PACIFIC FUSION

Affordable, manageable, practical, and scalable high-yield and high-gain inertial fusion

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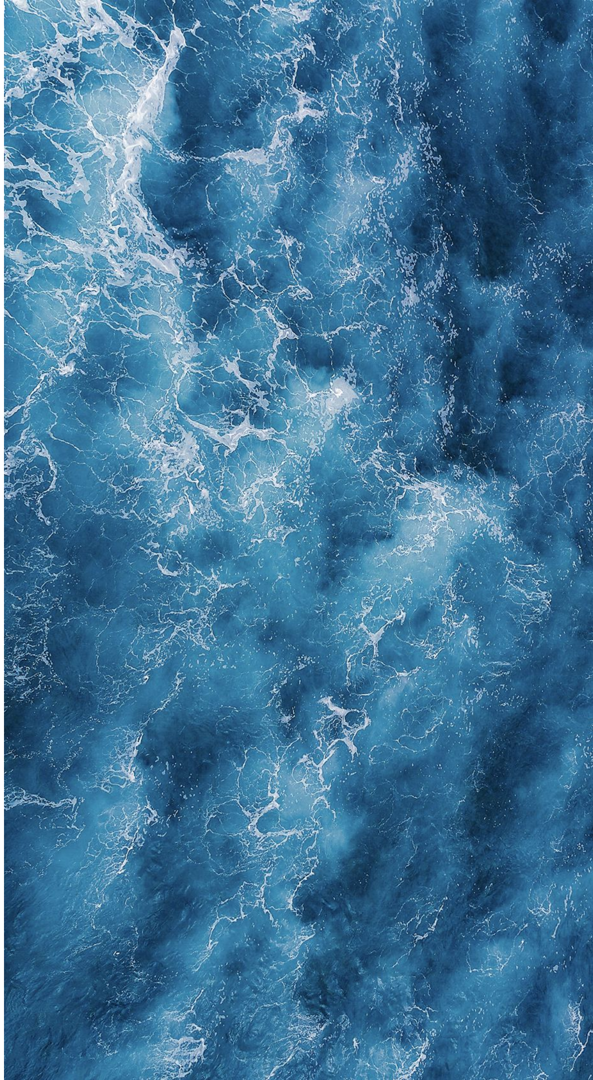
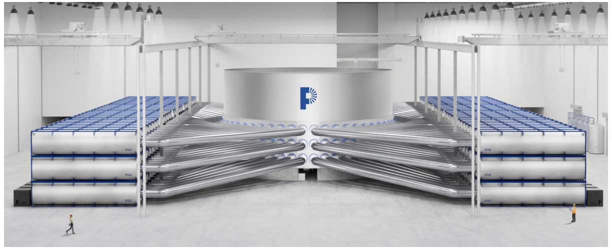
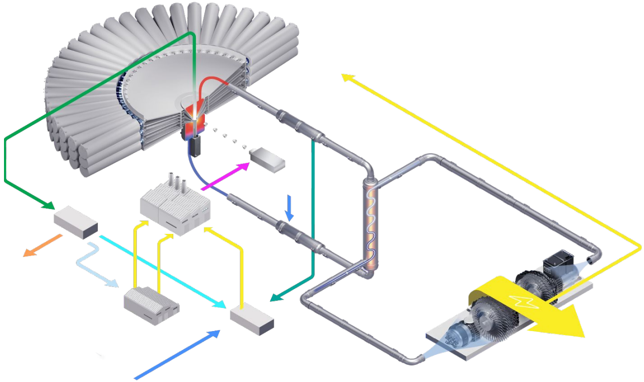
on behalf of the Pacific Fusion team

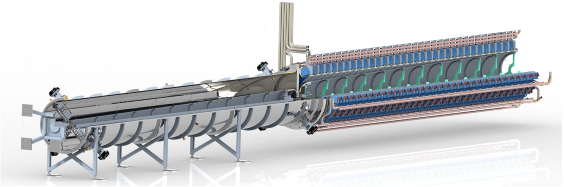
ARPA-E Fusion Programs, Denver CO 7/9/2025



What is Pacific Fusion doing with its Series A?







Building the Demonstration System. PF will be first to net facility gain and first to high yield (>100 MJ) fusion.

Driver technology, diagnostics, target design and fabrication, facility operations, etc

Designing the most affordable pulsed fusion power plant fleet to begin scaled deployment starting next decade

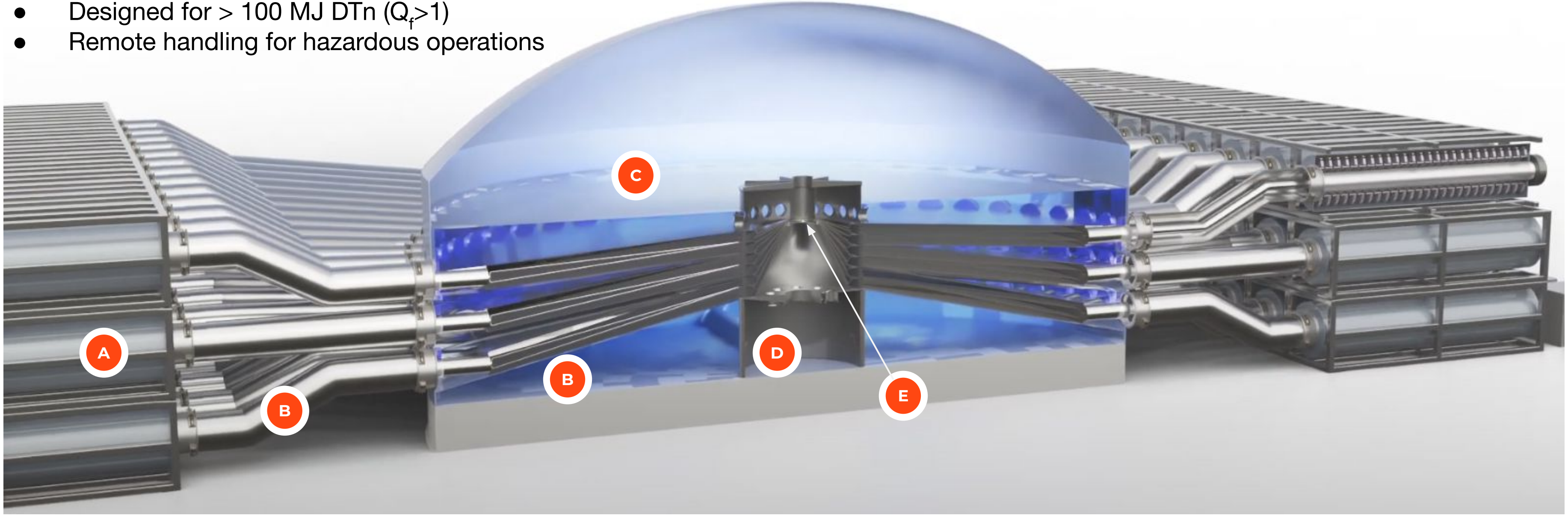
Repetitive firing, operations & maintenance, construction, regulatory, separations, balance of plant, etc

Developing additional applications and technologies that support both

Advanced manufacturing and fusion supply chain building, transportable radiation effects systems, pulsed power technologies

PF is building a fusion Demonstration System to achieve net facility gain

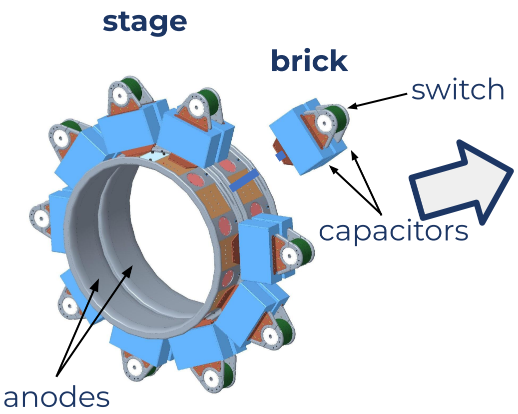
- 80 MJ stored energy
- >10 MJ coupled to target
- Flexible pulse shaping capabilities
- Designed for > 100 MJ DTn (Q_f>1)
- Remote handling for hazardous operations

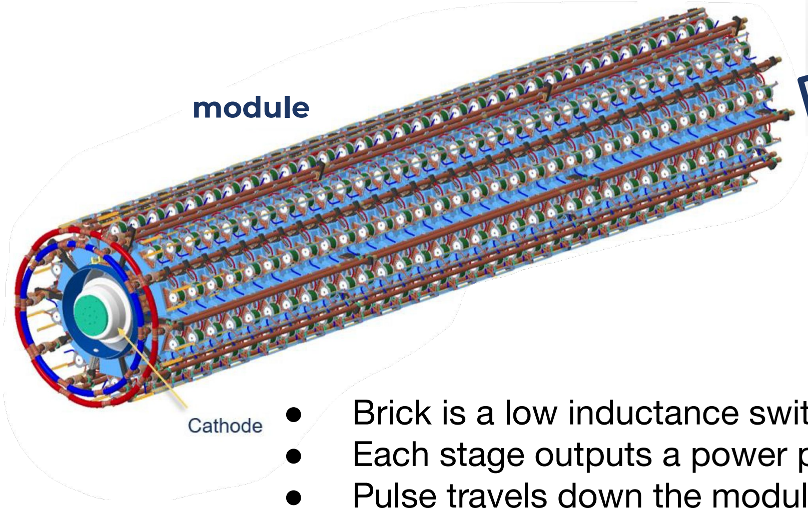


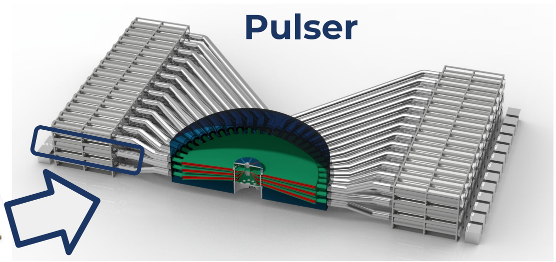
A Pulser module **B** Transmission line **C** Water Dome **D** Chamber **E** Target

PF’s Demonstration System is based on the Impedance-matched Marx Generator (IMG)[1]

1: W. Stygar et al., Phys. Rev. Acc. Beams 20, 040402 (2017)

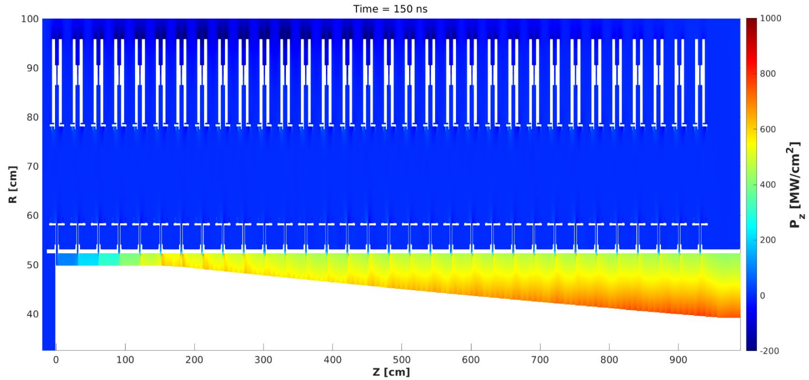


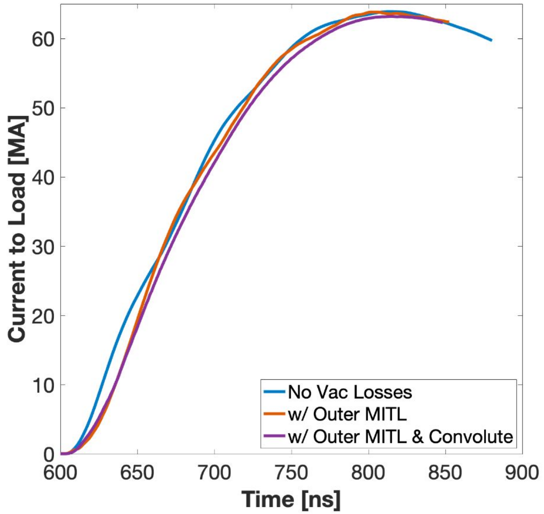




- Brick is a low inductance switch/cap configuration
- Each stage outputs a power pulse at the desired pulse length
- Pulse travels down the module, triggering the next stage
- No pulse sharpening needed
- Higher efficiency than traditional Marx generators (e.g. Z)
- Highly modular architecture enables operational flexibility

PF's DS system model combines transmission line circuits and 2D and 3D fully electromagnetic insulators and full vacuum plasmas





- Simulations have 1000+ circuit element circuit
- 2D/3D EM vacuum stack
- 3D plasma power flow at R < 1 m
- DS delivers >60 MA in a 4.5 nH inner MITL
  - ~80% of IMG power delivered to vacuum section
- Build waypoint: Half of DS towers delivers >45 MA (initial capability mid 2028)

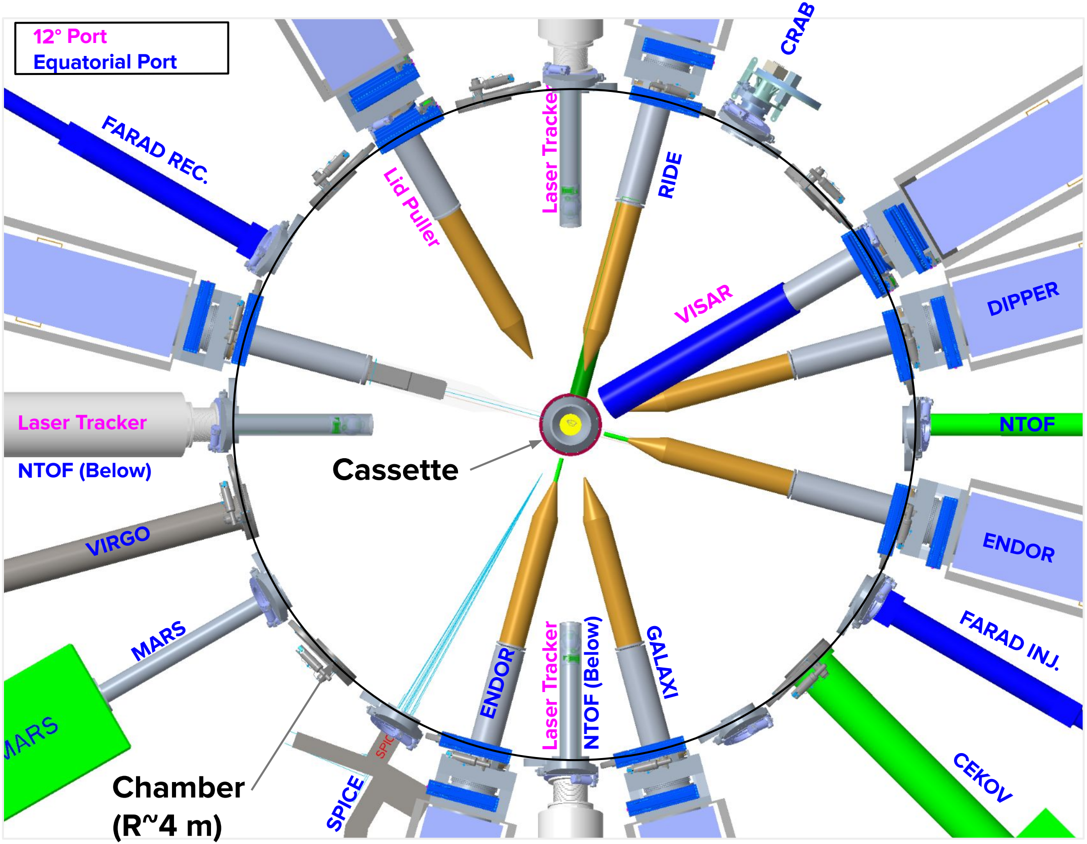
PF is developing a full range of diagnostic instruments to support DS experiments from commissioning to high yield (100+ MJ)

X-ray Imaging and radiography: GALAXI, DIPPER, VIRGO
X-ray power and energy: CRAB
X-ray Spectroscopy: SPICE
Neutron Spectra: nTOF (x3), MARS
Neutron Imaging: ENDOR (x2)
Burn History: RIDE, NGC, CEKOV
Optical: VISAR, PDV, FARAD

See AMPS paper for details

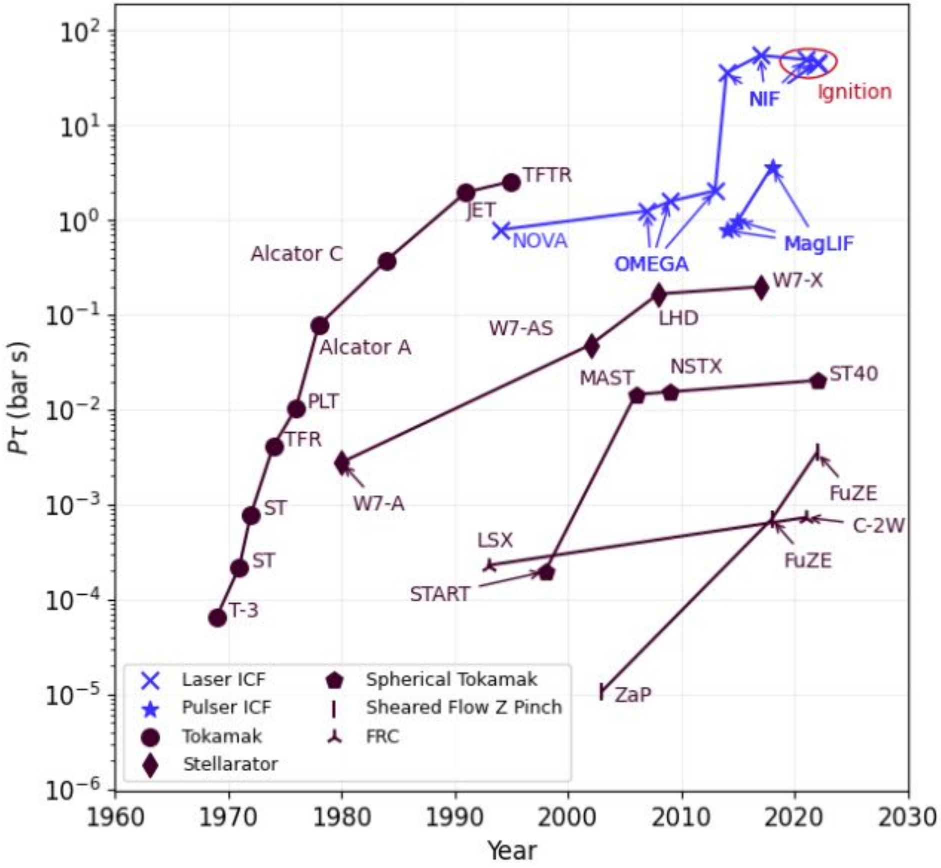
Target Cassette

- Remote insertion of precision target package
- Offline setup, metrology, vacuum prep, and cryogenics for target



PF's approach is Pulser IFE (MagLIF), which has demonstrated the second highest laboratory Pτ

- Pulser IFE is Inertial Fusion
- Pulser IFE has the advantages and benefits of ICF
  - Large flexible driver paired with small (~cm) flexible targets
  - Sound theoretical basis
  - A method to quantitatively measure proximity to ignition
  - ICF codes, institutions, and community
- Pulser IFE takes advantage of the high efficiency of the IMG
- Pulser IFE has favorable scaling paths to high yield



S. E. Wurzel and S. C. Hsu, *Phys. Plasmas* **29**, 062103 (2022), updated

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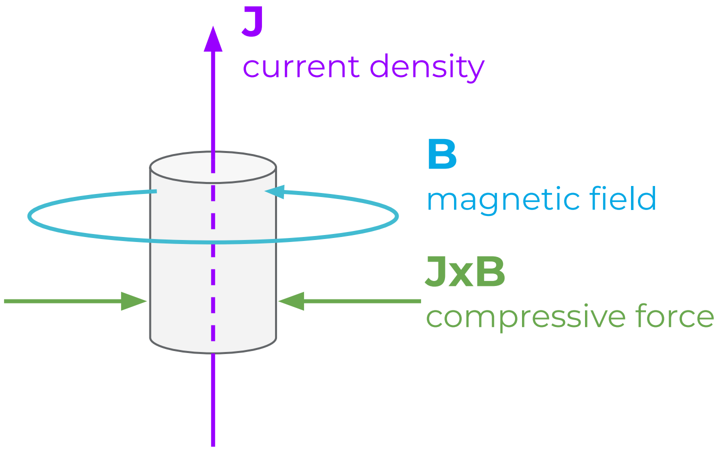
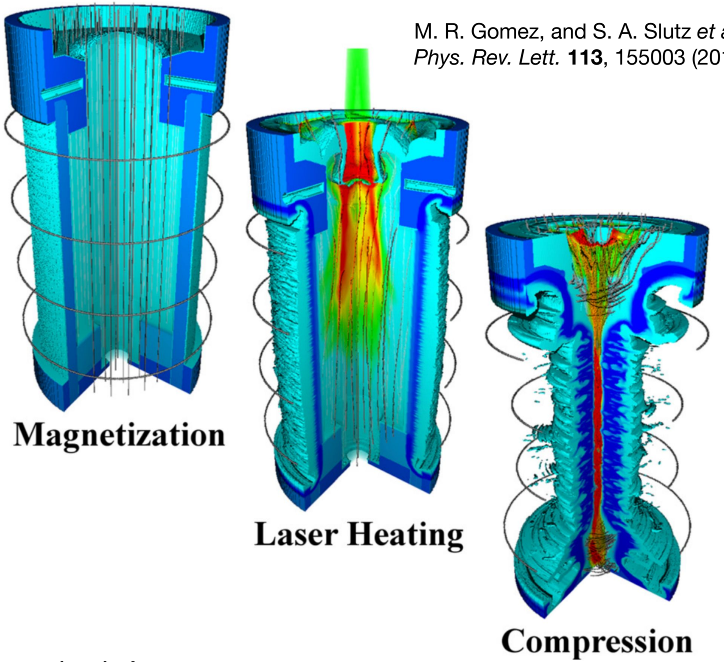


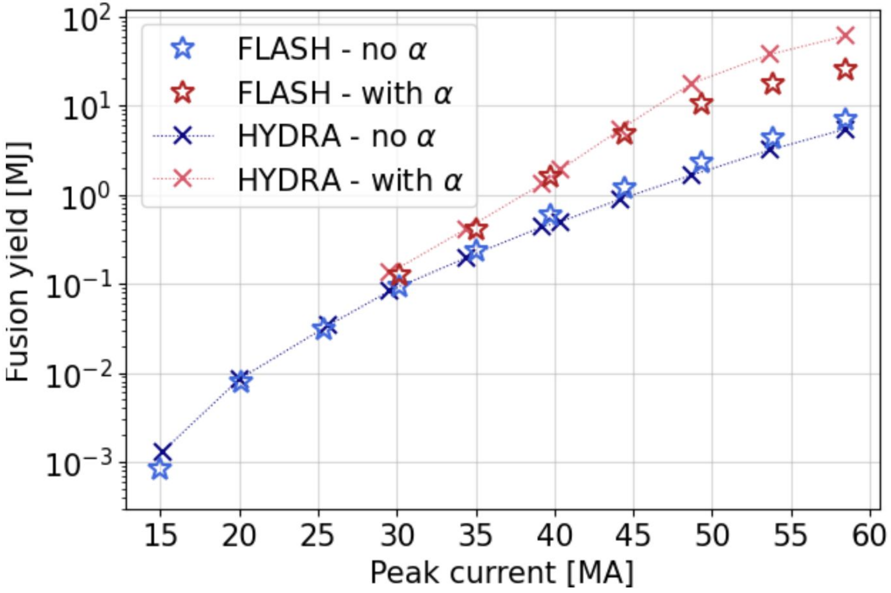


M. R. Gomez, and S. A. Slutz *et al.*, *Phys. Rev. Lett.* **113**, 155003 (2014)

- Implosion driven by magnetic forces
- Does not require maintaining an equilibrium
- At stagnation, magnetic forces are dwarfed by material pressure
- Target length scale ~ cm, time scale ~ 100 ns

PF is benchmarking target design capabilities against data and published laboratory rad-hydro MHD simulations

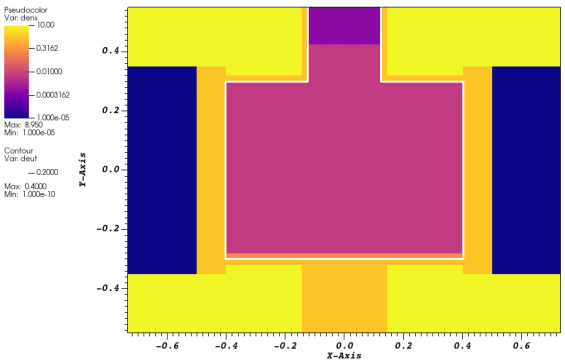
MagLIF Similarity Scaling from [Ruiz et al 2023]

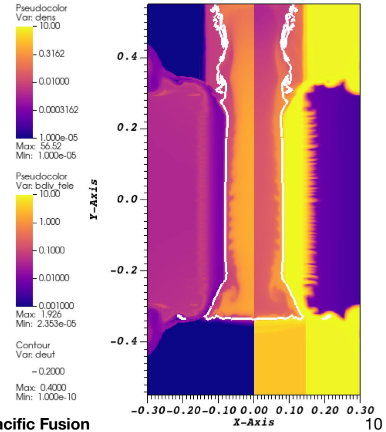


- FLASH is a 3D, multispecies, Eulerian AMR code with multigroup radiation diffusion and MHD
- FLASH is widely available, DOE/NNSA-funded, and used by >4000 researchers worldwide
- PF is co-developing FLASH with the Flash Center at the University of Rochester
- PF has validated FLASH against Z data and simulations:
    - Hydro instabilities (MRT, RM)
    - MagLIF experiments
    - Similarity scaling magLIF to 60 MA
- Validation shows excellent agreement with data and state-of-the-art ICF design codes.
    - [FLASH Validation Manuscript]

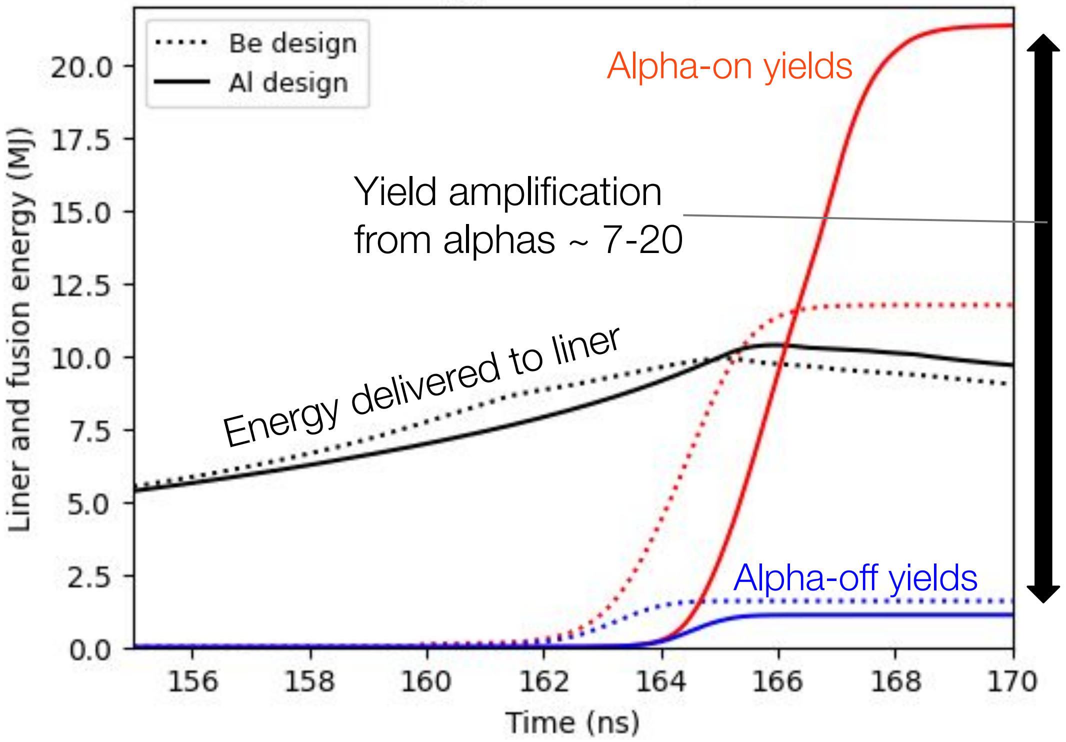
PF is using FLASH to design for ignition and high gain on the DS

2D MagLIF target in FLASH

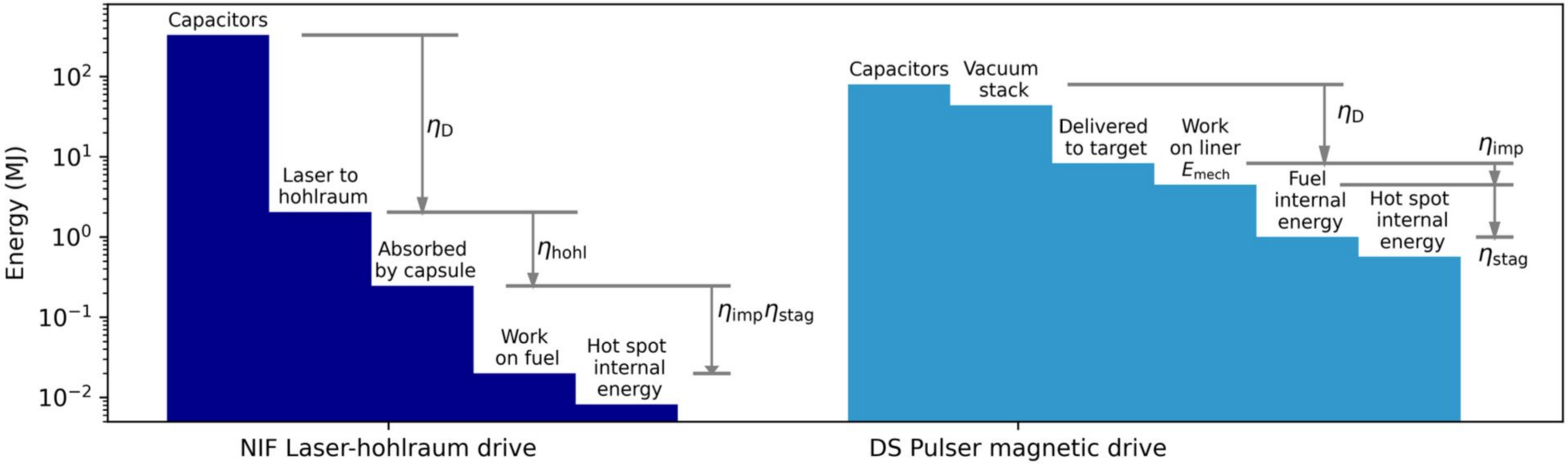




2D MagLIF FLASH results

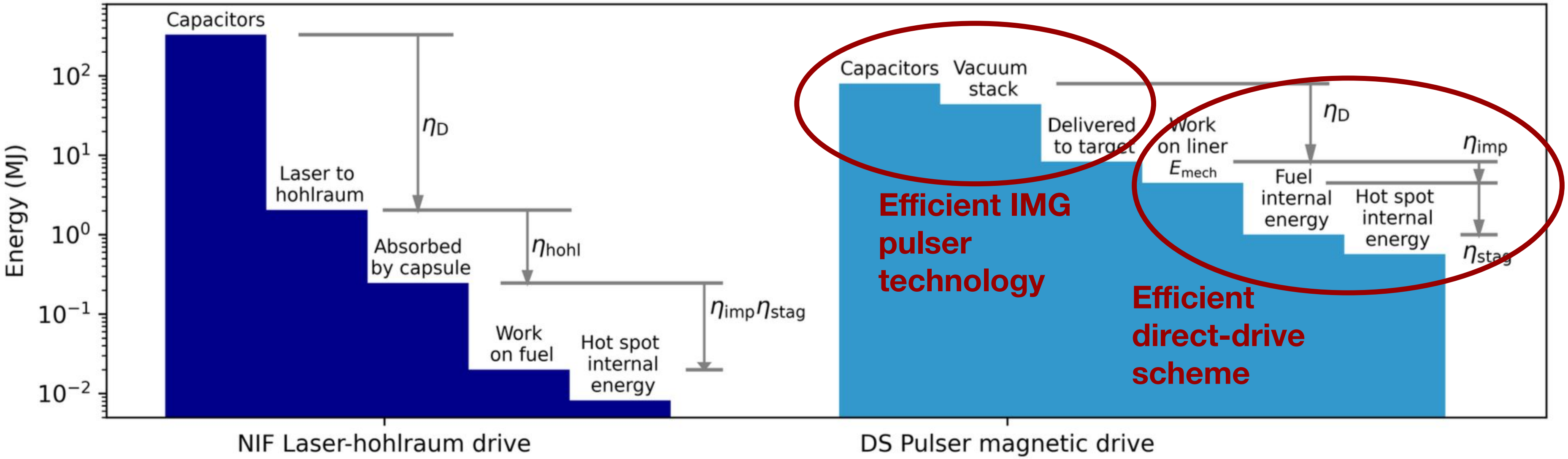


PF's IMG pulser + direct-drive IFE (MagLIF) is efficient and energy rich



At ~60 MA, PF's DS can deliver > 8 MJ to the target and ~ 1 MJ to the DT fuel

PF's IMG pulser + direct-drive IFE (MagLIF) is efficient and energy rich



PF's pulser IFE approach is efficient, low cost, and high tempo

Facility gain can be achieved for pulser ICF with NIF-ignition-like fuel gain and burn-up fraction

Consider a 6 mm-tall MagLIF-like design with 300 micron DT ice shell driven at $I_{max} \approx 60$ MA:

Metric	NIF Ignition	Be DS target	Al DS target
Energy stored in capacitors	330 MJ	80 MJ	80 MJ
Energy delivered to target	2.2 MJ	8.3 MJ	8.4 MJ
DT fuel mass	0.22 mg	$\approx$ 10.6 mg	$\approx$ 10.2 mg
Nuclear energy yield	5.2 MJ	109 MJ	380 MJ
$Q_{target} = Y_{TN} / E_{driver}$	$\approx$ 2.4	$\approx$ 13	$\approx$ 45
$Q_{fuel} = Y_{TN} / E_{int,DT}$	$\approx$ 260	$\approx$100	$\approx$350
DT burn-up fraction ϕ	7 %	3 %	10 %
Facility gain Q_f	0.016	1.36	4.75

* A. L. Kritcher *et al.*, *Phys. Rev. E* 109, 025204 (2024)
estimated from 8.2 kJ @ 2.0 MJ laser energy

NIF numbers should be revised upward based on shot generating 8.6 MJ from 2.08 MJ laser energy