Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Synchrotron Radiation Background Estimation in Track Hits

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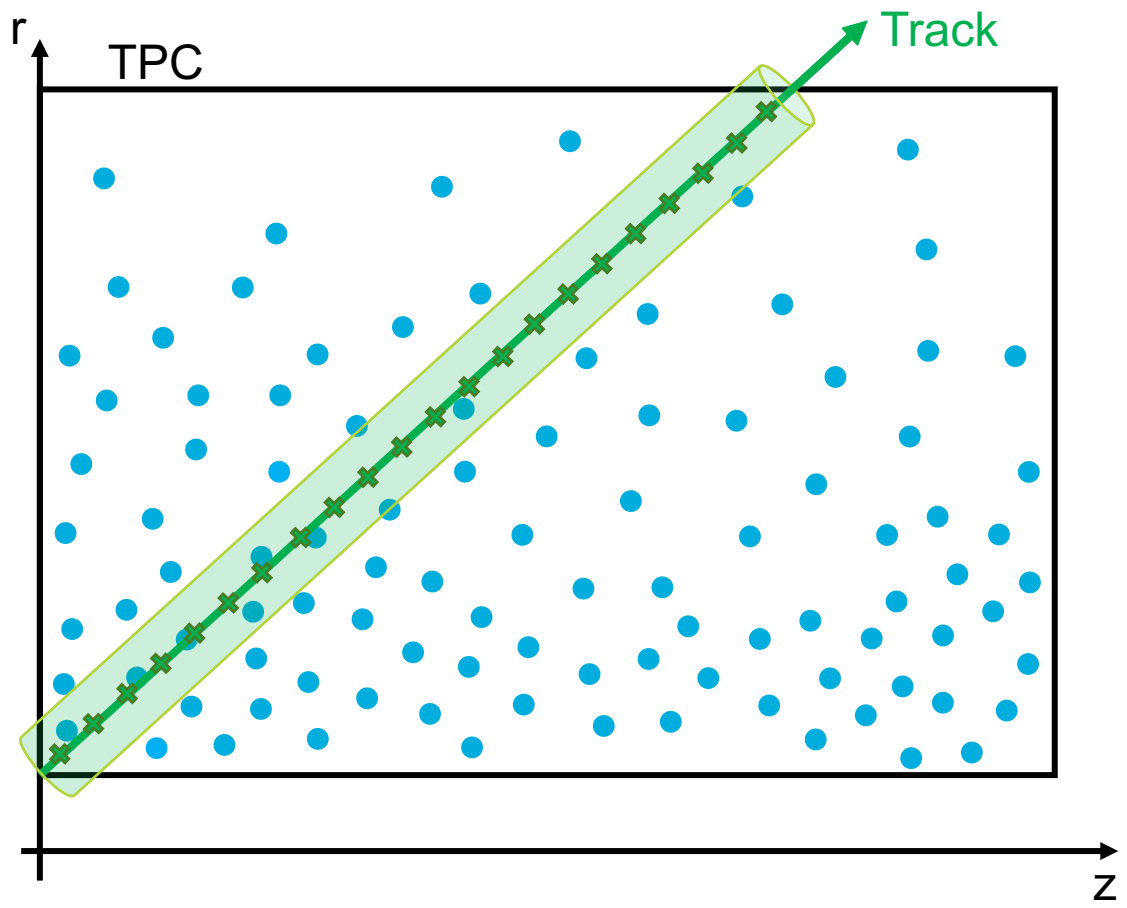
@BrookhavenLab

How Many Background hits along a Track

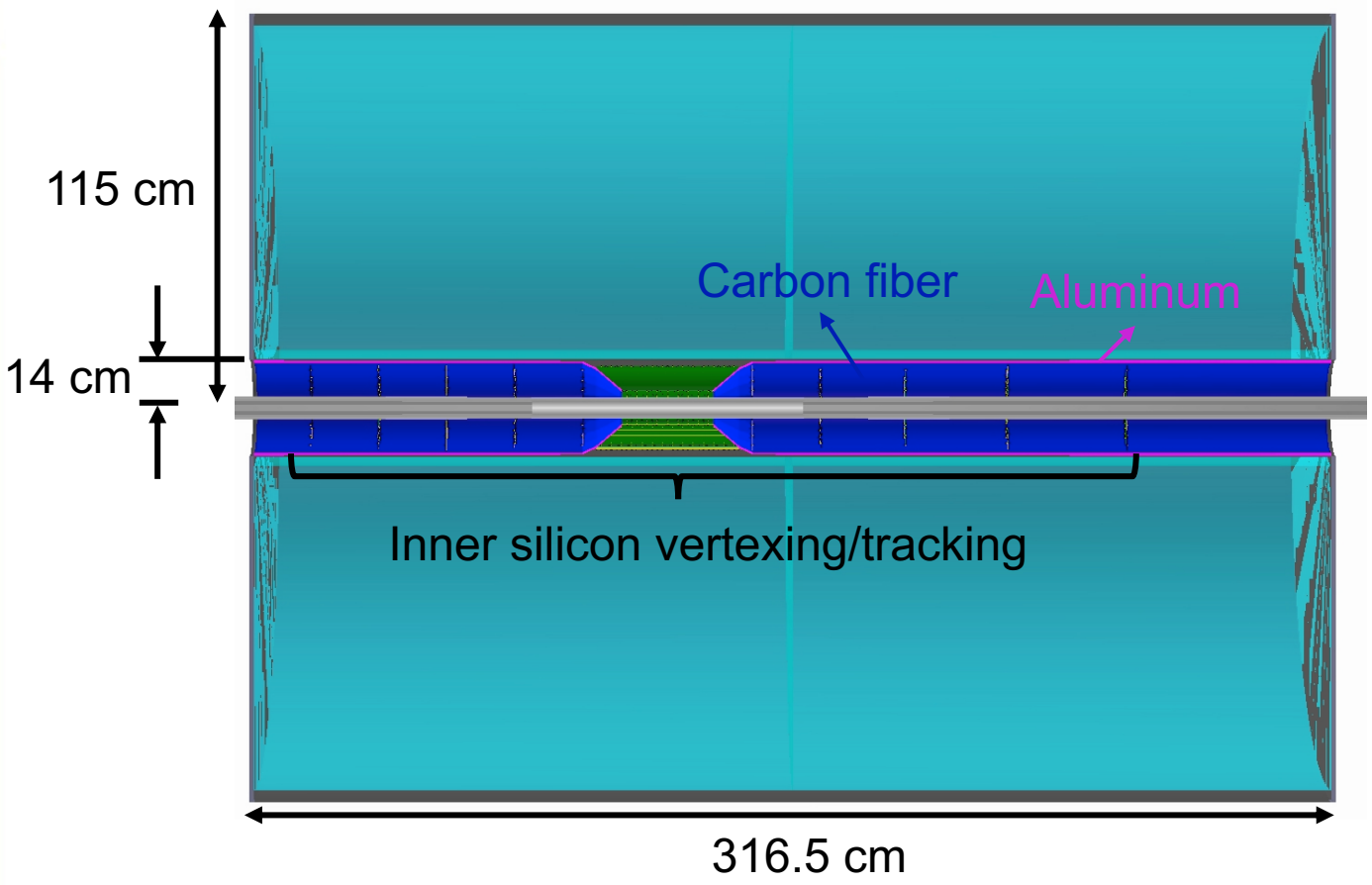


Thomas: in simplify scenario with a straight track (that is no magnetic field), if I draw a cylinder around the straight track,

1. How many synchrotron radiation hits within the cylinder?
2. What is the track hits to synchrotron radiation hits ratio?

If the track hits to synchrotron radiation hits ratio is large, we should be able to reconstruct the track.

TPC Dimensions



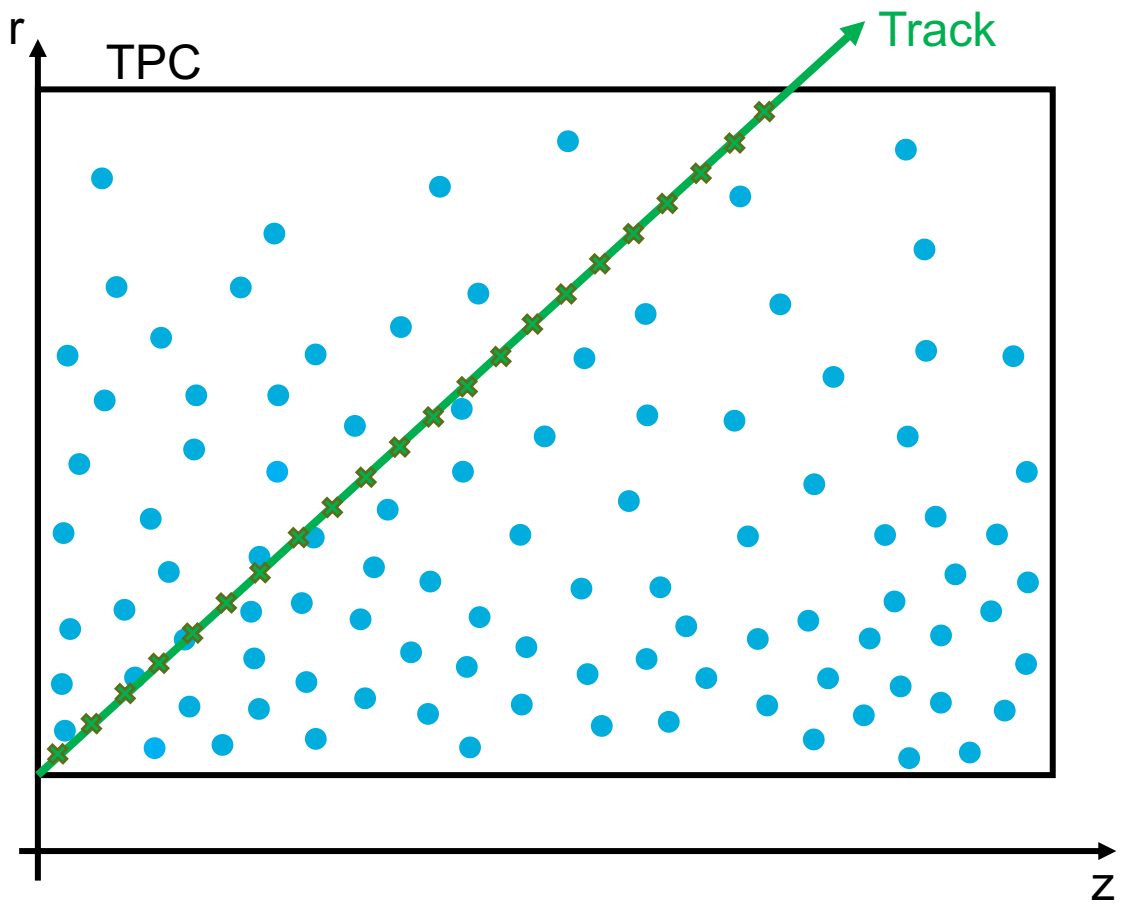
TPC

- Gas: Ar:CF4:iC4H10 (95:3:2)
- Field cage
  - carbon fiber
    inner cage t=2.62mm
    outer cage t=9.28mm
  - Kapton t=150um
  - Aluminum t =50um
- Central membrane: Kapton t=100um
- Endcaps:
  - aluminum t=13.4mm

No Magnetic field

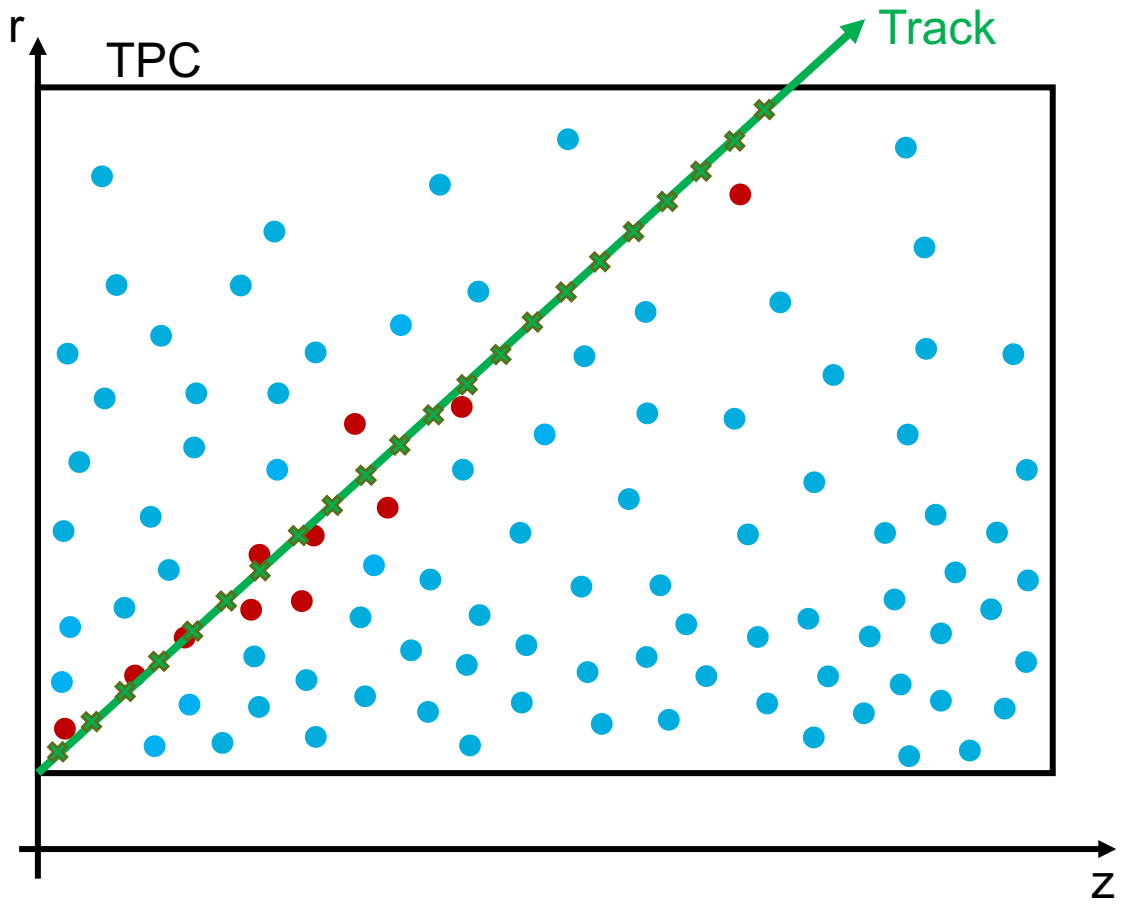
Transverse dispersion	$8.94/\left(\frac{2}{1.4}\right) = 6.258$ um/$\sqrt{\text{cm}}$ Assuming same gas as sPHENIX
Longitudinal dispersion	1 um/$\sqrt{\text{cm}}$
Transverse intrinsic resolution	55 um
Longitudinal intrinsic resolution	1 um
Radial intrinsic resolution	0 um
Vertical Pad Size	1 cm

Background Estimation



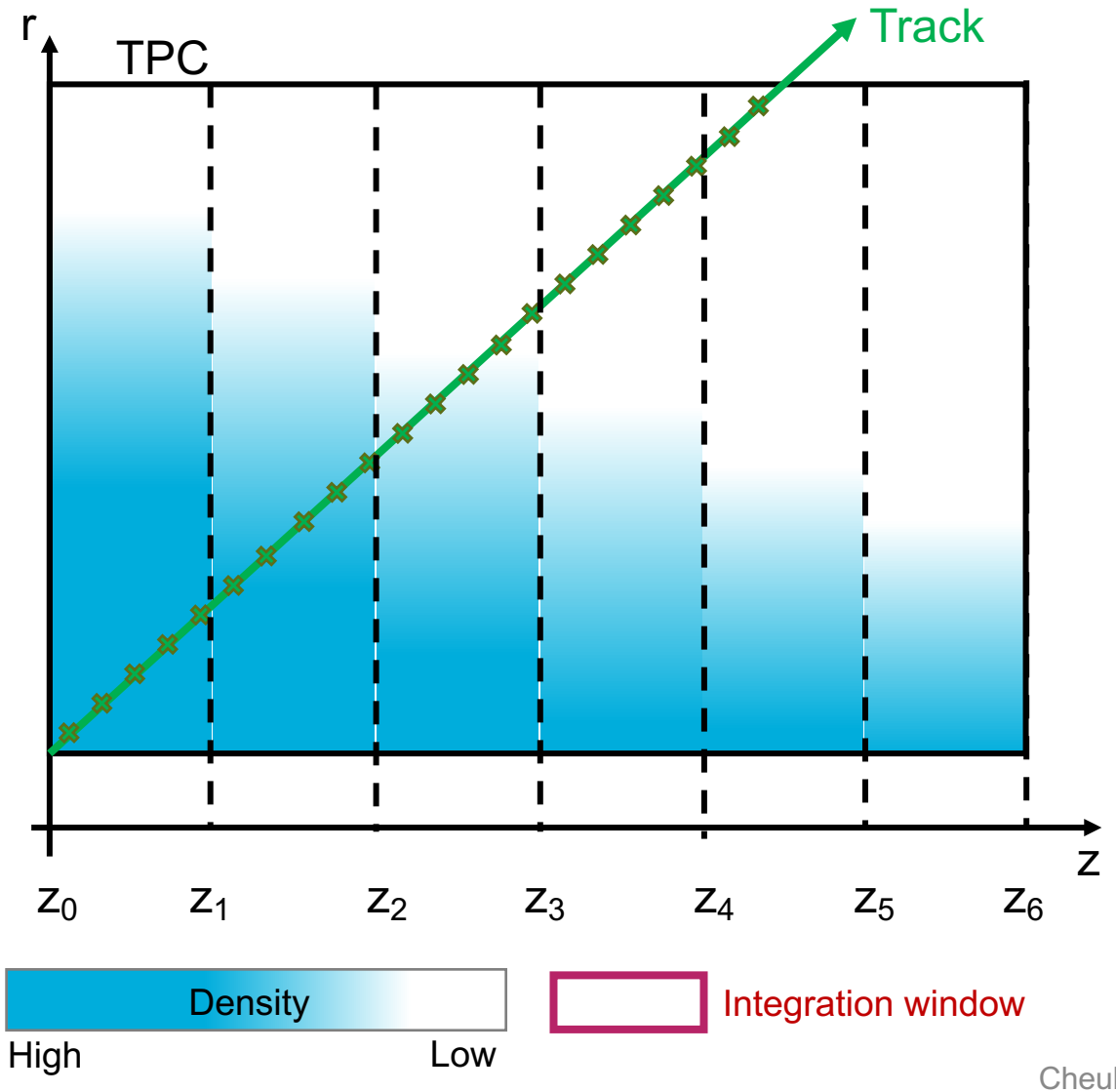
- Ideally, one should identify the number of synchrotron radiation hits that close to the track as background hits

Background Estimation

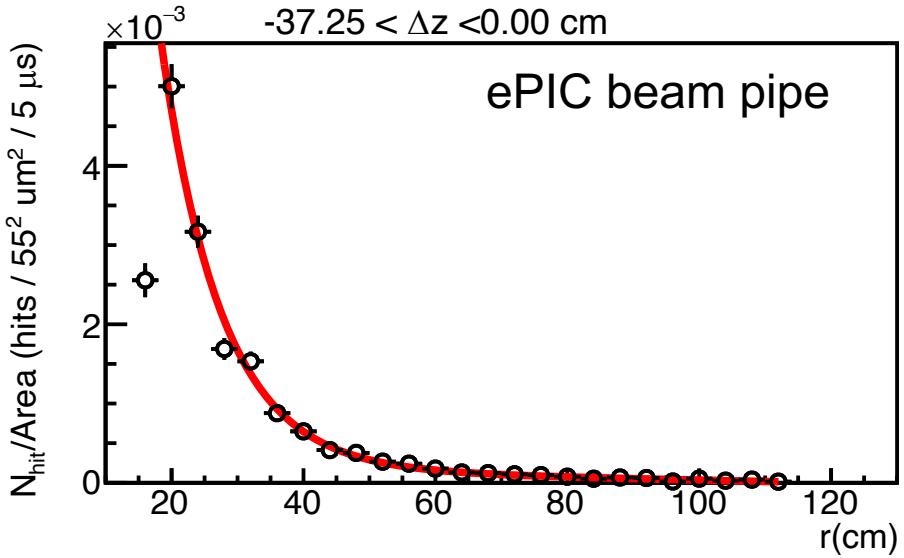


- Ideally, one should identify the number of synchrotron radiation hits that close to the track as background hits
- But I don't have enough statistics of the simulated synchrotron radiation events to perform a hit-by-hit study

Background Estimation

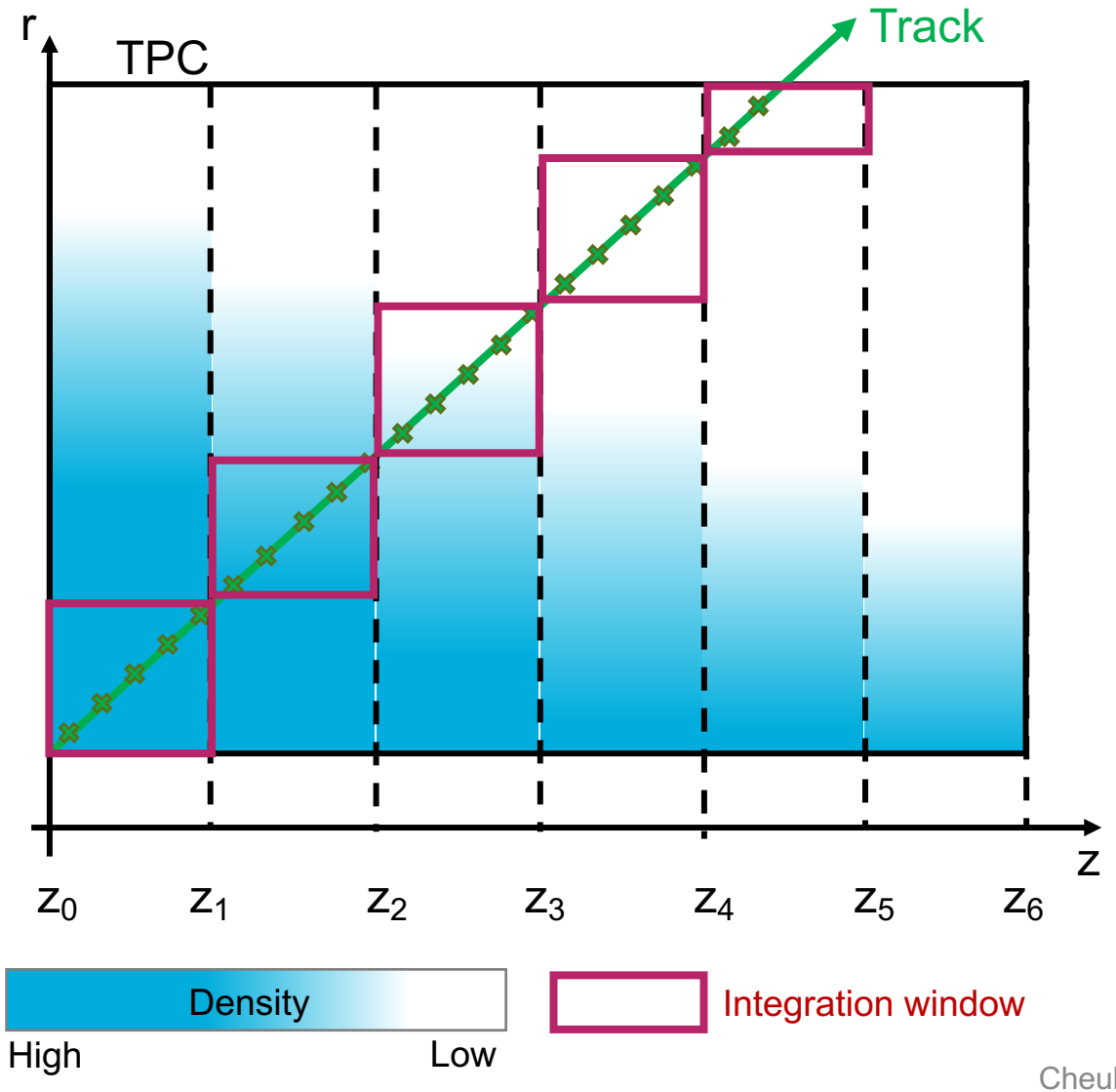


- Instead, I use the synchrotron radiation hit density that I generated a month ago to estimate how many synchrotron radiation hits in certain (z,r) range.

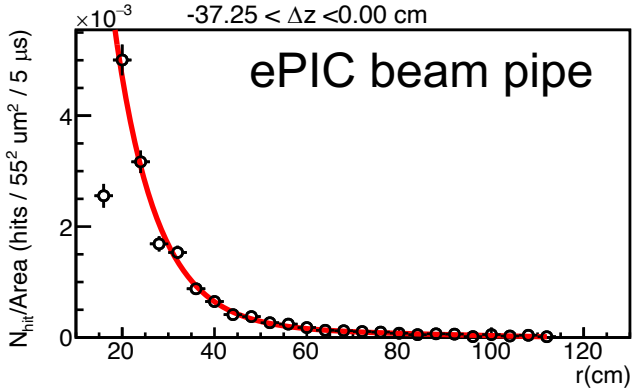


- No gold coating on the beam pipe, nor inner tracker service for higher statistics → better fit
- Can be scaled for different TPC transverse resolutions

Background Estimation



1. Formulate the track trajectory using the first and the last track hits
2. Using the trajectory formula to calculate the r range in each z bin
3. Integrate the synchrotron radiation density function over the r range

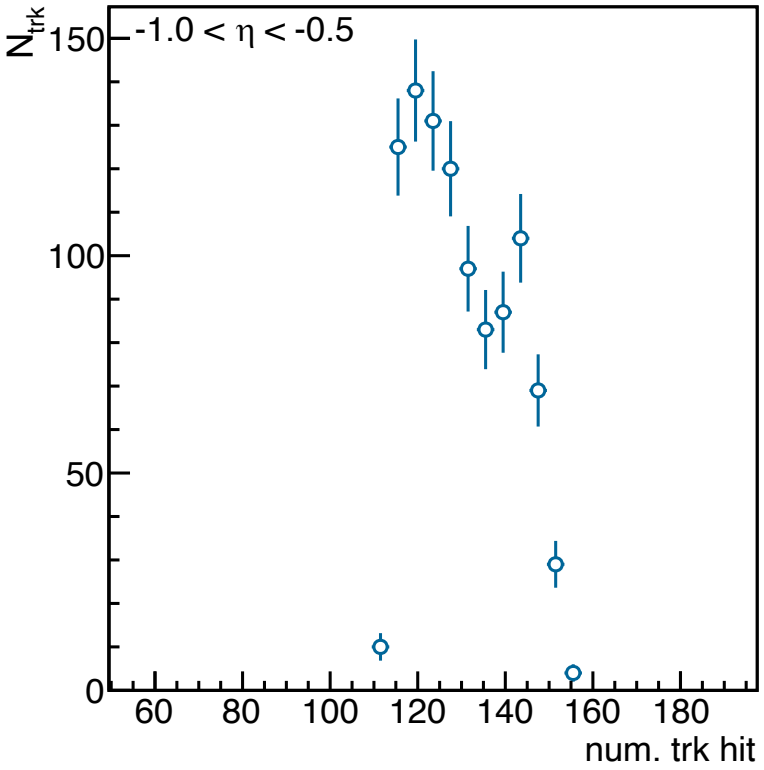


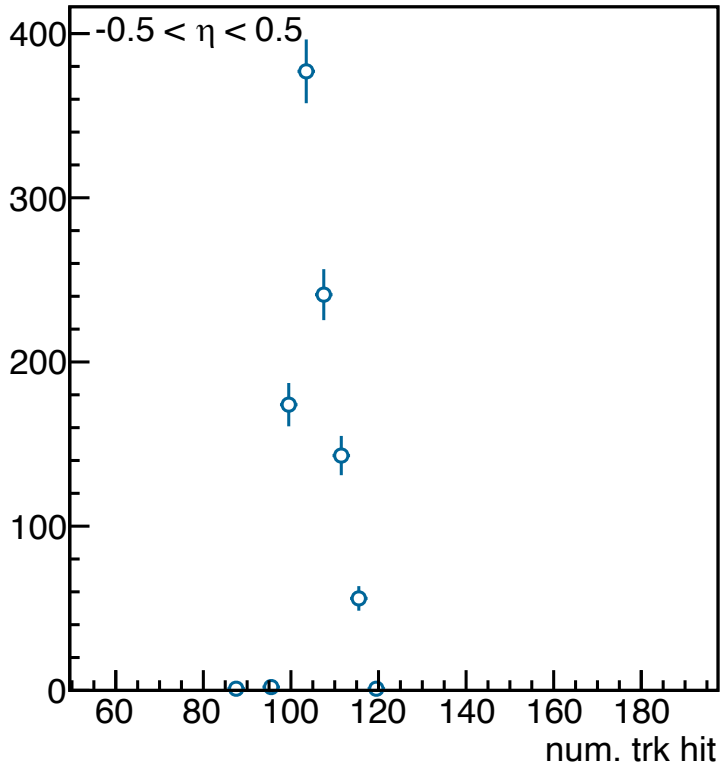
- Repeat this procedures for different sync. rad. hit densities with various TPC transverse resolutions
  - 55^2 um (ignore diffusion and space charge)
  - 100^2 um (~ sPHENIX TPC)
  - 500^2 um (STAR TPC)
  - 1000^2 um

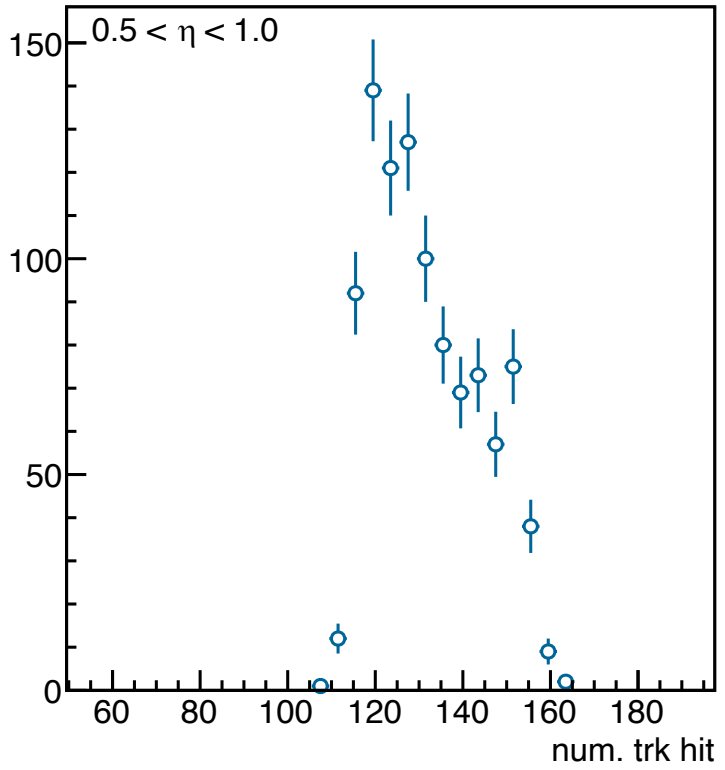
Number of Track Hit

π^-, $1 < p < 25$ GeV

A step with an energy deposit ≥ 20 eV is considered a hit

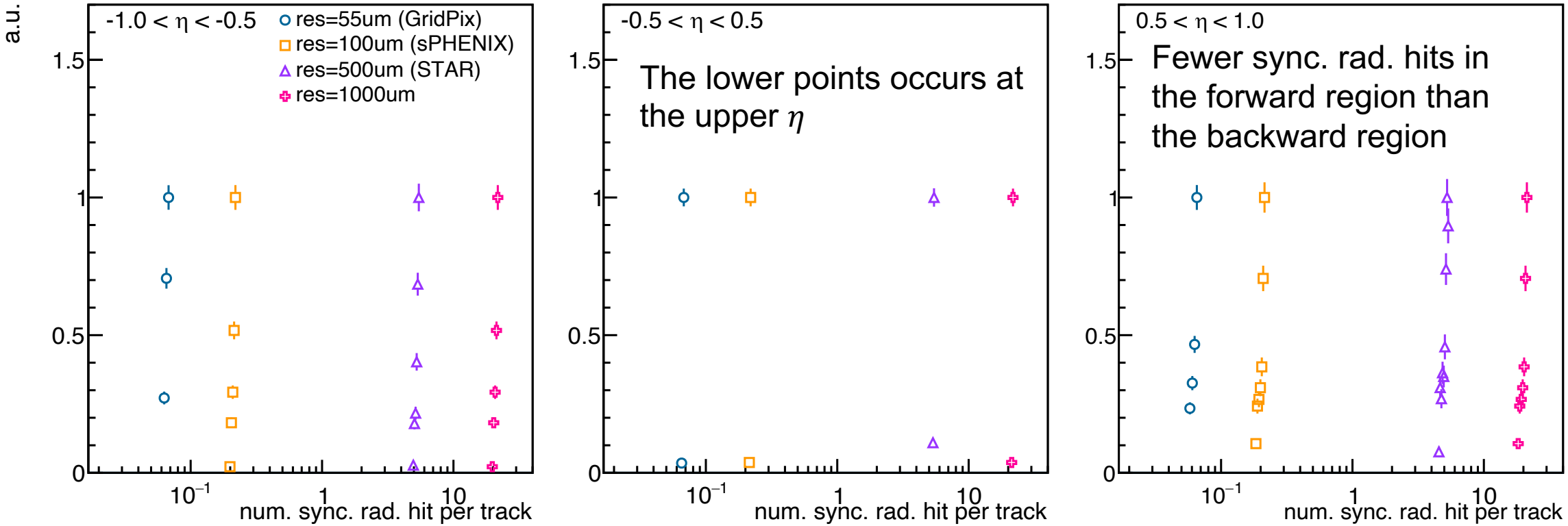




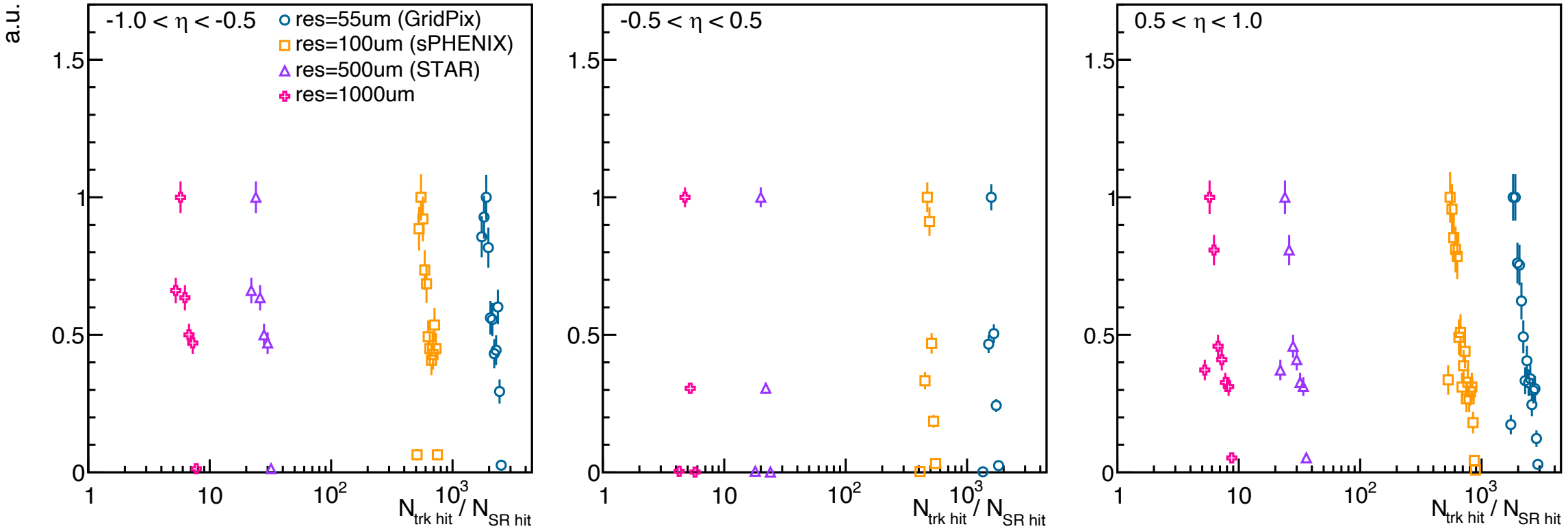


Number of Synchrotron Radiation Hits

A synchrotron radiation photon with an energy $\geq$ 20 eV that deposits energy in the TPC is considered a hit



Track Hits / Synchrotron Radiation Hits

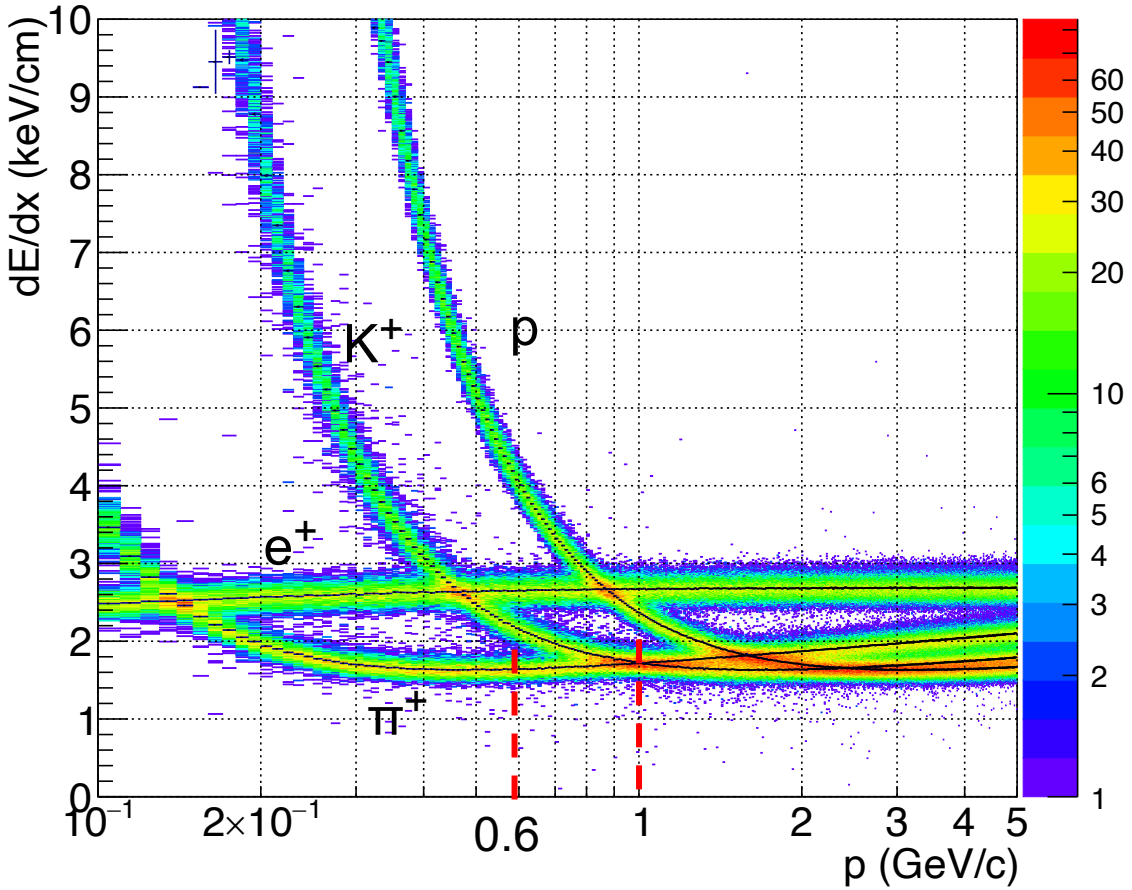


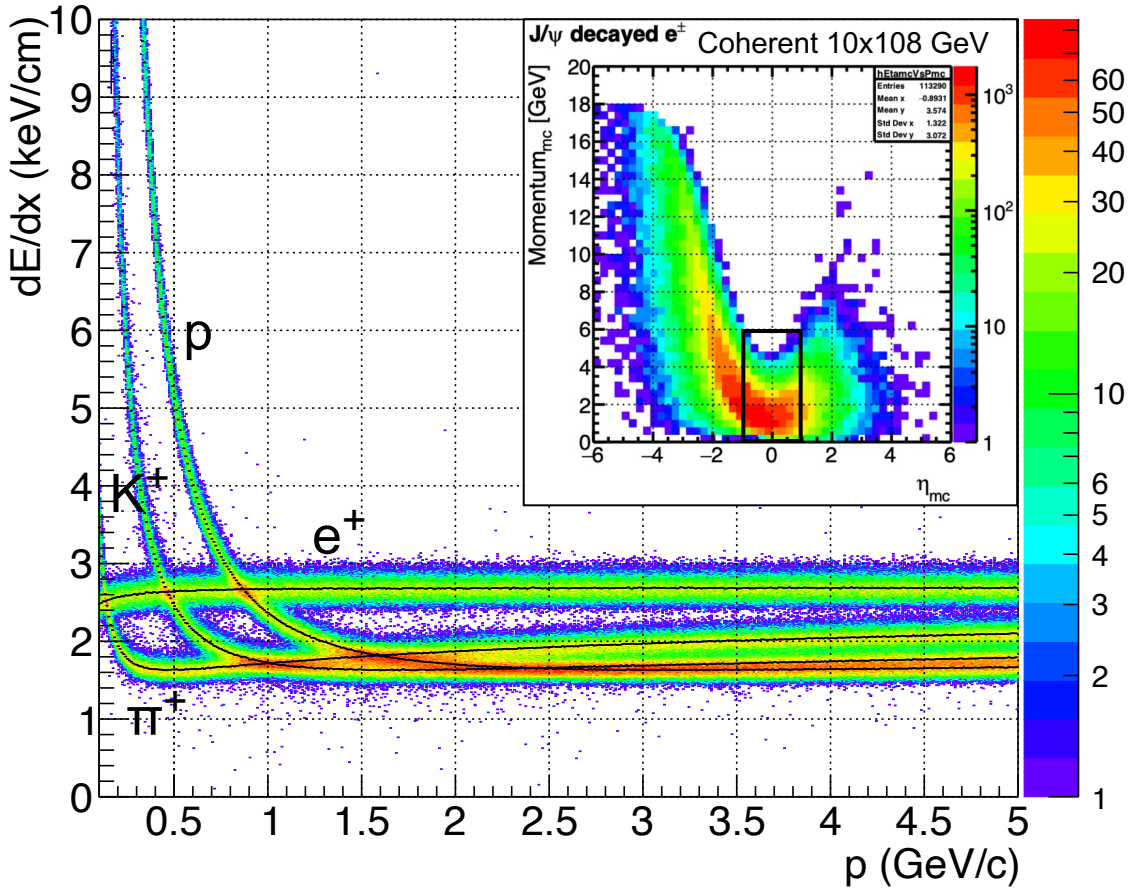
Summary

- Estimated the number of synchrotron radiation hits around a straight track
- The estimated values depends on the transverse position resolution
  → Finer resolution, fewer synchrotron radiation hits around a straight track
- Existing TPC technology with
  a transverse position resolution < 500 um gives
  a track hits to synchrotron radiation hits ratio > 10 at $|\eta| < 1$

dE/dx

- Single track events, no magnetic field
- True dE, dx

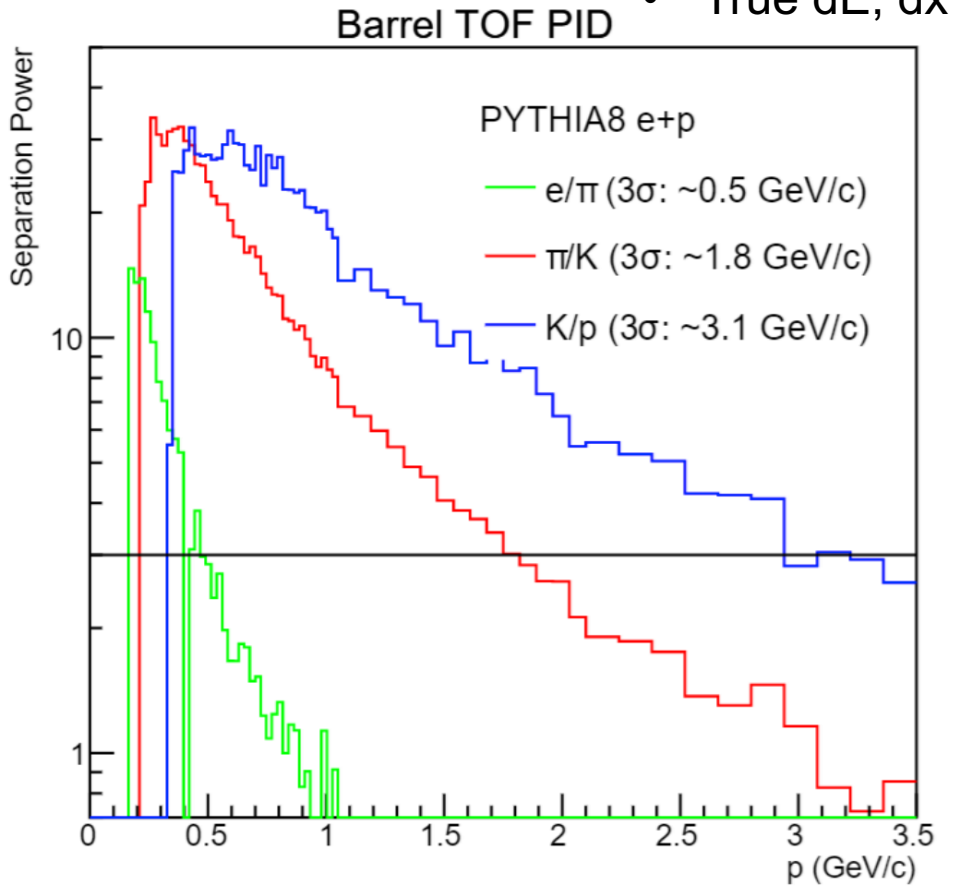


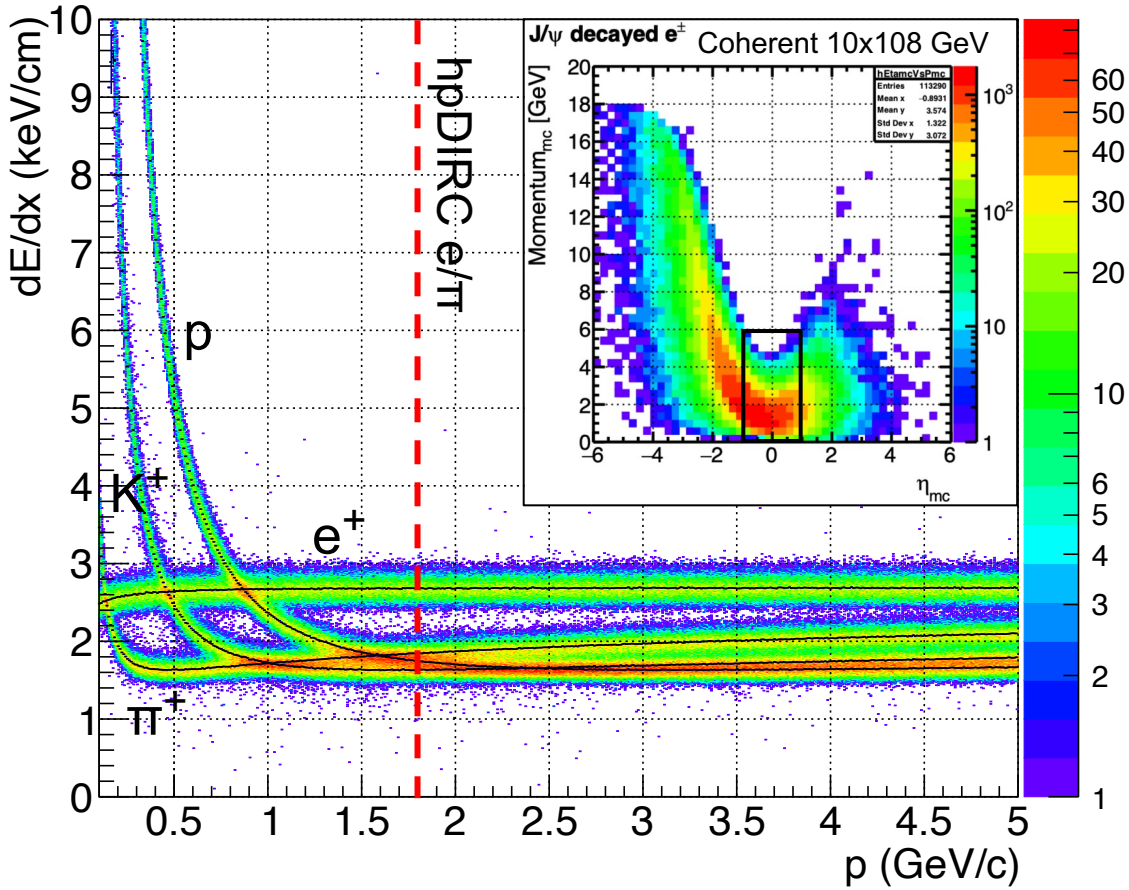


dE/dx: Compare to ePIC ToF

NIM A 1062 (2024) 169168
https://indico.bnl.gov/event/17621/contributions/71751/subcontributions/2172/attachments/45491/76755/EPIC_TOF_SIM_COLLAB.pdf

- Single track events, no magnetic field
- True dE, dx

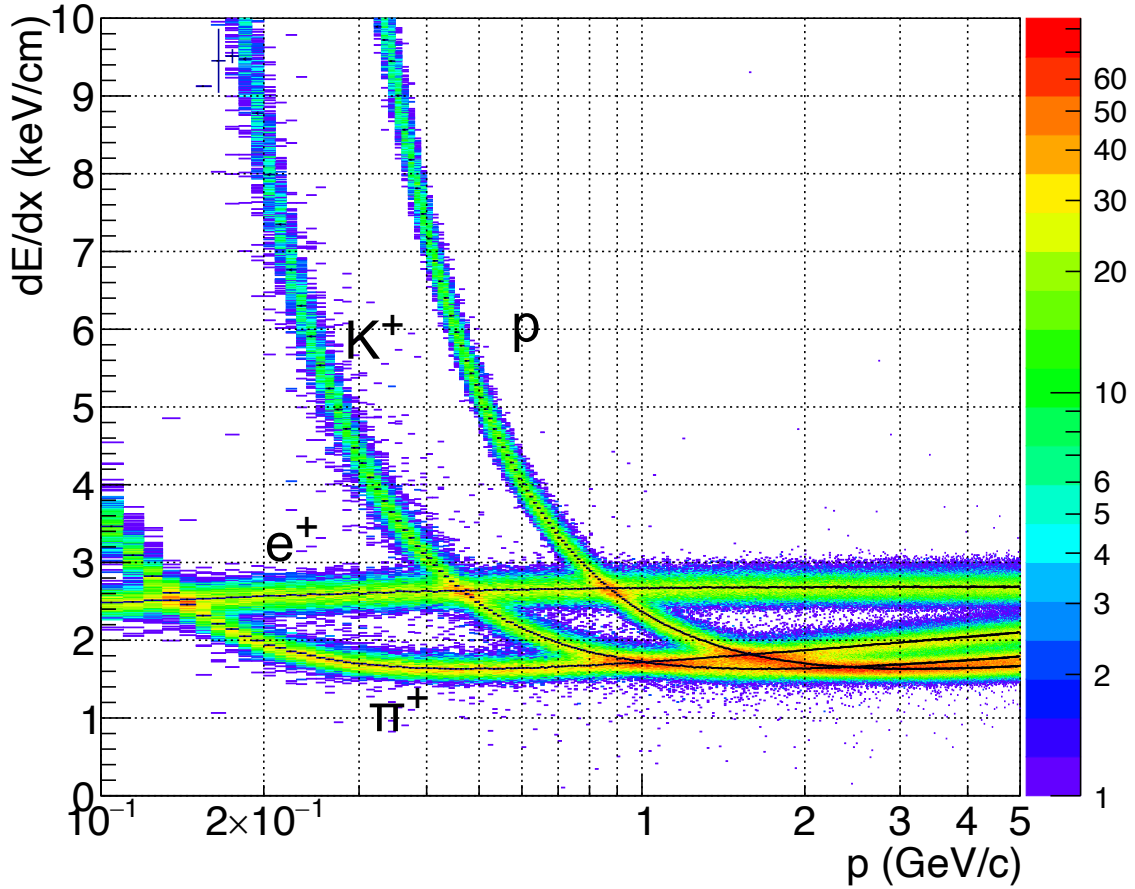


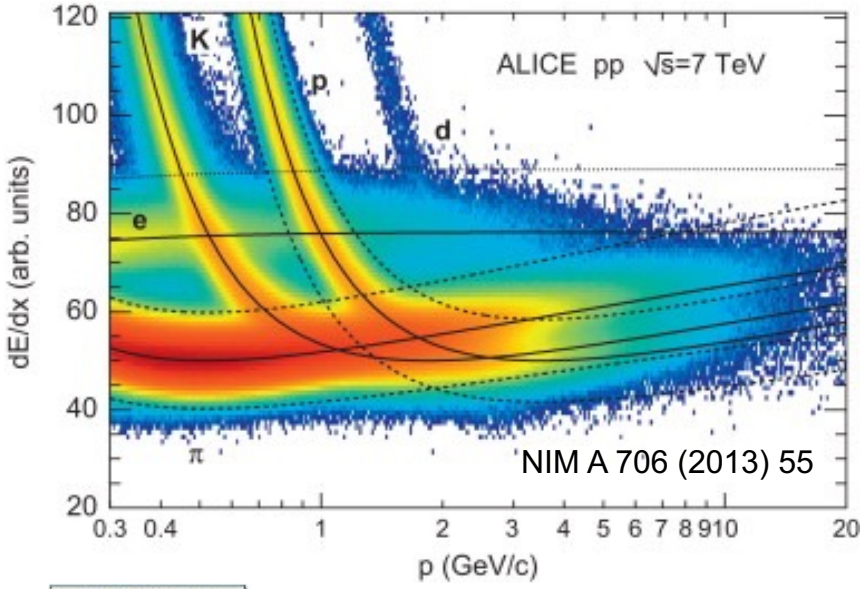


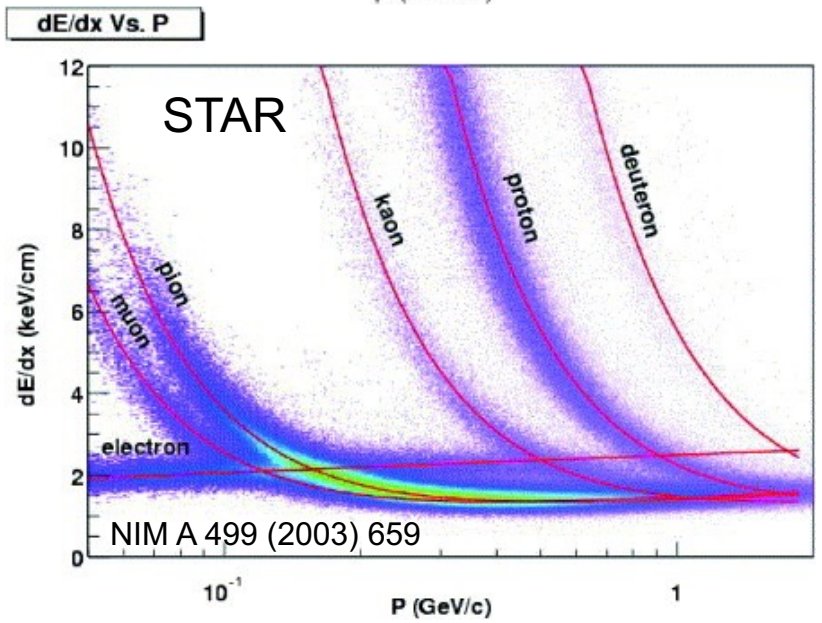
- ToF is better than TPC in terms of charged hadron PID
- TPC may achieve 3σ e/π separation above 2 GeV, potentially

dE/dx: Compare to Other Experiments

- Single track events, no magnetic field
- True dE, dx



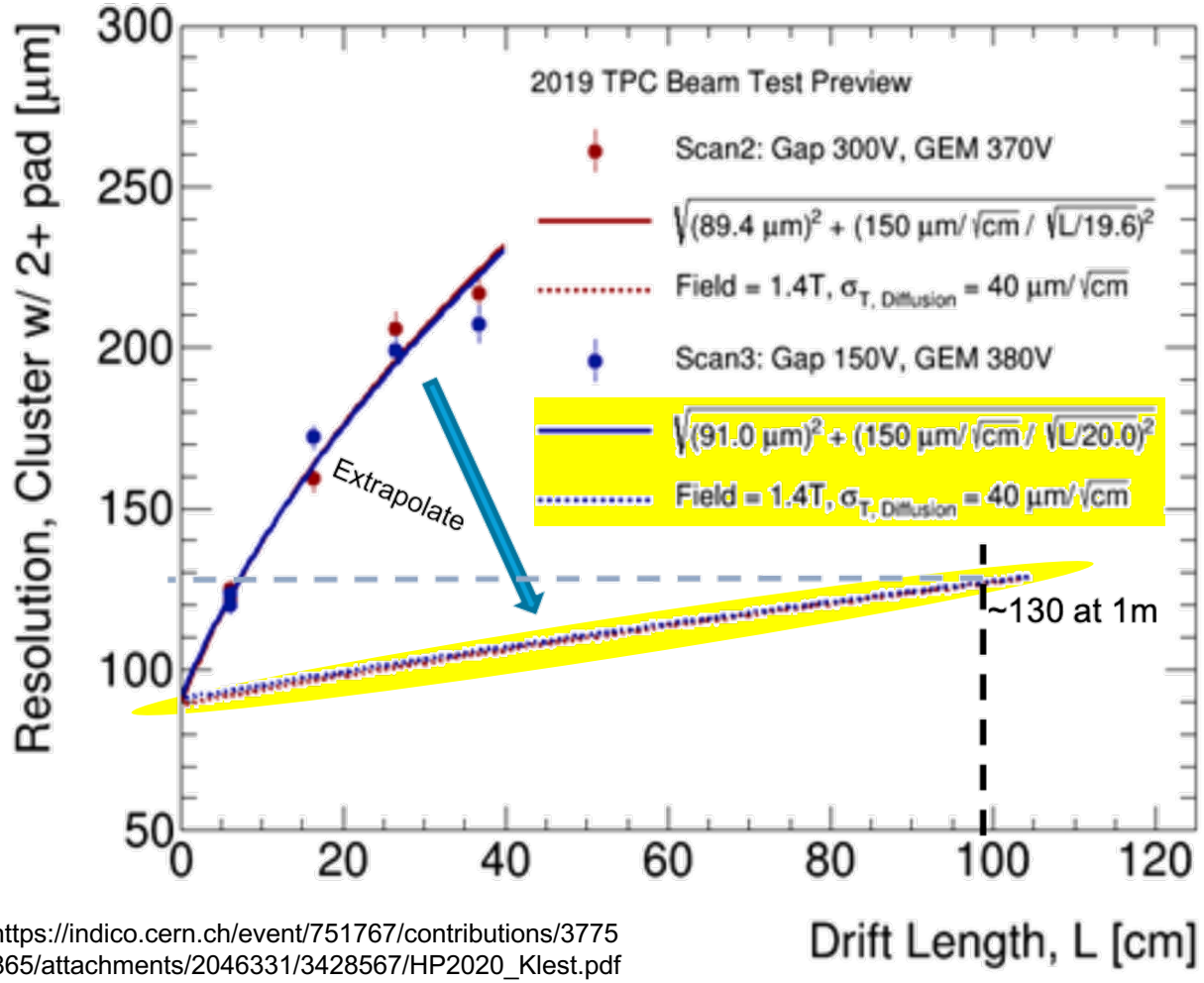




Back Up

sPHENIX TPC Beam Test Results

Space charge uncertainty is negligible in the beam test



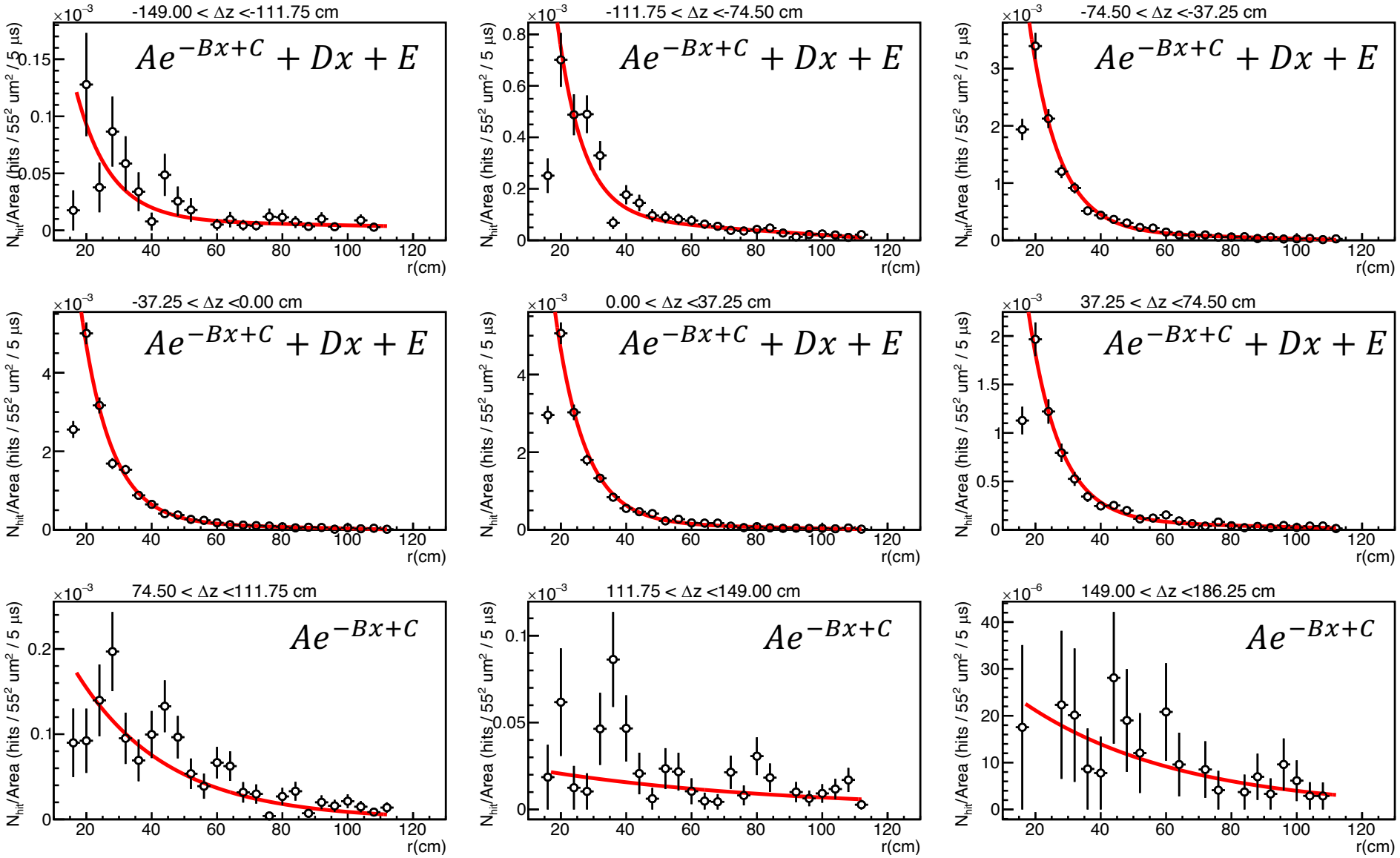
https://indico.cern.ch/event/751767/contributions/3775865/attachments/2046331/3428567/HP2020_Klest.pdf

$$\sigma_{tot}^2 = \sigma_{intrinsic}^2 + \frac{\sigma_{diffusion}^2}{N_{eff}} \cdot L + \sigma_{space\ charge}^2$$

- $\boldsymbol{\sigma_{intrinsic} = 91}$ **um**
  ($\sigma_{intrinsic} = 70$ um in doi:10.1088/1742-6596/1498/1/012024)
- $\boldsymbol{\sigma_{diffusion}}$ **= 40 um/√cm** (at B = 1.4 T)
- $\boldsymbol{\sigma_{space\ charge} = 50}$ **um**
  doi:10.1088/1742-6596/1498/1/012024
- $\boldsymbol{N_{eff} = 20}$ effective number of electrons
  ($N_{eff} = 20.5$ in doi:10.1088/1742-6596/1498/1/012024)

$$\sigma_{tot} = \sqrt{91^2 + \frac{40^2}{20}(1\ \text{m}) + 50^2} \approx 100\ \text{um}$$

Synchrotron Radiation Hit Densities with Fits



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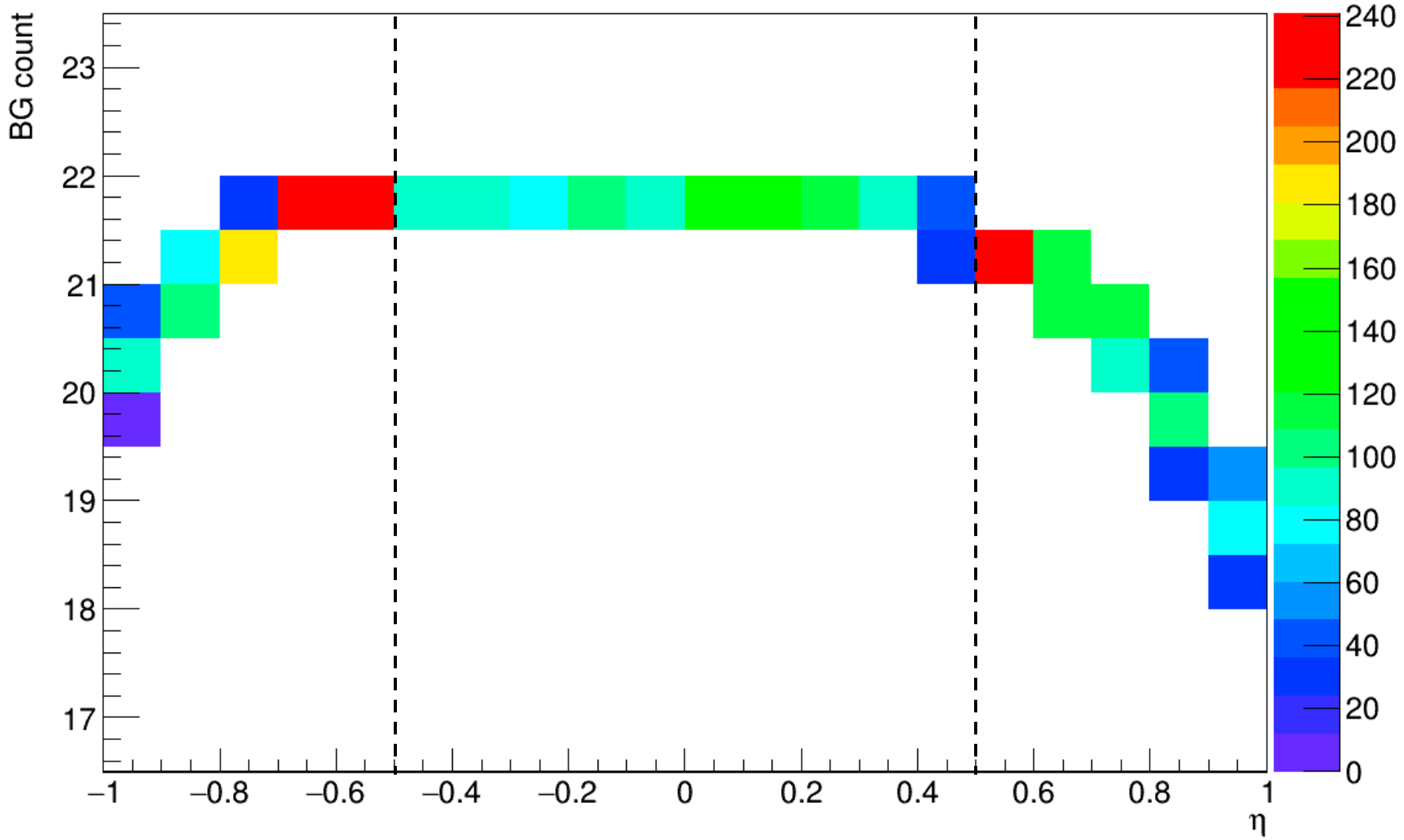
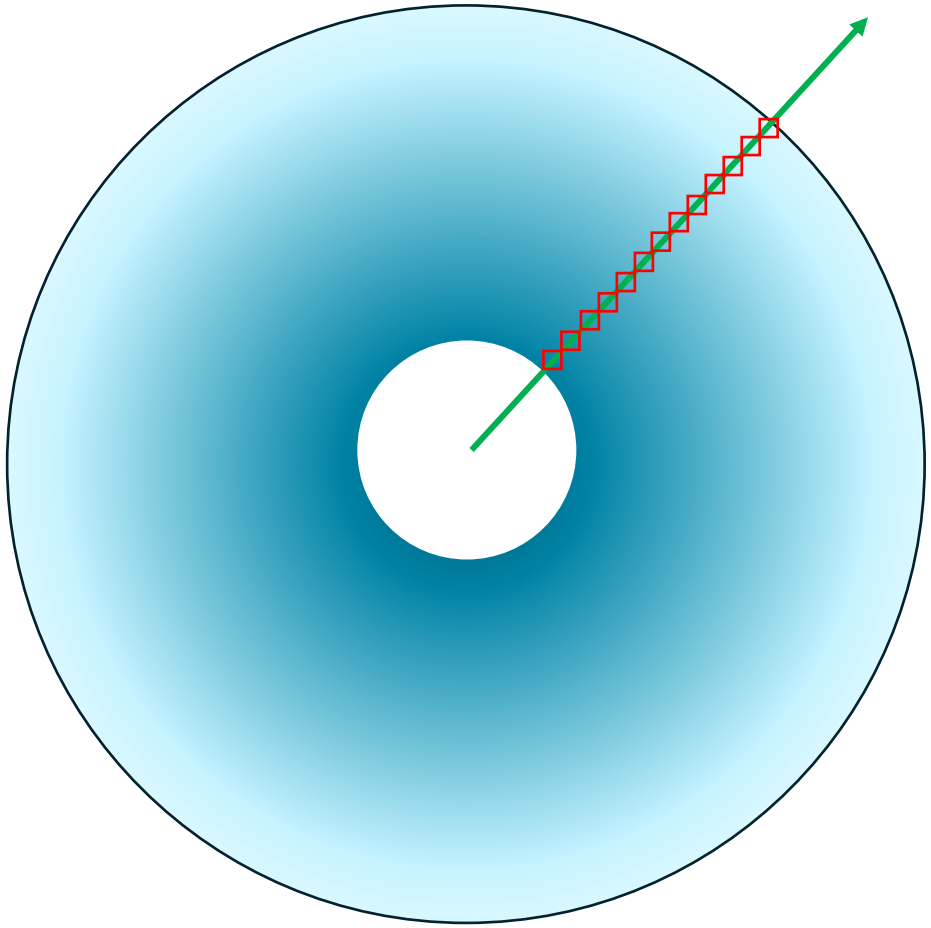
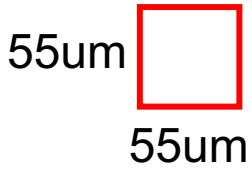
Synchrotron Radiation Hit Counts vs Track η






55um
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