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

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on behalf of the CEPC TPC working group

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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 3.5 Tesla
  - Position resolution in $r\Phi$
  - Pad pitch / no. padrows
  - Performance

- 2-hits resolution in $r\Phi$

**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 should have to be neutralized

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
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
  - 28 pad rows (176-192 pads/row)
  - 5152 pad per module
  - 10mm wide frame3 at top/bottom
  - No frames at sides
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, 48 bunches/beam
    - Local double ring scheme: 48 bunches/trains, 196ns bunch spacing, 9.4us/182us
  - No Gating device with open and close time
  - Continuous device for ions
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
  - $E \times B$ effect
  - UV Laser alignment and calibration for readout module, pad, PCB and assembled

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
Occupancy Simu.@250GeV CEPC

- 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

- **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

Simulation of background

- **1×6mm² Pads**
  - CLIC_ILD ~30%@3TeV
- **1×1mm² Pads**
  - CLIC_ILD ~12%@3TeV

NO TPC Options!

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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
Hybrid structure module option

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

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 $E_{\text{avalanche}}$ and $E_{\text{transfer}}$ of Micromegas detector is 216.8
  - The ratio of $E_{\text{transfer}}$ and $E_{\text{drift}}$ 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

Graph: Preliminary from April measurements
Laser calibration system for TPC modules

- 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
  - \( E \times B \) effect study
  - Drift Velocity measurement
- Laser features for TPC
  - \( \lambda = 266 \text{ nm} \) or \( E = h\nu = 4.66 \text{ eV} \)
  - Energy: \( \sim 100 \text{ uJ/pulse} \)
  - Duration of pulse: 5 ns
- Advantages
  - Transportable and flexible test beam setup
  - Good resolution in space and time
    - No production of \( \sigma \)-rays
    - No multiple scattering
  - No curvature in magnetic fields
  - Ionisation density controllable and small fluctuation
  - Simple beam reflection similar to light

Supported by the State Key Program of National Natural Science of China
First step: study on the laser and design prototype

- Laser transmissive window material@266nm
  - Nano SG120-20 Laser machine
  - Windows materials: Mylar foil, Kapton, PE plastic, Artificial sapphire (Al₂O₃), Fused silica
  - Fused silica (JS2): light transmittance 80%~90%
  - Working gas with fused silica windows: Ar+CO₂, light transmittance 80%~90%

- Design and test
  - Design and setup the prototype with the fused silica windows
  - Measurement the GEM modules using 266nm laser

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

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)

Targets:
- Simulation and optimize the Hybrid modules of TPC with the active area of 100mm$^2$ ~ 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 University, Beijing
IHEP, Beijing

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: ~200mm², Drift length: ~500mm
  - Position resolution: ~100um, Calibration for Drift velocity. Stability tests
- ASIC electronic readout
  - Goal: ~32Chs/CHIP, Channels: ~1K

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Summary and outlook

- Baseline design for the preCDR with an ILD-like structure
- 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 device reduced ions feedback
  - 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
Thanks very much for your attention!