Status and Prospects of CEPC-SppC

Yuanning Gao (Tsinghua University)

On Behalf of the CEPC-SppC Study group

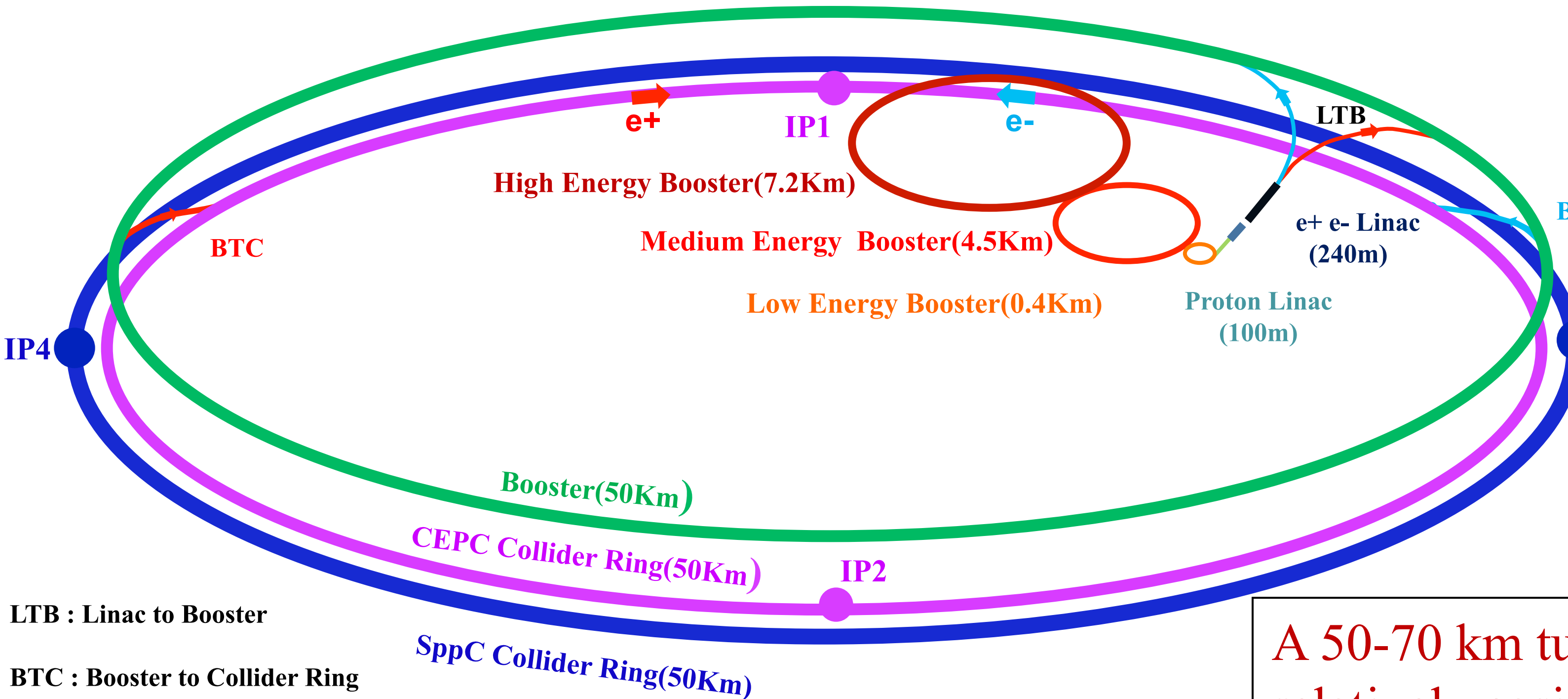
8th Workshop of the France-China Particle Physics Laborotaty
April 8-10 , 2015, USTC, Hefei, China

Outline

- An overview of CEPC-SppC
- Science case
- Accelerator design
- Baseline Detector design
- Civil construction
- Prospects & summay

CEPC+SppC

- A continuation of BEPC →BEPCII → CEPC
- Thanks to the discovery of the low mass Higgs boson, and stimulated by ideas of Circular Higgs Factories in the world, CEPC+SppC configuration was proposed in Sep. 2012



A 50-70 km tunnel is relatively easier NOW in China

CEPC-SppC Organization

J. Gao, ICHEP2014

(Since 2013-09-13)

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Q. Qin (IHEP)
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Detector
S. Jin (IHEP)
Y.N. Gao (TU)

Scientific goals

- CEPC (e+e-: 90-250 GeV)
  - Higgs Factory: Precision study of Higgs
    - Same as SM prediction ? Other Higgs ? Composite ? New properties ? CP effect ？
  - Z & W factory: precision test of SM
    - New phenomena ? Rare decays ?
  - Flavor factory: b, c, τ and QCD studies
- SppC (pp: 50-100 TeV)
  - Directly search for new physics beyond SM
  - Precision test of SM, e.g., h^3 & h^4 couplings

Precision measurement + searches: Complementary with each other

Timeline (dream)

- **CPEC**
  - **Pre-study, R&D and preparation work**
    - **Pre-study: 2013-15**
      - **Pre-CDR for R&D funding request**
    - **R&D: 2016-2020**
    - **Engineering Design: 2015-2020**
  - **Construction: 2021-2027**
  - **Data taking: 2028-2035**
- **SppC**
  - **Pre-study, R&D and preparation work**
    - **Pre-study: 2013-2020**
    - **R&D: 2020-2030**
    - **Engineering Design: 2030-2035**
  - **Construction: 2035-2042**
  - **Data taking: 2042 -**

Reviewed during Feb. 28 – March 1,2015

preCDR release scheduled for April 10

CEPC-SPPC

Preliminary Conceptual Design Report: Physics and Detector

CONTENTS

Science Case

CEPC-SppC Physics Program

- CEPC
  - 5 ab^{-1} for Higgs studies @240-250 GeV
  - 10^{10-12} Z's @~ 91 GeV
  - 10^{6-8} W's @~160 GeV

- SppC

  E_{cm} = 70 TeV or Higher

Standard Model, Final ?

- From neutrinos to top quark, masses differs by a factor 10^{13}, why ？
- Fine tuning of Higgs mass(naturalness)：

$$m_H^2 - m_{H,0}^2 \sim -\frac{3}{8\pi^2} y_t^2 \Lambda^2$$

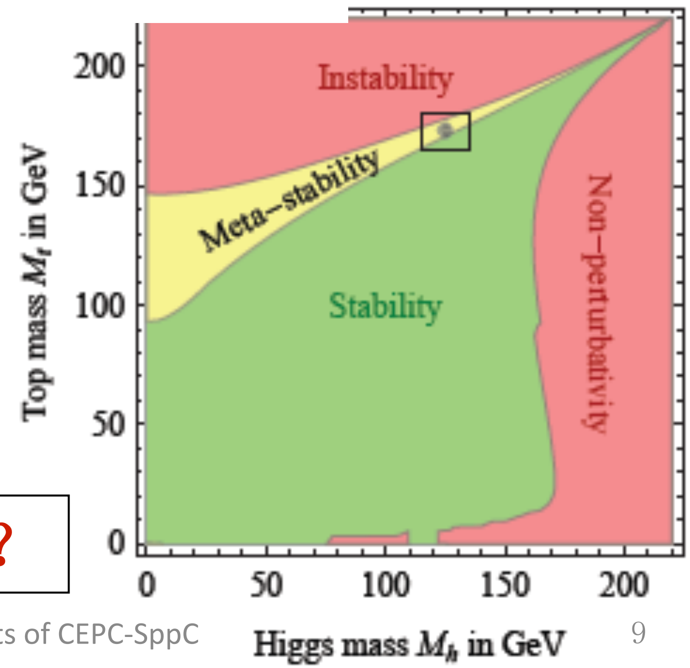
A coincidence of 10^{-34} ?
Never before even at 10^{-4}

For Λ(new physics) at the Planck scale ~ 10^{16} TeV：

m_H^2 = 36,127,890,984,789,307,394,520,932,878,928,933,023
−36,127,890,984,789,307,394,520,932,878,928,917,398
= $(125\ \text{GeV})^2$! ?

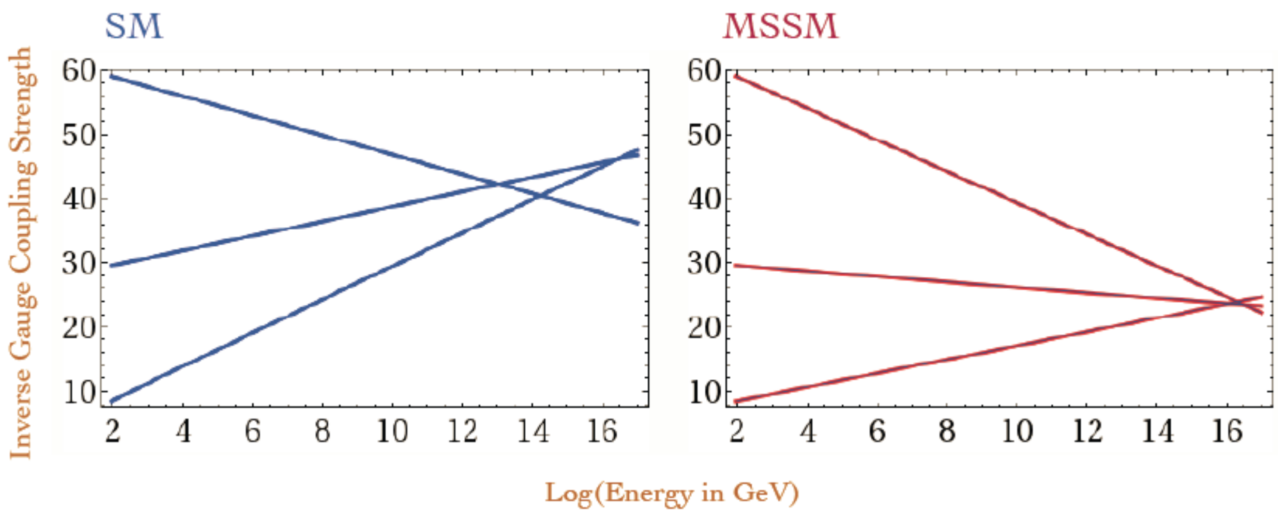
- Masses of Higgs and top quark are in the meta-stable region, why ? Fundamental reason ?
- Many of the free parameters in the SM are related to Higgs. Coincidence ?
- Neutrino mass

All related to Higgs！ ？



New Physics Beyond Standard Model ?

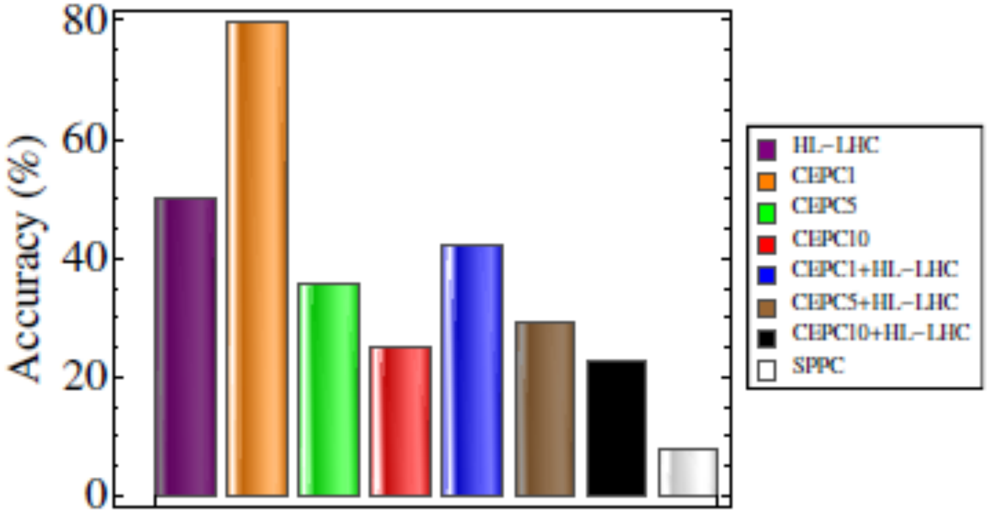
- **Experimental evidence ? No unification at the high energy.**



- **No dark matter particles in the Standard Model. Needed ? Where ?**
- **Matter-antimatter asymmetry in the SM ?**
- **How to describe neutrinos in the SM ?**
- **Why SUSY can find solution to these problems ? Incident ?**

New Tasks after the Higgs Discovery

- **Gauge interactions through vector boson with spin 1**
- **New type of interactions after Higgs:**
  - **Yukawa coupling through Higgs with spin 0:**
    - **hττ, hbb, htt coupling constant， ~10% after LHC**
  - **Self-coupling h^3 & h^4:**
    - **~ 50% after LHC; ~20 @ CEPC, 10% @ SPPC**

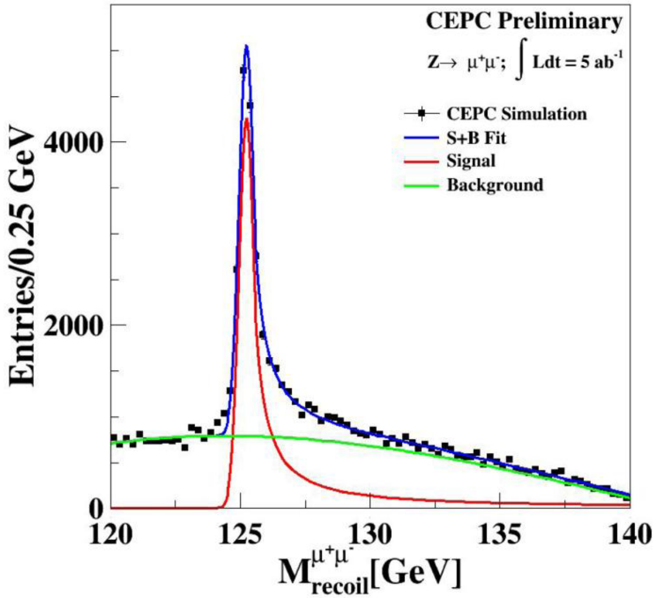


CEPC

- **Precision measurement, search for new physics, similar to ILC@250 GeV**

- **Higgs is a new type of elementary particle and the only one not being studied throughly. It is absolutely needed to precise measure and determine its properties.**
- **The main physics task in the next tens of years unless there are new major discoveries**

- LHC measurement is model dependent, particularly for the width.
- LHC and CEPC are complementary.

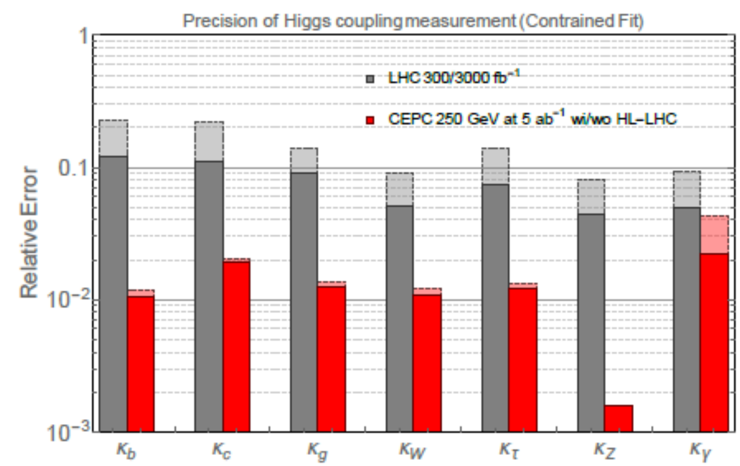


$$m^2_{\mathrm{recoil}} = (\sqrt{s} - E_{ff})^2 - p^2_{ff}$$

CEPC： Particle Factories

- 10^6 Higgs + $10^{11\text{-}12}$ Z^0 + 10^8 WW + …

- **Higgs factory： precision measurement of Higgs (mass, J^{PC}, hZZ, hWW, hbb, hττ, hcc, hγγ etc, ~ precision: 0.5-5%)**
  - Consistent with SM ?
  - Composite or elementary ?
  - Other Higgs ？
  - New properties ？
  - CP violation？



- **W & Z factory： precision test of SM**
  - Improve LEP measurement by a factor of 5-10
  - Improve rare decay sensitivity by a factor of ~10^3
- **Flavor factory： b， c， τ and QCD**

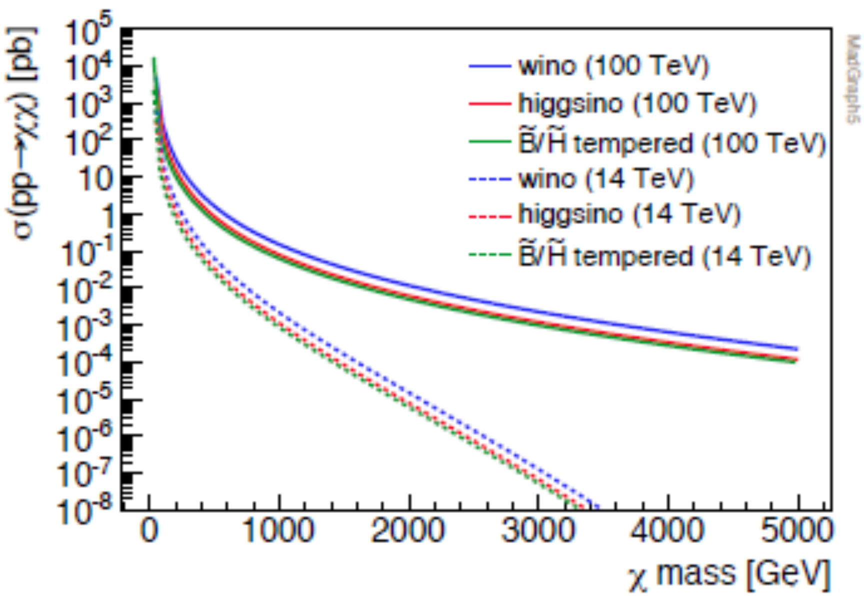
Complementary with ILC

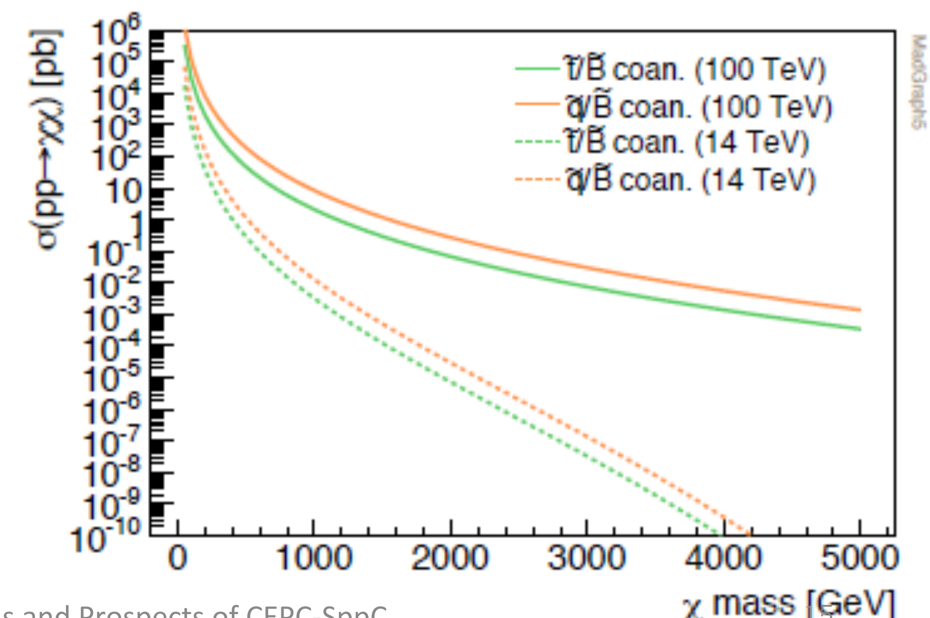
- **Energy：**
  - **CEPC for Z and Higgs (250 GeV)**
  - **ILC can go to 500 GeV for all couplings(Htt etc)**
- **Detector：**
  - **One detector each for ILC and CEPC . ILC give up Push-Pull.**
  - **ILC & CEPC: cross check**
- **Technology:**
  - **ILC rely on nano-beam techniques. Not there yet.**
  - **Luminosity for CEPC seems feasible.**
- **Timeline:**
  - **ILC starts from 2020 ?**
  - **CEPC starts from 2021 ?**
- **Why two ? One is enough ?**
  - **Two very different technology. Very different possibility for future.**
  - **Cross check： 2 accelerator + 2 detector is better than 1 (ILC) + 2 detector**

SppC

- **New physics**
  - **pp： a factor of 6 to LHC**
  - **ep： a factor of 100 to HERA**
  - **eA： a factor of 100 to EIC**
  - **AA： a factor of 6 to LHC/ALICE**

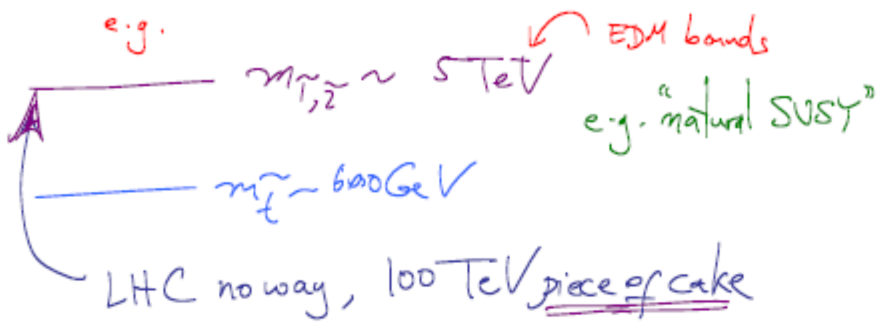
- **Advantages to look for new particles at high energies:**





If new particles at LHC:
a new era SppC can contribute

- **Beyond SM ➔ new energy scale**
- **New spectrum**
- **LHC can not complete:**



- **Detailed study needed ➔ more data**
- **Event No. ∝ $E^{\sim 5}_{CM}$ ➔ Higher than LHC by a factor of 1000**

New Physics for sure ?

- No new physics at LHC
  - Λ~ 1 TeV ➔ 10^{-2} fine tuning
- No new physics at SppC
  - Λ~ 10 TeV ➔ 10^{-4}fine tuning
- No fine tuning before at 10^{-4}
  - New physics law ？
  - New phenomena ？
  - How ？

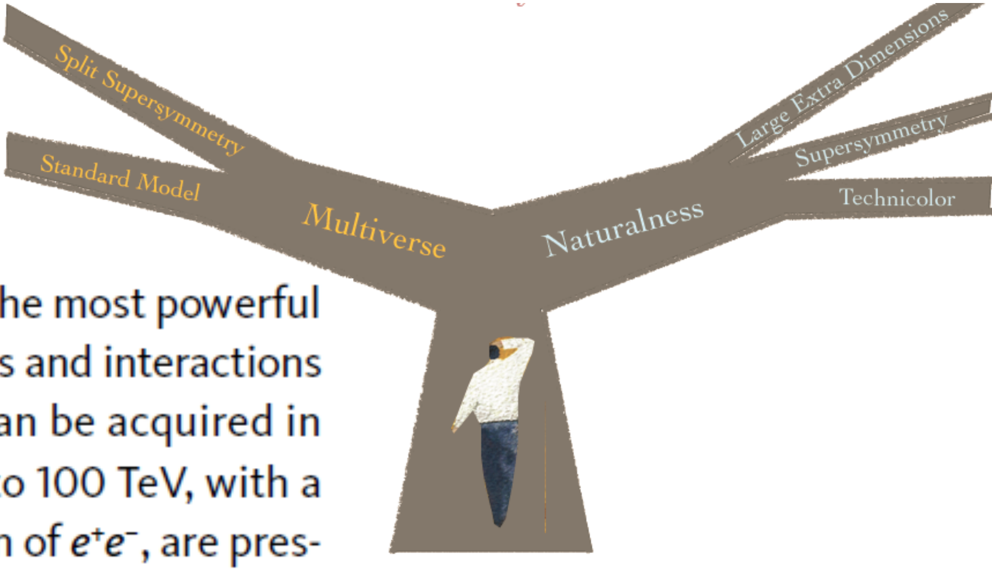
$$m_H^2 - m_{H,0}^2 \sim -\frac{3}{8\pi^2} y_t^2 \Lambda^2$$

Planck scale:
Λ ~ 10^{16} TeV ➔ 10^{-34} tuning

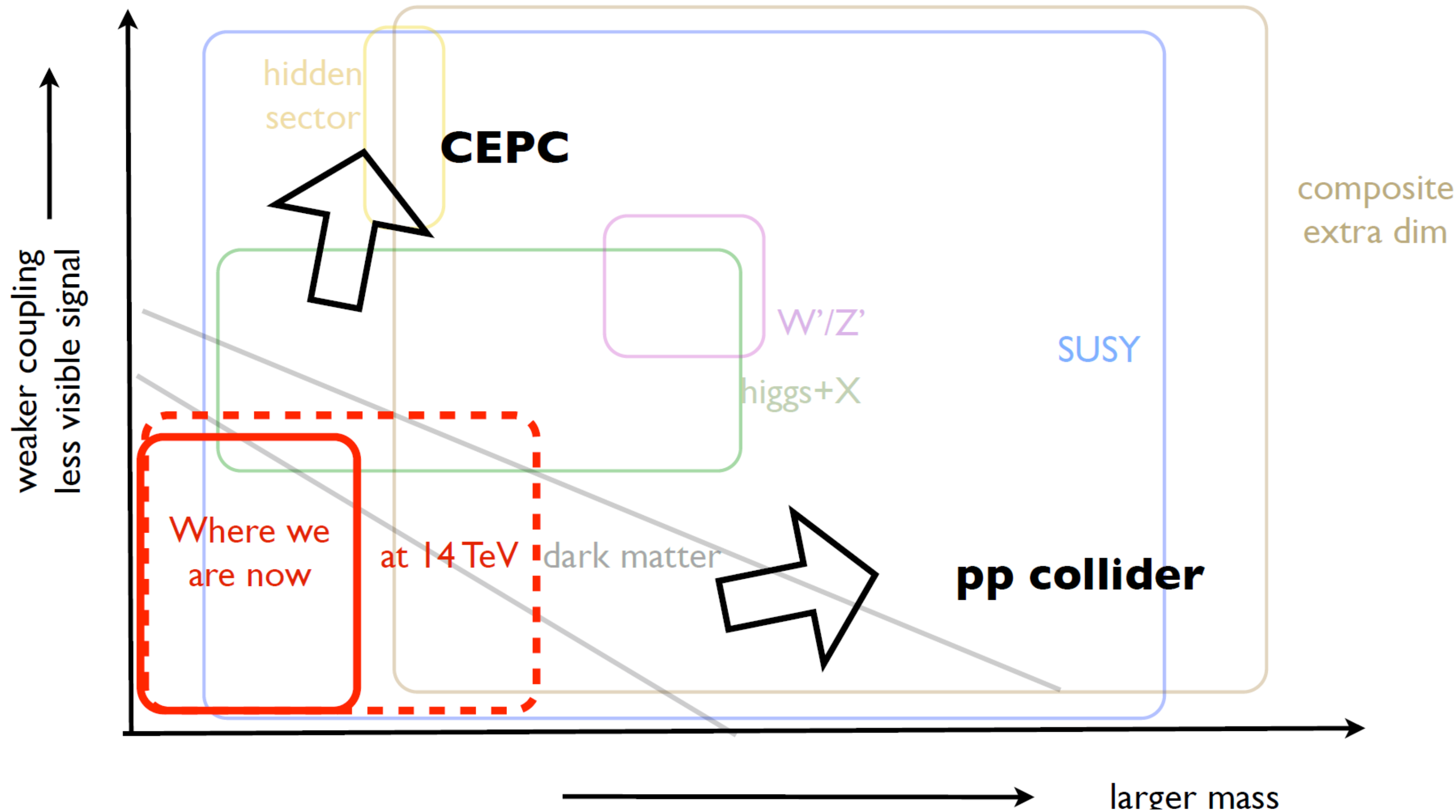
Report of the Particle Physics Project Prioritization Panel

Strategic Plan for U.S. Particle Physics

A very high-energy proton-proton collider is the most powerful future tool for direct discovery of new particles and interactions under any scenario of physics results that can be acquired in the P5 time window. Colliders of energy up to 100 TeV, with a circumference of about 100 km with an option of e^+e^-, are presently under study at CERN, in China, and in the U.S. Extensive



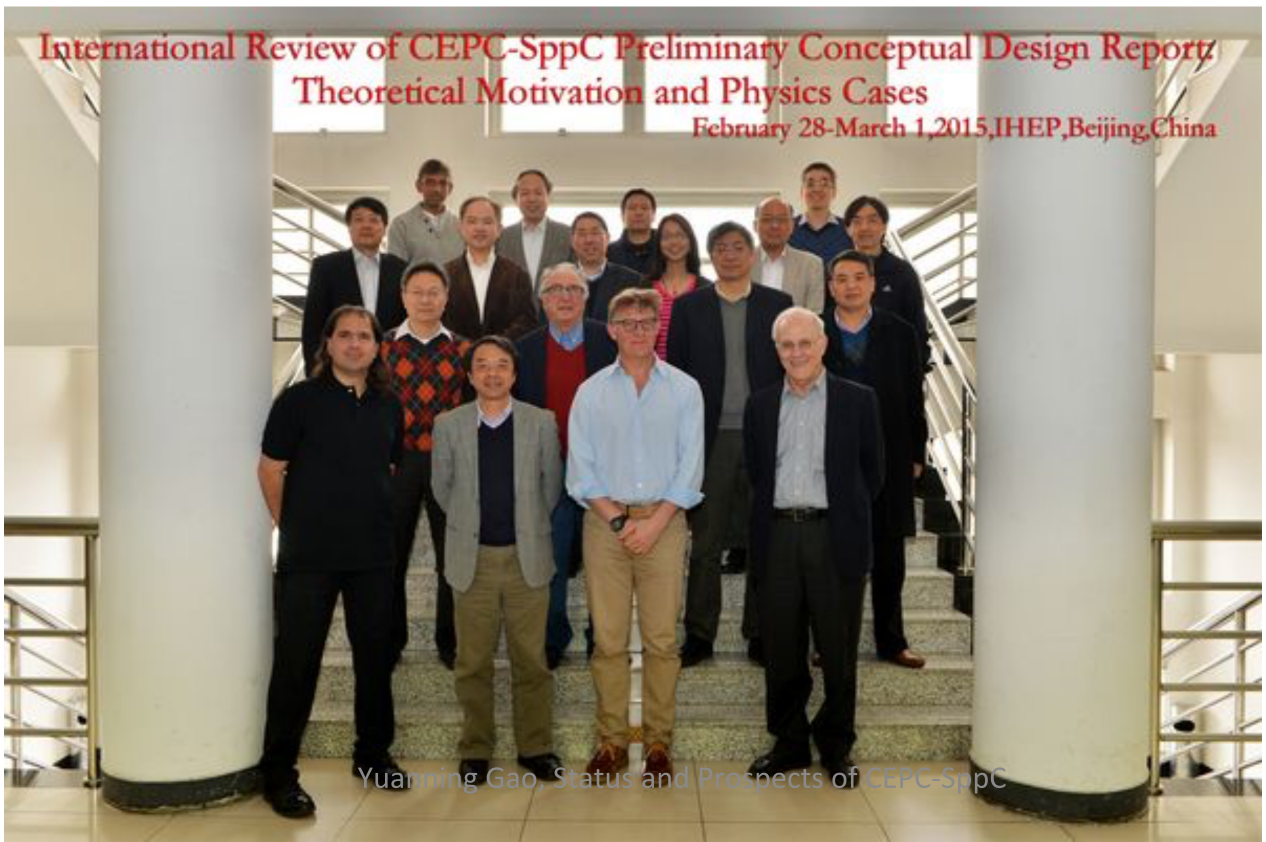
Particle Physics – the big picture



From L. T. Wang

Science case(theory)

- Review happened in Feb.28 – Mar. 1
- David Gross, M. Mangano (chair), Luciano Maiani, Raman Sundrum, Savas Dimopoulos(by video)， Hesheng Chen, Xiangdong Ji, Yueliang Wu, Guangda Zhao



Report of the International Review of CEPC-SppC Preliminary Conceptual Design Report: theoretical motivation and physics cases

The research program of the CEPC-SPPC embodies the primary future goals and ambitions of international research in High Energy Physics (HEP). These include the thorough exploration of the unification of electromagnetism with the weak nuclear force and its underlying mechanism of electroweak symmetry breaking (EWSB), as well as the solution to long-standing mysteries such as the origin of dark matter (DM), the dominance of matter over antimatter in the universe and the coexistence of very disparate distance scales in the fundamental laws describing nature from the microscopic to the cosmological scales.

These are among the most exciting and challenging issues faced by science today, driving the current research and the planning of future large-scale facilities throughout the world. Tackling this challenge would project China to world leadership in High Energy Physics. Developing such an advanced, large-scale project would also enable Chinese society to benefit from vast technological returns, in electronics, superconductivity, medical and industrial imaging, large data handling and transmission, to cite a few well-documented cases. Young generations would be deeply influenced by the intellectual excitement produced by the unraveling of the fundamental laws of Nature.

CEPC

The physics case of the CEPC-SPPC builds on three pillars: (a) the precise determination of the properties of the Higgs boson, which is the direct manifestation of and our probe into the dynamics of EWSB (b) the search for new physical phenomena through subtle deviations of precisely measured quantities from the expected Standard Model behavior and (c) through the production of new particles.

CEPC represents a logical step of the future Chinese engagement in HEP, also in view of the historical experience with electron-positron colliders. CEPC will improve the knowledge of the primary Higgs boson interactions by more than an order of magnitude with respect to what will be known at the time of its turn-on. This will magnify by a factor of 10 the picture of Higgs' properties, to a level where features signaling the existence of new physics phenomena may appear.

In these different ways, CEPC is capable of revolutionary discoveries, or of establishing for the first time that the Higgs structure significantly violates the naturalness hypothesis. In the event of new physics being discovered at the LHC, CEPC will be able to view it from different angles, crucial for uncovering the new underlying laws at work in Nature.

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.

SPPC

While the CEPC would represent a quantum jump in the exploration of fundamental physics beyond the LHC program, the fullest exploitation of the discovery opportunities presented by EWSB and correlated phenomena, and clarification of any possible anomalies found by the CEPC or LHC, strongly motivates the evolution of the project towards its SPPC stage.

The SPPC represents a necessary giant step in the progress of the field, and should be an integral component of the long-term Chinese strategy for HEP.

The committee strongly endorses the physics case of a long-term upgrade of the CEPC accelerator to a high-energy pp collider, with a target of ~100 TeV center of mass energy. The committee urges the project management to ensure that the CDR study gives high priority to the design of a tunnel in the range of 100km, to allow pp collisions at 100 TeV.

The committee strongly urges the project management to elaborate proposals for: (a) the organization and negotiation of external contributions to the accelerator construction, eventually including civil engineering works, and (b) the launching of calls for detector conception and for the formation of the proto-collaborations. Steps (a) and (b) are recommended to be taken since the early CDR phases.

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

Reviewed during Feb. 14 -16 ,2015

preCDR released on March 23

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

Accelerator Design

Accelerator design

Currently, we propose a tunnel circumference of 50 - 70 km, mainly for cost reasons.

CEPC basic parameters:

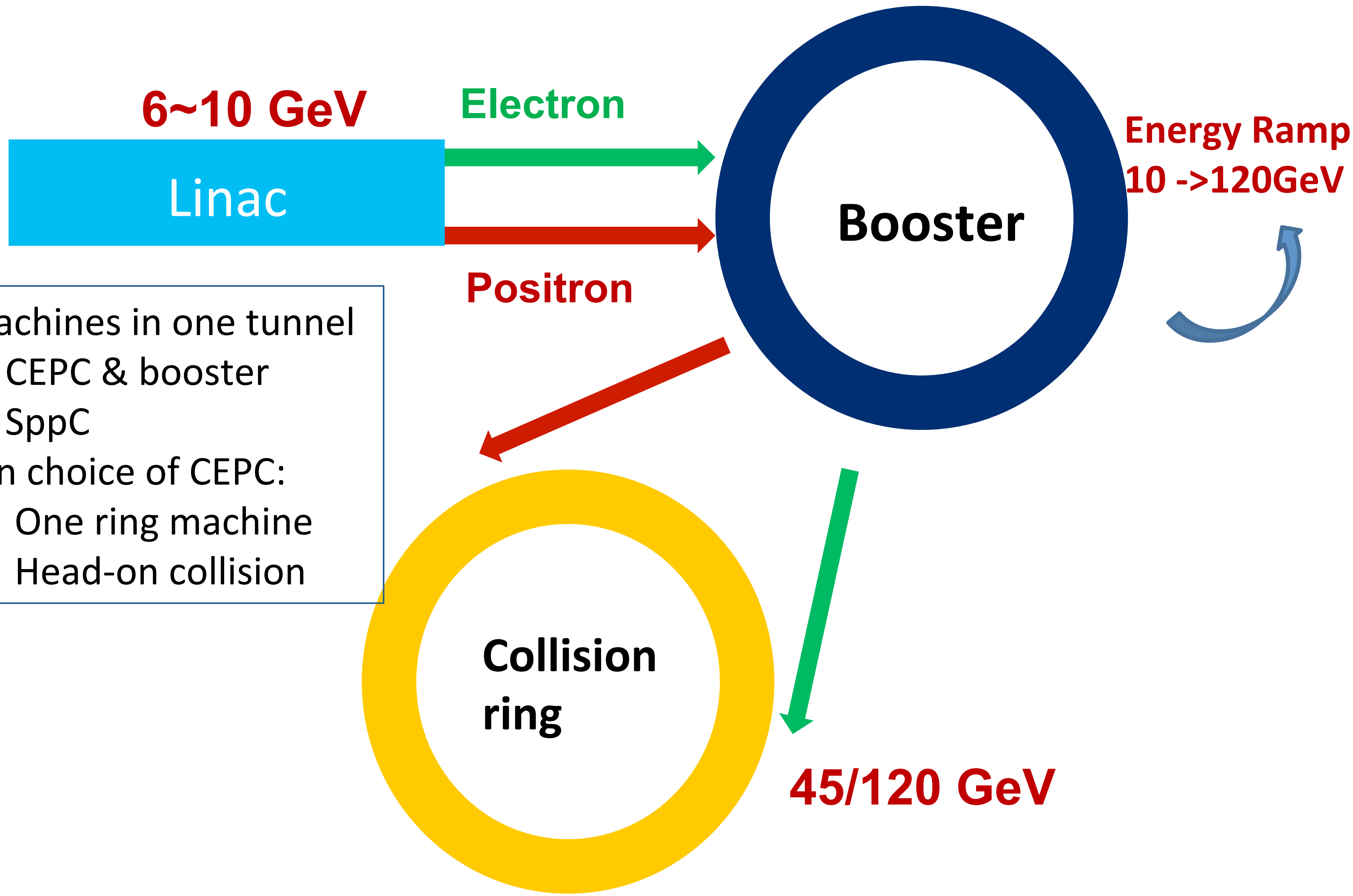
- Beam energy ~ 45 - 120 GeV.
- Synchrotron radiation power ~50 MW.

SppC basic parameters:

- Beam energy ~ 50 - 90 TeV
- B_{max} ~ 12 - 20T

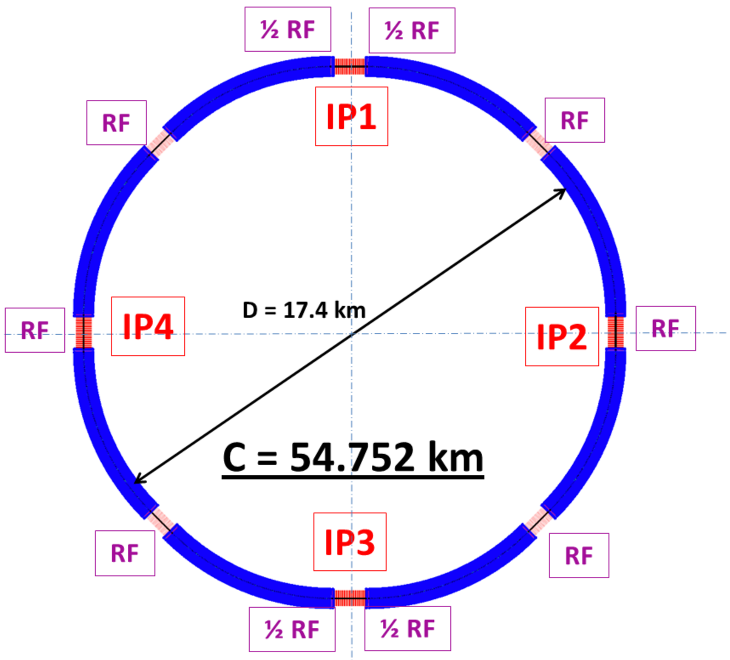
CEPC Accelerator

- 3 machines in one tunnel
  - CEPC & booster
  - SppC
- Main choice of CEPC:
  - One ring machine
  - Head-on collision



General info of CEPC

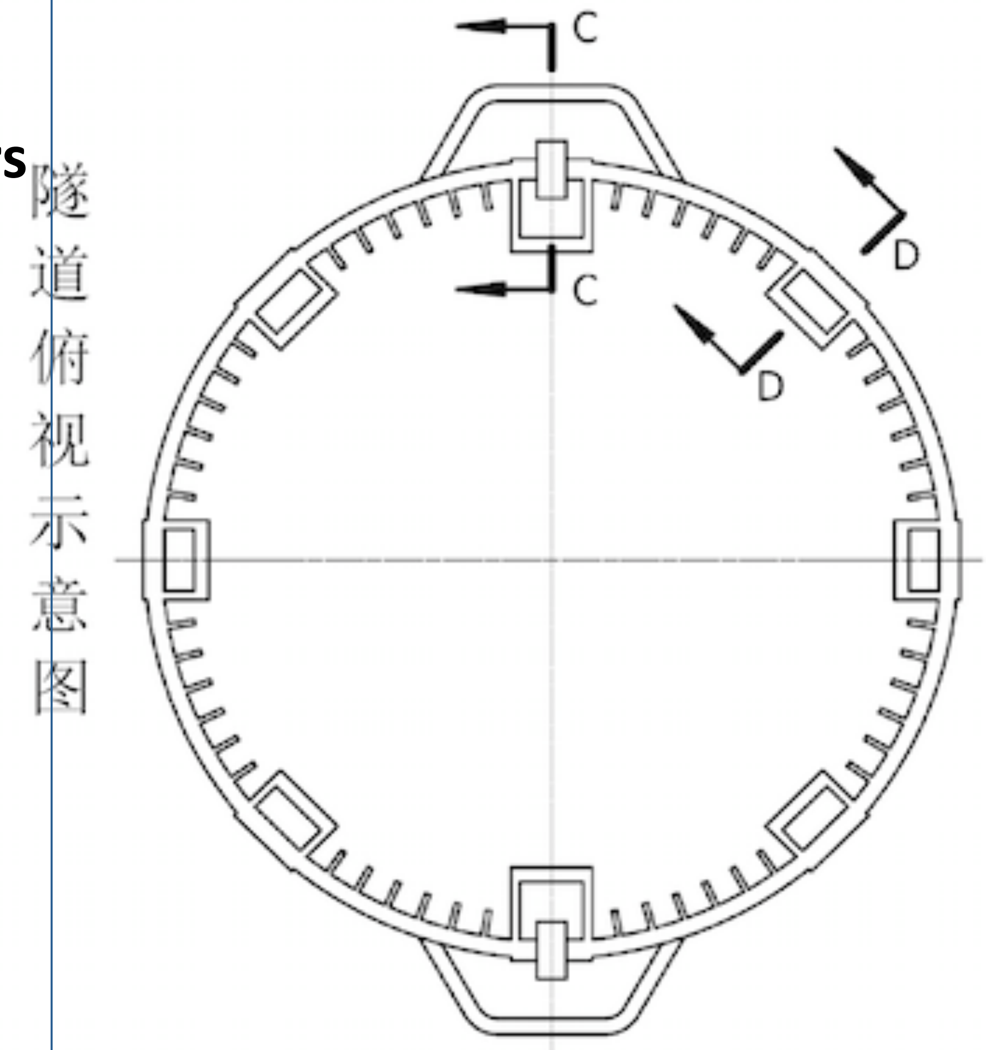
- CEPC is a Circular Electron Positron Collider to study the Higgs boson
- Critical parameters:
  - Beam energy: 120GeV
  - Circumference: 54 km
  - SR power: 51.7 MW/beam
  - 8*arcs
  - 2*IPs
  - 8 RF cavity sections (distributed)
  - Filling factor of the ring: ~70%

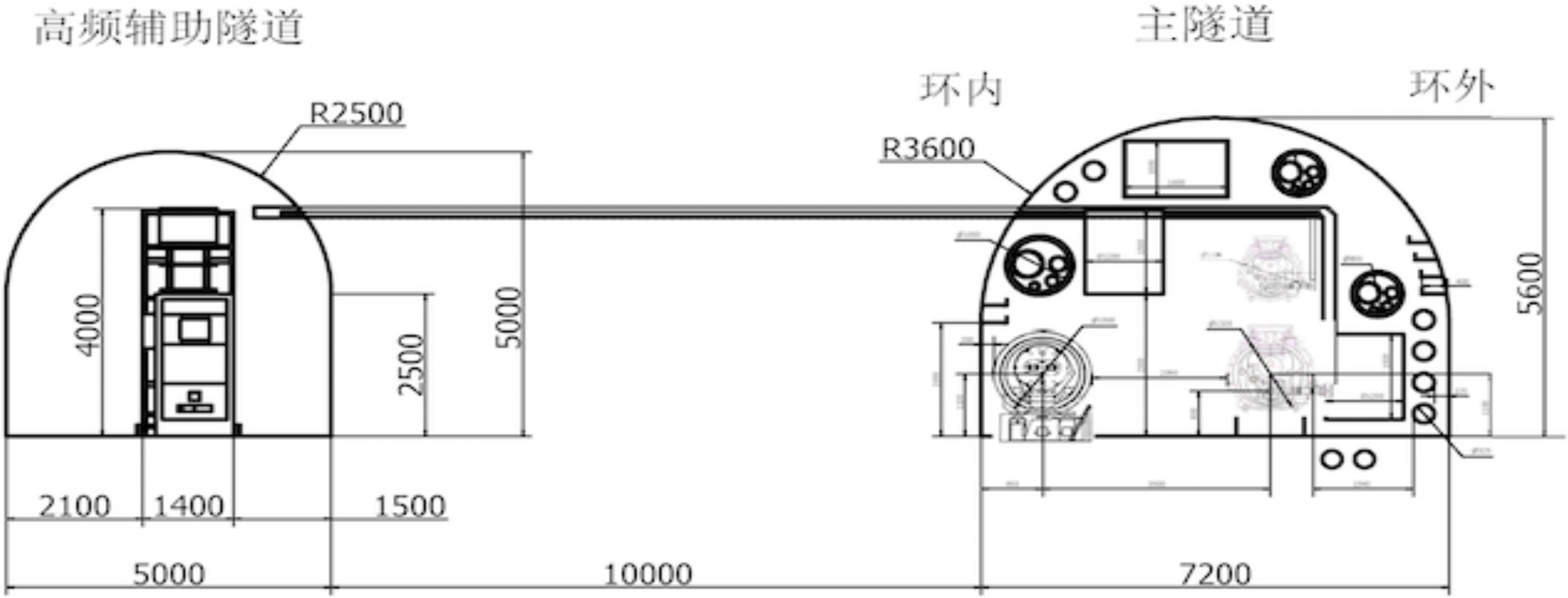


- Length of the straight sections are compatible with SppC requirement

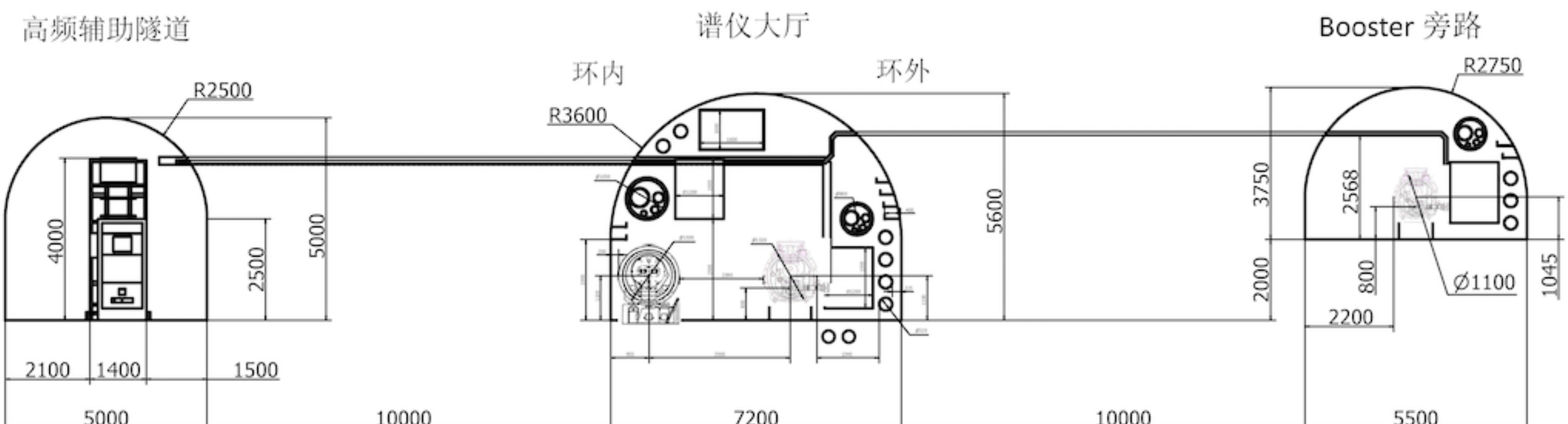
Compatibility: a Complicated Issue

- CEPC Injector
- SPPC injector
- Beam pipe detour for detectors
  - CEPC booster avoid storage ring
  - CEPC avoid SPPC detectors
  - SPPC avoid CEPC detectors
- SR beamlines
- Predict what SPPC needs
  - Collimators
  - Straight sections
  - Tunnel dimensions
  - Access tunnel
  - ....
- To be fully understood in the next 5 years





高频辅助隧道
主隧道
环内
环外
R2500
R3600
4000
2500
5000
5600
2100
1400
1500
5000
10000
7200



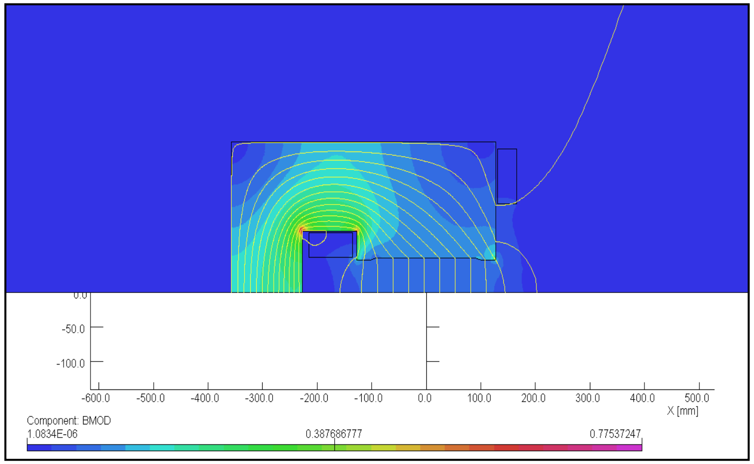
高频辅助隧道
谱仪大厅
Booster 旁路
环内
环外
R2500
R3600
R2750
4000
2500
5000
5600
3750
2568
2000
800
1045
Ø1100
2200
2100
1400
1500
5000
10000
7200
10000
5500

Priliminary CEPC parameter list

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	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	β_{IP}(x/y)	mm	800/1.2
Transverse size (x/y)	μm	69.97/0.15	$\xi_{x,y}$/IP		0.118/0.083
Beam length SR [$\sigma_{s.SR}$]	mm	2.14	Beam length total [$\sigma_{s.tot}$]	mm	2.65
Lifetime due to Beamstrahlung (simulation)	min	47	lifetime due to radiative Bhabha scattering [τ_L]	min	52
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 [Jε]		2
Energy spread SR [$\sigma_{\delta.SR}$]	%	0.132	Energy spread BS [$\sigma_{\delta.BS}$]	%	0.119
Energy spread total [$\sigma_{\delta.tot}$]	%	0.163	n_γ		0.23
Transverse damping time [n_x]	turns	78	Longitudinal damping time [n_ε]	turns	39
Hourglass factor	Fh	0.658	Luminosity /IP[L]	$cm^{-2}s^{-1}$	2.04E+34

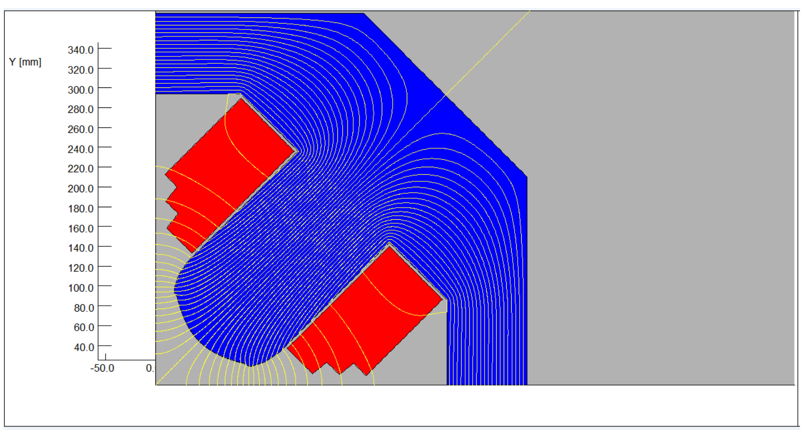
CEPC magnet deisgn

Dipole

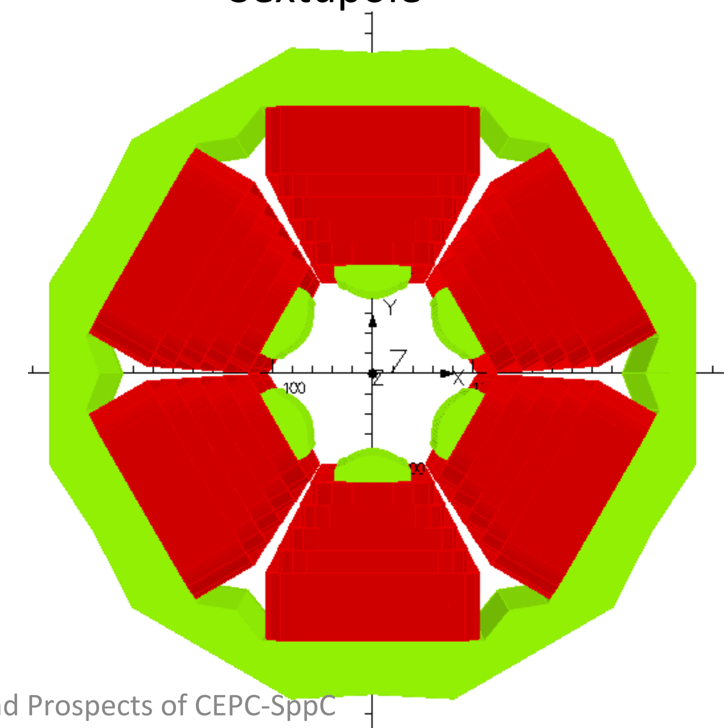


- 2432 dipole magnets, length 19m
- 1436 quadrupole magnets, length: 1m
- 1280 sextupole magnets, length: 0.4m
- Prototype will be made and tested first

Quadrupole



Sextupole



Courtesy of W. Kang

Vacuum chamber material

Courtesy of H. Dong

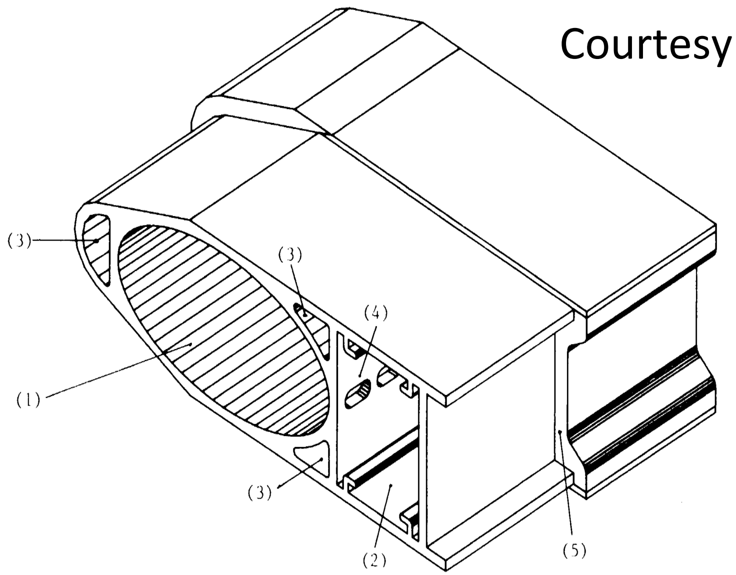
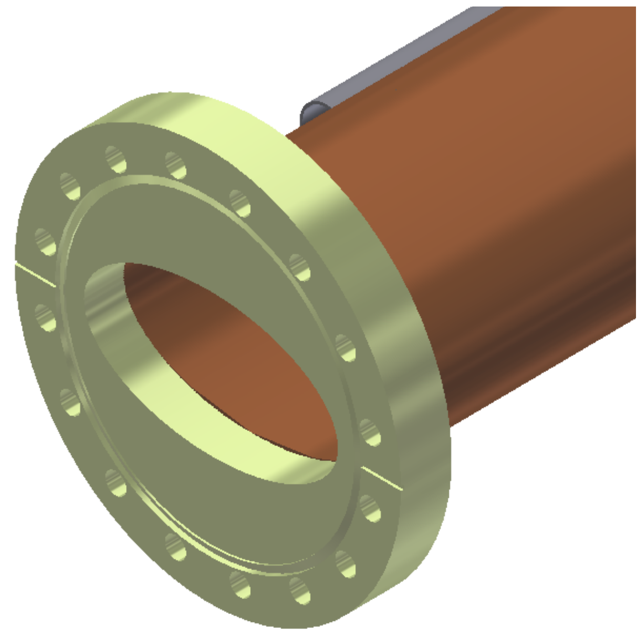


Fig. 8.4 LEP dipole vacuum chamber, with: 1) the elliptic beam channel (131 mm × 70 mm); 2) the rectangular pumping channel where the NEG strip is mounted; 3) three cooling channels; and 4) the pumping slots. The lead shielding (5) varies between 3 and 8 mm in thickness.

LEP aluminum vacuum chamber (11.7m long)



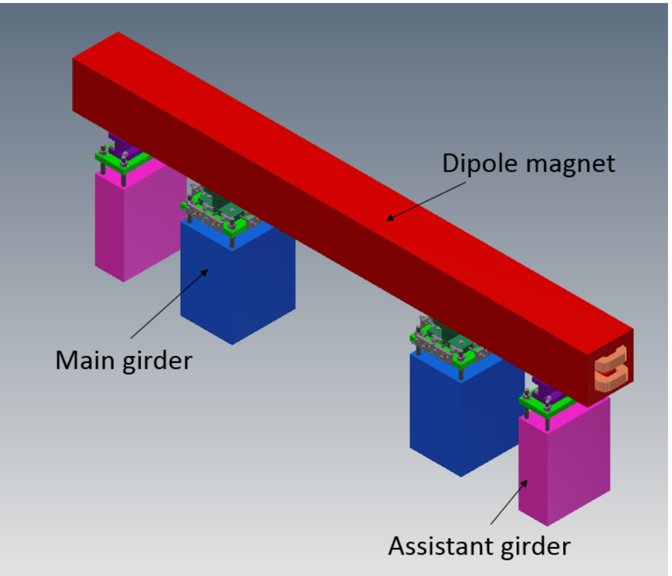
CEPC copper vacuum chamber
(elliptical100×55, thickness 6, length 8000)

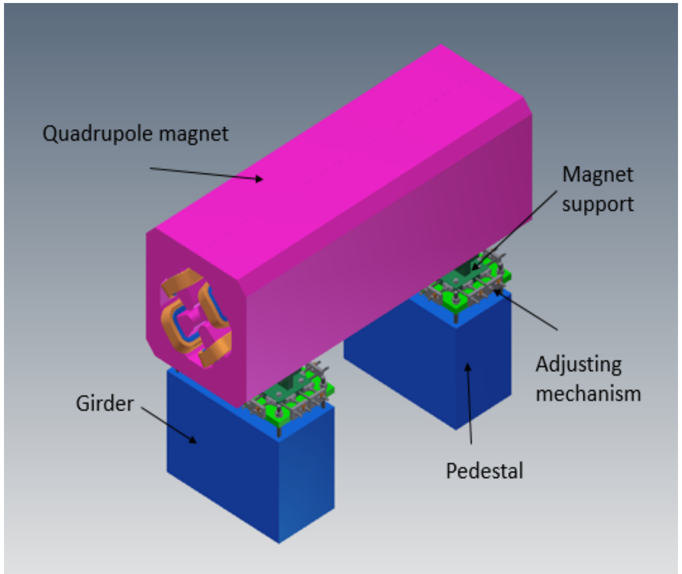
- Copper is prefered in CEPC dipole chamber design.
- SR power, gas load, pumping system, vacuum measurement and control were considered and designed in detail.

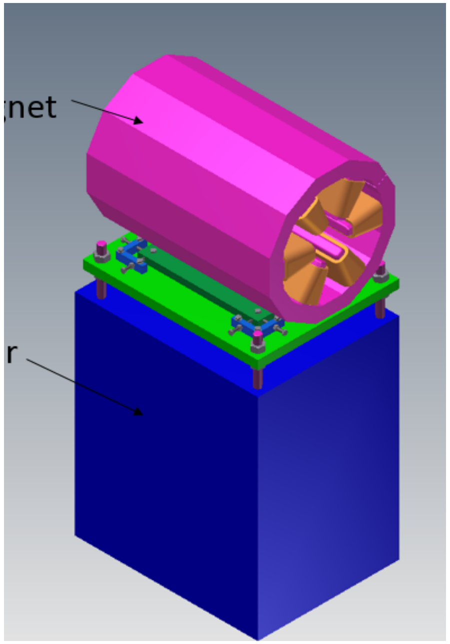
Girder system design

- Dipole girder system
- Quadrupole girder system
- Sextupole girder system
- Booster girder system

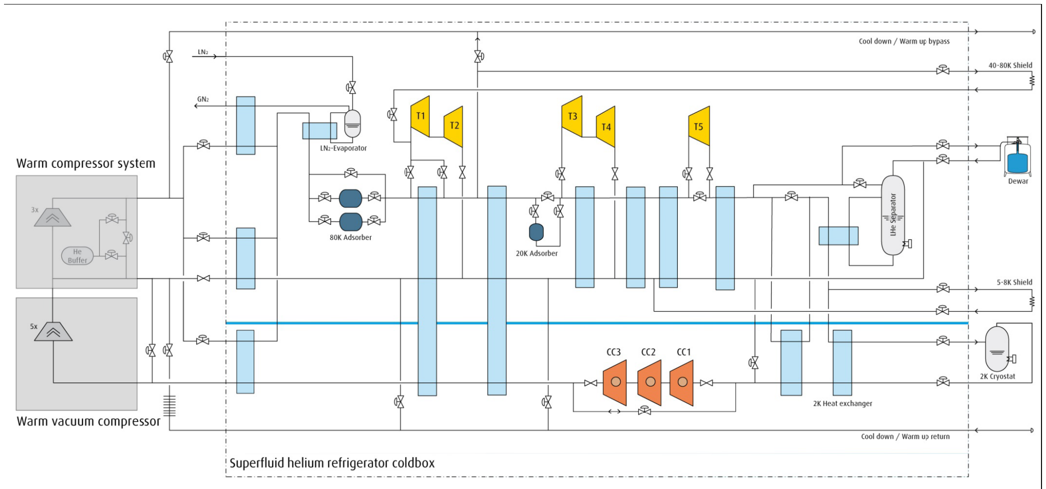
Courtesy of W. Kang

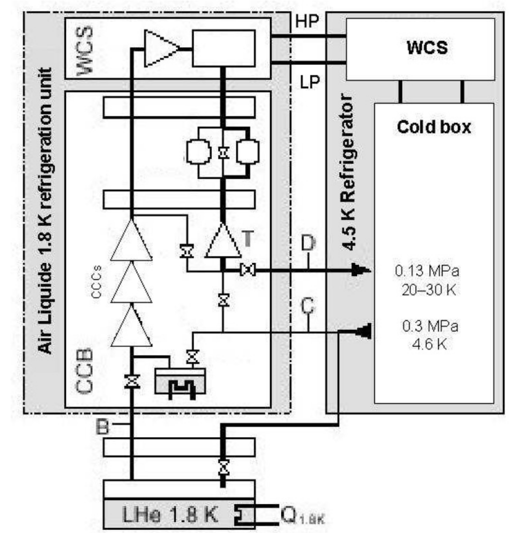






Cryogetic system design



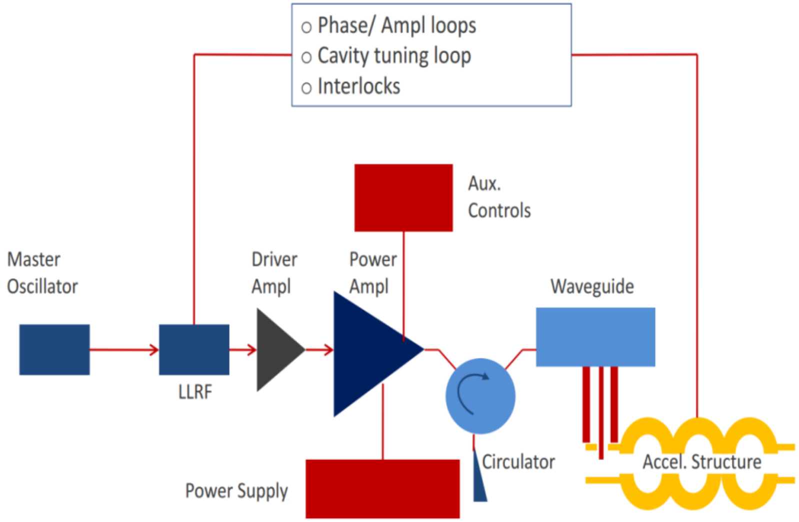


- The total heat loads of CEPC cryogenic system was estimated.
- The required refrigeration capacity is similar as that in LHC cryogenic system, which is the biggest in the world.
- The helium inventory is not so large and it is about 9.6% of LHC.
- The electric power consumption is huge and about 5.6% of CEPC.

Courtesy of S. Li

Power source design

Collider ring



The RF power delivered by the klystron will be fed into the cavity via a WR1500 waveguide as well as a circulator.

Courtesy of Z. Zhou

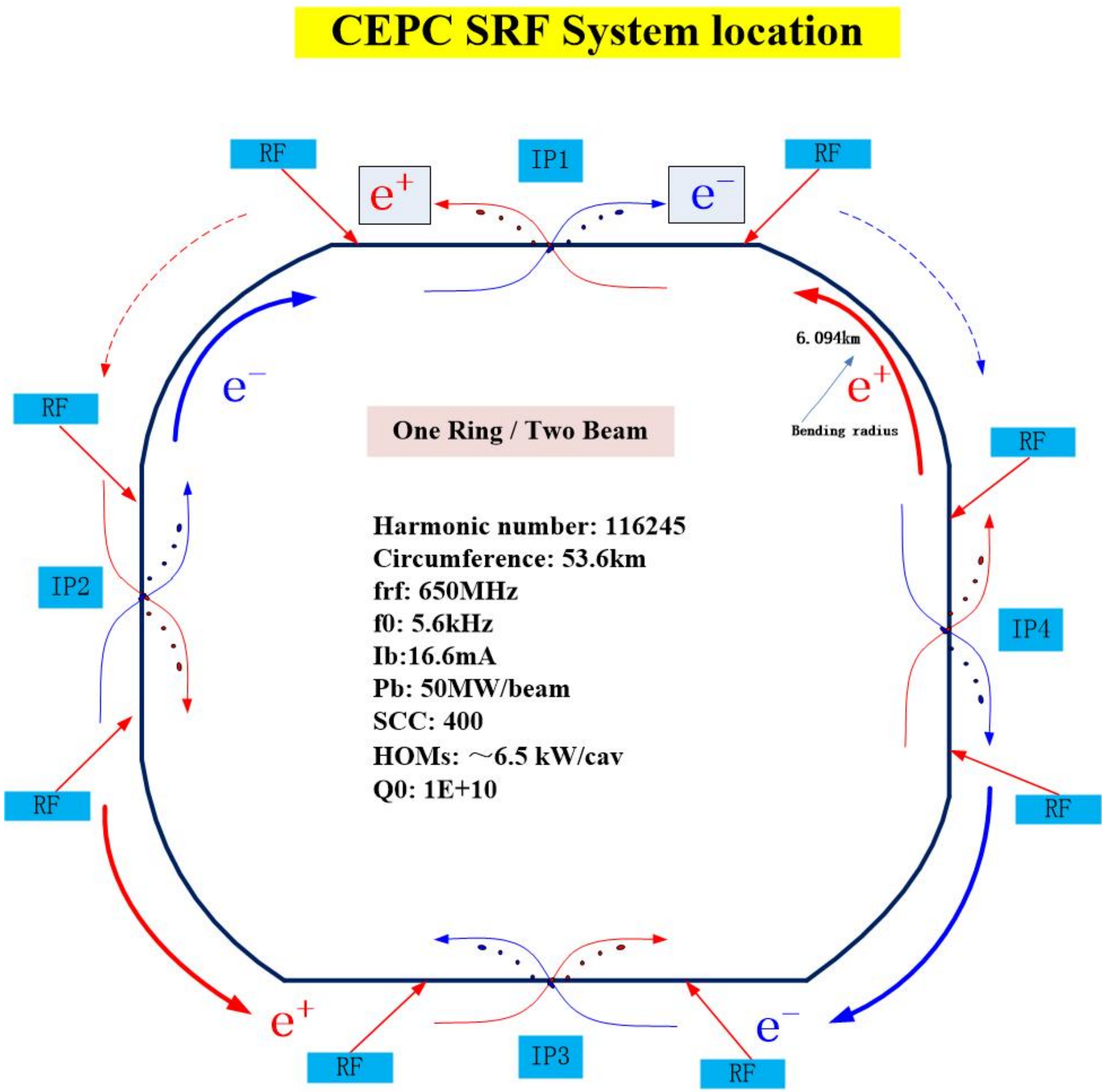
Booster ring

Source options @1. 3GHz/20kW level

1) Klystrons become costly per W at low power and lowest cost verisons only ~ 40 % efficient;
2) IOTs have higher efficiency (~ 60 %) but higher cost ;
3) Solid State Amplifiers (SSAs) cost competitive but currently have low efficiency (35%) - however, high availability (modular), and cost likely to decrease and efficiency increase (expect > 40 % soon).

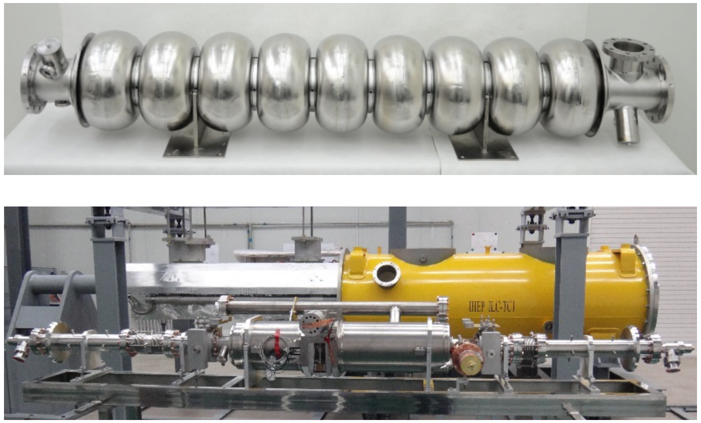
So Booster source option is Solid State Amplifier (SSA)

Key Technical System: SRF

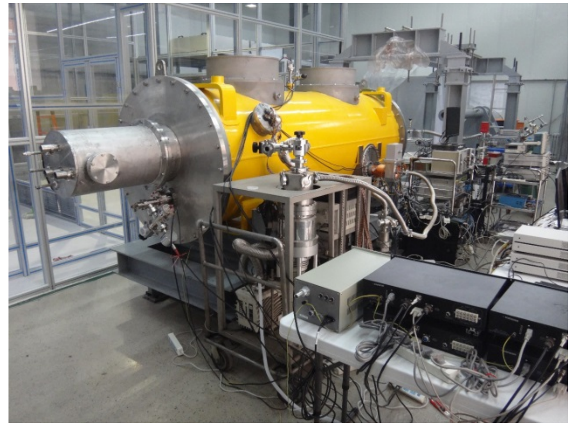


90cavities
180m

IHEP SRF Key Technology Experience



1.3 GHz 9-cell cavity
vertical test 20 MV/m, Q_0=1.4E10



1.3 GHz test cryomodule
horizontal test soon

12 m 1.3 GHz cryomodule
for Euro-XFEL

650 MHz β=0.82 5-cell cavity
vertical test soon

500 MHz coupler
420 kW CW TW

HOM absorber
ferrite 6kW

500 MHz cavity module
horizontal tested

SppC Design

- Proton-proton collider luminosity

$$L_0 = \frac{N_p^2 N_b f_{rep} \gamma}{4\pi \varepsilon_n \beta_{IP}} F \qquad (F = \sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\sigma_{x,IP}}\right)^2}) \qquad \xi = \frac{N_p r_p}{4\pi \varepsilon_n} \leq 0.004$$

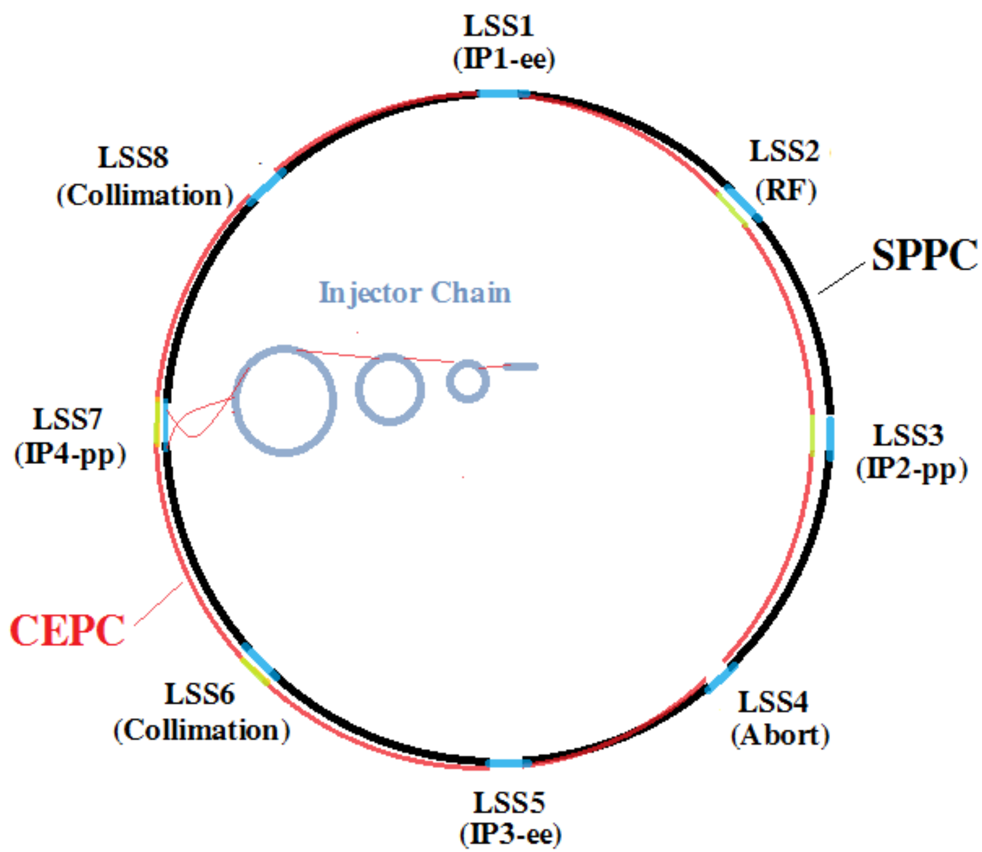
- Main constraint: high-field superconducting dipole magnets
  - **50 km**: B_{max} = 12 T, E = 50 TeV
  - **50 km**: B_{max} = 20 T, E = 70 TeV
  - **70 km**: B_{max} = 20 T, E = 90 TeV

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

General layout

SPPC rings:

- 8 arcs (5.9 km) and long straight sections (850m*4+1038.4m*4)
- 2 IPs for pp (perhaps one at IR6 for e-p in the future)
- 2 IRs for e+e detectors (pp: injection, RF?)
- 2 IRs for collimation
- 2 IRs for RF and beam abort



Courtesy of J.Y. Tang

SppC main parameters (very preliminary)

Parameter	Value	Unit
Circumference	54.36	km
Beam energy	35.3	TeV
Dipole field	20	T
Injection energy	2.1	TeV
Number of IPs	2 (4)	
Peak luminosity per IP	1.2E+35	$cm^{-2}s^{-1}$
Beta function at collision	0.75	m
Circulating beam current	1.0	A
Max beam-beam tune shift per IP	0.006	
Bunch separation	25	ns
Bunch population	2.0E+11	
SR heat load @arc dipole (per aperture)	56.9	W/m

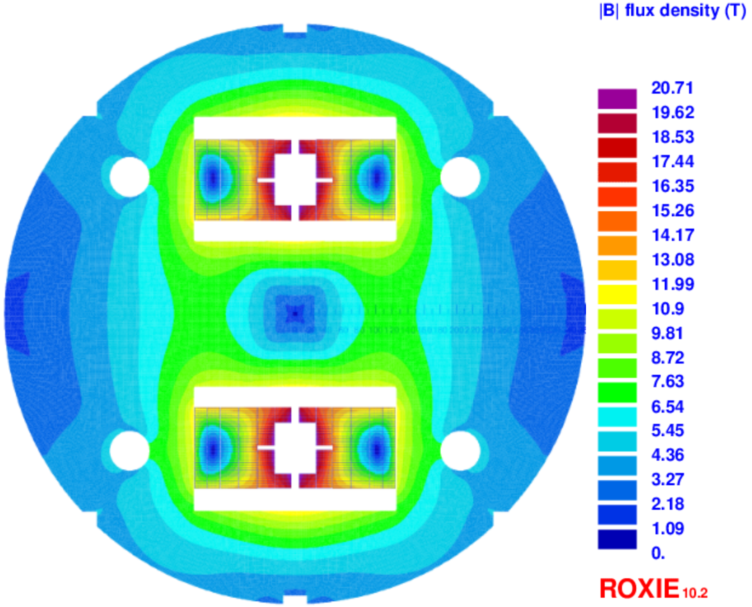
Main Features

- **High luminosity: 1.2×10^{35} cm^{-2}s^{-1}**
  - Supported by powerful injector chain and strong focusing at IPs
  - Integrated luminosity enhanced by emittance damping (synchrotron radiation)
- **High synchrotron radiation power: 56 W/m @dipole**
  - High current: 1 A (similar to HL-LHC)
- **Machine protection by sophisticated collimation system (6.3 GJ per beam; inefficiency: 10^{-7})**
- **Instability issues**
  - Electron cloud, resistive wall (beam screen) etc.
- **Challenges in lattice design**
  - Insertion lattice (IP, injection, extraction, collimation)
  - Compatible with the CEPC rings

Challenges

- **High field magnets: both dipoles (20 T) and quadrupoles (pole tip field: 14-20 T).**
- **Beam screen and vacuum: very high synchrotron radiation power inside the cold vacuum:**
- **Collimation system: high efficiency collimators in cold sections: new method and structure ?**
- **……**

A R&D plan is developed.
Main focus is the magnet

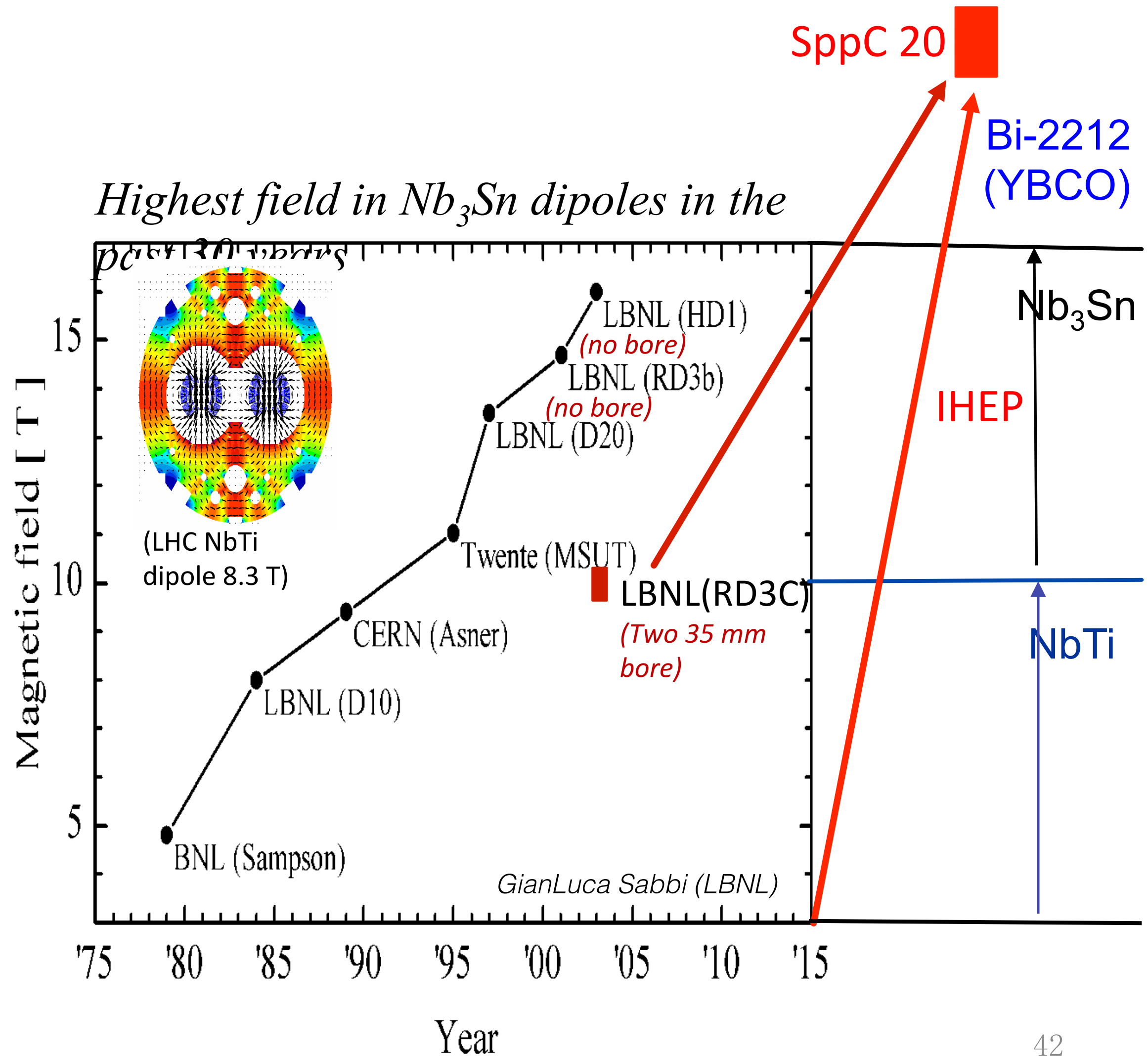


SppC Key technology

- **High field superconducting dipole magnet（20T）**

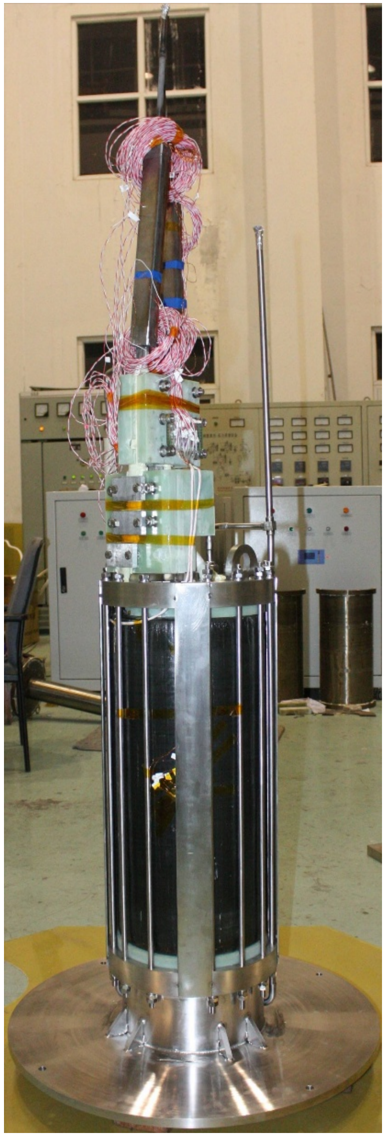
- **Currently at LHC： 8.3 T**
- **Currently in the Lab: 11.5 T**
- **Testing magnet at LBNL (Nb_3Sn) ： 14 T**
- **Goal： Nb3Sn 15 T + HTS 5 T ➔ 20 T**

A long way to go !
International coll. !



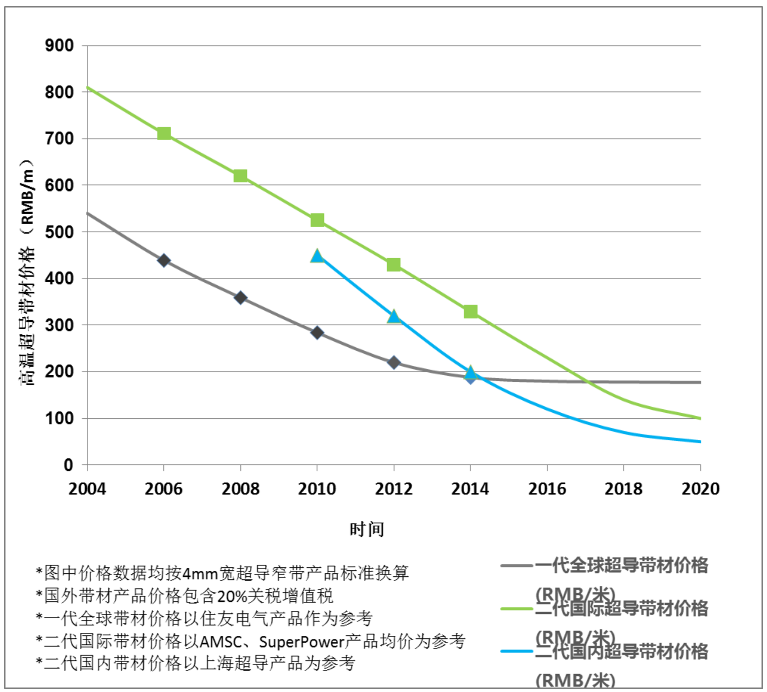
China Can Play a Role

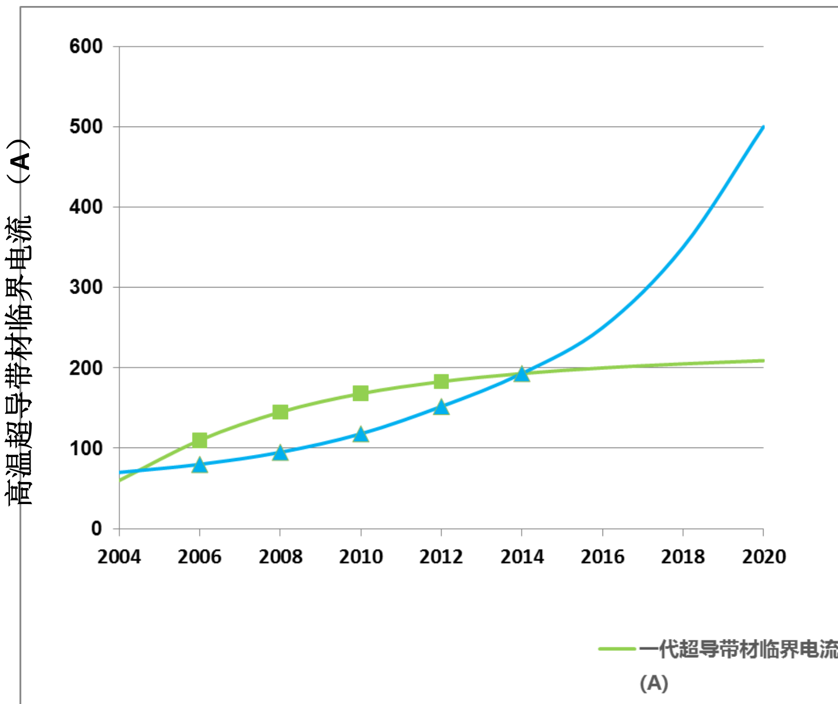
- Most of the rare earth materials from China
- China provided more than half superconducting cables to ITER
- Easy to get government support
- Past experience:
  - Superconducting solenoid magnets at IHEP
  - 11T Nb_3Sn magnet under development
  - Several companies with capabilities to manufacture Nb_3Sn, YBCO, Bi-2212 and Bi-2223 cables



Future of Superconducting cables：predictions (Y.F.Wang)

- Cost per meter is decreasing by ~ 3 times per 10 years
- Current limit per unit area is increasing by ~3 times per 10 years
- Unit price per meter can improve by ~20 times over 20 years, if past data can be used to predict the future ! This is all we need !





Accelerator Review

- Review happened in Feb.14 – 16
- Chaired by K. Oide
- Members:

Katsunobu Oide	KEK
Zhao Zhengtang	SSRC
Ilan Ben-zvi	BNL
John Seeman	SLAC
Eugene Levichev	BINP
Mike Koratzinos	CERN/U. Geneva
Bob Rimmer	Jlab
Marica Biagini	INFN
Ralph Assmann	DESY

Review Committee Report

The design work of CEPC has started just about a year ago. Tremendous effort has been made to prepare the *Preliminary Conceptual Design Report,* which is now nearly ready, and covers the entire project comprehensively. **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.**

The committee believes that the CEPC project and the required R&D will strengthen China's technological capacities in several areas, for example high-efficiency solid-state amplifiers, high-temperature superconducting materials and superconducting RF technology. Important spin-offs for industrial applications can be expected.

The committee appreciates the efforts to maximize the synergy with possible worldwide collaborators for an eventual CEPC consortium. This approach is applauded and the committee thinks that a strong international consortium can form around this approach, involving the leading accelerator laboratories of the world.

frontier. **The merit of this proposal is that the e+e- experiment starts as early as possible and will run concurrently with the HiLumi LHC. The construction of CEPC will not wait for the completion of the R&D for SPPC, relying on its progress during the CEPC construction and running period.**

Response to the Charge Letter

1. 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.
2. The design goals are well defined and comprehensive. We provided remarks and recommendations to improve the design, but we definitely consider this design to be credible and with sufficiently conservative assumptions.
3. The great majority of the accelerator physics issues are adequately addressed, and after addressing our recommendations, we expect that all the accelerator physics issues would be adequately addressed.
4. The designs of the technical systems and conventional facilities are effective for achieving the performance goals.
5. We find the CEPC design compatible with the future upgrade to the SPPC.
6. Technical risks and their potential impact were presented together with mitigation measures, while in some cases more study and R&D are needed.
7. The R&D program is clearly defined, and while we recommended a few additional R&D items, the program is adequate. We further believe that this R&D program will be highly beneficial to the science and technology infrastructure in China and will contribute to its economy.
8. We made a few suggestions for improvements of the design.

Reviewed during – March 11-12,2015

preCDR release scheduled for April 10

CEPC-SPPC

Preliminary Conceptual Design Report: Physics and Detector

CONTENTS

CEPC Detector

Strategy for the detector baseline design (1)

- **ILC detectors, especially ILD as a reference**
  - state-of-the-art detector, maximize the potential of the (rather expensive) machine
  - (hopefully) less technology challenges than ILD
  - take advantages from world-wide studies
  - sharing future critical R&D with ILC community

- **"The baseline detector" in PreCDR has similar performance as ILD, with special considerations**
  - interaction region
  - "power pulsing" not possible

Strategy for the baseline design (2)

- ILD as a reference reflects
  - manpower availability for the PreCDR
  - cost effectiveness?
  - technology maturity (in China)?
  -
- Physics at Z-pole has not been considered in-depth in the baseline design
  - Can TPC stand for (extremely) high event rate?
  - Particle Identification necessary for flavor physics?
  - Special designs to reduce systematic uncertainties of EW observables ?
  - …   → future R&D

Performance requirements of ILC detectors

- Vertexing $(h \to b\bar{b}, c\bar{c}, \tau^+\tau^-)$
  - ~1/5 $r_{beampipe}$, ~1/30 pixel size (wrt LHC)

$$\sigma_{ip} = 5\mu m \oplus 10\mu m / p\sin^{3/2}\theta$$

✔ CEPC

- Tracking $(e^+e^- \to Zh \to \ell^+\ell^- X;\quad \text{incl.}\ h \to \text{nothing})$
  - ~1/6 material, ~1/10 resolution (wrt LHC)

$$\sigma(1/p) = 5\times10^{-5}/GeV \quad \text{or better}$$

✔ CEPC

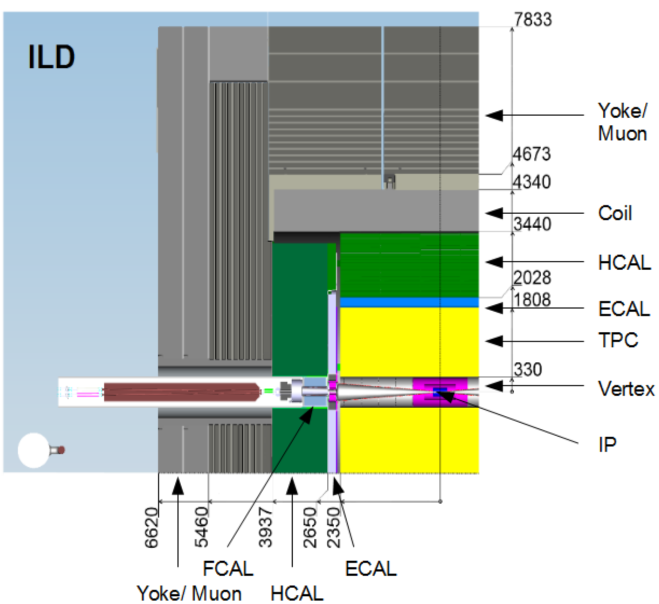
- Jet energy (Higgs self-coupling, W/Z separation)
  - ~1/2 resolution (wrt LHC)

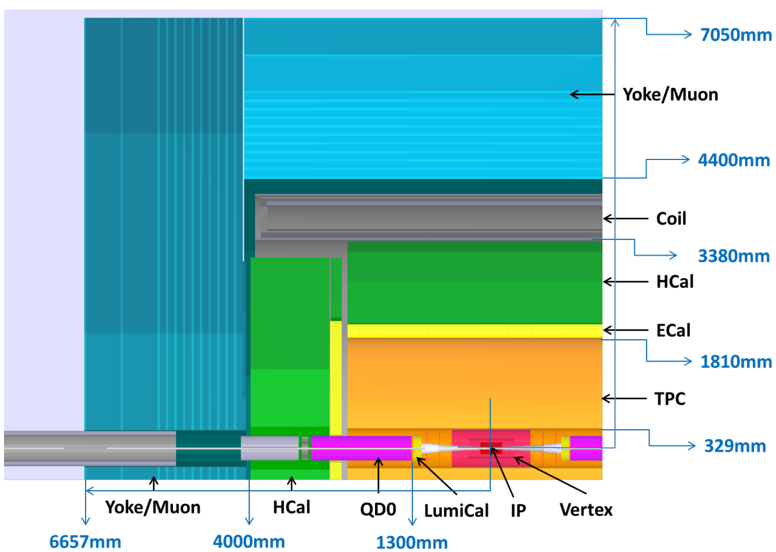
$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

less demanding at CEPC

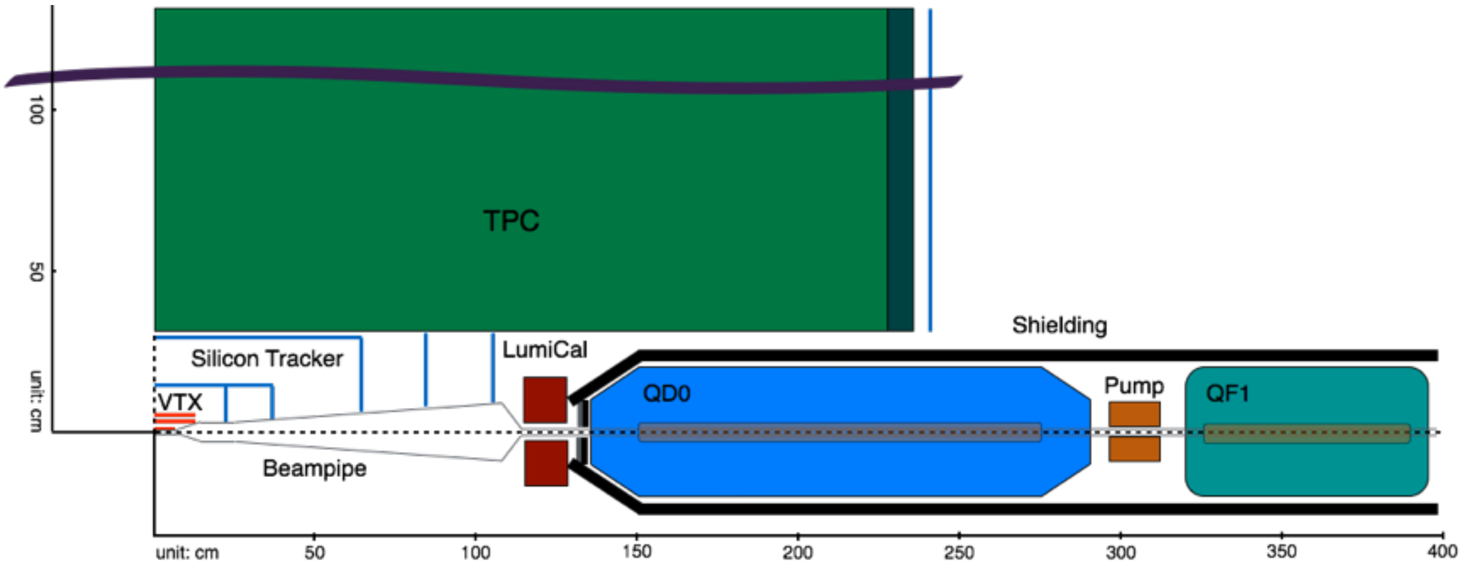
The baseline detector

- **Modifications to ILD**
  - **Less Yoke (no push-and-pull for CEPC)**
  - **Machine Detector Interface (MDI)**
  - ***Power pulsing* not possible**
- **Efforts on optimizing the size/geometry not implemented in the baseline detector, to make the comparisons easier**





Interaction region layout



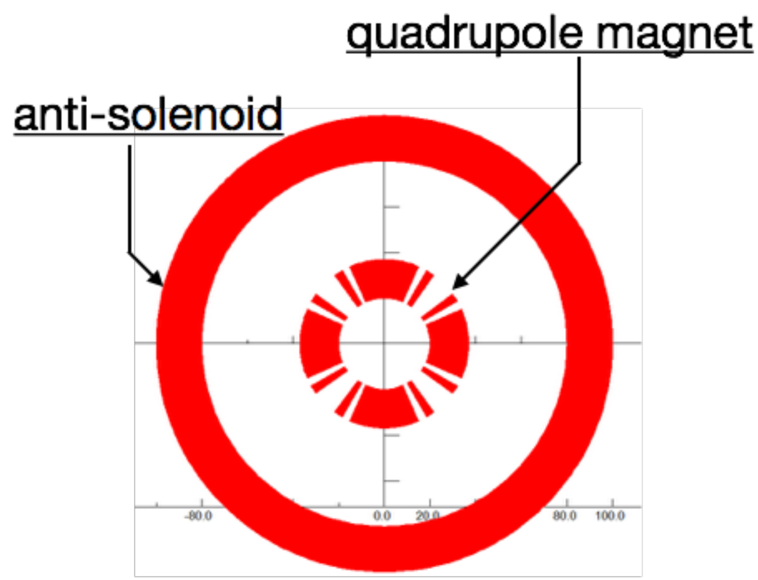
- **Short focal length of L* = 1.5 m (cf. ~3.5m at ILC)**
- **Final focusing magnets inside the detector →→ constraints on the detector design + QD0/QF1 design**
  - **No. of FTD's reduced to 5 (cf. 7 for ILD)**
  - **redesign of offline/online luminosity instrumentation**
  - **design of QD0/QF1**

Final Focusing Magnets

- Anti-solenoid (3.5 T) and quadrupole focusing magnet (6 T) → with superconducting magnet: NbTi/Nb3Sn

QD0 Parameters

Parameter	Unit	Value
Length	m	1.25
Field gradient	T/m	300
Coil inner radius	mm	20
Beampipe radius	mm	16
Cryostat diameter	mm	400



coil layout

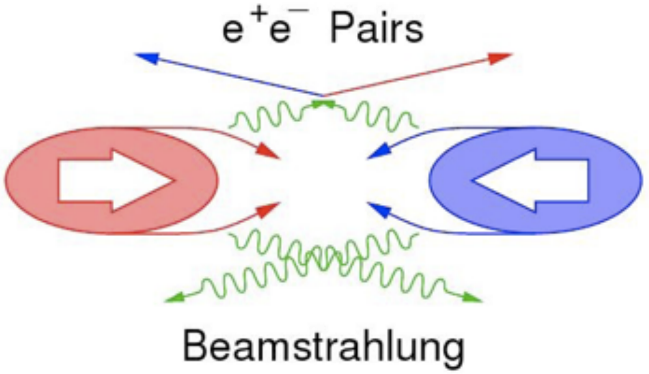
Background at CEPC

- **Background levels estimate by simulation studies**
  - **beamstrahlung**
  - **electron-positron pair production**
  - **hadronic background**

  → less critical compared to ILC
  → extra feasibility on detector design

  - **radiative Bhabha scattering**

  → proper shielding



- **Other important background sources**
  - **Synchrotron radiation**
  - **Beam-gas interactions**
  - **Beam-halo muons**
  - **Beam dumps**

  → To be minimized with careful machine design

Vertex Detector and Silicon Trackers

- Vertexing $(h \to b\bar{b}, c\bar{c}, \tau^+\tau^-)$
  - ~1/5 $r_{beampipe}$, ~1/30 pixel size (wrt LHC)

$$\sigma_{ip} = 5\mu m \oplus 10\mu m / p\sin^{3/2}\theta$$

✔ CEPC

- Tracking $(e^+e^- \to Zh \to \ell^+\ell^- X;\quad \text{incl.}\ h \to \text{nothing})$
  - ~1/6 material, ~1/10 resolution (wrt LHC)

$$\sigma(1/p) = 5\times 10^{-5} / GeV \quad \text{or better}$$

✔ CEPC

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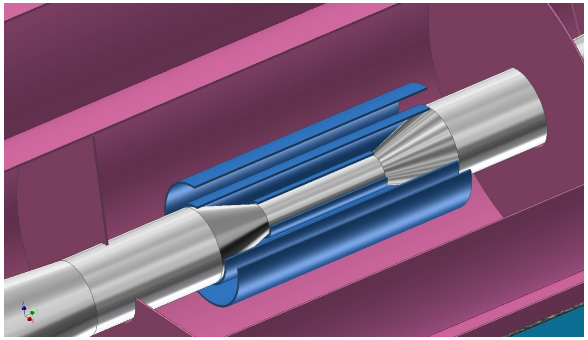
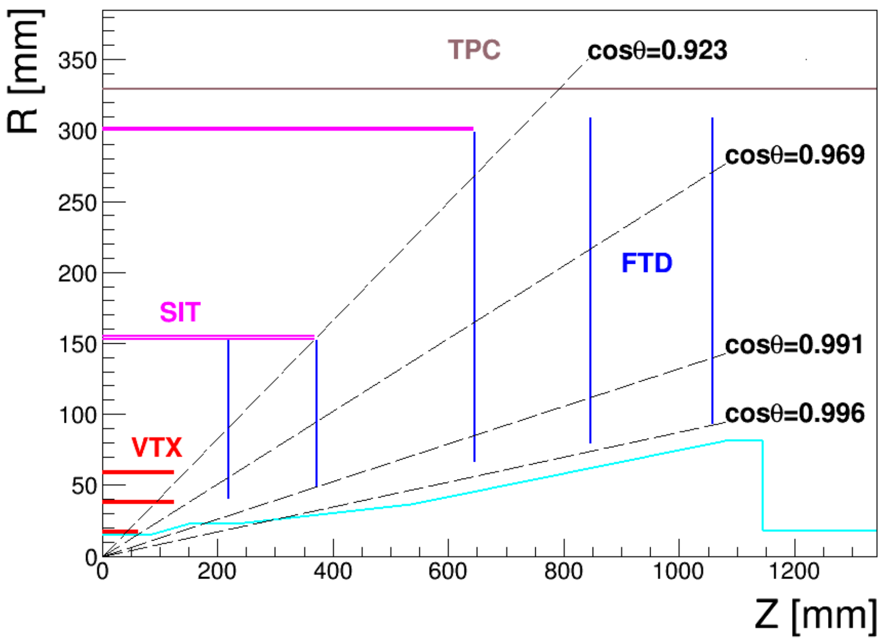
$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

less demanding at CEPC

Vertex Detector and Silicon Trackers





Vertex detector:

- 3 cylindrical and concentric double-layers of pixels

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

Silicon External Tracker (SET)

- 1 outer layer Si strip detector

End-cap Tracking Detector (ETD)

- 1 end-cap Si strip detector on each side

Vertex Detector and Silicon Trackers

Vertex detector specifications:

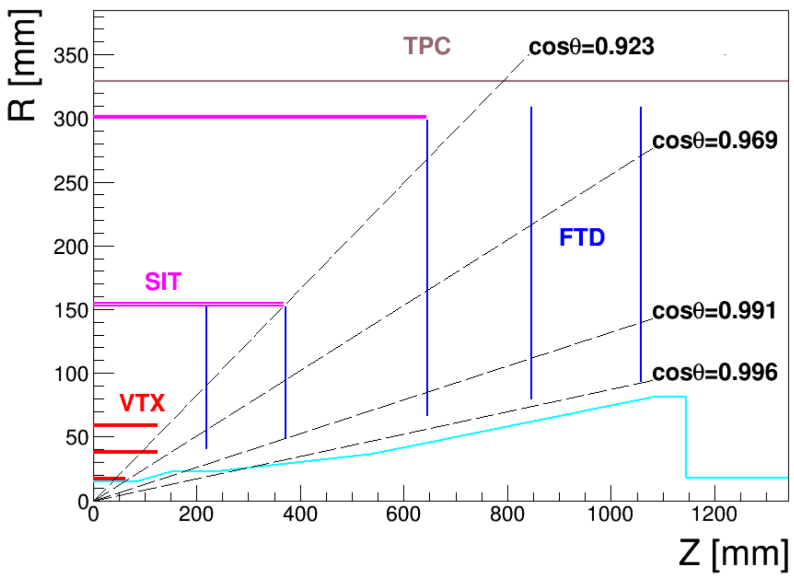
- σ_{SP} near the IP: *≤3 μm*
  - → small pixels 16×16μm^2 or below, digital readout
- material budget: *≤ 0.15%X_0/layer*
  - → low power circuits, air cooling
- pixel occupancy: *≤ 1 %*
- radiation tolerance:

  Total Ionising Does *≤100 krad/ year*

  Non-Ionising Energy Loss *≤3×10^{11}n_{eq}/ (cm^2 year)*
- first layer located at a radius: *~1.6 cm*

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

$$\sigma_{1/p_T} = 2\times10^{-5} \oplus 1\times10^{-3}/(p_T \sin\theta)$$

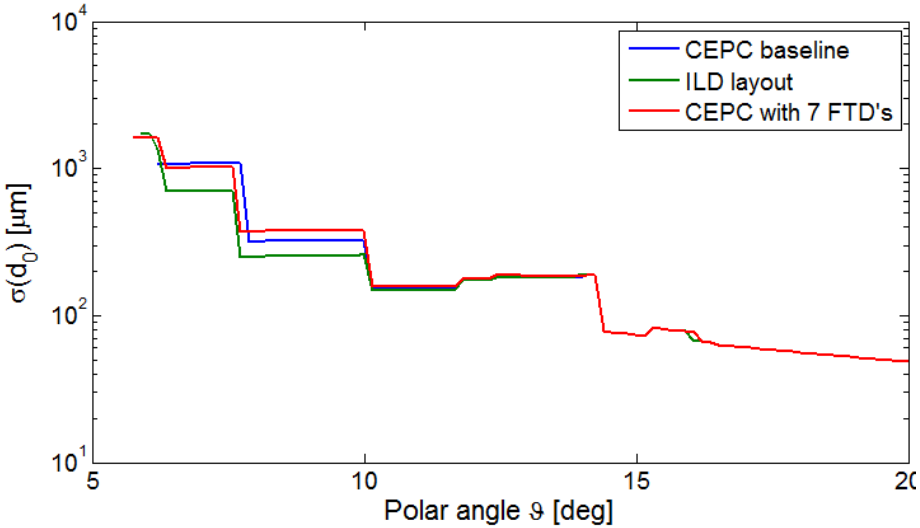


Silicon tracker specifications:

- σ_{SP} : *≤ 7 μm* → small pitch (50 μm)
- material budget: *≤ 0.65%X_0/layer*

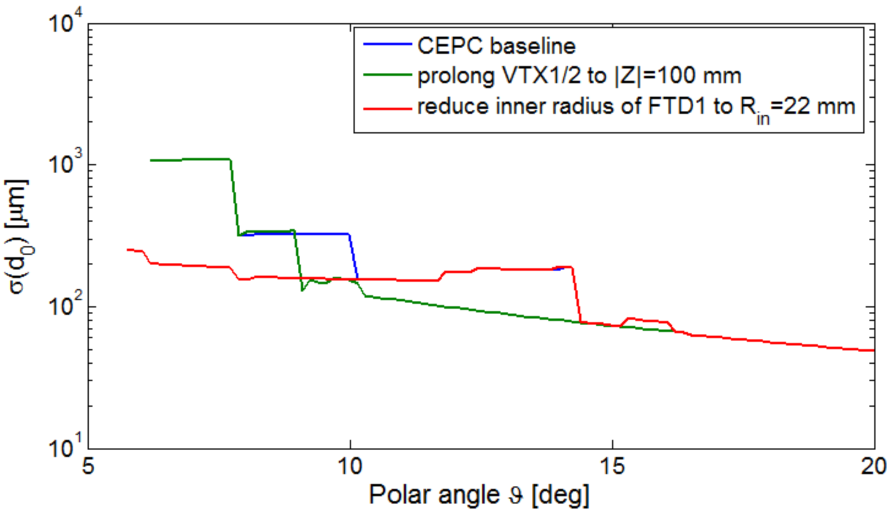
Forward region with L*=1.5m

- Impact parameter resolution studied with LDT - fast simulation using Kalman filter



Performance loss in the low polar angle region (< 10°) with reduced number of FTD disks

The performance loss can be recovered with extended coverage of the pixel detector layers, either by prolonging first two VTX barrel layers or extending the first FTD disk down to r=22mm



Technology options

Pixel sensor: power consumption < 50mW/cm^2 , if only air cooling used (CLIC study)
readout time $\leq$ 20μs

- HR-CMOS sensor with a novel readout structure —ALPIDE for ALICE ITS Upgrade
  - relatively mature technology
  - <50mW/cm^2 expected
  - Capable of readout every ~4μs
- SOI sensor with similar readout structure
  - Fully depleted HR substrate, potential of 15μm pixel size design
  - Full CMOS circuit
- DEPFET: possible application for inner most vertex layer
  - small material budget, low power consumption in sensitive area

Silicon microstrip sensor: p$^+$-on-n technology
pixelated strip sensors based on CMOS technologies

Critical R&D for VTX/FTD

- Pixel sensors with low power consumption and high readout speed

  In-pixel discriminator
  In-matrix sparsification

  Similar to ALPIDE sensor for ALICE ITS Upgrade

  – Starting design with HR-CMOS process
  – Exploring possibility with SOI process, especially for smaller pixel size
- Light weight mechanical design and cooling
  – 0.05%(0.1%) material budget without(with) cabling
  – Air cooling technology with acceptable vibration due to air flow
- Pixel sensor thinning to 50μm
- Slim edge silicon micro-strip sensors
- Low noise, low power consumption front-end electronics for silicon micro-strip detectors
- Detector layout optimization

TPC

- Vertexing $(h \to b\bar{b}, c\bar{c}, \tau^+\tau^-)$
  - ~1/5 $r_{beampipe}$, ~1/30 pixel size (wrt LHC)

$$\sigma_{ip} = 5\mu m \oplus 10\mu m / p\sin^{3/2}\theta$$

✔ CEPC

- Tracking $(e^+e^- \to Zh \to \ell^+\ell^- X;\ \text{incl.}\ h \to \text{nothing})$
  - ~1/6 material, ~1/10 resolution (wrt LHC)

$$\sigma(1/p) = 5\times 10^{-5}/GeV \quad \text{or better}$$

✔ CEPC

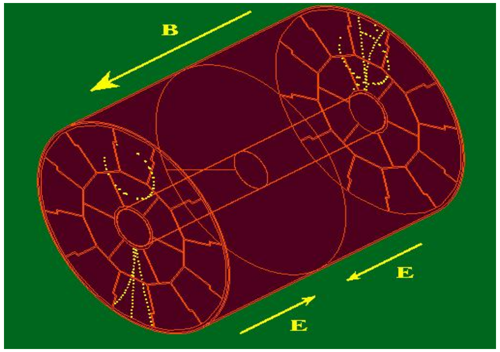
- Jet energy (Higgs self-coupling, W/Z separation)
  - ~1/2 resolution (wrt LHC)

$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

less demanding at CEPC

Performance/Design goals

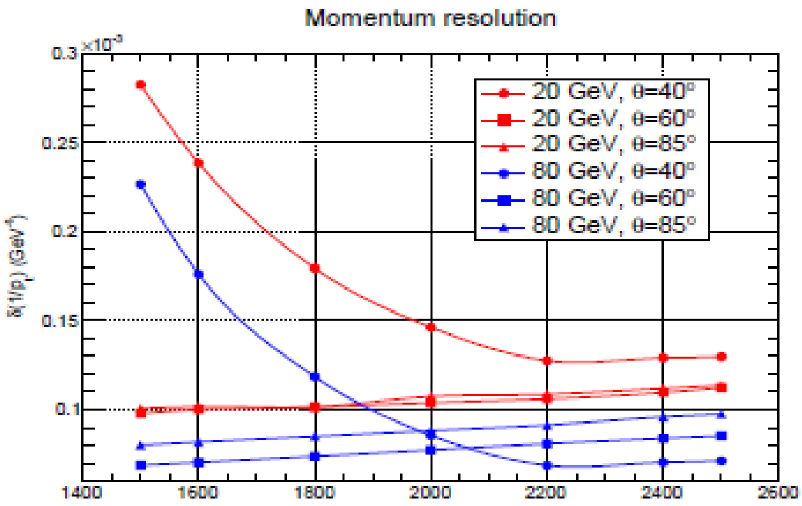
- ILD TPC Design adopted for the baseline detector at CEPC



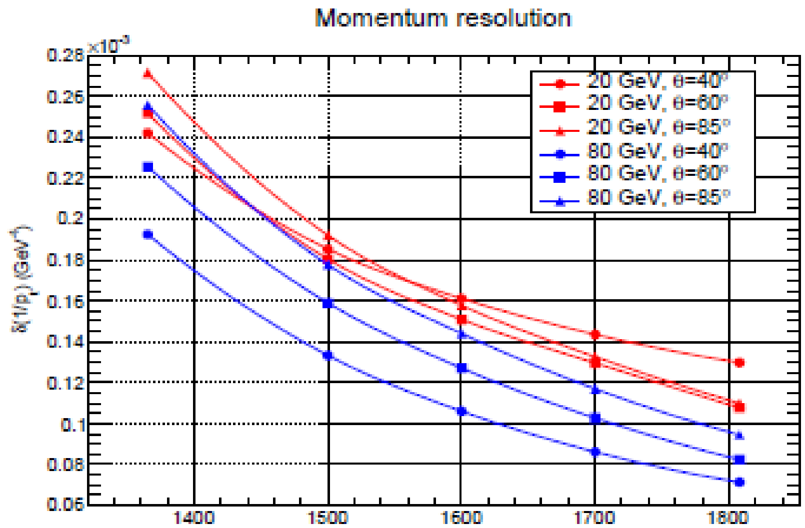
Momentum resolution at B=3.5T	$\delta(1/pt) \approx 10^{-4}$/GeV/c TPC only
δ_{point} in rΦ	<100μm (avg for straight-radial tracks)
δ_{point} in rz	≈0.4~1.4mm (for zero – full drift)
Inner radius	329mm
Outer radius	1800mm
Half length	2350mm
TPC material budgt	≈0.05X_0 including the outer field cage in r <0.25X_0 for readout endcaps in z
Pad pitch/no. padrows	≈1mm×4~10mm/≈200
2-hits resolution in rΦ	≈2mm (for straight-radial tracks)
Performance	>97% efficiency for TPC only (pt > 1GeV/c) >99% all tracking (pt > 1GeV/c)

Design of the TPC Geometry

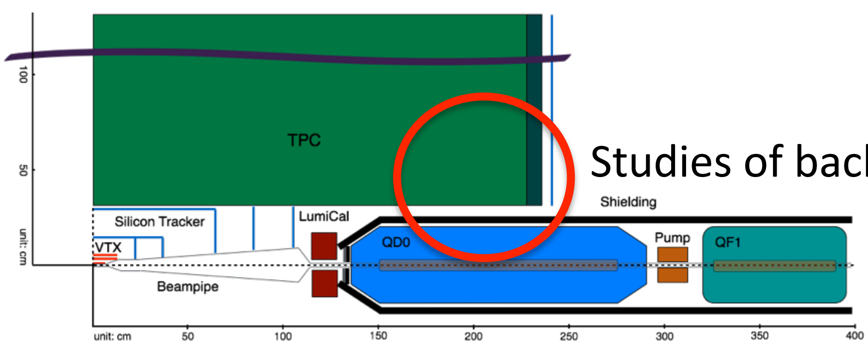
- Performance vs. the size of TPC studied with fast simulations



Half length (mm)



Outer radius (mm)



Studies of background needed

Critical R&D with LCTPC

- **LCTPC Collaboration has identified some critical R&D's**
  - Field distortion near boundaries
    - Insulator surface facing drift volume should be removed; Avoid charge up effects in GEM detector
    - Electric field distortion near module boundaries should be shaped away
  - High B-field performance
    - Is Neff at B=3.5T the same as at B=1T?
    - Is electron attachment by CF4 in amplification region negligible?
    - Tracking in non-uniform B-field: ExB and deviation from helix
  - Positive ions and Gate
    - Develop ion gate: transparency, distortion, ion leak
    - Is primary positive ion effect really negligible? (effects of heavy micro-curlers?)
    - Establish distortion correction method
  - Resolution near endcaps
    - Hodoscope effect?
    - Angular effect? (primary ionization statistics)
  - Neutron BG
    - Is gas mixture with a hydrocarbon molecule such as iso-C4H10 OK?
  - P/T control of gas volume
    - 2P CO_2 cooling of the whole gas volume?

From K. Fujii

Challenges for TPC at CEPC

- **Cooling for the readout electronics (at endcaps)**
  - **Required spacial resolution -> 10^6 channels**
  - **No power pulsing -> active cooling?**
- **Ion feedback (especially at Z pole)**
- **Open-Minded to other concepts (e.g. SiD) for the main tracker**

Calorimetry system

Haijun Yang's talk

- Vertexing $(h \to b\bar{b}, c\bar{c}, \tau^+\tau^-)$
  - ~1/5 $r_{beampipe}$,~1/30 pixel size (wrt LHC)

$$\sigma_{ip} = 5\mu m \oplus 10\mu m / p\sin^{3/2}\theta$$

✔ CEPC

- Tracking $(e^+e^- \to Zh \to \ell^+\ell^- X;\quad \text{incl.}\ h \to \text{nothing})$
  - ~1/6 material, ~1/10 resolution (wrt LHC)

$$\sigma(1/p) = 5\times 10^{-5}/GeV$$ or better

✔ CEPC

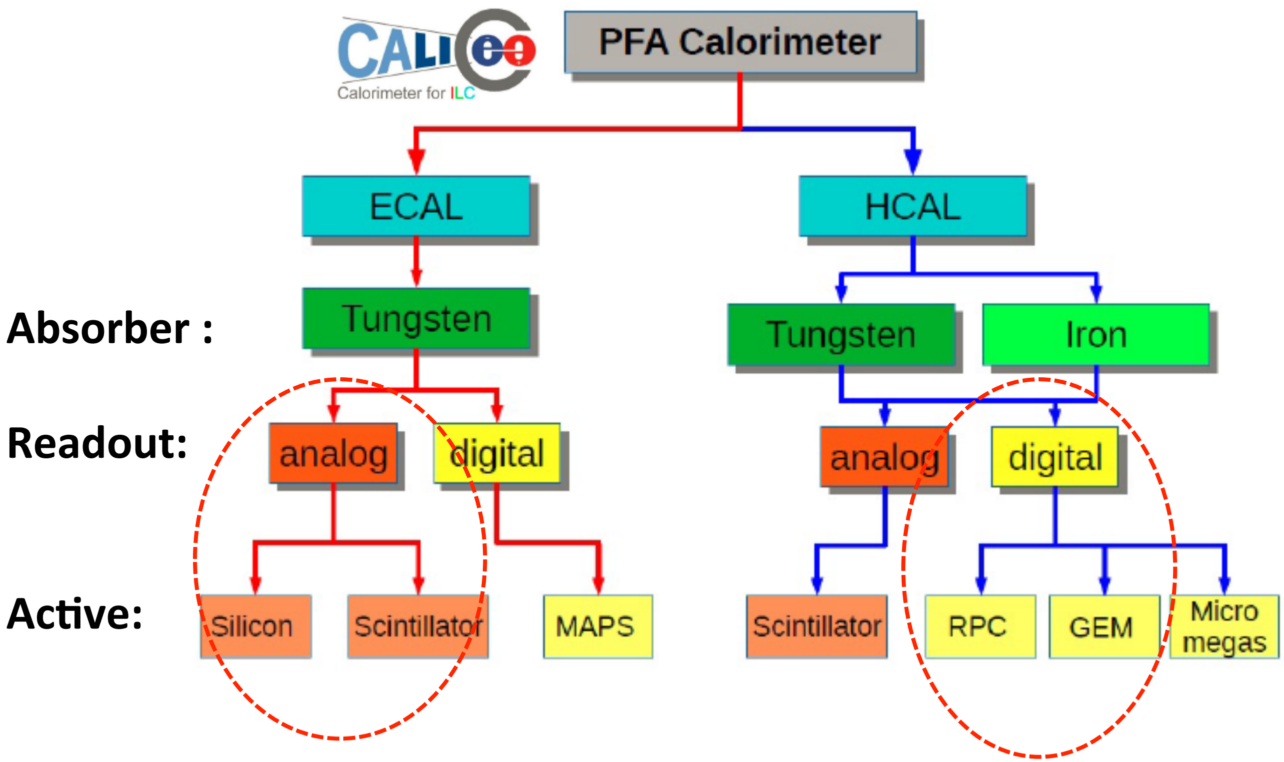
- Jet energy (Higgs self-coupling, W/Z separation)
  - ~1/2 resolution (wrt LHC)

$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

less demanding at CEPC

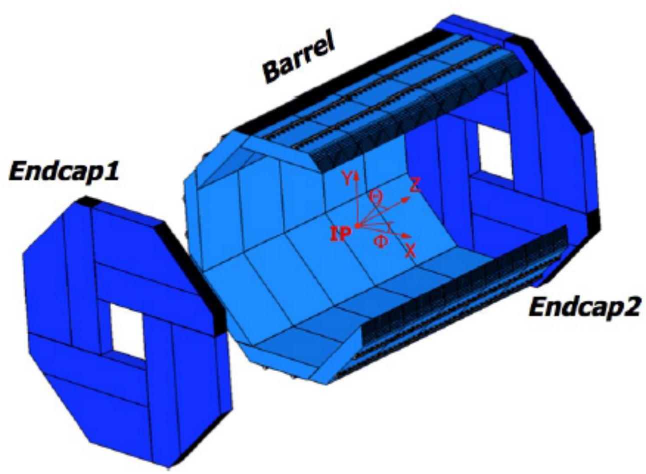
Global R&D of Imaging Calorimeters

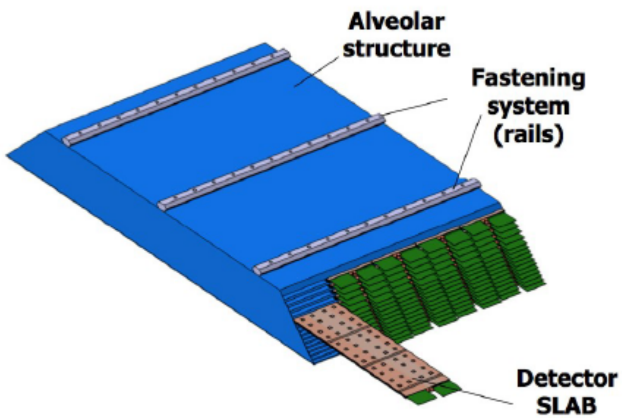
- Concept of Particle Flow Algorithm
  -> calorimeters with very fine granularity
- The calorimetry system at CEPC should be allowed to consider:
  - easier (less challenging) options
  - cost effective
  - active cooling



ECAL option: Silicon-W

- One of the ILD/SiD options
- The ECAL consists of a cylindrical barrel system and two large end caps.
  - One Barrel: 5 octagonal wheels
  - Two Endcaps: 4 quarters each
- 2 active sensors interleaved with tungsten absorber
  - silicon pixel 5 x 5 mm^2 with 725μm in thickness
  - PCB with Very Front-End ASIC



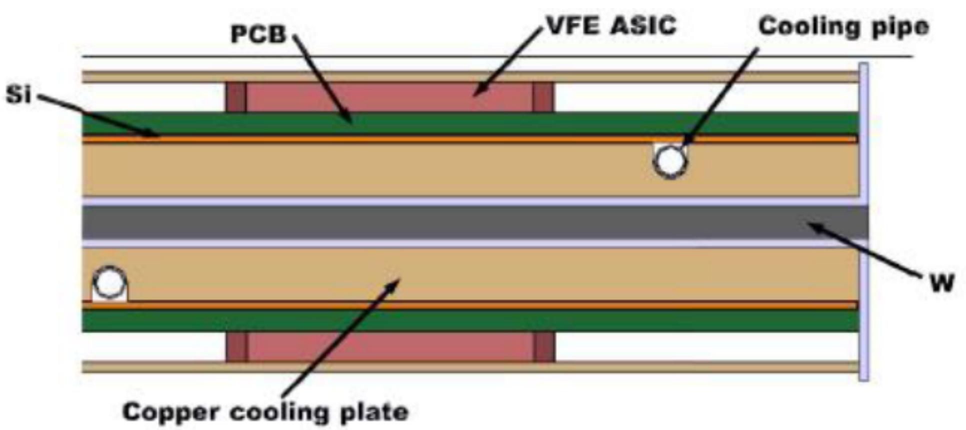


Example of active cooling

- CEPC is designed to operate at continuous mode with beam crossing rate: 2.8×10^5 Hz. Power pulsing will not work at CEPC.
- Passive Cooling: Too much gradient in Silicon …
- Active Cooling
  - Evaporative CO_2 cooling in thin pipes embedded in Copper exchange plate.
  - For CMS-HGCAL: 33 mW/cm^2, down to 0.6×0.6 cm^2 is OK (safety margin of 2)

➔ Transverse view of the slab with one absorber and two active layers.

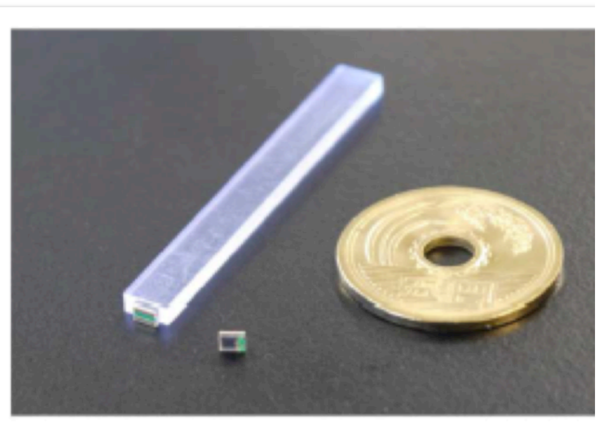
➔ The silicon sensors are glued to PCB with VFE chips, cooled by the copper plates with CO_2 cooling pipes.



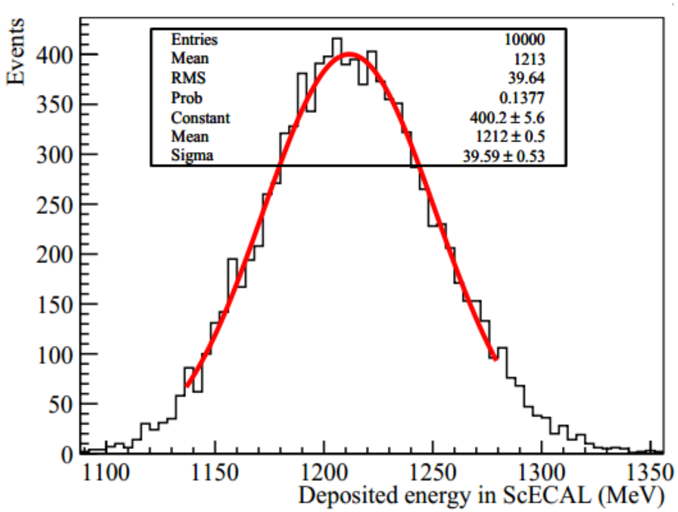
ECAL option: Scintillator-W

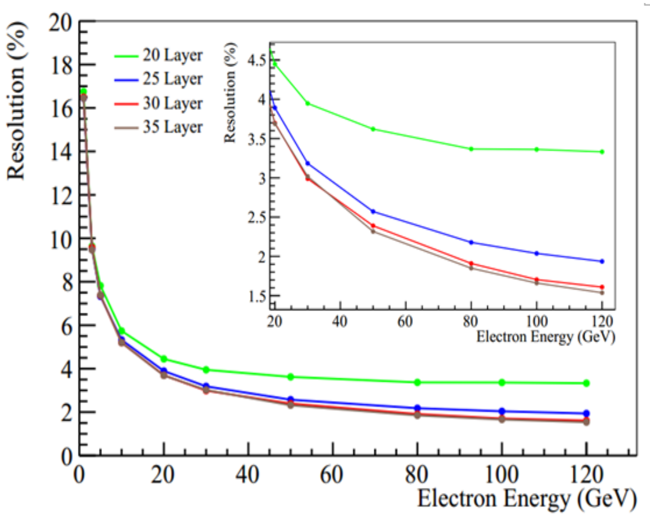
- **A super-layer (7mm) is made of**
  - tungsten plate (3 mm thick)
  - 5 x 45 mm^2 plastic scintillator strips (2 mm thick)
  - a readout/service layer (2 mm thick)

- **The energy resolution of 25 GeV electron is about 3.3% (cf. CALICE TB results)**
- **To achieve required energy resolution, the number of layers should be ~ 25.**



PS and SiPM

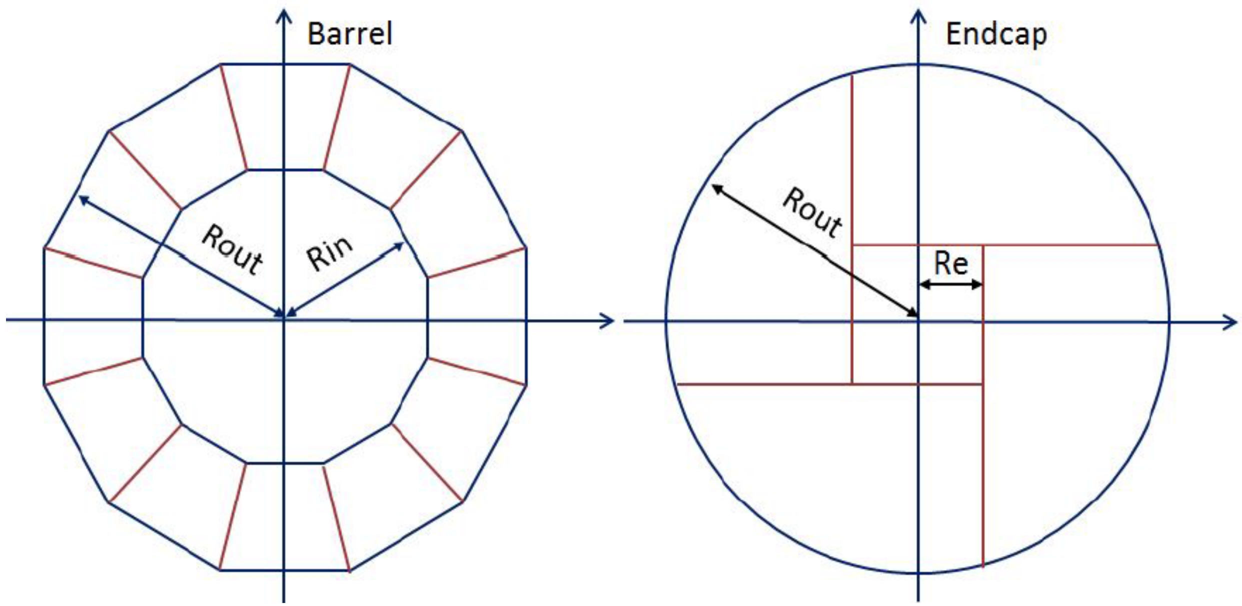




Hadron calorimeter

- The HCAL consists of
  - a cylindrical barrel system: self-support & negligible dead zones
  - two endcaps: 4 quarters
- Absorber: Stainless steel

- **Active sensor**
  - Glass RPC
  - Thick GEM
- **Readout ($1\times1cm^2$)**
  - Digital (1 threshold)
  - Semi-digital (3 thresholds)

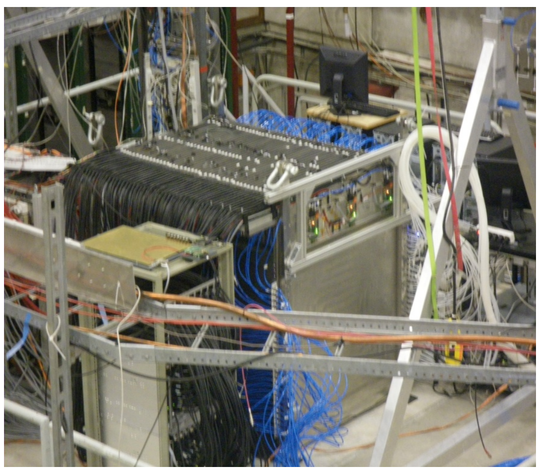


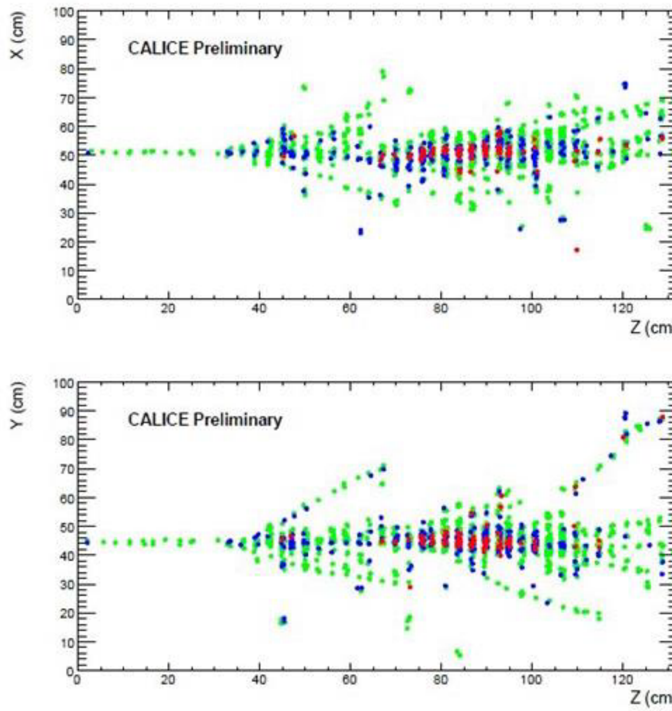
CALICE test beam studies

Prototypes of DHCAL based on RPC

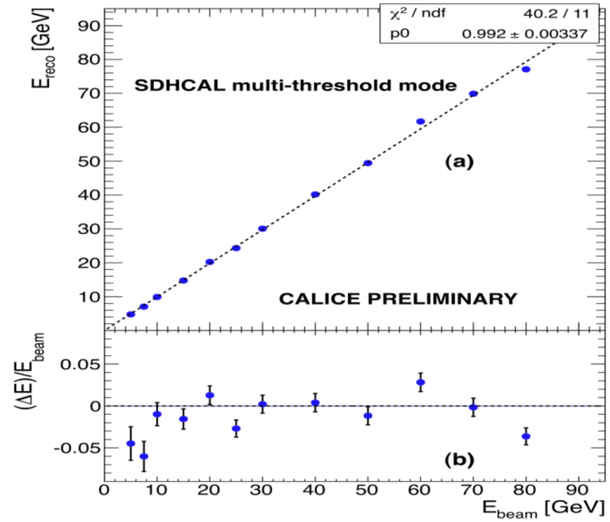
- **IPNL (I. Laktineh, R. Han et.al.)**

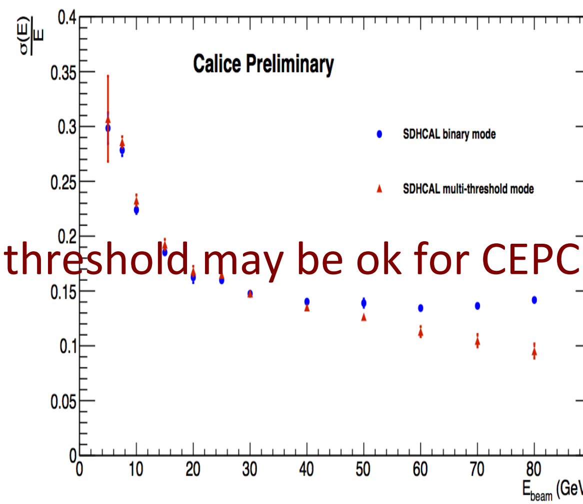
  1m³, 3 thresholds, Test Beam at CERN





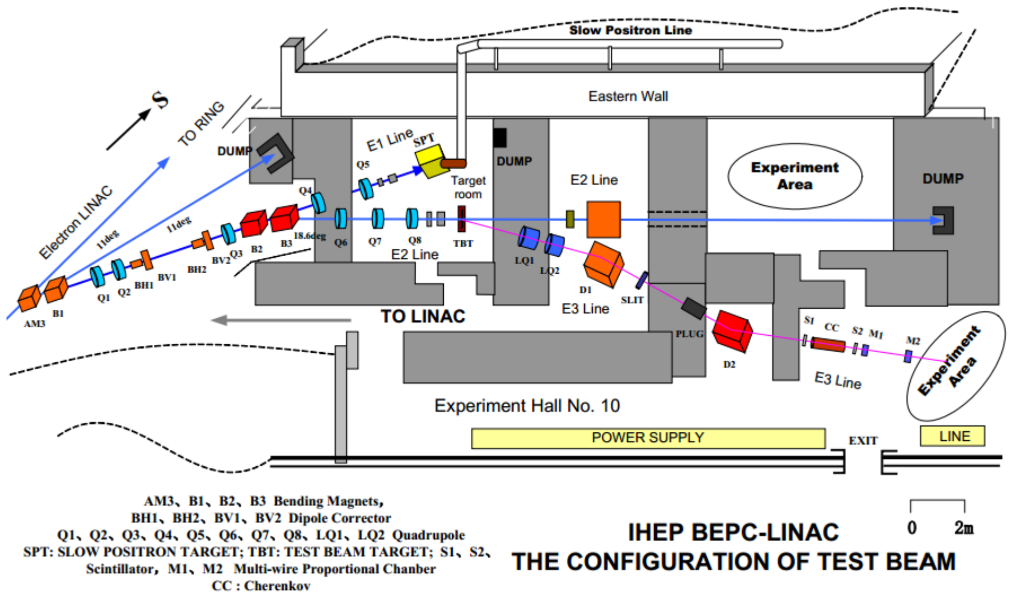
80 GeV Pion

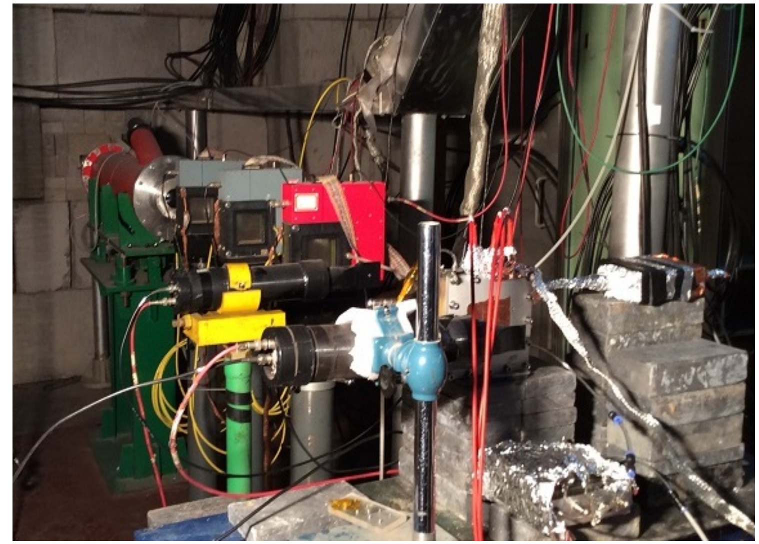


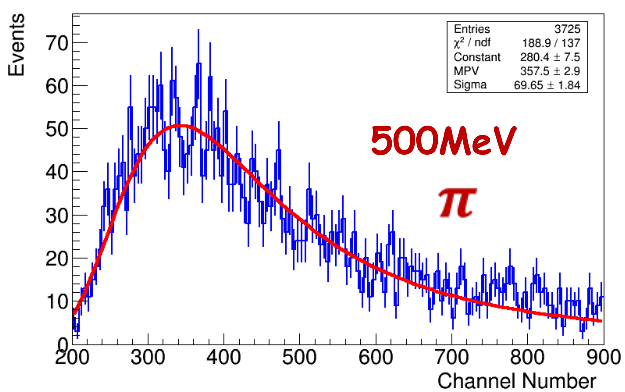


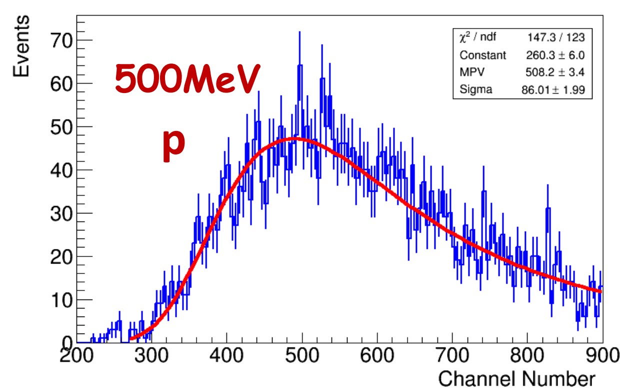
1 threshold may be ok for CEPC?

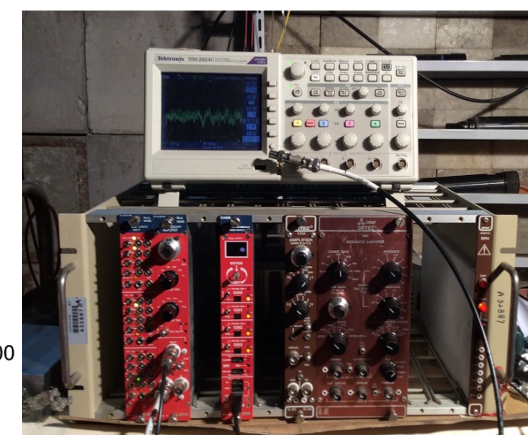
WELL-THGEM test beam at IHEP











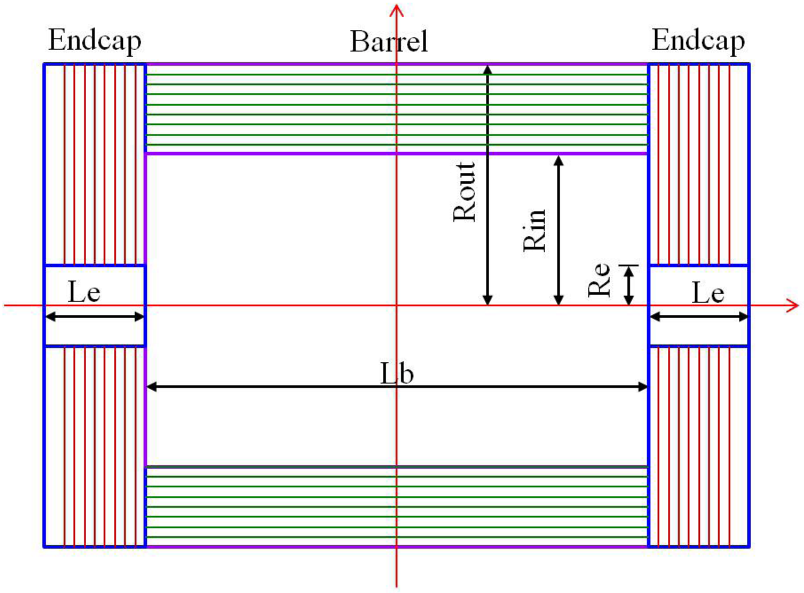
Well-THGEM, Ar/3%iC_4H_{10};

Critical R&D for ECAL/HCAL

- **Detector optimization**
  - Granularity of calorimeter
  - Number of layers of calorimeters, help to reduce the size of magnets and cost
- **Gas recirculation system, HV distribution system**
- **Readout Electronics (PCB, low power FEE ASIC)**
- **Cooling system**
  - Power pulsing will NOT work at the CEPC, effective cooling and power saving strategy need to be developed and tested
- **Calibration system**
  - Energy, position and density calibration etc.
- **Mechanical: self-support and compact module**

MUON System

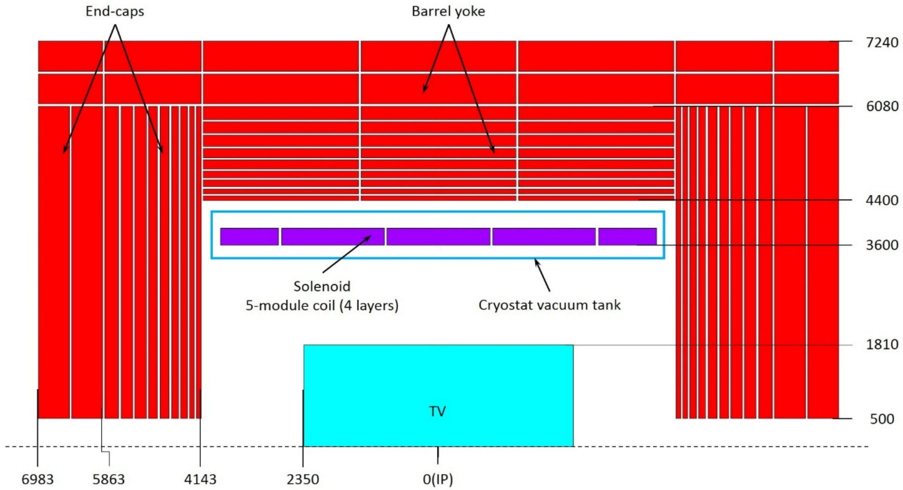
- Outside of the HCAL
  - a cylindrical barrel + two endcaps
  - Solid angle coverage 0.98 x 4π
- Options
  - RPC (bakelite RPC / glass RPC)
  - Scintillator strip (WLS+SiPM)

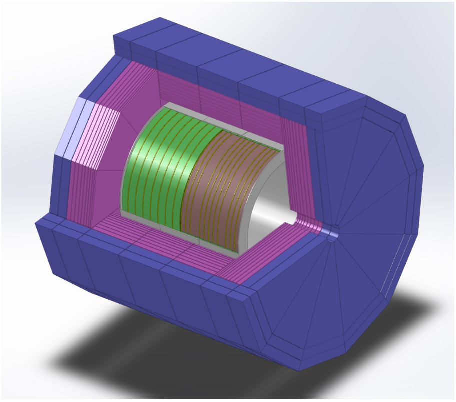


Item	Option	Baseline
Lb [m]	3.6 – 5.6	4.0
Rin [m]	3.5 – 5.0	4.4
Rout [m]	5.5 – 7.2	7.0
Le [m]	1.6 – 2.4	2.6
Re [m]	0.6 – 1.0	0.8
Segmentation	8/10/12	12
Number of layers	6 – 10	8 (∼4 cm per layer)
Total thickness of iron	6 – 10λ ($\lambda = 16.77$ cm)	8 (136 cm) (8/8/12/12/16/16/20/20/24)
Solid angle coverage	0.94 – 0.98×4π	0.98
Position resolution [cm]	$\sigma_{r\phi}$: 1.5 – 2.5	2
	σ_z : 1 – 2	1.5
Average strip width [cm]	Wstrip: 2 – 4	3
Detection efficiency	92% – 98%	95%
Reconstruction efficiency ($E_\mu > 6$ GeV)	92% – 96%	94%
P($\pi \rightarrow \mu$)@30GeV	0.5% – 3%	$< 1\%$
Rate capability [Hz/cm^2]	50 – 100	∼60
Technology	RPC	RPC (super module, 1 layer readout, 2 layers of RPC)
	Scintillating strip	
	Other	
Total area [m^2]	Barrel	∼4450
	Endcap	∼4150
	Total	∼8660
Total channels	Barrel	26500
	Endcap	29000
	Total	$\sim 5.55 \times 10^4$ (3 cm strip width, 1-D read-out, 2 ends for barrel, 1 end for end-cap)

Magnet

- A new design for baseline detector at CEPC

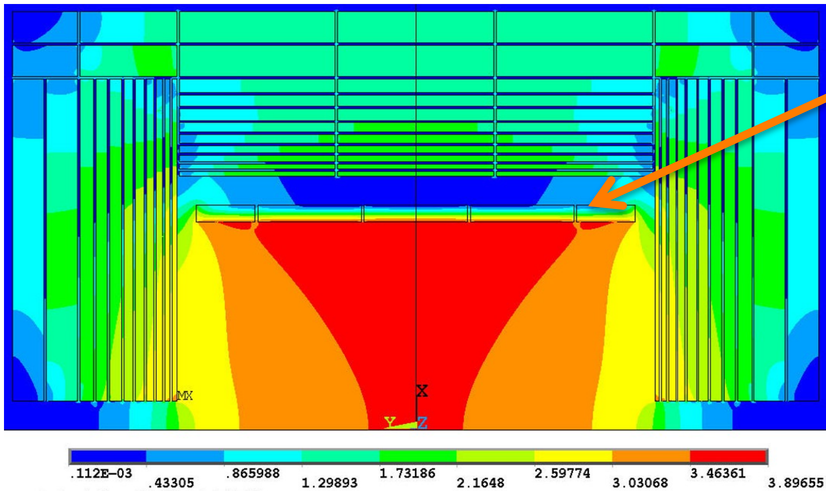




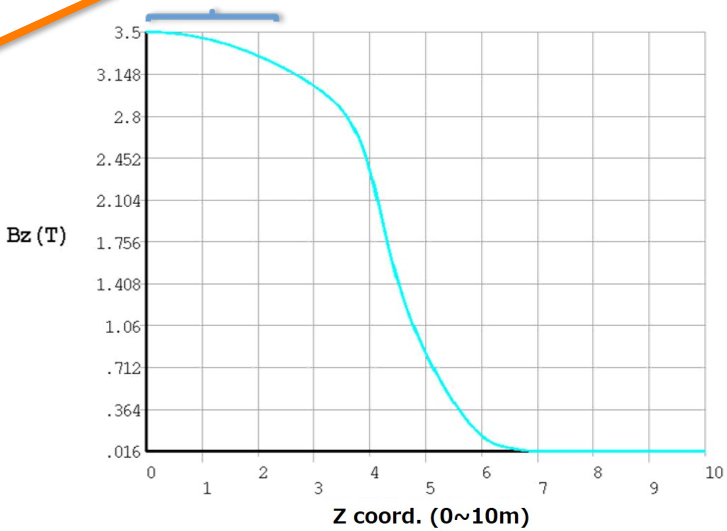
Cryostat inner radius(mm)	3400	Barrel yoke outer radius(mm)	7240
Cryostat outer radius(mm)	4250	Yoke overall length(mm)	13966
Cryostat length(mm)	8050	Barrel weight(t)	5775
Cold mass weight(t)	165	End cap weight(t)	6425
Barrel yoke inner radius(mm)	4400	Total yoke weight(t)	12200

Field Map

- Simulated field distributions



correction/fine tuning possible



The solenoid central field(T)	**3.5**	**Nominal current(KA)**	**18.575**
Maximum field on conductor(T)	3.85	Total ampere-turns of solenoid(MAt)	23.925
Coil inner radius(mm)	3600	Inductance(H)	10.4
Coil outer radius(mm)	3900	Stored energy(GJ)	1.8
Coil length(mm)	7600	Stored energy per unit of cold mass(KJ/kg)	10.91

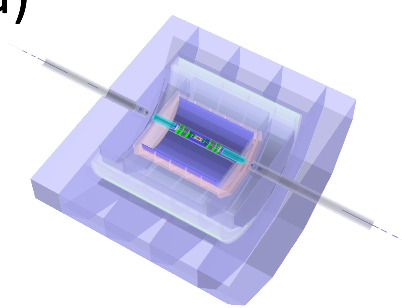
Physics performance

- Benchmark processes (so far, only Higgs-related) studied to validate the detector concept
- *The detector* in the simulation: ILD modified to cope with

  - modifications due to shorter L*

  - keep other sub-detectors same performance as ILD
- Arbor PFA used (similar performance as Pandora)
- ILD simulation/reconstruction software

  with relevant modifications



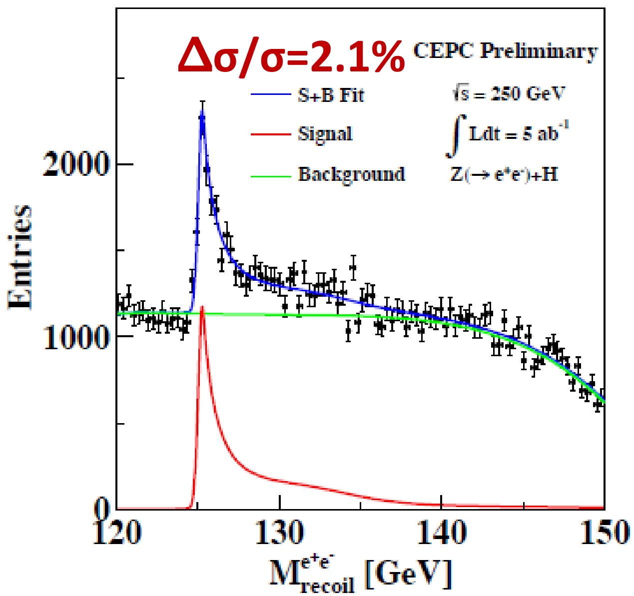
- Results from

  - analyses based on fully simulated signal processes + fast simulated bkg.

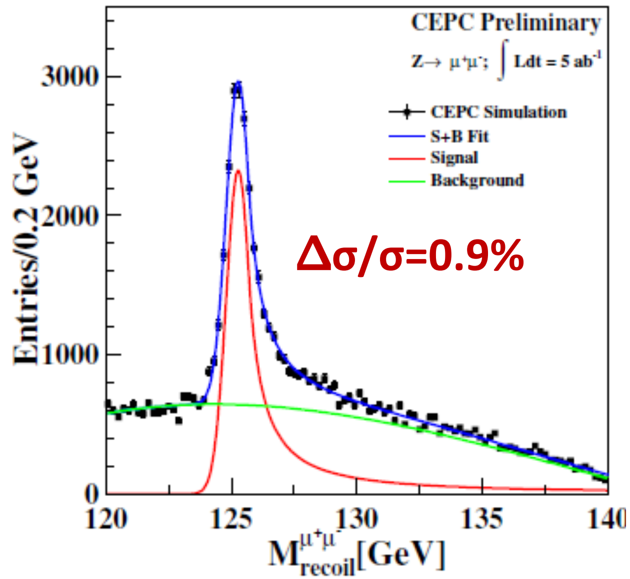
  - extrapolated from ILD, Fcc-ee studies

Direct measurement of Higgs cross-section

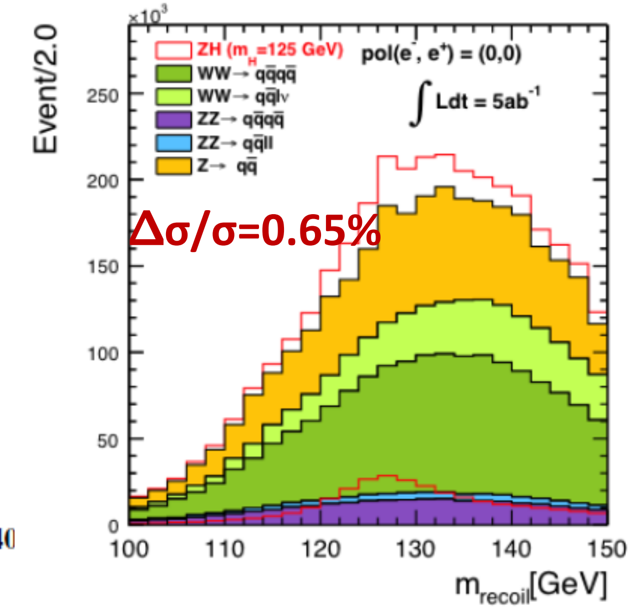
Full sim. signal



Full sim. signal

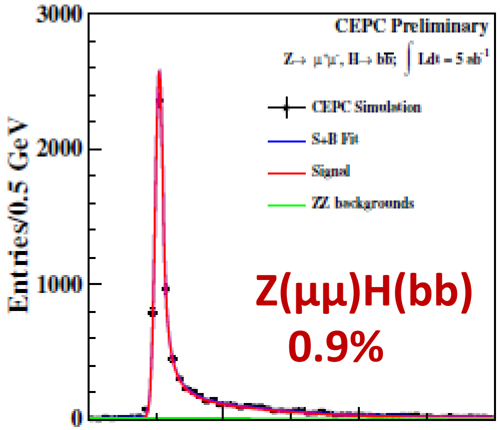


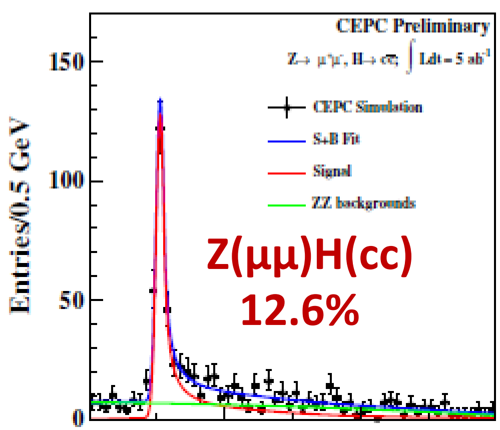
Full sim. all

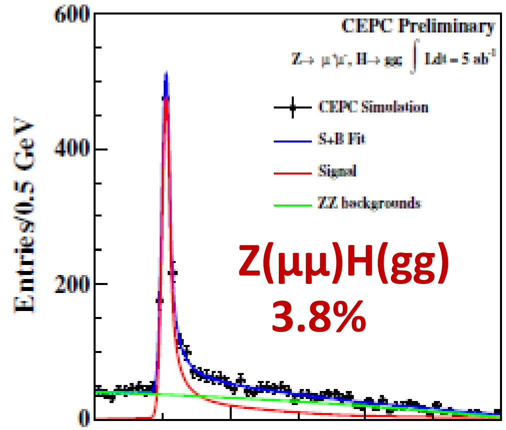


- ✓ ZZ,WW,Zγ and bhabha for Z->ll are dominant bkgs for Z(->ll)H.
- ✓ For hadornic decay of Z, Z(->qq) and WW(qqqq,qqlv) are the most dominant bkgs as the right plot shows.
- ✓ The combined precision with three channels is Δσ/σ=0.51%

Measurement of Δ(σ▪Br)/(σ▪Br) of ZH(jj)





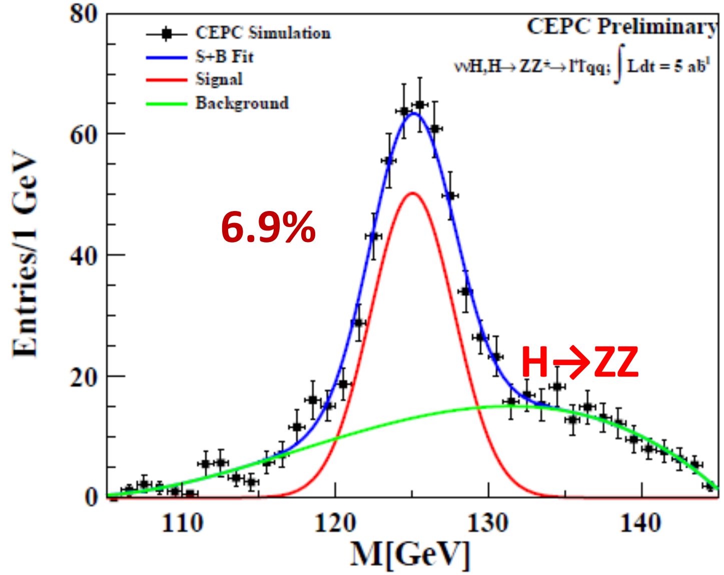


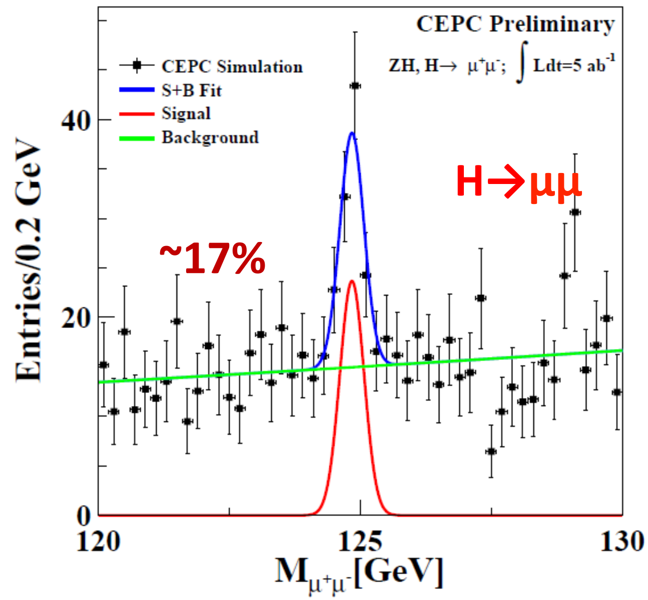
Channel		$H \to bb$	$H \to cc$	$H \to gg$
$\mu\mu H$	signal	11067	561	1808
	background	467	746	1838
	$\Delta(\sigma \times \mathrm{BR})/\sigma \times \mathrm{BR}$	0.9%	12.6%	3.8%
eeH	signal	11033	544	1914
	background	732	1369	3137
	$\Delta(\sigma \times \mathrm{BR})/\sigma \times \mathrm{BR}$	1.1%	14.6%	5.6%
$\nu\nu H$	$\Delta(\sigma \times \mathrm{BR})/\sigma \times \mathrm{BR}$	0.45%	3.2%	2.8%
qqH	$\Delta(\sigma \times \mathrm{BR})/\sigma \times \mathrm{BR}$	0.4%	3.0%	2.6%
Combined	$\Delta(\sigma \times \mathrm{BR})/\sigma \times \mathrm{BR}$	0.28%	2.1%	1.6%

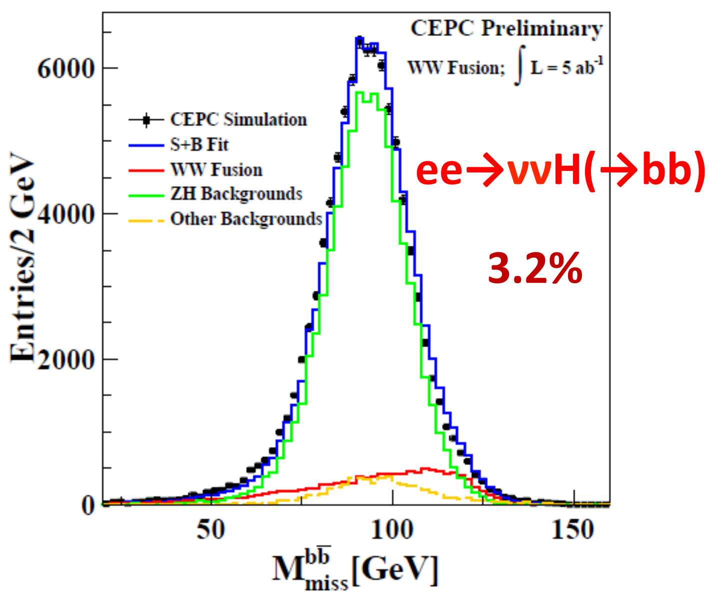
- ✓ **For Z(μμ),Z(ee), the recoil mass of Z is used as a discriminating variable to benefit from the good resolution of leptons.**
- ✓ **For leptonic channels, Full simulated samples for signal are used in this study.**
- ✓ **The combined precisions for the measurement of H->bb,cc,gg are 0.28%, 2.1%, 1.6% respectively.**

Expected measured precision of σ▪Br from other channels

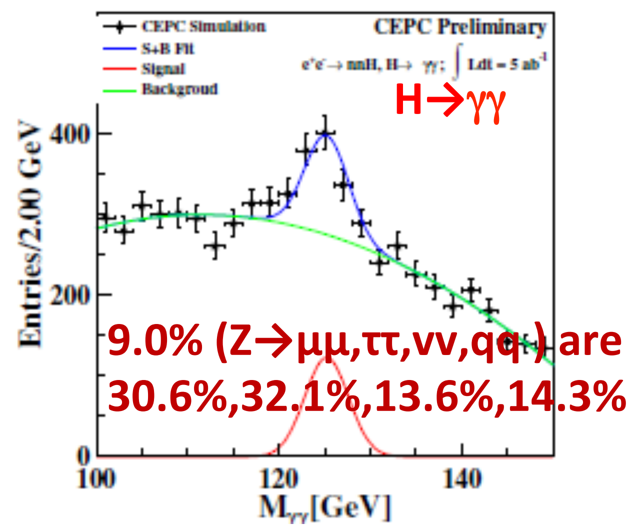
4.3% including other processes (extrapolated from FCC-ee)







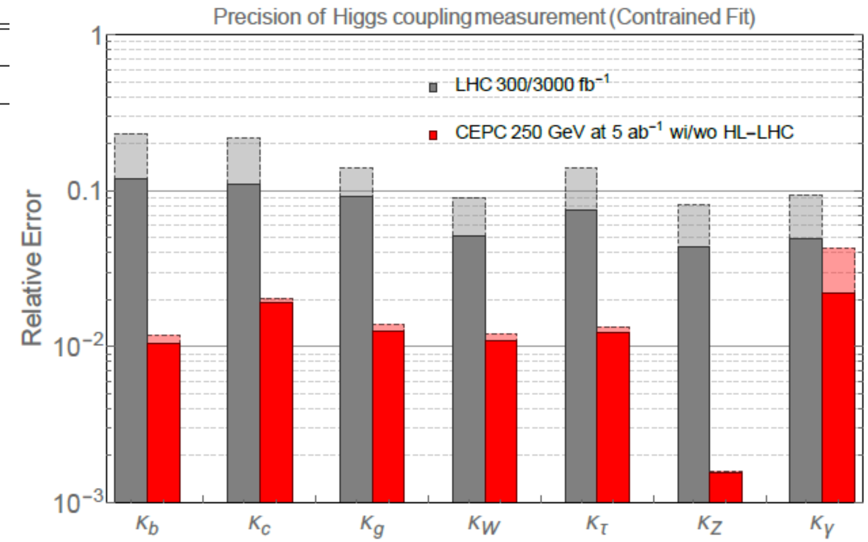
$$\frac{\delta(E)}{E} = \frac{16\%}{\sqrt{(E)}} \oplus 1\%$$



Summary of the precision for the measurement of Higgs

ΔM_H	Γ_H	$\sigma(ZH)$	$\sigma(\nu\nu H) \times \mathrm{BR}(H \to bb)$
5.9 MeV	2.7%	0.51%	2.8%

Decay mode	$\sigma(ZH) \times \mathrm{BR}$	BR
$H \to bb$	0.28%	0.57%
$H \to cc$	2.2%	2.3%
$H \to gg$	1.6%	1.7%
$H \to \tau\tau$	1.2%	1.3%
$H \to WW$	1.5%	1.6%
$H \to ZZ$	4.3%	4.3%
$H \to \gamma\gamma$	9.0%	9.0%
$H \to \mu\mu$	17%	17%
$H \to \mathrm{inv}$	–	0.28%

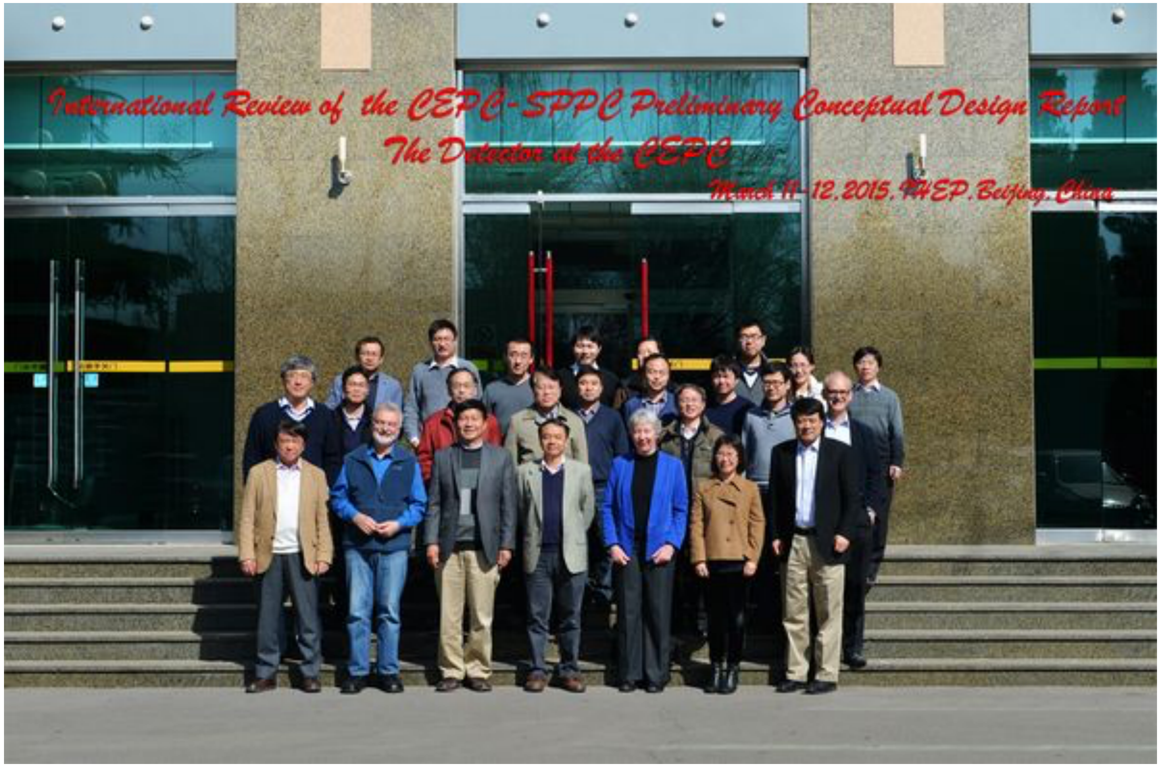


- ✓ **With combination of σ▪Br of ννH(→bb) /Br(H->bb)/Br(H->ww) and the direct measurement, one can obtain the decay width of Higgs with the precision at 2.8%.**
- ✓ **The measurement of Br is done by introducing the uncertainty of xsection of ZH from the direct measurement (no theoretical uncertainty needs to be taken into account).**
- ✓ **Most precisions are a few percent or lower (bb, invisible), allowing us to be sensitive to BSM deviation.**
- ✓ **In comparison with HL-LHC, CEPC is expected to have much better performance in the measurements of the coupling constants in particular for κ_z .**

Detector Review

- Review happened in March 11 – 12
- Chaired by Hendrik J. (Harry) Weerts
- Members:

Marcel Demarteau	ANL
Young-Kee Kim	Univ. Chicago
Rick Van Kooten	Indiana Univ.
Hendrik J. Weerts	ANL
Phillippa Wells	BINP
Hitoshi Yamamoto	Tohoku Univ.
Zheng Li	Xiang Tan Univ



Report of
Review of CEPC-SppC Detector preCDR
Beijing, March 11-12, 2015

Introduction

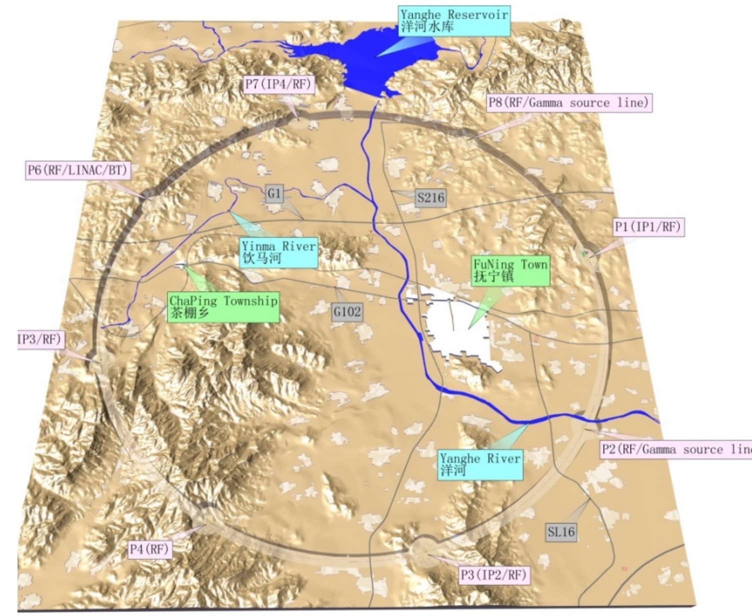
A review of the CEPC-SPPC Preliminary Conceptual Design Report for a detector at the CEPC was held at the Institute for High-Energy Physics in Beijing on March 11 and 12, 2015. The committee received two separate documents prior to the meeting titled "CEPC-SppC, Preliminary Conceptual Design Report: Physics and Detector", one describing the physics goals and the physics performance of the proposed detector and the other providing technical details of the detector subsystems. The review was organized around a series of overview talks covering aspects of the experimental program, the detector and all its subsystems

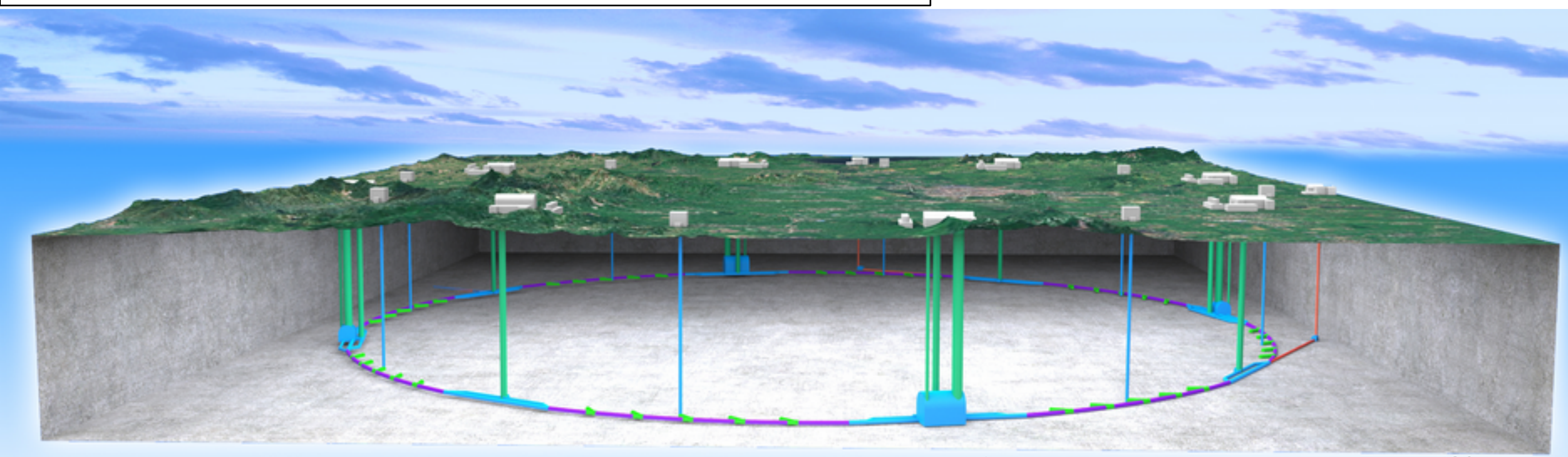
Observations

The assembled, local team was well organized, young, focused and enthusiastic with excellent leadership and vision. They made excellent, effective use of existing studies and the software framework resulting in an impressive achievement, given the short time scale. They are also either part of existing R&D collaborations (LCTPC) or associated with them (CALICE). Optimizing for the study on Higgs final states in a limited center-of-mass energy region has helped focus the effort. The proposed R&D program based on the current preCDR, resulting in a CDR in the next 5 years, followed by a TDR which enables a construction start in 2021 seems challenging but feasible.

Civil Construction

- **A credible design with cost estimate**
- **The key to keep the cost low**
  - **Find a site geologically the best(granite)**
  - **Optimize of the design**
  - **Choose the right designer & construction contractor**
  - **Management**





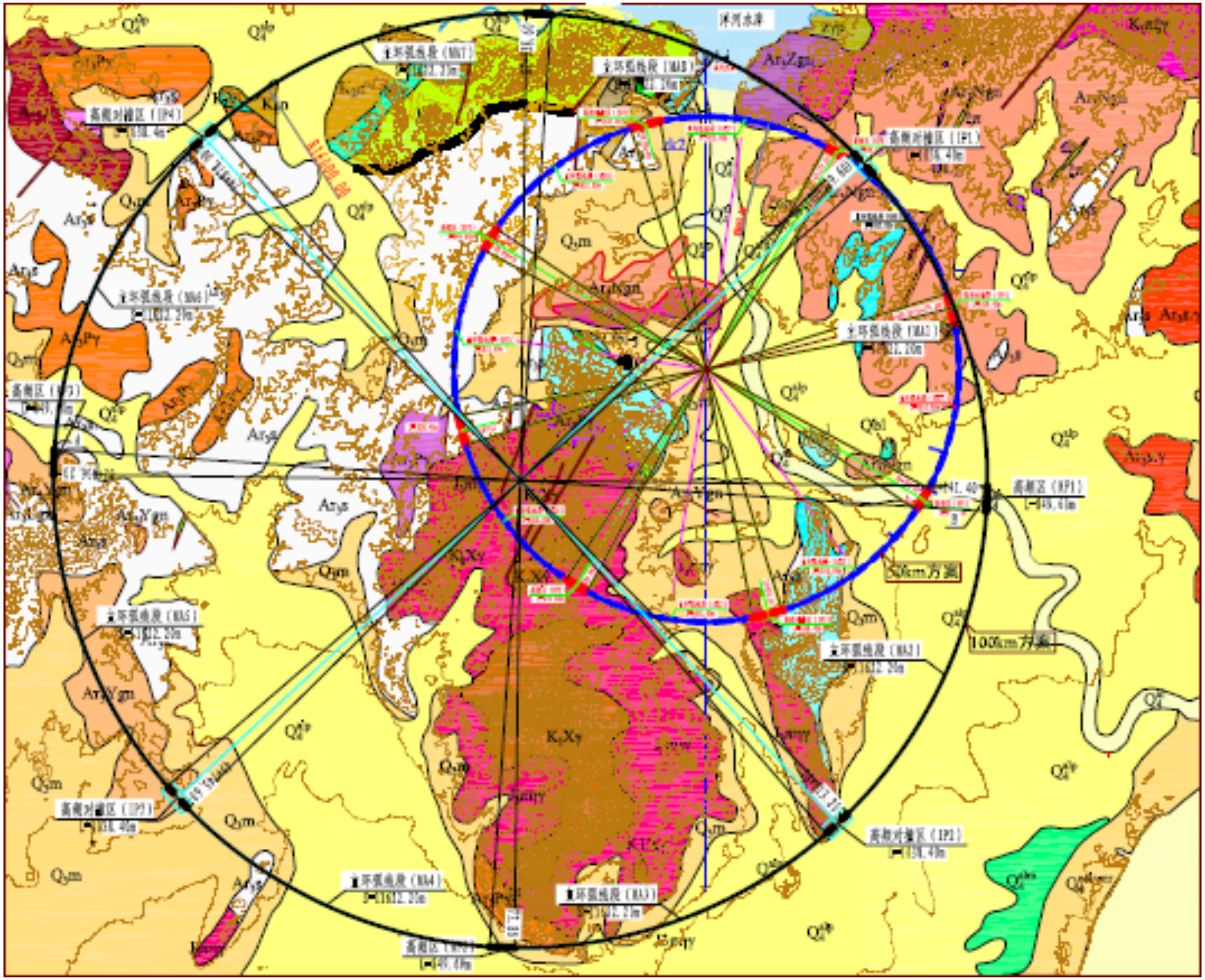
Site selection: compared 7 different sites

主要选址区域地质条件初步比较表

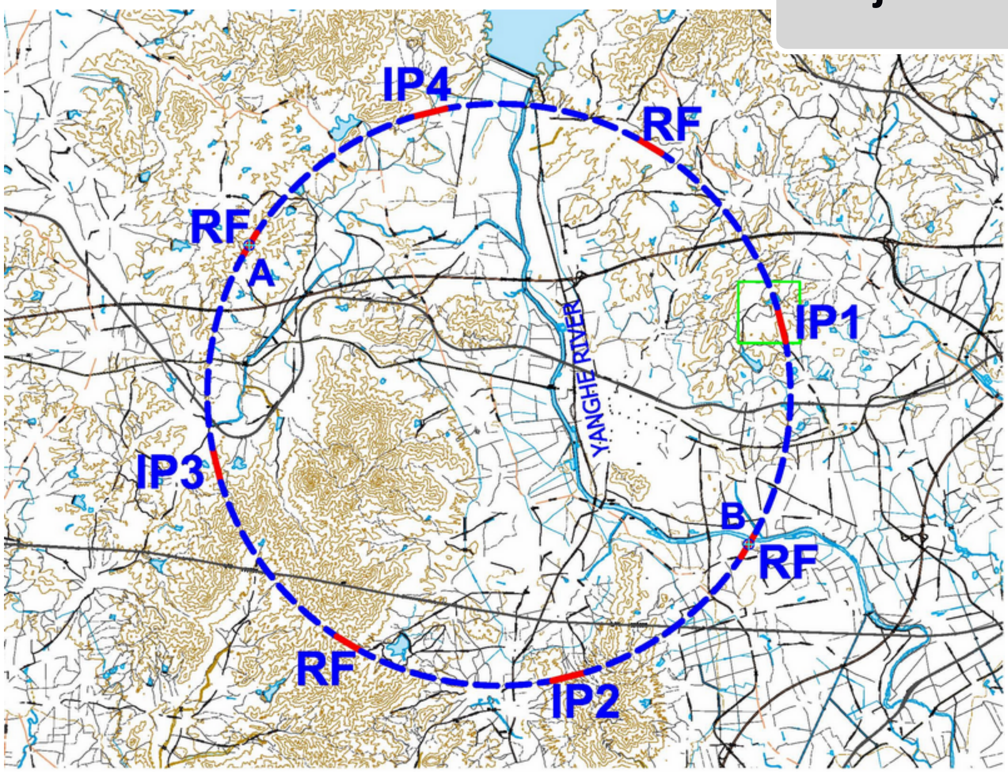
比较条件	抚宁县附近	山海关—绥中地区	花都区以北—清远以东区域	台山古兜山周围	新兴以东区域	汉中市东部	黄陵县南部	比较
地形地貌	西北高，东南低，丘陵为主，东南部为滨海平原，高程50～200m	西北高，东南低，丘陵地貌，沿海为平原，最高400m，东部小于100m	丘陵区，大部分区域一般100m左右，高差不大	低山丘陵区，中间高四周低，隧洞沿线小于100m高差不大	地势西高东低，丘陵区，高程100～200m	山间盆地丘陵区，高程500～700m	黄土高原沟壑区，高程700～1100m，塬面较平坦，沟谷深切	抚宁县附近、山海关—绥中、花都北、台山较好
地层岩性	片麻岩，花岗岩为主，洋河下游和昌黎县南部覆盖层可能较厚	花岗岩为主，片麻岩、碎屑岩、火山碎屑岩，滨海平原覆盖层厚度不明	花岗岩，第四系覆盖层较薄	花岗岩占70%，第四系主要分布于潭江的南岸和西岸	花岗岩占90%，少量变质碎屑岩，覆盖层较薄	主要为闪长岩，少量变质岩及碳酸岩	碎屑上覆黄土，属中硬岩和较软岩，部分地区可能有煤层	抚宁县附近、山海关—绥中、花都北、汉中东较好
构造及稳定性	无区域性断裂，地震动峰值加速度为0.10～0.15g，地震基本烈度为Ⅶ度	无区域性断裂，地震动峰值加速度为0.05g，地震基本烈度为Ⅵ度	区域内无区域性深大断裂，地震动峰值加速度为0.05g，相应地震基本烈度为Ⅵ度	无区域性深大断裂，地震动峰值加速度为0.05～0.1g，地震基本烈度Ⅵ～Ⅶ度	构造较不发育。地震动峰值加速度为0.05g，地震基本烈度为Ⅵ度	无大的区域构造，地震基本烈度为Ⅵ度	构造相对简单，地震基本烈度为Ⅵ度	抚宁县附近、花都北、汉中东、黄陵南较好
水文条件	年均降水量684mm，地下水类型为块状岩类裂隙水和松散岩类孔隙水	年均降水量652.5mm，地下水类型为块状岩类裂隙水和松散岩类孔隙水	年均降水量1900～2100mm，地下水类型为块状岩类裂隙水，水量丰富	年均降水量1936mm，地下水类型东部为块状岩类裂隙水，水量较丰富，西部层状岩类裂隙水，水量较贫乏	年均降水量1546mm，地下水类型以块状岩类裂隙水为主，水量较丰富	年均降水量700～1700mm，地下水类型为块状岩类裂隙水，水量较丰富	年均降水量568.8mm，地下水类型为基岩裂隙水	抚宁县附近、山海关—绥中、黄陵南较好
总体评价及可能问题	选址岩体条件有利，不存在工程制约问题，西、西北部竖井开挖深度较大，向西布置优于向东布置	选址岩体条件有利，不存在工程制约问题，西部竖井开挖深度较大，覆盖层厚度影响隧洞布置	选址有利，不存在工程制约问题，可能问题是裂隙和风化囊涌水，高地温	选址有利，不存在工程制约问题，可能问题是裂隙和风化囊涌水，注意东北部覆盖层厚度	选址有利，不存在工程制约问题，可能问题是裂隙和风化囊涌水	选址岩体条件有利，局部可能存在岩溶问题	部分区域可能存在有煤层，部分区域竖井开挖深度较大	抚宁县附近、花都北相对较好

Geologically 2-3 sites are OK.

Geology of a Candidate Site -- Qinhuangdao



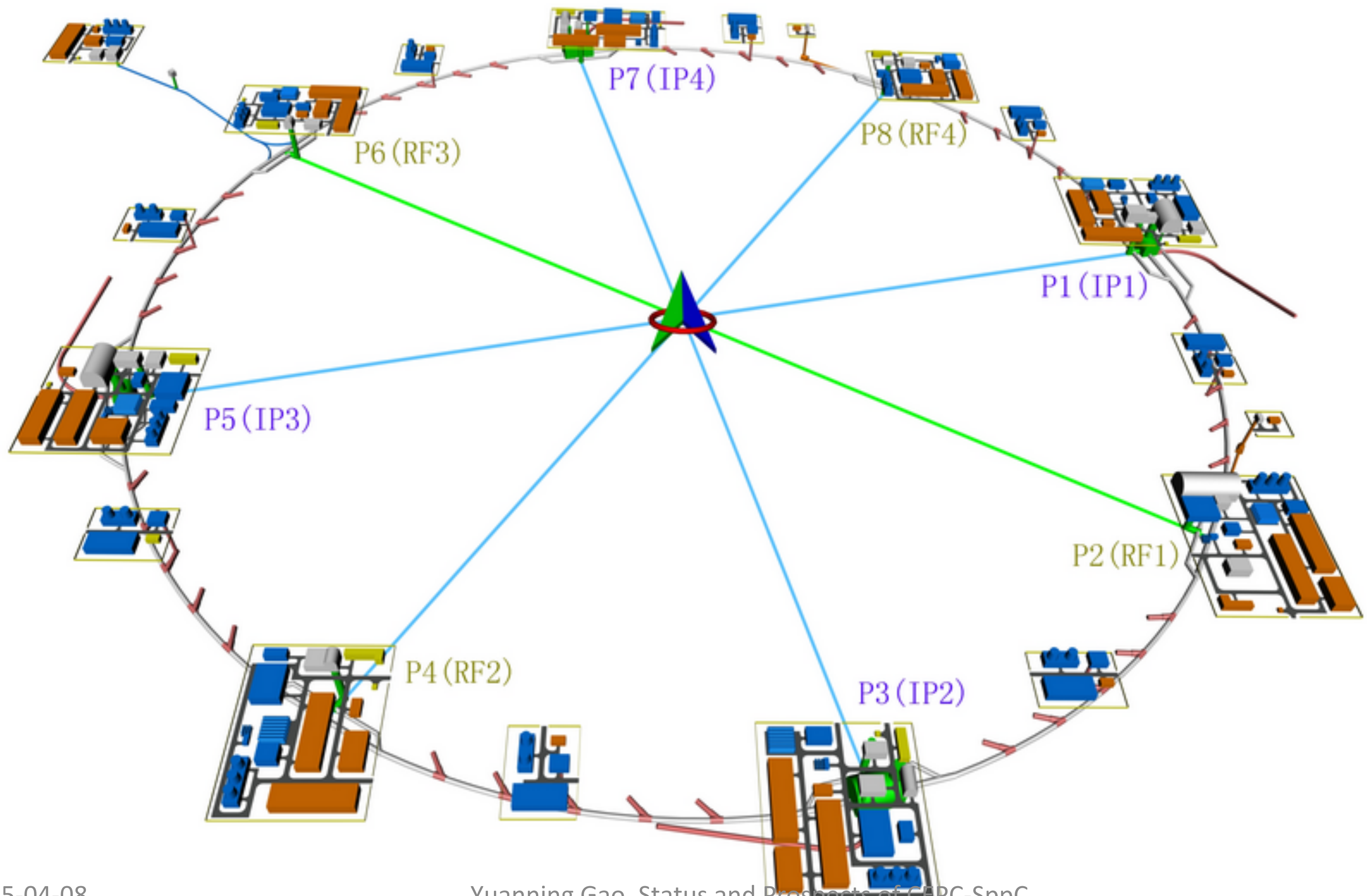
- **CEPC underground construction**
  - **Main Tunnel 54.374km**
    - **Straight section 8， 7552m**
      - **RF@IP 4×1038.4m**
      - **RF hall 4×849.6m**
    - **Arc 8×5852.8m = 46.82km**
  - **2 IP hall 2 reserved for SPPC**
  - **Injector**
    - **LINAC, 500m**
    - **Transfer lines, 1135m**



CEPC surface construction

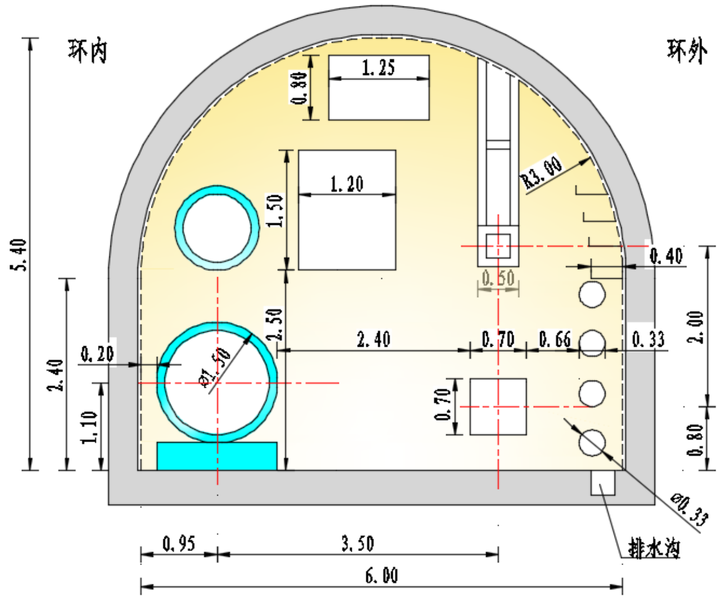
- Experimental hall
- SR hall
- Power, HVAC, Cryo.,
- …

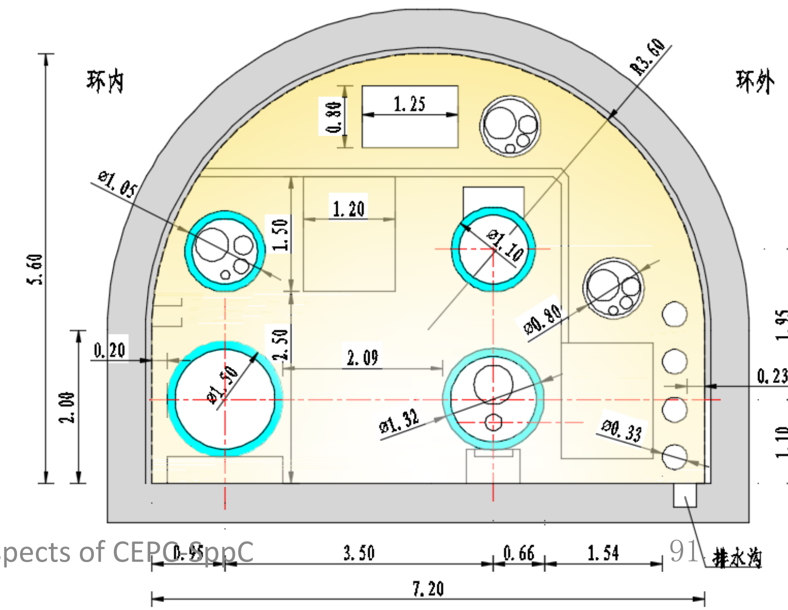
Surface and Underground Construction



Tunnel

- Concrete/Steel is not needed in granite for the stability of the structure
- Water leaks are mainly cured by Concrete + water proof material
- Concrete/Steel could bear more than half of the tunnel cost
- Solution: steel plate ➔ ~ 50% cost saving





Review of Civil Construction and Utilities

环形正负电子对撞机（CEPC）土建及通用系统配套工程

初步概念设计报告评审意见

中国科学院高能物理研究所于2015年3月5日在高能所组织召开了“环形正负电子对撞机（CEPC）土建及通用系统配套工程初步概念设计报告”评审会。专家组（名单附后）听取了黄河勘测规划设计有限公司(以下简称黄河设计公司)的汇报。经过讨论，形成评审意见如下：

一、黄河设计公司开展了大量工作，提出了选址方案，设计内容及深度基本满足高能所提出的初步概念设计阶段要求。

二、黄河设计公司通过资料搜集、现场调查及部分勘察工作，经过研究和评价，该选址区的区域稳定性分级为基本稳定，外动力地质现象不发育，无制约工程建设的重大地质问题。

专家认为，选址区适宜大范围地下工程建设。

三、总体布置满足工艺需求，方案设计基本可行。

四、基本同意报告推荐的结构选型和施工方案，以及电气、通风空调、给排水和消防等系统设计方案。

五、工程投资估算基本合理，编制深度满足本阶段要求。

六、建议

（1）进一步开展地质工作，优化隧道线路和实验大厅的布置；

（2）结合地质勘察资料，深化施工方案研究，优化工程筹划；

（3）根据场址环境条件，补充完善施工渣场规划；

（4）下阶段应根据工程需求，尽量做到永临结合；

（5）根据调整优化后的方案，进一步细化投资估算。

专家组长签名：

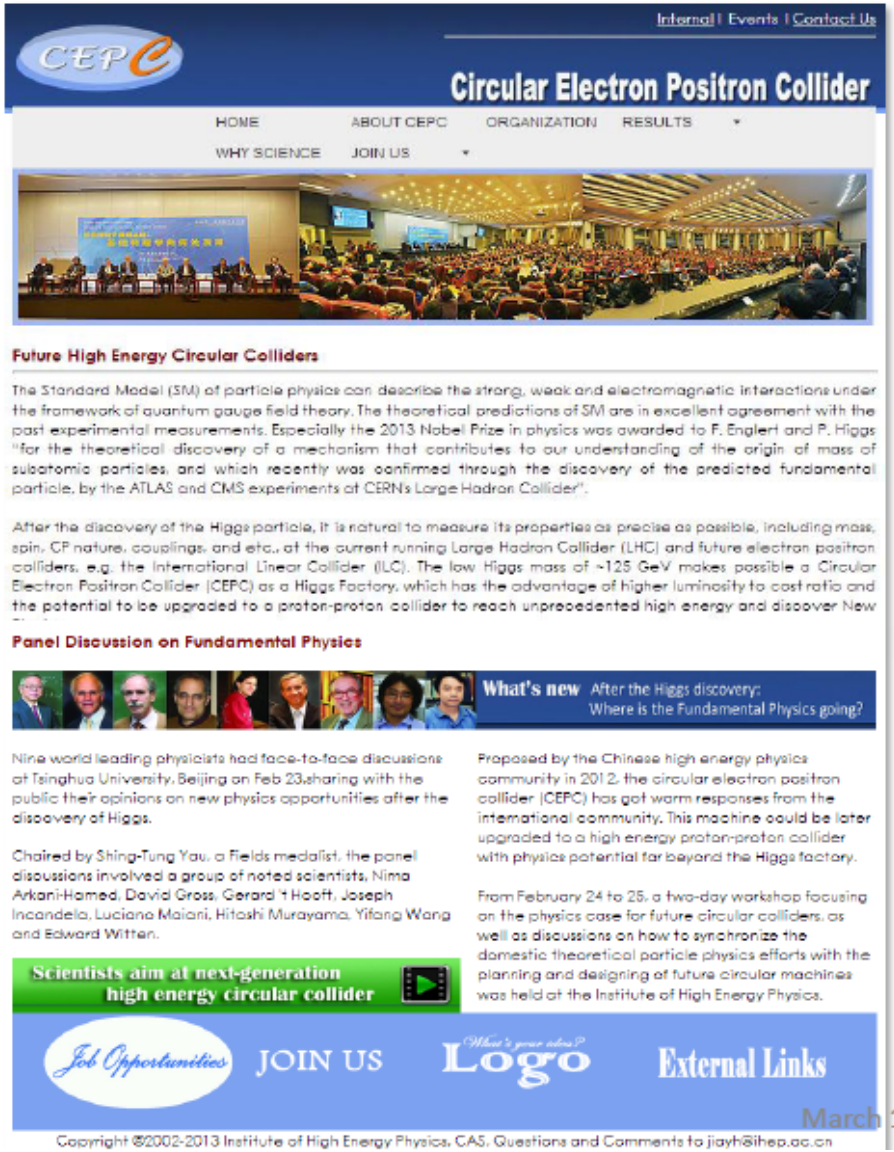
2015. 3. 5

- **The current design, including surface and underground construction, electricity, water, HVAC & firefight system as well as the construction method & organization satisfy all the requirements by IHEP at current stage**
- **The studied candidate site has no geological issues and is suitable for this project**
- **The level of details and the total budget estimate is adequate at this stage**

International Collaboration

- Right now the pre-CDR is mainly Chinese efforts with international help
  - An excise for us
  - Build confidence for the Chinese HEP community
- A new scheme of international collaboration to be explored:
  - Not the same as ITER, ILC, CERN, …
  - A new institution, a consortium, or just a new project ?
- An international advisory board will be formed soon to discuss this issue and many others
- Welcome suggestions

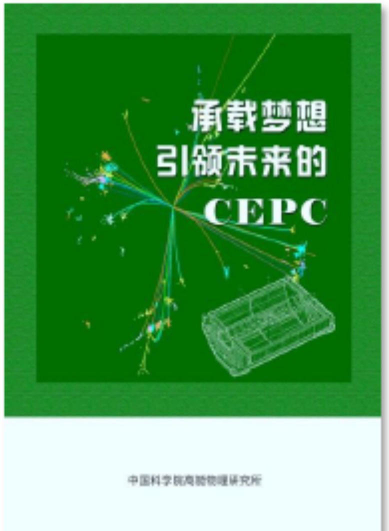
Communication & outreach



March 11, 2015 31

Outreach & education

CEPC Outreach



～ 30000字

～ 6700字

～ 27000字

～ 5600字

CEPC建议
引起巨大国际反响

～10000字

CEPC
大事记

高能物理的
社会效益

进行中

未来的
希格斯工厂

进行中

From Xinchou Lou

Y. Y. Zhong

Activities for 2015 and beyond

preCDR

- review and finalization
- author-institute list.....

  signup at http://cepcdoc.ihep.ac.cn:7080/cepc/precdr/reg.htm
- Chinese preCDR for domestic consumption

funding

- seek funding & grants for preliminary R&D
- 13^{th} 5-year planning for funding CEPC R&D

manpower

- training students, postdocs
- move some IHEP staff to CEPC; recruitment

CDR and Organization

- begin CDR process; pre-R&D
- expand study group to be more internalized
- ....

From Xinchou Lou

Summary

- Tremendous efforts up to now
- Real progress in all fronts
- A promising future: please be optimistic !
- Let work together to make it happen

DEV-TSINGHUA-CEA-future-colliders: R&D for physics at future colliders

DEV-TSINGHUA-CEA-future-colliders: **R&D for physics at future colliders**						
Members	**French Group**			**Chinese Group**		
	Name	**Title**	**Affiliation** (institute)	**Name**	**Title**	**Affiliation** (institute)
	Leader R. Aleksan	Dr.	CEA	*Leader* Yuanning Gao	Prof.	Tsinghua University
	M. Besançon	Dr.	CEA	Xianglei Zhu	Prof.	Tsinghua
	F. Couderc	Dr.	CEA	Bo Li	Dr.	Tsinghua
	F. Deliot,	Dr.	CEA	Tao Hu	Prof.	IHEP
	S. Ganjour	Dr.	CEA	Manqi Ruan	Dr.	IHEP
	E. Lançon	Dr.	CEA	Huirong Qi	Dr.	IHEP
	Ph. Schwemling	Pr.	CEA			

Activities in 2014

- French Group: Strongly involved in FCC

  - EuroCIRCOL Design Study proposal approved/funded

  - Physics studies the measurement of the invisible H and Z width and direct Higgs production in e+e- collisions

  - Detector studies operation and resolution of a TPC in the FCC-ee environment, establishment of a TPC test stand in Saclay, investigation of wireless detector data transmission…

Activities in 2014

- Chinese Group: leading role in CEPC (detector)

  - CEPC PreCDR (detector)

  - Physics studies exploring physics potential for favor physics at Z pole, some special considerations on the detector design (e.g. particle identification) is under discussion

  - Detector studies Performing track finding and reconstruction in a TPC with non-uniform magnetic field, a C++ package has been developed and tested in the framework of the ILD detector

Activities & plan

- Exchanges
  - regular phone meetings between two project leaders

  - Progress made by each side was reported regularly
  - The topics that are of common interest were discussed
  - Possibilities for exchanging students were investigated.

- Plan for 2015 Our proposal is to organize common working groups between Chinese and CEA-Saclay teams in the fields of detector design, software developments and physics studies. In particular the areas of interest of our teams include (although not limited to) the areas of tracking detectors and measurement of the invisible width of Z and H bosons