Status and Plan of TPC Hybrid Detector Module for Circular Collider @IHEP

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Outline

- Motivation and Activities
- Circular and Linear collider
- Towards CEPC TPC
- Status of TPC Hybrid Module
- List of Critical R&D Topics

Motivation and goal

- Critical Physics requirements for CEPC tracker Detector

Performance/ Design Goals

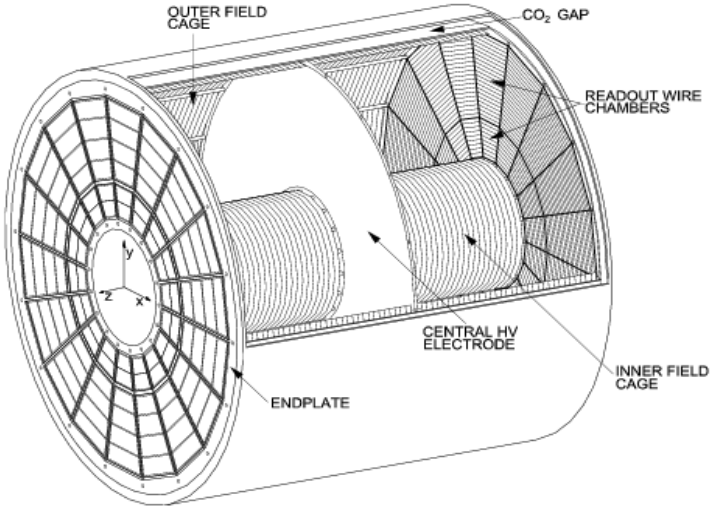
Momentum resolution at B=3.5T	**$\delta(1/pt) \approx 10^{-4}$/GeV/c TPC only**
δ_{point} in rΦ	**<100μm (avg for straight-radial tracks)**
δ_{point} in rz	**≈0.4~1.4mm (for zero – full drift)**
Inner radius	**329mm**
Outer radius	**1800mm**
Half length	**2350mm**
TPC material budgt	**≈0.05X_0 including the outer field cage in r** **<0.25X_0 for readout endcaps in z**
Pad pitch/no. padrows	**≈1mm×4~10mm/≈200**
2-hits resolution in rΦ	**≈2mm (for straight-radial tracks)**
Performance	**>97% efficiency for TPC only (pt > 1GeV/c)** **>99% all tracking (pt > 1GeV/c)**

Requirements for the ILD-TPC

- Goal similar as the ILD
  - Position resolution ~100μm
  - Momentum resolution $\sigma(1/p_T) = 10^{-4}\text{GeV}^{-1}$

Tracker detector option

- Options of the tracker detector
  - Main drift chamber (MDC)
  - Silicon tracker detector (SiD)
  - Time projection chamber (TPC)
- TPC detector
  - Detector consists of
    - Chamber of working gas
    - Field Cage for the uniformity electron field
    - MPGD as readout on the two sides
  - Advantage
    - Angle of coverage: ~ 4π
    - dE/dx, Particle identification
    - Multi-hits resolution
    - Low material budget: working gas

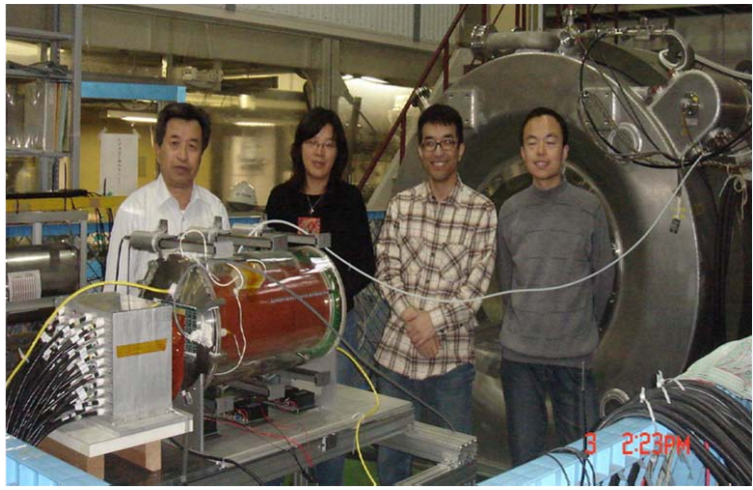


TPC Detector overview (ALICE, STAR, ILD-TPC, etc.)

Just one option !

Activities @China

- Tsinghua University and Hubei University as the members signed MoA of ILD-TPC collaboration(2007, 2015)
- GEM-TPC Prototype cosmic test@2007
  - Active area: 100mm×100mm
  - Readout pad size: 9.5 mm ×1.5 mm
  - Pitch: 10 mm ×1.6 mm
  - Staggered 10 x 62 pads placed
- Readout PCB for GEM@2009
  - Size: 220mm×170mm for KEK Module
  - 28 pad rows, 4829 channels
- Joint meeting with Saclay@2015
  - R&D in the laser calibrations for TPC detector
- Further cooperation plan
  - Software of simulation and reconstruction
  - Common module beam test
  - Laser alignment and calibration
  - Electronics
  - Cooling technology



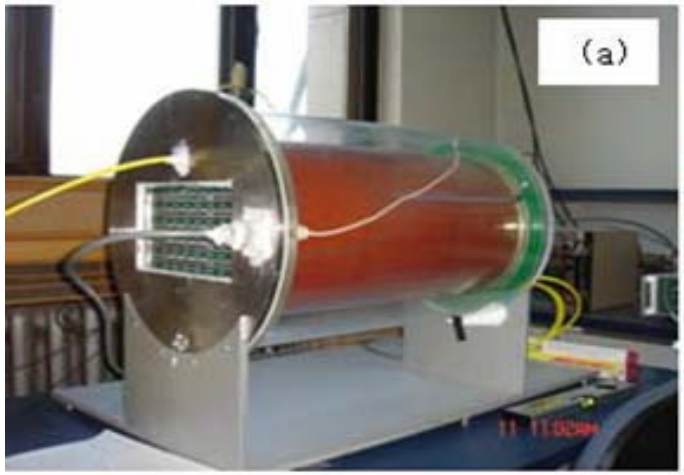
TPC Prototype cosmic test@1T/2007/KEK

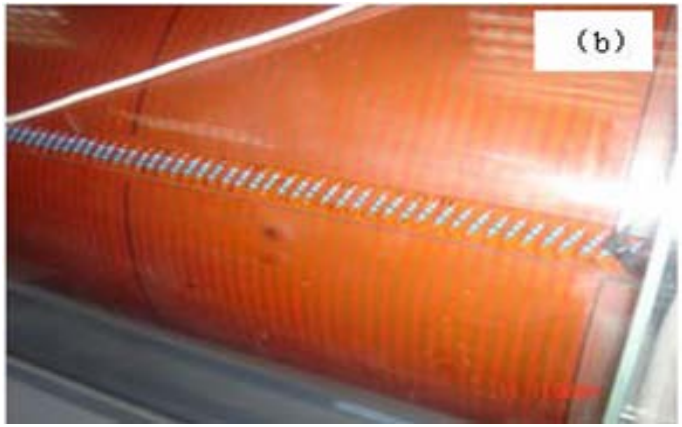
Joint meeting@2015/Saclay

Designed PCB for GEM@2009/KEK

Activities @Tsinghua University

- GEM-TPC Prototype
  - Readout pad size: 9.5 mm ×1.5 mm
  - Pitch: 10 mm ×1.6 mm
  - Staggered 10 x 62 pads placed
  - Triple-Standard GEMs
  - Active area: 100mm×100mm
  - Drift length: 500mm
  - 1 Tesla@KEK
  - Working Gas:
    - P10 (Ar : CH4 = 90 : 10)
    - ISO(Ar : CH4 : iC4H10 = 96 : 3 : 1)





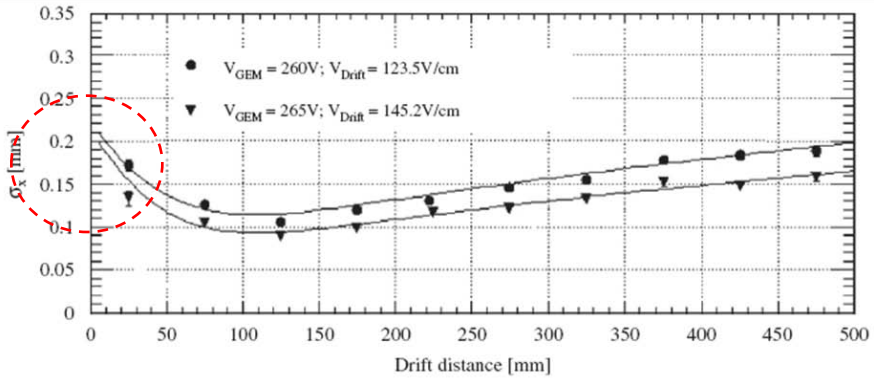
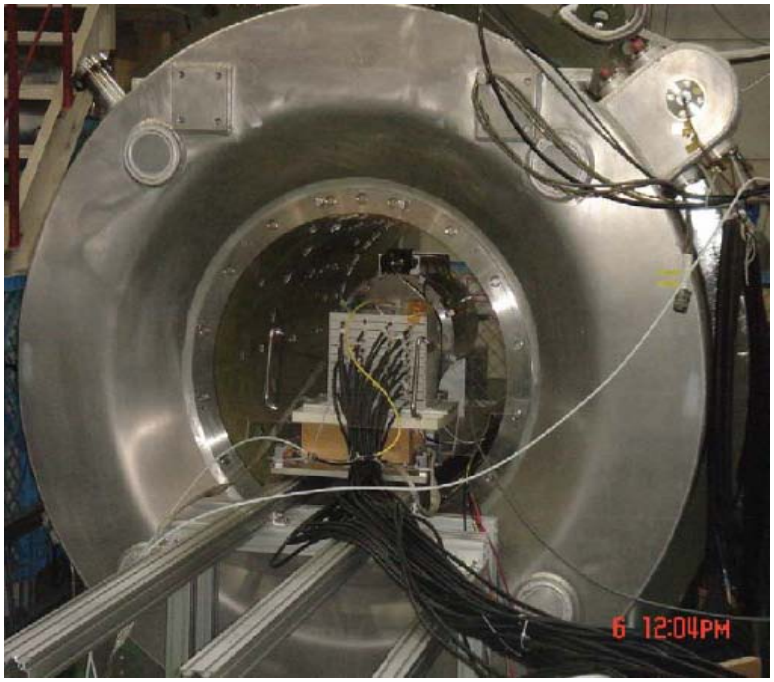
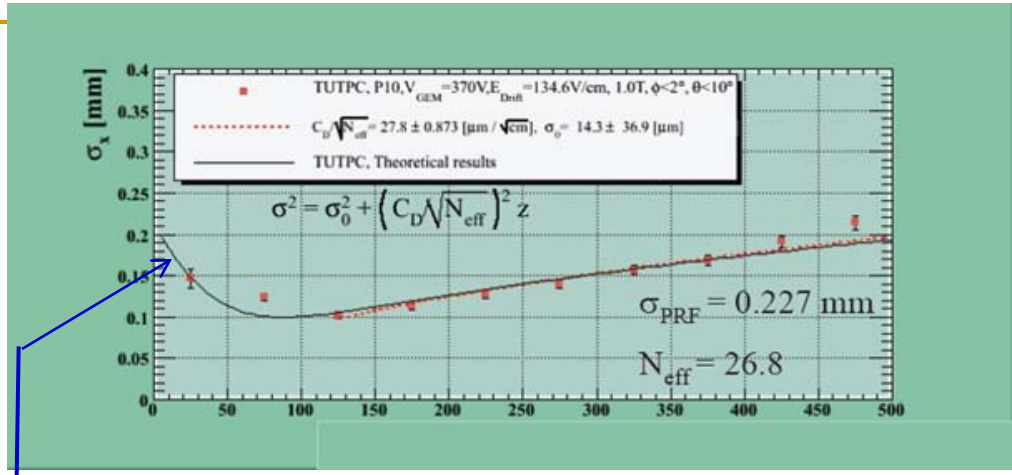


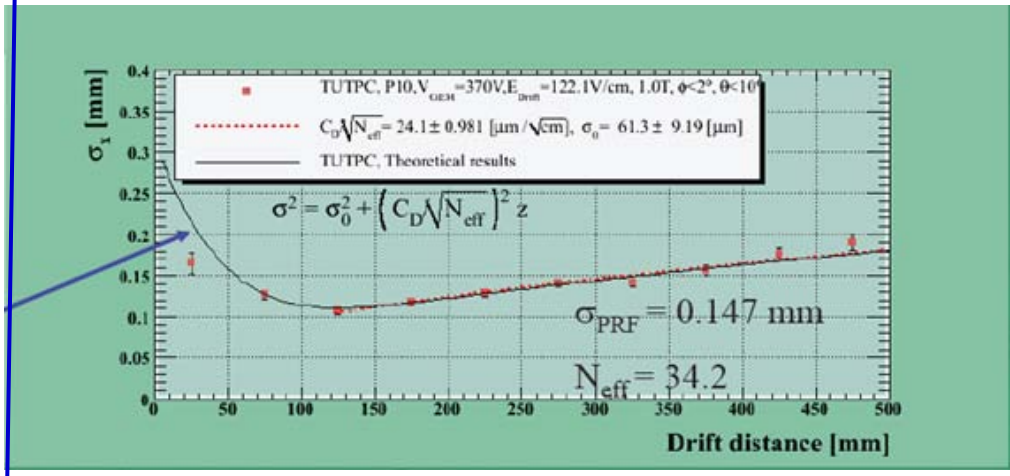
Fig. 6. x-Resolution for Ar–Iso–CF4 = 96.3–3.1–0.6 gas with B = 1T under two different test conditions (φ <2°, θ <10°).

GEM TPC Prototype and cosmic test

GEM TPC Prototype







Test @ KEK, Japan, 2007

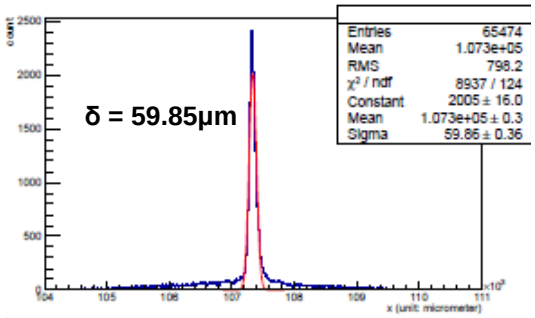
Measurement points fit the analytical formula very well

Hodoscope effect more obvious

Resolution can be as good as 100 μm@ Z ≈100 mm

Activities @IHEP,CAS

- 2D GEM Detector for X-ray
  - Triple GEM Model
  - Active Area: 200mm×200mm
  - Working Gas: Ar/CO2-90/10
  - Readout Channels: 704
  - X Direction
    - Channels of Strips Readout: 267
    - Pitch: 0.752mm
  - Y Direction
    - Channels of Strips Readout: 437
    - Pitch: 0.457mm



Position Resolution :59.85 μm (Sigma) @ 20μm collimator

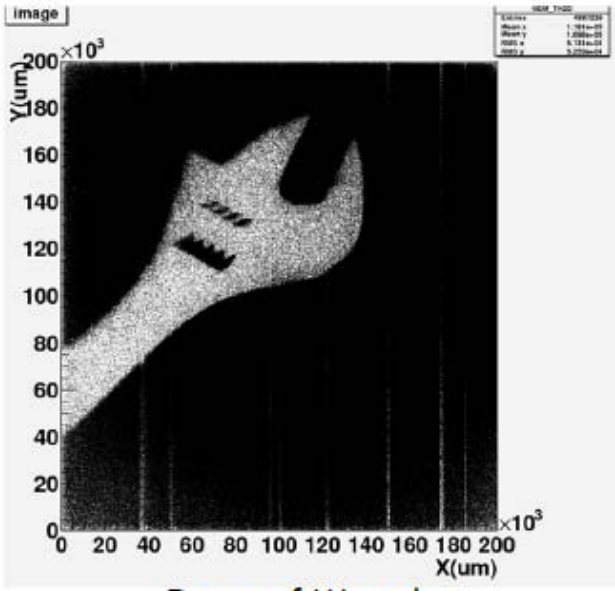


Image of Wrench

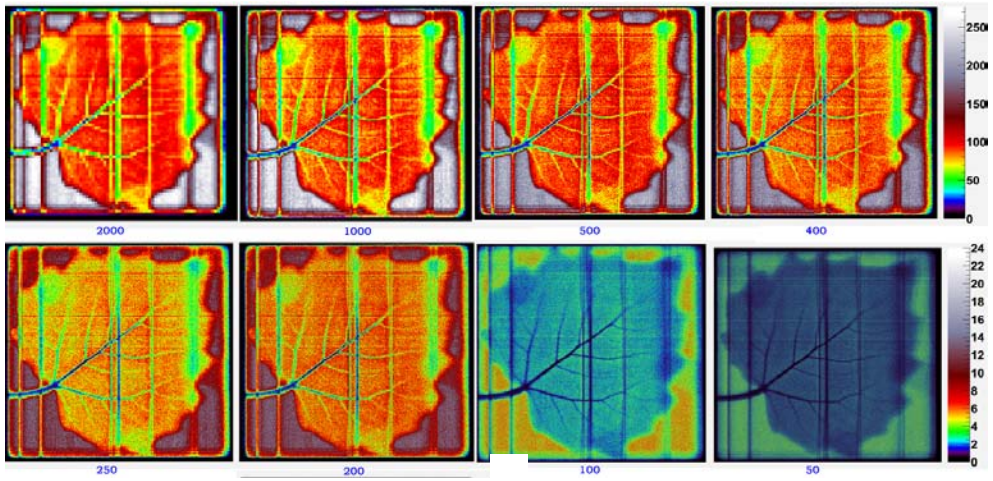
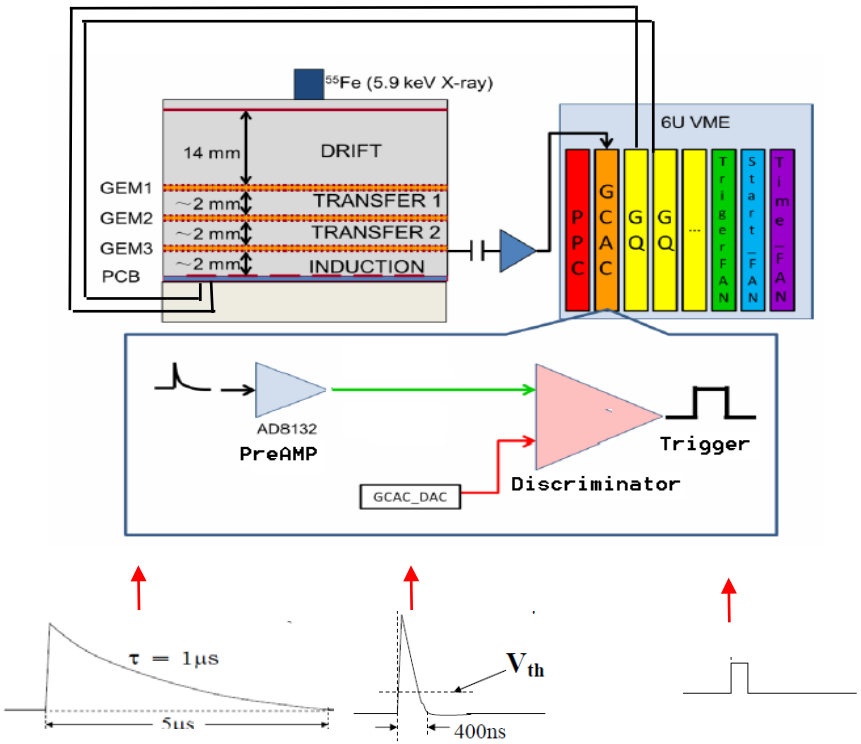
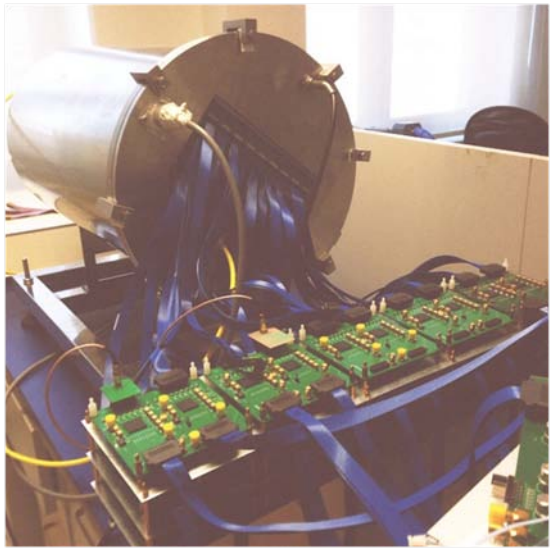
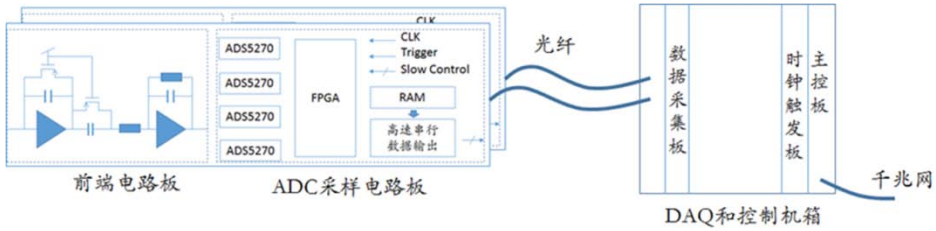


Image of 2D GEM at X-ray

Activities@Electronics







DAQ @IHEP

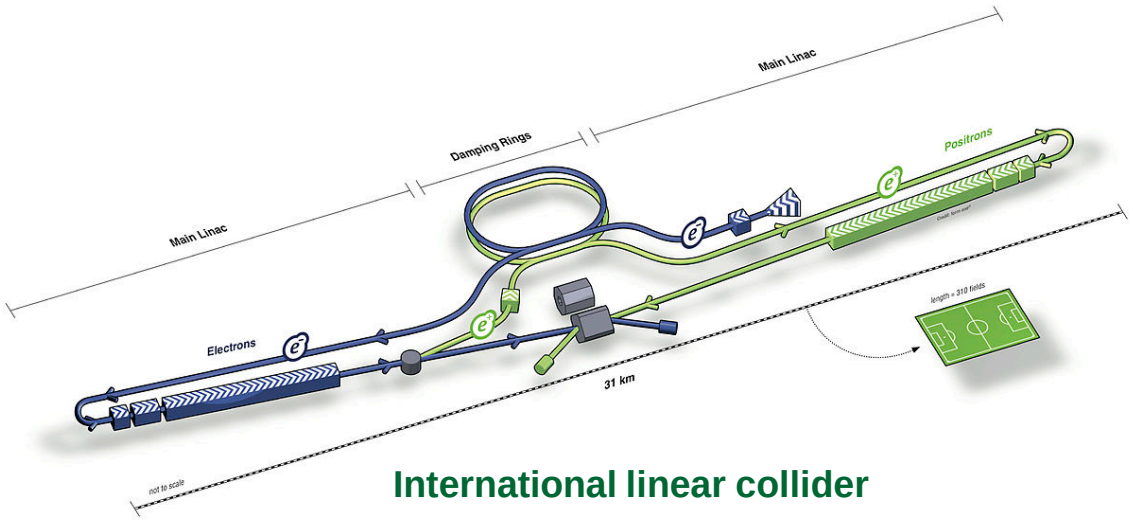
- Trigger: signal from the third GEM
- GQ Modules
  - FPGA +Amplifier/Module
  - Peak searching method in the time windows
- All DAQ Boards mounted in 6U VME crate
  - Readout Channels: 704

DAQ Module@Tsinghua

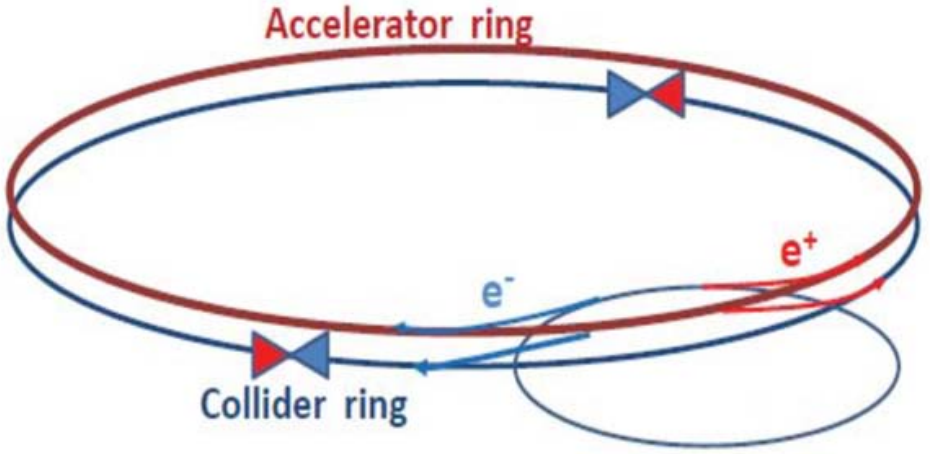
- Pre-amplifier：10~40mV/fc(Gain)
- CASAGEM: 32 channels/ASIC
- Width of signal: 200ns~1us
- Waveform sampling method: SCA
- Interger NonLine (INL)： <1%
- Readout Channels: 1000

CEPC and ILD detector requirements (Similar)

- e+e- collider
  - Linear collider
  - Circular collider
  - Collision energy: 250~500Ge
  - Higgs physics, even Z pole
  - Drift length: 2.25m
  - Length: 31km~50km
  - Inner diameter: ~0.6m
  - Outer diameter: 3.6m
  - L* of machine: 1.5m~2.5m



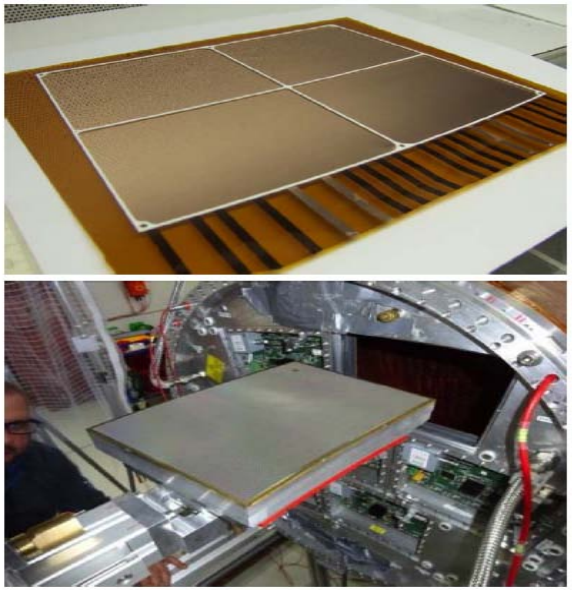
International linear collider



Circullar collider

CEPC and ILD TPC Module (Similar)

- The large prototype has been built to compare different detector readout under identical conditions and to address integration issues @ILD-TPC
- DESY modules:
  - Size: 220mm×170mm
  - 1.26mm×5.85mm/Pad, Saggered
  - 28 pad rows, 4829 channels per module
  - Thin frames – 1mm all around
  - 20 HV connected at top
  - Gain: ~4000
- KEK modules:
  - Size: 220mm×170mm
  - 1.2mm×5.4mm/Pad，Staggered
  - 28pad rows（176-192 pads/row）
  - 5152 pad per module
  - 10mm wide frame3 at top/bottom
  - No frames at sides

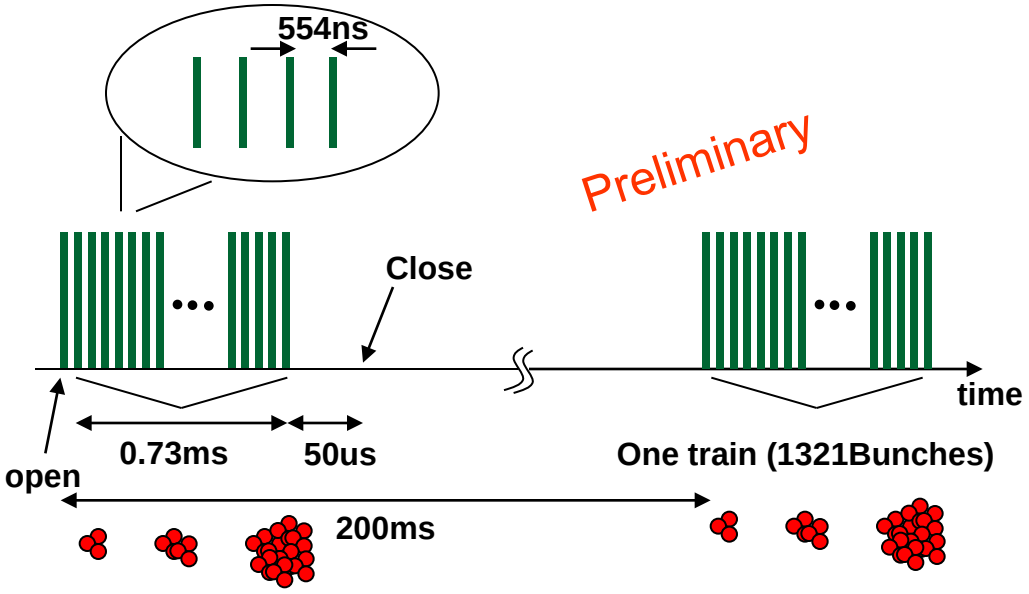


GEM and Micromegas detector as readout

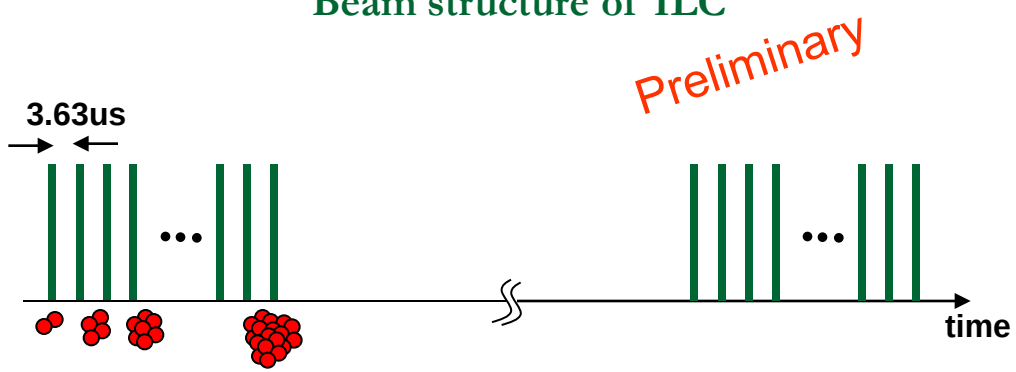
→ Common module@2015 ILD-TPC

Beam structure of ILC and CEPC (different)

- 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)
  - No Gating device with open and close time
  - Continuous deviece for ions
  - Long working time



Beam structure of ILC

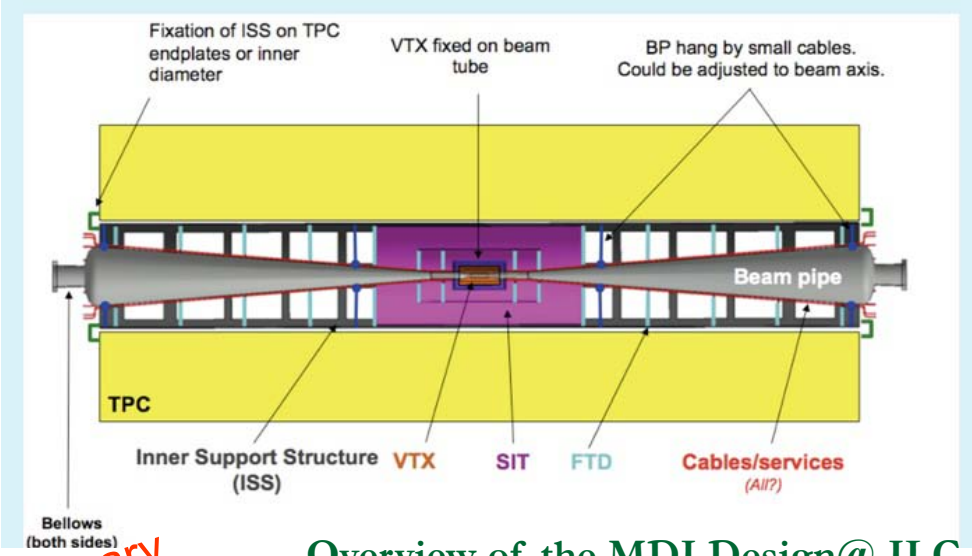


Beam structure of CEPC

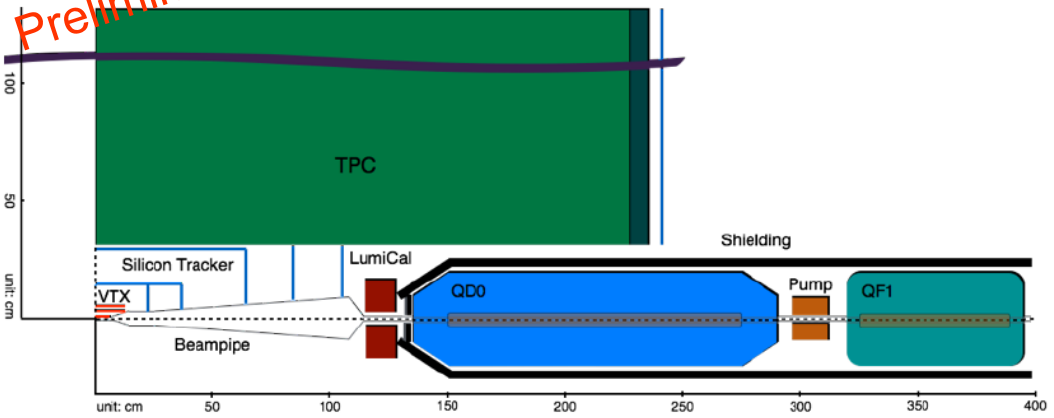
NO Gating device !

CEPC and ILD TPC (different)

- Calibration for the distortion
  - Complex MDI design
  - Short L*
  - QD0, LumiCal will inside in the drift length
  - E field distortion in drift length
  - B field distortion in drift length
  - E×B efforts
  - Laser alignment and calibration for readout module, pad, PCB and assembled



Overview of the MDI Design@ ILC



Overview of the MDI Design@ CEPC

NEED Calibration of E/B !

Towards CEPC TPC– Consideration

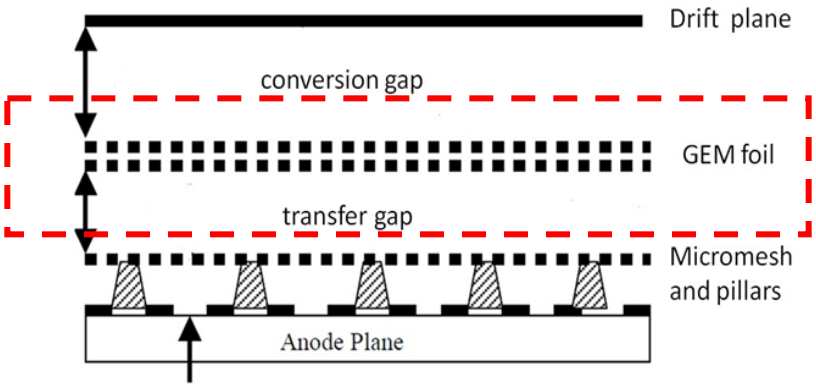
- **Optimization of working gas:**
  - Fast velocity at low drift electron field
  - Small attachment coefficient
  - Low transverse and longitudinal diffusion
- **Hybrid Detector Module:**
  - Continuous deviece reduced ions feed back
  - Working stable of the detector

Critical Challenge

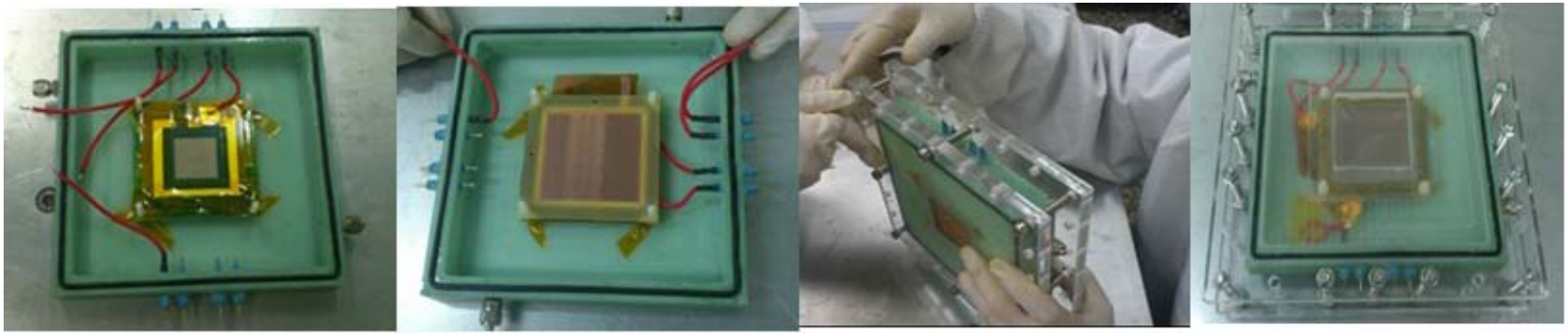
- **Laser Calibration:**
  - Alignment of module, pad, readout, etc.
  - Calibration of drift velocity, E/B effect,etc.
- **Estimation of High counting rate:**
  - High events rate, even Z pole
  - High counting rate and multi-track

Status of TPC Hybrid Module and Consideration

- Hybrid Detector for
  - Active area:50mm×50mm
  - One GEM as the pre-amplifier device under Micromegas
  - GEM as the device to reduce the ion back flow continuously
  - Hybrid detector has the more stable working time than standard GEM or Micromegas at the same gain
  - Reach to the very smaller IBF(simu.)

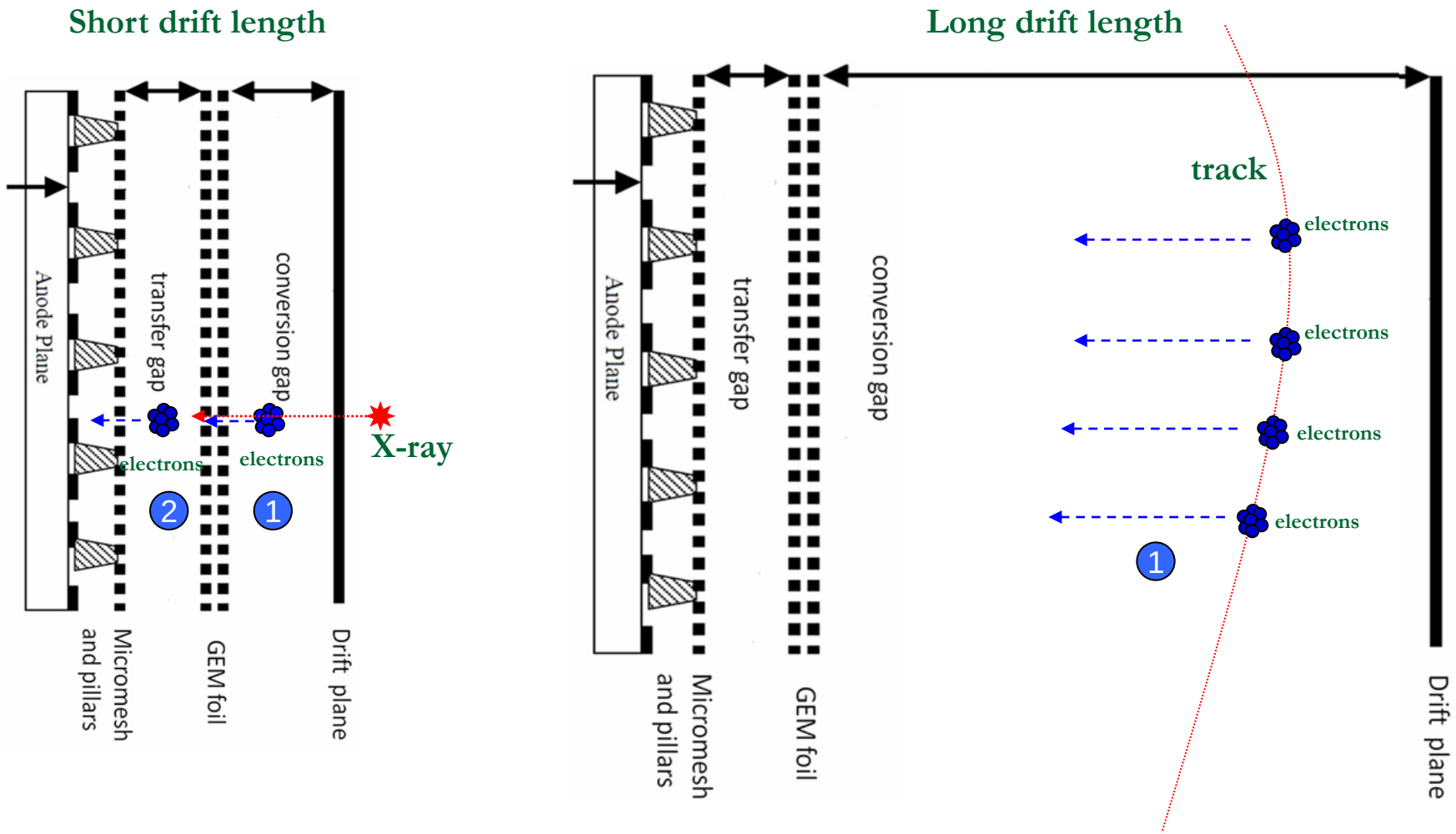


GEM+Micromegas detector



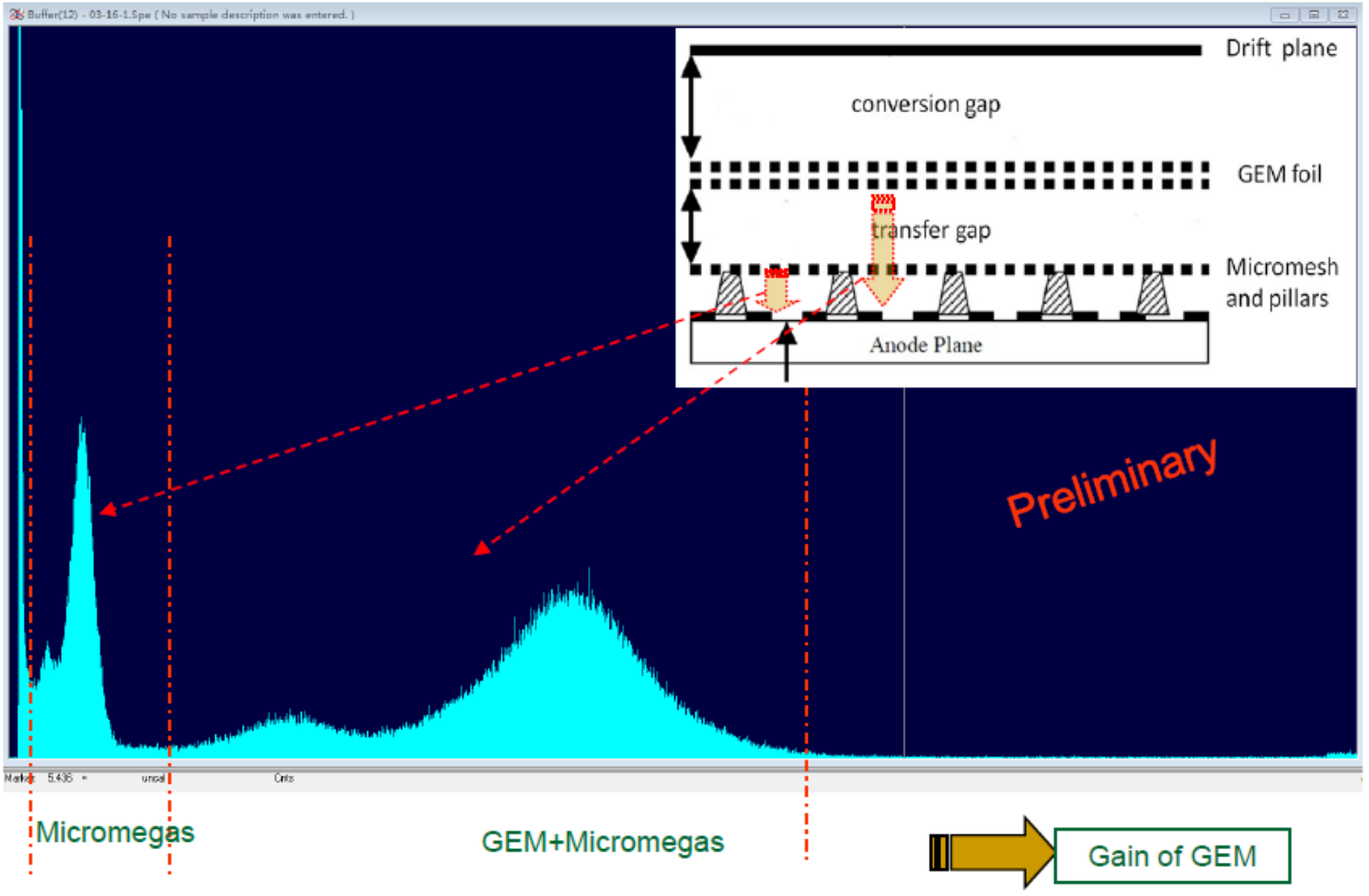
GEM+Micromegas assembled

Detector modules @X-ray and particle track



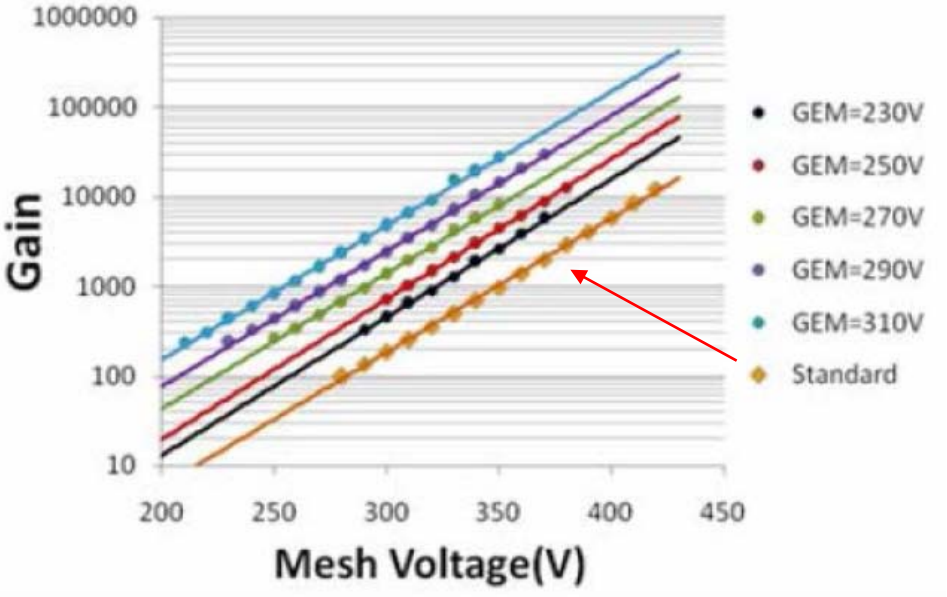
X-ray and particle track for modules

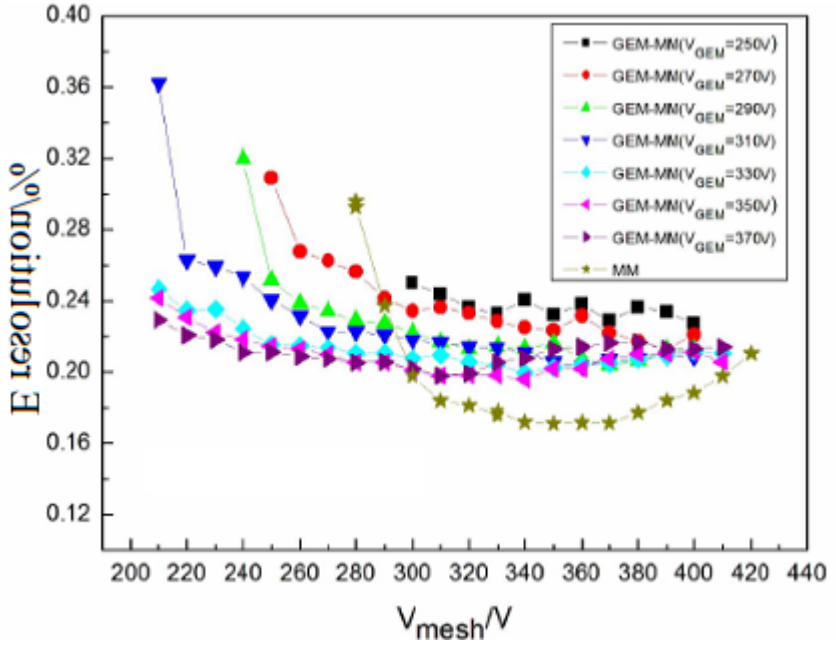
CEPC-TPC Hybrid Module



Energy spectrum@55Fe

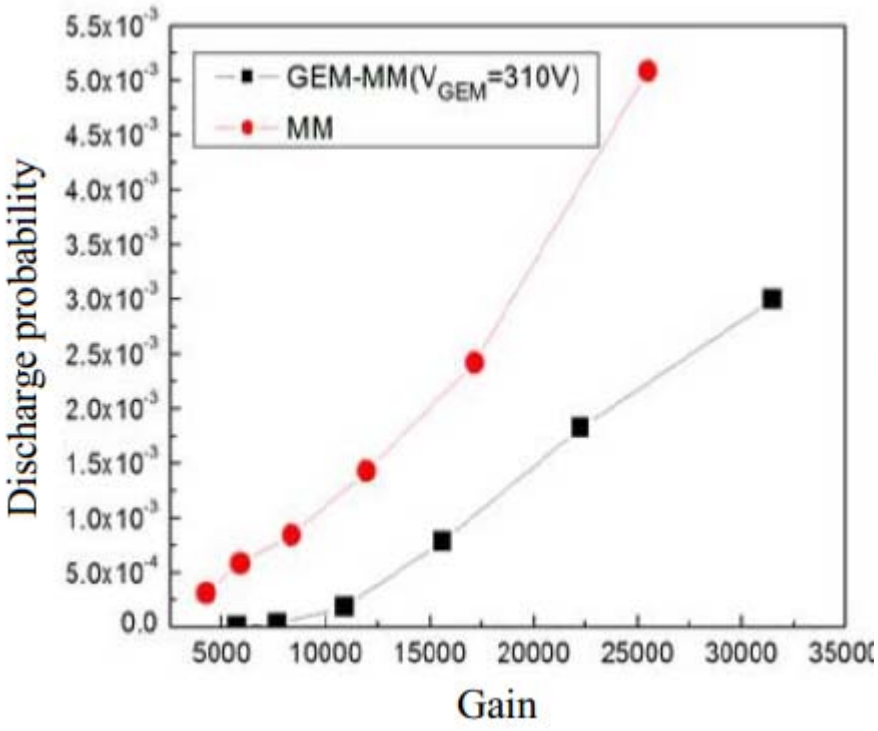
Gain and E-resolution

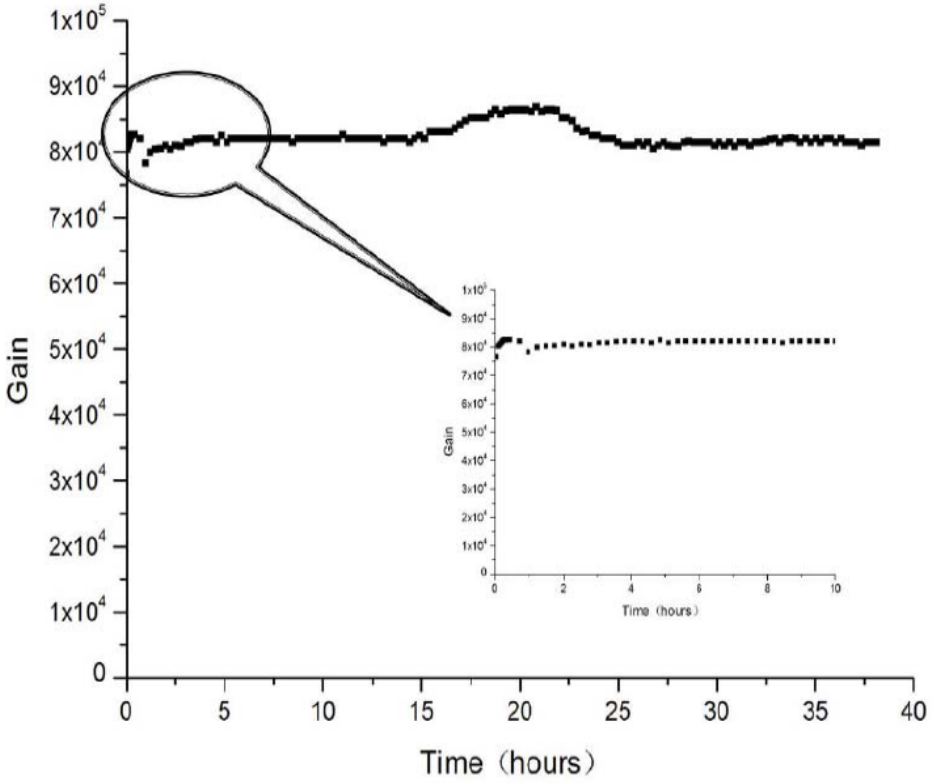




- Test with Fe-55 X-ray radiation
  - Reach to the higher gain than standard Micromegas
  - Similar Energy resolution as the standard Micromegas
  - Changed the working voltage of GEM detector
  - Same working voltage as the standard Micromegas

Discharge and working time

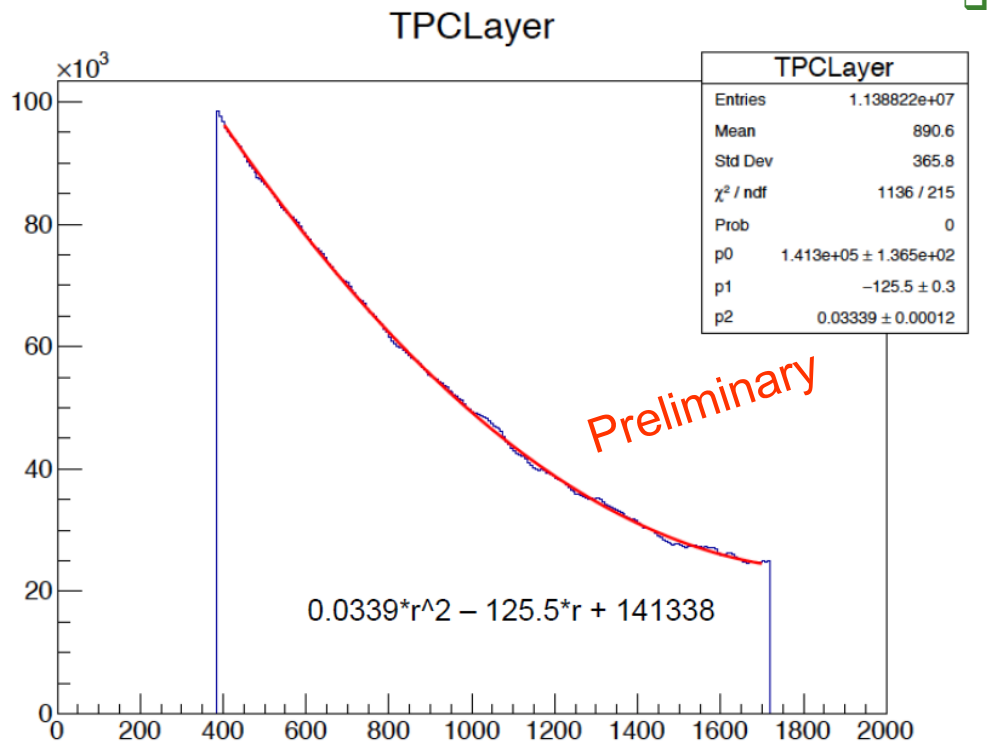




- Test with Fe-55 X-ray radiation
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module could keep the longer working time in stable

Estimation of event rate in TPC

250 GeV vvH event

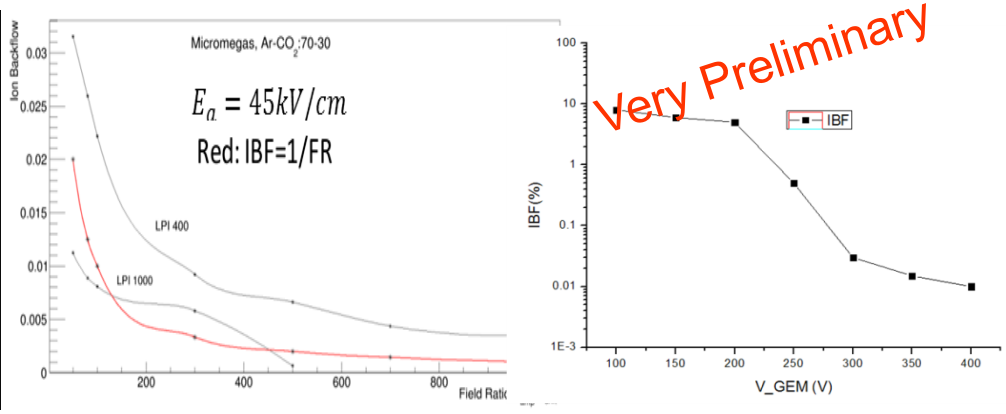


Bin Size ~ 6 mm ~ 1 TPC Layer Thickness

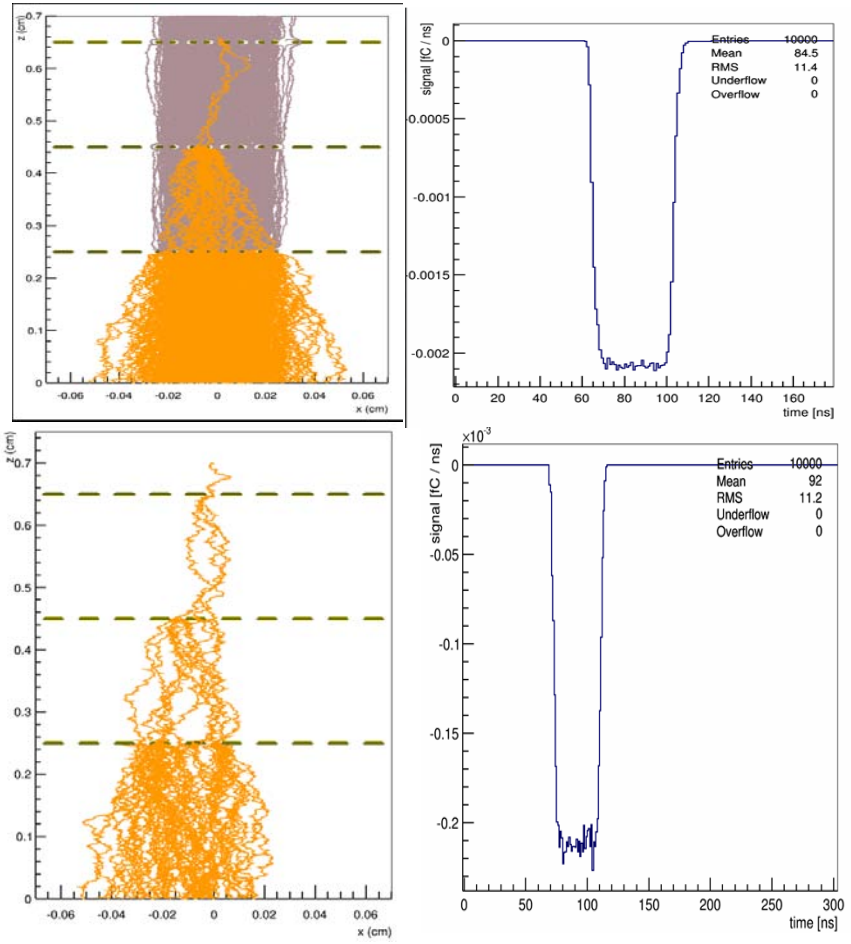
- Event rate estimation
  - Inclusive Xsec: 5*10^4 fb
  - Assume the inclusive Hit Multiplicity & Polar angle distribution is similar to that of vvH (Not a good assumption!!)
  - Event Rate
    - – 250 ifb per IP per year ~
    - – 1.25E7 second per year: 2E-5 ifb per second
    - – 1 event Per Second!!
  - NO background considered!
- From Dr. Ruan Manqi

Simulation IBF - preliminary

- Estimation of simulation model
  - Triple GEM
    - Gain/4000, 5.9keV/200e-,I/100nA
    - Gain/100, 5.9keV/200e-,I/0.2nA
  - Micromegas
    - Electric filed of amplifier
    - Electric field of drift@200V/cm
    - IBF could be smaller



Micromegas IBF simulation



GEM IBF simulation

Status R&D of CEPC-TPC Module

- Manpower and starting project in next 3 years

IHEP	Li Jin, Qi Huirong, Zhang Yulian, Wang Haiyun
Tsinghua University	Gao Yuanning, Li Yulan, Deng Zhi, Li Bo
CIEA	Li Xiaomei, Hu Shouyang, Zhou Jing
Shandong University	Zhu Chengguang
UCAS	Zheng Yangheng, Liu Qian, Wang Binlong
Lanzhou University	Hu Bitao, Zhang Yi

- Starting project supported by IHEP and NSFC funding
  - Simulation and optimize the geometry of TPC
  - Simulation and design the system of alignment and calibration by laser
  - Design and assembled low material detector modules for prototype
  - Measurement the detector modules and optimize performance
  - Simulation and design the alignment and calibration TPC prototype detector
  - Solved key issues technology for new modules
  - Aimed to CEPC CDR

Plan and critical R&D

- Reconsider performance parameters; need input/check from CEPC performance studies:
  - Simulation of single point resolution RΦ and point resolution z
  - Checked and optimized detector geometry
  - Two-hit sepration (i.e. of occupancy in the beam structure)
  - dE/dx
    - What is needed?
  - Pad size and Hybrid detector test
- Gas selection and simulation
  - Long drift gas studies
  - Fast drift velocity
  - Low electric field
- ILD-TPC cooperation
  - ILD-TPC Large prototype (understanding, learning, joining?)
  - Beam test and data analysis

Things to be done
Short time scale 1~3 years
To CDR of CEPC

Plan and critical R&D

- Ion back flow
  - Optimized of Hybrid detector with pre-amplifier GEM detector
  - Optimized of the resistive Micromegas
  - Hybrid detector performance
- UV laser test for modules
  - Calibration in the working gas
  - Alignment in the modules
- Electronics and DAQ
  - Common
  - …
- Some else?

Things to be done
Short time scale 1~3 years
To CDR of CEPC

Thanks for your attention!