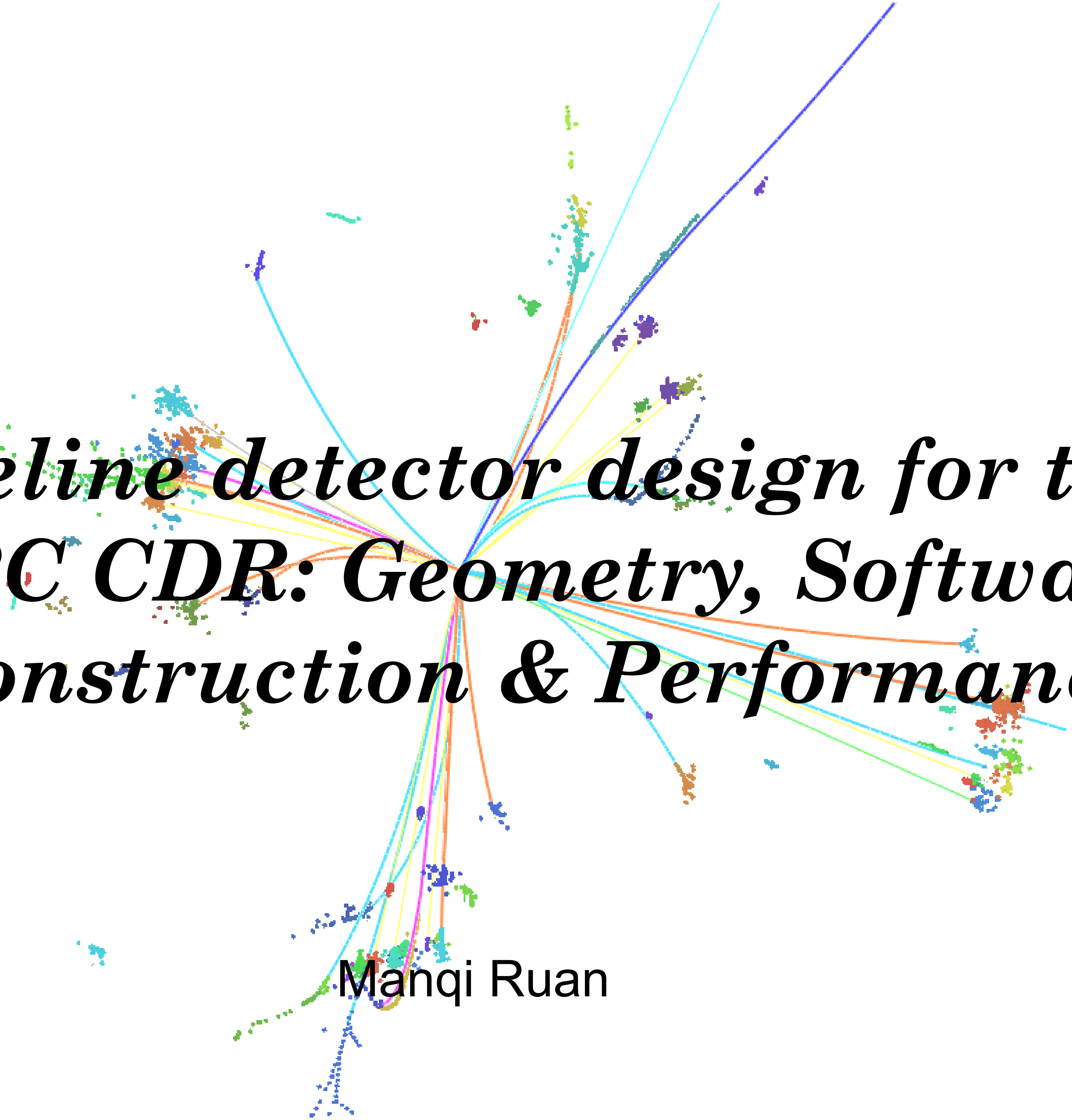
Baseline detector design for the CEPC CDR: Geometry, Software Reconstruction & Performance

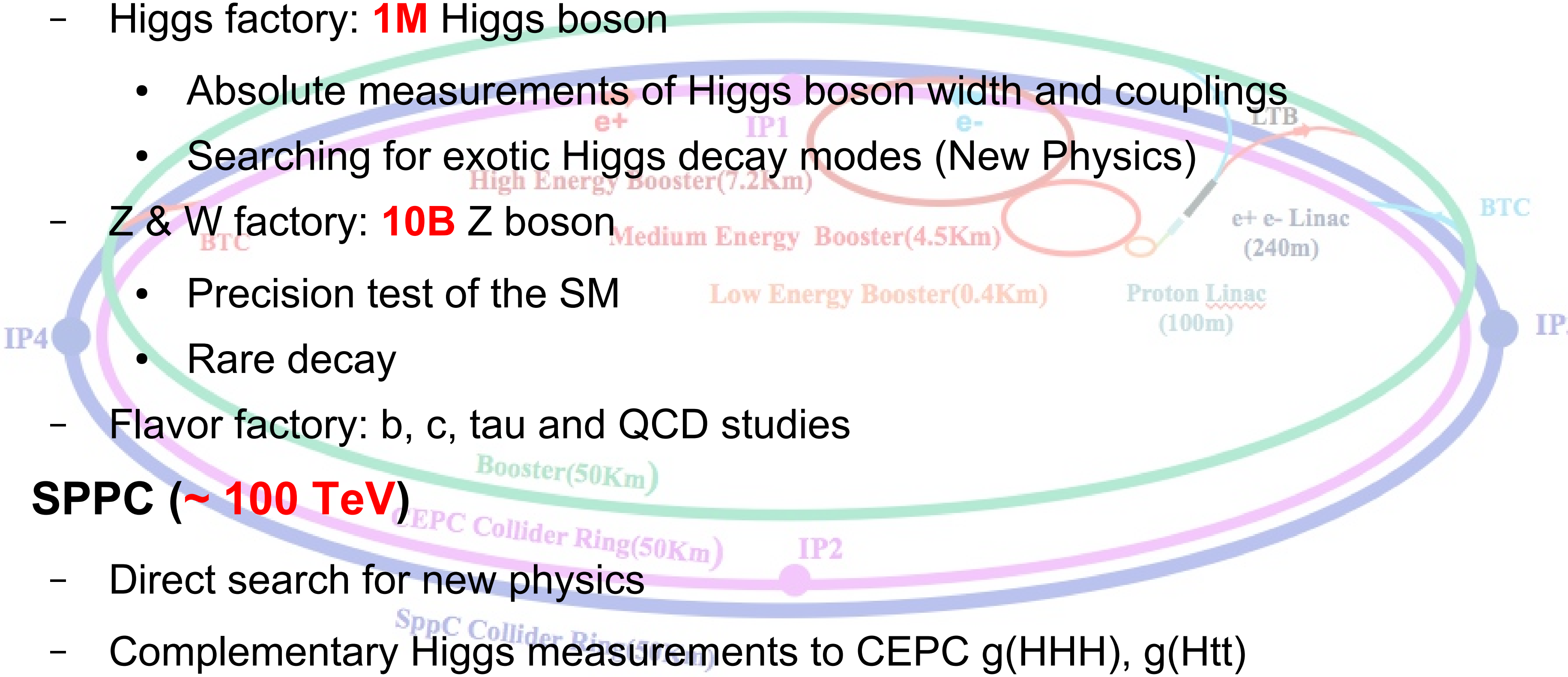


Manqi Ruan

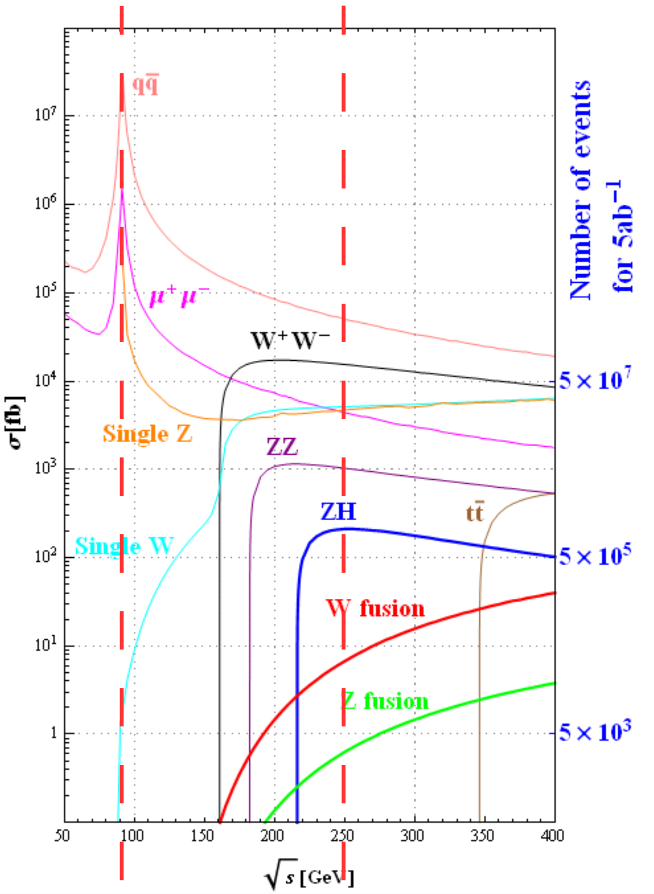
Science at CEPC-SPPC

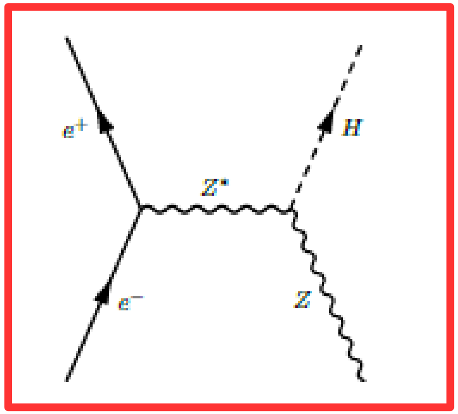
- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **10B** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor 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...**

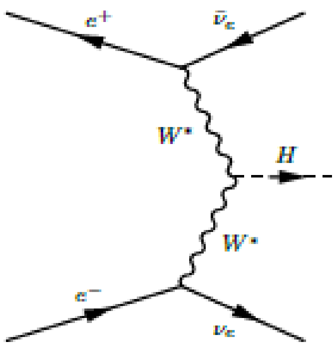
Complementary

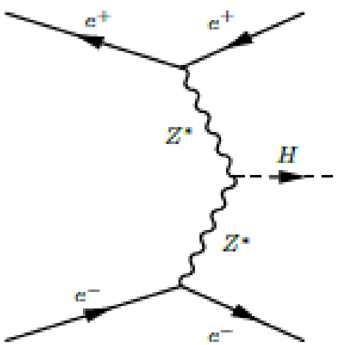


Higgs @ CEPC









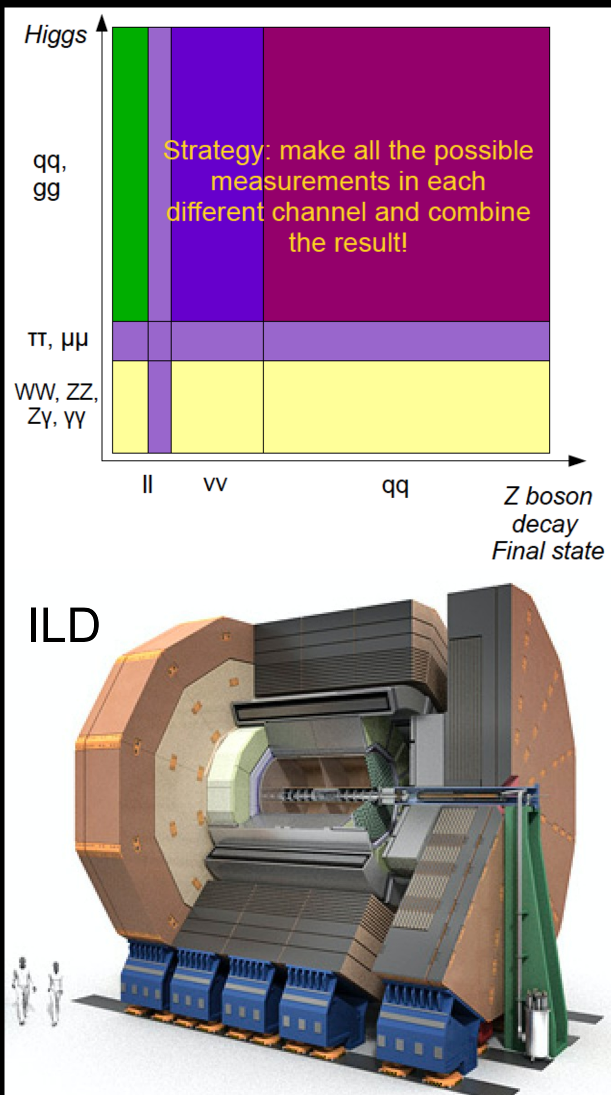
Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

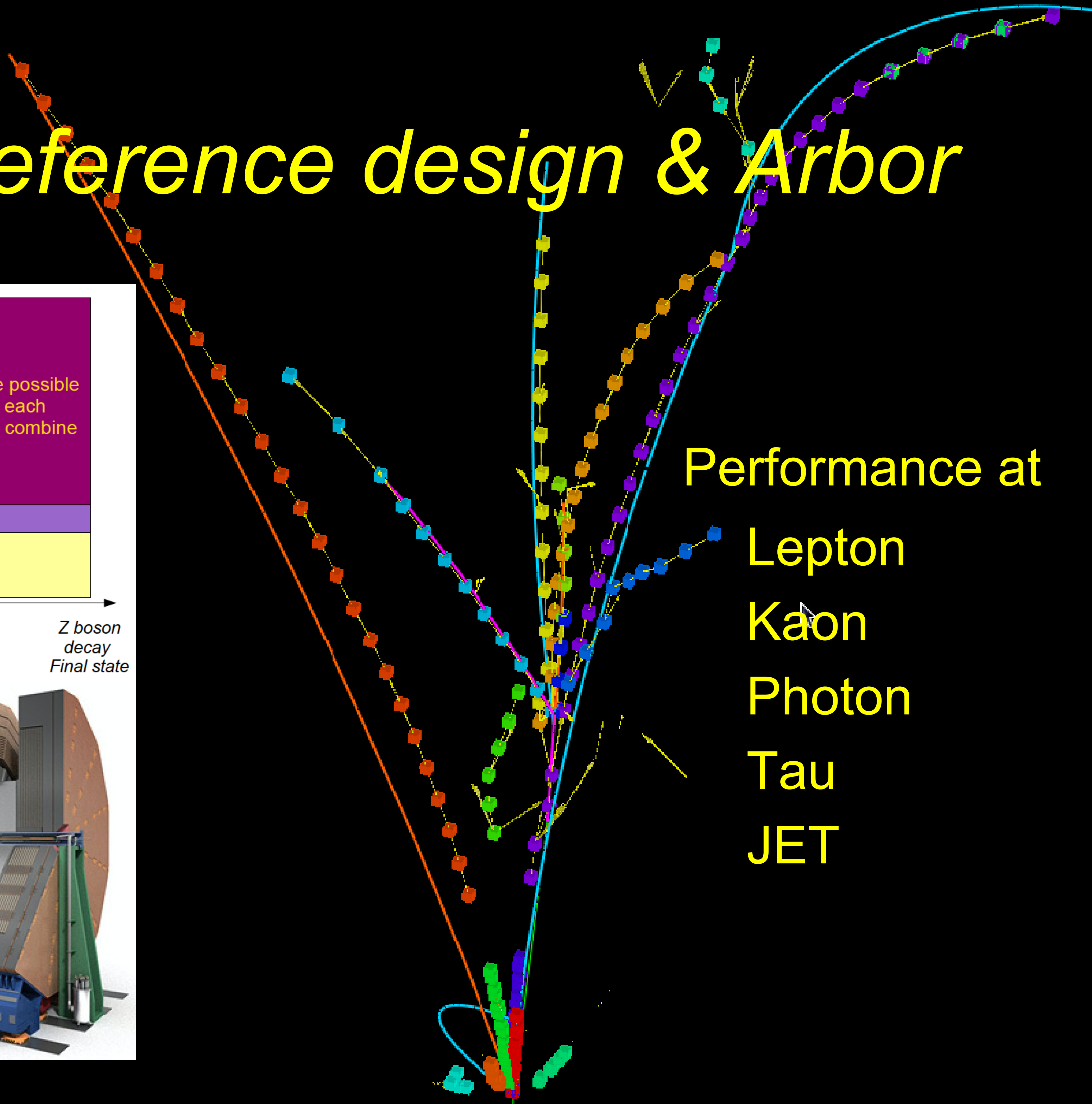
S/B ~ 1:100 - 1000

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

Derive: Absolute Higgs width, branching ratios, couplings

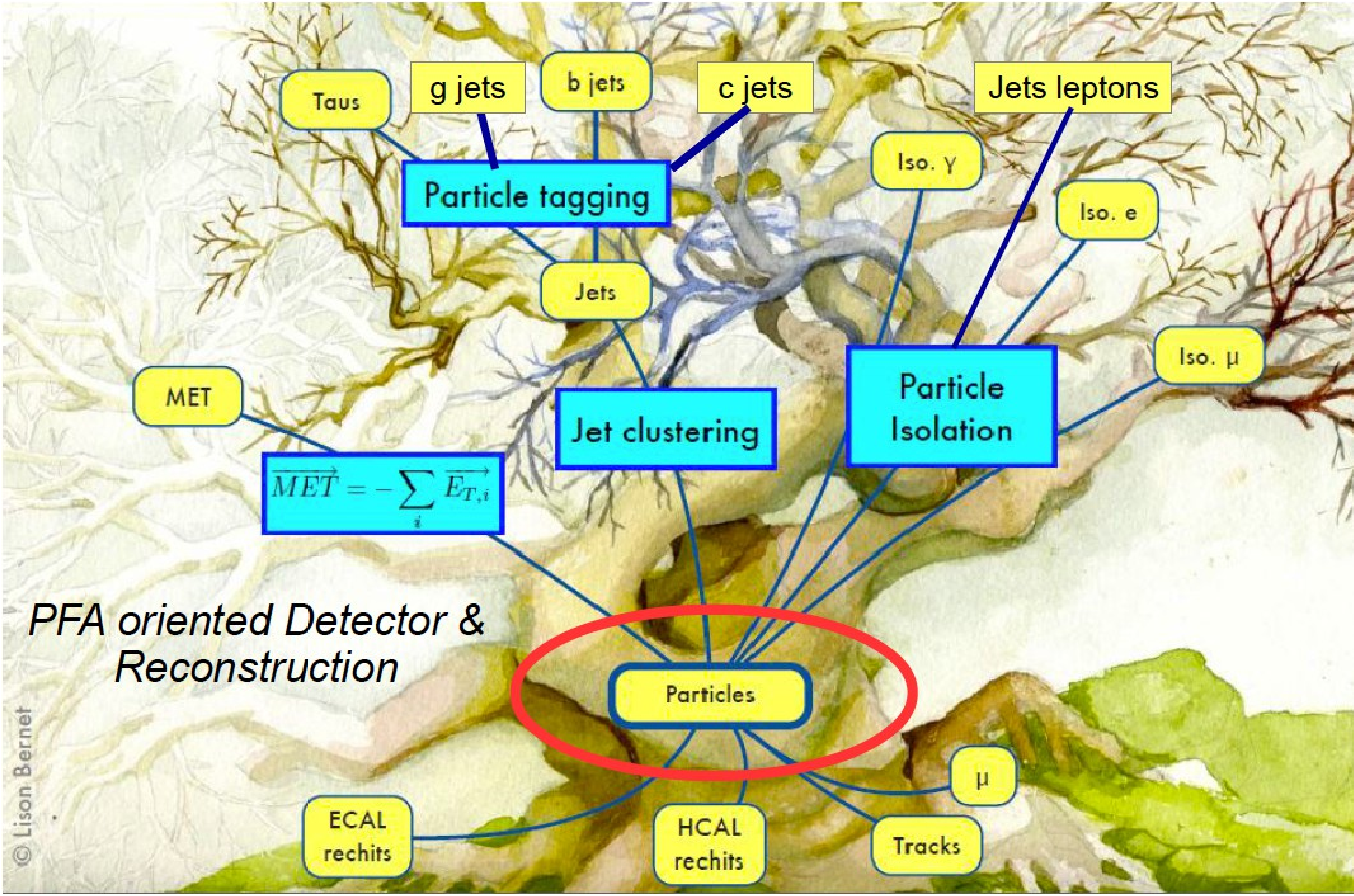
Reference design & Arbor



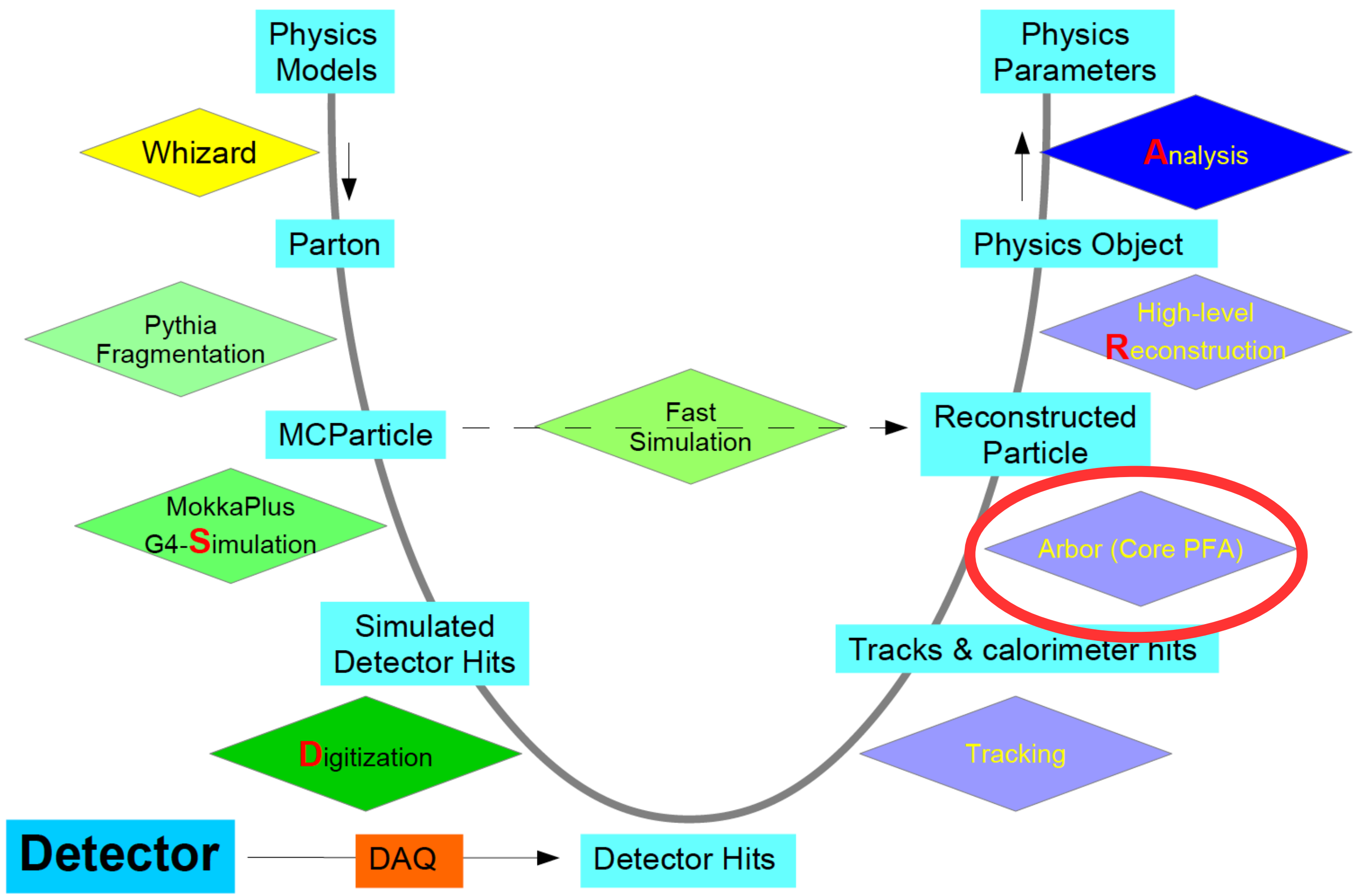


Performance at

- Lepton
- Kaon
- Photon
- Tau
- JET


Taus
g jets
b jets
c jets
Jets leptons
Particle tagging
Iso. γ
Iso. e
Jets
Iso. μ
MET
Jet clustering
Particle Isolation
$\overrightarrow{MET} = -\sum_i \overrightarrow{E_{T,i}}$
PFA oriented Detector & Reconstruction
Particles
μ
ECAL rechits
HCAL rechits
Tracks
© Lison Bernet

以 Arbor 为核心的完整软件工具



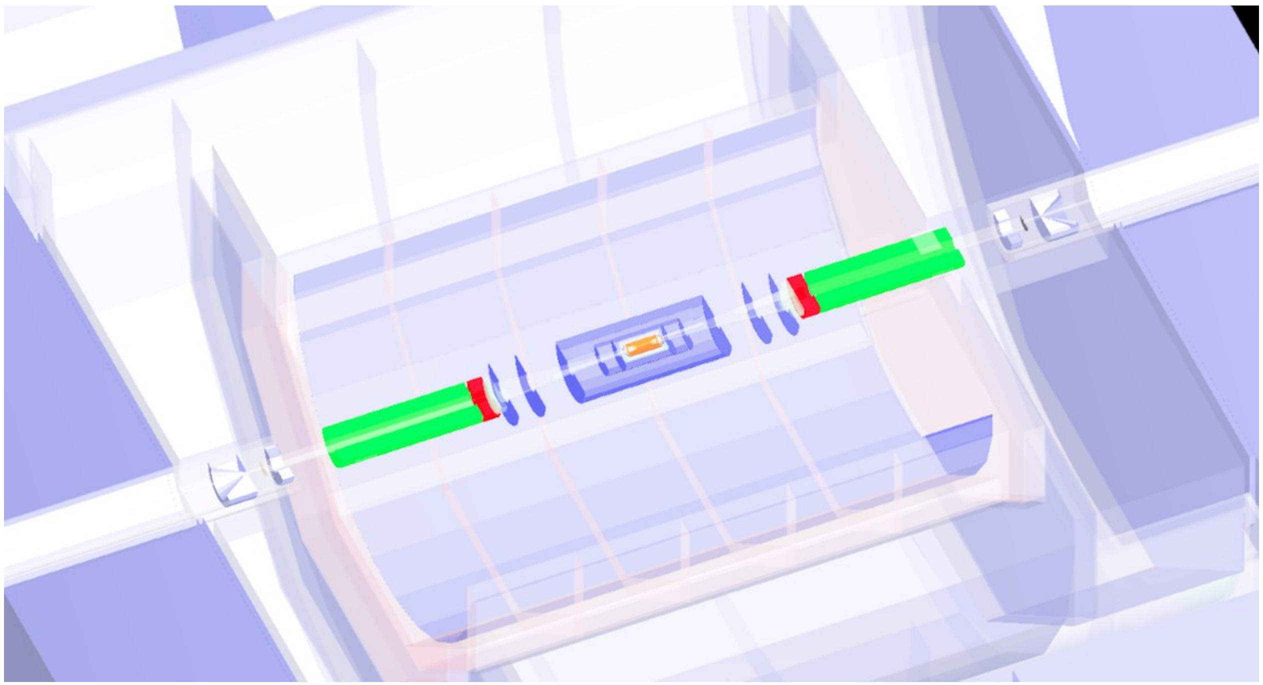
Generators (Whizard & Pythia)
Data format & management (LCIO & Marlin)
Simulation (MokkaC)
Digitizations
Tracking
PFA (Arbor)
Single Particle Physics Objects Finder (LICH)
Composed object finder (Coral)
Tau finder
Jet Clustering (FastJet)
Jet Flavor Tagging (LCFIPLus)
Event Display (Druid)
General Analysis Framework (FSClasser)
Fast Simulation (Delphes + FSClasser)

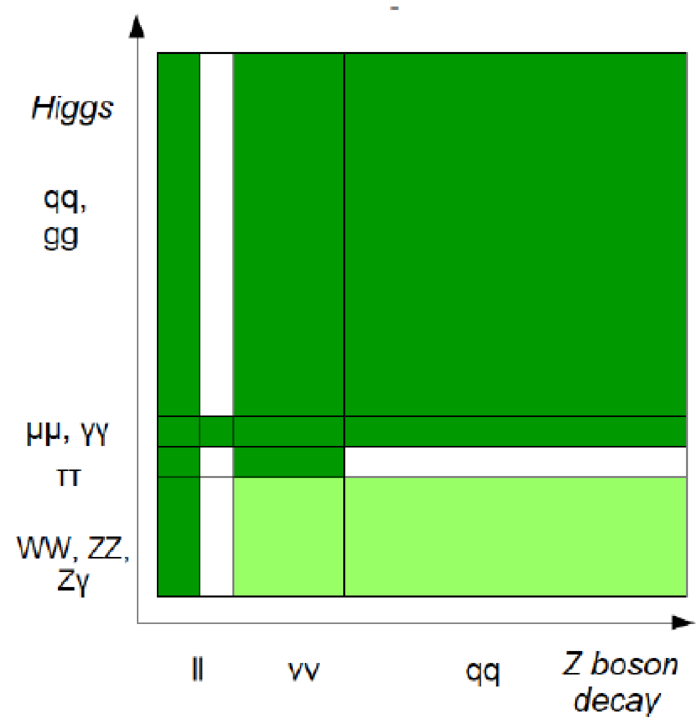
CEPC-SIMU-2017-001,
CEPC-SIMU-2017-002,
(DocDB id-167, 168, 173)

从 ILC 软件工具开始，重新开发大部分软件工具。

通用工具	ILC 软件工具	ILC 软件工具 + 自主开发并存	自主开发

CEPC-v1, reference detector for the CEPC PreCDR studies





Supports most of the CEPC physics analysis till now;

Summarized into the CEPC PreCDR.

To be summarized in Higgs white paper, in final polishing stage

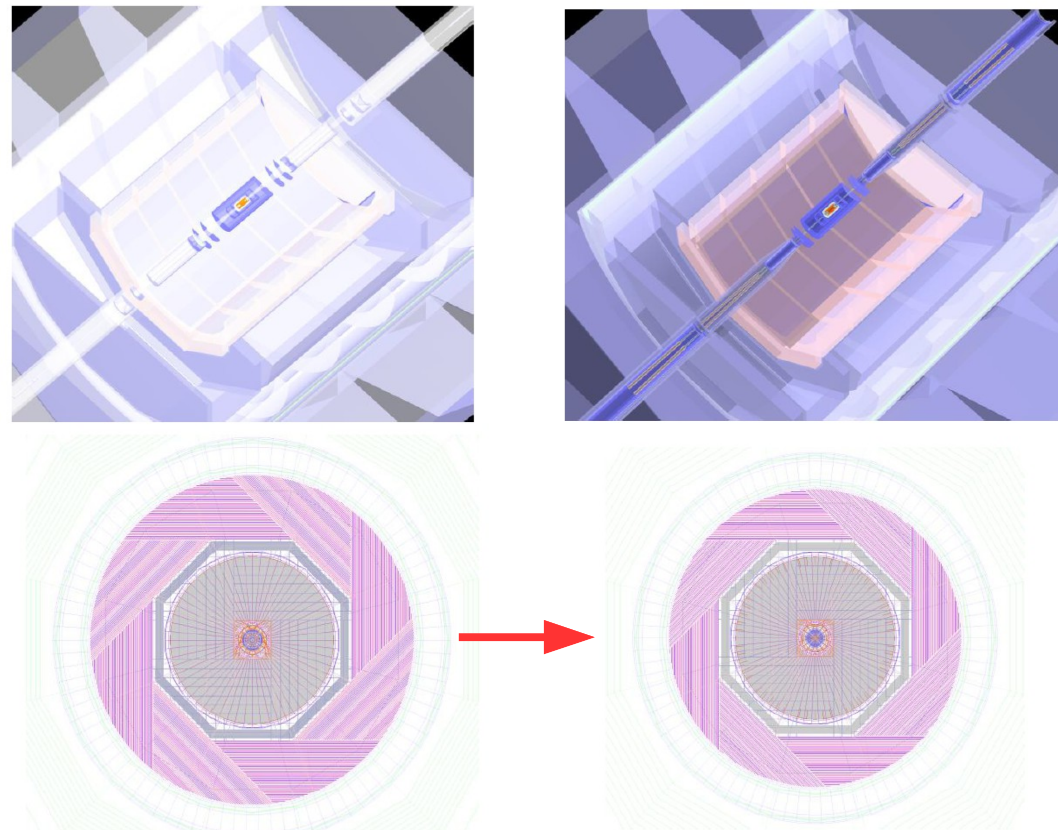
Feasibility & Optimized Parameters

Feasibility analysis: TPC is valid for CEPC

	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	84 mm is optimized on Br(H->di photon) at 250 GeV; 90mm for bhabha event at 350 GeV
ECAL Cell Size	5 mm	10 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV; Margin might be reserved for 350 GeV.

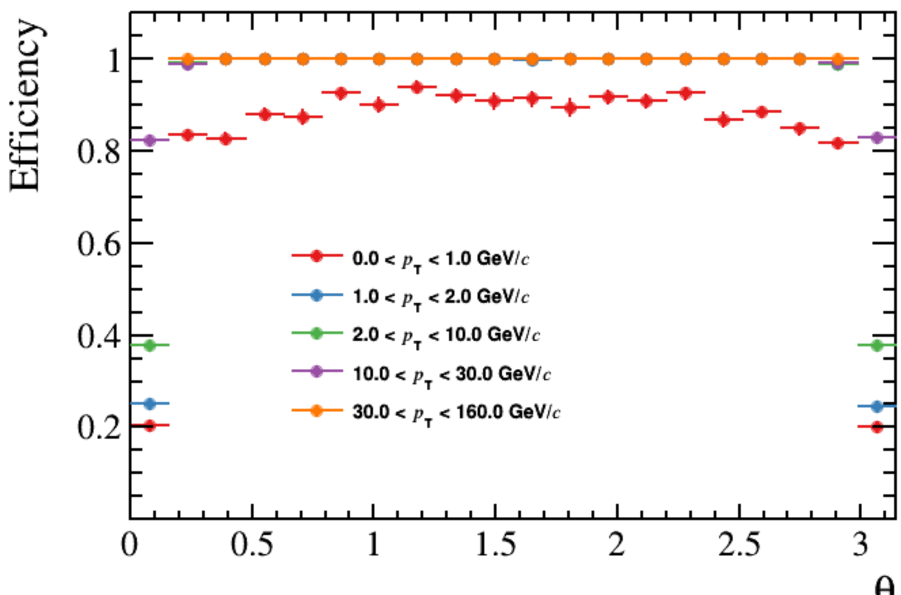
CDR 基线探测器 **APODIS**

- 在概念上确认可使用于 CEPC 环境，通过标志性测量对各子探测器参数进行优化
- 相对 LHC 实验
  - 径迹精度提高一个量级
  - 喷注精度提高 3-4 倍（ Arbor ）
  - 光子测量精度降低 30-50%
- 相对 ILD （ CEPC-v1 ）
  - 在 Higgs 测量方面性能基本一致
  - 大大增强了 Kaon id 性能
- 功耗、造价、重量大幅下降
  - 电磁量能器功耗削减 75 - 80%
  - 轭铁重量下降削减 60 -70%
  - 造价削减 30%
  - 。。。

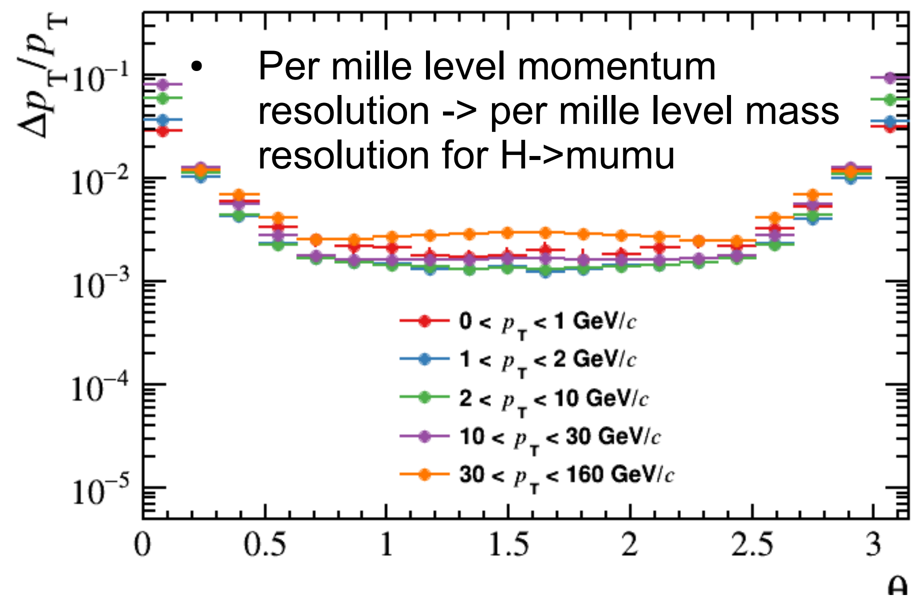


2015 PreCDR　　　2017 CDR

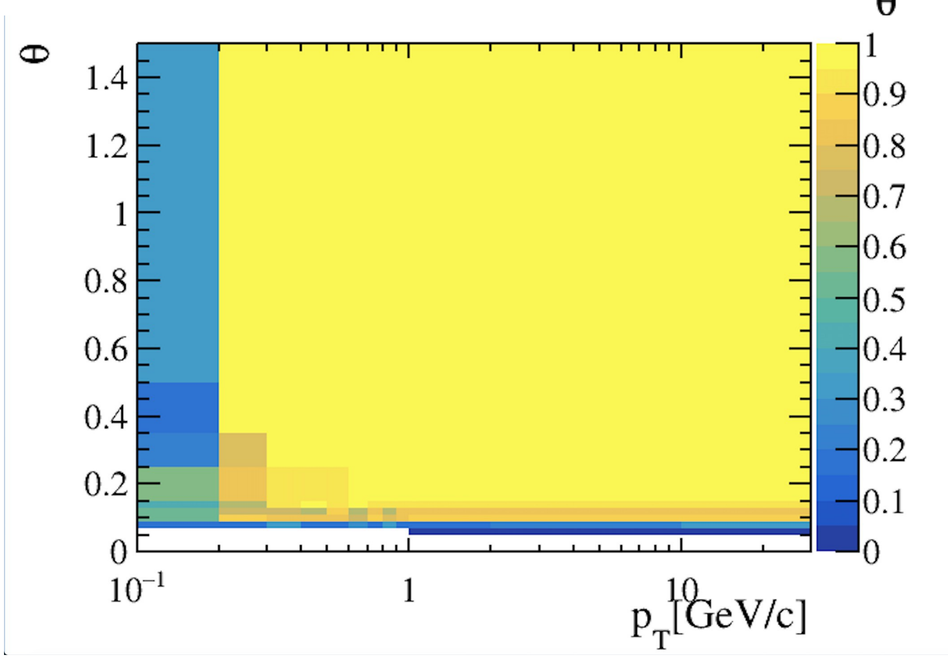
Tracking



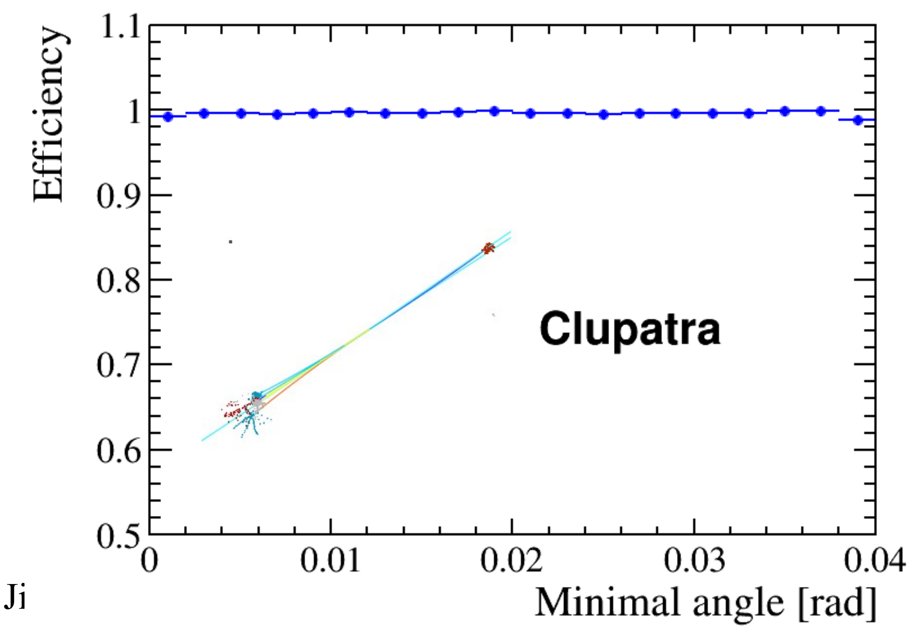
Efficiency
0.0 < p_T < 1.0 GeV/c
1.0 < p_T < 2.0 GeV/c
2.0 < p_T < 10.0 GeV/c
10.0 < p_T < 30.0 GeV/c
30.0 < p_T < 160.0 GeV/c
θ



$\Delta p_T/p_T$
• Per mille level momentum resolution -> per mille level mass resolution for H->mumu
0 < p_T < 1 GeV/c
1 < p_T < 2 GeV/c
2 < p_T < 10 GeV/c
10 < p_T < 30 GeV/c
30 < p_T < 160 GeV/c
θ

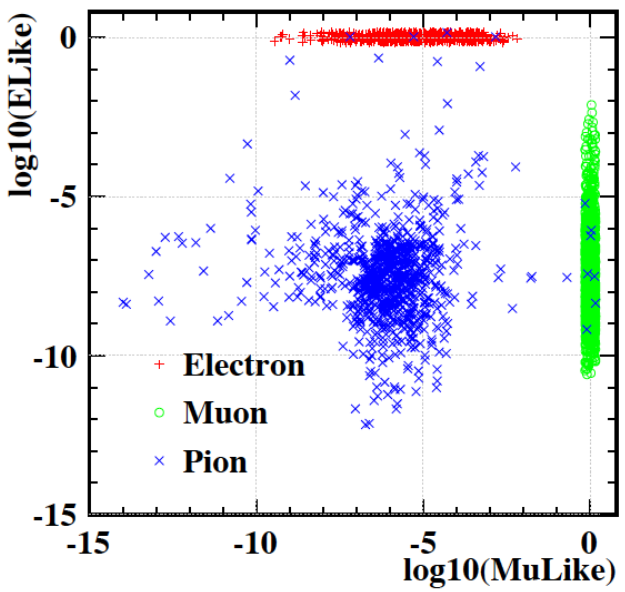


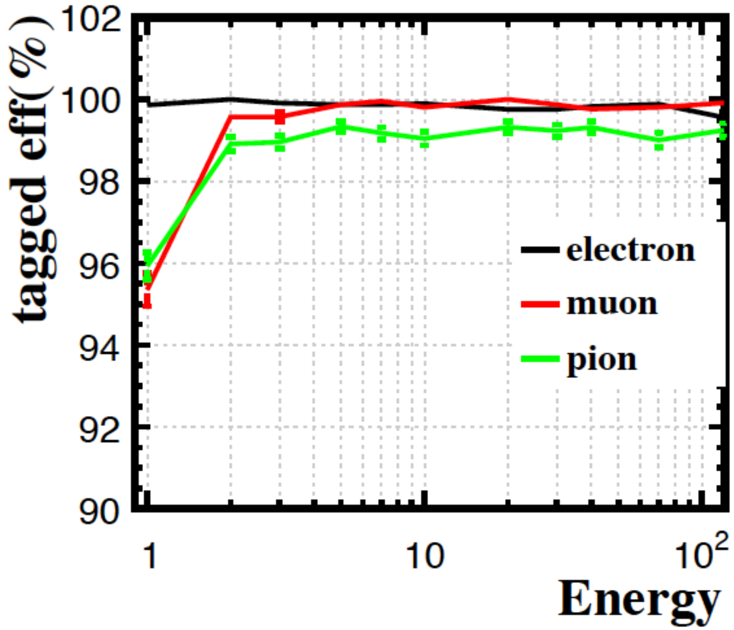
θ
p_T[GeV/c]

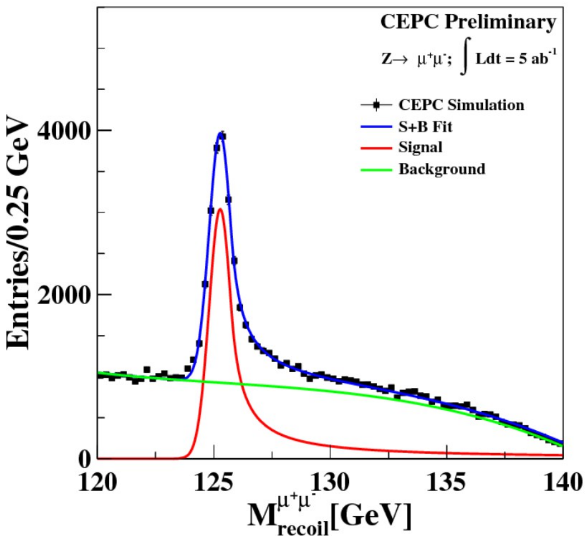


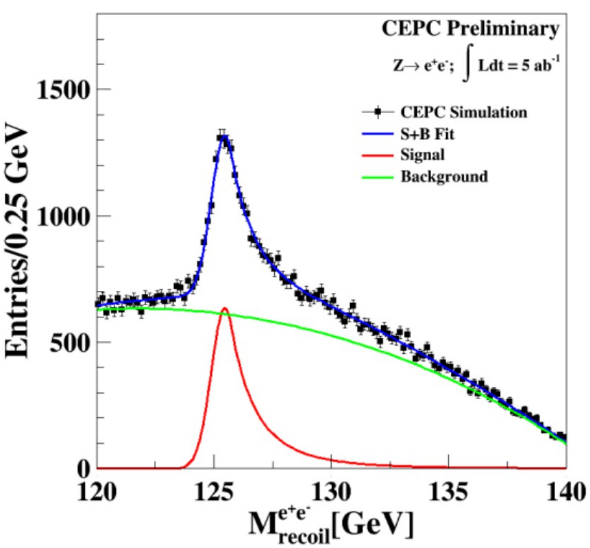
Efficiency
Clupatra
Minimal angle [rad]

Lepton







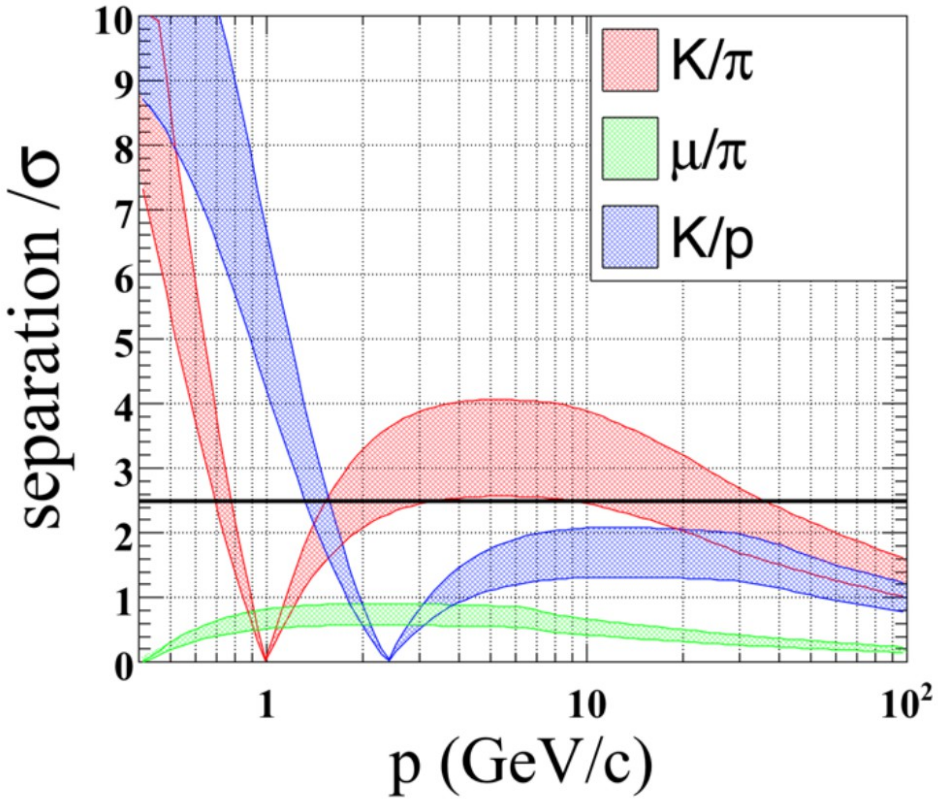


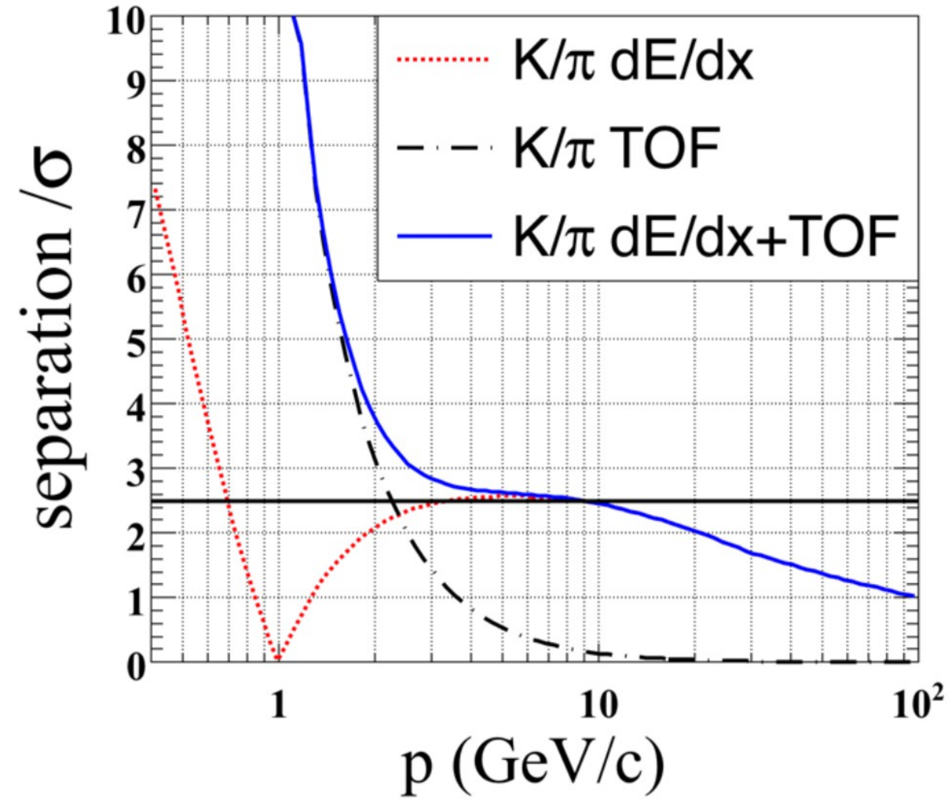
BDT method using 4 classes of 24 input discrimination variables.

Test performance at: 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://link.springer.com/article/10.1140/epjc/s10052-017-5146-5
CEPC-DocDB-id:148, Eur. Phys. J. C (2017) 77: 591

Kaon



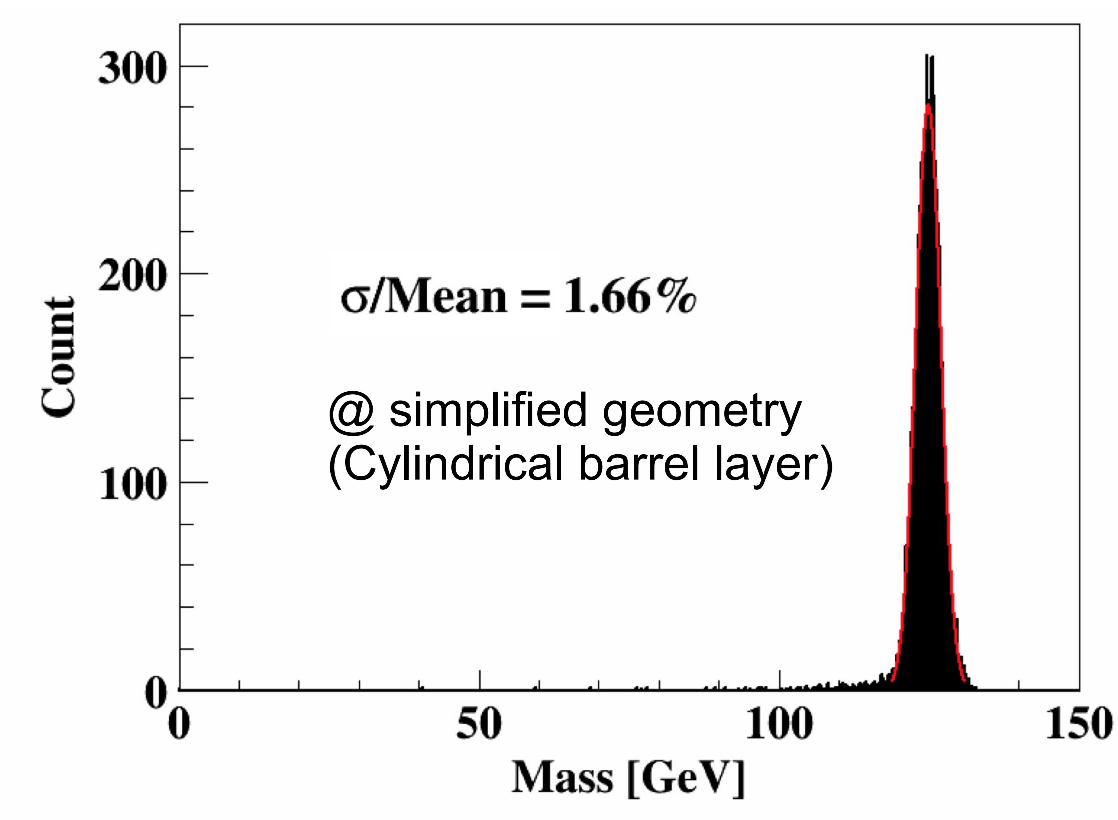


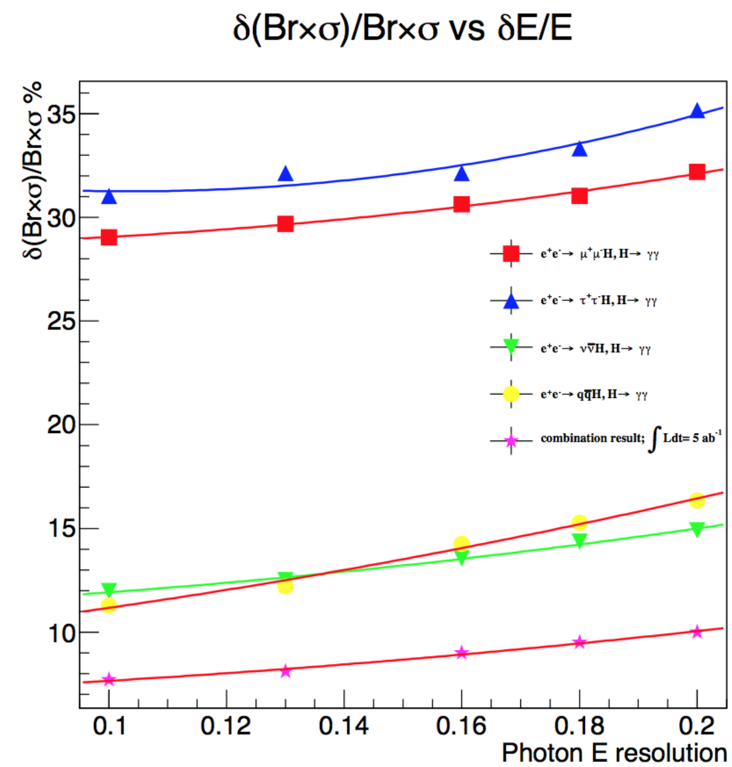
Highly appreciated in flavor physics @ CEPC Z pole
- TPC dEdx + ToF of 50 ps

At inclusive Z pole sample:
- Conservative estimation gives efficiency/purity of 91%/94% (2-20 GeV, 50% degrading +50 ps ToF)
- Could be improved to 96%/96% by better detector/DAQ performance (20% degrading + 50 ps ToF)

CEPC-DocDB-id: 172
https://arxiv.org/abs/1803.05134
Eur. Phys. J. C (2018) 78:464

Photon



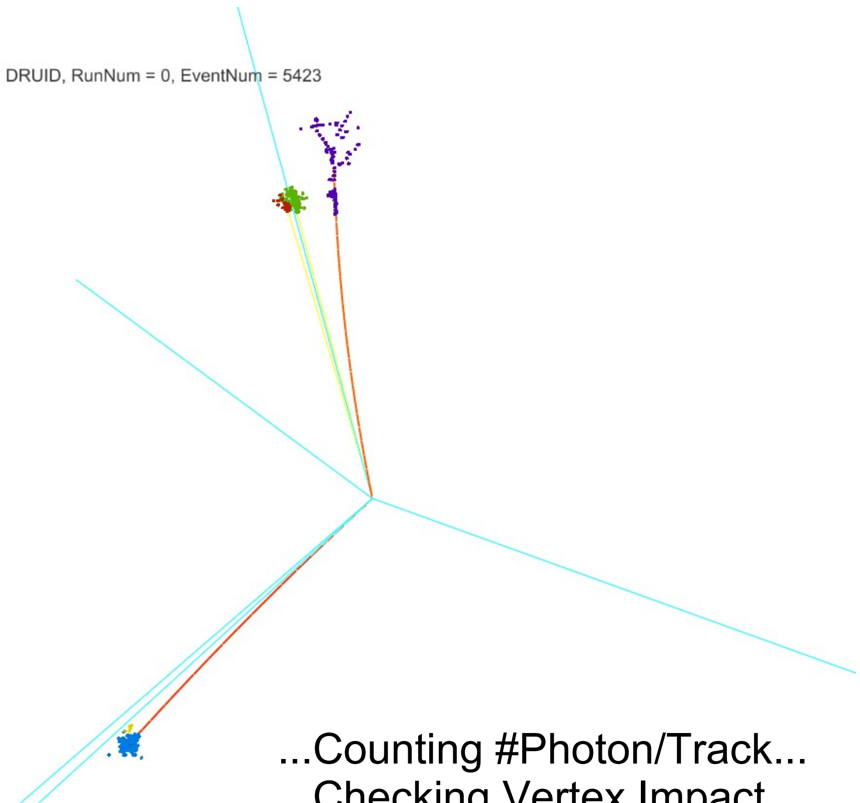


Relative Accuracy: ~ 8.5%

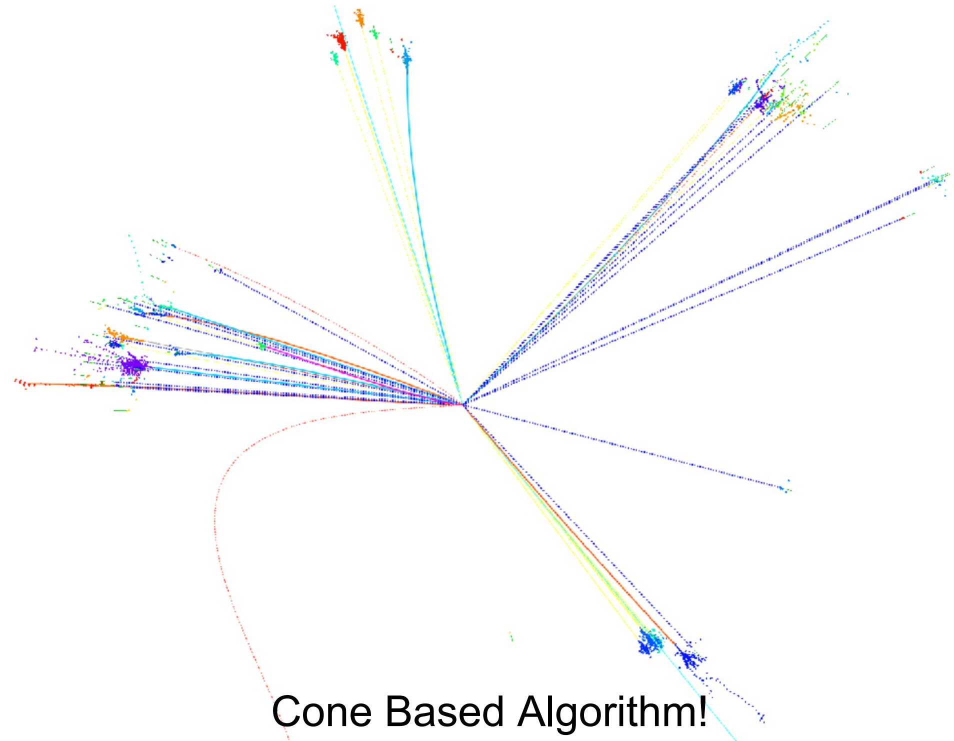
Inhomogeneity degrades the resolution significantly.
Physics requirement: constant term < 1%
Detector geometry defects degrades the mass resolution to **2.2%/2.6%** (CEPC-v1/APODIS);

http://iopscience.iop.org/article/10.1088/1748-0221/13/03/P03010
CEPC-DocDB-id (149, 169)
https://arxiv.org/pdf/1712.09625.pdf

Tau



...Counting #Photon/Track...
...Checking Vertex Impact...

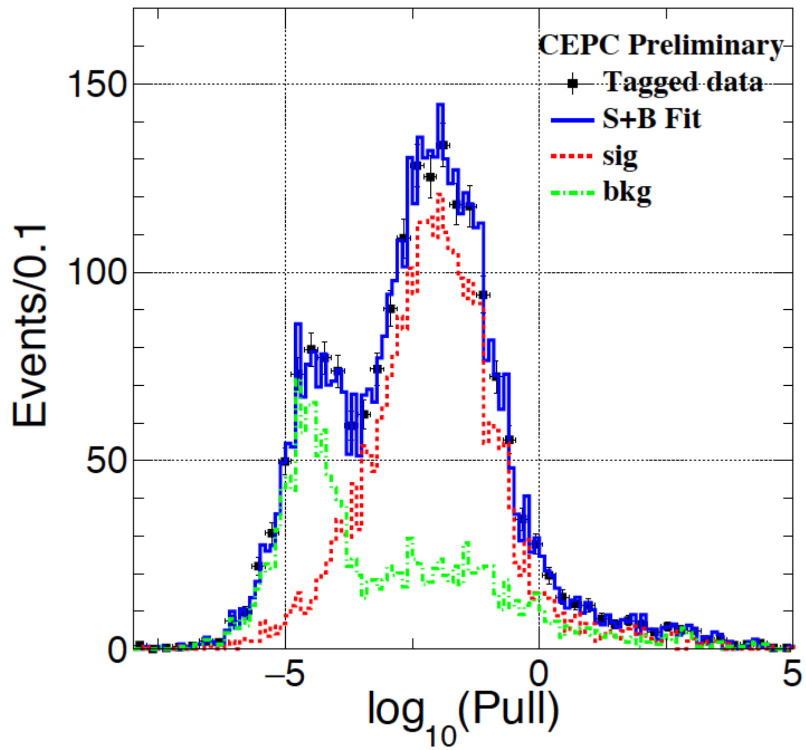


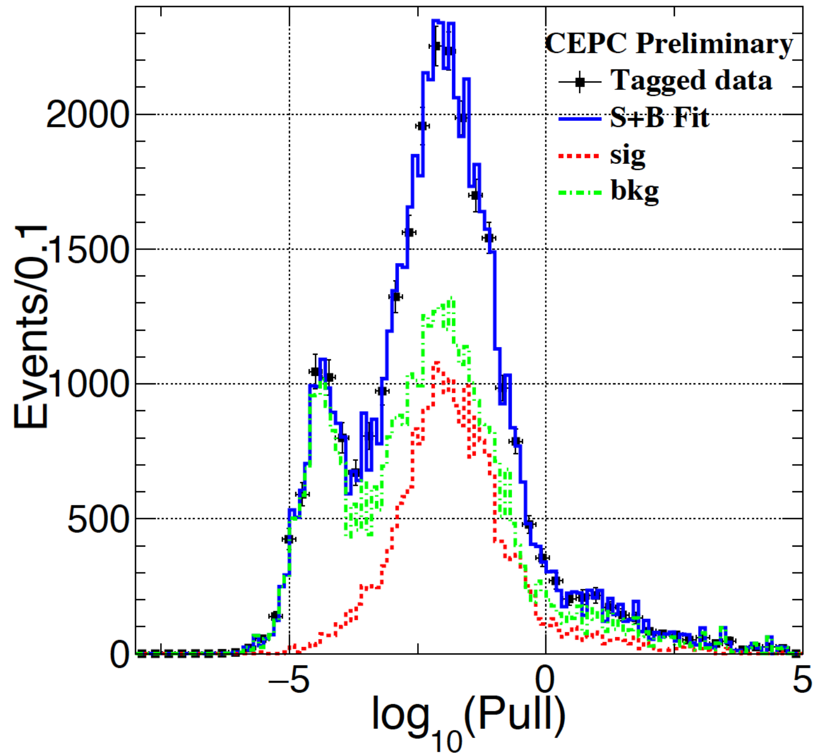
Cone Based Algorithm!
Para. Optimization

- Two catalogues:
  - Leptonic environments: i.e, llττ(ZZ/ZH), ννττ(ZZ/ZH/WW), Z→ττ;
  - Jet environments: i.e, ZZ/ZH→qqττ, WW→qqντ;

Ph.D thesis: D. Yu, reconstruction of leptonic objects at e+e- Higgs factory

g(Hττ) measurement





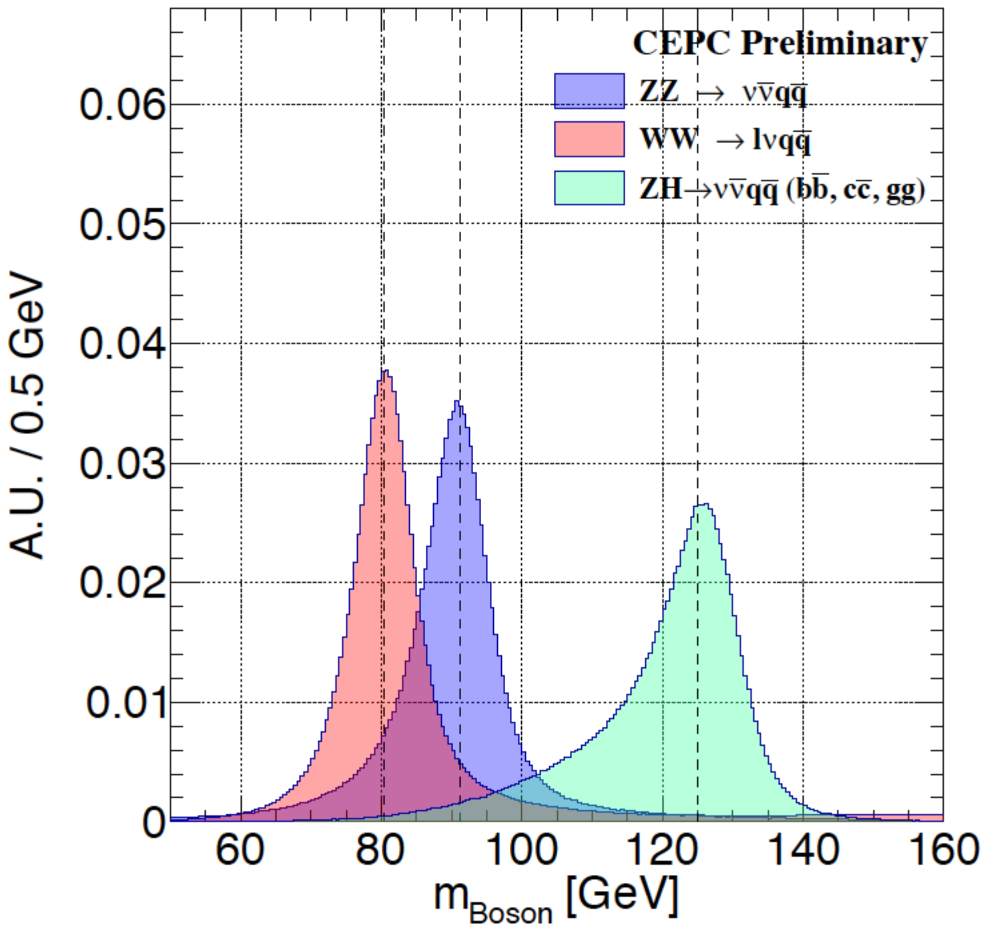
- ZH→μμττ
- Extremely Efficient Event Selection
- Signal efficiency of 93% - entire SM background reduced by 5 orders of magnitude

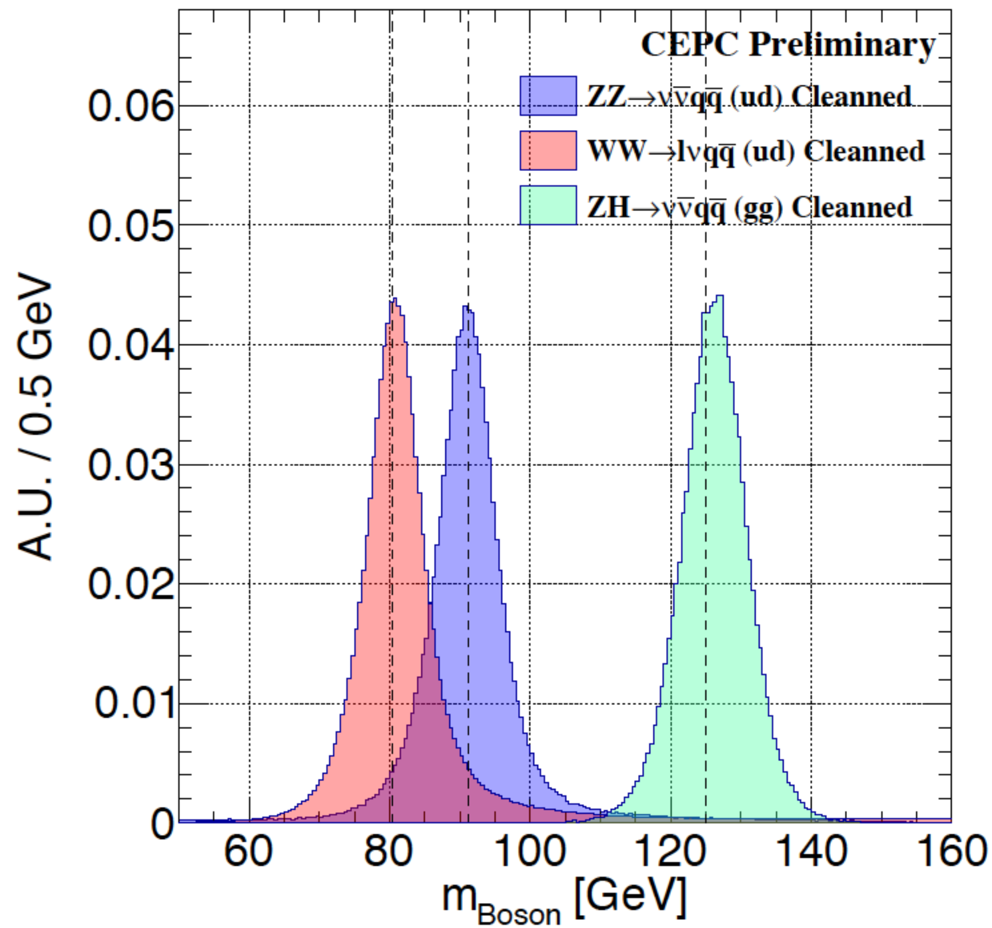
- ZH→qqττ
- Cone based tau finding algorithm, Compromise the efficiency & purity
- Signal efficiency of 51%

Jets

- Boson Mass Resolution: Separate W, Z and Higgs in hadronic decay mode
  - Essential for Higgs measurement
    - Separate Higgs from Z/W (relatively easy)
    - Separate $H \rightarrow ZZ/WW$ events (challenging)
  - Appreciated in Triplet Gauge Boson Coupling measurements
    - Separate WW (Signal) from ZZ, ISR return Z, etc.
  - ...
- Jet Clustering & Single jet response
  - To understand the Degrading induced by Jet Clustering, Matching, etc
  - Search for the most suited jet clustering algorithm (Presumably channel dependent) – Understand the Corresponding Systematic
  - ...

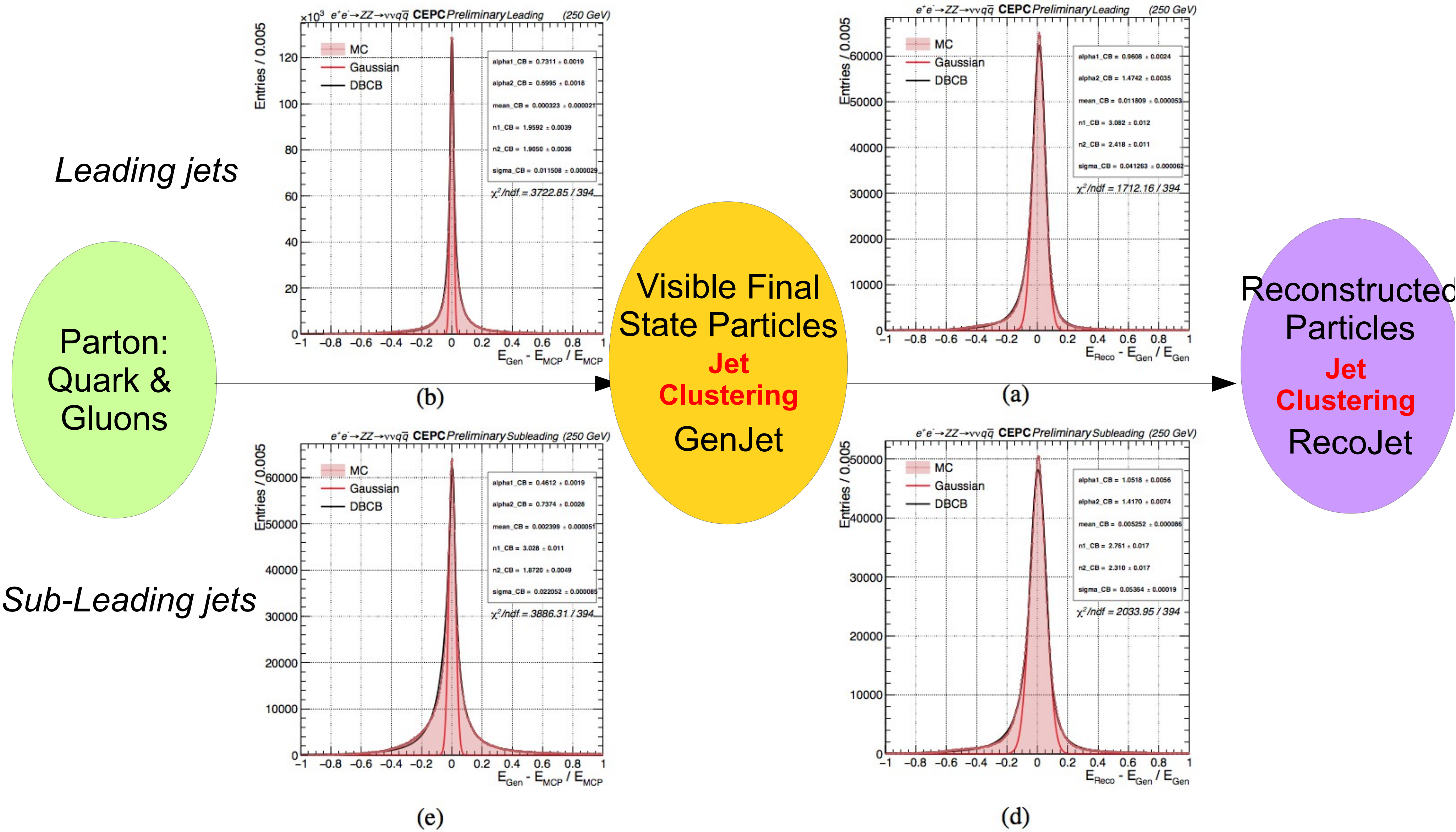
Massive Boson Separation





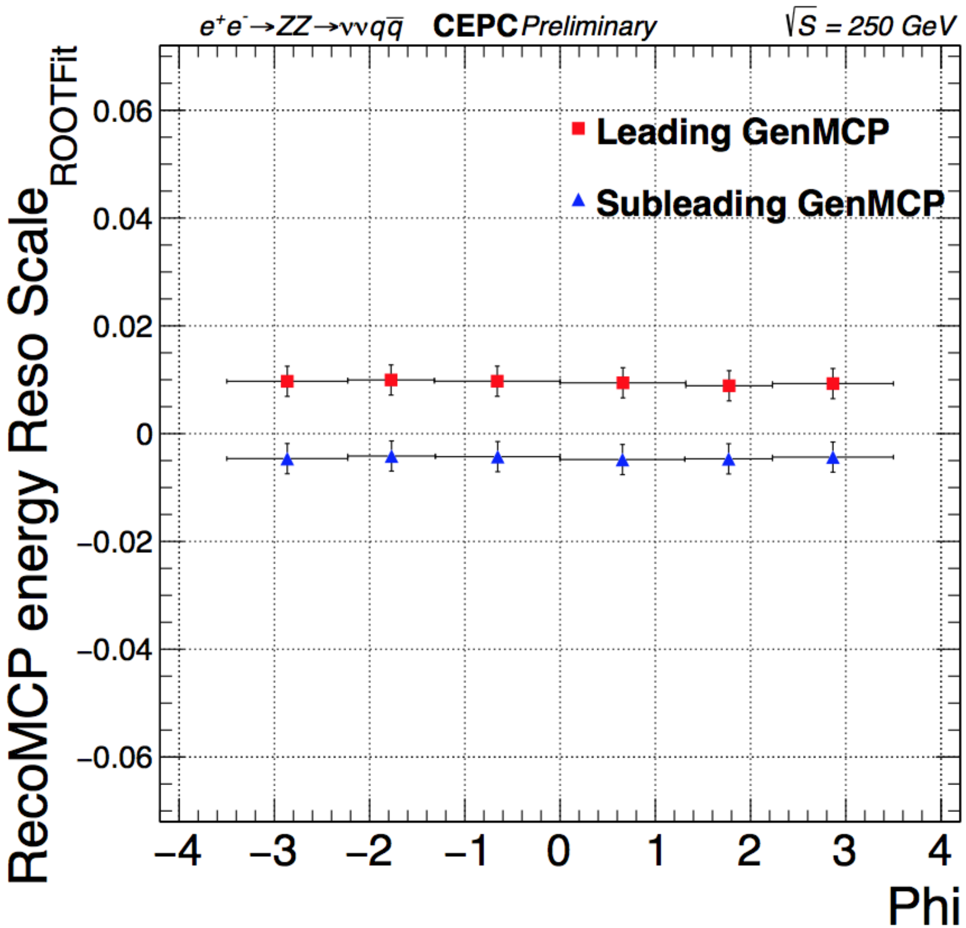
CEPC-RECO-2017-002 (DocDB id-164),
CEPC-RECO-2018-002 (DocDB id-171),
Eur.Phys.J. C78 (2018) no.5, 426

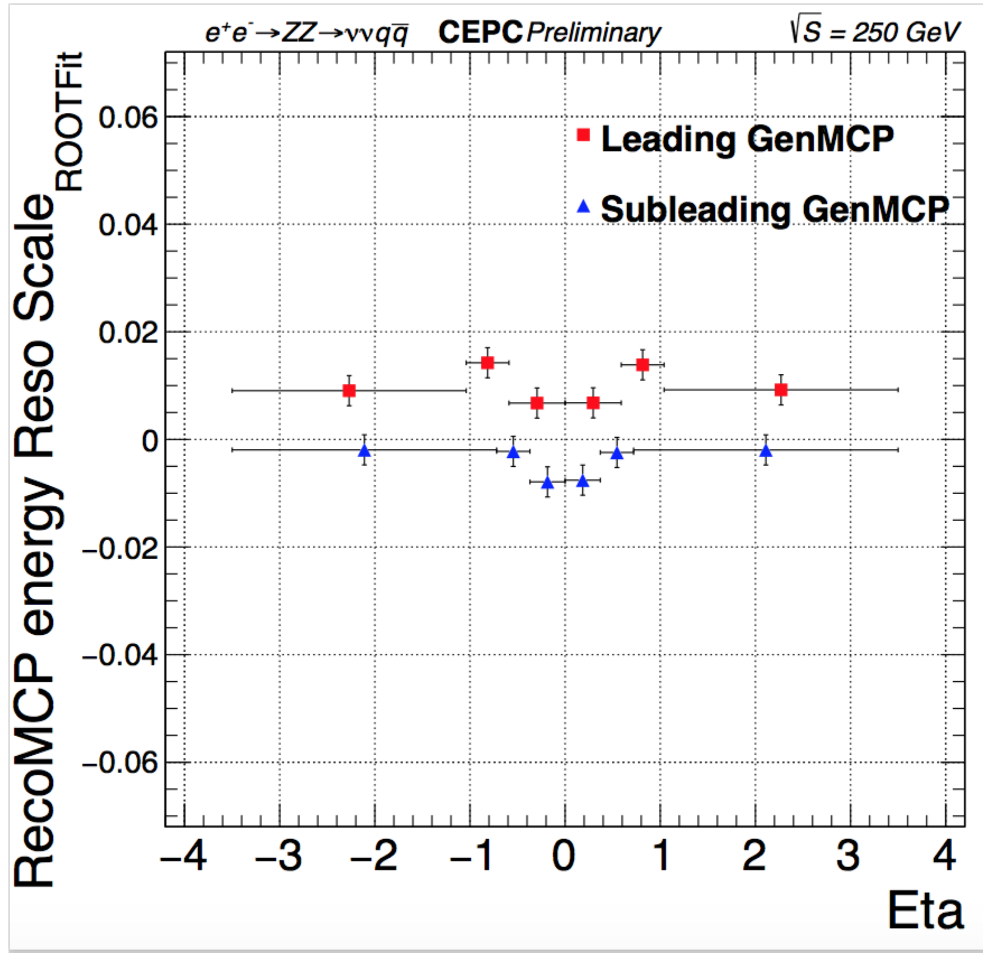
Impact of Jet Clustering: Significant



Jet Clustering is Mainly responsible for the tails

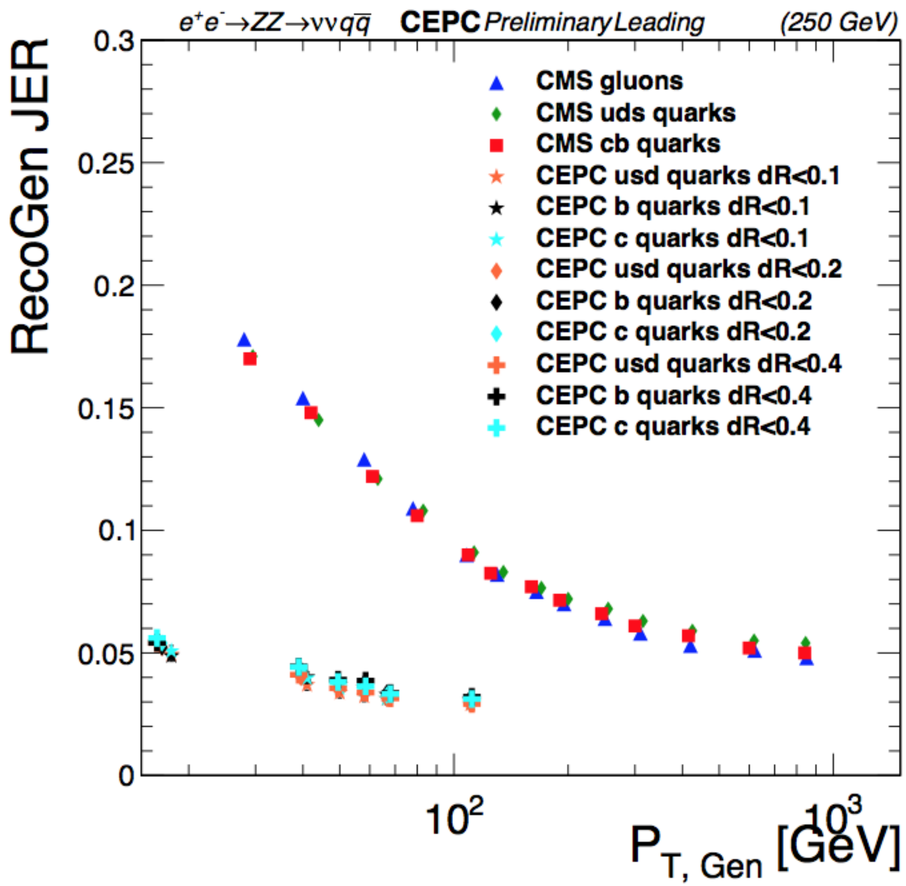
Jet energy Scale

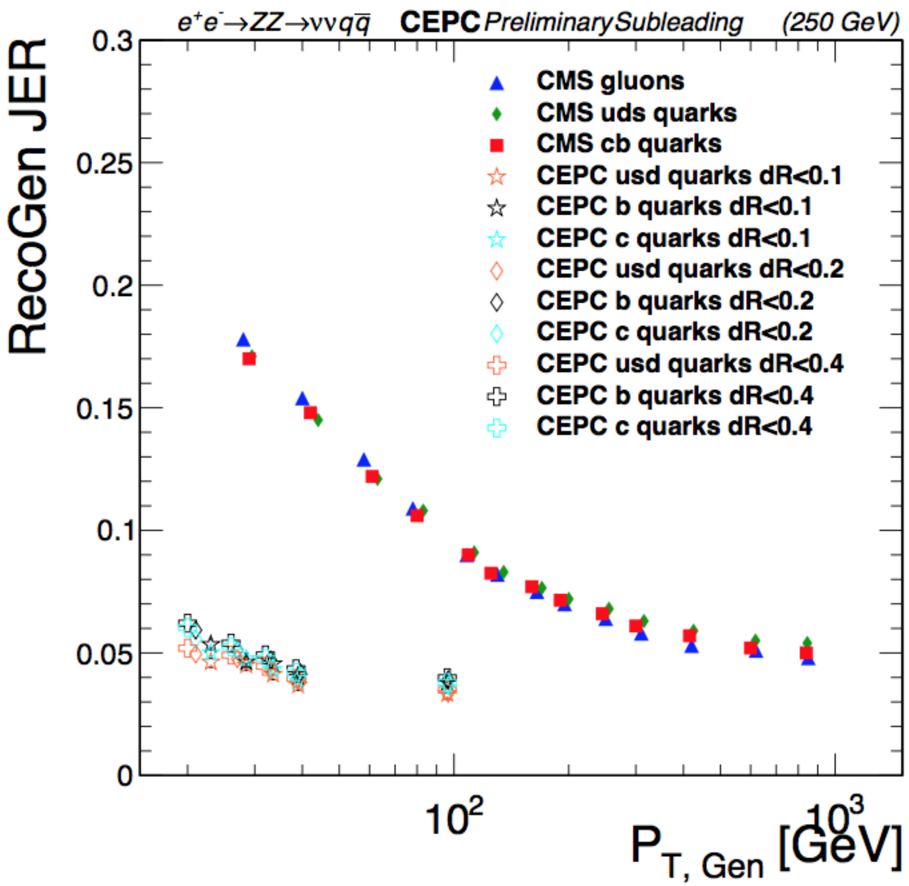




Amplitude ~ 1%
Large JES observed at Leading Jet (Correlated), and at overlap region (Increasing of Splitting)

Jet Energy Resolution



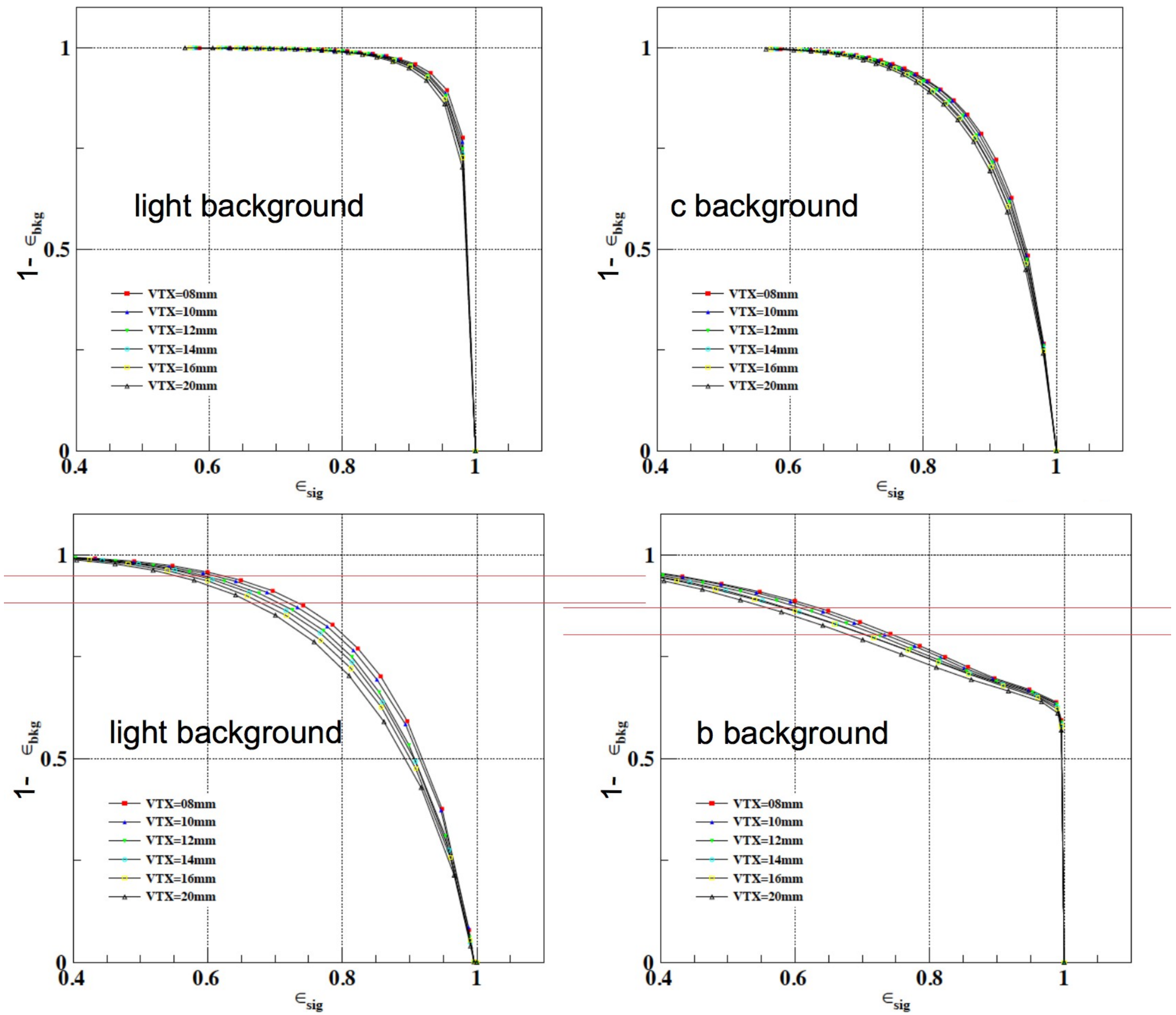


CMS Reference: CMS-JME-13-004,

Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV

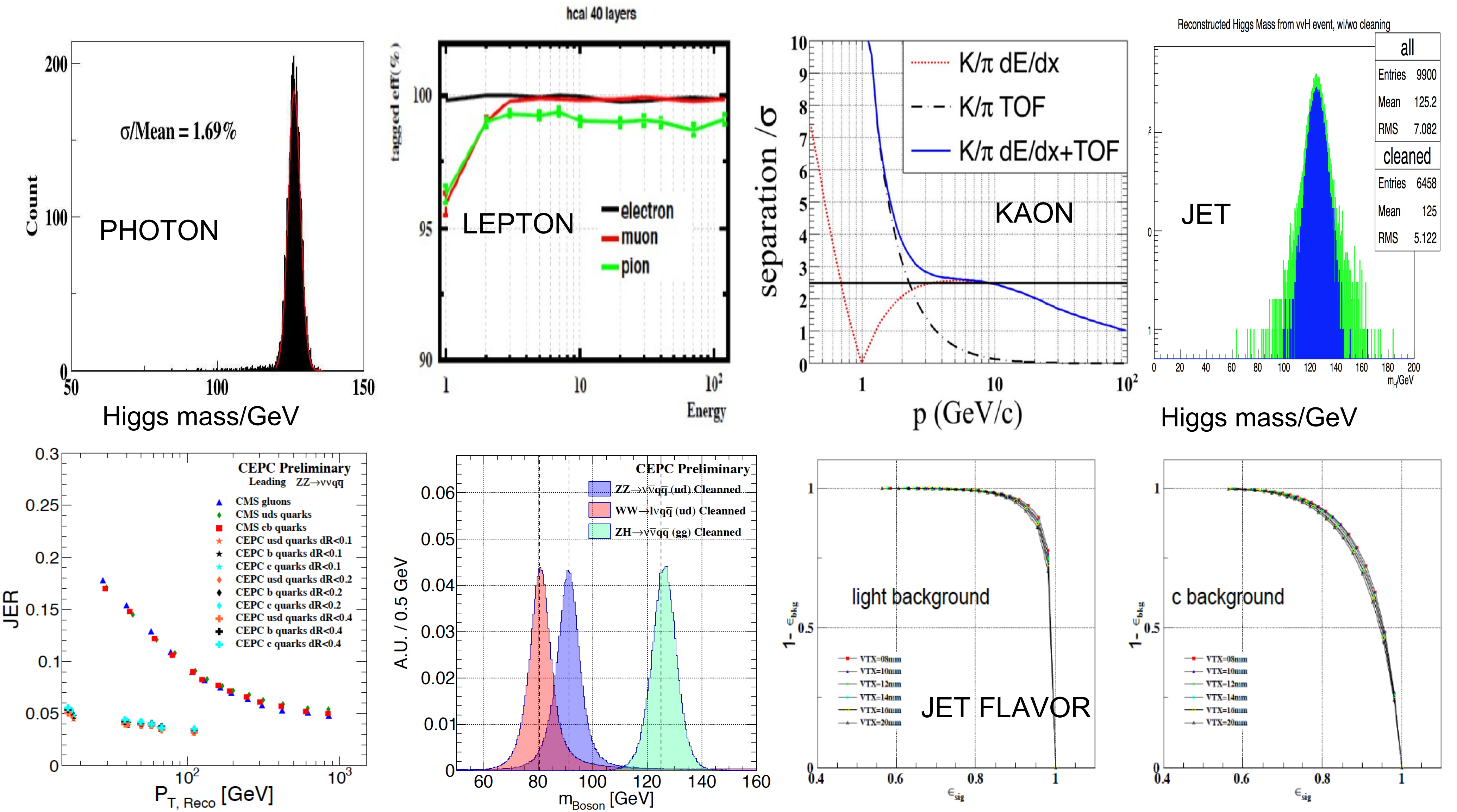
Flavor Tagging

- LCFIPlus Package
- Typical Performance at Z pole sample:
  - *B-tagging: eff/purity = 80%/90%*
  - *C-tagging: eff/purity = 60%/60%*
- Geometry Dependence of the Performance evaluated



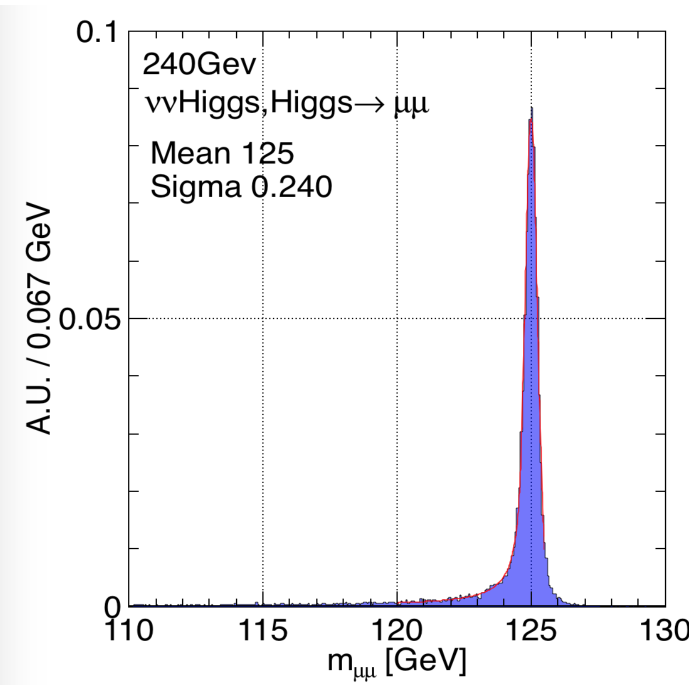
https://agenda.linearcollider.org/event/7645/contributions/40124/

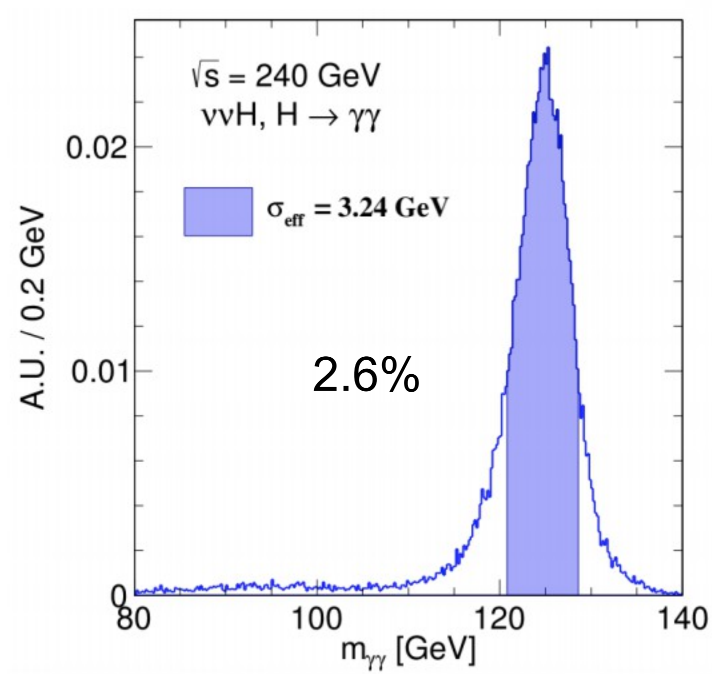
性能：完成所有物理标的物的高精度重建

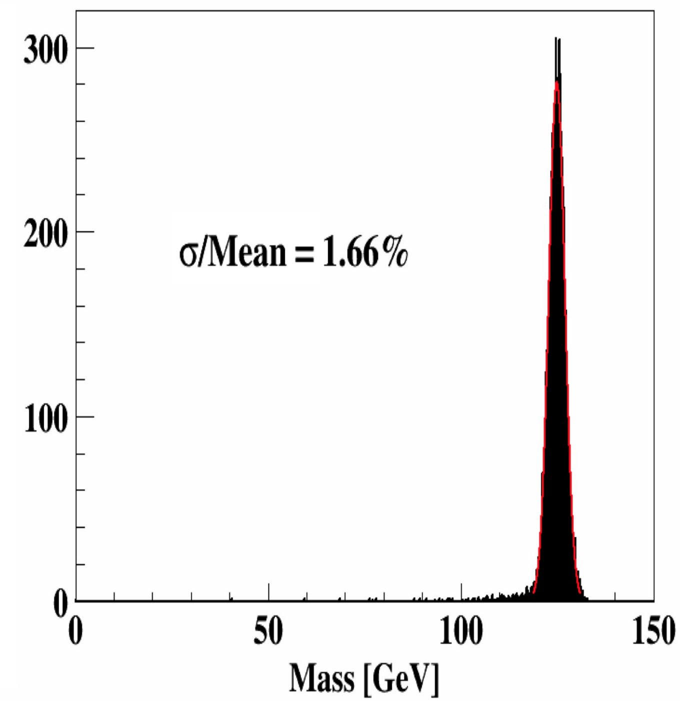


Higgs Signal at APODIS

- Tracks - Leptons & Photons





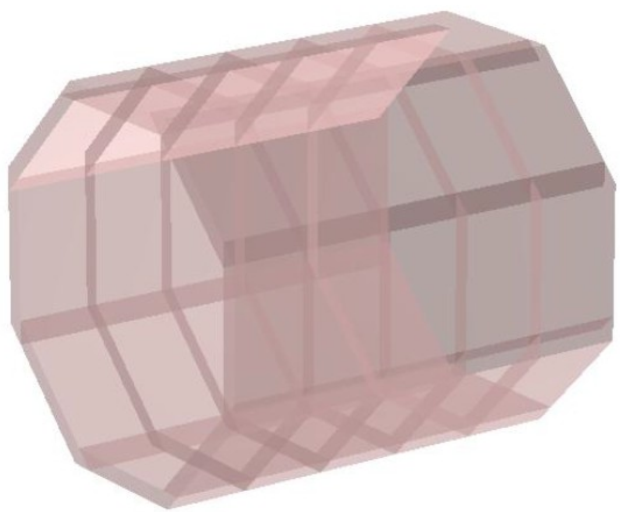


H→γγ at CEPC-v4/Simplified geometry

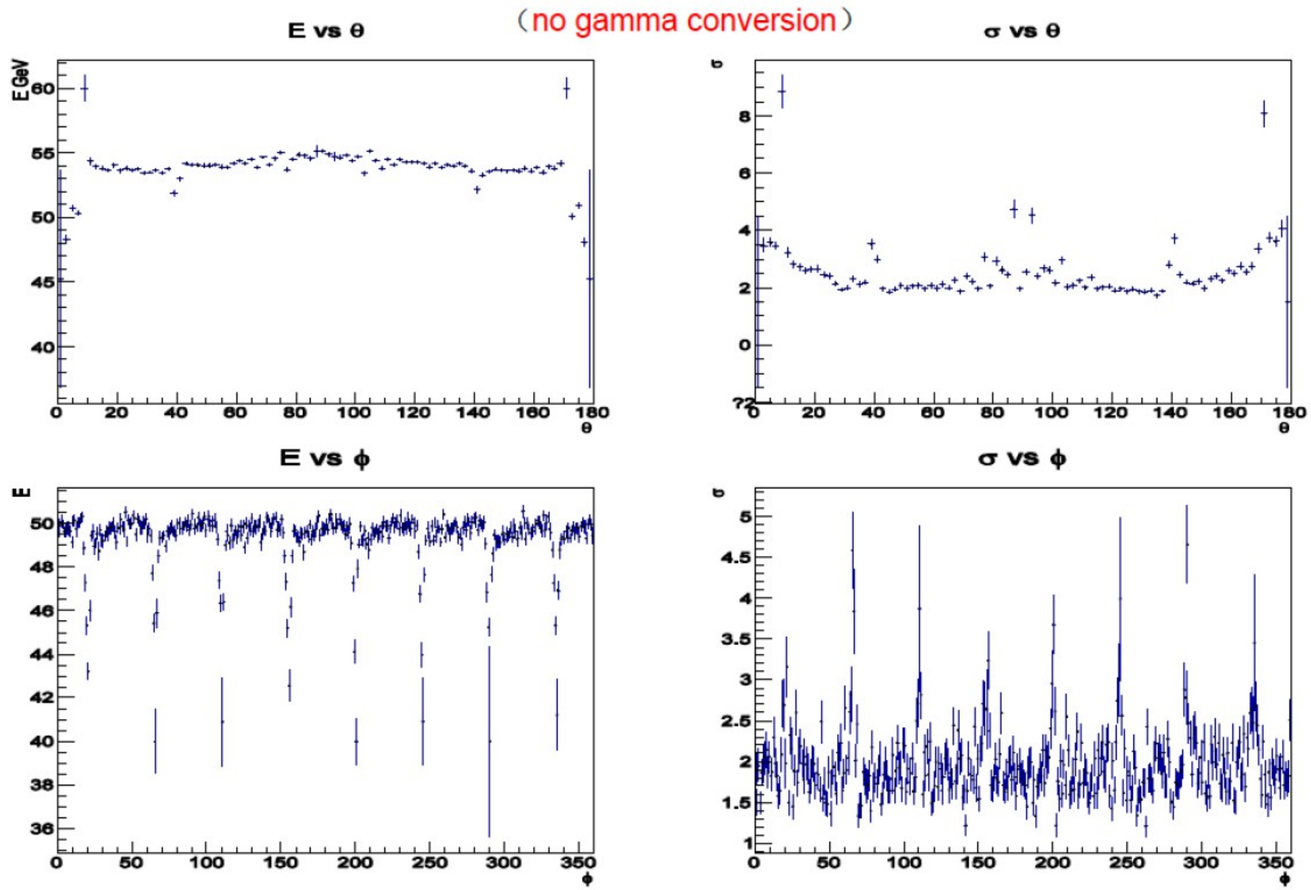
CEPC-RECO-2018-002
CEPC-Doc id 174, 175

Asymmetric tails in CEPC-v4 induced by geometry defects need careful geometry corrections

Arbor: photon reconstruction

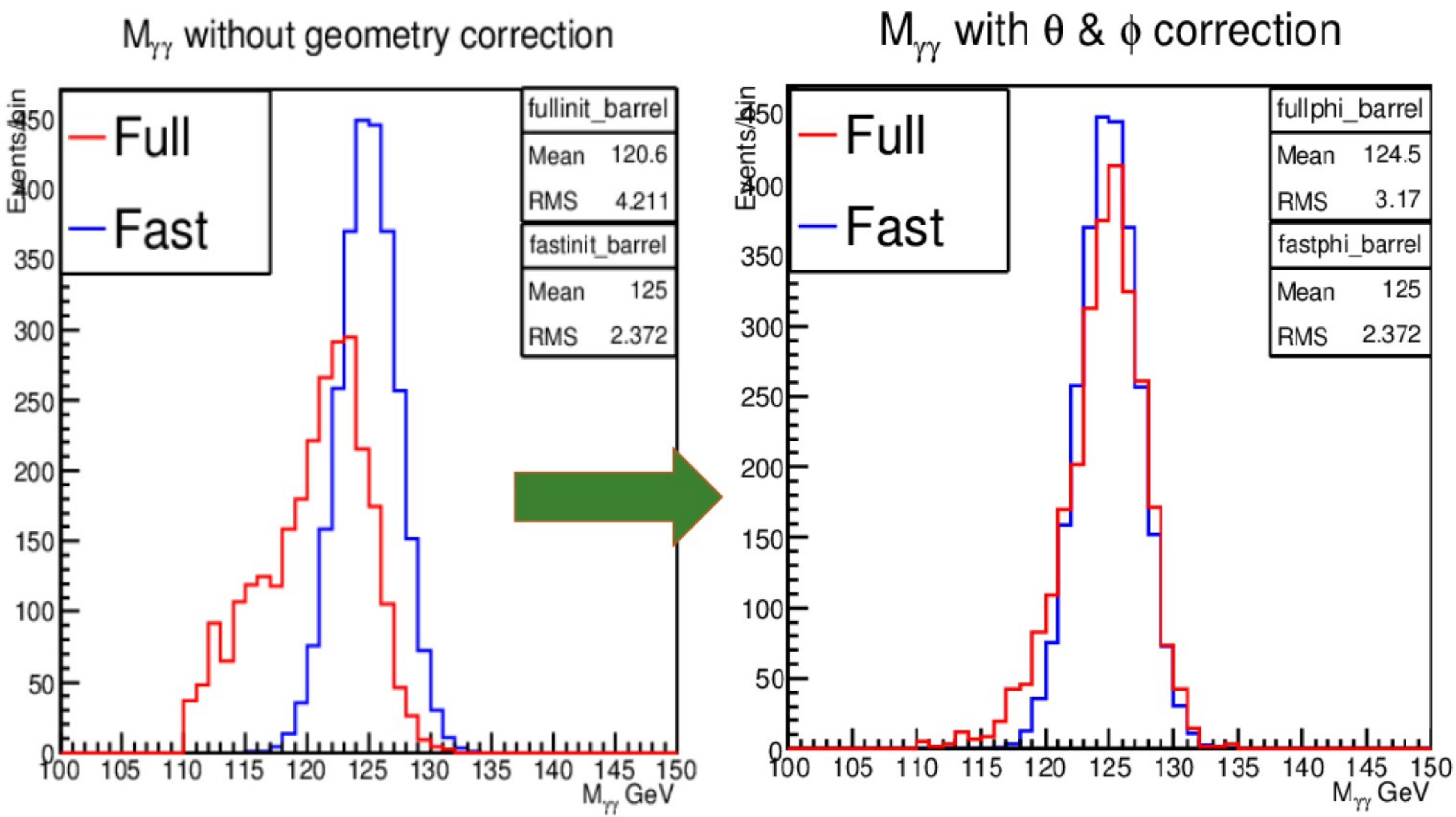


ECAL Barrel of ILD/CEPC_v1

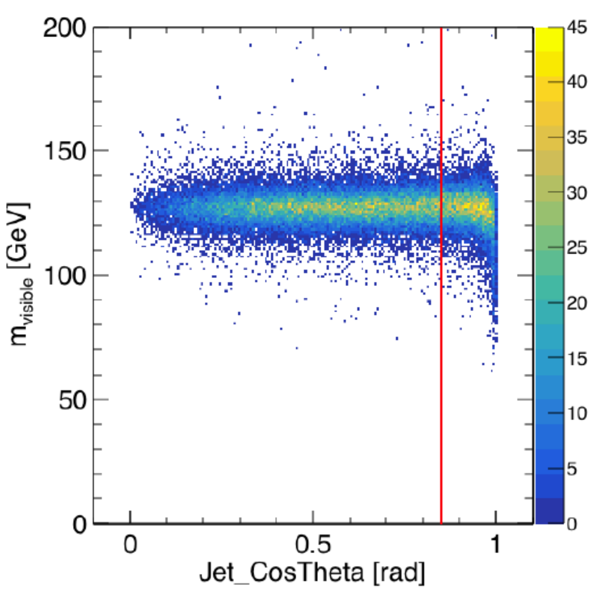


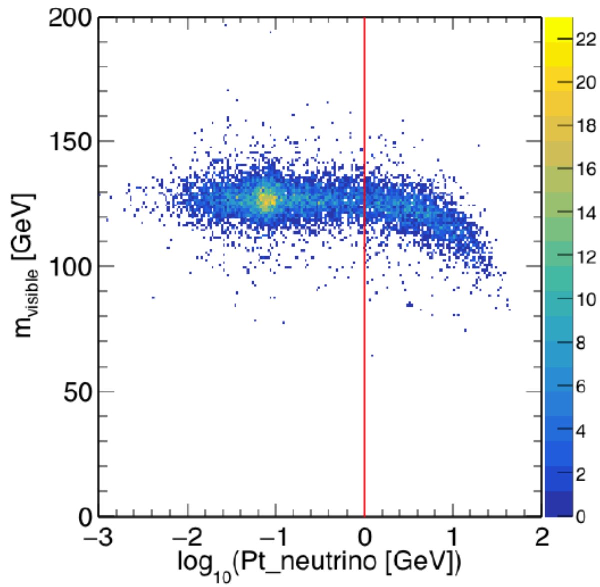
Angular Correlation of EM Shower energy response

Arbor: photon reconstruction



H to gluons: total visible mass





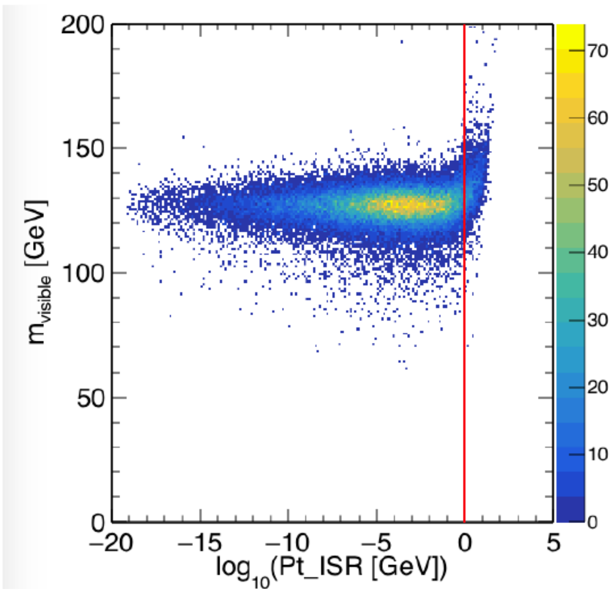
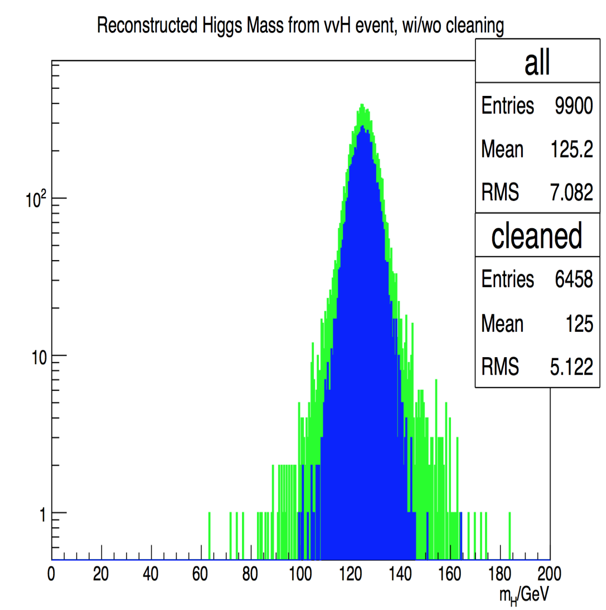


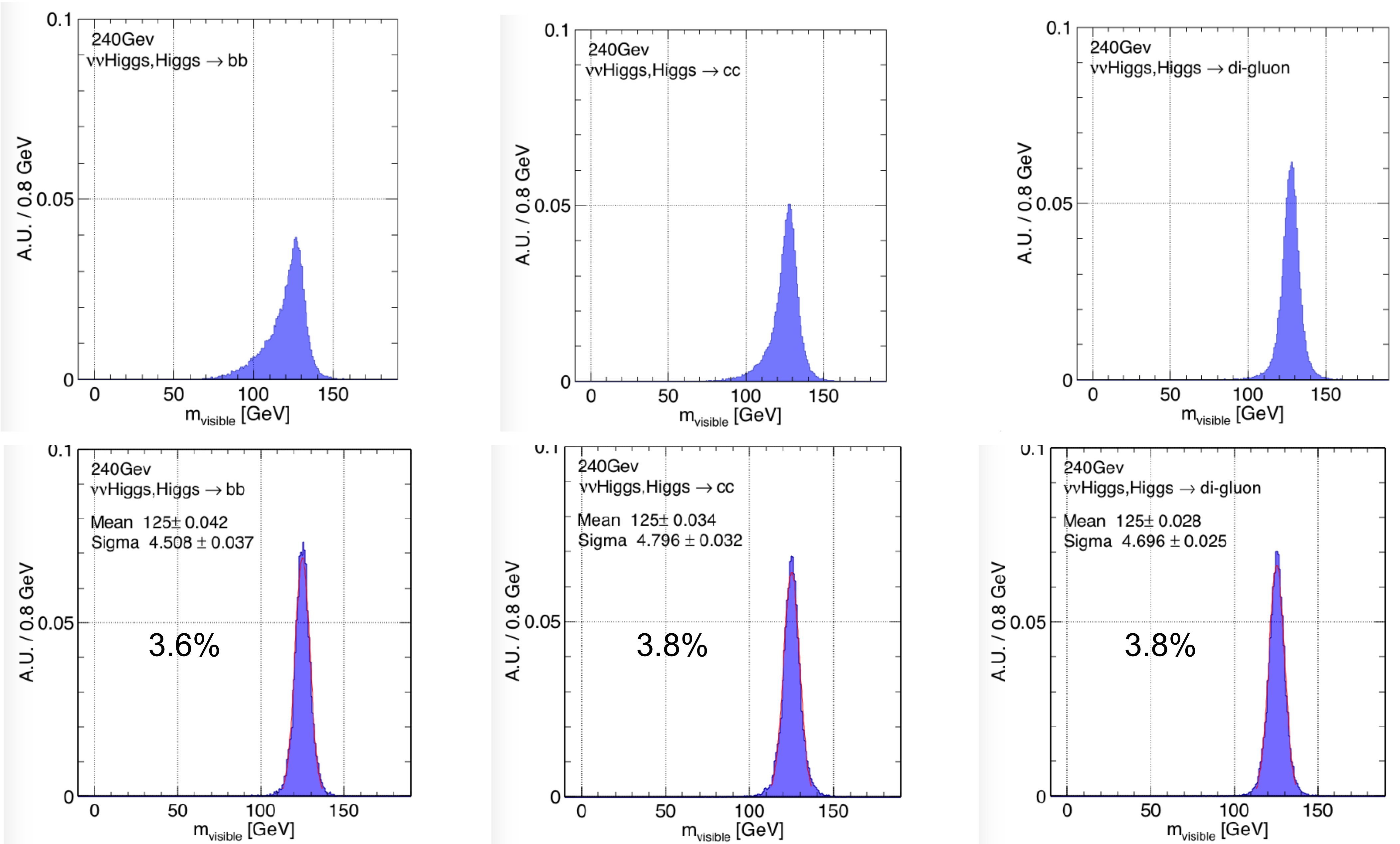
Table 1. Event selection efficiency for Higgs boson exclusive decay at CEPC with $\sqrt{s} = 240$ GeV.

	$\mu\mu$	$\gamma\gamma$	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%



Welcome Jianming!

Higgs to bb, cc, gg



Higgs to WW, ZZ

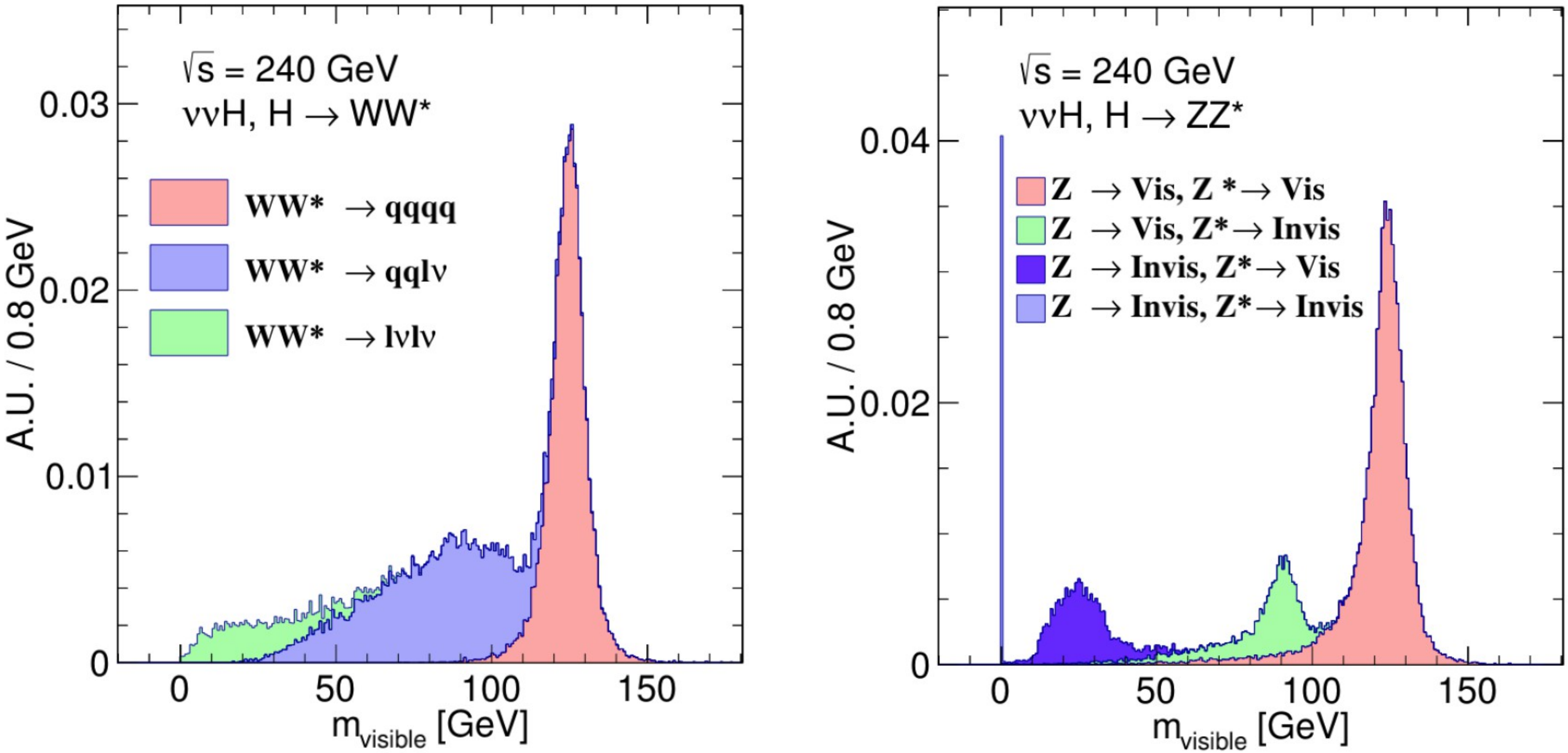


Table 2. Benchmark resolutions ($\sigma/Mean$) of reconstructed Higgs boson mass, comparing to LHC results.

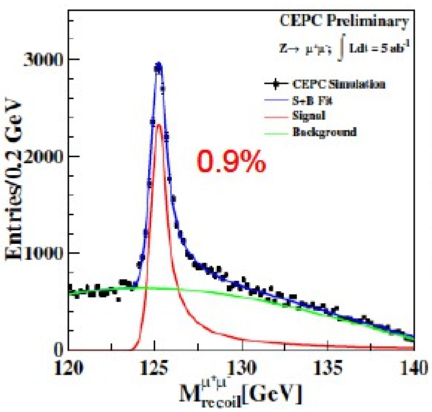
	Higgs→ $\mu\mu$	Higgs→ $\gamma\gamma$.	Higgs→bb
CEPC (APODIS)	0.20%	2.59%[1]	3.63%
LHC (CMS, ATLAS)	~2% [19, 20]	~1.5% [21, 22]	~10% [23, 24]

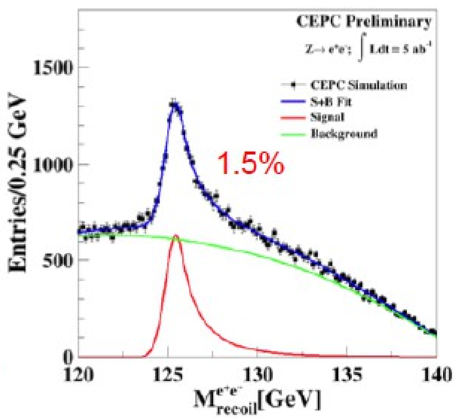
[1] primary result without geometry based correction and fine-tuned calibration. https://arxiv.org/abs/1806.04992

Benchmark Higgs Analysis

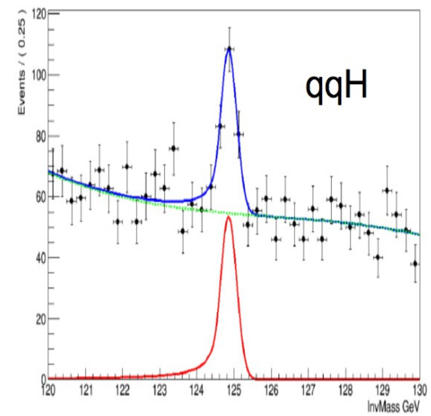
We are preparing Higgs white paper in preparation

Zhenxing Chen & Yacine Haddad

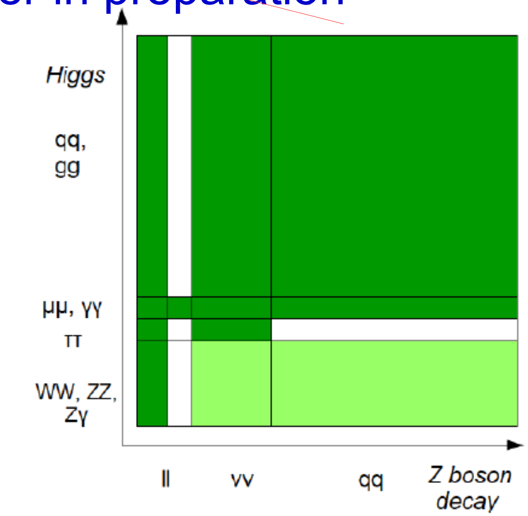




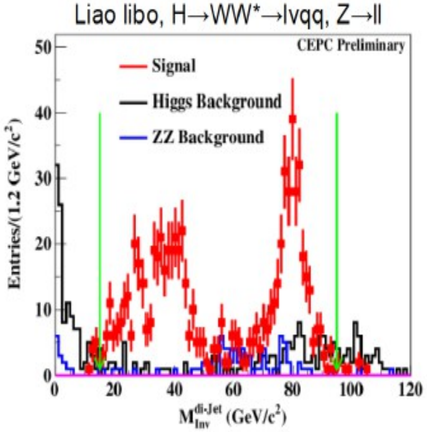
σ(ZH) measurements



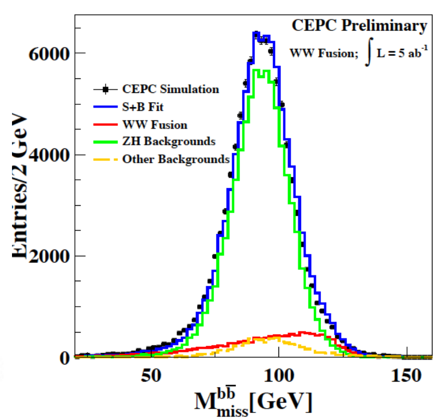
Br(H→μμ)



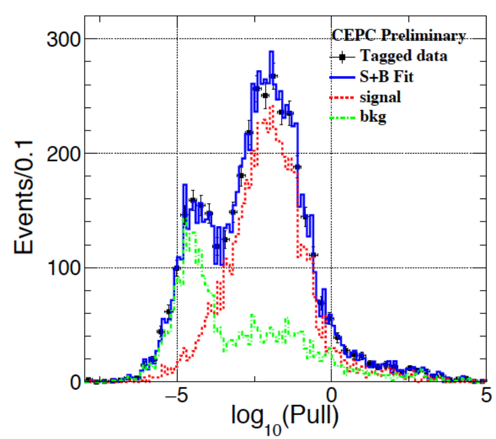
Liao libo, H→WW*→lνqq, Z→ll



Br(H→WW)



σ(ννH)*Br(H→bb)



Br(H→ττ)

	PreCDR (Jan 2015)	Now (Aug 2016)
σ(ZH)	0.51%	0.50%
σ(ZH)*Br(H→bb)	0.28%	0.21%
σ(ZH)*Br(H→cc)	2.1%	2.5%
σ(ZH)*Br(H→gg)	1.6%	1.2%
σ(ZH)*Br(H→WW)	1.5%	1.0%
σ(ZH)*Br(H→ZZ)	4.3%	4.3%
σ(ZH)*Br(H→ττ)	1.2%	1.0%
σ(ZH)*Br(H→γγ)	9.0%	9.0%
σ(ZH)*Br(H→Zγ)	-	~4 σ
σ(ZH)*Br(H→μμ)	17%	12%
σ(ννH)*Br(H→bb)	2.8%	2.8%
Higgs Mass/MeV	5.9	5.0
σ(ZH)*Br(H→inv)	95%. CL = 1.4e-3	1.4e-3
Br(H→ee/emu)	-	1.7e-4/1.2e-4
Br(H→bbχχ)	$<10^{-3}$	3.0e-4

Most operated with CEPC-v1 @ 250 GeV (PreCDR set up)
Several key benchmarks are re-performed in APODIS

Issues to be addressed

- Tracking
  - Dedx/material effect correction (induces o(100) MeV bias in Higgs mass at in H->mumu) (20, 30, 20)
  - Development, Performance analysis & Integration of CEPC tracking (Arbor & Conformal & ...) (50, 90, 90)
- PFA
  - Cluster energy estimator development
    - Photon (EM Shower) Geometry dependent energy correction (50, 90, 20)
    - HAD? (40, 50, 50)
  - Usage of Timing information... (60, 90, 80)
  - Optimization of HCAL geometry (50, 60, 70)
- Lepton ID & P ID:
  - Integration & Usage of Timing information (60, 80, 20)

Urgency, Importance, Difficulties

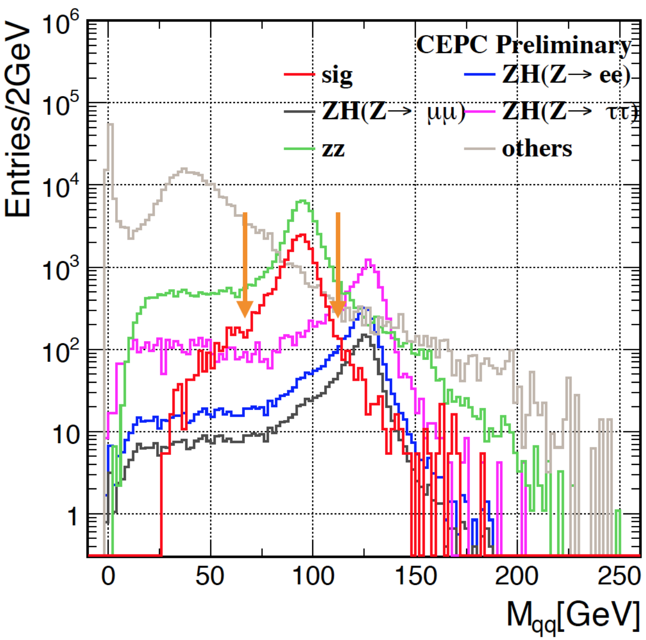
Issues to be addressed

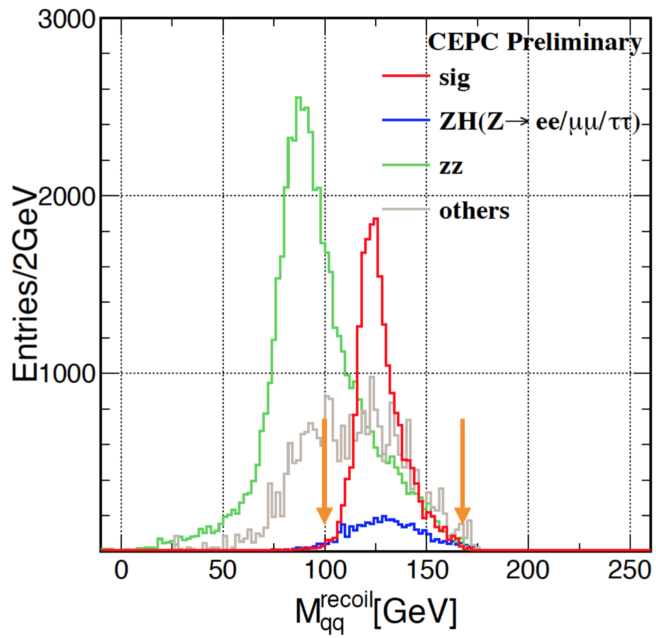
- Composited object finder: **CORAL** (finding Pi0, Kshort, Lambda, J/Psi, ...)
  - Framework is ready... and lots of performance study and optimization awaits (40, 90, 50)

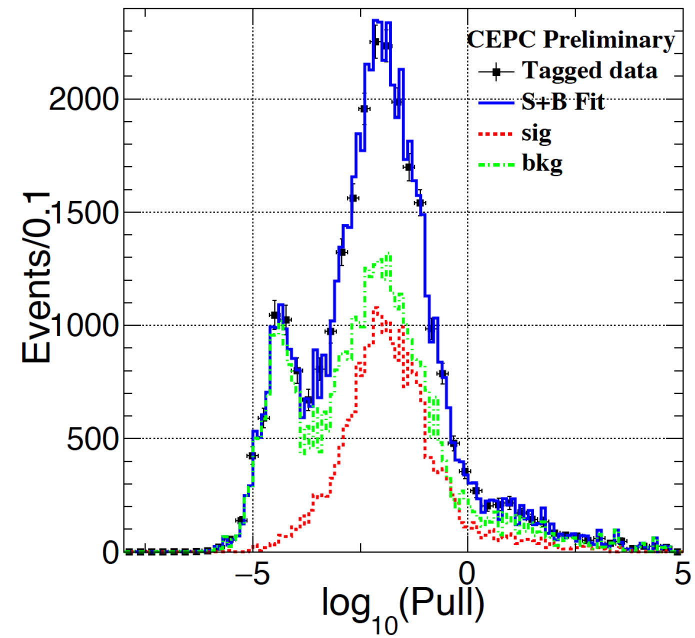
Urgency, Importance, Difficulties

- Jets
  - Jet Clustering: finding the color singlet? (40, 90, 90)
  - Distinguish between 2 jet, 3 jet, 4jet, 5jet, 6jet events.... (80, 80, 60)
    - Mila's analysis (ZH->6 jets) gives a very good example
- **Jet Flavor Tagging** (**90**, **99**, **80**)
  - The efficiency of reconstruct 2nd Vertex in Z->cc events is ONLY 20%!!!
- Separation of gluon to quark jets? (**50**, **50**, 50)
- Usage of Deep learning at reconstruction... (**30**, **90**, 50)
- ...Lots Lots of Detector Optimization & Integration....

An Analysis Example (Dan): *g(Hττ)* at qqH







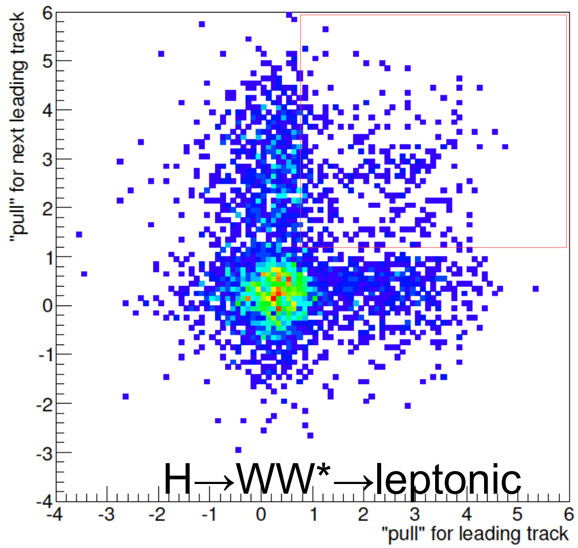
- Cone based tau finding: di-tau system
- The other particles are define as the di-jet system: to distinguish the qqττ background
- Isolated tracks are intensionally defined as tau candidate: be distinguished by the VTX

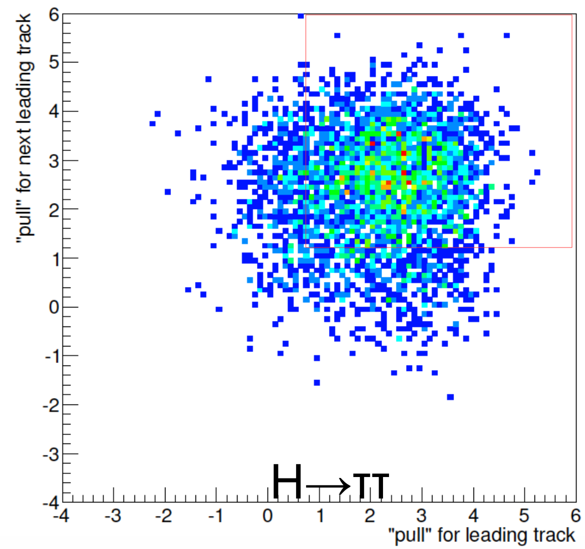
	m_{jj}	$m_{jj\text{-recoil}}$
Signal: Z(qq)H(ττ)	91.2	125
Z(ττ)H(qq)	125	91.2
ZZ	91.2	91.2

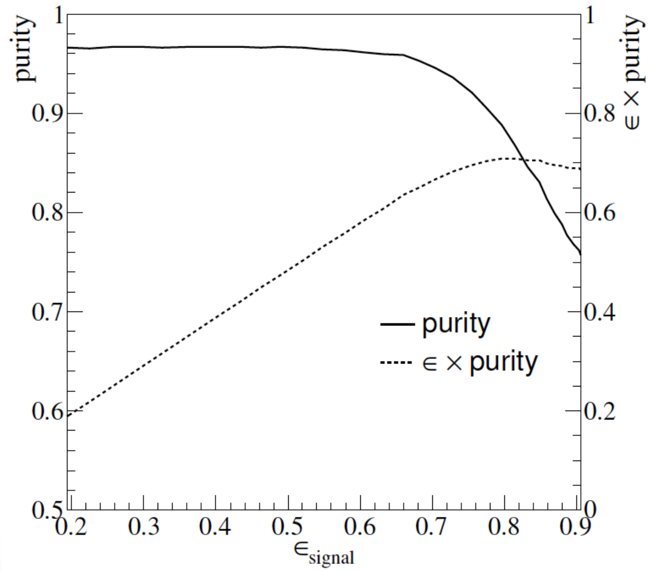
Ph.D thesis of D. Yu

An Optimization example (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%





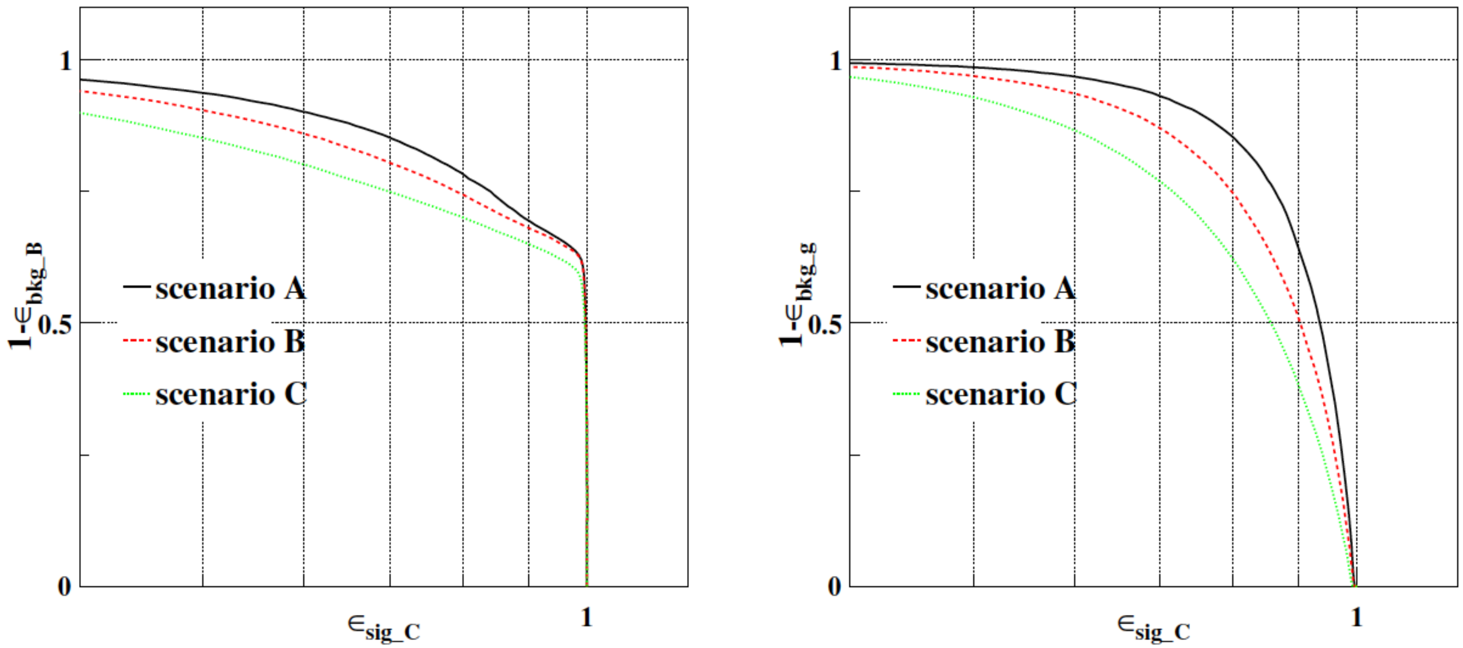


situations	best	baseline	worst
$\epsilon \cdot$ purity	0.77±0.01	0.71±0.01	0.68±0.01

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

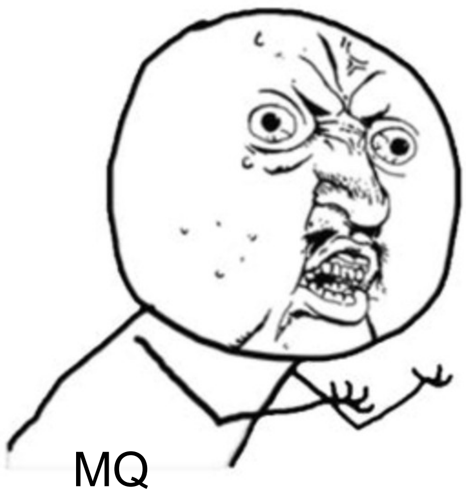
Table 2. Reference geometries

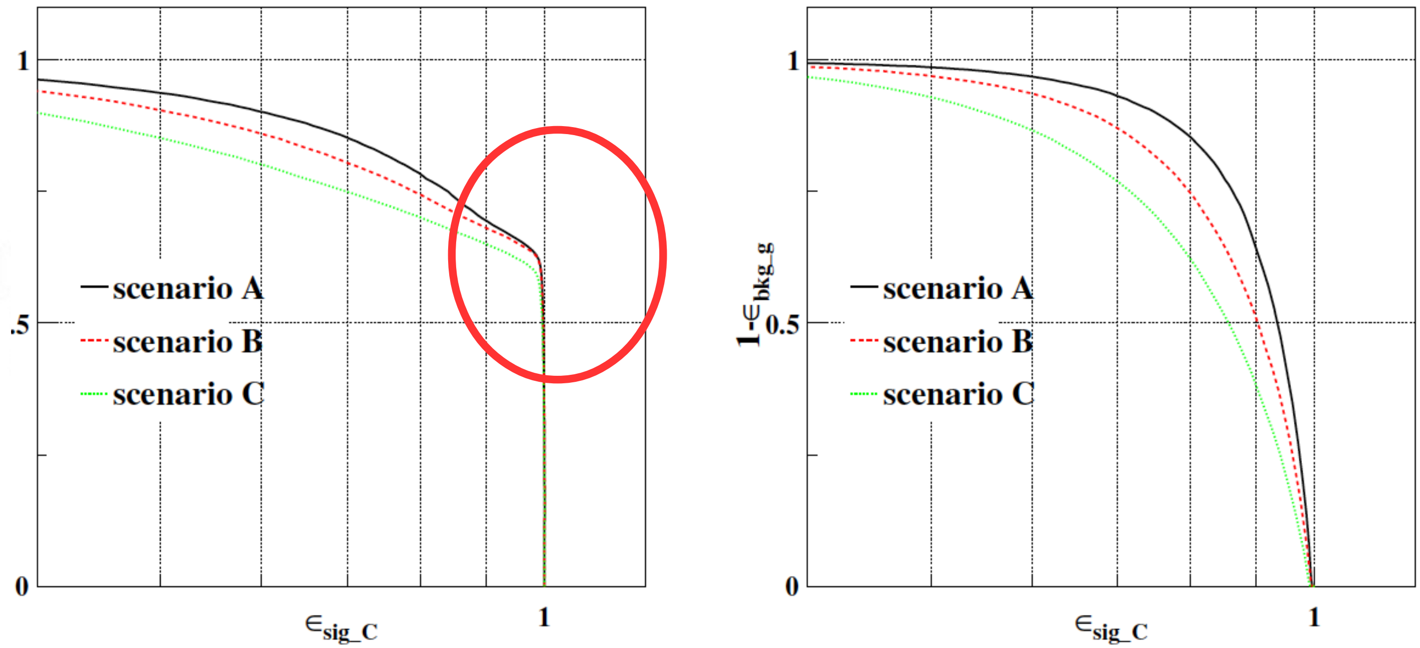
	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
Material per layer/X_0	0.075	0.15	0.3
Spatial resolution/μm	1.4 - 3	2.8 - 6	5 - 10.7
R_{in}/mm	8	16	23

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

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

But c-tagging??



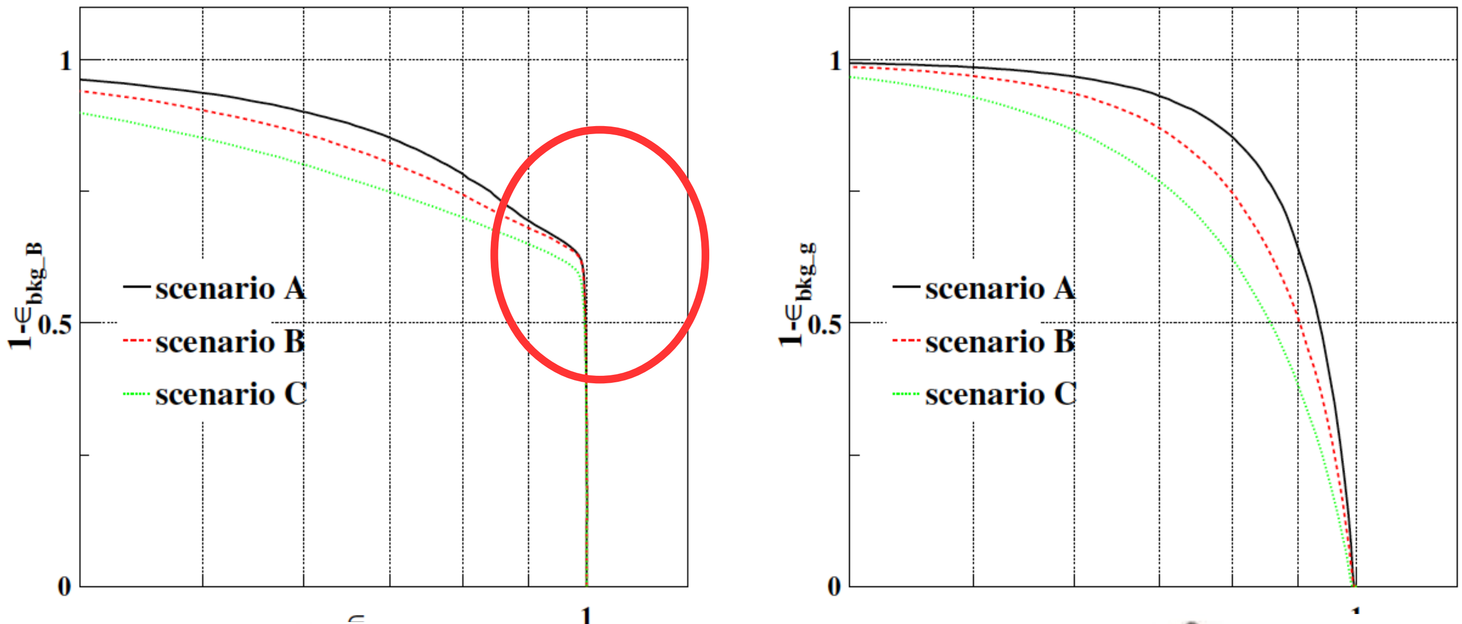


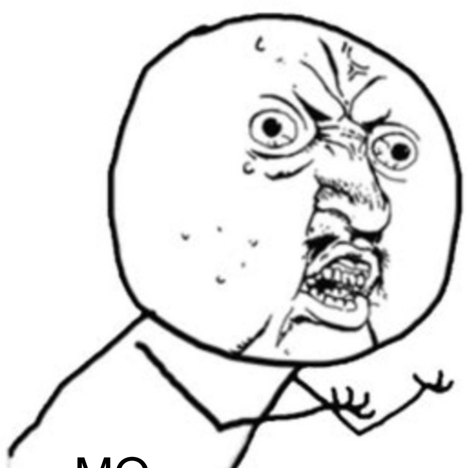
(a) b background

(b) g background

Figure 2. The ROC curve of c-tagging at different scenarios for b background (a) and g background (b).

But c-tagging??



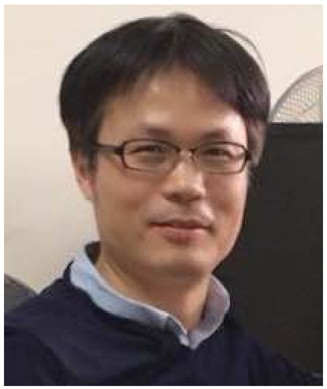


MQ

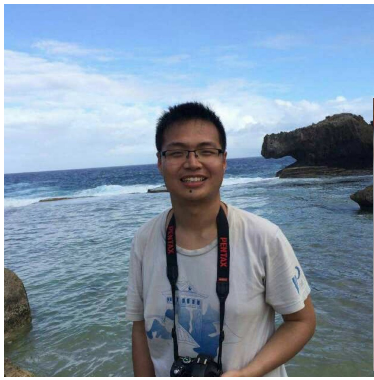
LG

Figı ... ging at differ ... ound (b).

软件队伍



成栋：几何及寻迹



新人：赵祥虎 软件－计算

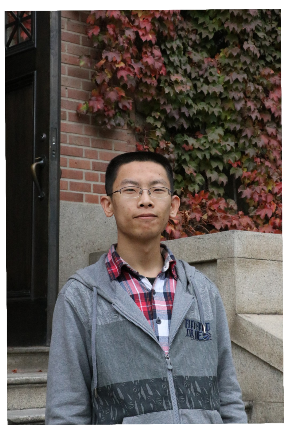
于丹：轻子甄别 PFA，tau

新人：赖培筑 喷注

安芬芬：Pid，软件

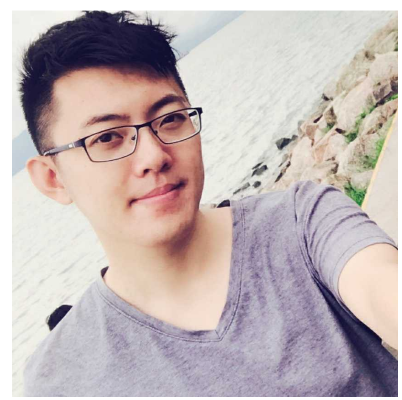
吴志刚 顶点优化

徐音：几何



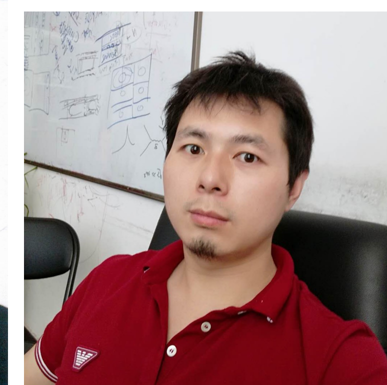
赵明锐：寻迹，软件

李刚：产生子，喷注味道甄别



赵航：PFA，量能器优化

李亮：轻子



曼奇：探测器设计软件，分析

Summary

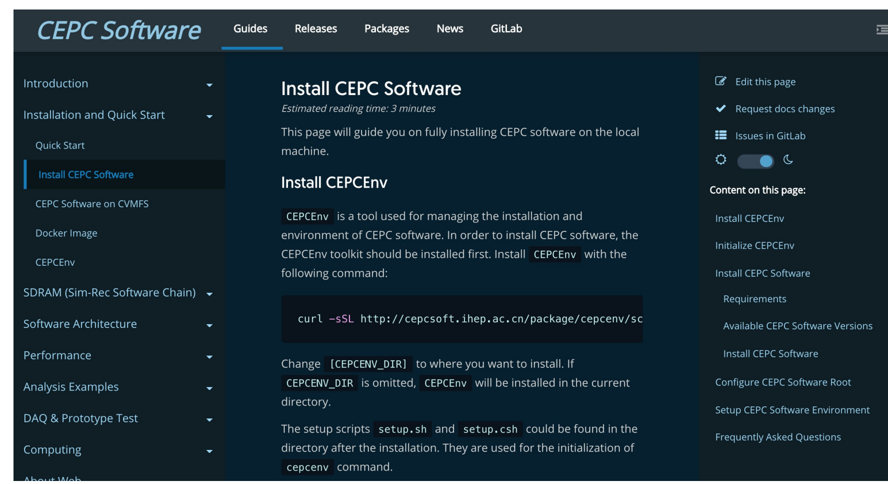
- The Particle Flow oriented detector is well established and serves as the baseline detector for the CEPC CDR studies
  - High efficiency/accuracy reconstruction of all key physics objects;
  - Clear Higgs signature in all SM Higgs decay mode
  - **Mature software/reconstruction tool/team**
- APODIS, Optimized for the CEPC collision environments
  - Significantly reduced B-Field (15%), #readout channels (75% in ECAL) & HCAL layer-thickness (20%) & cost (15%/30% w.r.t CEPC-v1/ILD)
  - Same Higgs performance & enhanced Pid Performance
  - Iterate with hardware studies
- Todo:
  - Physics study, especially flavor tagging & EW measurements (τ leptons)
  - Towards the TDR, **Integration**, Sub detector modeling, **Systematic** Studies

Summary

- My personal suggestion for the physics analysts
  - **Understand profoundly** your key object(s), final states, and distributions
  - Take reference to the performance study of APODIS, if that's not consistent with what you observed in both Signal/Background – try to understand what happened before you process further
  - Join the reconstruction development and made your own object!
- Contacts
  - **Chengdong**, Yin: For the Detector Geometry
  - **Xianghu**, Dan, Hang, Yongfeng: sample production status, sample (Bkgrd validation), and software usage
  - Gang: For massive production request, flavor tagging and analysis framework
  - Yaquan: ...If you got crazy with statistics/analysis skills...
  - Manqi: ...when you don't know who else you can contact...

Advertise

- 软件：
  - 怎么装？
  - 怎么知道装对了？
  - 怎样正确设置（版本，版本，版本！）？
- 样本：
  - 去哪找？
  - 没有怎么办？（提交申请！！）
  - 要等多久能产生？
- 我有资源，怎么贡献？



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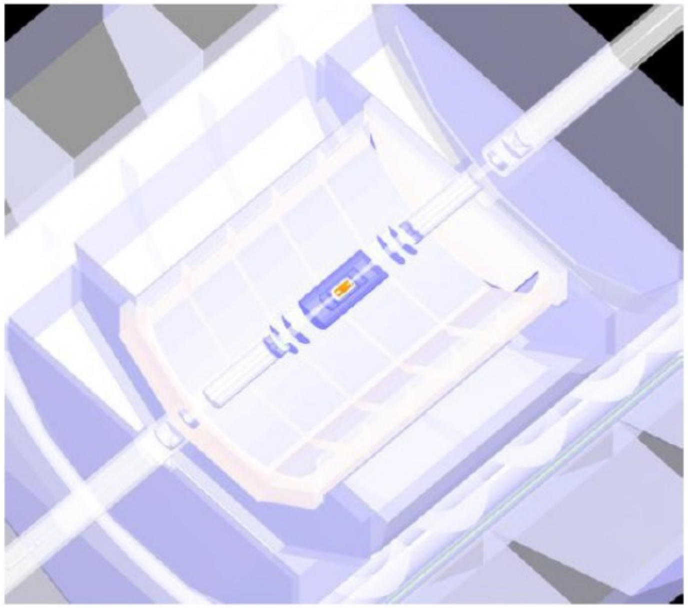
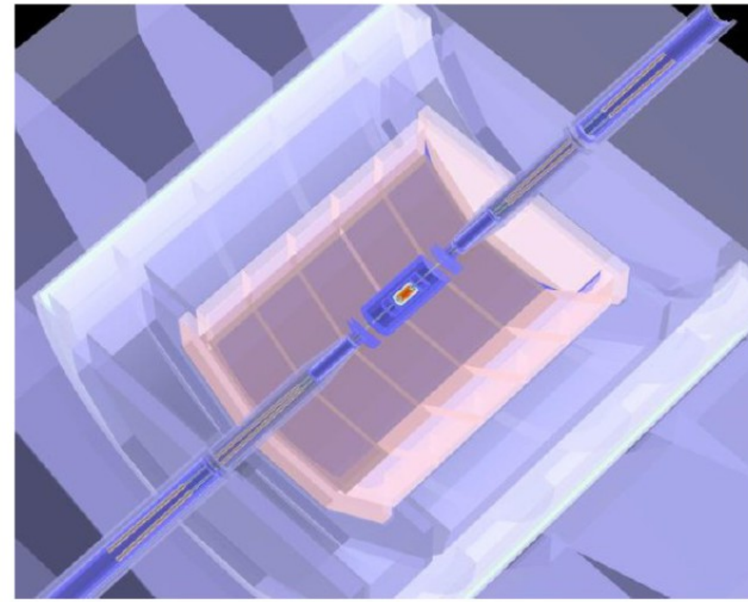
backup

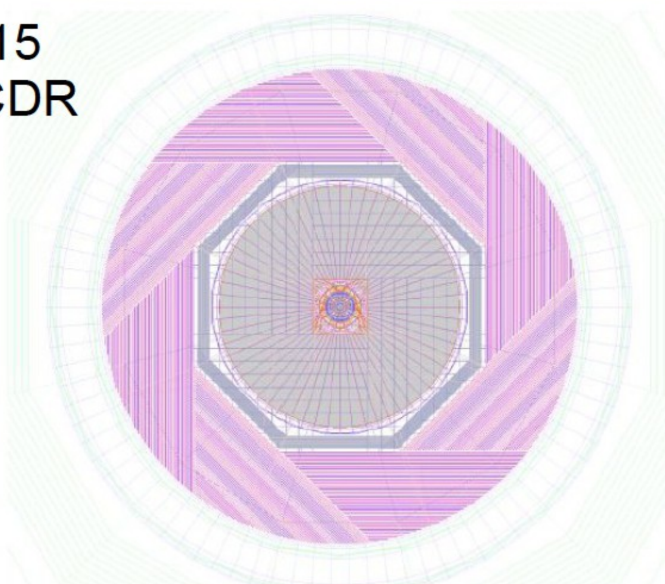
Benchmark detector for CDR: APODIS

(A PFA Oriented Detector for HIggS factory. a.k.a CEPC_v4)





2015
PreCDR



2017
CDR

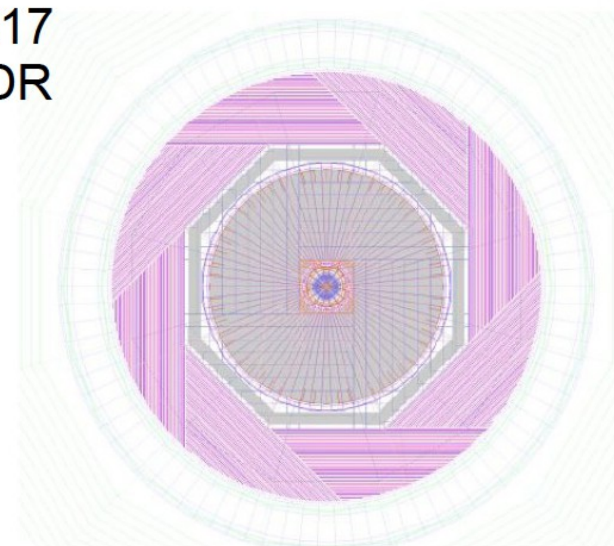
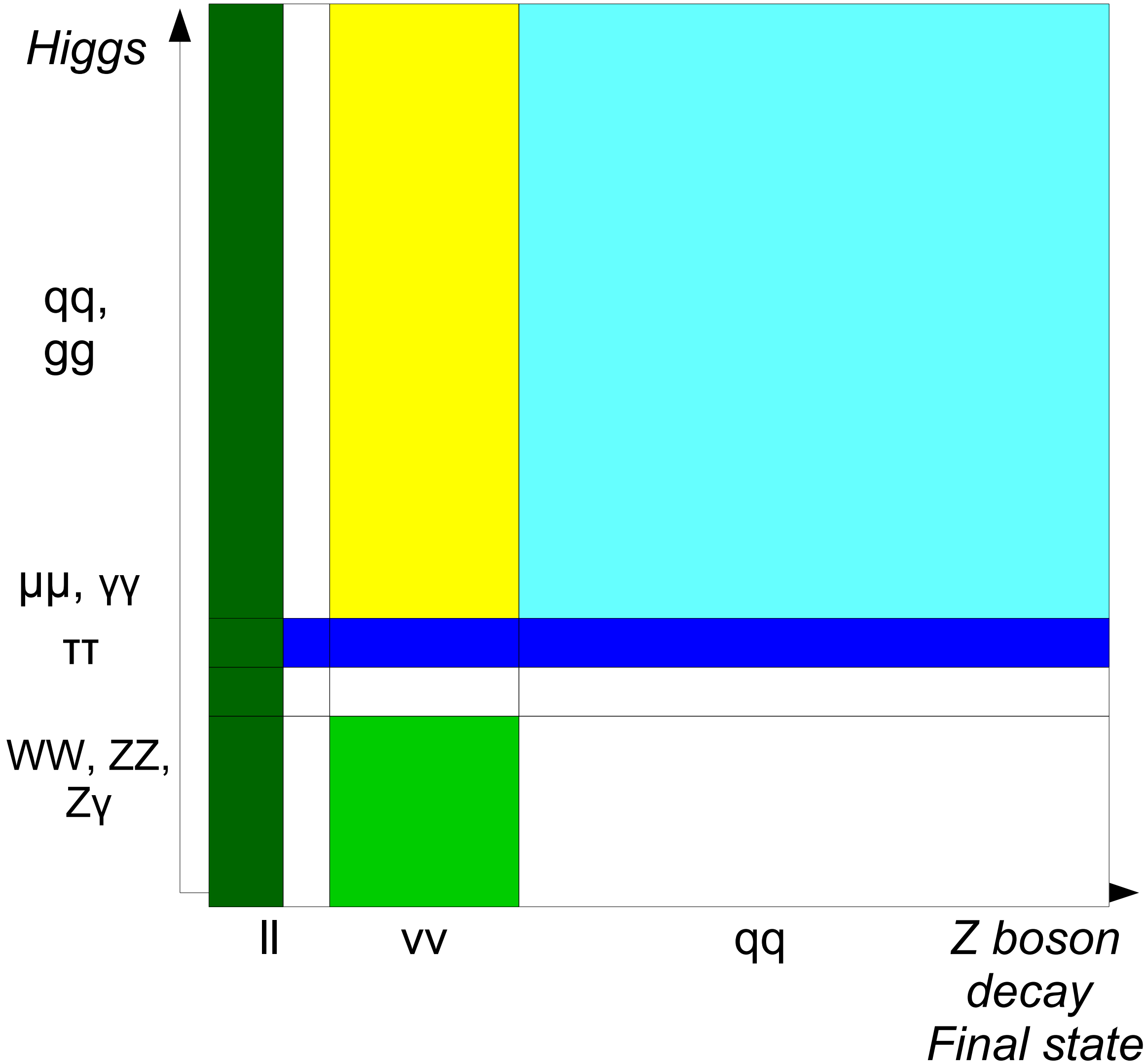


Table 9 Cut Flow of MC sample for $qqH \to \tau\tau$ selection on signal and inclusive SM backgrounds

	$qqH\tau\tau$	qqH inclusive bkg	ZH inclusive bkg	ZZ	WW	single$W$	single$Z$	$2f$
total generated (scaled to 5 ab^{-1})	45597	678158	357249	5711445	44180832	17361538	7809747	418595861
1st preselection	45465	677854	310245	5039286	42425195	1267564	1398362	148401031
2nd preselection	45145	174650	226059	293306	12452091	125735	117306	547402
$N_{\tau^+} > 0, N_{\tau^-} > 0$	24674	7342	33721	93955	723989	33887	54386	103642
$20GeV < M_{\tau^+\tau^-}$ < 120GeV	24284	6290	32344	88245	597480	24927	36039	56615
$70GeV < M_{qq}$ <110GeV	22937	2103	4887	65625	21718	738	1893	556
$100GeV < M_{qq}^{Rec}$ <170GeV	22703	2045	4524	23789	13154	315	306	193
efficiency	49.97%	0.31%	1.26%	0.41%	0.04%	<0.01%	<0.01%	$<$ 0.01%

Benchmark measurements



Lepton & Momentum resolution: Br = 6.7%

Flavor Tagging & JER: Br = 14%

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

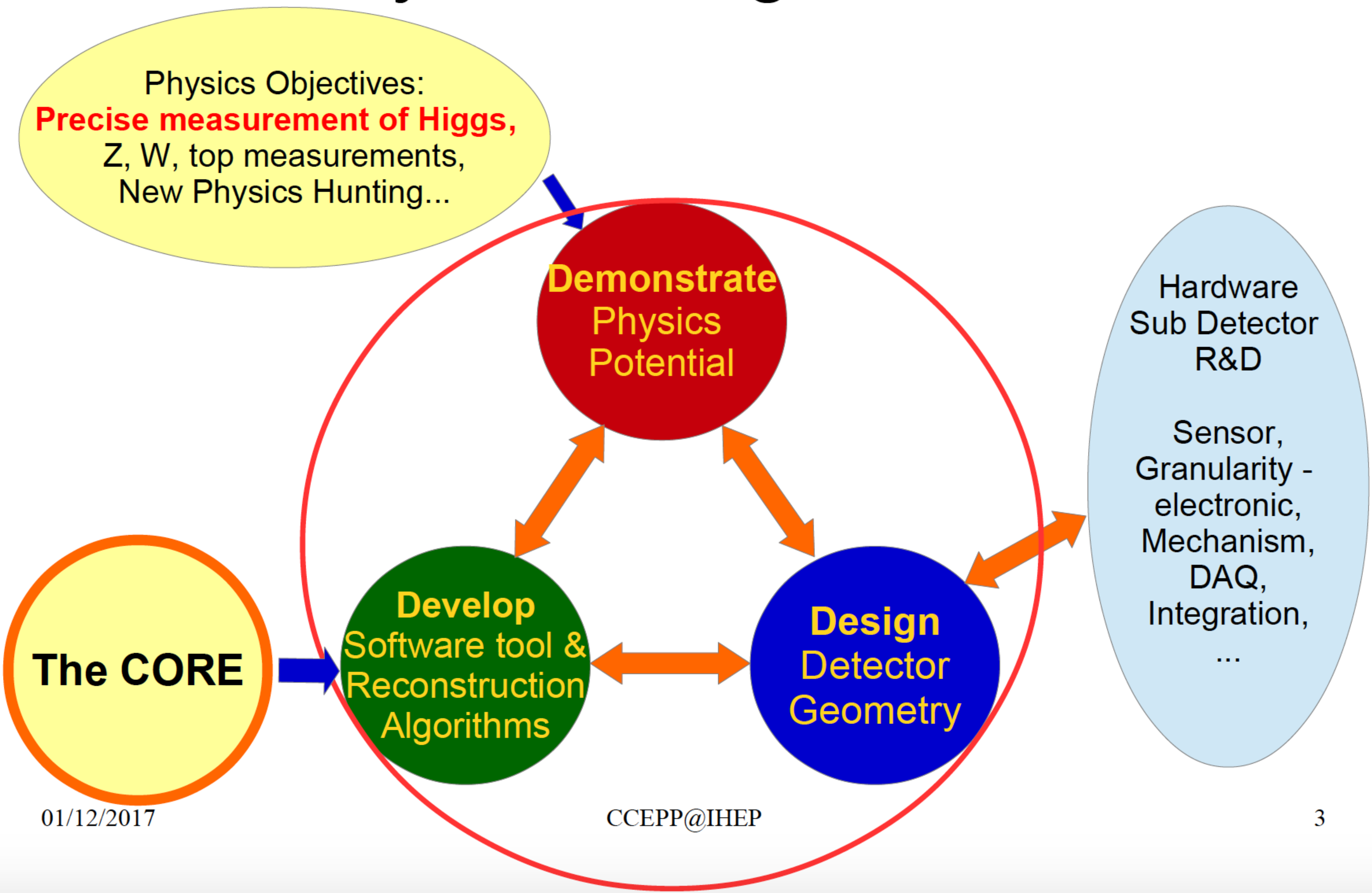
Jet Clustering: Br = 50%

Photon/ECAL: Br = 0.2%

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

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

Key SOFT ingredients



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175-v2	Higgs Signal Reconstruction at CEPC-v4 Baseline Detector when CEPC Operate at 240GeV	YongFeng Zhu	Software Higgs Physics	13 May 2018
174-v1	Higgs Signal Reconstruction at CEPC-v4 Baseline Detector for the CEPC CDR	Hang Zhao	Simulation: Full/Fast Simulation Higgs Physics	10 Apr 2018
173-v1	Detector Geometry in Model CEPC IDEA	Yin Xu	Implementation into Full Simulation Software Framework General of CEPC	27 Mar 2018
172-v1	Performance study of particle identification at the CEPC using TPC dE/dx information	fenfen An	TPC Physics at CEPC	15 Mar 2018
171-v1	Reconstruction of physics objects at the Circular Electron Positron Collider with Arbor	Manqi RUAN	Physics at CEPC General	06 Mar 2018
170-v1	Optimization for CEPC vertex	Zhigang Wu	VTX	10 Jan 2018
169-v1	PFA Oriented ECAL Optimization for the CEPC	Hang Zhao	Simulation: Full/Fast Simulation Calo	27 Dec 2017
166-v3	Jet Energy Deposition Studies with CEPC Electromagnetic Calorimeter, Hadronic Calorimeter and Muon Detector	Jifeng Hu *et al.*	Calo Muon Reconstruction Higgs Physics General of CEPC	14 Nov 2017
168-v1	Manual of the CEPC software	Gang LI	Software	02 Nov 2017
167-v1	Full Simulation Software at CEPC	Chengdong Fu	Software	23 Oct 2017
165-v1	Physics Impact of the Solid Angle Coverage at CEPC	Peizhu Lai	Detector Design Physic Analysis	17 Oct 2017
164-v1	Jet Reconstruction at CEPC	Peizhu Lai	Detector Design Physic Analysis	17 Oct 2017

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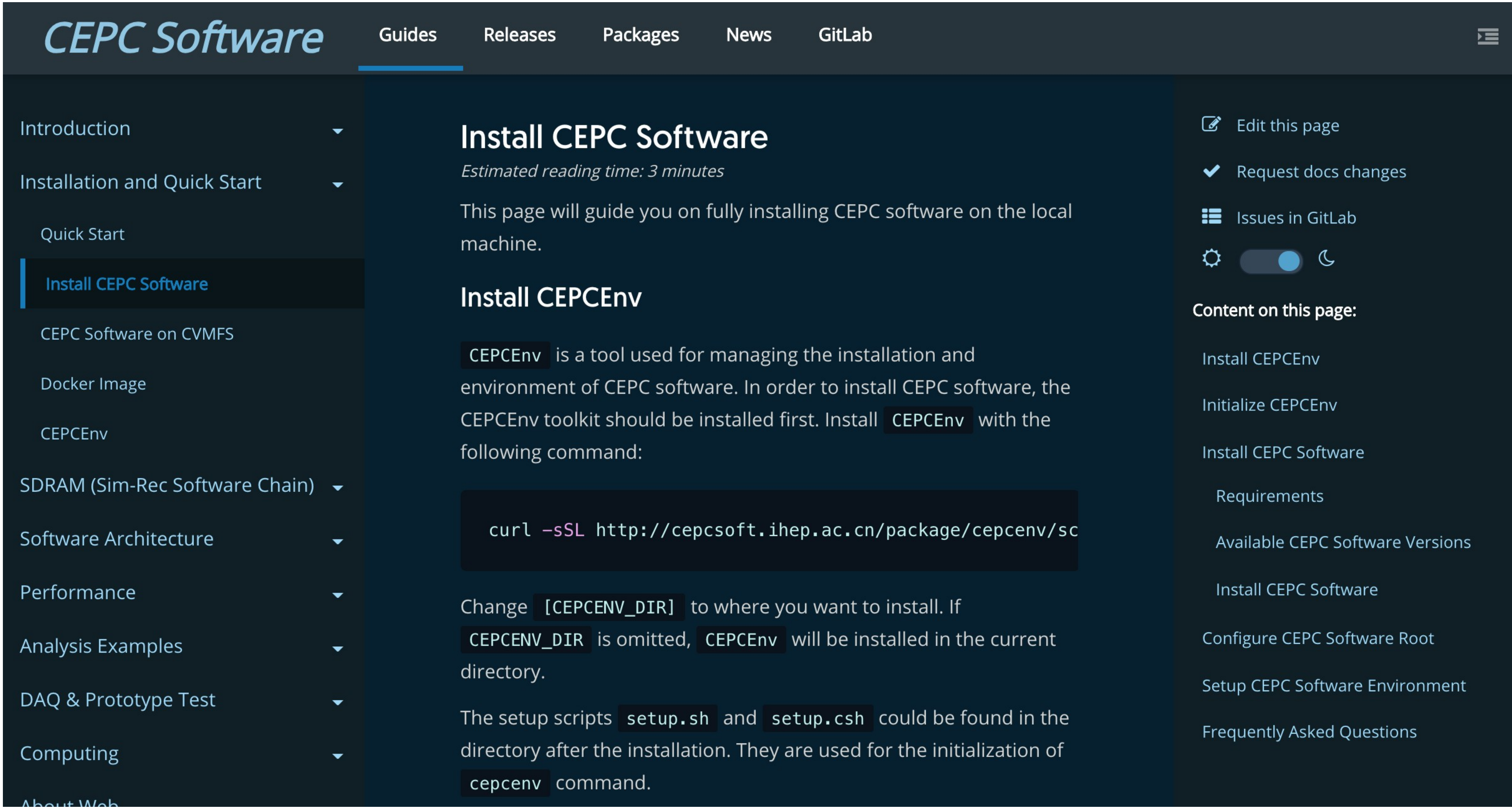
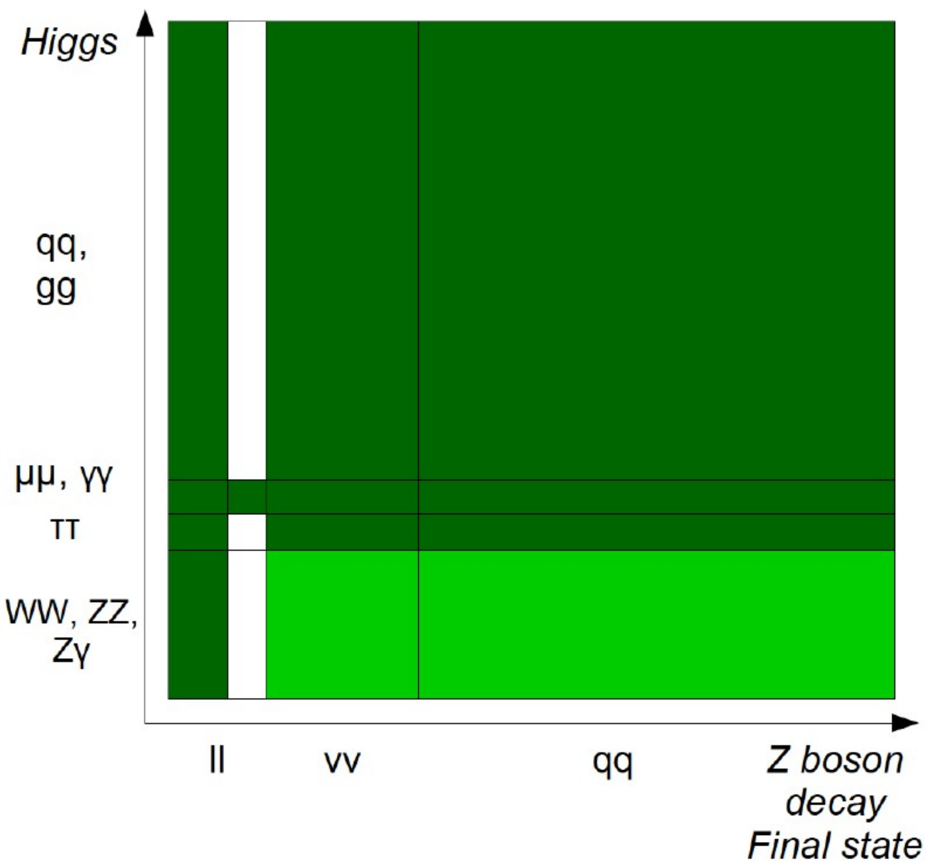


5 commands & you got the cepcsoft installed on an SL6 machine

CEPC Higgs Analyses



	PreCDR (Jan 2015)	Now (Aug 2016)
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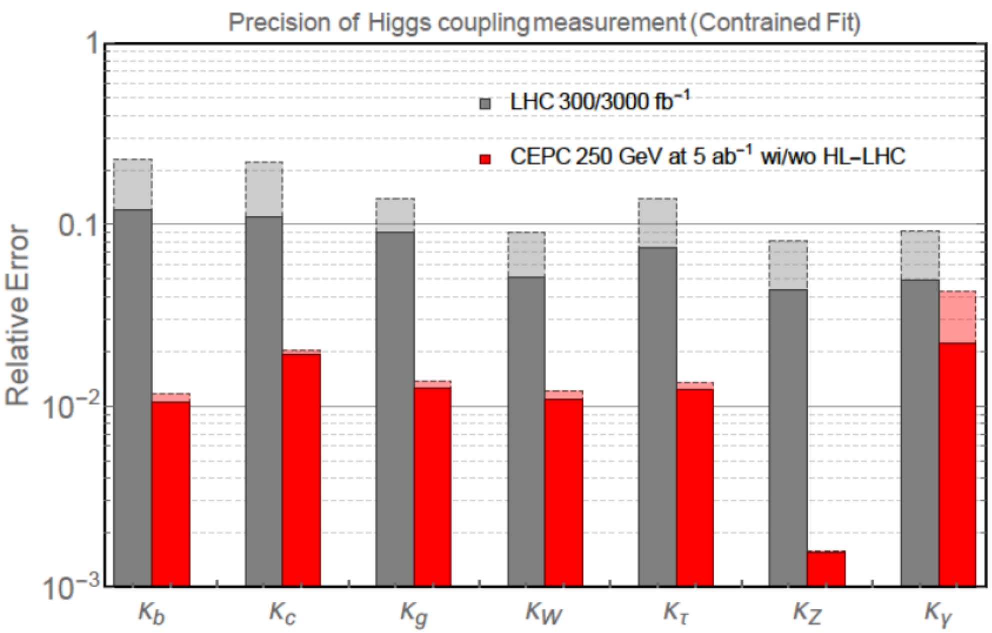
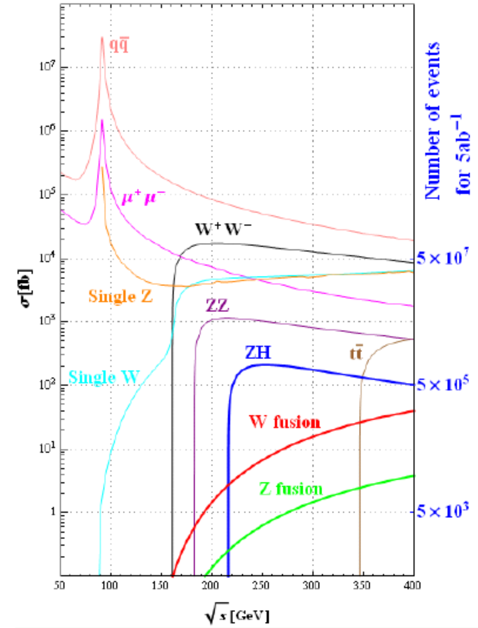
σ(ZH)*Br(H→ττ)	1.2%	1.0%
σ(ZH)*Br(H→γγ)	9.0%	9.0%
σ(ZH)*Br(H→Zγ)	-	~4 σ
σ(ZH)*Br(H→μμ)	17%	17%
σ(ννH)*Br(H→bb)	2.8%	2.8%
Higgs Mass/MeV	5.9	5.0
σ(ZH)*Br(H→inv)	95%. CL = 1.4e-3	1.4e-3
Br(H→ee/emu)	-	1.7e-4/1.2e-4
Br(H→bbχχ)	$<10^{-3}$	3.0e-4

Higgs Physics @ CEPC-v1: event rate measurements almost fully covered
(*mostly with* ***old*** *reconstruction...*)

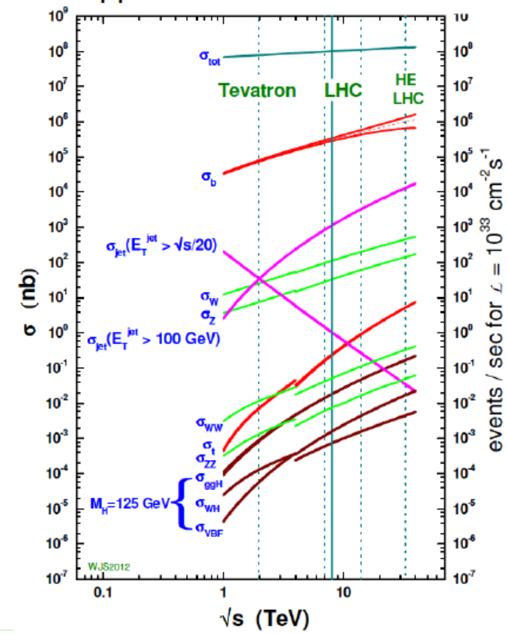
Higgs measurement at e+e- & pp



e+e- cross sections



pp cross sections



	Yield	efficiency	Comments
LHC	Run 1: 10^6 Run 2/HL: 10^{7-8}	$\sim o(10^{-3})$	High Productivity & High background, Relative Measurements, Limited access to width, exotic ratio, etc, Direct access to g(ttH), and even g(HHH)
CEPC	10^6	**~o(1)**	Clean environment & Absolute measurement, Percentage level accuracy of Higgs width & Couplings

IDEA Simulation & Validation

CEPC NOTE

CEPC_TLS_SIM_2018_001

March 27, 2018

Nankai University

Detector Geometry in Model CEPC_IDEA

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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

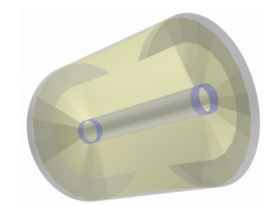
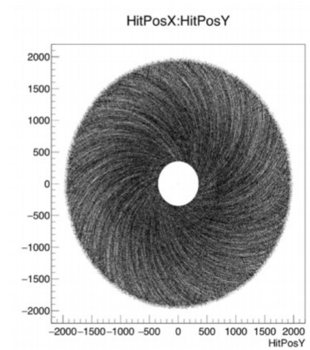
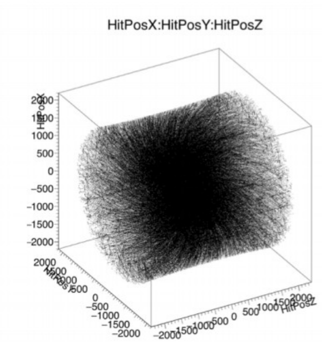
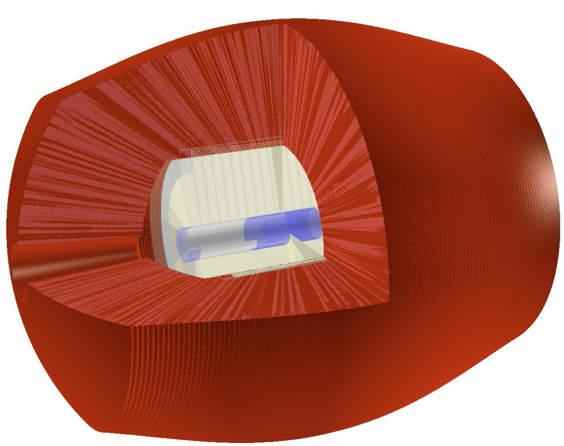
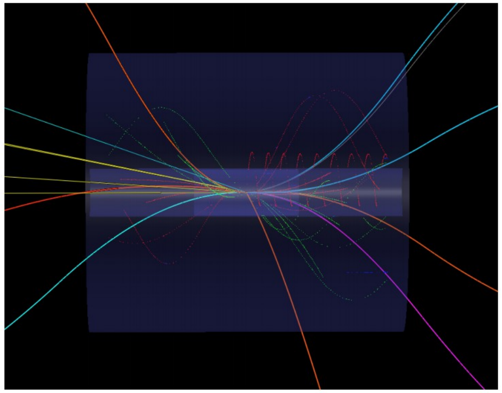


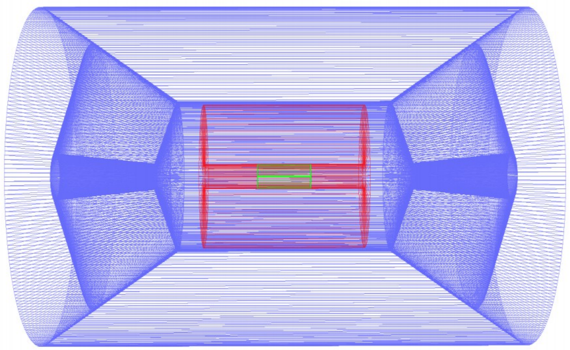
Figure 5: CDCH



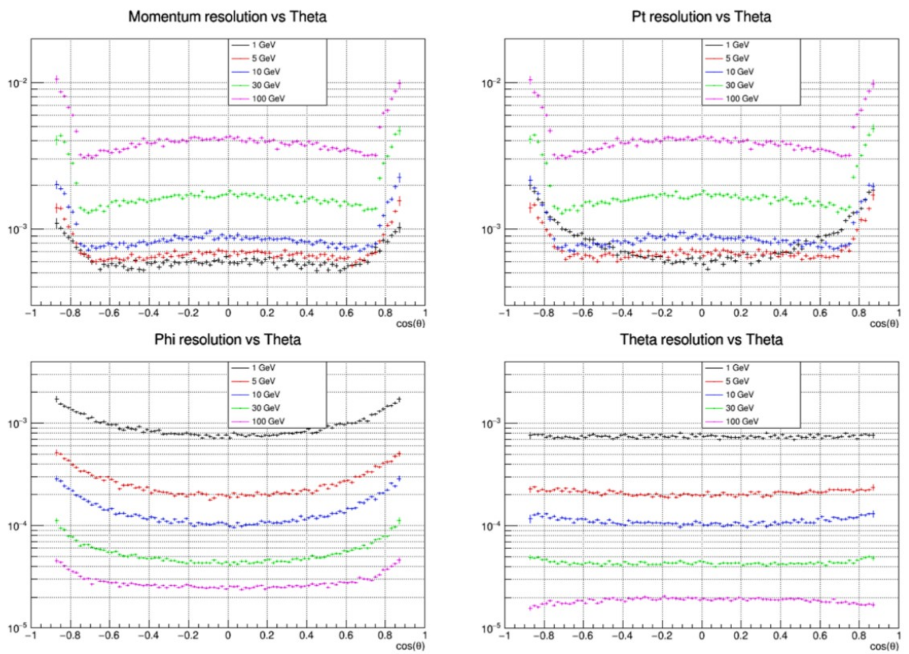




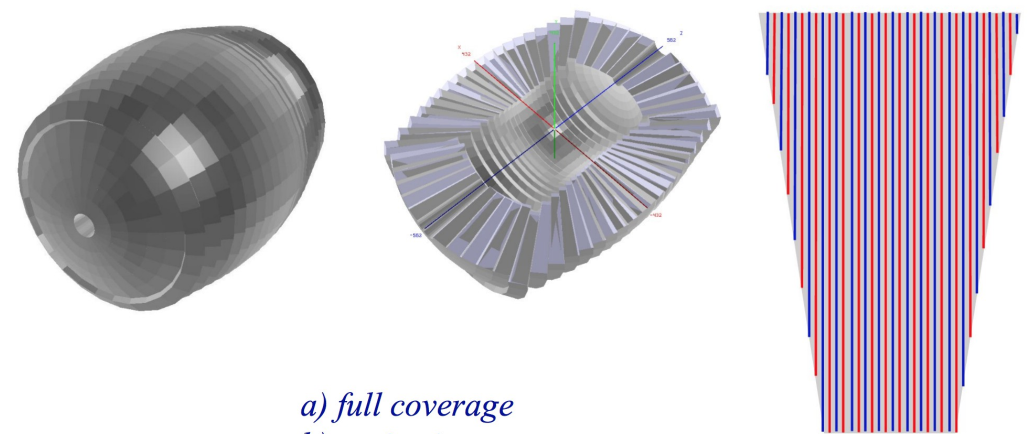




Implemented into Simulation



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



a) full coverage
b) projective geometry

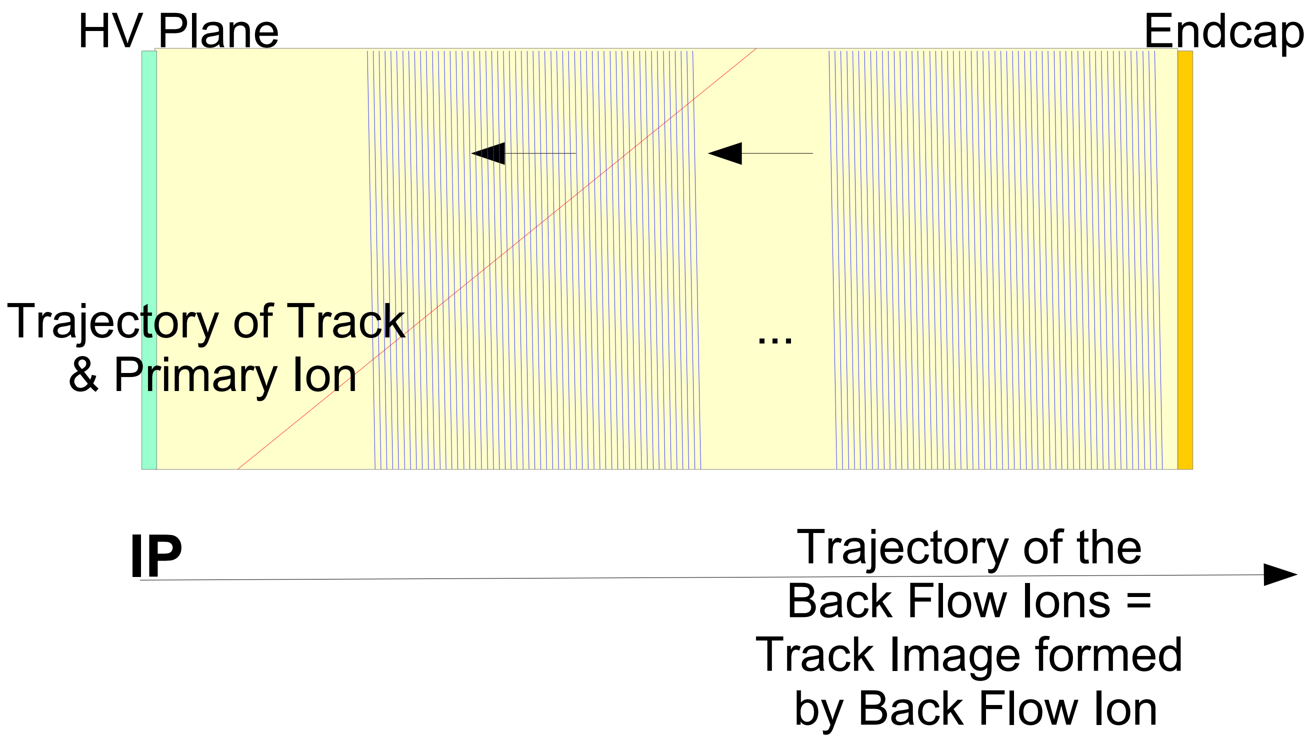
Both Wire Chamber & Dual readout Calorimeter have been implemented;

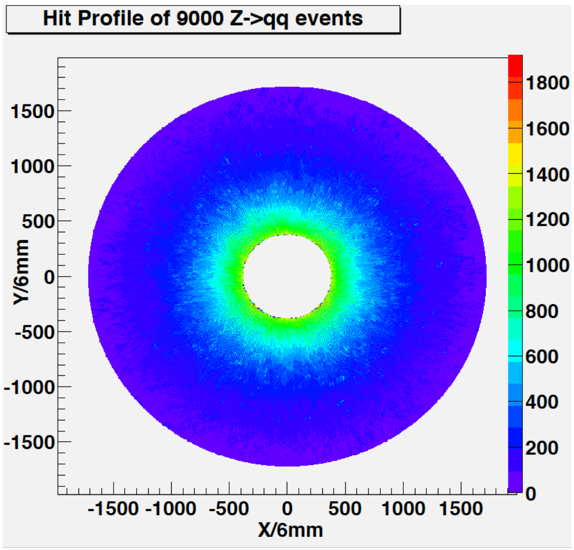
Need Validation, Digitization & Dedicated Analysis to Study the performance at jet and Physics event level

TPC Usage

- Feasibility not limited by
  - Voxel occupancy (1E-4 - 1E-6)
  - IBF & Ion Charge Distortion
- Dedx: TPC +50 ps ToF: a full range pi-kaon separation at Z pole operation
- Tech. Difficulties to be further studied
  - Complex, unstable field maps
  - Stability & Homogeneity of Amplification/DAQ system, temperature/pressure monitoring & corrections
  - Radiation background: Working Gas selection is essential
    - Neutron Flux + Working gas with hydrogens
    - Delta Ray Noise
    - Gamma Ray Noise
- Be iterated with Hardware/Electronic Design & Test beam studies

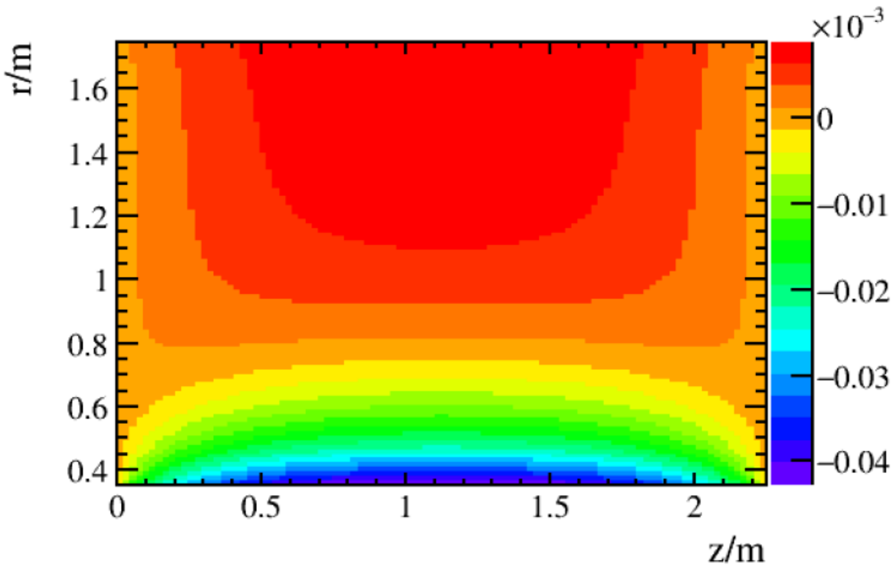
Feasibility of TPC at Z pole

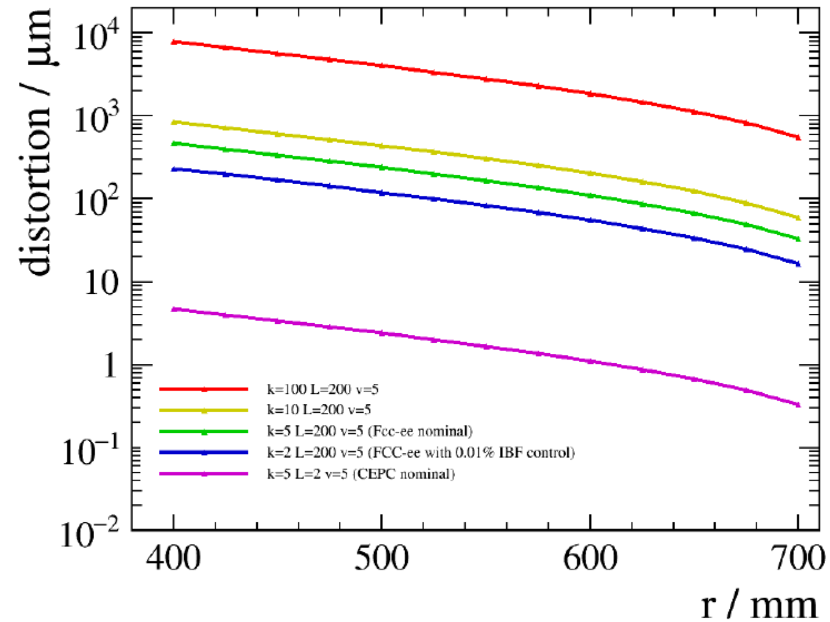




- 600 Ion Disks induced from Z->qq events at 2E34$cm^{-2}s^{-1}$
- Voxel occupancy & Charge distortion from **Ion Back Flow** (IBF)
- Cooperation with CEA & LCTPC

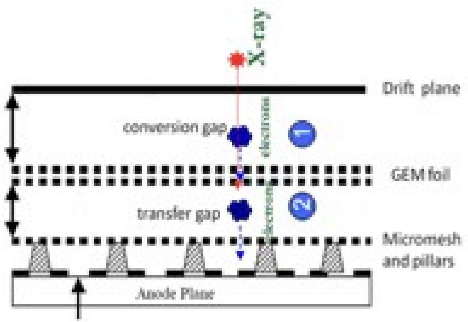
TPC Feasibility

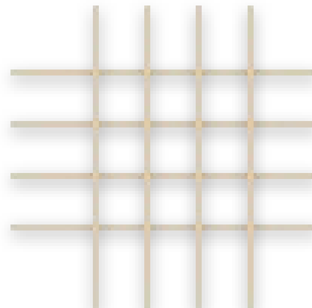


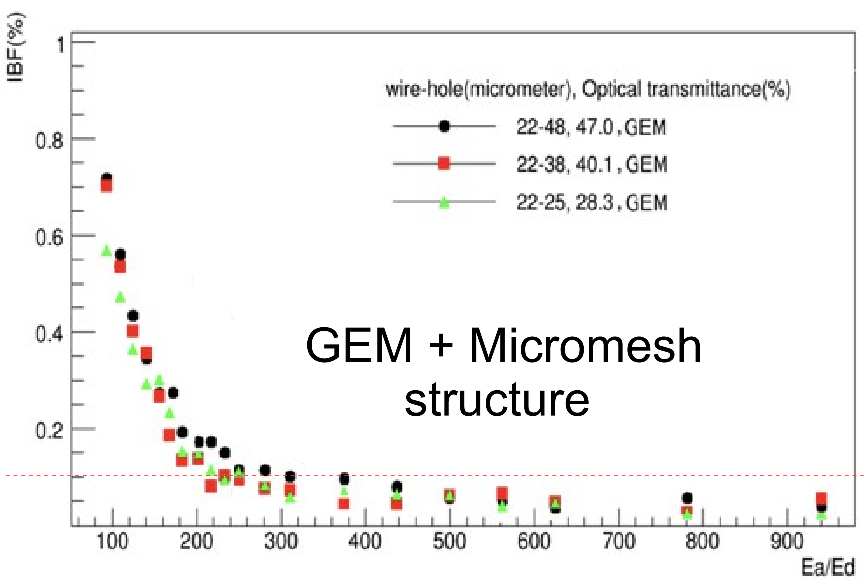


- Conclusion (JINST_12_P07005, CEPC-DocDB-id-147):
  - Voxel occupancy ~ (10^-4 – 10^-6) level, safe
  - **Safe for CEPC If the ion back flow be controlled to per mille level** (k = 5) -
    - The charge distortion at ILD TPC would be one order of magnitude then the intrinsic resolution (L = 2E34 $cm^{-2}s^{-1}$)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

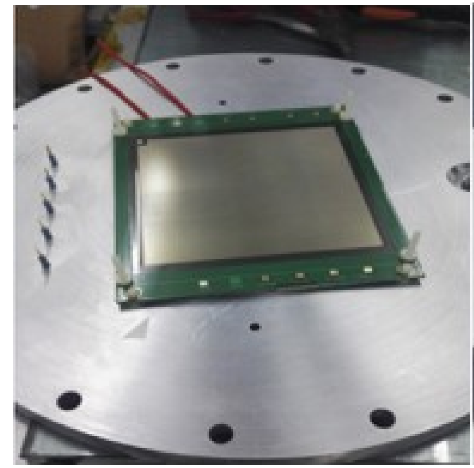
R&D on the IBF control



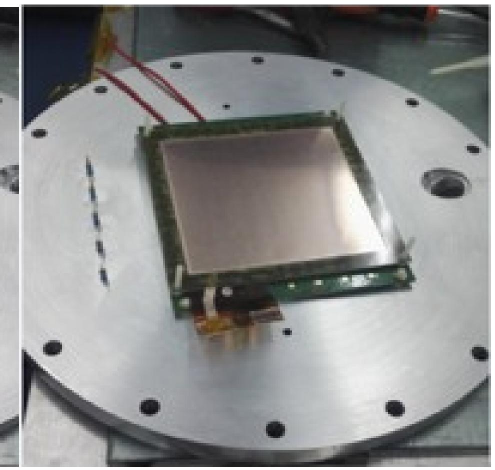




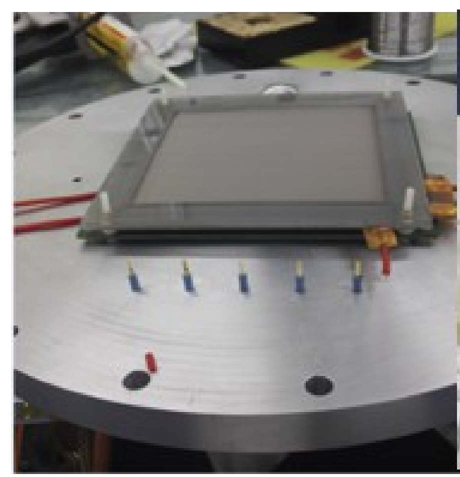
GEM + Micromesh structure



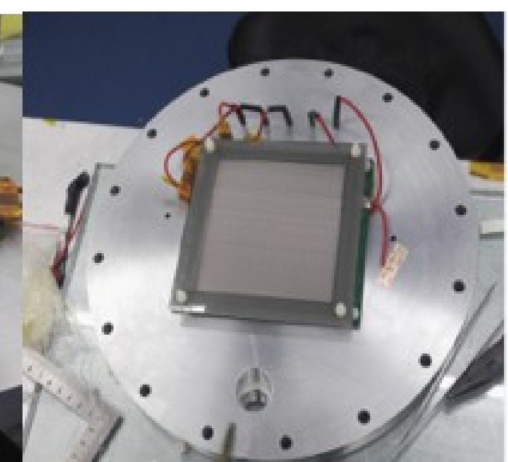
Micromegas(Saclay)



GEM(CERN)



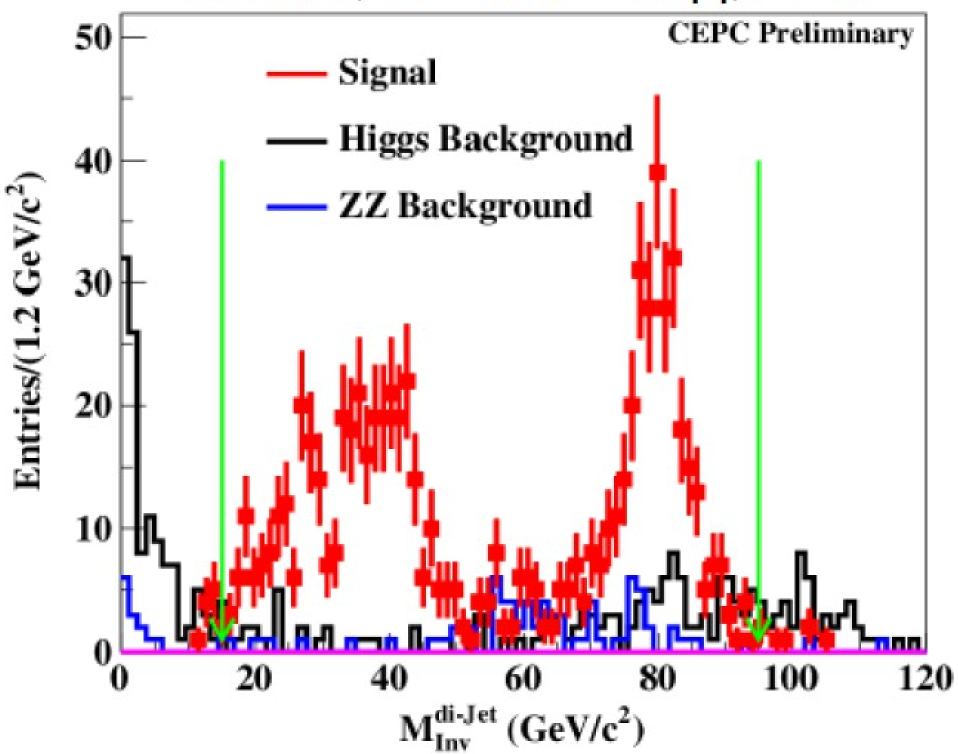
Cathode with mesh

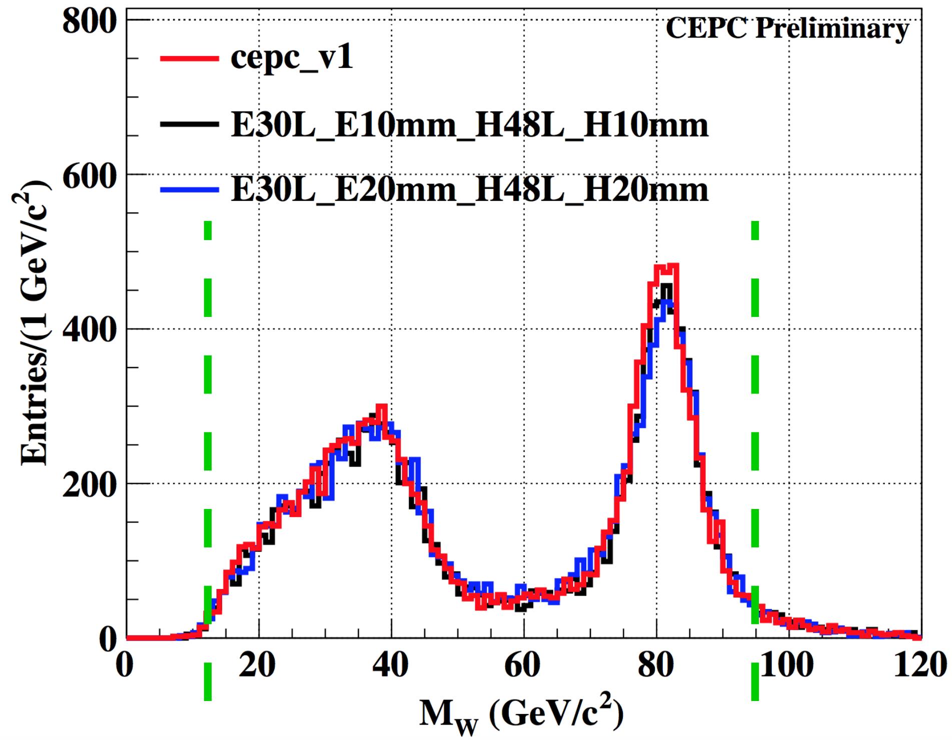


GEM-MM Detector

Br(H→WW) @ 10mm/20mm Cell size

Liao libo, H→WW*→lvqq, Z→ll



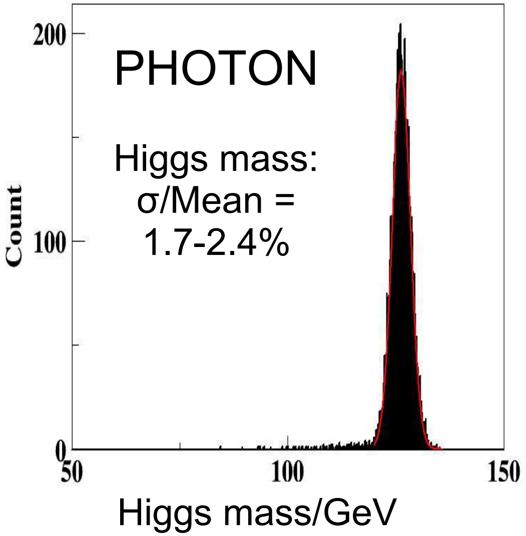


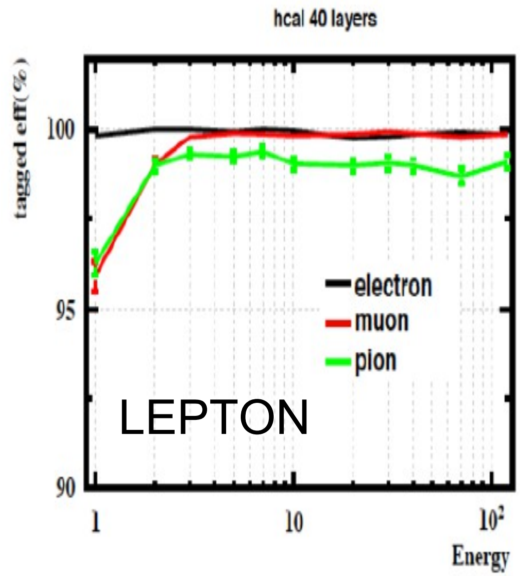
Br(H→WW) via vvH, H→WW*→lvqq

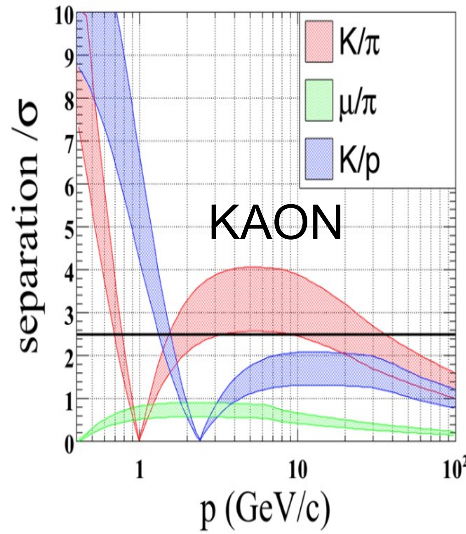
No lose in the object level efficiency: JER degraded, ~ 5/10% at 10/20 mm

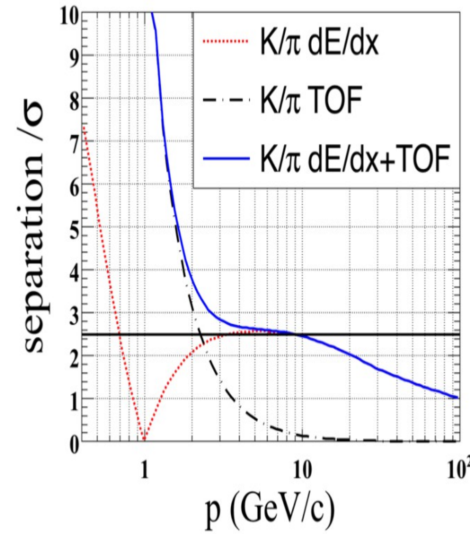
Over all: event reco. efficiency varies ~1%

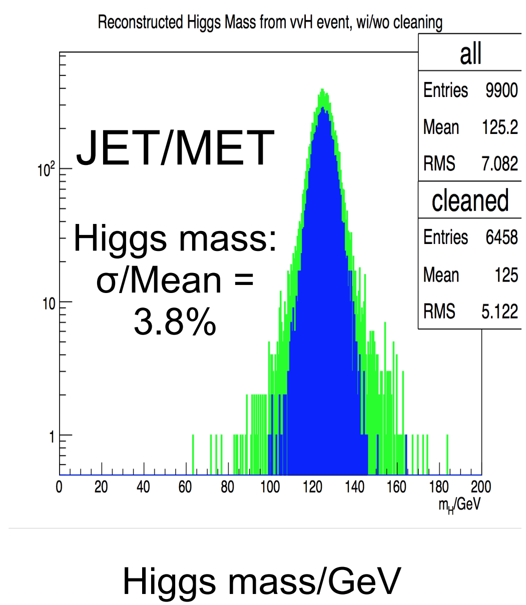
PFA Oriented Reconstruction

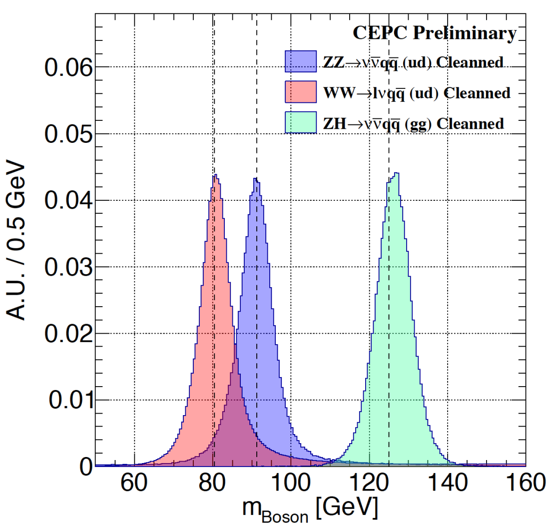


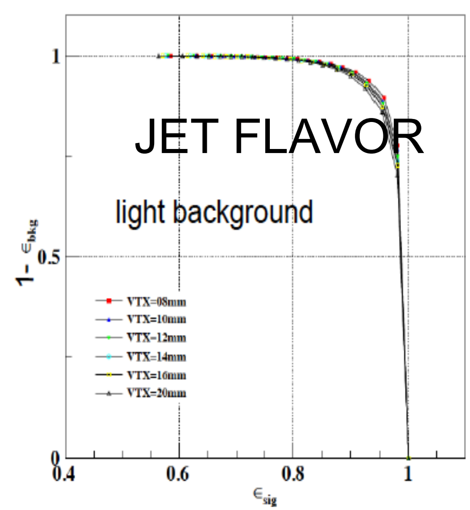


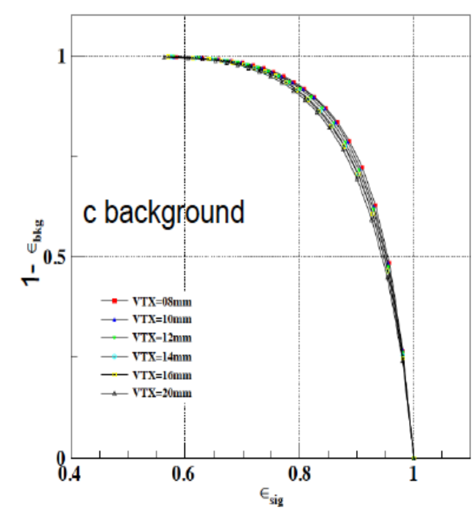










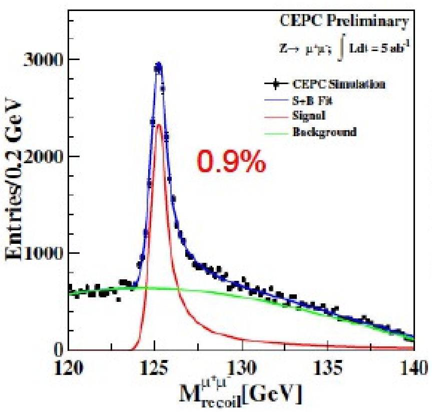


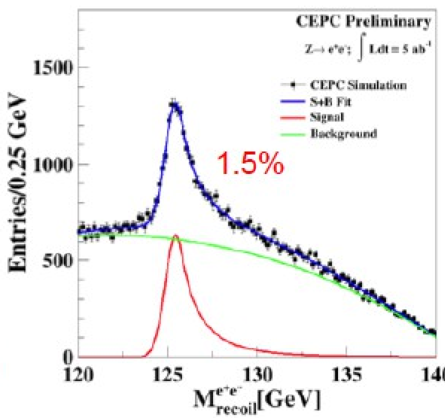
Example Working Points & Performance for Object identification (Preliminary)

	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(Neutron → γ) = 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%

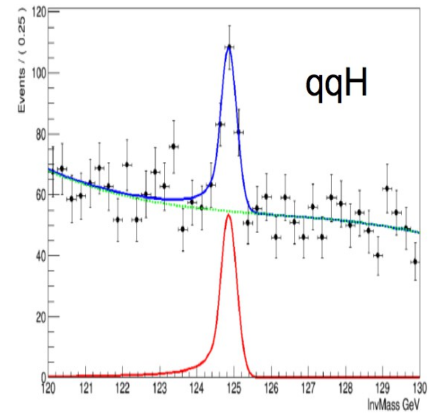
CEPC: absolute Higgs measurements

Zhenxing Chen & Yacine Haddad

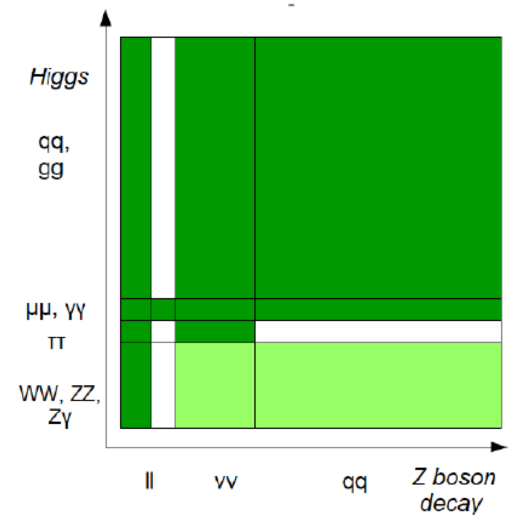




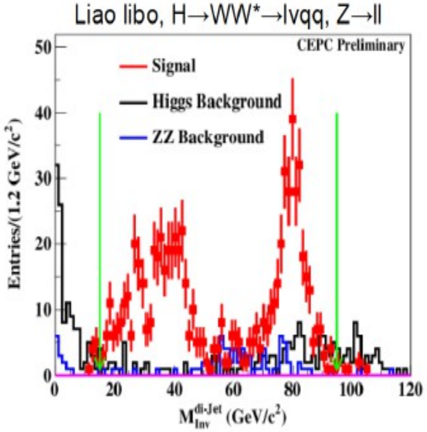
σ(ZH) measurements



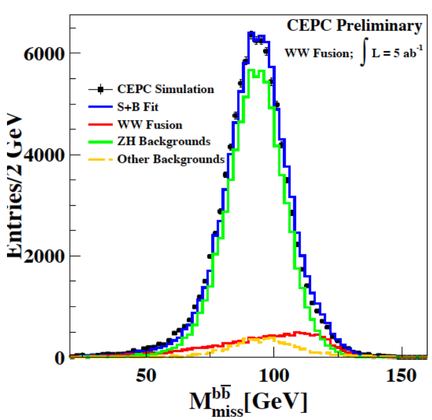
Br(H→μμ)



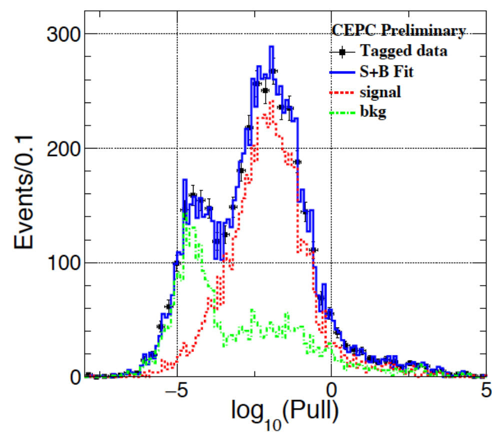
Liao libo, H→WW*→lνqq, Z→ll



Br(H→WW)



σ(ννH)*Br(H→bb)

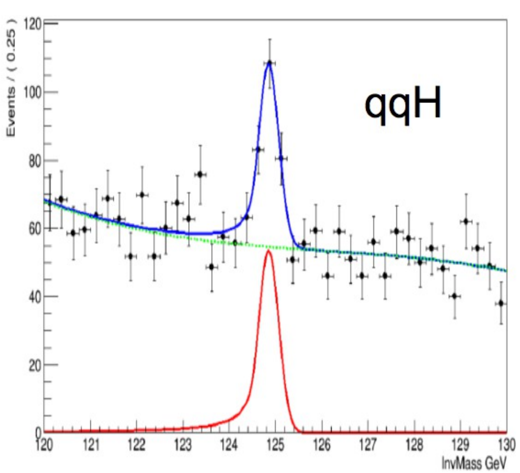


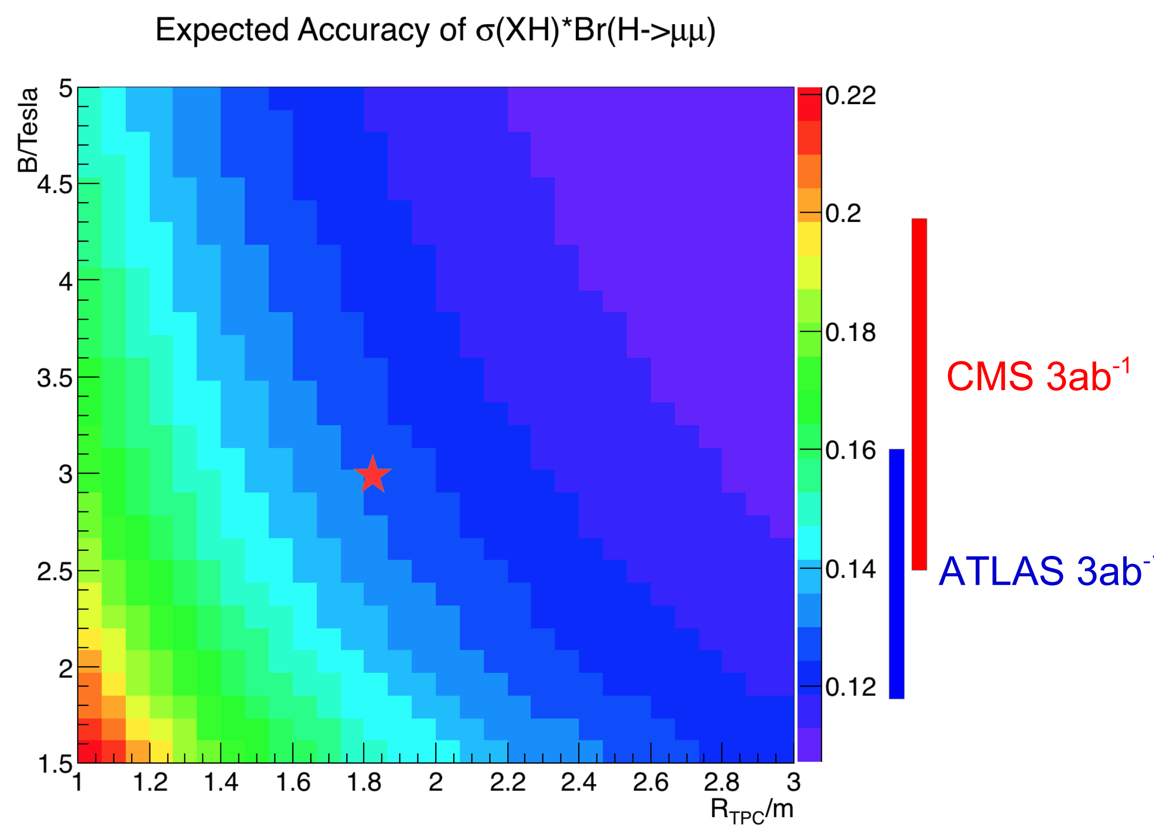
Br(H→ττ)

	PreCDR (Jan 2015)	Now (Aug 2016)
σ(ZH)	0.51%	0.50%
σ(ZH)*Br(H→bb)	0.28%	0.21%
σ(ZH)*Br(H→cc)	2.1%	2.5%
σ(ZH)*Br(H→gg)	1.6%	1.2%
σ(ZH)*Br(H→WW)	1.5%	1.0%
σ(ZH)*Br(H→ZZ)	4.3%	4.3%
σ(ZH)*Br(H→ττ)	1.2%	1.0%
σ(ZH)*Br(H→γγ)	9.0%	9.0%
σ(ZH)*Br(H→Zγ)	-	~4 σ
σ(ZH)*Br(H→μμ)	17%	12%
σ(ννH)*Br(H→bb)	2.8%	2.8%
Higgs Mass/MeV	5.9	5.0
σ(ZH)*Br(H→inv)	95%. CL = 1.4e-3	1.4e-3
Br(H→ee/emu)	-	1.7e-4/1.2e-4
Br(H→bbχχ)	$<10^{-3}$	3.0e-4

Tracker Radius: the optimized value

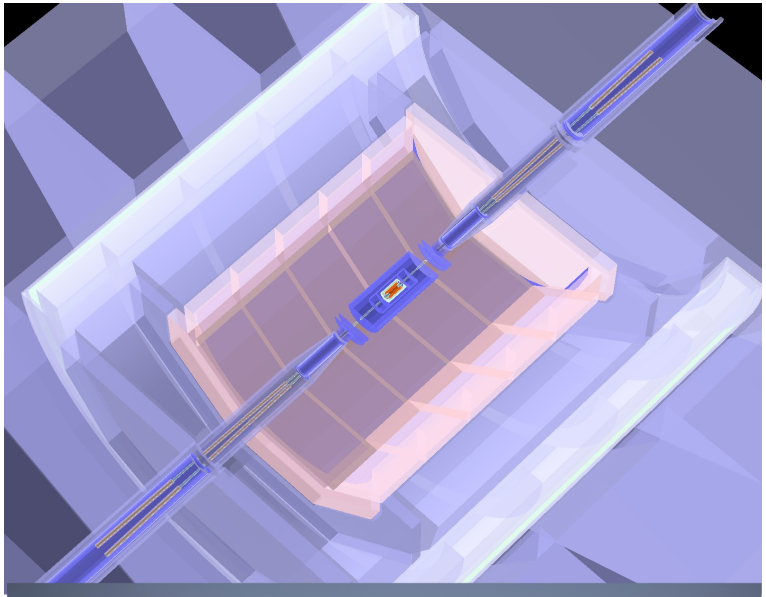
- Detector cost is sensitive to tracker radius, however, I recommend TPC radius >= 1.8m:
  - Better separation & JER
  - Better dEdx
  - **Better (H->di muon) measurement**

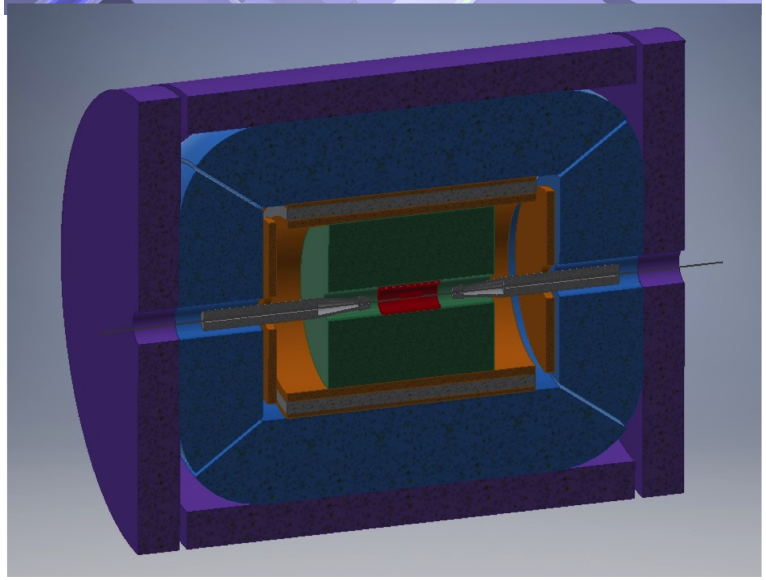


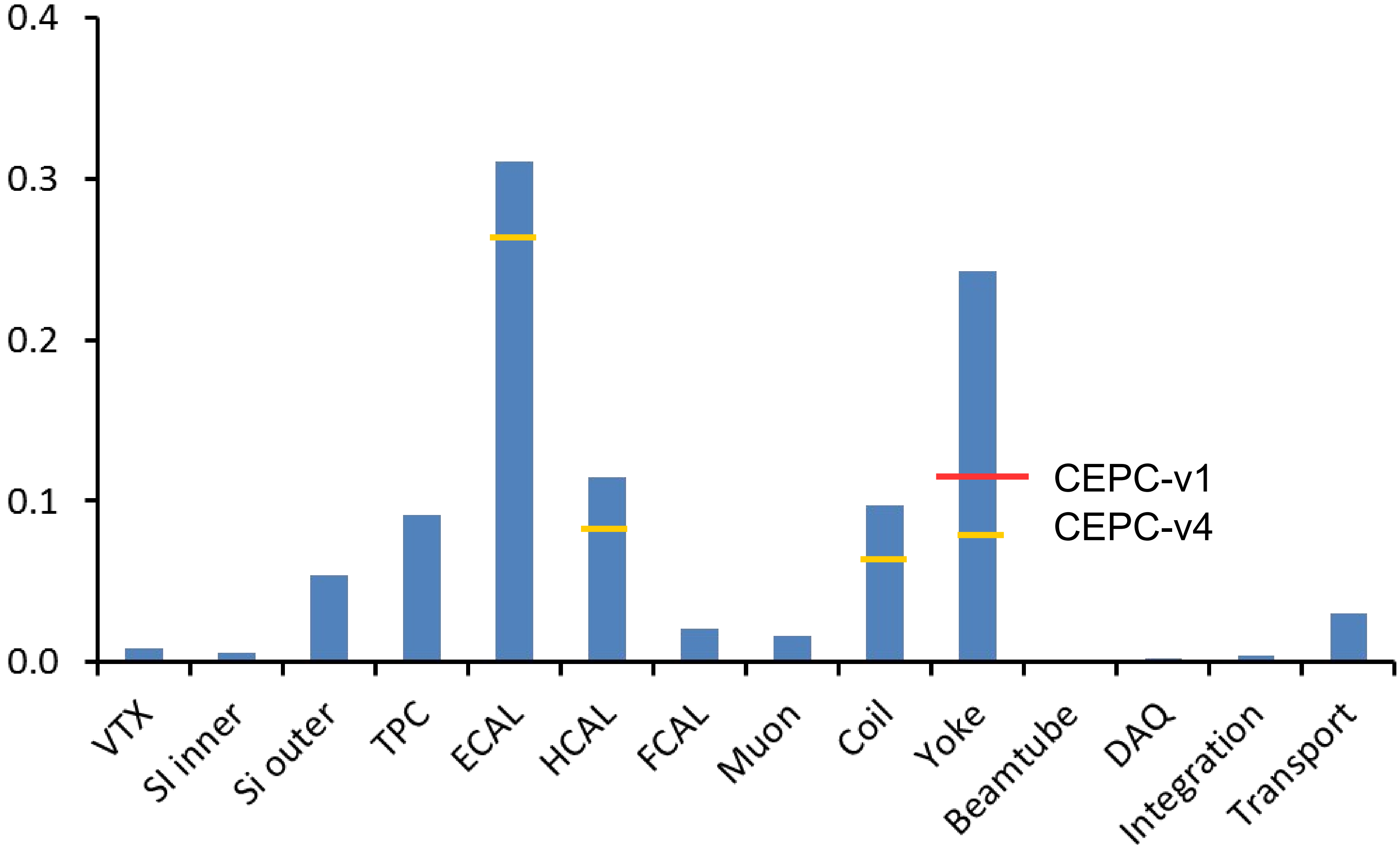


Detectors for the CDR

- APODIS (Baseline)
  - A PFA Oriented Detector for HIggS factory (Reference: ALEPH, SiD and **ILD**)
  - Low material tracker + ultrahigh granularity calorimeter (serve also as ToF) + large Solenoid
  - Dedicated MDI (Ongoing)
  - Fully implemented into Geant 4 simulation and full reconstruction
  - Optimized versus Physics Benchmarks
- IDEA (Alternative)
  - Wire Chamber + Dual Readout based: implementing into full simulation
- Multiple detectors & New ideas are welcome!







0.4
0.3
0.2
0.1
0.0
VTX
SI inner
Si outer
TPC
ECAL
HCAL
FCAL
Muon
Coil
Yoke
Beamtube
DAQ
Integration
Transport
CEPC-v1
CEPC-v4

- 以 Arbor 为核心的完整软件工具
- CEPC-v1, reference detector for the CEPC PreCDR studies
- Feasibility & Optimized Parameters
- CDR 基线探测器 APODIS
- Lepton
- Kaon
- Photon
- Tau

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- Benchmark Higgs Analaysis
- An Analysis Example: g(Hττ) at qqH
- An Optimization Example: g(Hττ) at μμH
- Issues to be solved at performance
- 软件队伍
- Summary
- Summary
- Advertise
- backup