Status and plan of the hybrid detector module for CEPC TPC

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Outline

- Critical challenges of CEPC TPC
- Some activities and progress
- Plan of some real activities
CEPC and its beam structure

Circular $e^+e^-$ Higgs (Z) factory two detectors, 1M ZH events in 10yrs
$E_{cm} \approx 240$ GeV, luminosity $\sim 2 \times 10^{34}$ cm$^{-2}$s$^{-1}$, can also run at the Z-pole

Pretzel Scheme
- Baseline design in pre-CDR
- 48 bunches / beam
- Colliding every $3.6\mu s$, continuously
  →Power pulsing not applicable

Partial Double-ring Scheme
- Crab-waist collision to reduce beam and AC power
- Avoiding pretzel scheme to increase the flexibility and luminosity
- 196ns bunch spacing
- 48 bunches / train
- Duty cycle: $9.4\mu s/181\mu s$

Reference: CEPC/SppC with ILC (FCC), J. Gao, LCWS 2015, Nov. 2-6, 2015, Whistler, Canada
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.
Critical challenges of CEPC-TPC

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

- 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

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

TPC as one option for CPEC-TPC YES or NO

To reduce IONS
To reduce distortion

~100um positron resolution with calibration

2015~2016, some activities for the critical challenges
- Some activities and progress
  - Simulations -
CEPC Detector-TPC

- Simulation
- Refer to ILD
- For CEPC
- Occupancy
- Gas mixture
- Ion back flow

Choosing a gas mixture – simu.

- Faster drift velocity \( v_d \approx 300 \text{ cm/s} \)
- Refer to T2K gas
- Ar/CO2/CF4/iC4H10/nC5H12/C2H6

- Defined:
  \[ f_{\text{Gas}} : \text{Ar-CF4-C2H6} = 92:7:1 \]

Drift velocity \( 1T, 0 \text{ atm, } 20\text{C} \)

Requirements of Ion Back Flow @CEPC

- Electron:
  - Drift velocity \( \approx 6-8 \text{ cm/s@200V/cm} \)
  - Mobility \( \mu \approx 30-40000 \text{ cm}^2/\text{V.s} \)

- Ion:
  - Mobility \( \mu \approx 2 \text{ cm}^2/\text{V.s} \)
  - in a “classical mixture” (Ar/Iso)

Position resolution of the TPC function

- Evaluation of track distortion due to space charge effects of positive ions

Simulated drift velocity in different gas mixture
New ideas for the ions?

- Our group was asked to “think” on an alternative option for CEPC TPC concept design
- And we did our best …
- We proposed and investigated the performance of a novel configuration for TPC gas amplification: GEM plus a Micromegas (GEM+Micromegas)
- Hybrid micro-pattern gaseous detector module

- 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
  - Low material budget of the module
IBF simulation

- Garfield++/ANSYS to simulate the ions back to drift
  - GEM and Micromegas Module using ANSYS
  - Record the ions to drift layer, mesh layer, and sensitive layer

Ions not actually drift along electric field lines
IBF simulation

- Garfield++/ANSYS to simulate the ions back to drift
  - 350LPI/ 420LPI/ 500LPI/ 1000LPI
  - $E_a$ is electric field of amplifier of Micromegas

![Graph showing Electric field of amplifier VS Electric field of Drift](image)
IBF simulation

- Garfield++/ANSYS to simulate the ions back to drift
  - Standard GEM module (70-50-70)

Voltage of the GEM detector

GEM 70-50-70 (micrometer)
Some activities and progress

- Experiment
- Collaboration
CEPC Detector-TPC

- Minimize the effect of ion backflow in TPC and test the new module

Test of the new module

- Test of GEM+Micromegas module
  - Assembled with the GEM and Bulk-Micromegas
  - Active area: 50mm × 50mm
  - X-tube ray and X-ray radiation source
  - Simulation using the Garfield
  - Ion back flow with the higher X-ray: from 1% to 3%
  - Stable operation time: more than 48 hours
  - Separated GEM gain: 1~10

- Calibrate the tracker using laser and design the prototype

Laser calibration for TPC prototype

- Goals of laser for TPC detector
  - The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
  - Drift velocity, gain uniformity
  - To reduce the distortion effect
  - E × B effect study
  - Drift Velocity measurement
  - Good resolution in space and time
  - No production of γ-rays
  - No multiple scattering

- Baseline design (DONE)
  - Nd:YAG laser device
  - λ = 266 nm or E = hν = 4.66 eV
  - Energy: ~100 uJ/pulse
  - Duration of pulse: 5 ns
  - Active area: 200mm × 200mm
  - Drift length: 500mm
  - Outer diameter: ~400mm
  - GEM readout

- Laser map design
  - The assembled module test with 266nm laser
CEPC Detector-TPC

- **Promote domestic cooperation and exchanges**
- **Participate in the international collaboration group (ILC-TPC)**

**Participate in the collaboration group**

**Collaboration for the IBF R&D:**
- CEA Scalay (France)
- IHEP, Tsinghua Univ. (China)

- **Aleksan Roy (Saclay)**
- **GAO Yuanning (THU)**
- **QI Huirong (IHEP)**

**Collaboration for the Beam test with Asia Module:**
- KEK (Japan)
- DESY (Germany)
- IHEP, Tsinghua Univ. (China)

- **Keisuke Fujii (KEK)**
- **Schrader, Andrea (DESY)**
- **GAO Yuanning (THU)**
- **QI Huirong (IHEP)**

**Targets:**
- **R&D of IBF used UV light**
  - Goal: ~0.1% IBF, Resistive Micromegas modules, Hybrid modules
- **TPC Prototype design with Laser calibration**
  - Readout active area: ~200mm², Drift length: ~500mm
- **Beam test experiment and data analysis**
  - Fixed date: 30, Oct./2016~14, Nov./2016
  - GEM module with the field shaper in 1.0 Tesla in PCMAG
- **Toward CEPC CDR**
Plan of some real activities

Next steps for R&D

Collaboration
Next steps: R&D

- The present situation is somewhat clear
  - Some works started (high priority for Micromegas+GEM, because of excellent backflow suppression)
  - The present module are used in several mounting cycles. The new module will be assembled for more test.
  - Do we have the resources to switch to a bigger module? (Almost YES) This would take at least ~1 years.
  - Pre-R&D projects should be do well in next five years including the TPC prototype.
  - All designs and materials would be considered for the beam test in the magnetic field.
  - More simulations would be started with some comments from ILC-TPC’s experts. (Prof. Fujjii, Paul, Jochen, Sugiyama….)
Next steps: Collaboration

- Increasing interest and getting more collaboration in IHEP for the hybrid gaseous detector R&D
  - Saclay-Tsinghua-IHEP lab activities
  - Meeting at Tsinghua/Saclay/IHEP on October 14
  - Real progress in the resistive Micromegas and bulk Micromegas with Saclay
  - Participation in the beam test experiments in DESY-KEK on 1,Nov.~14,Nov.
  - Starting to learning and joining in the analysis for the raw data with Japanese colleagues

- On the longer term, R&D should continue on IBF suppression in the MPGD detector
Summary

- Critical requirements for CEPC TPC modules
  - Beam structure
  - Continuous Ion Back Flow

- Some activities for the module
  - Simulation of the occupancy of the detector, the hybrid structure gaseous detector’s IBF
  - TPC gas amplification setup GEM+MM investigated as a high rate TPC option
  - Some preliminary IBF results

- Some plans in next years
Thanks very much for your attention!