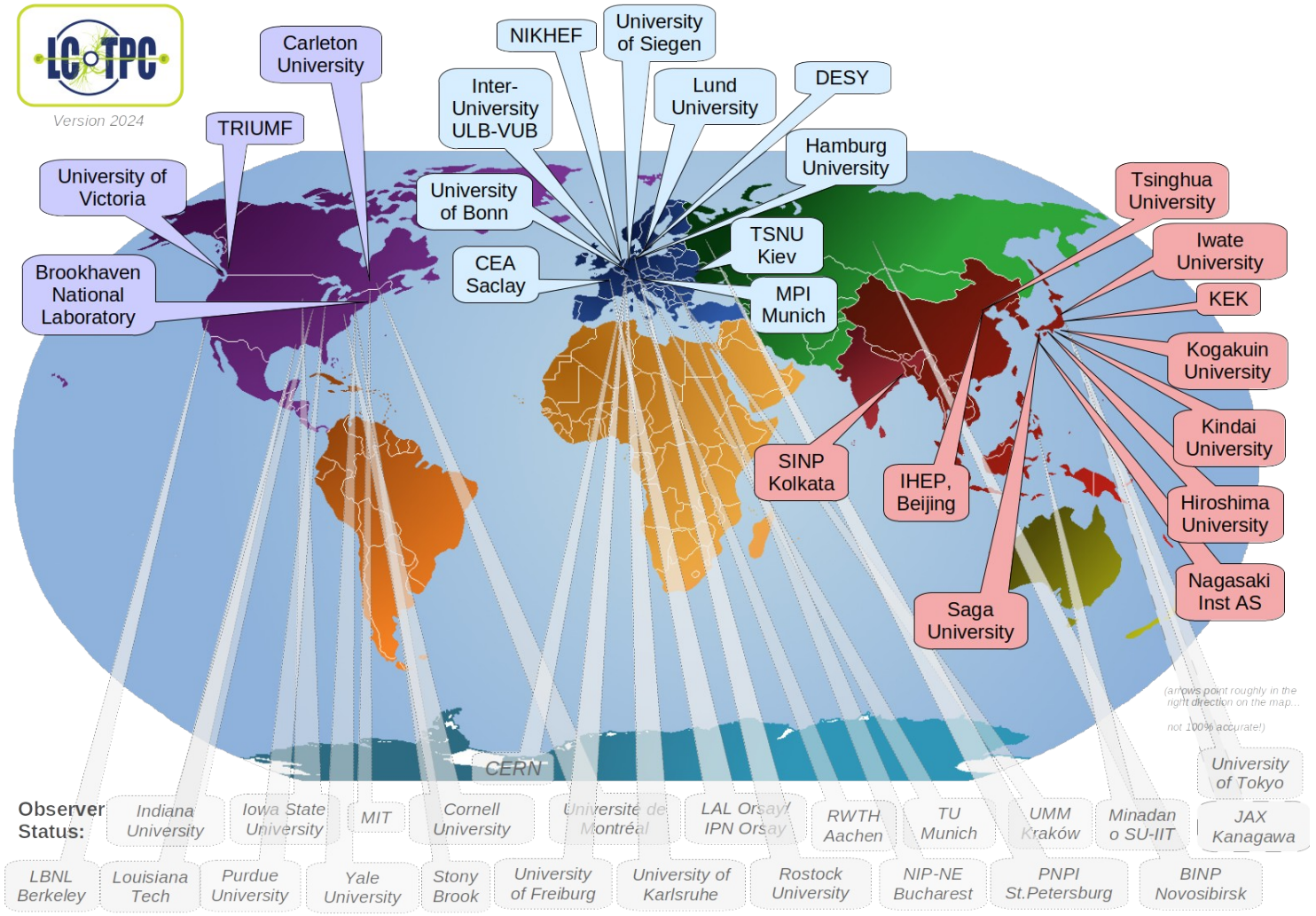
Summary of the LCTPC collaboration meeting

DESY, 12.-13.3.2024

UNIVERSITÄT BONN

Situation



Basically no funding – except for CEPC.

Some studies for CEPC and FCC-ee are being done.

Some interest of other experiments in our work – most notably by EIC, where a TPC for PID is considered for the second detector.

Synergies with T2K, etc.

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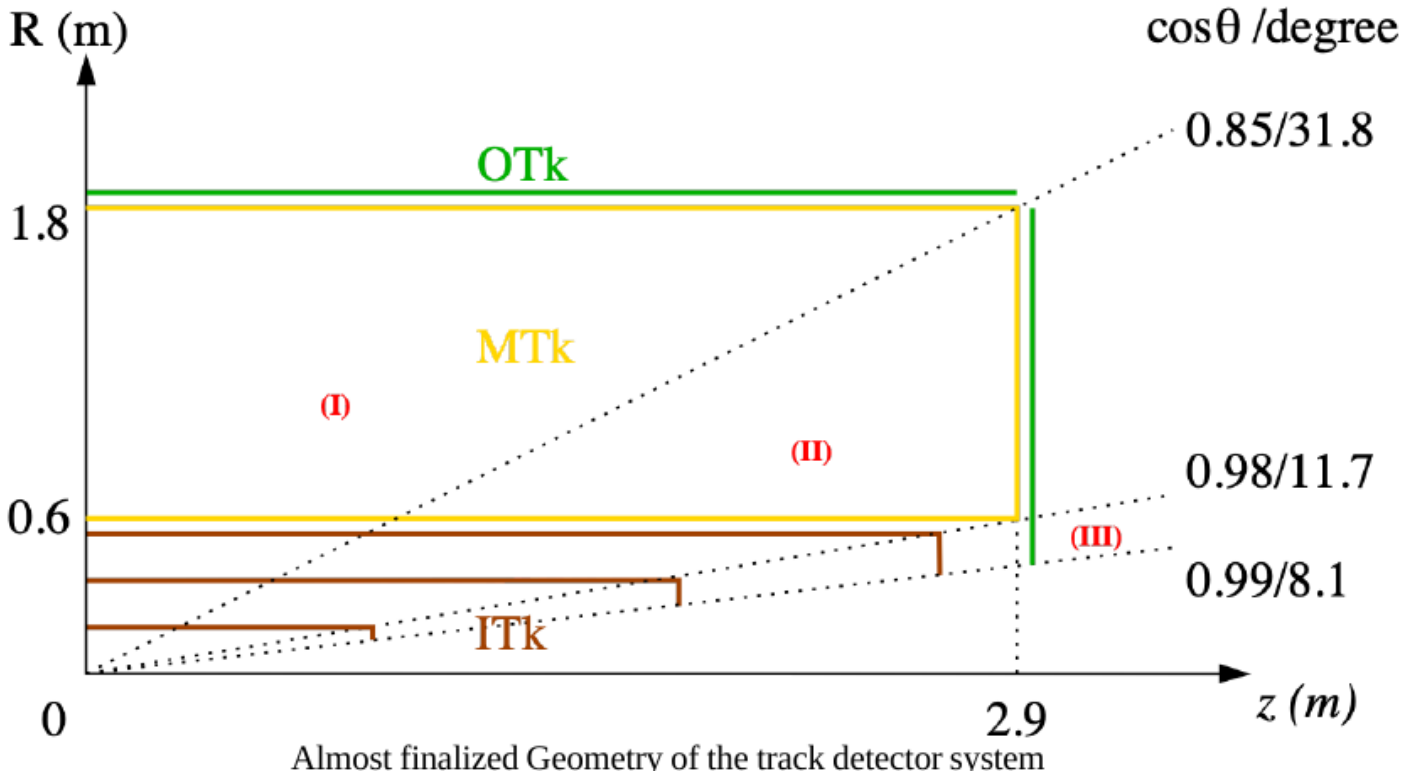
Studies for CEPC

- High granularity readout TPC for CEPC TDR
  - TPC **SELECTED** as the baseline track detector



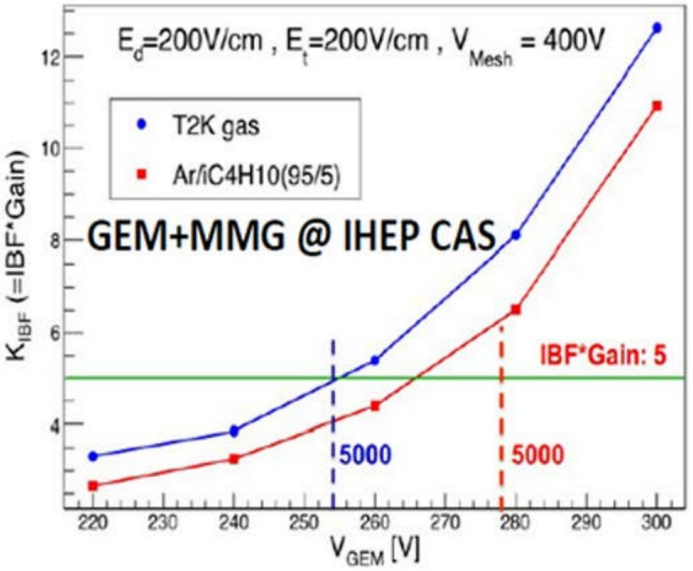
Almost finalized Geometry of the track detector system

PID is very important for CEPC, in particular for Tera-Z running (dE/dx < 4%).

Studies for CEPC + IBF reduction

Main R&D aspects for the CEPC TPC are
- Suppression of ion feed back
- Study of pad size
- Reduction of power consumption
- Improvement of dE/dx

Ion backflow reduction from the gas amplification stage by using multi-stage gas amplification devices (GEMs + MM).
=> gain x IBF < 5

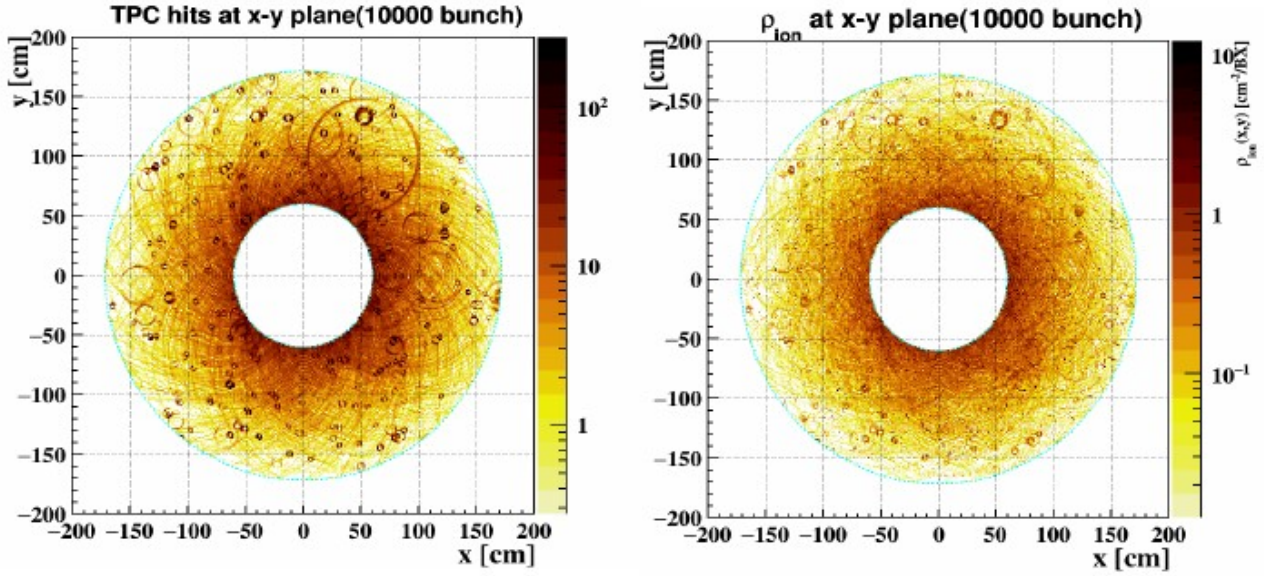


New project: Study graphene layer on GEMs / MMs as ion absorbers.

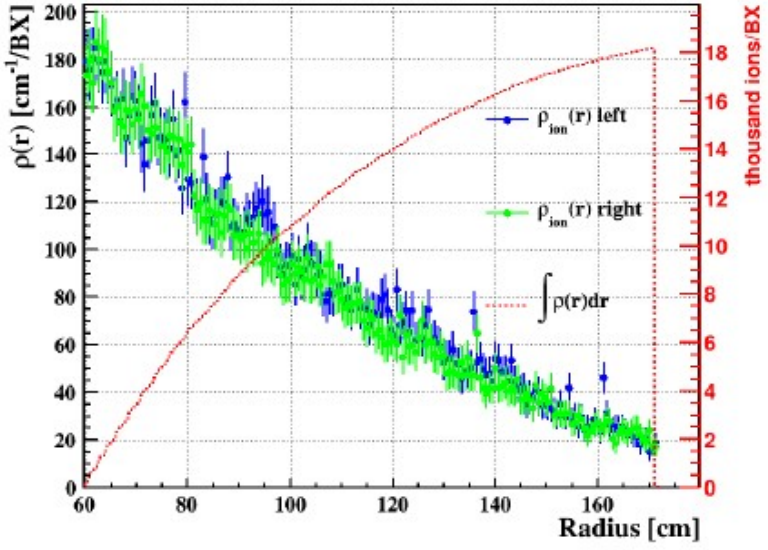
Simulation of beam backgrounds CEPC

- Primary ions per bunch crossing in TPC
  - 10000 bunch crossing
  - Edep ~4.73GeV in total
  - Number of primary ions: BX freq. ~ 1/23ns
    - Edep/effective ionization potential of Ar [26eV] ~18.20k ions/BX

Collider Detector Model	CEPC_v4	CEPC_v4
Beamstrahlung pairs	CEPC Z-pole(91GeV)	CEPC Higgs(240GeV)
BX freq.	1/23 ns	1/680 ns
primary ions/BX	18.20 k	39.26 k
primary ions at any time	2.07×10^{11}	1.5×10^{10}
average primary ρ_{ion} [nC/m^3]	0.63	0.05
max (single BX) [nC/m^3/BX]	0.6×10^{-6}	1.8×10^{-6}
max (steady state) [nC/m^3]	5.46	0.62



Hits map (left) & Ion density(right) at x-y plane



Tera-Z $\rho_{ion}(r)$ distribution

Xin She

Running a Pixel TPC at Z run @ CEPC

Comparison of the background rate with Z rate.

- Beam background Ions per BX = 18.2 k primary ions/electrons per BX
- Per single pixel mean number of hits is 28.17 (pixels 55x55 µm and 60% coverage) in 30 µs. This means a single pixel TPC readout rate of 0.94 M hits/sec.
- This is high but the readout can handle that. (26% occupancy)
- Assume Z at CEPC high luminosity rate of 50 kHz (BX rate = 1/23 ns)
- With a track multiplicity of 20, 100 hits/cm and a 150 cm long track we get 300 kHits (single electrons/ions) per Z
- The hit rate from Z decays is 15 G hits per sec.
- The Z hit rate is 345 primary ions/electrons per BX.
- So the number of background hits at the CEPC is a factor 52 times higher than the Giga Z hit rate
- Obviously the pixel TPC occupancy is very low and the pad occupancy higher than 1. A readout with 500x500 µm would work for the Zs but not for the beam background

Therefore it is VERY important to design a MDI reduces the background

Daniel Jeans has indications, that the main contributiuon is from backscattering of the LumiCal.

Peter Kluit

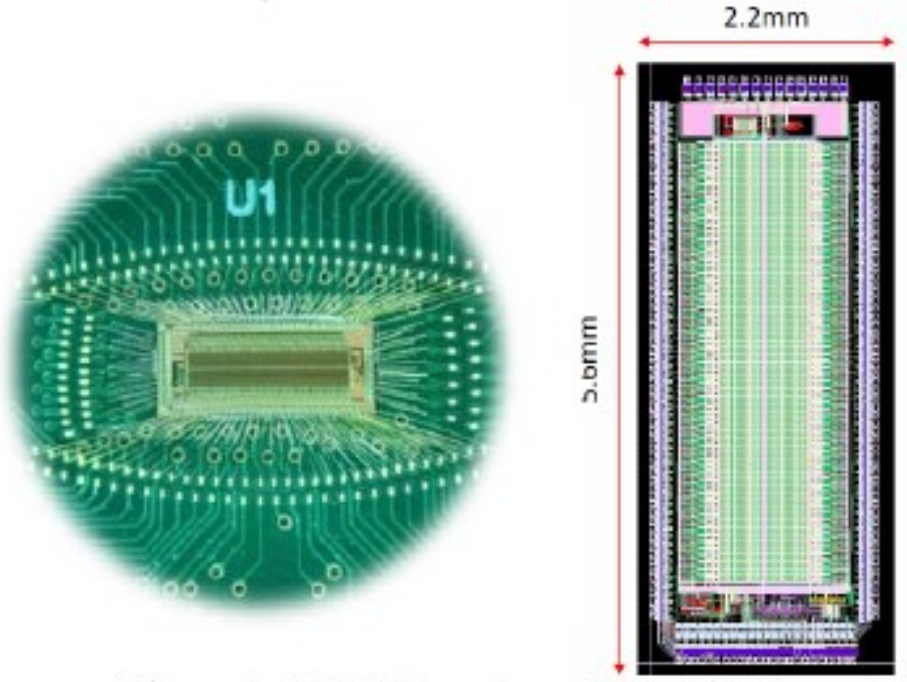
Pad Size Studies and Power Con.

Investigating performance of
- 1x6 mm² pads
- 0.5 x 0.5 mm² pads
- 55 x 55 µm² pixels

Huirong Qi

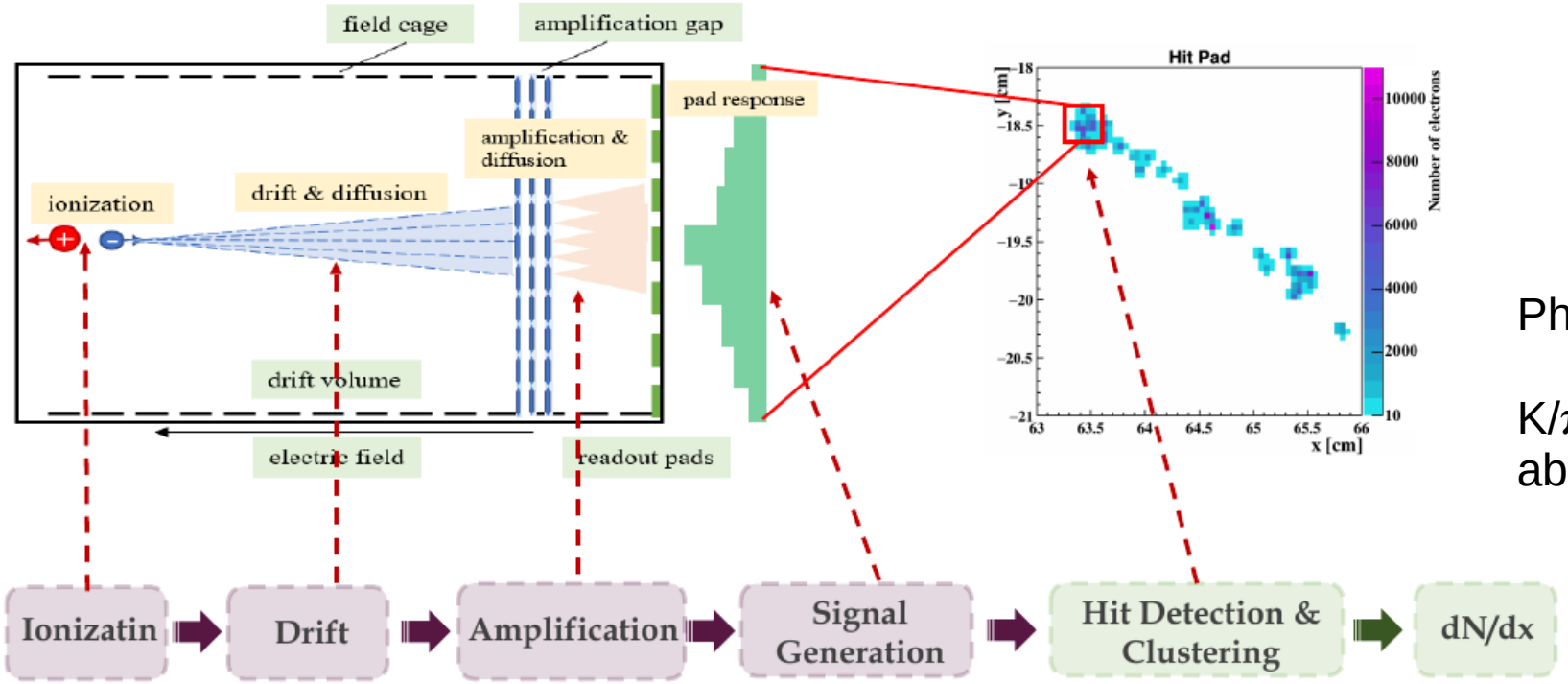
Development of a new ASIC for small pads/large pixels – IHEP + U Tsinghua:

- **R&D on Macro-Pixel TPC readout for CEPC**
  - Macro-Pixel TPC ASIC chip was started to developed and **2nd prototype wafer has done**.
  - The first version ROIC has been received and under testing.
  - The **TOA and TOT** can be selected as the initiation function in the ASIC chip.
    - 1mm×6mm → 500µm×500µm pixel readout
    - Time resolution: **14bit** (5ns bin)
    - Time discriminator: TOA (Time of Arrival)
    - **Power consumption: <1mW/pixel (1st prototype)**
      - **~400mW/cm²**
      - **~100mW/cm² (Goal and final design)**
    - Technology: 180nm CMOS -> 60nm CMOS
    - High metal coverage: 4-side bootable



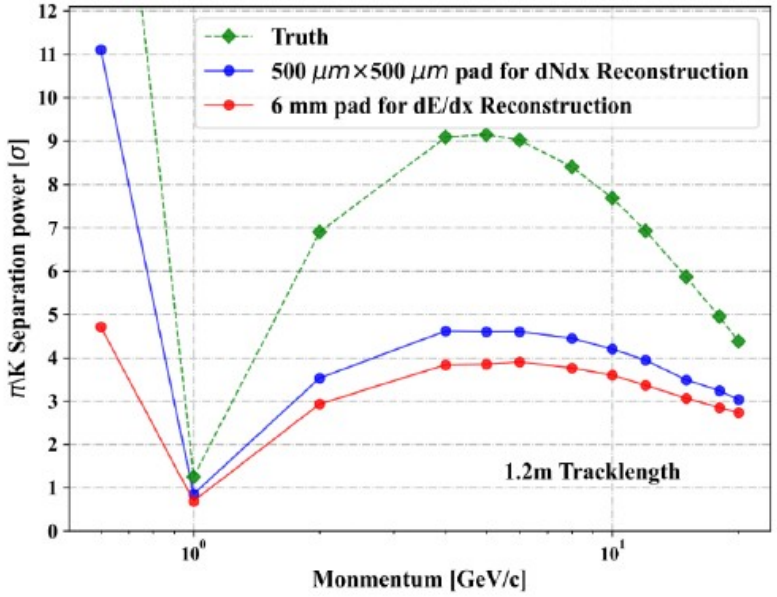
1st readout PCB board and the ASIC layout

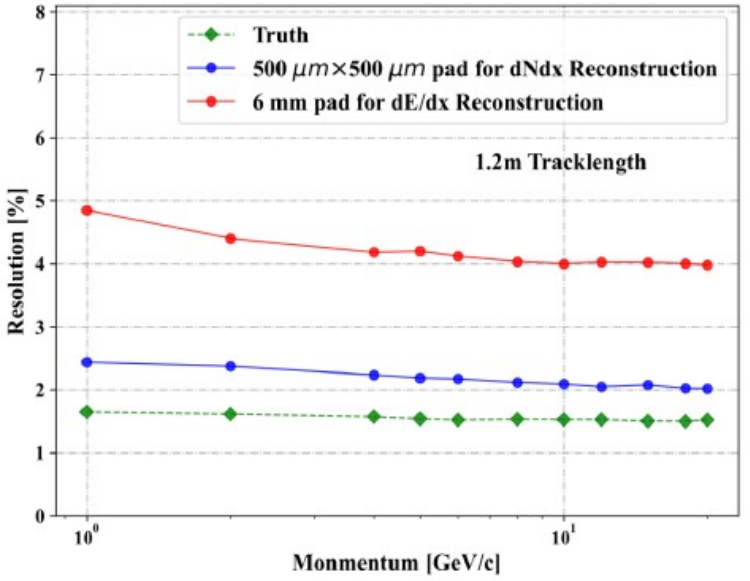
Simulation of PixelTPC for CEPC



Physics Target:

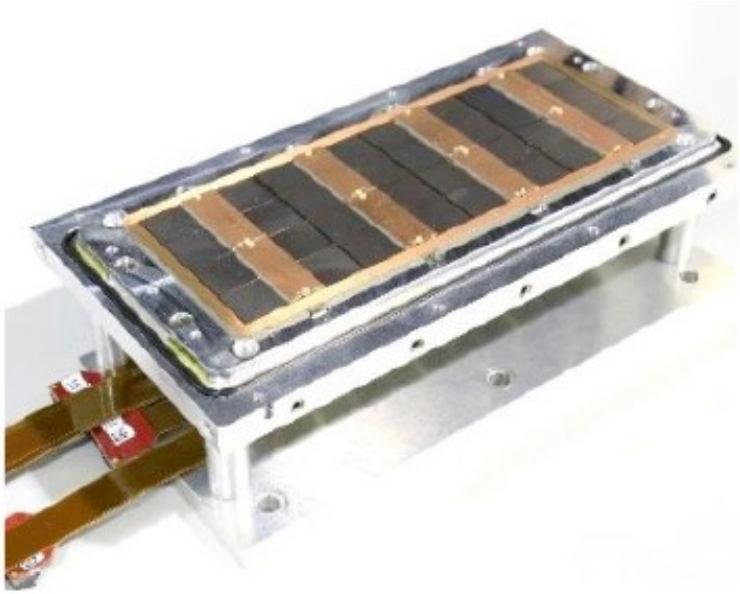
K/π separation power above 3σ at 20 GeV/c

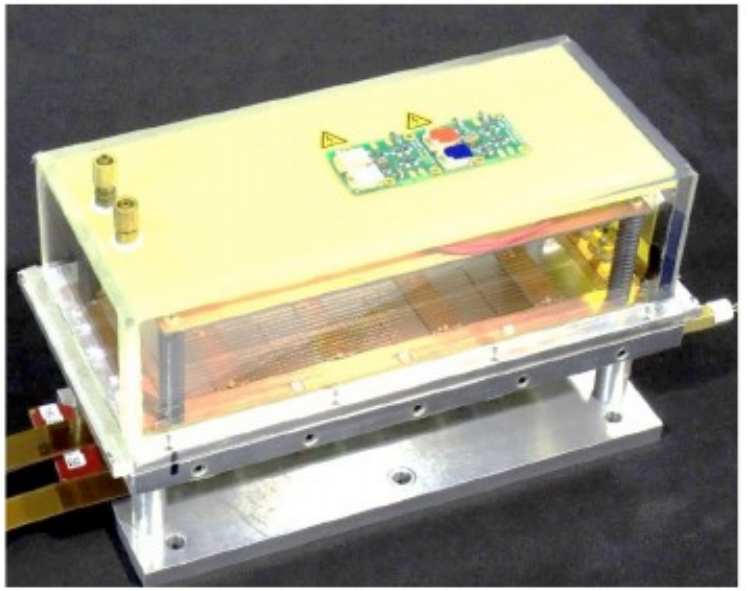


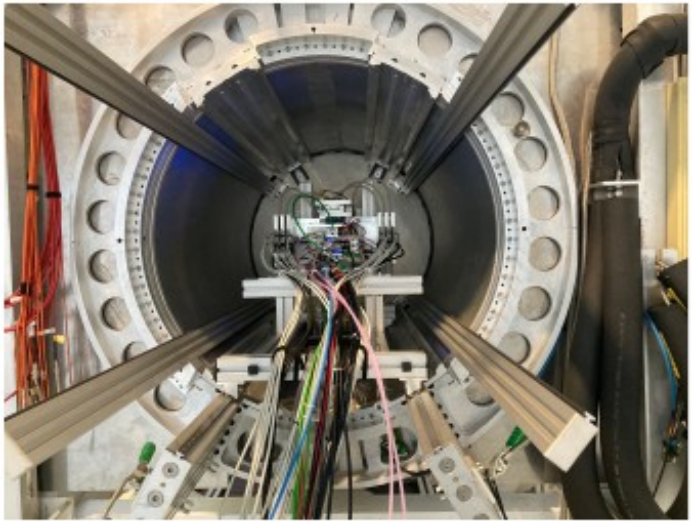


Yue Chang

PixelTPC – Detector Studies



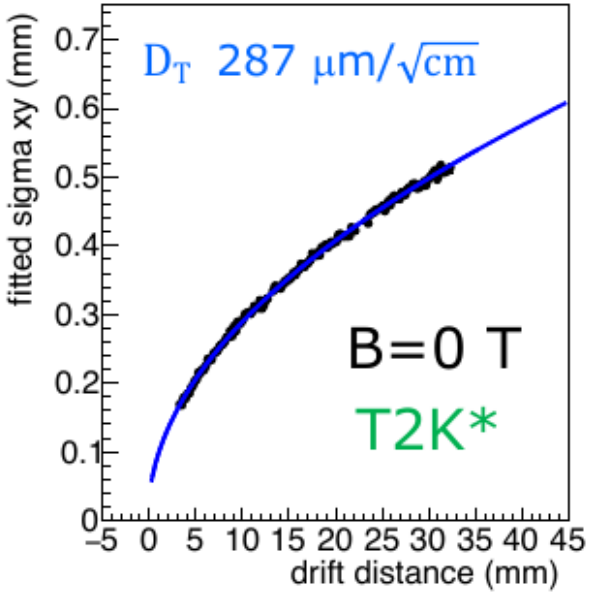




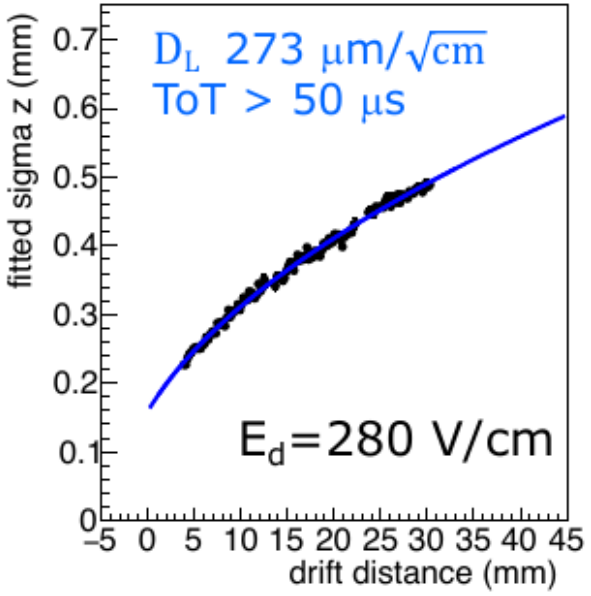
Test beam with 8x4 GridPixes in thebeam:
June 2021
→ analysis is drawing to a close

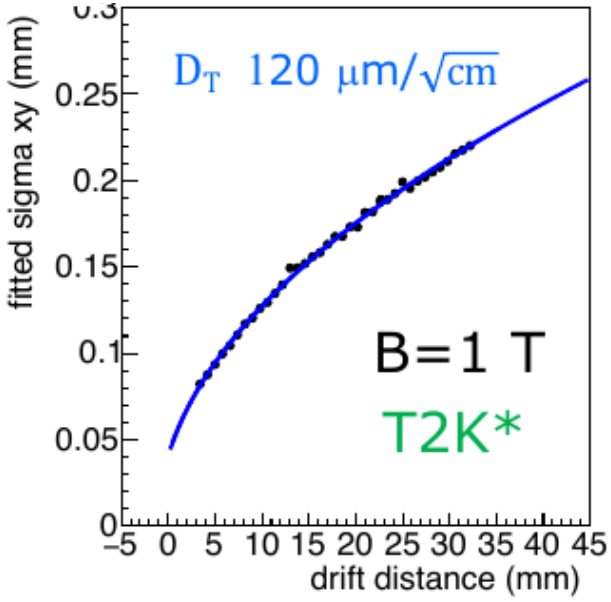
Peter Kluit

PixelTPC – Spatial Resolution

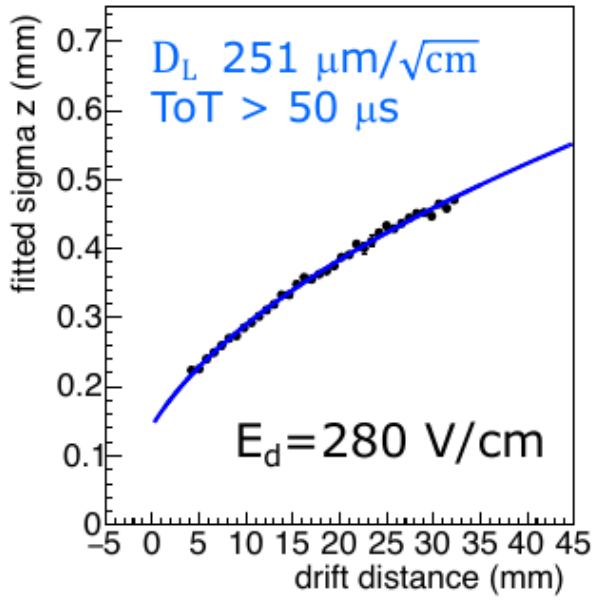


Preliminary





Preliminary



Diffusion in agreement with MAGBOLTZ simulation.

$$\sigma_{xy,z}^2 = \sigma^2_{xy_{0,z_0}} + D^2_{xy,z}(z - z_0)$$

$$\sigma^2_{xy0} = \sigma^2_{pixel} + \sigma^2_{xy\ tele}$$

$$\sigma^2_{pixel} = 55^2/12\ \mu m^2$$

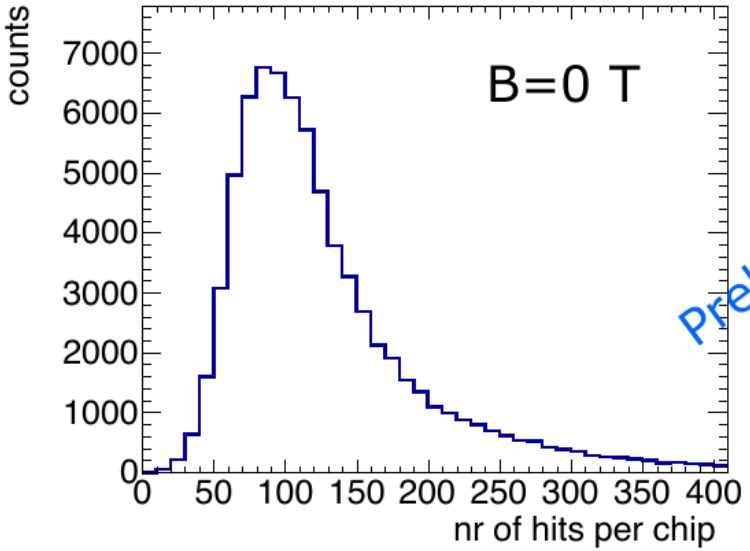
$$\sigma_{xy\ tele} = 42\ \mu m$$

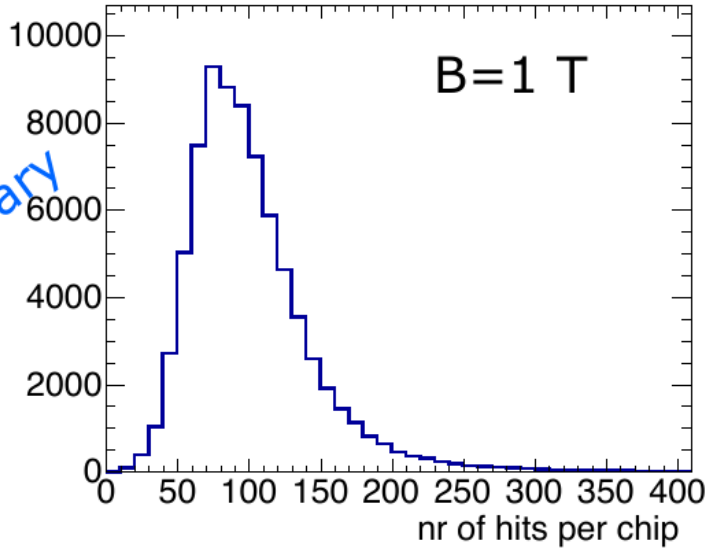
Mean residuals are very homogenous (distortions only in corners and around 1 disconnected grid).

Distriubtion of mean residuals sigma= 11-20 µm

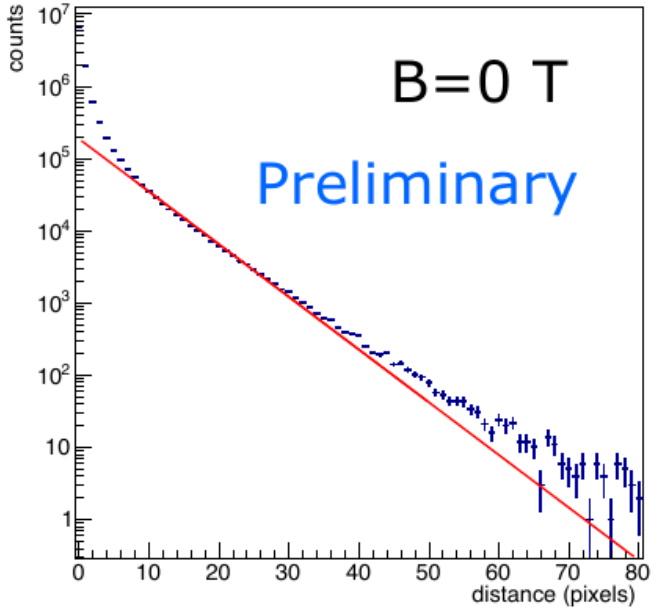
Peter Kluit

PixelTPC - PID





Hit counting
→ improved performance
→ no Polya of gas amplification

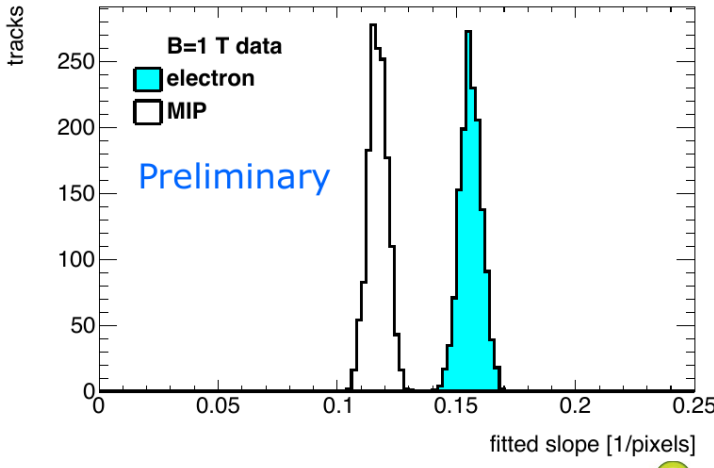


Determine distance between hits

Fit slope of distribution after reweighting.

Scaling 5/6 Gev electrons to mips.

Event summation
→ 1m tracks



Extrapolation to ILD parameters

Peter Kluit

Preliminary

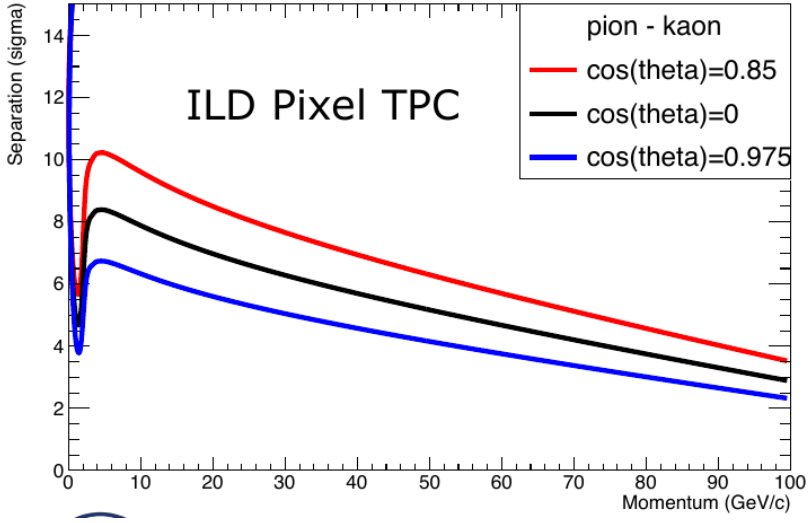
The dEdx resolution for electrons from data by combining tracks to form a 1 m long track with realistic coverage ~60% coverage.

Method	B=0 Resolution (%)	B= 1 T Resolution (%)
(1) dEdx 90 tail	6.0	3.6
(2) Fit slope	5.4	2.9

The "dEdx 90 tail" method is truncation at 90% where large clusters are identified and removed (tail reduced)
For the "Fit slope" method (2) an exponential distribution (with the slope and amplitude as free parameters) is fitted to the distribution of distance between the hits (as discussed: after applying the weights)

Extrapolating to ILD conditions (longer tracks) dE/dx performance (methode 2) down to 2.5 % are Possible. Separtion power on right side.

In case of B=2T, the performance is probably worse (~2.9 %)



Conclusion by Peter Kluti

Conclusions: Pixel TPC at a circular collider

- YES: a pixel TPC can reconstruct the Z events in one readout cycle
- YES: the current readout of the Timepix3 chip can deal with the rate
- The current power consumption is 1W/cm^2. By running the TPX chips in low power mode this can be reduced by a factor of 10. Still good cooling is important no show stopper; but needs extensive R&D.
- Track distortions in the TPC drift volume are a concern at high lumi Z running:
  - Track distortions from Z decays in TPC are O(100) μm
  - It is possible to reduce the IBF for a pixel TPC by making a device with a double grid
  - A double grid needs dedicated R&D that can be performed in the new lab in Bonn
- The Z physics program at FCC-ee or CEPC with an ILD-like detector with a Pixel TPC (with double grid structures) sliced between two silicon trackers (VTX-SIT and SET) can be fully exploited. The reduction of beamstrahlung needs more study.
- A pixel TPC can perfectly run at WW, ZH or tt energies where track distortions are several orders of magnitude smaller

Peter Kluit