Nuclear engineering considerations for pulsed, magneto-inertial fusion using field reversed configurations

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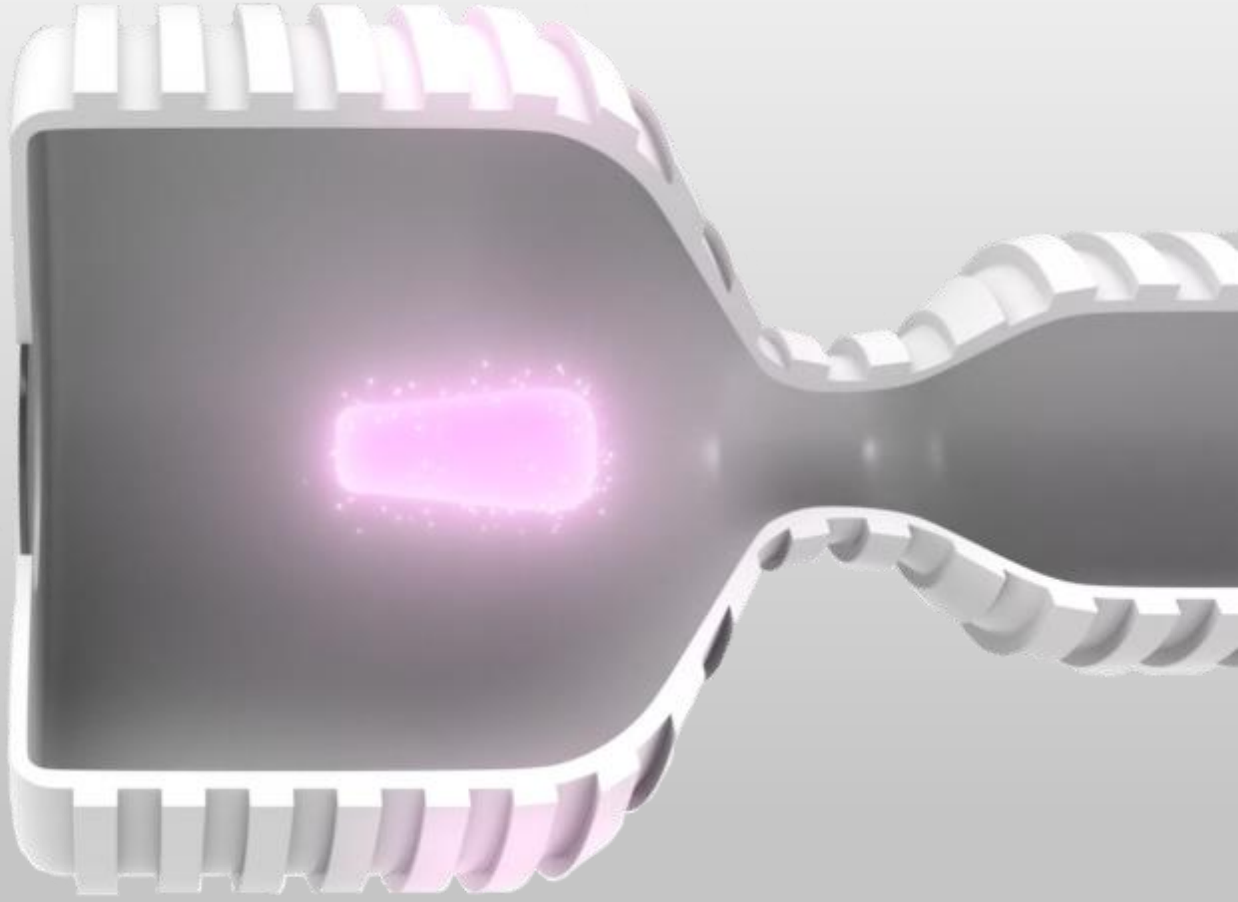
Fusion Energy: where are we at?



Fusion: where are we at?

Outline:

1. Introduction to Helion
2. Today and Next Steps: Polaris and Commercialization
3. Current Nuclear Engineering Work

Introducing Helion

- Now based in Everett, WA (founded 2013)
- *Doing fusion today*
- 200 people | Expected to reach 300+ in 2024
- Fully funded to reach commercialization ($600M)

I have been waiting for yesterday for 52 years... They have the premier fusion device in the world.

Independent auditor Pace Van Devender
Former CTO Sandia National Laboratories

Current, 6th prototype: Trenta

Fuchsia glow from hydrogen x-rays (Balmer series)

Trenta: *6th-generation prototype*

Technical Achievements:

- First private company to reach 100M degrees (9 keV ion)
- Held the machine under vacuum for 16-months, 1000s pulses

1 Formation

Deuterium and helium-3 are heated to plasma conditions. Magnets confine the plasma in a Field Reversed Configuration (FRC).

2 Acceleration

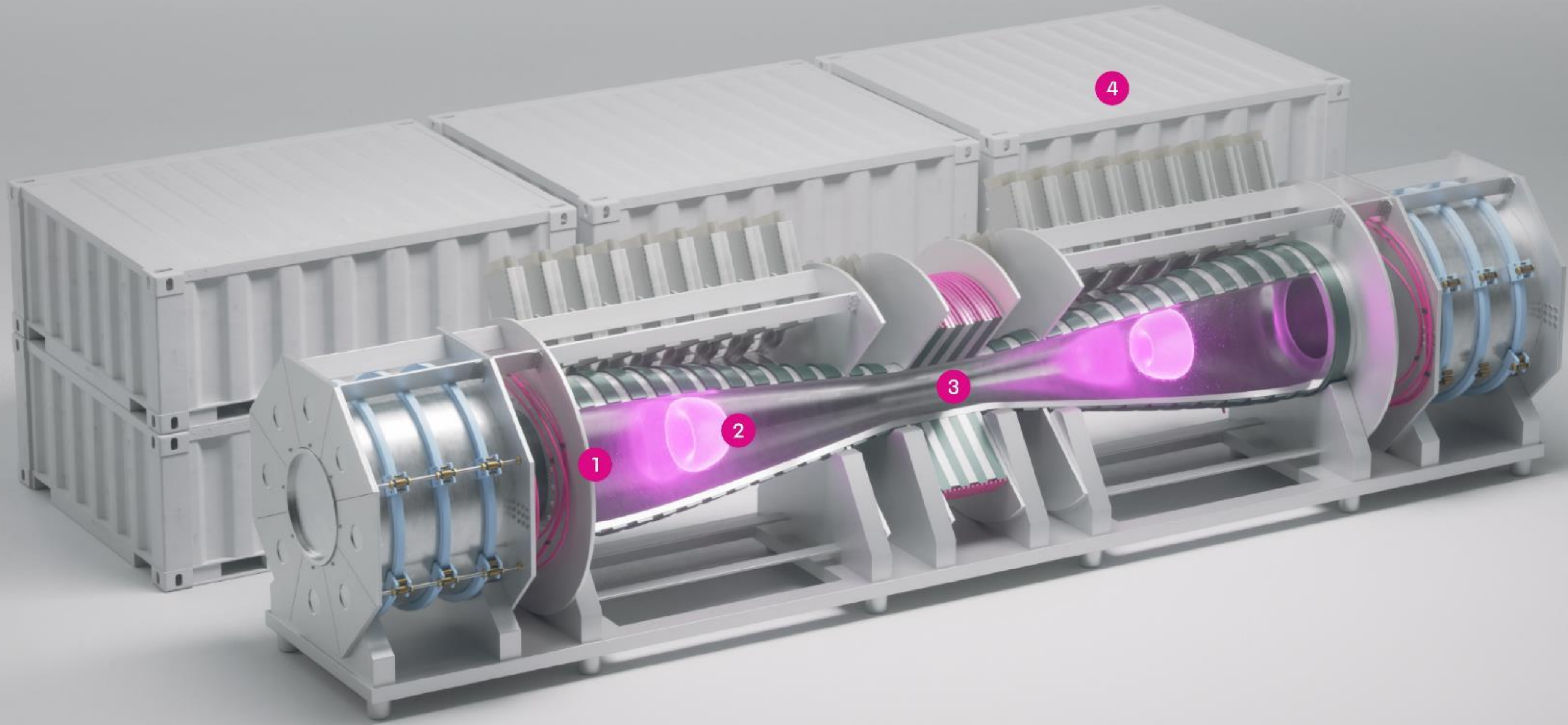
Magnets accelerate the FRCs until they collide in the center of the device.

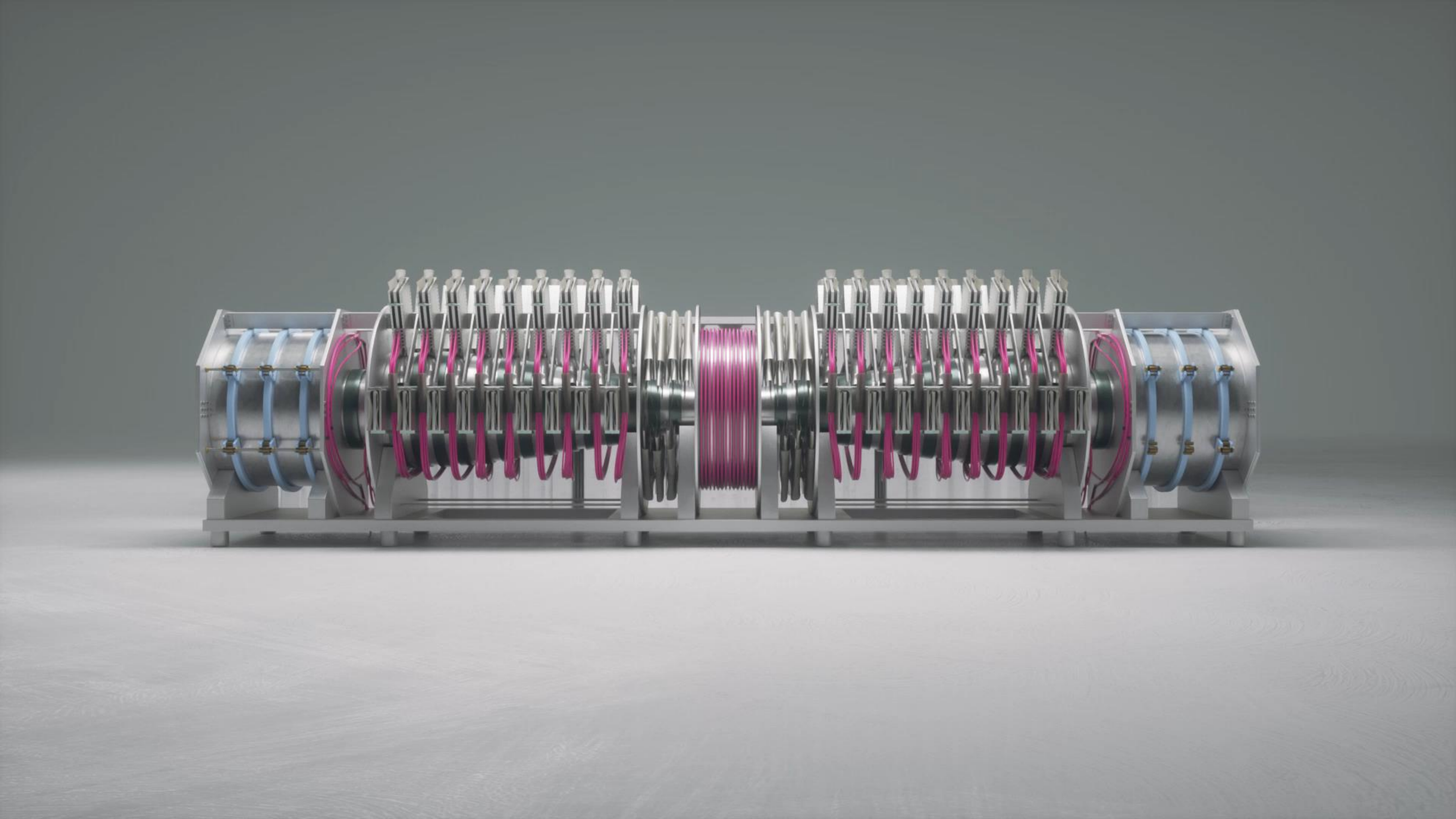
3 Compression

The merged plasma is compressed until it reaches 100 M°C. Fusion occurs and the plasma expands.

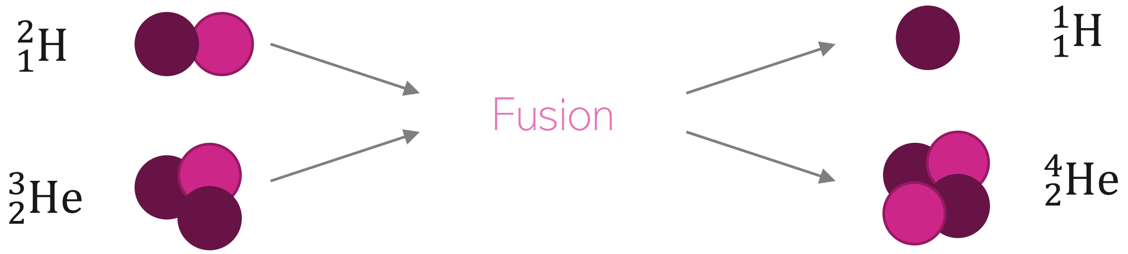
4 Electricity Recapture

As the plasma expands, it pushes back on the magnetic field. The change in field induces current, which is directly recaptured as electricity.



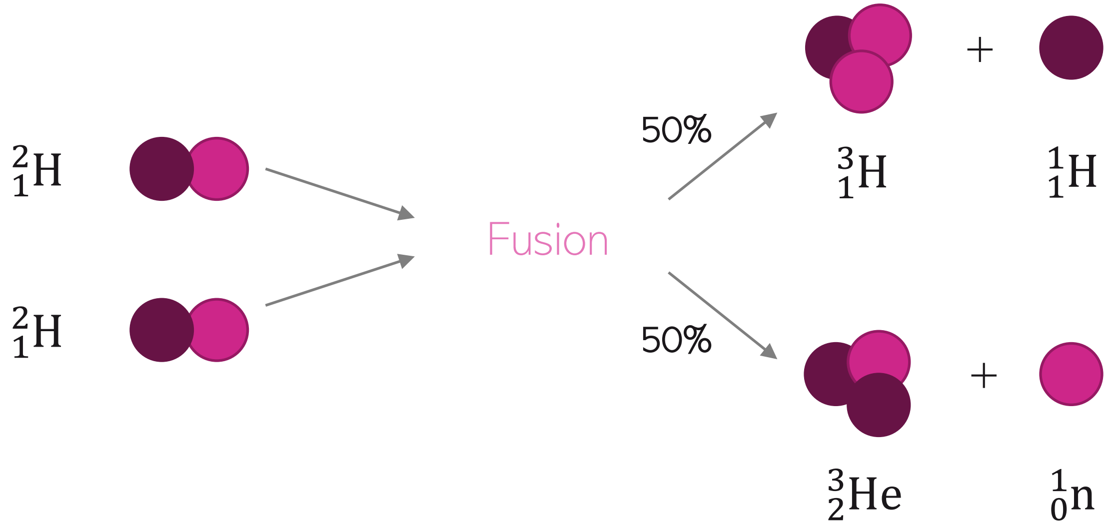


Helion’s device uses deuterium-helium-3 fuel



$$^{2}_{1}H + ^{3}_{2}He \rightarrow ^{1}_{1}H + ^{4}_{2}He$$

The deuterium-helium-3 fusion does not produce radioactive byproduct nor radiation

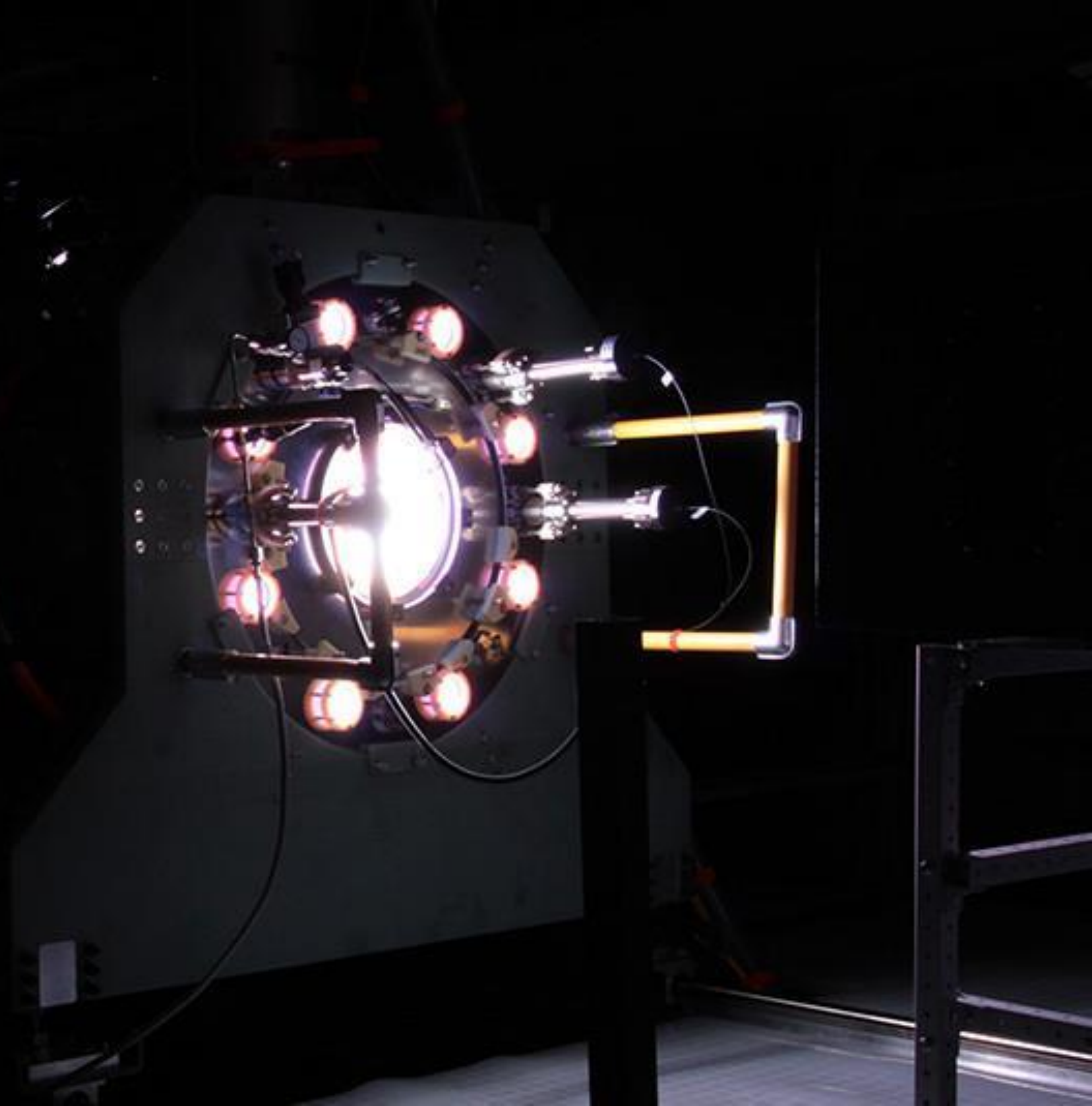


$$^{2}_{1}H + ^{2}_{1}H \rightarrow \begin{cases} ^{3}_{1}H + ^{1}_{1}H & (50\%) \\ ^{3}_{2}He + ^{1}_{0}n & (50\%) \end{cases}$$

The deuterium-deuterium fusion side reaction does produce radioactive radiation (neutrons, $^{1}_{0}n$) and byproduct (tritium, $^{3}_{1}H$)

Helion’s Features

- Field-reversed configurations (FRCs)
- Pulsed (e.g., 10 Hz)
- Direct electricity recapture
- Alternate fuel: D-He3



Next Steps

Building Polaris and Commercializing

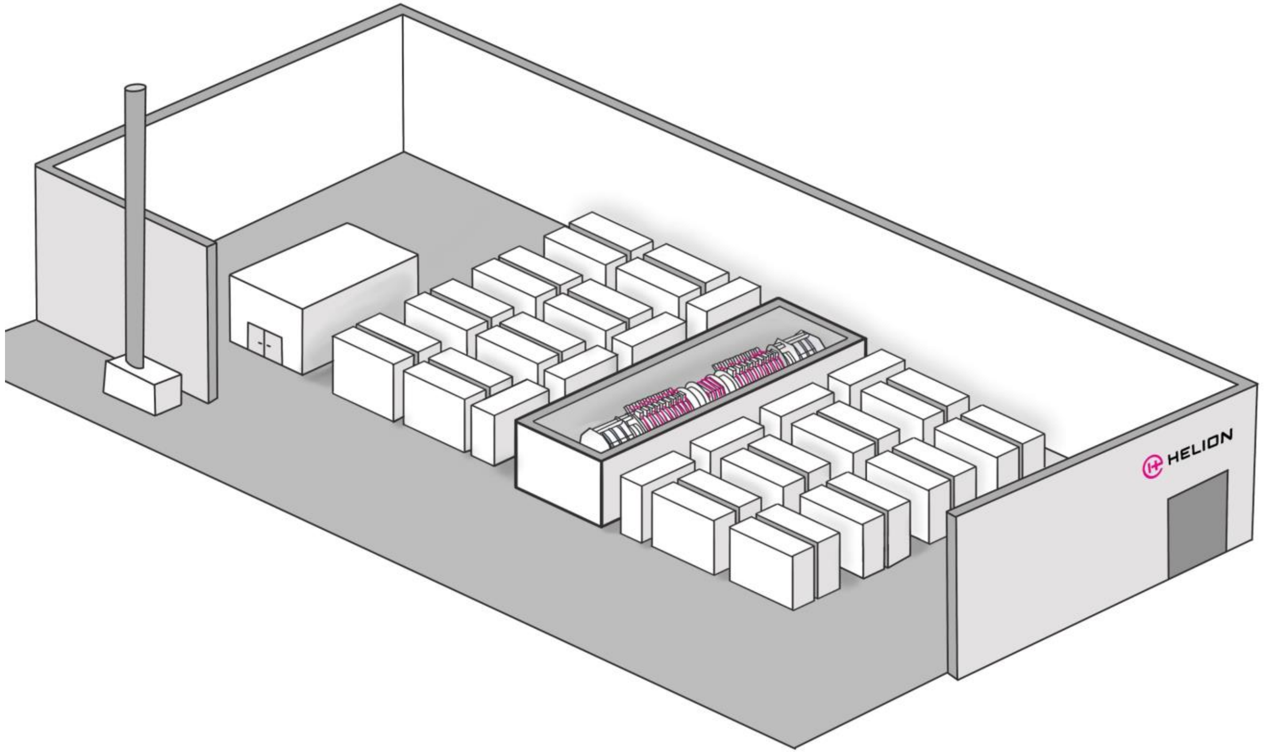
Polaris:

- demonstrate electricity recapture from fusion for the first time
- commercial scale for a 50 MW generator

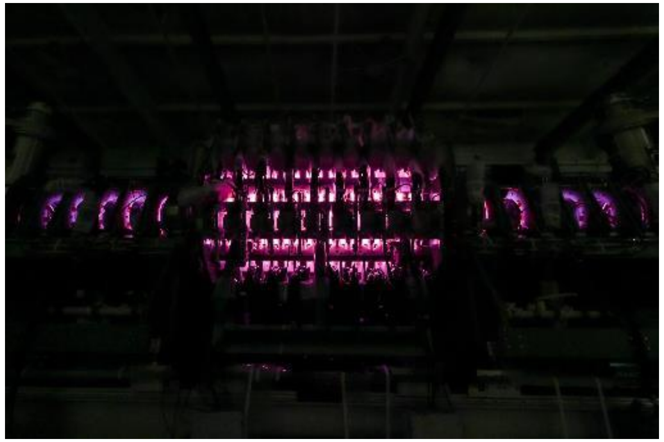
Commercial system: 50 MW

- Fits in 30,000 sq. ft. building
- Borated concrete and BPE shielding
- Entire process occurs within a closed system
- No secondary steam cycle

- E.g., 85% capacity factor

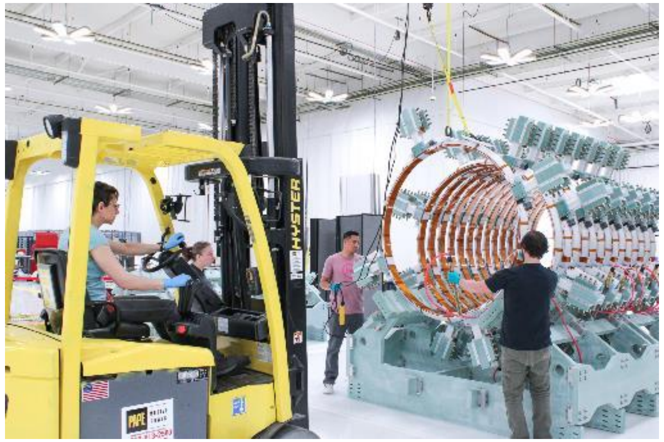


Ongoing progress: Preparing Polaris and Manufacturing



Optimizing fuel injection technology

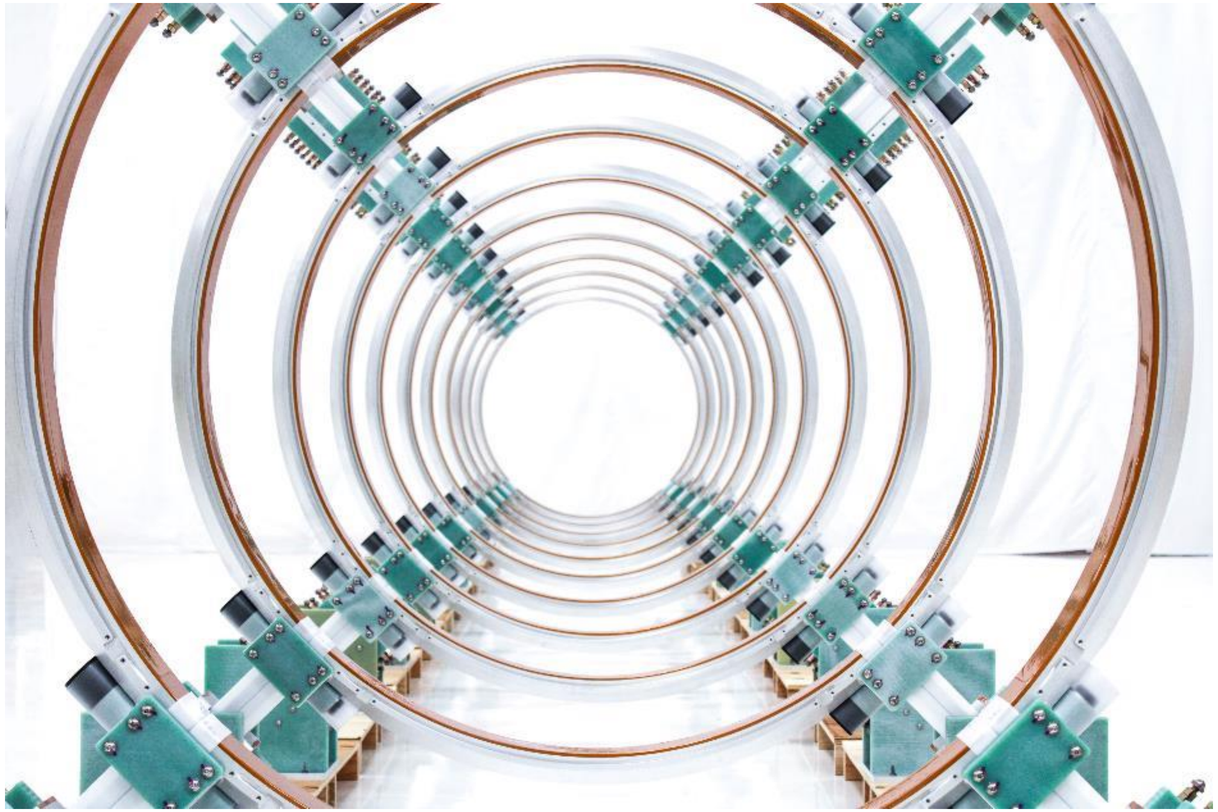
Scaling in-house capacitor manufacturing



Installing our 7th fusion prototype, Polaris

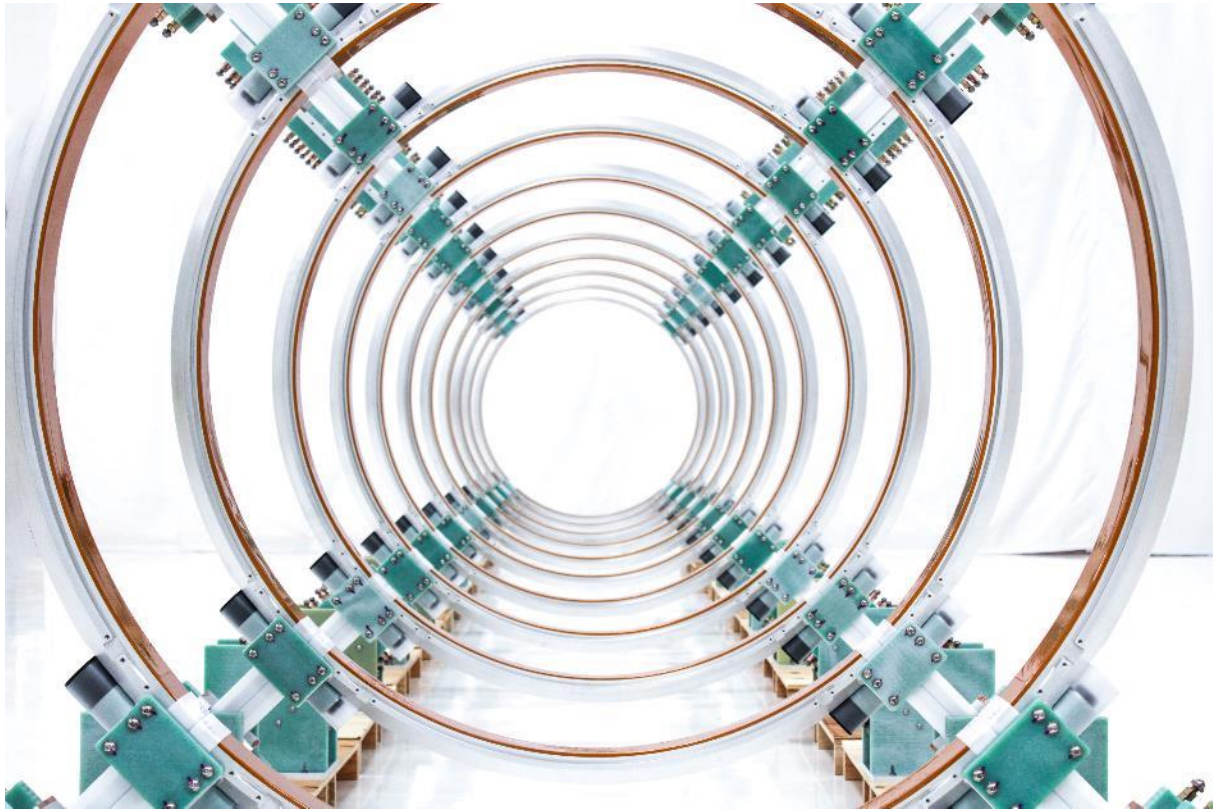
World’s first fusion PPA: Helion and Microsoft

• Expected completion:	2028
• First customer:	Microsoft
• Power Marketer:	Constellation
• Site:	Washington
• Output:	50 MW+



Decarbonizing industrial manufacturing with Nucor

Expected completion:	After 2030
Collaborator:	Nucor
Power distributor:	Direct to site
Site:	TBD
Output:	500 MW

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A brief look at:

Nuclear Engineering on the Frontier of Commercial Fusion Energy

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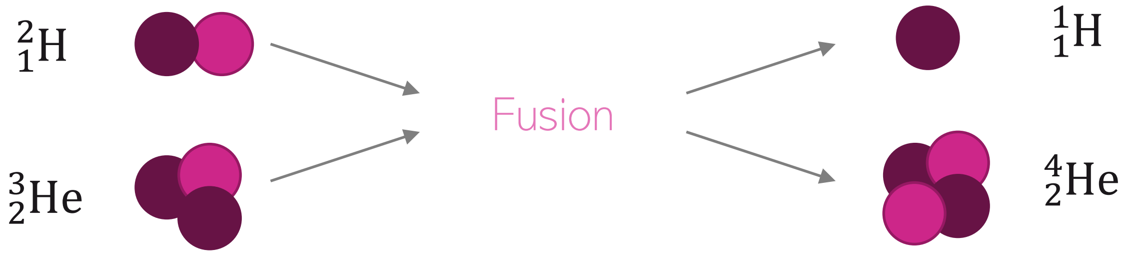

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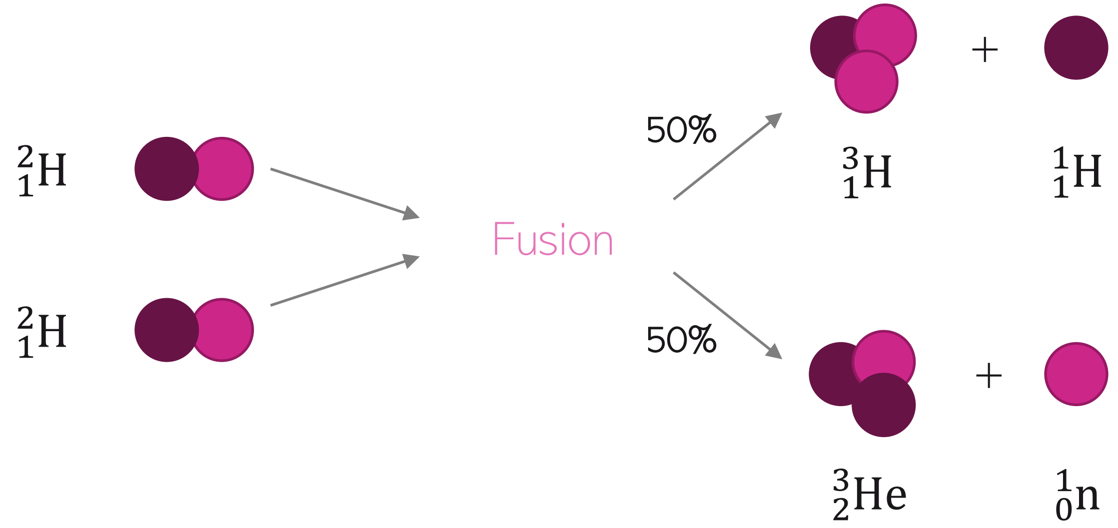

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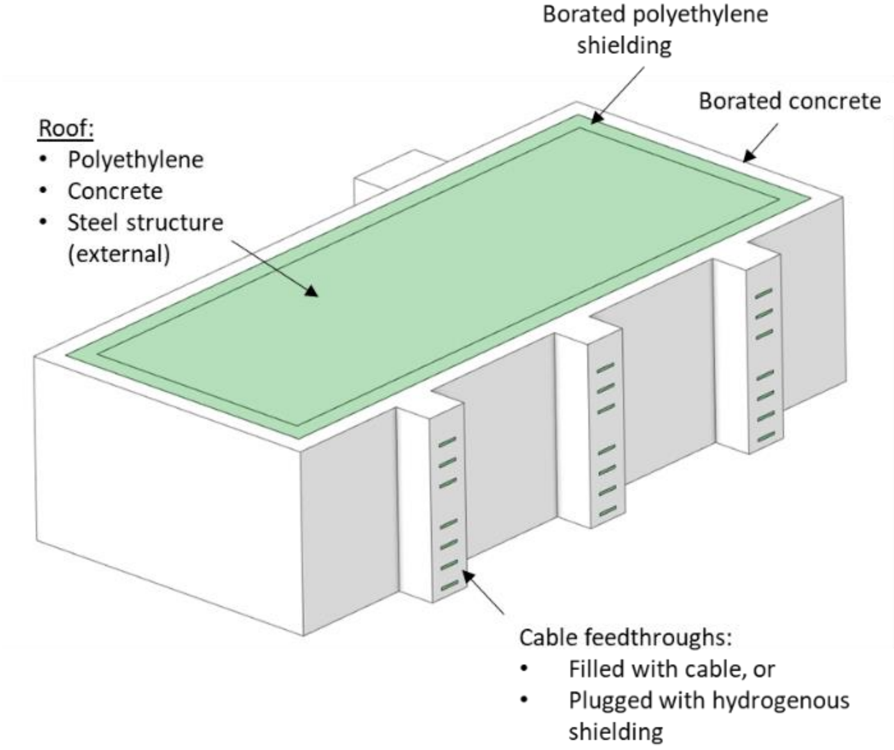
Radiation safety: tools to minimize exposure

Shielding



Tritium Capture and Gas Processing

Getter beds are used to capture and store tritium in a bound state

Air is exhausted only if tritium air monitors show very low levels

Facets of Helion's Radiation Safety and Nuclear Science Team

- Radiation Safety and Regulatory Affairs
  - Agreement States and NRC
  - International Atomic Energy Agency

- Chemical/Fuel Cycle Engineering
  - Isotopic purification: He-3, H-2, H-3
  - He-3 recovery from H-3

- Nuclear Engineering
  - Diagnostics
  - Neutronics

- Materials Engineering
  - R&D and testing
  - Radiation Effects

Sample national lab collaborations.

Coming online:

- Princeton Plasma Physics Laboratory
- Oak Ridge National Laboratory

Pacific Northwest NATIONAL LABORATORY

- Hydrogen transport

Lawrence Livermore National Laboratory

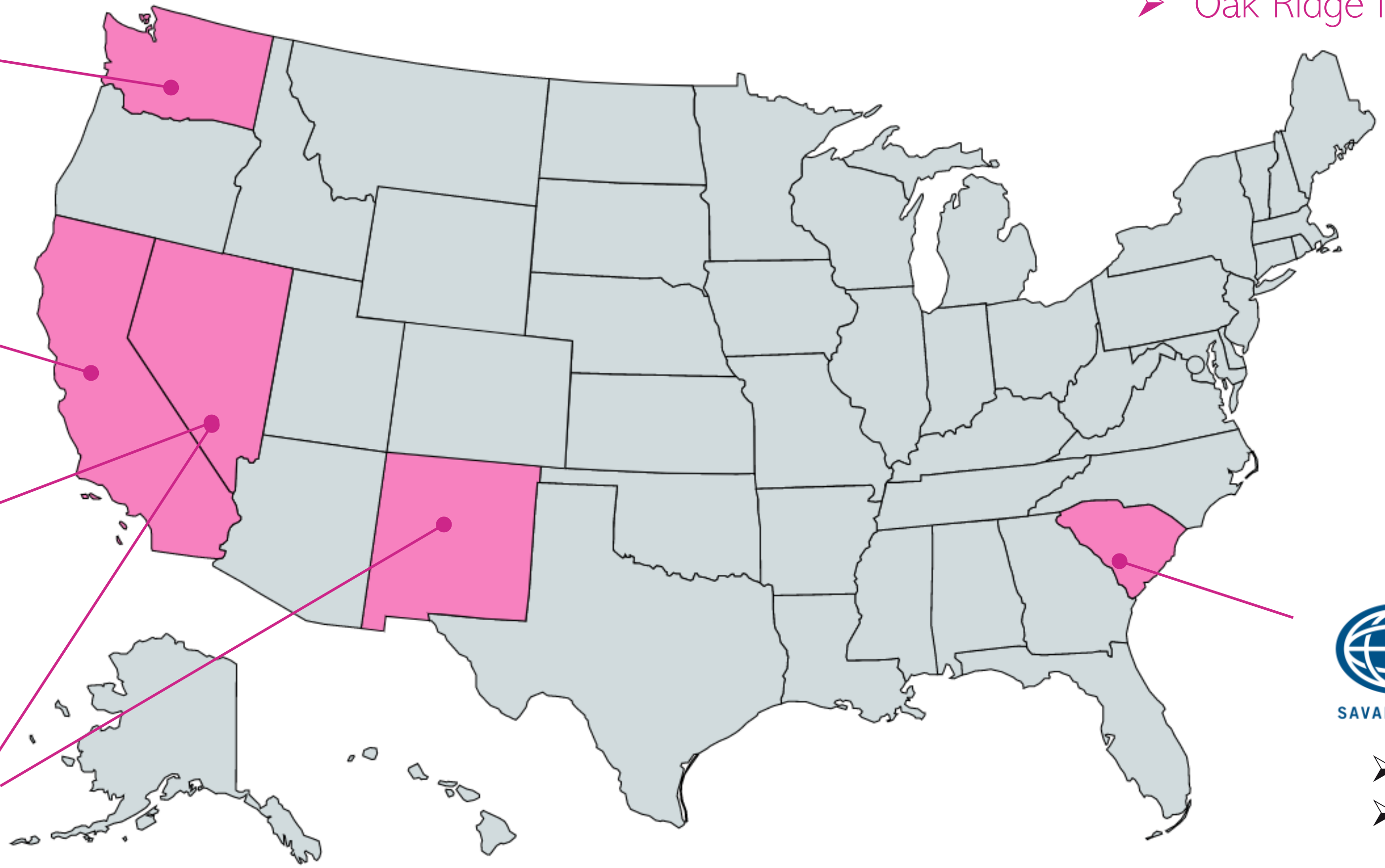
- Diagnostic calibration

NEVADA NATIONAL NNSS SECURITY SITE

- Diagnostic calibration

Los Alamos NATIONAL LABORATORY

- Diagnostic calibration



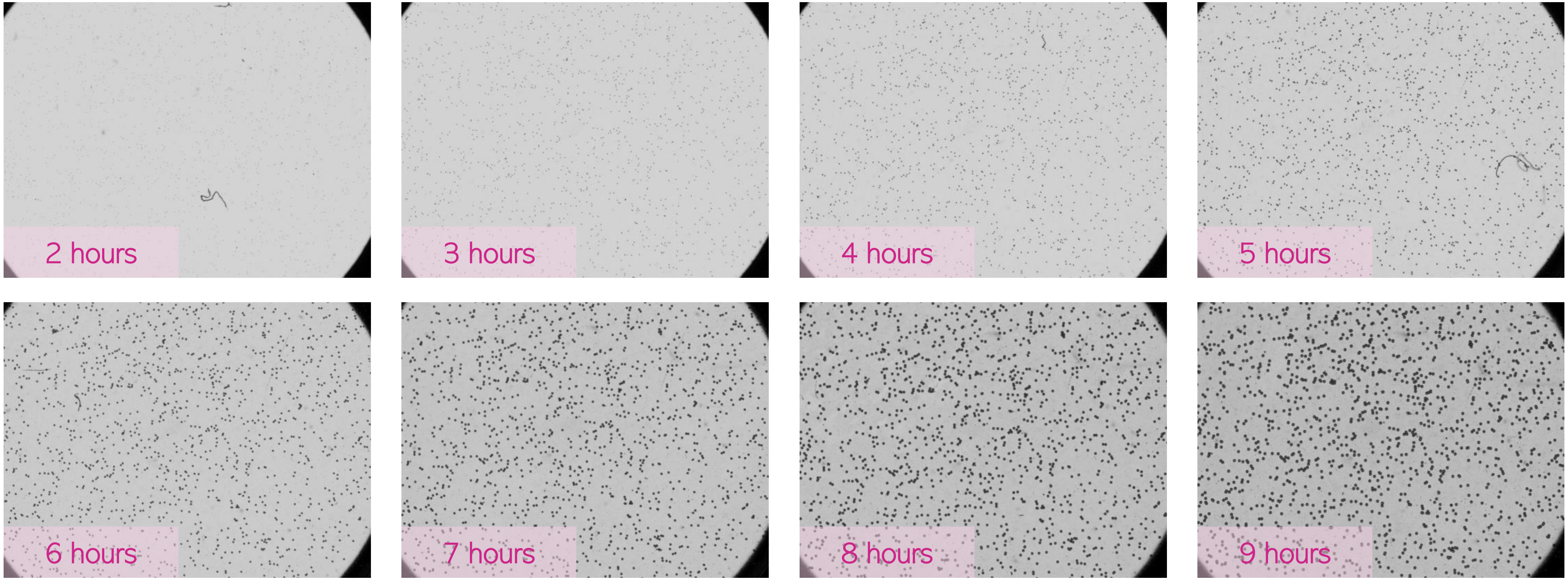
SRNL® SAVANNAH RIVER NATIONAL LABORATORY

- Tritium handling
- Materials

Additional partners:

- Universities
- Industry/vendors

Nuclear diagnostics: CR-39 for neutrons and charged particles



- Recent calibration campaign conducted with DOE/LLNL/MSTS with a 10^{11} DD dense plasma focus
- Results to be presented at APS DPP next week

Materials: post-Trenta wall analysis

- Windows
  - Minimum damage per shot, primary center ablation
- Cusp face
  - Extensive damage over time, Silica removed
- Divertor face
  - Extensive build up of Silica monolayer and active crystal growth on the surface
- Challenge: first wall material…
  - Heat loading
  - Dielectric
  - Fast soak-through time (B)

Quartz sample after plasma-facing operation in Helion's 6^{th}-generation prototype, Trenta.


HELION