



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



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

CEPC polarized electron source R&D

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- **CEPC Electron Source**
- **Generation of polarized electron beams**
- **Polarized electron source related R&D**
 - Polarized electron source R&D plan for CEPC at IHEP
 - Domestic R&D on the superlattice GaAs photocathode
 - Preliminary test on the superlattice GaAs photocathode
 - A Polarized electron gun design for CEPC
- **Summary**

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■ 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
Energy spread	σ_E		1.5×10^{-3}
Emittance	ϵ_r	nm	6.5

CEPC Electron Source

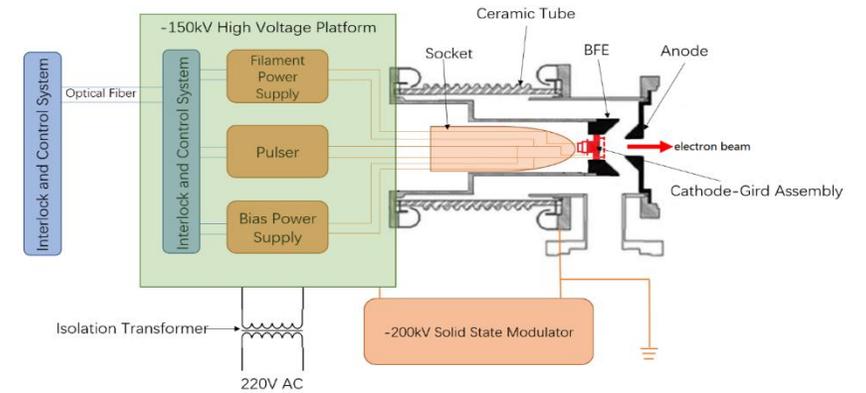
■ Introduction to CEPC Electron Source

The electron source is used for generating an electron beam with a specific longitudinal distribution that can be accelerated for injection and positron production.

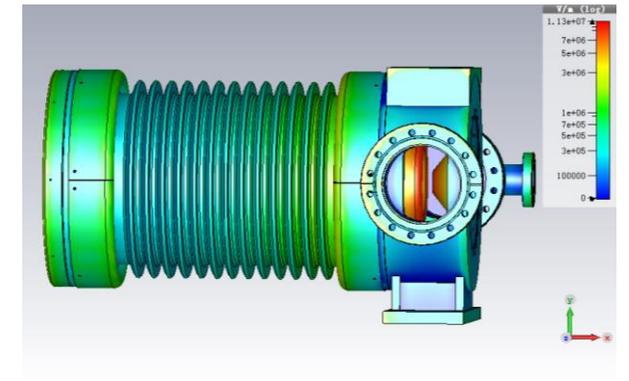
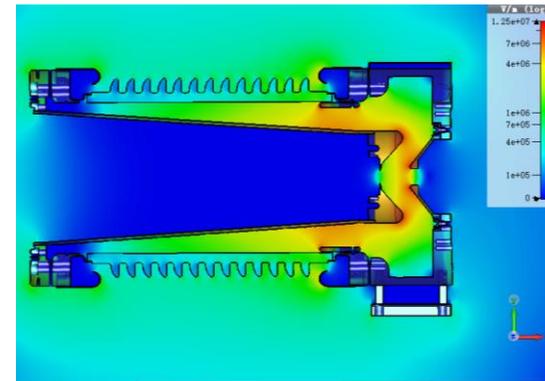
– Electron Gun (Baseline design)

- A traditional thermionic triode gun with two operation modes
- **1.5nC** for electron injection
- **10nC** for positron generation

– Has been verified at **BEPCII** and **HEPS Linac**



Parameter	Unit	Value
Type	-	Thermionic Triode Gun
Cathode	-	Dispenser cathode
Beam current	A	> 10
High voltage of anode	kV	150
Bunch charge 1	nC	1.5 (e ⁻ injection)
Bunch charge 2	nC	10 (e ⁺ production)
Repetition	Hz	100



CEPC electron source parameters and its design

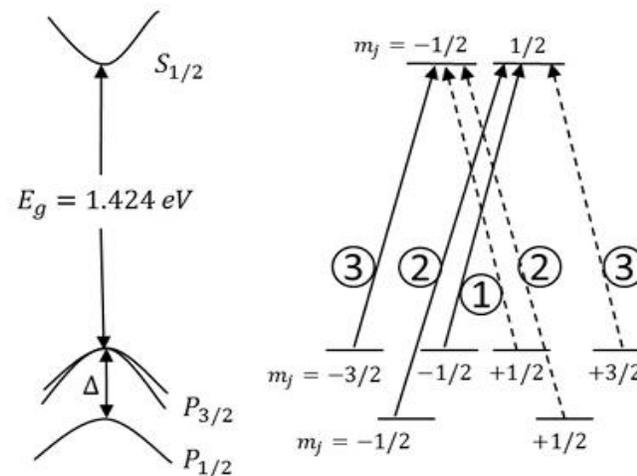
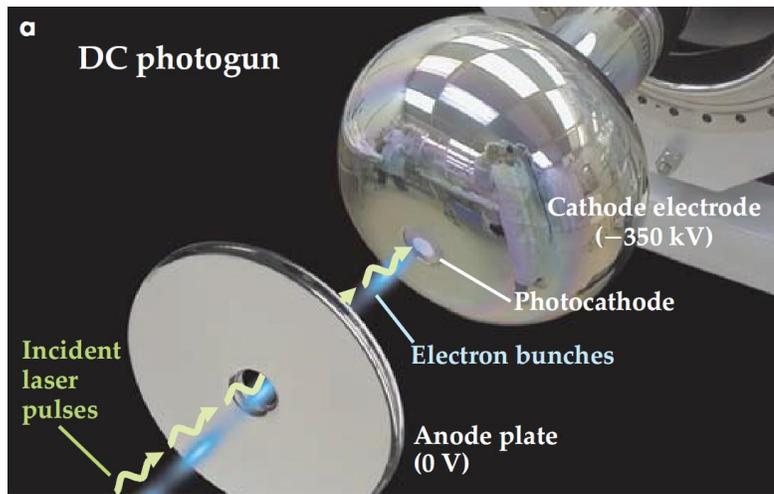
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Generation of polarized electron beams

■ Polarized electron generation

- One effective method for generating polarized electrons is using GaAs photocathode in a photocathode HV electron gun (**Extremely high vacuum**)
- The unique band structure of GaAs determines that electron beams with a certain polarization can be generated under the driving of circularly polarized laser at a specific wavelength
- For a common bulk GaAs, a maximum polarization in theory is 50%, considering depolarization effect it usually is about **30-35%** at **780nm** laser wavelength



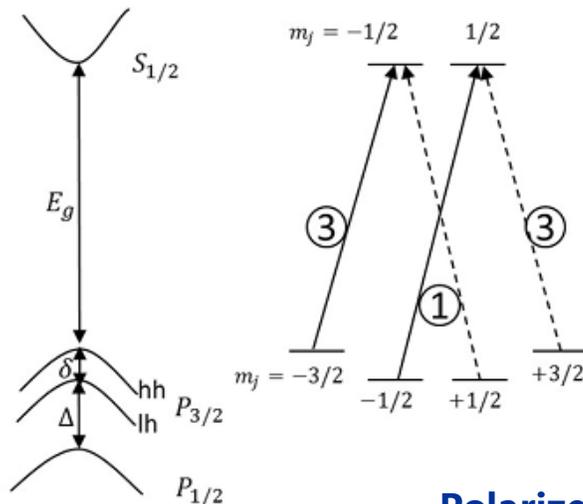
$$P = \left| \frac{1 - 3}{1 + 3} \right| = 50\%$$

Polarized electron generation from a common bulk GaAs

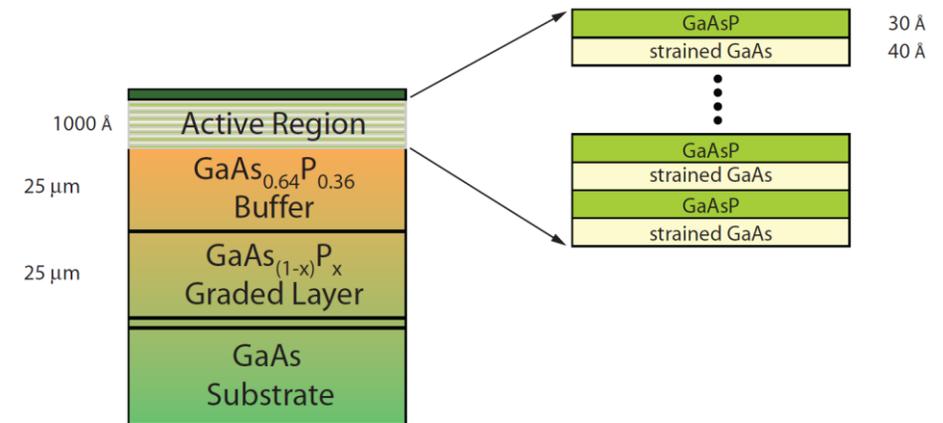
Generation of polarized electron beams

■ Polarized electron generation

- Strained GaAs and its energy band structure
- For a strained GaAs, a maximum polarization in theory is 100%, considering depolarization effect it usually is about **85%** at 780nm
- Constructing **superlattice** structure is an effective way to obtain strained GaAs
- This type of photocathode is not easy to obtain and needs to be grown on a substrate using MBE equipment



$$P = \left| \frac{3}{3} \right| = 100\%$$



Polarized electron generation from superlattice GaAs

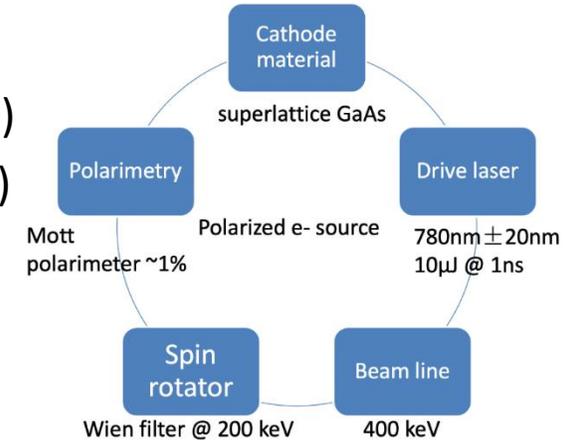
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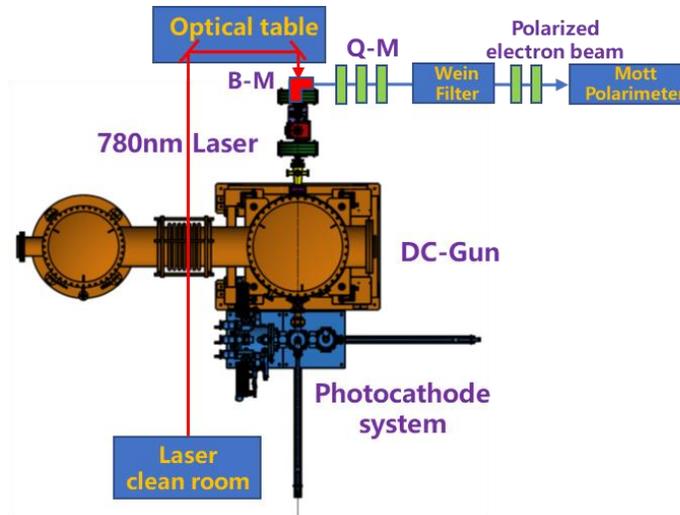
Polarized electron source related R&D

Polarized electron source R&D plan for CEPC at IHEP

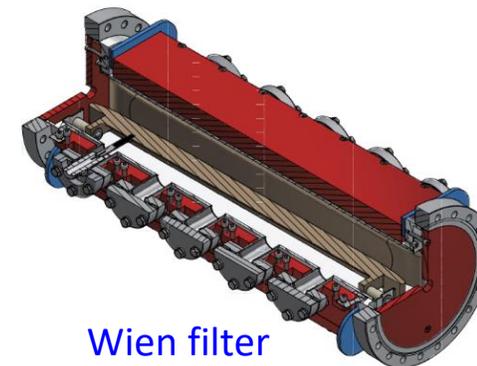
- Goals: Generation of electron beams with a bunch charge ($\geq 2\text{nC}$) and high polarization ($\geq 85\%$)
- Based on a photocathode DC gun developed by IHEP with an extremely high vacuum (10^{-10}Pa)
- Beam line setup and beam dynamics study has been carried out
- Key components such as Wien filter and Mott polarimeter has been designed
- We expect a beam commissioning scheduled in 2027



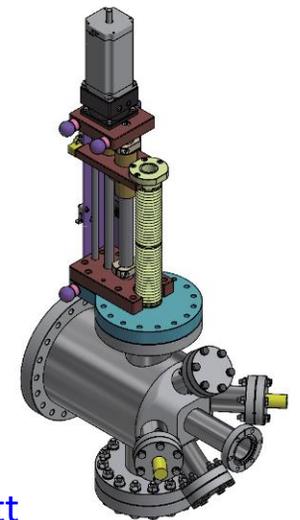
A photocathode DC gun @IHEP



Scheme of PES R&D based on DC gun



Wien filter



Mott polarimeter

Polarized electron source related R&D

Domestic R&D on the Superlattice GaAs photocathode

- One of the most important part for Polarized electron source is Superlattice GaAs Photocathode
- Since the beginning of 2025, we have been starting the R&D of Superlattice GaAs
- In collaboration with a domestic company Acken Optoelectronics Ltd. @ Suzhou
- Superlattice GaAs photocathode produced by MBE system, main requirements are Polarization $\geq 85\%$ and QE $\geq 0.5\%$
- The first the batch of photocathodes have been produced

GaAs	5 nm	$p=5 \times 10^{19} \text{ cm}^{-3}$
GaAs/GaAsP SL	(4/3 nm) $\times 14$	$p=5 \times 10^{17} \text{ cm}^{-3}$
GaAsP _{0.35}	2750 nm	$p=5 \times 10^{18} \text{ cm}^{-3}$
Graded GaAsP _x (x = 0~0.35)	5000 nm	$p=5 \times 10^{18} \text{ cm}^{-3}$
GaAs buffer	200 nm	$p=2 \times 10^{18} \text{ cm}^{-3}$
p-GaAs substrate ($p > 10^{18} \text{ cm}^{-3}$)		

Structure of Superlattice layers



MBE system in Acken

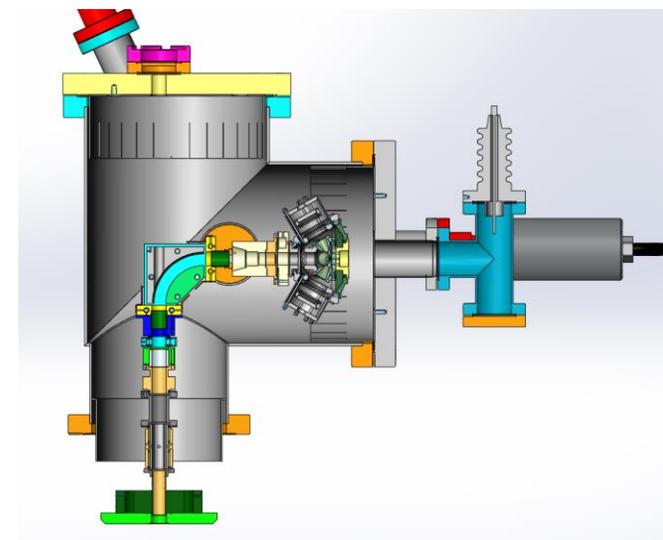
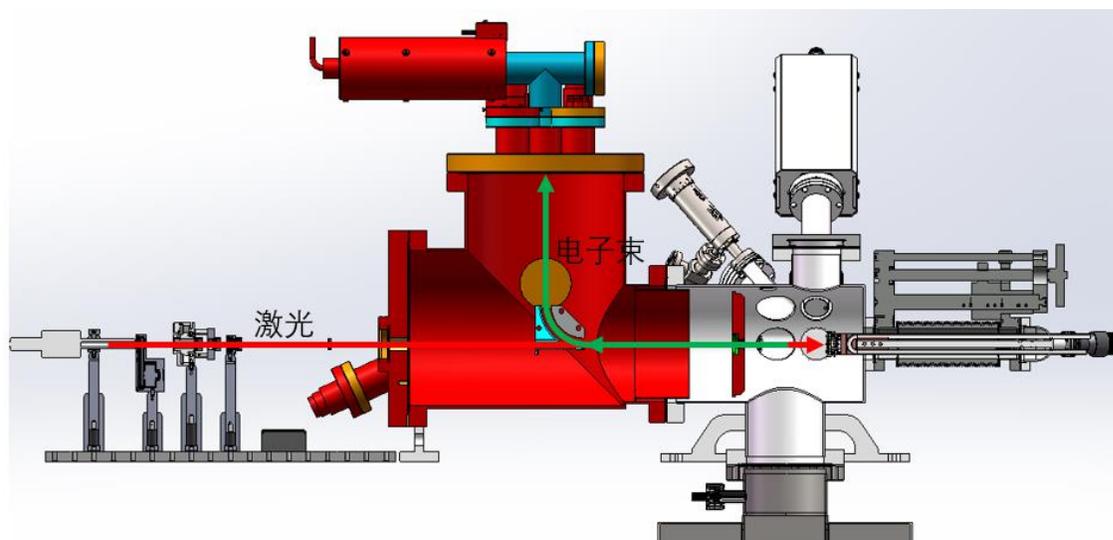
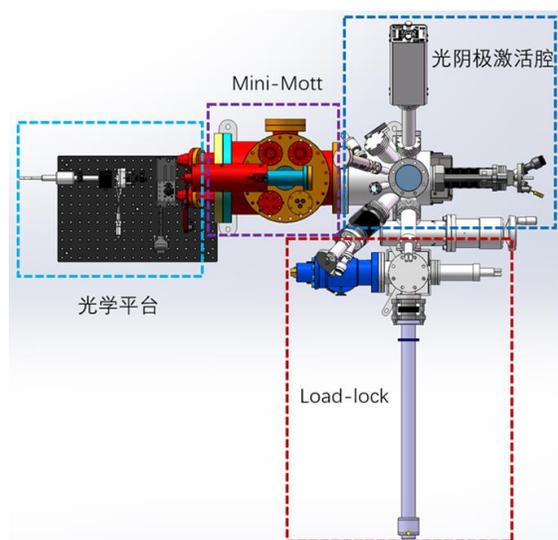


Samples of superlattice GaAs/GaAsP

Polarized electron source related R&D

Domestic R&D on the Superlattice GaAs photocathode

- Build a platform for photocathode performance test (both pol & QE), this platform has been designed and is currently under development, expected to start experimental study on superlattice GaAs this year
- Including a photocathode load-lock chamber, an activation chamber and a testing laser system
- A Mini-Mott polarimeter for a low energy electron beam has been designed, we will start to develop it ASAP



Platform for photocathode performance test

Polarized electron source related R&D

Preliminary test on the Superlattice GaAs photocathode

- From 2024, Valery Tyukin from Inst. of Nuclear Physics, JGU Mainz participated in research on PES (**PIFI 2024/2025**)
- A superlattice GaAs wafer has been cut, and a quarter had been delivered to the Inst. of Nuclear Physics, JGU Mainz
- Activation experiment of the Superlattice GaAs has been carried out in JGU Mainz
- **To test the performance** of Superlattice GaAs (both QE and polarization)
- As a very important experimental data for our Mott polarimeter **calibration** in future



Valery Tyukin



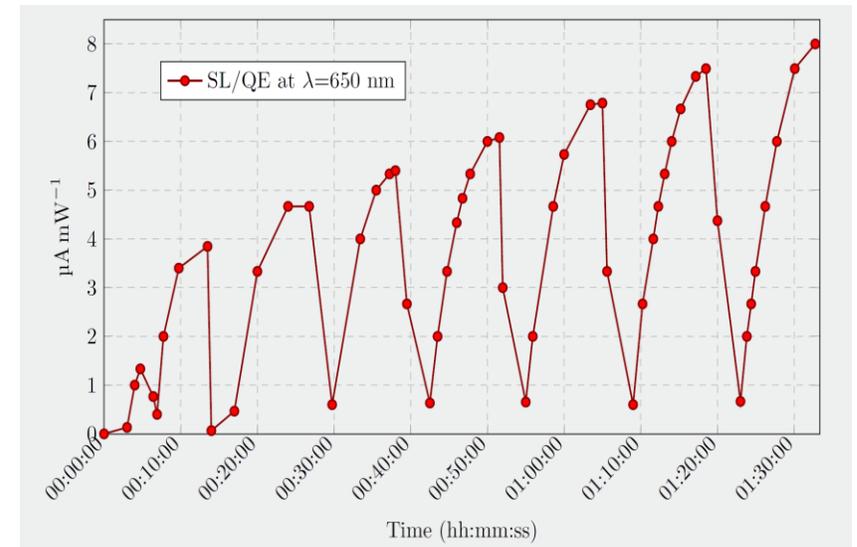
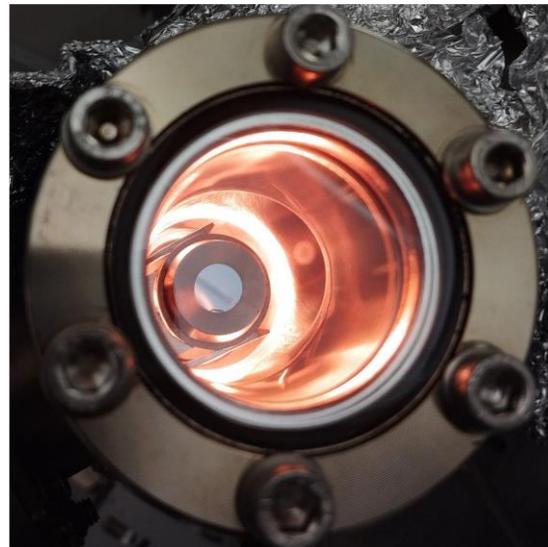
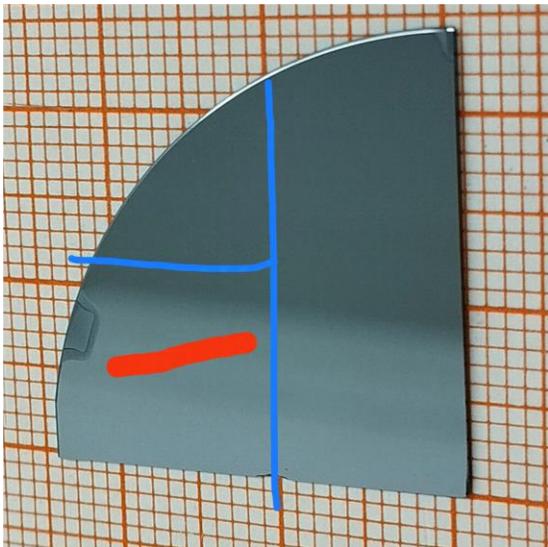
Superlattice GaAs wafer cut in Acken



Polarized electron source related R&D

Preliminary test on the Superlattice GaAs photocathode

- The QE is two to three times lower than that of bulk GaAs (Need more activation experiment to increase QE)
- The lifetime of the Superlattice GaAs in preparation chamber is a few hundred hours, which is a good indicator
- The central part of Superlattice will be used for future beam experiments on the main accelerator at Mainz



- The SL structure is cut along blue lines
- Piece on the left bottom is tested

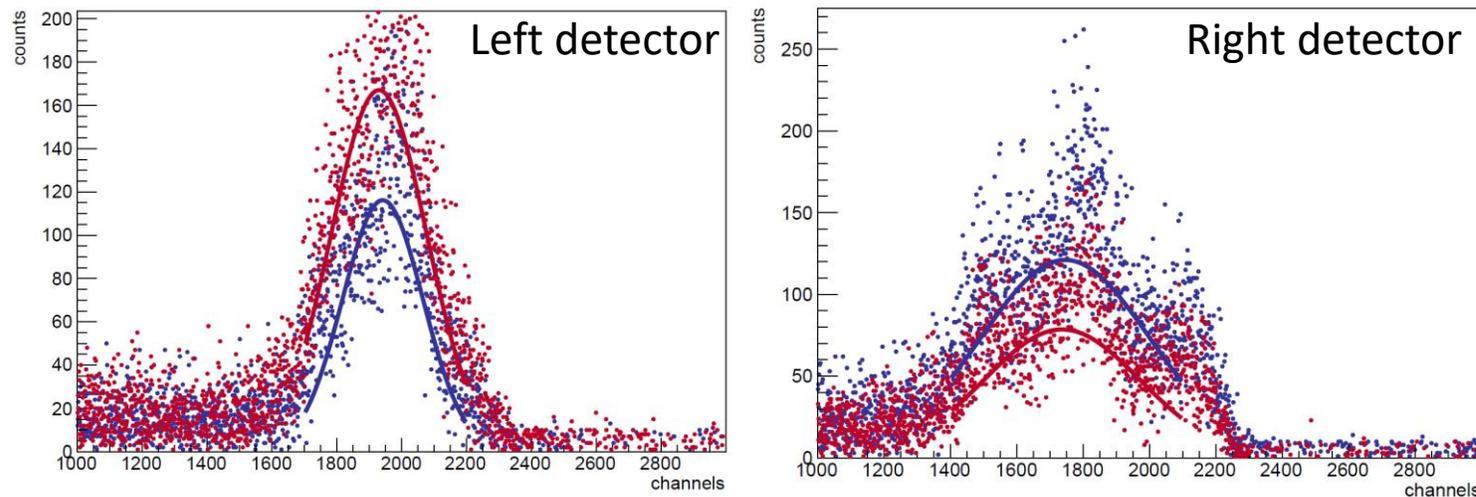
- SL in loadlock chamber
- Preheating in loadlock chamber

- Yo-Yo method, Cs + NF₃
- Maximal QE=3.4% @650nm

Polarized electron source related R&D

Preliminary test on the Superlattice GaAs photocathode

- Polarization measurement at an electron beam energy of **100.0 keV** with a laser $\lambda \sim 776\text{nm}$ has been carried out
- The effective Sherman function S_{eff} is directly affecting the results of polarization measurement, and in this time experiment polarization is estimated at **70%** when using $S_{\text{eff}}=0.28$ that was determined years ago
- The preliminary polarization measurement results show that **Superlattice structure is working**, the next step is to further confirm the polarization with an energy of several MeV on the main accelerator at Mainz with a higher accuracy



Asymmetry measurements: left and right detectors

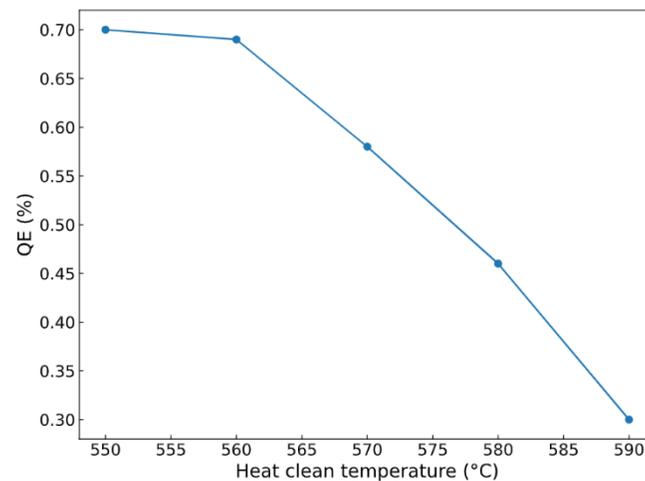
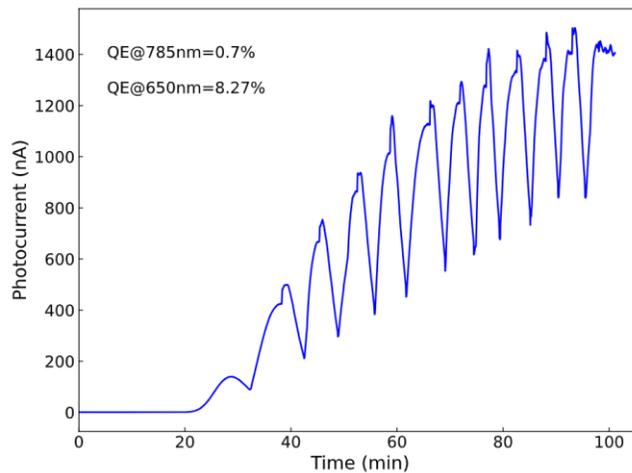
$$A_{\text{mes}} = \frac{1-q}{1+q} = 0.196 \quad P = \frac{A_{\text{mes}}}{S_{\text{eff}}} = 70\%$$

Cathode	QE $\frac{\text{mA}}{\mu\text{W}}$	$A_{\text{mes}}, \%$	$P, \%$
bulk GaAs	$\sim 8.00 - 10.0$	~ 8.00	~ 28.5
SL SVT	$\sim 0.10 - 2.00$	~ 16.6	~ 60.0
SL Acken	$\sim 0.025 - X.XX$	~ 19.6	~ 70.0

Polarized electron source related R&D

Preliminary test on the Superlattice GaAs photocathode

- Considering the low QE results of Superlattice at Mainz, cross check of activation experiment was carried out on the platform of Chongqing University in China (only activation experiment and QE measurement) based on another quarter.
- Yo-Yo method by using Cs+O₂ activation
- QE is **0.7% @785nm** and **8.27% @650nm**, and QE of Superlattice decreasing with the increase of heat clean temperature
- For CEPC polarized electron source, Superlattice with a QE≥0.5% will be enough to meet the requirements

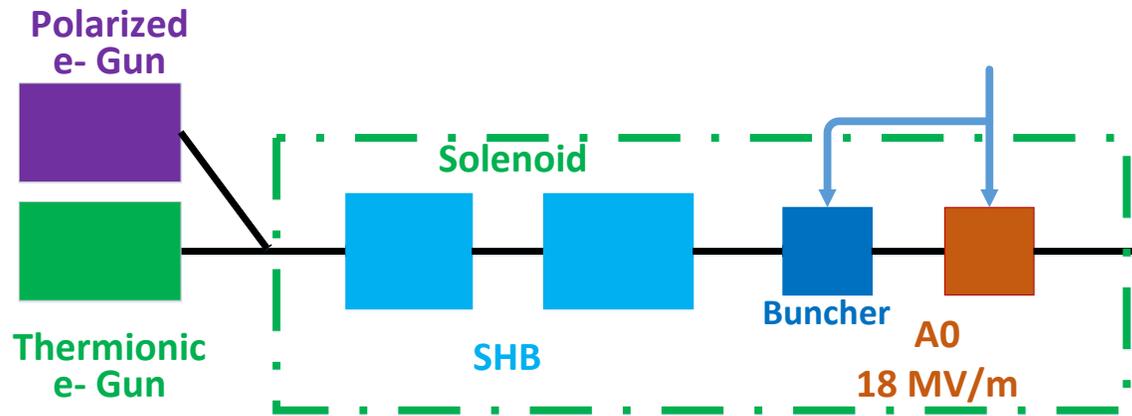


Activation experiment study on Superlattice GaAs at Chongqing University

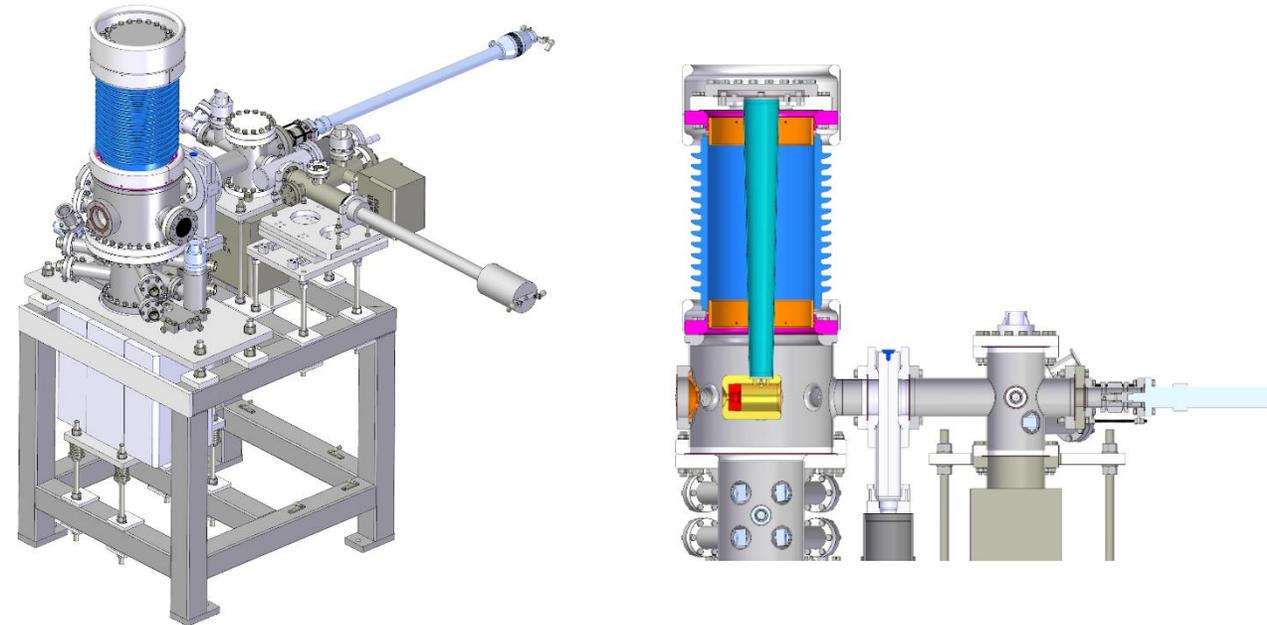
Polarized electron source related R&D

A Polarized electron gun design for CEPC

- A 150kV HV photocathode electron gun has been designed (Beam parameters are consistent with the thermionic gun)
- We proposed a two electron guns scheme and do not change the layout of the injector, share the bunching system
- As an alternative solution for CEPC electron source
- It can also be adopted in BEPCII as a polarized electron source



Two electron guns scheme for CEPC



A 150kV HV photocathode electron gun

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Summary

- Introduction of electron source for CEPC.
- The method of generating polarized electrons.
- Introduced progress of polarized electron source related R&D plan.
- Domestic R&D on the superlattice GaAs photocathode and preliminary test results.
- A polarized electron gun design for CEPC.

Thank you for your attention!

