The Vision of CEPC-SppC

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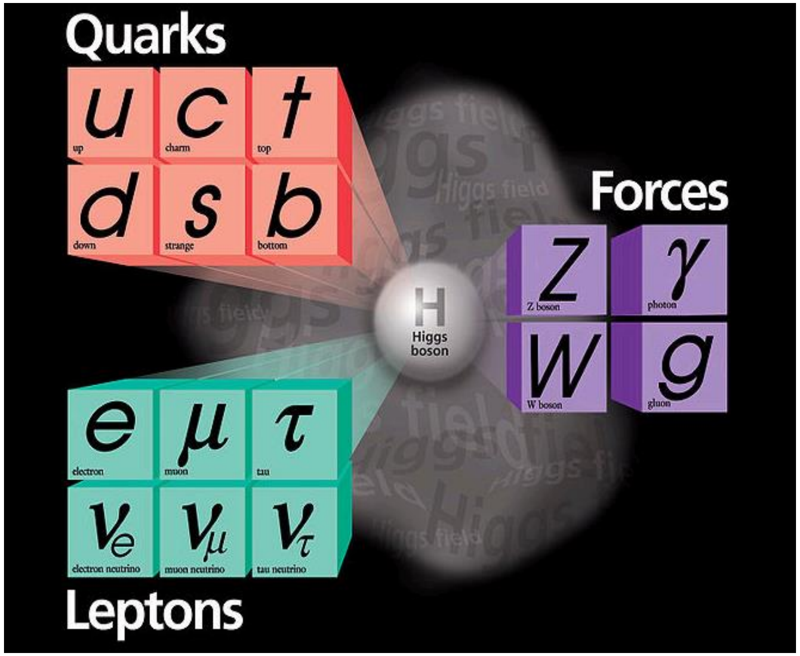
Where Are We Going ?

- After the Higgs, game is over ?
- Shall we wait for results from LHC/HL-LHC ?
- ILC ?
  - If yes, enough ? Next ?
  - If no, then ?



- What is the future of our field ?

Standard Model Is not Complete

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

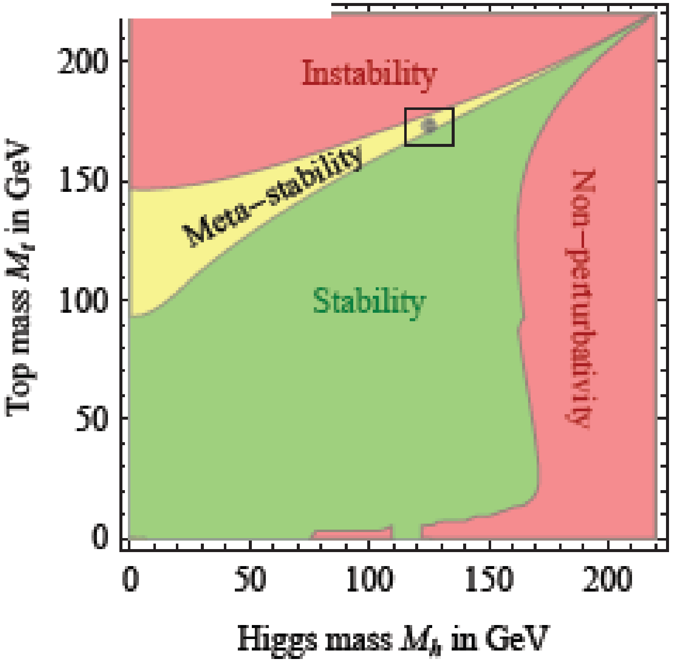
$$m_H^2 - m_{H,0}^2 \sim -\frac{3}{8\pi^2} y_t^2 \Lambda^2$$

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 GeV)^2 ! ?

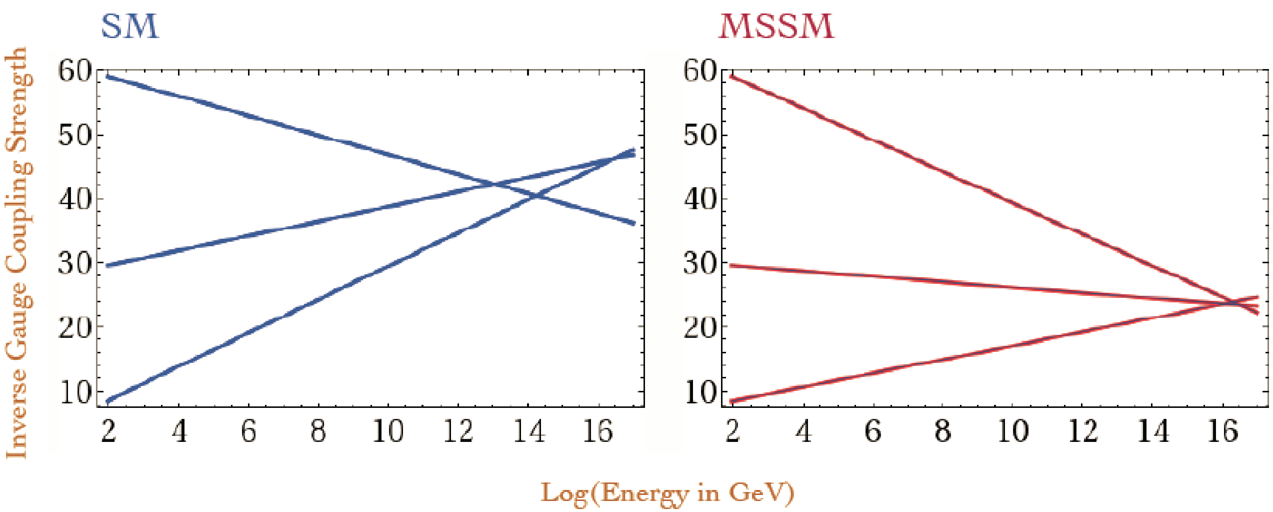
- Masses of Higgs and top quark are in the meta-stable region, why ? Fundamental reason ?
- Many of the free parameters in the SM are related to Higgs. A deeper theory ?



Fundamental reason(s) beyond SM ?!

Evidence Beyond the Standard Model

- **Unification at a high energy ?**

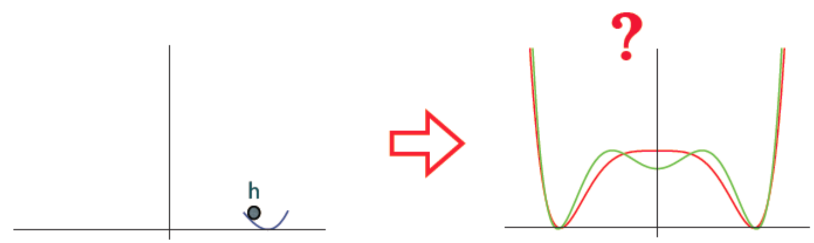


- **No dark matter particles in the SM, Needed ? Where ?**
- **No CP in the SM to explain Matter-antimatter asymmetry, why ?**
- **How to describe neutrinos in the SM ?**
- **SUSY can provide solutions to many of these problems, incident ?**

New Tasks after the Higgs Discovery

- **Open questions about Higgs**
  - Consistent with SM ?
  - Composite or elementary ?
  - Other Higgs ？
  - New properties ？
  - Responsible for CP violation？
  - What type of potential ?

Higgs is the only elementary particle with spin 0 !
Never seen point-like scalars !



- **New type of interactions concerning only the Higgs:**
  - Yukawa coupling through Higgs with spin 0:
    - hττ, hbb, htt coupling constant， ~10% @ LHC
  - Self-coupling h^3 & h^4:
    - ~ 50% @ LHC

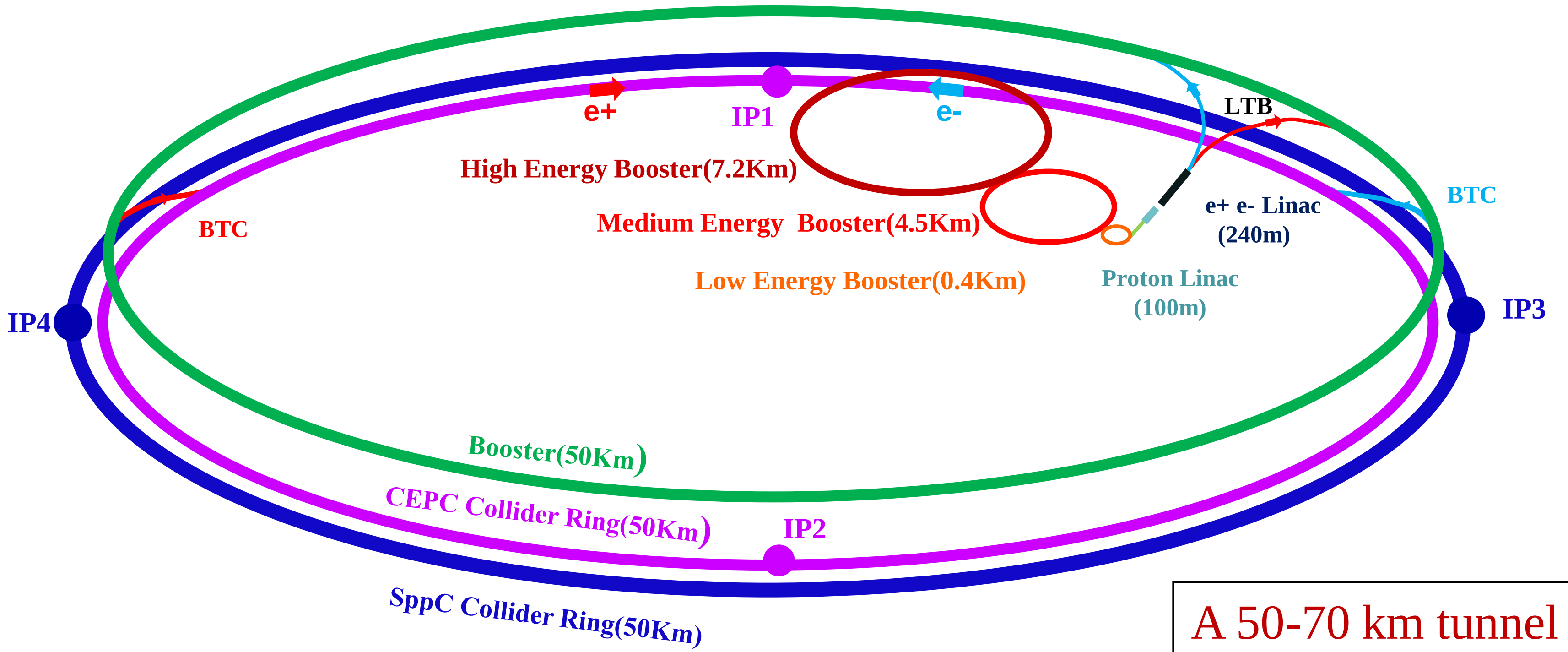
Need a factor of ~10 improvement over LHC !

- Yes, there are new physics, and also “standard” physics to be learned
- ILC is not enough, even if it can be built soon
- High energy frontier is still the center of particle physics

What to do ?

Our Proposal: CEPC+SppC

- Thanks to the low mass Higgs, we can build a Circular Higgs Factory(CEPC), followed by a proton collider(SppC) in the same tunnel
- A natural continuation of BEPC➔BEPCII➔CEPC➔SppC



In Europe, TLEP ➔ FCC

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

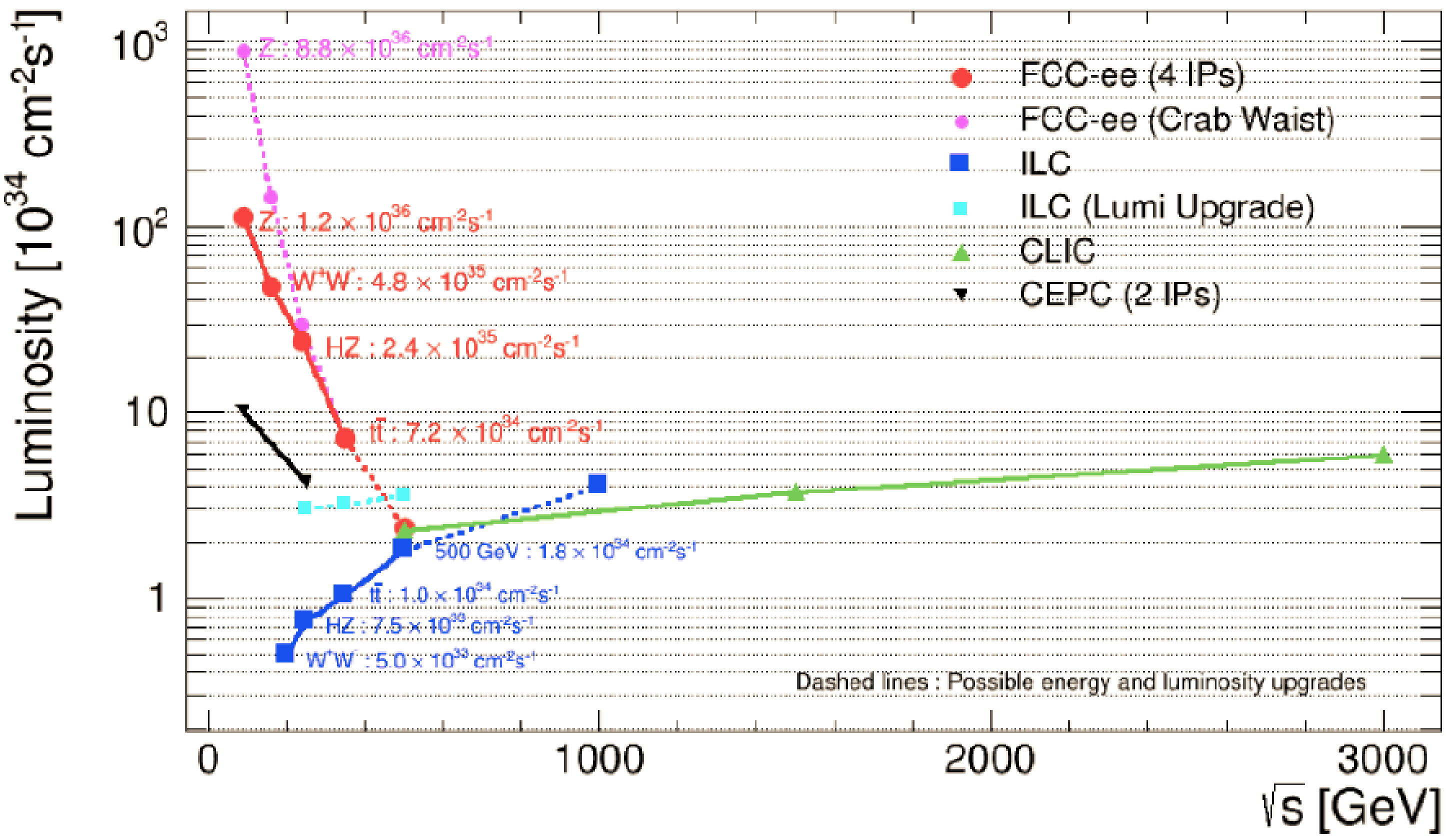
Science

- **Electron-positron collider(90, 250, 350 GeV)**
  - Higgs Factory: Precision study of Higgs(m_H, J^{PC}, couplings)
    - Similar & complementary to ILC
    - Looking for hints of new physics
  - Z & W factory: precision test of SM
    - Deviation from SM ? Rare decays ?
  - Flavor factory: b, c, τ and QCD studies
- **Proton-proton collider(~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 !

Design Goal of CEPC/FCC-ee

- Limit SR power to 50 MW per beam
- CEPC: single ring, head-on collision, up to 250 GeV
- FCC-ee: double ring, large crossing angle, up to 350 GeV



CEPC:
- 10^6 Higgs
- 10^{10} Z

FCC-ee:
- 10^7 Higgs
- $10^{12\text{-}13}$ Z

Design Goal of SPPC/FCC-pp

- Technology to bend the proton beam is limited by the field strength of the dipole magnet. Currently we can only imagine up to 20 T.
- Hence, ~ 100 km ring and ~ 100 TeV is a generic desire

Why in China？

Physics wise，
CEPC+SPPC is ideal

- Timing (after BEPCII)
- Technological feasibility (experience at BEPC/BEPCII)
- Economy ➔ new funding to the community
- Large & young population ➔ new blood to the community
- Affordable tunnel & infrastructure ➔ still cheap in China now
- Money will be taken by somebody anyway ➔ It is a pity if we miss it
- Too expensive ?
  - BEPC cost/4 y/GDP of China in 1984 ≈ 0.0001
  - SSC cost/10y/GDP of US in 1992 ≈ 0.0001
  - LEP cost/8y/GDP of EU in 1984 ≈ 0.0002
  - LHC cost/10y/GDP of EU in 2004 ≈ 0.0003
  - ILC cost/8y/GDP of Japan in 2018 ≈ 0.0002
  - CEPC cost/6y/GDP of China in 2020 ≈ 0.0001
  - SPPC cost/10y/GDP of China in 2036 ≈ 0.0001- 0.0002

Current Status

- Initiated a global effort for the Conceptual design
- Pre-CDR completed
  - No show-stoppers
  - Technical challenges identified → R&D issues
  - Preliminary cost estimate
- R&D issues identified and funding request underway
  - Seed money from IHEP available: 12 M RMB/3 years
  - MOST: ~ 100 M / 5yr, hopefully next year
  - NCDR: ~1 B RMB / 5 yr, maybe 2017
- Working towards CDR by 2016
  - A working machine on paper
- Site selection
- Internationalization & organization

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 -

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

Can be downloaded from

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

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

403 pages, 480 authors

The CEPC-SPPC Study Group

March 2015

IHEP-CEPC-DR-2015-01

IHEP-AC-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

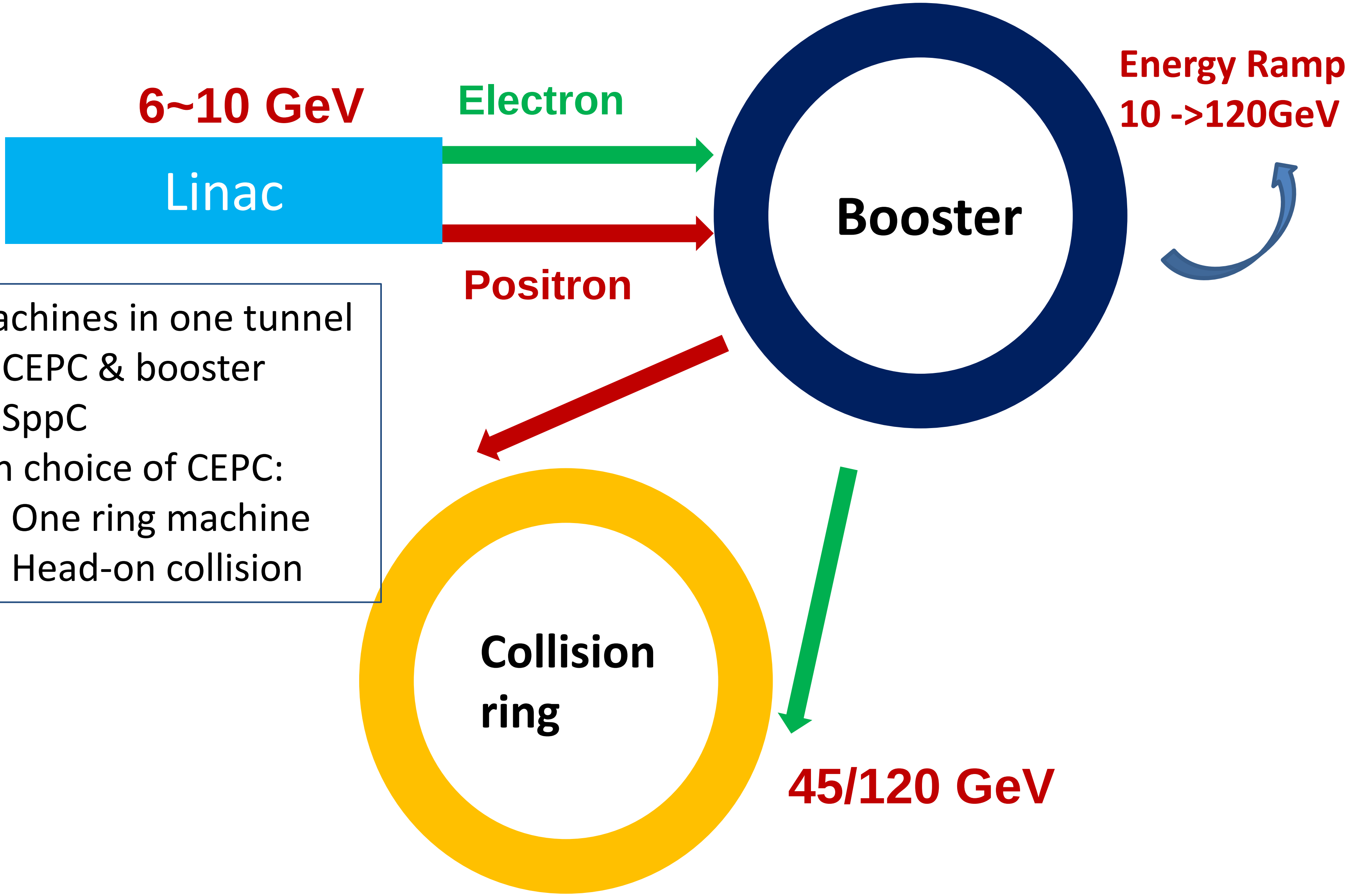
328 pages, 300 authors

The CEPC-SPPC Study Group

March 2015

International Review of Pre-CDR

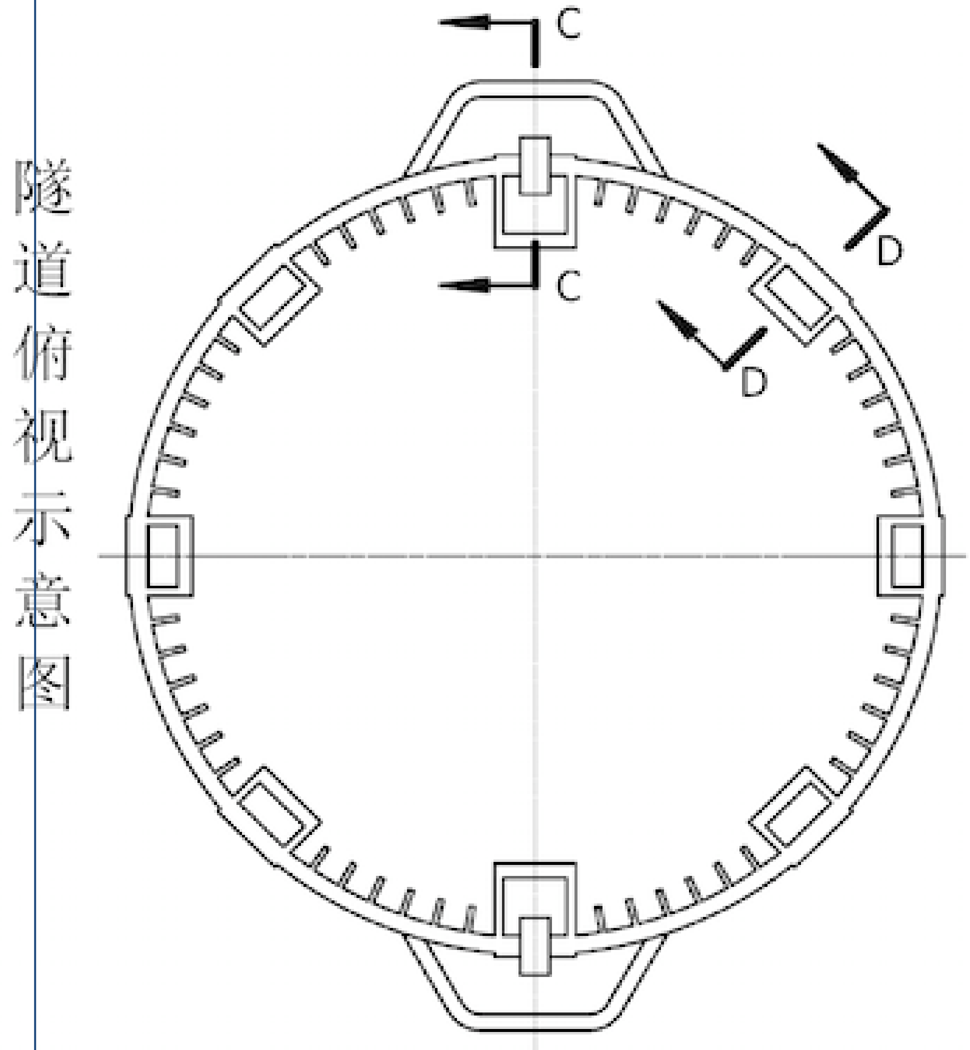
CEPC Accelerator



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

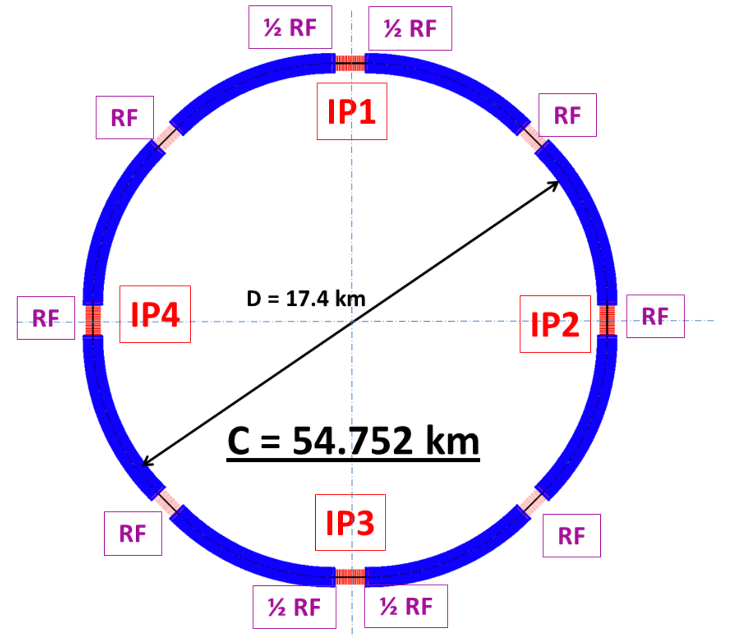
Compatibility: a Complicated Issue

- 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



CEPC Design

- Critical parameters:
  - SR power: 51.7 MW/beam
  - 8*arcs, 2*IPs
  - 8 RF cavity sections (distributed)
  - RF Frequency: 650 MHz
  - Filling factor of the ring: ~70%



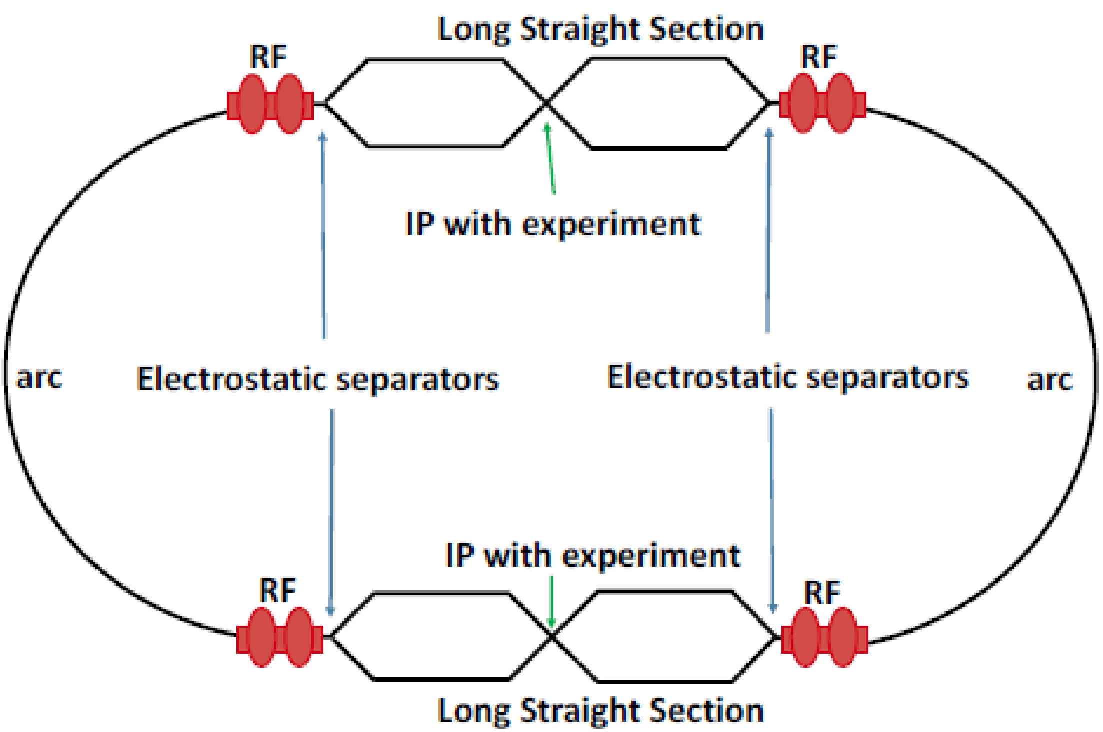
Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	**Circumference [C]**	m	54752
Number of IP[N_{IP}]		2	**SR loss/turn [U_0]**	GeV	3.11
Bunch number/beam[n_B]		50	**Energy acceptance RF [h]**	%	5.99
SR power/beam [P]	MW	51.7	**Beam current [I]**	mA	16.6
emittance (x/y)	nm	6.12/0.018	**β_{IP}(x/y)**	mm	800/1.2
Transverse size (x/y)	μm	69.97/0.15	**Luminosity /IP[L]**	$cm^{-2}s^{-1}$	2.04E+34

Main Challenges

- Beam physics: dynamic aperture, momentum acceptance, electron cloud, pretzel scheme, …
- Superconducting cavity: High-Q cavity, HOM dumping, mass production, power consumption,…
- Total power consumption: ~ 500 MW ! ➔ need a green machine
  - Reuse the thermal power, ~ 200 MW
    - Heating of houses ➔ close to a big city, summer ?
    - Gasifying liquified natural gas ➔ close to a harbor
    - Agricultural greenhouse ➔ summer ?
  - Increase the efficiency of the RF power supply to more than 70%, even 80%
  - ICFA established a panel this summer for this issue
  - Partial double ring for reduced power and higher luminosity ?

Partial Double-Ring Machine ?

- ~ 10% double-ring
- Large crossing angle & Crab waist & small β_y
- O(1000) bunches
- Luminosity close to double-ring machine ?
- Issues
  - Electrostatic separators
  - RF systems
  - Electron Cloud Issues



M. Koratzinos, talk given at HF2014, Beijing
M. Koratzinos & F. Zimmermann, this Conf.
J. Gao, IHEP-AC-LC-Note2013-012

SppC Design

- Proton-proton collider luminosity

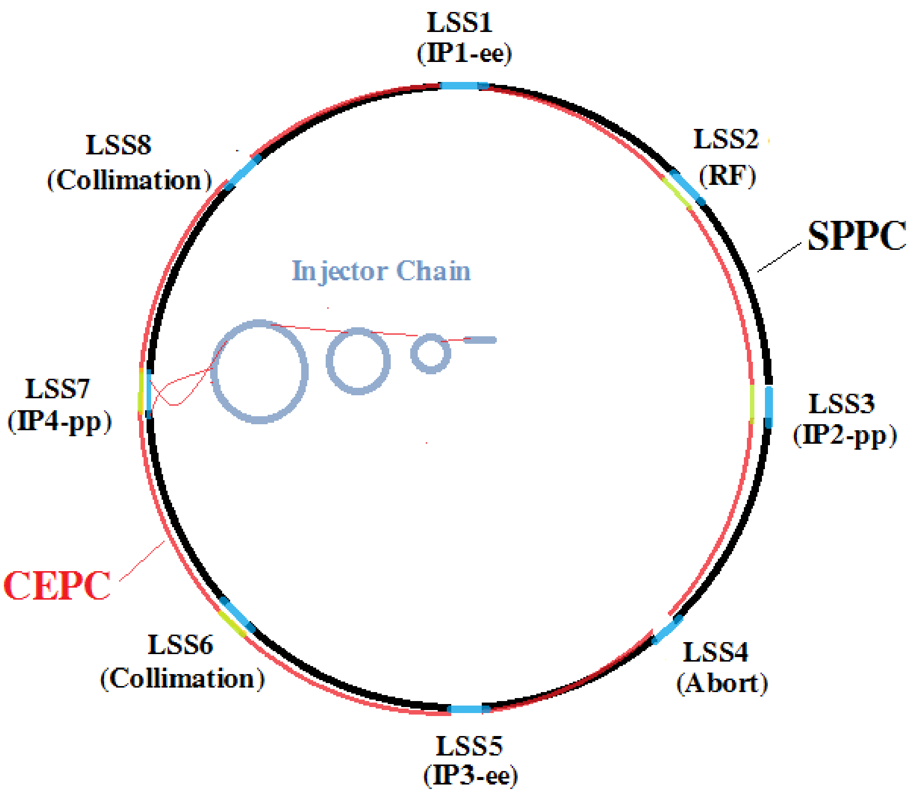
$$L_0 = \frac{N_p^2 N_b f_{rep} \gamma}{4\pi\varepsilon_n \beta_{IP}} F \qquad (F = \sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\sigma_{x,IP}}\right)^2})$$

$$x = \frac{N_p r_p}{4pe_n} \text{ £ } 0.004$$

- 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

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

SppC General design



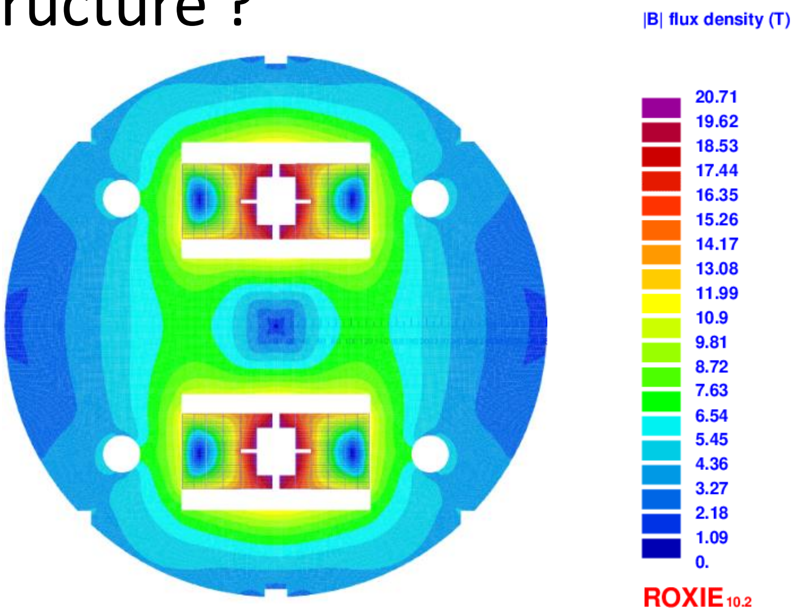
- 8 arcs (5.9 km) and long straight sections (850m*4+1038.4m*4)

Parameter	Value
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

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 ?
- ……

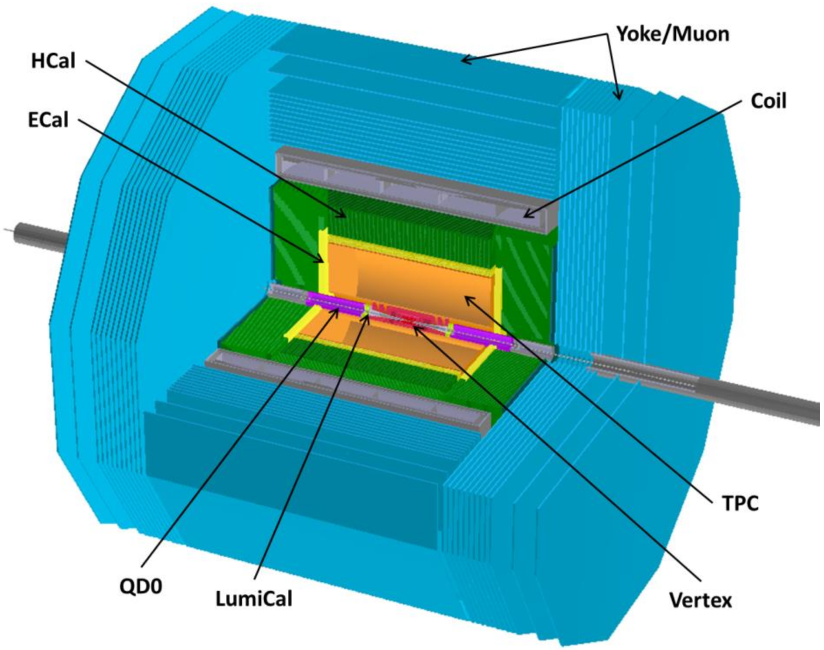
A R&D plan is developed.
Main focus is the magnet



A Conceptual design of *20-T Nb_3Sn + HTS common coil dipole magnet* from IHEP

CEPC Detector

- **Similar performance requirements to ILC detectors**
  - **Momentum:** $\sigma_{1/p} < 5\times10^{-5}\ \mathrm{GeV}^{-1}$ ← **recoiled Higgs mass**
  - **Impact parameter:** $\sigma_{r\phi} = 5 \oplus 10/(p\cdot\sin^{\frac{3}{2}}\theta)\ \mu\mathrm{m}$ ← **flavor tagging, BR**
  - **Jet energy:** $\frac{\sigma_E}{E} \approx 3-4\%$ ← **W/Z di-jet mass separation**
- **Beneficial from 20 years of ILC study**

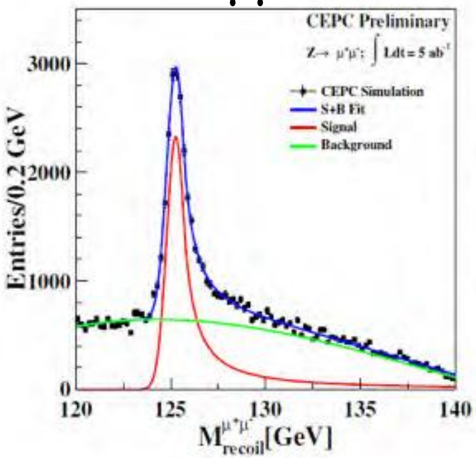


ILD-like detector but (*incomplete*):

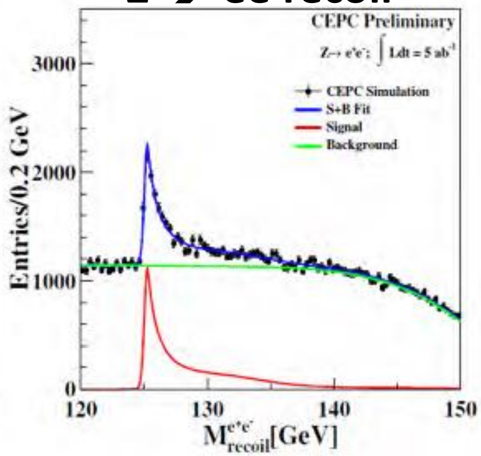
- Shorter L* (1.5m) → constraints on space for the Si/TPC tracker
- No power-pulsing → cooling issues
  Limited CoM (up to 250 GeV) → calorimeters of reduced size
- Lower radiation background → vertex detector closer to IP
- …

Simulation and Physics

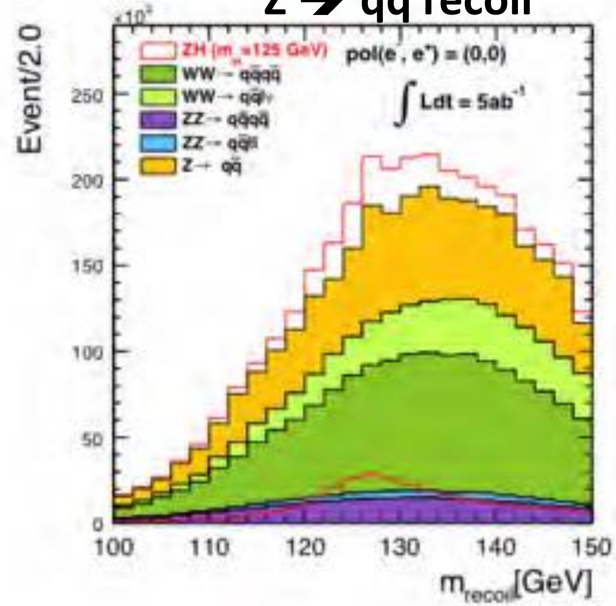
Z → μμ recoil



Z → ee recoil



Z → qq recoil

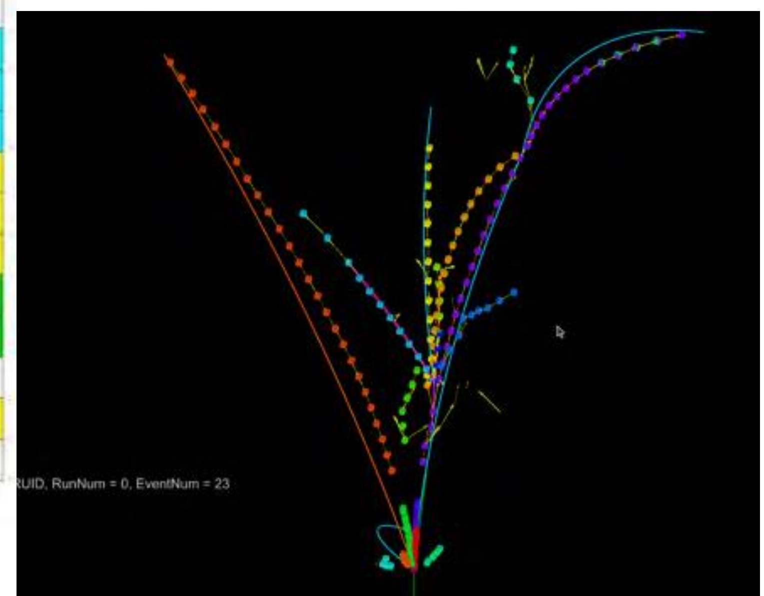


	di-muon	di-electron	di-neutrino	di-jets
σ(ZH)			-	
M_H				
σ(ZH)*Br(H→bb)				
σ(ZH)*Br(H→cc)				
σ(ZH)*Br(H→gg)				
σ(ZH)*Br(H→WW)				
σ(ZH)*Br(H→ZZ)				
σ(ZH)*Br(H→ττ)				
σ(ZH)*Br(H→γγ)				
σ(ZH)*Br(H→μμ)				
σ(νν H)*Br(H→bb)	-	-		-
Br(H→invisible)			-	
Br(H→exotic)				

Signal with CEPC Full Simulation, Bkgrd with Fast Simulation

CEPC Fast Simulation

Extrapolated from ILC/FCC-ee results

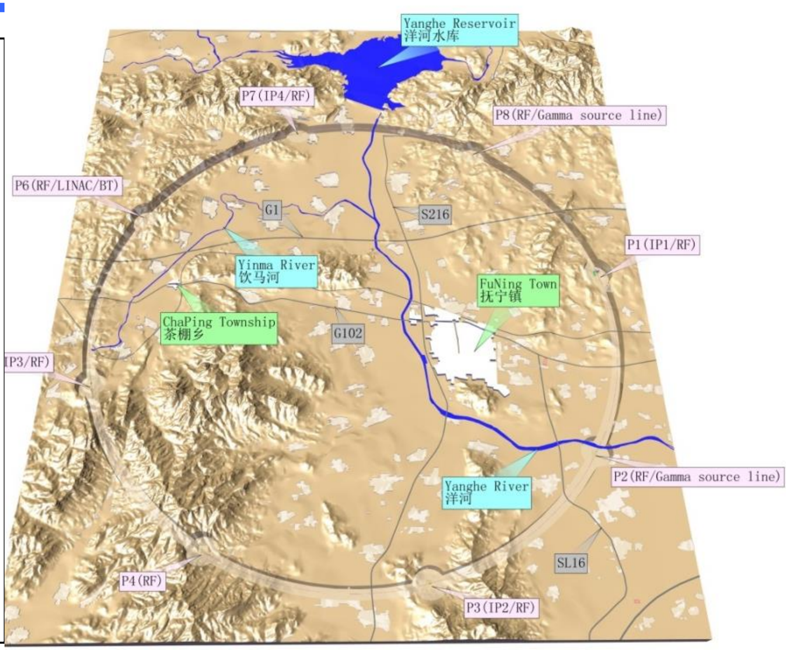


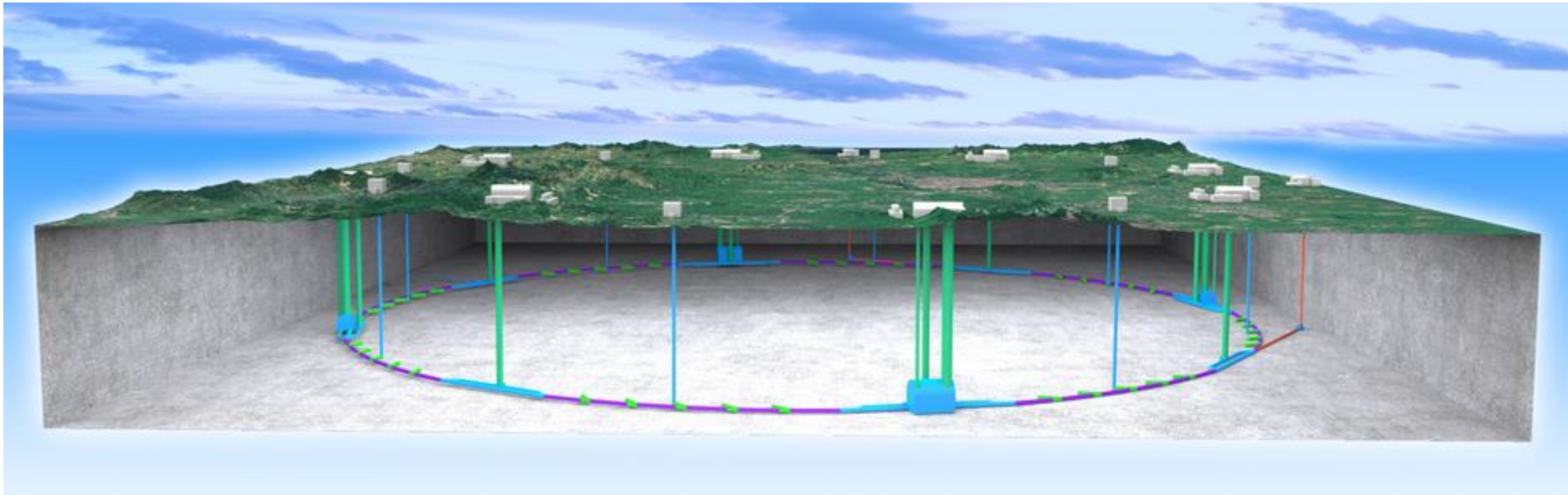
A Candidate Site

- 300 km from Beijing
- 3 h by car
- 1 h by train

Civil Construction

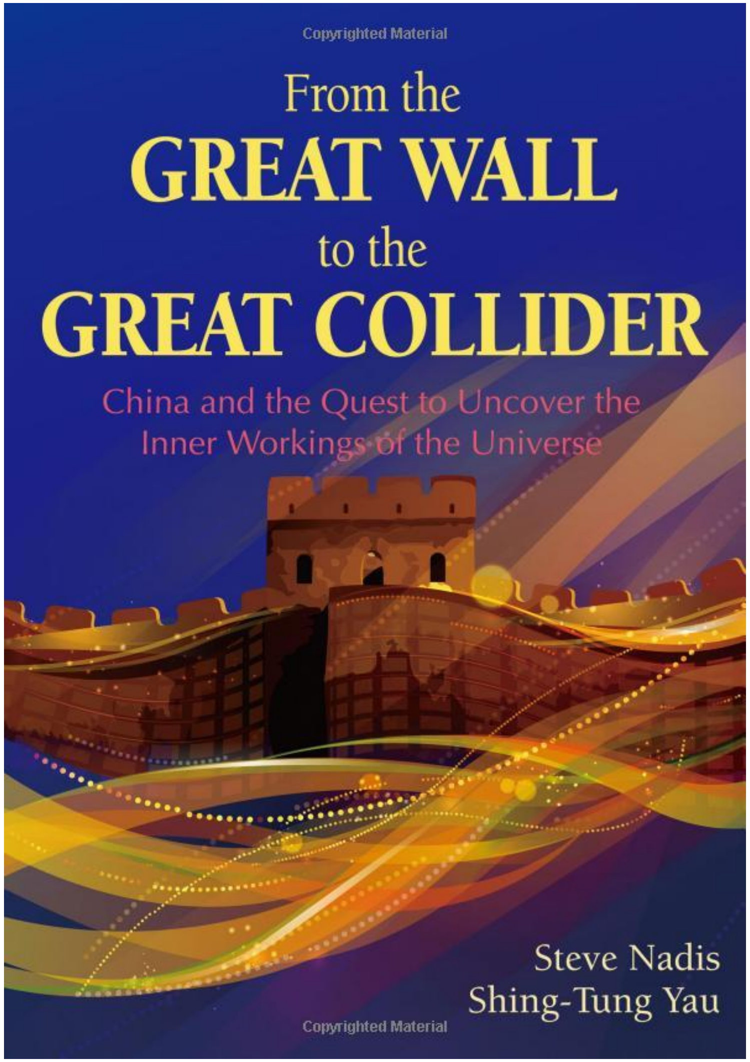
- A credible design with cost estimate
- The key to keep the cost low
  - Find a site geologically the best(granite)
  - Optimize of the design
  - Choose the right designer & construction contractor
  - Management





Organization and Activities

- International workshops
  - ICFA Higgs factory workshop, Oct. 2014
  - Workshop on CEPC organized by IAS HKUST, Jan. 2015
  - ICFA workshop on SC Magnet, June 2015
  - IHEP-DOE CEPC physics workshop in Aug. 10-12, 2015
  - Beijing-Chicago workshop on CEPC in Sep. 2015
- Training & professional development
- Communication, education & Outreach
- An international advisory Board establishe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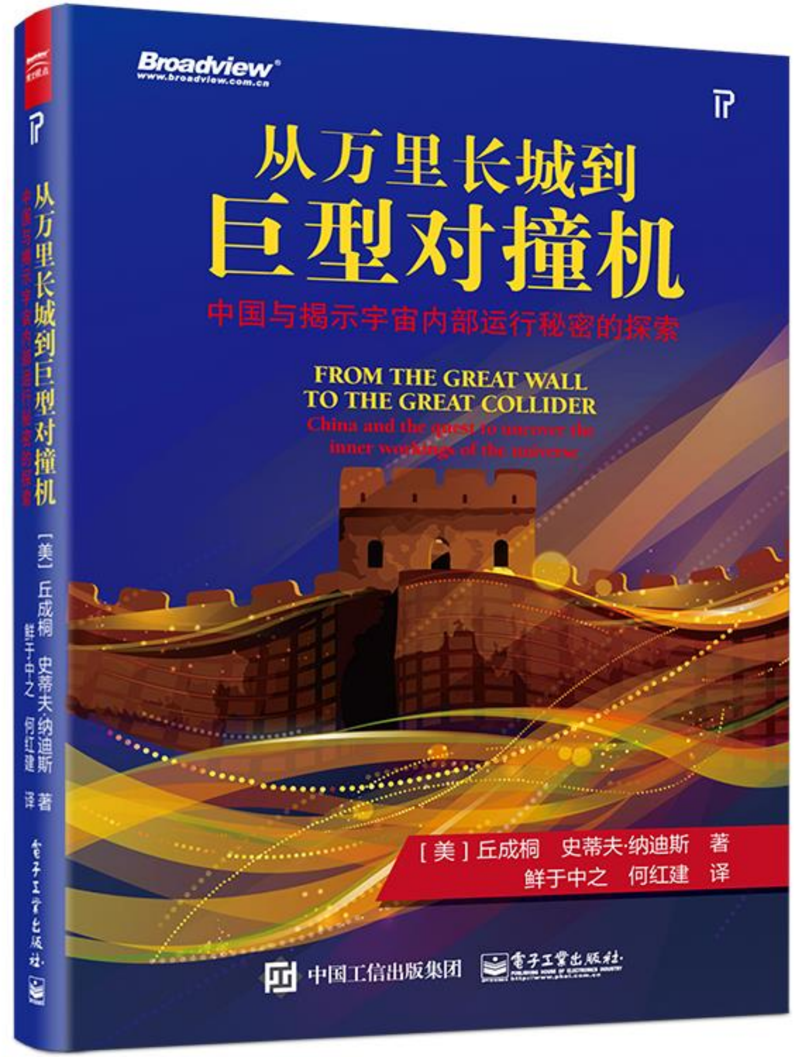
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Summary

- It is difficult but very exciting
- Tremendous efforts up to now with real progress in all fronts
- A promising future: please be optimistic !
- Let work together to make it happen

Even if it is not in China, it is still very beneficial to our field and to the Chinese HEP & Science community. We fully support a global effort