Status of the TPC detector module and R&D activities at CEPC

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on behalf of the CEPC TPC working group

April 8th, 2016, IHEP, Beijing

Outline

- Detector requirements
- TPC detector concept
- Current R&D activities
- Summary and outlook

Detector requirements

General detector requirements

- Design and performance goals of TPC (Stand alone)
  - Momentum resolution at 3.5Tesla $\delta(1/pt) \approx 10^{-4}$/GeV/c
  - Position resolution in rΦ <100μm (avg for straight-radial tracks)
  - Pad pitch /no. padrows ≈1mm×4~10mm/≈200
  - Performance >97% efficiency for TPC only (pt > 1GeV/c)

    >99% all tracking (pt > 1GeV/c)
  - 2-hits resolution in rΦ ≈2mm (for straight-radial tracks)

Target:

- Fine detector modules
- Stable and low material budget structure
- Low power readout electronics
- Alignment and calibration system for distortion

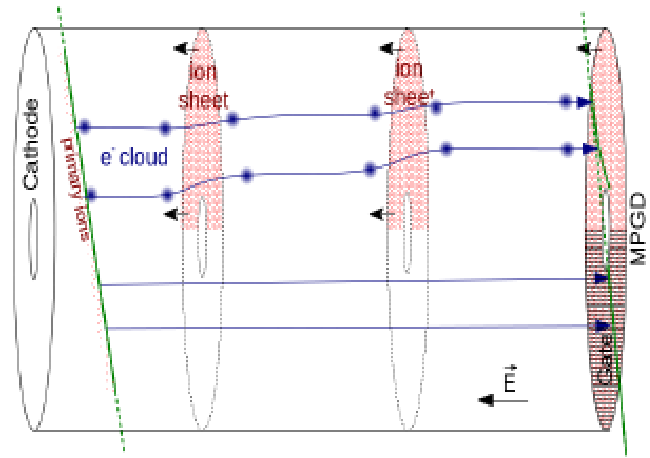
Critical detector requirements @CEPC

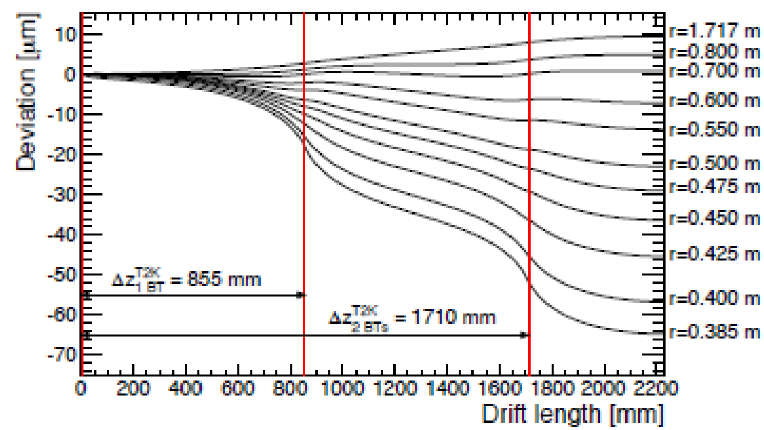
- NO power pulse mode
  - Detector module without the Gate Device for IBF: <0.1%
  - Continuous device for ions
  - Continuously working time
  - Lower power of the electronics readout: <5mW/ch
  - Lower material budget structure
  - Precise time stamping of signal

- Complex MDI design
  - Obvious E/B field distortion in the chamber
  - Alignment and calibration for drift velocity, track,…

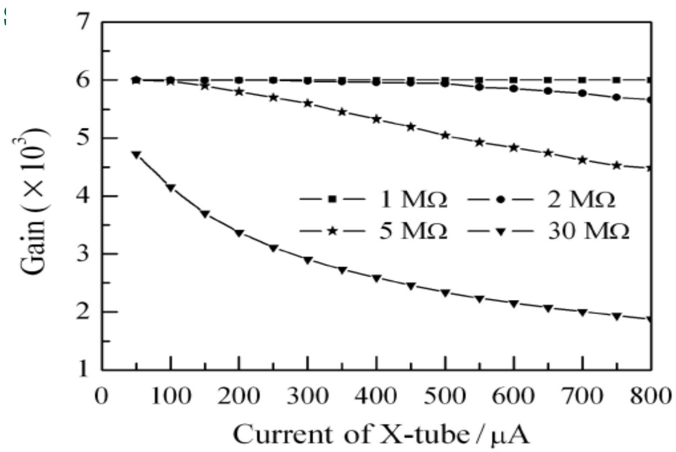
Critical challenge: Ion Back Flow

- **High performance requirements by the TPC relies strongly on the quality of the electric field in the drift volume!**
  - Ions drift back into the gas volume in CEPC TPC
  - Many such the discs in the chamber with ions
  - Ions could reduce the momentum resolution along the drift length
  - Ions





Ions simulation @ILD TPC

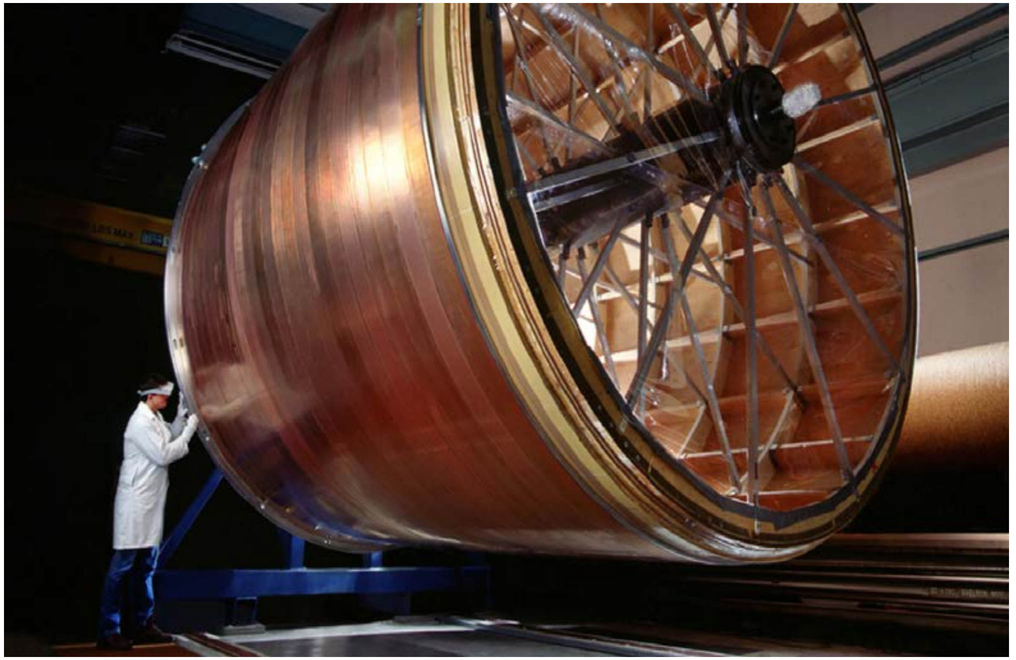


High X-ray dose to reduce the Double GEMs Gain @ IHEP

TPC detector concept @CEPC

Detector layout

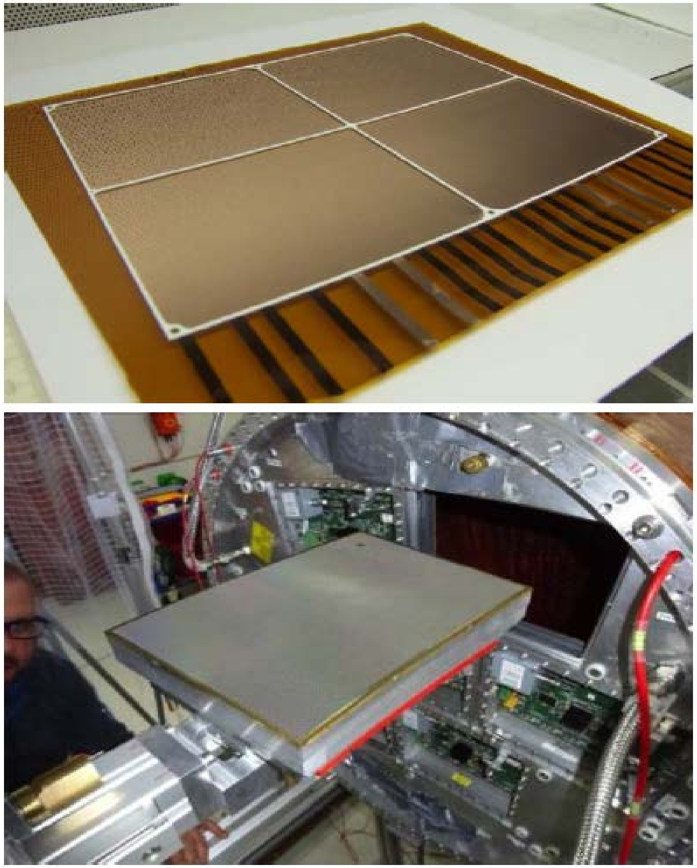
- Time Projection Chamber detector
  - Detector module (Critical technical challenges)
  - Drift chamber
  - Electronics readout
  - Working gas supply
  - Alignment and calibration system
  - Inner radius
  - Pad size
  - Number of tracker
  - B Field
  - Support structure
  - Drift cathode



Overview of the TPC detector

Detector modules options

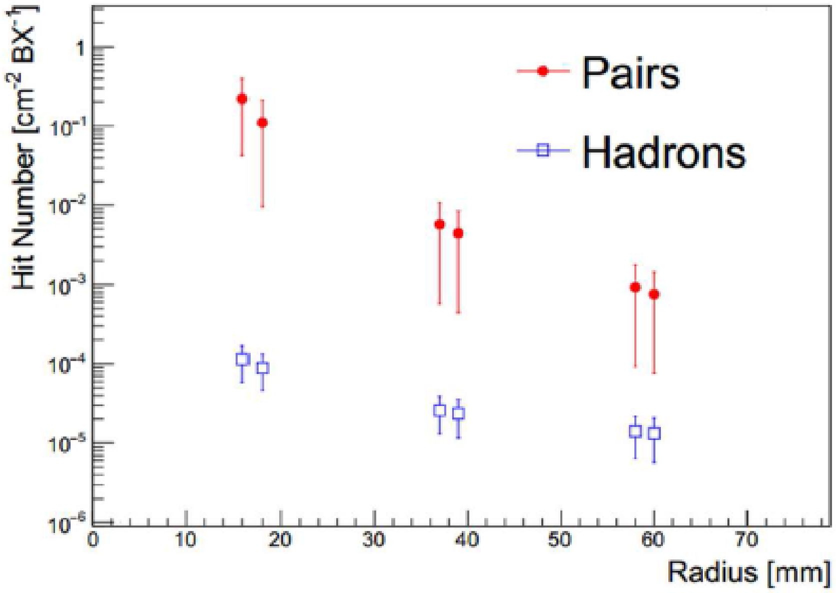
- The large prototype (LP1)@ILD-TPC
  - 7 Modules design
  - Magnetic field: PCMAG 1.0T
  - Magnetic field: KEK 1.0T
- DESY modules /Micromegas:
  - Size: 220mm×170mm
  - 1.26mm×5.85mm/Pad, Saggered
  - 28 pad rows, 4829 channels per module
  - Thin frames – 1mm all around
- KEK modules /GEM:
  - Size: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

Backgrounds @CEPC

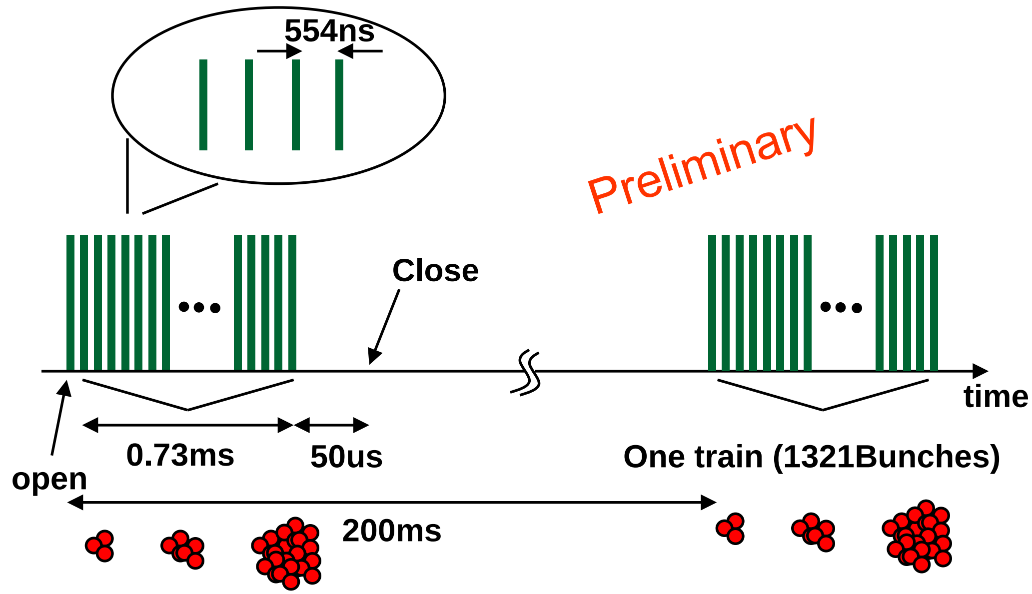
- **Beamstrahlung (e+e- pairs)**
  - Pair production
  - Hadronic background
- **Lost Particles (Beam Halo)**
  - Radiative Bhabha
  - Beamstrahlung
  - Beam-Gas Scattering
  - …
- **Synchrotron Radiation**
  - More than 100keV of Gamma (No damage or effect for working gas)
  - Just consider at endcap (readout and modules for TPC)



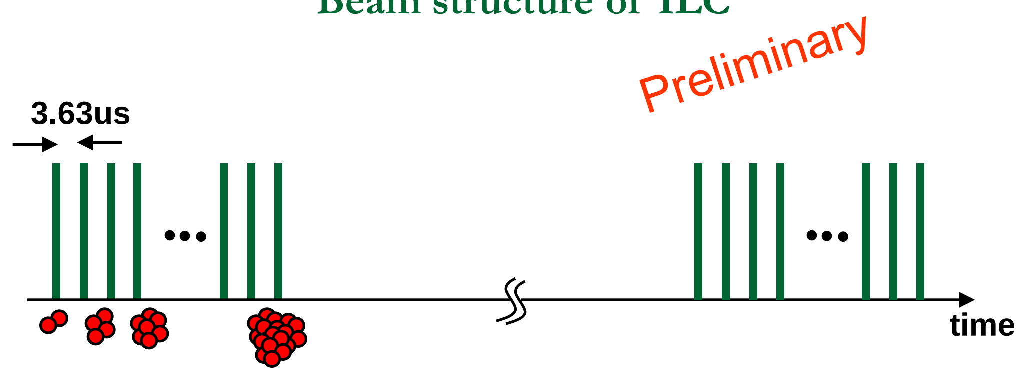
Hit density ~1 hits cm^{-2} BX^{-1}
(Preliminary from Qing Lei)

Beam structure of CEPC

- 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
    - Pretzel scheme: 3.63μs, 48buches/beam
    - Local double ring scheme: 48buches/trains.196ns buche spacing, 9.4us/182us
  - No Gating device with open and close time
  - Continuous device for ions



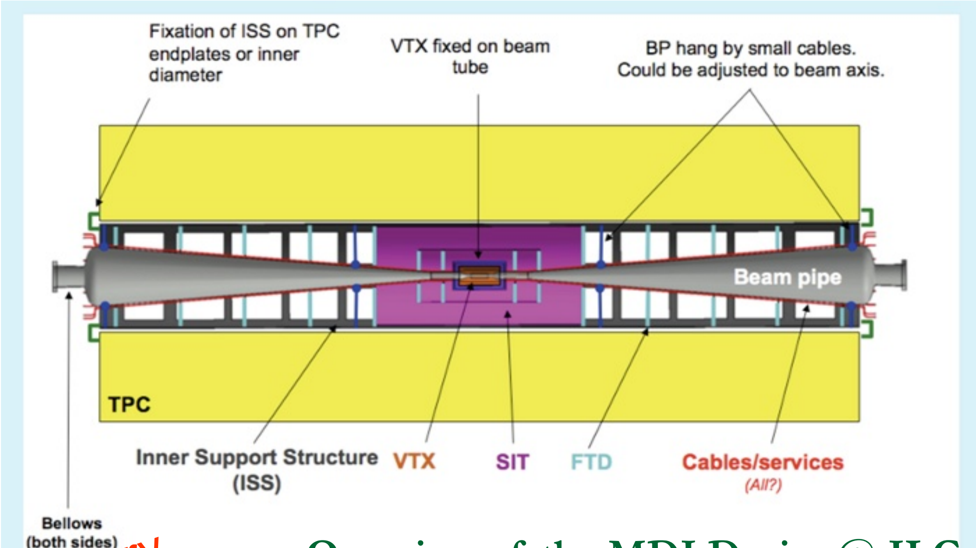
Beam structure of ILC



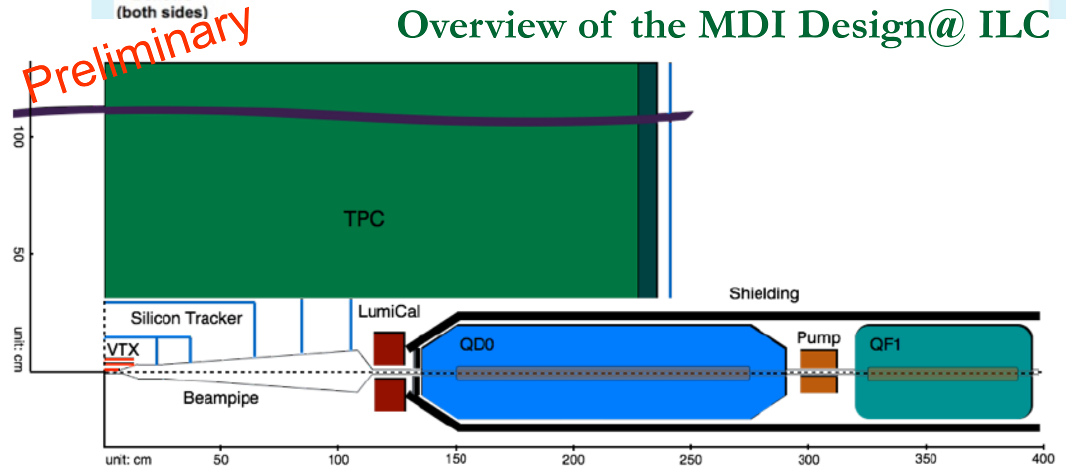
Beam structure of CEPC

MDI design for TPC

- 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

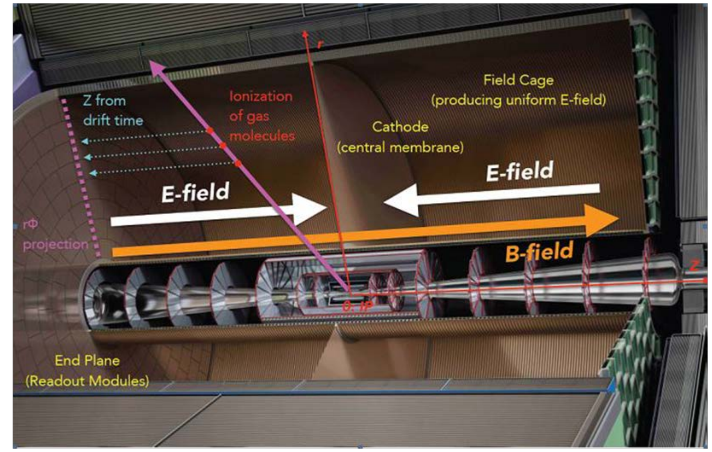
Obvious E/B distortion!

Current R&D activities

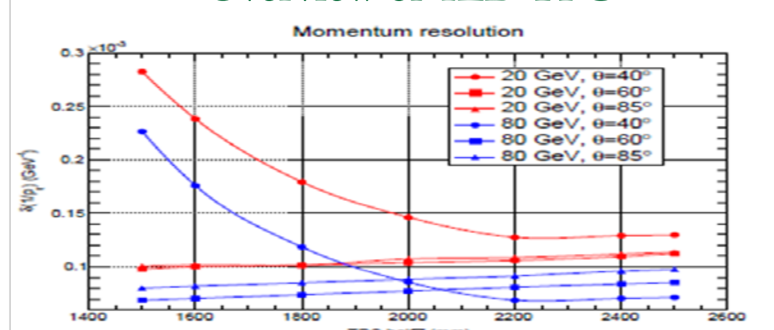
Detector baseline design

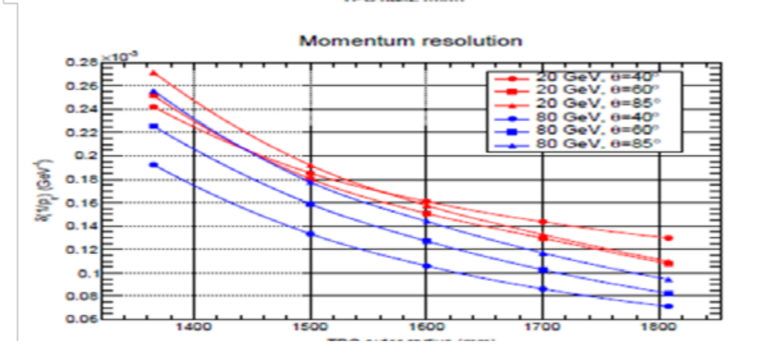
- TPC detector
  - Detector module
  - Drift chamber
  - Electronics
  - Working gas supply

- Simulation base on ILC design
  - Change Half Z@1.805m outer radius
  - Change outer radius@2.35m Half Z
  - Inner radius of 329 mm
  - Pad size: 1mm×6mm
  - Number of tracker:~200
  - B = 3.5 Tesla
  - With multiple scattering and smearing



Overview of ILD TPC





Momentum resolution VS Length, Radius
(Preliminary from Li Bo)

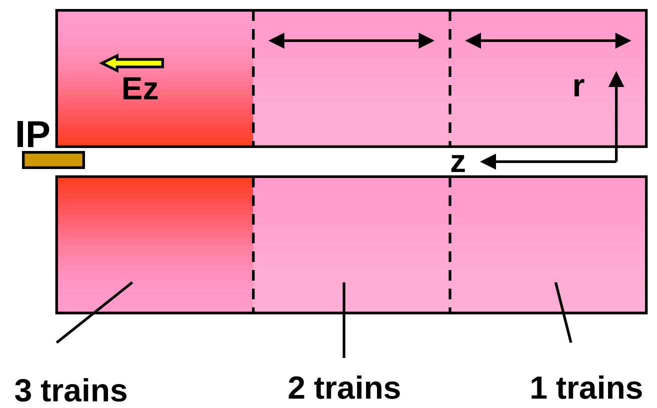
Simulation: Ion back flow

In the case of ILD-TPC

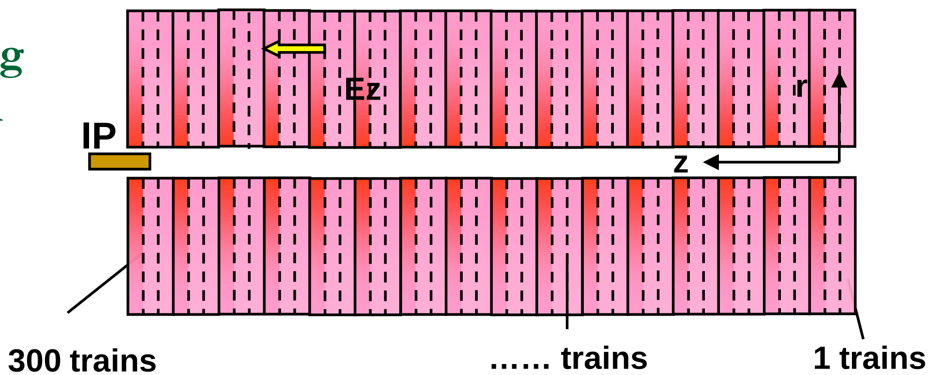
- Distortions by the primary ions at ILD are negligible
- Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume Shorter working time
- 3 discs co-exist and distorted the path of seed electron
- The ions have to be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

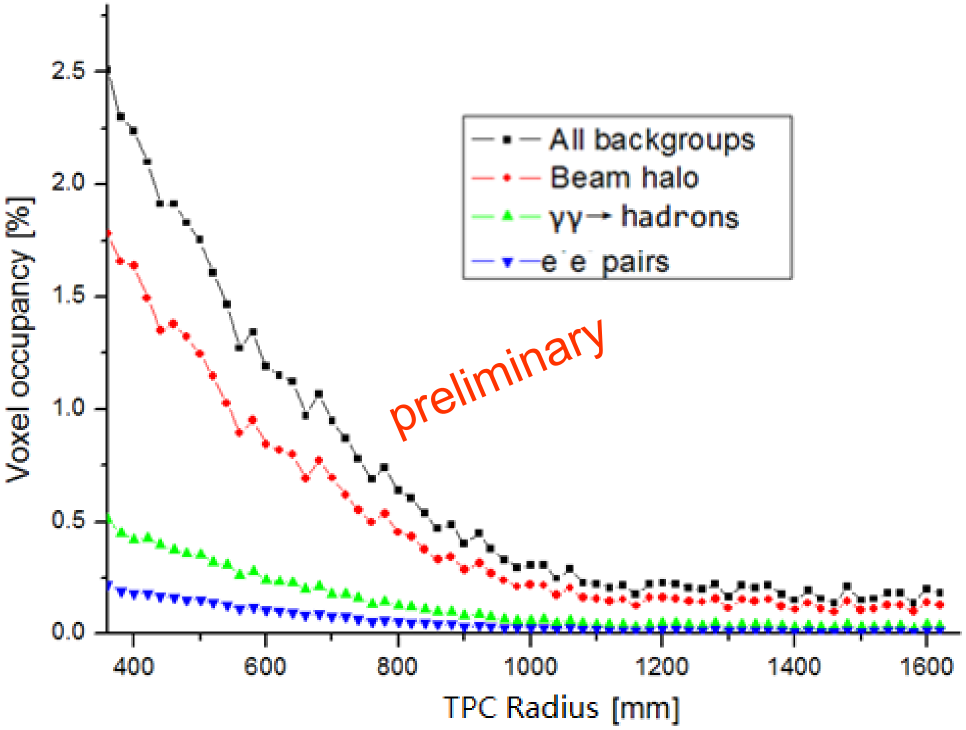


Amplification ions@CEPC

Occupancy Simu.@250GeV CEPC

Supported by 高能所创新基金

- Voxel occupancy
  - Very important parameter of TPC could determine to use or NOT as the tracker detector
  - No consideration for the beam collimator and synchrotron radiation, the value might larger



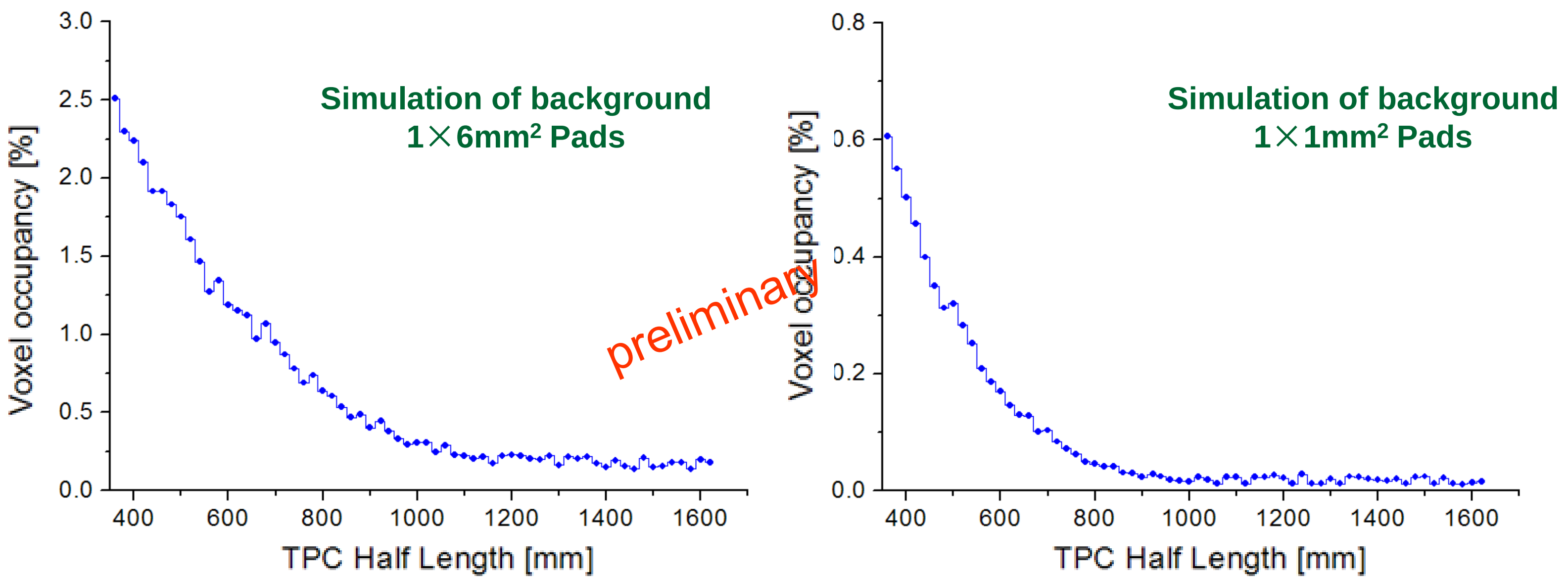
TPC voxel occupancy simulated in TPC radius

Simulation of occupancy

Supported by 高能所创新基金

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



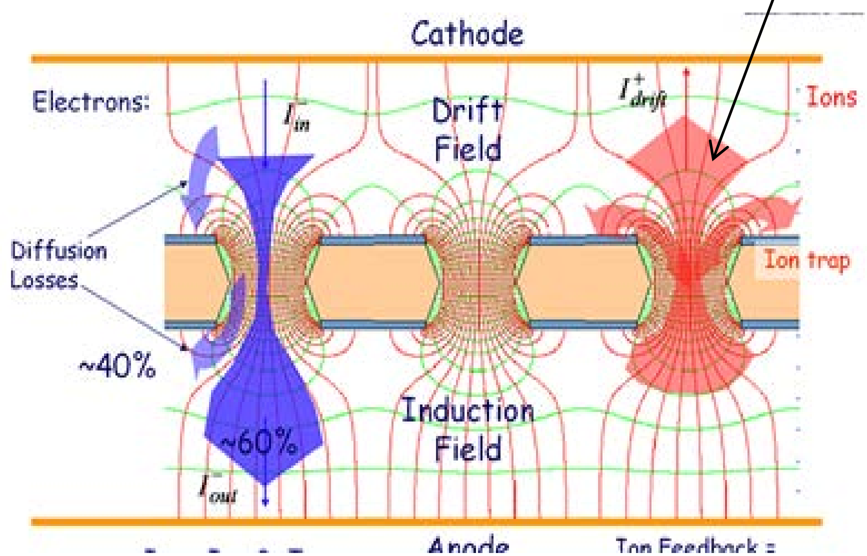
Preliminary of occupancy

New ideas for the ions?

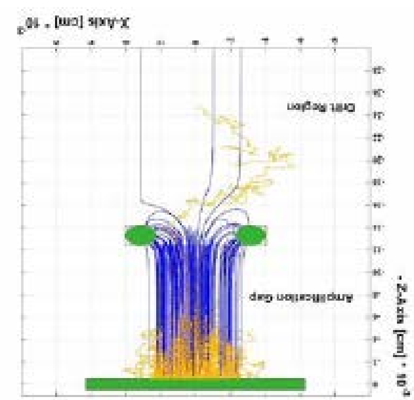
- GEM detector could be as the amplification detector, Micromegas could be as the amplification device too.
- GEM detector could be reduced the IBF as the gating, Micromegas could be decrease the IBF too.

- 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

Ions



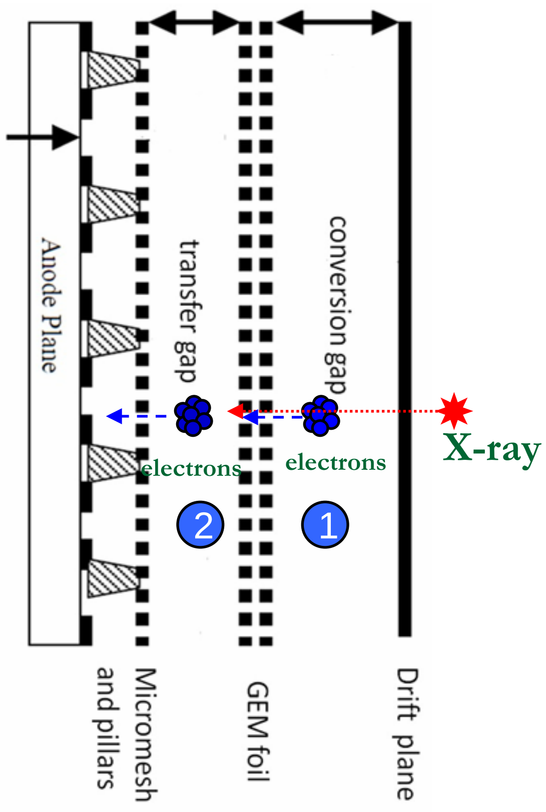
IBF of GEM



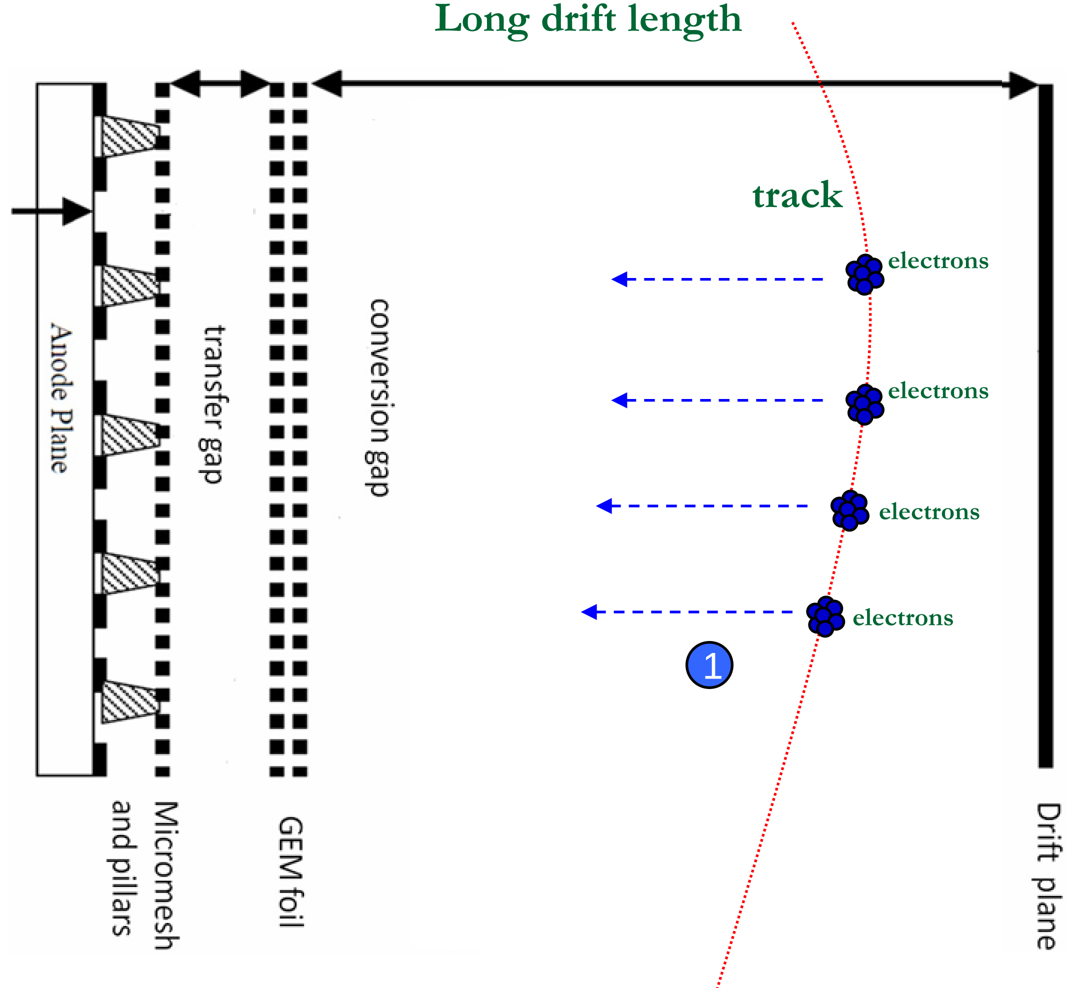
IBF of Mciromegas

Hybrid structure module option

Short drift length



Long drift length



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

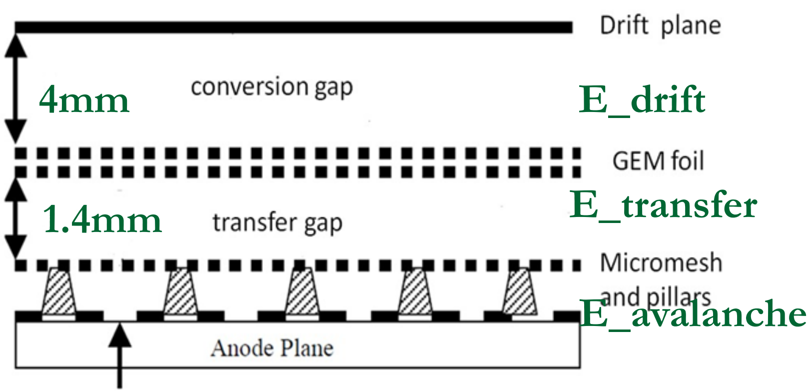
Hybrid detector measurement

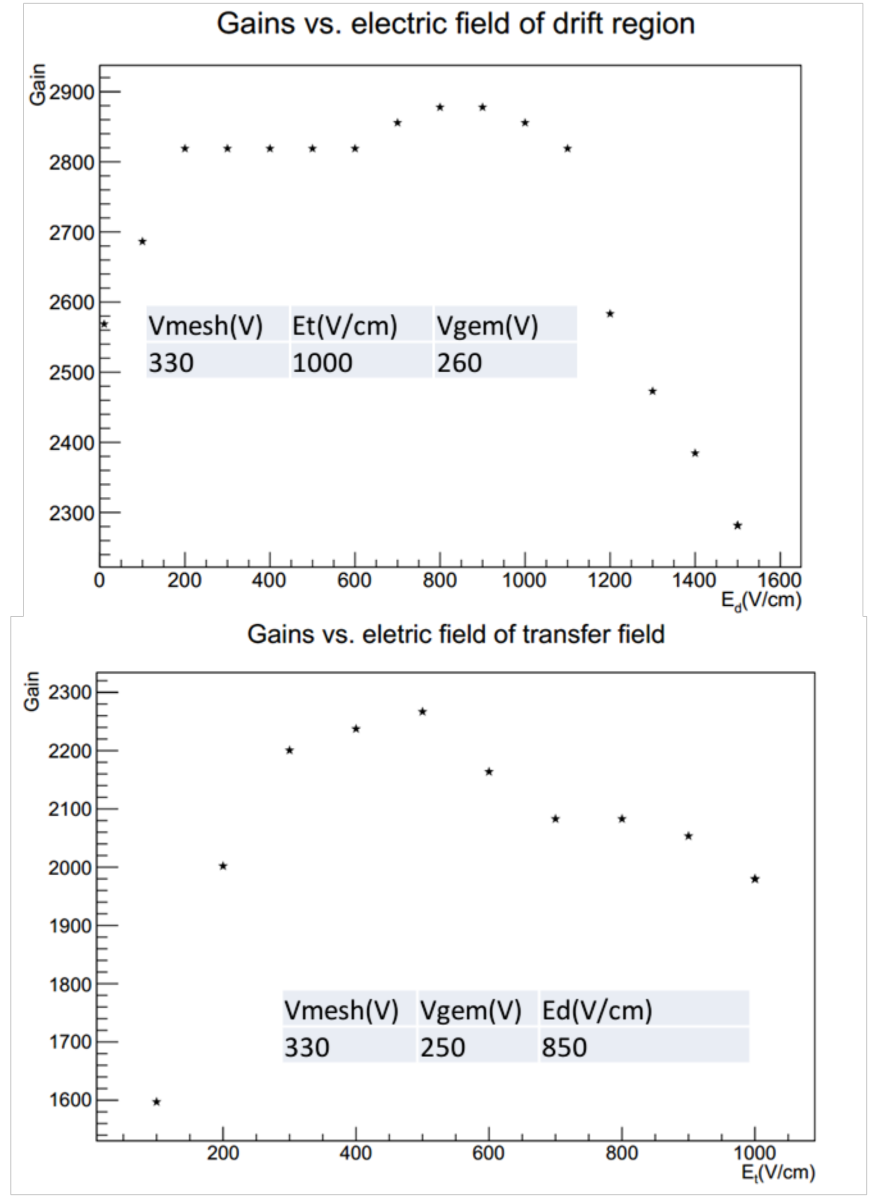
Supported by 高能所创新基金

Photos of the measurement with X-tube

Hybrid structure module

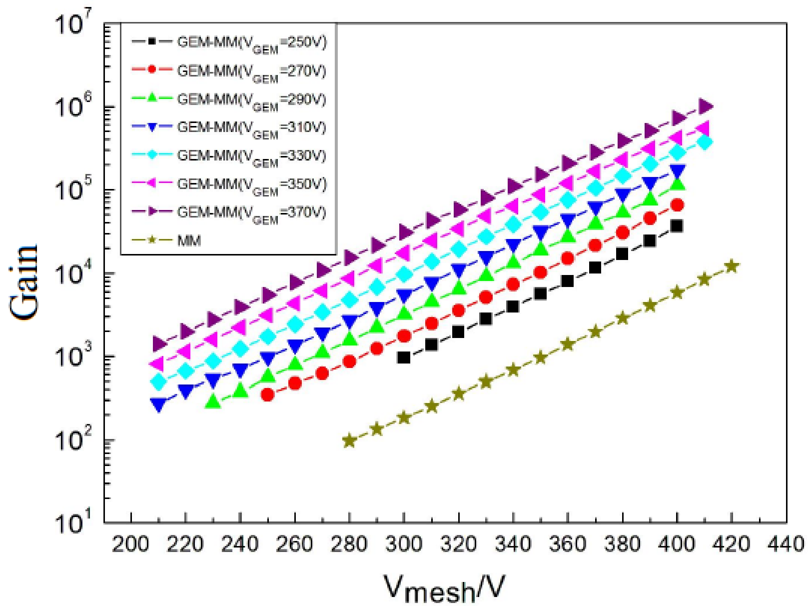
- Optimized operating voltage
  - To achieve the higher electron transmission in the hybrid structure module
  - The ratio of E_avalanche and E_transfer of Micromegas detector is 216.8
  - The ratio of E_transfer and E_drift of GEM detector is 67.08

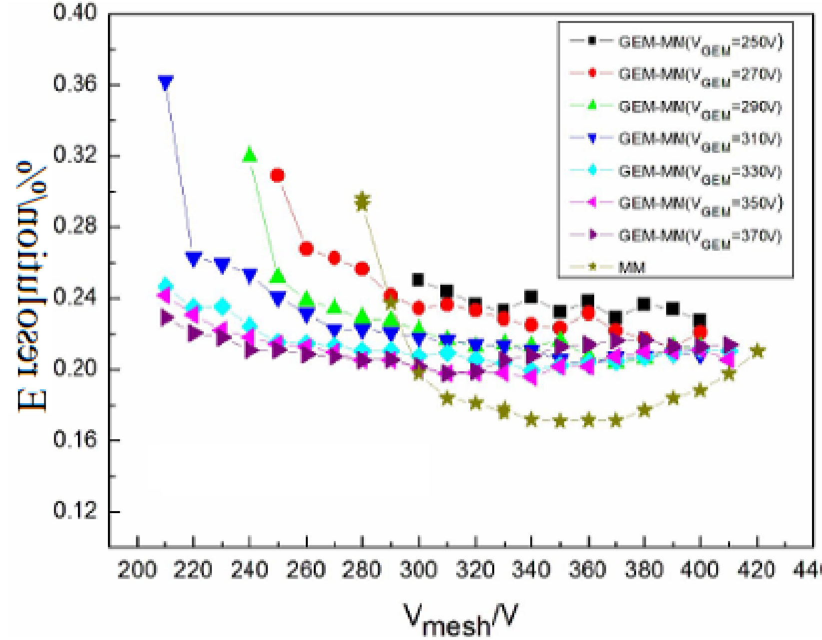




Electron transmission in GEM and Micromegas

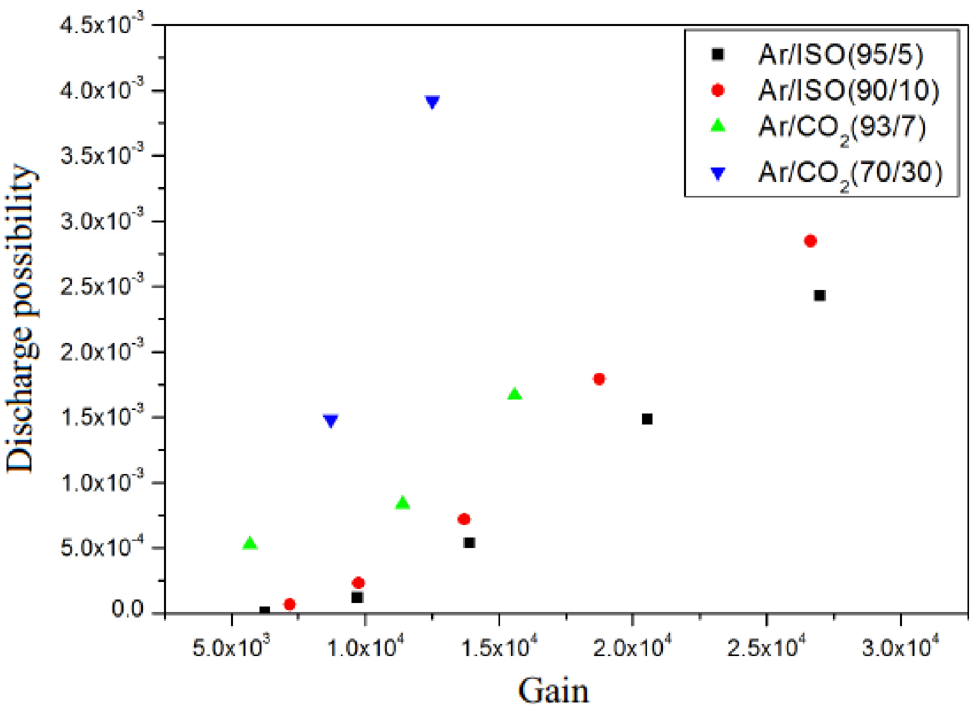
Gain and energy resolution

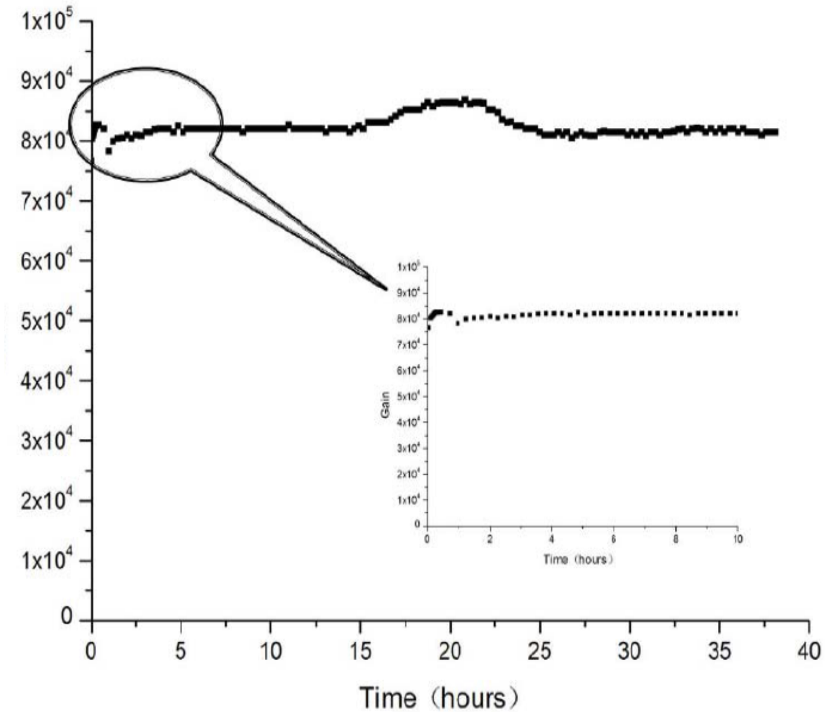




- Test with Fe-55 X-ray radiation source
  - Reach to the higher gain than standard Micromegas with the pre-amplification GEM detector
  - Similar Energy resolution as the standard Micromegas
  - Increase the operating voltage of GEM detector to enlarge the whole gain

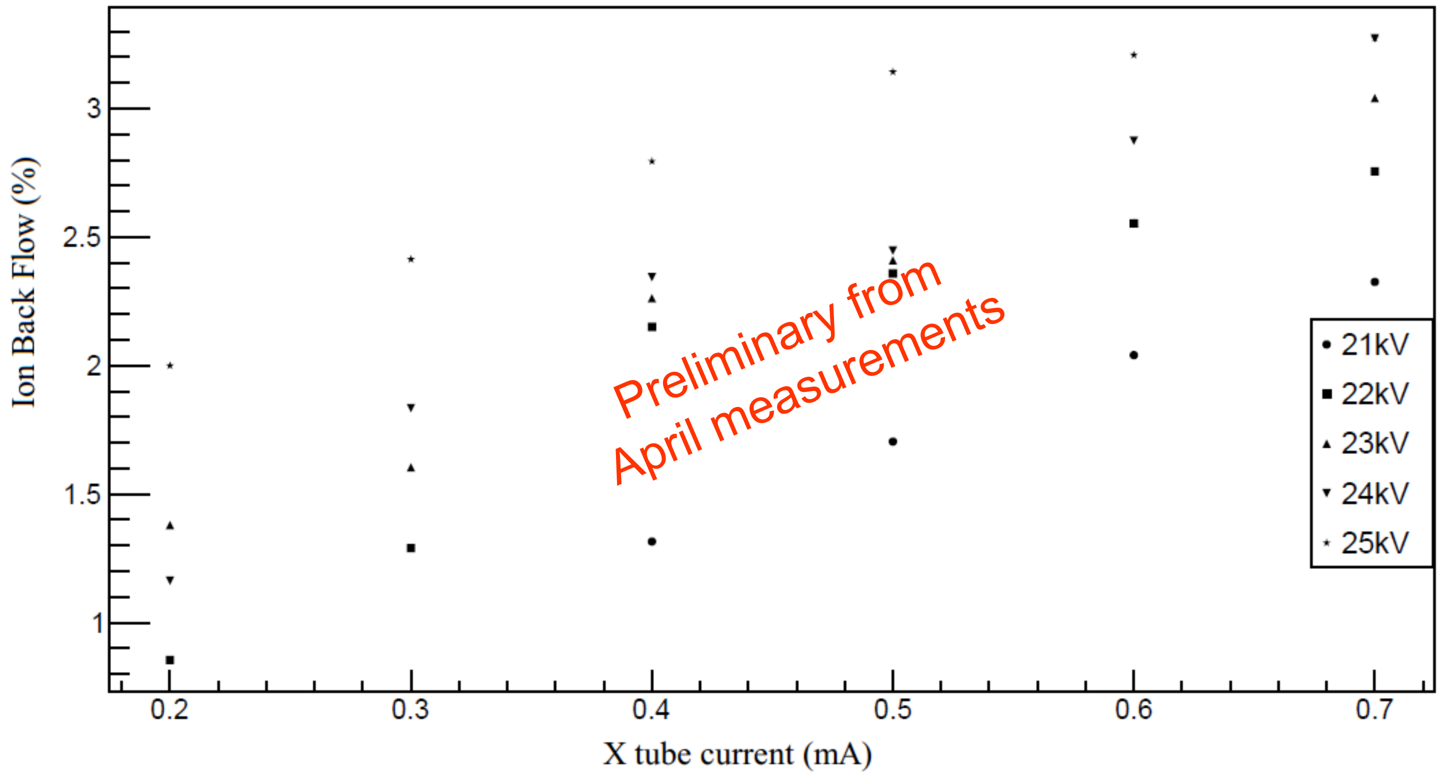
Working gas and duration time





- Test with Fe-55 X-ray radiation source
  - Discharge possibility could be mostly reduced than the standard Bulk-Micromegas
  - Discharge possibility of hybrid detector could be used at Gain~10000
  - To reduce the discharge probability more obvious than standard Micromegas
  - At higher gain, the module could keep the longer working time in stable

IBF preliminary result

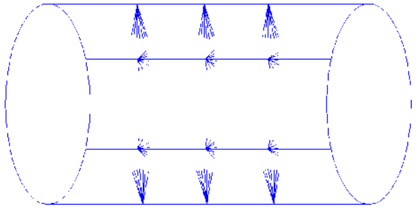


- Test with X-tube@21kV~25kV using the Hybrid module
  - Charge sensitive preamplifier ORTEC 142IH
  - Amplifier ORTEC 572 A
  - MCA of ORTEC ASPEC 927
  - Mesh Readout
  - Gas: Ar-iC4H10(95-5)
  - Gain: ~6000

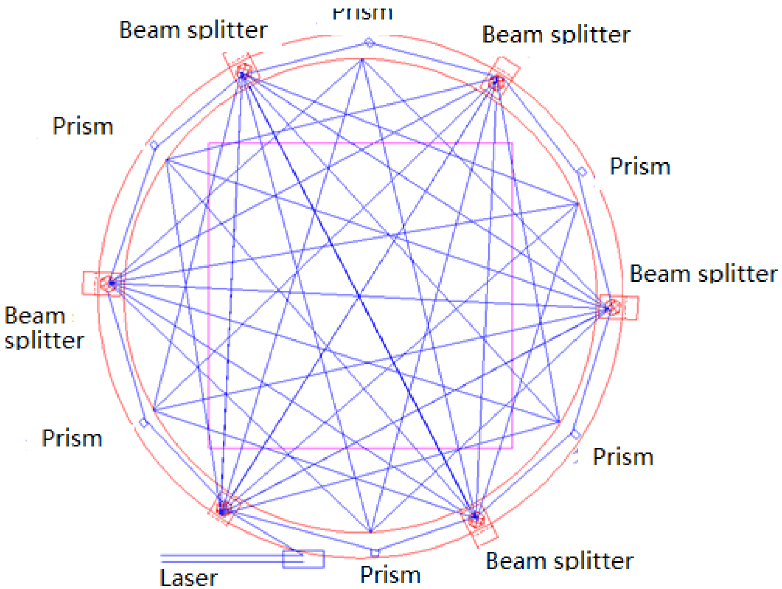
Laser calibration system for TPC modules

Supported by the State Key Program of National Natural Science of China

- Principle of laser for TPC detector
  - The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
- To reduce the distortion effect
  - E×B effect study
  - Drift Velocity measurement
- Laser features for TPC
  - λ = 266 nm or E = hν = 4.66 eV
  - Energy: ~100 uJ/pulse
  - Duration of pulse: 5 ns
- Advantages
  - Transportable and flexible test beam setup
  - Good resolution in space and time
    - No production of σ-rays
    - No multiple scattering
  - No curvature in magnetic fields
  - Ionisation density controllable and small fluctuation
  - Simple beam reflection similar to light



Laser in Drift length

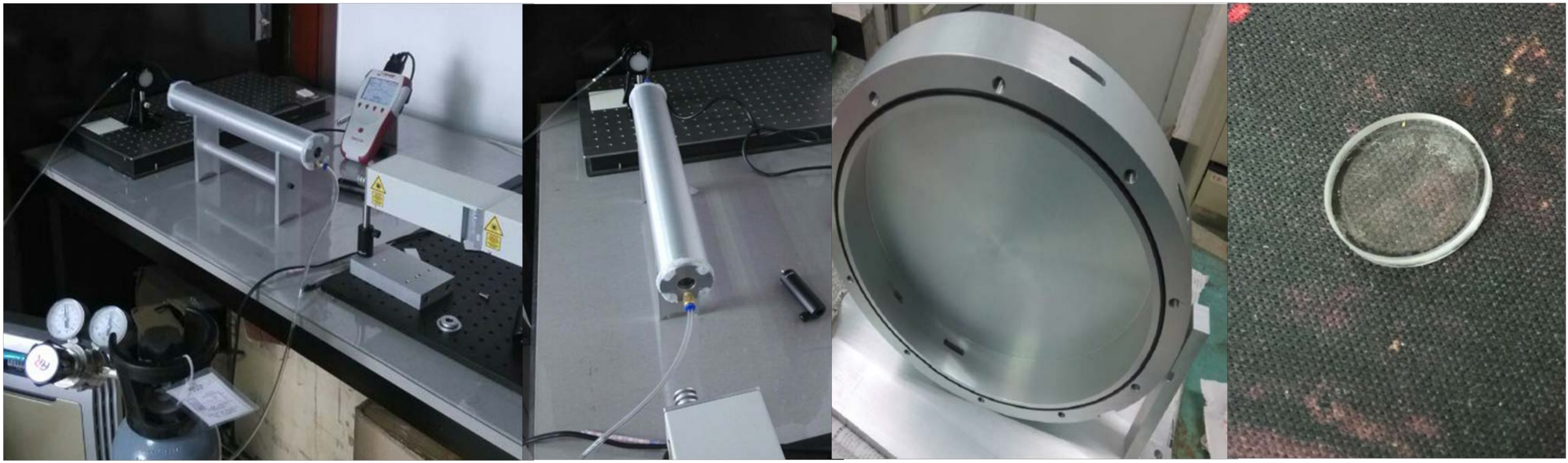


Laser profile map in TPC

First step: study on the laser and design prototype

Supported by the State Key Program of National Natural Science of China

- Laser transmissive window material@266nm
  - Nano SG120-20 Laser machine
  - Windows materials: Mylar foil, Kapton, PE plastic, Artificial sapphire(Al_2O_3), Fused silica
  - Fused silica (JS2) : light transmittance 80%~90%
  - Working gas with fused silica windows: $Ar+CO_2$, light transmittance 80%~90%
- Design and test
  - Design and setup the prototype with the fused silica windows
  - Measurement the GEM modules using 266nm laser



266nm Laser test photos

Common efforts on IBF R&D

Collaboration for the future electron-positron colliders:

CEA Scalay (France)

IHEP, Tsinghua Univ., CIAE, Shandong Univ.,

Lanzhou Univ., UCAS (China)

Aleksan Roy (Saclay)
GAO Yuanning (TH)
QI Huirong (IHEP)

Targets:

- Simulation and optimize the Hybrid modules of TPC with the active area of $100mm^2 \sim 200mm^2$
- R&D of IBF used UV light
  - Goal: ~0.1% IBF, Resistive Micromegas modules, Hybrid modules
- Assembled Bulk Micromegas detector
- Toward CEPC CDR
- …

Common efforts on Laser calibration R&D

Collaboration for the future electron-positron colliders:

Tsinghua Unviversity,Beijing

IHEP, Beijing

LI Yulan (THU)
DENG Zhi (THU)
QI Huirong (IHEP)

Targets:

- **Simulation and optimize the calibration methods and the TPC detector for CEPC**
- **Laser optical design**
  - **Wave length: 266nm, Optical power: ~15mJ, independent optical tracks**
- **TPC Prototype design with Laser calibration**
  - **Readout active area: ~200mm^2, Drift length: ~500mm**
  - **Position resolution: ~100um, Calibration for Drift velocity. Stability tests**
- **ASIC electronic readout**
  - **Goal: ~32Chs/CHIP, Channels: ~1K**

Summary and outlook

- **Baseline design for the preCDR with an ILD-like sturcture**
- **Critical requirements for CEPC**
  - **Beam structure**
  - **Obvious distortion**
  - **Complex MDI design**
- **Some activities and simulations**
  - **Simulation of the occupancy of the detector, the hybrid structure gaseous detector's IBF**
  - **Hybrid structure detector**
  - **Some preliminary IBF results**
  - **Design and test of the detector prototype for the laser calibration**
- **The international workshop of the CEPC TPC detector will be scheduled in September, 2016.**
- **And next development…**

Towards CEPC TPC CDR– 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

Critical Challenge

- **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

Thanks very much for your attention !