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Progress of CRAFT Negative Ion Source Neutral Beam Injection Test Facility

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BACKGROUND

- Negative ion source neutral beam injection (NNBI) is a promising plasma heating and current driver method for future super-large scale magnetic confinement fusion reactors.
- A test facility to tackle the key technology of NNBI is under constructed in the project of the Comprehensive Research Facility for Fusion Technology (CRAFT) at Hefei, China.
- CRAFT NNBI test facility hosts two test stands: Hefei Open-facility for Negative-ion Source Research (HONOR) and CFETR Advance Neutral Beam Equipment (CANBE).

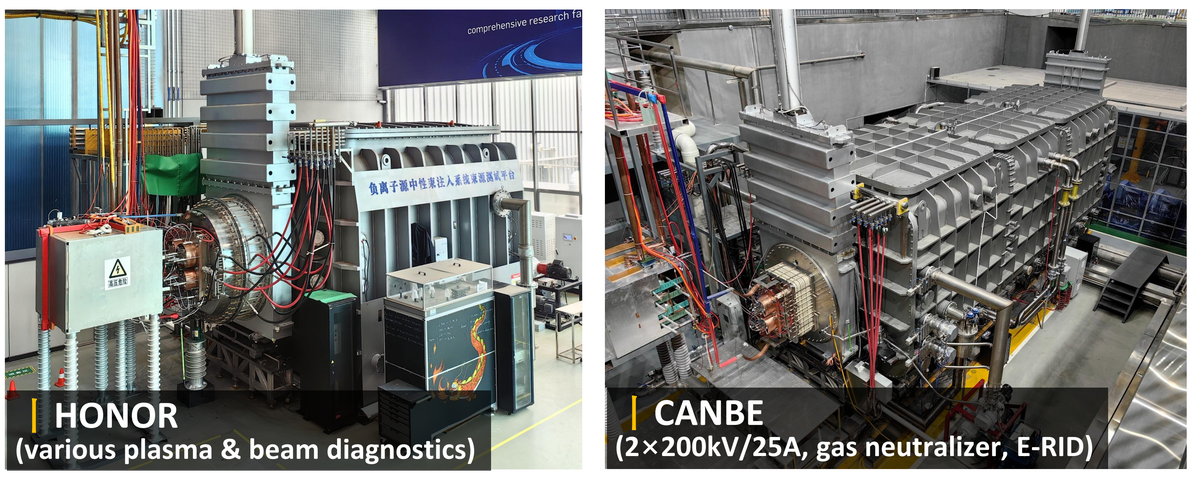

Figure 1. *Main test stands of CRAFT NNBI test facility*

DEVELOPMENT OF NEGATIVE ION SOURCES

- Three negative ion sources with similar physical design but different size have been developed step by step for the CRAFT NNBI since Y2021.
- **Negative ion generator** (ITER-like design) mainly consists of one/two/four RF drives of 1 MHz and an expansion chamber.
- **Negative ion accelerator** mainly consists of multi-aperture multi-grid electrodes, grid supporting frames and several insulators.
- The achieved negative ion beam were improved gradually year by year especially in the form of **triple product of beam energy, beam current and beam pulse** (above 280 MJ).

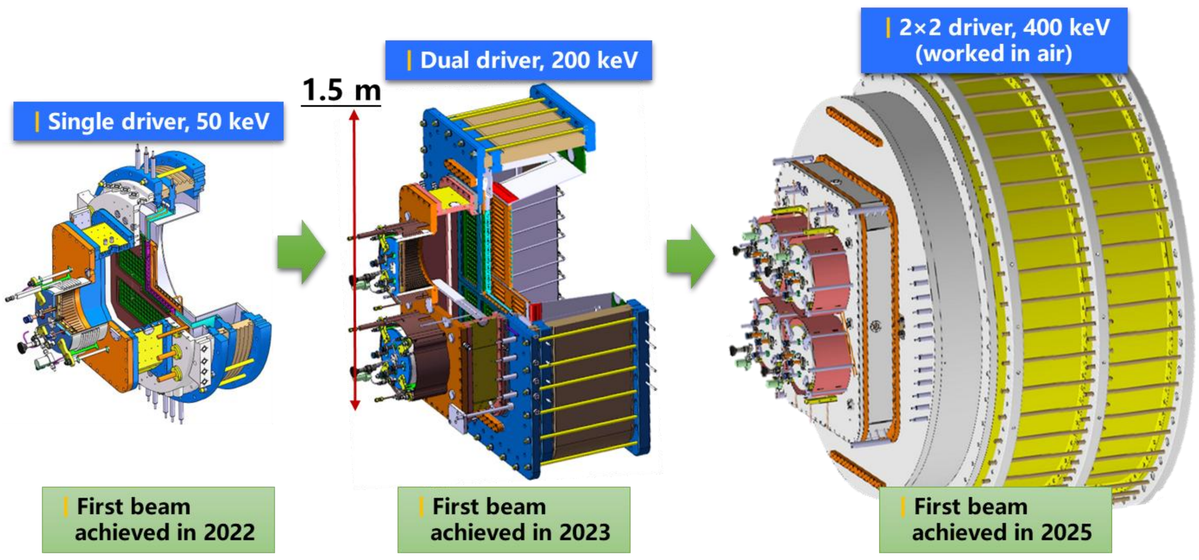

Figure 2. *CRAFT negative ion sources that already tested*

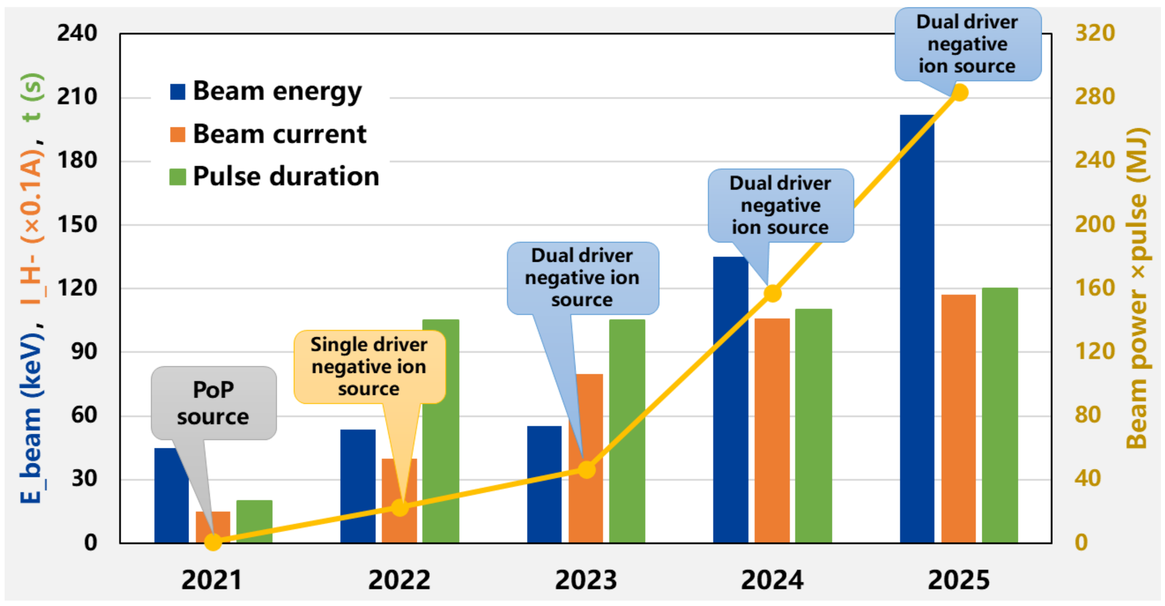

Figure 3. *Evolution of the best negative ion beam parameters for CRAFT NNBI*

OUTCOMES OF CRAFT NNBI PHYSICS ACTIVITY

- CRAFT NNBI Physics Activity (CNPA) was established to synergically study on six major research topics of NNBI: **RF Plasma Coupling**, **Plasma Confinement & Transport**, **Negative Ions Productions**, **Beam Optics & Steering**, **HV Holding & Breakdown**, **Neutralization & Beam Transport**.
- Several physics and engineering issues have been studied or improved in recent two years under the framework of CNPA:
  - Structure of the **internal radiation shield** of accelerator was modified to suppress the e-field concentration and charge accumulation.
  - **Beam divergence** was analyzed in different operation conditions (especially the gas pressure effect).
  - Beam neutralization was analyzed & **E-RID concept** was firstly tested.

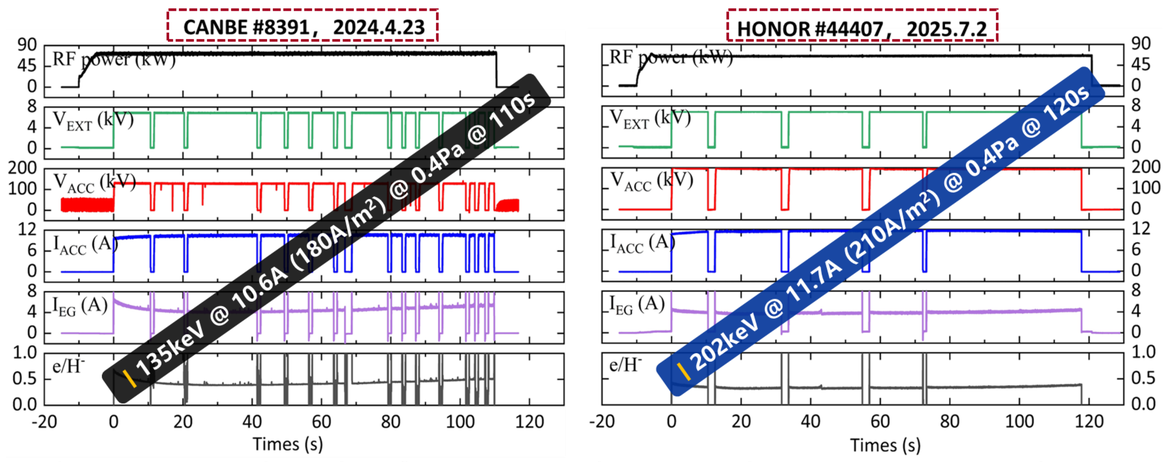

Figure 4. *Typical results of negative ion beam acceleration in Y2024 and Y2025*

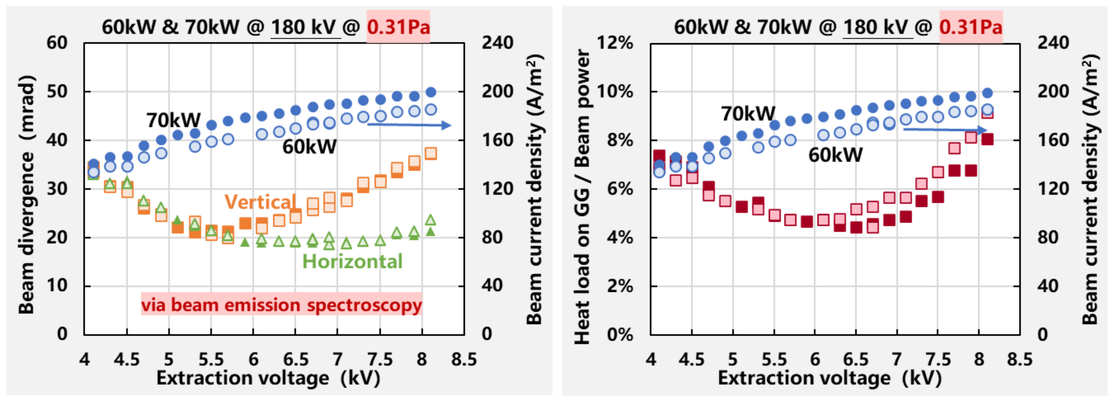

Figure 5. *Beam divergence study with dual-driver negative ion source*

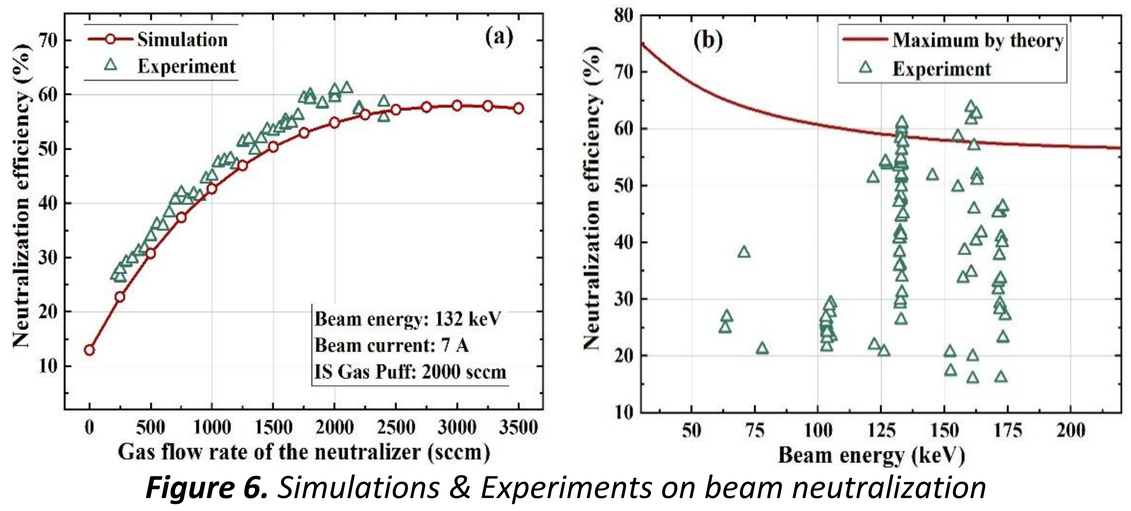

Figure 6. *Simulations & Experiments on beam neutralization*

CONCLUSIONS

- Two test stands have been constructed in the CRAFT NNBI test facility, accompanied with three RF driven negative ion sources.
- A negative hydrogen ion beam with beam energy of 202 keV, beam power of 2.3 MW, beam pulse of 120 s has been achieved.
- The goal in the next two years is to attain a 200 keV and 2 MW neutral beam and a 400 keV negative ion beam for long pulse of 100-3600 s.

ACKNOWLEDGEMENTS & REFERENCES

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- Jianglong WEI *et al* 2025 *Plasma Sci. Technol.* **27** 044001