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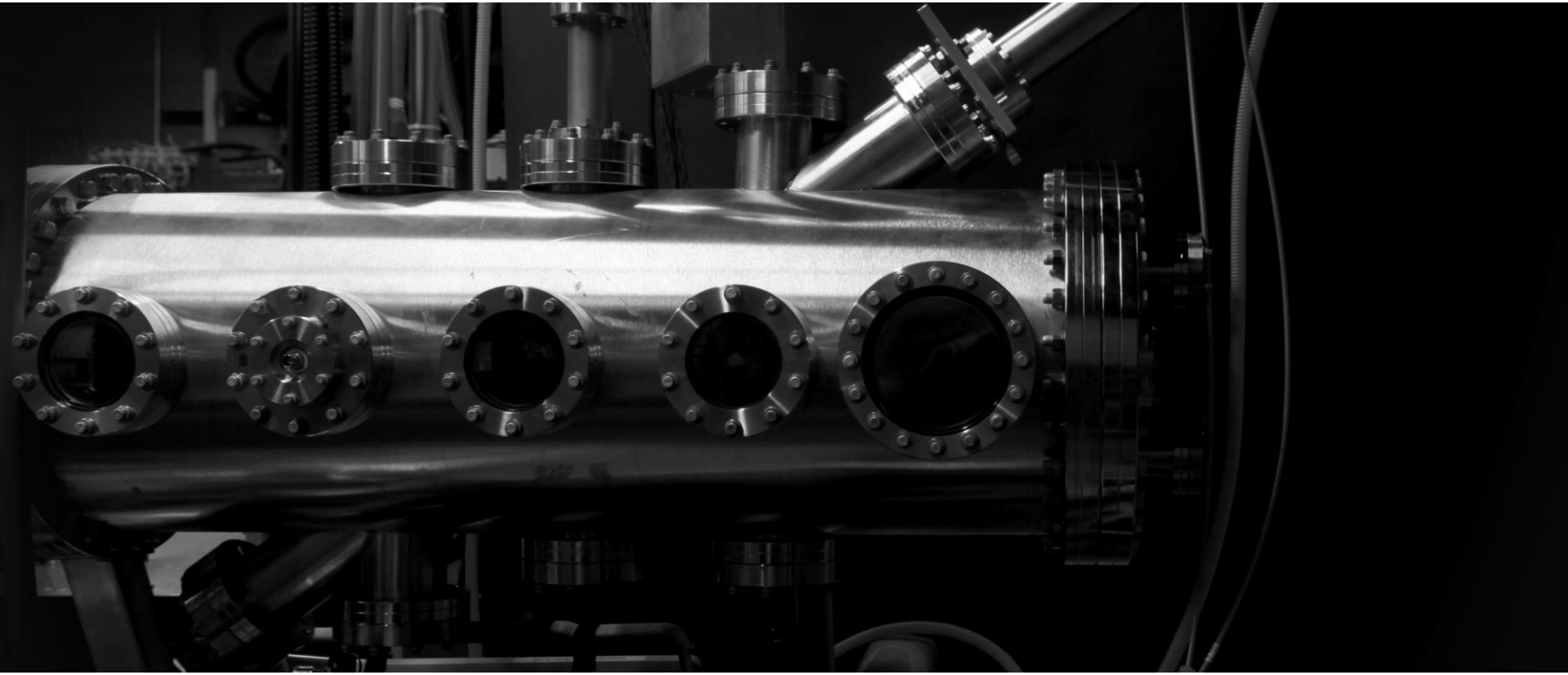
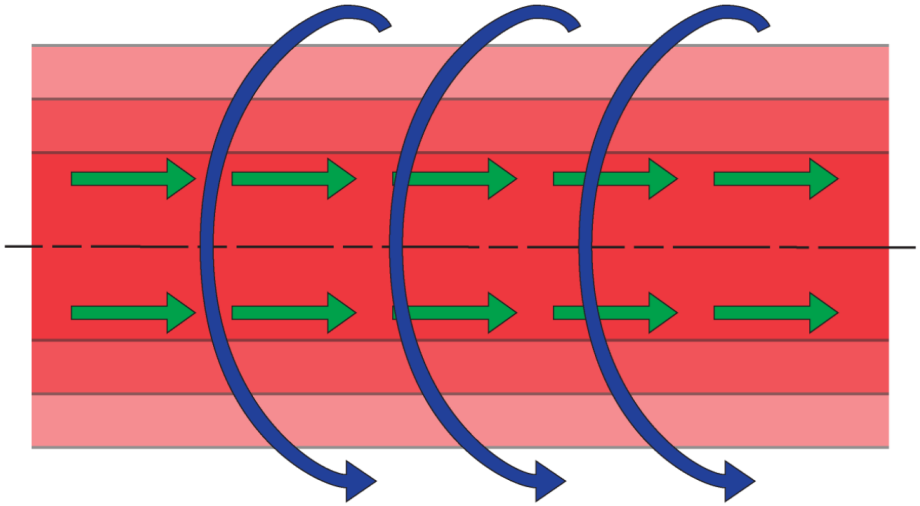
SHEARED-FLOW STABILIZED (SFS) Z-PINCH REACTOR CONCEPT



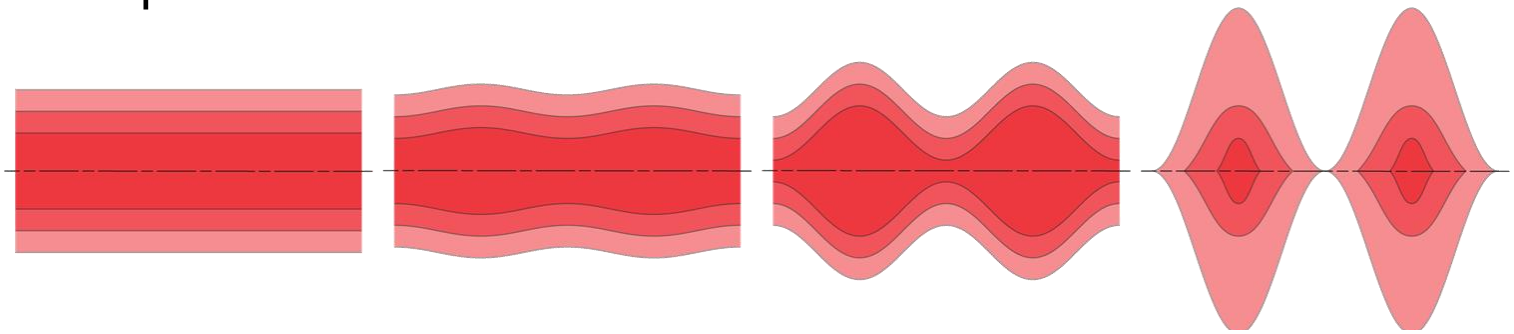
FPA ANNUAL MEETING – 16 DECEMBER 2020
BRIAN A. NELSON, CTO, http://zap.energy

SFS Z pinch: Stability *via* Sheared Flow

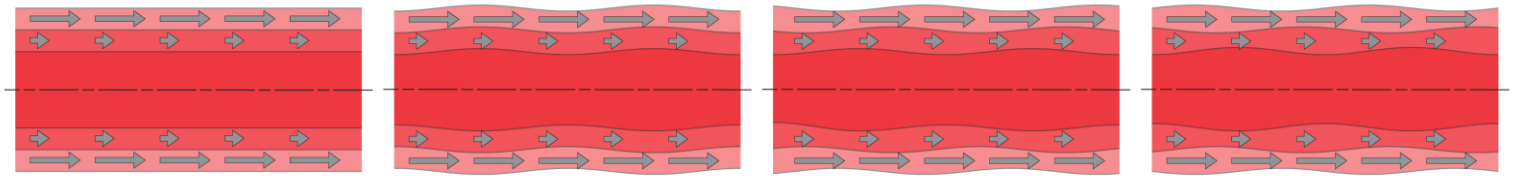
- Z pinch
  - Axial current (“z” direction)
  - Azimuthal magnetic field
  - Field compresses plasma
- Radial shear in axial flow stabilizes the Z pinch



No flow



Sheared flow



$$\frac{dv_z}{dr} \neq 0$$

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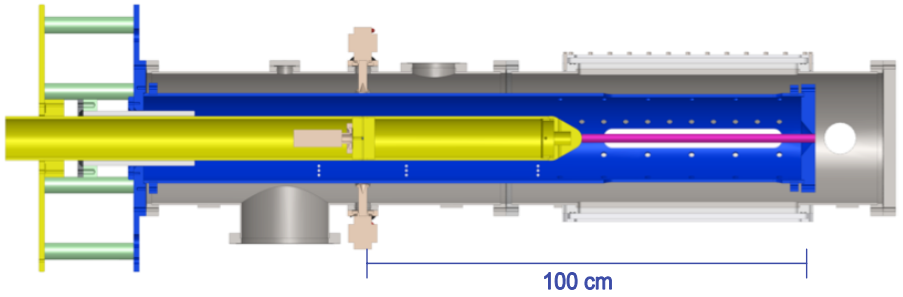
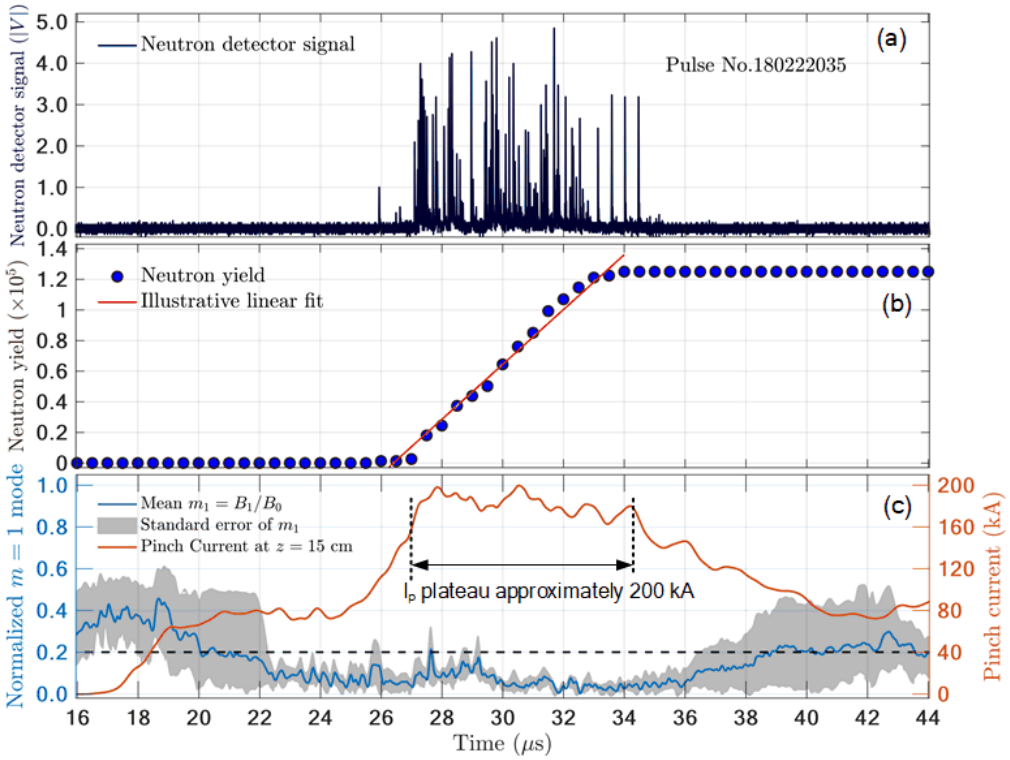
FuZE Demonstrates Sustained Neutron Production

- ARPA-E ALPHA supported project UW & LLNL
- Neutron production for ~10 us, thousands of MHD growth times (Zhang *et al.*, PRL 2019)
- Neutron spectra consistent with thermonuclear production; any D beam < 7.5 keV (Mitrani *in preparation*)
- Over 400 kA pinch current averaged over a flow time
- Results are guiding next steps and reactor development





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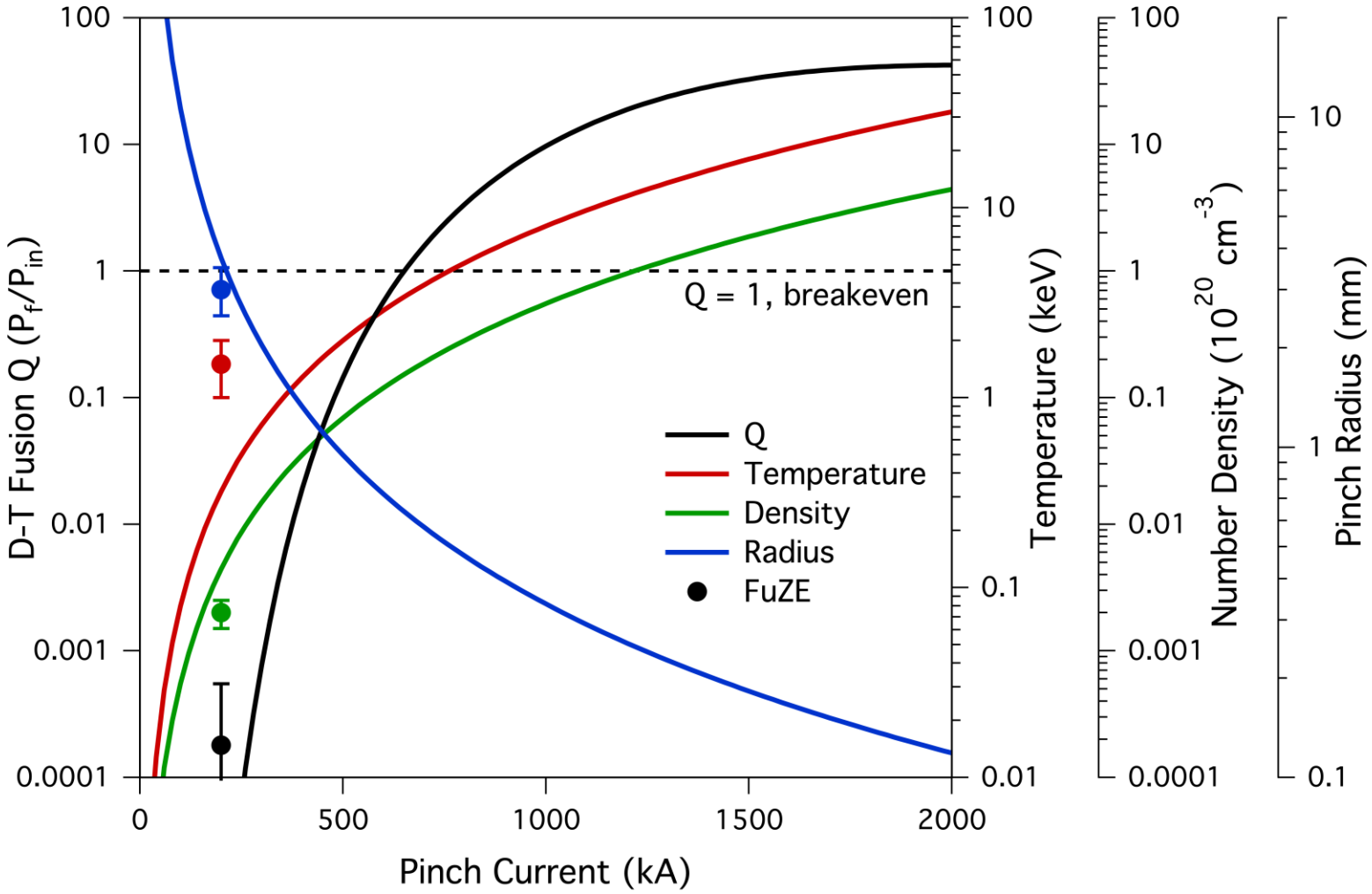
Development Path for the SFS Z-pinch Fusion Core

Increase in plasma current is the key step along the development path for the SFS Z-pinch fusion core.



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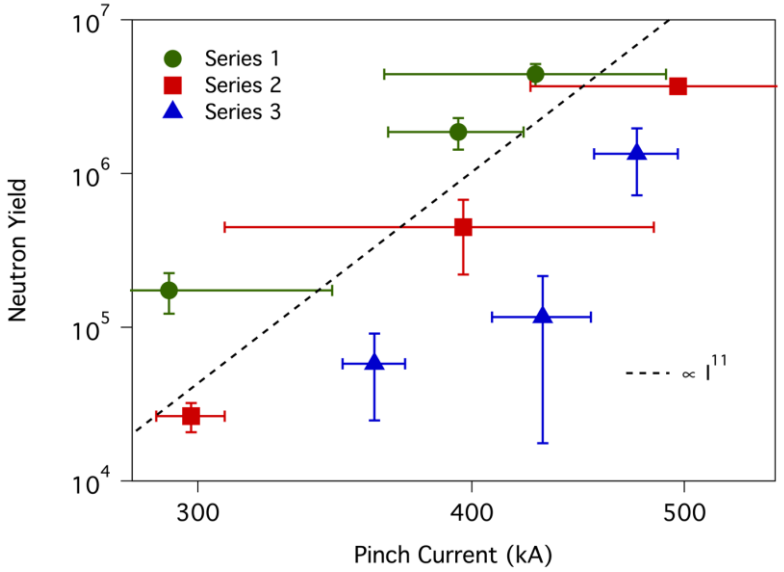
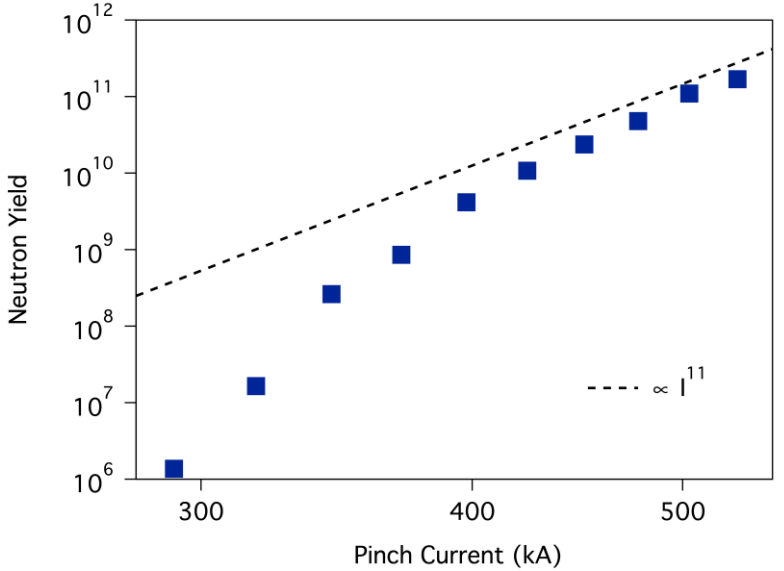
Zap Energy's Next SFS Z Pinch: FuZE-Q

- ARPA-E OPEN, BETHE, & Series A
- Increasing current to over 600 kA
- Further improvement of fusion triple product and neutron yield*

$$n\,kT\,\tau \propto I^5 \quad \text{and} \quad Y_n \propto I^{11}$$

- $Y_n \propto I^{11}$ observed in 0-D scaling, experimental and computational results
- Improved diagnostics for higher performance SFS Z pinches
  - Increased resolution for smaller pinches at high current
  - Working with ARPA-E Diagnostic Teams
- High-fidelity modeling and validation with experimental results
  - PMI, electrode durability, improved operational domains, *etc.*





*Shumlak *JoAP* 2020

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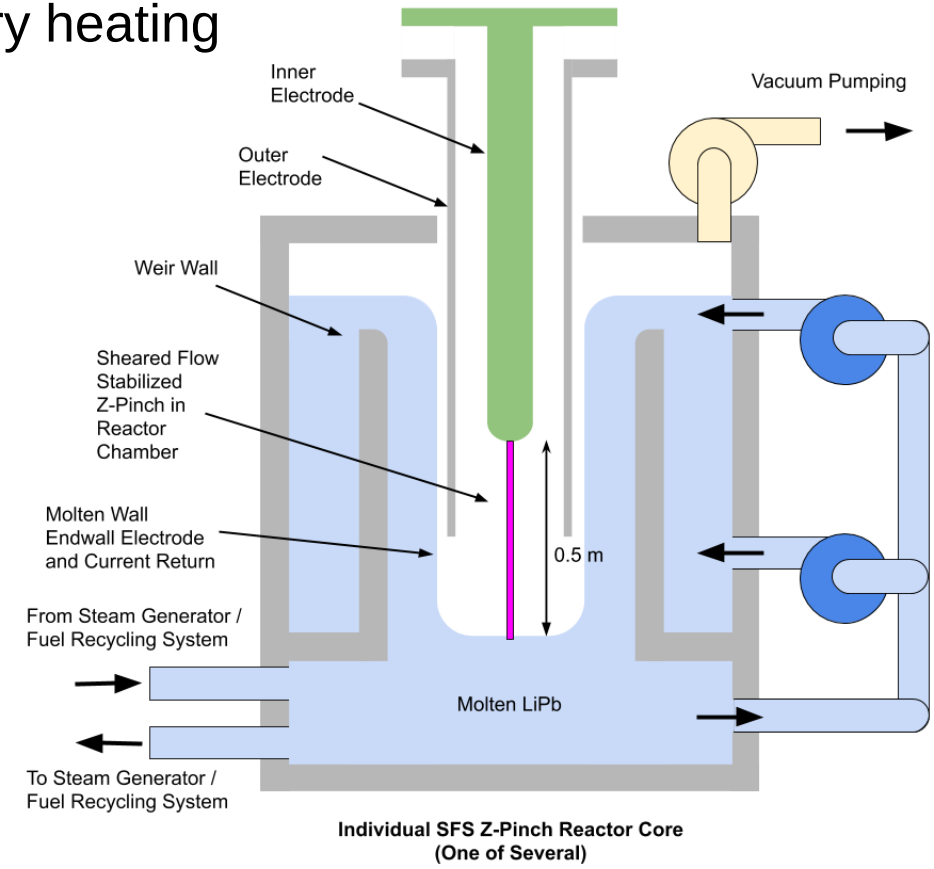
Zap Energy Reactor: Liquid LiPb Outer Wall

- No magnetic field coils nor auxiliary heating
- Liquid LiPb outer wall
  - Return electrode
  - Heat-transfer fluid
  - Tritium breeding
  - Biological shield
- Pulses several times per second
  - ~200 MWth per core
- Multiple fusion cores in plant
  - Aids maintenance
  - Common tritium-handling facility
  - Can vary generating capacity to match demand



Individual SFS Z-Pinch Reactor Core (One of Several)

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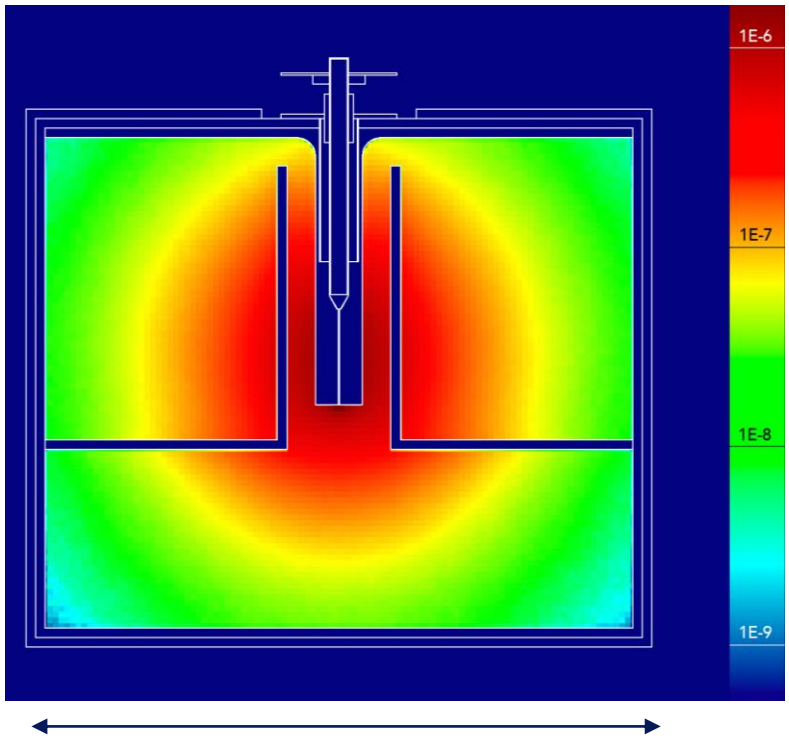
3-m LiPb Blanket Yields TBR~1.1

- Limited number of components in direct line of D-T neutrons
- TBR ~ 1.1 w/eutectic LiPb & natural 6-Li enrichment
- Bootstrap from D-D to 50-50 D-T in about 1 month
- Refining pilot plant development and reactor design

Tritium Breeding Ratio (TBR) ~ 1.1
(from MCNP)



~3 m (10 ft)

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Summary

http://zap.energy

- A radial shear in the axial flow stabilizes the Z-pinch
- FuZE has demonstrated sheared-flow stabilized (SFS) Z-pinches:
  - SFS Z-pinch lifetimes 10,000x the static-pinch MHD growth time
  - D-D neutron production $Y_n \propto I^{11}$ & consistent w/thermonuclear production
  - Over 400 kA pinch current, averaged over the flow-through time
  - n kT $\tau \sim 10^{17}$ keV s m^{-3}
- FuZE-Q underway to push to over 600 kA pinch current (~breakeven)
- SFS Z-pinch reactor concept is compact: ~3-m cylinder, no coils
  - LiPb walls
  - TBR ~ 1.1; D-D to 50-50 D-T bootstrap in ~ 1 month
  - Modular 200-MWth cores
- Pilot plant and reactor design under development

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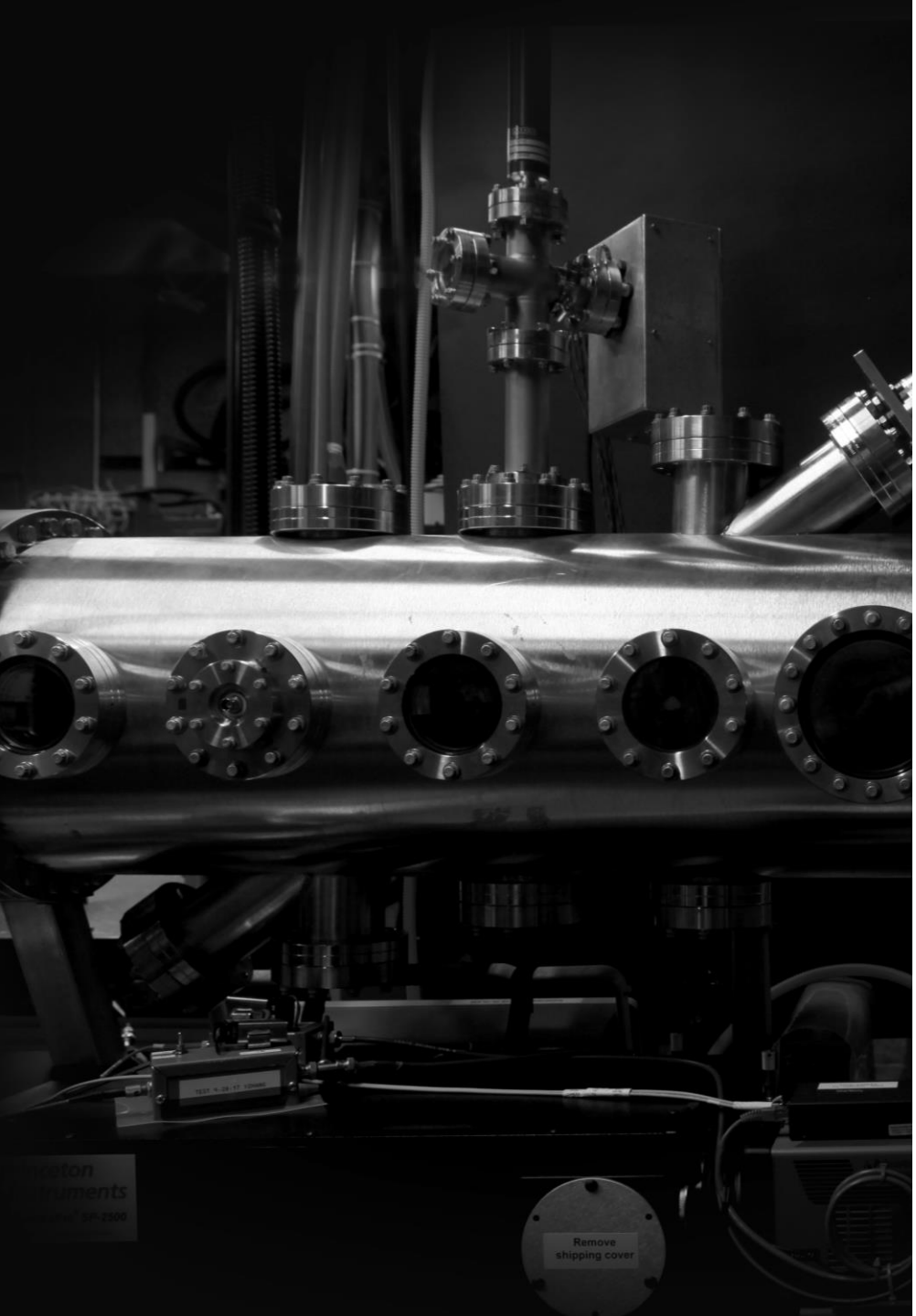

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