Momentum resolution of Pixelated TPC

Gang LI, Linghui Wu, and Huirong QI

CEPC physics & detectors plenary

Pixelate readout TPC could provide huge number of measurement and better spatial resolution

- A prototype of 55x55μm by NIKHEF
  - ✓ 28 k hits of $\sigma_{r\phi}$ =16 μm
- CEPC plans to investigate (assuming 1.4 m thickness)
  - ✓ 200x200 μm
    - ✓ 7 k hits, 58 μm
  - ✓ 300x300 μm
    - ✓ 4.6 k hits, 87 μm
  - ✓ …
- Here calculates σ_{pT} for different pixel size designs

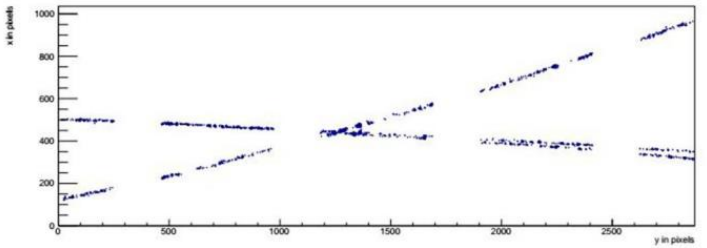
Huirong’ s talk at CEPC day

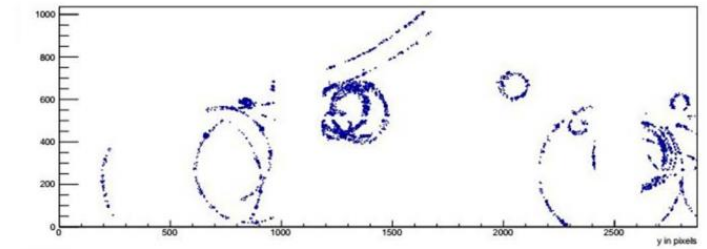
- **Good spatial resolution**
  - **Intrinsic resolution 100um → 16um**
- **Good track reconstruction**
- **Good momentum resolution**

$$\sigma_{r\phi}^{pads} = \sqrt{\sigma_{r\phi 0}^2 + \sigma_{\phi 0}^2 \sin^2(\phi_{pad}) + \frac{D_{r\phi}^2}{N_{Eff}} \sin(\theta_{pad}) \left(\frac{6\ mm}{h_{pad}}\right) \left(\frac{2.0\ T}{B}\right)^2 L}$$

$$\sigma_{r\phi}^{pixels} = \sqrt{\sigma_{r\phi 0}^2 + D_{r\phi}^2 \left(\frac{2.0\ T}{B}\right)^2 L}$$

$$\sigma_z = \sqrt{\sigma_{z0}^2 + D_z^2 L}$$





Intrinsic resolution	Pad TPC (1mm×6mm)	Pixel TPC (55um×55um)
$\sigma_{r\varphi 0}$	100um	16um
$\#Hits/track$	~220	~28k
$Gain$	5000	2000

Analytic calculation method

Least square: $\chi^2 = (\boldsymbol{y} - \boldsymbol{Ga})^T \boldsymbol{C_y^{-1}} (\boldsymbol{y} - \boldsymbol{Ga})$

Covariance of ***a*** (helix parameters) is our goal, and ingredients needed are

- y: measurements (rϕ, z)
- C_y: covariance of y, constructed according to tracker geometries
  1. Spatial resolutions ($\sigma_{r\phi}$, σ_z)
  2. Multiple scattering effect (layout and materials: X/X_0)
- G: the Jacobian $\boldsymbol{G_{mn}} = \frac{\partial F(a,y)}{\partial a_m}$

  Exact helix used to calculate G_{mn}:

Trick to avoid treating big matrix and speed up:

- adding each 25 layers of TPC together
- resolution/5

Covariance of 5 track parameters

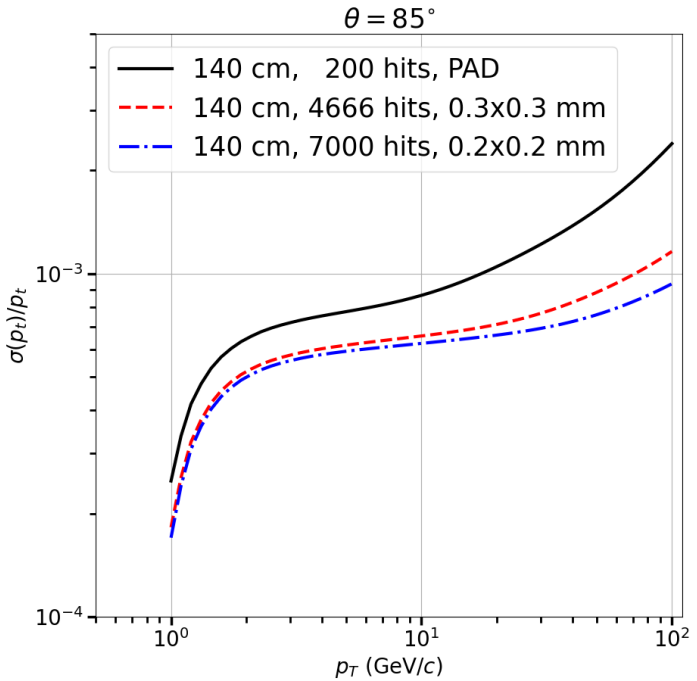
$$\boldsymbol{C_a} = \left(\boldsymbol{G^T C_y^{-1} G}\right)^{-1}$$

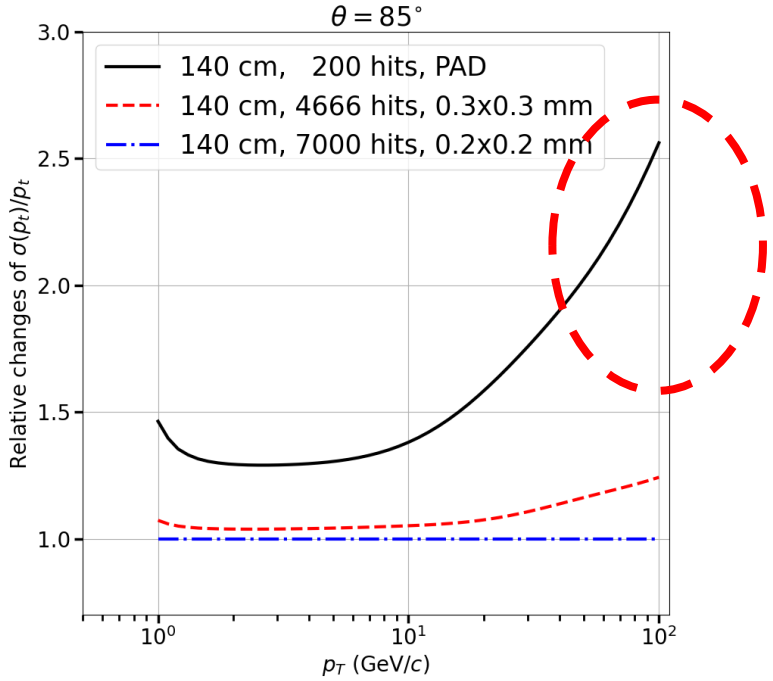
Comparing PAD TPC and pixelated TPC

$\sigma_{r\phi}$ = pixel/sqrt(12)
(diffusion under control)
σ_z = 2000 μm

Geometries

- Beam pipe (same for all)
- 3 double layers of VXD, 3 silicon tracker layers, and another silicon layer as TPC wrapper (same for all)
- TPC: 40 ~180 cm, only change spatial resolution (readout configuration)



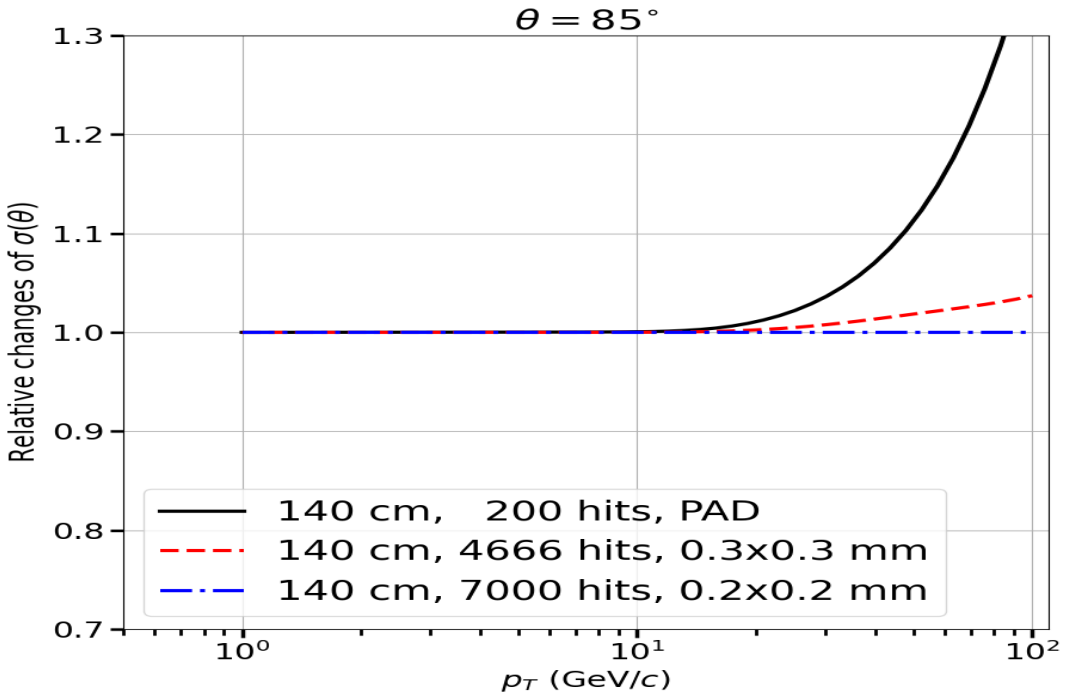


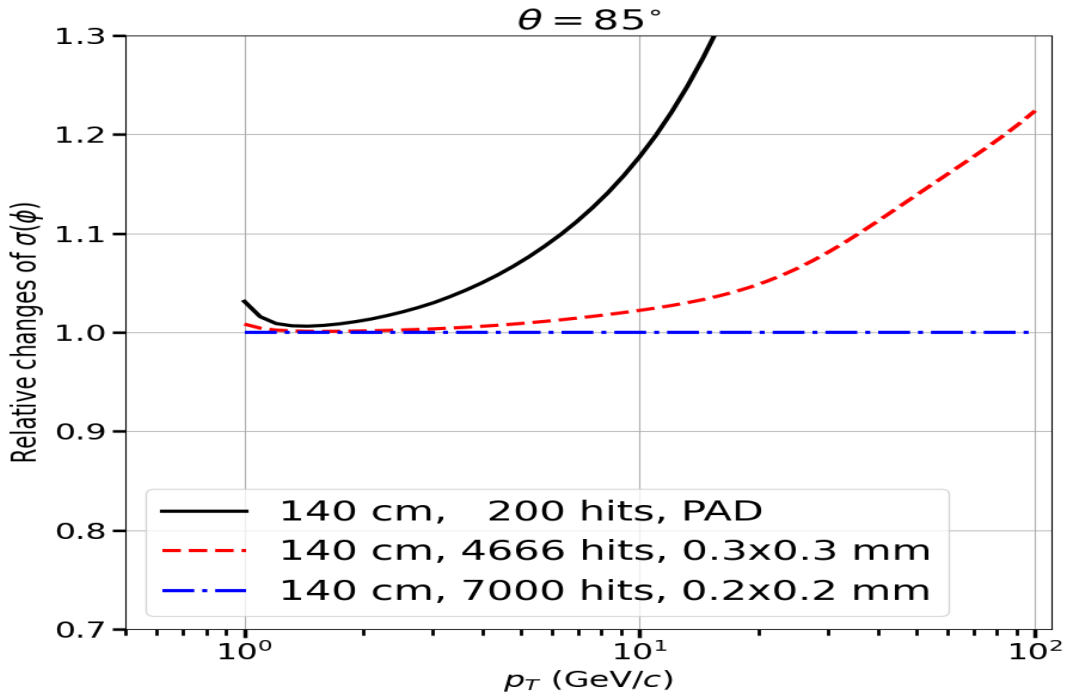
>100% improvement

- ✓ Pixelated TPC improves momentum resolution significantly
  - ➢ > 25% for p< 50 GeV (PAD TPC already very good)
  - ➢ >100% for p> 50 GeV (more precise measurements around sagitta)
- ✓ Very beneficial for the model independent study of the eeH/μμH and 360 GeV running

100% eff. w/o backgrounds

Angular resolution can also be improved significantly for high momenta tracks



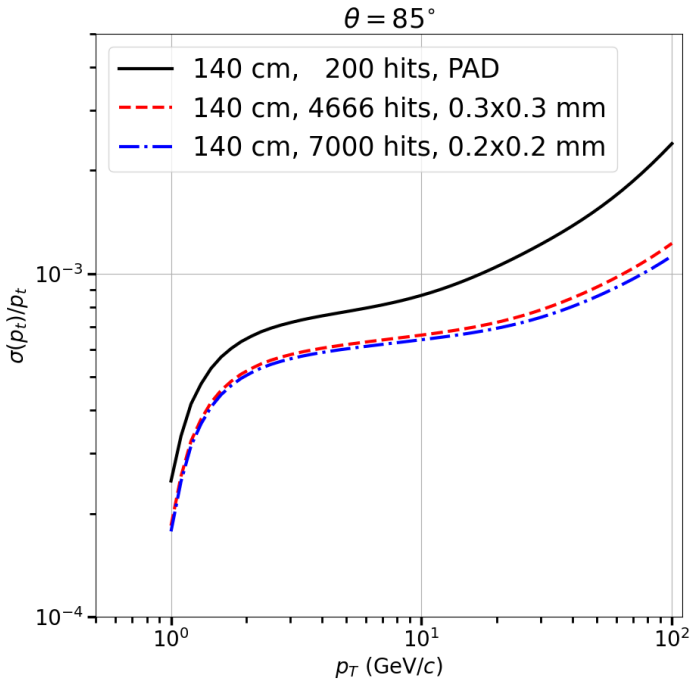


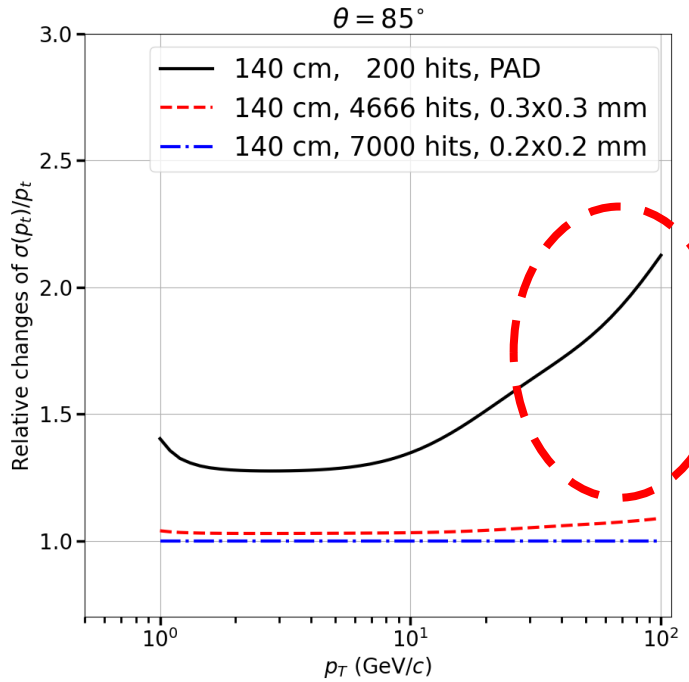
Comparing PAD TPC and pixelated TPC

Conservative assumption on the spatial resolution

(taking diffusion effect into account)

$\sigma_{r\phi}$ = 100 μm
σ_z = 2000 μm





>50% improvement

- ✓ Pixelated TPC improves momentum resolution significantly by only increasing # of measurements
  - ➢ > 25% for p< 20 GeV (PAD TPC already very good)
  - ➢ > 50% for p> 20 GeV (more precise measurements around sagitta)

Summary of the numerical results

	200x200 μm (ideal)	200x200 μm (conservative)	300x300 μm (ideal)	300x300 μm (conservative)	PAD
a (10^{-5}/GeV)	0.50	0.73	0.77	0.85	2.08
b (10^{-3})	0.57	0.57	0.58	0.58	0.73

The CDR reference

$$a \sim 2 \times 10^{-5}\,\mathrm{GeV}^{-1} \quad \text{and} \quad b \sim 1 \times 10^{-3}$$

$$\sigma_{1/p_\mathrm{T}} = a \oplus \frac{b}{p \sin^{3/2}\theta} \quad [\mathrm{GeV}^{-1}]$$

Summary

Needs X-checks with realistic full Sim & Rec

- TPC with pixelated readout
  - ➢huge amount of precise measurements
  - ➢dN/dx + dE/dx, hopeful to achieve 2% resolution
  - ➢other advantages : easily engineering, less materials, …
- Simple calculation with some ideal assumptions
  - The momentum resolution could be improved by 100% for high momentum tracks
  - Significant improvement on the angular resolutions for high momenta

Conservative assumption on the spatial resolution

(taking diffusion effect into account)