CLAS Collaboration Meeting

July 22, 2020

Particle Identification and Fiducial Volumes for the First SIDIS Publications

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Stefan Diehl

Justus Liebig University Giessen

University of Connecticut

Introduction

➔ The eventbuilder PID will be used as a basis for all particles

➔ Fiducial cuts are needed for the PCAL (electrons and photons) and for the DC (electrons and hadrons)

➔ Small refinements have been added for the single particle types

electrons	hadrons	photons
evb. PID 11	evb. PID	evb. PID 22
PCAL fiducial	DC fiducial	PCAL fiducial
DC fiducial	cut on the vertex difference to electrons	cut on β
cut on z-vertex, PCAL energy deposition and E/p	cut on chi2PID	

Eventbuilder Particle ID and Refinements

a) Electron ID

➔ For the first SIDIS publications, only electrons in the FD will be used

➔ This is ensured by a cut on the status of the particle

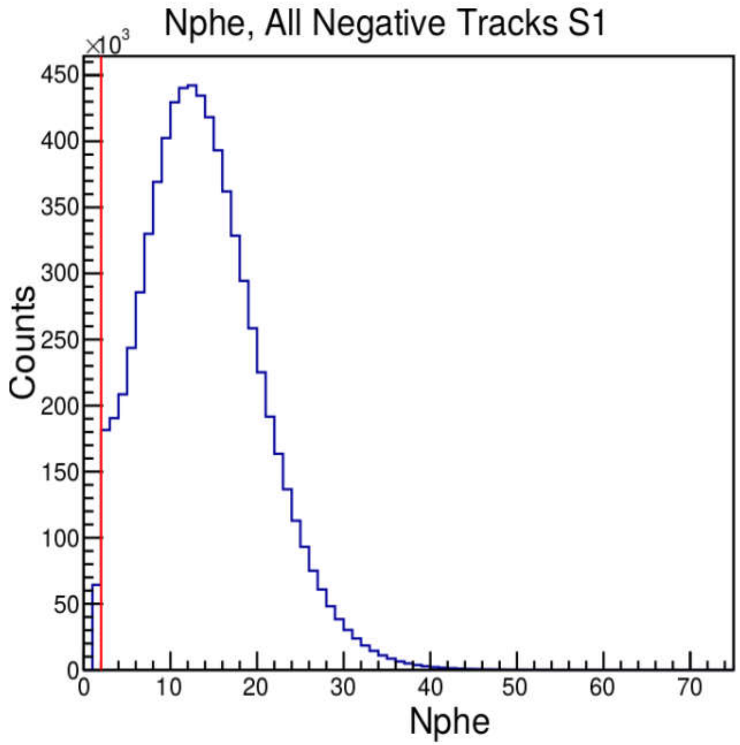
➔ In addition, the following cuts are applied

Cut	Limits	refinement
Charge	-1	
Number of Photoelectrons	$N_{ph} > 2$	
Min. PCAL Energy	$\mathrm{PCAL}_{dep} > 60$ MeV	> 70 MeV
Sampling Fraction vs E_{dep}	$\pm 5\sigma$	E/p > 0.17

+ z-vertex cut

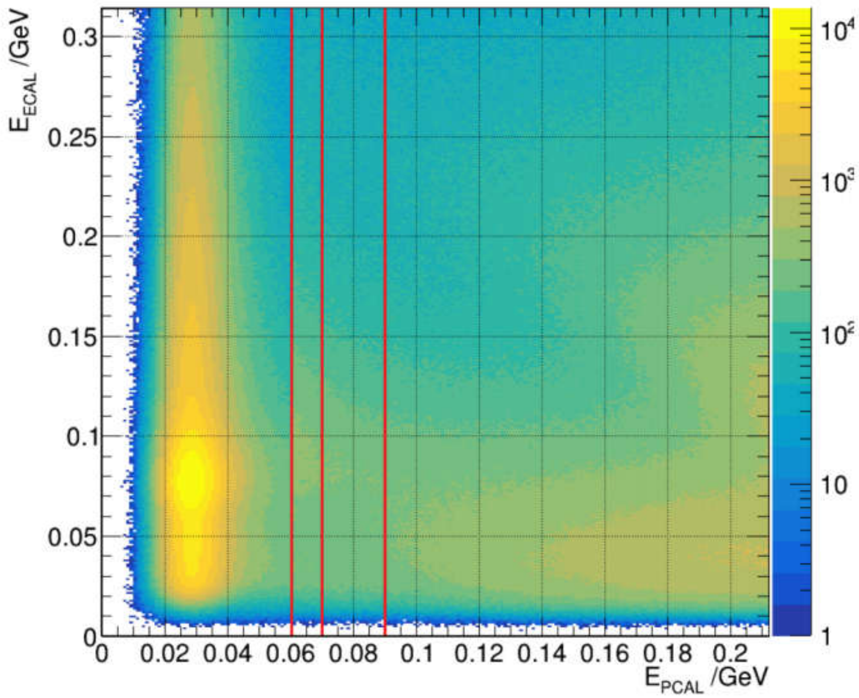
Electron ID

Number of Cherenkov Photoelectrons



$$N_{ph} > 2$$

Minimum PCAL Energy Threshold Cut

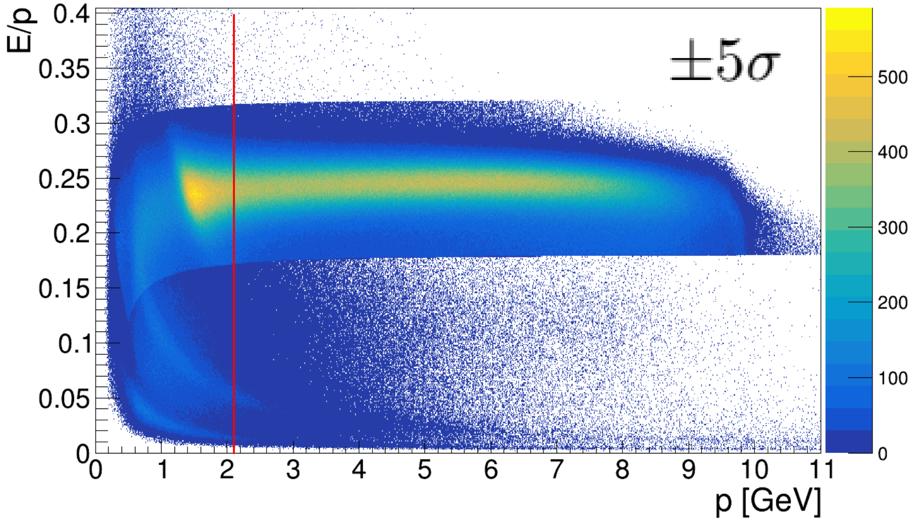


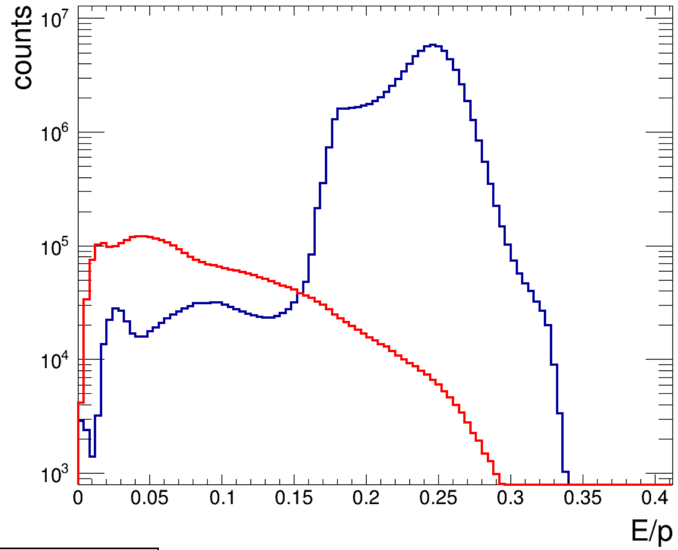
eventbuilder: 0.06 GeV **refined cut: 0.07 GeV**

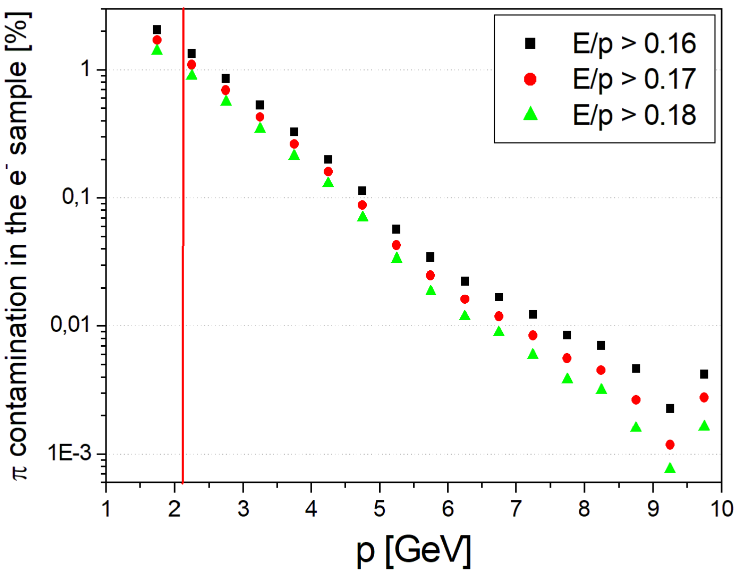
- The refined cut is survived by 99.85 % of PID 11 electrons

➔ No significant effect, motivated by the distribution

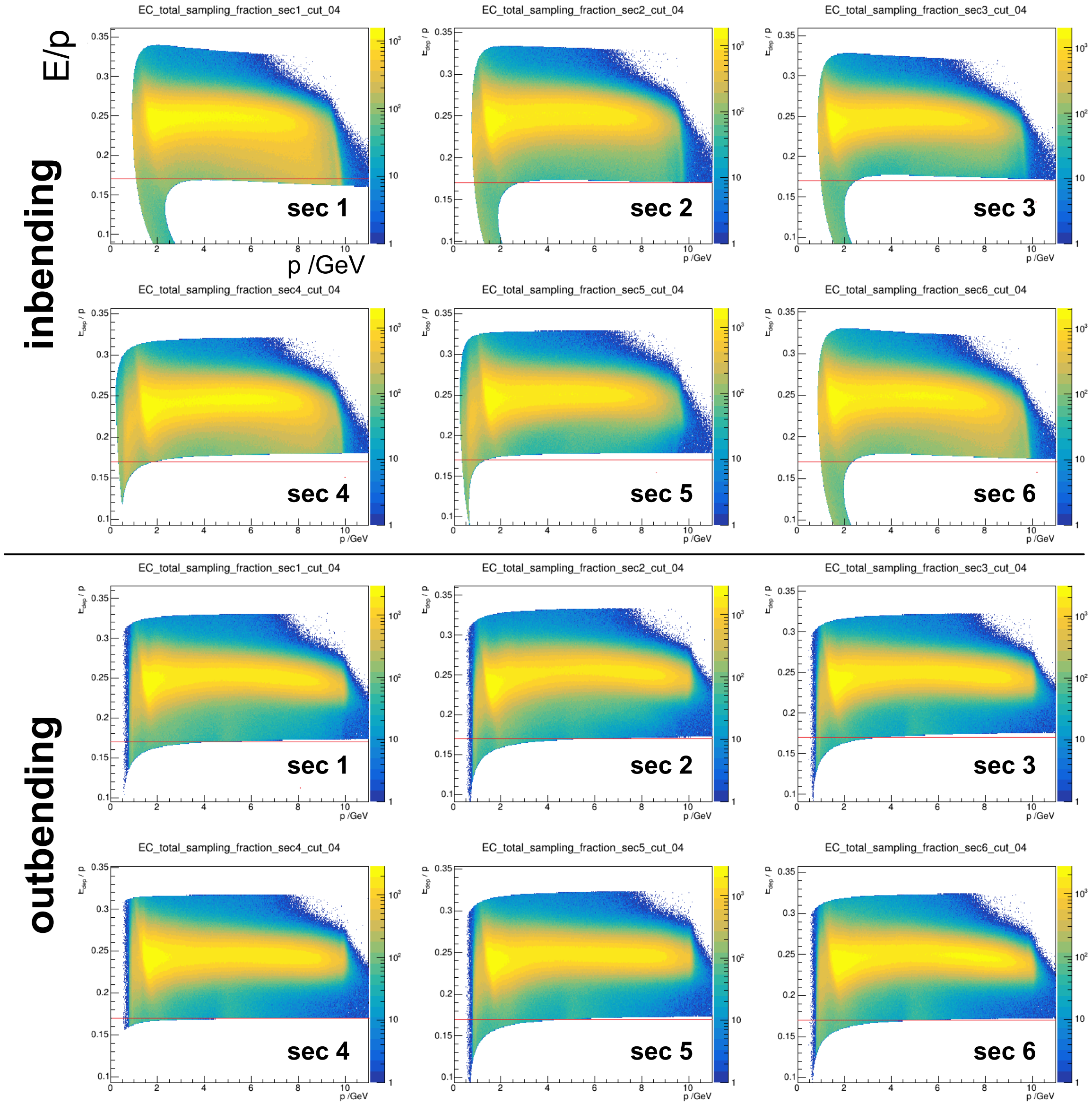
Electron ID


E/p
$\pm5\sigma$
p [GeV]
0
1
2
3
4
5
6
7
8
9
10
11
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
100
200
300
400
500


counts
E/p
10^3
10^4
10^5
10^6
10^7
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


π contamination in the e$^-$ sample [%]
p [GeV]
E/p > 0.16
E/p > 0.17
E/p > 0.18
1
0,1
0,01
1E-3
1
2
3
4
5
6
7
8
9
10

Electron ID



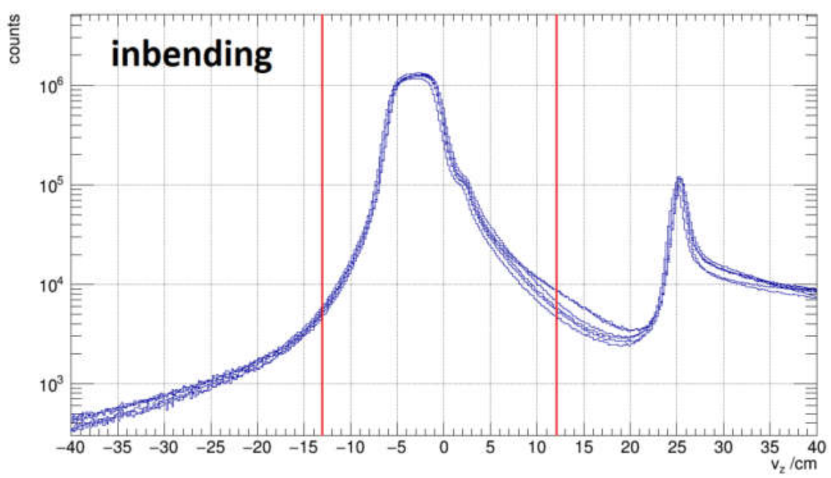
- For BSA a well defined sampling fraction cut border is not required as for cross sections
- The 5 σ region provided by the eventbuilder is sufficient to keep the pion contamination small
- lower threshold for E/p:
  - reduce the contamination at small momenta
  - catch slightly wrong parametrisation from the evb

$$\boxed{E/p > 0.17}$$

- Very small effect for p > 2.1 GeV!

Electron ID

Refinement: Cut on the z-vertex position



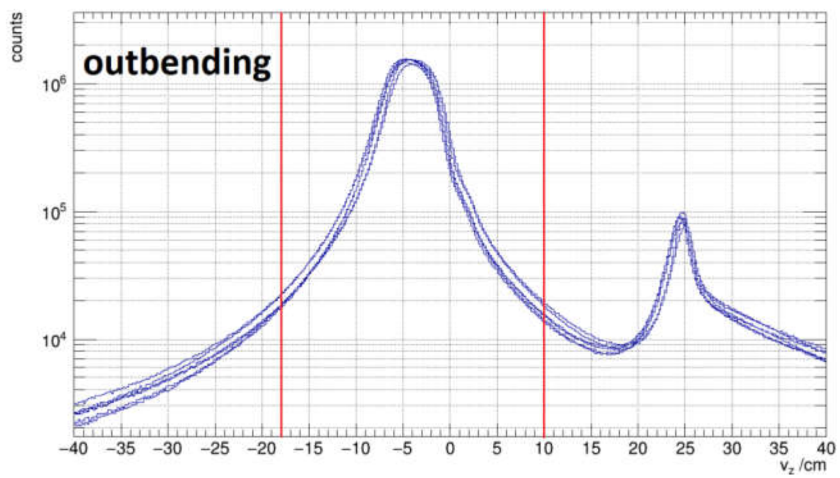


Figure 3.3: Distribution of the z-vertex position overlapped for the 6 sectors for in-bending (left) and out-bending (right) electrons.

$v_z \in$ [-13, +12] $\qquad$ $v_z \in$ [-18, +10]

Hadron ID

b) Hadron ID

➔ For the first SIDIS publications, only hadrons in the FD will be used

➔ This is ensured by a cut on the status of the particle

➔ A particle is only considered a hadron, when it did not pass the electron ID

➔ The difference between the start-time corrected time recorded at the TOF detector and expected (calculated) time based on the path length and track momentum is used as a PID criterium.

The PID is assigned which minimizes:

$$\Delta t = t_{start_time} - \left[t_{FTOF} - \frac{L}{\beta_h(p)} \right] \qquad \beta(p) = \frac{p}{\sqrt{p^2 + m_h^2}}$$

Define: chi2PID as the number of sigmas in Δt, the particle is away from 0

➔ Assign particle to the species which minimizes chi2PID

Hadron ID

Refinement: Cut on the vertex difference between electrons and hadrons

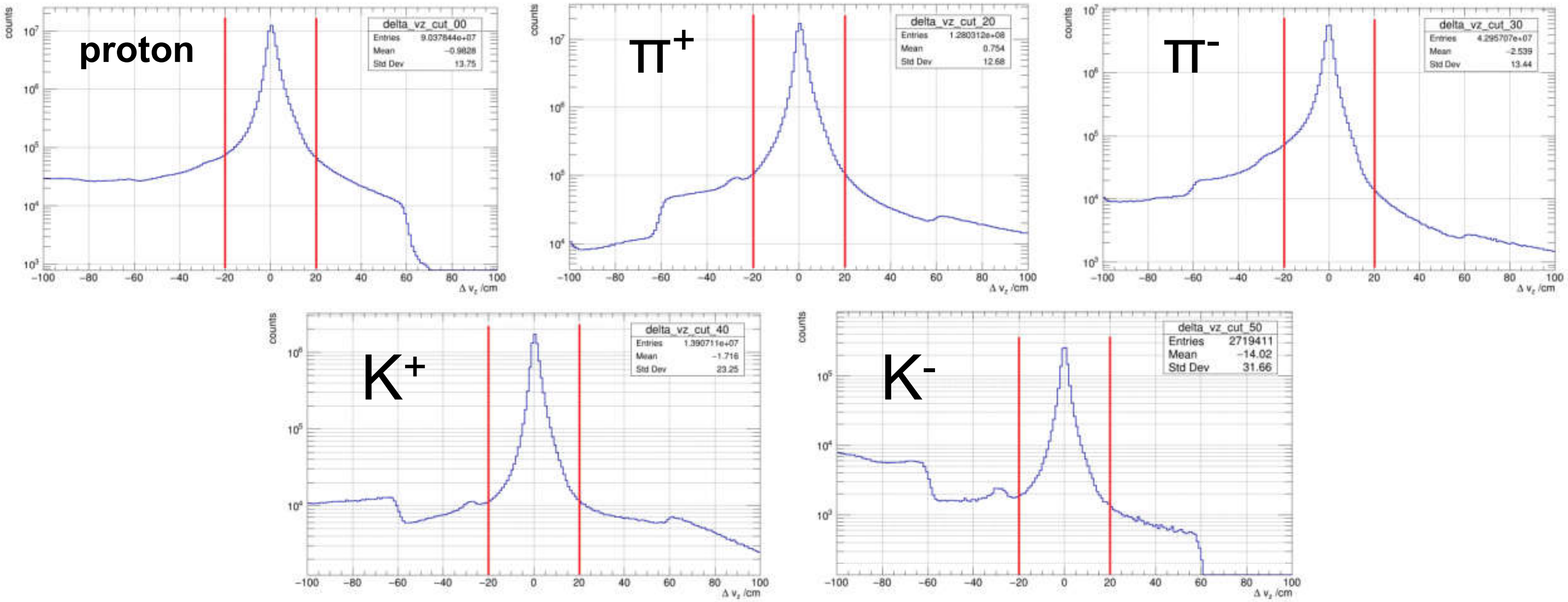
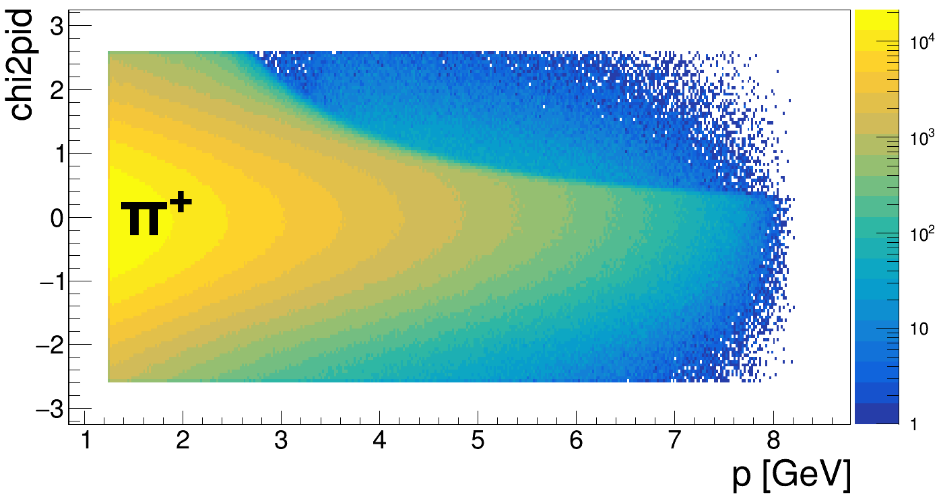


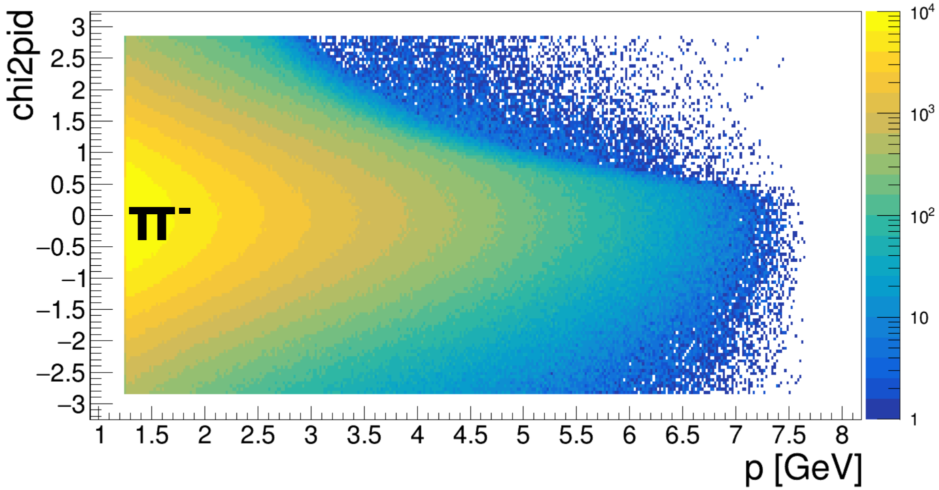
Figure 3.4: Vertex difference between the hadrons and the electron for the different hadron species: protons, π^+, π^-, K^+ and K^- (from left to right and top to bottom). The cut positions are marked as vertical red lines.

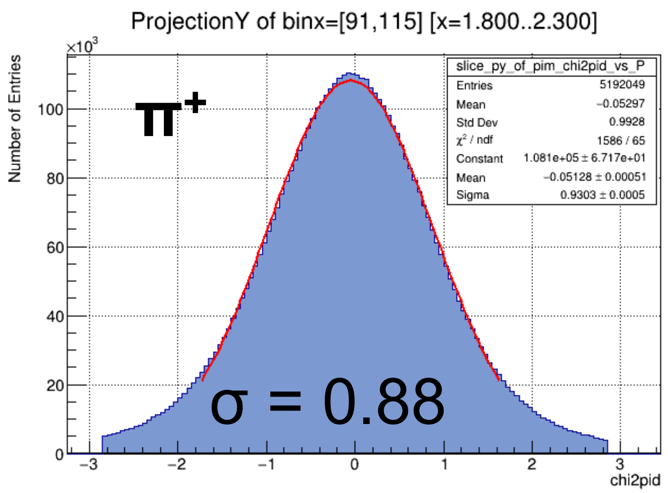
$$|v_z(ele) - v_z(had)| < 20cm$$

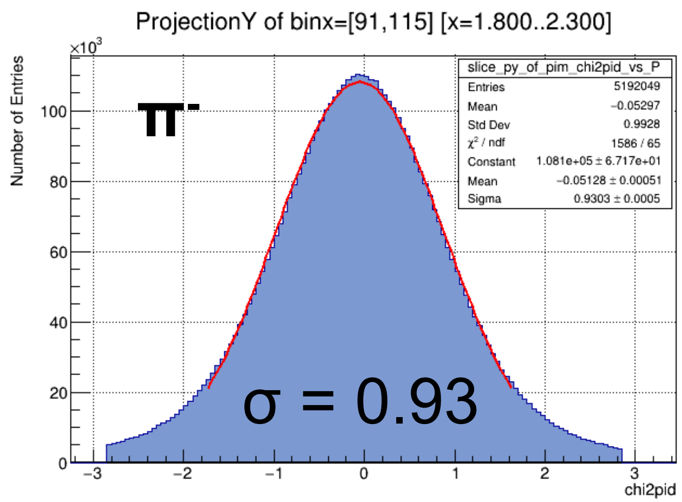
Hadron ID Refinement

Eventbuilder χ²PID distributions from the eventbuilder for SIDIS pions:









Hadron ID Refinement

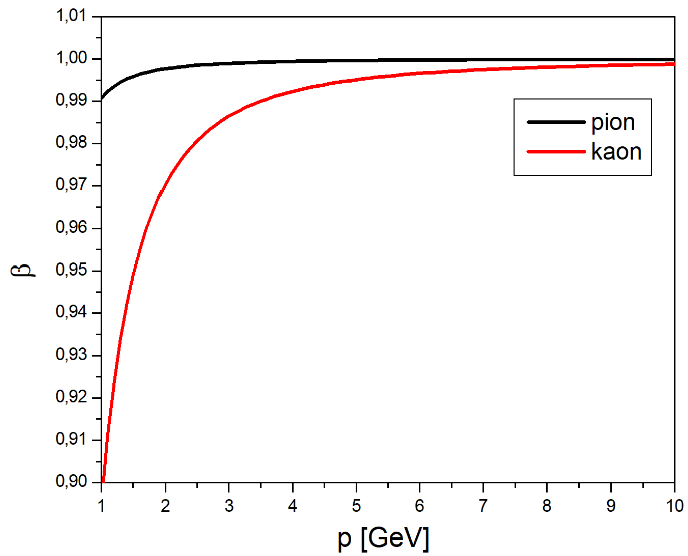
- Kaons are expected at positive chi2PID values

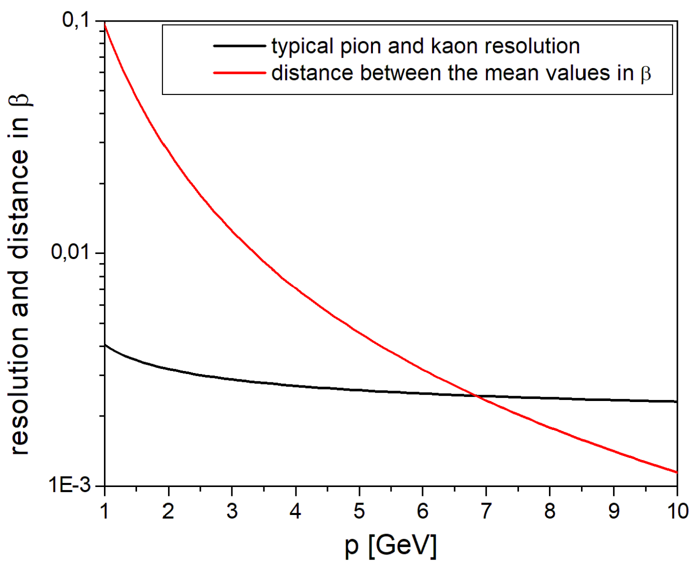
Lower cut border: No contamination expected → Use the 3 sigma region

$$\chi^2\mathrm{PID} > 3 * 0.88 = 2.64 \text{ for } \pi^+$$

$$\chi^2\mathrm{PID} > 3 * 0.93 = 2.79 \text{ for } \pi^-$$

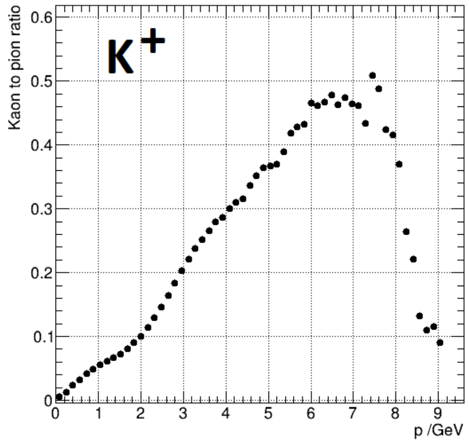
Upper border: contamination from Kaons

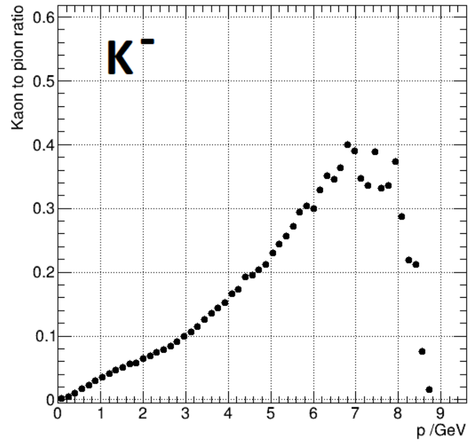




Hadron ID Refinement

Expected Kaon to Pion ratio from the MC:





Upper border: A momentum dependent cut is needed to keep the pion contamination under control

➔ The closest distance assignment of the eventbuilder already reduces the Kaon contamination significantly

➔ Refine the eventbuilder PID to get a clear cut border

➔ Require that the cut is at half the distance in beta between the pions and kaons

➔ Contamination limited to 20 – 30 % at the highest pion momenta

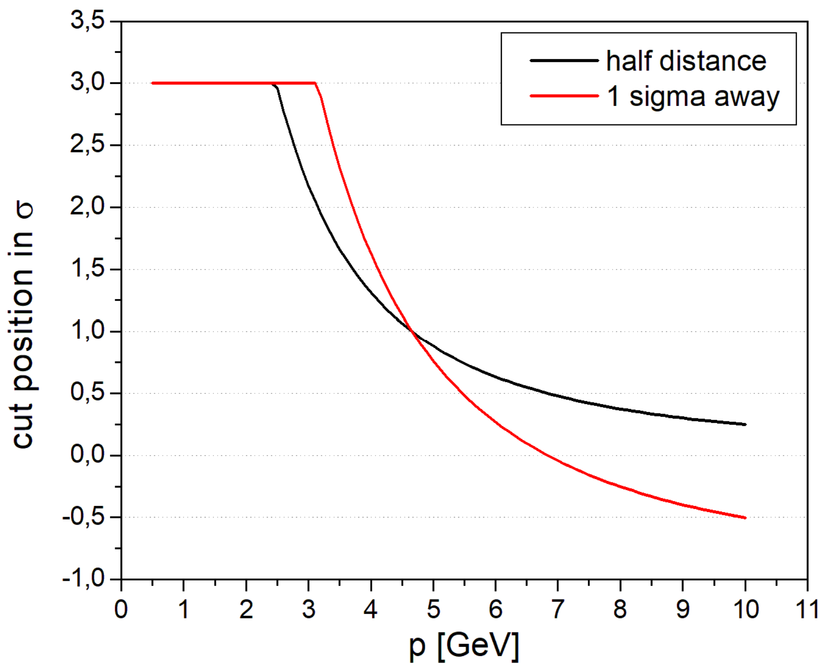
Hadron ID Refinement

More clean version for systematics: Require that the cut is 1 sigma away from the mean value of the pion distribution

➔ Contamination < 10 - 15 % at highest pion momenta

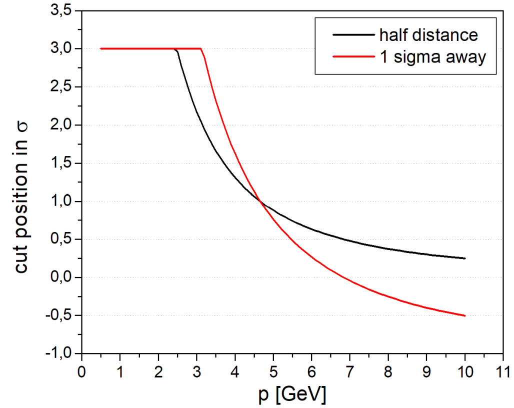
➔ Contamination of < 5 - 8 % in the intermediate momentum range

➔ Pion survival rate at high momenta reduced compared to the standard method



Hadron ID Refinement

C = 0.88 for π^+ C = 0.93 for π^-



standard cut:

p < 2.44 GeV: chi2PID < C * 3

p >= 2.44 GeV:

chi2PID < C * (0.00869 + 14.98587 * exp(-p/1.18236) + 1.81751 * exp(-p/4.86394))

stricter cut:

p < 2.44 GeV: chi2PID < C * 3

2.44 <= p < 4.6 GeV:

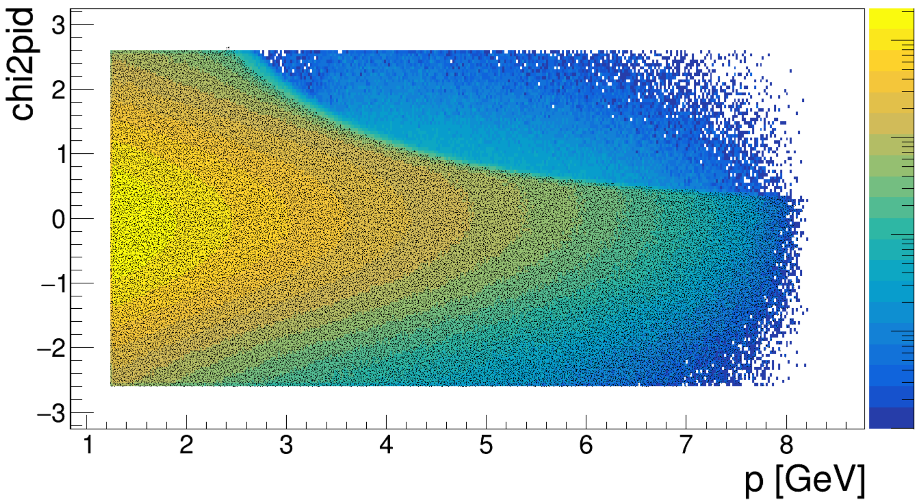
chi2PID < C * (0.00869 + 14.98587 * exp(-p/1.18236) + 1.81751 * exp(-p/4.86394))

p >= 4.6 GeV:

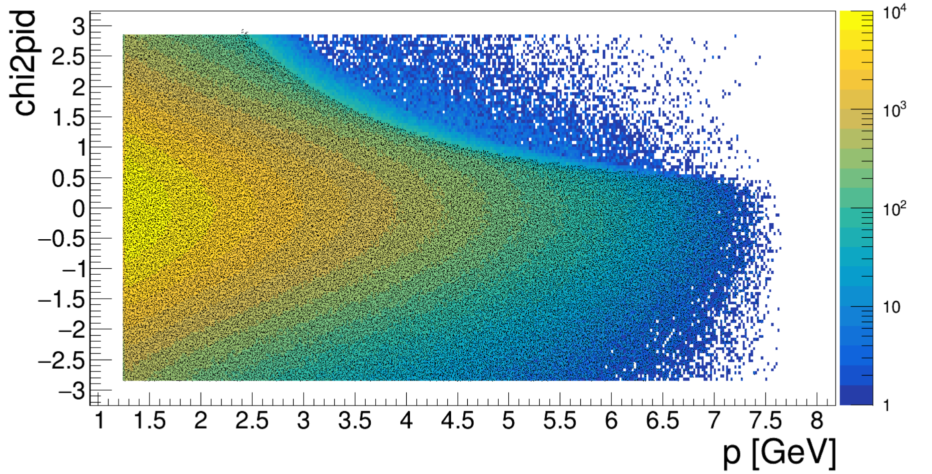
chi2PID < C * (-1.14099 + 24.14992 * exp(-p/1.36554) + 2.66876 * exp(-p/6.80552))

Hadron ID Refinement

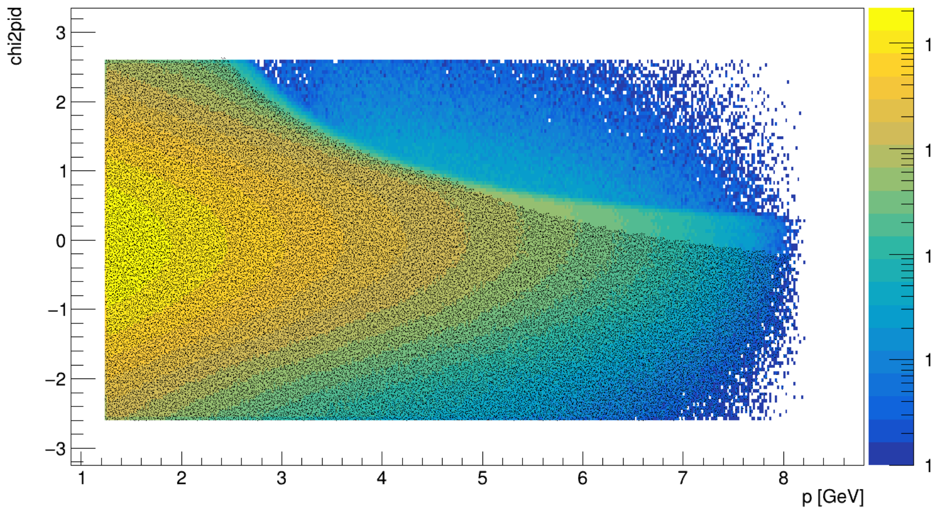
standard: π^+



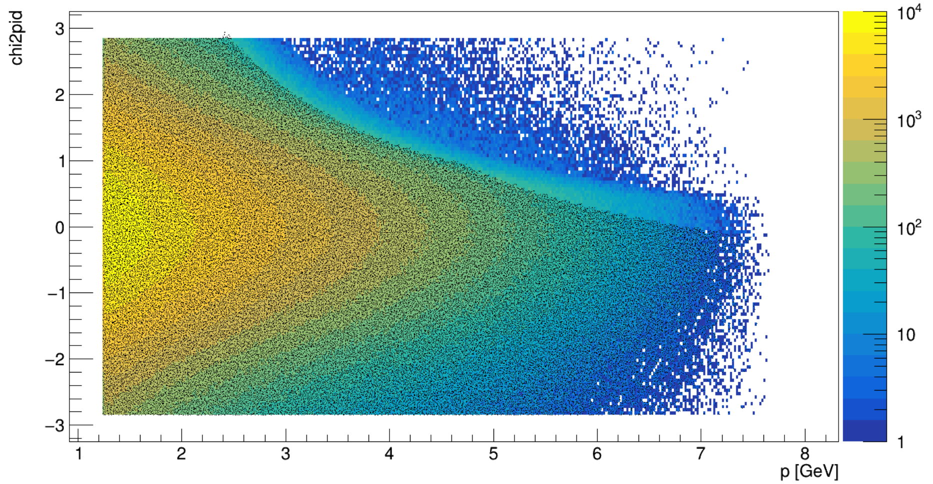
π^-



stricter: π^+



π^-



Photon ID Refinement

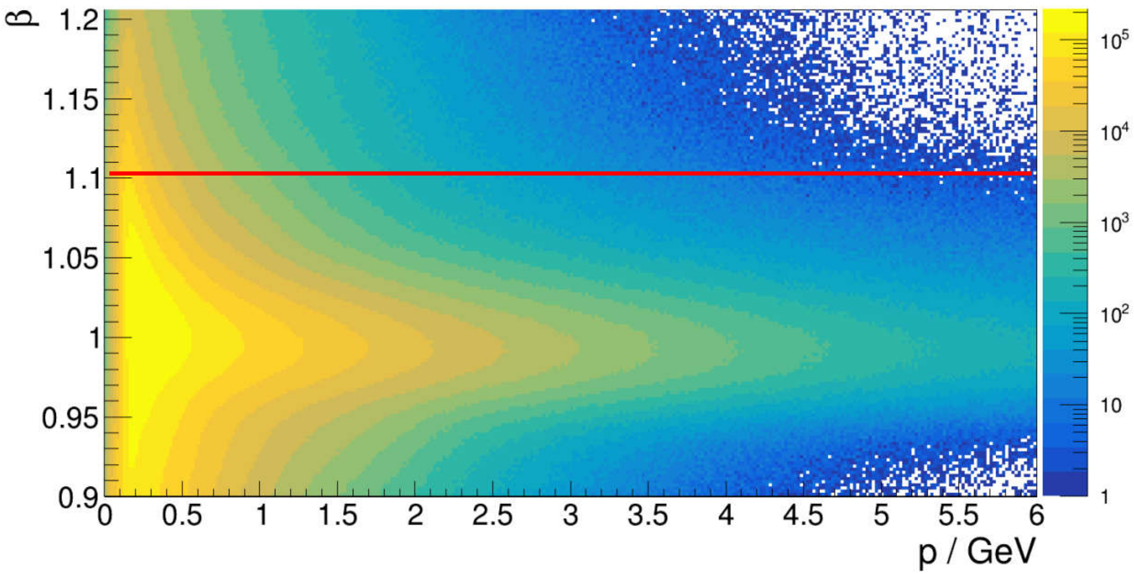
c) Photon ID

➔ For the first SIDIS publications, only photons in the FD will be used

➔ This is ensured by a cut on the status of the particle

➔ The eventbuilder requires a neutral charge (no DC track)

➔ The photon – neutron separation is done via the β value from the calorimeter



$$\beta > 0.9$$

(neutron rejection from evb)

refinement:

$$\beta < 1.1$$

➔ rejection of randoms from next beam bunch

PCAL Fiducial Cuts

• PCAL fiducial cuts are needed for electrons and photons

electrons

The correct sampling fraction and a proper cluster formation are only needed for PID

photons

The correct sampling fraction is essential to reconstruct a correct photon energy

A correct sampling fraction reduces the background below the π^0 peak

PCAL Fiducial Cuts

MC simulation

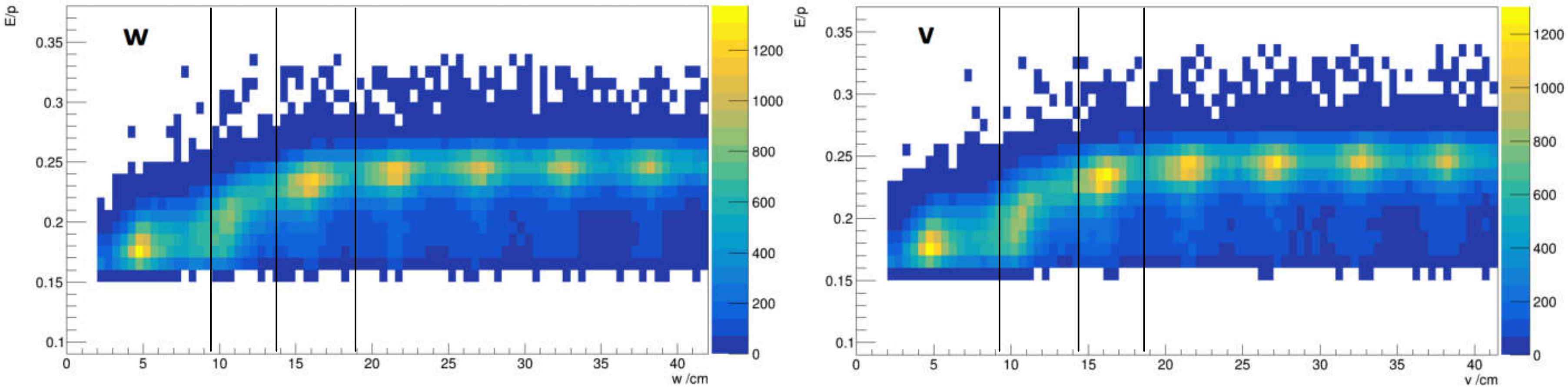


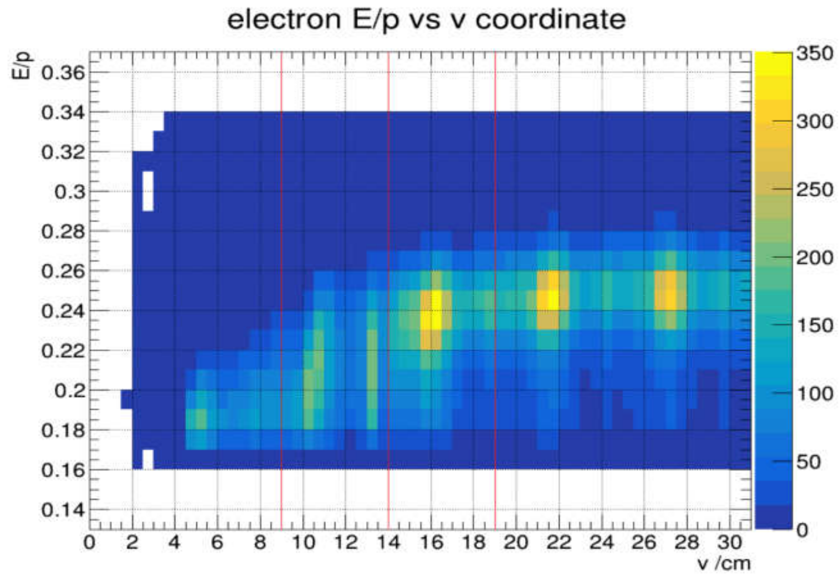
Figure 50: Monte Carlo simulation of the sampling fraction as a function of the V and W coordinates.

strictness	V	W
loose	> 9.0 cm	> 9.0 cm
medium	> 14.0 cm	> 14.0 cm
tight	> 19.0 cm	> 19.0 cm

Table 14: Parameters for the PCAL fiducial cuts.

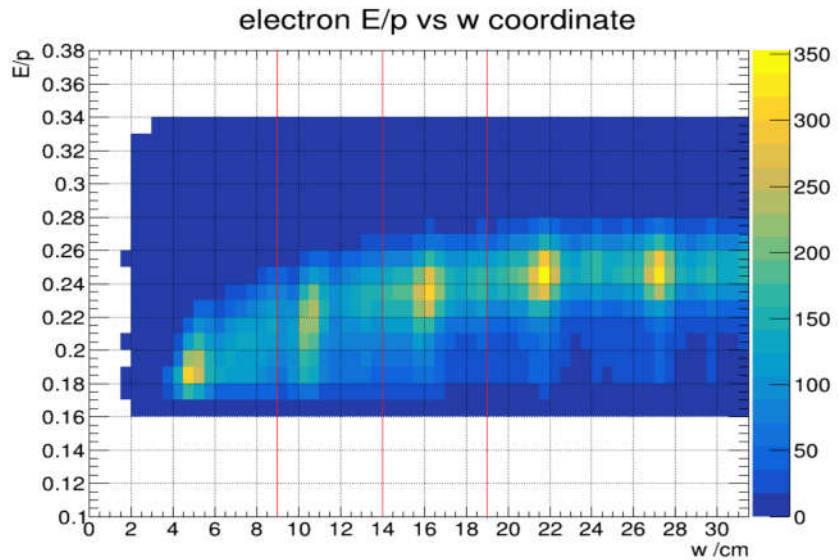
➔ At least 1 bar of each calorimeter
➔ Reasonable sampling fraction
➔ Plateau of the sampling fraction reached

PCAL Fiducial Cuts



Experiment:

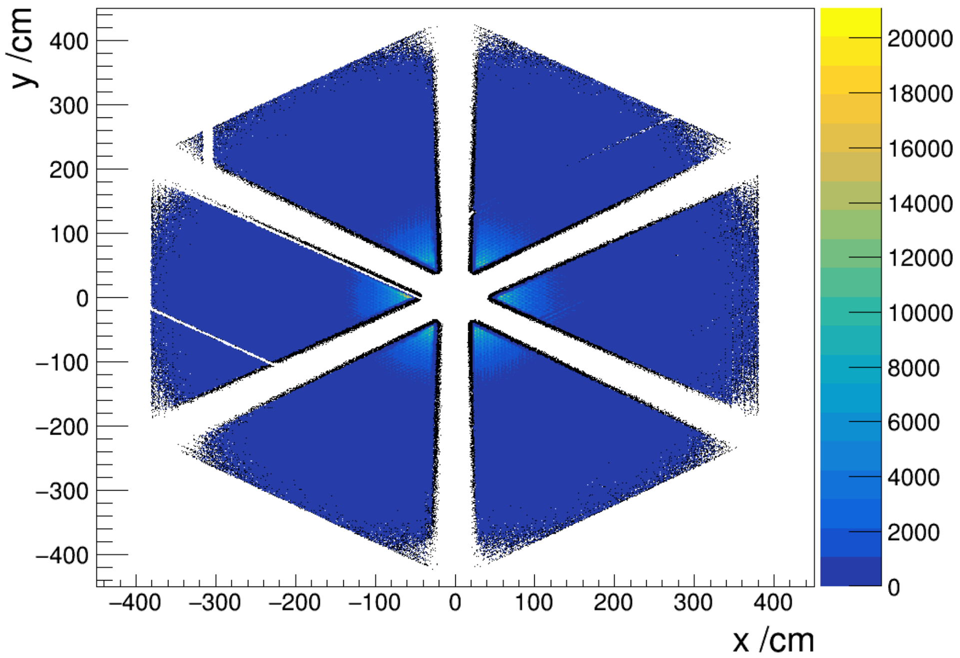
- Plots are integrated over all sectors
- Single sectors can show a slightly different behaviour due to dead bars in one of the calorimeter parts
- Since we only want to ensure a proper cluster formation, we do not consider this for BSA



PCAL Fiducial Cuts

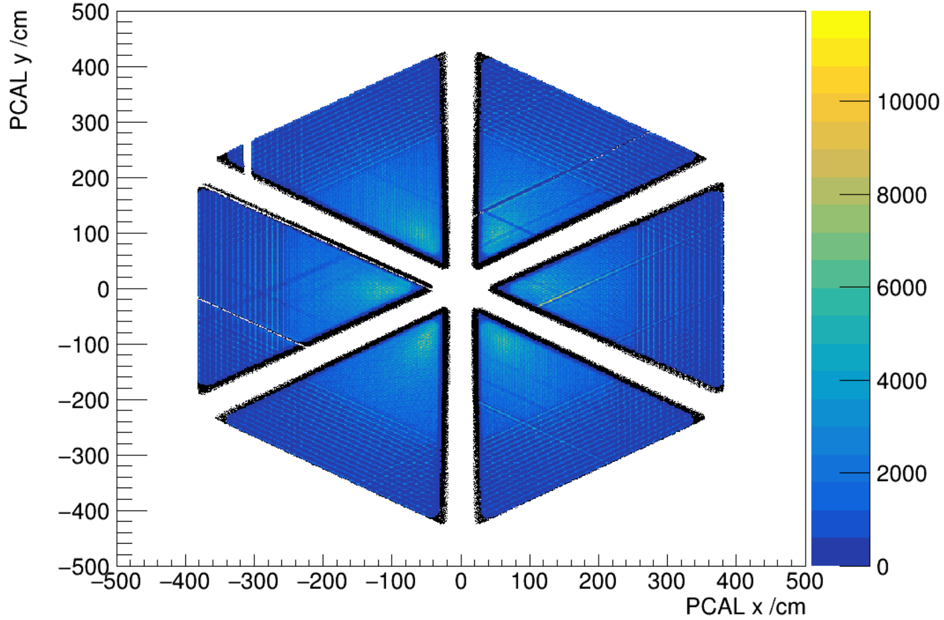
SIDIS BSA publications:

electrons: loose cut: v, w > 9 cm



→ Sufficient to ensure a resonable cluster formation for PID

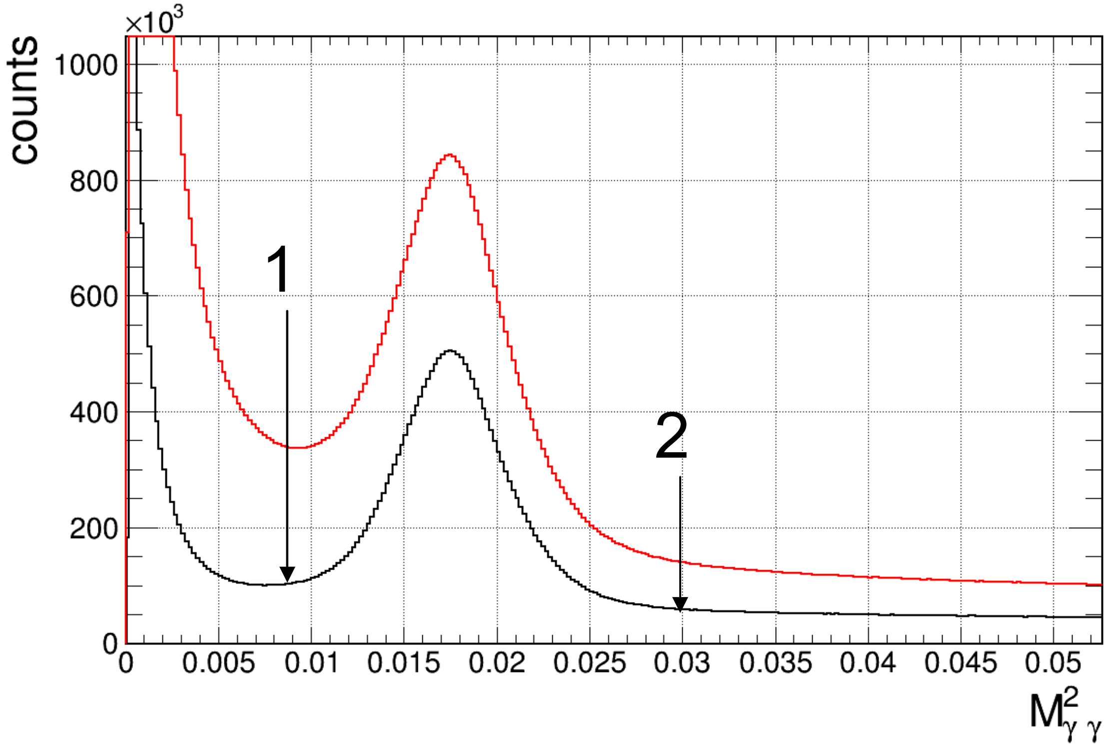
photons: loose cut: v, w > 9 cm
medium cut: v, w > 14 cm for systematics



→ Compromise between good E/p and statistics

PCAL Fiducial Cuts

Effect of the PCAL fiducial cut on the π^0 reconstruction:



no cut

1: P/V = 2.5
2: P/V = 6.1

with fid. cut

1: P/V = 5
2: P/V = 8.5

- We loose 30 % good pi0 but we significantly reduce the background

DC Fiducial Cuts (A. Kripko, JLU Gießen)

➔ The DC fiducial cuts are based on the distribution of chi2/NDF from the track

➔ Cuts can be extracted in the xy- plane and in the local θϕ-plane

➔ Very similar results but best description of the edge depends on the particle

i) Extraction in the local θϕ-plane

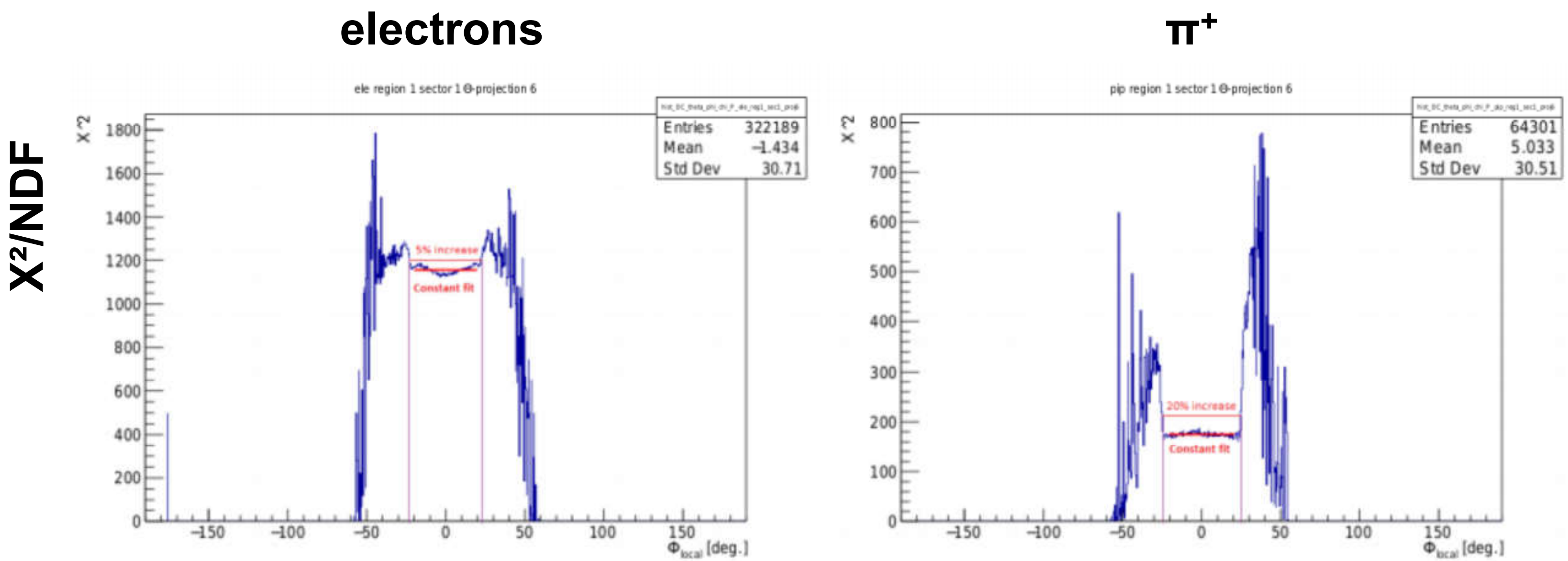


Figure 61: Illustration of the determination of the Φ values in the Θ bins. The plots show a typical averaged χ^2/NDF distribution for electrons (left) and π^+ (right).

DC Fiducial Cuts

X² / NDF for different θ bins for electrons

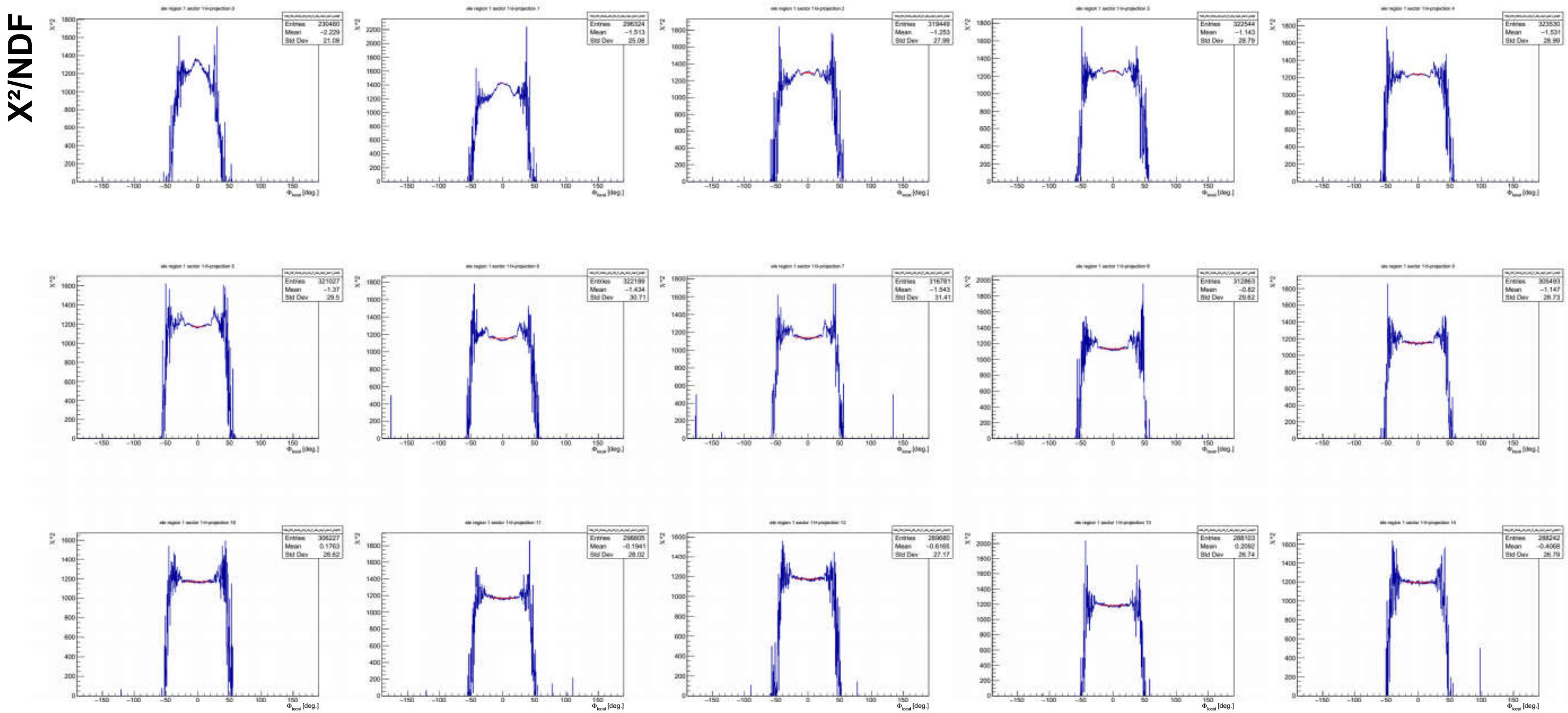


Figure 64: Electron tracking χ^2/NDF distributions as a function of Φ in Θ bins in region 1 sector 1

DC Ffiducial Cuts

X² / NDF for different θ bins for π^+

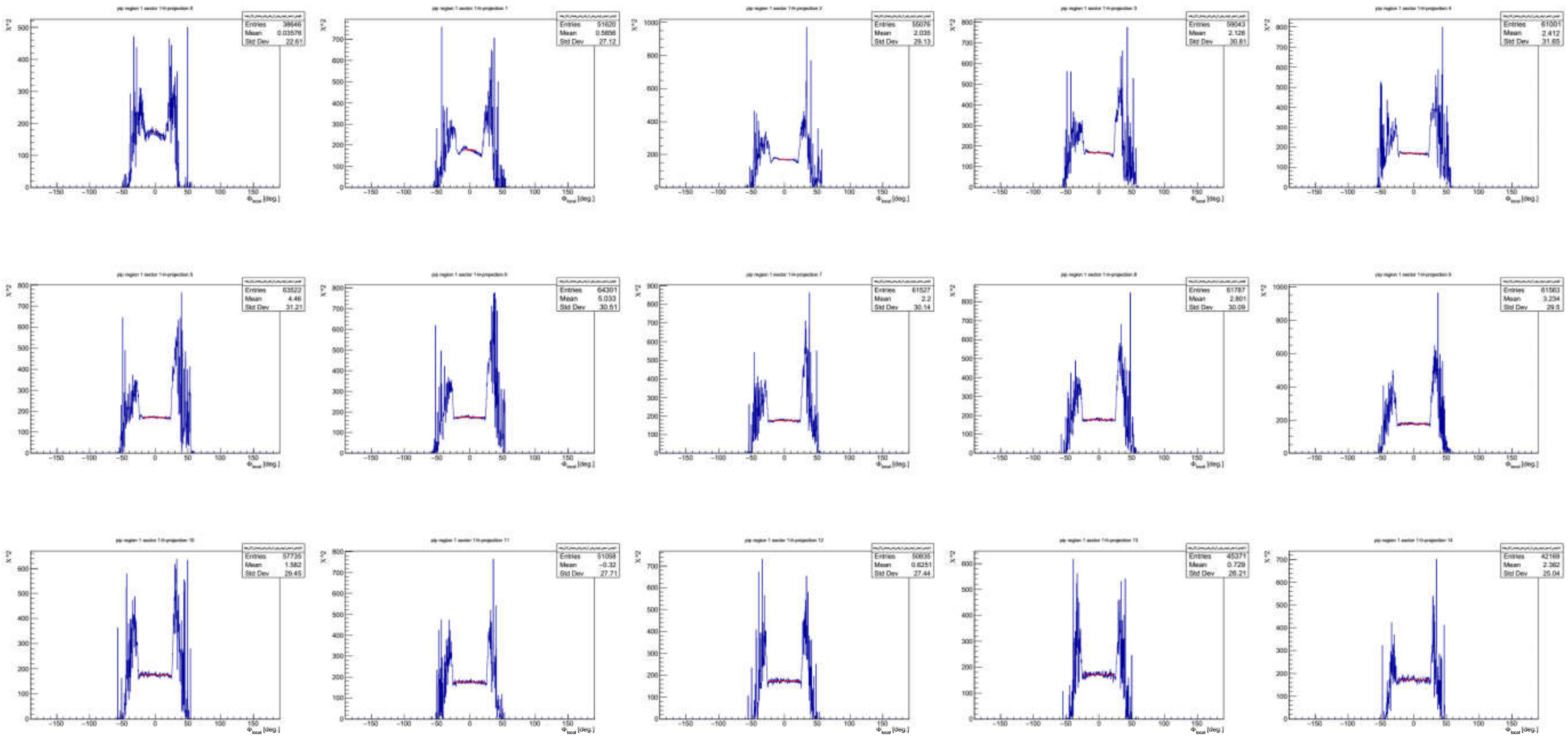


Figure 65: π^+ tracking χ^2/NDF distributions as a function of Φ in Θ bins in region 1 sector 1

DC Fiducial Cuts

Fitted edge of the fiducial volume for π^+ in region 3, sector 1

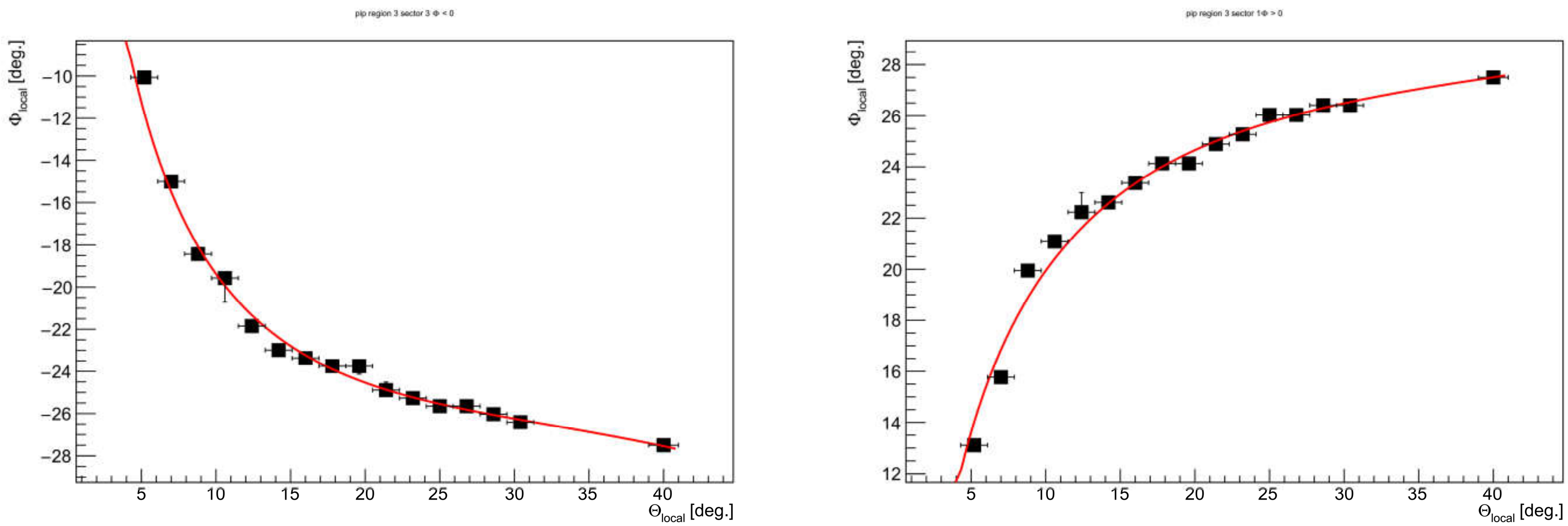


Figure 63: An example for the fitting of the cut border in region 3 sector 1 for π^+

$$\Phi = a + b * \log(\Theta) + c * \Theta + d * \Theta^2$$

DC Fiducial Cuts

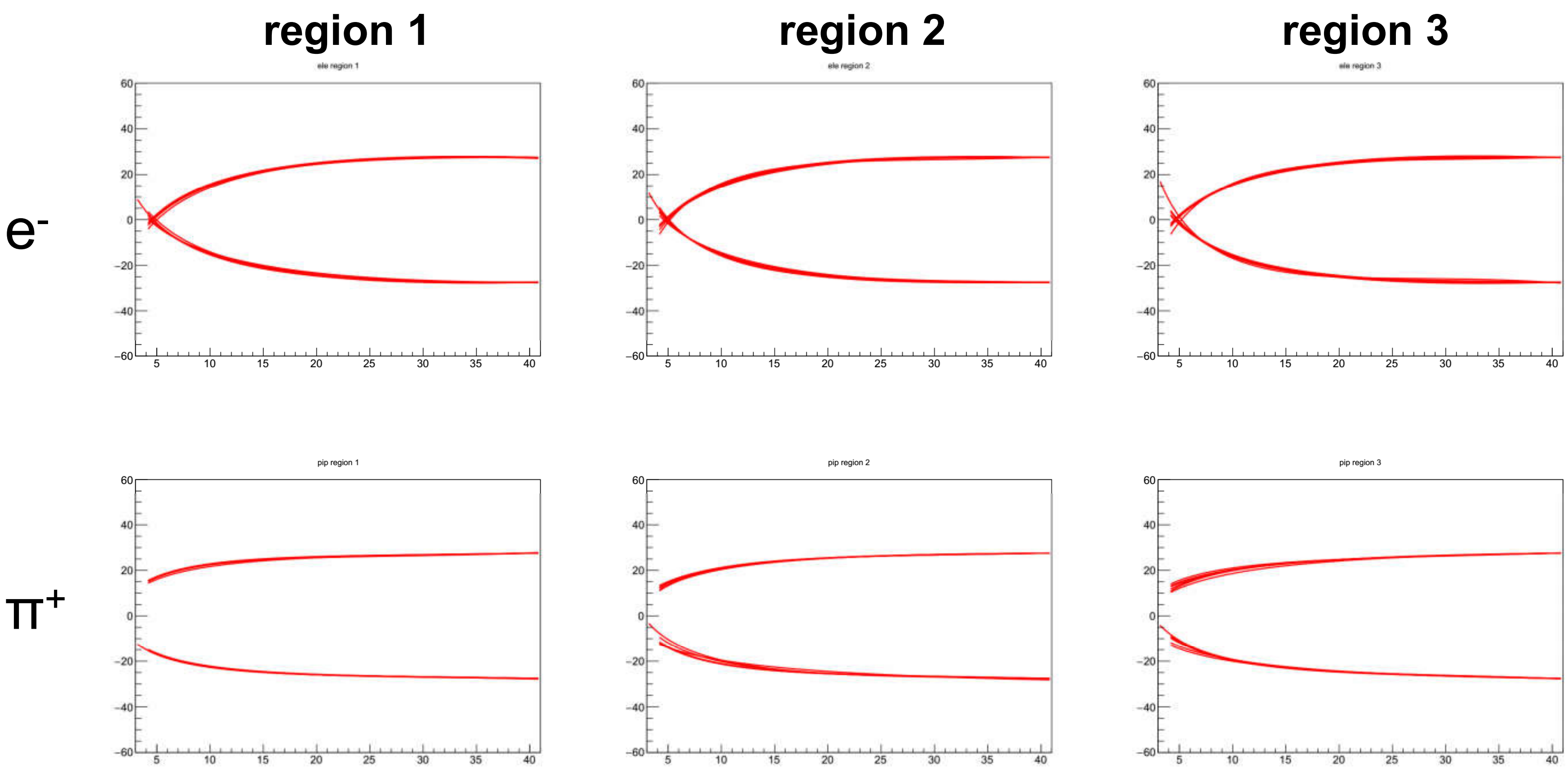


Figure 68: Sector comparison of fiducial cuts in region 1 (left), 2 (middle) and 3 (right) for electrons (top) and π^+ (bottom).

DC Fiducial cuts

results for electrons

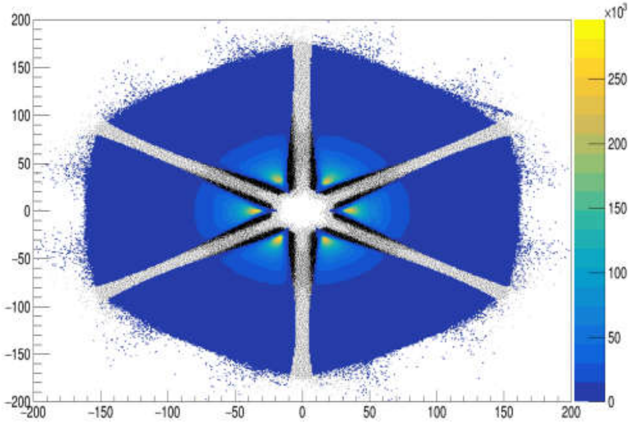


Figure 69: Result of the fiducial cuts for electrons in region 1.

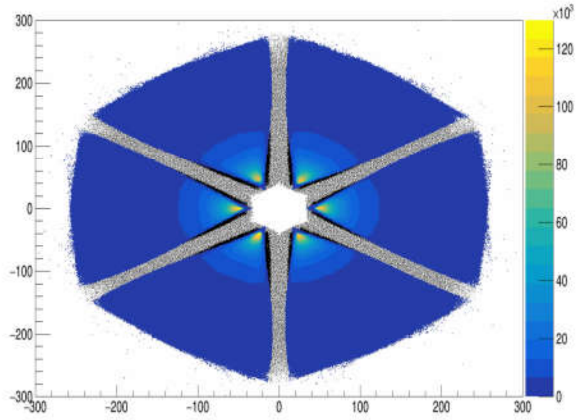


Figure 70: Result of the fiducial cuts for electrons in region 2.

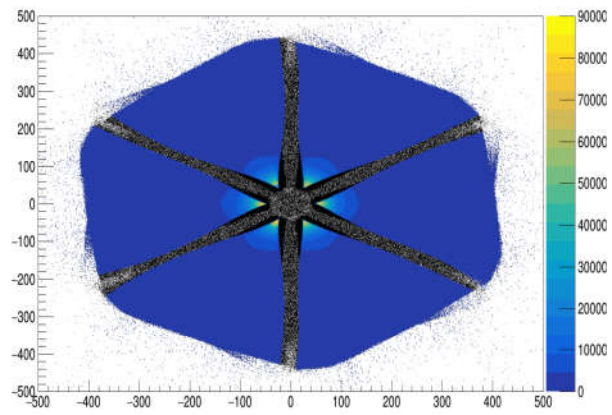


Figure 71: Result of the fiducial cuts for electrons in region 3.

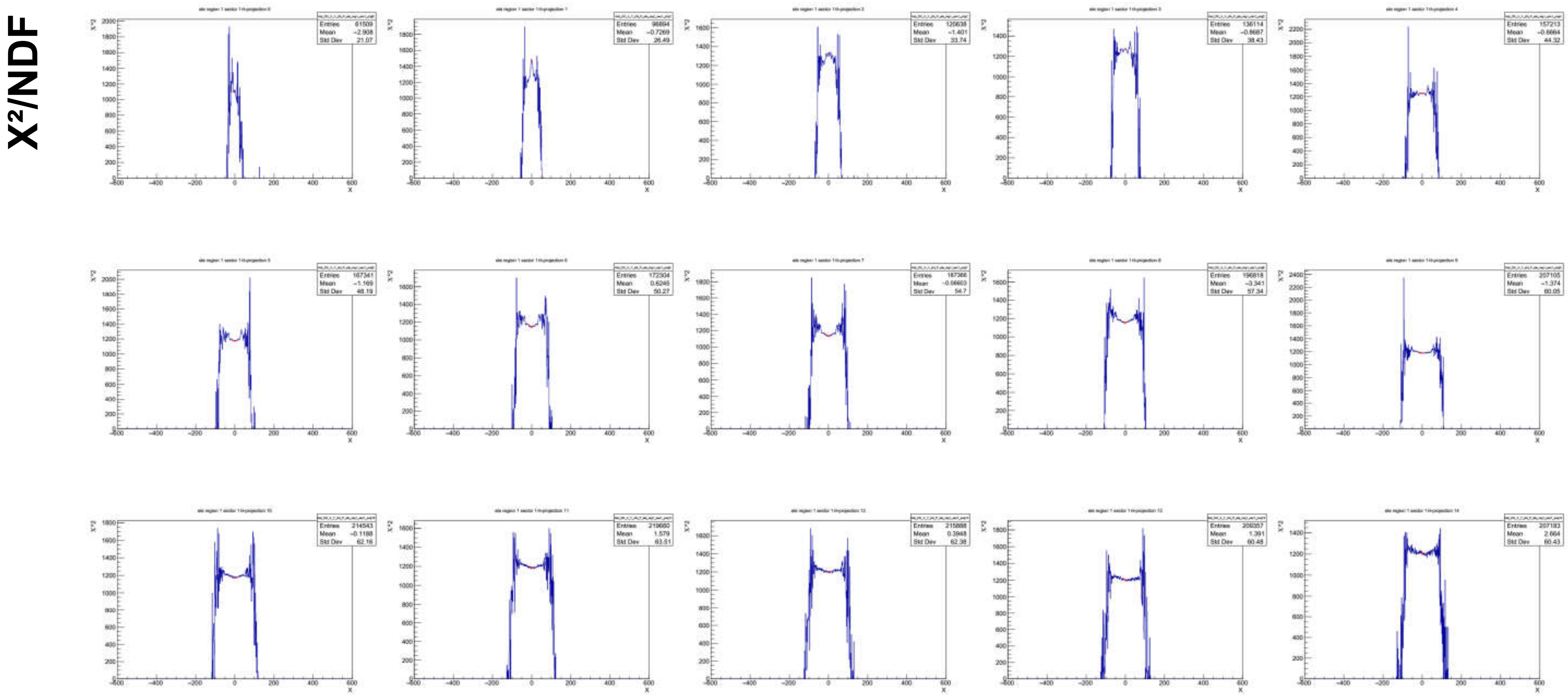
Survival rate of eventbuilder particles

	Electron	Proton	π^+	π^-	K^+	K^-
Region 1	94.3 %	98.6 %	98.9 %	98.5 %	98.1 %	97.6 %
Region 2	98.2 %	100 %	99.8 %	99.3 %	99.9 %	99.7 %
Region 3	93.5 %	99.8 %	99.5 %	99.2 %	99.6 %	99.4 %

DC Fiducial Cuts

ii) Extraction of the cut borders in the xy hit plane

X² / NDF vs x for different y bins



DC Fiducial Cuts

Resulting border of the fiducial volume for electrons

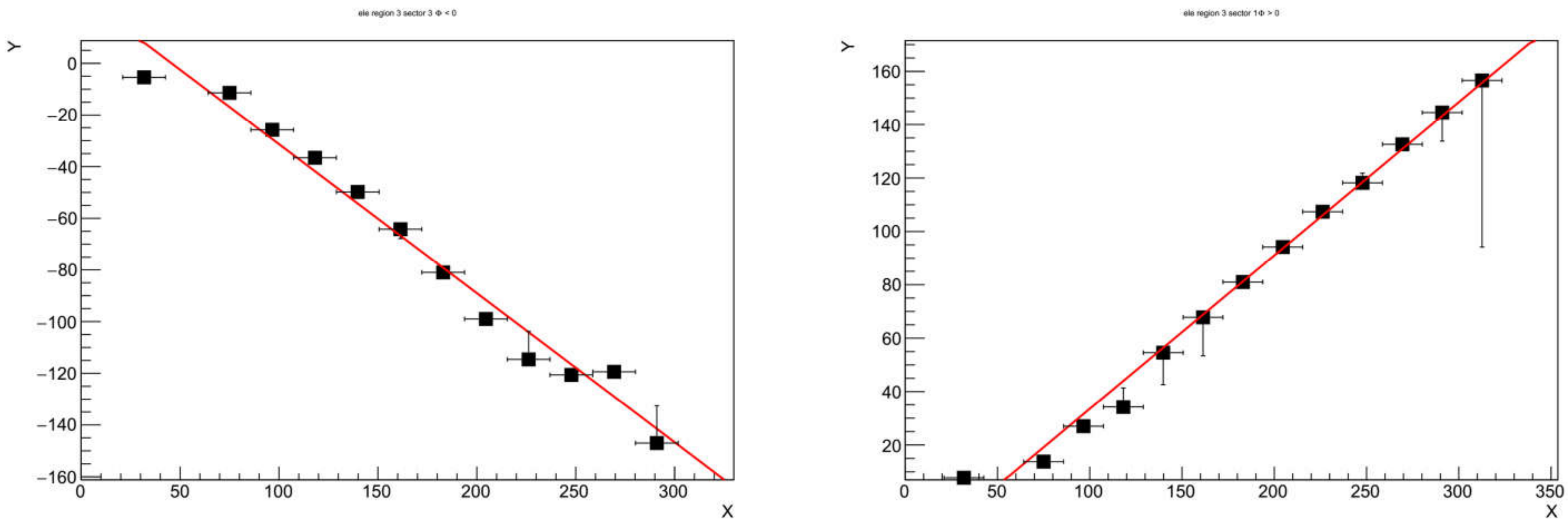


Figure 74: An example for the fitting of the cut border in region 3 sector 1.

$$x = a + b * y$$

Comparison for the Different Sectors (Electrons)

Resulting border of the fiducial volume for electrons

region 1 **region 2** **region 3**

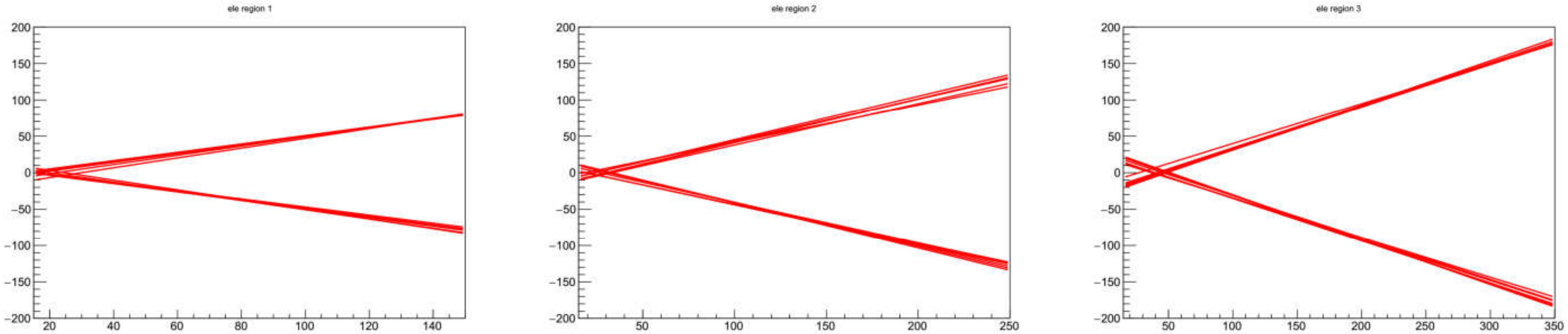


Figure 77: Sector comparison of fiducial cuts in region 1 (left), 2 (middle) and 3 (right).

Results for Electrons

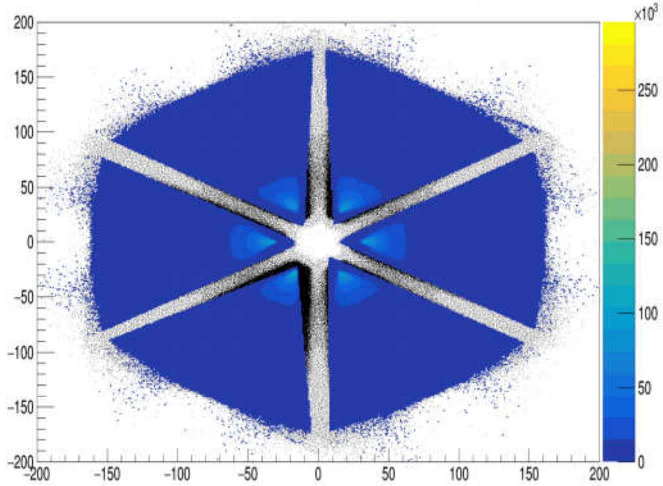


Figure 78: Result of the fiducial cuts in region 1.

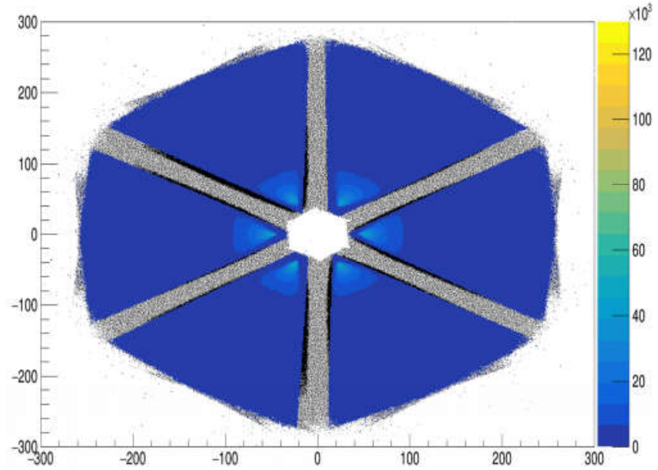


Figure 79: Result of the fiducial cuts in region 2.

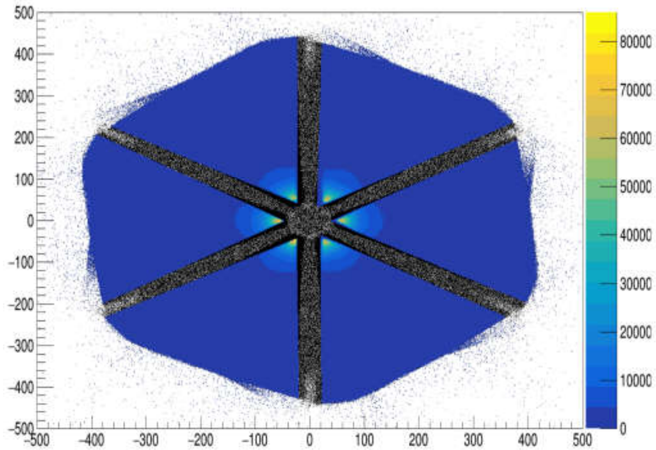


Figure 80: Result of the fiducial cuts in region 3.

Conclusion of the DC fiducial cuts

DC fiducial cuts for the SIDIS publications:

➔ Which cut is used in which case is determined by the accuracy with which the borders can be extracted from the increase in χ^2/NDF

➔ Both cuts provide very similar results

a) inbending:

→ The polynomial cut can be used for electrons and hadrons

→ The linear cut is only recommended for electrons, but works very well for them

➔ **Use linear cut for electrons and polynomial cuts for hadrons!**

b) outbending:

→ The linear cut works well for electrons and hadrons

➔ **Use the linear cut for electrons, protons and pions!**