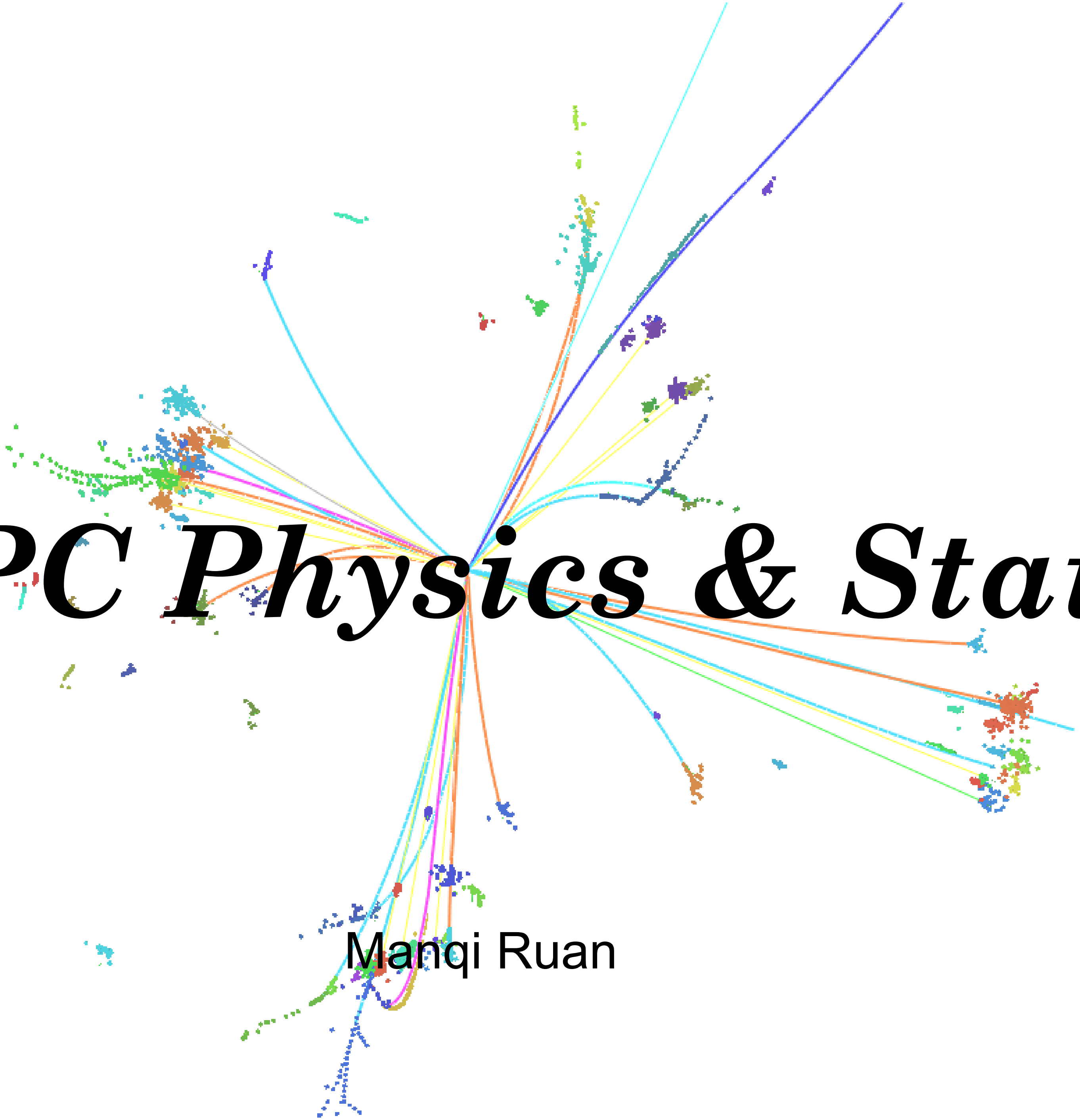
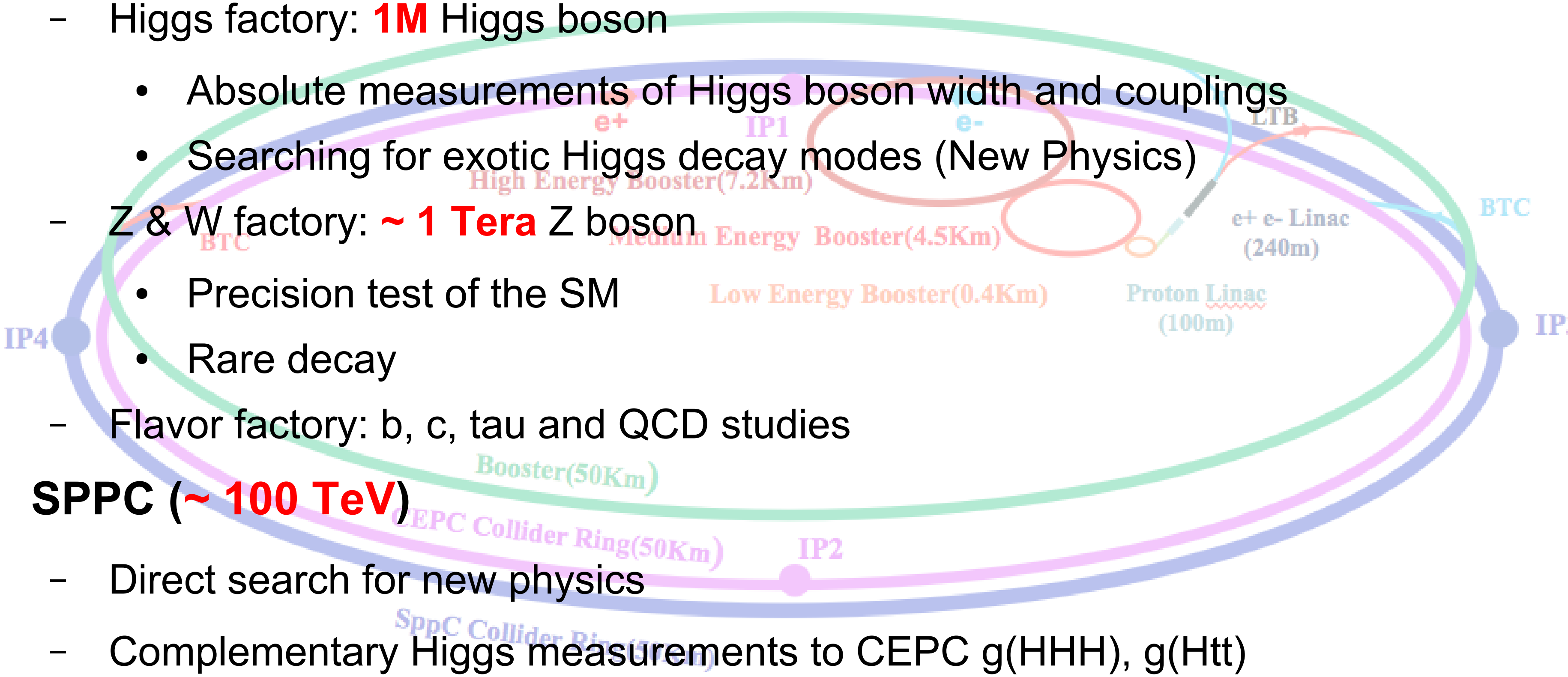
CEPC Physics & Status



Manqi Ruan

Key figures of the CEPC-SPPC

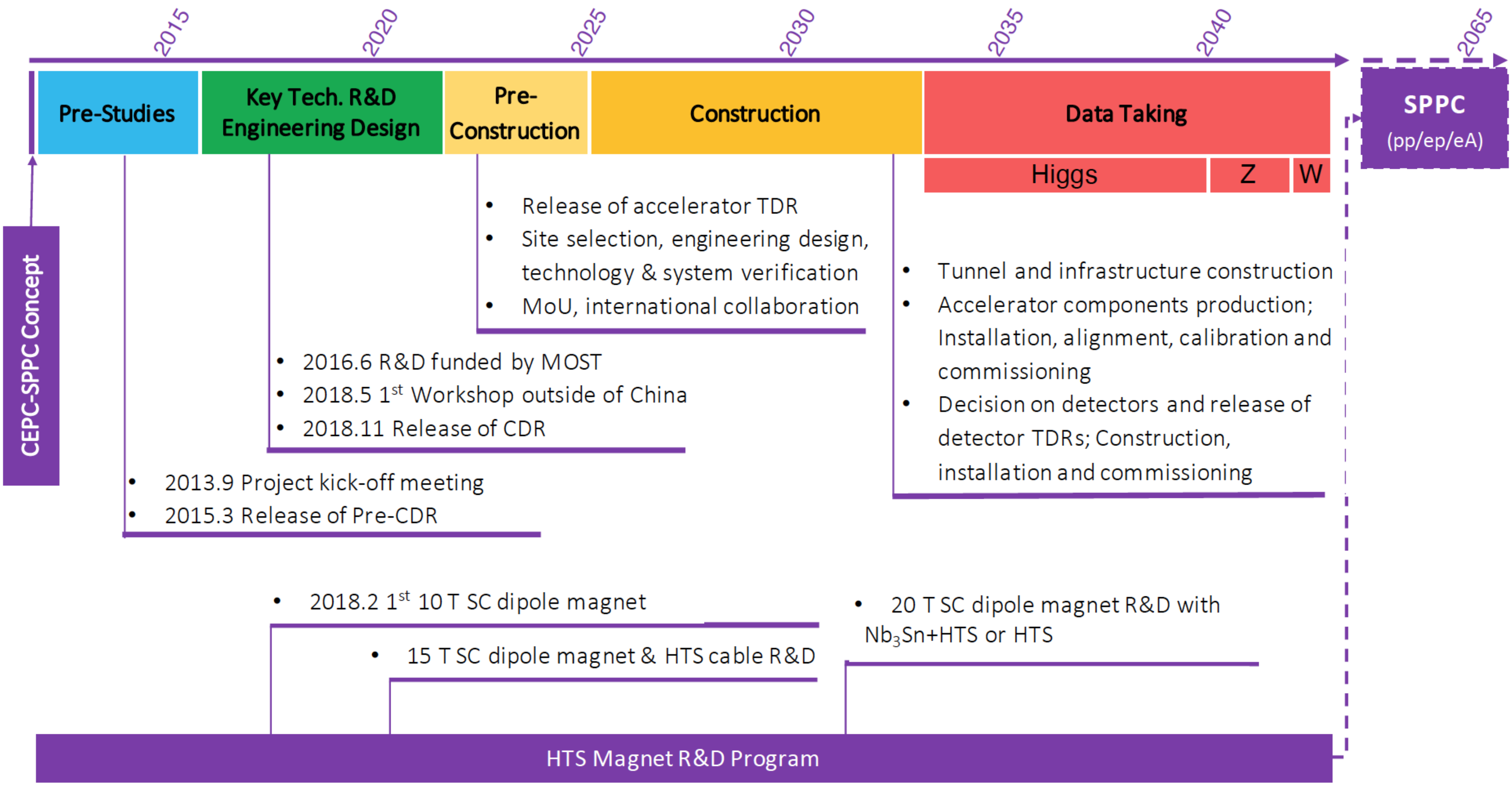


- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **~ 1 Tera** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor 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...**

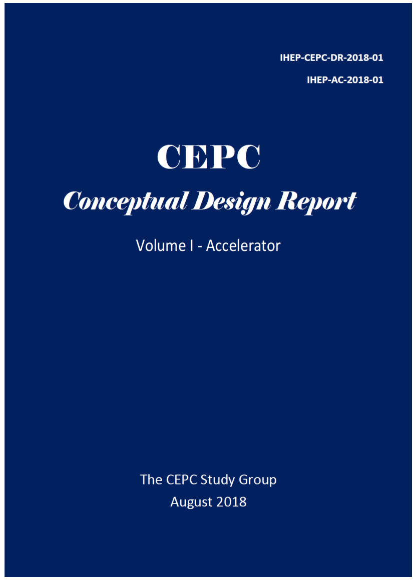
Complementary

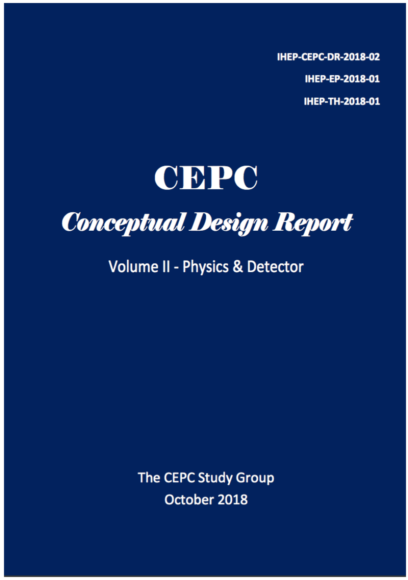
Timeline

CEPC Project Timeline



CDR released in Nov. 2018





- Baseline designs for the Accelerator, Detector & Software
  - Subsystems' designs supported with Prototype construction & test
- Physics potential

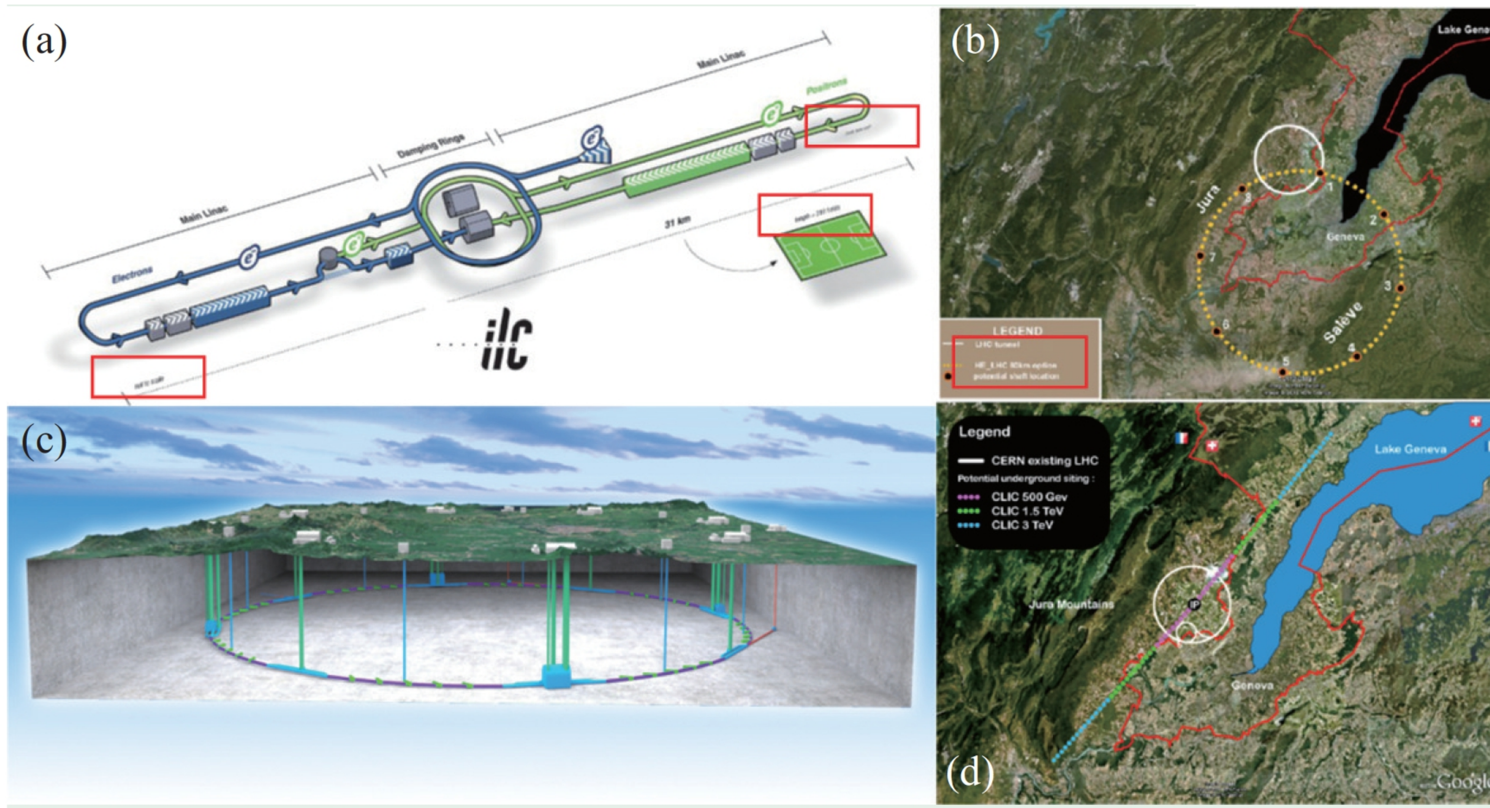
Electron Positron Higgs factories

High-priority future initiatives

An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

ILC (a):	TDR @ 2013
FCC (b):	CDR @ 2019
CEPC (c):	CDR @ 2018
CLIC (d):	CDR @ 2013

Direct Competition!



Recent focuses

- Accelerator: pursuing TDR & promote Critical R&D
  - Higher Luminosity
  - SRF
  - Klystron
  - Magnet: High Temperature Iron Based Super Conductor Technology

- Physics studies: white papers, etc:
  - To quantify the physics potential & especially its discover power
  - Guide facility design & optimization!

- Detector & Software innovative R&D: 4^{th} concept, etc

New beam parameters: in progress

- Luminosity @ Higgs: increases by 60% (3→5*10^{34} $cm^{-2}s^{-1}$/IP) by squeezing the beam size at IP
- Luminosity @ Z: increased by ~4 times (32→115*10^{34} $cm^{-2}s^{-1}$/IP) by increasing bunch charge
- Upgrading option: Luminosity @ top ~ 0.5*10^{34} $cm^{-2}s^{-1}$/IP

Stage 1 (H/W run)

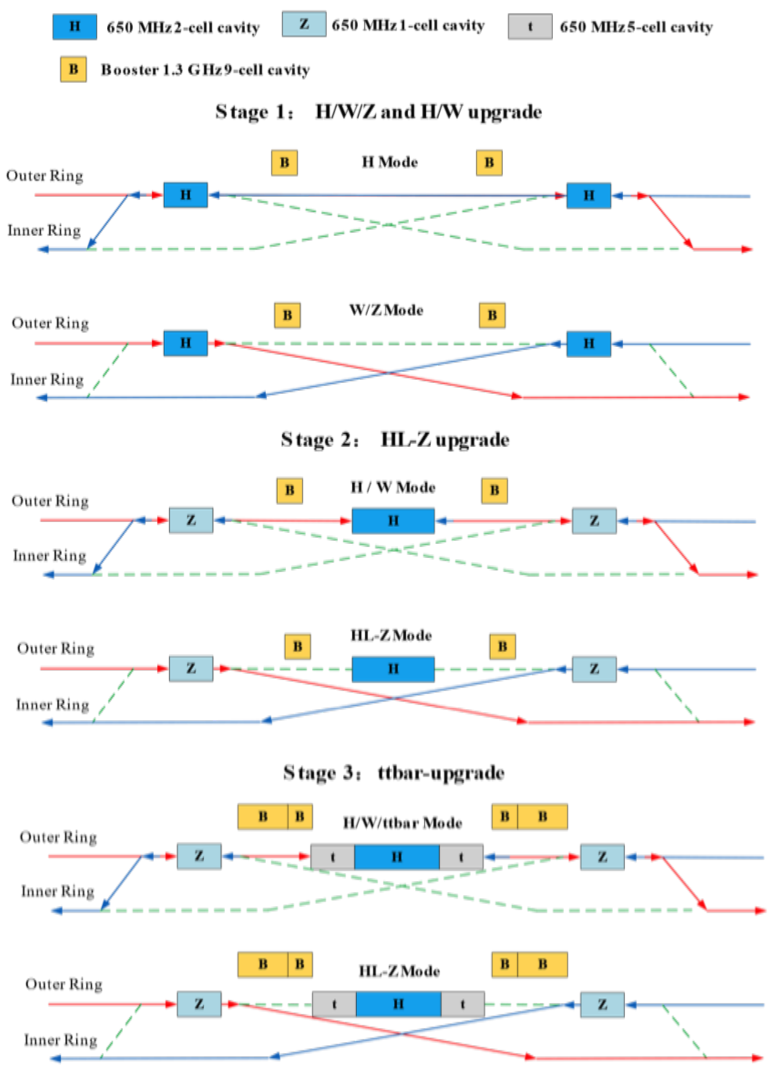
- Layout and parameters are same with CDR except longer central part
- Medium or low luminosity at Z

Stage 2 (HL-Z upgrade)

- Move Higgs cavities to center and add high current Z cavities.
- By-pass low current H cavities.

Stage 3(ttbar upgrade)

- Add ttbar cavities (low current, high gradient, high Q)
- Nb3Sn@4.2 K or others to significant reducing the cost of cryo-system and AC power.



Energy Flow in the Collider

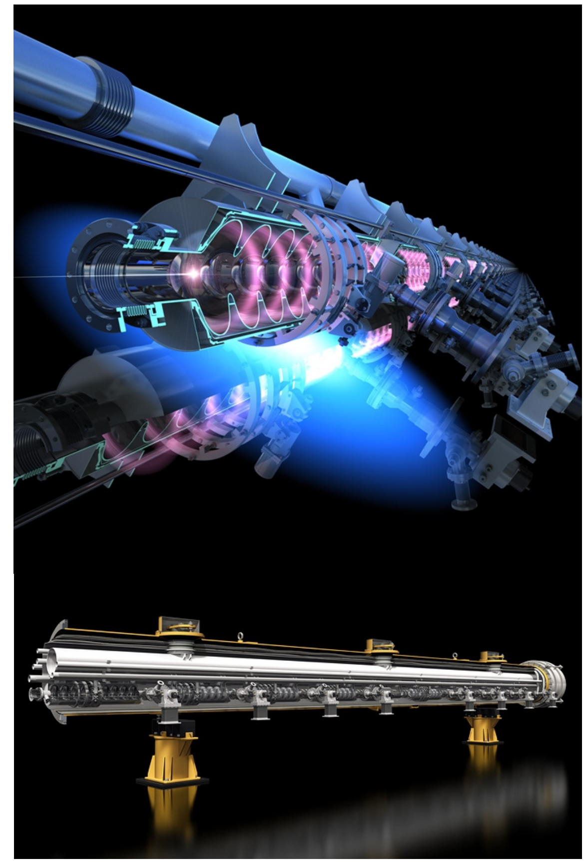
Electricity

Heat

Klystron (From SNS, ORNL, US)

RF Wave

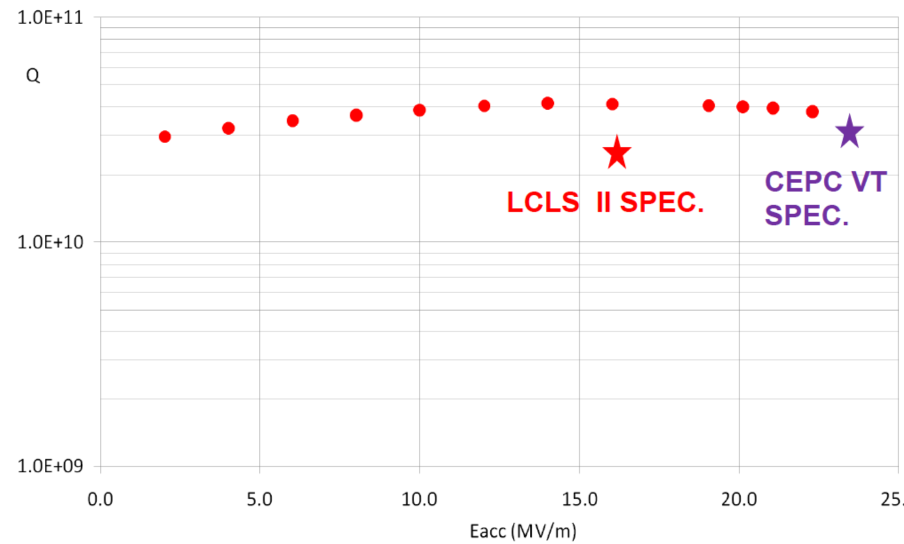
High energy beam, SR light, ...

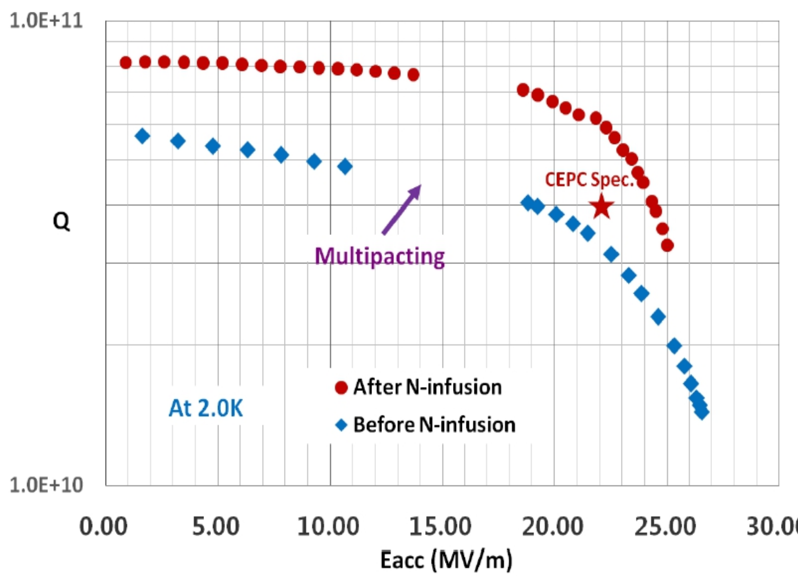


RF Cavities (From ILC design)

Heat

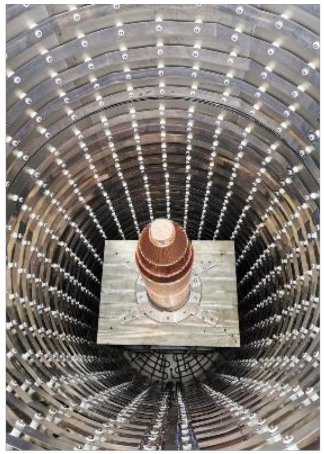
SRF Cavity: design goal reached





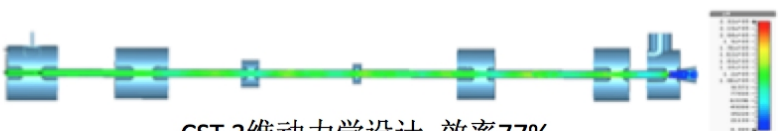
RF Cavity for both Booster & Collider ring reaches Design goal

High efficiency Klystron: awaiting for critical test

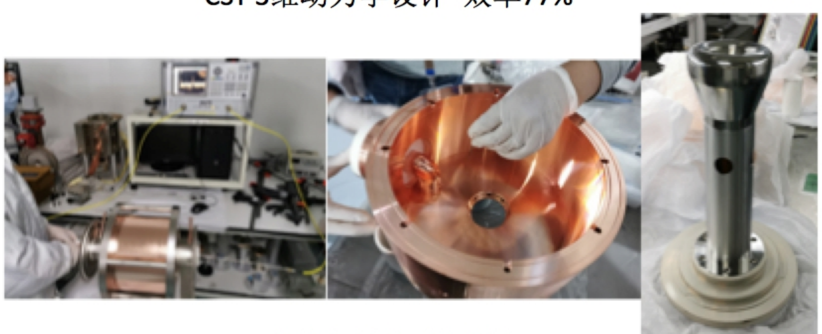




Tests show

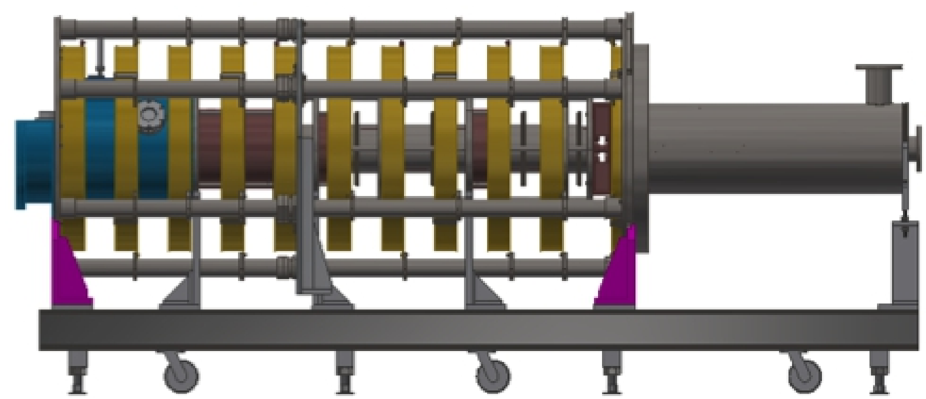
- **the output power reaches pulsed power of 800kW (400kW CW due to test load limitation)**
- **efficiency 62% and band width ±0.5Mhz.**



CST 3维动力学设计 效率77%



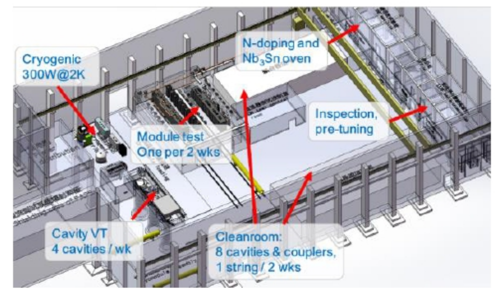
高效率样管零部件加工

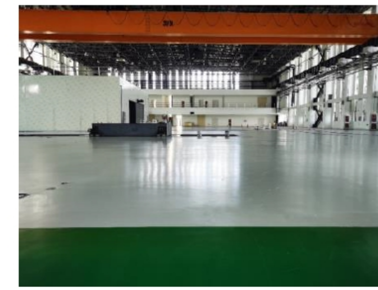


- High efficiency prototype (eff~77%) in construction: to be delivered soon!
- New design (eff ~ 81%) starts mechanic design

IHEP SC Lab @ Huairou: in operation

Facility: CEPC SCRF test facility (lab) is located in IHEP Huairong Area of 4500m^2





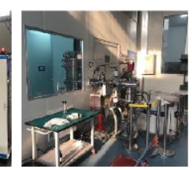
New SC Lab Design (4500m^2)

Crygenic system hall in Jan. 16, 2020

New SC Lab will be fully functional in 2021

Vacuum furnace (doping & annealing)

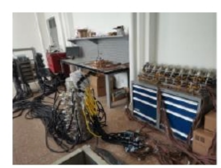
Nb3Sn furnace



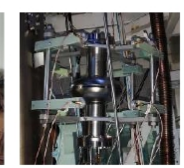
Nb/Cu sputtering device

Cavity inspection camera and grinder

9-cell cavity pre-tuning machine



Temperature & X-ray mapping system



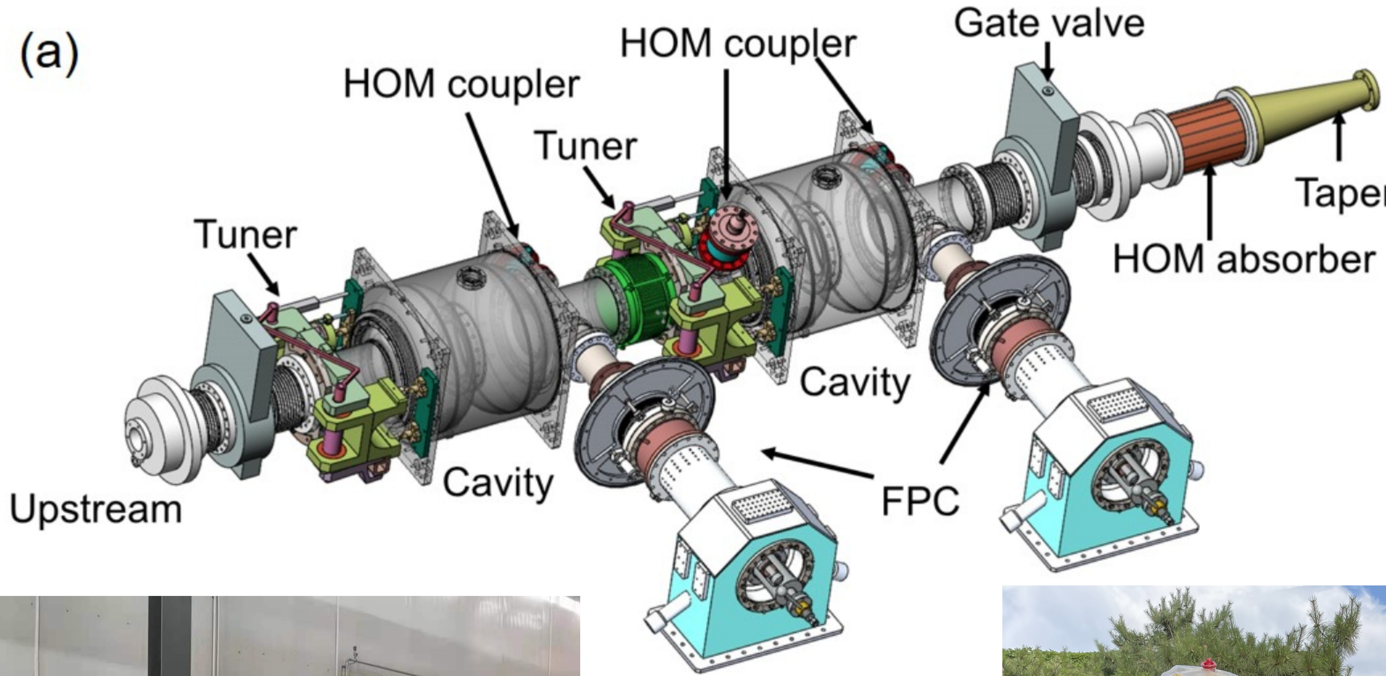
Second sound cavity quench detection system

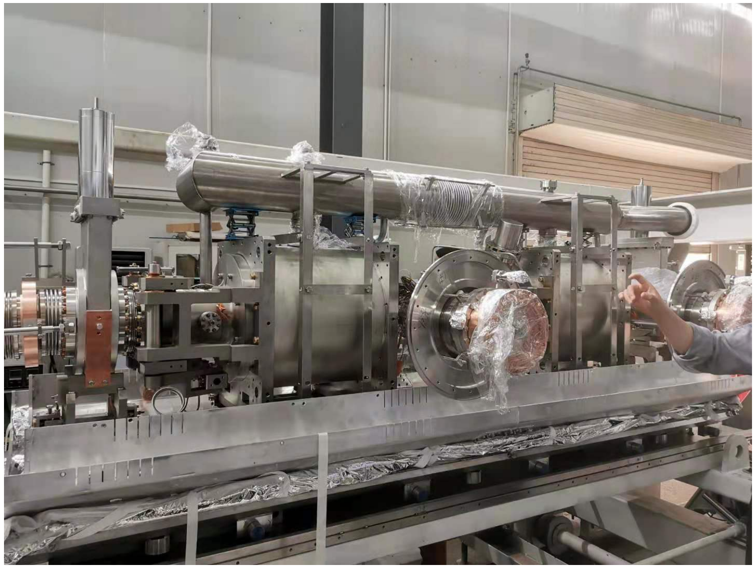
Helmholtz coil for cavity vertical test

Vertical test dewars

Horizontal test cryostat

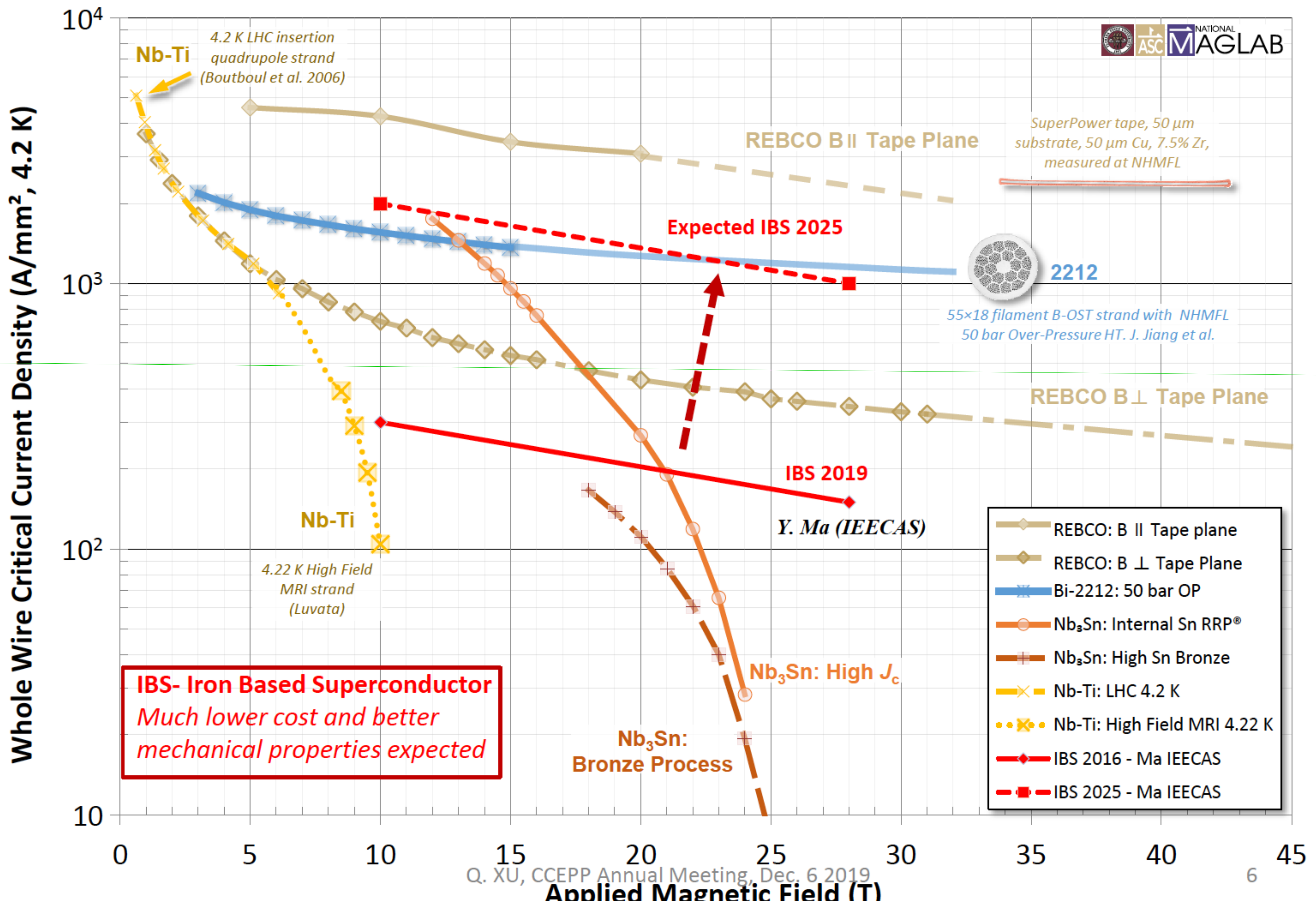
Joint test of critical components






(b)
Distribution valve box
DC photocathode gun
• 10~15 MeV
• 1~10 mA
Beam
650 MHz test cryomodule

J_e of IBS: 2016-2025



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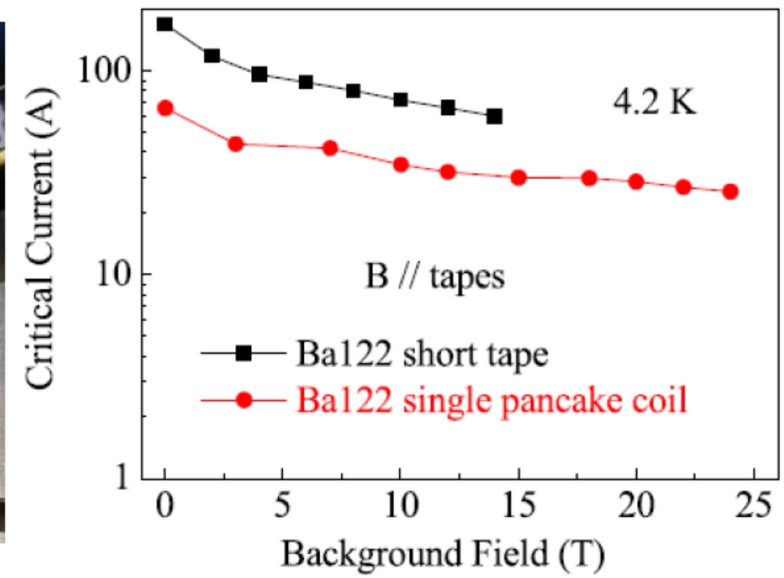
[2] University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[3] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[4] High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, People's Republic of China



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

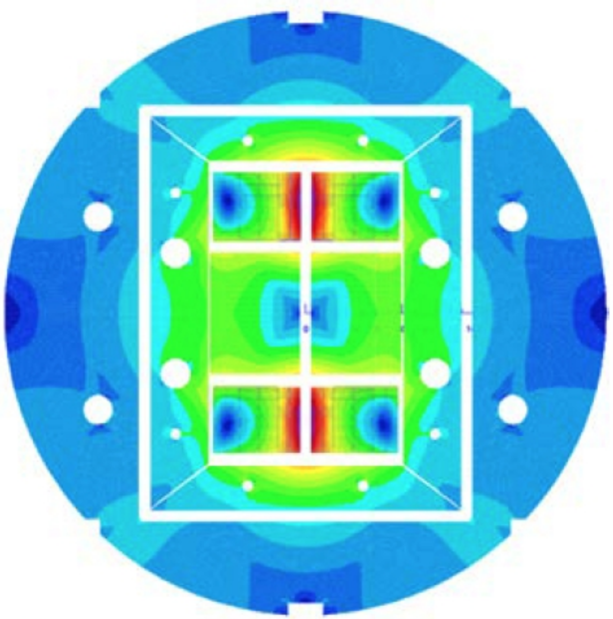
Jan Jaroszynski
National High Magnetic Field, Laboratory, Tallahassee, FL, 32310, United States of America
E-mail: jaroszy@magnet.fsu.edu

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

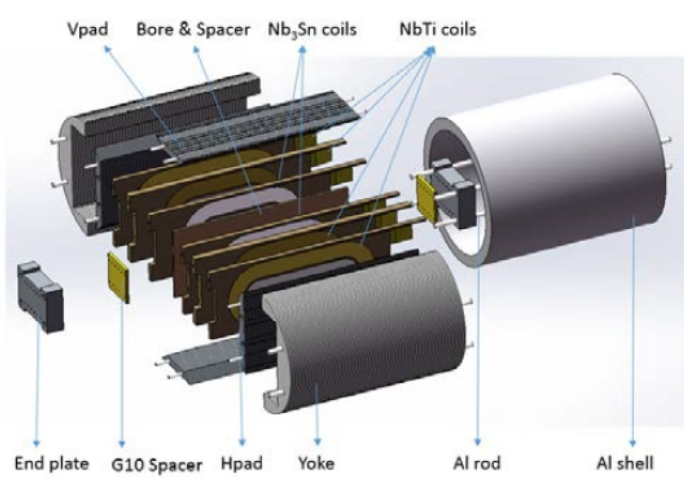
Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty

The 1st High-Field Model Dipole LPF1 in China

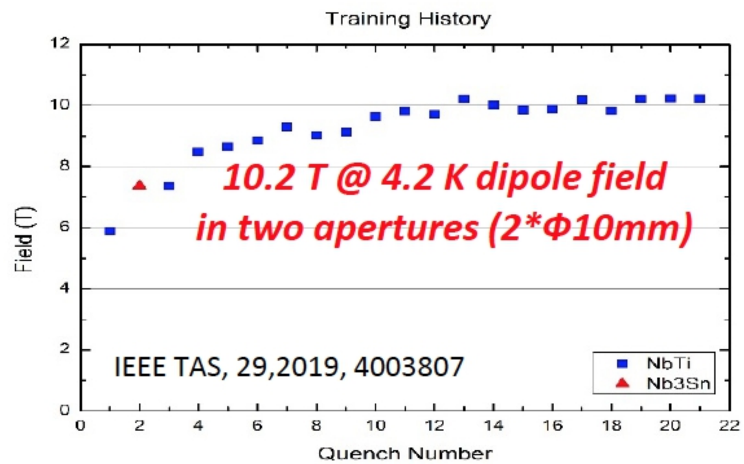
Twin aperture model dipole magnet with NbTi+Nb_3Sn

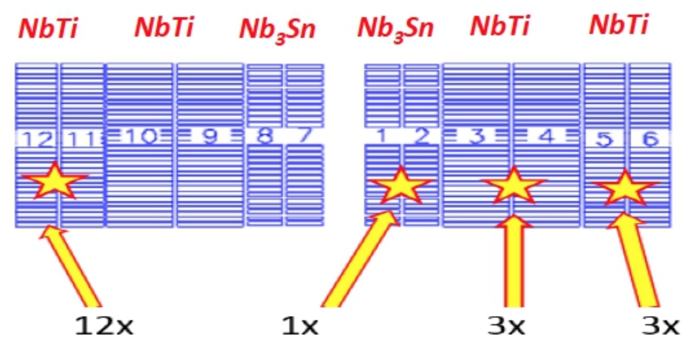


Common coil dipole magnet

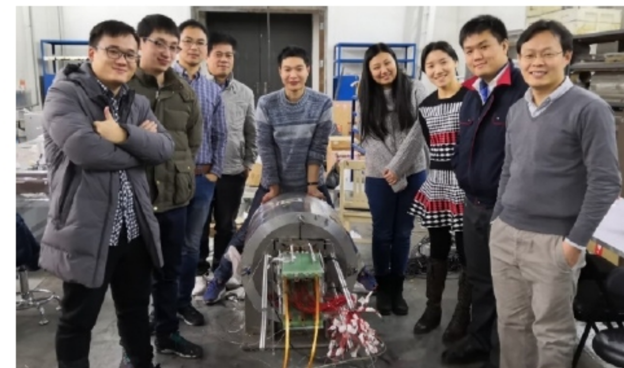


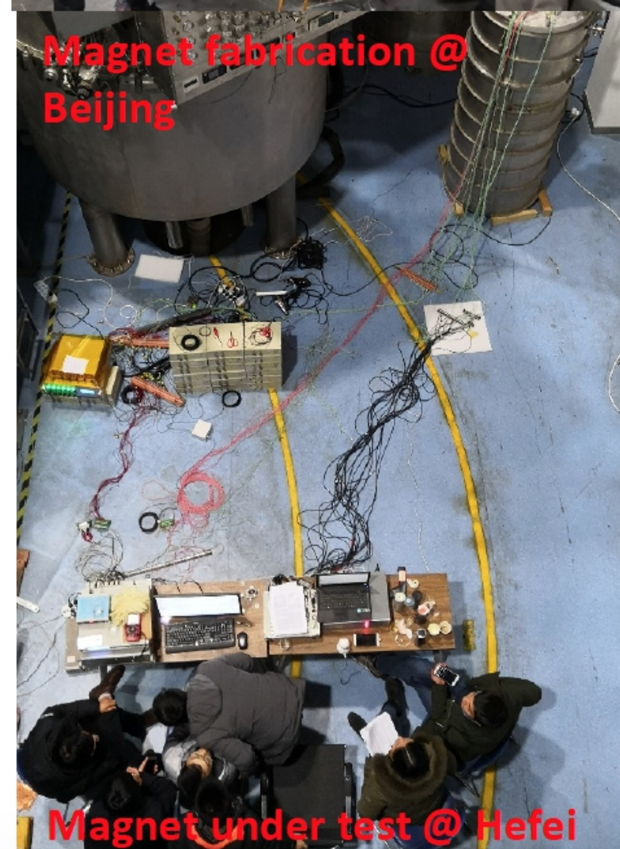
Shell-based Support structure



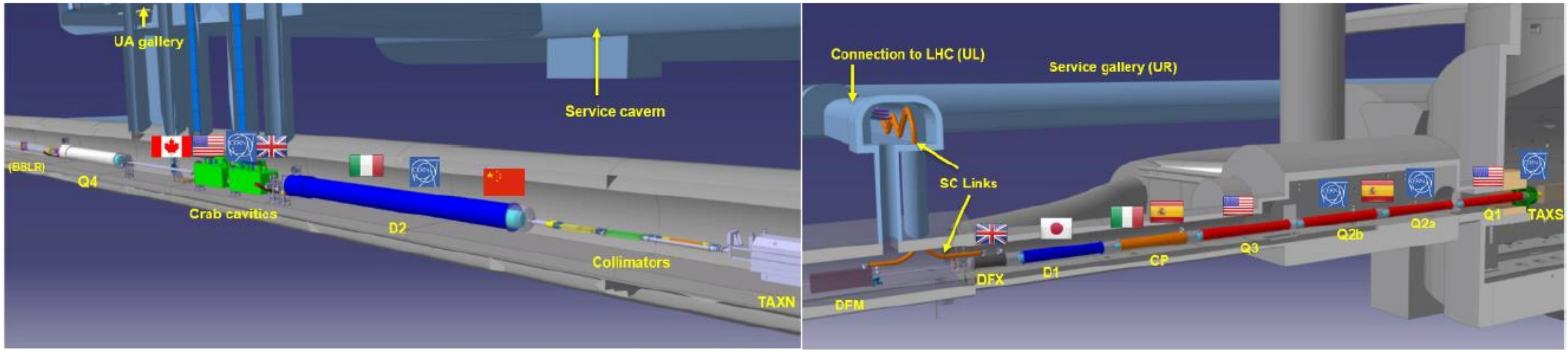


- *Performance* ***limited by the outermost NbTi coil.***
- *Very possibly due to the* ***less of pre-stress.***





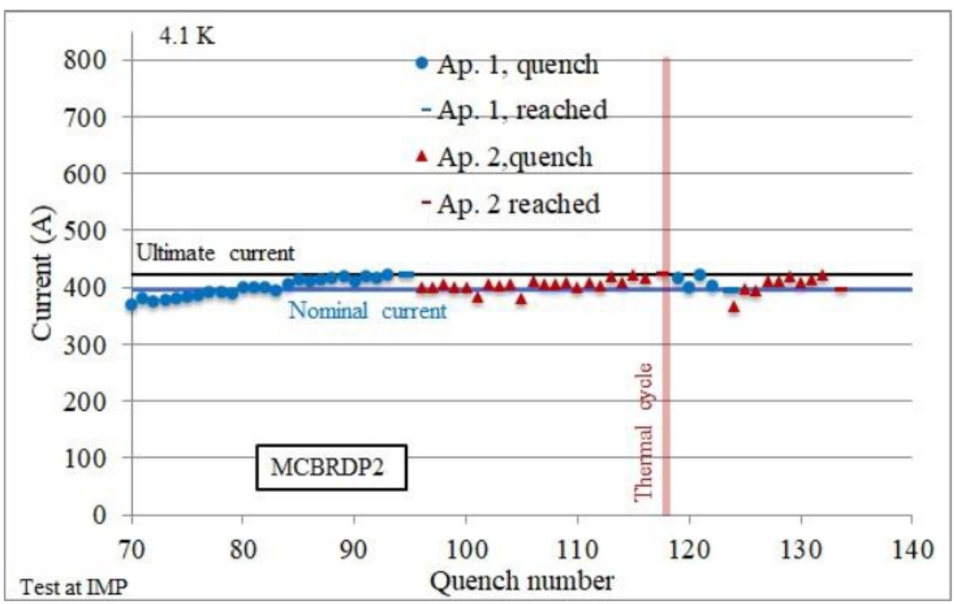
Status of the China-CERN HL-LHC CCT Project

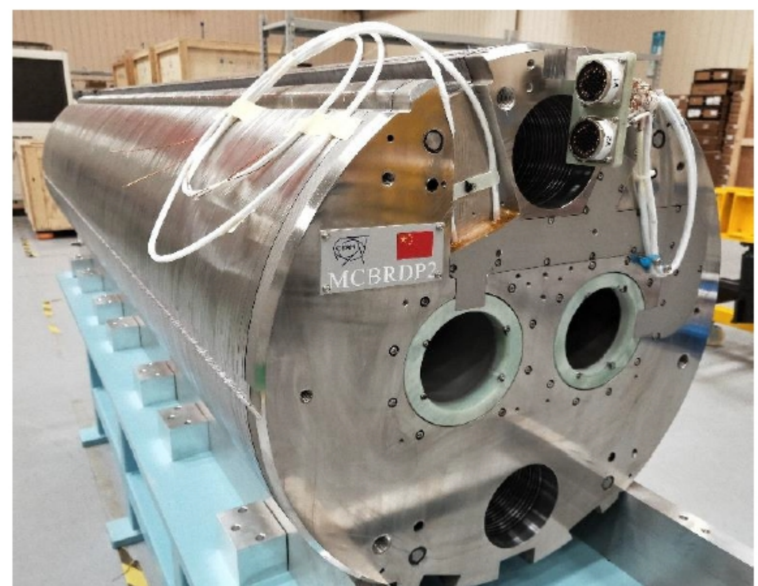


Layout of the HL-LHC Magnets and Contributors

China will provide 12+1 units CCT superconducting magnets for the HL-LHC project

After more than 1 month test and training at 4.2K, both apertures reached the design current and ultimate current, and the field quality is within the limit.





Qingjin XU, also merged slide from Jie.

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.

Physics white papers

- CEPC is a high precision Higgs factory, and a Discovery machine!
  - Need to quantify CEPC physics potential at Higgs, EW, Flavor, QCD & BSM, with benchmark analyses, and Global interpretation
  - Guide the design/optimization of the facility & Maximize the physics output: to quantify the requirements on Luminosity, beam quality, & detector performance

- White paper activities:
  - 2019.3 Higgs White Paper delivered
  - 2019.7 WS @ PKU: EW, Flavor, QCD working group formed
  - 2020.1 WS @ HKIAS: Review progress & iterate. EW Draft Ready
  - 2021.4 WS @ Yangzhou: BSM working group formed

White paper Status

- CEPC Physics/Detector WS, April 2021 @ Yangzhou
  - ~ 45 Physics reports
  - ~ 10 Performance/Optimization study
  - Significant Fresh

- *Higgs: Impact of 360 GeV Runs*
- *EW: Draft ready*
- *QCD: intensive discussions...*
- *Flavor + BSM:*
  - *Many Performance & Benchmark analyses*

Higgs white paper delivered

Chinese Physics C Vol. 43, No. 4 (2019) 043002

Precision Higgs physics at the CEPC*

Fenfen An(安芬芬)[4,23] Yu Bai(白羽)[9] Chunhui Chen(陈春晖)[23] Xin Chen(陈新)[5] Zhenxing Chen(陈振兴)[3]
Joao Guimaraes da Costa[4] Zhenwei Cui(崔振崴)[3] Yaquan Fang(方亚泉)[4,6,34;1)] Chengdong Fu(付成栋)[4]
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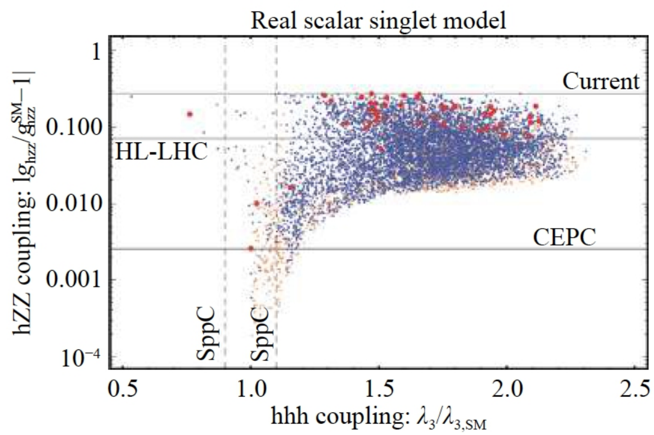
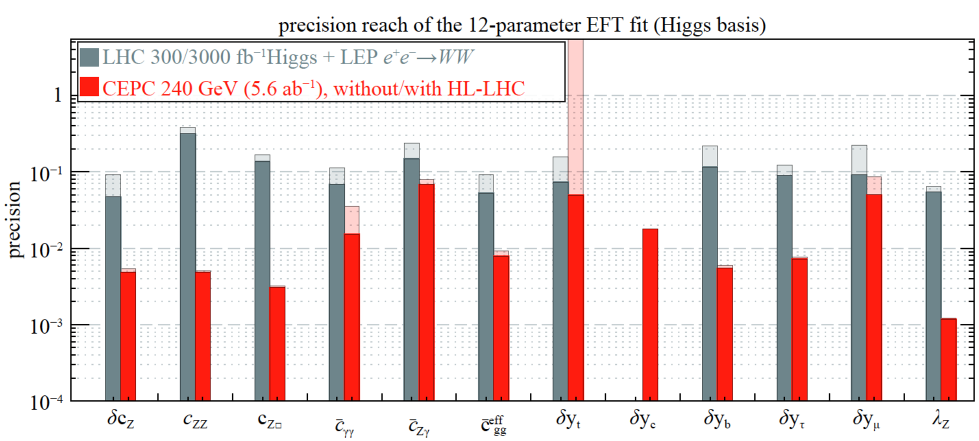
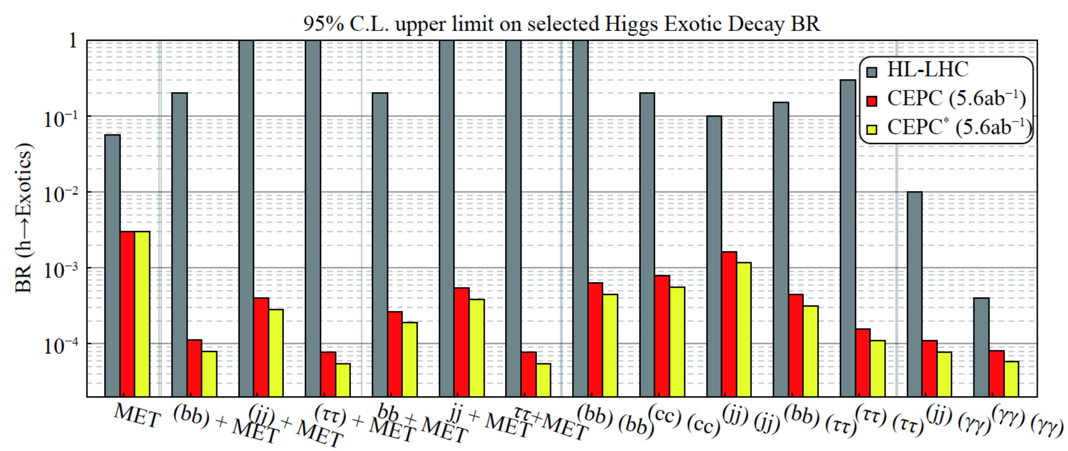
Hongjian He(何红建)[11,10] Xianke He(何显柯)[10] Xiaogang He(何小刚)[11,10,20] Jifeng Hu(胡继峰)[10]
Shih-Chieh Hsu(徐士杰)[32] Shan Jin(金山)[8] Maoqiang Jing(荆茂强)[4,7] Susmita Jyotishmati[33] Ryuta Kiuchi[4]
Chia-Ming Kuo(郭家铭)[21] Peizhu Lai(赖培筑)[21] Boyang Li(李博扬)[5] Congqiao Li(李聪乔)[3] Gang Li(李刚)[4,34;3)]
Haifeng Li(李海峰)[12] Liang Li(李亮)[10] Shu Li(李数)[11,10] Tong Li(李通)[12] Qiang Li(李强)[3] Hao Liang(梁浩)[4]
Zhijun Liang(梁志均)[4] Libo Liao(廖立波)[4] Bo Liu(刘波)[4,23] Jianbei Liu(刘建北)[1] Tao Liu(刘涛)[14]
Zhen Liu(刘真)[26,30;4)] Xinchou Lou(娄辛丑)[4,6,33,34] Lianliang Ma(马连良)[12] Bruce Mellado[17,18] Xin Mo(莫欣)[4]
Mila Pandurovic[16] Jianming Qian(钱剑明)[24;5)] Zhuoni Qian(钱卓妮)[19] Nikolaos Rompotis[22]
Manqi Ruan(阮曼奇)[4;6)] Alex Schuy[32] Lianyou Shan(单连友)[4] Jingyuan Shi(史静远)[9] Xin Shi(史欣)[4]
Shufang Su(苏淑芳)[25] Dayong Wang(王大勇)[3] Jin Wang(王锦)[4] Liantao Wang(王连涛)[27;7)]
Yifang Wang(王贻芳)[4,6] Yuqian Wei(魏彧骞)[4] Yue Xu(许悦)[5] Haijun Yang(杨海军)[10,11] Ying Yang(杨迎)[4]
Weiming Yao(姚为民)[28] Dan Yu(于丹)[4] Kaili Zhang(张凯栗)[4,6;8)] Zhaoru Zhang(张照茹)[4]
Mingrui Zhao(赵明锐)[2] Xianghu Zhao(赵祥虎)[4] Ning Zhou(周宁)[10]

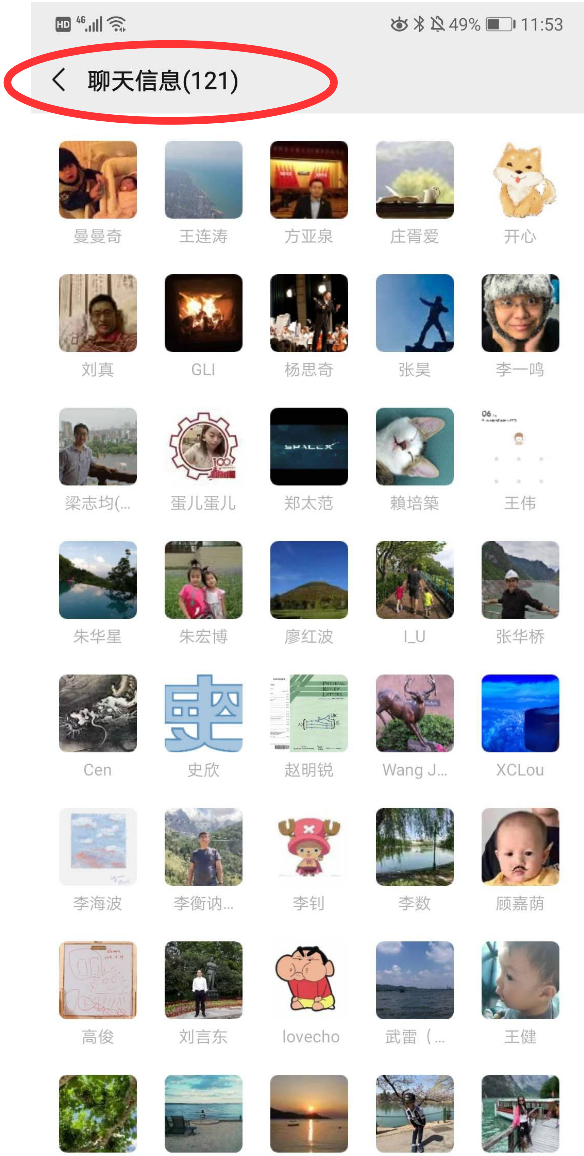






- *g(HXX), g(HHH), Br(H→exo)*

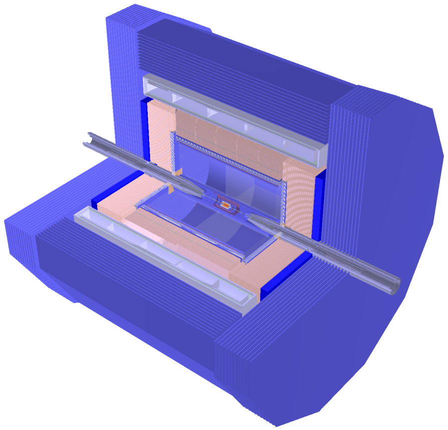
CEPC @ Snowmass

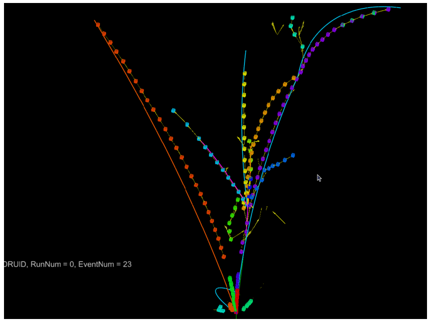


title	ID	author	link	
Study of electroweak phase transition in exotic Higgs decays with CEPC Detector simulation	229-v1	Michael Ramsey-Musolf	URL	
Exclusive Z decays	226-v1	Qin Qin	URL	
Measurement of the leptonic effective weak mixing angle at CEPC	233-v1	Siqi Yang	URL	★
Heavy Neutrino search in Lepton-Rich Higgs Boson Rare Decays	244-v1	Yu Gao	URL	★
Higgs boson CP properties at CEPC	227-v1	Xin Shi	URL	
Measurement of branching fractions of Higgs hadronic decays	228-v1	Yanping Huang	URL	
Feasibility study of CP-violating Phase phi_s measurement via Bs->J/PsiPhi channel at CEPC	230-v1	Mingrui Zhao	URL	★
Probing top quark FCNC couplings tqr, tqZ at future e+e- collider	231-v1	Peiwen Wu	URL	
Searching for $B_s \to \phi\nu\nu$ and other b->dvv processes at CEPC	232-v1	Yanyun Duan	URL	★
Probing new physics with the measurements of e+e- -> W+W- at CEPC with optimal observables	234-v1	Jiayin Gu	URL	
NNLO electroweak correction to Higgs and Z associated production at future Higgs factory	235-v1	Zhao Li	URL	
SUSY global fits with future colliders using GAMBIT	237-v1	Peter Athron	URL	
Probing Supersymmetry and Dark Matter at the CEPC, FCCee, and ILC	238-v1	Waqas Ahmed	URL	
Search for t + j + MET signals from dark matter models at future e+e- collider	239-v1	Peiwen Wu	URL	
Search for Asymmetric Dark Matter model at CEPC by displaced lepton jets	240-v1	Mengchao Zhang	URL	
Dark Matter via Higgs portal at CEPC	241-v1	Tianjun Li	URL	
Lepton portal dark matter, gravitational waves and collider phenomenology	242-v1	Jia Liu	URL	★
CEPC Detectors Letter of Intent	245-v1	Jianchun Wang	URL	

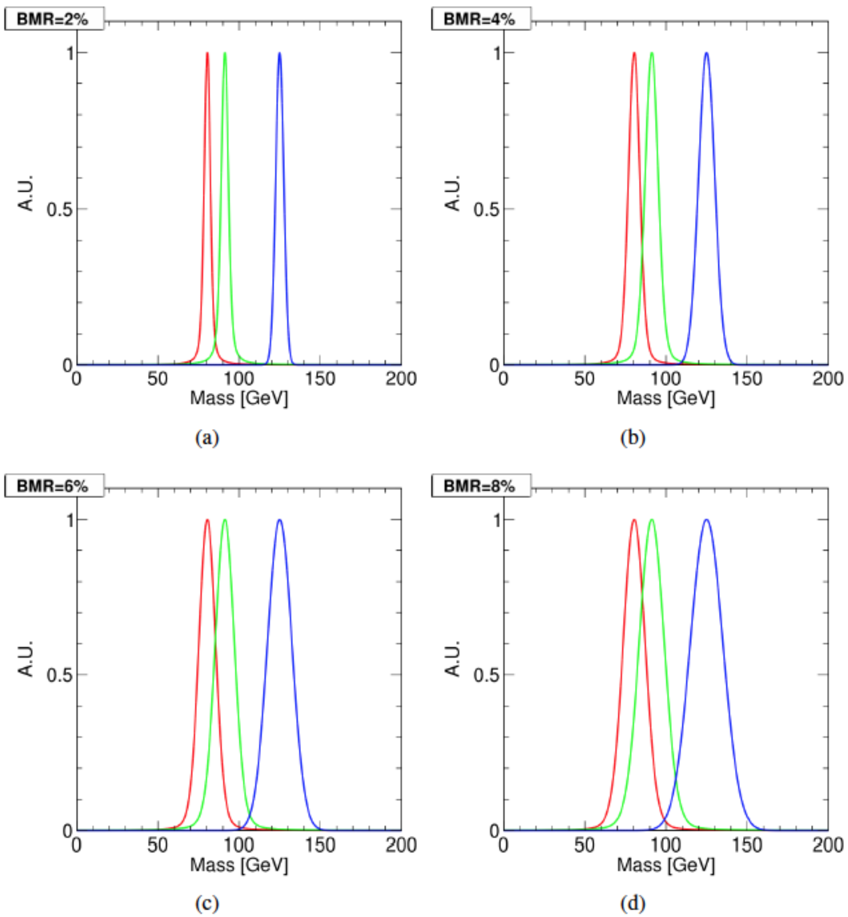
Baseline Detector Performance for flavor physics

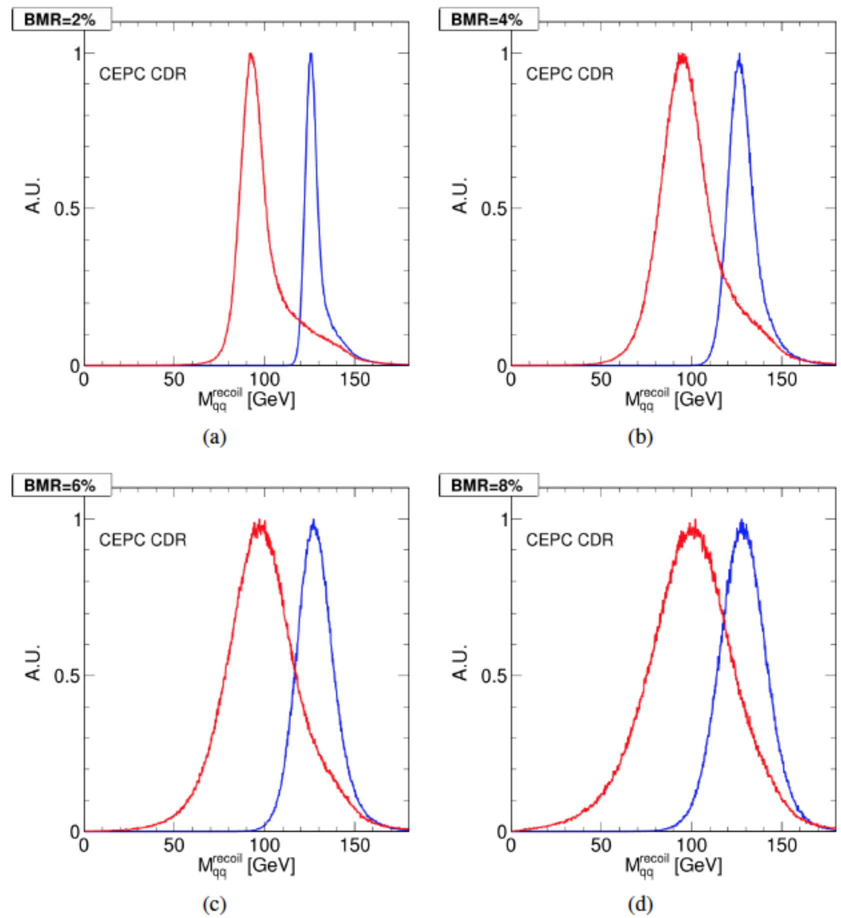
- Acceptance: |cos(θ)| < 099
- Tracks:
  - Pt threshold, ~ 100 MeV
  - δp/p ~ o(0.1%)
- Photons:
  - Energy threshold, ~ 100 MeV
  - δE/E: 3 – 15%/sqrt(E)
- Pi-Kaon separation: 3-sigma
- Pi-0: rec. eff*purity @ Z→qq > 60% @ 5GeV
- B-tagging: eff*purity @ Z→qq: 70%
- C-tagging: eff*purity @ Z→qq: 40%
- Jet charge: eff*$(1-2\omega)^2$ ~ 15%/30% @ Z→bb/cc
- Lepton inside jets: eff*purity @ Z→qq ~ 90% (energy > 3 GeV)
- Tau: eff*purity @ WW→tauvqq: 70%, mis id from jet fragments ~ o(1%)
- Reconstruction of simple combinations: Ks/Lambda/D with all tracks @ Z→qq: 60/75 – 80/85%
- BMR: 3.7%
- Missing Energy: Consistent with BMR.





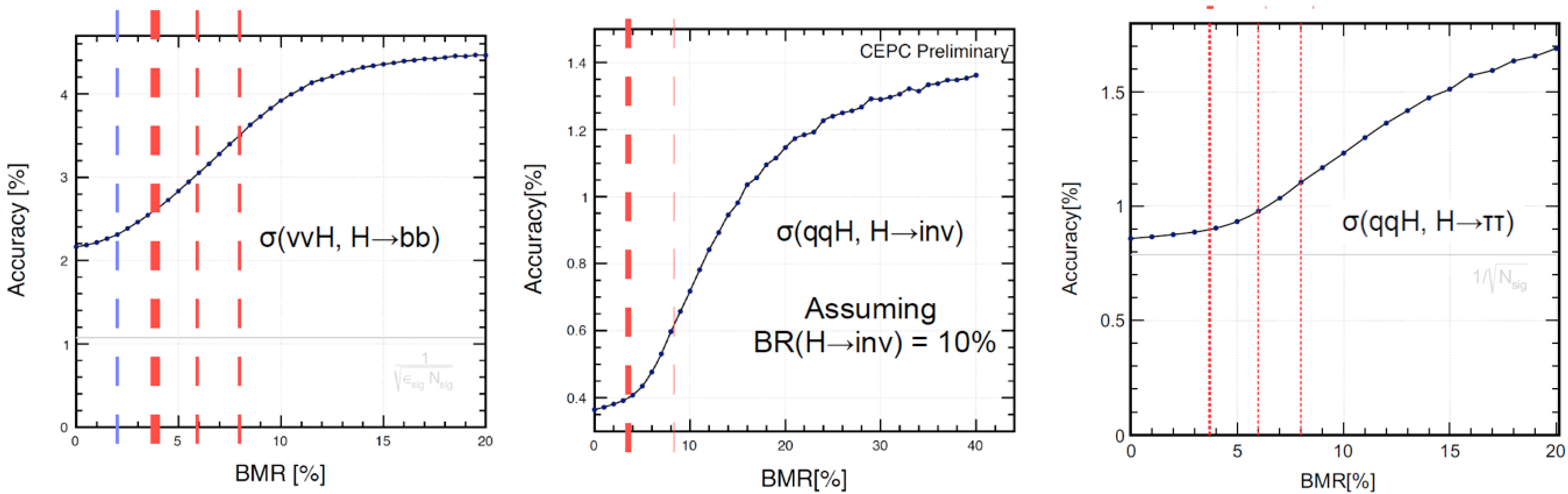
Key requirement on detector performance: BMR < 4%





- BMR: relative mass resolution of the hadronic system, especially for the hadronically decayed massive Bosons: W, Z, H
- BMR < 4%: to separate qqH signal from qqX background with recoil mass

BMR V.S. benchmark accuracy



- Boson Mass Resolution: relative mass resolution of vvH, H→gg events
  - Free of Jet Clustering
  - Be applied directly to the Higgs analyses
- The CEPC baseline reaches 3.8%

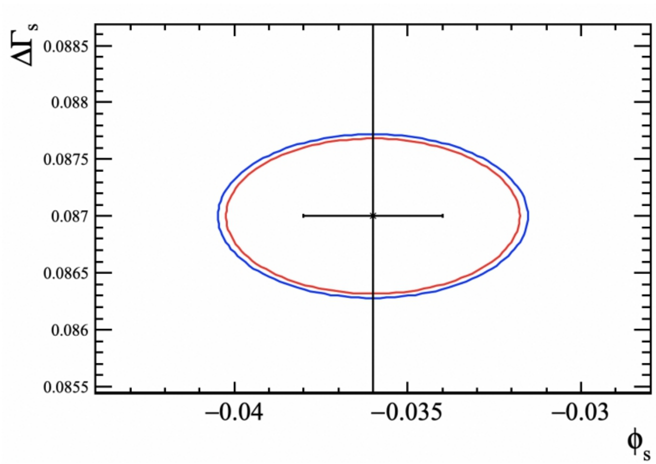
	BMR = 2%	4%	6%	8%
σ(vvH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(vvH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%

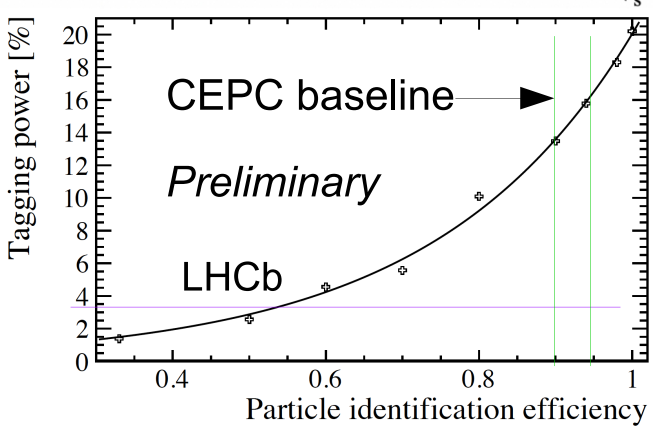
CP measurement with Bs->J/psi Phi... & requires good Pid!

$\Delta\Gamma_s \equiv \Gamma_L - \Gamma_H, \phi_s = -2\arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*)$

SM: small CPV phase ϕ_s

Contributions from physics beyond the SM could lead to much larger values of ϕ_s.

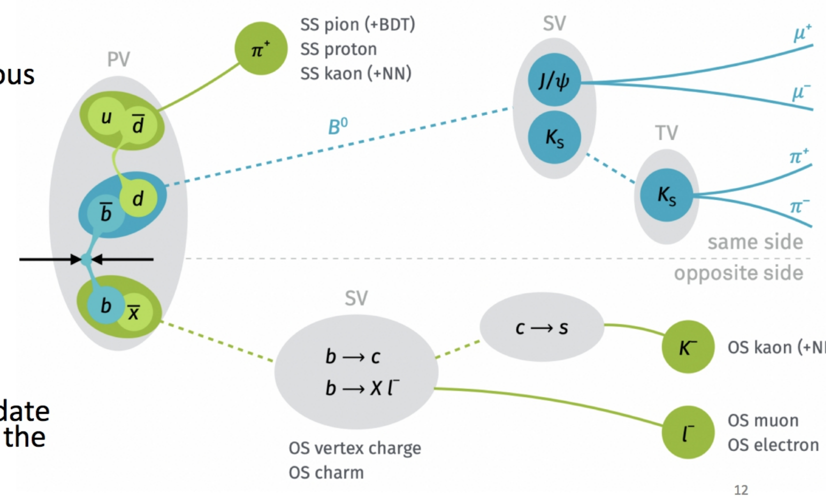




Flavour tagging power

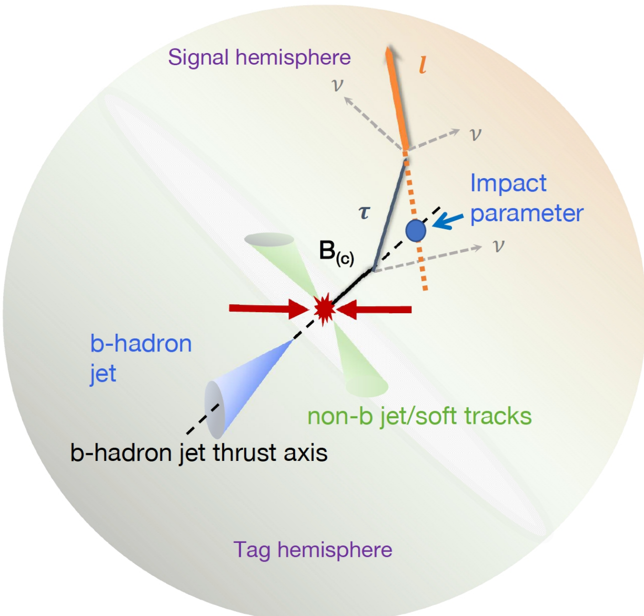
- LHCb: 3~4%
- CEPC: 15% (Previous estimation)
- B factory: ~30%

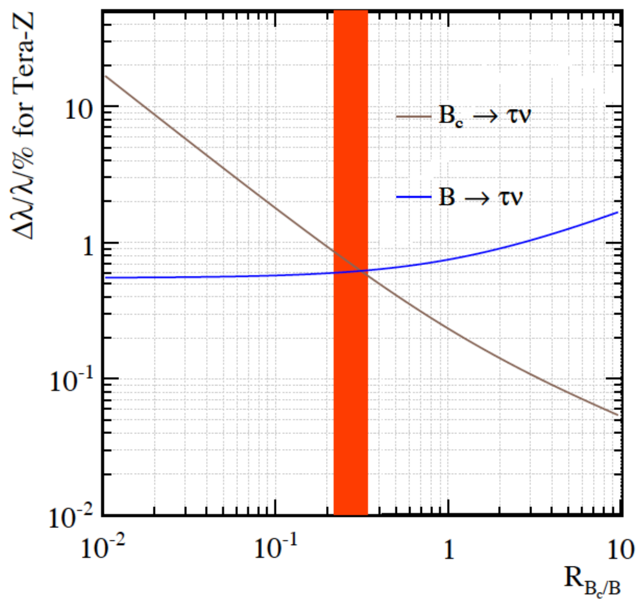
- For Bs:
  - OS lepton
  - OS kaon
  - SS kaon
- A naïve algorithm developed to validate the robustness of the estimation



- With decent Pid, the effective tagging power on jet Charge can be 5-6 times better than LHCb, which compensates the statistic difference between LHCb & CEPC.
- Strong motivation to higher Luminosity at Z pole
  - 1E13 Z? Why not?

Bc→τν... requires jet tau/lepton id!





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Analysis of $B_c \to \tau\nu_\tau$ at CEPC*

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Taifan, etc, Published @ CPC.
Collaborate with Wei Wang, et.al.

Lepton id & Baseline is good enough!

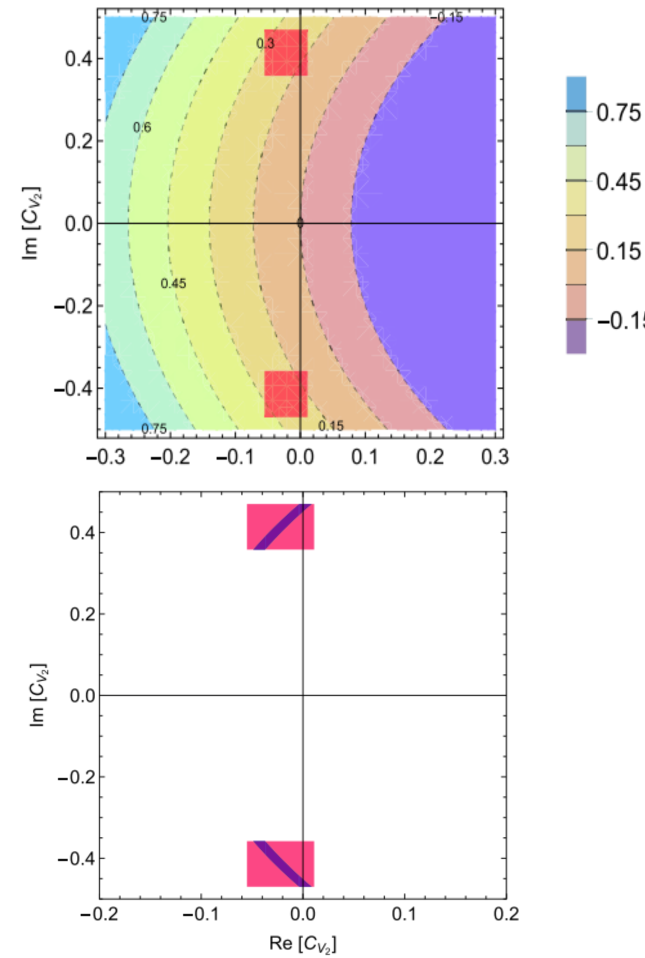
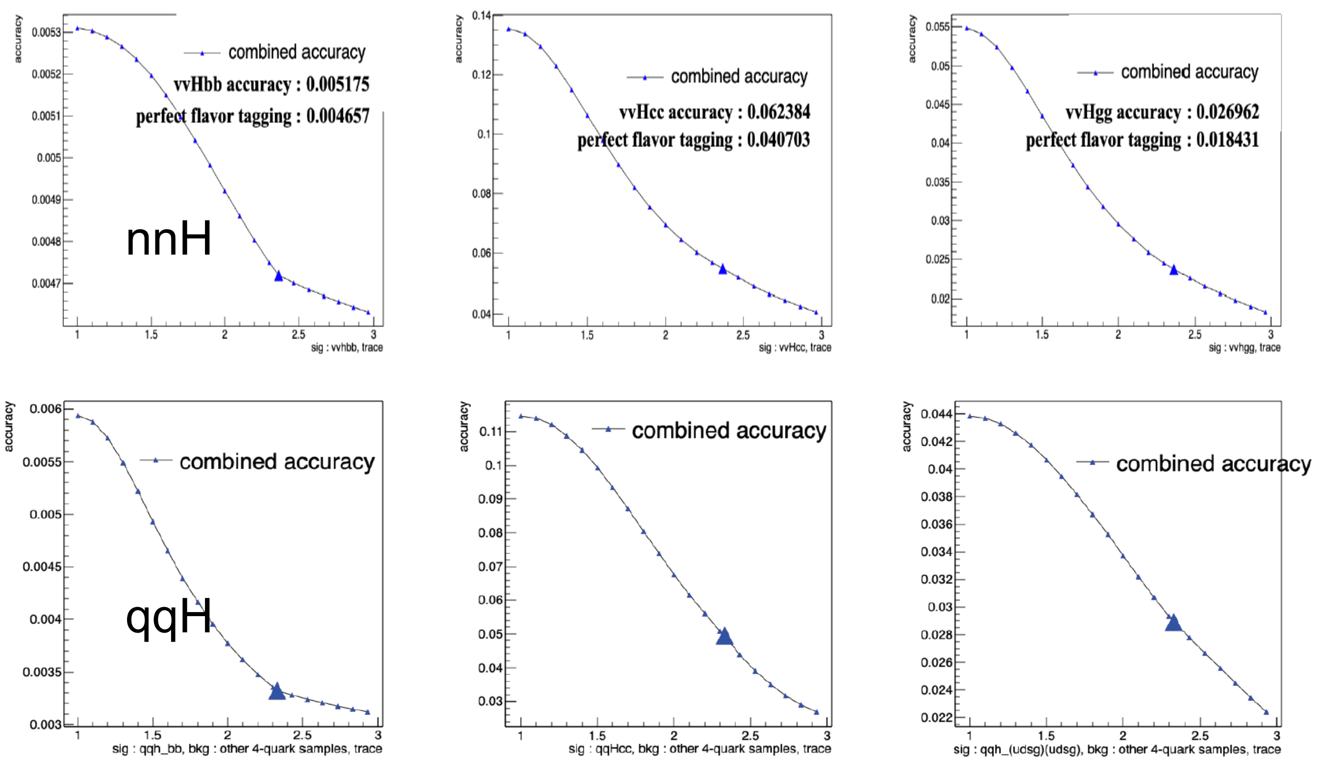
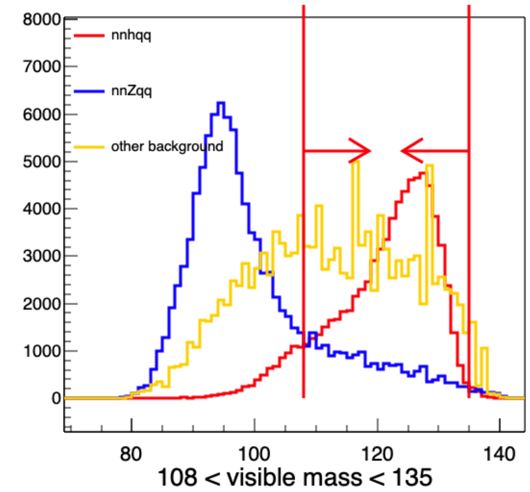
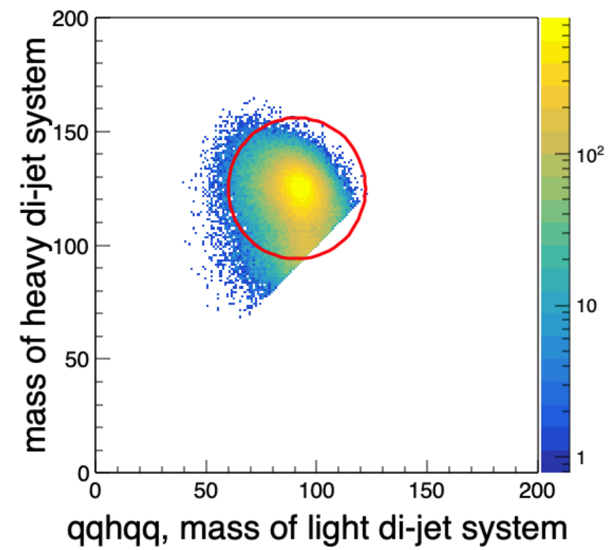


Fig. 10. (color online) Constraints on the real and imaginary parts of C_{V_2}. The red shaded area corresponds to the current constraints using available data on $b \to c\tau\nu$ decays. If the central values in Eq. (9) remain while the uncertainty in $\Gamma(B_c^+ \to \tau^+\nu_\tau)$ is reduced to 1%, the allowed region for C_{V_2} shrinks to the dark-blue regions.

H→bb, cc, gg: BMR, Color Singlet id (CSI) & Flavor tagging (Preliminary)



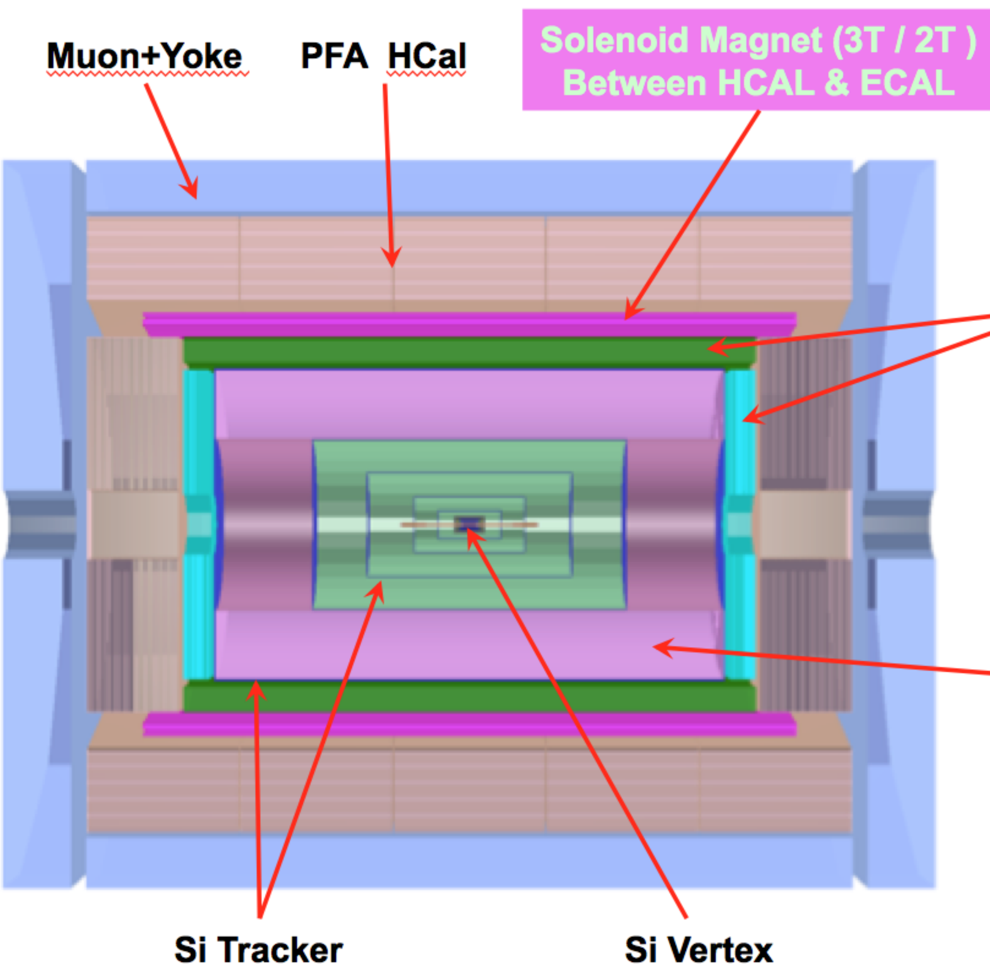




BMR is good enough... Huge penitential compared to Baseline FT + Naive CSI (ee-kt jet clustering & matching)

- Ideal CSI improves the accuracies by up to 2 times...
- Ideal Flavor tagging improves the accuracy of of Hcc by 2 times @ qqH, & 50% @ nnH

The 4th Conceptual Detector Design



Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

Drift chamber that is optimized for PID

Advantage: Work at high luminosity Z runs

Challenges: sufficient PID power; thin enough not to affect the moment resolution.

6

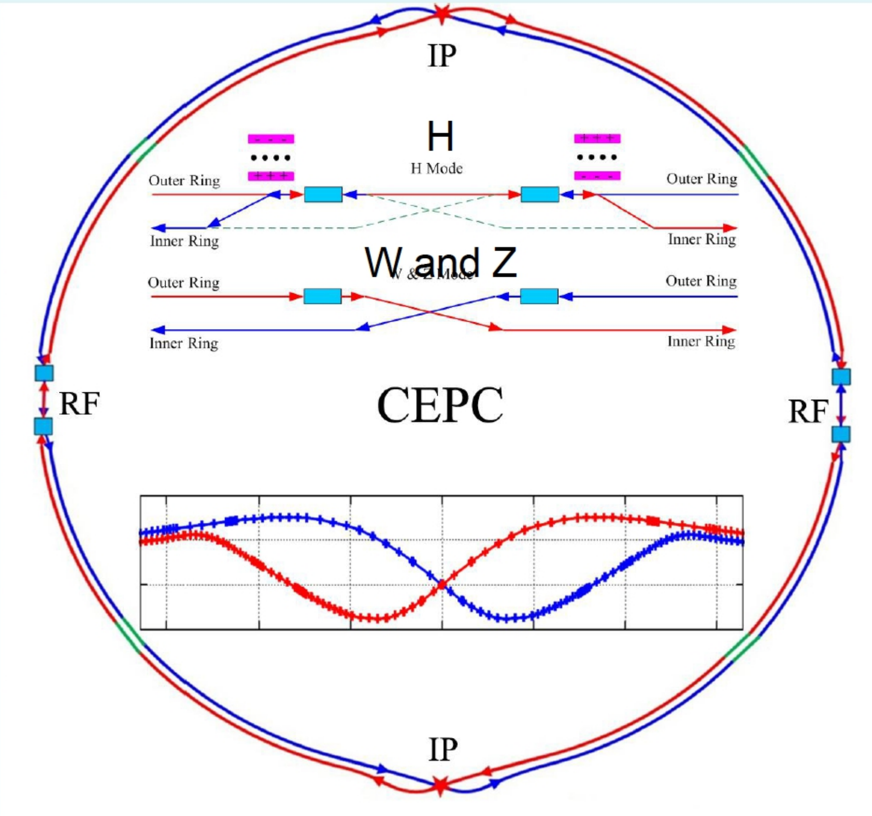
+ innovative software system...

Summary

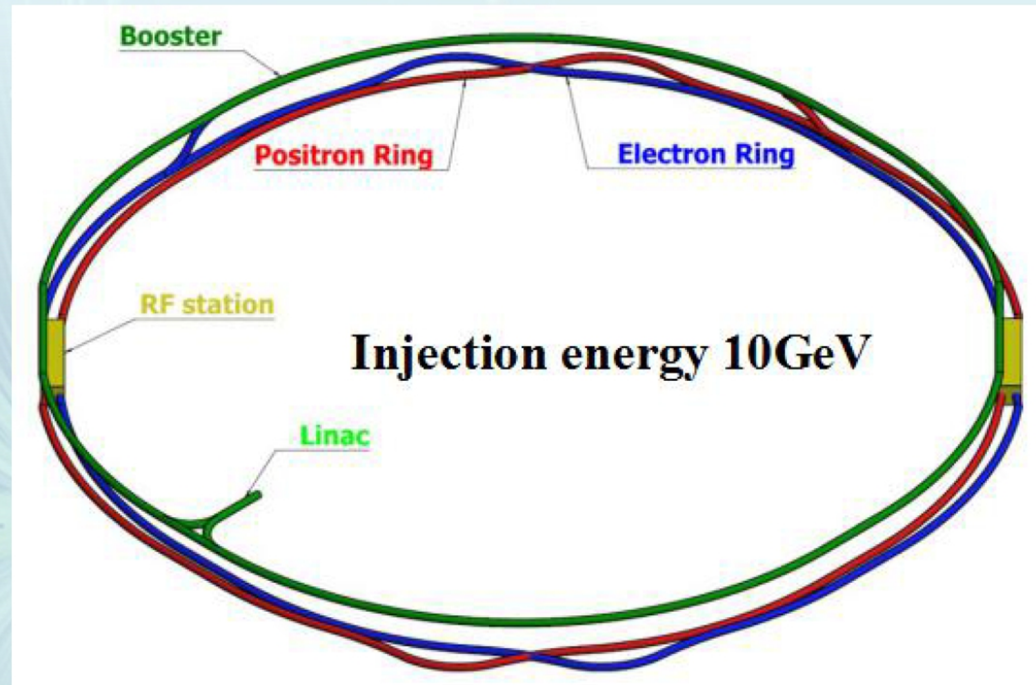
- CEPC, a precision & upgradable Higgs/W/Z factory, and a Discover machine!
  - Boost the Higgs/EW precision by ~ 10 times w.r.t HL-LHC/current boundary
  - Huge potential on QCD, Flavor, BSM
- CDR released
  - Accelerator baseline secures high productivity for Higgs, Z and W bosons.
  - Detector baseline fulfills the requirements: clear physics objects + Higgs signal
- Key technology development:
  - Towards the TDR & significant progresses & link to industrial
- White paper studies in good shape: progress with Performance analyses and benchmark studies
  - Your input is more than welcome!
- Giving the importance of electron positron Higgs/Z 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

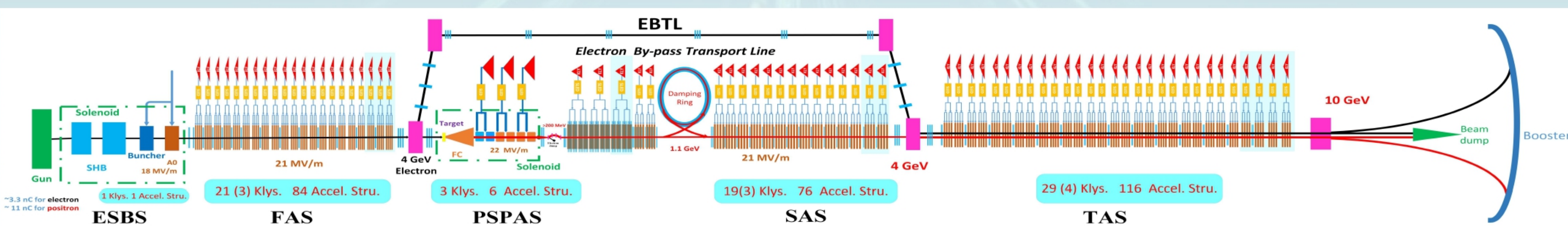
CEPC Accelerator Baseline Layout



CEPC collider ring (100km)



CEPC booster ring (100km)

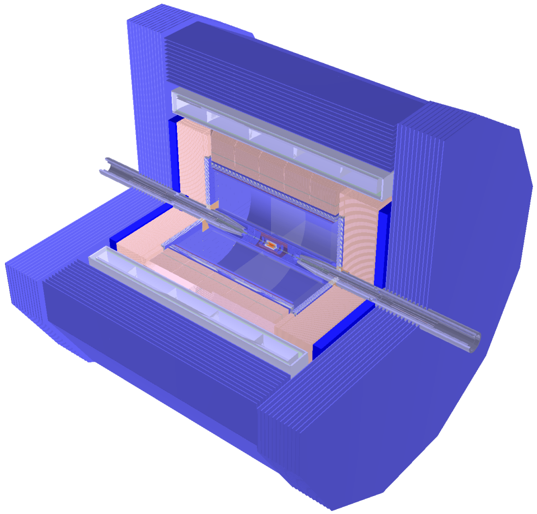


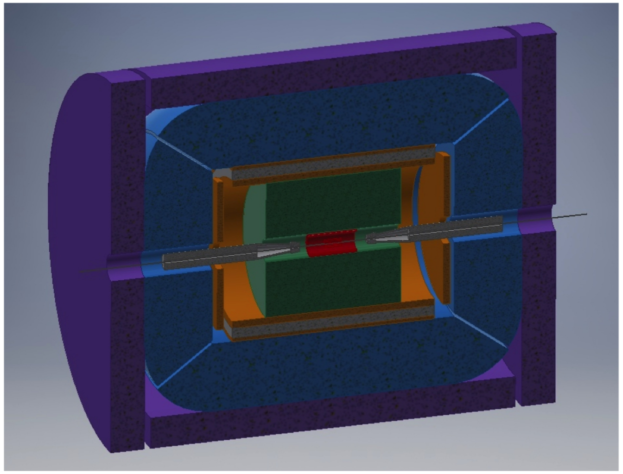
CEPC CDR Parameters

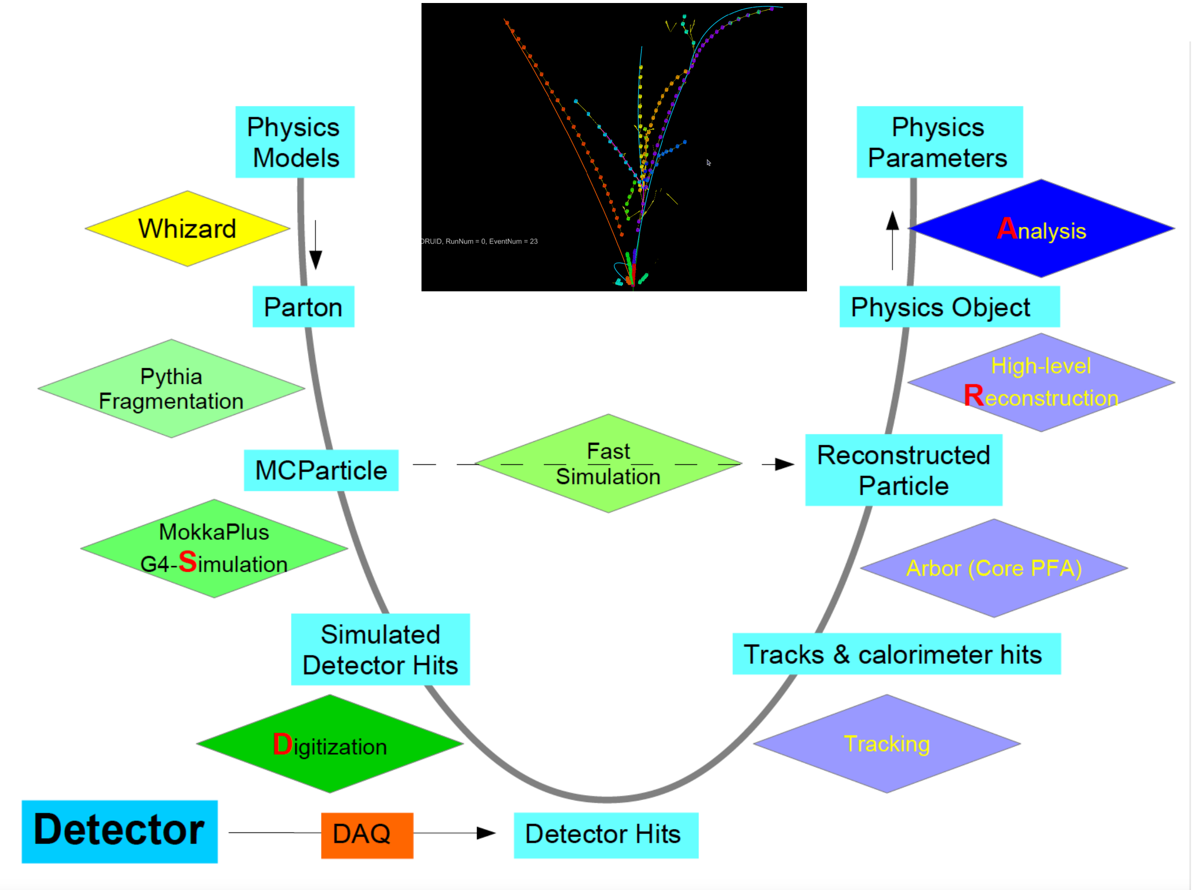
D. Wang

	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**

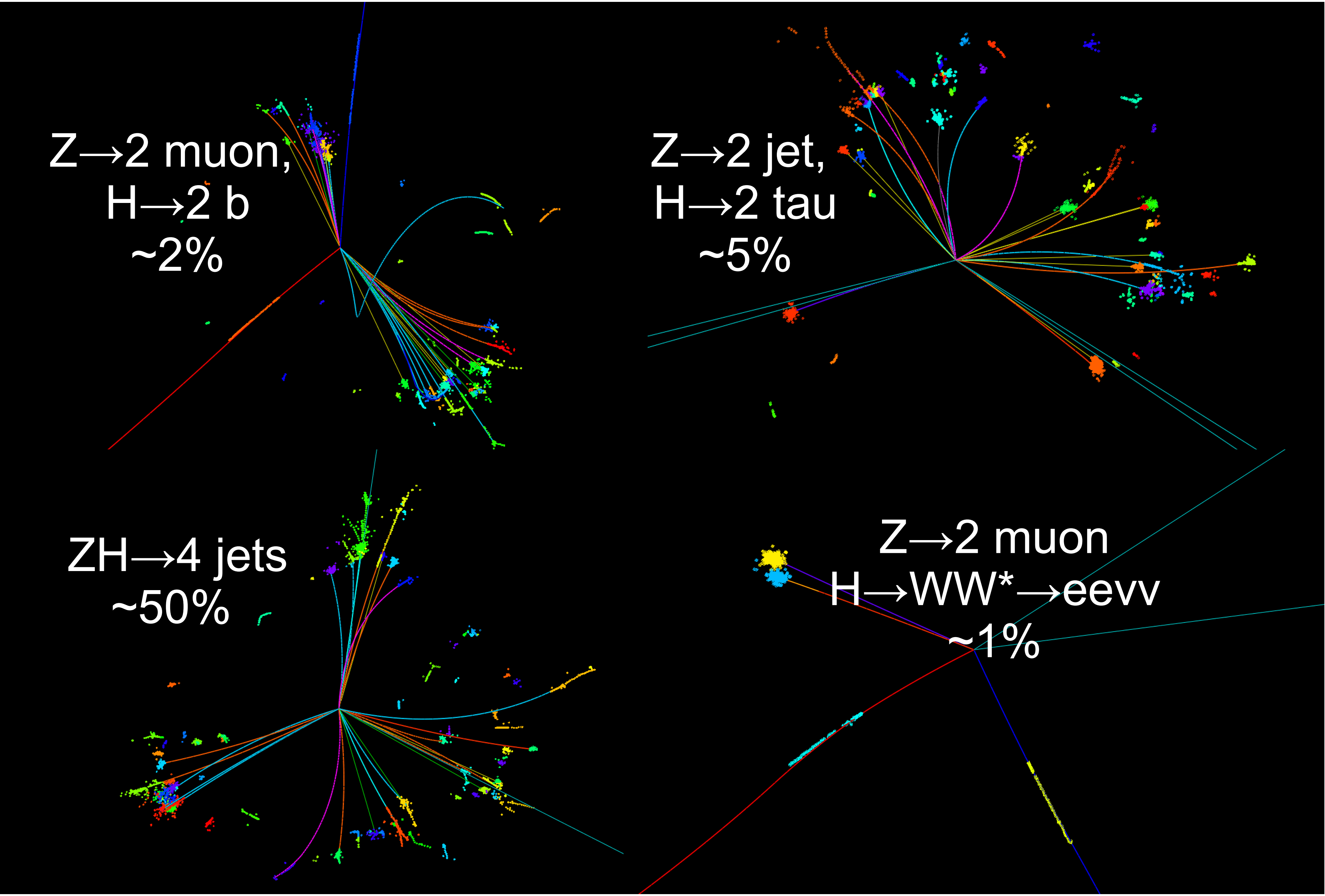
Detector & Software



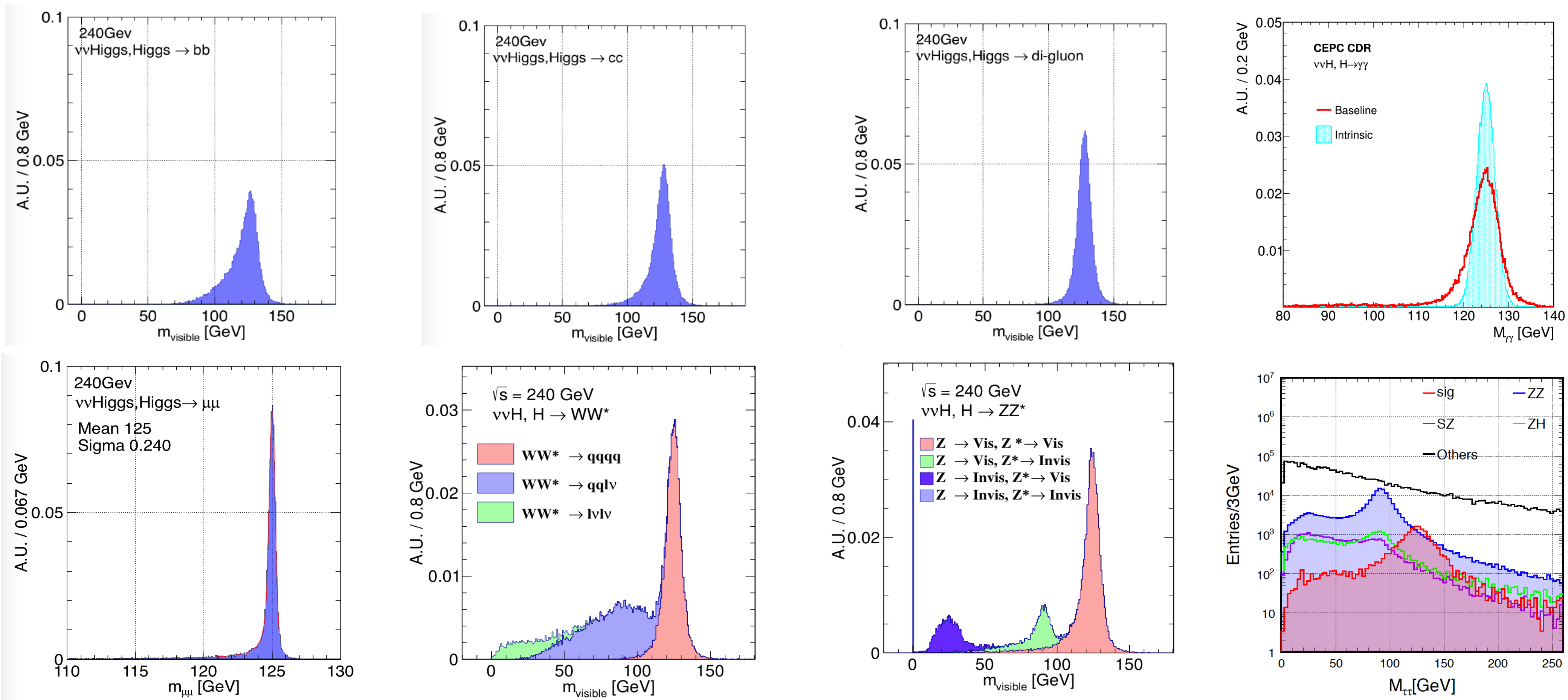




Full simulation reconstruction Chain functional, iterating/validation with hardware studies


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

Reconstructed Higgs Signatures

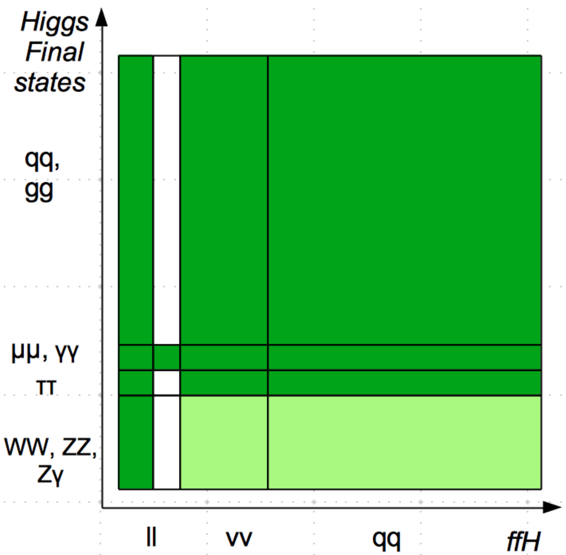


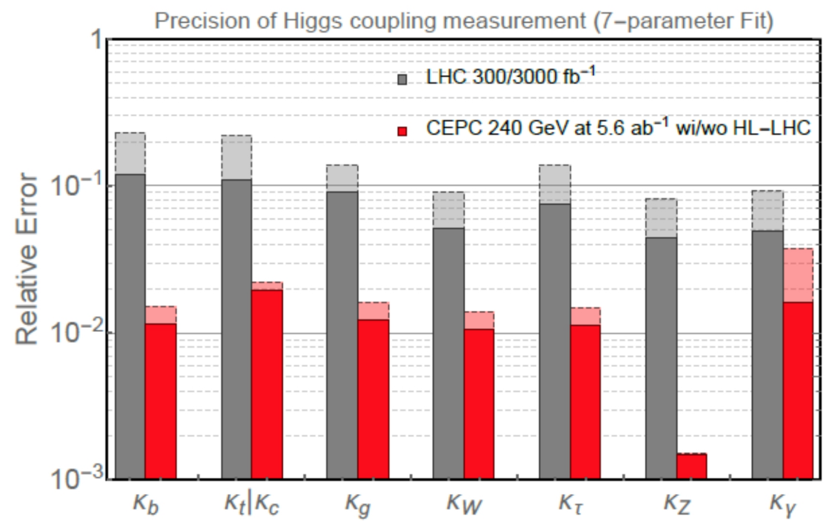
Clear Higgs Signature in all SM decay modes

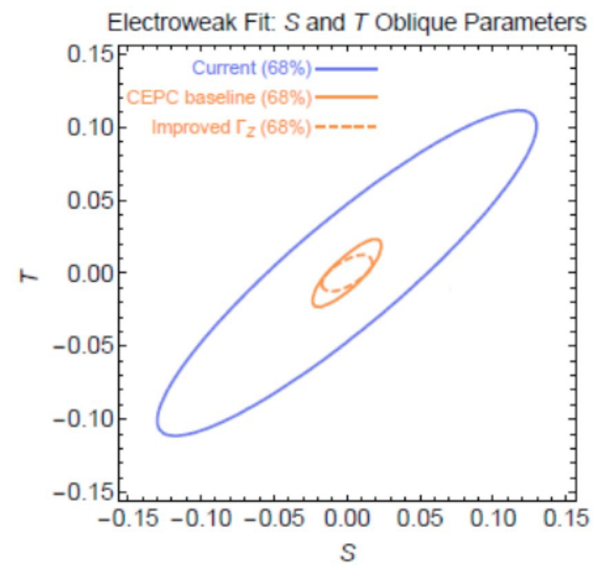
Massive production of the SM background (2 fermion and 4 fermions) at the full Simulation level

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

Quantify the physics potential







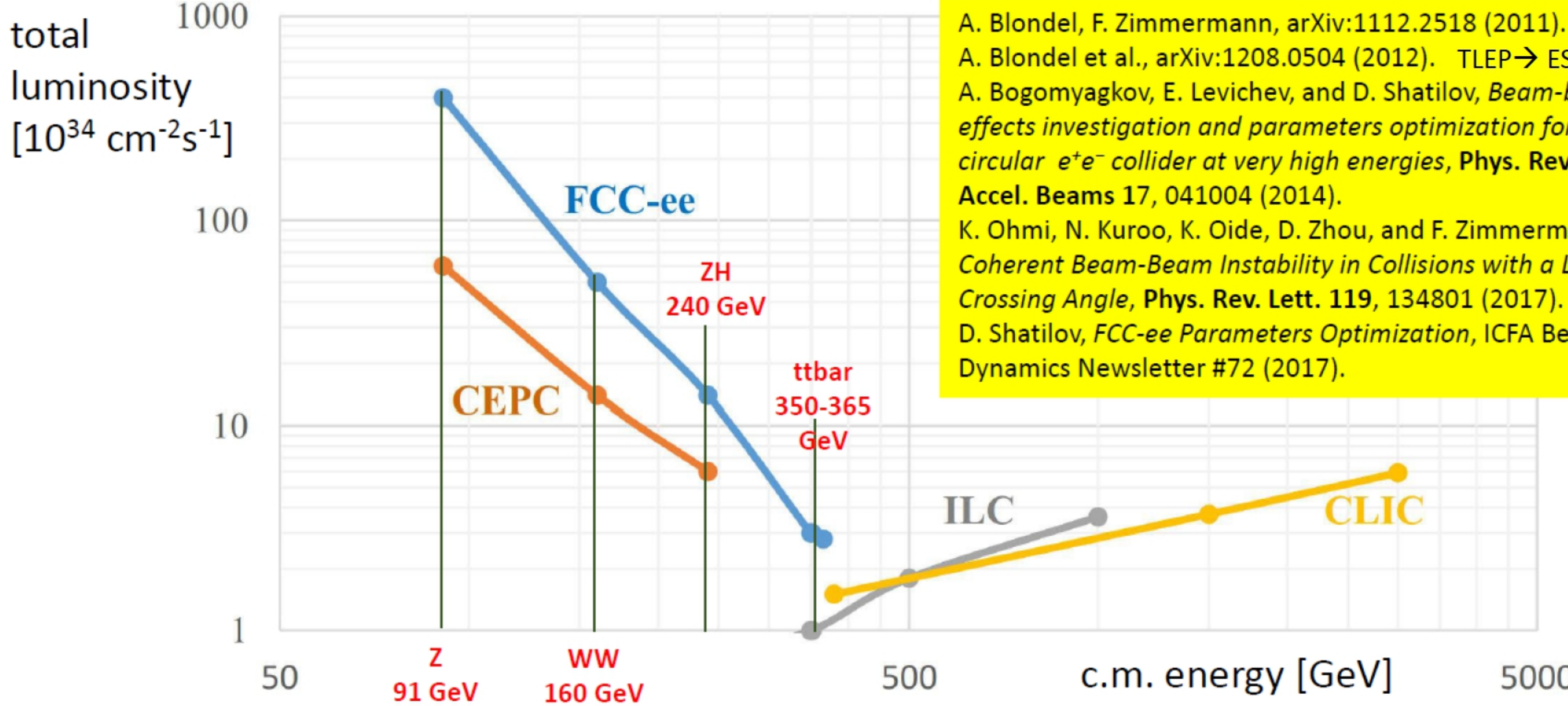
70 OVERVIEW OF THE PHYSICS CASE FOR CEPC

Particle	Tera-Z	Belle II	LHCb
b hadrons			
B^+	6×10^{10}	3×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	3×10^{13}
B^0	6×10^{10}	3×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	3×10^{13}
B_s	2×10^{10}	3×10^{8} (5 ab^{-1} on $\Upsilon(5S)$)	8×10^{12}
b baryons	1×10^{10}		1×10^{13}
Λ_b	1×10^{10}		1×10^{13}
c hadrons			
D^0	2×10^{11}		
D^+	6×10^{10}		
D_s^+	3×10^{10}		
Λ_c^+	2×10^{10}		
τ^+	3×10^{10}	5×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	

Observable	Current sensitivity	Future sensitivity	Tera-Z sensitivity
BR($B_s \to ee$)	2.8×10^{-7} (CDF) [438]	$\sim 7 \times 10^{-10}$ (LHCb) [435]	$\sim$ few $\times 10^{-10}$
BR($B_s \to \mu\mu$)	0.7×10^{-9} (LHCb) [437]	$\sim 1.6 \times 10^{-10}$ (LHCb) [435]	$\sim$ few $\times 10^{-10}$
BR($B_s \to \tau\tau$)	5.2×10^{-3} (LHCb) [441]	$\sim 5 \times 10^{-4}$ (LHCb) [435]	$\sim 10^{-5}$
R_K, R_{K^*}	$\sim 10\%$ (LHCb) [443, 444]	$\sim$few% (LHCb/Belle II) [435, 442]	$\sim$few %
BR($B \to K^*\tau\tau$)	–	$\sim 10^{-5}$ (Belle II) [442]	$\sim 10^{-8}$
BR($B \to K^*\nu\nu$)	4.0×10^{-5} (Belle) [449]	$\sim 10^{-6}$ (Belle II) [442]	$\sim 10^{-6}$
BR($B_s \to \phi\nu\bar{\nu}$)	1.0×10^{-3} (LEP) [452]	–	$\sim 10^{-6}$
BR($\Lambda_b \to \Lambda\nu\bar{\nu}$)	–	–	$\sim 10^{-6}$
BR($\tau \to \mu\gamma$)	4.4×10^{-8} (BaBar) [475]	$\sim 10^{-9}$ (Belle II) [442]	$\sim 10^{-9}$
BR($\tau \to 3\mu$)	2.1×10^{-8} (Belle) [476]	$\sim$ few $\times 10^{-10}$ (Belle II) [442]	$\sim$ few $\times 10^{-10}$
$\frac{\text{BR}(\tau\to\mu\nu\bar{\nu})}{\text{BR}(\tau\to e\nu\bar{\nu})}$	3.9×10^{-3} (BaBar) [464]	$\sim 10^{-3}$ (Belle II) [442]	$\sim 10^{-4}$
BR($Z \to \mu e$)	7.5×10^{-7} (ATLAS) [471]	$\sim 10^{-8}$ (ATLAS/CMS)	$\sim 10^{-9} - 10^{-11}$
BR($Z \to \tau e$)	9.8×10^{-6} (LEP) [469]	$\sim 10^{-6}$ (ATLAS/CMS)	$\sim 10^{-8} - 10^{-11}$
BR($Z \to \tau\mu$)	1.2×10^{-5} (LEP) [470]	$\sim 10^{-6}$ (ATLAS/CMS)	$\sim 10^{-8} - 10^{-10}$

Table 2.5: Order of magnitude estimates of the sensitivity to a number of key observables for which the tera-Z factory at CEPC might have interesting capabilities. The expected future sensitivities assume luminosities of 50 fb^{-1} at LHCb, 50 ab^{-1} at Belle II, and 3 ab^{-1} at ATLAS and CMS. For the tera-Z factory of CEPC we have assumed the production of 10^{12} Z bosons.

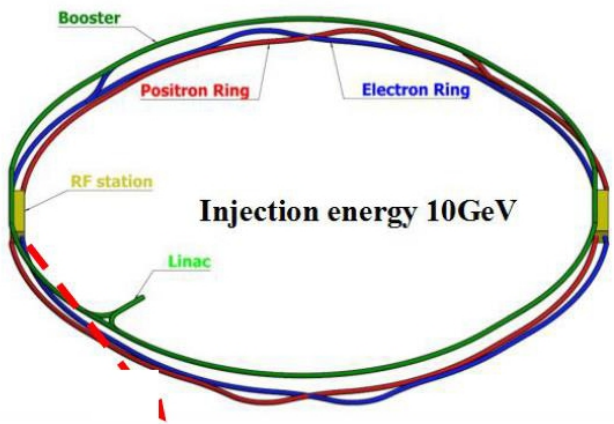
Comparison: Linear & Circular

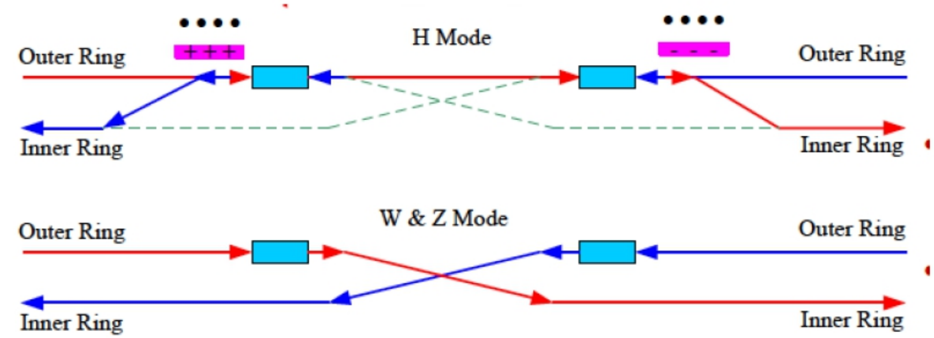


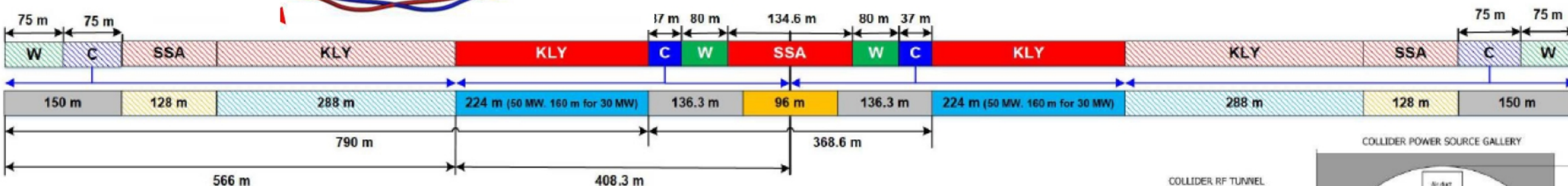
A. Blondel, F. Zimmermann, arXiv:1112.2518 (2011).
A. Blondel et al., arXiv:1208.0504 (2012). TLEP→ ESPP2012
A. Bogomyagkov, E. Levichev, and D. Shatilov, *Beam-beam effects investigation and parameters optimization for a circular e^+e^- collider at very high energies*, **Phys. Rev. ST Accel. Beams 17**, 041004 (2014).
K. Ohmi, N. Kuroo, K. Oide, D. Zhou, and F. Zimmermann, *Coherent Beam-Beam Instability in Collisions with a Large Crossing Angle*, **Phys. Rev. Lett. 119**, 134801 (2017).
D. Shatilov, *FCC-ee Parameters Optimization*, ICFA Beam Dynamics Newsletter #72 (2017).

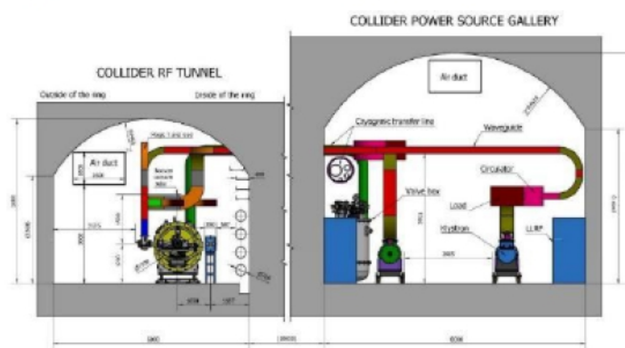
From A. Blondel's presentation at CEPC Oxford WS

CEPC SCRF Cavities





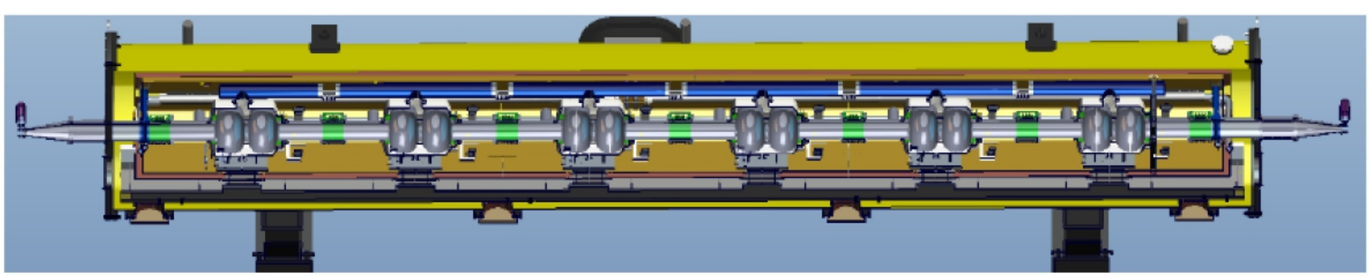


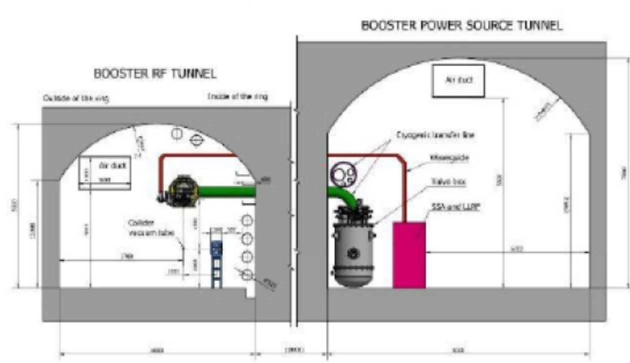


30 MW Higgs:

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).

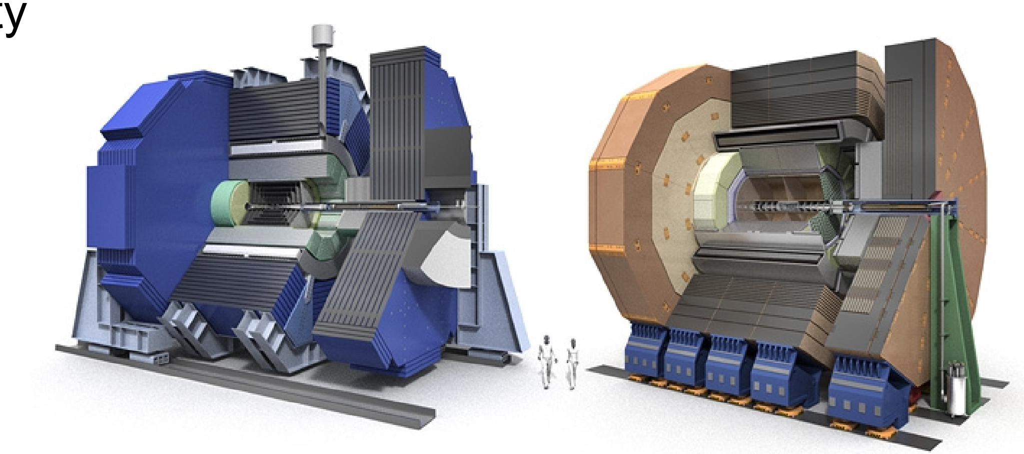




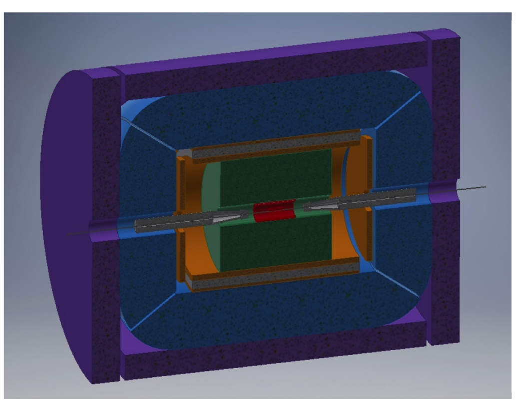
For higher Z lumi, look at 1-cell cavity design.

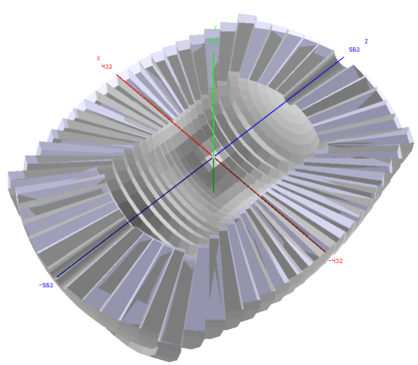
Two classes of Concepts

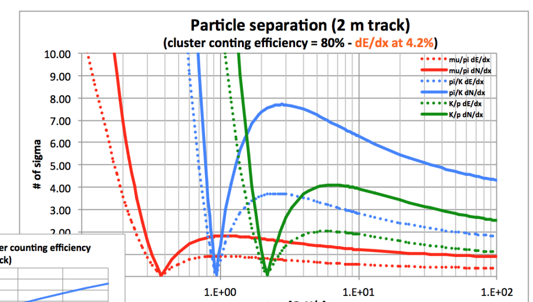
- PFA Oriented concept using High Granularity Calorimeter
  - + TPC (ILD-like, **Baseline**)
  - + Silicon tracking (SiD-like)

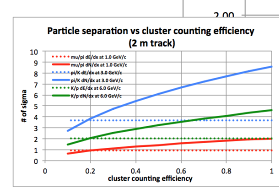


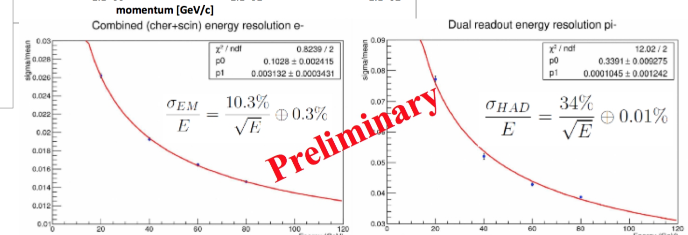
- Low Magnet Field Detector Concept (IDEA)
  - Wire Chamber + Dual Readout Calorimeter











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

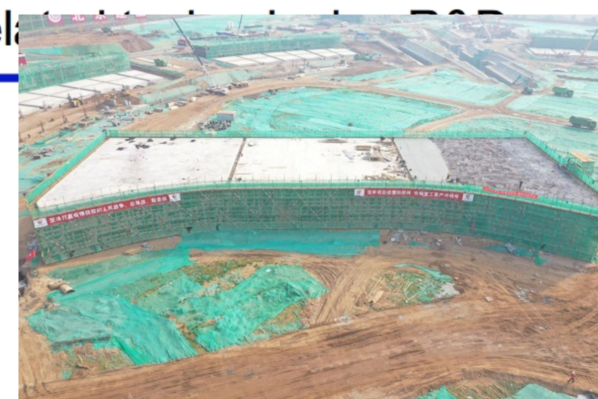
https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=14816

Platform of Advanced Photon Source Technology R&D

: 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 rel



Main structure of HEPS booster RF system complete

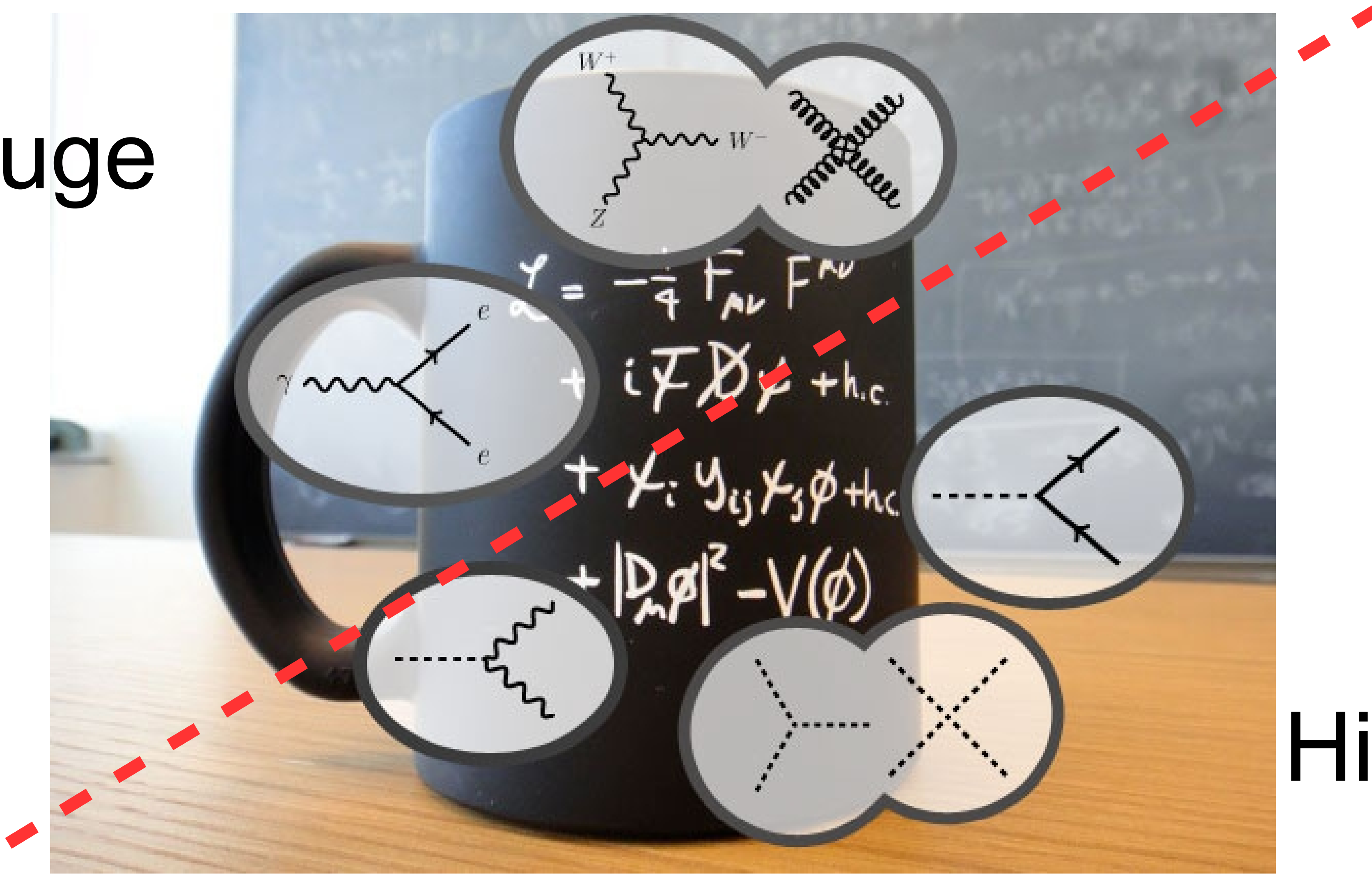
White paper Status

- CEPC Physics/Detector WS, April 2021 @ Yangzhou
  - ~ 45 Physics reports
  - ~ 10 Performance/Optimization study
  - Significant Fresh

- *Higgs: Impact of 360 GeV Runs*
- *EW: Draft ready*
- *QCD: intensive discussions...*
- *Flavor + BSM:*
  - *Many Performance & Benchmark analyses*

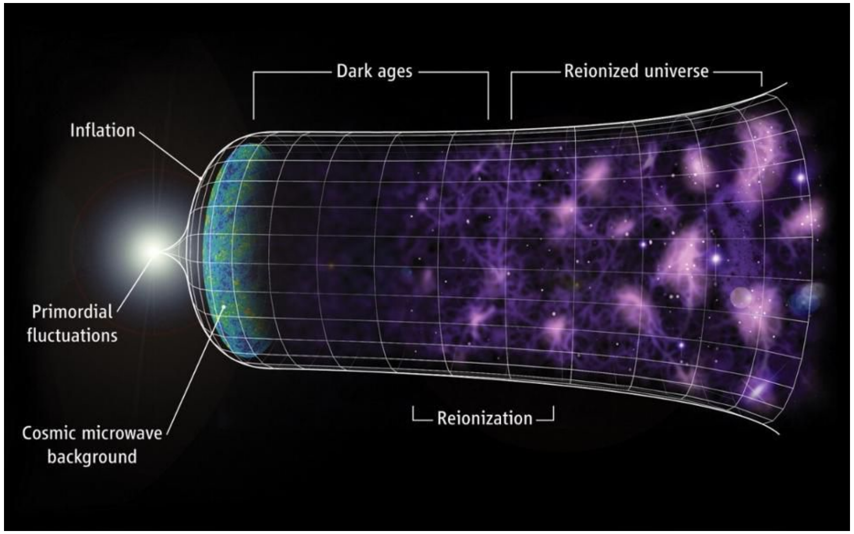
The Higgs field: one of the two pillars of the SM

Gauge



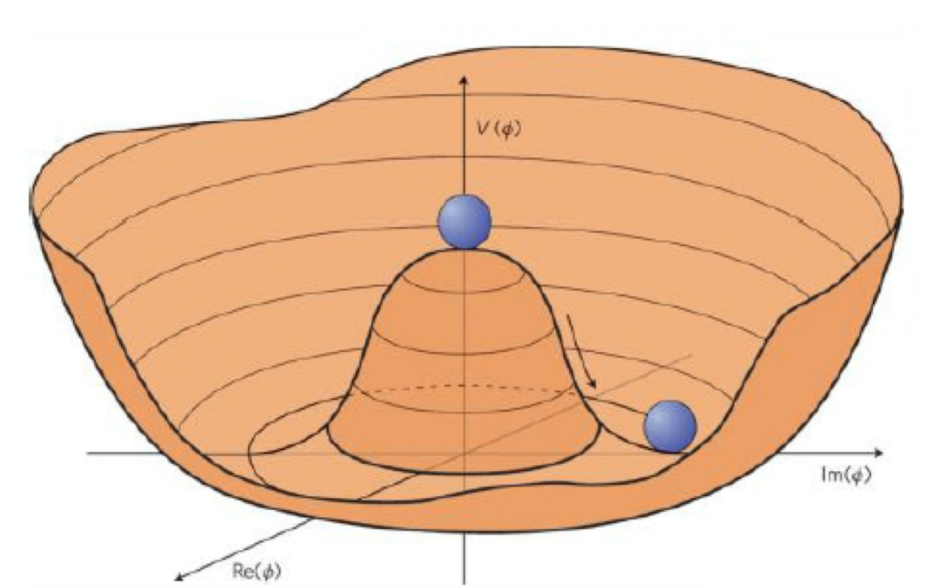
Higgs

Known Unknowns of the SM



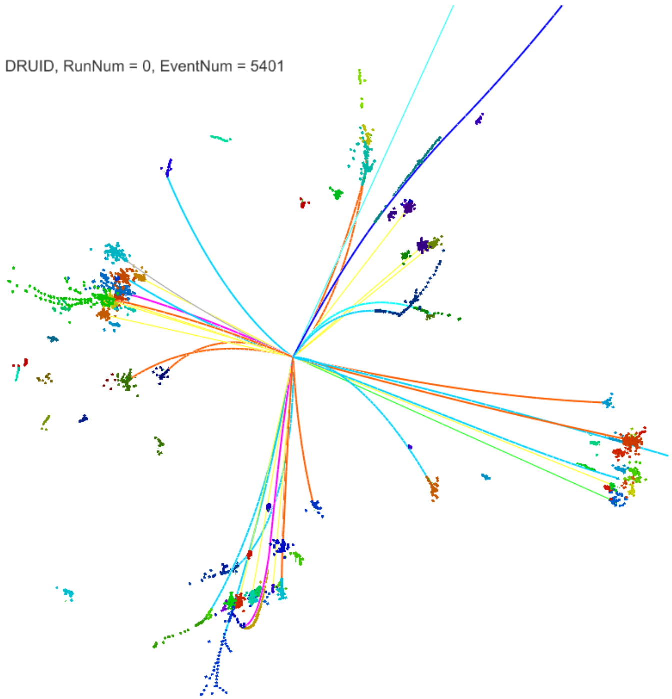
- Inflation
- Mass hierarchy
- Neutrino mass & Oscillation
- Matter anti-matter asymmetry
- Vacuum stabilities: depends on particle mass
- Dark matter, Dark energy: nature & origin of its/their mass
- Naturalness: EW (Higgs mass) V.S. Planck scale
- ...

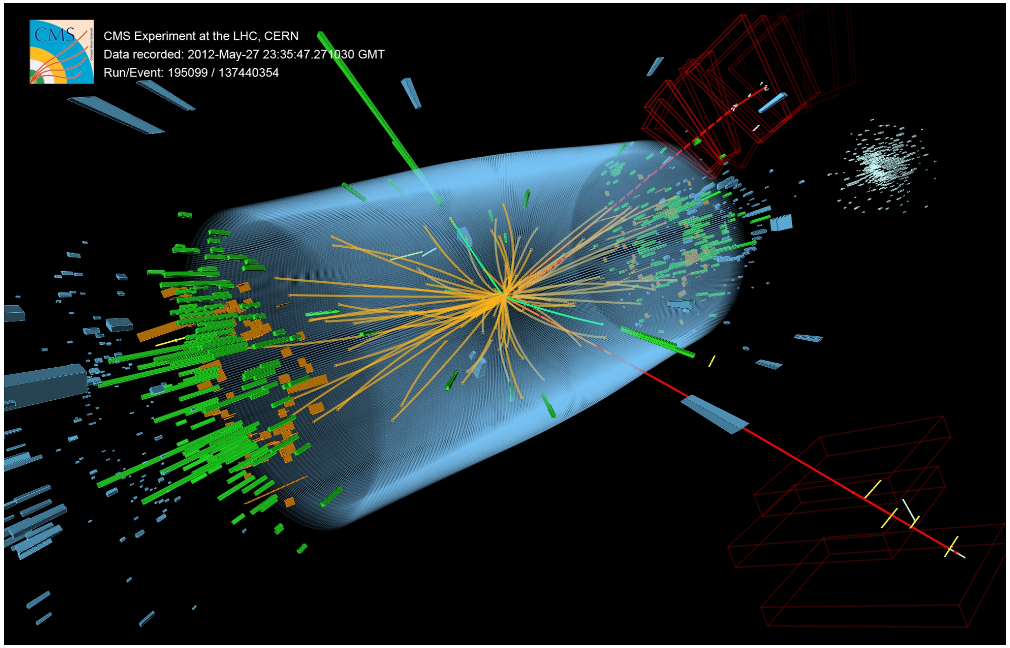
Known Unknowns of the SM



- The Clue:
- Inflation
- Mass hierarchy
- Neutrino mass & Oscillation
- Matter anti-matter asymmetry
- Vacuum stabilities: depends on particle mass
- Dark matter, Dark energy: nature & origin of its/their mass
- Naturalness: EW (Higgs mass) V.S. Planck scale
-

Higgs measurement at e+e- & pp



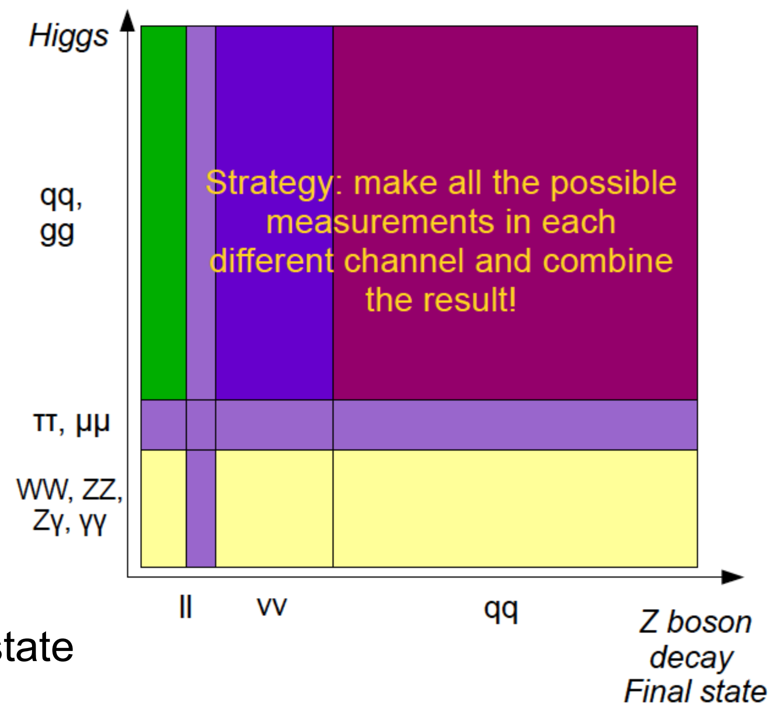


	Yield	efficiency	Comments
LHC	Run 1: 10^6 Run 2/HL: $10^{7\text{-}8}$	~o(10^{-3})	High Productivity & High background, Relative Measurements, Limited access to width, exotic ratio, etc, Direct access to g(ttH), and even g(HHH)
CEPC	10^6	~o(1)	Clean environment & Absolute measurement, Percentage level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

Complementary

Jets at 240 GeV Higgs factory

- SM Higgs
  - ***0 jets: 3%:*** *Z→ll, νν (30%); H→0 jets (~10%, ττ, μμ, γγ, γZ/WW/ZZ→leptonic)*
  - ***2 jets: 32%***
    - *Z→qq, H→0 jets. 70%*10% = 7%*
    - *Z→ll, νν; H→2 jets. 30%*70% = 21%*
    - *Z→ll, νν; H→WW/ZZ→semi-leptonic. 3.6%*
  - ***4 jets: 55%***
    - *Z→qq, H→2 jets. 70%*70% = 49%*
    - *Z→ll, νν; H→WW/ZZ→4 jets. 30%*15% = 4.5%*
  - ***6 jets: 11%***
    - *Z→qq, H→WW/ZZ→4 jets. 70%*15% = 11%*

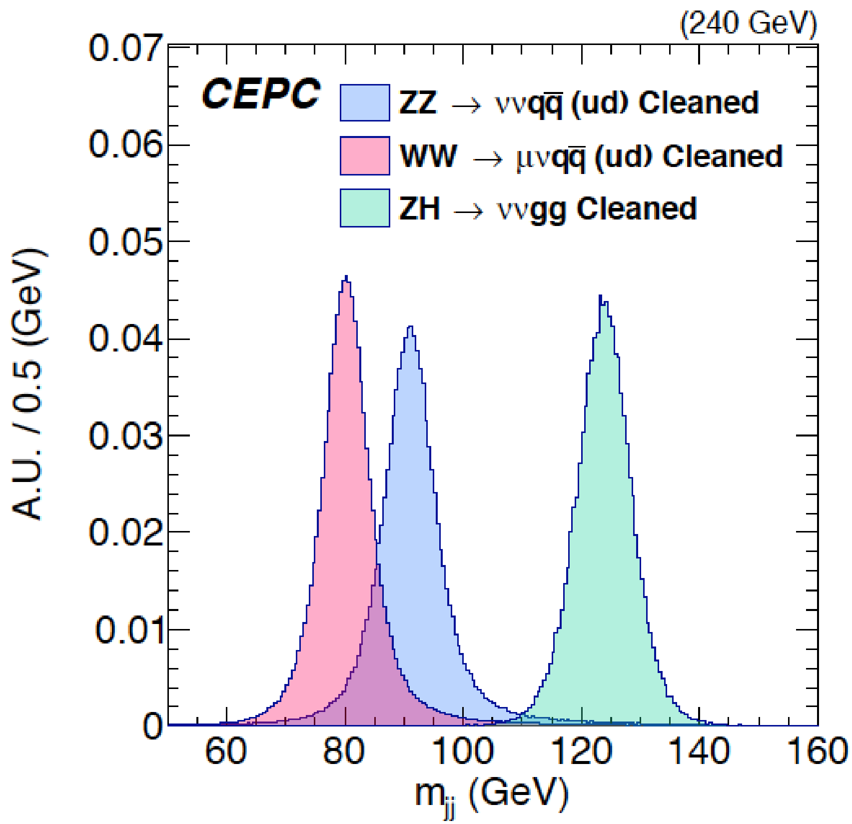


- **97%** of the SM Higgsstrahlung Signal has Jets in the final state
- **1/3** has only 2 jets: include all the SM Higgs decay modes
- **2/3** need color-singlet identification: grouping the hadronic final sate particles into color-singlets
- Jet is important for EW measurements & jet clustering is essential for **differential** measurements

Hadronic system (jet)

- Identify the hadronic system
  - lepton identification & missing energy measurements
- 4-momentum measurement of hadronic system - BMR: Invariant Mass Resolution of Hadronic system, benchmarked with vvH, H→gluons process),
- Jet response (Scale/Resolution of jet energy & angular observables)
  - Essential for differential measurements with jet energy/directions
    - Applied to events with more than one color singlet fragment into jets: WW/ZZ/ZH event separation in 4-jet final state
    - ...
  - Jet Clustering & Matching, or beyond?

CEPC Baseline: BMR = 3.75%



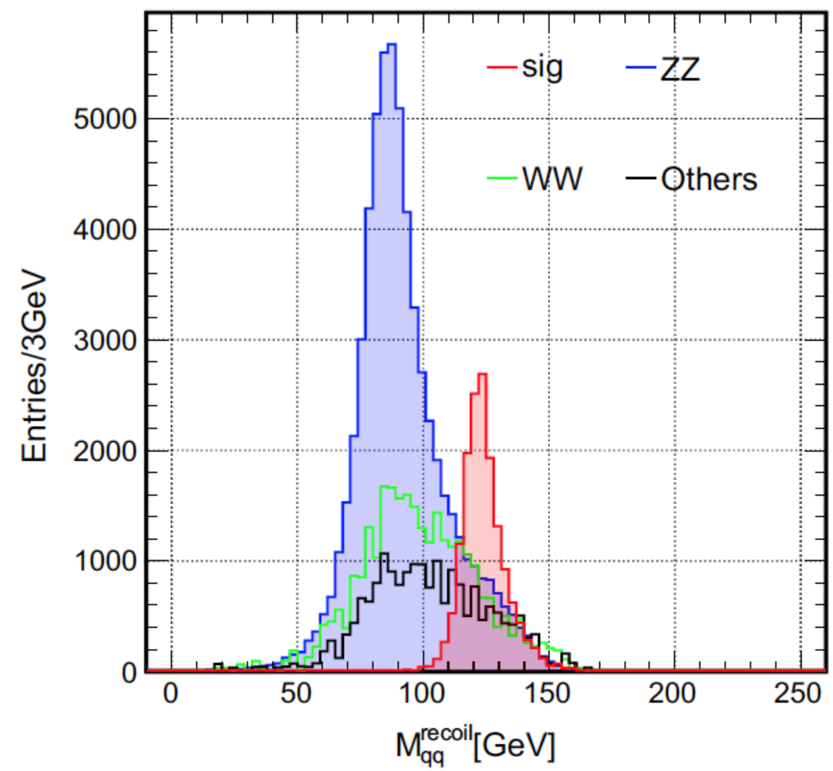
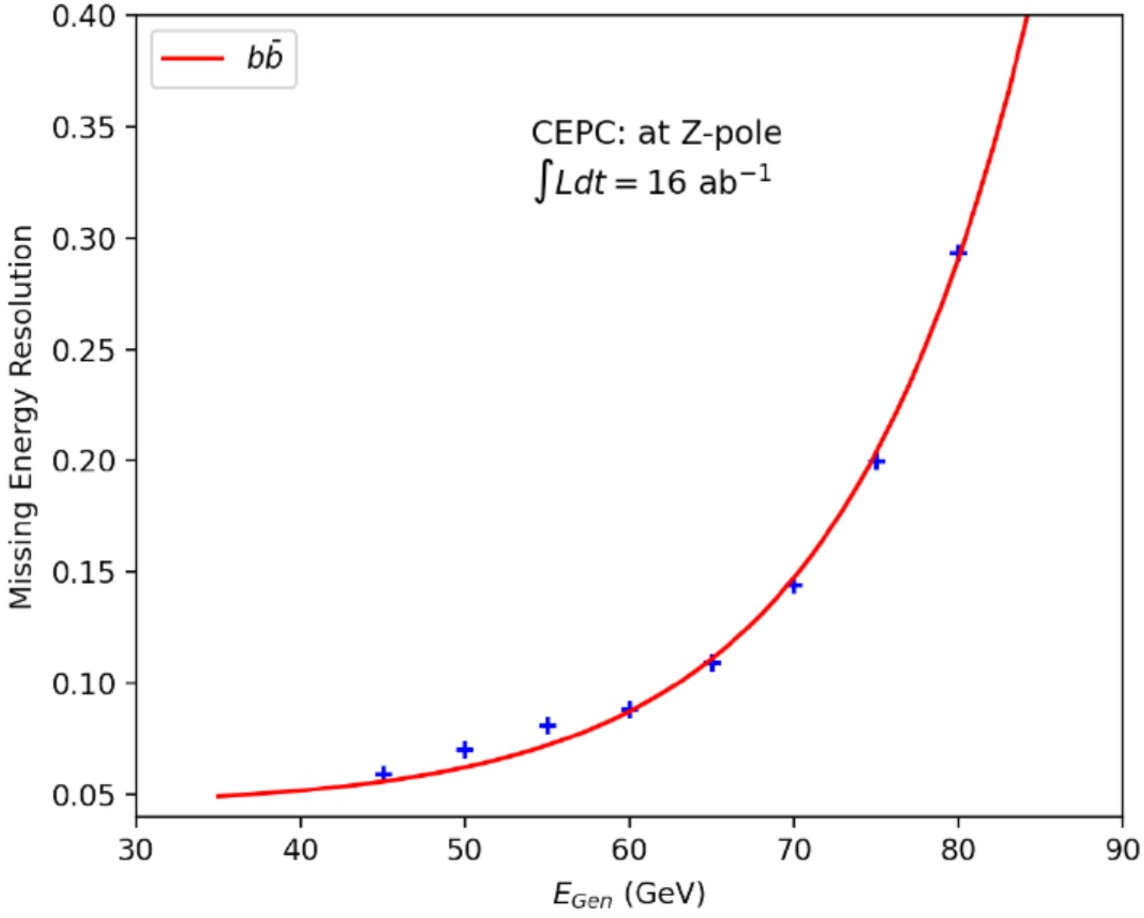


Fig. 7 Distribution of the recoil mass of the qq, M_{qq}^{recoil} for $Z \to qq$, $H \to \tau\tau$ and each background at $\sqrt{s} = 240$ GeV after the previous cuts

Missing energy: from Yudong



- Preliminary
- Extracted from Bs @ Z pole sample
- Will include other channels @ other c.m.s.