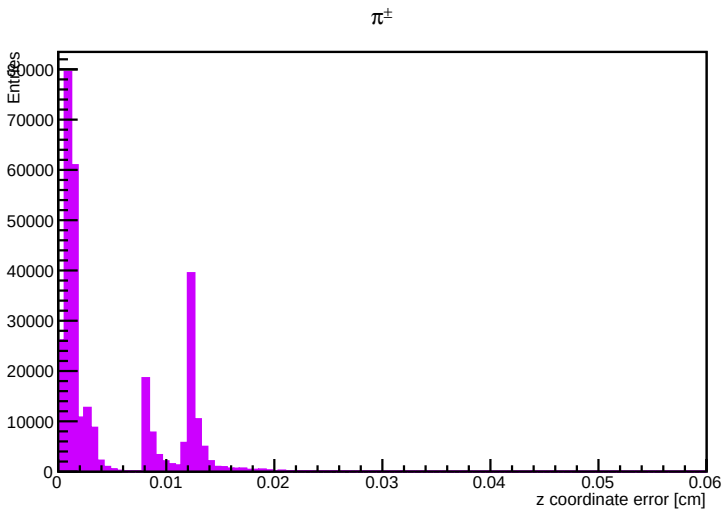

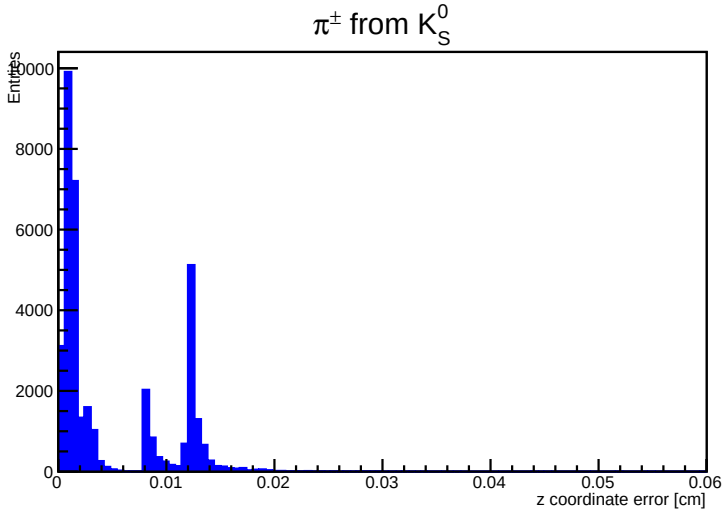

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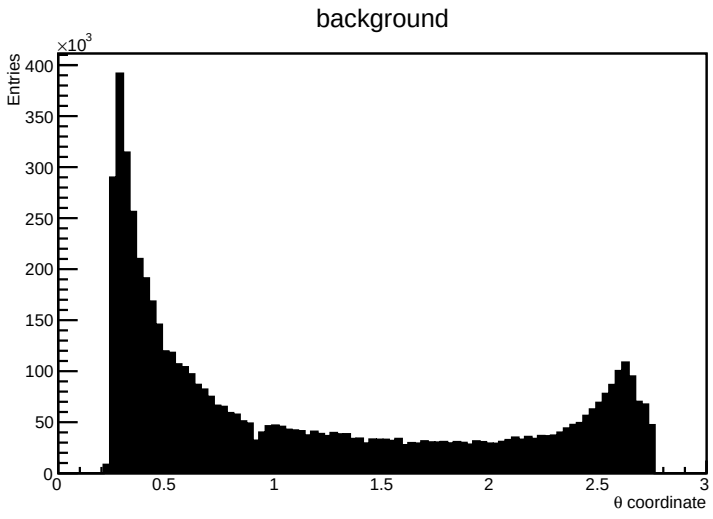

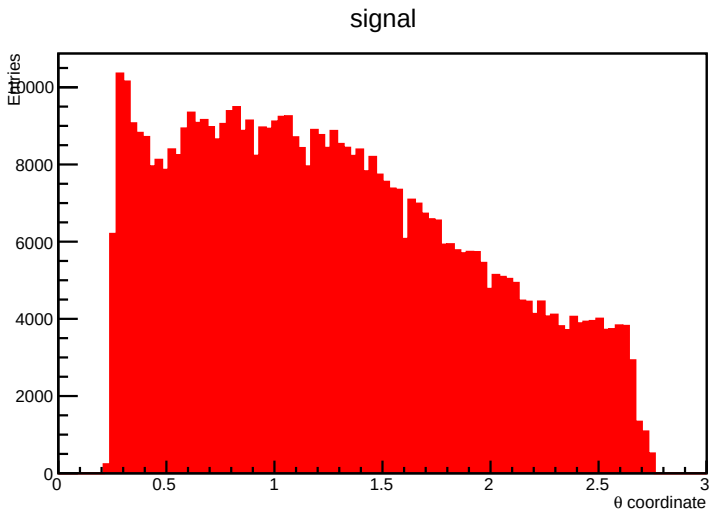

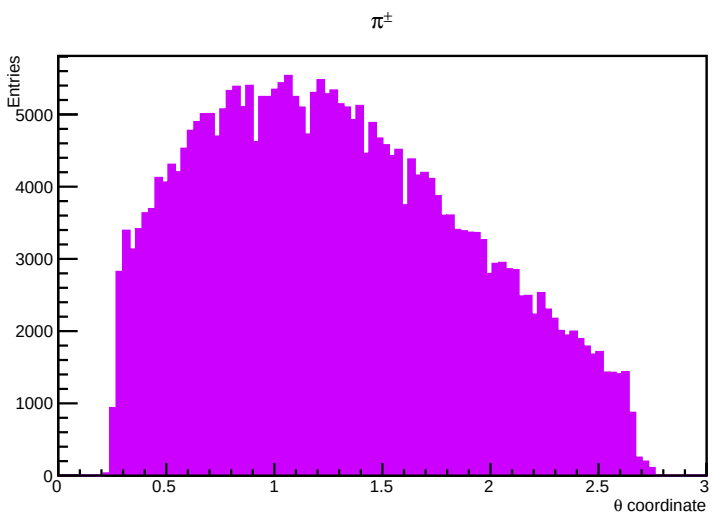

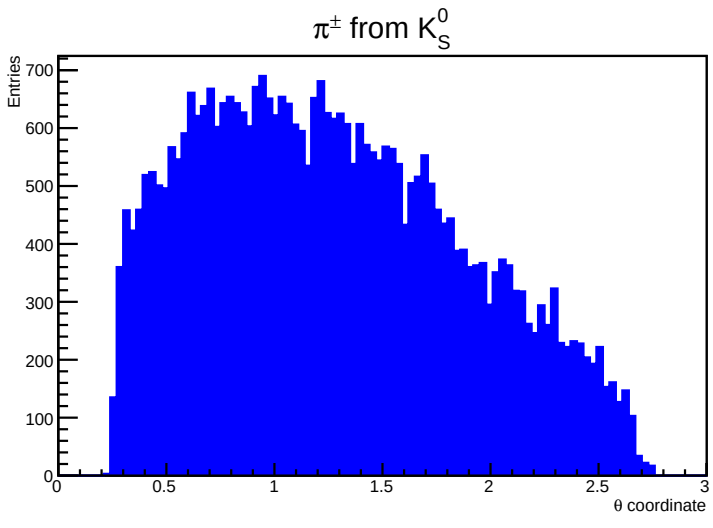

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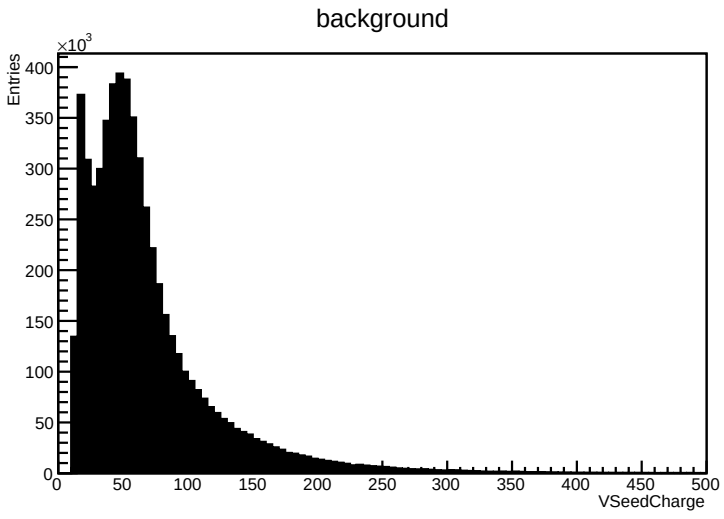

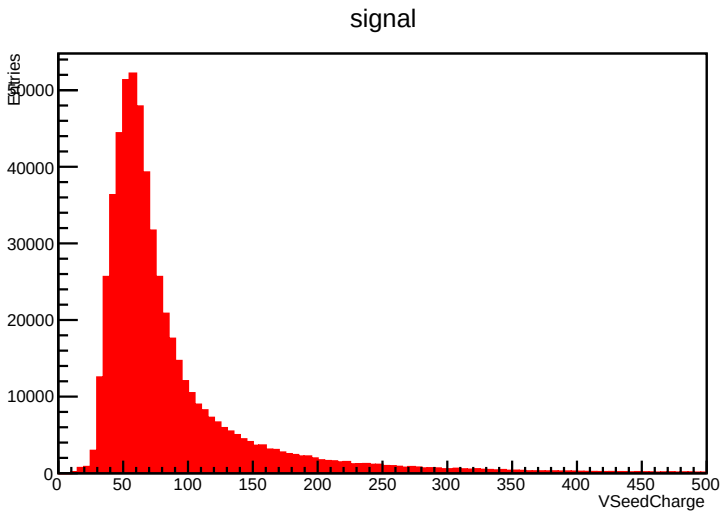

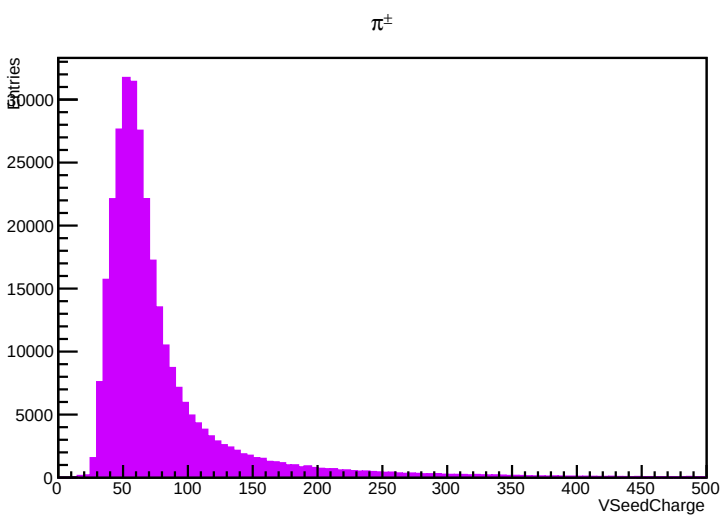

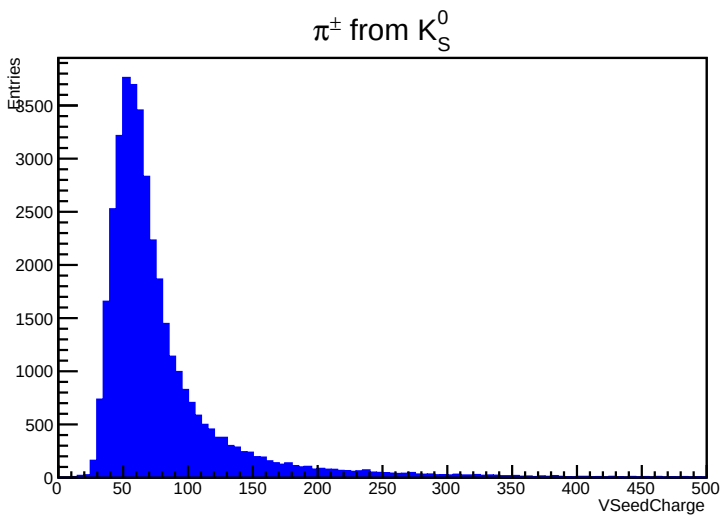

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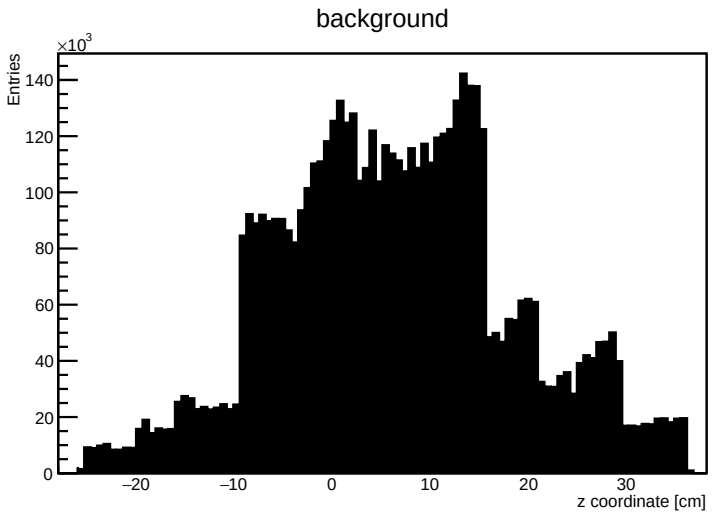

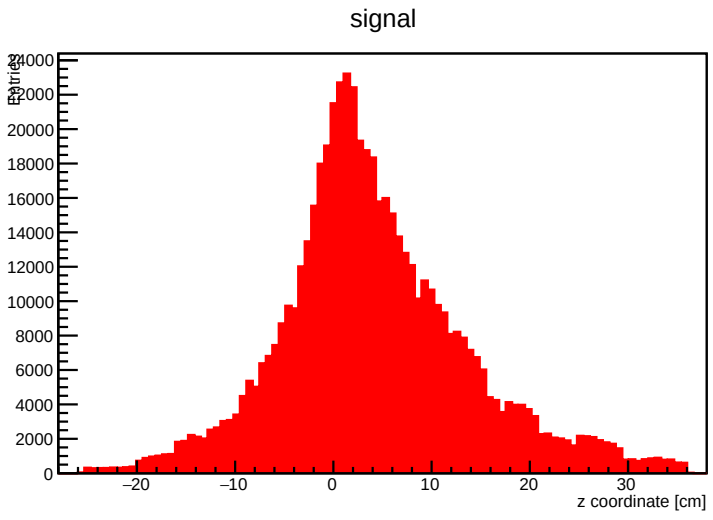

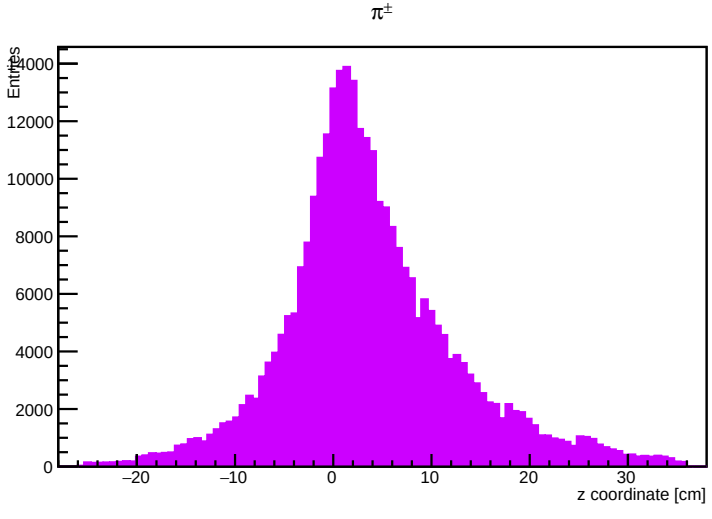

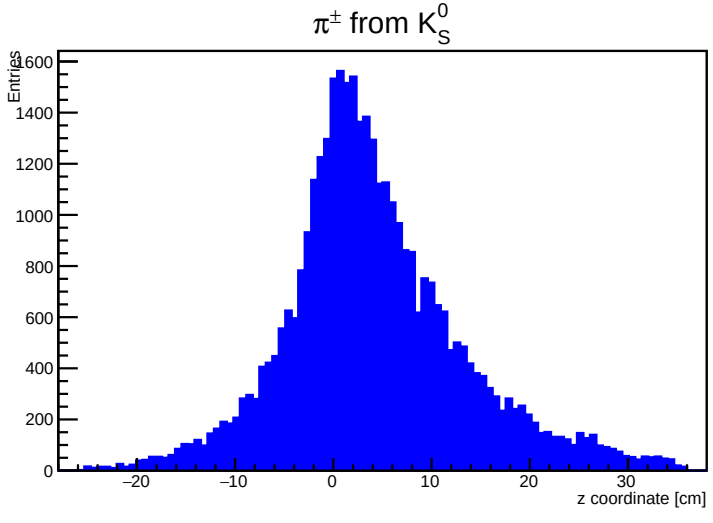

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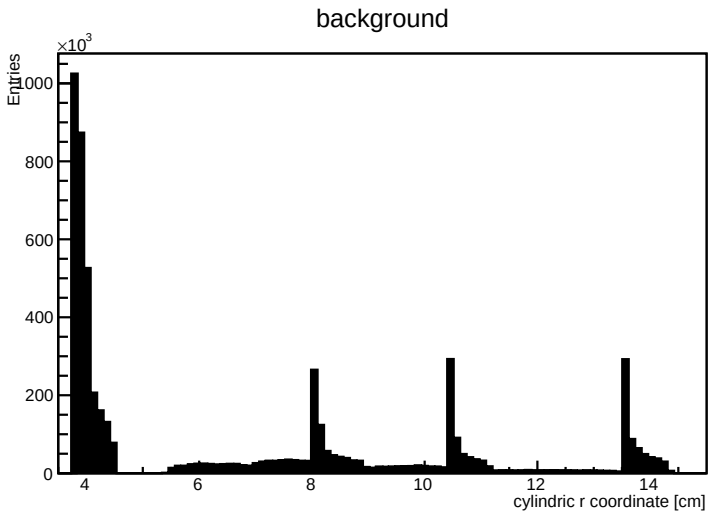

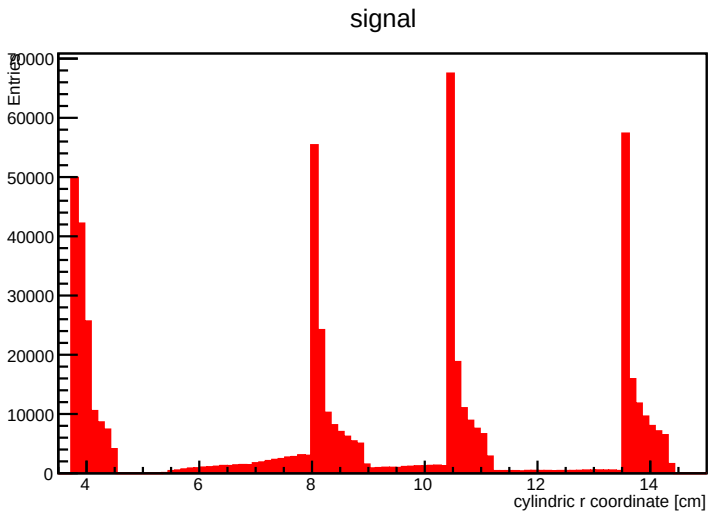

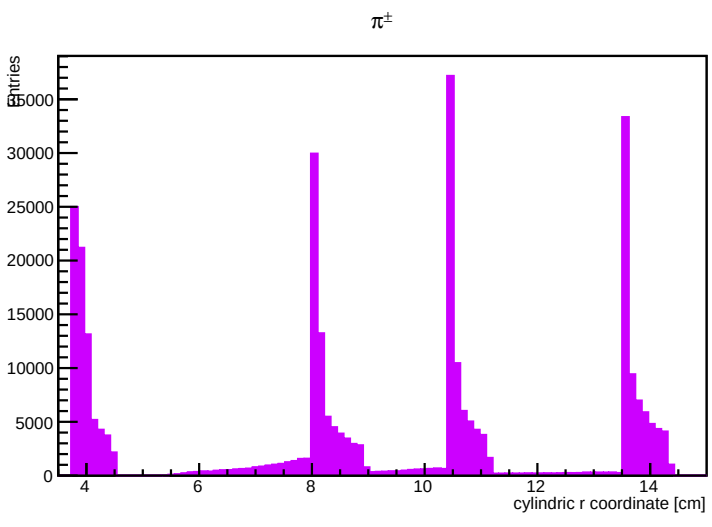

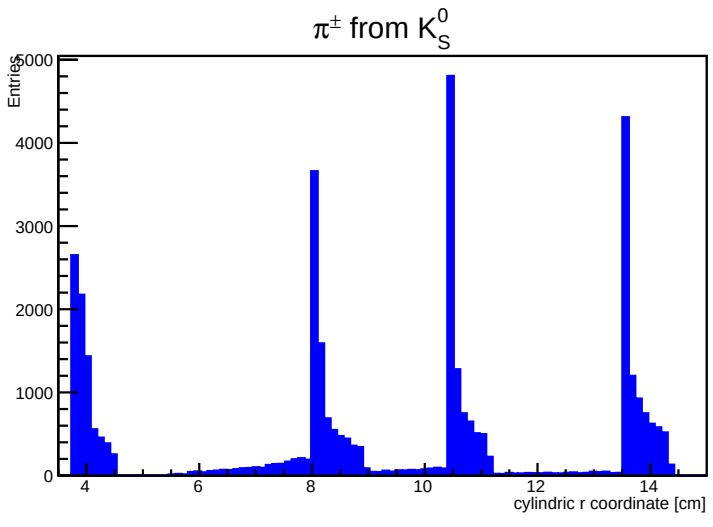

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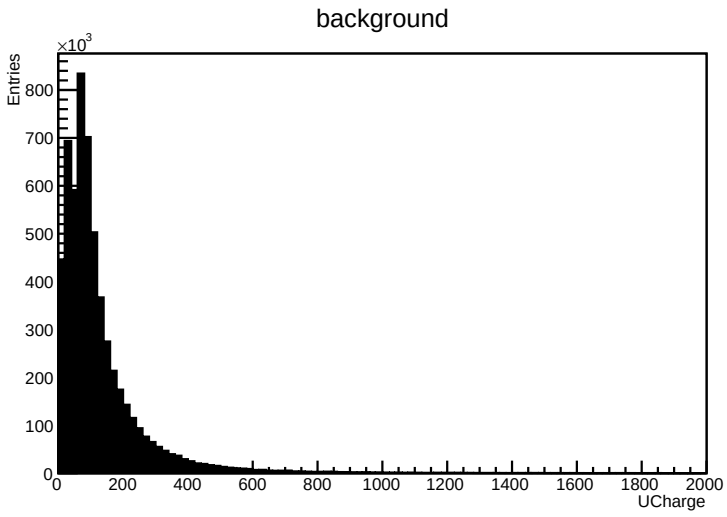

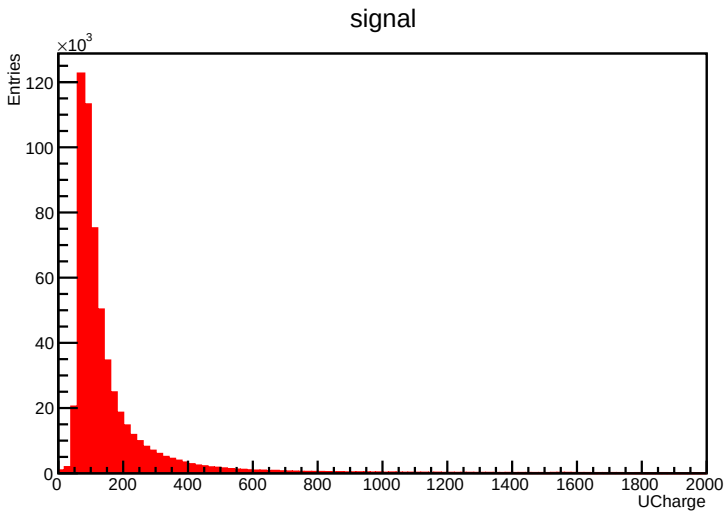

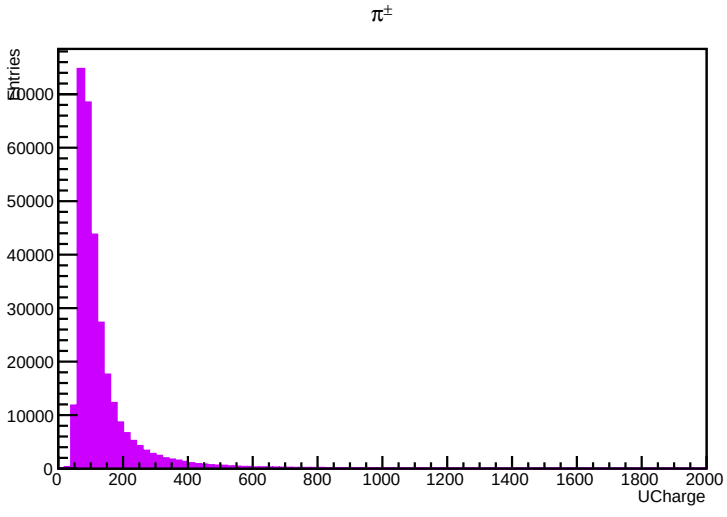

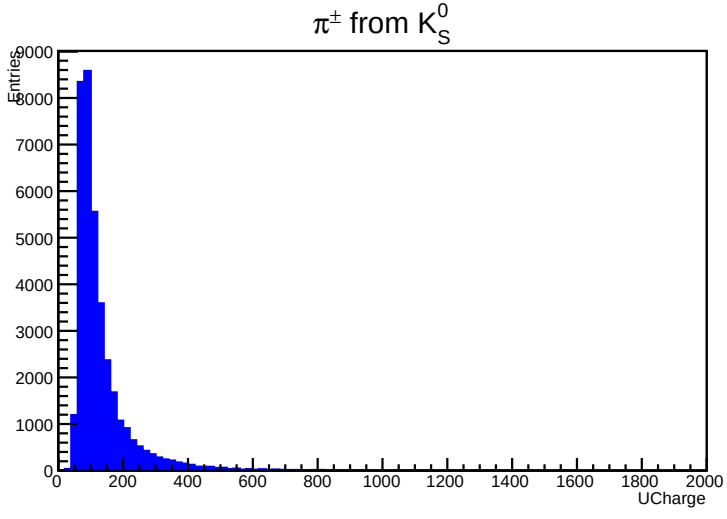

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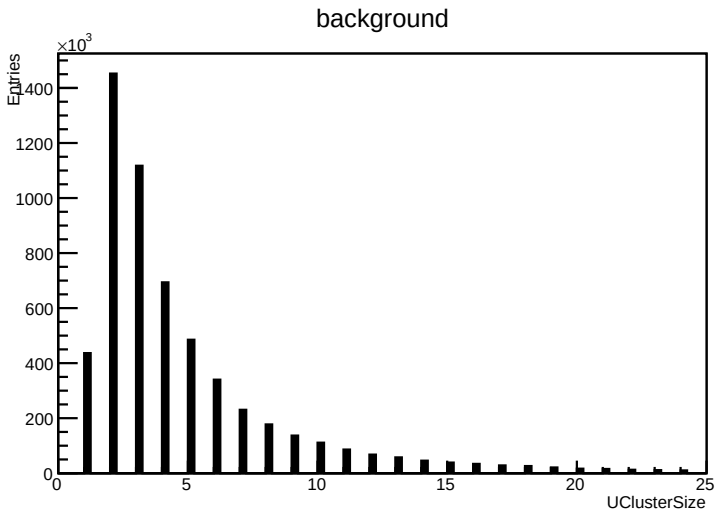

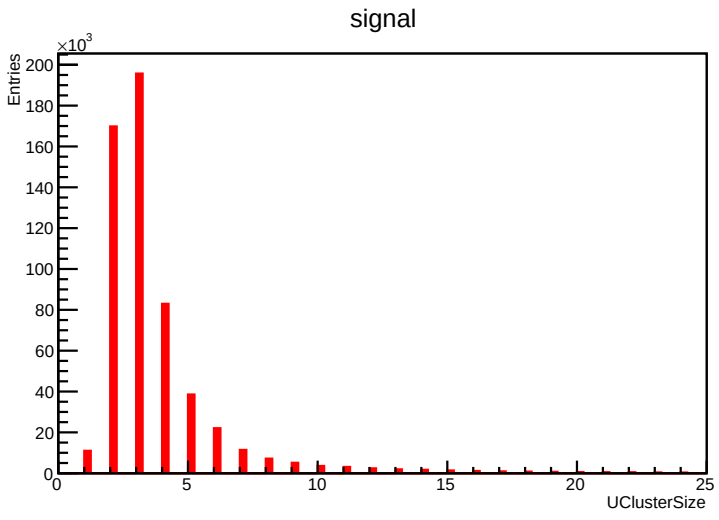

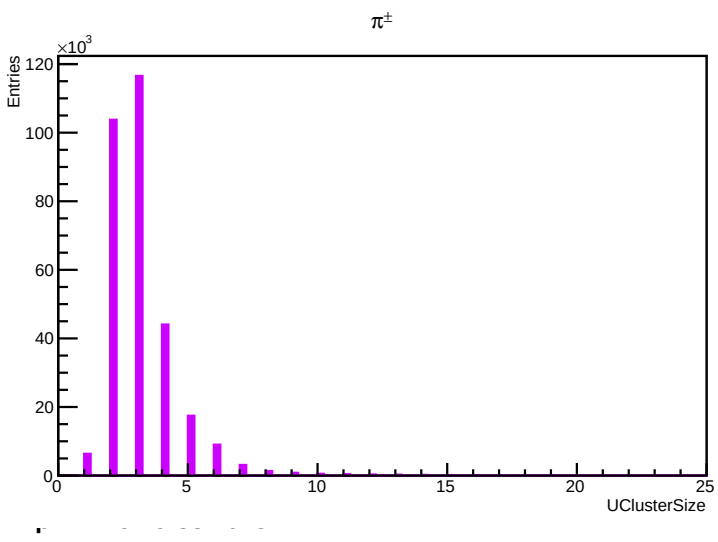

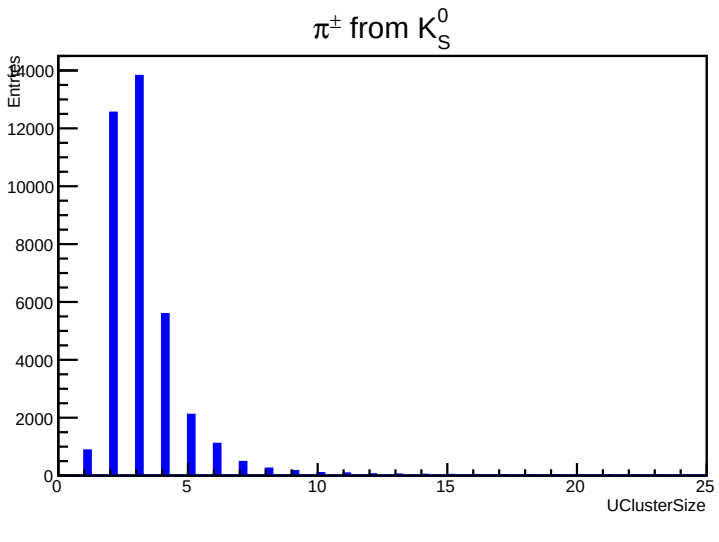

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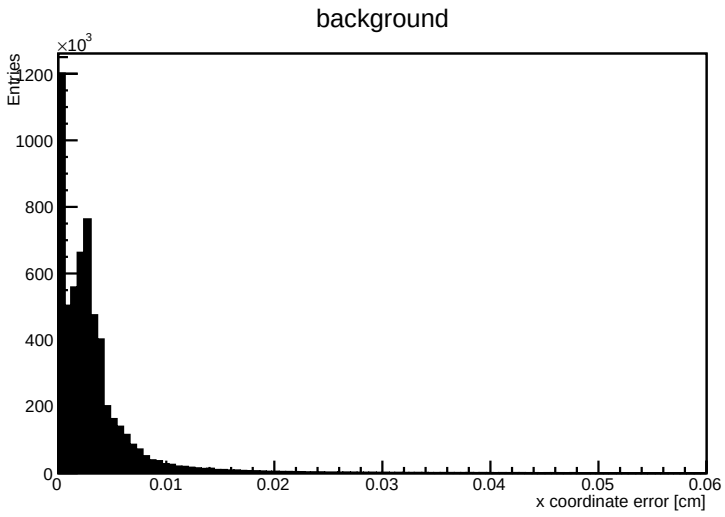

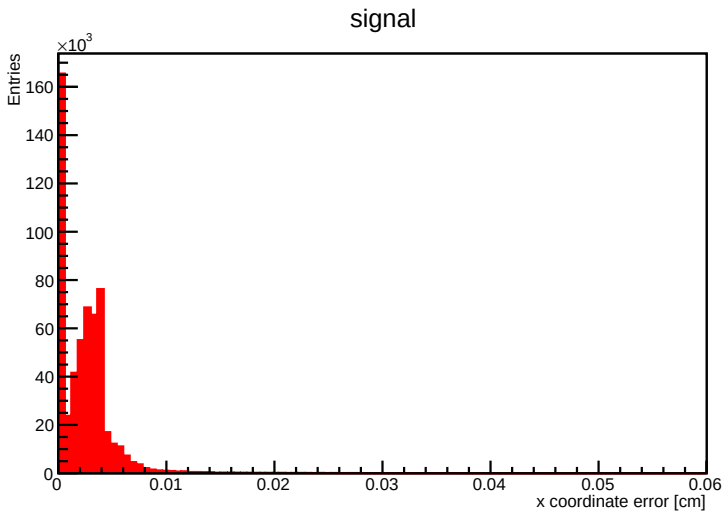

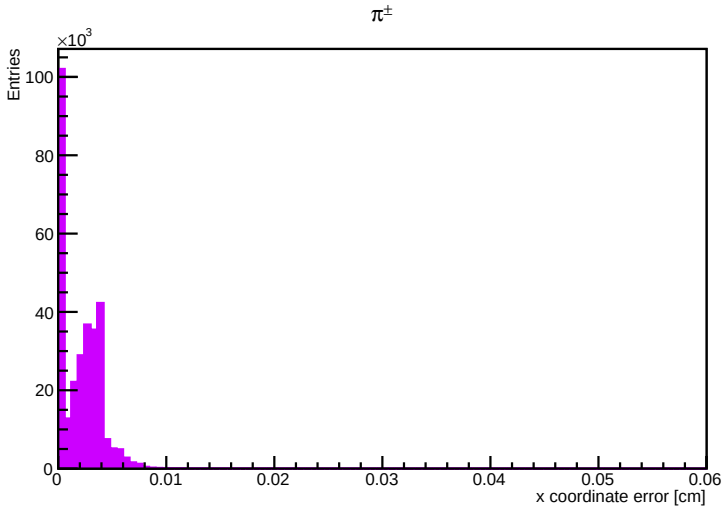

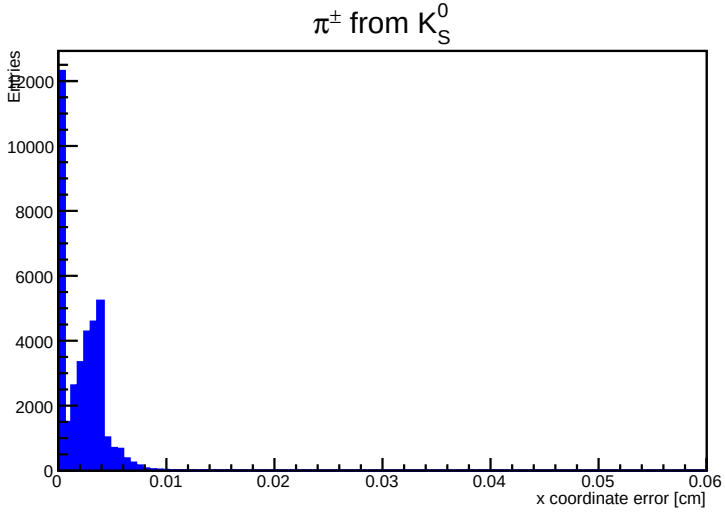

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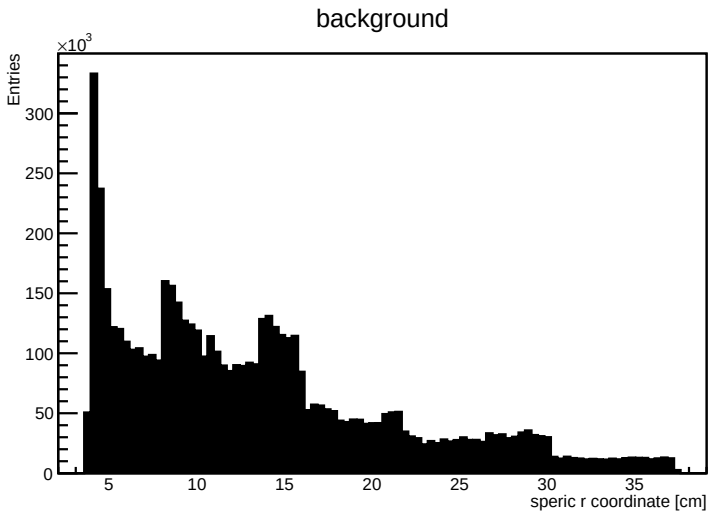

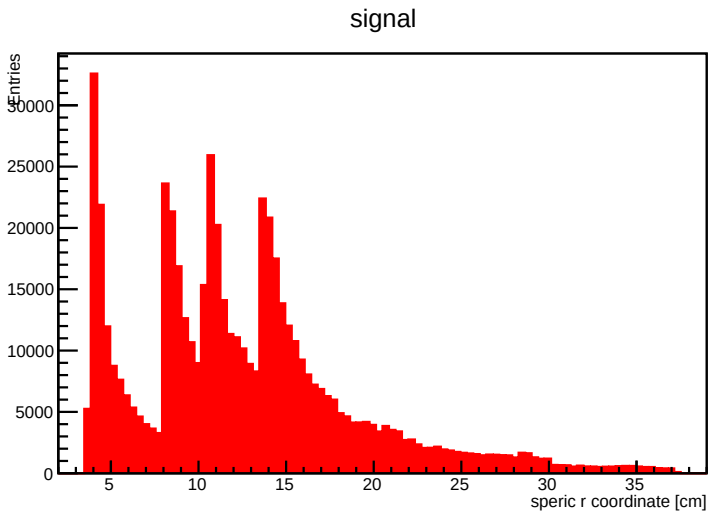

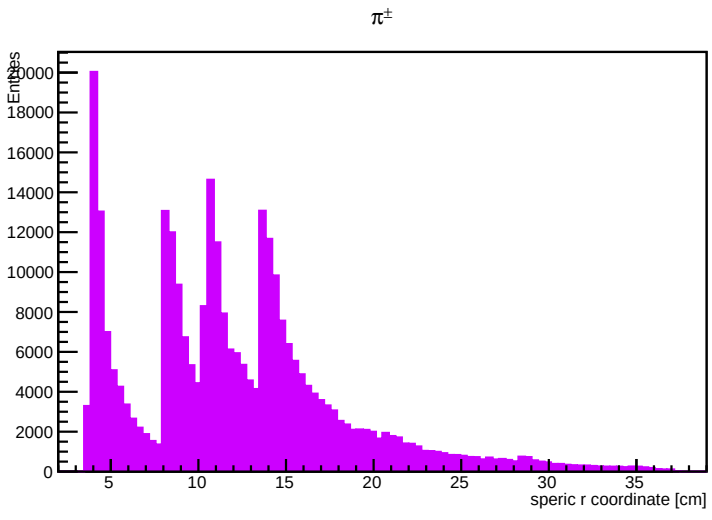

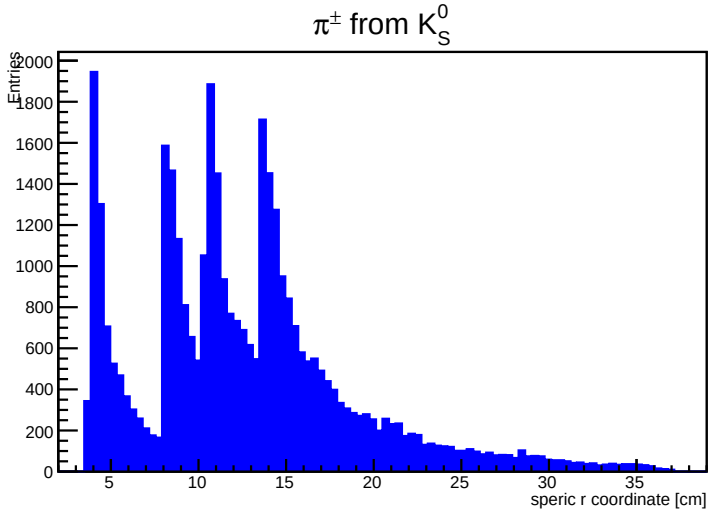

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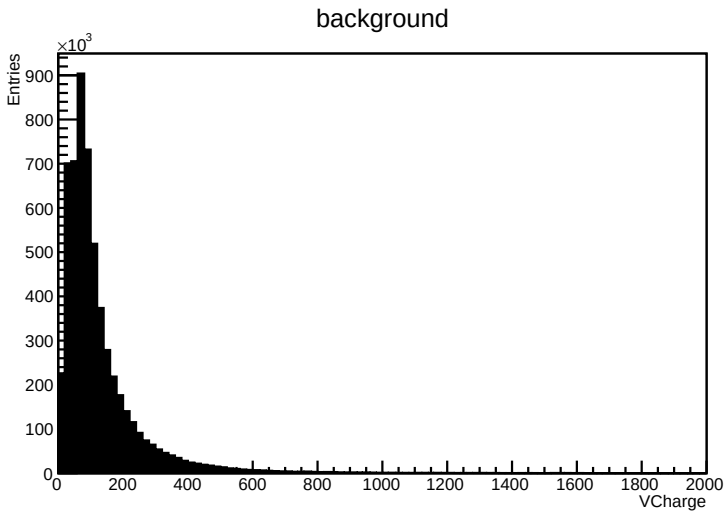

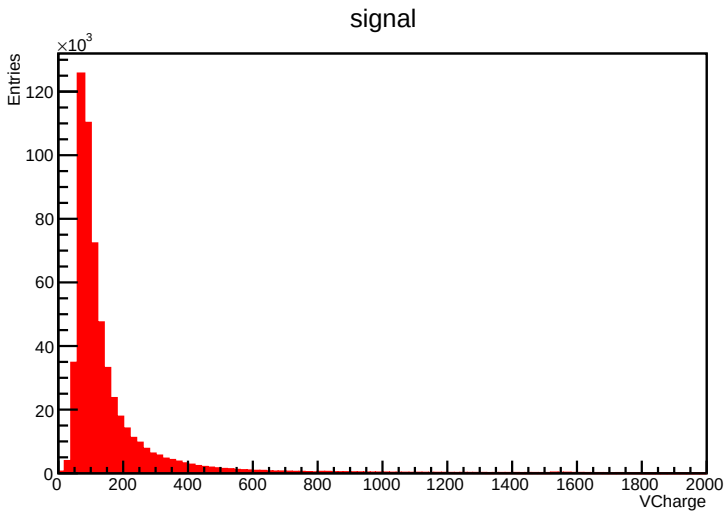

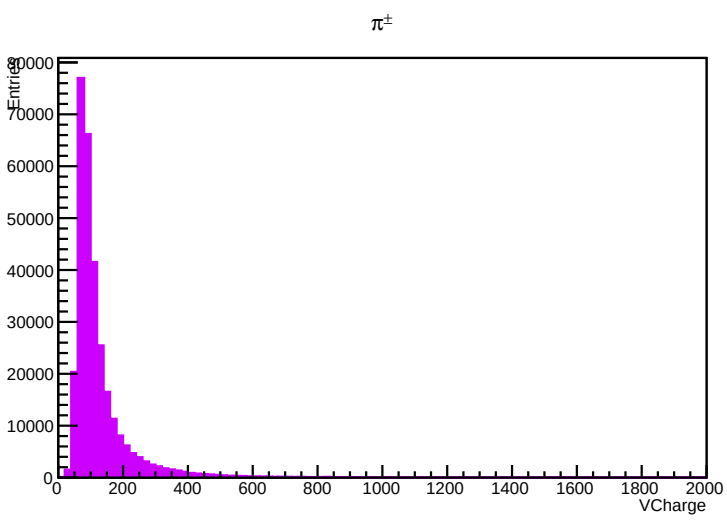

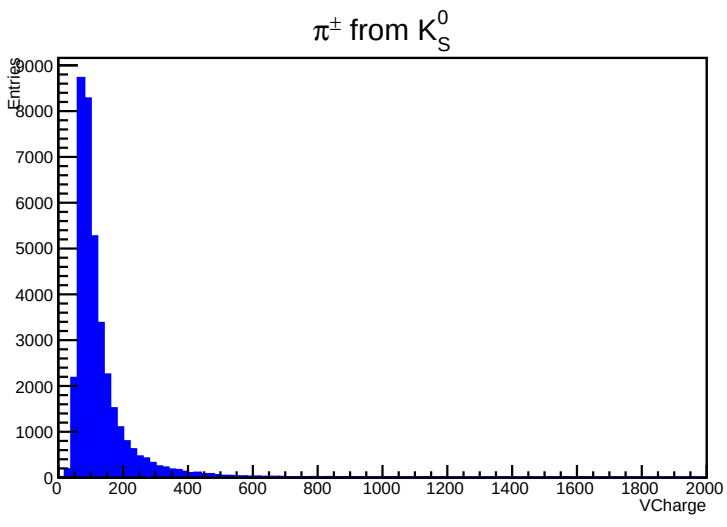

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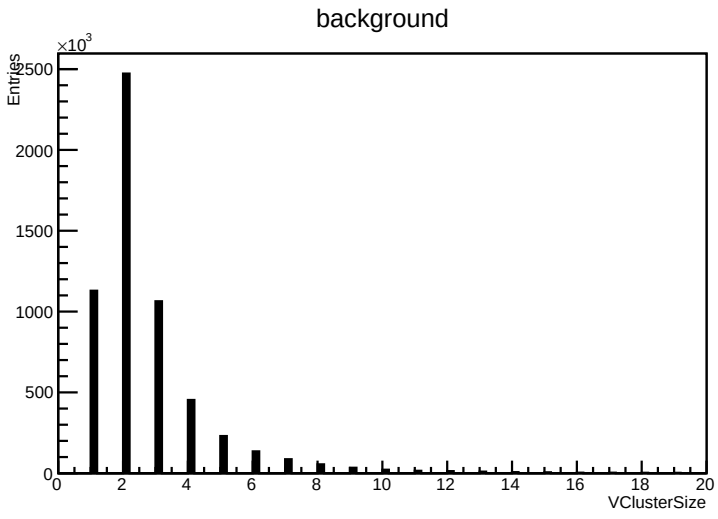

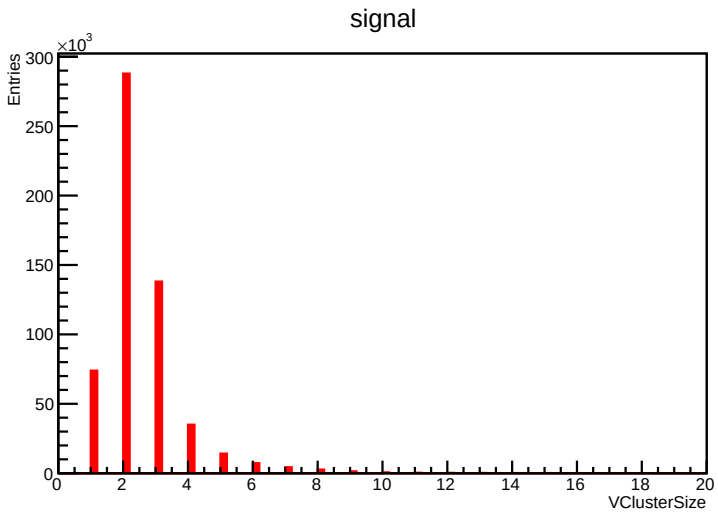

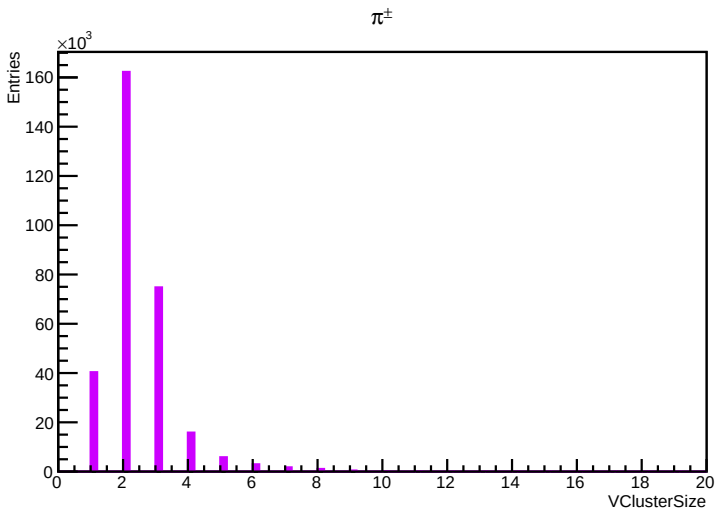

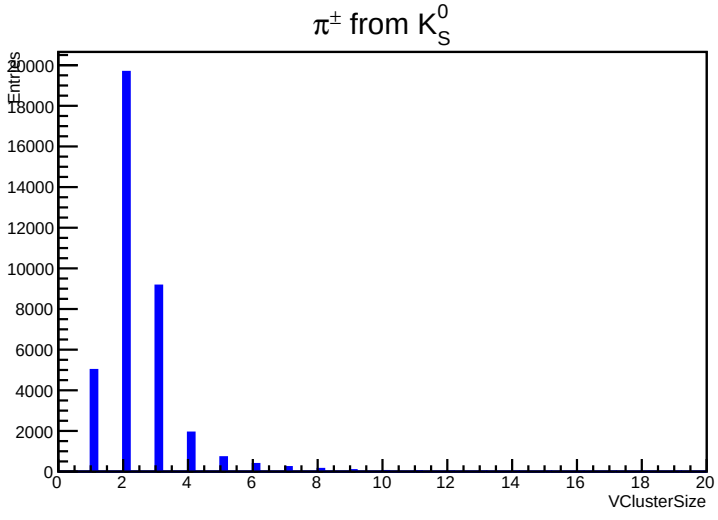

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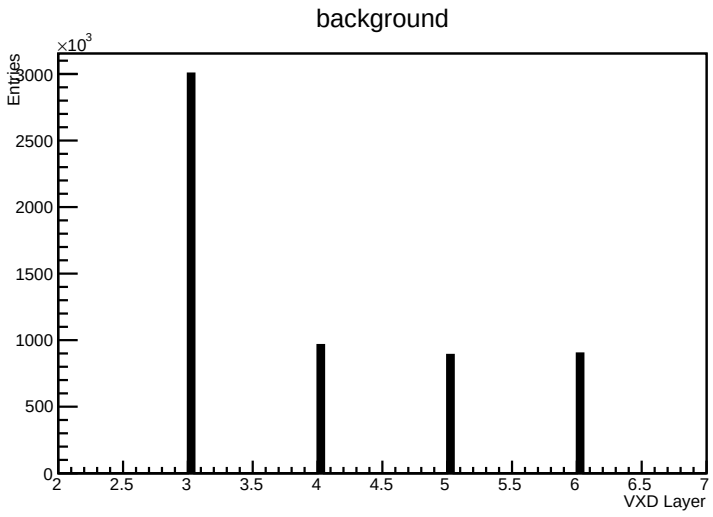

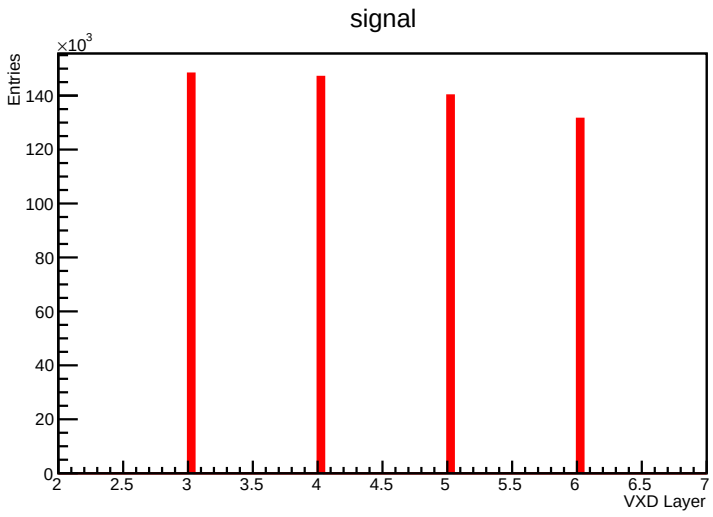

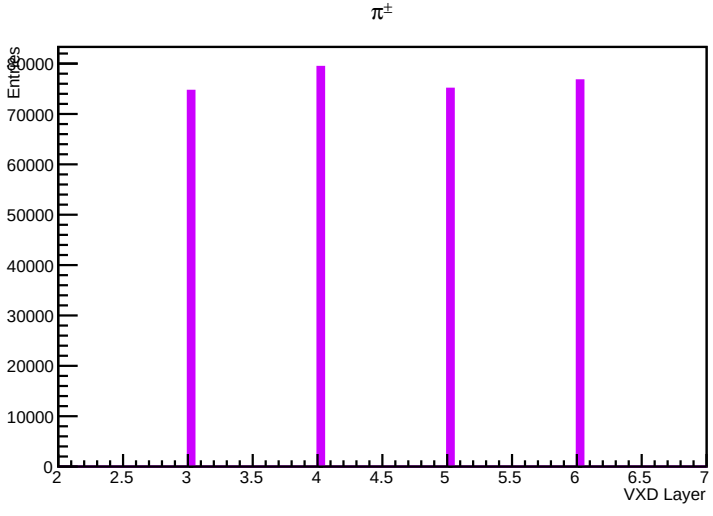

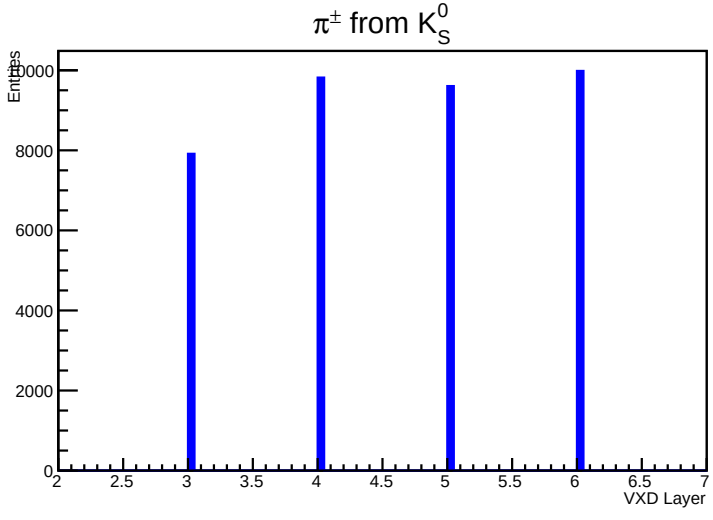

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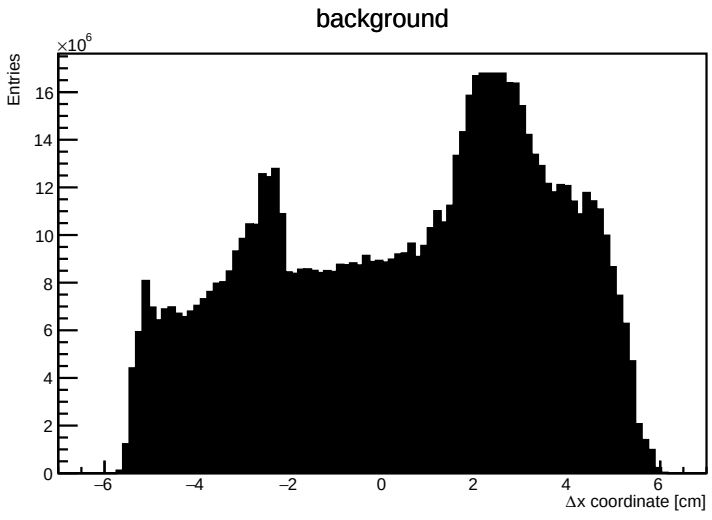

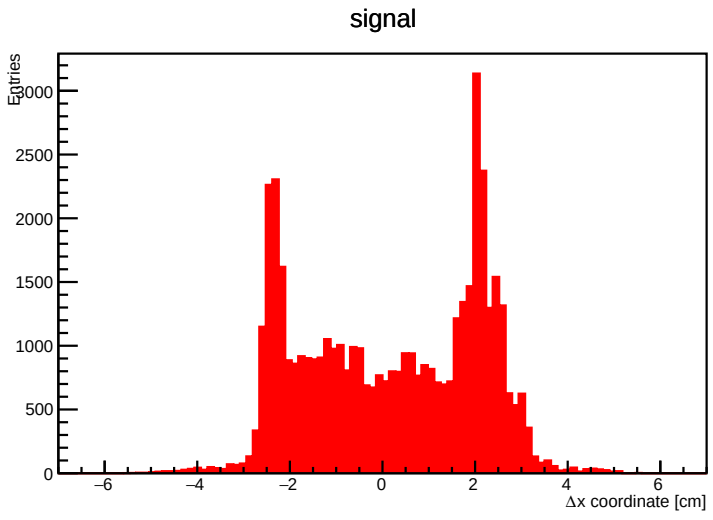

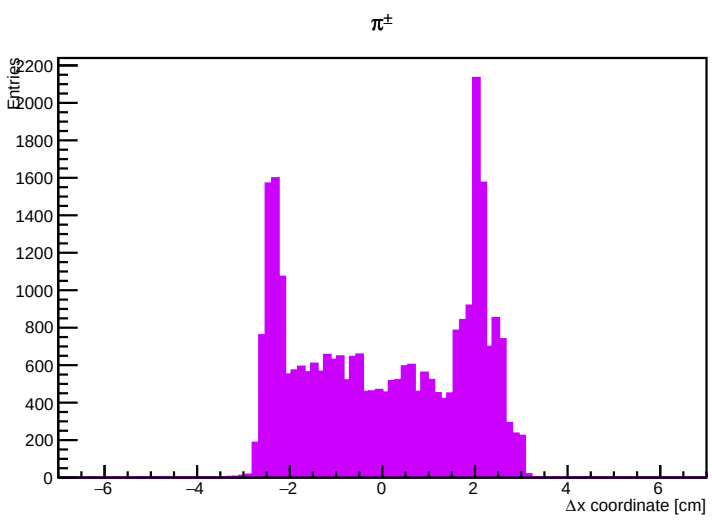

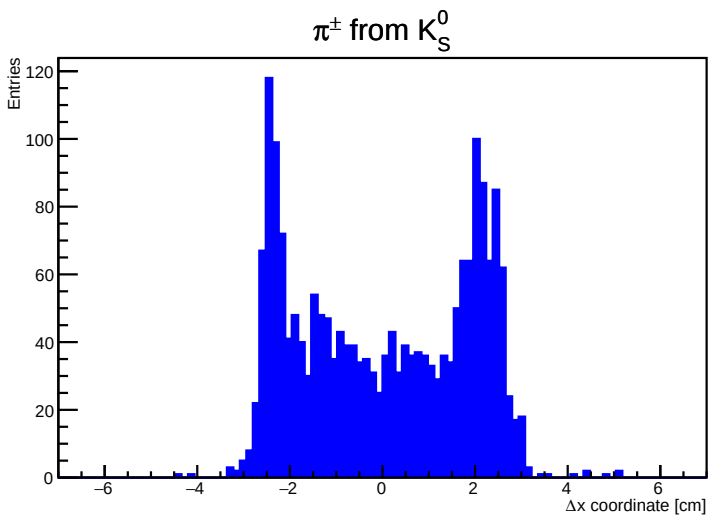

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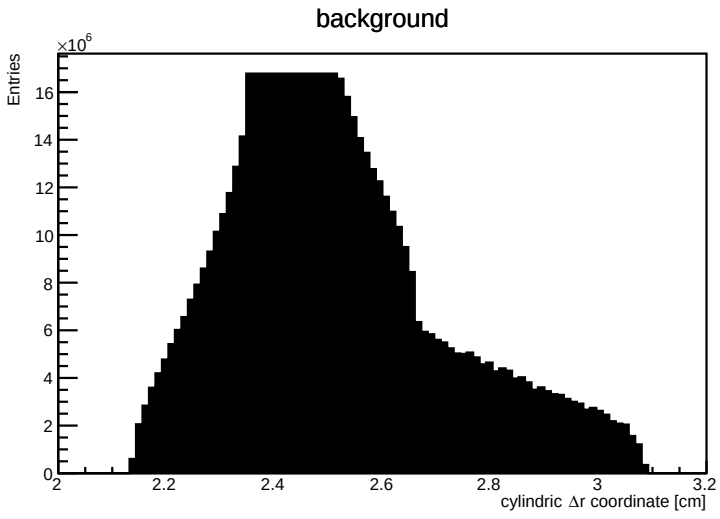

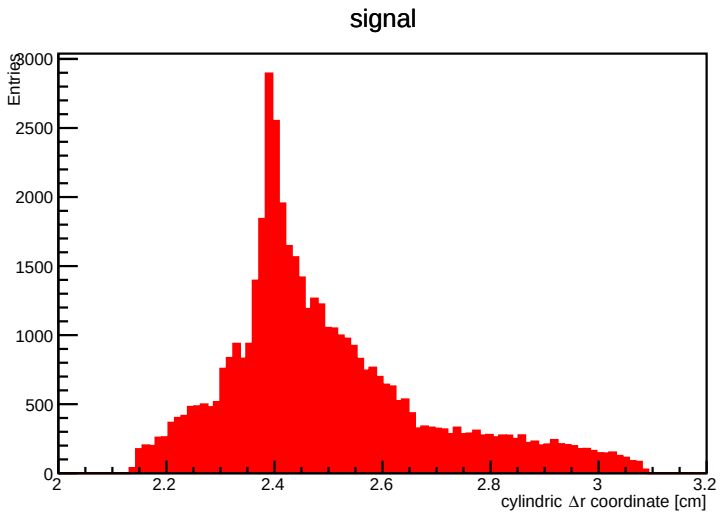

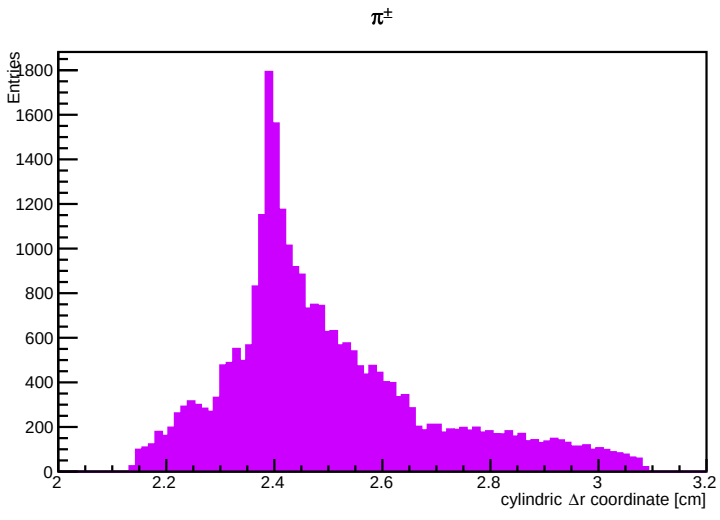

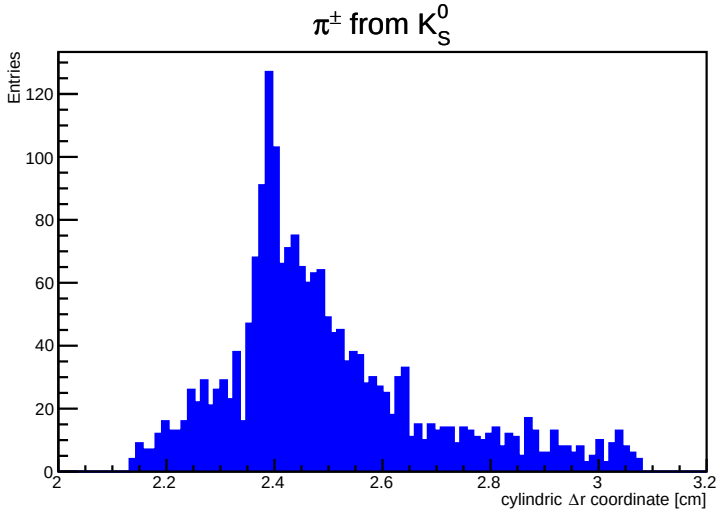

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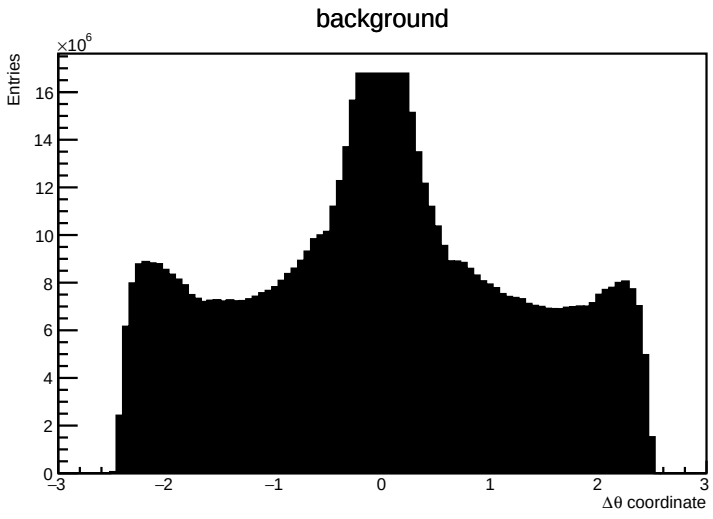

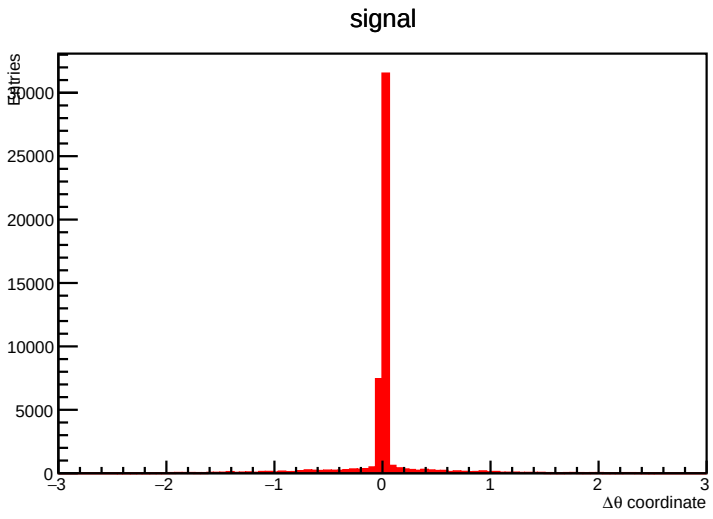

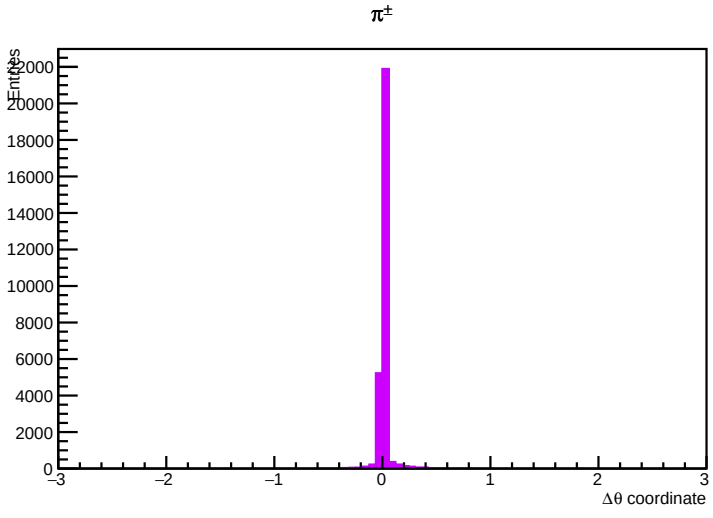

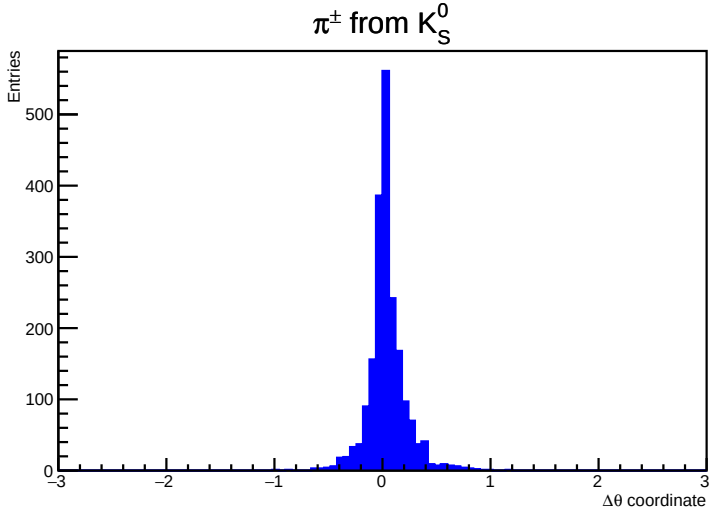

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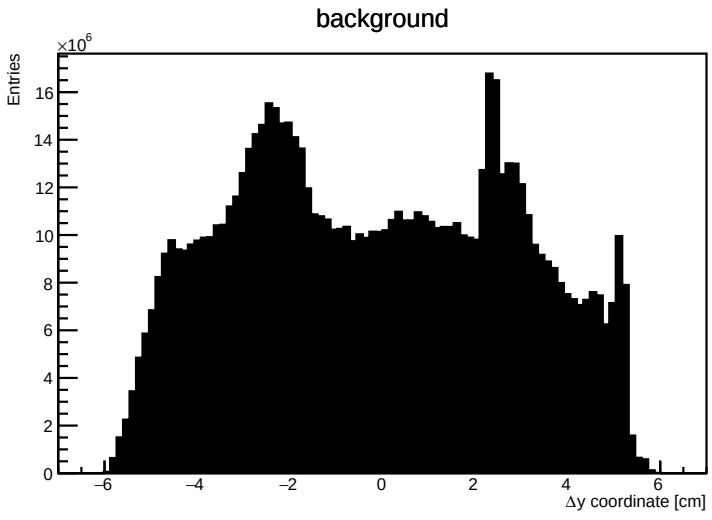

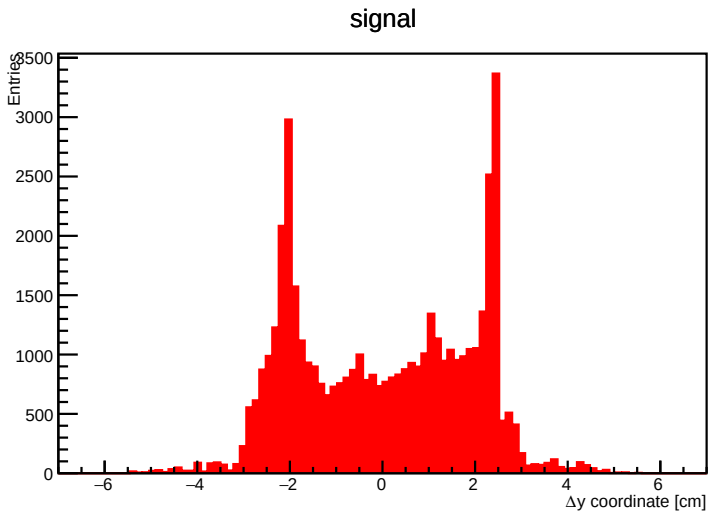

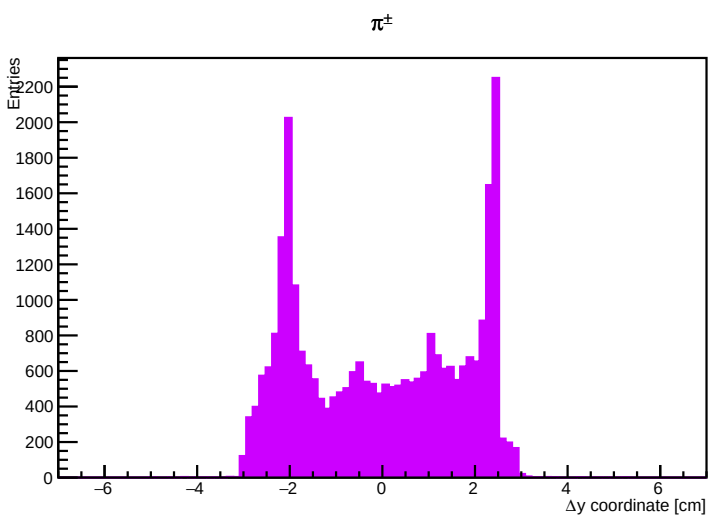

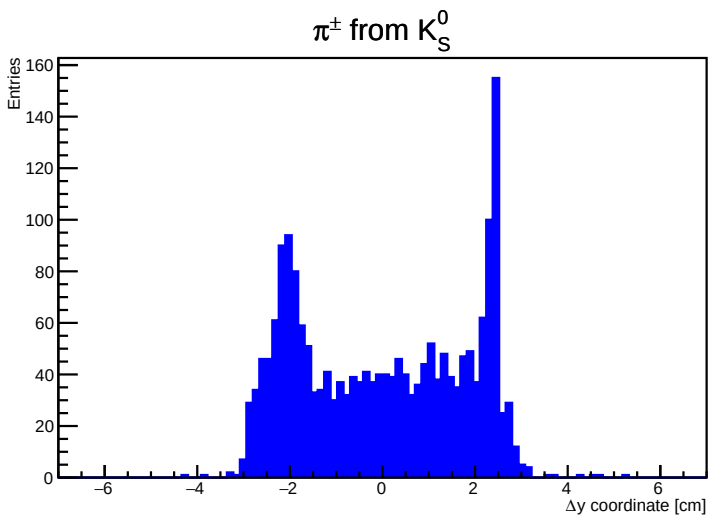

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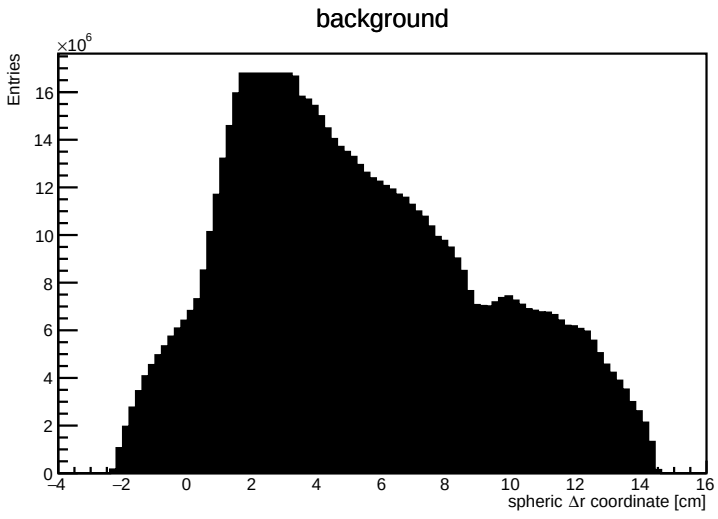

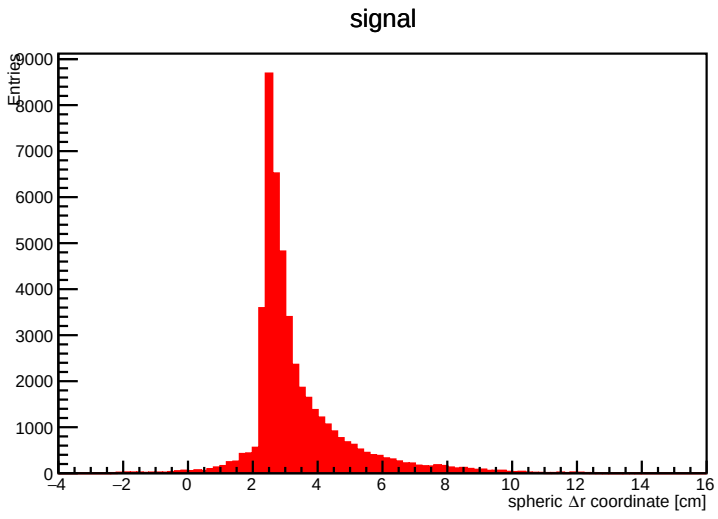

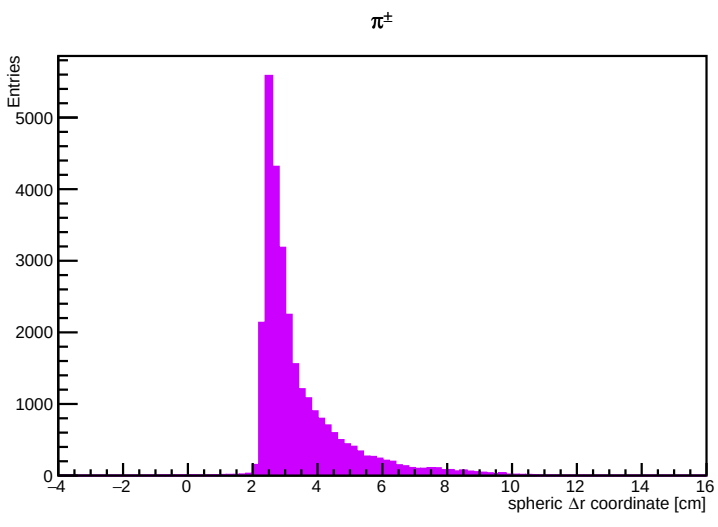

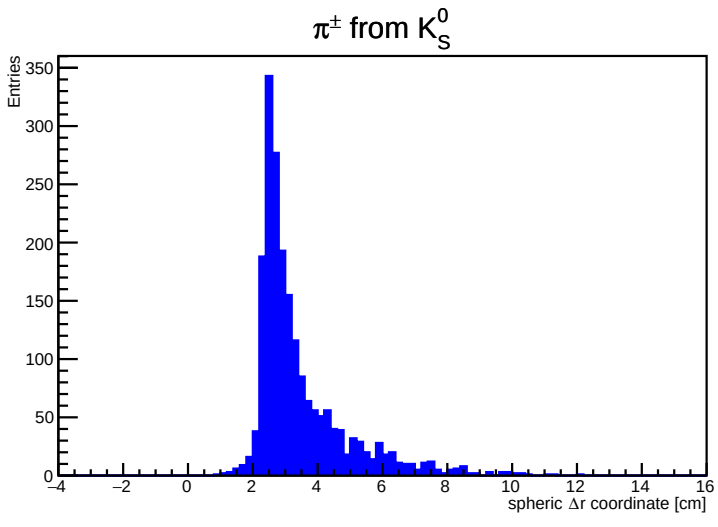

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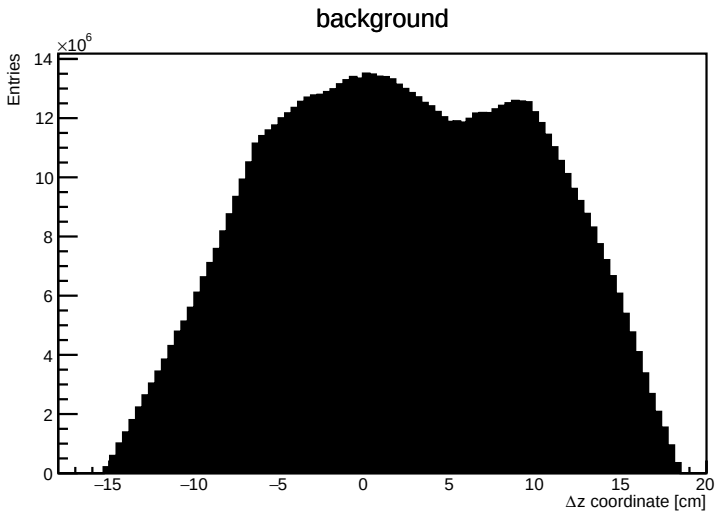

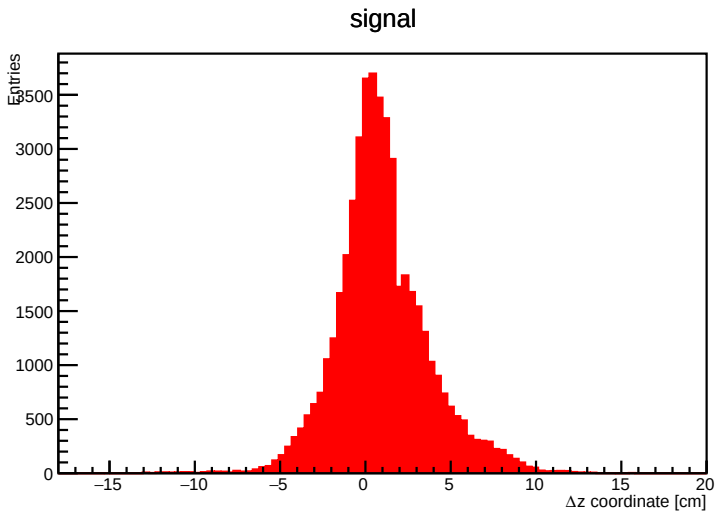

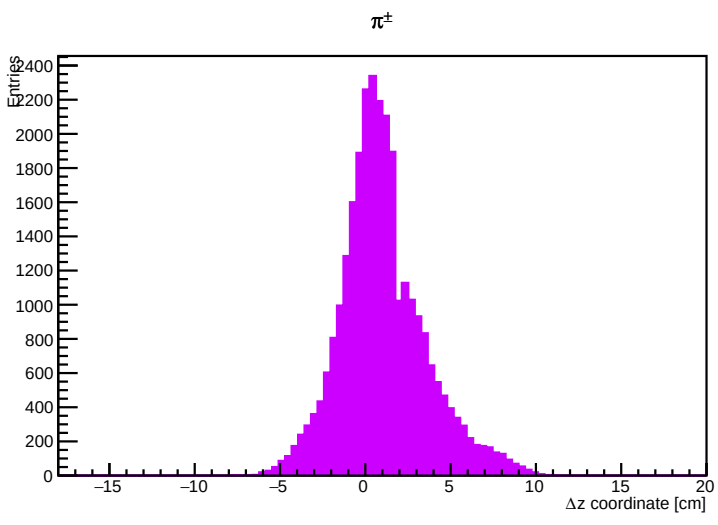

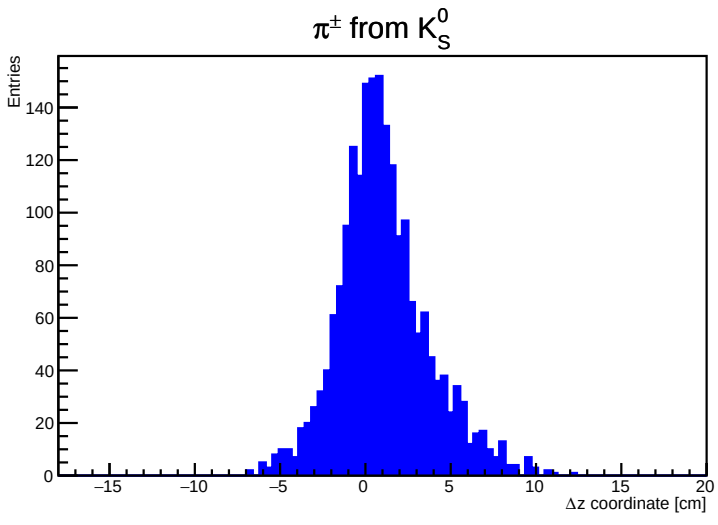

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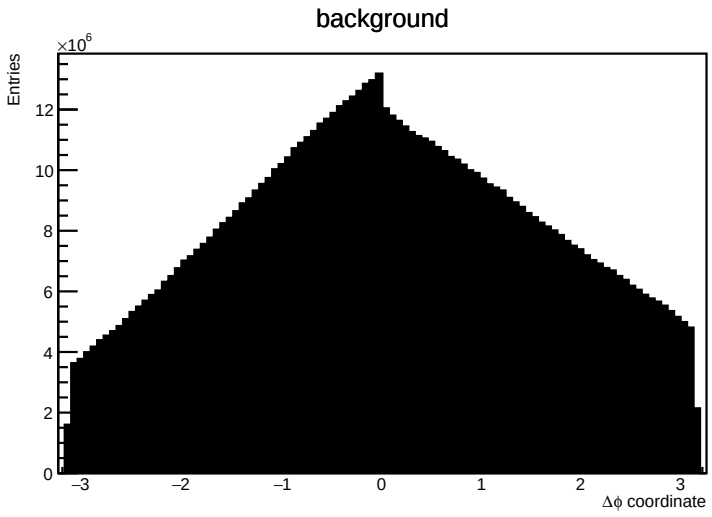

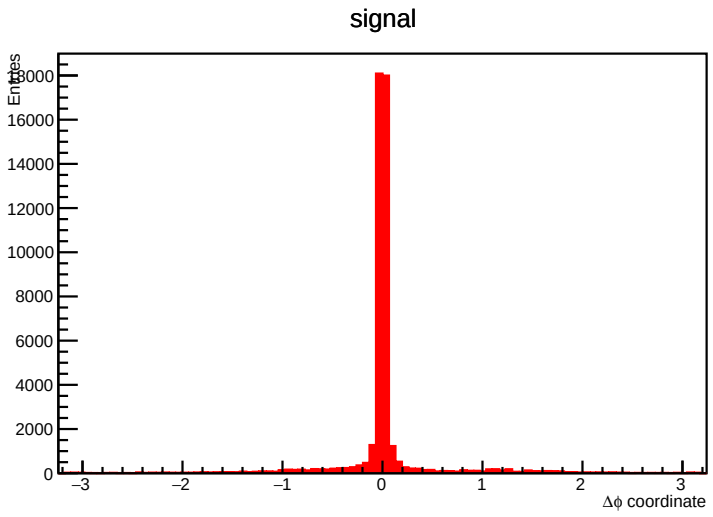

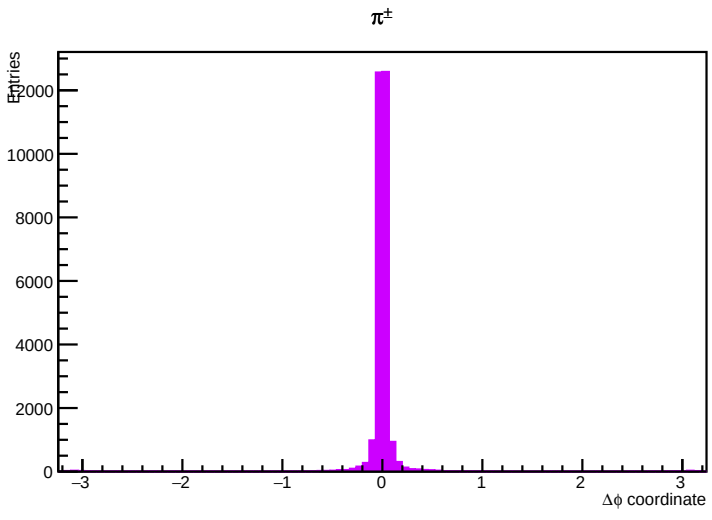

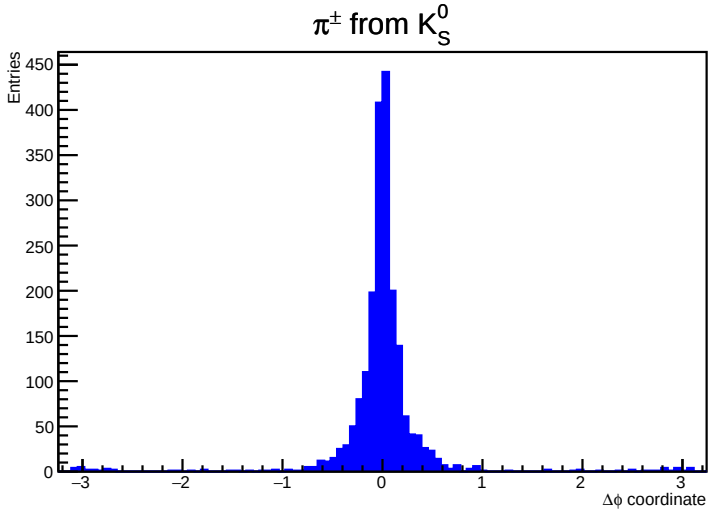

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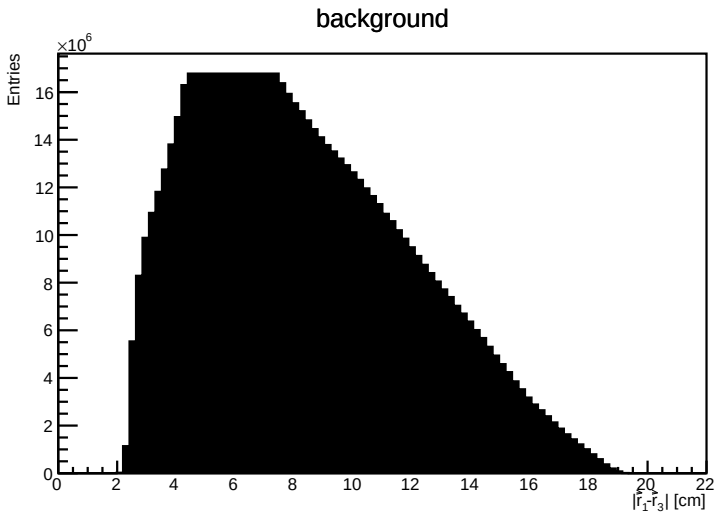

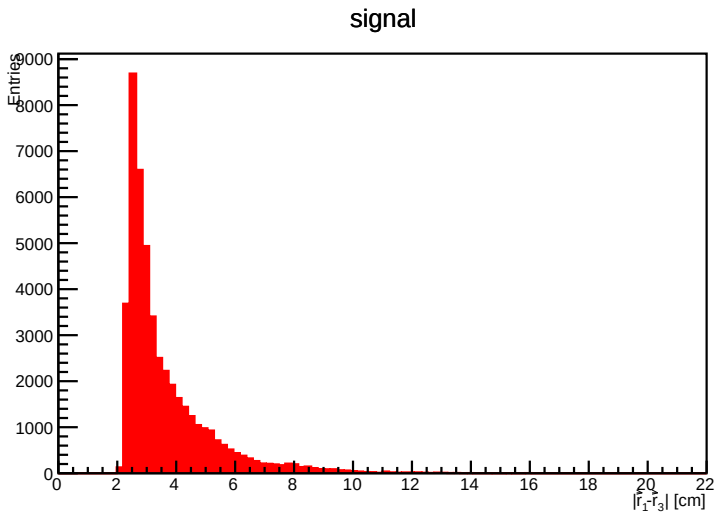

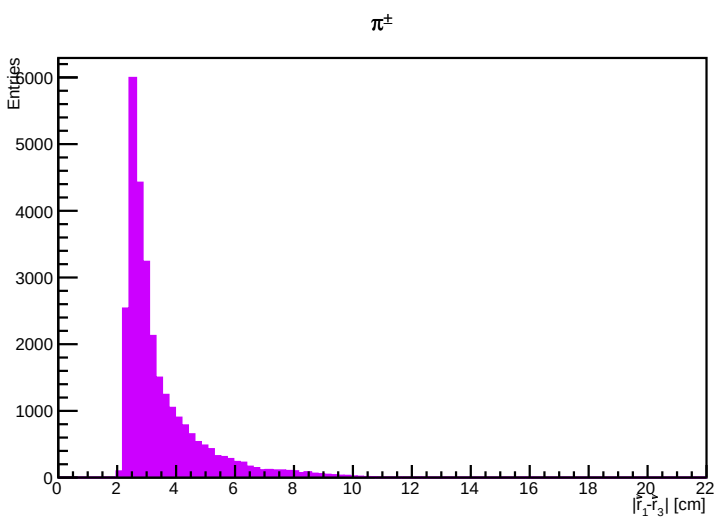

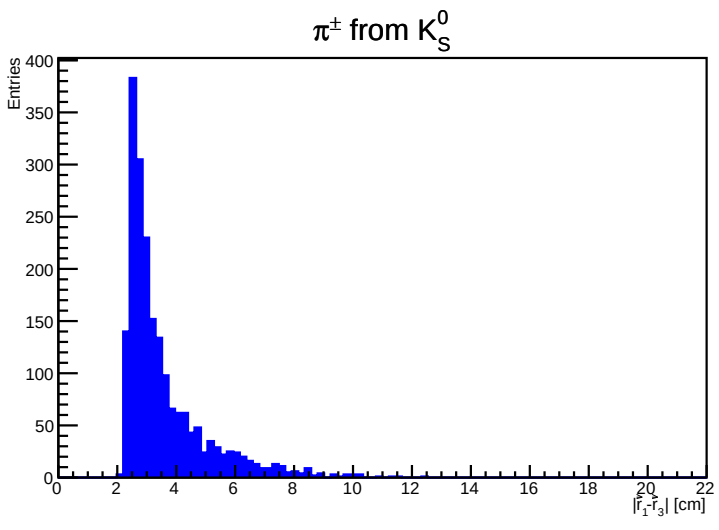

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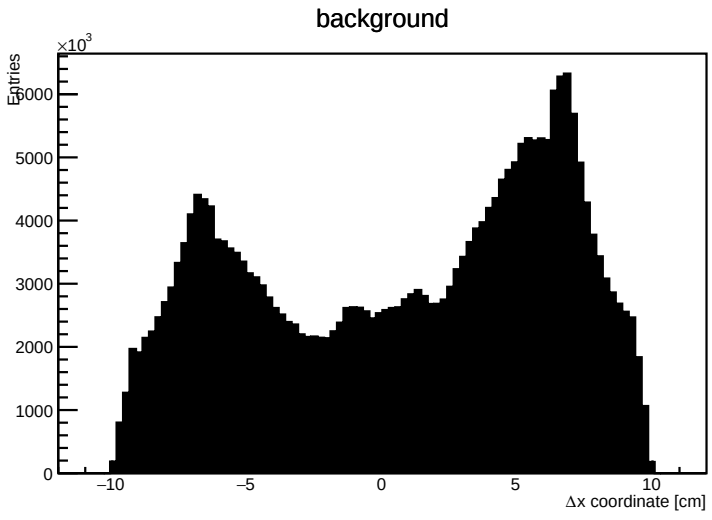

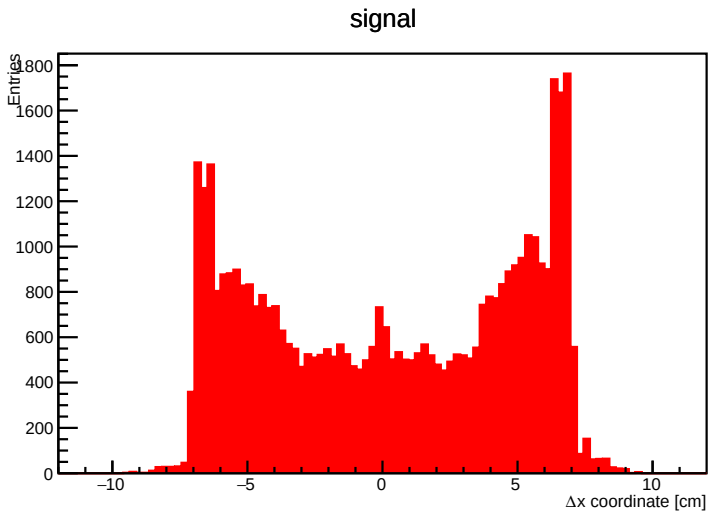

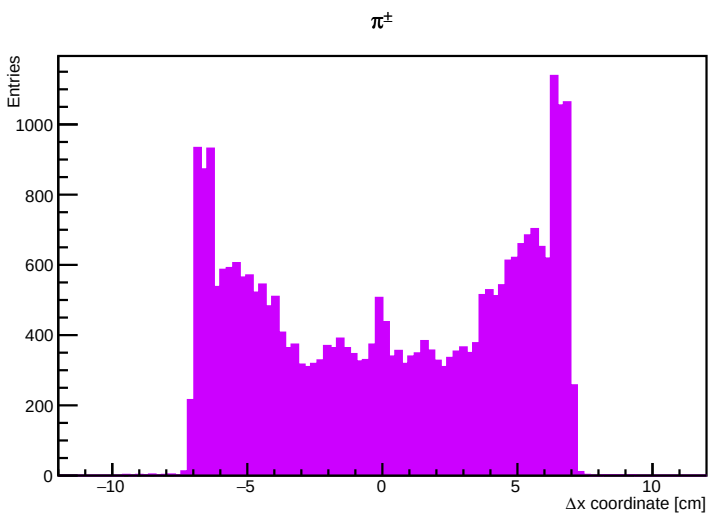

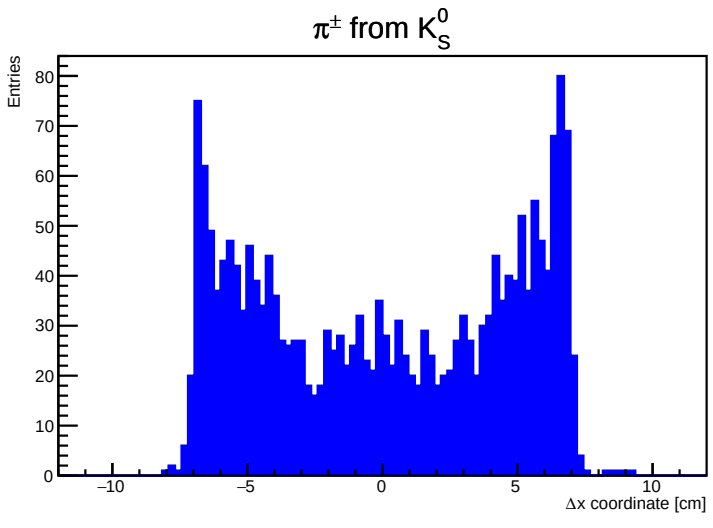

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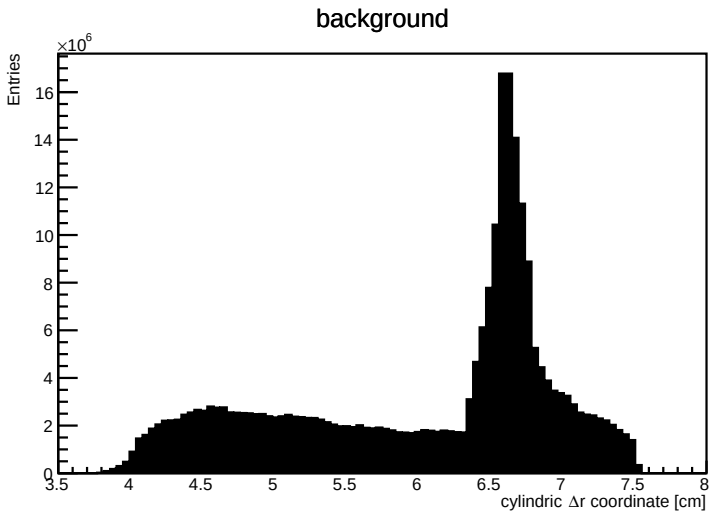

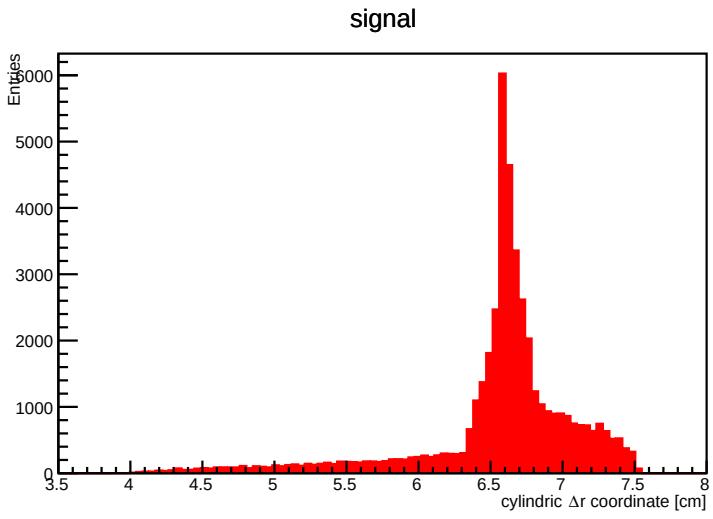

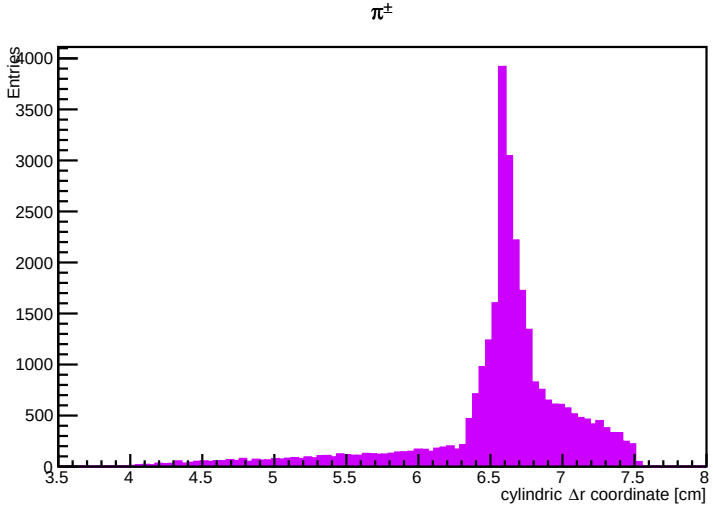

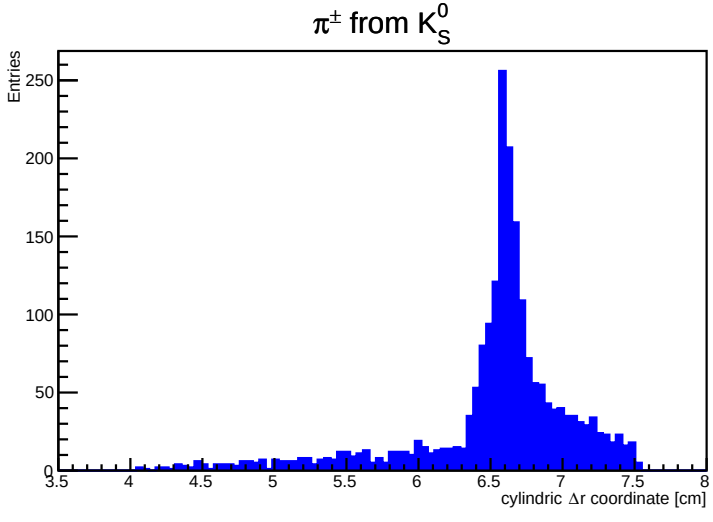

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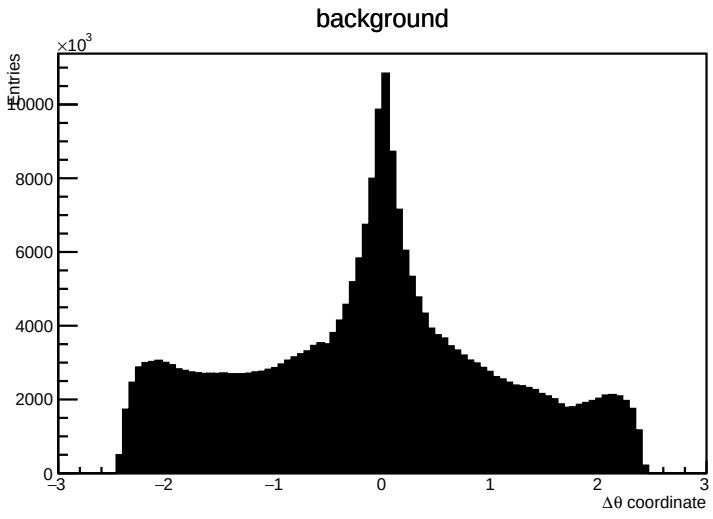

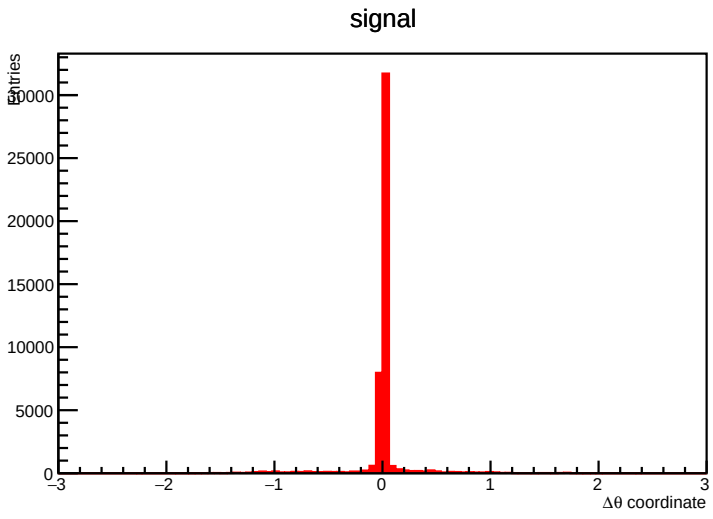

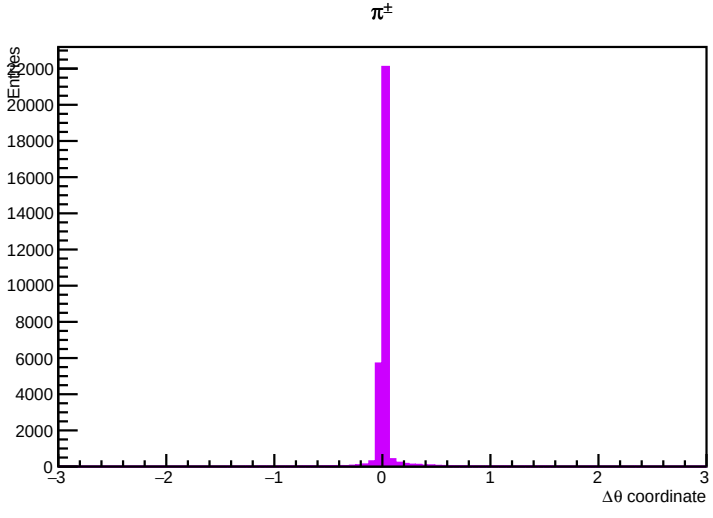

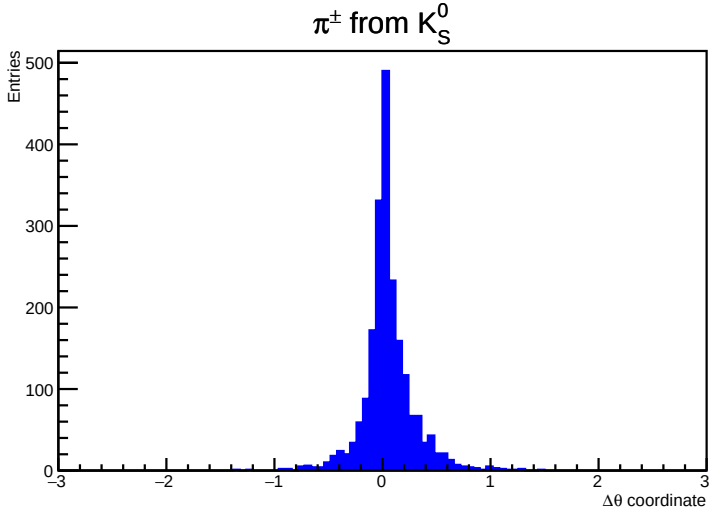

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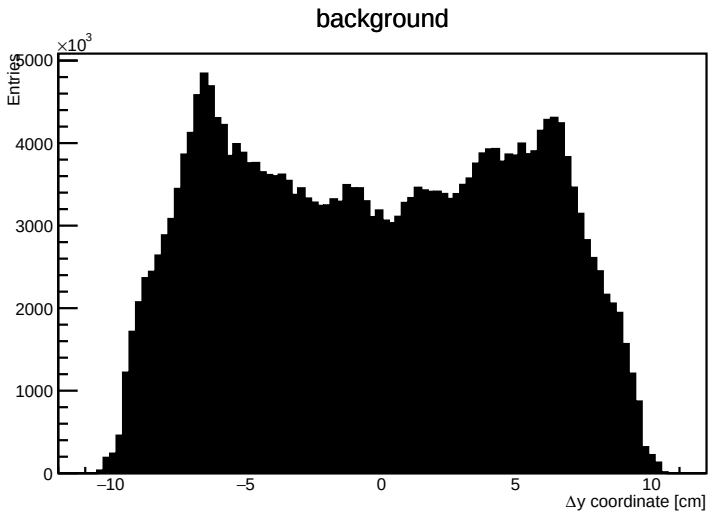

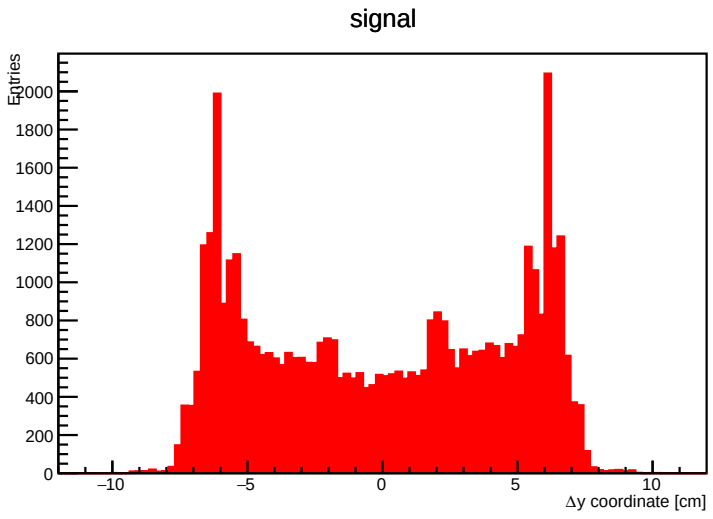

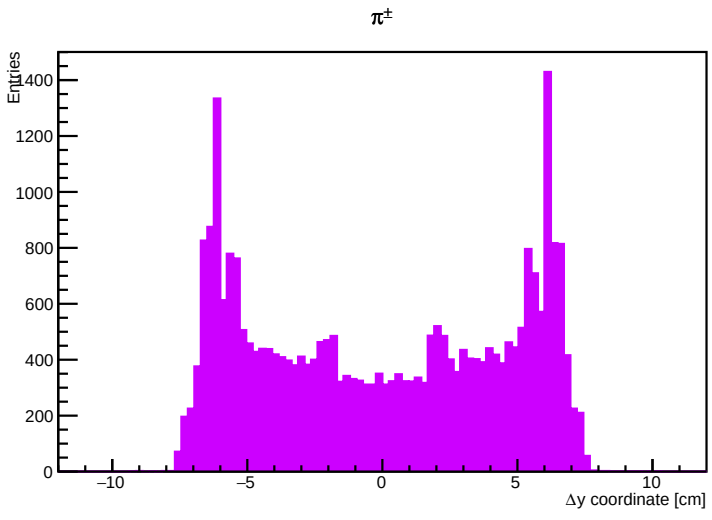

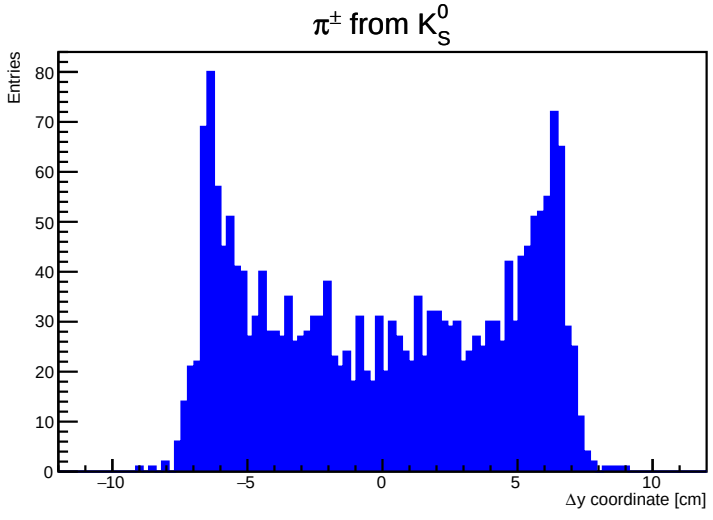

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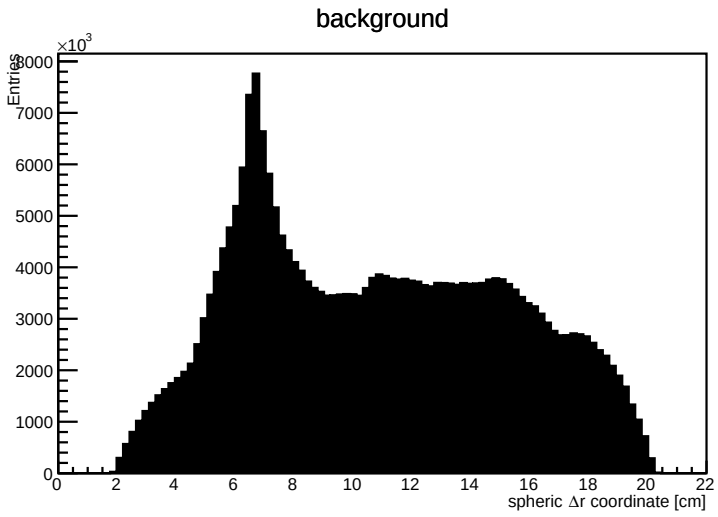

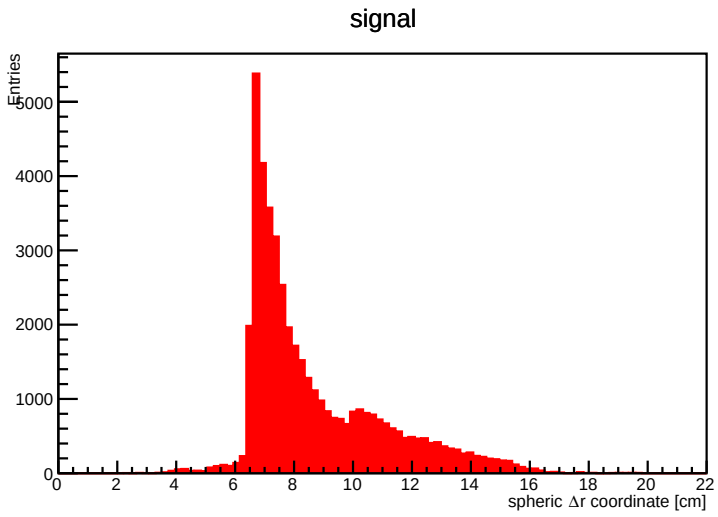

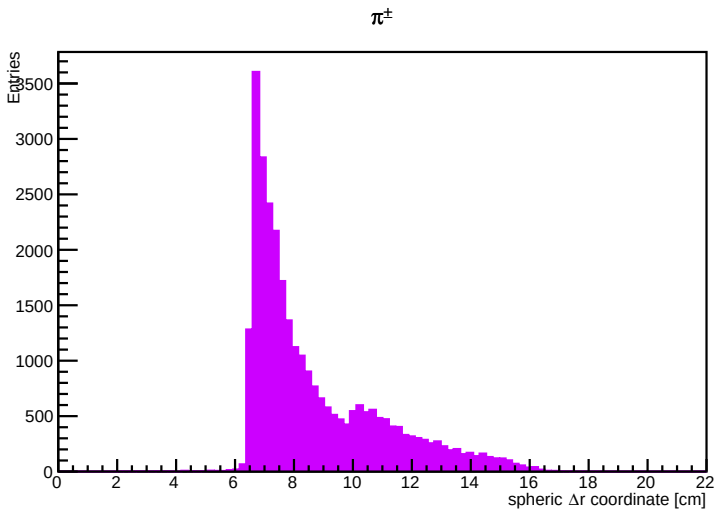

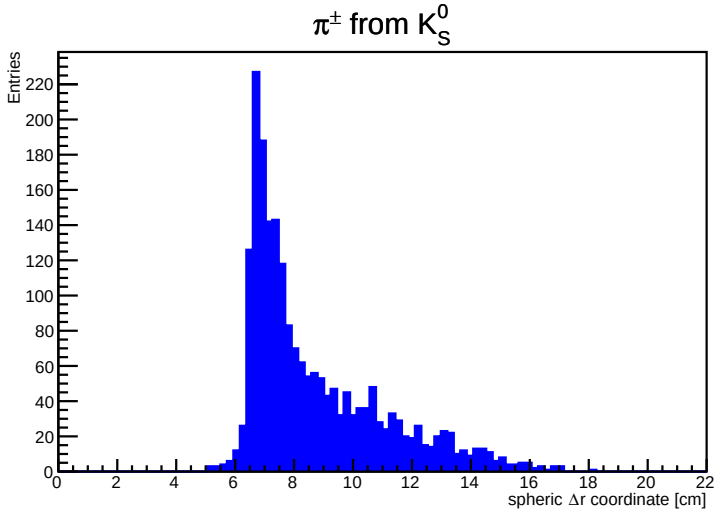

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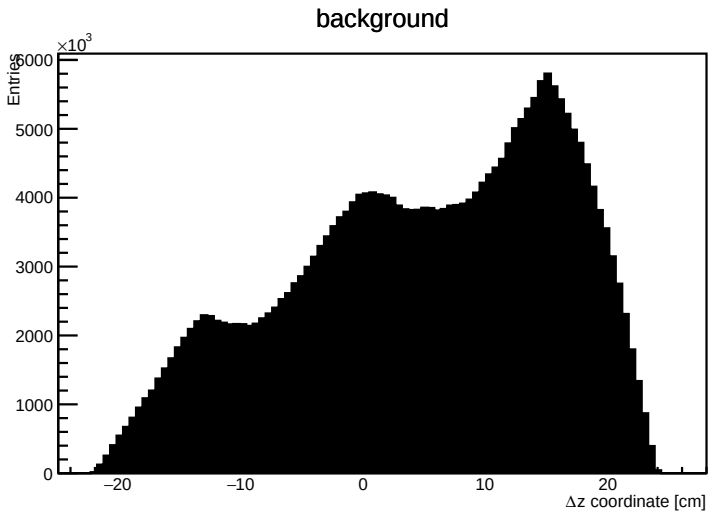

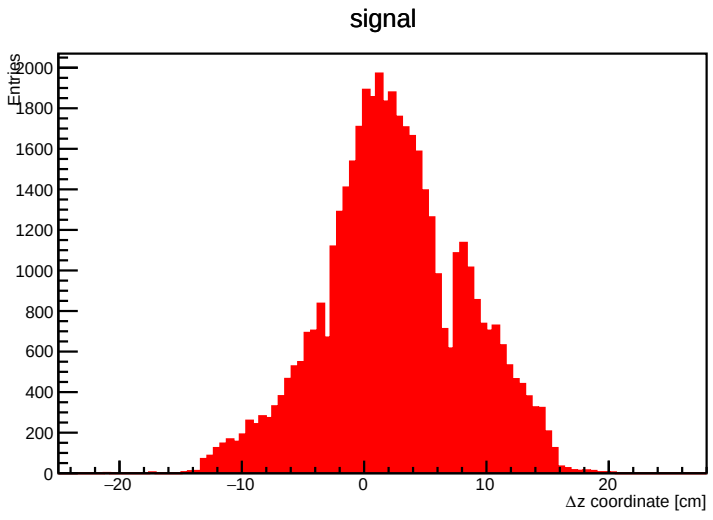

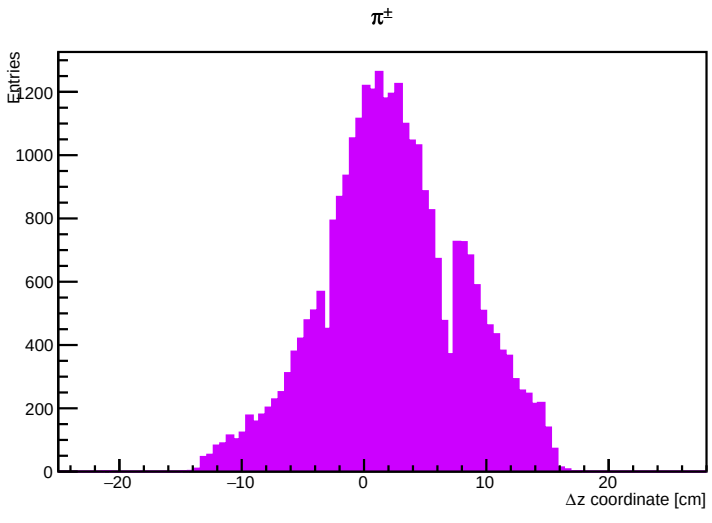

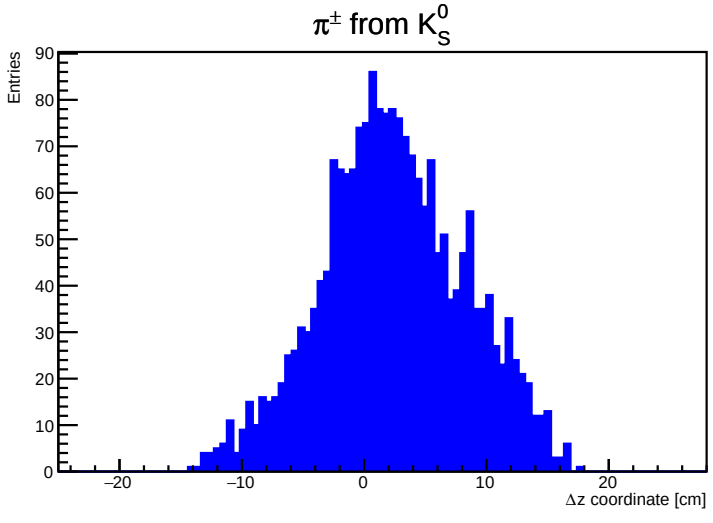

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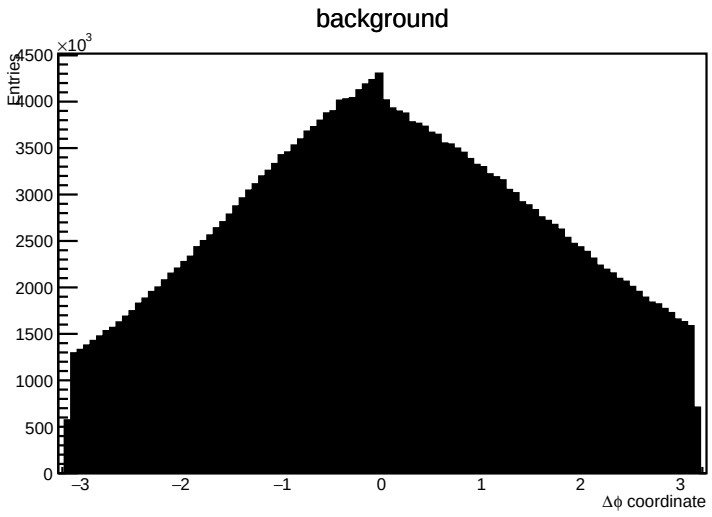

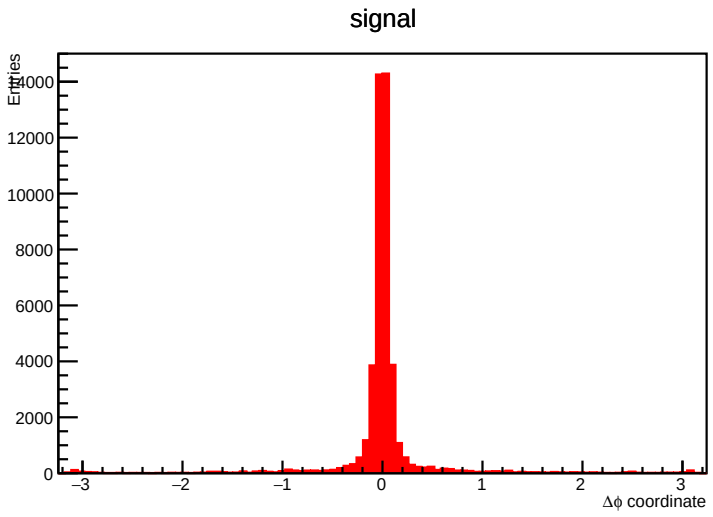

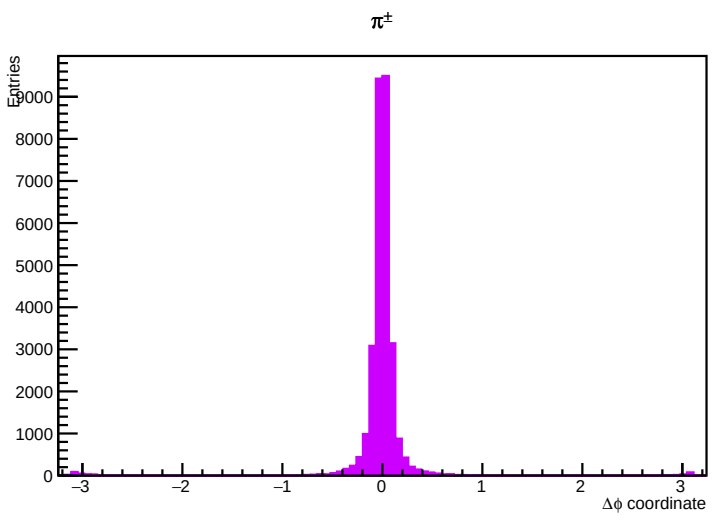

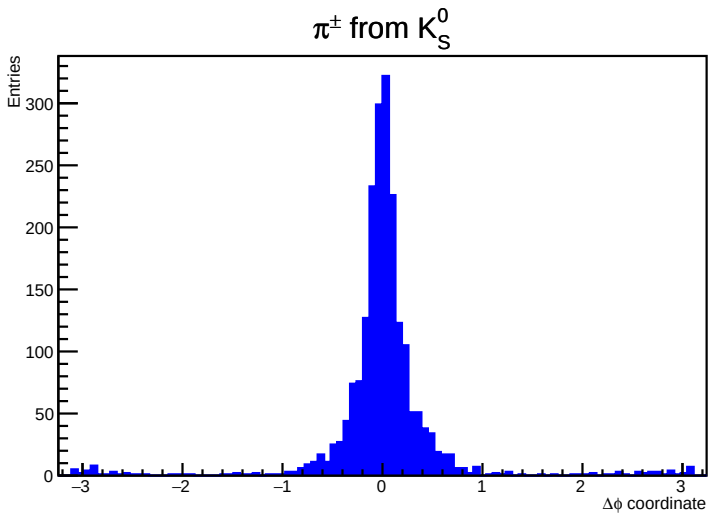

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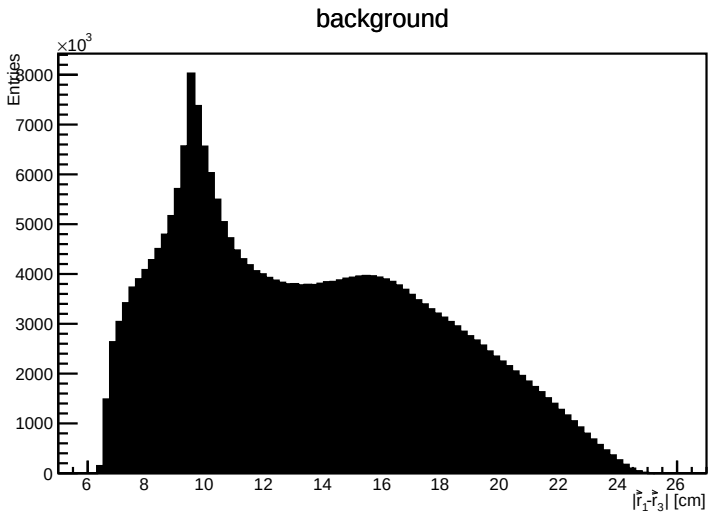

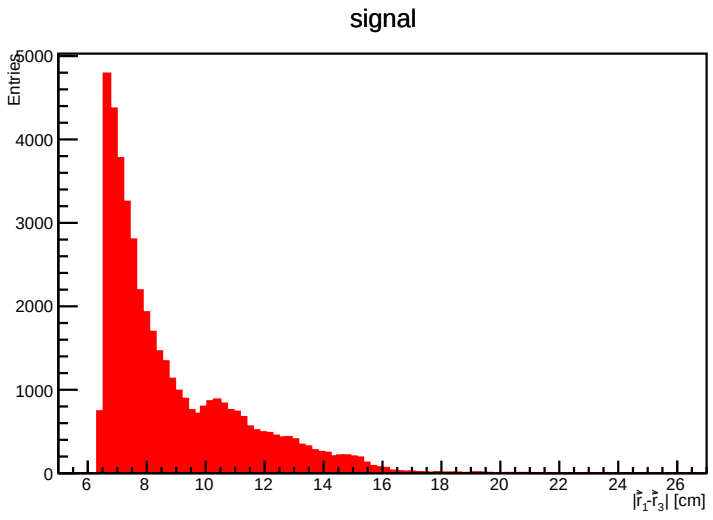

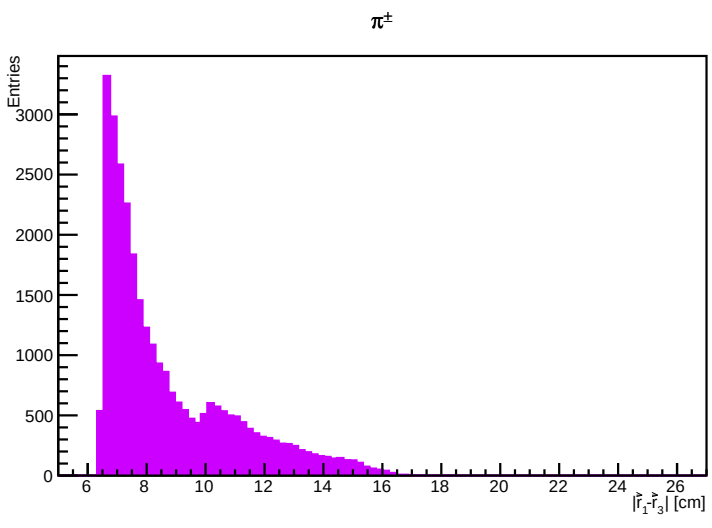

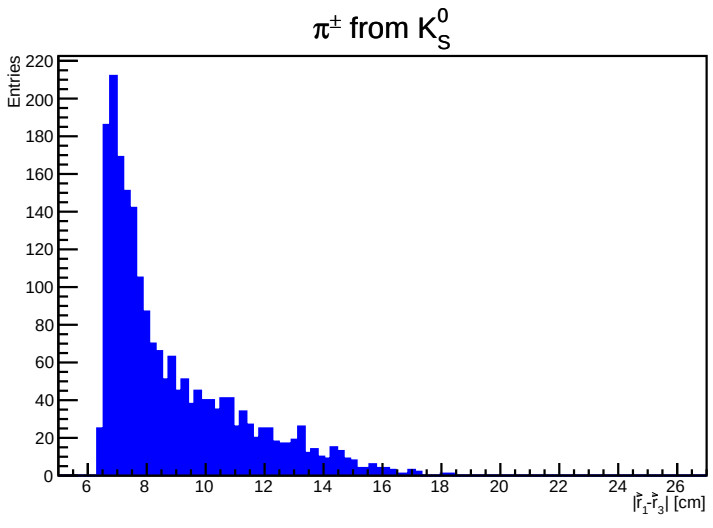

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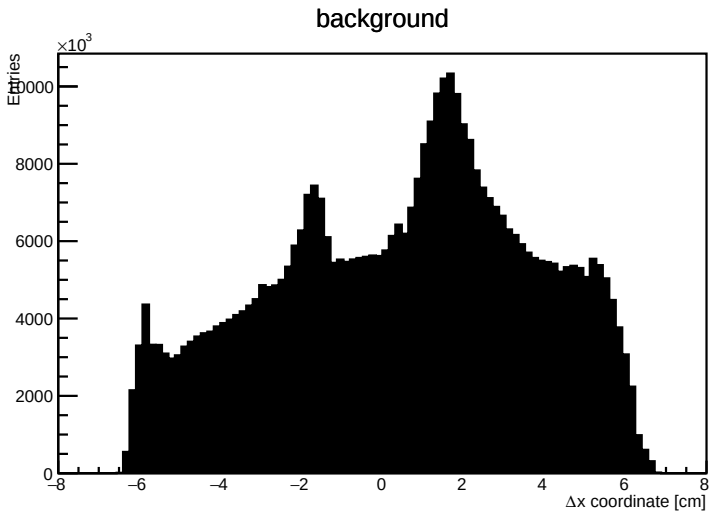

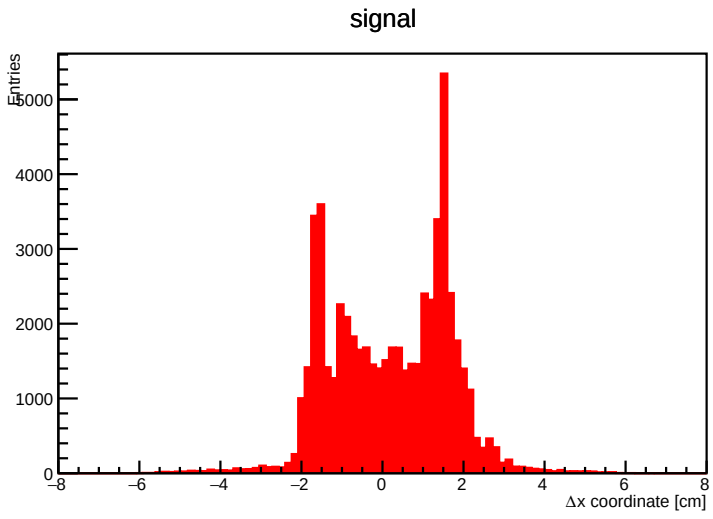

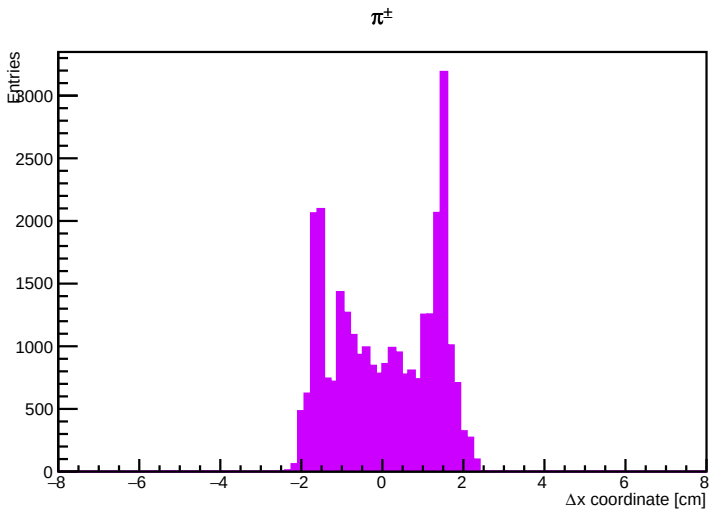

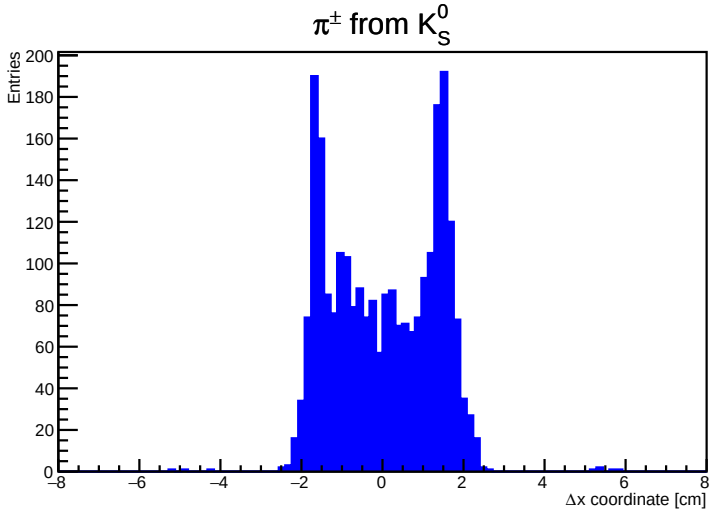

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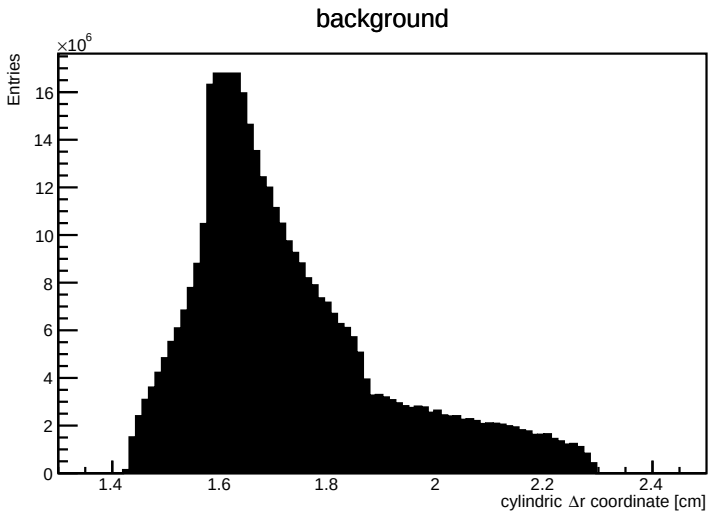

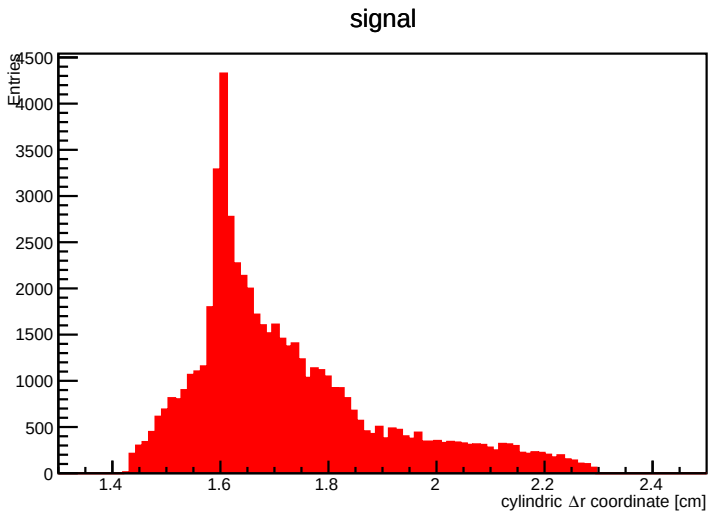

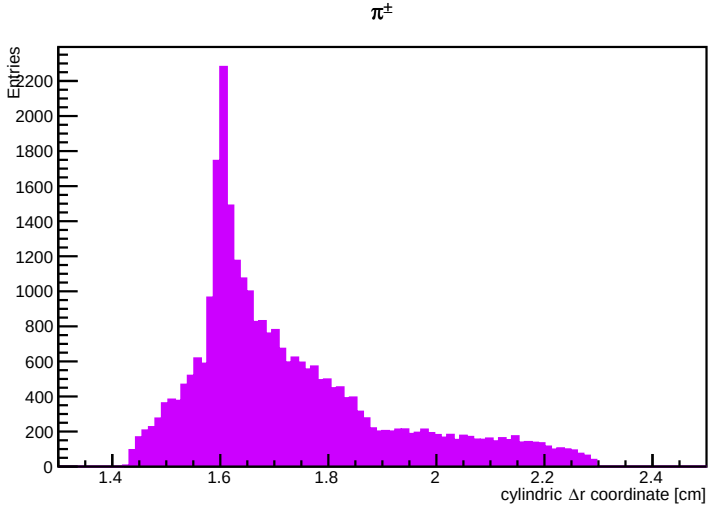

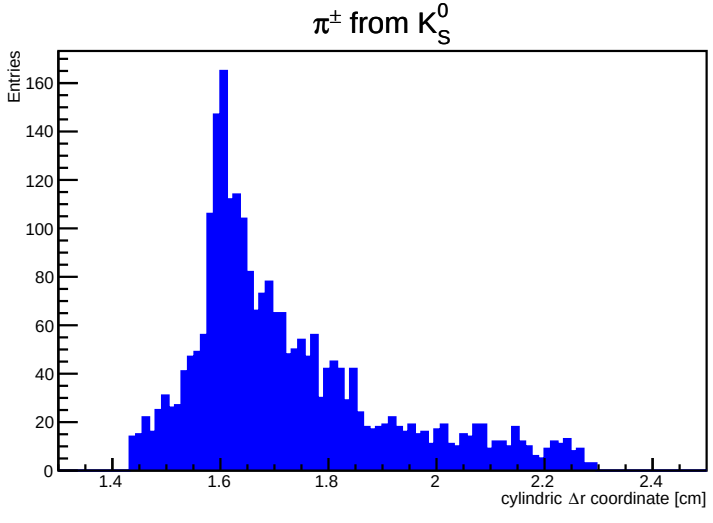

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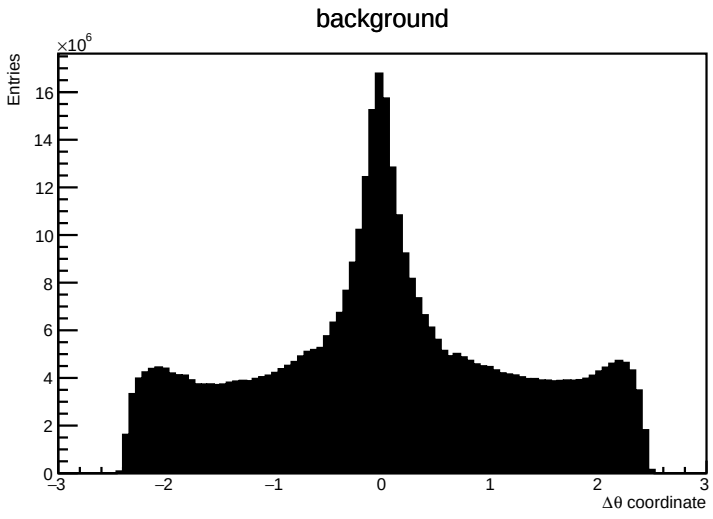

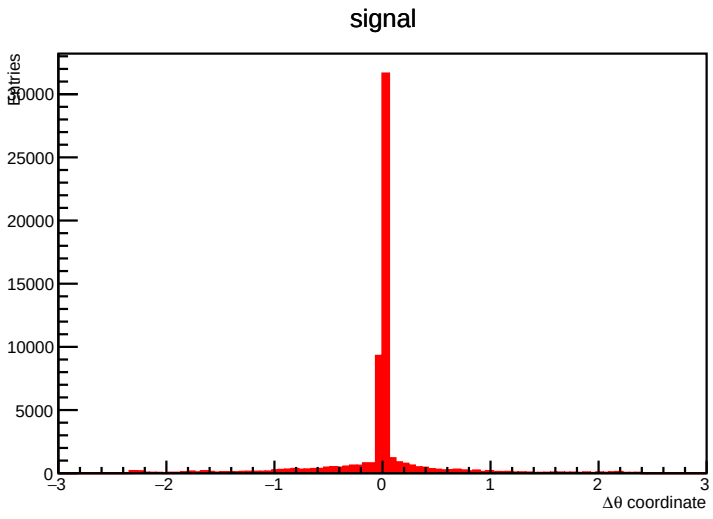

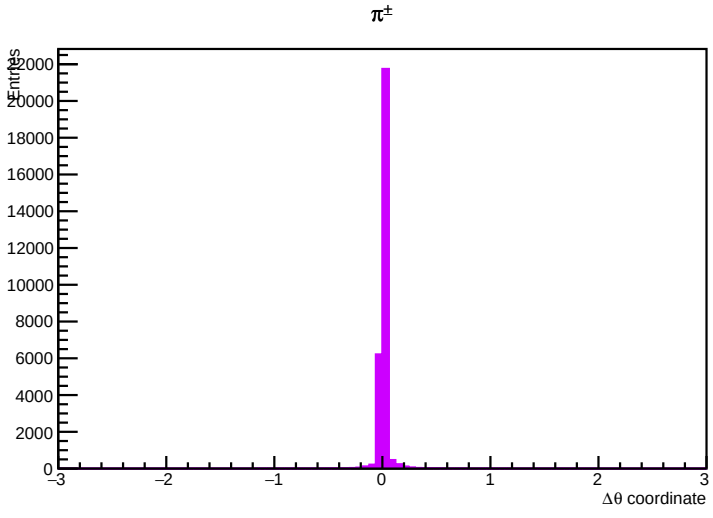

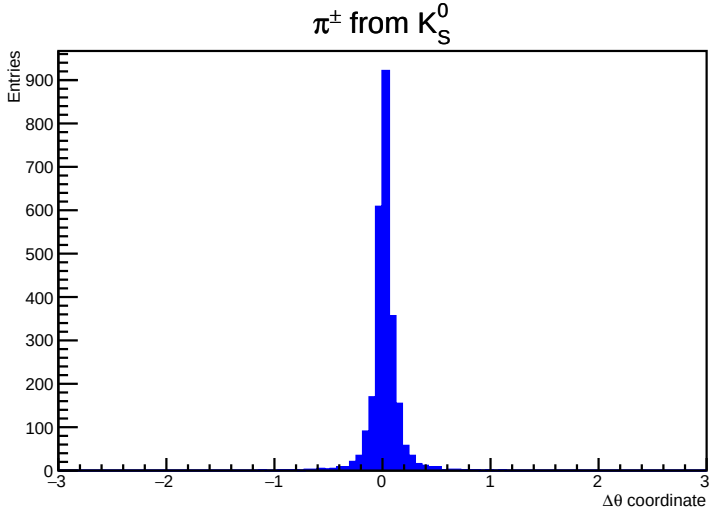

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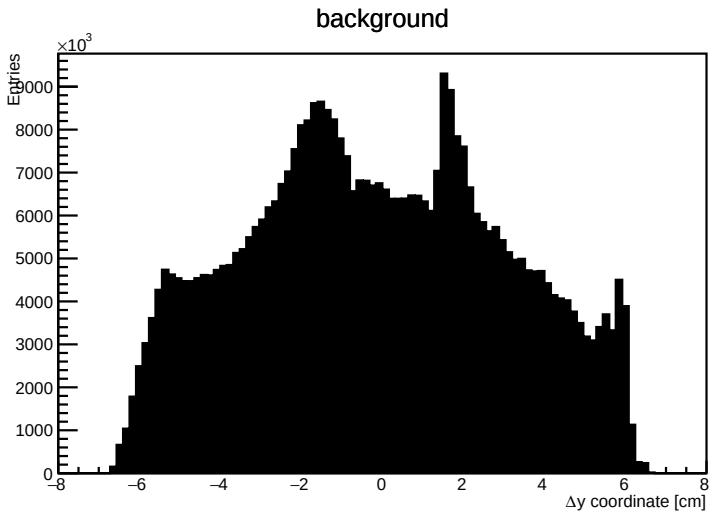

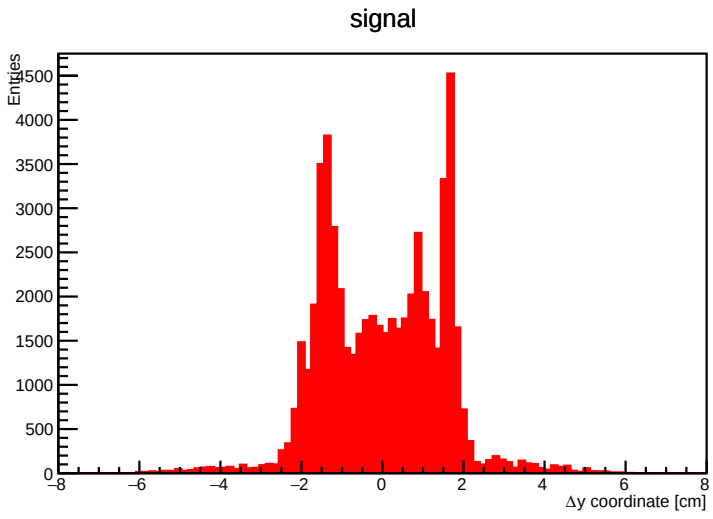

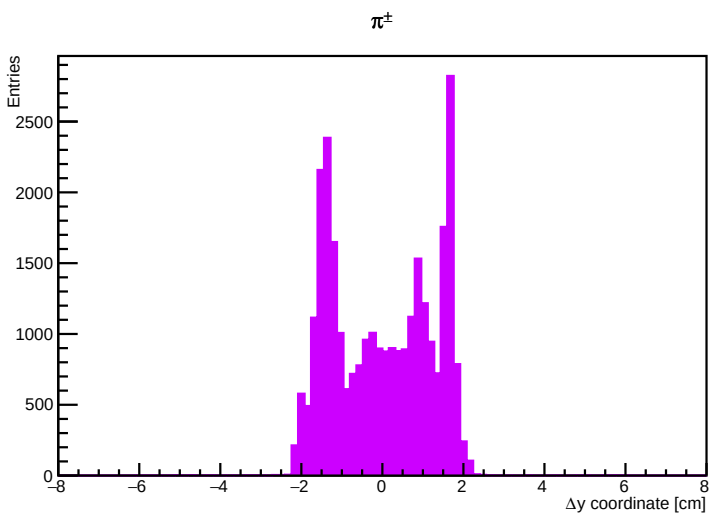

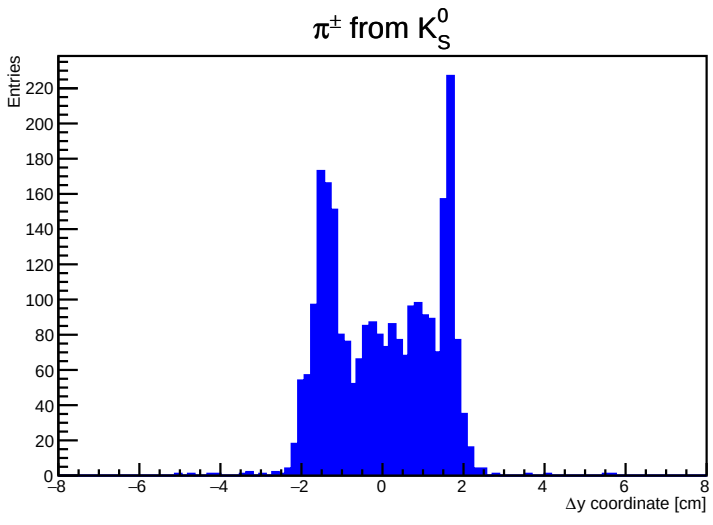

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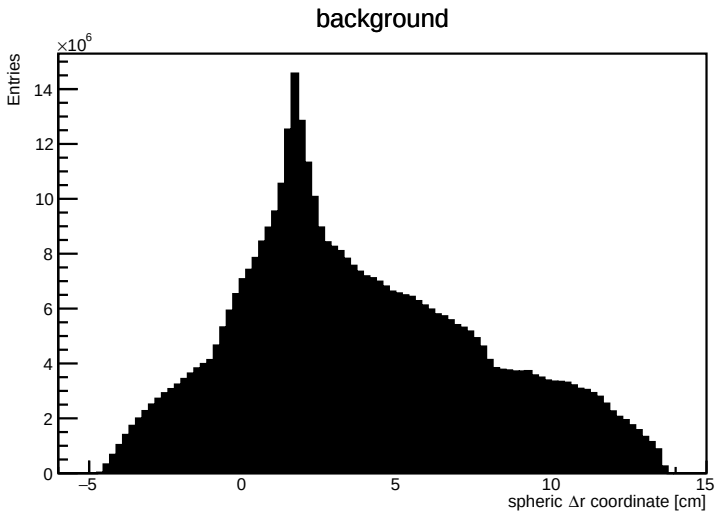

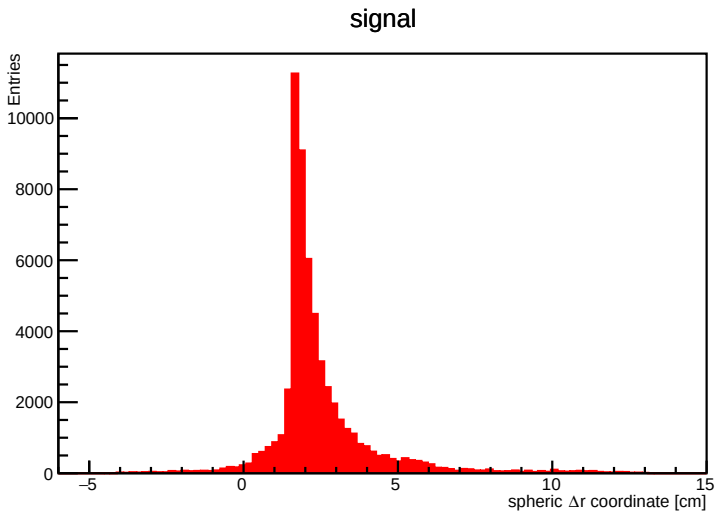

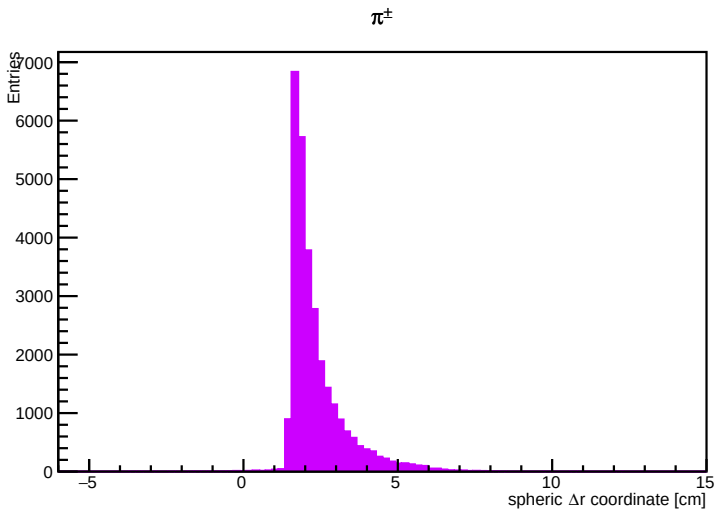

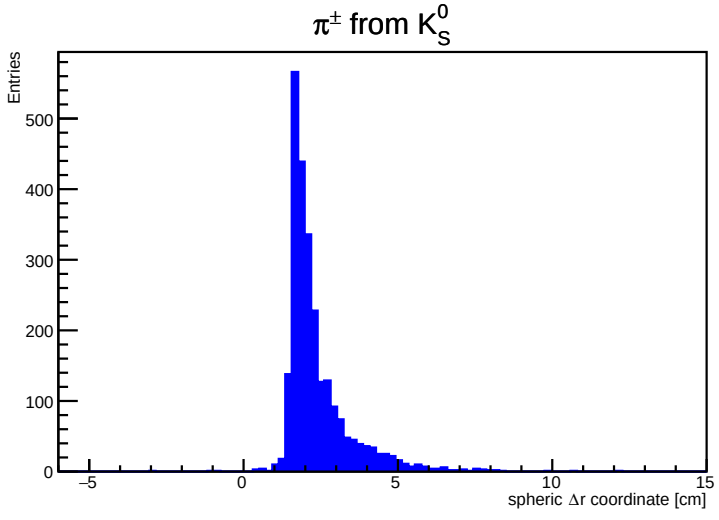

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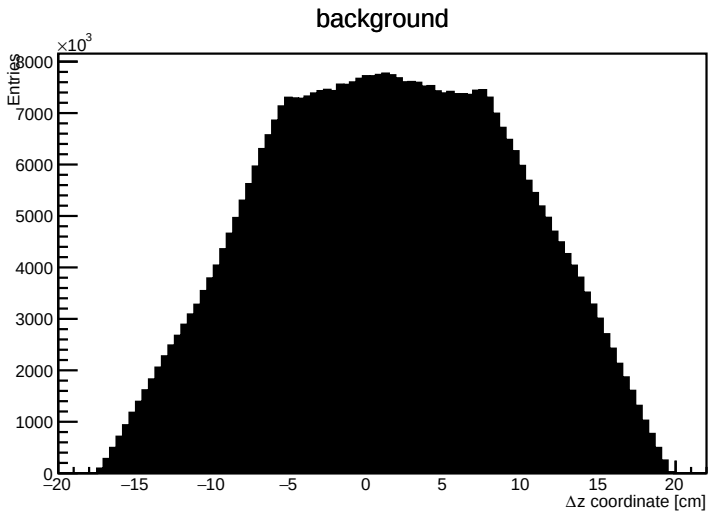

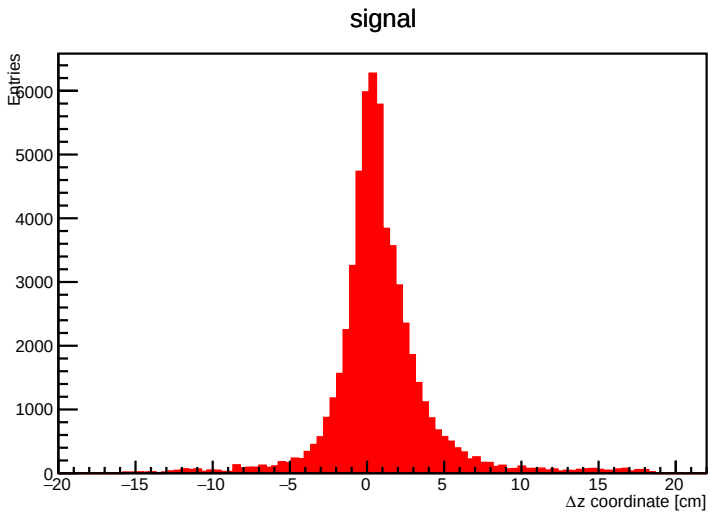

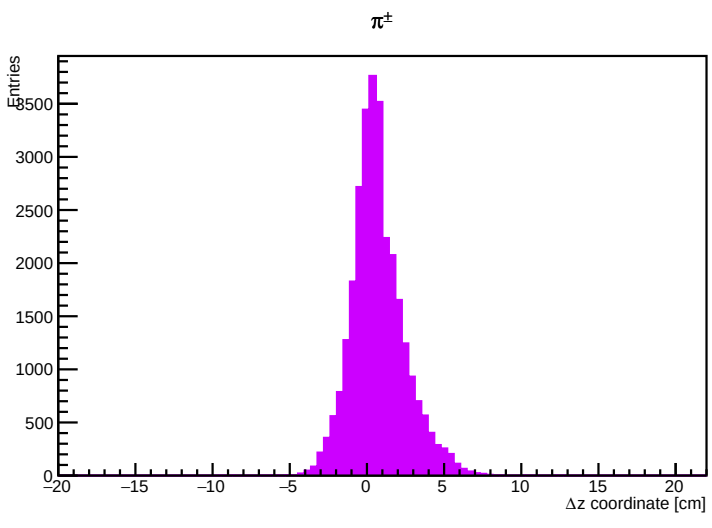

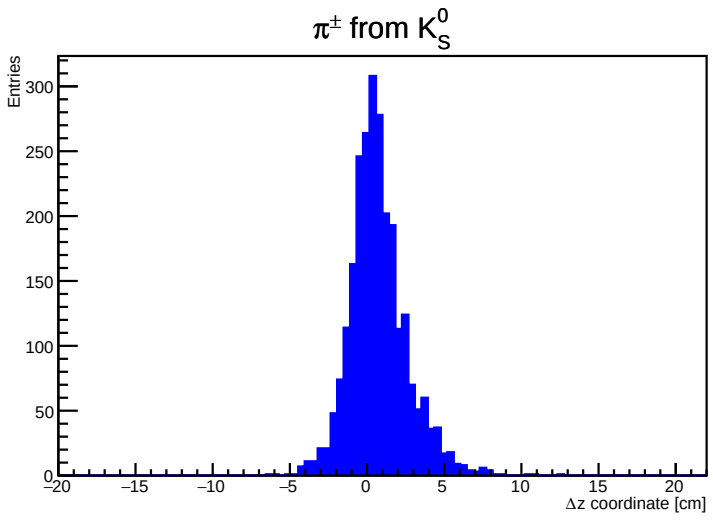

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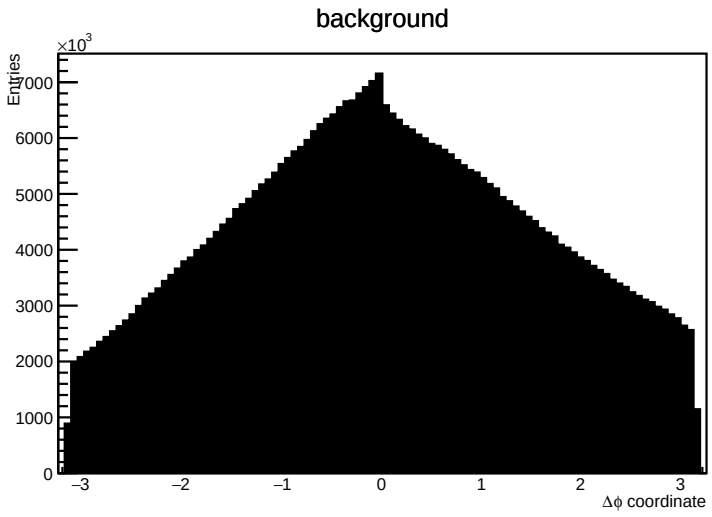

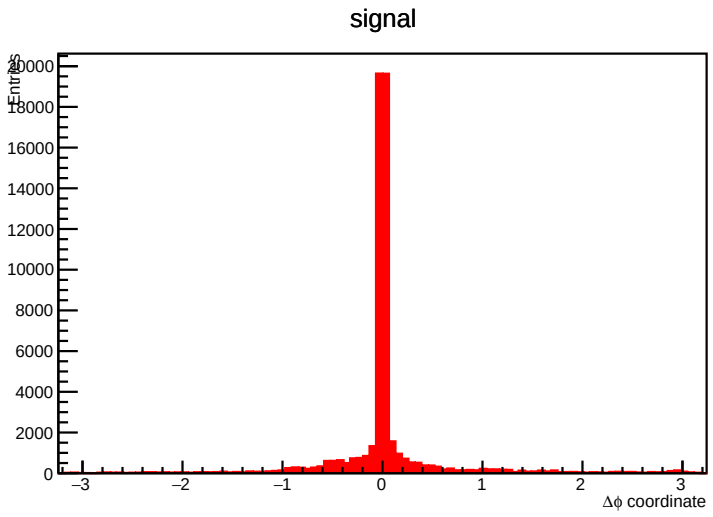

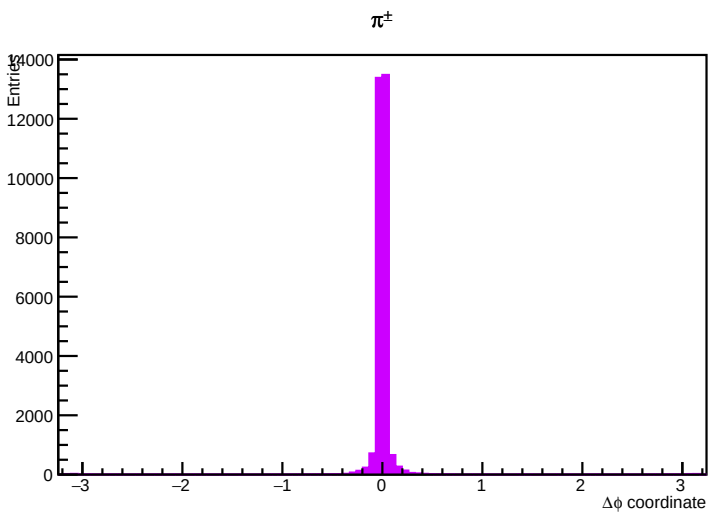

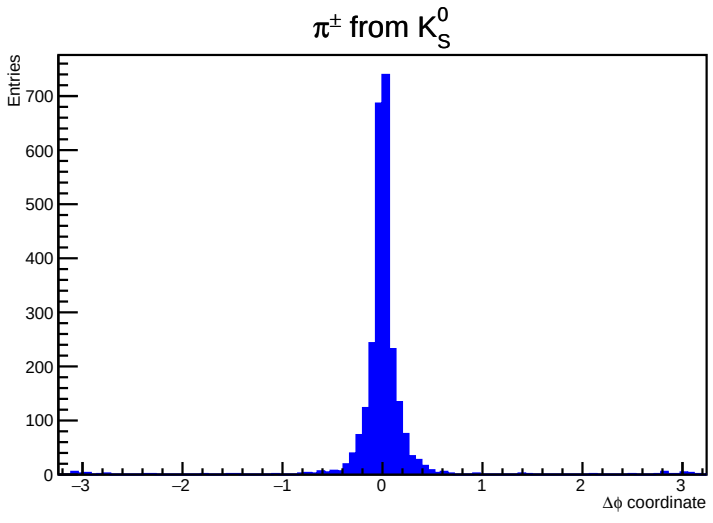

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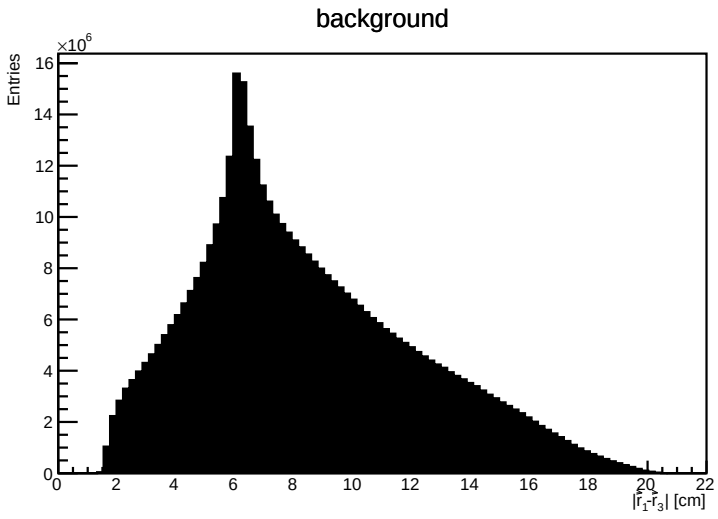

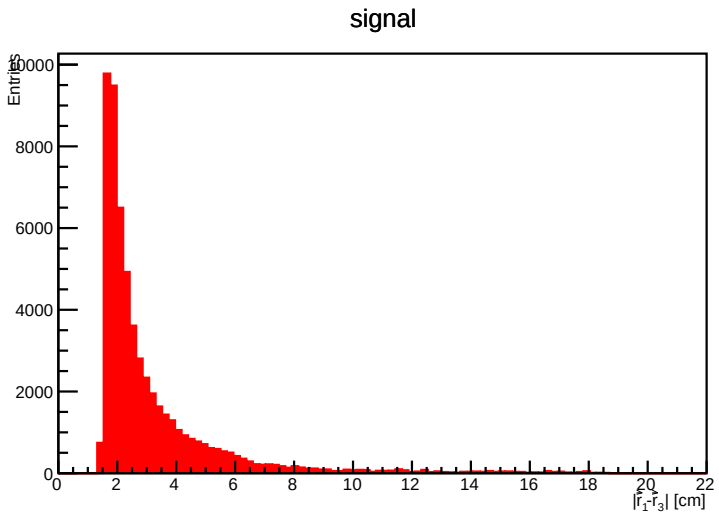

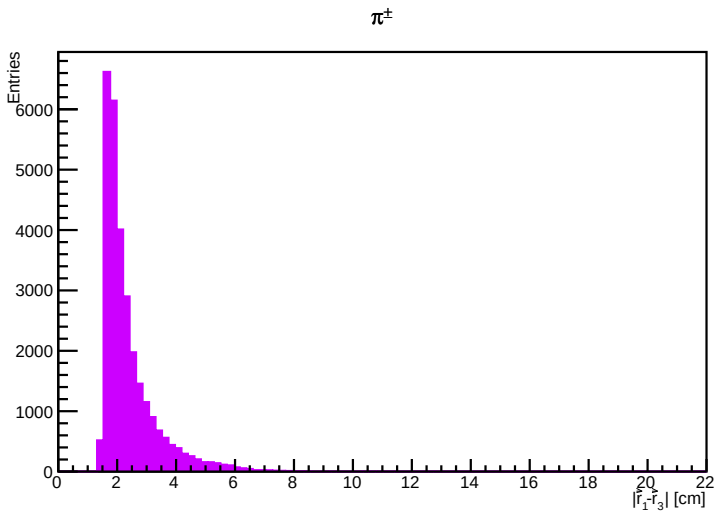

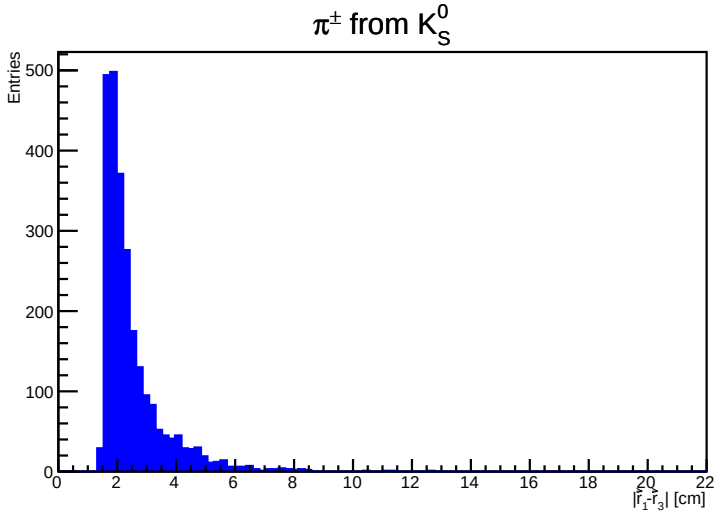

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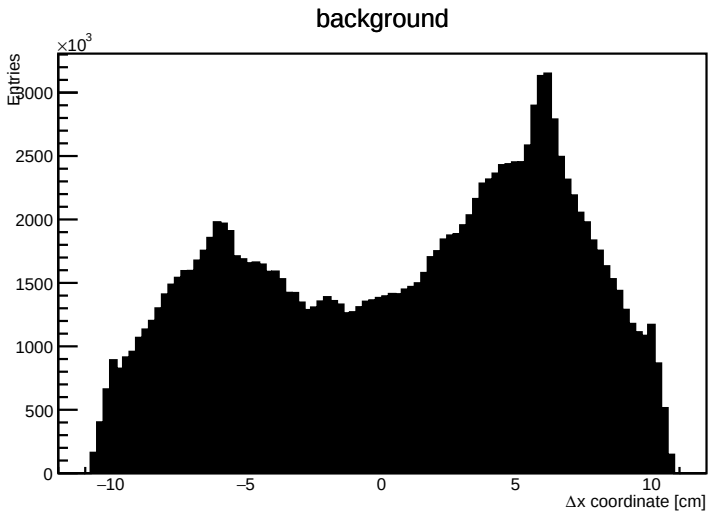

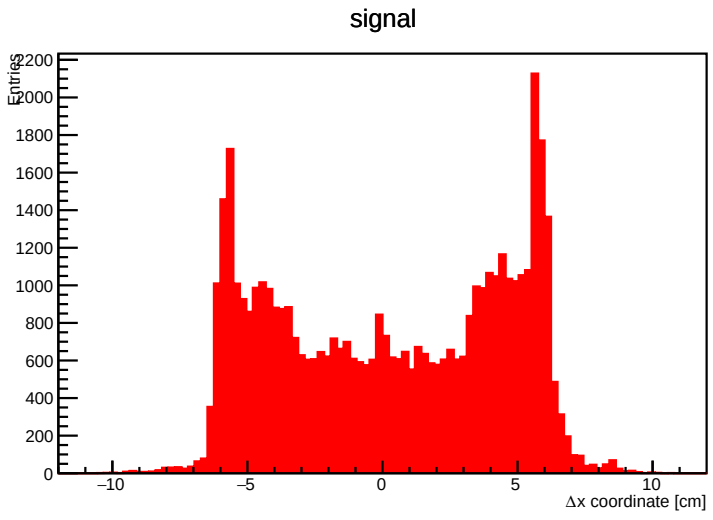

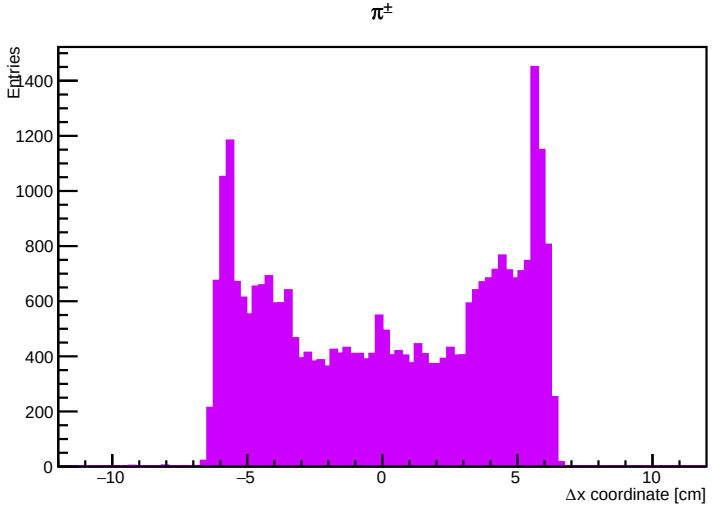

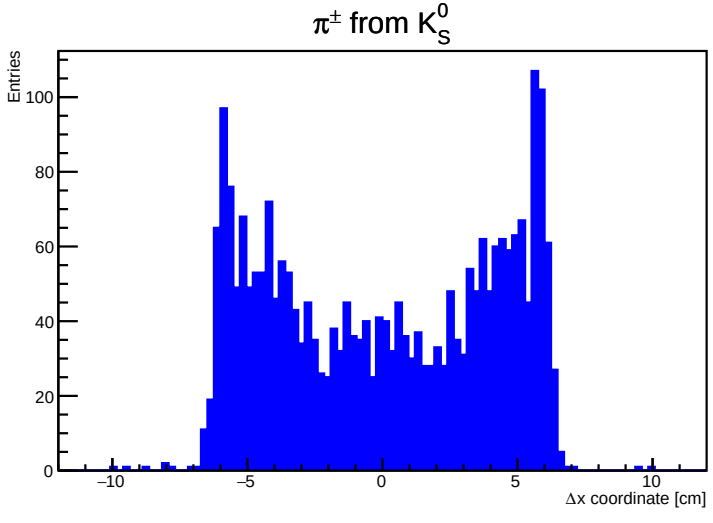

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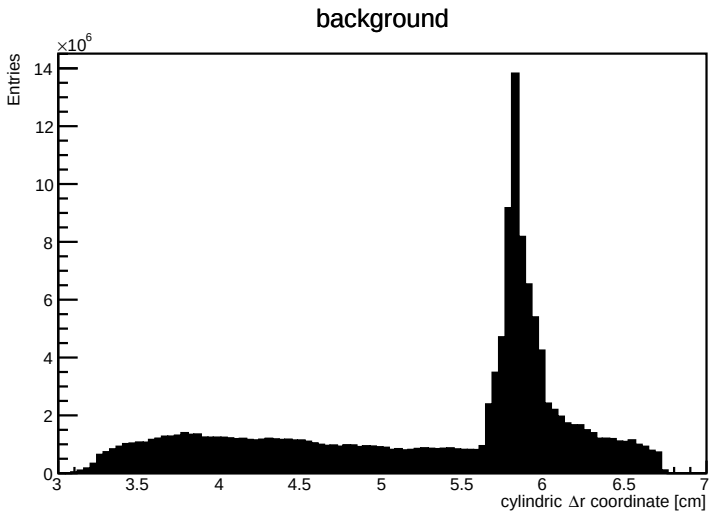

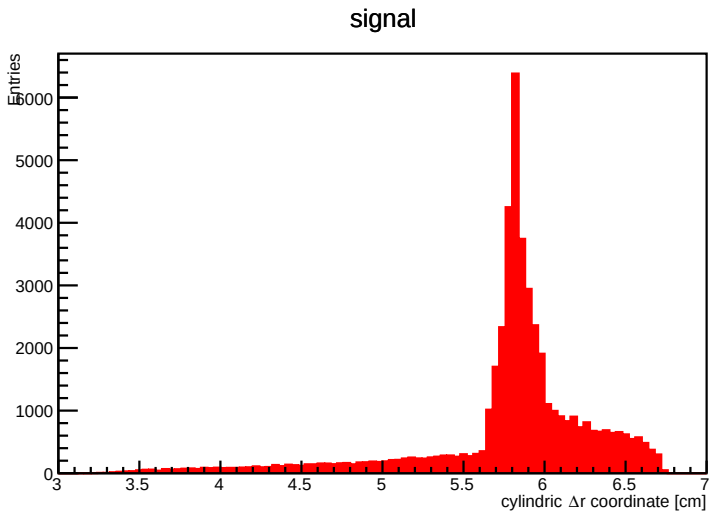

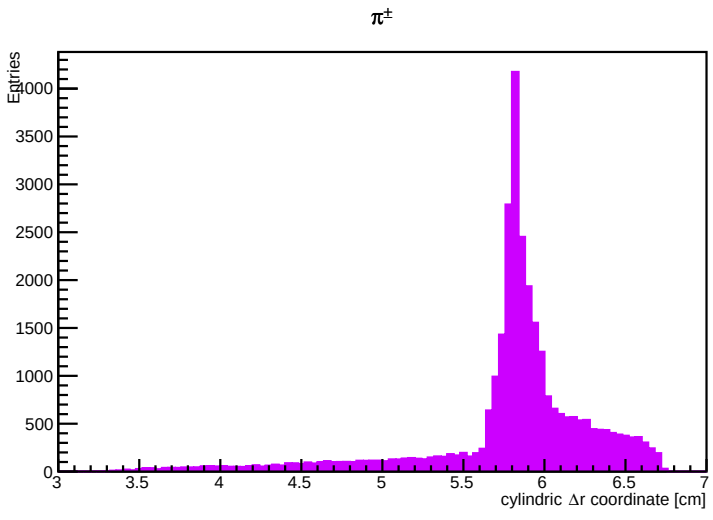

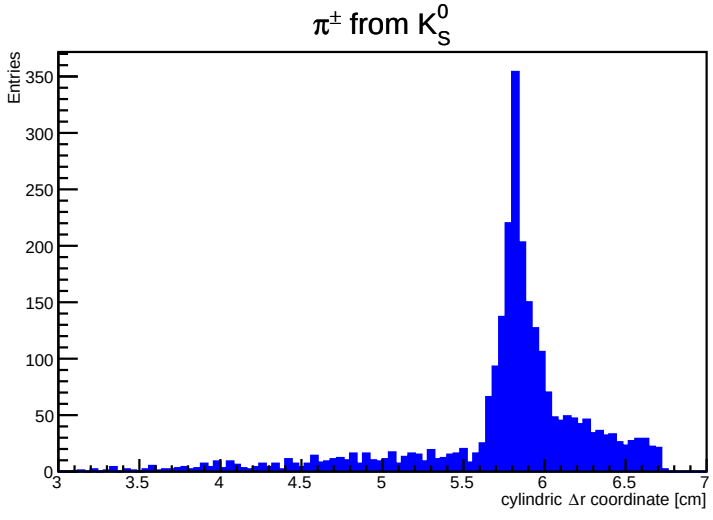

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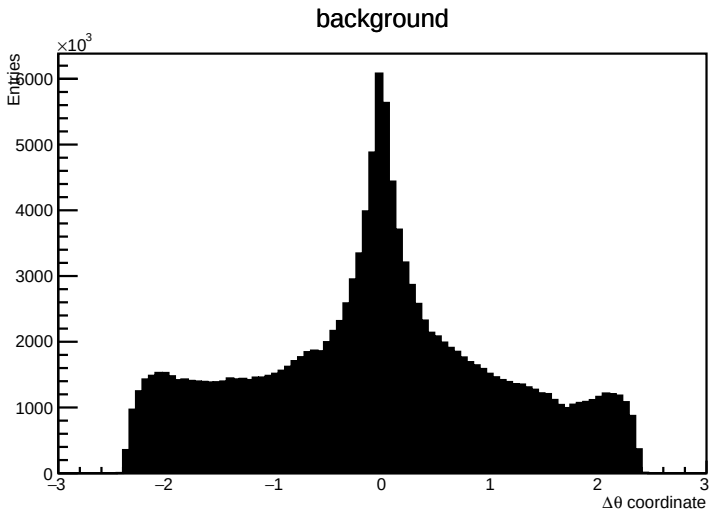

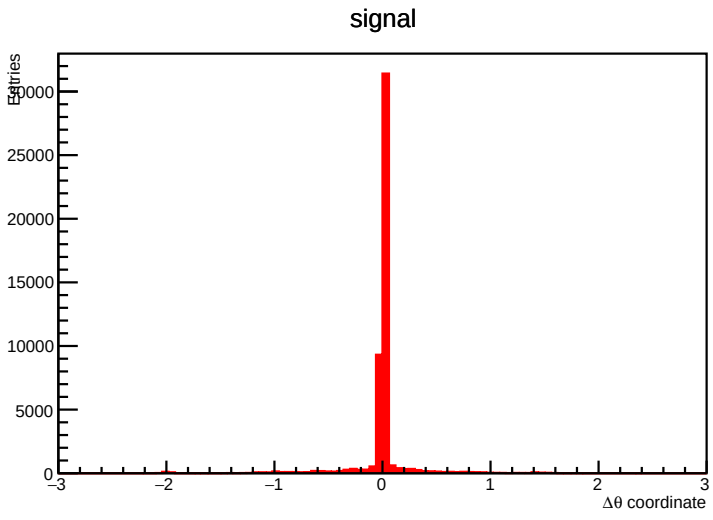

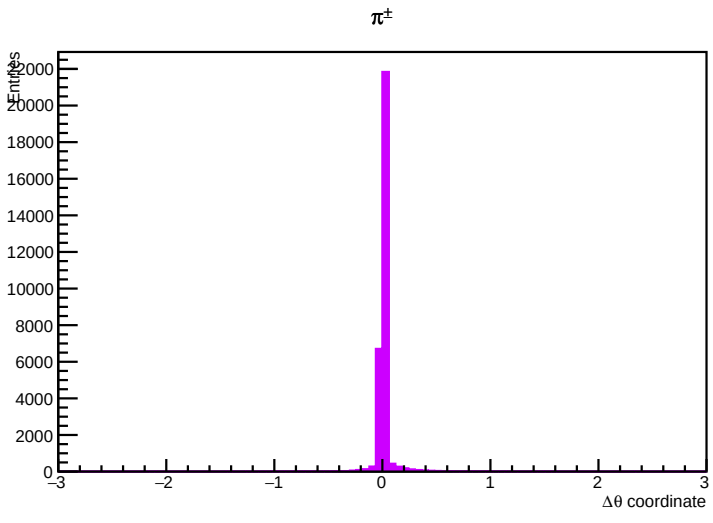

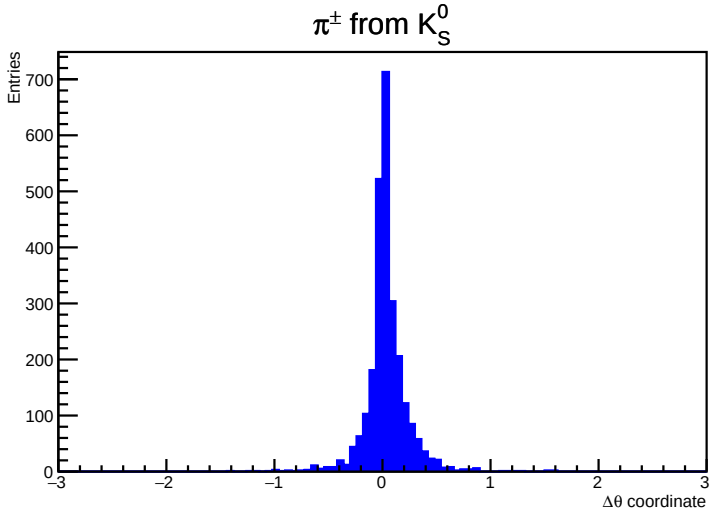

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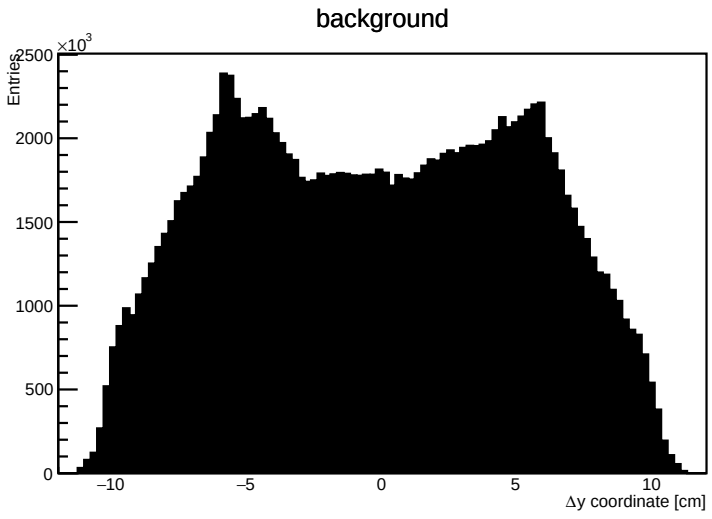

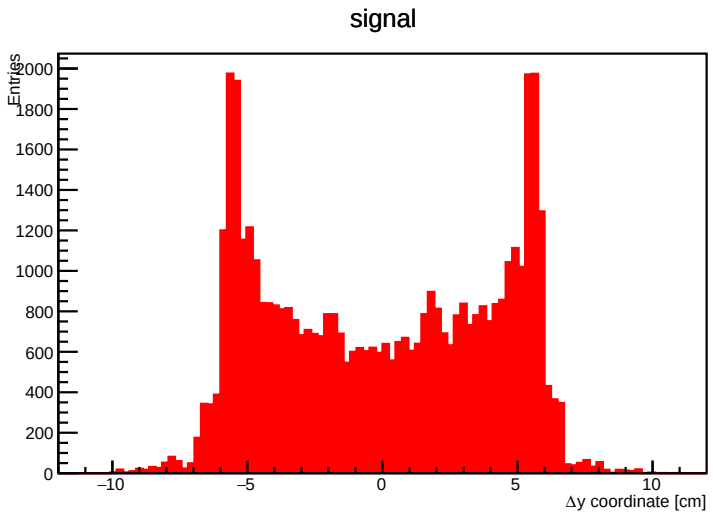

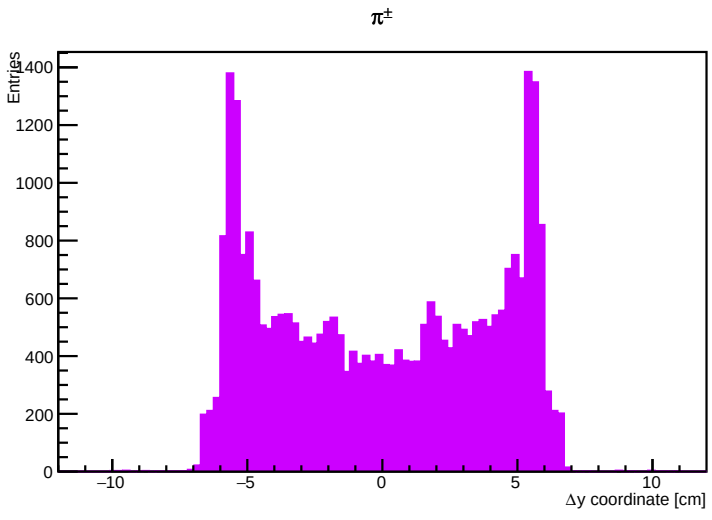

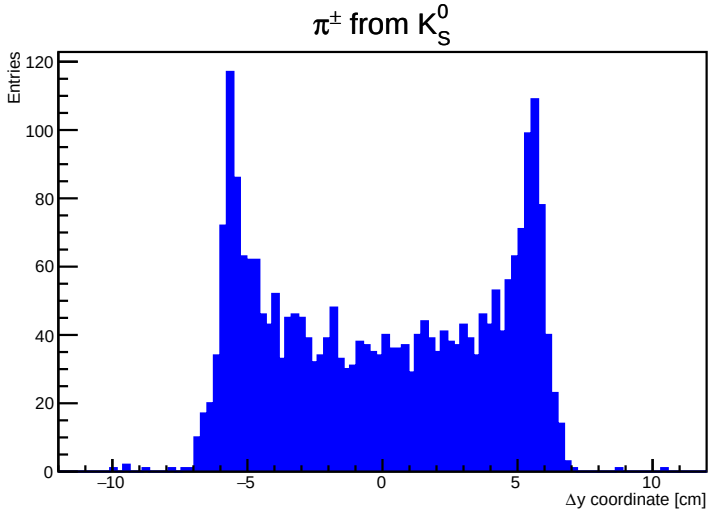

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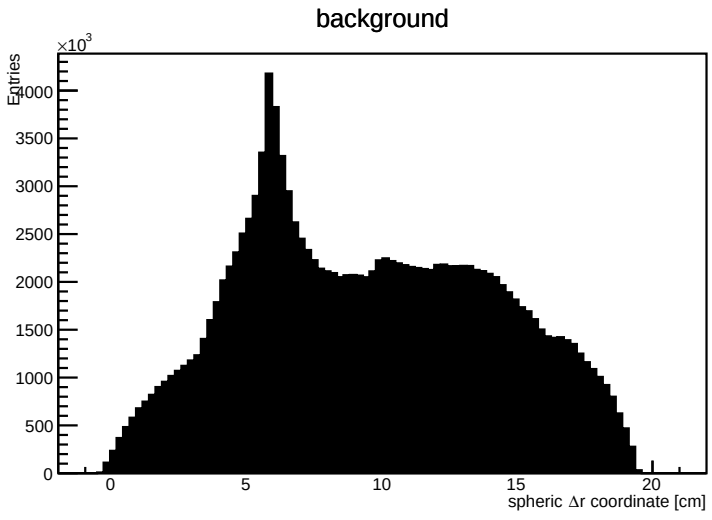

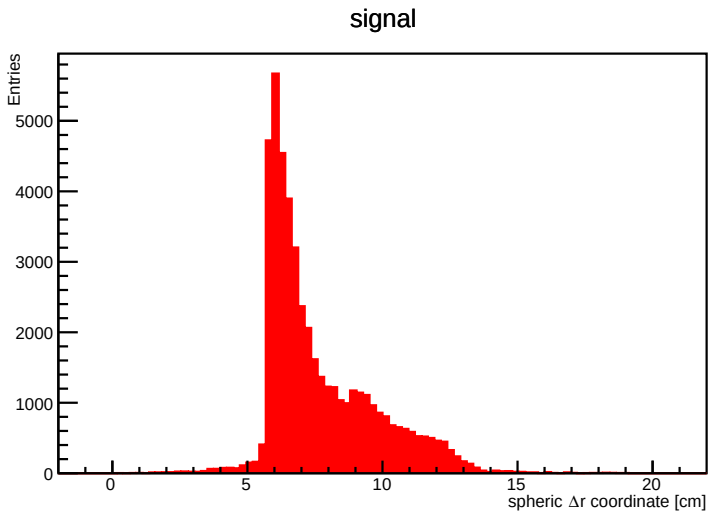

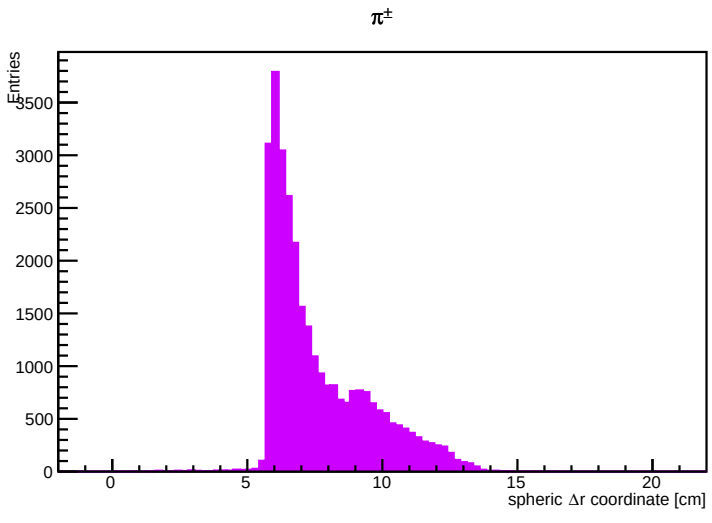

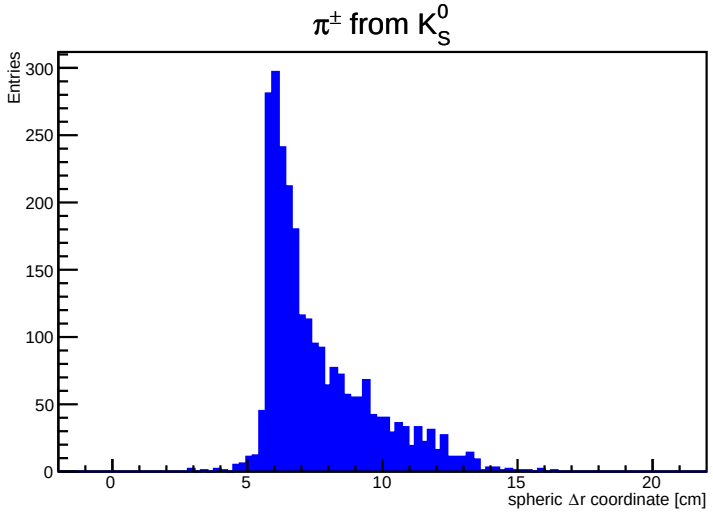

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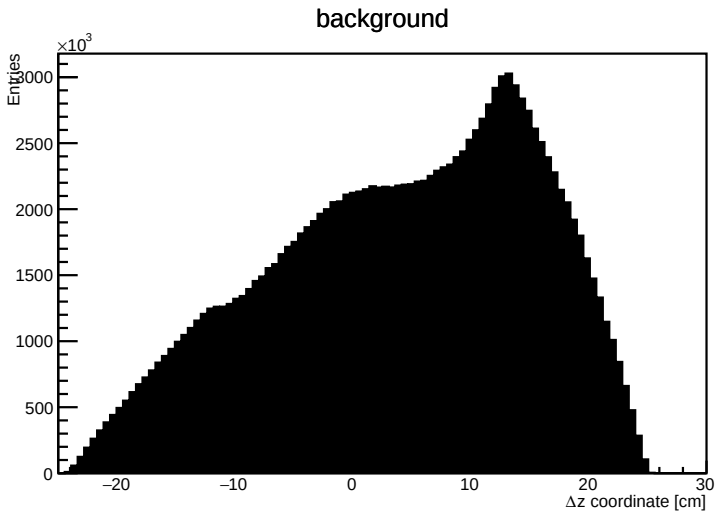

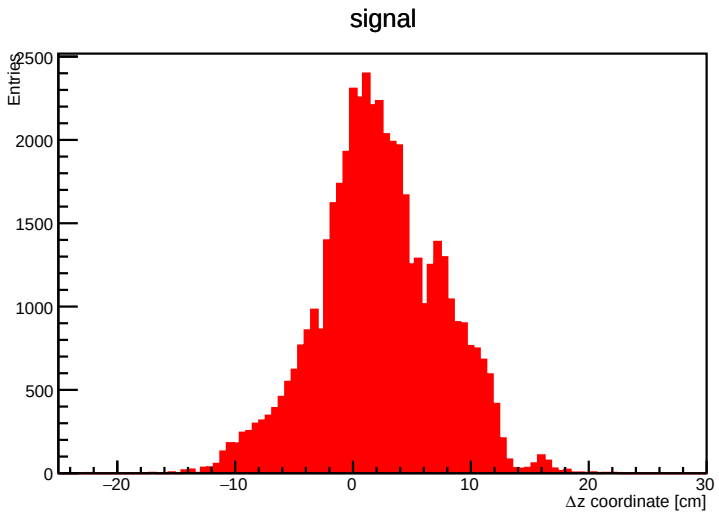

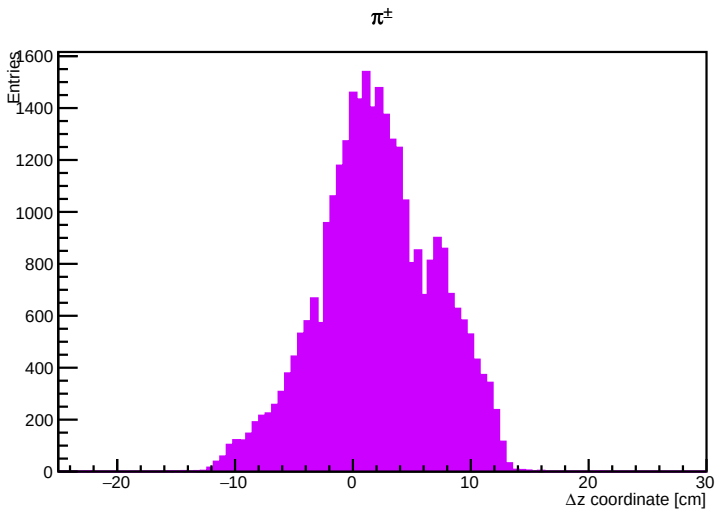

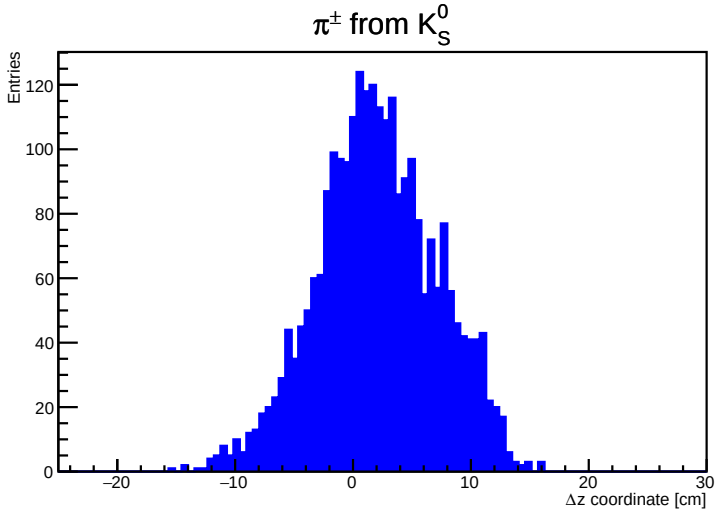

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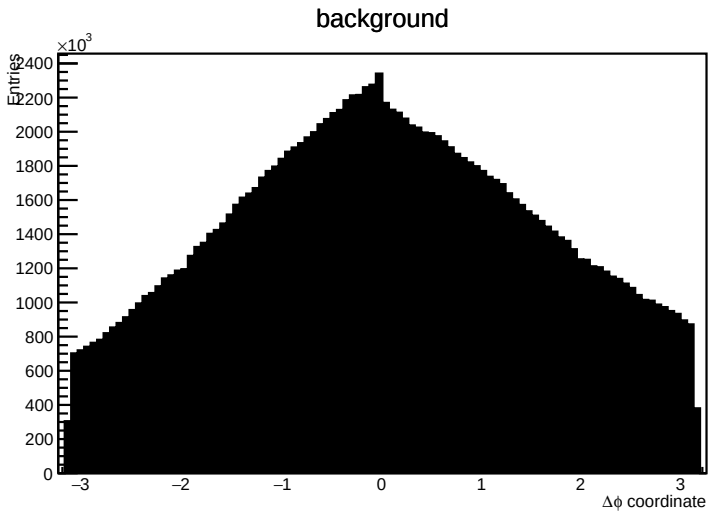

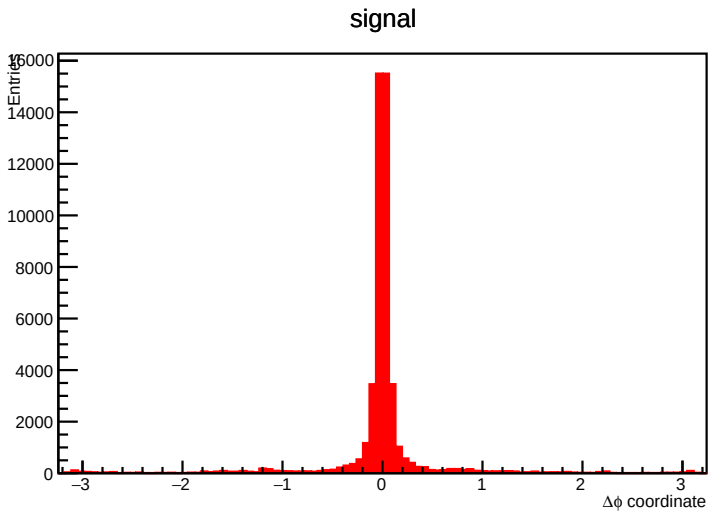

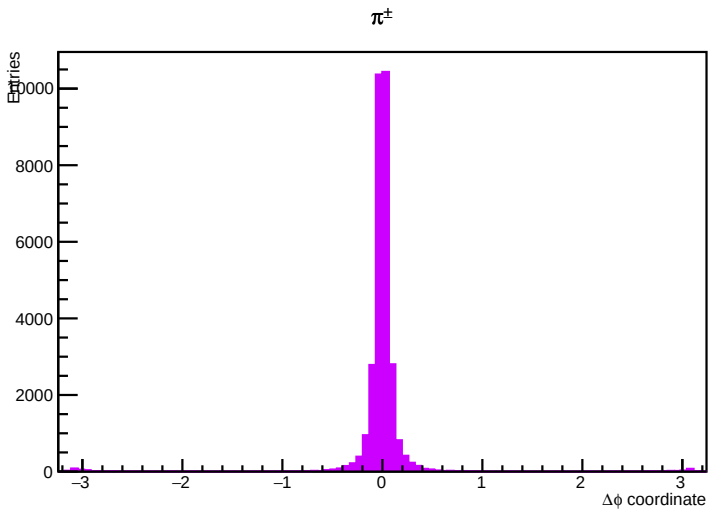

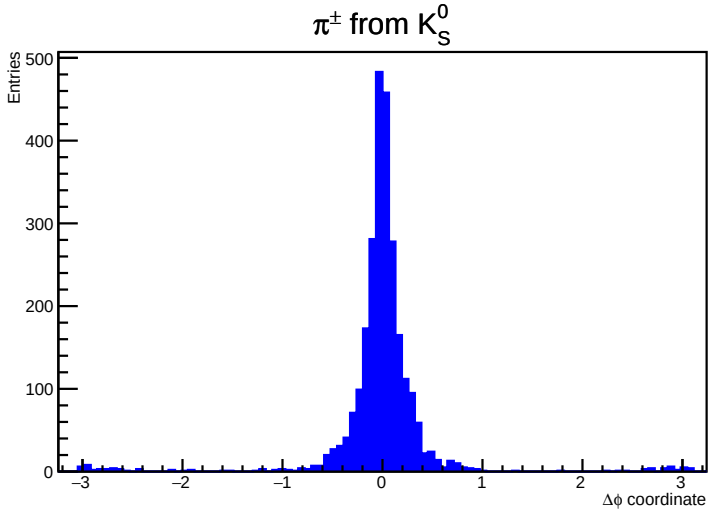

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