Recent Status of the CEPC

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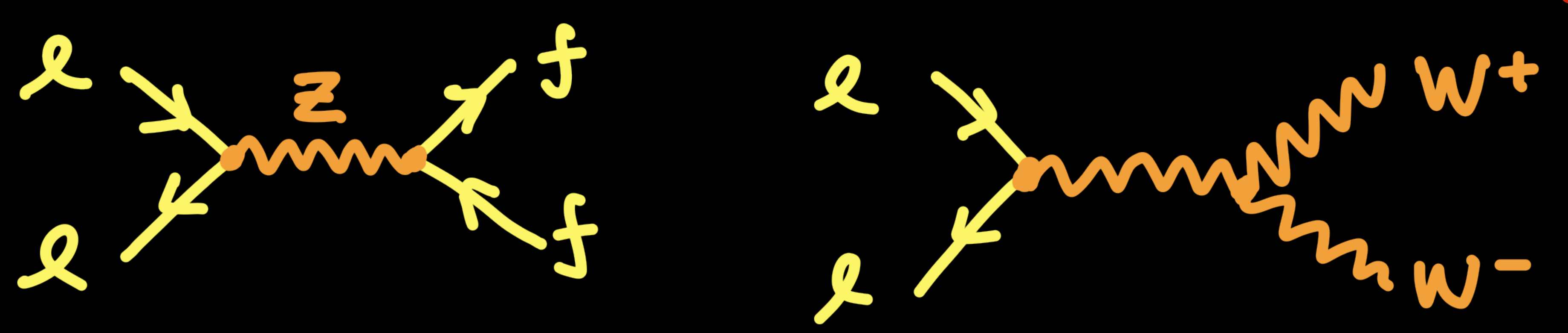
Outline

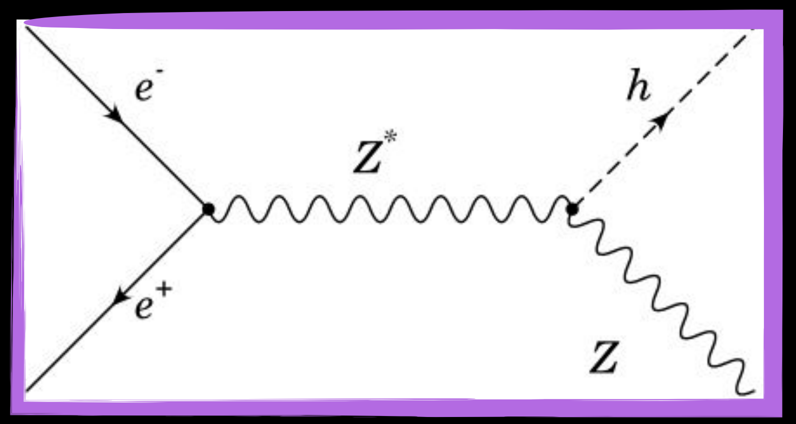
- Physics program of CEPC
- CEPC accelerator and detectors
- CEPC activities
- Final remarks

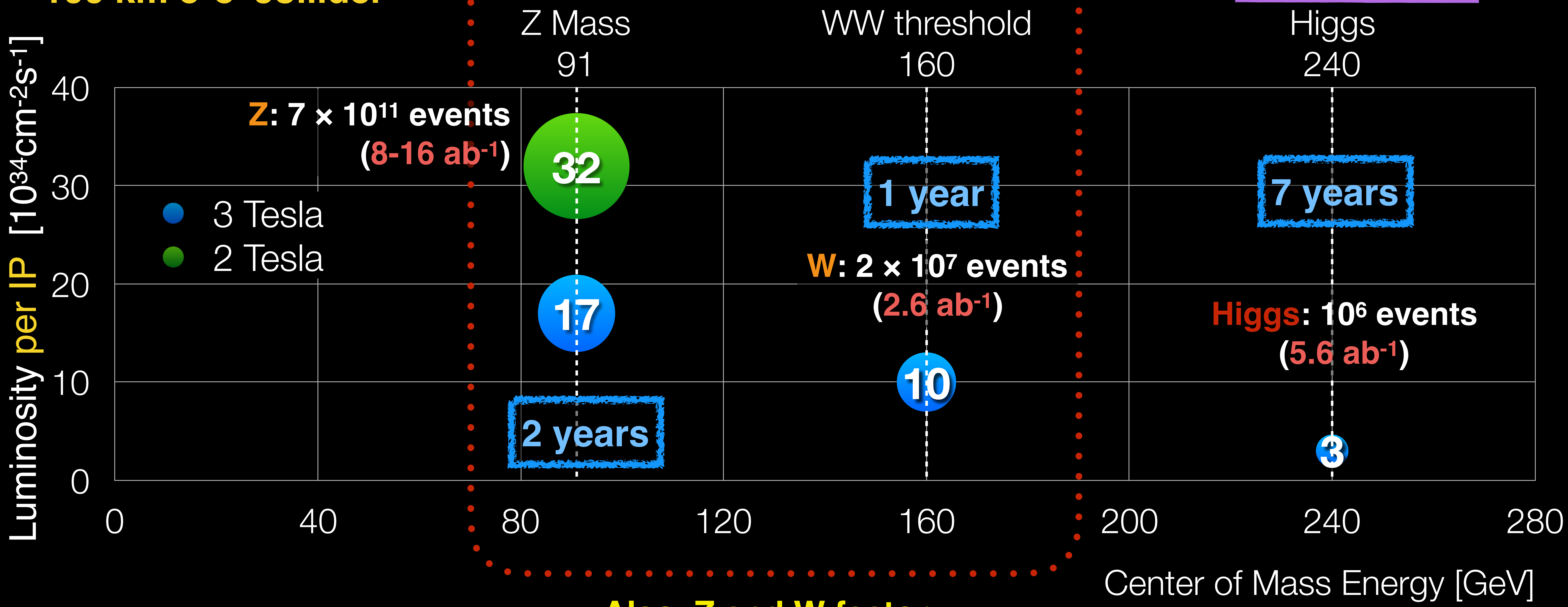
Physics at the CEPC

The CEPC Physics

100 km e^+e^- collider



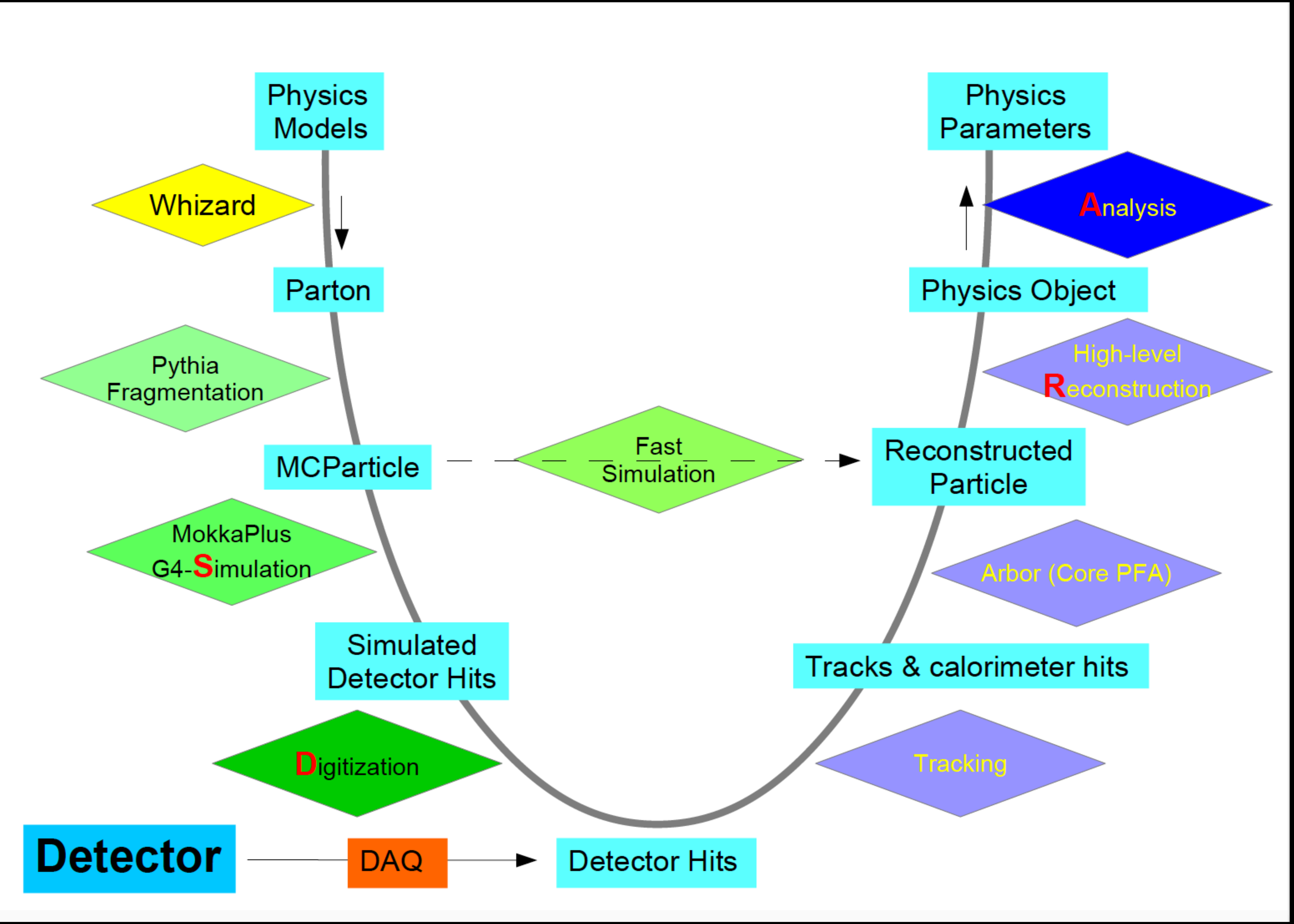




Also, Z and W factory

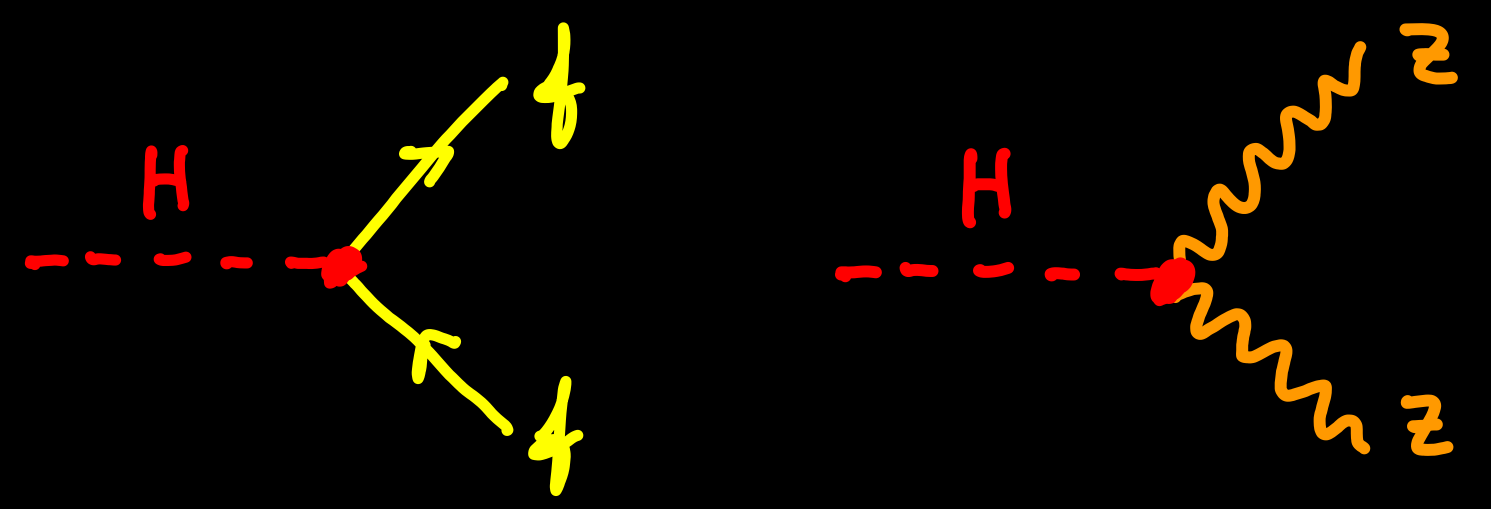
2 IPs planned

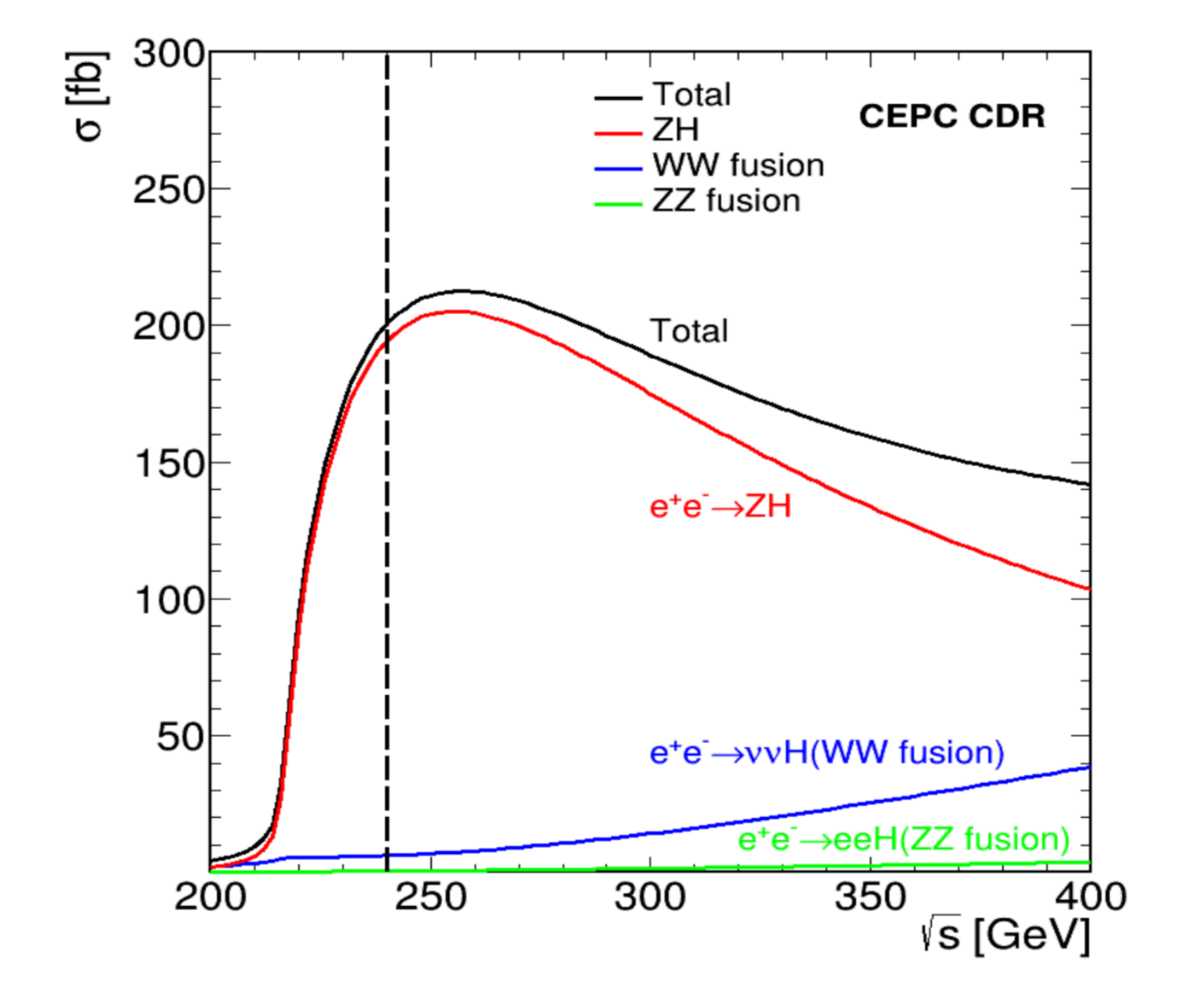
CEPC baseline software — http://cepcsoft.ihep.ac.cn/



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)

Higgs production in e^+e^- collisions





Events at 5.6 ab^{-1}

ZH: 10^6 events

ννH: 10^4 events

e^+e^-H: 10^3 events

S/B
1:500-1000

Observables:

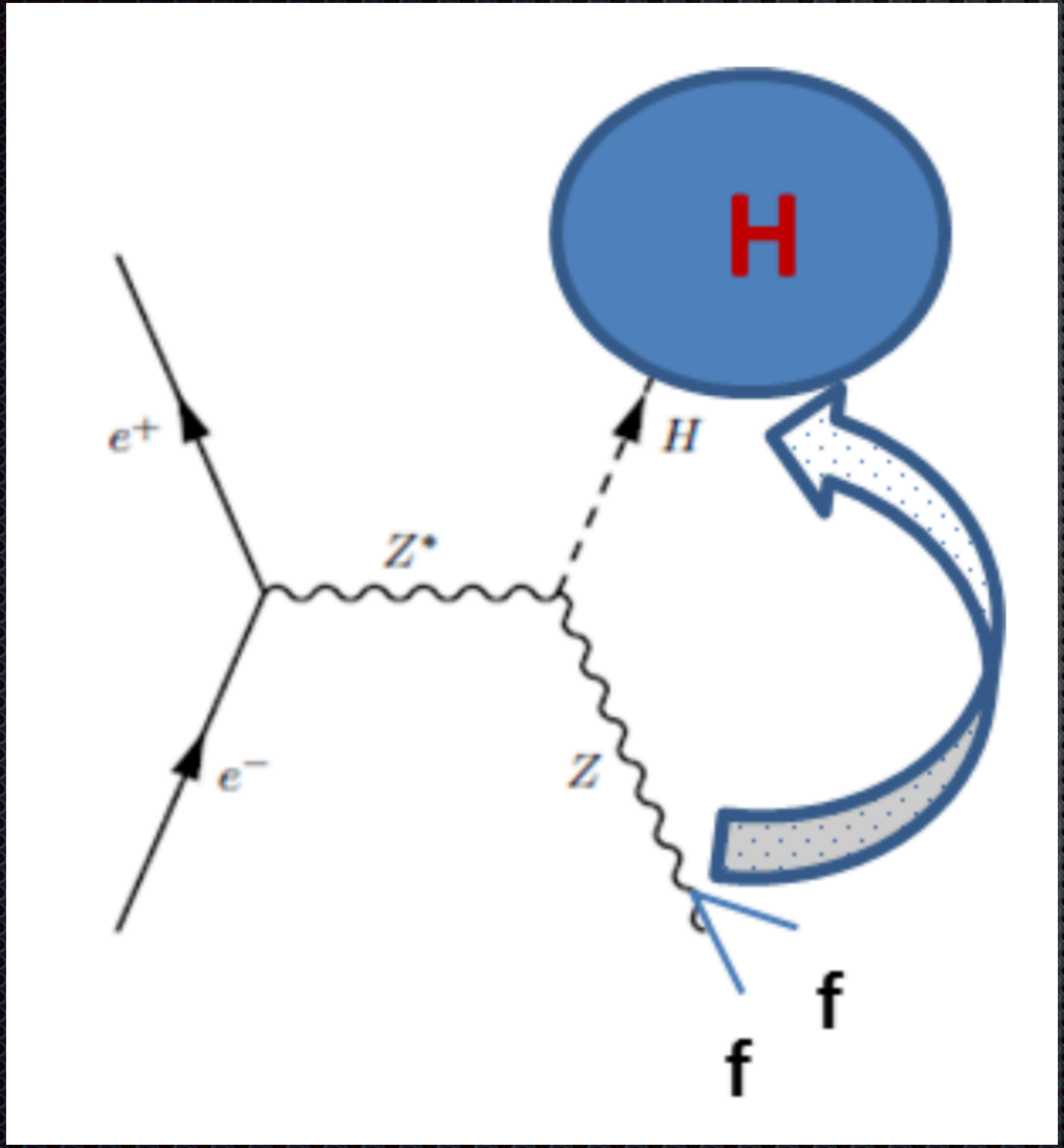
Higgs mass, CP, σ(ZH),
event rates (σ(ZH, ννH)*Br(H→X)),
differential distributions

Extract:

Absolute Higgs width, couplings

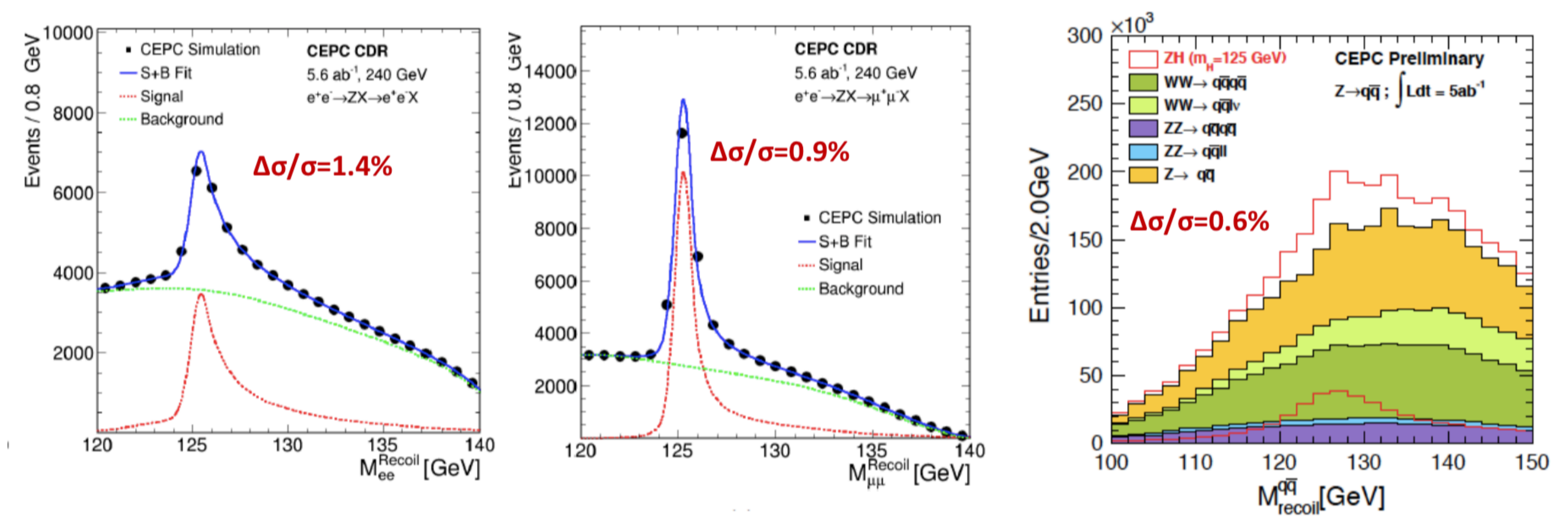
Direct measurement of Higgs cross-section

$$M^2_{\mathrm{recoil}} = (\sqrt{s} - E_{ff})^2 - p^2_{ff} = s - 2E_{ff}\sqrt{s} + m^2_{ff}$$



- For this model independent analysis, we reconstruct the recoil mass of Z without touching the other particles in a event.
- The M_{recoil} should exhibit a resonance peak at m_H for signal; Bkg expected to be smooth.
- The best resolution can be achieved from $Z(\rightarrow e^+e^-, \mu^+\mu^-)$.

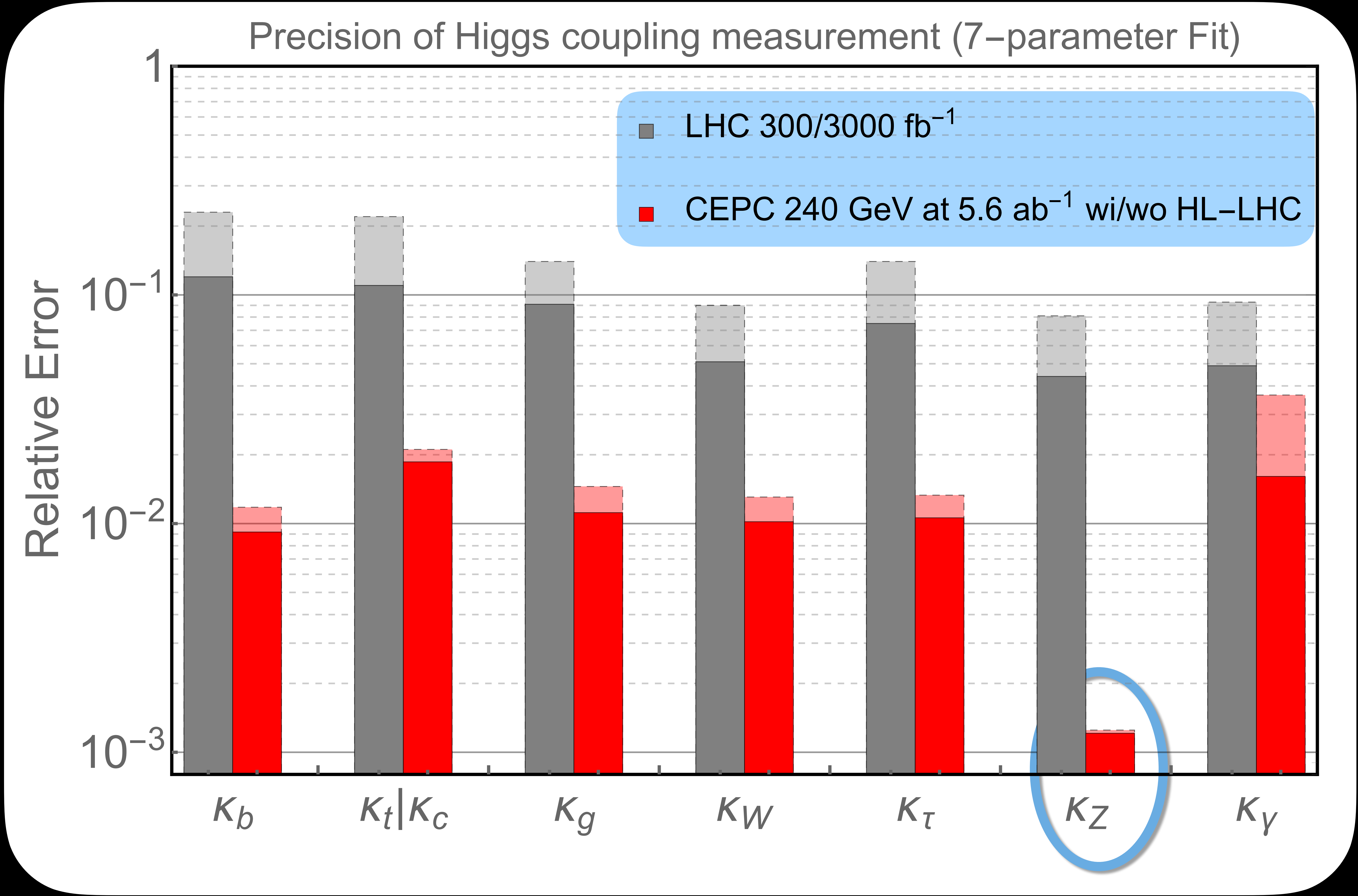
Direct measurement of Higgs cross-section and m_H



- The combined precision with three channels is $\Delta\sigma/\sigma=0.5\%$
- Similar sub-percent level for ILC/FCC-ee
- The mass of Higgs can be measured with a precision 6 MeV combining Z→ee (14 MeV) and Z→μμ (6.5 MeV)

Higgs Couplings Measurement

Precision of Higgs couplings measurement compared to HL-LHC



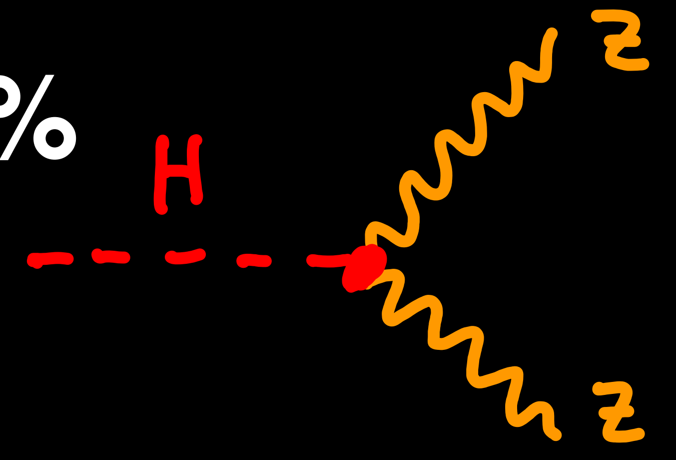
$$\kappa_f = \frac{g(hff)}{g(hff;\mathrm{SM})}, \quad \kappa_V = \frac{g(hVV)}{g(hVV;\mathrm{SM})}$$

HL-LHC

CEPC

~1% uncertainty

***κ_Z* ~ 0.2 %**



ATL-PHYS-PUB-2014-016

Higgs couplings variations due to BSM physics

CEPC will be sensitive to these

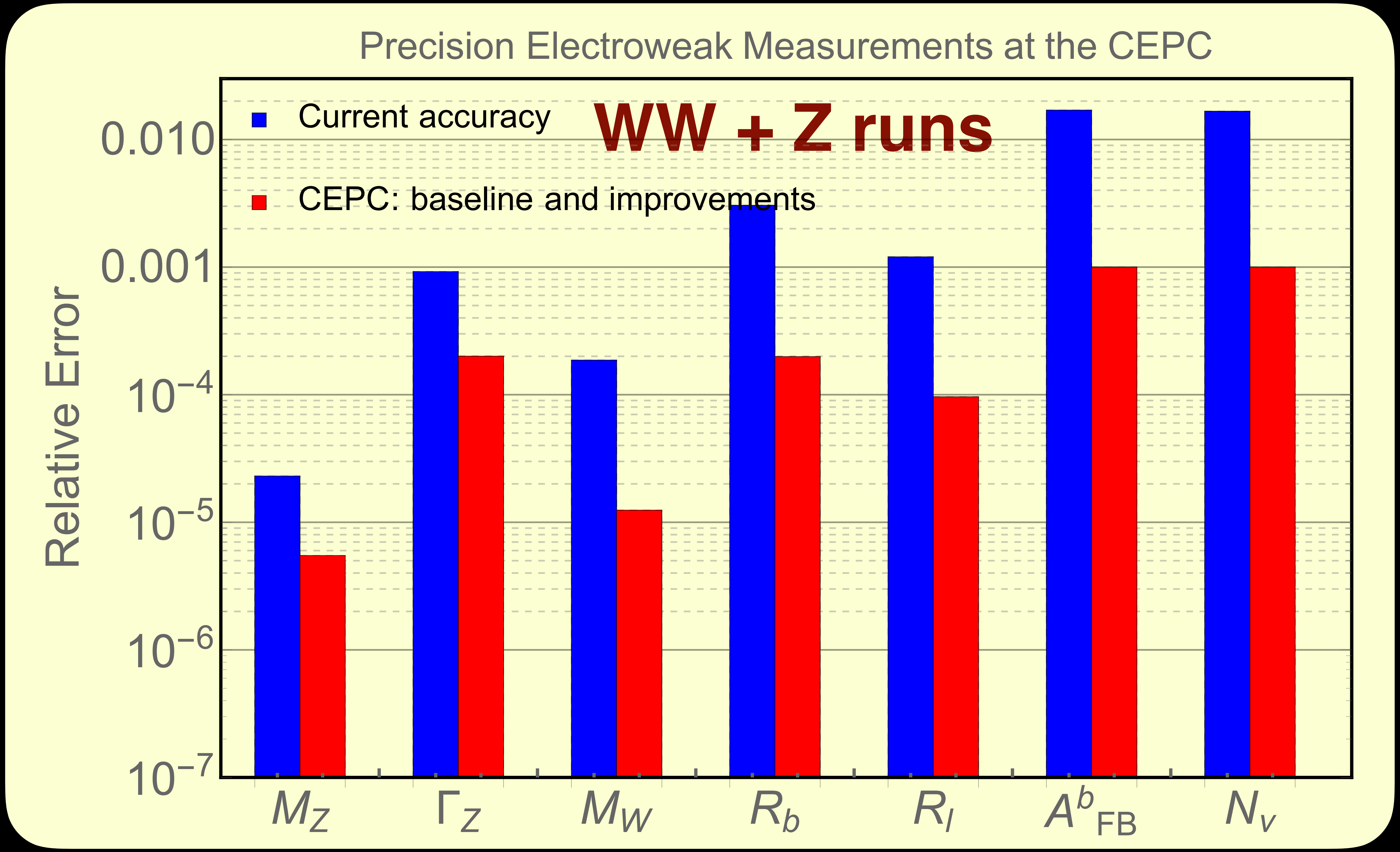
percentage variation relative to SM

	Model	$b\bar{b}$	$c\bar{c}$	gg	WW	$\tau\tau$	ZZ	$\gamma\gamma$	$\mu\mu$
1	MSSM [38]	+4.8	-0.8	- 0.8	-0.2	+0.4	-0.5	+0.1	+0.3
2	Type II 2HD [39]	+10.1	-0.2	-0.2	0.0	+9.8	0.0	+0.1	+9.8
3	Type X 2HD [39]	-0.2	-0.2	-0.2	0.0	+7.8	0.0	0.0	+7.8
4	Type Y 2HD [39]	+10.1	-0.2	-0.2	0.0	-0.2	0.0	0.1	-0.2
5	Composite Higgs [40]	-6.4	-6.4	-6.4	-2.1	-6.4	-2.1	-2.1	-6.4
6	Little Higgs w. T-parity [41]	0.0	0.0	-6.1	-2.5	0.0	-2.5	-1.5	0.0
7	Little Higgs w. T-parity [42]	-7.8	-4.6	-3.5	-1.5	-7.8	-1.5	-1.0	-7.8
8	Higgs-Radion [43]	-1.5	- 1.5	+10.	-1.5	-1.5	-1.5	-1.0	-1.5
9	Higgs Singlet [44]	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5

LHC not likely to be sensitive to these models even with full HL-LHC dataset

arXiv: 1710.07621

Precision Electroweak observables at CEPC

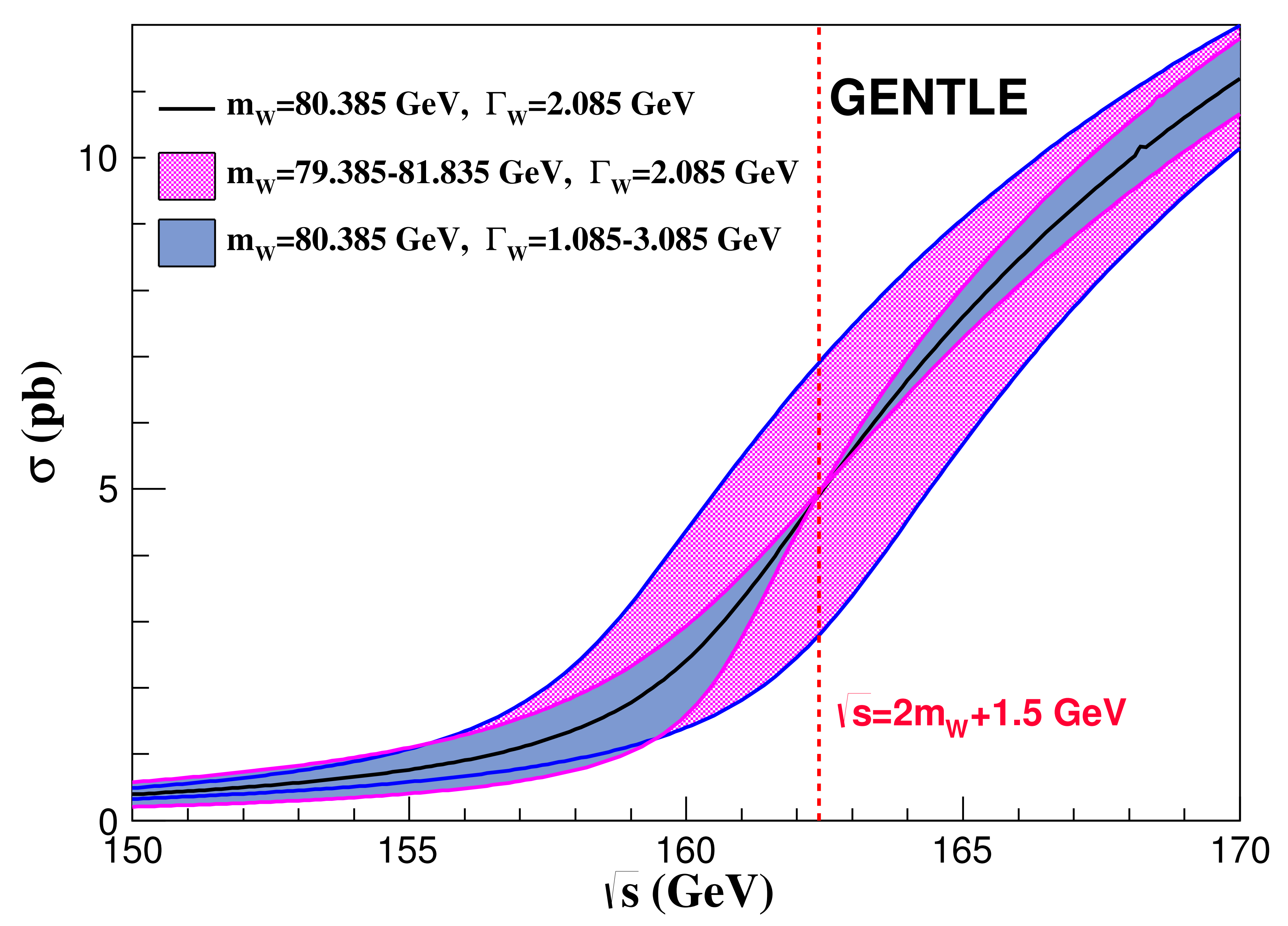


Including detector performance

Assumes: 2-year run at Z-pole and
1-year run at WW threshold

Beam energy calibration !

W Mass from Threshold Scan



Similar to LEP technique
Use 3 √s points: 157.5, 161.5 and 162.5 GeV

Beam energy spread: 0.13-0.1%
E_{CM} uncertainty: 0.5 MeV

L = 2.6 ab^{-1} → $\Delta M_W \sim 1$ MeV

Working together with FCC-ee

The Physics Goals

Precision tests of Standard Model (H, W, and Z) → **Potential to find new physics**

Higgs boson and electroweak symmetry breaking

Directly exploring new physics

- Precision measurements of Higgs couplings
- Exotic Higgs decays
- Exotics Z decays
- Dark matter and hidden sectors
- Extended Higgs sector

QCD precision measurements

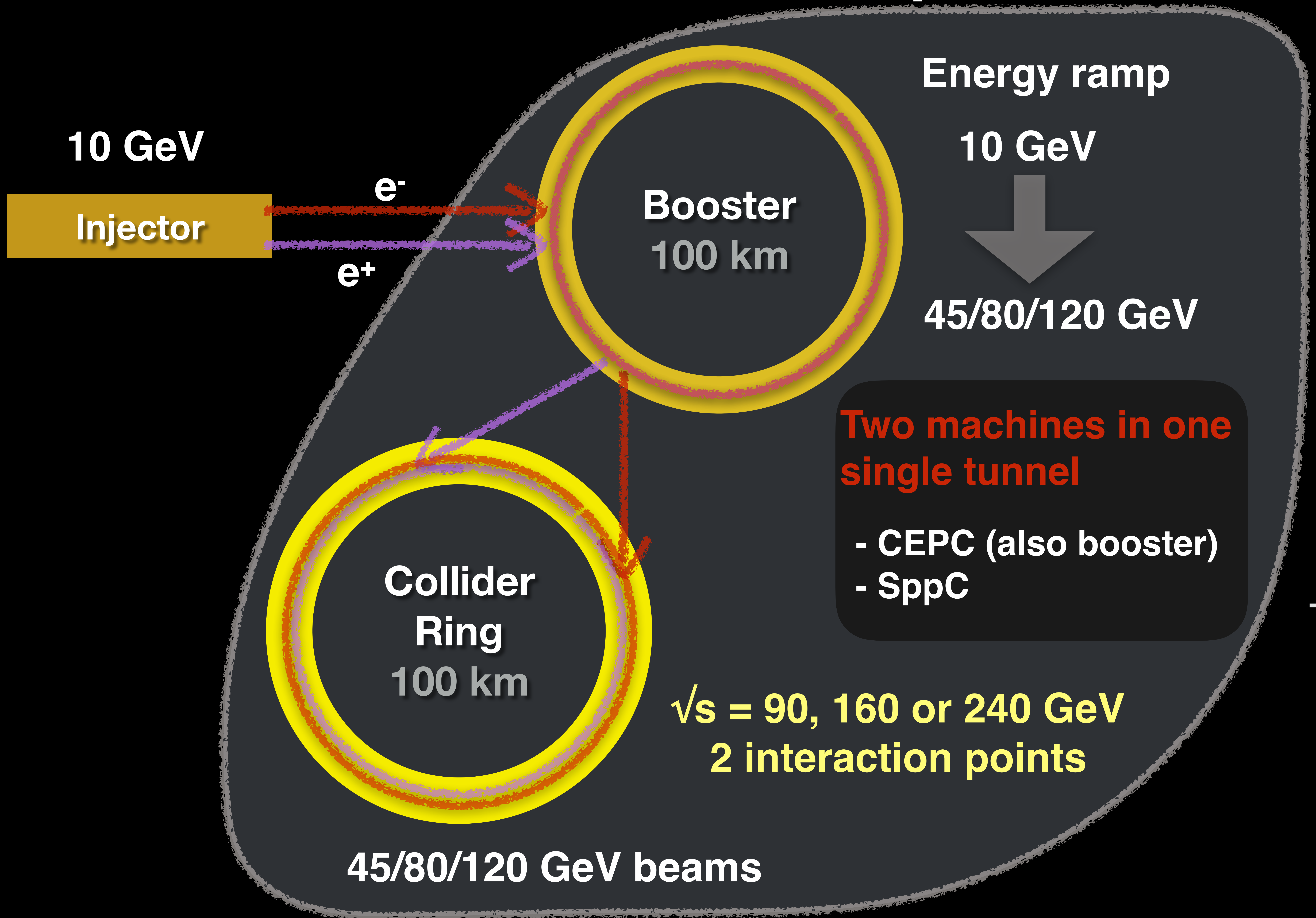
- Precision α_S determination
- Jet rates at CEPC
- QCD dynamics, soft QCD effects, fragmentation functions
- QCD event shapes and light-quark Yukawa couplings

Flavor physics at the *Z* pole

- Rare B decays
- Heavy flavor baryons
- Tau decays
- Flavor violating *Z* decays

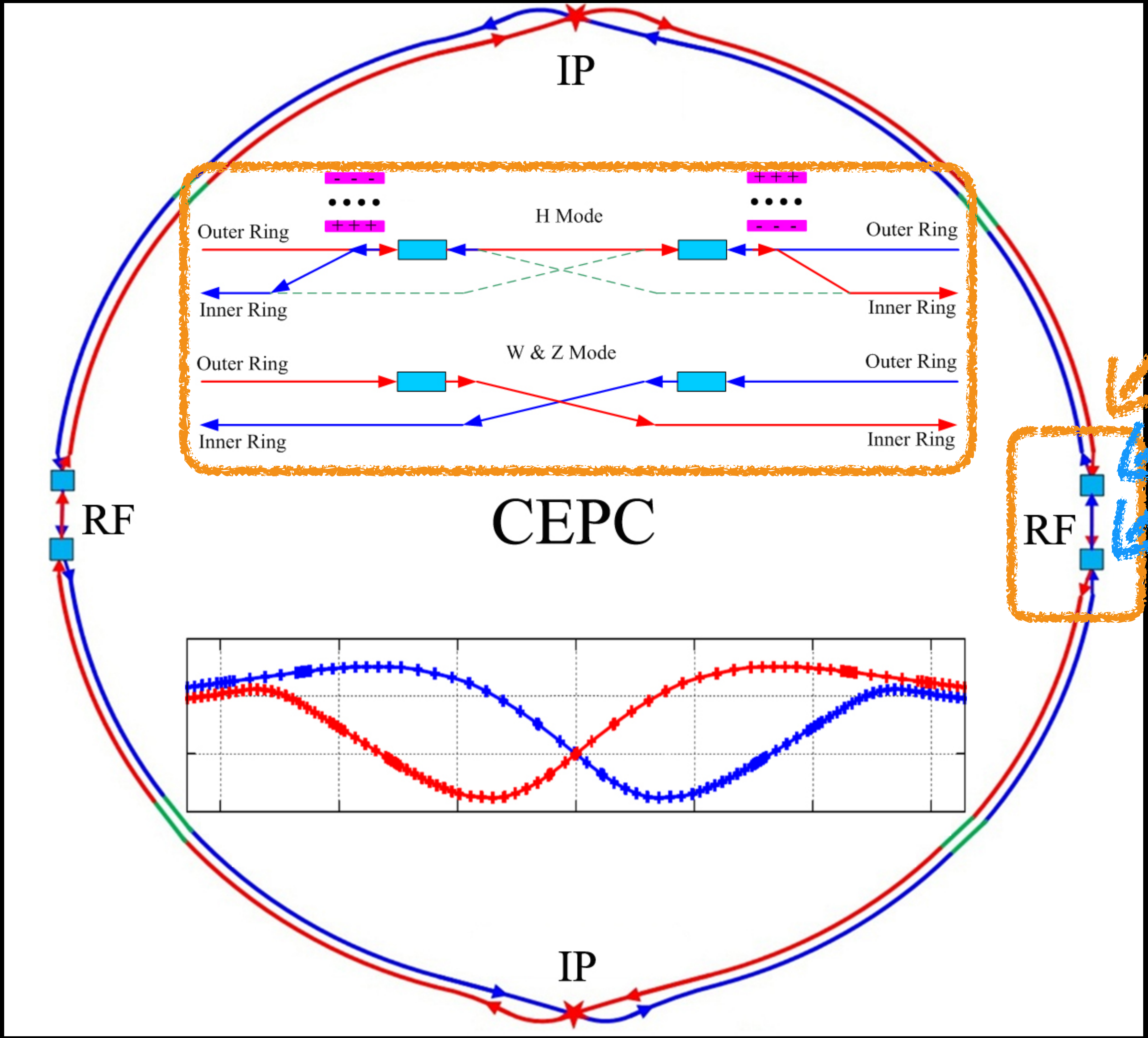
CEPC
Accelerator and Detectors

CEPC Accelerator Chain and Systems



The key systems of CEPC:
1) Linac Injector
2) Booster
3) Collider ring
4) Machine Detector Interface
5) Civil Engineering

The CEPC Baseline Collider Design



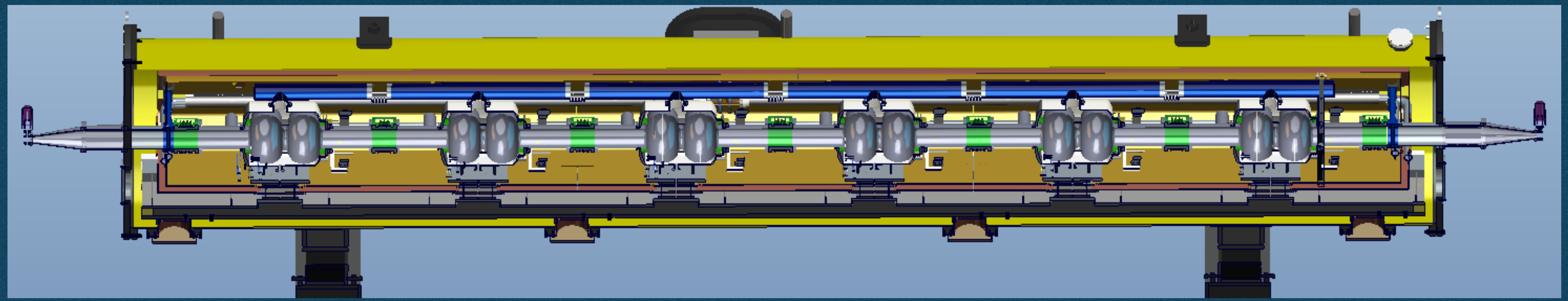
Double ring

Common RF cavities for Higgs

Two RF sections in total

Two RF stations per RF section

10 x 2 = 20 cryomodules

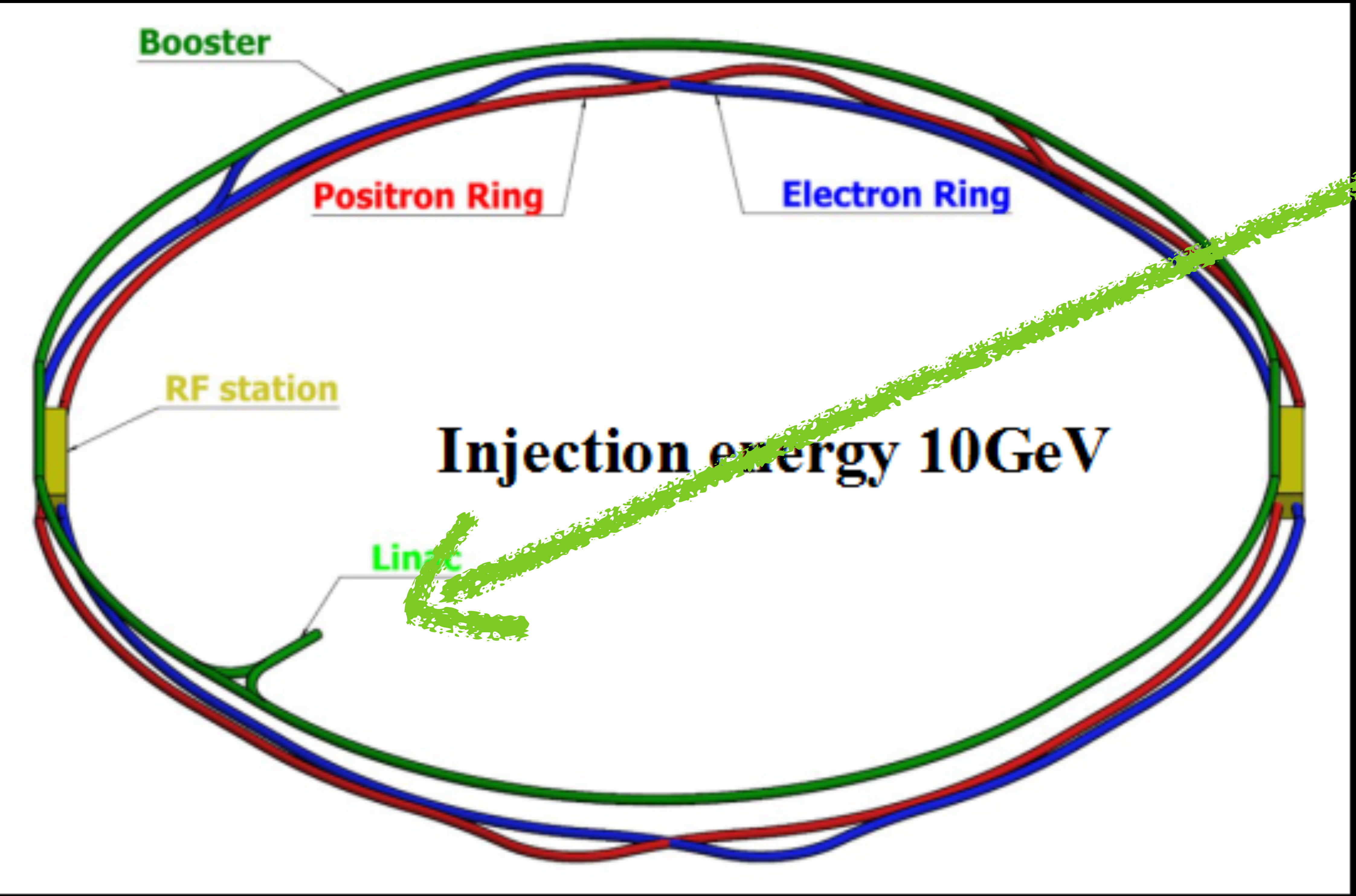


Six 2-cell cavities per cryomodule

The CEPC Baseline: LINAC Injector

LINAC: 1.2 km

Positron target

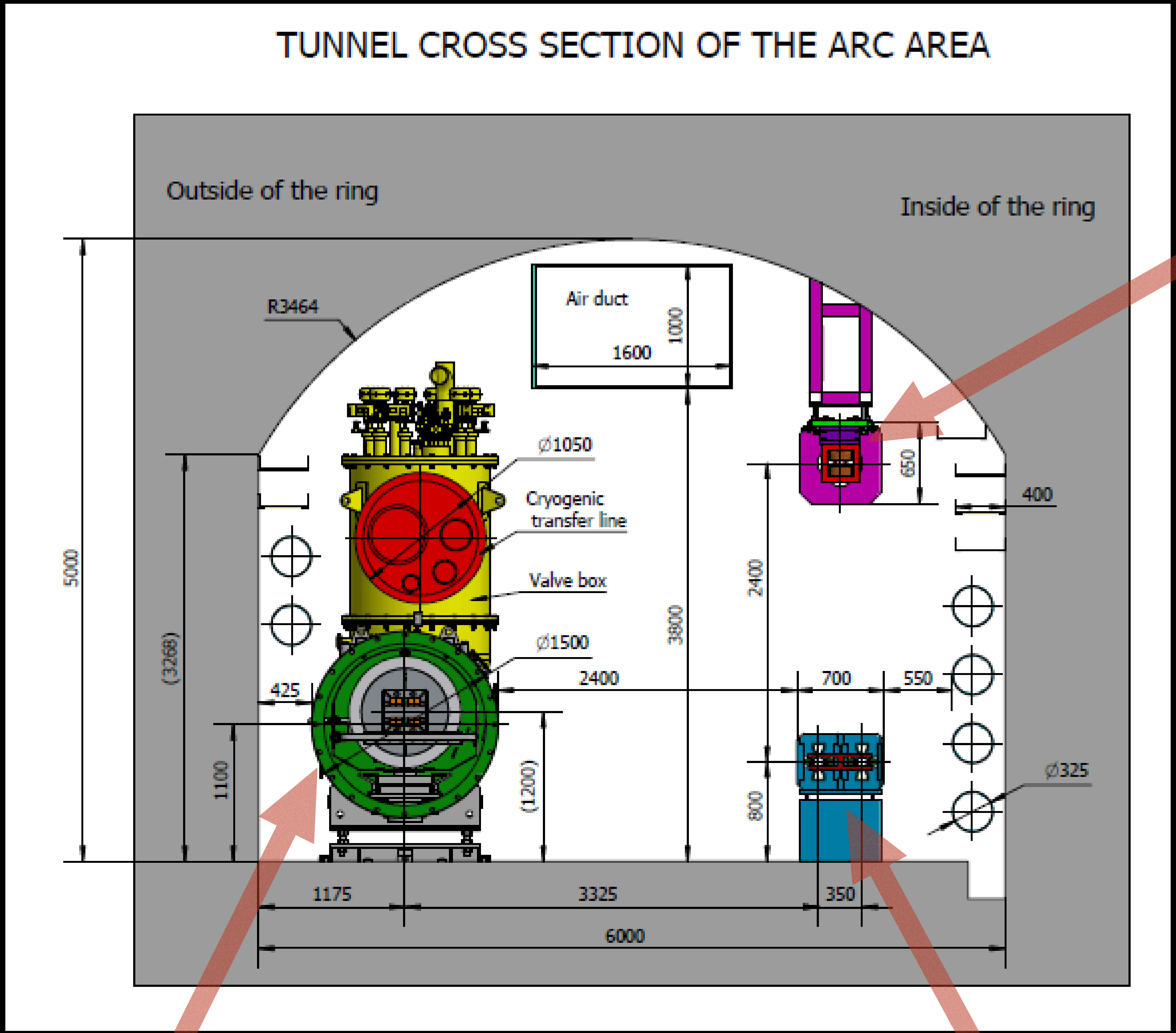


e+/e- beam energy: **10 GeV**

Total beam transfer efficiency: **90%**

45 GeV **Plasma Wakefield Accelerator** considered as an alternative

The 100k tunnel cross section



5 meters tall

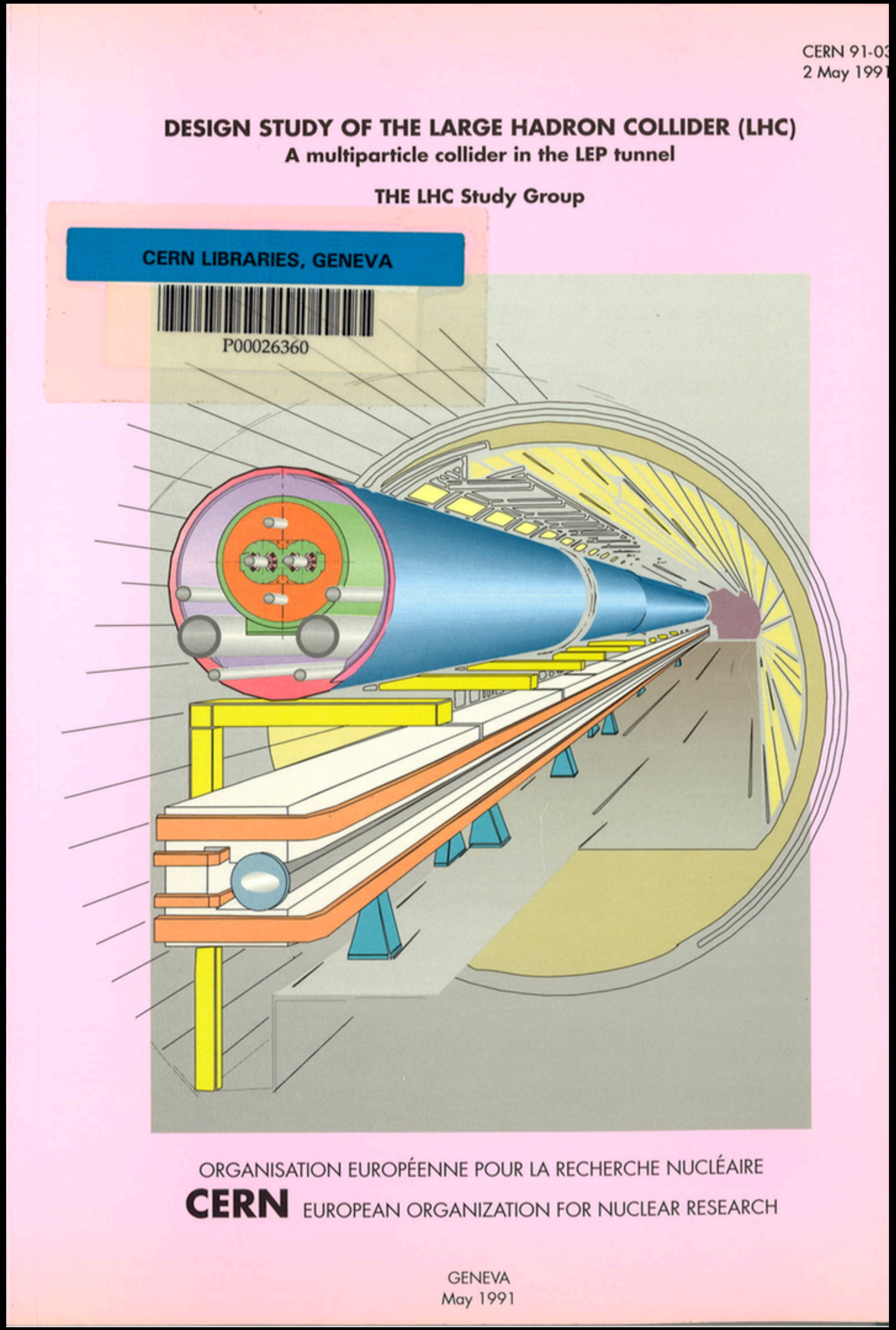
CEPC Booster

SppC collider

6 meters wide

CEPC collider

Proposed in Lausanne Workshop in 1984



CEPC Civil Engineering Design very advanced

LEP tunnel internal diameter is 3.8 meters in the arcs

4.4 or 5.5 meters in the straight sections

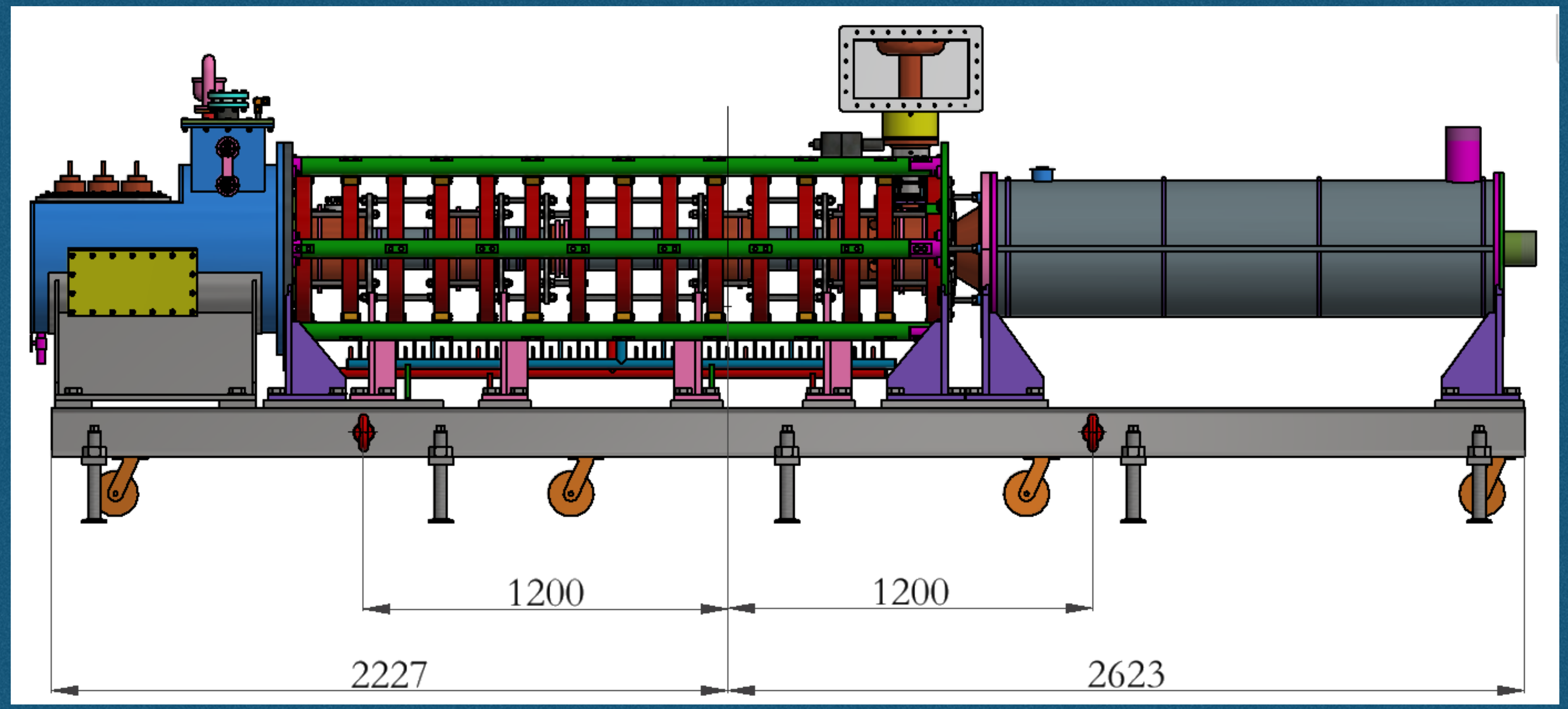
Accelerator key technologies R&D — prototypes

CEPC 650 MHz Cavity

Collaboration with Photon Source projects in Shanghai and Beijing (1.3 GHz cavities)

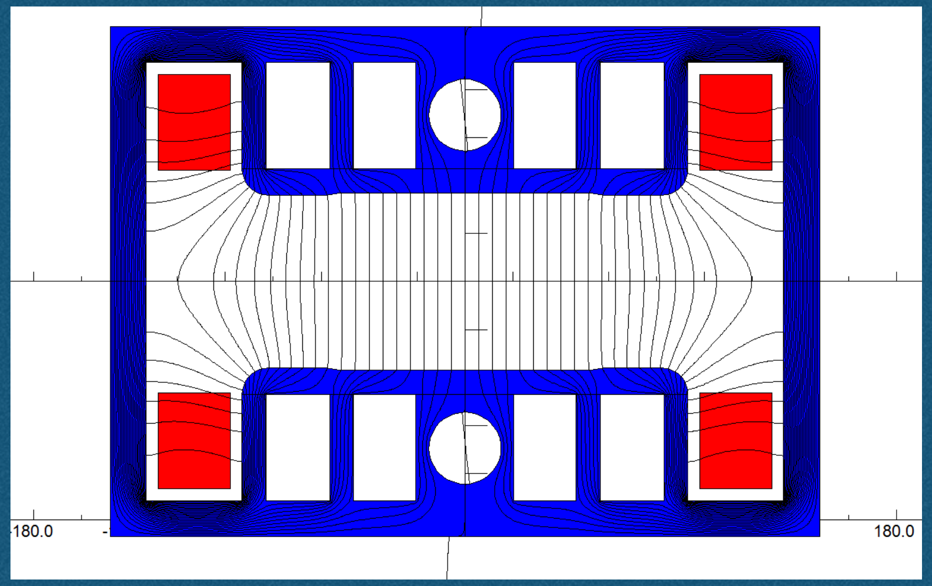
High Efficiency Klystron

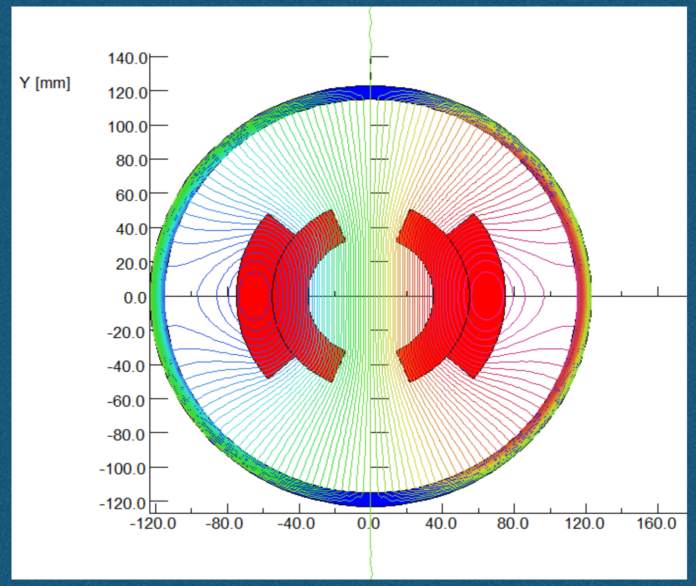
"High efficiency klystron collaboration consortium", including IHEP, Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.



3 high-efficiency klystron (up to 80%) prototypes to be built by 2021

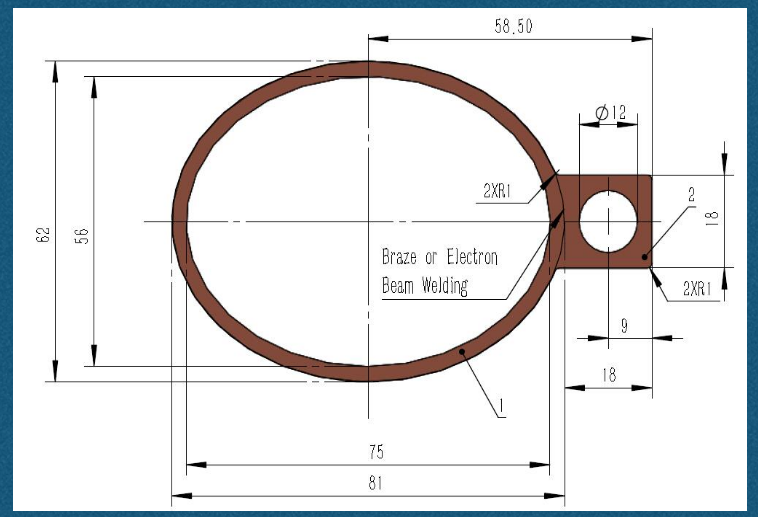
Booster low-field dipole magnets

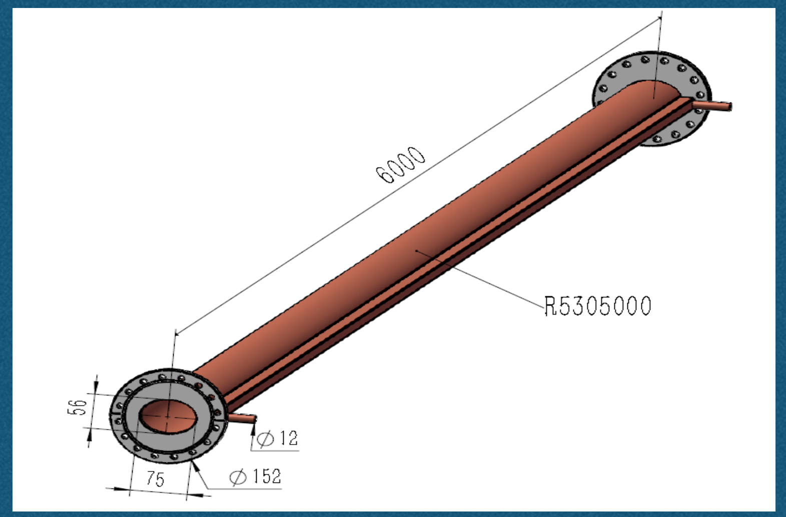


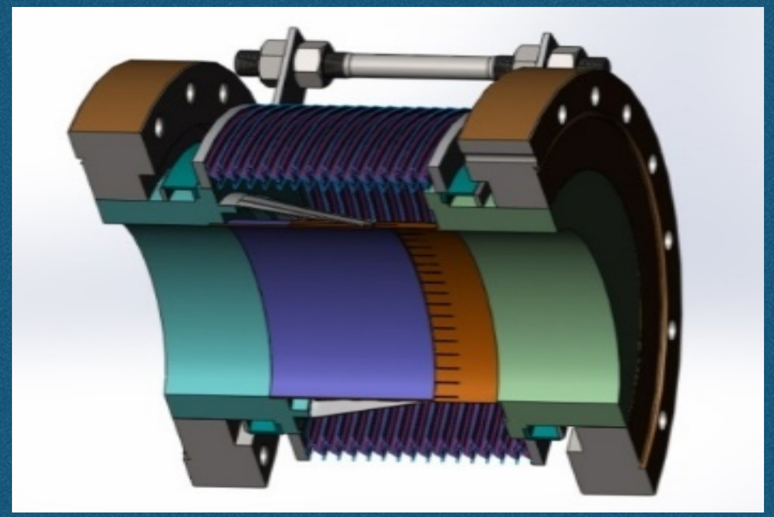


$L_{mag} = 5$ m, $B_{min} = 30$ Gs, Errors $<5\times10^{-4}$

Vacuum system R&D



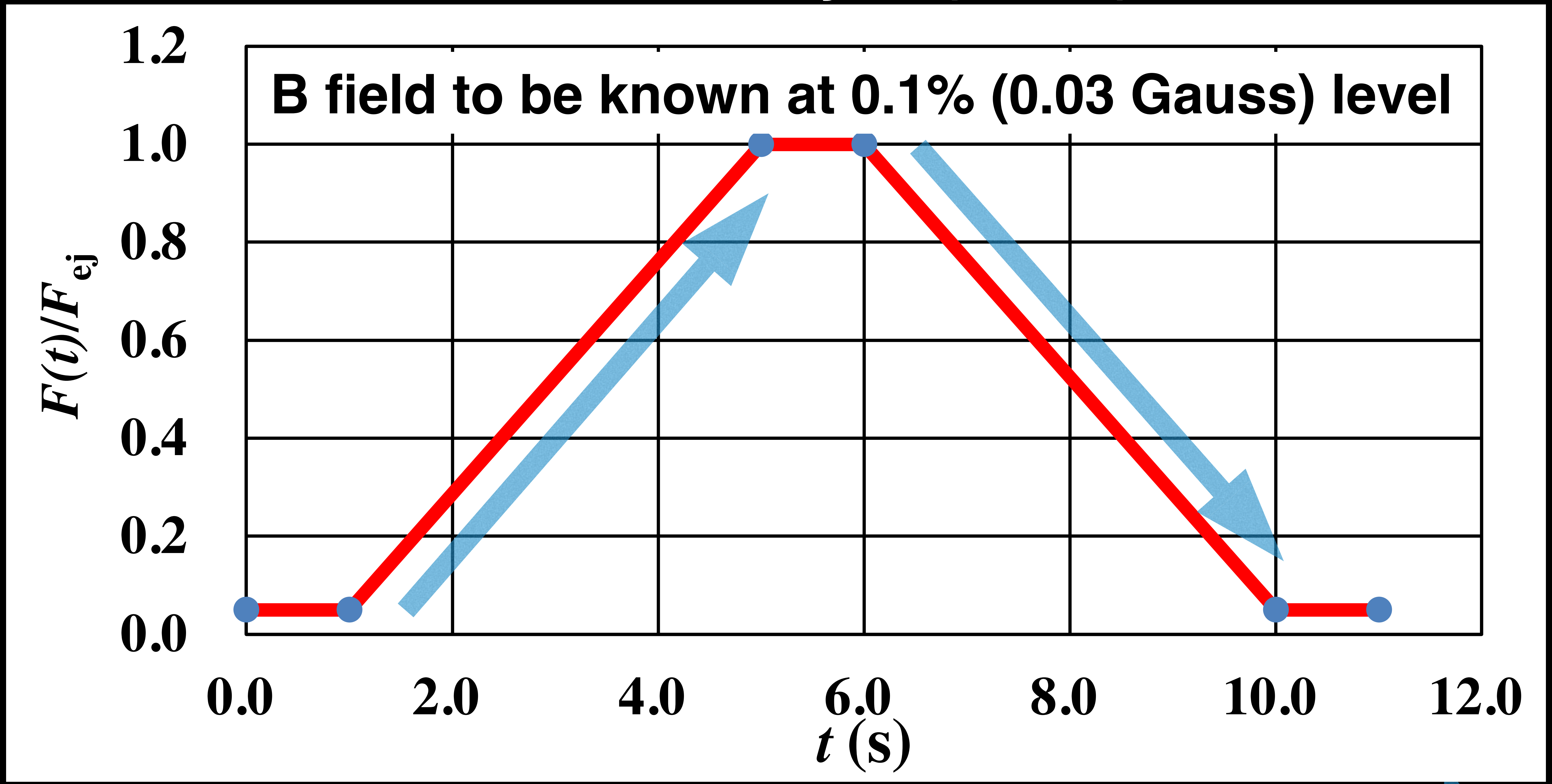


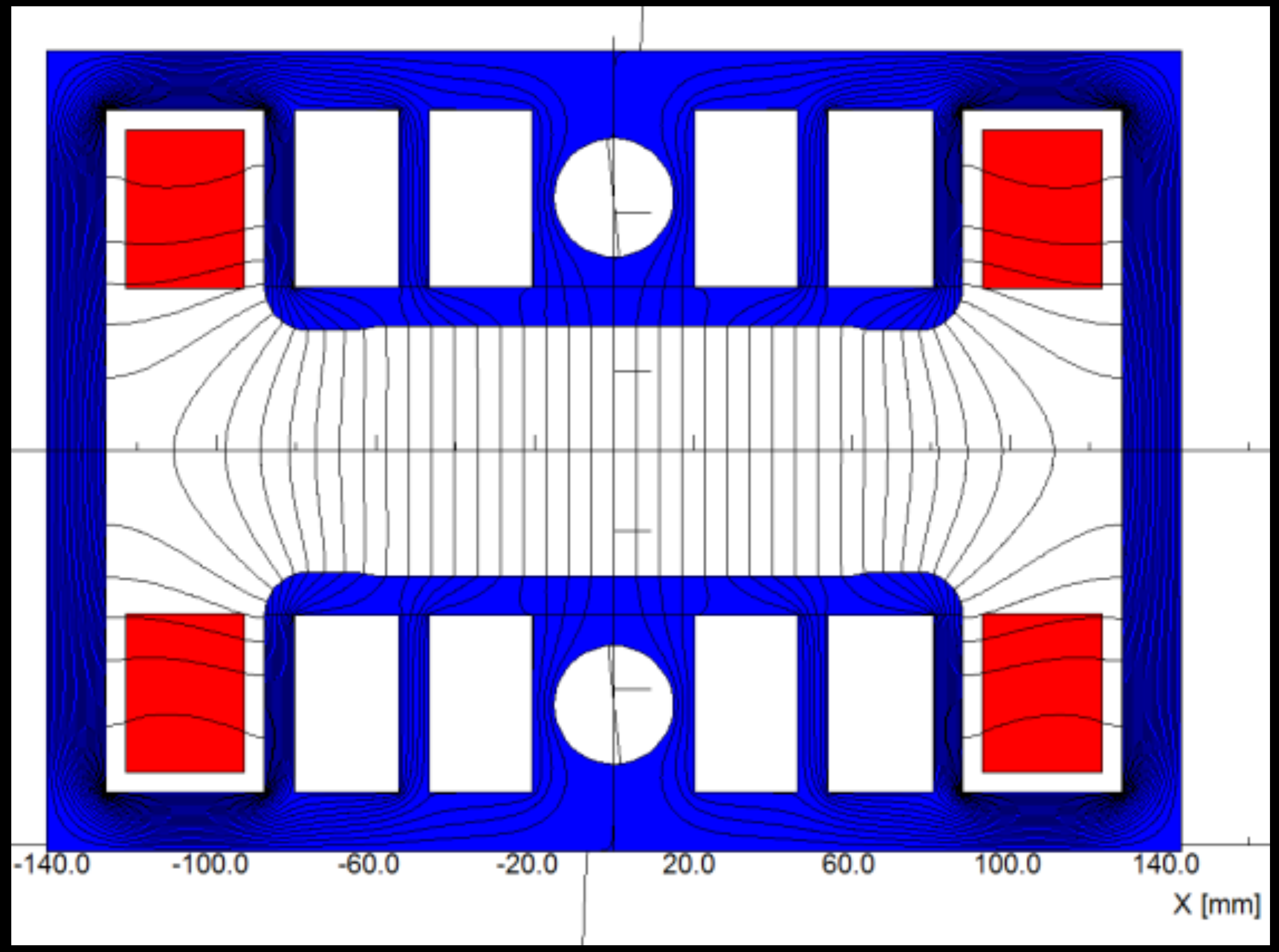


- 6m copper vacuum chamber: pressure 2×10^{-10} torr
- Bellows module: allow thermal expansion, alignment

Challenge: Low–field dipole magnets in Booster ring

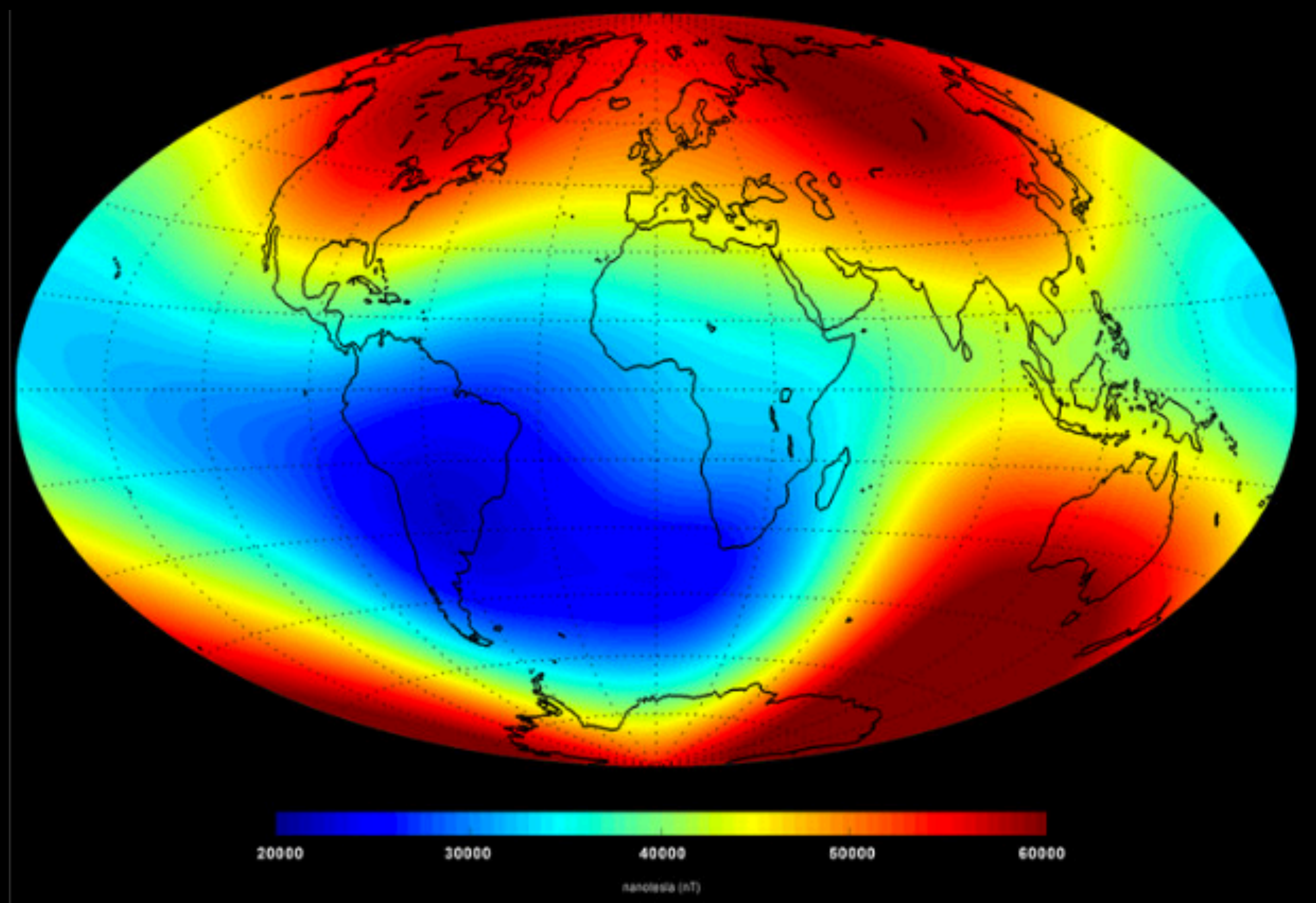
Booster Cycle (0.1 Hz)





Earth magnetic field:
0.25 to 0.65 Gauss

29 Gauss	338 Gauss	29 Gauss
10 GeV from Linac	120 GeV injection to collider	10 GeV from Linac



On-going R&D program

Updated Parameters of Collider Ring

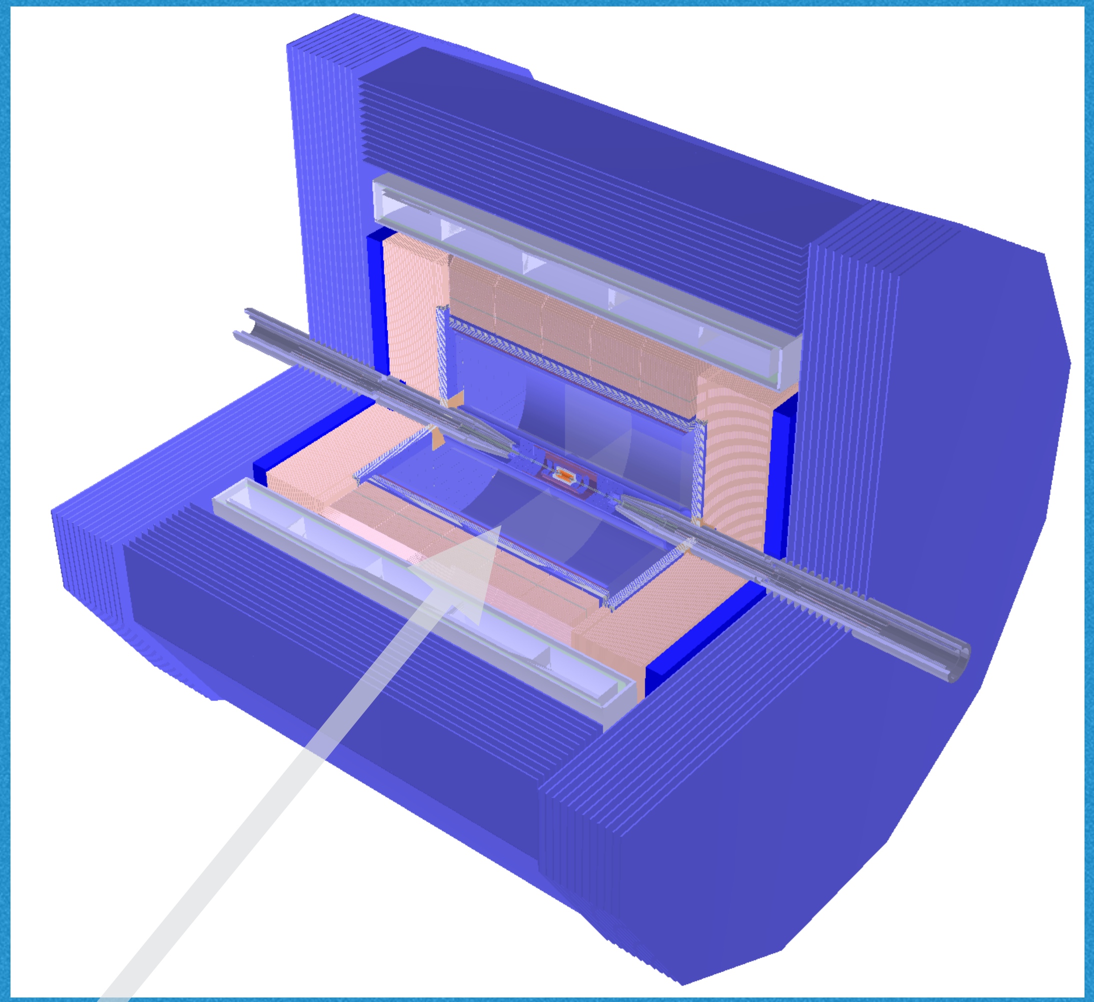
	Higgs		Z (2T)	
	CDR	Updated	CDR	Updated
Beam energy (GeV)	120	-	45.5	-
Synchrotron radiation loss/turn (GeV)	1.73	1.68	0.036	-
Piwinski angle	2.58	3.78	23.8	33
Number of particles/bunch N_e (10^{10})	15.0	17	8.0	15
Bunch number (bunch spacing)	242 (0.68μs)	218 (0.68μs)	12000	15000
Beam current (mA)	17.4	17.8	461.0	1081.4
Synchrotron radiation power /beam (MW)	30	-	16.5	38.6
Cell number/cavity	2	-	2	1
β function at IP β_x^* / β_y^* (m)	0.36/0.0015	0.33/0.001	0.2/0.001	-
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.89/0.0018	0.18/0.0016	-
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	17.1/0.042	6.0/0.04	-
Bunch length σ_z (mm)	3.26	3.93	8.5	11.8
Lifetime (hour)	0.67	0.22	2.1	1.8
Luminosity/IP L (10^{34} cm^{-2}s^{-1})	2.93	5.2	32.1	101.6

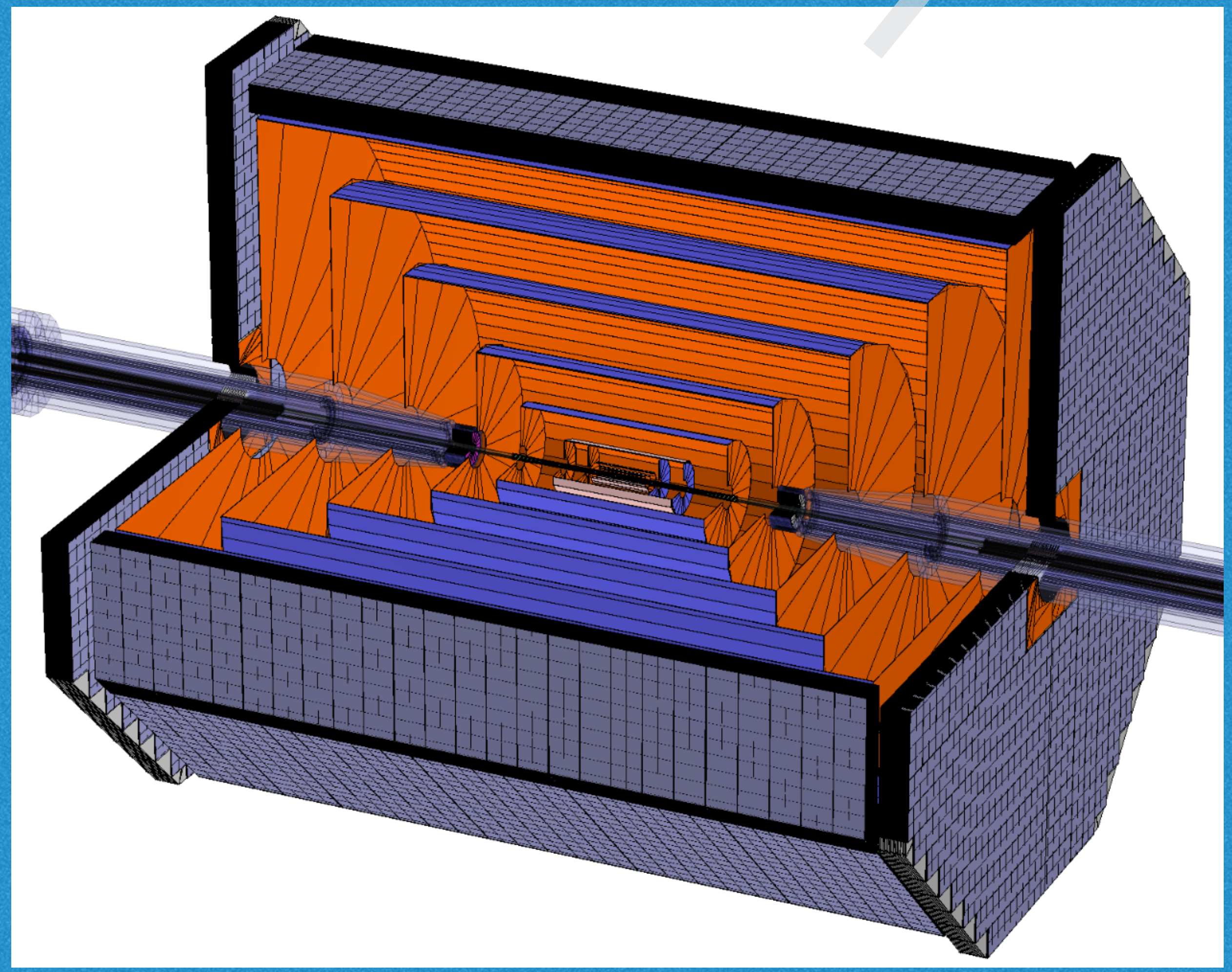
Luminosity increase factor: × 1.8 × 3.2

CEPC: 2.5 Detector Concepts

Particle Flow Approach

Baseline detector ILD-like (3 Tesla)

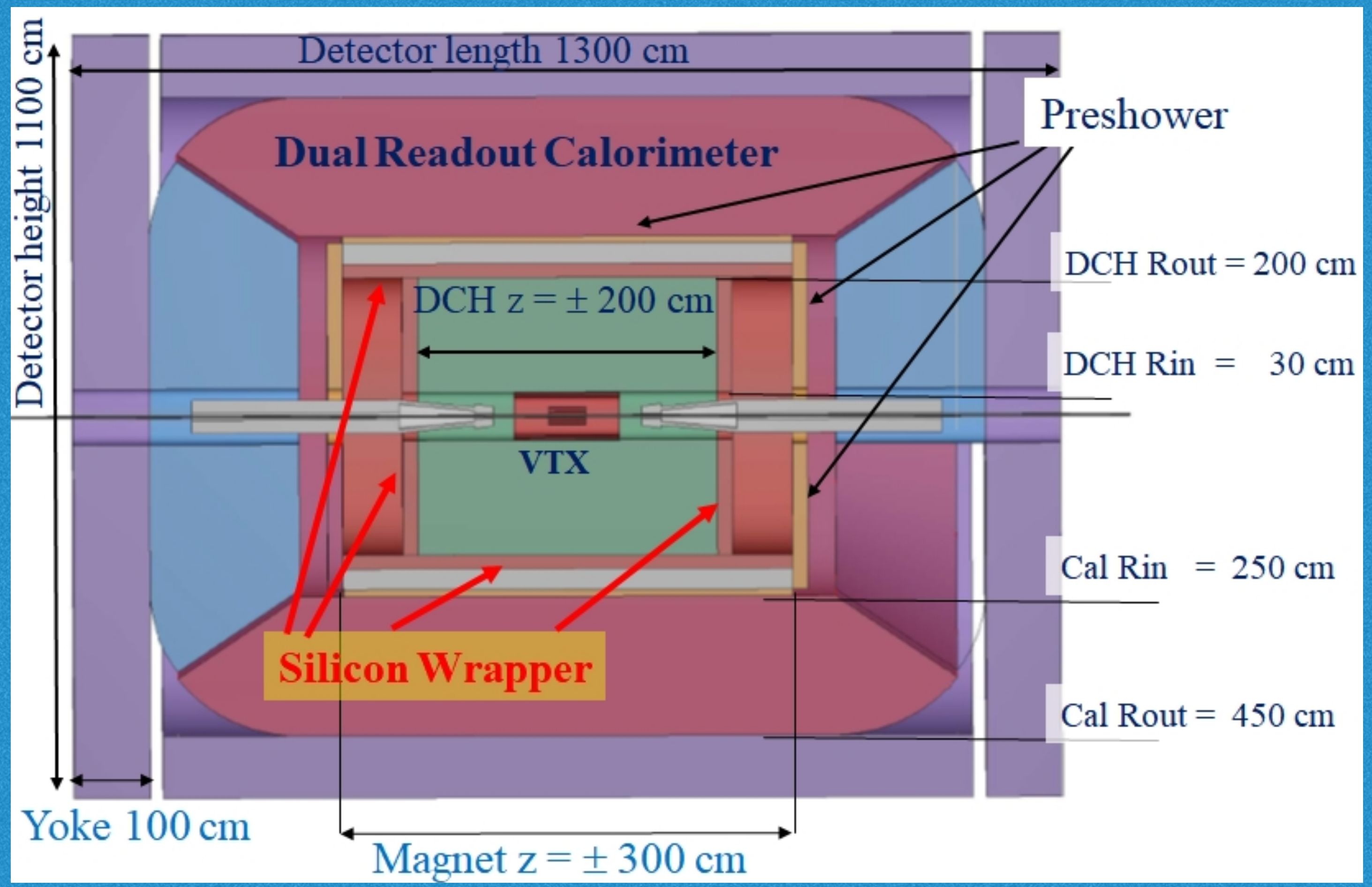




Full silicon tracker concept

CEPC plans for 2 interaction points

Low magnetic field concept (2 Tesla)



IDEA Concept

also proposed for FCC-ee

Final two detectors likely to be a mix and match of different options

Baseline detector
and
Particle flow philosophy

Particle flow: make use of the optimal sub-detector information in reconstruction and a high granularity calorimetry system required

Particles in jet	Fraction of E	Measured by	Resolutions (σ^2)
Charged tracks	~60%	Tracker	Negligible
Photons	~30%	Ecal	0.20^2E_{jet}
Neutral hadron	~10%	Ecal+Hcal	0.50^2E_{jet}
Conclusion	Required for 30%/sqrt(E)		0.20^2E_{jet}

CEPC CDR: Particle Flow Conceptual Detector

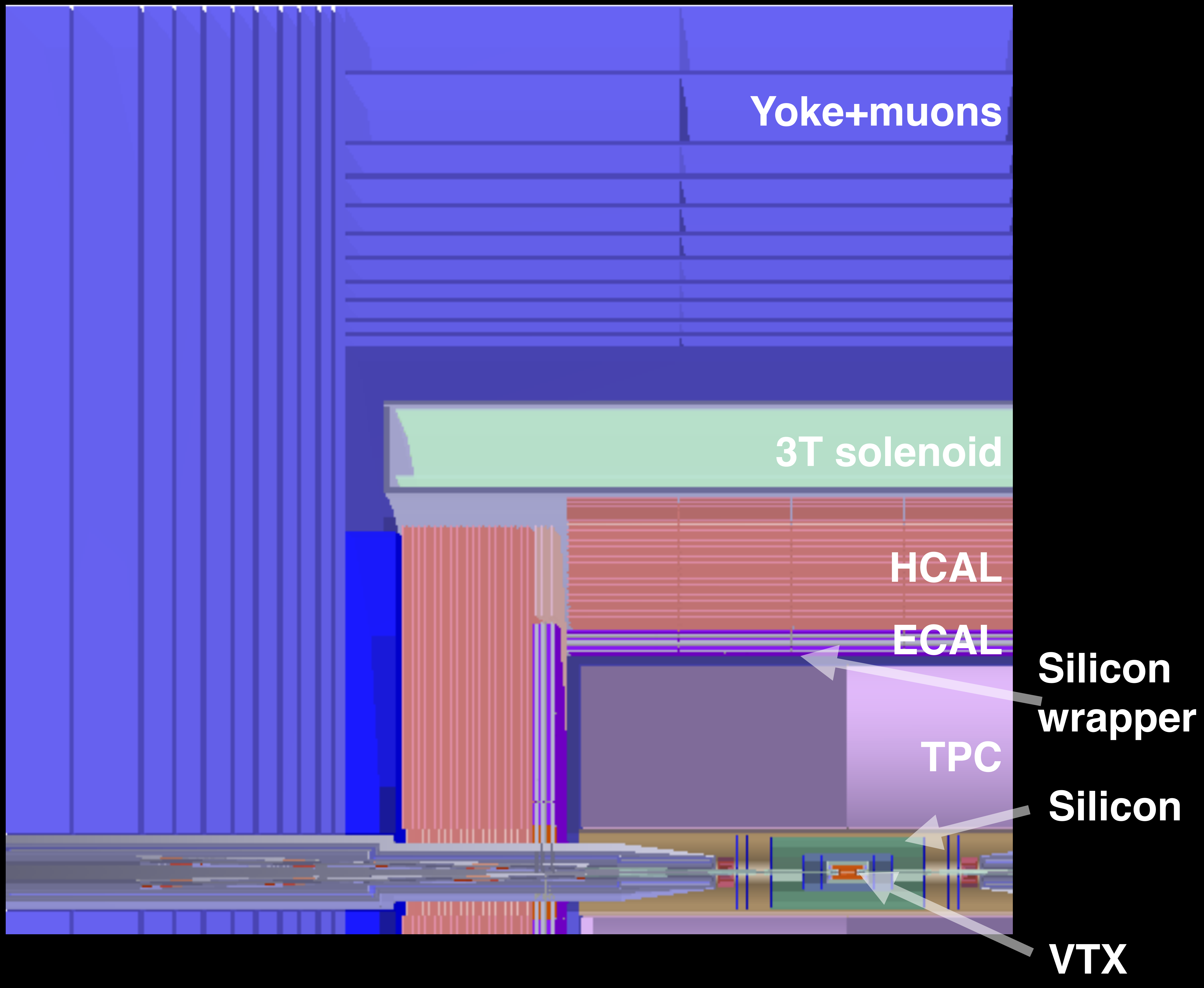
Major concerns

1. MDI region highly constrained
L* = 2.2 m
Compensating magnets

2. Low-material Inner Tracker design

3. TPC as tracker in high-luminosity Z-pole scenario

4. ECAL/HCAL granularity needs
Passive versus active cooling
Electromagnetic resolution



Magnetic Field: 3 Tesla

Machine-detector interface (MDI) in CEPC

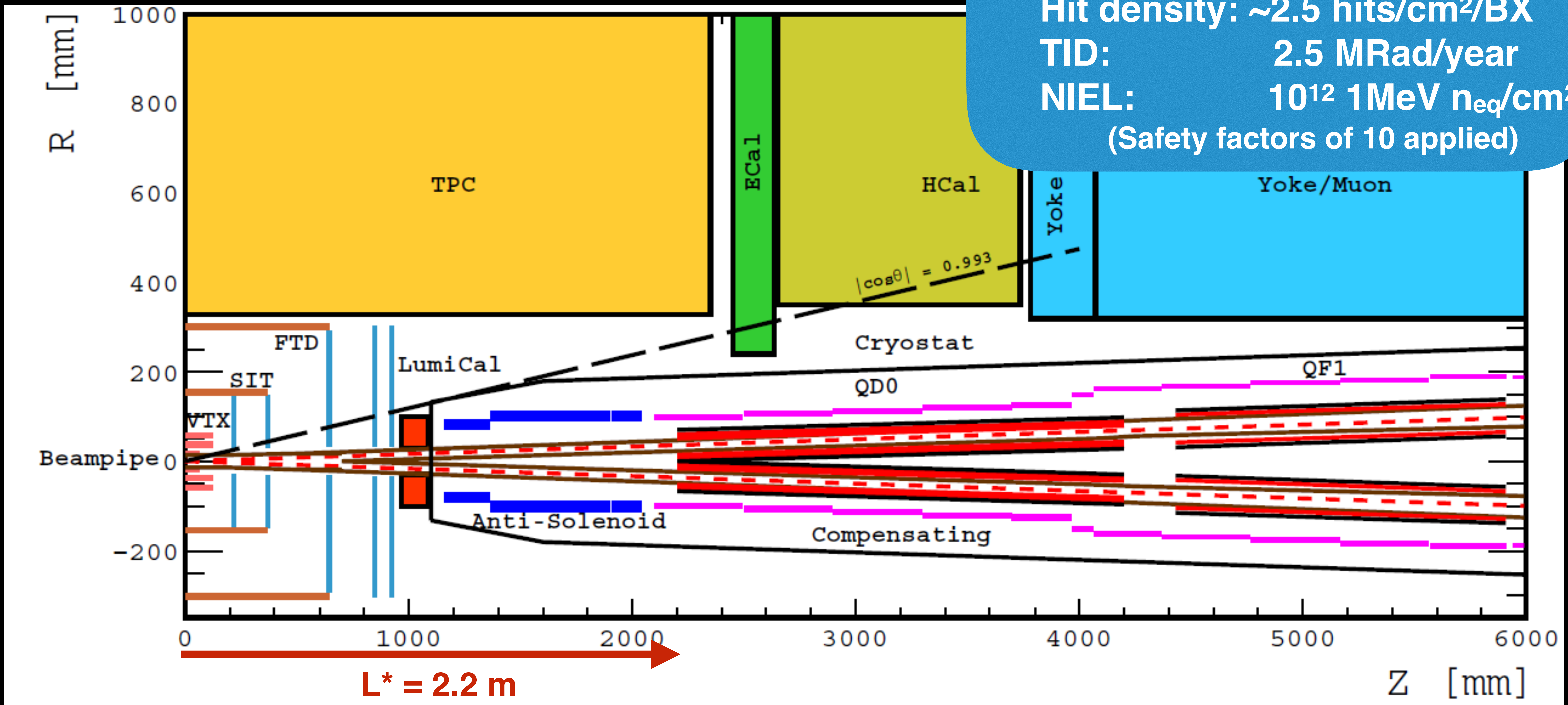
High luminosities ➡ Final focusing quadrupoles (QD0) need to be very close to IP

Detector acceptance:
> ± 150 mrad

Solenoid magnetic field limited:
2-3 Tesla

due to beam emittance blow up

Head-on collision crossing angle: **33 mrad**



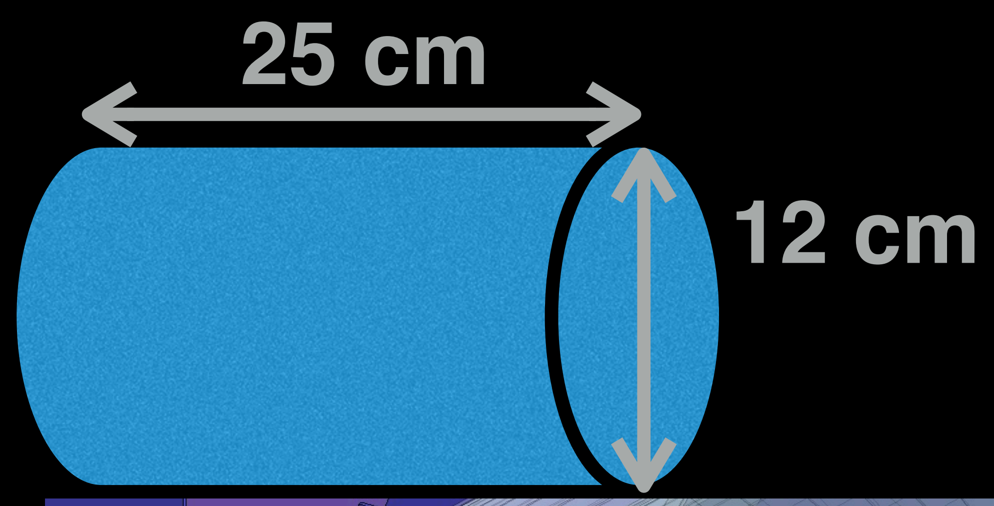
Rates at the inner layer (16 mm):

- Hit density: ~2.5 hits/cm²/BX
- TID: 2.5 MRad/year
- NIEL: 10^{12} 1MeV n_{eq}/cm^2

(Safety factors of 10 applied)

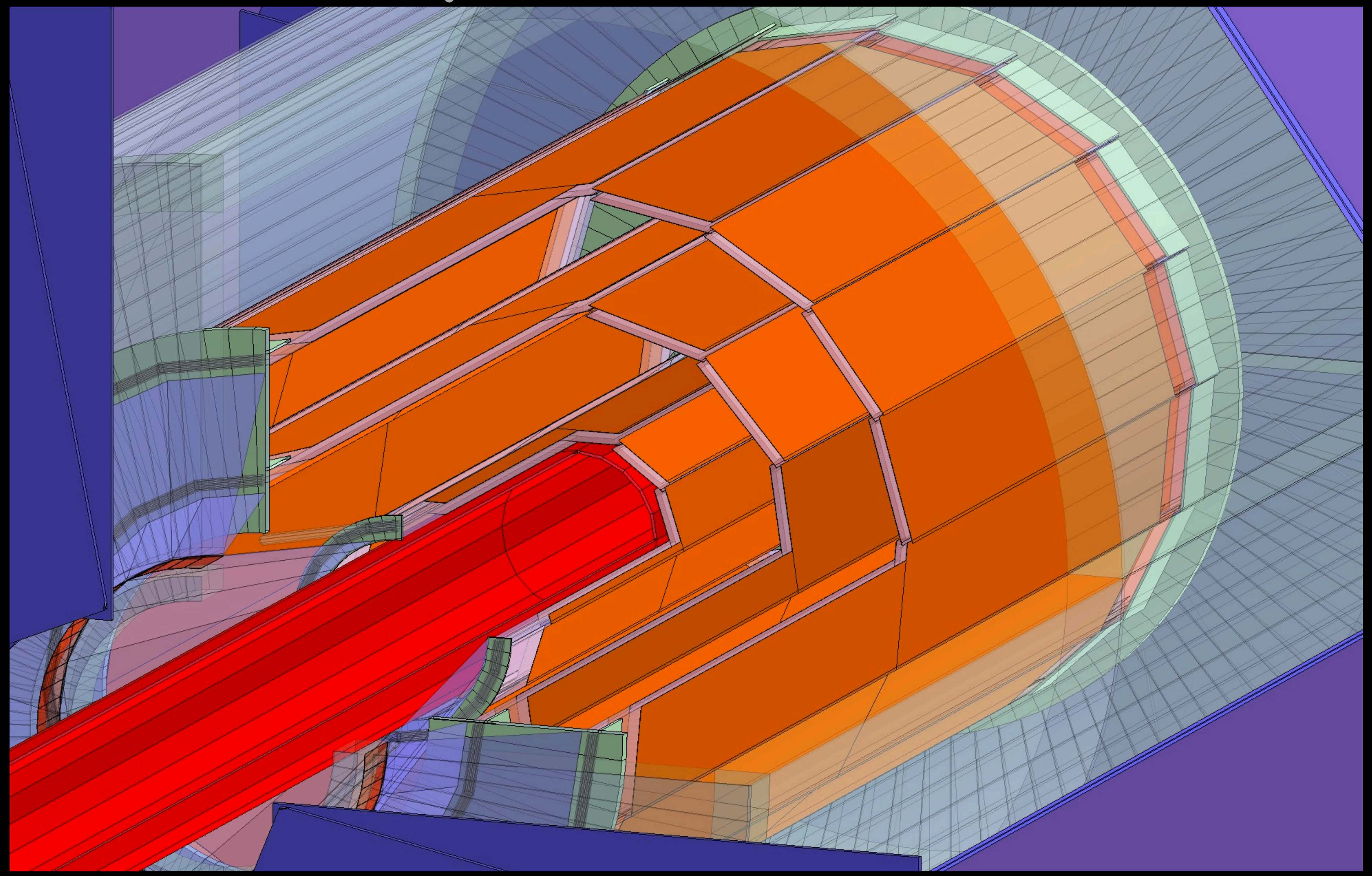
Cooling of beampipe needed → increases material budget near the interaction point (IP)

Baseline Pixel Detector



3 double ladders of silicon pixel sensors

✦ Innermost layer: σ_{SP} = 2.8 μm

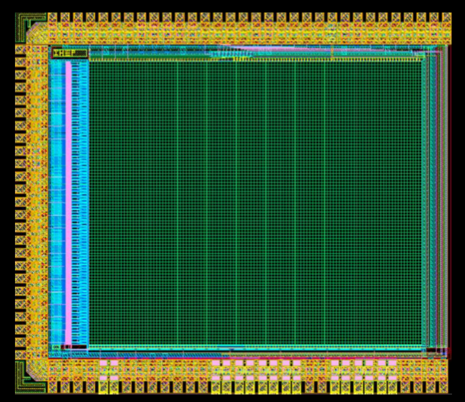


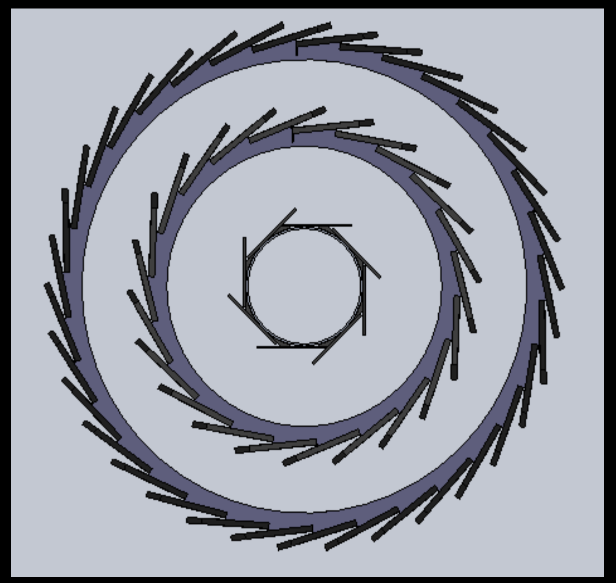
Low material budget
~ 0.15%X_0 per layer

CMOS {
Integrated sensor and readout electronics on the same silicon bulk with "standard" CMOS process:
- low material budget,
- low power consumption,
- low cost …

Pixel Detector prototype: (by 2023)

Towerjazz

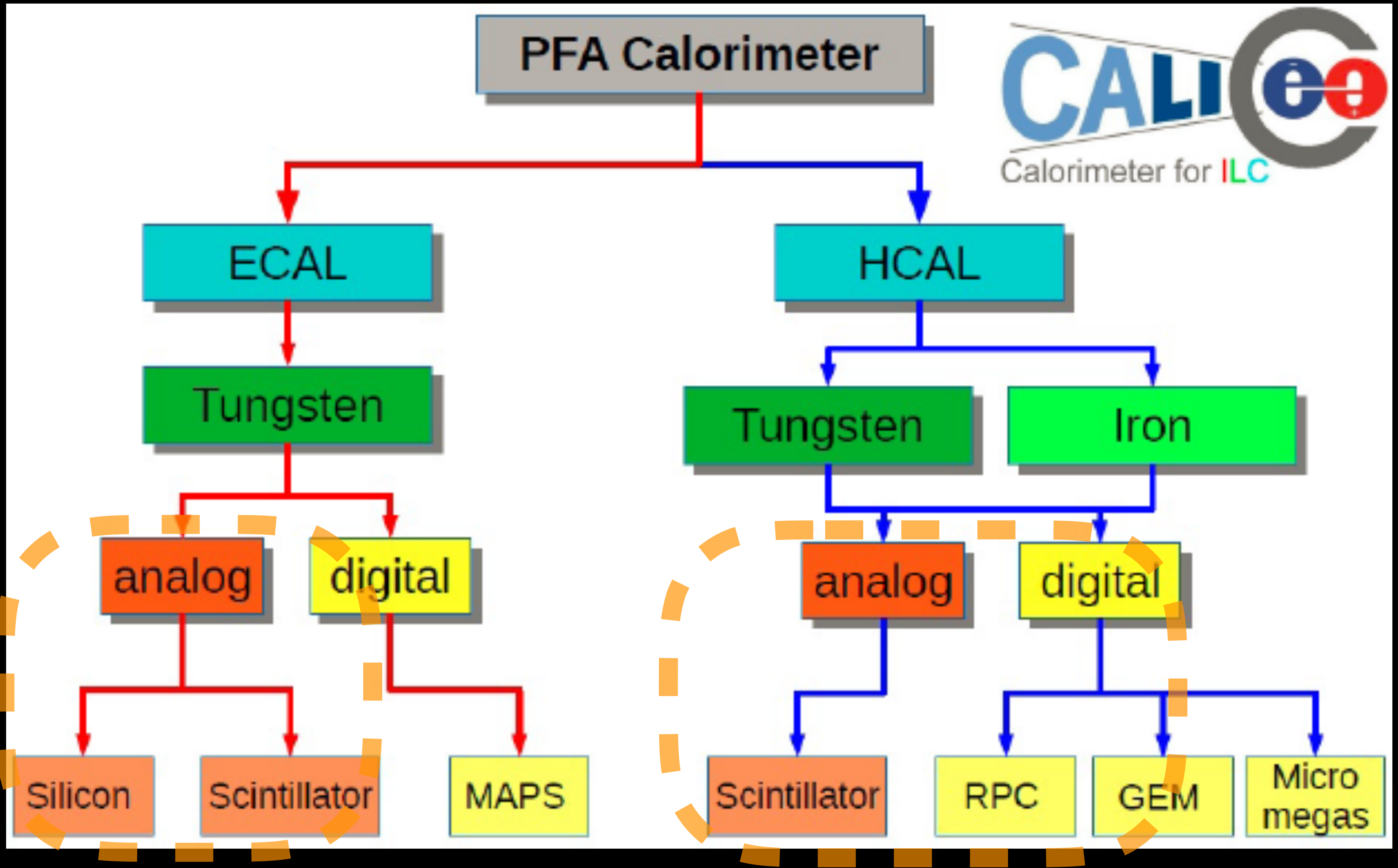




Collaborating with: {
- Barcelona, IFAE
- Liverpool
- Oxford
- RAL
- QMU
- UMass, US

- Developing full size CMOS sensor for use in real size prototype, with good radiation hardness

Calorimeter options

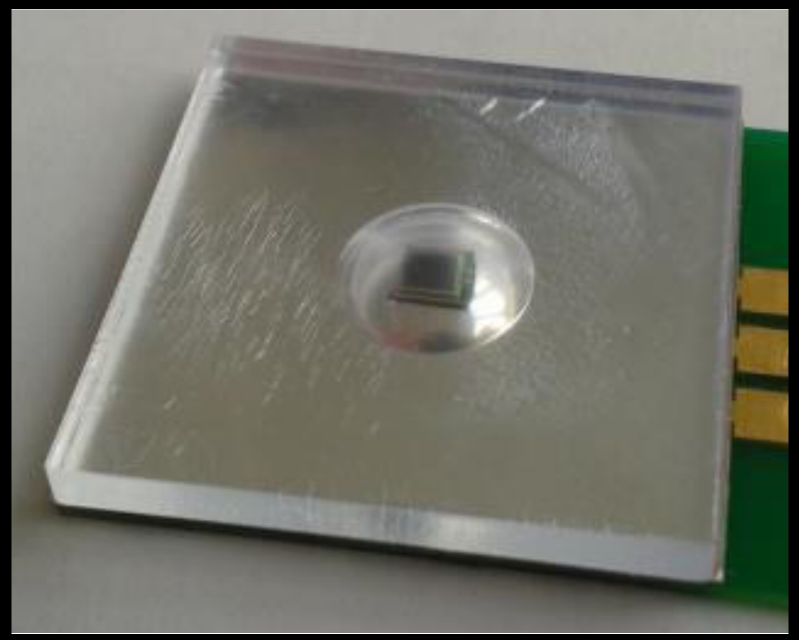


Chinese institutions have been focusing on Particle Flow calorimeters

Detector challenges:

- Compact design
- Calibration of channels
- Cooling
- Cost

Scintillator tiles/strips (here 3 × 3 cm^2) + SiPMs



International collaboration with several institutes (Italy, France, USA)

Prototypes of up to ~1 m^3 to be produced by 2023

Studies started on a Crystal (LYSO:Ce + PbWO) ECAL/ Dual readout calorimetry

CEPC activities

Conceptual Design Report

Download from:
http://cepc.ihep.ac.cn/

Preliminary CDR

March 2015

IHEP-CEPC-DR-2015-01
IHEP-EP-2015-01
IHEP-TH-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

480 authors

The CEPC-SPPC Stu

March 201

IHEP-CEPC-DR-2015-01
IHEP-AC-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

300 authors

The CEPC-SPPC Study Group

March 2015

Australia, Canada, China, France, Germany, Israel, Italy, Japan, Korea, Mexico, Morocco, Pakistan, Russia, Serbia, South Africa, Switzerland, UK, USA

Public release: November 2018

IHEP-CEPC-DR-2018-01
IHEP-AC-2018-01

CEPC

Conceptual Design Report

Volume I - Accelerator

arXiv: 1809.00285

The CEPC Study Group
August 2018

IHEP-CEPC-DR-2018-02
IHEP-EP-2018-01
IHEP-TH-2018-01

CEPC

Conceptual Design Report

Volume II - Physics & Detector

arXiv: 1811.10545

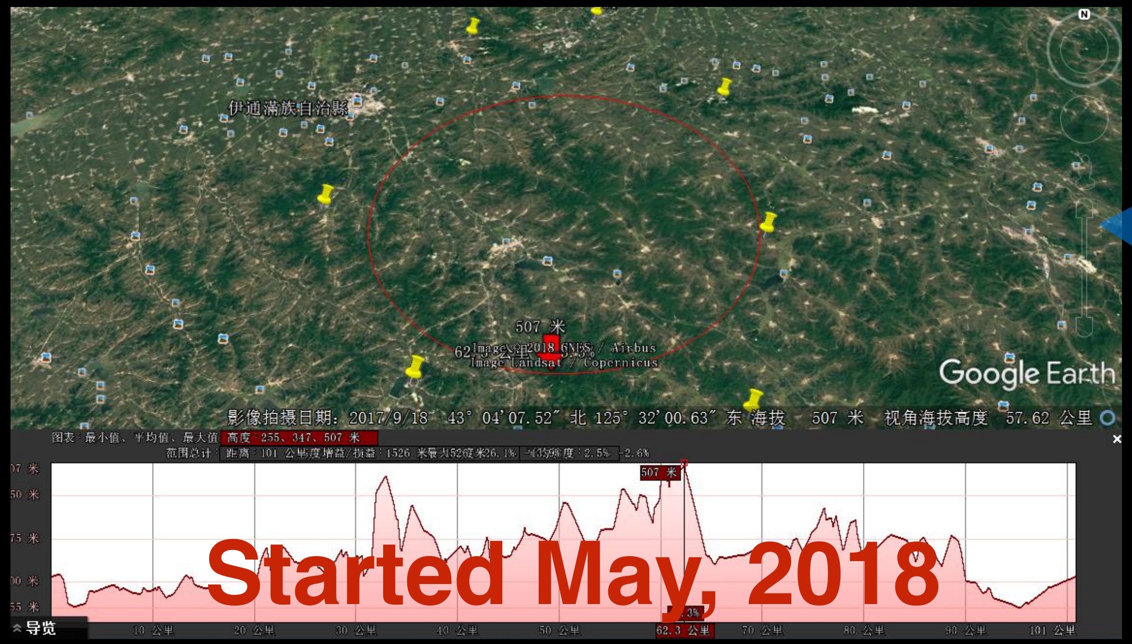
The CEPC Study Group
October 2018

1143 authors
222 institutes (140 foreign)
24 countries

Editorial Team: 43 people / 22 institutions/ 5 countries

Site selection

Chuangchun, Jilin
吉林长春



Huangling, Shanxi
陕西黄陵

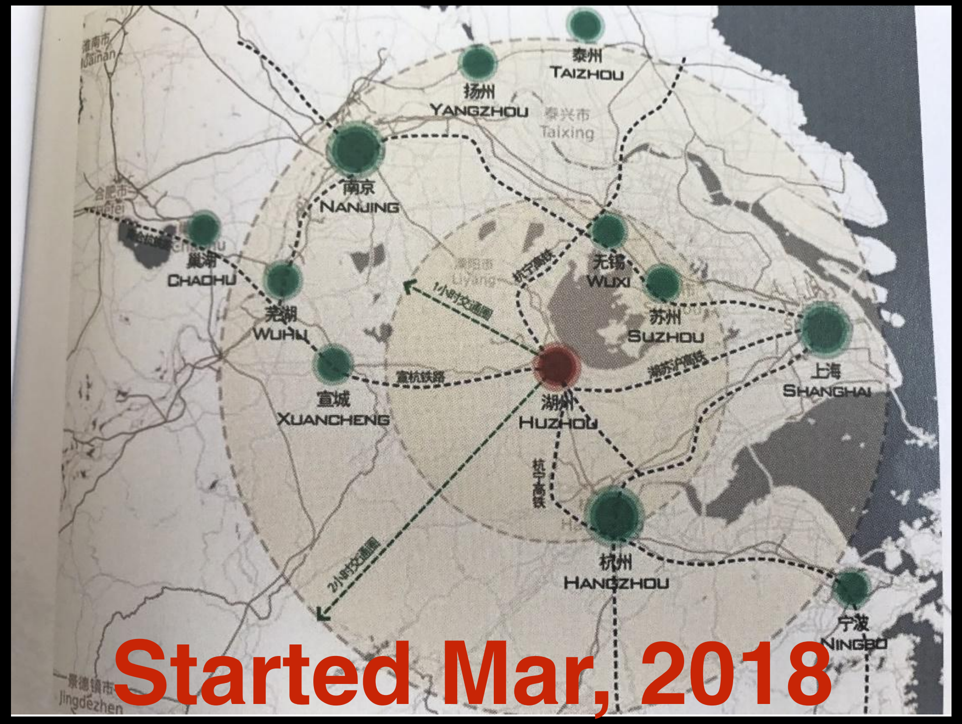
Considerations:
1. Available land
2. Geological conditions
3. Good social, environment, transportation and cultural conditions
4. Fit local development plan: mid-size city → + science city

Shenshan, Guangdong
深汕合作区

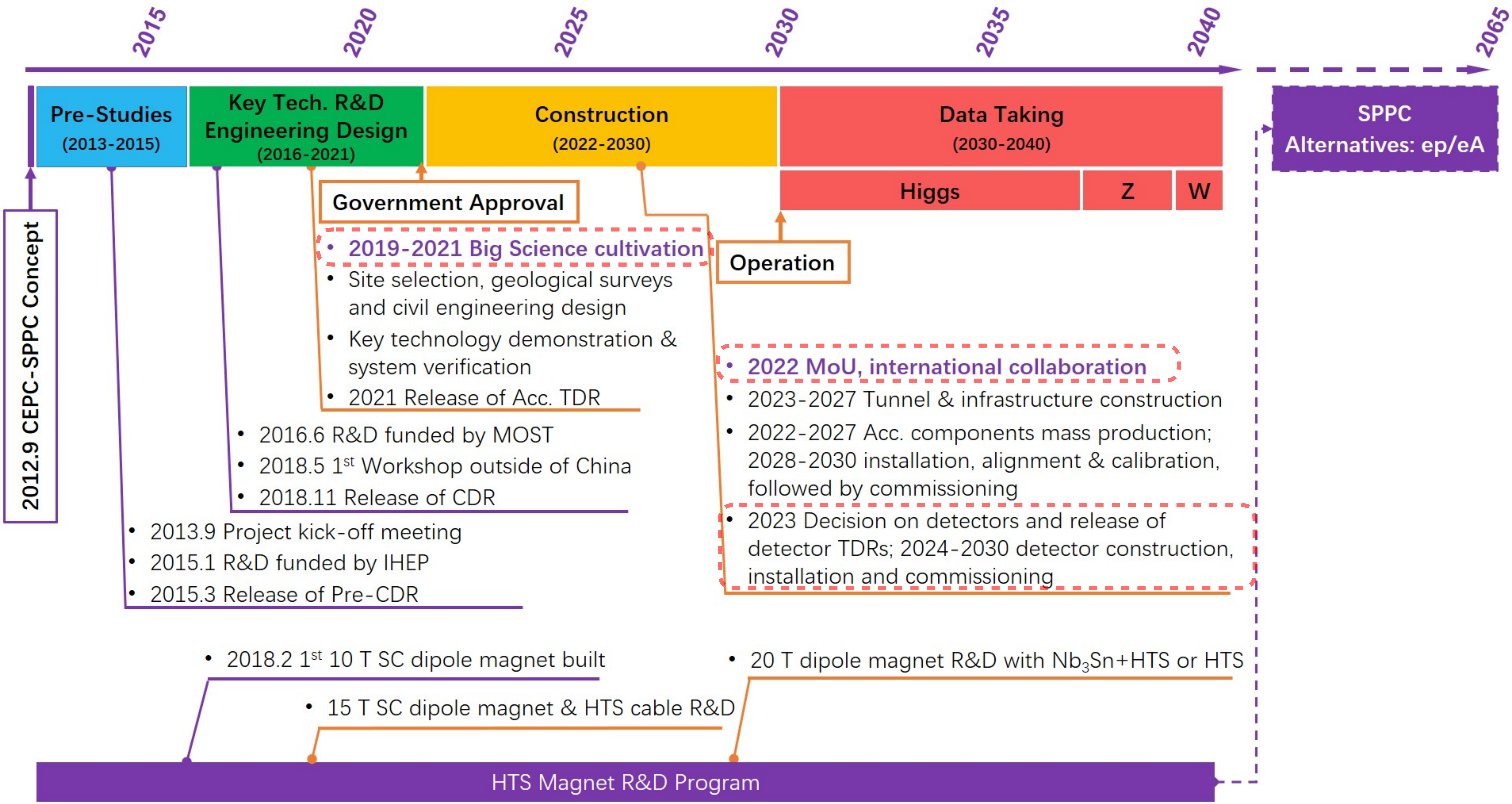
Qinhuangdao, Hebei
河北秦皇岛

Xiong an, Hebei
河北雄安

Huzhou, Zhejiang
浙江湖州



CEPC Project Timeline



CEPC International Workshops

Beijing

INTERNATIONAL WORKSHOP ON HIGH ENERGY CIRCULAR ELECTRON POSITRON COLLIDER

November 6-8, 2017
IHEP, Beijing

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

International Advisory Committee

Young-Kee Kim, U. Chicago
Barry Barish, Caltech
Hesheng Chen, IHEP

Local Organizing Committee

Xinchou Lou, IHEP (Chair)
Qinghong Cao, PKU
Joao Guimaraes Costa, IHEP

260 attendees
30% from foreign institutions

THE 2018 INTERNATIONAL WORKSHOP ON HIGH ENERGY CIRCULAR ELECTRON POSITRON COLLIDER

November 12-14, 2018
Institute of High Energy Physics, Beijing, China
https://indico.ihep.ac.cn/event/7389
Submissions of abstracts are encouraged.

International Advisory Committee

Local Organizing Committee

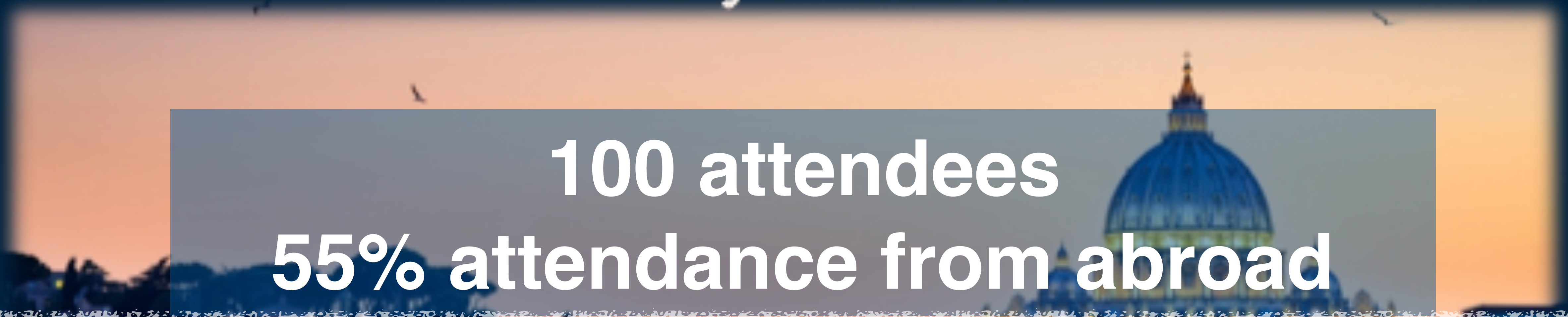
330 attendees
22% from foreign institutions

Europe

Workshop on the Circular Electron-Positron Collider

EU Edition

Roma, May 24-26 2018
University of Roma Tre



100 attendees
55% attendance from abroad

The International workshop on the Circular Electron Positron Collider
EU EDITION 2019

Oxford, April 15-17, 2019

150 attendees
67% attendance from abroad

This year workshops:

Chicago: September 16-18

US-centric workshop

https://indico.cern.ch/event/820586/

IHEP, Beijing: November 18-20

https://indico.ihep.ac.cn/event/9960/

360 attendees

Furture: 2020 European Edition

Marseille, France

Final remarks

CEPC CDR: http://cepc.ihep.ac.cn/

The 125 GeV Higgs makes e+e- circular machines an exciting possibility

CEPC accelerator studies well advanced

Two significantly different detector concepts being developed

High-magnetic field (3 Tesla)
PFA-oriented — with TPC or full-silicon tracker

Low-magnetic field (2 Tesla)
Drift chamber and dual readout calorimeter

Key accelerator and detector technologies R&D continues and are put to prototyping

2021: CEPC Accelerator TDR expected
2023: CEPC International Detectors TDRs
2030: Data-taking ideal starting date

Large synergies between needed R&D and already approved projects

CEPC aims to be an International project

At least one future high-energy e^+e^- collider should be built

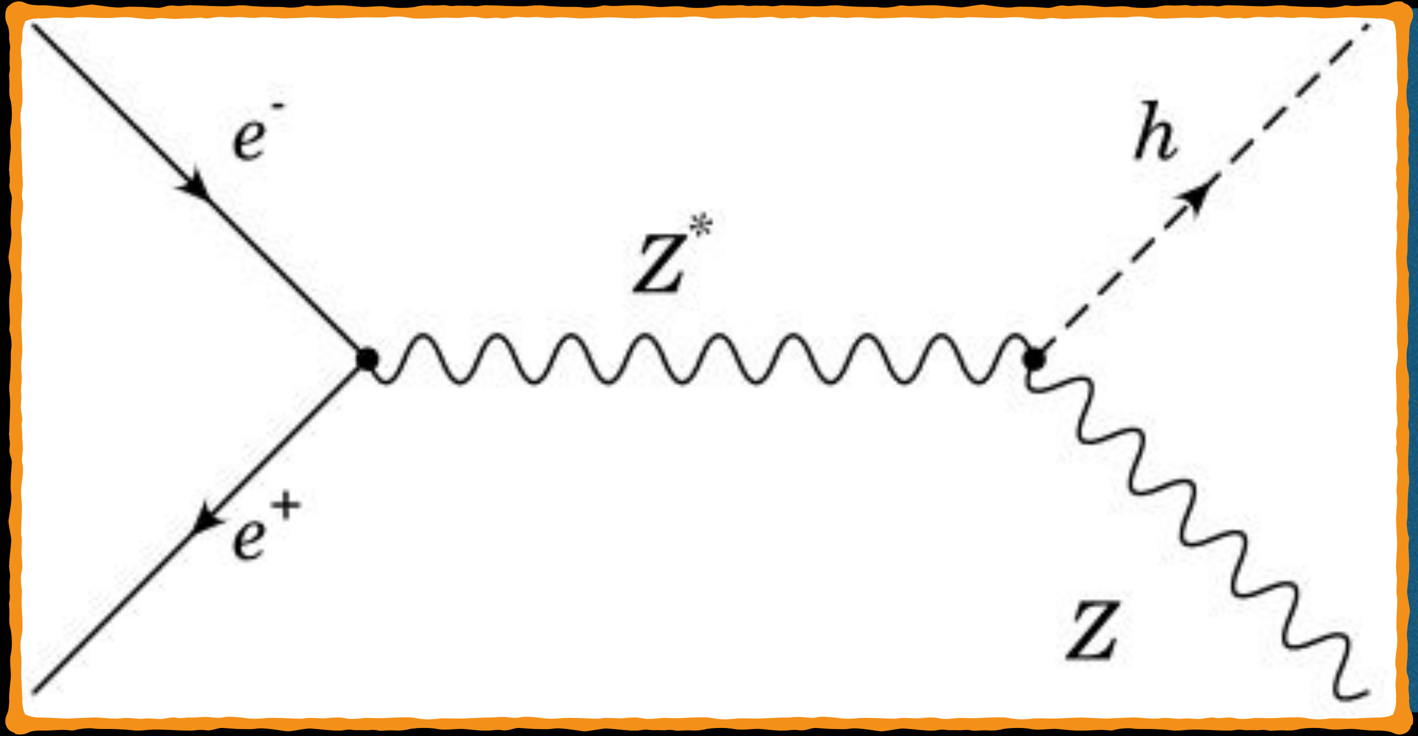
CEPC study group ready to participate in FCC project if it is built first

World-wide coordination effort is crucial to realize such project

Extras

Revival of e^+e^- Circular Colliders

Relatively low Higgs mass:
m_H = 125 GeV



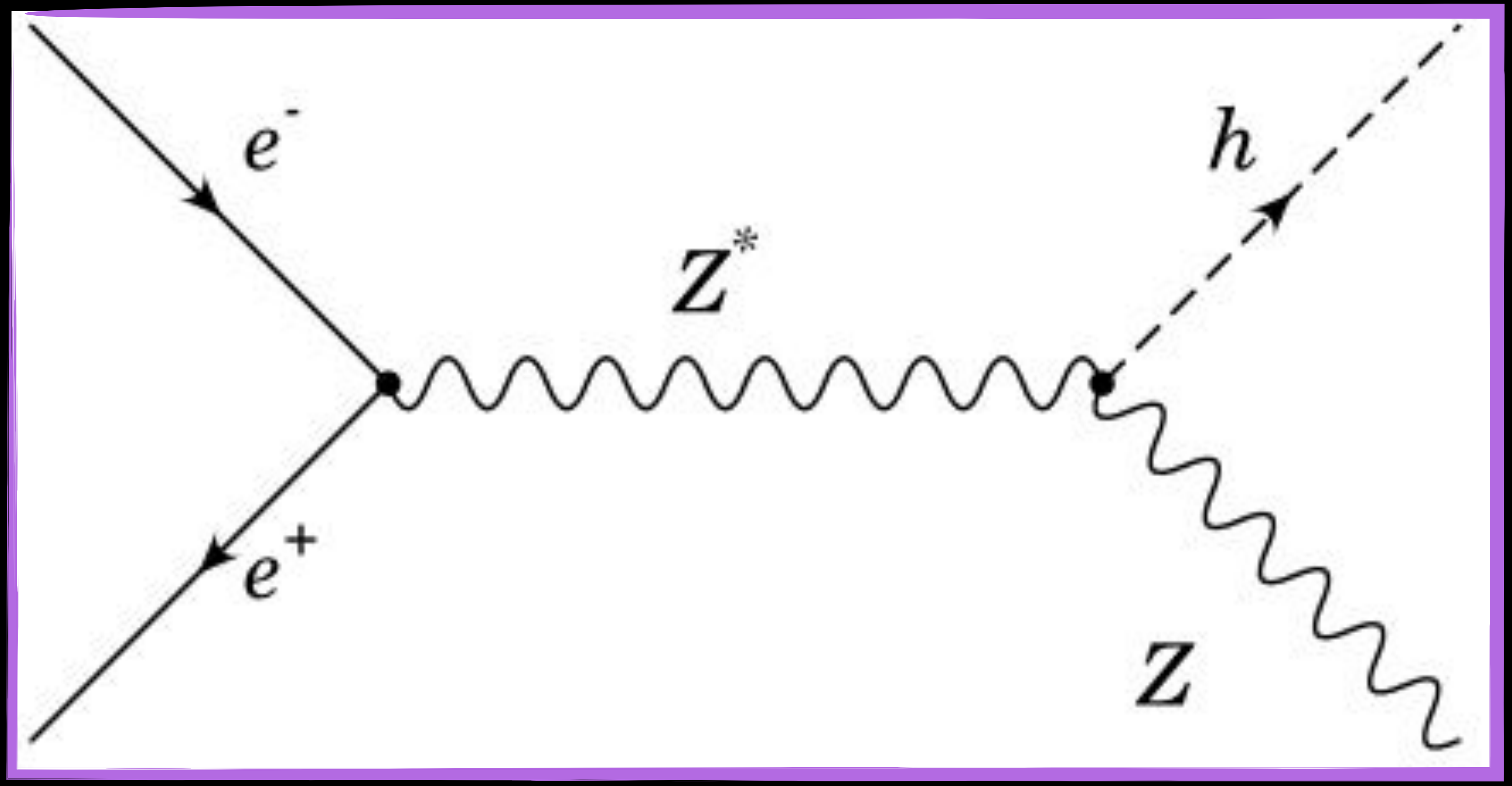
$\sqrt{s}$ = ~240 GeV

LEP stopped in 2000, limited by synchrotron energy loss, at $\sqrt{s}$ = 209 GeV

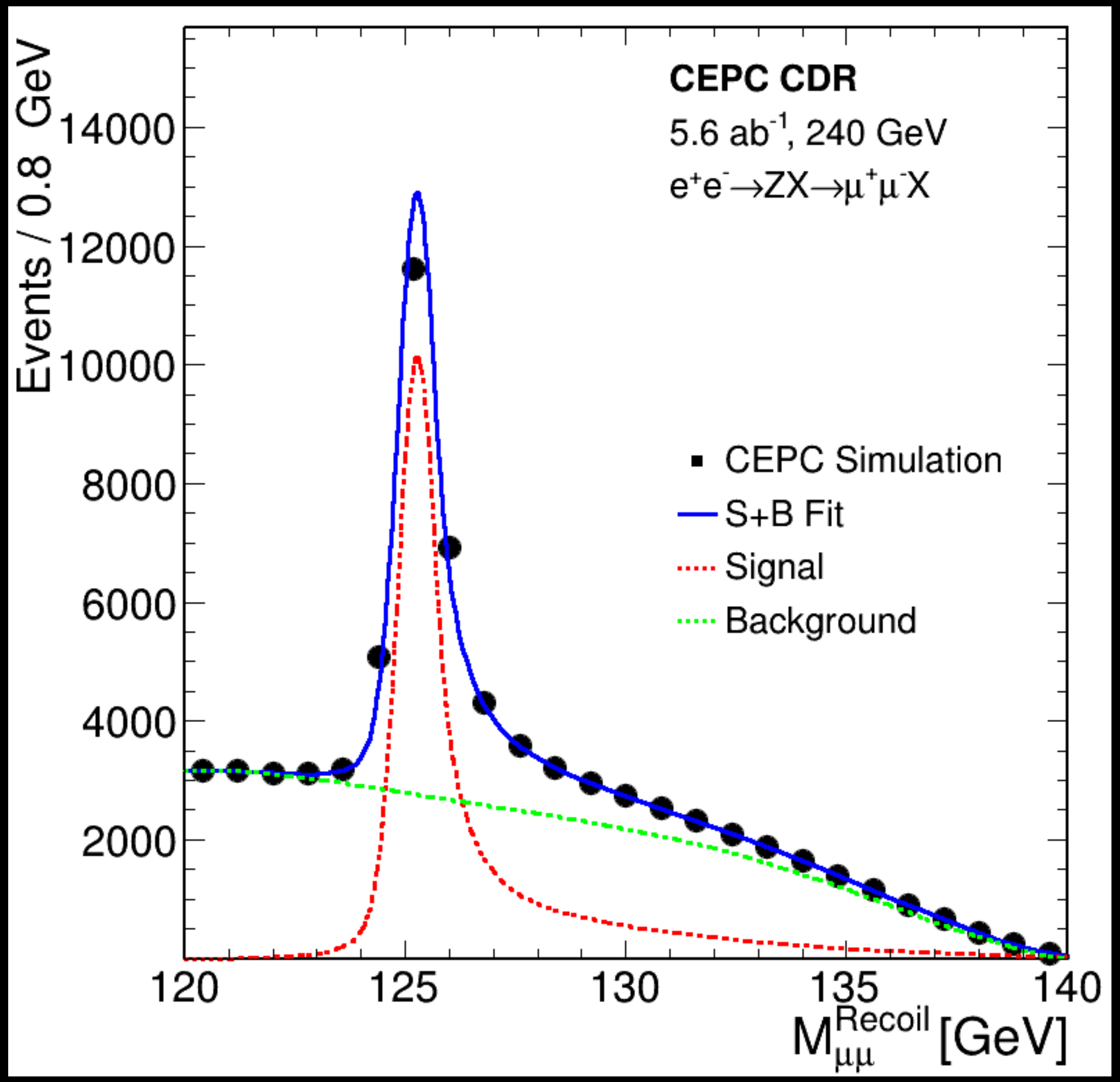
$$\frac{240\ \mathrm{GeV}}{209\ \mathrm{GeV}} \sim 1.14$$

Radius	50 km	70 km	100 km
Synchrotron energy loss relative to LEP $\frac{E_b^4}{r}$	~0.9	~0.65	~0.5

2012
Scientists in China proposed **Circular Electron-Positron Collider (CEPC)**
— precision Higgs studies



$$M^2_{recoil} = (\sqrt{s} - E_{ff})^2 - p^2_{ff}$$



Tag

$$\sigma(ee \to ZH)$$

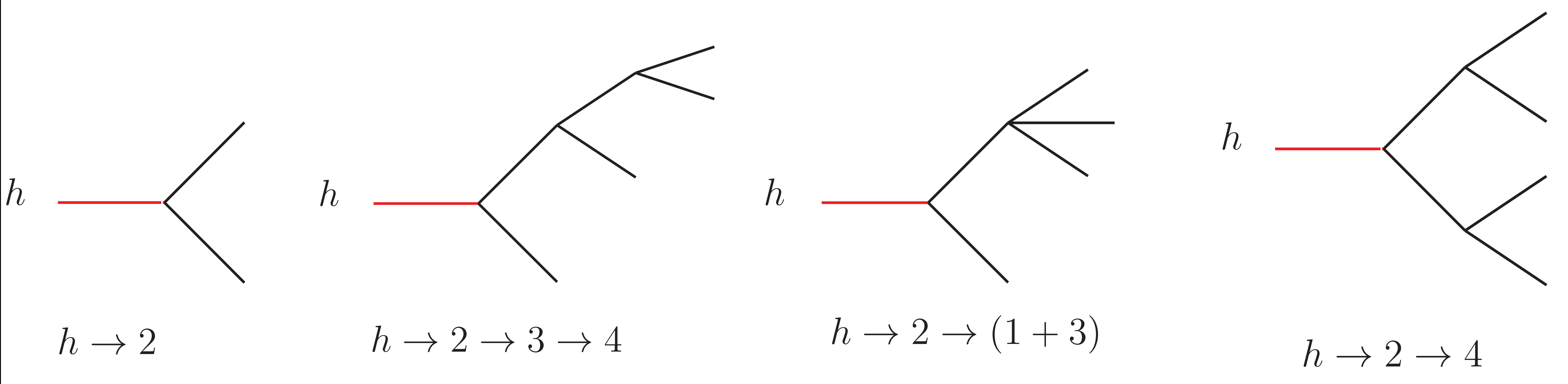
$$\sigma(ee \to ZH) \times \mathrm{BR}(H \to ZZ) \propto \frac{g^4}{\Gamma}$$

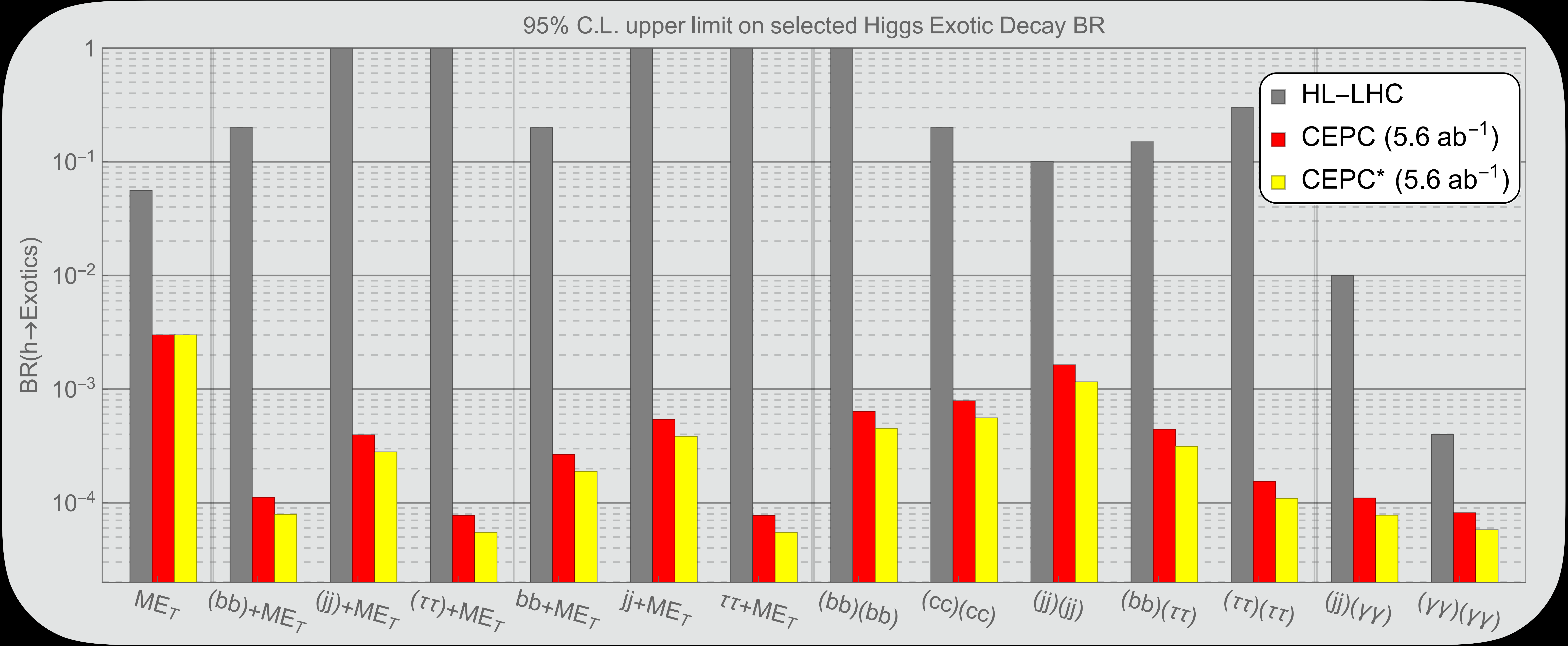
Extract Higgs total width → **Invisible BSM?**

BSM Physics through Exotic Higgs Decays

General search for BSM

e+e- collider better than HL-LHC for MET + hadronic final states





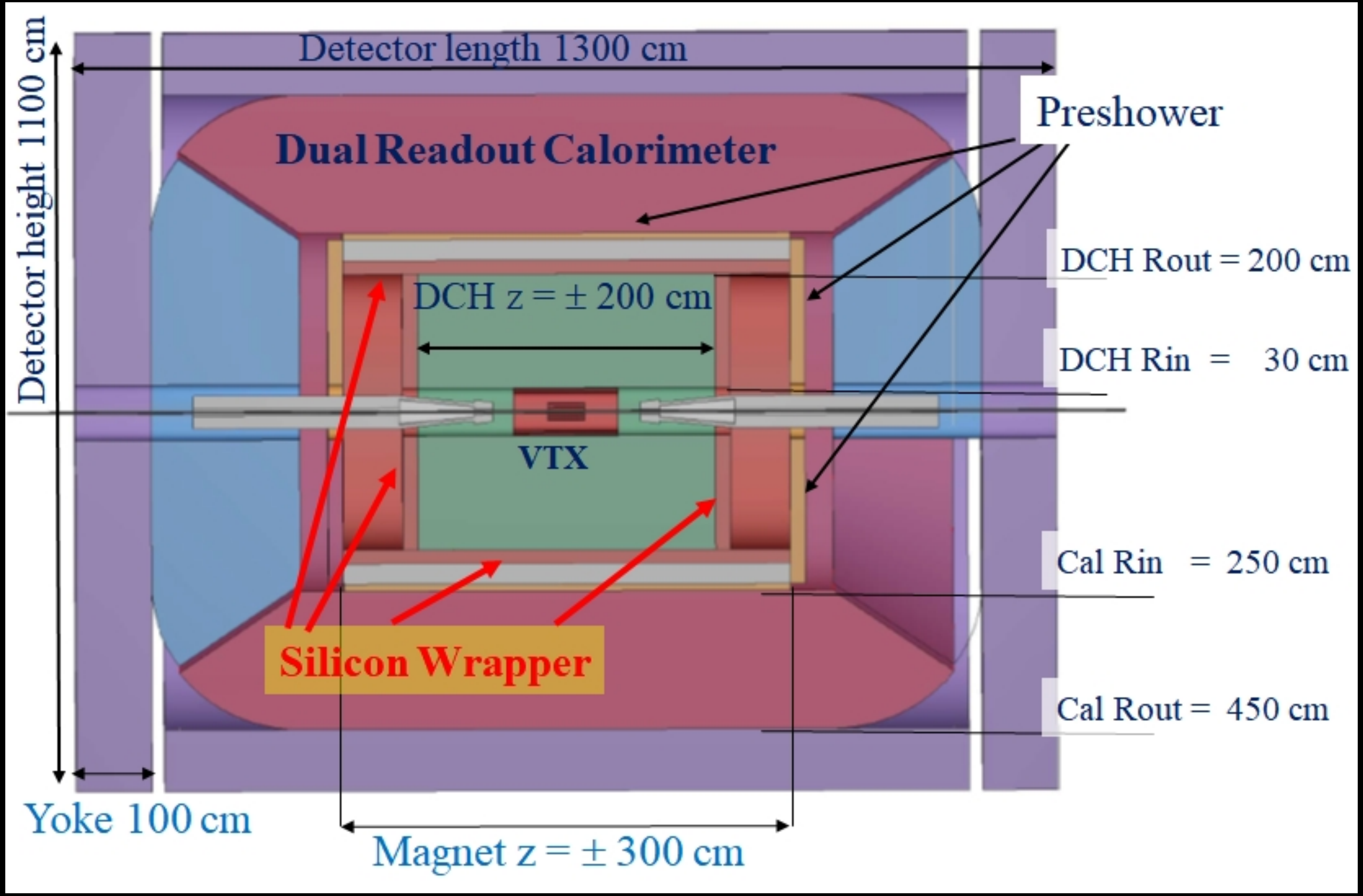
Z boson decays
Leptonic
+Hadronic

from CDR, based on Z. Liu, H. Zhang, LT Wang, 1612.09284

CEPC CDR: IDEA Conceptual Detector (CEPC + FCC-ee)

Inspired on work for 4th detector concept for ILC

Only concept with calorimeter outside the coil



Magnet: 2 Tesla, 2.1 m radius
Thin (~ 30 cm), low-mass (~0.8 X_0)

Vertex: Similar to CEPC default

* **Drift chamber:** 4 m long; Radius ~30-200 cm, ~ 1.6% X_0 , 112 layers

Preshower: ~1 X_0

* **Dual-readout calorimeter:** 2 m/8 λ_{int}

* **(yoke) muon chambers**

International Science City

Overall Scale : 3.3km² of construction area for short-term use & 6.7km² for future use.

We have gave a preliminary plan to CEPC International Science City , it involves

CEPC web site

http://cepc.ihep.ac.cn/

SCAN ME

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Circular Electron Positron Collider

HOME | ABOUT CEPC | ORGANIZATION | RESULTS | WHY SCIENCE | JOIN US | pre-CDR Author

Future High Energy Circular Colliders

The Standard Model (SM) of particle physics can describe the strong, weak and electromagnetic interactions under the framework of quantum gauge field theory. The theoretical predictions of SM are in excellent agreement with the past experimental measurements. Especially the 2013 Nobel Prize in physics was awarded to F. Englert and P. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

After the discovery of the Higgs particle, it is natural to measure its properties as precise as possible, including mass, spin, CP nature, couplings, and etc., at the current running Large Hadron Collider (LHC) and future electron positron colliders, e.g. the International Linear Collider (ILC). The low Higgs mass of ~125 GeV makes possible a Circular Electron Positron Collider (CEPC) as a Higgs Factory, which has the advantage of higher luminosity to cost ratio and the potential to be upgraded to a proton-proton collider to reach unprecedented high energy and discover New Physics.

The CEPC input for the European Strategy

Accelerator

Accelerator Addendum

Physics and Detector

Physics and Detector Addendum

Recent Events

The 2019 International Workshop on the High Energy Circular Electron Positron Collider, IHEP, Nov. 18-20th, 2019

The 2018-2019 yearly Meeting of MOST project "High Energy Circular Electron Positron Collider Key Technology Research and Validation" was held in IHEP

More...

CEPC Conceptual Design Report

CEPC CDR Volume I (Accelerator)

CEPC CDR Volume II (Physics and Detector)

More...

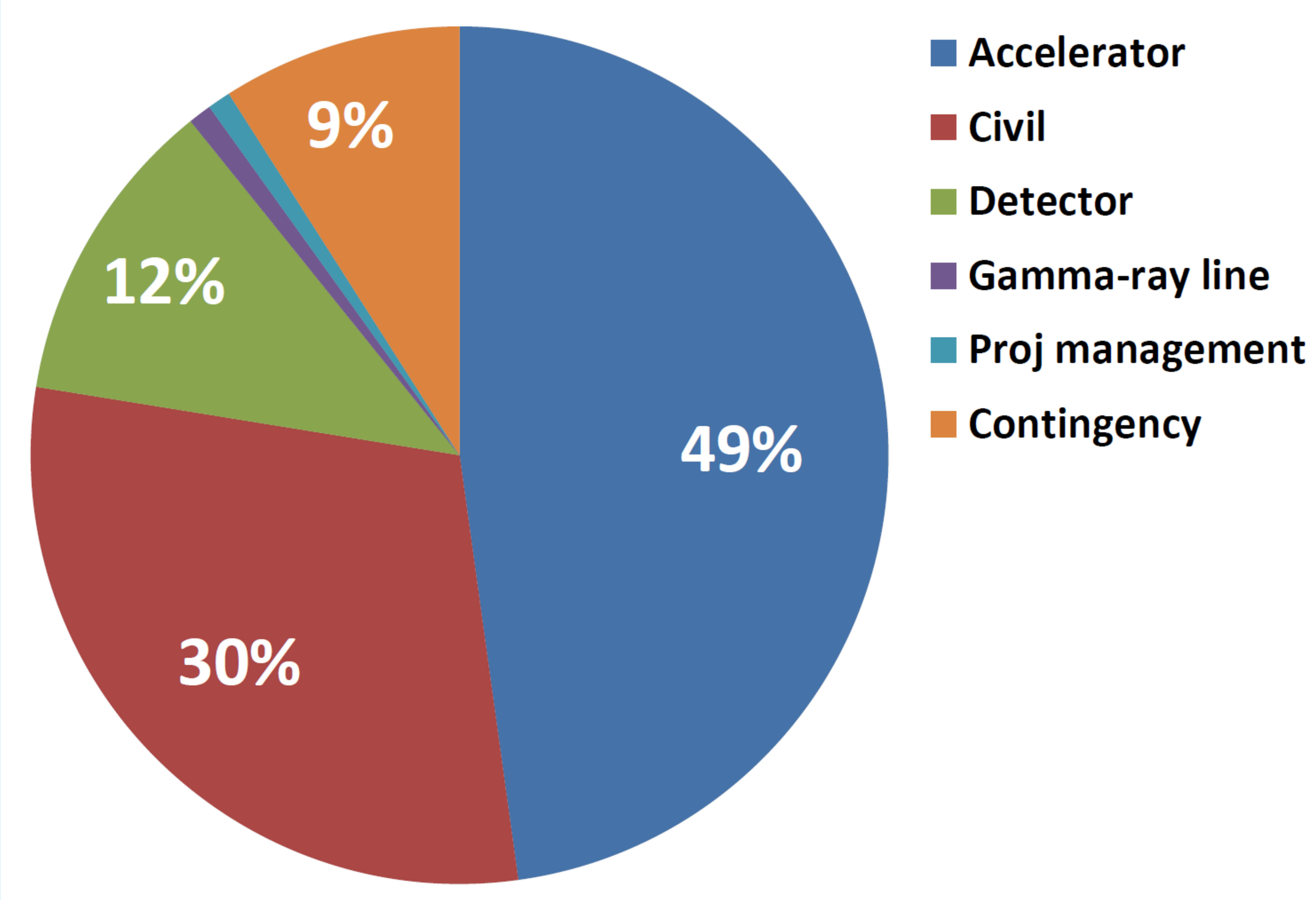
CDR Download

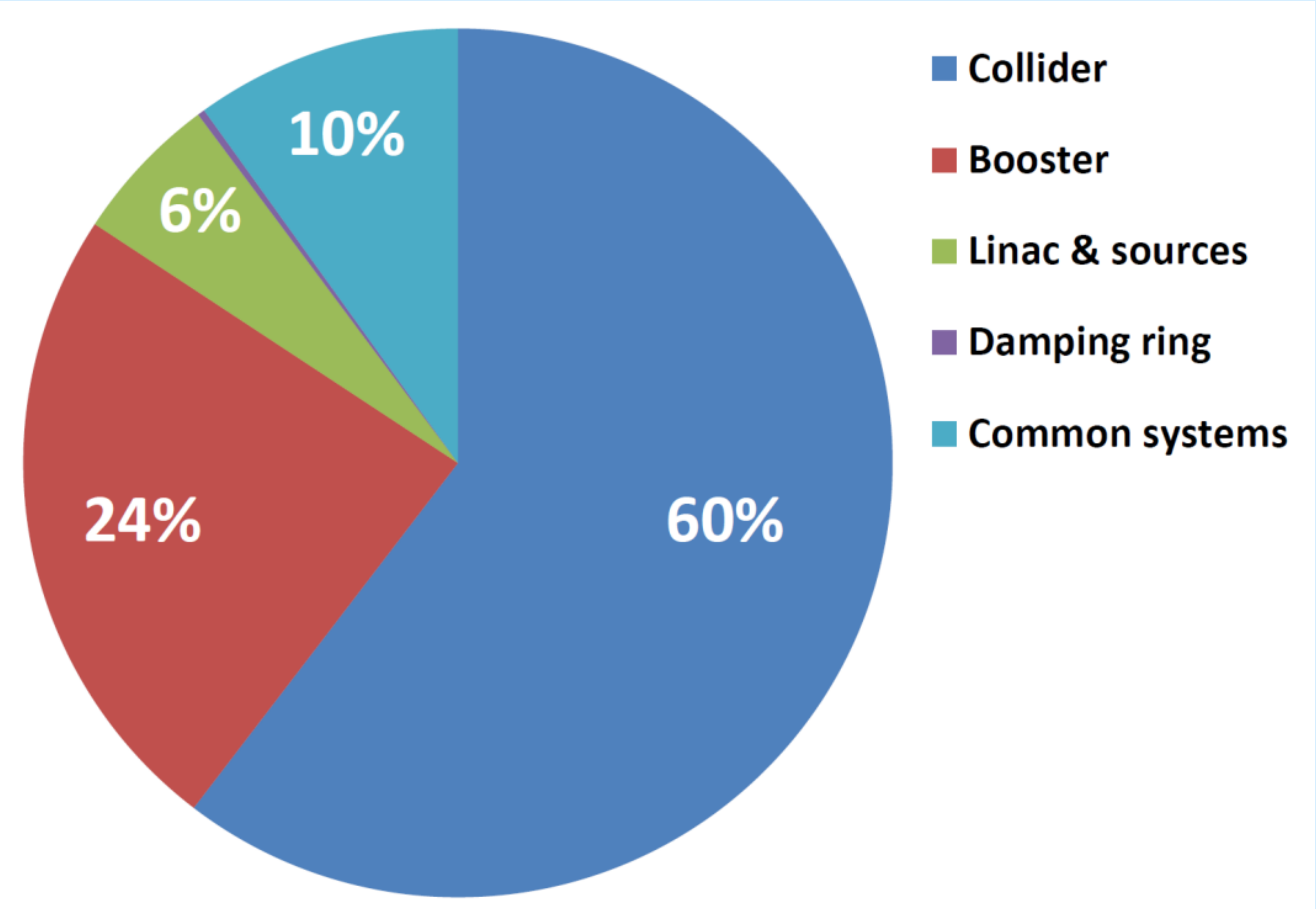
Panel Discussion on Fundamental Physics

Cost of project

Total cost of CEPC: $US 5 Billion

General evaluation of the relative cost of the project provided in the accelerator CDR





Cost of detectors not evaluated in detail and not part of the Conceptual Design Report

Careful costing estimates will be done moving forward towards the TDR

Higgs Width measurement

$$\sigma(W\ fusion) = \sigma(ee \rightarrow \nu\nu WW^* \rightarrow \nu\nu H)$$

$$\sigma(W\ fusion) \times Br(H \rightarrow WW^*) \propto \frac{g^4}{\Gamma}$$

$$\sigma(ee \rightarrow ZH)$$

$$\sigma(ee \rightarrow ZH) \times \mathrm{BR}(H \rightarrow ZZ) \propto \frac{g^4}{\Gamma}$$

Most Immediate Path for the CEPC Realization

March, 2018: Chinese Government New Plan

”actively initiating major-international science project…”

http://www.gov.cn/zhengce/content/2018-03/28/content_5278056.htm

focuses on

“frontier science, large-fundamental science, global impact, international collaboration”

Plan Goals

By 2020: 3-5 projects will be chosen into “preparatory stage”, among which 1-2 projects will be selected later

By 2035: 6-10 projects will be cultivated

The Ministry of Science and Technology (MOST) will select and develop the projects

committees formed and writing the guidelines

Pre-application submitted by CEPC team about a month ago

Key task (4): Actively participate in large scientific projects initiated by other countries

Possible scenarios of future colliders