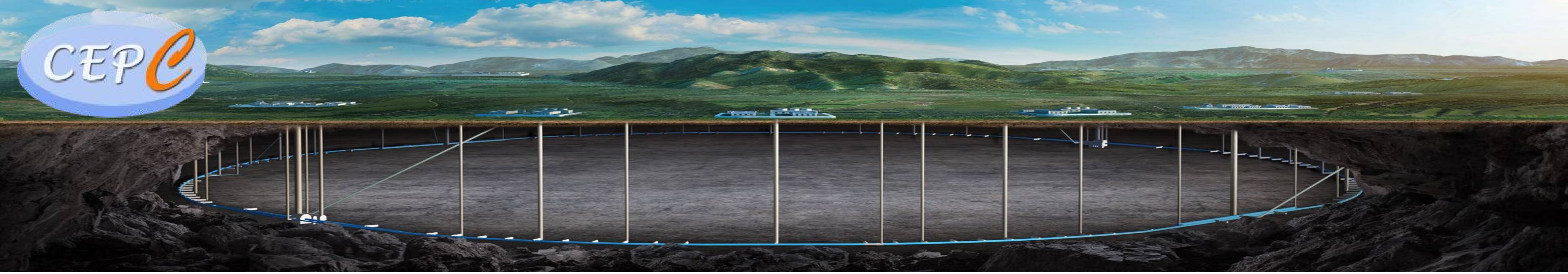

Trigger simulation and algorithm for cepc reference detector

Boping Chen
On behalf of CEPC TDAQ Group

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

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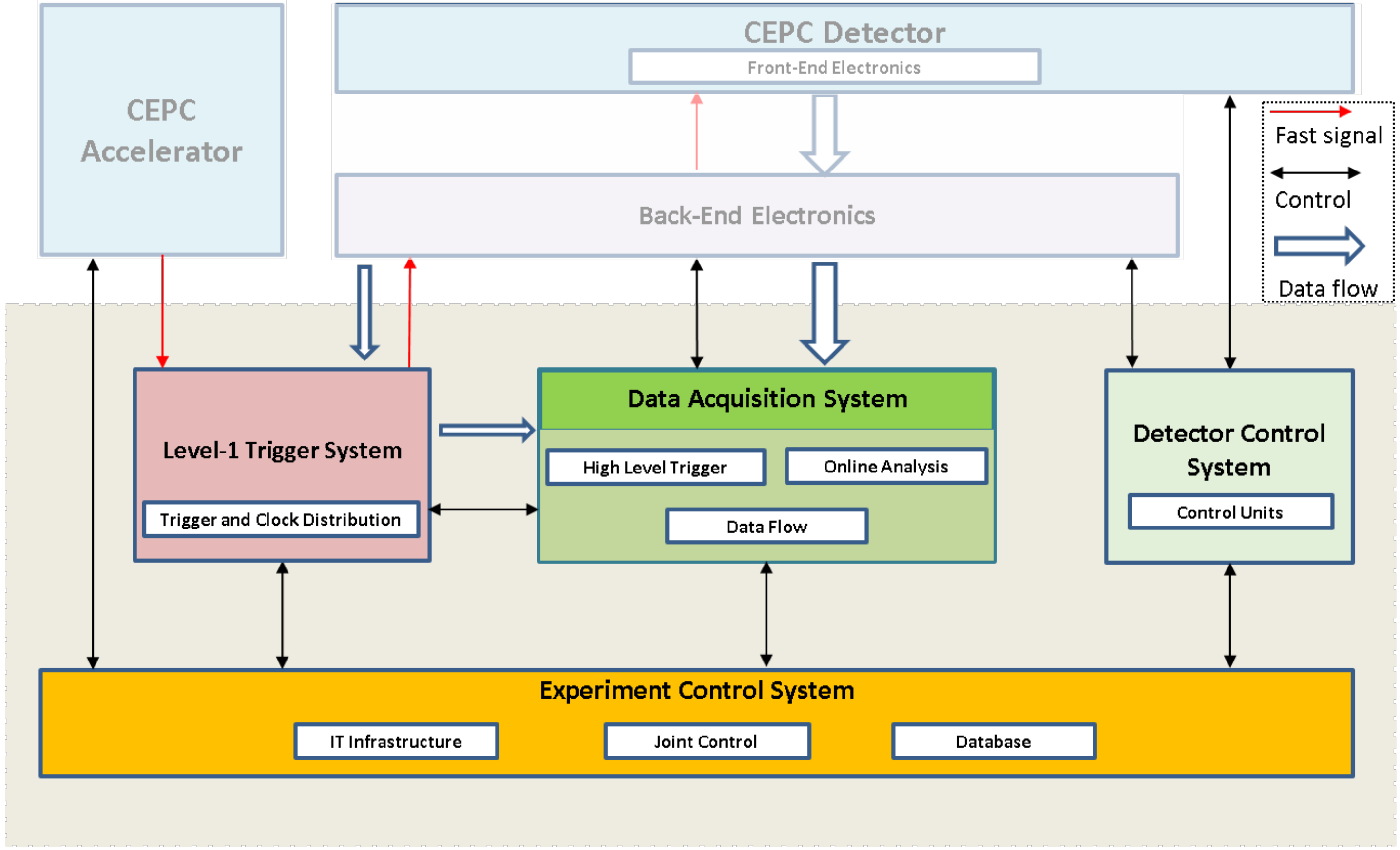
Outline

- Introduction
- MC Simulation
  - Physics requirement
  - Detection response
- Trigger Algorithm
- Efficiency Performance
- Summary and outlook

Introduction

- TDAQ overall design:
  - Level 1 hardware trigger(L1) + High level trigger(HLT)
  - Provide both normal and fast trigger menu
  - L1: Calorimeter+Muon+(Tracker?)
  - HLT: Full detector information



Physical event rate

- Higgs mode (240GeV) bunch crossing rate: 1.33 MHz
  - Higgs boson production rate: ~0.017Hz
  - qq rate: 5Hz
- Z mode (91GeV) bunch crossing rate: 12/39.4 MHz
  - Visible Z rate: 10.5/41.9 kHz
- Cosmic ray: ~56 Hz
- Di-photon processes: 4kHz ~ 9kHz
- Generated by BesTwoGam(only for Di-photon), Whizard(for all other processes)
- Detector simulation using CEPCSW tdr25.3.6

Table 12.1: CEPC baseline parameters

Operation phase	I			II	III
Run mode	ZH	Z	W	Z	$t\bar{t}$
SR power per beam (MW)	50	10	50		
Bunch number	446	3978	2162	13104	58
Bunch spacing (ns)	277 (x12)	69.2 (x3)	138.5 (x6)	23.1 (x1)	2700.0 (x117)
Train gap (%)	63	17	10	9	53
Bunch crossing rate(MHz)	1.33	12	6.5	39.4	0.17
Luminosity per IP (10^{34}cm^{-2}s-1)	8.3	26	26.7	95.2	0.8
Run time (years)	10	1	1	2	5
Event yields [2 IPs]	4.3x10^6	2.9x10^{11}	2.1x10^8	2.0x10^{12}	6x10^5

Table 12.2: Expected event rate at the ZH mode for 50 MW

Processes	Cross section (fb)	Event rate (Hz)
ZH	203.66	0.017
Two Fermions background (exclude Bhabha)	6.4×10^4	5.3
Four Fermions background	1.9×10^4	1.6
Bhabha	1.0×10^6	80
$\gamma\gamma \to bb$	1.6×10^6	128
$\gamma\gamma \to cc$	2.1×10^6	168
$\gamma\gamma \to qq$	59.8×10^6	4784

Table 12.3: Expected event rate at the Z mode for 10 MW

Processes	Cross section (fb)	Event rate (Hz)
qq	31×10^6	7970
$\mu\mu$	1.5×10^6	400
$\tau\tau$	1.5×10^6	396
Bhabha	6.6×10^6	1714
$\gamma\gamma \to bb$	2.8×10^5	73
$\gamma\gamma \to cc$	5.1×10^5	132
$\gamma\gamma \to qq$	34.7×10^6	9011

MC simulation at Higgs mode

- Physical processes:
  - Higgs: ee→ZH
    - Z→ee, μμ, ττ, νν
    - H→bb, WW, ττ, cc, ZZ, ɣɣ, Zɣ, μμ ...
  - 2/4 fermions: ee→qq, μμ, ττ, ZZ, WW...
  - Di-photon: ee→ee+ɣɣ→ee+bb/cc/qq
- Background:
  - Beam induced background(10000 events by Haoyu)
    - Each event contains 10 BX(safe factor 10)
  - Detector noise and other background(to be studied)

Signal MC simulation: ee→ZH

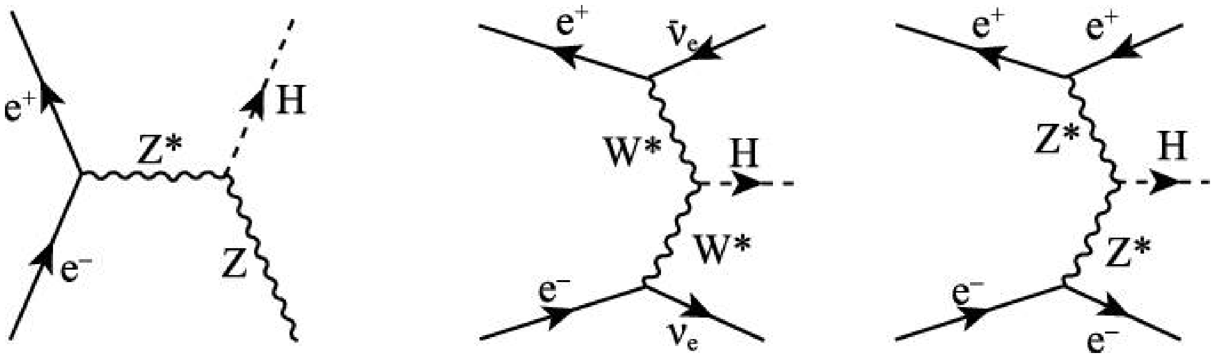
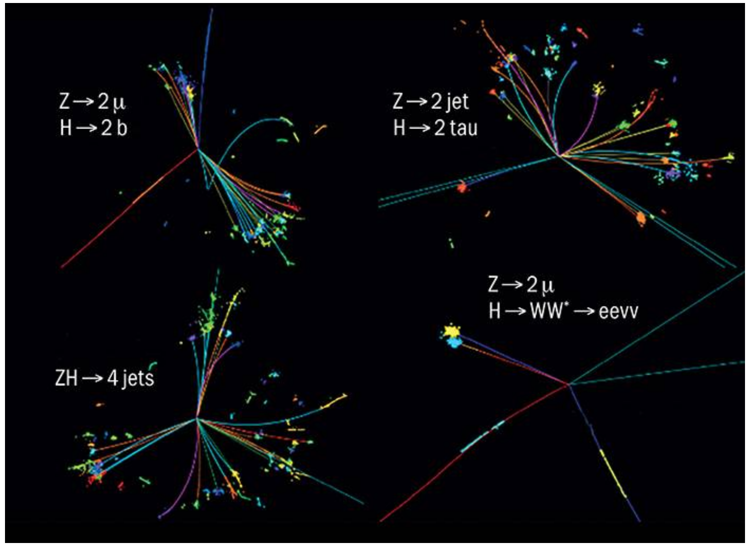


Table 11.3: The branching ratios and the relative uncertainty for a SM Higgs boson with $m_H = 125\,\text{GeV}$ [39, 40].

Decay channel	Branching ratio	Rel. uncertainty
$H \to \gamma\gamma$	2.27×10^{-3}	2.1%
$H \to ZZ$	2.62×10^{-2}	±1.5%
$H \to W^+W^-$	2.14×10^{-1}	±1.5%
$H \to \tau^+\tau^-$	6.27×10^{-2}	±1.6%
$H \to b\bar{b}$	5.82×10^{-1}	$^{+1.2\%}_{-1.3\%}$
$H \to c\bar{c}$	2.89×10^{-2}	$^{+5.5\%}_{-2.0\%}$
$H \to Z\gamma$	1.53×10^{-3}	±5.8%
$H \to \mu^+\mu^-$	2.18×10^{-4}	±1.7%

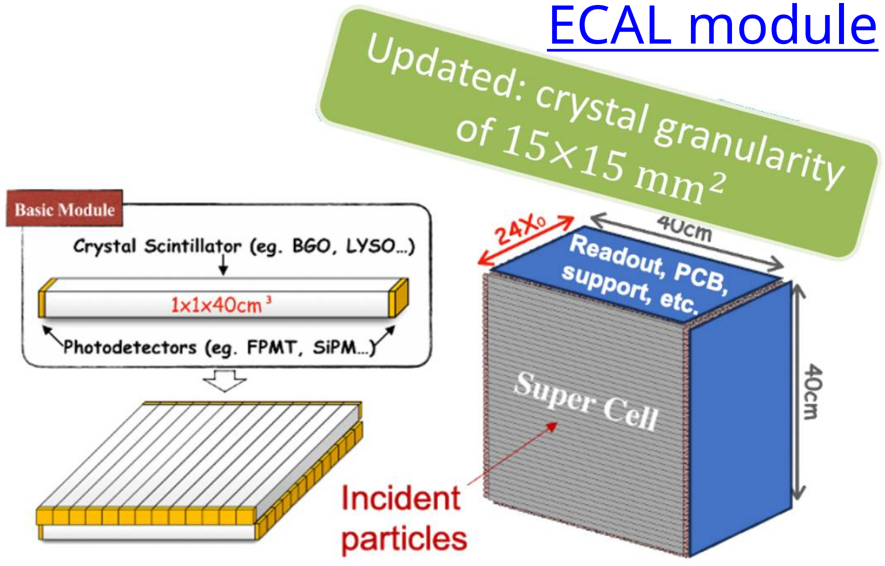
- ZH sample presented in this talk
  - Z→νν
  - H→bb, WW, ττ, ZZ, ɣɣ, Zɣ, μμ
    - Final state: jet, photon, and muon
    - bb, ɣɣ and μμ will be shown as example
  - 5000 events for each process



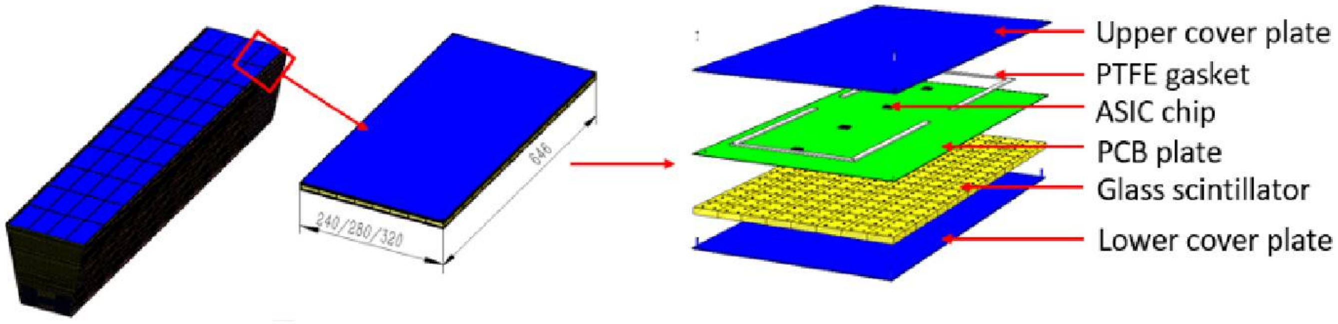
Calorimeter module

- Basic module for ECal: ～1.5x1.5x40cm^3
  - Cluster modules into 40x40cm^2 supercell
  - Use supercell as trigger input
  - 15(Z)x32(ϕ) in Z-ϕ plane
- Basic module for HCal: Barrel-Box(240/280/320 x 646mm^2)
  - Combine two in ϕ and split into two in Z
  - 20(Z)x32(ϕ) in Z-ϕ plane(~match ECal)

ECAL module

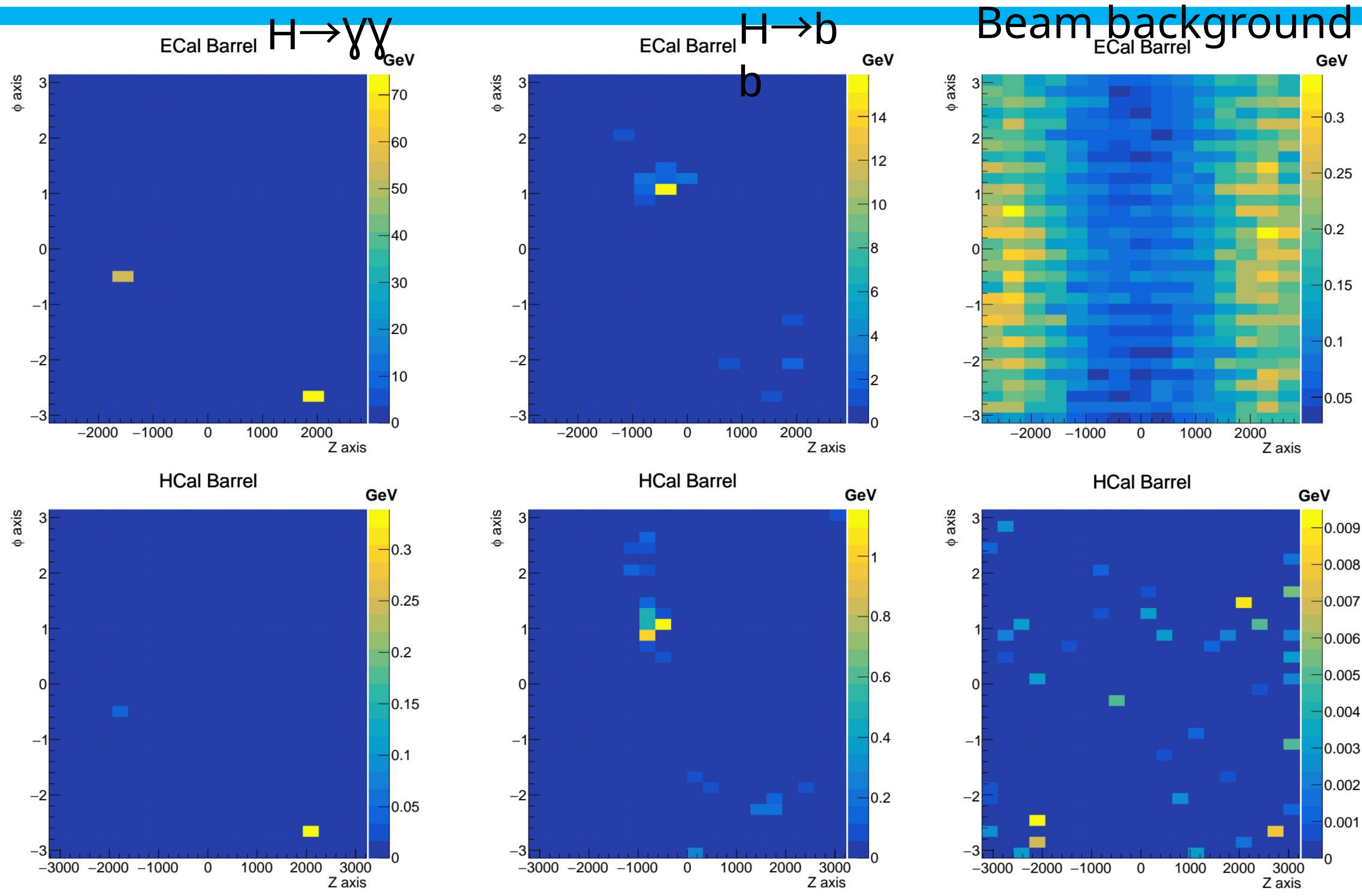


HCAL module



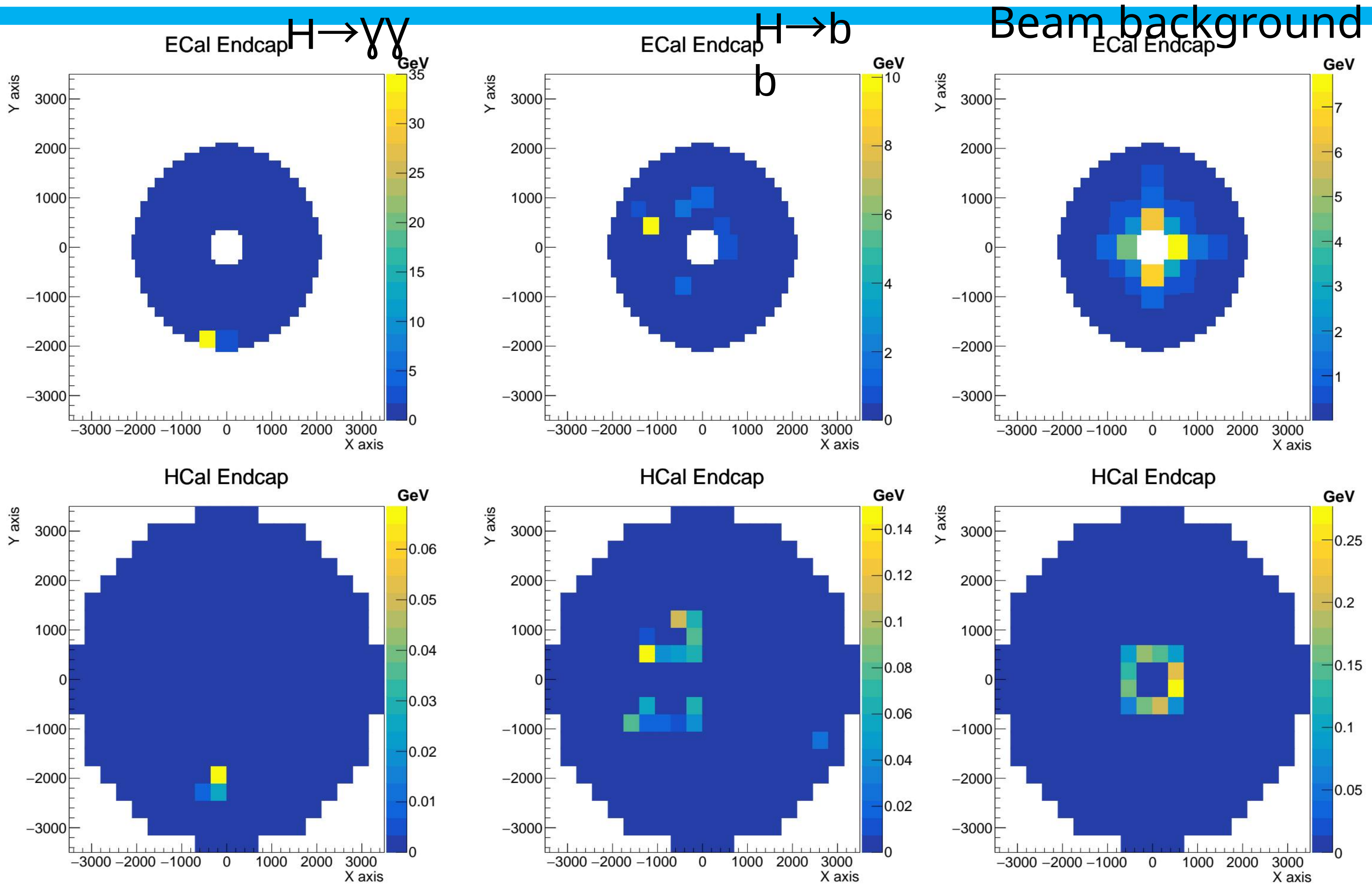
Barrel supercell energy distribution

- Large energy deposition(>10GeV) for signal(H→γγ, H→bb)
- Very tiny energy deposition(<0.5 GeV) for beam background, mostly from pair production
    - **One** beam background event contains **10** BX



Endcap supercell energy distribution

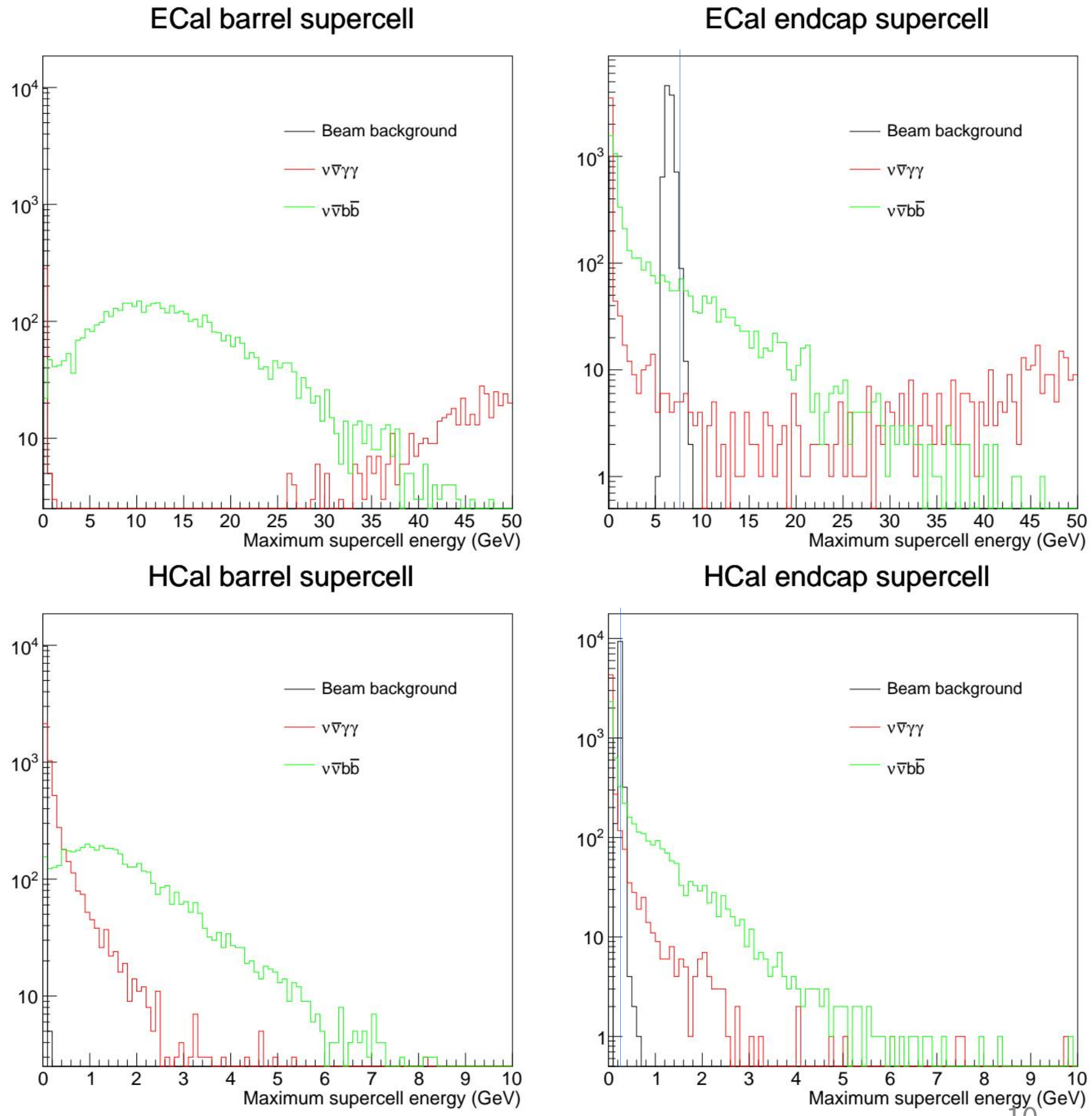
- Similar to barrel for signal
- Relatively large energy deposition(~5GeV) for beam background
- Use supercell energy as input



Maximum energy distribution

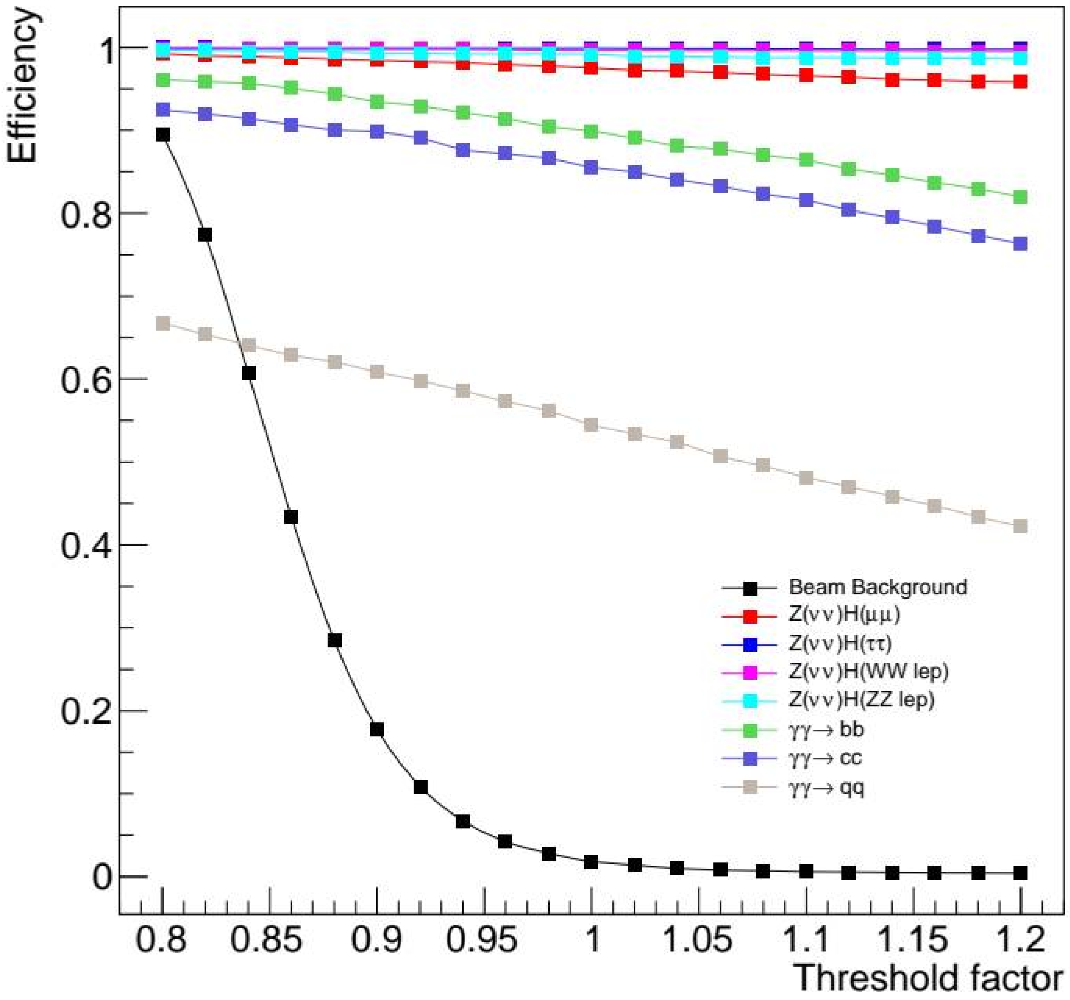
- Maximum energy for each sub-detector
- Beam induced background contributes little(<1GeV) on calorimeter, except ECal Endcap
- A baseline set of energy threshold
  - Background efficiency is less than 0.5% when any single threshold is used alone
  - A blue line shows the value for Endcap

Subdetector	Threshold(GeV)
ECAL Barrel	0.38
ECAL Endcap	7.7
HCAL Barrel	0.05
HCAL Endcap	0.33



Efficiency vs threshold

- Threshold value can be modified for different physics requirement
- A group of sets are tested based on the baseline set, by multiply a "threshold factor" to all the four threshold
- Only the ZH production with an efficiency below 99%, the di-photon processes and background are shown
- Signal processes are affected if the final state contains only neutrinos and muon



Efficiency for baseline threshold

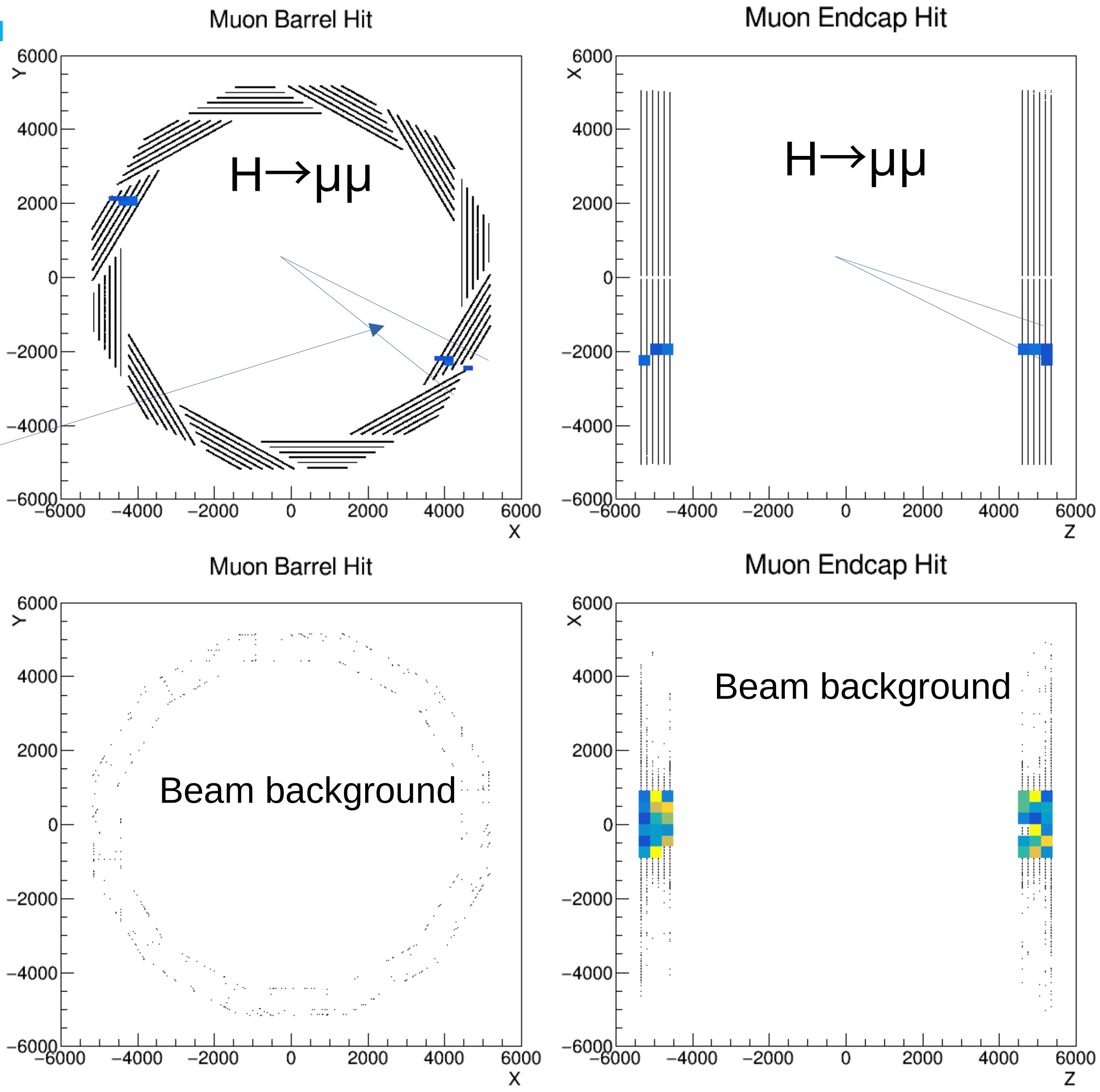
- For most of the signal events, efficiency > 0.99
- μμ too forward
  - Efficiency up to 0.935 if at least one muon inside calorimeter
- Three 4-fermions contain only neutrinos and muon at final state
  - Neutrinos energy > 200GeV

Table 12.8: Calorimeter threshold efficiency at the ZH mode for 50 MW

Process	Efficiency	Process	Efficiency	Process	Efficiency
Two Fermions					
Bhabha	0.998	$\mu^+\mu^-$	0.852	$\tau^+\tau^-$	0.958
Higgs production					
$Z(\nu\bar{\nu})H(\gamma\gamma)$	>0.999	$Z(\nu\bar{\nu})H(\gamma Z)$	0.999	$Z(\nu\bar{\nu})H(b\bar{b})$	>0.999
$Z(\nu\bar{\nu})H(\mu^+\mu^-)$	0.979	$Z(\nu\bar{\nu})H(\tau^+\tau^-)$	0.996	$Z(\nu\bar{\nu})H(W^+W^-)$	>0.999
$Z(\nu\bar{\nu})H(W^+W^-)$lep	0.995	$Z(\nu\bar{\nu})H(ZZ)$	>0.999	$Z(\nu\bar{\nu})H(ZZ)$lep	0.992
Four Fermions					
sw_l0mu	0.997	sw_l0tau	>0.999	sw_sl	>0.999
sze_l0e	>0.999	sze_l0mu	0.877	sze_l0nunu	0.998
sze_l0tau	0.994	sze_sl	>0.999	szeorsw_l	>0.999
sznu_l0mumu	0.621	sznu_l0tautau	0.933	ww_h0ccbs	>0.999
ww_l	0.988	ww_sl0muq	>0.999	ww_sl0tauq	>0.999
wwbosons	>0.999	zz_h0dtdt	>0.999	zz_l04mu	0.900
zz_l04tau	0.988	zz_l0mumu	0.658	zz_l0taumu	0.971
zz_l0tautau	0.950	zz_sl0mu_down	>0.999	zz_sl0mu_up	>0.999
zz_sl0nu_down	>0.999	zz_sl0nu_up	>0.999	zz_sl0tau_down	>0.999
zz_sl0tau_up	0.998	zzbosons	0.958	zzorww_h0cscs	>0.999
zzorww_l0mumu	0.925	zzorww_l0tautau	0.992		
Di-photon process					
$\gamma\gamma \to b\bar{b}$	0.888	$\gamma\gamma \to c\bar{c}$	0.846	$\gamma\gamma \to q\bar{q}$	0.533
Background	**Veto rate**				
Beam Background	0.982				

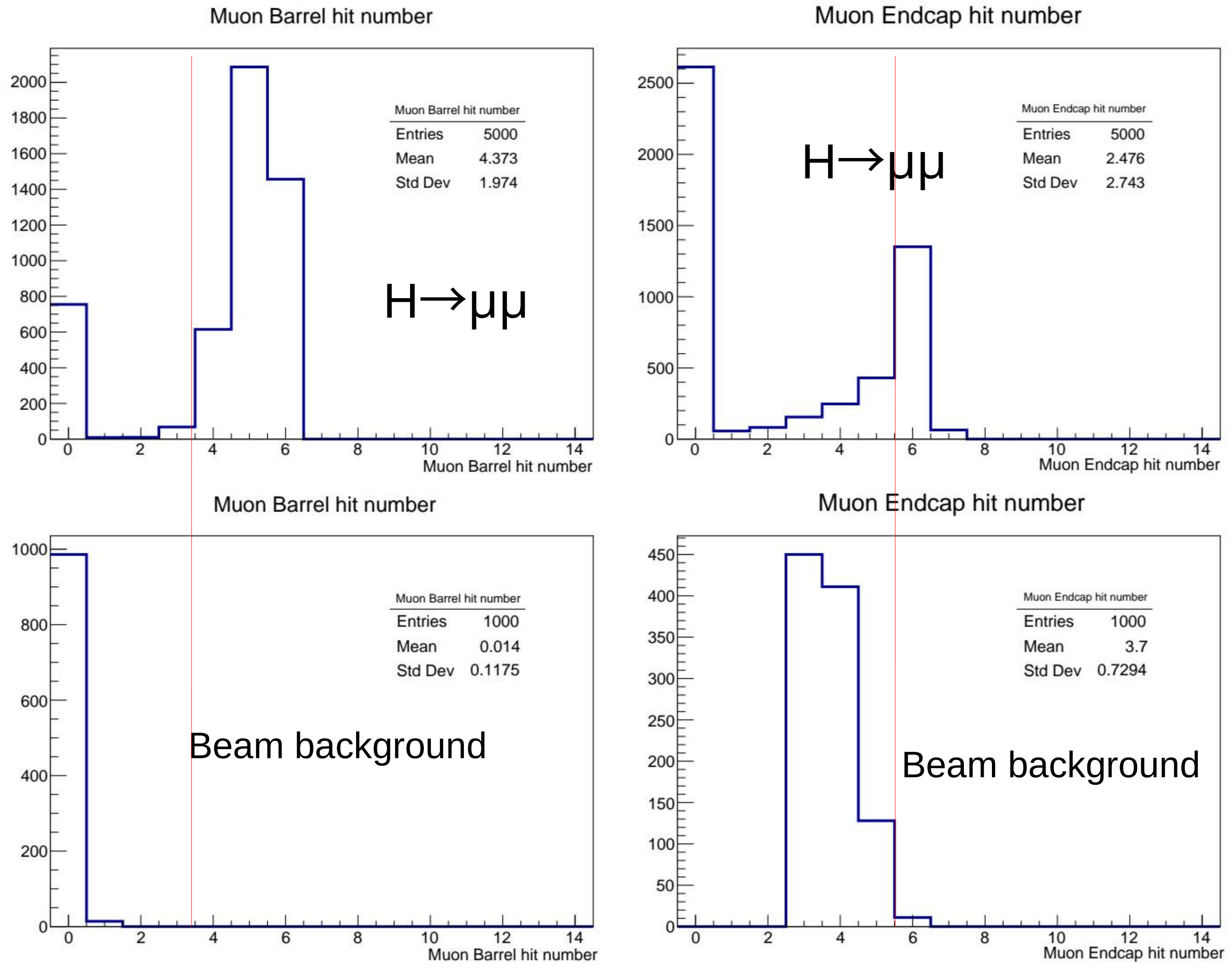
Muon detector

- Top: signal Z(νν)H(μμ)
- Bottom: beam background
  - Black hits: hits for all 2000 events
  - Color hits: hits for single events
- Count number of muon hit inside a small cone(baseline radius)
  - Barrel: dR<0.05
  - Endcap: dR<0.007



Number of hit

- Red line: baseline cut for the number of hit
  - Barrel > 3
  - Endcap > 5
- Background efficiency: 0.0119
- H→μμ efficiency: 0.9648



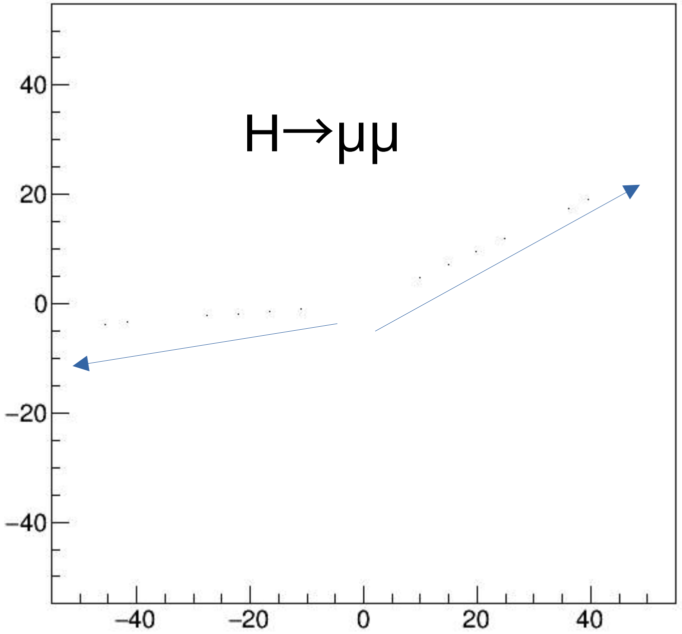
Combine efficiency

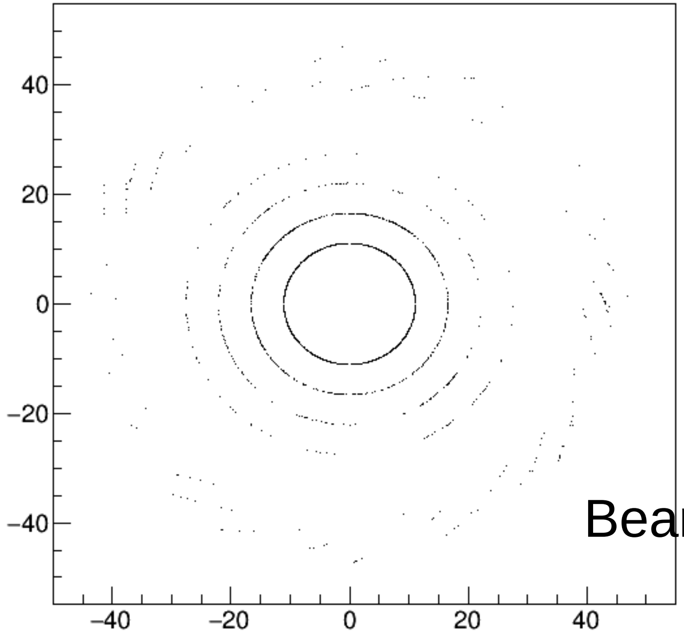
- Efficiency improve for Z(νν)H(μμ) and ee→μμ
- Beam background increase to 0.03

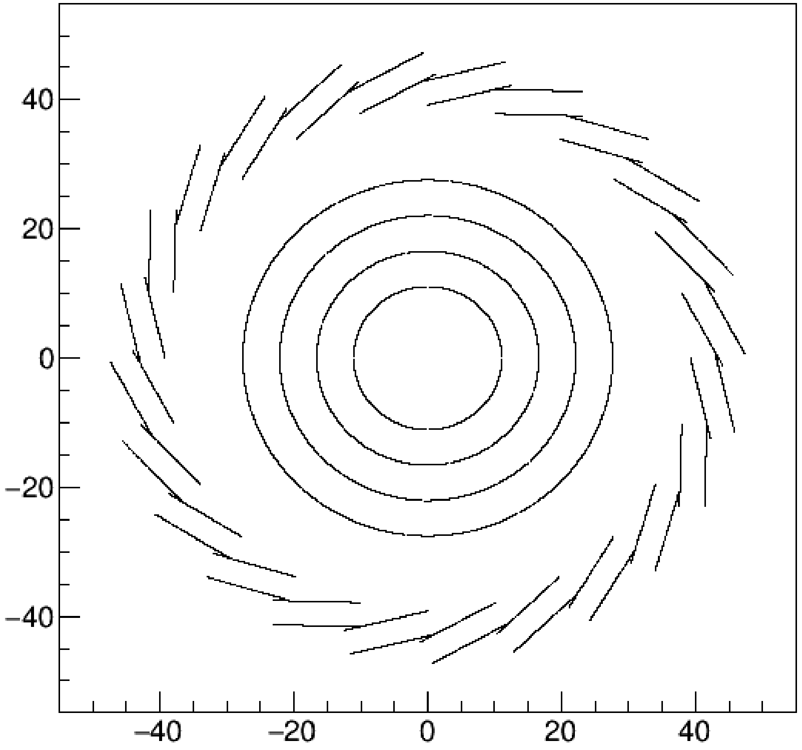
	Calo only	Muon only	Combine
Z(νν)H(μμ)	0.979	0.965	0.994
ee→μμ	0.935	0.854	0.96
Beam bkg	0.019	0.012	0.030

Tracker: Vertex

- Left: Z(νν)H(μμ); Right: Beam background
- Too many hits from beam bkg, difficult to use



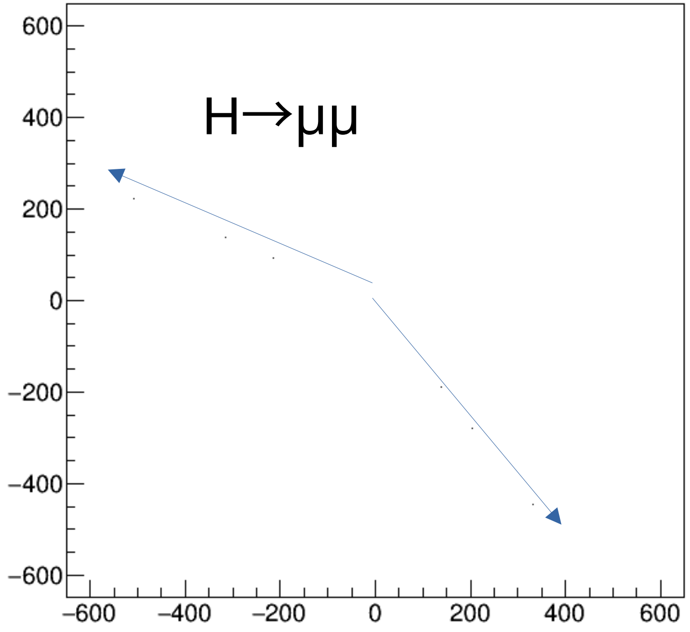


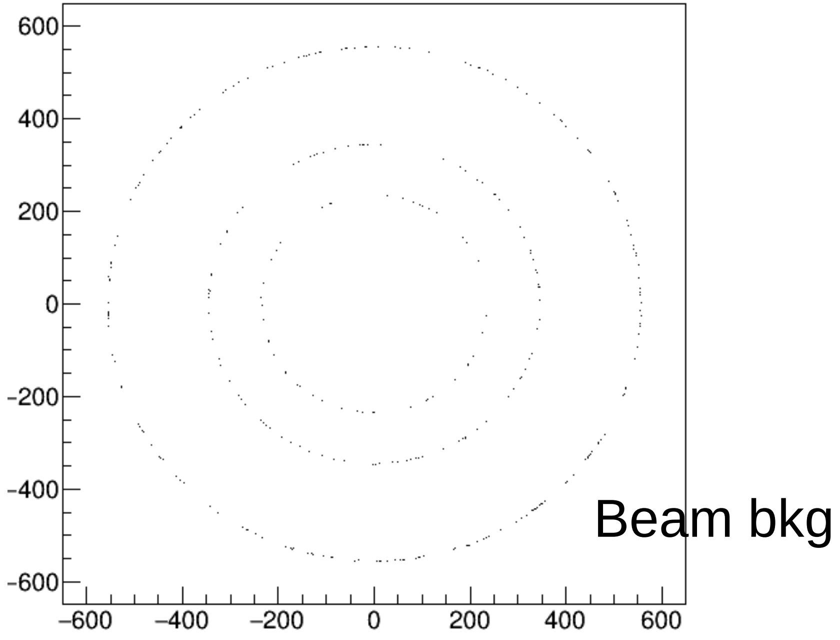


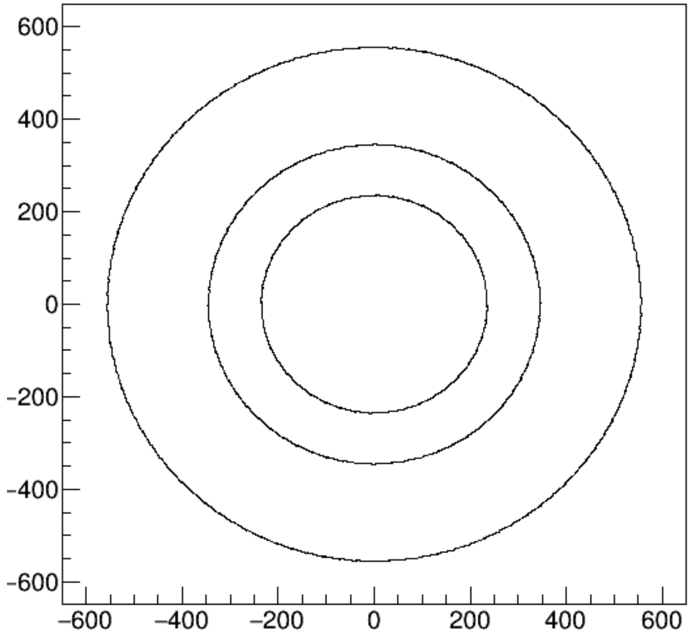
Beam bkg

Tracker: ITK

- Left: Z(νν)H(μμ); Right: Beam background
- Less hits than vertex
  - Only 3 layers(+1 layers for OTK), difficult to do tracking
  - May be able to reconstruct 2D track, need further study
- Combine ITK/OTK and Muon doesn’t improve Muon efficiency

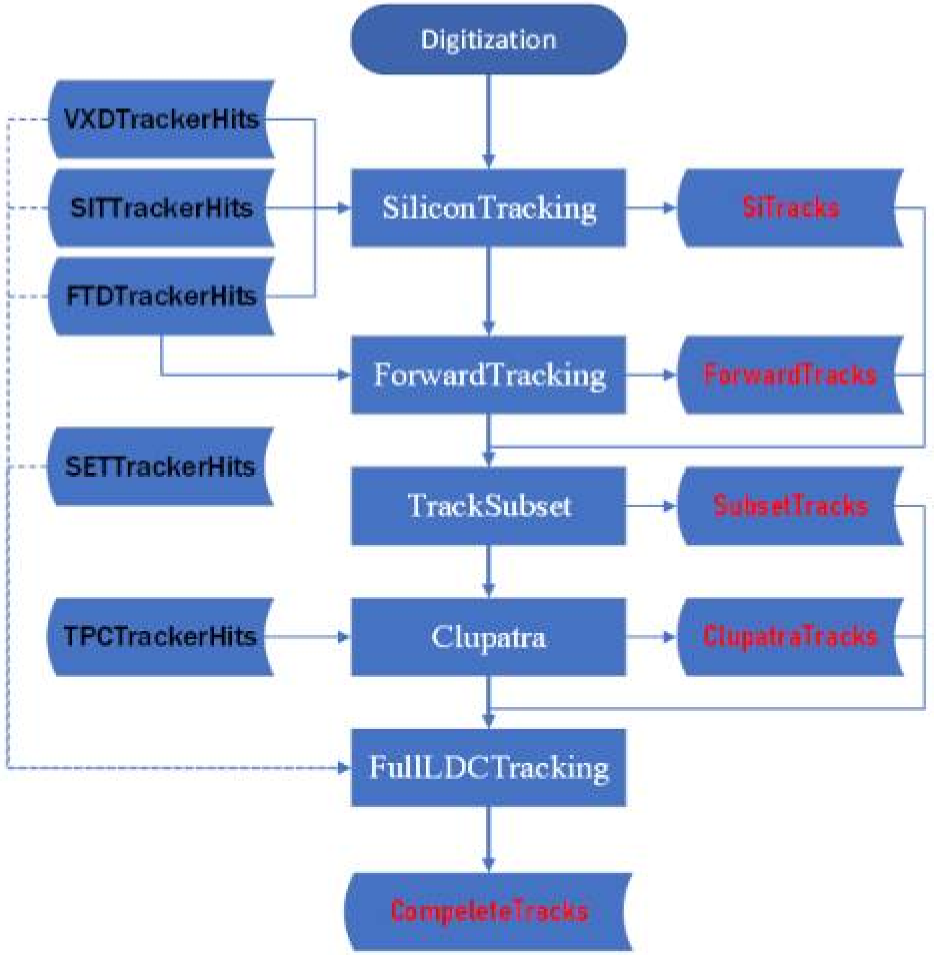






Software trigger

- Offline track reconstruction
- Build “CompleteTracks” from all tracking subdetector
- Beam background:
  - ~1s / event for both ZH and Z mode
  - Efficiency: ~20%(N track > 0)
  - Other tracking information(pT) will be studies
  - Need more background events for HLT



Summary and Outlook

- Trigger simulation & algorithm results are shown in this talk
  - L1: use Calorimeter&Muon(Track to be studied)
  - HLT: apply offline track reconstruction algorithm

- Future:
  - Detail calorimeter cluster algorithm: isolation/depth/location(back to back)/CoM…
  - Tracking algorithm for L1
  - Optimize different sets of threshold
  - Detector noise
  - ML(BDT, DNN, CNN…)
  - Trigger for BSM
  - …

Findings

- The requirements for the TDAQ system are dictated by the need to collect all ZH, WW and Z pole events and provide the bandwidth needed to store these data. The data rates, before trigger, range from <1 TB/s for ZH running up to several TB/s at the Z peak with an expected event size below 2MB. The storage rate after the trigger ranges from 0.1 for ZH to 100 kHz at the Z pole. Contributions from beam-related backgrounds (for both single-beam and sources that scale with luminosity) are based on dedicated simulations and are included in rate estimates and preliminary trigger design.
- The baseline plan is to transmit the full raw data to the front-end electronics and connect the trigger to the back-end electronics. This strategy is sound. Similar strategies have been successfully implemented in CMS and LHCb, where data rates are much higher. A hierarchical trigger scheme is foreseen to bring event data rates down from ~3MHz to ~1kHz in HZ running and ~40 MHz to ~100 kHz at the Z pole.
- Early trigger studies are based on primitives from the calorimeter and muon detector which show promise for selecting desired physics at high efficiency while rejecting beam backgrounds. These studies do not yet include any high-level trigger information, which should be very effective at further refining the selection.
- The system design foresees a common hardware trigger board to collect trigger primitives from the BEE common boards and send trigger accept signals to the BEEs. High-throughput DAQ and processing building on the RADAR framework used in previous projects will be extended to meet the requirements at CEPC. Initial designs for the Timing, Clock, and Control Distribution System (TCDS/TTC), as well as the Detector Control System (DCS) and Experiment Control System (ECS), are currently under development. The hardware trigger scheme is also in progress, with a preliminary design already presented. As more detailed information about data volumes from individual detectors becomes available, several key design decisions will need to be made to ensure optimal system performance
- The RDT has extensive experience in TDAQ and has designed and built hardware boards, firmware and software for several leading projects: BESIII, PANDA at GSI, Belle2 and CMS as well as several neutrino experiments, and have implemented machine learning (a NN for tau reconstruction) in the ATLAS global trigger upgrade. Their expertise is consistent with providing the TDAQ for the CEPC reference detector, and they are planning to increase capacity by adding additional members.

Comments

Feedback to 1st IRDC review

- The detailed (bottom-up) design of the TDAQ must await further details on the subdetector design.
- Work on the trigger primitives is needed to bring the rate down to an acceptable input for the second-level trigger, and to inform further planning for the processing farms in the DAQ design. Should it be needed, a track trigger could provide a powerful additional primitive.
- High-level triggering will also need to weigh the physics-versus-bandwidth tradeoff for lower-energy events, e.g. from gamma-gamma collisions.

- Agree. Especially background study and data rate estimation from each sub detectors.
- The beam background could be dramatically compressed using basic trigger primitives from Ecal/Hcal and a simple muon tracking algorithm. Offline tracking algorithm is studied for HLT.
- Based on the study from the generator and some theory papers, the event rate for gamma-gamma is up to a few kHz. The current trigger algorithm is able to select about 50% of the hadronic gamma-gamma events. The algorithm also has freedom to veto more gamma-gamma events if we don’t want them.

Recommendations

Feedback to 1st IRDC review

1. Prioritizing a straightforward simulation of subdetector-based trigger inputs using robust algorithms is essential. The simulation should include an appropriate safety factor for beam-related backgrounds. This approach will enable a more detailed specification of the requirements for TDAQ hardware and help identify areas that require further attention.
2. Further work should include an evaluation of benefits of implementing a track trigger as a complement to the calorimeter and muon primitives, and to clarify the bandwidth foreseen for gamma-gamma events.

- We conducted simulations using this approach, yielding promising results and demonstrating good efficiency in both the calorimeter energy and muon track trigger conditions. A 10-fold safety factor for beam related backgrounds has been investigated.
- Muon tracking is studied for L1, and the offline tracking algorithm is studied for HLT. The current trigger algorithm can keep gamma-gamma events up to about 50%, or veto them if we don’t want them.

Computing Requirements: Data Volume

- 5 year data taking, 1 IP
  - 4 years: Higgs, 1 year: Low Z (collected in 5 years)
  - Running time per year: 3600 hours
  - Reconstruction data: 10% raw
  - MC and Rec: 2 versions/year
- Total data volume: 484PB
  - Higgs: 48PB (12PB/year)
  - Z: 436PB

First 5 year	Data(PB)	MC(PB)	Total (PB)
Higgs (4 years)	32 +~100	16 +?	48
Low Z (1 year)	156 +~80	280 +?	436
Total			484

Table 12.5: Trigger rate estimation table for different run conditions.

Condition	Higgs	Z(10MW)	Z(50MW)	W	$t\bar{t}$
Luminosity ($10^{34}/cm^2/s$)	8.3	26	95.2	26.7	0.8
Bunch space (ns)	277	69.3	23.1	253.8	4523.1
Bunch crossing rate (MHz)	1.34	12	39.4	6.5	0.18
Background data size/bunch crossing (kbyte)	300	162	162	300	300
Background data rate (Tbyte/s)	0.4	1.94	7.7	1.95	0.048
Physical event rate (kHz)	0.087	10.5	41.9	0.1	0.002
L1 triger rate (kHz)	13	120	400	65	2
Background event size (kbyte)	695	448	1070	-	-
Readout event size (kbyte)	1000	1000	2000	1000	1000
DAQ readout rate (Gbyte/s)	13	120	800	65	2
High level trigger rate (kHz)	1	20	80	6	1
Storage event size (kbyte)	500	500	1000	500	500
DAQ storage rate (Gbyte/s)	0.5	10	80	3	0.5

Offline Software and Computing

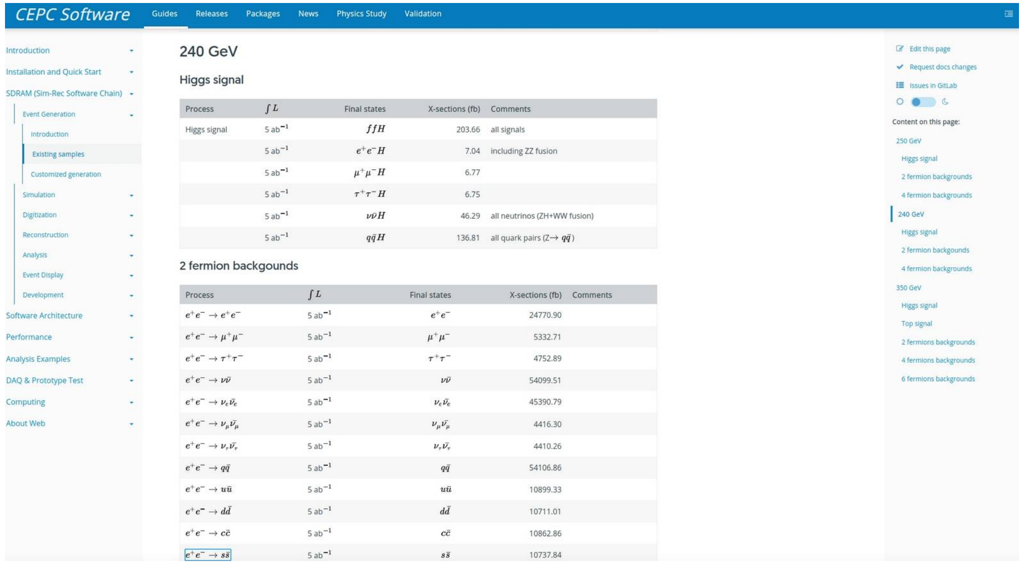
Backup

MC name

Total_name	Abbreviation	Process	Final states	X-sections(fb)	Events generate	Scale factor	Events expected	Total
single_w	single_w	sw_l0mu	e,nu_e,mu,$nu_{\mu,\tau}$	436.70	2205350	110.89%	2445520	19517400
		sw_l0tau	e,nu_e,tau,$nu_{\mu,\tau}$	435.93	2201471	110.89%	2441208	
		sw_sl0qq	e,nu_e,up,down	2612.62	13193721	110.89%	14630672	
single_z	single_sze	sze_l0e	uncertain:e^-,e^+,e^-,e^+	78.49	396388	110.89%	439544	9072951
		sze_l0mu	e^-,e^+,μ^-,μ^+	845.81	4270357	110.92%	4736536	
		sze_l0nunu	$e^-,e^+,\nu_{\mu,\tau},\overline{\nu}_{\mu,\tau}$	28.94	146138	110.90%	162064	
		sze_l0tau	e^-,e^+,τ^-,τ^+	147.28	743781	110.89%	824767	
		sze_sl0dd	e,e,down,down	125.83	635351	110.91%	704648	
		sze_sl0uu	e,e,up,up	190.21	960556	110.89%	1065176	
	single_sznu	sznu_l0mumu	$\nu_e,\overline{\nu}_e,\mu^-,\mu^+$	43.42	219278	110.89%	243152	
		sznu_l0tautau	$\nu_e,\overline{\nu}_e,\tau^-,\tau^+$	14.57	100000	81.59%	81592	
		sznu_sl0nu_down	$\nu_e,\overline{\nu}_e,down,down$	90.03	454649	110.89%	504168	
		sznu_sl0nu_up	$\nu_e,\overline{\nu}_e,up,up$	55.59	280749	110.88%	311304	
zorw	zorw	szeorsw_l0l	$e^-,e^+,\nu_e,\overline{\nu}_e$	249.48	1259867	110.89%	1397088	1397088
ww	ww_h	ww_h0ccbs	cq,cq,bq,sq	5.89	100000	32.84%	32984	50826214
		ww_h0ccds	cq,cq,dq,sq,	170.18	859417	110.89%	953008	
		ww_h0cuxx	cq,uq,down,down	3478.89	17562880	110.93%	19481784	
		ww_h0uubd	uq,uq,bq,dq	0.05	100000	0.28%	280	
		ww_h0uusd	uq,uq,sq,dq	170.45	860029	110.99%	954519	
	ww_l	ww_l0ll	mu,tau,nu_μ,nu_τ	403.66	2036465	111.00%	2260496	
	ww_sl	ww_sl0muq	mu,nu,up,down	2423.43	12238338	110.90%	13571207	
		ww_sl0tauq	tau,nu,up,down	2423.56	12238057	110.90%	13571936	
zz	zz_h	zz_h0cc_nots	cq,cq,(dq,bq),(dq,bq)	98.97	499812	110.89%	554232	6389430
		zz_h0dtdt	down,down,down,down	233.46	1178944	110.89%	1307376	
		zz_h0utut	up,up,up,up	85.68	432679	110.89%	479808	
		zz_h0uu_notd	uq,uq,(sq,bq),(sq,bq)	98.56	496703	111.11%	551936	
	zz_l	zz_l04mu	μ^-,μ^+,μ^-,μ^+	15.56	99902	87.22%	87136	
		zz_l04tau	$\tau^-,\tau^+,\tau^-,\tau^+$	4.61	99901	25.84%	25816	
		zz_l0mumu	$\nu_\tau,\overline{\nu}_\tau,\mu^-,\mu^+$	19.38	99900	108.64%	108528	
		zz_l0taumu	$\tau^-,\tau^+,\mu^-,\mu^+$	18.65	99900	104.54%	104440	
		zz_l0tautau	$\nu_\mu,\overline{\nu}_\mu,\tau^-,\tau^+$	9.61	99900	53.87%	53816	
	zz_sl	zz_sl0mu_down	mu,mu,down,down	136.14	705743	108.80%	762383	
		zz_sl0mu_up	mu,mu,up,up	87.39	448844	109.03%	489383	
		zz_sl0nu_down	$nu_{\mu,\tau},nu_{\mu,\tau},down,down$	139.71	708671	110.40%	782376	
		zz_sl0nu_up	$nu_{\mu,\tau},nu_{\mu,\tau},up,up$	84.38	429037	110.14%	472528	
		zz_sl0tau_down	tau,tau,down,down	67.31	339928	110.89%	376936	
		zz_sl0tau_up	tau,tau,up,up	41.56	209898	110.88%	232736	
zzorww	zzorww	zzorww_h0cscs	cq,sq,cq,sq	1607.55	8117636	110.90%	9002280	20440840
		zzorww_h0udud	uq,dq,uq,dq	1610.32	7811146	115.45%	9017792	
		zzorww_l0mumu	mu,mu,nu_μ,nu_μ	221.10	1116551	110.89%	1238160	
		zzorww_l0tautau	tau,tau,nu_τ,nu_τ	211.18	1066451	110.89%	1182608	

Cross section

- CEPC software & Sample generation for CEPC
- Sample generated by Kaili



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240 GeV

Higgs signal

Process	$\int L$	Final states	X-sections (fb)	Comments
Higgs signal	5 ab^{-1}	ffH	203.66	all signals
	5 ab^{-1}	e^+e^-H	7.04	including ZZ fusion
	5 ab^{-1}	$\mu^+\mu^-H$	6.77	
	5 ab^{-1}	$\tau^+\tau^-H$	6.75	
	5 ab^{-1}	$\nu\bar{\nu}H$	46.29	all neutrinos (ZH+WW fusion)
	5 ab^{-1}	$q\bar{q}H$	136.81	all quark pairs (Z→ $q\bar{q}$)

2 fermion backgounds

Process	$\int L$	Final states	X-sections (fb)	Comments
$e^+e^- \to e^+e^-$	5 ab^{-1}	e^+e^-	24770.90	
$e^+e^- \to \mu^+\mu^-$	5 ab^{-1}	$\mu^+\mu^-$	5332.71	
$e^+e^- \to \tau^+\tau^-$	5 ab^{-1}	$\tau^+\tau^-$	4752.89	
$e^+e^- \to \nu\bar{\nu}$	5 ab^{-1}	$\nu\bar{\nu}$	54099.51	
$e^+e^- \to \nu_e\bar{\nu}_e$	5 ab^{-1}	$\nu_e\bar{\nu}_e$	45390.79	
$e^+e^- \to \nu_\mu\bar{\nu}_\mu$	5 ab^{-1}	$\nu_\mu\bar{\nu}_\mu$	4416.30	
$e^+e^- \to \nu_\tau\bar{\nu}_\tau$	5 ab^{-1}	$\nu_\tau\bar{\nu}_\tau$	4410.26	
$e^+e^- \to q\bar{q}$	5 ab^{-1}	$q\bar{q}$	54106.86	
$e^+e^- \to u\bar{u}$	5 ab^{-1}	$u\bar{u}$	10899.33	
$e^+e^- \to d\bar{d}$	5 ab^{-1}	$d\bar{d}$	10711.01	
$e^+e^- \to c\bar{c}$	5 ab^{-1}	$c\bar{c}$	10862.86	
$e^+e^- \to s\bar{s}$	5 ab^{-1}	$s\bar{s}$	10737.84	

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Higgs signal
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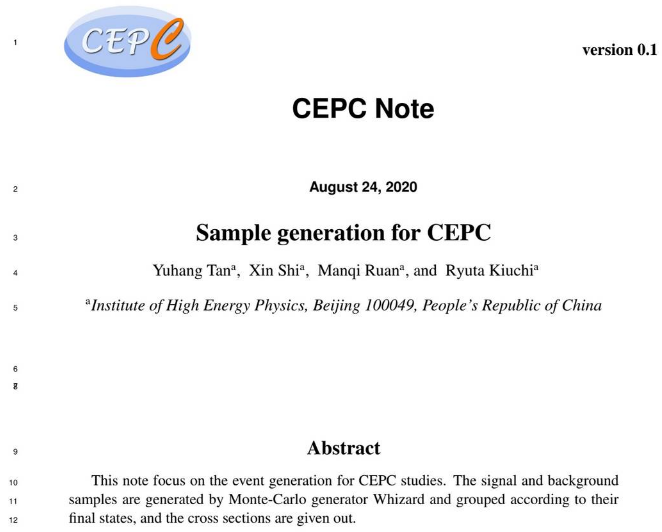
Higgs signal
Top signal
2 fermions backgrounds
4 fermions backgrounds
6 fermions backgrounds



version 0.1

CEPC Note

August 24, 2020

Sample generation for CEPC

Yuhang Tan[a], Xin Shi[a], Manqi Ruan[a], and Ryuta Kiuchi[a]

[a]*Institute of High Energy Physics, Beijing 100049, People's Republic of China*

Abstract

This note focus on the event generation for CEPC studies. The signal and background samples are generated by Monte-Carlo generator Whizard and grouped according to their final states, and the cross sections are given out.

Bhabha cross section from generator

- From babayaga， remove energy cut， add theta cut [8, 172]
  - Higgs: ~1000 pb，～100Hz; Z: 6593pb，～2kHz
- From Whizard：
  - Higgs: 743 pb; Z: 13147pb，～6kHz
- BesIII bhabha from babayaga： 800Hz, 800nb

Bhabha cross section from theory paper

- Large-angle Bhabha scattering, Link
  - 10<θ<170 （CEPC: 8-172）
  - Z pole: ~6000pb=6nb， close to babayaga result

- Naive calculation:
  - σ~1/CoM^2
  - ZH pole bhabha xsec = Z pole bhabha xsec *91GeV*91GeV/240GeV/240GeV
  - =Z pole bhabha xsec （~6nb） *0.144~0.9nb

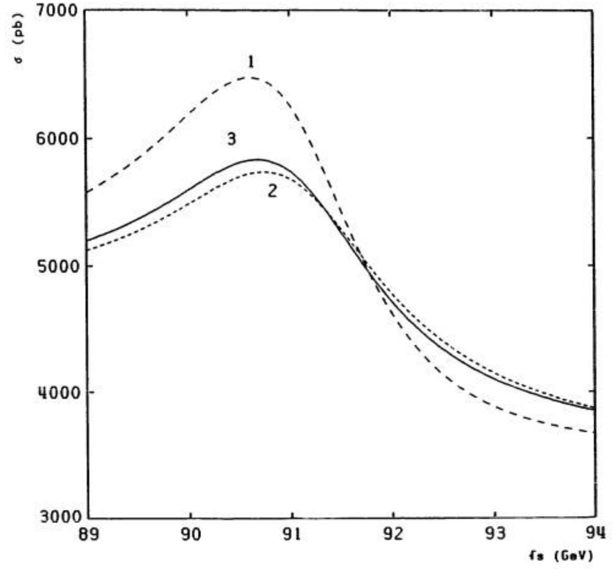
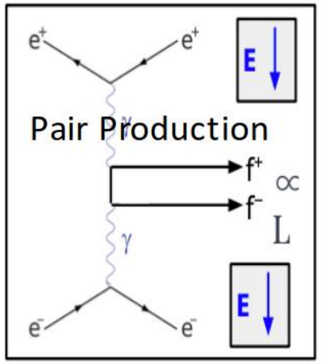


Fig. 3. The total cross section as a function of the energy, using an angular cut of 10° and an energy cut of 10 GeV. The conventions are the same as in fig. 2.

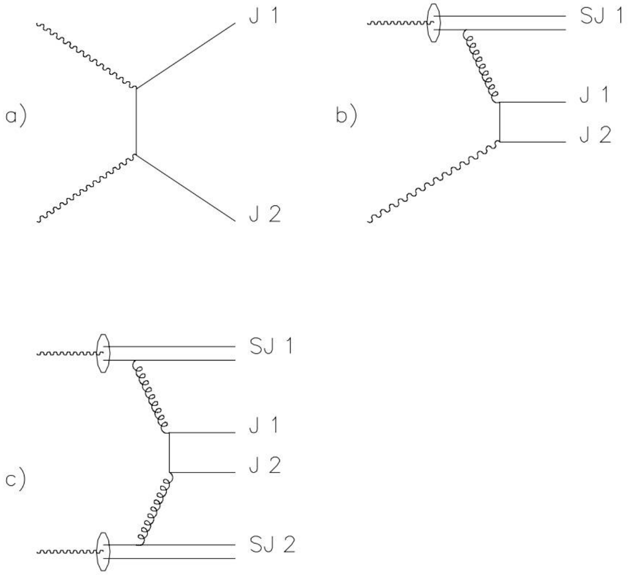
$$\frac{d\sigma}{d(\cos\theta)} = \frac{\pi\alpha^2}{s}\left(u^2\left(\frac{1}{s}+\frac{1}{t}\right)^2+\left(\frac{t}{s}\right)^2+\left(\frac{s}{t}\right)^2\right)$$

Di-photon from Guinea-Pig

- Beam background： electron pair production($\gamma\gamma \rightarrow ee$)
  - Generated using GUINEA-PIG by Haoyu
  - For higgs mode: ~1000 collision for one BX
- Hadron final state($\gamma\gamma \rightarrow qq$) using GUINEA-PIG：
  - Total hadron final state: 2 kHz, 25 nb
  - Minijet ($\gamma\gamma \rightarrow jj$): 33 Hz, 413 pb (pT>2GeV)



Photon BG



Di-photon paper 1

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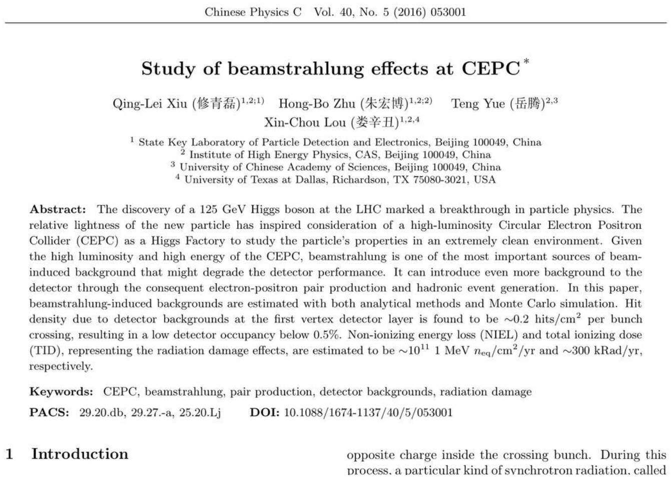
- Top: di-photon cross section vs energy
- Bottom left: di-photon energy distribution, theory calculation by prof. 代建平
- Integrate to get the final cross section:
  - From 0.1GeV to 200GeV
    - Higgs: 850pb (68Hz)
    - Z: 917pb
  - From 0.01GeV to 200GeV
    - Higgs: 4150pb (~300Hz)
    - Z: 4560pb;



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Study of beamstrahlung effects at CEPC*

Qing-Lei Xiu (修青磊)[1,2;1)] Hong-Bo Zhu (朱宏博)[1,2;2)] Teng Yue (岳腾)[2,3]
Xin-Chou Lou (娄辛丑)[1,2,4]

[1] State Key Laboratory of Particle Detection and Electronics, Beijing 100049, China
[2] Institute of High Energy Physics, CAS, Beijing 100049, China
[3] University of Chinese Academy of Sciences, Beijing 100049, China
[4] University of Texas at Dallas, Richardson, TX 75080-3021, USA

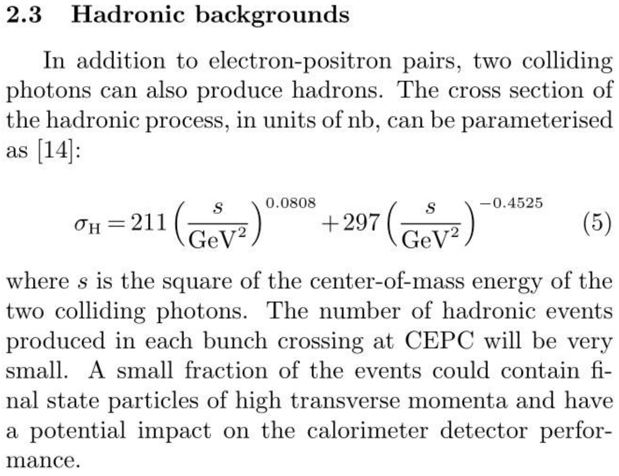
Abstract: The discovery of a 125 GeV Higgs boson at the LHC marked a breakthrough in particle physics. The relative lightness of the new particle has inspired consideration of a high-luminosity Circular Electron Positron Collider (CEPC) as a Higgs Factory to study the particle's properties in an extremely clean environment. Given the high luminosity and high energy of the CEPC, beamstrahlung is one of the most important sources of beam-induced background that might degrade the detector performance. It can introduce even more background to the detector through the consequent electron-positron pair production and hadronic event generation. In this paper, beamstrahlung-induced backgrounds are estimated with both analytical methods and Monte Carlo simulation. Hit density due to detector backgrounds at the first vertex detector layer is found to be ~0.2 hits/cm^2 per bunch crossing, resulting in a low detector occupancy below 0.5%. Non-ionizing energy loss (NIEL) and total ionizing dose (TID), representing the radiation damage effects, are estimated to be ~10^{11} 1 MeV n_{eq}/cm^2/yr and ~300 kRad/yr, respectively.

Keywords: CEPC, beamstrahlung, pair production, detector backgrounds, radiation damage

PACS: 29.20.db, 29.27.-a, 25.20.Lj **DOI:** 10.1088/1674-1137/40/5/053001

1 Introduction

opposite charge inside the crossing bunch. During this process, a particular kind of synchrotron radiation, called

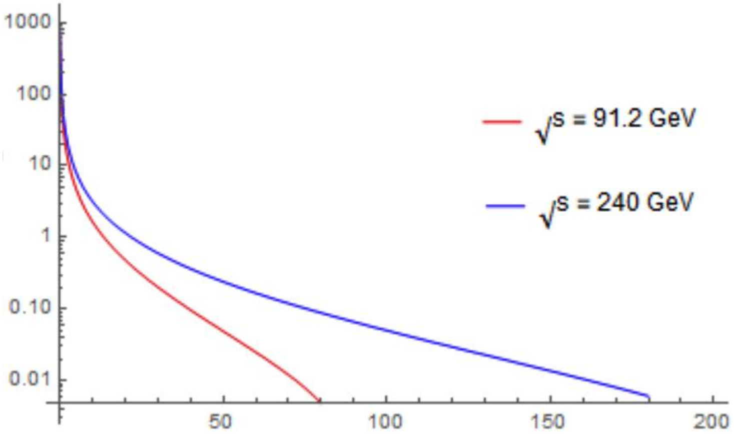


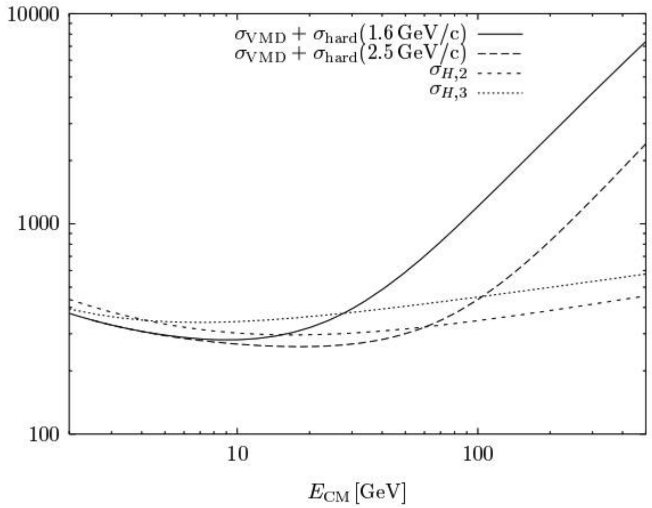
2.3 Hadronic backgrounds

In addition to electron-positron pairs, two colliding photons can also produce hadrons. The cross section of the hadronic process, in units of nb, can be parameterised as [14]:

$$\sigma_{\mathrm{H}} = 211\left(\frac{s}{\mathrm{GeV}^2}\right)^{0.0808} + 297\left(\frac{s}{\mathrm{GeV}^2}\right)^{-0.4525} \quad (5)$$

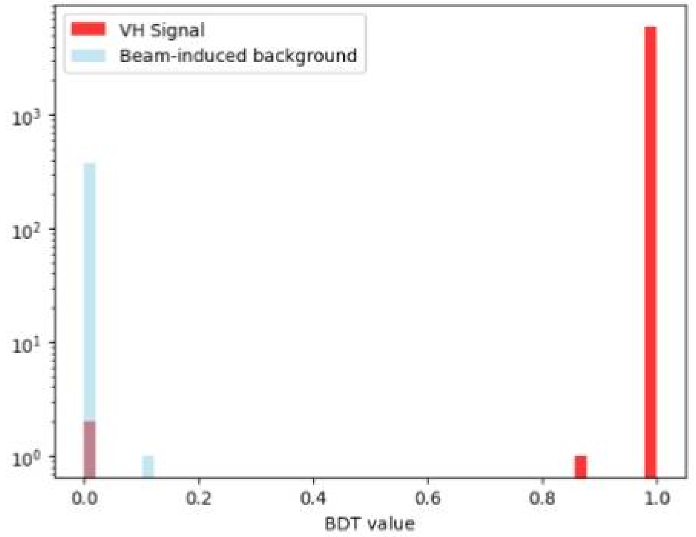
where s is the square of the center-of-mass energy of the two colliding photons. The number of hadronic events produced in each bunch crossing at CEPC will be very small. A small fraction of the events could contain final state particles of high transverse momenta and have a potential impact on the calorimeter detector performance.

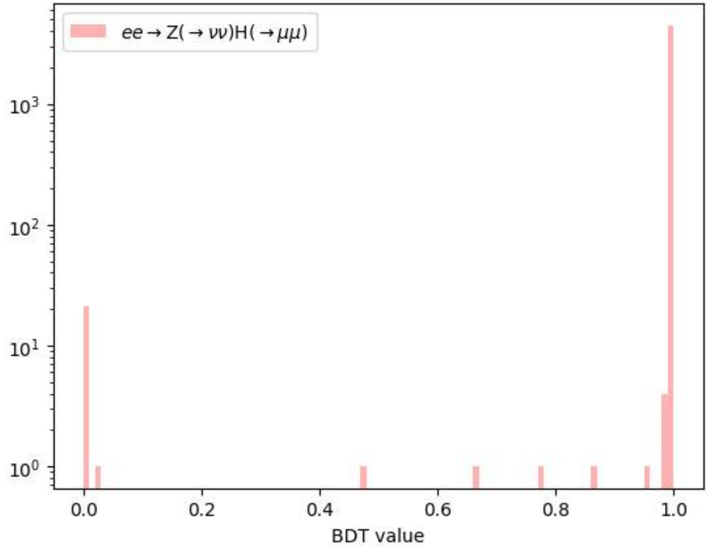




Boost Decision Tree

- Choose two leading energy supercells for Ecal/Hcal; Barrel/Endcap
  - Totally 8 values(input features)
  - Signal: Z(νν)H(γγ, γZ, bb, ττ , WW, and ZZ)
  - n estimators=20, learning rate=1.0, max depth=3
  - Background: 2000 beam background events
  - Signal: 5000 for each process
  - 80% for training, 20 for validation
  - Total signal efficiency: 99.97%; background efficiency: <0.1%
  - Z(νν)H(μμ) efficiency： 99.45%

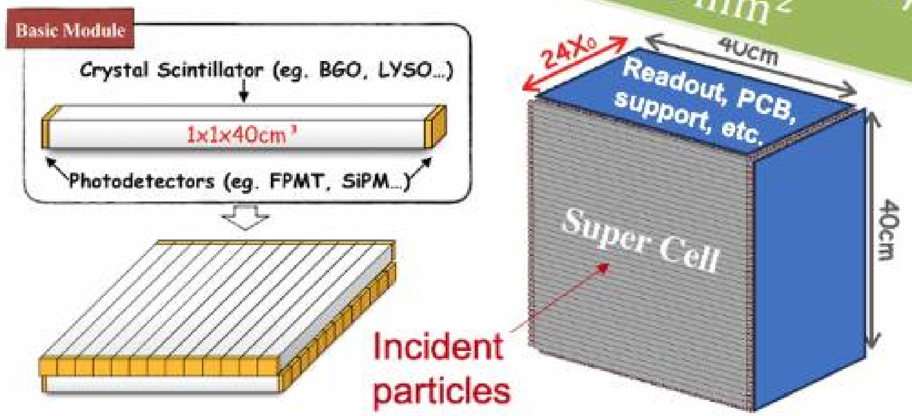




Crystal ECAL option compatible with PFA

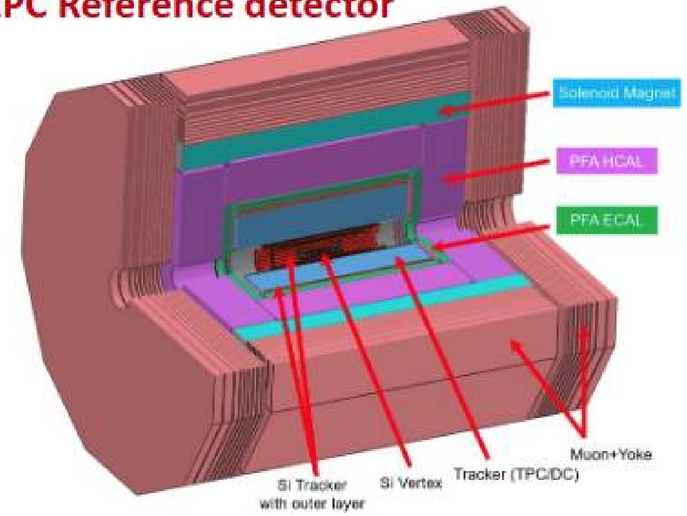
Updated: crystal granularity of 15×15 mm^2

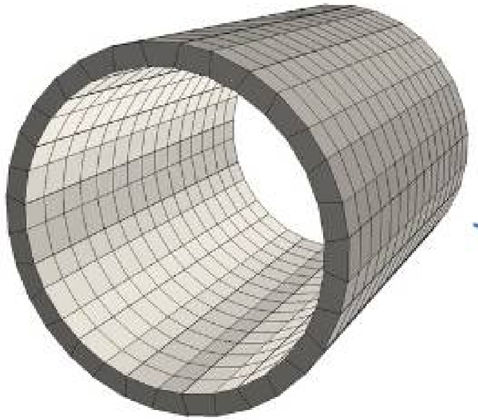
- A new option: R&D activities started since ~2020
- Compatible for PFA: Boson mass resolution (BMR) < 4%
- Optimal EM performance: $\sigma_E/E < 3\%/\sqrt{E}$
- Minimal longitudinal dead material: orthogonal arranged bars
  - 3D positioning with two-sided readout for timing



CEPC Electromagnetic Calorimeter

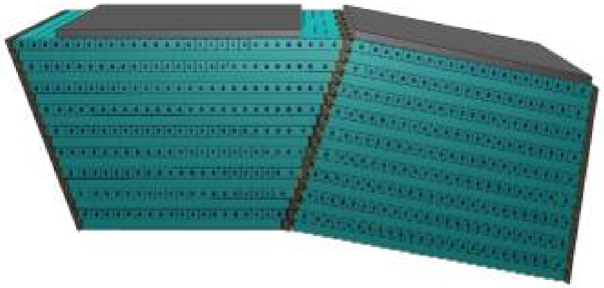
CEPC Reference detector



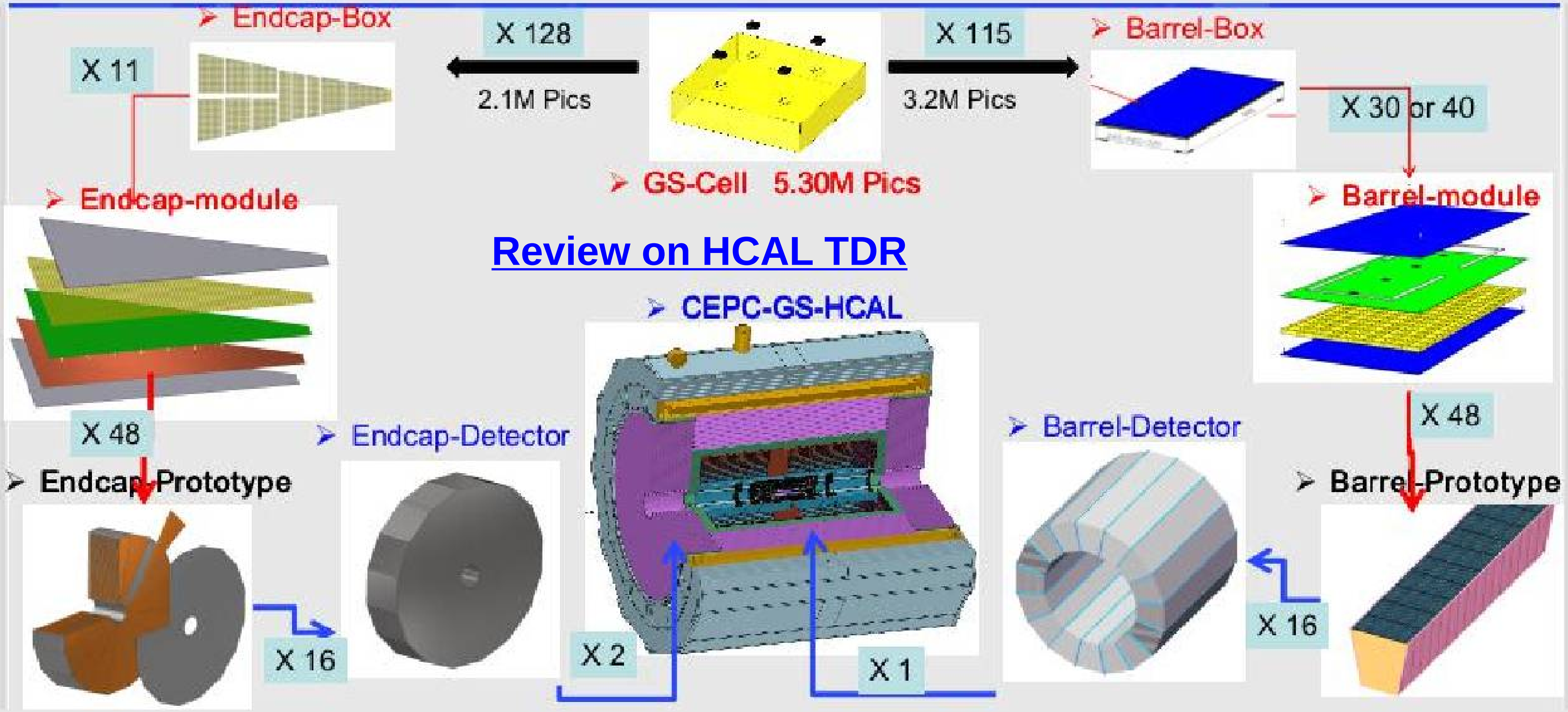


- Total depth of 24 X_0 with 18 longitudinal layers
- Modularity: 32-sided polygons in azimuthal angle

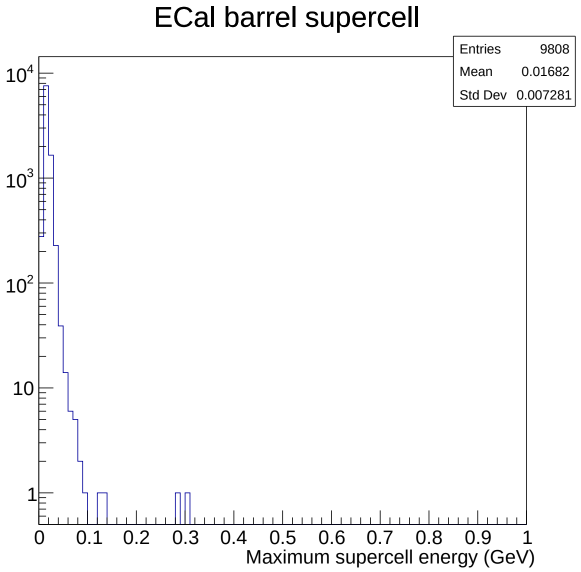
- BGO bars in $1.5\times1.5\times\sim40$ cm^3
- Effective granularity 1.5×1.5 cm^2
- Modules with cracks not pointing to IP (with an inclined angle of 12 degrees)

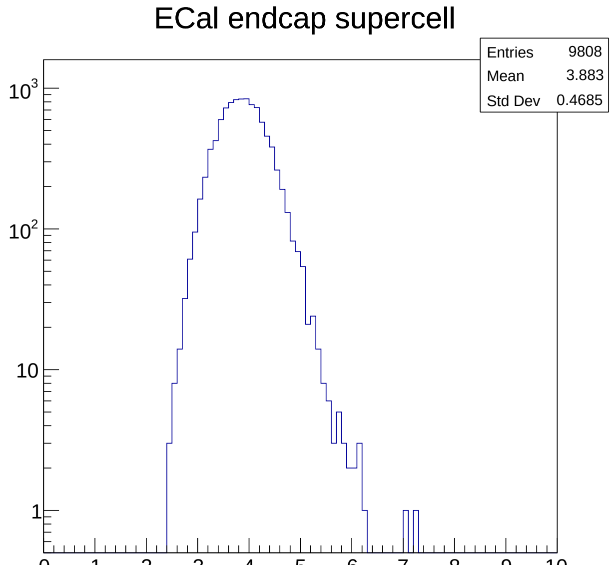


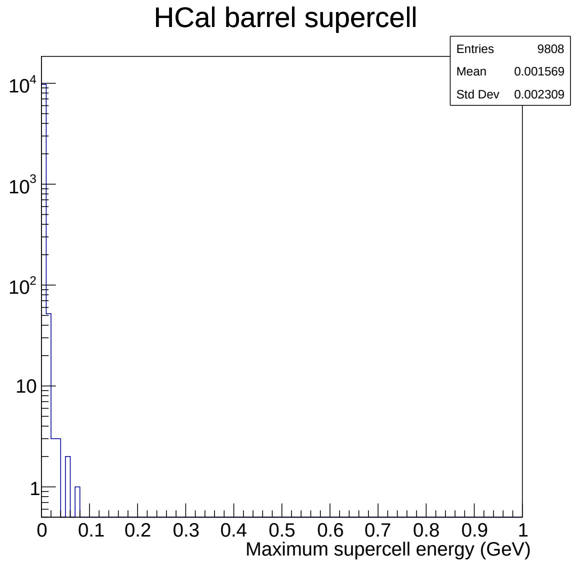
Review on HCAL TDR

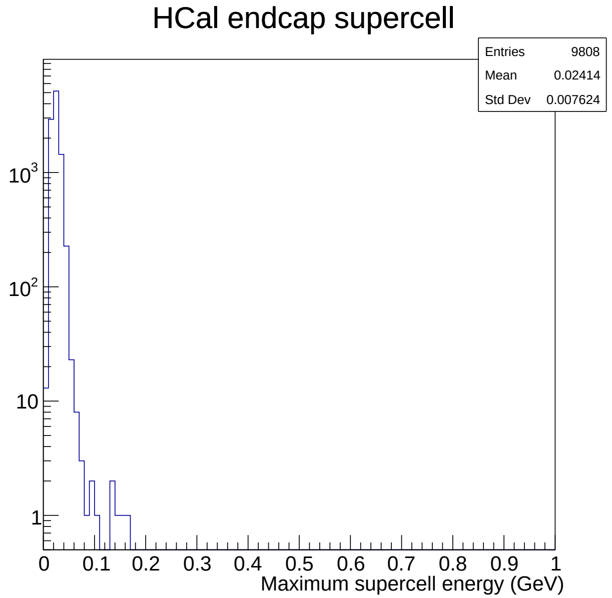


1Bx


ECal barrel supercell
Entries 9808
Mean 0.01682
Std Dev 0.007281
Maximum supercell energy (GeV)


ECal endcap supercell
Entries 9808
Mean 3.883
Std Dev 0.4685


HCal barrel supercell
Entries 9808
Mean 0.001569
Std Dev 0.002309
Maximum supercell energy (GeV)


HCal endcap supercell
Entries 9808
Mean 0.02414
Std Dev 0.007624
Maximum supercell energy (GeV)