Plan of The Fourth Conceptual Detector

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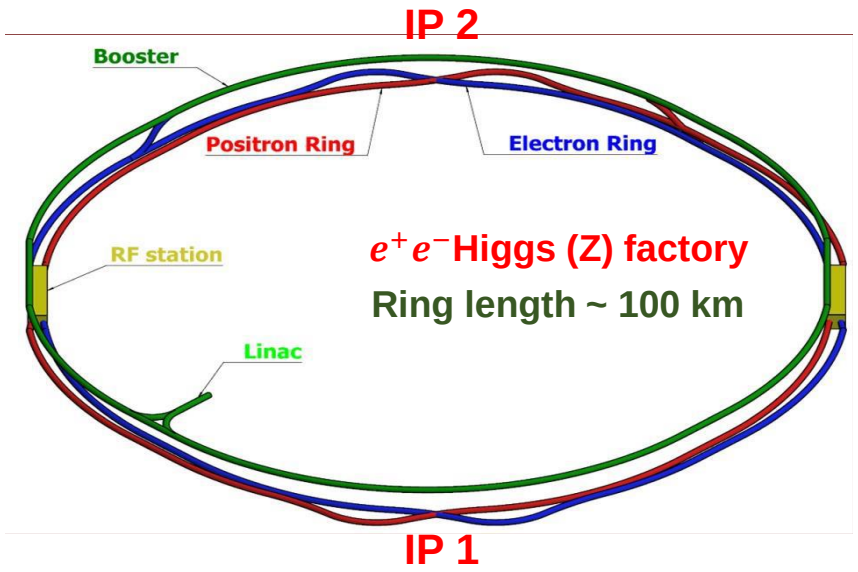
Joint Workshop of the CEPC Physics,
Software and New Detector Concept

Yangzhou, April 14-17, 2021

Physics Motivation of CEPC

- The CEPC aims to start operation in 2030's, as a Higgs (Z) factory in China. The plan is to operate
  - Above **ZH** threshold ($\sqrt{s}$ ~ 240 GeV) for 7 years.
  - Around and at the **Z** pole for 2 years.
  - Around and above **W^+W^-** threshold for 1 year.
  - It is upgradeable to run at the **$t\bar{t}$** threshold.
- Possible *pp* collider (SppC) of $\sqrt{s}$ ~ 50–100 TeV in the future.

Operation mode		ZH	Z	W^+W^-
$\sqrt{s}$ [GeV]		~240	~91.2	158-172
Run time [years]		7	2	1
CDR	L / IP [10^{34} $cm^{-2}s^{-1}$]	3	32	10
	$\int L\,dt$ [ab^{-1}, 2 IPs]	5.6	16	2.6
	Event yields [2 IPs]	1×10^6	7×10^{11}	2×10^7
Latest	L / IP [10^{34} $cm^{-2}s^{-1}$]	5	105.5	18.7



- The large samples from 2 IPs: **10^6** Higgs, **10^{12}** Z, **10^8** W bosons, provide a unique opportunity for
  - High precision Higgs, EW measurements,
  - Study of flavor physics (b, c, tau) and QCD,
  - Probe physics beyond the standard model.
  - …

Requirements of The CEPC Detector

The physics motivations dictate our selection of detector technologies

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV})\sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV})\times\sin^{3/2}\theta}(\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

- Flavor physics $\Rightarrow$ Excellent PID, better than 2σ separation of π/K at momentum up to ~20 GeV.
- EW measurements $\Rightarrow$ High precision luminosity measurement, $\delta L / L \sim 10^{-4}$.

CEPC Detector in CDR (I)

Particle Flow Approach
(ILD-like)

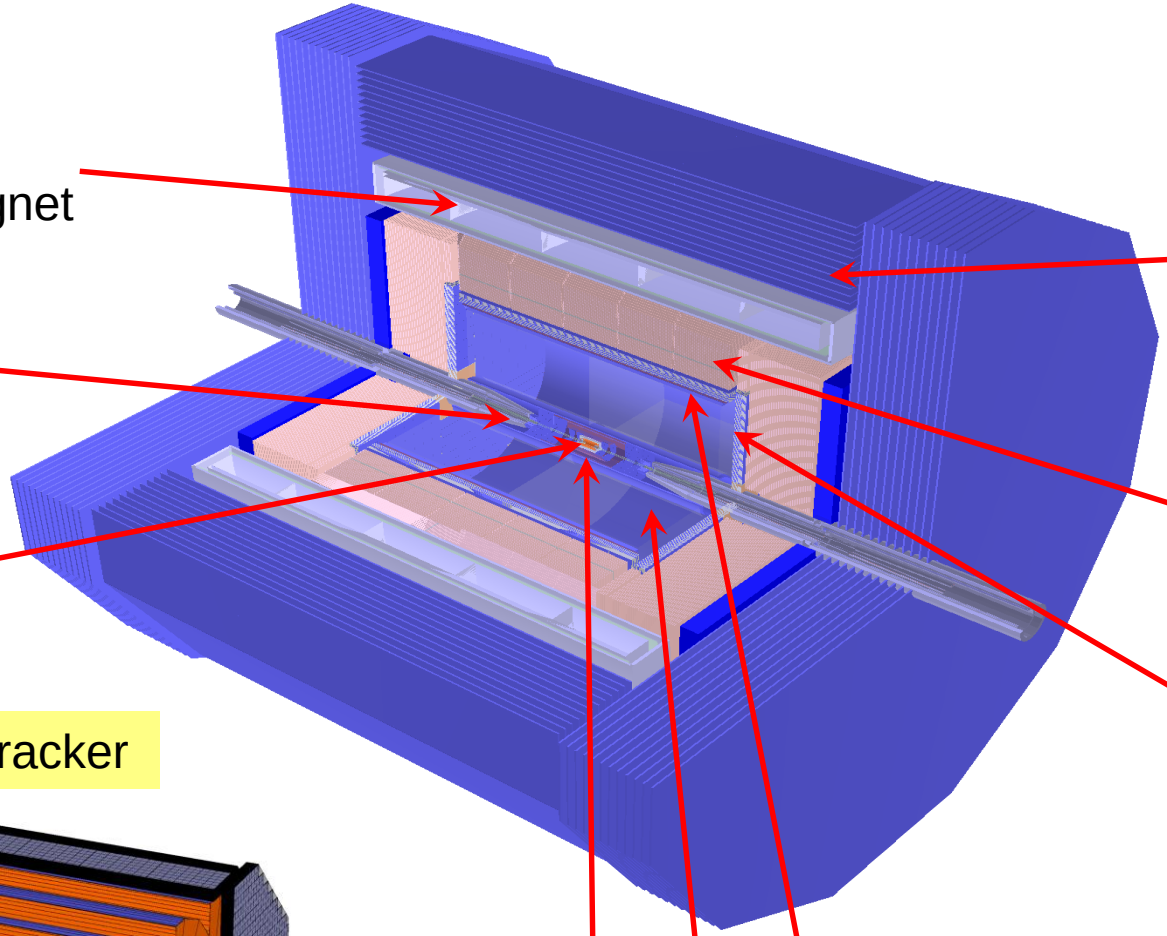
3T / 2T
Solenoid Magnet

LumiCal

Si Pixel Vertex

Yoke + Muon (RPC or μ-RWELL)

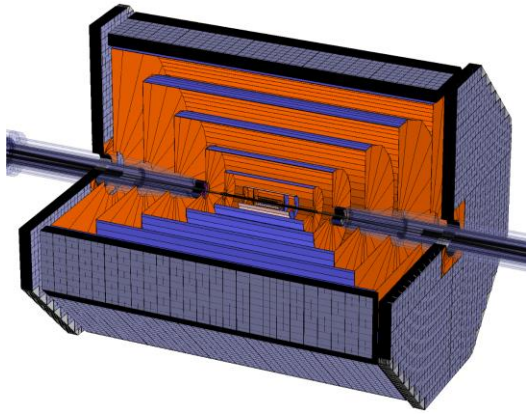
High granularity
sampling calorimeters



PFA ECAL
Tungsten
Analog
Silicon
Scintillator

PFA HCAL
Steel
Analog
Digital
Scintillator
RPC
GEM/THGM
AHCAL
SDHCAL

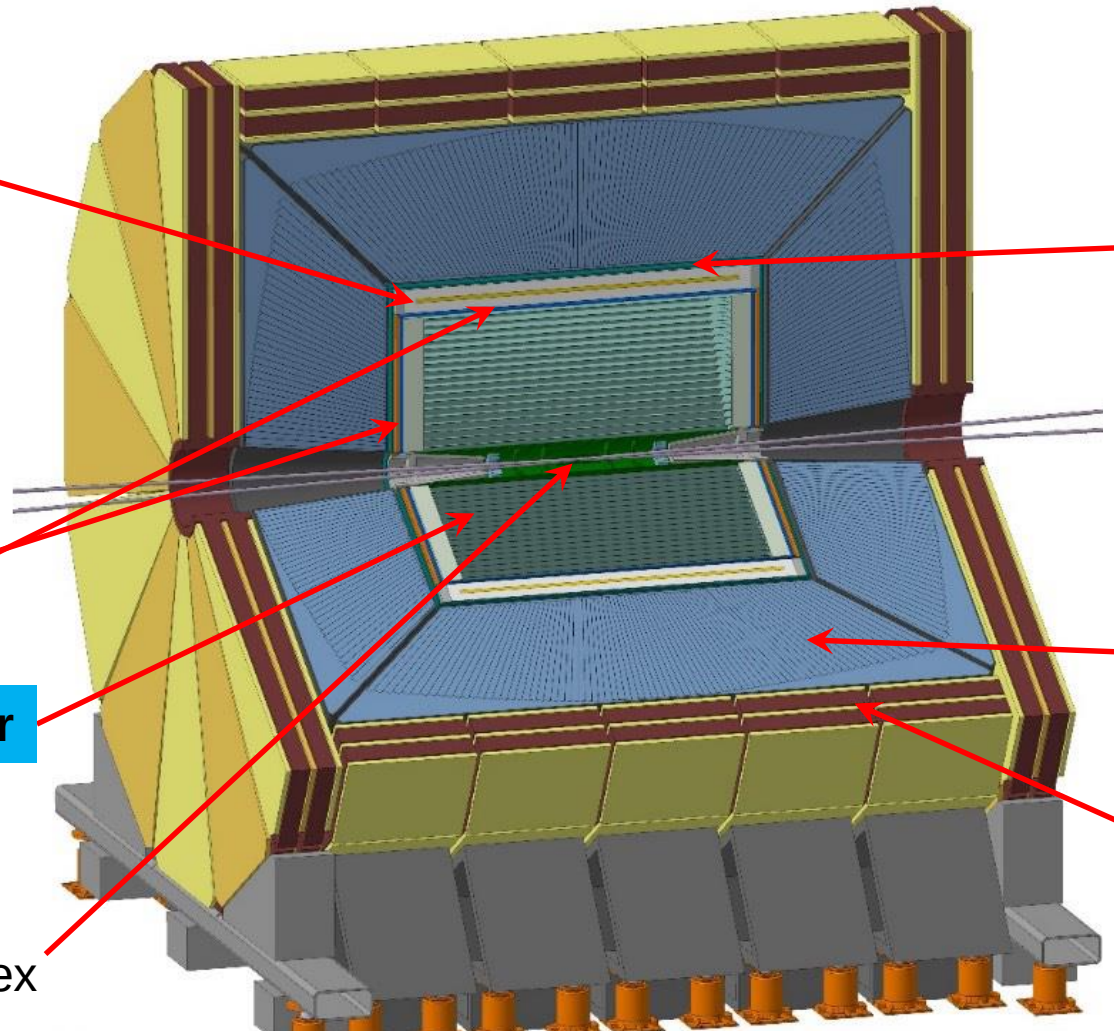
Full Silicon Tracker



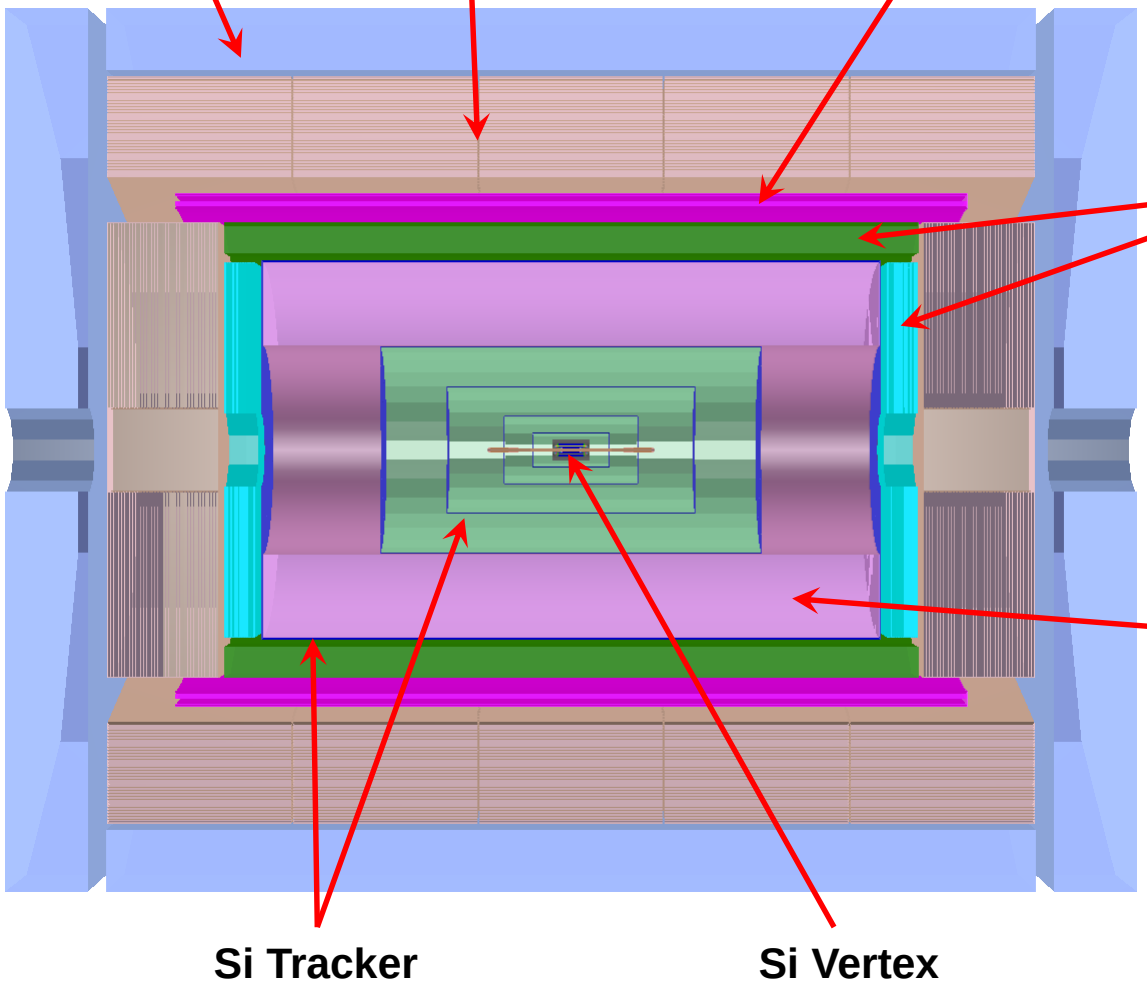
SIT TPC SET
FTD ETD

CEPC Detector in CDR

IDEA concept
(also proposed for FCC-ee)



The 4th Conceptual Detector Design



Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

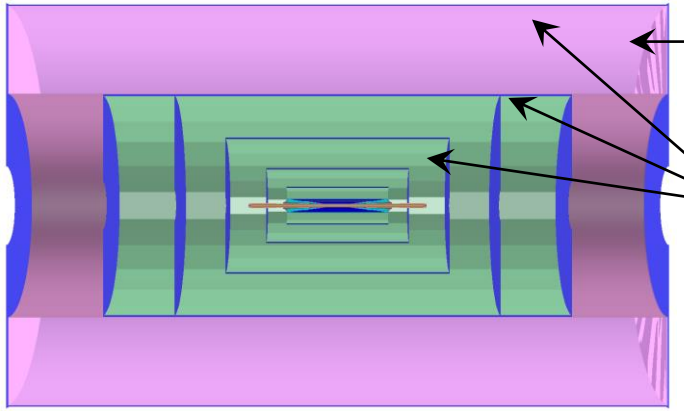
Drift chamber that is optimized for PID

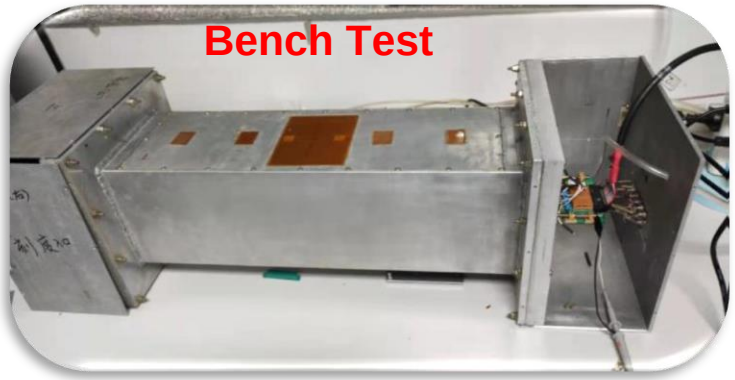
Advantage: Work at high luminosity Z runs

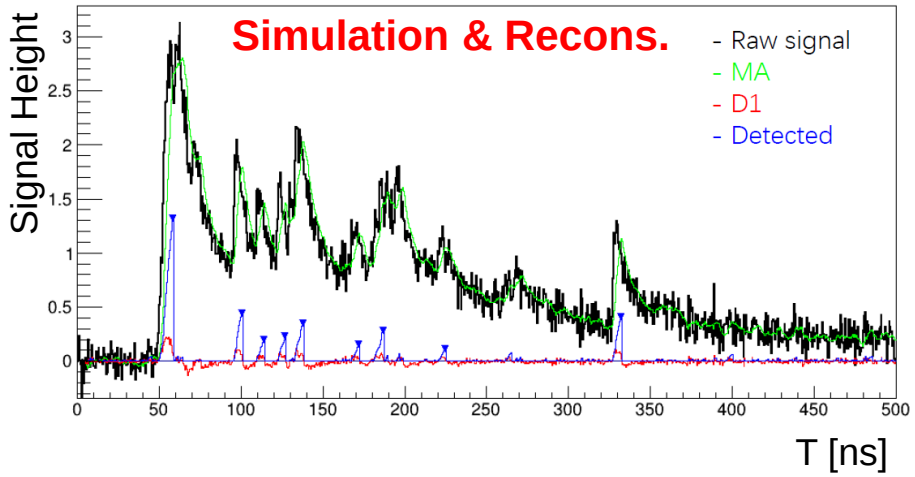
Challenges: sufficient PID power; thin enough not to affect the moment resolution.

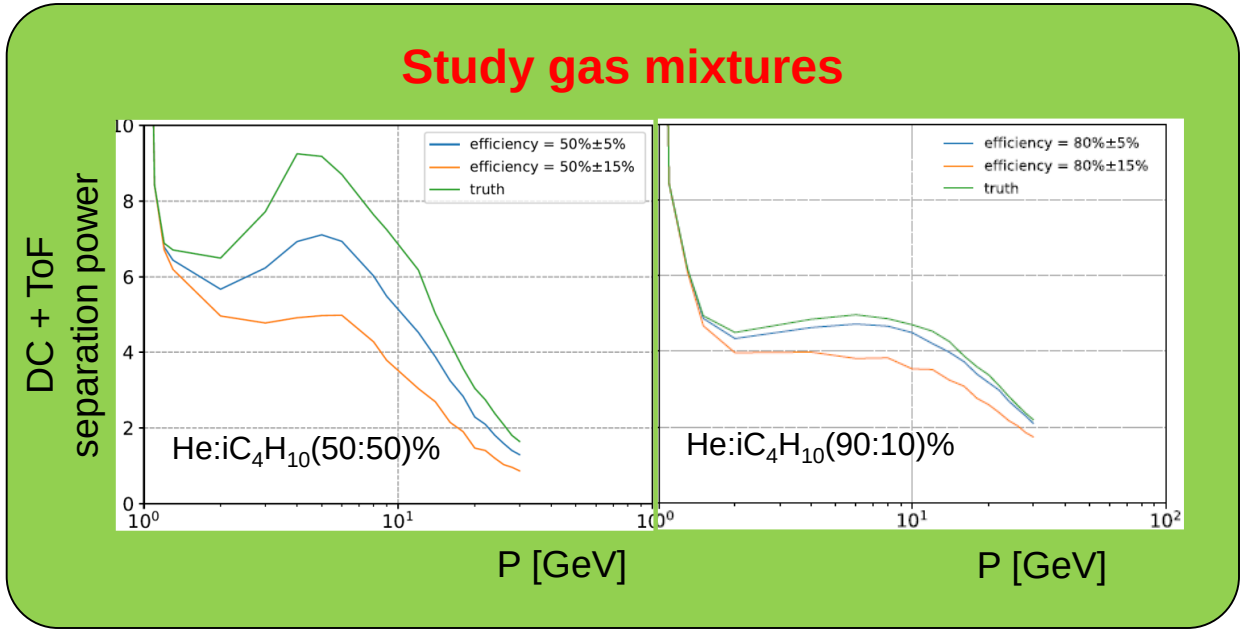
A Drift Chamber That is Optimized for PID

- Goal: 2σ π/K separation at P < ~ 20 GeV/c.
- For FST a supplement PID detector(s) is needed: DC to measure dN/dX, ToF of ~10 ps resolution, aerogel or gaseous RICH



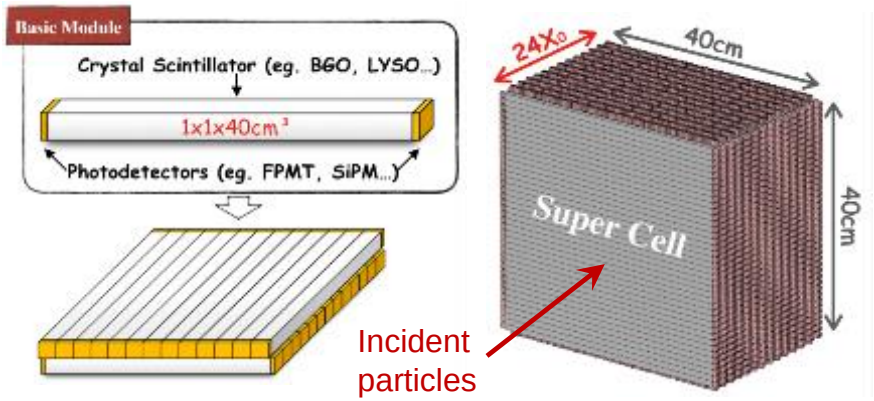






More discussions on Thursday afternoon

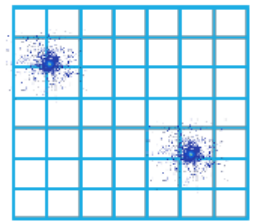
High Granularity Crystal ECAL

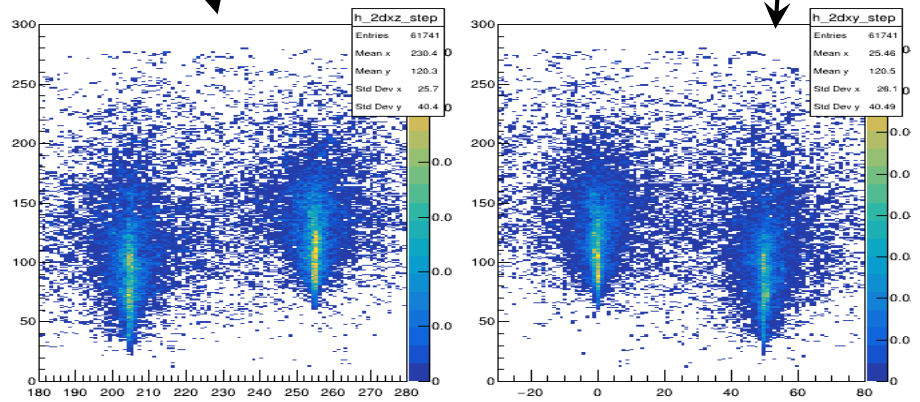


- Timing at two ends for positioning along bar.
- Significant reduction of number of channels.

Design Idea

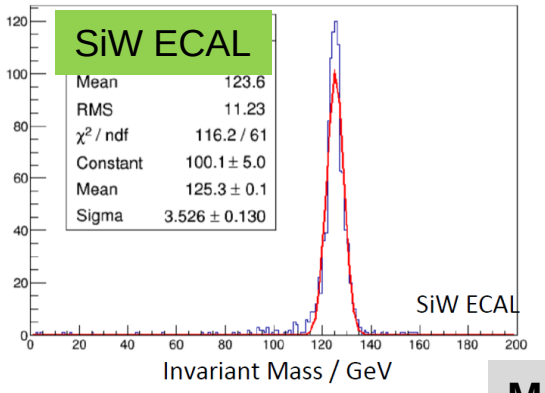
Energy & time matching provide a solution of ambiguity / ghost hits.

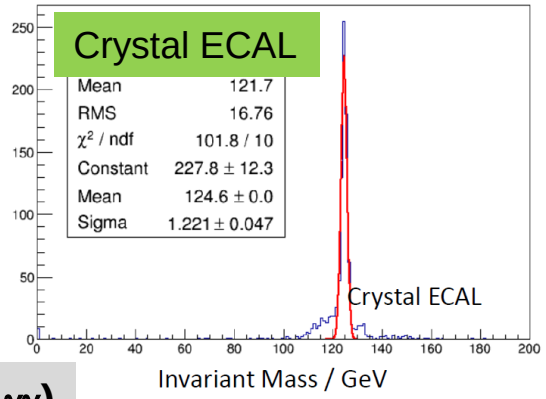




Recon. Algorithm

MC Simulation



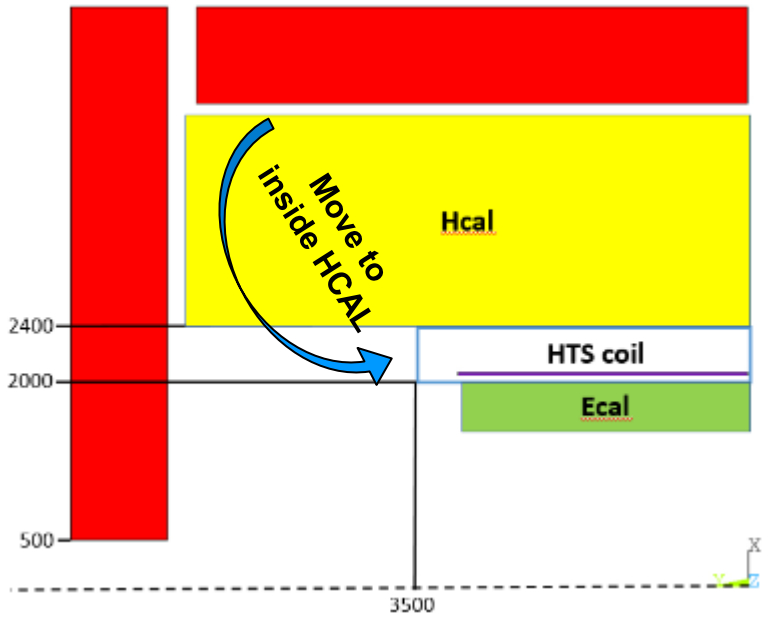


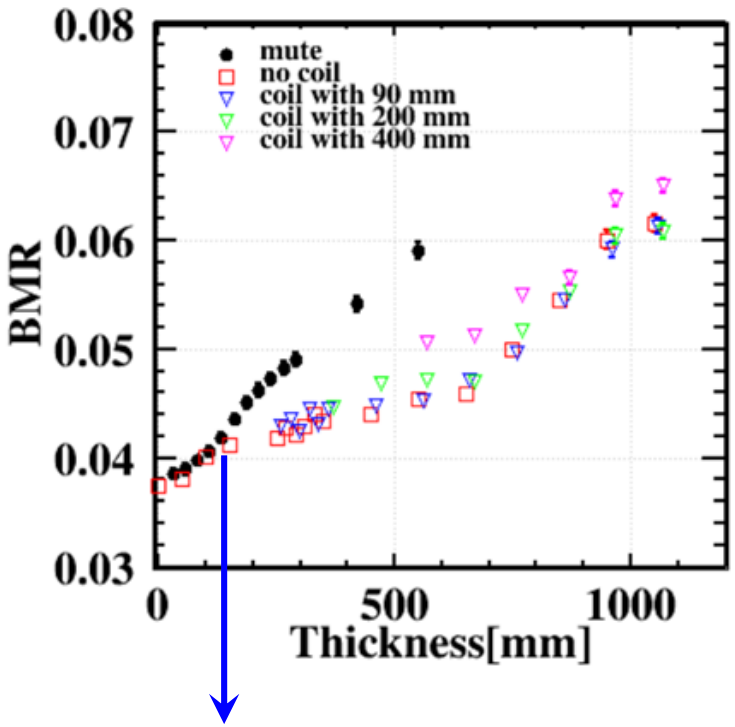
M(H→γγ)

Bench Test

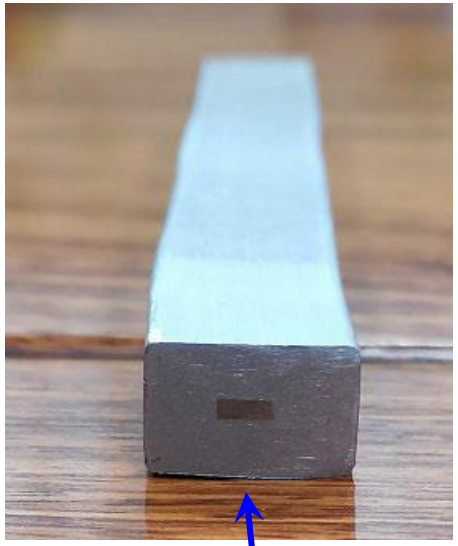
More discussions on Thursday Morning

Solenoid Magnet



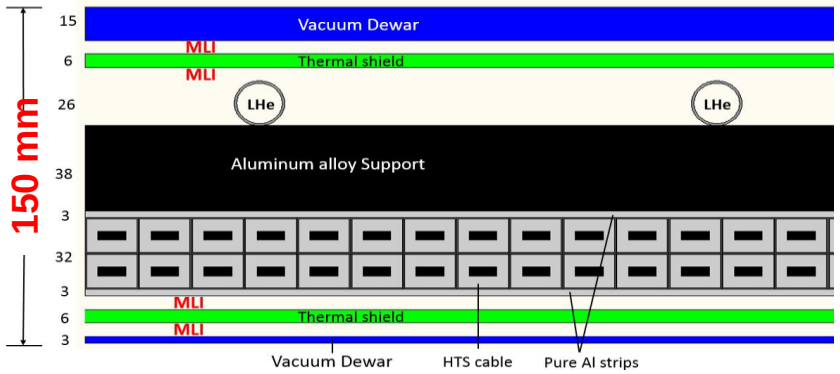


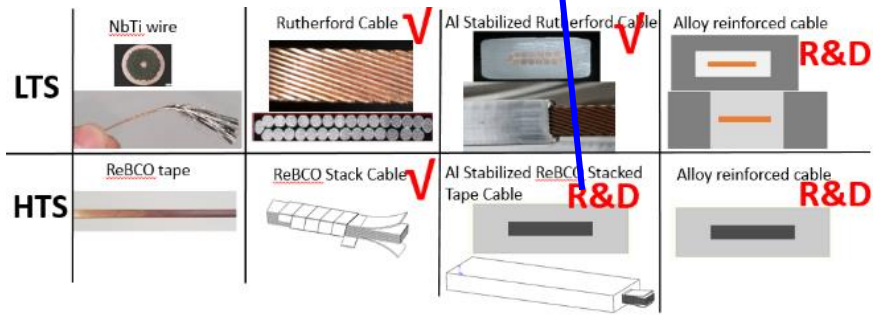
Al stabilized ReBCO stacked tape cable



Challenges

Low mass, ultra-thin, high strength cable





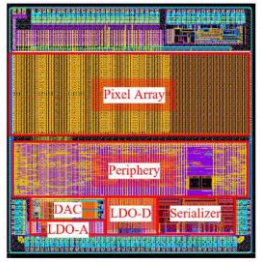
More discussions on Friday Morning

Selection of Detector R&Ds

Pixel Vertex

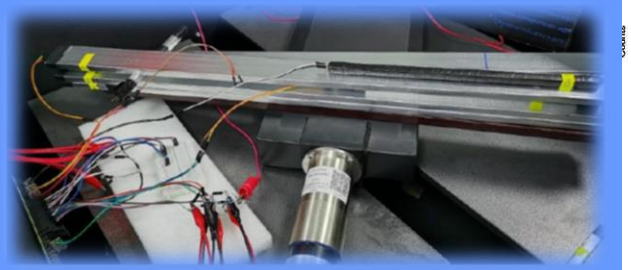
JadePix-3

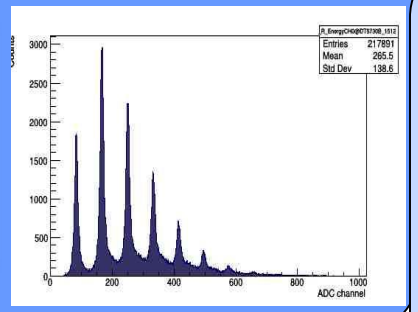
TaichuPix-2



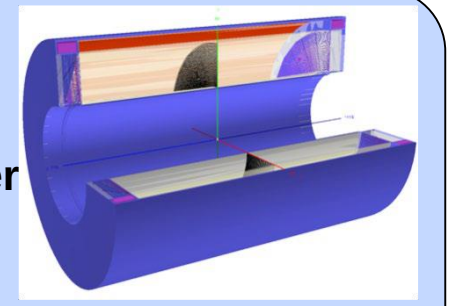
CPV3 test

Scintillator Bar Muon





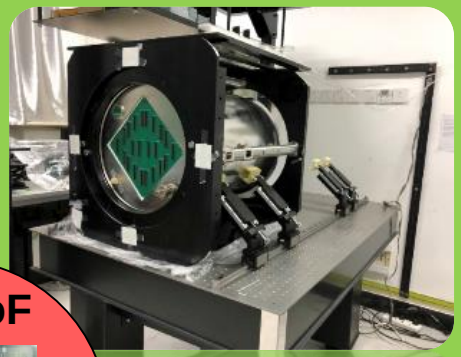
Drift Chamber

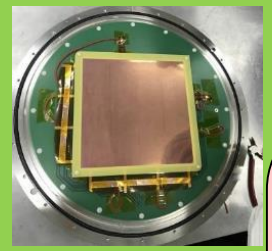


AD9689 – 2000 EBZ

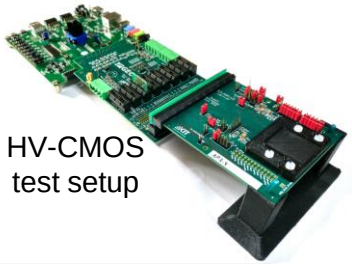
Xilinx KCU105

TPC Prototype



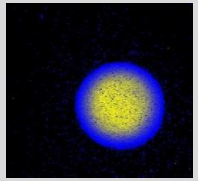


HV-CMOS Tracker

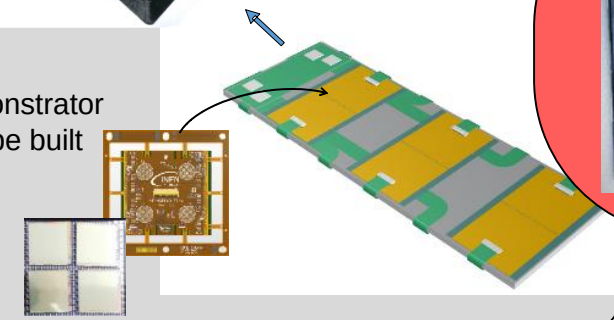


HV-CMOS test setup

Fe source test

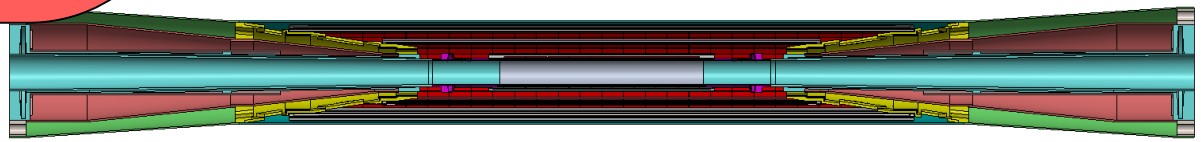


Demonstrator To be built

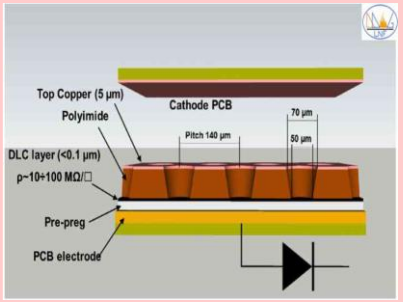


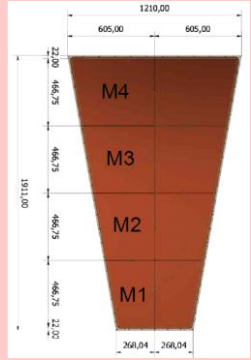
LGAD ToF

Beampipe Design



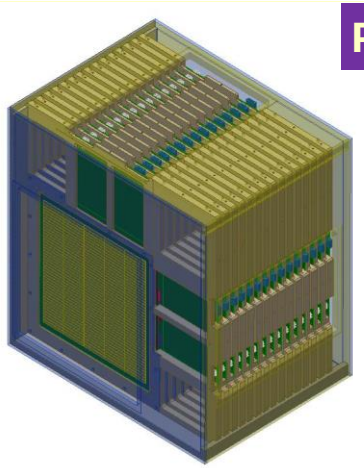
μRWELL for PS & Muon

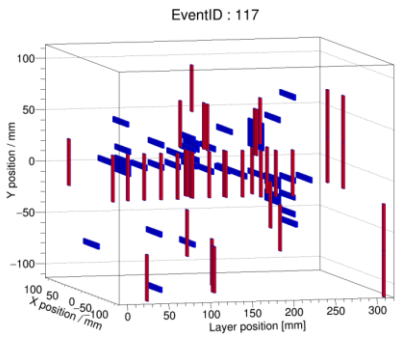




Selection of Calorimeter R&D's

Prototype ScECAL





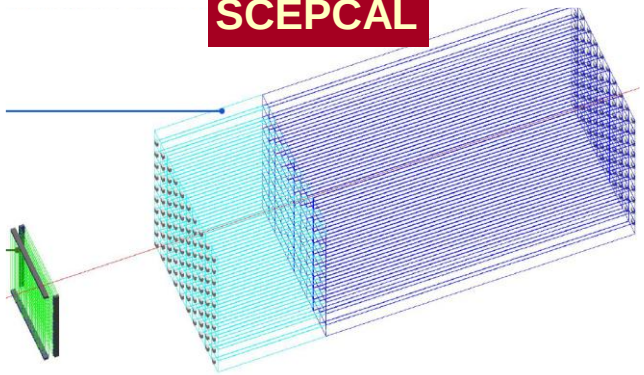
SciW HCAL

USTC

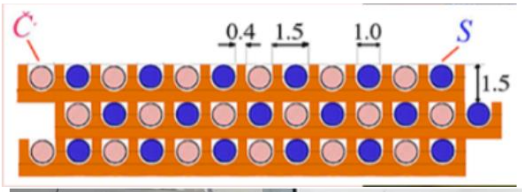
SJTU

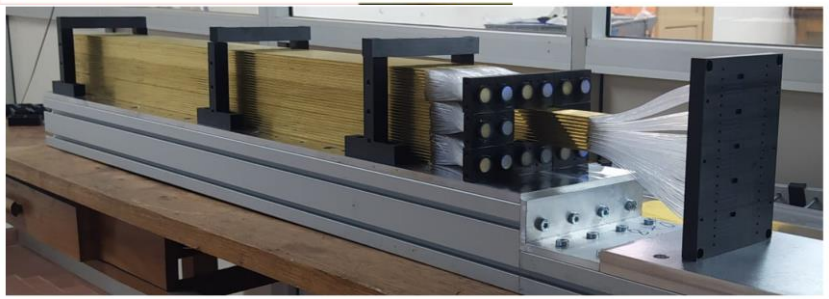
IHEP

SCEPCAL



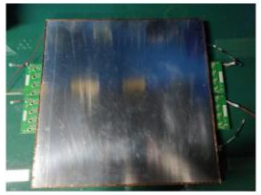
Dual Readout CAL



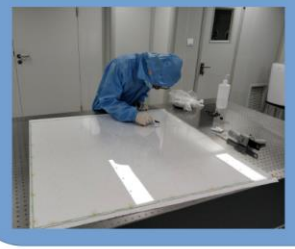


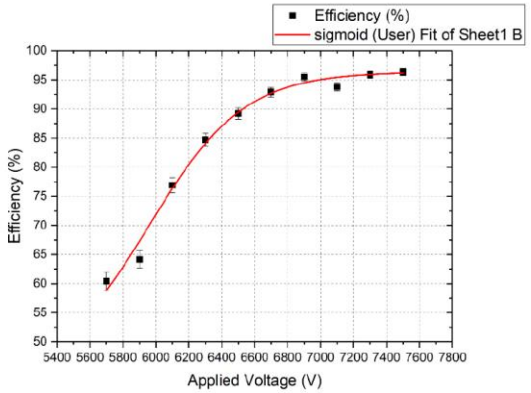
GRPC for SDHCAL

SJTU group built 50cm x 35cm, 100cm x 100cm RPCs



We are now building 1m × 1m chambers.





Detector & Software Presentations

Discussions are encouraged at each session. There will be general discussions on Saturday.

Calorimeters + Muon

Session II, April 15, Thursday (Haijun Yang, Huaqiao Zhang)		
8:30	Status and planning of ECAL R&D	Yunlong Zhang
9:00	Progress of the crystal ECAL	Yong Liu
9:30	Reconstruction algorithm for ECAL	Shengsen Sun
10:00	break (30')	
10:30	Progress of the CEPC AHCAL	Yukun Shi
11:00	Progress of the CEPC SDCAL	Qiuping Shen
11:30	The CEPC muon detector	Xiaolong Wang

MDI, Mech., Magnet, Lumin, Ebeam

Session IV, April 16, Friday (Peilian Liu, Hongbo Zhu)		
8:30	Progress and planning of MDI	Hongbo Zhu
9:00	Status of beam background study	Haoyu Shi
9:30	Beam pipe, overall mechanics and integration	Quan Ji
10:00	break (30')	
10:30	Status and plan of the LumiCal	Suen Hou
11:00	Solenoid magnet	Feipeng Ning
11:30	Beam energy measurement	Yongsheng Huang

Si Vertex / Tracker + TDAQ

Session I, April 14, Wednesday (Lei Zhang, Qun Ouyang)		
13:30	Progress and planning of the Vertex detector	Zhijun Liang
14:00	Progress of the TaichuPix chip	Wei Wei
14:30	Progress of the JadePix chip	Yunpeng Lu
15:00	Wireless readout and control	Jun Hu
15:30	break (30')	
16:00	Progress and planning of the Silicon Tracker	Harald Fox
16:30	HV-CMOS sensor design and test	Jaap Velthuis
17:00	Tracking for Silicon Tracker at CEPC	Chengdong Fu
17:30	Plan of the TDAQ	Zhenan Liu

TPC, Drift chamber, PID

Session III, April 15, Thursday (Kai Yi, Linghui Wu)		
13:30	Progress and planning of the TPC	Huirong Qi
14:00	Front end ASIC and readout electronics for TPC	Zhi Deng
14:30	Charge particle ID	Mingyi Dong
15:00	Drift chamber dN/dX simulation and reconstruction	Guang Zhao
15:30	break (30')	
16:00	Tracking software for the Drift Chamber	Yao Zhang
16:30	Simulation of PID with cluster counting technique	Federica Cuna
17:00	Physics impact of the PID	Shanzhen Chen
17:30	Optimization of the tracking system	Xin Shi

Software

Session V, April 16, Friday (Weidong Li, Xingtao Huang)		
13:30	The status of CEPCSW software framework	Jiaheng Zou
14:00	The simulation software for the CEPC experiment	Tao Lin
14:30	Automated validation system for CEPC	Teng Li
15:00	Jet tagging algorithm	Gang Li
15:30	break (30')	
16:00	Integration of Pandora to CEPCSW	Wenxing Fang
16:30	Status of ACTS integration to CEPCSW	Jin Zhang
17:00	Data Management with Rucio and Xcache	Xiaomei Zhang

Towards A Paper of "The 4th Conceptual Detector"

- Aim for a "CDR-ish" paper on the new detector concept, to be submitted to NIMA (or RDTM) before the CEPC annual workshop at the end of October.
- From the discussions, we should have concensus on:
  1) Which detectors and sub-systems should be included? Info in the CDR do not need to be repeated. However, it may be a good idea to have a complete detecting system.
  2) What are the competitive technologies? Some comparisons may be necessary.
  3) What are the major technical challenges, and projections to the time of construction?
  4) What have already been achieved so far? What do we expect in a few months?
  5) Refine our selection of physics benchmarks to aid the detector design.
  6) …
- Drafting of the paper may start very soon. A core group of editors will be formed.

Wish you all a pleasant stay & fruitful discussions !