

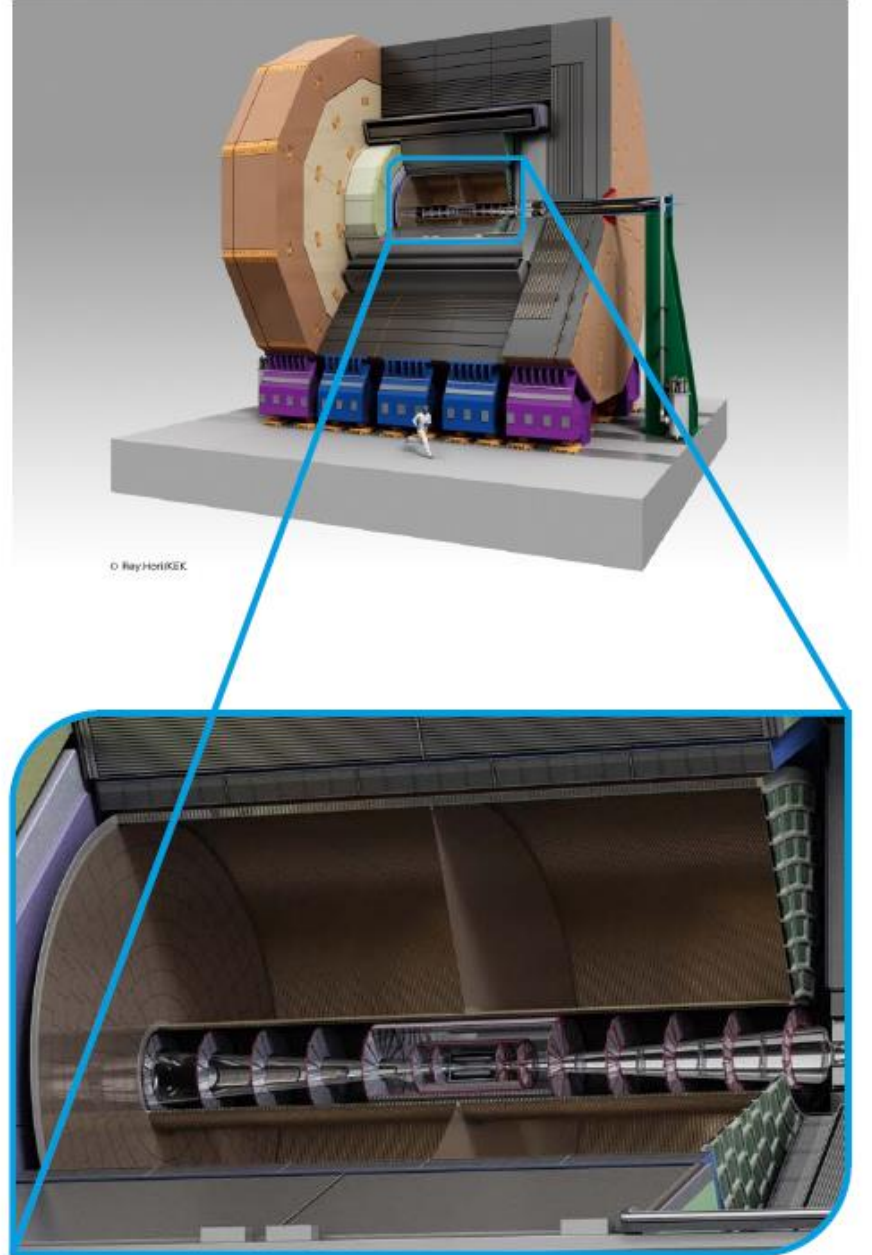


Paris, October 8th, 2024

TPC developments

P. Colas (CEA/Irfu U. Paris Saclay)

ILD meeting in Paris

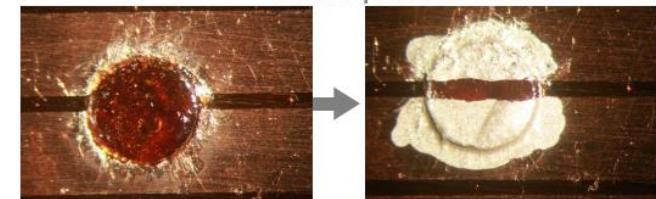


Field cage

- Talk by [Oliver Schäfer](#) at LCWS2024 in Tokyo
- New prototype field cage being built at DESY
 - Previous one used until 2019 was skewed
 - Keep in-house know-how
 - New precision mandrel
 - HV stability issues 2020-21 now solved
 - Simplified stip pattern with negligible impact on field homogeneity : 1-piece foil produced at CERN



Field strip side



Mirror strip side



Pixel readout

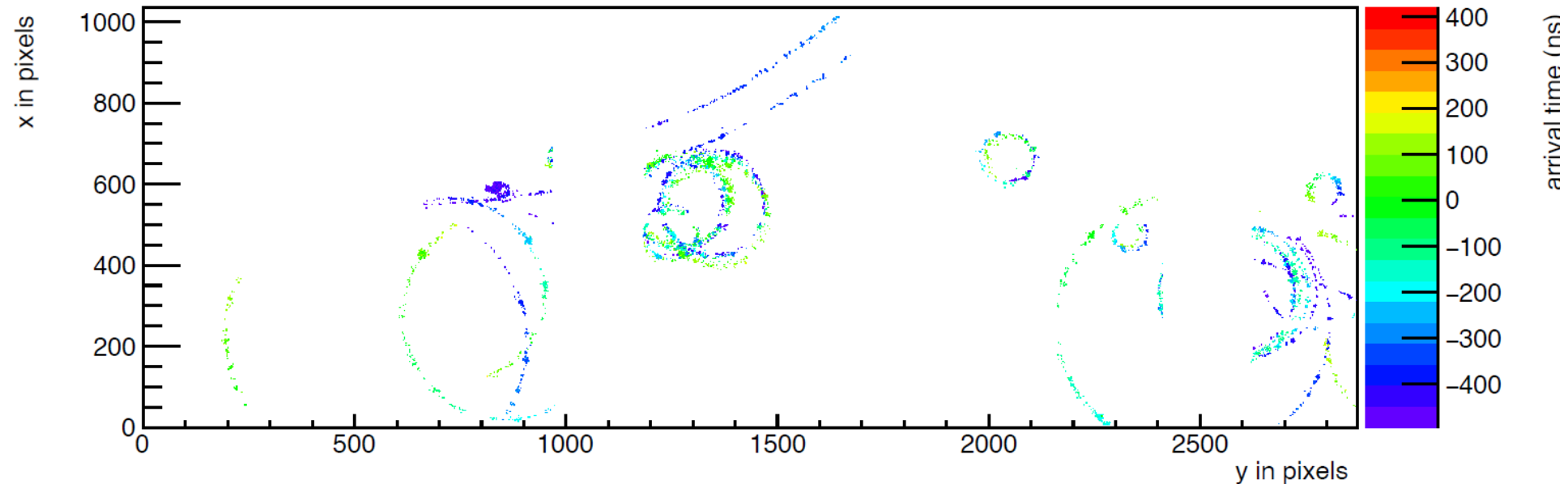
See [Peter Kluit's talks](#) at the ECFA Paris meeting



DESY testbeam June 2021



DESY LCTPC-Pixel Testbeam Run 6969 Event 2 Bfield 1.0 T beam momentum 6 GeV/c



ECFA Paris october 2024

Peter Kluit (Nikhef)



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Pixels

- Performance studies going on using DESY 2021 test beam data and simulations. dE/dx , dN/dx , resolution, chip alignment, distortions.



DESY testbeam Module Analysis

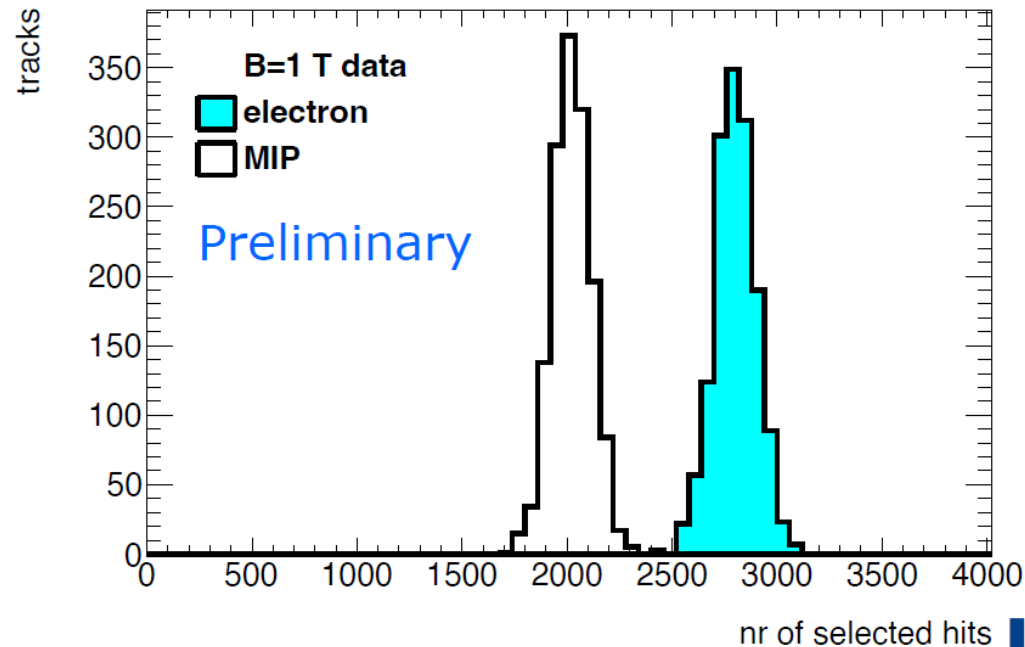


dE/dx performance method 1

Electron resolution
3.6%
1 m track 60% and
coverage

Linearity MIP-e = 1.03
z drift=5-15 mm (flat)

MIP distribution is obtained
by dropping 30% of the hits



ECFA Paris october 2024

Peter Kluit (Nikhef)



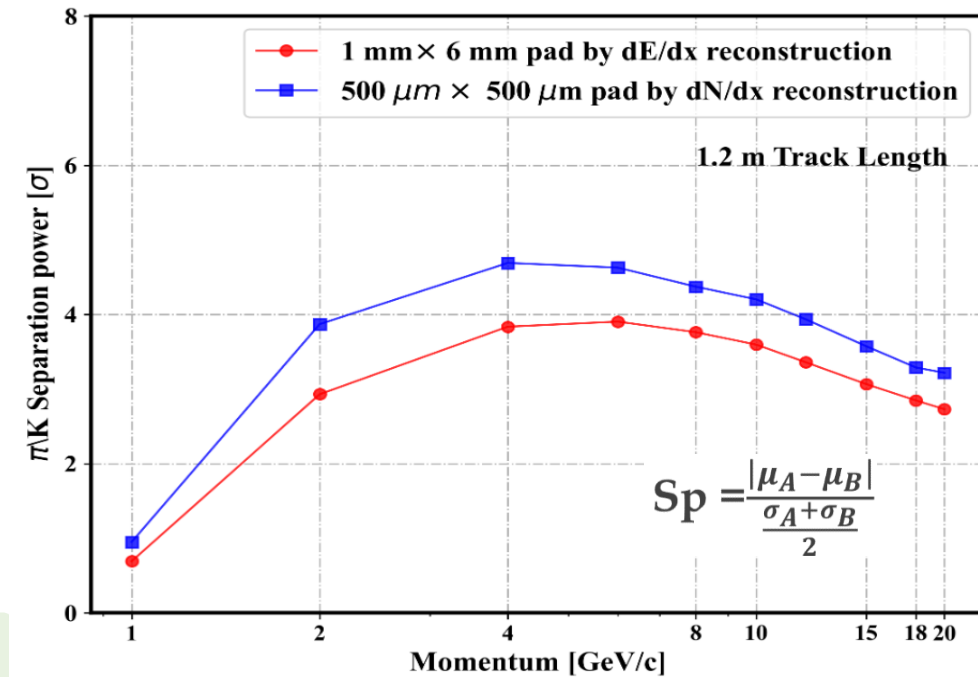
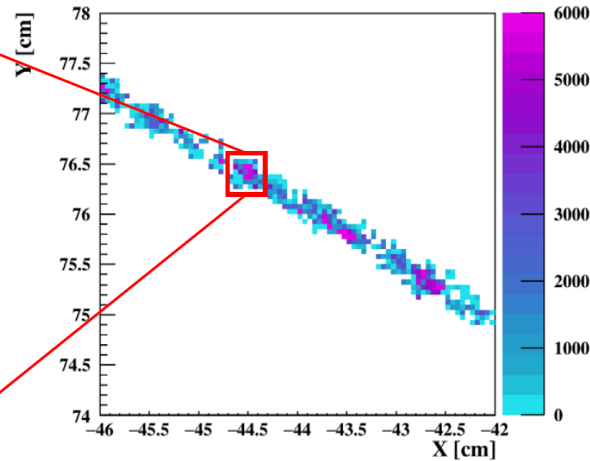
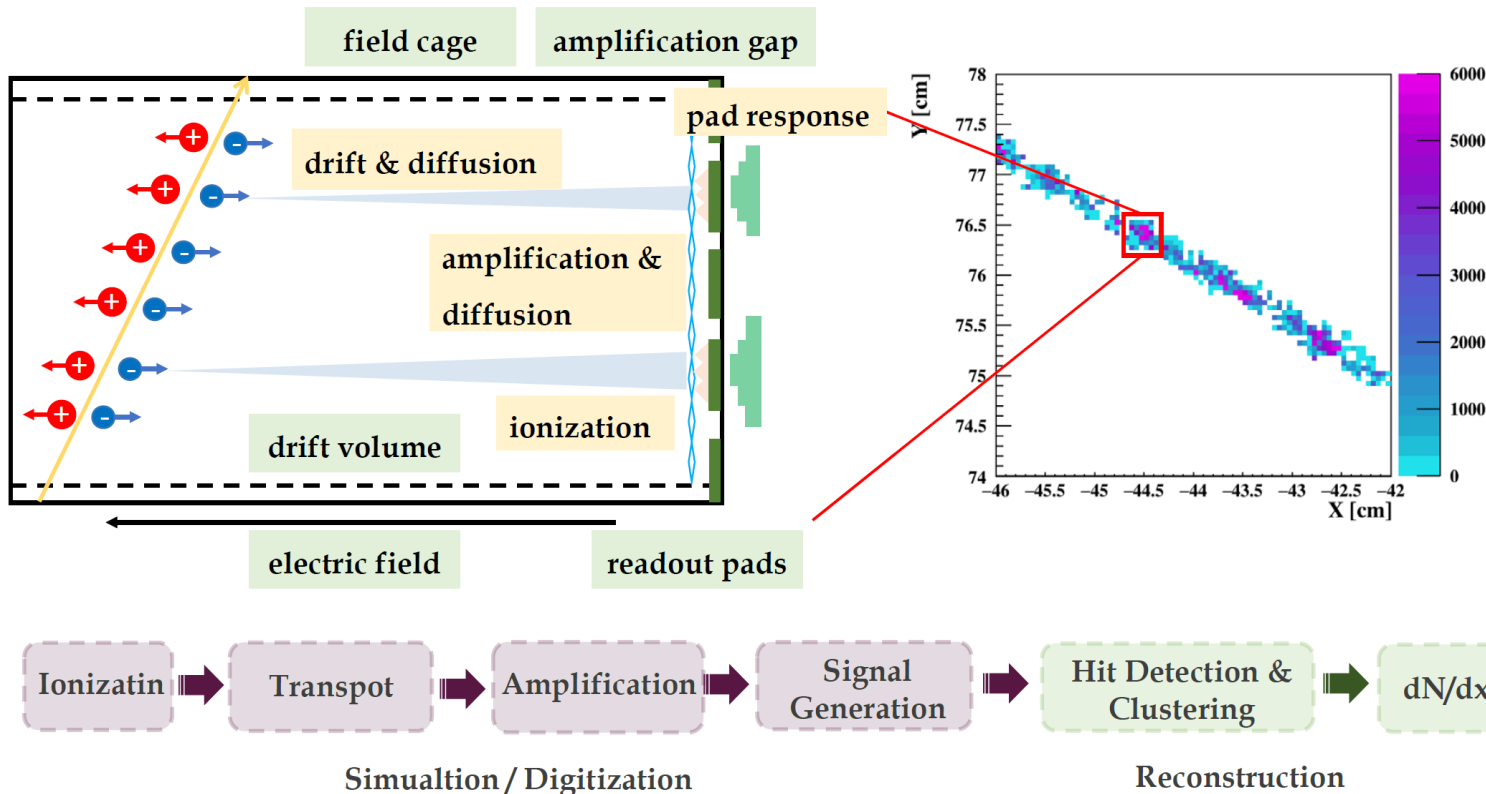
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Pixels for CEPC

Huirong Qi presented the TPC for the baseline detector at CEPC (LCWS2024 and also LCTPC)

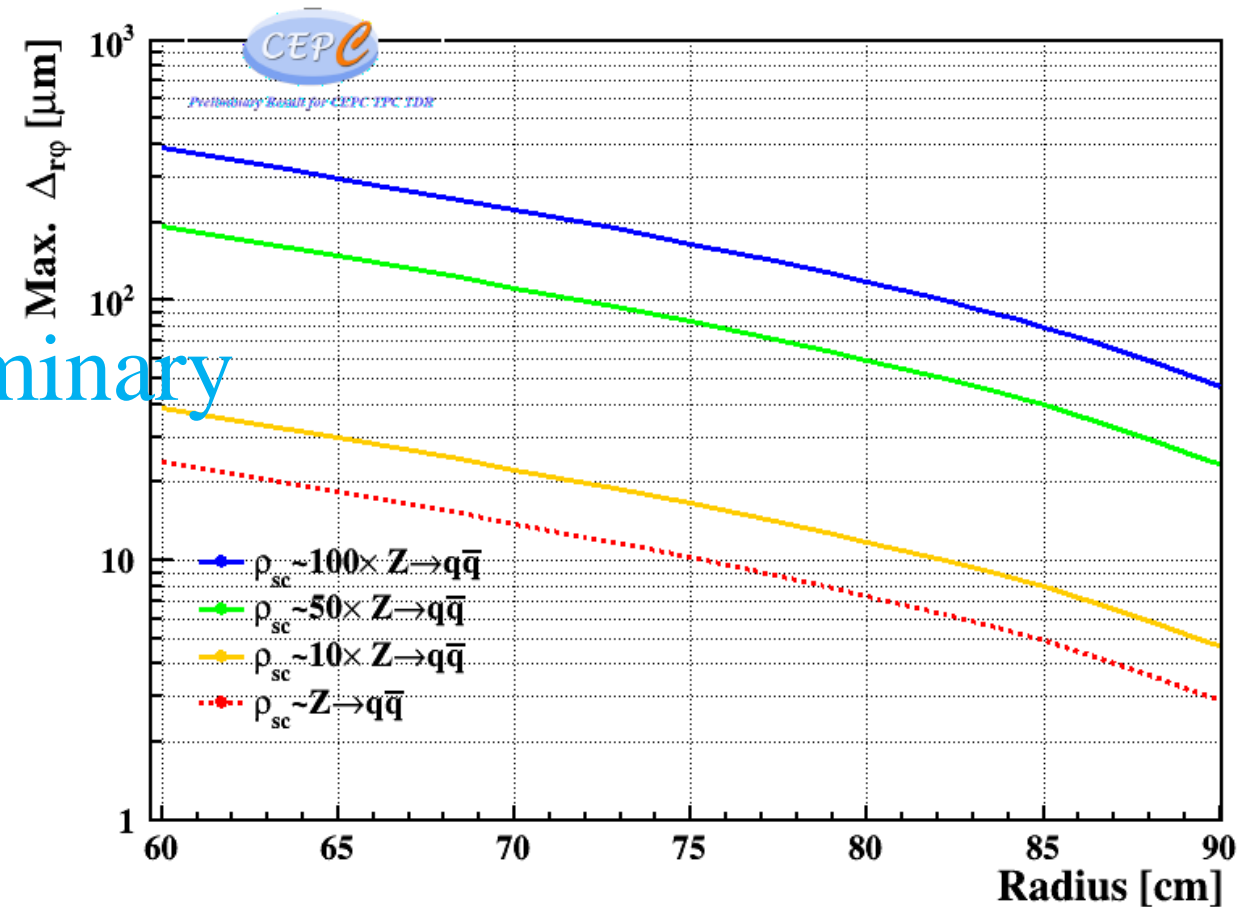
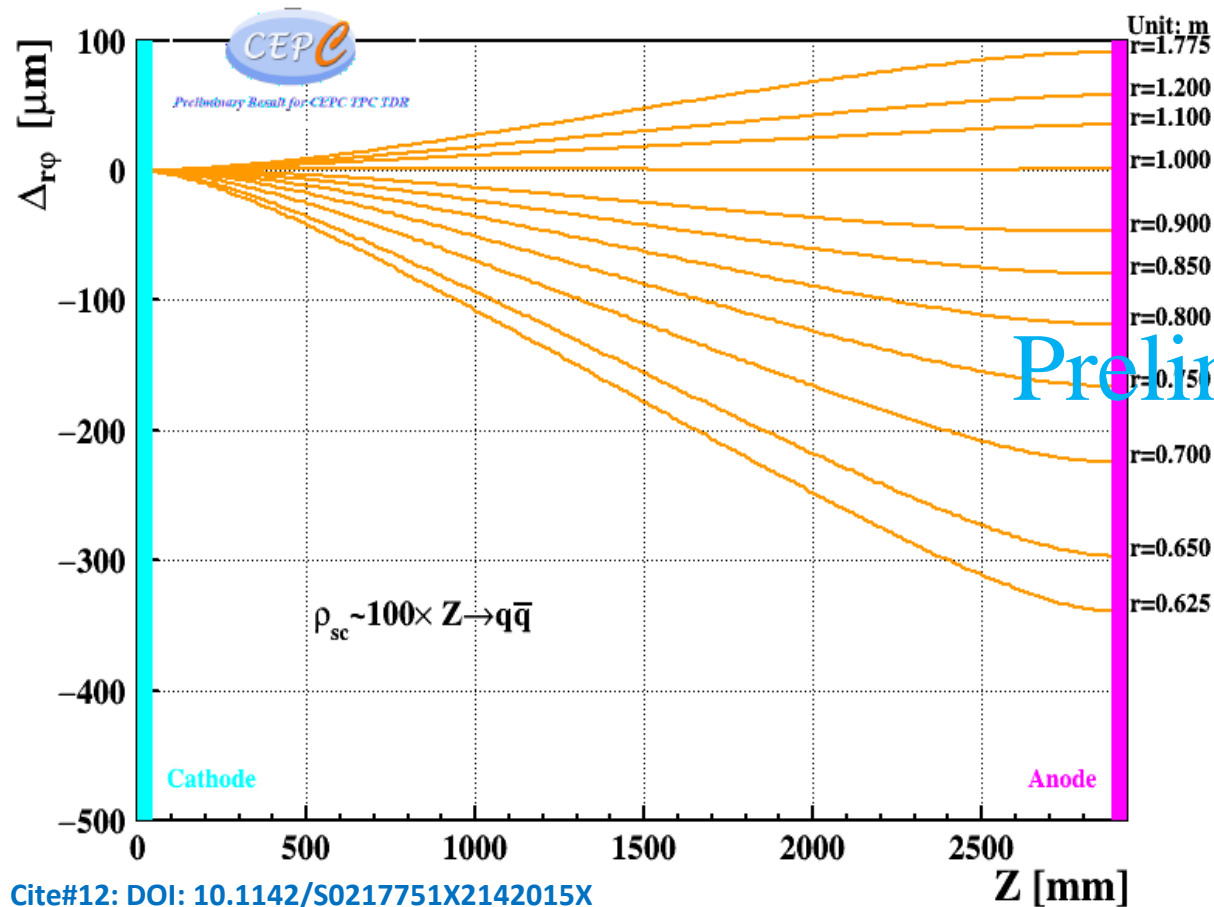
Full Simulation of Pixelated readout TPC

- developed using Garfield++ and Geant4 at IHEP
- Investigating the π/K separation power using reconstructed clusters, **a 3σ separation at 20 GeV** with 120cm drift length can be achieved
- dN/dx significantly **improves PID (π/K separation)**



Simulation of TPC detector under 3T/2T and T2K mixture gas

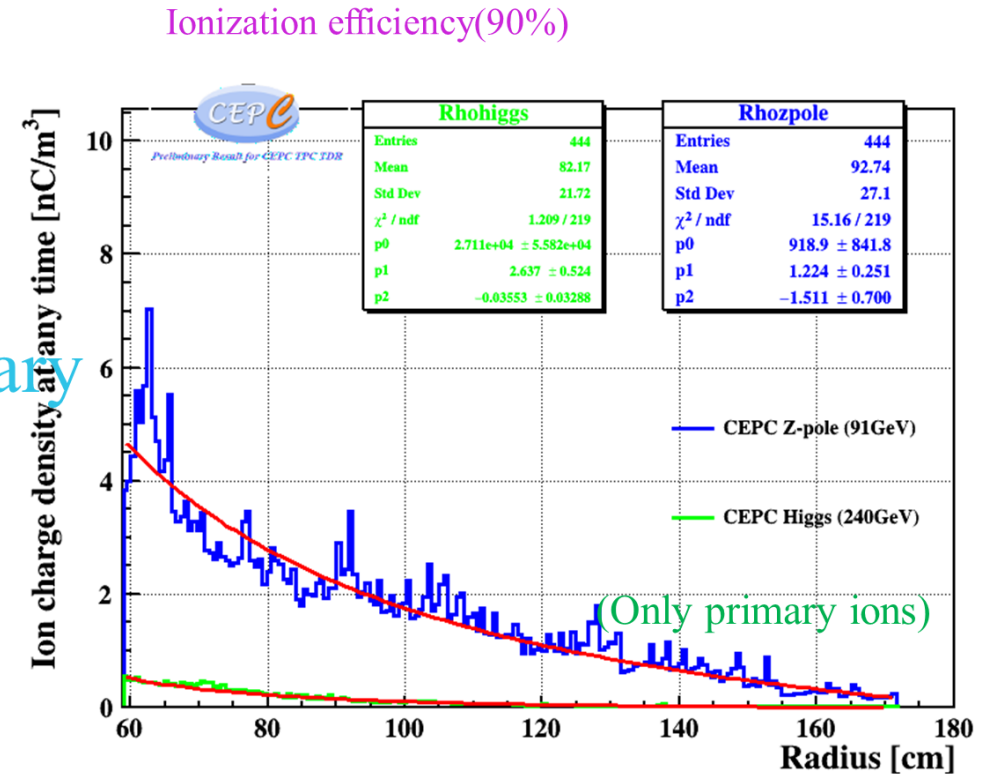
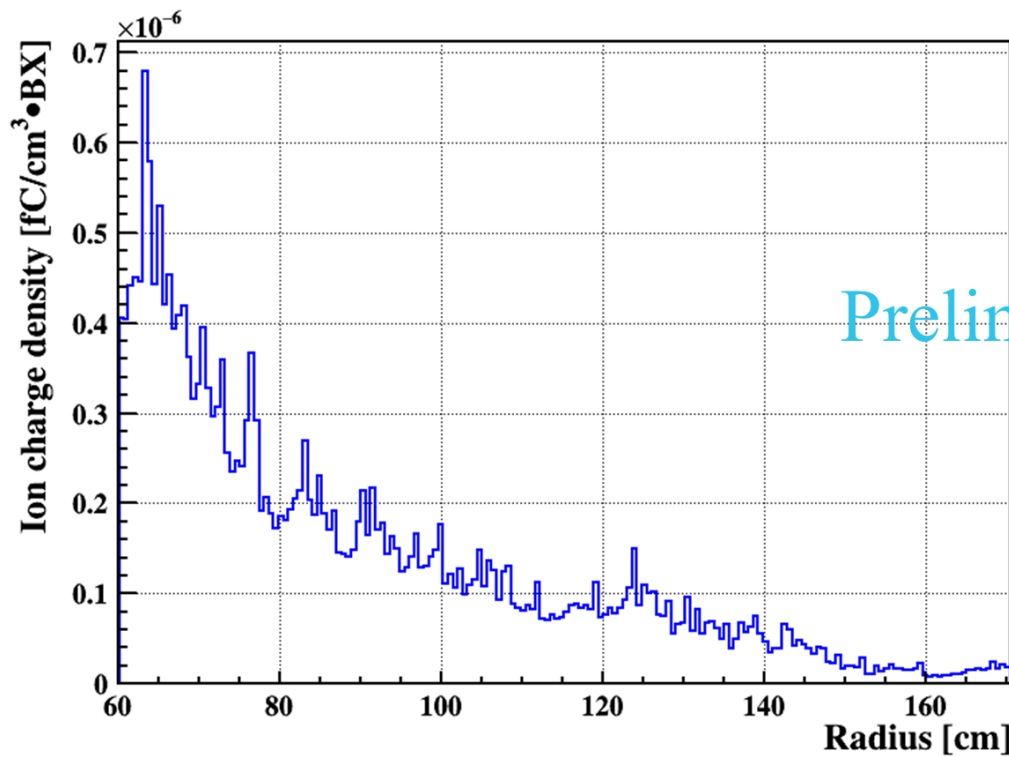
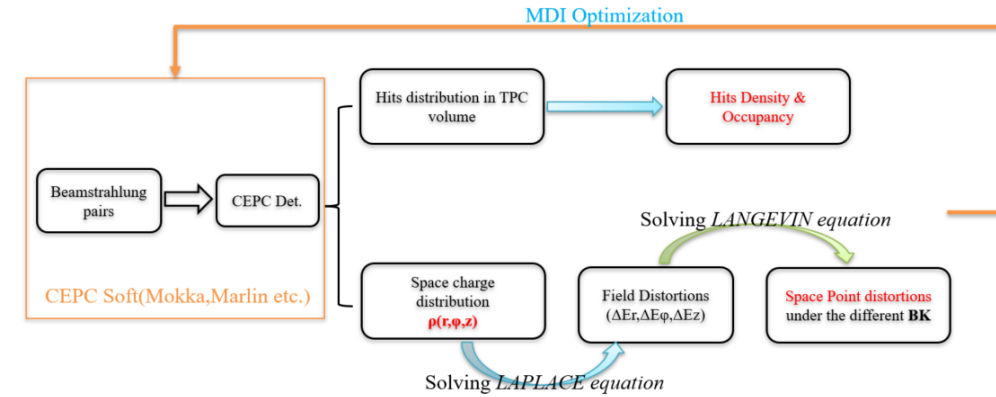
- Maximum distortion with e+e- to qq at Z pole (Physics events only)
- Maximum distortion under the different Beamstrahlung background (×10, ×50, ×100 times Physics events)
 - MDI design at Z need carefully optimized with MDI group in CEPC



Cite#12: DOI: 10.1142/S0217751X2142015X
 Cite#13: DOI: 10.1016/j.nima.2022.167241
 Cite#14: DOI: 10.1088/1748-0221/12/07/P07005

- Updated simulation results from CEPC Software

- Single BX, $\rho_{sc}(\text{single BX}) \sim 0.6e-6 \text{ nC/m}^3/\text{BX}$ @Z-pole
- $\rho_{sc}(\text{steady state}) \sim \rho_{sc}(\text{single BX}) \times \text{BX freq.} \times \text{max. drift time} \times 50\% \times \eta = 5.46 \text{ nC/m}^3$ (r=60cm) @Z-pole
 - $\times 5$ smaller than FCCee -91

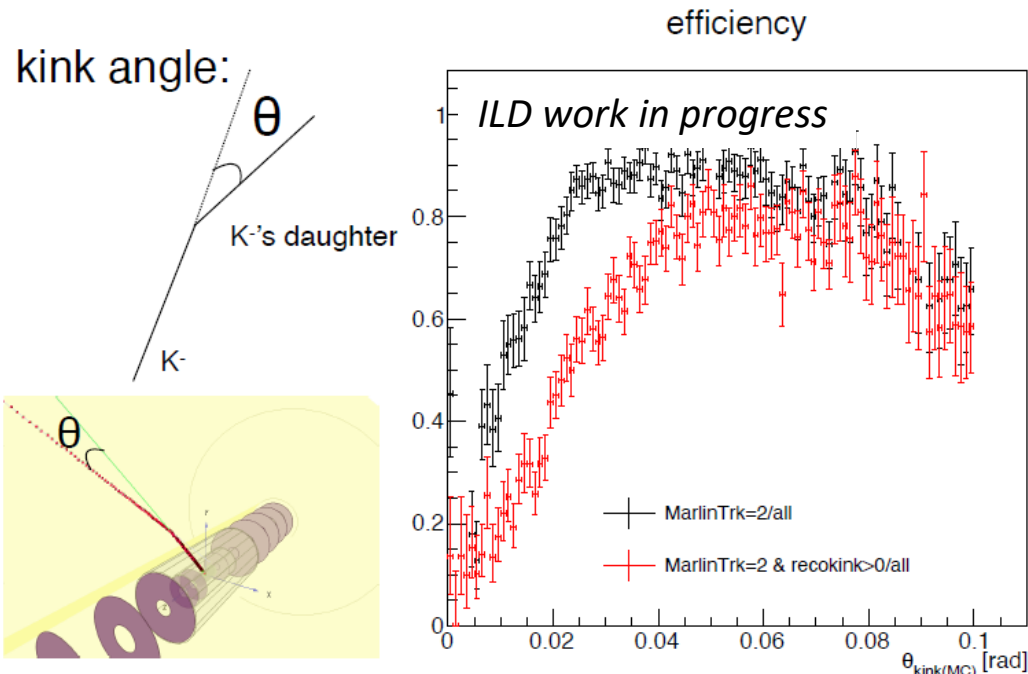


$\rho_{sc}(r)$ (single BX) distribution Left & $\rho_{sc}(r)$ (steady state) Right

Preliminary

Application to Long-Lived Particles (LLP) search

- The continuous tracking allowed by a TPC can help finding a LLP signal by revealing kinks (Daniel Jeans, Jurina Nakajima, KEK/SOKENDAI)
- Presentation at LCWS2024 by Jurina
- MC study of $K^- \rightarrow \pi^- \pi^0$. Trackfinder in MarlinTPC: efficiency 80% at $p_K=10$ GeV/c

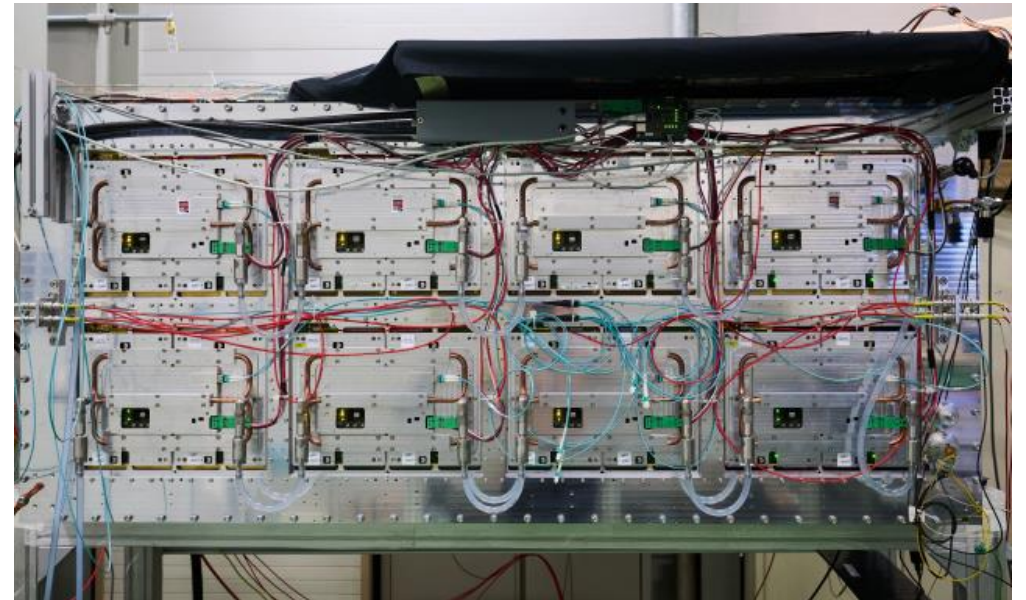
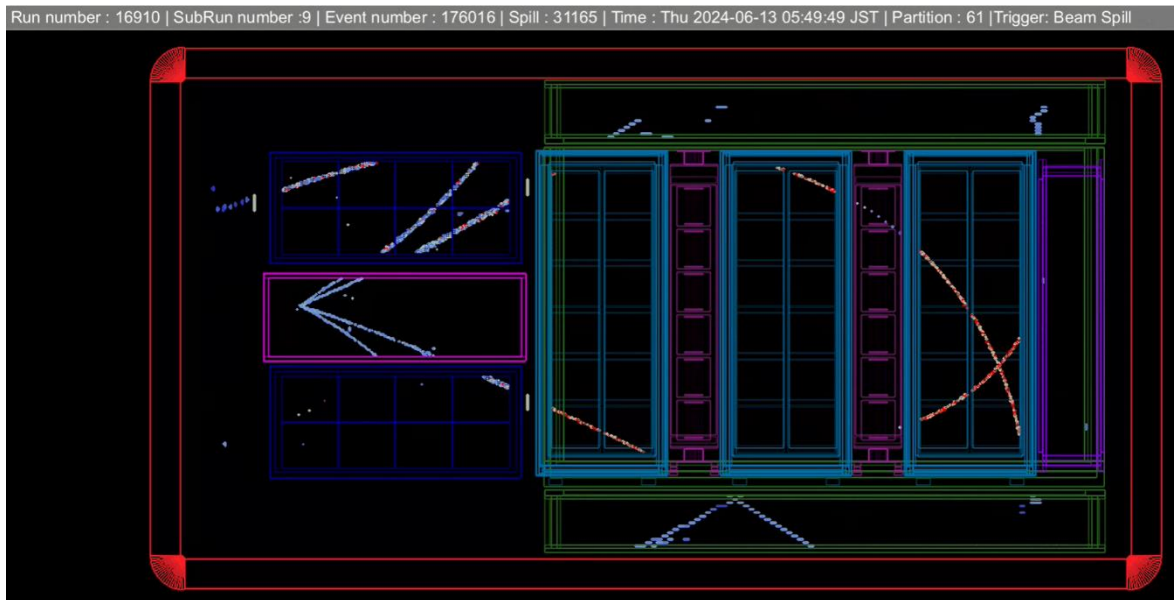


$$m_{\text{kink}} \equiv \sqrt{(E_{\text{chg2}} + E_0)^2 - P_{\text{chg1}}^2}$$

- Estimate of Δm between track1 and track2
- Next : extend to other momenta, kinematic fitting
- Interpretation in BSM

Micromegas with charge sharing

- T2K built two TPCs for ND280 upgrade, with the new resistive-capacitive charge spreading developed for ILC
- Started operation in September 2023 and May 2024 at JPARC
- Gained experience in operating, calibration and measuring the RC parameter which governs the charge spreading

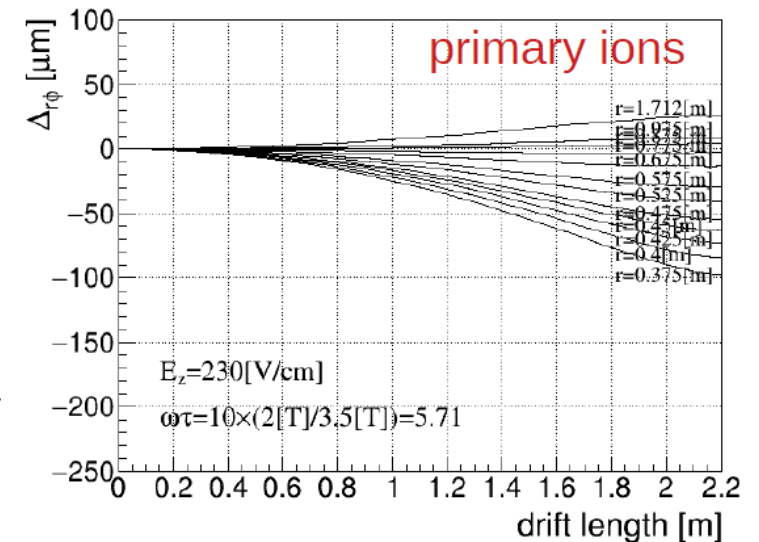


Distortions from ion space charge

- Large ionization at the Z peak produces a large ion density. As ions drift very slowly ($O(m/s)$) the TPC integrates a high ion space charge, which causes a transverse electric field, which in turn makes large distortions of the ionization electrons paths.
- These have been calculated (K. Fujii, S. Ganjour et al.) and amount to $\sim 60 \mu m$ at the HZ for ILC, and $O(mm)$ distortions for the tracks at the Z pole at the TeraZ.
- Correcting for this is necessary and is similar to what Alice attempts to do at the Pb-Pb run
- See my talks at HKUST 2024, FCC workshop in Krakow, etc...

Beamstrahlung background at ILD and FCC

- **Daniel Jeans** presented simulation results at LCWS2024 in July, and again at a FCC detector concept meeting on September 9.
- Beamstrahlung BG produced ~200 times more ionization than hadronic Z decays (20mm distortions)
- Beamstrahlung higher at ILC, but MDI more intrusive at FCC. Optimization of MDI necessary if one is to use a TPC



Alice is facing similar distortions in Run3 Pb-Pb collisions at 50 kHz. We contact them to try and learn from their experience in correcting space charge distortions



Summary

Jens Wiechula, talk at LCTPC annual meeting in January 2023

- Different types of distortions present in the TPC (static, charge-up, space-charge)
 - Different scaling over time and detector load to be taken into account
- Large distortions due to space-charge expected $O(5-10\text{cm})$
 - Correction down to intrinsic tracking precision envisaged $O(\text{few } 100\mu\text{m})$
- Two main ingredients for distortion corrections
 - Direct measure of distortions via interpolation from external detector points
 - Measure of fluctuations using continuously integrated digital currents on the pad plane (IDCs)
- Different procedures foreseen for corrections
 - Scaling of absolute distortion map
 - Scaling of local derivative distortion map
 - Linear regression / ML using derivative map and 1D FFT coefficients of IDCs
 - ML using NDim IDC fluctuation information

Activity in progress

Preparation of the inputs to the European Strategy Update

Many meetings :

- Oct. 9-11 : 3rd ECFA in Paris EW-Higgs-top e+e- factories
- Oct. 21-22 : International Detector Review in Beijing
- Oct. 23-26 : CEPC workshop in Hangzhou
- Nov. 4-6 : FCC France-Italie à Venise
- ...
- June 23-27 : Open ESPPU symposium in Venice

LCTPC Abstracts submitted to ECFA Paris, IEEE-NSS-2024 and VCI-2025. Talk by Huirong Qi at ICHEP-2024. (LCTPC speaker's bureau chaired by Maxim Titov)