status of CEPC pre-CDR on detector

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on behalf of the Physics & Detector WG
CFHEP Symposium, Beijing, 2014.8.11

SHANDONG UNIVERSITY

outline

- introduction
- on subsystems
  - physics analysis and optimization
  - vertexing (with silicon tracking)
  - tracking
  - calorimetry and muon
- summary & outlook

on accelerator ➔ see GENG Huiping's talk

aims of detector pre-CDR

- clarify basic physics requirements
- determine detector challenges and performance requirements
- skeletonize a baseline detector design
- identify potential technologies
- figure out critical R&D's

→ a cornerstone for a **TDR** (Technical Design Report) in the future

organization

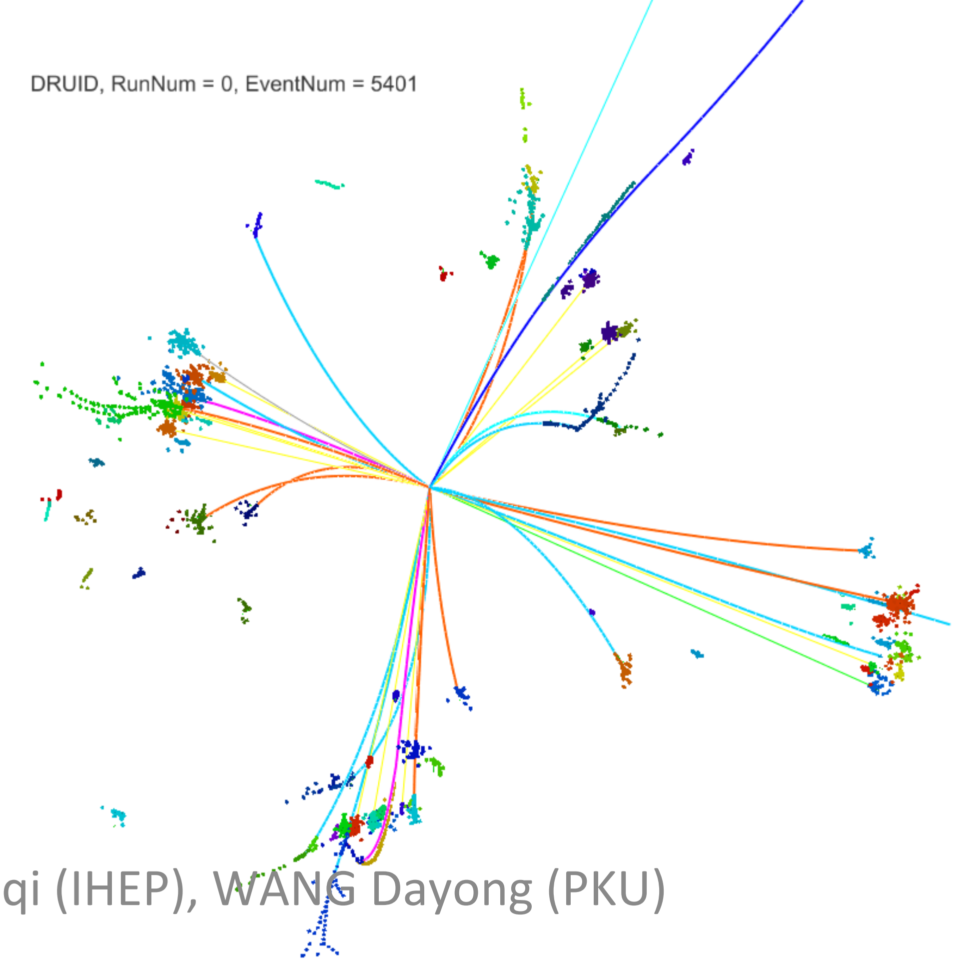
- physics and detector WG:
  GAO Yuanning (THU), JIN Shan (IHEP)
- sub-groups
  - physics analysis and optimization:
    LI Gang, RUAN Manqi (IHEP), WANG Dayong (PKU)
  - vertexing: OUYANG Qun (IHEP), WANG Meng (SDU)
    - silicon tracking: TU Yanjun (HKU), ZHU Hongbo (IHEP)
  - tracking: LI Yulan (THU), QI Huirong (IHEP)
  - calorimetry and muon:
    HU Tao (IHEP), YANG Haijun (SJTU)

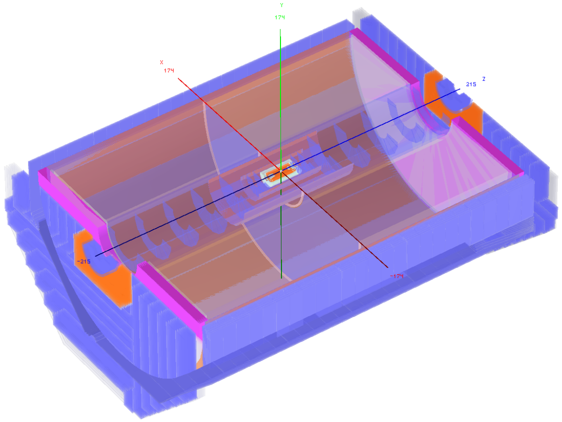
Strategy

- ILC detectors, especially ILD as a reference
- Special issues
  - Power pulsing not possible:
    more cooling and/or less channels?
  - Limited to lower c.m.s. energy:
    smaller detector
    very fine granularity not necessary?
  - L* = 1.5m or 2.5m (cf. 3.5m at ILC)
    less solid angle coverage
    special considerations at the interaction region
- "The detector" in pre-CDR
  - Similar performance as ILD for the physics to be addressed
  - (Hopefully) less technology challenges than ILD

technical preparation for pre-CDR

- typeset with LaTeX
  - a template prepared
- a subversion repository created for co-writing
  - http://cepcdoc.ihep.ac.cn/svn/cepcsvn/pCDR
- technical support
  - LI Gang, WEN Shuoping (IHEP)





conveners: LI Gang, RUAN Manqi (IHEP), WANG Dayong (PKU)

PHYSICS ANALYSIS & OPTIMIZATION

layout of physics pre-CDR

- Chapter X.1: General Introduction
- Chapter X.2: Higgs Measurements
  - Higgs at CEPC
  - Main observables →
  - Global Fit (M. Chen, Y. Fang, T. Chen, etc)
  - Interpretation (Y. Tu)
- Chapter X.3: SM Measurements
  - LEP (Z. Liang)
  - Neutrino Generation (Z. Liang)
  - Rare decay limits of Z & its daughters
  - W mass, width & Triplet Gauge Boson Coupling (Q. Li, Y. Wu, etc)
  - Interpretation
- Chapter X.4: Conclusion

Mass, σ(ZH): Y. Yang, L. Yuan, G. Li,

Br(H→μμ): B. Wang, L. Yuan, G. Li

Br(H→inv): L. Yuan, etc

Br(H→bb, cc, gg): H. Yang, etc

Br(H→WW): Z. Chen

Br(H→ττ): J. Liu, etc

Br(H→γγ): F. Wang, G. Li

Br(H→ZZ): C. Feng, X. Yang, L. Shan, X. Li,

Br（H→Zγ） ?

sigma(vvH)*Br(H→bb): S. Liu

Higgs CP: N. Chen, Y. Tu

Higgs analysis at CEPC

	CEPC @ 5 ab^{-1}	Current Status	Responsable & perspective
mH (Model Independent)	8 MeV	12 MeV (μμH)	IHEP, CCNU
σ(ZH)	0.7 %	1.2 %	IHEP, CCNU
Higgs CP		Theoretically Investigated	THU, HKU
Δ(σ*Br)/(σ*Br)			
ZH, H→bb	0.4%	0.22% (qqH channel)	SJTU, IHEP
H→cc	2.1%	2.2 – 2.8%	SJTU, IHEP
H→gg	1.8%	1.8 – 2.4%	SJTU, IHEP
H→WW*	1.3%		IHEP, PKU
H→ττ	1.2%	Efforts initialized	IHEP, USTC
H→ZZ*	5.1%		SDU
H→γγ	8%	~ 12% (ννH)	WhU, IHEP
H→μμ	?		UCAS, IHEP
H→Inv.	0.3%		IHEP, HKU, HKUST
ννH, H→bb	3.8%		PKU, IHEP

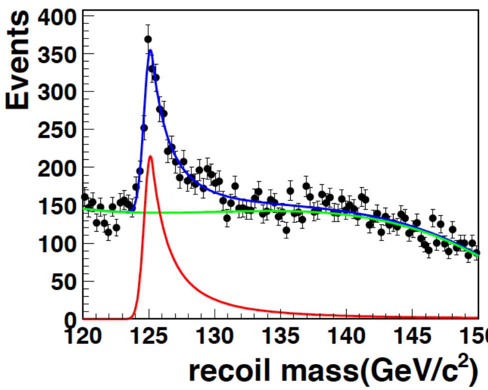
Optimistic Perspective
By the end of 2014

To be validated by Full Simulation

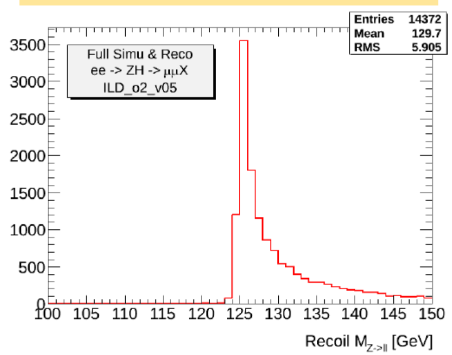
Stat at Fast Simulation Level

some analyses on Higgs measurements

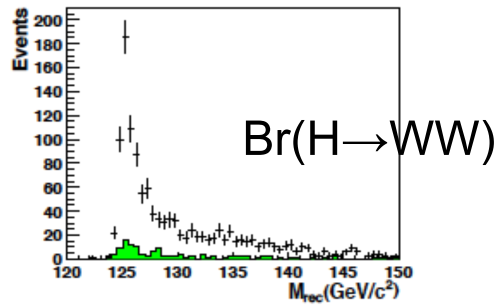
Higgs
recoil mass & Xsec

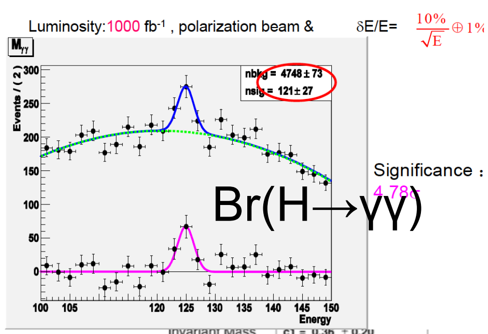


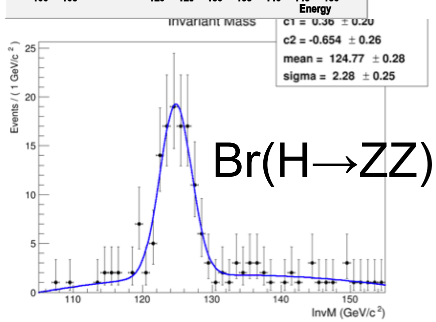
→Recoil Mass of Z → μμ
Mean = 129.7 GeV
RMS = 5.9 GeV



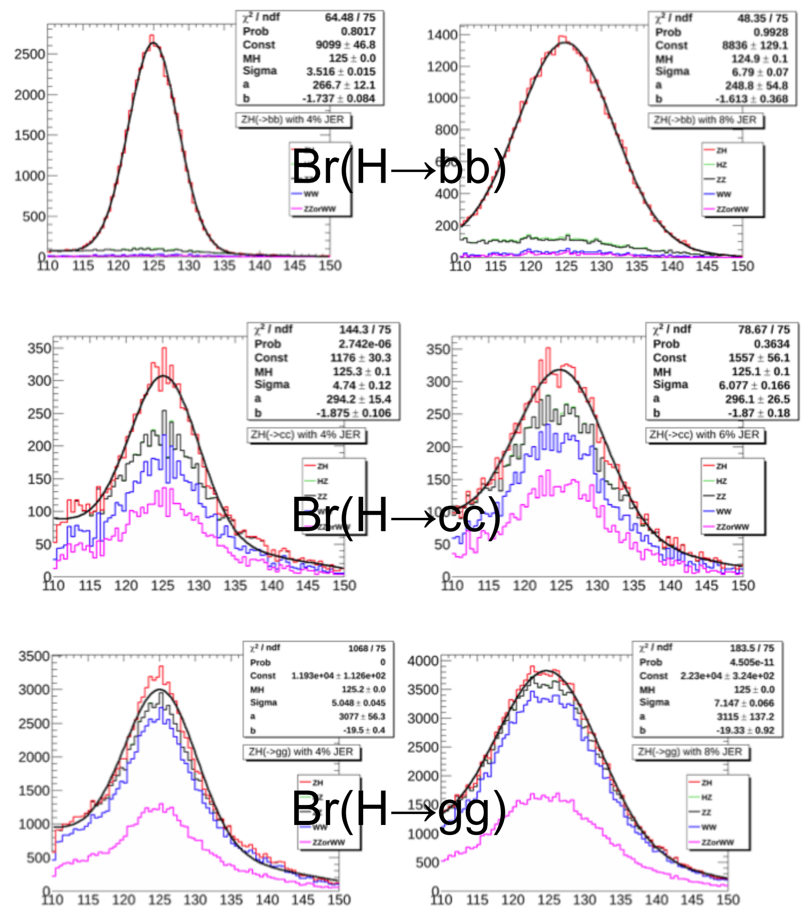
Br(H→bosons)





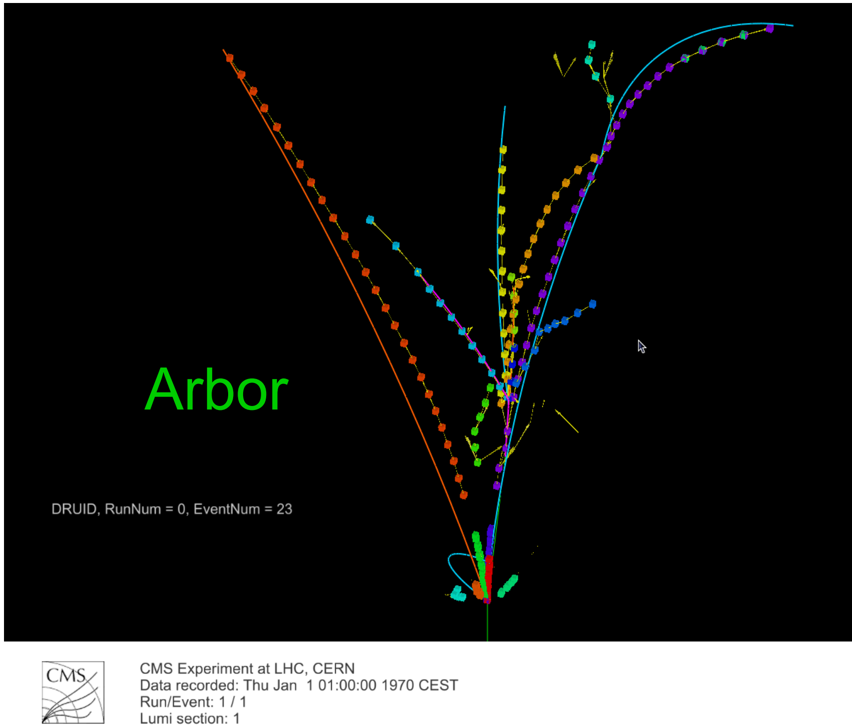


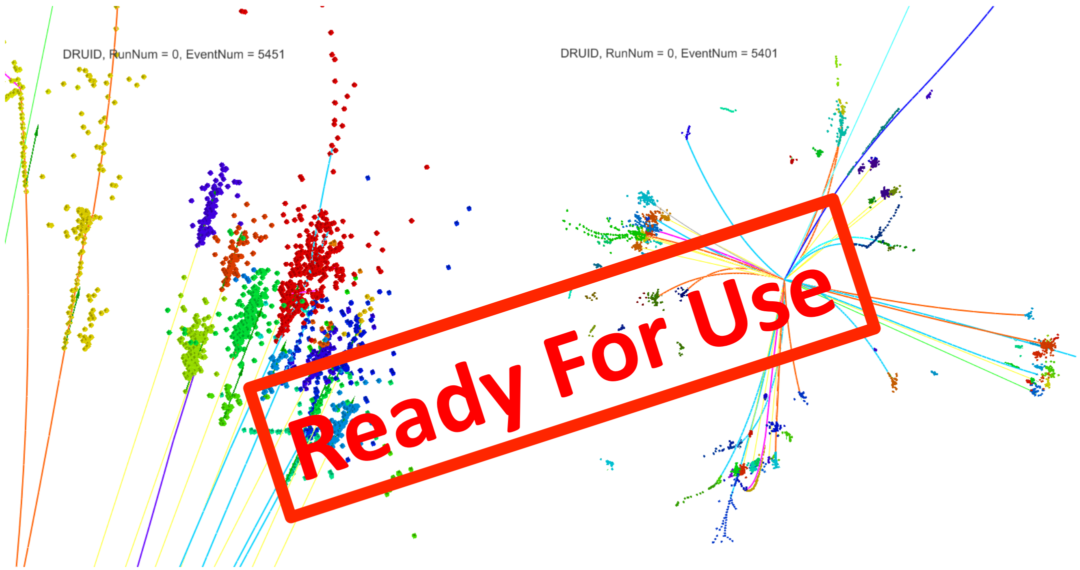
Br(H→2 jets)

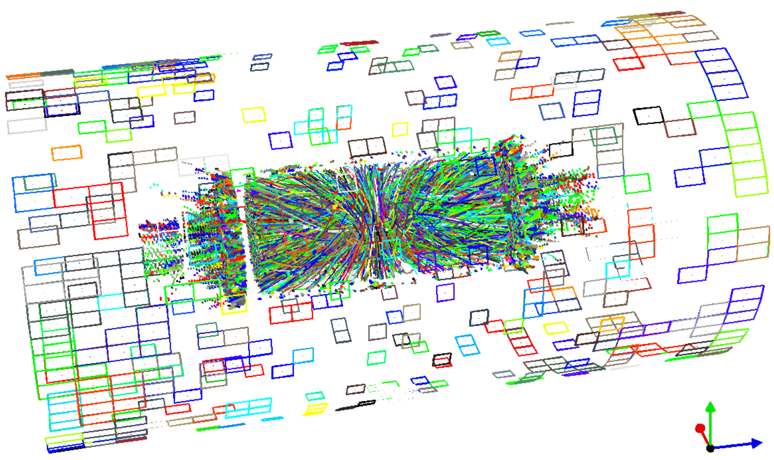


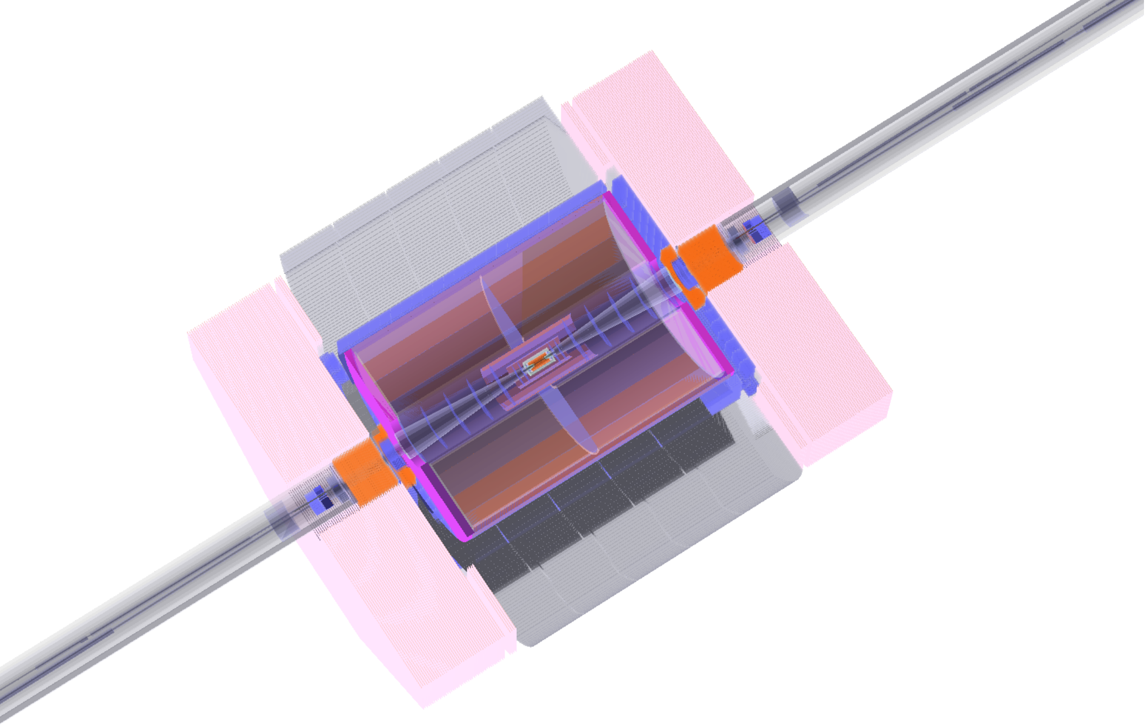
Arbor PFA

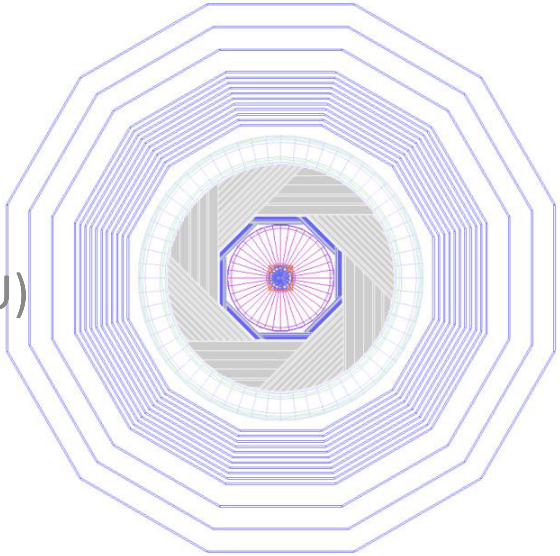
- generic PFA fully appreciating high-granularity Calorimeter System
  - Excellent separation & sub-shower structure recognition
- breakthrough at speed: < 1min to process an event with ~100k hits (eg, CMS detector with 140 pile-up)
- applied to Full Simulation at CEPC











conveners: OUYANG Qun (IHEP), WANG Meng (SDU)

VERTEXING & SILICON TRACKING

layout of vertex pre-CDR

- vertex detector
  - introduction (OUYANG Qun)
  - physics motivation (WANG Meng)
  - detector challenges and performance requirements (WANG Meng)
  - baseline design (OUYANG Qun)
  - sensor options (LU Yunpeng)
  - simulation and reconstruction (LIU Beijing)
  - mechanics and integration (DONG Mingyi)
  - critical R&D (WANG Meng)
  - cost estimation (OUYANG Qun)
- silicon tracker (ZHU Hongbo, TU Yanjun)

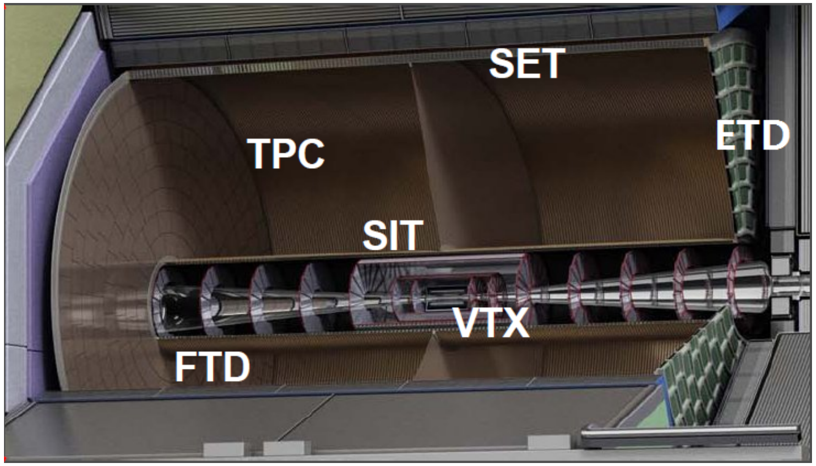
vertex detector

- Dedicated project to explore the feasibility of CMOS based pixel sensor technologies
  - already used for STAR and approved for ALICE ITS upgrade
  - candidate technologies for the ILC VTX

- Project kick-off meeting on 21 July
  formed a group of electronics/detector experts
  - identify the MPW (Multi-Project Wafer) availability of the promising CIS (CMOS Imaging Sensor) technologies
  - perform TCAD simulation and design the pixel cell structure
    ➔ important to submit test structure early next year to achieve better understanding
  - design in-pixel electronics and readout electronics
    ➔ exploring to achieve fast readout but with low noise and low power consumption

Important preparation work for intensive R&D efforts from next year on

Silicon Tracker



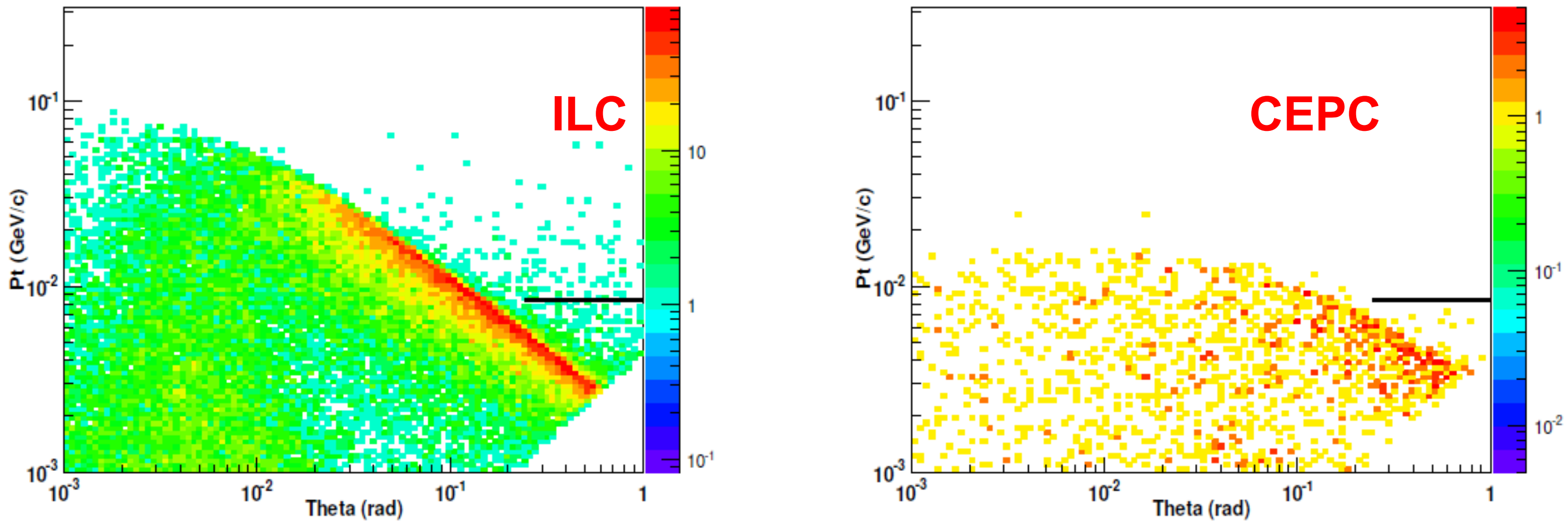
"**Silicon Envelope**" surrounding **TPC**

- Silicon layers: **SIT/SET/FTD/ETD**
- Improved momentum resolution and better interface to Calorimeter/**VTX**
- Impact of removing **SET** (half of the silicon area, **expensive**) *to be evaluated*

- **R&D prospects:**
  - **Silicon microstrip sensors**: edgeless (< 100 μm), thin (< 200 μm), pitch adapter (connection to readout chip), large wafer size (4' available from domestic vendor but 8' preferred ← cost effective)
  - **Front-end electronics**: low power consumption, low noise, 65nm CMOS technology, potential unified application with calorimeter readout
  - **Powering and cooling**: DC-DC powering, air cooling (or more aggressive cooling, e.g. silicon micro-channel cooling)
  - **Mechanics**: low mass supporting structure but with sufficient stiffness and stability, easy integration (and replacement), etc.

Radiation Background

- beam induced background imposes large impacts on detector design (e.g. detector occupancies, radiation damage, etc.)
- may degrade detector performance (additional noise in finding tracks/vertices)
- **Guinea-Pig** (beam-beam interaction simulation) + **Geant4**



two main processes: **beamstrahlung photons** + **pair production**
The black line indicates the polar angle coverage of the vertex detector

conveners: LI Yulan (THU), QI Huirong (IHEP)

TRACKING

participants of tracking sub-group

Tsinghua University	Gao Yuanning, Li Yulan, Li Bo, Deng zhi
IHEP	Li Jin, Qi Huirong, Zhang Yulian
Shandong University	Zhu Chengguang
UCAS	Zheng Yangheng, Liu Qian, Wang Binlong
Lanzhou University	Hu Bitao, Zhang Yi
Nankai University	Fu Chunxu, Yang Yujiao
Shanghai Jiaotong University	Yang Haijun, Fu Changbo
Nanjing University	Zhang Huijun
CIAE	Li Xiaomei, Zhou Shuhua, Zhoujing, Hu Shouyang

layout of tracker pre-CDR

Contents	Prepared by
1 Overview 1.1 PhysicsRequirement 1.2 Detector Options 1.3 TPC Review 1.4 Detector Layout ..	Zhu Chengguang Shandong Unviersity
2 Design of the TPC 2.1 Physical Design 2.2 Working Gas 2.3Structure 2.3.1Chamber 2.3.2Endplate 2.3.3Field cage	Qi Huirong IHEP
2.4Readout Module 2.4.1 GEMs + pad readout 2.4.2Micromegas + resistive pad readout	Li Yulan Tsinghua
2.5Electronics 2.5.1 FEE 2.5.2 DAQ 2.5.3 Cooling	Dengzhi Tsinghua

layout of tracking pre-CDR (cont'd)

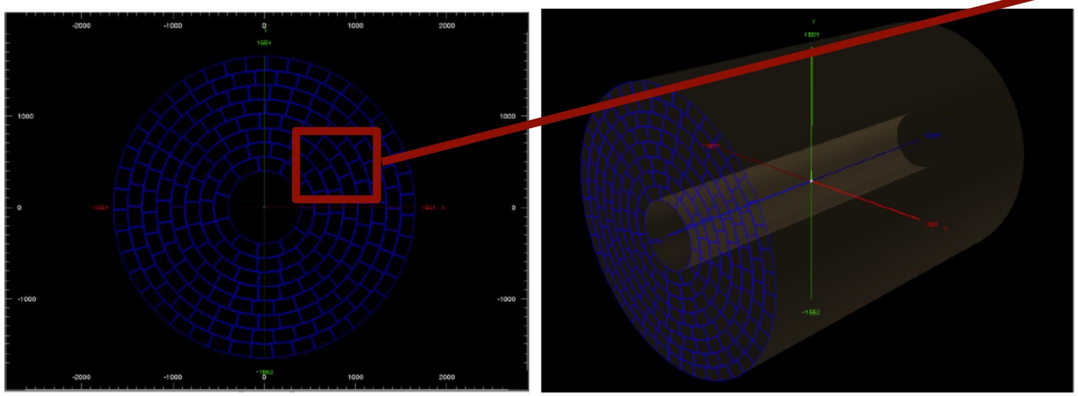
2.6 Support Structure . . 2.7 Gas Supply system 2.8 High Voltage system (V and I)	Zhangyi Lanzhou University
3 Calibration and Internal Alignment of the TPC 3.1 Alignment of the Tracking System 3.2 Hardware alignment system 3.3 Structural and Environmental Monitors 3.4 Track-based Alignment 3.5 Calibration Scheme	Li bo Tsinghua
4Challenge and pre-study	
4.1 Challenge 4.1.1 IBF	Liu Qian UCAS
4.1.2 Calibration	Li bo Tsinghua
4.1.3 Electronics anti-irradiation 4.1.4 Power consume and control	Dengzhi Tsinghua
4.2 Pre-study 4.2.1 Prototype design and construction 4.2.1.1 Gas 4.2.1.2 Endplate 4.2.2 Performance study（simulation and exp.）	Qi Huirong IHEP
5 Cost: Merge with all section 6 Table ： HV、GAS、Chamber、	ALL

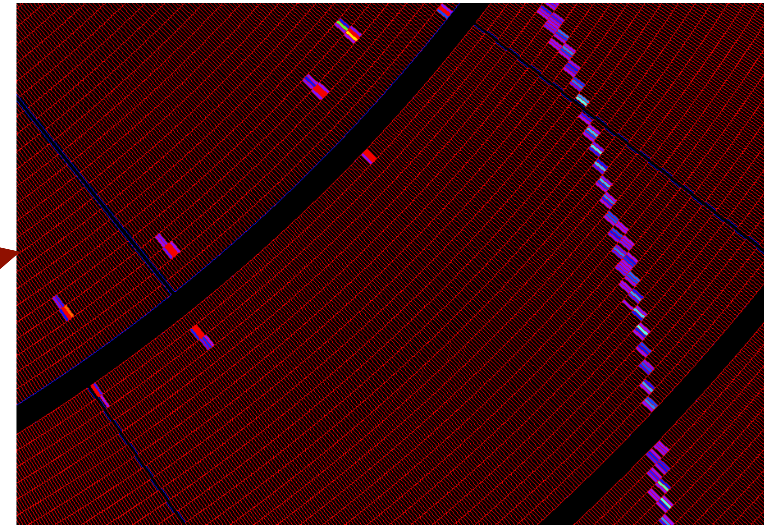
plans for simulation

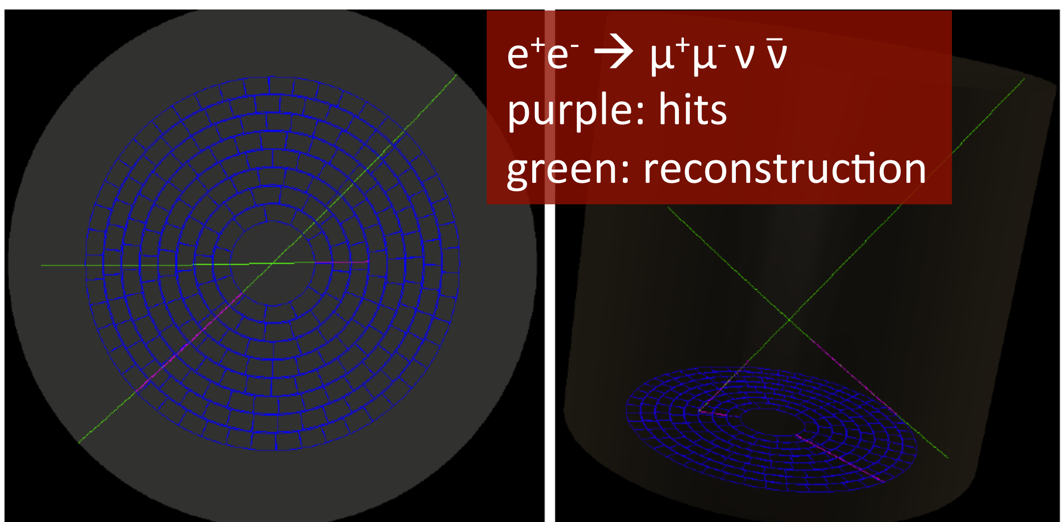
- Mokka for detector simulation: the track of charged particle; energy deposit; particle decay and scattering.
- Digitization by MarlinTPC
  - Available gas: TDR, P10, P5, T2K
  - However, it seems that the progresses of gas amplification and charge distribution are very time-consuming.
- Two options for track reconstruction:
  - Clupatra
  - MarlinTPC: maybe more suitable for detailed TPC research; **need further optimization.**
- Occupancy
  - Input of beam parameters: luminosity, bunch crossing rate ...
  - **The impact of occupancy on tracking and ion back flow.**
- **TPC tracking performance in non-uniform magnetic field.** The effect of electron drifting should be also be considered.

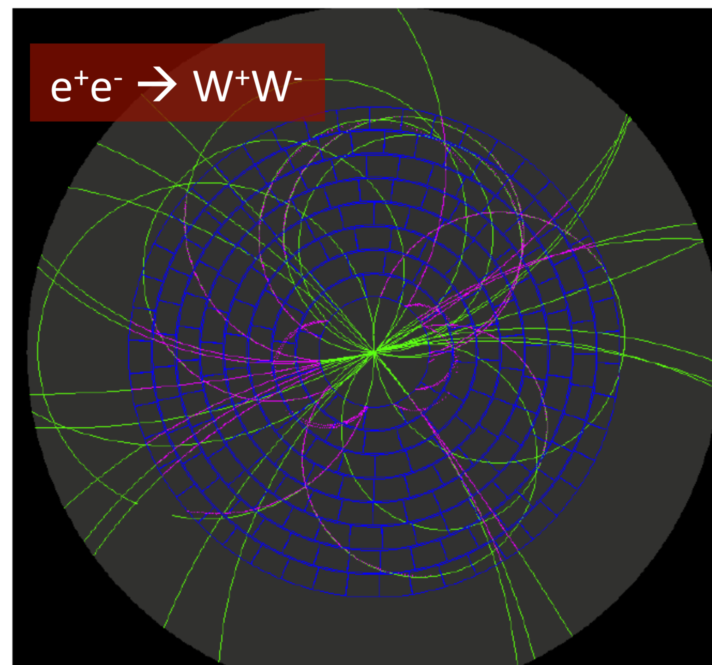
simulation with geometry as ILD TPC

- half-Z: 2200 mm
- inner radius: 329 mm
- outer radius: 1808 mm
- pad pitch: 1.2 mm, height: 5.6 mm



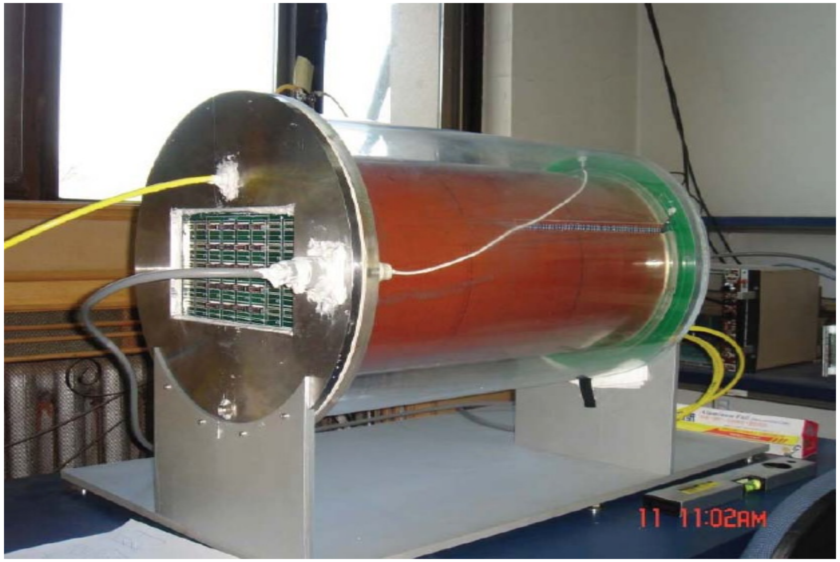






test of a TPC prototype at THU

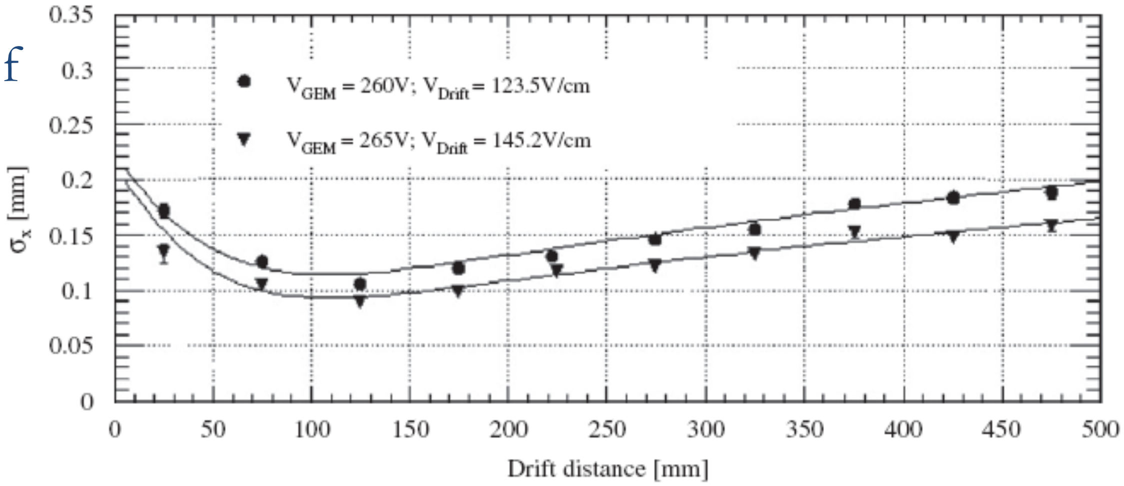
- cylinder length: 500 mm
- readout GEM: 100 x 100 mm^2
- 10 x 62 pads, staggered placement
  - pad size: $9.5 \times 1.5\ mm^2$
  - pitch: $10\ mm \times 1.6\ mm$
- 10 x 32 pads used due to limited number of electronic channels

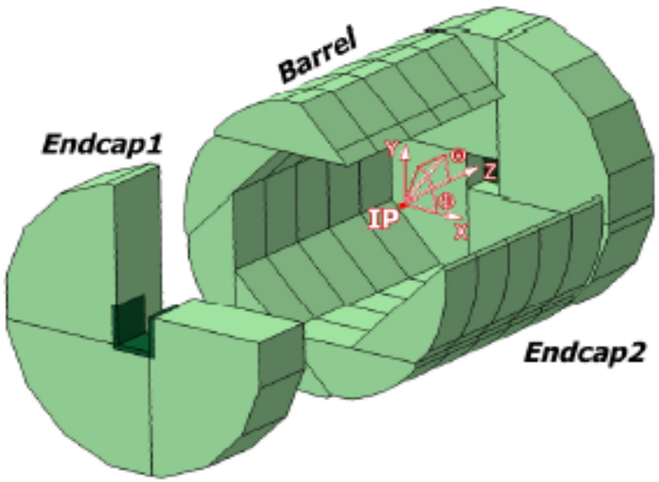


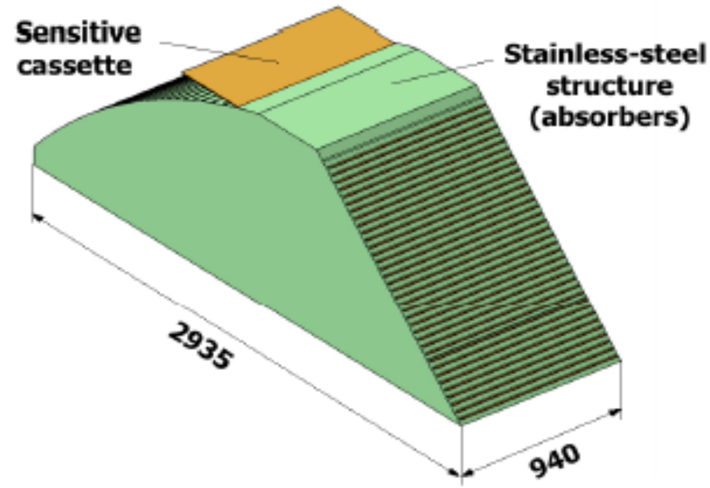
spatial resolution as a function of drift distance (B = 1 T)

best reach:

$\sigma_X = 100\ \mu m\ @\ Z \approx 100\ mm$







conveners: HU Tao (IHEP), YANG Haijun (SJTU)

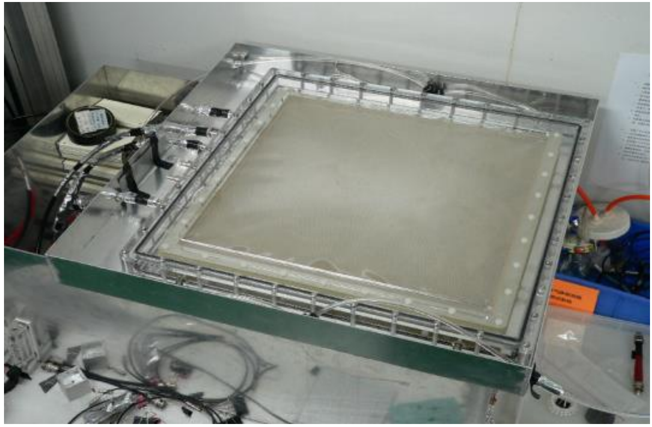
CALORIMETRY & MUON

layout of Calorimeter pre-CDR

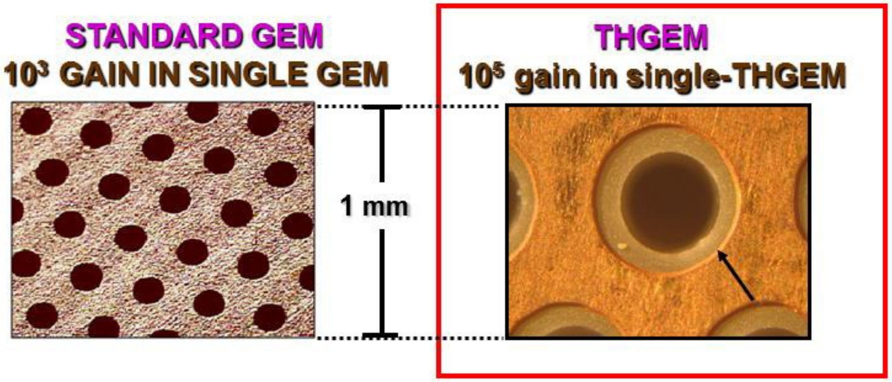
1st draft is circulating

- Introduction and general layout to calorimeters
- ECAL for Particle Flow Approach
  - Scintillator-Tungsten Sandwich – WANG Zhigang (IHEP)
  - Silicon-Tungsten Sandwich - Jean Claude Brient, Vincent Boudry (IN2P3)
- HCAL for Particle Flow Approach
  - DHCAL (ThGEM) – YU Boxiang (IHEP)
  - DHCAL (RPC) – XIA Lei (ANL/SJTU)
  - SDHCAL (GRPC) – HAN Ran (NCEPU), Imad LAKTINEH (IPNL)
- Muon system – XIE Yuguang (IHEP)
- Calorimeter Calibration and Alignment (included in sub-detector option)
- Front-End Readout System (included in sub-detector option)
- Power and Cooling System (included in sub-detector option)
- Cost Estimation (included in sub-detector option)

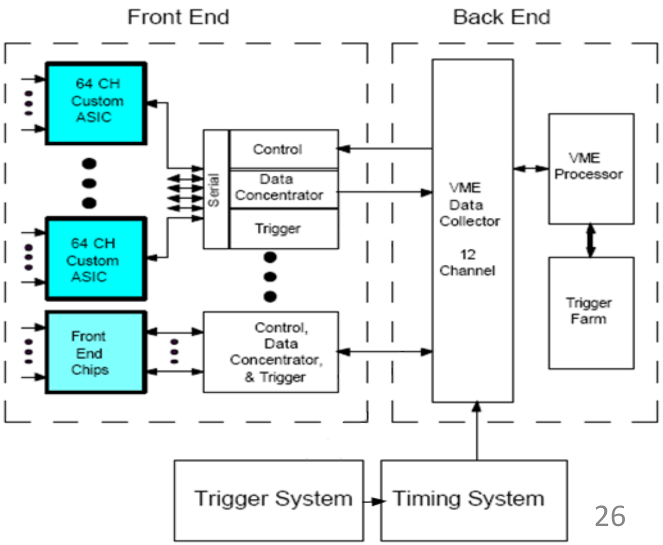
about DHCAL (ThGEM)



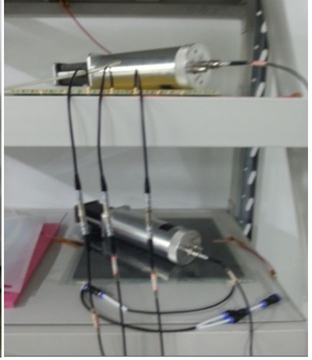
- Contents
  - Introduction
  - Digital Hadronic Gas Calorimeter
  - The Active Layers
  - Energy Reconstruction & Calibration
  - Digital readout system
  - Cost of THGEM DHCAL
  - Reference



Content	Unit cost	Total require	Total cost
THGEM	0.8 yuan/cm^2	50 M cm^2	￥ 40 M
Electronics	8 yuan/channel	50 M channel	￥ 400 M
Absorber	30 k yuan/ton	1200 ton	￥ 36 M
total			￥ 476 M



about SDHCAL


Contents

1.2.2 Readout electronics

1- Semi-digital readout.
2- HARDROC .
3- PCB

1.2.3 cassette

1- Description.

1.3 Technological SDHCAL prototype

1- Description 2- Construction 3- Commissioning 4- Test beam results.

1.4 Optimization of the Calorimeter Design

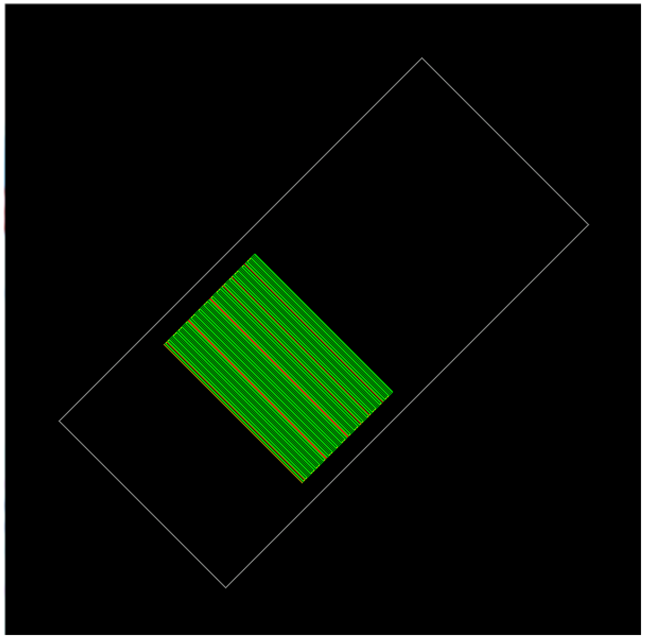
1.4.1 Detector optimization

1- Cell size optimization (stand alone simulation).
2- binary, semi-digital, analog readout options.
3- Optimization of the absorber thickness (stand alone simulation).
4- SDHCAL reconstruction algorithms optimization (stand alone simulation).
5- Simulation and reconstruction based on CEPC tool.

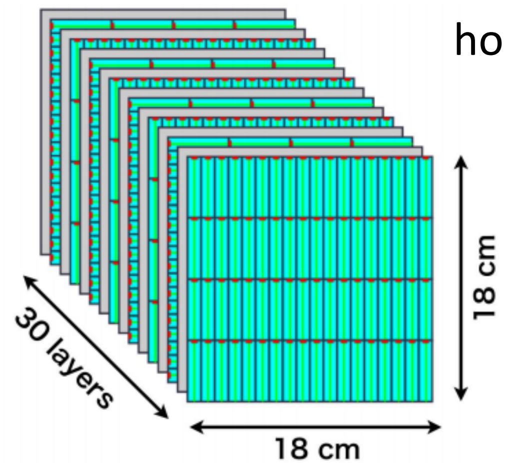
1.4.2 Other consideration for production

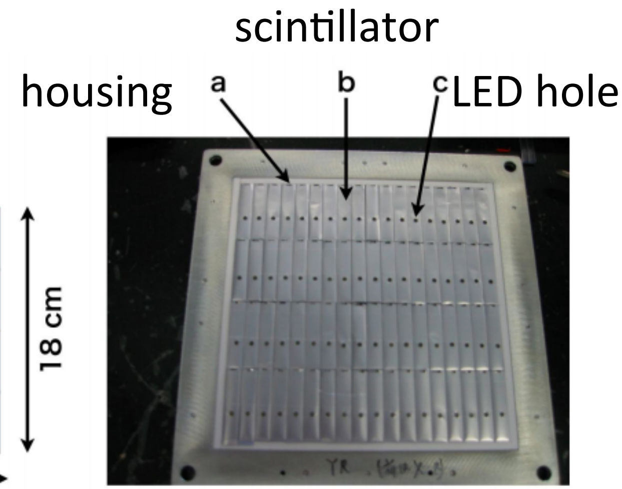
1- Mechanical structure.
2- Power consumption consideration : cooling
2- HCAL construction strategy.
2- the cost.
3- the future *R&D*.

about ECAL – simulation

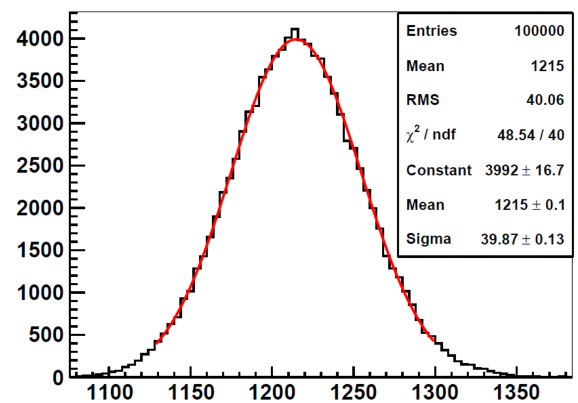


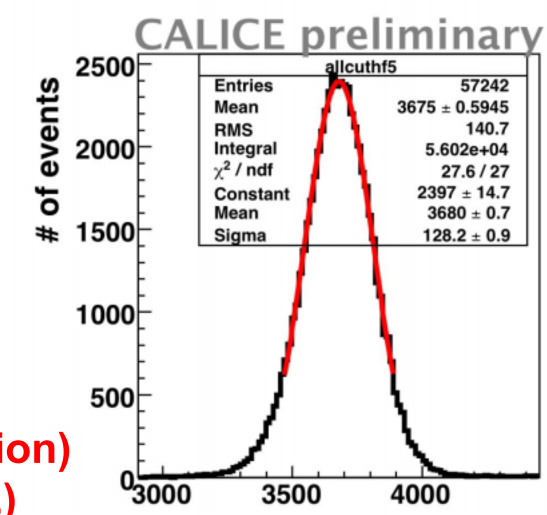
ECAL simulation geometry
Tungsten: 2mm/3mm/4mm
Plastic Scintillator: 50 layers
2mm x 40cm x 40cm
by WANG Zigang (IHEP)





ScECAL test module at FNAL



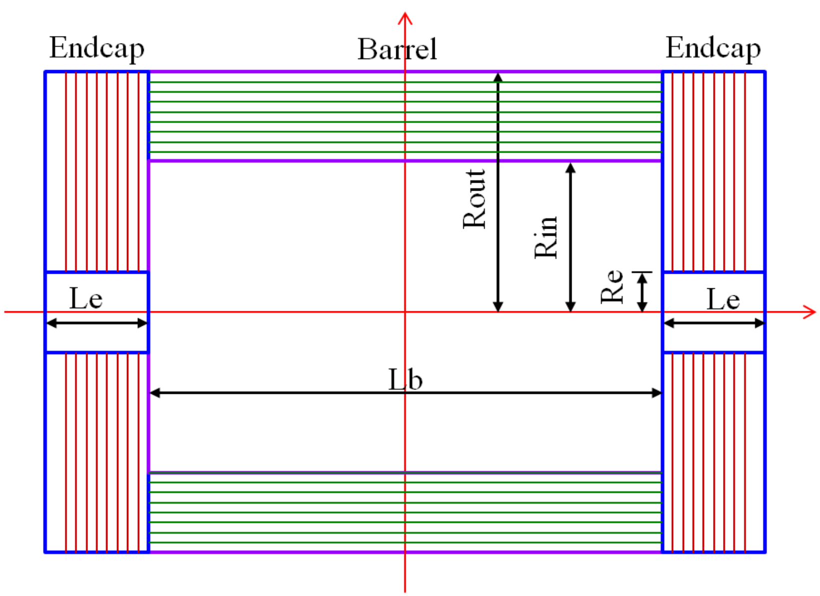


σ/mean(25 GeV) = 3.28% (simulation)
σ/mean(25 GeV) = 3.48% (CALICE)

Muon pre-CDR

	RPC	Scintillator strip
Performance	★★★★	★★★★★
Long-term stability	★★★	★★★★★
Mass production	Ready	Need development
Global difficulty	Easy	Hard
Cost	Normal	higher
Attraction	Normal	High

- Introduction
- Physics requirement
- Baseline design
- Technologies
  - RPCs or Scintillator strips
- Cost estimation



Item	Option	Baseline
Lb	3.6~5.6m	~4.6
Rin	2.5~3.5m	~3.0
Rout	4.5~5.5m	~5.0
Le	1.6~2.4m	~2.0
Re	0.6~1.0 m	~0.8
Segmentation	8/10/12	10
Number of layers	6~10	8(~3cm per layer)
Total thickness of iron	6~10λ (λ=16.77cm)	8 (8/8/12/12/16/16/20/20/24cm, Sum=136cm)
Solid angle coverage	0.92~0.96 × 4π	0.94
Position resolution	$\sigma_{r\phi}$:1.5~2.5cm	2cm
	σ_z: 2~4cm	3cm
Detection efficiency	92%~98%	95%
Reconstruction efficiency(E_μ > 6GeV)	92%~96%	94%
$P(\pi \to \mu)$@40GeV	0.5%~3%	1%
Rate capability	50~100Hz/cm²	60
Technology	RPC Scintillating strip Other	RPC
Total area	1100~1500m²	~1300
Total channels	Barrel	12000
	Endcap	4000
	Total	~1.6×10⁴(3cm strip width, 1-D readout, 2 ends for barrel, 1 end for endcap)
Total cost		~1.6×10⁷ (1000RMB/ch, absorber not included)

SUMMARY & OUTLOOK

summary

- All main components of the CEPC detector have had the pre-CDR layout defined, with corresponding authors assigned.
  - at least 50 persons involved
- A few R&D's have been carried out.
- The pre-CDR on CEPC detector has clear perspective.
  - Tight is a schedule, but possible ***be*** it will!
    → see next slide for a Schedule Guideline

Schedule Guideline for CEPC pre-CDR

August – December 2014

Questions? Please contact Xinchou Lou (xinchou@ihep.ac.cn)

August 1-15	August 16-31	September 1-15	September 16-30	October 1-15	October 16-31	November 1-15	November 16-30	December 1-15	December 16-31

(1) pre-CDR draft version 0 from each (sub-)group (with all required elements, some contents may be missing); (2) identify loose ends & address them at the (sub)group level.

(1) external reviewers identified and invitations sent out during first period; (2) additions and revisions being worked on; (3) formation of editorial board at SJTU workshop; (4) internal reviews within (sub-)groups.

(1) revision and finalization of pre-CDR chapters; (2) internal reviews of chapters (**theory, detector-simulation, accelerator, site design and civil engineering**); (3) draft **Introduction** and **Summary** sections available for comments and revisions.

(1) reviews of chapters (**theory, detector-simulation, accelerator, site design and civil engineering**) by external review committees; (2) revisions of and improvements to the pre-CDR chapters .

(1) final edition (including **Introduction & Summary**) in English; (2) translation of pre-CDR into Chinese completed and reviewed.

(1) proof; (2) print and release to CAS and public.

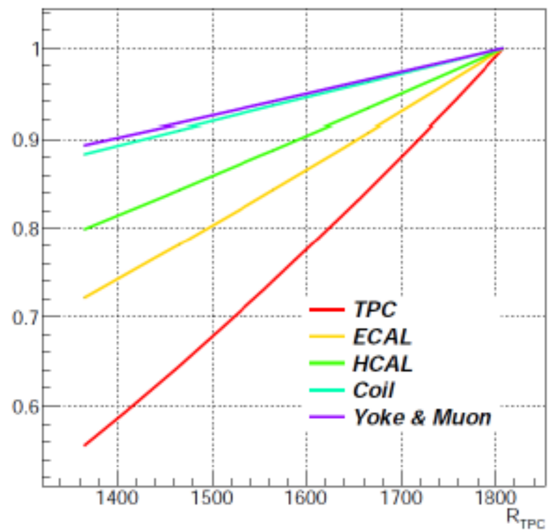
August 5, 2014

THANKS!
谢谢!

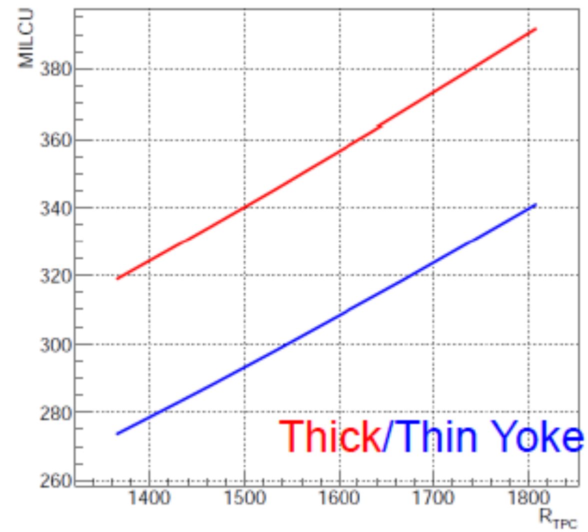
Geometry optimization and cost

- Optimized geometry with ILD as reference: reduce the total radius by 25%
- Assumption: 5 yr/1 detector & 10 yr/2 detector
- Total efficiency will be increased by ~ 1%

Sub Detector Cost Scale With TPC Radius



Total Cost as a function of TPC Radius



ILD Cost ~ 400 MILCU (PPP)
CEPC detector ~ 270 MILCU
~ 1.6 Billion CNY
~ 3 B CNY for 2 detectors;

Without manpower