Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

TPC Tracking Simulation in EicRoot

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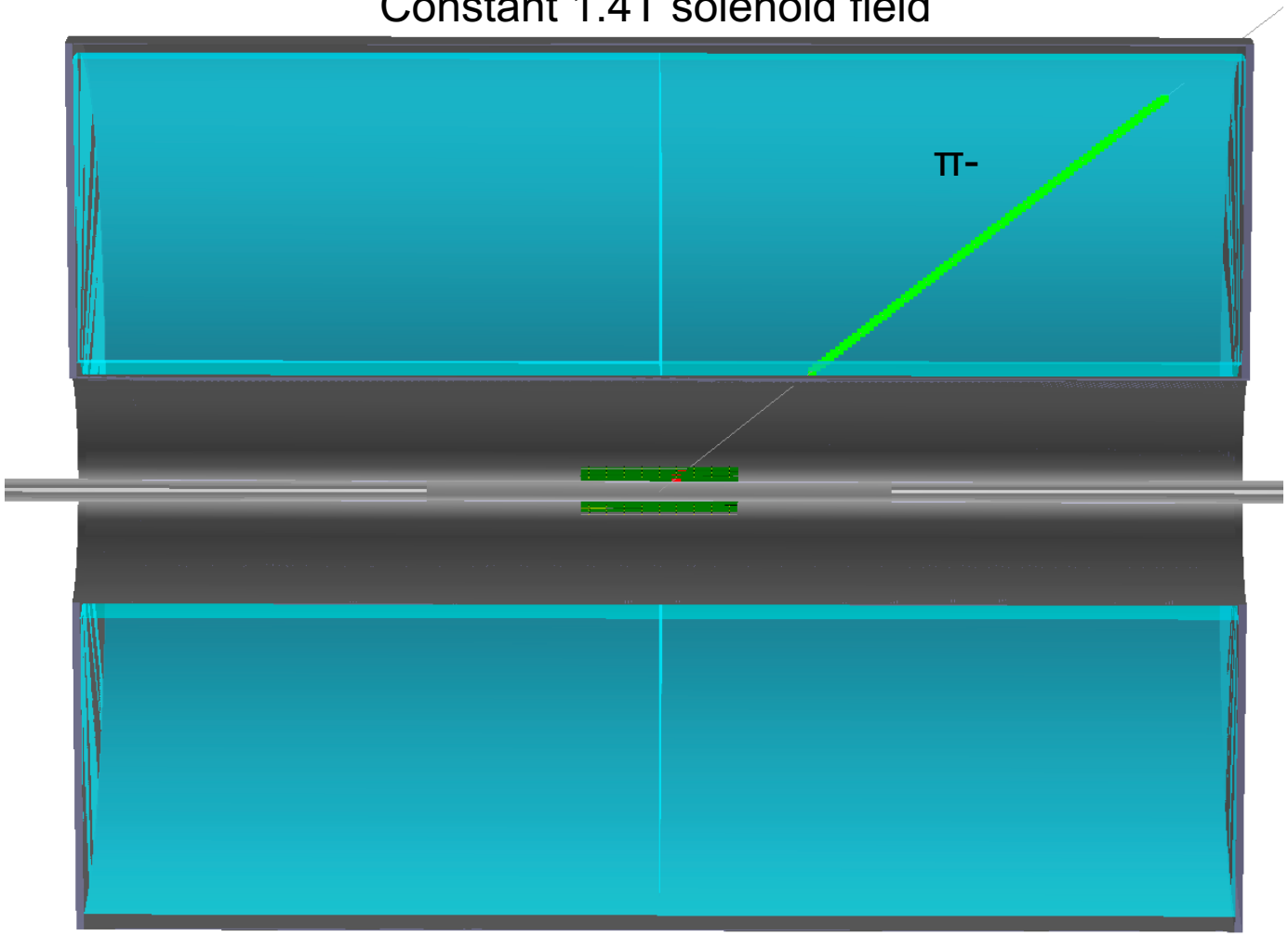
@BrookhavenLab

Reproduce sPHENIX Tracking Performance

sPHENIX Tracking System in EICRoot

Constant 1.4T solenoid field



MVTX
- 3 layers: r_1=24.61mm, r_2=31.98mm, r_3=39.93mm
- Pixel size: 27 x27 μm^2
- X/X_0=0.3%

TPC
- r_{in}=30cm, r_{out}=78cm
- L=200cm
- Ar:CF4:iC4H10 = 75:20:5
- Inner/outer field cage
  Carbon fiber t=0.0254 cm x2
  Kapton 0.2286+0.0051 cm (insulating & circuit card)
  Copper 0.0017 cm x2
  ~~Epoxy~~

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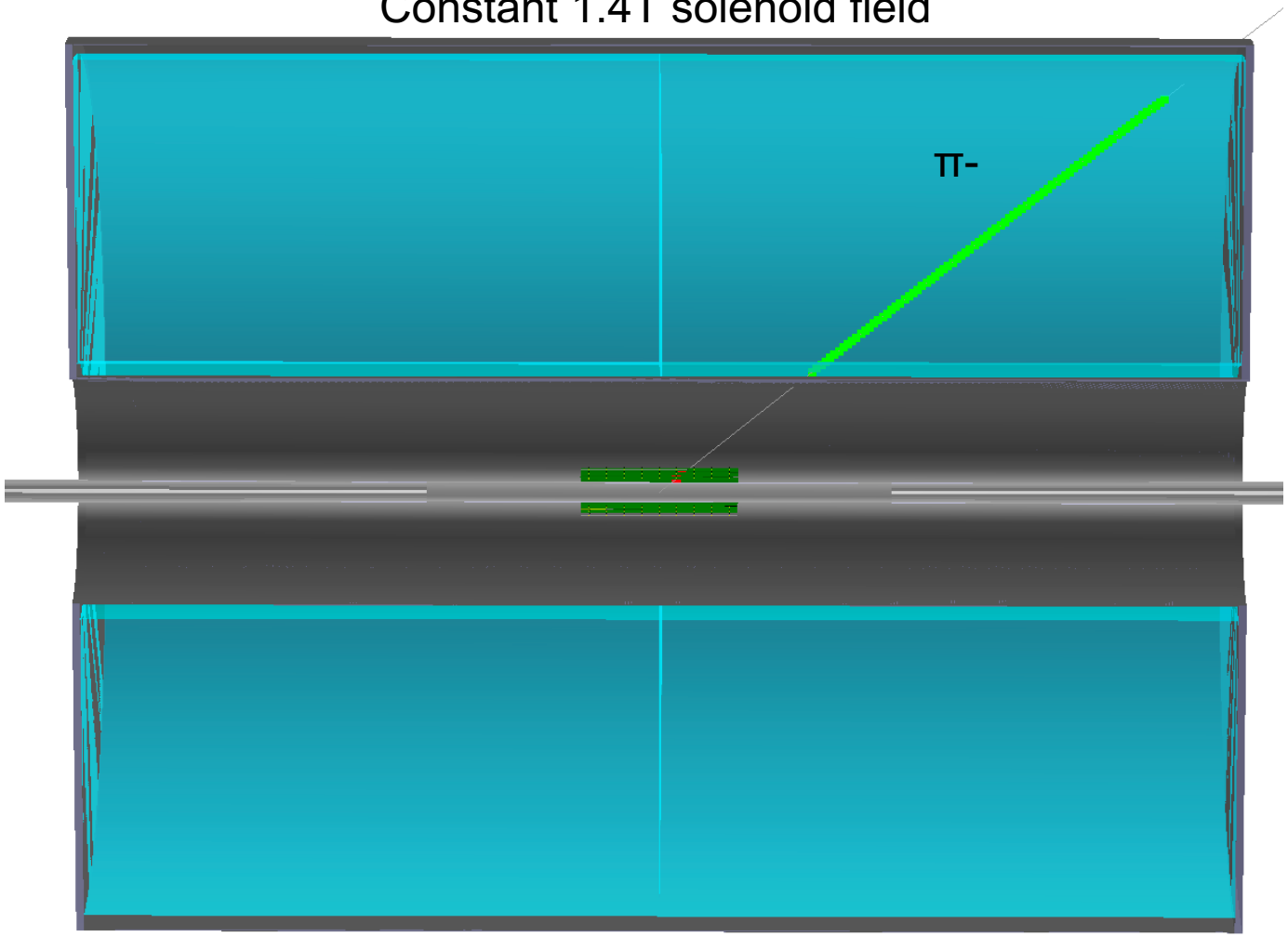
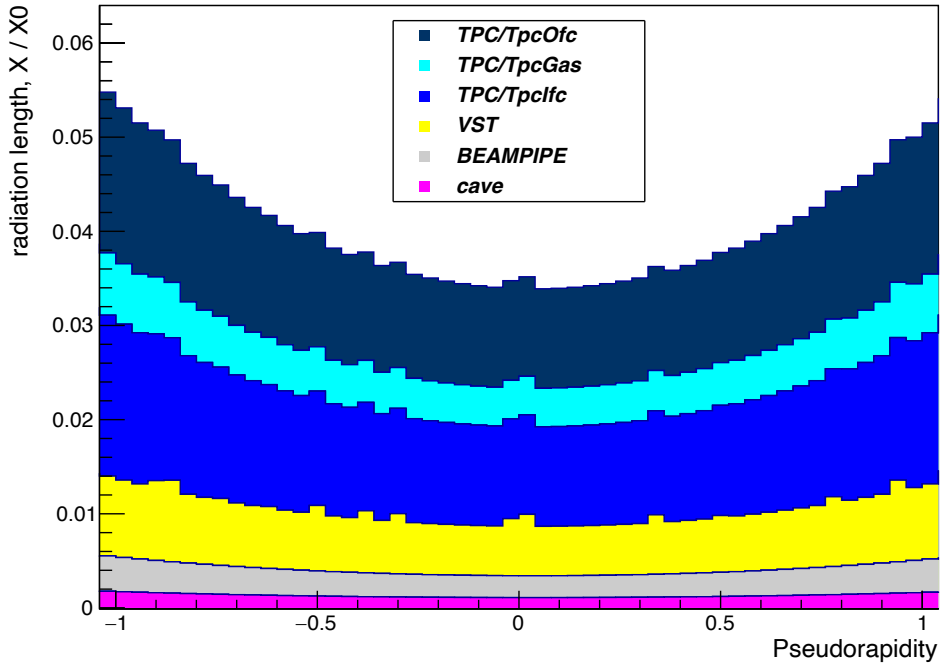
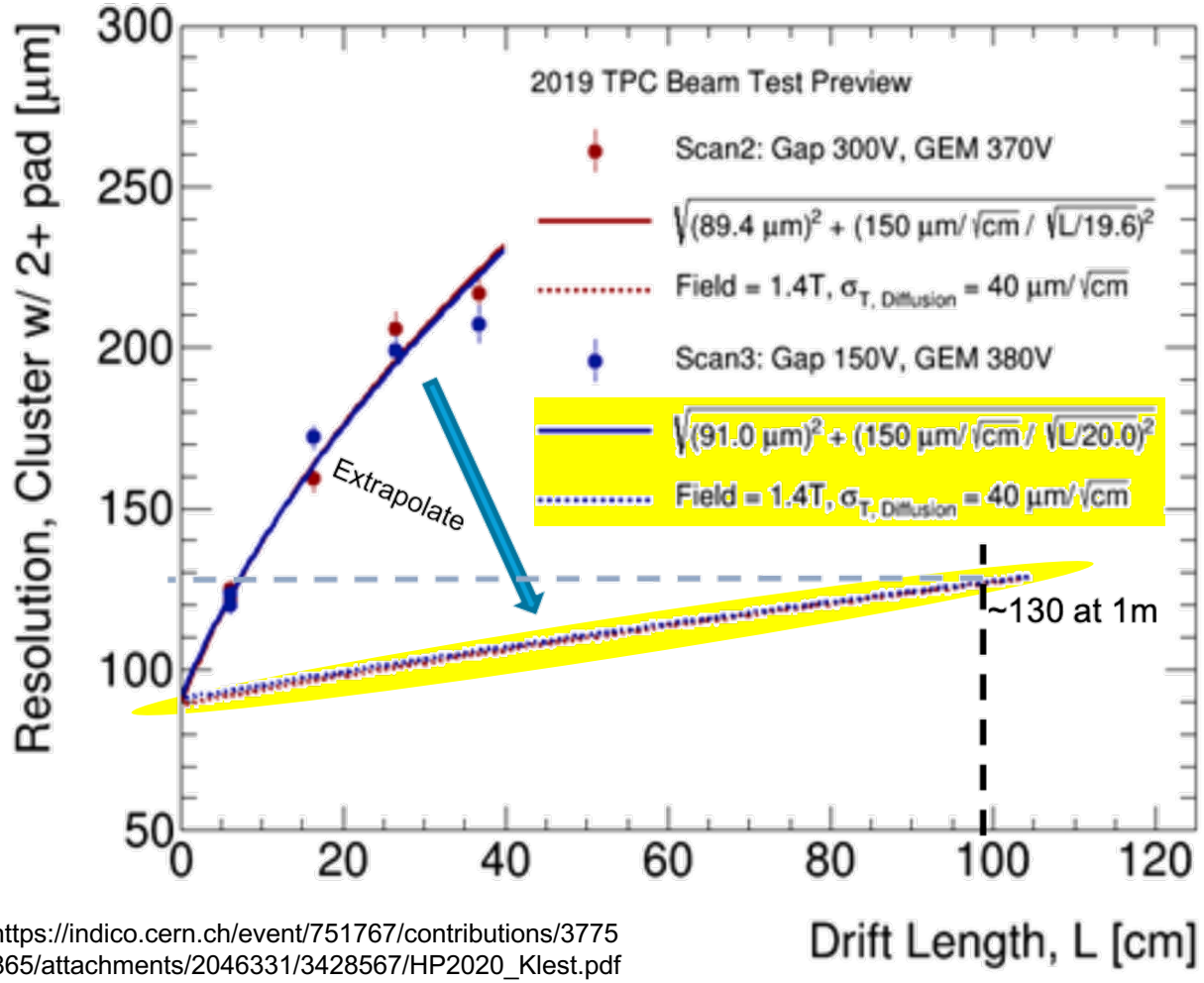




sPHENIX TPC Beam Test Results

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/$\sqrt{\text{cm}}$** (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)

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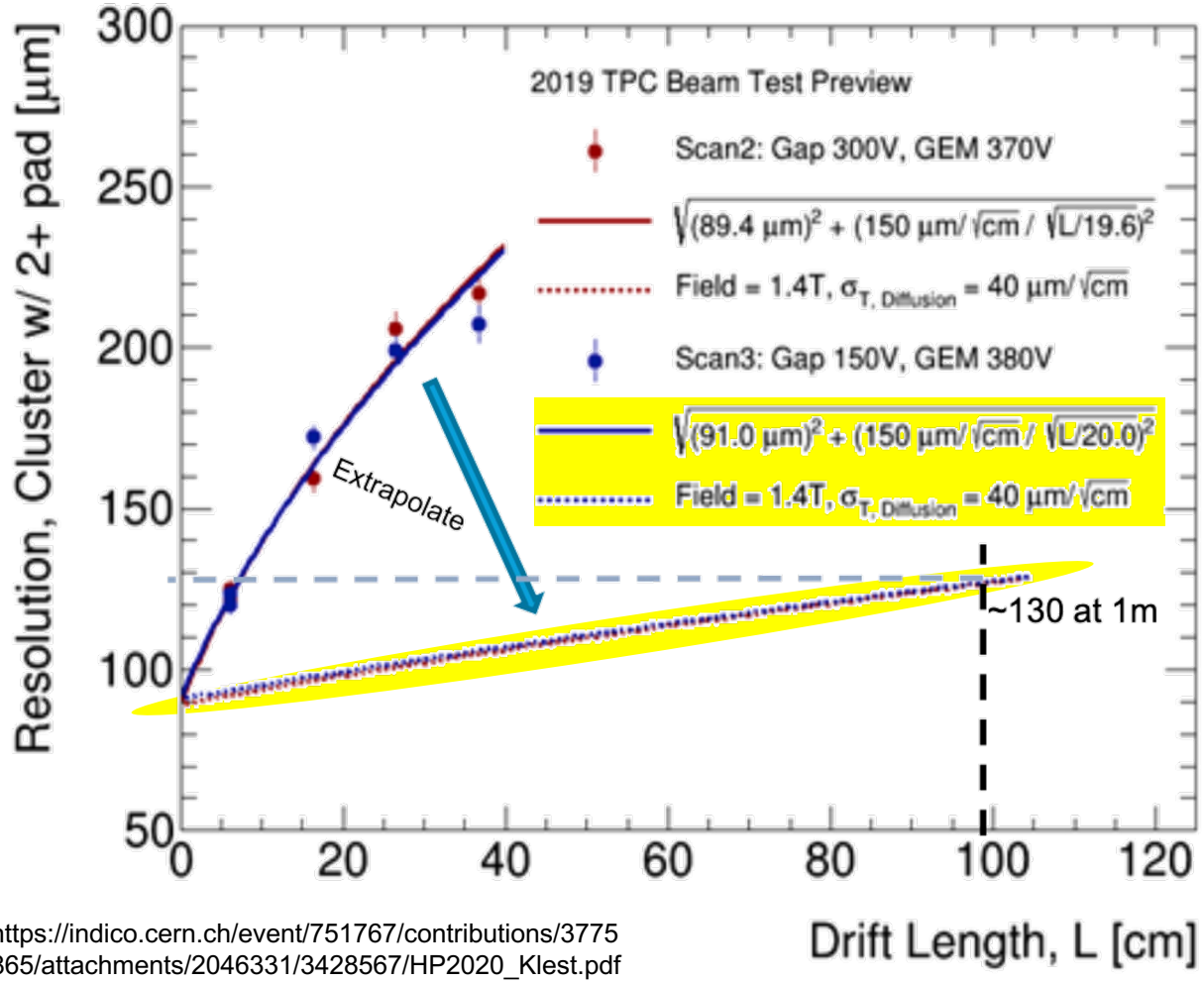

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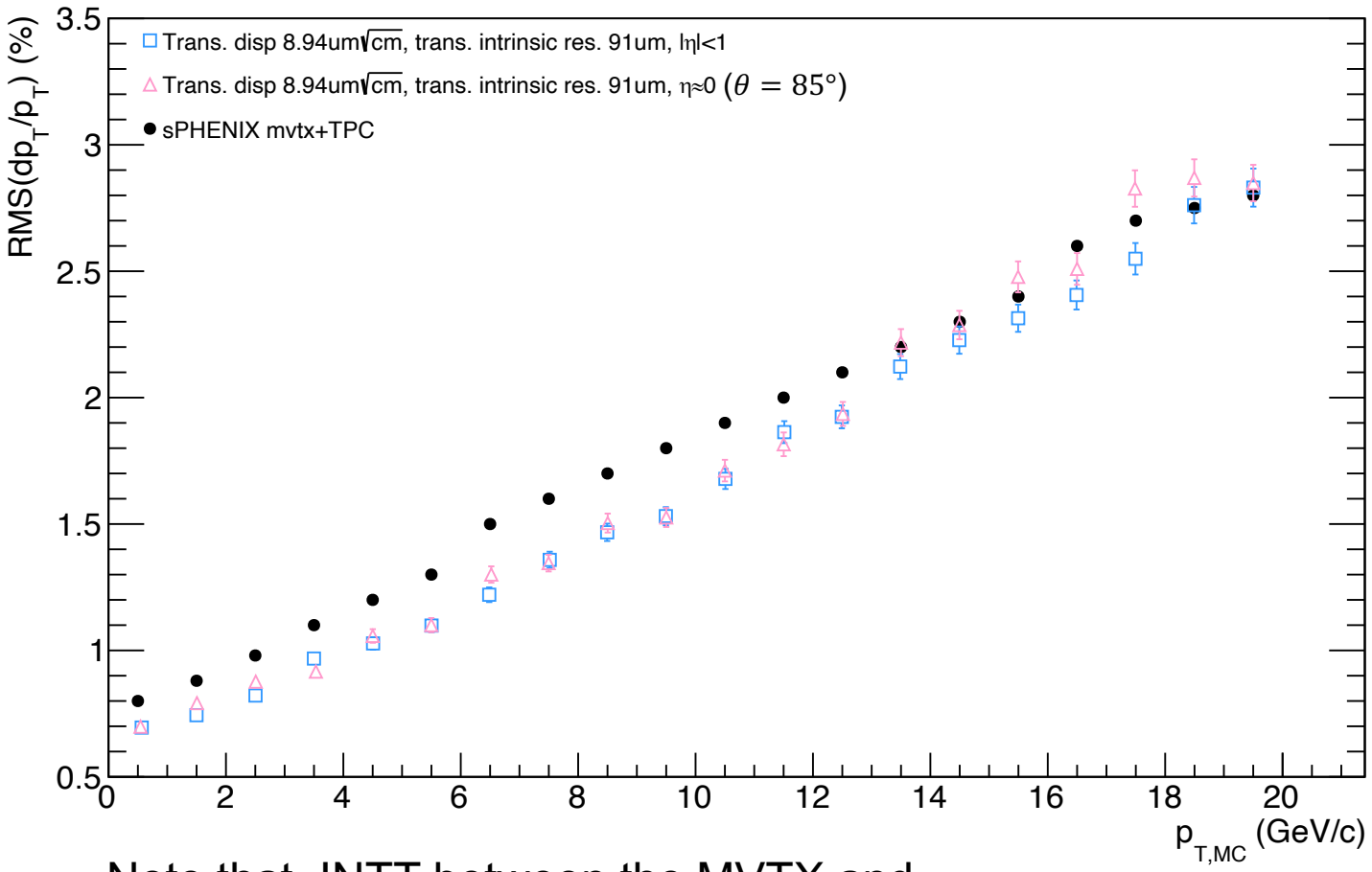
Transverse dispersion	$\frac{40}{\sqrt{20}} = 8.94$ um/$\sqrt{\text{cm}}$
Longitudinal dispersion	1 um/$\sqrt{\text{cm}}$
Transverse intrinsic resolution	91 um
Longitudinal intrinsic resolution	1 um
Radial intrinsic resolution	0 um
Vertical Pad Size	0.96 cm

❖ Dispersion cannot be zero in EICRoot

p_T Resolutions of sPHENIX with Different Transverse Dispersions



Note that, INTT between the MVTX and theTPC is not implemented in the simulation

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Longitudinal dispersion	1 um/$\sqrt{\text{cm}}$
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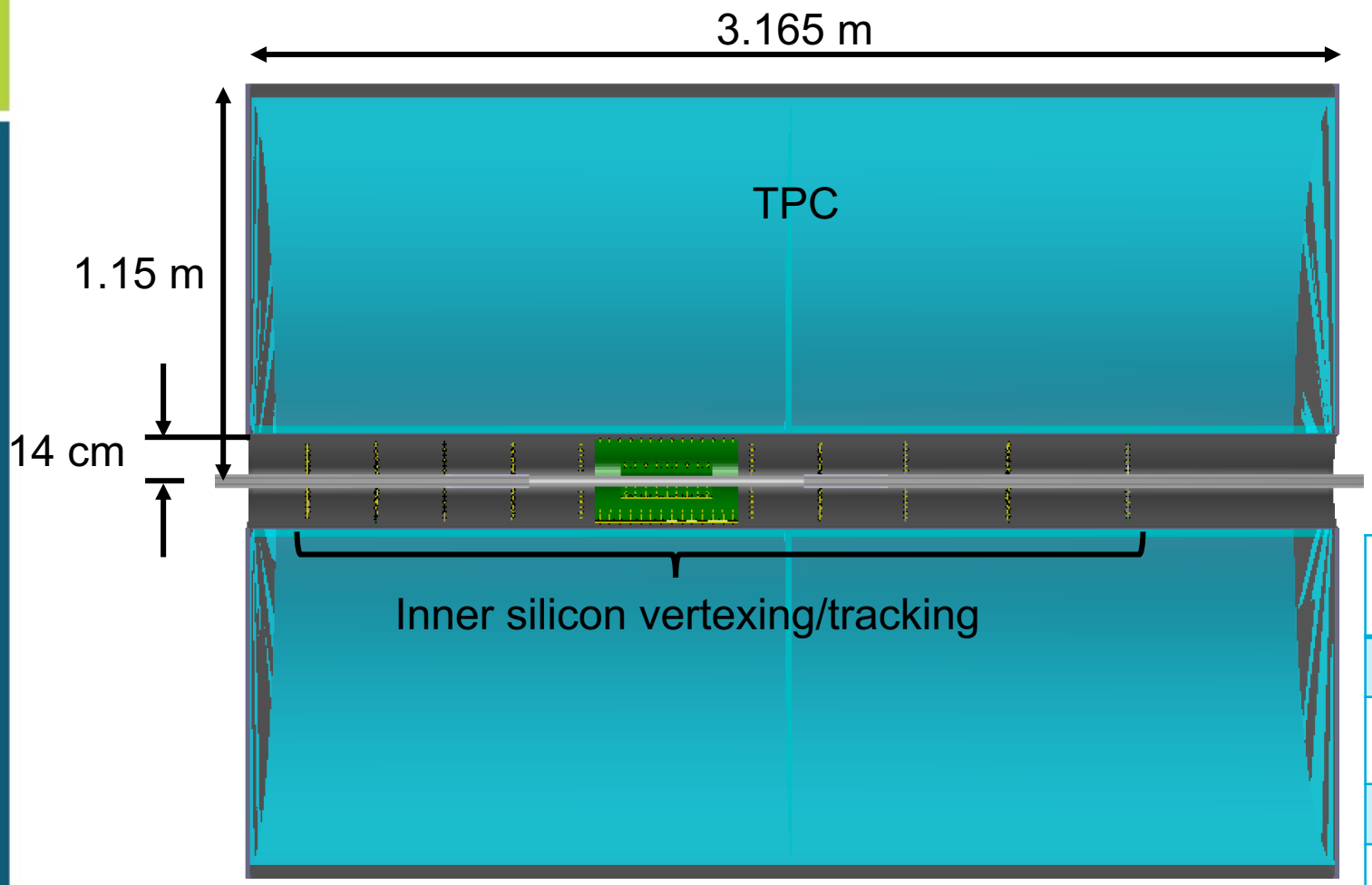
Reproduce sPHENIX Tracking Performance

Detector 2 Tracking Setup

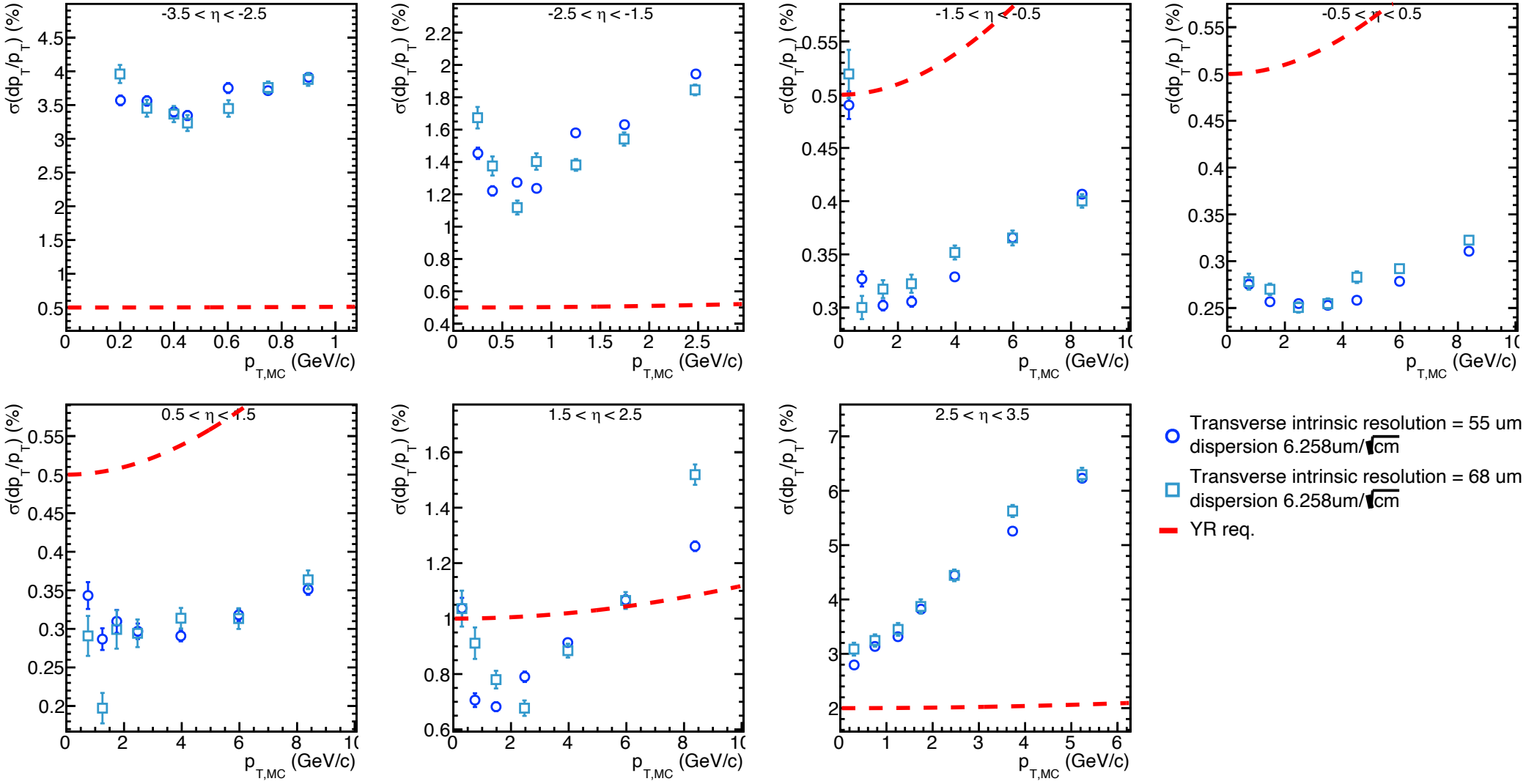


TPC
- Gas: Ar:CF4:iC4H10 (95:3:2)
- Field cage
  - carbon fiber
    inner cage t=2.62mm
    outer cage t=9.28mm
  - Kapton t=150um
  - Aluminum t =50um
- Central membrane: Kapton t=100um
- Endcaps:
  - aluminum t=13.4mm

Magnetic field
Constant 2T, solenoid

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 or 68um (with space charge)
Longitudinal intrinsic resolution	1 um
Radial intrinsic resolution	0 um
Vertical Pad Size	1 cm

p_T Resolution of Detector 2 Tracking with GridPix



Summary

- Reproduced sPHENIX tracking performance
- GridPix TPC with inner silicon
  - Satisfy Yellow Report requirements at $-1.5 < \eta < 2.5$
  - At $\eta < -1.5$ or $\eta > 2.5$, we need to reduce TPC inner field cage materials and play around the inner silicon tracker layout

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
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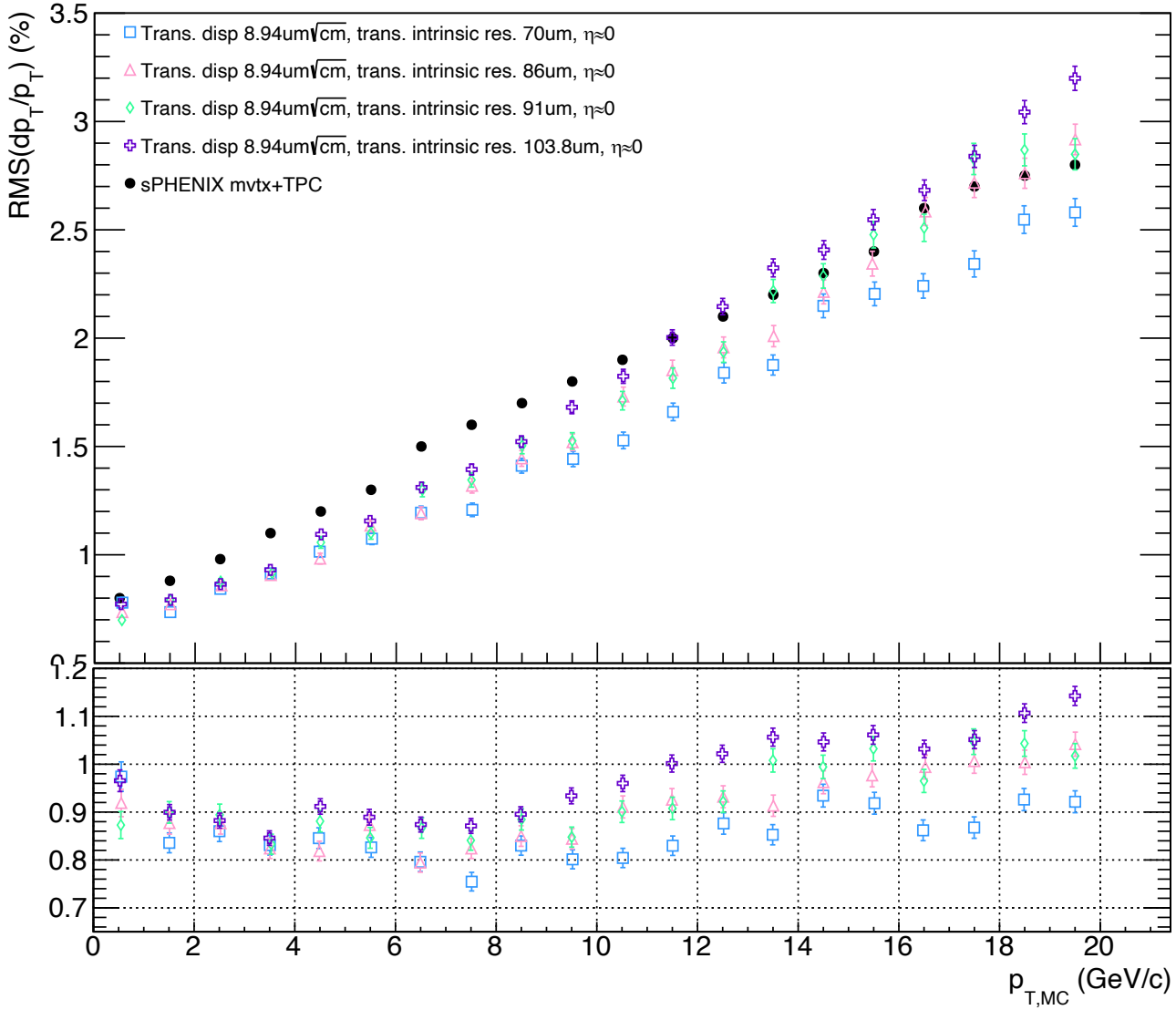
Vertical Pad Size	0.96 cm

Back Up

p_T Resolutions with Different Intrinsic Resolutions



Possible values of the transverse intrinsic resolution

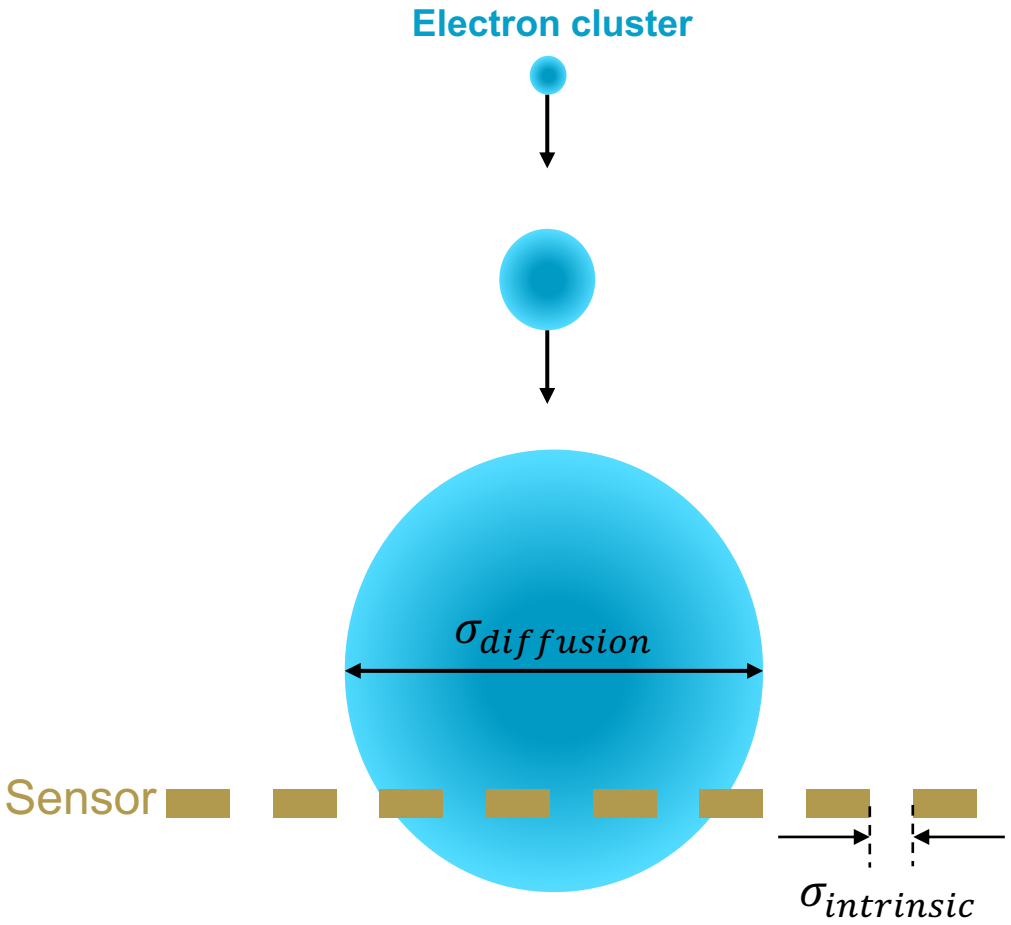
Intrinsic res \ Space charge	0 um	50 um
91 um	91 um	$\sqrt{91^2 + 50^2} = 103.8$ um
70 um	70 um	$\sqrt{70^2 + 50^2} = 86$ um

Both transverse intrinsic resolution = 91 um or 86 um give good descriptions of the TPC p_T resolutions

→ I cannot conclude whether the space charge uncertainty should be part of the intrinsic resolution in EicRoot

- Transverse dispersion = 8.94 um/$\sqrt{\text{cm}}$ in these cases
- Vertical Pad Size = 0.96 cm in all cases
- Longitudinal parameters are set to 1 um, radial intrinsic resolution is set to 0 um

TPC Uncertainties



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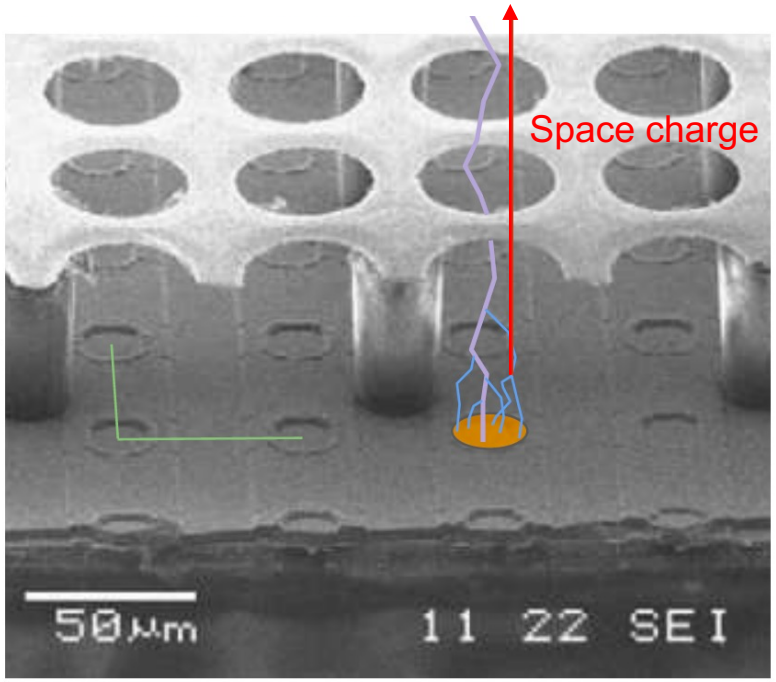
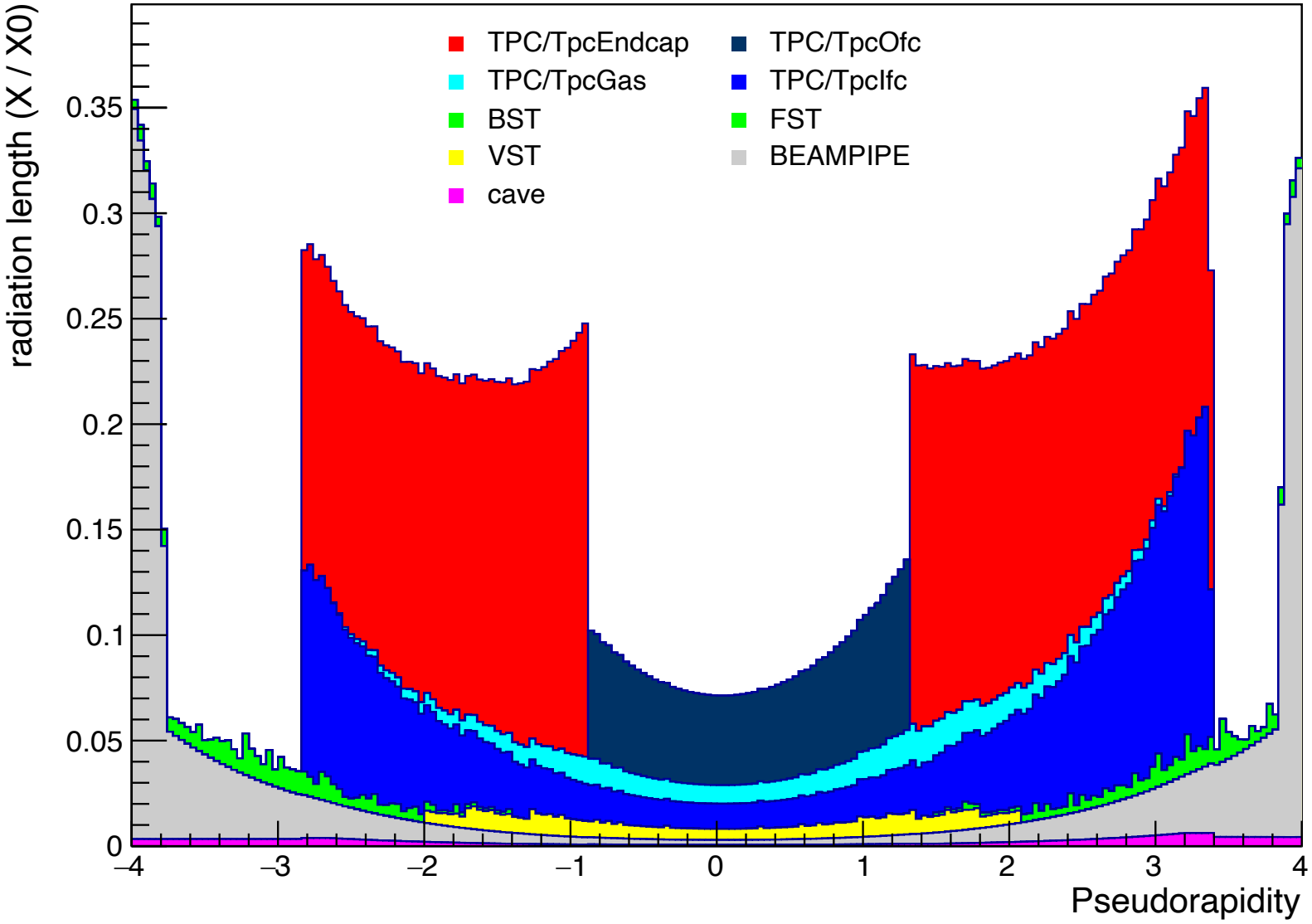


Space charge
→ Ion backflow
→ Distortion of the electric field

Material Budgets of Detector 2 Tracking



p_T Resolutions of Detector 2 with GridPix