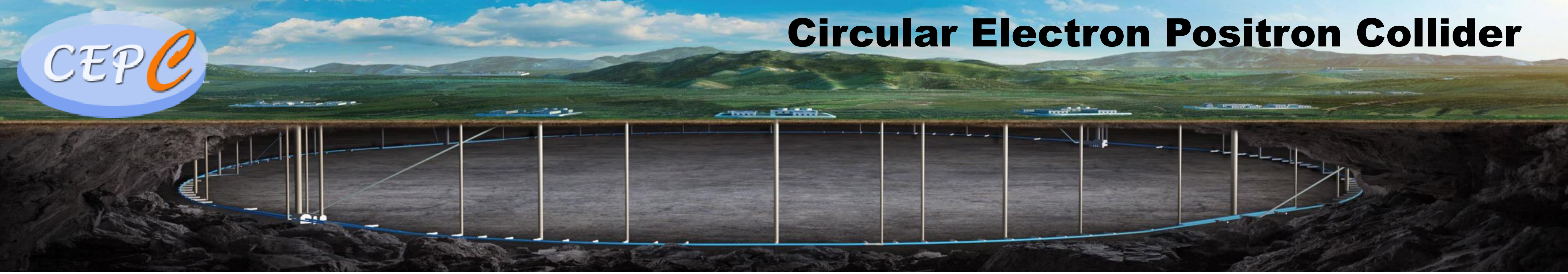

CEPC: overall status and prospects for beam polarization

Zhe Duan
On behalf of the CEPC Study Group

Institute of High Energy Physics, CAS

Courtesy of Yuhui Li, Jie Gao, Xinchou Lou, Manqi Ruan, Dazhang Li, Qingjin Xu for their help in preparing the slides.

Detailed updates see presentations in HKUST-IAS HEP Conf Jan 22-25, 2024, Hong Kong, in particular Jie Gao's overview

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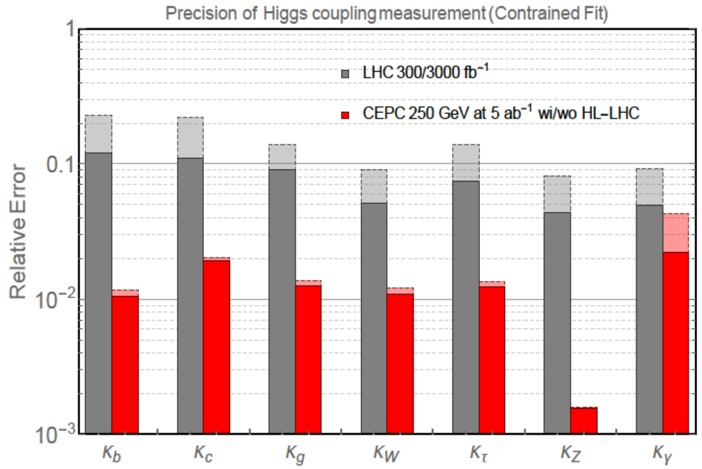
Outline

- Overall status of CEPC
- Prospects for beam polarization @ CEPC

A brief introduction of CEPC

- ❑ Circular Electron-Positron Collider (CEPC) as a Higgs (Z / W / $t\bar{t}$) factory in China
  - ❑ Higgs Factory (>1M Higgs, ~1% precision)
  - ❑ Z Factory (~Tera Z)
  - ❑ The W^+W^- pair and then $t\bar{t}$ pair production thresholds
  - ❑ Higgs, EW, flavor physics & QCD, probe to new physics up to 10 TeV
- ❑ Possible *pp* collider (SppC) of $\sqrt{s}$ ~ 125 TeV (TDR spec.) in the far future.



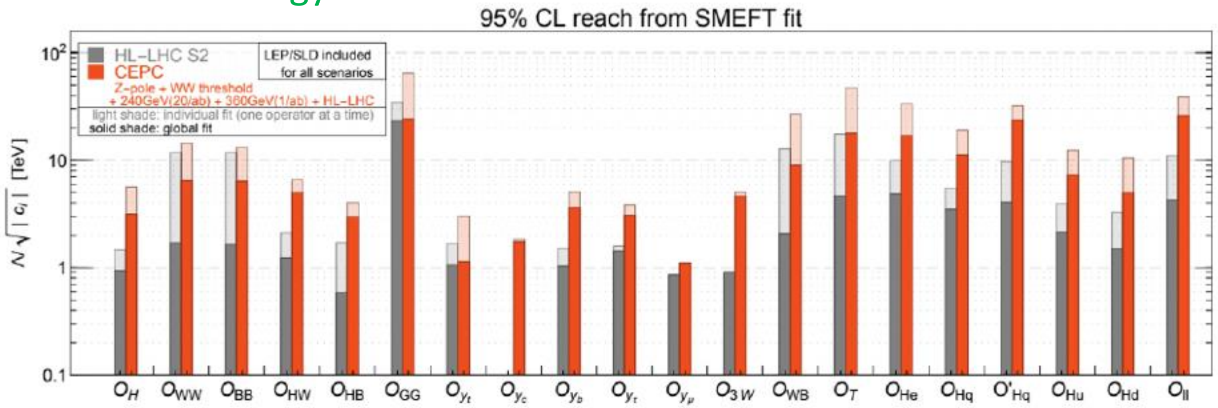
Anticipated accuracy on Higgs properties at CEPC versus at LHC/HL-LHC

CEPC Operation Plan and Goals

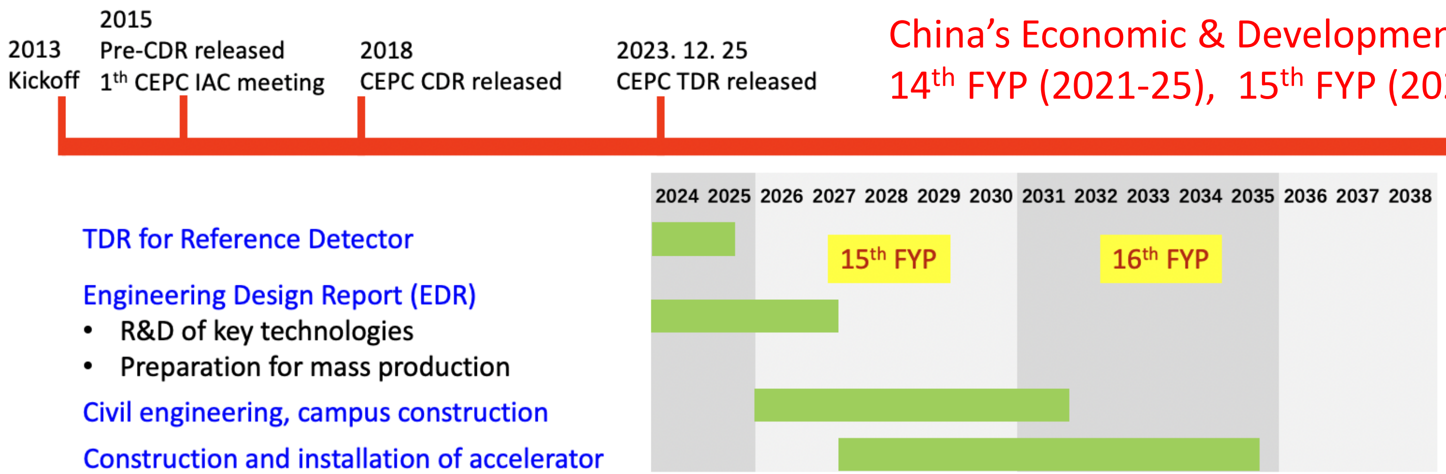
Particle	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. /IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. /yr (ab^{-1}, 2 IPs)	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

* Higgs is the top priority. The CEPC will commence its operation with a focus on Higgs.
** Detector solenoid field is 2 Tesla during Z operation, 3Tesla for all other energies.
*** Calculated using 3,600 hours per year for data collection.

Covered energy scales of NP

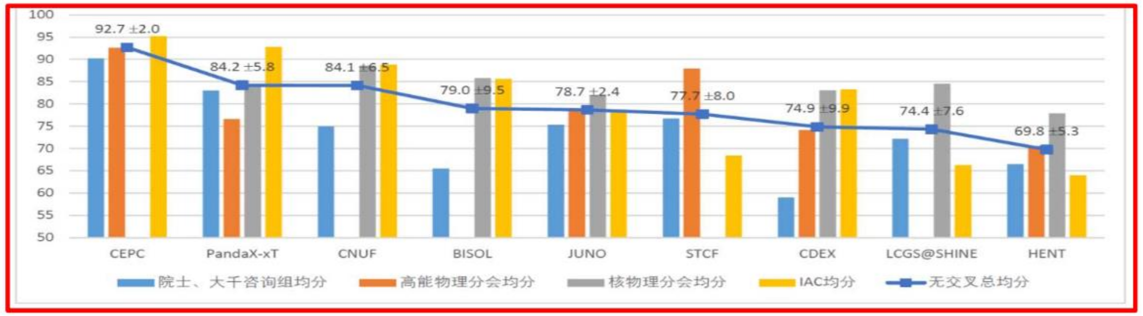


Timeline and status



China's Economic & Development follow a 5-year cycle:
14th FYP (2021-25), 15th FYP (2026-30) , 16th FYP (2030-35)

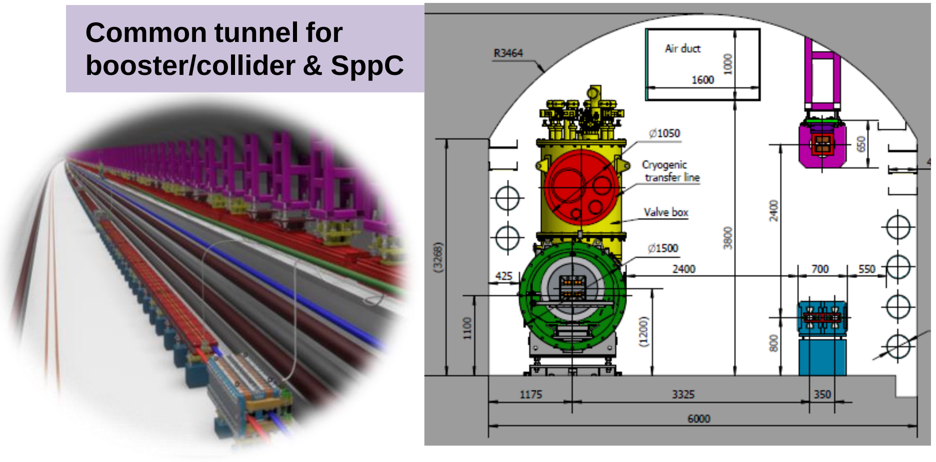
- **Chinese Academy of Sciences (CAS) is planning for the 15th 5-year-plan (2026-2030) for large science projects,** a steering committee has been established, **chaired by the President of CAS.**
  - **High energy physics & nuclear physics**, **is one of the 8 groups (fields) .**
  - **CEPC is ranked No. 1, with the smallest uncertainties, by every evaluation committee both domestic and international ones among all the collected proposals in this group.**
  - **A final report has been submitted to CAS for consideration.**
- **The abovementioned process is within CAS.**
- **The following national selection process around 2025 will be decisive.**

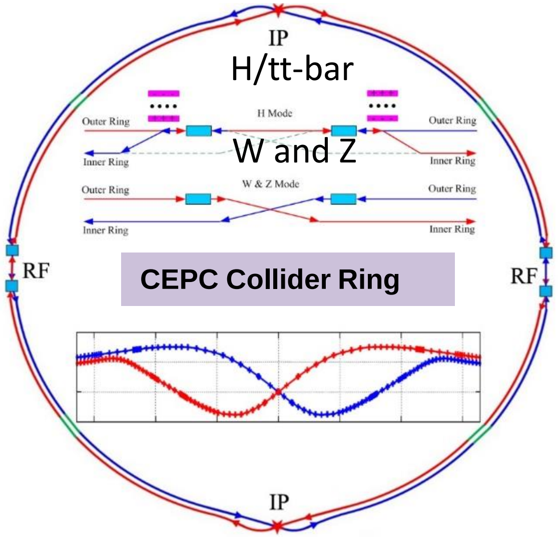


Accelerator Considerations in TDR

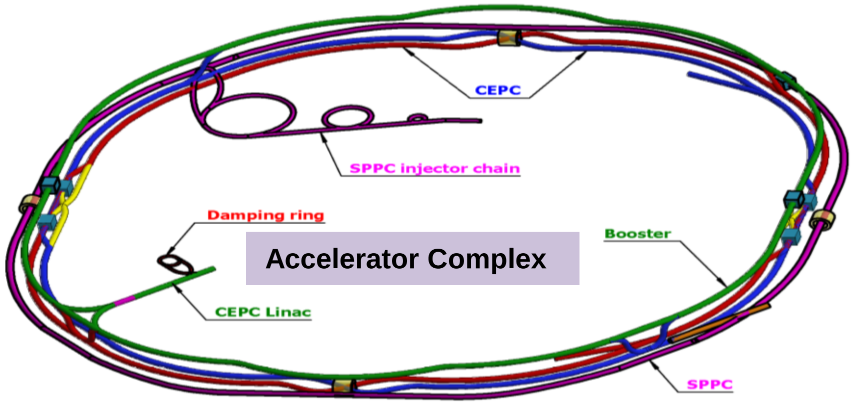
- **Circular collider**: Higher luminosity than a linear collider
- **100km circumference**: Optimal total cost
- **Shared tunnel**: Compatible design for CEPC and SppC
- **Seamless switchable operation**: Higgs/W/Z/(ttbar)
- Accelerator complex comprised of a 30 GeV Linac, a 100 km booster and a double-ring e+/e- collider with two IPs
- **High energy & high flux synchrotron light source** provides γ-ray up to 300 MeV, critical for multi-disciplinary sciences

Common tunnel for booster/collider & SppC

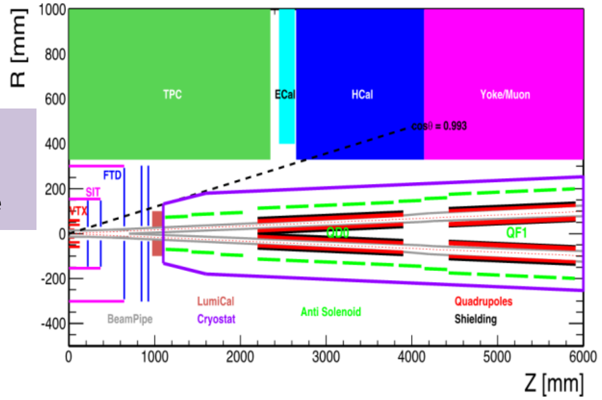


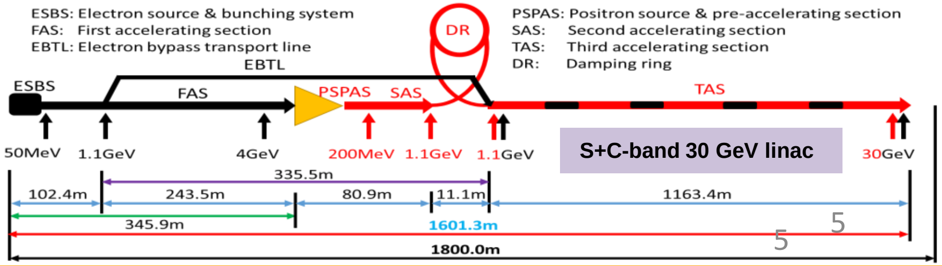


Seamless mode switch for Higgs/Z/W/(ttbar)



Machine Detector Interface



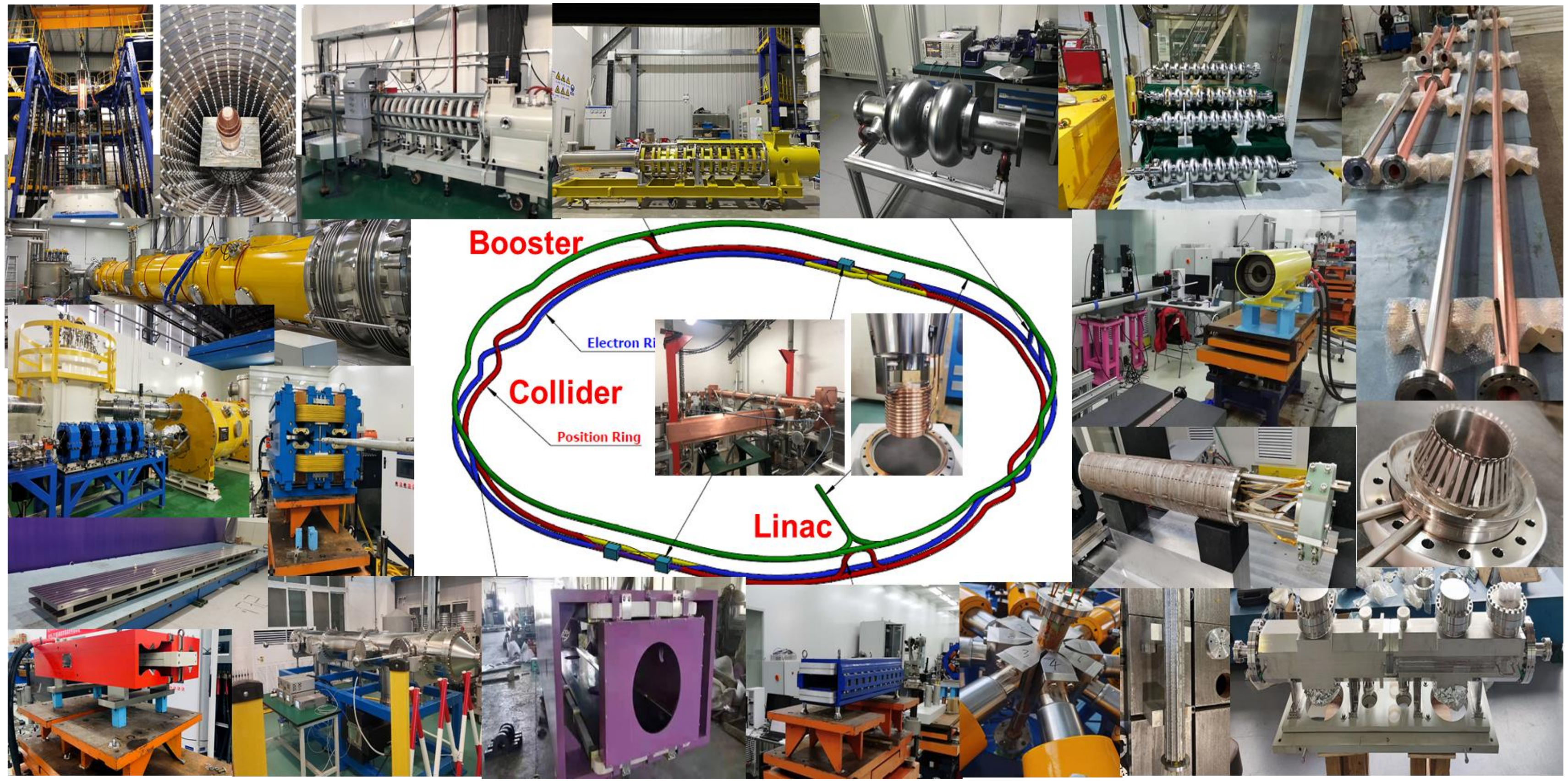


Baseline: 100 km, 30 MW; Upgradable to 50 MW, High Lumi Z, ttbar

Hardware R&D progress in the TDR

representative Key Technologies for the CEPC

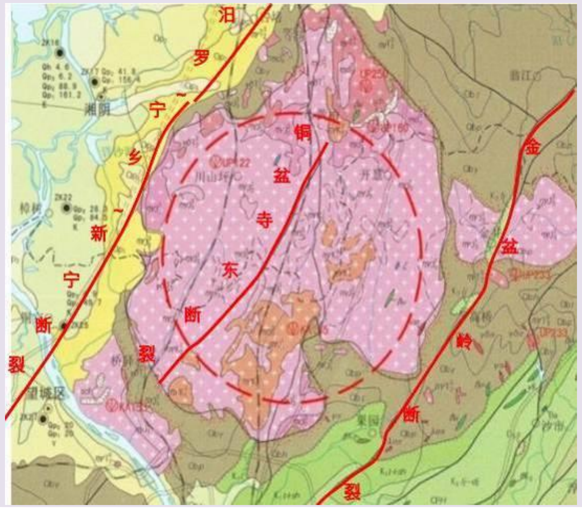
Specification Met ✓ — Prototype Manufactured ✓

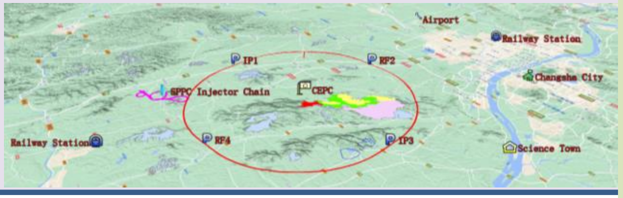


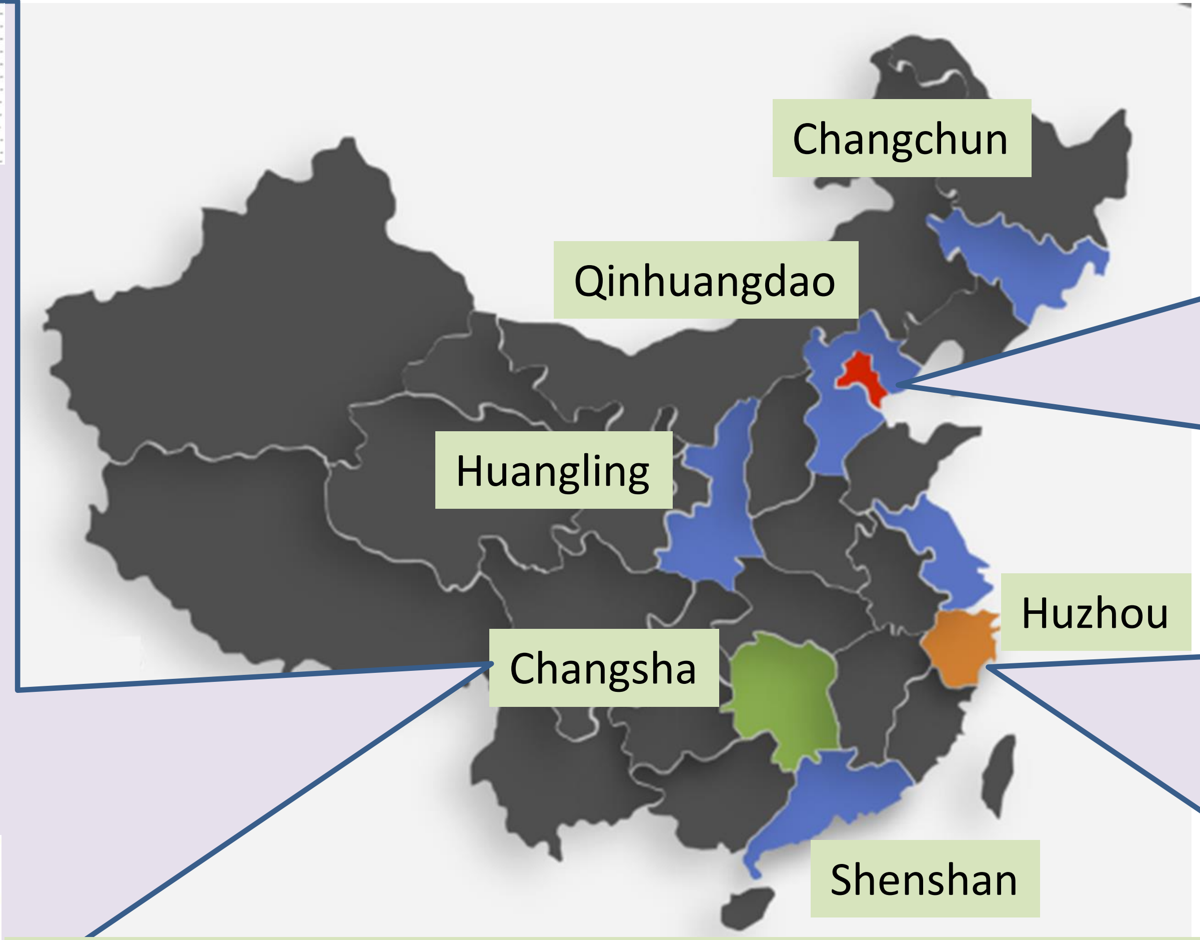
Accelerator	Fraction
✓ Magnets	27.3%
✓ Vacuum	18.3%
✓ RF power source	9.1%
✓ Mechanics	7.6%
✓ Magnet power supplies	7.0%
✓ SC RF	7.1%
✓ Cryogenics	6.5%
✓ Linac and sources	5.5%
✓ Instrumentation	5.3%
✓ Control	2.4%
✓ Survey and alignment	2.4%
✓ Radiation protection	1.0%
✓ SC magnets	0.4%
✓ Damping ring	0.2%

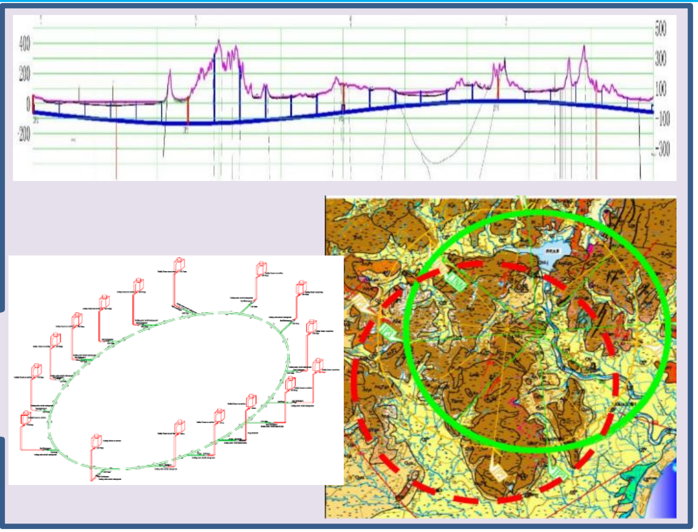
Key technology R&D spans all component lists in CEPC CDR

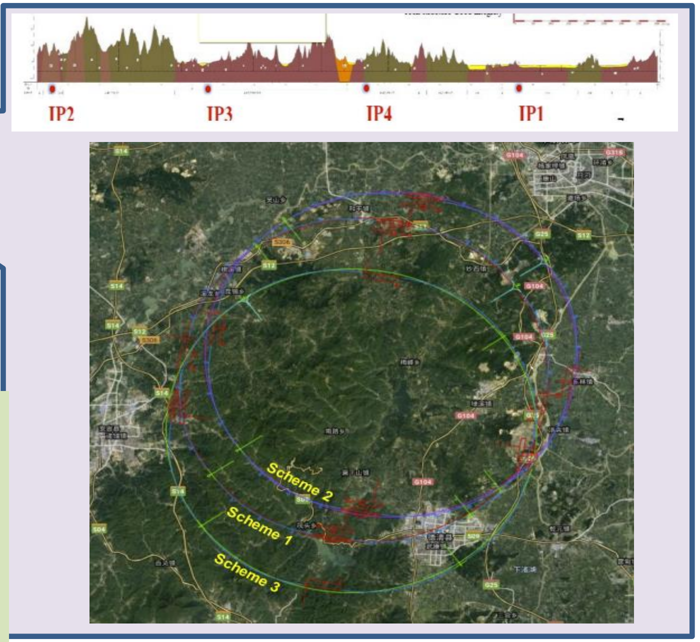
Site Preparation









- Six cities were investigated as potential site for the CEPC;
- Geodetic survey were conducted on all candidate sites
- Qinghuangdao, Changsha and Huzhou are selected for demonstration in TDR;

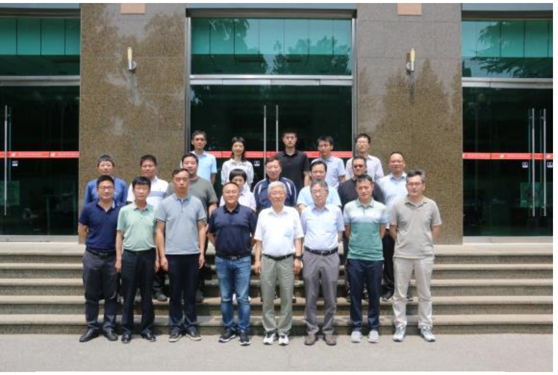
CEPC Accelerator TDR Reviews & Release in 2023

Chaired by Frank Zimmermann

CEPC Accelerator TDR Review
June 12-16, 2023, Hong Kong

Chaired by Leonid Rivkin

CEPC Accelerator TDR Cost Review
Sept. 11-15, 2023, Hong Kong



Domestic Civil Engineering
Cost Review, June 26, 2023, IHEP

Chaired by Brian Foster

9th CEPC IAC 2023 Meeting
Oct. 30-31, 2023, IHEP

The IAC also support another conclusion in the TDR Review Report that the accelerator team is well prepared to **enter the EDR phase**

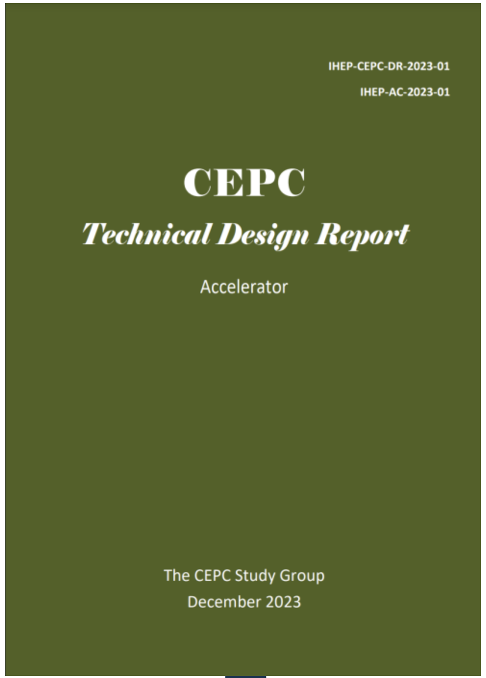
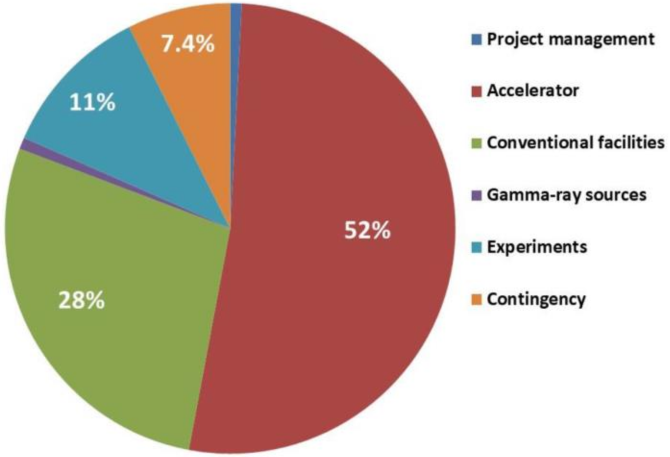


Table 12.1.2: CEPC project cost breakdown, (Unit: 100,000,000 yuan)

Total	**364**	**100%**
Project management	3	0.8%
Accelerator	190	52%
Conventional facilities	101	28%
Gamma-ray beam lines	3	0.8%
Experiments	40	11%
Contingency (8%)	27	7.4%



Distribution of CEPC Project total TDR cost of **36.4B RMB (4.67B EUR)**

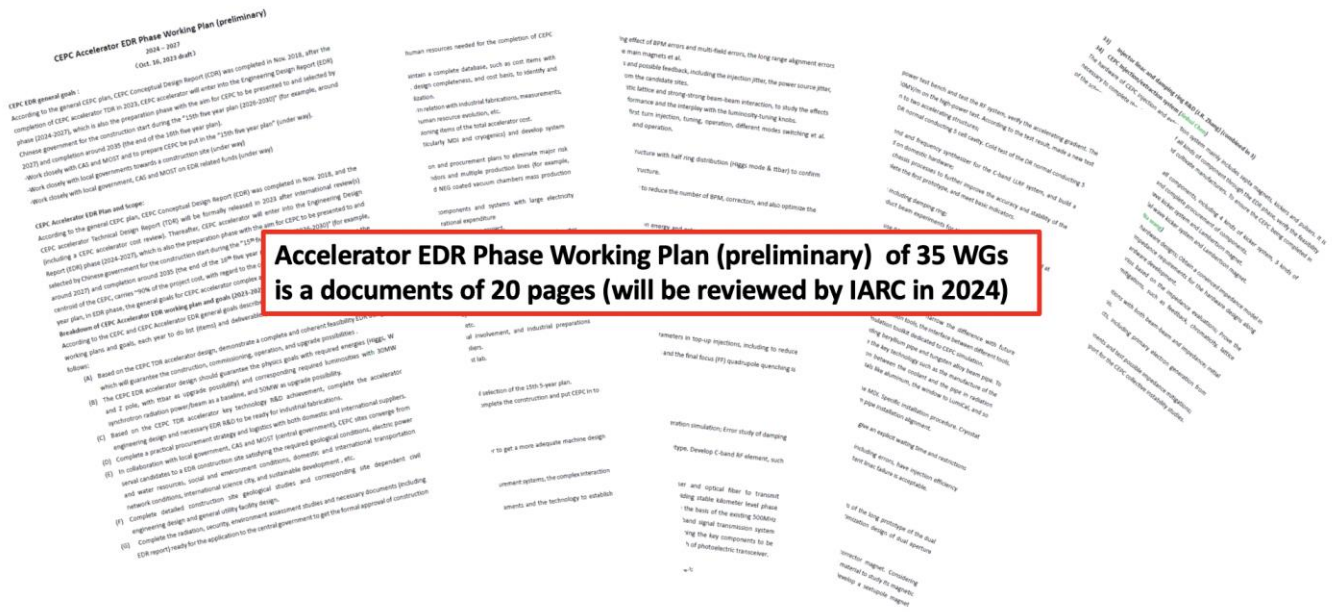
CEPC accelerator TDR has been completed and formally released on December 25, 2023

CEPC accelerator TDR link: (arXiv:2312.14363)

CEPC accelerator TDR releasing news:
http://english.ihep.cas.cn/nw/han/y23/202312/t20231229_654555.html

CEPC Accelerator EDR: Goal, Scope and Plan

- Engineering Design Report (EDR) 2024-2027: preparation phase for
  - CEPC proposal to be presented and selected by Chinese Government around 2025
  - Construction start around 2027 (in **15th Five Year Plan** 2025-2023) and completion around 2035 (the end of **16th Five Year Plan** 2030-2035)



Examples of some key R&D items

- More prototypes
  - SRF
  - Klystron
- More detailed design and planning
  - MDI
  - Control and Timing
  - Alignment and Installation Plan
  - Tunnel Mockup for installation
- Mass production preparation
  - Magnets' Automatic Production Lines
  - Massive Production Line of NEG Coating Vacuum Chamber

CEPC Detector R&D Status

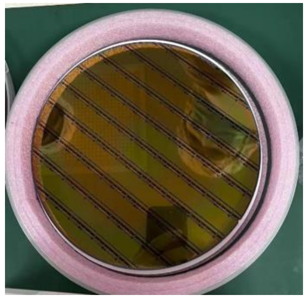
- **Extensive detector R&D benefitted from experiences**
  - Silicon strip detector: Experience from ATLAS upgrade
  - MDI, Drift chamber, SC magnet: Experience from BESIII
- **CEPC R&D on key technologies**
  - Vertex detector
  - TPC/drift chamber
  - PFA calorimeter

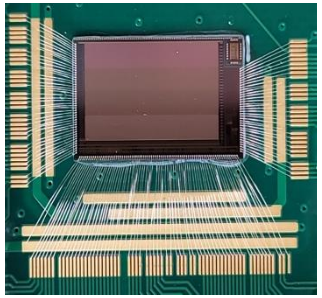
CEPC Detector TDRrd
(rd=reference design)
will be released in June, 2025

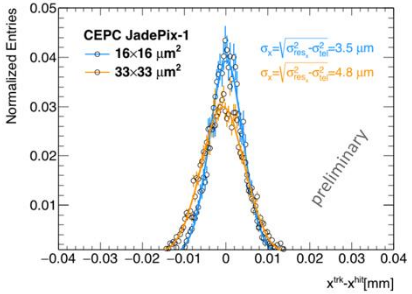
Prototype Manufactured

Sub-detector	Specification	Requirement	World-class level	CEPC prototype
Pixel detector	Spatial resolution	$\sim 3\ \mu m$	$3-5\ \mu m$ [12, 13]	$3-5\ \mu m$ [14–16]
TPC/drift chamber	dE/dx (dN/dx) resolution	$\sim 2\%$	$\sim 4\%$ [17, 18]	$\sim 4\%$ [19–21]
Scintillator-W ECal	Energy resolution Granularity	$< 15\%/\sqrt{E(\mathrm{GeV})}$ $\sim 2\times 2\ \mathrm{cm}^2$	12.5% [22]	Prototype built to be measured $0.5\times 0.5\ \mathrm{cm}^2$
4D crystal ECal	EM energy resolution 3D Granularity	$\sim 3\%/\sqrt{E(\mathrm{GeV})}$ $\sim 2\times 2\times 2\ \mathrm{cm}^3$	$2\%/\sqrt{E(\mathrm{GeV})}$ [23, 24] N/A	Prototyping [25] $\sim 3\%/\sqrt{E(\mathrm{GeV})}$ $\sim 2\times 2\times 2\ \mathrm{cm}^3$
Scintillator-Steel HCal	Support PFA, Single hadron σ_E^{had}	$< 60\%/\sqrt{E(\mathrm{GeV})}$	$57.6/\sqrt{E(\mathrm{GeV})}\%$ [26]	Prototyping
Scintillating glass HCal	Support PFA Single hadron σ_E^{had}	$\sim 40\%/\sqrt{E(\mathrm{GeV})}$	N/A	Prototyping $\sim 40\%/\sqrt{E(\mathrm{GeV})}$
Low-mass Solenoid magnet	Magnet field strength Thickness	2 T – 3 T < 150 mm	1 T – 4 T [27–29] > 270 mm	Prototyping

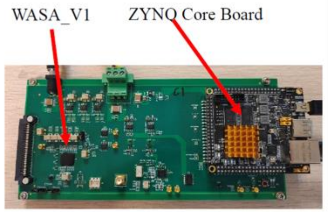
Vertex detector R & D (3- 5 μm reso.)

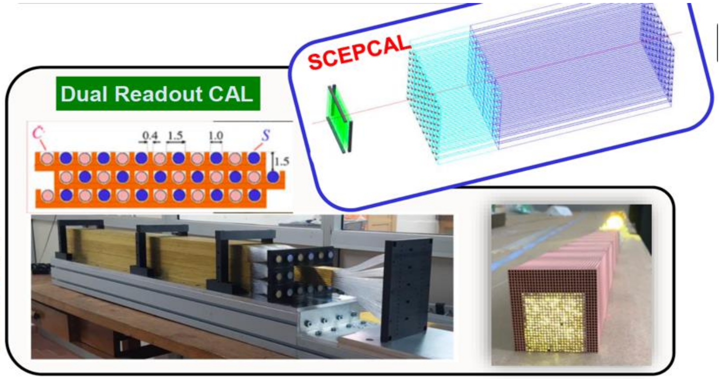






TPC prototype (low power electronics)





4,5 prototypes, 15⁺ years of R&D, all [to be] tested

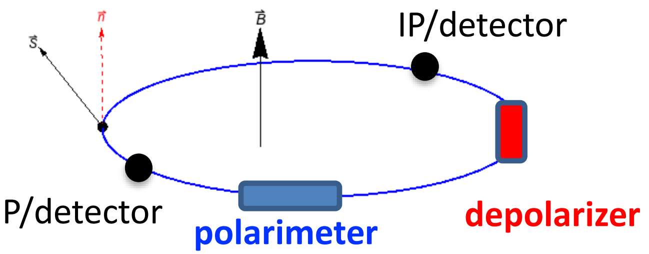
Outline

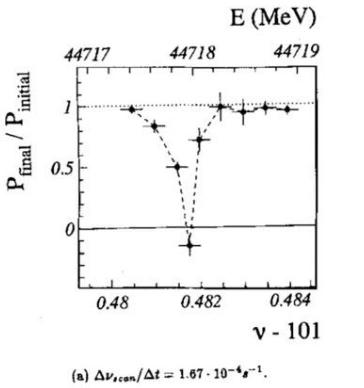
- Overall status of CEPC
- Prospects for beam polarization @ CEPC

Motivation of CEPC polarized beam program

Vertical polarization for resonant depolarization

- Essential for precision measurements of Z and W properties
- > 5% ~ 10% polarization, for both e+ / e- beams

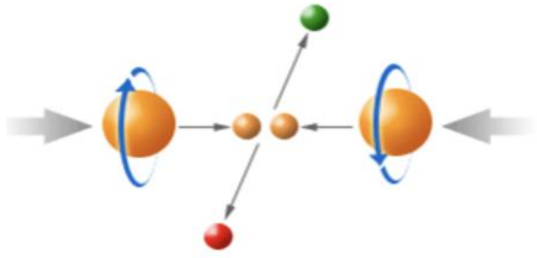




L. Arnaudon, et al., Z. Phys. C 66, 45-62 (1995).

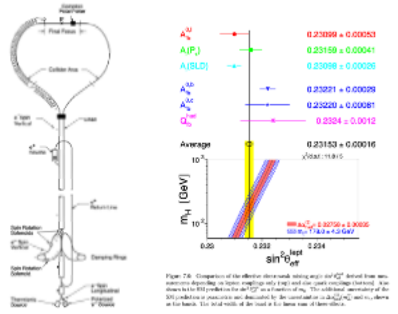
Longitudinal polarization for colliding beams

- Figure of merit: Luminosity * f(P_{e+}, P_{e-})
- 50% or more polarization is desired, for at least one beam; polarizing both beams is beneficial



Actively pursued in ILC, CLIC, EIC, STCF, SuperKEKB etc.

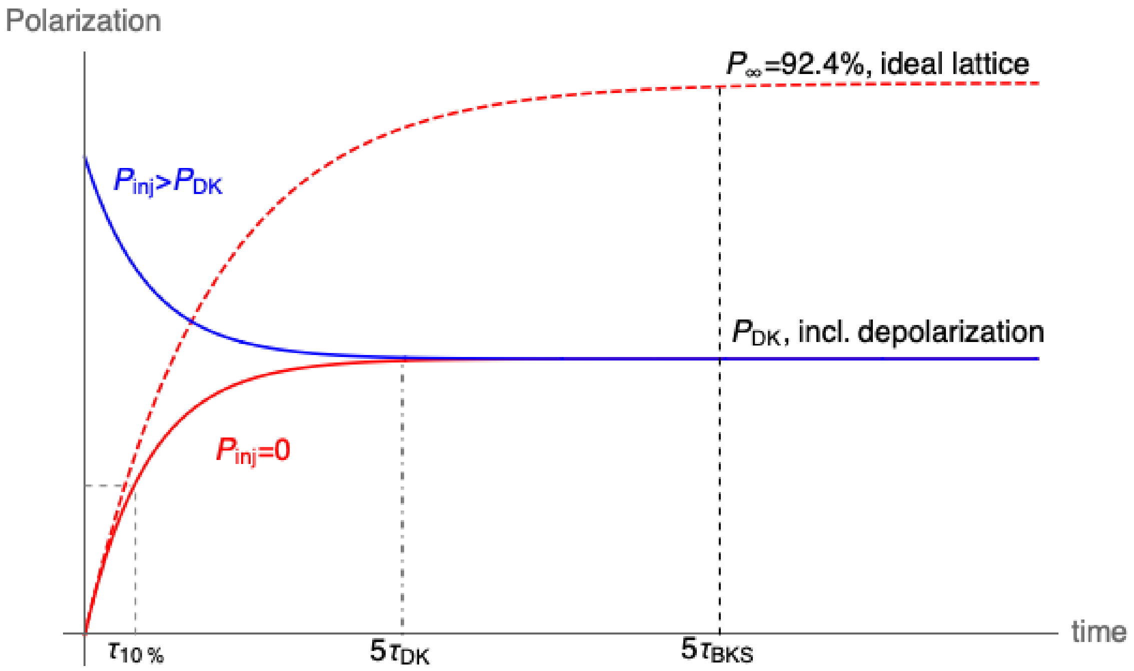
Most notably the measurement of the weak mixing angle @ SLC



	LEP	SLC
No. Z decays events	17 million	0.6 million
Longitudinal polarization	None	e- ~ 80%

- Supported by National Key R&D Program 2018-2023 to design longitudinally polarized colliding beams at Z-pole.
- **Summarized as a chapter in the Appendix of CEPC TDR.**

Self-polarization in the CEPC



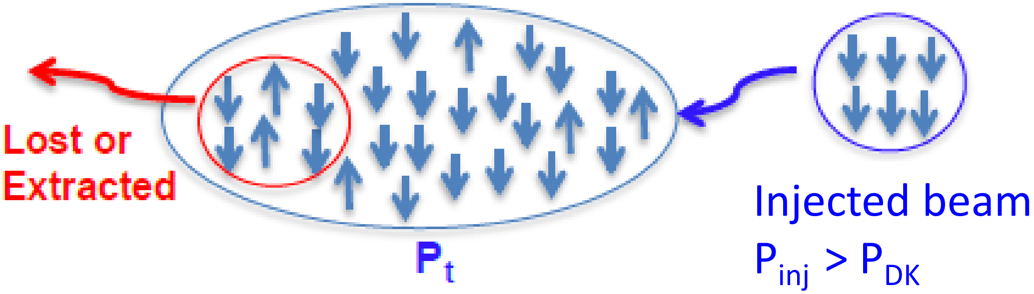
- e+/e- beams become "self-polarized" via the Sokolov-Ternov effect in a storage ring
  - $\tau_{BKS} \propto E^{-5}\rho^2 R$
- Beam polarization build-up rate much slower than the beam decay rate @ Z
  - Boosted with asymmetric wigglers in the Collider (FCC EPOL)
  - Hard to achieve a high-level polarization
  - In conflict with a high luminosity

CEPC CDR parameters	45.6 GeV (Z, 2T)	80 GeV (W)	120 GeV (Higgs)
Polarization build-up time w/o radiative depolarization τ_{BKS} (hour)	256	15.2	2.0
Beam lifetime τ_b (hour)	2.5	1.4	0.43

How to achieve a high-level polarization?

- A high-level polarization (time-averaged) P_{avg} in the Collider is attainable if
  - Top-up injection of highly polarized beam
  - Depolarization rate (τ_{DK}^{-1}) << beam loss rate (τ_b^{-1})

$$P_{\text{avg}} = \frac{P_{\text{inj}}}{1 + \frac{\tau_b}{\tau_{BKS}} \frac{P_\infty}{P_{\text{DK}}}} + \frac{P_{\text{DK}}}{1 + 1/\frac{\tau_b}{\tau_{BKS}} \frac{P_\infty}{P_{\text{DK}}}}$$



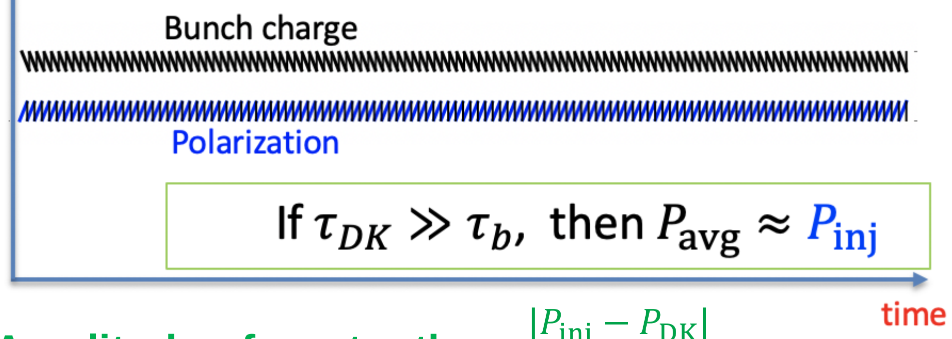
P_{DK} depends on machine imperfections, spin rotators

Assume $P_\infty = 90\%$

$P_{\text{avg}} > 50\%$ requires a minimum value of P_{DK}

	45.6 GeV (Z)	80 GeV (W)	120 GeV (Higgs)
P_{inj} = 50%	P_{DK}>50%	P_{DK}>50%	P_{DK}>50%
P_{inj} = 60%	P_{DK}>4%	P_{DK}>23%	P_{DK}>33%
P_{inj} = 70%	P_{DK}>2%	P_{DK}>15%	P_{DK}>25%
P_{inj} = 80%	P_{DK}>1%	P_{DK}>11%	P_{DK}>20%

Sawtooth-shape evolution during top-up injection

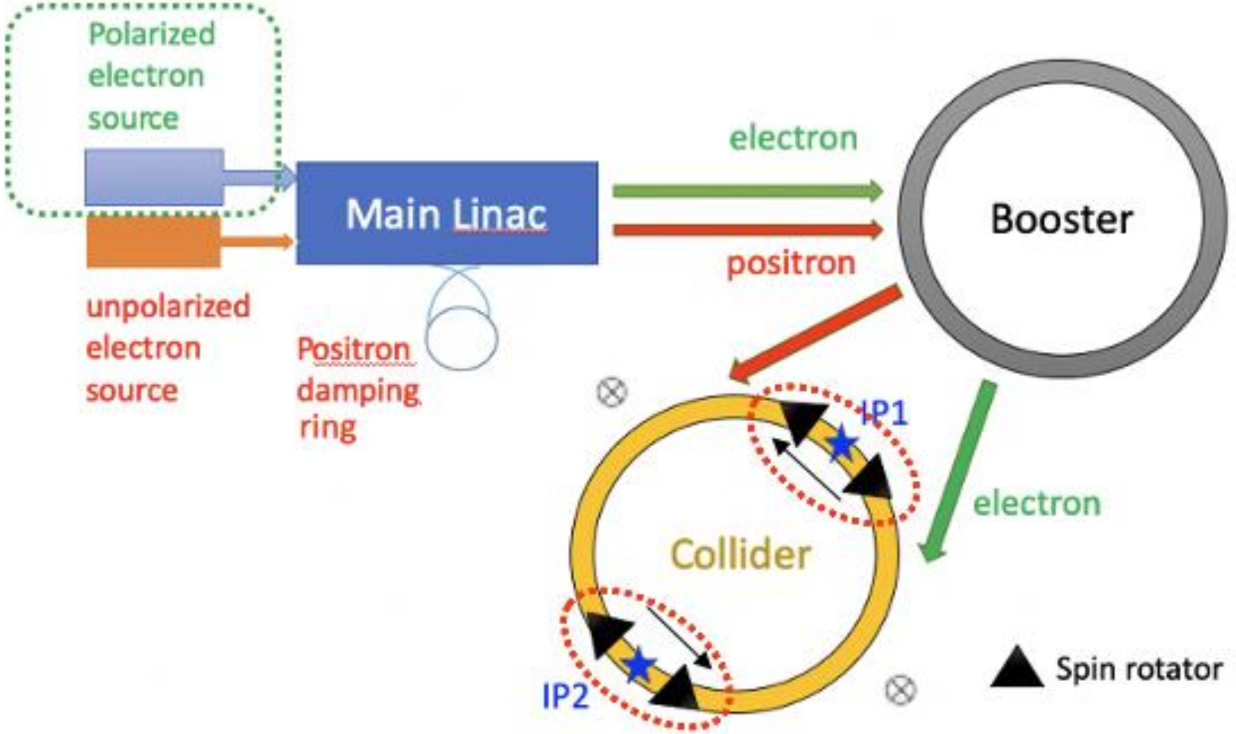


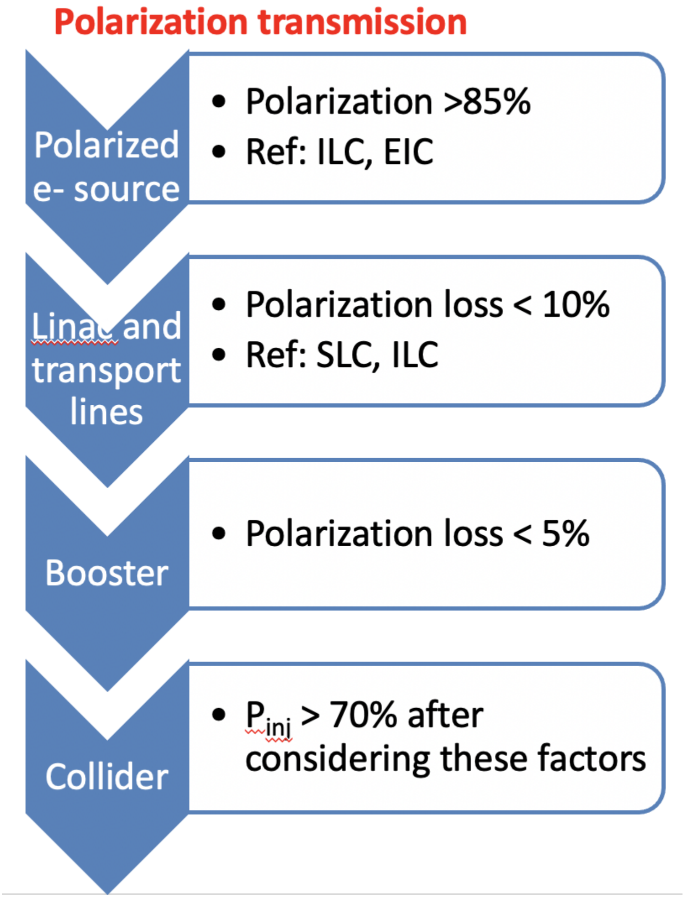
Amplitude of sawtooth ~ $\frac{|P_{\text{inj}} - P_{\text{DK}}|}{(\tau_b + \tau_{\text{DK}})/dt}$

A high-level longitudinal polarization @ Z-pole

- 50%-70% longitudinal polarization **for e- bunches** is a reasonable goal

- **Over 70% injected e- beam polarization is possible.**
- Polarized e+ source is challenging for CEPC [1], polarization transmission efficiency is similar otherwise.



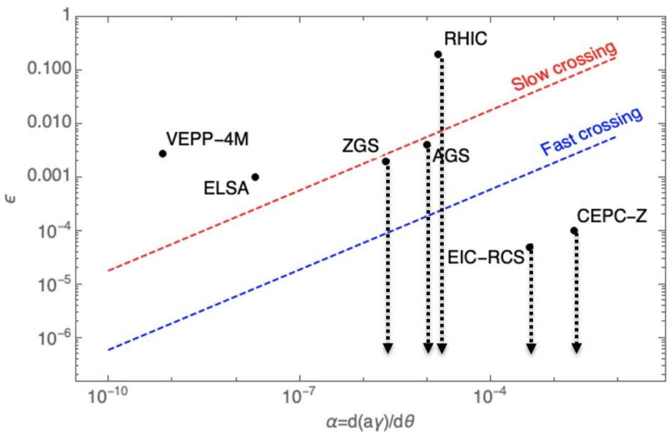


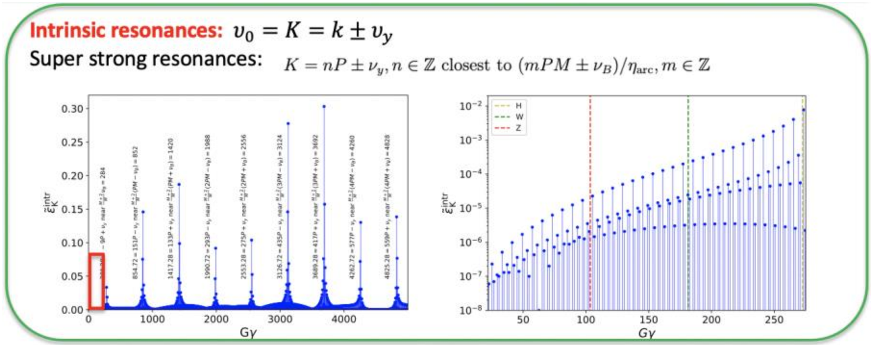
[1] P. Musumeci et al., Positron Sources for Future High Energy Physics Colliders, ArXiv:2204.13245 Phys. (2022).

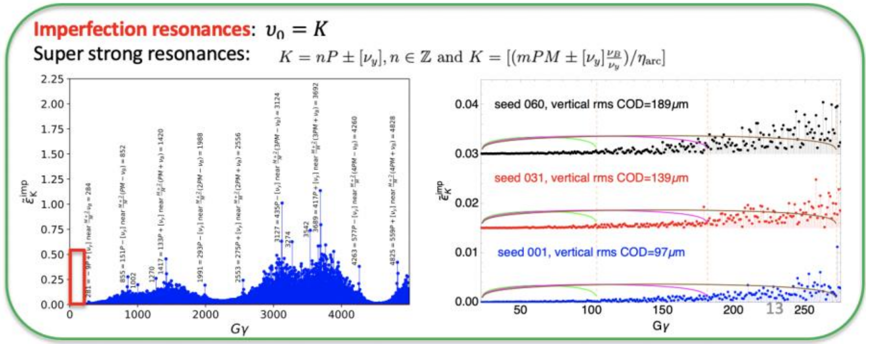
Polarization Maintenance in the Booster

- Concern
  - Depolarization due to crossings of hundreds of spin resonances, during Booster acceleration
- Finding
  - Highly periodic lattice -> structural cancellation -> weak spin resonances
  - Spin resonance crossings lead to **negligible depolarization** to Z

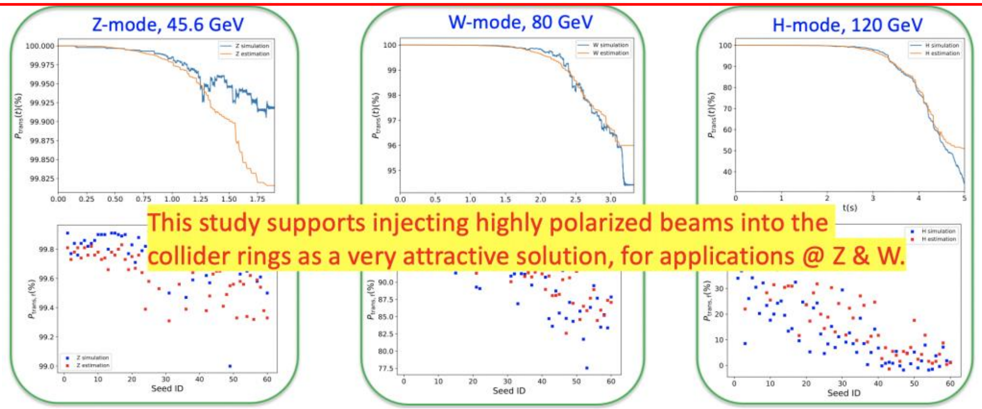
Resonance strength vs ramping rate:
CEPC-Z in the regime of negligible depolarization







Polarization transmission to Z, W and Higgs energies in **Booster:**
Z: over 99%, W: 77.5%~ 98%, Higgs: no better than 40%

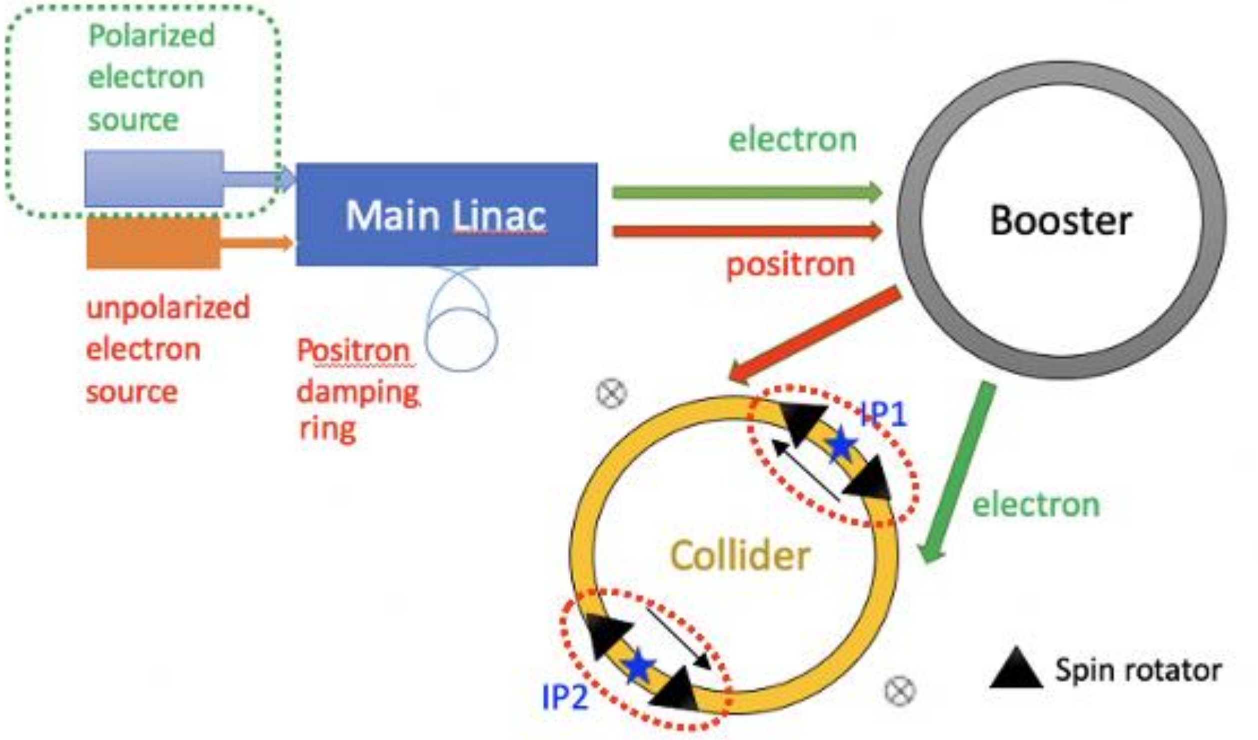


T. Chen, et al., Booster free from spin resonance for future 100-km-scale circular e+e- colliders, Phys. Rev. Accel. Beams, 26, 051003 (2023).

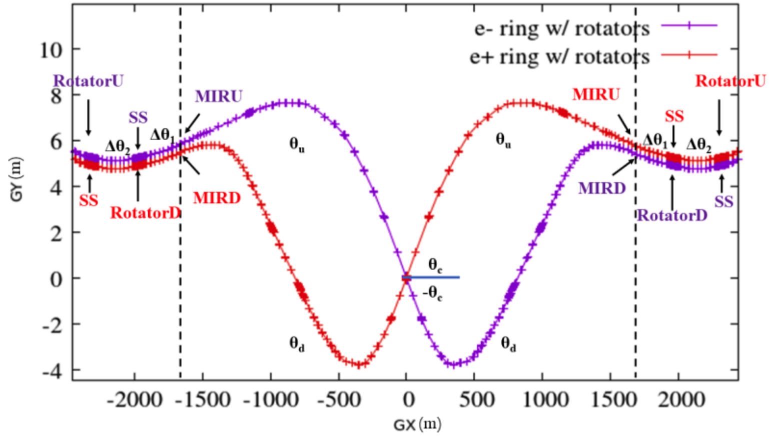
A high-level longitudinal polarization @ Z-pole

- 50%-70% longitudinal polarization for **e- bunches** is a reasonable goal

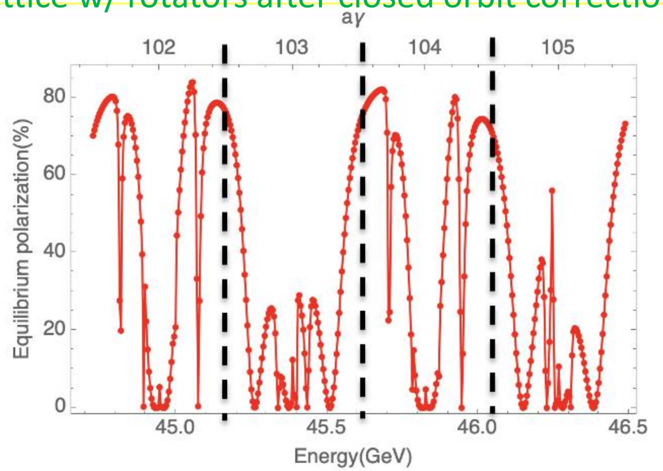
- Over 70% injected e- beam polarization is possible.
- **Simulated equilibrium longitudinal polarization > 70%, leaving a large margin for effects not yet covered.**



Implementation of the spin rotators adjacent to the IR



Simulated equilibrium polarization for an imperfect lattice w/ rotators after closed orbit correction



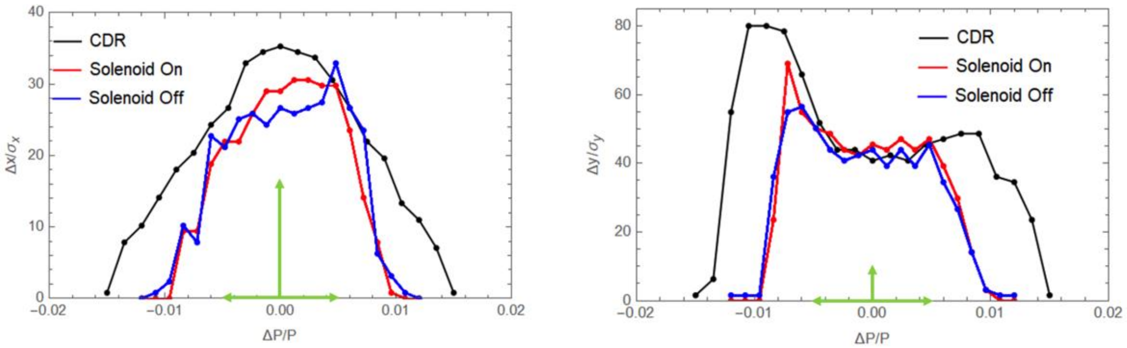
Polarization, luminosity and beam lifetime

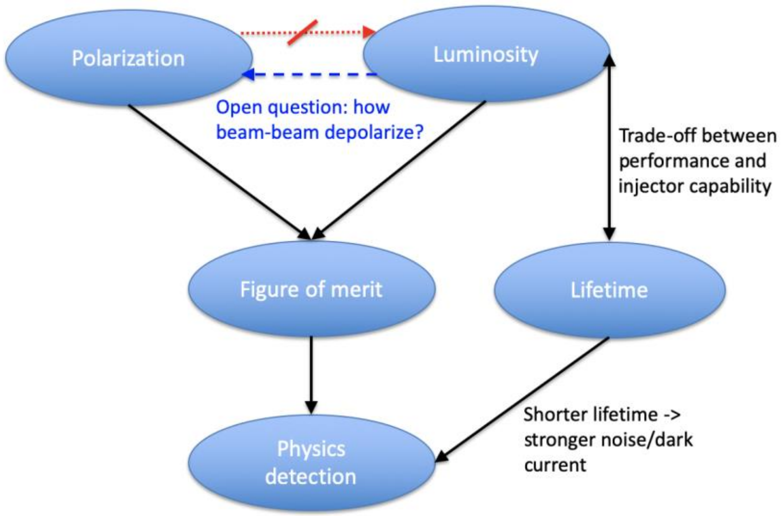
- It is possible to attain 50%-70% e- longitudinal polarization at the **nominal luminosity** and simultaneously with a decent lifetime @ Z-pole

<u>Two pairs of spin rotators</u>

- **240 T·m solenoid each**
- Occupy a space of 2.8 km, can be optimized
- **No interference with the complicated IR design**
- Influence to DA & beam lifetime can be recovered by dedicated sextupole optimization.

Comparison of the dynamic aperture





Contributors to the beam lifetime

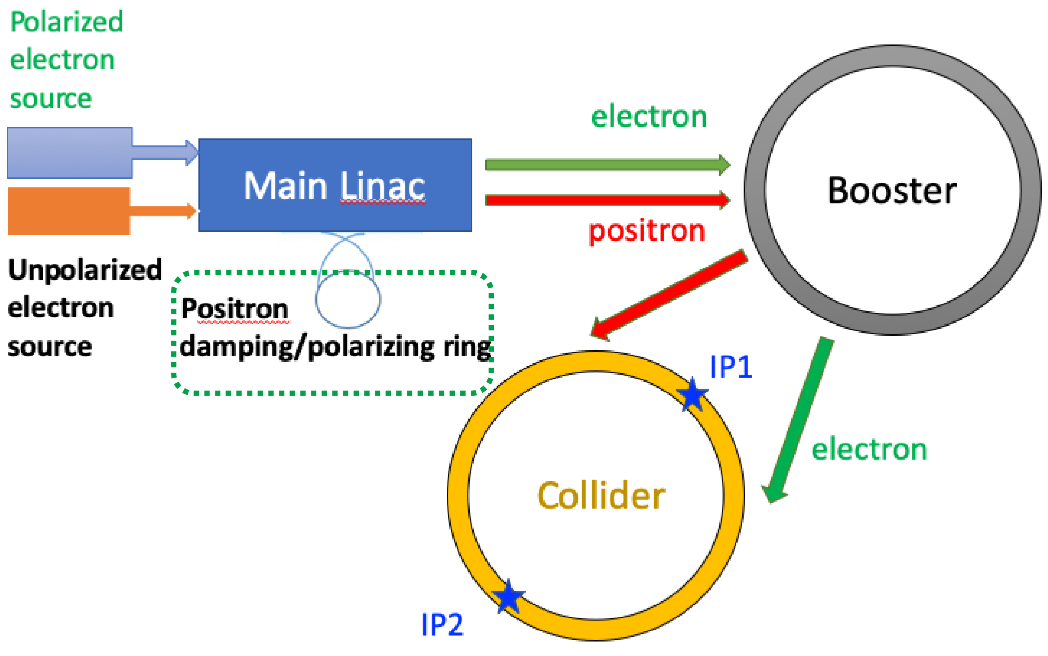
Beam lifetime contribution	CDR lattice w/ spin rotators	Comments
Radiative Bhabha	2.9 hour	ref: CEPC TDR
Vacuum lifetime	3 hour	ref: CEPC TDR
Touschek lifetime	4.63 hour	
Lifetime limited by dynamic aperture	**> 9.53 hour**	**no loss in 100 k turns in the tracking simulations**
Total beam lifetime	**> 1 hour**	

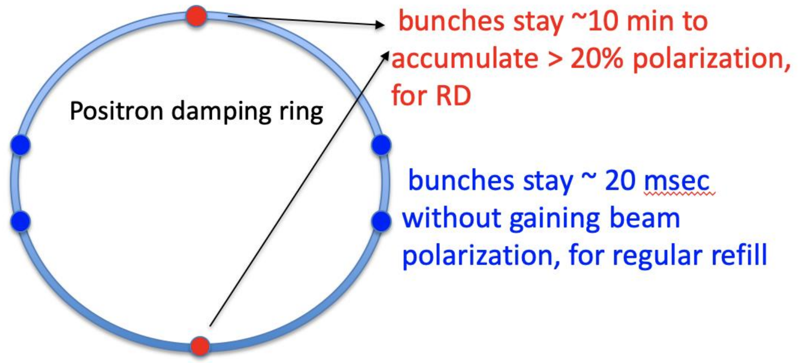
W. Xia et al., Investigation of spin rotators in CEPC at the Z-pole, Radiat. Det. Tech. Meth. 6:490 (2022).

Resonant Depolarization at Z

- It's possible to inject > 20% polarized beams to enable RD measurements at Z-pole
  - **No dead time for physics, a few pilot bunches**
  - Polarized e+ source ? Dual-purpose damping/polarizing ring (could accommodate both e+/e- beams to gain sufficient polarization)

Approaches		Self-polarization in the collider	Injection of polarized beams
Hardware	Polarized electron gun	None	Yes
	Asymmetric wigglers	In the colliders	In the e+ damping ring or None
Polarization level		5% ~ 10%	> 70% for e-, > 20% e+
Dead time for physics		**Initial 1~2 hours in each fill**	**None**
Frequency of RD measurements		Every ~10 min per beam	More frequent for e- beam
RD on colliding beams		None	Possible at lower bunch charge





One typical design:
beam energy ~ 2 GeV, circumference ~ 150 m
polarization build-up time ~ 14.5 min
Extracted beam polarization @ 10min ~ 44%

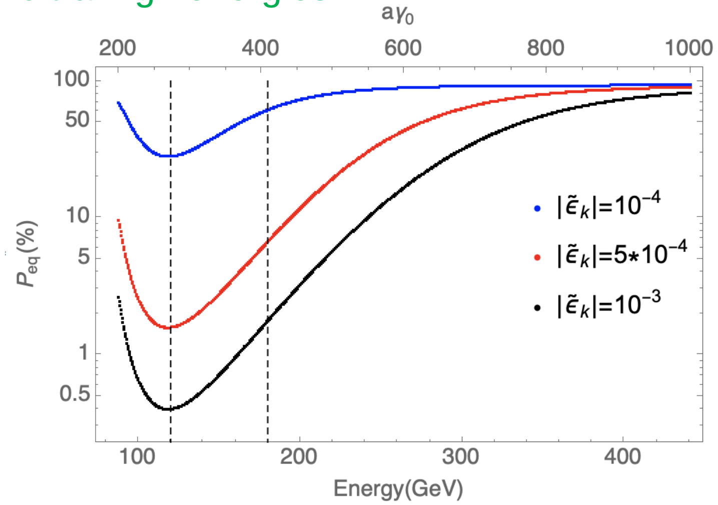
Prospects of Z-pole polarization for CEPC

- Injecting polarized beam(s) to the Collider
- 50%-70% longitudinal polarization for e- versus unpolarized e+
  - Polarized e+ source requires technology innovations; self-polarization at a low energy ring is possible, a tradeoff between the challenges & costs of the ring versus reduction injection rate & luminosity (need more study);
- E- spin helicity flexibly adjusted by changing laser helicity at polarized e- source
- RD measurements w/ a few pilot non-colliding bunches, no physics deadtime
- Accurate 3D polarimetry is needed
  - Inside the IR -> deduce longitudinal polarization @ IP
  - Outside the IR -> RD measurements

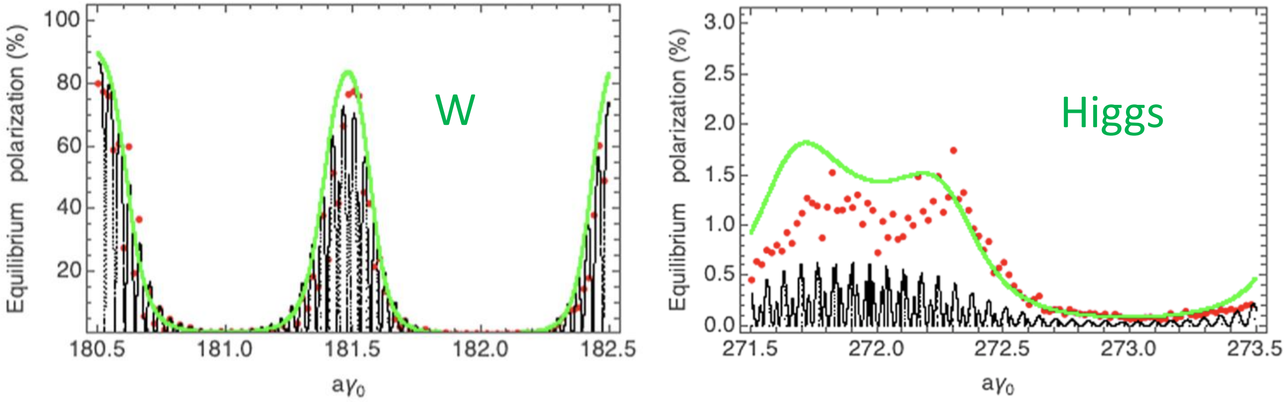
Longitudinal polarization at W & Higgs?

- A good chance for >50% e- longitudinal polarization at W
  - Assume injected polarization > 60%, then P_{DK} needs to be above 23%
- More challenging at Higgs (Under study)
  - Simulated injected polarization < 30% -> improvements in Booster lattice design & mitigation to machine imperfections etc
  - Simulated equilibrium polarization ~ 1% -> mitigate depolarization by harmonic CO spin matching, cancellation of Sokolov-Ternov effect etc
- Strength of solenoid spin rotators scales linearly with energy

Prediction of resonant spin diffusion theory at ultra-high energies

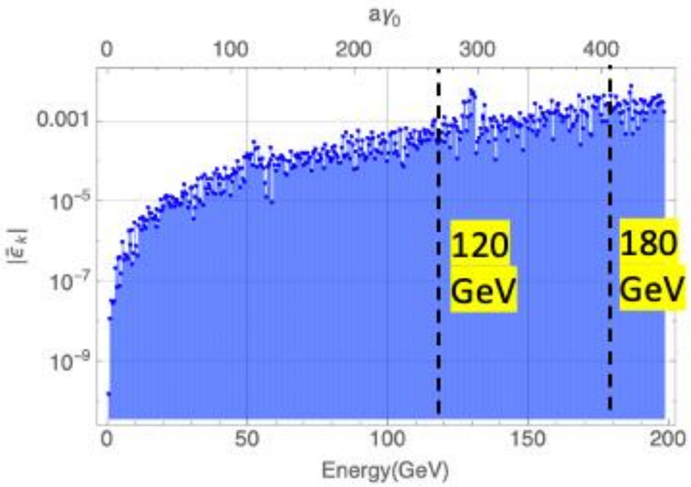


Simulated equilibrium polarization of Collider at W & Higgs



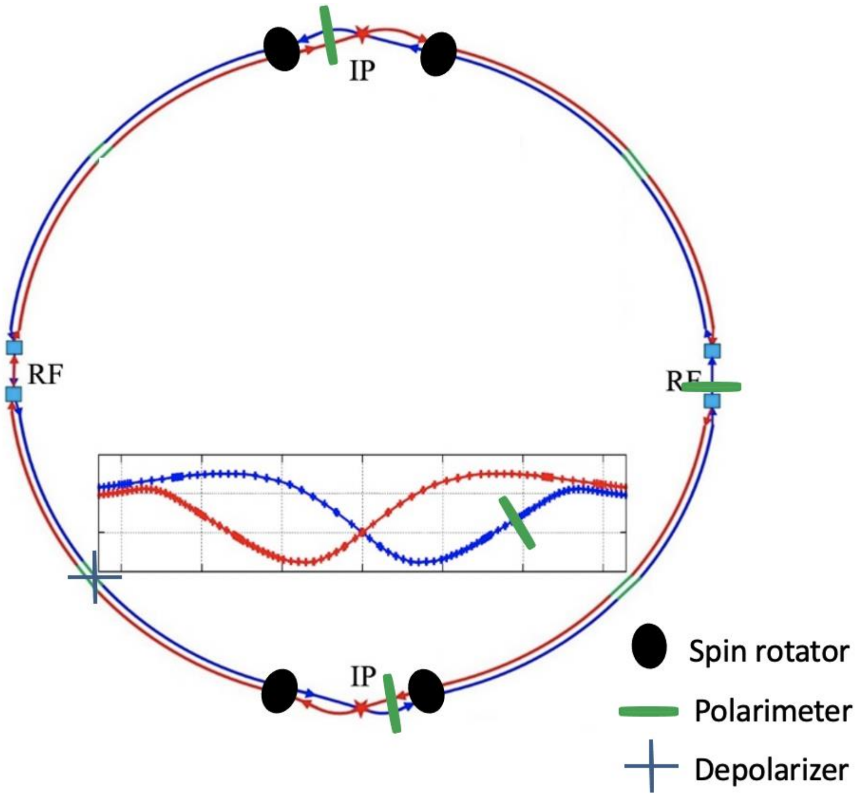
W. H. Xia, et al, Evaluation of radiative depolarization in the future circular electron-positron collider, Phys. Rev. Accel. Beams, 26, 091001, (2023).

The key is to reduce the spin resonance strength by a factor of 10

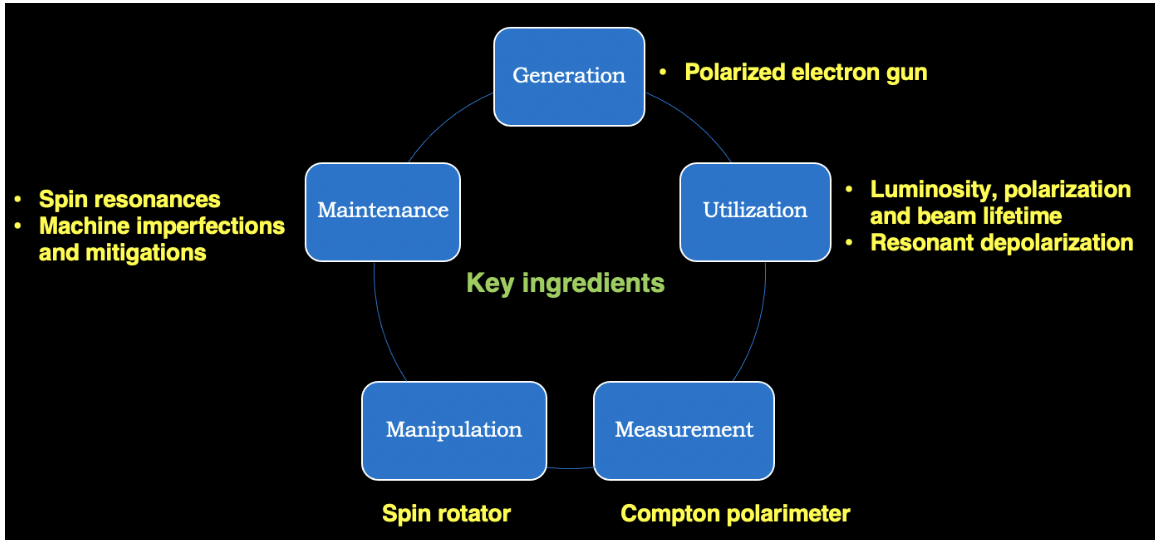


Polarization R&D plan in the CEPC EDR Phase

- Implement the spin components in the post-TDR lattice designs
- Study the polarization utilities at Higgs and W energies
- Polarization-related key hardware R&D



Modify the PAPS photocathode DC gun to a Polarized Electron Source



RD @ BEPCII

R&D of high-field SC solenoids

A vertical polarimeter for BEPCII

Summary

- CEPC Accelerator TDR has been released on Dec 25, 2023, arXiv:2312.14363
- CEPC EDR phase (2024-2027) working plan and beyond has been preliminarily established, with the aim for CEPC proposal to be presented to and selected by Chinese government around 2025, for the construction starting around 2027, and completion around 2035.
- Injecting polarized beams is promising for longitudinal polarization and RD measurements.
- 50%-70% longitudinally polarized e- versus unpolarized e+ at Z with nominal luminosity is a reasonable goal.
- Further studies of polarized beams towards higher energies as well as related hardware R&D are planned for the CEPC EDR phase.
- International collaboration and participation are warmly welcome.

2024 European Edition of the International Workshop on the Circular Electron-Positron Collider

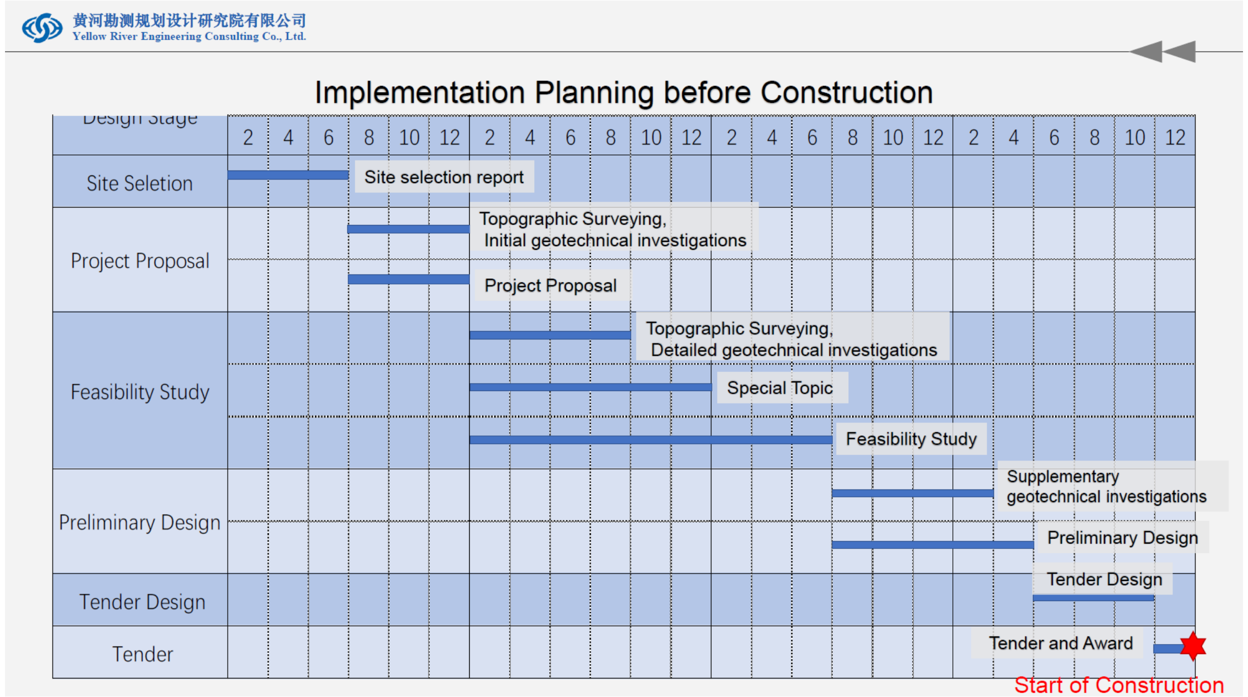
Workshop website:
https://indico.in2p3.fr/event/20053/

Your participation is very welcome!

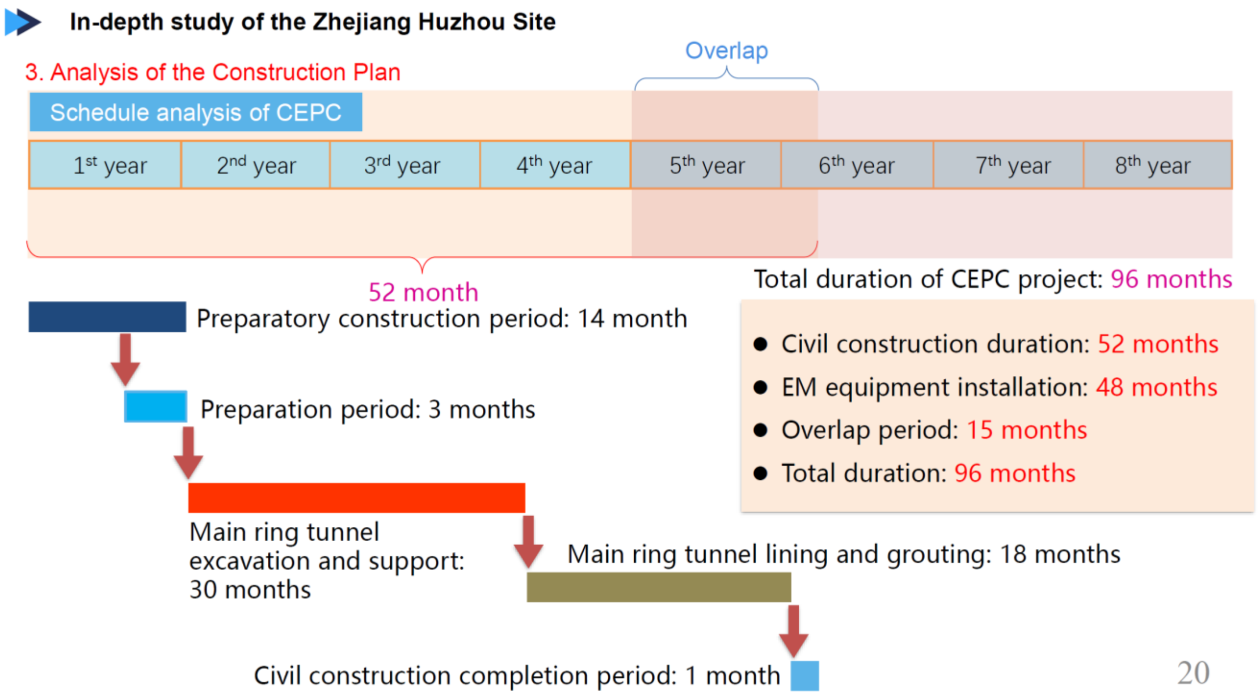
Thank you for your attention!

CEPC Site Implementation and Construction Plans

CEPC site implementation plan in EDR



CEPC construction plan



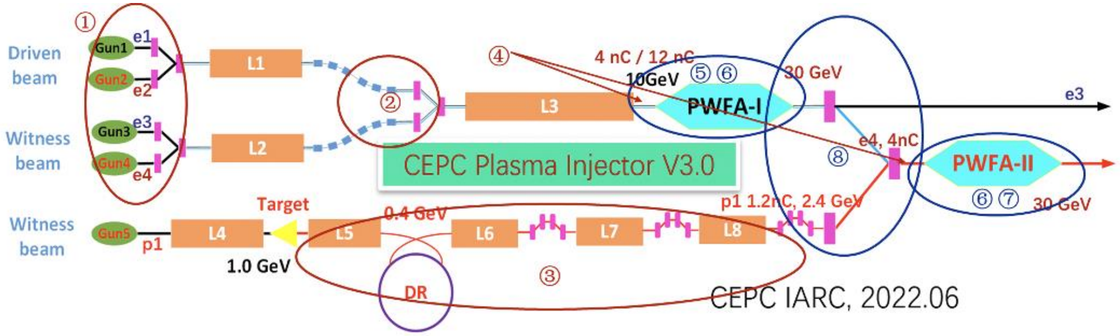
CEPC Plasma Injector (alternative option) and TF plan

Plasma accelerators are promising candidates for future colliders.

CEPC plasma injector scheme:

From 10 GeV → 30 GeV → **TR ≥ 2** **as a potentially low cost replacement of conventional technologies**

- Works on paper via simulations
- Key issues call for experimental justifications

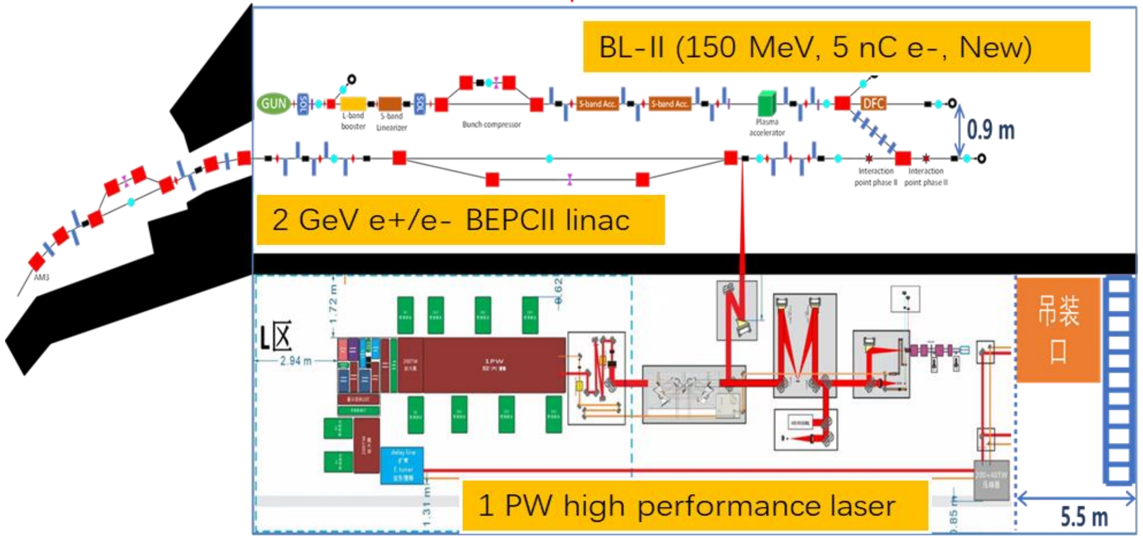


Key issues for conventional accelerator:

1. High charge longitudinal shaped bunch;
2. High current beams combination;
3. Low emittance e+ beamline
4. Final focus system design and optimization

Key issues for plasma wakefield accelerator:

5. High TR e- PWFA and hosing instability;
6. High repetition rate stable plasma sources
7. High quality and high efficiency e+ PWFA
8. Staging / Cascaded acceleration



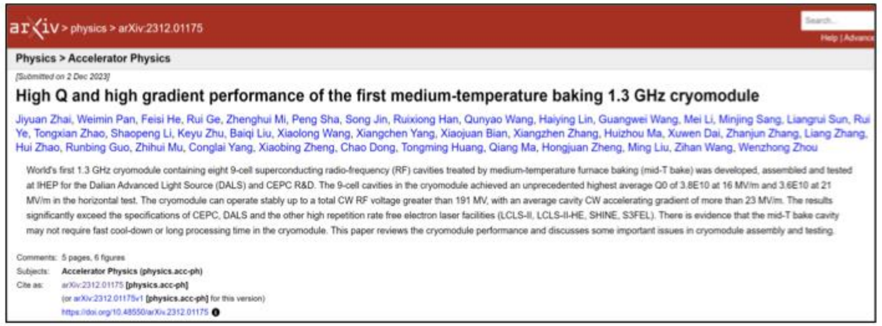
PWFA/LWFA Test Facility based on BEPC-II Linac and HPL has been funded by CAS in Sept. 2023.
Other TF plans under consideration. See Dazhang Li's presentation

CEPC Booster 1.3 GHz 8*9-cell High Q Cryomodule

CEPC booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects.

World's first 1.3 GHz cryomodules containing 8*9-cell SRF cavities with medium-temperature furnace baking

Parameters	Horizontal test results	CEPC Booster Higgs Spec	LCLS-II, SHINE Spec	LCLS-II-HE Spec
Average usable CW E_{acc} (MV/m)	23.1	3.0×10^{10} @ 21.8 MV/m	2.7×10^{10} @ 16 MV/m	2.7×10^{10} @ 20.8 MV/m
Average Q_0 @ 21.8 MV/m	3.4×10^{10}			


arXiv > physics > arXiv:2312.01175

Physics > Accelerator Physics

[Submitted on 2 Dec 2023]

High Q and high gradient performance of the first medium-temperature baking 1.3 GHz cryomodule

Jiyuan Zhai, Weimin Pan, Feisi He, Rui Ge, Zhenghui Mi, Peng Sha, Song Jin, Ruixiong Han, Qunyao Wang, Haiying Lin, Guangwei Wang, Mei Li, Minjing Sang, Liangrui Sun, Rui Ye, Tongxian Zhao, Shaopeng Li, Keyu Zhu, Baiqi Liu, Xiaolong Wang, Xiangchen Yang, Xiaojuan Bian, Xiangzhen Zhang, Huizhou Ma, Xuwen Dai, Zhanjun Zhang, Liang Zhang, Hui Zhao, Runbing Guo, Zhihui Mu, Conglai Yang, Xiaobing Zheng, Chao Dong, Tongming Huang, Qiang Ma, Hongjuan Zheng, Ming Liu, Zihan Wang, Wenzhong Zhou

World's first 1.3 GHz cryomodule containing eight 9-cell superconducting radio-frequency (RF) cavities treated by medium-temperature furnace baking (mid-T bake) was developed, assembled and tested at IHEP for the Dalian Advanced Light Source (DALS) and CEPC R&D. The 9-cell cavities in the cryomodule achieved an unprecedented highest average Q0 of 3.8E10 at 16 MV/m and 3.6E10 at 21 MV/m in the horizontal test. The cryomodule can operate stably up to a total CW RF voltage greater than 191 MV, with an average cavity CW accelerating gradient of more than 23 MV/m. The results significantly exceed the specifications of CEPC, DALS and the other high repetition rate free electron laser facilities (LCLS-II, LCLS-II-HE, SHINE, S3FEL). There is evidence that the mid-T bake cavity may not require fast cool-down or long processing time in the cryomodule. This paper reviews the cryomodule performance and discusses some important issues in cryomodule assembly and testing.

Comments: 5 pages, 6 figures
Subjects: Accelerator Physics (physics.acc-ph)
Cite as: arXiv:2312.01175 [physics.acc-ph]
(or arXiv:2312.01175v1 [physics.acc-ph] for this version)
https://doi.org/10.48550/arXiv.2312.01175

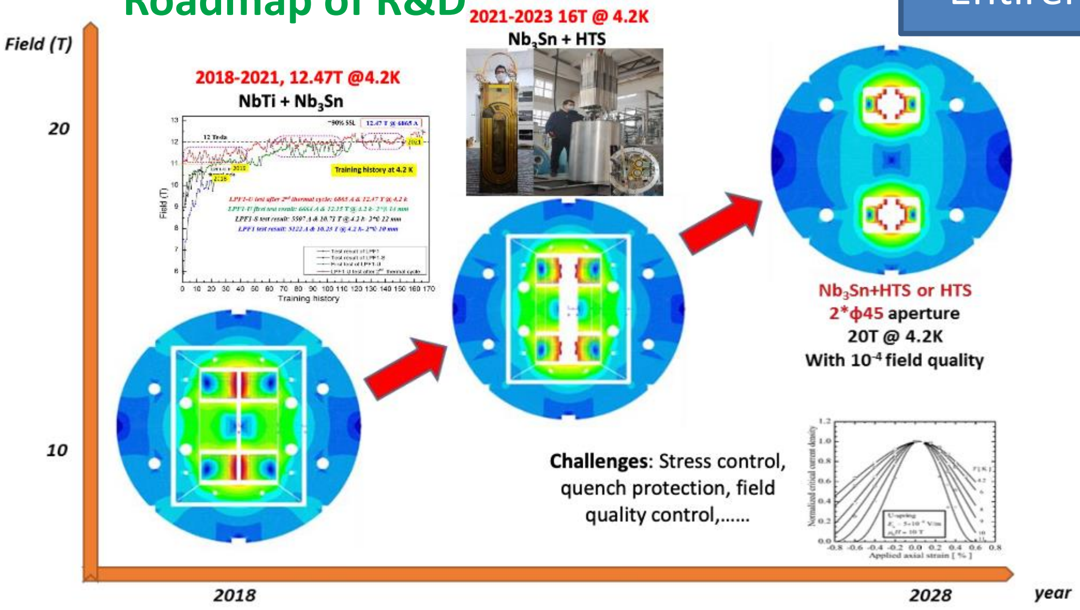
See Jiyuan Zhai's presentation

High-field superconducting magnets for SppC

- Motivation: $E[GeV] = 0.3 \times B[T] \times \rho[m]$
  - IBS 20-24 T to reach $\sqrt{s}$ ~125-150 TeV for SppC, Nb_3Sn etc as options
- Progress
  - A 16T (Nb_3Sn + HTS) model dipole under performance test with very promising results

Entirely fabricated in China

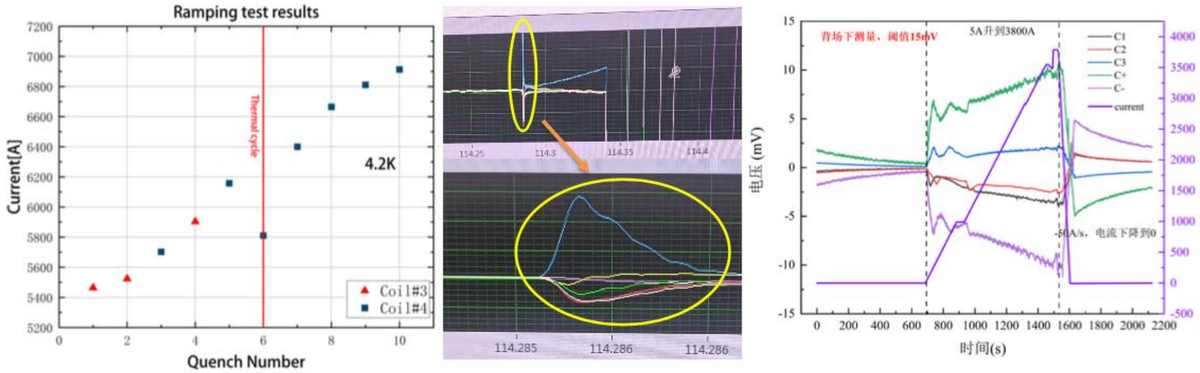
Roadmap of R&D



Performance test ongoing from Sep 2023

Wei Li et al

- The Nb_3Sn coils were trained firstly, maximum current reached ~85% of I_{op} in Dec 2023.
- HTS block coil was ramped independently to 100% of I_{op} with negligible terminal voltage
- Present test results indicate the promising performance of the LTS and HTS coils. Test to be continued in Feb 2024



16 T Model Dipole LPF3: Nb_3Sn 13 T (*Common Coil with 55 mm gap*) + HTS 3 T inserts (*Block & CCT with ∅20 mm*)

See [Qingjin Xu's presentation]()