



The negative beam source with single driver for CRAFT NNBI: design and conditioning results

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Outline



- **Background**
- **Negative ion source with single driver**
- **Experimental results**
- **Future plan and Summary**



CRAFT Project

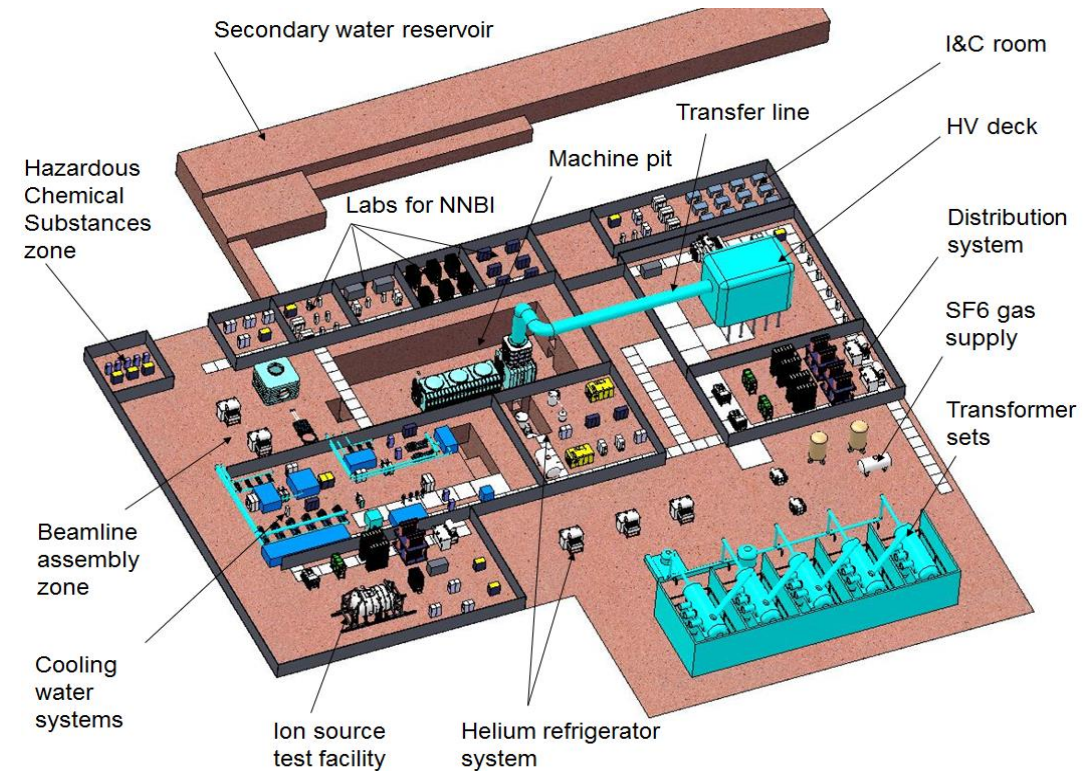


Comprehensive Research Facility for Fusion Technology (CRAFT)

National big science facility (2019.9-2025.5, 4 Billion RMB)



Layout of CRAFT NNBI system

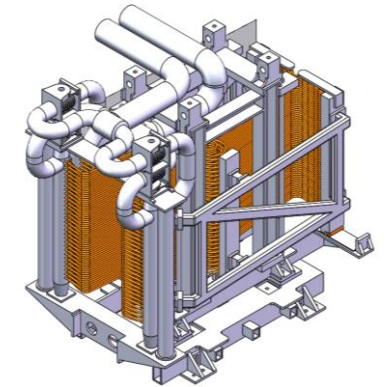
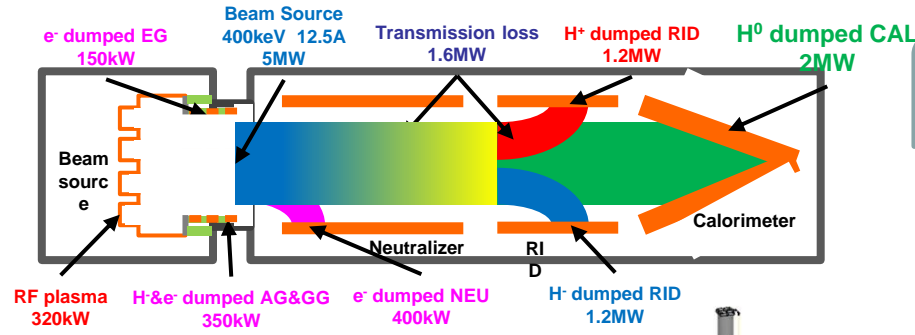


Project target: 200-400 keV, 2 MW, 100s

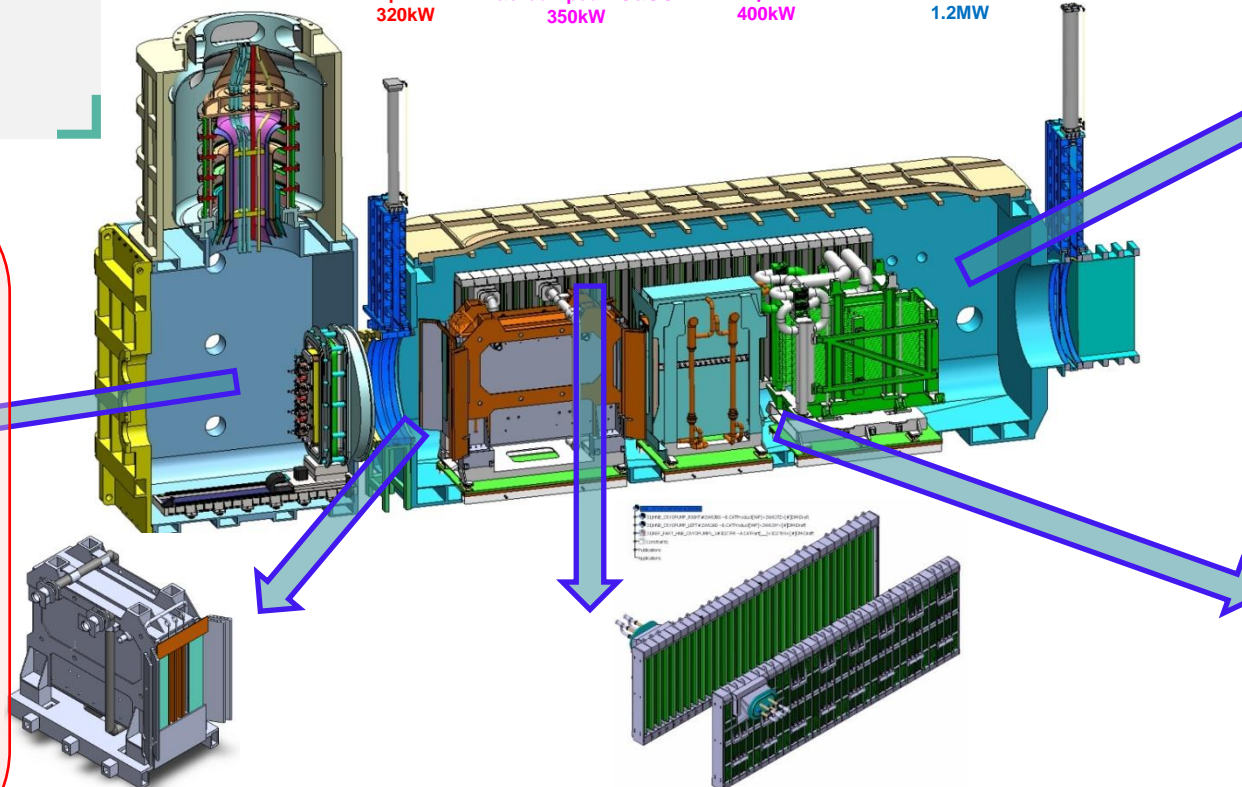
Key technology

- Negative ions generation
- Negative beam acceleration
- HVPS and transmission
- High speed cryopump

CRAFT NNBI components



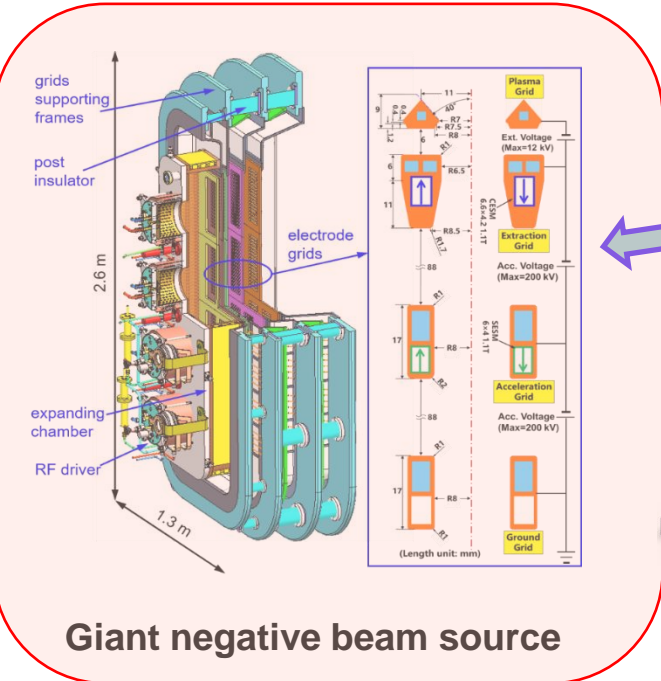
Calorimeter



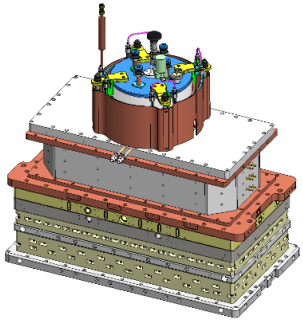
Neutralizer

Cryopump panels

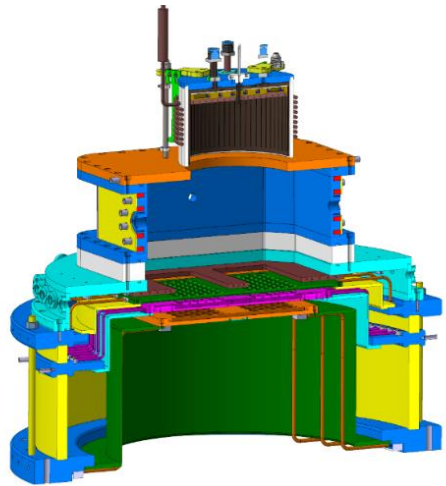
Electrostatic residual ion dump



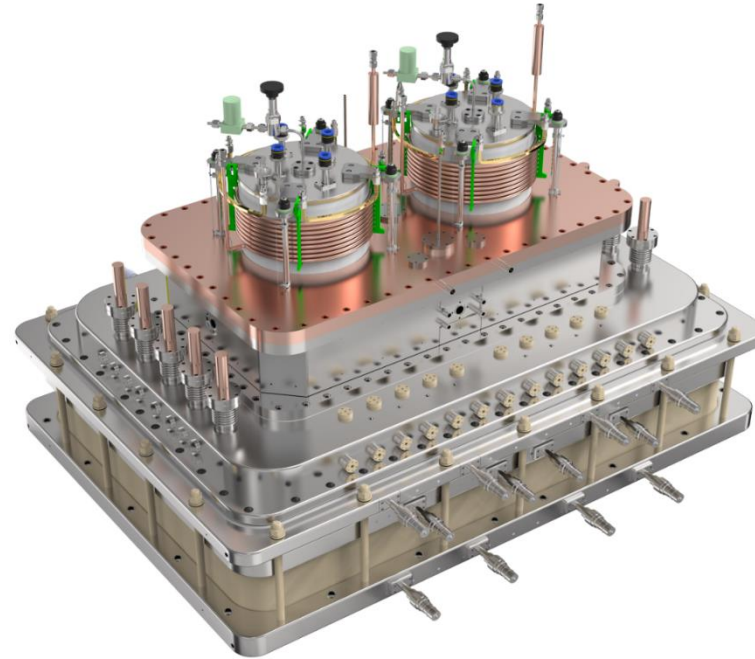
Giant negative beam source



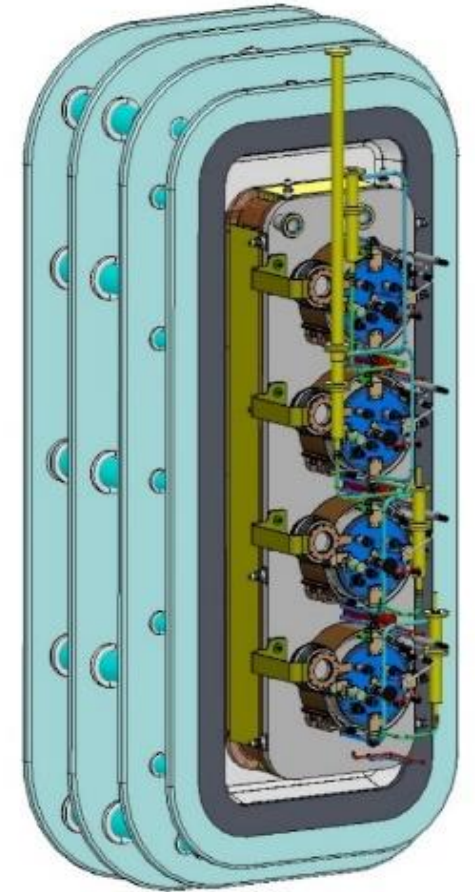
Prototype of NIS
2020-2021



1/4 size of NIS
2021-2022



Half size of NIS
2022-2023



Full size of NIS
2023-2024



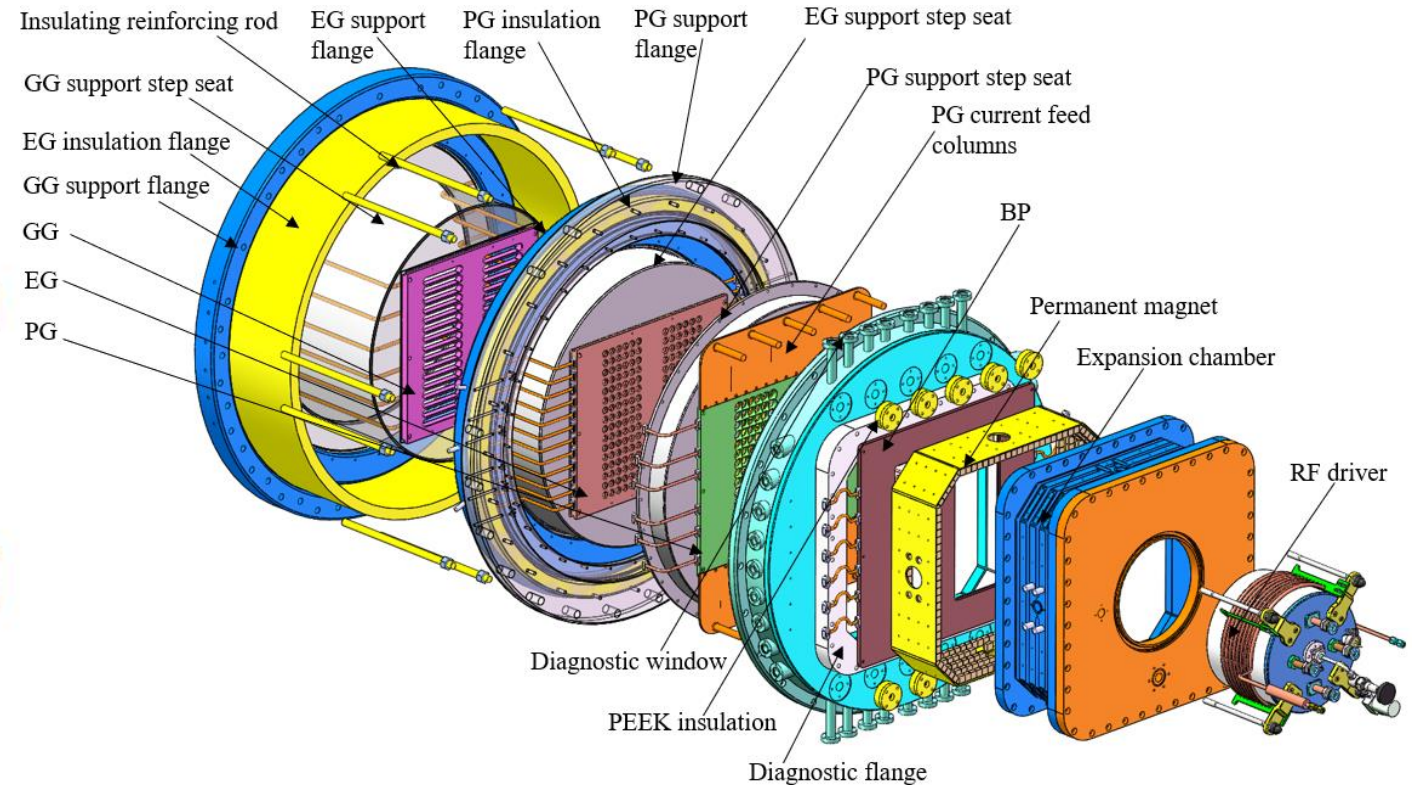
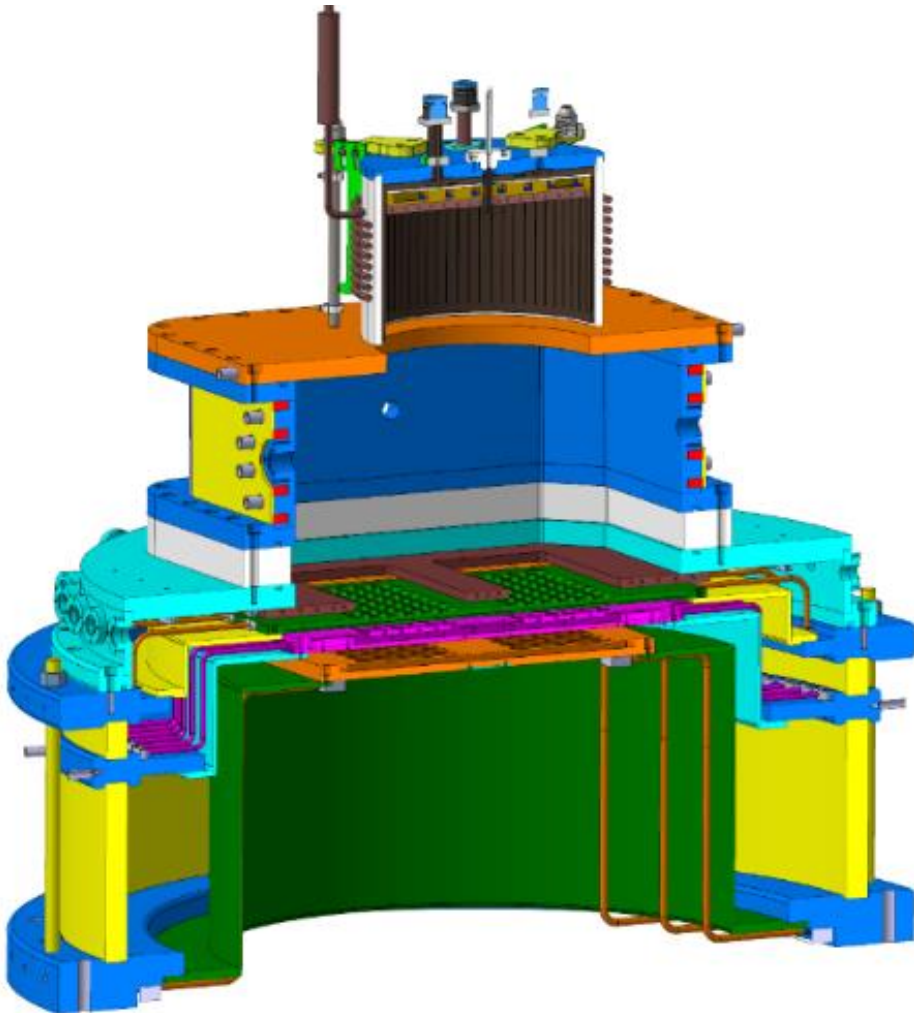
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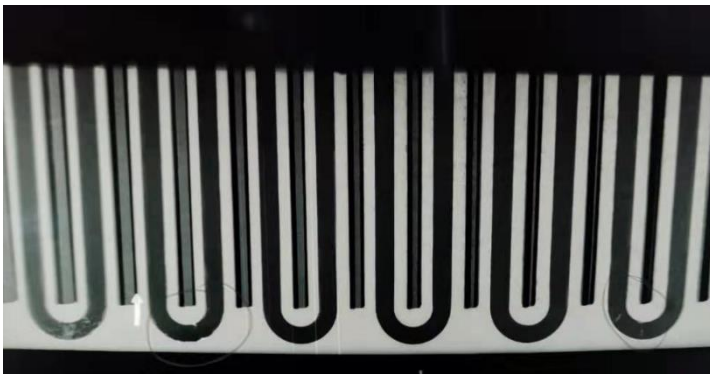
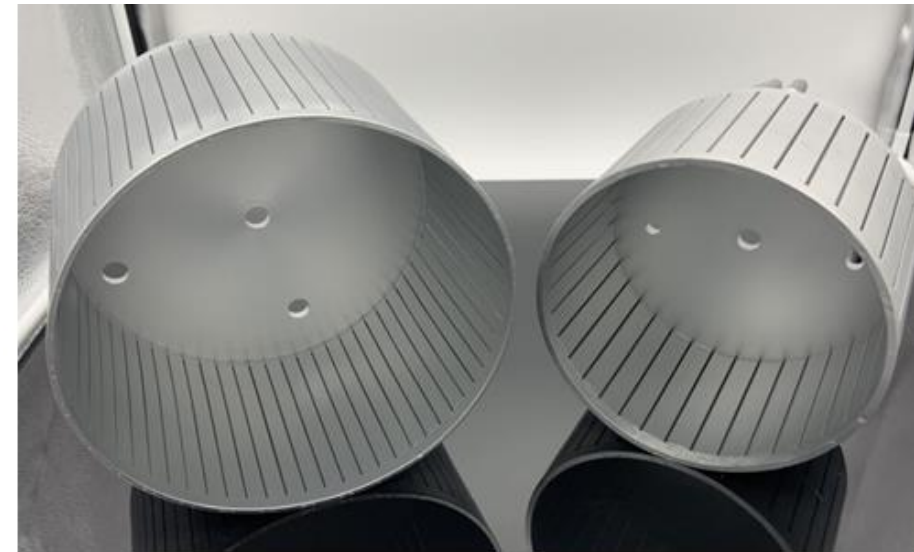
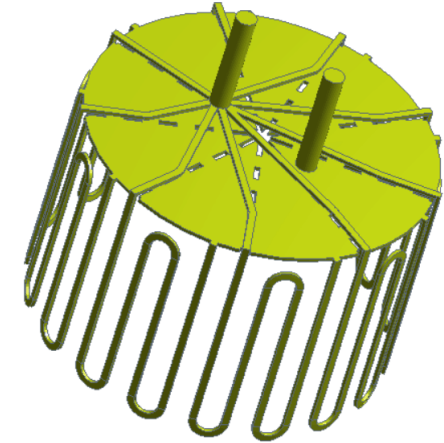
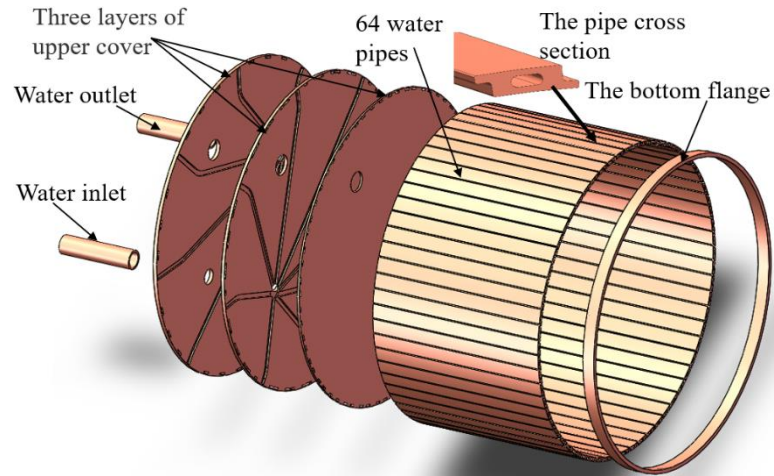
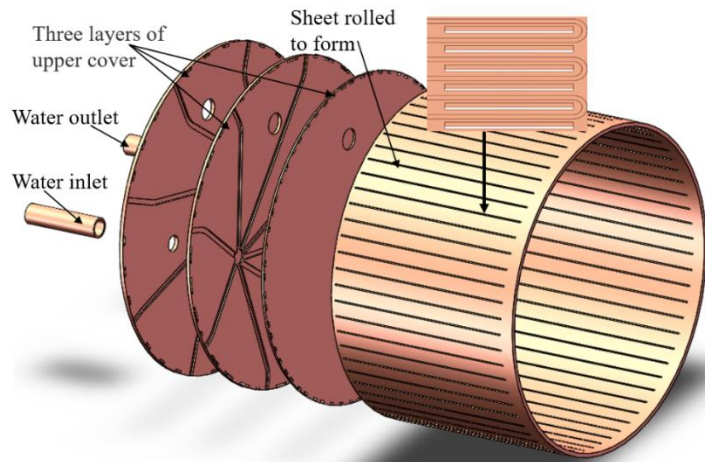
Development of 1/4 size beam source

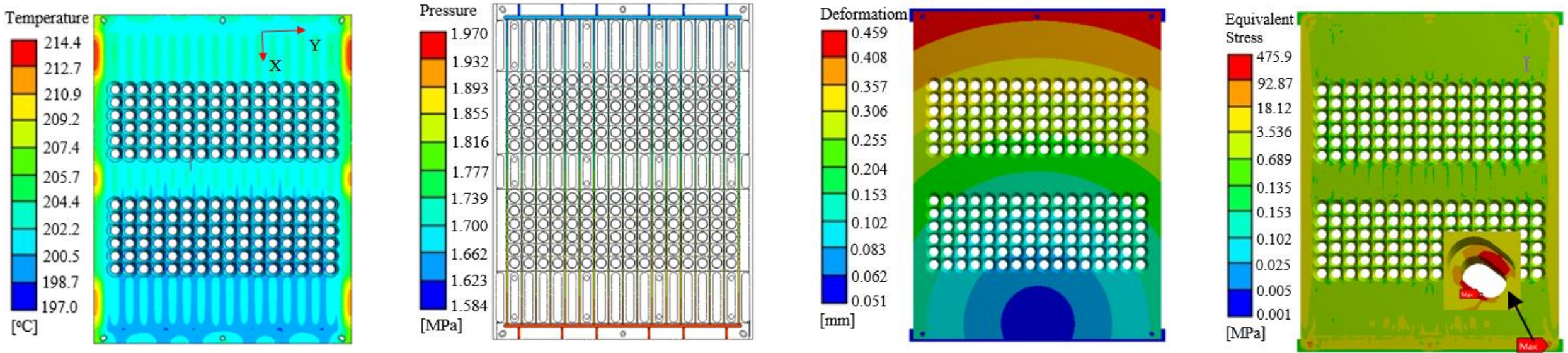
Parameter	Value
RF Power(kW)	100
RF Frequency(MHz)	1
RF driver Height(cm)	13.4
RF driver Diameter(cm)	24
Bucket chamber(cm)	45(L)×45(W)×19(H)



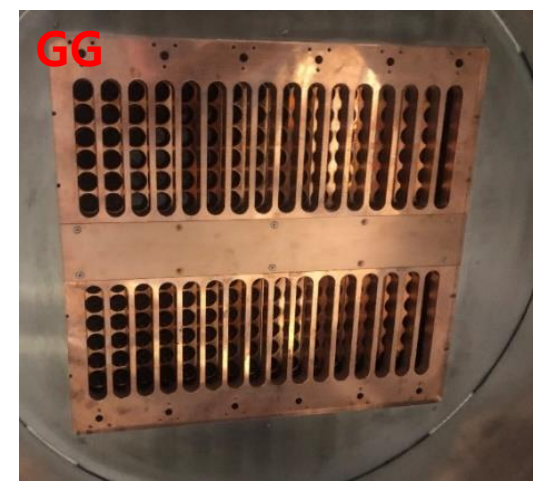
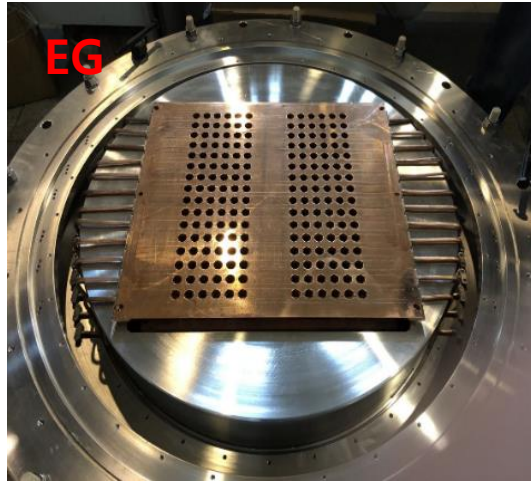
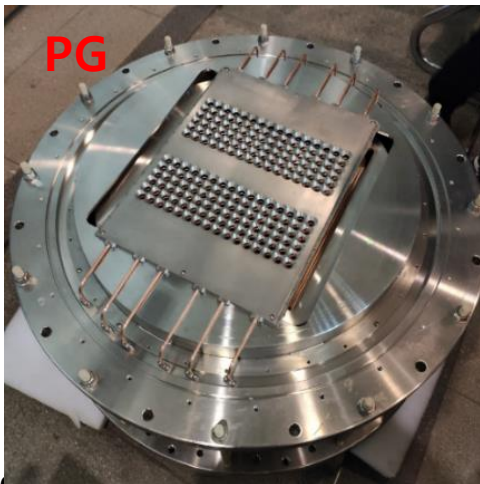
The manufacture of faraday shield

- ❑ The faraday shield was manufactured by two technology: diffusion welding(left) and vacuum brazing(right)
- ❑ The FS made by diffusion welding is better than vacuum brazing using the X ray checking



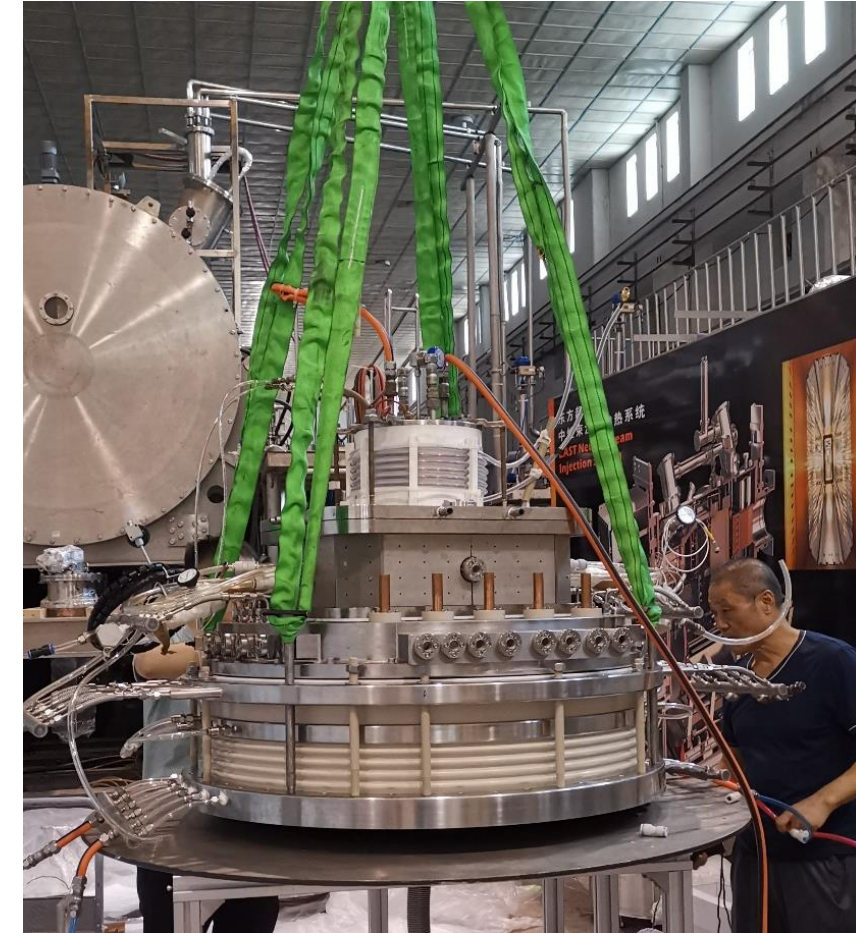
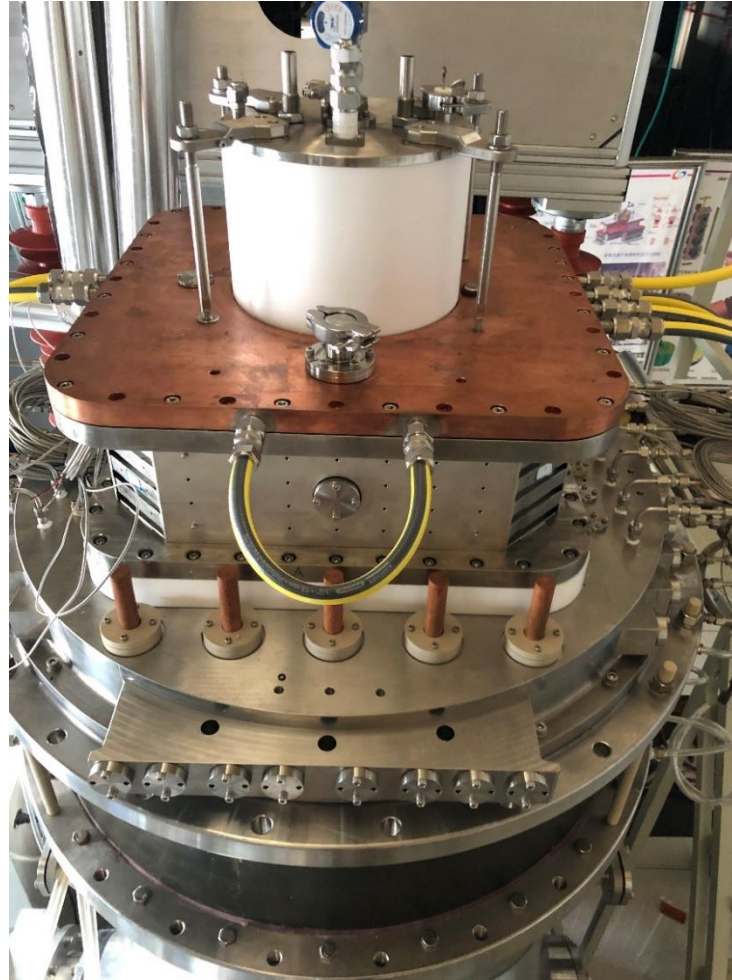
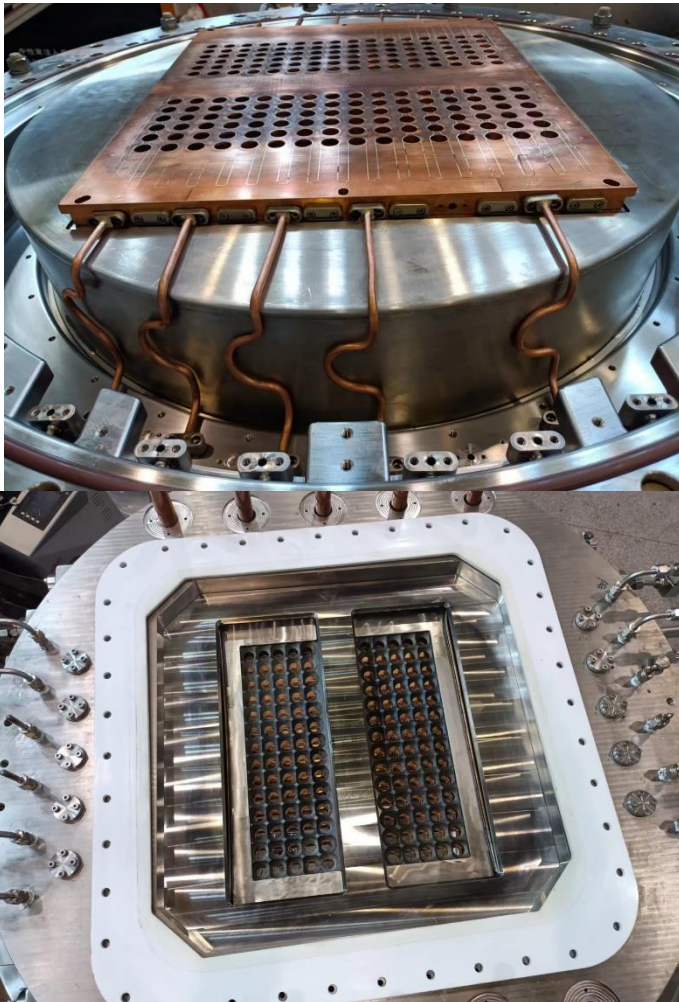


Fluid-thermal-structural analysis of PG: (a) Temperature distribution; (b) Internal water pressure distribution; (c) Thermal displacement; (d) Equivalent (Von Mises) stress



Assemble of negative beam source

- ❑ The negative beam source was assembled and initial checked (leakage detecting)
- ❑ The main insulator made by epoxy and changed to PEEK in the recent campaign





Negative ion source installed on the test facility



- ❑ RF power: 100kW @ 1MHz
- ❑ EG power: -16kV@20A
- ❑ AG power: -50kV@100A
- ❑ PG active heating ~180 degree
- ❑ Expansion chamber ~50 degree
- ❑ Diagnostics tools: Langmuir probe\ MWI\OES\CRDS
- ❑ Gas pumping system: Cry-pump (100,000L/s) and turbo pump (4600L/s) for H





Outline



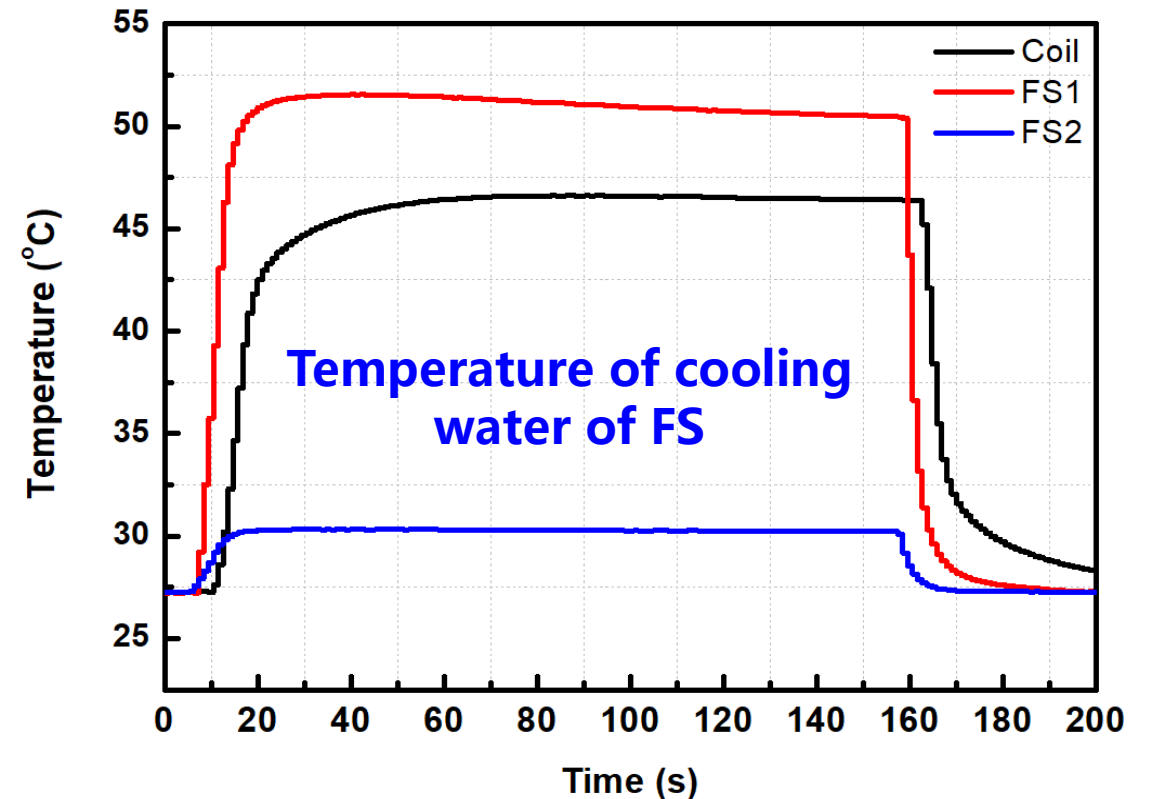
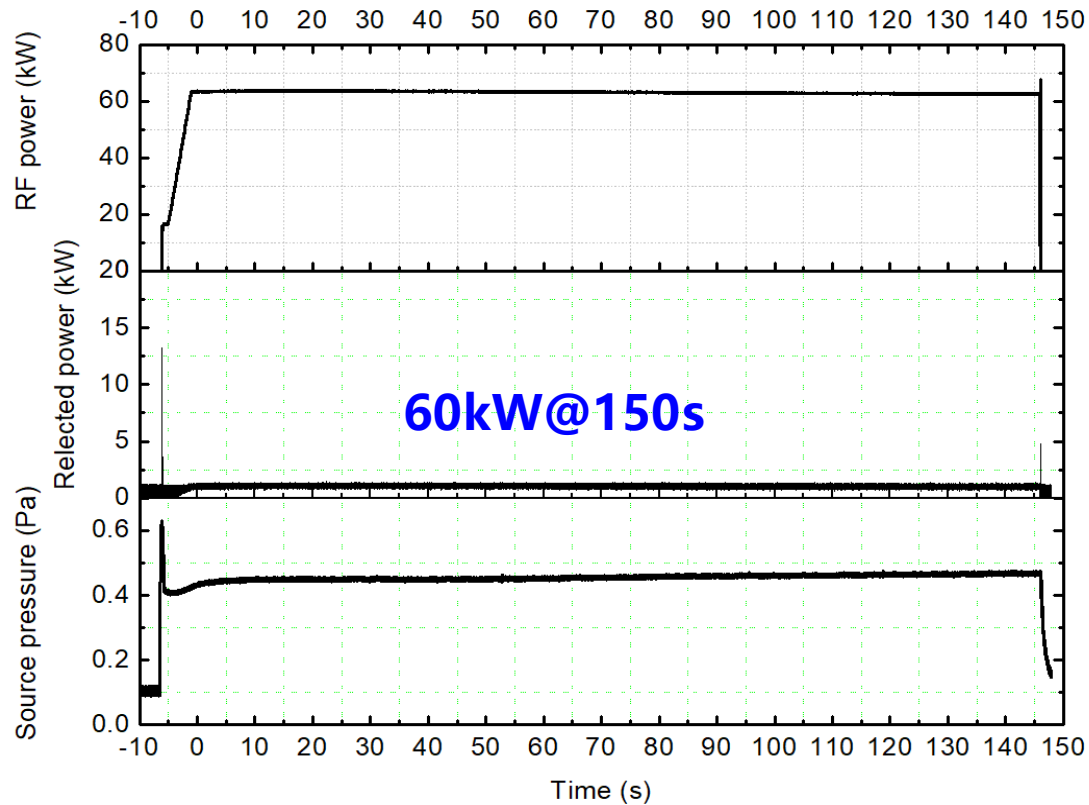
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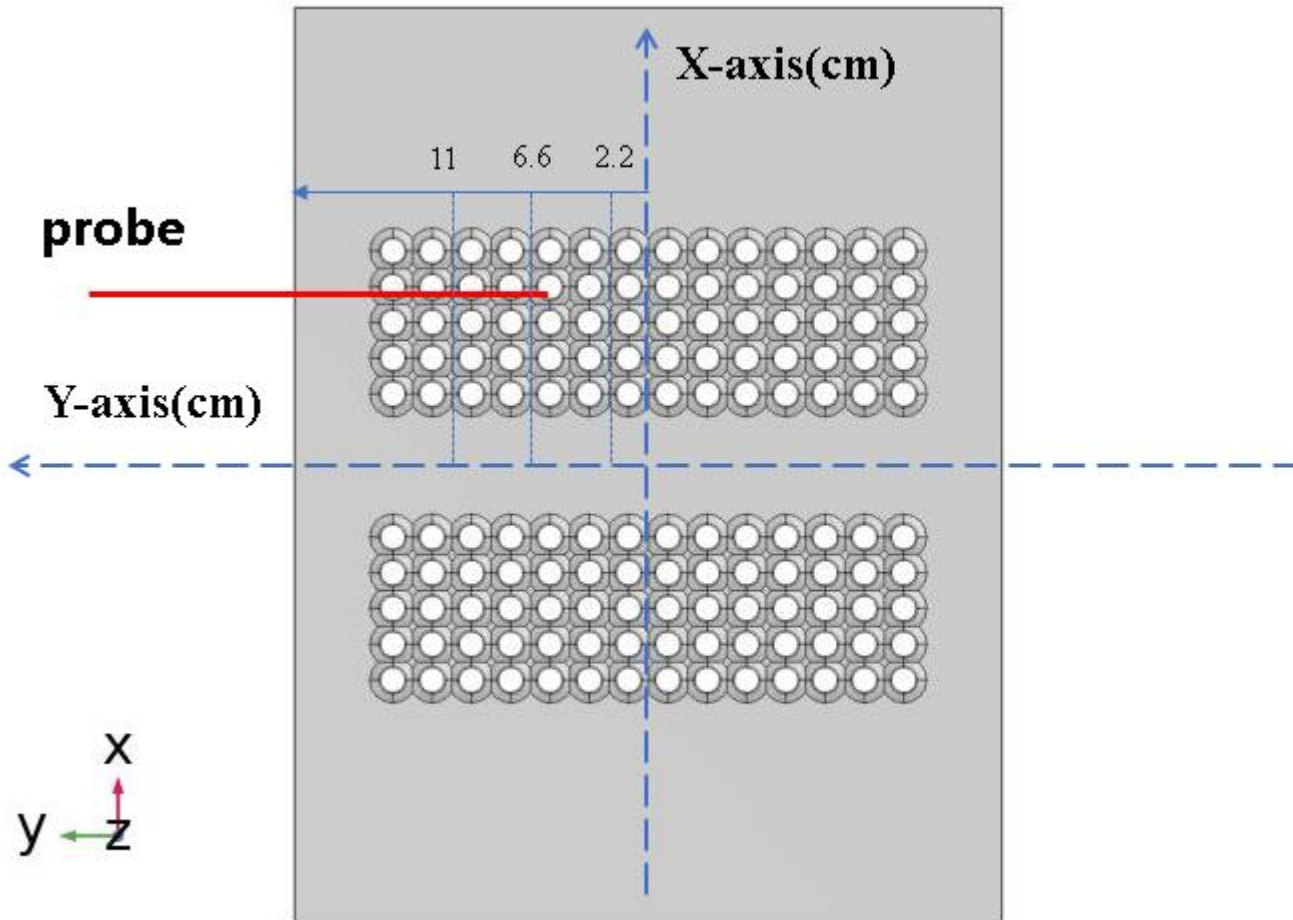
PF plasma discharge conditioning



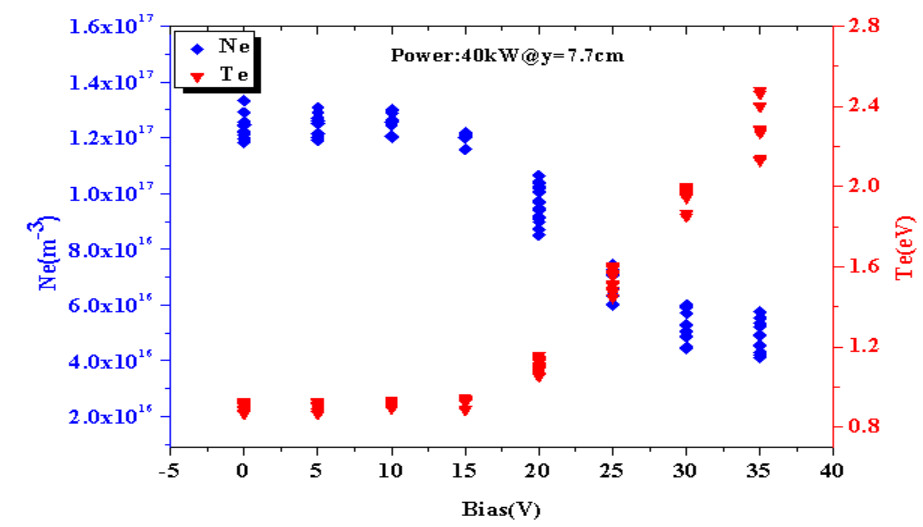
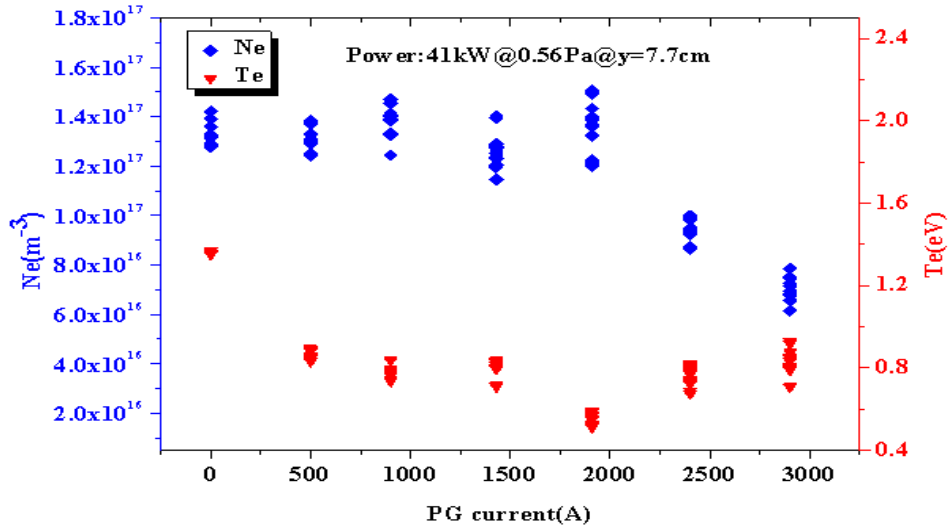
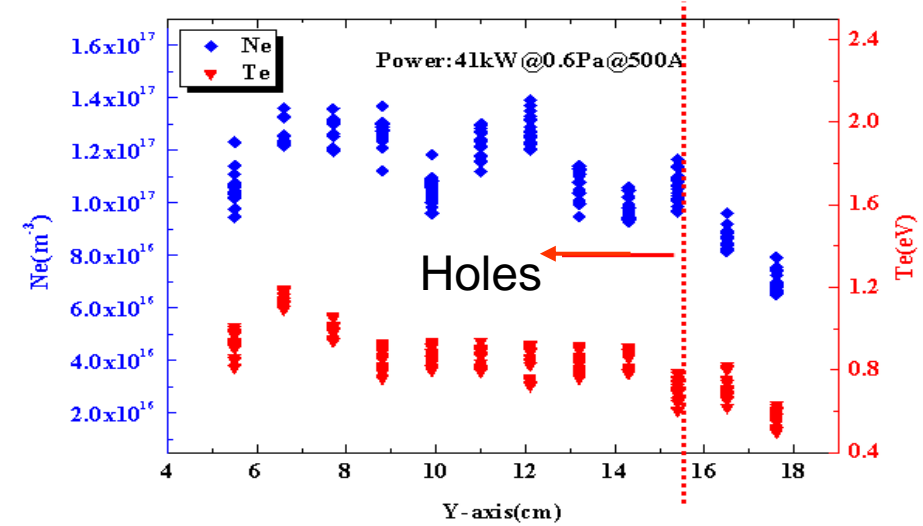
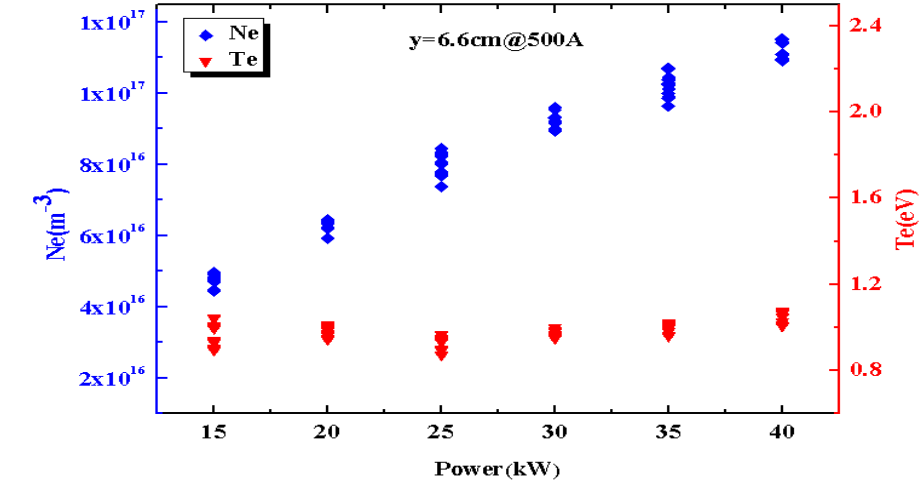
- The plasma was generated with high pressure and start filament
- Through plasma condition, long pulse of 150s plasma was achieved with 60 kW RF power



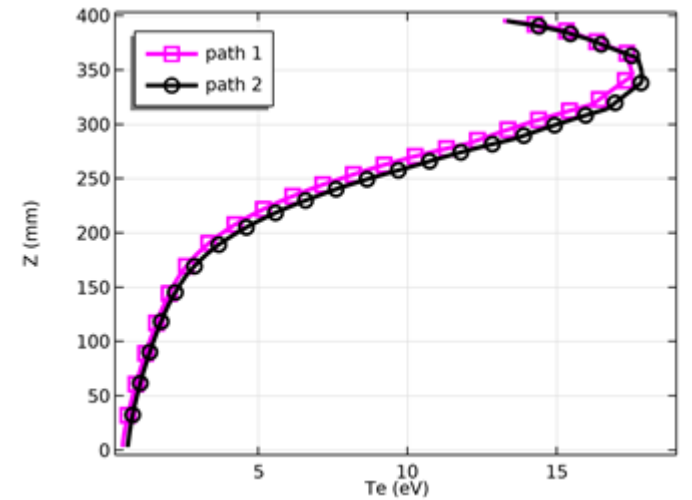
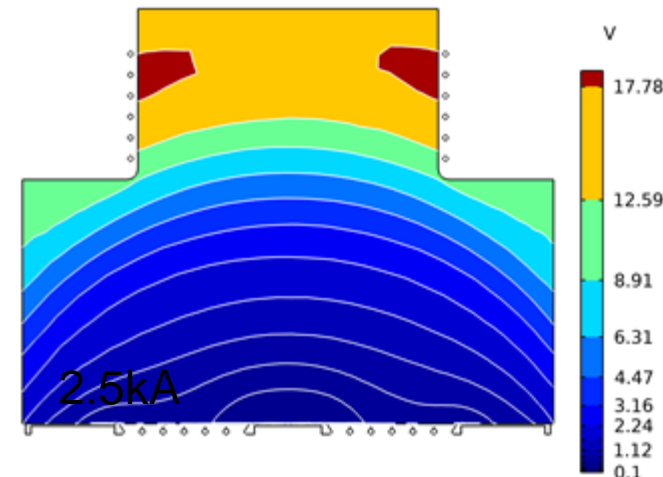
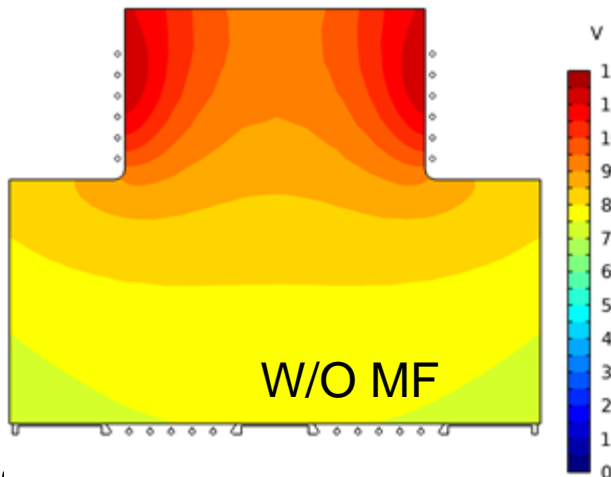
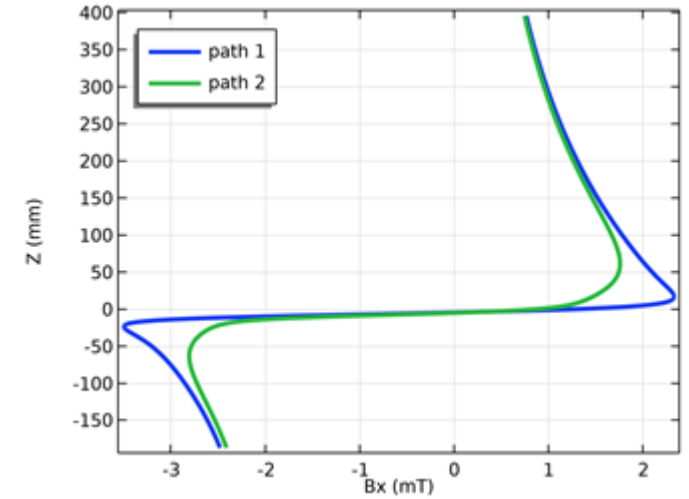
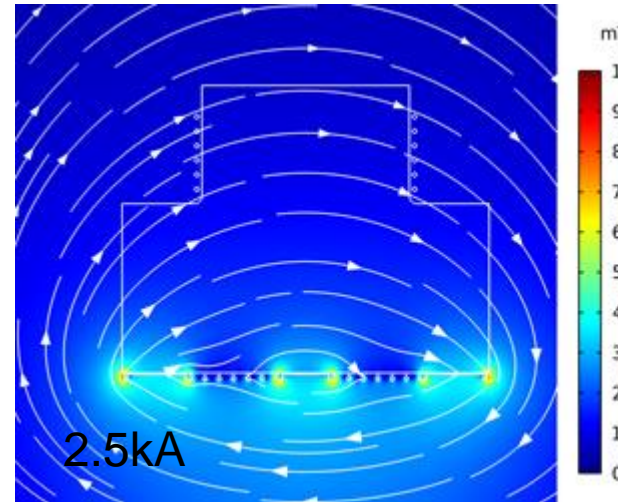
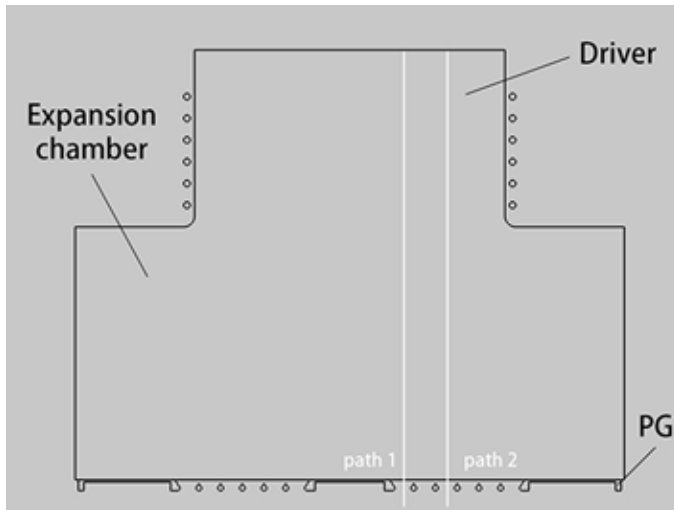
- In order to measure the plasma parameters, a moveable Langmuir probe installed on the plasma chamber (8mm to PG)



□ The plasma parameters were measured with different conditions



- ❑ The magnetic filter was designed use the current flow through PG
- ❑ Through the simulation, the electron temperature can decreased to 1 eV

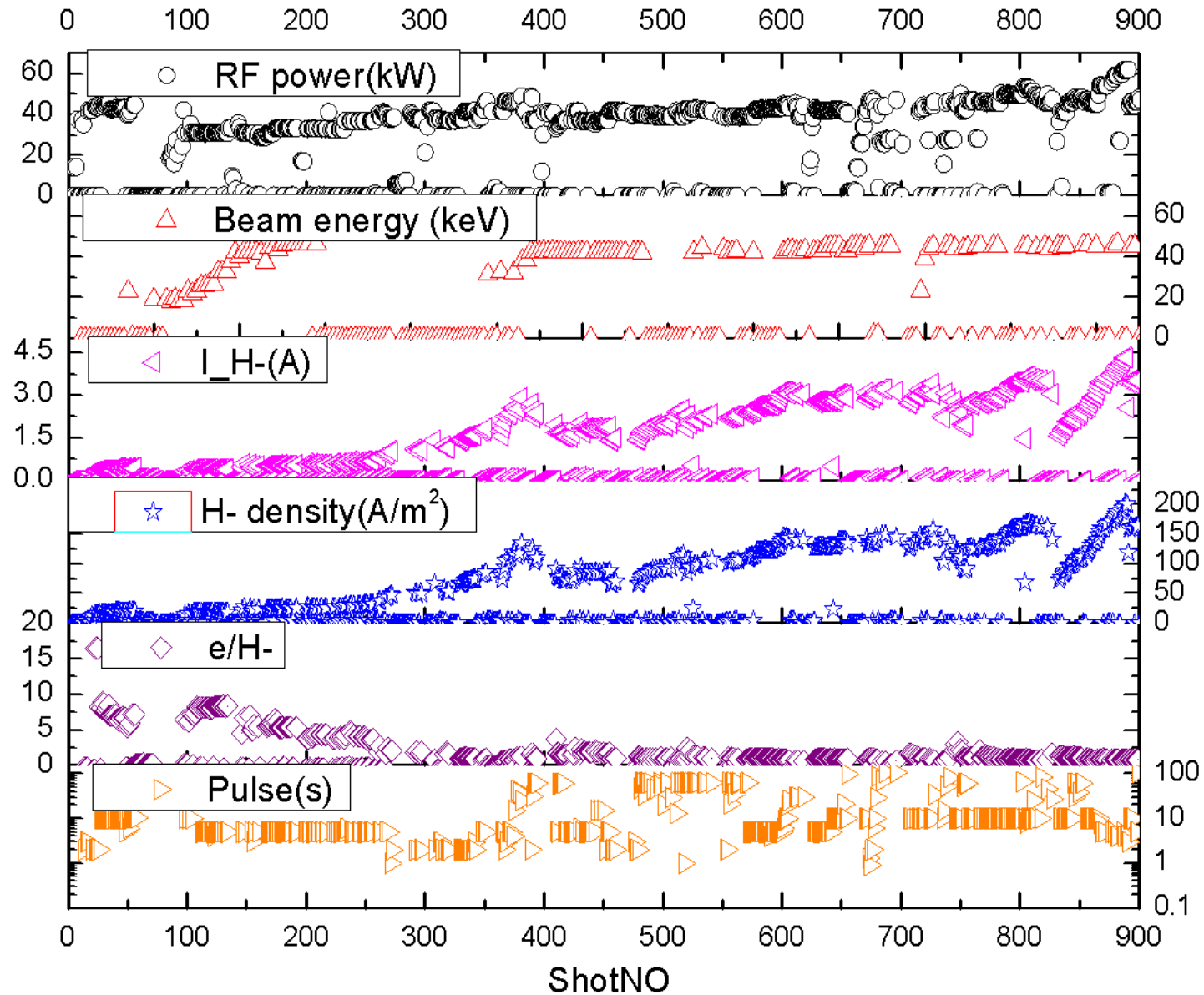
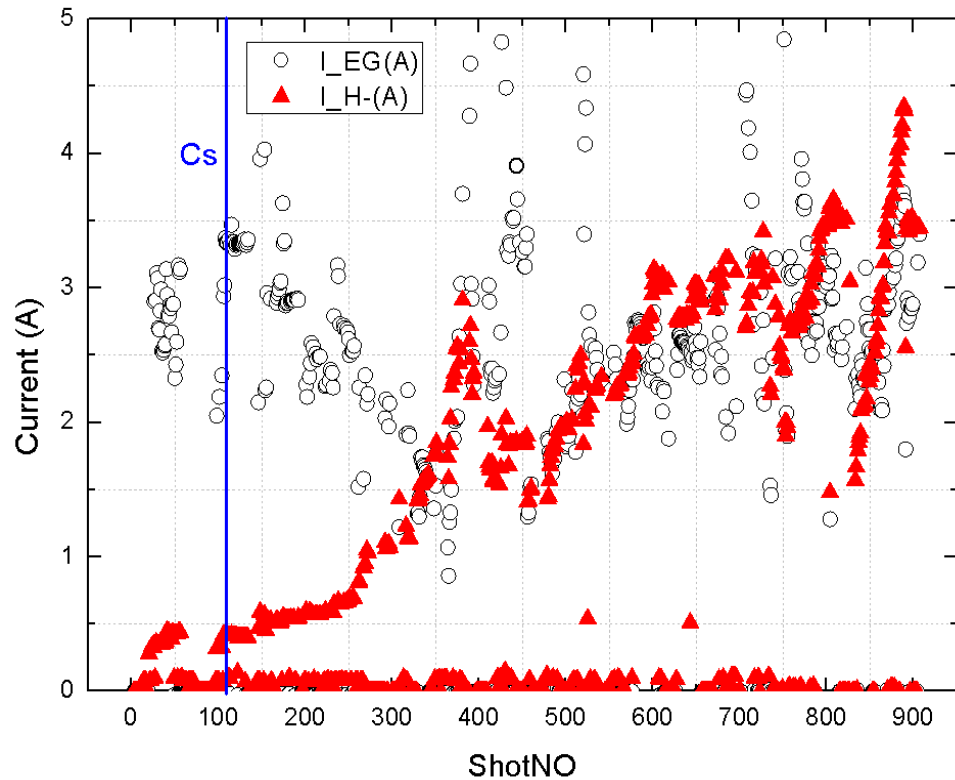




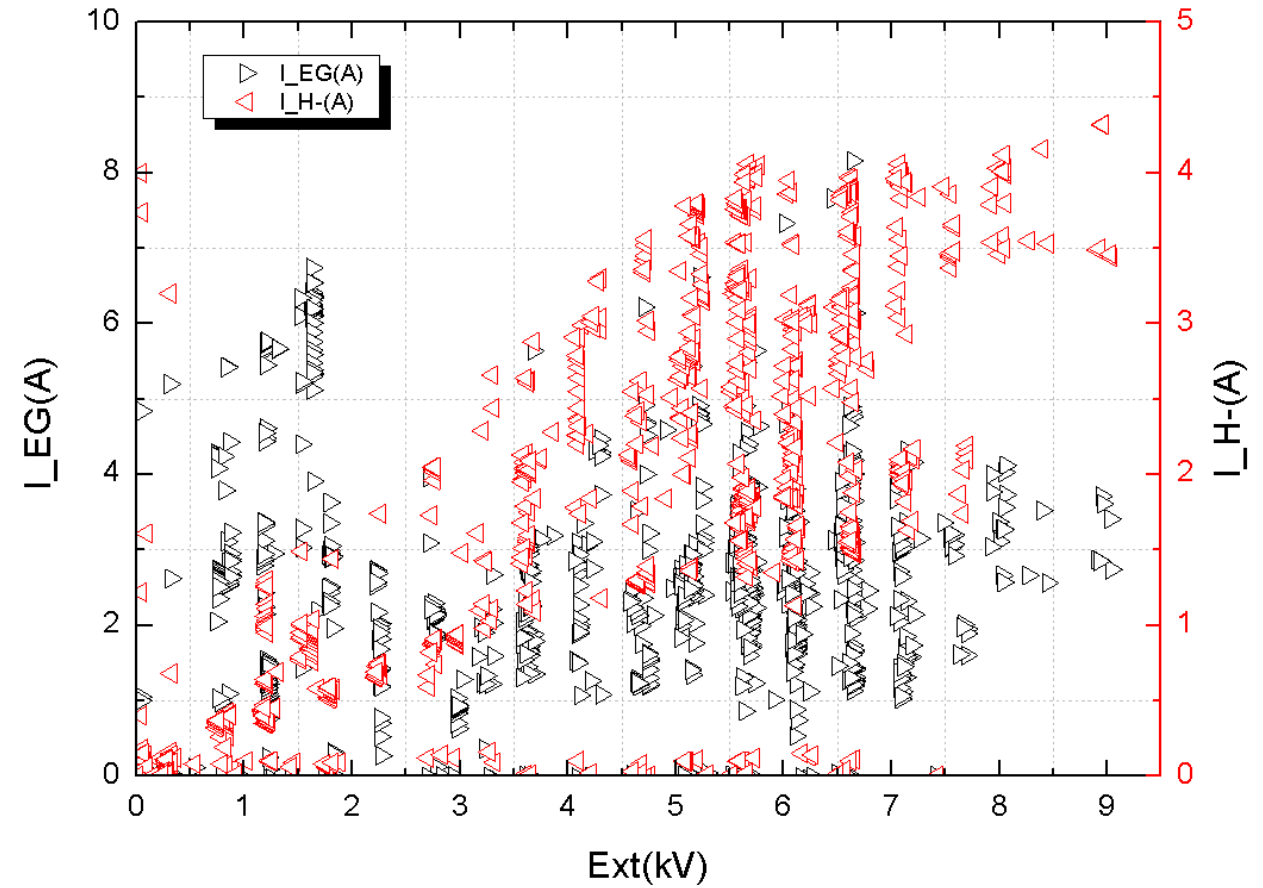
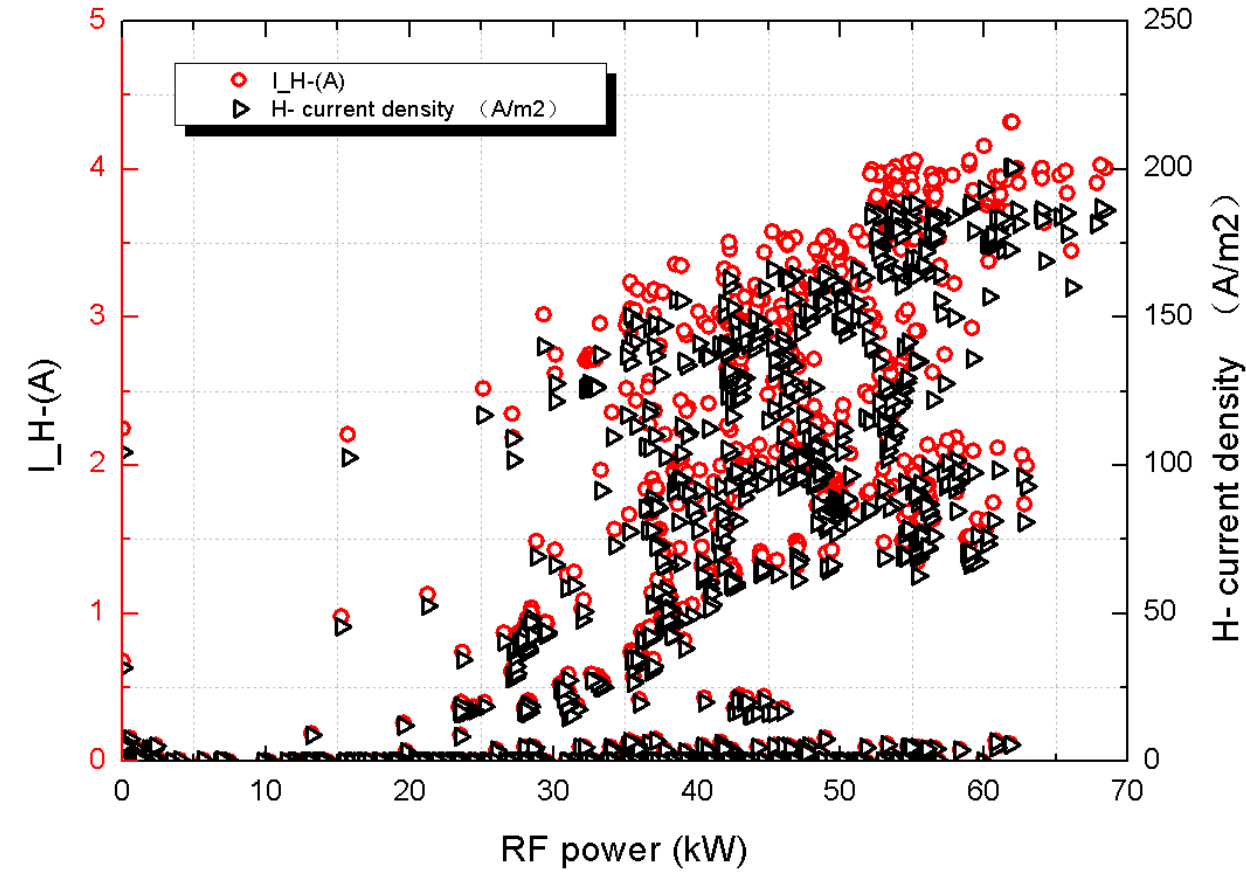
Beam conditioning



- Beam conditioning W/O and with Cs injection
- The Cs works after about 150 shots



□ The negative ions and co-extracted electrons as function of RF power and extraction voltage

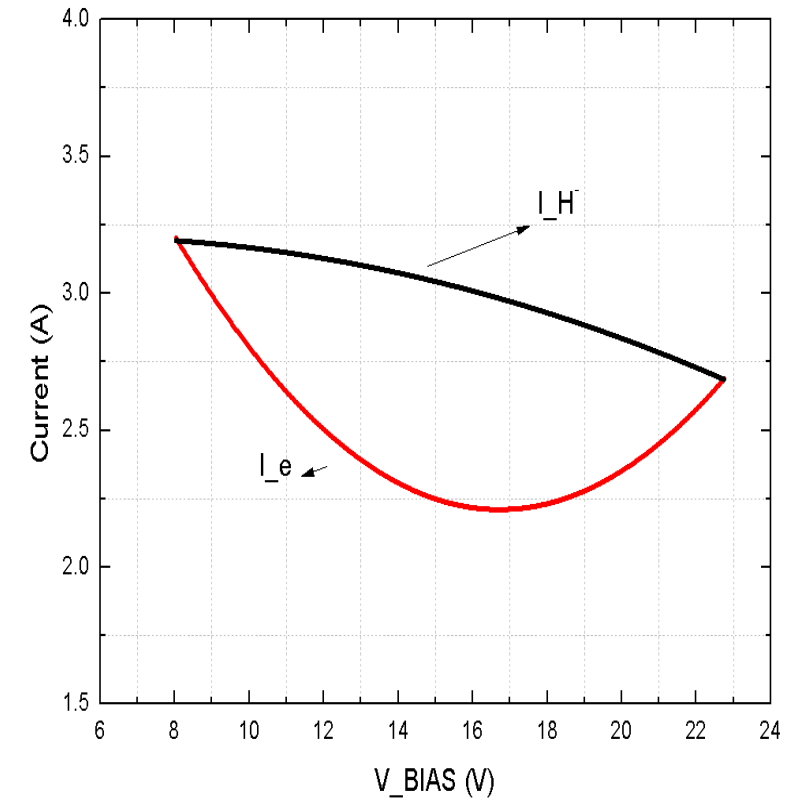
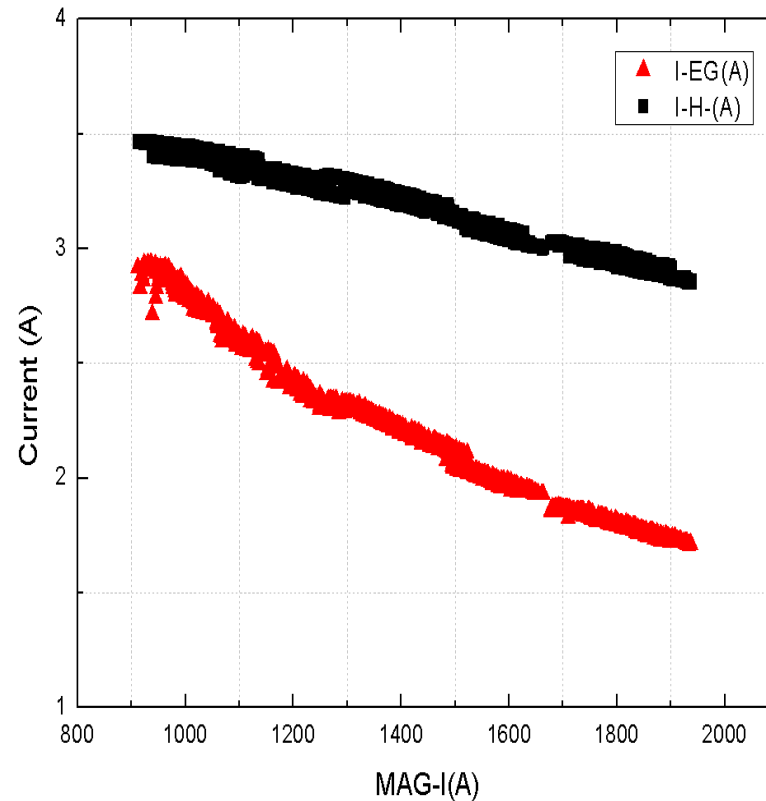
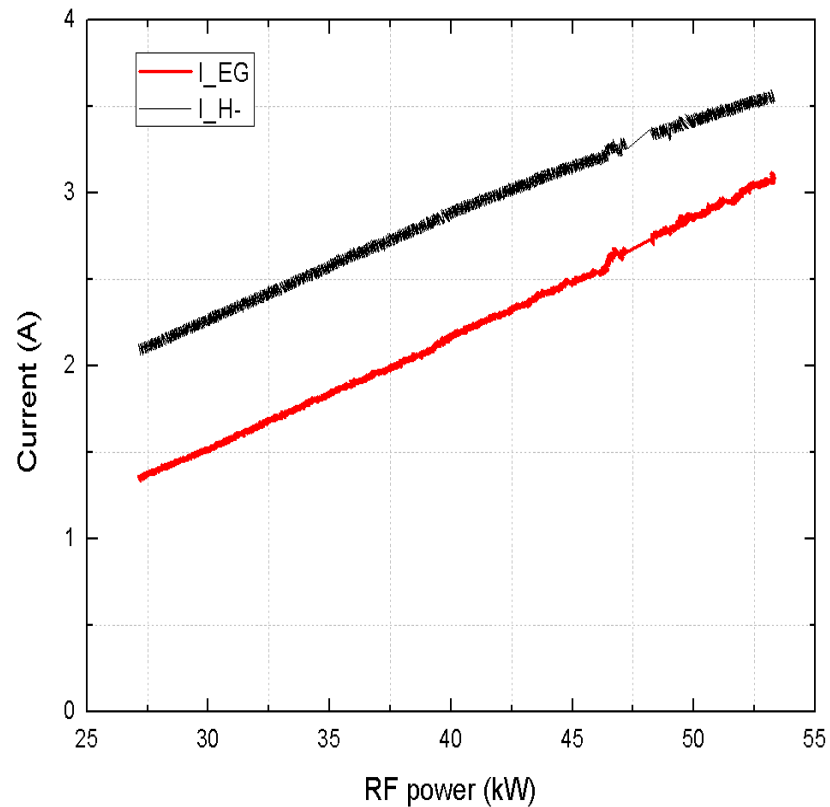




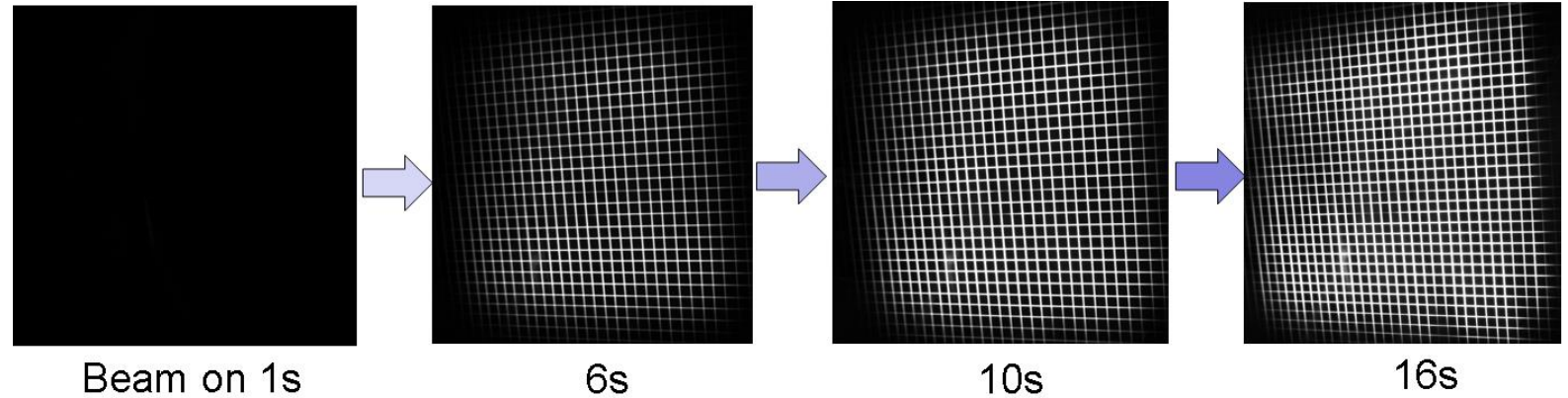
H- and co-extracted electrons behaviour



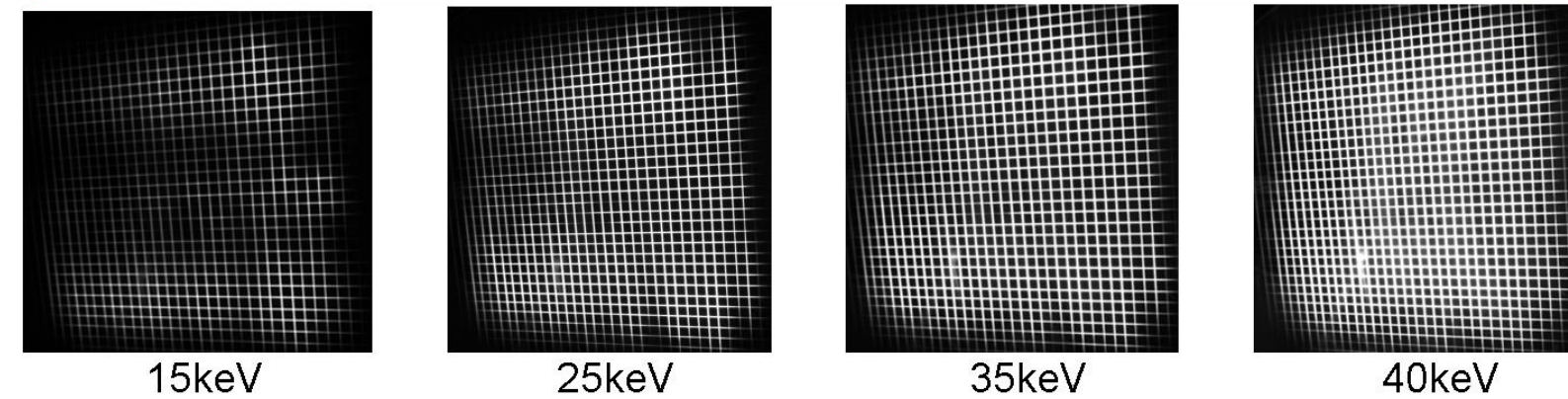
- ▶ The magnetic filter can affect the co-extracted electrons strongly
- ▶ The bias voltage has an optimum value



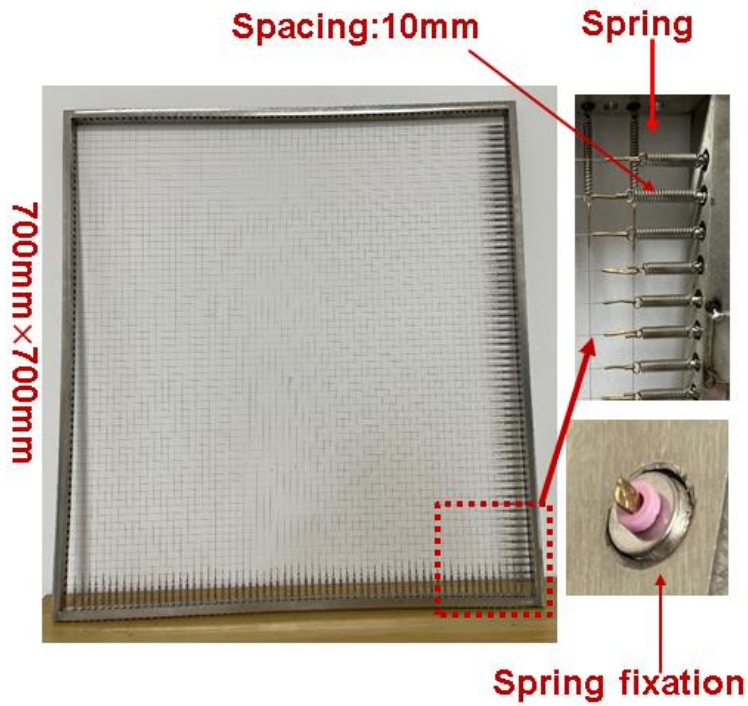
- A tungsten wire calorimeter was installed for beam profile evaluation (about 1m to GG)



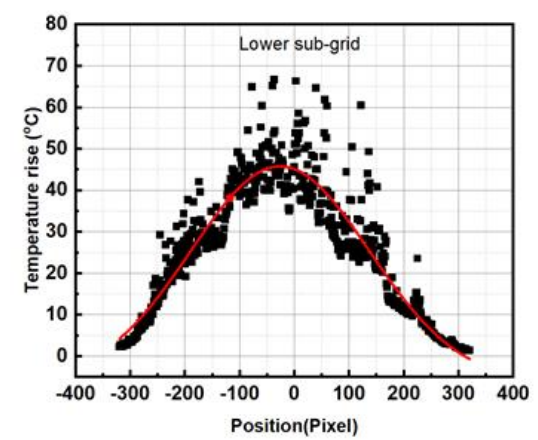
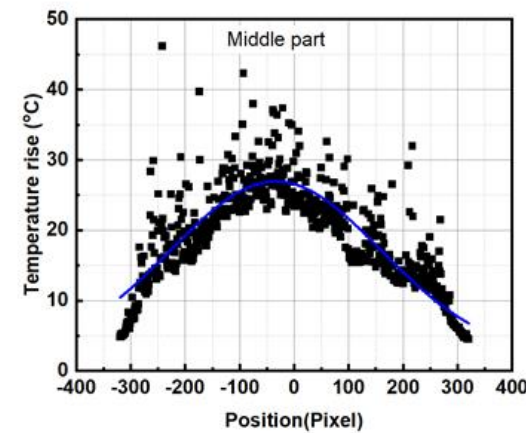
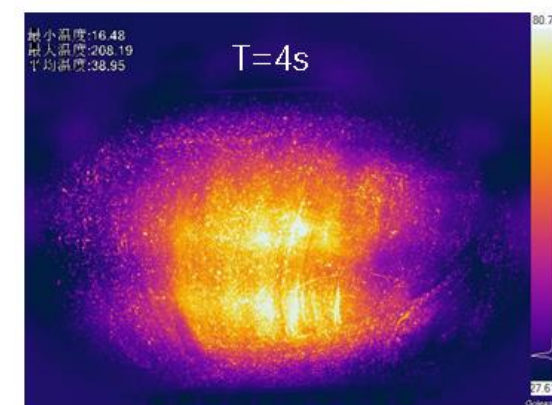
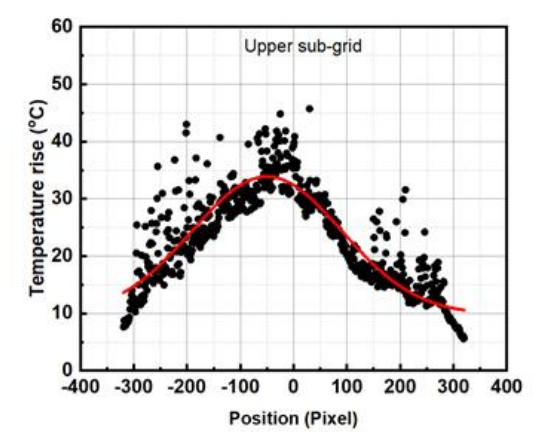
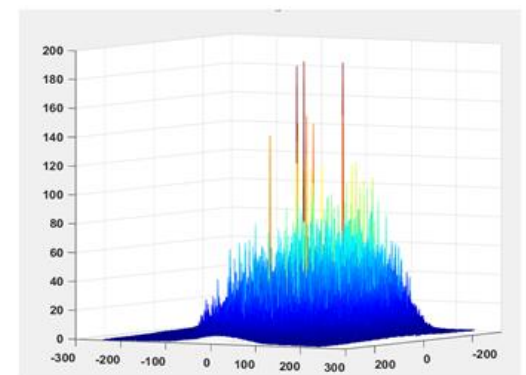
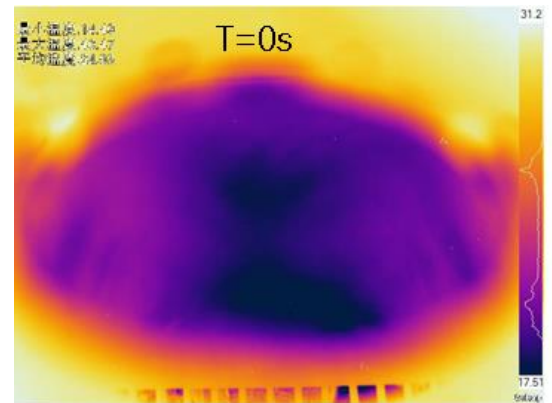
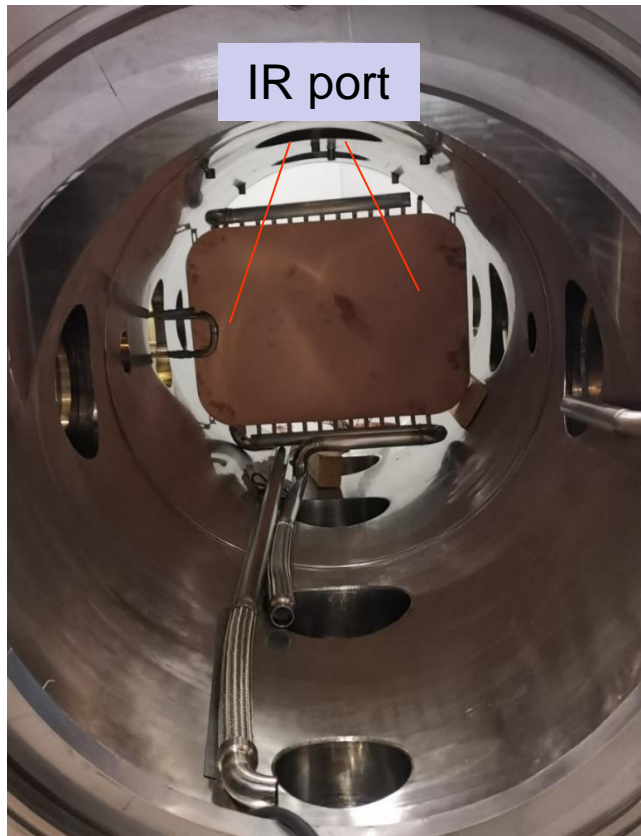
The light intensity of tungsten wire varies with time during beam bombardment (Beam energy 38keV; beam current 0.57A, exposure time is 1200 μ m, and aperture is f/5.5)



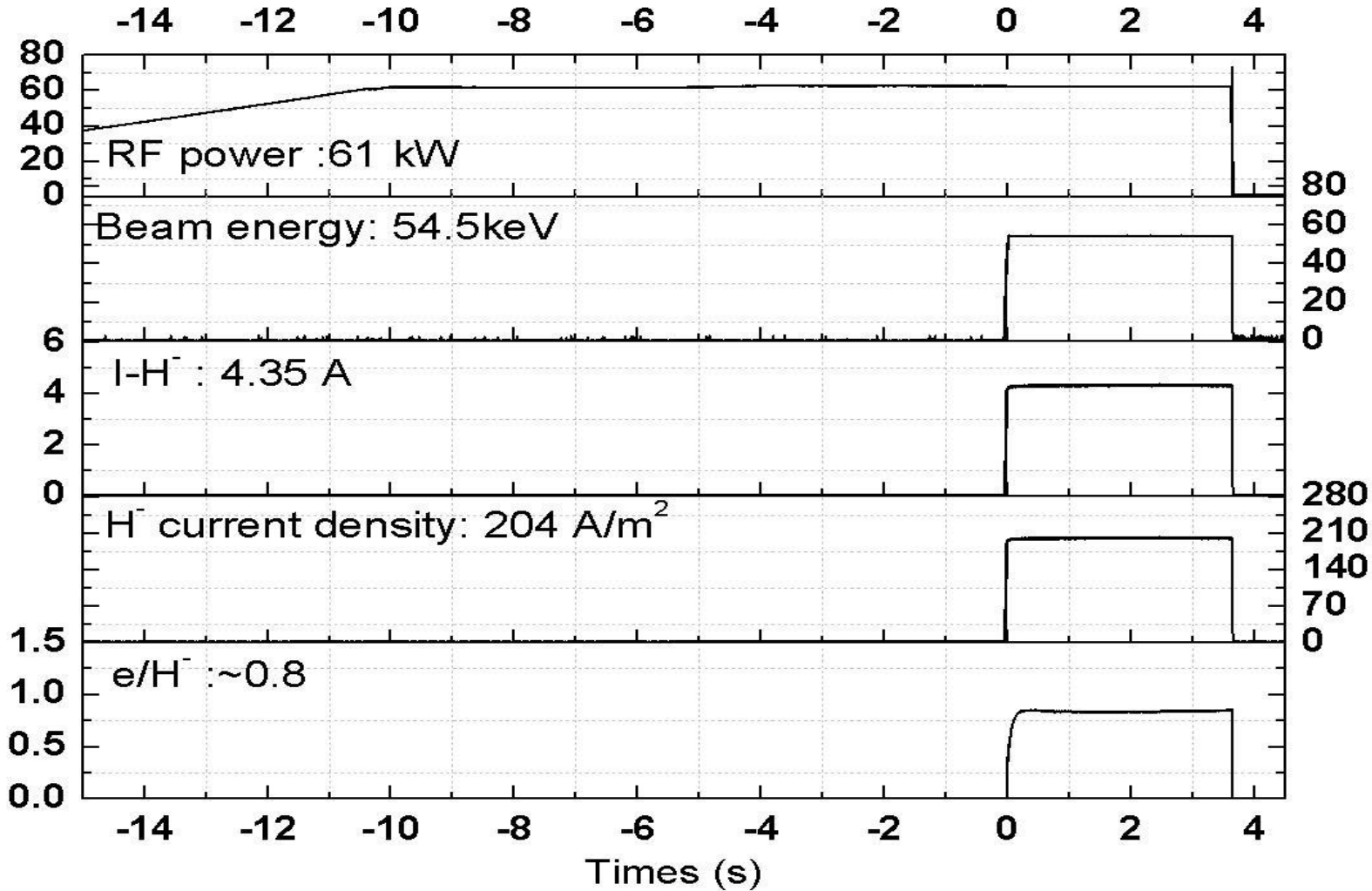
The light intensity distribution of tungsten wire under different beam energies (Beam current is about 0.5A; exposure time is 1200 μ m, sampling rate is 1 F/s, and aperture is f/5.5)



- A infrared camera was installed to measure the temperature on the calorimeter
- The beam profile was evaluated by IR camera(about 2.2 m to GG)
- Beam intensity of lower grids is higher than upper grids



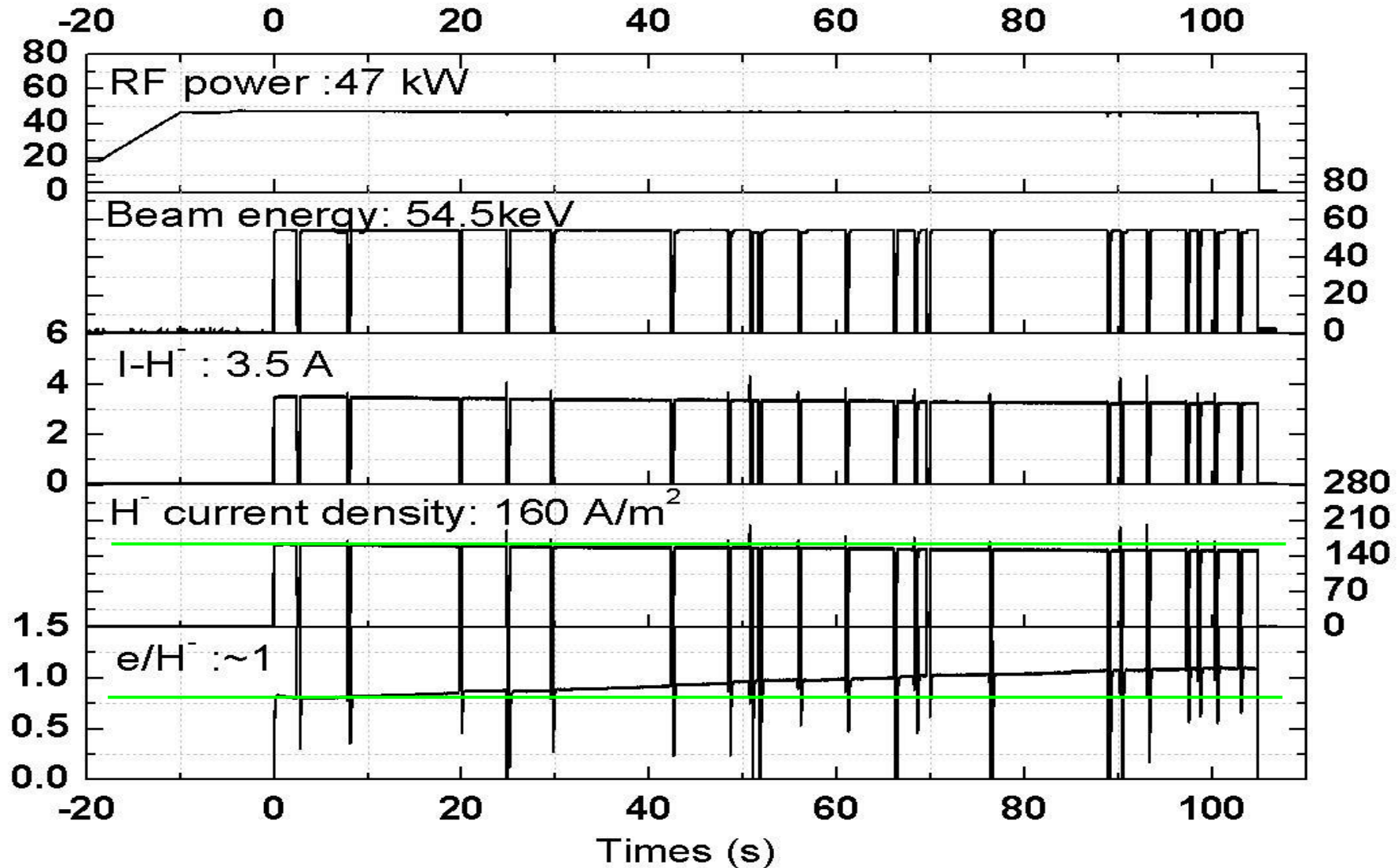
Negative beam extraction



204A/m² @4.35A @ 54.5keV @ 3.65s with 140 holes



Long pulse beam extraction



160A/m² @ 3.5A @ 53keV @ 105s @ 140Holes



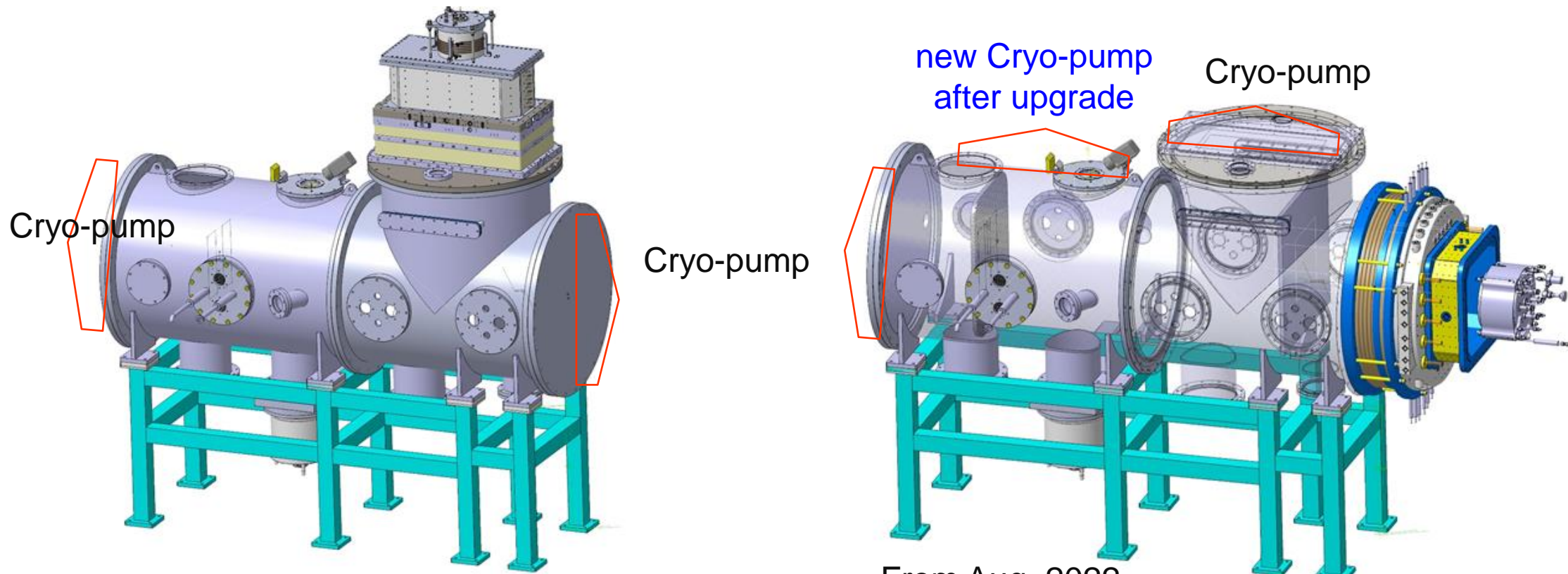
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Optimization of beam source test facility

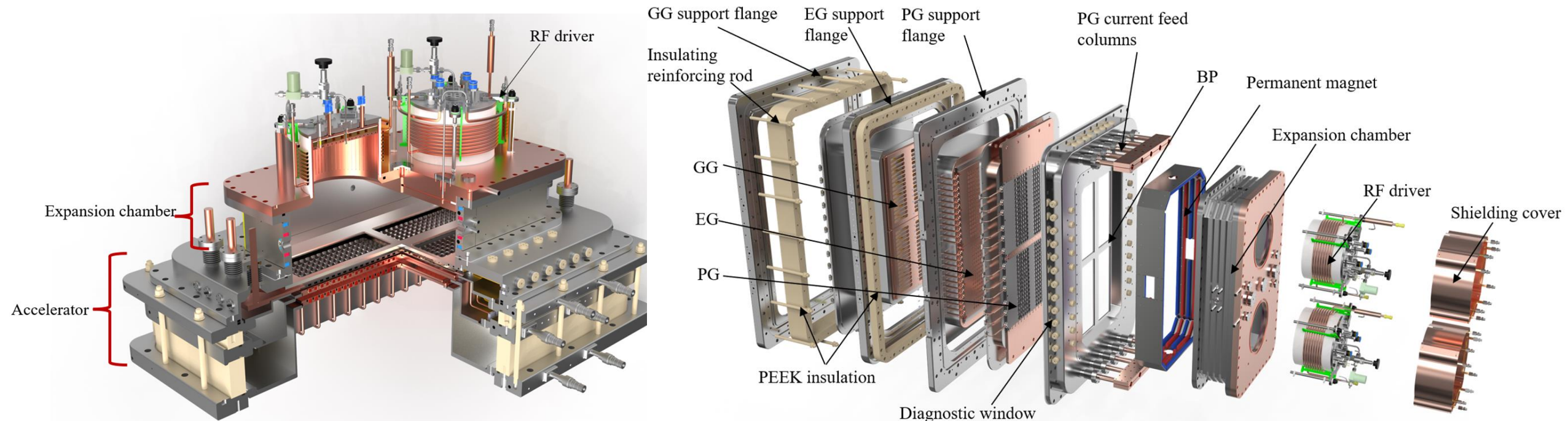
- The pumping speed is still weak for beam source (75,000 L/s)
- Optimize the vacuum chamber to increase the pumping ability
- More experiment for plasma and beam studies with more diagnostics



From Aug. 2022

Development of half size beam source

- ❑ The half size beam source was under manufacture and will be assembled in end of Oct.
- ❑ The test facility in the new site was also under construction
- ❑ The plasma conditioning will start at end of 2022





Summary



- ❑ A quarter size negative ion source with singer driver was tested for CRAFT NNBI system
- ❑ Long pulse plasma discharge of 150s was achieved with RF power of 60 kW
- ❑ The negative ion production and extraction was tested (3.5A,105s,160 A/m² and 4.35 A, 3.6s,204A/m²)
- ❑ A half size beam source and its test facility in the new site was under developed and will be tested in the end of this year

Thanks for your attention !