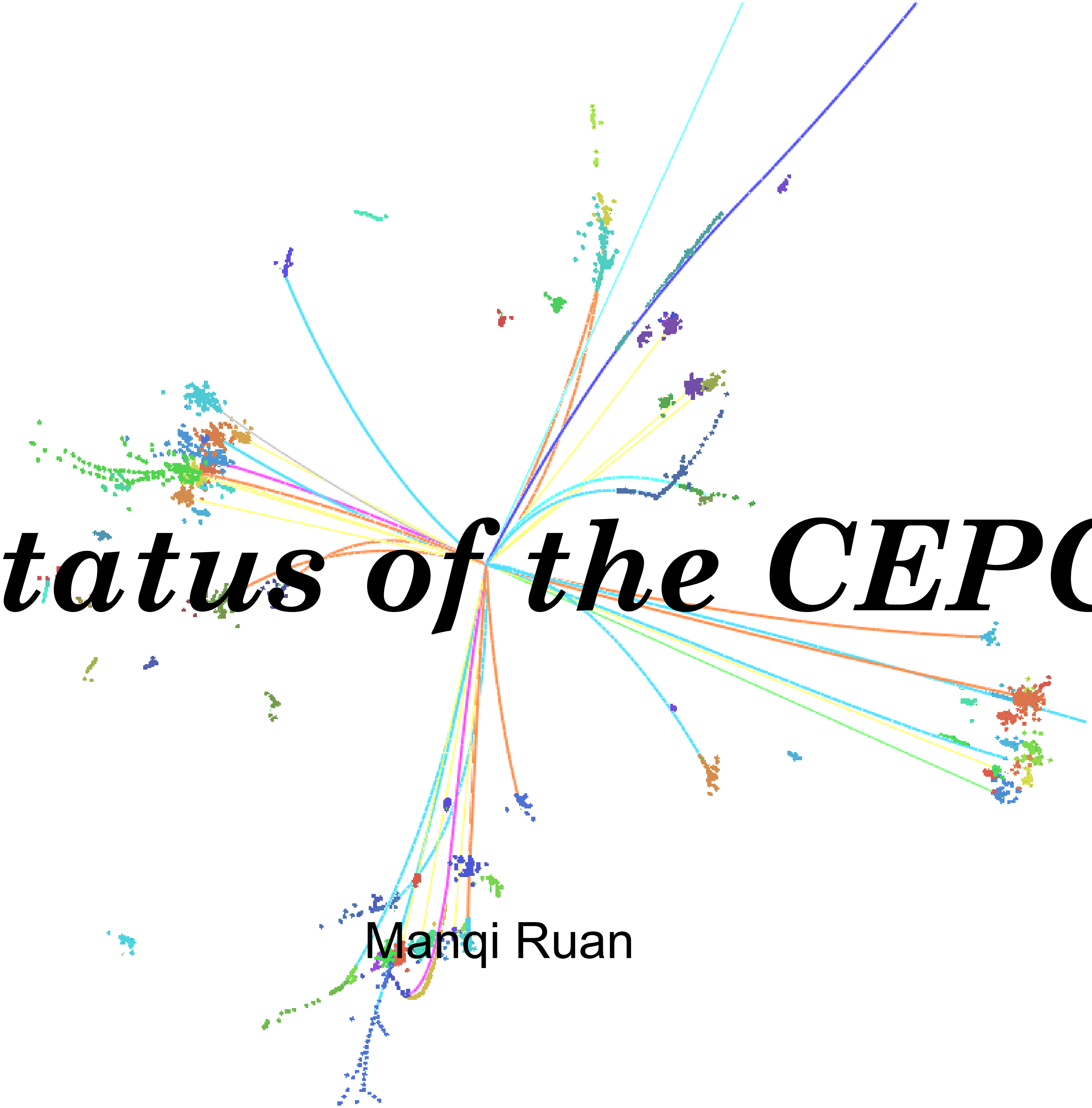
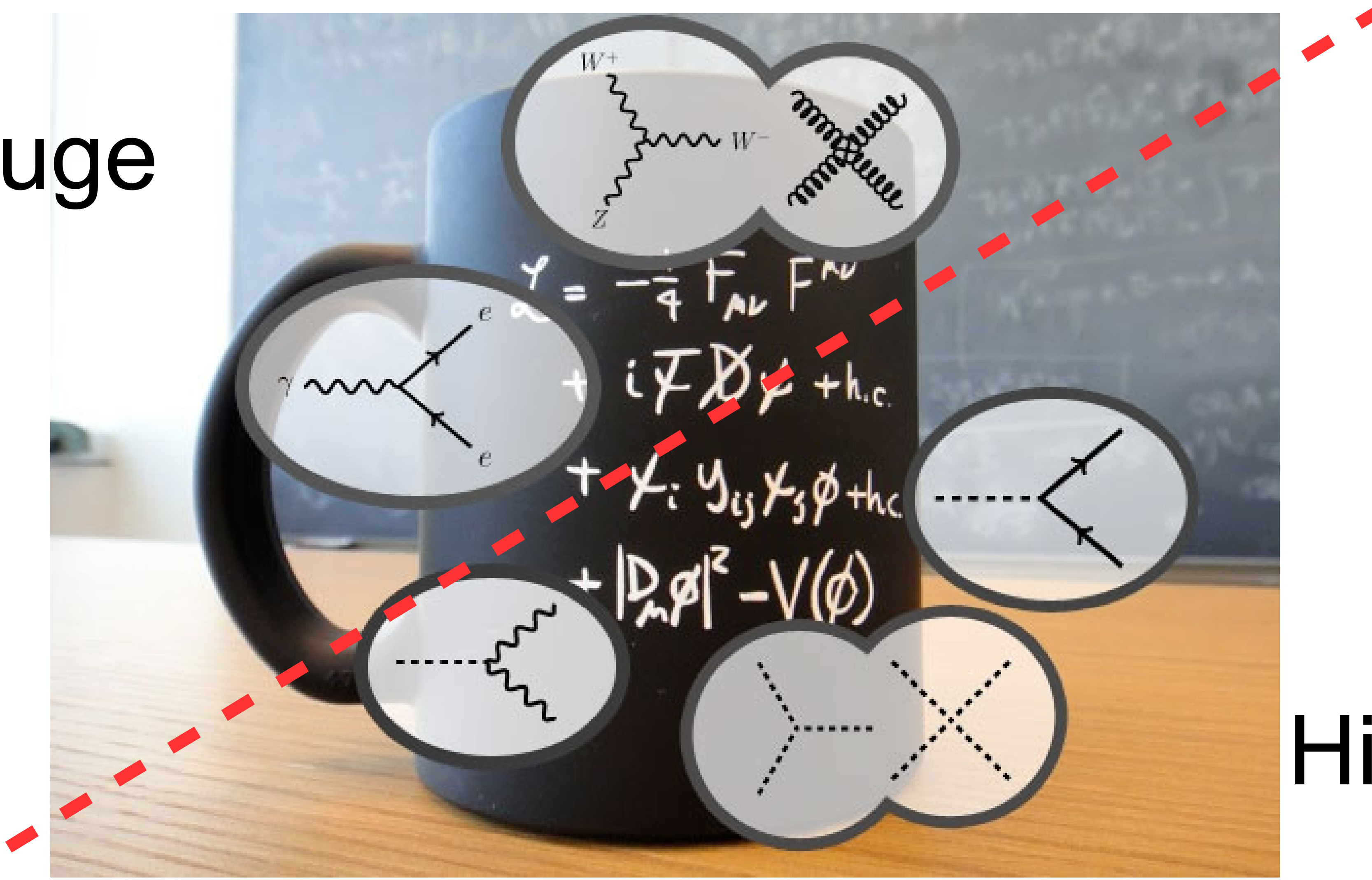
Status of the CEPC



Manqi Ruan

The Higgs field: one of the two pillars of the SM

Gauge

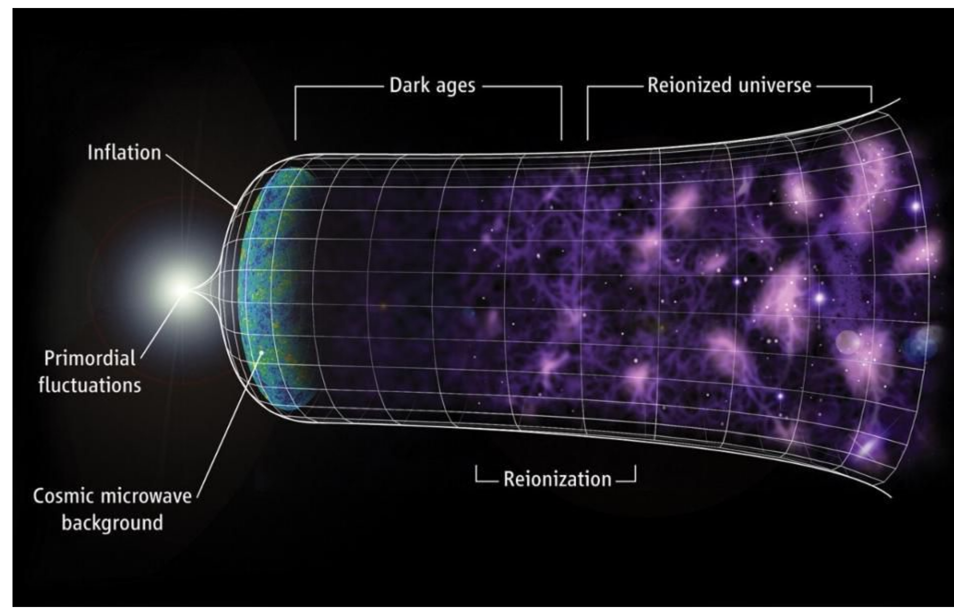


Higgs

Higgs: linked to many known unknowns of the SM

- Hierarchy: From neutrinos to the top mass, masses differs by 13 orders of magnitude
- Naturalness: Fine tuning of the Higgs mass
- Masses of Higgs and top quark: meta-stable of the vacuum
- Unification?
- Dark matter candidate?
- Not sufficient CP Violation for Matter & Antimatter asymmetry

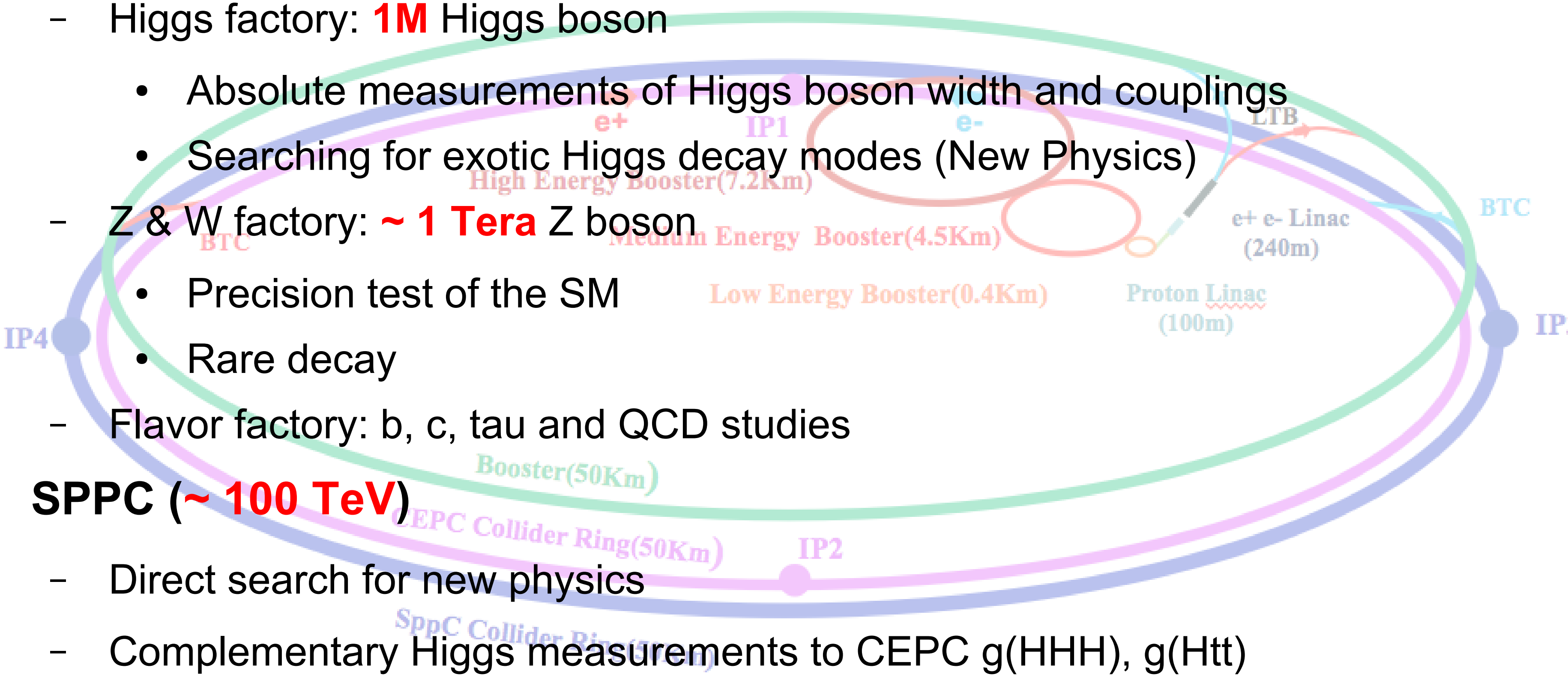
$$m_H^2 = 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}933{,}023$$
$$-36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}917{,}398$$
$$= (125\ \text{GeV})^2\ !\ ?$$



- **Most issues related to Higgs**

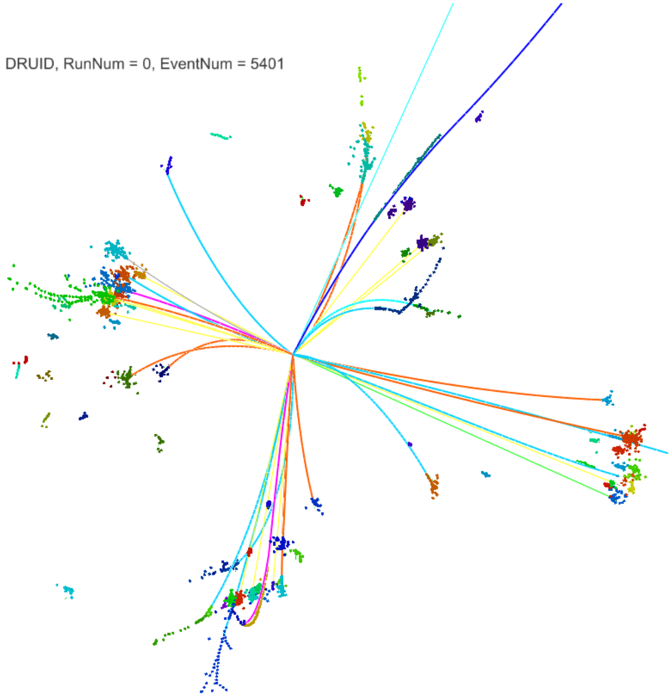
Science at CEPC-SPPC

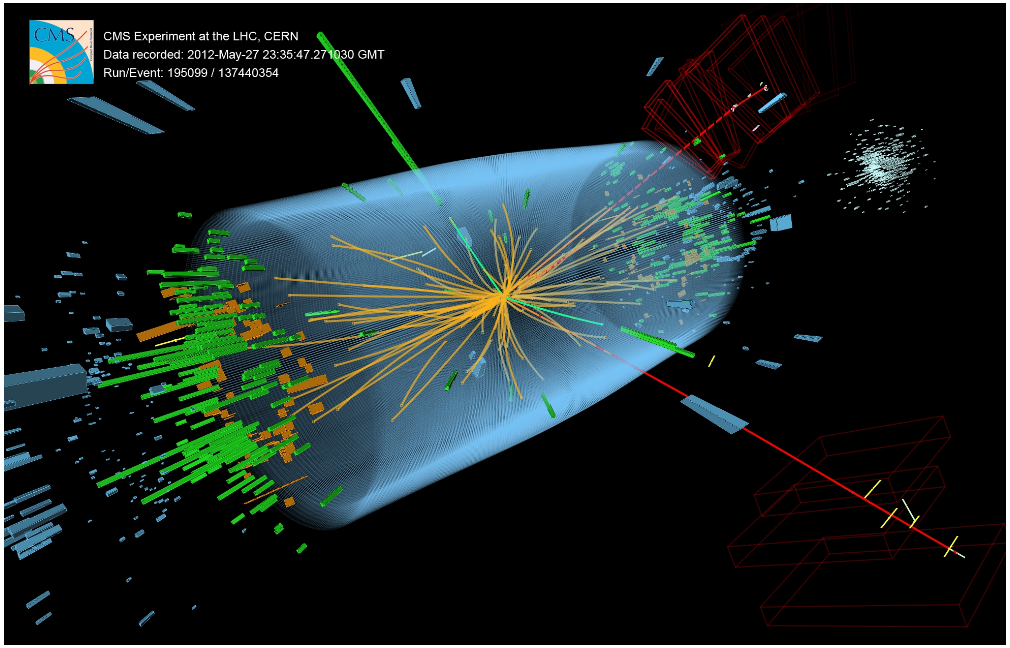
- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **~ 1 Tera** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**



Complementary

Higgs measurement at e+e- & pp

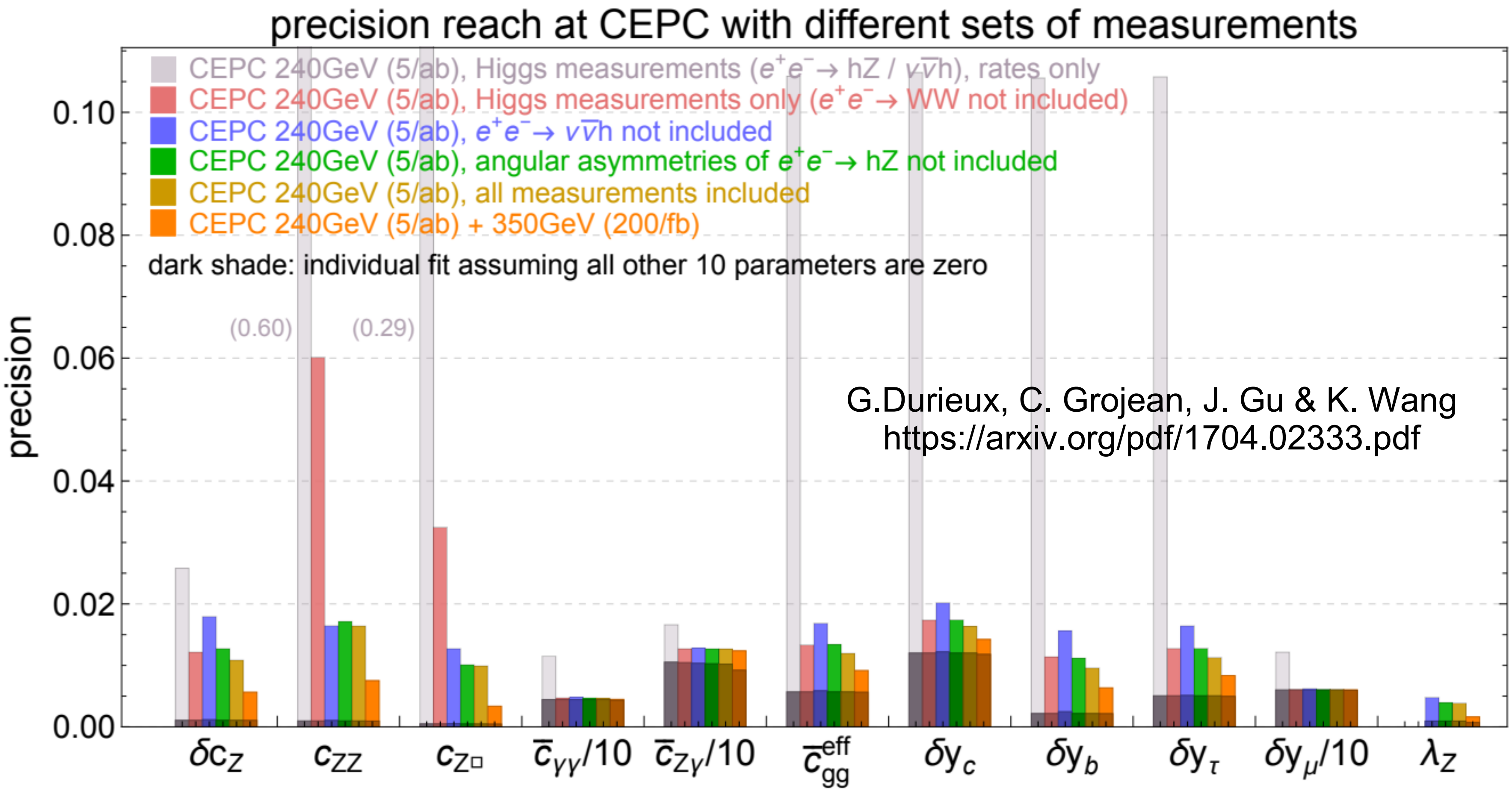




	Yield	efficiency	Comments
LHC	Run 1: 10^6 Run 2/HL: 10^{7-8}	$\sim o(10^{-3})$	High Productivity & High background, Relative Measurements, Limited access to width, exotic ratio, etc, Direct access to g(ttH), and even g(HHH)
CEPC	10^6	$\sim o(1)$	Clean environment & Absolute measurement, Percentage level accuracy of Higgs width & Couplings

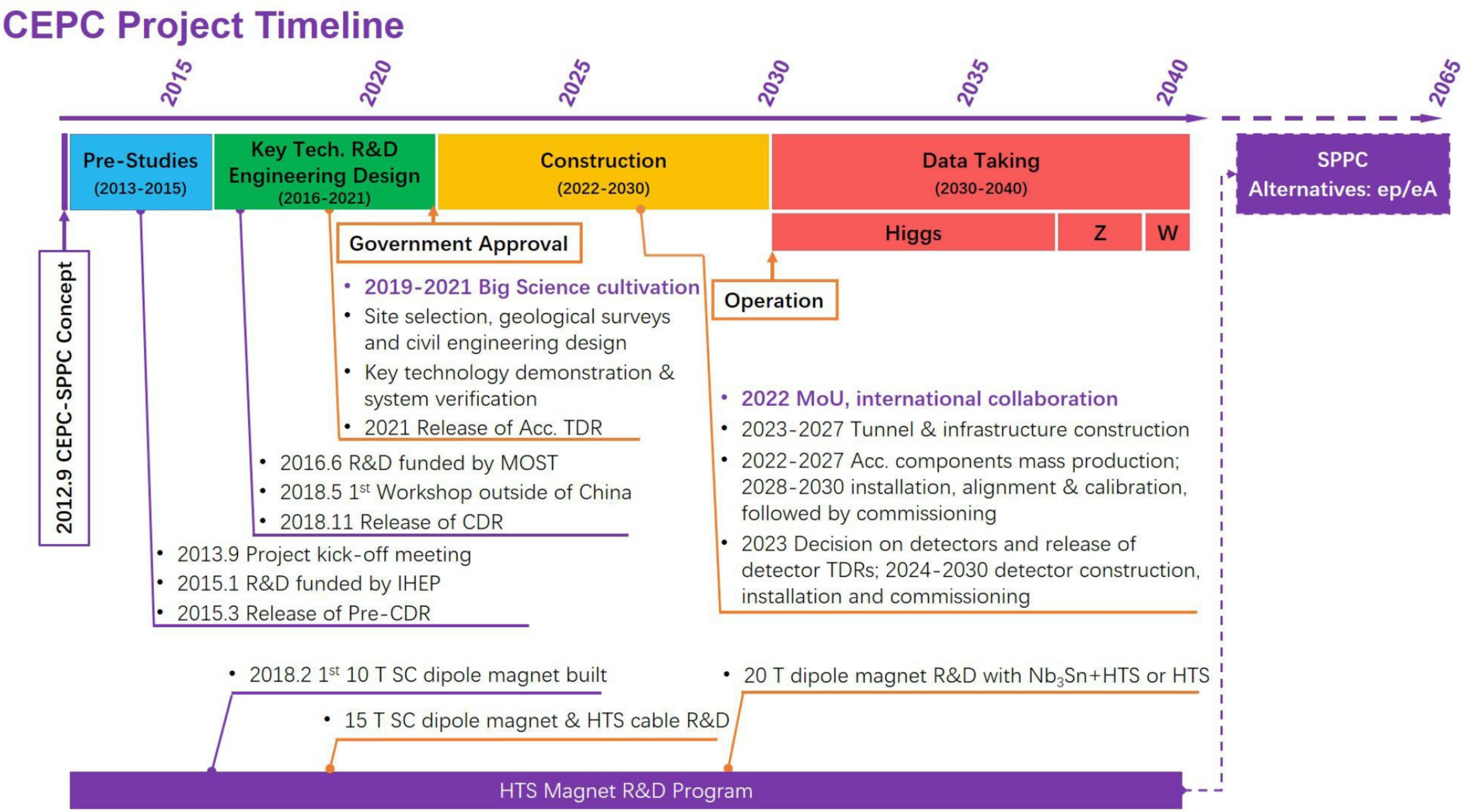
Complementary

Pheno-studies: EFT & Physics reach

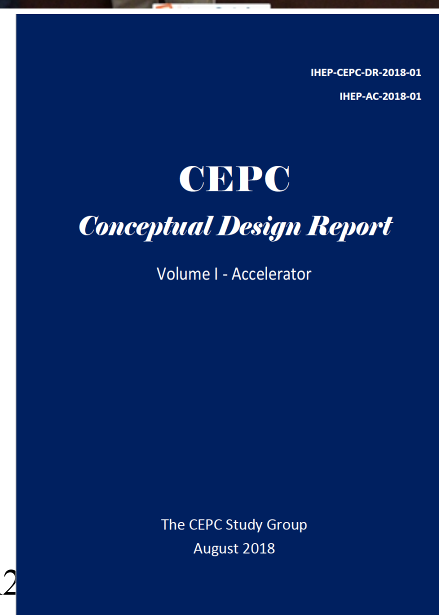


The Physics reach could be largely enhanced if the EW measurements is combined With the Higgs measurements (in the EFT)

Timeline


CEPC Project Timeline
2015
2020
2025
2030
2035
2040
2065
Pre-Studies
(2013-2015)
Key Tech. R&D
Engineering Design
(2016-2021)
Construction
(2022-2030)
Data Taking
(2030-2040)
SPPC
Alternatives: ep/eA
Higgs
Z
W
2012.9 CEPC-SPPC Concept
Government Approval
• 2019-2021 Big Science cultivation
• Site selection, geological surveys and civil engineering design
• Key technology demonstration & system verification
• 2021 Release of Acc. TDR
Operation
• 2022 MoU, international collaboration
• 2023-2027 Tunnel & infrastructure construction
• 2022-2027 Acc. components mass production; 2028-2030 installation, alignment & calibration, followed by commissioning
• 2023 Decision on detectors and release of detector TDRs; 2024-2030 detector construction, installation and commissioning
• 2016.6 R&D funded by MOST
• 2018.5 1st Workshop outside of China
• 2018.11 Release of CDR
• 2013.9 Project kick-off meeting
• 2015.1 R&D funded by IHEP
• 2015.3 Release of Pre-CDR
• 2018.2 1st 10 T SC dipole magnet built
• 20 T dipole magnet R&D with Nb3Sn+HTS or HTS
• 15 T SC dipole magnet & HTS cable R&D
HTS Magnet R&D Program

CDR released in Nov. 2018

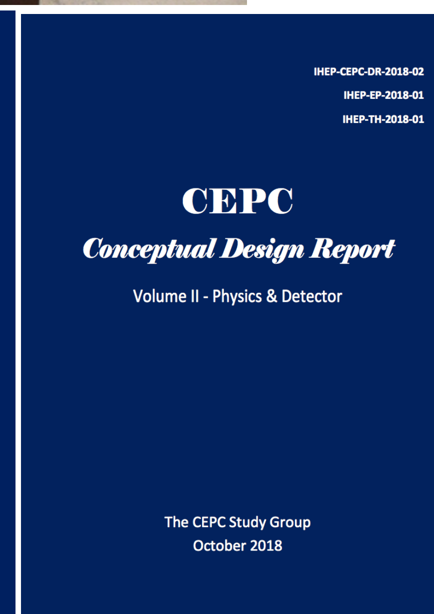

IHEP-CEPC-DR-2018-01
IHEP-AC-2018-01

CEPC

Conceptual Design Report

Volume I - Accelerator

The CEPC Study Group
August 2018


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

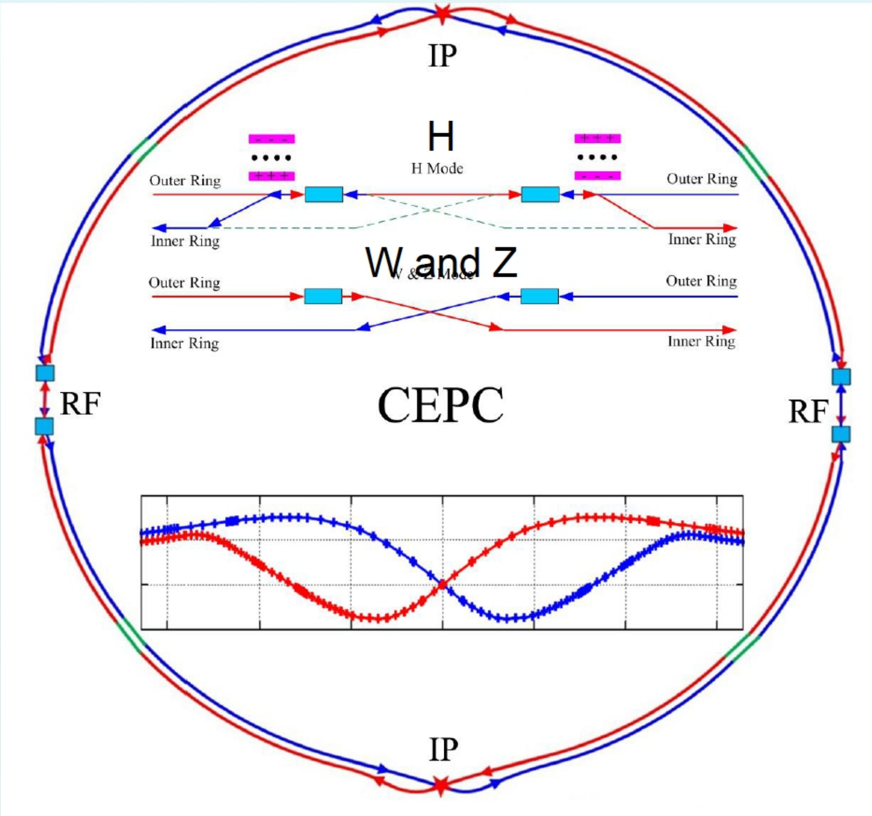
CEPC

Conceptual Design Report

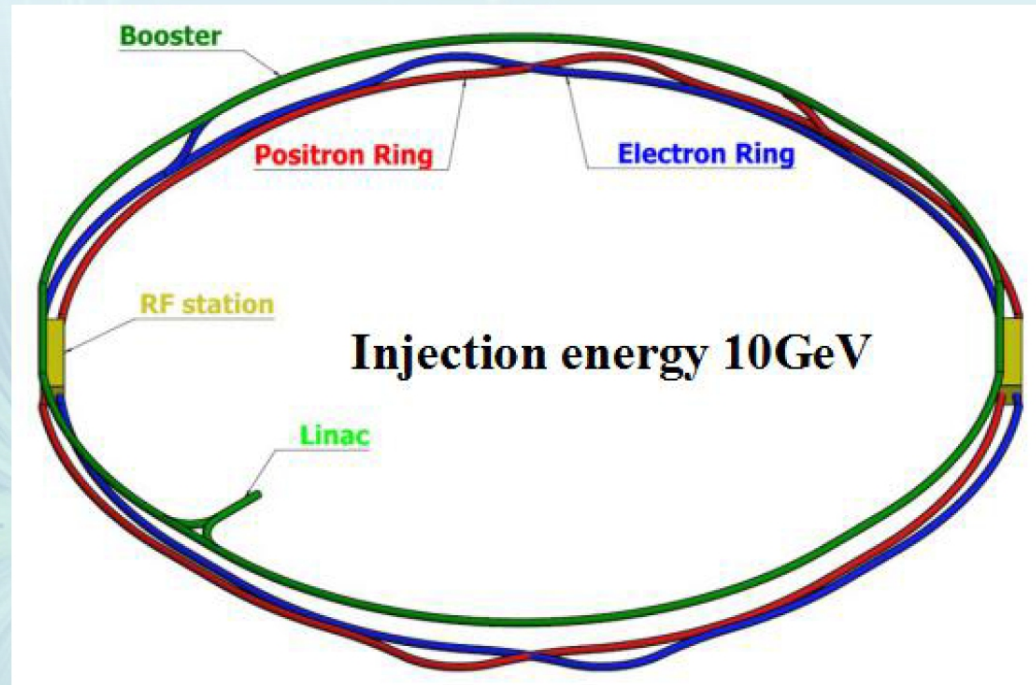
Volume II - Physics & Detector

The CEPC Study Group
October 2018

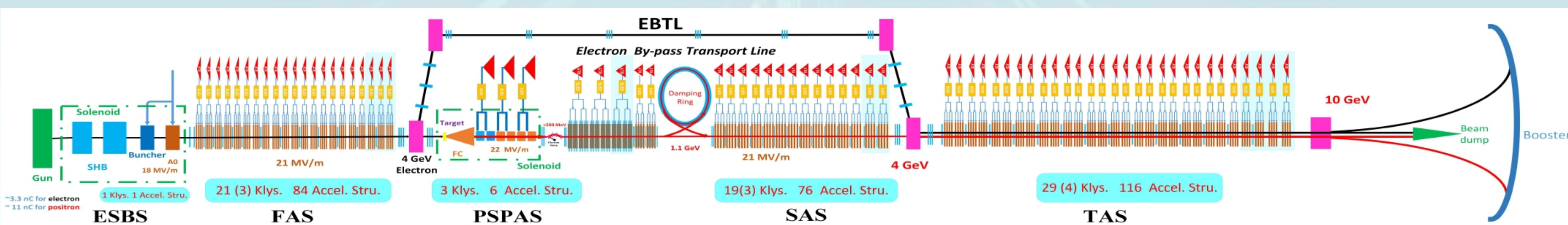
CEPC Accelerator Baseline Layout



CEPC collider ring (100km)



CEPC booster ring (100km)



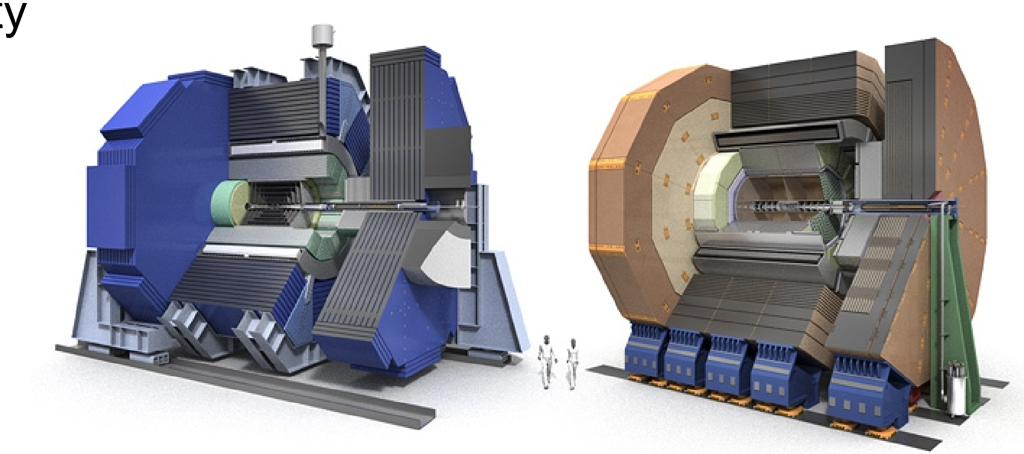
CEPC CDR Parameters

D. Wang

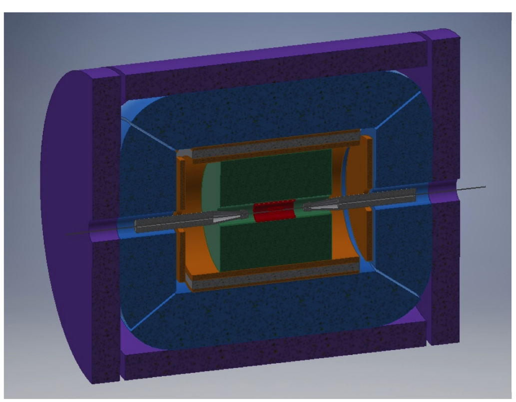
	Higgs	*W*	*Z* (3T)	*Z* (2T)
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	**242 (0.68μs)**	**1524 (0.21μs)**	**12000 (25ns+10%gap)**	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	**30**	**30**	**16.5**	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^* / β_y^* (m)	**0.36/0.0015**	**0.36/0.0015**	**0.2/0.0015**	**0.2/0.001**
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	**1.94**	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	**1.35**	**0.4**	**0.23**	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime _simulation (min)	100			
Lifetime (hour)	**0.67**	**1.4**	**4.0**	**2.1**
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP *L* ($10^{34}cm^{-2}s^{-1}$)	**2.93**	**10.1**	**16.6**	**32.1**

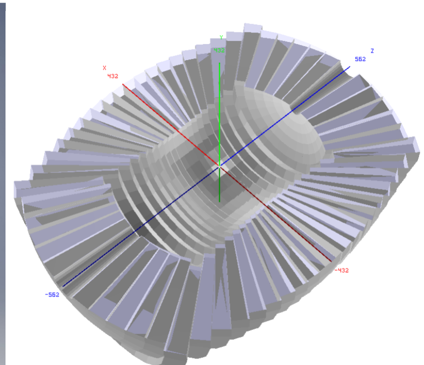
Two classes of Concepts

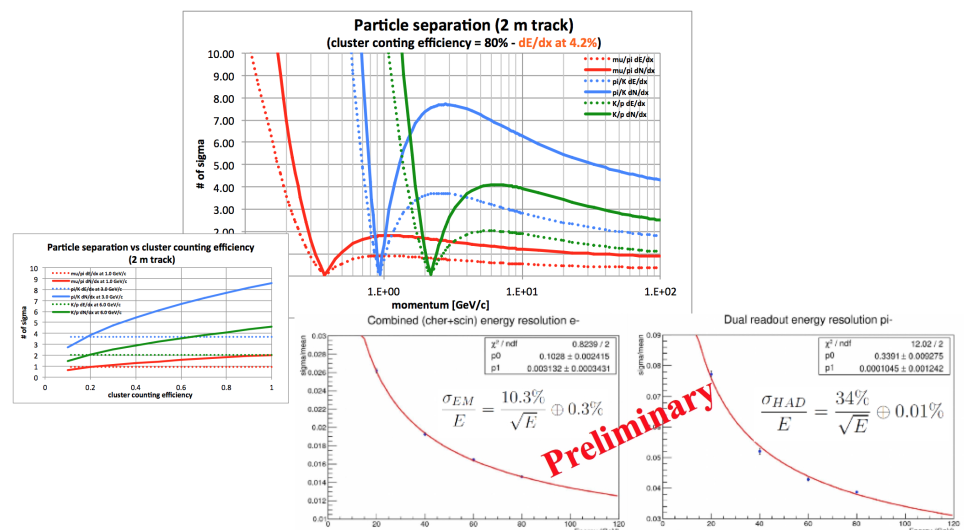
- PFA Oriented concept using High Granularity Calorimeter
  - + TPC (ILD-like, **Baseline**)
  - + Silicon tracking (SiD-like)



- Low Magnet Field Detector Concept (IDEA)
  - Wire Chamber + Dual Readout Calorimeter



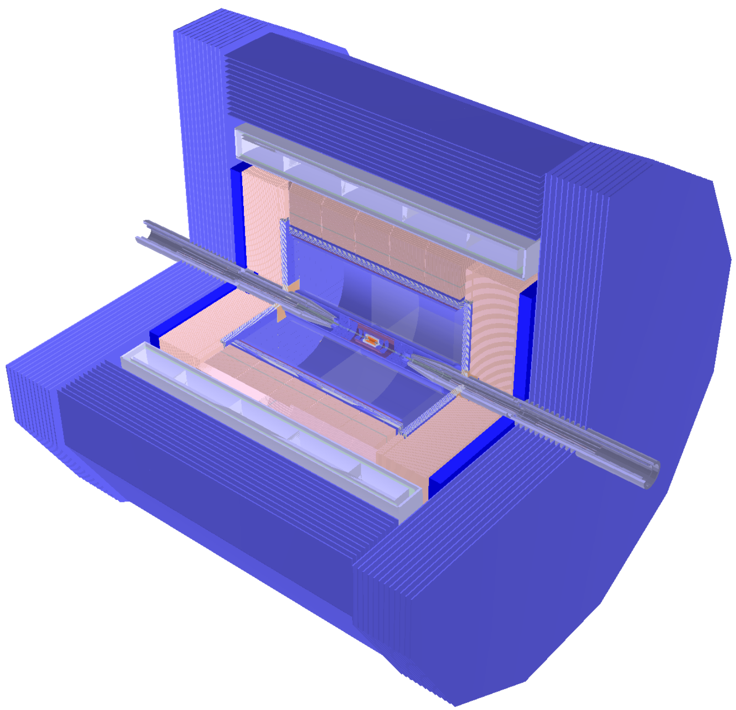


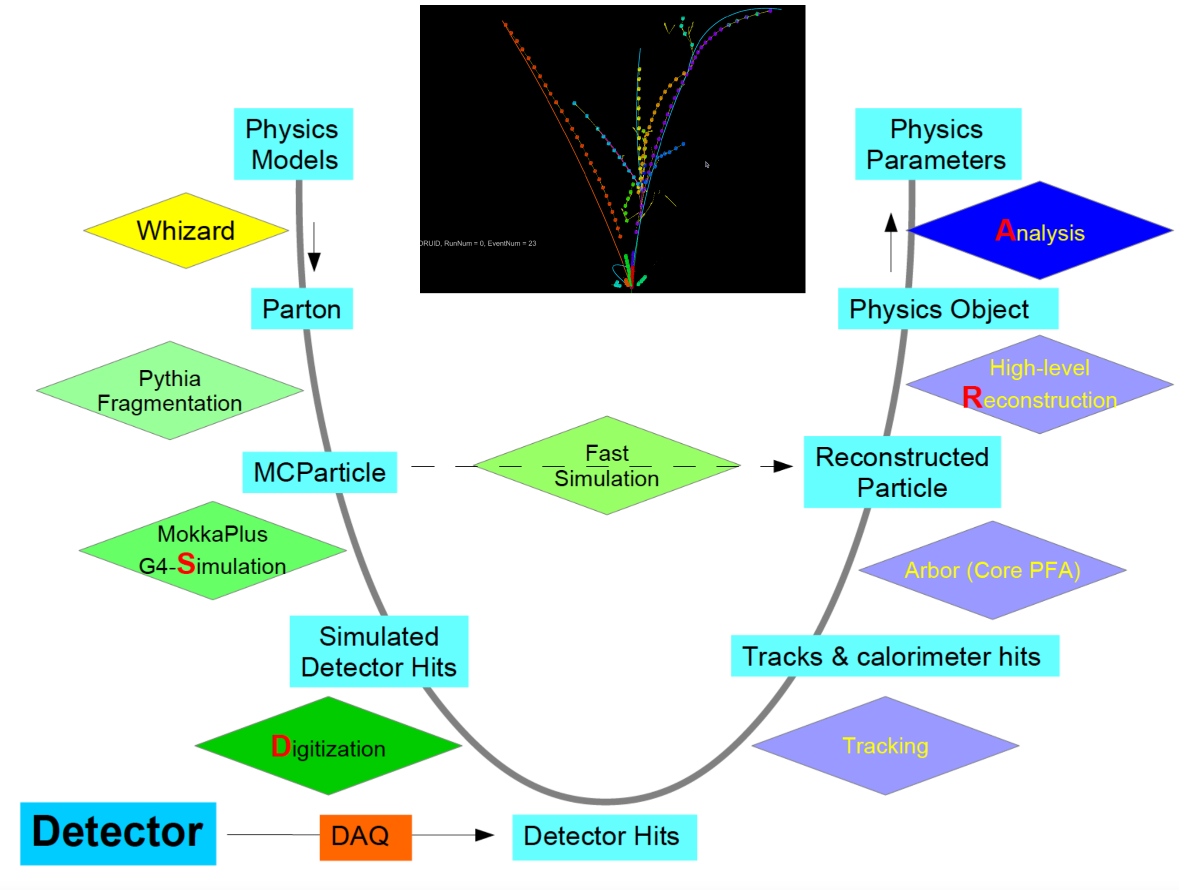


https://indico.ihep.ac.cn/event/6618/

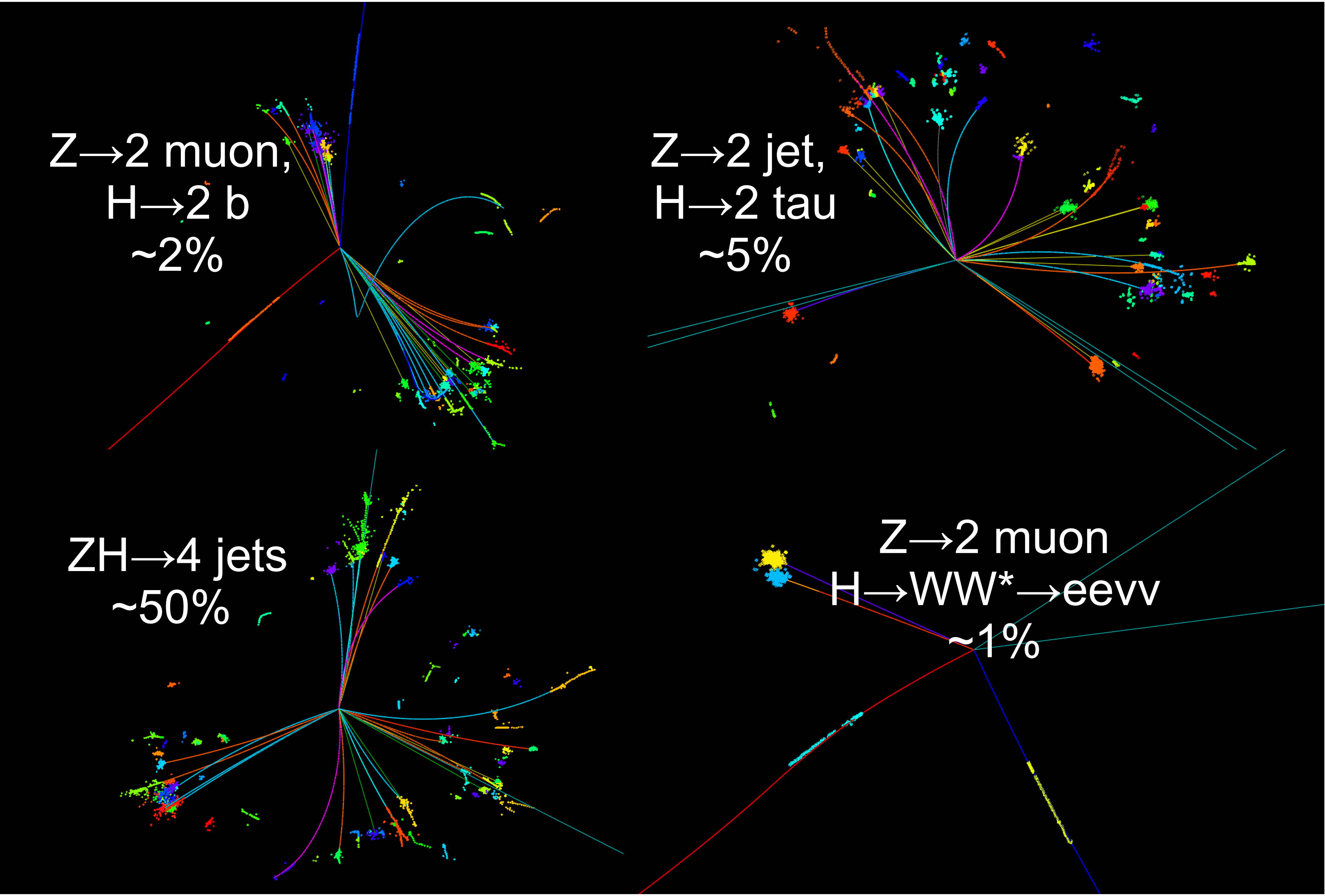
https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=14816

Software & Reconstruction

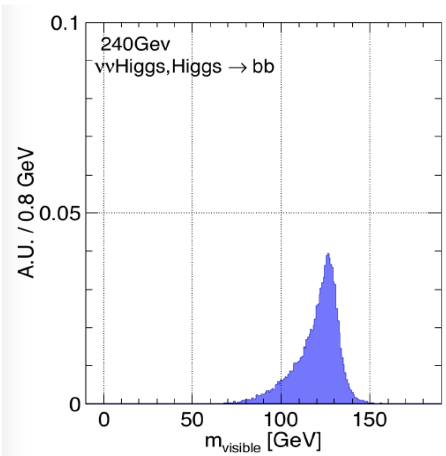


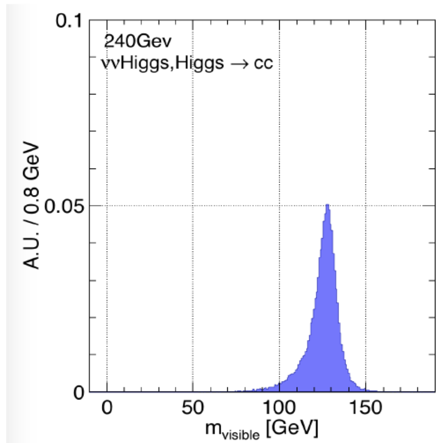


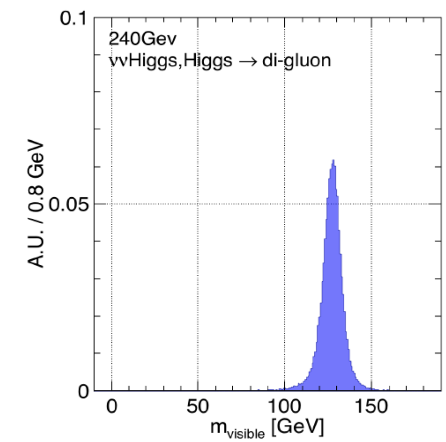
Starting from the ilcsoft & rewriting all the PFA/high-level reconstruction algorithms.

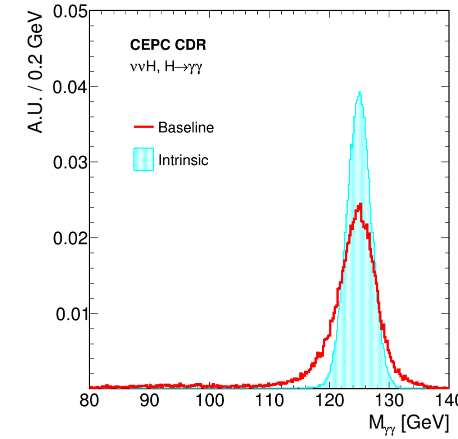

Z→2 muon,
H→2 b
~2%
Z→2 jet,
H→2 tau
~5%
ZH→4 jets
~50%
Z→2 muon
H→WW*→eeνν
~1%

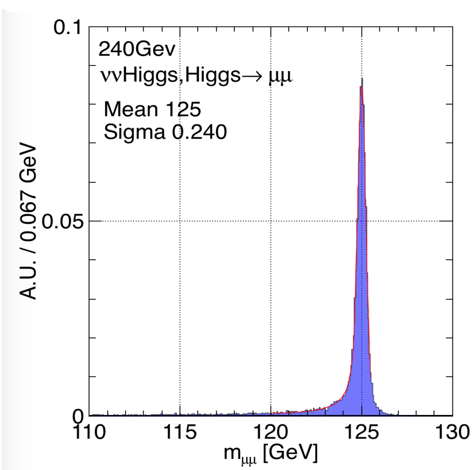
Reconstructed Higgs Signatures

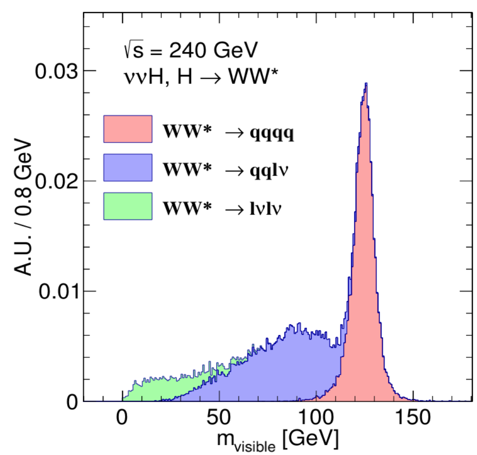


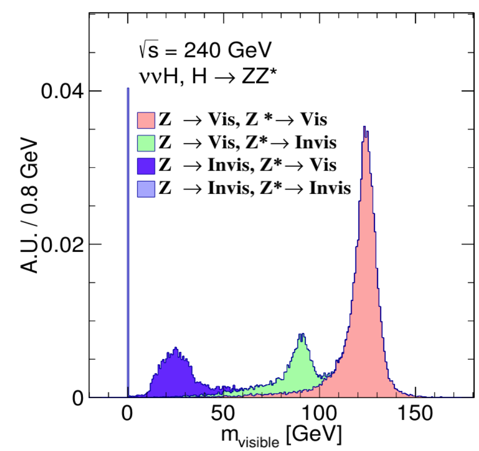


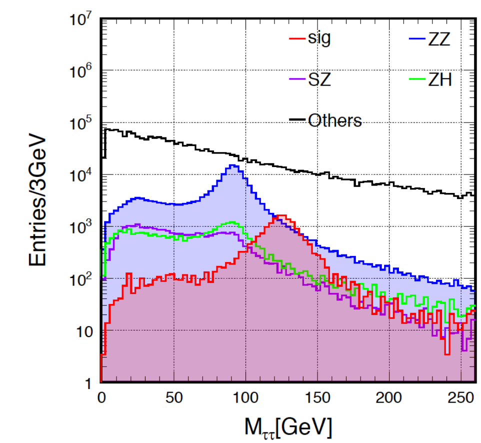










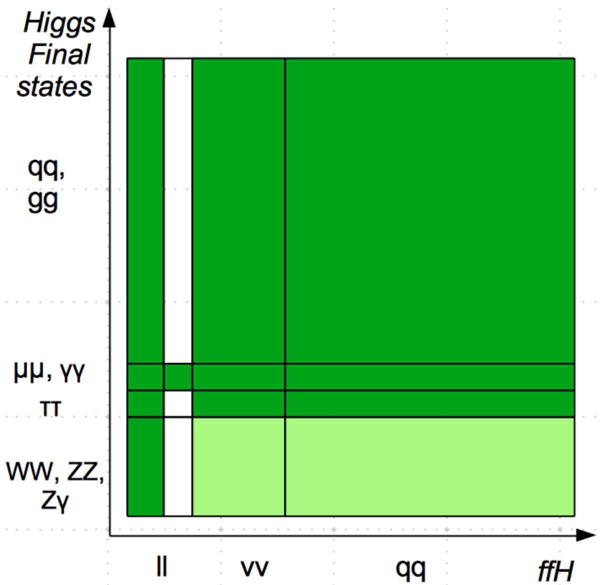


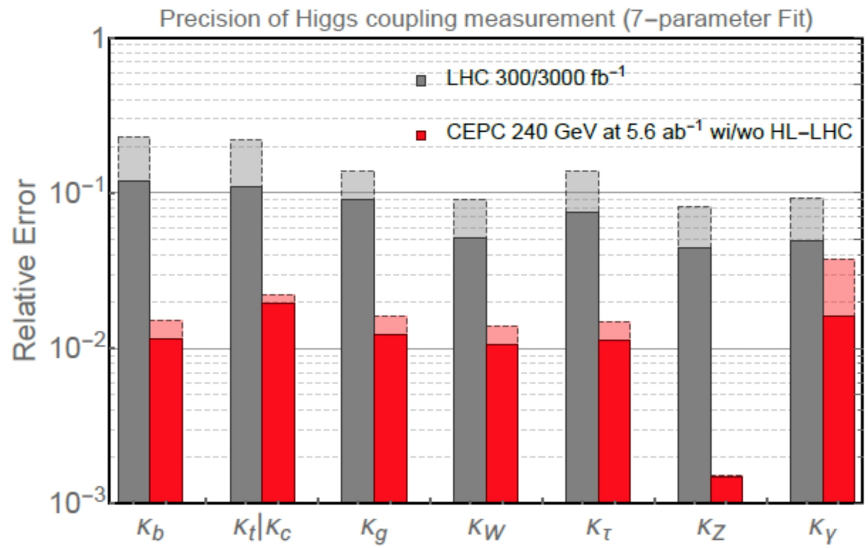
Clear Higgs Signature in all SM decay modes

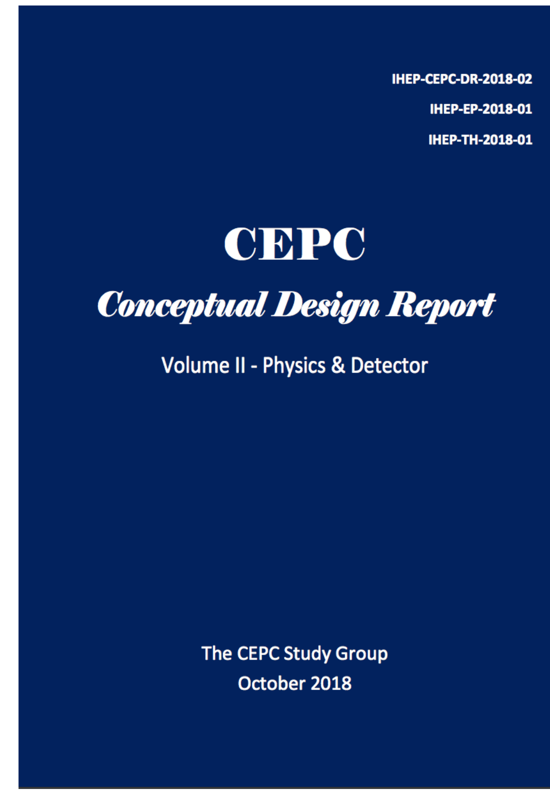
Massive production of the SM background (2 fermion and 4 fermions) at the full Simulation level

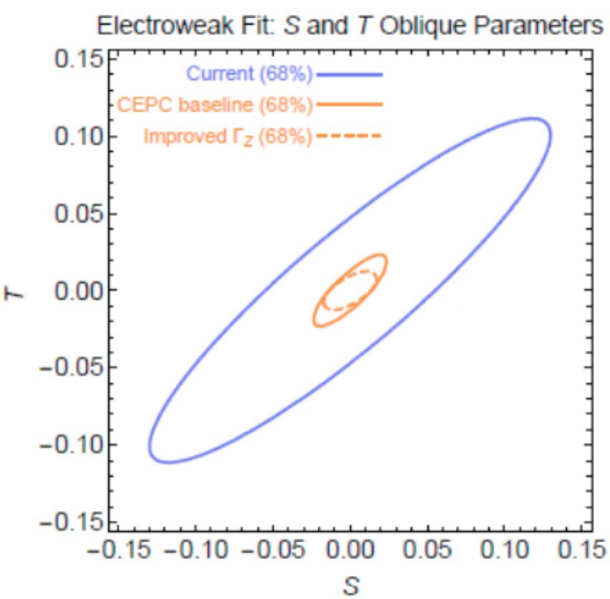
Right corner: di-tau mass distribution at qqH events using collinear approximation

Quantify the physics potential









Precision Higgs Physics at CEPC

Initial assessments of Higgs physics potential at the CEPC based on the white paper (to be submitted)

Chinese Physics C Vol. XX, No. X (201X) 010201

Precision Higgs Physics at the CEPC*

Fenfen An[4,21] Yu Bai[9] Chunhui Chen[21] Xin Chen[5] Zhenxing Chen[3] Joao Guimaraes da Costa[4] Zhenwei Cui[3] Yaquan Fang[4,6] Chengdong Fu[4] Jun Gao[10] Yanyan Gao[20] Yuanning Gao[5] Shao-Feng Ge[15,27] Jiayin Gu[13] Fangyi Guo[1,4] Jun Guo[10,11] Tao Han[5,29] Shuang Han[4] Hong-Jian He[10,11] Xianke He[10] Xiao-Gang He[10,11] Jifeng Hu[10] Shih-Chieh Hsu[30] Shan Jin[8] Maoqiang Jing[4,7] Ryuta Kiuchi[4] Chia-Ming Kuo[19] Pei-Zhu Lai[19] Boyang Li[5] Congqiao Li[3] Gang Li[4] Haifeng Li[12] Liang Li[10] Shu Li[10,11] Tong Li[12] Qiang Li[3] Hao Liang[4,6] Zhijun Liang[4] Libo Liao[4] Bo Liu[4,21] Jianbei Liu[1] Tao Liu[14] Zhen Liu[24,28] Xinchou Lou[4,6,31] Lianliang Ma[12] Bruce Mellado[17] Xin Mo[4] Mila Pandurovic[16] Jianming Qian[22] Zhuoni Qian[18] Nikolaos Rompotis[20] Manqi Ruan[4] Alex Schuy[30] Lian-You Shan[4] Jingyuan Shi[9] Xin Shi[4] Shufang Su[23] Dayong Wang[3] Jing Wang[4] Lian-Tao Wang[25] Yifang Wang[4,6] Yuqian Wei[4] Yue Xu[5] Haijun Yang[10,11] Weiming Yao[26] Dan Yu[4] Kaili Zhang[4,6] Zhaoru Zhang[4] Mingrui Zhao[2] Xianghu Zhao[4] Ning Zhou[10]

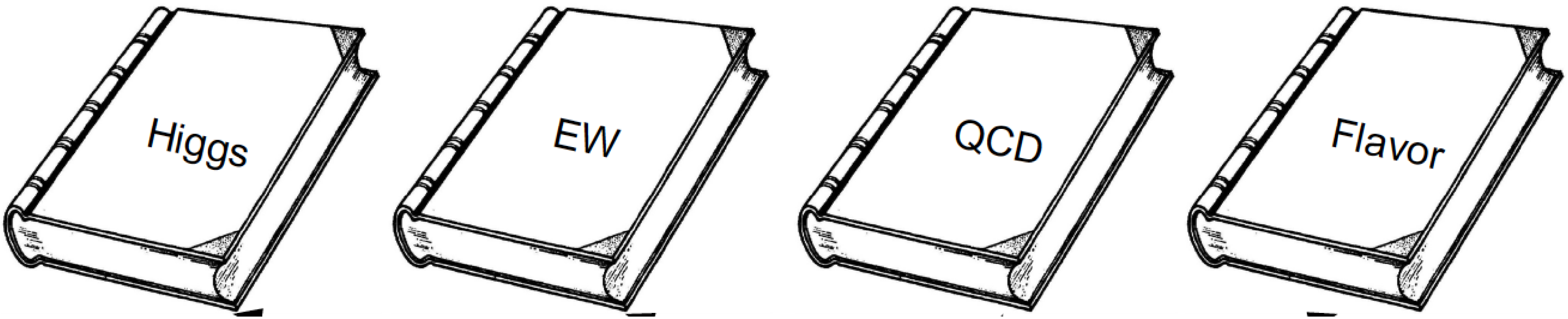
https://arxiv.org/pdf/1810.09037.pdf

Recent Progresses

- Physics studies
- New beam parameters
- Accelerator technologies
  - SRF
  - Klystron
- High Temperature Super Conductor
- Link to the industrial

- *Reference to Prof. Foster and Prof. Gao's summary talks at the CEPC Oxford Workshop as well as Prof. Chi's slides at HK IAS meeting*

Ongoing physics potential studies



- To promote the physics study at TDR & to converge to the Physics White Papers
- Physics white papers:
  - Physics handbooks for new comers: PostDoc/Student
  - Official references for the physics potential
  - Guideline for future detector design/optimization
- Current Focus: Flavor

Beam parameters: higher Luminosity

	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
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Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	**30**	**30**	**16.5**	

CDR Parameters:

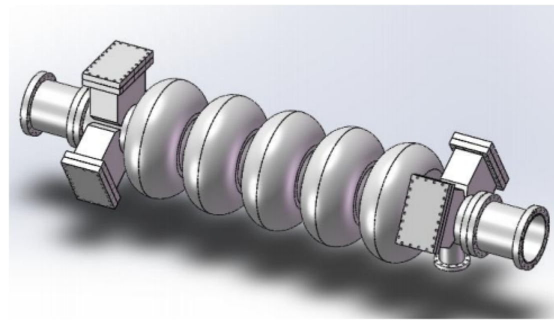
Lifetime (hour)	**0.67**	**1.4**	**4.0**	**2.1**
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP *L* (10^{34}cm^{-2}s^{-1})	**2.93**	**10.1**	**16.6**	**32.1**

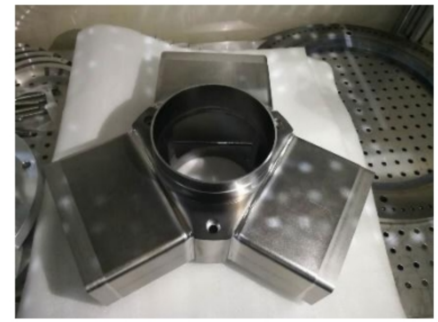
HL-Higgs operation Parameters:

Lifetime (hour)	**0.22**	**1.2**	**3.2**	**2.0**
F (hour glass)	0.85	0.92	0.98	
Luminosity/IP *L* (10^{34}cm^{-2}s^{-1})	**5.2**	**14.5**	**23.6**	**37.7**

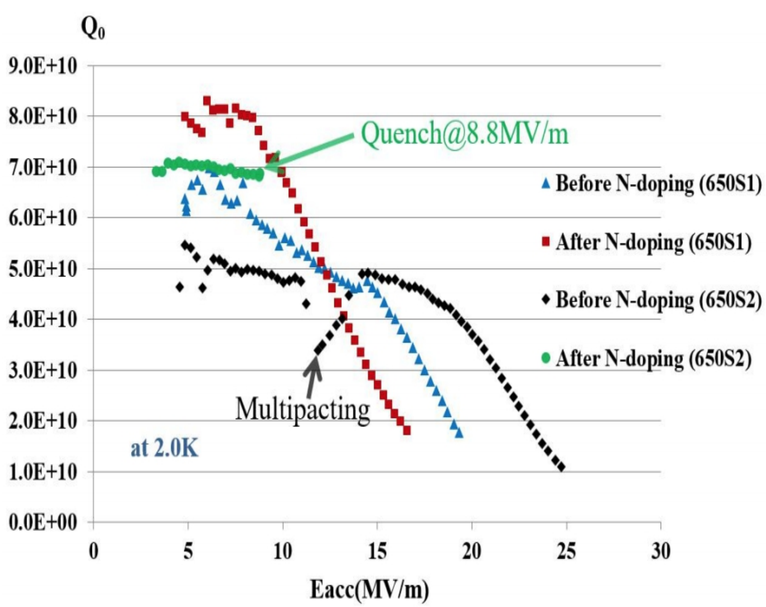
SRF prototyping & tests

650 MHz 2-cell cavity





650 MHz 5-cell cavity with waveguide HOM coupler



New furnaces for
N-doping and infusion study

Helmholtz coil & flux gate
for high Q research

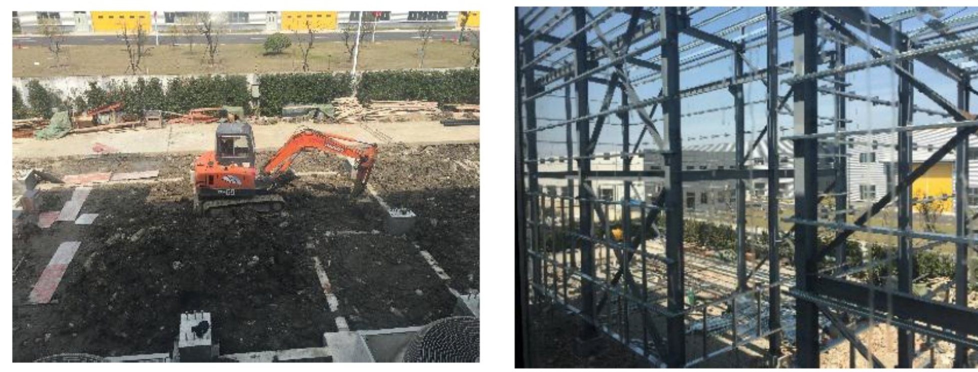
1st 650MHz Klystron Manufacturer and Infrastructure Preparation Progress

Z.S. Zhou

Modulator anode components

Cavities components

Klystron output window



Assembly plant construction

Large size baking furnace commissioning

Domestic Collaboration for HTS R&D

Applied High Temperature Superconductor Collaboration (AHTSC)

- R&D from **Fundamental sciences** of superconductivity, **advanced HTS superconductors** to **Magnet & SRF technology**.
- **Regular meetings every 3 months** from Oct. 2016
- **Goal**:

• **Increasing J_c** of iron-based superconductor **by 10 times**.

• **Reducing the cost** of HTS conductors to be **similar with "NbTi conductor"**

• Industrialization of the **advanced superconductors, magnets and cavities**

Proposal for
Strategic Priority Research Program
of Chinese Academy of Sciences (CAS)
Science and Technology Frontier
Research
for High Field Applications of High
Temperature Superconductors

中科院B类先导专项
360M RMB for 2018-2023

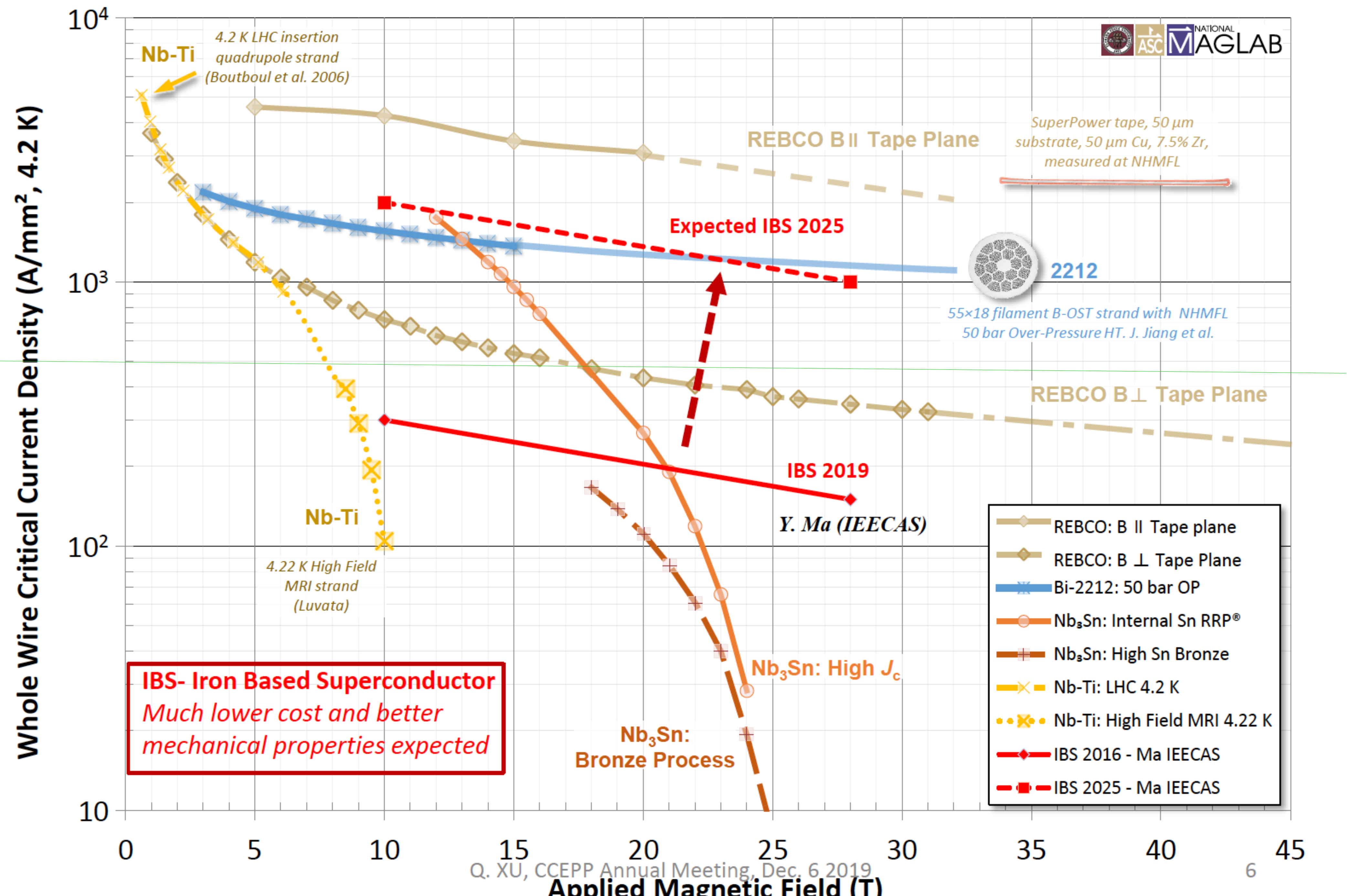
Ranked No. 1 in 7 candidates

The National Key Research and
Development Program of China

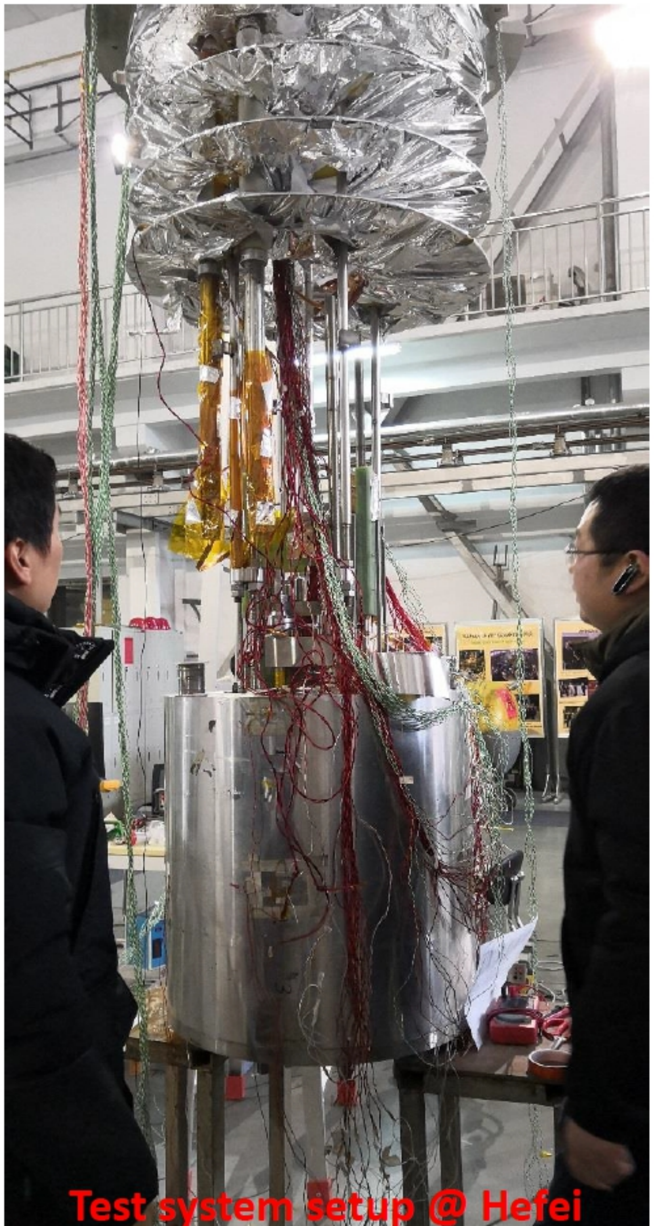
科学技术部
高技术研究发展中心
43M RMB for 2019-2024
国科高发计字〔2019〕55 号

关于印发国家重点研发计划
"变革性技术关键科学问题"重点专项
2018 年度项目立项的通知

J_e of IBS: 2016-2025

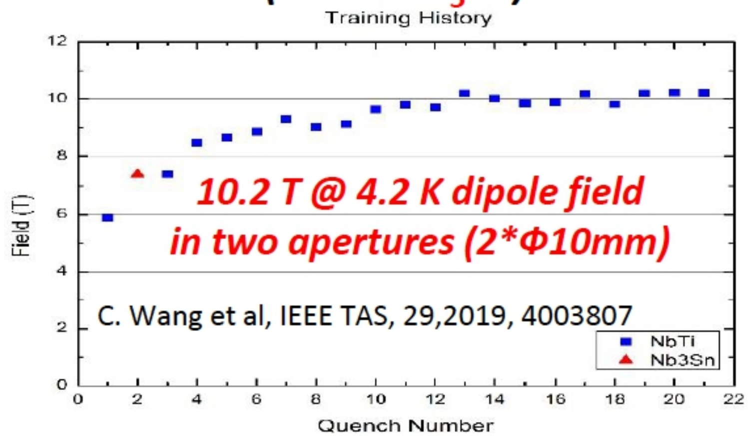


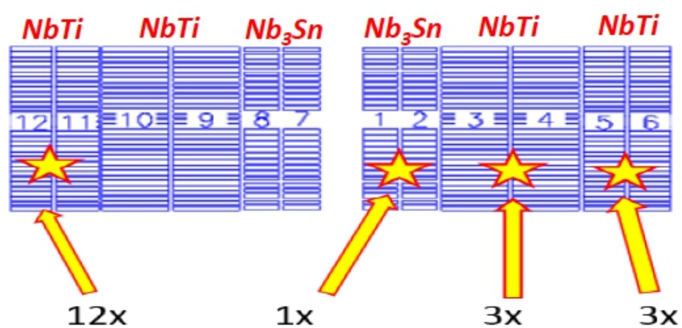
The 1st High-Field Dipole Magnet LPF1



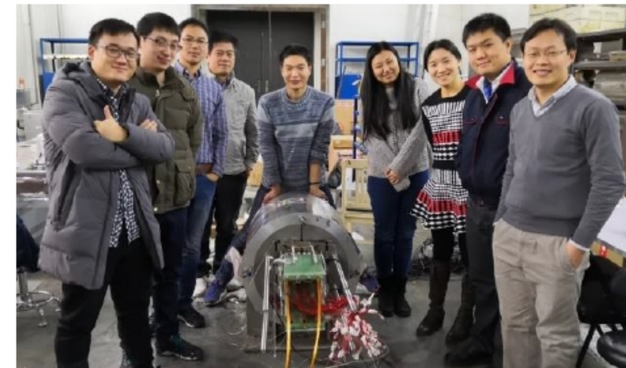
Test results of LPF1

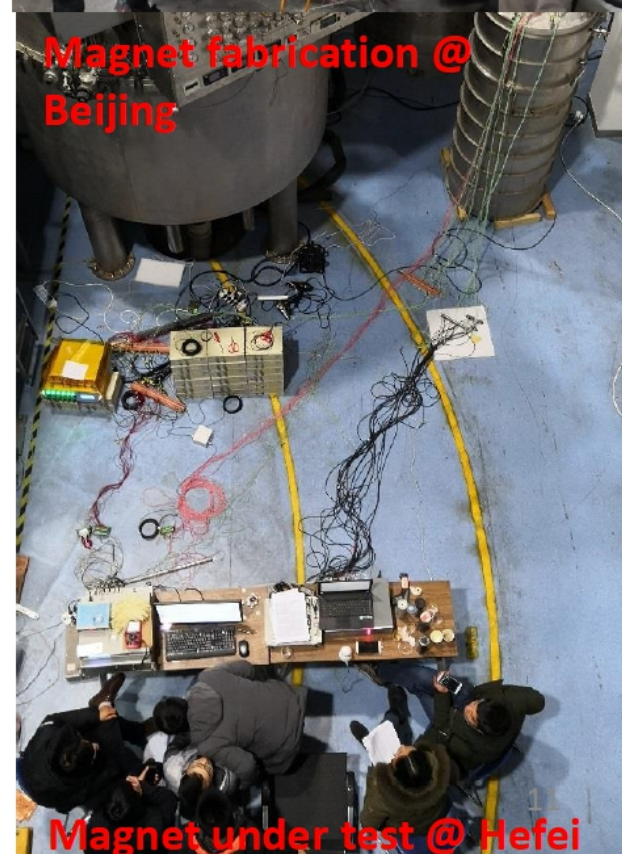
($NbTi+Nb_3Sn$)





- ***Performance limited by the outermost NbTi coil.***
- ***Very possibly caused by less of pre-stress.***
- ***Being tested again with higher Pre-stress (from 30 MPa to 80 MPa).***





Performance of the 1st IBS solenoid Coil

Fabrication and test of IBS solenoid coil at 24T

IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 04LT01 (5pp) https://doi.org/10.1088/1361-6668/ab09a4

Letter

First performance test of a 30mm iron-based superconductor single pancake coil under a 24T background field

Dongliang Wang[1,2,5], Zhan Zhang[3,5], Xianping Zhang[1,2], Donghui Jiang[4], Chiheng Dong[1], He Huang[1,2], Wenge Chen[4], Qingjin Xu[3,6] and Yanwei Ma[1,2,6]

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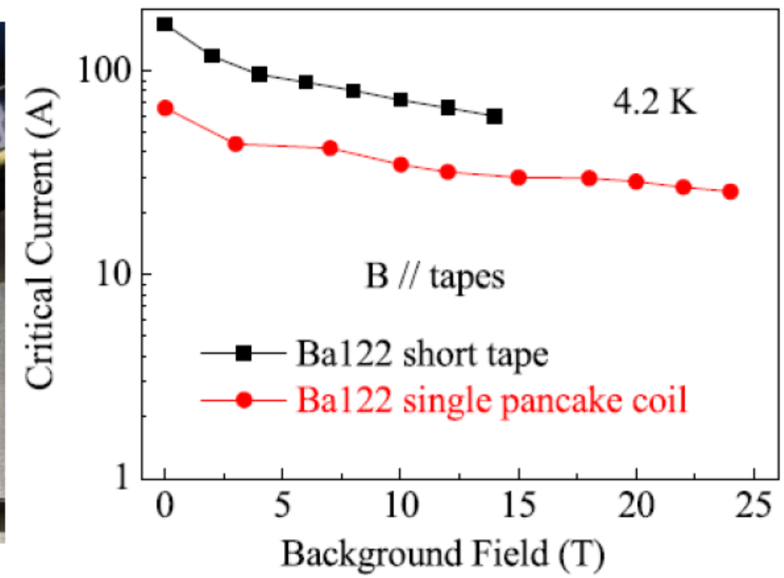
[3] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[4] High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, People's Republic of China



Viewpoint by NHMFL

'From a practical point of view, **IBS are ideal candidates for applications**. Indeed, some of them have quite a **high critical current density, even in strong magnetic fields**, and a low superconducting anisotropy.
Moreover, **the cost of IBS wire can be four to five times lower than that of Nb_3Sn**……

IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 070501 (3pp) https://doi.org/10.1088/1361-6668/ab1fc9

Viewpoint

CrossMark

Constructing high field magnets is a real tour de force

Jan Jaroszynski
National High Magnetic Field, Laboratory, Tallahassee, FL, 32310, United States of America
E-mail: jaroszy@magnet.fsu.edu

This is a viewpoint on the letter by Dongliang Wang *et al* (2019 *Supercond. Sci. Technol.* 32 04LT01).

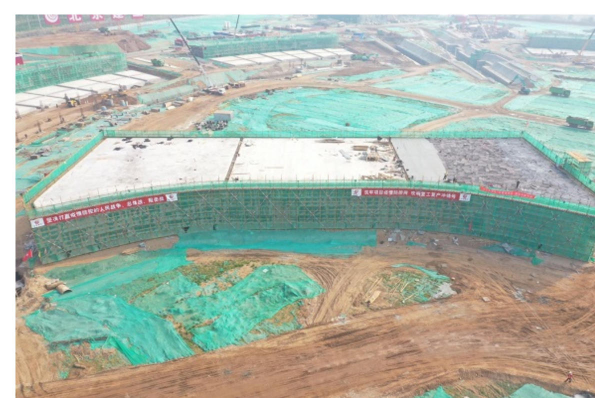
Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty

PAPS- Platform of Advanced Photon Source Technology R&D

- Budget: 500M CNY funded by Beijing Gov., from 2017.5-2020.6

http://ias.usthk.cn/program/shared_doc/2020/202001hep/conf/20200121_lt_pm_Yunlong_CHI.pdf

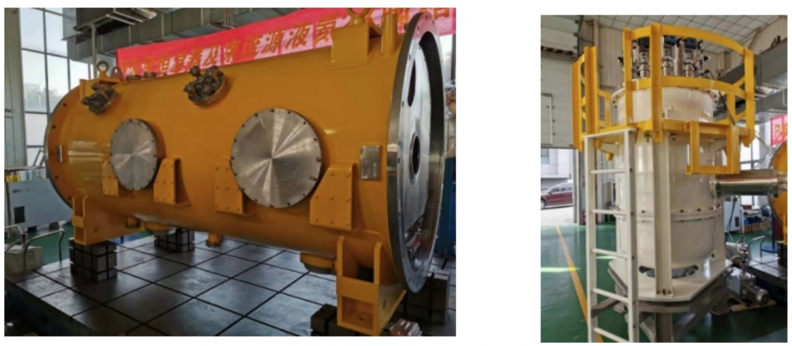
- $4500m^2$ SRF Lab for Superconducting Accelerator Projects R&D
- Cryogenic system with a capacity of 2.5kW@4.5K/300W@2K
- Beam Test System
- Precision Magnet center for precision machining and measurement for HEPS magnets
- X-ray research center for advanced X-ray related technologies R&D



Main structure of HEPS booster RF system complete

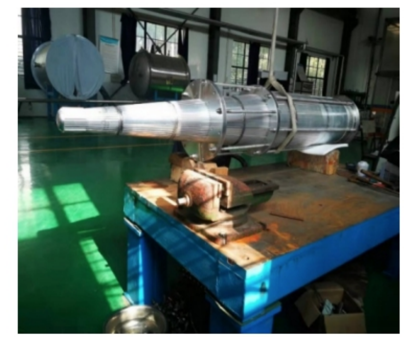
PAPS SRF Facility implementation
- Beam test system

- Complete the development of a 650MHz test Cryomodule
- A 1.3GHz CW operation buncher, a 1.3GHz coupler and a 1.3GHz/10kW solid state amplifier have been developed
- A 150kW beam collector, magnets and vacuum boxes for beam line is ready

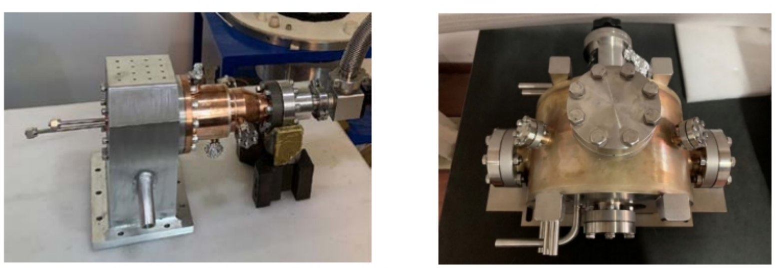


A 650MHz test cryomodule

1.3GHz/10kW amplifier



150kW beam collector



1.3GHz-CW buncher and coupler

Magnets

http://ias.usthk.cn/program/shared_doc/2020/202001hep/conf/20200121_lt_pm_Yunlong_CHI.pdf

Collaboration with industry

The CEPC Industrial Promotion Consortium (CICP) is established in Nov 2017. Till now, More than 60 companies joined CICP, with expertise on superconductor, superconducting cavities, cryogenics, vacuum, klystron, electronics, power supply, civil engineering, precise machinery, etc. The CIPC serves as a communication forum for the industrial and the HEP community.

Summary

- CEPC, a productive and clean Higgs/W/Z factory,
  - Boost the Higgs/EW precision by ~ 10 times w.r.t HL-LHC/current boundary
  - Huge potential on QCD, Flavor, BSM
- CDR released
  - Accelerator baseline secures high productivity for Higgs, Z and W bosons.
  - Detector baseline fulfills the requirements: clear physics objects + Higgs signal
  - Alternative designs, New ideas are always welcome
- Key technology – civil development:
  - Towards the TDR & significant progresses & link to industrial
- Giving the importance of electron positron Higgs factory, we hope at least one of them (ILC, CLIC, CEPC, FCC) can be realized. We fully support this global effort, no matter where it will be constructed

Backup

Civil Engineering & Site Selection

Factors affecting site selection:

1、Social factors:

National planning, Regional economic conditions, Cultural environment, Immigration, Environmental protection.

2、Natural conditions and engineering factors:

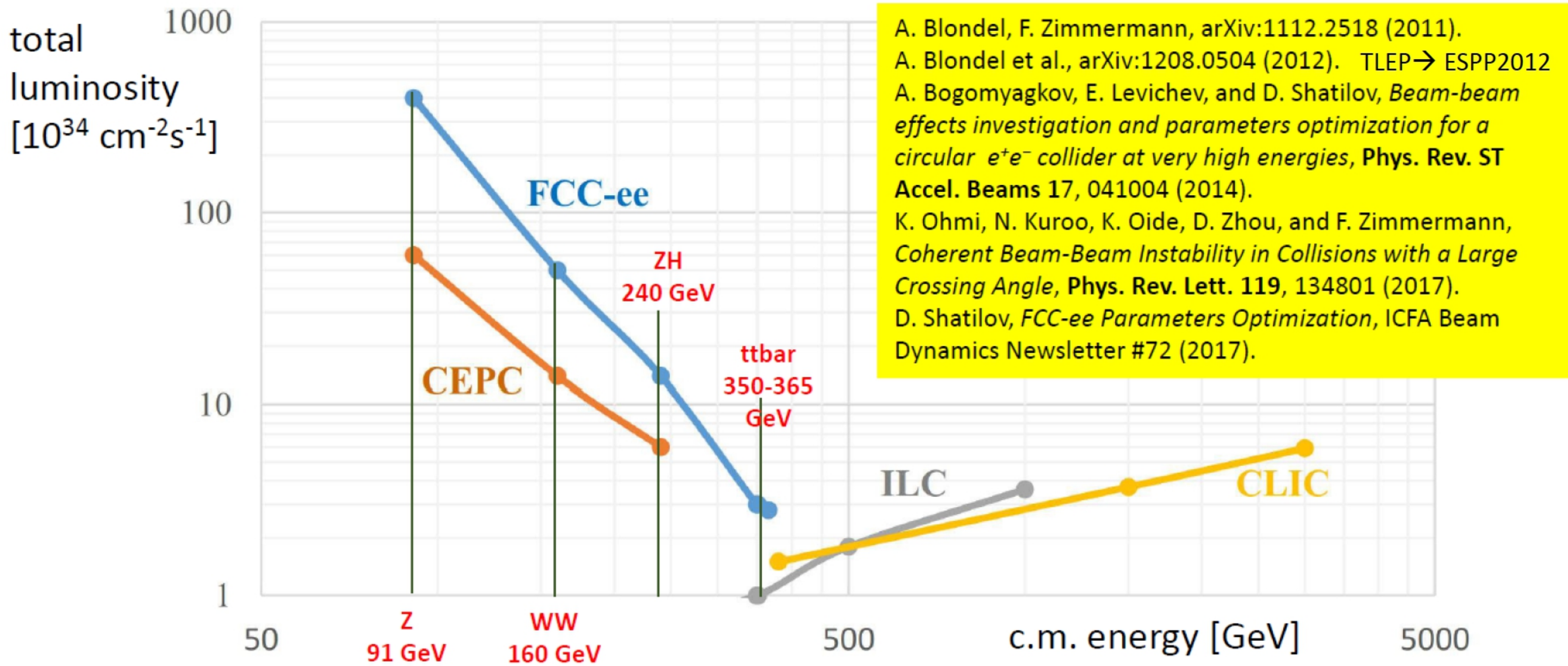
Climate, Traffic, Topographical geology, Engineering layout, Construction Conditions, Engineering investment.

3、Operating factor:

Water supply, power supply, operating costs

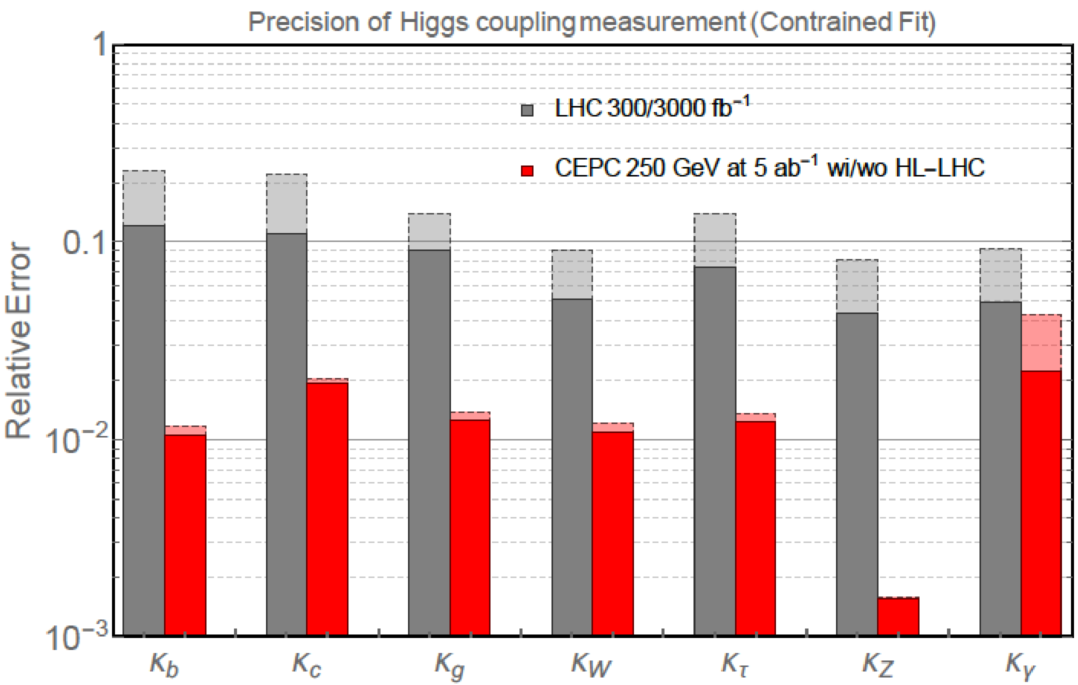
In China, there are many sites that meet the construction conditions.

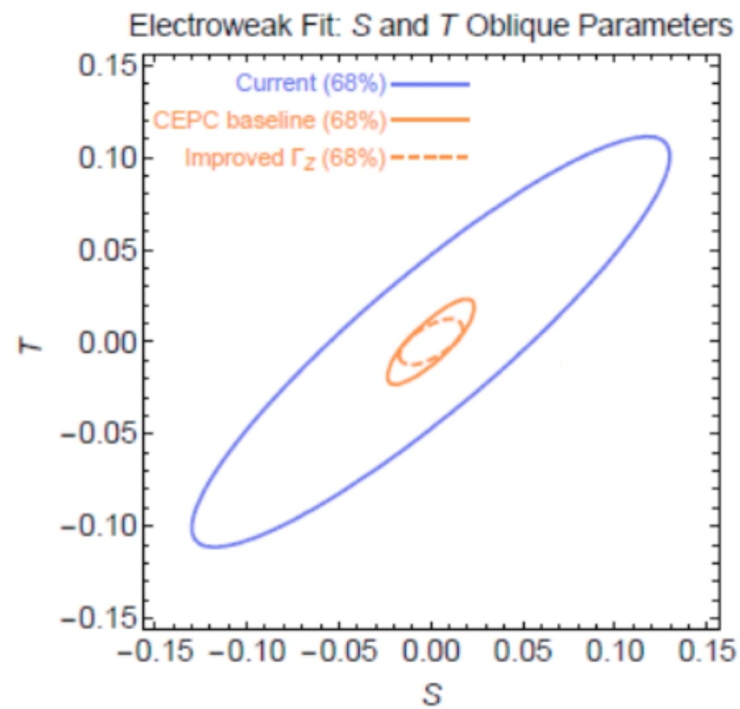
Comparison: Linear & Circular



From A. Blondel's presentation at CEPC Oxford WS

Physics Potential



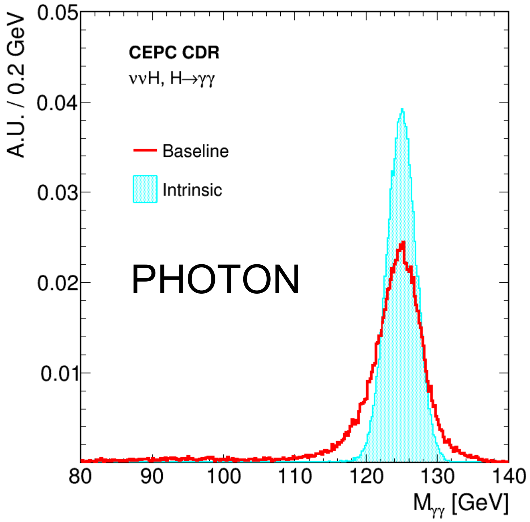


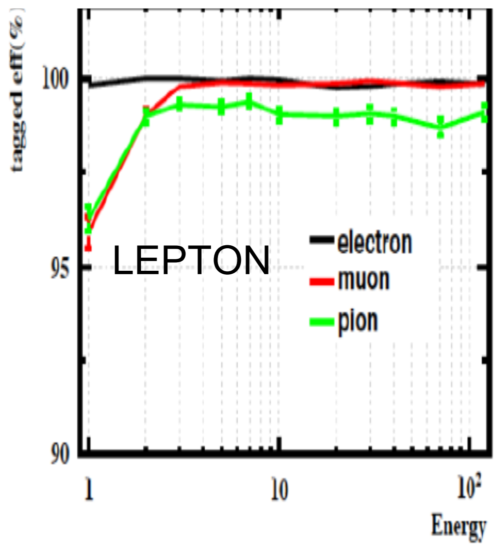
- The nature of Higgs boson & EWSB, + flavor physics...
  - Higgs signal strengths (In kappa framework): expected accuracy roughly 1 order of magnitude better than HL-LHC
  - Absolute measurement to the Higgs boson: 2-3% level accuracy of Higgs boson width, 10^{-3} - 10^{-5} up limit to Higgs invisible/exotic decay modes (improved by at least 2 orders of magnitude comparing to HL-LHC)
  - Improve EW measurement precision by also 1 order of magnitude

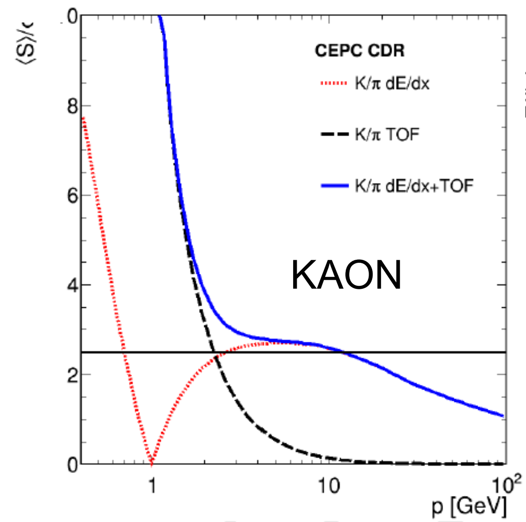
Physics Objects

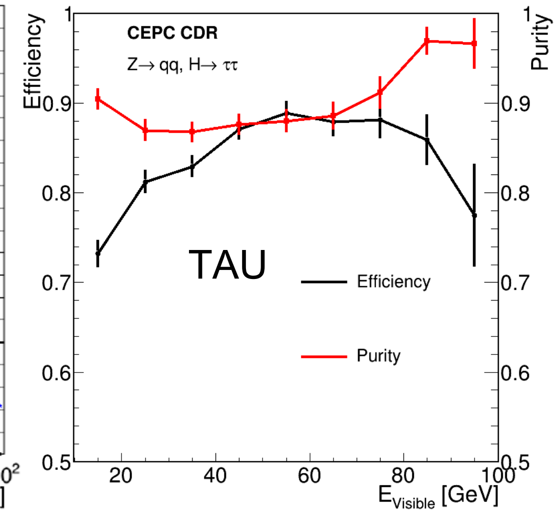
Eur. Phys. J. C (2017) 77: 591

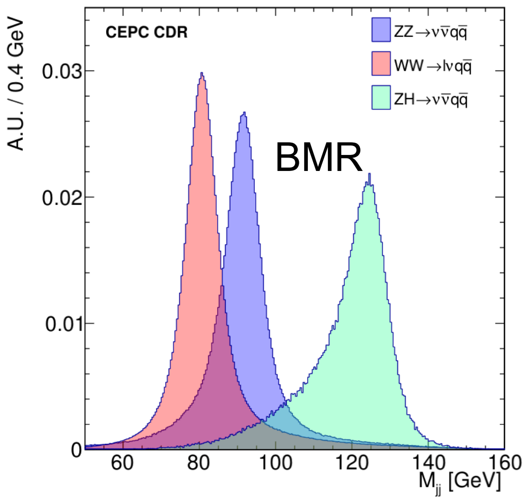
Eur. Phys. J. C (2018) 78:464

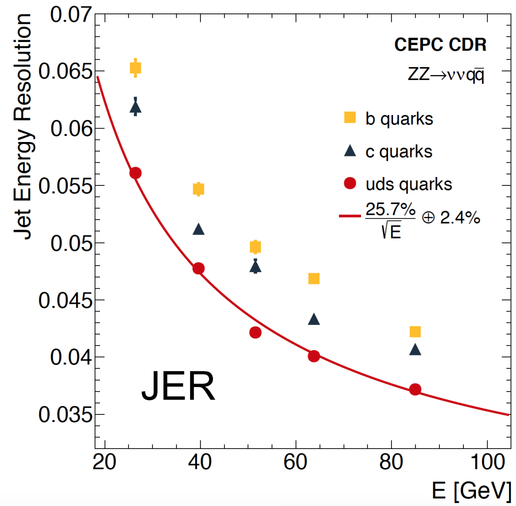


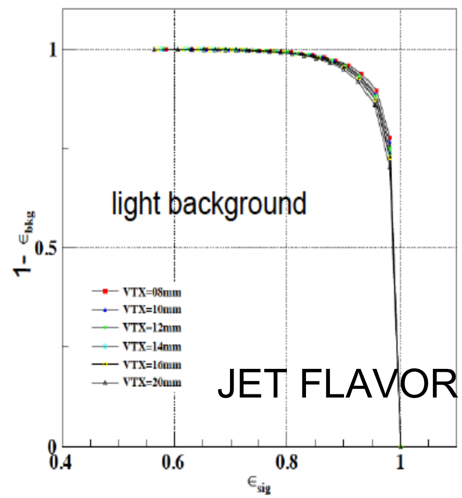


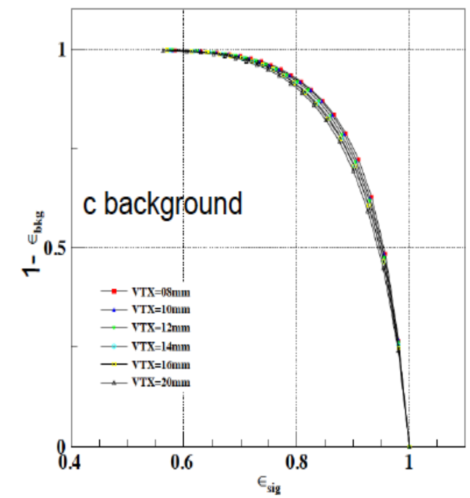






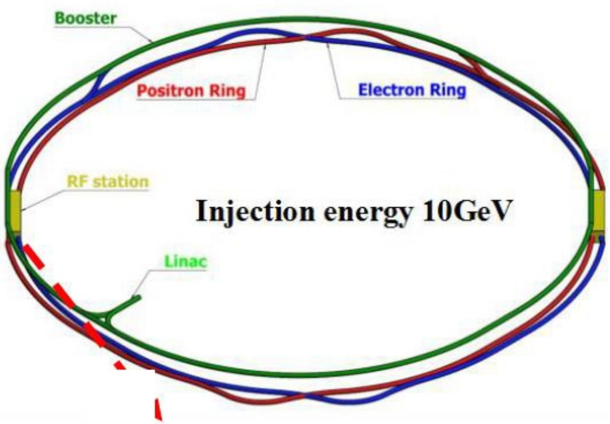


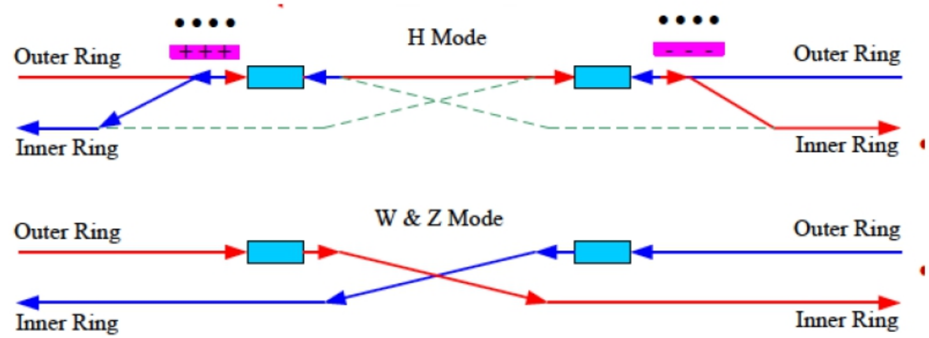


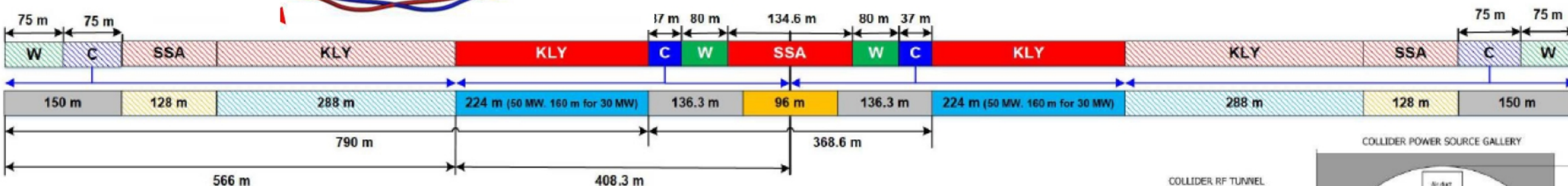


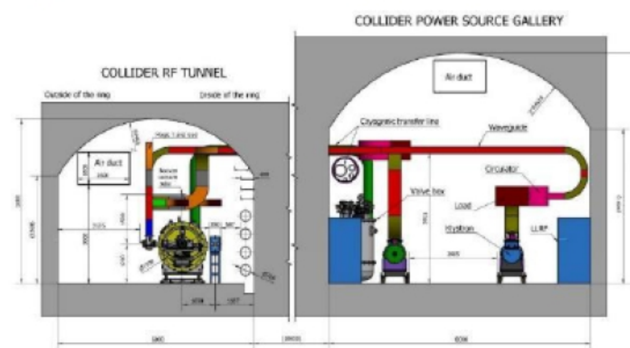
Eur. Phys. J. C (2018) 78: 426

CEPC SCRF Cavities





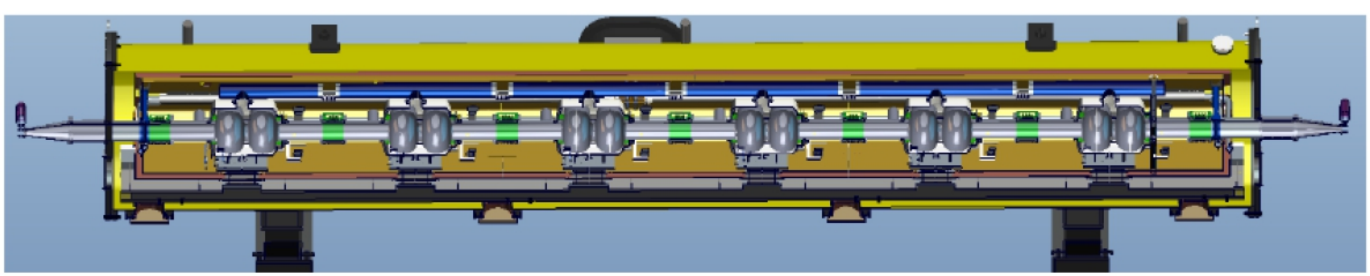


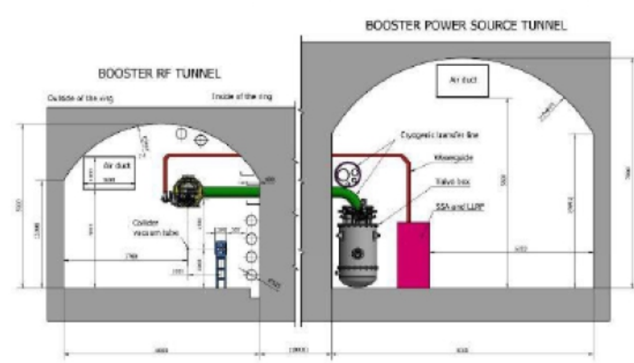


30 MW Higgs:

Collider: 240 650 MHz 2-cell cavities in 40 cryomodules (6 cav./ module).

Booster: 96 1.3 GHz 9-cell cavities in 12 cryomodules (8 cav. / module).





For higher Z lumi, look at 1-cell cavity design.

75 registrant + several visitors; ~ 50 talks. Covers Physics, Pheno, and Performance studies

Supported by IHEP CFHEP & PKU

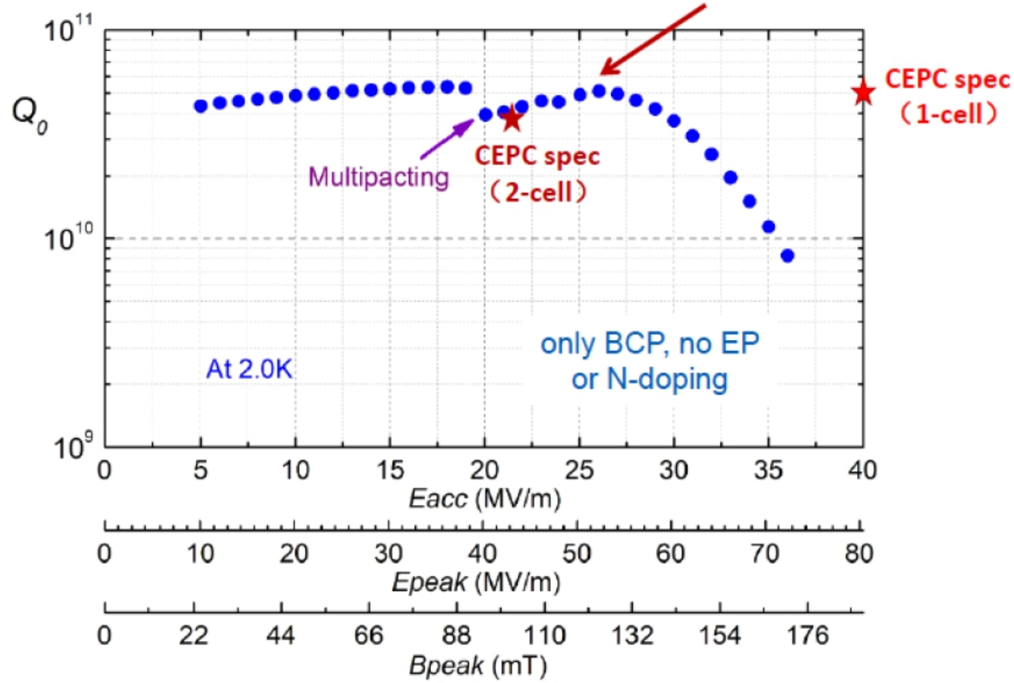
CEPC SCRF Cavities

650 MHz 1-cell cavity

Accelerating gradient (Eacc) reach 36.0 MV/m, **Q = 5.1E10 @ Eacc = 26 MV/m。**

Next, increase the Q and Eacc through N-doping, EP, etc. Target: **5E10@42MV/m** for vertical test.

Record highest Q-factor in China



650 MHz 1-cell cavity