Positron source for CEPC

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CEPC
环形正负电子对撞机
Circular Electron Positron Collider

Content

- **Parameters and layout of the CEPC Linac**
- **Positron source for CEPC**
  - Electron beam for positron production
  - Positron generation and Pre-acceleration
  - R&D of key components for positron source
- **Other sources related research activities**
- **Summary**

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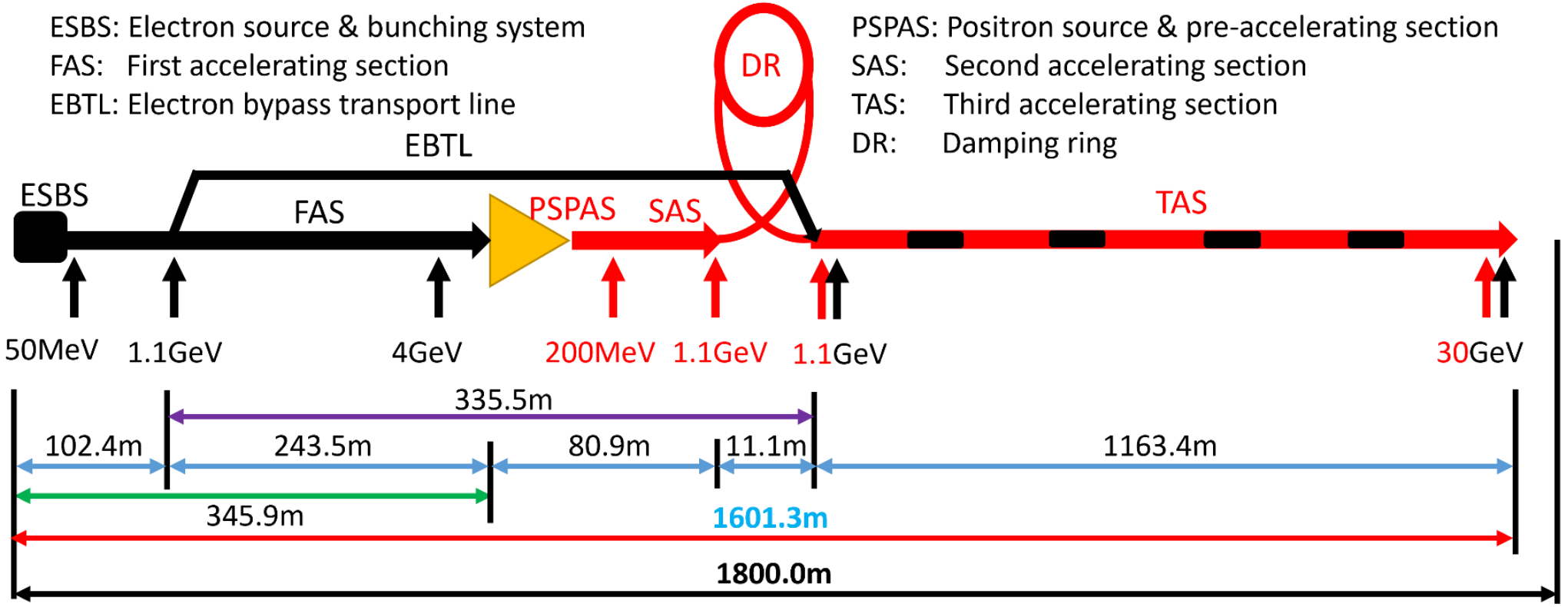
Parameters and layout of the CEPC Linac

- **Baseline design of the CEPC Linac**
  - A **30GeV** room temperature Linac
  - A combination of **S-Band (2860MHz)** and **C-Band (5720MHz)**
  - The Linac tunnel length is **1.8km**

Parameter	Symbol	Unit	Baseline
Energy	E_{e-}/E_{e+}	GeV	30
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	1.5 (3)
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

Parameters and layout of the CEPC Linac

- **Layout of the CEPC Linac**
  - **FAS+PSPAS+SAS:** S-Band
  - **TAS:** C-Band (Higher gradient → Shorter linac tunnel length)



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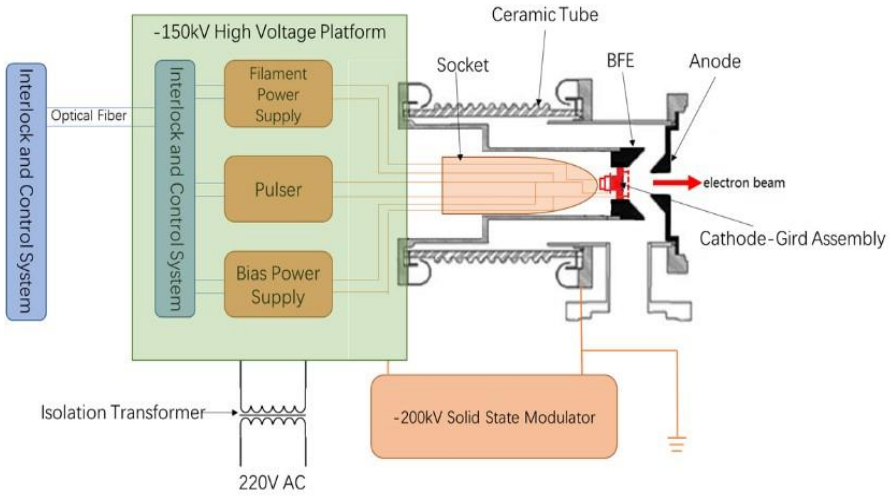
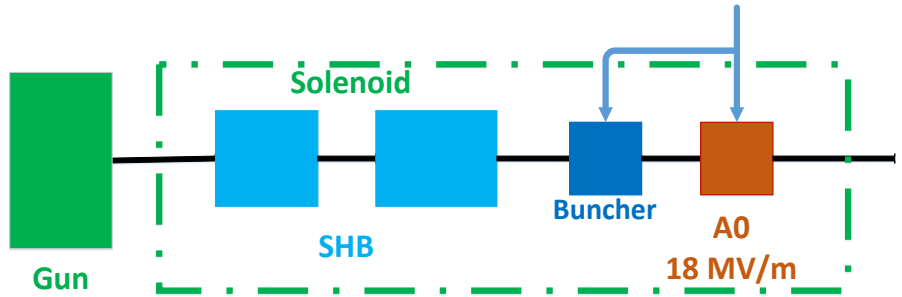
- **Electron source and bunching system (Baseline)**
  - **Electron Gun**
    - A traditional thermionic triode gun
    - **3nC** for electron injection
    - **11nC** for positron generation
  - **Bunching**
    - Two SHBs (158.89MHz/476.67MHz)
    - Buncher(2860MHz)
    - Accelerating structure (2860MHz)
  - **Energy:** 50MeV
  - **Normalized Rms Emittance:** 80mm-mrad
  - **Transmission**
    - 90%
  - **Verified at BEPCII and HEPS Linac**



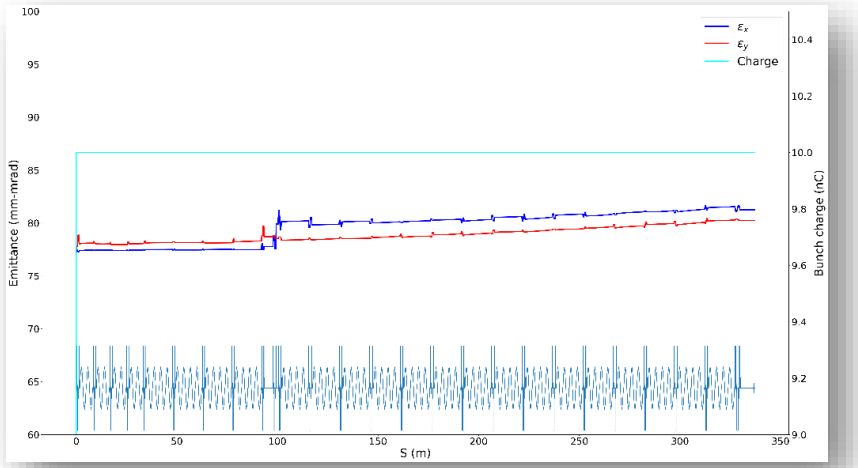


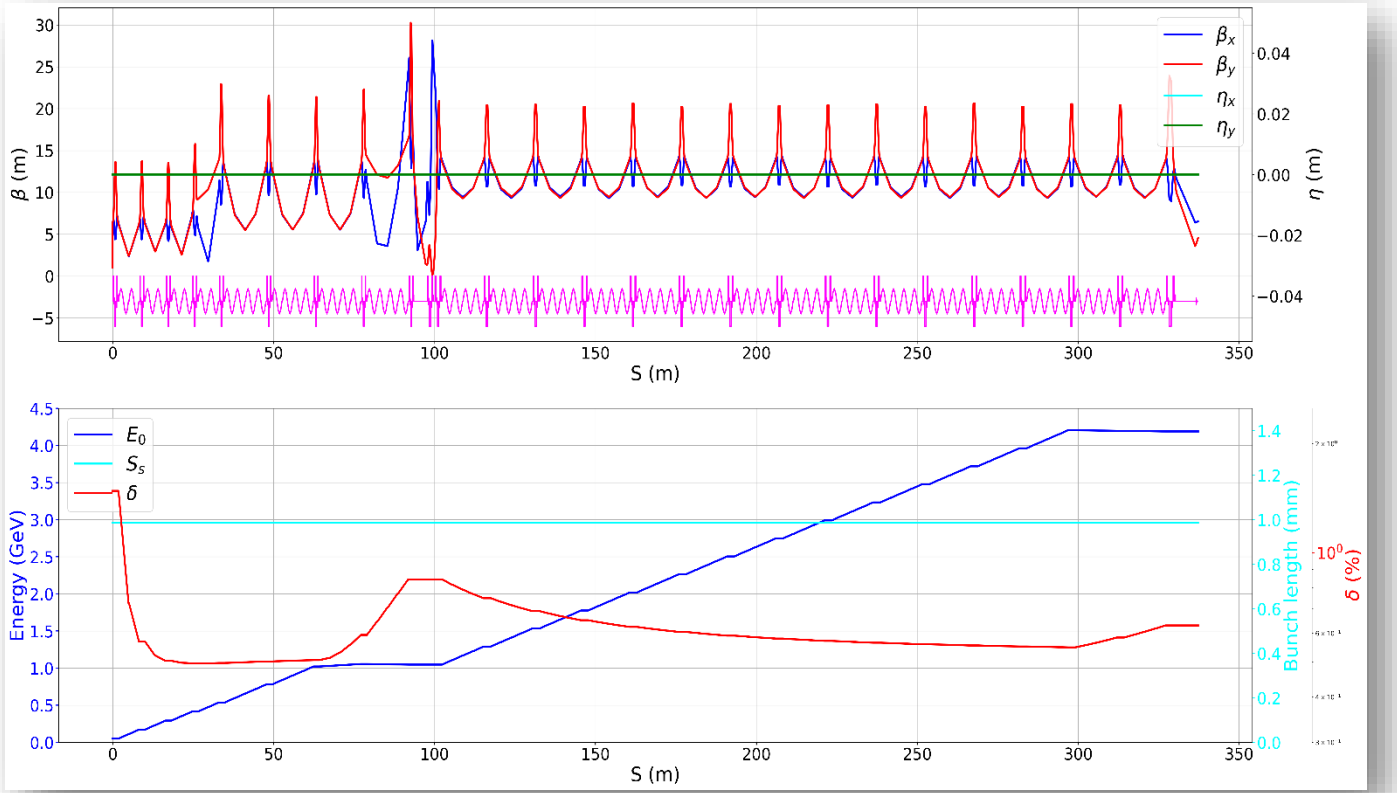
Positron source for CEPC

Electron beam for positron production

- **Acceleration: 50MeV→4GeV**
  - 18+3(redundancy) S-band klystron
  - 1 klystron →4 accelerating structures
  - Gradient: 22MV/m
- **Simulation results**
  - Energy: 4GeV
  - Bunch charge: 10nC
  - Energy spread: 0.63%

10nC@4GeV electron beam for positron production





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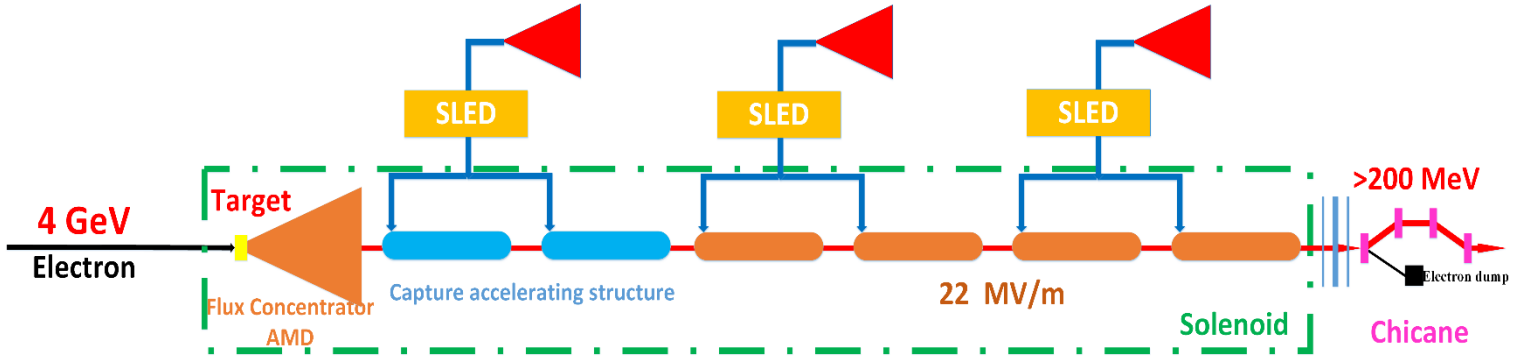
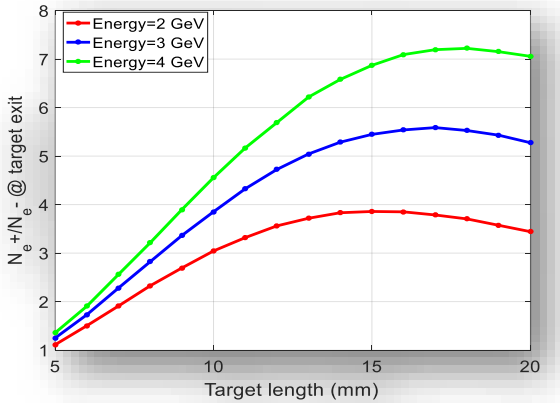
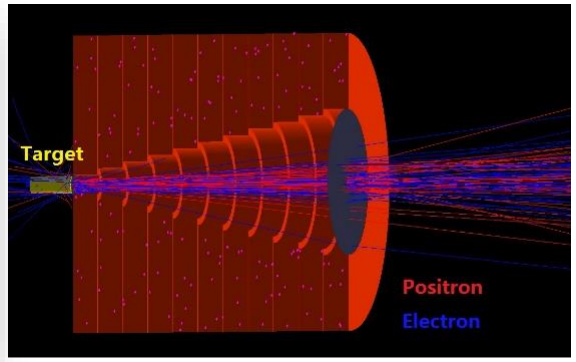
Positron source for CEPC

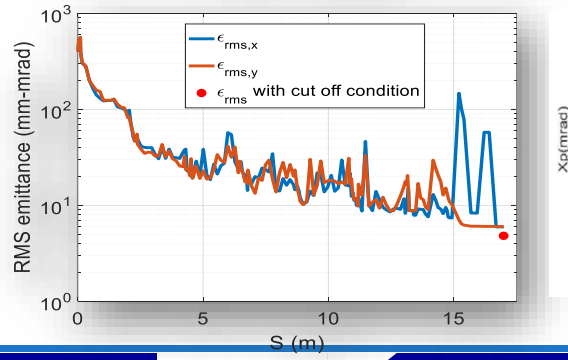
Positron source and Pre-acceleration

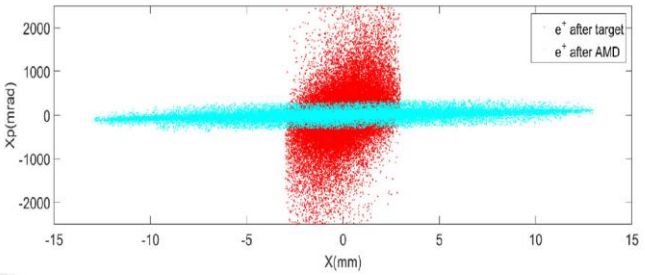
- **Positron source**
  - Target (Conventional)
    - Electron beam: 10nC@4GeV
    - Tungsten@**15 mm**
    - Beam size: **0.5 mm**
- **AMD (Adiabatic Matching Device)**
  - A flux concentrator
  - Magnetic field: (5.5T→0T) + 0.5T Solenoid
- **Capture & Pre-accelerating section**
  - 1 klystron → 2 accelerating structures
    - Larger aperture S-band accelerating structure with aperture is 25 mm, gradient is 22 MV/m and length is 2 m
- **Chicane @ 200MeV**
  - Wasted electron separation
  - Exit: **~5.5nC**, Nor. Emittance: **2370mm-mrad**







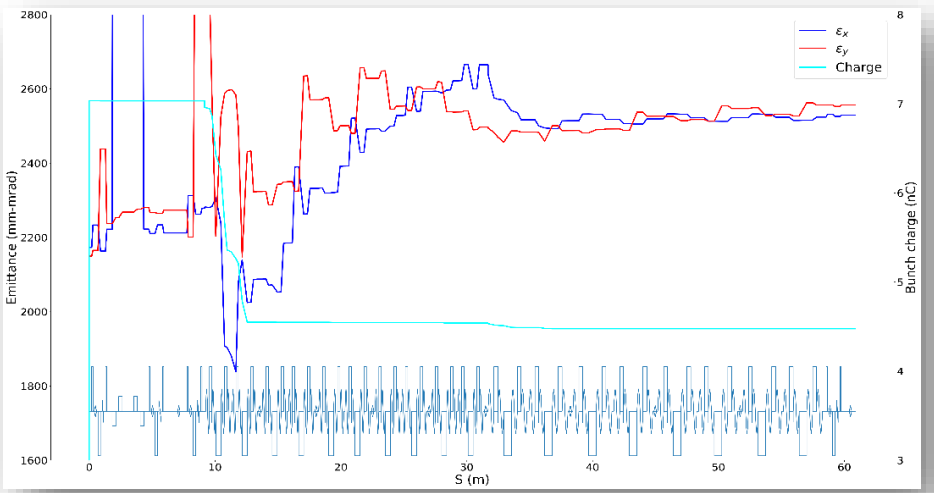


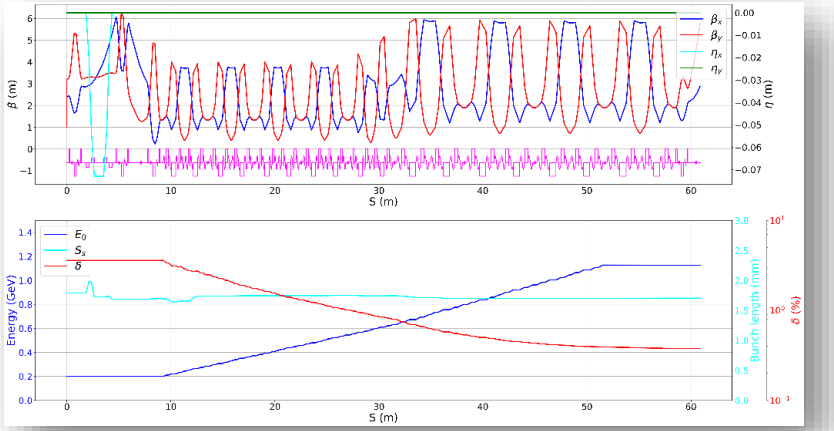


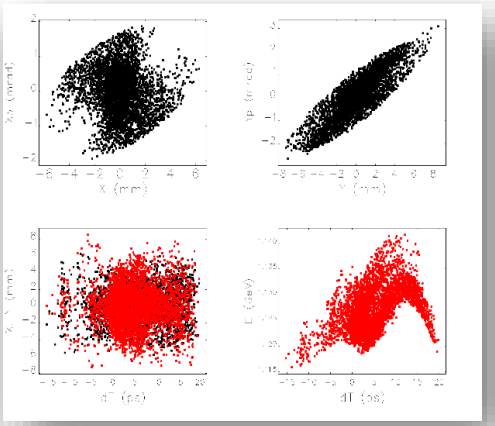
Positron source for CEPC

Positron source and Pre-acceleration

- **Acceleration：200MeV→1.1GeV**
  - 8+1(redundancy) S-band klystron
  - 1 klystron →2 accelerating structures
    - 10 Larger aperture S-band accelerating structure@22MV/m
    - 8 normal S-band accelerating structure@27MV/m
- **Transverse focusing**
  - Triplet quadrupoles are outside of each accelerating structure
- **Simulation results**
  - Energy: **1.1GeV**
  - Energy spread: **0.4%**
  - Bunch charge: **~4.5nC**
  - Normalized rms Emittance: **2500mm-mrad**







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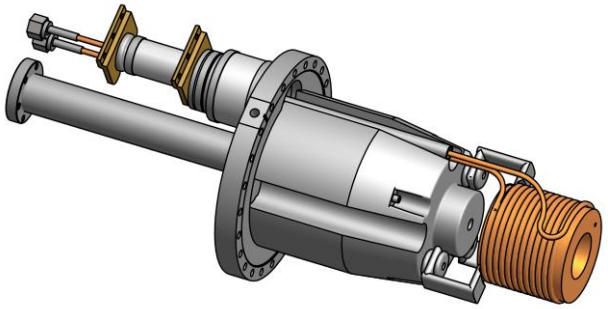
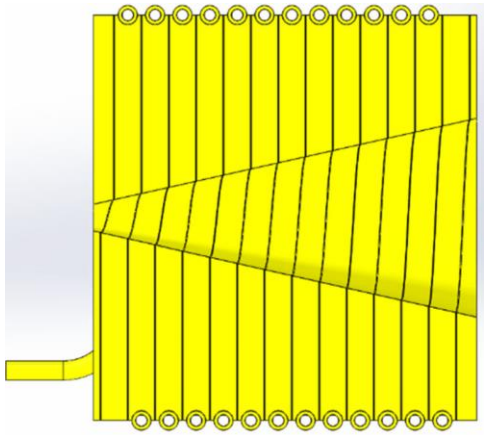
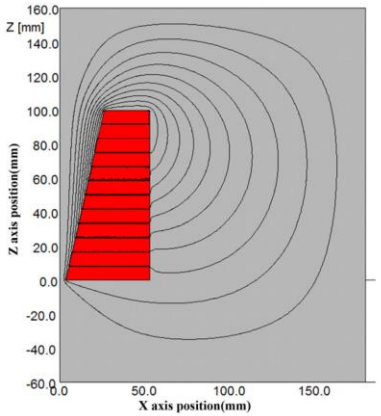
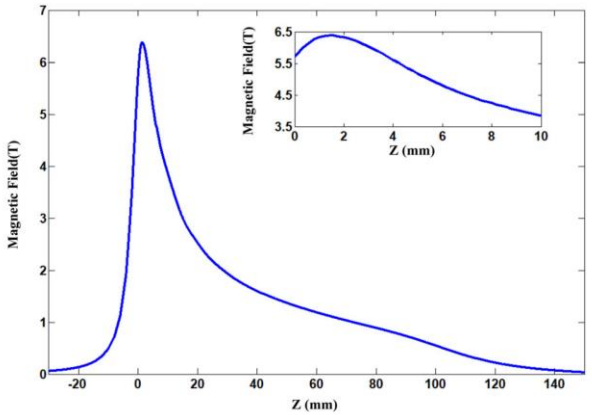
A flux concentrator prototype has been successfully developed

- Manufactured under a **cooperation MOU with KEK**
- A trumpet-shaped copper coils： **12 turns**
- The inner diameters： **7 to 52 mm**
- Coils distance: **0.2 mm**
- Total length: **100 mm**
- Peak current: **15A**
- Max pulse magnetic field: **>6T@15kA**



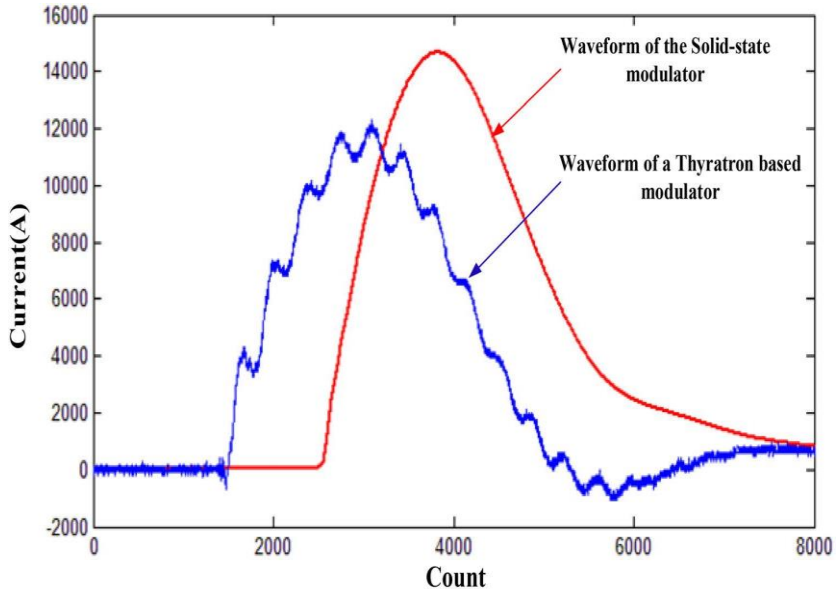




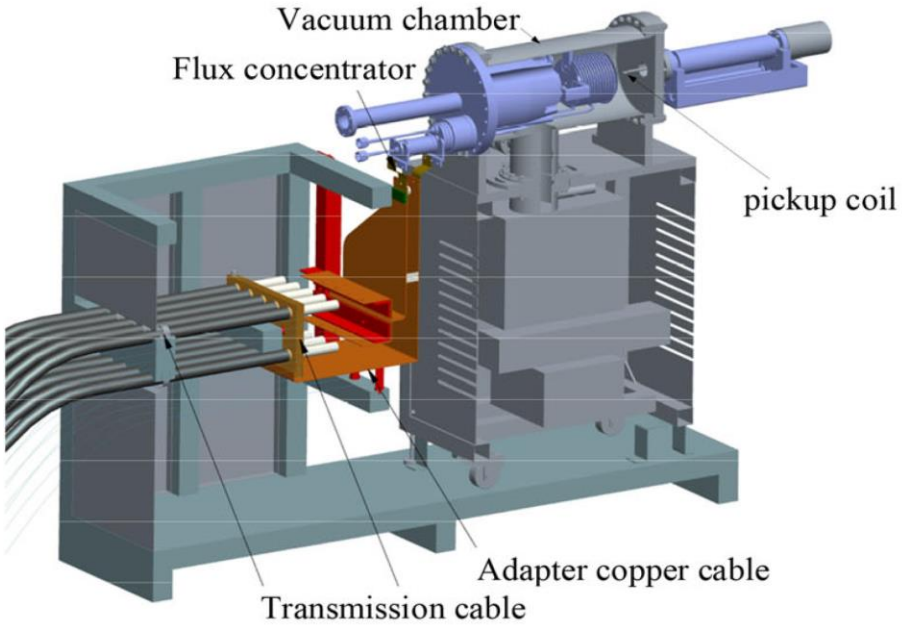


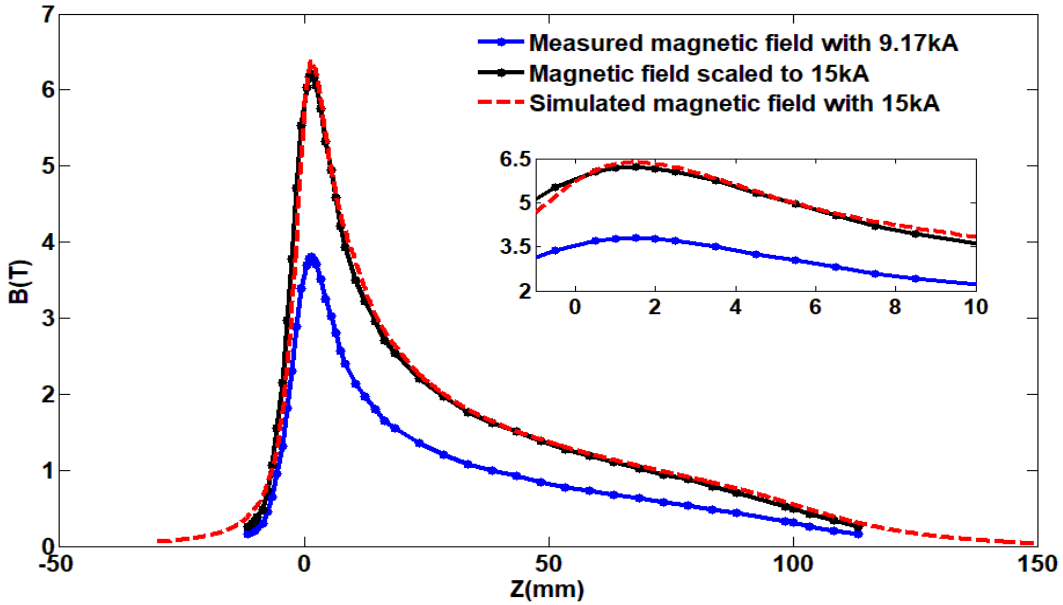
- **A new pulse modulator has been developed for FC**
  - All-solid-state switching components IGCT instead of hydrogen thyratron (BEPC II)
  - Obtained a higher peak current without high-frequency ripples
  - Will be used for BEPCII operation this September

Parameters	Value
Input voltage	380 V ±10%
Output pulse current	15 kA
Pulse width	5 μs
Output waveform	Half sine
Capacity peak voltage	15 kV
Current stability	< 0.1%



- **Test results of the FC**
  - A test bench has been built up for performance verification of the FC
  - The test results of FC agreed well with the designed parameters
  - A peak magnetic field of **6.2 T** had been obtained inside the FC at a **15kA** driving current
  - Can meet the requirements of CEPC positron source baseline design





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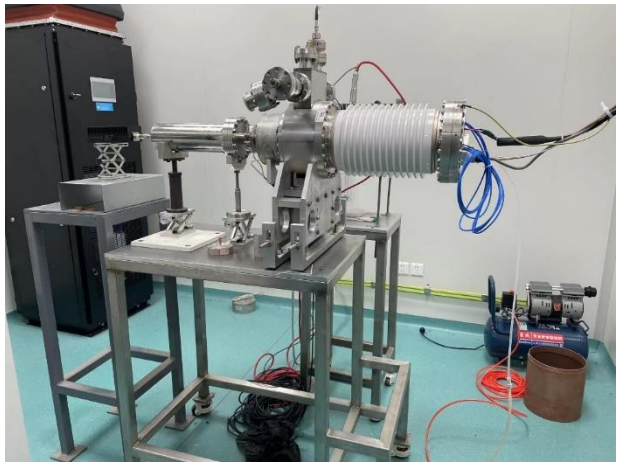
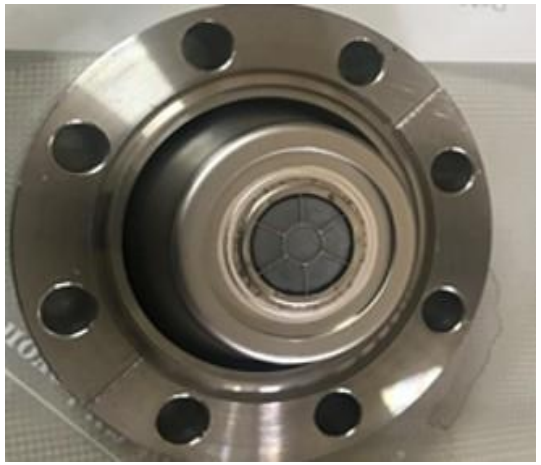
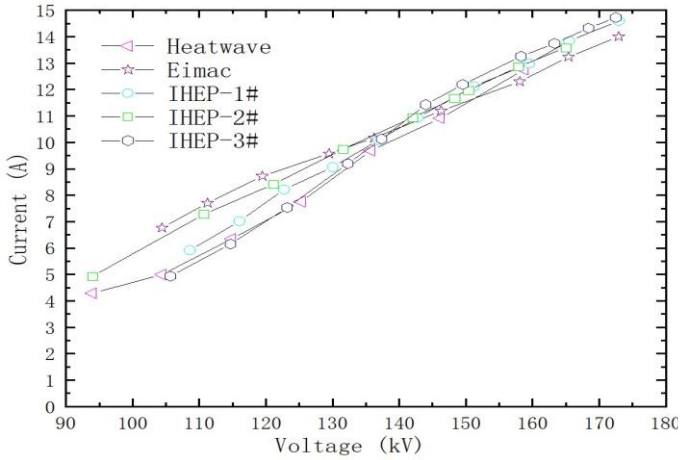
Other sources related research activities

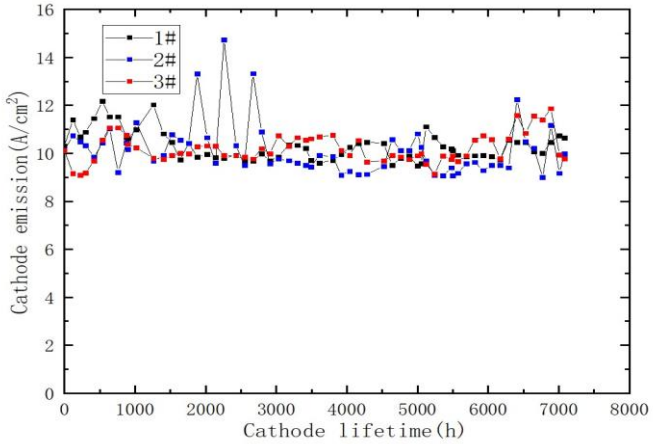
A thermionic triode gun

- A prototype of electron gun and its test platform had been built up
  - Used for **domestic** cathode-grid assembly R&D
  - The cathode emission capacity had been tested up to **12A@150kV**
  - The emission capacity does not decrease within 7000 hours operation



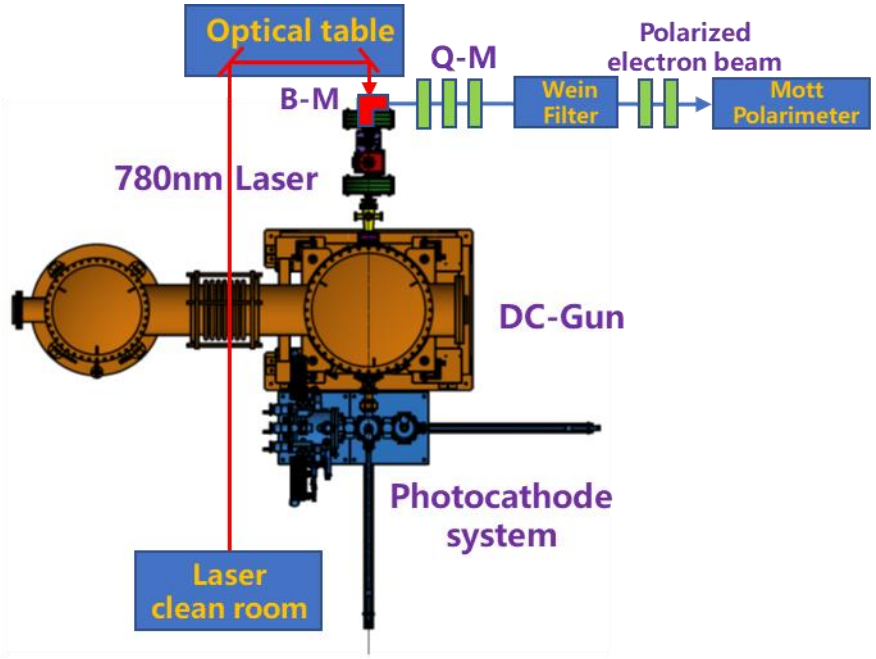






Other sources related research activities

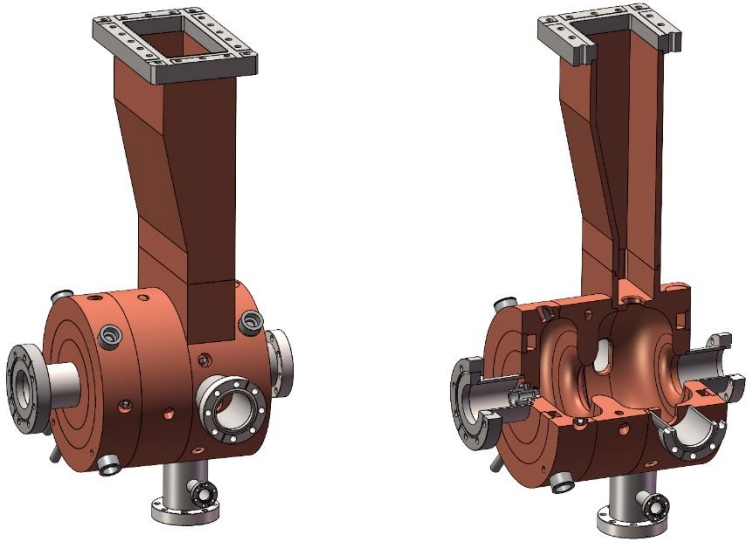
- **A polarized electron source R&D plan**
  - Based on a 500kV photocathode dc-gun has been built up at PAPS, Huairou, Beijing
    - Superlattice photocathodes R&D collaborating with a domestic company (Acken, Suzhou)
    - Research on the polarization manipulation and measurement (Collaborate with JGU, Mainz)
    - Two-stage experiments will be considered in near future (200kV/400kV)



Other sources related research activities

A L-Band photocathode RF Gun

- A L-Band photocayhode RF Gun has been developed (Under processing now)
- Potential for generating high bunch charge electron beam (**≥10nC**)
  - An alternative solution for the thermionic gun of CEPC Linac
  - Avoiding additional frequency introduced by SHBs which lead to a complex timing system for CEPC
- Developed for PWFA experiment research on BEPCII (A project has been approved by CAS)

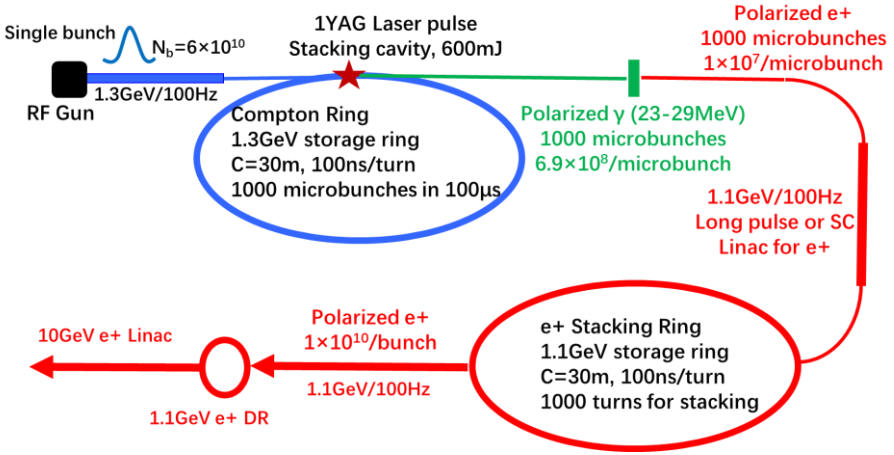


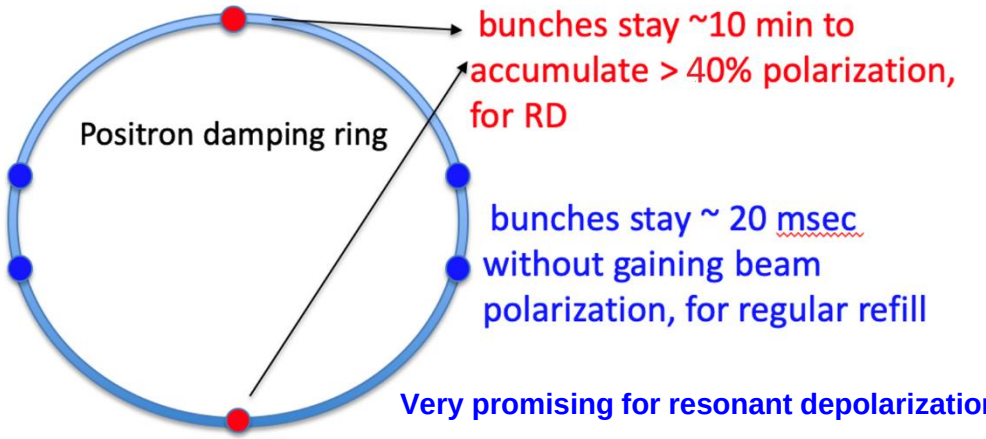
Parameters	Value	Unit
Frequency	1299.48	MHz
Cell	1.55	cell
Input power	6.5	MW
Q factor	24291	-
Gradient at cathode	60	MV/m
RF pulse length	10	μs

Other sources related research activities

Polarized positron beam generation

- Preliminary consideration on a Compton Ring and a Stacking Ring for the generation of polarized e+ beams~**1×10^{12}e+/second**
  - A potential solution to generate polarized positrons in CEPC
  - Up to now, just a conceptual consideration (requires a lot of further simulation works in future)
- Using the self-polarization to generate polarized e+ beams in DR
  - Need a higher energy in DR around 2GeV and a strong dipole strength
  - Current research shows that extracted beam polarization @ **10min ~ 44%**





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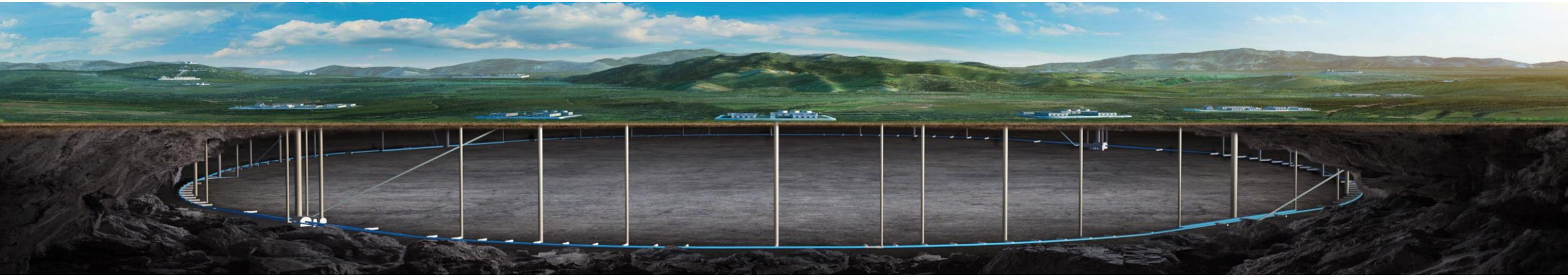
Summary

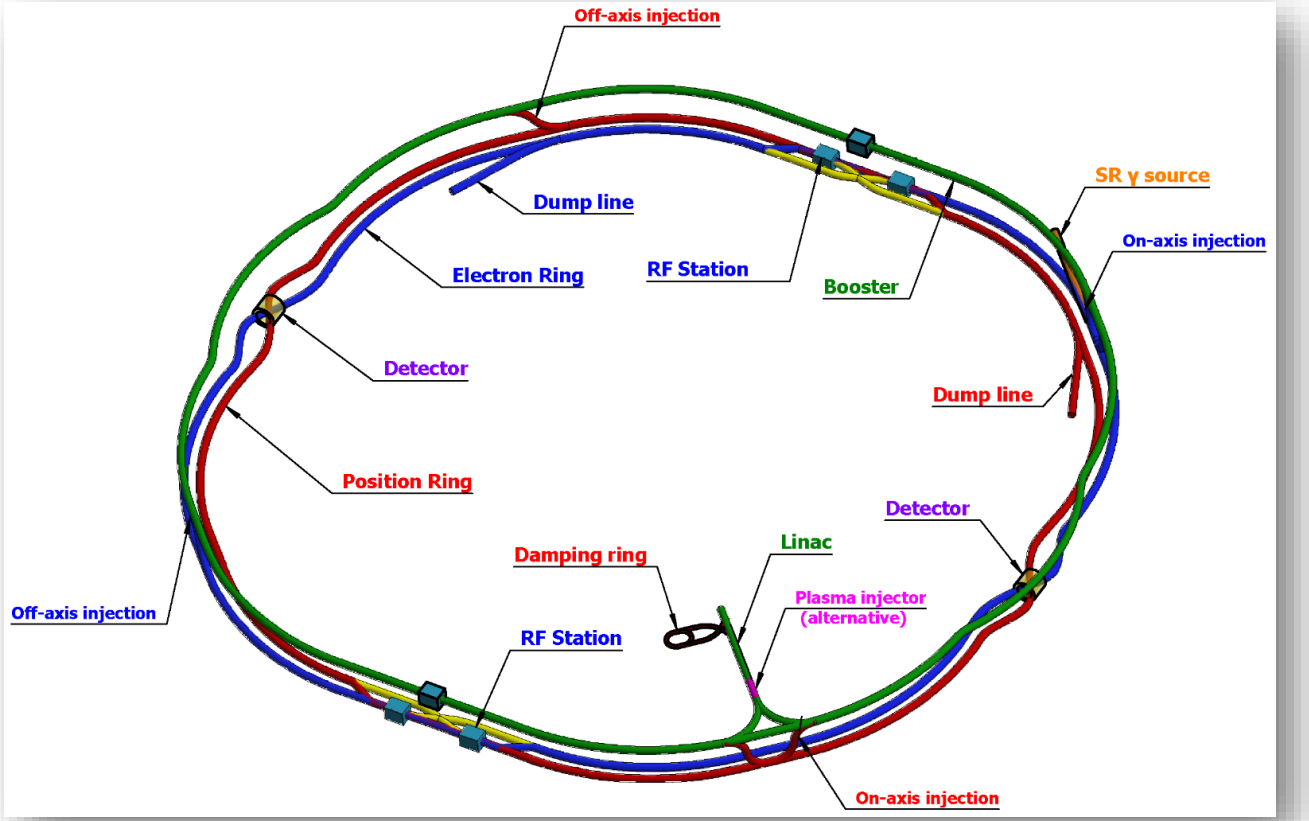
- The CEPC Linac is a 30 GeV room temperature S-band and C-Band combined linear accelerator working at 100Hz.
- Positron source for CEPC adopting a conventional scheme.
- A flux concentrator prototype and its pulse modulator has been developed and tested.
- Other sources related research activities in IHEP are mentioned.

Thank you for your attention!



Introduction: CEPC Layout

- CEPC as a Higgs (ttbar,H, W, Z) Factory
  - **Linac, 30GeV, 1.8km**
  - Full energy Booster, 100km
  - Collider, 100 km
  - Transport lines
- Linac design
  - Meet requirements
  - High availability
  - Reserve upgrade potential



$$L_{\text{int}} = \int_0^T L(t)dt = \langle L \rangle \cdot T_s \cdot \eta$$

Introduction: Linac energy

- The maximum energy of booster is 180GeV and circumference is 100 km
  - Large circumference & Low injection energy → Low magnetic field
    - design difficulty in magnet (*field*) and power supply (*stability*)
  - Large extraction energy → Large field range
    - design difficulty in magnet (*excitation efficiency*) and power supply (*power*)
- Increasing the energy of the Linac is the easiest way: 30 GeV

Wen Kang
Session M2-2: #1

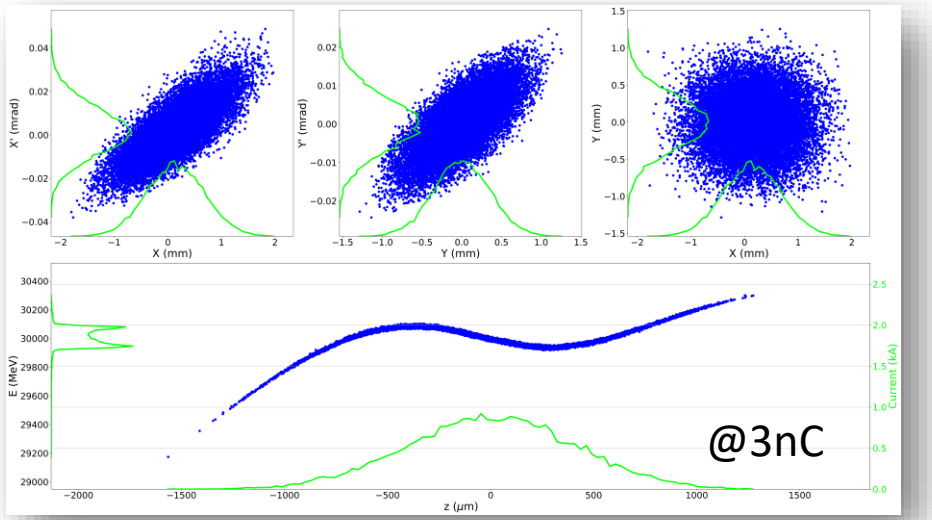
Magnet		Low injection energy			Max. Extraction energy	Cost
		10GeV	20GeV	30GeV	180GeV	
CT Air-core coil		Yes	Yes	Yes	No	Very high
iron-corn magnet	oriented silicon steel sheet	No	Yes	Yes	Yes	high
	Non-oriented silicon steel sheet	No	No	Yes	Yes	low

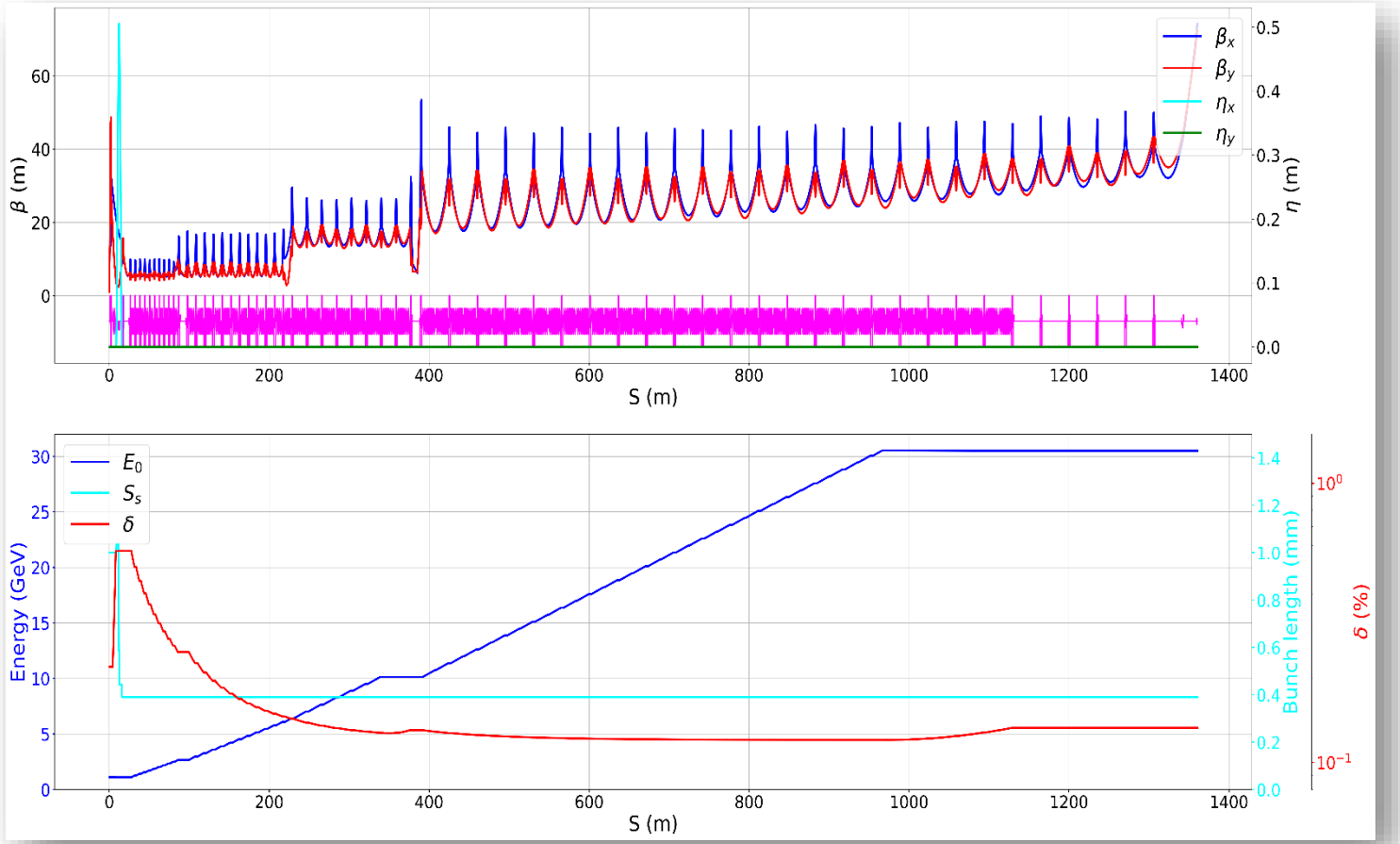
effect of residual magnetism

Positron Linac: TAS

- Simulation results(including Wakefield & CSR)

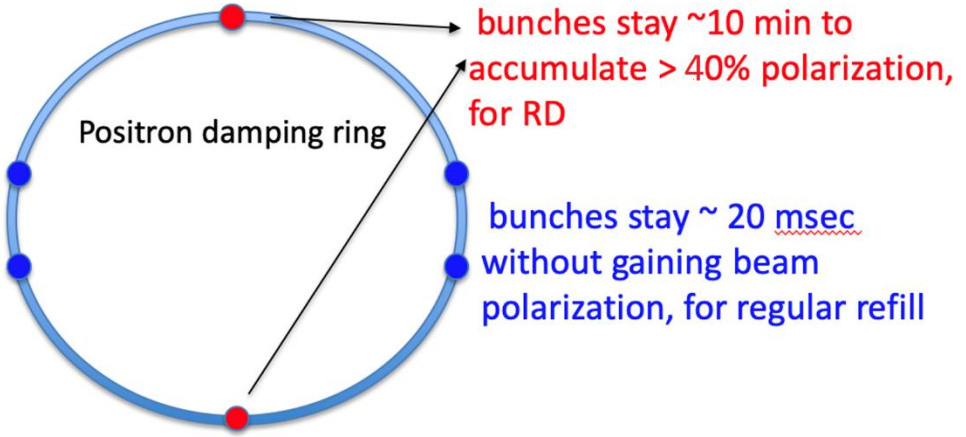
Parameter	Unit	Value	Simulated	
			Positron	
Beam energy	GeV	30	30.50	30.01
Repetition rate	Hz	100	/	
Bunch charge	nC	1.5	1.5	3.0
Energy spread	10^{-3}	1.5	1.33	2.19
Emittance(x/y)	nm	6.5	3.37/1.68	3.90/1.71
Bunch length (RMS)	mm	/	0.4	0.4



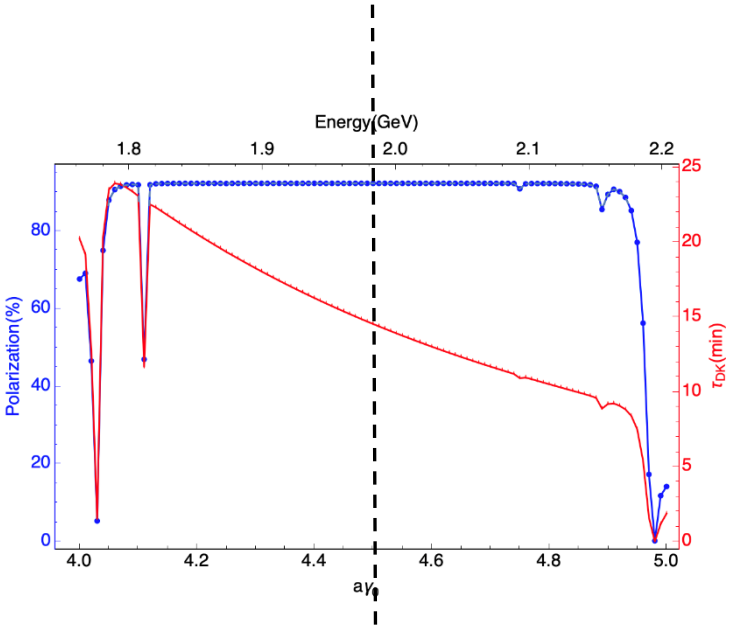


Positron damping/polarizing ring

- Using the self-polarization to generate polarized e+ beams
  - For Resonant depolarization (very promising)
    - extracted beam polarization @ 10min ~ 44%
    - **No physics dead time, improved availability & int. luminosity**
  - for polarized colliding beams (under study)
    - Higher energy and/or asymmetric wigglers
    - More bunches



DR V4.0	unpolarized e+	polarized e+
Energy (Gev)	1.983	
Circumference (m)	144.2	
Number of trains	2(4)	
Number of bunches/trian	1(2)	
Total current (mA)	12.4	
Dipole strength B_0 (T)	1.92	
U_0 (kev/turn)	397.9	
Damping time x/y/z (ms)	4.8/4.8/2.4	
Momentum compaction	0.0078	
Storage time	20 ms	10 min
δ_0 (%)	0.0917	
ε_0 (mm.mrad)	132	
injection σ_z (mm)	6	
Extract σ_z (mm)	6.7	6.6
ε_{inj} (mm.mrad)	2500	
$\varepsilon_{ext\ x/y}$ (mm.mrad)	133/13	132/13
$\delta_{inj}/\delta_{ext}$ (%)	0.18 /0.092	
RF acceptance (%)	1.85	
Longitudinal tune	0.025	

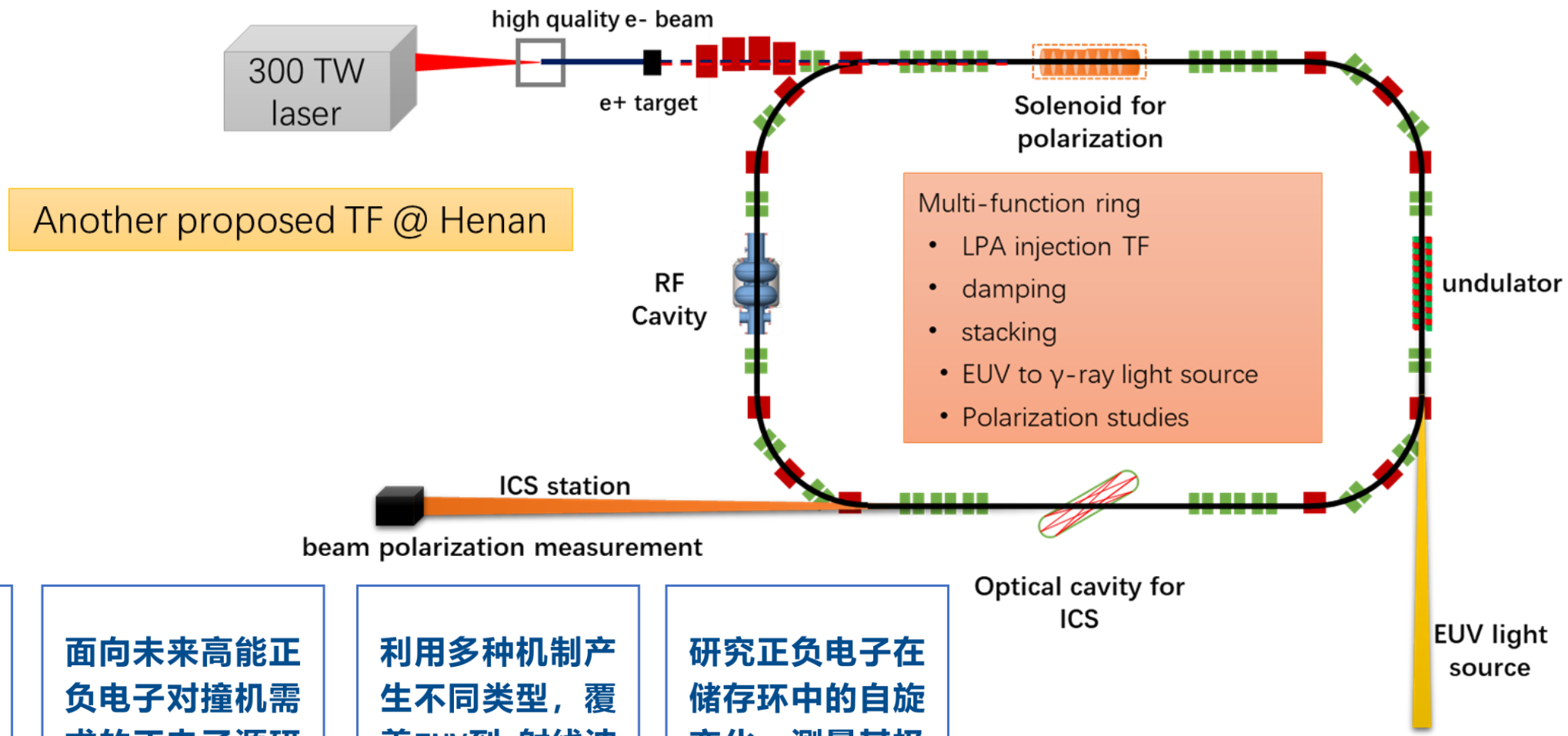


Approaches		Self-polarization in the collider	Injection of polarized beams
Hardware	Polarized electron gun	None	Yes
	Asymmetric wigglers	In the colliders	In the e+ damping ring or None
Polarization level		5% ~ 10%	> 70% for e-, > 20% e+
Dead time for physics		**Initial 1~2 hours in each fill**	**None**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

基于BEPCII，打造正电子加速、级联加速独特研究平台

针对**正电子加速、尾场级联加速及外注入级联**等关键科学挑战的研究需求，基于BEPCII高能正负电子束流，结合大电量电子驱动器，建设**世界独有**的束流驱动尾场加速研究平台

激光等离子加速器 + 储存环 test facility @ 河南



基于超高稳定性桌面型激光器的等离子体尾场电子加速

面向未来高能正负电子对撞机需求的正电子源研究

利用多种机制产生不同类型，覆盖EUV到γ射线波段的辐射

研究正负电子在储存环中的自旋变化，测量其极化度