Development of a physics program and detectors for experiments at CEPC

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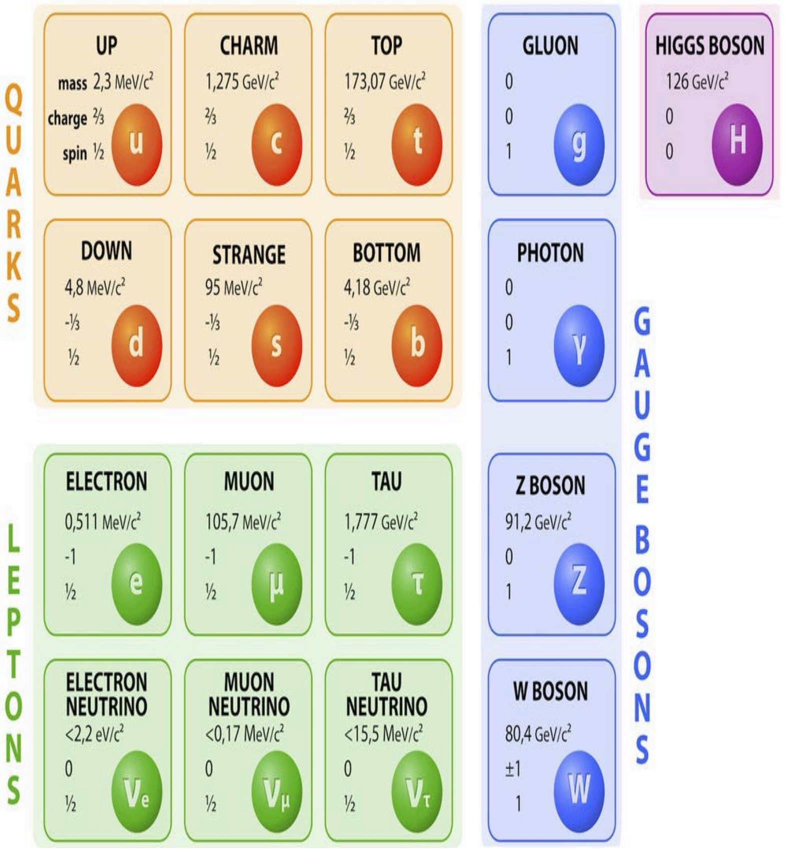
Standard Model

- The SM describes the fundamental constituents of matter and their interactions
- The SM of particle physics is the theory describing 3 of the 4 known fundamental forces (electromagnetic, weak and strong interactions — *excluding gravity*) in the universe and classifying all known elementary particles



- **Quantum chromodynamics sector**
- **Electroweak sector**
- **Higgs sector**
- **Yukawa sector**

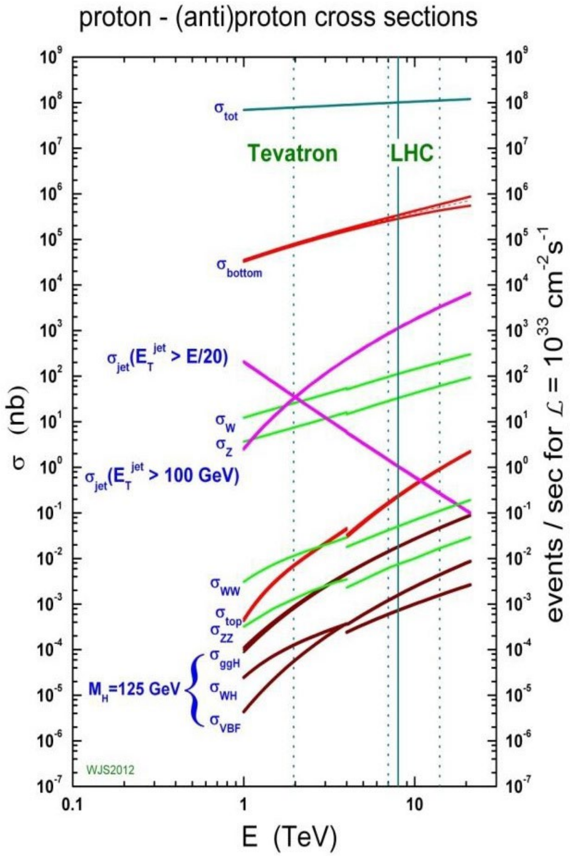
Interaction / Property	Gravitational	Weak	Electromagnetic	Strong	
		Electroweak		Fundamental	Residual
Acts on:	Mass - Energy	Flavor	Electric charge	Color charge	Atomic nuclei
Particles experiencing:	All particles	quarks, leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (Not yet observed)	W^+, W^- and Z^0	γ (photon)	Gluons	Mesons
Strength at the scale of quarks:	10^{-41}(predicted)	10^{-4}	1	60	Not applicable to quarks
Strength at the scale of protons/neutrons:	10^{-36}(predicted)	10^{-7}	1	Not applicable to hadrons	20

Standard Model problems: an incomplete theory

- Unknown nature of **Dark Matter**
- **Very small cosmological constant** and **very weak gravity interaction**
- **CP violation Cabibbo–Kobayashi–Maskawa** (CKM) phase (**small effect**)
- **Particle–antiparticle asymmetry in the Universe**
- **Problem of neutrino masses, mixing, oscillations**
- **B-anomalies (4.5σ): semi-leptonic B-decays**

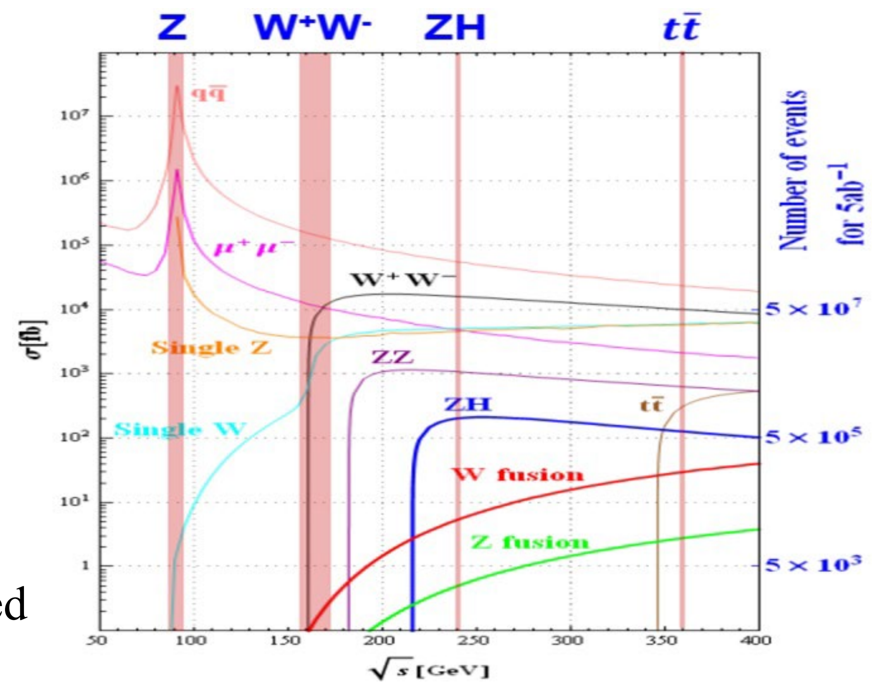
  - **What is a generation?** Why there are only 3 generations?
  - What is a nature of **quark-lepton analogy**?
  - **Are there additional gauge symmetries?**
  - **What is responsible for a formation of the Higgs potential?**
  - **Why gravity is so weak comparing** to other interactions?
  - **What is responsible for gauge symmetries**, why charges are quantize?
  - **To which accuracy the Charge, Parity & Time reversal symmetry (CPT) is exact?**

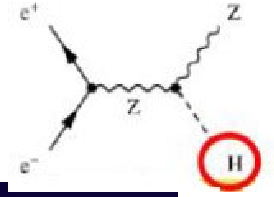
Advantages of high-energy e+e colliders



LHC :

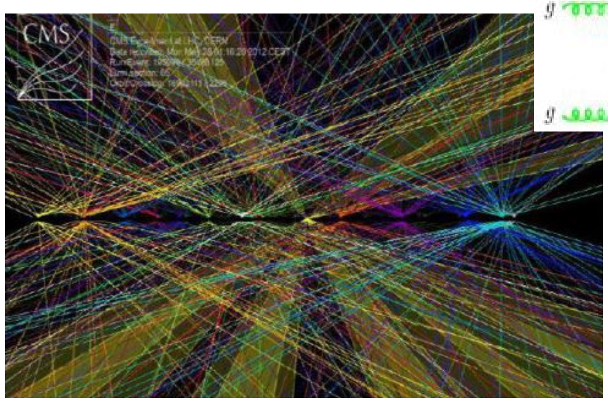
- Large Higgs cross section
- 150M Higgs per exp.
- dominated by QCD events
- **S**(H)/**B**(All) 10^{-10}
- Pile-up and jet overlap
- Not knowing $(\vec{P}_H, E_H)_{initial}$

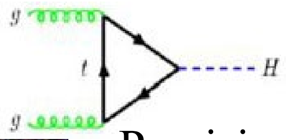




e^+e^- :

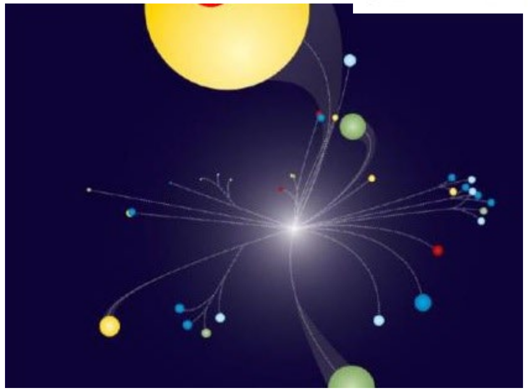
- Higgs cross section, predicted with (sub)% levels
- Know $(\vec{P}_H, E_H)_{initial}$ allowing for recoil mass reconstruction
- Clean events
- Low Higgs cross section





Precisions on H couplings ~(5-10)% expected

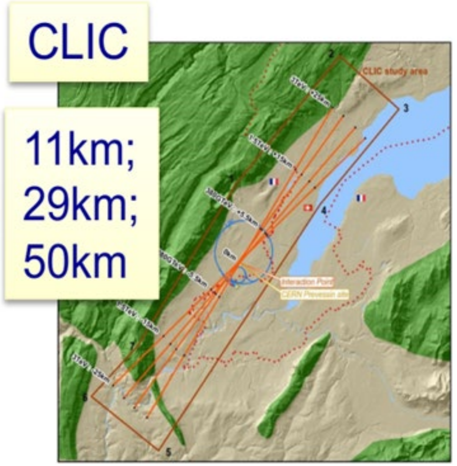
Precisions on H couplings ~1% or less expected



Future colliders

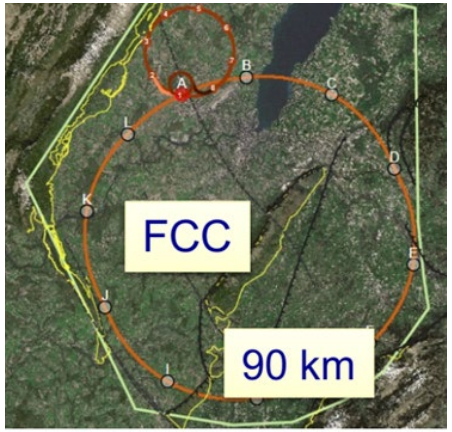
ILC (Japan):

- Linear collider with high-gradient superconducting acceleration
- Ultimate: 0.5-1(?) TeV
- To secure funding: reduce cost by starting at 250 GeV (H factory)



CLIC (CERN):

- Linear collider with high gradient normal-conducting acceleration
- Ultimate: multi-TeV (3) e^+e^- collisions
- Use technology to overcome challenges



FCC-ee/FCC-hh (CERN):

- Protons to extend energy frontier
- **90 km** ring with 16T magnets
- Use FCC-hh tunnel for e^+e^- collider
- Technology for ee: **standard**

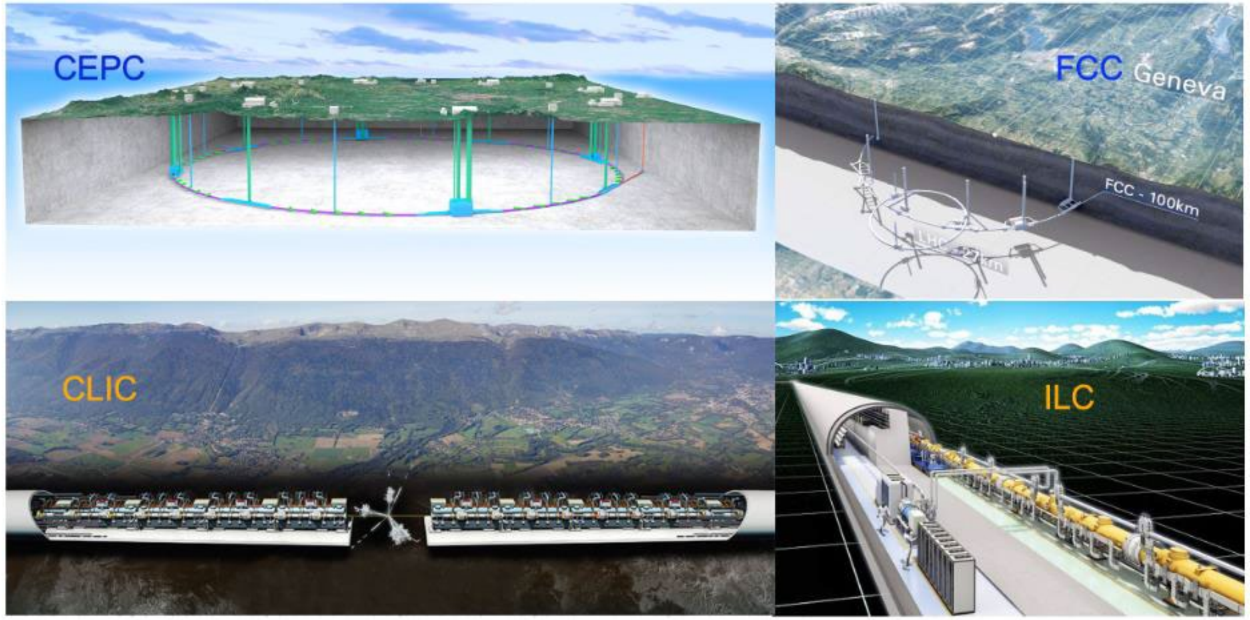
CEPC: multiple candidate sites in China

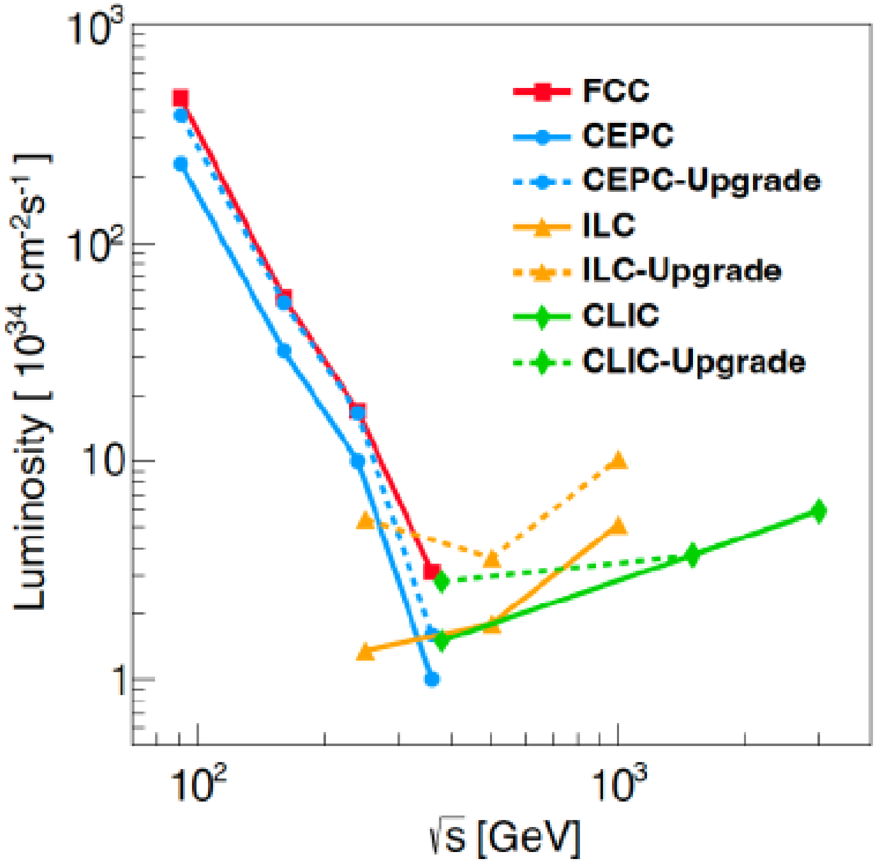
CEPC/SppC:

- Essentially an FCC-ee, then hh with more conservative luminosity estimates
- in China

In April 2022, the International Committee for Future Accelerators (ICFA) "reconfirmed the international consensus on the importance of a Higgs factory as the highest priority for realizing the scientific goals of particle physics"

Circular or Linear?

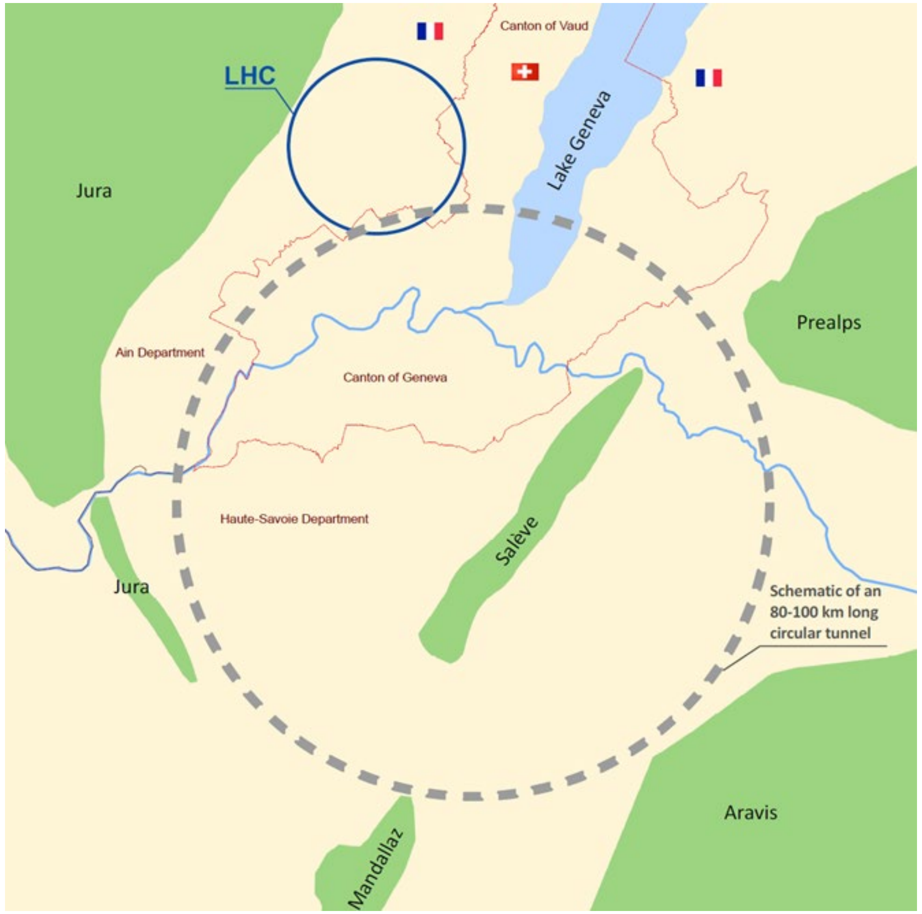




Electron-positron Higgs factories identified as top priority for future colliders
Complementarity between Circular and Linear colliders

FCC project

2021- 25: Feasibility Study → **2028:** project approval by CERN Council → **2032:** construction starts → **2041:** HL- LHC ends → **2045:** Operation of FCC-ee → **2070:** Operation of FCC-hh



Future Circular Collider (FCC) performance

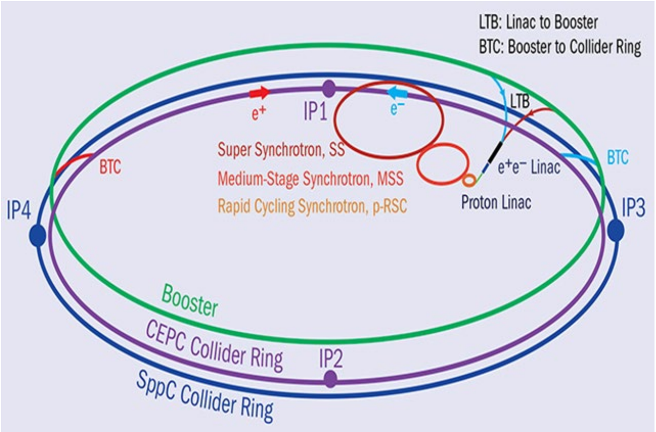
- Center of mass energy: **100 TeV**
- Peak luminosity ultimate: **$\leq 30\text{x}10^{34}$**
- Bunch Crossing **<5 ns**
- Integrated luminosity ultimate **~1000 fb^{-1}** (average per year)
- 25 years operation, leading to **~20 ab^{-1}**

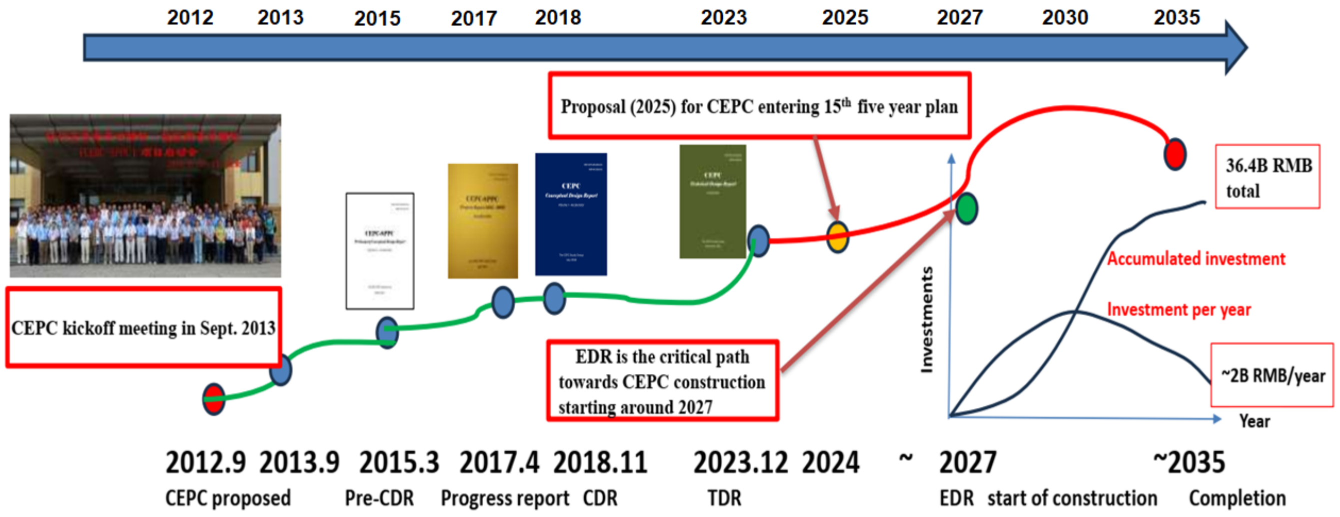
Consequence on detectors

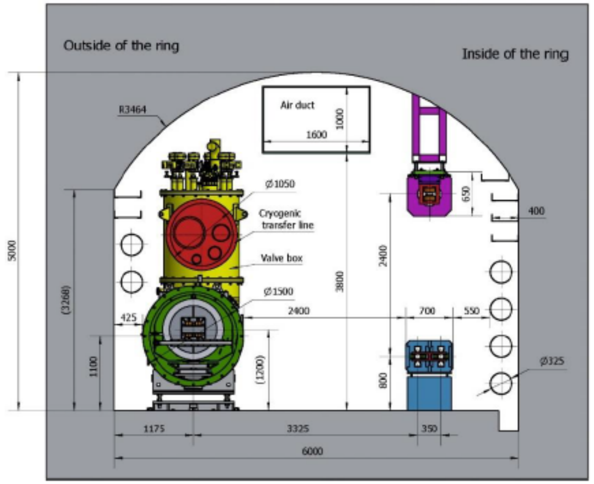
- Boosted objects → up to **|η|=6** coverage
- High pileup and fast Bunch-Crossing (BC) →
- very fast and granular detectors
- Momentum resolution **≈15% at p_T=10 TeV**
- **~1 ns** sharp Bunch-Crossing Identification (BCID)
- Particle flow capability for calorimeters with high granularity **25 mrad^2**
- Fine timing against pileup → **< 100 ps**

CEPC layout

- **Circular collider:** Higher luminosity than a linear collider
- **100km circumference:** Optimal total cost
- **Shared tunnel:** Compatible design for CEPC and SppC
- **Switchable operation: Higgs, W/Z, top**
- **Accelerator complex:** Linac, a 100 km booster and a collider ring





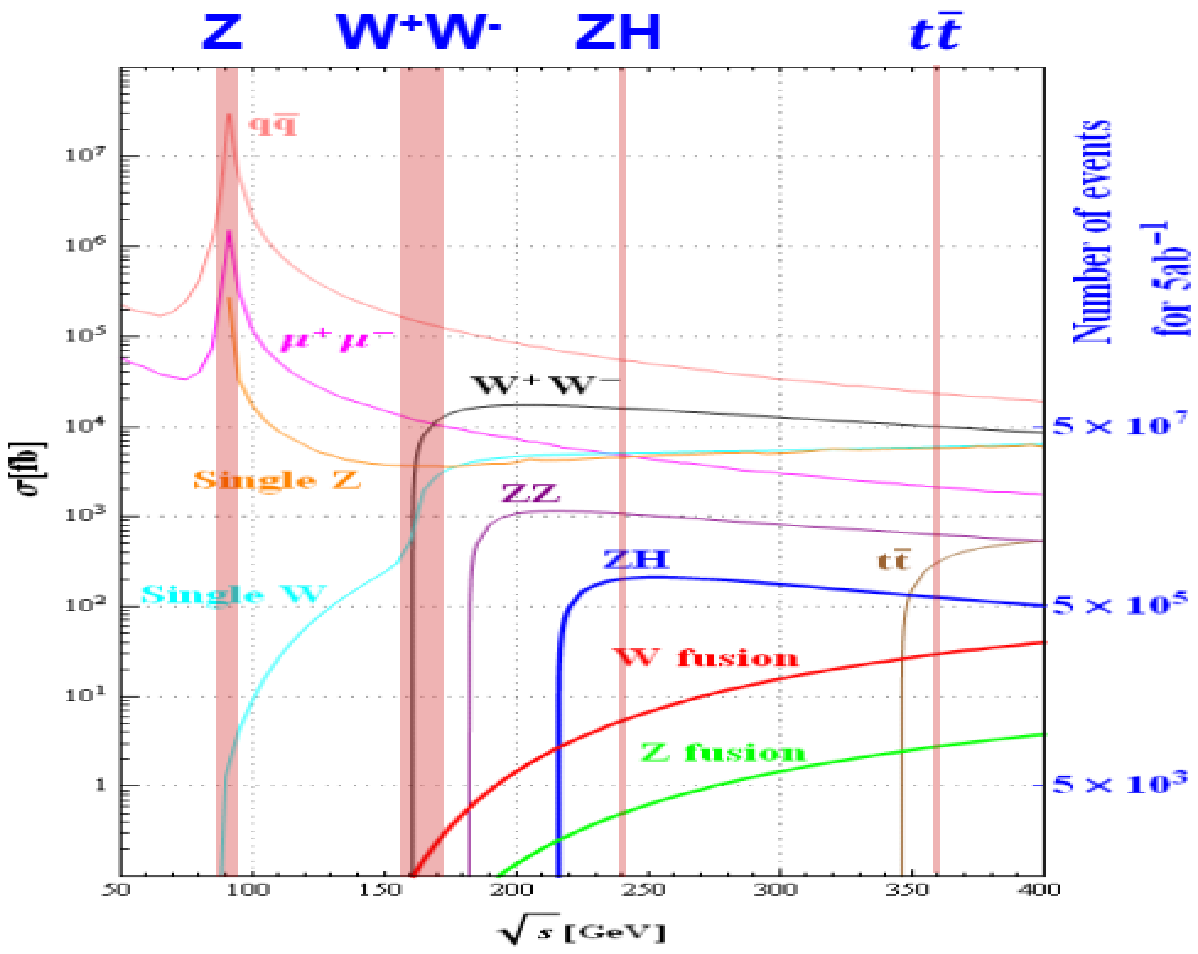


Common tunnel for booster/collider & SppC

CEPC has strong advantages among mature electron-positron Higgs factories (design report delivered),
•**Earlier data**: collision expected in 2030s (vs. FCC-ee ~ 2040s), **larger tunnel cross section** （ee, pp coexistence)
•**Higher precision** vs.linear colliders with more Higgs & Z; potential for **proton collider upgrade**.

Physics goals of CEPC

- **91** (Z), **160** (WW), **240** (ZH), **360** (tt) GeV
- **Higgs Factory (>10^6 Higgs bosons)**:
  - **Precision study of Higgs** (m_H, main quantum numbers JPC, couplings)
  - **Complementary** to **Linear** colliders
  - Looking for hints of **BSM physics:**
    - **Dark Matter**
    - **ElectroWeak phase transition** (EWPT)
    - **Long-Lived Particles (LLP), …**
- **Z & W factory (>10^{12} Z_0):**
  - **Precision test of SM**
  - **Rare decays**, …
- **Flavor factory: b, c, t and QCD studies**



Physics at CEPC

The Higgs boson has a special role in the quest to answer some of the most profound questions

These questions include the

- nature of **the *EW phase transition*** that governed the ***evolution of the early Universe***
- **why the *gravitational*** *force is* ***so weak* compared** with other forces in nature.

- The **Higgs boson in e^+e^- collisions** is ***practically free of systematic uncertainties*** that limit the measurements at the **HL-LHC**
- ***Precise measurements of the Higgs boson properties*,** along with those of the mediators of the weak interaction will provide critical tests of the ***underlying fundamental physics principles of the SM*** and are ***vital in the exploration of new physics BSM***

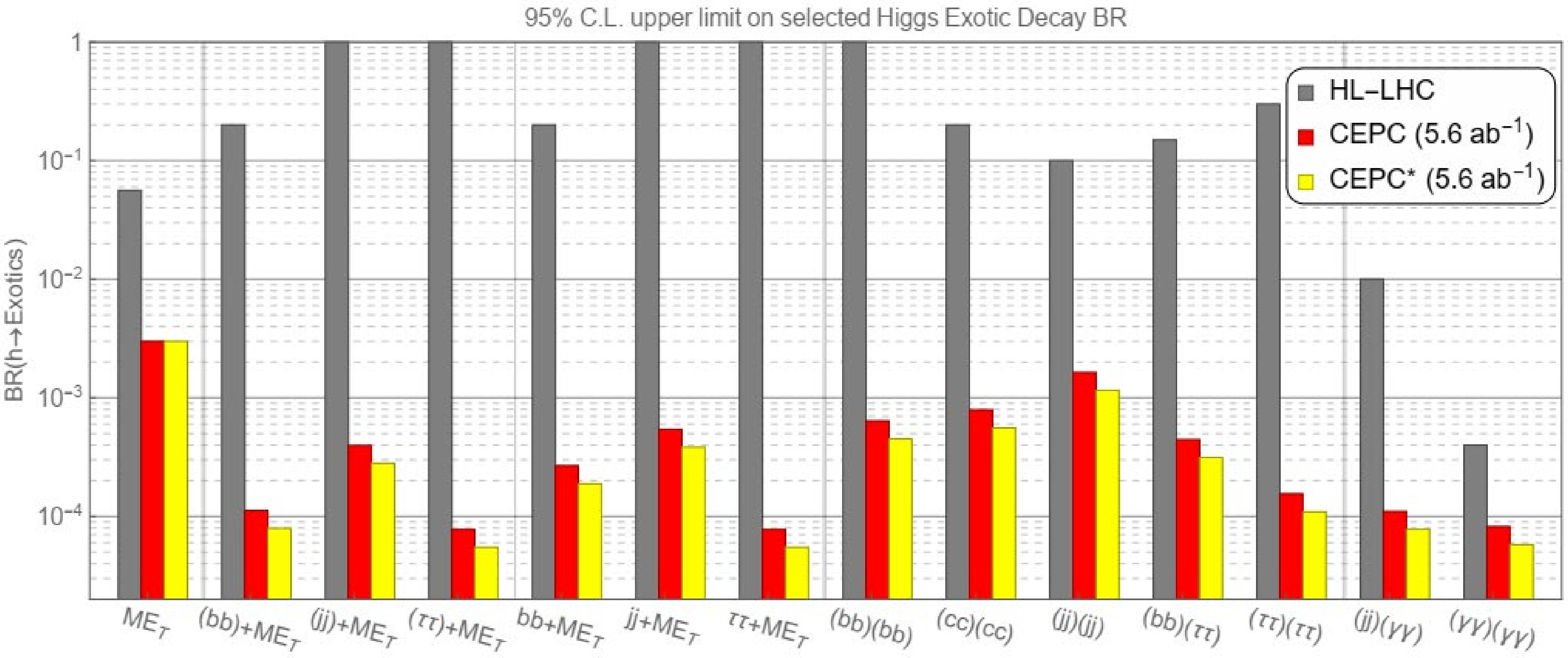
The experiments at **CEPC** will

- measure the ***Higgs boson properties*** in ***greater detail*** and in ***a model-independent way***
- ***reach a new level of precision*** for the ***measurements of the W, Z bosons properties***
- allow ***the search for potential unknown decay modes***
- Also, ***could uncover deviations from the SM predictions*** and ***reveal the existence of new particles*** that ***are beyond the reaches of direct searches at the current experiments***.

Physics at CEPC

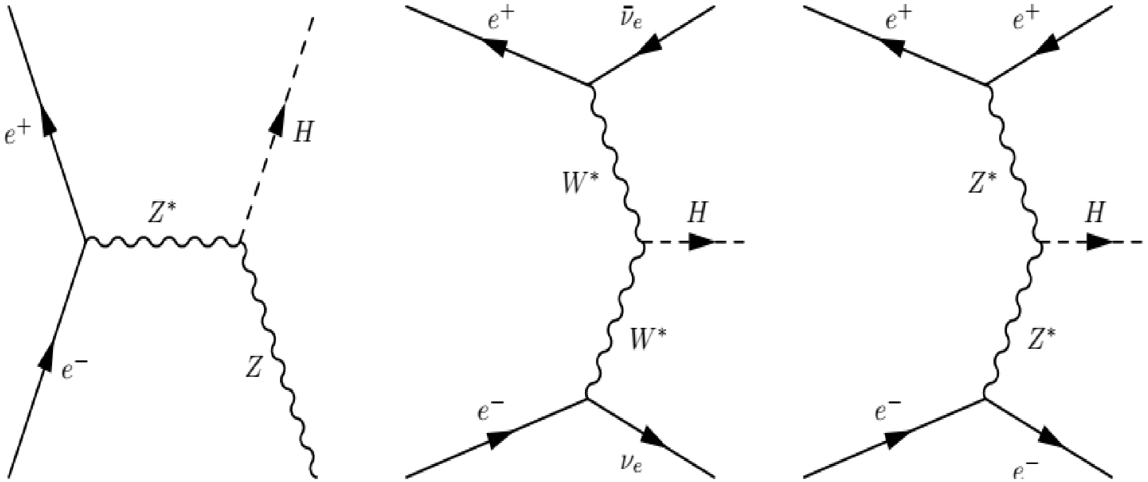
- The ***precision Higgs boson measurements*** could potentially ***reveal crucial physics mechanism*** that determines ***the nature of the EW phase transition***.
  - It will be ***another milestone*** in our ***understanding of the early history of our Universe***, &
  - could hold the key to unlock the ***origin of the matter and antimatter asymmetry*** in the Universe
  - These results could test the ideas that explain ***the vast difference between the energy scales associated with the EW and gravitational interaction.***
- The **CEPC** will also search for a ***variety of new particles.***
- Running as both a **Higgs factory and a Z factory**, the ***exotic decays of Higgs and Z bosons are*** **sensitive vehicles the search of new physics**, such as those with ***light new particles.***
- ***The dark matter*** can be searched for through ***its direct production and its indirect effects on the precision measurements***.
- The **CEPC**, as ***B and τ-charm factories***, can perform studies that help to understand **the origin of different species of matter and their properties.**
- The **CEPC** is also an excellent facility to perform ***precise tests of the theory of the strong interaction***

Branching of selected Higgs boson exotic decays



- The 95% CL upper limit on selected Higgs exotic decay branching fractions at **HL-LHC and CEPC**.
- **The red bars correspond to the results using only leptonic decays of the spectator Z-boson.**
- **The yellow bars** further include extrapolation with **the inclusion of the hadronic decays** of the spectator Z-boson

Feynman diagrams for Higgs boson production & decay



Higgs boson production processes:

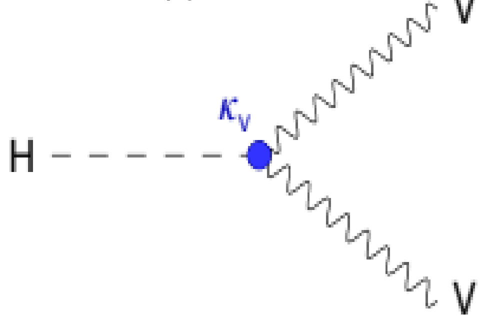
$e^+e^- \to ZH$ (ZH associate production)

$e^+e^- \to \nu\bar{\nu}H$ (WW fusion),

$e^+e^- \to e^+e^-H$ (ZZ fusion)

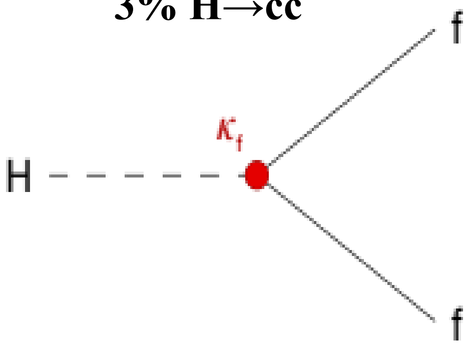
g

22% H→WW
3% H→ZZ



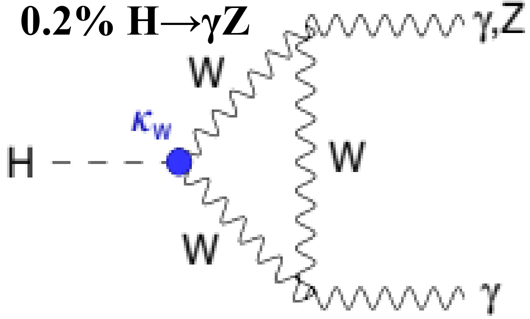
h

56% H→bb
3% H→cc

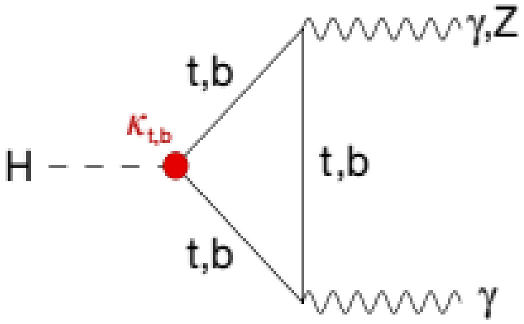


i

0.2% H→γγ
0.2% H→γZ



j



Higgs boson decays into **heavy vector boson pairs (g), fermion–antifermion pairs (h)** and photon pairs or **Zγ (i,j)**

JINR contribution to the physics program

Theoretical support:

- Development of physics program
- Calculation of radiative corrections
- Creation of advanced Monte Carlo tools

Contributions to the Physics Program

- Higgs
- EW Physics
  - precision EW at the Z peak and WW threshold
  - High energy EW: diboson, difermion
  - precision theoretical calculations
  - Monte-Carlo generators and fitting formulae
- Flavour physics:
  - heavy quarks
  - tau lepton
- Top quark (includes the dedicated precision theory calculations, MC generators, fitting formulae)

JINR contribution to the physics program (2)

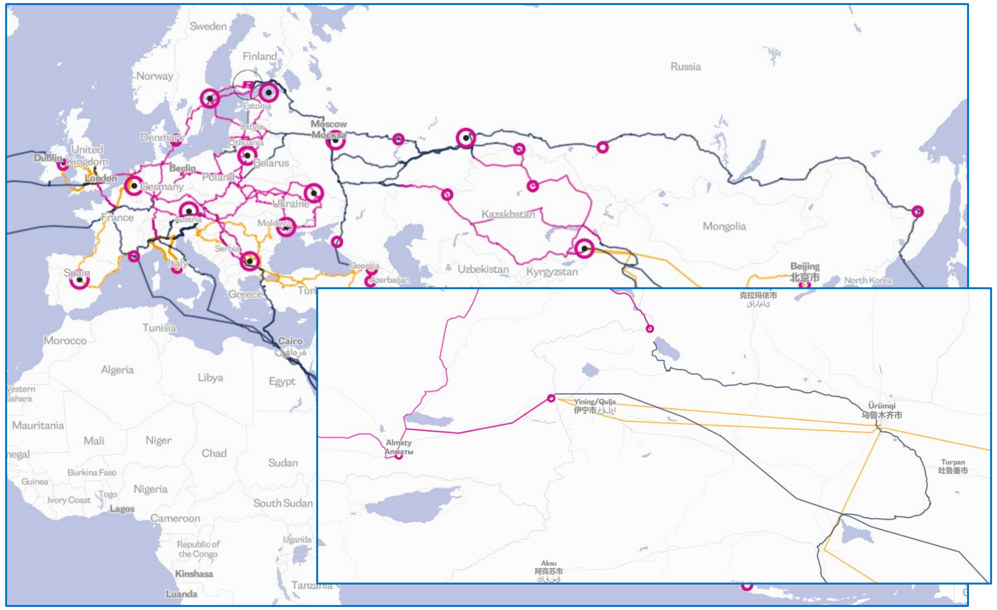
Higgs:

- The Higgs boson physics is the main task of the experiments at CEPC for the first 10 years
- Higgs boson production at the energy $\sqrt{s}$~240–250 GeV: $e^+e^- \to ZH$, $e^+e^- \to \nu\bar{\nu}H$, and $e^+e^- \to e^+e^-H$
- Higgs boson candidates can be identified using a mass recoil method, without labeling their decays
- The branching ratios of the Higgs boson decay can be determined by studying its individual decay modes
- Higgs boson decays, identified by their unique signatures, will be studied in the following modes: $H \to b\bar{b}/c\bar{c}/gg$, $H \to WW^*$, $H \to WZ^*$, $H \to W\gamma$, $H \to \tau^+\tau^-$, $H \to \mu^+\mu^-$, $H \to inv$
- A systematic study of the $e^+e^- \to ZX$ processes will be carried out to determine properties of the Higgs bosons with the best accuracy and new physics BSM searches using Monte Carlo generations for full detector simulations of signal and background events
- Based on this analysis, values of the Higgs boson characteristics are expected to be obtained with accuracy an order of magnitude better than in the experiments at the HL-LHC

CEPC Computing vs JINR–China IT collaboration

- JINR in Computing for the China HEP projects
  - ✓ Tier-1 Center for JUNO Distributed Computing (realization MoU since 2022)
  - ✓ BES-III and JUNO grid development (DIRAC, grid monitoring system, etc)
- China-JINR Workshop on Software and Computing for Future HEP Experiment (15–19 Sept 2024, Baikal lake)
  - ✓ issues of cooperation between IHEP and JINR in the field of computing and software BESIII, JUNO experiments, planned experiments at CEPC and NICA colliders
  - ✓ R&D of new computational technologies in particle physics
- CEPC Computing (JINR Side) in 2026-2027
  - ✓ refining (fitting) the CEPC computing model
    - data model, data processing model
    - requested resources and sites are involved in
    - workload, job submission
  - ✓ JINR obligations in CEPC Computing (to be discussed and elaborated)
    - responsibility of JINR site, incl. pledges (CPU/disks/tapes)
    - site participation/part of CEPC distributed infrastructure (MoU?)
    - participation in development of interware and applied (physics) SW (reco algorithms, collaboration tools, etc)

Strategic long-term plan



- Organizing a high-speed links between JINR and China centers are being studied
  - ✓ negotiations with network operators in RF
  - ✓ commitment of JUNO/BESIII/NICA/Baikal-GVD/?
  - ✓ actual interest of China scientific centers

Vital matter of JINR teams in China projects

CEPC operation plan and goals

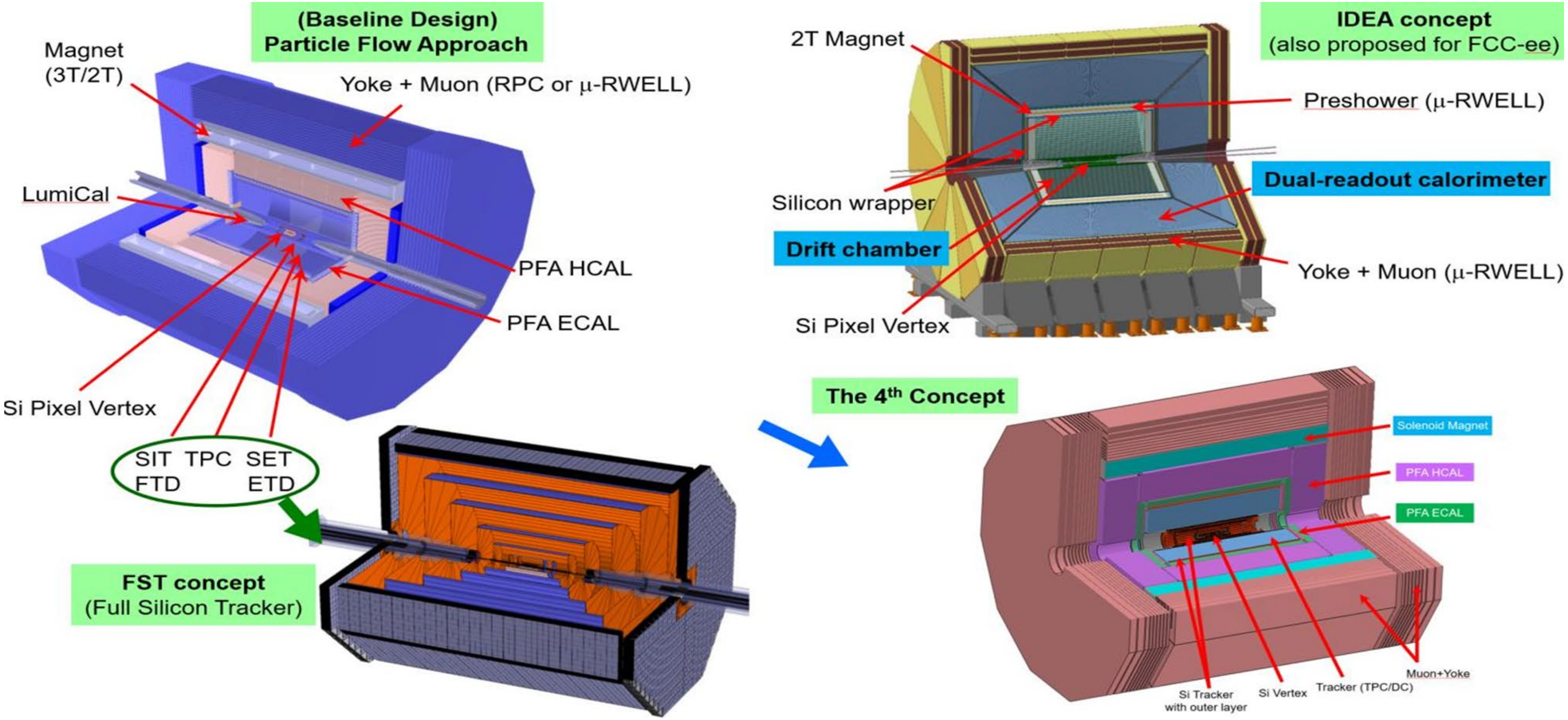
Particle	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. per IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. per year (ab^{-1}, 2 IPs)	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

* Higgs is the top priority. The CEPC will commence its operation with a focus on Higgs.

** Detector solenoid field is 2 Tesla during Z operation, 3Tesla for all other energies.

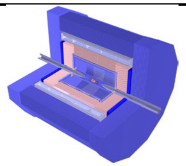
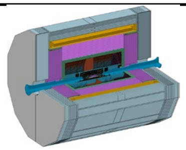
*** Calculated using 3,600 hours per year for data collection.

CEPC detector designs

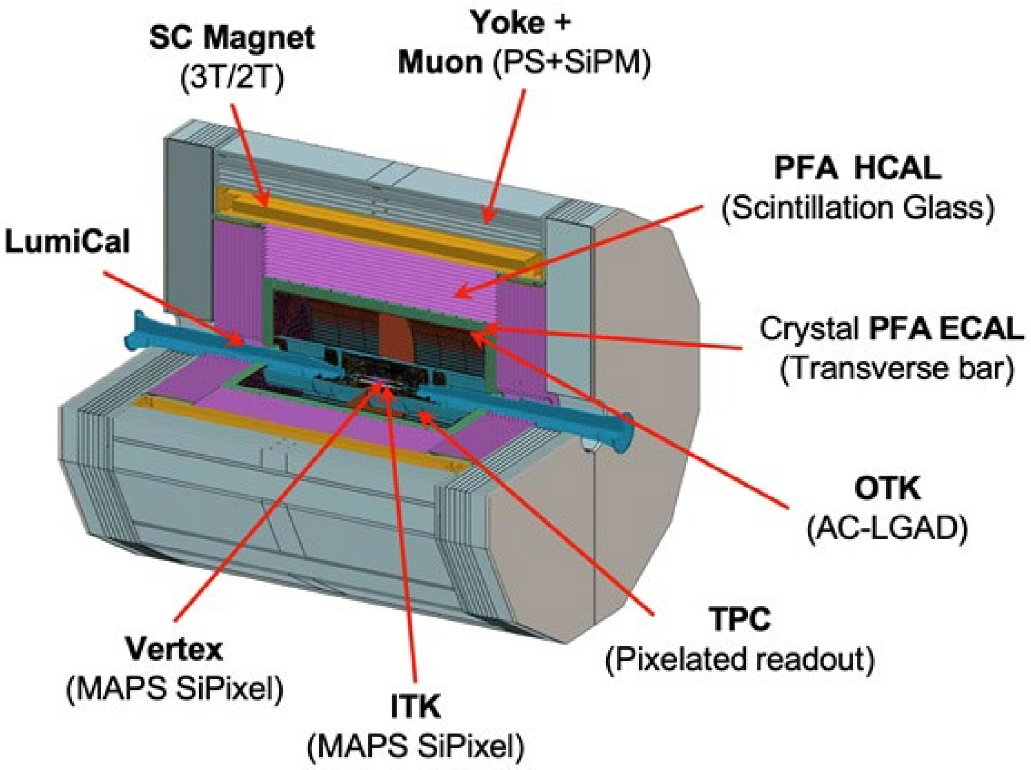


CDR baseline, *arXiv:1811.10545*

From CDR to Reference-Detector TDR

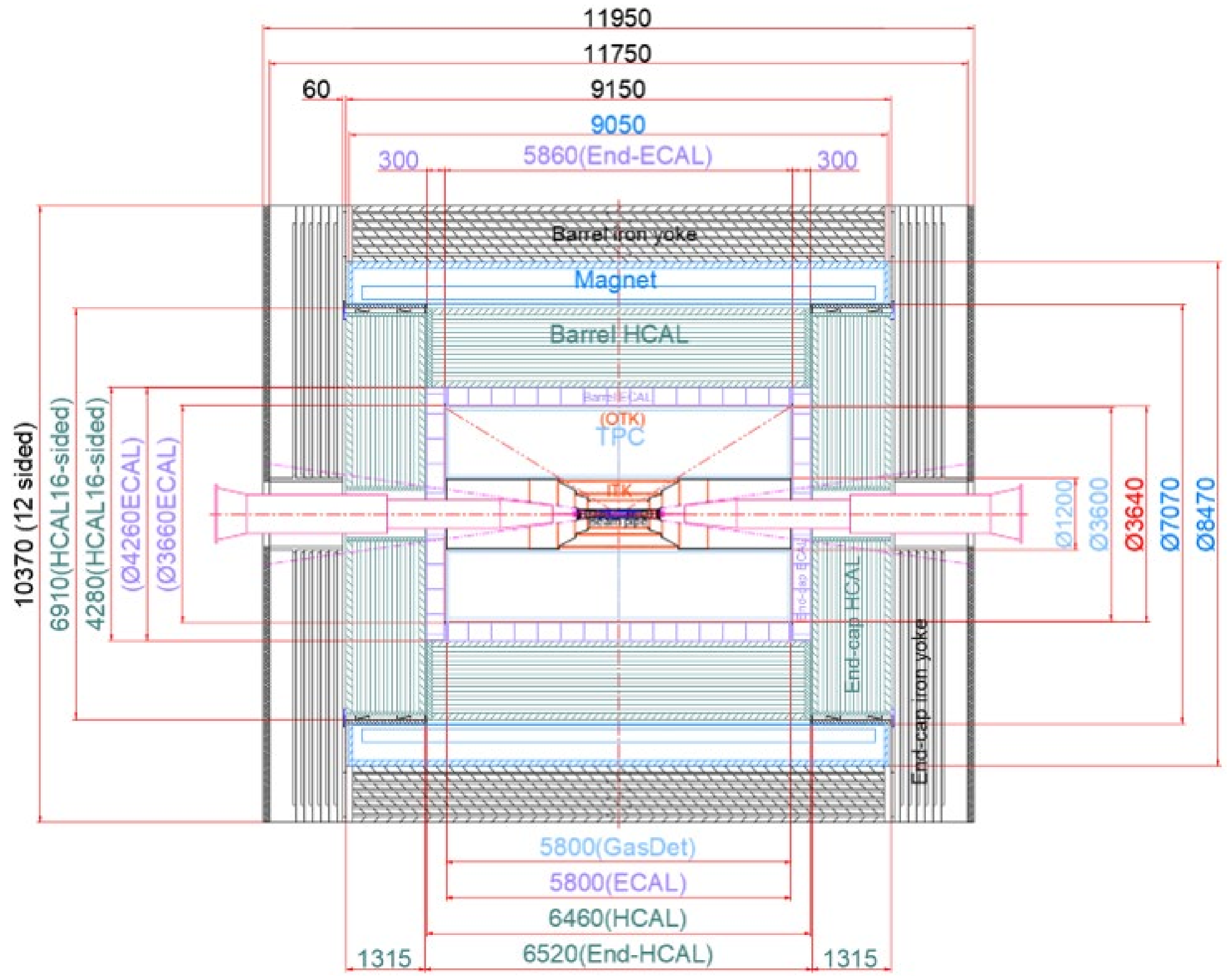
	CDR 	**RefDet-TDR** 
VTX	Inner radius of **16 mm**	Inner radius of **11 mm**
	Material Budget: 0.15%*6+0.14%(beampipe)= **1.05% X_0**	Material Budget: 0.06%*4(inner)+0.165%*2(outer)+0.2%(beampipe)= **0.77% X_0**
Gaseous Tracker	TPC with **1 mm* 6 mm** readout	TPC with **0.5 mm* 0.5 mm** readout **dN/dx resolution 3%**
ToF	-	AC-LGAD, with **50 ps** per MIP
ECAL	Si-W-ECAL: **17%**/√E ⨁ 1%	Crystal Bar-ECAL: **1.3%**/√E ⨁ 0.7%
HCAL	RPC-Iron: **60%**/√E ⨁ 2%	Glass-Iron: **30%**/√E ⨁ 6.5%

Reference detector concept



- **Ultra-low-mass vertex detector:** four inner layers utilize 65 nm large-area single-layer **stitched sensors**, with the innermost detector radius reaching **11 mm,** + a double-layer ladder structure.
- **ITK:** based on **monolithic HV-CMOS pixel sensors**, 3 barrel layers and 4 disk layers at each endcap, **~20m²**.
- **TPC: pixelated** readout, **500×500μm²**
- **OTK:** one barrel layer and two endcap disk layers, based on **AC-LGAD** to measure **timing and position**
- **PFA-oriented calorimetry:** high-granularity homogeneous **crystal** ECAL and novel **glass scintillator** HCAL
- **Superconducting solenoid** → **3 T** magnetic field.
- **Muon** detectors in the return yoke.
- **LumiCal**: an AC-LGAD silicon wafer layer and a calorimeter utilizing LYSO crystals.

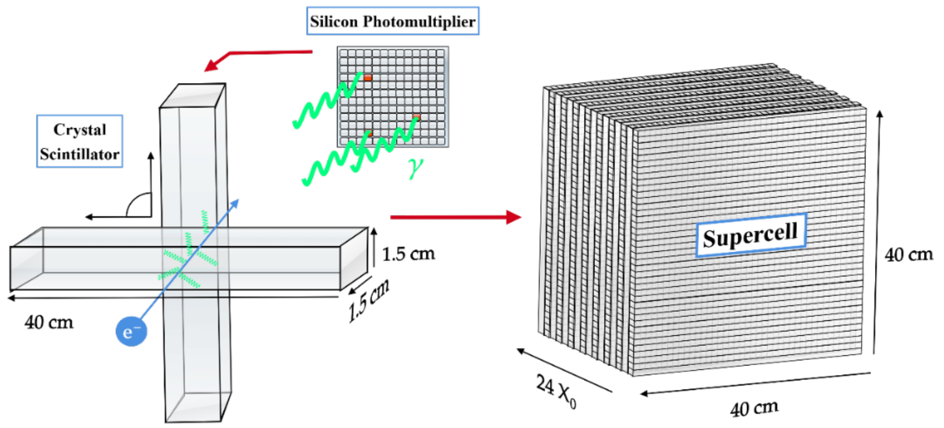
CEPC ref-TDR detector geometry



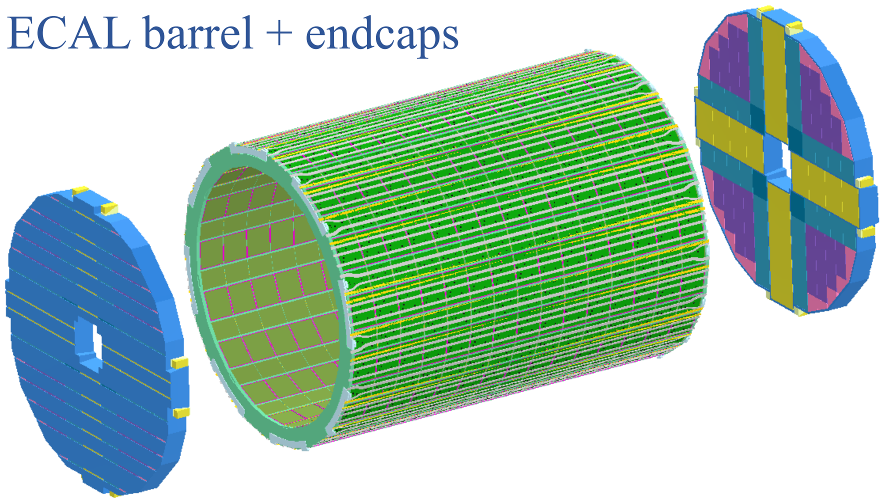
Crystal ECAL

- Compatible for PFA: Boson mass resolution (BMR) < 4%
- Optimal EM performance: $\sigma_E/E < 3\%/\sqrt{E}$
- A new option: R&D activities started since 2019
- Long crystal bars in orthogonal arrangement
  - Minimum longitudinal dead material
  - Significant reduction of readout channels
  - 3D positioning with two-sided SiPM readout

ECAL module schematics



ECAL barrel + endcaps



- ECAL design features: high granularity, modularity and hermeticity
  - Nominal crystal bar dimensions: 15×15×~400 mm^3
  - Transverse (effective) granularity: 15×15 mm^2
  - Total depth of 24 X_0 with 18 longitudinal layers
- ECAL barrel: 480 modules (411k channels, ~17.9 m^3 crystals)
- ECAL endcaps: 224 modules (160k channels, ~6.3 m^3 crystals)

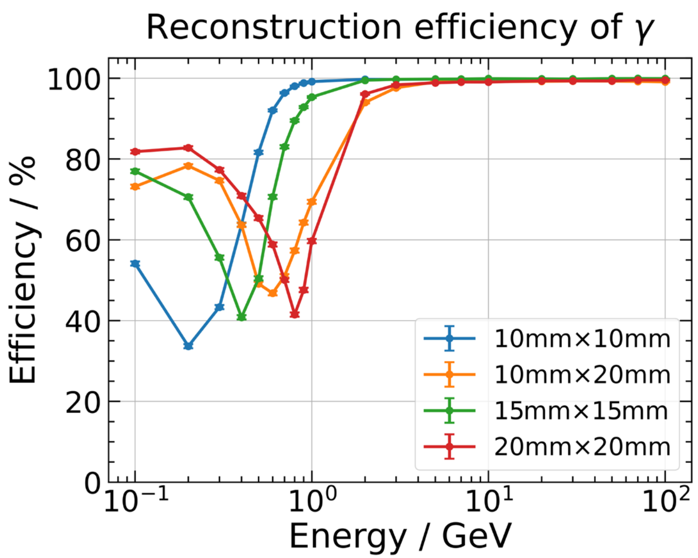
ECAL granularity optimization

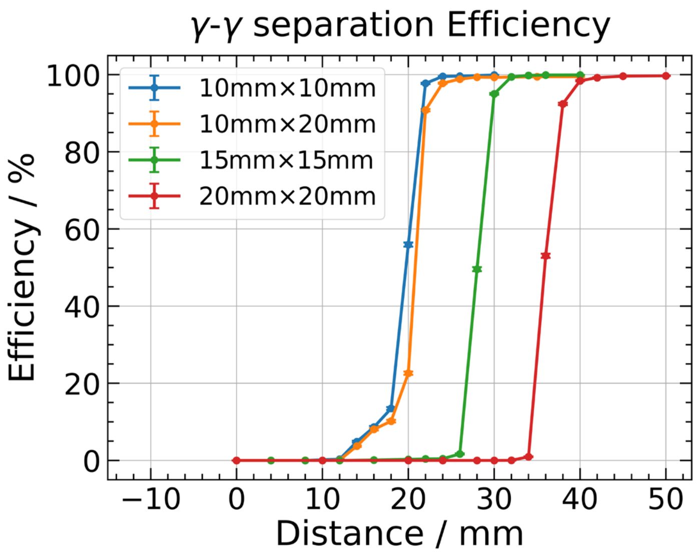
- Four typical scenarios of transverse granularity investigated

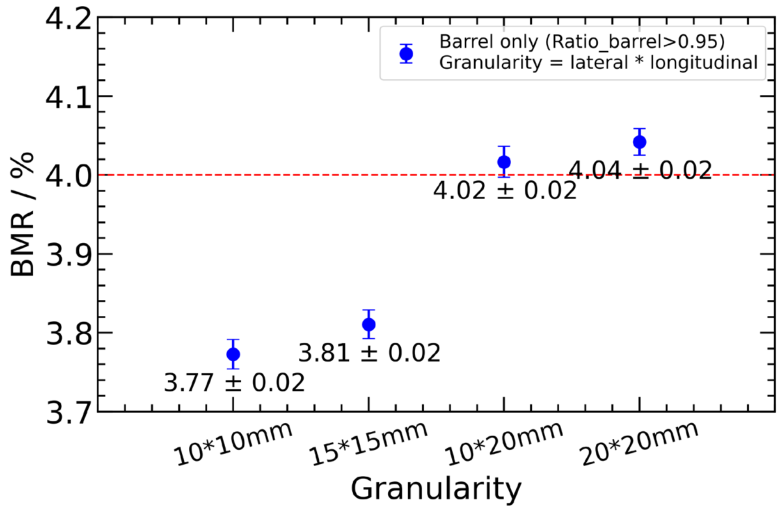
  10×10mm, 10×20mm, 15×15 mm and 20×20mm

- Figures of merit

  Single photon reconstruction, separation power and jet performance







Calibration schemes and precision

- ECAL in-situ calibration based on collision data
  - Bhabha events: 14k events/h at Z-pole for a central barrel module
  - $Z \rightarrow e^+e^-$ events: calibrations for inter-calibration of modules and absolute energy scale
  - π^0 calibration: 40 kHz production rate at Z-pole ($e^+e^- \rightarrow q\bar{q}$); selection of isolated π^0
  - MIP calibration: muons and also “punch-through” hadrons in ECAL (MIP tracking algorithm)
- Calibration precision: target 1% (channel-wise)
  - Contribution of 0.3% to the constant term from 1% of inter-channel calibration precision

Crystal ECAL: working plan

- Calibration schemes: statistics estimates of MIP data samples for in-situ ECAL calibration
- Particle-flow studies: optimization for endcaps, joint efforts on physics performance
- R&D on crystal units: joint efforts on crystal, SiPM R&D, SiPM readout ASIC
  - Especially, crystal-SiPM non-linearity effects: measurements and validation of MC model
- Fast timing (5D calorimetry): studies on technology and physics potentials
- Full-scale crystal calorimeter prototype and beam tests: integrated with mechanics/cooling
- Irradiation studies on crystal and SiPM

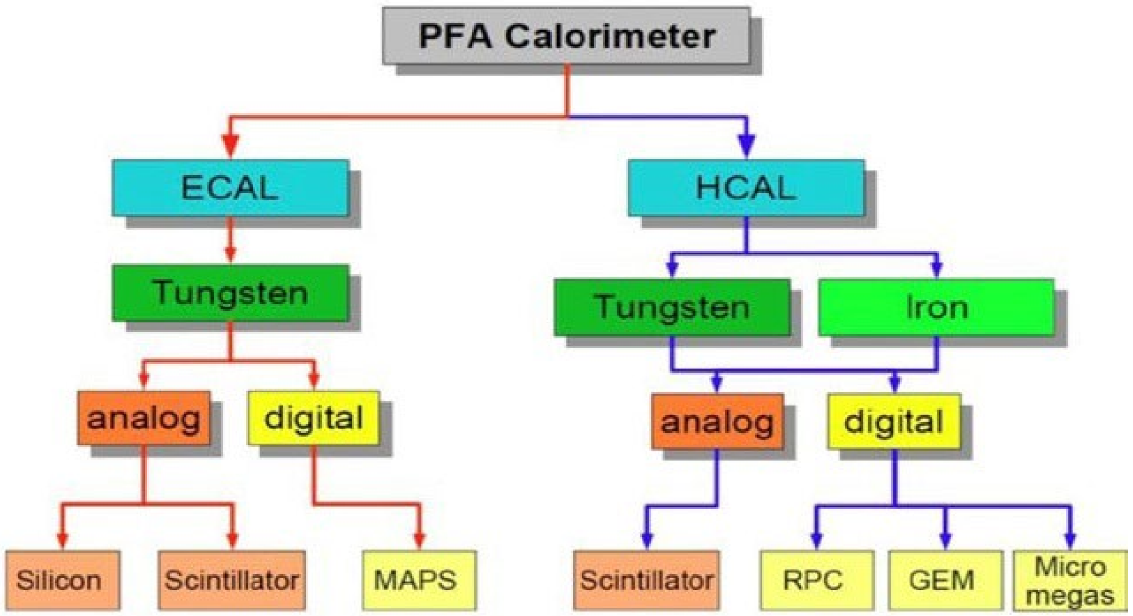
Physics requirements of HCAL

CEPC as Higgs/W/Z bozon factory require:

Boson mass resolution (BMR)<4% (critical for qqH and qqZ separation using recoil mass to di-jet)
Improve BMR to <3% (motivated by BSM&Flavor Physics)
The Particle Flow Approach (PFA) calorimeter concept was proposed (high granularity, good track finding, good energy resolution)

Three options for HCAL were considered

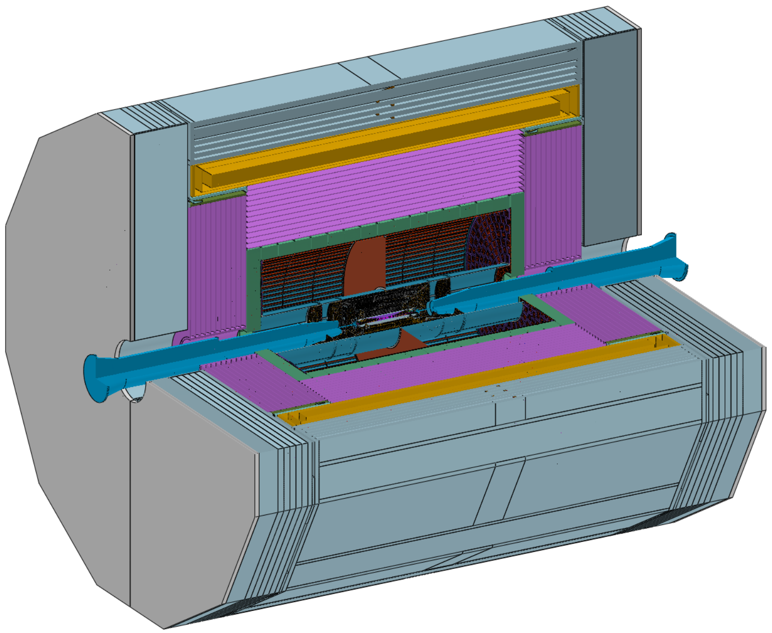
- RPC-DHCAL, SDHCAL, 48 layers
- Plastic scintillator-AHCAL, PS-HCAL, 40 layers
- Glass Scintillator-AHCAL, GS-HCAL, 48 layers

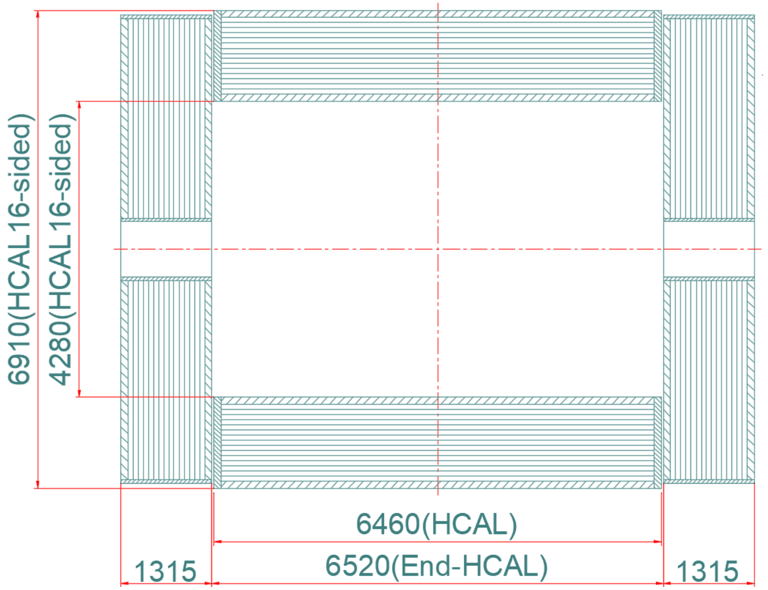


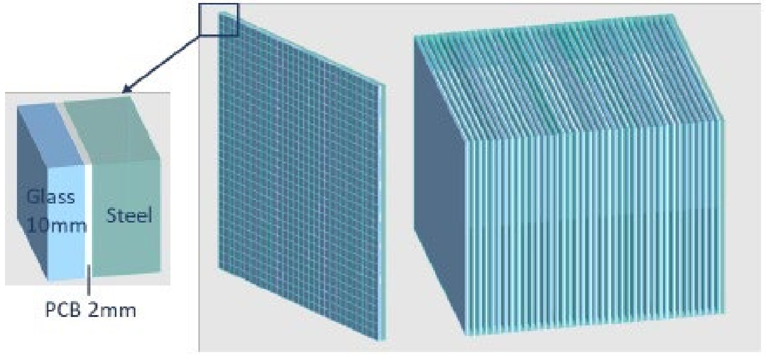
CDR baseline, *arXiv:1811.10545*

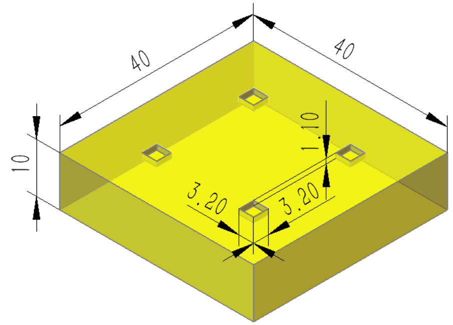
Design of the GS-HCAL

- GS-HCAL: One Barrel (16 wedges) and Two Endcaps
  - Thickness of the Barrel : 1315 mm
  - Inner radius of the Barrel : 2140mm
  - Barrel length along beam direction : 6460 mm
  - Number of Layers : 48 (6 λ_I)

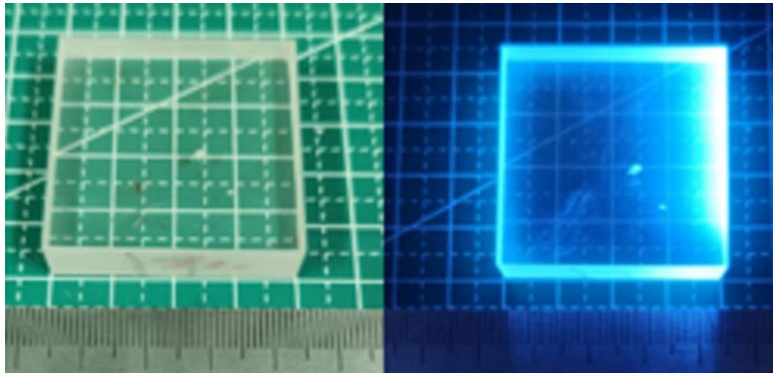


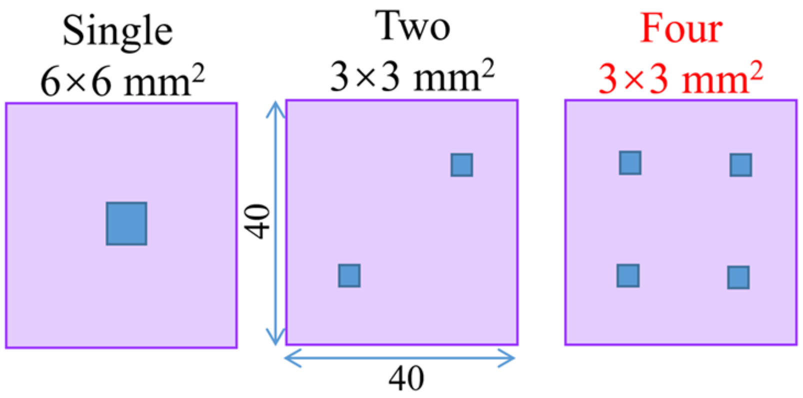






GS+SiPM study





Gadolinium Fluoro-Oxide

Key parameters	GFO	GFO+	BGO[18]	DSB Glass [17]
Density (g/cm^3)	6.0	6.0	7.13	4.2
Melting point (°C)	1250	1150	1050	1550
Radiation Length (cm)	1.59	1.64	1.12	2.62
Molière radius (cm)	2.49	2.50	2.23	3.33
Nuclear interaction length (cm)	24.2	24.1	22.7	31.8
Z_{eff}	56.6	56.9	71.5	49.7
dE/dX (MeV/cm)	8.0	8.0	8.99	5.9
Emission peak (nm)	400	390	480	430
Refractive index	1.74	1.76	2.15	
Light yield (ph/MeV)	985	2445	7500	2500
Energy resolution (% @662keV)	30.3	25.8	9.5	
Scintillation decay time (ns)	36, 105	101, 1456	60, 300	90, 400

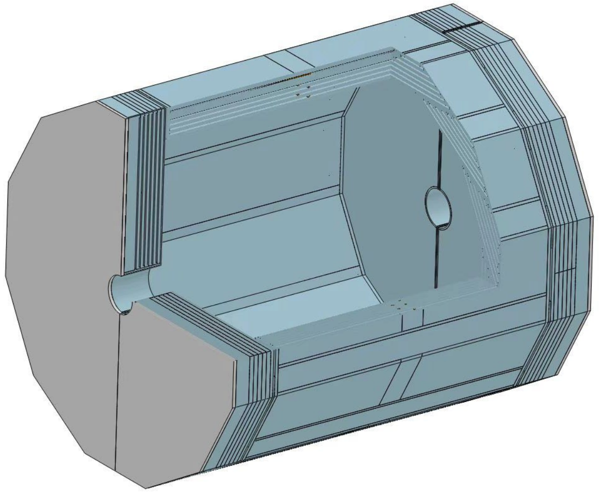
Settings	$3\mu s$ gate	$1\mu s$ gate	ratio
	P.E./MeV		$1\mu s/3\mu s$
1 pcs 3×3 mm^2 (NDL)	35	26	0.743
2 pcs 3×3 mm^2 (NDL)	**114**	**100**	**0.877**
3 pcs 3×3 mm^2 (NDL)	146	130	0.89
4 pcs 3×3 mm^2 (NDL)	163	146	0.896
1 pcs 6×6 mm^2 (HPK)	88	77	0.877

Haijun Yang, CEPC IDRC Meeting, April 2025

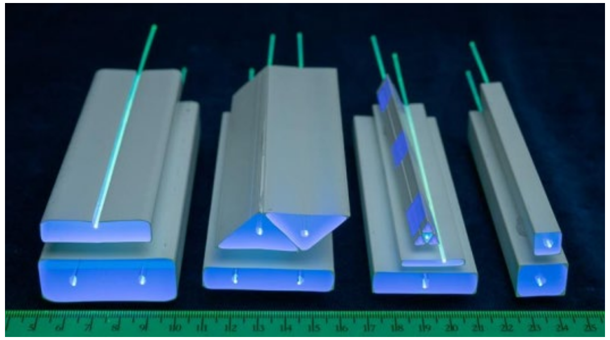
GS-HCAL future plans

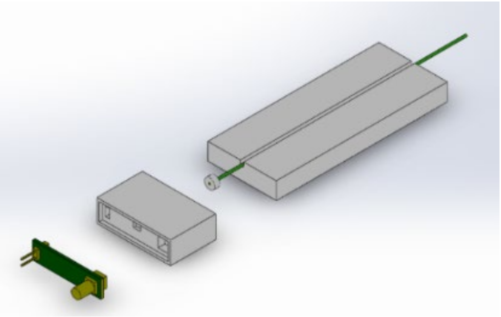
- **Future R&D plans**
  - To develop techniques for mass production of GS, SiPM with low cost
  - To further optimize GS-SiPM coupling, cooling and readout electronics
  - To develop calibration methods for GS-HCAL jointly with ECAL and separately
  - To prepare full-size GS-HCAL prototype with integrated electronics for beam test

CEPC muon detector



- Solid angle coverage: $0.98 \times 4\pi$
- Detection efficiency: $> 95\%$ (at least 3 layers)
- Fake $\pi \rightarrow \mu$ @ $30\ \mathrm{GeV}/c$: $< 1\%$
- Position resolution: $\sim 1\ cm$
- Time resolution: $\sim 1\ ns$
- Rate capability: $\sim 60\ \mathrm{Hz}/cm^2$

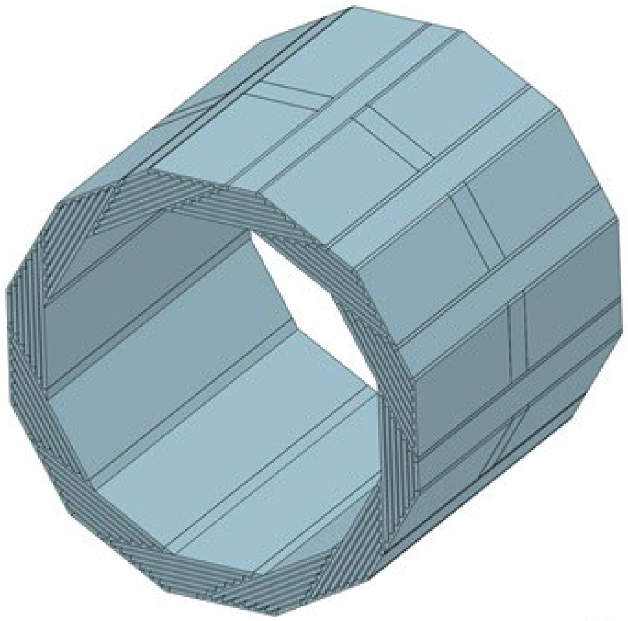




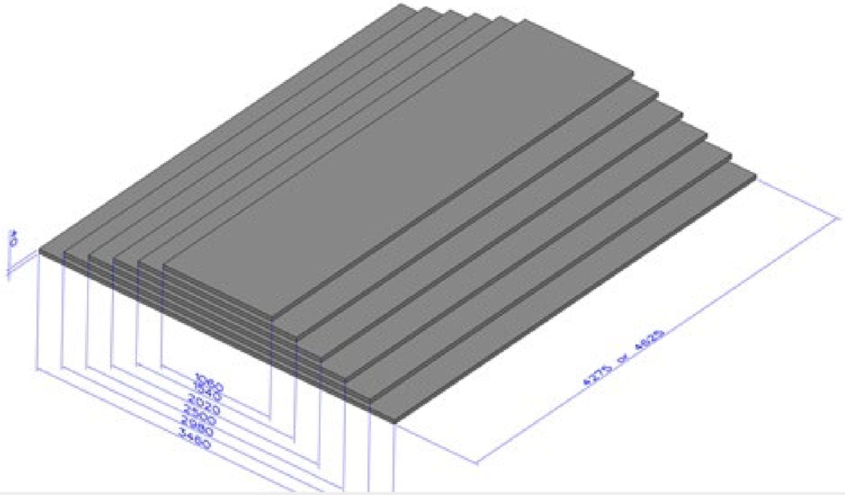
Muon detector is designed for muon identification, but not limited to this:

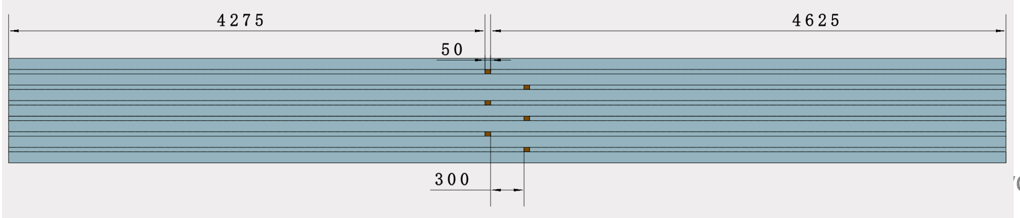
- Could be used to detect the leakage of HCAL
- Can be used for trigger
- Can be used to search for Long-lived particles

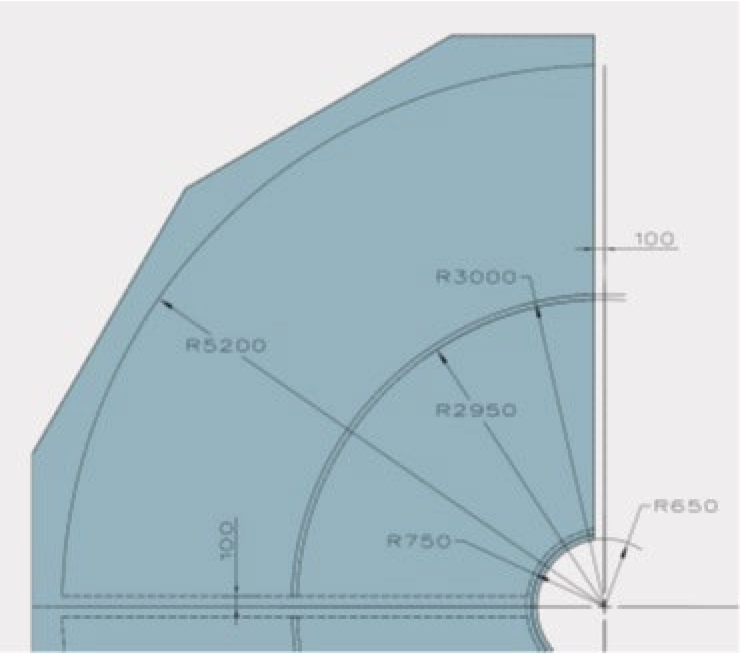
Muon detector design

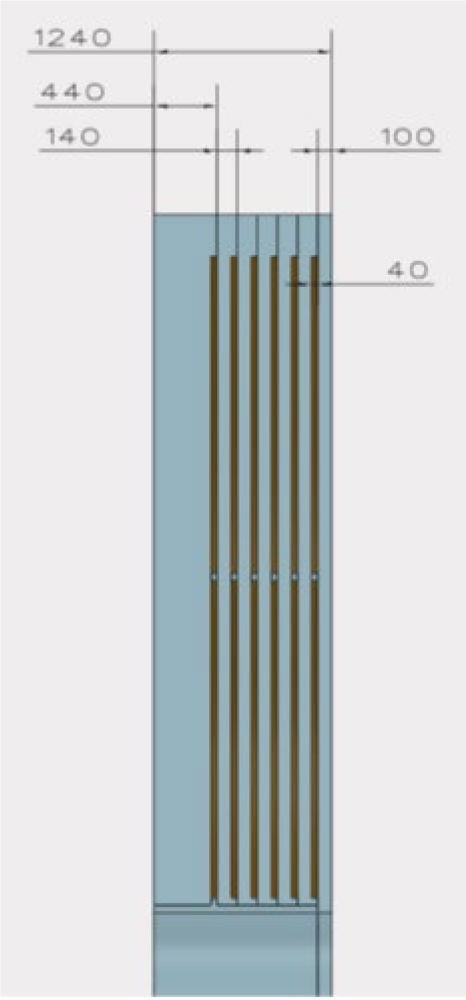


- Barrel: 6 layers, 2 long modules per layer, helix dodecagon
- Endcaps: 6 layers, 4 sectors per layer, two modules (inner and outer) per sector
- Large area modules with long PS bars.
- $43k$ channels, $4.8 \times 10^3\ m^2$ area, and $119\ km$ long fiber, in total.





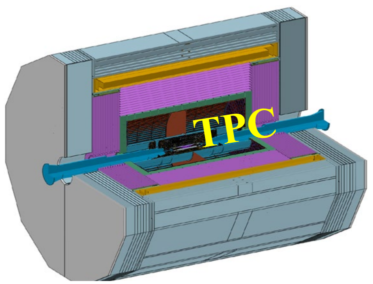




Muon detector: working plan

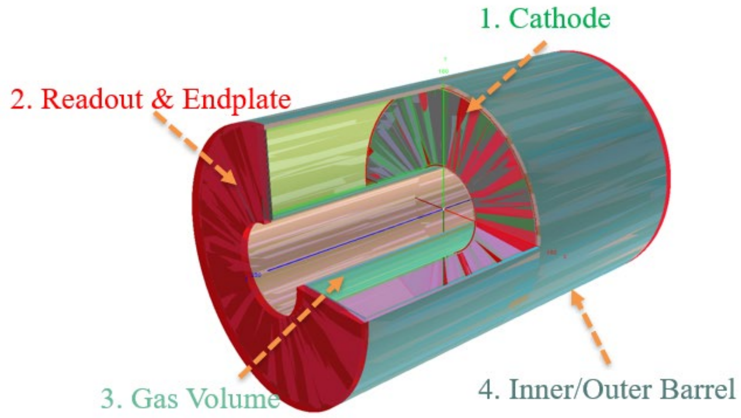
- Prototype and testing
  - Long strips with a length of up to 5m, increase the light yield and light collection
  - Multiple modules for system testing
  - Long term stability and radiation hardness testing
- Software simulation
  - Track reconstruction and low momentum measurement
  - Study the potentials, such as searching for LLP

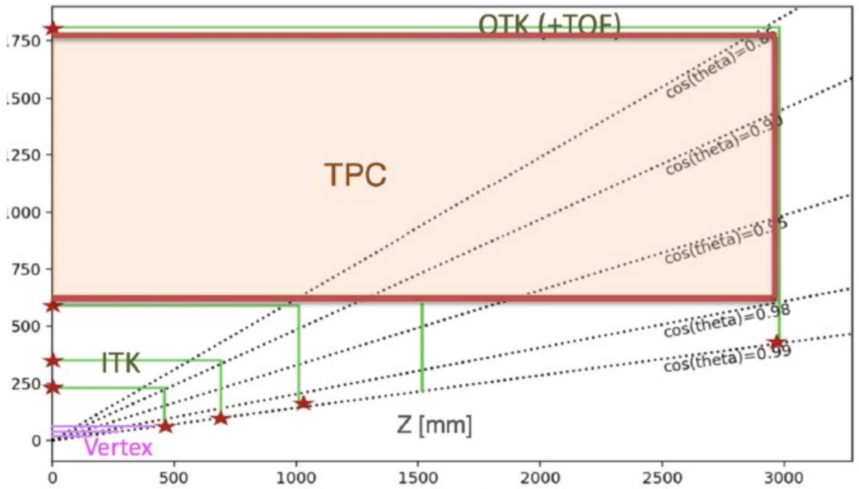
Pixelated readout TPC

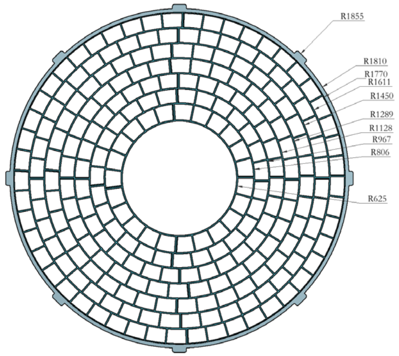


Pixelated TPC is baseline detector as main track in CEPC ref-TDR. The simulation framework has been developed using Garfied++ and Geant4.

- Aiming to Higgs and low luminosity Z run at future e+e- collider
- Radius of TPC from 0.6 m to 1.8 m, readout size 500μm x 500μm
- Ultra light material budget of the barrel and endplate
- dn/dx has much better PID by getting rid of fluctuations from energy deposition and amplification
- Beam-induced backgrounds studied based on Garfield++ and CEPCSW







TPC detector	Key Parameters
Modules per endcap	248 modules /endplate
Module size	206mm×224mm×161mm
Geometry of layout	Inner: 1.2m Outer: 3.6m Length: 5.9m
Potential at cathode	- 62,000 V
Gas mixture	T2K: Ar/CF4/iC4H10=95/3/2
Maximum drift time	34μs @ 2.75m
Cooling	Water cooling circulation system
Detector modules	Pixelated Micromegas

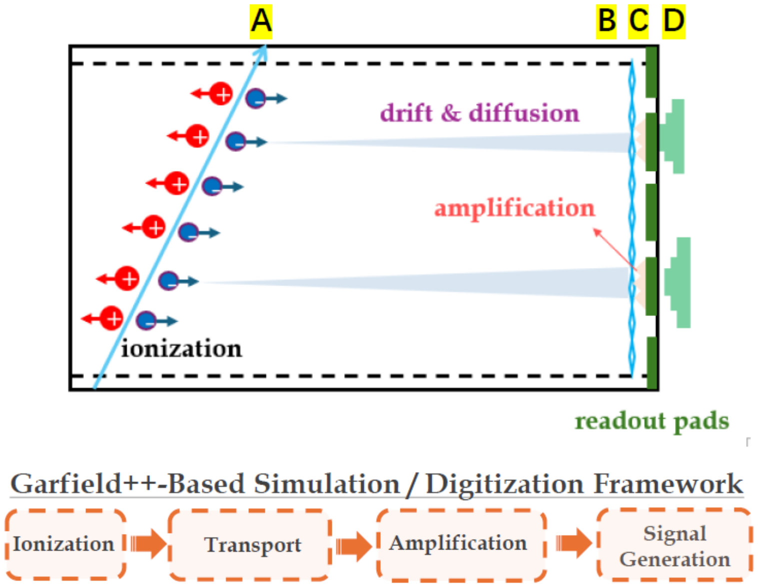
Simulation and performance

PID:

- dn/dx: Count the number of pixels with small-pixel-size readout
- dE/dx: Measure the total energy loss
- dn/dx has much better PID by getting rid of fluctuations from energy deposition and amplification

Simulation:

- With the full TPC geometry
- Ionization simulated with Garfield++
- Drift and diffusion from parameterized model based on Garfield++



Plans:

- Development of TPC prototype with low power consumption FEE
- Development of Micromegas prototypes
- Development of the full drift length prototype
- Drift velocity. Attachment coefficient, T/L Diffusion, etc.

Summary

- The preparation of the CEPC project is progressing successfully and is approaching the stage of readiness of the TDR and the creation of international collaborations. A decision on whether to begin construction of the collider is expected in about a year.
- The JINR group is already in close contacts with Chinese colleagues working on the preparation of the CEPC project.
- The JINR group plans to join the work on preparing the CEPC project and actively participate in the development of the physics research program at the collider, in R&D for the creation and development of calibration methods for hadron and electromagnetic calorimeters, a muon detector, and a pixelated TPC.
- Over the next two years, the foundation will be laid for future full-fledged participation of JINR in experiments at CEPC, provided the construction of this accelerator is approved by the Chinese government.

THANK YOU FOR ATTENTION!

Backup

JINR team

DLNP: K.Afanaciev, A.Artikov, N.Atanov, O.Atanova, V.Baranov, A.Boikov, I.Boyko, D.Chokheli, Yu.Davydov, D.Dedovich, O.Dolovova, Y.Dydyshka, L.Gladilin, A.Gongadze, N.Huseinov, L.Kalinovskaya, A.Kampf, Yu.Kulchitsky, V.Kiseeva, R.Lee, G.Lykasov, V.Lyubushkin, T.Lyubushkina, V.Malyshev, V.Moskalenko, E.Plotnikova, A.Prokhorov, V.Rogozin, L.Rumyantsev, R.Sadykov, A.Sapronov, A.Shalyugin, A.Simonenko, I.Suslov, P.Tsiareshka, A.Tropina, I.Vasilyev, I.Yeletskikh, V.Yermolchyk, I.Zimin, A.Zhemchugov,

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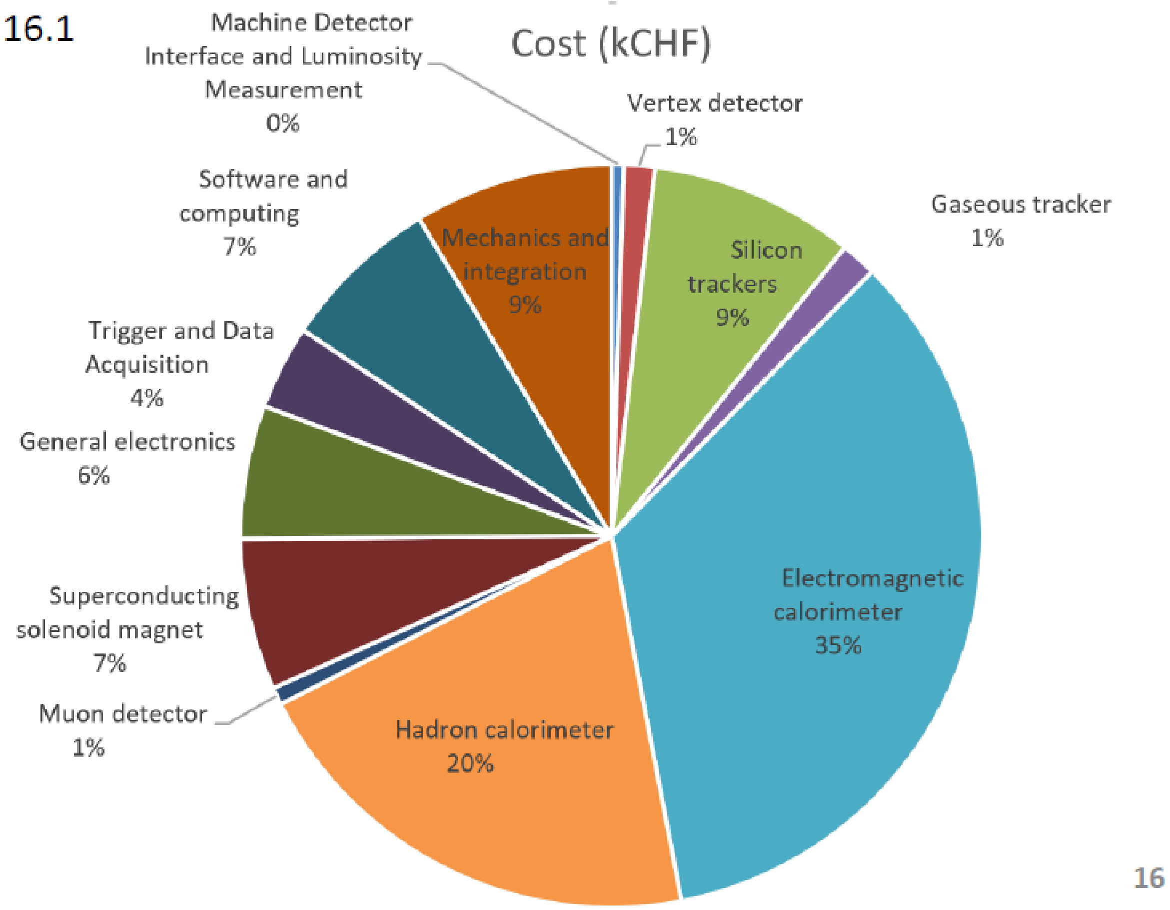
MLIT: O.Kodolova, Yu.Korsakov, A.Nikitenko, D.Oleynik, I.Pelevanyuk, A.Petrosyan, K.Slizhevsky, S.Shmatov, N.Voytishin

Cost budget in terms of systems

System	Cost (MCHF)	Ratio
MDI and Luminosity	1.8	0.5%
Vertex detector	4.5	1.4%
Silicon trackers	29.7	8.9%
Gaseous tracker	5.2	1.6%
Electromagnetic calorimeter	115.0	34.6%
Hadron calorimeter	68.3	20.5%
Muon detector	2.5	0.8%
Superconducting solenoid	22.0	6.6%
General electronics	19.3	5.8%
Trigger and Data Acquisition	12.2	3.7%
Software and computing	23.1	7.0%
Mechanics and integration	28.9	8.7%
Total	**332.3**	100.0%

Table 16.1



3% installation included; 8% contingency not included.

Miao He, CEPC IDRC Meeting, April 2025

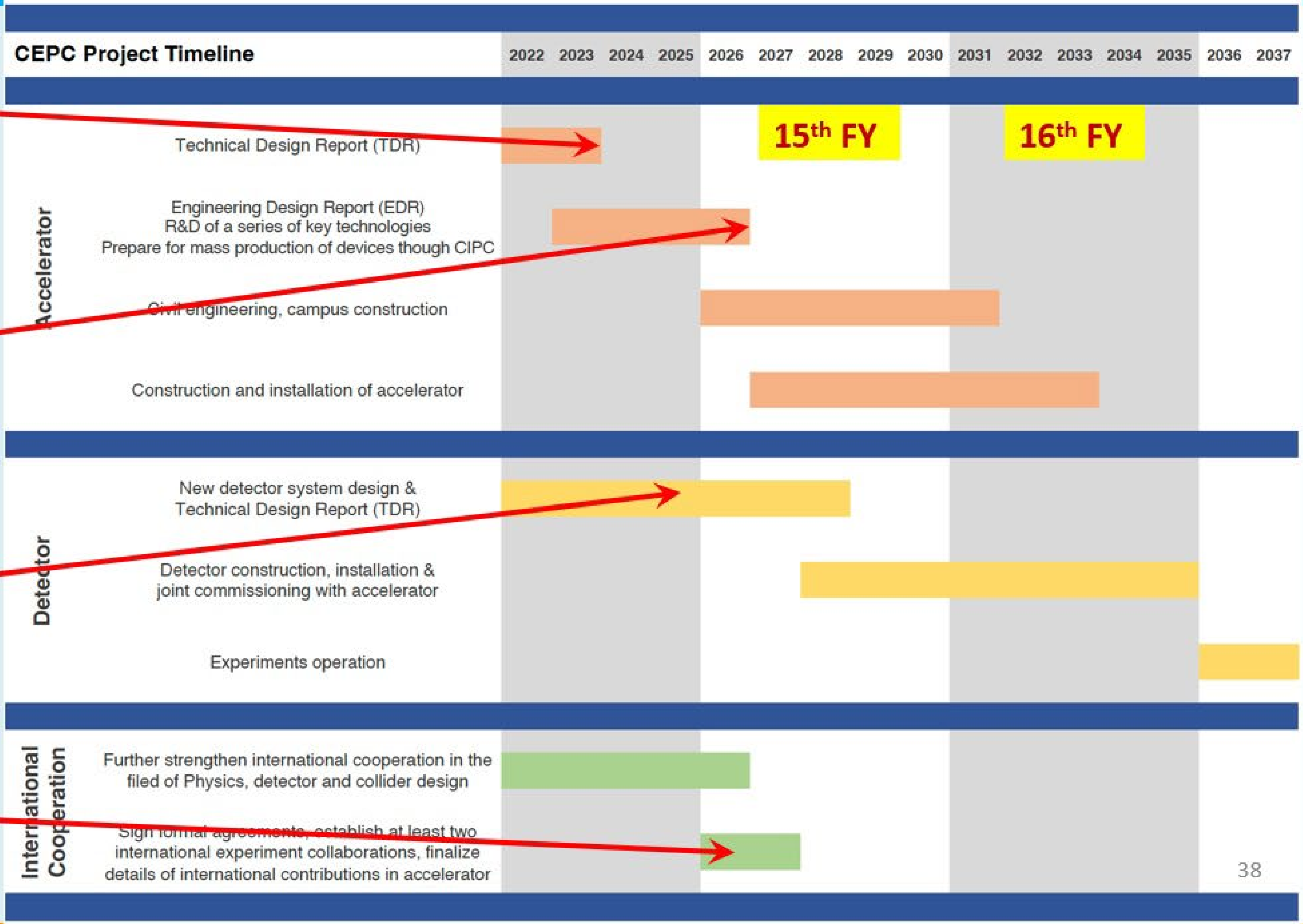
Ideal Timeline of CEPC

Completion of Accelerator TDR

Completion of Accelerator EDR

TDR of a Ref-Detector @ June 30, 2025

International Collaborations



Jianchun Wang IHEP CAS IDRC meeting, April 2025