Critical challenges and requirements of CEPC TPC

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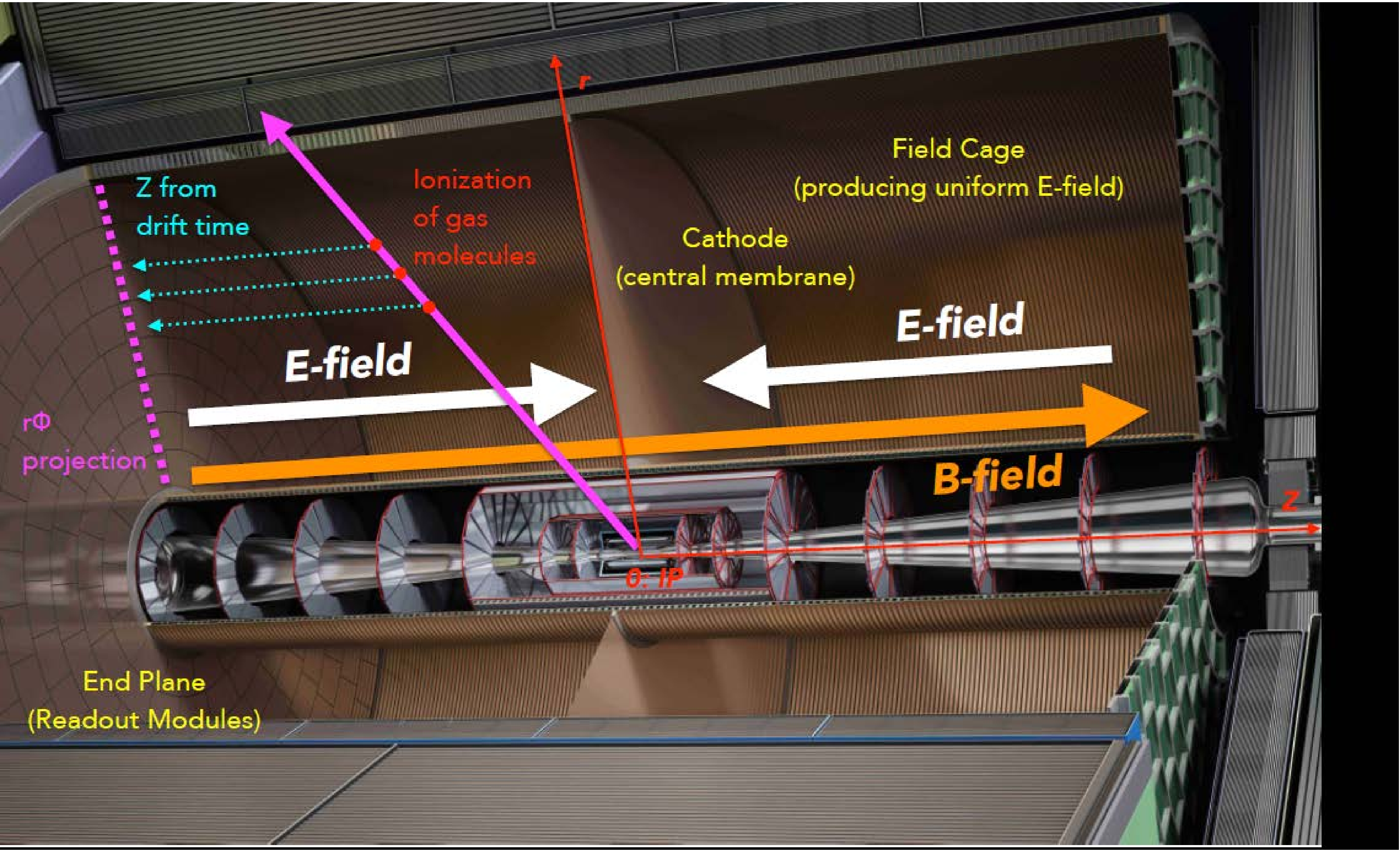
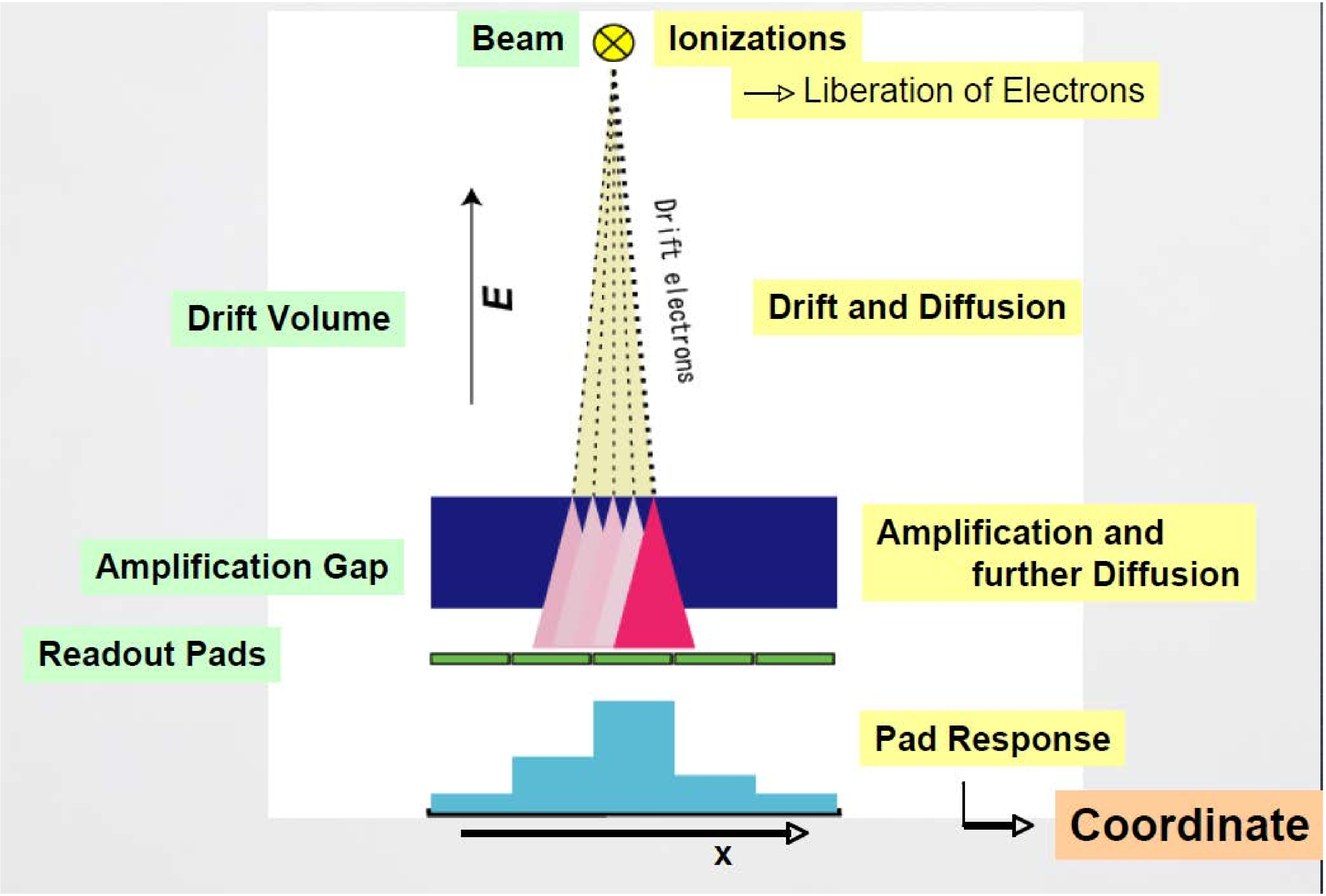
- TPC Detector
- Critical challenges
- Simu. requirements
- Discussion

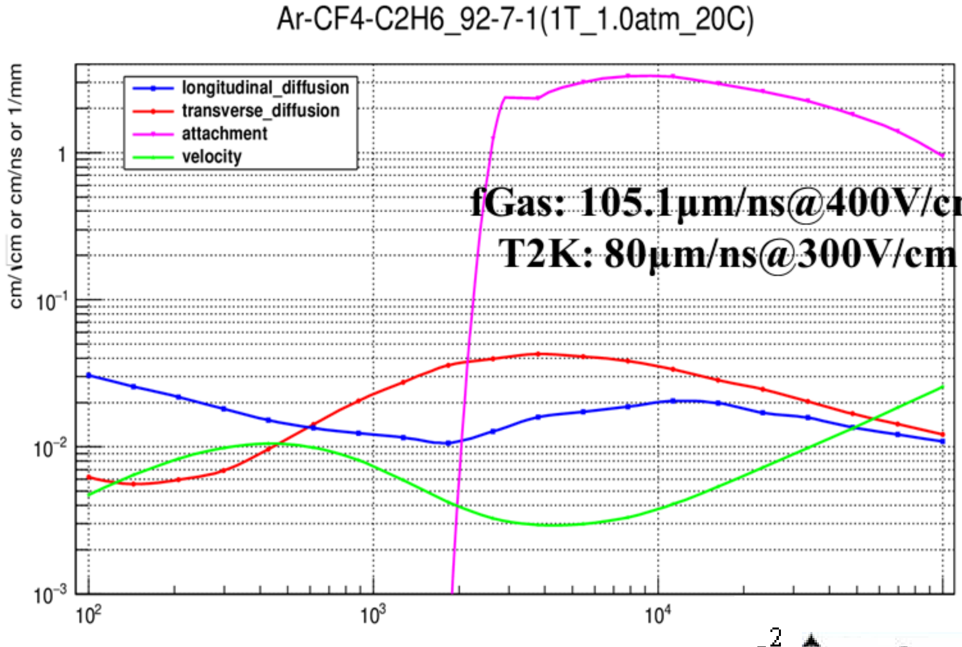
TPC detector-layout

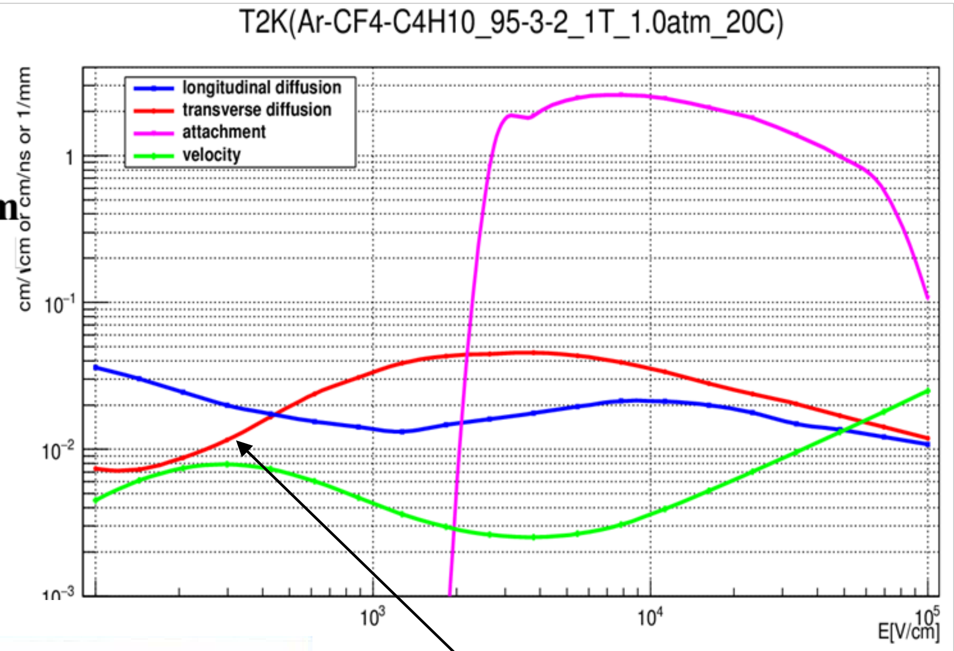


TPC detector-fundamental processes



TPC detector-operation gas

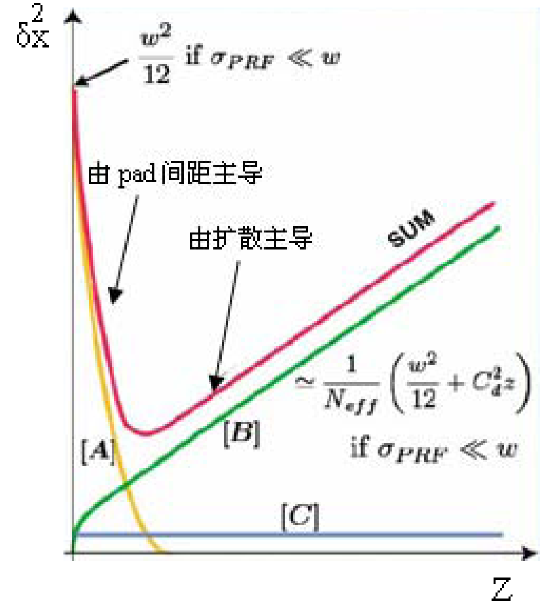




fGas: 105.1µm/ns@400V/cm

T2K: 80µm/ns@300V/cm

Ar-CF4-C2H6 gas



T2K gas

$$\delta_{\bar{x}}^2 \simeq \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_D^2 z\right)$$

Neff

- Neff ➡ The effective number of electrons which take part in measurement. We expect that it is same with the averaged (ionized) #electrons <N>. But it is reduced due to “ionization” and “gas gain” fluctuations in reality.
  - <N> × 30 ~ 40 % = Neff

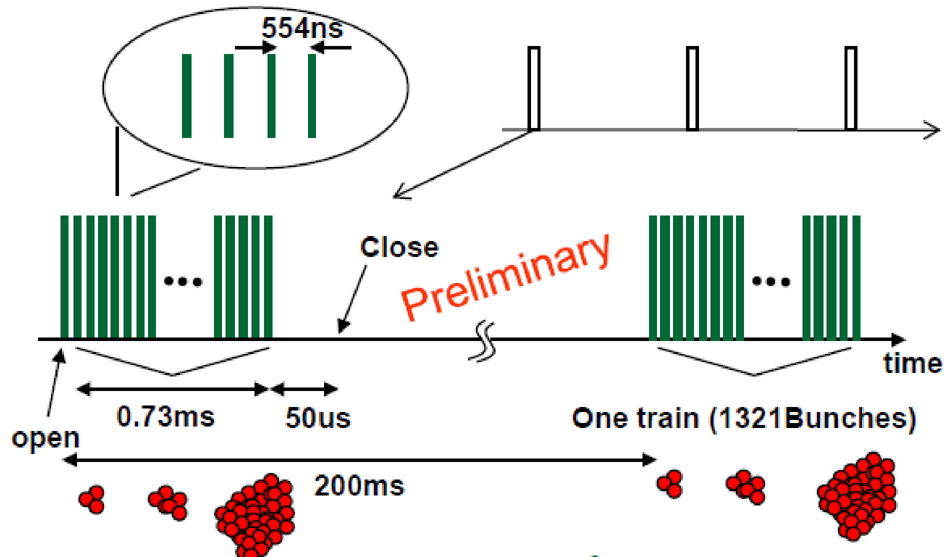
$$N_{\rm eff} = 1/\left(\left\langle \frac{1}{N} \right\rangle (1+f)\right)$$

NIMA A 562 (2006) 136–140	➡	Simulation of Neff with Ar based gas Result : Neff ~ 22 (f = 0.67 is assumed)
NIMA A 641 (2011) 37–47	➡	Performance test of ILC-prototype TPC (T2K gas) Result : Neff ~ 22 ± 2 (Indirect measurement of f ~ 0.6)

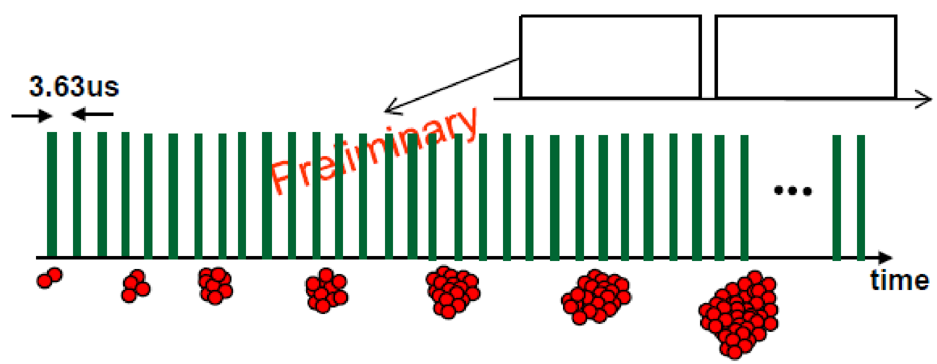
Critical challenges

Compare with ILC beam structure

- In the case of ILD-TPC
  - Bunch-train structure of the ILC beam (one ~1ms train every 200 ms)
  - Bunches time ~554ns
  - Duration of train ~0.73ms
  - Used Gating device
  - Open to close time of Gating: 50μs+0.73ms
  - Shorter working time
- In the case of CEPC-TPC
  - Bunch-train structure of the CEPC beam (one bunch every 3.63μs) or partial double ring
  - No Gating device with open and close time
  - Continuous device for ions
  - Long working time



Beam structure of ILC



Beam structure of CEPC

NO Gating device !

Critical challenges

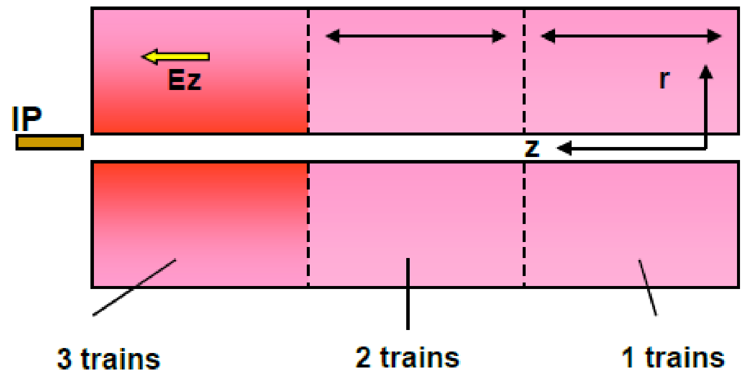
Critical challenge: Ion Back Flow and Distortion

In the case of ILD-TPC

- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the 200 ms period used gating system

In the case of CEPC-TPC

- Distortions by the primary ions at CEPC are negligible too
- More than 10000 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the ~4us period continuously



Amplification ions@ILC

Amplification ions@CEPC

Critical challenges

- Occupancy: at inner diameter
  - Low occupancy
  - Overlapping tracks
  - Background at IP

→ TPC as one option for CPEC-TPC YES or NO

- Ion Back Flow
  - Continuous beam structure
  - Long working time with low discharge possibility
  - Necessary to fully suppress the space charge produced by ion back flow from the amplification gap

→ To reduce IONS
To reduce distortion

- Calibration and alignment
  - Complex MDI design
  - Laser calibration system

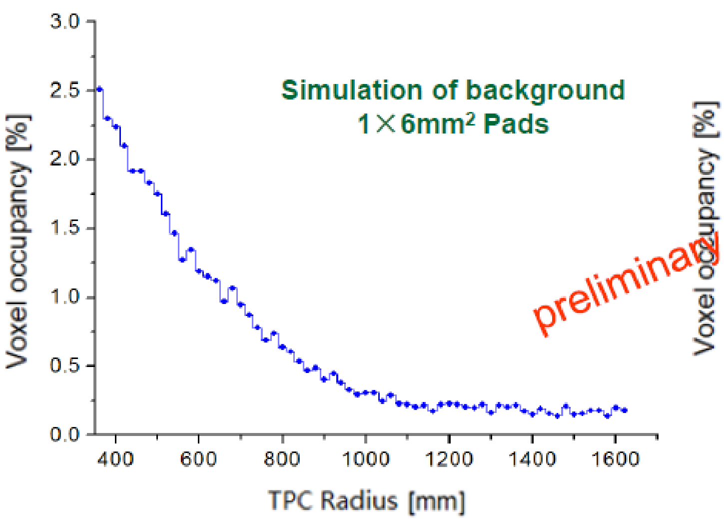
→ ~100um positron resolution with calibration

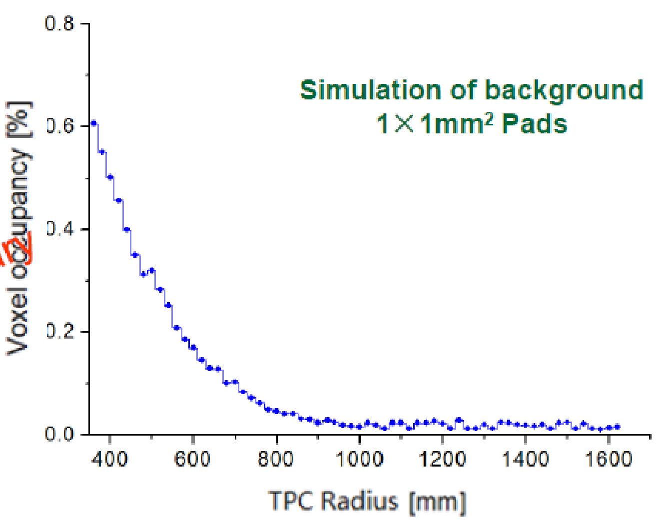
Critical challenges - Occupancy

Simulation of occupancy

- Occupancy@250GeV
  - Very important parameter for TPC
  - Detector structure of the ILD-TPC like
  - ADC sampling 40MHz readout
  - Time structure of beam:·4us/Branch
  - Beam Induced Backgrounds at CEPC@250GeV(Beam halo muon/e+e- pairs)+γγ→hadrons with safe factors(×15)
  - Value of the occupancy inner radius smaller
  - Optimization for the pad size in rΦ

CLIC_ILD ~30%@3TeV
$1\times6mm^2$ Pads
CLIC_ILD ~12%@3TeV
$1\times1mm^2$ Pads
NO TPC Options!

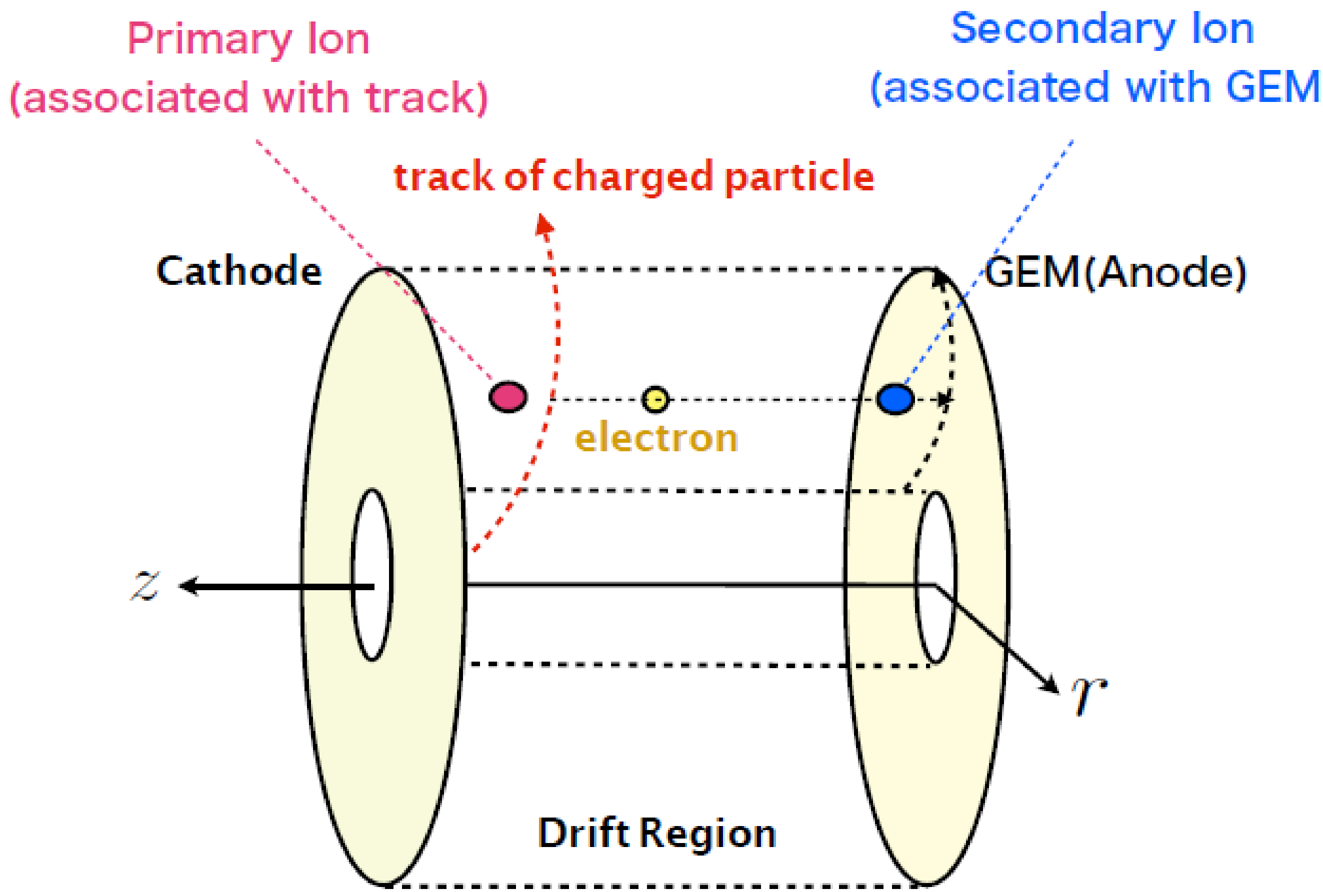




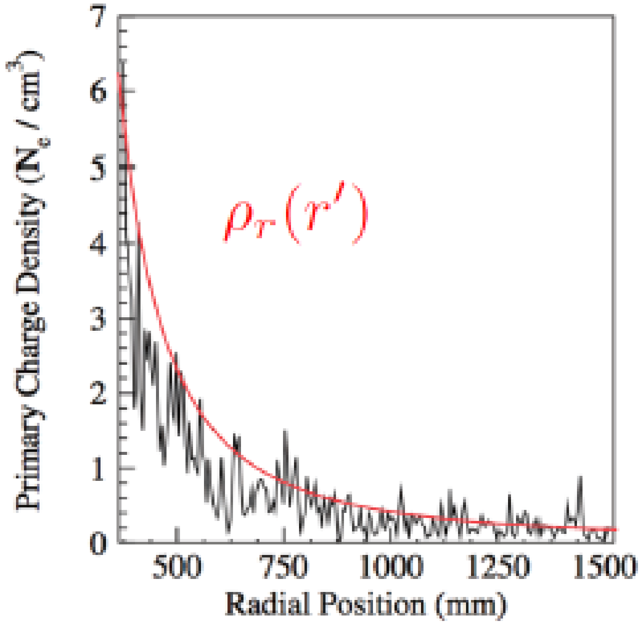
Critical challenges - IBF

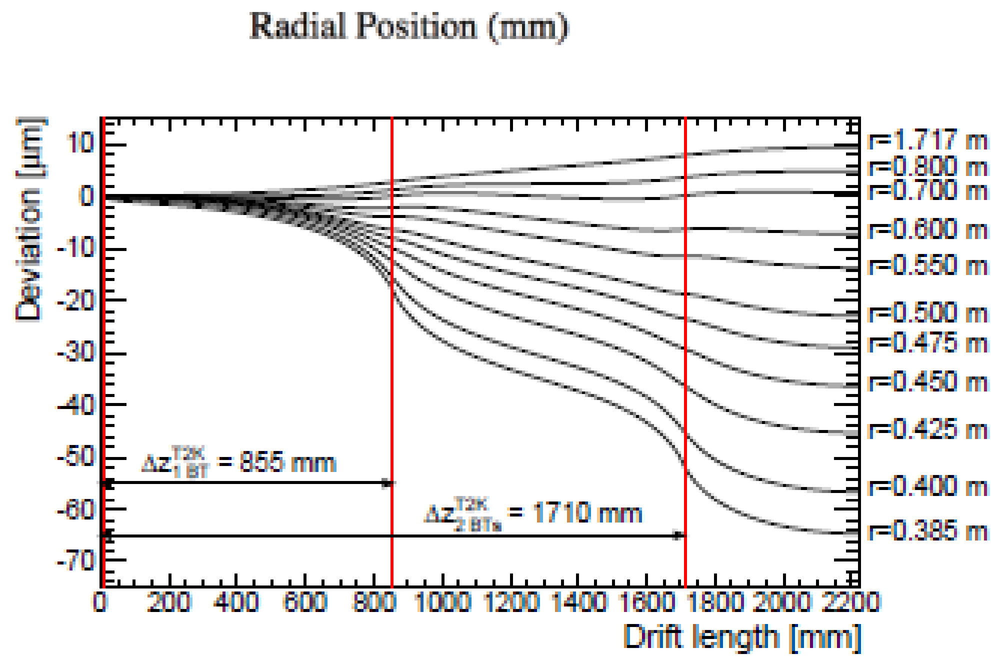
Field Distortion

$$(\Delta E_r, \Delta E_\phi, \Delta E_z)$$



ILC Ion Back Flow: Calculation





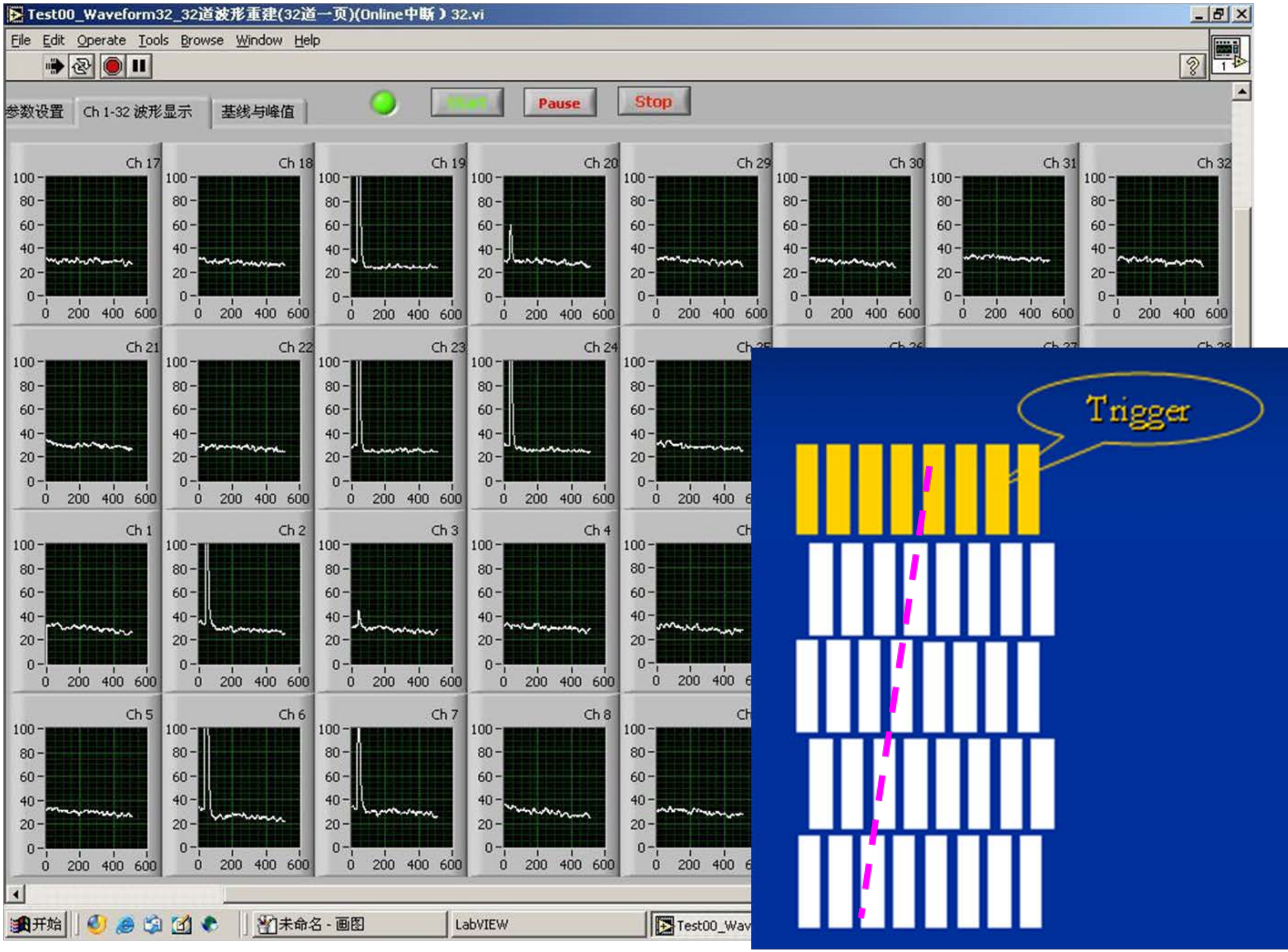
Simu. requirement

- Z- pole run
  - Voxel Occupancy
  - IBF
  - Alignment
  - Calibration
- Higgs run
  - Voxel Occupancy
  - IBF
  - Alignment
  - Calibration

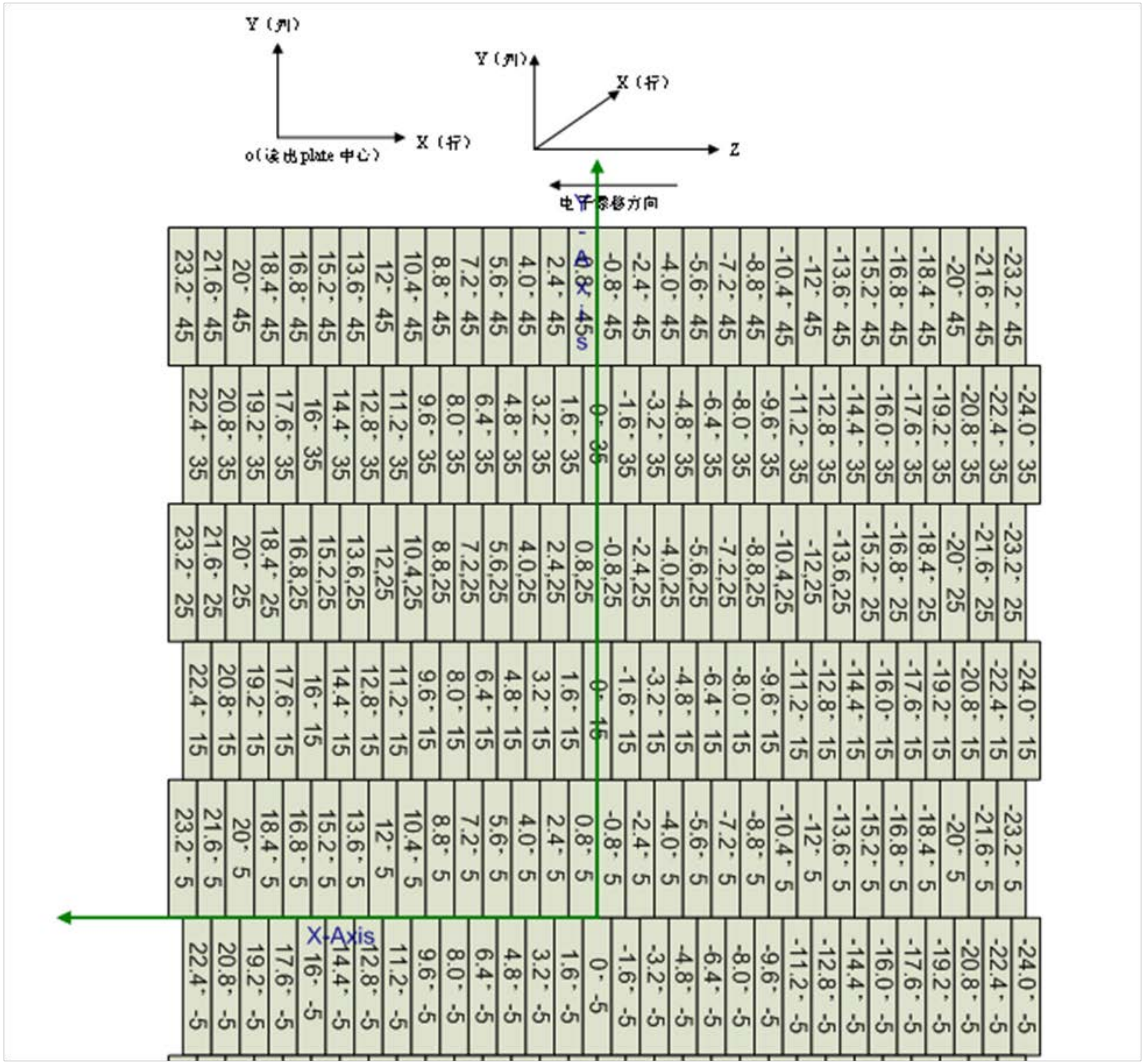
Simu. requirement

- Tracker reconstruction
  - Marlin TPC framework
  - Kalman filter
  - …

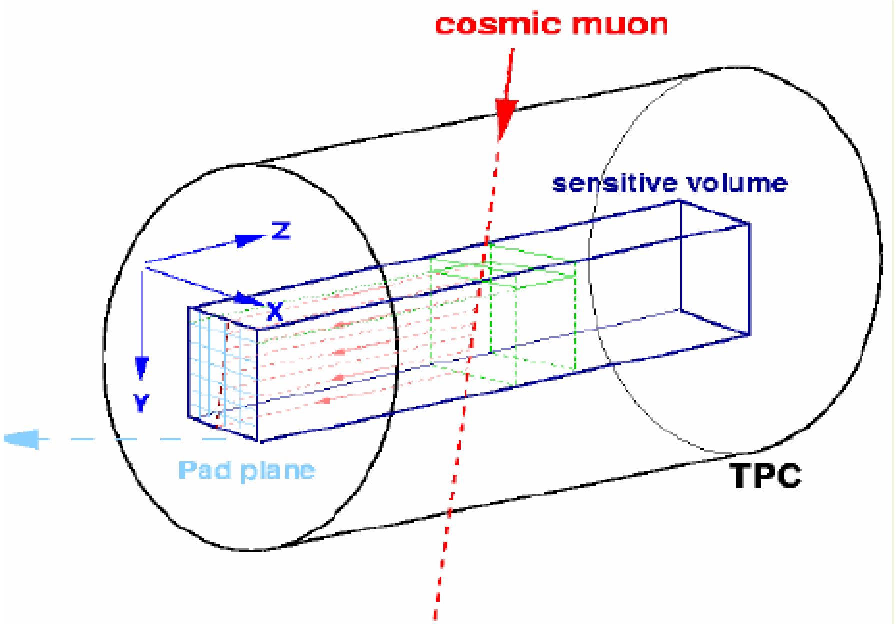
Example GEM TPC

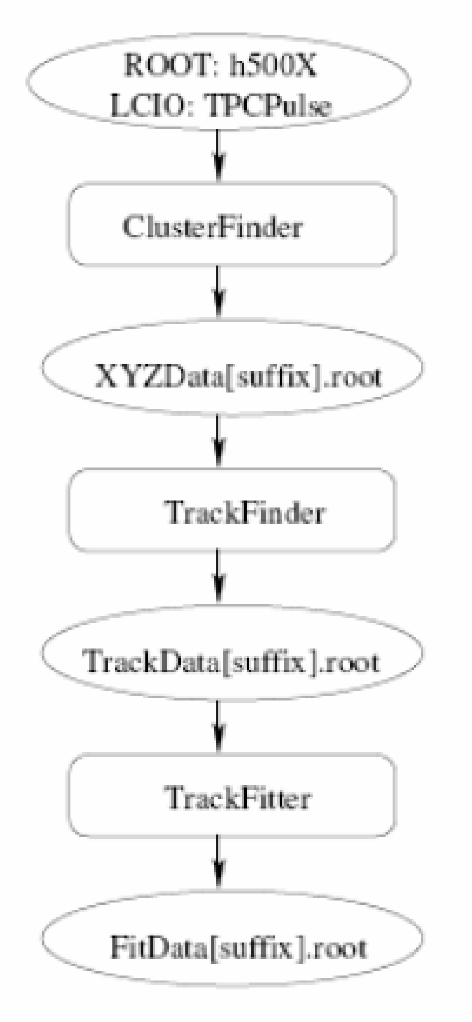


Example GEM TPC



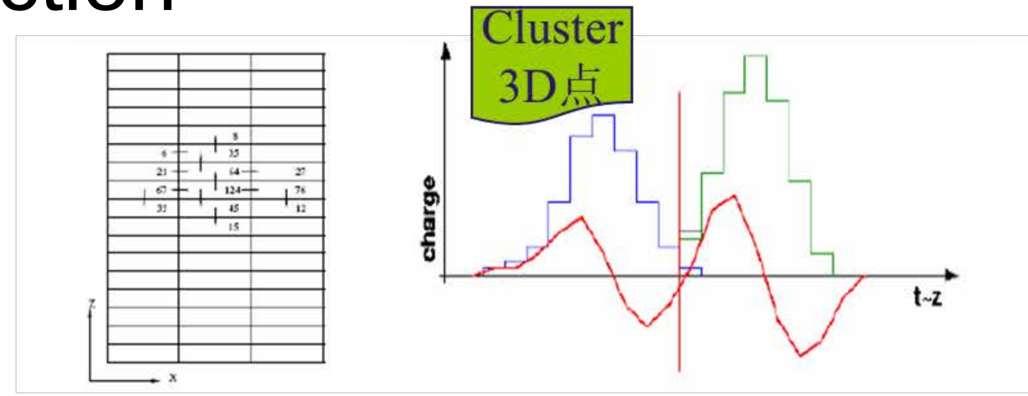
Example GEM TPC



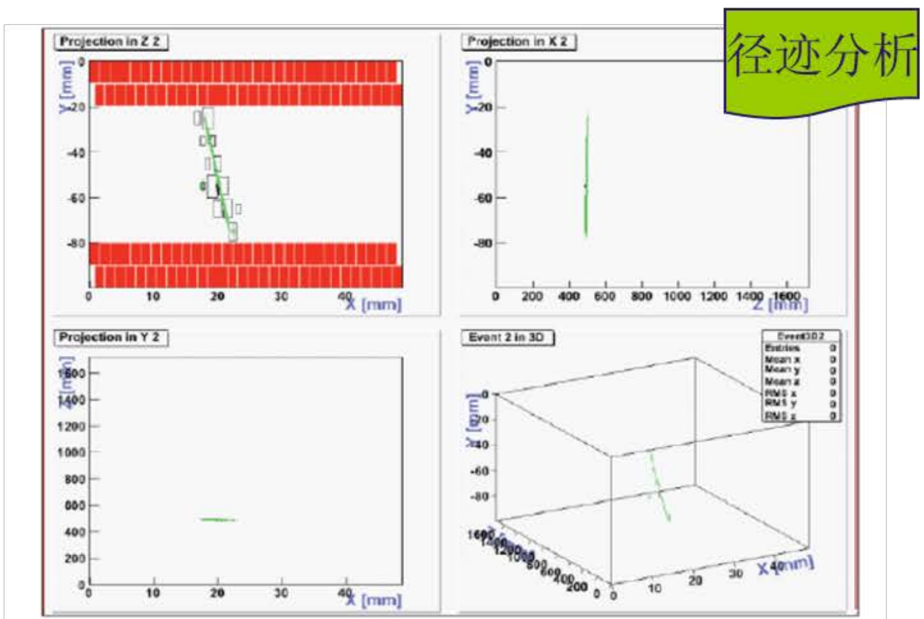


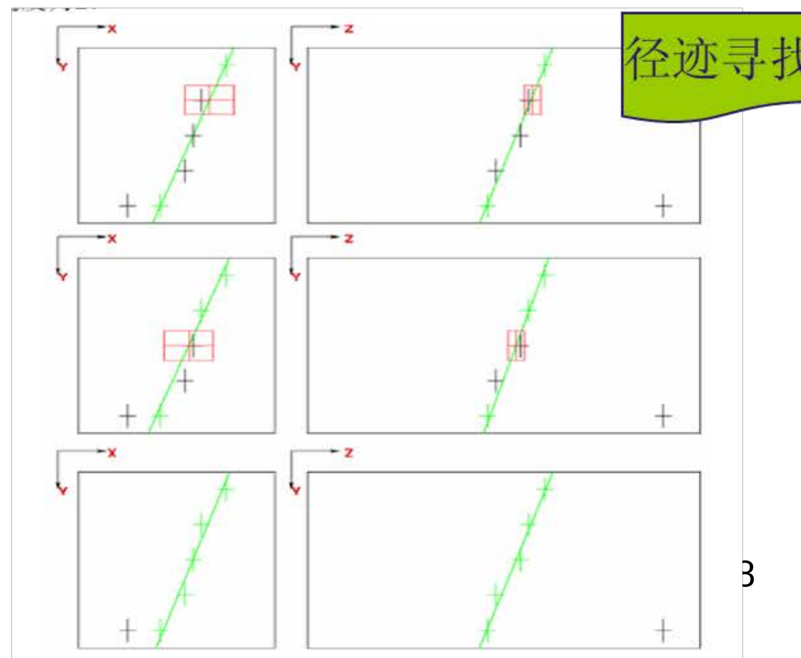
Example GEM TPC

- Tracker reconstruction

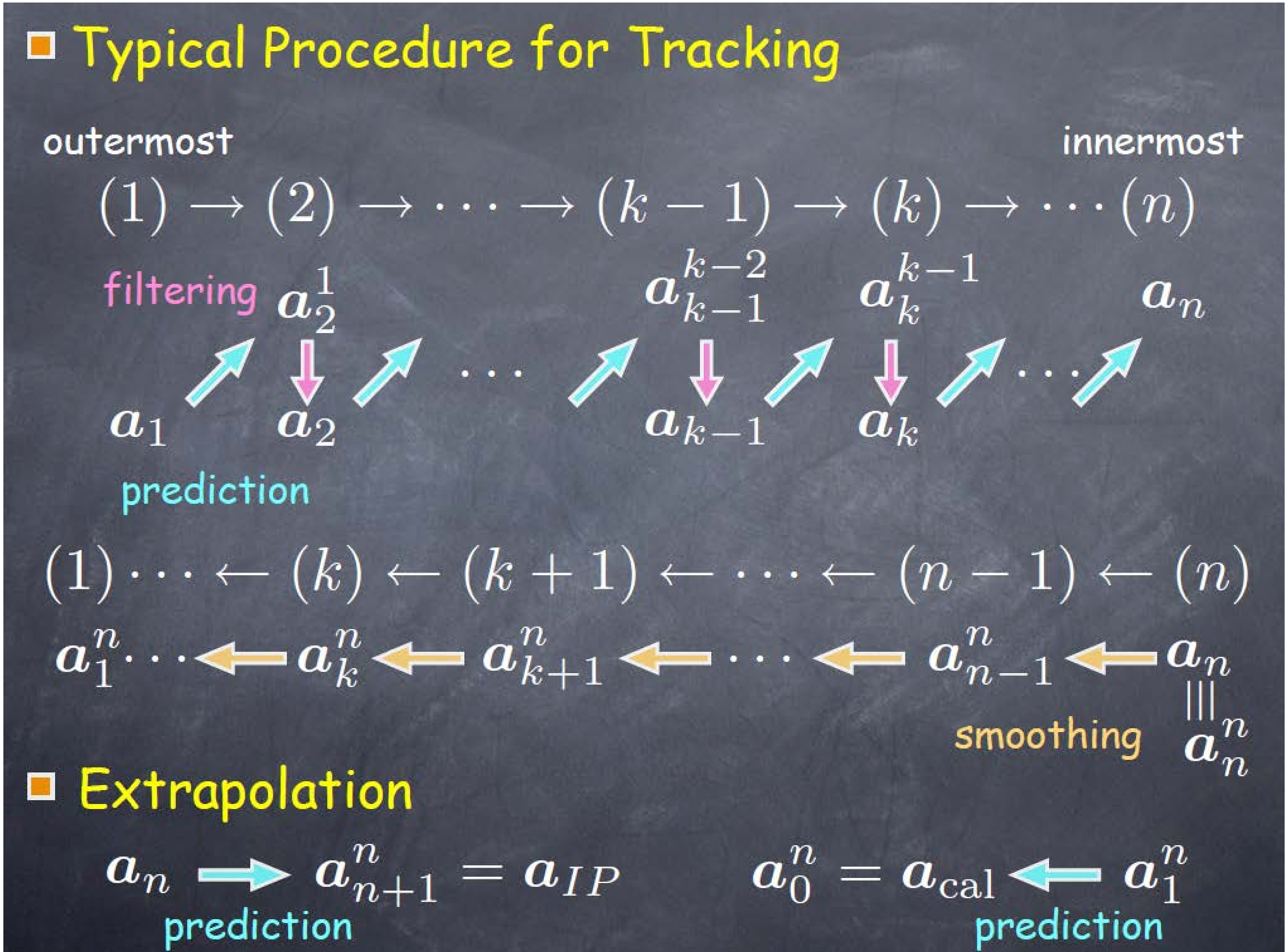


➢Doublefit径迹分析程序
径迹事例的判选过程





Kalman Filter in Tracking



Kalman Filter in Tracking

- Alignment, Resolution Study, etc.

Need to eliminate point (k)

$$(1) \cdots\cdots\cdots (k-1) \quad (k) \quad (k+1) \cdots\cdots\cdots (n)$$

↓ Inverse Kalman Filter

$\boldsymbol{a}_k^{n*}$ Reference Track Param.

↓

$\boldsymbol{h}_k(\boldsymbol{a}_k^{n*})$ Expected Hit Position

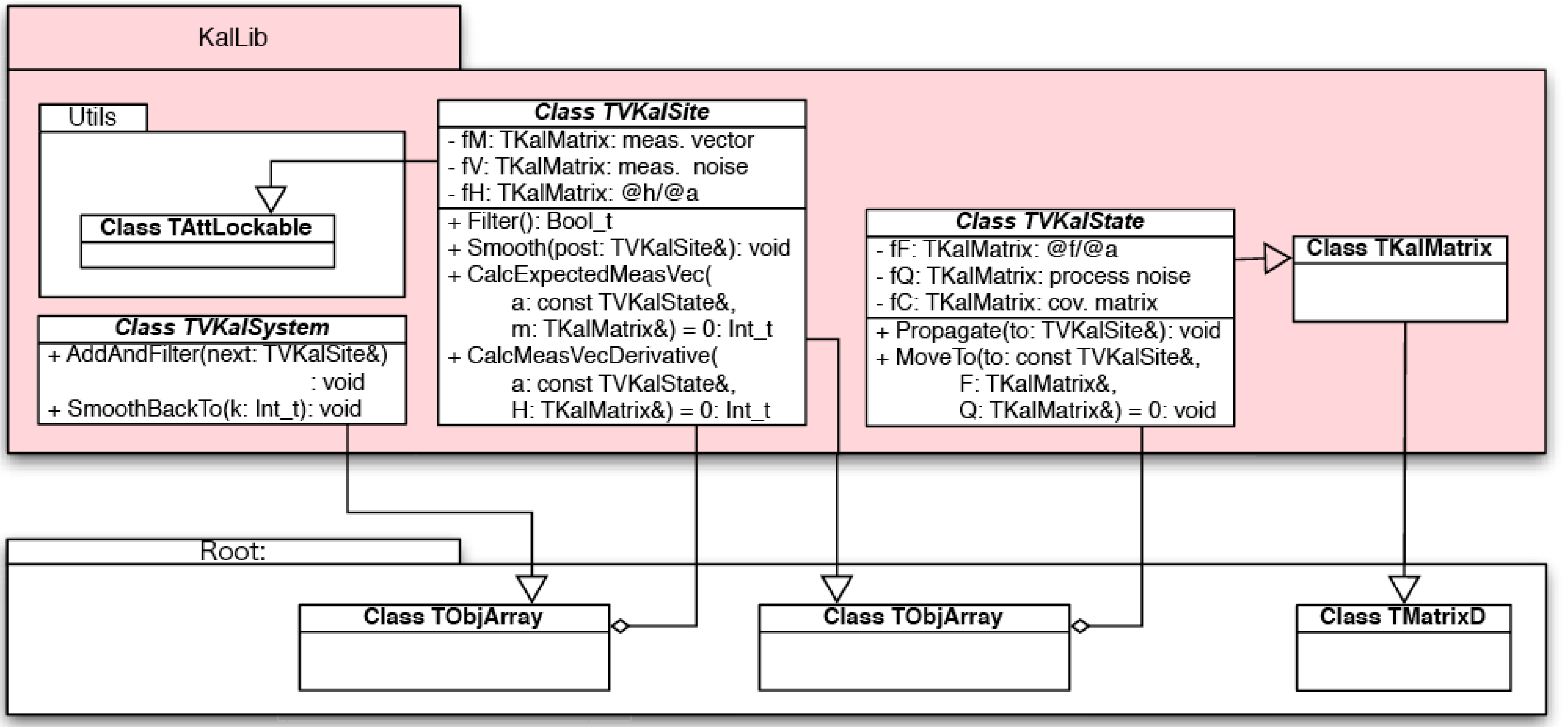
↓

$\boldsymbol{r}_k^{n*} = \boldsymbol{m}_k - \boldsymbol{h}_k(\boldsymbol{a}_k^{n*})$ Residual to Look At

C++ Implementation Kalman Filter Library

- KalLib: general base classes that implement algorithm
  - TVKalSystem, TVKalSite, TVKalState
- KalTrackLib: that implements pure virtuals of KalLib for track fitting purpose
- GeomLib: geometry classes that provide
  - track models (helix, straight line, ...)
  - surfaces (cylinder, hyperboloid, flat plane, ...)
- Minimum number of user-implemented classes
  - MeasLayer : measurement layer
  - KalDetector : an array containing MeasLayers
    - You can put different kinds of MeasLayers
  - Hit : coordinate vector as defined by the MeasLayer
- Track model can change site to site which allows B-field variation along a particle trajectory

Kalman Filter Class Organization



More information available from the following URL:
http://www-jlc.kek.jp/subg/offl/kaltest/

Discussion

- Expert person
  - ...
- Manpower
  - Zhang Yulian
  - Cai Yiming
  - Wang Haiyun
  - Anyone interested
- Requirements
  - Occupancy
  - IBF
  - Alignment
  - Reconstruction

Thanks