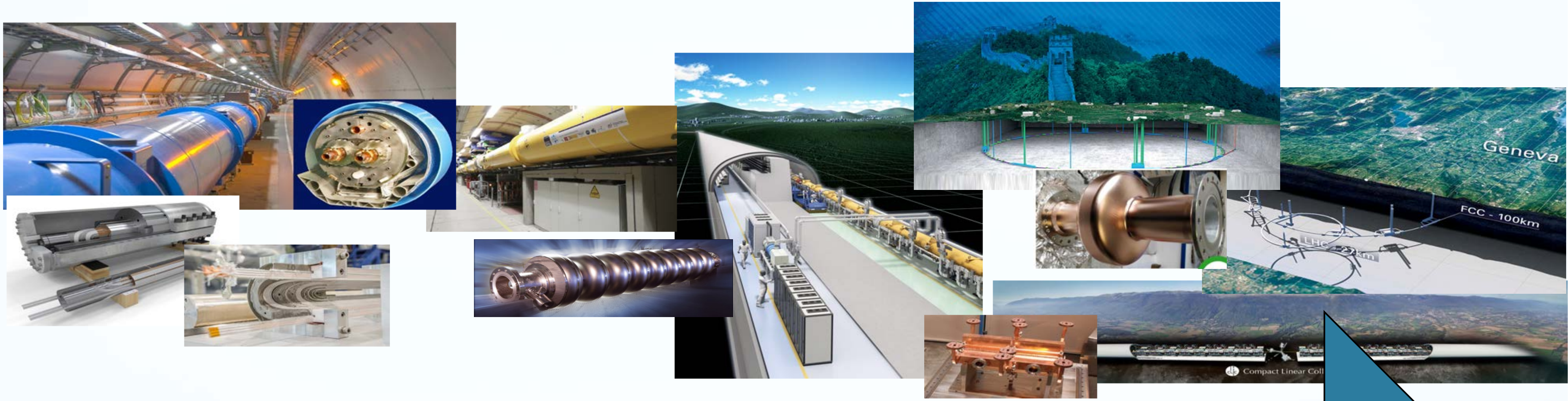
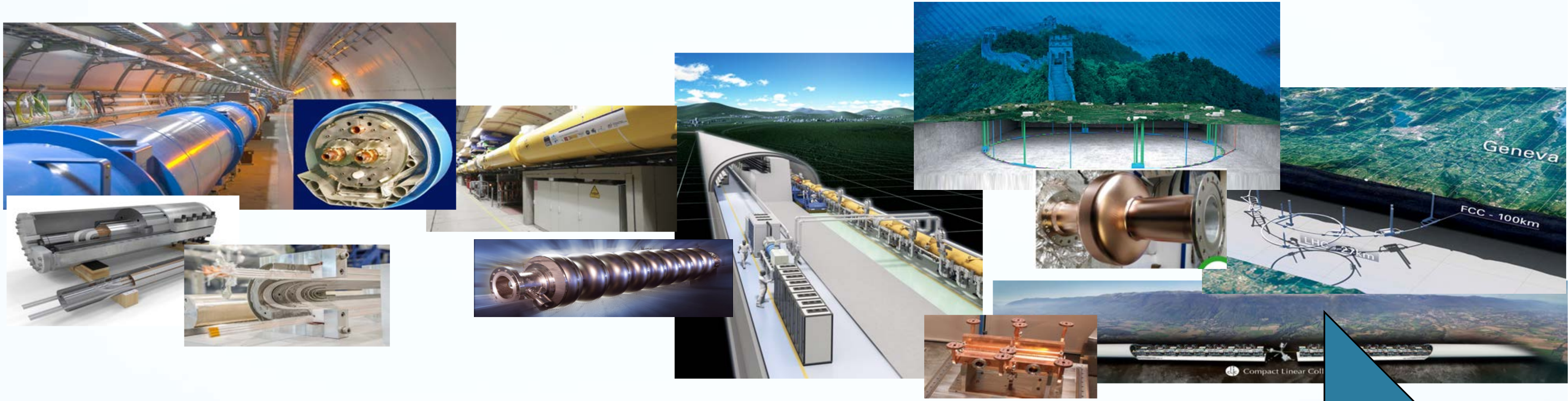


Highlights and Perspectives of Future HEP Accelerators

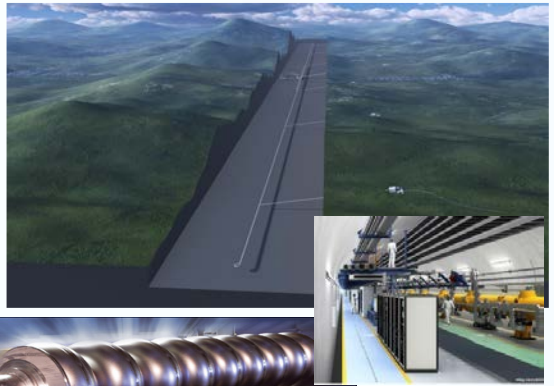
A. Faus-Golfe



Highlights and Perspectives of Future Accelerators

A. Faus-Golfe

Outline

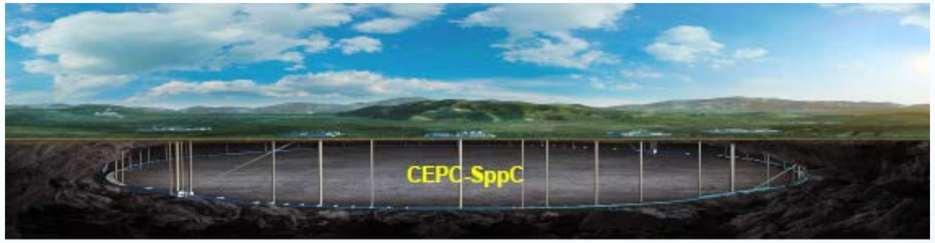


- Overview of e^+e^- HEP colliders

  LC projects: ILC, CLIC

  CC projects: FCC-ee, CepC

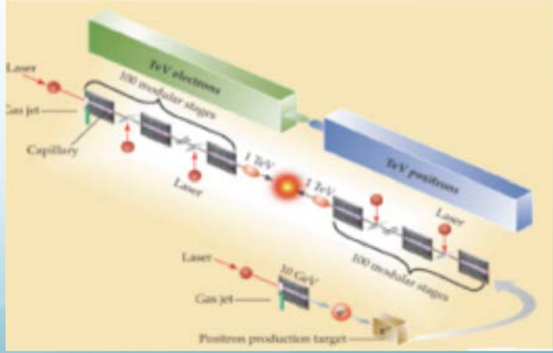
- The CepC project



  Luminosity, Lattices and Beam dynamics

  Injection Schemes

  Technologies: SCRF, Klystrons, Magnets, Instrumentation, SR, Vacuum....



- Issues, Challenges and Perspectives

Luminosity recipe: linear vs circular

$$L = f_c \frac{N_{e-} N_{e+}}{4\pi\sqrt{\beta_x^* \varepsilon_x}\sqrt{\beta_y^* \varepsilon_y}} = \frac{I_{e-} I_{e+}}{4\pi\sqrt{\beta_x^* \varepsilon_x}\sqrt{\beta_y^* \varepsilon_y} \cdot f_c \cdot e^2}$$

$$P_{SR} = V_{SRe-} I_{e-} + V_{SRe+} I_{e+}$$

The way to reduce SR power is to reduce beam currents in both electron and positron beam.
To keep luminosity high, one would need to reduce one, two or all in

$$\sqrt{\beta_x^* \beta_y^*} \cdot \sqrt{\varepsilon_x \varepsilon_y} \cdot f_c$$

Luminosity recipe: linear vs circular

- In **storage rings** additional limitations appear: **beam-beam tune shift** and IP chromaticity (small β_y^*) which favors **high beam currents**, **large emittance** and **high collision frequencies**

$$\xi_{x,y} = \frac{N\, r_0 \beta^*_{x,y}}{2\pi\gamma\, \sigma_{x,y}\,(\,\sigma_x + \sigma_y)} < 0.1 - 0.5$$

- In **linear** the relevant number is the **disruption parameter**

$$D_{x,y} = \frac{N_e}{\gamma_e} \frac{2r_e}{(\sigma_x + \sigma_y)\sigma_{x,y}} \sigma_z$$

- At **high-energies** the most dangerous effect **is beamstrahlung**: SR in strong EM field of opposing beam during collision. It can cause significant amount of energy loss, induce large energy spread and loss of the particles. Using very **flat beams** is the main way of mitigating this effect

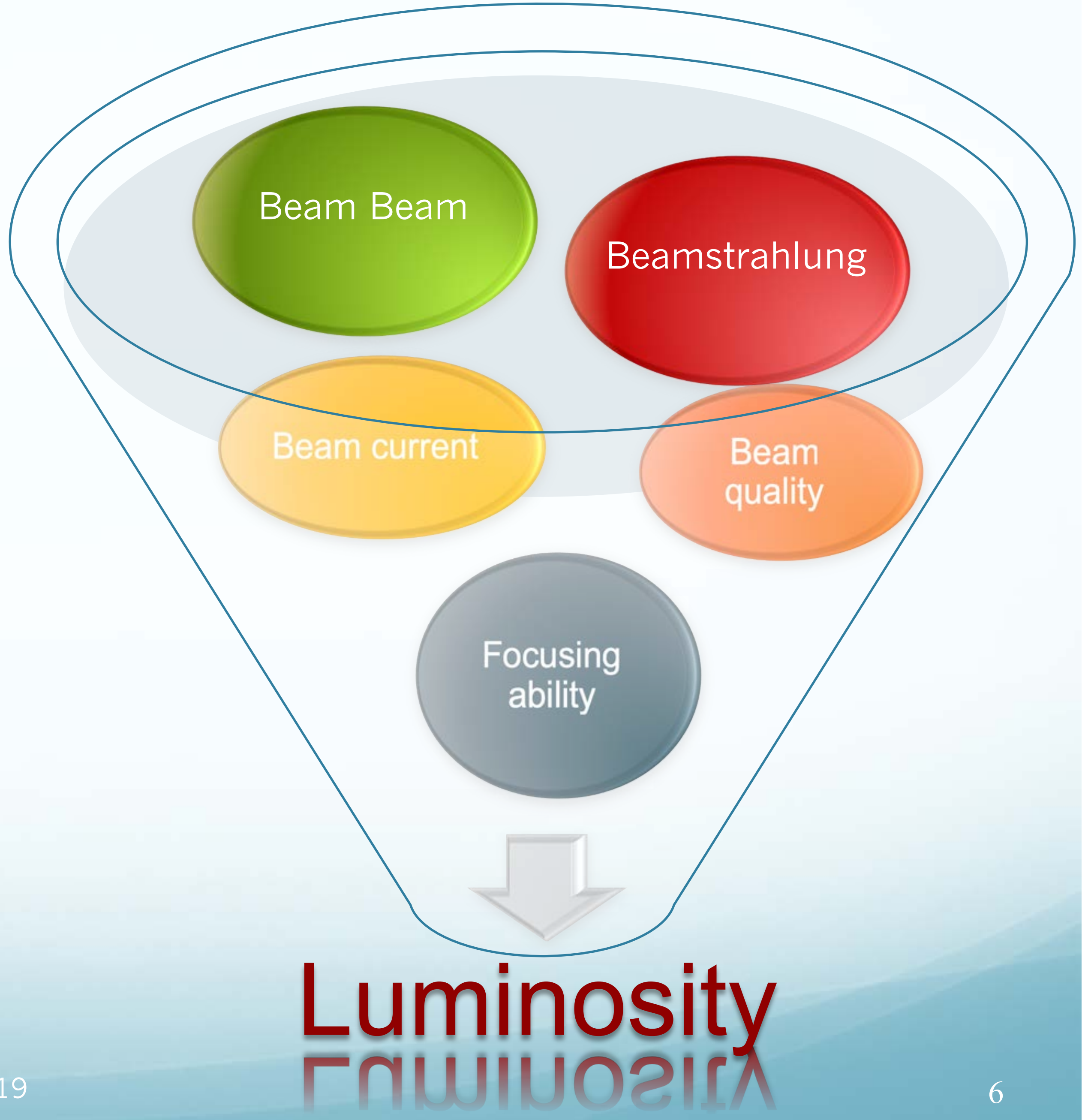
$$\langle \Delta\gamma \rangle = \frac{4}{9}\sqrt{\frac{\pi}{3}} N^2 \frac{r_e^3}{\sigma_x^2 \sigma_z} \gamma^2$$

$$for\ \sigma_x \gg \sigma_y$$

Luminosity recipe

Luminosity cannot be fully demonstrated before project implementation:

- Luminosity is a feature of the facility not the individual technologies
- Relying in experience, theory and simulations
- Foresee margins

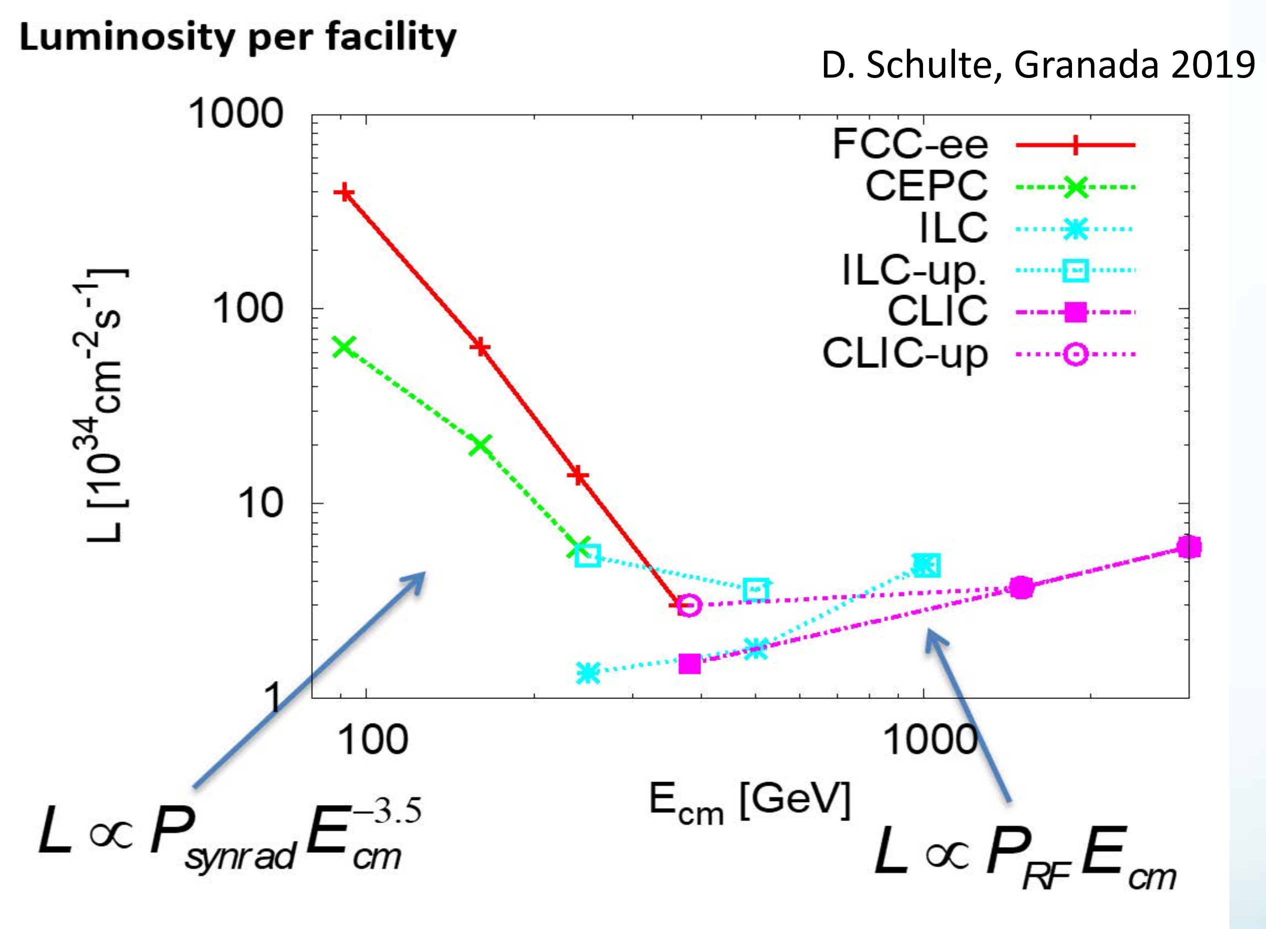


Luminosity recipe: the “dreamt” Luminosity

Energy dependence:

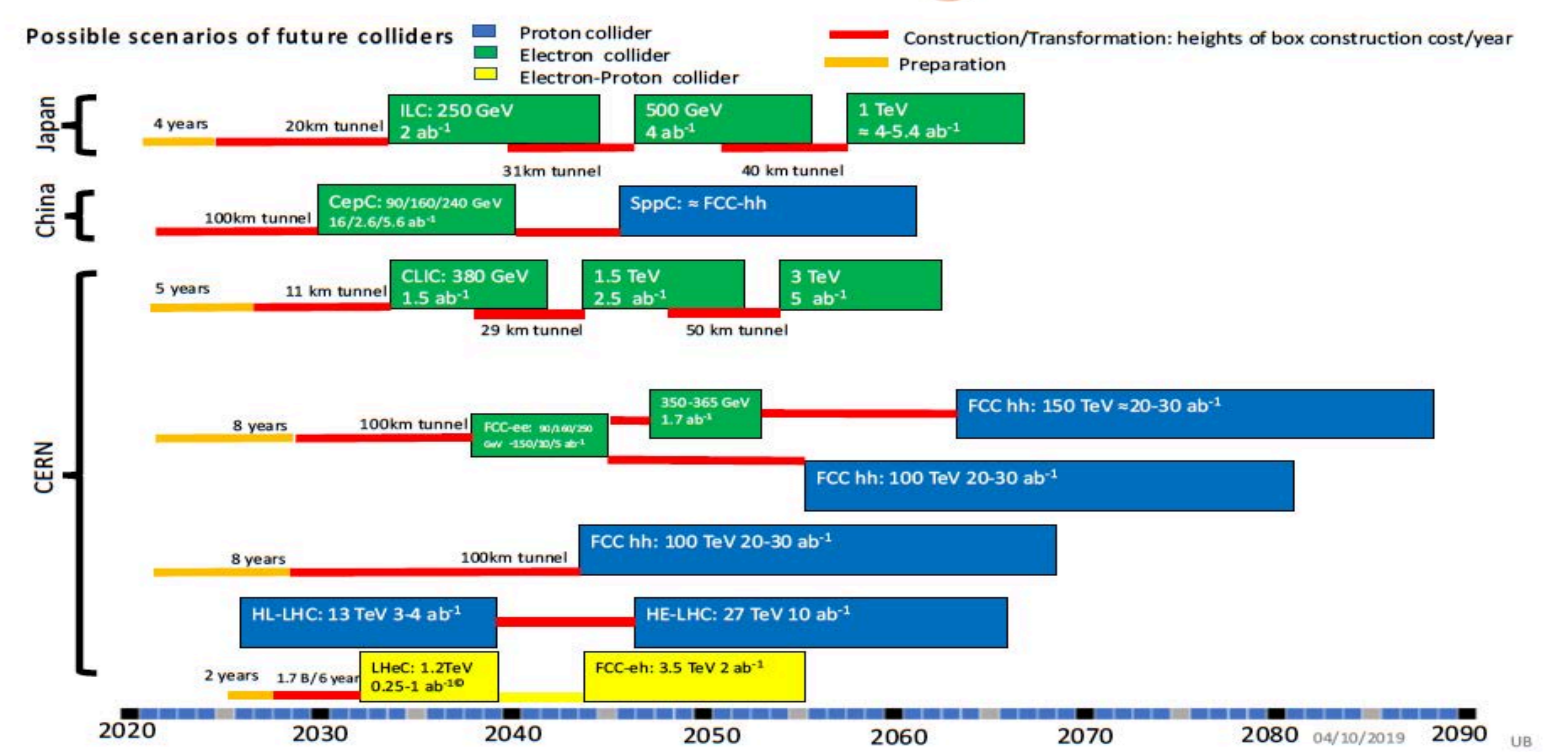
At **low energies circular** colliders surpass
- Reduction at high energy due to SR

At **high energies linear** colliders excel
- Luminosity per beam power roughly constant



Note: The typical higgs factory energies are close to the cross over in luminosity
Linear collider have polarised beams (80% e^-, ILC also 30% e^+) and beamstrahlung

Schedule Implementation



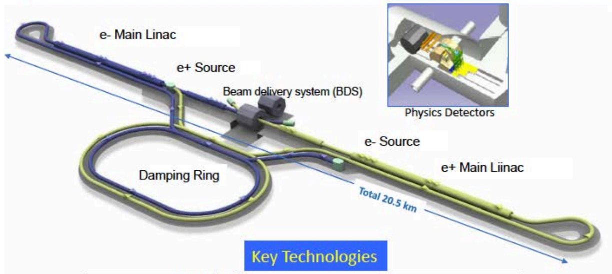
Note: U. Bassler CERN-ESU-005, 29 September 2019

Schedule Implementation

HEP is Global, planning facilities is not independent. High level of cooperation and collaboration are needed.

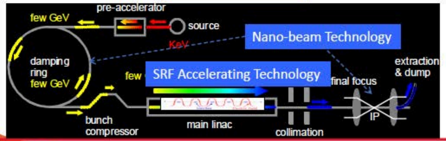
Note: U. Bassler CERN-ESU-005, 29 September 2019

ILC250 accelerator facility



Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35×10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	7.7 nm@250GeV
SRF Cavity G.	31.5 MV/m (35 MV/m)
Q_0	$Q_0 = 1 \times 10^{10}$

Key Technologies

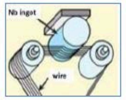


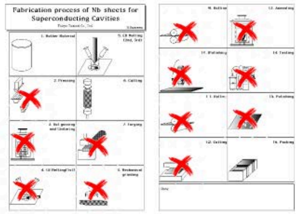
8,000 SRF cavities will be used.

ILC Cost-Reduction R&D in US-Japan Cooperation

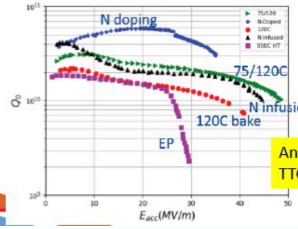
Based on recent advances in technologies;

- Nb material/sheet preparation
  - w/ optimum Nb purity and clean surface

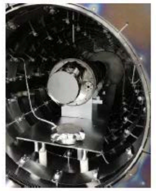




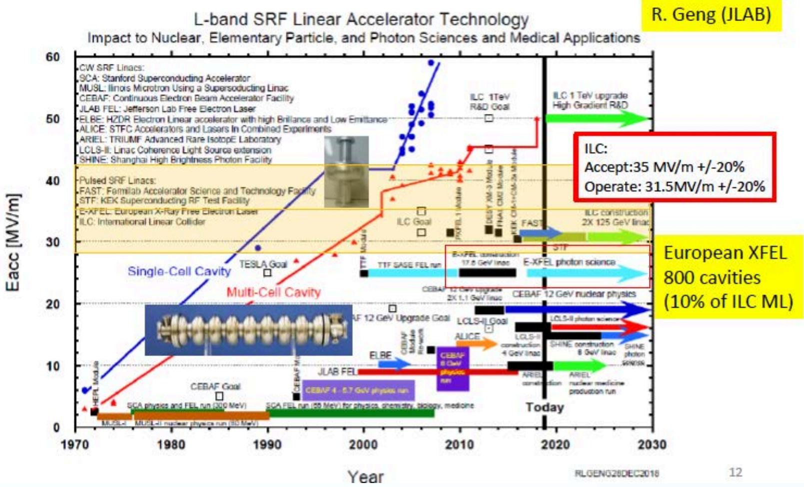
- Surface treatments for high-Q and high-G



Anna Grassellino
TTC2019 Vancouver



Matured SRF technologies



Nano-beam R&D at ATF2

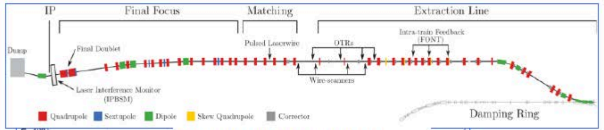
東京大学 THE UNIVERSITY OF TOKYO · SLAC · IFIC · ROYAL HOLLOWAY UNIVERSITY OF LONDON · UNIVERSITY OF OXFORD · lapp · LAL · CERN · Fermilab · Institute of High Energy Physics Chinese Academy of Sciences

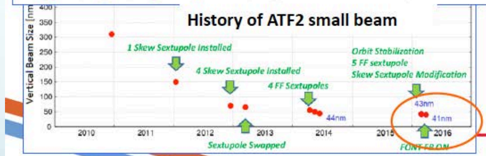
Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

ATF2 Goal : 37 nm → ILC 7.7 nm (ILC250); achieved 41 nm (2016)

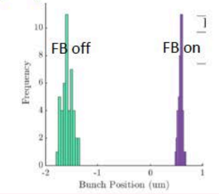
Goal 2: Develop the position stabilization for the ILC collision

- FB latency 133 nsec achieved (target: < 366 nsec)
- positon jitter at IP: 106 → 41 nm (2018) (limited by the BPM resolution)

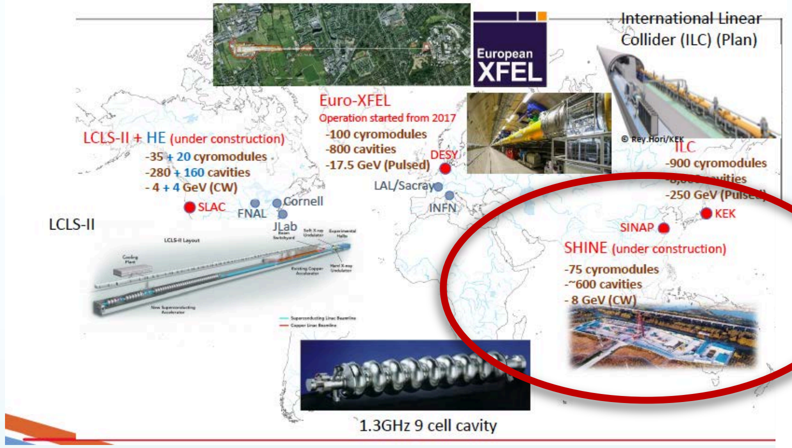




Nano-meter stabilization at IP (2018)



Worldwide large scale SRF accelerators



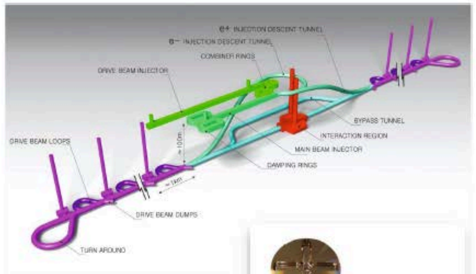
International Development Team (IDT)

Pre-preparatory Phase	Main Preparatory Phase	Construction Phase
2020.8 (2022)	About 4 years (2026)	About 9 years (2035)
LCB/LCC · International Development Team	ILC Pre-Lab	ILC Laboratory

IDT: to prepare for smooth transition to the ILC Pre-lab

- Prepare a proposal for the organization and governance of the ILC Pre-Lab
- Prepare the work and deliverables of the ILC Pre-laboratory and workout a scenario for contributions with national and regional partners

Proposed e⁺e⁻ linear colliders – CLIC



Accelerating structure prototype for CLIC: 12 GHz (L~25 cm)

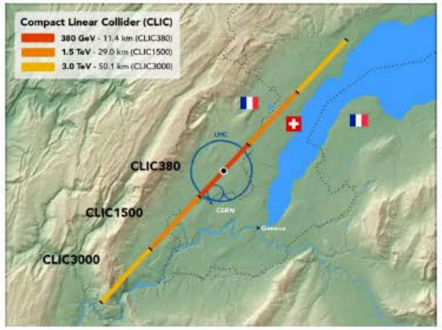
The Compact Linear Collider (CLIC)

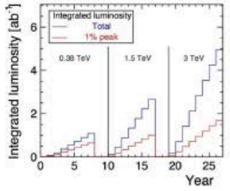
- **Timeline:** Electron-positron linear collider at CERN for the era beyond HL-LHC (~2035 Technical Schedule)
- **Compact:** Novel and unique two-beam accelerating technique with high-gradient room temperature RF cavities (~20' 500 cavities at 380 GeV), ~11km in its initial phase
- **Expandable:** Staged programme with collision energies from 380 GeV (Higgs/top) up to 3 TeV (Energy Frontier)

- CDR in 2012. Updated project overview documents in 2018 (Project Implementation Plan). See resource slide.

- **Cost:** 5.9 BCHF for 380 GeV (stable wrt 2012)
- **Power:** 168 MW at 380 GeV (reduced wrt 2012), some further reductions possible

CLIC timeline

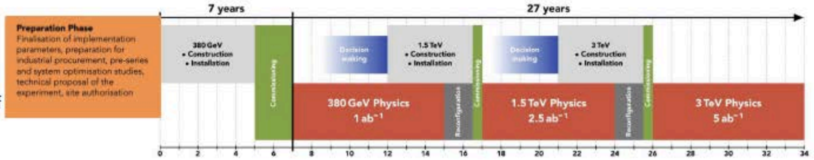




Ramp-up and up-time assumptions: arXiv:1810.13022, Bordry et al.

Technology Driven Schedule from start of construction on the right.

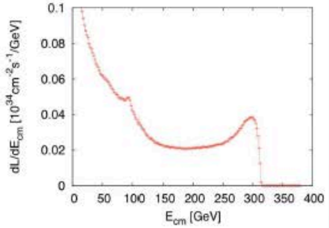
A preparation phase of ~5 years is needed before (estimated resource need for this phase is ~4% of overall project costs)

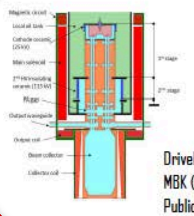


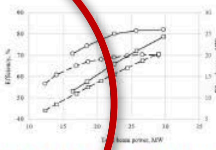
CLIC acc. studies 2019/20 – some examples

Further work on luminosity performance, possible improvements and margins, operation at the Z-pole and gamma-gamma

- Z pole performance, 2.3×10^{32} – 0.4×10^{34} cm^{-2} s^{-1}
  - The latter number when accelerator configured for Z running (e.g. early or end of first stage)
- Gamma – Gamma spectrum (example)
- Luminosity margins and increases
  - Baseline includes estimates static and dynamic degradations from damping ring to IP: 1.5×10^{34} cm^{-2} s^{-1}, a "perfect" machine will give : 4.3×10^{34} cm^{-2} s^{-1}, so significant upside
  - In addition: doubling the frequency (50 Hz to 100 Hz) would double the luminosity, at a cost of +50 MW and ~5% cost increase
- CLIC note about these studies

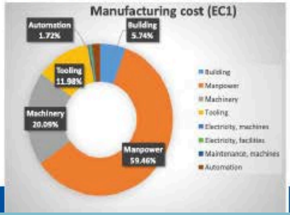






Drivebeam klystron: The klystron efficiency (circles) and the peak RF power (squares) simulated for the CLIC TS MBK (solid lines) and measured for the Canon MBK E37503 (dashed lines) vs total beam power. See more later.
Publication: https://ieeexplore.ieee.org/document/9115885

Industrial questionnaire:
Based on the companies feedback, the preparation phase to the mass production could take about five years. Capacity clearly available. Talk of of Anastasiya



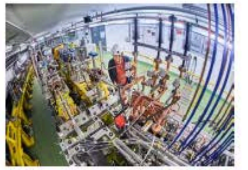
CLIC studies 2021-25

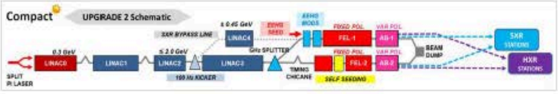
X-band technology:

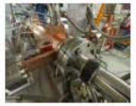
- Design and manufacturing of X-band structures and components
- Study structures breakdown limits and optimization, operation and conditioning
- Baseline verification and explore new ideas
- Assembly and industry qualification
- Structures for applications, FELs, medical, etc

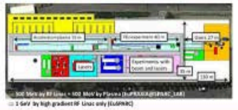
Technical and experimental studies, design and parameters:

- Module studies (see some targets for development below)
- Beamdynamics and parameters: Nanobeams (focus on beam-delivery), pushing multi TeV region (parameters and beam structure vs energy efficiency)
- Tests in CLEAR (wakefields, instrumentation) and other facilities (e.g. ATF2)
- High efficiency klystrons
- Injector studies suitable for X-band linacs (coll. with Frascati)









Application of X-band technology (examples):

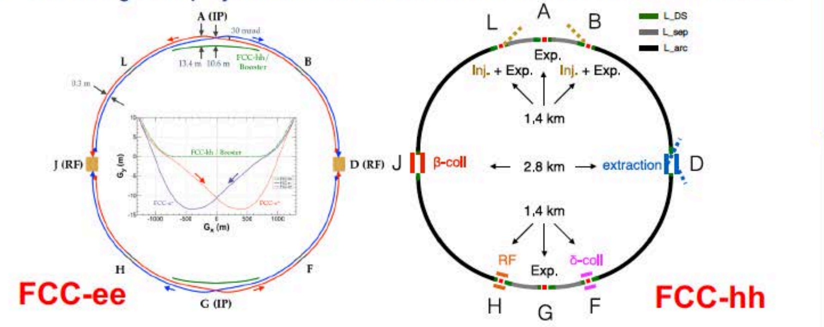
- A compact FEL (CompactLight: EU Design Study 2018-21)
- Compact Medical linacs (proton and electrons)
- Inverse Compton Scattering Source (SmartLight)
- Linearizers and deflectors in FELs (PSI, DESY, more)
- 1 GeV X-band linac at LNF
- eSPS for light dark matter searches (within the PBC-project)

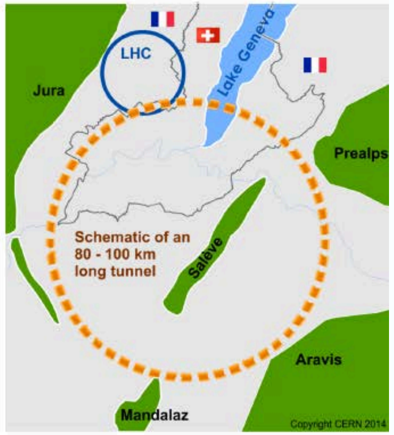
More information: CLIC mini week (1.10.2020)

Succeeding the HL-LHC?: The FCC integrated program inspired by successful LEP – LHC programs at CERN

Comprehensive cost-effective program maximizing physics opportunities

- **Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities**
- **Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after HL-LHC





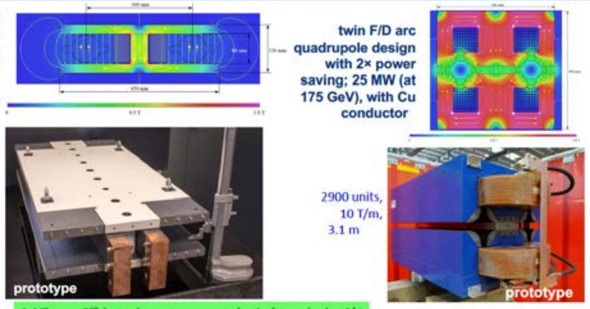
FCC-ee low-cost, energy-efficient arc magnets

twin-dipole magnet design with 2× power saving 16 MW (at 175 GeV), with Al busbars

twin F/D arc quadrupole design with 2× power saving; 25 MW (at 175 GeV), with Cu conductor

2900 units, 0.057 T, ~22 m

2900 units, 10 T/m, 3.1 m

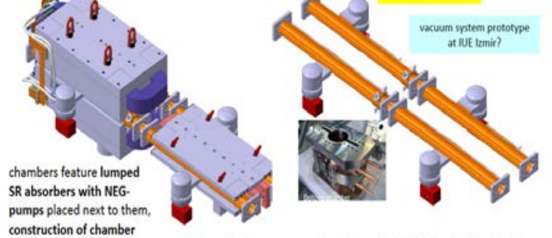


A. Milanese, *Efficient twin aperture magnets for the future circular e+/e- collider*, **Phys. Rev. Accel. Beams 19**, 112401 (2016)

FCC-ee arc vacuum chambers and integration

R. Kersevan, C. Garion

vacuum system prototype at IUE Izmir?



chambers feature lumped SR absorbers with NEG-pumps placed next to them, construction of chamber prototypes and integration with twin magnets

vacuum chamber cross section: 70 mm ID with "winglets" in the plane of the orbit (SuperKEKB-like)

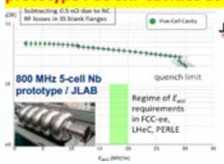
FCC-ee R&D: RF, cryo-modules, power sources

R&D aimed at improving performance & efficiency and reducing cost:

- improved Nb/Cu coating/sputtering (e.g. ECR fibre growth, HiPIMS)
- new cavity fabrication techniques (e.g. EHF, improved polishing, seamless…)
- coating of A15 superconductors (e.g. Nb_3Sn), · cryo-module design optimisation
- bulk Nb cavity R&D at FNAL, JLAB, Cornell, also KEK and CEPC/IHEP
- MW-class fundamental power couplers for 400 MHz; · novel high-efficiency klystrons

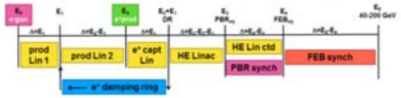
prototype FCC SRF cavities at JLAB

high-efficiency klystron at CERN



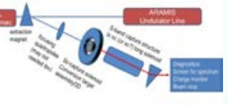
New klystron bunching methods: LHC klystron **retrofit** as proof of principle for FCC

FCC-ee pre-injector work program



Task 0 Coordination and parameter optimization - PSI/CERN
Task 1 e+/e- 6 GeV Injector Linacs – CERN/PSI
Task 2 e+ and e- Linac extension study (Linac 4) - PSI/CERN
Task 3 Positron source: target and capture system – IJCLab/CERN/PSI/BINP
Task 4 Damping ring and transfer lines – LNF/CERN
Task 5 CDR+ PSI/CERN,IJClab/LNF,BINP
Task 6 PoP e+ source in SwissFEL – PSI/CERN/IJClab/BINP

SwissFEL 6 GeV C-band Linac



FCC-ee demonstrator e+ source at SwissFEL for e-/e+ conversion & capture efficiency

FCC-ee basic design choices

double ring e+e- collider ~100 km

follows footprint of FCC-hh, except around IPs

asymmetric IR layout & optics to limit synchrotron radiation towards the detector

presently 2 IPs (alternative layouts with 3 or 4 IPs under study), **large** horizontal crossing angle **30 mrad, crab-waist optics**

synchrotron radiation power 50 MW/beam at all beam energies; tapering of arc magnet strengths to match local energy

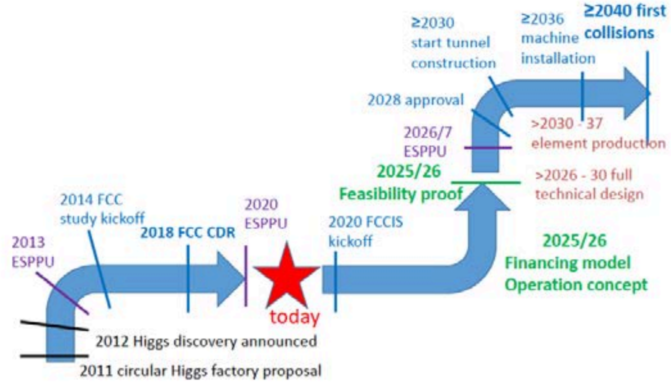
common RF for $t\bar{t}$ running

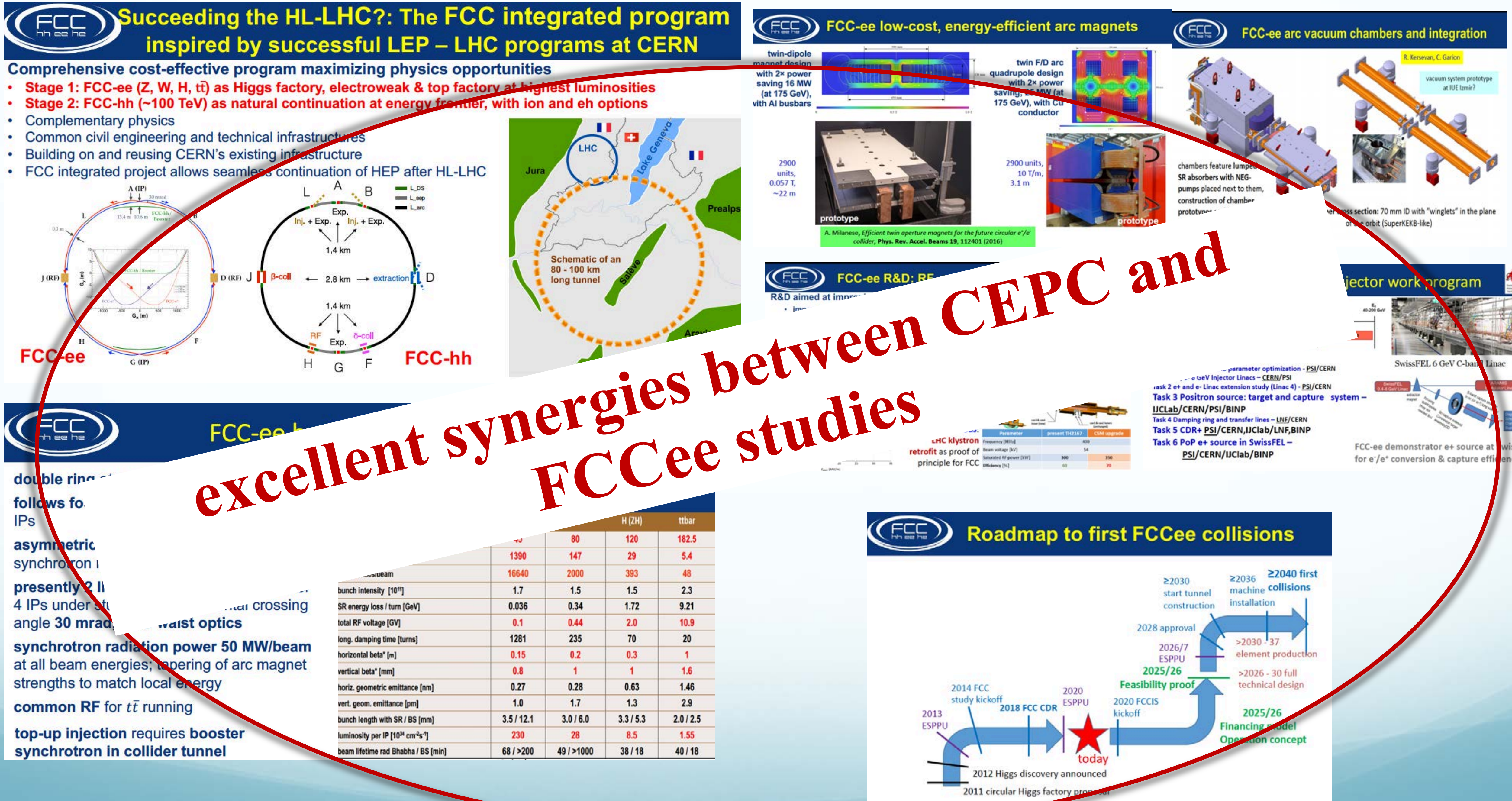
top-up injection requires booster synchrotron in collider tunnel

FCC-ee Collider Parameters

parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45	80	120	182.5
beam current [mA]	1390	147	29	5.4
no. bunches/beam	16640	2000	393	48
bunch intensity [10^{11}]	1.7	1.5	1.5	2.3
SR energy loss / turn [GeV]	0.036	0.34	1.72	9.21
total RF voltage [GV]	0.1	0.44	2.0	10.9
long. damping time [turns]	1281	235	70	20
horizontal beta* [m]	0.15	0.2	0.3	1
vertical beta* [mm]	0.8	1	1	1.6
horiz. geometric emittance [nm]	0.27	0.28	0.63	1.46
vert. geom. emittance [pm]	1.0	1.7	1.3	2.9
bunch length with SR / BS [mm]	3.5 / 12.1	3.0 / 6.0	3.3 / 5.3	2.0 / 2.5
luminosity per IP [10^{34} cm^{-2}s^{-1}]	230	28	8.5	1.55
beam lifetime rad Bhabha / BS [min]	68 / >200	49 / >1000	38 / 18	40 / 18

Roadmap to first FCCee collisions





		H (ZH)	ttbar
	80	120	182.5
1390	147	29	5.4
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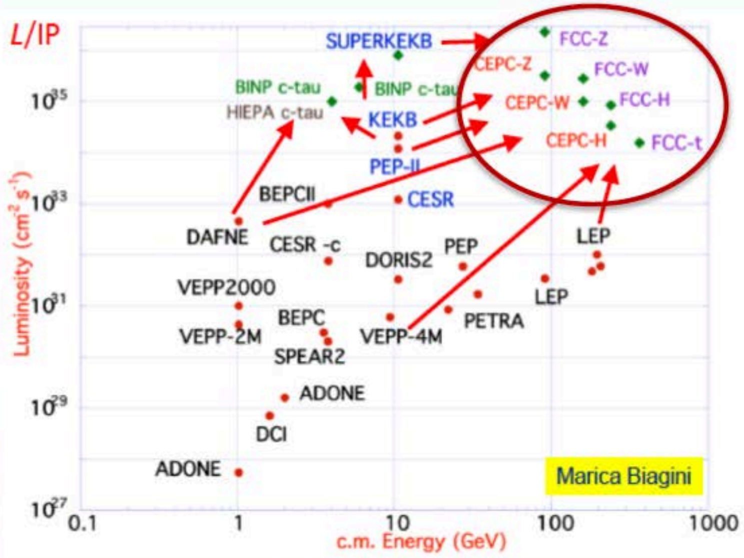
horiz. geometric emittance [nm]	0.27	0.28	0.63	1.46
vert. geom. emittance [pm]	1.0	1.7	1.3	2.9
bunch length with SR / BS [mm]	3.5 / 12.1	3.0 / 6.0	3.3 / 5.3	2.0 / 2.5
luminosity per IP [10^{34} cm^{-2}s^{-1}]	230	28	8.5	1.55
beam lifetime rad Bhabha / BS [min]	68 / >200	49 / >1000	38 / 18	40 / 18

excellent synergies between CEPC and FCCee studies

CC based on proven techniques from past colliders and light sources



B-factories: KEKB & PEP-II:
- double-ring lepton colliders,
- high beam currents,
- top-up injection

DAFNE: crab waist, double ring

Super B-factories, S-KEKB: low β_y^*

LEP: high energy, SR effects

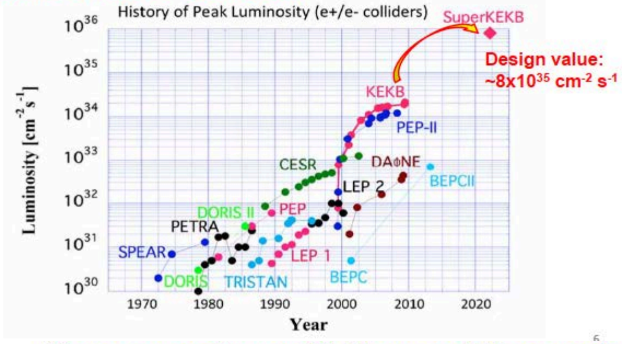
VEPP-4M, LEP: precision E calibration

KEKB: e^+ source

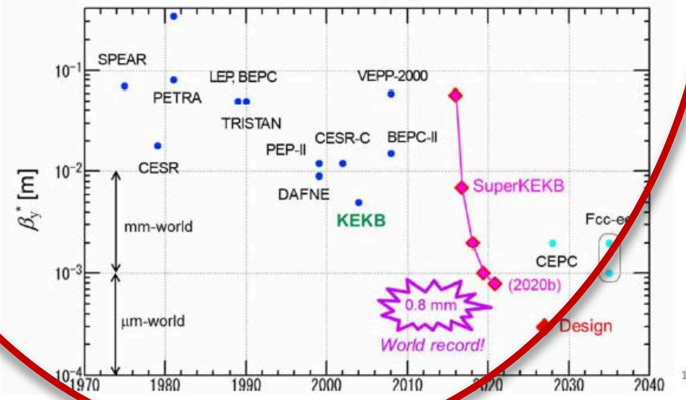
HERA, LEP, RHIC: spin gymnastics

combining successful ingredients of several recent colliders → highest luminosities & energies

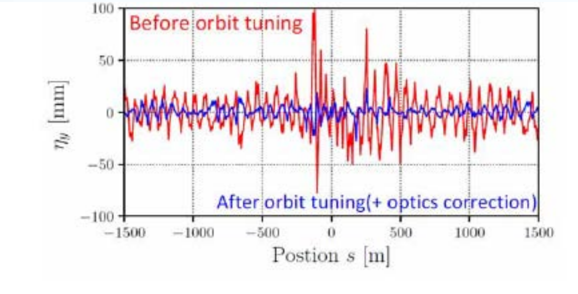
Aim the world-highest luminosity (a measure of collision frequency) by using a novel "nano-beam scheme" collision.



Now operating with the world's smallest β_y^* of 0.8 mm, lower than the bunch length of ~6 mm.

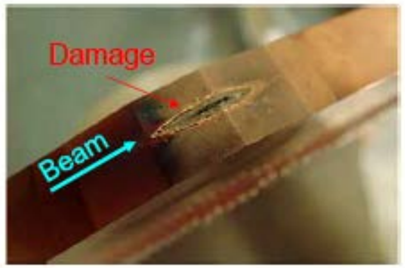


Difficulties in optical correction of the rings

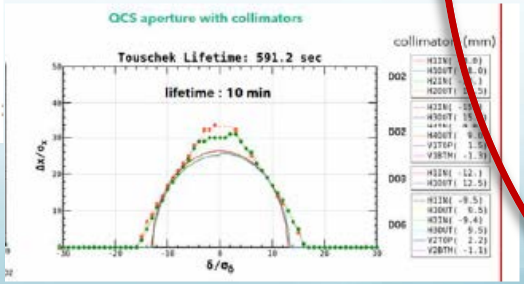


Background noise to the detector

Damage of head (D02_V1) generated 2019b run

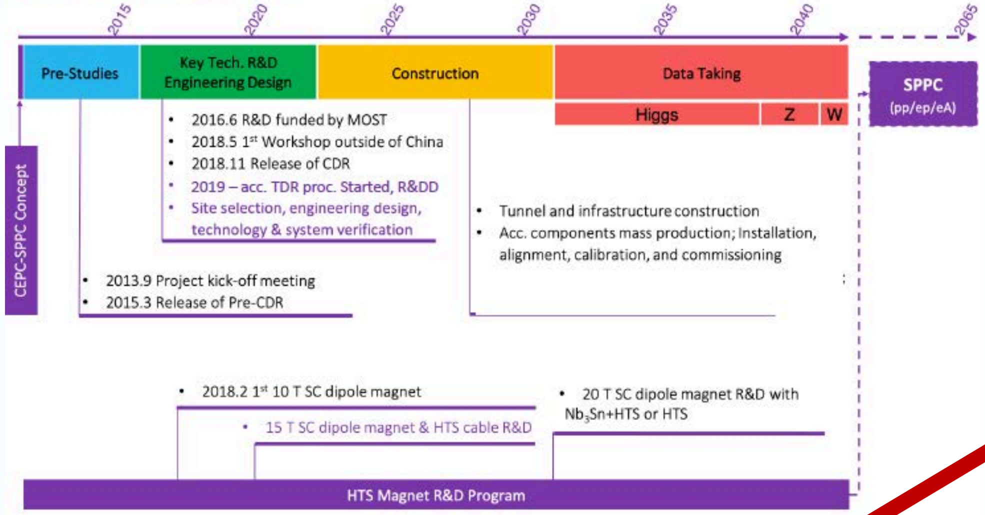


Very short beam lifetime



Maintaining (very) aged hardware including buildings

CEPC Roadmap and Schedule (ideal)



Goals and Plan

- Design enhancement + R&D
- Validation, & industrial preparation
- Best prepare CEPC for national government's approval
- Realization of the CEPC project, the experimental program and pursue the science
- International collaboration and coordination

CEPC Site Selection Status

1) Qinhuangdao, Hebei Province（Completed in 2014）
2) Huangling, Shanxi Province（Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Huzhou, Zhejiang Province (Started in March 2018)
5) Chuangchun, Jilin Province (Started in May 2018)
6) Changsha, Hunan Province (Started in Dec. 2018)

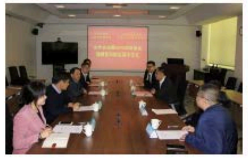
Strong support from local governments

CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

Established in Nov. 7 , 2017

Task forces for CEPC and SppC R&D: Institutions such as IHEP +CIPC (>70 companies)

Now:
-Huanghe Company,Huadong Engineering Cooperation Company,and Zhongnan Company on CEPC civil engineering design, site selection, implementation...
-Shenyang Huiyu Company on CEPC MDIRVC design
-Keye Compant on CEPC magntes desgins and SC Quadupole, DR cavity, detector hall...
-.Wuhan University:Alignmnent,
-Kuanshan Guoli on CEPC 650MHz high efficiency klystron
-Huadong Engineering Cooperation Company,on CEPC alignement and installation logistics...
-Beijing Pudaditai company: on Alignment and installation



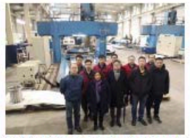
2020.1.2

Fujian Digital Valey on information signed CEPC Propmotion Fund Contribution with IHEP

2020.6.5

Hefei Keye and Beijing Puda Ditai Company signed CEPC Propmotion Fund Contribution with IHEP

2019.12.25-26,Nanchong, Sichuan Jiutian Vacuum company



2019.1218-19 visit Keye Company

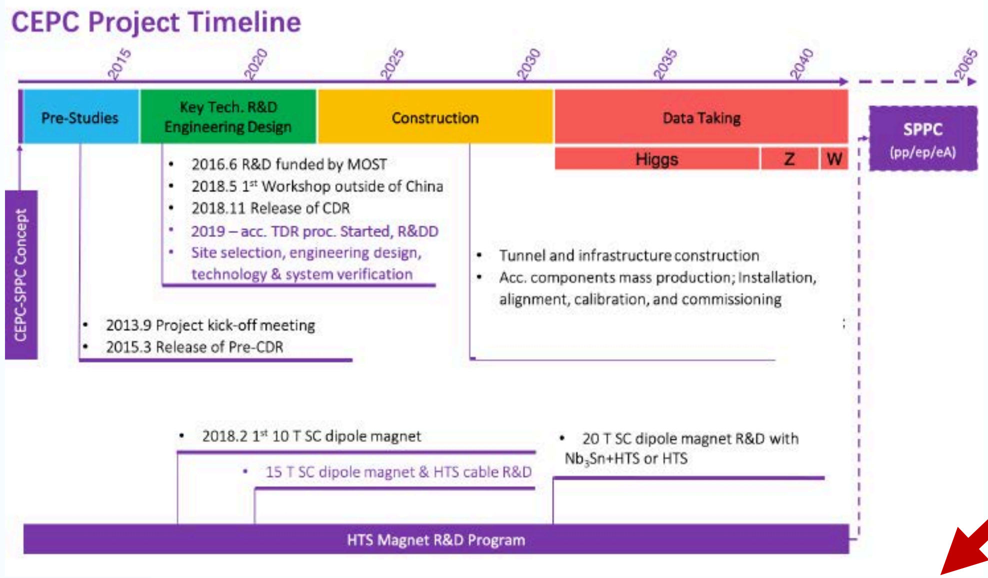
Progress and updates – Intl Collaboration

- Strengthen cooperation with CERN （paying close attention to EPPSU)
- Active in CALICE collab., ILD TPC collab., RD collab.

- First international workshop on CEPC in Europe – Rome May, 2018
- Second CEPC workshop (EU) in Oxford, UK, April 15-17, 2019
- Third planned for Marseille, France, May 4-6, 2020
  postponed to 2021 due to the COVID-19 pandemic
- First US workshop at UChicago, September 16-18, 2019
- Second US workshop April, 2020 (online)
  Catholic University in Washington DC, USA

- HongKong IAS HEP Program, 2019, 2020, …
- 2019 CEPC International workshop at IHEP (~360)
- Fifth CEPC IAC meeting (Nov. 21-22, 2019), 6th Oct. 29-30,2020

CEPC Roadmap and Schedule (ideal)



Goals and Plan

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CEPC Accelerator TDR R&D Priority, Plan and Test Facilities

Red Color means R&D issues have test facilities

1) CEPC 650MHz 800kW high efficiency klystron (80%) (at the end of 2021 complete the fabriation, finish test in 2022)

2) High precision booster dipole magnet (critical for booster operation) (Complete real size magnet model in 2021)

3) CEPC 650MHz SC accelerator system, including SC cavities and cryomules (Complete test cryomodule in 2022)

4) Collider dual aperture dipole magnets, dual aperture qudrupoles and sextupole magntes(Complete real size model in 2022)

5) Vacuum chamber system (Complete fabrication and costing test in 2022)

6) SC magnets including cryostate (Complete short test model in 2022)

20

7) MDI mechanic system (Remote vacuum connection be test in 2022)

8) Collimator (Complete model test in 2022)

9) Linac components (Complete key components test in 2022)

10) Civil engineering design (Reference implementation design complete in 2022)

11) Plasma injector (Complete electron accelerator test in 2022)

12) 18KW@4.5K cryoplant (Company)

...

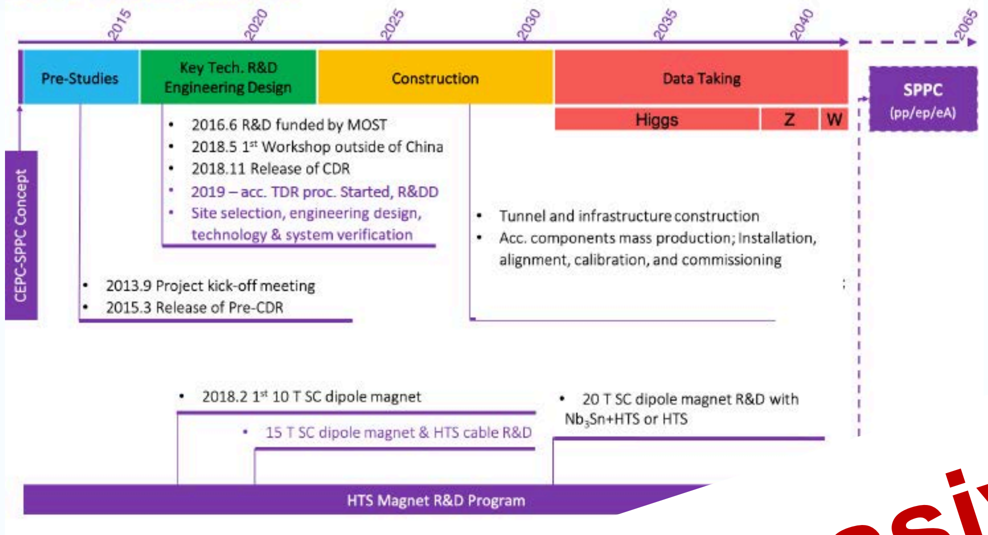
SppC technology R&D

Ion based supercondcuting materials and high field magnets

21

CEPC Roadmap and Schedule (ideal)

CEPC Project Timeline



Goals and Plan

- Design enhancement + R&D
- Validation, & industrial ... paration
- Best prepa... ...nal government's approval
- ... ...t, the experimental program
- ... coordination

Impressive on going Accelerator R&D program

CEPC Accelera...

1) CEPC 650MH... complete the fa...

2) High precision ... (Complete real size ...

3) CEPC 650MHz SC ... (Complete test cryom... ...dules

4) Collider dual apertur... ...aperture qudrupoles and sextupole magntes(Com... ...model in 2022)

5) Vacuum chamber system (Complete fabrication and costing test in 2022)

6) SC magnets including cryostate (Complete short test model in 2022)

20

...ection be test in 2022)

...st in 2022)

...nts (Complete key components test in 2022)

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11) Plasma injector (Complete electron accelerator test in 2022)

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SppC technology R&D

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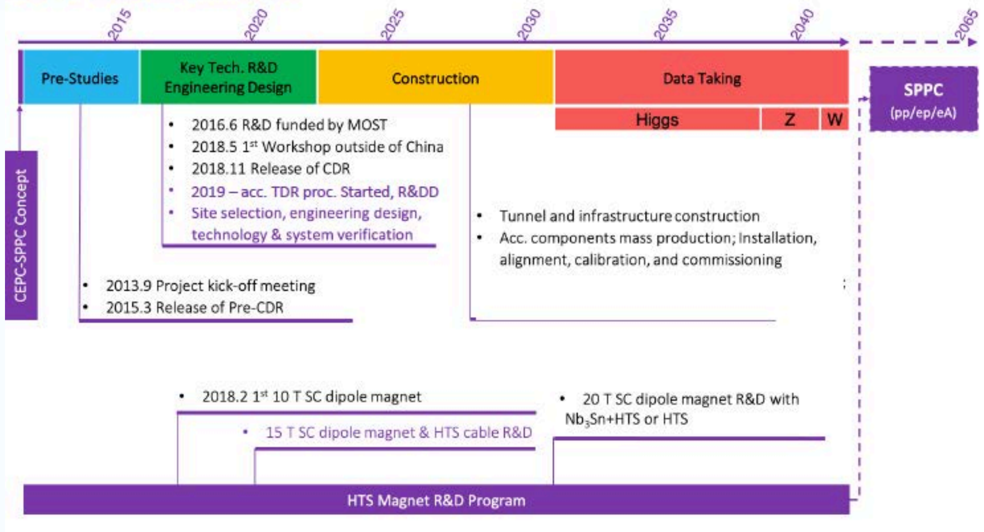
CEPC Roadmap and Schedule (ideal)

CEPC Project Timeline



Goals and Plan

- Design enhancement + R&D
- Validation, & industrial preparation
- Best prepare CEPC for national government's approval
- Realization of the CEPC project, the experimental program and pursue the science
- International collaboration and coordination

Monday, October 26, 2020

Accelerator
Conveners: Dr. Anton Bogomyagkov (BINP), Dr. wenhui huang (Tsinghua University)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia.zoom.com.cn/j

08:30 **CEPC Beam dynamics general and beam-beam** *20'*
Speakers: Chenghui Yu (IHEP), Dr. Yuan Zhang (IHEP, Beijing)

08:50 **CEPC Collider ring lattice** *20'*
Speaker: Yiwei Wang (IHEP)

09:10 **CEPC Booster** *20'*
Speaker: Dou Wang (IHEP)

09:30 **CEPC collective effects and impedance** *20'*
Speaker: Na WANG /Yudong Liu (CEPC collective effects and impedance)

09:50 **CEPC orbit and errors** *20'*
Speaker: Yuanyuan Wei (IHEP)

Accelerator
Conveners: Prof. Jie Gao (IHEP), Younguk Sohn (POSTECH)
Location: Grand Ballroom B (Online Meeting Room: https:/

10:30 **SuperKEKB status** *20'*
Speaker: Makoto Tobiyama

10:50 **CEPC linac** *20'*
Speaker: Mr. Cai Meng (高能所)

11:10 **CEPC transport lines** *20'*
Speaker: Xiaohao Cui (CEPC transport lines)

11:30 **RAON SC linac** *20'*
Speaker: Younguk Sohn (Postech)

11:50 **PAL-XFEL linac** *20'*
Speaker: Chang-Ki Min (Postech)

Accelerator
Conveners: Marica Biagini, Eiji Kako (KEK)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia.z

14:00 **CEPC SCRF system and R&D** *20'*
Speaker: Mr. Jiyuan Zhai (IHEP)

14:20 **CEPC klystron R&D** *20'*
Speaker: Dr. Zusheng Zhou (Institute of High Energy Physics)

14:40 **CEPC Linac and damping ring R&D** *20'*
Speaker: Jingru Zhang (IHEP)

15:00 **Alternatives injection design** *20'*
Speaker: Bowen Bai (IJClab-UPSay/IHEP)

15:20 **CEPC synchrotron radiation** *20'*
Speaker: HUANG Yongsheng

15:40 **CEPC controls** *20'*
Speaker: Dr. Gang Li (EPD.IHEP) (高能所)

Accelerator
Conveners: Prof. Angeles Faus-Golfe (IJCLab), Prof. Xueqing Yan (PKU)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia.zoom.com.cn/j/6

16:30 **CEPC collider ring magnets R&D** *20'*
Speaker: Mei Yang (IHEP)

16:50 **CEPC booster magnets R&D** *20'*
Speaker: Wen Kang (IHEP)

17:10 **CEPC vacuum R&D** *20'*
Speakers: Yongshen Ma (IHEP), Haiyi Dong (IHEP)

17:30 **CEPC instrumentation R&D** *20'*
Speaker: Dr. Yanfeng Sui (高能所)

17:50 **CEPC cryogenics system** *20'*
Speakers: Mr. Tongxian ZHAO (高能所), Shaopeng Li (IHEP)

18:10 **CEPC power sources and electro-magnetic separators R&D** *20'*
Speaker: Bin Chen (IHEP)

Tuesday, October 27, 2020

Accelerator
Convener: Prof. Xueqing Yan (PKU)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia.zoom.c

08:30 **CEPC injection/extraction** *20'*
Speaker: Jihui Chen (IHEP)

08:50 **Plasma injector** *20'*
Speakers: Dr. Dazhang LI (IHEP), Dr. Wei Lu (Tsinghua University)

09:10 **SPPC issues** *20'*
Speaker: Jingyu TANG/Yiwei Wang (IHEP)

09:30 **CLIC collaboration issues** *20'*
Speaker: Dr. JIARU SHI (Tsinghua University)

09:50 **Polarization at CEPC and FCC-ee** *20'*
Speaker: Dr. Sergei Nikitin (Budker Institute of Nuclear Physics)

Accelerator
Convener: Prof. Jie Gao (IHEP)
Location: Grand Ballroom B (Online Meeting Room: ht

10:30 **CEPC mechanics** *20'*
Speaker: Haijing Wang (IHEP)

10:50 **CEPC alignment and installation** *20'*
Speaker: Mr. Xiaolong Wang (高能所)

11:10 **CEPC civil engineering** *20'*
Speaker: Yu Xiao (Huanghe)

11:30 **CEPC civil engineering** *20'*
Speaker: Ke Huang (Huangdong)

11:50 **CEPC civil engineering** *20'*
Speaker: Jiangyang Pan (Zhongnan)

Accelerator
Conveners: Younguk Sohn, Dr. Frank Zimmermann (CERN)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia

14:00 **Laser Plasma Wakefield Positron Acceleration** *20'*
Speaker: Xueqing Yan (Peking Uni)

14:20 **CEPC radiation protection and dumps** *20'*
Speaker: Zhongjian Ma (IHEP)

14:40 **FCC-ee issues and FCC-hh key issues** *20'*
Speaker: Dr. Frank Zimmermann (CERN)

15:00 **FCC-hh lattice design** *20'*
Speaker: CEA A. Chance or B. Dalena

15:20 **Status and lessons from Super Tau Charm project** *20'*
Speaker: Dr. Anton Bogomyagkov (BINP)

15:40 **Non conventional positron targets** *20'*
Speaker: Mr. Yanliang Han (IJCLab)

MDI, Magnet and Integration
Conveners: Dr. Manuela Boscolo (INFN), Dr. Sha BAI (高能所), Suen Hou (IPAS), Hiroyuki Nakayama (KEK)
Location: Grand Ballroom B (Online Meeting Room:https://zoom.com.cn/j/96000048278 Password:123456)

16:30 **FCC-ee MDI layout & SR masks in the FCC-ee MDI area** *30'*
Speaker: Marian Luckhof

17:00 **FCCee Interaction Region Backgrounds** *30'*
Speaker: Georgios Voutsinas

17:30 **Belle II beam background simulation** *20'*
Speaker: Andrii Natochii (University of Hawaii)

17:50 **Beam background in CEPC MDI** *20'*
Speaker: Haoyu SHI (IHEP)

18:10 **Impact of electromagnetic deflection of initial state in luminosity measurement at the CEPC Z pole** *20'*
Speakers: Prof. Ivanka Bozovic (Vinca Institute of Nuclear Sciences), Ivan Smiljanić (V), Goran Kacarevic (V)

Wednesday, October 28, 2020

MDI, Magnet and Integration
Conveners: Dr. Manuela Boscolo (INFN), Dr. Sha BAI (高能所), Suen Hou (IPAS), Hiroyuki Nakayama (KEK)
Location: Grand Ballroom B (Online Meeting Room: https://weidijia.zoom.com.cn/j/64951721990)

10:30 **Latest beam background measurements at Belle II and future prospects** *30'*
Speaker: Hiroyuki Nakayama (KEK)

11:00 **Superconducting magnets design in CEPC IR** *20'*
Speaker: Yingshun Zhu

11:20 **Progress of Beampipe mechanical design** *20'*
Speaker: Ruiqiang ZHANG/Quan JI

11:40 **The geometry and acceptance for CEPC LumiCalA** *20'*
Speaker: Suen Hou (IPAS)

2020 International Workshop on CepC - CIPC

Monday, October 26, 2020

CIPC
Convener: Yongming 李永明 Li
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoom.

08:30 **Klystron** *15'*
Speaker: 少哲 王 (N)

08:45 **(Klystron) Circulator&load** *15'*
Speaker: 立强 王 (航天二院二十三所)

09:00 **Klystron** *15'*
Speaker: 瑞 张 (中科院空天信息研究院)

09:15 **(CEPC magnet) Collider, booster and linac magnets** *15'*
Speaker: 旭文 戴 (高能锐新)

09:30 **(CEPC magnet) Company introduction** *15'*
Speaker: 明涛 康 (上海普東科技有限公司)

09:45 **(CEPC magnet) CEPC booster magnet** *15'*
Speaker: 光亮 朱 (合肥科烨电物理设备制造有限公司)

CIPC
Convener: Dawei 刘大炜 Liu
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoom.com.cn/

10:30 **(CEPC magnet) CEPC collider ring dual aperture quadrupole** *15'*
Speaker: 大鹏 尹 (合肥科烨电物理设备制造有限公司)

10:45 **(Electro-magnet seperator)** *15'*
Speaker: 盘林 郭 (N)

11:00 **(CEPC SC magnet)0.5mm NbTi超导股线** *15'*
Speaker: 维涛 刘 (西部超导材料科技股份有限公司)

11:15 **(CEPC SC magnet)0.5m超导四极磁体QD0短样机制造** *15'*
Speaker: 艺 万 (合肥科烨电物理设备制造有限公司)

11:30 **(CEPC MDI)** *15'*
Speaker: 涛 孙、 洪清 吕 (无锡创新低温环模设备科技有限公司)

CIPC
Convener: Ming 李明 Li
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoor

14:00 **CEPC MDI** *15'*
Speaker: 绍栋 何 (北京空间机电研究所（航天508所）)

14:15 **(SCRF)Linac structure and SCRF cavity fabrication** *15'*
Speaker: 旭文 戴 (北京高能锐新公司)

14:30 **SCRF** *15'*
Speaker: 众 李 (otic)

14:45 **SCRF** *15'*
Speaker: 海根 邵 (安徽华东光电技术研究所有限公司)

15:00 **SCRF** *15'*
Speaker: 承业 郑 (N)

15:15 **SCRF** *15'*
Speaker: 文清 李 (北京富斌盛世真空设备有限公司)

15:30 **Vacuum** *15'*
Speaker: 东林 章 (shzkvalve)

15:45 **Vacuum** *15'*
Speaker: 宇 蔺 (川北真空科技（北京）有限公司)

CIPC
Convener: Liqiang 刘立强 Liu
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoom.com.cn/

16:30 **Vacuum** *15'*
Speaker: 易晓 关 (SKY)

16:45 **(Vacuum) 超高真空全金属阀门研究开发** *15'*
Speaker: 魁榜 张 (四川九天真空科技股份有限公司)

17:00 **Cryogenics** *15'*
Speaker: 立强 刘 (北京中科富海低温科技有限公司-中国科学院理化技术研究所)

17:15 **Cryogenics** *15'*
Speaker: 家屿 周 (安徽万瑞冷电科技有限公司)

17:30 **Cryogenics** *15'*
Speaker: 文 董 (中船重工鹏力（南京）超低温技术有限公司)

17:45 **Cryogenics** *15'*
Speaker: 洪清 吕 (W)

18:00 **Cryogenics** *15'*
Speaker: 杰峰 吴 (合肥聚能电物理高技术开发有限公司)

18:15 **Cryogenics** *15'*
Speaker: 大明 孙 (江苏克劳特低温技术有限公司)

Tuesday, October 27, 2020

CIPC
Convener: Daming孙大明 Sun
Location: Grand Ballroom C (Online Meeting Room: https://weidi

08:30 **Instrumentation** *15'*
Speaker: 海根 邵 (华东光电研究院)

08:45 **Instrumentation** *15'*
Speaker: 子燕 谢 (浩德科仪真空技术有限公司)

09:00 **Instrumentation** *15'*
Speaker: 顺和 于 (沈阳科学仪器厂)

09:15 **Radiation protection** *15'*
Speaker: 龙 张 (北京市射线应用研究中心)

09:30 **Radiation protection** *15'*
Speaker: 泽学 郭 (天津市万木辐射防护工程有限公司)

09:45 **(Mechnics)介绍公司情况** *15'*
Speaker: 宝瑞 刘 (北京空间机电研究所（航天508所）

CIPC
Convener: Shenghong 范生宏 Fan
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zo

10:30 **(Mechnics) MDI远程真空连接设计** *15'*
Speaker: 奇 杨 (沈阳慧宇真空技术有限公司)

10:45 **(Mechnics)隧道磁铁、支架等设备运输车辆** *15'*
Speaker: 超 孙 (北车618所)

11:00 **(Alignment)非接触式精密测量和智能视觉系统** *15'*
Speaker: 生宏 范 (北京普达迪泰科技有限公司)

11:15 **(Alignment)精密基准件研制** *15'*
Speaker: 长河 朱 (汉中远航精密机械制造有限公司)

11:30 **(Alignment)高分辨率对地观测系统、机械设计、系统集成** *15'*
Speaker: 兴泽 王 (中国空间技术研究院总体部)

11:45 **(Alignment)精密光电测量系统** *15'*
Speaker: 维虎 周 (中国科学院微电子所)

CIPC
Convener: Jidong孙继东 Sun
Location: Grand Ballroom C (Online Meeting Room: htt

14:00 **(Alignment)大地测量，工程测量** *15'*
Speaker: 宜斌 姚/进贵 邹 (武汉大学 测绘学院)

14:15 **CEPC地质研究** *15'*
Speaker: 祥金 冉 (Jilin University)

14:30 **Installation and store** *15'*
Speaker: 佳斌 王 (华侨大学)

14:45 **SppC magnet** *15'*
Speaker: 建伟 刘 (西部超导)

15:00 **SppC magnet** *15'*
Speaker: 跃 赵 (上海超导)

15:15 **SppC magnet** *15'*
Speaker: 传兵 蔡 (上海大学/上创超导)

15:30 **SppC magnet** *15'*
Speaker: 和安 廖 (统力电工)

15:45 **(SppC magnet)HL-LHC CCT磁体进展** *15'*
Speaker: 洪明 汤 (shangcitech)

2020 International Workshop on CepC - CIPC

Monday, October 26, 2020

CIPC
Convener: Yongming 李永明 Li
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoom.

08:30 **Klystron** *15'*
Speaker: 少哲 王 (N)

08:45 **(Klystron) Circulator&load** *15'*
Speaker: 立强 王 (航天二院二十三所)

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Speaker: 瑞 张 (中科院空天信息研究院)

09:15 **(CEPC magnet) Collider, booster and linac magnets** *15'*
Speaker: 旭文 戴 (高能锐新)

09:30 **(CEPC magnet) Company introduction** *15'*
Speaker: 明涛 康 (上海普束科技有限公司)

09:45 **(CEPC magnet) CEPC booster magnet** *15'*
Speaker: 光亮 朱 (合肥科烨电物理设备制造有限公司)

CIPC
Convener: Dawei 刘大炜 Liu
Location: Grand Ballroom C (Online Meeting Room: https://we

10:30 **(CEPC magnet) CEPC collider ring dual aperture**
Speaker: 大鹏 尹 (合肥科烨电物理设备制造有限公司)

10:45 **(Electro-magnet seperator)** *15'*
Speaker: 盘林 郭 (N)

11:00 **(CEPC SC magnet)0.5mm NbTi超导股线** *15'*
Speaker: 维涛 刘 (西部超导材料科技股份有限公司)

11:15 **(CEPC SC magnet)0.5m超导四极磁体QD0短样机制造** *15'*
Speaker: 艺 万 (合肥科烨电物理设备制造有限公司)

11:30 **(CEPC MDI)** *15'*
Speaker: 涛 孙、洪清 吕 (无锡创新低温环模设备科技有限公司)

CIPC
Convener: Ming 李明 Li
Location: Grand Ballroom C (Online Meeting Room: https://weidijia.zoor

14:00 **CEPC MDI** *15'*
Speaker: 绍栋 何 (北京空间机电研究所 (航天508所))

14:15 **(SCRF)Linac structure and SCRF cavity fabrication** *15'*
Speaker: 旭文 戴 (北京高能锐新公司)

14:30 **SCRF** *15'*
Speaker: 众 李 (otic)

14:45 **SCRF** *15'*
Speaker:

15:00

温科技有限公司-中国科学院理化技术研究所)

家屿 周 (安徽万瑞冷电科技有限公司)

Cryogenics *15'*
Speaker: 文 董 (中船重工鹏力 (南京) 超低温技术有限公司)

17:45 **Cryogenics** *15'*
Speaker: 洪清 吕 (W)

18:00 **Cryogenics** *15'*
Speaker: 杰峰 吴 (合肥聚能电物理高技术开发有限公司)

18:15 **Cryogenics** *15'*
Speaker: 大明 孙 (江苏克劳特低温技术有限公司)

Tuesday, October 27, 2020

CIPC
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MDI远程真空连接设计 *15'*
Speaker: 奇 杨 (沈阳慧宇真空技术有限公司)

10:45 **(Mechnics)隧道磁铁、支架等设备运输车辆** *15'*
Speaker: 超 孙 (北车618所)

11:00 **(Alignment)非接触式精密测量和智能视觉系统** *15'*
Speaker: 生宏 范 (北京普达迪泰科技有限公司)

11:15 **(Alignment)精密基准件研制** *15'*
Speaker: 长河 朱 (汉中远航精密机械制造有限公司)

11:30 **(Alignment)高分辨率对地观测系统、机械设计、系统集成** *15'*
Speaker: 兴泽 王 (中国空间技术研究院总体部)

11:45 **(Alignment)精密光电测量系统** *15'*
Speaker: 维虎 周 (中国科学院微电子所)

CIPC
Convener: Jidong孙继东 Sun
Location: Grand Ballroom C (Online Meeting Room: htt

14:00 **(Alignment)大地测量，工程测量** *15'*
Speaker: 宜斌 姚/进贵 邹 (武汉大学 测绘学院)

14:15 **CEPC地质研究** *15'*
Speaker: 祥金 冉 (Jilin University)

14:30 **Installation and store** *15'*
Speaker: 佳斌 王 (华侨大学)

14:45 **SppC magnet** *15'*
Speaker: 建伟 刘 (西部超导)

15:00 **SppC magnet** *15'*
Speaker: 跃 赵 (上海超导)

15:15 **SppC magnet** *15'*
Speaker: 传兵 蔡 (上海大学/上创超导)

15:30 **SppC magnet** *15'*
Speaker: 和安 廖 (统力电工)

15:45 **(SppC magnet)HL-LHC CCT磁体进展** *15'*
Speaker: 洪明 汤 (shangcitech)

48 Speakers for CIPC

40 Speakers Accelerators

Luminosity, Lattices, Beam Dynamics

CEPC CDR Parameters

	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	
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

CEPC High Luminosity Parameter after CDR

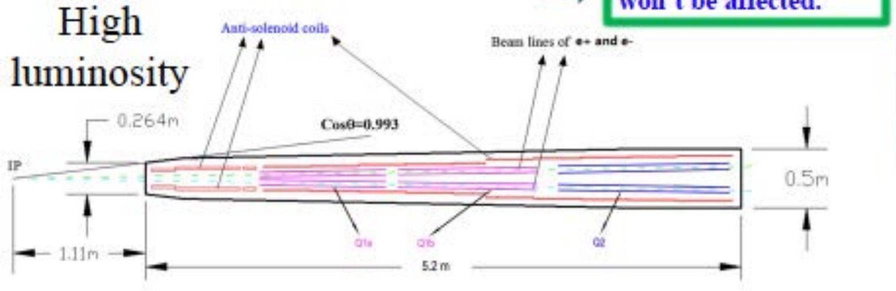
	Higgs (high_lum.)	*Z (high_lum.)*
Number of IPs	2	2
Beam energy (GeV)	120	45.5
Circumference (km)	100	100
Synchrotron radiation loss/turn (GeV)	1.8	0.036
Crossing angle at IP (mrad)	16.5	16.5
Piwinski angle	4.87	18.0
Number of particles/bunch N_e (10^{10})	16.3	16.1
Bunch number (bunch spacing)	214 (0.7us)	10870 (27ns)
Beam current (mA)	16.8	841.0
Synchrotron radiation power /beam (MW)	30	30
Bending radius (km)	10.2	10.7
Momentum compact (10^{-5})	7.34	2.23
β function at IP β_x^* / β_y^* (m)	0.33/0.001	0.15/0.001
Emittance e_x/e_y (nm)	0.68/0.0014	0.52/0.0016
Beam size at IP σ_x/σ_y (μm)	15.0/0.037	8.8/0.04
Beam-beam parameters ξ_x/ξ_y	0.018/0.115	0.0048/0.129
RF voltage V_{RF} (GV)	2.27	0.13
RF frequency f_{RF} (MHz)	650	650
Natural bunch length σ_z (mm)	2.25	2.93
Bunch length σ_z (mm)	4.42	9.6
Energy spread (%)	0.19	0.12
Energy acceptance requirement (%)	1.7	1.4
Energy acceptance by RF (%)	2.5	1.5
Beamstruhlung lifetime /quantum lifetime (min)	41	-
Lifetime (hour)	21	1.8
Luminosity/IP *L* ($10^{34}cm^{-2}s^{-1}$)	5.0	101.1

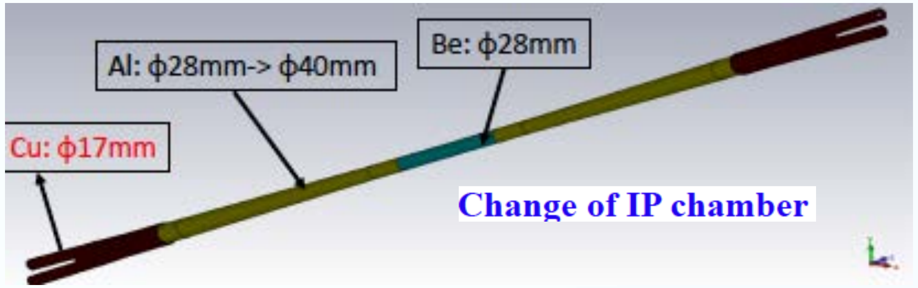
* High luminosity Z's lattice is same as Higgs CDR lattice. but high luminosity Higgs has a new lattice than that of CDR

Luminosity, Lattices, Beam dynamics

- The design of high luminosity scheme with $5\times10^{34}cm^{-2}s^{-1}$ & 30MW has been designed. It doesn't meet strong limitation and also won't affect the current mechanical design of detector.
- The L* can be set as 1.9m from IP with lower emittance and smaller beam pipe within the region of SCQ.
- For the consideration of high luminosity Z, if it's a strong limitation from local HOM heating problem due to the narrow SCQ beam pipe, replacing the whole cryostat is the best option. The shape and size of cryostat stay the same and the inner aperture of SCQ beam pipe can be made large enough.
- More detailed studies will be done. Such as DA optimization with errors, detector background evaluation, etc.

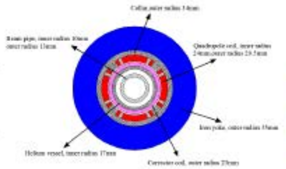
For the part of cryostat inside the detector, the shape and size stay the same as CDR. → The design of detector won't be affected.





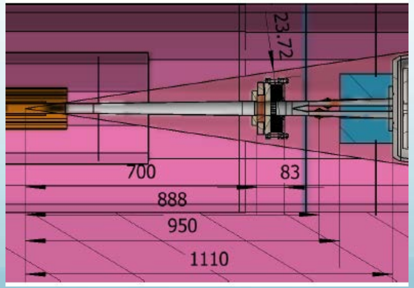
Change of final focusing quadrupole coils

- ✓ Q1a is the most challenging.
- ✓ The design of quadrupoles and anti-solenoid is similar to that in CDR.
- ✓ Iron yoke is adopted to eliminate the field crosstalk between the two apertures.



IR Mechanical Design

Difficulties:
- Vacuum chamber connection
  - Longitudinal space: bellows should absorb deformation when baking. →Add Z-direction support, length has been decreased to 83mm.
  - Transversal space: all the structure should be within detection angle.
- Hardware protection
  - Avoid SR



Change of HOM deposition nearby the IP

HOM Power distribution	High luminosity Be pipe: 28mm SCQ Pipe:17mm		CDR Be pipe: 28mm SCQ Pipe:20mm	
	Higgs	Z	Higgs	Z
Be pipe	3.46w	52.1w	2.66w	40.74 w
Al	22.62w	335.4w	21.32w	317.2w
Y-shape crotch	13.4w	199w	12.9w	191.5w
Total power	39.48w	586.5w	36.88w	549.5w

Shrinking the SCQ pipe aperture from 20mm to 17mm, the power deposition will increase 10% which is acceptable.

Luminosity, Lattices, Beam dynamics

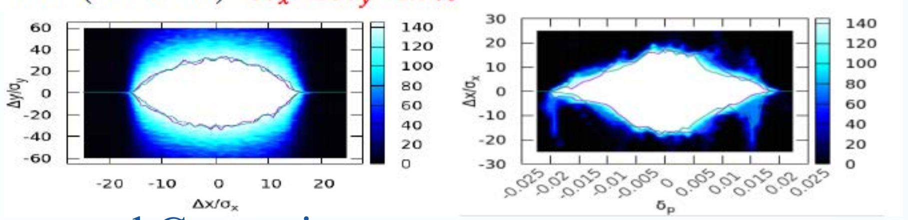
- Fit parameter list with luminosity of $5.0\times10^{34}/cm^2/s$
  - Stronger optimization and stricter hardware requirement should be made to get enough dynamic aperture
- Optimization of the quadrupole radiation effect
  - Interaction region: longer QD0/QF1
  - ARC region: longer quadrupoles
- Reduction of dynamic aperture requirement from injection
  - Straight section region: larger βx at injection point
- Maximization of bend filling factor to minimize the synchrotron radiation loss per turn
  - ARC region: sextupoles in two rings changed from staggered to parallel; The left drifts are used for the bends.
  - RF region: shorter phase tuning sections
- Optimization of high order chromaticity for arc region
- Reduction of the length from IP to 1st quadrupole without changing the front-end position of the FD cryo-module (2.2m to 1.9m)
  - make the lattice robust and provide good start point for DA

- For other modes
  - RF region: A possible scheme of the RF region was proposed for the RF staging and by pass.
  - ARC region: the phase advance of each cell will be changed from 90/90 to 60/60 and the additional sextupoles need to be installed for the Z mode (Ref: FCC-ee CDR).
  - Interaction region: refitted with the matching quadruples to get as high as possible luminosity. New final-doublet quadrupoles will be installed for a even higher luminosity.

Achieved (without errors): $16\sigma_x\times32\sigma_y\times1.9\%$

Goal (with errors): $8\sigma_x\times15\sigma_y\times1.7\%$

Dynamic aperture



Imperfections and Corrections

- The optics correction is very challenging for the relaxed tolerance of the imperfections.
- The lattices with **IR=50μm** and **IR=100μm** case are corrected, the passing rates are increased to **89.1%** and **72.4%**, respectively.
- Include more types of imperfections.
- Optimize the correction strategy to achieve finer tuning of optics.
- Study off-momentum correction.
- The development of the error correction algorithm for high luminosity lattice.

Booster

- Booster design in CDR was refined. Become more solid.
- Issues about booster dynamic operation was considered.
- Explore new booster design with smaller emittance — prepare for CEPC high lum. Higgs

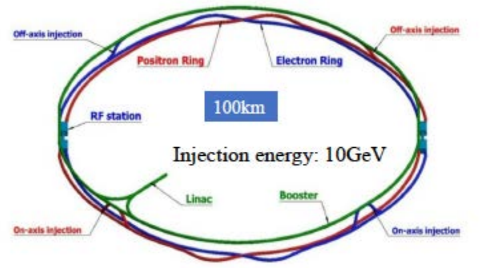
Impedance and HOM from IP chamber is critical for Z mode with high current operation and new chamber structure or absorber will be necessary.

Impedance requirements

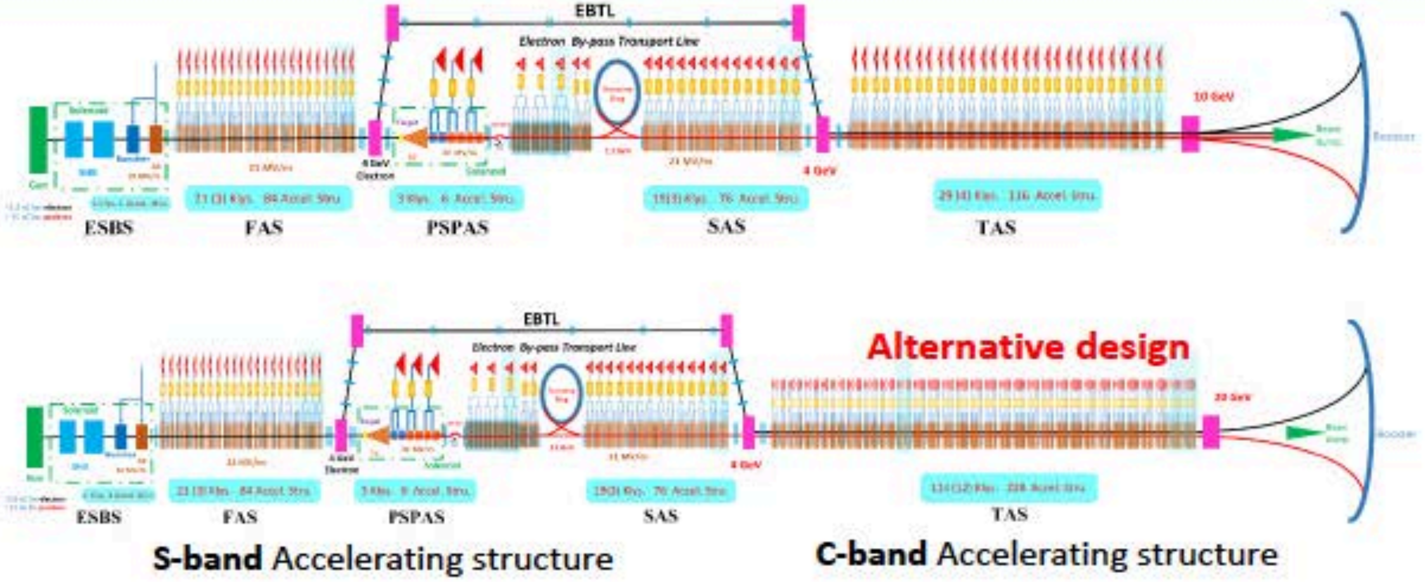
Estimations with analytical formulae give rough requirements on both broadband and narrowband impedances.
For different operation scenarios, the design of Z/Z-High Lumi maybe the most critical restriction for both broadband and narrowband impedances.

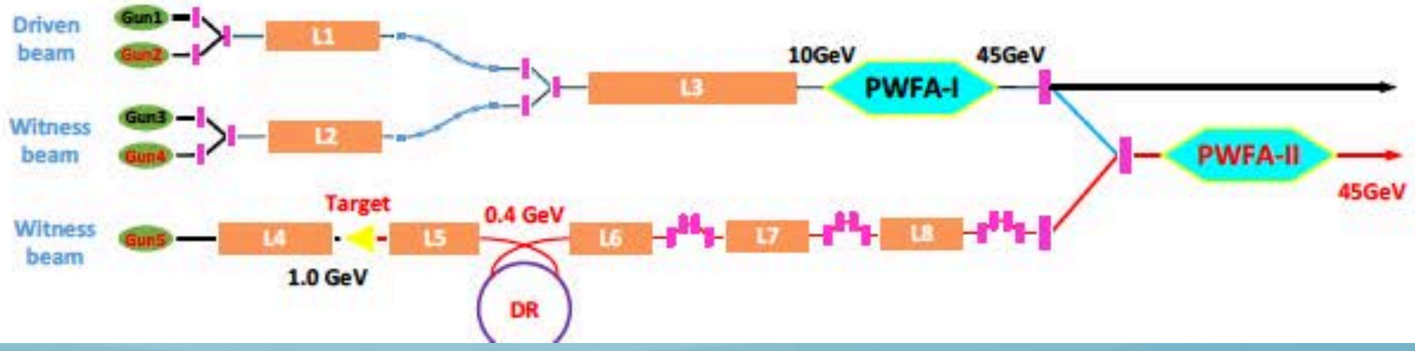
Parameter	Symbol, unit	Higgs(CDR)	W(CDR)	Z(CDR)	Higgs-High Lumi	Z-High Lumi
Beam energy	E, GeV	120	80	45.5	120	45.5
Beam current	I_0, mA	17.4	87.9	461	16.8	841.0
Bunch number	n_b	242	1524	12000	214	10870
Bunch current	I_b, mA	0.072	0.058	0.038	0.079	0.077
Bunch Population	N_e ,[10^{10}]	15	12	8.0	16.3	16.1
Threshold of broadband ZL	$\lvert Z_L/n\rvert_{eff}$, mΩ	8.8	3.2	0.9	58.6	11.9
Threshold of broadband ZY	κ_y, kV/pC/m	65.6	32.7	20.1	4.6	5.2×10^{-4}
Threshold of narrowband ZL	$\frac{f}{GHz}\frac{Re Z_L}{G\Omega}e^{-(2\pi f\sigma_t)^2}$	3.5	0.08	1.1E-3	3.0	7.1×10^{-4}
Threshold of narrowband ZY	$\frac{Re Z_\perp}{G\Omega/m}e^{-(2\pi f\sigma_t)^2}$	2.3	0.09	1.8E-3	16.8	841.0

Injection Schemes: Updates and Alternatives

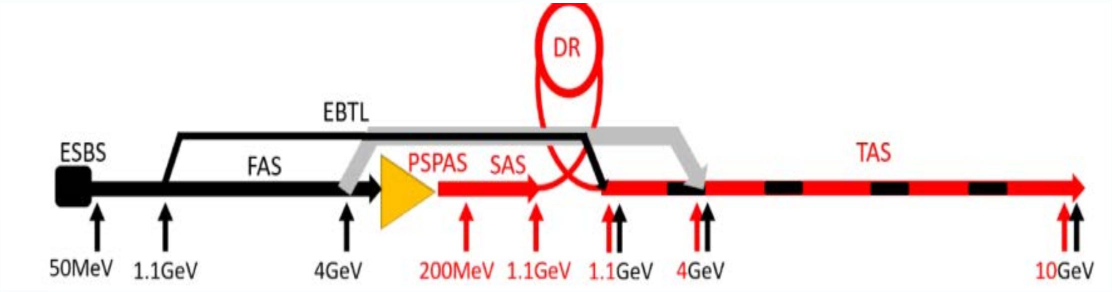


- CEPC layout
  - 10 GeV Linac
  - 10-120GeV Booster
  - 120 GeV Collider
  - Transport lines
- CEPC Linac
  - Baseline scheme
    - ✓ 10 GeV (S-band)
  - Alternative scheme
    - ✓ 20 GeV (S+C-band)
  - PWFA scheme
    - ✓ 45 GeV
    - ✓ S-band driven linac
    - ✓ Plasma acceleration





Injection Schemes: Updates and Alternatives



- The energy of electron bypass transport line (EBTL) is from 4GeV to 1.1 GeV
  - Reduce the survey design difficulty of the positron source
  - Better compatibility between baseline scheme and alternative scheme
    - ✓ In this case the starting energy of the C-band accelerating structure of the alternative scheme can be 1.1 GeV just after damping ring;
    - ✓ For the alternative scheme or lower emittance (no smaller than 10 nm) baseline scheme, only the design of the third acceleration section (TAS) need update and other parts can basically fixed.

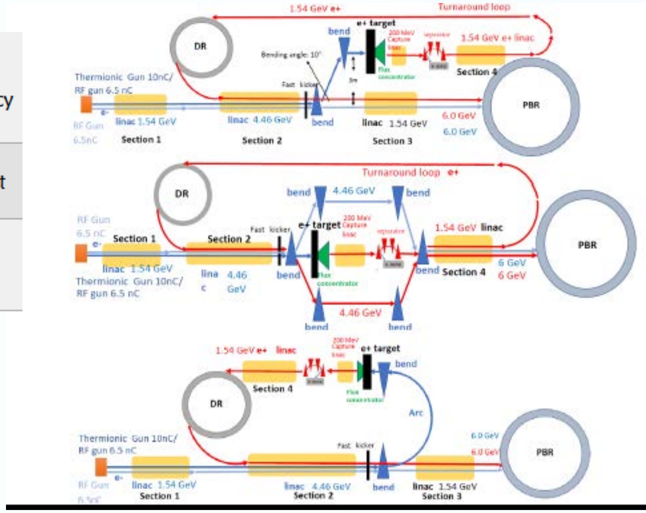
- The deflection direction of the EBTL is from horizontal to vertical, the distance between EBTL and main linac is from 2 m (H) to 1.2 m (V)
  - Easier layout design to avoid the interference with energy analyzing station, transport lines between the Linac and damping ring, waveguide and positron source
  - Reduce the tunnel width and maybe no need to increase the height (3.5m)
- 8 normal accelerating structures are replaced by 10 larger aperture accelerating structure (same type in PSPAS) at the beginning of the second acceleration section (SAS) to reduce the risk of beam loss

Alternatives injection design

Dogleg scheme	Simple bypass (2 bends) + Additional 1.54 GeV linac (section 4) + 1.54 GeV e+ turnaround loop (arc)	High efficiency
Chicane scheme	Complex bypass (4 bends) + 1.54 GeV e+ turnaround loop (arc)	Less cost
Arc scheme	Most complex bypass (6 bends) + 4.46 GeV e- arc Additional 1.54 GeV linac (section 4)	Simple system

The three schemes design can meet the requirement of the Z mode of FCCee.

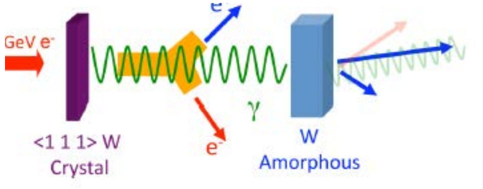
e+ yield is about 1.2.



Non-conventional target Scheme

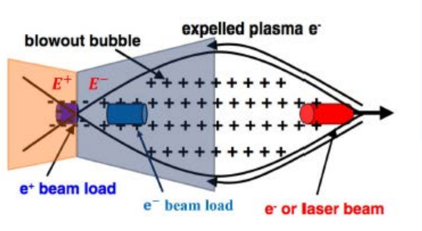
One solution is the hybrid target scheme:

- Use a thin crystal radiator to provide a huge photons flux
- Spent the charged particle between radiator & converter
- Use amorphous target as converter



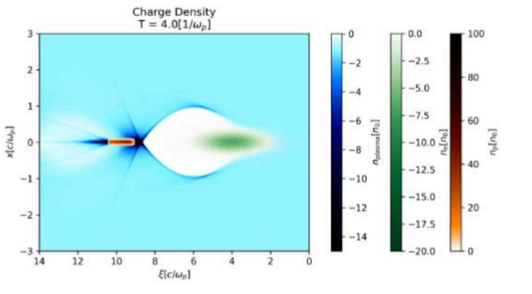
- The hybrid target scheme can largely reduce the PEDD for the FCC, with the cost of lower positron yield
- It is very promising to use the hybrid scheme when the incident electron beam energy can be 18.5 GeV.

Injection Schemes: Updates and Alternatives

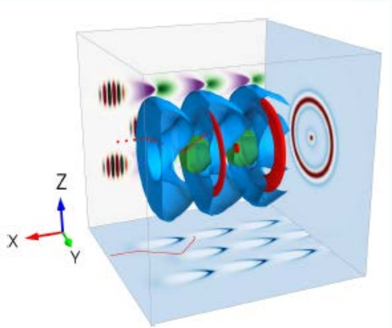


Recent progress on CEPC plasma injector

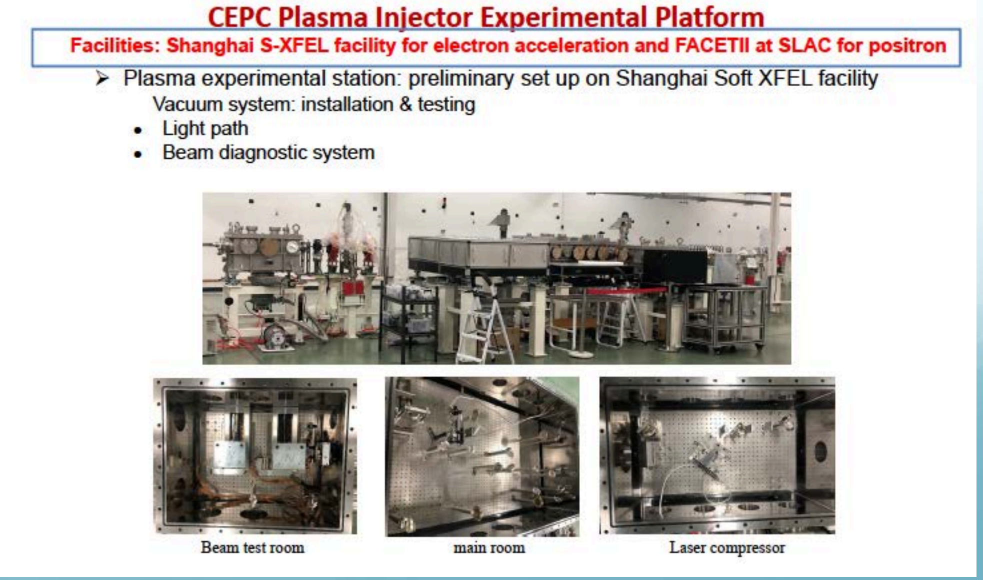
- **HTR e- acceleration**
  - Start-to-end simulation performed, linac and CPI requirement updated
  - Detailed error analysis is ongoing, multi-parameter effects are under consideration
  - Linac can not meet the CPI requirement yet, both sides work on it
  - For plasma acceleration, increase the plasma wavelength and lower the TR will be the effective methods
- **e+ acceleration**
  - New methods are studied
  - Fix the baseline parameters at the end of 2020
  - EA and related linac design will start as soon as baseline fixed
- **Experiments affected by COVID-19, but much better now**
  - Test facility for PWFA is crucial and under consideration
- **Feasibility report → CDR → TDR: it's a long way to go**



Efficiency ~22%, Energy Spread~1.6% (not well optimized)

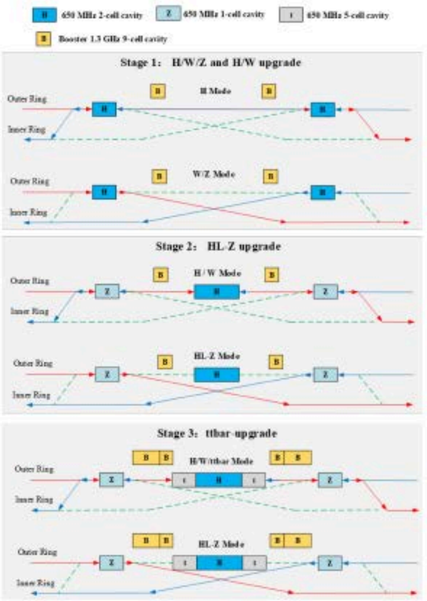


positron ballistic injection scheme



SCRF

- **TDR design of CEPC SRF system is aiming to fulfill requirements of improvements over CDR:**
  - higher luminosity at H (5.2×10^{34} vs 2.9×10^{34}) → RF basically no change
  - "high-lumi" for Z (102×10^{34} vs 32×10^{34}) → RF staging and bypass scheme
  - assuring compatibility for top-pair production → reserved tunnel space
  - capability to handle 50 MW SR power → reserved tunnel space, RF staging and bypass scheme
- **New RF layout and parameters optimization at each energy with the new schemes is ongoing. SRF layout, configuration, parameters, specifications and cost will be upgraded and re-baselined accordingly.**



New RF Staging & By-pass Scheme for CEPC

Stage 1 (H/W run for 8 years): Keep CDR RF layout for H(HL-H)/W and 50 MW upgrade. Common cavities for H. Separate cavities for W/Z. Z initial operation for energy calibration and could reach CDR luminosity. **Minimize first phase construction cost and hold Higgs priority.**

Stage 2 (HL-Z upgrade): Move Higgs cavities to center and add high current Z cavities. **By-pass low current H cavities.** International sharing (modules and RF sources): Collider + 130 MV 650 MHz high current cryomodules.

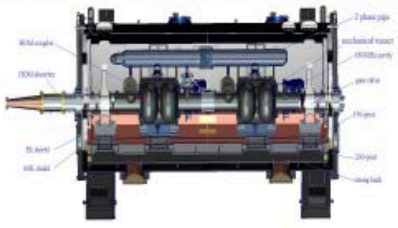
Stage 3 (ttbar upgrade): add ttbar cavities (international sharing): Collider + 7 GV 650 MHz 5-cell cavity, Booster + 6 GV 1.3 GHz 9-cell cavity. Both low current, high gradient, high Q. Nb_3Sn@4.2 K or others.

- **Unleash full potential of CEPC with operational flexibility.**
- **Seamless mode switching with unrestricted RF performance at each energy until AC power limit.**
- **Stepwise construction cost, technology risk and international involvement.**

6

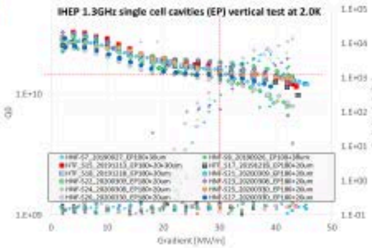
CEPC SCRF R&D Progresses

CEPC 2*2cell 650MHz cryomodule with beam test later



General superconducting cavity test cryomodule in IHEP New SC Lab

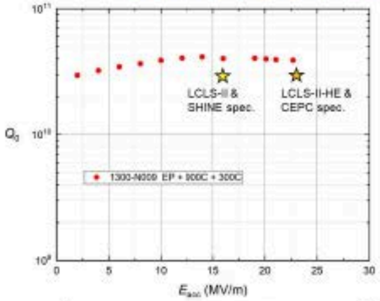
SC cavity vertical test temperature monitor system established

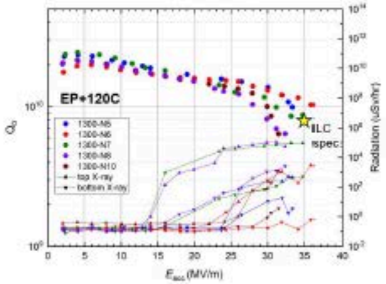


1.3GHz fine grain single cell:
1) 46MV/m
2) 43MV/m@Q01.3×10¹⁰

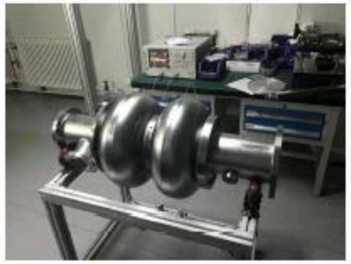
General superconducting cavity test cryomodule in IHEP New SC Lab

IHEP 650MHz 2cell and 1.3 GHz 9-cell Cavities

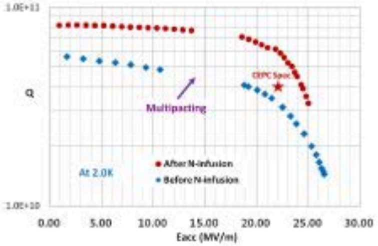




Booster 1.3GHz 9 cell cavity



Collider ring 650Mhz 2 cell cavity



650 MHz 2-cell cavity reached 6E10@22MV/m after N-infusion, which has exceeded CEPC Spec （Q=4E10@Eacc=22MV/m）.

Cryogenics

Booster ring:

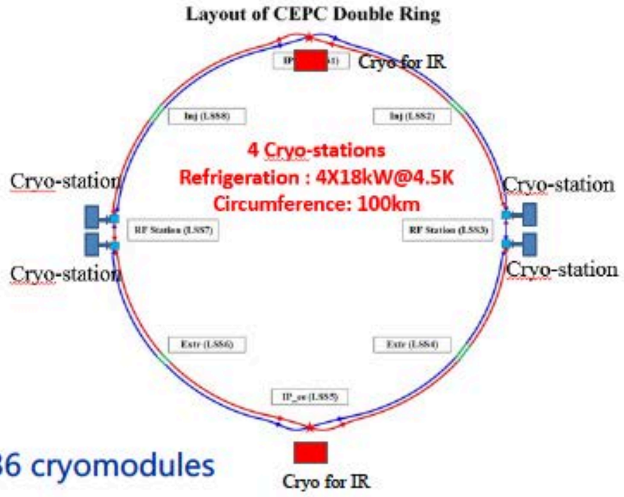
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K Saturated He II

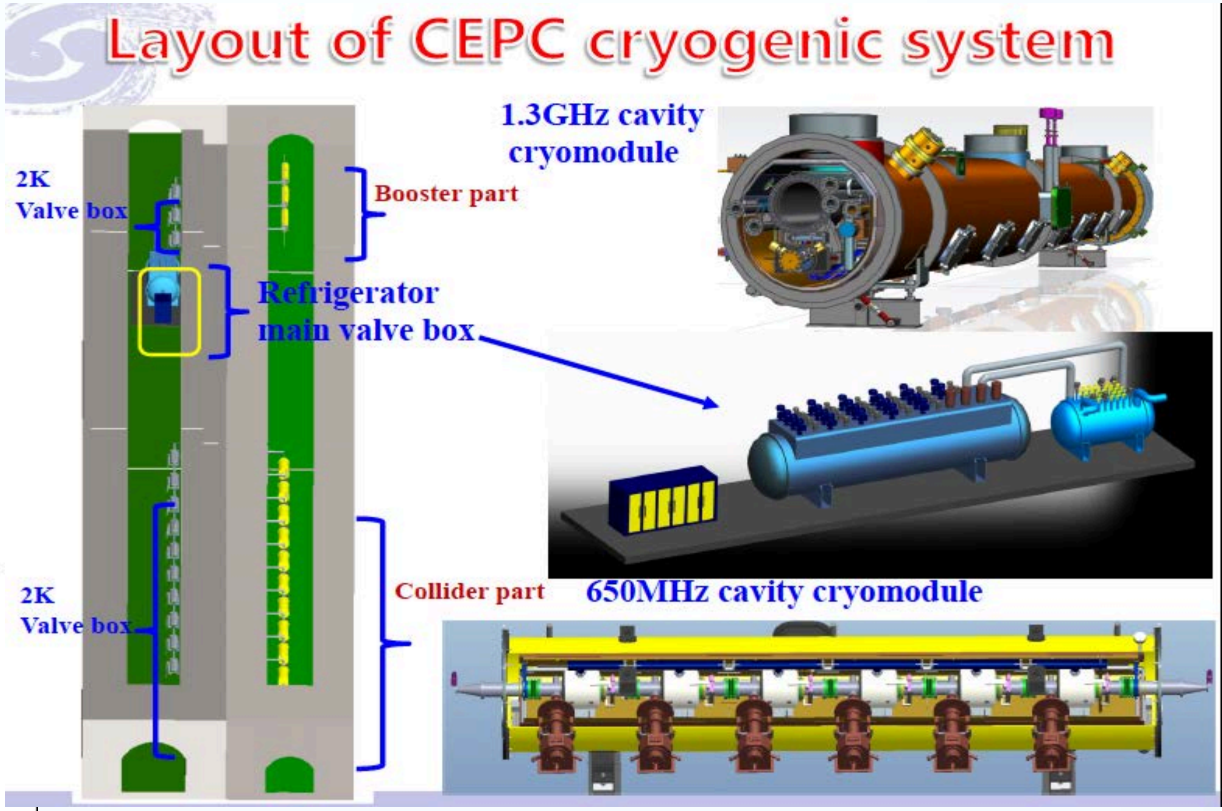
Collider ring:

- 650MHz 2-cell cavities, 240 cavities
- 40 cryomodules
- 10 cryomodules/each station
- Temperature: 2K Saturated He II

IR magnets:

- 4 IR magnets, 32 Sextupole magnets, 36 cryomodules
- 18 cryomodules/each cryo-station
- Temperature: 2K Pressurized He II / 4.2K helium
- Detectors:
- LTS Solenoid: 4.2K Helium





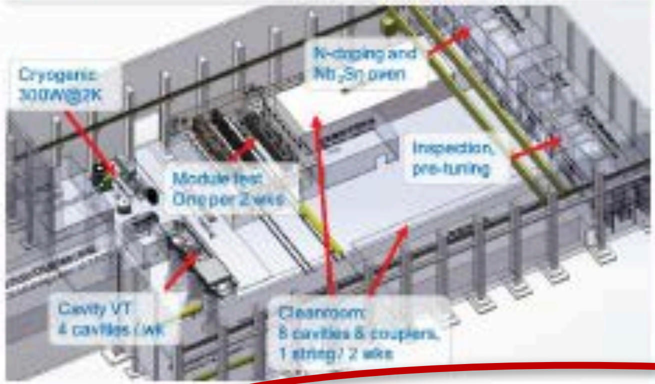
A test cryomodule with two 2-cell 650 MHz superconducting cavities will be operated in the PAPS system in 2021.

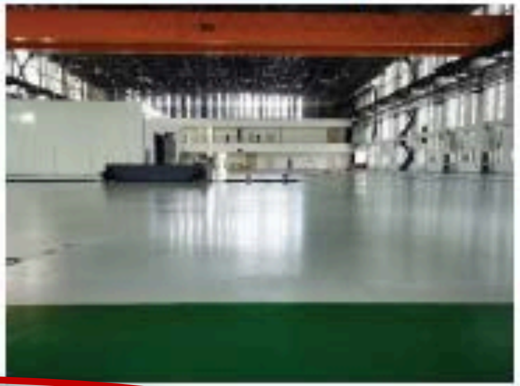
SCRF

PAPS SRF Facility Status

IHEP New SC Lab under Construction (Status in Nov. 2019)

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





New SC Lab Design (4500m^2)

SC New Lab will be available in 2021

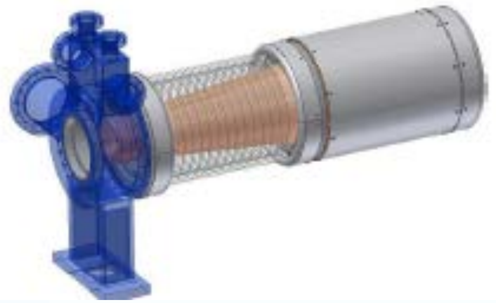
Crygenic system hall in Jan. 16, 2020

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

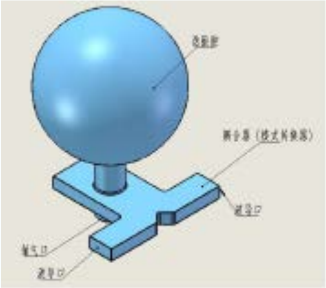
NCRF: linacs and DR

Tranditional thermionic triode gun



Parameter	Unit	Value
Type		Thermionic Triode Gun
Cathode		Y796 (Eimac) Dispenser
Beam Current (max.)	A	10
High Voltage of Anode	kV	120 ~ 200
Bias Voltage of Grid	V	0 ~ -200
Pulse duration	ns	1

Pulse compressor



Parameter	Value
SLED water temperature	30 ℃
Room temperature	25 ℃
Filling time	780 ns
Klystron output power	80 MW
Pulse width	4 μs
Pulse repetition rate	100 Hz

FLUX concentrator

The mechanical design of FLUX concentrator

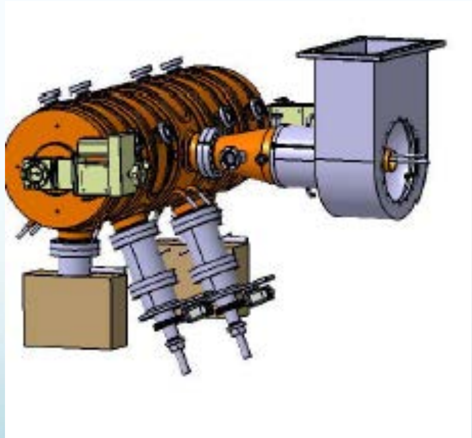
The finished FLUX concentrator

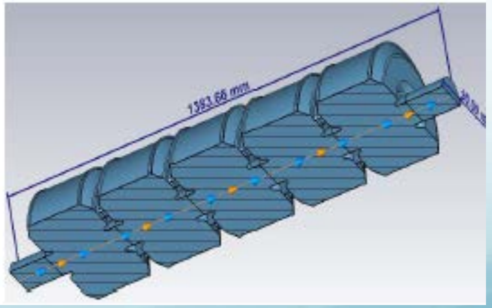
Accelerating structure

Parameters	Values	Unit
No. of Cells	84+2*0.5	-
Phase advance	2π/3	rad
Total length	3.1	m
Length of cell (d)	34.988	mm
Disk thickness (t)	5.5	mm
Shunt impedance (Rs)	60.3~67.8	MΩ/m
Quality factor	15465~15373	-
Group velocity: Vg/c (%)	2% ~ 0.94%	-
Filling time (t_f)	784	ns
Attenuation factor (τ)	0.46	Np
Power (@30MV/m)	74	MW

Damping Ring RF cavity

Beta tune	3.84
Bunch length	5mm
Bunch number	2
Synchtron tune	0.062
Beam current	10mA





CEPC 650MHz High Efficiency Klystron Development

Facility: CEPC high power and high efficincy test facility (lab) is located in IHEP

Established "High efficiency klystron collaboration consortium", including IHEP & IE(Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

Klystrons

- 2016 – 2018: Design conventional & high efficiency klystron
- 2017 – 2018: Fabricate conventional klystron & test
- 2018 - 2019 : Fabricate 1st high efficiency klystron & test
- 2020 - 2021 : Fabricate 2nd high efficiency klystron & test
- 2021 - 2022 : Fabricate 3rd high efficiency klystron & test

Parameters	Conventional efficiency	High efficiency
Centre frequency (MHz)	650+/-0.5	650+/-0.5
Output power (kW)	800	800
Beam voltage (kV)	80	-
Beam current (A)	16	-
Efficiency (%)	~65	> 80

On March 10, 2020, the first CEPC650Mhz klystron output power has reached pulsed power of 800kW (400kW CW due to test load limitation), efficiency 62% and band width>+-0.5Mhz.

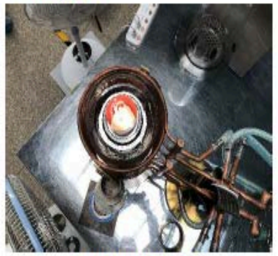
1st klystron prototype

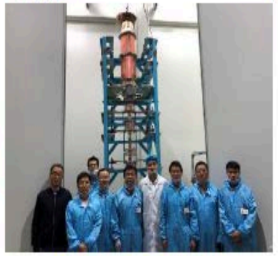

Cavity part


Cavity


Cold test


Collector brazing


Gun processing


Vacuum Assy assembly

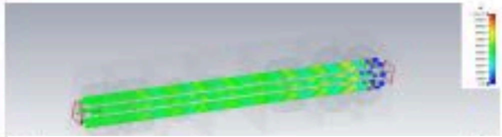

Coil&Gird


1st Klystron of 62% efficiency


800kW Load


2nd Klystron of 77% efficiency

3nd Klystron of 80% efficiency

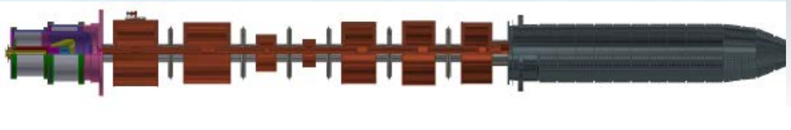


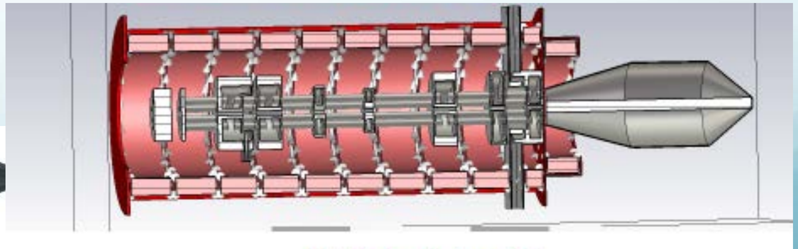
Multi-beam klystron

Cavity

High efficiency klystron (2nd klystron)

gun




MBK physical model

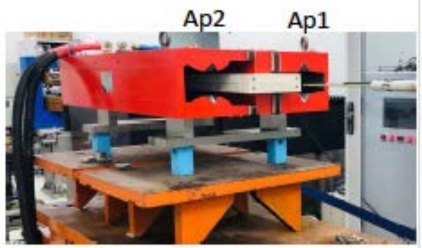
Collider Magnets

	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34

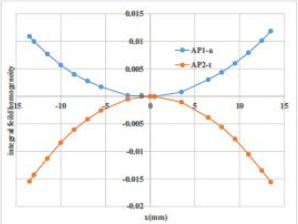
- The most important issues are Cost & Power Consumption.
  - Make the magnets compact and simple.
  - Aluminum wire is used for the excitation coils.
  - Dual aperture magnets save nearly 50% power consumption.
  - Consider the combined function magnets.
  - Increase the coil cross section and decrease the operating current.

Dual Aperture Dipole(DAD)

Short DAD

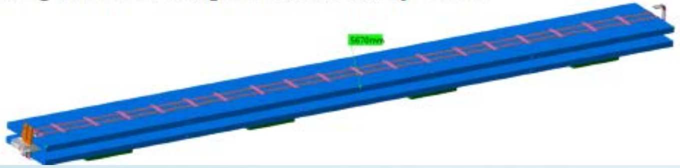


Dipole measured by a hall probe system



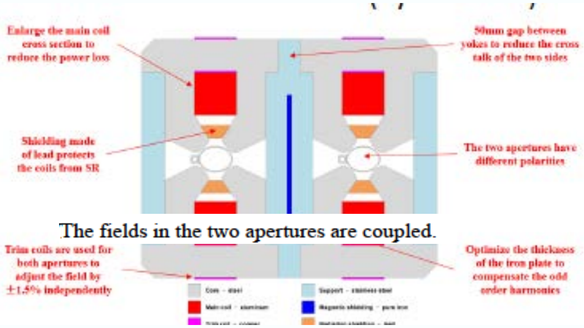
Long DAD

- The mechanical design of the long DAD has been completed. The physical and mechanical design review was performed in July 2020.

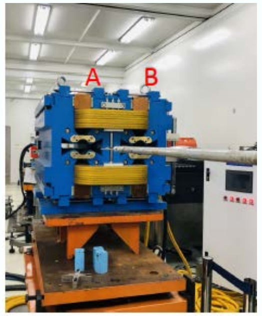


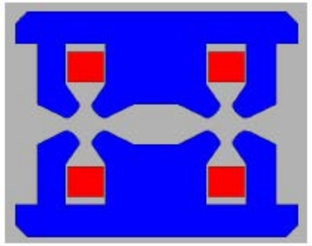
- The design of combined dipole and sextupole magnet with aluminum bus bars is accessible. The center dipole field and sextupole strength is basically consistent with the design value.
- The long DAD was designed and will be manufactured. The water cooled coils is used and the anodizing treated face is used for coil insulation.

Dual aperture quadrupole prototype(DAQ)



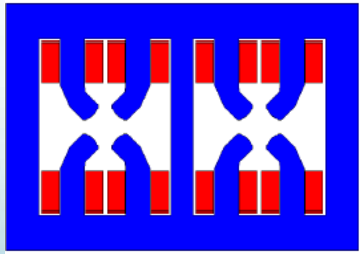
The fields in the two apertures are coupled.





The fields in the two apertures are coupled.

- The DAQ prototype with F/D polarity has a strong cross talk effect which results in large b1 and b3 component and the field harmonics varies when the field is not symmetric, especially when the trim coil is added. The further modification is in progress.
- Another solution with the same polarity in the two apertures is initially designed. This kind of quadrupole with 8 coils can work but consume much more power.

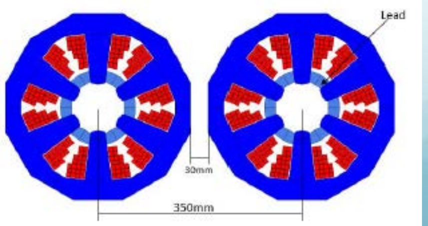


Two quadrupole magnets locate side by side

- Nearly no cross talk effect between the two apertures.

Sextupole

Two single aperture sextupoles are installed side by side



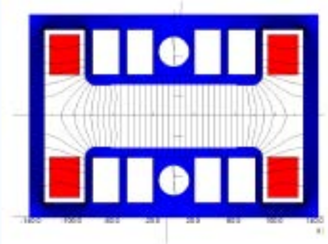
A sextupole magnet has been redesigned and the mechanical is in progress. The prototype is planned.

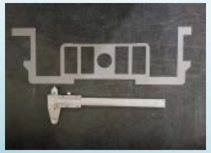
Booster Magnets

	BST-63B
Quantity	16320
Minimum field (Gs)	28
Maximum field (Gs)	338
Gap (mm)	63
Magnetic Length (mm)	4700
Good field region (mm)	55
Field uniformity	0.1%
Field reproducibility	0.05%

Two kinds of the subscale prototype magnet **with** and **without iron cores** have been designed and developed. The field quality of the magnet without iron cores reaches the specifications.

dipole magnet with iron cores

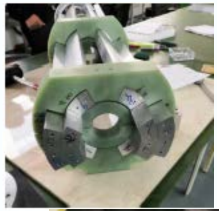
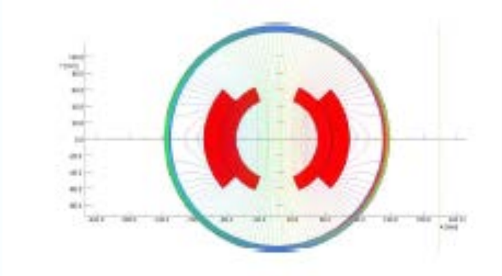


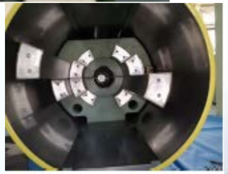
The dipole magnet with iron core was tested in the lab.

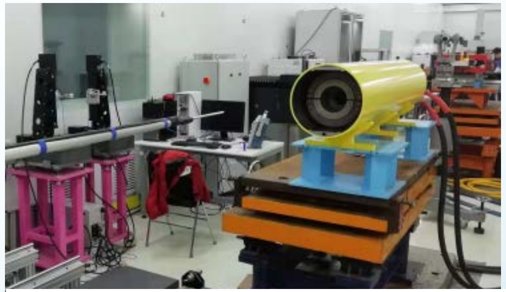
The field uniformity in GFR is about 0.3% at low field level of 28Gs and 0.1% at high field level, which can not meet the requirements.

dipole magnet without iron cores

The Cosθ (CT) coil is a conventional measure for high field superconducting magnets, it is the first time for design of the high precision low field magnet.



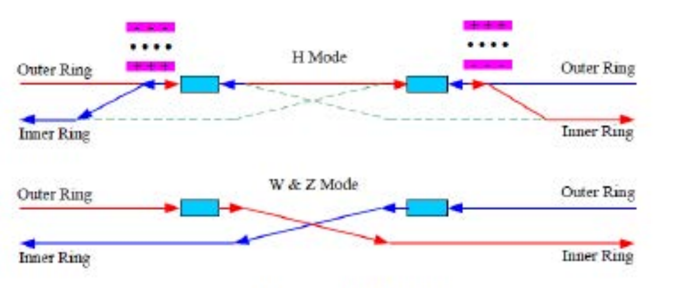



The CT coil dipole magnet was tested in the lab.

The CT coil dipole magnet without iron cores has high precision and good reproducibility field both at low and high field level, which is satisfied with the requirements. The full-scale CT dipole magnet has been designed on the basis of the good test results of the subscale prototype magnet and will be fabricated in the Jun. of next year.

Special Magnets

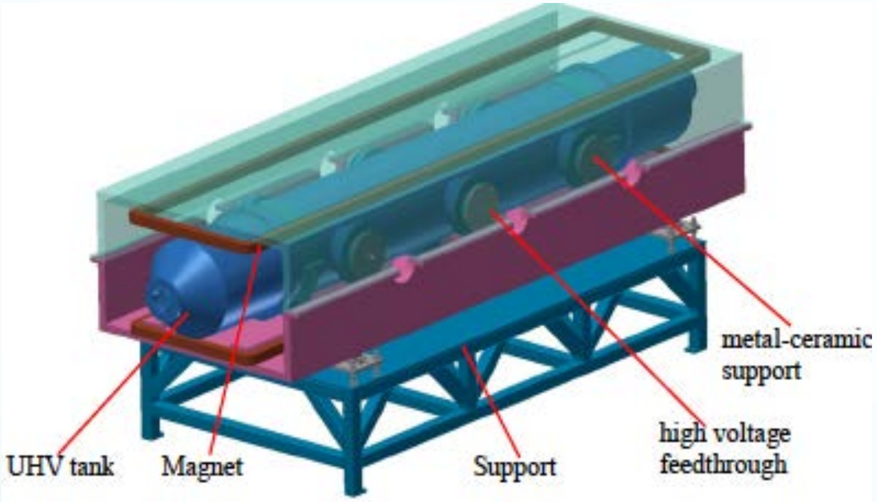
Electro-Magnetic Separator



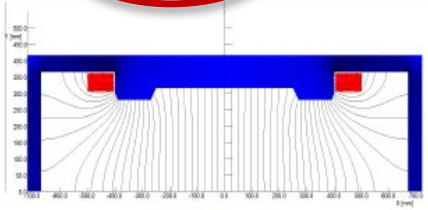
Layout of RF region

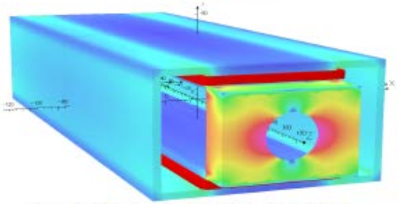
	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm x 11mm	5×10^{-4}
Dipole	66.7Gauss	4m	46mm x 11mm	5×10^{-4}

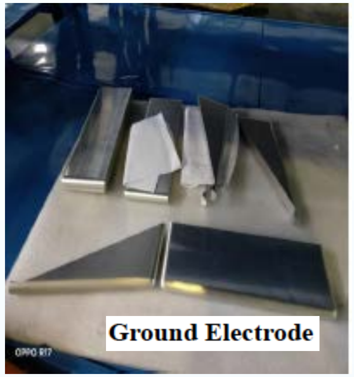
The Electro-Magnetic Separator is a device consisting of perpendicular electric and magnetic fields. One set of Electro-Magnetic Separators including 8 units, total 32 units will be need for CEPC.

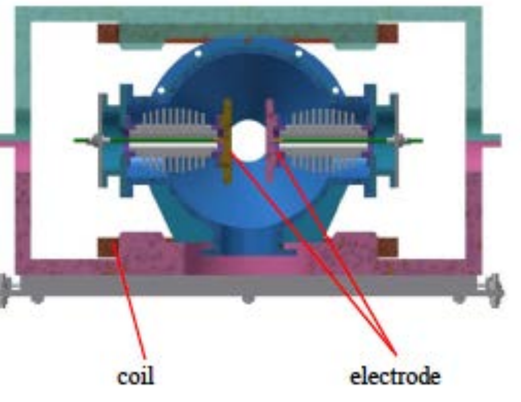


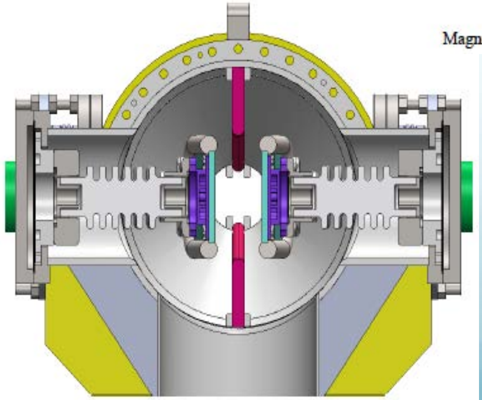
structure drawing of Electro-Magnetic Separator

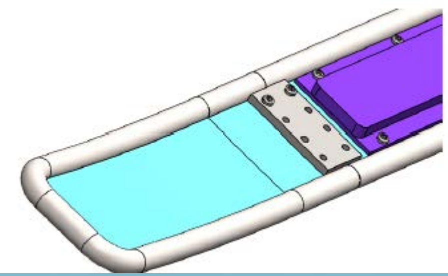

Field Distribution


Magnetic flux density distribution in 3D Model










Titanium rod an plate at both ends


Titanium rod processing completed

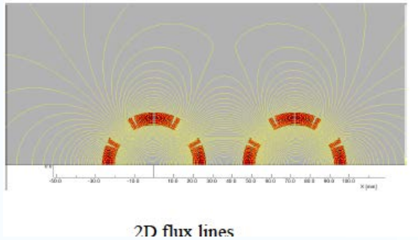
Special Magnets

To greatly squeeze the beam for high luminosity, compact high gradient final focus quadrupole magnets are required on both sides of the IP points in CEPC collider ring.

CEPC IR Superconducting Magnets

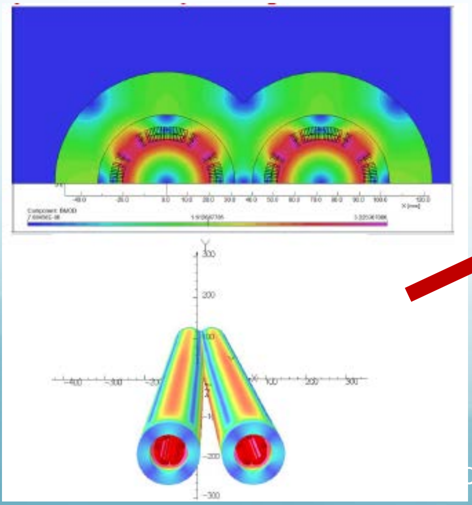
Facility: CEPC IR SC magnet test facility (lab) is located in Keye company joinly with IHEP

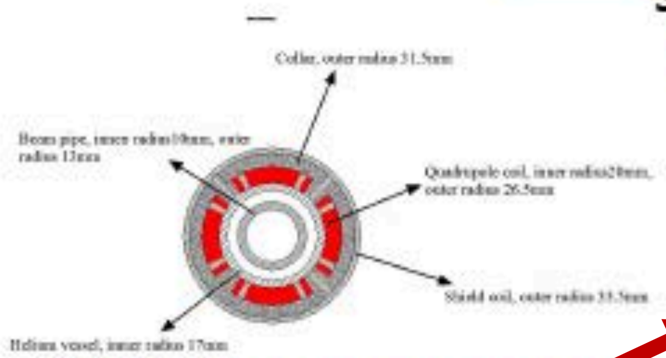
Option1: Iron-free design of QD0 (CDR)



2D flux lines

Option2: QD0 design with iron



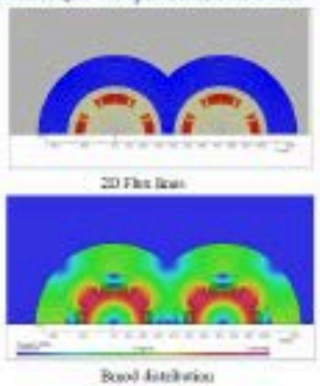


Room-temperature vacuum chamber with a clearance gap of 4 mm

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QD0	136	2.0	19.51	72.61

Superconducting QD coils

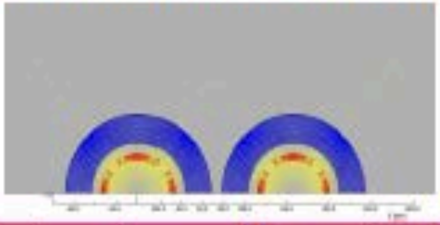
- 2D field cross talk of QD0 two apertures near the IP side.



2D Flux lines

Bmod distribution

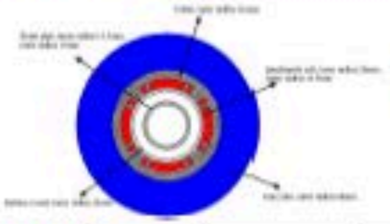
Superconducting QF coils



There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

QF1 Integral field harmonics with shield coils ($\times 10^{-4}$)

n	B_n/B_2@R=13.5mm
2	10000
6	1.08
10	-0.34
14	0.002



One of QF1 aperture (Peak field 3.8T)

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QF1	110	1.48	27.0	146.20

Beam Instrumentation

	Item	Method	Parameter	Amounts
Linac	Beam position	Stripline BPM	Resolution：30um	140
	Beam current	ICT	2.5%@1nC-10nC	42
	Beam profile	YAG/OTR	Resolution: 30um	80
	Beam emittance	Q+PR	10%	3
	Beam energy & spread	AM+PR	0.1%	3
Damping ring	Average current	DCCT	Resolution :50uA@0.1mA-30mA	1
	Beam position	Button BPM	Resolution : 20um @ 5mA TBT	40
	Tune measurement	Frequency sweeping	Resolution:0.001	1

	Item		Method	Parameter	Amounts
Booster	Beam position monitor	Turn by turn	Button electrode BPM	Measurement area (x × y) ：±20mm×±10mm Resolution：<0.02mm Measurement time of COD：< 4 s	1808
		Bunch by bunch	Button electrode BPM	Measurement area (x × y) ：±40mm×±20mm Resolution：0.1mm	
	Bunch current		BCM	Measurement range：10mA / per bunch Relatively precision：1/4095	2
	Average current		DCCT	Dynamic measurement range：0.0~1.5A Resolution:50uA@0.6-8mA Linearity：0.1 % Zero drift: <0.05mA	2
	Beam size		Double slit interferometer x ray pin hole	Resolution:0.2 μm	2
	Bunch length		Streak camera Two photon intensity interferometer	Resolution:1 ps	2
	Tune measurement		Frequency sweeping method	Resolution:0.001	2
			DDD	Resolution:0.001	
	Beam loss monitor		optical fiber	Space resolution:0.6m	400
	Feedback system		TFB	Damping time<=3ms	2
	Feedback system		LFB	Damping time<=35ms（50ms）	2

	Item		Method	Parameter	Amounts
Storage ring	Beam position monitor	Closed orbit	Button electrode BPM	Measurement area (x × y) ：±20mm×±10mm Resolution：<0.6um Measurement time of COD：< 4 s	2900
		Bunch by bunch	Button electrode BPM	Measurement area (x × y) ：±40mm×±20mm Resolution：0.1mm	
	Bunch current		BCM	Measurement range：10mA / per bunch Relatively precision：1/4095	2
	Average current		DCCT	Dynamic measurement range：0.0~1.5A Linearity：0.1 % Zero drift: <0.05mA	2
	Beam size		Double slit interferometer x ray pin hole	Resolution:0.2 μm	4
	Bunch length		Streak camera Two photon intensity interferometer	Resolution:1ps@10ps	2
	Tune measurement		Frequency sweeping method	Resolution:0.001	2
			DDD	Resolution:0.001	
	Beam loss monitor		PIN-diode	Dynamic range:120 dB Maximum counting rates≥10 MHz	5800
	Feedback system		TFB	Damping time<=47ms	2
			LFB	Damping time<=100ms	2

- To **reduce the budget** of **BI system**, due to a large number of monitors and the high price of commercial products. Such as BPM and beam loss monitor
- Key technologies of beam diagnostics. Beam instrument at IP and beam feed back system
- Easy to maintain and upgrade

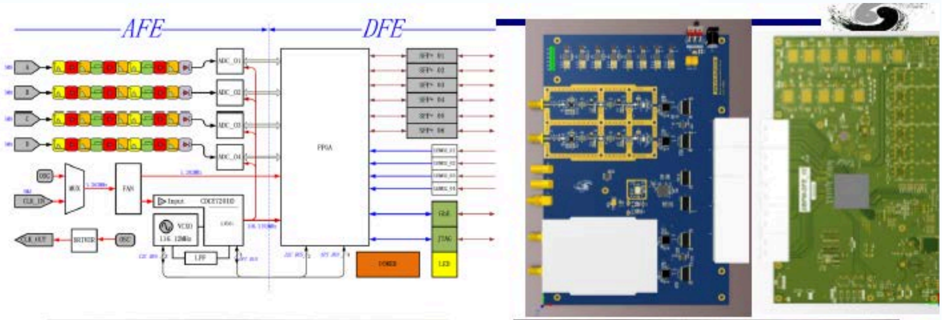
Beam Instrumentation

CEPC beam instrumentation R&D

- Beam position monitor system
  - BPM electronics
  - Feed through R&D
  - BPM at interaction point（IP）
- Beam loss monitor
- Feedback systems

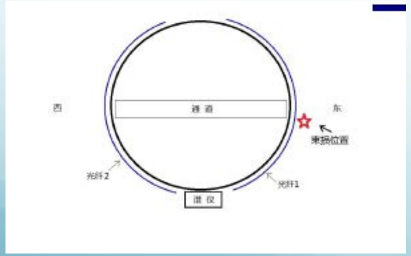
BPM feed-through V2.0

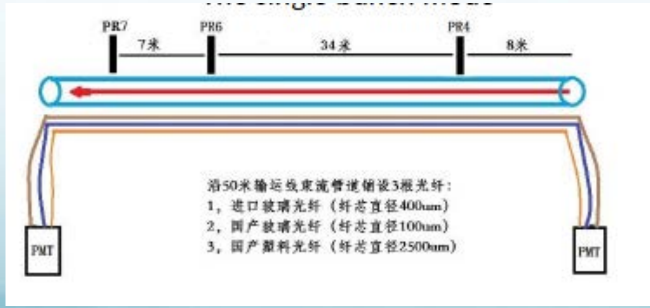
BPM electronics version 2.0



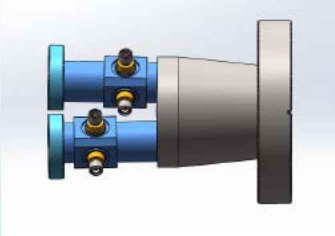
Application of BPM electronics in BEPCII

Optical fiber based BLM test in BEPCII

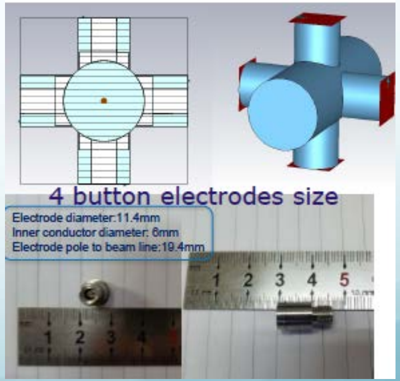




beam instrumentation of IP



4 button electrodes structure



Many others... Not less important

- Injection / Extraction
- Vacuum
- Mechanics
- Alignment
- Civil Engineering
- High-Field Magnets

- ....

Talk CEPC Accelerator Status and TDR Progress by J. Gao and Accelerator sessions

Many others... Not less important

- Injection / Extraction
- Vacuum
- Mechanics
- Alignment
- Civil Engin-
- Hig'
- ....

In Summary:

Amazing effort on Accelerator technology R&D

Talk CEPC Acc ... by J. Gao and Accelerator sessions

Issues, Challenges and Perspectives

Issues requiring further beam dynamics studies I

- Design for **maximum energy efficiency.**
- **Attainable vertical emittance** in presence of various errors and with colliding beams, and further luminosity optimization. **Alignment tolerances** and alignment system.
- Complete **impedance model**, with an evaluation of transverse multibunch resistive-wall instability and single-bunch longitudinal microwave instability. **Ion and electron-cloud instabilities** with mitigation measures. Design and performance of a **bunch-by-bunch feedback system. Interplay of impedance and beam-beam effects**.
- **Finalisation, integration & completion of beam optics**, incl. tuning flexibility, injection & extraction systems. Design for **different numbers of collision points**. **Dynamic aperture optimization.**
- **Collimation / masking and machine protection strategy.**
- **Specification of beam instrumentation and the required measurement precision/accuracy.**
- **Optimization of the injector complex** (higher-energy linac versus pre-booster, linac pulse)
- Energy calibration **resonant depolarization process**

Issues, Challenges and Perspectives

Issues requiring further beam dynamics studies II

- **Interaction region optimization and shielding of the hard synchrotron radiation** including radiation from the final quadrupoles.
- Further **off-momentum dynamic aperture optimisation** to maximize beamstrahlung lifetime.
- **Operational scenarios supporting higher luminosity and shorter beam lifetimes** with more frequent injections.
- **Single-bunch beam instabilities with highest bunch charge.**
- **RF system changes for collider and booster, with associated modified optics configuration.**
- **Machine protection and radioprotection**.

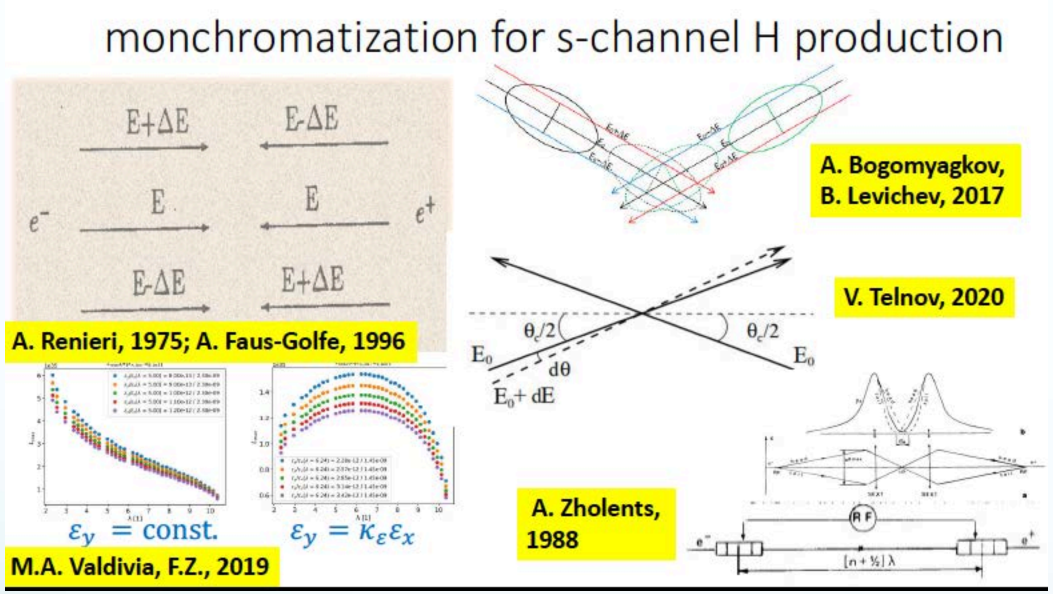
More info in talk FCC-ee issues and FCC-hh key issues by F. Zimmermann

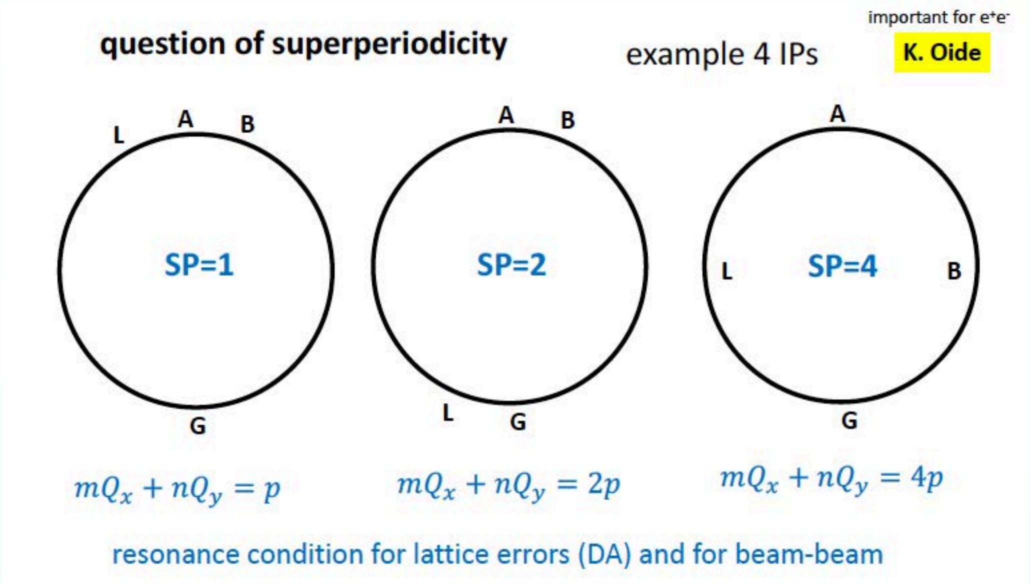
Challenges

- **Consolidation and Realization of the on going Accelerator R&D**
- **Industrialization and the participation of the industries in the process from the beginning**

Issues, Challenges and Perspectives

Perspectives ....some dose of fantasy and exoticism

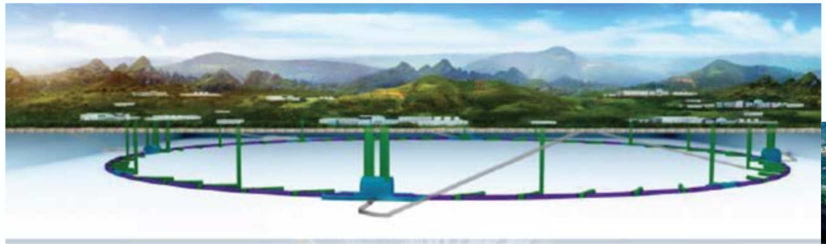


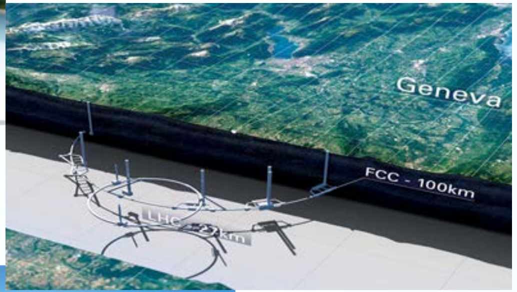


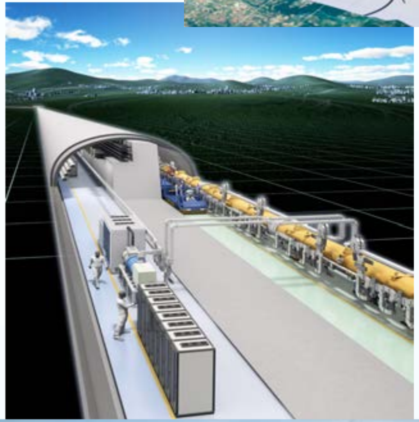
Issues, Challenges and Perspectives

Perspectives ....some dose of fantas

Young, novel fresh ideas.. are needed.
Lots of work still ahead of us,
excellent synergies between CEPC
and all the other collider studies to be reinforced

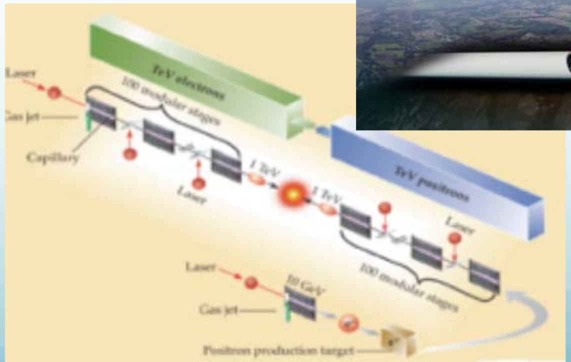


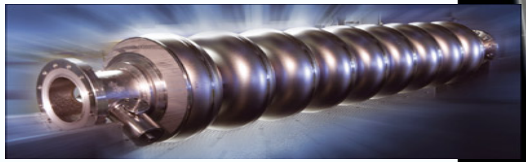


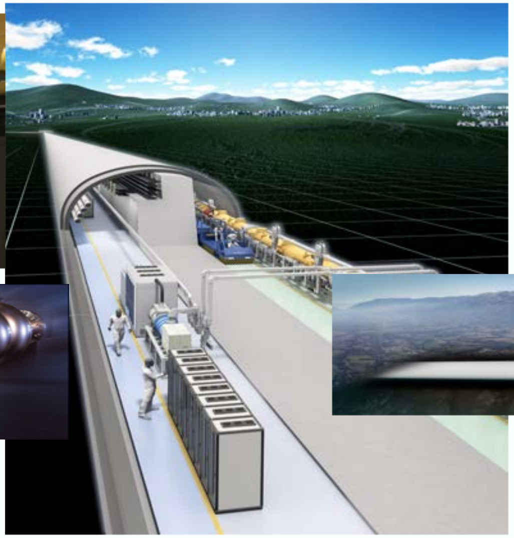


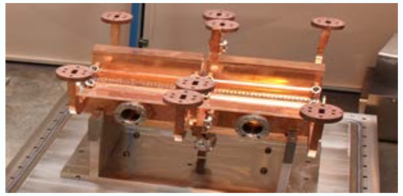
……..But when theorists are more confused, it's the time for more, not less experiments.

(Nima Arkani-Hamed Cern Courier March 2019)









Thanks for your attention