Status Report about the TPC Detector and Module at CEPC

Huirong QI

On behalf of CEPC TPC subgroup, IHEP, CAS

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Content

- Goals and options
- Some considerations
- Preliminary simulation
- Hybrid structure module
- Summary

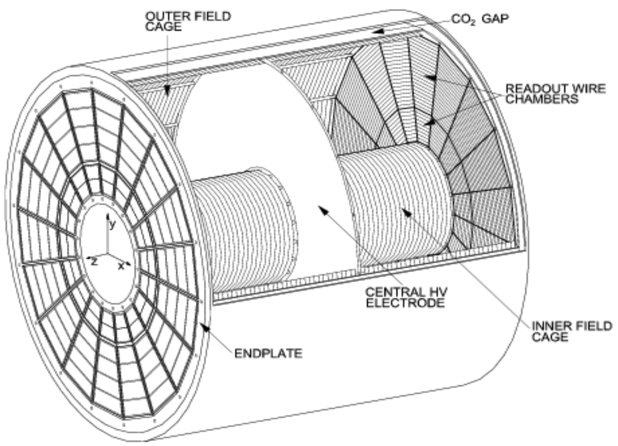
Tracker detector option

- Tracker detector
  - Main drift chamber (MDC)
  - Silicon tracker detector (SiD)
  - Time projection chamber (TPC)
- TPC detector
  - Detector structure
    - Chamber with 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

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)

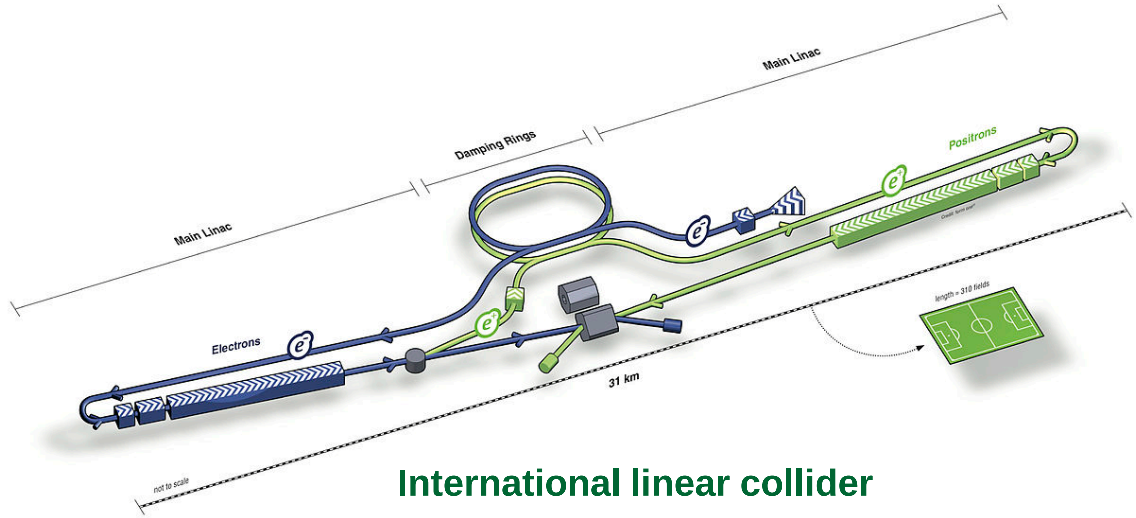
Just one option !



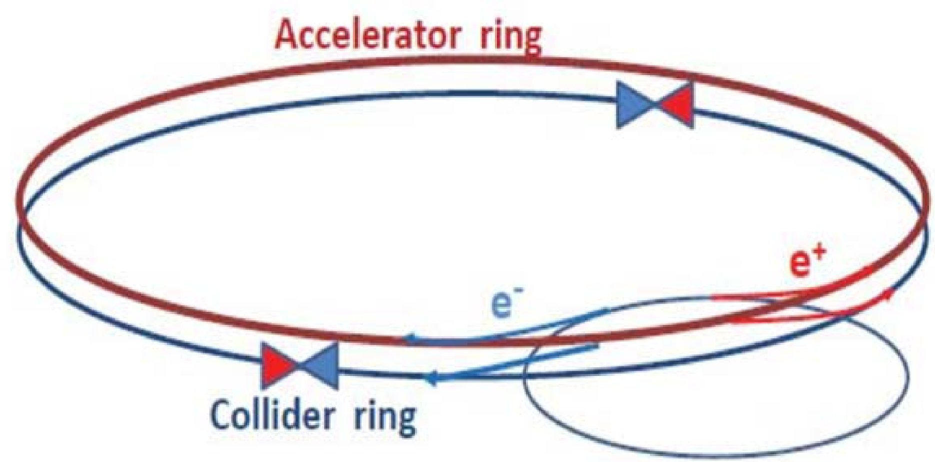
TPC Detector overview
(ALICE, STAR, ILD-TPC, etc.)

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



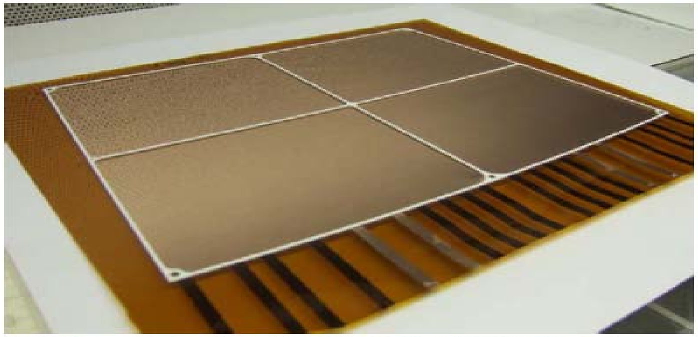
International linear collider



Circullar collider

CEPC and ILD TPC Module (Similar)

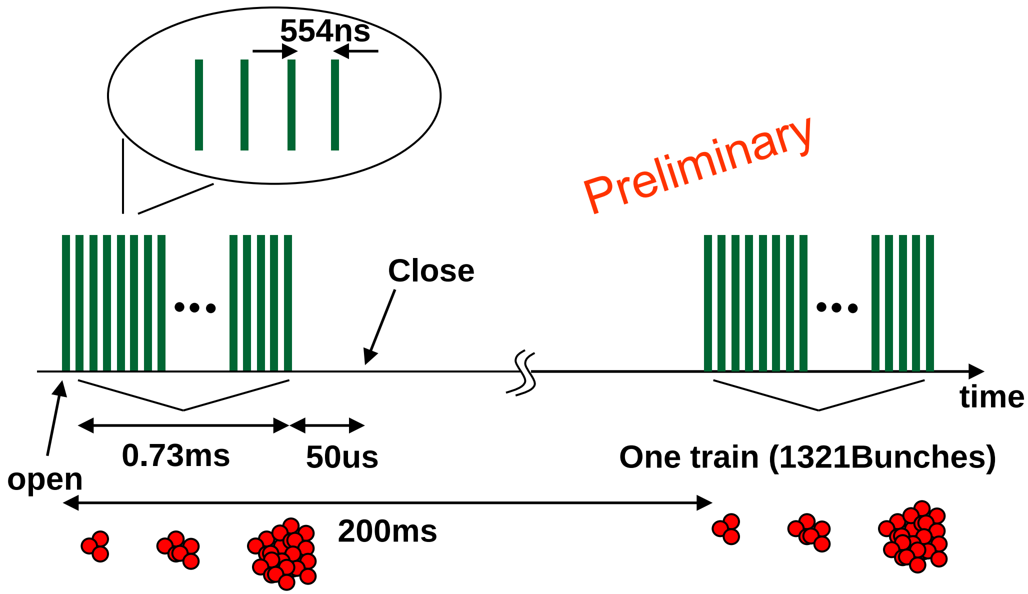
- The large prototype (LP1)@ILD-TPC
  - 7 Modules design
  - Magnetic field: PCMAG 1.0T
  - Magnetic field: KEK 1.0T
- DESY modules /Micromegas:
  - Size: 220mm×170mm
  - 1.26mm×5.85mm/Pad, Saggered
  - 28 pad rows, 4829 channels per module
  - Thin frames – 1mm all around
- KEK modules /GEM:
  - Size: 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



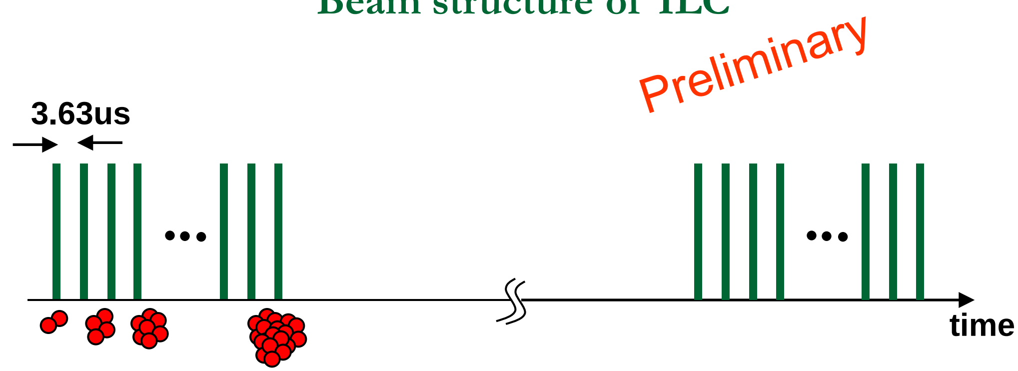
GEM and Micromegas detector as readout

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 device for ions
  - Long working time



Beam structure of ILC



Beam structure of CEPC

NO Gating device !

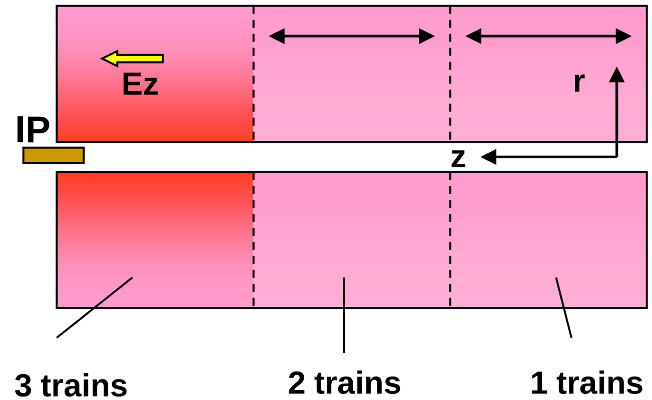
Ion back flow (different)

In the case of ILD-TPC

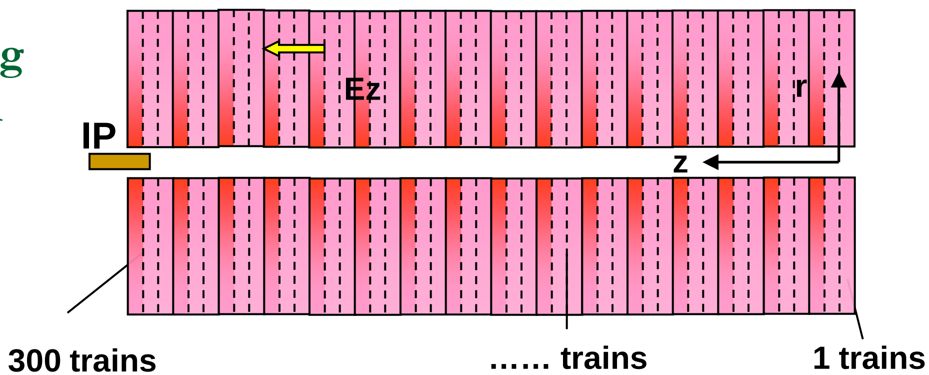
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be 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
- 300 discs co-exist and distorted the path of seed electron
- The ions have to be neutralized during the ~4us period continuously



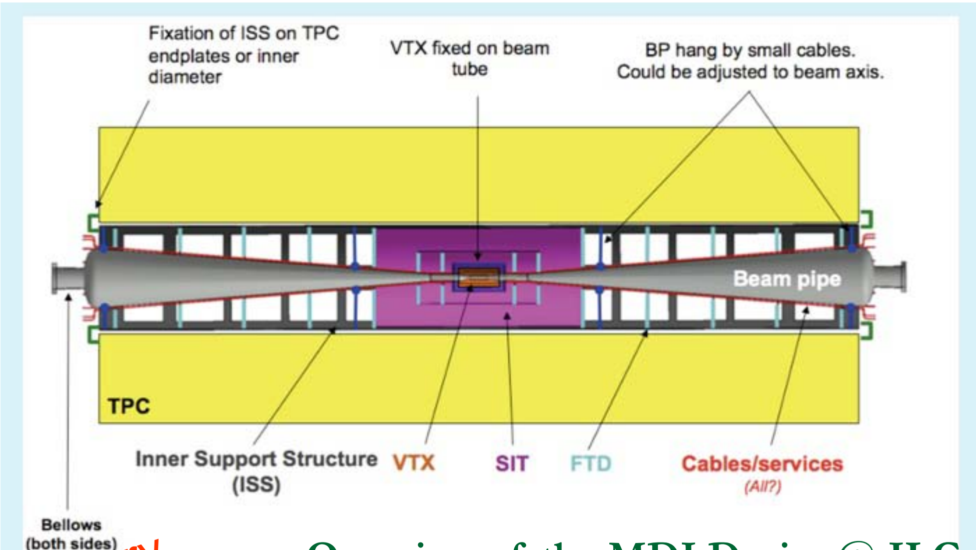
Amplification ions@ILC



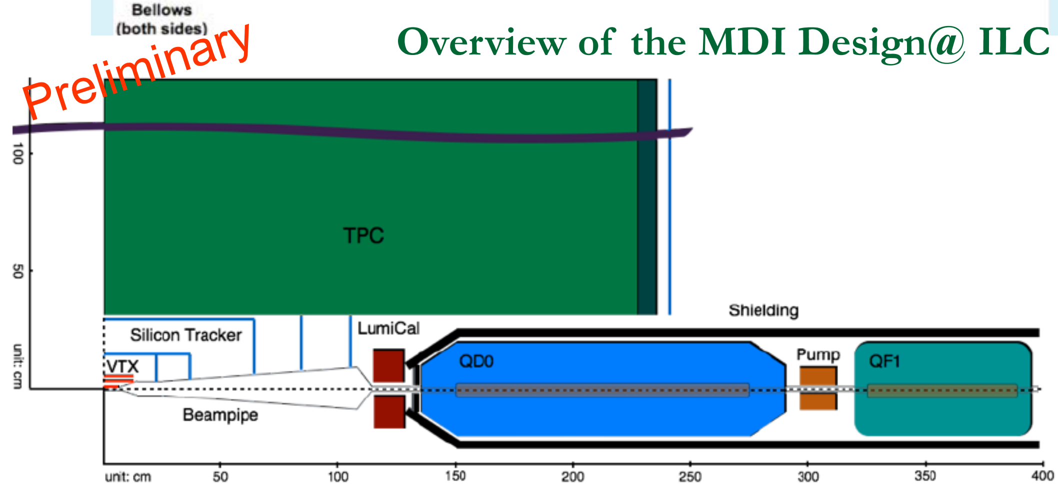
Amplification ions@CEPC

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 effect
  - UV 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– Considerations

- **Optimization of working gas**:
  - Fast velocity at low drift electron field
  - Small attachment coefficient
  - Low transverse and longitudinal diffusion
- **IBF Detector Module**:
  - Continuous deviece reduced ions feed back
  - Working stable in the longer time
- **Alignment and Calibration**:
  - Alignment of module, pad, readout, etc.
  - Calibration of drift velocity, E/B effect,etc.
  - UV laser option
- **Estimation at High counting rate**:
  - High events rate, even Z pole
  - High counting rate and multi-track

Critical Challenge

Preliminary simulation

- Key points
  - **Occupancy**: Very important parameter of TPC could determine to use or NOT as the tracker detector
  - **Stable operation**: Discharge and spark damaged the detector in the high gain or in the long working time
  - **Ion back flow**:
    - Distortion of the electric field in drift volume
    - Reduction of the effective gain
  - …

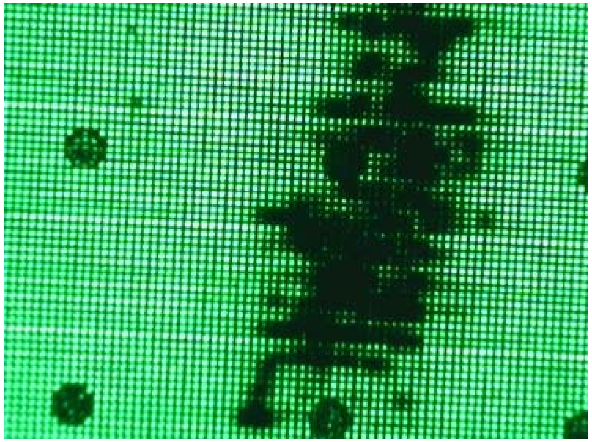
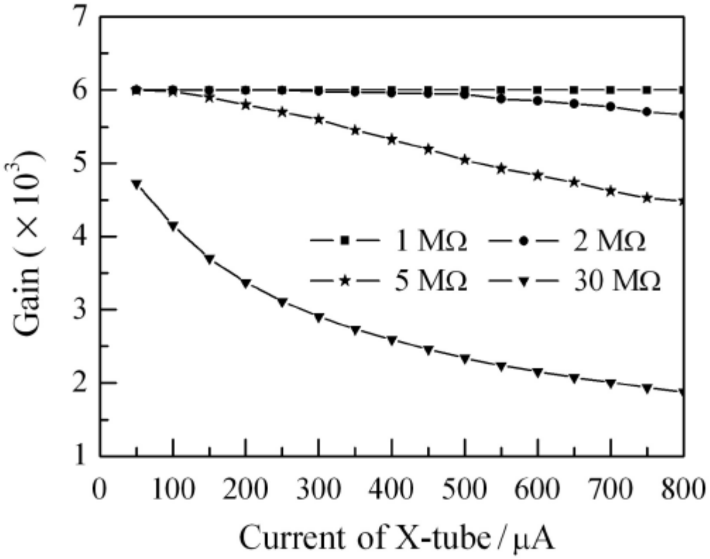


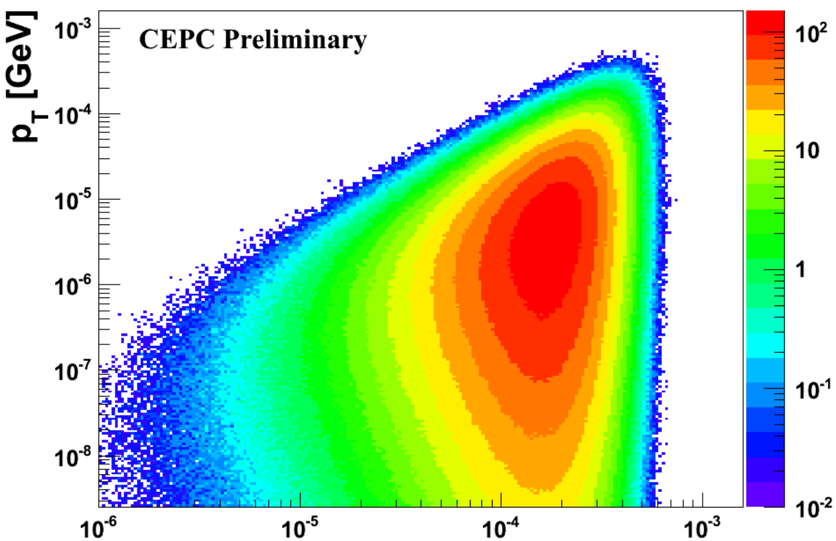
Photo of the spark damaged Micromeags



High X-ray dose to reduce the Gain (IBF)

Backgrounds at CEPC

- Beamstrahlung (e+e- pairs)
  - Pair production
  - Hadronic background
- Lost Particles (Beam Halo)
  - Radiative Bhabha
  - Beamstrahlung
  - Beam-Gas Scattering
  - …
- Synchrotron Radiation
  - More than 100keV of Gamma
  - Just consider at endcap (readout and modules for TPC)
- From Dr. Zhu Hongbo and Xiu Qinglei

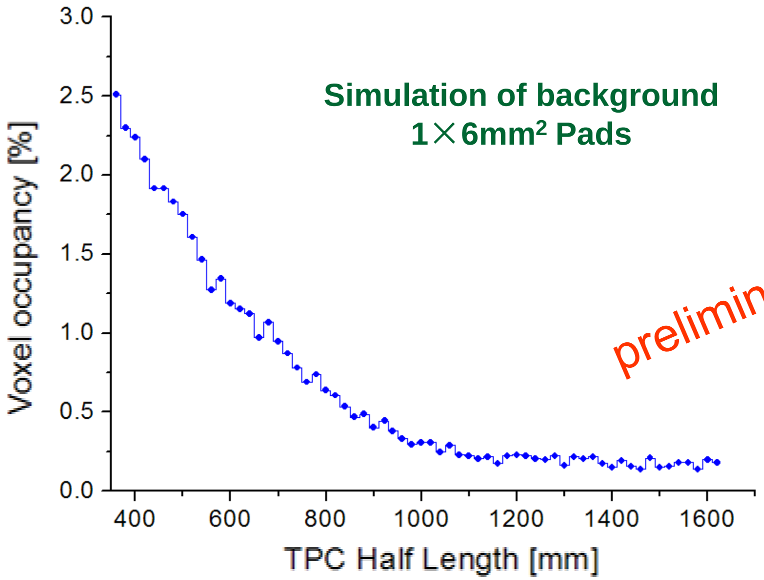


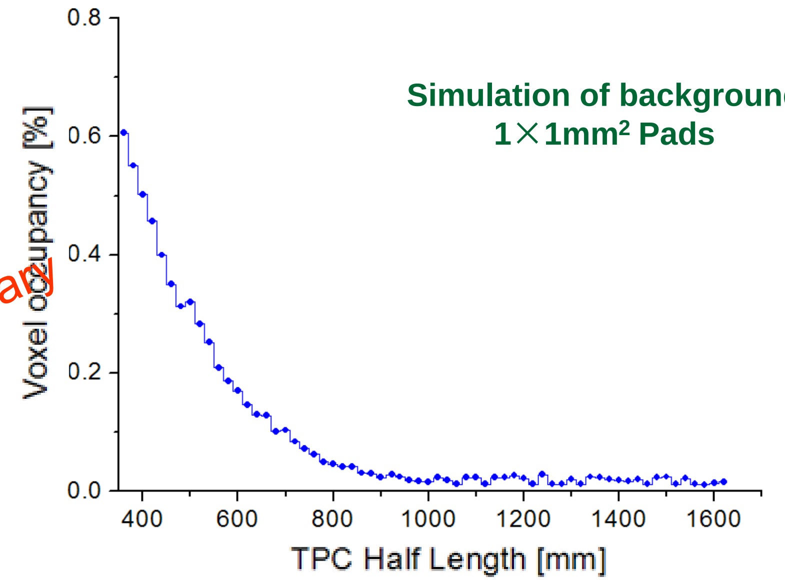
p_T v.s. θ

Simulation of occupancy

CLIC_ILD ~30%@3TeV
1×6mm² Pads
CLIC_ILD ~12%@3TeV
1×1mm² Pads
NO TPC Options!

- Occupancy@250GeV
  - Very good for Silicon pixel tracking
  - Very important parameter for TPC
  - Detector structure of the ILD-TPC
  - 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)

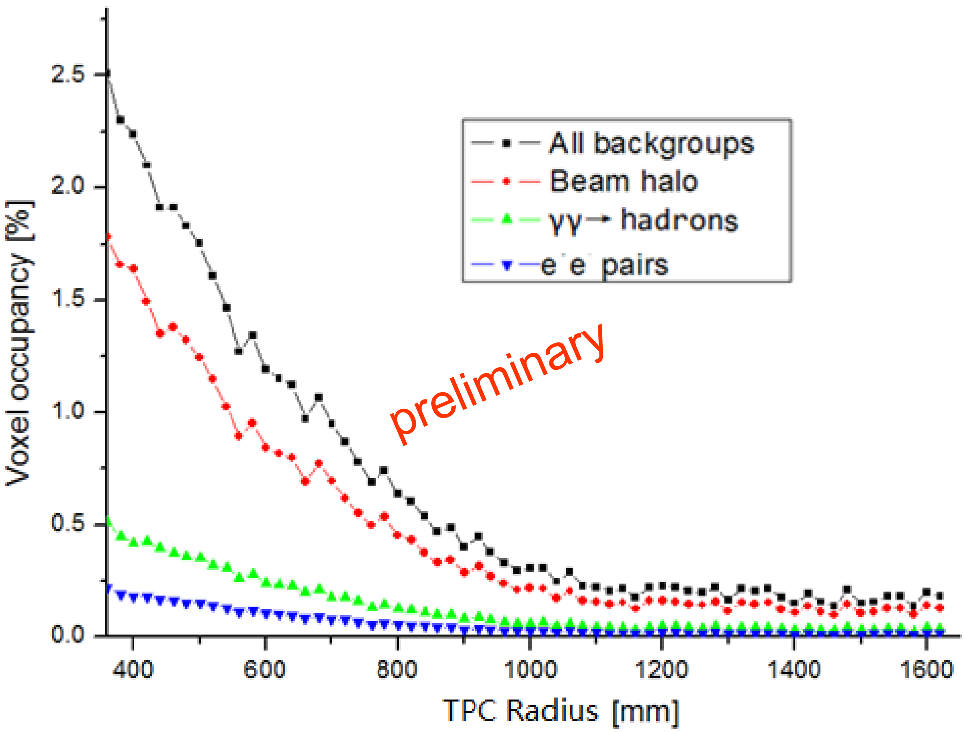




Preliminary of occupancy

Occupancy@250GeV

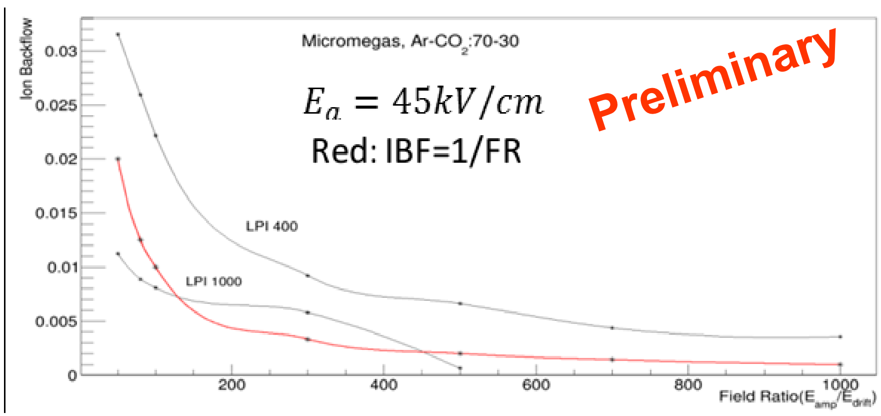
- Voxel occupancy
  - Pad size: 1mm×6mm
  - No consideration for the beam collimator , the value of occupancy might larger
  - No consideration for Synchrotron Radiation



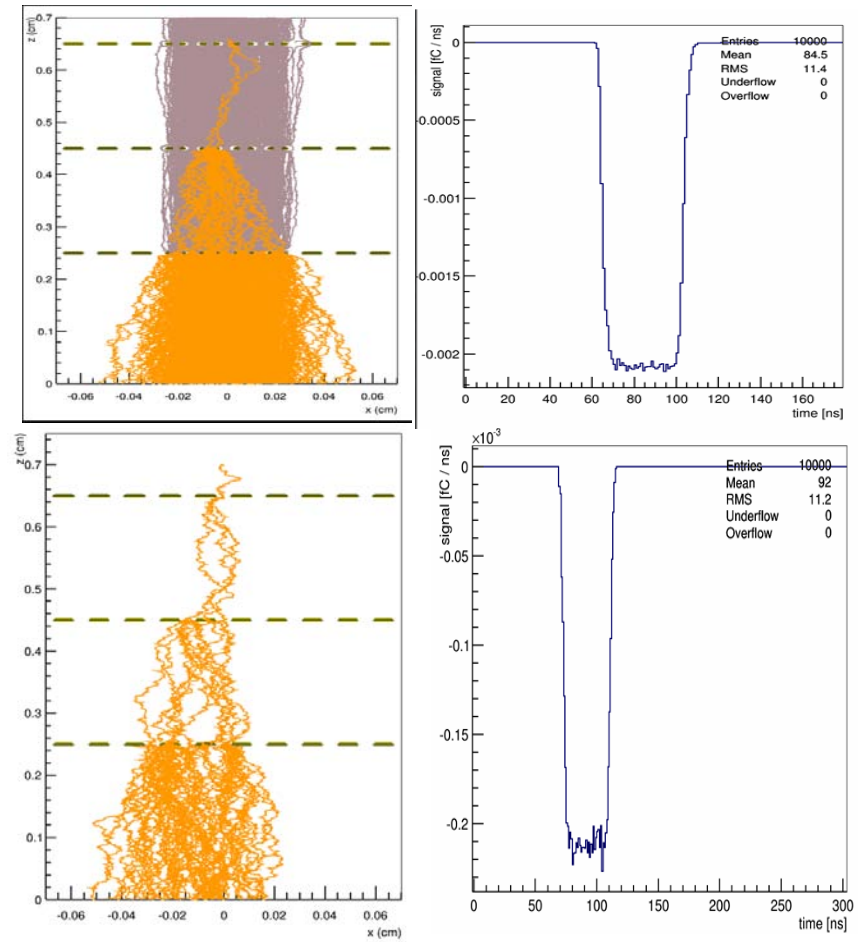
TPC voxel occupancy simulated in TPC radius

Simulation IBF - preliminary

- Estimation of simulation
  - ANSYS and Garfield/Garfield++
  - Triple GEM
    - Gain/4000, 5.9keV/200e-,I/100nA
    - Gain/100, 5.9keV/200e-,I/0.2nA
  - Bulk-Micromegas
    - Electric filed of amplifier
    - Electric field of drift@200V/cm
    - IBF could be reduced



Micromegas IBF simulation

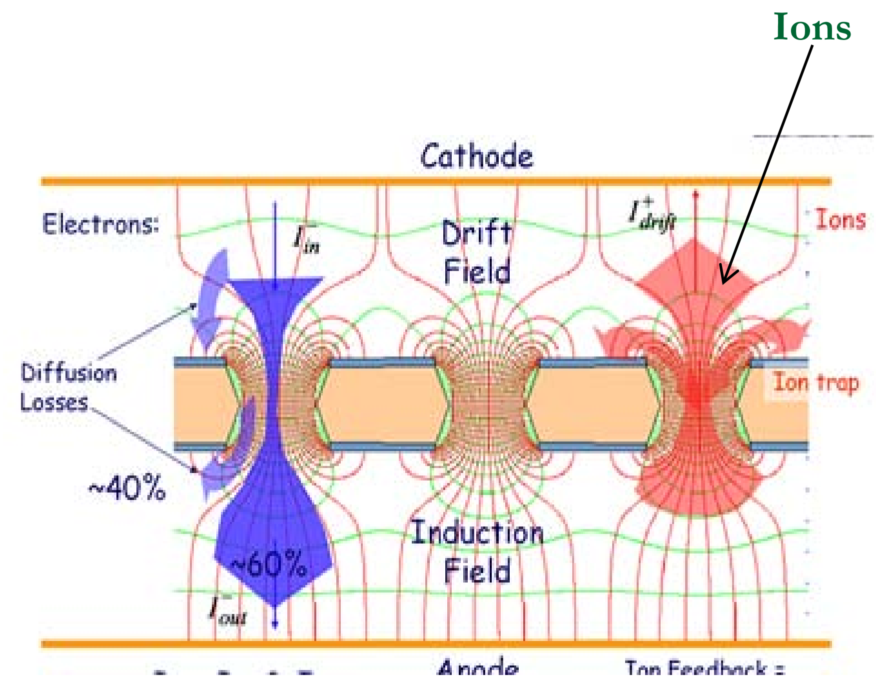


GEM IBF simulation

Some considerations

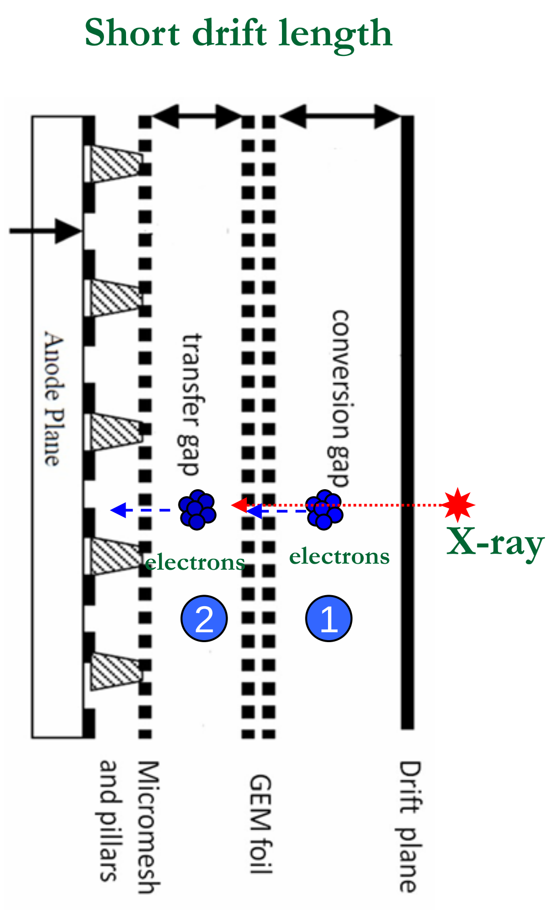
- GEM detector could be as the amplification detector, Micromegas could be as the amplification device too.
- GEM detector could be reduced the IBF as the gating, Micromegas could be decrease the IBF too.

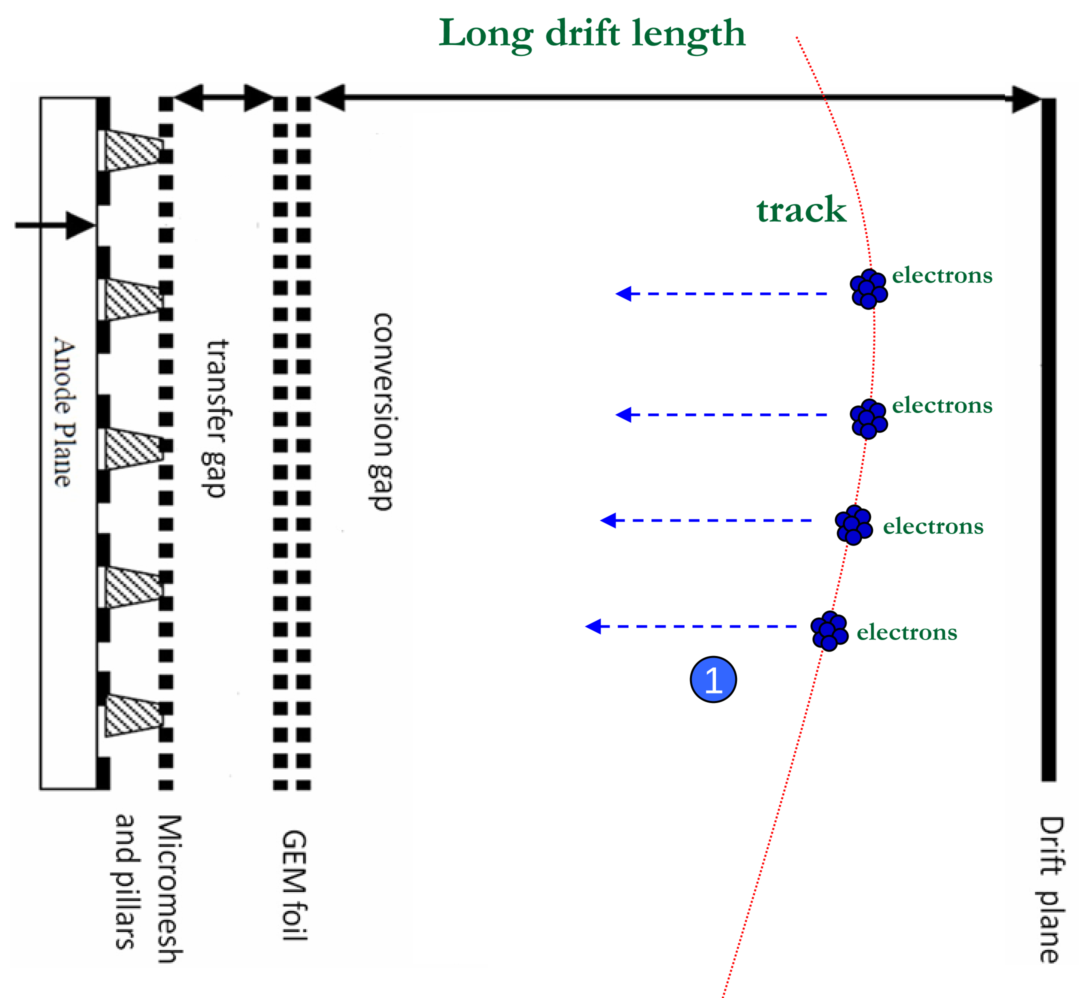
- GEM+Micromegas detector module
  - GEM as the preamplifier device
  - GEM as the device to reduce the ion back flow continuously
  - Stable operation in long time



IBF of GEM

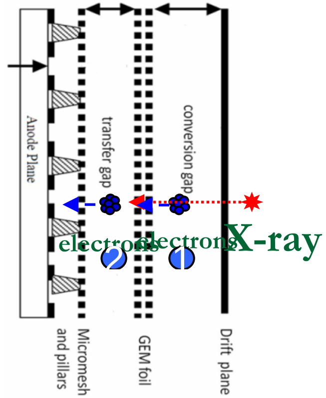
Hybrid structure module

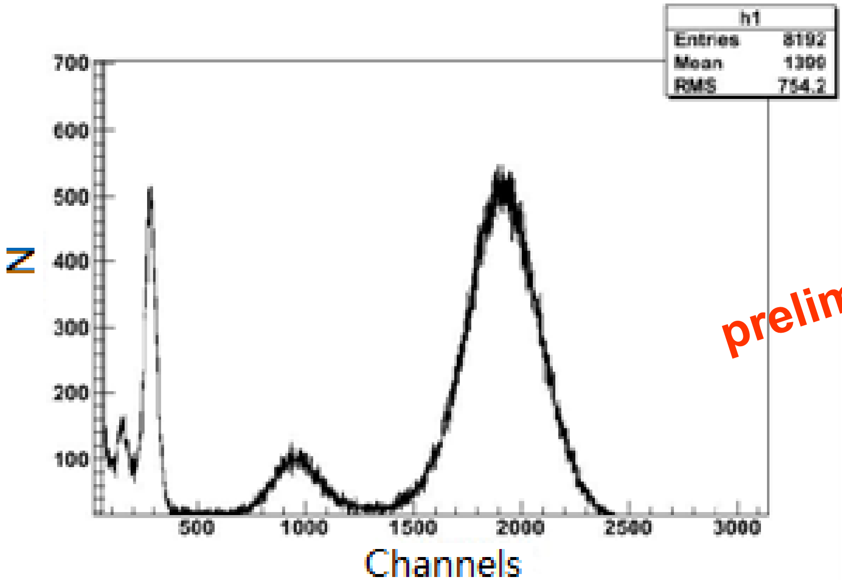


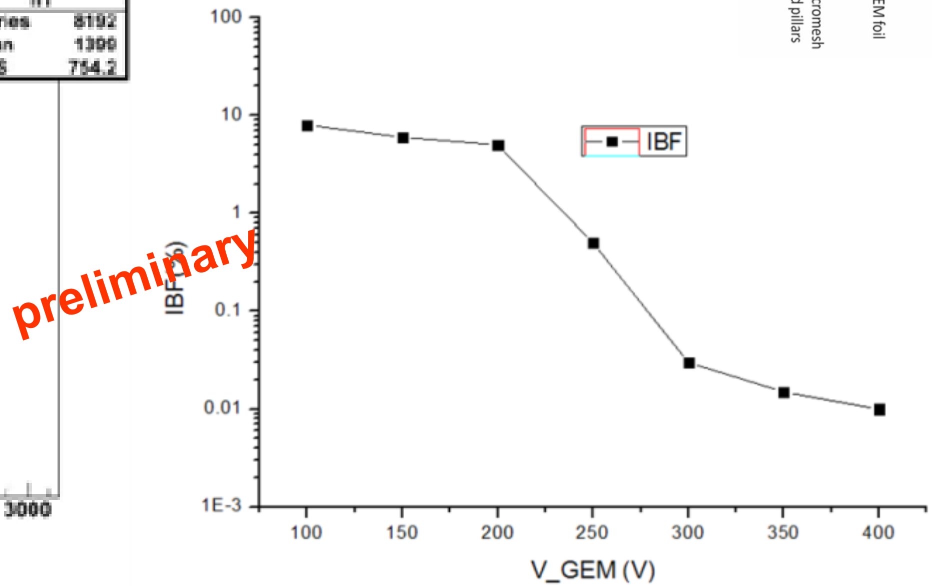


Measurement method: X-ray and particles track in the module

Simulation IBF - preliminary





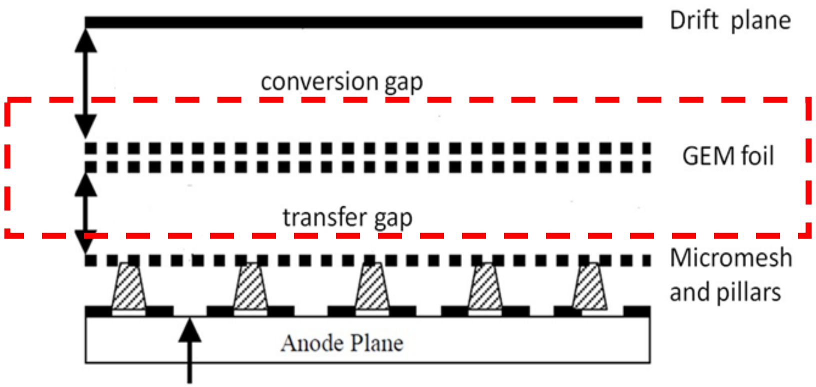


GEM+Micromegas detector's energy spectrum (5.9keV X-rays)

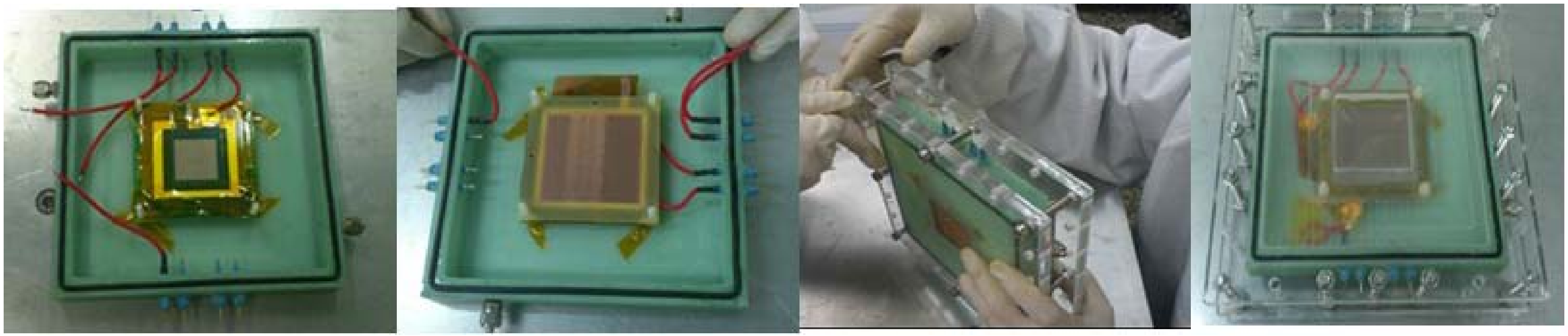
IBF simulation of GEM+Micromegas (very preliminary, just as geometry)

Hybrid structure module

- Hybrid structure detector
  - 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
  - Meet to the very smaller IBF



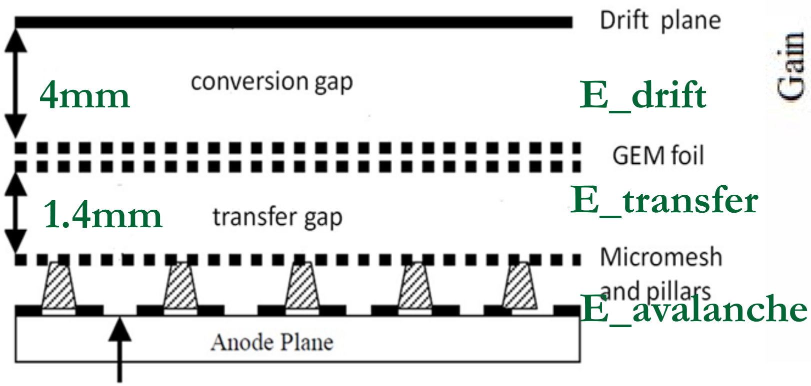
GEM+Micromegas detector

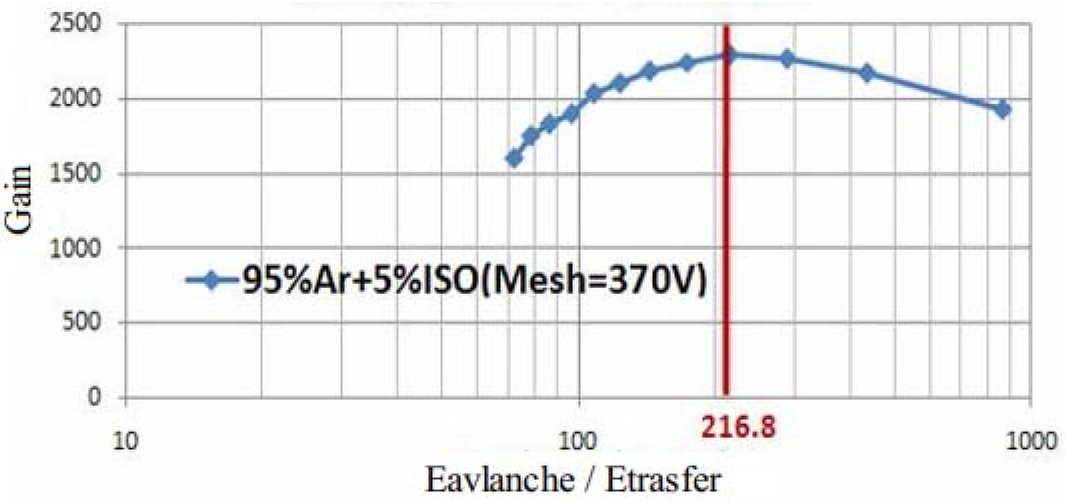


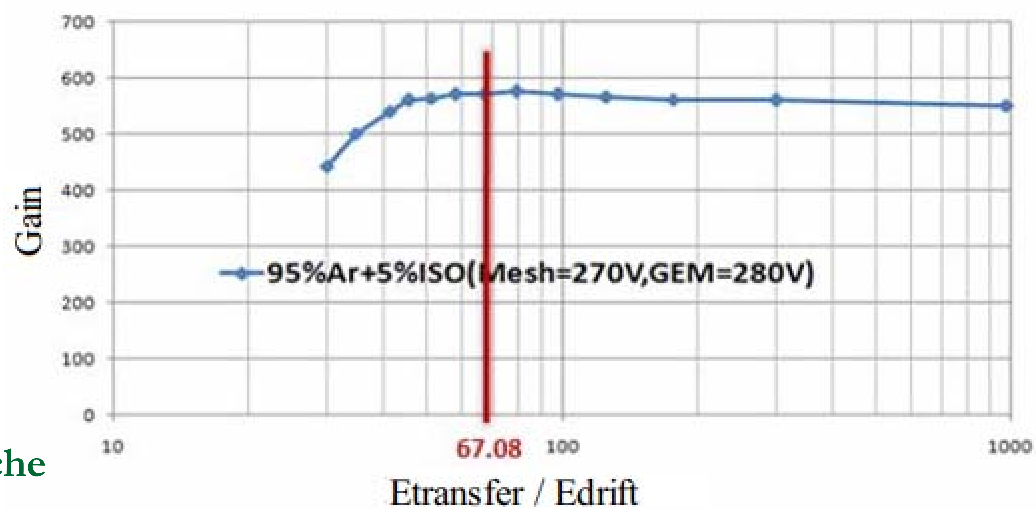
GEM+Micromegas assembled

Hybrid structure module

- Optimized operating voltage
  - To achieve the higher electron transmission in the hybrid structure module
  - The ratio of E_avalanche and E_transfer of Micromegas detector is 216.8
  - The ratio of E_transfer and E_drift of GEM detector is 67.08







Electron transmission in GEM and Micromegas

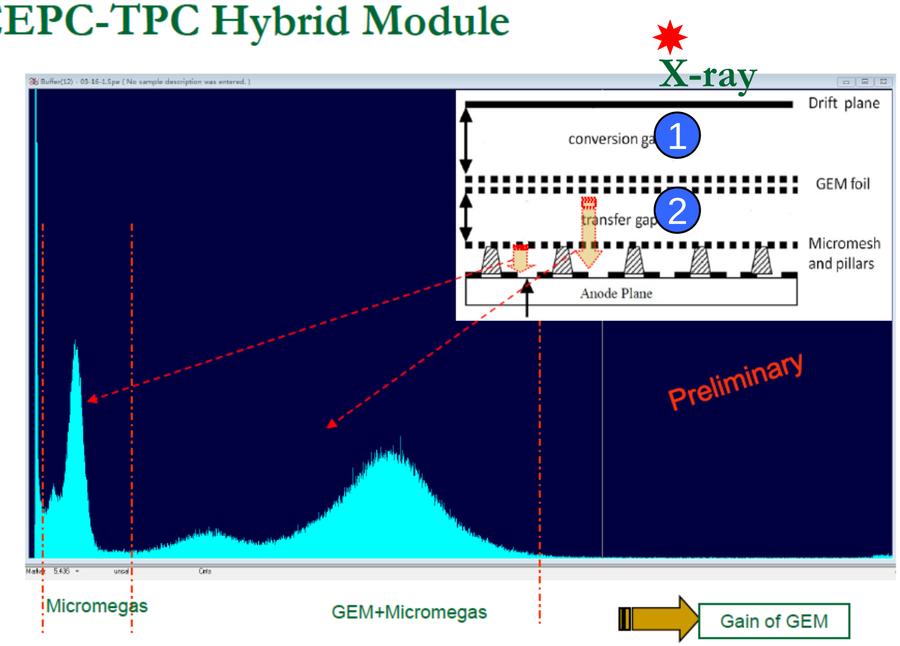
Hybrid structure module

- Case (1): the conversion happens in the drift region, so that the produced electrons have to pass the pre-amplification GEM and Miromegas, the signal and ions are affected by the GEM transmission

- Case (2): a small portion of the X-rays are converted in the region between the the amplification GEM and Micromegas, which produces signal without any effect to reduce

- Electron transmission: calculated as the ratio of the two signals

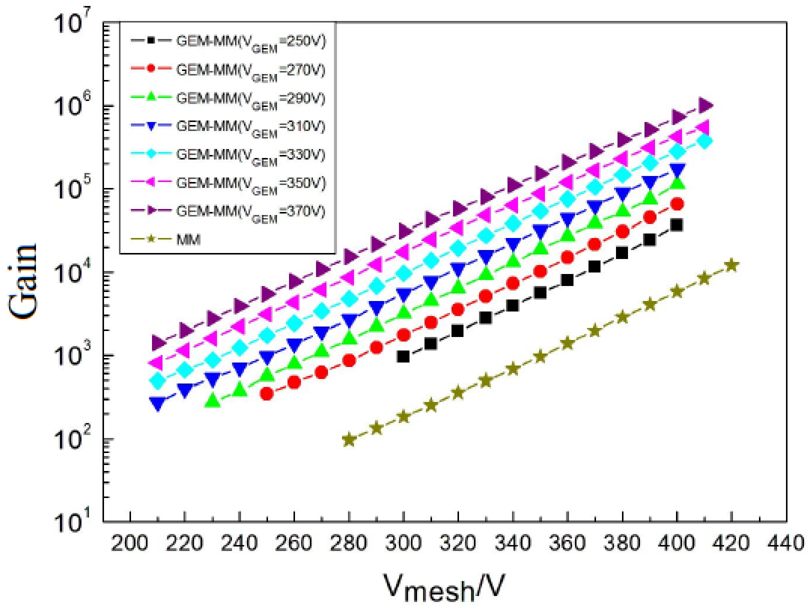
CEPC-TPC Hybrid Module

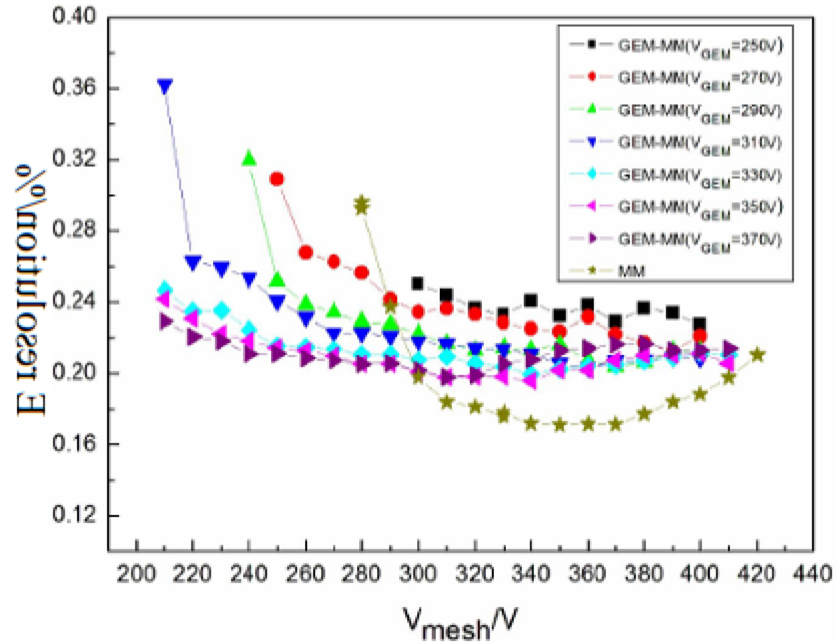


Energy spectrum@55Fe

Using a CERN standard GEM and one Bulk-Micromeagas assembled in IHEP

Gain and energy resolution

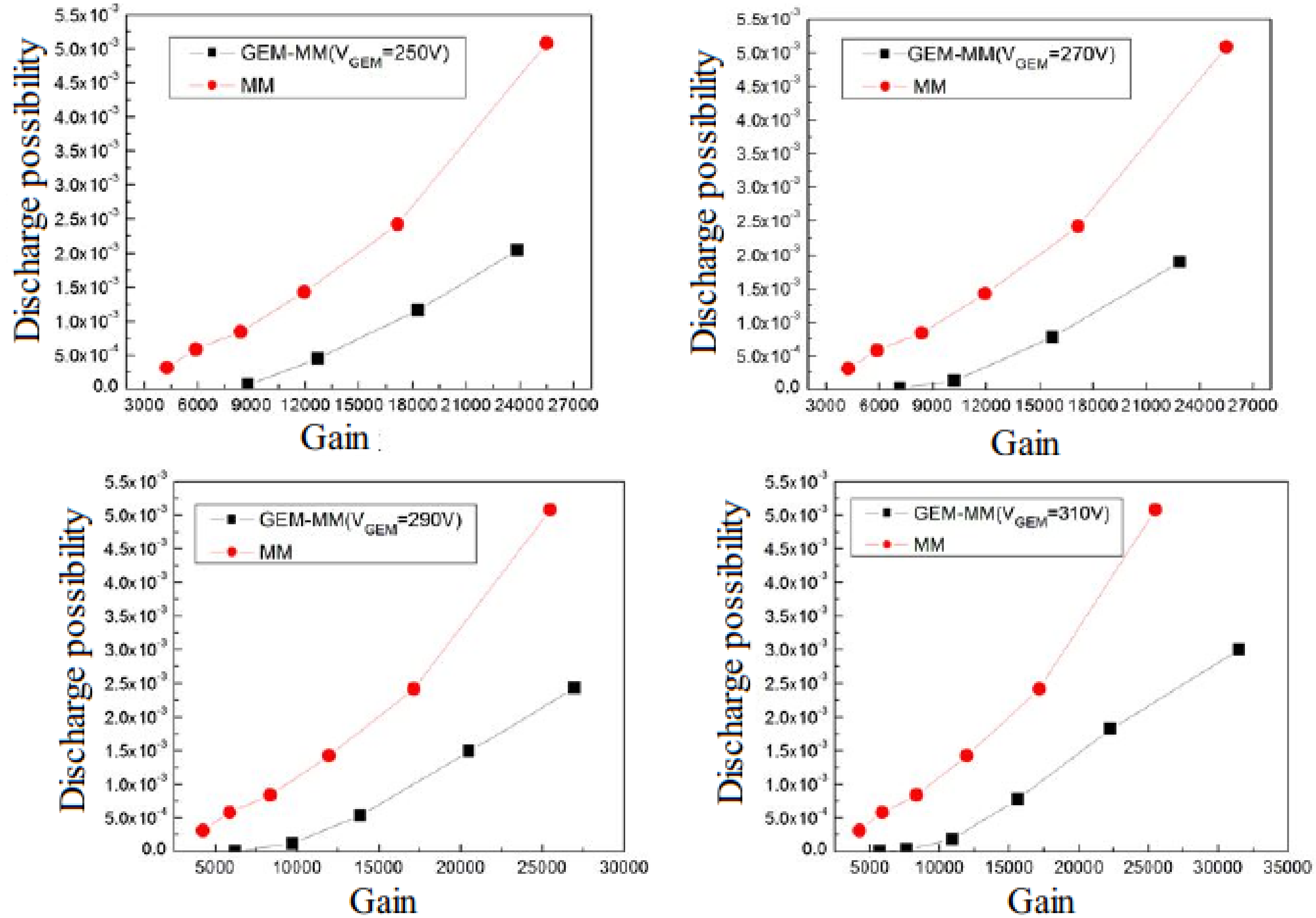




- Test with Fe-55 X-ray radiation source
  - Reach to the higher gain than standard Micromegas with the pre-amplification GEM detector
  - Similar Energy resolution as the standard Micromegas
  - Increase the operating voltage of GEM detector to enlarge the whole gain

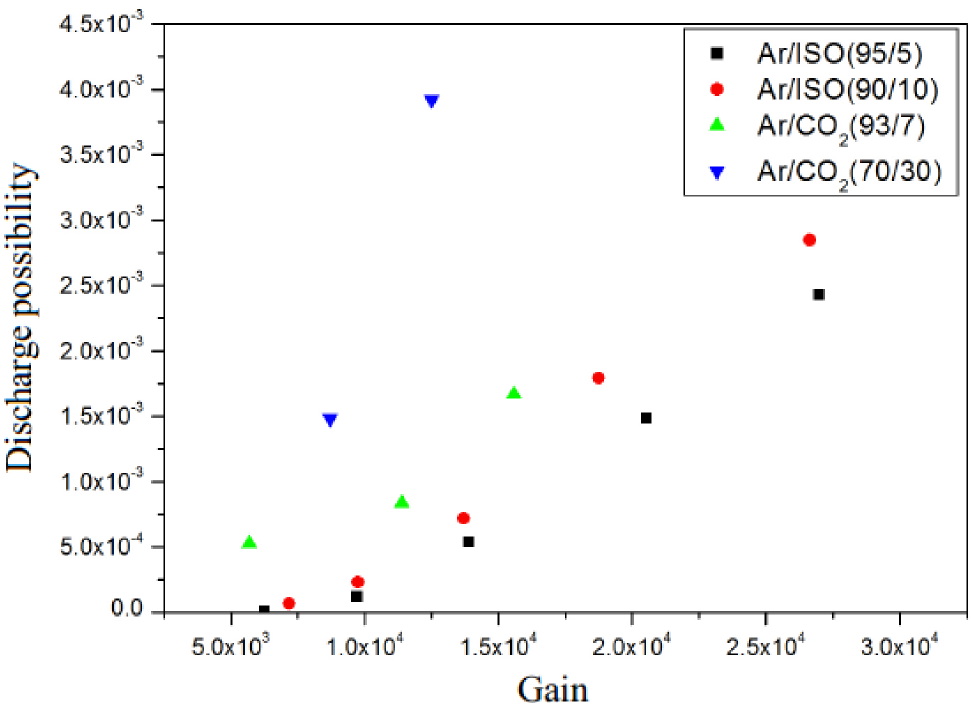
Discharge VS gain

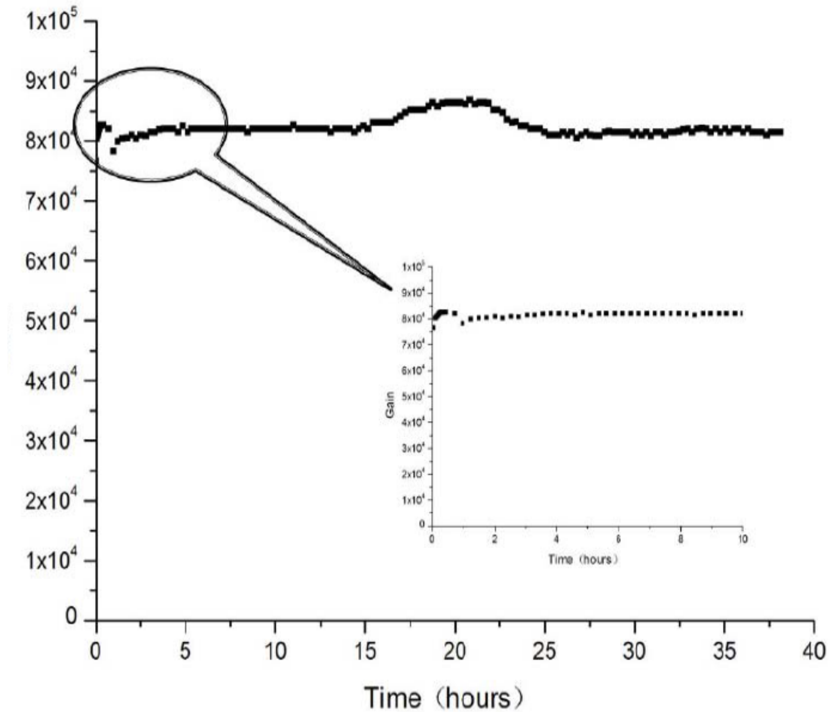
- Discharge possibility VS the whole effetive gain
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000



Discharge possibility VS gain @V_{GEM}

Working gas and duration time





- Test with Fe-55 X-ray radiation
  - Discharge possibility should been considered in different working gas.
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module could keep the longer working time in stable

To do list

NOT good uniformity electric field for IBF test,
Need to design the big active area detector modules. (E.g 100mm^2)

Understand transfer length/GEM hole size /efficiency
-> ongoing

Activities@2015 and wish list

- **Obtained support funding from IHEP and NSFC**
- **Joint meeting and discussion with CEA-Saclay@ July. 17 and December. 14, 2015**
  - **TPC detector modules**
  - **R&D of Ion Back Flow using the UV light**
  - **Common module beam test**
  - **Personnel exchanges**
- **Measurement of the hybrid structure detector module**

- **Wish list**
  - **Simulation and optimize the Hybrid modules of TPC with the active area of 100mm^2**
  - **R&D of IBF used UV light**
  - **International conference of CEPC-TPC at September,2016**
  - **Toward CEPC CDR**

Summary

- For the physics requirements of CEPC tracker detector, some considerations of the beam structure, the IBF effect, the detector modules and the critical challenges have been given.
- Some parameters of the occupancy of the detector, the hybrid structure gaseous detector's IBF and the energy spectrum have been preliminary simulated.
- The hybrid structure detector with the active area of 50mm×50mm have been assembled and measurement used the X-ray radioactive source.
- Some wish list of the further cooperation and R&D of CEPC-TPC detector modules would be done in the next years.

Thanks very much for your attention!