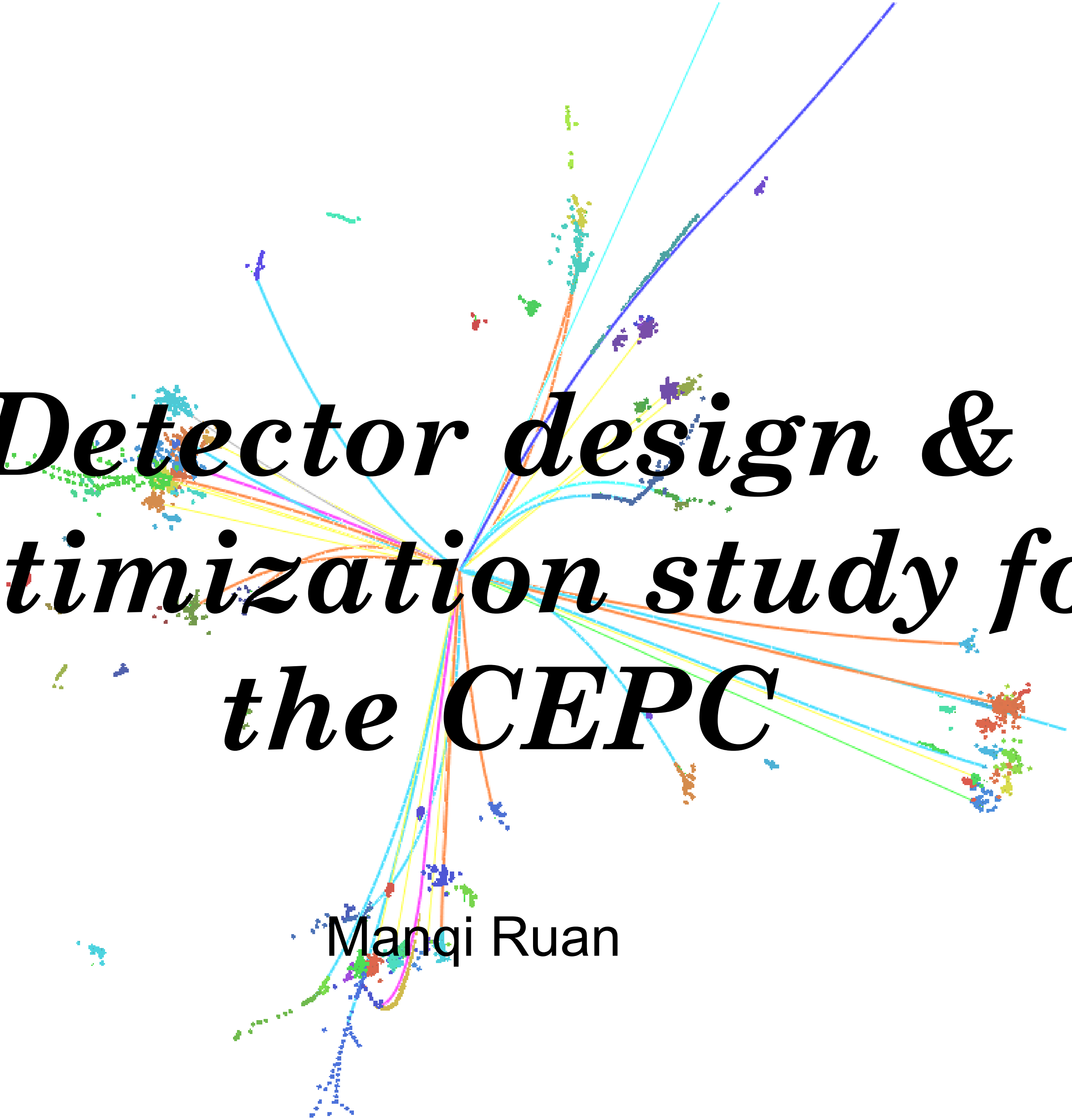
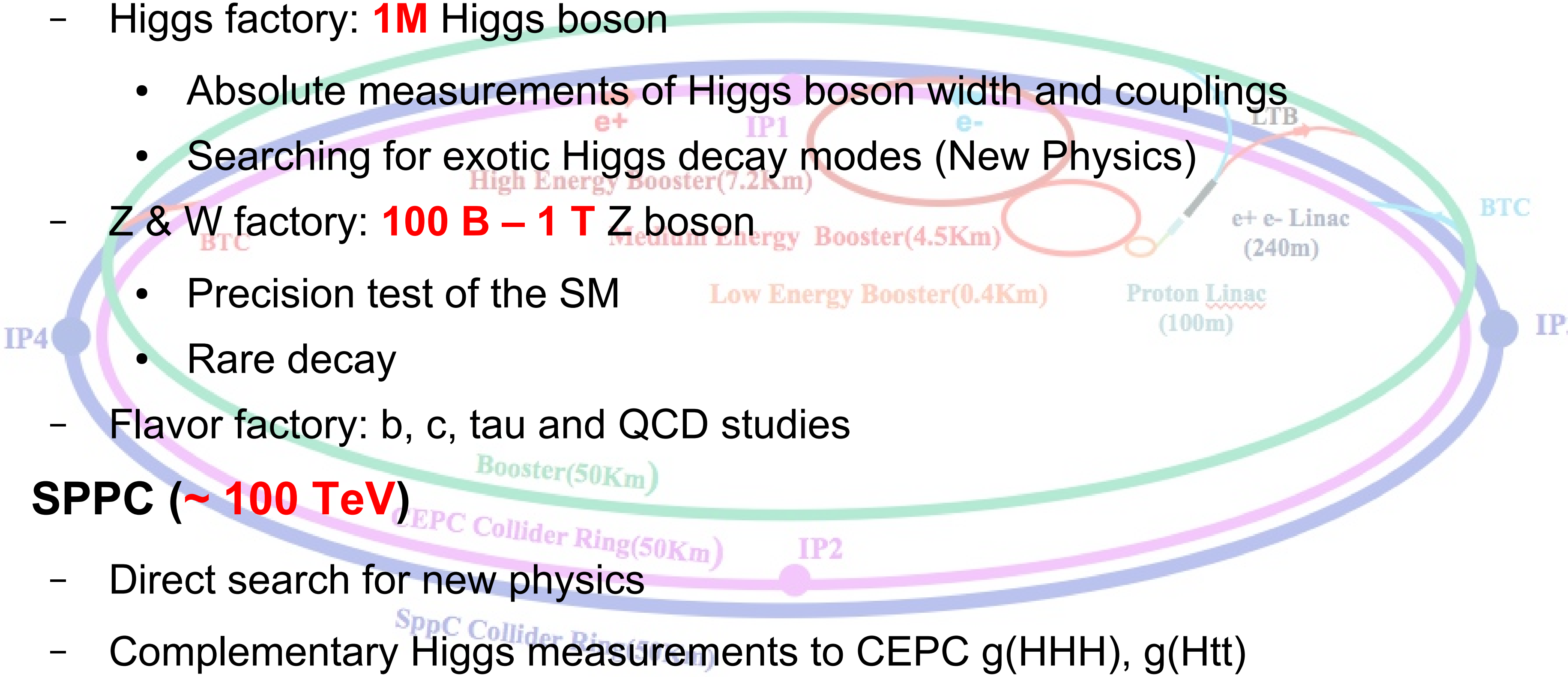
Detector design & Optimization study for the CEPC



Manqi Ruan

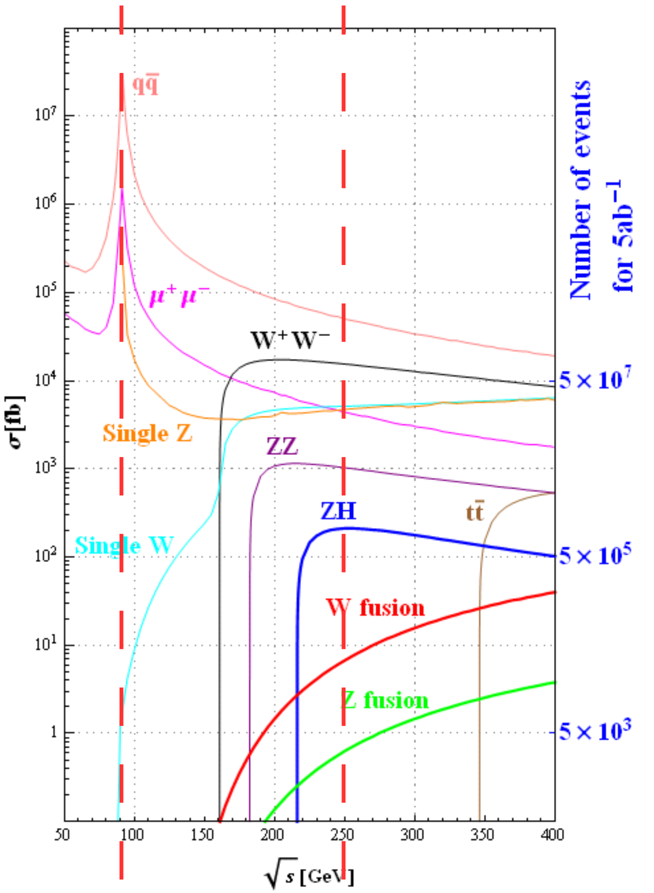
Science at CEPC-SPPC

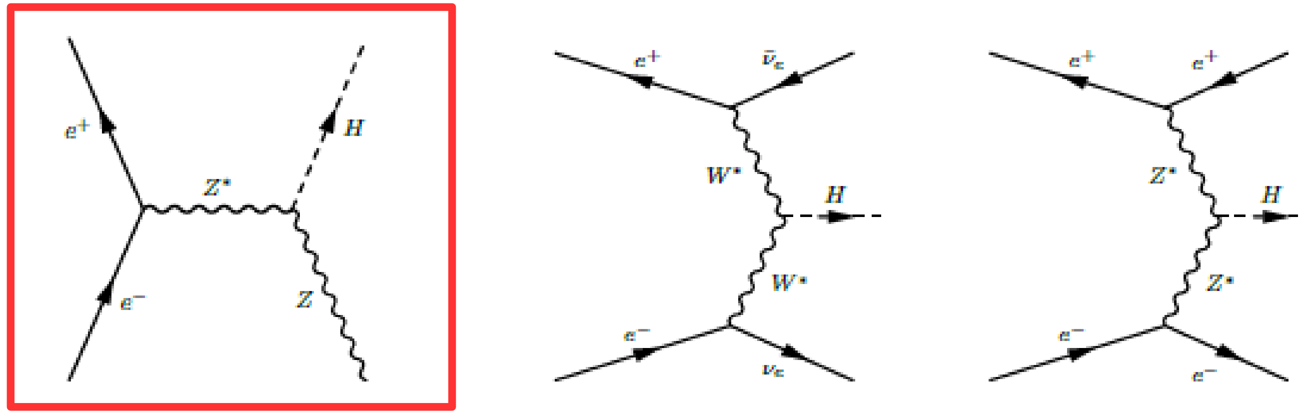
- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **100 B – 1 T** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**



Complementary

CEPC: 1M Higgs & 100B -1T Z





Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

Observables: EW Precision, tau physics, Flavor Physics...

Higgs mass, CP, σ(ZH), event rates (σ(ZH, vvH)*Br(H→X)), Diff. distributions

Derive: Absolute Higgs width, branching ratios, couplings

Physics & Performance

- CEPC, a super Higgs/W/Z factory
- Physics Potential
  - Higgs:
    - Absolute determination of Higgs couplings, width...
    - 1 order of magnitude improvement w.r.t HL-LHC (Signal Strength)
    - Exotic decay: 2-3 orders of magnitude better than HL-LHC
  - EW: boost by at least 1 order of magnitude
  - Rich program on Flavor physics
- Performance at the baseline design (APODIS + Arbor)
  - High efficiency/accuracy reconstruction of all key physics objects
  - Clear Higgs signature in all SM Higgs decay modes
  - Clear distinguish between the Signal and SM backgrounds
  - Fulfills the physics requirements of the CEPC Higgs operation

Timeline

Milestones

1st, PreCDR (end of 2014)

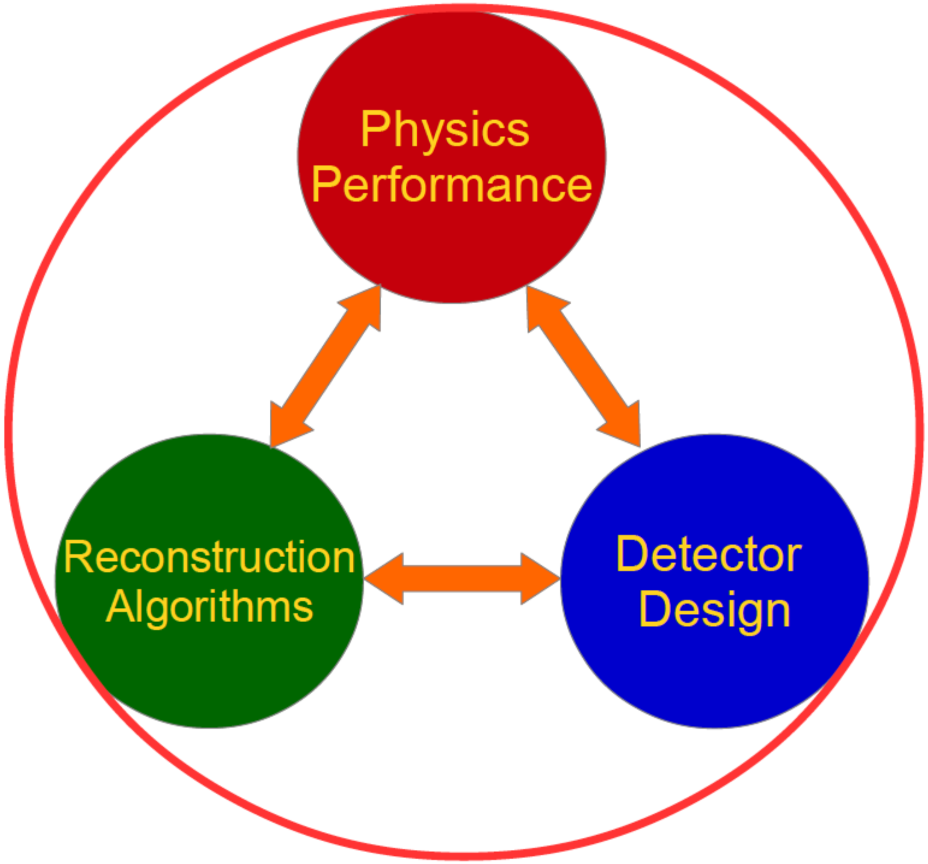
2nd, R&D funding from MOST (Middle 2016, 35 M CNY/5yr for the 1st phase)

3rd, CDR (end of 2017)

...

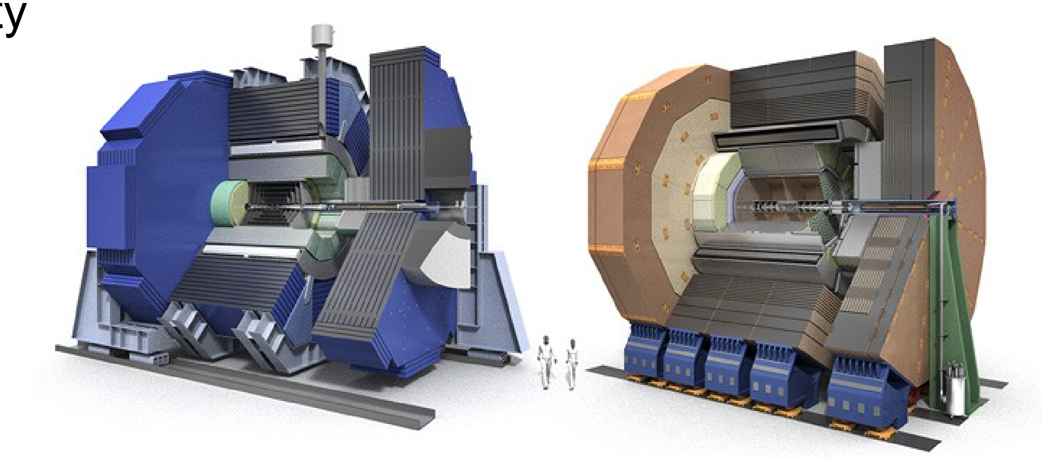
Detector Geometry

- Physics Requirements
- Benchmarks analysis & Comparison
- Key ingredient
  - Input from Accelerator
  - Input from Detector Hardware
  - Iterating...

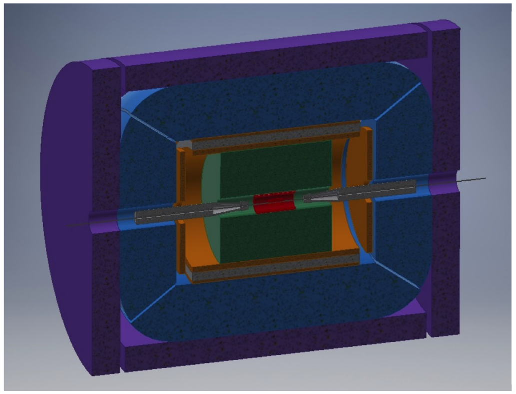


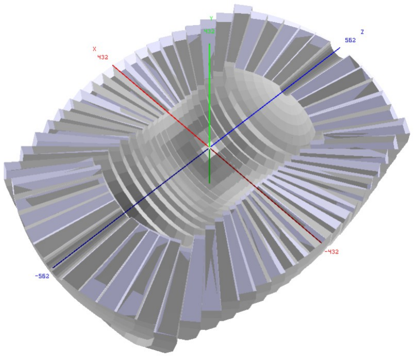
Two classes of Concepts

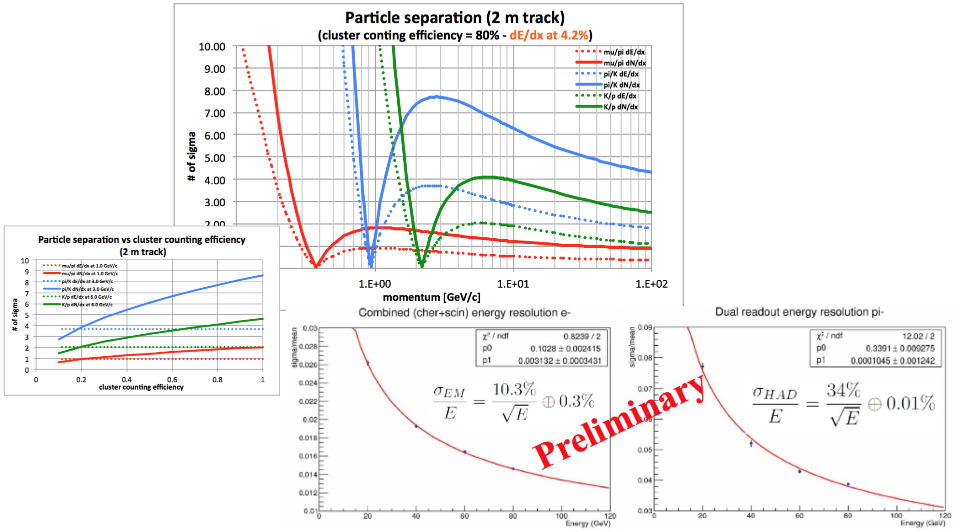
- PFA Oriented concept using High Granularity Calorimeter
  - + TPC (ILD-like, **Baseline**)
  - + Silicon tracking (SiD-like)



- Low Magnet Field Detector Concept (IDEA)
  - Wire Chamber + Dual Readout Calorimeter



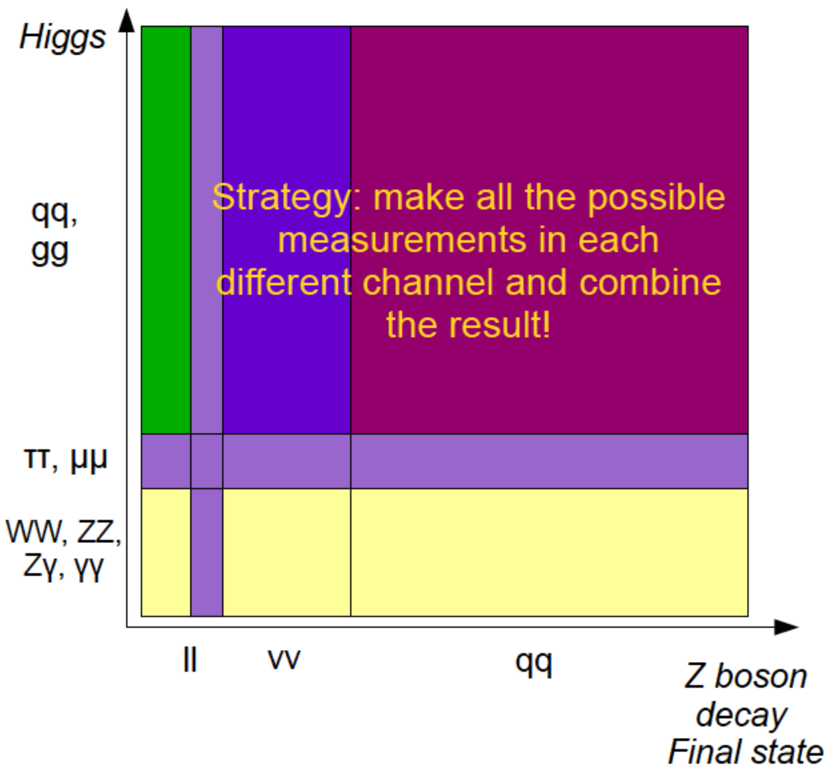


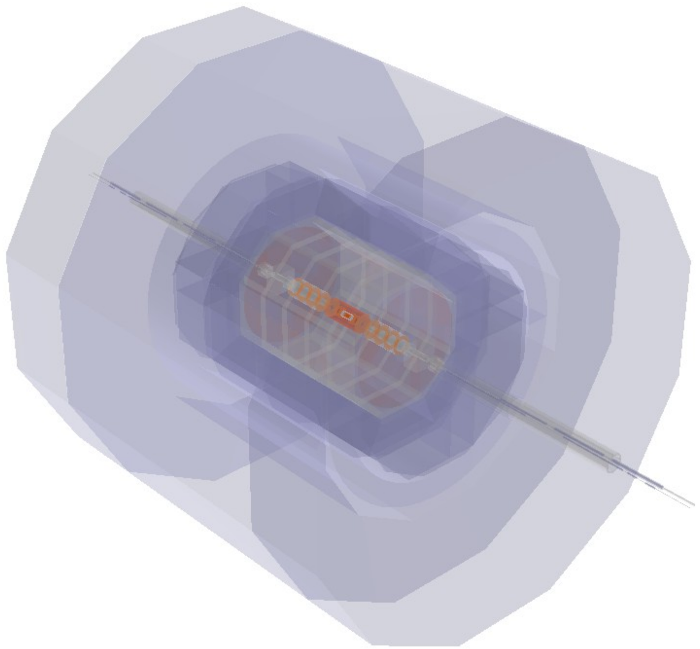


https://indico.ihep.ac.cn/event/6618/

https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=14816

ILD, reference of CEPC detector



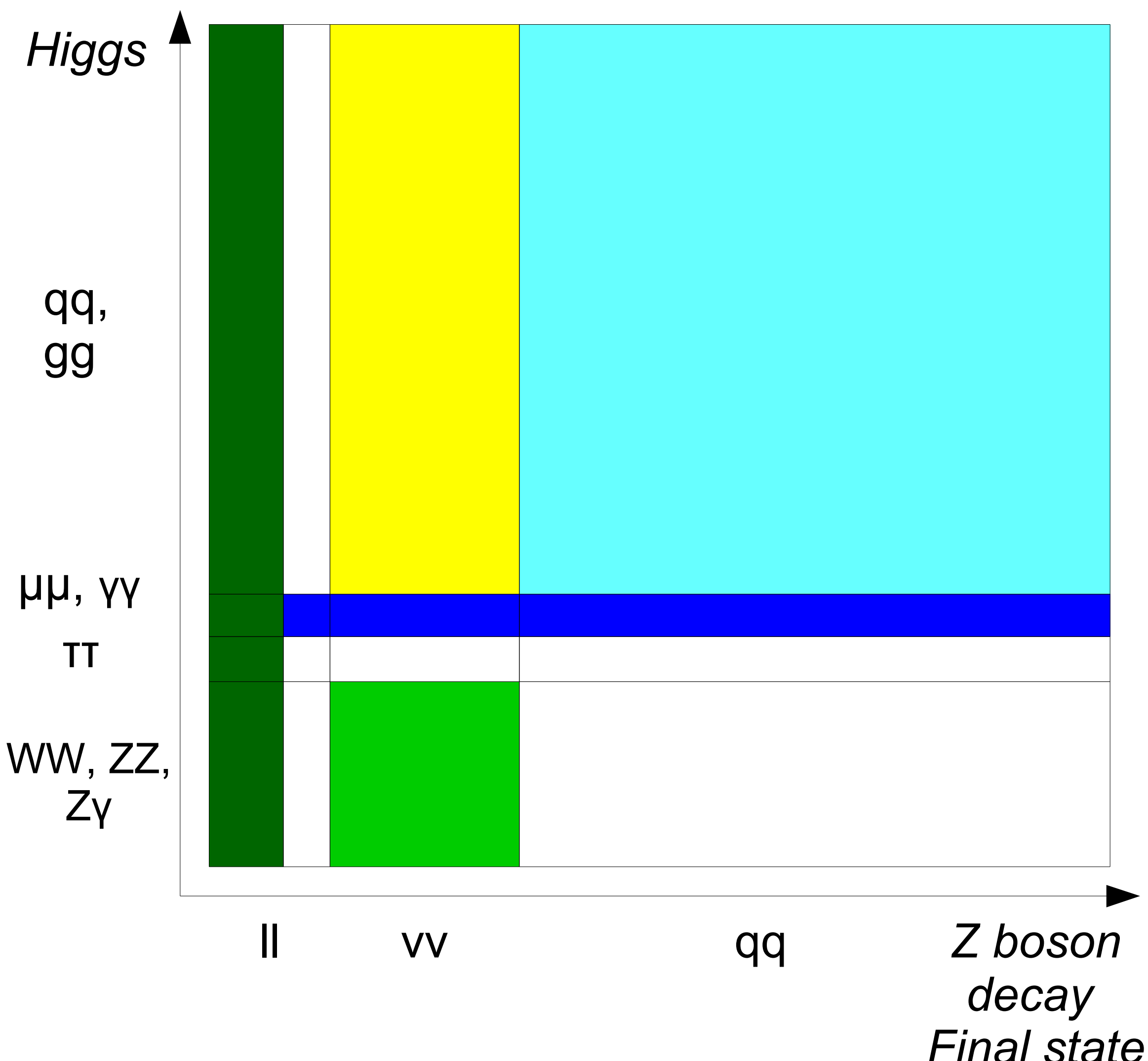


High precision VTX located close to IP: b, c, tau tagging

High precision tracking system

PFA oriented calorimetry system (~o(10^8) channels): PID, jet energy resolution, etc.

Physics Benchmarks for Optimization



Lepton & Momentum resolution: Br = 6.7%

Flavor Tagging & JER: Br = 14%

Composition of Jet/MET, lepton: Br = 4%

Jet Clustering: Br = 50%

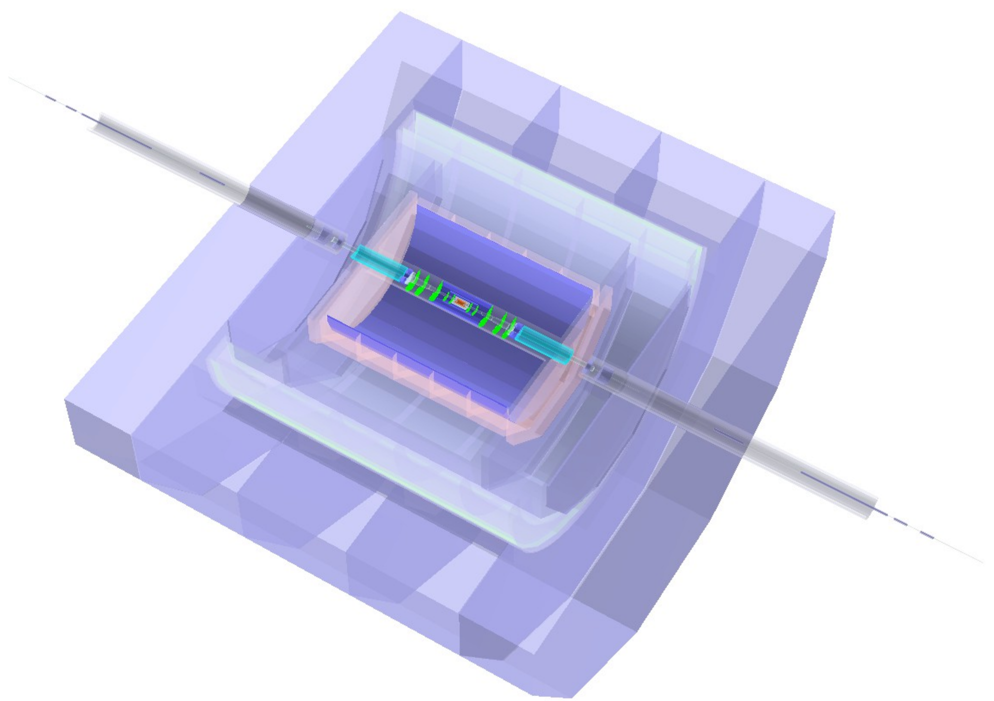
Photon/ECAL: Br = 0.2%

qqH, H->inv. MET & NP: SM Br = 0.1%

EW, Br(tau->X) @ Z pole: Separation

Key issues

- In terms of the collision environment, The CEPC is fundamentally different w.r.t ILC/CLIC
  - Different beam parameter & Machine Detector Interface (MDI)
  - Much high event rate at the Z pole operation: Z->qq events ~ 10^{3-4} Hz
  - Continuous beam: No power pulsing, need to reduce the #readout, especially at the Calorimeter
  - Multiple IP: No push-pull, and much thinner Yoke
- Key optimization at CDR
  - MDI Redesign
  - TPC Feasibility
  - Calo Geometry
  - VTX Dependence

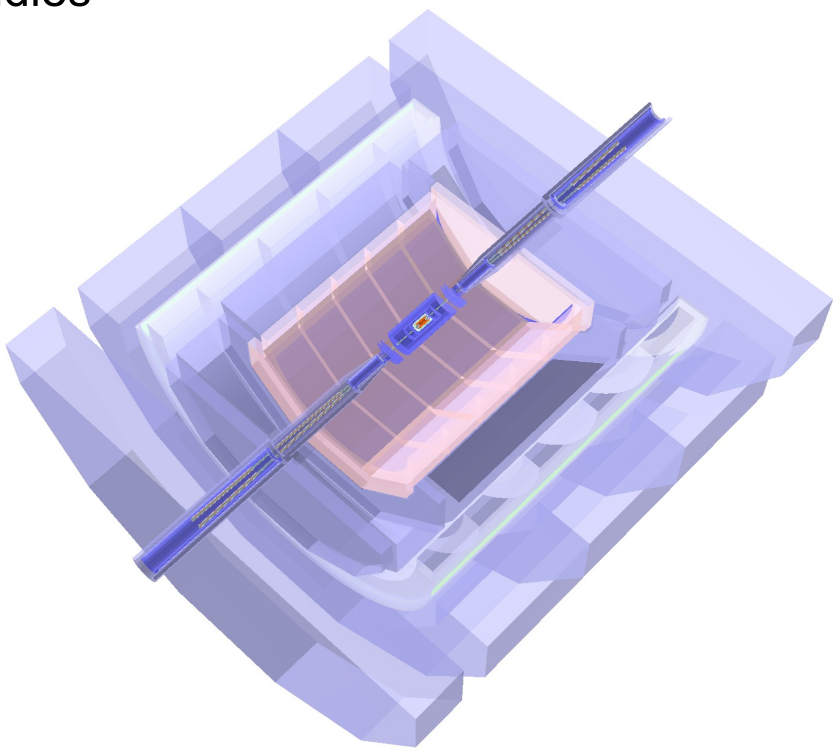


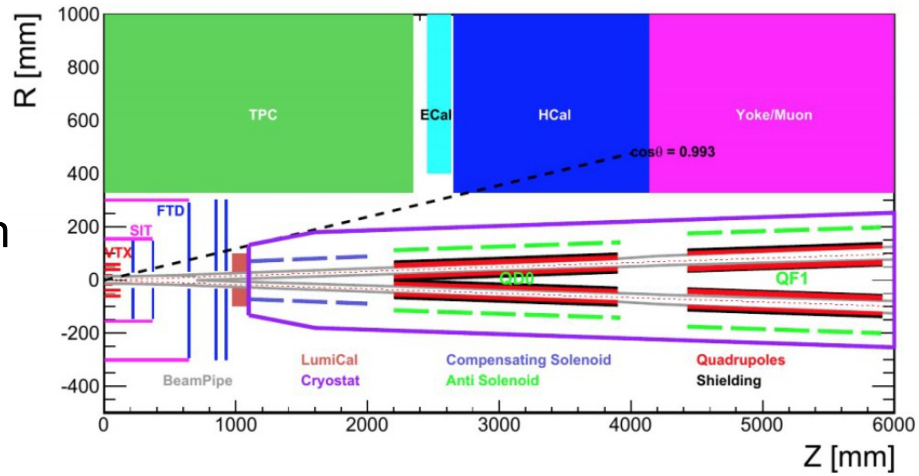
CEPC_v1
Forward Region & Yoke Thickness
Modified w.r.t ild_o2_v05

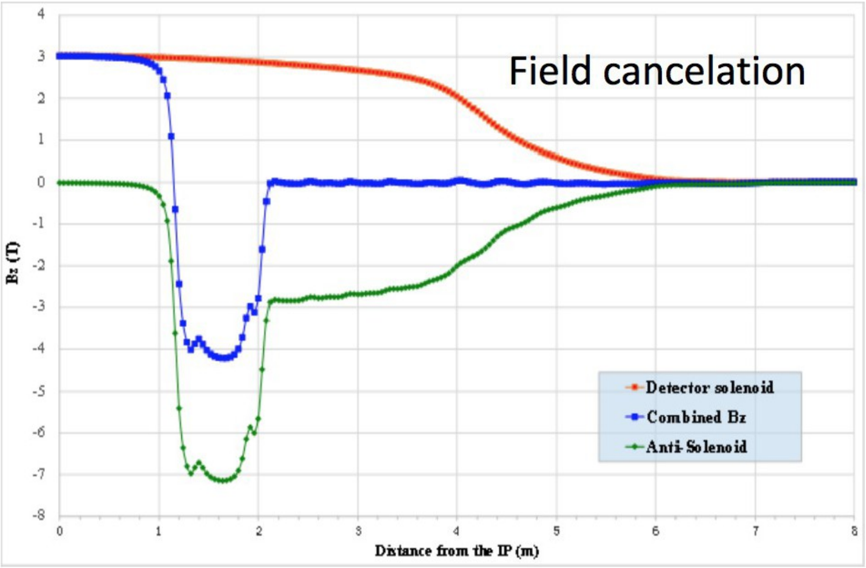
Reference detector for CEPC PreCDR Study

MDI design & Implementation

- The most challenge part for the detector
- Extremely compact, complicated configuration
- Iterated with the radiation & detector protection studies

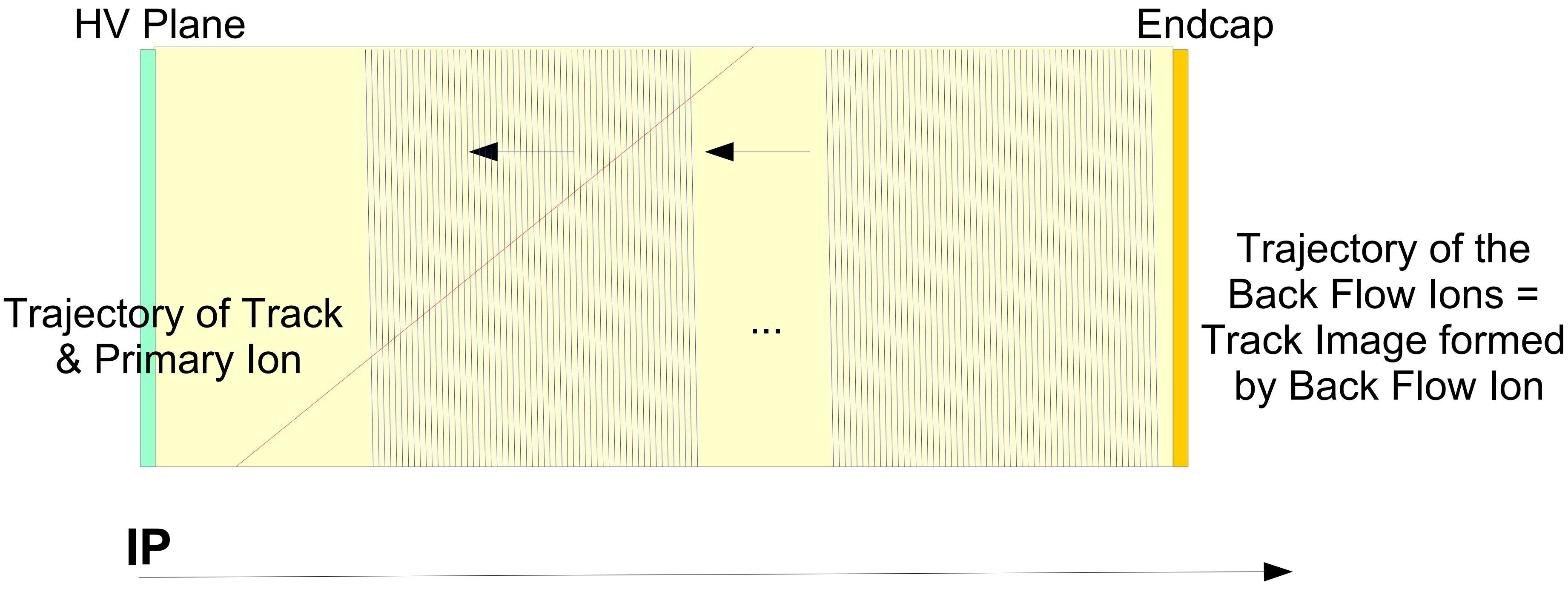




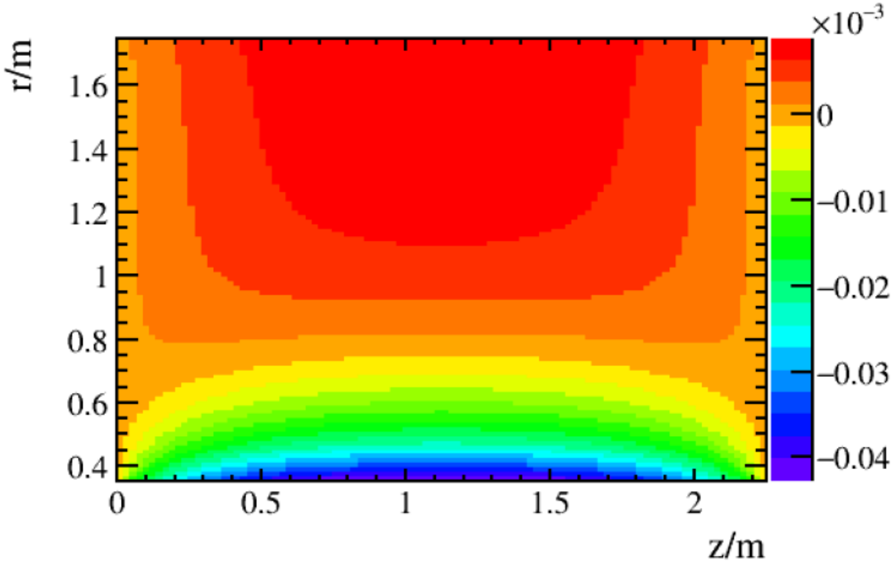


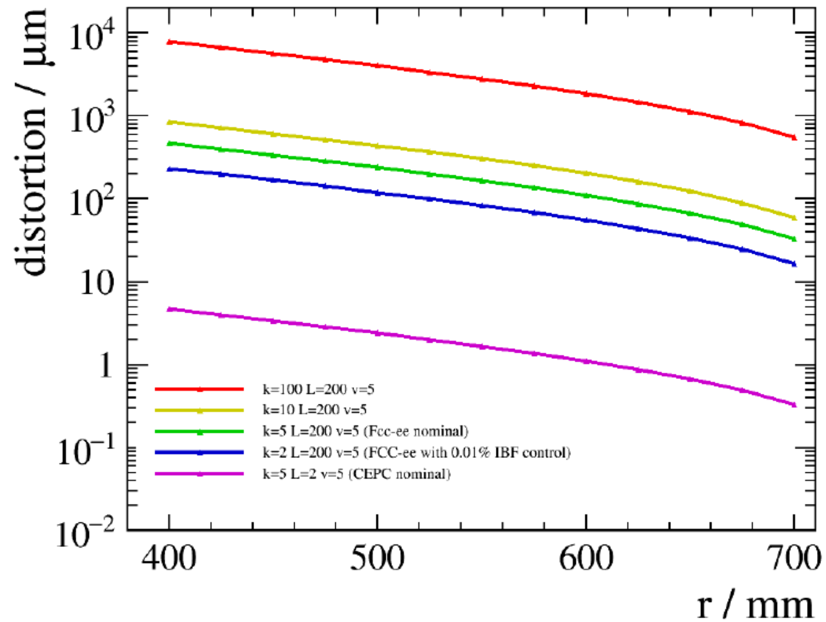
Feasibility of TPC at Z pole

- 600 Ion Disks induced from Z->qq events at 2E34cm^{-2}s^{-1}
- Voxel occupancy & Charge distortion from **Ion Back Flow** (IBF)
- Cooperation with CEA & LCTPC



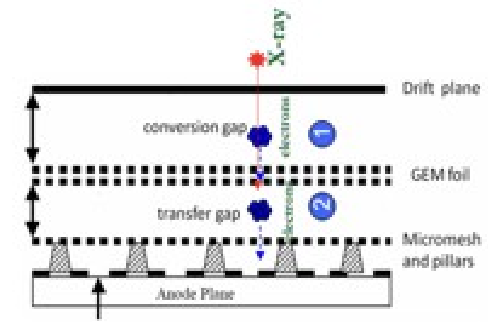
TPC Feasibility

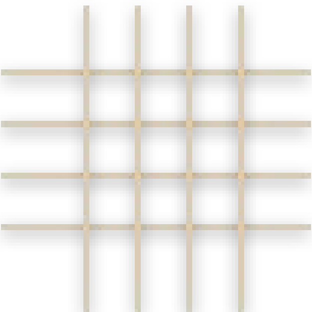


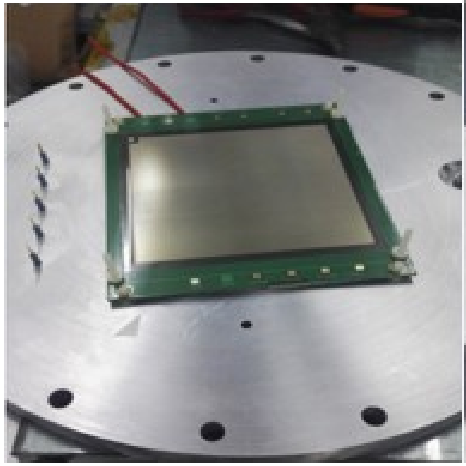


- Conclusion (JINST_12_P07005, CEPC-DocDB-id-147):
  - Voxel occupancy ~ (10^-4 – 10^-6) level, safe
  - **Safe for CEPC If the ion back flow be controlled to per mille level** (k = 5) -
    - The charge distortion at ILD TPC would be one order of magnitude then the intrinsic resolution (L = 2E34 $cm^{-2}s^{-1}$)
    - TPC usage is not limited by the Physics Hits;
    - Beam background needs further investigation (a priori not the dominant source at Z pole)

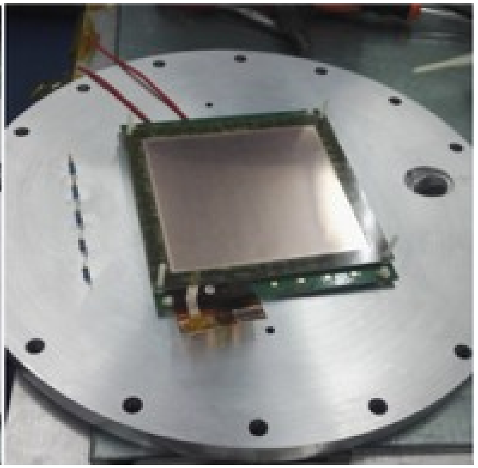
R&D on the IBF control



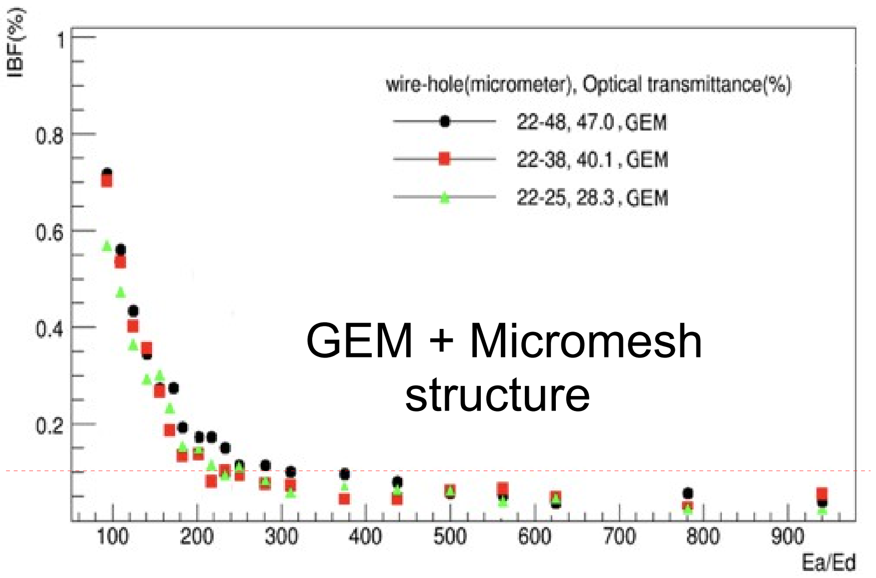


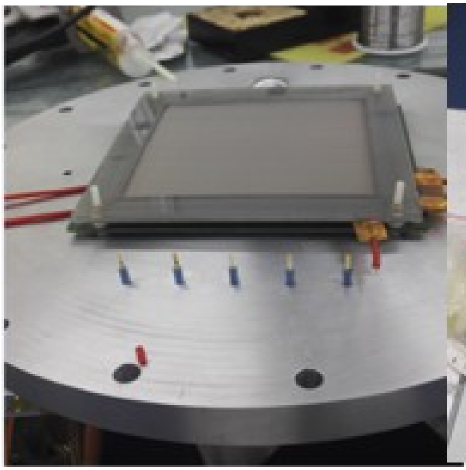


Micromegas(Saclay)

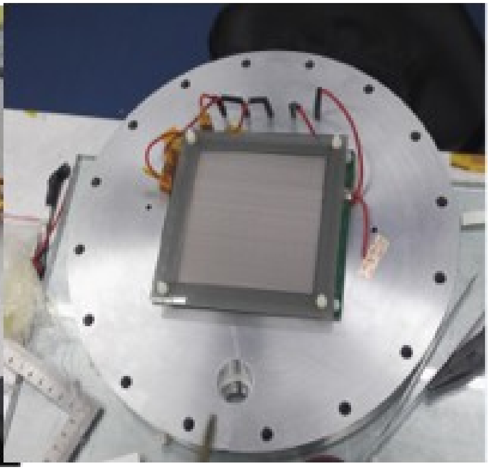


GEM(CERN)





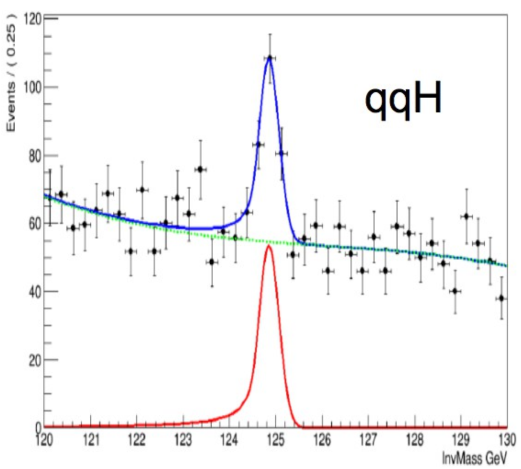
Cathode with mesh

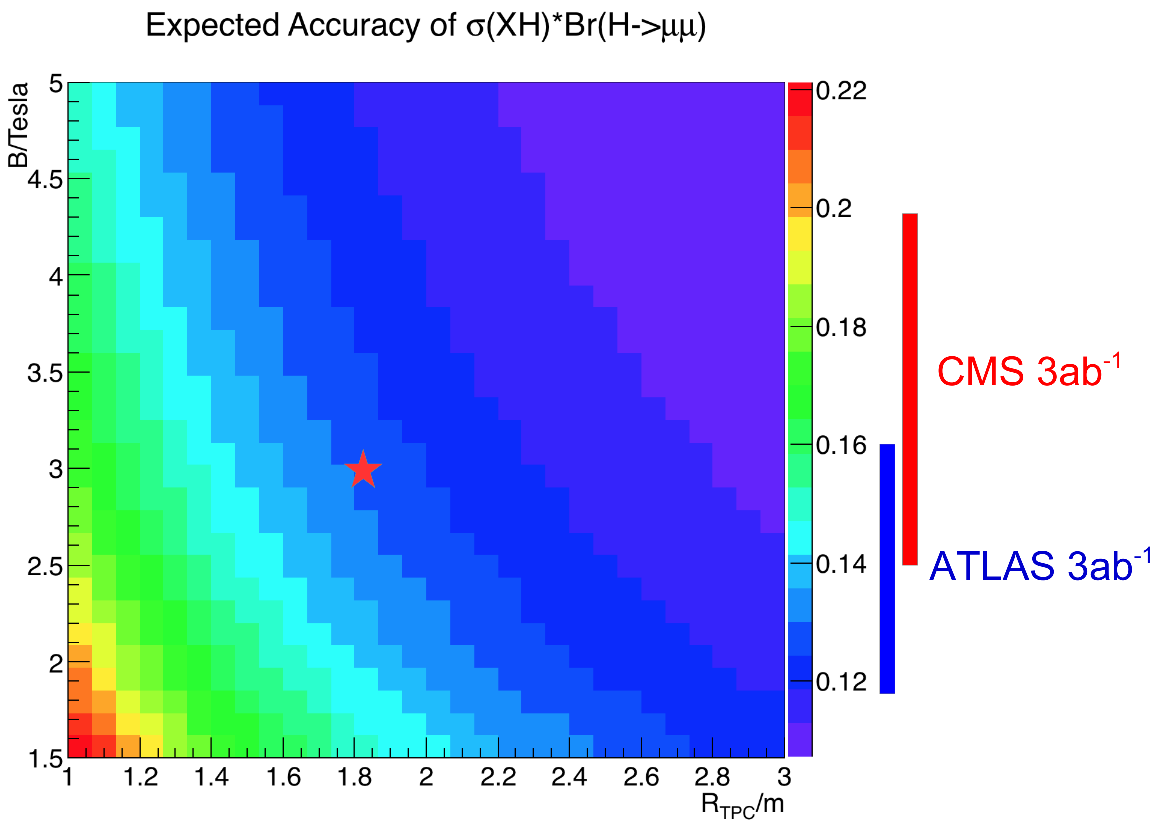


GEM-MM Detector

Tracker Radius: the optimized value

- Detector cost is sensitive to tracker radius, however, I recommend TPC radius >= 1.8m:
  - Better separation & JER
  - Better dEdx
  - **Better (H->di muon) measurement**





The optimization of the Vertex

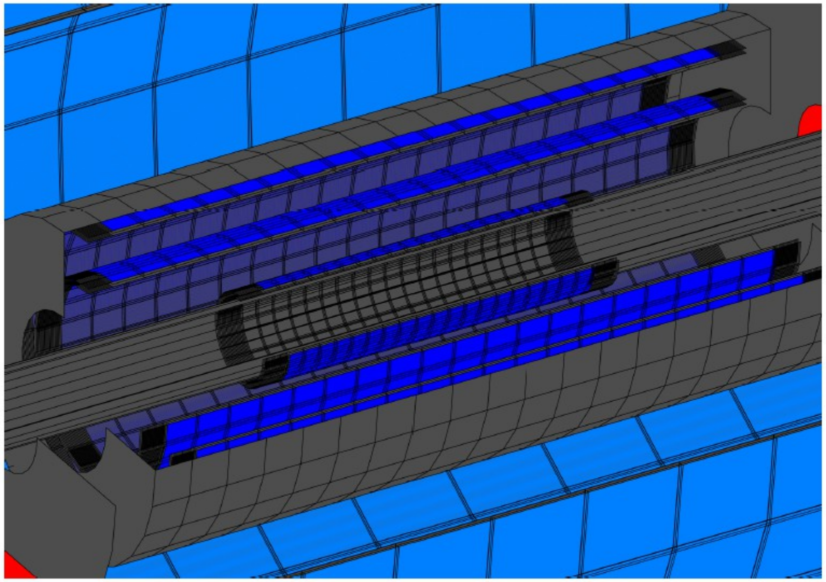


Figure 1. The vertex system schematic at the CEPC.

Table 1. Design parameters of the CEPC vertex system.

	R(mm)	$\|Z\|$(mm)	$\sigma(\mu m)$	material budget
Layer 1	16	62.5	2.8	0.15%/X_0
Layer 2	18	62.5	6	0.15%/X_0
Layer 3	37	125.0	4	0.15%/X_0
Layer 4	39	125.0	4	0.15%/X_0
Layer 5	58	125.0	4	0.15%/X_0
Layer 6	60	125.0	4	0.15%/X_0

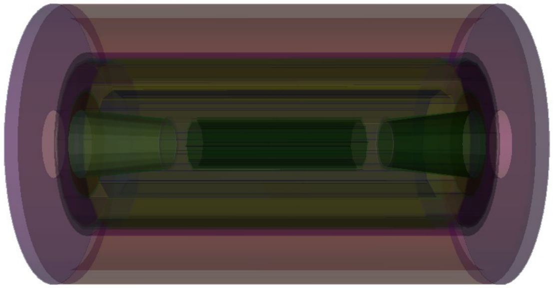
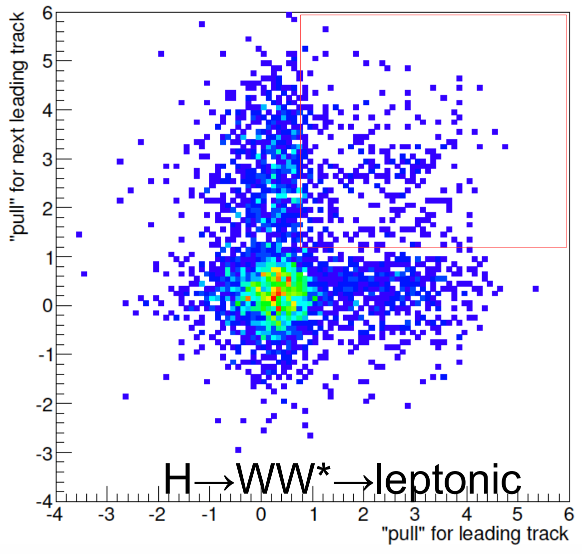


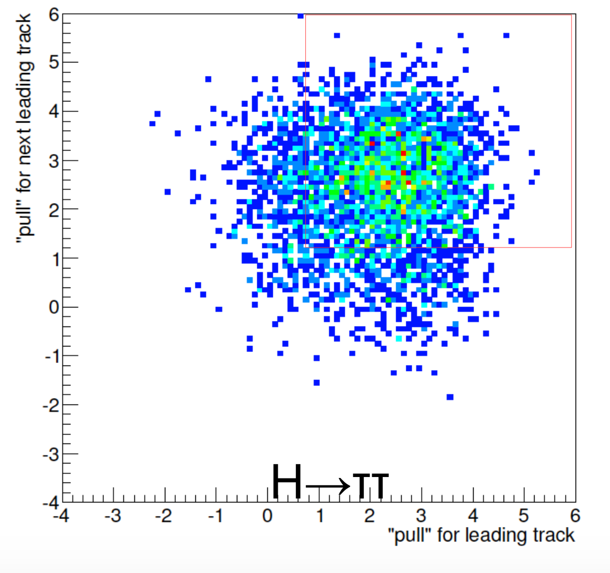
Table 2. Reference geometries

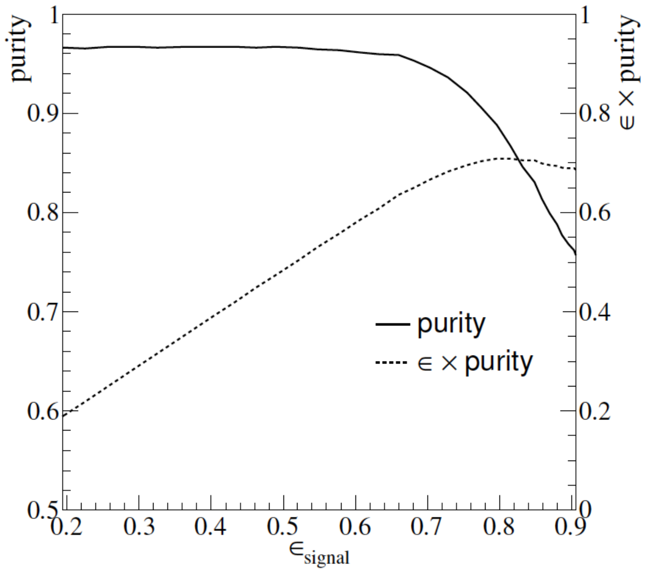
	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
Material per layer/X_0	0.075	0.15	0.3
Spatial resolution/μm	1.4 - 3	2.8 - 6	5 - 10
R_{in}/mm	8	16	23

Zhigang & Dan: *g(Hττ)* at μμH

	$\mu\mu H\tau\tau$	$\mu\mu H$ inclusive bkg	ZZ	WW	single$W$	single$Z$	$2f$
total generated	2292	33557	5711445	44180832	15361538	7809747	418595861
after preselection	2246	32894	122674	223691	0	86568	1075886
$N_{Trk}(A/B) < 6$ & $N_{Ph}(A/B) < 7$	2219	1039	2559	352	0	9397	25583
BDT>0.78	2135	885	484	24	0	157	161
efficiency	93.15%	2.63%	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%





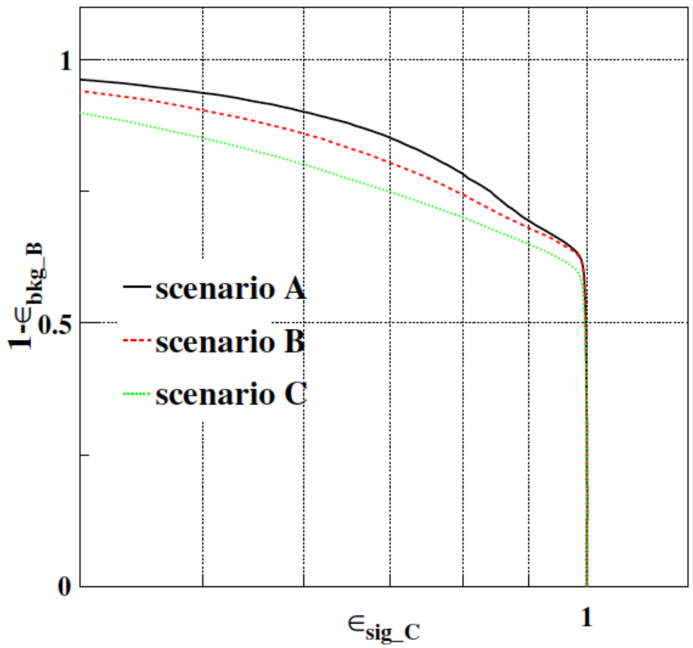


situations	best	baseline	worst
$\epsilon \cdot$ purity	0.77±0.01	0.71±0.01	0.68±0.01

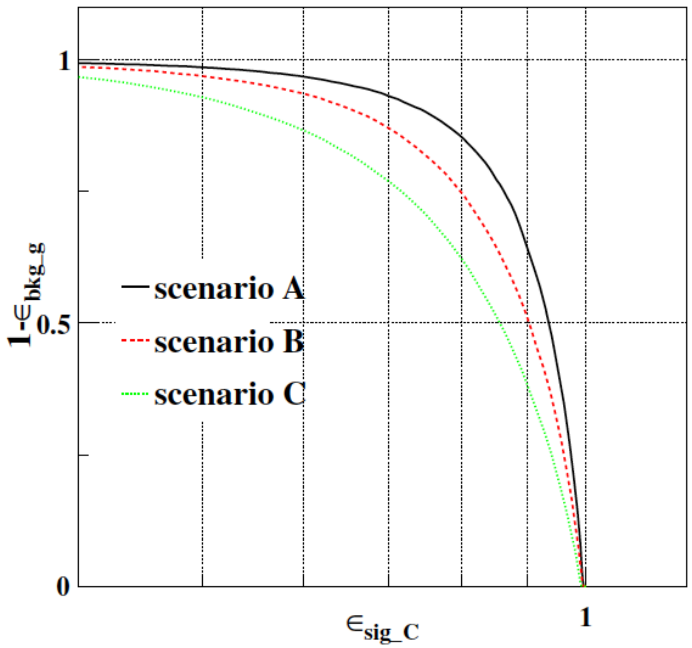
Worst: ALICE ITS parameter
Best: 2 times more aggressive w.r.t baseline
In inner Radius, Material & resolution

Conclusion: in this benchmark channel, VTX is sensitive but not crucial

VTX Optimization (Zhigang & Dan): *g(Hbb)* & *g(Hcc)*



(a) b background



(b) g background

Table 2. Reference geometries

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Spatial resolution/μm	1.4 - 3	2.8 - 6	5 - 10.7
R_{in}/mm	8	16	23

Table 6. $\epsilon \cdot$ p comparison for all three benchmarks.

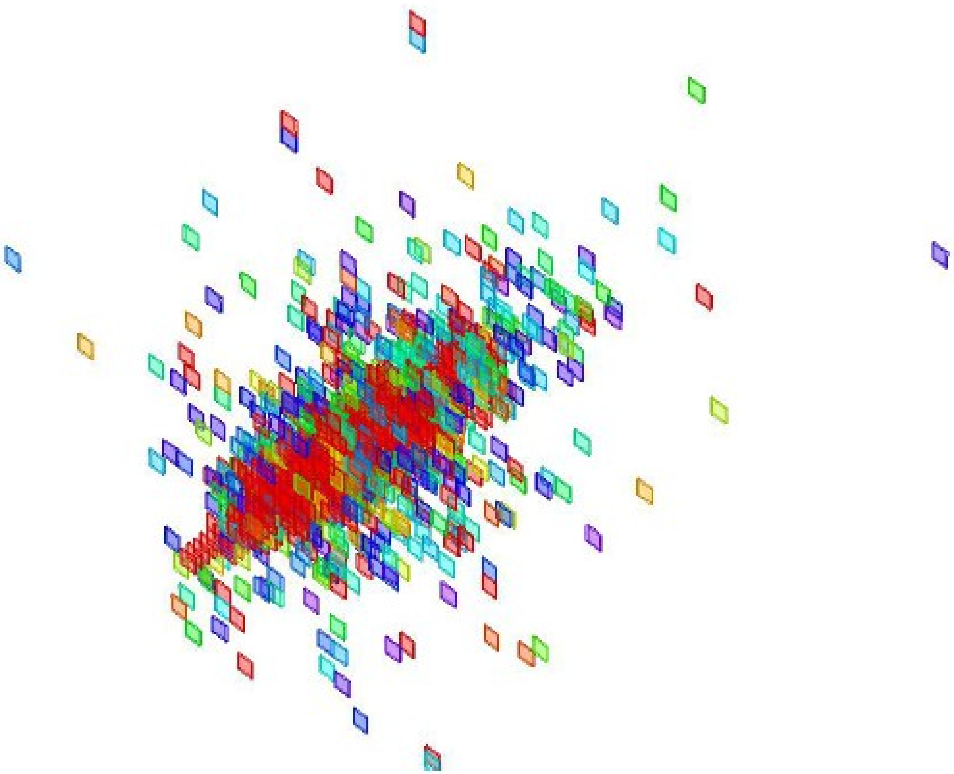
Benchmark	Scenario A	Scenario B	Scenario C
$Br(H \to c\bar{c})$	0.133±0.002	0.095±0.001	0.078±0.001
$Br(H \to b\bar{b})$	0.925±0.001	0.914±0.001	0.900±0.001
$Br(H \to \tau^+\tau^-)$	0.77±0.01	0.71±0.01	0.68±0.01

Calorimeter Optimization

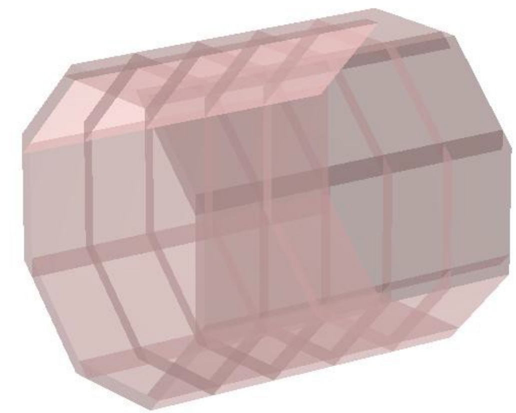
- No Power Pulsing: Feasibility study of Passive Cooling
  - Number of channels need to reduced by more than 1 orders of magnitudes, test Geometries implemented (10-20 mm ECAL/HCAL Cell + reduced layers)
  - Performance on objects & Higgs Benchmarks
    - Photon & H->photons
    - Lepton & Higgs recoil
    - Jets & H->gluons
  - Cooperation with In2p3-LLR (MoU signed) & CALICE

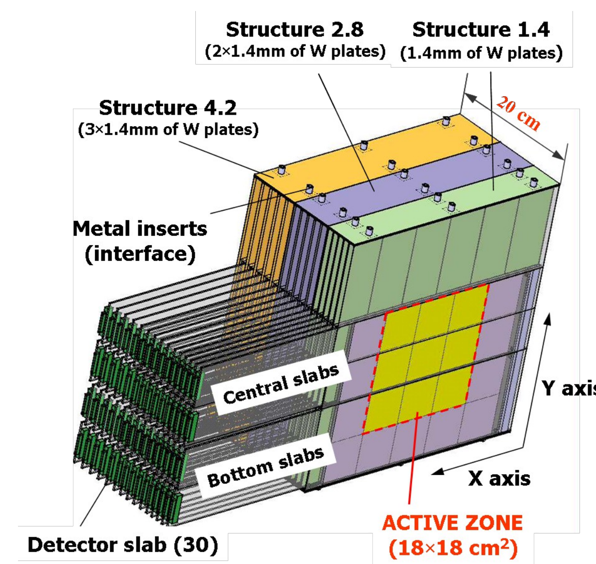
- Determination of the geometry parameters for the calorimeter
  - HCAL Thickness
  - ECAL Thickness, Number of Layers & Cell Size

ECAL Saturation/Linear Range Study

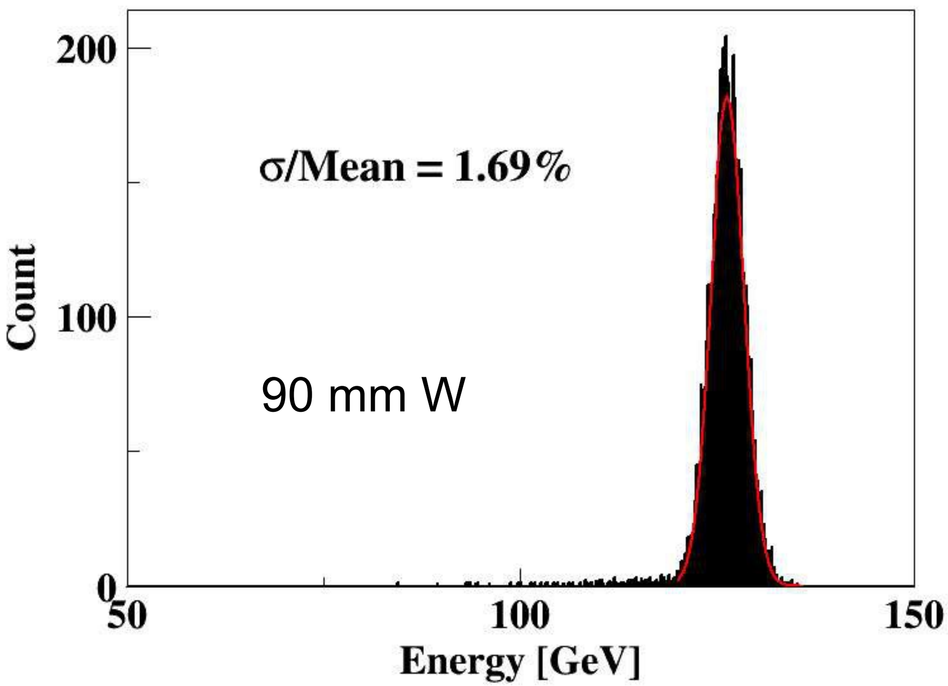


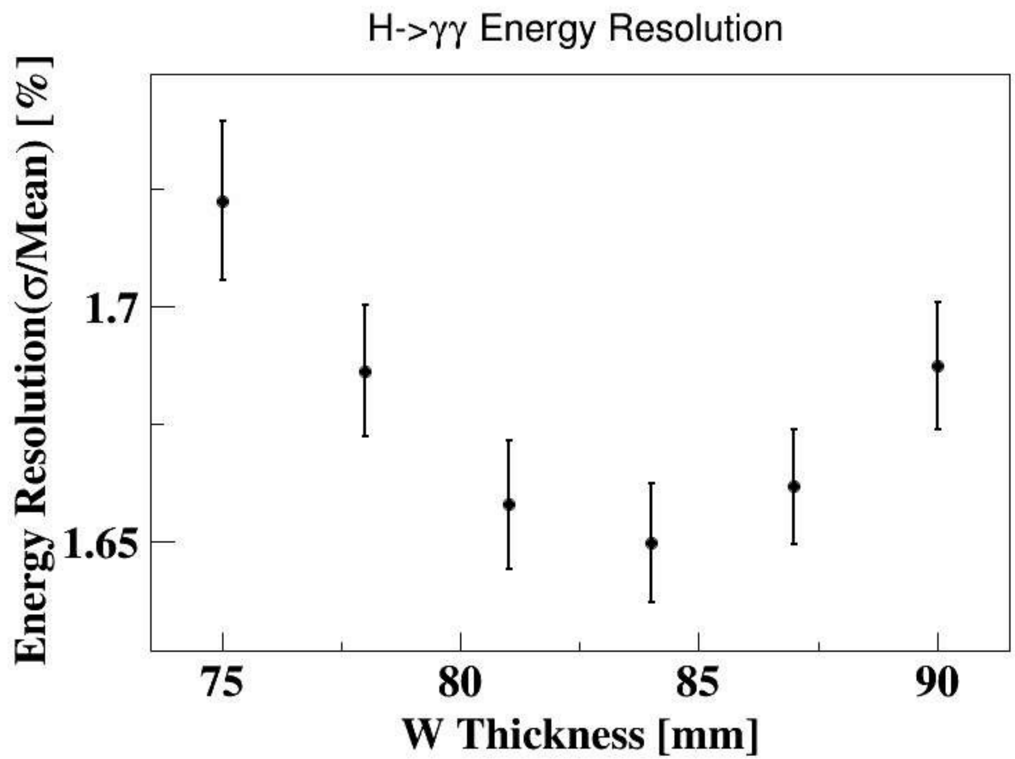
50 GeV Photon Cluster
at ECAL with 10 mm Cell Size





H->di photon Vs W thickness

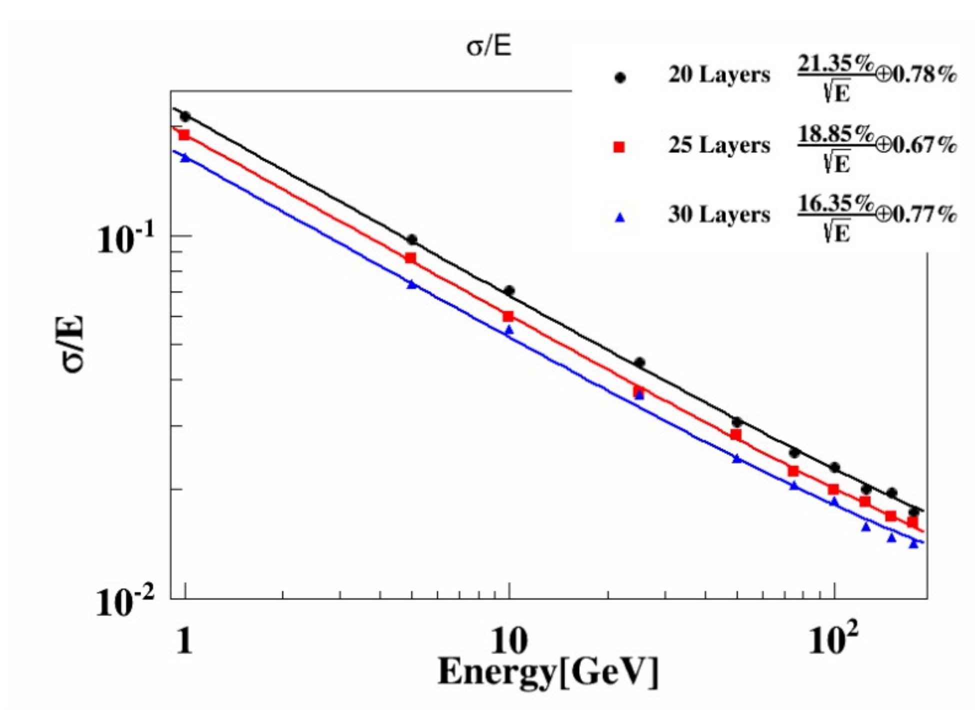


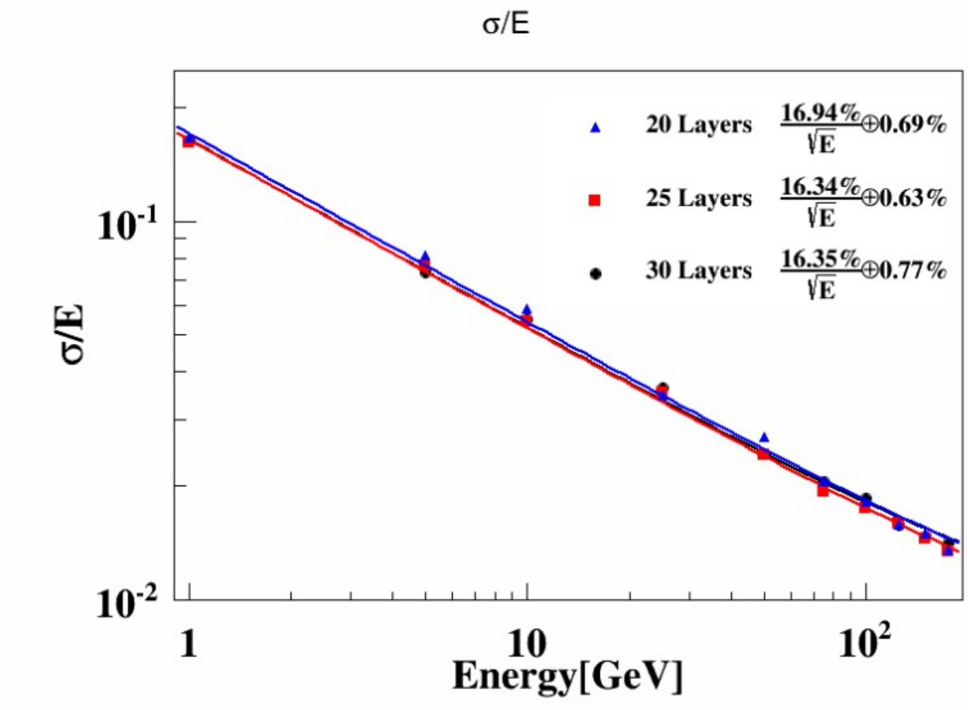


30 Layers, each layer with 0.5 mm Si + 2 mm PCB
ECAL only performance

Optimization on the in-homogeneous longitudinal structure (i.e, Absorber thickness at different layer) not applied

Photon energy measurement Vs Longitudinal structure: #Layer & Si Thickness





Performance @ Photon with E > 1 GeV:

Energy Resolution is comparable at:

20 * 1.5 mm Si + 4.5 mm W
25 * 1 mm Si + 3.6 mm W
30 * 0.5 mm Si + 3 mm W

What's the maximal viable silicon wafer thickness?

Separation performance

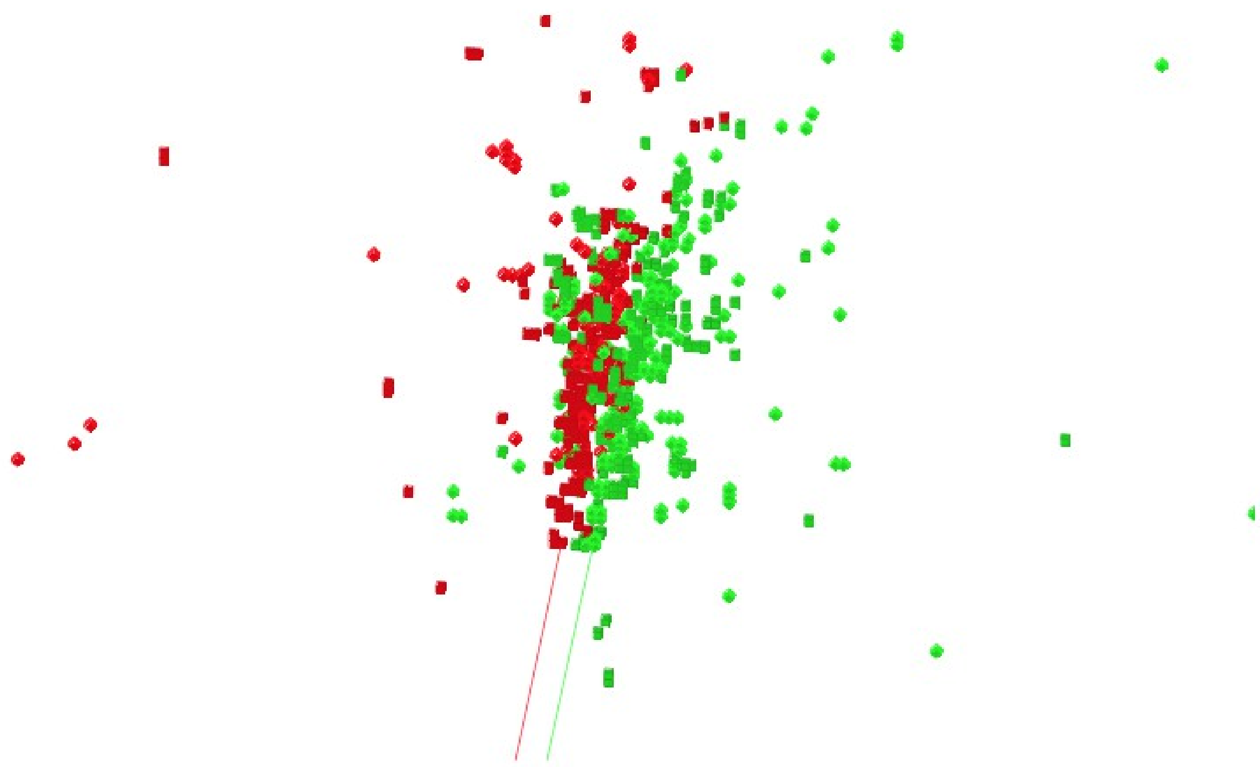
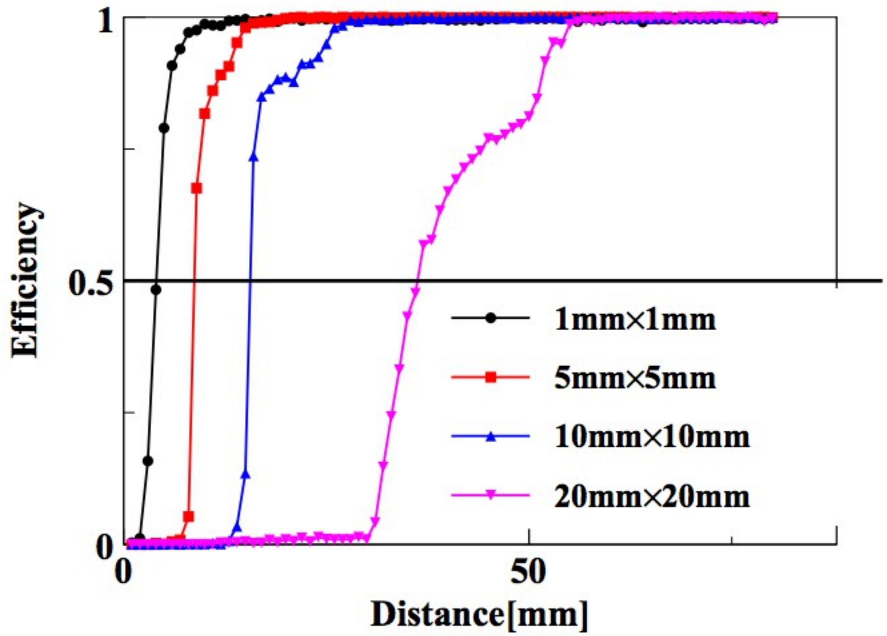
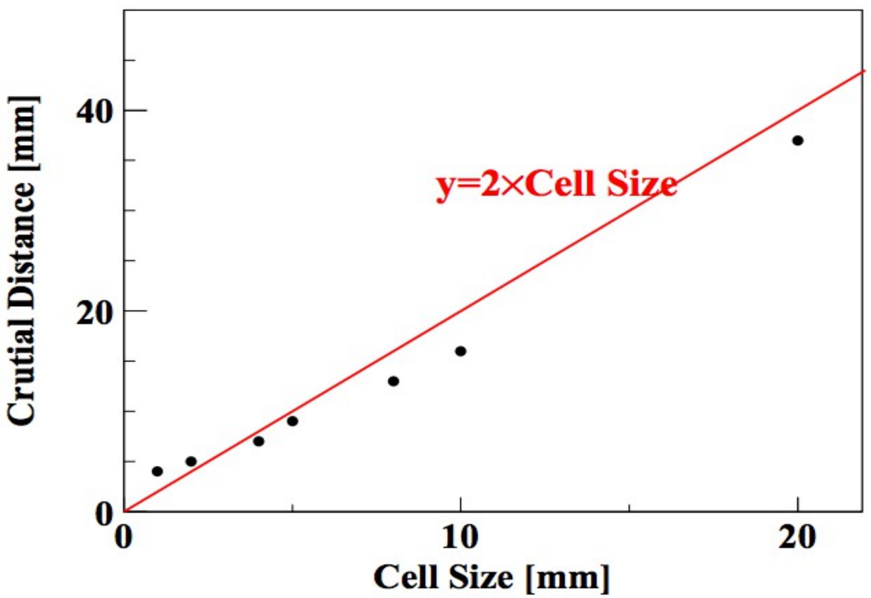


Figure 11. Event display of reconstructed di-photon.

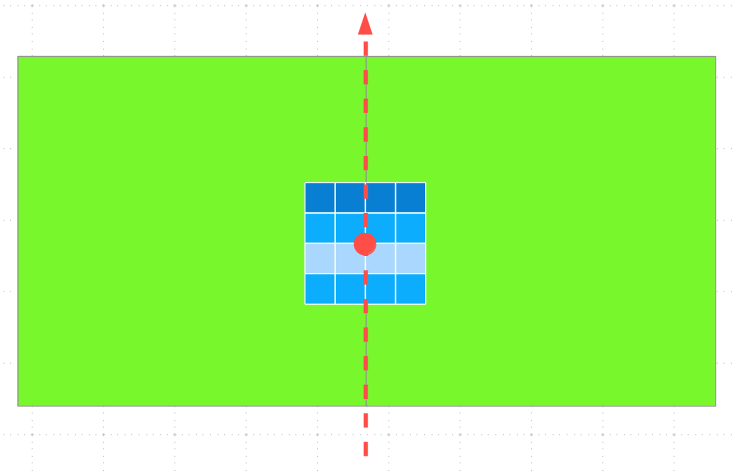
Critical distance: ~ 2*Cell Size



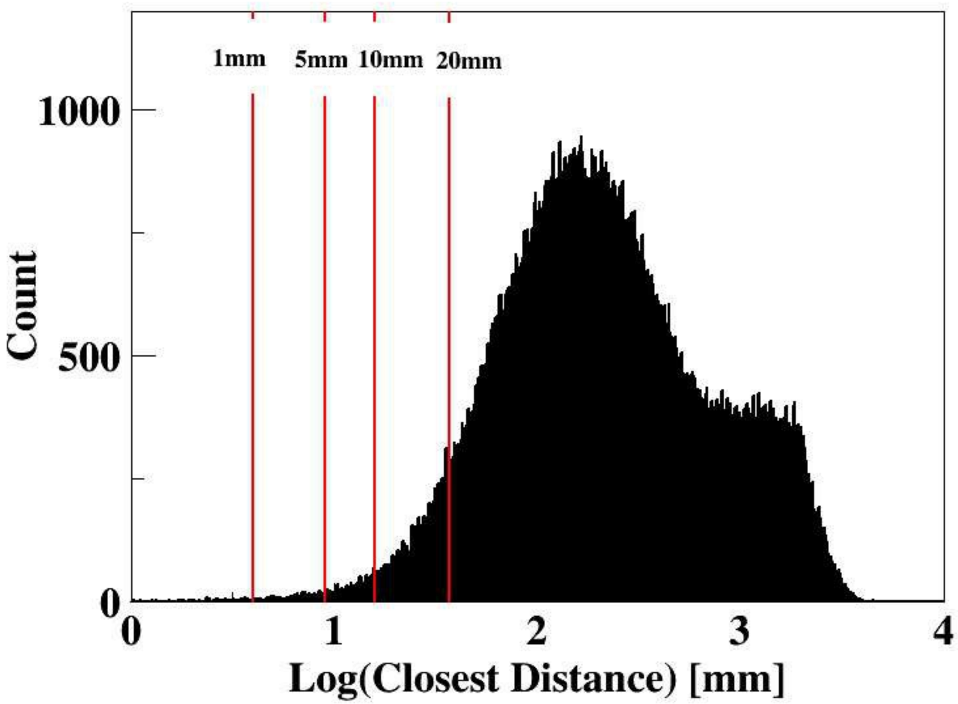


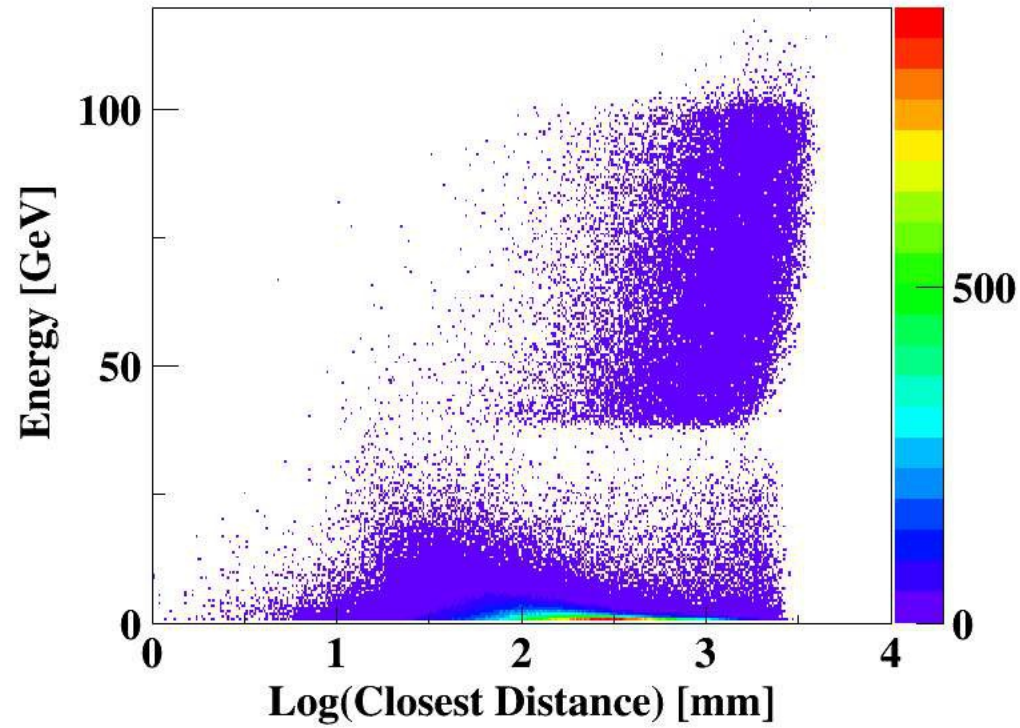
Simulation at 1 mm Cell & Digitized
To large cell size

Scan step = 1 mm



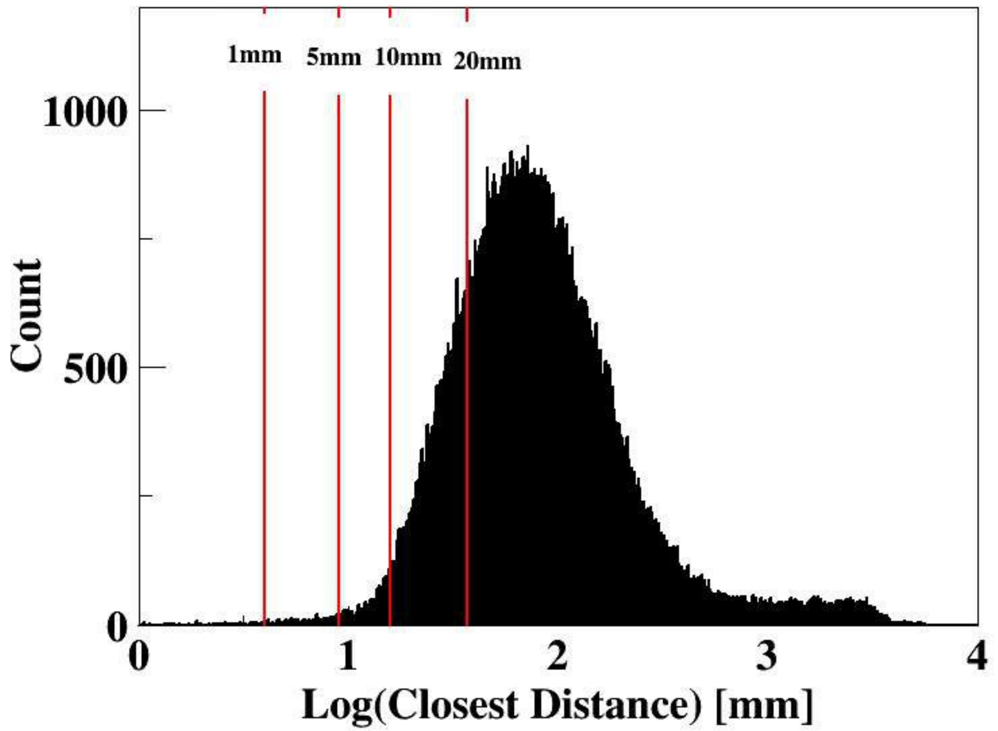
Impact of Separation: qqH, H->γγ @ 250 GeV

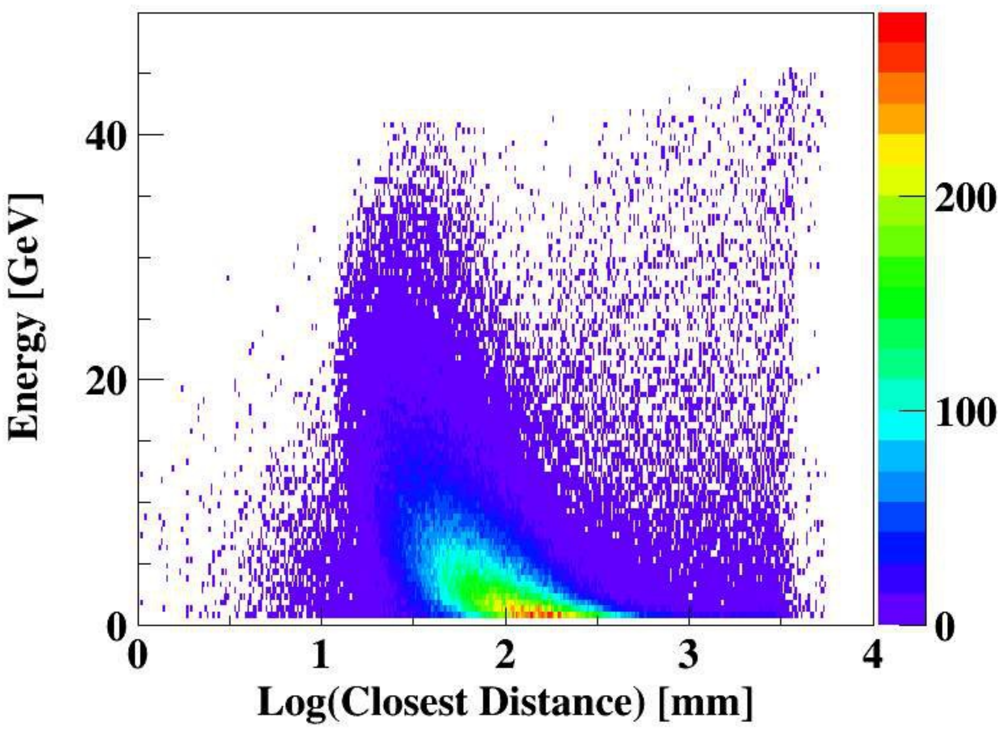




Cell Size/mm	1	5	10	20
Crucial Dis/mm	4	9	16	37
Percentage of potentially overlap photon: E > 30 GeV	0%	0%	0.1%	0.4%
E < 30GeV	0.1%	0.35%	1.1%	6.4%

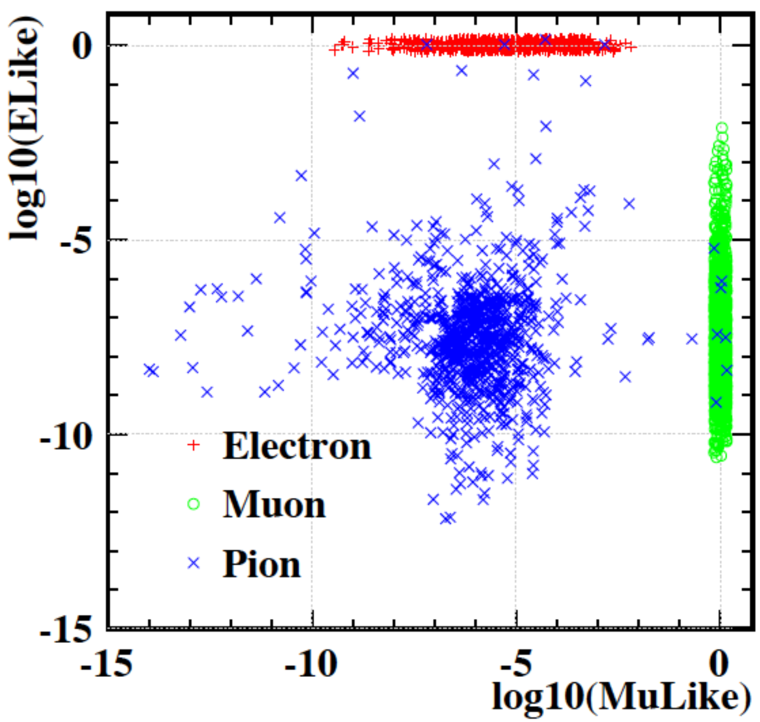
Impact of Separation: Z->tau tau @ Z pole

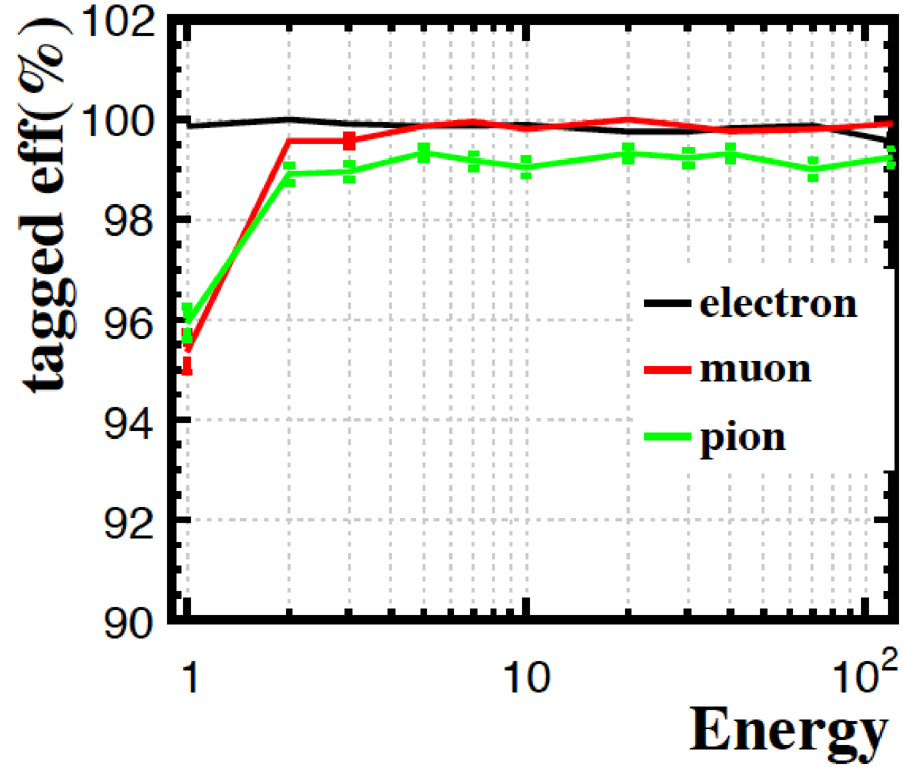




Cell Size/mm	1	5	10	20
Crucial Dis/mm	4	9	16	37
Percentage of potentially overlap photon	0.07%	0.4%	1.7%	18.6%

Dan: general Lepton ID for Calorimeter with High granularity (LICH)





BDT method using 4 classes of 24 input discrimination variables.

Test performance by requesting

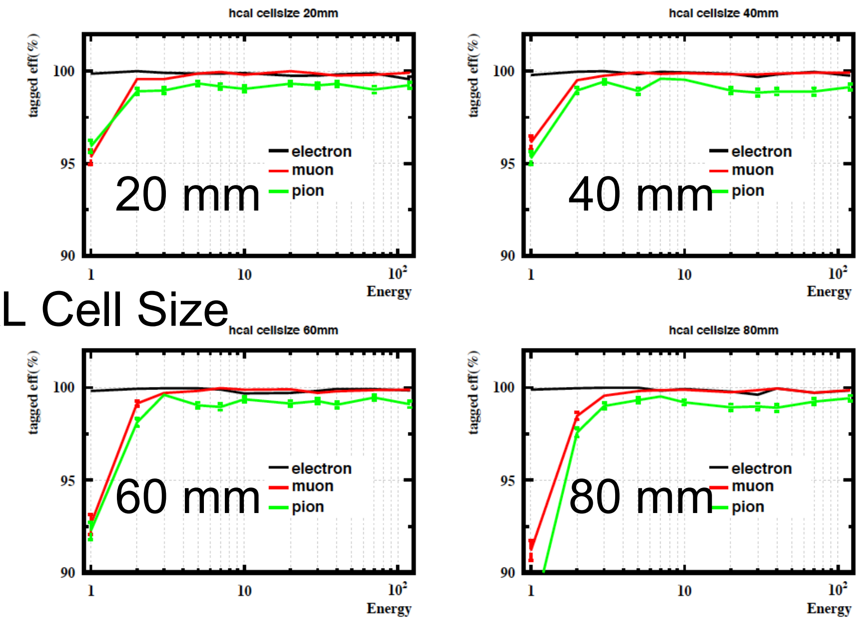
Electron = E_likeness > 0.5 ; Muon = Mu_likeness > 0.5

Single charged reconstructed particle, for E > 2 GeV: lepton efficiency > 99.5% && Pion mis id rate ~ 1%

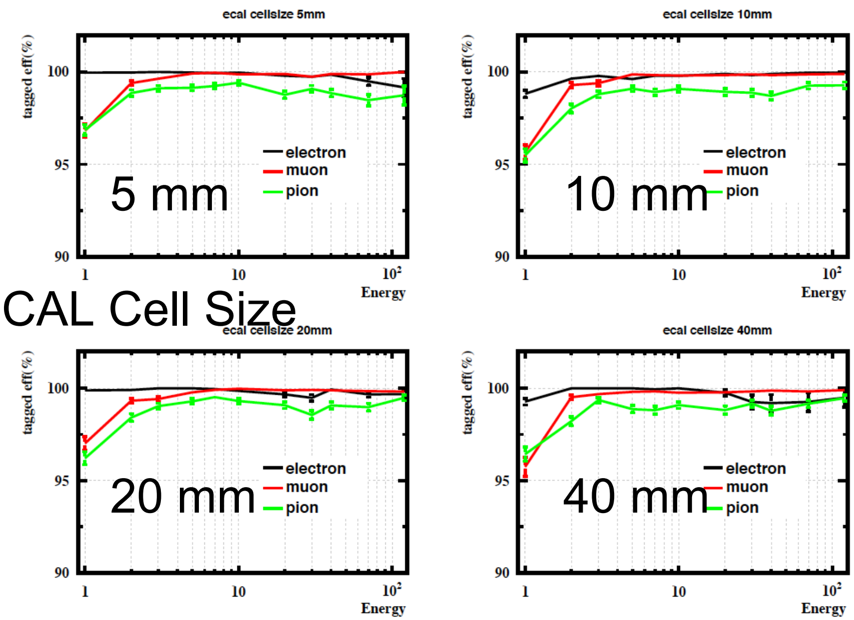
 https://arxiv.org/abs/1701.07542

Vary the granularity

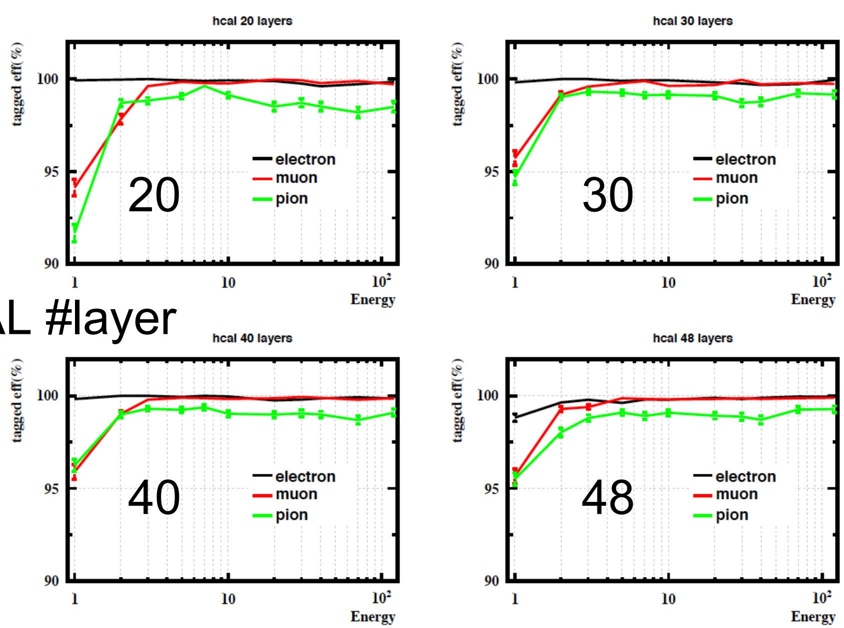
HCAL Cell Size



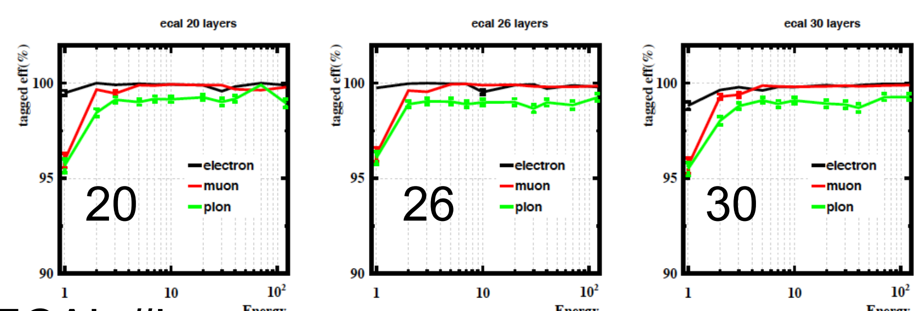
ECAL Cell Size



HCAL #layer

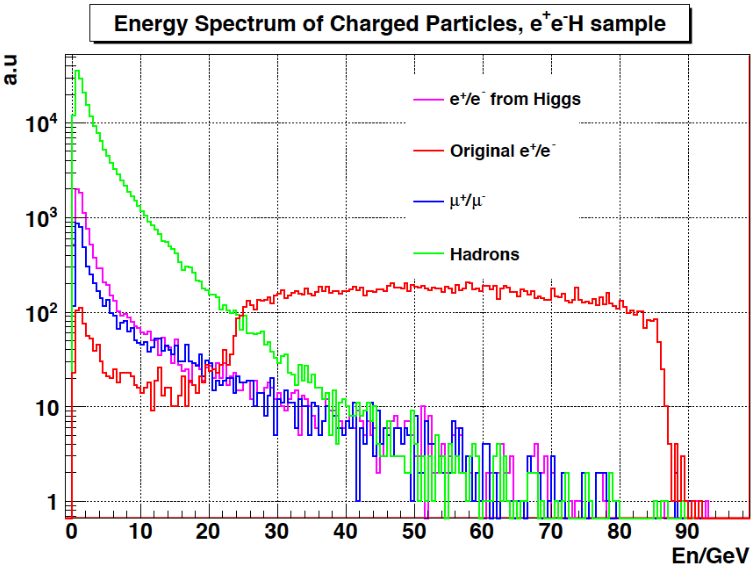


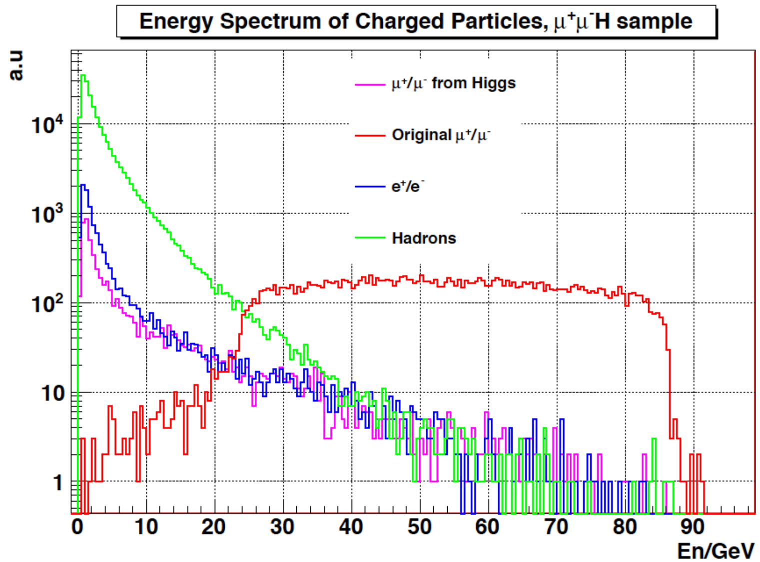
ECAL #layer

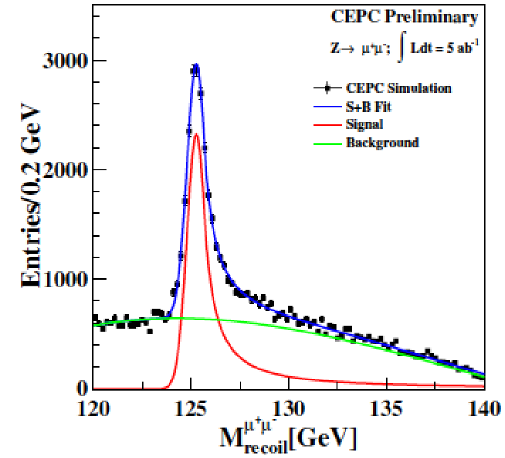


No Significant effect for E > 2 GeV charged Particles

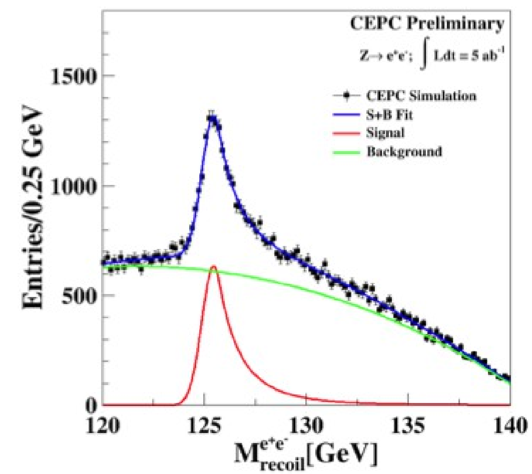
Lepton id @ Higgs recoil







	Geom 1		Geom 2	
	$\mu\mu$H	eeH	$\mu\mu$H	eeH
Cut$_\mu$	0.1	0.1	0.1	0.1
Cut$_e$	0.01	0.001	0.01	0.001
ε_E	93.41 ± 0.92	**98.64 ± 0.08**	91.60 ± 1.02	**97.89 ± 0.11**
η_E	92.02 ± 1.00	**99.74 ± 0.04**	89.89 ± 1.10	**99.67 ± 0.04**
ε_μ	**99.54 ± 0.05**	95.53 ± 0.76	**99.19 ± 0.06**	86.48 ± 1.26
η_μ	**99.60 ± 0.04**	96.31 ± 0.70	**99.83 ± 0.03**	95.38 ± 0.81
ε_{event}	98.53 ± 0.13	97.06 ± 0.19	97.24 ± 0.18	95.40 ± 0.24



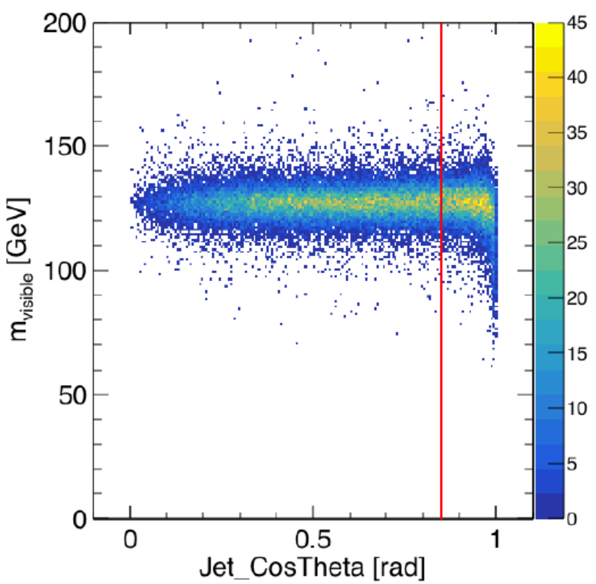
Geom 1/2: 10 (20) mm ECAL/HCAL Cell

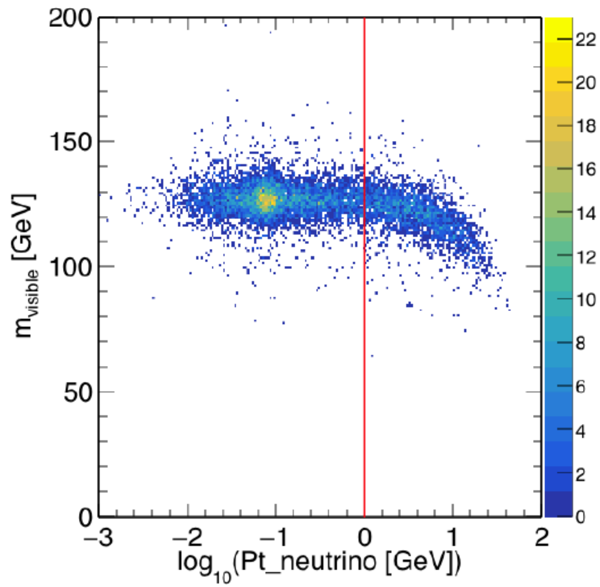
Initial Leptons identified at satisfactory efficiency & purity (limited by separation power)

More stringent requirement arrises from jet leptons...

https://arxiv.org/abs/1701.07542

H to gluons: total visible mass





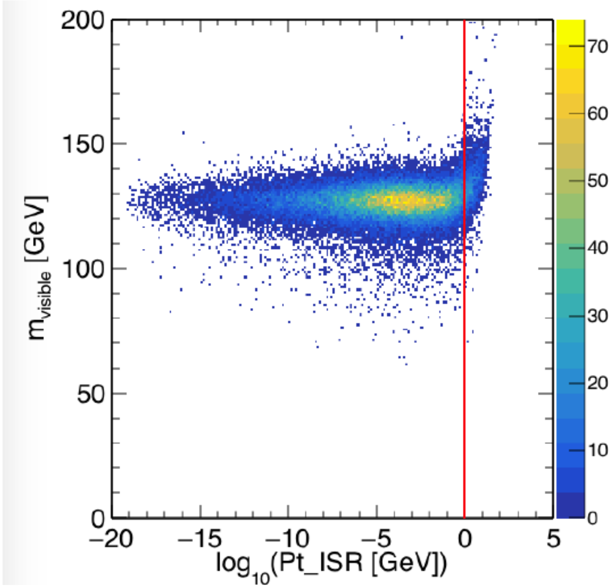
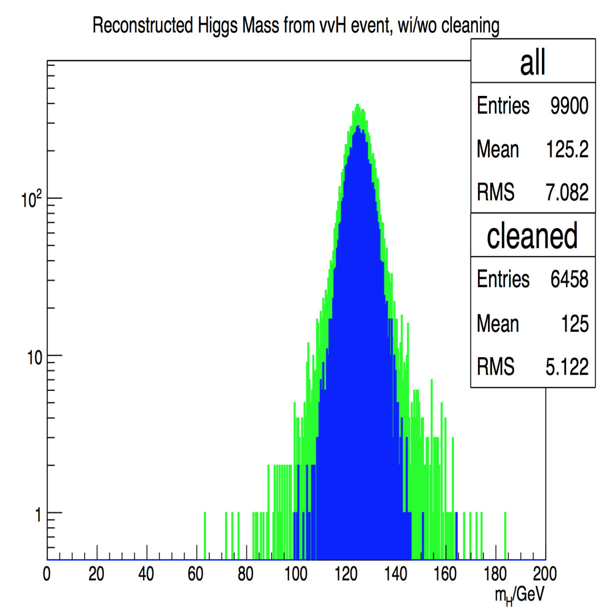
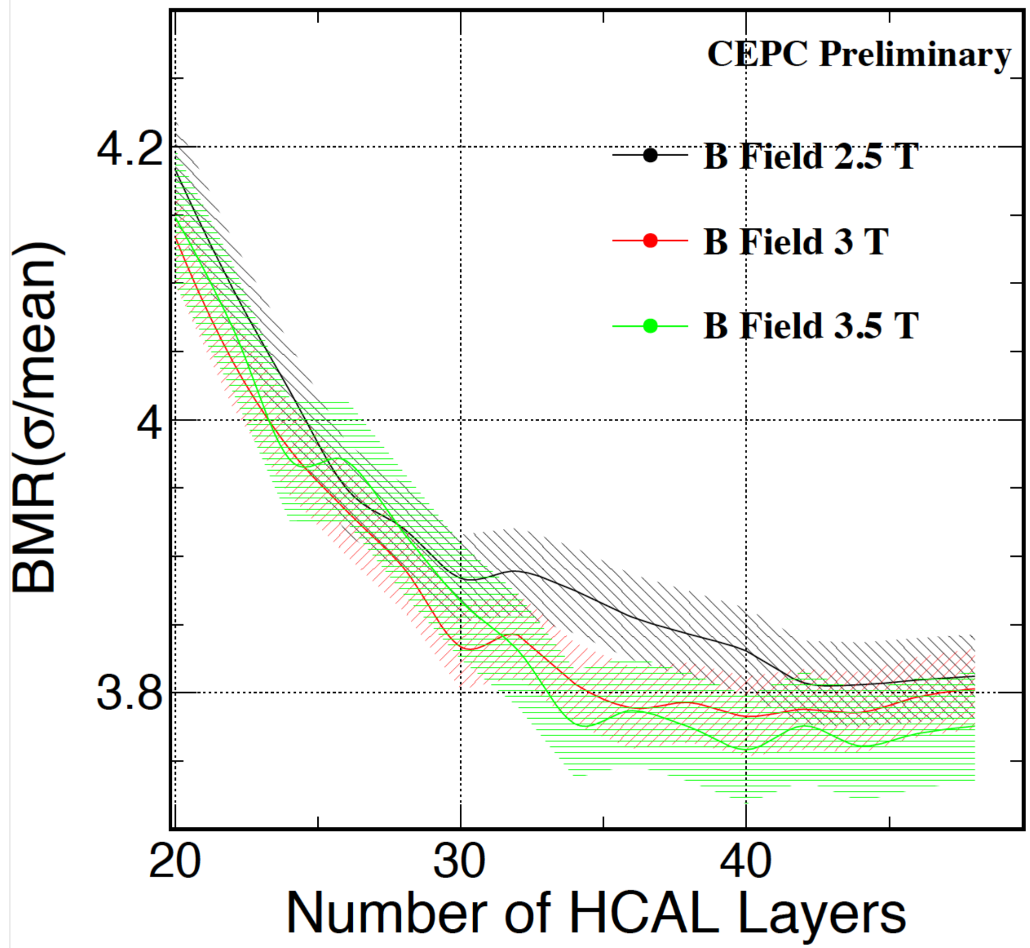


Table 1. Event selection efficiency for Higgs boson exclusive decay at CEPC with $\sqrt{s} = 240$ GeV.

	$\mu\mu$	$\gamma\gamma$	*di_gluon*	bb	cc	WW^*	ZZ^*
Total	45000	48000	48000	45000	46000	47000.	45000
$Pt\_ISR < 1GeV$	-	95.52%	95.14%	95.37%	95.27%	95.19%	95.22%
$Pt\_neutrino < 1GeV$	-	-	89.35%	39.00%	66.30%	37.41%	41.42%
$\lvert costheta \rvert < 0.85$	-	-	67.27%	28.58%	49.23%	37.03%	40.91%



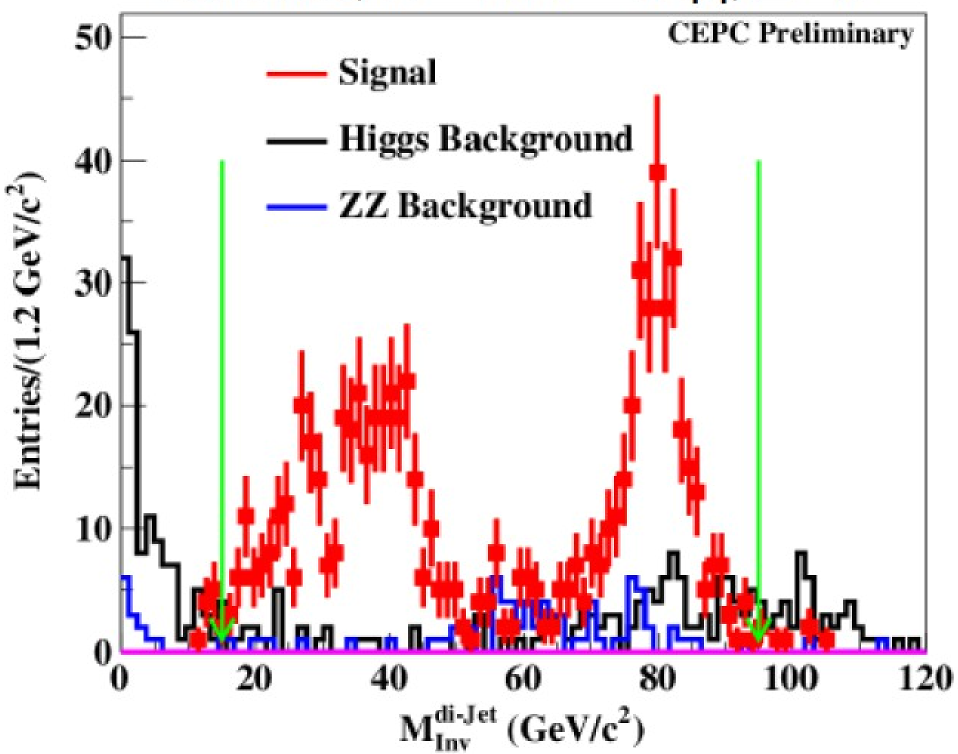
Boson Mass Resolution

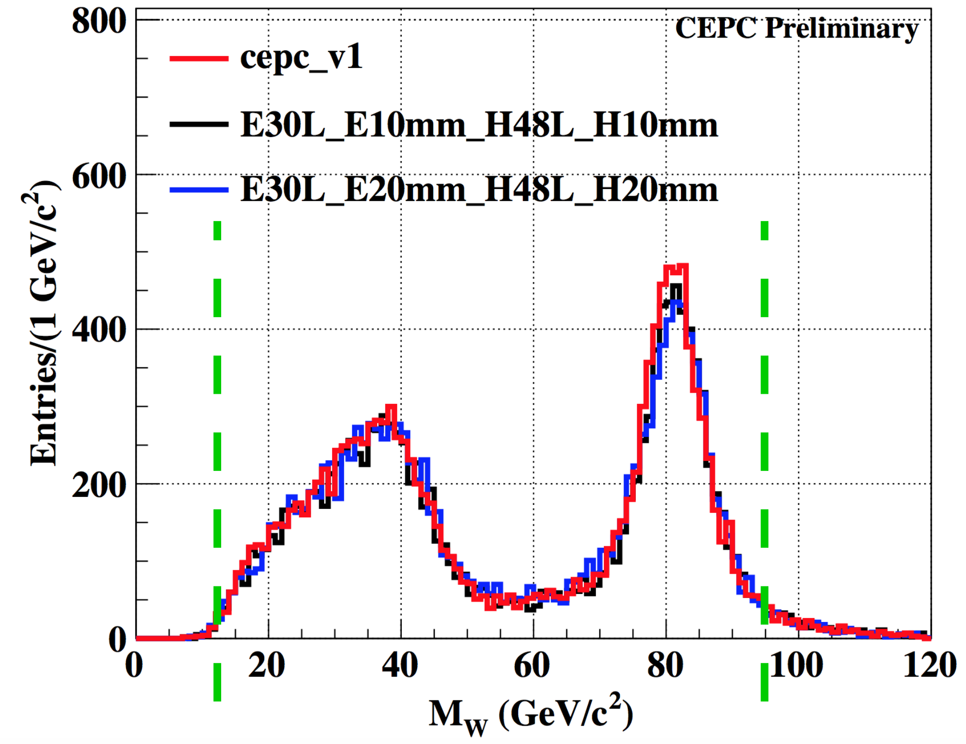


Number of HCAL Layers: 48->40;
No Significant effect on B-Field reduction from 3.5 -> # Tesla

Br(H→WW) @ 10mm/20mm Cell size

Liao libo, H→WW*→lvqq, Z→ll



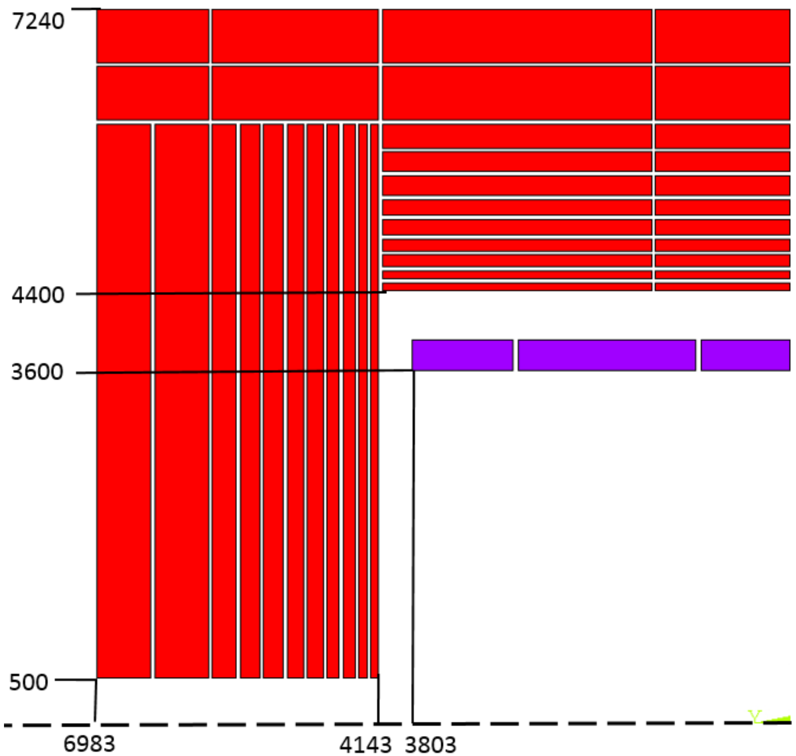


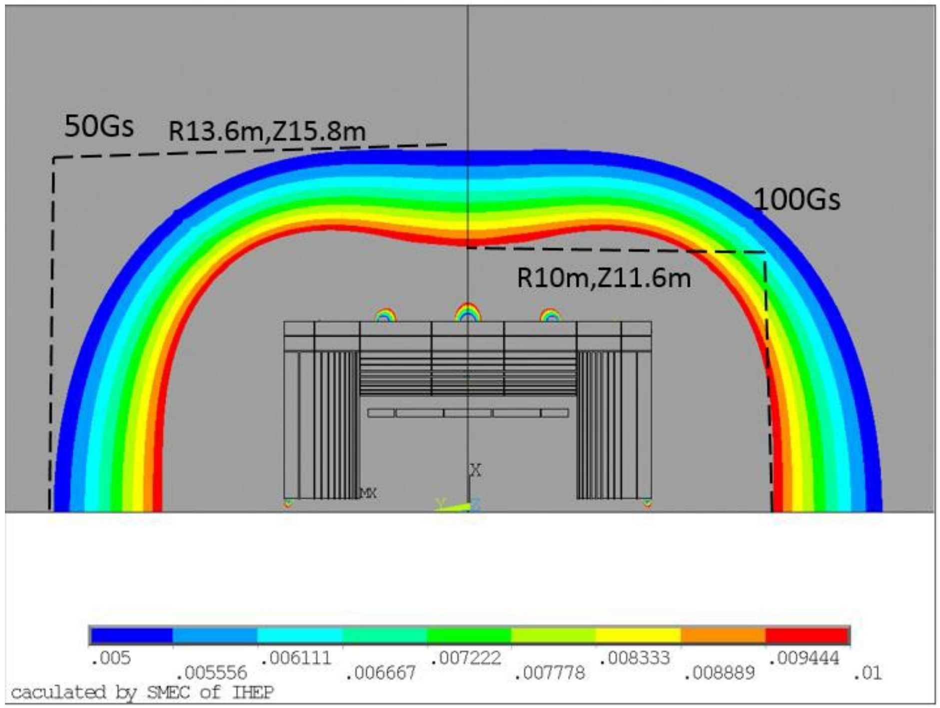
Br(H→WW) via vvH, H→WW*→lvqq

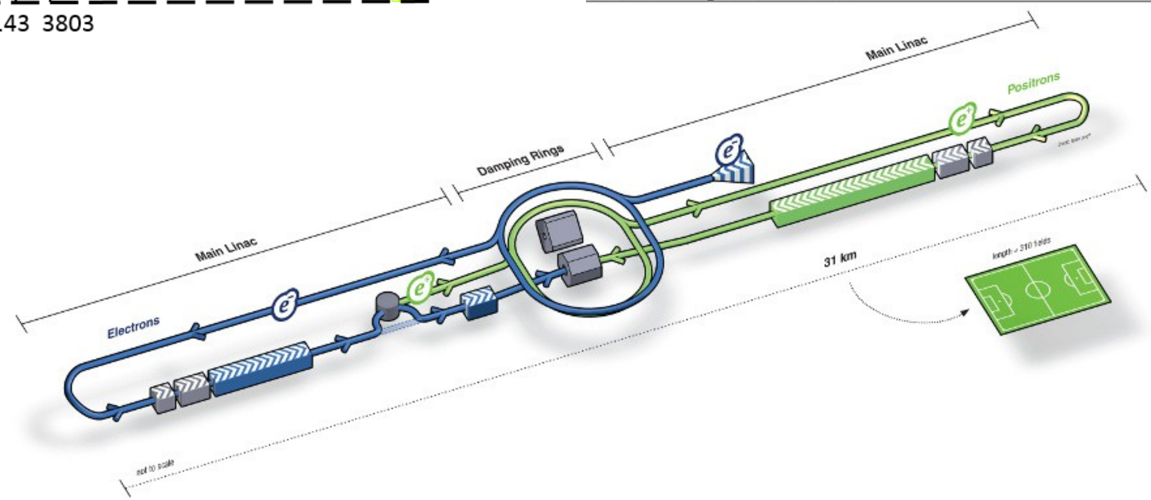
No lose in the object level efficiency: JER slightly degraded, ~ 5/10% at 10/20 mm

Over all: event reco. efficiency varies ~1%

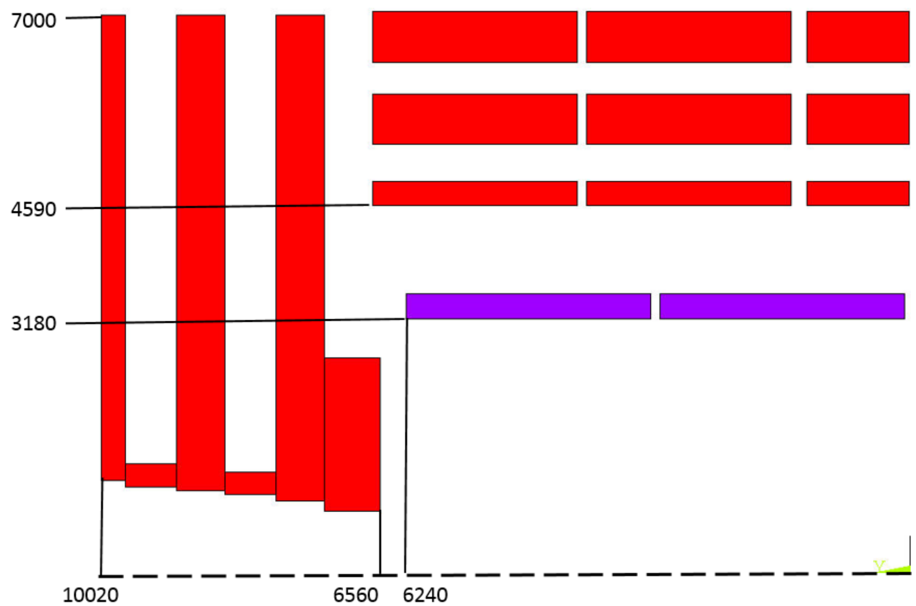
Yoke optimization

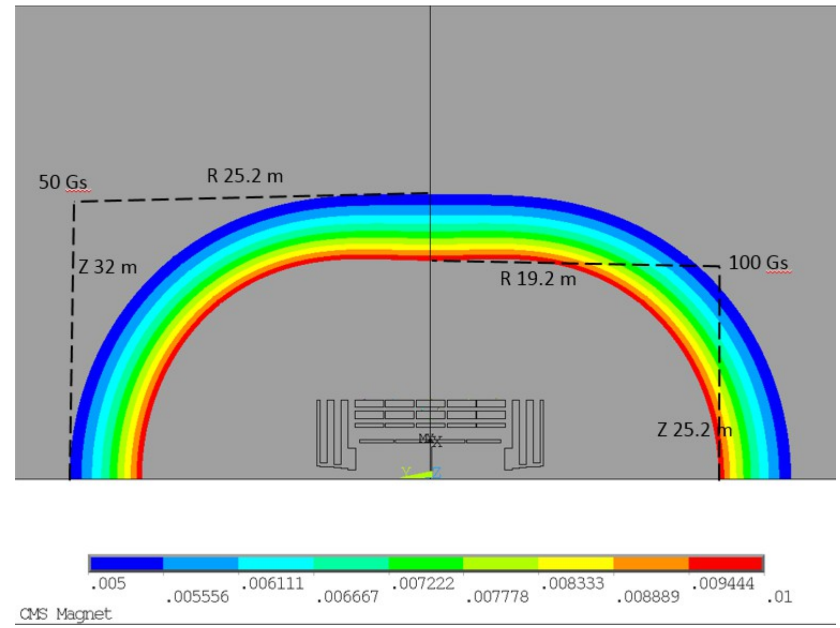


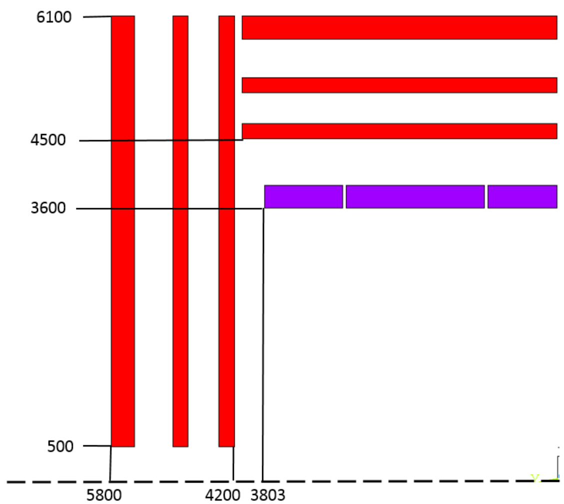


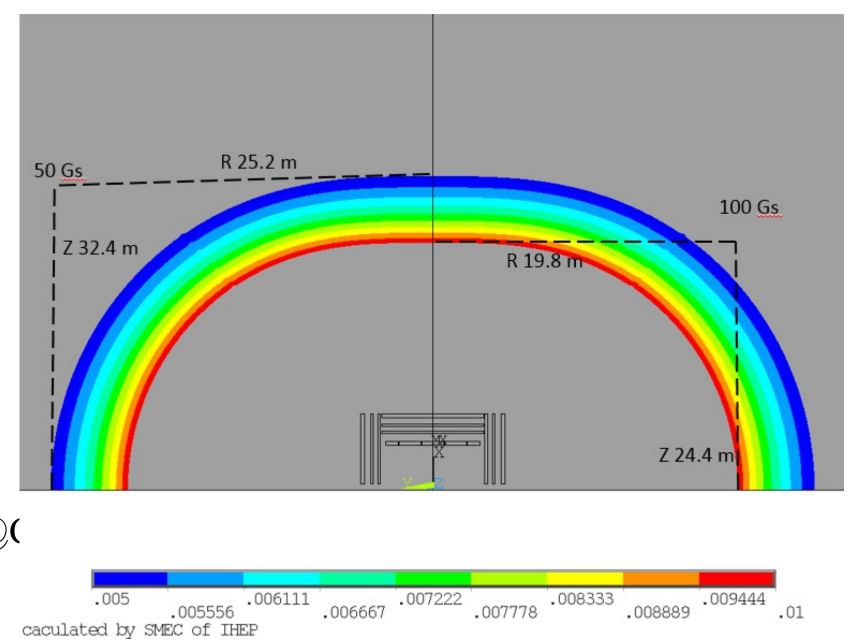


Yoke Optimization: reference - CMS

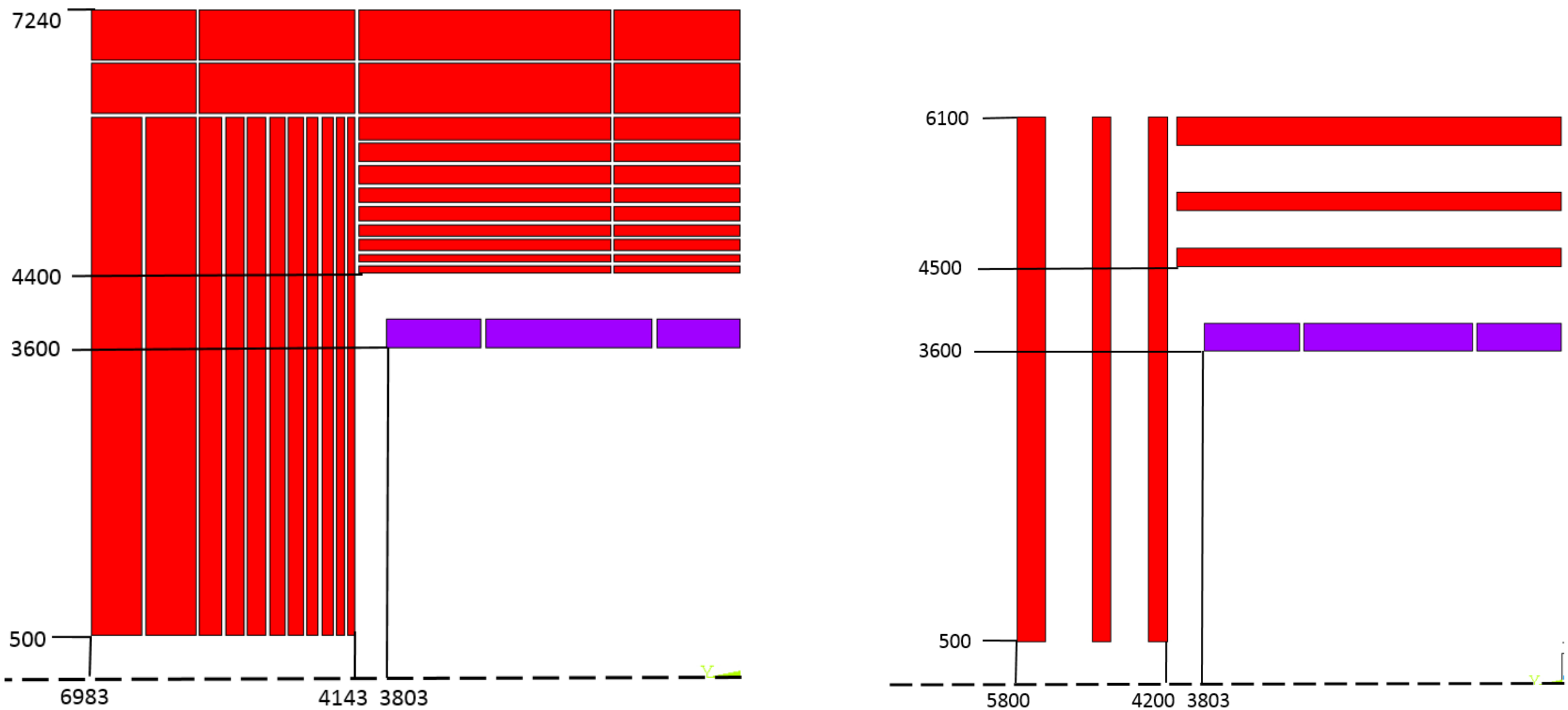








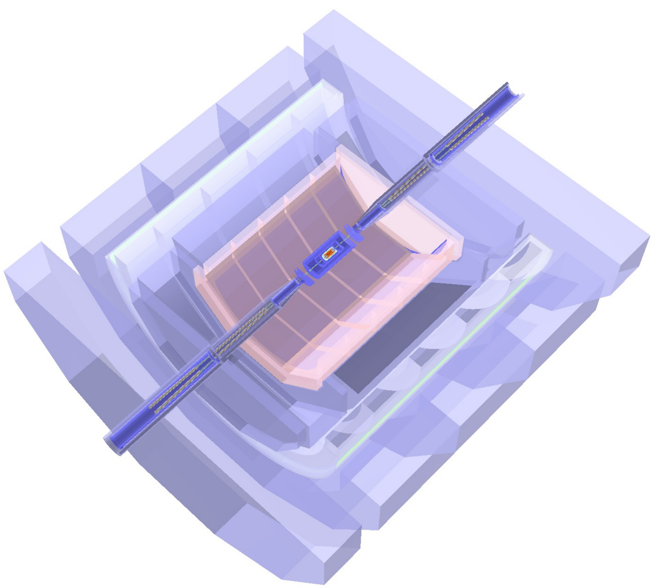
Yoke optimization (Preliminary)

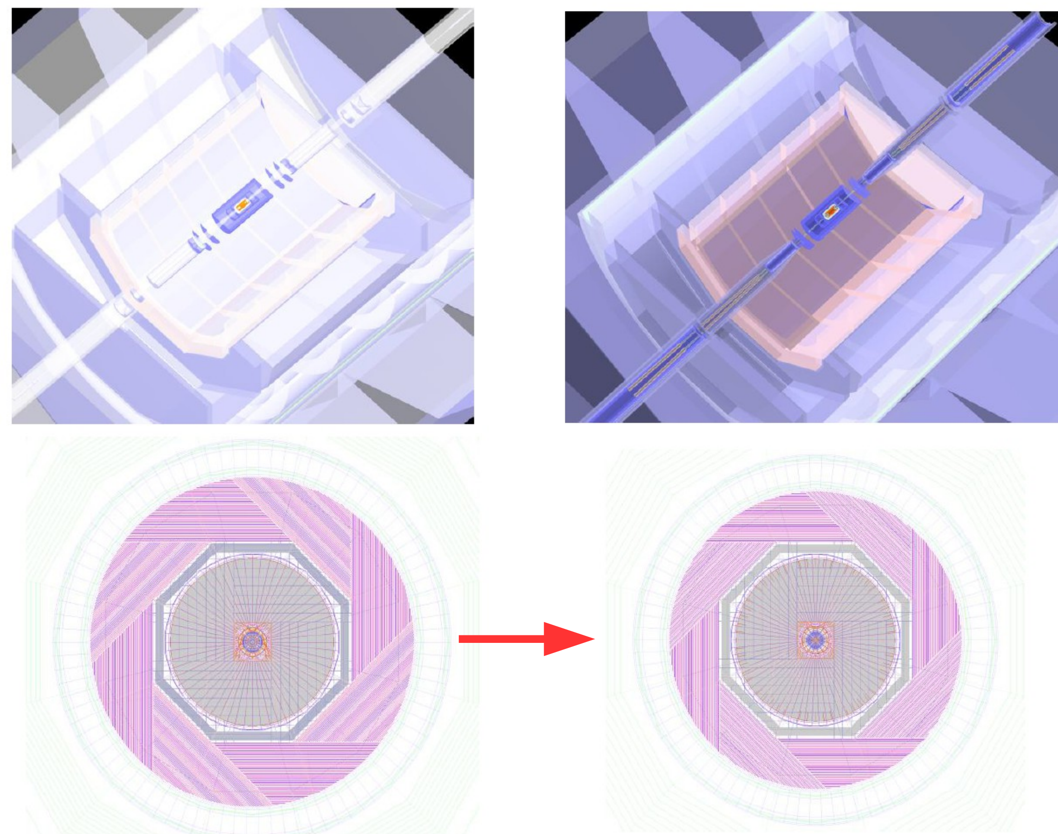


- The physics requirements on the large Xangle and low energy Z pole operation needs to be included, local shielding might be feasible
- Stay tuned

APODIS

- Operational at CEPC Collision environment & Geometry parameter Optimized
- Significantly reduced Cost/Energy Consumption
  - ECAL power: 75 - 80%
  - Yoke weight: 60 -70%
  - Construction cost: 30%





2015 PreCDR   2017 CDR

See Joao's talk for details...

Geometry: APODIS (A PFA Oriented Detector for HIggS factory)

Feasibility analysis: TPC is OK for CEPC (2017 JINST 12 P07005)

	CEPC_v1 (~ ILD)	APODIS (Optimized)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	Optimized on Br(H->di photon) at 250 GeV
ECAL Cell Size	5 mm	10 mm	Passive cooling request ~ 20 mm. 10 mm is required for EW measurements
ECAL NLayer	30	30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs mass resolution with jet final states

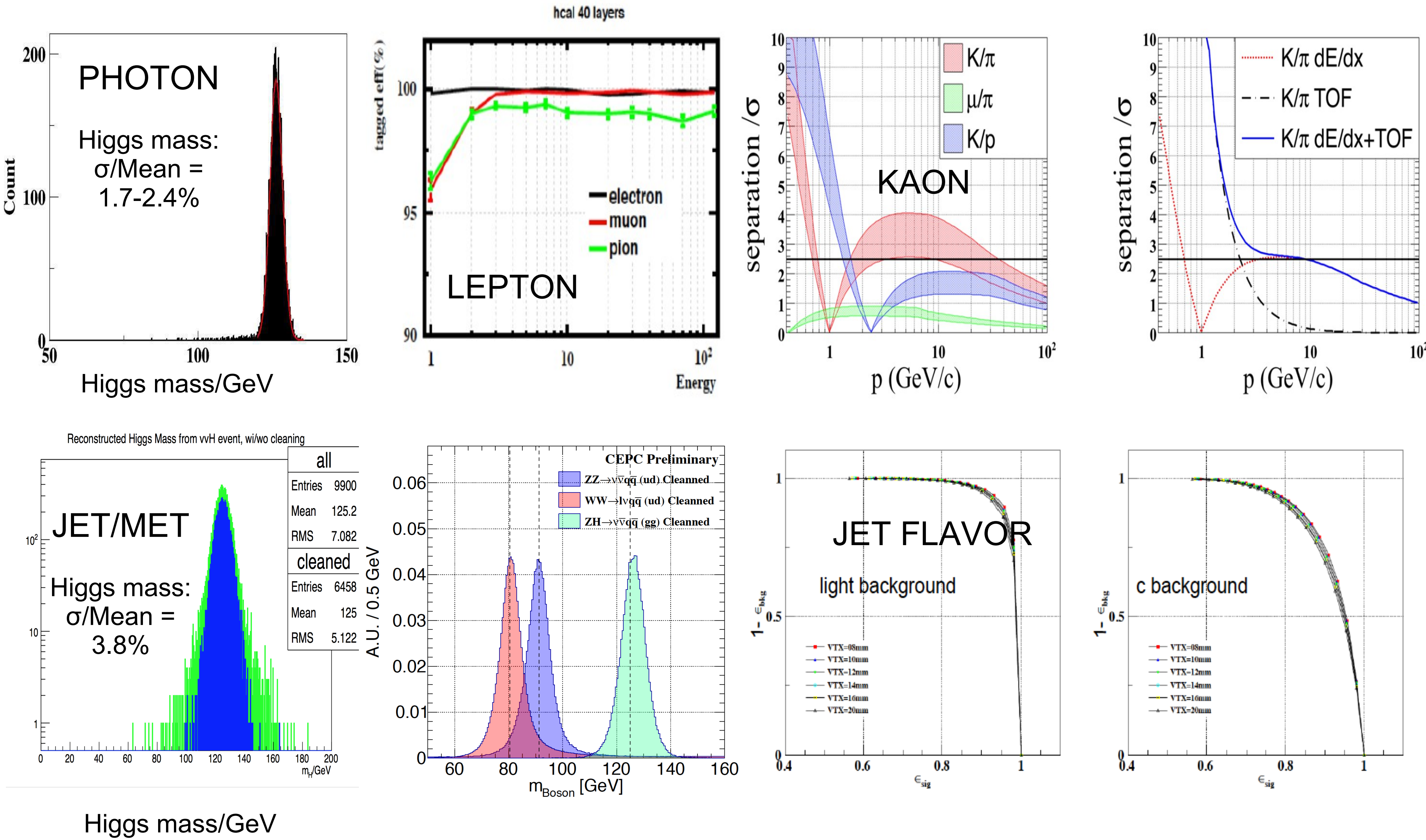
Typical Performance

- Tracking:
  - eff ~100% for tracks with Pt > 200 MeV in the fiducial region
  - Relative Resolution ~ 0.1%
- ECAL
  - Eff ~100% for photons with Energy > 200 MeV
  - Resolution ~ 16%/sqrt(E)
- Jet
  - Boson Mass Resolution ~ 4%, Jet Energy Scale ~ 1%, Jet Energy Resolution 3 – 6%
- VTX
  - Impact parameter ~ 5 μm

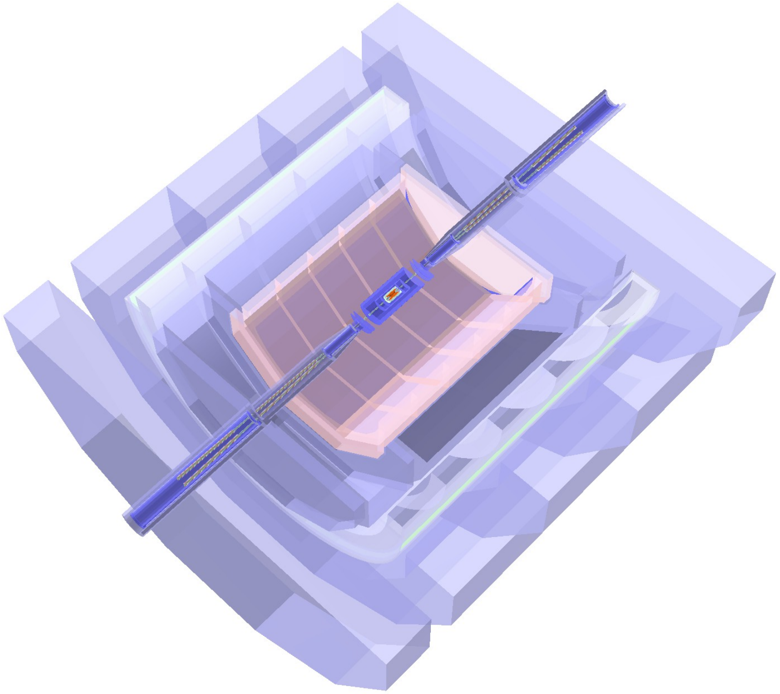
	Efficiency	**Purity**	**Mis-id Probability from Main Background**
Leptons	99.5 – 99.9%	99.5 – 99.9% at Higgs Runs(c.m.s = 240 GeV), Energy dependent	$P(\pi^{\pm} \rightarrow leptons) < 1\%$
Photons*	99.3 – 99.9%	99.5 – 99.9% at Higgs Runs Energy Dependent	$P(\text{Neutron} \rightarrow \gamma) = 1\text{-}5\%$
Charged Kaons**	86 – 99%	90 – 99% at Z pole Runs (c.m.s = 91.2GeV, Track Momentum 2- 20 GeV)	$P(\pi^{\pm} \rightarrow K^{\pm}) = 0.3 - 1.1\%$
b-jets	80%	90% at Z pole runs ($Z \rightarrow qq$)	$P(uds \rightarrow b) = 1\%$ $P(c \rightarrow b) = 10\%$
c-jets	60%	60% at Z pole runs	$P(uds \rightarrow c) = 5\%$ $P(b \rightarrow c) = 15\%$

Fulfills the physics requirement

PFA Oriented Reconstruction



Hardware Studies



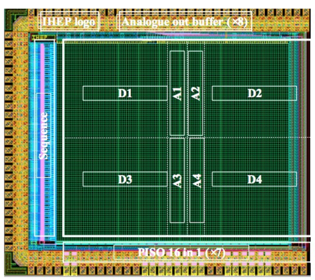
Task forces organized corresponding to the Baseline Design

International Collaborations: with LCTPC, CALICE, LLR, IPNL...

Vertex

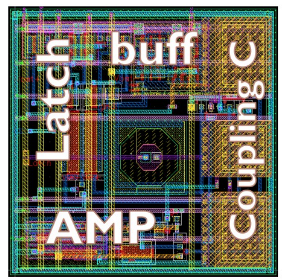
JadePix2 in CMOS technology

JadePix2: joint 0.18 µm CMOS process MPW submission with IPHC in May. 2017

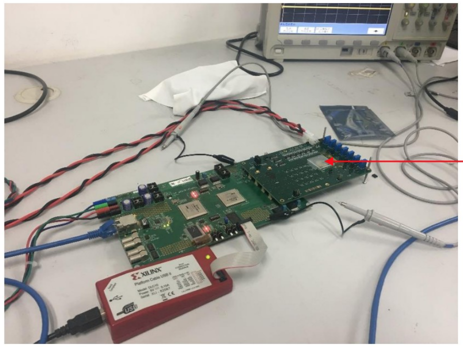


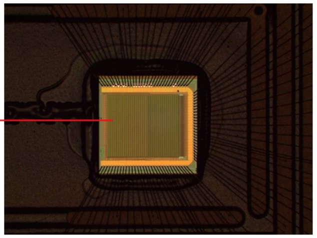
Layout of JadePix2

Pitch size: 22 µm

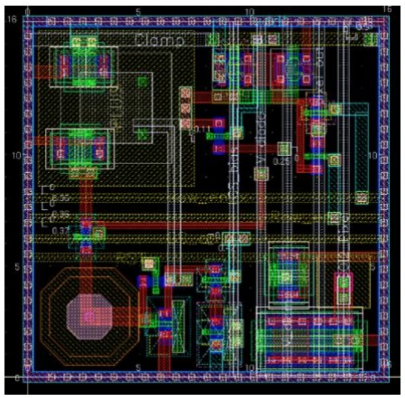


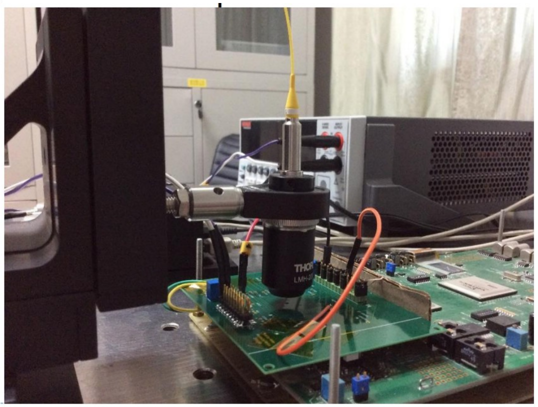
Layout of a single pixel in JadePix2





Compact Pixel sensor for Vertex (SoI)



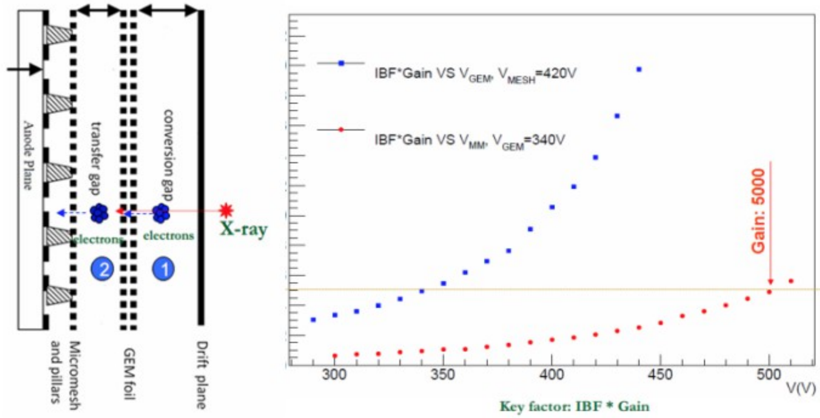


CPV2 digital pixel layout

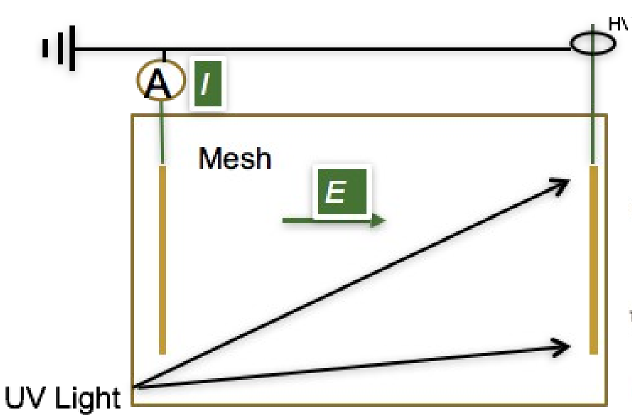
	ASTRAL	ALPIDE	JadePix2	CPV2
Process technology	0.18 µm CMOS			0.2 µm SOI
Readout strategy	Rolling shutter	asynchronous	Rolling shutter	
Readout time	20 µs	<2 µs	100ns/row or 80ns/row	50ns/row
Power	85 mW/cm²	39 mW/cm²		
Pixel size	22 × 33 µm²	27 ×29 µm²	22 ×22 µm²	16 ×16 µm²
Spatial resolution	≈ 5µm		Not tested yet	Possibly < 3µm
Total signal for MIP	≈1600 e⁻ (≈20µm epi-layer)			≈4000 e⁻ (back thinning to 50µm, fully depleted)

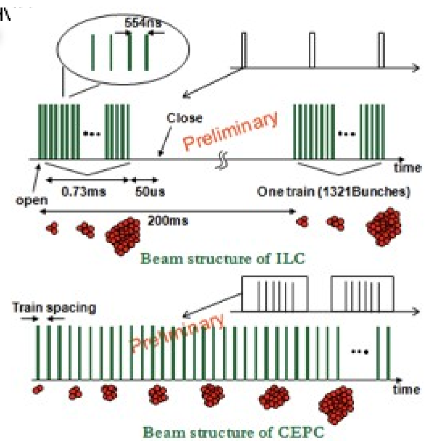
TPC

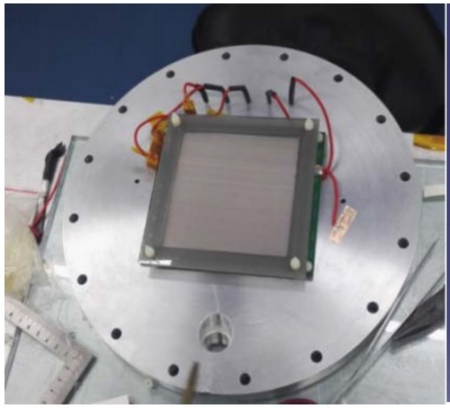
- Collaborating with LCTPC
  - Optimization of the TPC gas/HV parameters
  - Designing & IBF Control of the amplification structure
  - Laser Alignments System
  - Readout studies

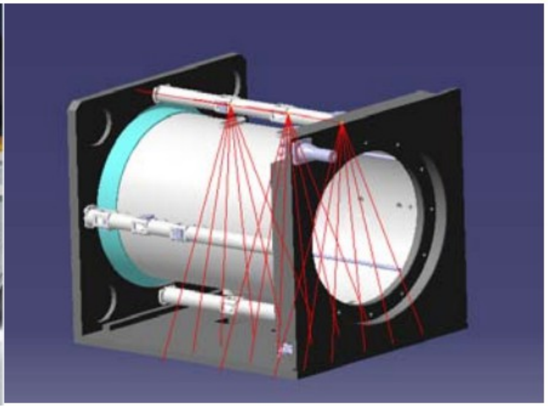


Continuous IBF prototype and IBF × Gain





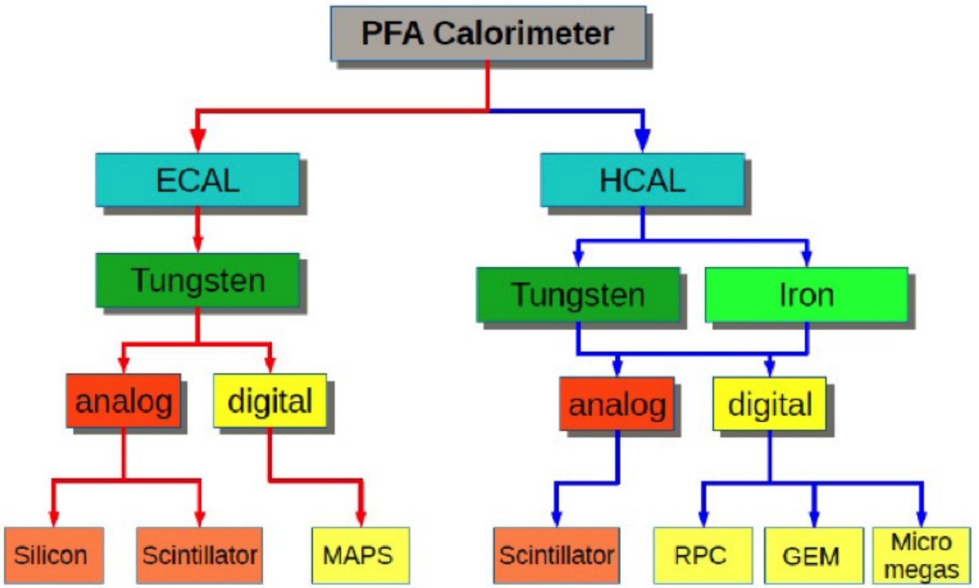


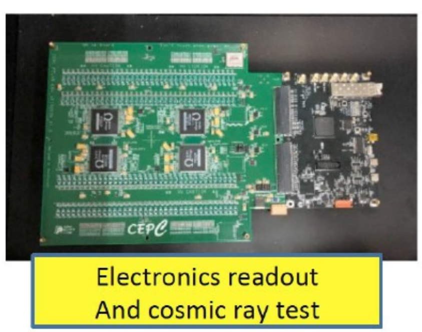


To Mimic the bunch structure & the Ion Distortion by Laser beam

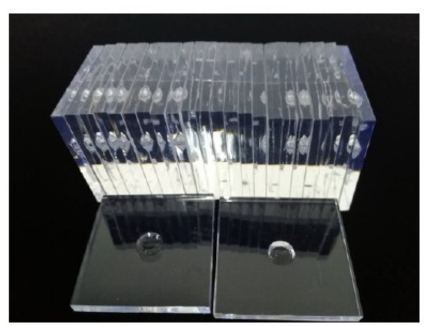
Calorimeter

- PFA Oriented
  - Si-ECAL: Cooperating with CALICE - LLR
  - Sc-ECAL: Local tests
  - MPGD-HCAL
  - RPC-HCAL: Cooperating with CALICE - IPNL
  - CO_2 Cooling Study
- Making Synergy with CMS Upgrade

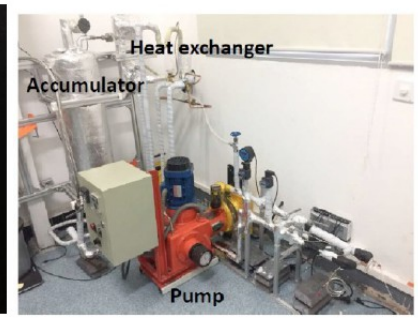


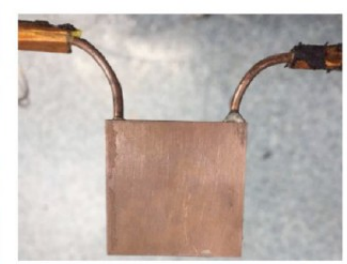


Sc-ECAL 读出单元及单层样机



Sc-HCAL 国产闪烁单元 NDL-SiPM 测试

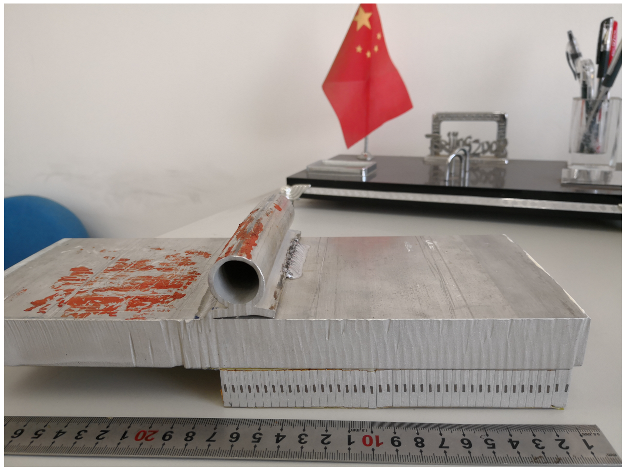


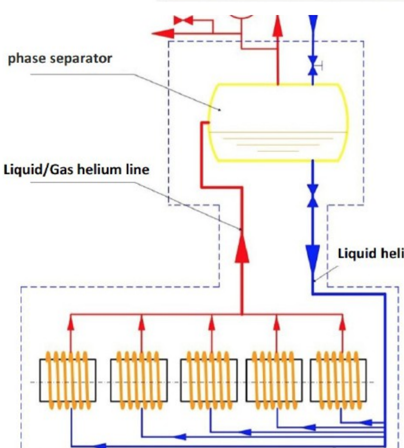


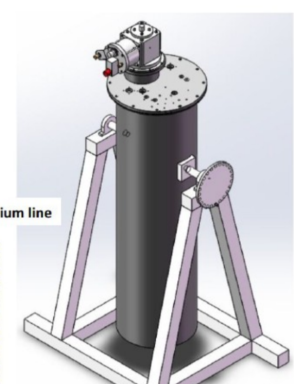
Small prototype , 3cm*3cm*3mm

冷却系统测试

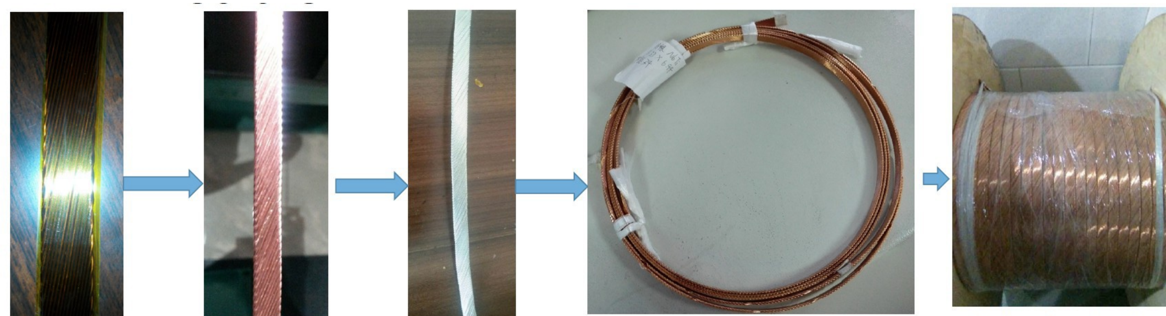
Magnet







Siphon Cooling System Study



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

Number of strands : 32
Strand diameter : 1.2mm
Materiel: Nb/Ti
Tangle: 17.32
Length: 》100m
RRR: 》100
Complete time: 2016.5

- **Completed two rounds of insert process:**
  Hollow aluminum alloy, Aluminum alloy + copper cable
- **Result: Depression in the middle and the tooling needs to be improved(2016.4)**
  The strands of the cable are separate after the tooling improvement.
- **There is a great improvement from the latest result, but the shear strength 8MPa not enough to reach 20MPa.**

2016.1
Hollow aluminum alloy

2016.2
Aluminum alloy + copper cable

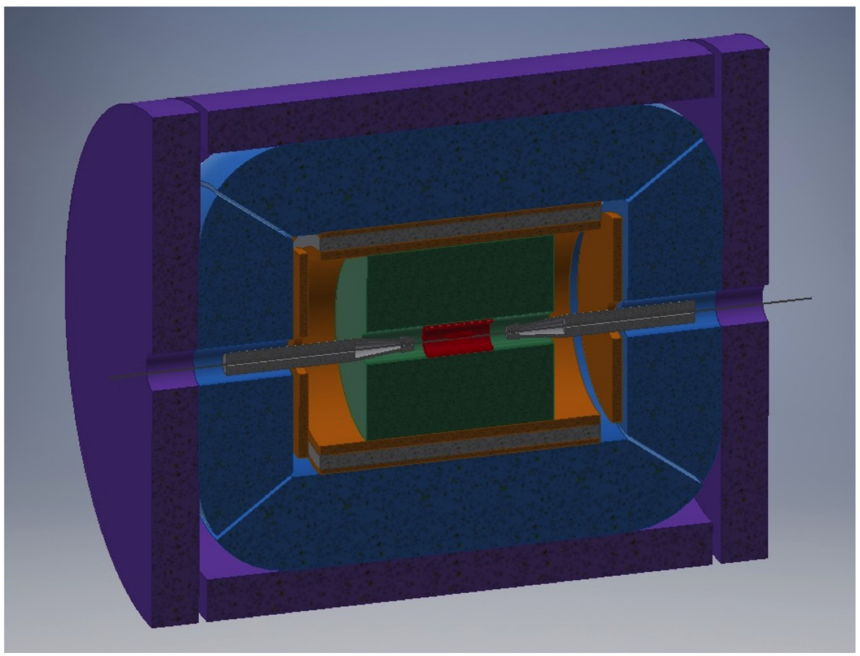
2016.5~6:
Aluminum alloy + copper cable

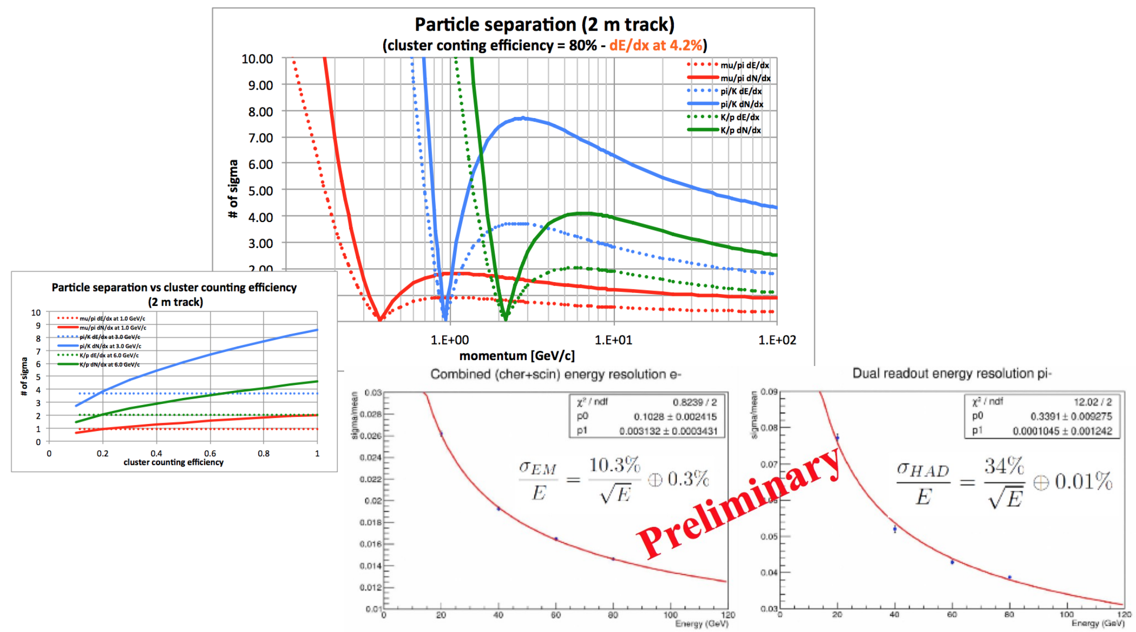
2016.8:
Aluminum alloy + copper cable

The alternative concept (IDEA)

Low Magnet Field Detector Concept (IDEA)

- Wire Chamber + Dual Readout Calorimeter

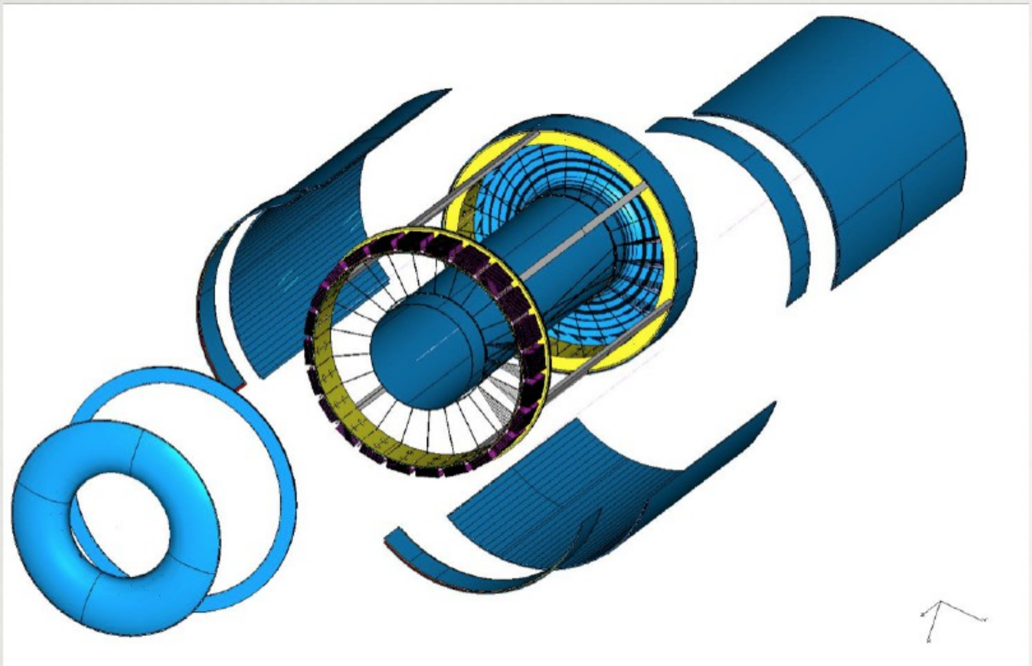




https://indico.ihep.ac.cn/event/6618/

https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=14816

its BIG BROTHER is being proposed as the main tracker of IDEA:

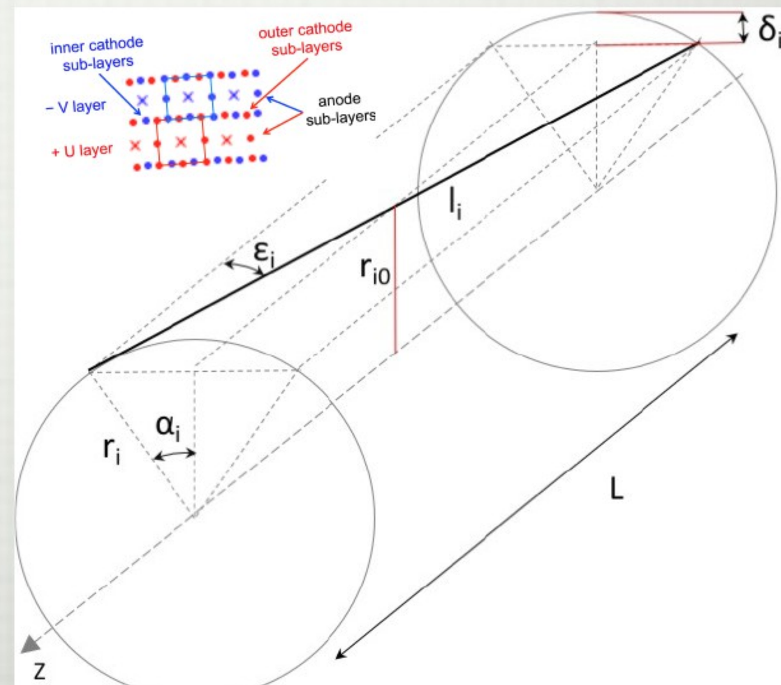


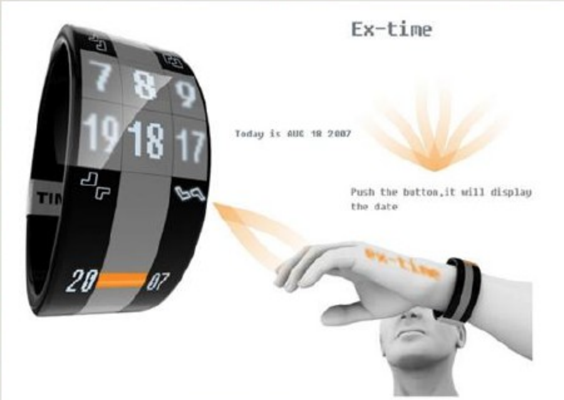
The IDEA drift chamber by numbers:

- L = 400 cm
- R_{in} = 35 cm
- R_{out} = 200 cm
- 112 layers for each 15° azimuthal sector
- 56 448 squared drift cells of about 12-13.5 mm edge
- max drift time: 350 ns in 90%He-10%iC_4H_{10}

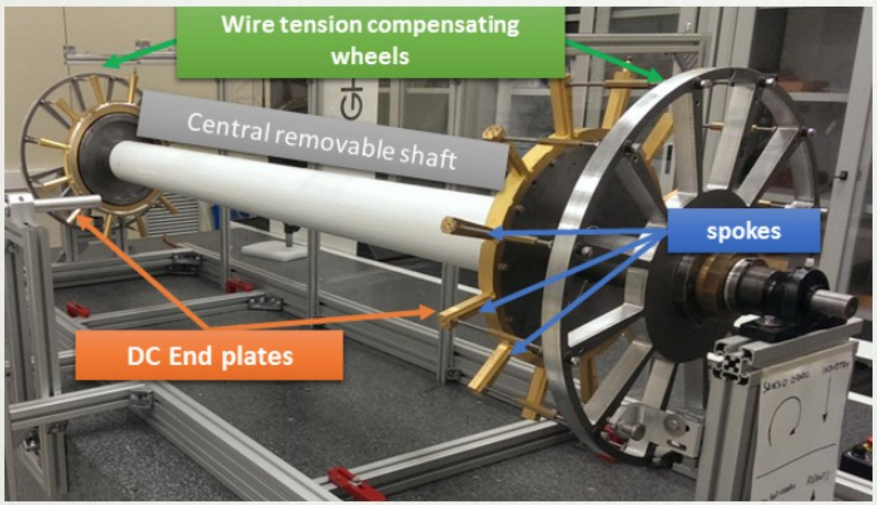
The "wire cage" and the "gas envelope" are decoupled

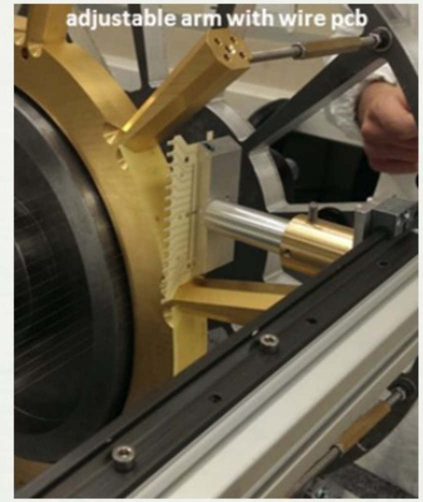
- The stereo angle α is generated stringing the wire between spokes @ 2 sectors (30°) distance
- $\alpha \in$ [20 mrad (1.1°); 180 mrad (10.3°)], increasing with R
- the electrostatic stability is achieved when the wire tension is about 25g, for a total load of about 7,7 tons!

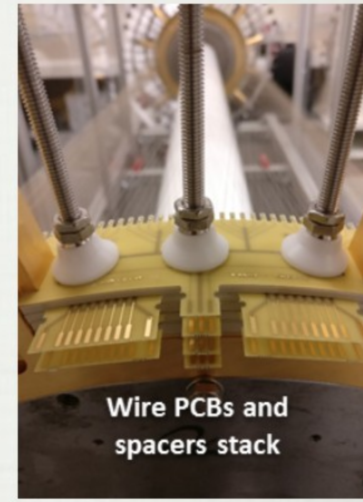




Time Projection is not the only way and DRIFT chambers have been shown* to be an interesting alternative:

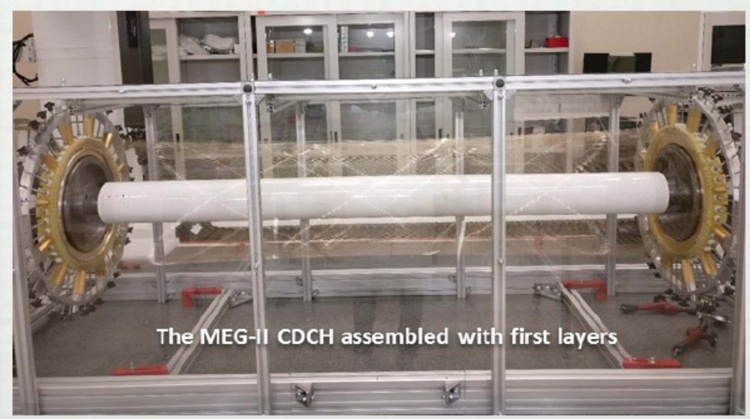






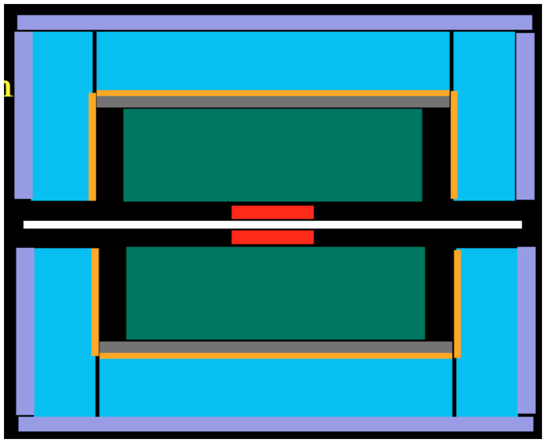
Dimensions of the MEG II chamber:

- L = 193 cm
- R_{in} = 17 cm
- R_{out} = 30 cm
- 10 layers for each 30° azimuthal sector

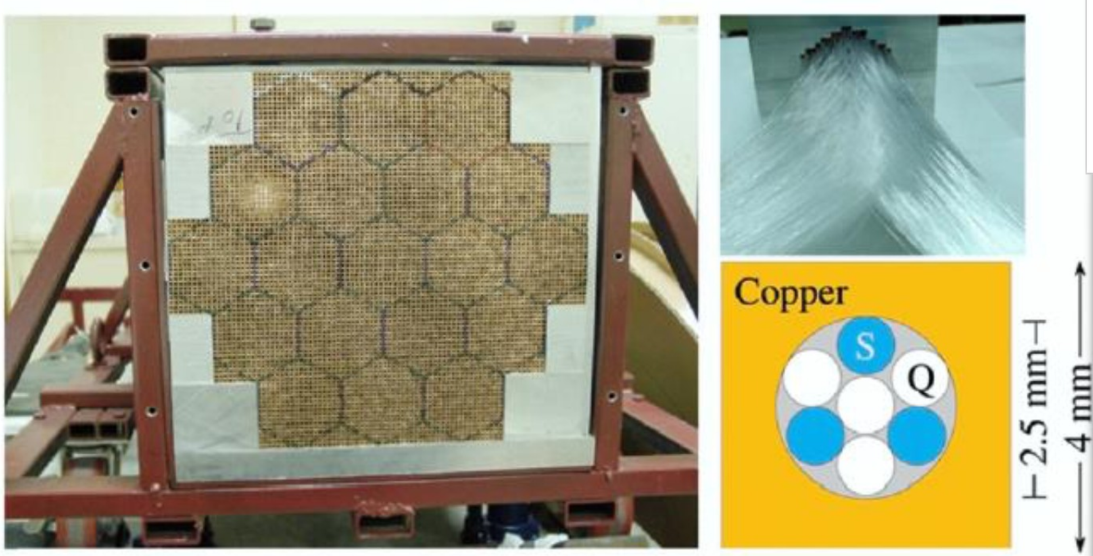


* - M. Adinolfi et al., The tracking detector of the KLOE Eexperiment. NIM. A 488 (2002) 51
- A. M. Baldini et al., Single-hit resolution measurement with MEG II drift chamber prototypes. 2016 JINST 11 P07011
- G. Chiarello, The full stereo drift chamber for the MEG II experiment, 2017 JINST 12 C03062

The “IDEA” detector concept



DREAM: Structure

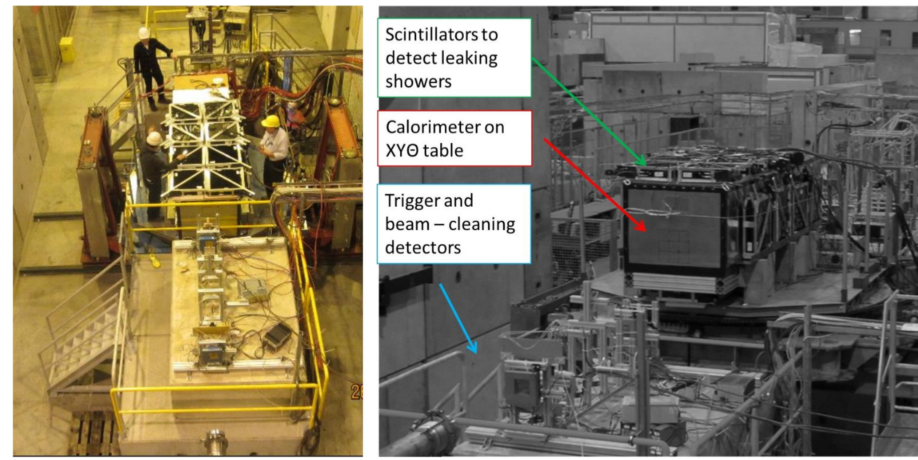


Test beam @ SPS - CERN

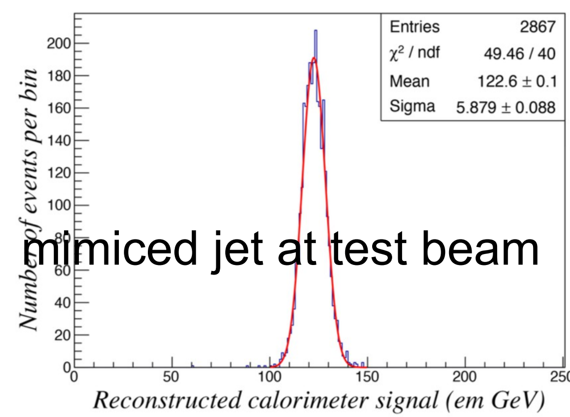
RD52 DREAM

15

S. Franchino - Dual Readout Calorimetry - H.E.P.@ IAS. Hong Kong 2016



Used particles (both polarities): 4 – 180 GeV electrons, pion/protons, muons



mimiced jet at test beam

Fig. 18. Signal distribution for 125 GeV multiparticle events obtained with the rotation method described in the text. The energy scale is set by electrons showering in this detector.

IDEA Simulation & Validation

CEPC NOTE

CEPC_TLS_SIM_2018_001

March 27, 2018

Istituto Nazionale di Fisica Nucleare

Nankai University

Detector Geometry in Model CEPC_IDEA

Yin Xu

Abstract

Geant4 Based full simulation is indispensable for the CEPC physics analyses and detector optimization studies. So we integrated IDEA detector geometry into the simulation framework – Mokka [1]. This note introduces the IDEA model and how to develop with Mokka, some simple examples are also given.

Figure 4: SVX

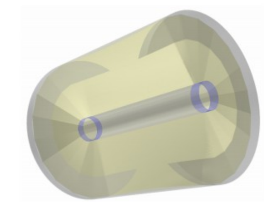
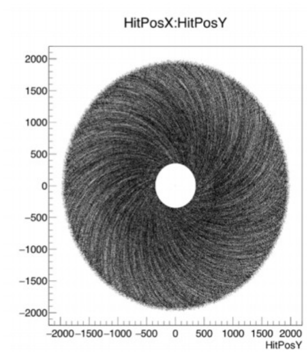
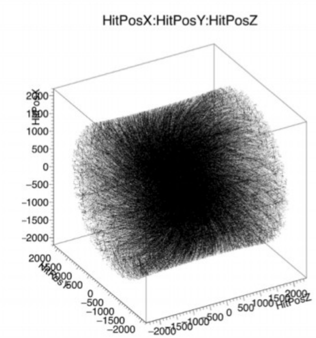
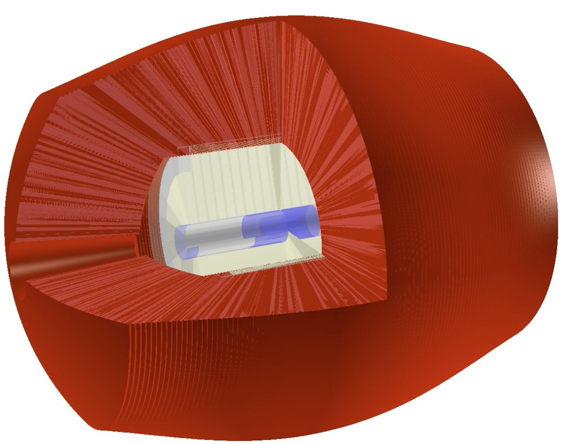
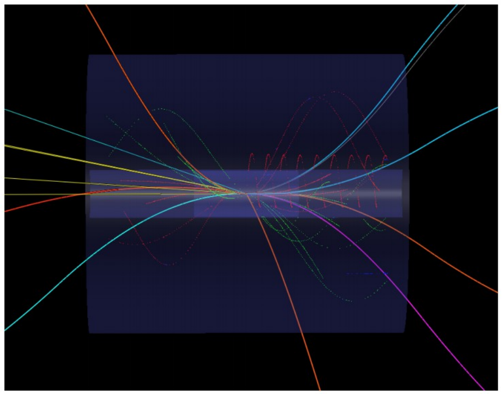


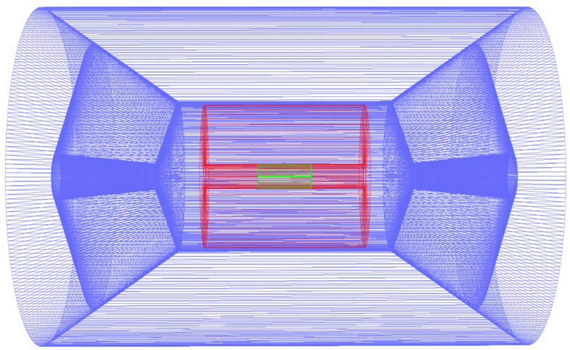
Figure 5: CDCH



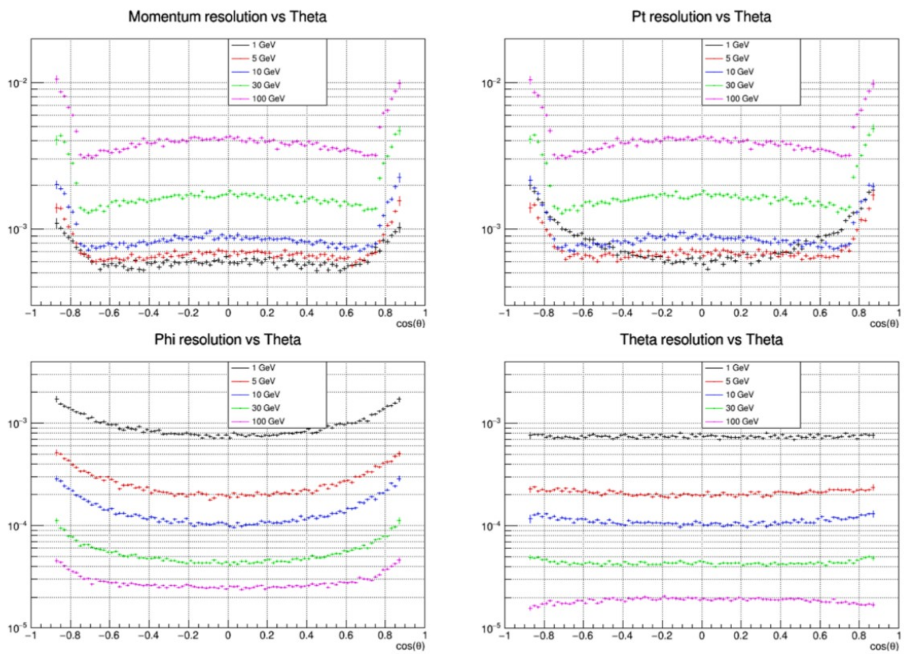




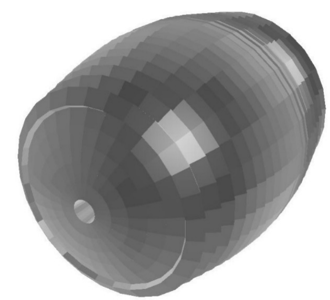


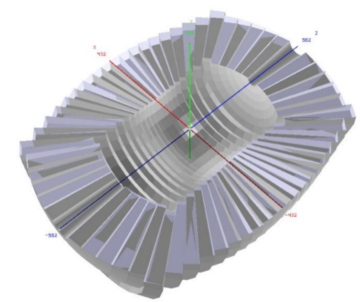


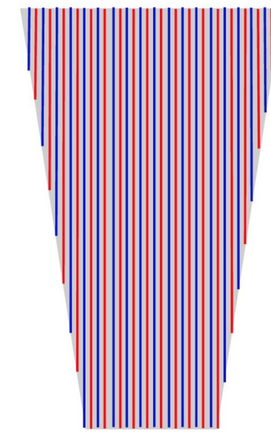
Implemented into Simulation



Dual-readout calorimeter description for CepC/FCCee simulation sw:







a) full coverage
b) projective geometry

Both Wire Chamber & Dual readout Calorimeter have been implemented;

Need Validation, Digitization & Dedicated Analysis to Study the performance at jet and Physics event level

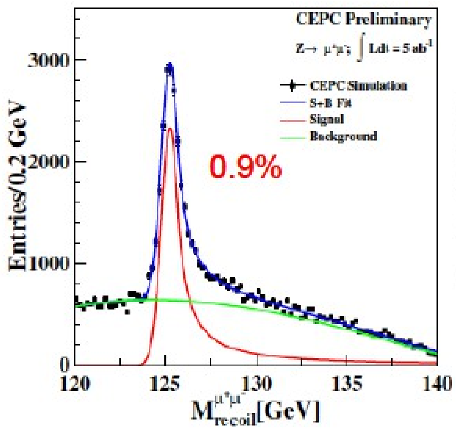
Summary

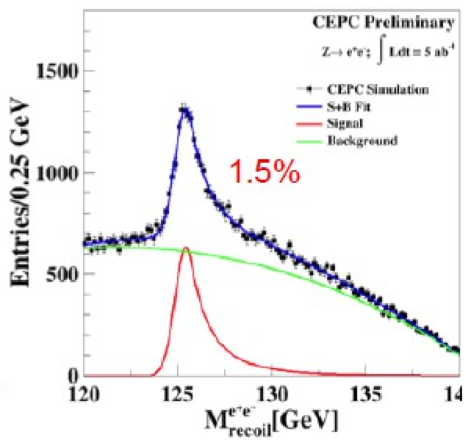
- As a powerful Higgs/Z/W factory, the CEPC poses stringent requirements on the detector
- Two classes of concepts are currently proposed
  - PFA oriented detector: The baseline design
    - Optimized at CEPC collision environments
    - Supported by dedicated task forces at each sub-system
    - Active International collaboration
  - Alternative design: IDEA
    - Lots of hardware R&D
    - Implemented into Full Simulation
- Significant progress now, and tremendous efforts needed for the TDR
  - Integration: DAQ, Cooling, Mechanism
  - Systematic control for the EW!
- **International Collaboration is indispensable for the CEPC detector: any help, idea, contributions are more than welcome & highly appreciated!**

Thanks

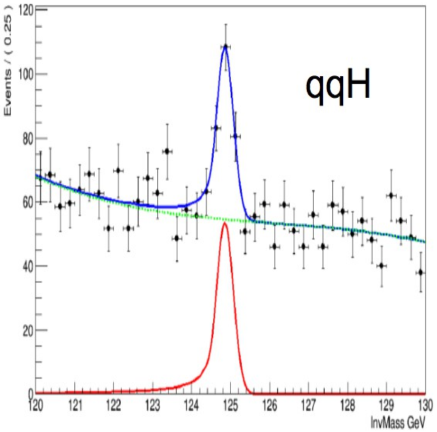
Higgs benchmark analyses

Mostly done with CEPC-v1 geometry @ 250 GeV c.m.s...

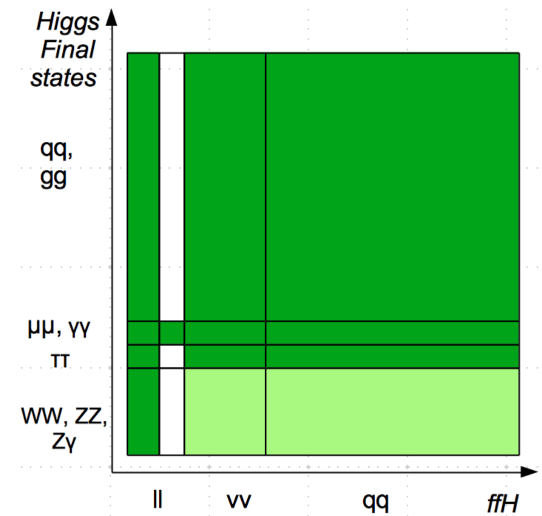


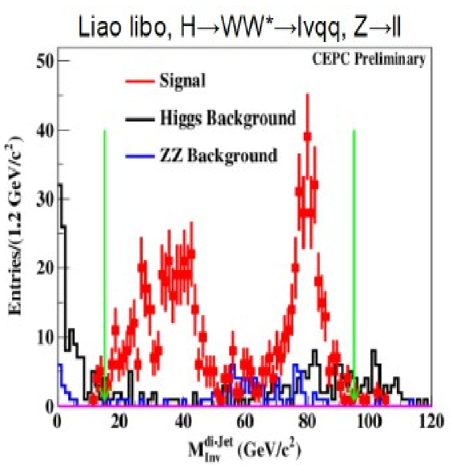


σ(ZH) measurements

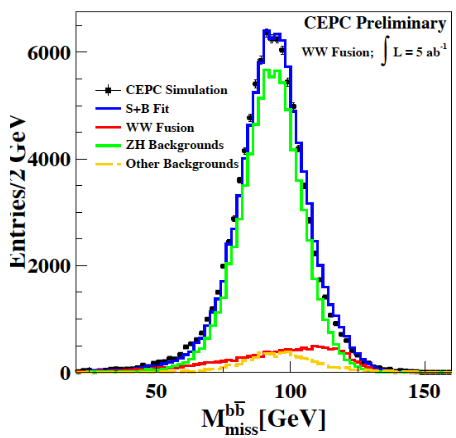


Br(H→μμ)

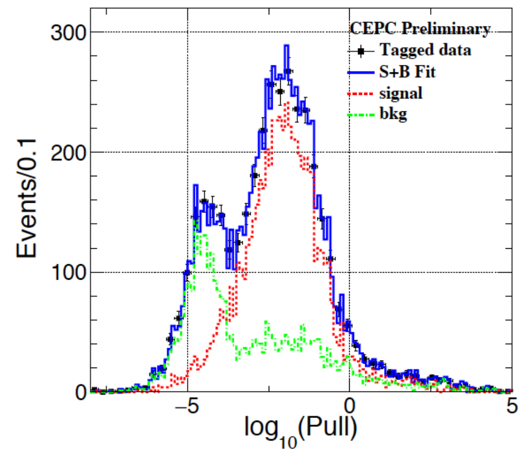




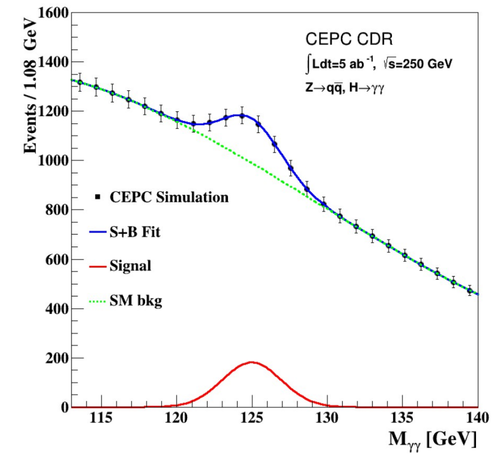
Br(H→WW)



σ(νvH)*Br(H→bb)



Br(H→ττ)



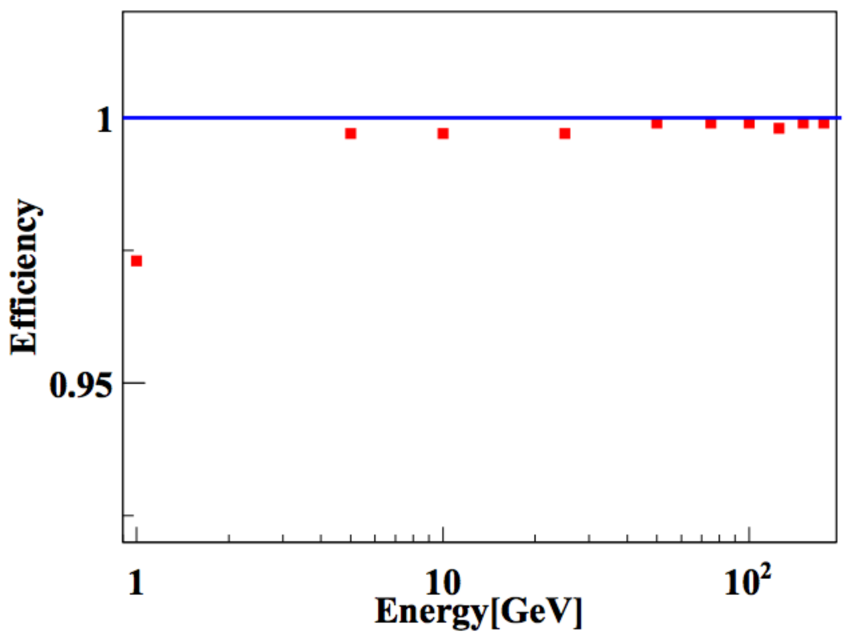
Br(H→γγ) (Asimov)

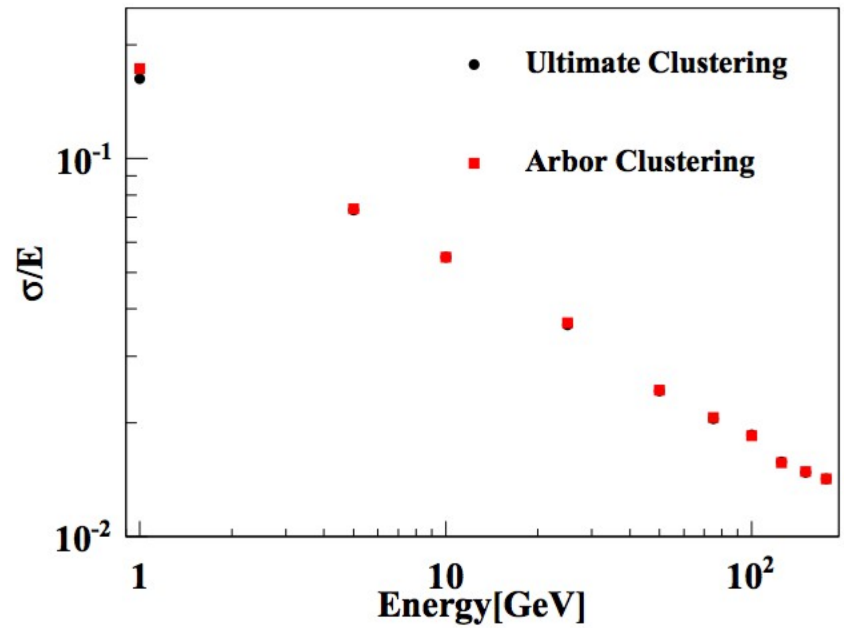
CEPC Higgs White Paper – be available soon

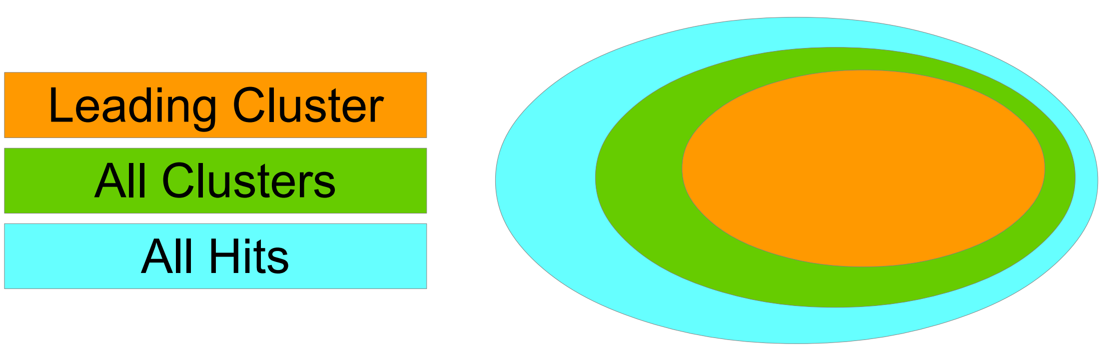
Example Working Points & Performance for Object identification (Preliminary)

	Efficiency	Purity	Mis-id Probability from Main Background
Leptons	99.5 – 99.9%	99.5 – 99.9% at Higgs Runs(c.m.s = 240 GeV), Energy dependent	$P(\pi^{\pm} \rightarrow leptons) < 1\%$
Photons*	99.3 – 99.9%	99.5 – 99.9% at Higgs Runs Energy Dependent	$P(\text{Neutron} \rightarrow \gamma)$ = 1- 5%
Charged Kaons**	86 – 99%	90 – 99% at Z pole Runs (c.m.s = 91.2GeV, Track Momentum 2- 20 GeV)	$P(\pi^{\pm} \rightarrow K^{\pm})$ = 0.3 – 1.1%
b-jets	80%	90% at Z pole runs $(Z \rightarrow qq)$	P(uds → b) = 1% P(c → b) = 10%
c-jets	60%	60% at Z pole runs	P(uds → c) = 5% P(b → c) = 15%

Photon: Ideal & Realistic Clustering



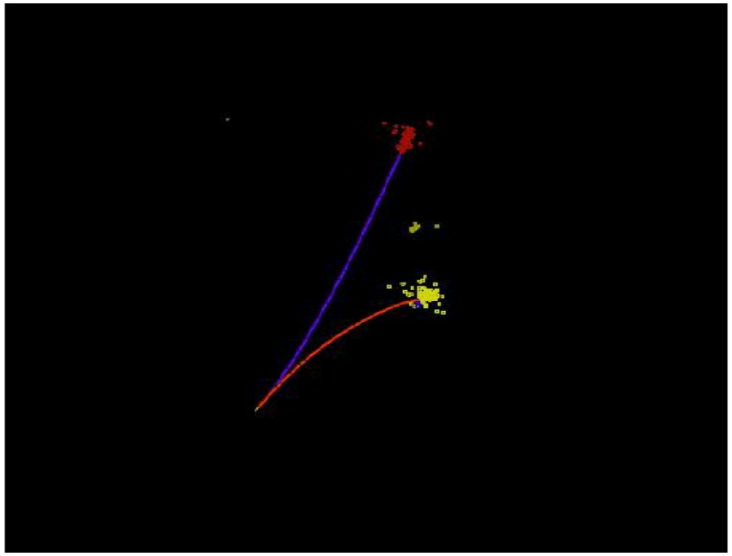


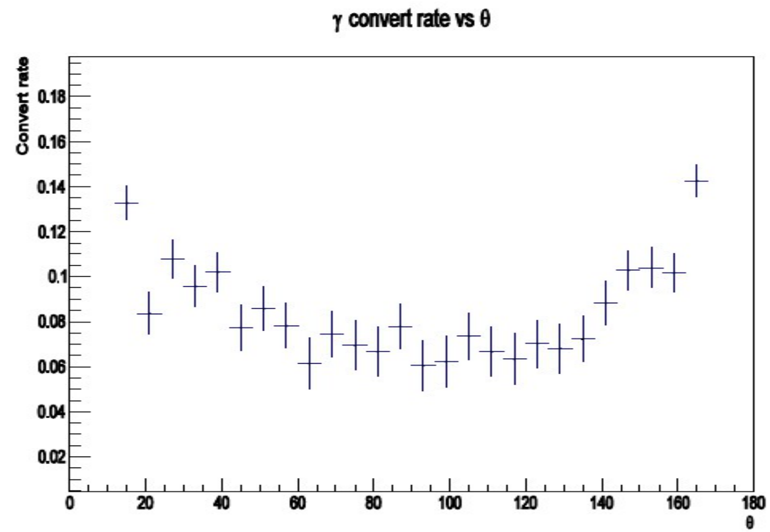


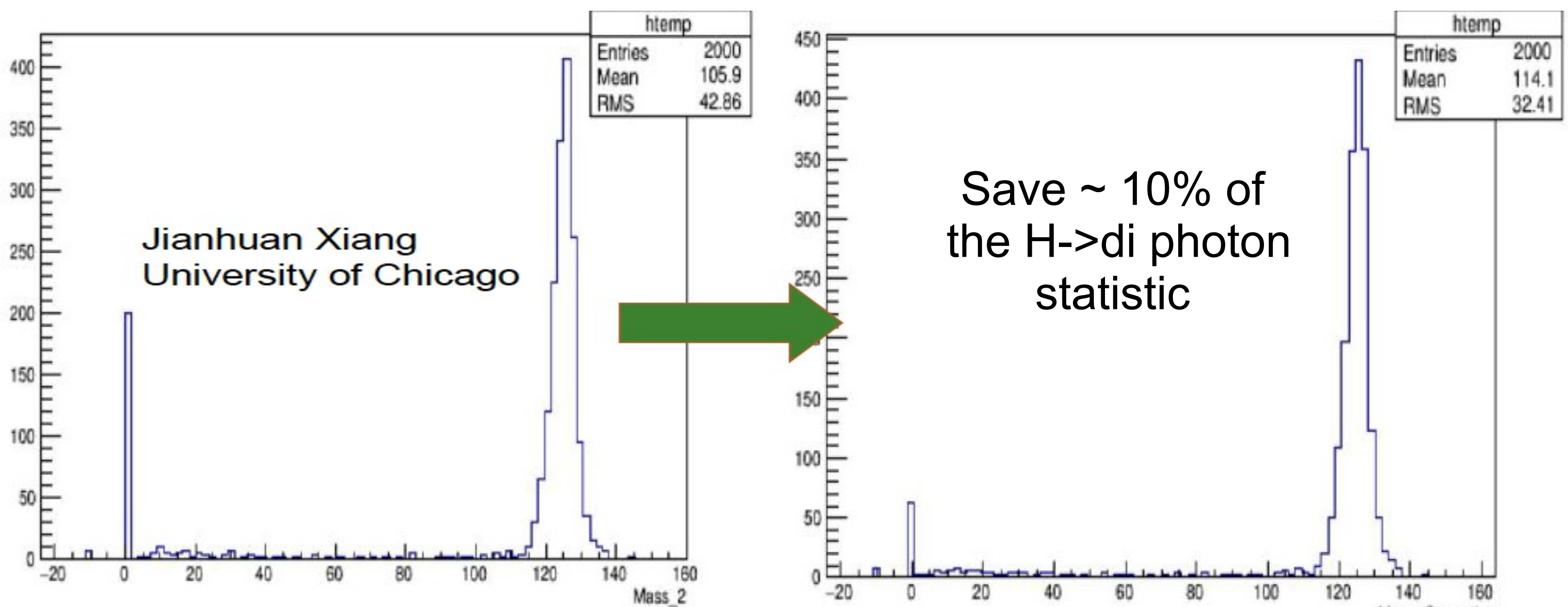
Efficiency
= LC Energy/total hit energy

@ 5 mm Cell Size

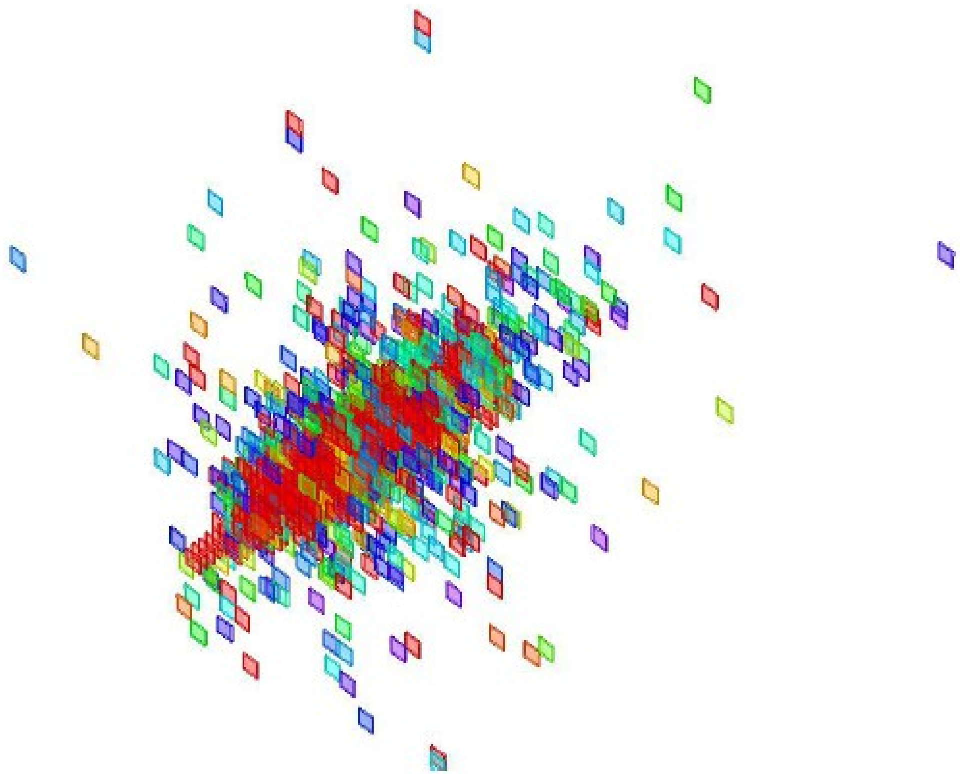
Photon conversion & recovery





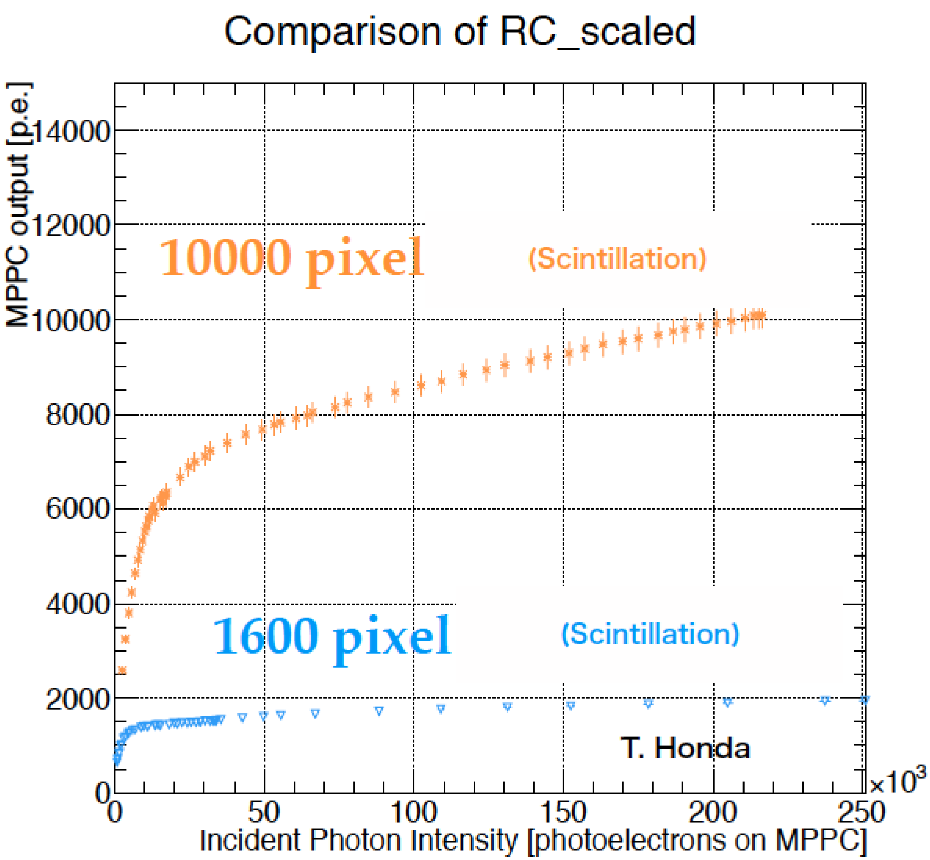


ECAL Saturation/Linear Range Study



50 GeV Photon Cluster
at ECAL with 10 mm Cell Size

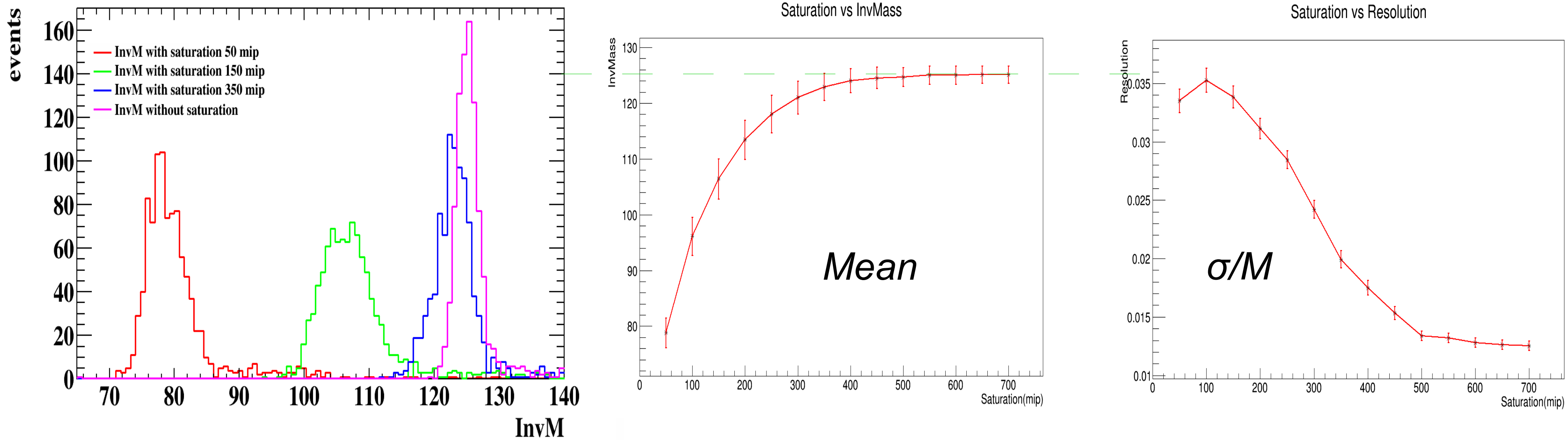
~o(1k) hits, hottest hit with E ~ 1k MIP.



T.Takeshita, ILDDET@KEK

Scintillator: MIP→Photon→P.E

Impact on H→γγ measurement



ECAL Linear Ranger: recommended to be >1k/1.8k MIP (for 10/20 mm Cell)

10k pixel SiPM readout is very challenging (If Photon generation > 10 per mip)

Empirical formula on needed ranger of a single photon:

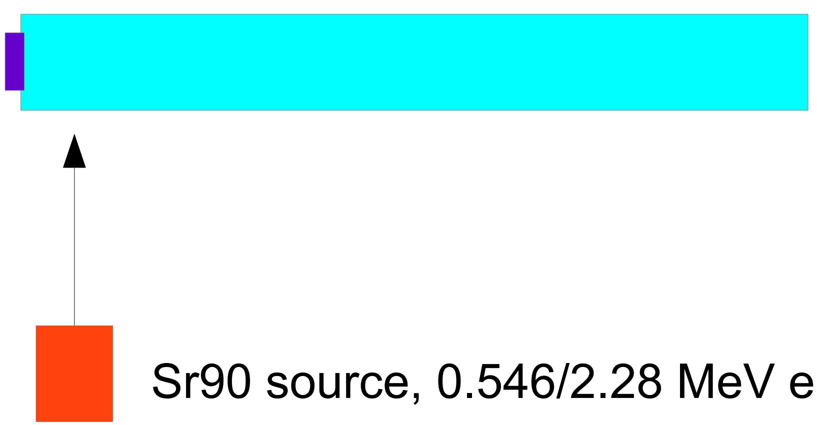
$$\log10(\text{Ranger}) = 0.87*x + 0.97*y - 0.24*y^2 + 1.26$$

$$x = \log10(E),\ y = \log10(\text{Cell Size/cm})$$

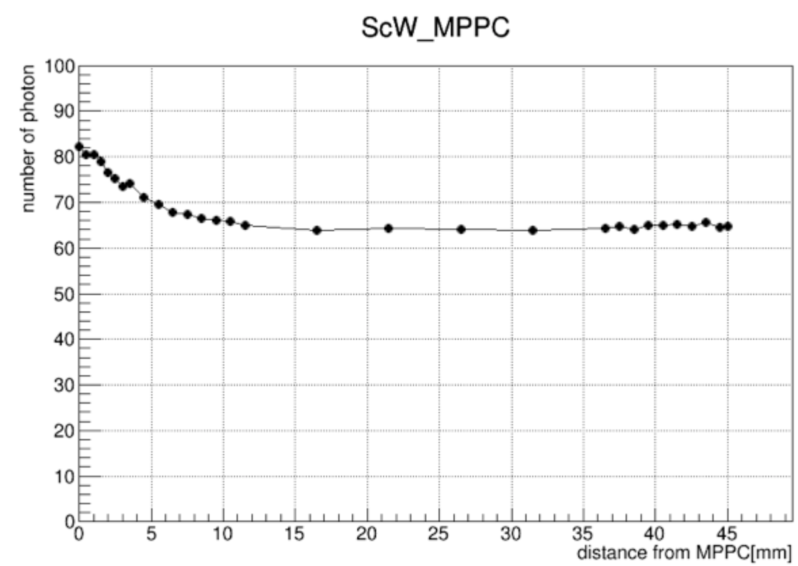
Shuzheng Wang

In-Homogeneity

- Performance degrades
  - Cracks: **20-30%** (σ/M ~ 2.4% @ CEPC_v1, with corrections)
  - By the photo yield in-homogenity (20% along the strip): **12%**
  - Local dead zone (1mm dead region along the strip of 5mm*45 mm): **8%**



Sr90 source, 0.546/2.28 MeV electron



#pixel with different hit position