Universität Münster

Dielectron Analysis at $\sqrt{s_{NN}}$ =3.19 GeV

Luisa Faber

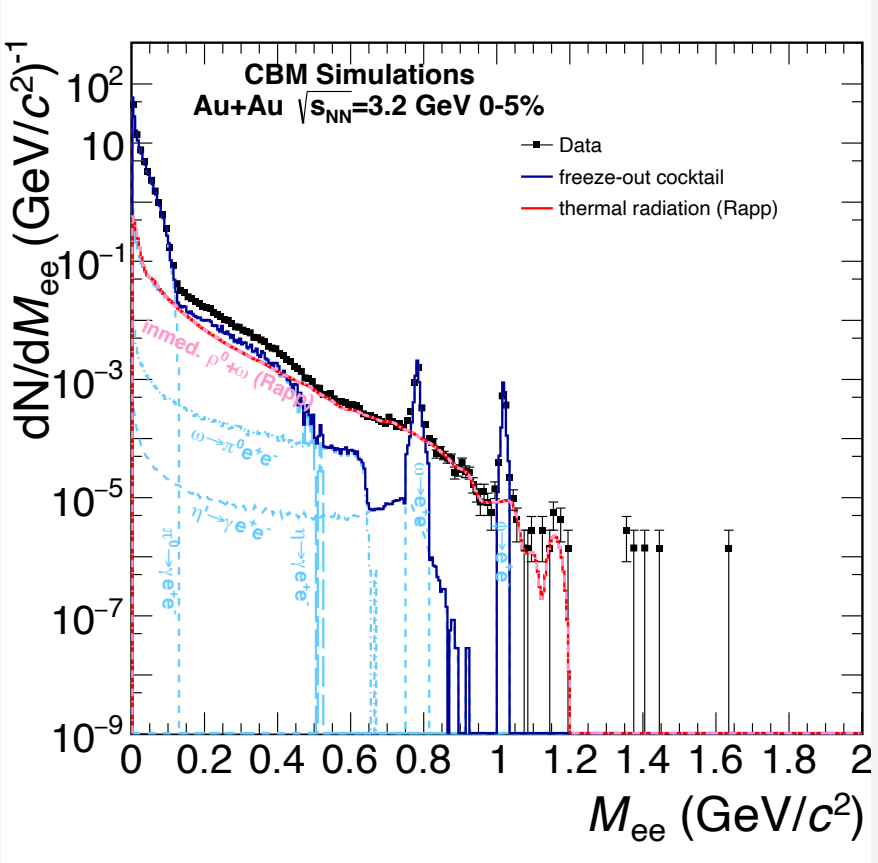
October 21st 2025

46th CBM Collaboration Meeting

wissen.leben

Dielectrons

- Escape the fireball undisturbed
- Emitted throughout whole evolution
- Mass spectrum
  - Freeze-out cocktail
  - Thermal radiation → No QGP at $\sqrt{S_{NN}}$ =3.19 GeV
- Temperature measurement in intermediate mass range
  - New simulations



T. Galatyuk

Universität Münster

Simulation

Used Geometry

Beampipe: v21d:v24e
Magnetic field scaling: 0.5
Platform: v22b
Magnet: v22a
STS: v22d

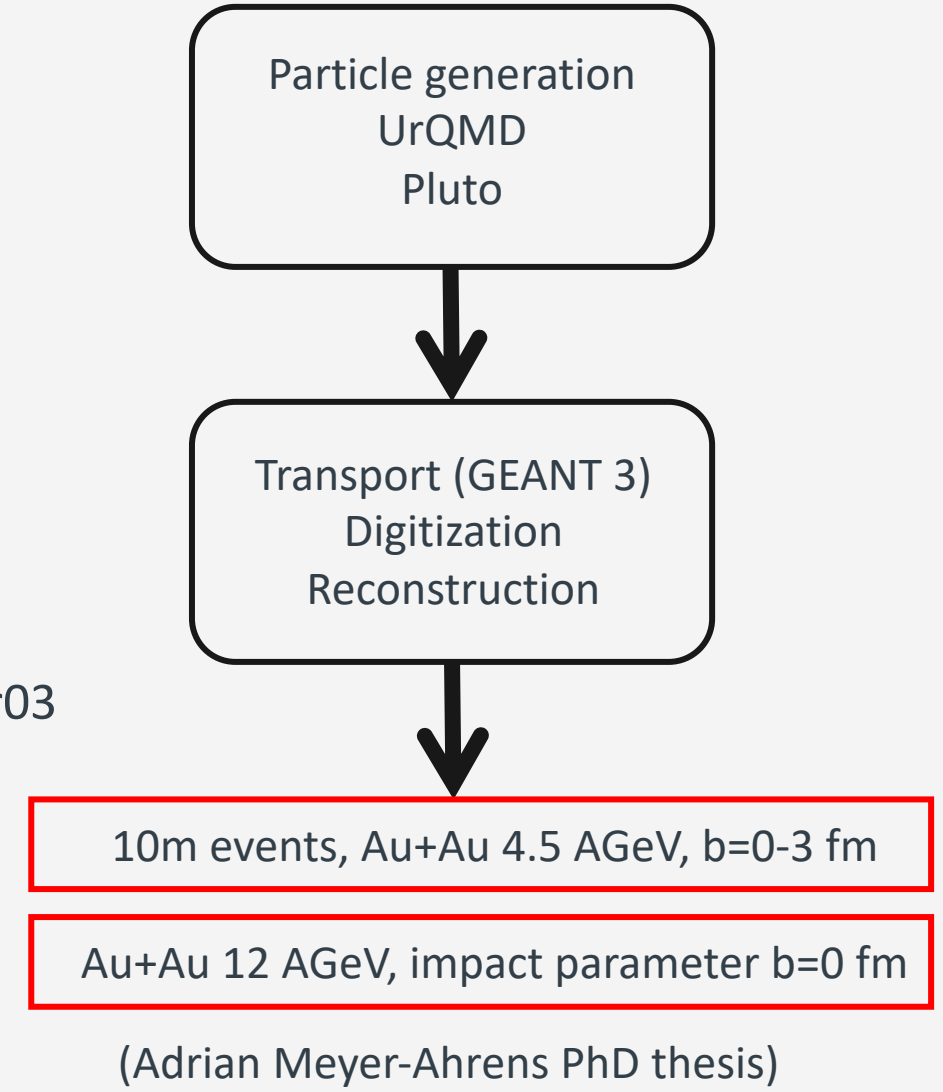
MVD: v20d_tr
TOF: v21a_1e
TRD: v20b_1e
RICH: v24a

- New Simulations (CBMROOT: jul_24patches)
- Two event generators are used
  - UrQMD (collision simulation)

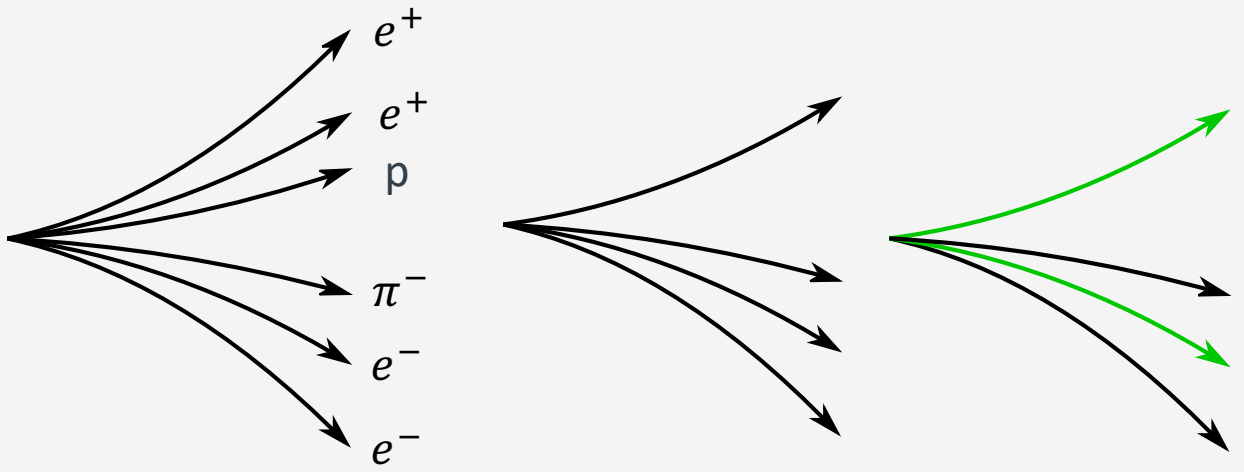
    /lustre/cbm/users/lfaber/urqmd/auau/4.5gev/4p5gev/centr03
  - Pluto event generator to increase rare dielectron decays

  → Embedded and scaled by expected yield per event

  /lustre/cbm/users/ameyerah/fseck_pluto/zips/VM_4p5/

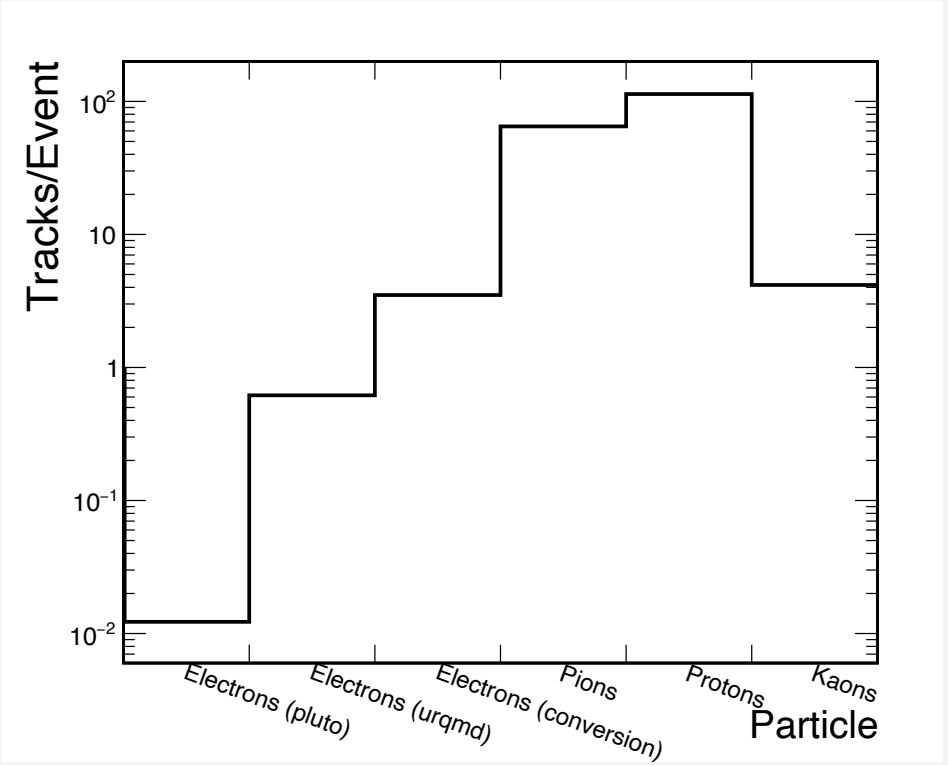


(Adrian Meyer-Ahrens PhD thesis)



Analysis

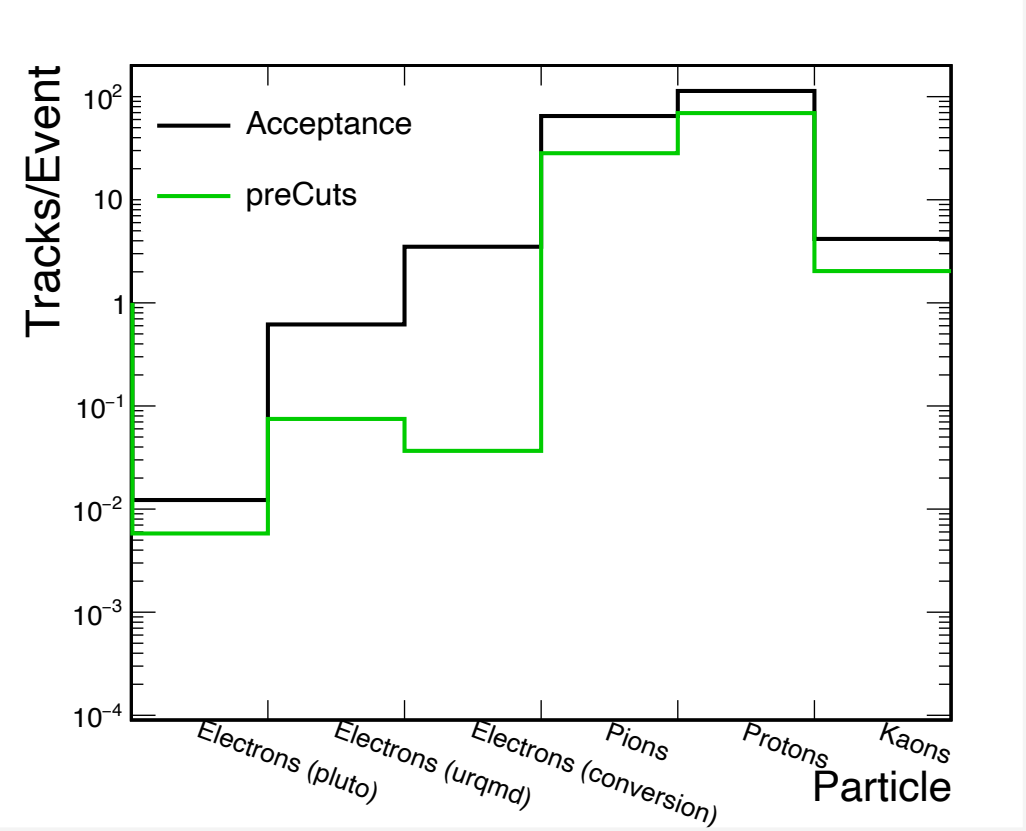
- Pair analysis carried out with “Pair Analysis Package” (PAPA) in cbmroot
- Pairing all positive and negative tracks
  - All originating from primary vertex
- Reconstructed thermal radiation and meson freeze-out cocktail
- Reduction of background
  - Misidentified hadrons
  - Electrons
  - Combinatorical Background

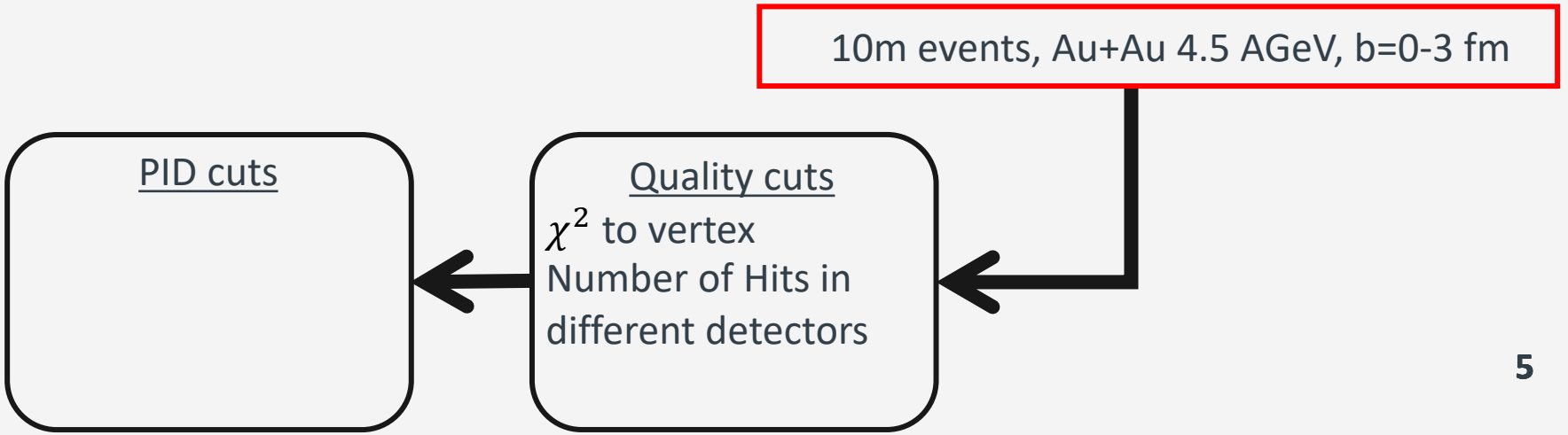


Universität Münster

Analysis

- Quality cuts to ensure quality of the tracks
- PID Cuts
  - Reduce hadronic background



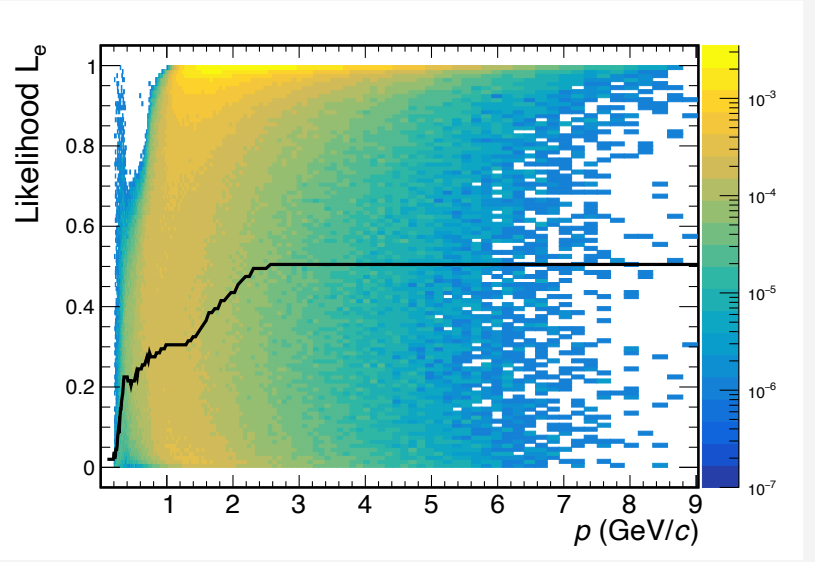


Universität Münster

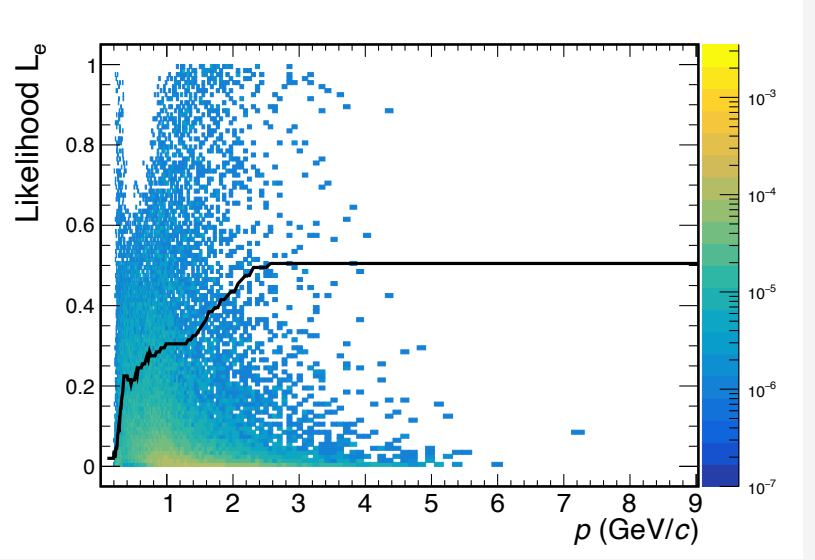
PID Cuts

- Momentum dependent cuts
- RICH: Ellipse parameters
  - Use ANN
- TRD: Energy loss in detector layers
  - Use Likelihood
- TOF : Time-of-flight information
  - Use $\Delta\beta_{\mathrm{electron}}$
- STS: Energy loss in detector layers
  - Use Median energy loss (only rejects low momentum protons)

Example: TRD



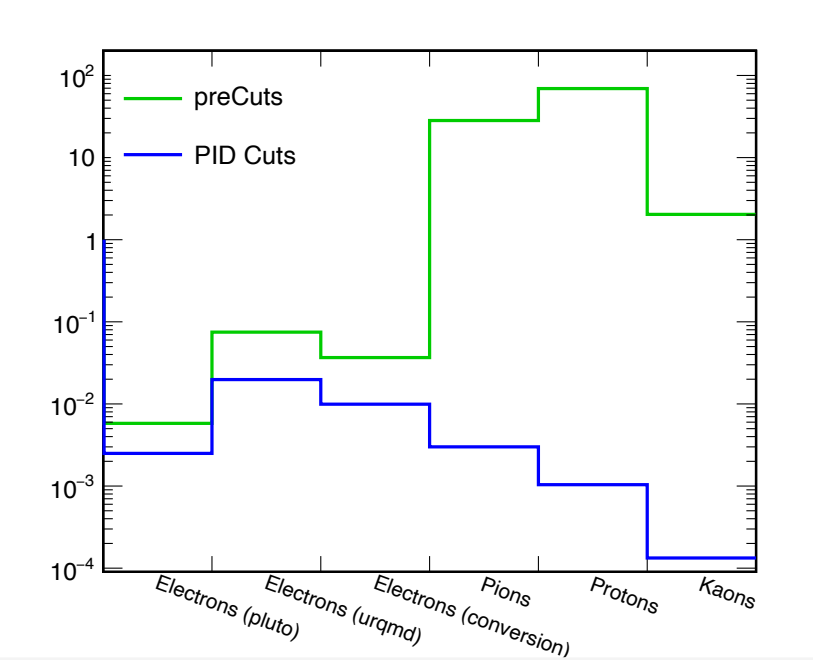
Electrons

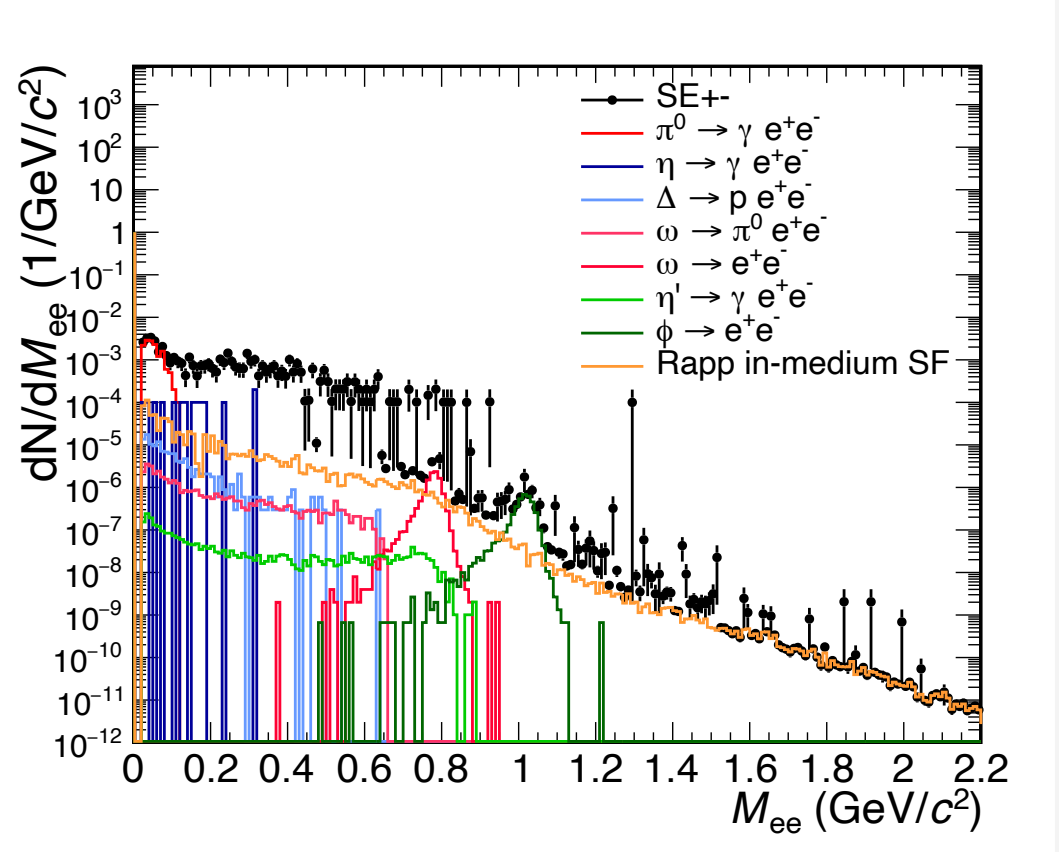


Pions

Universität Münster

Result of PID Cuts





10m events, Au+Au 4.5 AGeV, b=0-3 fm

Quality cuts

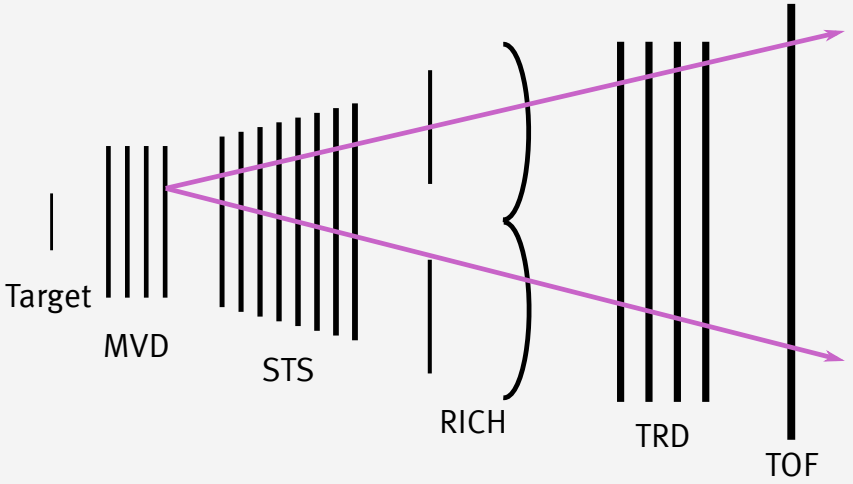
χ^2 to vertex
Number of Hits in different detectors

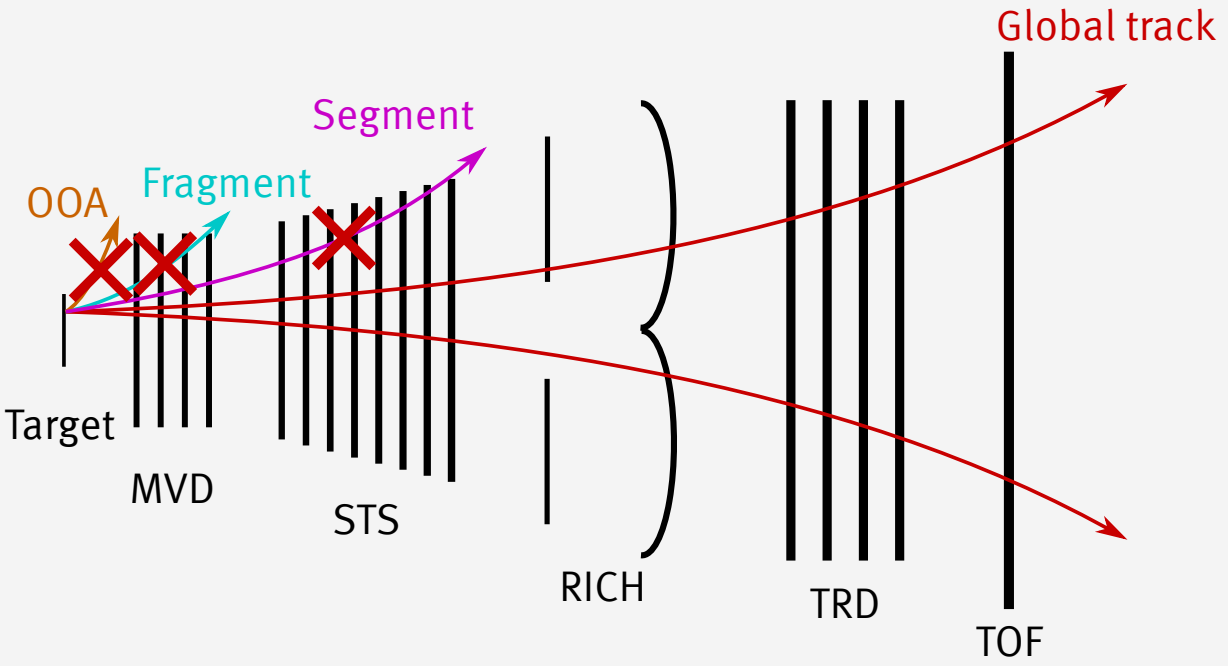
PID cuts

RICH Ellipse
TRD Likelihood
TOF $\Delta\beta_{\text{electron}}$
STS energy loss

Electron Background rejection

- Photon conversions $\gamma \rightarrow e^+ e^-$
  - Use invariant mass and position
- Incomplete pairs
  - Tracks leaving the detector
    - → Rejected by PID cuts
    - → Tracks without partner are background
  - Use opening angle



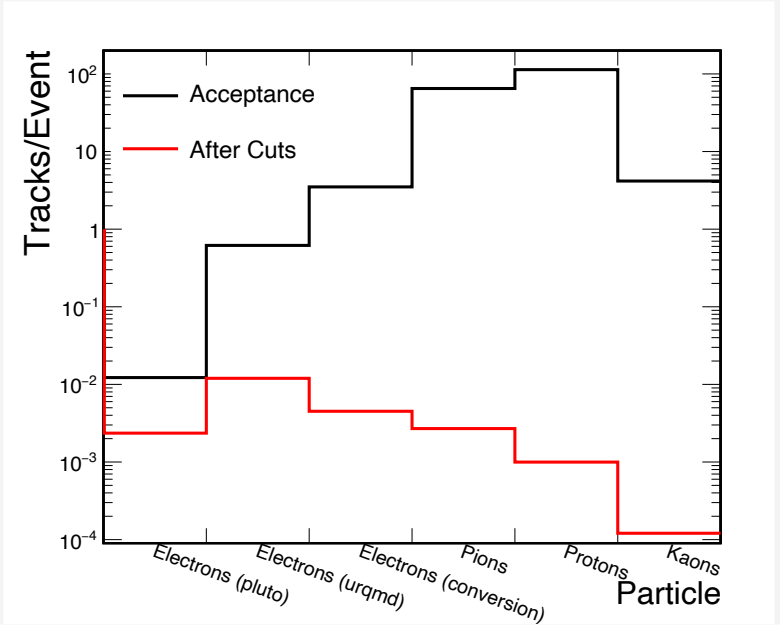


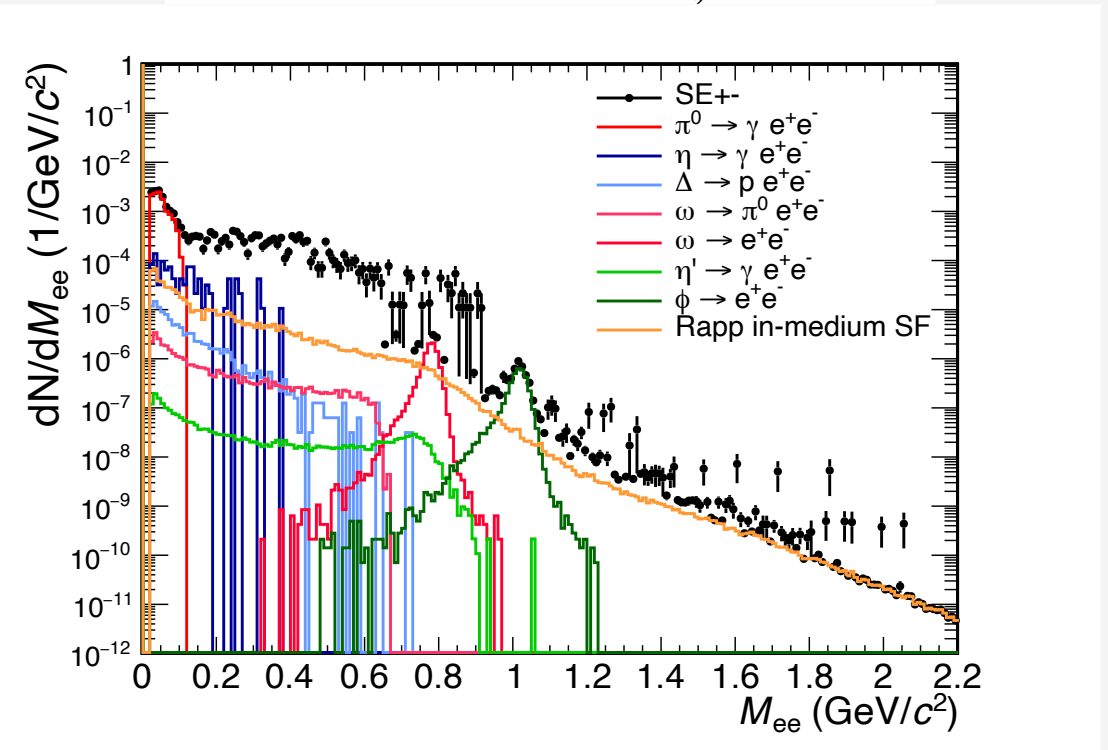
Universität Münster

Results so far

- Reconstructed invariant mass spectrum
- Higher masses: thermal contribution
- Multiplicity values for $\sqrt{S_{NN}}$ =2.9 GeV used

  → Pluto signals slightly underestimated (~ factor 1.4)
- Improve statistics
  - Rebinning
  - Additional simulations

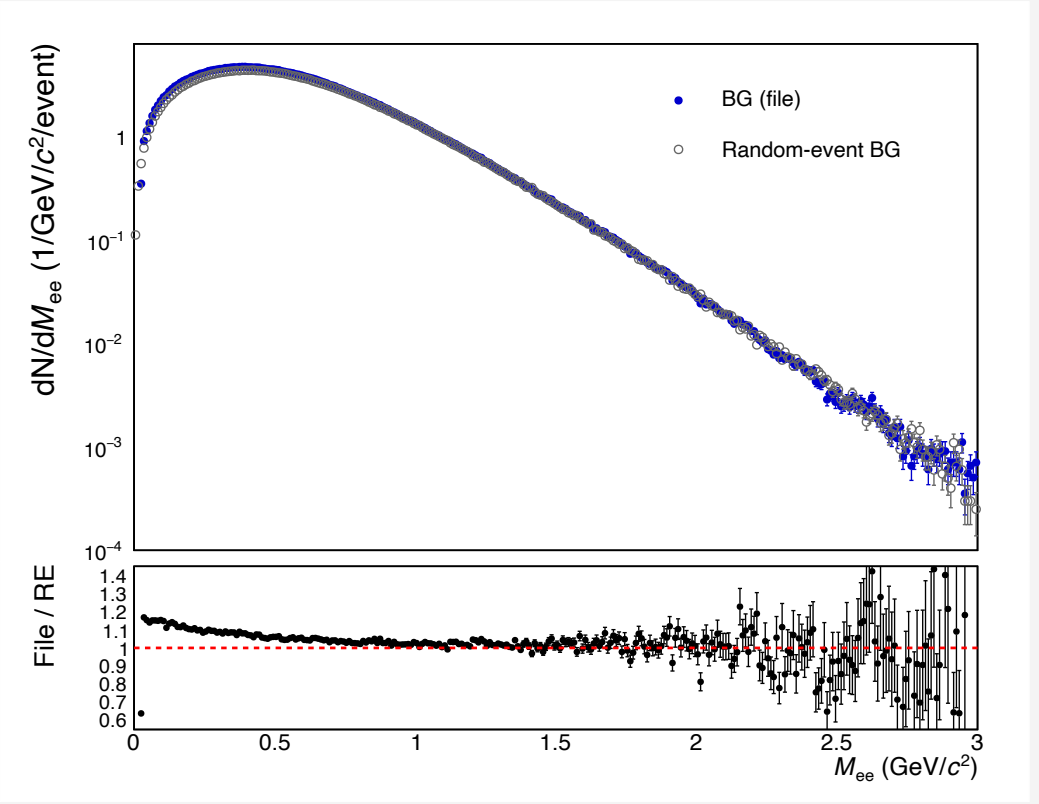




Random event background

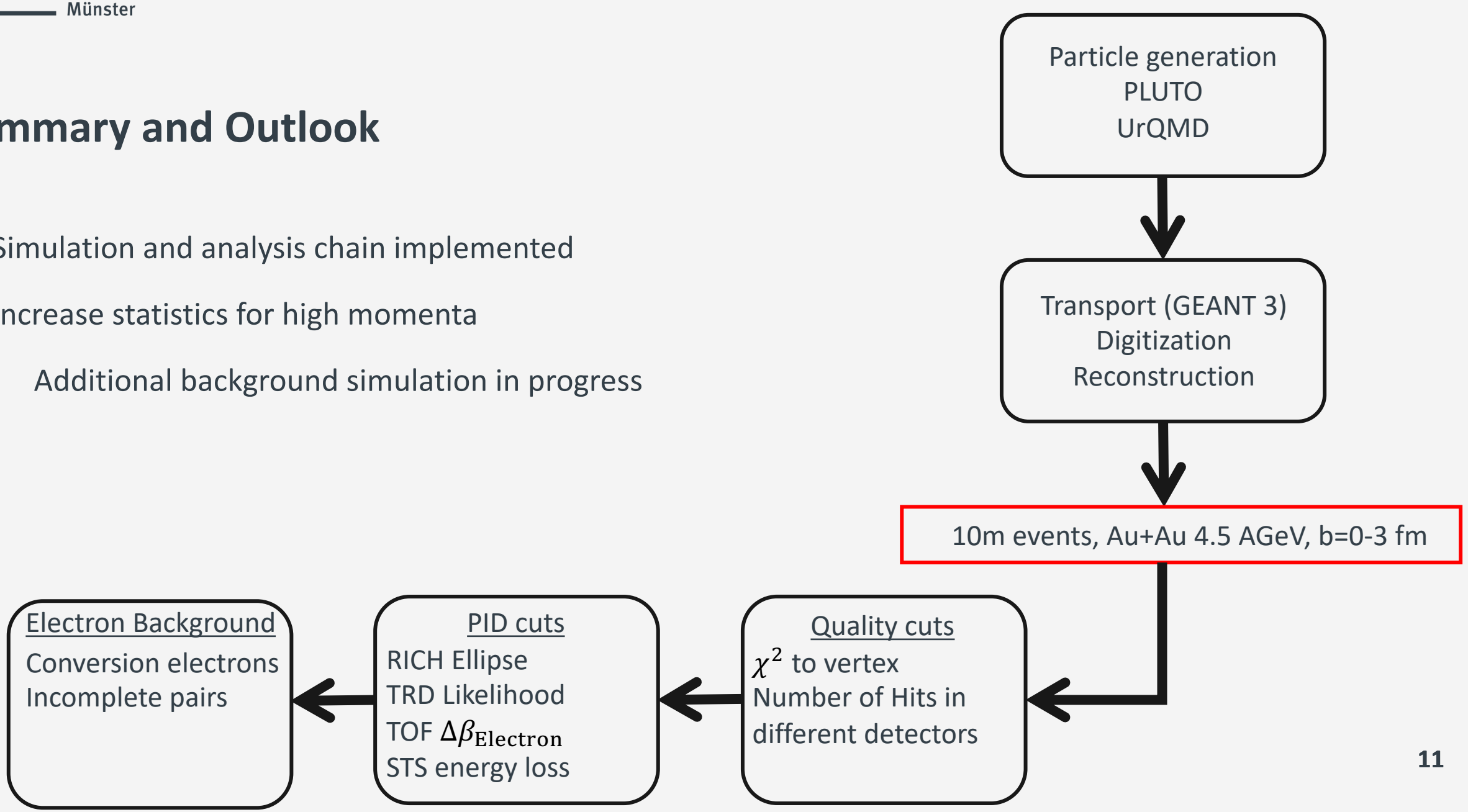
- Fast simulation approach introduced by Cornelius Feier-Riesen
  1. Run full simulation
  2. Run analysis (File)

     → Save Multiplicity and three-momentum distribution for each particle
  3. Randomly sample multiplicity and three-momentum distribution (RE)
- Difference to background in file → Under investigation



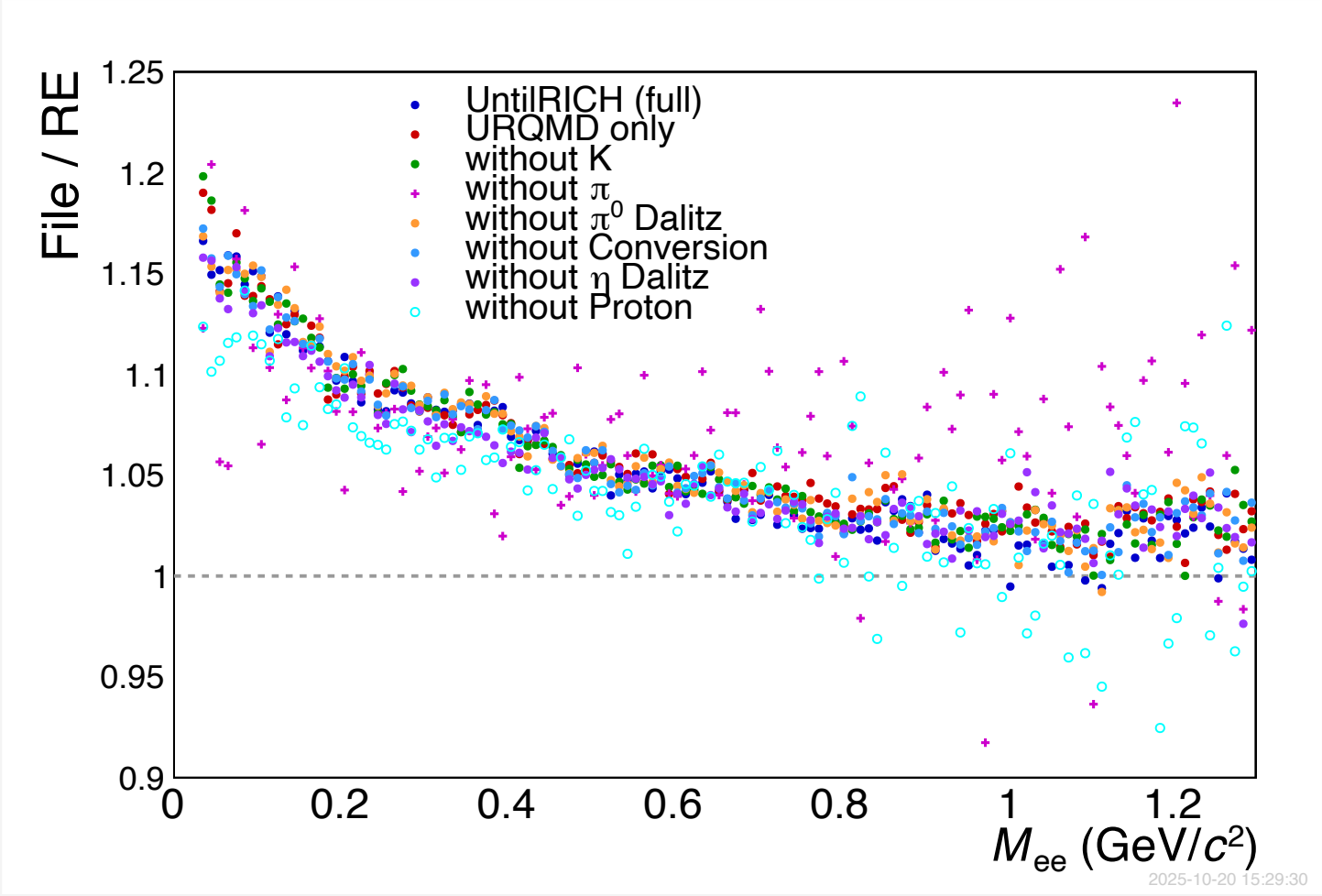
Summary and Outlook

- Simulation and analysis chain implemented
- Increase statistics for high momenta
  - Additional background simulation in progress



Backup

Background simulation



Universität Münster

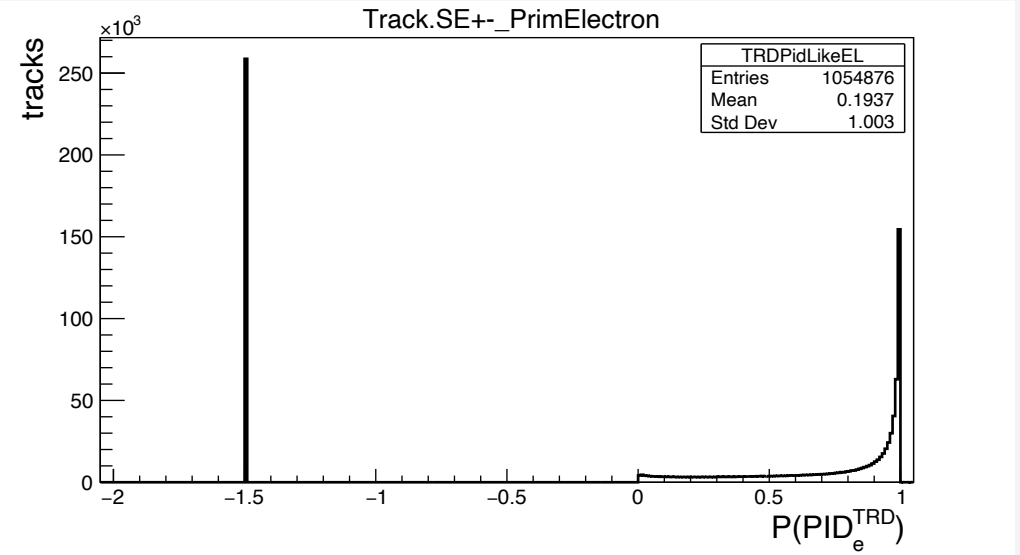
Likelihood Calculation

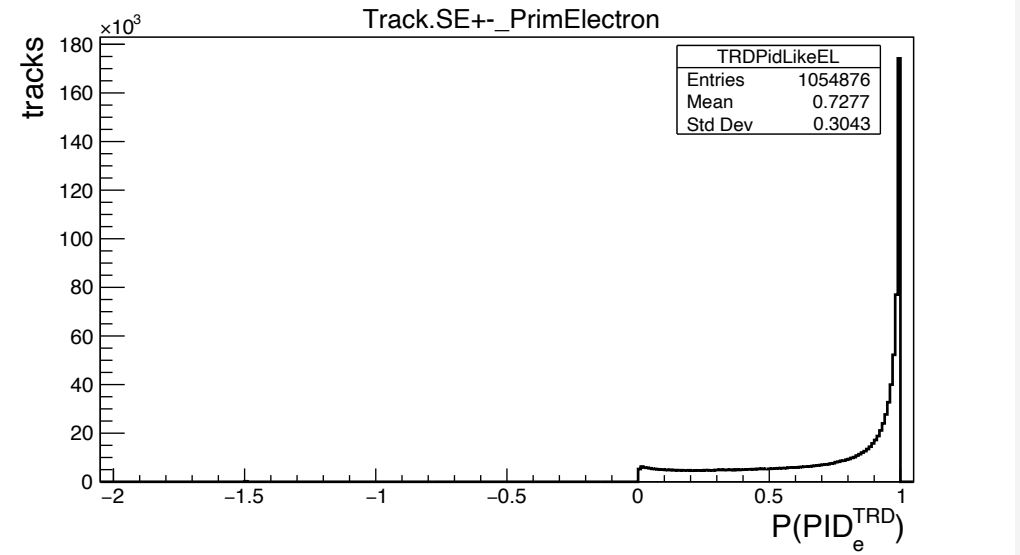
- Shift in electron efficiency
- Negative energy loss leads to negative Likelihood
  - Losing good tracks
- Ignoring negative energy loss

Likelihood: -1.500
eloss 0: 67.97
eloss 1: -1.000
eloss 2: 23.22
eloss 3: 8.820

→

Likelihood: 0.9631
eloss 0: 67.97
eloss 1: -1.000
eloss 2: 23.22
eloss 3: 8.820



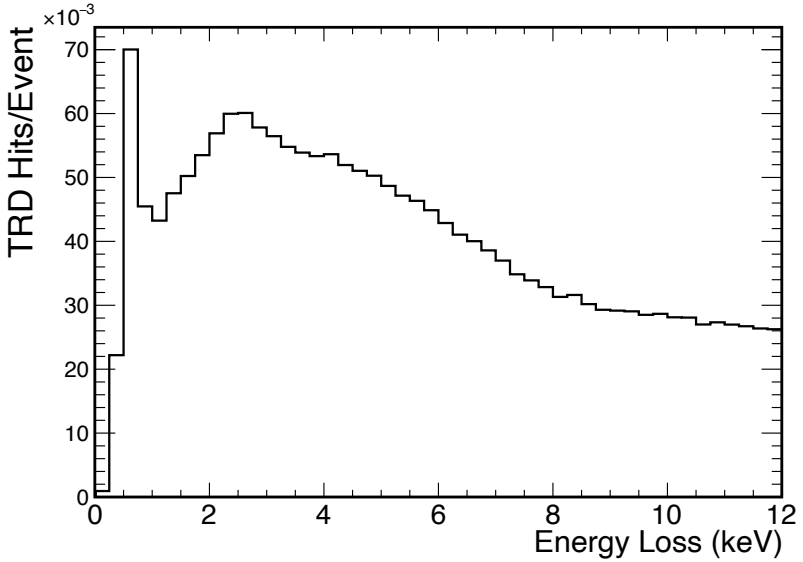


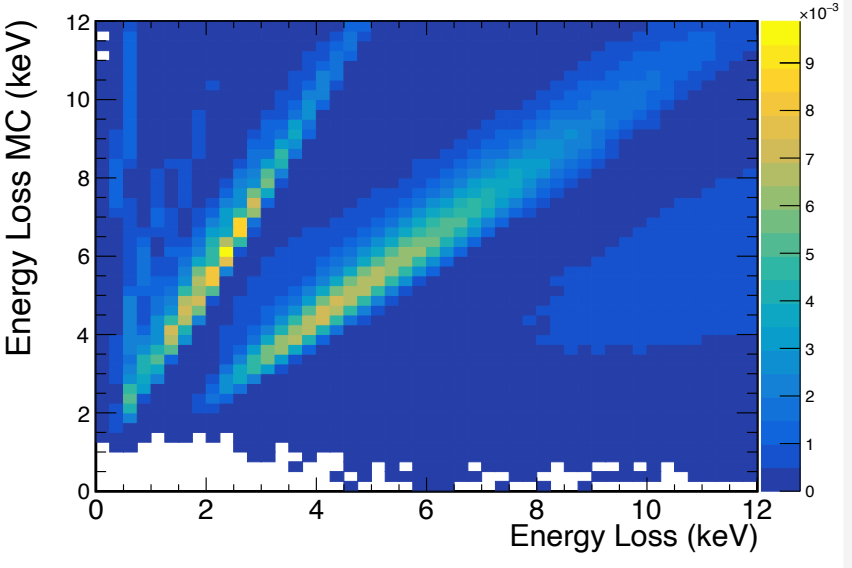
Universität Münster

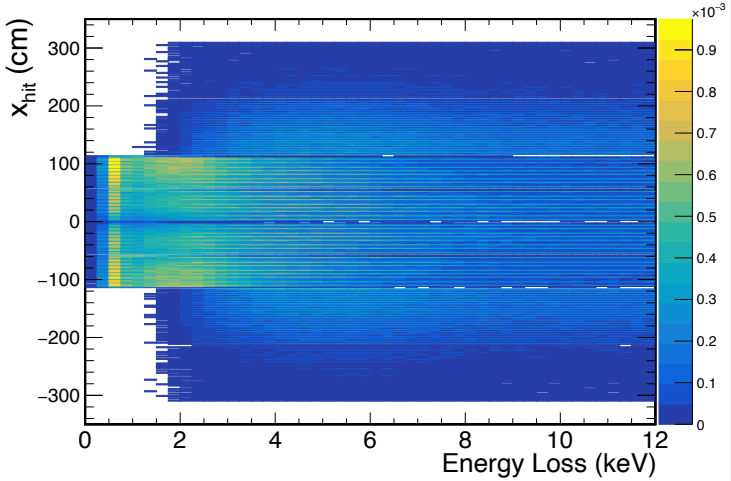
Future improvement by using TRD2d

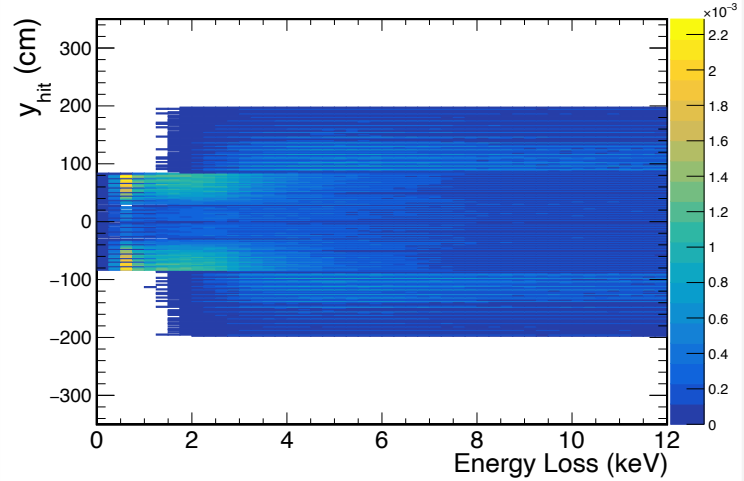
- Wrong energy loss
- Hits positioned in the center

  → TRD2d
- Issue reported and old geometry used





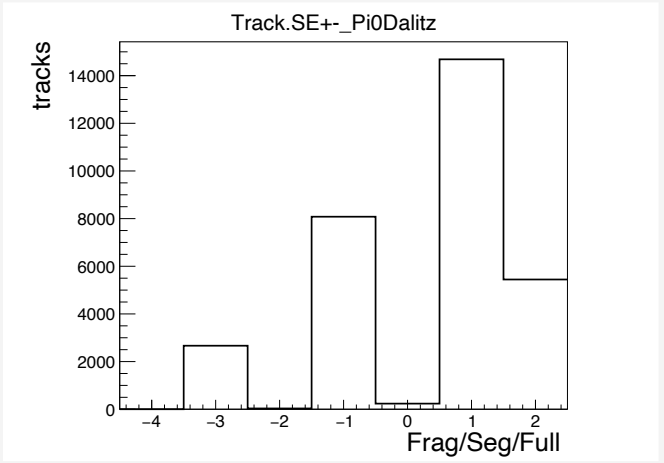


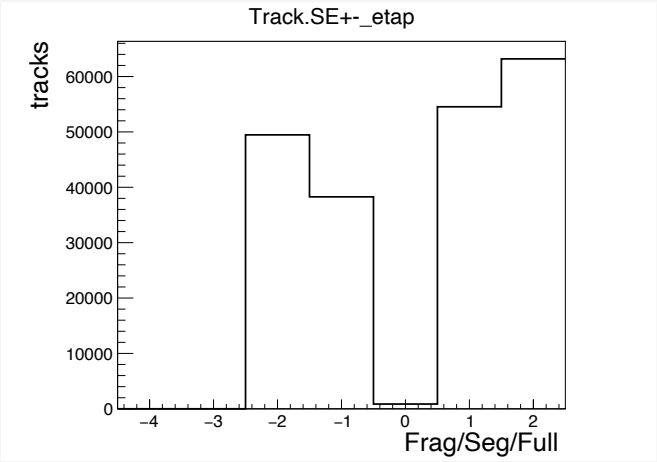


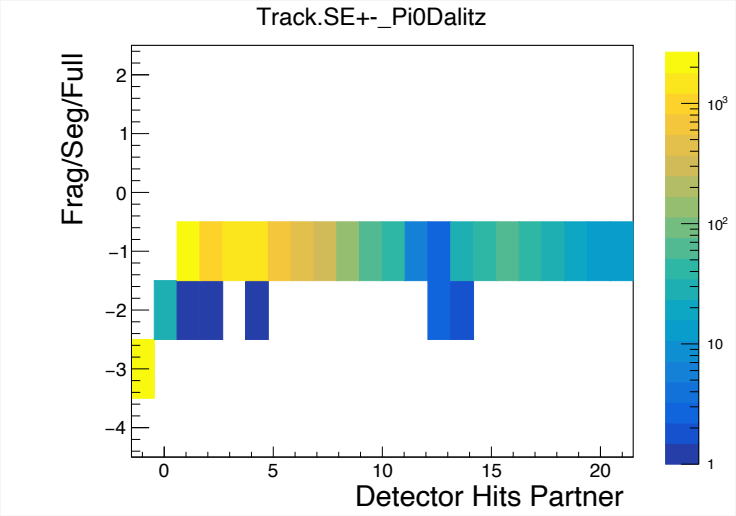
Universität Münster

UrQMD problem

- Particles with partners without MC track
  - Comparison to PHQMD simulation

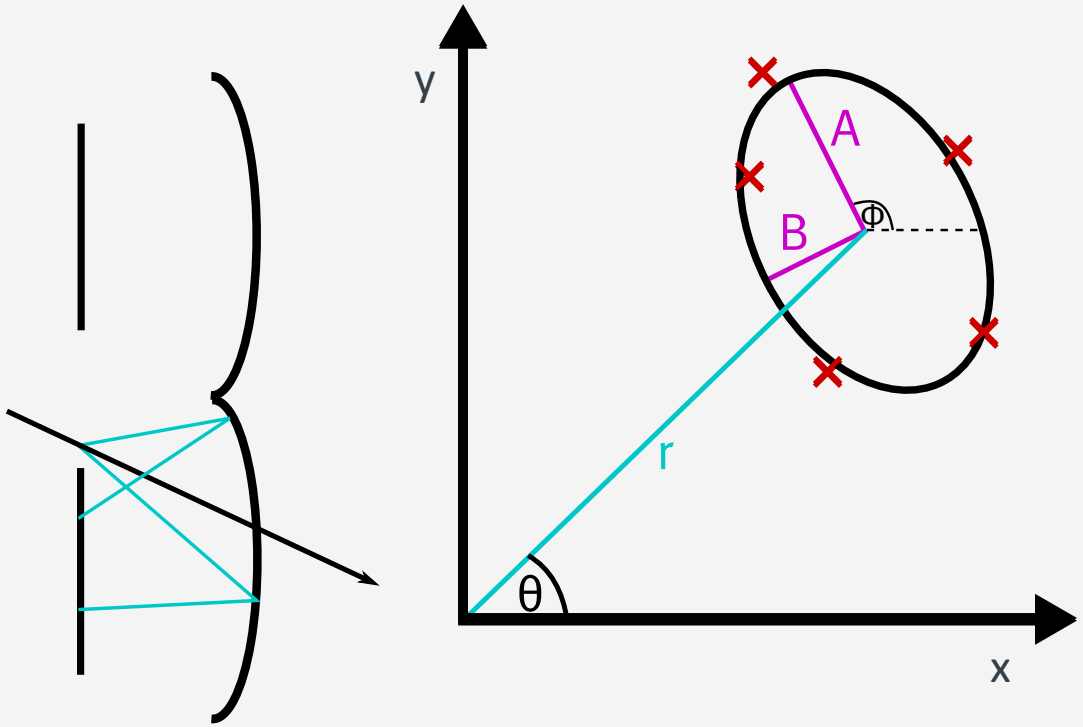






RICH

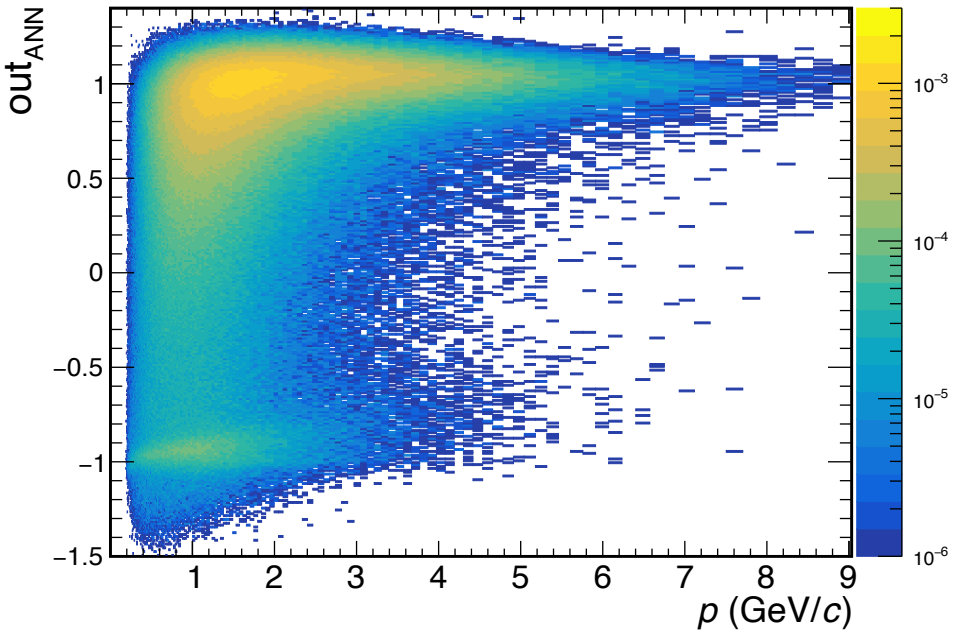
- Ring Imaging Cherenkov detector
- Cherenkov light production pions
  - From $p = 4.65 \frac{\mathrm{GeV}}{\mathrm{c}}$
- Reject tracks without ring
- Further reduction: Input ring parameters into ANN



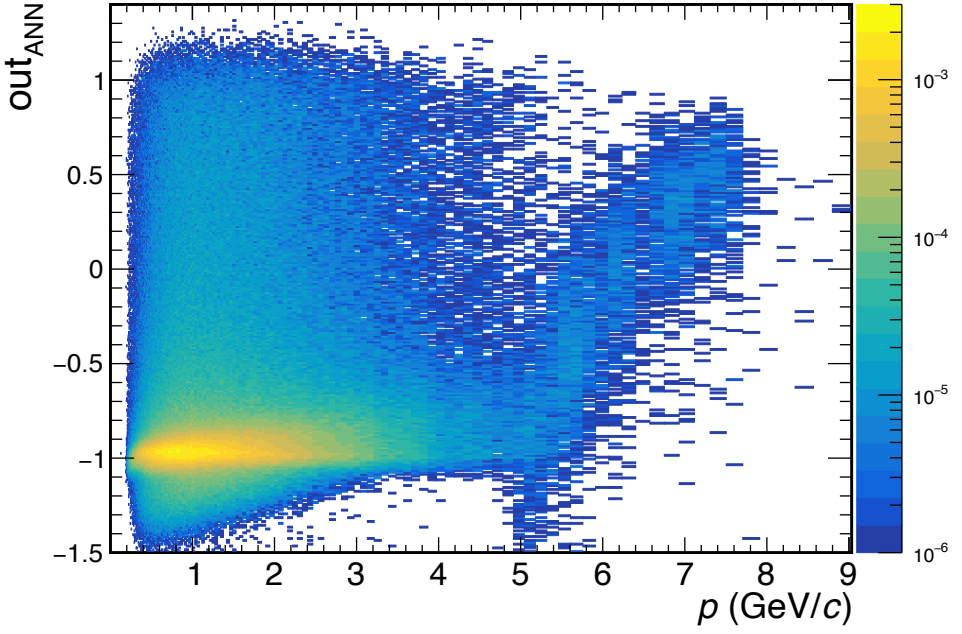
Universität Münster

RICH PID Cut

- PID Cuts: Fix electron efficiency
- Cherenkov light production pions
  - From $p = 4.65\ \mathrm{GeV/c}$



Electrons

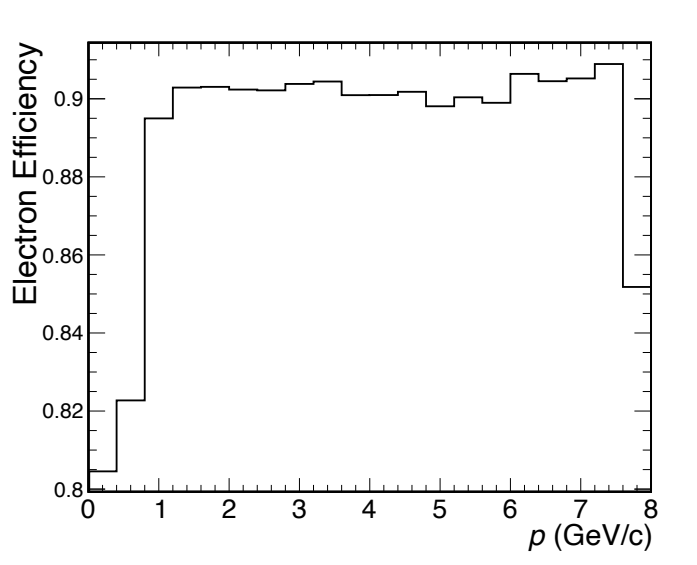


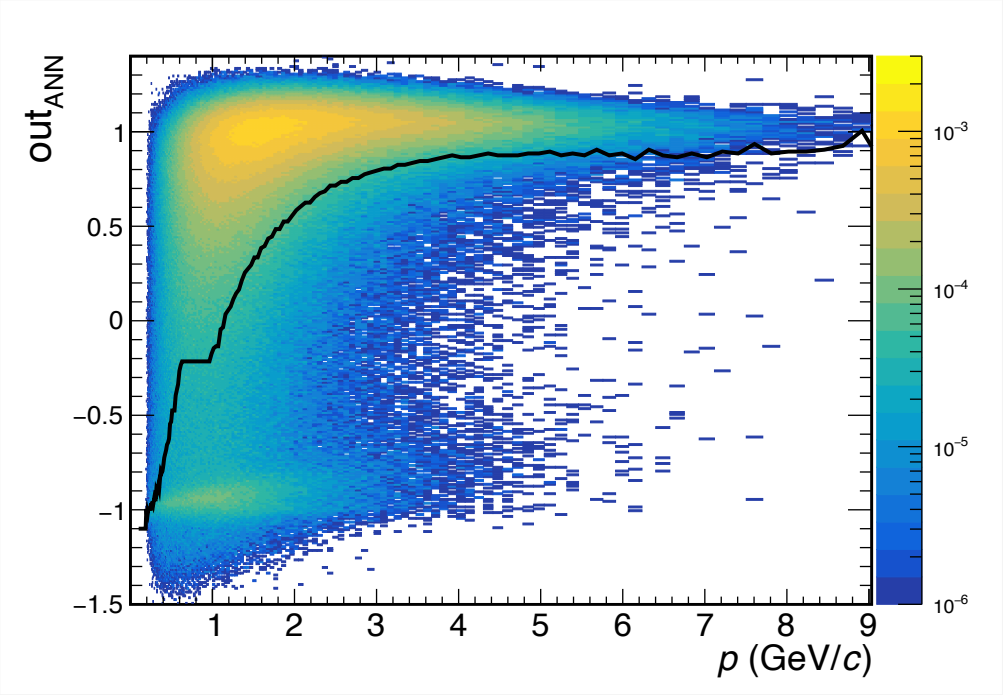
Pions

Universität Münster

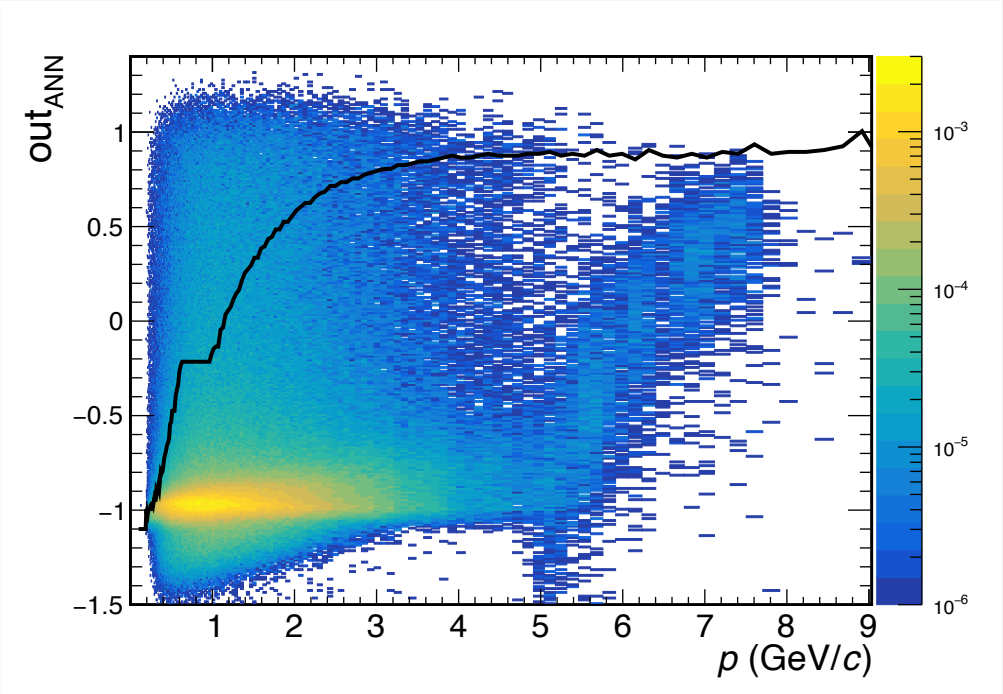
RICH PID Cut

- PID Cuts: Fix electron efficiency
- Cherenkov light production pions
  - From $p = 4.65\ \mathrm{GeV/c}$





Electrons

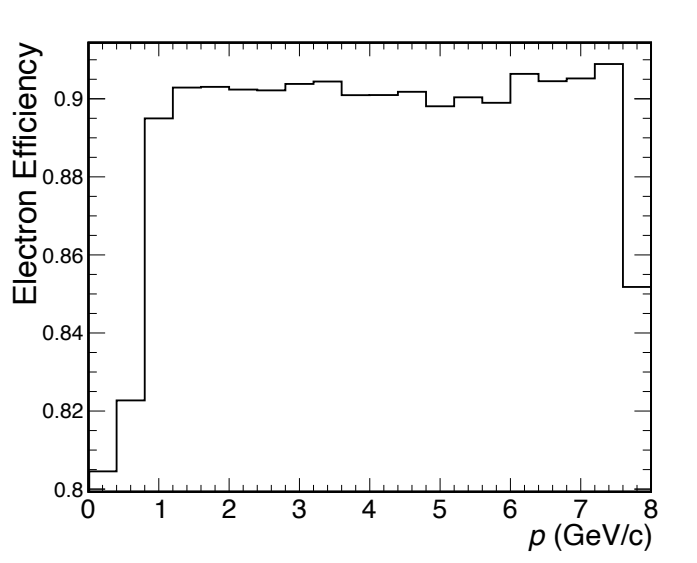


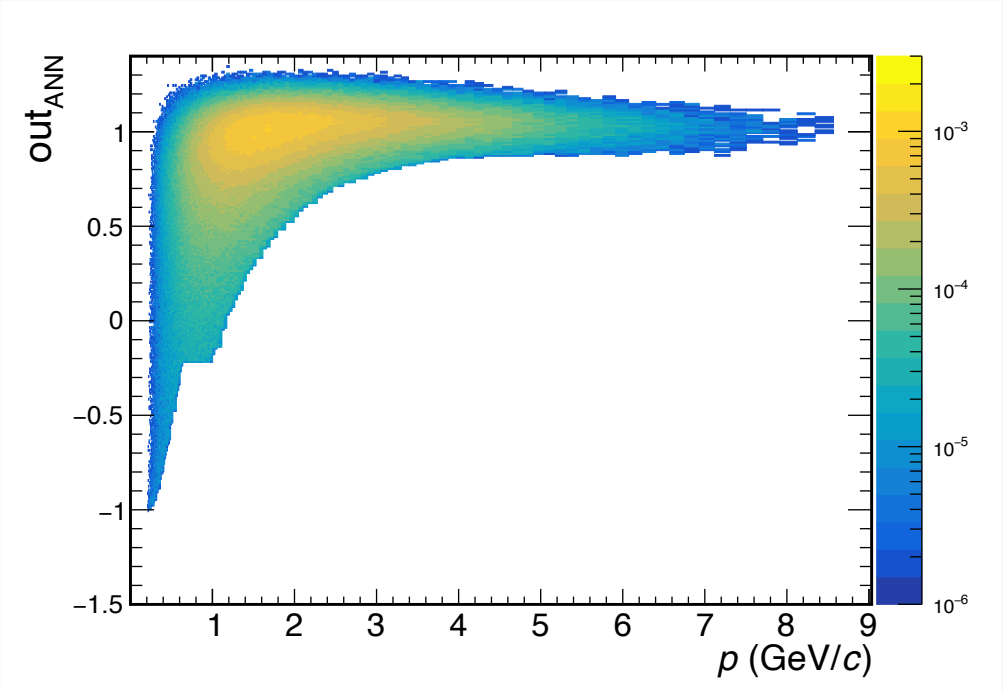
Pions

Universität Münster

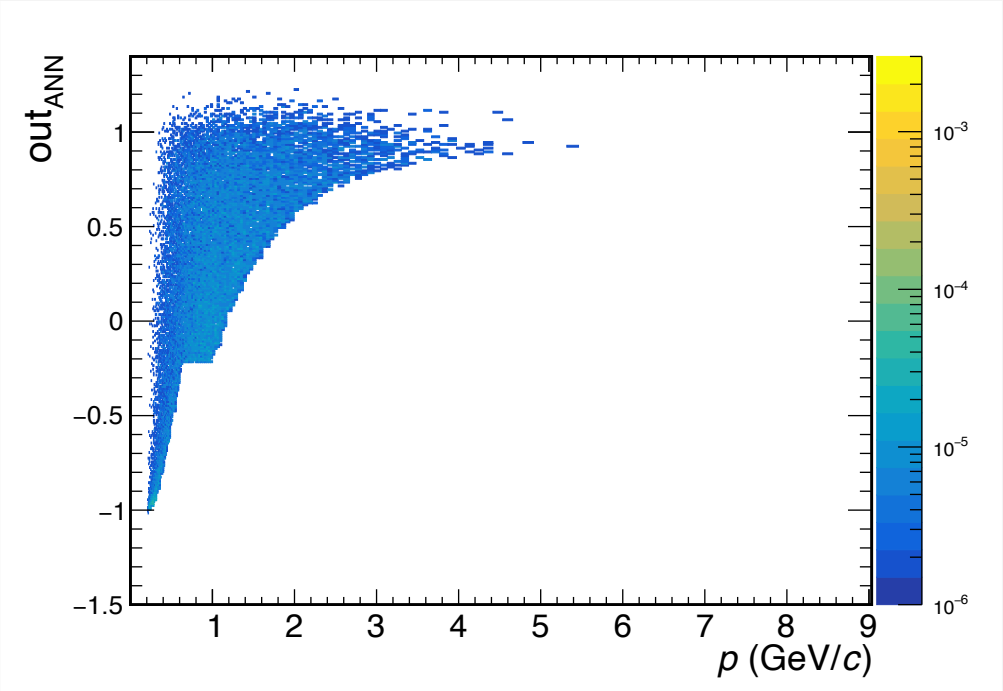
RICH PID Cut

- PID Cuts: Fix electron efficiency
- Cherenkov light production pions
  - From $p = 4.65\ \mathrm{GeV/c}$





Electrons

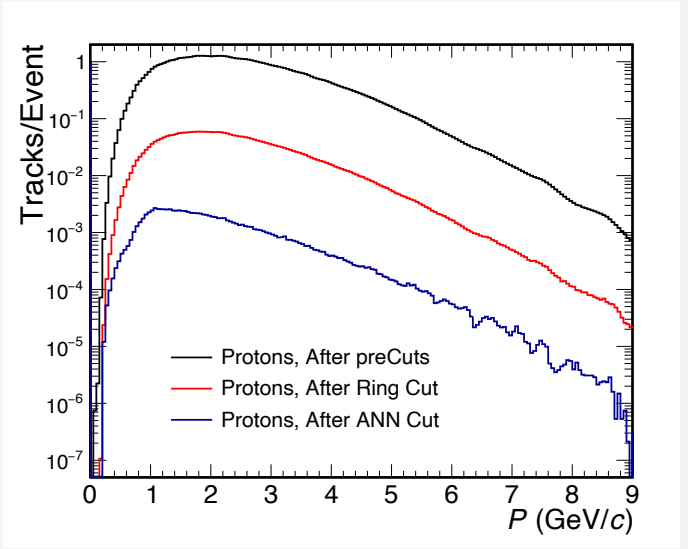


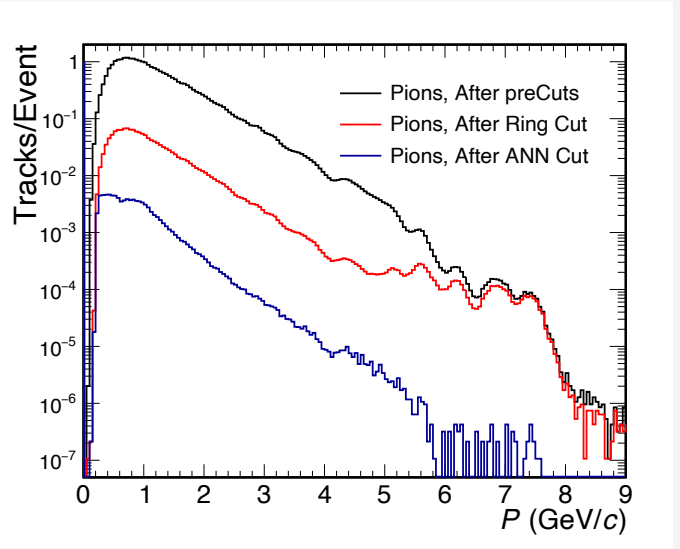
Pions

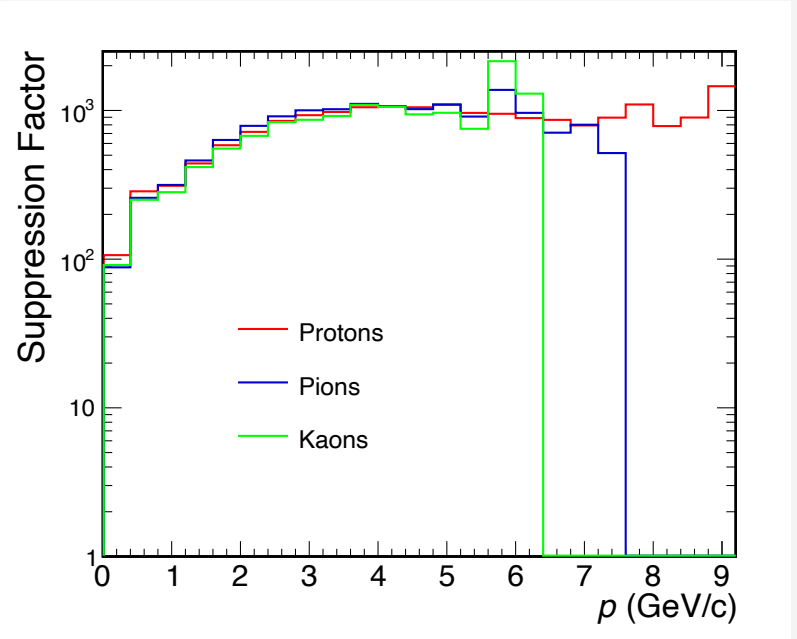
Universität Münster

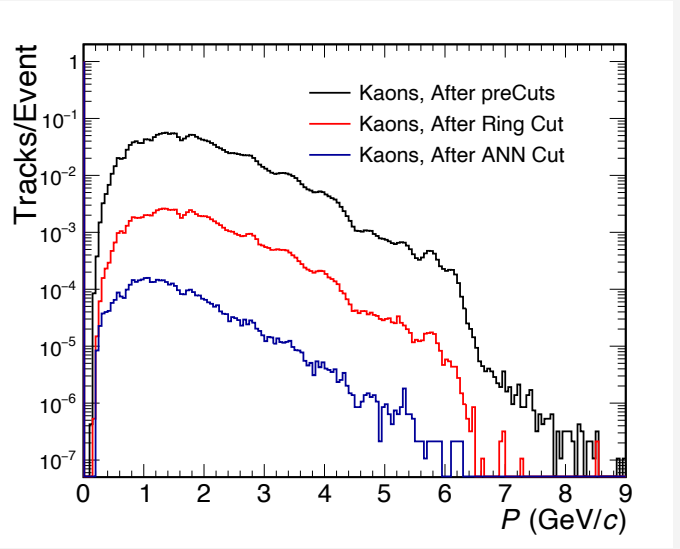
RICH Cut

- Reject tracks without ring
- Further reduction: Input ring parameters into ANN
- Cherenkov light production pions
  - From $p = 4.65 \frac{\mathrm{GeV}}{\mathrm{c}}$
  - Ring cut below
- Fake ring matches
  - Distance between track and ring
  - Lower momenta



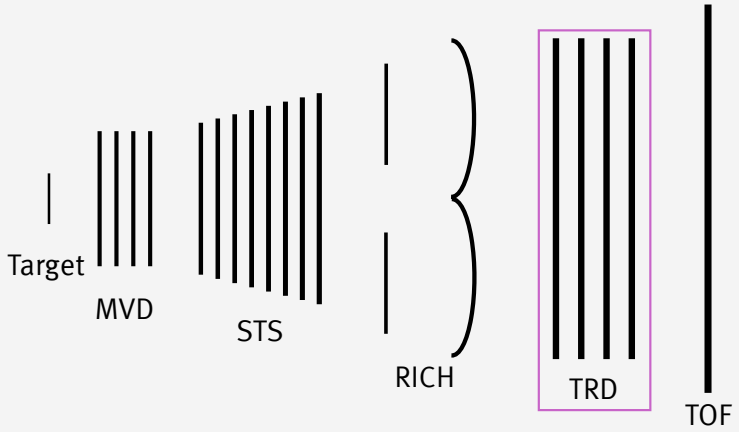






Universität Münster

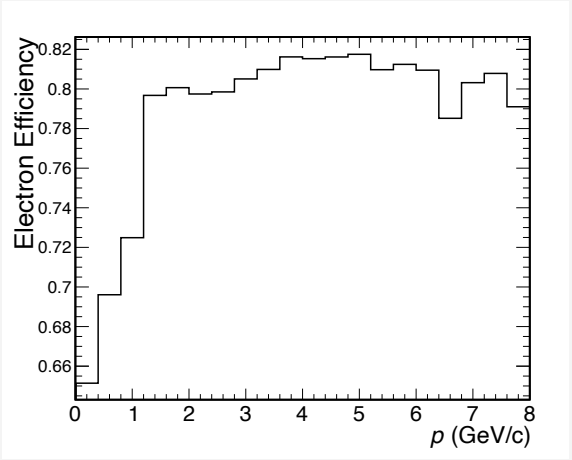
TRD Cut

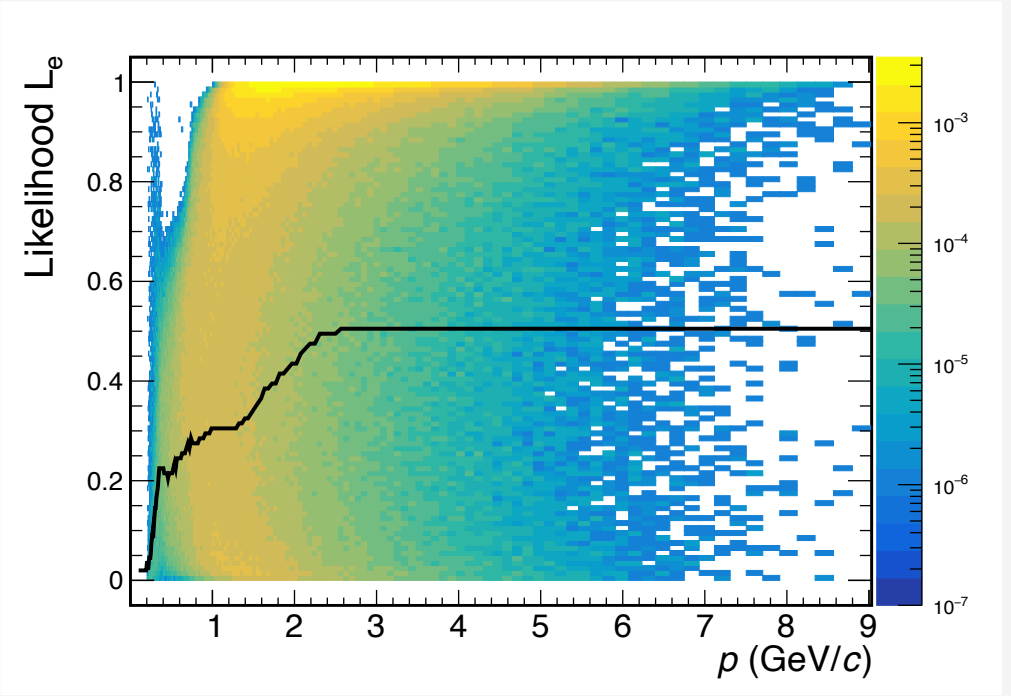


- TR-production depending on γ

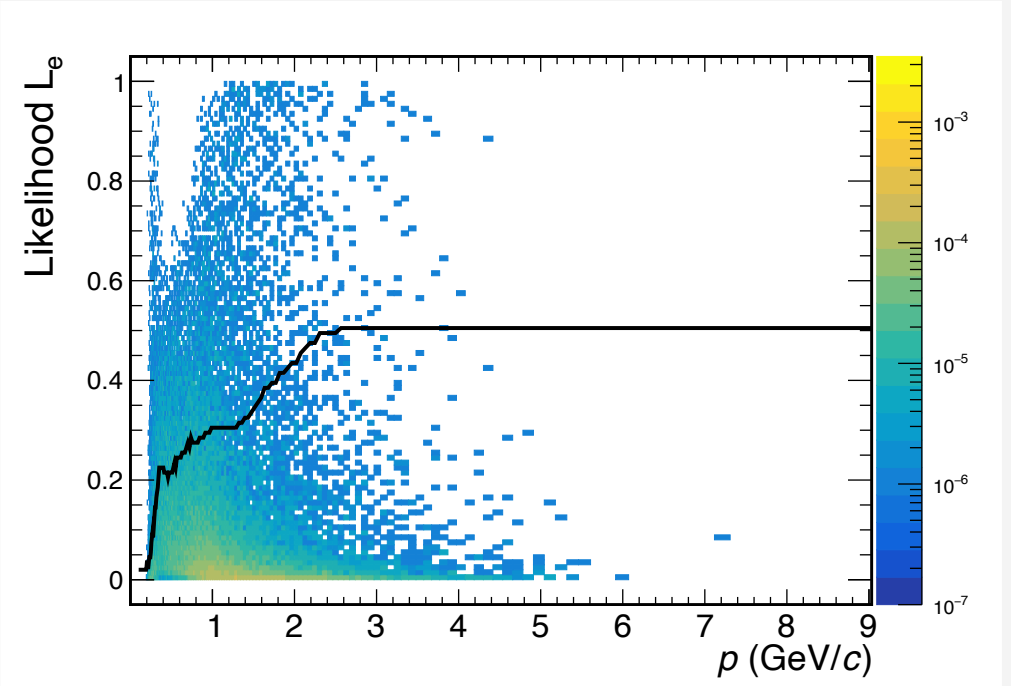
  → More likely for electrons

- Higher energy deposit of electrons
  - Likelihood L_e
- Less TR at low momenta





Electrons



Pions

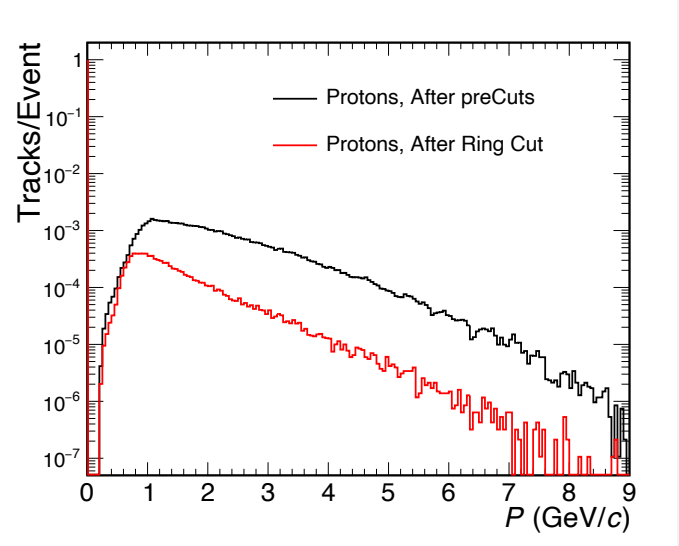
Universität Münster

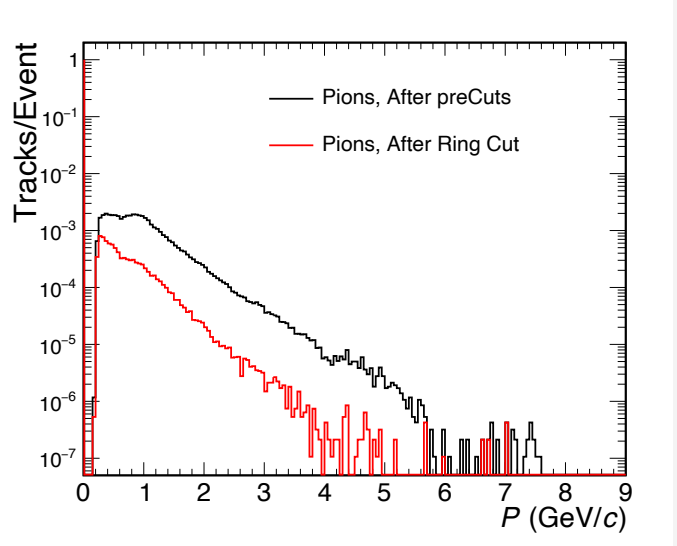
TRD Cut

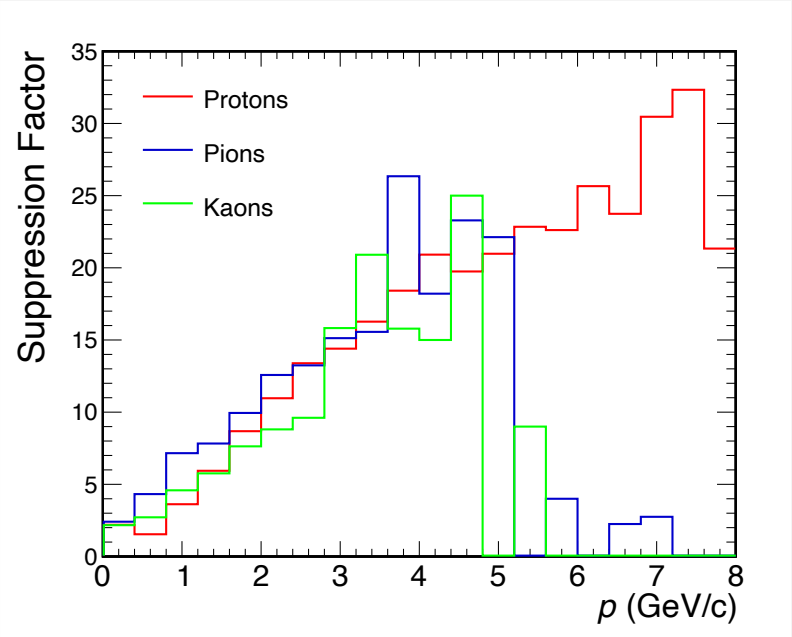
- TR-production depending on γ

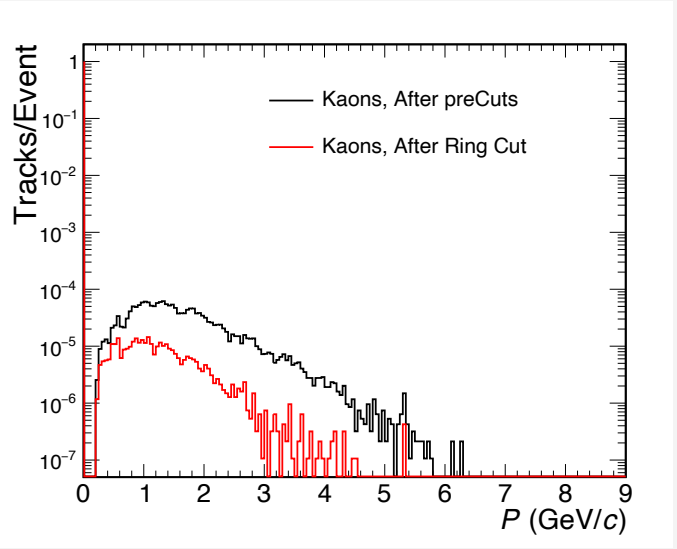
  → More likely for electrons

- Higher energy deposit of electrons
  - Likelihood L_e
- Less TR at low momenta
  - Low suppression

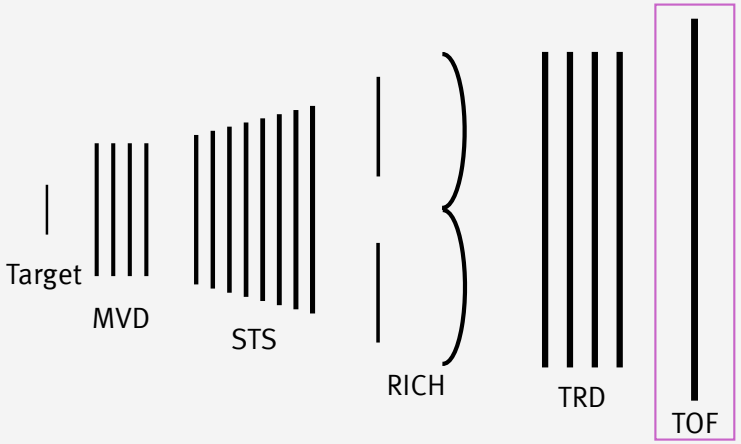






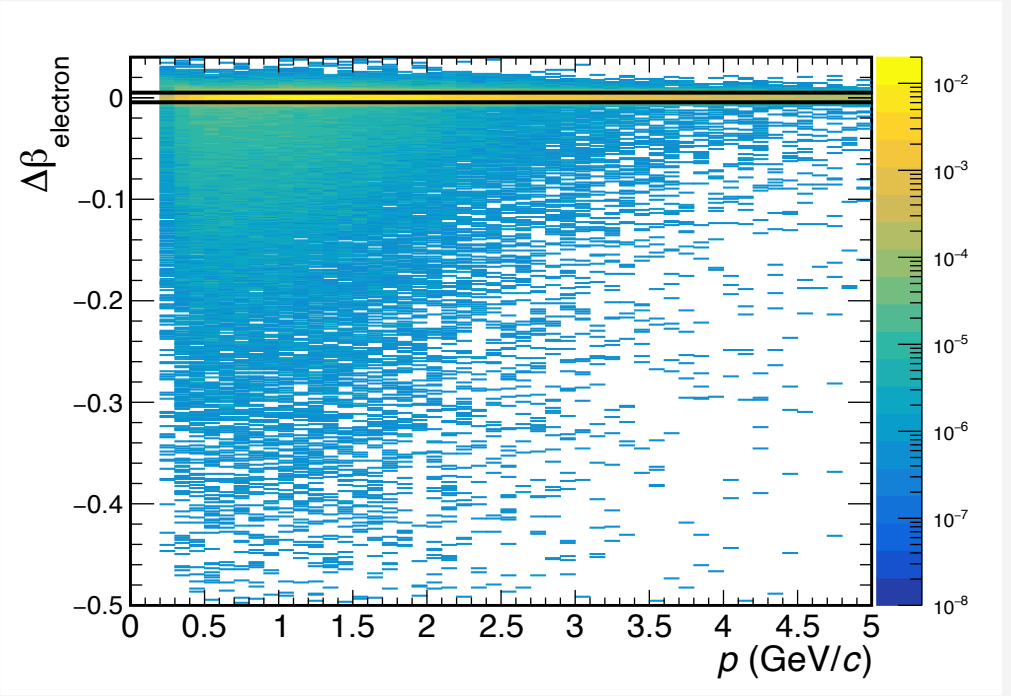


TOF Cut

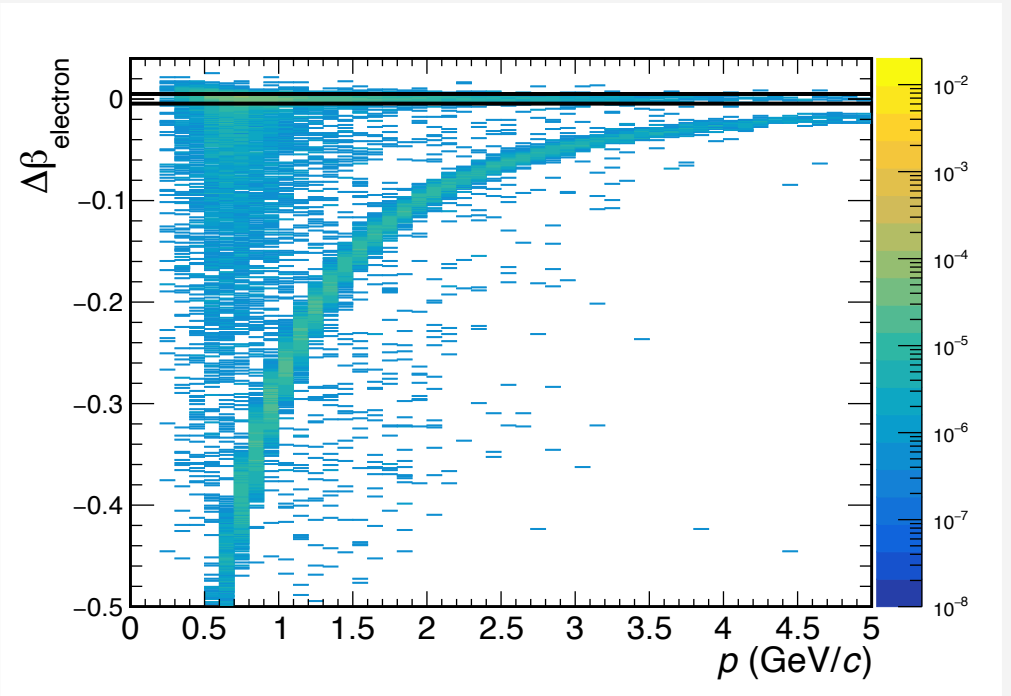


- Arrival time of charged particles
- $\Delta\beta_{electron} = \beta_{track} - \beta_{electron}$
- Mass dependence

  → Low momenta
- Mismatches for $\Delta\beta_{electron} = 0$



Electrons



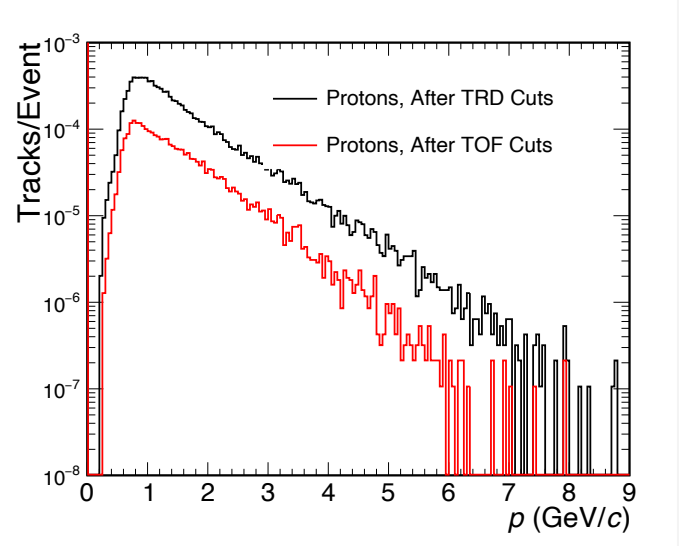
Protons

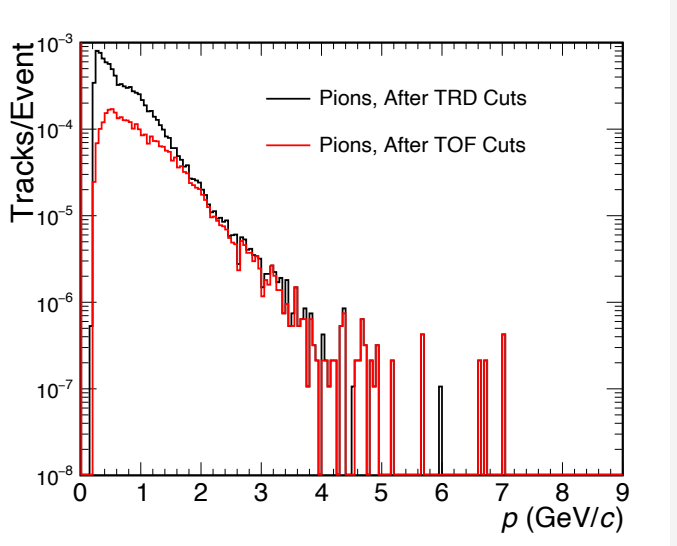
Universität Münster

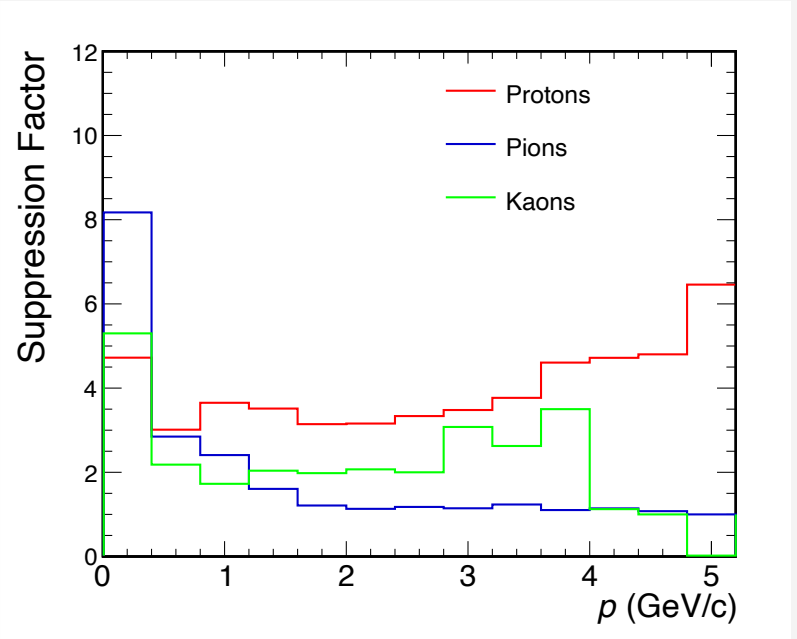
TOF Cut

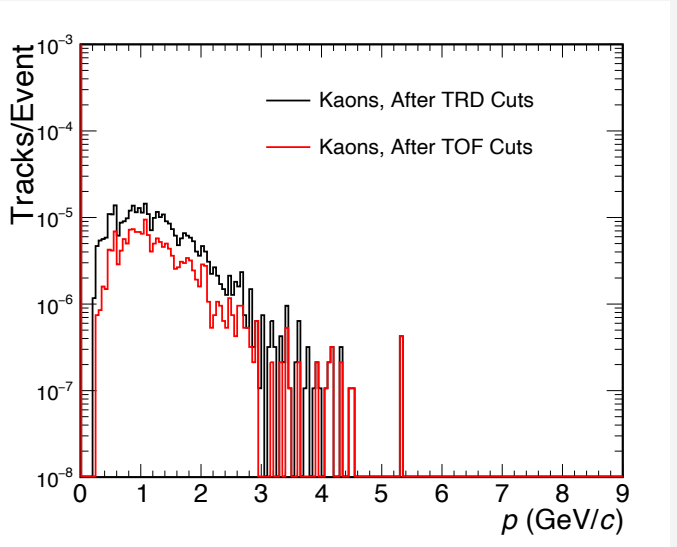
- Arrival time of charged particles
- $\Delta\beta_{electron} = \beta_{track} - \beta_{electron}$
- Mass dependence

  → Low momenta
- Mismatches for $\Delta\beta_{electron} = 0$



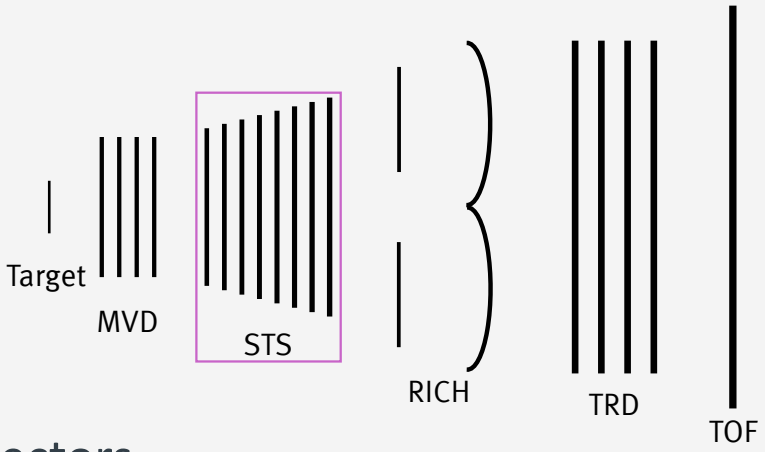




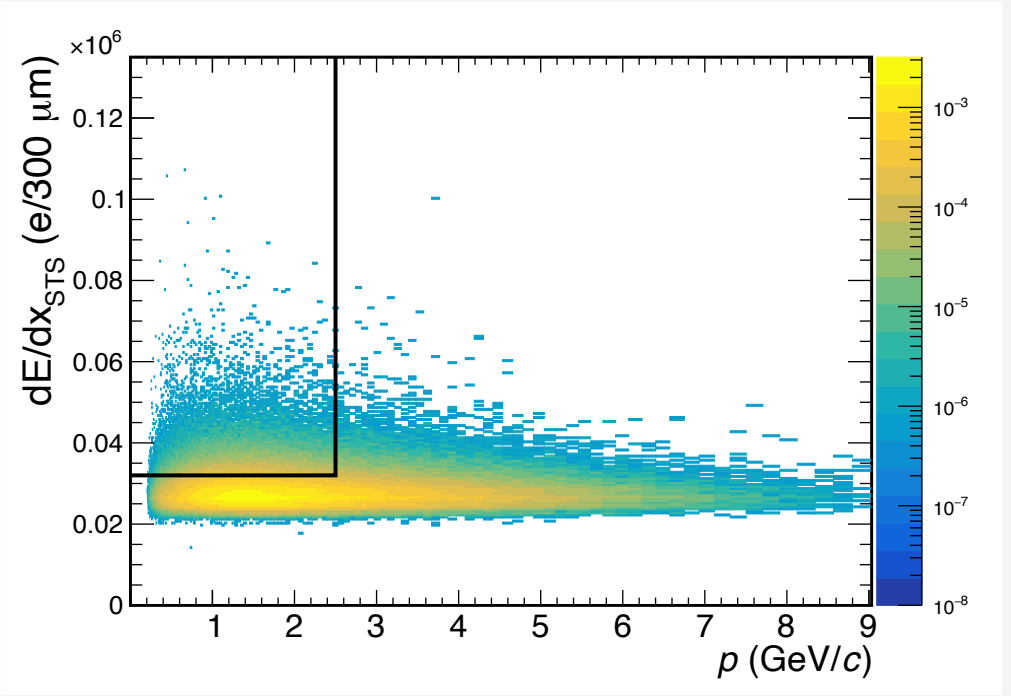


Universität Münster

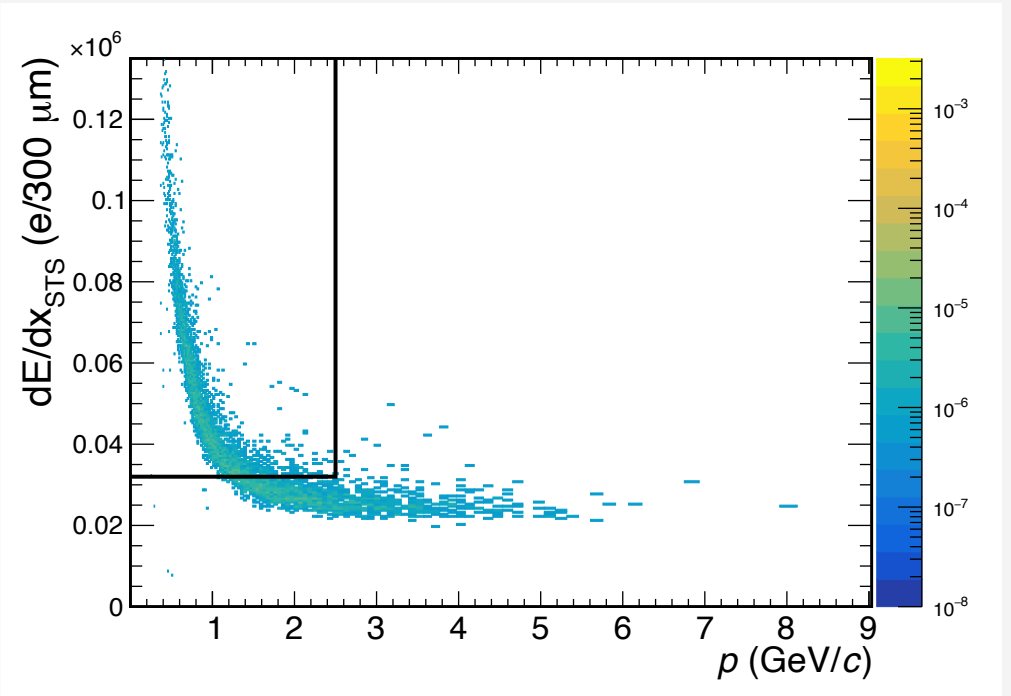
STS Cut



- Silicon strip detectors
- Energy loss
- High proton stopping power for $p \leq 1.5$ in silicon



Electrons



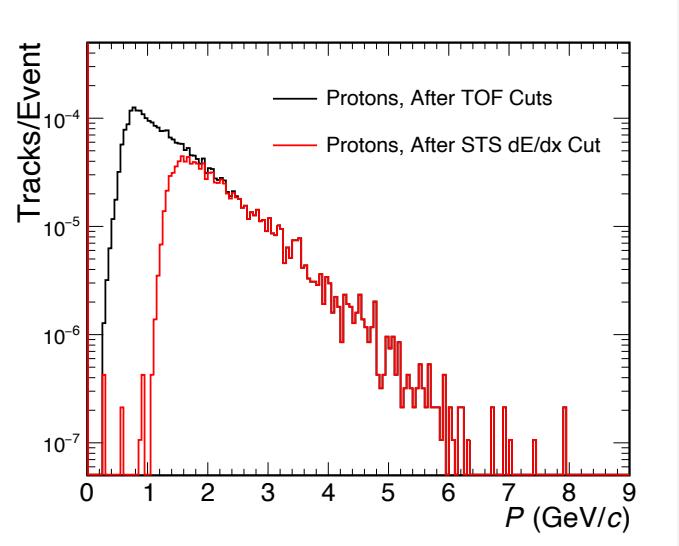
Protons

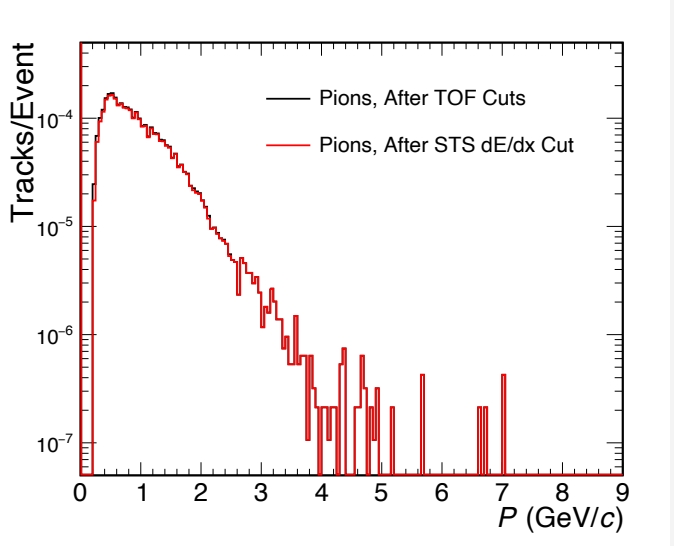
Universität Münster

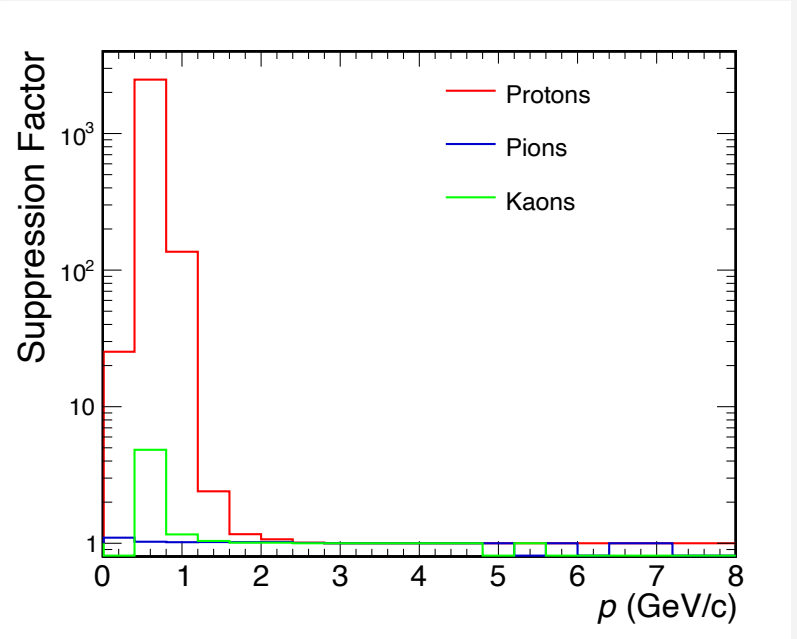
STS Cut

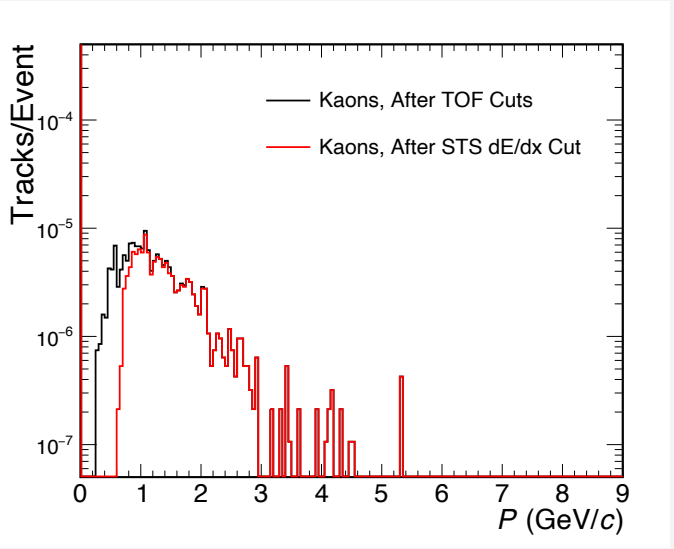
- Silicon strip detectors
- Median in each station used because of Landau shape
- High proton stopping power for $p \leq 1.5$ in silicon

  → High suppression for low momenta

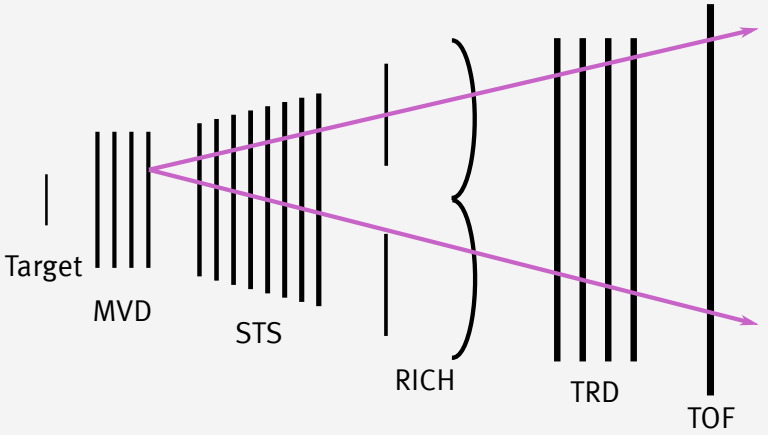








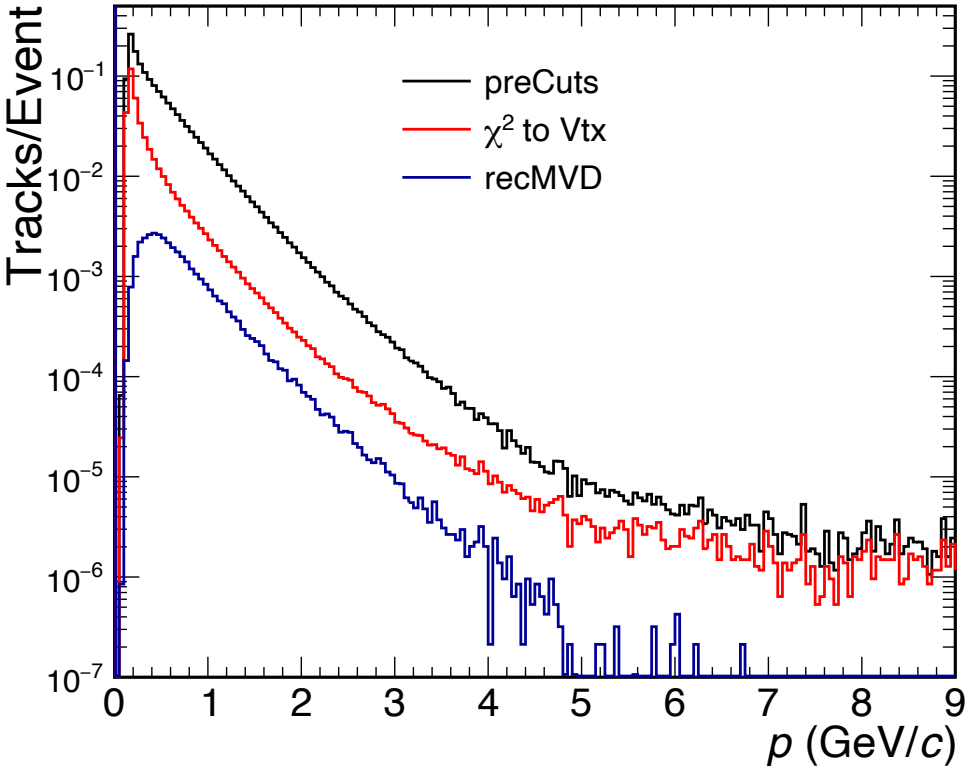
Electron Background rejection



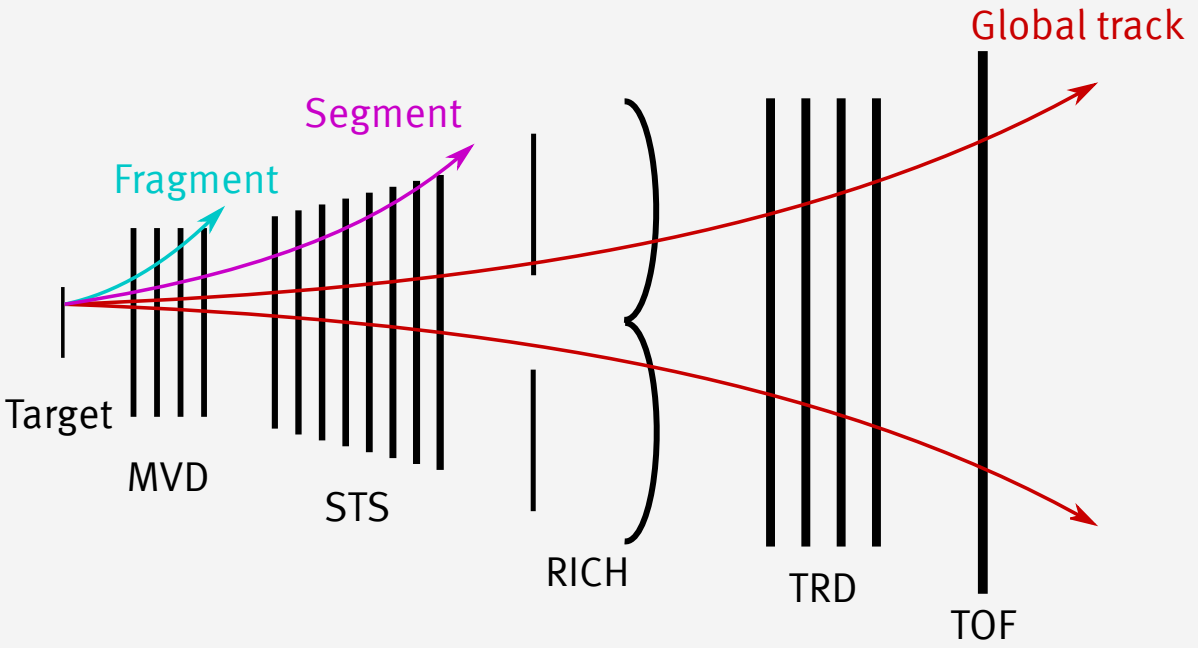
- Photon conversions

$$\gamma \rightarrow e^+ e^-$$

- Invariant mass cut
  - Assuming all tracks as electrons
- Created in detector
  - χ^2 to vertex
  - MVD hits



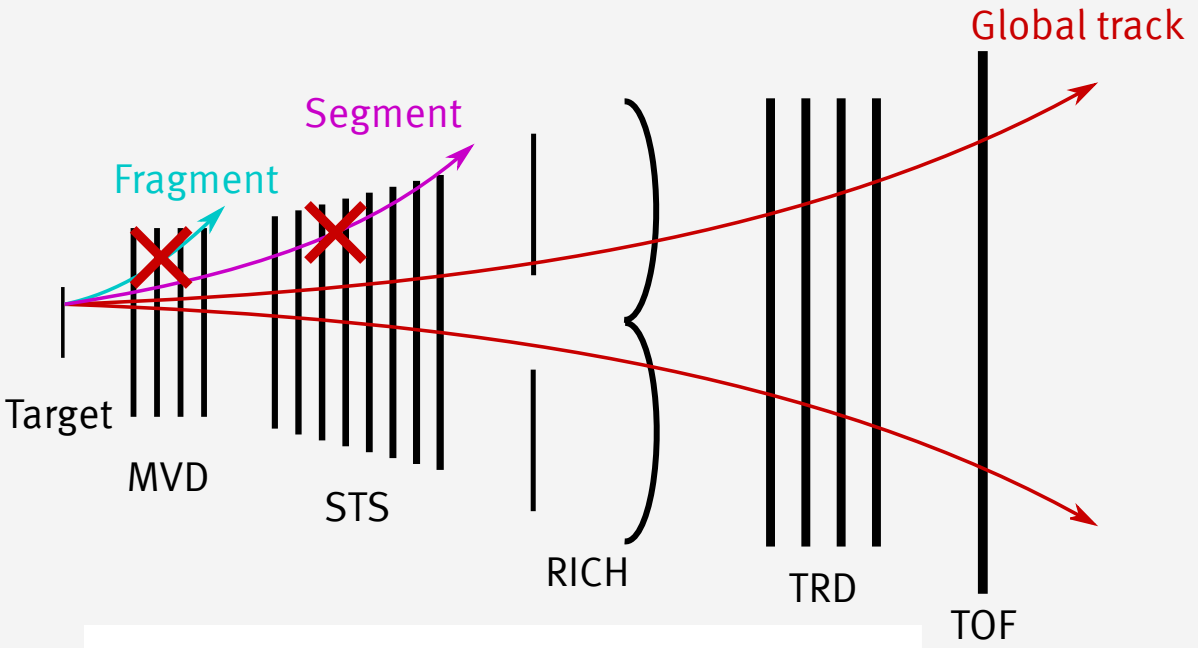
Electron Background rejection

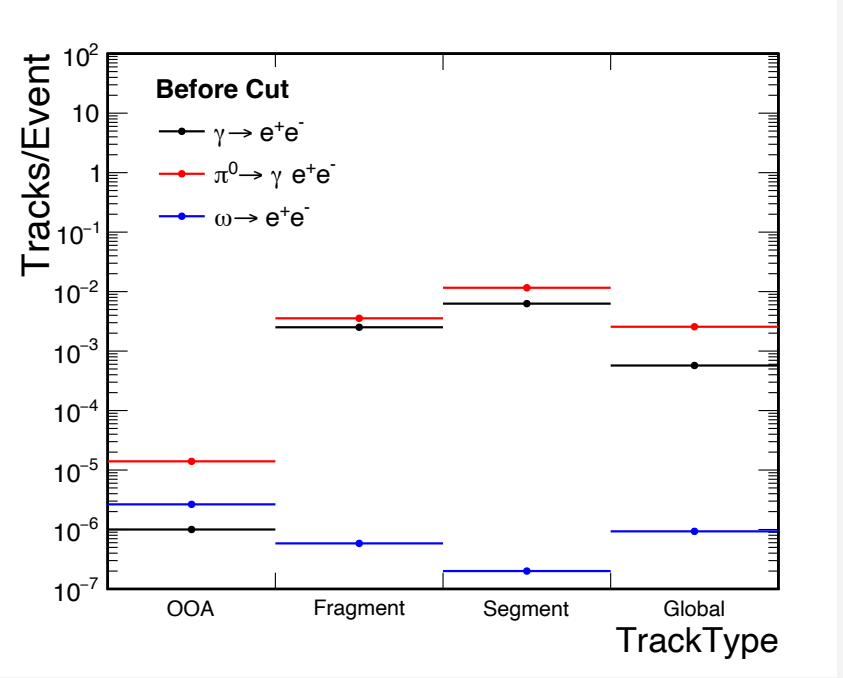


- Incomplete Pairs
- Track type using MC
  - OOA: Out of acceptance
  - Fragment: Less than 4 Hits in MVD+STS
  - Segment: 4 Hits in MVD+STS
  - Global: 4 Hits in MVD+STS and TOF, TRD, RICH
- Global Tracks with rejected partner are background
- Segments for low M_{inv} decays

Electron Background rejection

- Incomplete Pairs
- Track type using MC
  - OOA: Out of acceptance
  - Fragment: Less than 4 Hits in MVD+STS
  - Segment: 4 Hits in MVD+STS
  - Global: 4 Hits in MVD+STS and TOF, TRD, RICH
- Global Tracks with rejected partner are background
- Segments for low M_{inv} decays



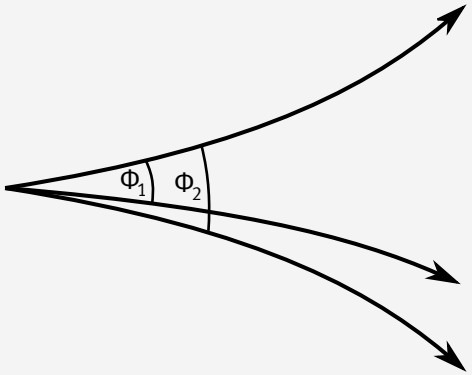


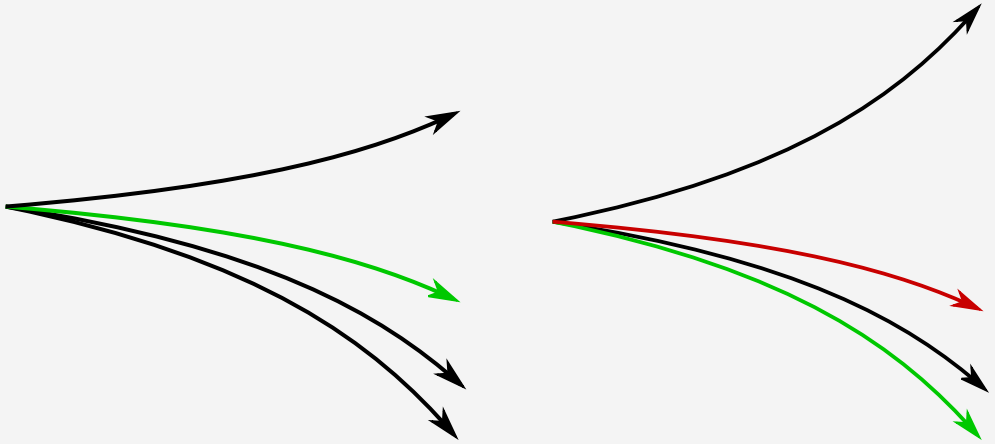
Electron Background rejection

- Incomplete Pairs
- Low mass decays → small opening angle

$$M_{inv} \approx 2 \sin \frac{\phi}{2} \sqrt{p_1 p_2}$$

- Match smallest opening angle





True Match

Fake Match

Universität Münster

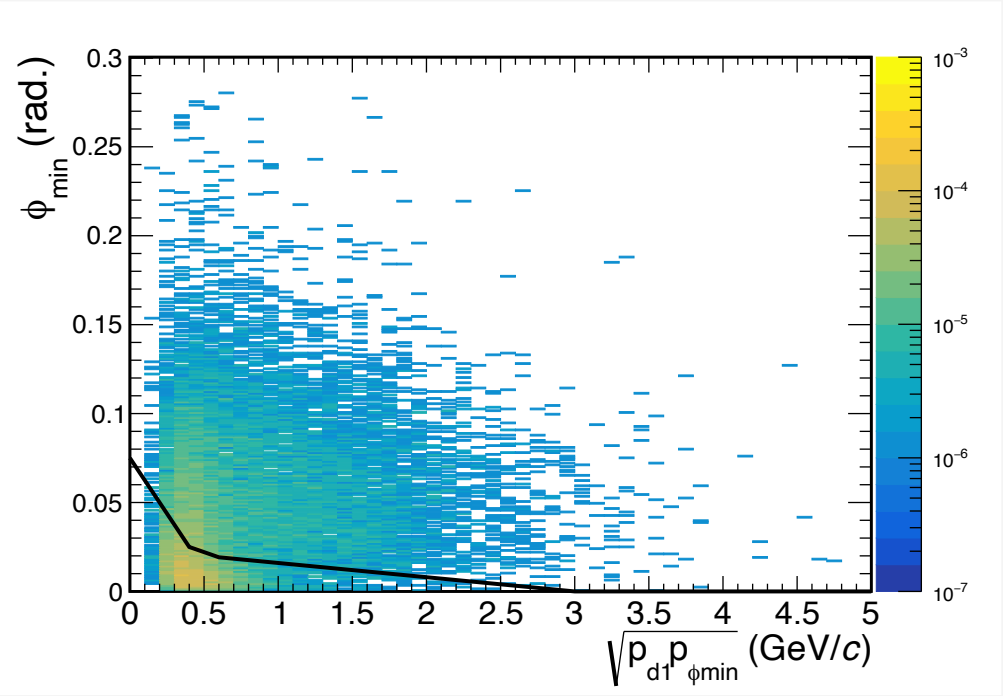
Electron Background rejection

- Incomplete Pairs
- Low mass decays → small opening angle

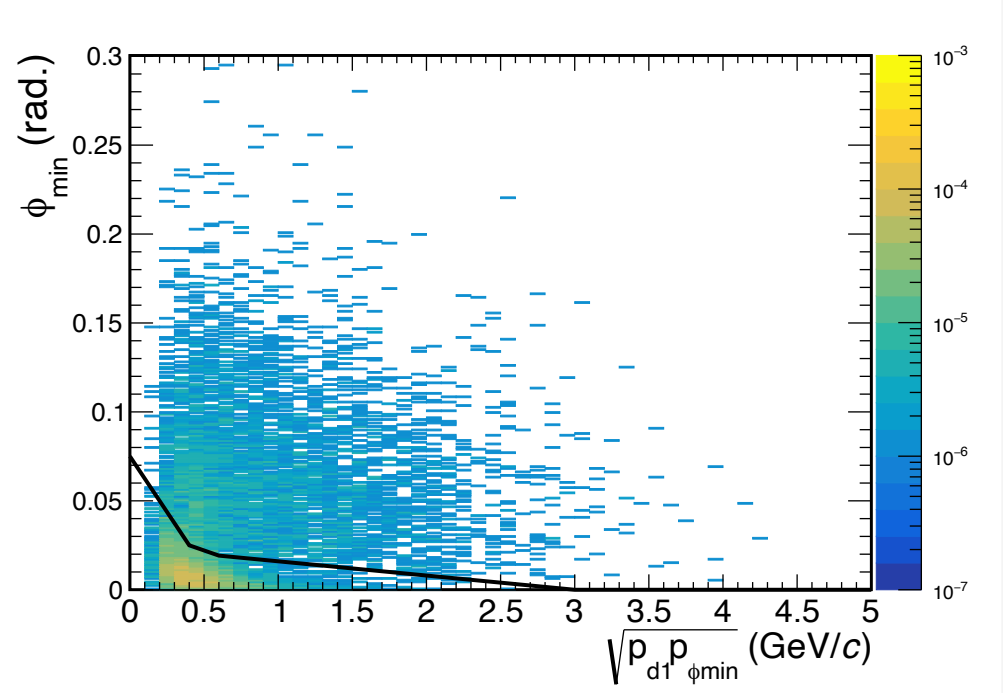
$$M_{inv} \approx 2 \sin \frac{\phi}{2} \sqrt{p_1 p_2}$$

- Match smallest opening angle
- True matches shows correlation between $\sqrt{p_1 p_2}$ and ϕ

  → Low mass decays



$\pi^0 \rightarrow \gamma e^+ e^-$



$\gamma \rightarrow e^+ e^-$

Universität Münster

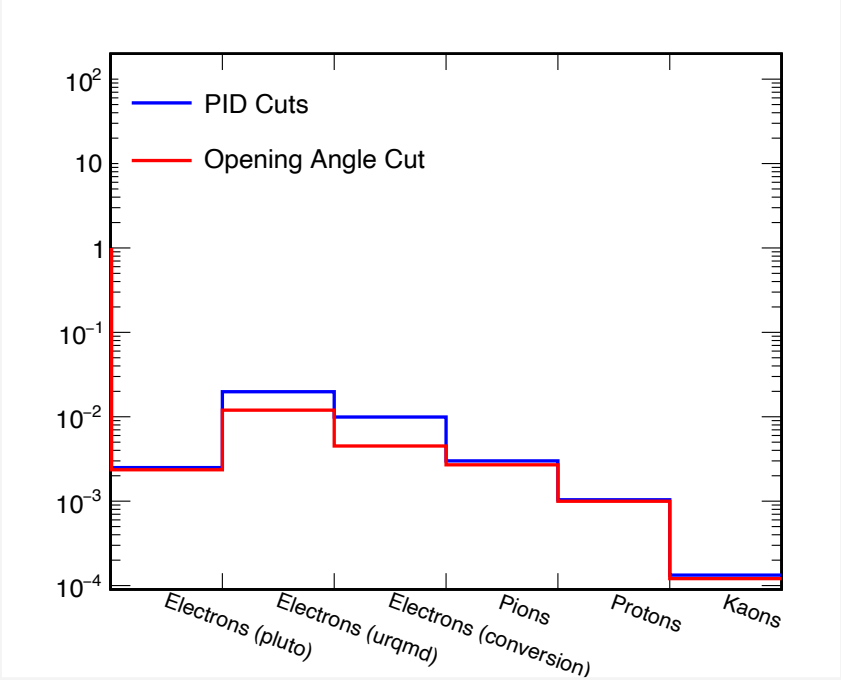
Electron Background rejection

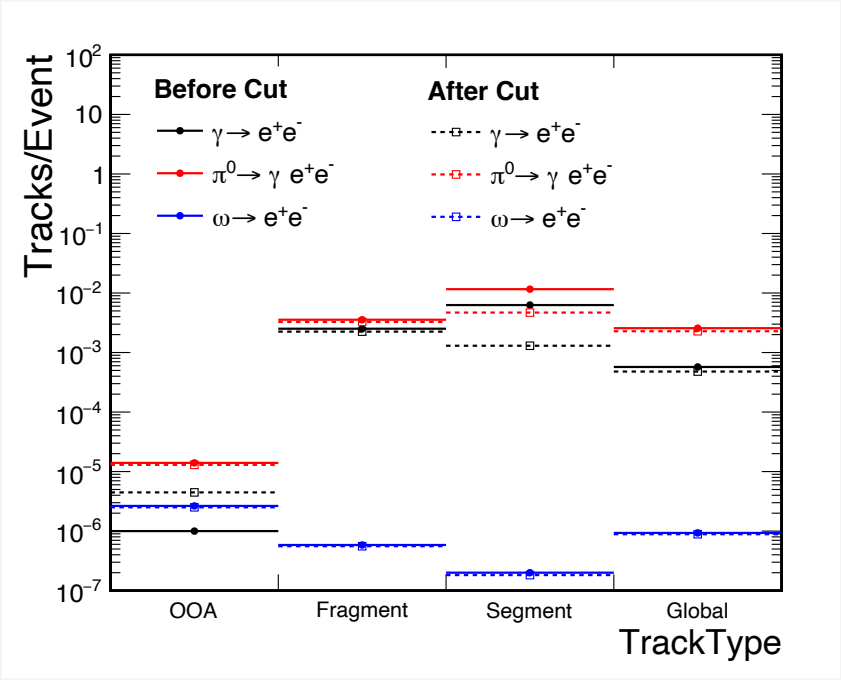
- Incomplete Pairs
- Low mass decays → small opening angle

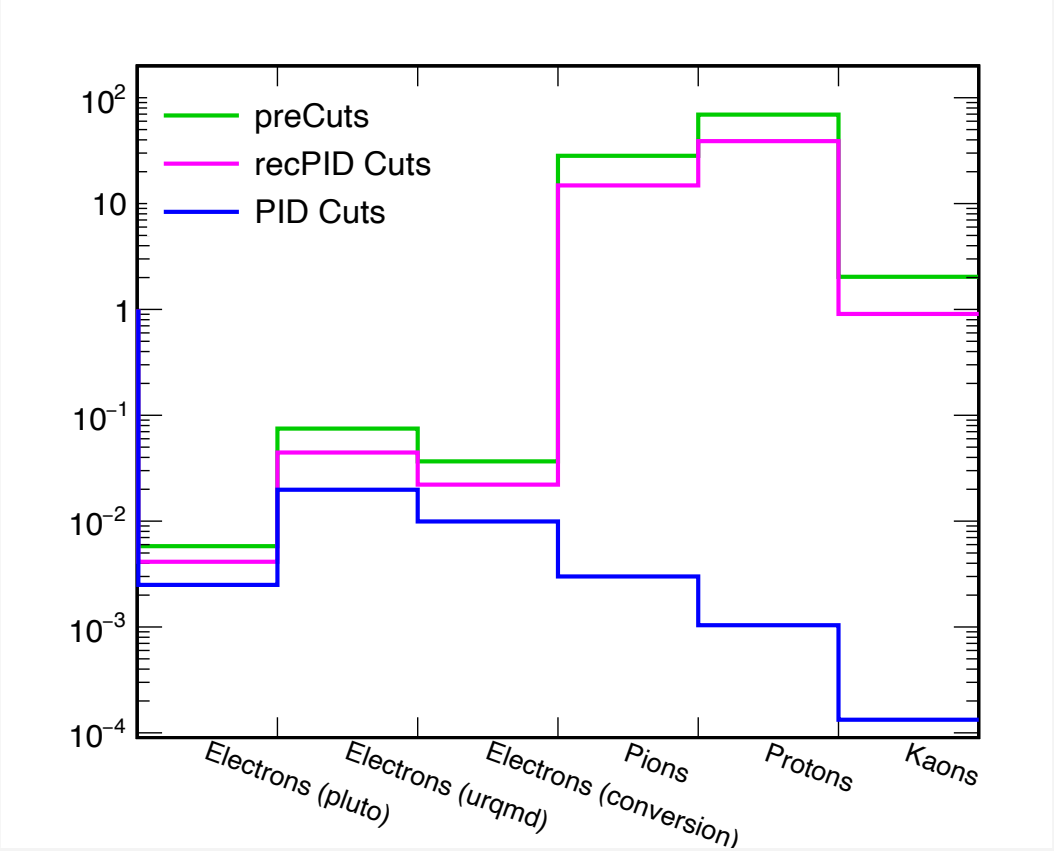
$$M_{inv} \approx 2 \sin \frac{\phi}{2} \sqrt{p_1 p_2}$$

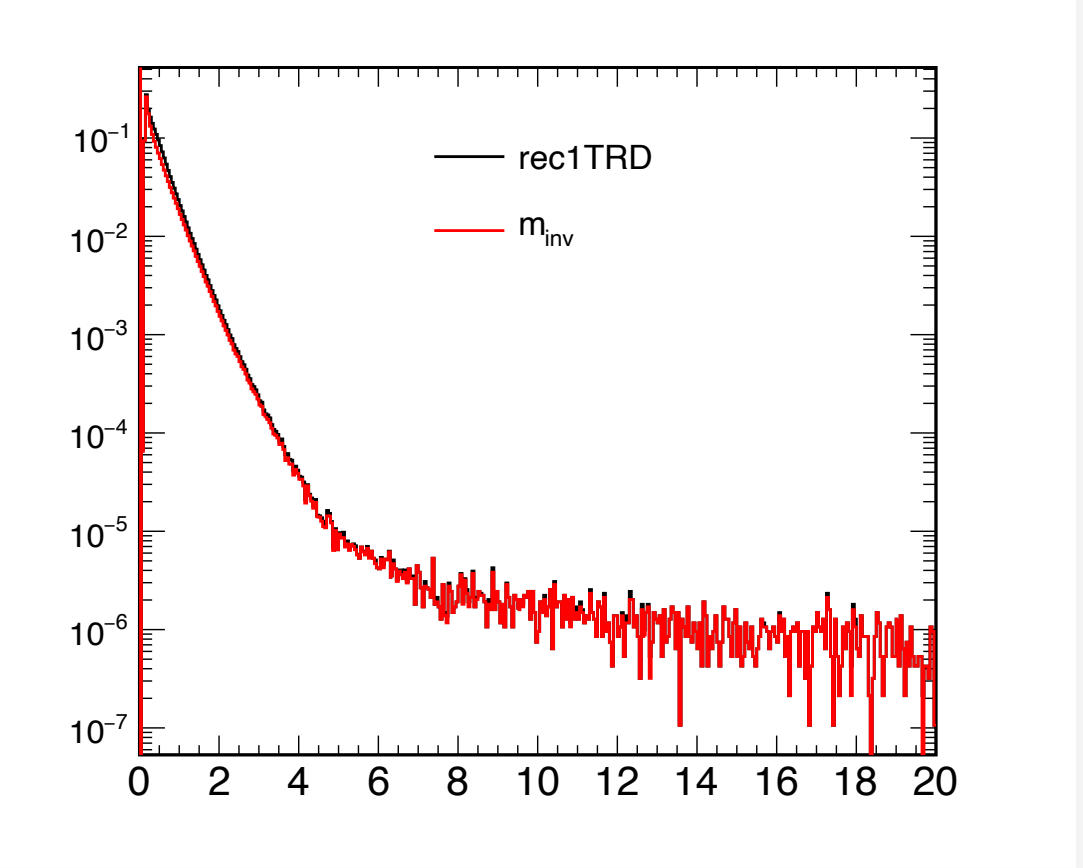
- Match smallest opening angle
- True matches shows correlation between $\sqrt{p_1 p_2}$ and ϕ

  → Low mass decays
- Reduction of segments as partners






preCuts
recPID Cuts
PID Cuts
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Electrons (pluto)
Electrons (urqmd)
Electrons (conversion)
Pions
Protons
Kaons


rec1TRD
m_{inv}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
2
4
6
8
10
12
14
16
18
20