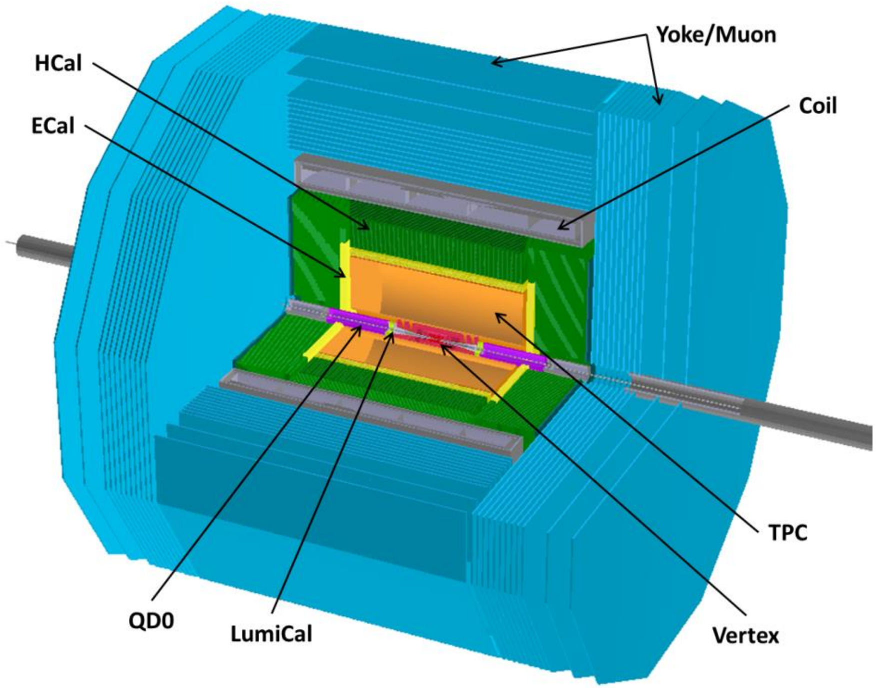
Physic & Detector: Summary

高原宁（清华大学）

CEPC Detector (preCDR) a reminder

X.-C. Lou



ILD-like detector with additional considerations (*incomplete list*):

- Shorter L* (**1.5**/2.5m) → constraints on space for the Si/TPC tracker
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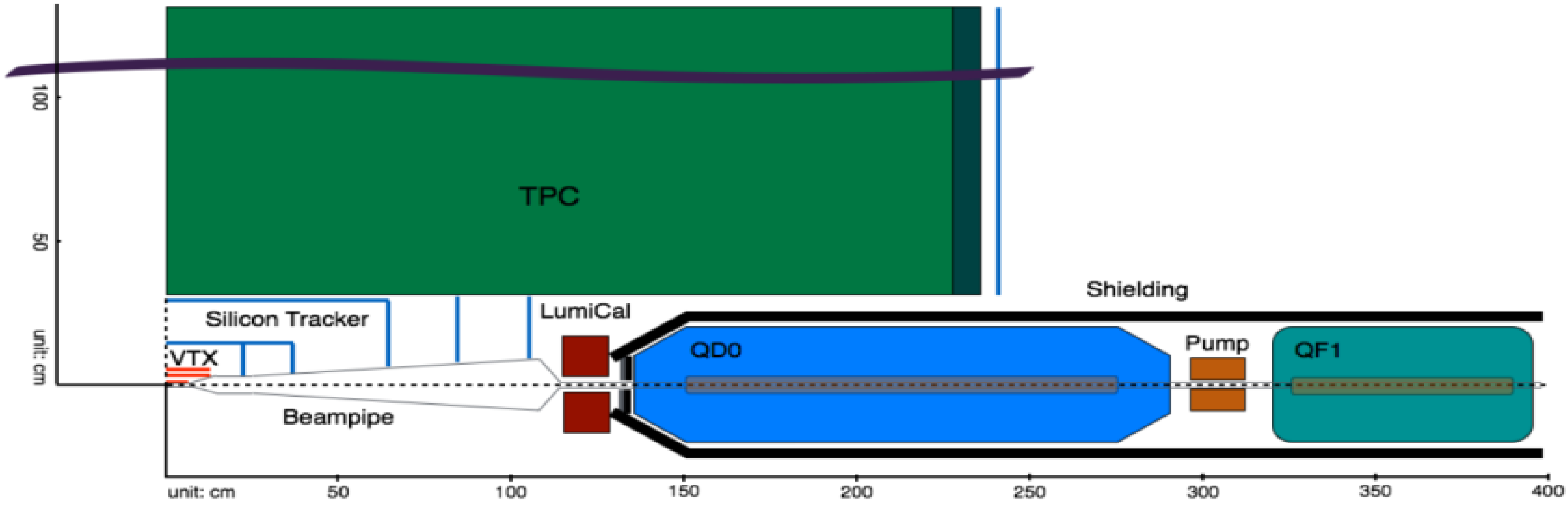
- Lower radiation background → vertex detector closer to IP
- …

- **Similar performance requirements to ILC detectors**
  - Momentum: $\sigma_{1/p} < 5\times10^{-5}\ \mathrm{GeV}^{-1}$ ← recoiled Higgs mass
  - Impact parameter: $\sigma_{r\phi} = 5 \oplus 10/(p\cdot\sin^{\frac{3}{2}}\theta)\ \mu\mathrm{m}$ ← flavor tagging, BR
  - Jet energy: $\frac{\sigma_E}{E} \approx 3-4\%$ ← W/Z di-jet mass separation

Circular machine IS different…

IR Layout -- Single Ring

Q. Xiu

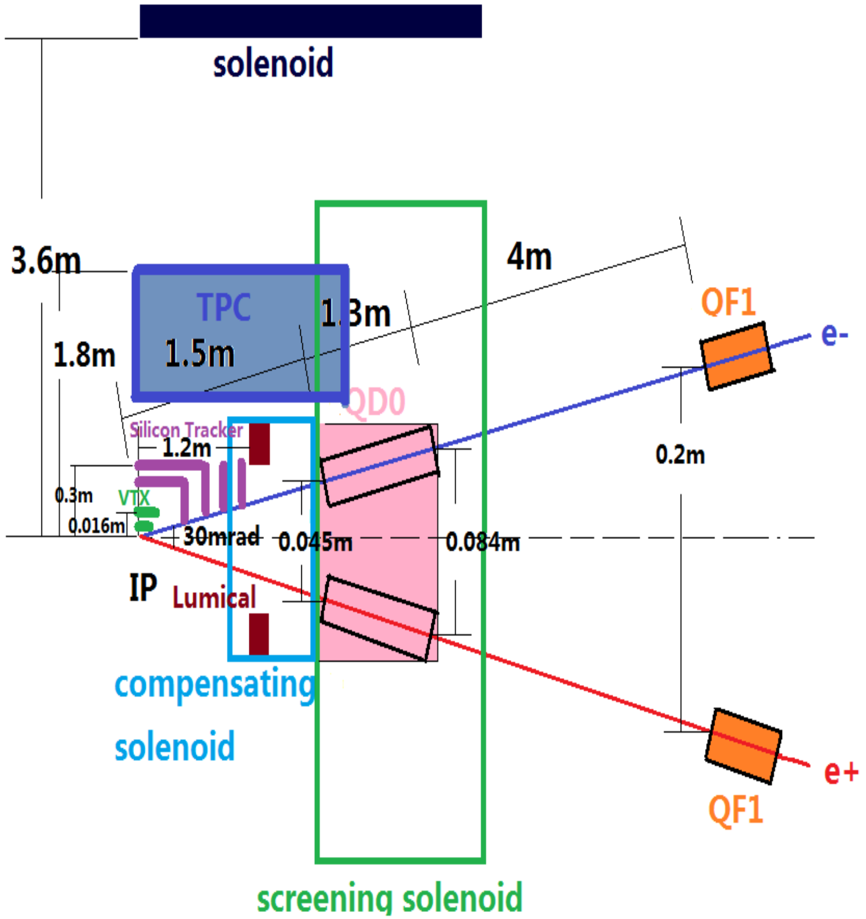


- $L^* = 1.5m$
- To meet requirements from both accelerator and detector
- Suppress the beam backgrounds as more as possible

Circular machine IS different…

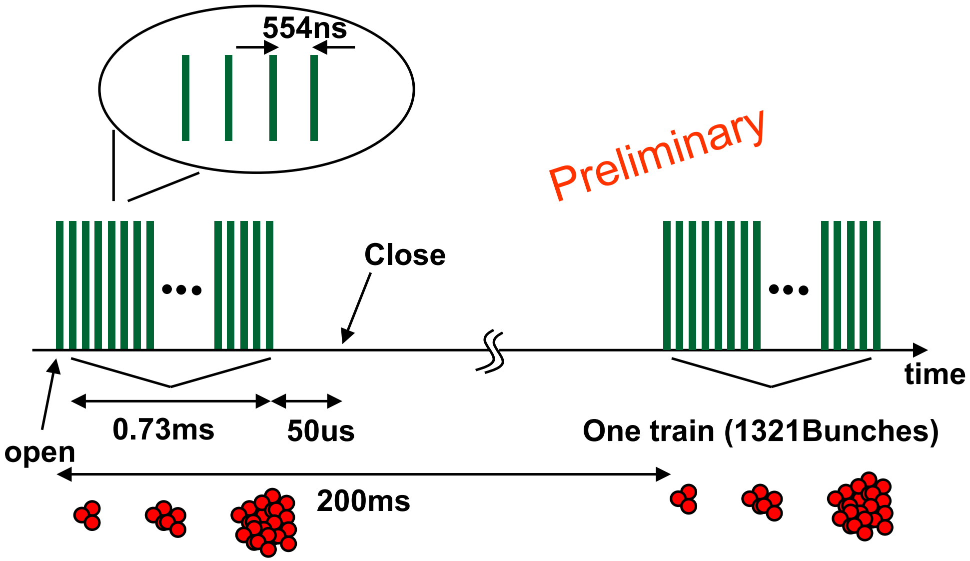
IR Layout -- Partial Double Ring

S. Bai



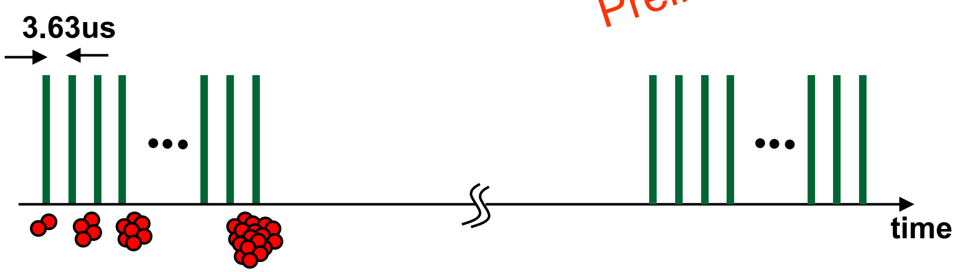
- Crossing Angle = $30mrad$
- L* = 1.5m
- Influence on the detector is under study

Circular machine IS different…



Beam structure of ILC

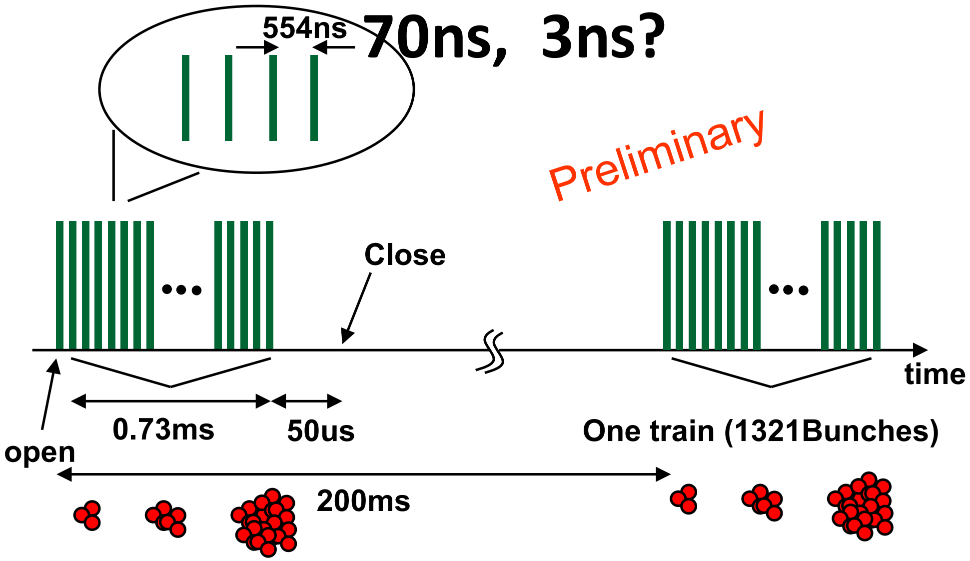
ILC



Beam structure of CEPC

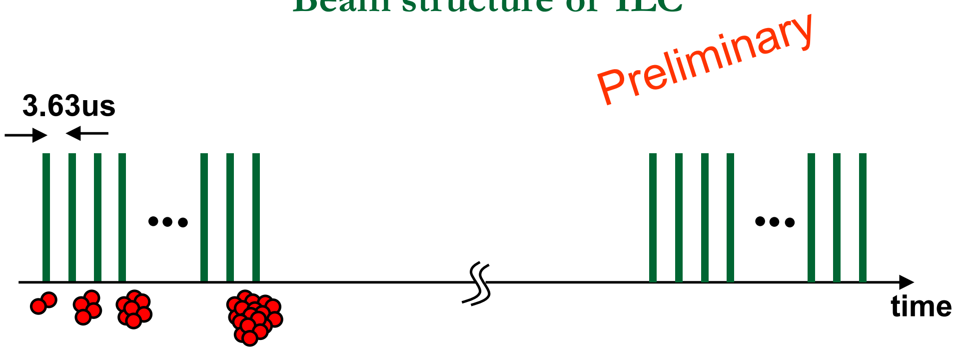
CEPC-Single Ring

Circular machine IS different…



Beam structure of ILC

CEPC-Partial Double Ring

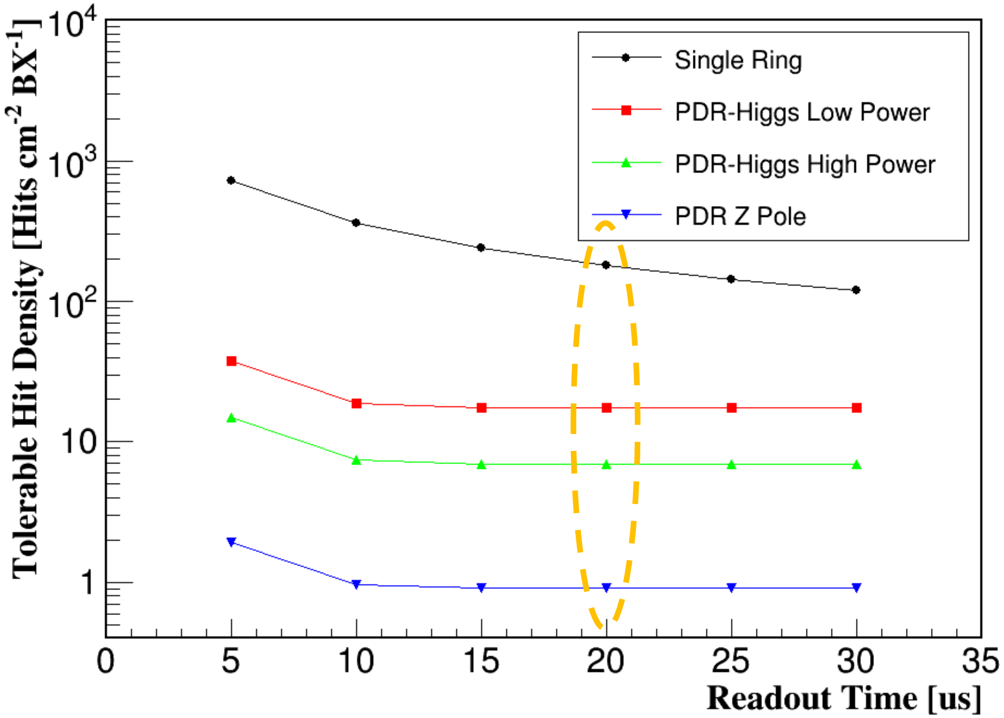


Beam structure of CEPC

CEPC-Double Ring

Physical Requirement to Background Level

- Vertex Detector Requirement: Occupancy not exceeding 1%
  - VTX Pixel Density: $5 \times 10^5\ cm^{-2}$ (Pixel pitch: $\sim 14\ \mu m$)
  - Safe factor: 5
- The tolerable hit density in partial double ring will be much lower than that of single ring.

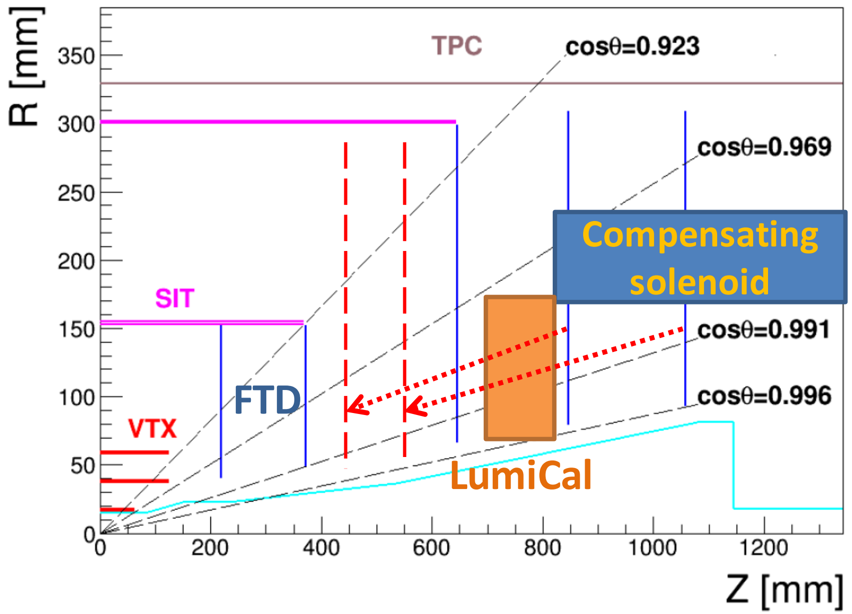


Parameters	Single Ring	PDR-H Low Power	PDR-H High Power	PDR Z Pole
Number of Bunches	50	57	144	1100
Bunch Spacing (μs)	3.6	0.187	0.074	0.0097
Hit Density in VTX ($\mathrm{Hits} \cdot cm^{-2} \cdot BX^{-1}$)	< 200	< 20	< 10	< 1

Circular machine IS different…

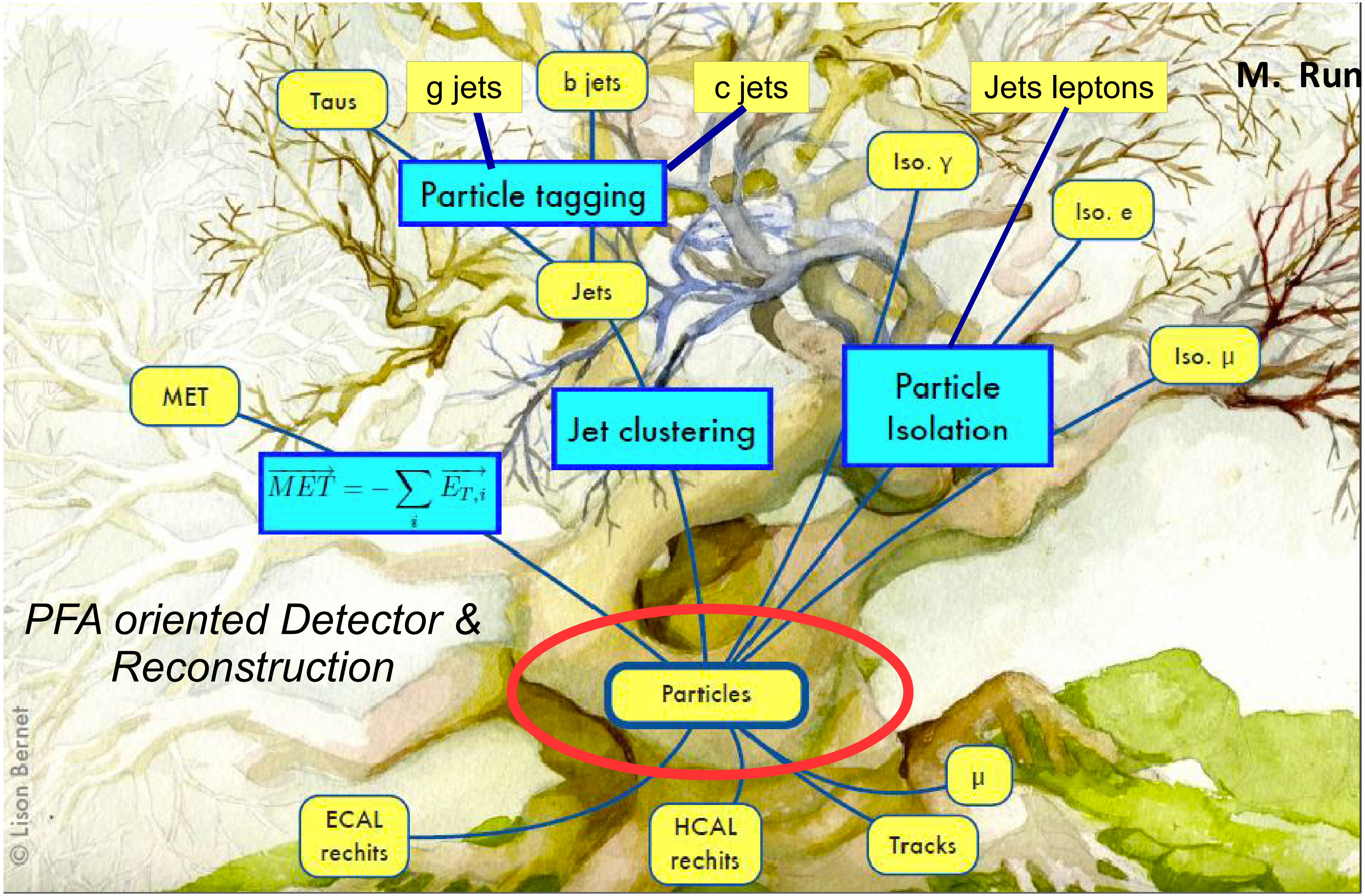
Influences on the Detector

Q. Xiu



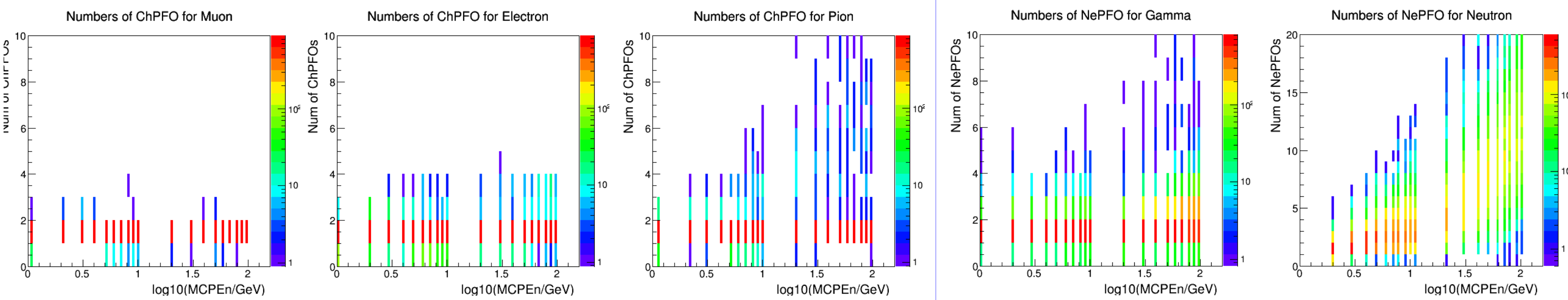
- length of anti-solenoid is 0.7m
  - The FTD detector need be more compact
  - Dead area to TPC (Reduce Length of TPC ?)
  - Very tight space for LumiCal
  - More backscattered backgrounds to VTX and FTD

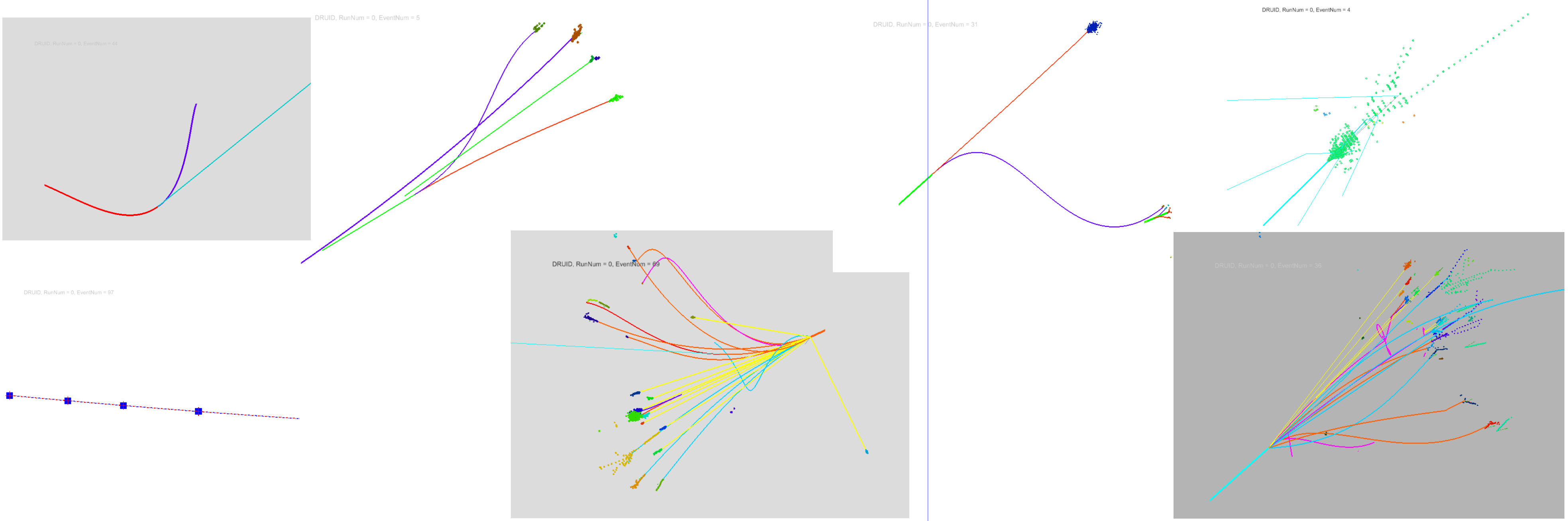
CEPC is beautiful



Arbor @ single particle

M. Run





07/04/2016

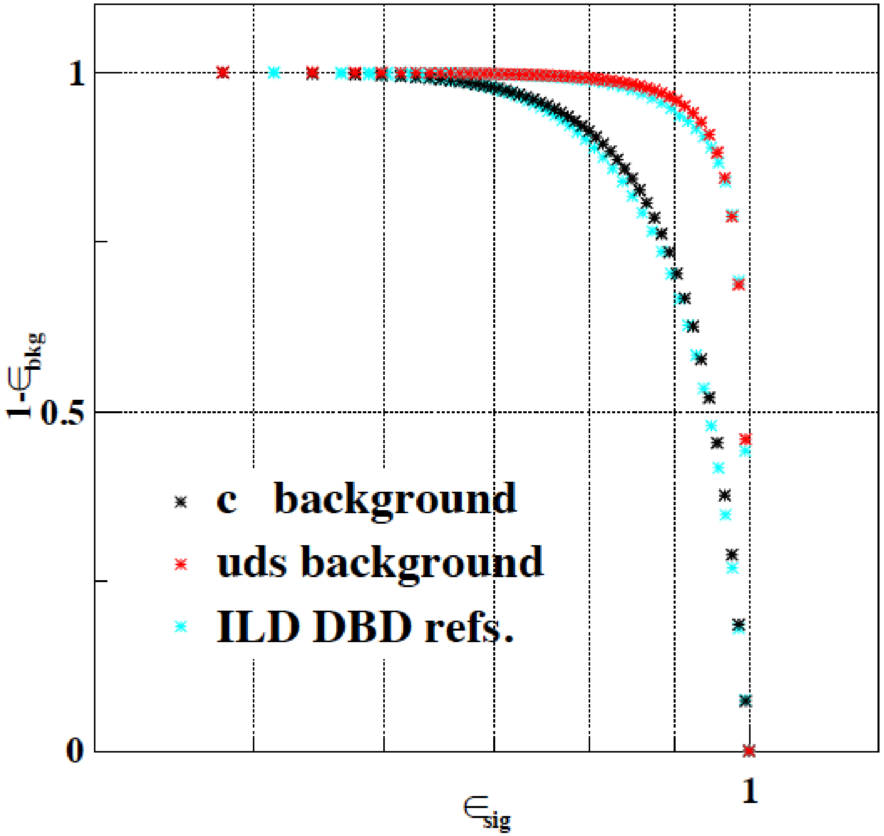
9

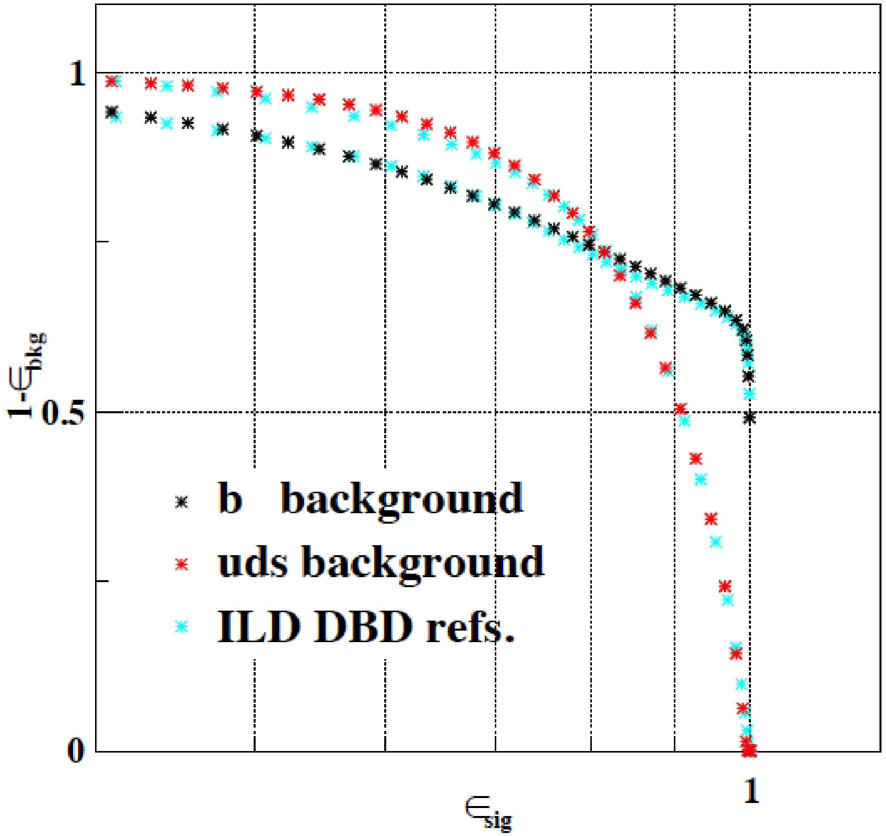
Charged

Neutral

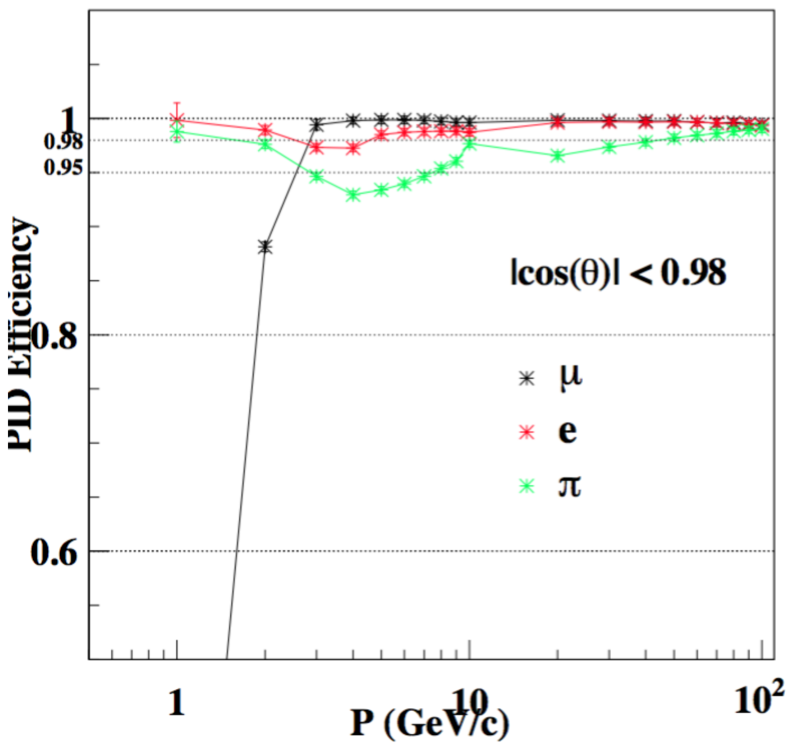
Flavor Tagging

M. Run

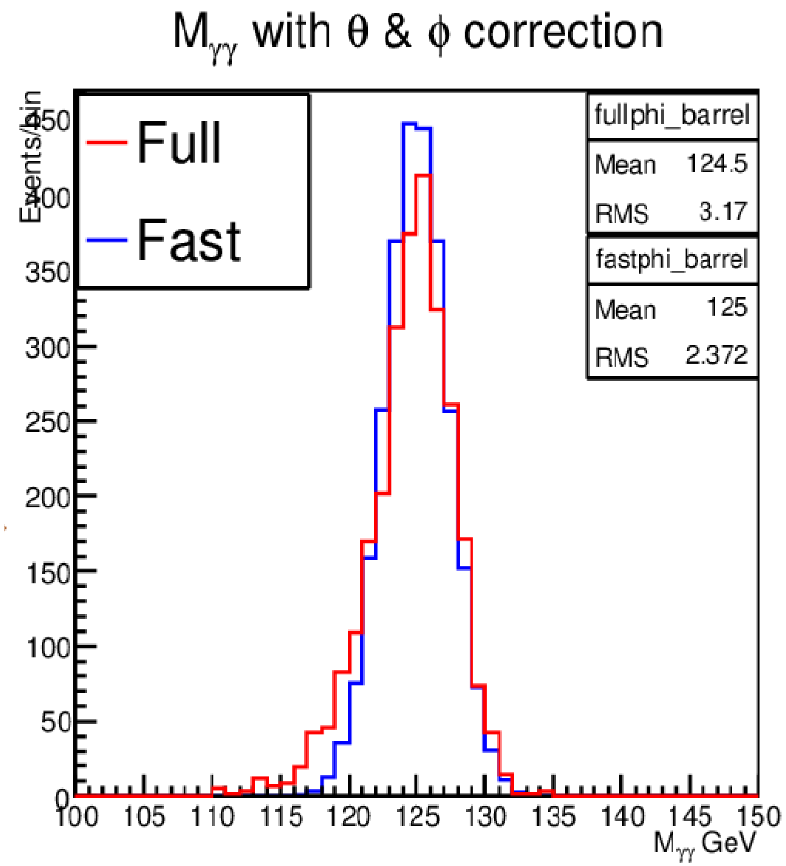




TMVA based method from ILC Study:
http://indico.ihep.ac.cn/event/5592/contribution/16/material/slides/0.pdf



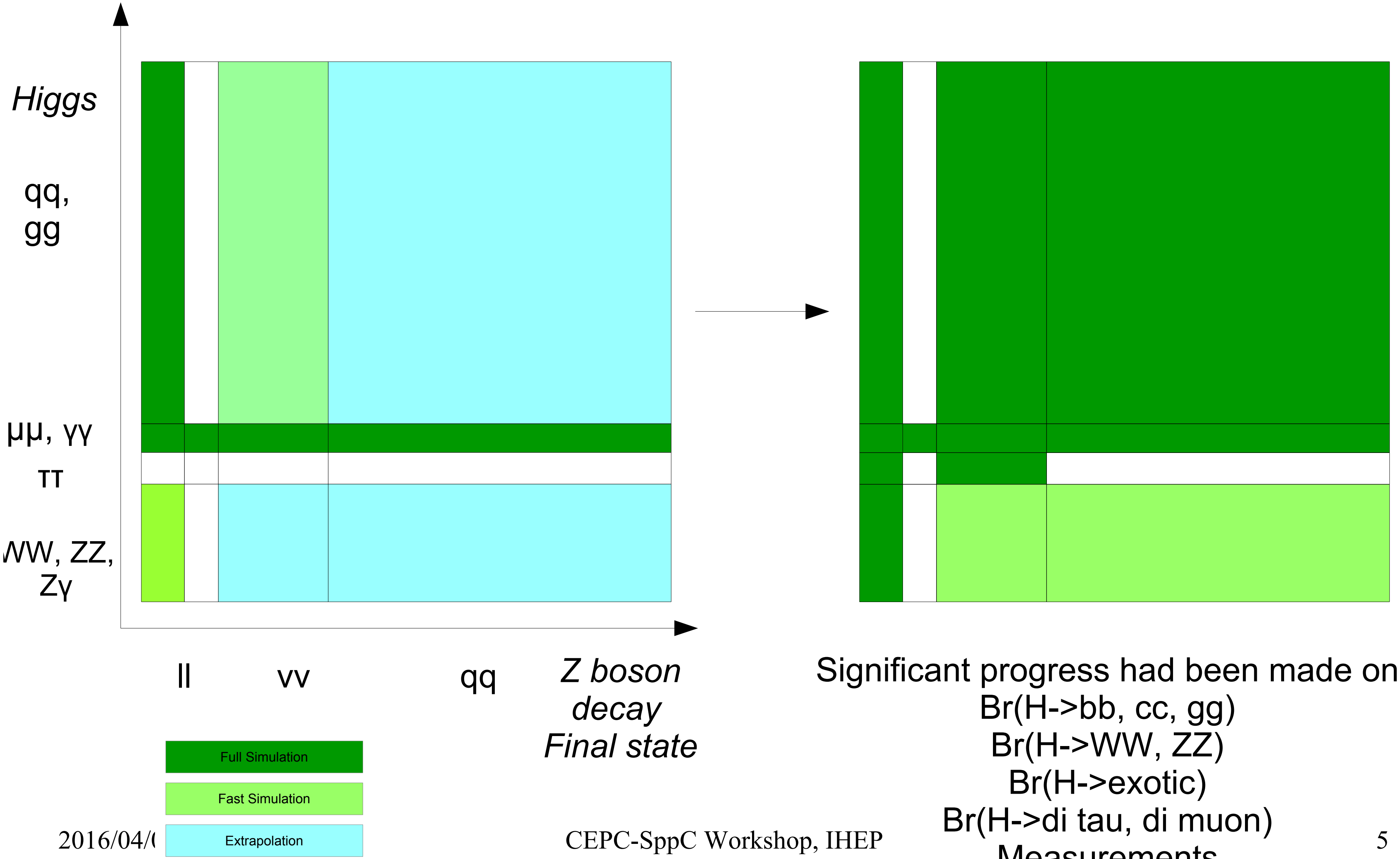
PID Efficiency
1
0.98
0.95
0.8
0.6
|cos(θ)| < 0.98
μ
e
π
1
10
10^2
P (GeV/c)



$M_{\gamma\gamma}$ with θ & ϕ correction
Events/bin
Full
Fast
fullphi_barrel
Mean 124.5
RMS 3.17
fastphi_barrel
Mean 125
RMS 2.372
0
50
100
150
200
250
300
350
400
450
100 105 110 115 120 125 130 135 140 145 150
$M_{\gamma\gamma}$ GeV

preCDR -> present

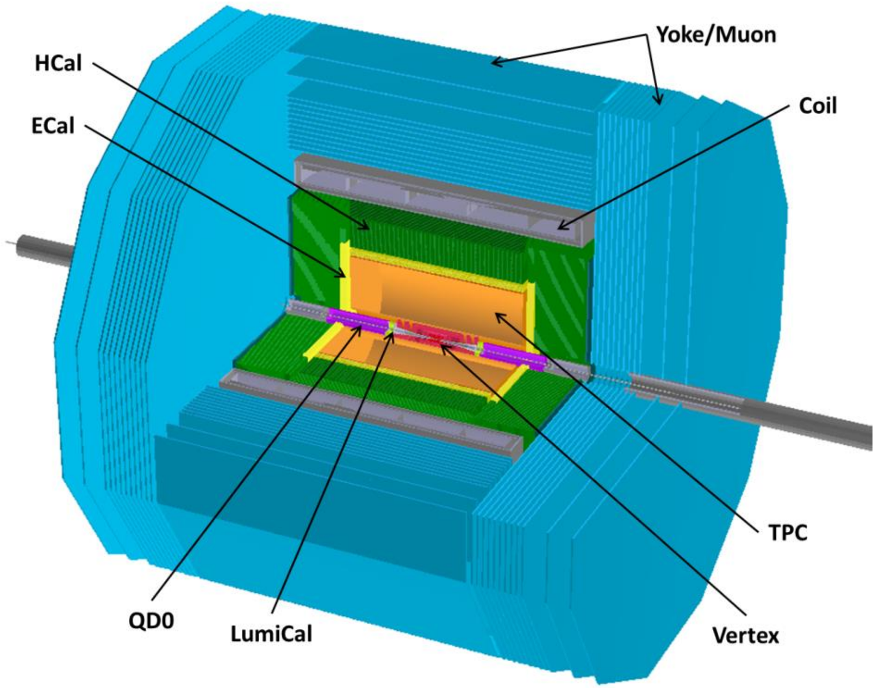
G. Li



Significant progress had been made on
Br(H->bb, cc, gg)
Br(H->WW, ZZ)
Br(H->exotic)
Br(H->di tau, di muon)
Measurements

CEPC Detector (preCDR) a reminder

X.-C. Lou



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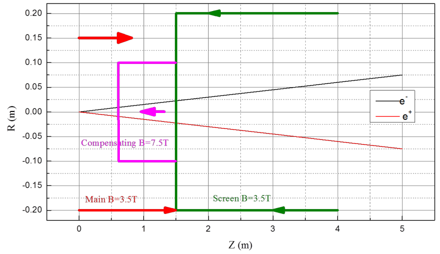
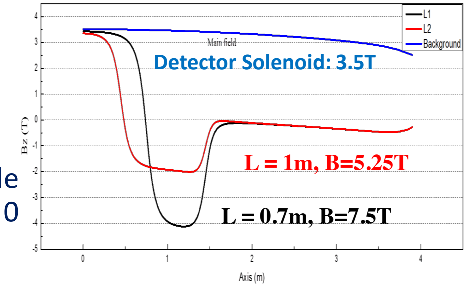
Anti-solenoid Design

- Solenoid field of detector will cause the beam coupling between horizontal and vertical direction, which will degrade the luminosity
- $\int B_z ds = 0$
  - The coupling should be cancelled before beam enter the quadrupoles (Compensating solenoid)
  - The longitudinal field inside the quadrupole should be 0 (Screening solenoid)



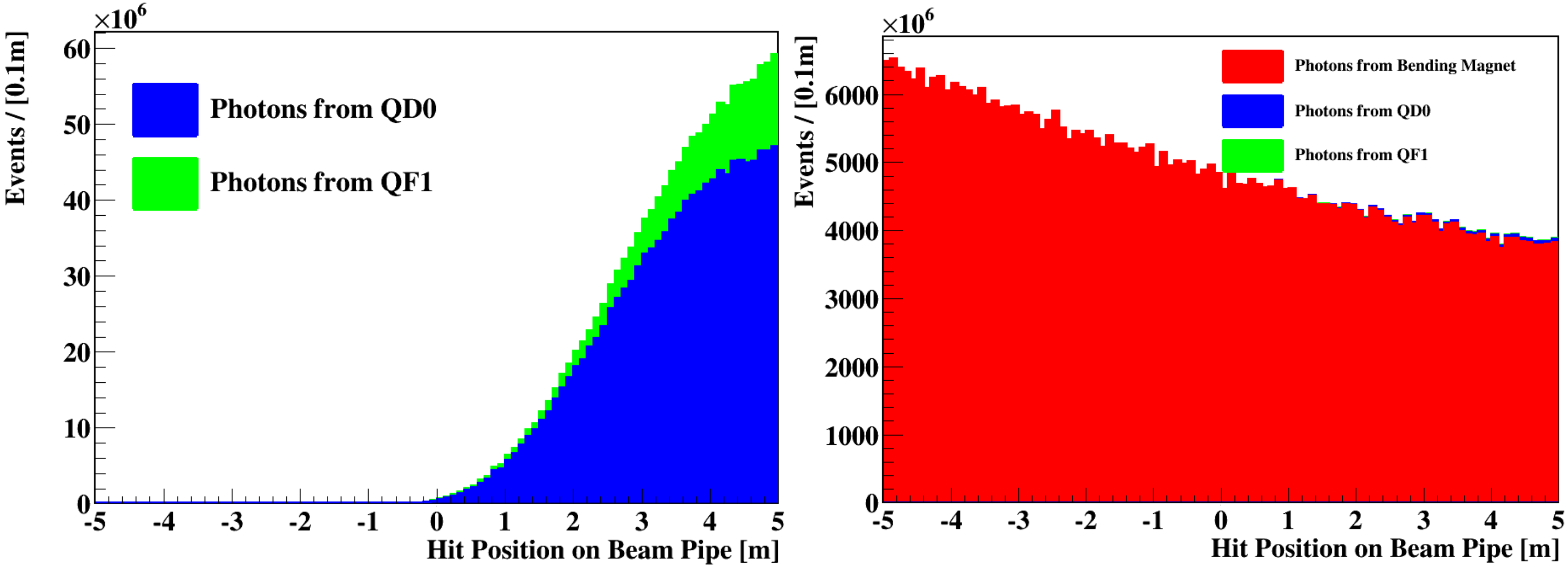


Can the Anti-Solenoid be Shorter?

- Stronger magnets (Larger Size)
  - 8T @ 4.2K:
  - Known Maximum: 11.7T
    - Lower temperature, higher cost, worse maintainability
- Reduce the detector field
- Anyway, the IR will be more crowded

Anti-Solenoid / Detector Solenoid	7.5T	8T
3.5T	**0.7m**	**0.66m**
3T	**0.6m**	**0.56m**

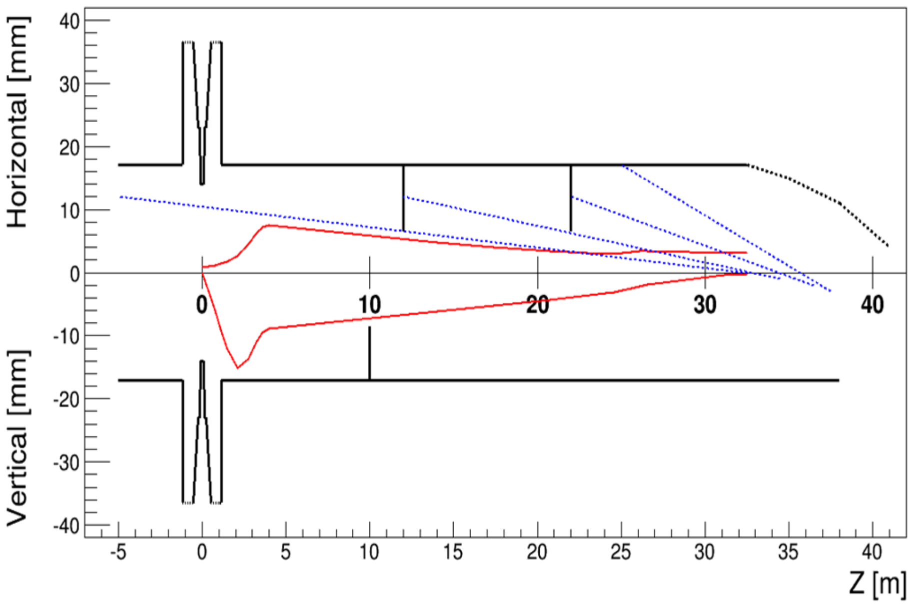
Flux of Synchrotron Radiation

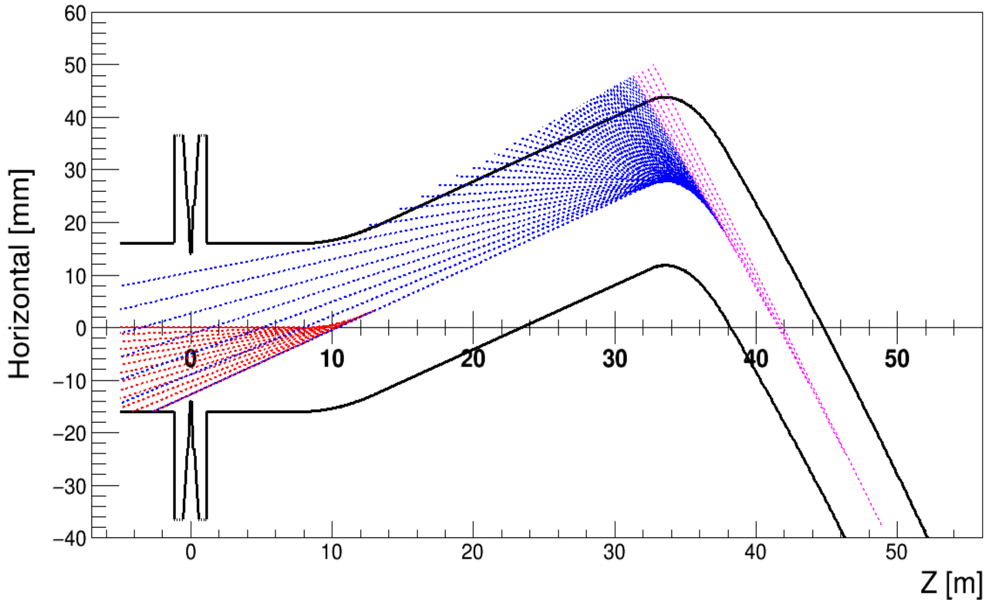


Number of photons hit the beam pipe in each 10 cm

- Beam pipe radius 16mm (Uniform)
- Photons from the bending magnets will be dominant
- Quadrupoles can not be neglected due to the back scattering effects

Methods to Suppress Background Level





- Synchrotron Radiation
  - Shielding the synchrotron photons with collimators
  - Let the synchrotron photons pass through the IR by well designed beam orbit.
- Lost Beam Particles
  - Add collimators along the storage ring.

Detector requirements

B=3.5T

Efficient tagging of heavy quarks

- momentum resolution

$$\sigma_{1/p_T} = 2\times10^{-5} \oplus 1\times10^{-3} / (p_T \sin\theta)$$

- impact parameter resolution

$$\sigma_{r\phi} = 5\mu m \oplus \frac{10}{p(GeV)\sin^{3/2}\theta}\mu m$$

Vertex detector specifications:

- σ_{SP} near the IP: *≤3 μm*
  - → small pixels 16×16μm^2 or below, digital readout
- material budget: *≤ 0.15%X_0/layer*
  - → low power circuits, air cooling
- pixel occupancy: *≤ 1 %*
- radiation tolerance: Ionising dose *≤100 krad/ year*
  Non-ionising fluences *≤$10^{11} n_{eq}$/ (cm^2 year)*
- first layer located at a radius: *~1.6 cm*

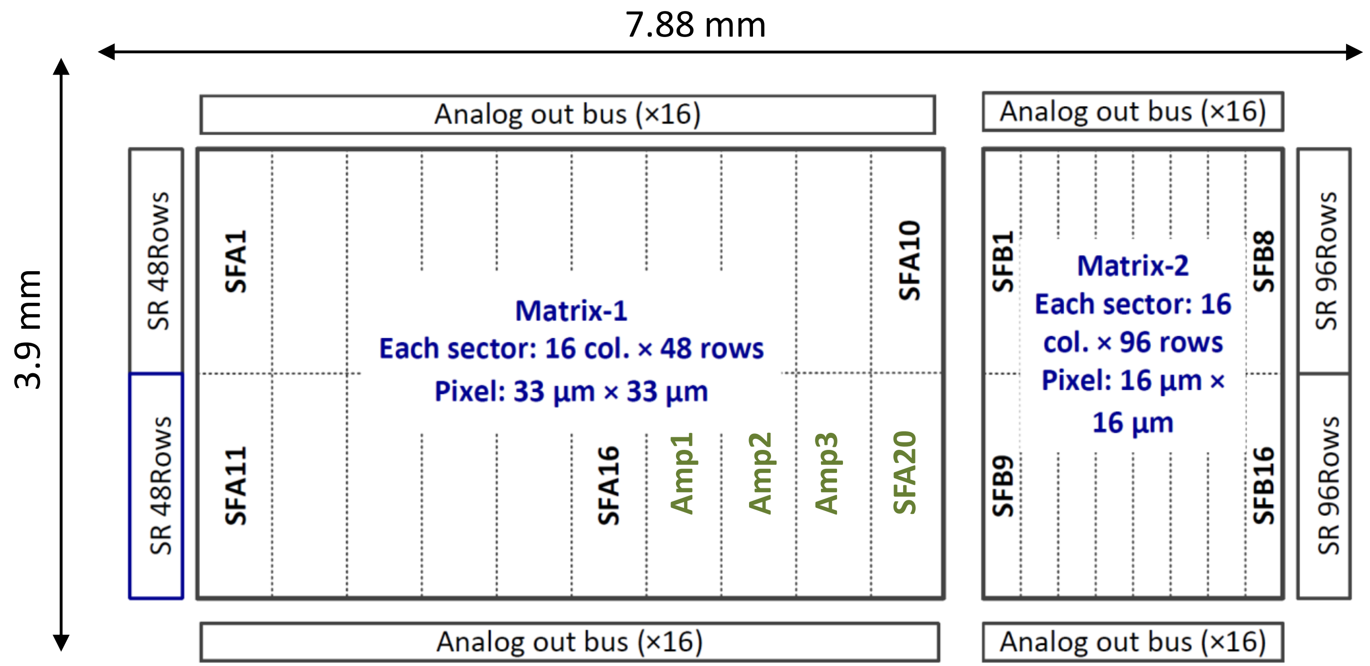
Silicon tracker specifications:

- σ_{SP} : *≤ 7 μm* → small pitch (50 μm)
- material budget: *≤ 0.65%X_0/layer*

1st CMOS prototype

由高能所创新经费支持

- Goals: sensor optimization and radiation hardness 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: 20 sectors, each sector includes 48 rows and 16 columns
  - Matrix-2: 16 sectors, each sector includes 96 rows and 16 columns



TowerJazz CIS
0.18 μm
November 2015
submission

1st SOI prototype

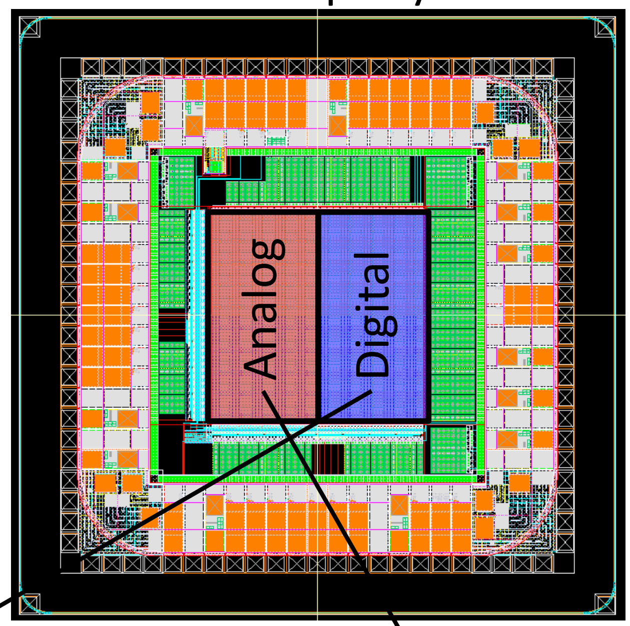
由自然科学基金支持

Y. Lu, J. DONG

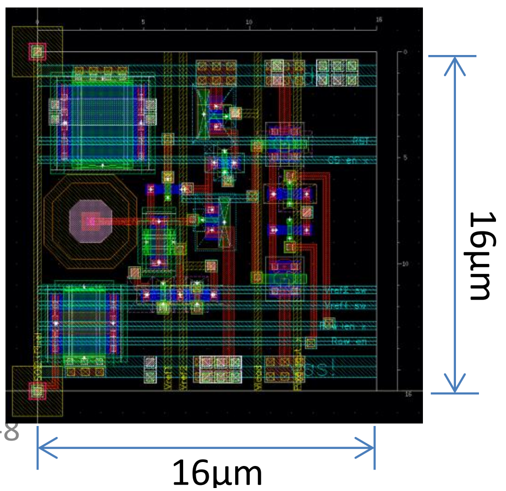
- Compact Pixel for Vertex (CPV1)
  - Designed in line with the technology roadmap
  - 16*16 μm with in-pixel-discrimination
  - Based on the measurement of full depletion*
  - Pixel array: 64*32 (digital) + 64*32 (analog)
  - Double-SOI process for shielding and radiation Enhancement
  - Submitted June, 2015

* Y. LIU, Y. LU, X. JU, Q. OUYANG, Chinese Physics C, Vol.40, No. 1 (2016)

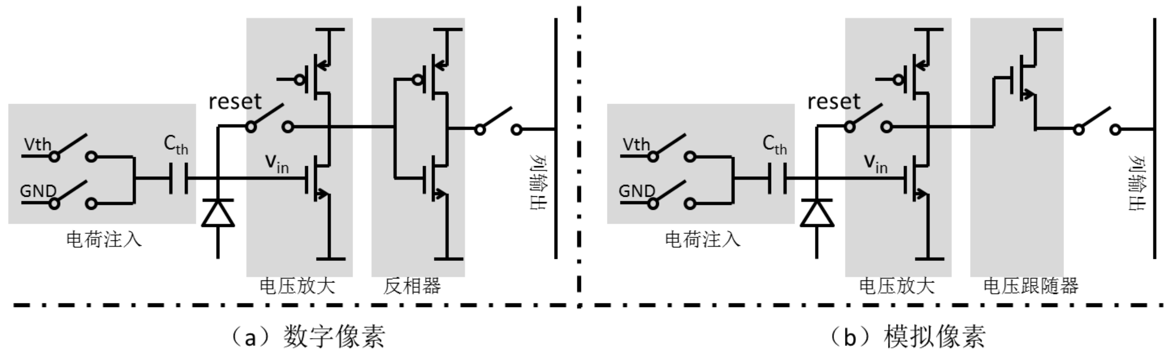
CPV1 chip Layout



CPV1 digital pixel layout

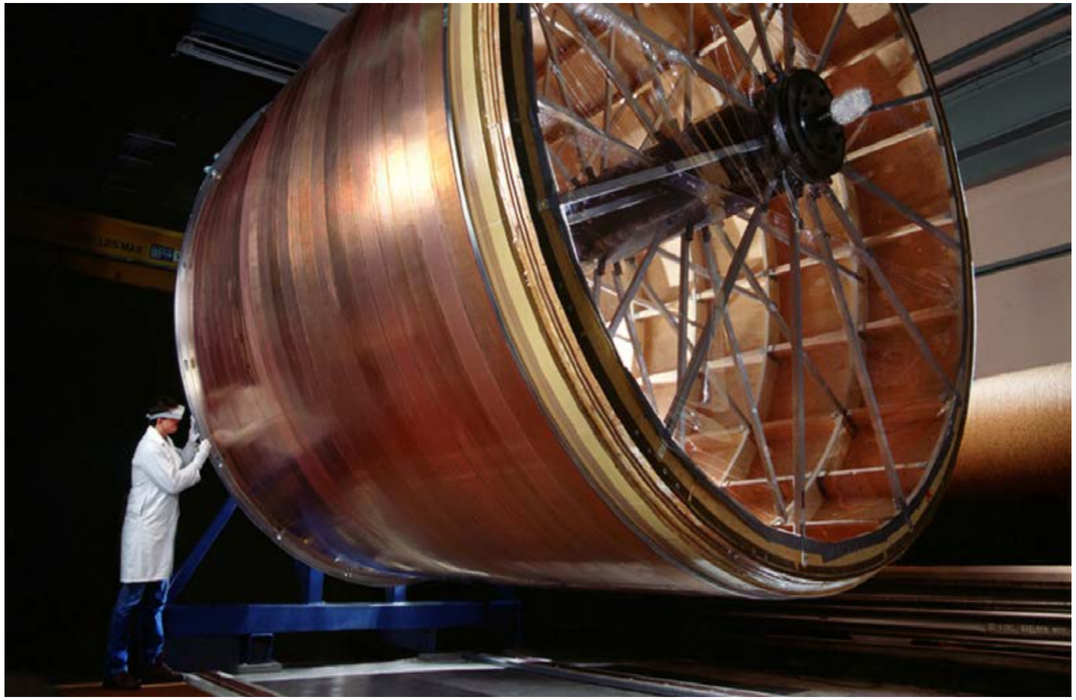


64row*32col. digital pixel   64row*32col. analog pixel



Detector layout

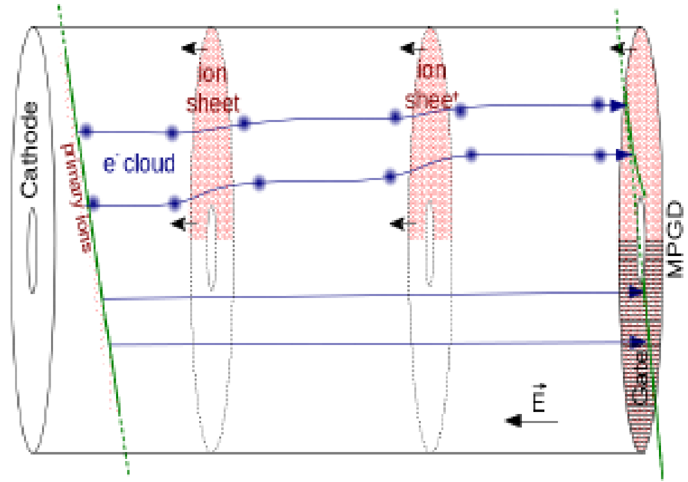
- Time Projection Chamber detector
  - Detector module (Critical technical challenges)
  - Drift chamber
  - Electronics readout
  - Working gas supply
  - Alignment and calibration system
  - Inner radius
  - Pad size
  - Number of tracker
  - B Field
  - Support structure
  - Drift cathode

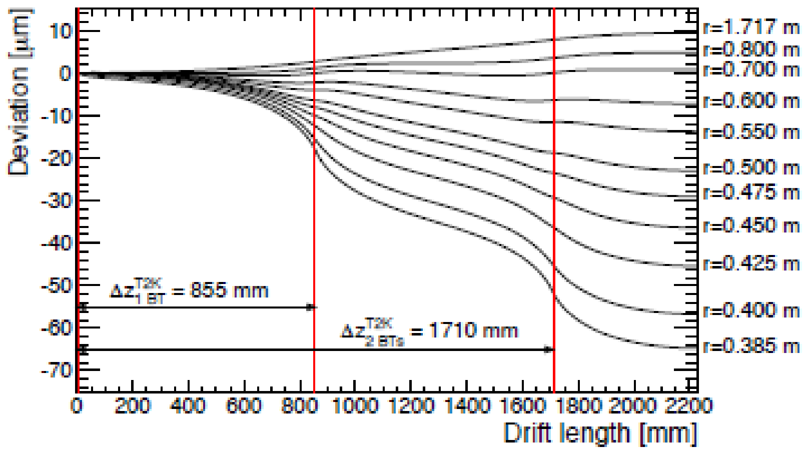


Overview of the TPC detector

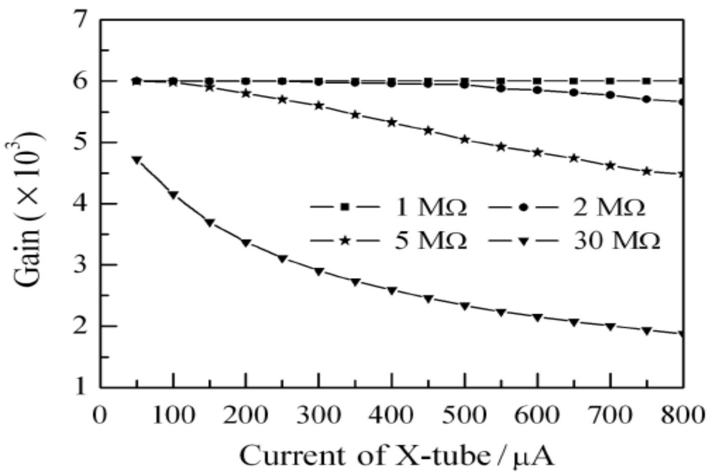
Critical challenge: Ion Back Flow

- 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





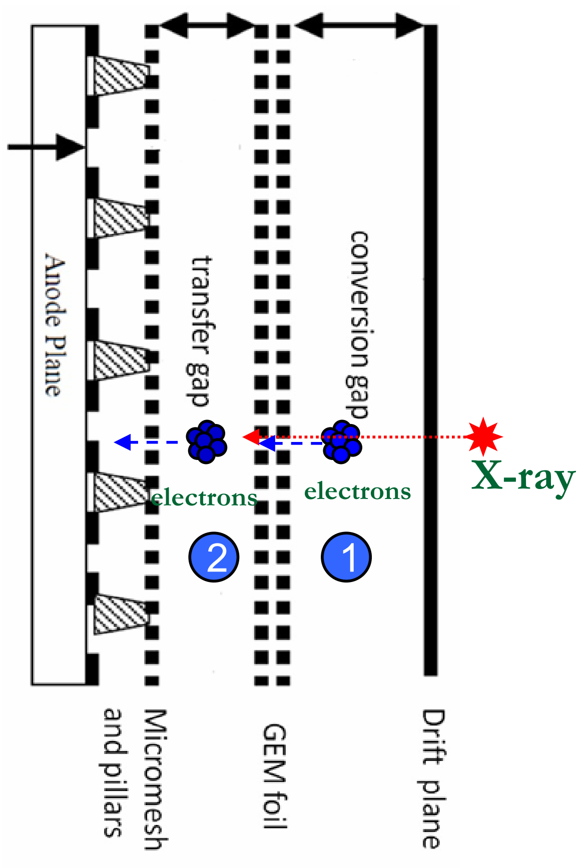
Ions simulation @ILD TPC



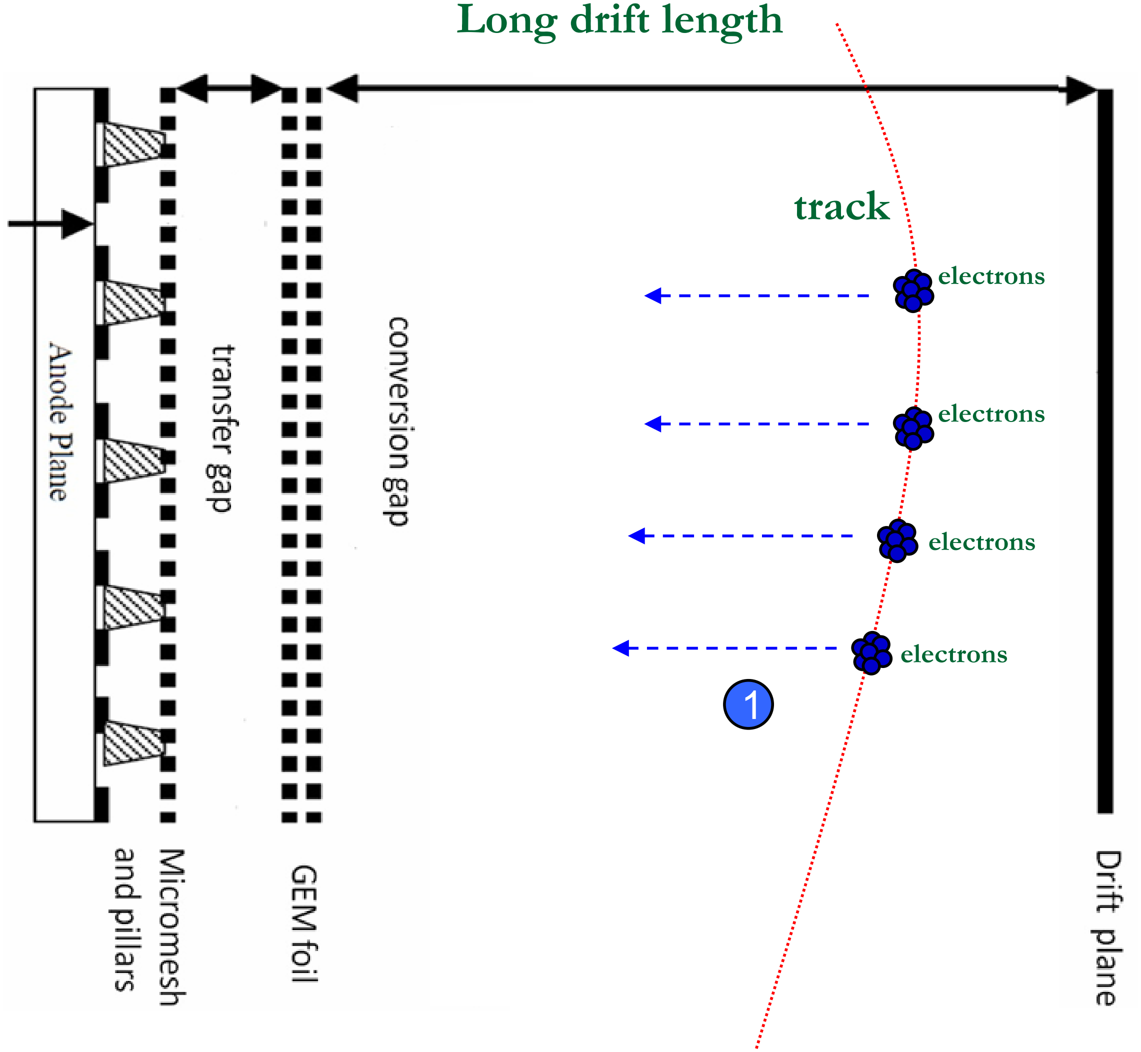
High X-ray dose to reduce the Double GEMs Gain @ IHEP

Hybrid structure module option

Short drift length

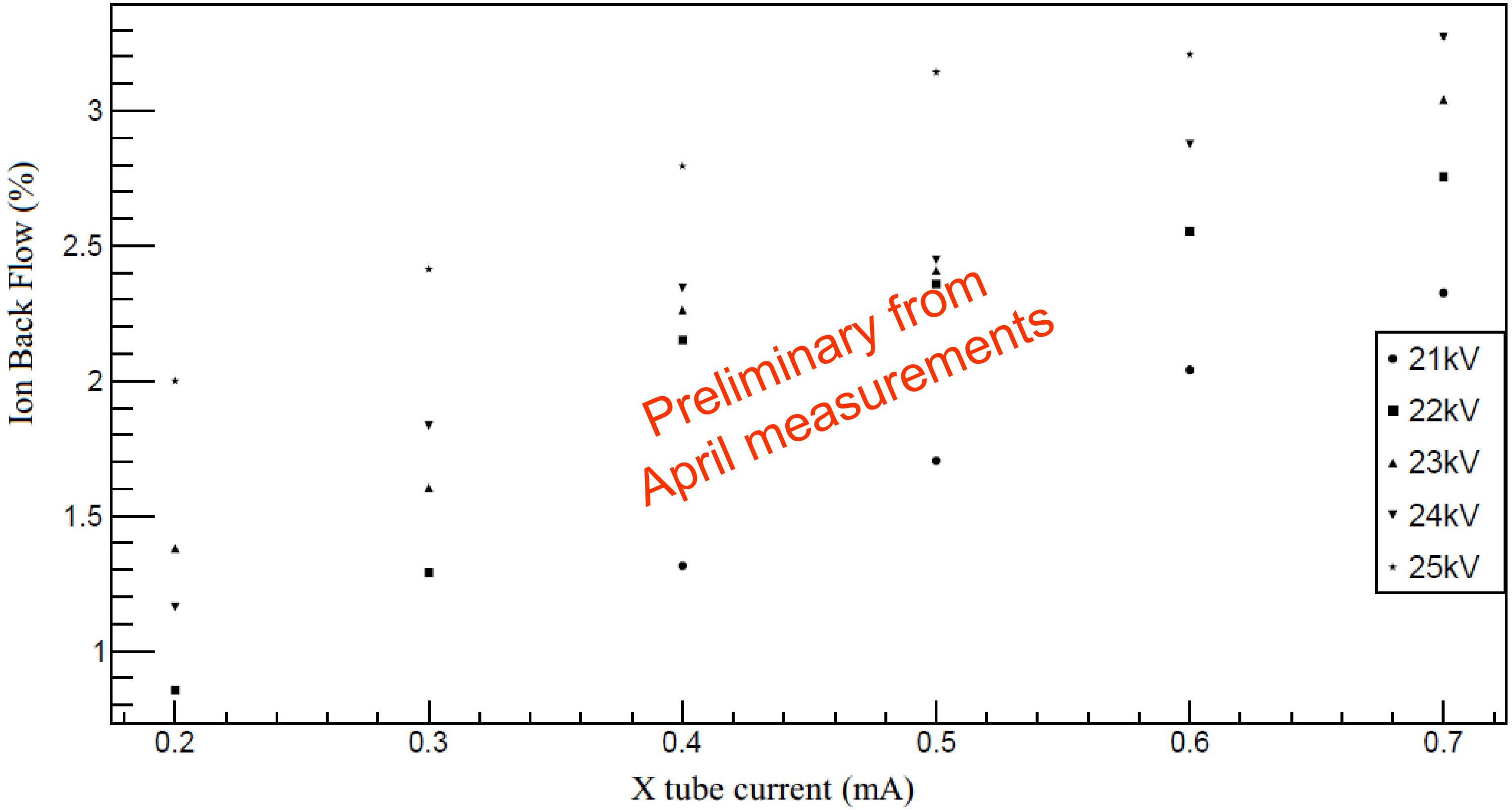


Long drift length



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

IBF preliminary result

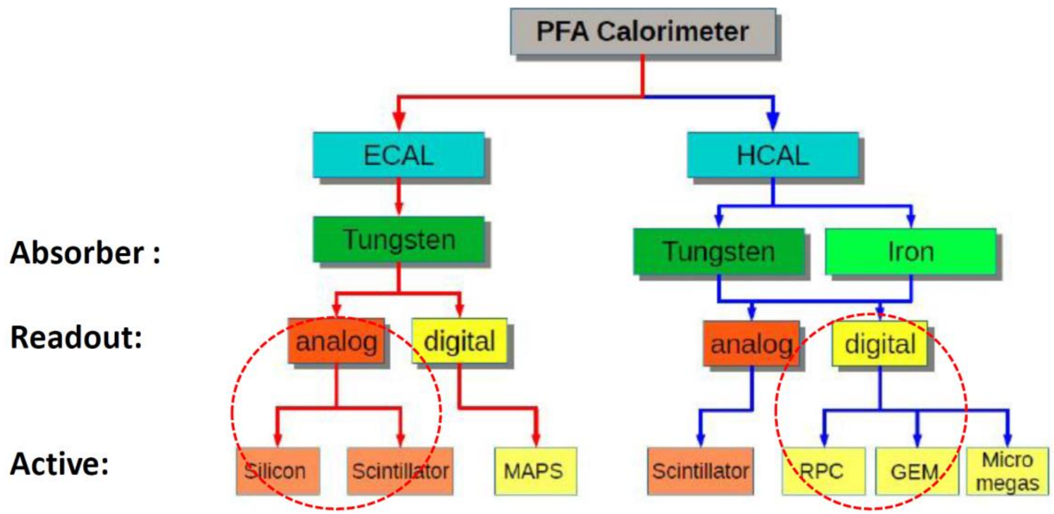


- Test with X-tube@21kV~25kV using the Hybrid module
  - Charge sensitive preamplifier ORTEC 142IH
  - Amplifier ORTEC 572 A
  - MCA of ORTEC ASPEC 927
  - Mesh Readout
  - Gas: Ar-iC4H10(95-5)
  - Gain: ~6000

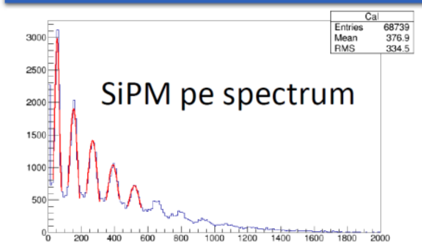
CEPC Detector – Calorimeters

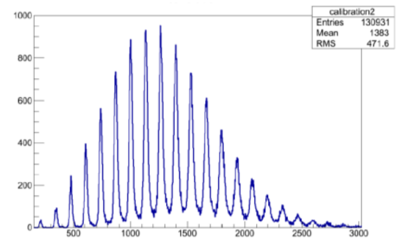
T. Hu *et. al.*

Funding：IHEP IF



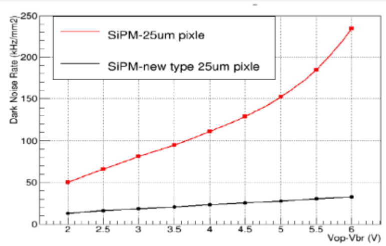
Tests of SiPM at IHEP



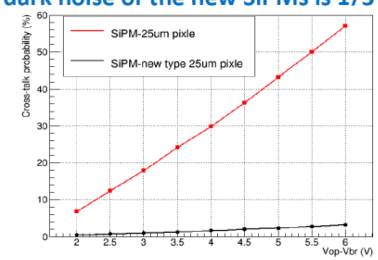


pulse height spectrum.

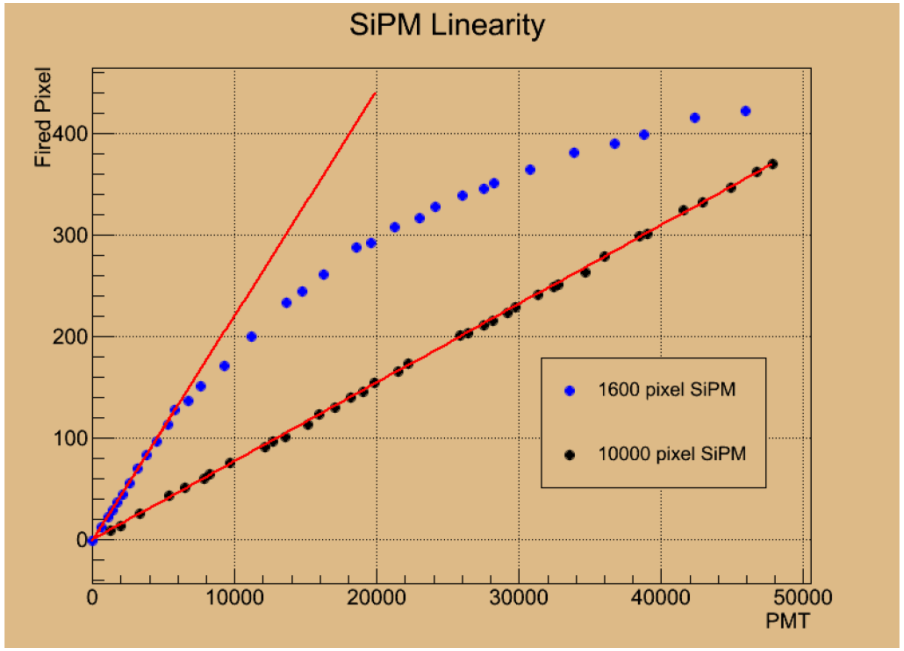
Excellent photon counting



The dark noise of the new SiPMs is 1/3 to the old



The cross-talk of the new SiPMs is 10% to the old



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CEPC Detector – Calorimeters

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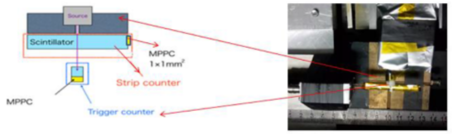
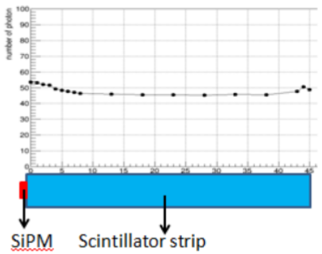
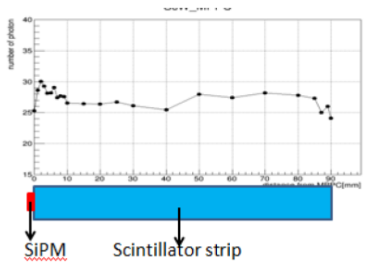
Tests of Scintillator strip at IHEP



Scintillator strip irradiated with β collimated (1mm) from Sr-90



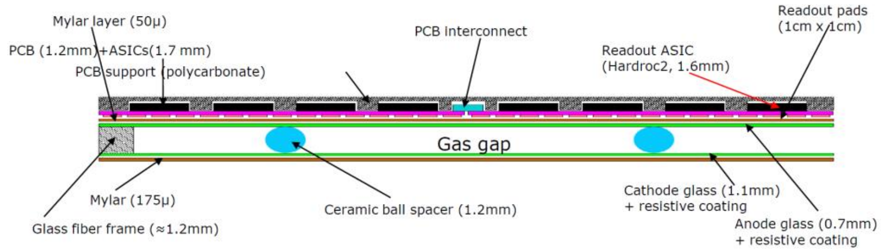
Strip: 5mm×45mm×2mm



Strip: 10mm×90mm×2mm

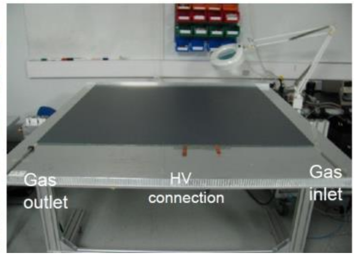
- Peaky Npe near MPPC
- Larger Npe than ILD probably due to different scintillator material and reflector.
- Significant reduction of Npe with long strip.

HCAL: GRPC Study



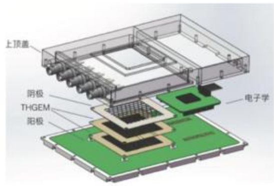
Large GRPC R&D

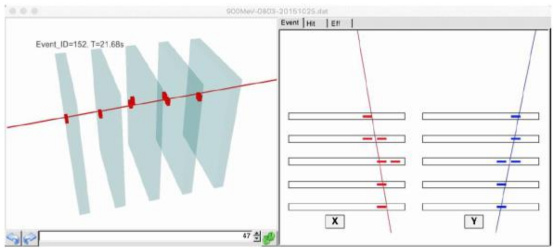
- ✓ Negligible dead zone (tiny ceramic spacers)
- ✓ Large size: 1 × 1 m^2
- ✓ Cost effective
- ✓ Efficient gas distribution system
- ✓ Homogenous resistive coating

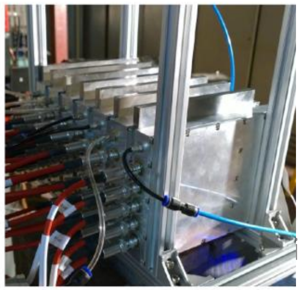


WELL-THGEM Beam Test at IHEP in Oct., 2015

- 7 THGEMs ware installed, and 5 of them were used, and flushed with Ar/iso-butane = 97:3.
- 1 threshold, binary readout
- 900 MeV proton beam was used
- 5cm x 5cm sensitive region

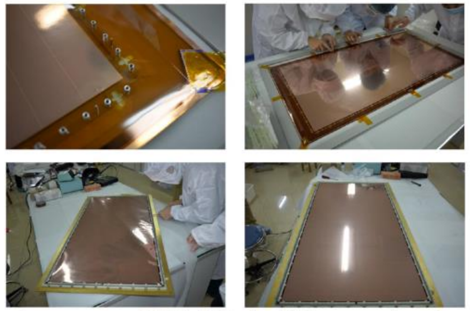






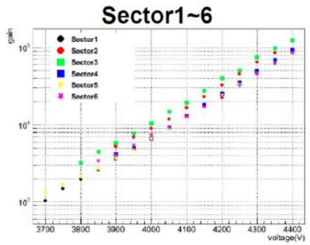
Large-area GEM @ USTC

GEM assembly using a novel self-stretching technique



APV25 GEM readout

INFN APV25 chip



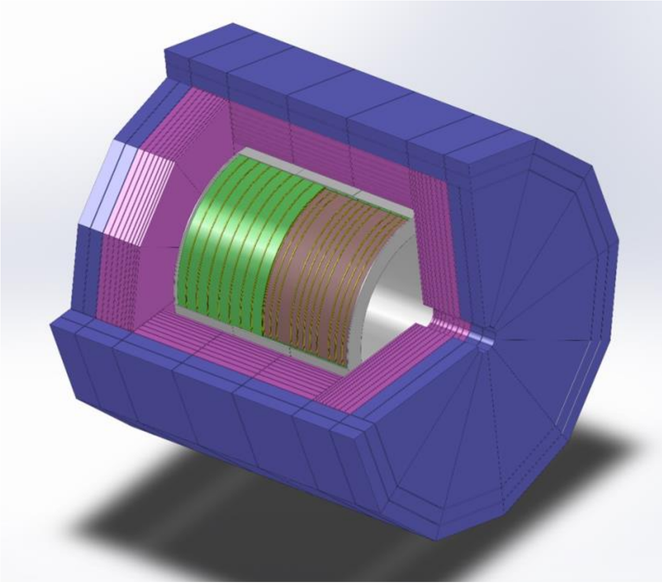
- Large-area GEM (0.5x1m^2) is one of main detector R&D focuses at USTC recently.
- Technology has been developed and matured to produce high-quality GEM detectors as large as ~1m^2 that are also applicable to CEPC DHCAL.

➔ Resolution uniformity ~11%
➔ Gain uniformity ~16%
➔ Can reach gain of 10^4 at 4000V

CEPC Detector – Detctor Magnet

L. Zhao *et. al.*

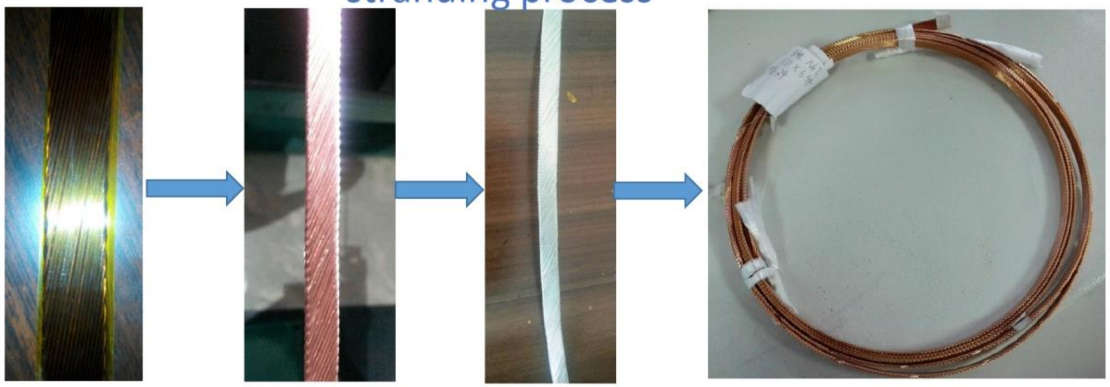
Funding： IHEP IF



Key technology:

- Optimization of Magnetic filed
- Superconductor
- Inner winding and impregnating
- Coil cryogenic system
- Power lines with HTS
- Manufacturing and assembling of huge scale yoke

stranding process



Number of strands: 20
Strand diameter: 1.0mm
Materiel: Copper
Complete time:2015.5

Number of strands： 17
Strand diameter： 0.727mm
Materiel :Nb/Ti
Complete time:2015.7

Number of strands： 24
Strand diameter： 0.727mm
Materiel :Nb/Ti
Complete time:2015.8

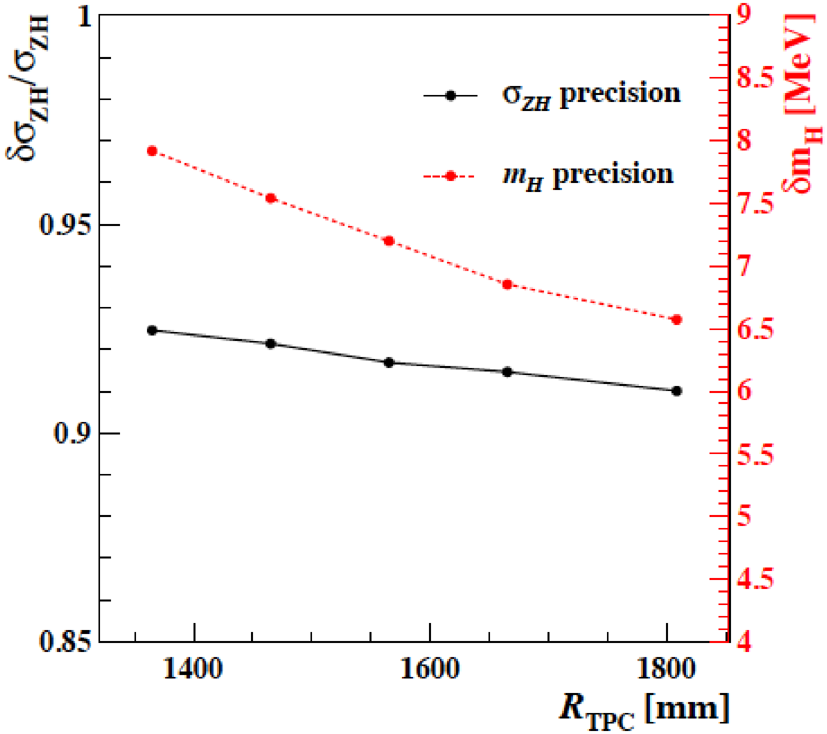
Number of strands： 18
Strand diameter： 1.2mm
Materiel :Nb/Ti
Complete time:2016.2

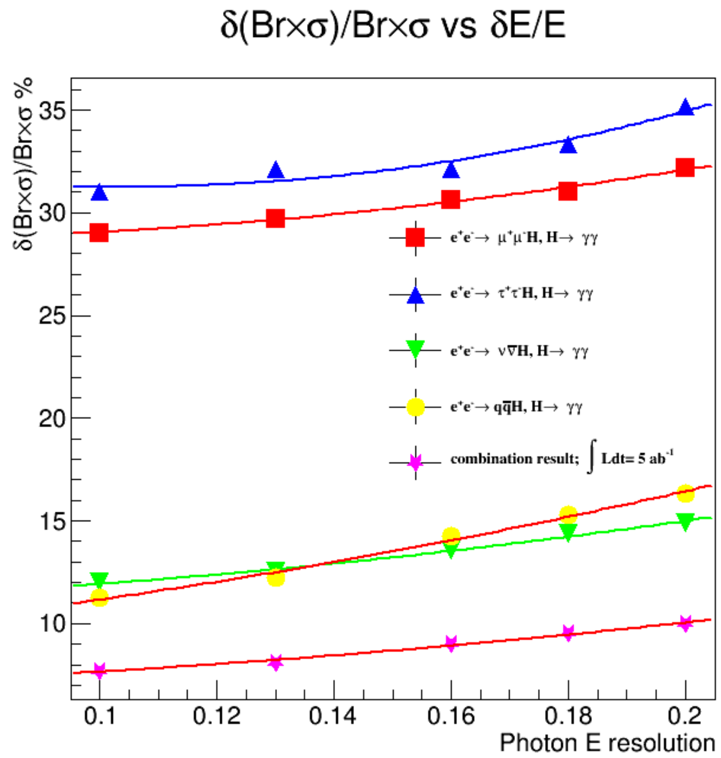
insert process

Copper cable +Aluminum alloy

Test results:
1.RRR value declined by about 1/3 after the stranding process.
2.The decrease of the critical current is less than 5%.

TPC Radius & ECAL resolution





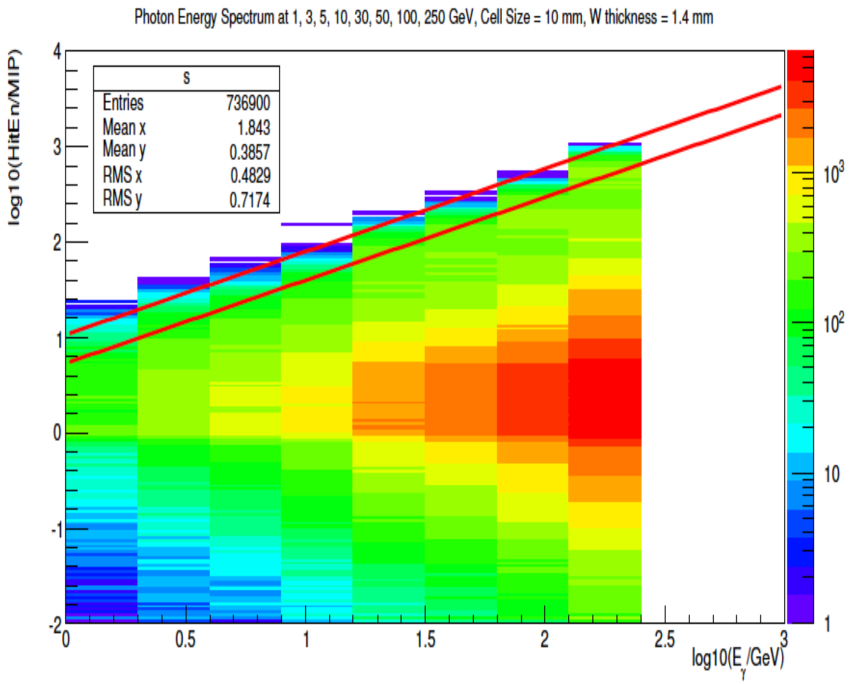
$$\delta m_H = 36.286 \times (1+0.092\times e^{-1.820\cdot R_{TPC}})\text{MeV}.$$

$$\frac{\delta\sigma_{ZH}}{\sigma_{ZH}} = 0.485 \times (1+e^{-0.094\cdot R_{TPC}})$$

H->di photon branching ratio measurement

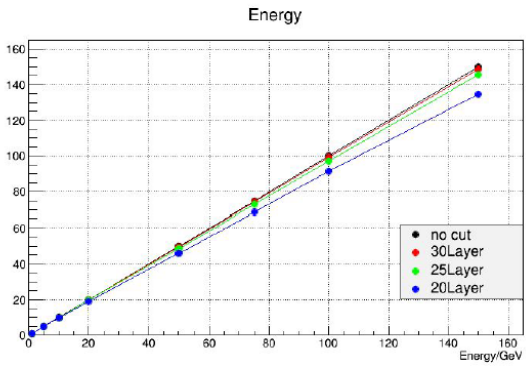
Calorimeter: Saturation & Leakage

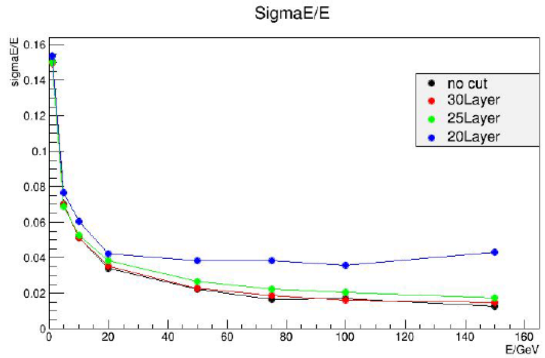
Calo optimization effort: UCAS(陈石)， IHEP(成栋，赵航，树正，学正， etc)

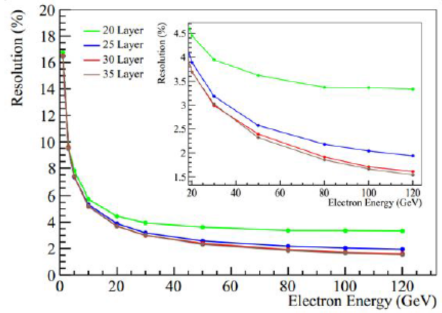


单层结构：2mm塑闪+2mmPCB+3mmW

入射粒子为gamma







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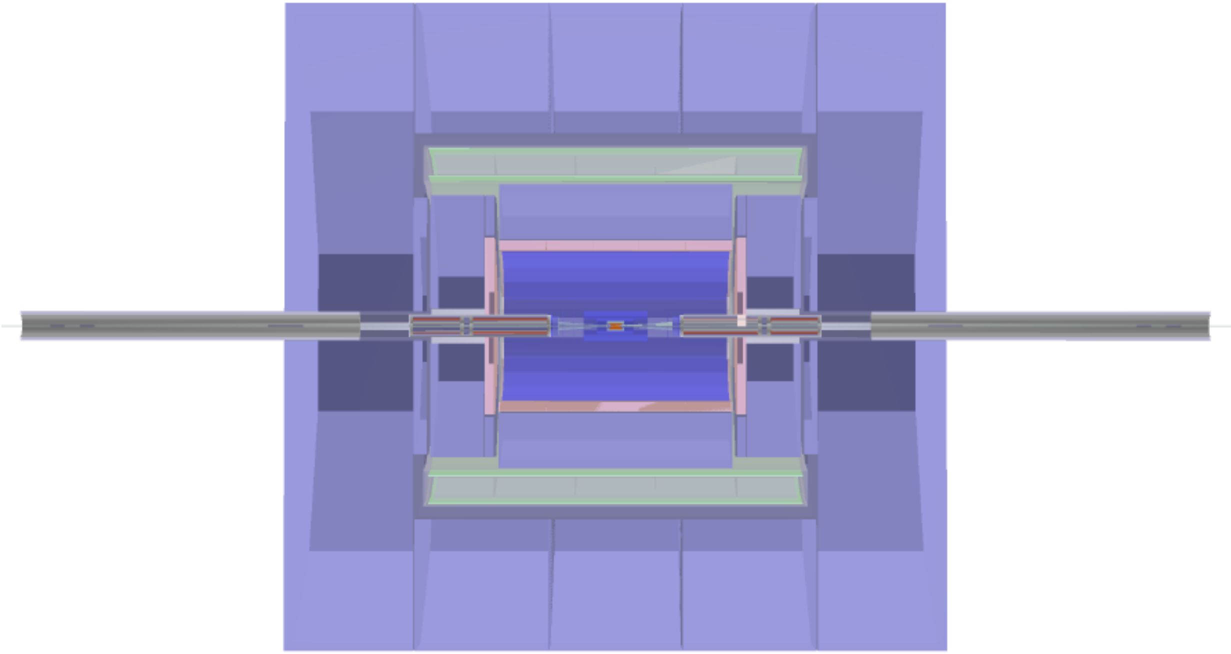
L 1sigma value = 0.87x - 0.24yy + 0.97y - 0.43z + 0.82

x = log10(energy) y = log10(cell size) z = log10(angle)

Eg, Saturate at 175 GeV photon, 20mm cell size: 2500 MIP

CEPC_o_v2



Parameter	CEPC_o_v2	CEPC_v1
LStar_zbegin	1150	1146.9
VXD_inner_radius	12	15
VXD_radius_r1	12	15
VXD_radius_r3	35	37
TPC_outer_radius	1500	1808
Hcal_nlayers	40	48
Ecal_cells_size	10	4.9
Field_nominal_value	3	3.5
Yoke Layers	2	3

Parameter put by hand, motivated by:

Saving the cost.

Closer VTX inner layer, better flavor tagging?

Reconstruction: be aware of TPC boundary & B-Field Strength

Implemented by Xuyin (NanKai U)

CEPC_v1 → CEPC_o_v2

W.R.T CEPC_v1, Reduce:

Total cost ~ 25%;
ECAL power/FEE: 75%;
HCAL thickness/channels ~ 20%;
B-Field to 17% (3.5 → 3);
VTX inner radius: 25%;

Qualitatively: everything goes into the expected direction

Quantitatively: ???

Reconstruction: Adapted, lots of effects needed for **OPTIMIZATION,** especially the PFA

Performance	adapted	optimized*	Manpower/ people*month
Tracking: D0, Z0	20% ↑ @ E < 20 GeV (VTX); 5% ↓ @ E > 20 GeV (B-Field);		4
Theta, Phi	worse	-	
Omega	worse	-	
PFA:Clustering	Slightly worse	same	-
Matching	~10% ↓	~5% ↓	6
Separation	~10% ↓	~2% ↓	2
PID	3-5% ↓ @ E > 10 GeV; 10% ↓ @ E < 10 GeV;	~1%↓	4
JER	20% ↓	~10%↓	4
Flavor Tagging	Improved up to 5%↑	?	3

*Given the current status, 23 people*month is needed to fully optimize the performance.*
For the next geometry, the needed manpower will be half

The prospect of CEPC electroweak physics in pre-CDR study

Table 4.1 The expected precision in a selected set of EW precision measurements and the comparison with the precision from LEP experiments. The current precisions for $\sin^2\theta_W^{\rm eff}$ and R_b include the measurement at the SLC.

Observable	LEP precision	CEPC precision	CEPC runs	$\int\mathcal{L}$ needed in CEPC
m_Z	2 MeV	0.5 MeV	Z lineshape	> 150 fb^{-1}
m_W	33 MeV	3 MeV	ZH (WW) thresholds	> 100 fb^{-1}
A_{FB}^b	1.7%	0.15%	Z pole	> 150 fb^{-1}
$\sin^2\theta_W^{\rm eff}$	0.07%	0.01%	Z pole	> 150 fb^{-1}
R_b	0.3%	0.08%	Z pole	> 100 fb^{-1}
N_ν (direct)	1.7%	0.2%	ZH threshold	> 100 fb^{-1}
N_ν (indirect)	0.27%	0.1%	Z lineshape	> 150 fb^{-1}
R_μ	0.2%	0.05%	Z pole	> 100 fb^{-1}
R_τ	0.2%	0.05%	Z pole	> 100 fb^{-1}

Towards CDR

- Milestones
  - theory working group
  - detector working group
  - advisory committee
  - 1^{st} draft: summer 2017

- International collaboration
  - develop 2^{nd} detector concept