Physics and Detector Status Report

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Institute of High Energy Physics
Chinese Academy of Sciences

Outline

- Plans for CDR
- Physics and simulation
- Machine Detector Interface
- Pixel Detector
- TPC Detector
- Calorimeters
- International Collaboration

Plans for CDR

- Goal: Complete CDR by end of 2017 — based on pre-CDR
- Started regular meeting to discuss strategies on what to include

Current R&D

- PDR schemes
- Z-pole requirements

Integration

Examples

Vertex and Si Tracker

TPC

Simulation and Estimation
- Higgs run
- Z-pole run
- Occupancy
- Distortion
- Something could do
- Something could not do

Current R&D
Mechanics and integration
- MDI integration

Alignment and calibration
- Field map in the magnetic
- Alignment used laser
- Distortion correction
- Gas/HV/Readout
- Software/correction methods

(For any module and any track reconstruction)

Simulation group

- Provides:
  - Detector geometry design (ILD-like detector)
  - Software chain
  - Physics potential studies
    - Higgs: Mostly done. Benchmarks will be used to iterate new geometry
    - Electroweak, flavor physics, …. needs works
- CDR:
  - Benchmark detector geometry and benchmark performances
- Benchmark detector geometry requires several months to be finalized (HCAL layout, PFA performance, integration with reliable MDI?)
  - Manpower is needed here
  - Potential area to include international partners

Physics Benchmarks

Benchmarks	Main observables	Key performances	Status
llH, H->X	Higgs recoil spectrum	Lepton Id efficiency, Tracker intrinsic momentum resolution	Well understood
H+X, H->di photon	Event reconstruction efficiency, Higgs invariant mass peak width	Tracker Material, Intrinsic ECAL energy Resolution	
ZH->4 jets,	Br(H->bb, cc, gg)	Jet clustering, PFA: Jet Energy Resolution, Jet Flavor Tagging	Studied at CEPC conceptual Detector (CEPC_v1)
vvH, H->di tau	Efficiency of Tau reconstruction with different tau decay mode	PFA separation, Impact parameter resolution	
qqH, H->invisible	Higgs recoil spectrum	PFA: Jet Energy Resolution	
vvH, H->WW->lvqq	Event Reconstruction Efficiency di-jet mass distribution	PFA, Simultaneous reconstruction of Lepton, Jets and Missing Energy	Studied at different Calorimeter Granularity
H+X, H->di muon	Event reconstruction efficiency, Higgs invariant mass peak width	Lepton Id efficiency, Tracker intrinsic momentum resolution	Studied at CEPC conceptual Detector
vvH, H->2 jets	Br(H->bb, cc, gg)	Jet Energy Resolution & Flavor Tagging	
WW->lvqq	W mass	Jet Energy resolution & Systematic controls	Full simulation analysis not accomplished yet

Each analysis will be repeated at different geometry, with full Higgs signal sample (and potentially WW sample)

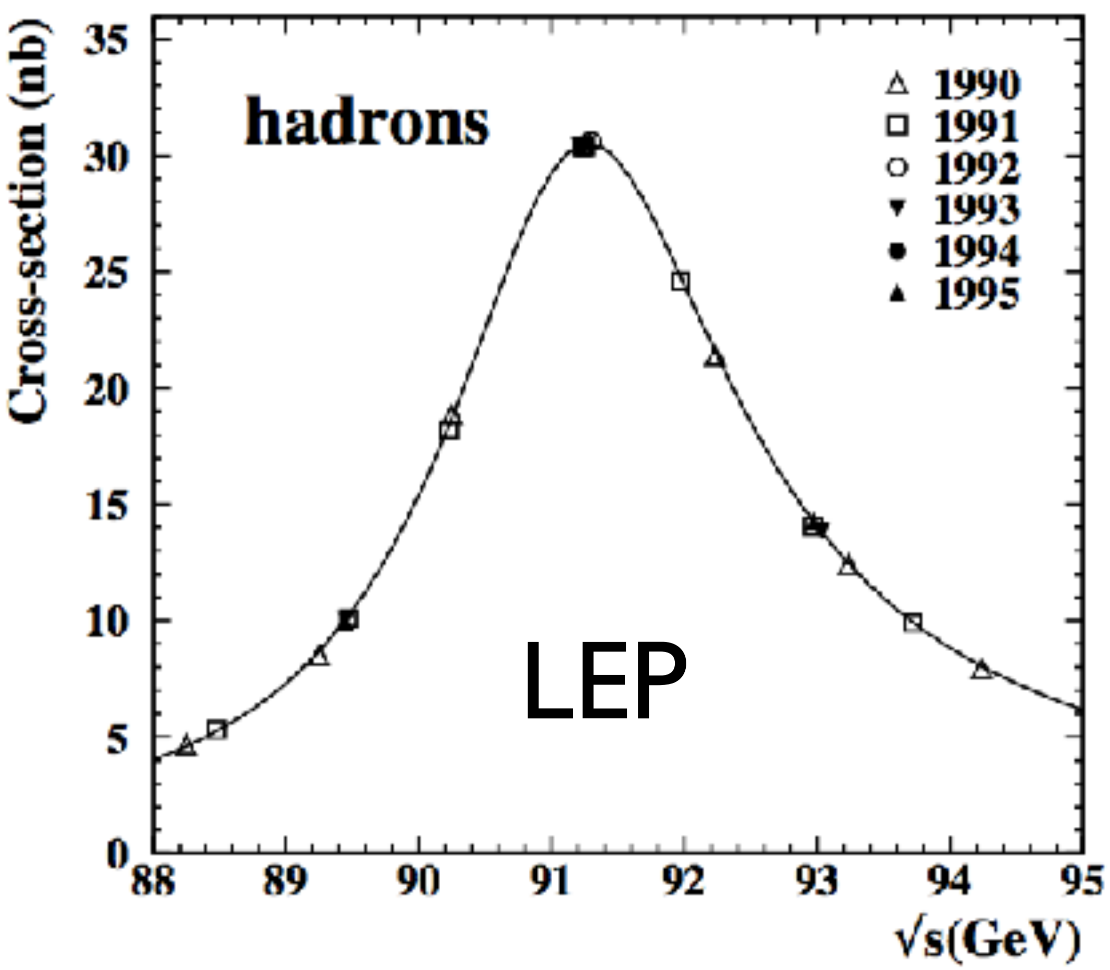
CEPC electroweak physics in pre-CDR study

- Estimated precision on some key measurements in **CEPC Pre-CDR** study were based on projections from LEP and ILC.
  - http://cepc.ihep.ac.cn/preCDR/volume.html
- Plan to update the study for Conceptual Design Report (**CDR**) with full detector simulation - until end of year

Observable	LEP precision	CEPC precision	CEPC runs
m_Z	2 MeV	0.5 MeV	Z lineshape
m_W	33 MeV	3 MeV	ZH (WW) thresholds
A_{FB}^b	1.7%	0.15%	Z pole
$\sin^2\theta_W^{\rm eff}$	0.07%	0.01%	Z pole
R_b	0.3%	0.08%	Z pole
N_ν (direct)	1.7%	0.2%	ZH threshold
N_ν (indirect)	0.27%	0.1%	Z lineshape
R_μ	0.2%	0.05%	Z pole
R_τ	0.2%	0.05%	Z pole

Accelerator impact on Z mass resolution

- Z mass measurement precision (threshold scan method)
  - **LEP** precision : 2.1 MeV
  - **CEPC** expected precision : 500 keV (10^{11} Z)
  - **FCC-ee** expected precision : 100 keV (10^{13} Z)
  - Beam energy uncertainty is major systematics for CEPC and FCC-ee

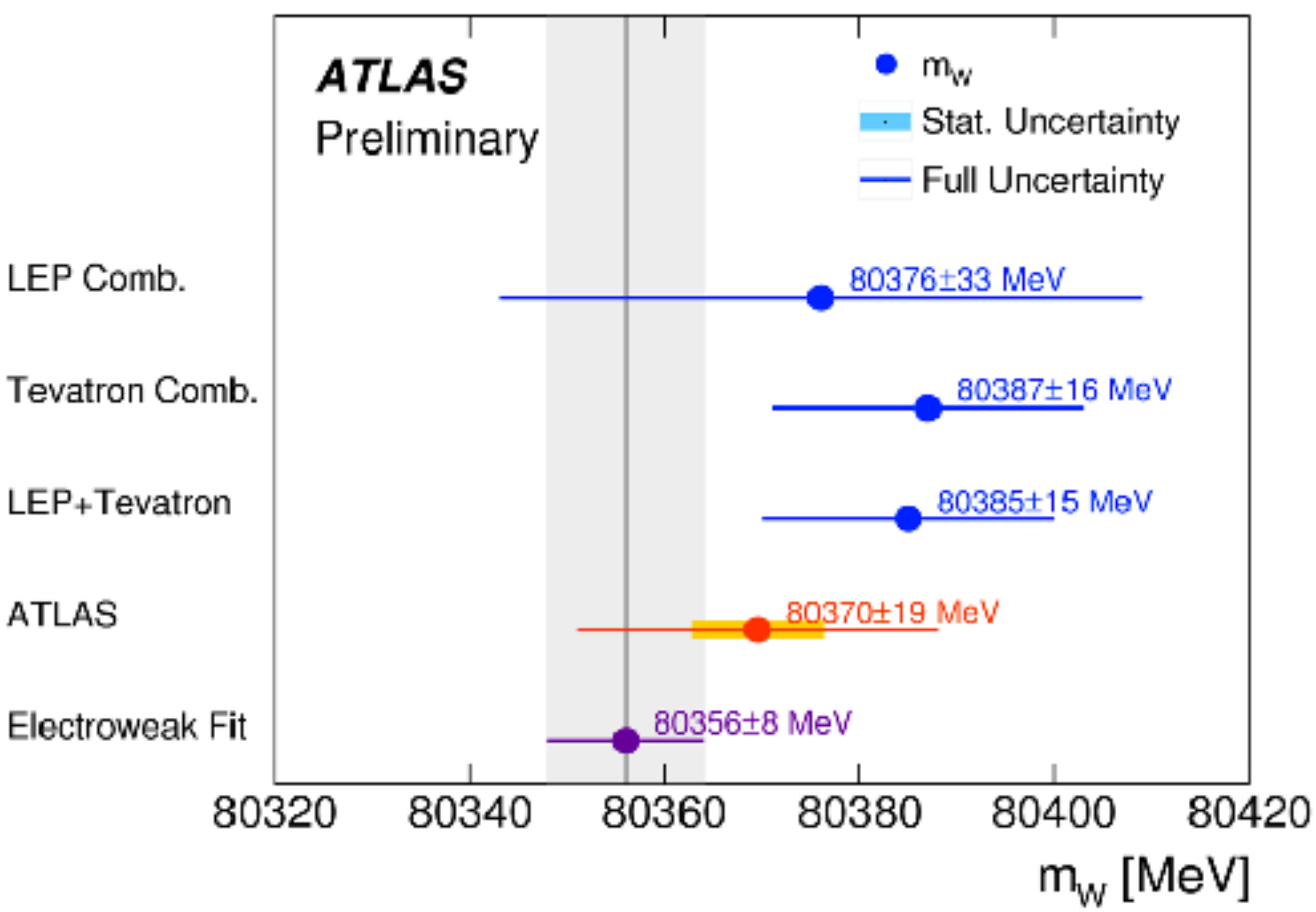


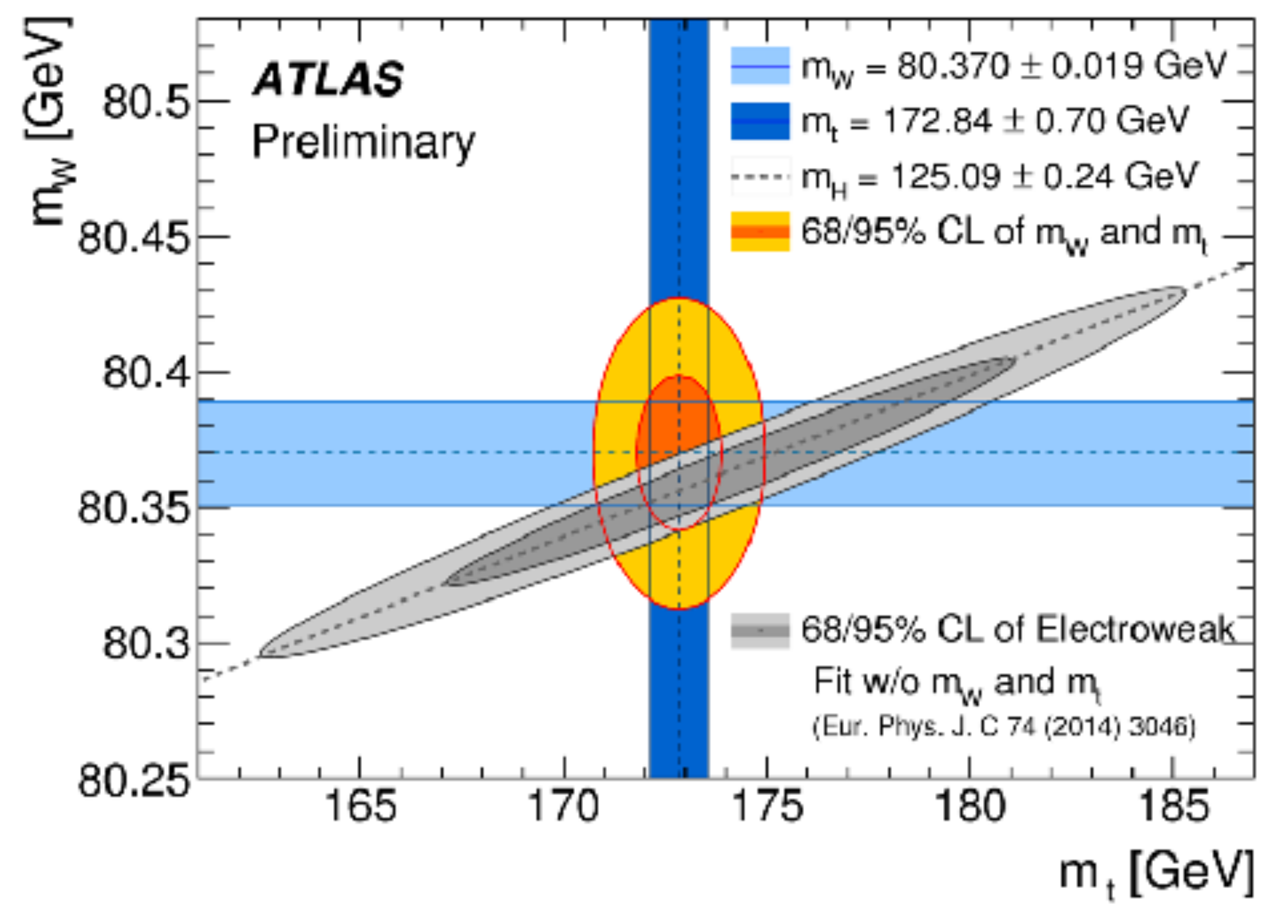
CEPC and FCC-ee Z pole comparison

- Dedicated meeting with **FCC-ee** experts to understand the difference between **CEPC** and **FCC-ee** in the Z pole running scenario
  - **FCC-ee** assumes beam energy measurement can reach 100 keV precision with resonant depolarization method
    - Plan to take more data in Z pole (10^{13} Z) to keep stat uncertainty smaller than systematics
  - Precision of beam energy measurement may have a big impact to Z pole running program.
  - **CEPC** has not decided on beam polarization yet
    - Not sure whether **CEPC** can use resonant depolarization method
  - **CEPC** looking into beam energy measurement with Compton Scattering (BEPC-II approach)
    - Can reach 1 MeV precision from preliminary study
      - preliminary study in G-Y.Tang's talk http://indico.ihep.ac.cn/event/6495/session/4/contribution/29/material/slides/0.pdf
  - **CEPC** also looked at $\mu\mu\gamma$ events (ISR)
    - Can reach a few tens of MeV
      - Studies by Qinglei at: http://indico.ihep.ac.cn/event/6541/; Note in progress.

W mass precision measurement

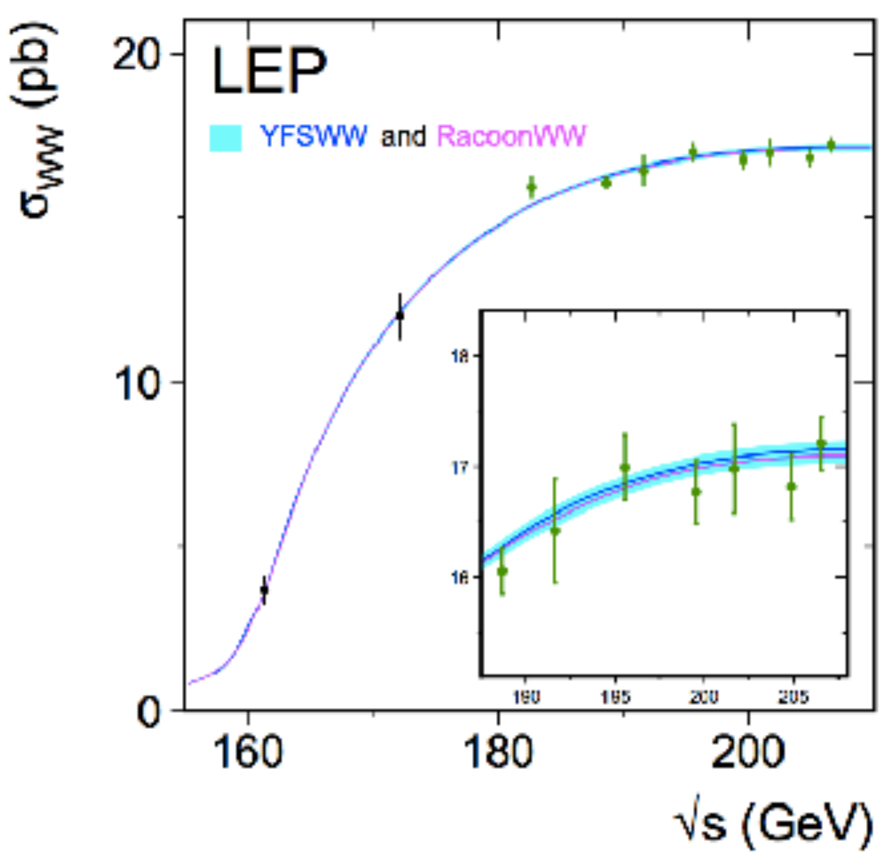
- PDG precision : 80.385±0.015 GeV
- New W mass measurement from ATLAS





W mass measurement

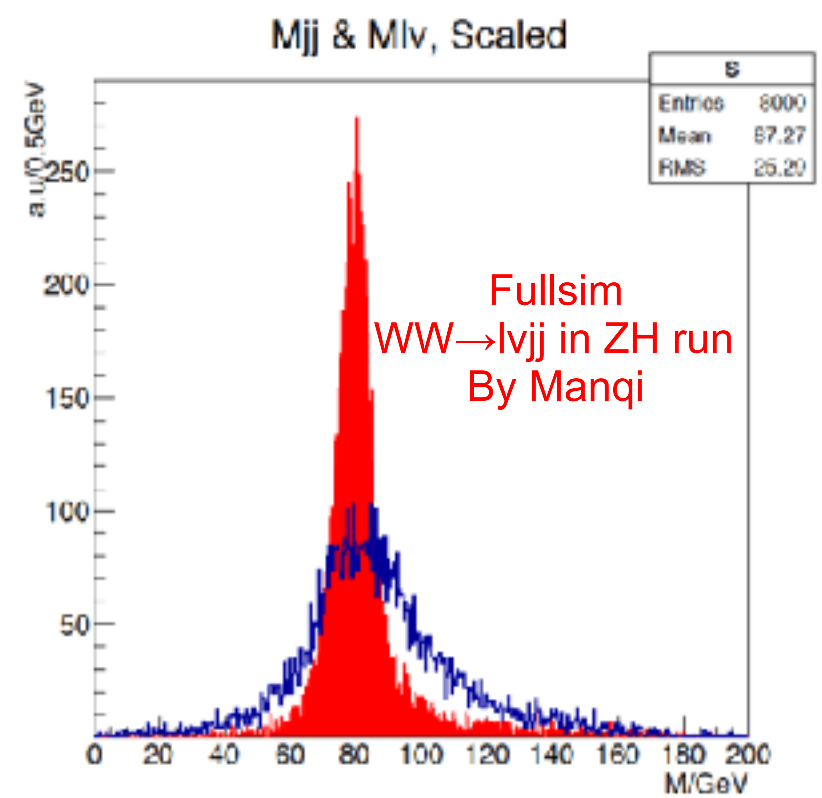
- Two methods for W mass measurements:
  1. **WW threshold scan** ($\sqrt{s}$=160 GeV): beam energy measurement is main systematic
     - Advantage: Very robust method, can achieve high precision
       can reach 500 keV to 1MeV precision.
     - Disadvantage: Higher cost
       requires dedicated runs > 5000fb^{-1} on WW threshold(~160GeV)



W mass measurement (2)

2. **Direct measurement** of the hadronic mass (method for pre-CDR)

- Based on 10^{10} Z → hadrons sample to calibrate jet energy scale (< 3MeV)
- Advantages:
  - No additional cost: measured in ZH runs (sqrt(s) = 250GeV)
  - Higher statistics: 10 times larger than WW threshold region
  - Lower requirement on beam energy uncertainty.
- Disadvantages:
  - Can not get better precision than 3 MeV
    - Precision is about 3-10 times worse than WW threshold scan method.
  - Require Beam momentum measurement in WW run (~160GeV)
    - 10ppm level on P_{beam}

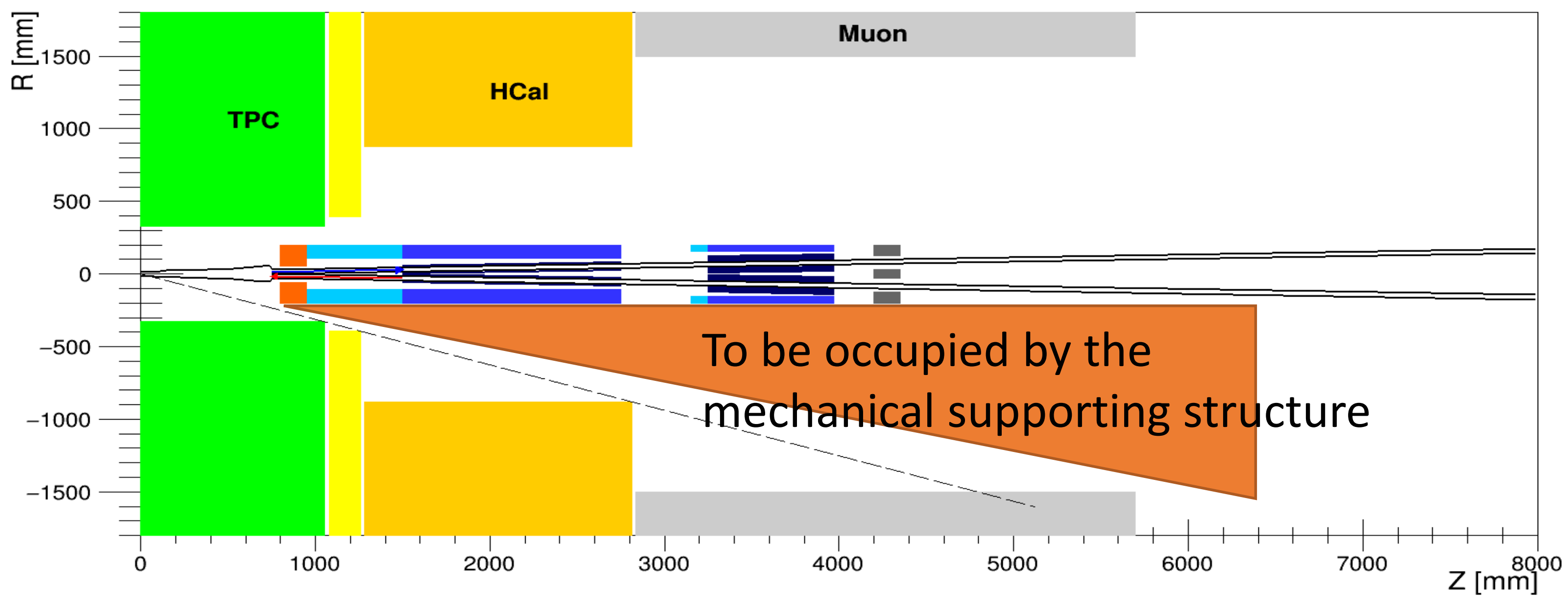


Electroweak physics summary

- Major concern of EWK physics in CEPC
  - Whether we will have beam polarization for Z mass measurement
  - What is beam energy measurement precision in Z runs and WW runs
  - Whether we can have dedicated WW threshold scan.
    - The precision of W mass may gain by a factor of 3-10 times using dedicated WW threshold runs.

Machine Detector Interface

- Interaction region (S. Bai, Q. Xiu & H. Zhu)
  - Working on updated version with more reasonable layout of the machine and detector elements
- Mechanical Support (H. Qu)

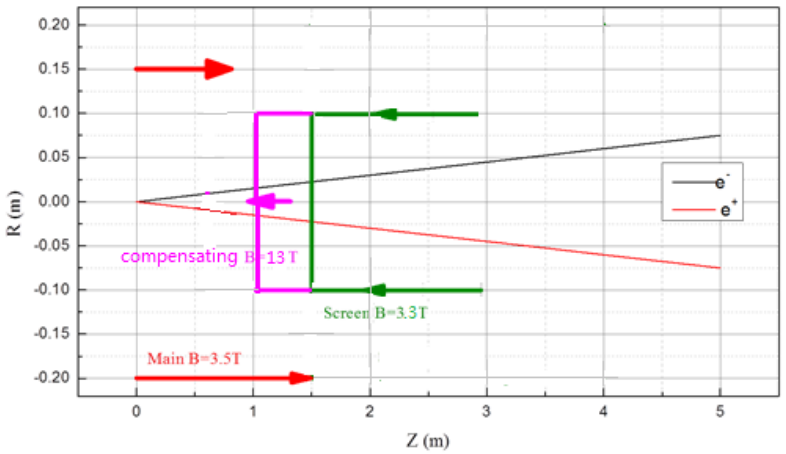


ELEMENT	WEIGHT (kg)
LumiCal	130
QD0 (Including solenoids)	900
QF1	600
Pump	20

  - First iteration: understand the general requirements and total weight to be supported
    - Space required for support structure: 150-300 mrad
    - Supporting point ~ 6 meters from IP
    - Feasibility studies on-going: Stress, deformation and vibration

Machine Detector Interface

- Radiation Background Estimation (Q. Xiu + student)
  - Working on estimate of radiation backgrounds for the baseline design
    - Provide guidelines for collimator and shielding design → iterative studies
- Collimator and Shielding Design (S. Bai)
  - Suppress radiative Bhabha scattering and synchrotron radiation
- Final Focusing Magnets Design (Y. Zhu & W. Yao)
  - Conceptual design of the final focusing magnets
  - Screening magnet to cancel detector solenoid
    - Conflict between magnetic field strength and space in front of QD0
    - Consider lowering down the field of the detector solenoid



- Luminosity Calorimeter
  - Estimating the acceptance of the radiative Bhabha scattering events with different configurations → limited space available

Pixel Detector Status and Plans

New funding from MOST (2016-2021)

Vertex detector R&D Target:

- Single point resolution near the IP: $\leq 3\ \mu m$ → *high granularity*
- Power consumption: <100 mW/cm^2
- Material budget: $\leq 0.15\% X_0$/layer → *Low power dissipation, thinned, monolithic pixel sensor*
- Pixel occupancy: $\leq 1\%$ → *High granularity and/or short readout time*
- Radiation tolerance: ~100 krad/y (TID) and ~10^{11} N_{eq}/cm^2/y (NIEL)
- Integration time: 10-100 μs

CMOS Pixel Sensor (CPS):

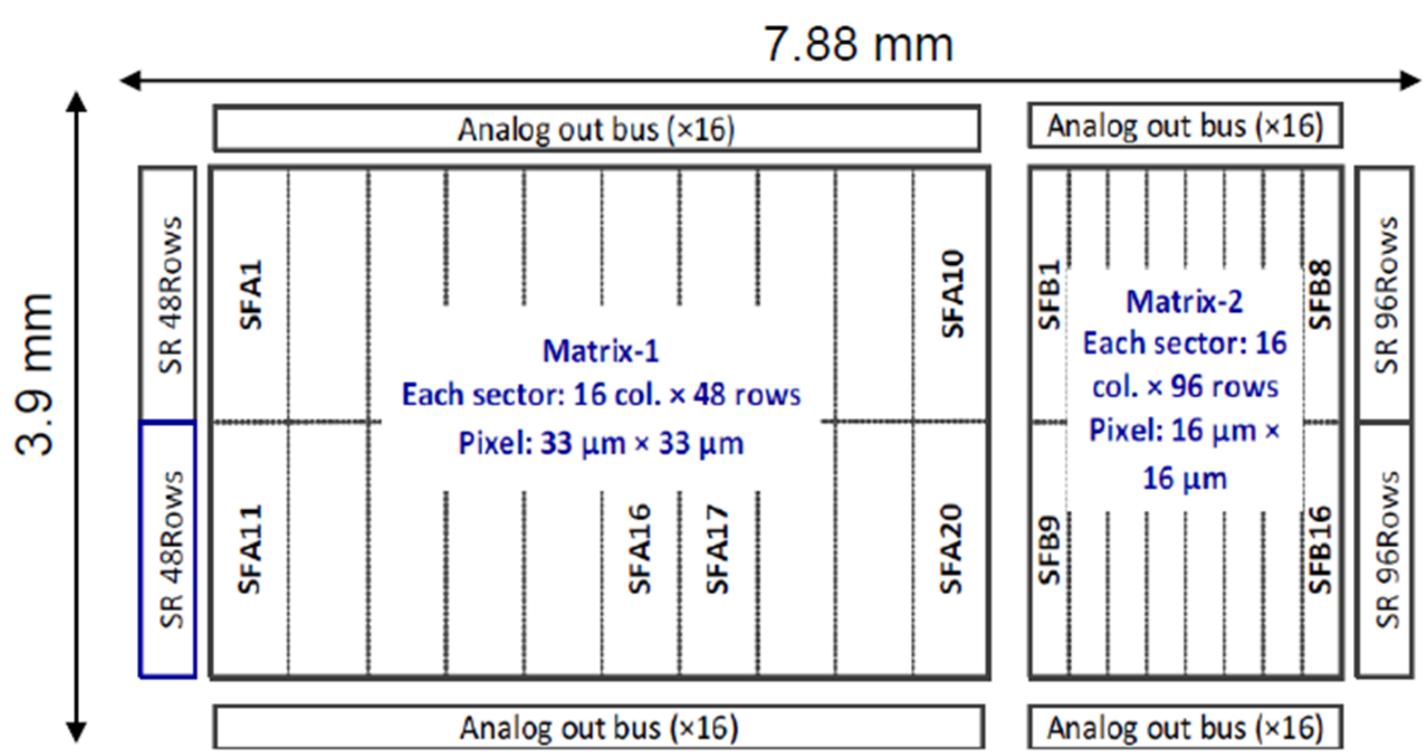
- Small pixel size
- In-pixel functionality circuitry
- Novel readout scheme → faster and less power
- Tower Jazz CiS 0.18μm process

First CPS prototype design

Joint TowerJazz 0.18 um CMOS process MPW submission with IPHC in Nov. 2015

Goal: sensor optimization and in-pixel pre-amplifier study

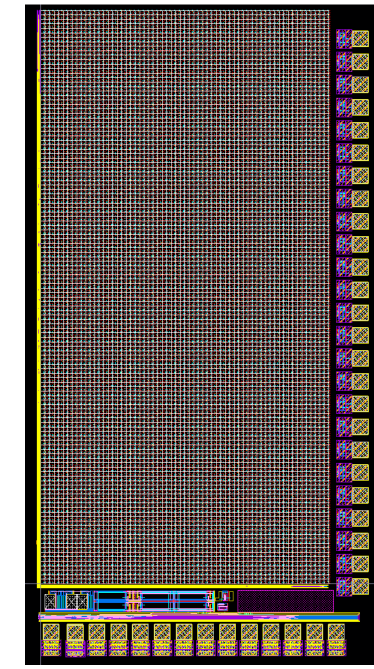
- Floorplan overview:
  - Two independent matrices: Matrix-1 with 33 × 33 μm² pixels (except one sector SFA20 with 16 × 16 μm² pixels), Matrix-2 with 16 × 16 μm² pixels.
  - Matrix-1 includes 3 blocks with in-pixel pre-amplifier
  - SFA20 in Matrix-1 contains pixel with AC-coupled pixels



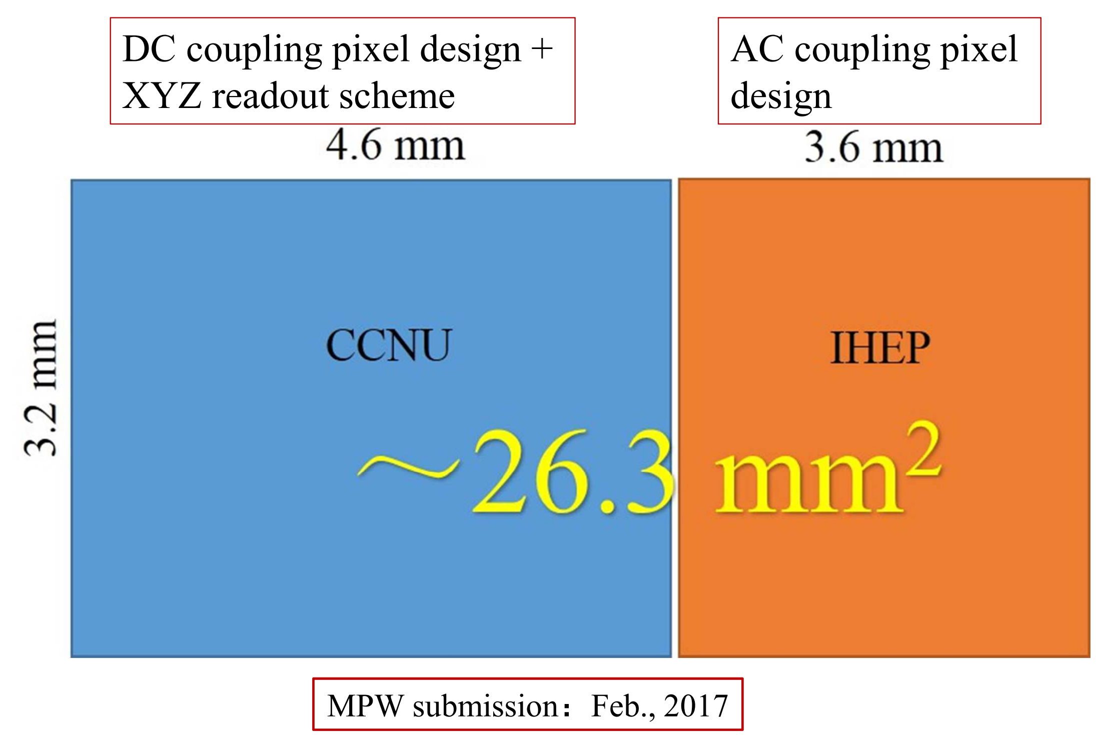
- Tower Jazz CIS 0.18 μm, November 2015 submission
- Two types of wafer:
  - 18μm HRES epi-layer wafer
  - 700Ω Czochralski wafer
- Sensor arrival at IHEP June 2016
- Test board and system in preparation, including the NIEL measurement.

Second CPS prototype design

IHEP: Y. Zhang, Y. Zhou
CCNU: P. Yang



- Purpose: small-size digital pixel design verification, fast readout
- Pixel design:
  - Pixel size: smaller than 22 $\times$22 μm^2
  - Each pixel contains a sensing diode, a pre-amplifier and a discriminator
  - AC coupling: rolling-shutter readout with higher biased voltage
  - DC coupling: asynchronous readout with high gain and low noise
- Readout design:
  - Matrix readout using XYZ solution
  - Pixel size: 26$\times$26μm^2
  - Signal duration time:< 3μs
  - Readout speed: 25 ns/hit
  - Power consumption: < 80 mW/cm^2



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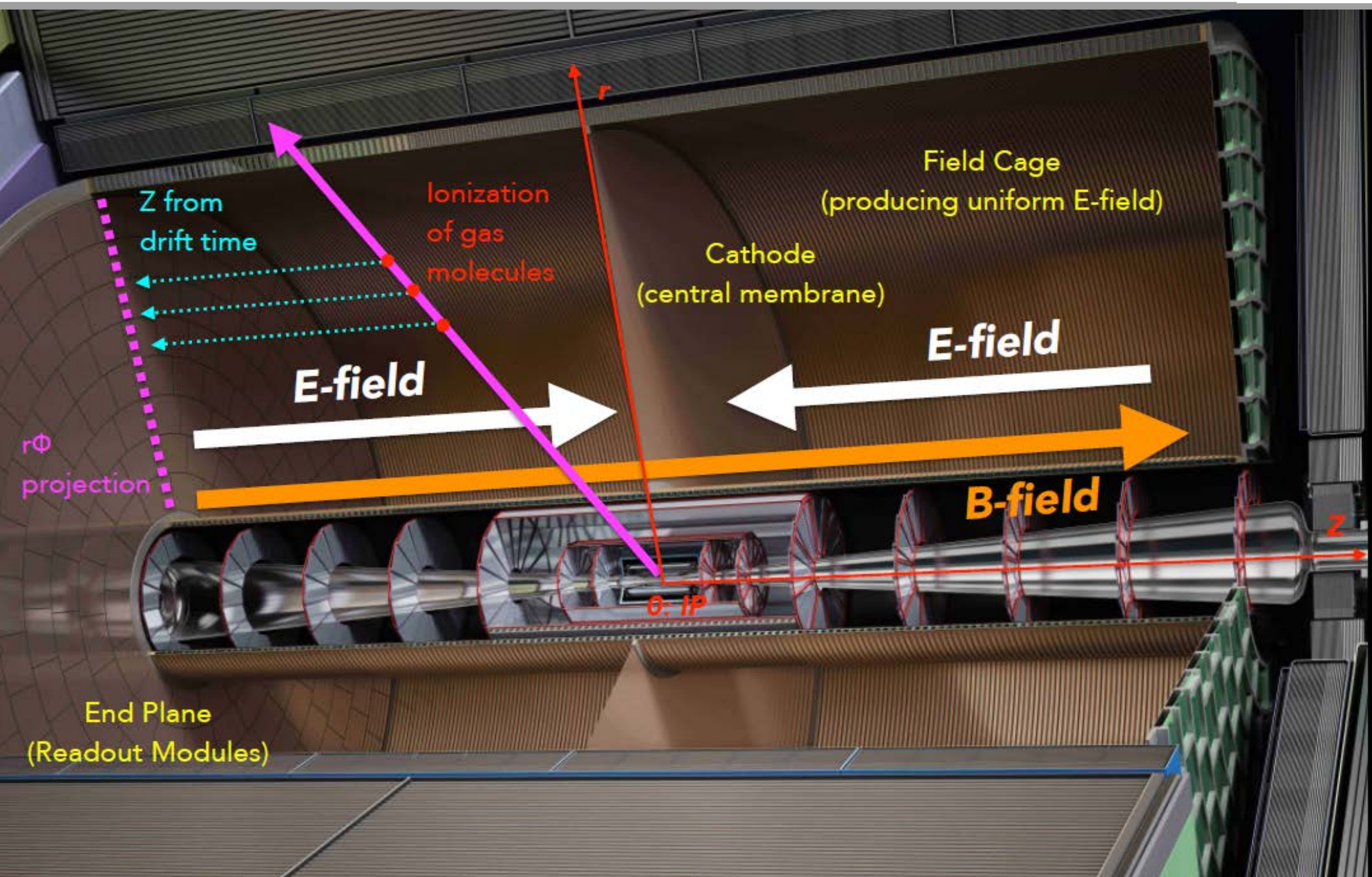
TPC Detector

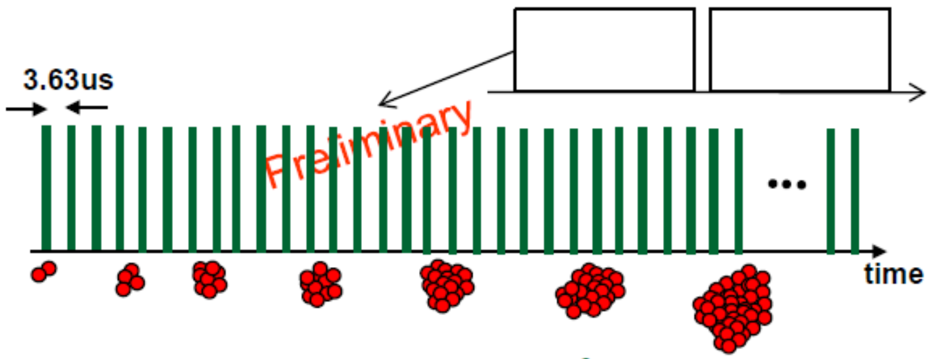


TPC: Critical Challenges

- **Occupancy at Inner Diameter**
  - Need low occupancy
  - Reduced overlapping tracks
  - Understand beam induced background at IP

TPC as an option for CEPC
Defines size of readout pads

- **Ion Back Flow**
  - Continuous beam structure
  - Long working time with low discharge possibility
  - Need to fully suppress space charge produced by ion back flow from the amplification gap



Beam structure of CEPC

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

~ 100μm position resolution with calibration

TPC: Current R&D

- Simulation and estimation
  - Z-pole run for CEPC R&D (prepared one NOTE)
  - Tracker alignment and calibration (~100um resolution)
  - Hybrid detector module concept

- Experiment and module R&D
  - Continuous Ion Back Flow detector module (GEM+MM)
    - IBF could reach to ~0.1%
    - Stable long time operation
    - Maintaining the electron transmittance
    - Plan to design and study in 1.0T magnetic (In LCTPC collaboration) /1~2years

    MOST funding/IHEP+THU
  - Prototype with laser system
    - Laser system with 266nm
    - Drift velocity
    - Electric field in fieldcage
    - Waveform sampling electronics
    - Plan to assemble and test/~1 year

    Key NSFC funding/IHEP+THU

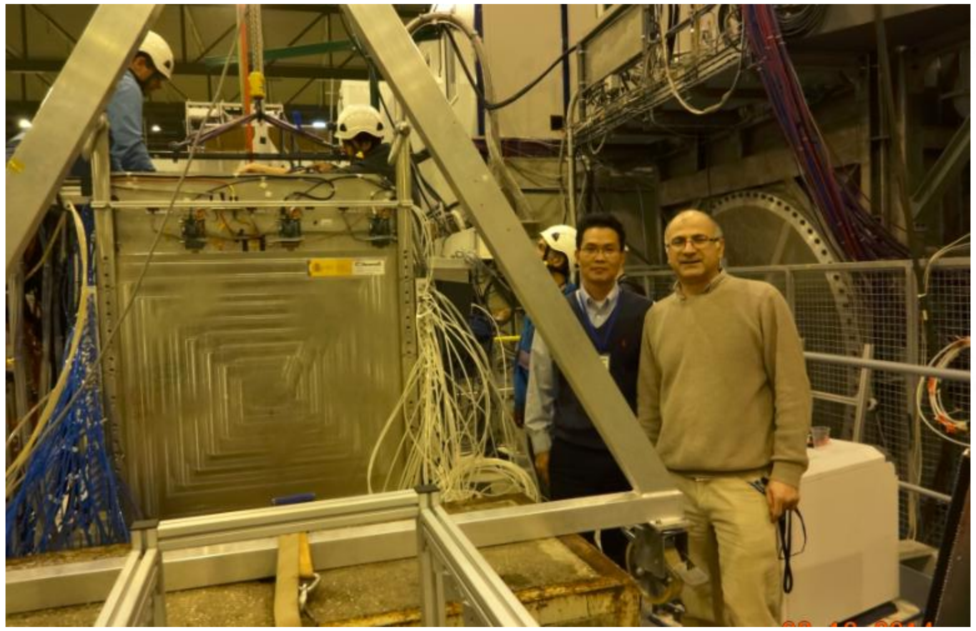
CEPC Calorimeters

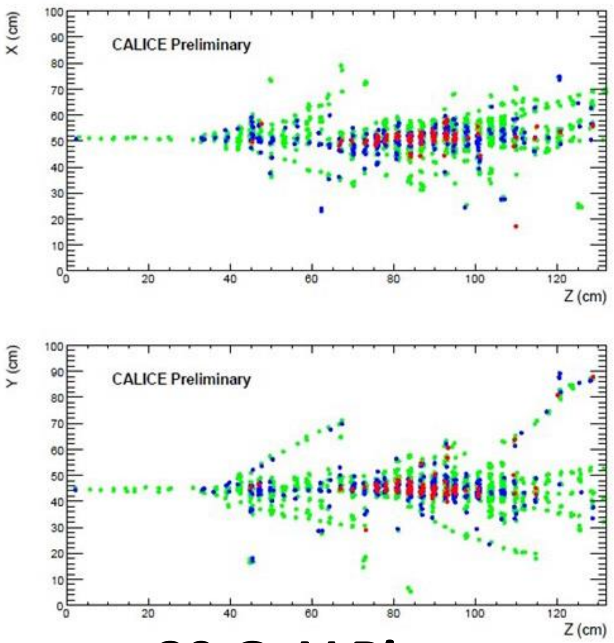
- **ECAL with Silicon and Tungsten**
- **ECAL with Scintillator and Tungsten**
  - Test of SiPM (IHEP, USTC)
  - The uniformity of scintillator strip light output need to be optimized
  - Electronics board of ECAL (USTC) produced, firmware being designed
- **HCAL with RPC and Stainless Steel** (BISEE, SJTU, ANL, IPNL)
  - Test beam at CERN
- **HCAL with Thick GEM and Stainless Steel**
  - Thick GEMs produced in China (UCAS, GXU, IHEP)
- **HCAL with GEM and Stainless Steel**
  - GEM and electronics board being designed at USTC

DHCAL with RPC

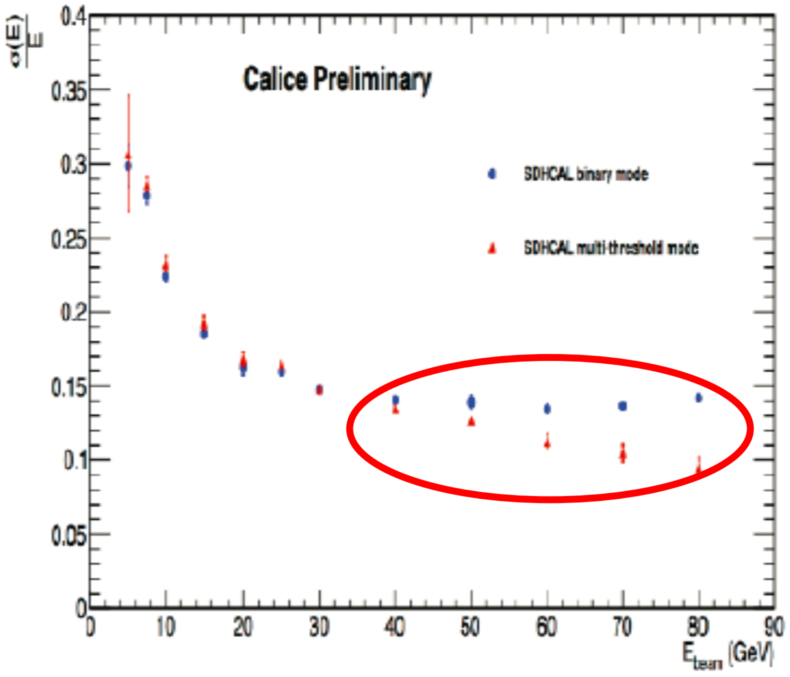
Prototypes of DHCAL based on RPC

- **ANL (J. Repond, L. Xia et.al.)**
  1m^3, 1 threshold, TB at CERN/Fermilab
- **IPNL (I. Laktineh, R. Han, B. Liu et.al.)**
  1m^3, 3 thresholds, TB at CERN since 2012



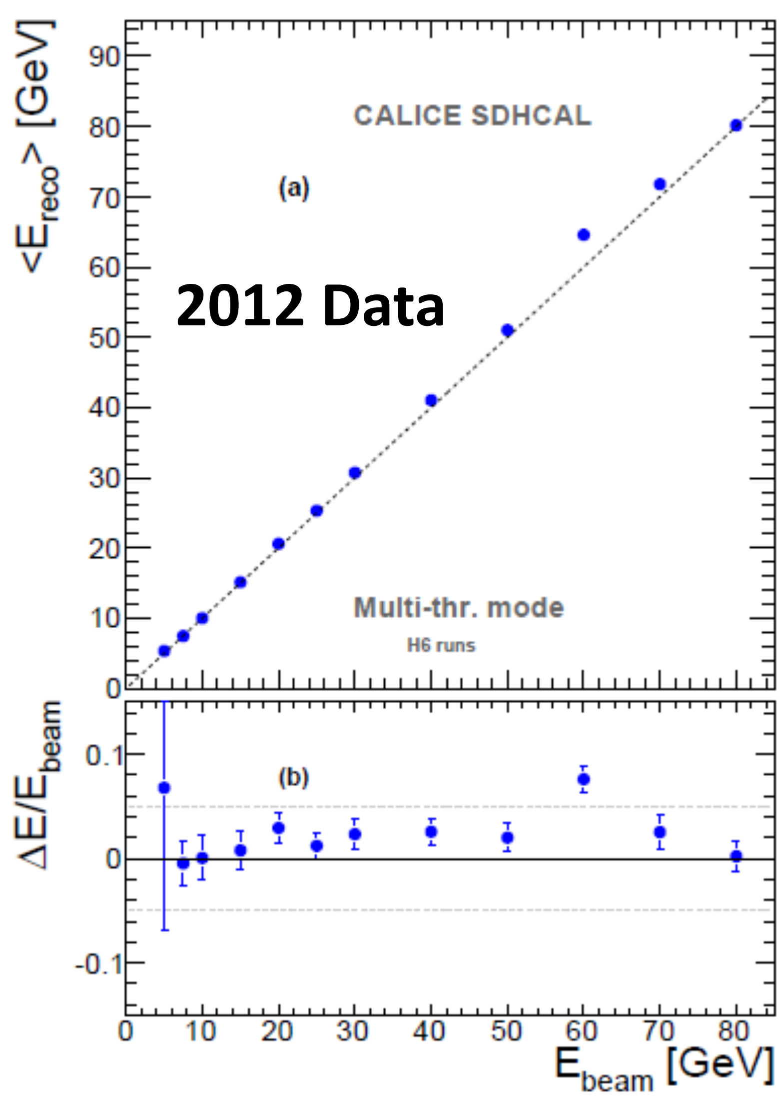


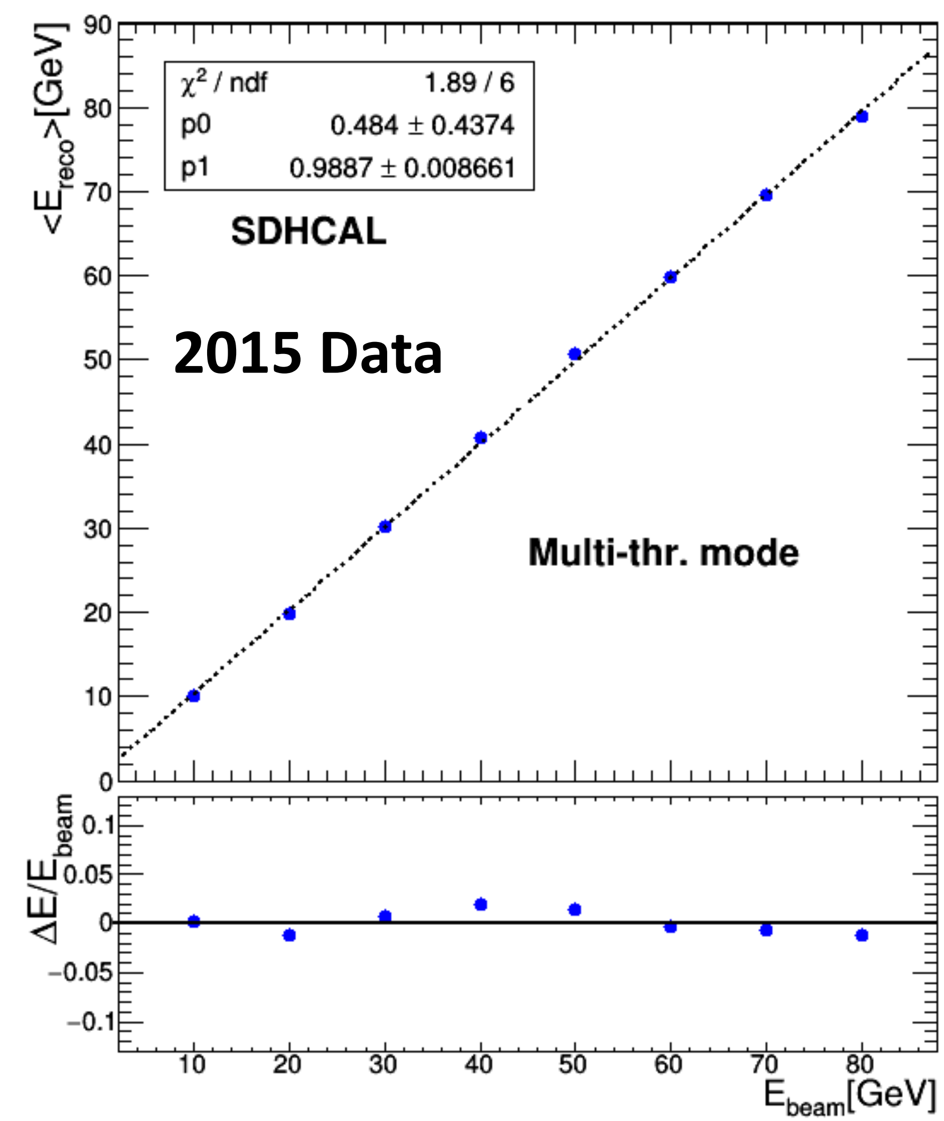
80 GeV Pion



DHCAL with RPC

Collaborating with Imad Laktineh at IPNL since Sept. 2016, Bing Liu was attending TB at CERN in Oct. 2016 and analyzing 2015 data now. He will apply for joint Ph.D program (CSC) between SJTU and IPNL.





Calorimeter R&D plan (near term)

1. CEPC ScW ECAl simulation and optimization

- Number of layers, Cell size, Scintillator thickness
- SiPM test and performance study
- Performance of Scintillator strip
- Design of readout electronics
- Optimization of ECAL using H->$\gamma\gamma$ benchmark

2. CEPC DHCAL performance study and optimization

- Number of layers, Cell size
- SDHCAL (RPC) TB energy resolution, linearity
- THGEM and GEM performance study
- Design of readout electronics
- Optimization of HCAL using H->WW benchmark

Manpower for Calorimeter R&D

- IHEP: Zhigang Wang, Hang Zhao, Tao Hu
  - ScW ECAL optimization
  - SiPM Test and scintillator strip optimization
- USTC: Yunlong Zhang, Shensen Zhao, Jianbei Liu
  - SiPM linearity test
  - Electronics board design and test for ECAL and HCAL
- SJTU: Haijun Yang, Liang Li, Jifeng Hu, Bing Liu, Jing Li
  - SDHCAL (RPC) TB performance study, PCB design
  - Calorimeter design based on benchmark $H\rightarrow\gamma\gamma$ and WW
- IHEP+UCAS: Boxiang Yu, Zhe Wu, Qian Liu, H.B. Liu
  - Thick GEM study with large active area ($20x20cm^2$)
  - HCAL based on Scintillator + SiPM

More manpower still needed

(Specially on ECAL based on scintillator and SiPM)

International Collaboration

- Italian Collaboration
  - Interested in Silicon detectors and new ideas for detectors (drift chamber, particle identification, muon detector) — See Hong Kong Conference
- Taiwan Collaboration
  - Interested in software and physics studies — Lumical, EW measurements (Sinica), Jet energy scale studies (NCU) and ECAL Studies (Taiwan U) (https://indico.cern.ch/event/579684/overview)
- Chicago/Beijing Collaboration
  - Workshop with Chicago students (tentatively towards mid/end of March); most interested in simulation studies
- Several institutions expressing interest in CMOS/Silicon collaboration:
  - SLAC, Barcelona, Liverpool, Univ. of Geneva, MPI
- Other general interest:
  - Weizmann Institute (Israel); Mainz U.

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Hong Kong Conference - Experiment/Detector Sessions

24 Jan 2017 (Tue)

Time	Event	Venue
	Chair: Charles Young (SLAC National Accelerator Laboratory)	
09:00-09:45	**ILC Technical Status and Readiness** Akira Yamamoto (Kō Enerugī Kasokuki Kenkyū Kikō)	IAS Lecture Theater, G/F
09:45-10:30	**FCC-ee** Michael Koratzinos (CERN)	
10:30-11:00	Coffee break & Group-photo taking	Lobby, G/F
11:00-11:45	**CLIC Status** Philip Burrows (University of Oxford)	IAS Lecture Theater, G/F
11:45-12:30	**Physics at e+e- Colliders** Lian Tao Wang (University of Chicago)	
12:30-14:00	Lunch (Self-arranged)	
14:00-15:40	**Parallel Session (Accelerator Physics - Part III)** **Chair: Akira Yamamoto KEK (Kō Enerugī Kasokuki Kenkyū Kikō)**	
14:00-14:20	**SC Cavity Industrialization** Carlo Pagani (University of Milan and Italian Institute of Nuclear Physics)	IAS Lecture Theater, G/F
14:20-14:40	**Accelerator RF System** Robert Rimmer (Thomas Jefferson National Accelerator Facility)	
14:40-15:00	**Super KEKB RF System** Tetsuya Kobayashi (Kō Enerugī Kasokuki Kenkyū Kikō)	
15:00-15:20	**CEPC rf System** Jiyuan Zhai (Institute of High Energy Physics, Chinese Academy of Sciences)	
15:20-15:40	**Rf Power Source System** Shigeki Fukuda (Kō Enerugī Kasokuki Kenkyū Kikō)	
14:00-15:40	**Parallel Session (Experiment / Detector - Part I)** **Chair: Joao Guimaraes da Costa (Institute of High Energy Physics, Chinese Academy of Sciences)**	
14:00-14:20	**Detector Optimization and Physics Simulation Toward the CEPC CDR** Manqi Ruan (Institute of High Energy Physics, Chinese Academy of Sciences)	IAS2042, 2/F
14:20-14:40	**Status of CEPC Calorimeters R&D** Haijun Yang (Shanghai Jiaotong University)	
14:40-15:00	**Status of CEPC Software** Gang Li (Institute of High Energy Physics, Chinese Academy of Sciences)	
15:00-15:20	**ILC Software & Grid Usage** Jan Strube (Pacific Northwest National Laboratory)	
15:00-15:40	**SUSY Searches at LHC and Beyond** Xuai Zhuang (Institute of High Energy Physics, Chinese Academy of Sciences)	

25 Jan 2017 (Wed)

Time	Event	Venue
	Chair: Weiren Chou (Fermi National Accelerator Laboratory)	
09:00-09:45	**Summary of High Temperature Magnet Workshop** Soren Prestemon (Lawrence Berkeley National Laboratory)	IAS Lecture Theater, G/F
09:45-10:30	**Review of ep Colliders** Yuhong Zhang (Thomas Jefferson National Accelerator Facility)	
10:30-11:00	Coffee break	Lobby, G/F
11:00-11:45	**Overview of Composite Higgs at Future Collider** Ian Low (Northwestern University)	IAS Lecture Theater, G/F
11:45-12:30	**Physics at FCC** Michelangelo Mangano (CERN)	
12:30-14:00	Lunch (Self-arranged)	
14:00-15:40	**Parallel Talks (Theory - Part III)** **Chair: Ian Low (Northwestern University)**	
14:00-14:20	**Electroweak Phase Transition** Patrick Meade (Stony Brook University)	IAS Lecture Theater, G/F
14:20-14:40	**Probing Higgs Self-coupling at the LHC and Future Colliders** King Man Cheung (National Tsing Hua University)	
14:40-15:00	**Double Higgs Production at the 14 TeV LHC and the 100 TeV pp-collider** Gang Li (Peking University)	
15:00-15:20	**Higgs Pair Production in CPV 2HDM** Ligong Bian (Chongqing University)	
15:20-15:40	**Vector Z' and Anomaly Cancellation** Wai Yee Keung (University of Illinois at Chicago)	
14:00-15:40	**Parallel Talks (Experiment / Detector - Part II)** **Chair: Joao Guimaraes da Costa (Institute of High Energy Physics, Chinese Academy of Sciences)**	
14:00-14:20	**CEPC TPC** Huirong Qi (Institute of High Energy Physics, Chinese Academy of Sciences)	IAS2042, 2/F
14:20-14:40	**A Second Detector Concept for CEPC** Franco Bedeschi (Italian Institute of Nuclear Physics)	
14:40-15:00	**Test Beam Results of a Silicon Photomultiplier Based Dual Readout Calorimeter Module** Massimo Caccia (Italian Institute of Nuclear Physics)	
15:00-15:20	**RICH Detectors and Gaseous Single Photon Detectors** Silvia Dalla Torre (Italian Institute of Nuclear Physics)	
15:20-15:40	**Machine Detector Interface for CEPC** Qingjei Xu (Institute of High Energy Physics, Chinese Academy of Sciences)	

Time	Event	Venue
15:40-16:10	Coffee break	Lobby, G/F
16:10-17:50	**Parallel Session (Accelerator Physics IV)** **Chair: Weiren Chou (Fermi National Accelerator Laboratory)**	
16:10-16:30	**CEPC R&D** Yunlong Chi (Institute of High Energy Physics, Chinese Academy of Sciences)	IAS Lecture Theater, G/F
16:30-16:50	**CEPC Power Source** Zusheng Zhou (Institute of High Energy Physics, Chinese Academy of Sciences)	
16:50-17:10	**Superconducting Quadrupole for Final Focus** Ivan Okunev (Budker Institute of Nuclear Physics)	
17:10-17:30	**Polarized Electrons Source for BINP c-tau Factory** Ivan Koop (Budker Institute of Nuclear Physics)	
17:30-17:50	**Discussions**	
16:10-17:50	**Parallel Talks (Experiment / Detector - Part III)** **Chair: Joao Guimaraes da Costa (Institute of High Energy Physics, Chinese Academy of Sciences)**	
16:10-16:30	**CEPC Vertex Detector** Ping Yang (Central China Normal University)	IAS2042, 2/F
16:30-16:50	**SiD - An All-silicon Detector for the ILC** Marcel Stanitzki (Deutsches Elektronen-Synchrotron)	
16:50-17:10	**HV-CMOS Status and Prospects** Daniela Bortoletto (University of Oxford)	
17:10-17:30	**A Drift Chamber Option for the CEPC** Franco Grancagnolo (Italian Institute of Nuclear Physics)	
17:30-17:50	**Discussions**	

Final remarks

- **Main Goal: Detector CDR by end 2017**
- Physics and detector meetings:
  - Monday at 2 pm
  - http://indico.ihep.ac.cn/category/324/
- Need to improve current collaborative tools
  - Twiki page:
    - http://cepc.ihep.ac.cn/~cepc/cepc_twiki/index.php/Main_Page
- Grow international collaborations is a major step to increase manpower
  - IAS Conference (Jan 23-26): HEP future colliders
    - http://iasprogram.ust.hk/hep/2017/

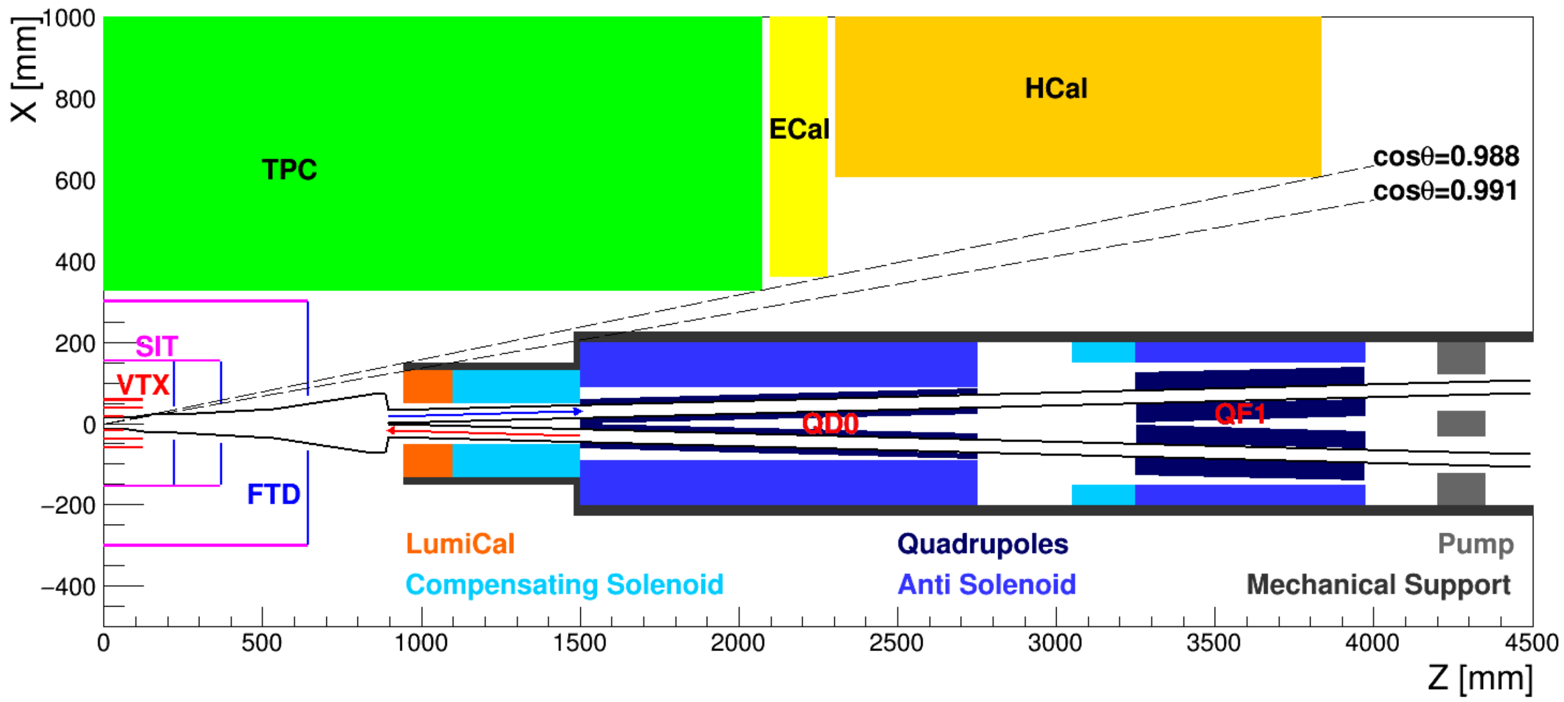
BACKUP

Machine Detector Interface

Interaction Region

S. Bai, Q. Xiu & H. Zhu

- Require comprehensive understanding of both machine and detector → identify critical elements and optimize the overall performance



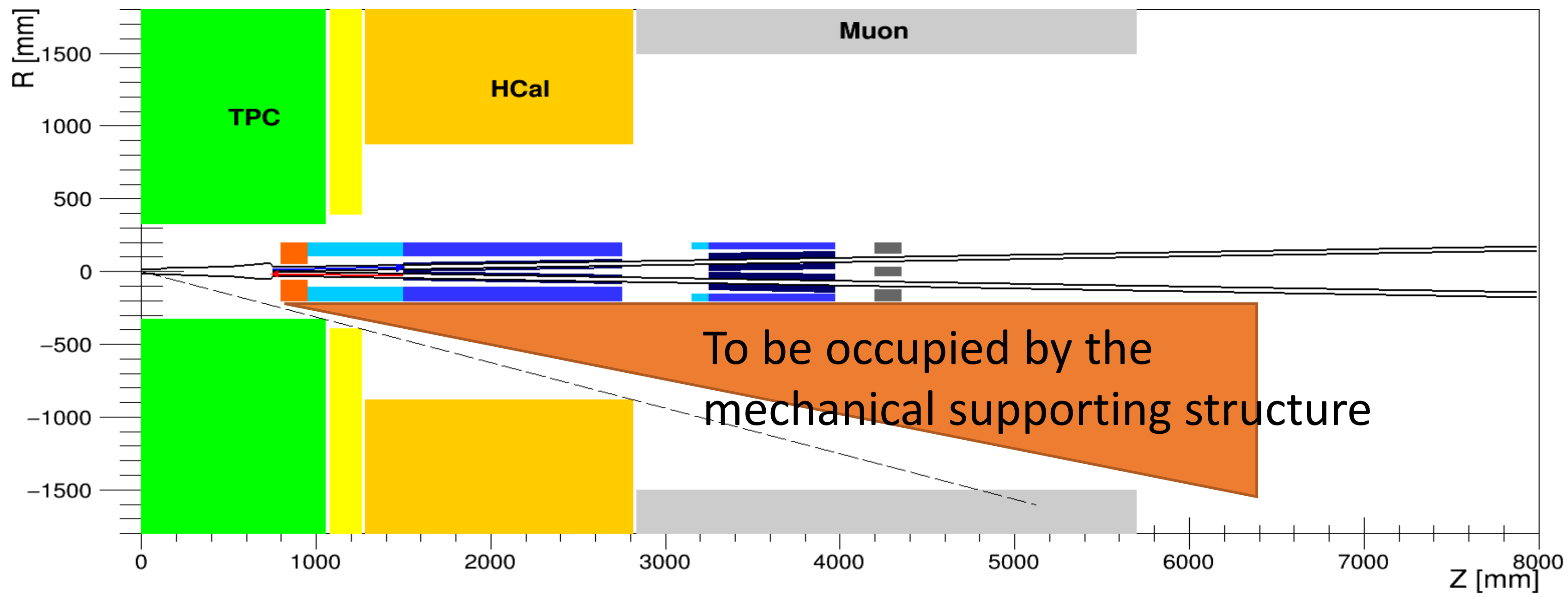
- *To deliver*: updated version with more reasonable layout of the machine and detector elements

Machine Detector Interface

Mechanical Structure

H. Qu

- Request sent to the accelerator mechanics group and contact person identified → first iteration to understand the general requirements and rough estimate of the total weight to be supported



- On going feasibility studies on stress, deformation and vibration
- *To deliver:* conceptual design of the mechanical structure

Machine Detector Interface

Radiation Background Estimation

Q. Xiu + student

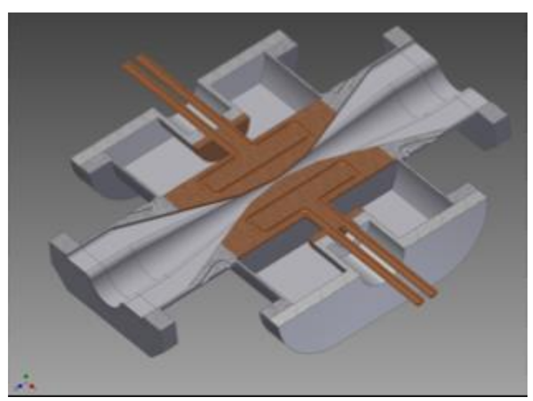
- Sources of radiation backgrounds: beamstrahlung, radiative Bhabha scattering, synchrotron radiation, gas scattering … for the baseline machine design and interaction region layout
  - Radiation tolerance requirements on silicon devices → design parameters for sub-detectors
- Complete the generic software framework for background estimation – basic structure in place, functionality to be extended
- Provide guideline for collimator and shielding design and estimate their effectiveness of mitigating backgrounds → iterative studies
- *To deliver*: estimate of radiation backgrounds for the baseline design

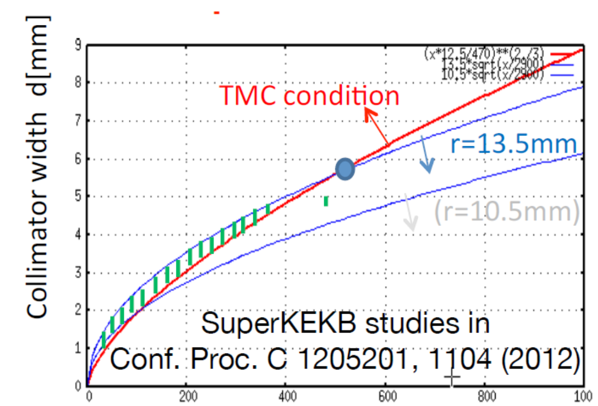
Machine Detector Interface

Collimator and Shielding Design

S. Bai +

- Collimator to stop electrons/positrons deviating from the orbit after loosing energy due to radiative Bhabha scattering → critical measure to suppress the radiative Bhabha scattering induced backgrounds
  - *To deliver*: conceptual design (shape and location optimization)





- Shielding to prevent particles directly penetrating or backscattering into the detector volume, *to deliver:*
  - Collimator/masks to suppress SR photons
  - Shielding structure (material option + thickness) outside of the QD0

Machine Detector Interface

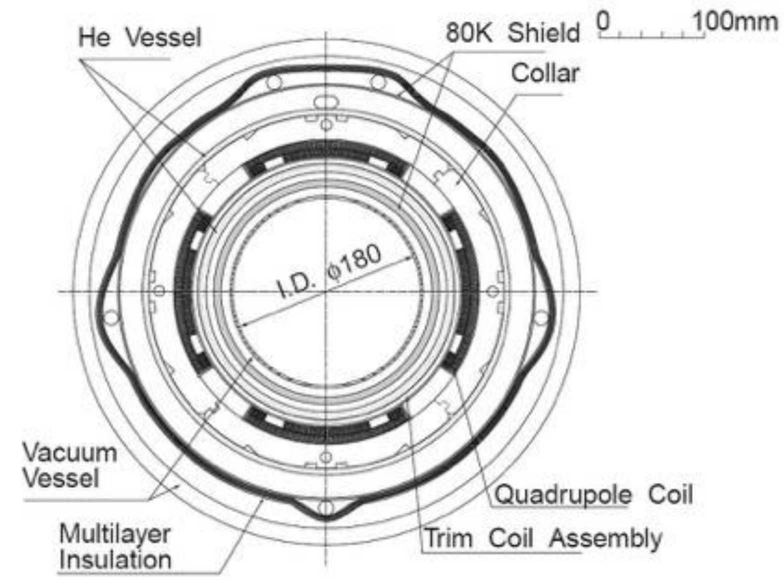
Final Focusing Magnets Design

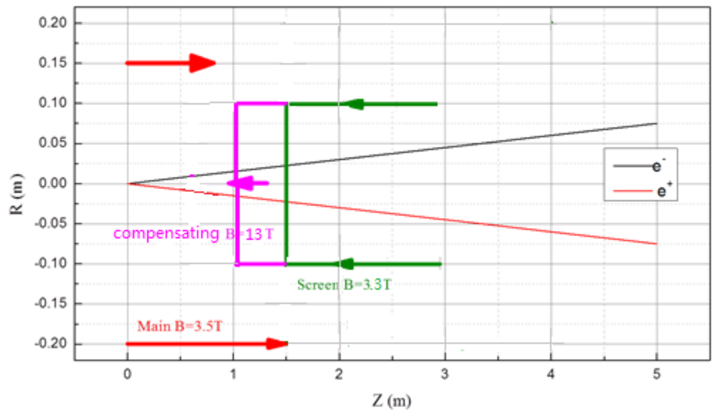
Y. Zhu & W. Yao

- *To deliver*: conceptual design (mechanical structure, prototype?) of the final focusing magnets

- Screening magnet to cancel out the detector solenoid → to be integrated into the final focusing magnet (possible common mechanics and cryogenics)

- Critical issues related to the compensating magnet → B×L
  - Conflicting between magnetic field strength and space in front of QD0
  - Shall consider lowering down the detector solenoid without not too much performance loss

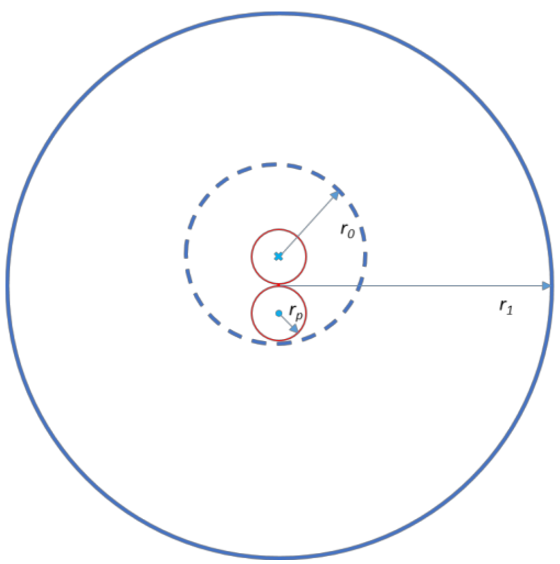


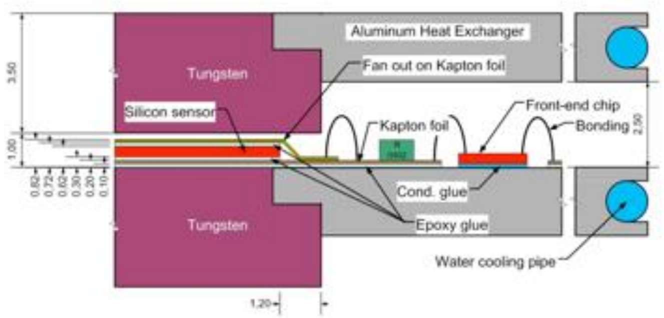


Machine Detector Interface

Luminosity Calorimeter

K. Zhu





- Limited space for luminosity calorimeter → estimate the acceptance of the radiative Bhabha scattering events with different configurations of inner and outer radius, starting and ending z-axis positions
  - Calculation on-going, overall performance in simulation

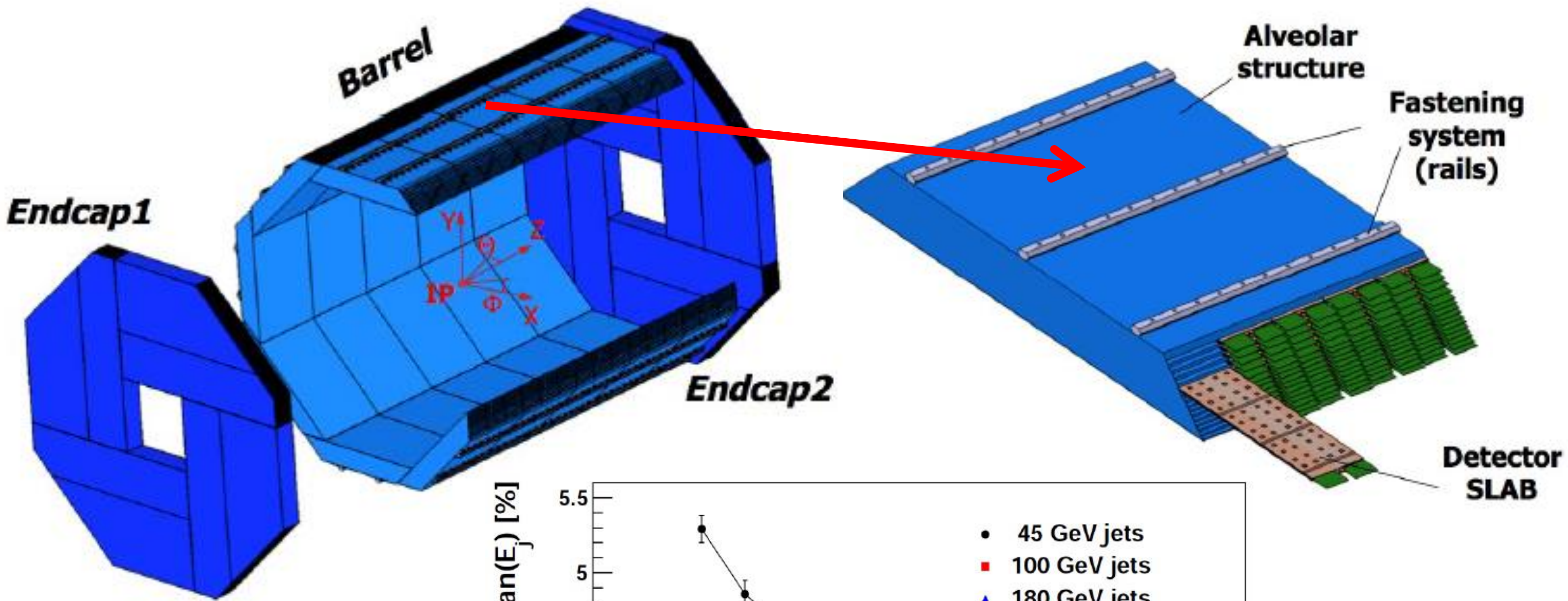
- Conceptual design with reasonable choice of detector structure and sensor options, and mechanical constraints

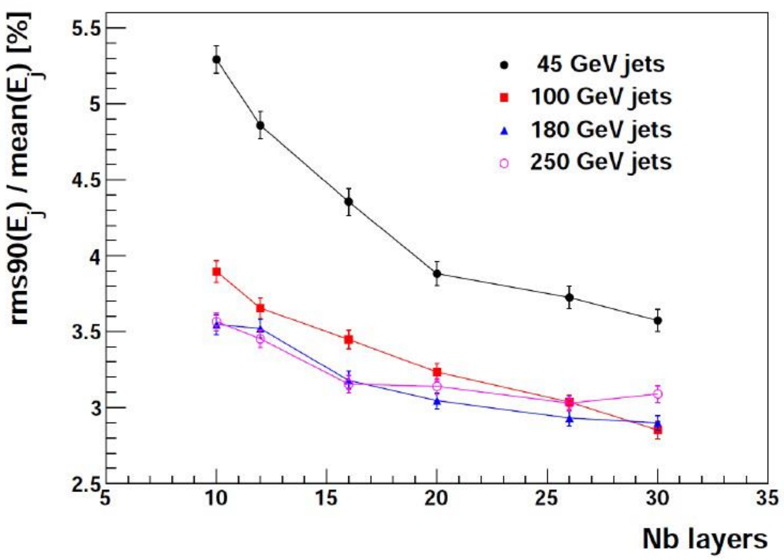
- *To deliver:* layout of the luminosity calorimeter and sensible detector structure

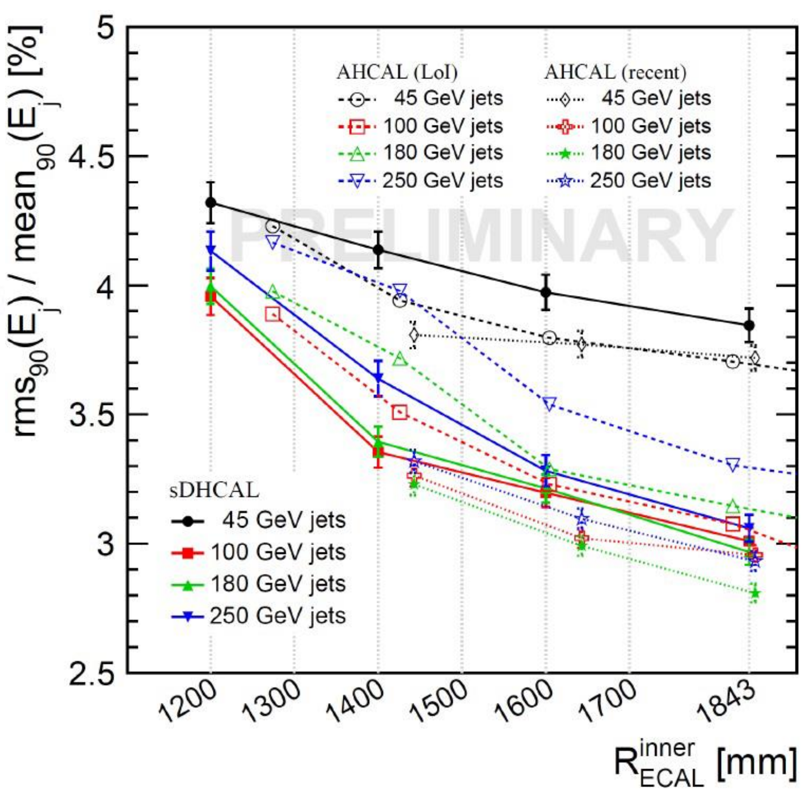
CEPC ECAL: Silicon-W

V. Boudry @ IN2P3

- The ECAL consists of a cylindrical barrel system and two large end caps.
- Two detector active sensors interleaved with tungsten absorber
  - silicon pixel 5 x 5 mm^2; PCB with VFE ASIC





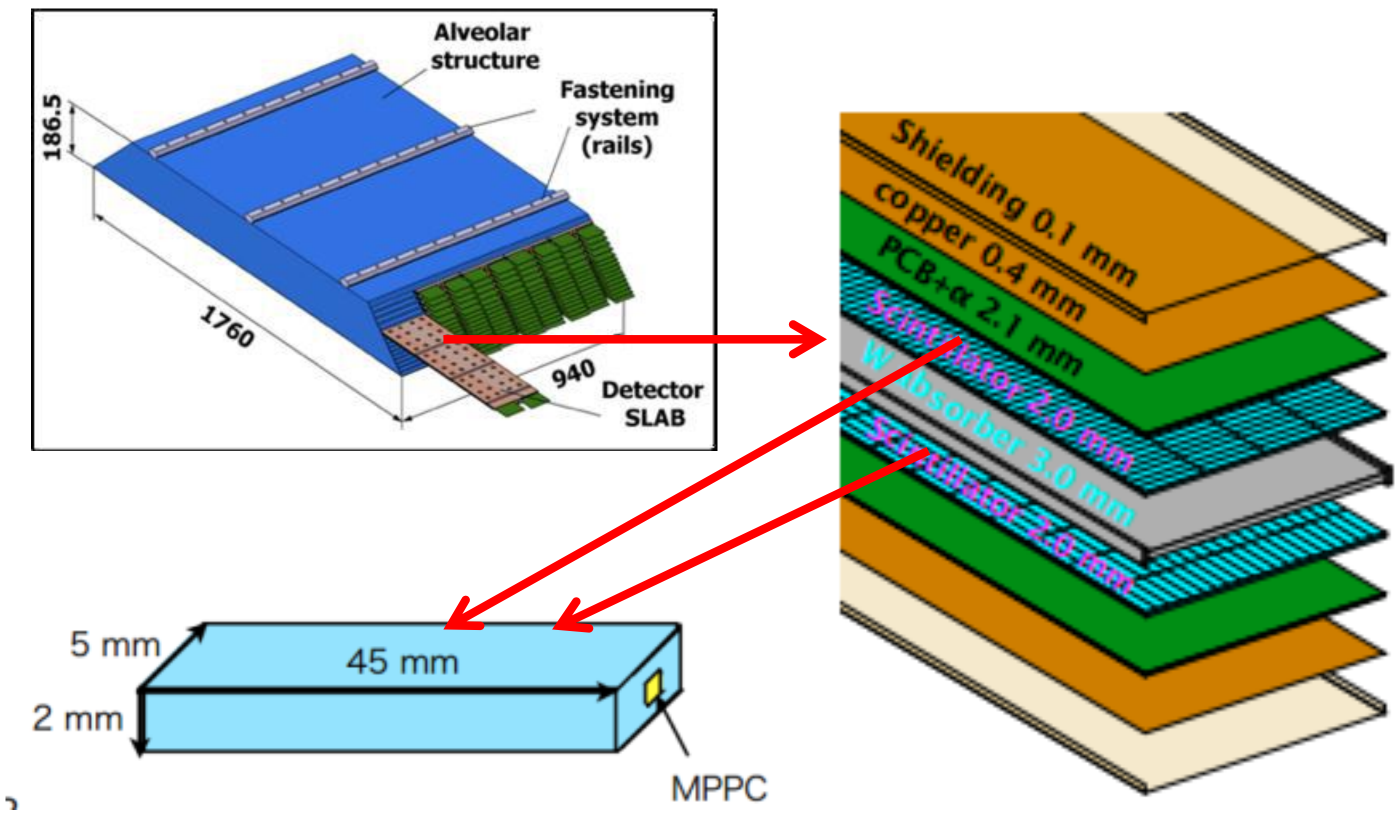


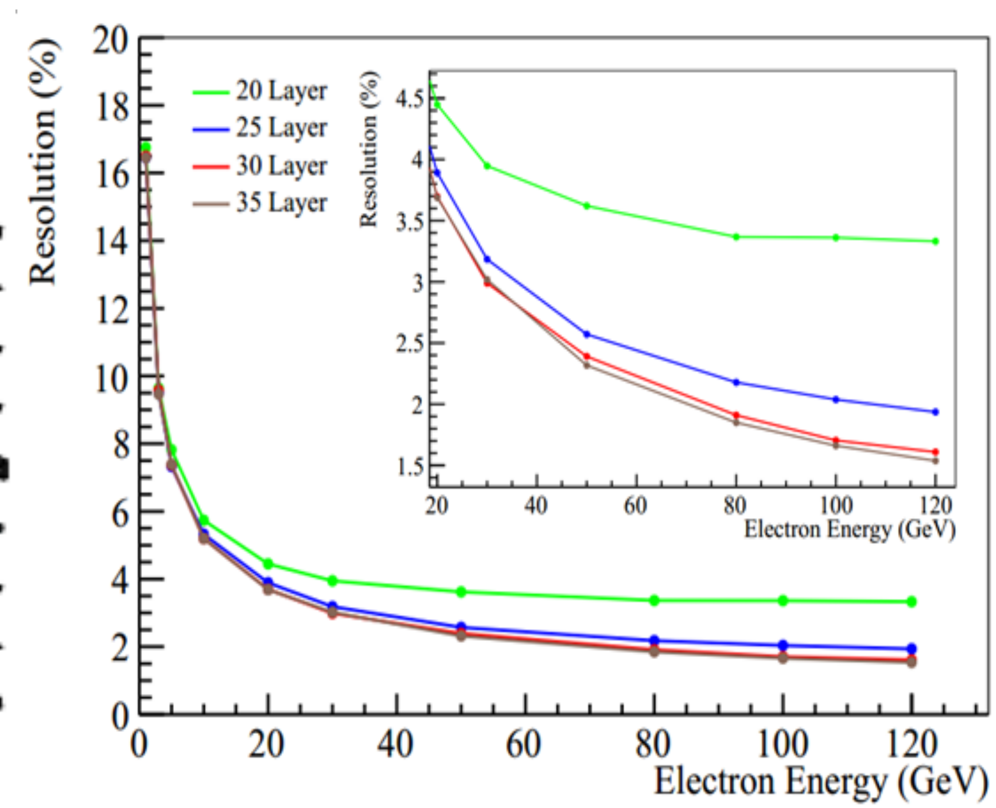
ECAL: Scintillator-W

Zhigang Wang et.al.

A super-layer (7mm) is made of:

- Plastic scintillator (2mm) + Tungsten plate as absorber (3mm thick)
- A readout/service layer (2mm thick)





Scintillator + W + Scintillator

- **The energy resolution of 25GeV electron is about 3.3% (cf. CALICE TB results)**
- **To achieve required energy resolution, the number of layers should be ~ 25.**

CEPC HCAL

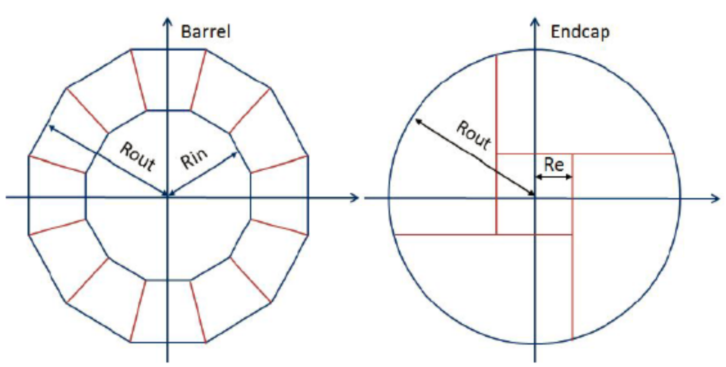
- The HCAL consists of
  - a cylindrical barrel system: 12 modules
  - two endcaps: 4 quarters
- Absorber: Stainless steel

- **Active sensor**
  - Glass RPC
  - Thick GEM or GEM
- **Readout (1×1 cm^2)**
  - Digital (1 threshold)
  - Semi-digital (3 thresholds)

CEPC DHCAL OPTIMIZATION

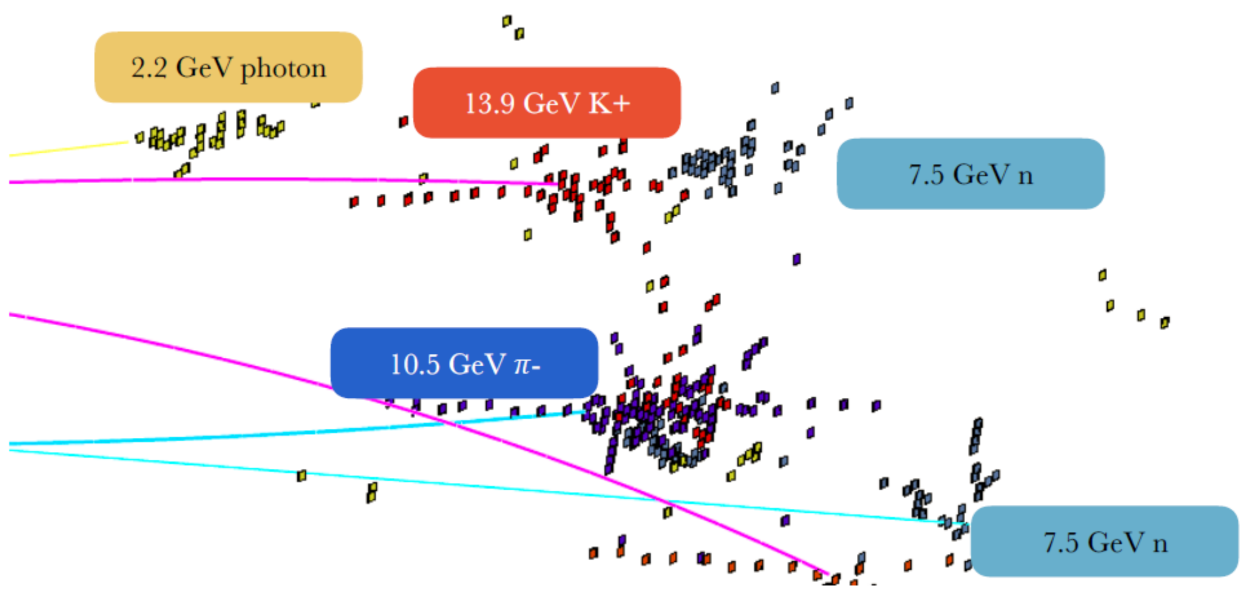
- To full fill the requirements of CEPC PFA, the DHCal is optimized by the following:
  - layers of DHCal, scanned from 20 layers to 48 layers.
  - size of each cell, scanned from 10 mm to 80 mm.
  - digitization (Q spectrum, spatial resolution, semi-Digi, etc..)

- The HCAL consists of
  - a cylindrical barrel system: 12 modules
  - two endcaps: 4 quarters
- Absorber: Stainless steel



SIMULATION - PRELIMINARY

By Shi CHEN (UCAS)



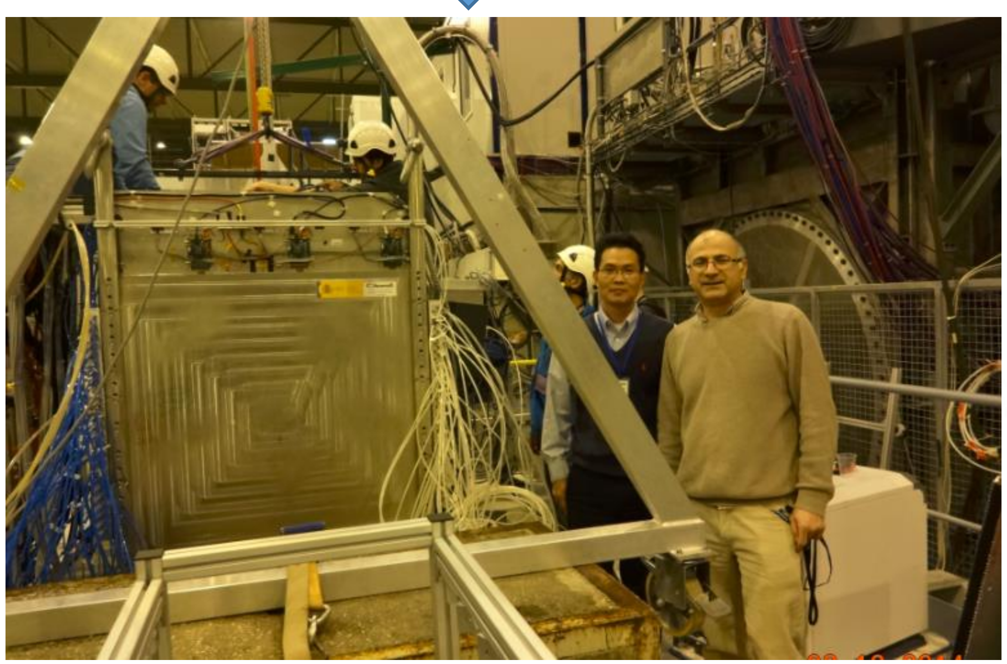
„typical" jet:

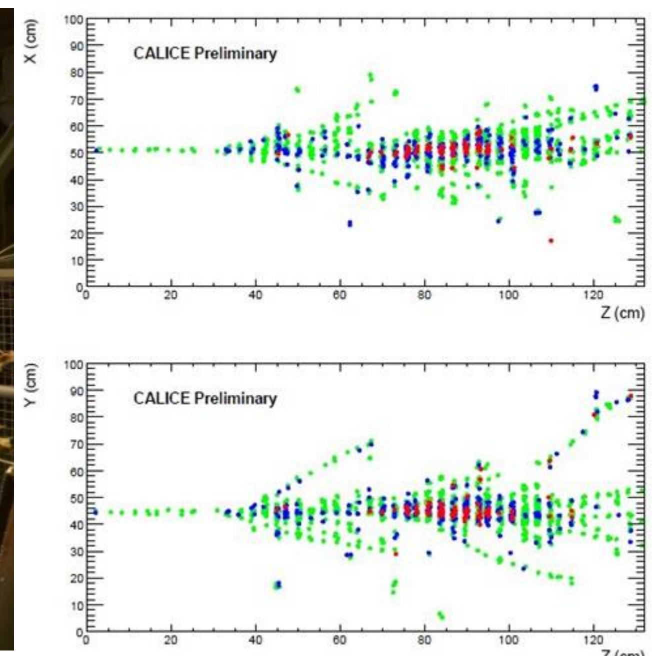
~ 60% charged particles	tracking	$(\sigma_{jet})^2 = (\sigma_{tracks})^2$
~ 30% photons	EM calorimeter	$+ (\sigma_{EMCalo})^2$
~ 10% neutral hadrons	HAD calorimeter	$+ (\sigma_{HADCalo})^2$
~~ 1% neutrinos~~		$+ (\sigma_{loss})^2 + (\sigma_{confusion})^2$

DHCAL with RPC

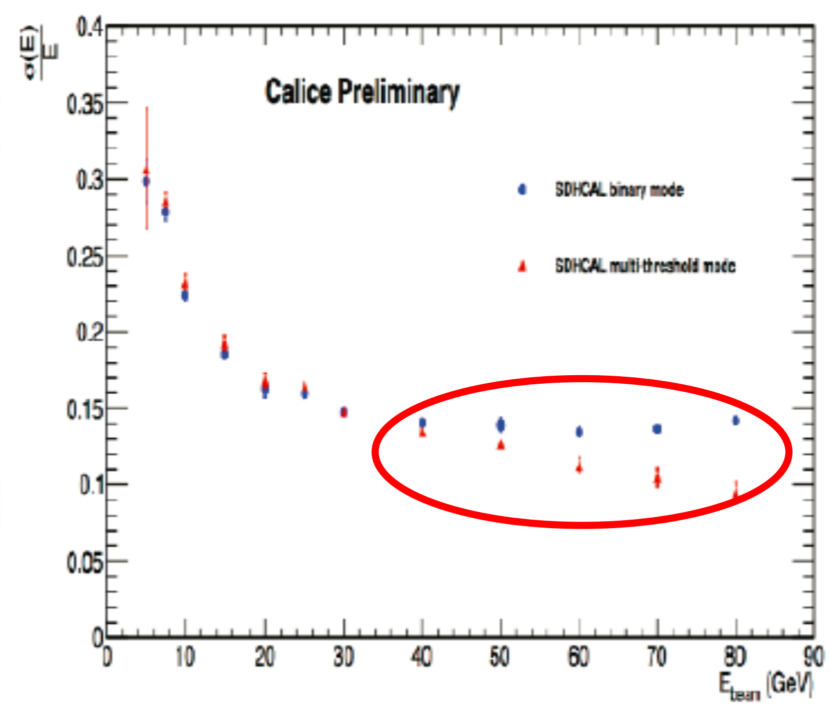
Prototypes of DHCAL based on RPC

- **ANL (J. Repond, L. Xia et.al.)**
  1m^3, 1 threshold, TB at CERN/Fermilab
- **IPNL (I. Laktineh, R. Han, B. Liu et.al.)**
  1m^3, 3 thresholds, TB at CERN since 2012





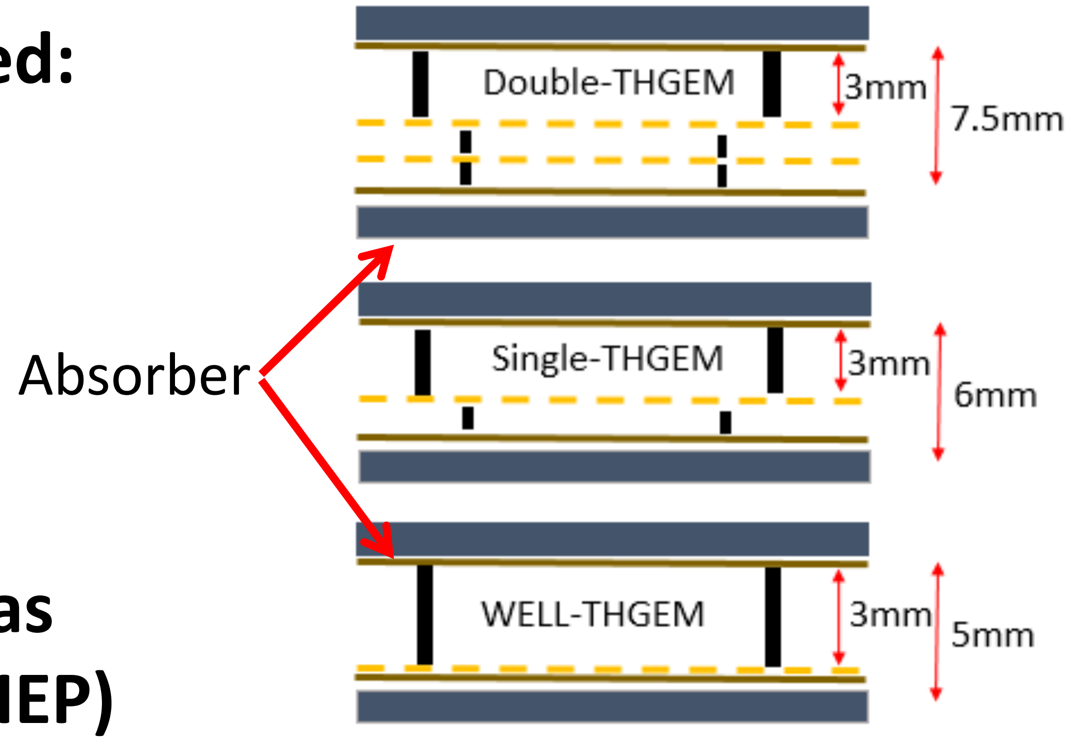
80 GeV Pion

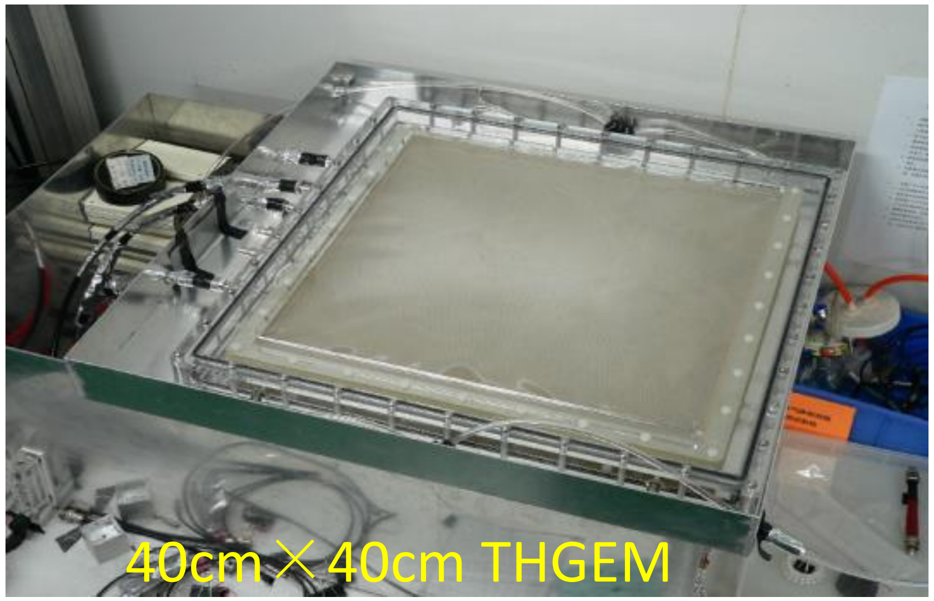


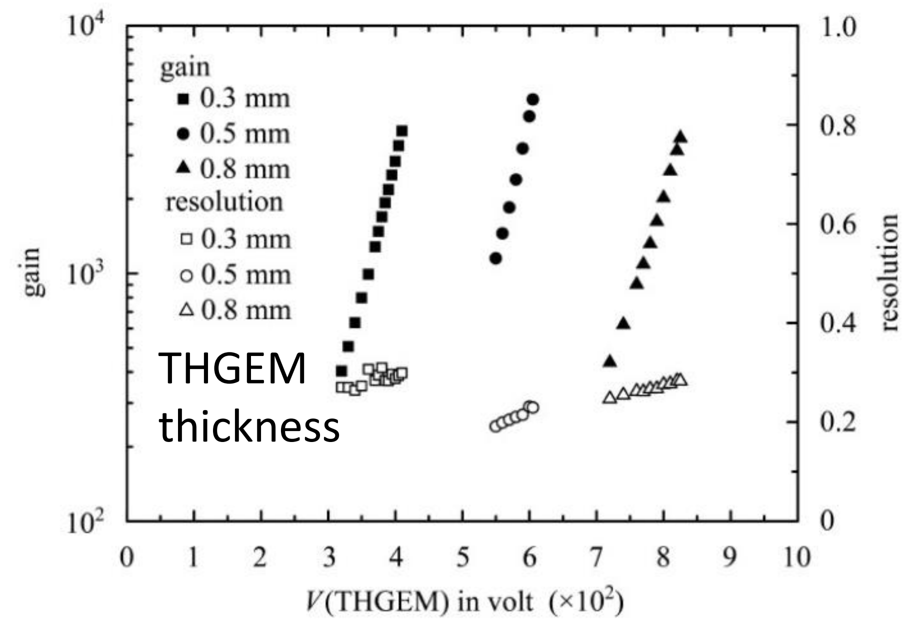
DHCAL based on THGEM

Boxiang Yu (IHEP)

- Three THGEM options are explored:
  - Double - THGEM
  - Single - THGEM
  - WELL - THGEM
- WELL-THGEM is optimal choice
  Thinner, lower discharge
- 40 × 40 cm^2 of THGEM (below) was produced in China (UCAS, GXU, IHEP)



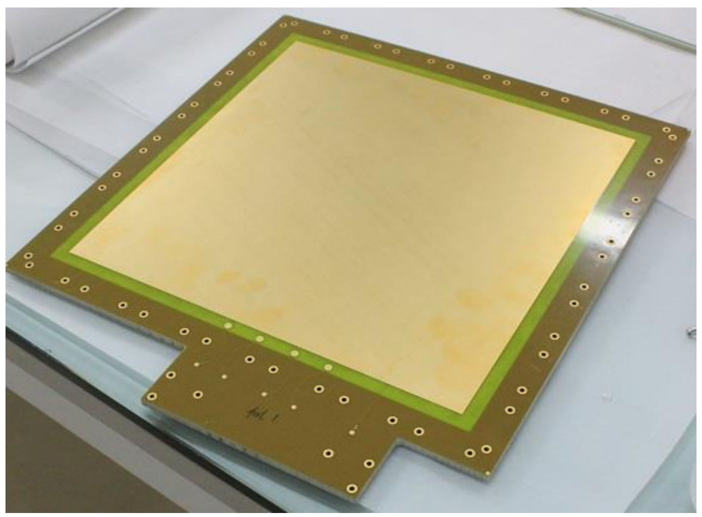


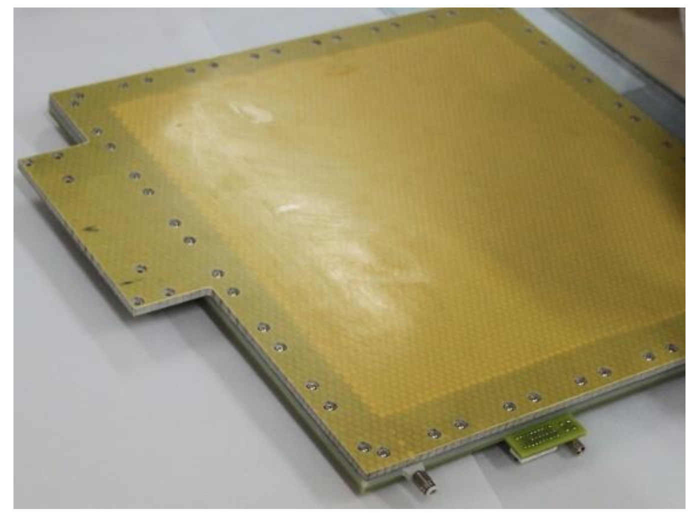


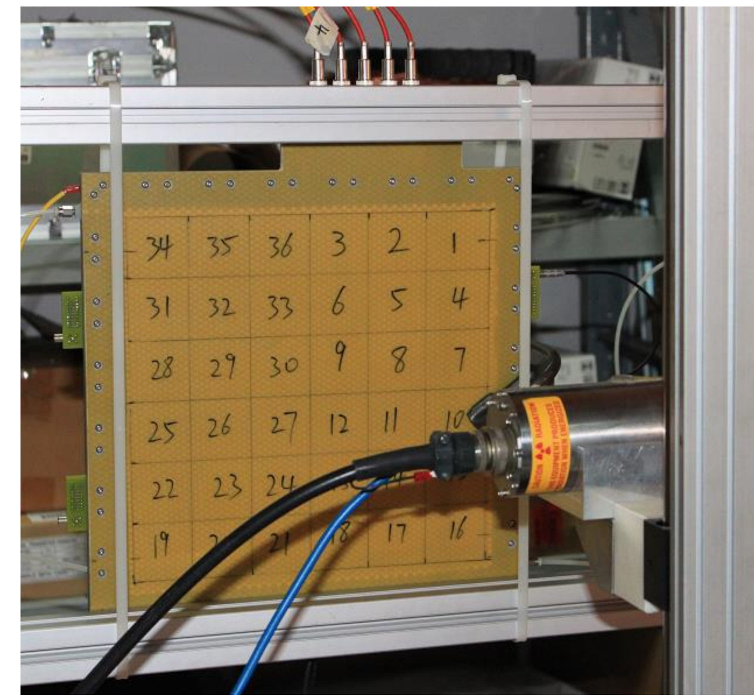
HCAL Based on GEM (USTC)

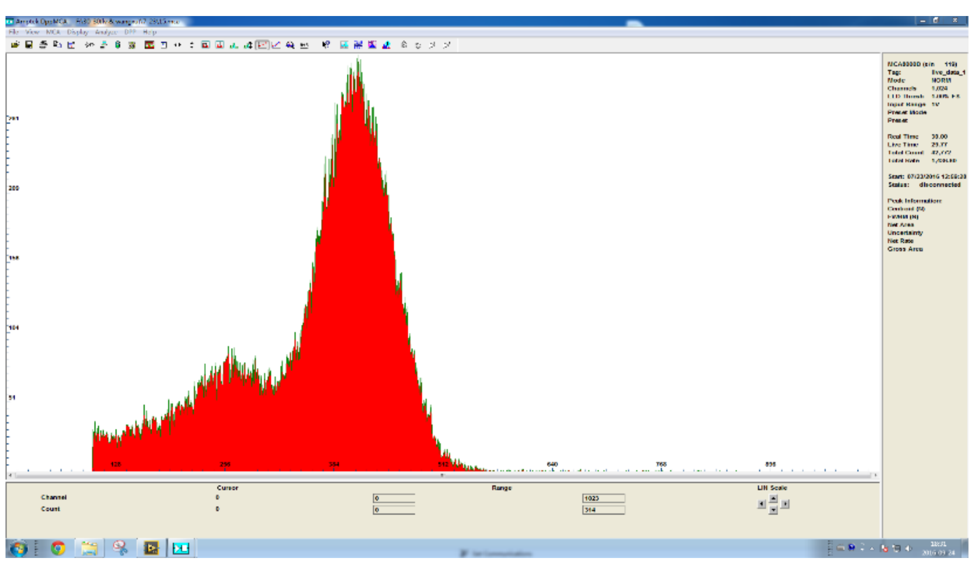
Jianbei Liu, Yunlong Zhang (USTC)

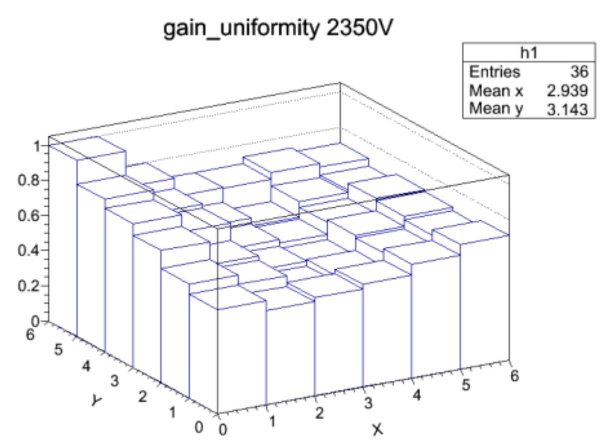
Construction of GEM at USTC

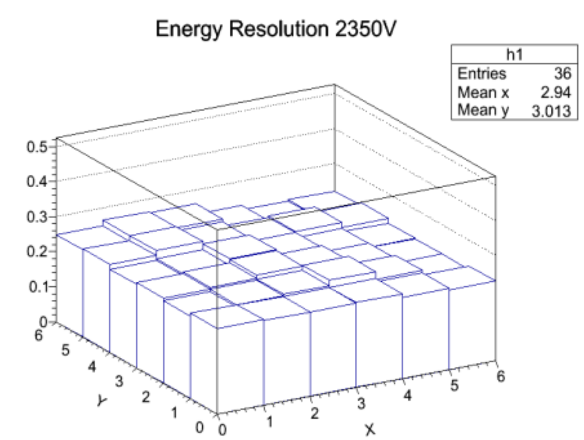












✓ **Gain:** ~4000
Non-uniformity ~15.6%

✓ **Energy resolution:** ~24.1%
✓ Non-uniformity: ~5.4%