

FUSE

Fuse's Capabilities for Nuclear Security and Fusion Energy

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2025

Presentation outline:

I. FAETON-I Results:

- Device parameters and experimental highlights
- Key data: neutron yield, X-rays, pinch voltage correlation
- Lessons for next-generation DPFs

II. FAETON-X Development:

- Design features of the 1 MJ / 4 MA DPF
- Neutron and X-ray outputs
- Applications in advanced radiation testing

III. ICECAP Facility:

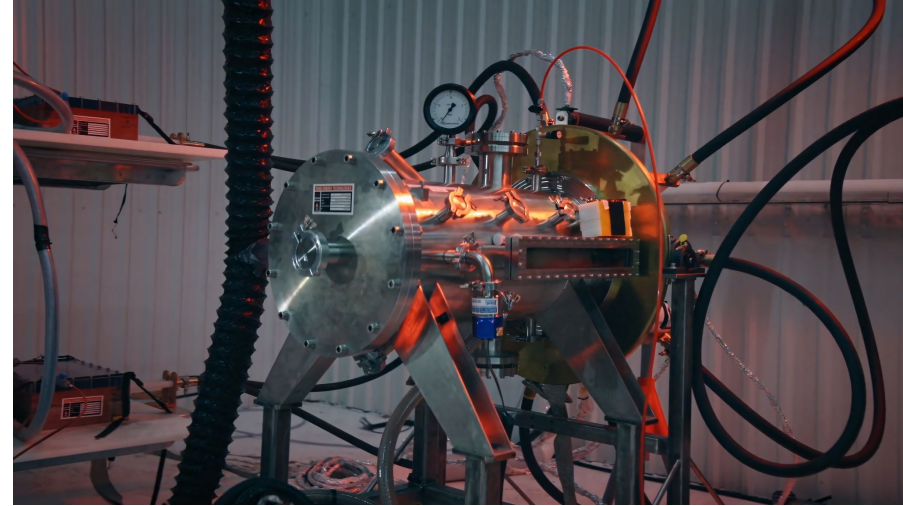
- Integrated, pulsed neutron and gamma environment
- Multi-source, customizable radiation fluence platform
- Synergistic radiation effects studies
- Facility infrastructure and safety

IV. TITAN Impedance-Matched Marx Generator:

- TITAN design parameters
- Experimental results and operational insights
- Path to future upgrades

FAETON 1

- FAETON-I is the highest direct-charged DPF, at 100 kV & 1 MA peak current.
- Conducted more than 1300 experimental shots.
- Achieved a record-high Z-pinch voltage of 194 kV, enabling superior neutron output.
- 10x higher efficiency than traditional pulsed fusion neutron sources.
- Servicing Global Fortune 500 customer today.
- Experimental results are published in *Nature Scientific Reports*¹.



nature

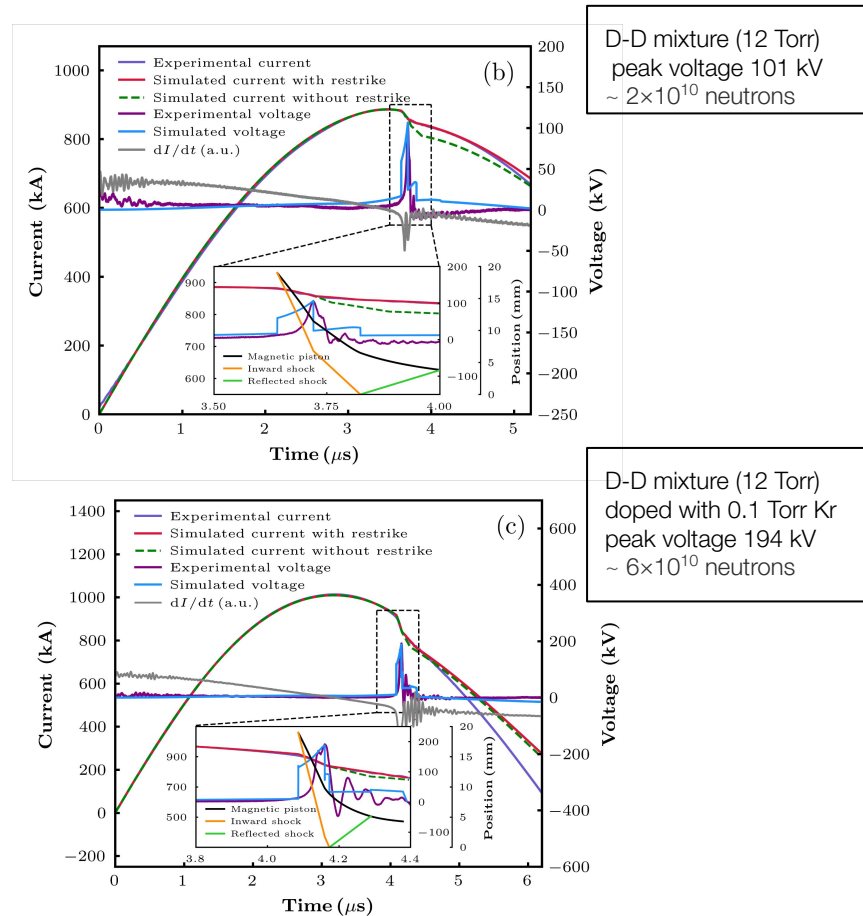
SCIENTIFIC
REPORTS

¹ Damideh, V., Btaiche, J.C., et al. Experimental results and analysis of plasma dynamics and radiation output of the 100 kV dense plasma focus FAETON-I, *Scientific Reports* 15, 23048 (2025) <https://doi.org/10.1038/s41598-025-07939-x>



FAETON 1

- FAETON-I consistently produces $\sim 2.5 \times 10^{10}$ neutrons/shot at 2.45 MeV; peak yields up to 8×10^{10} neutrons/shot at 12 Torr.
- For the first time, neutron yield was shown to correlate strongly with peak pinch voltage.
- Generated X-rays exceeding 3 MeV and deuteron beams near 350 keV.
- Excellent candidate for combined neutron and gamma radiation testing environments.
- FAETON-I serves as the foundation for the design of FAETON-X, a 1 MJ dense plasma focus machine with a peak current of 4 MA.



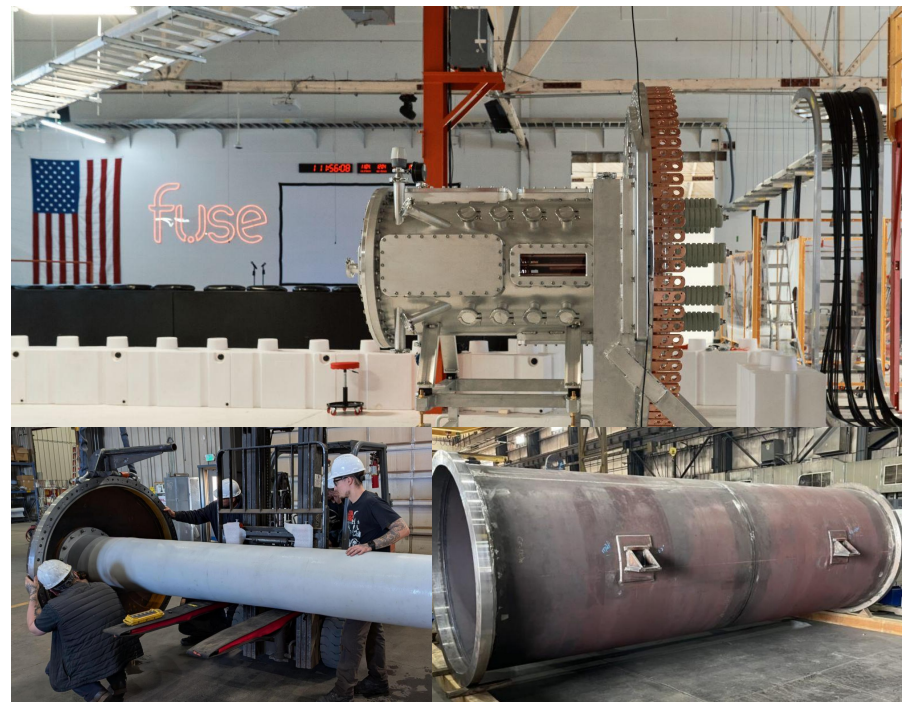
FAETON X

- FAETON-X DPF system operates at 65 kV and stores ~ 1 MJ of energy.
- Upon discharge, current goes up to ~ 4 MA with ~ 9 μ s rise time.
- Optimized in-house using FAETON-I experimental data and upgraded Lee model code simulations.
- Designed to generate intense, pulsed neutron and X-ray bursts—enabling realistic simulation of harsh environments.
- Operates with D-D at 10–20 Torr, producing on average 5×10^{11} neutrons/shot at 2.45 MeV.
- Operates with D-T at 10–20 Torr, producing on average 5×10^{13} neutrons/shot at 14.1 MeV.
- First test expected before end of year, operational machine in 1H26.



ICECAP

- ICECAP is a next generation combined neutron and gamma radiation test platform.
- Enables cutting-edge synergistic radiation effects studies.
- ICECAP designed to deliver synchronized pulses of neutrons and X-rays.
- Hosts FAETON-X and a high-power flash X-ray source (FXR).
- FXR delivers radiation dose of $\sim 2 \times 10^{11}$ rad(Si)/s at the converter.
- Facility allows flexible testing: position and radiation fluence are adjustable.



TITAN I

- TITAN-I demonstrated the first Impedance-matched Marx generator (IMG), achieving up to 90% energy transfer efficiency.
- 14-stage prototype delivered 1.4 MV and 780 kA peak current with 140 ns rise time.
- Each stage contains 17 bricks connected in parallel, and all stages are electrically connected in series.
- Intra-stage advanced triggering system enables precise pulse delivery and reliability improvements.
- TITAN provides compact, scalable, and cost-efficient pulsed power driver, supporting fusion research and high-energy-density physics.
- Experimental results are published in *Nature Scientific Reports*¹.



nature

SCIENTIFIC
REPORTS

¹ Damideh, V., Btaiche, J.C., et al. Experimental results of a 330 GW impedance-matched Marx generator, *Scientific Reports* 14, 16889 (2024)
<https://doi.org/10.1038/s41598-024-67774-4>



Future IMG-based pulsed power facilities

- Delivers high energy transfer efficiency, reaching up to 90%—twice that of traditional Marx generators with pulse forming lines.
- Provides long operational lifetime, exceeding 10,000 shots for reliable and repeatable experiments.
- Supports high repetition rates from the drivers with shot frequency potentially up to 0.1 Hz.



TECHNOLOGY

The path ahead
is *harder*

+

Radiation Testing as a Service,
becomes fusion power once we
optimize these 3 curves

RADIATION ENERGY OUTPUT

1 GJ

REPETITION RATE

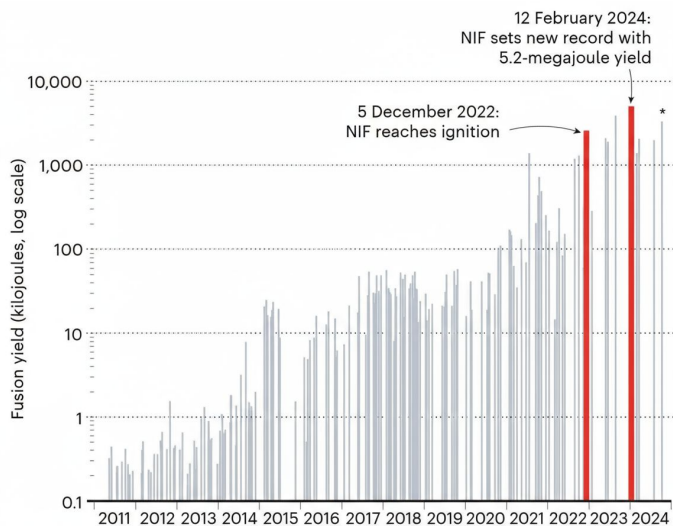
0.1 Hz

ENERGY COST

\$40/MWh

Path to 1 GJ of energy output

NIF fusion yield progress¹



¹ <https://doi.org/10.1103/PhysRevLett.132.065103>

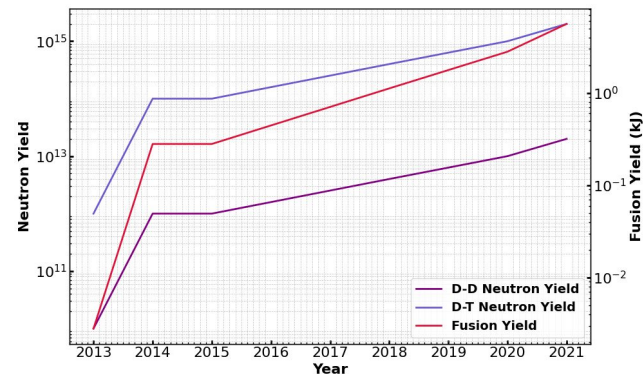
² <https://doi.org/10.1103/PhysRevLett.125.155002>

³ <https://doi.org/10.1063/1.5054317>

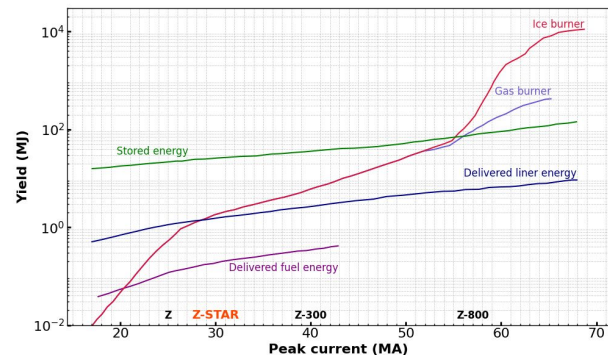
⁴ <https://doi.org/10.1063/5.0007476>

⁵ <https://doi.org/10.1063/1.4941100>

Z Machine fusion yield progress^{2,3,4}



Projected implosion fusion path to over GJ yields⁵

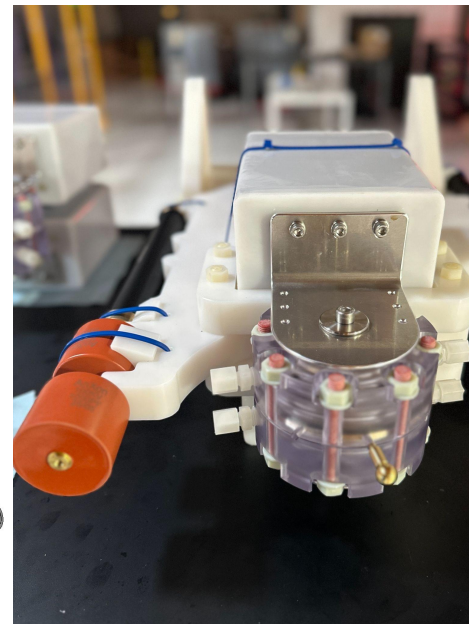
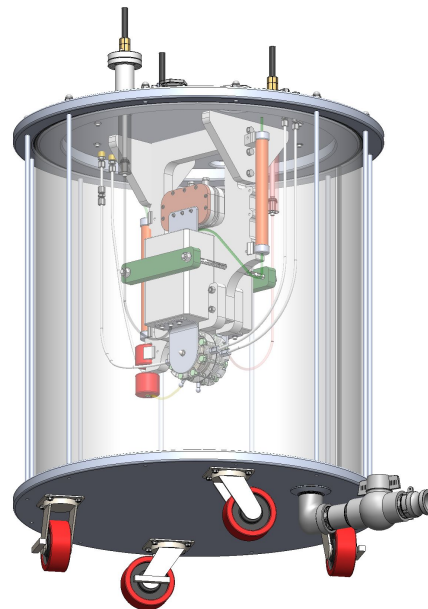


Increasing the Rep rate

Brick test goal to fire 10,000 shots at 0.1 Hz to test the reliability and life time of components before EOY.

TITAN II will be optimized over time to get to 0.016 Hz.

Z STAR will allow us to experiment with ideas to increase the machine shot rep rate.



Driving the \$ per J down as we scale

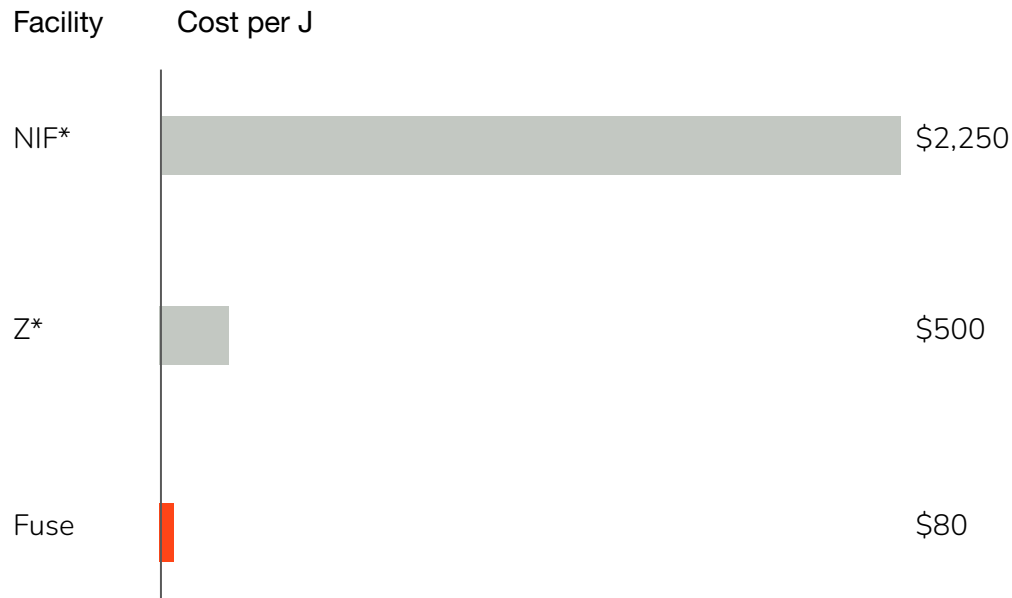
TITAN technology proved that we can get to \$80/J delivered on target. We need to bring that number down even further.

28x

cheaper than the
National Ignition Facility

6.25x

cheaper than the
Z Machine



*Note that these numbers are estimate and are considered in 2025 USD value

Challenges Remain

- Driver repetition rate & lifetime
- Target Design, cost, and mass manufacturing
- MITLs for higher currents
- Driver-Target Coupling
- ...

Thank you!

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