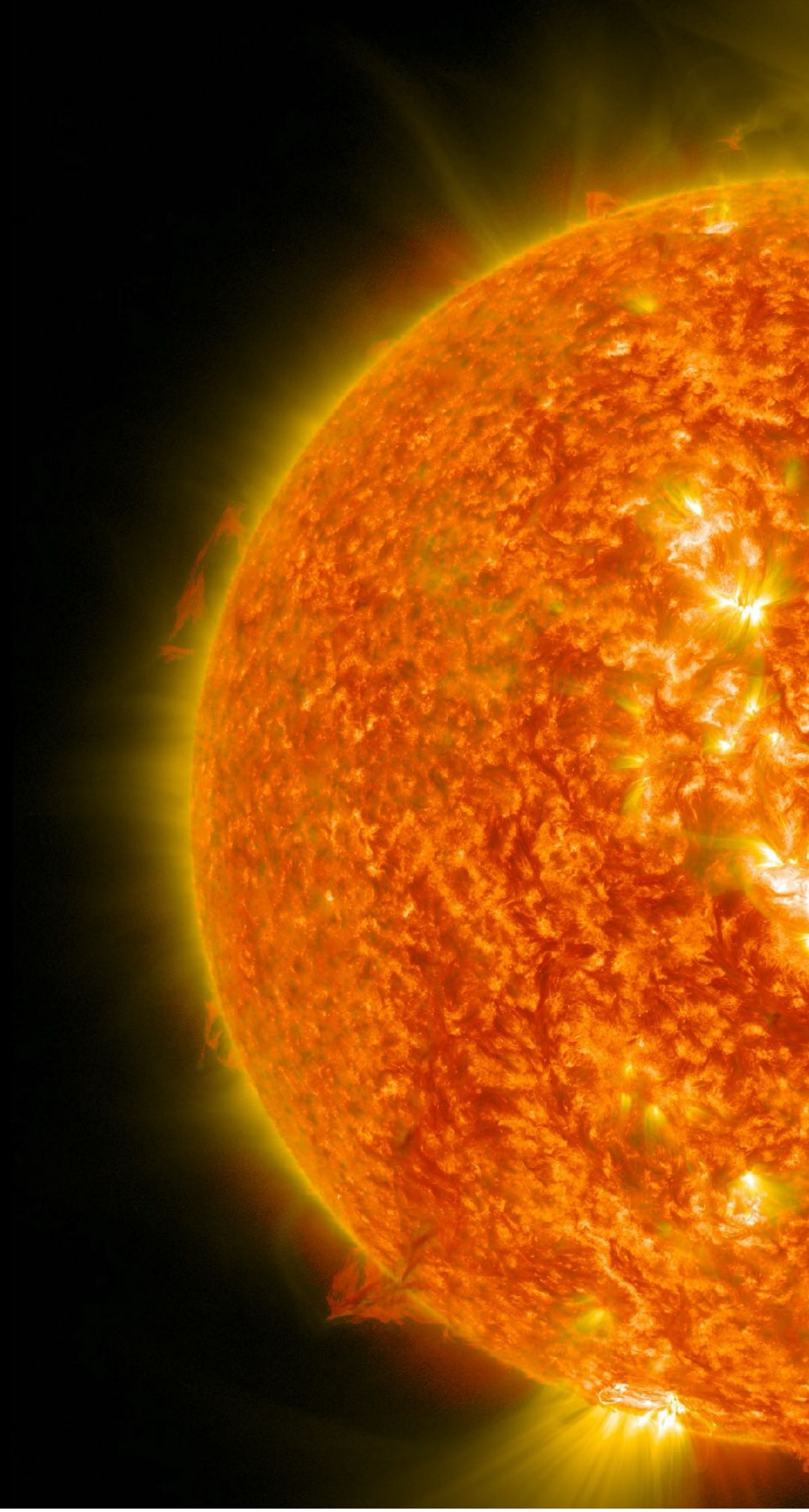
REALTA FUSION

INDUSTRIAL HEAT & POWER FROM FUSION



Dec 2023 – Japan – Industry Introduction

Vision

Realta Fusion’s development of

compact high-field magnetic mirrors

and a strategic focus on **industrial heat & power** will be

the lowest capital, least complex path to

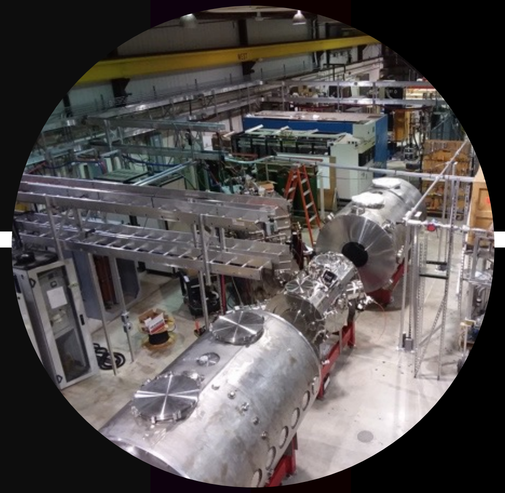
commercially competitive fusion energy

outline

- Introduction to Realta Fusion
- The high field and compact magnetic mirror path to fusion
- Status report on Realta Fusion activities
    - status of WHAM
    - Digital Twins
    - Engineering of BEAM
- Summary

timeline

October 2020

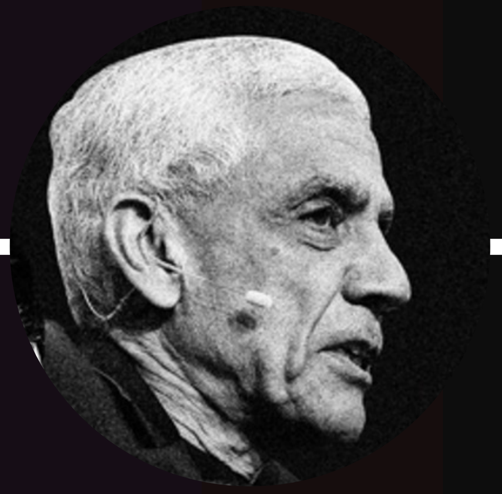


$10M ARPA-E funded project, WHAM

September 2022

Spin-out company established

May 2023

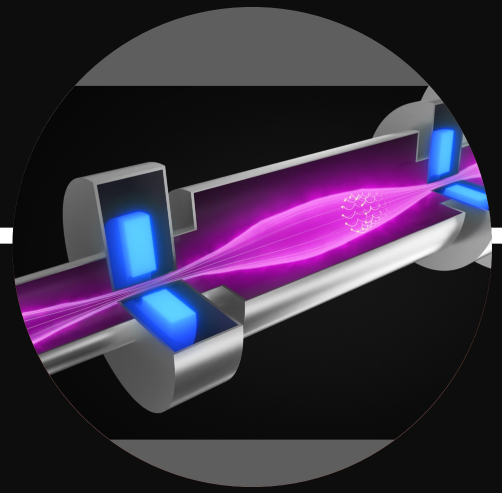


Seed round led by Kholsa Ventures

May 2023

Selected for U.S. Dept. of Energy Milestone Award

2028



Break-even class device operating

2030s

Decarbonizing heavy industry

Realta Fusion Team

Cary Forest, PhD
CSO & Co-Founder

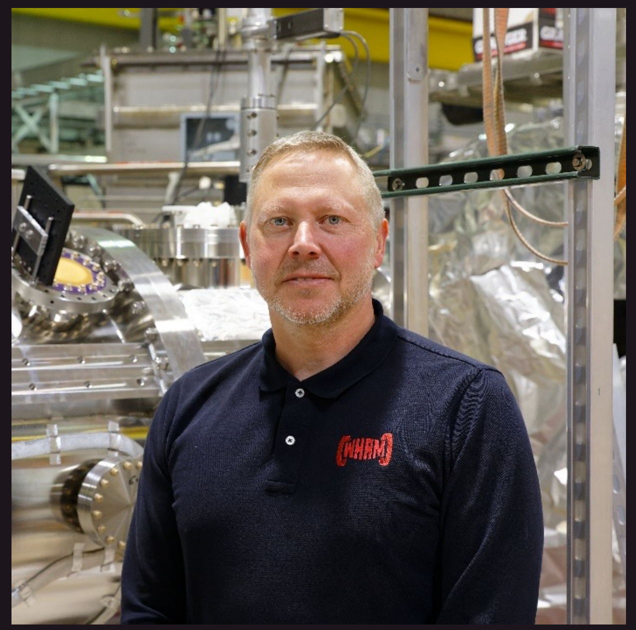
Kieran Furlong, MBA
CEO & Co-Founder

Doug Endrizzi, PhD
Research Scientist

Sam Frank, PhD
Theorist

Dominick Bindl, PhD
Director of Technical Development

Craig Jacobson, PhD
Systems Engineering Manager



Jay Anderson, PhD
Co-Founder

Oliver Schmitz, PhD
Co-Founder

Ben Lindley, PhD
Co-Founder

Toni Hofhine, B.Sc
VP Operations

Jesse Viola, B.Sc
Research Associate

& growing...

The mirror path was abandoned by the US in the mid-80s: Why now?

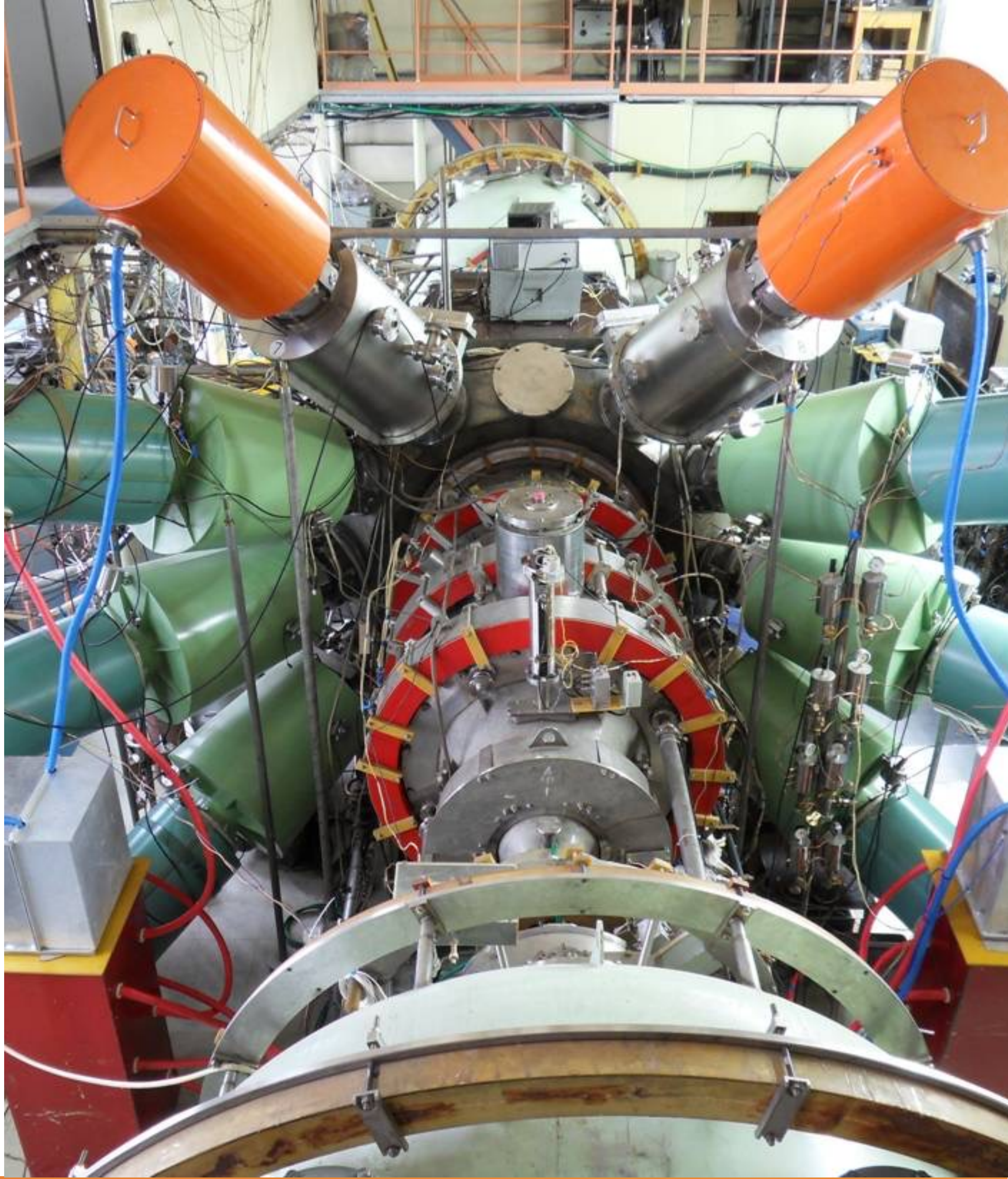
Apply new enabling technologies to a mature concept that was ahead of its time

High Temperature Superconducting (HTS) Magnets
...up to 32T

Breakthrough in plasma stability
shear stabilization of plasma in GDT (Budker Institute)

Extreme Computing Power
simulating plasmas at particle level & "fly-by-wire"

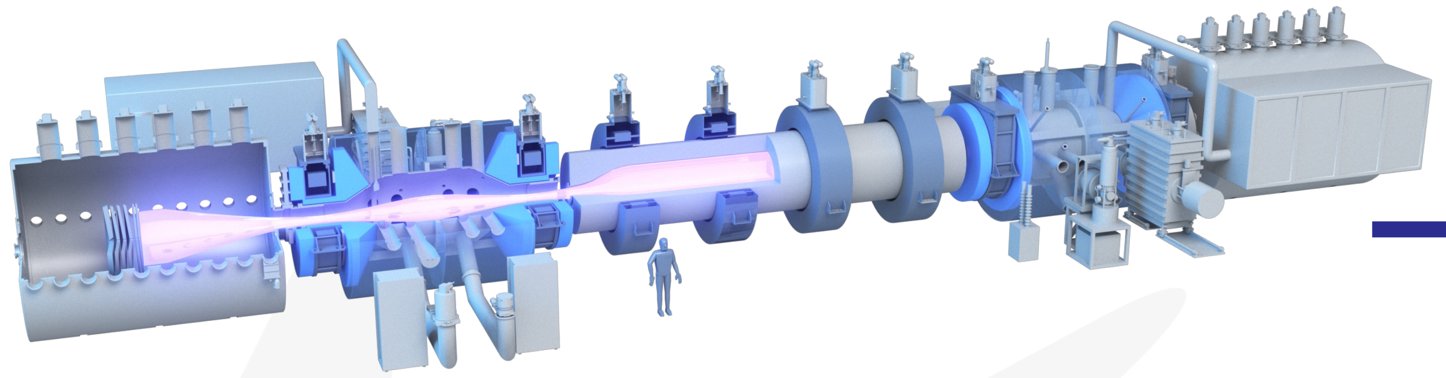
Advances in fusion technologies
High energy Neutral Beam Injectors, Gyrotrons, Plasma Facing Materials, etc.



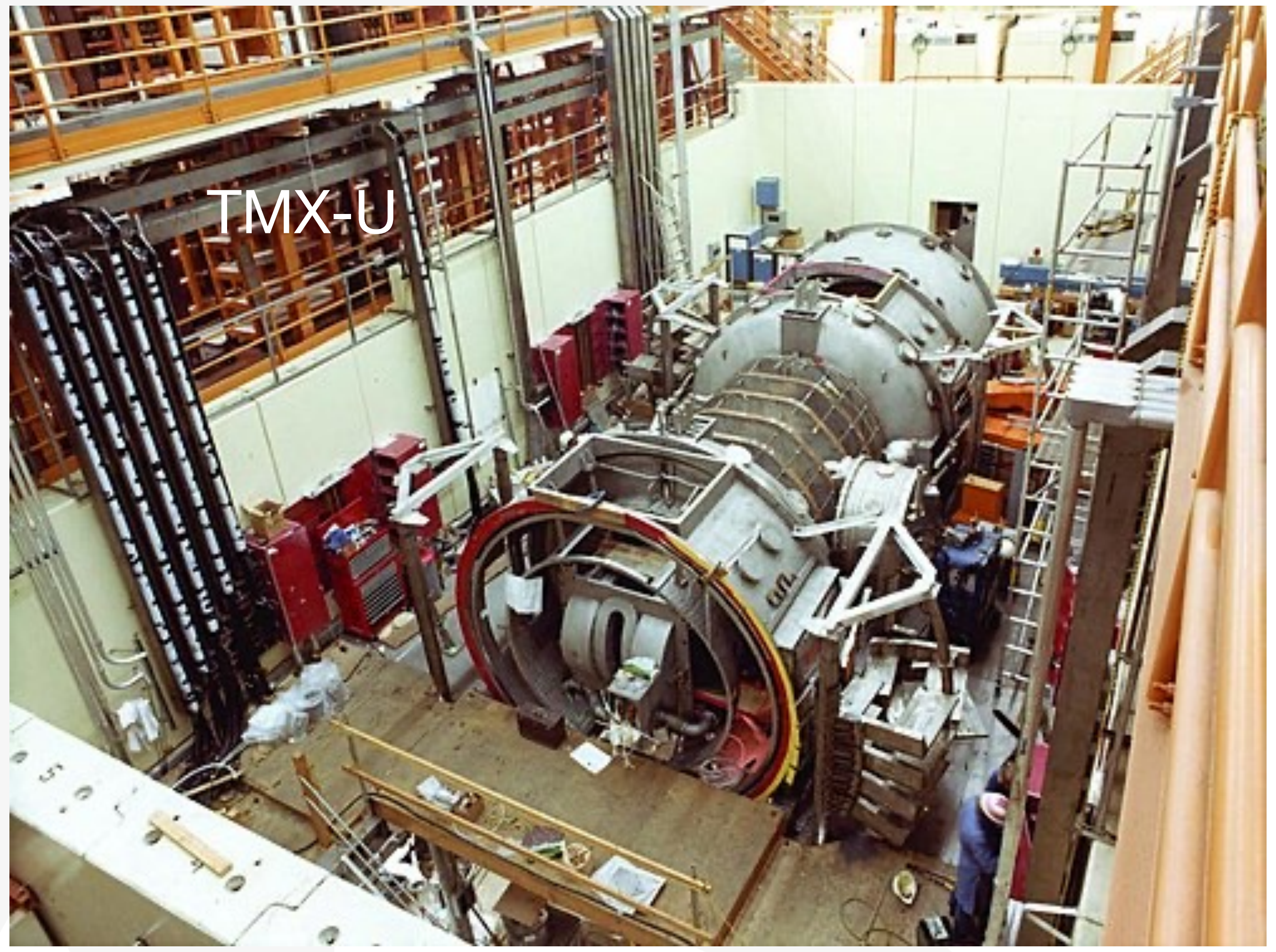
Gas Dynamic Trap experiment, Budker Institute

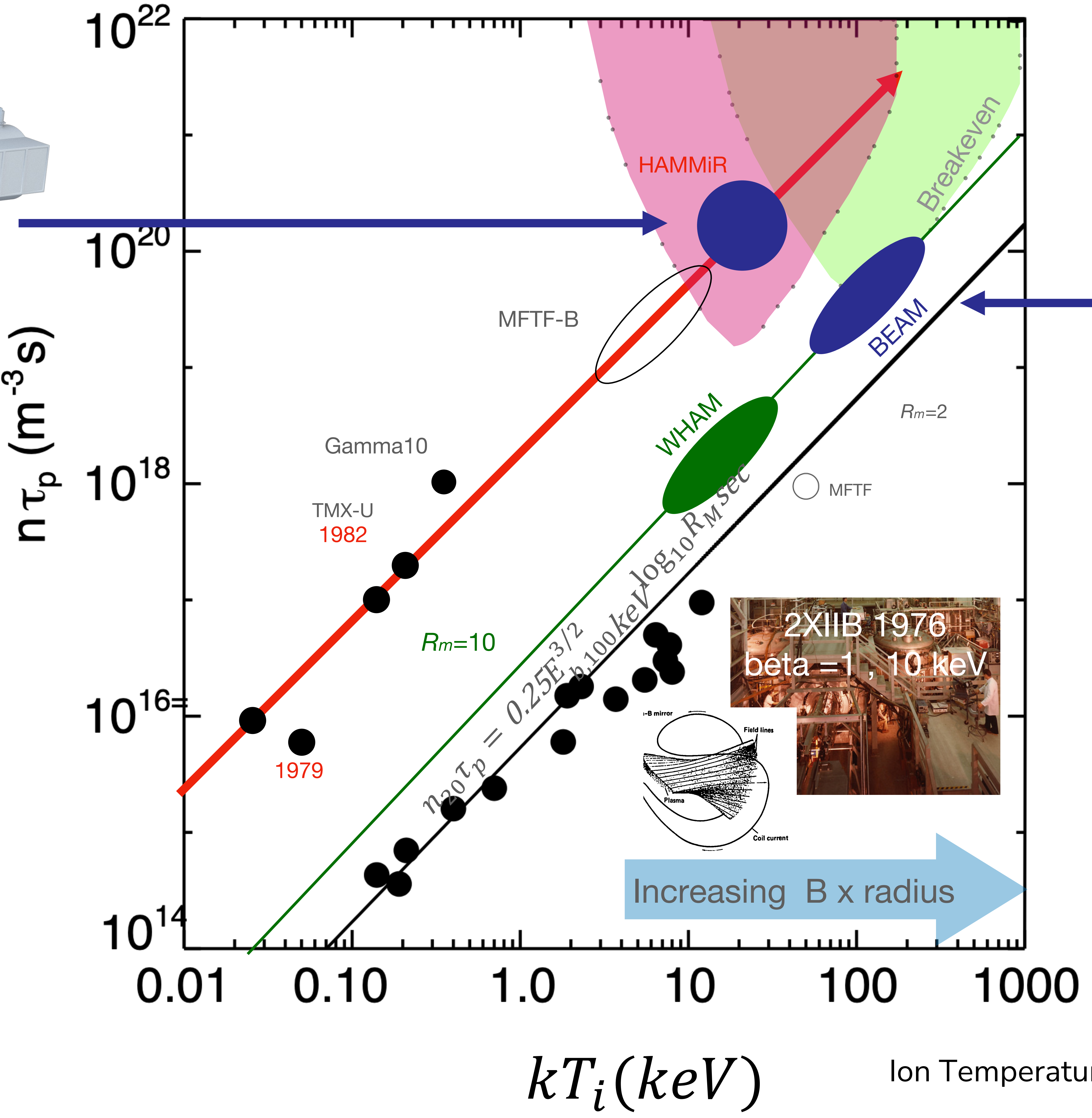
High magnetic fields and axisymmetry open up a path to high mirror ratio and breakeven in a single mirror and simplifies the tandem mirror reactor

High-field **A**xisymmetric **M**agnetic **M**irror **R**eactor



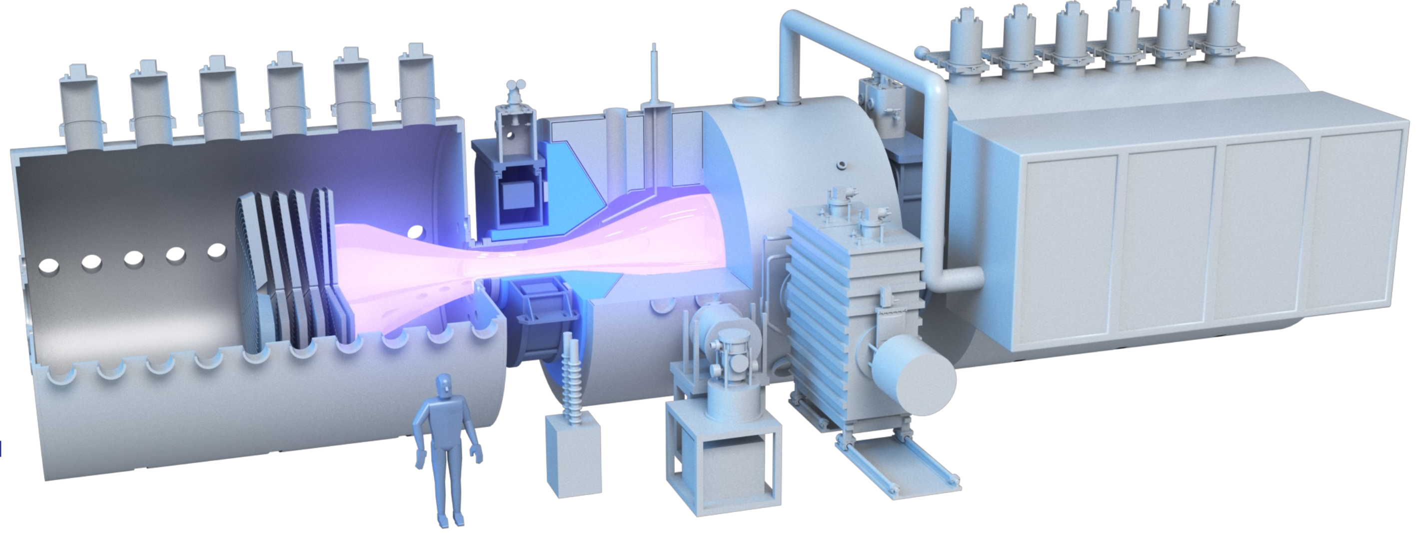
T. K. Fowler, R. W. Moir, and T. C. Simonen, *A New Simpler Way to Obtain High Fusion Power Gain in Tandem Mirrors*, Nucl Fusion **57**, 056014 (2017).



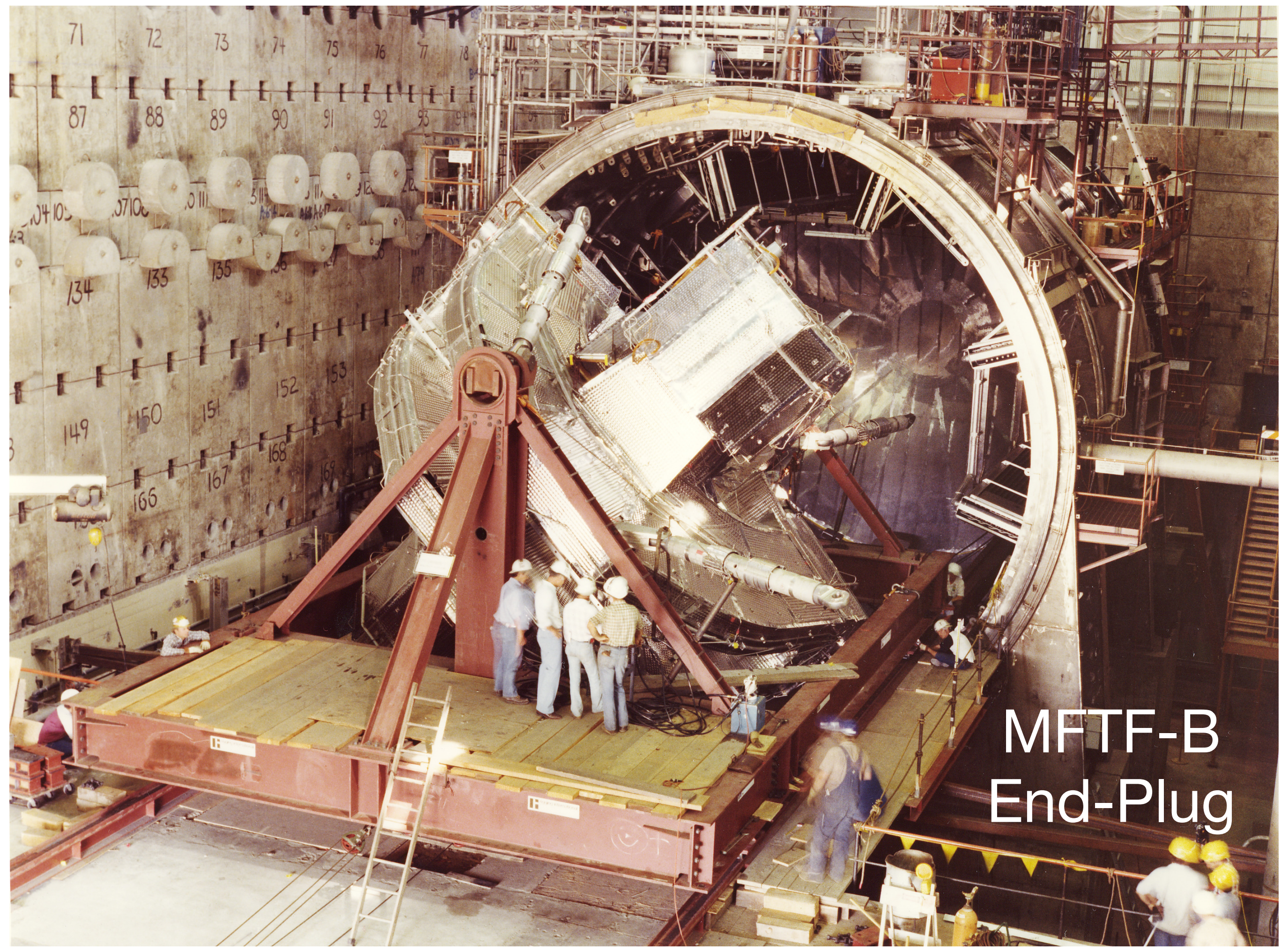


Ion Temperature

Break-**E**ven **A**xisymmetric **M**irror



C.B. Forest et al, *Prospects for a high-field, compact Break-Even Axisymmetric Mirror and Applications*, Journal of Plasma Physics (2023).



Technology risk reduction path

Higher

RISK

Lower

"Bench scale"
WHAM + upgrades

Demonstrate magnets

Validation of Plasma stability models

Direct energy conversion (DEC)

RF acceleration of beam ions

"Pilo

Plasr
mode

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plasr

Test
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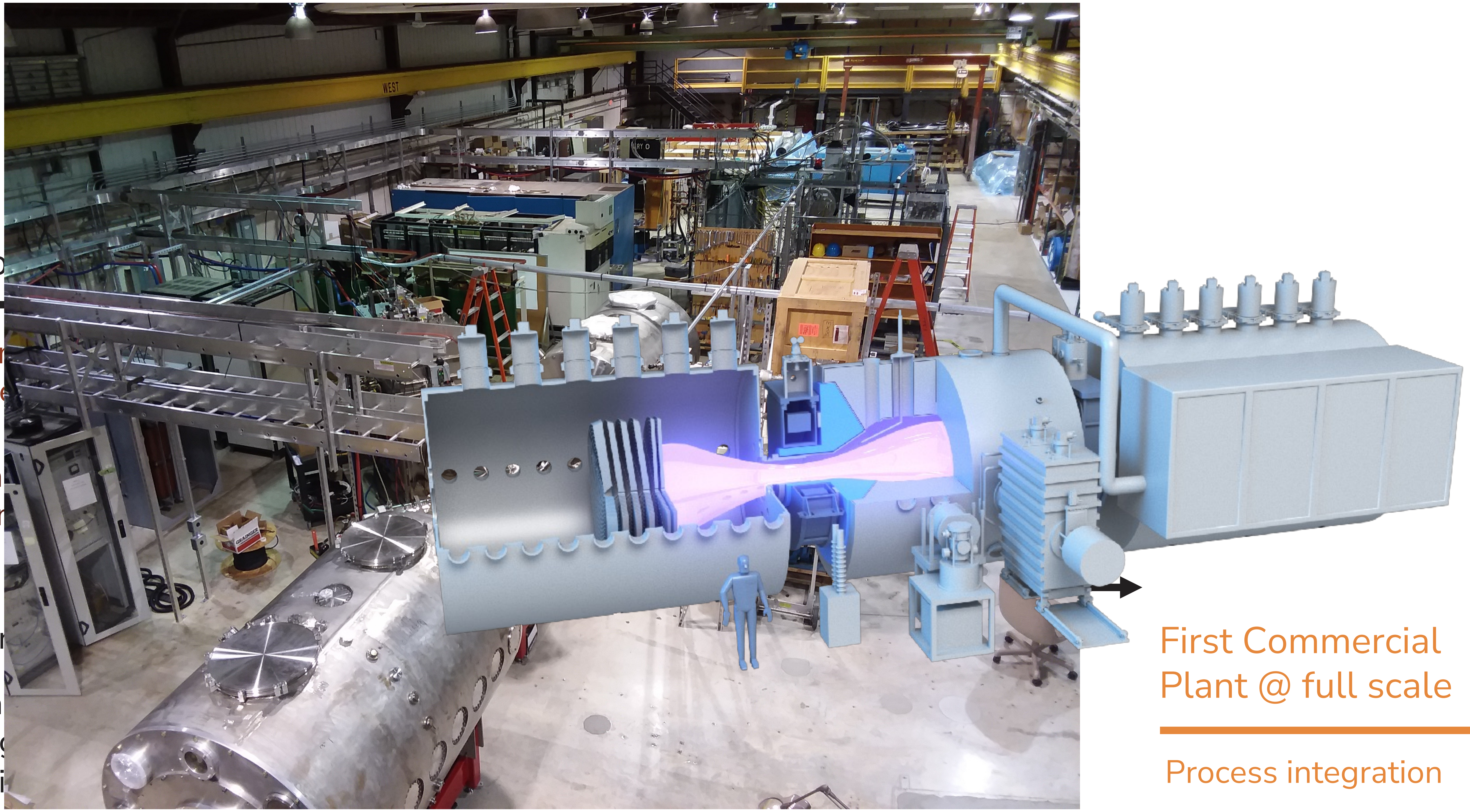


First Commercial Plant @ full scale

Process integration

2023 | 2028 | 2029 | early 2030s | Mid 2030s

TIME

WHAM: Vessel assembled and under vacuum

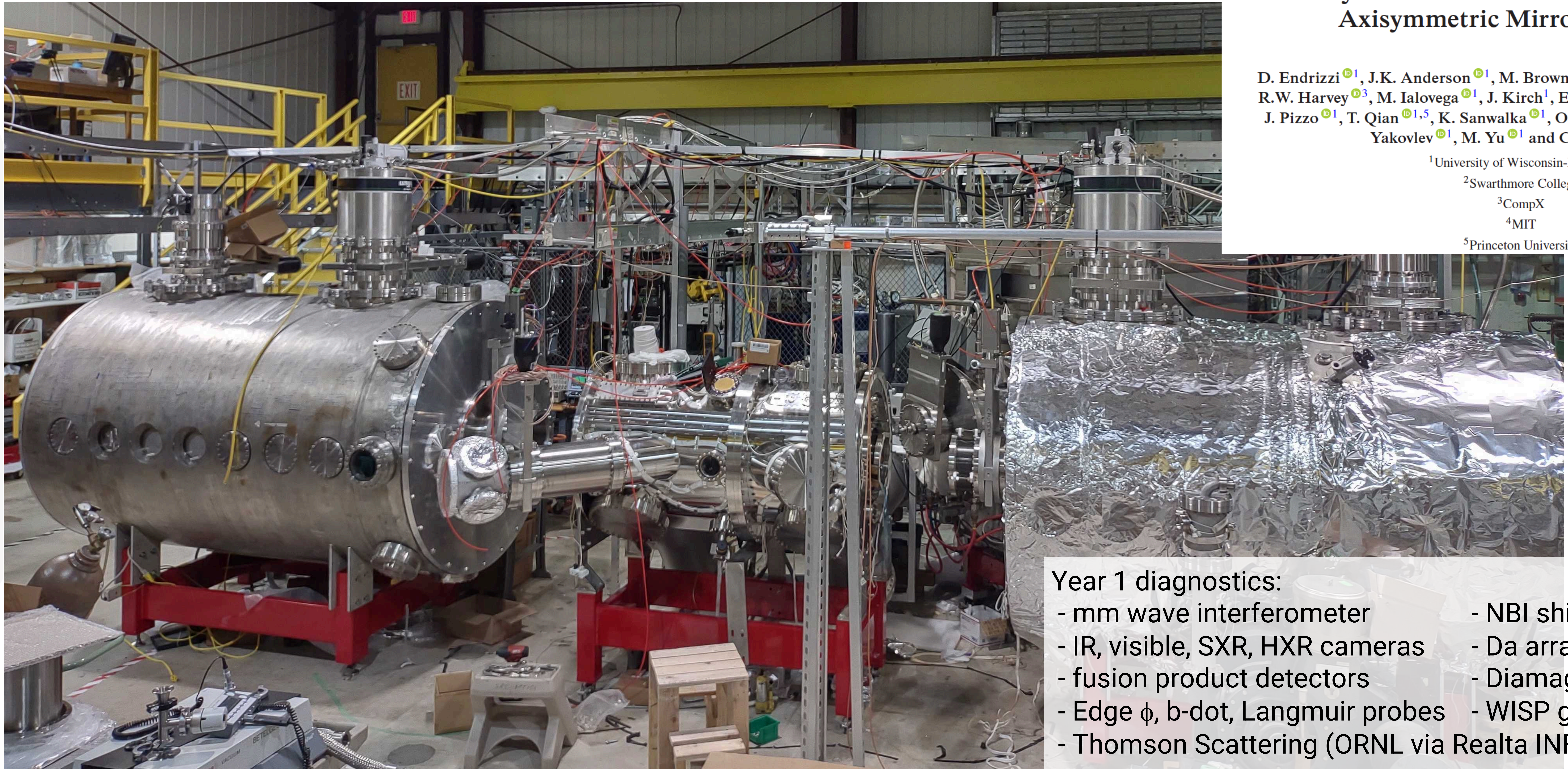
ealta is leading the diagnostic coordination and V&V of digital twins (above and beyond ARPA-E)

J. Plasma Phys. (2023), vol. 89, 975890501
doi:10.1017/S0022377823000806

Physics basis for the Wisconsin HTS Axisymmetric Mirror (WHAM)

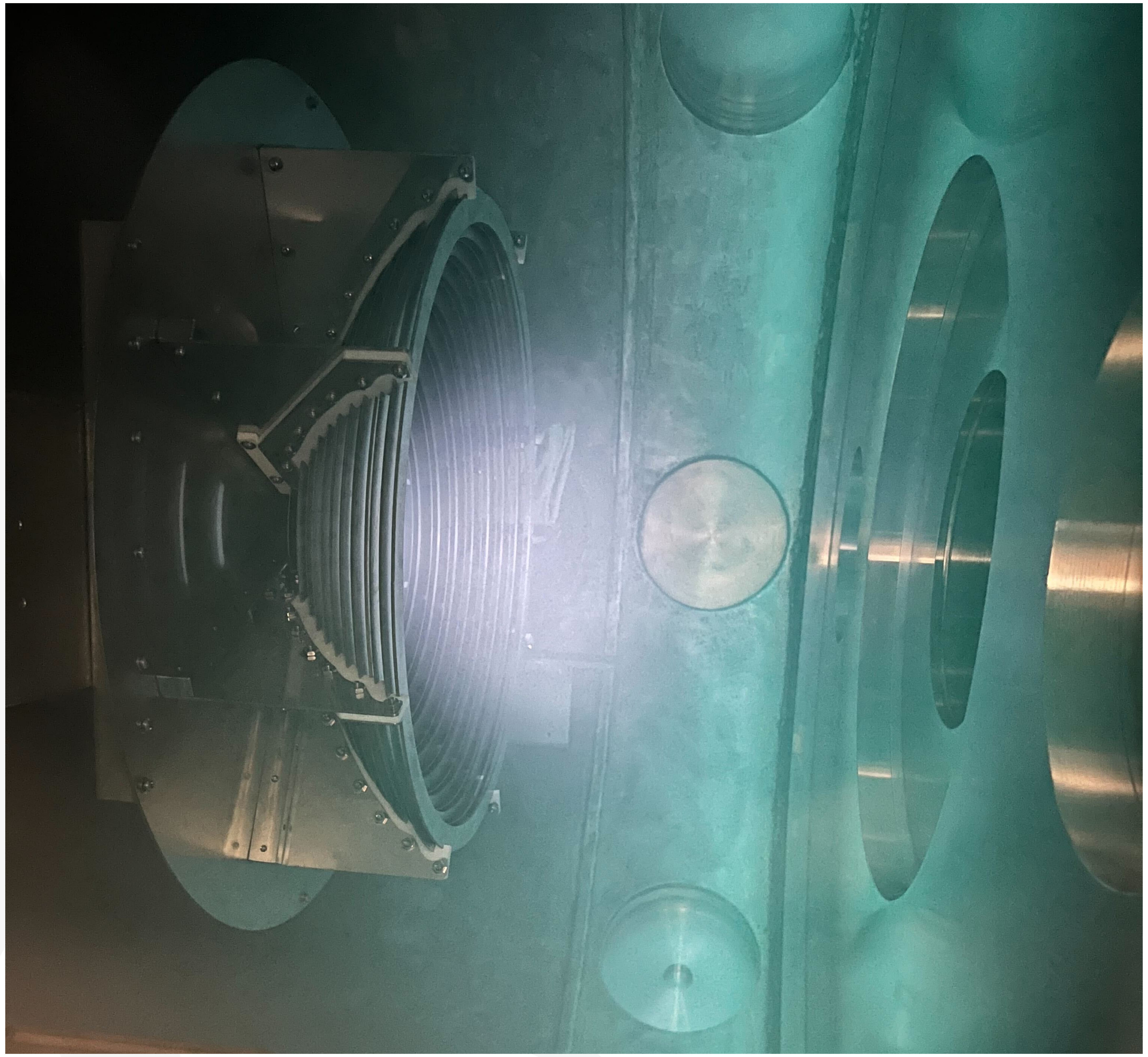
D. Endrizzi[1], J.K. Anderson[1], M. Brown[2], J. Egedal[1], B. Geiger[1], R.W. Harvey[3], M. Ialovega[1], J. Kirch[1], E. Peterson[4], Yu.V. Petrov[3], J. Pizzo[1], T. Qian[1,5], K. Sanwalka[1], O. Schmitz[1], J. Wallace[1], D. Yakovlev[1], M. Yu[1] and C.B. Forest[1,†]

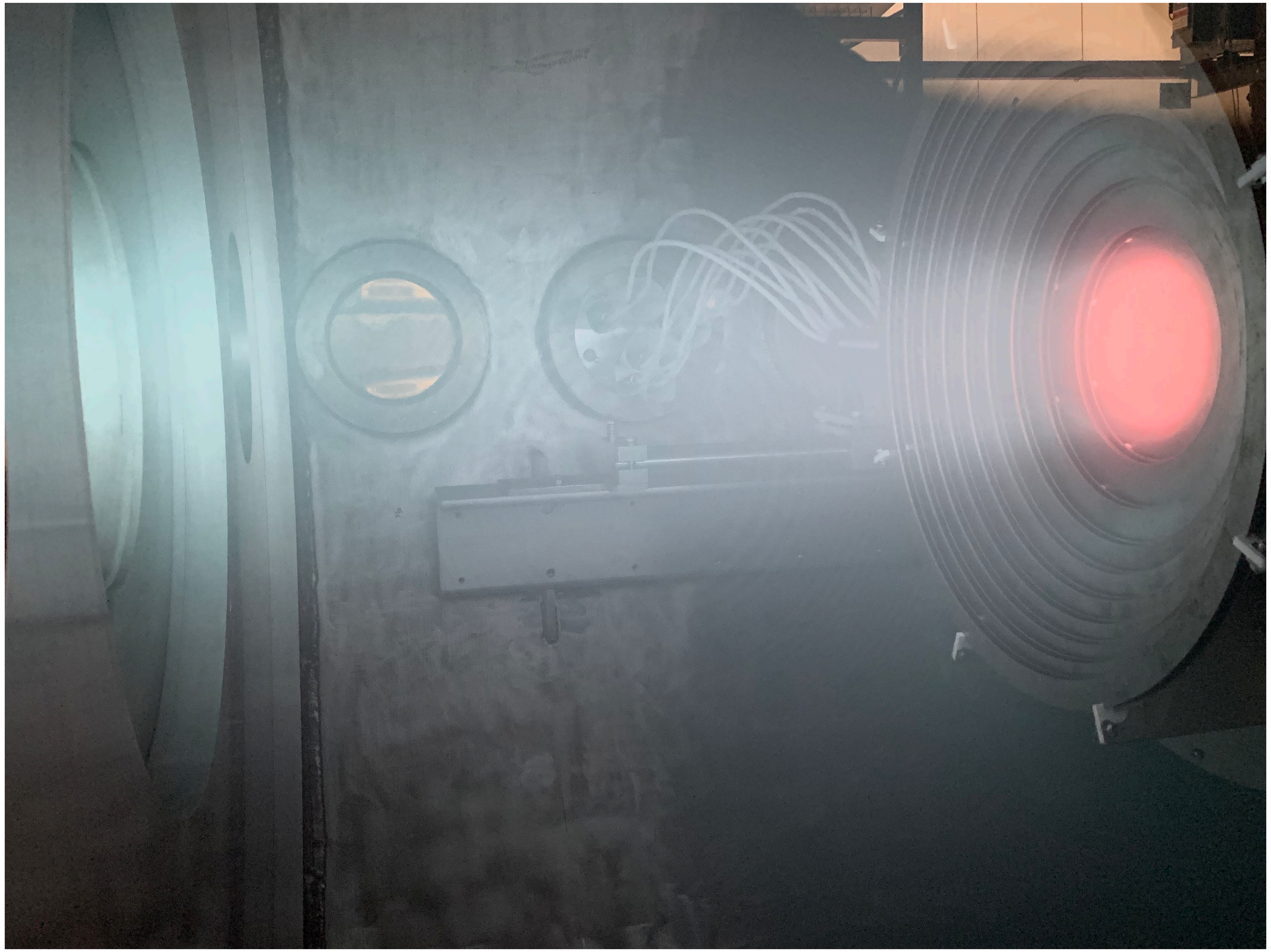
[1]University of Wisconsin-Madison
[2]Swarthmore College
[3]CompX
[4]MIT
[5]Princeton University



Year 1 diagnostics:
- mm wave interferometer
- IR, visible, SXR, HXR cameras
- fusion product detectors
- Edge ϕ, b-dot, Langmuir probes
- Thomson Scattering (ORNL via Realta INFUSE)
- NBI shine thru array
- Da array
- Diamagnetic loops
- WISP gauges

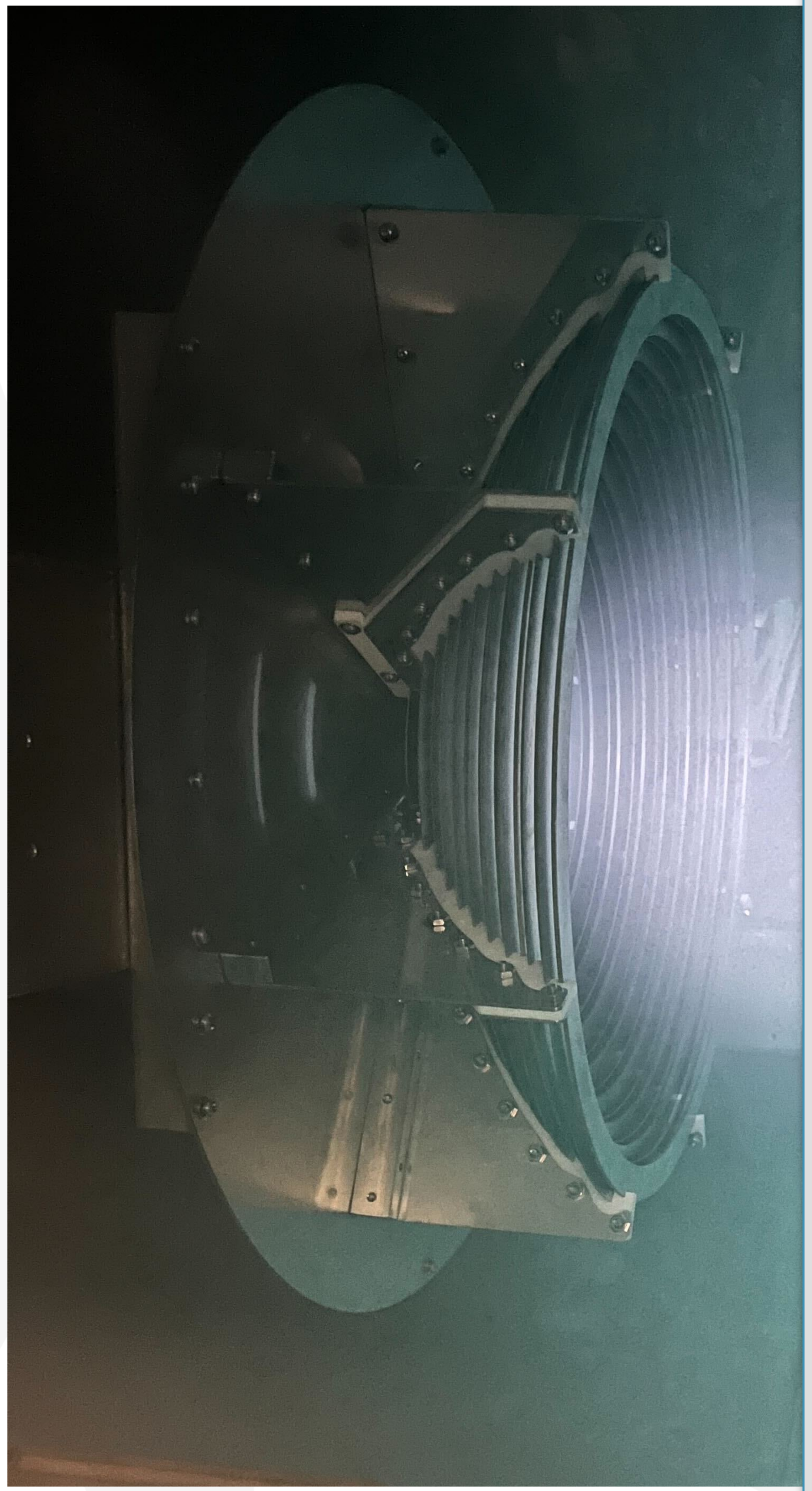
WHAM Milestone: Glow discharge created 11/27/23

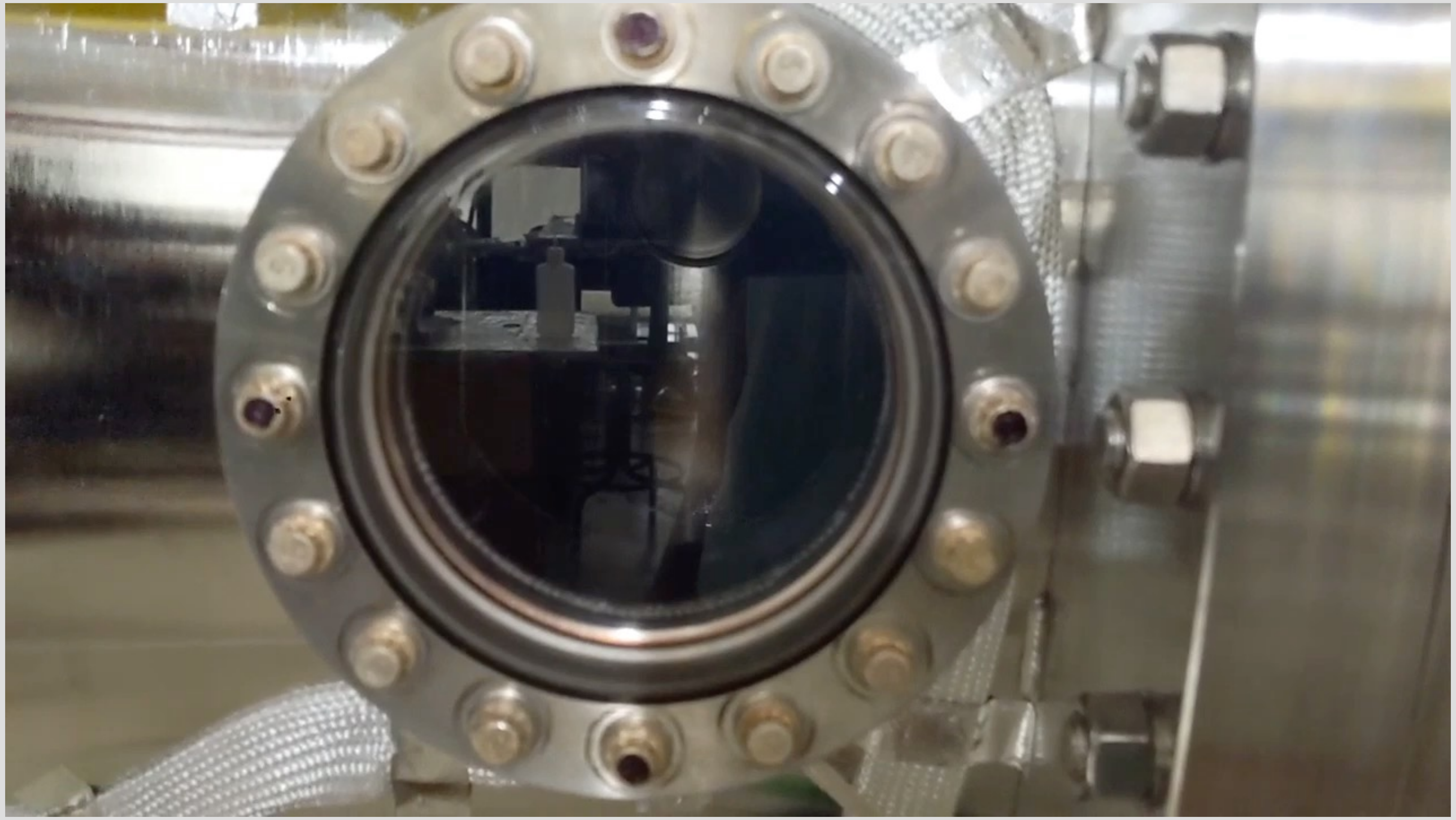


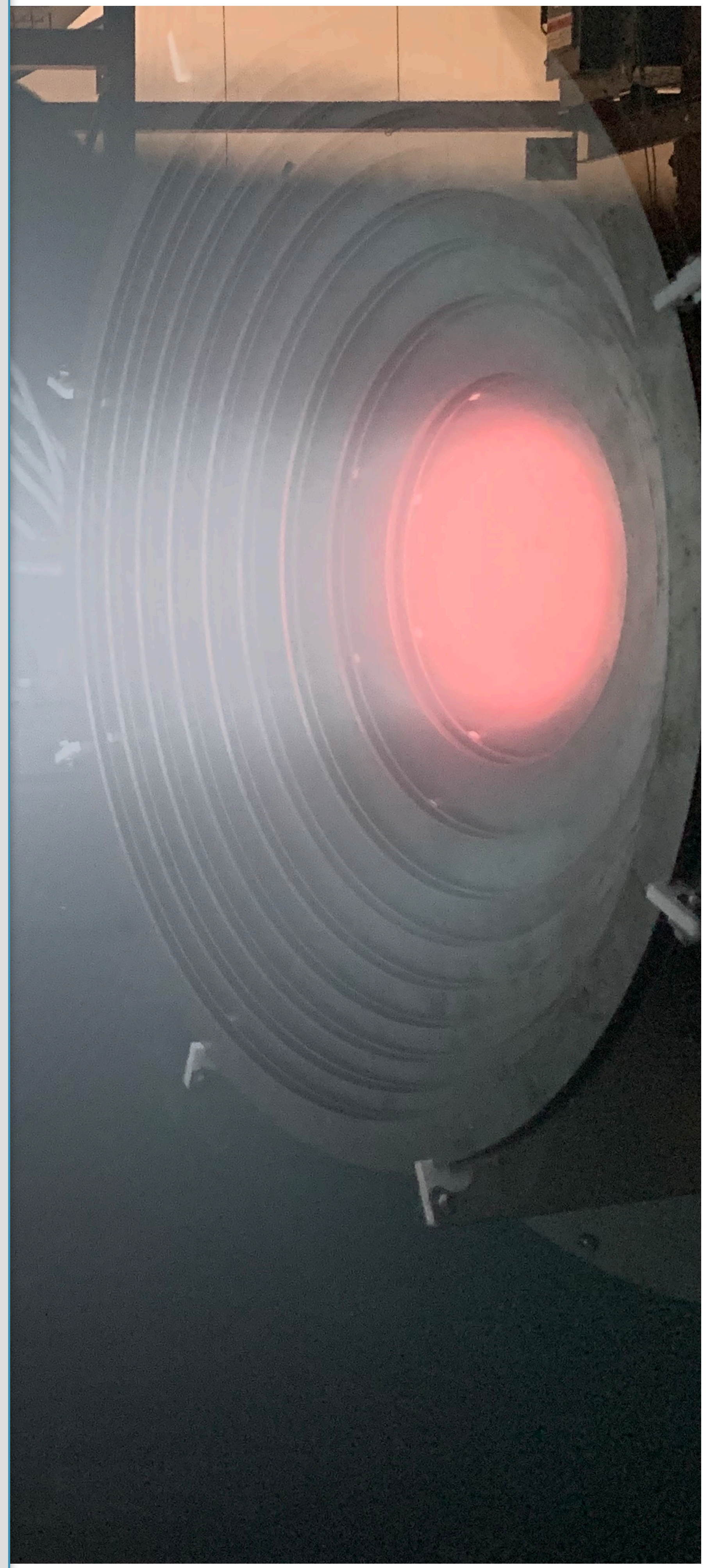


CHANGING WHAT'S POSSIBLE

WHAM Milestone: Glow discharge created 11/27/23

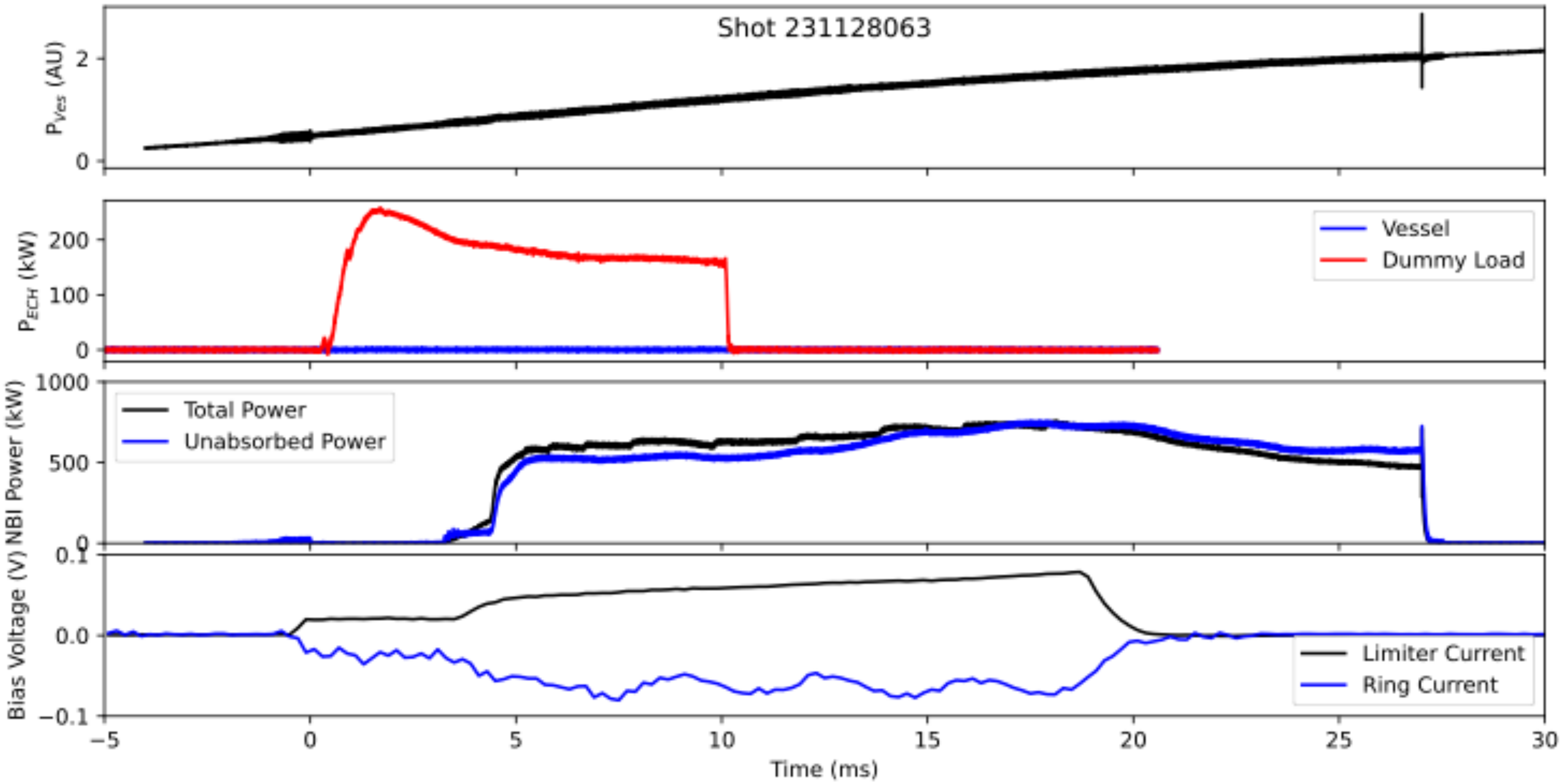






CHANGING WHAT'S POSSIBLE

WHAM: Control, data acq and 4 critical subsystems ready

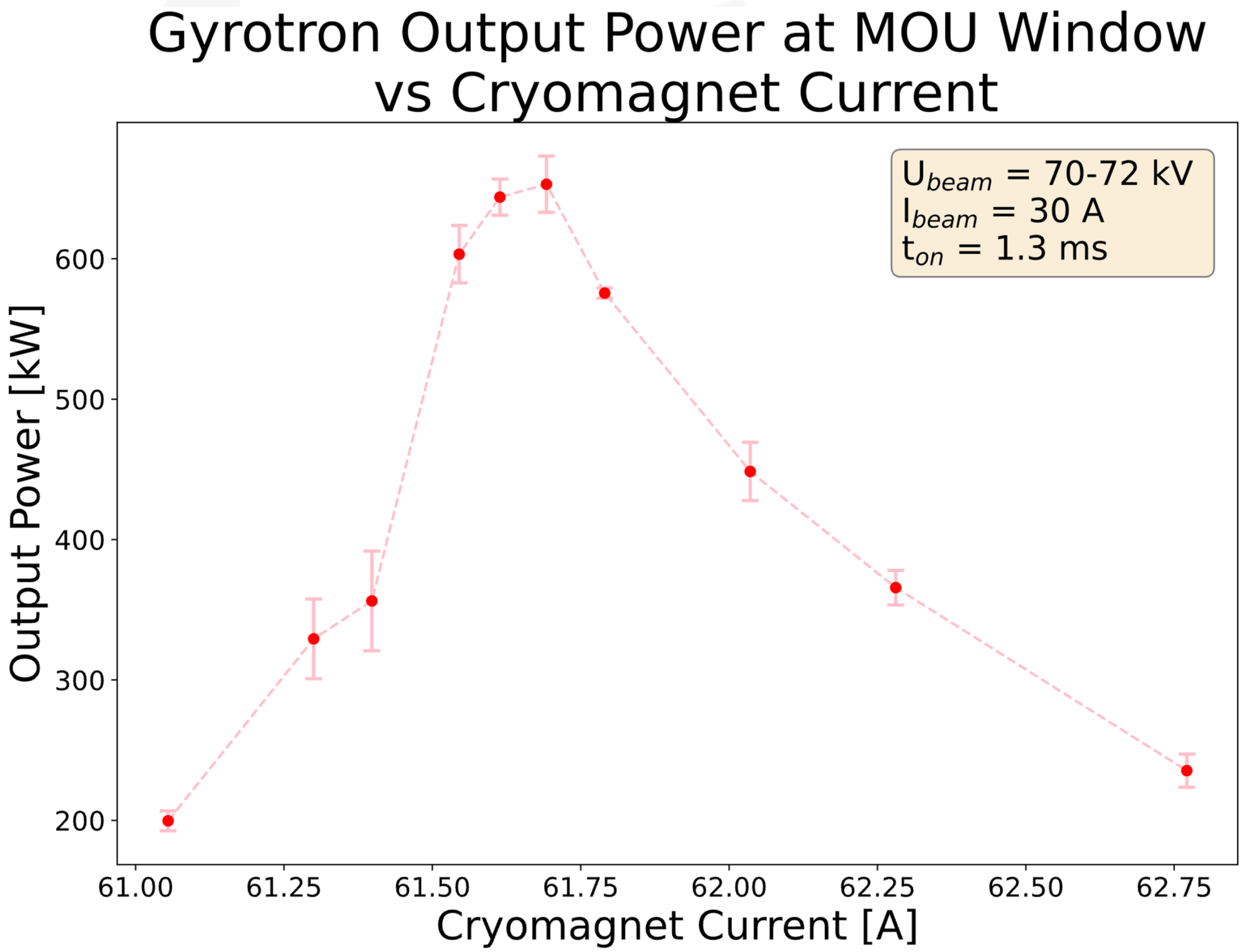


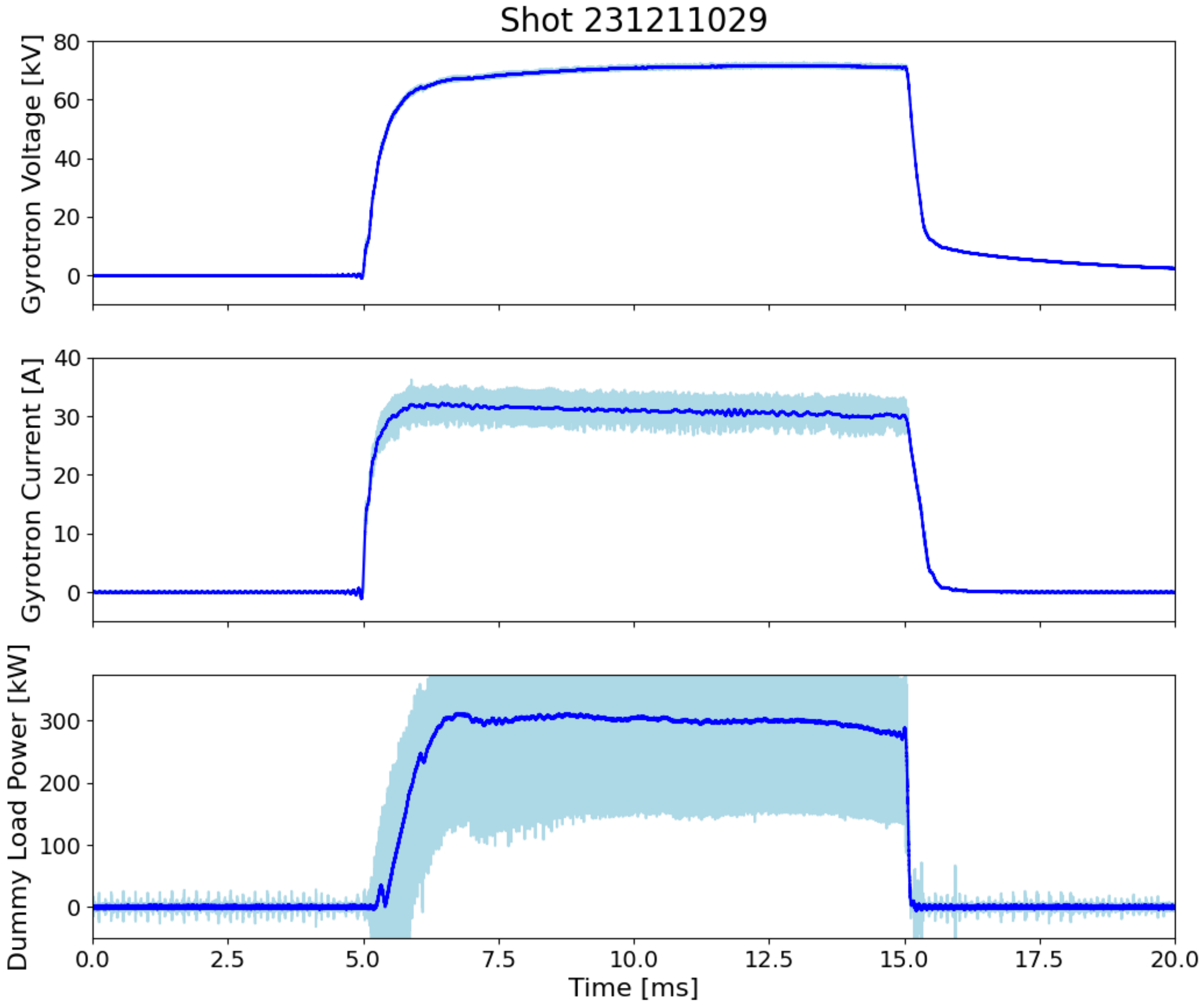
- Fuel system prefills vessel
- ECH breakdown timed at t=0
- 1 MW NBI after density buildup
- Bias supplies for limiters and bias rings ready for experiments

CHANGING WHAT'S POSSIBLE

Electron Cyclotron Heating ready

- Power supply internally rebuilt with more robust IGBTs and drivers;
- several improvements to capacitor bank and bus work implemented (including output fuse)
- 20 msec pulse demonstrated at target 70kV; 30A
- Power supply fault 11/17/23: output filter. Repairs underway.



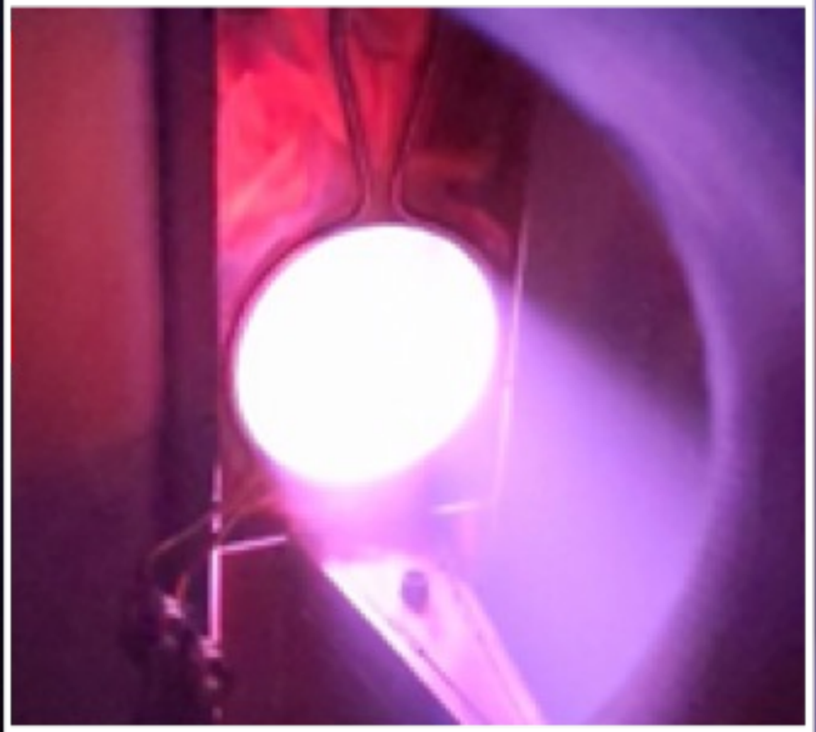


Gyrotron power output >600kW; controllable.

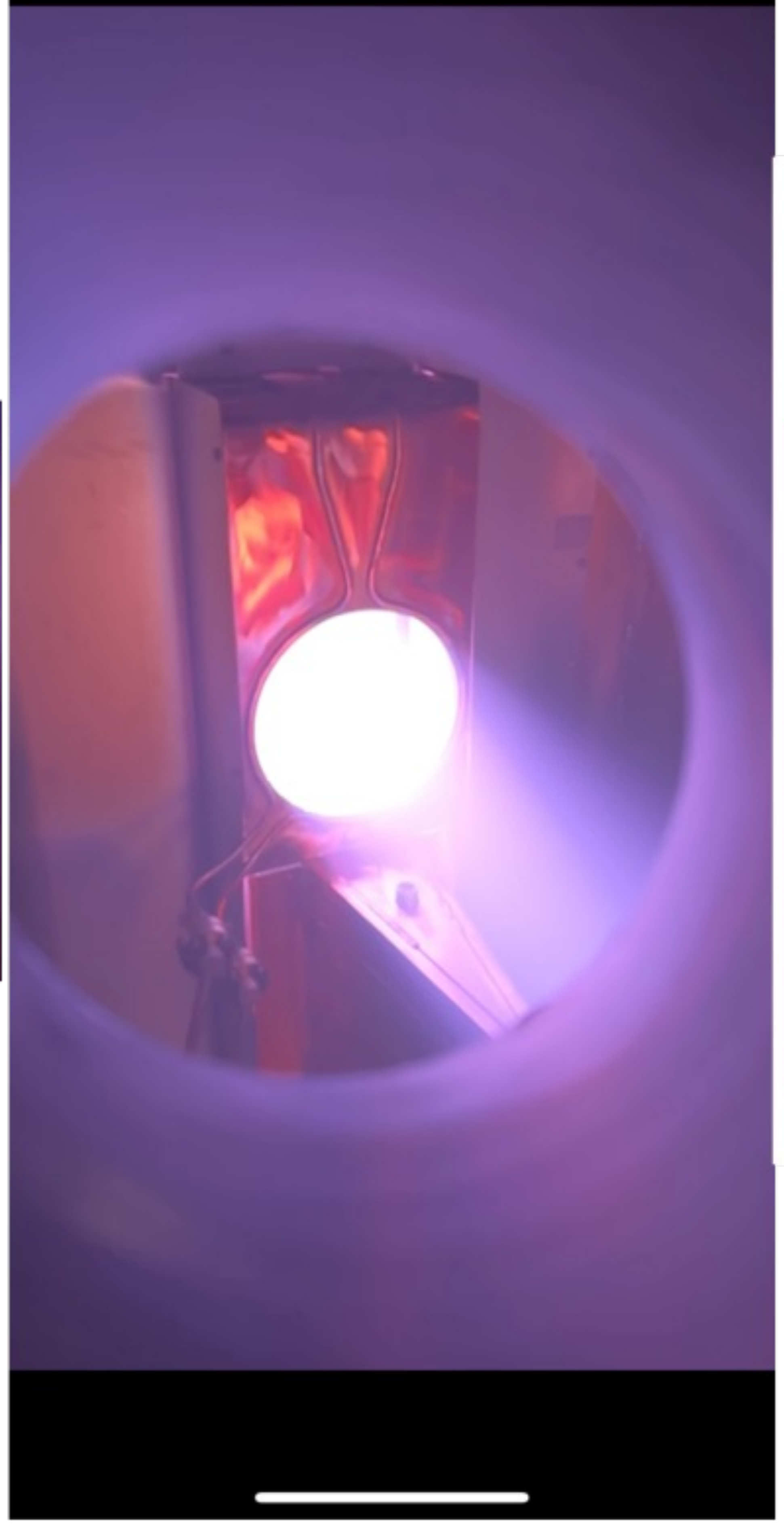
NBI conditioning progress

2023 10/09

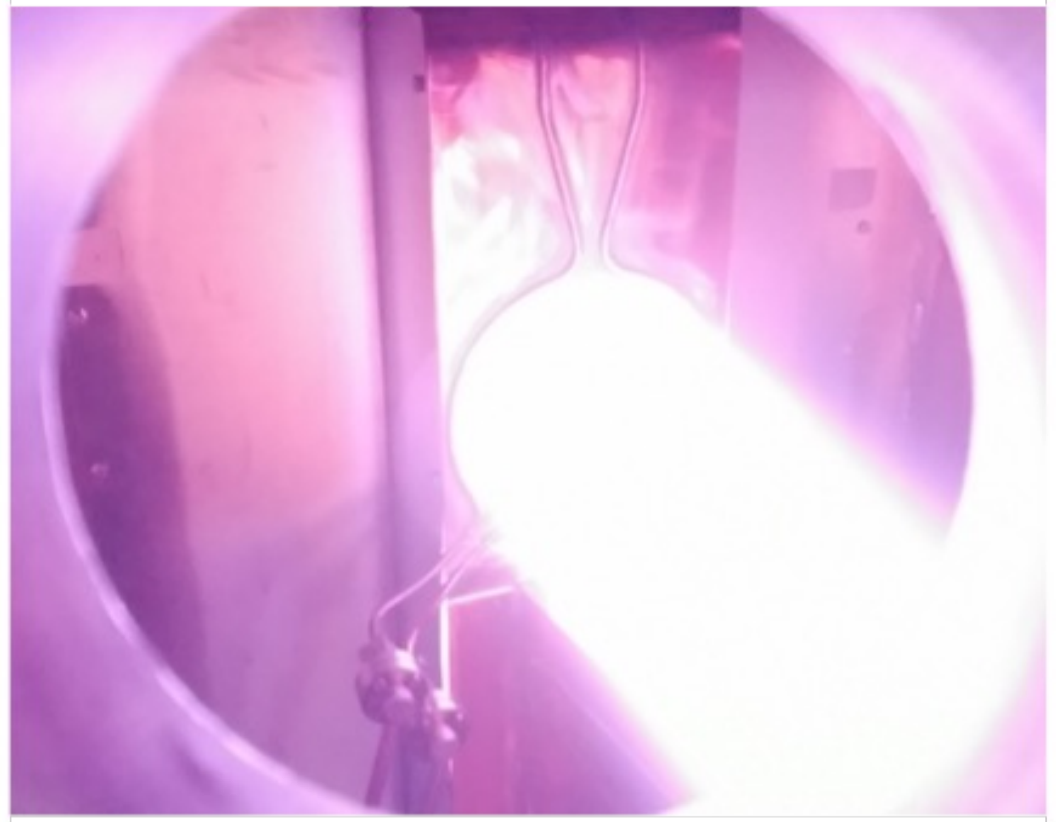
2023 10/23



2023 11/07



2023 11/21



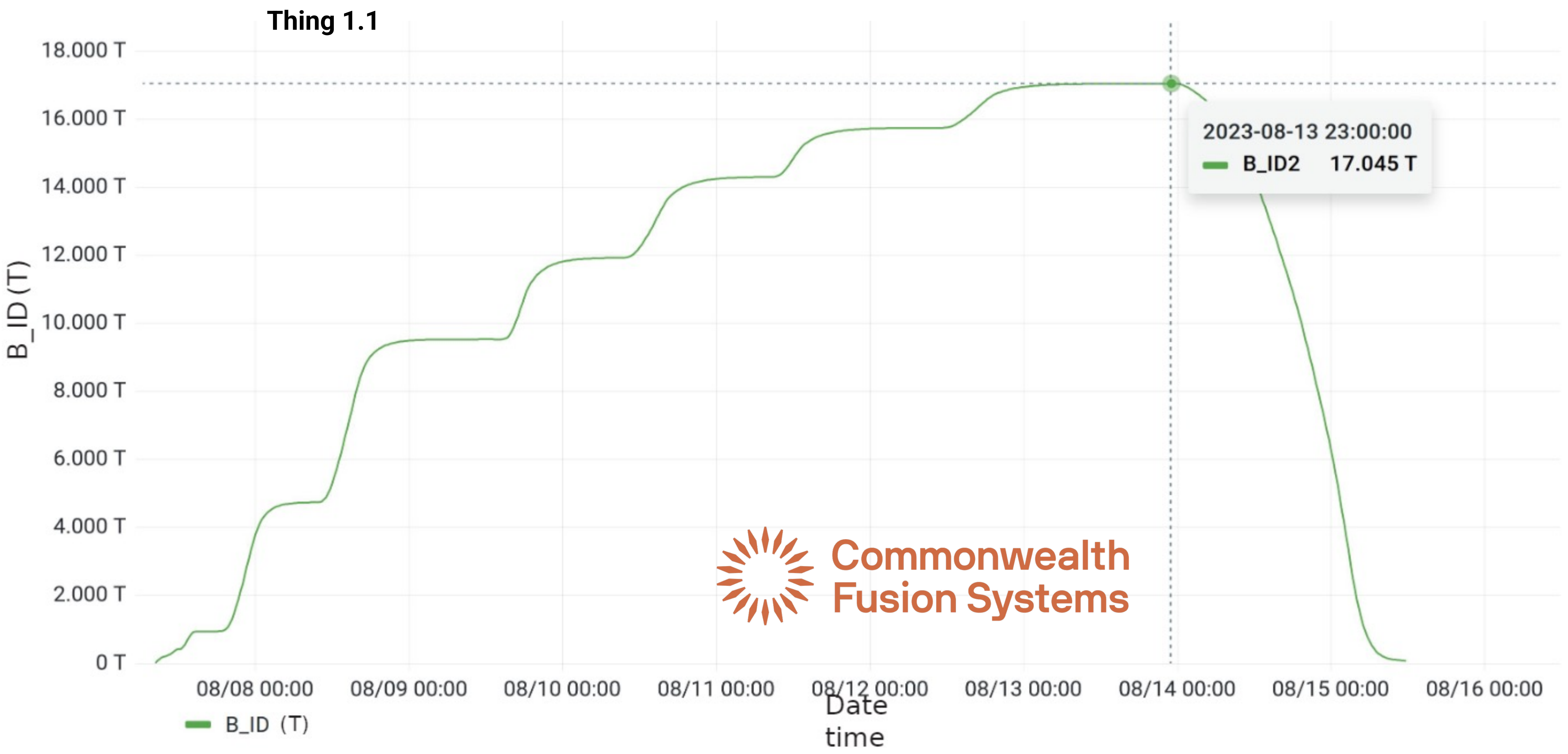
P_ion ~ 836 kW

WHAM Mirror coils *(pacing item)* (Feb 2024)

Commonwealth Fusion Systems

- Thing 1.1 tested to full field: 17.05 T, 8/13/23 2:22:00 AM, 8/13/23.
  - Outperformed design: 12% more dense superconducting winding pack, decreased internal resistance.
  - L/R *Increased* required test time at CFS on Thing 1; schedule adjusted.

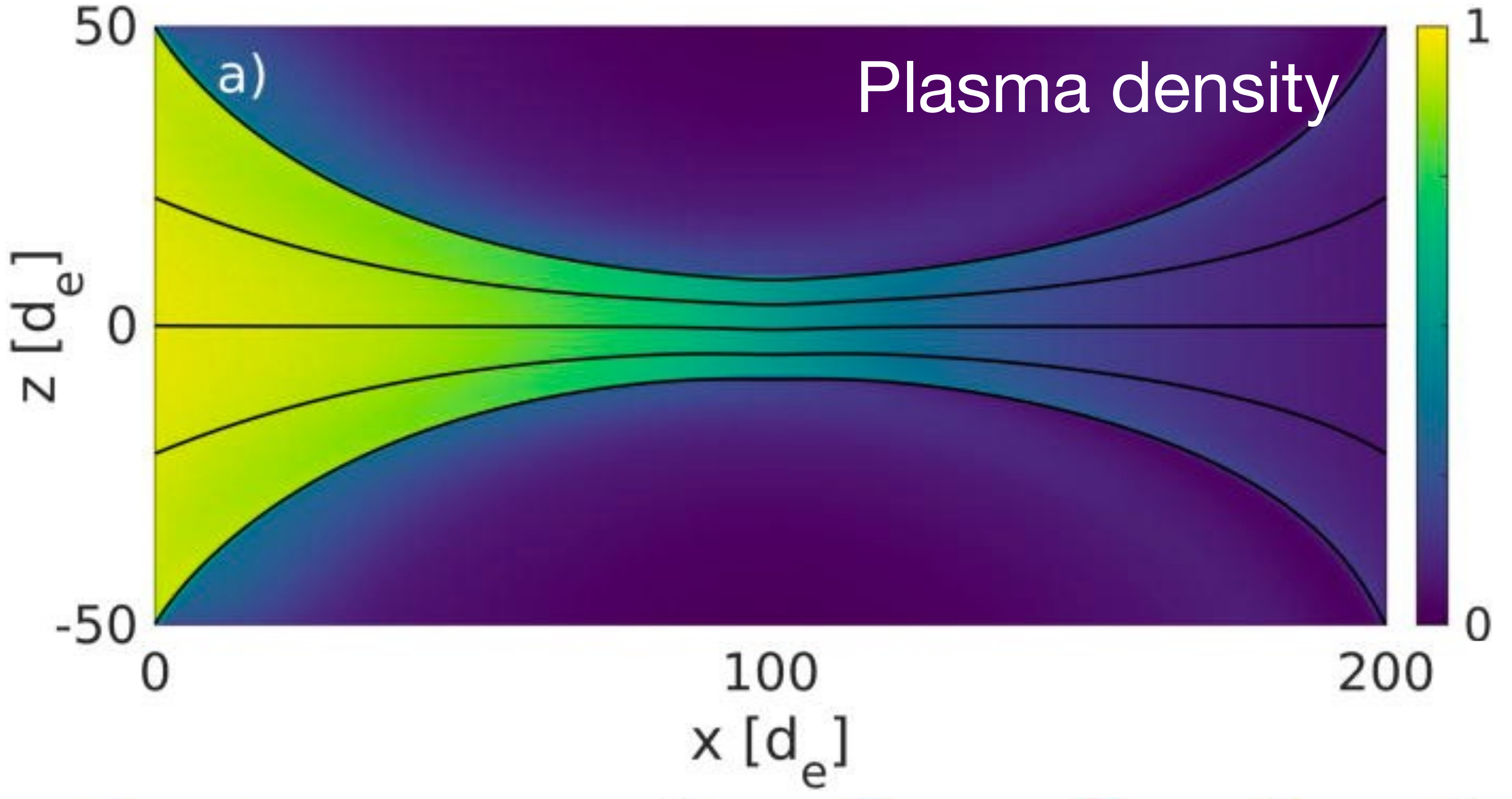
- Thing 2 into final assembly with testing scheduled for January 2024 .

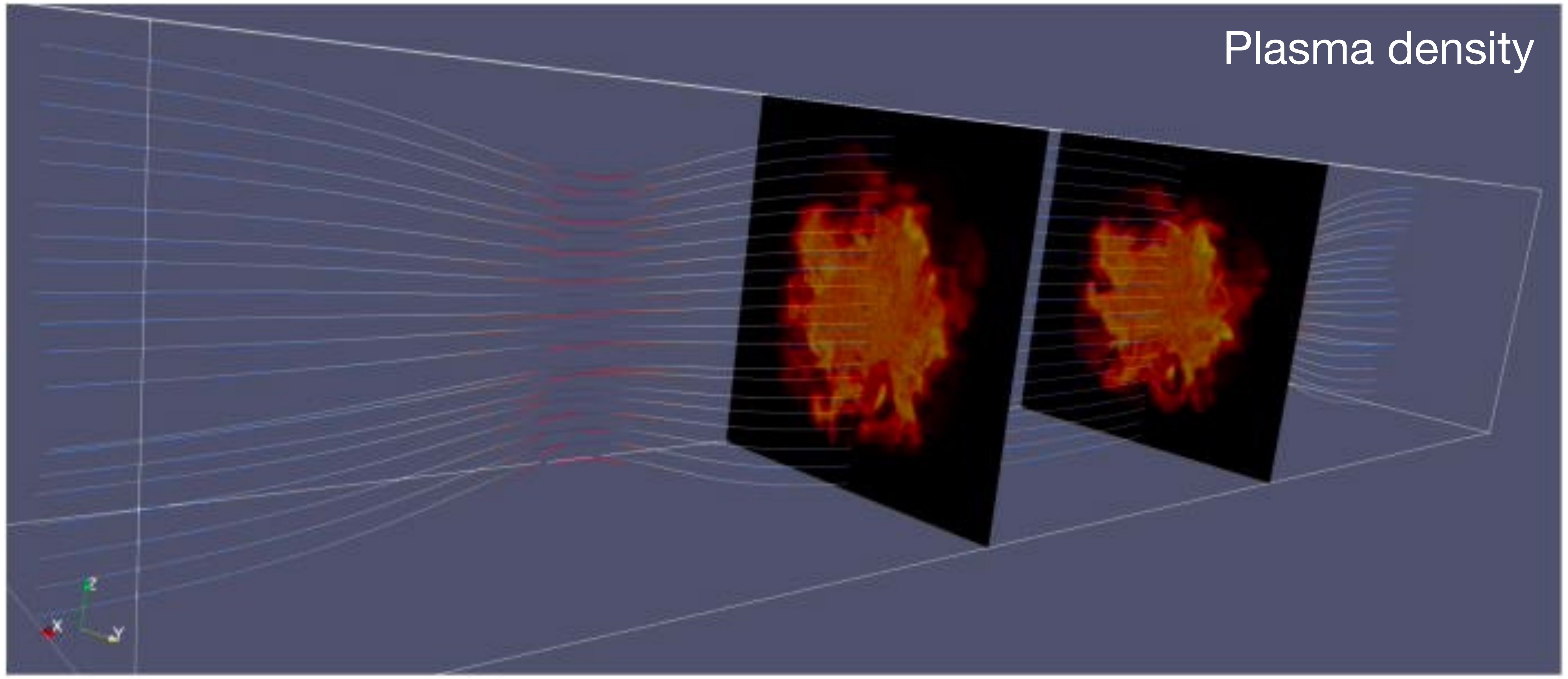


arpa·e
CHANGING WHAT'S POSSIBLE

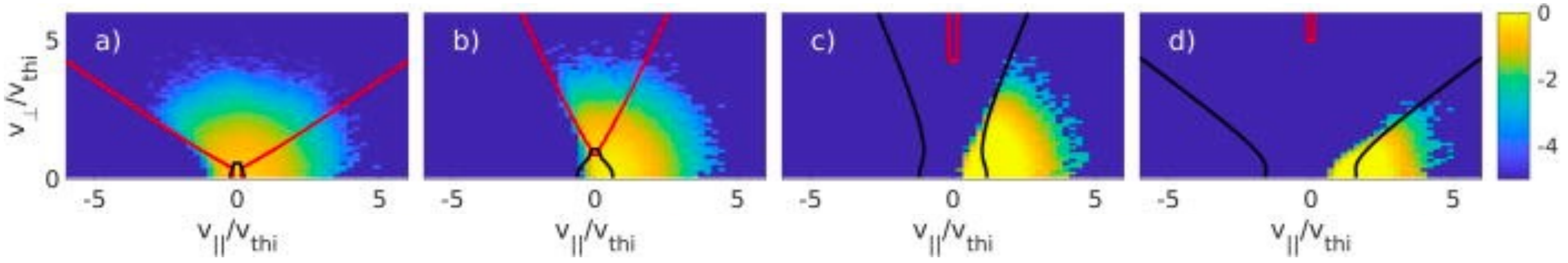
2D & 3D kinetic simulations of open-field devices out of reach ~30 years ago

Mirror expander in 2D full PIC,
mi/me=400 (Wetherton+ 2021, PoP)
matches kinetic model of electric potential





3D mirror device in Hybrid-VPIC:
particle ions, fluid electrons
(Le+ 2023, PoP)



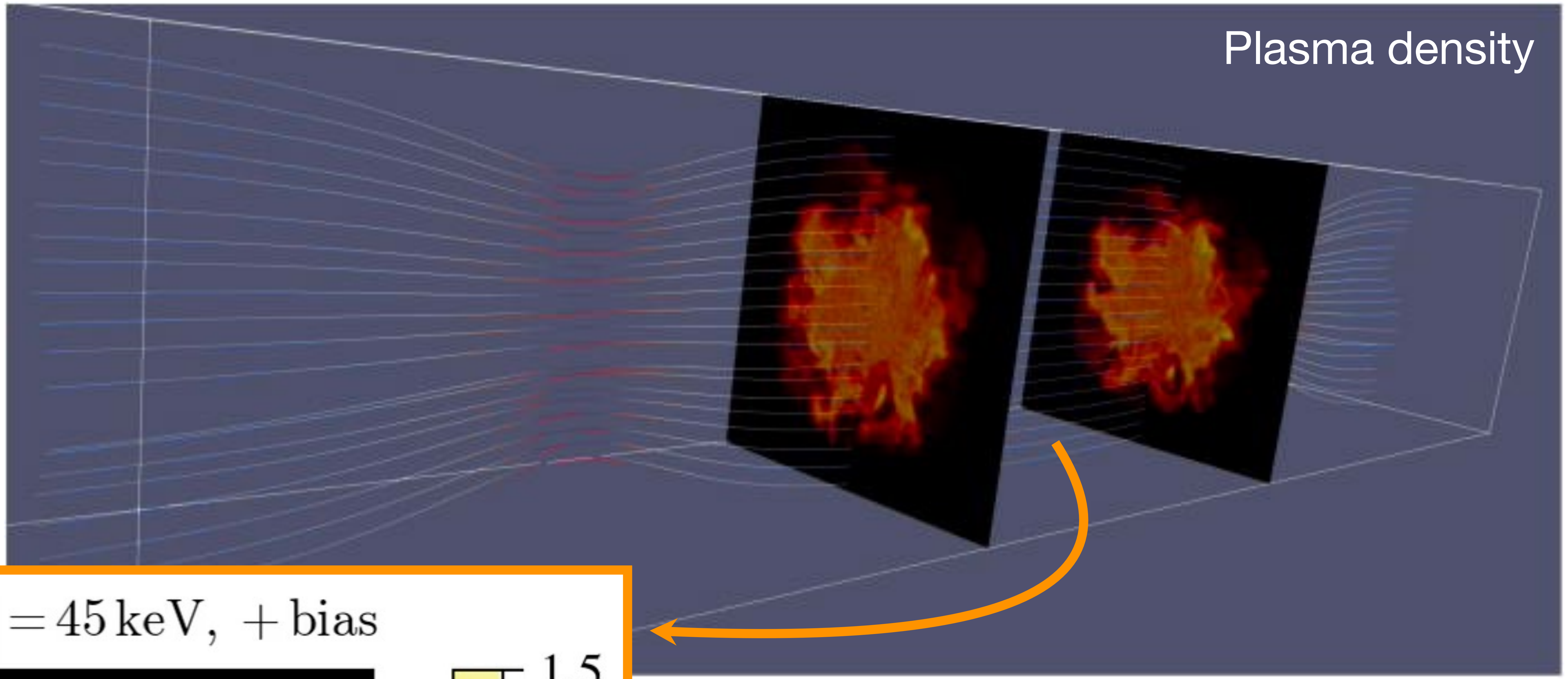
On-axis ion distributions, left to right
(x = 25,75,125,175)

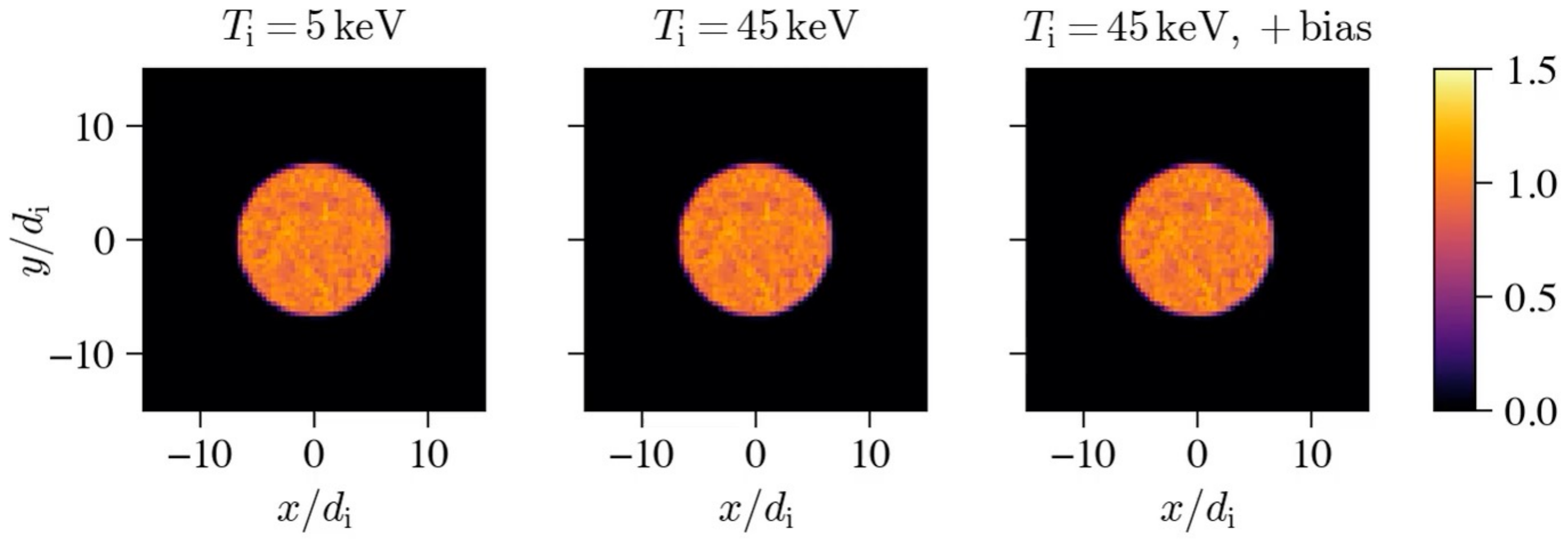
See also:
GBS drift-reduced two-fluid (Rogers+ 2010; Fisher+ 2015,2017)
Gkeyll gyrokinetics (Shi+ 2017,2019; Francisquez+ 2023)

High ion beta and radial voltage biasing suppress interchange turbulence

Simulations catching up to theory and experiment for mirror devices

Mirror ratio R_M = 5; duration 8 (left) and 24 (middle/right) thermal-ion bounce times $L\ /\ v_{th,ion}$





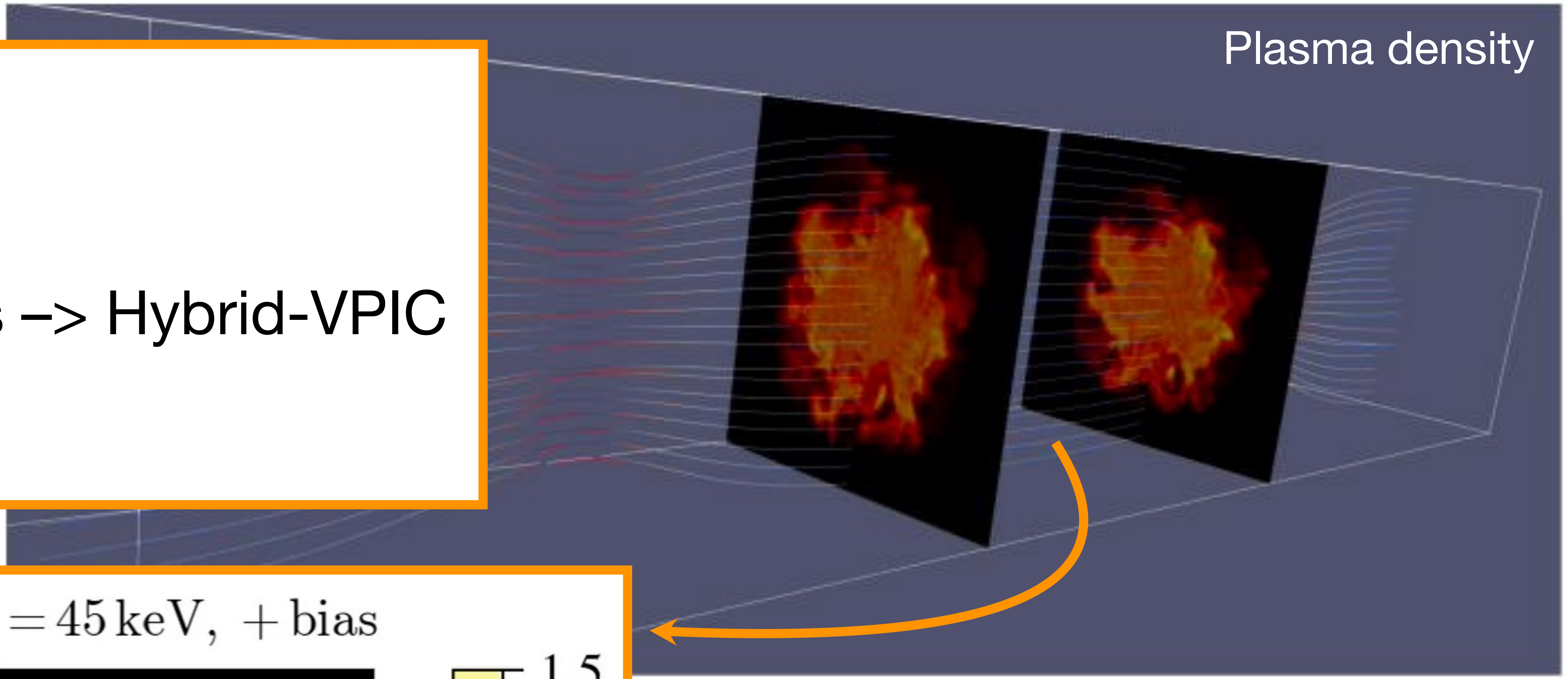
3D mirror device in Hybrid-VPIC: particle ions, fluid electrons
(Le+ 2023, PoP)

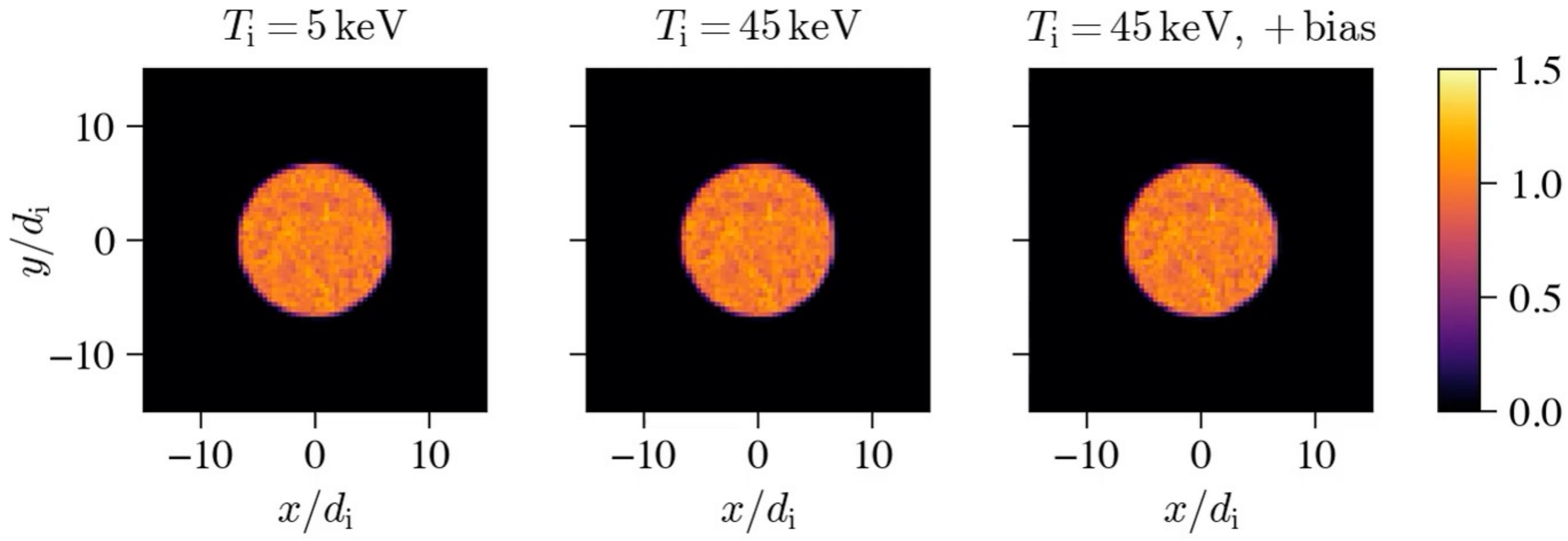
Plasma radius:
$a\ /\ \rho_{ion}$ = 24 (left), 8 (middle/right)
Ion composition: thermal + beam.
Beam ions ~1–10% by number, 40x energy, 45 deg. pitch angle

High ion beta and radial voltage biasing suppress interchange turbulence

Low cost! (~10k CPU-hr) –> tight iteration loop
Looking ahead:

- WHAM Phase 2 simulations (R_M = 20)
- Collisional Fokker-Planck model distributions –> Hybrid-VPIC to test kinetic-ion instability
- Tuning of bias control (cf. LAPD results)





3D mirror device in Hybrid-VPIC: particle ions, fluid electrons
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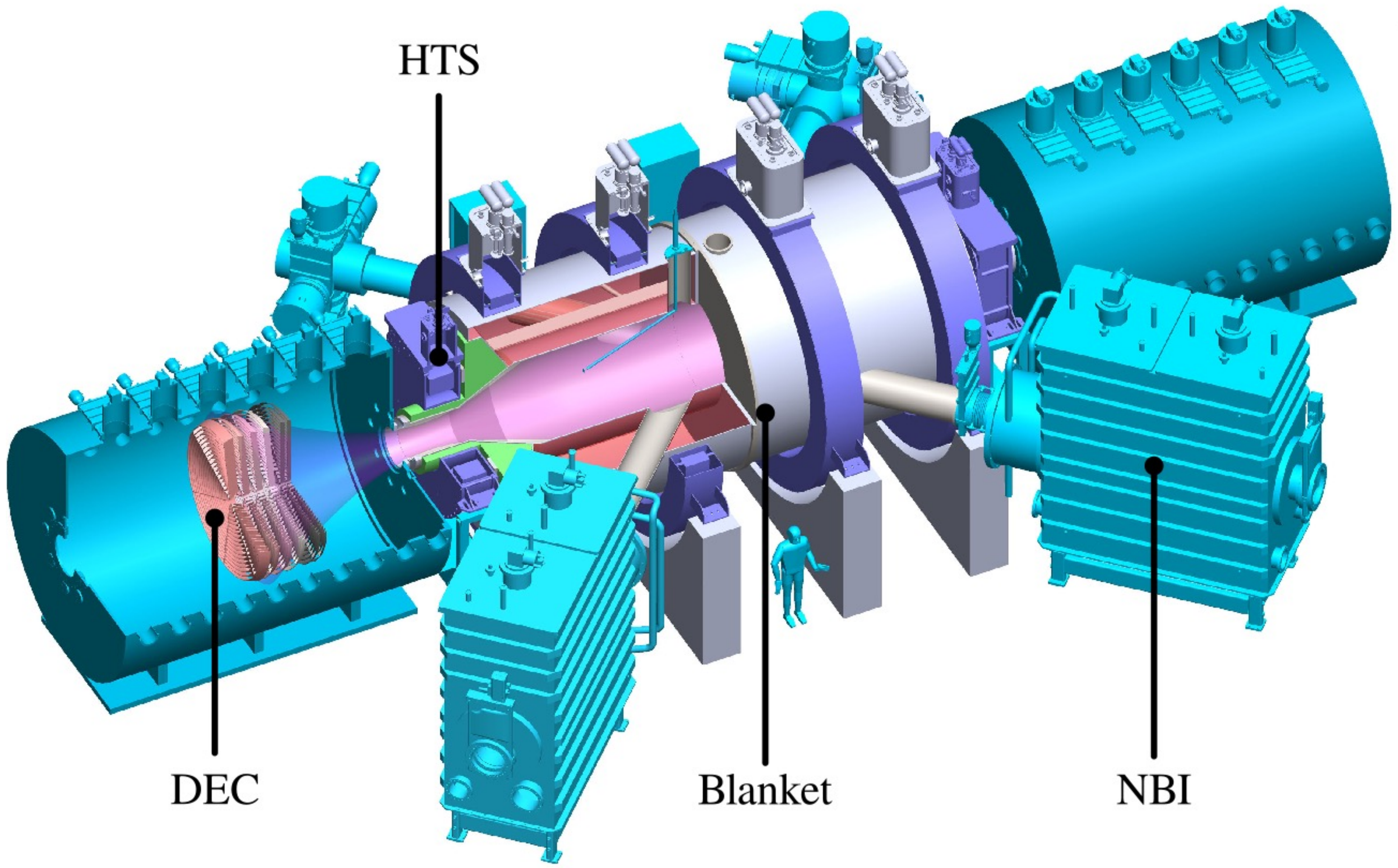
BEAM could be FIRST—integrated DT blanket testing at ~1-10 MW scale

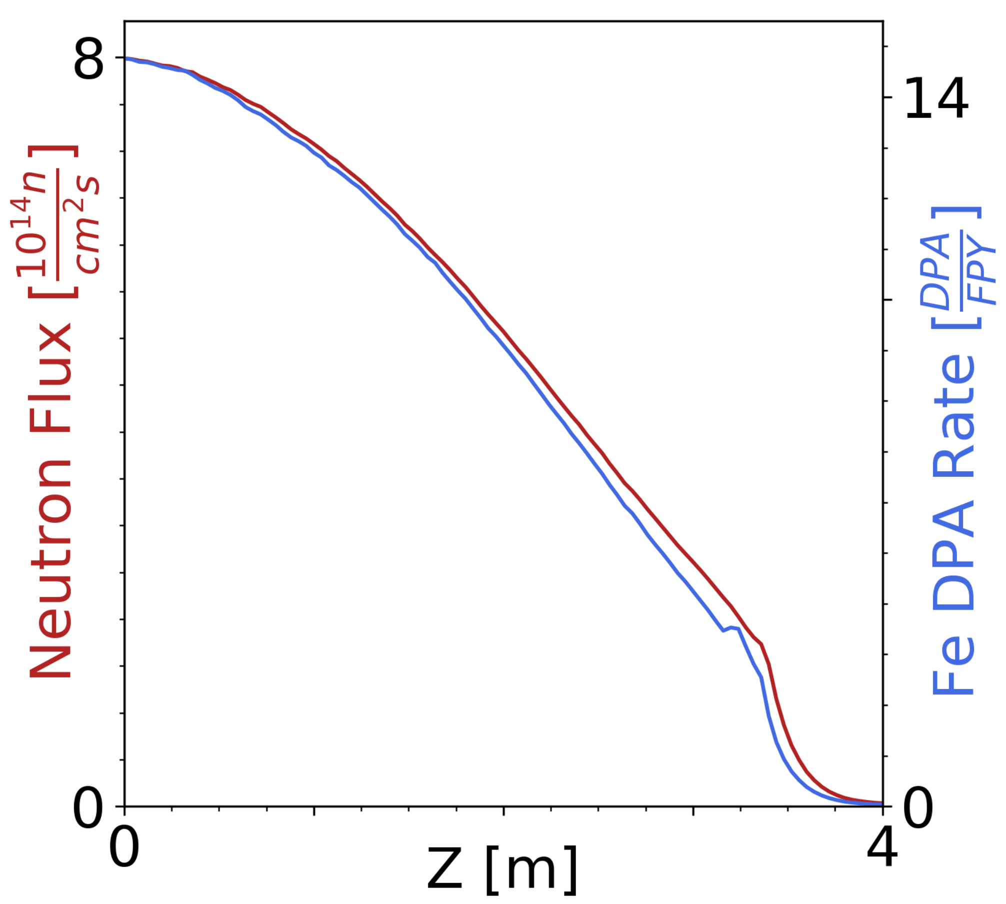
- Realta has started the integrated project planning for BEAM
- mission being refined
- Major technical challenges have been identified
  - high field, larger bore magnets
  - steady-state NBI at 100 keV

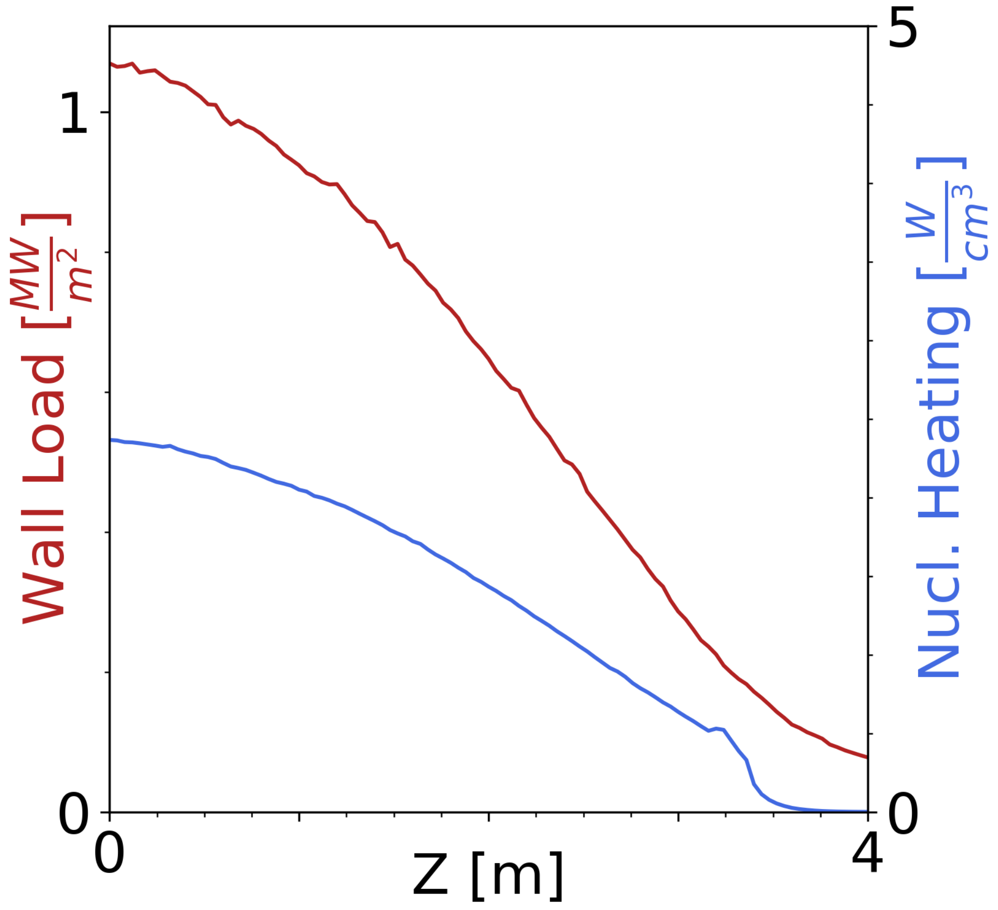
As FIRST:

- Low tritium usage (< 1 kG/FPyr)
- Single facility to allow full scope integration testing with DT
- Geometry in principle allows multiple blanket concepts to be tested at same time
- Phased approach would also derrick the FPNS mission: start with short pulse D-D fusion and gradually work towards extended D-T operation.
- Beam is of the technical maturity to meet FIRST requirements on a competitive timeline



	WHAM	BEAM
Q_{DT}	~ 0.05	~ 1
β	0.3	0.3
L_p (m)	2.0	8
a_0 (m)	0.12	0.30
a_M (m)	0.025	0.10
R_M	20	10
B_0 (Tesla)	0.85	2.5
B_M (Tesla)	17	25
E_{NBI} (keV)	30	100
P_{NBI}(MW)	< 1	10
T_i (keV)	17	80
T_e (keV)	2.5	10
n_{20} (m^{-3})	0.3	1
τ_p (sec)†	0.15	0.25
$nT\tau$ ($10^{20}\mathrm{m}^{-3}\cdot$keV$\cdot$sec)	0.7	20
pulse length (sec)	< 2	> 5
kA$\cdot$m of HTS tape	$\sim 10^4$	4.3×10^5
Cost of tape ($M)	~ 1	40





Journal of Plasma Physics (2023)

Prospects for a high-field, compact Break Even Axisymmetric Mirror (BEAM) and applications

C.B. Forest[1], J.K. Anderson[1], D.Endrizzi[2], J. Egedal[1], S. Frank [2], K. Furlong[2], M. Ialovega [1], J. Kirch [1], R.W. Harvey[4], B. Lindley[1], Yu.V. Petrov[4], J. Pizzo[1], T. Qian[3], K. Sanwalka[1], O. Schmitz[1], J. Wallace[1], D. Yakovlev[1], and M. Yu [1]†

Summary

- Realta is an early stage startup pursuing the high-field, compact mirror path to fusion

- Realta has hit the ground running
    - boots on the ground for WHAM first plasma
    - leading validation efforts (diagnostics and theory) for digital twins on WHAM for projection to BEAM
    - Has started engineering project for BEAM

- BEAM could be FIRST