

Introduction to the CEPC

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Slides borrowed from Xinchou

Outline

The CEPC-SppC Study Group – a brief reminder

Progress and Status

- **Preliminary CDR**

 - Volume 1: Physics, detector, simulation and physics reach

 - Volume 2: Accelerators: CEPC, SPPC

 - Volume 3: Civil engineering and site consideration

 - preCDR: Technical review & Completion

- **Communication, outreach and education**

- **Training and professional development**

Pre. R&D and funding requests

CDR

Project evaluation

Summary

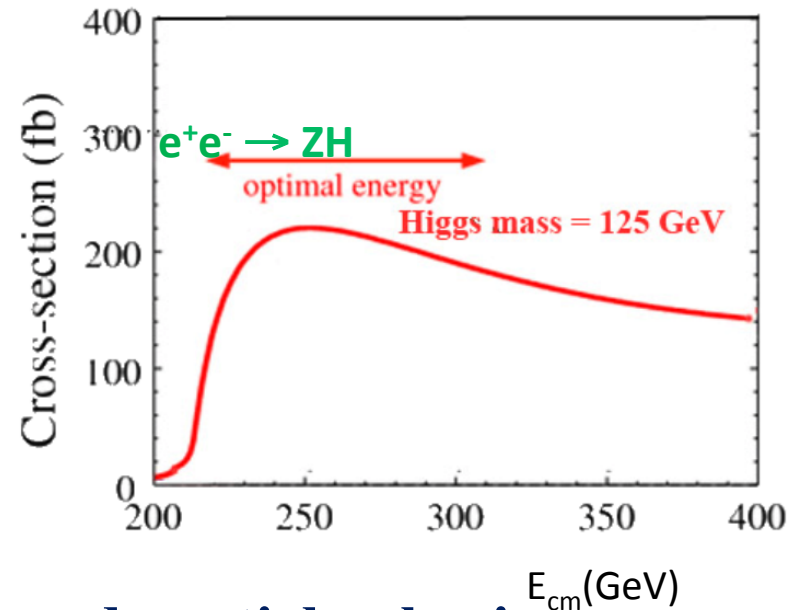
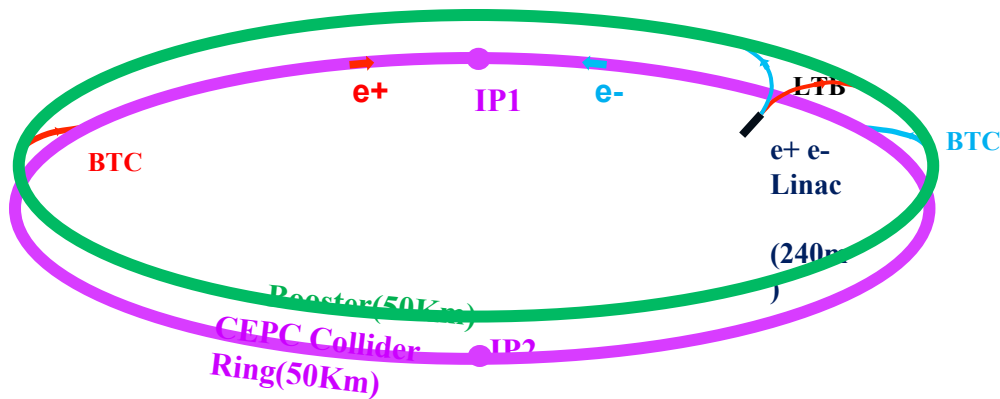
Reminder:

CEPC-SppC Study Group

CEPC-SppC

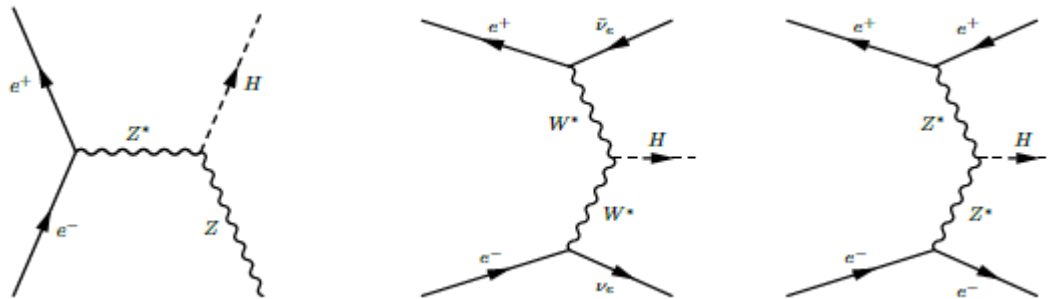
Phase 1: e^+e^- Higgs (Z) factory two detectors, 1M ZH events in 10yrs
 $E_{cm} \approx 240\text{GeV}$, luminosity $\sim 2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, can also run at the Z-pole
Precision measurement of the Higgs boson (and the W/Z boson)

Phase 2: a discovery machine; pp collision with $E_{cm} \approx 50\text{-}100 \text{ TeV}$; ep, HI options
Discovery machine for BSM

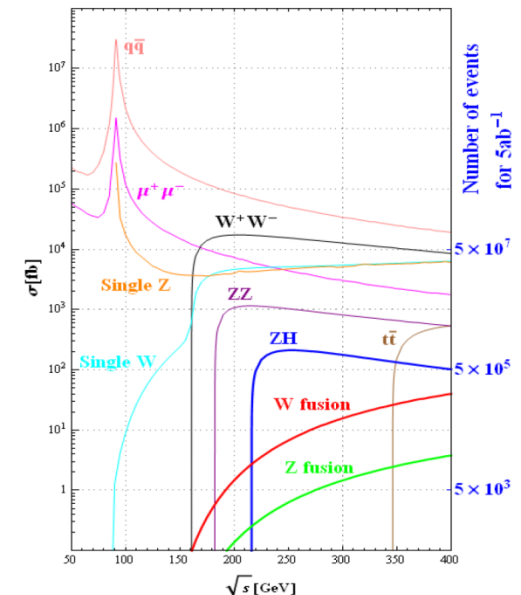


avored post BEPCII accelerator based particle physics program in China

- Precise measurements of the Higgs properties as a Higgs Factory (similar to ILC@250 GeV)
 - Mass, J^{PC} , couplings, etc. → reach (sub-) percentage accuracy

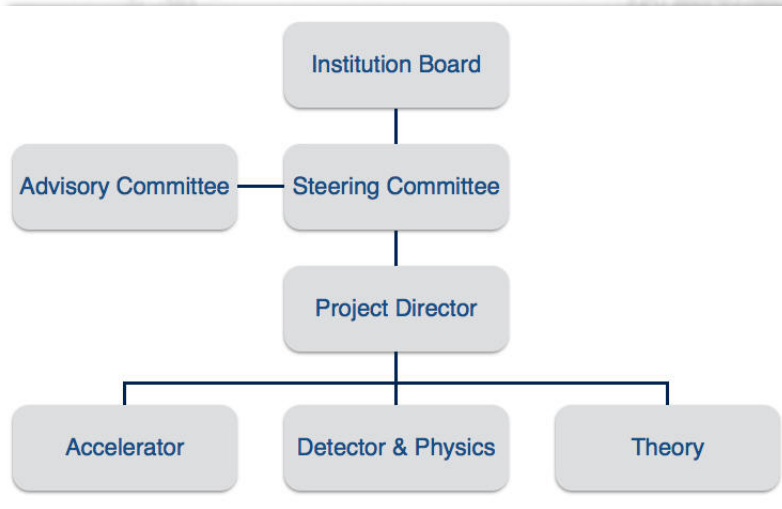


Process	Cross section (fb)	Nevents in 5 ab^{-1}
Higgs boson production		
$e^+e^- \rightarrow ZH$	209	1×10^6
$e^+e^- \rightarrow \nu\bar{\nu}H$	6.9	3.5×10^4
$e^+e^- \rightarrow e^+e^-H$	0.6	3.0×10^3



- Precise measurements of Electroweak Symmetry-Breaking parameters at Z-pole and WW threshold
 - $m_Z, m_W, \Gamma_Z, \sin^2 \theta_W^{\text{eff}}, \alpha_S$, etc. + searches for rare decays

CEPC Organization



- Institution Board and Steering Committee formed in the kick-off meeting in September 2013; conveners appointed for the three

Office of Engineering and Support at IHEP

- The CEPC management was reorganized in May 2015, after the preCDR, to move forward with the CDR process;
- Int'l advisory committee formed; first meeting in September.

Preliminary Conceptual Design Report (preCDR)

Volume 1: Physics, detector, simulation and physics reach

Volume 2: Accelerators: CEPC, SPPC

Volume 3: Civil engineering and site consideration

- **Getting preliminary answers to critical questions**
- **Identify critical physics, technologies & tools for R&D**
- **Develop estimates for R&D costs**
- **Formal review by int'l committees & completion**

Document ready for 13th 5 Year Plan (2015)

Status and Progress

ACCELERATORS

Preliminary

CEPC-SppC Accelerators

- **e^+e^- collider**

Higgs produced above the $e^+e^- \rightarrow ZH$ threshold

Collide e^+e^- at $E_{\text{cm}} \sim 240\text{GeV}$, $\sigma \sim 200\text{ fb}$

Need $250\text{ fb}^{-1}/\text{y/IP} \rightarrow 1\text{M Higgs particles in 10 years}$

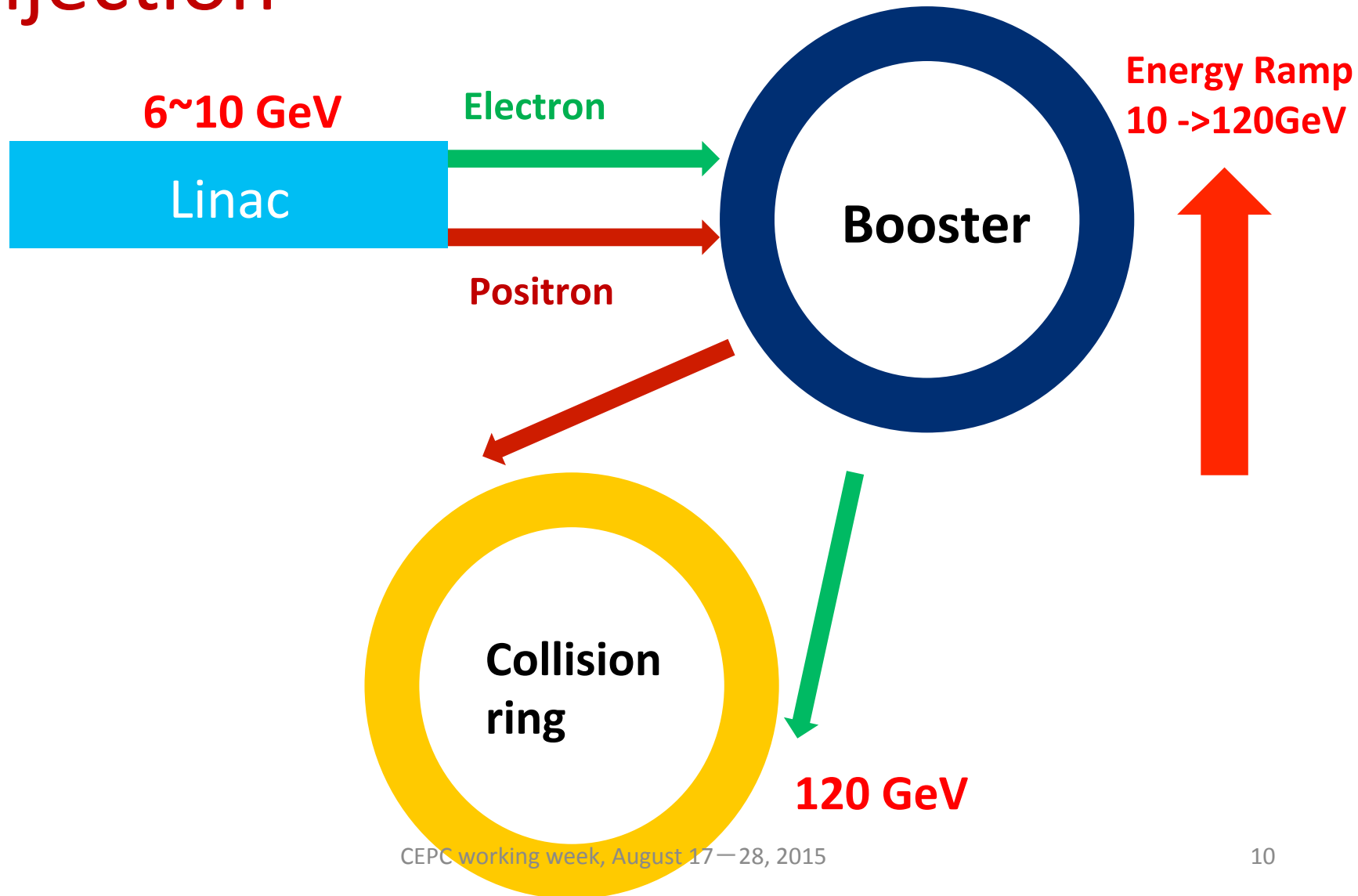
Goal

- **pp collider**

$E_{\text{cm}} = 70\text{ TeV}$ or higher

CEPC Accelerator Baseline Design

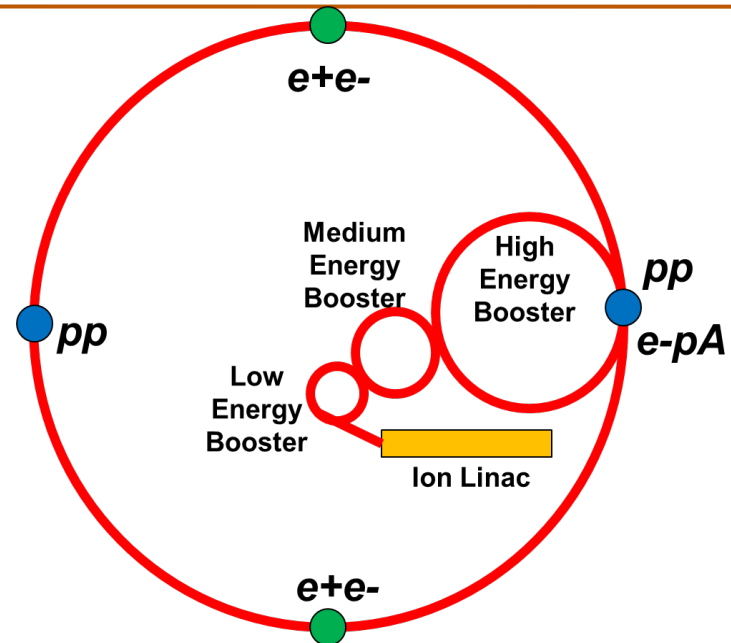
Injection



CEPC main parameters

Parameter			Design Goal		
Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	Circumference [C]	m	54752
Number of IP [N_{IP}]		2	SR loss/turn [U_0]	GeV	3.11
Bunch number/beam [n_B]		50 (48)	Bunch population [Ne]		3.79E+11
SR power/beam [P]	MW	51.7	Beam current [I]	mA	16.6
Bending radius [ρ]	m	6094	momentum compaction factor [α_p]		3.36E-05
Revolution period [T_0]	s	1.83E-04	Revolution frequency [f_0]	Hz	5475.46
emittance (x/y)	nm	6.12/0.018	$\beta_{IP}(x/y)$	mm	800/1.2 (3)
Transverse size (x/y)	μm	69.97/0.15	$\xi_{x,y}/IP$		0.118/0.083
Bunch length SR [$\sigma_{s,SR}$]	mm	2.14	Bunch length total [$\sigma_{s,tot}$]	mm	2.65
Lifetime due to Beamstrahlung	min	47	lifetime due to radiative Bhabha scattering [τ_L]	min	51
RF voltage [V_{rf}]	GV	6.87	RF frequency [f_{rf}]	MHz	650
Harmonic number [h]		118800	Synchrotron oscillation tune [ν_s]		0.18
Energy acceptance RF [h]	%	5.99	Damping partition number [J_E]		2
Energy spread SR [$\sigma_{\delta,SR}$]	%	0.132	Energy spread BS [$\sigma_{\delta,BS}$]	%	0.096
Energy spread total [$\sigma_{\delta,tot}$]	%	0.163	n_y		0.23
Transverse damping time [n_x]	turns	78	Longitudinal damping time [n_e]	turns	39
Hourglass factor	Fh	0.68	Luminosity /IP[L]	$\text{cm}^{-2}\text{s}^{-1}$	2.04E+34

SppC Accelerator Design considerations



- Proton-proton collider luminosity

$$L_0 = \frac{N_p^2 N_b f_{rep} \gamma}{4\pi \epsilon_n \beta_{IP}} F \quad \left(F = \sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\sigma_{x,IP}} \right)^2} \right)$$

$$\xi = \frac{N_p r_p}{4\pi \epsilon_n} \leq 0.004$$

- Main constraint: **high-field superconducting dipole magnets**

– 50 km: $B_{\max} = 12 \text{ T}, E = 50 \text{ TeV}$

– 50 km: $B_{\max} = 20 \text{ T}, E = 70 \text{ TeV}$

– 70 km: $B_{\max} = 20 \text{ T}, E = 90 \text{ TeV}$

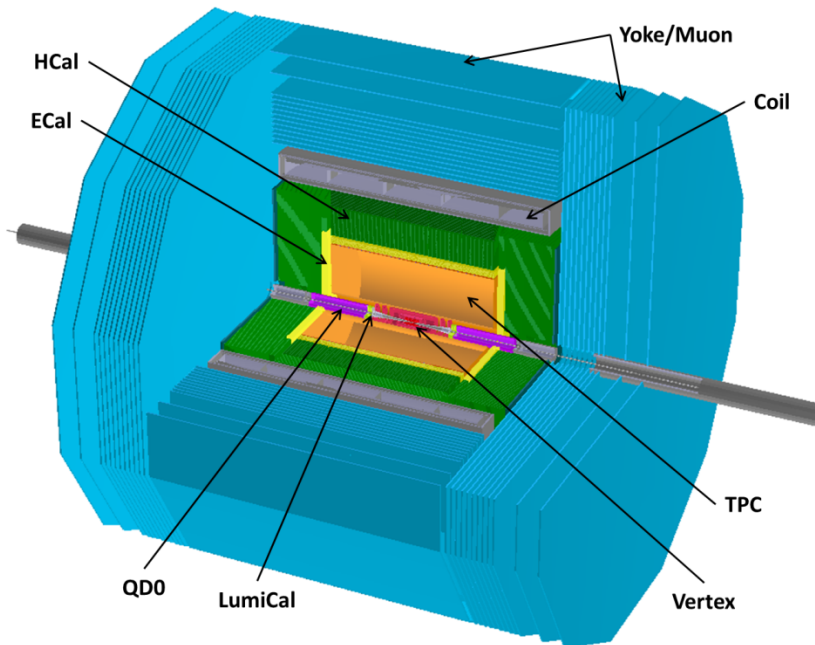
$$B_{\min} = \frac{2\pi(B\rho)}{C_0}$$

Status and Progress

DETECTOR

- aim at coming up with a credible prel. CDR
- identify “R&D” for CDR & TDR

CEPC Detector considerations



ILD-like detector with additional considerations (*incomplete list*):

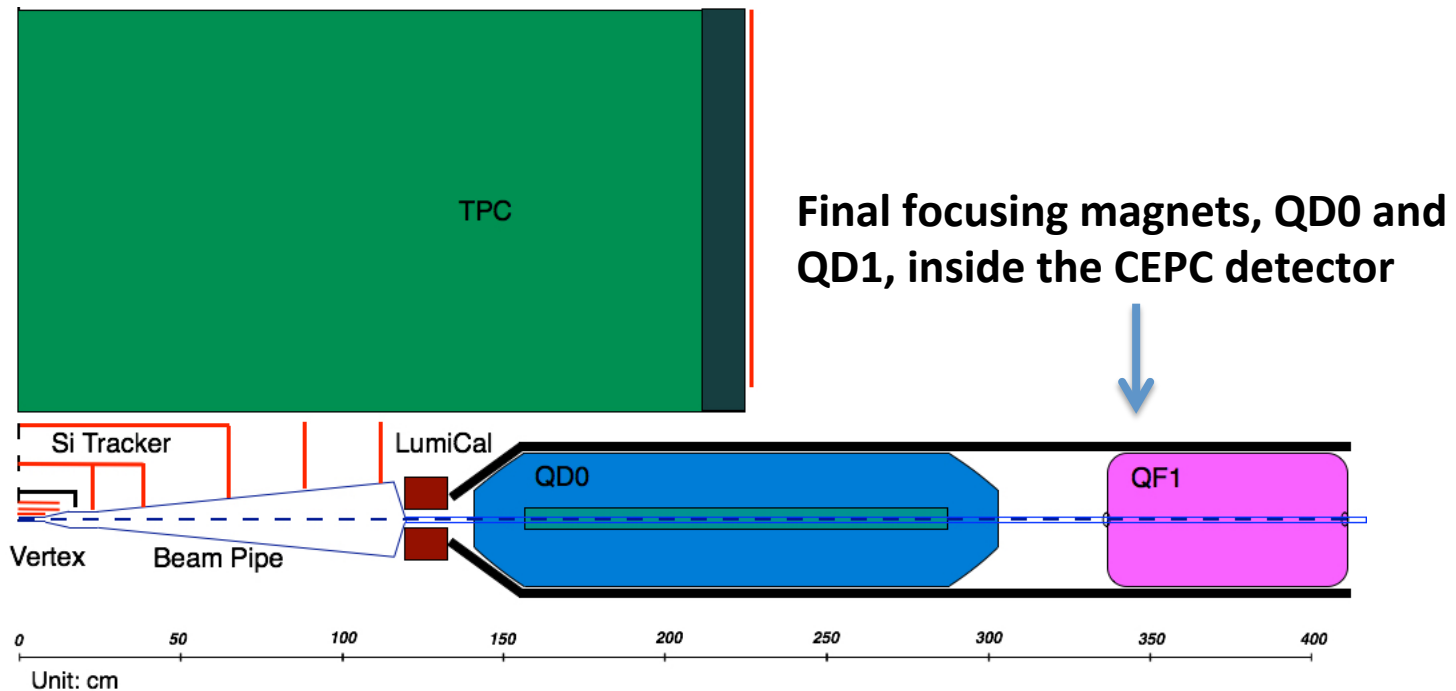
- Shorter L^* (1.5/2.5m) → constraints on space for the Si/TPC tracker
- No power-pulsing → lower granularity of vertex detector and calorimeter
- Limited CM (up to 250 GeV) → calorimeters of reduced size
- Lower radiation background → vertex detector closer to IP
- ...

• Similar performance requirements to ILC detectors

- Momentum: $\sigma_{1/p} < 5 \times 10^{-5} \text{ GeV}^{-1}$ ← recoiled Higgs mass
- Impact parameter: $\sigma_{r\phi} = 5 \oplus 10 / (p \cdot \sin^{\frac{3}{2}} \theta) \mu\text{m}$ ← flavor tagging, BR
- Jet energy: $\frac{\sigma_E}{E} \approx 3 - 4\%$ ← W/Z di-jet mass separation

Sub-detector groups consider design options, identify challenges, plan R&D

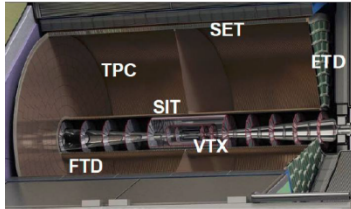
CEPC Detector considerations



- Focal length (L^*), the distance between QD0 and the interaction point, shortened to 1.5 m to allow realization of high luminosity without large chromaticity corrections
- Comprehensive understanding and optimization of both detector and collider performance are needed in future studies

CEPC Detector considerations

Vertex Detector

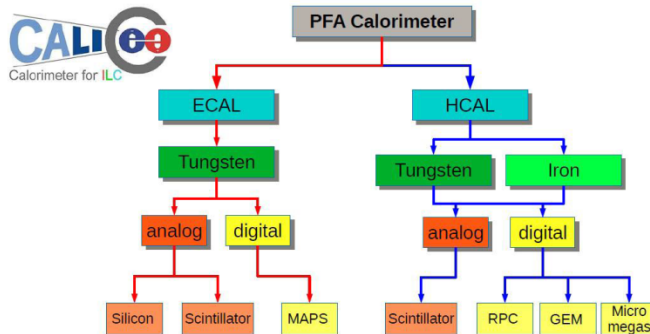


Detector	Geometric dimensions	Material budget [X/X ₀]
SIT	Layer 1: r = 153 mm, z = 371.3 mm	0.65%
	Layer 2: r = 300 mm, z = 664.9 mm	0.65%
SET	Layer 3: r = 1811 mm, z = 2350 mm	0.65%
FTD	Disk 1: r _{in} = 39 mm, r _{out} = 164 mm, z = 220 mm	0.50%
	Disk 2: r _{in} = 49.6 mm, r _{out} = 164 mm, z = 371.3 mm	0.50%
	Disk 3: r _{in} = 70.1 mm, r _{out} = 308 mm, z = 644.9 mm	0.65%
	Disk 4: r _{in} = 79.3 mm, r _{out} = 309 mm, z = 846 mm	0.65%
	Disk 5: r _{in} = 92.7 mm, r _{out} = 309 mm, z = 1057.5 mm	0.65%
ETD	Disk: r _{in} = 419.3 mm, r _{out} = 1822.7 mm, z = 2420 mm	0.65%

- Silicon Internal Tracker (SIT)** – 2 inner layers Si strip detectors
- Forward Tracking Detector (FTD)** – 5 disks (2 with pixels and 3 with Si strip sensor) on each side, comparing 7 disks on ILD, due to smaller L*
- Silicon External Tracker (SET)** – 1 outer layer Si strip detector
- End-cap Tracking Detector (ETD)** – 1 end-cap Si strip detector on each side

Calorimeters

- Particle Flow Algorithm (PFA) oriented electromagnetic and hadronic calorimeters, expected jet energy resolution of 3-4% combined with the tracking detectors



- Intensive detector R&D efforts in the CALICE collaboration, selective on the technologies most suitable for CEPC

- b/c-quark and tau lepton identification (*essential for the precision physics program*) requiring **impact parameter resolution** in the transverse plane better than:

$$\sigma_{r\phi} = 5 \oplus \frac{10}{(p \cdot \sin^{3/2} \theta)} \mu\text{m}$$

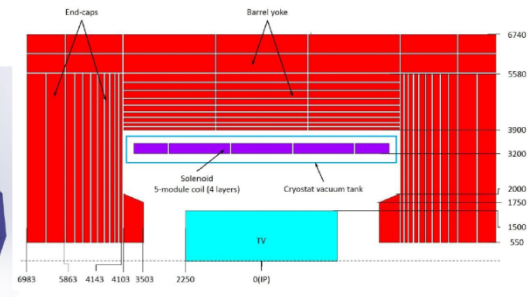
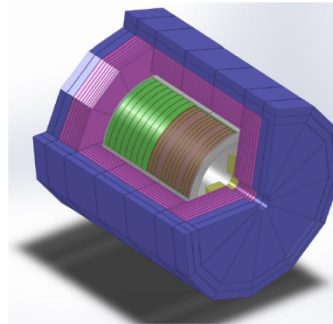
- The vertex detector should comply with:
 - Spatial resolution near the IP better than 3 μm
 - Material budget ≤ 0.15% radiation length (X₀) per layer
 - 1st detector layer close to the IP (r = 16 mm)
 - Detector occupancy not exceeding 1%

Requirements on pixel sensor

Single-point resolution < 3 μm, power consumption < 50mW/cm² (air cooling), readout time < 20μs
radiation tolerance: annual TID ~ 100 kRad and NIEL ~ 3 × 10¹⁰ n_{eq}/cm²

Magnet

- 3.5 T central field of superconducting solenoid in a warm aperture of 6 m in diameter and 8.05 m length (total yoke weight ~ 10840t)



The solenoid central field [T]	3.5	Nominal current [kA]	17.82
Maximum field on conductor [T]	3.75	Total ampere-turns of solenoid [MA]	22.24
Coil inner radius [mm]	3200	Inductance [H]	8.62
Coil outer radius [mm]	3500	Stored energy [GJ]	1.368
Coil length [mm]	7400	Stored energy per unit of cold mass [kJ/kg]	9.44

CEPC Detector R&D considerations

Critical R&D for pixel detector

- Pixel sensors with **low power consumption and fast readout**
 - Optional technologies: HR-CMOS, SOI, DEPFET, etc.
 - Novel readout architecture and enhanced in-pixel and sensor level electronics functionality
- Mechanical design and cooling
 - Light weight mechanical support structure and cables
 - Vibration under forced-air cooling: *impacts on position precision and consequentially the impact parameter resolution*
 - Air cooling or more aggressive CO2 cooling

Critical R&D for PTC

- Techniques and design to fully suppress the Ion backflow
- Understand the impacts of magnetic/electric field distortion on readout modules and track reconstruction and figure out possible solution
- Readout options (GEM or Micromegas) and front-end electronic (ASICs fabricated with 65 nm CMOS technology)
- Efficient cooling techniques: two-phase CO2 cooling or more efficient micro-channel CO2 cooling
- Alignment and calibration system

Critical R&D for strip detector

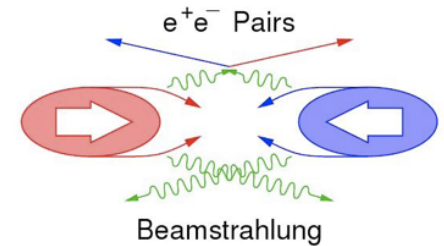
- Silicon microstrip sensor with high spatial resolution
 - **Conventional p+-on-n sensor** with small pitch size ~ 50um fabricated with large size wafer (6" or even 8")
 - Preferably to be thinned down to below 200 um (less material) and with slim-edge (maximal sensitive area)
 - Alternatively **pixelated strip sensors based on CMOS technology** as being pursued by the ATLAS experiment for HL-LHC
- Front-end electronics
 - Fabricated with 90/65 nm CMOS technology
 - Fast electronics with low noise and low power consumption
- Mechanics, powering and cooling

DHCAL R&D

- Detector optimization including **pad size, number of detector layers, gas recirculation system, HV distribution system**
- Readout Electronics (PCB, **low power ASIC FEE**)
- **Effective cooling** together with power saving strategy
- Calibration
 - **Energy, position and density calibration**
 - Detailed shower measurement gives possibility to use track segments (from data itself) to calibrate calorimeter

Beam Related Backgrounds

- Backgrounds originating from beam-beam interactions
 - Beamstrahlung (**negligible**)
 - Electron-positron pair production (**dominant**)
 - Hadronic background (**negligible**)
 - Radiative Bhabha scattering (**small**)



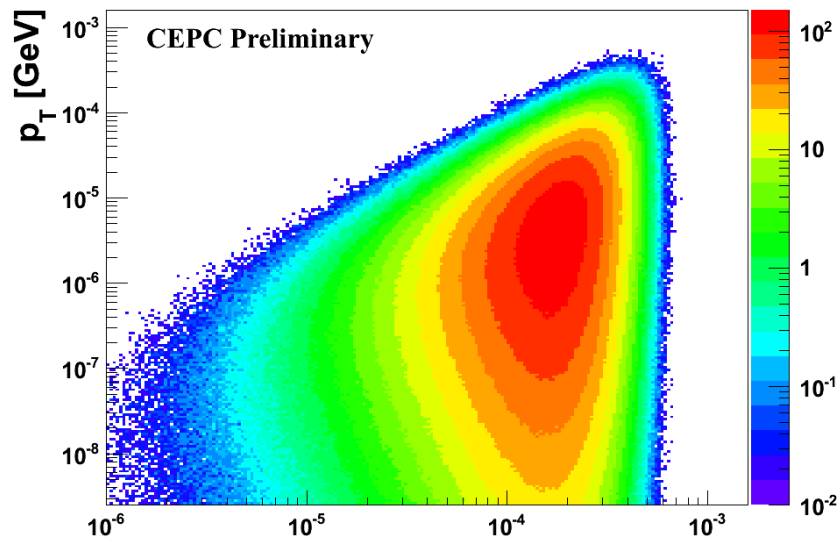
On the inner most detector layer

Hit density : 0.8 hits/cm²/BX

Radiation levels: annual TID~100 kRad and NIEL~3 ×10 n_{eq}/cm²

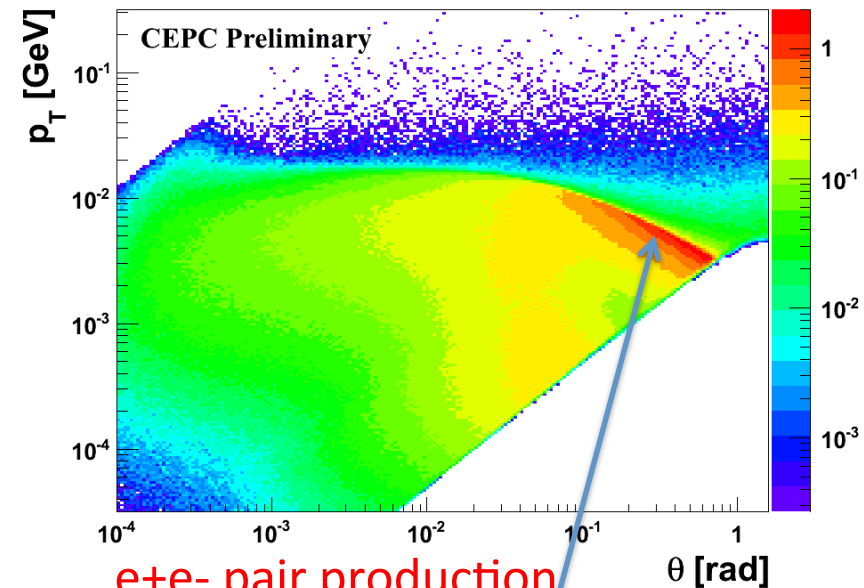
- Other backgrounds also studied
 - Synchrotron radiation (**partially evaluated, detectors safe**)
 - Beam-gas interactions (**negligible**)

- Beam induced backgrounds (beam-gas, beam-beam, synchrotron radiation) imposes large impact on detector design (eg, occupancies, radiation damage)
- Beam-beam interactions simulated with Guinea-Pig, including Beamstrahlung, e^+e^- pair production, hadronic backgrounds, etc.



Beamstrahlung photons θ [rad]

Low momentum and small polar angle \rightarrow negligible, but should avoid directing any detector component



e^+e^- pair production θ [rad]

Dominant detector background with sharp kinematic edge \rightarrow detector components (beampipe) to be placed away

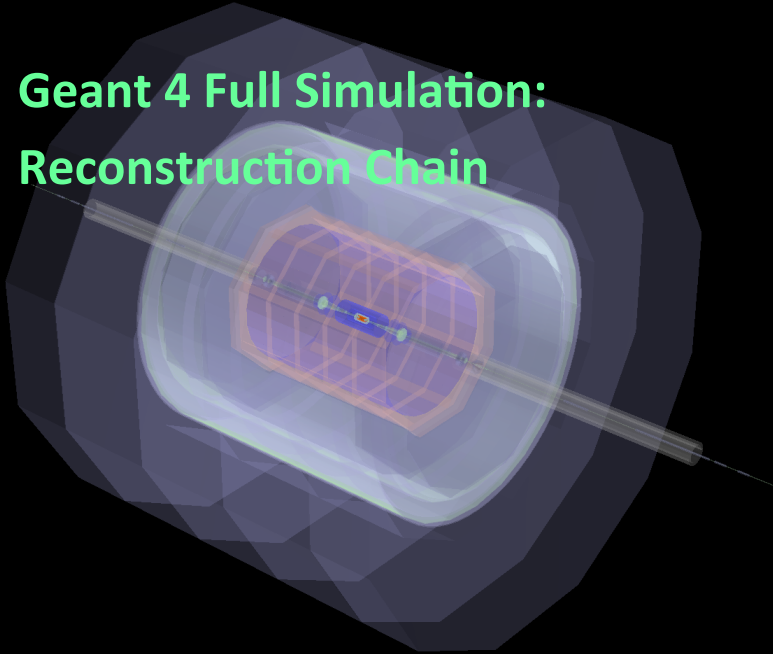
Status and Progress

SIMULATION & PHYSICS REACH

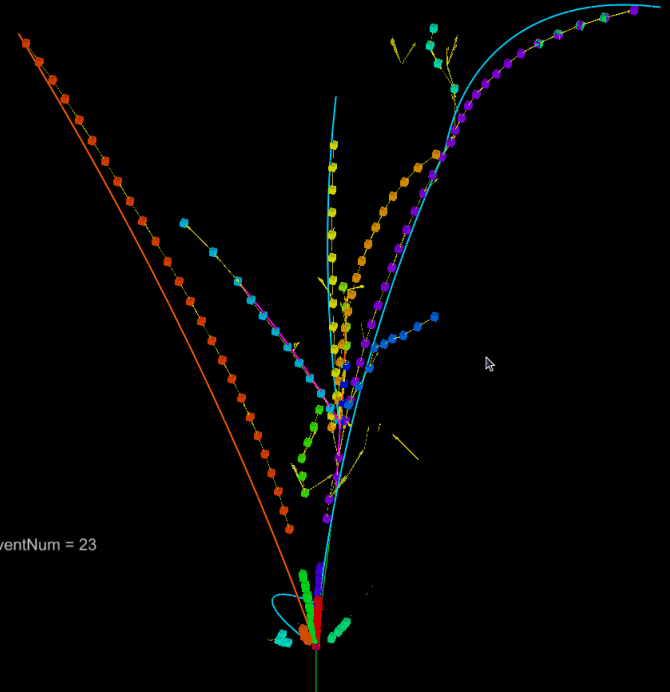
Preliminary

CEPC simulation & physics

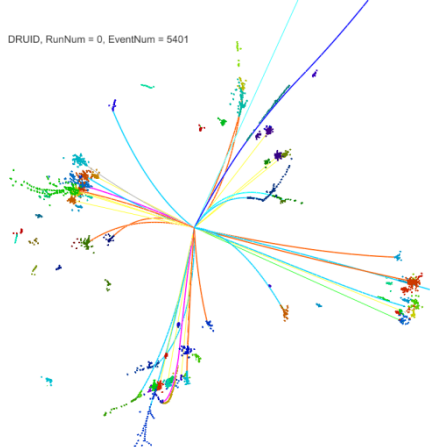
- Geant 4 Full Simulation:
- Reconstruction Chain



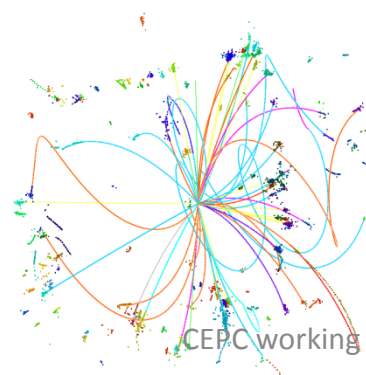
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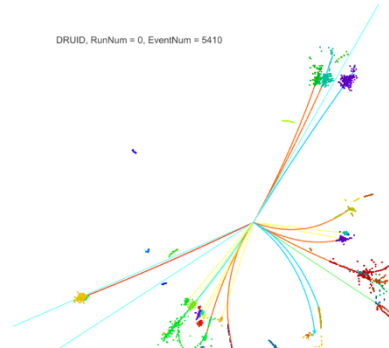
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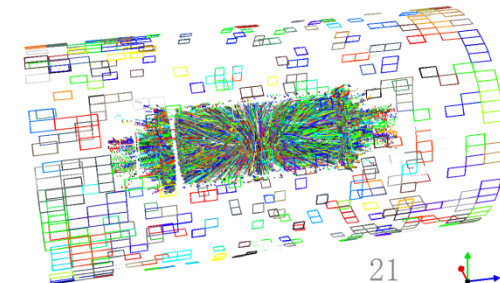
DRUID, RunNum = 0, EventNum = 5410



CEPC working week, August 17–28, 2015



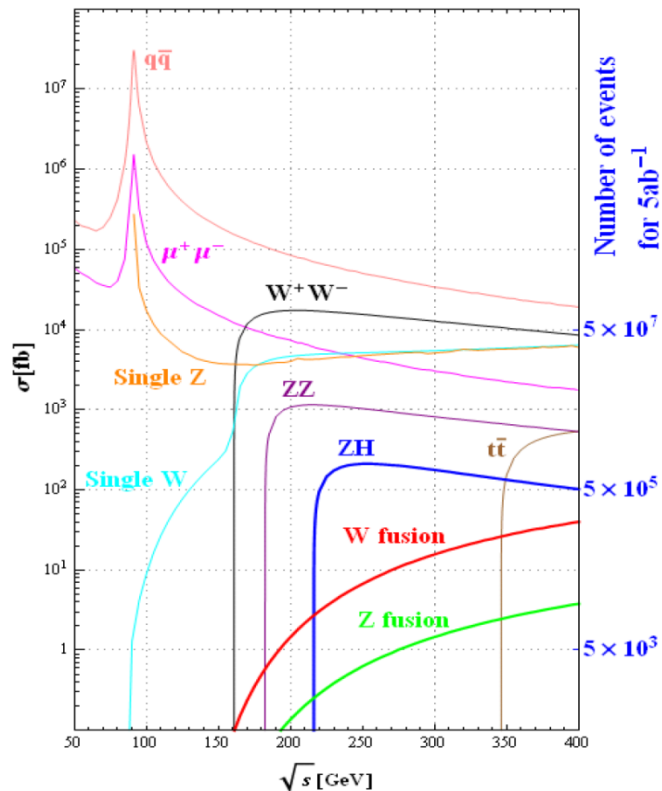
CMS Experiment at LHC, CERN
Data recorded: Thu Jan 1 01:00:00 1970 CEST
Run/Event: 1 / 1
Lumi section: 1



CEPC simulation & physics

MC Samples

- Generators: Full SM sample + Several BSM Signals



CEPC preCDR Higgs sensitivity study

	di-muon	di-electron	di-neutrino	di-jets
$\sigma(\text{ZH})$	Green	Green	-	Cyan
M_H	Green	Green		
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \text{bb})$	Green	Cyan	Yellow	Cyan
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \text{cc})$	Green	Cyan	Yellow	Cyan
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \text{gg})$	Green	Cyan	Yellow	Cyan
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \text{WW})$	Green	Cyan	Yellow	Yellow
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \text{ZZ})$	Yellow	Yellow	Cyan	Yellow
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \tau\tau)$	Yellow	Yellow	Yellow	Yellow
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \gamma\gamma)$	Green	Green	Green	Green
$\sigma(\text{ZH}) \cdot \text{Br}(\text{H} \rightarrow \mu\mu)$	Green	Green	Green	Green
$\sigma(\text{vvH}) \cdot \text{Br}(\text{H} \rightarrow \text{bb})$	-	-	Cyan	-
$\text{Br}(\text{H} \rightarrow \text{invisible})$	Green	Yellow	-	Yellow
$\text{Br}(\text{H} \rightarrow \text{exotic})$	Cyan	Cyan		

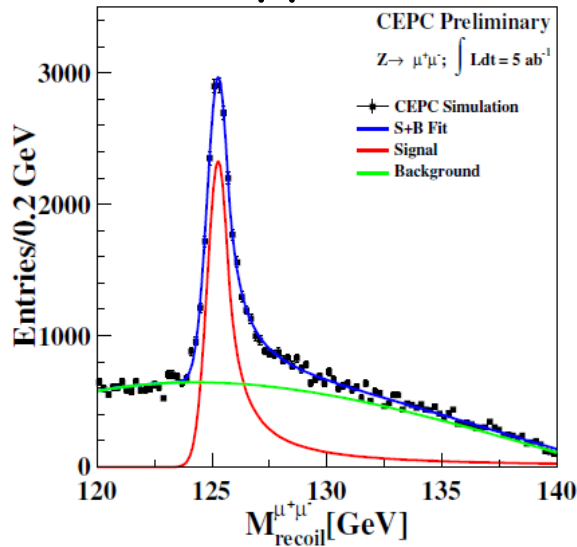
Signal with CEPC Full Simulation, Bkgrd with Fast Simulation

CEPC Fast Simulation

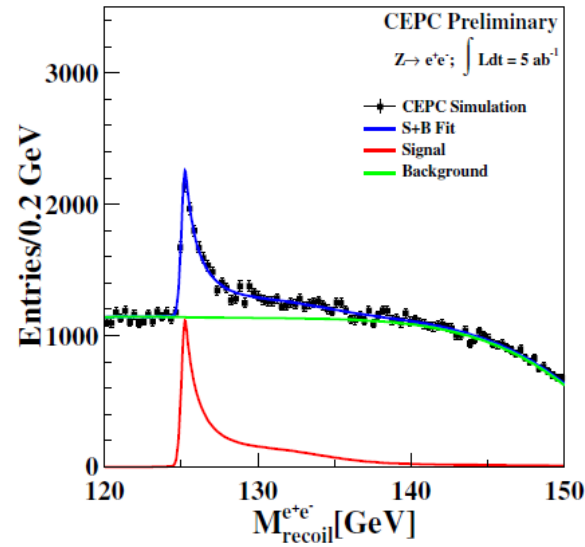
Extrapolated from ILC/FCC-ee results

CEPC simulation & physics

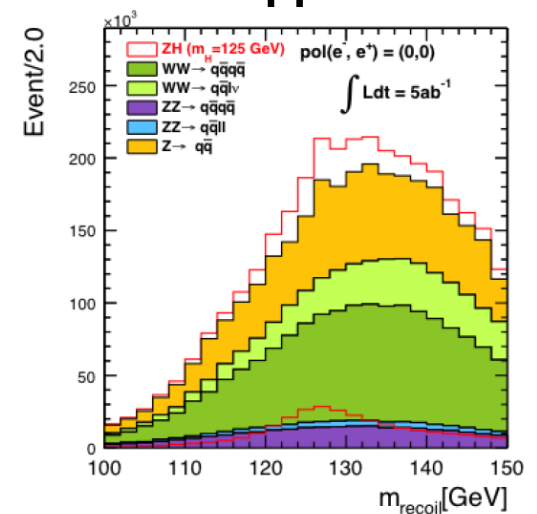
Z → μμ recoil



Z → ee recoil



Z → qq recoil



$$m_{\text{recoil}}^2 = (\sqrt{s} - E_{ff})^2 - p_{ff}^2$$

Z decay mode	ΔM_H (MeV)	$\Delta\sigma(ZH)/\sigma(ZH)$	$\Delta g(HZZ)/g(HZZ)$
ee	14	2.1%	
$\mu\mu$	6.5	0.9%	
$ee + \mu\mu$	5.9	0.8%	0.4%
$q\bar{q}$		0.65%	0.32%
$ee + \mu\mu + q\bar{q}$		0.51%	0.25%

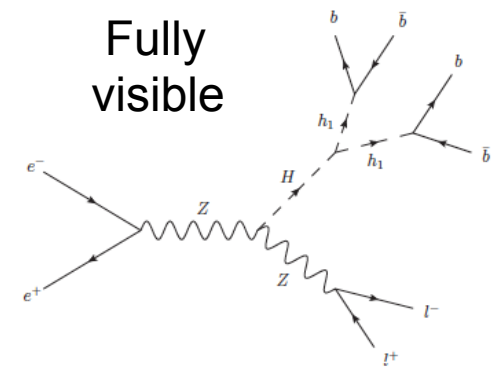
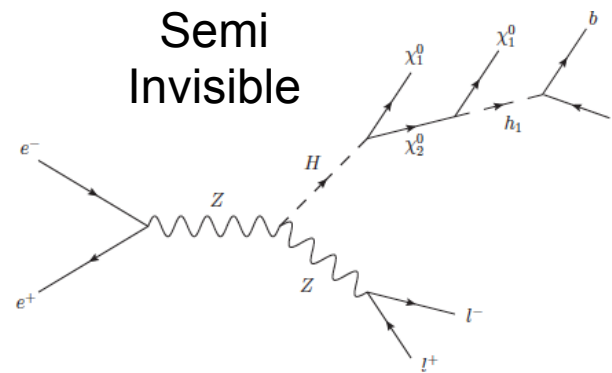
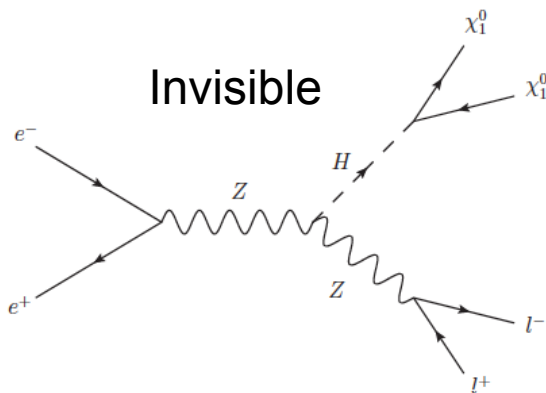
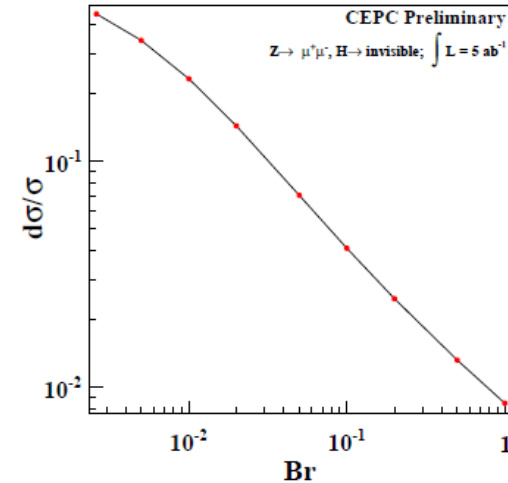
~0.5% accuracy on $\sigma(ZH)$, the anchor of absolute Higgs measurements

CEPC simulation & physics

- Model independent tagging of Higgs boson (via Z recoil mass)
- Make CEPC extremely sensitive to BSM Higgs decay

Channel	Accuracy	Methods
$Z \rightarrow \mu\mu, H \rightarrow \text{invisible}$	0.8%	CEPC Full Simulation
$Z \rightarrow ee, H \rightarrow \text{invisible}$	1.1%	Estimation
$Z \rightarrow qq, H \rightarrow \text{invisible}$	0.14%	Extrapolated from ILC result
Combined	0.14%	

- $\text{Br}(H \rightarrow \text{inv})$: **0.14%** accuracy with $\text{Br} = 100\%$
- $\text{Br}(H \rightarrow b\bar{b} + \text{MET})$: 9.4σ deviation with $\text{Br} = 0.2\%$
- $\text{Br}(H \rightarrow b\bar{b}b\bar{b})$: 8.4σ sigma deviation with $\text{Br} = 0.04\%$



CEPC simulation & physics

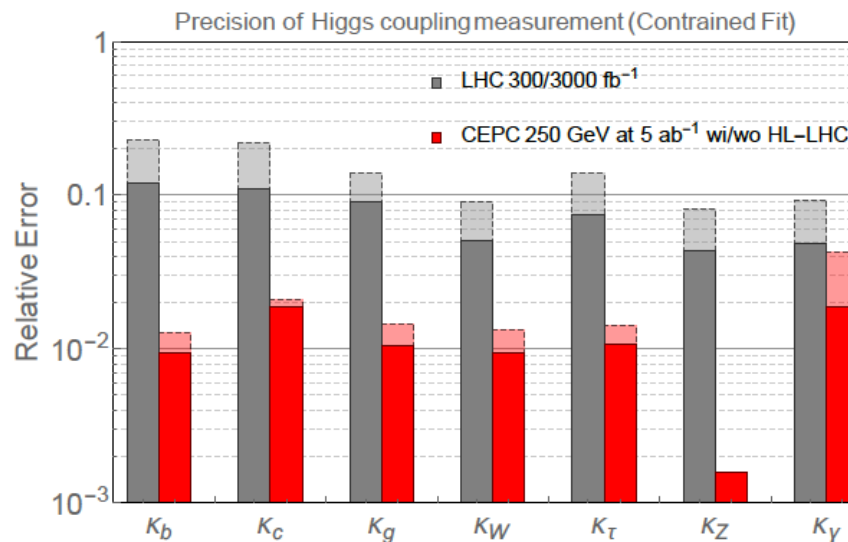
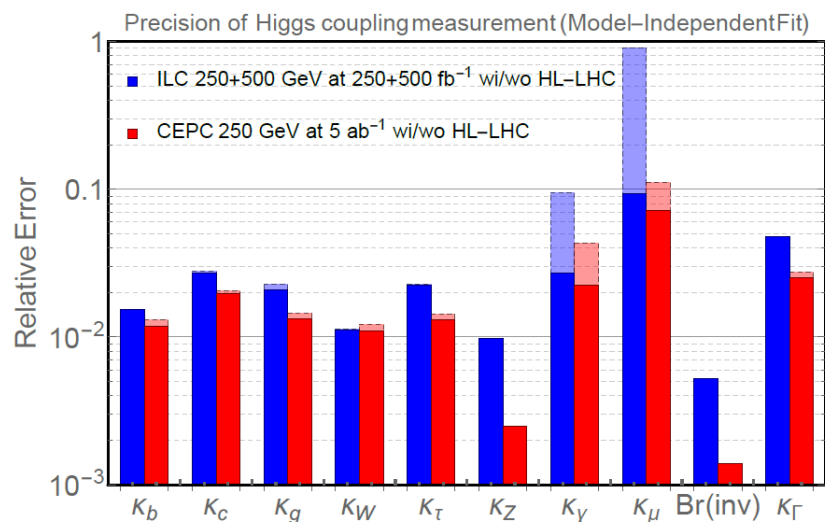
ΔM_H	Γ_H	$\sigma(ZH)$	$\sigma(\nu\bar{\nu}H) \times \text{BR}(H \rightarrow b\bar{b})$
5.9 MeV	2.8%	0.51%	2.8%

Decay mode	$\sigma(ZH) \times \text{BR}$	BR
$H \rightarrow b\bar{b}$	0.28%	0.57%
$H \rightarrow c\bar{c}$	2.2%	2.3%
$H \rightarrow gg$	1.6%	1.7%
$H \rightarrow \tau\tau$	1.2%	1.3%
$H \rightarrow WW$	1.5%	1.6%
$H \rightarrow ZZ$	4.3%	4.3%
$H \rightarrow \gamma\gamma$	9.0%	9.0%
$H \rightarrow \mu\mu$	17%	17%
$H \rightarrow \text{inv}$	–	0.28%

CEPC Combination group:

Model independent result compared to ILC

Model dependent result compared to LHC
(LHC: very limited access to model independent measurement)



preliminary

CEPC working week, August 17–28, 2015

preliminary

25

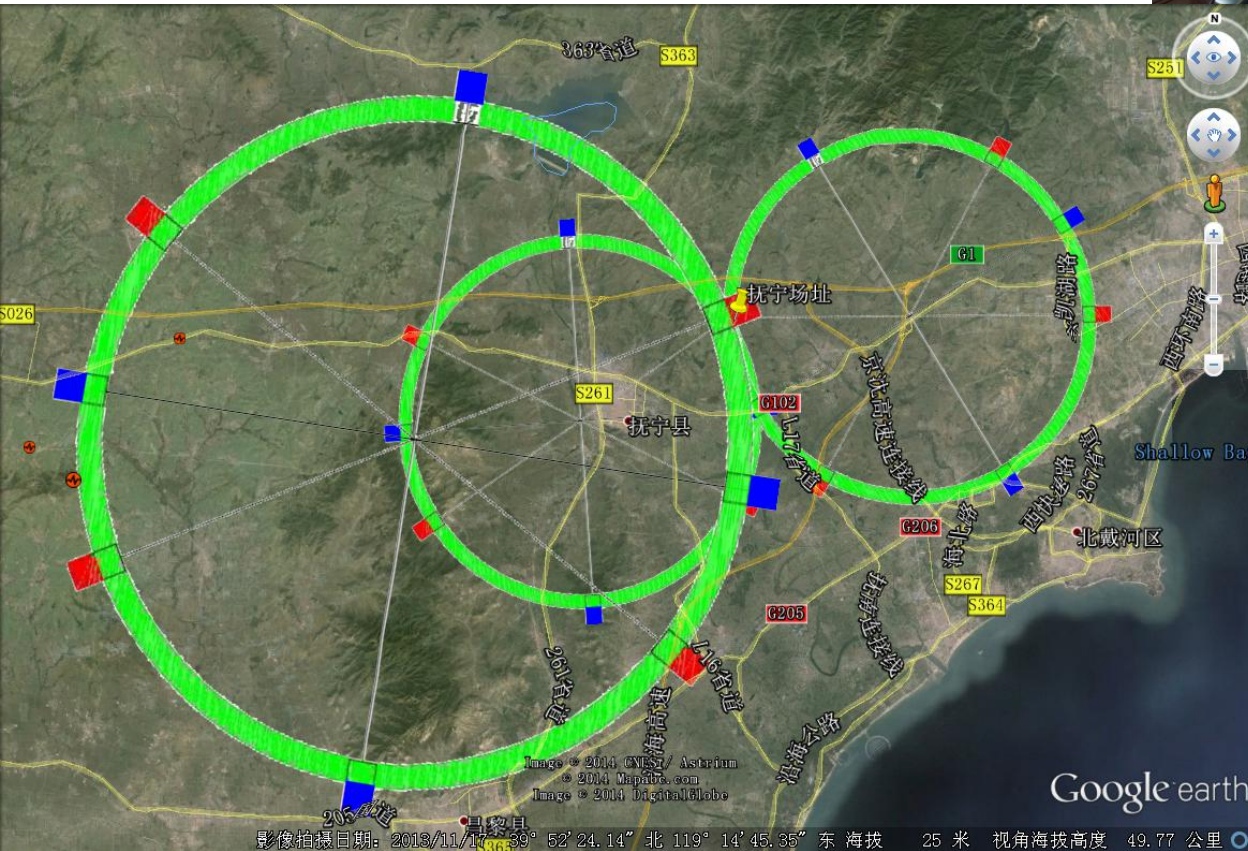
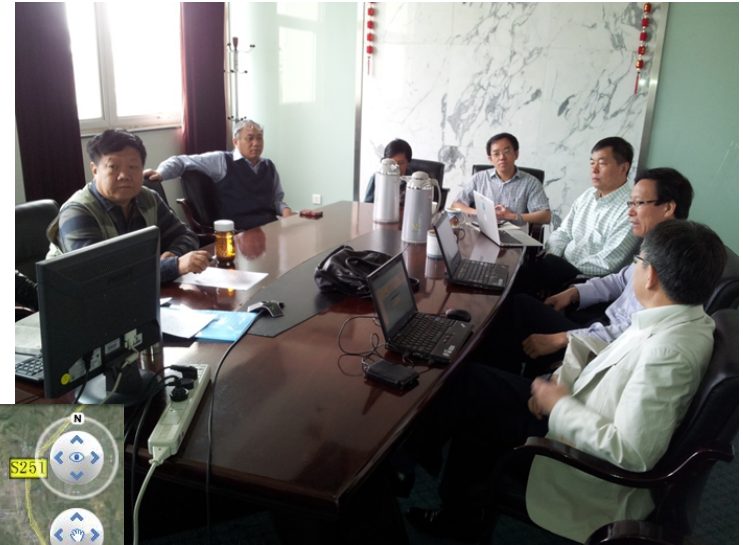
Status and Progress

CIVIL ENGINEERING & SUPPORT

Office of Engineering and Support at IHEP

- appointed by IHEP director Y. F. Wang on April 15, 2014
- veterans and very experienced professionals

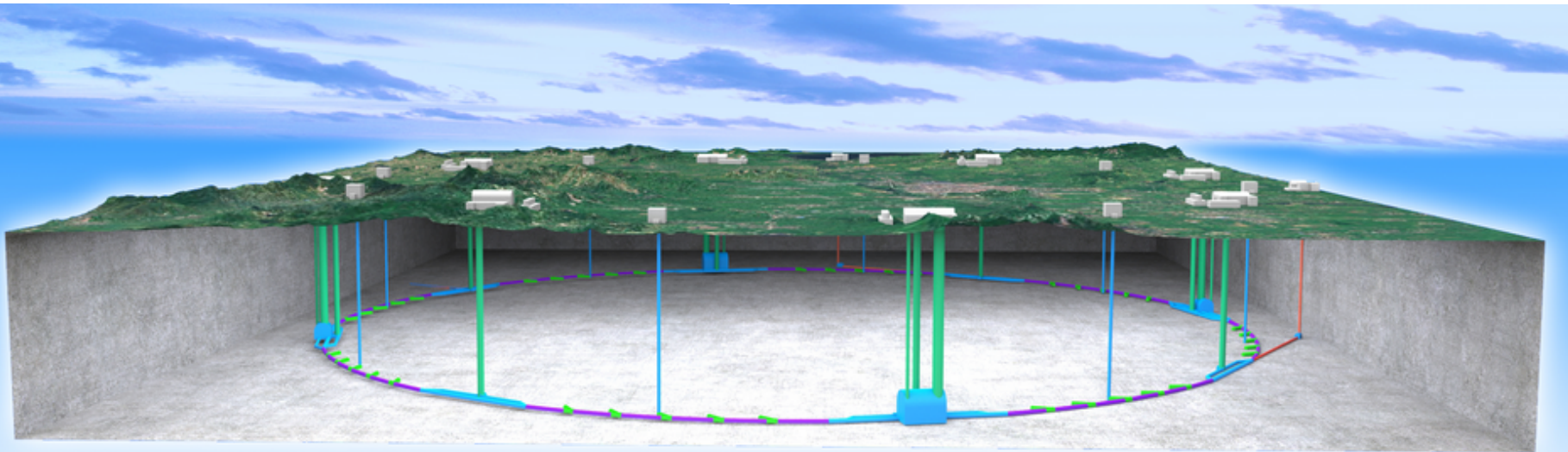
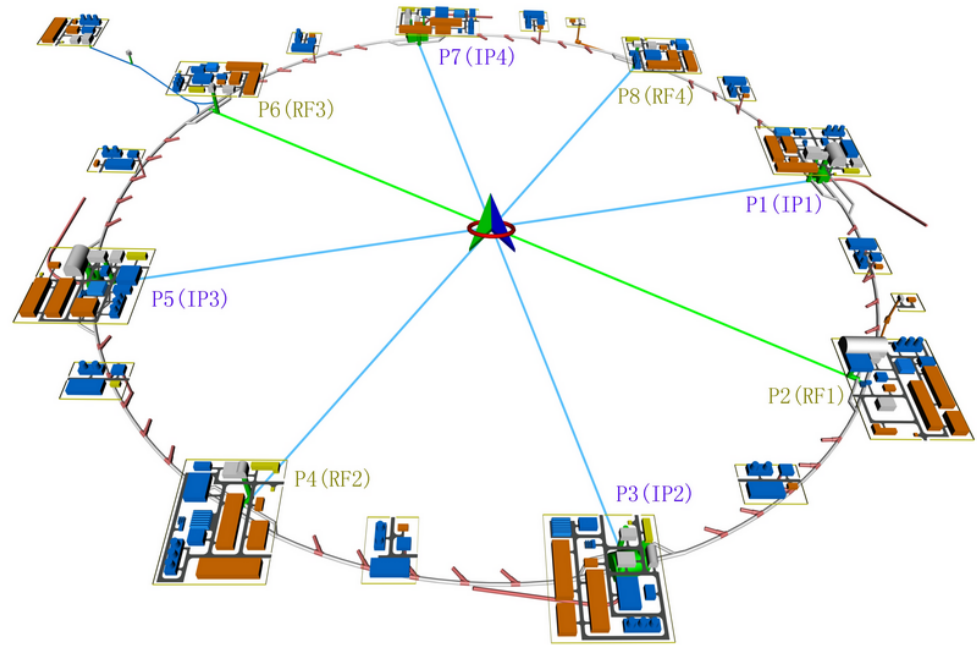
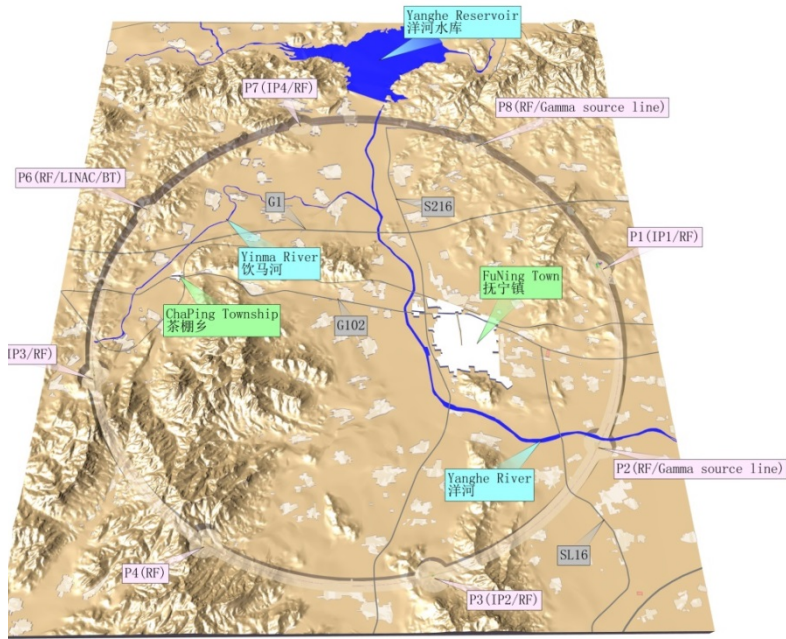
“enormous amount of effort & progress”



QingHuangDao site Investigation

- 300km from Beijing
- Geo well suited
- Great environment

CEPC “Qinghuandao Site” Investigation



Preli. CDR

Reviews and completion

<http://cepc.ihep.ac.cn/preCDR/volume.html>

➤ **The preliminary CDR volumes**

- Volume I: Physics and the Detector
- Volume II: The CEPC-SppC Accelerators
- Volume III: Civil Engineering (in Chinese)

➤ **The reviews**

➤ **Revisions and Chinese edition**

CEPC-SPPC
Preliminary Conceptual Design Report

Volume II - Accelerator
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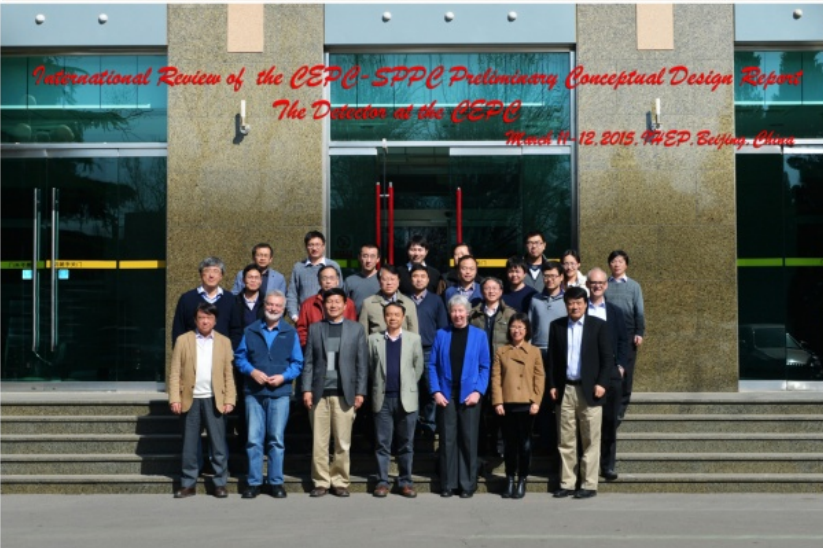
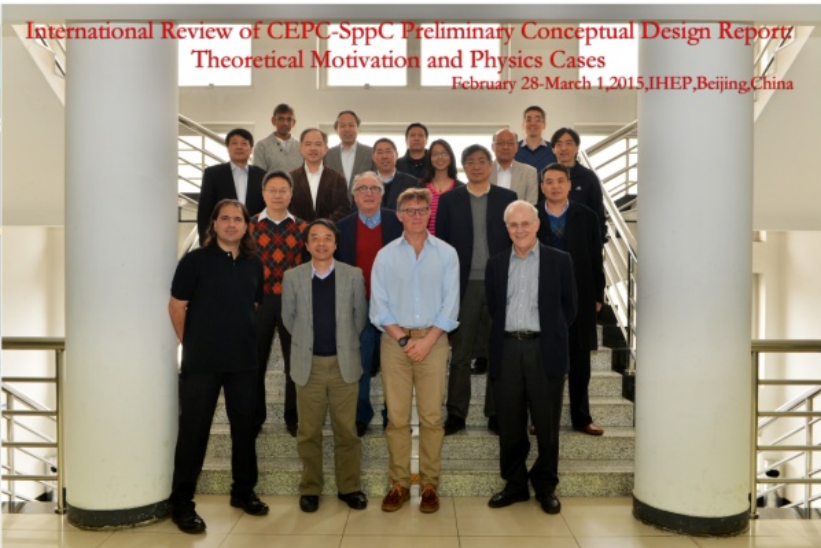
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CEPC-SPPC
Preliminary Conceptual Design Report
Volume I - Physics & Detector

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CEPC preCDR 初步概念设计 - Reviews



CEPC preCDR 初步概念设计 - Reviews

“The committee considers the CEPC-SPPC to be well aligned with the future of China’s HEP program, and in fact the future of the global HEP program.”

“The committee strongly endorses the physics case of the CEPC, as outlined in the preCDR, recognizing it as an essential step in the understanding of Nature”

“The Committee has been very impressed with the progress during such a short period of time, as well as the work and presentations shown, mostly done by the young generation, who are the ones that can devote their carriers to this project through the coming decades”

- Physics goals and precision reachable (preliminary)
- No technological obstacles that can not be overcome
- Specification of R&D items
- Initial cost estimate
- Complete preCDR (implement reviewers comments),

Status and Progress

COMMUNICATION, OUTREACH & EDUCATION

Communication: CEPC Web site (English, Chinese)



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

Panel Discussion on Fundamental Physics



What's new After the Higgs discovery:
Where is the Fundamental Physics going?

Nine world leading physicists had face-to-face discussions at Tsinghua University, Beijing on Feb 23, sharing with the public their opinions on new physics opportunities after the discovery of Higgs.

Chaired by Shing-Tung Yau, a Fields medalist, the panel discussions involved a group of noted scientists, Nima Arkani-Hamed, David Gross, Gerard 't Hooft, Joseph Incandela, Luciano Maiani, Hitoshi Murayama, Yifang Wang and Edward Witten.

Proposed by the Chinese high energy physics community in 2012, the circular electron positron collider (CEPC) has got warm responses from the international community. This machine could be later upgraded to a high energy proton-proton collider with physics potential far beyond the Higgs factory.

From February 24 to 25, a two-day workshop focusing on the physics case for future circular colliders, as well as discussions on how to synchronize the domestic theoretical particle physics efforts with the planning and designing of future circular machines was held at the Institute of High Energy Physics.

Scientists aim at next-generation high energy circular collider

Job Opportunities JOIN US What's your idea? Logo External Links

CEPC working week, August 17-28, 2015

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Y. Y. Zhong

Outreach & education

CEPC Outreach

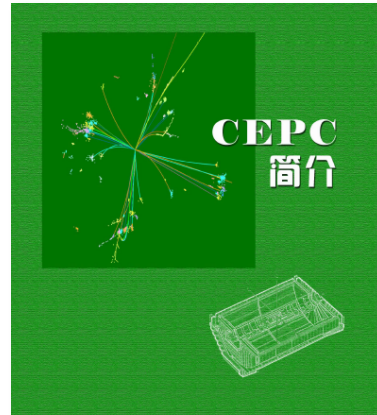


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~ 30000字

CEPC建议
引起巨大国际反响

~10000字



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~ 6700字

CEPC
大事记

CEPC working week, August 17—28, 2015



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~ 27000字

高能物理的
社会效益

进行中



中国科学院高能物理研究所

~ 5600字

未来的
希格斯工厂

进行中

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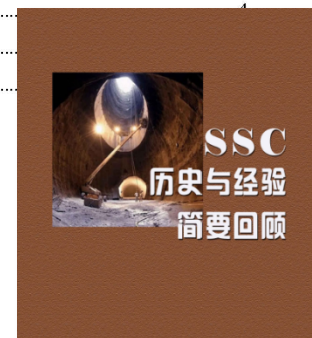


中国科学院高能物理研究所

CEPC working week, August 17—28, 2015

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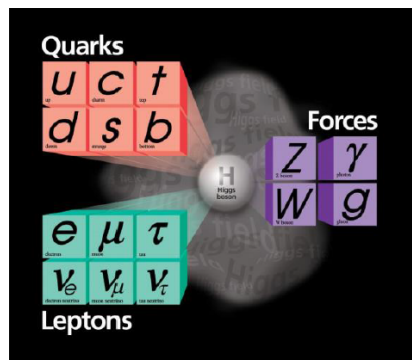
Y. Y. Zhong

希格斯粒子究竟是什么？为什么全球数千位科学家，花费数十亿美元，坚持50年在寻找它？它被喻为粒子物理标准模型“最后的一块拼图”，可是为什么它终于被发现，科学家们却说这是人类探索基本粒子的新开端？中国科学家为什么想要建造下一代环形正负电子对撞机来“批量生产”它？为什么这是我国高能物理研究，甚至国家发展的难得机遇？

关于“希格斯粒子”与“环形正负电子对撞机”，太多网友表示“不明觉厉”，小编就联合高能所的粒子物理学家为你解开疑惑。

1、什么是粒子物理的“标准模型”？

粒子物理的“标准模型”是一个描述物质世界的基本构成（基本粒子）及其相互作用的理论，于20世纪60至70年代在弱电统一理论以及量子色动力学的基础上逐步完善起来。物理学家温伯格(Steven Weinberg)、萨拉姆(Abdus Salam)和格拉肖(Sheldon Lee Glashow)等是标准模型的奠基人。



粒子物理标准模型示意图

该模型把基本粒子分为夸克、轻子和玻色子三大类别，共62种，这些粒子后来陆续被高能物理实验所证实。

标准模型预言的希格斯粒子是自旋为零的玻色子。与之相关的希格斯机制为基本粒子的质量起源提供了动力学解释，因此是整个标准模型的基石之一。假如希格斯粒子不存在，那将成为标准模型的重大缺陷。

2、什么是希格斯粒子？它为什么被称作“上帝粒子”？

希格斯粒子是粒子物理标准模型预言的一种自旋为零的玻色子，以英国理论物理学家彼得·希格斯(Peter Higgs)的名字命名。标准模型中的一些其他基本粒子受希格斯场的作用产生惯性，最终形成质量。因此可以说，希格斯机制为物质世界的形成奠定了质量基础。基本粒子有了质量才能产生引力，才会形成宇宙和生命。在过去几十年中，寻找希格斯粒子是许多大型高能粒子物理实验的最重要目标。

3、什么是希格斯场和希格斯机制？

简单来说，希格斯场是一种不可见的、遍及整个宇宙的能量场；希格斯机制是基本粒子的质量产生机制。在希格斯机制中，希格斯场引起弱电规范对称性的自发破缺，将质量赋予传递弱相互作用的规范玻色子以及费米子。希格斯粒子是希格斯场的量子激发，它通过自相互作用而获得质量。

根据粒子物理标准模型和宇宙大爆炸理论，宇宙起源于一次大爆炸，无数的正反粒子同时产生，轻子和夸克通过与希格斯场的相互作用获得了质量。这些粒子构成物质，通过长时间的演化形成了星系，最终形成今天的物质世界。



用漫画来解释希格斯机制。作者：David J. Miller

1993年，英国科技大臣曾向科学家们发出挑战，让他们用一页纸的篇幅向他解释清楚希格斯机制。他共收到117份作品，其中英国伦敦大学学院的物理学家戴维·米勒(David J. Miller)的解释被评为最优。

米勒把希格斯场比作在一个均匀分散着的一大群政客的房间，把一个没有质量的基本粒子比作前英国首相撒切尔夫人(Margaret Hilda Thatcher)。普通人可以任意穿过房间，就像光子一样。但是撒切尔夫人的到场，一定会吸引大量的关注：人们会围拢在她周围，减慢她穿行的速度，使她获得“质量”。这个类比形象地说明了没有质量的基本粒子是如何通过与希格斯场的相互作用而获得质量的。

4、希格斯粒子为什么如此难以捕获？

希格斯粒子作为质量之源，在137亿年前的宇宙大爆炸初始就已经完成了它的使命。现在，物理学家要再次捕获希格斯粒子的踪迹，就只有建造高能对撞机，通过高能粒子的对撞，来模拟宇宙起源的时刻，“复活”希格斯粒子。

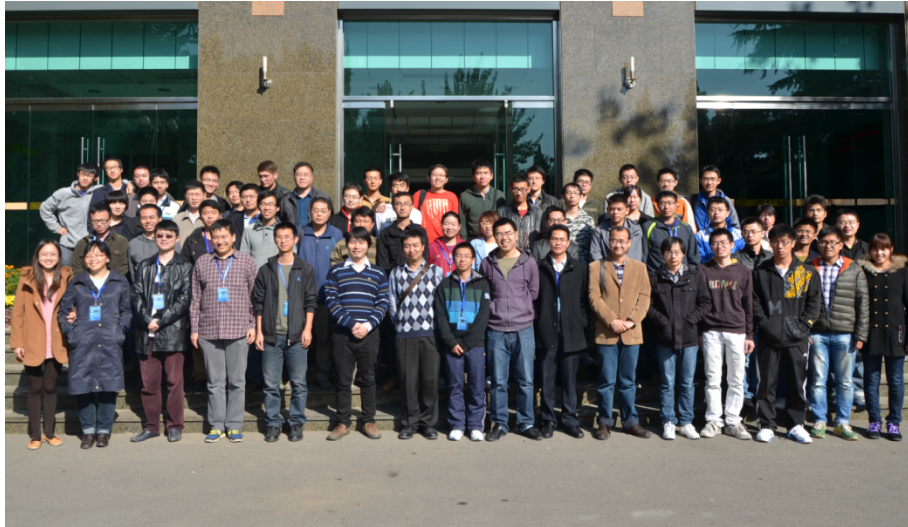
Status and Progress

TRAINING & PROFESSIONAL DEVELOPMENT

Training and Professional development for CEPC

We need more professionals to undertake the CEPC-SppC project to good completion

- Training young people to address manpower shortage



- Professional development for current staff and faculty
- Recruitment: postdocs and staff at IHEP
- Increase size of HEP graduate students (quality, too)
-



Training

August 2014

11 Aug - 15 Aug **Detector Simulation and Geometry editing**

October 2013

19 Oct - 20 Oct **CEPC Training: Physics Analysis, Detector Optimization and Software tools**

International Summer school on TeV Experimental Physics (iSTEP)

20-29 August 2014
IHEP
Asia/Shanghai timezone

Overview
CEPC working week, August 17 - 28, 2015

CEPC Study Group

Pre. R&D and funding requests

- 1. IHEP internal investment ~10M RMB**
organize teams, initialize preliminary R&D
- 2. Seek funding from Chinese Ministry of Sci. & Tech.**
kick-off R&D
- 3. Seek Chinese 13th 5 year plan approval for R&D and validation**
CDR, TDR and preparation for construction

CEPC Study Group

CDR and IAC

In May 2015, the CEPC Study Group decided to begin the CDR process, with a preliminary target date of completion: end of 2016

An International Advisory Committee has been formed to advise the CEPC SG on int'l collaboration, organizational structures, governance, Science & Technology issues, etc.

CEPC Study Group

Project evaluation

- **The Ministry of Science and Technology (MOST) has been asked to lead the evaluation of the CEPC-SppC project, with several other central government agencies joining in the process**
- **In May MOST held a discussion session on CEPC-SppC**
- **We anticipate more actions by MOST, including possibly a formal project evaluation, later this year**

SUMMARY

- Tremendous efforts have been made, real progress in all fronts on the CEPC-SppC study
- preCDR volumes have been reviewed and finalized; no technological show stoppers
- CEPC-SppC study group will make the case to the government
- Much work ahead: funding requests, project evaluation, CDR, ...;
- More internationalization expected for CEPC