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Understanding The Impact Of Applied Magnetic Fields On Z Machine Current Coupling

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Z machine generates ~20 MA current pulse

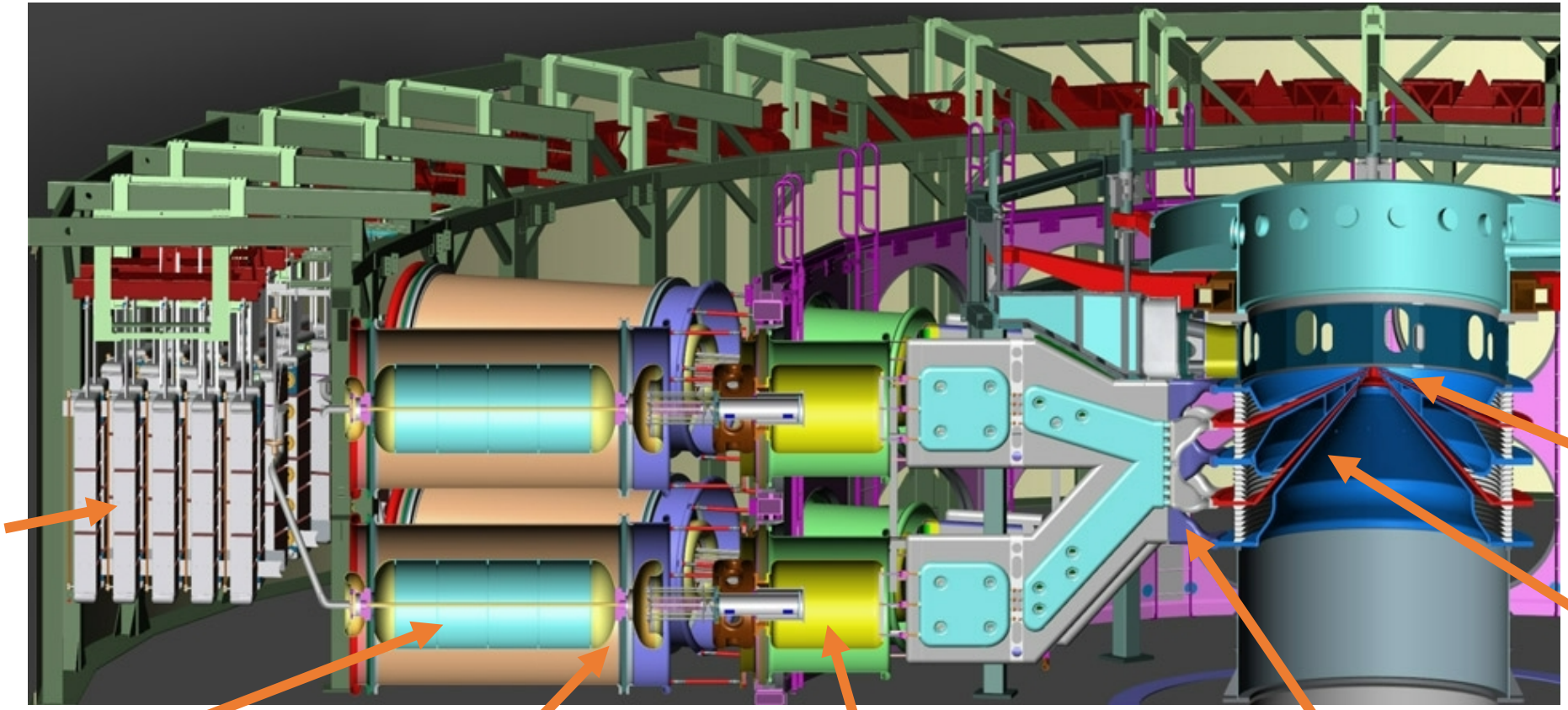

Image: https://www.sandia.gov/z-machine/about_z/how-z-works.html

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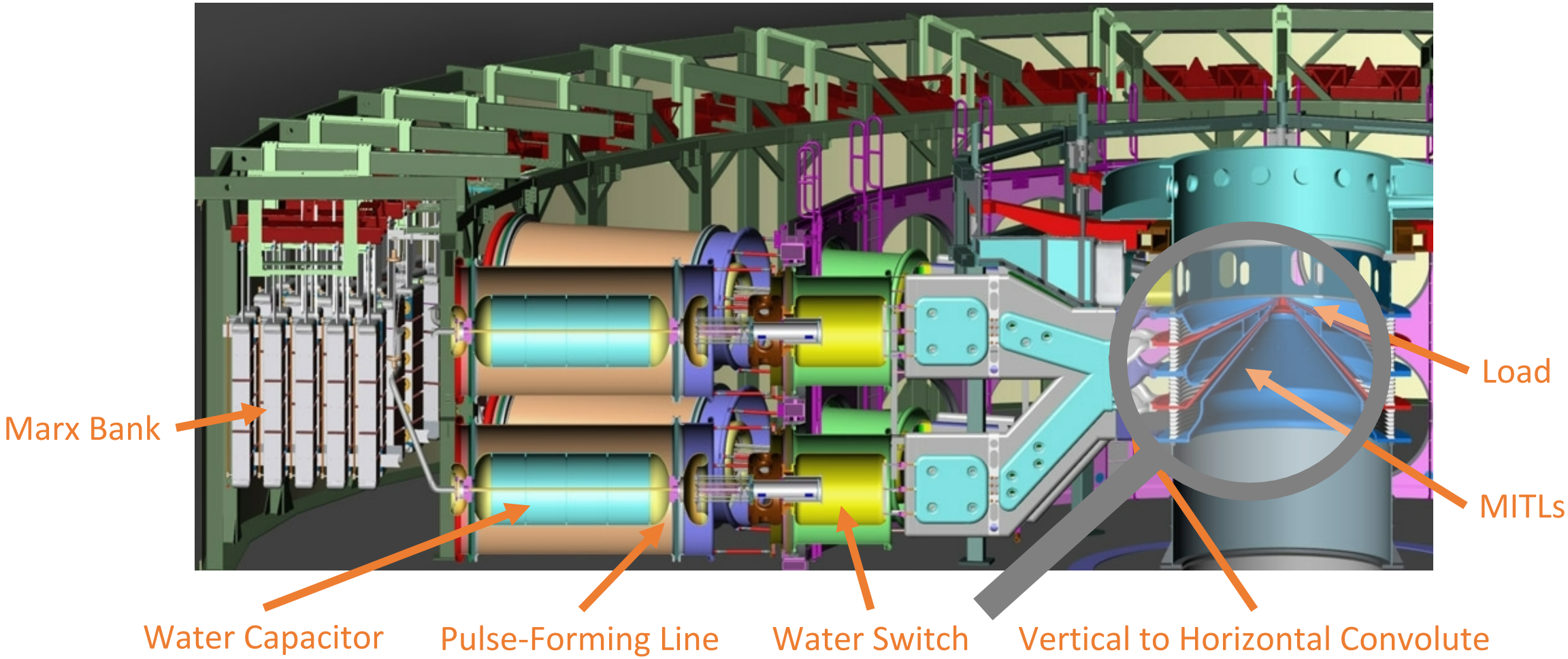

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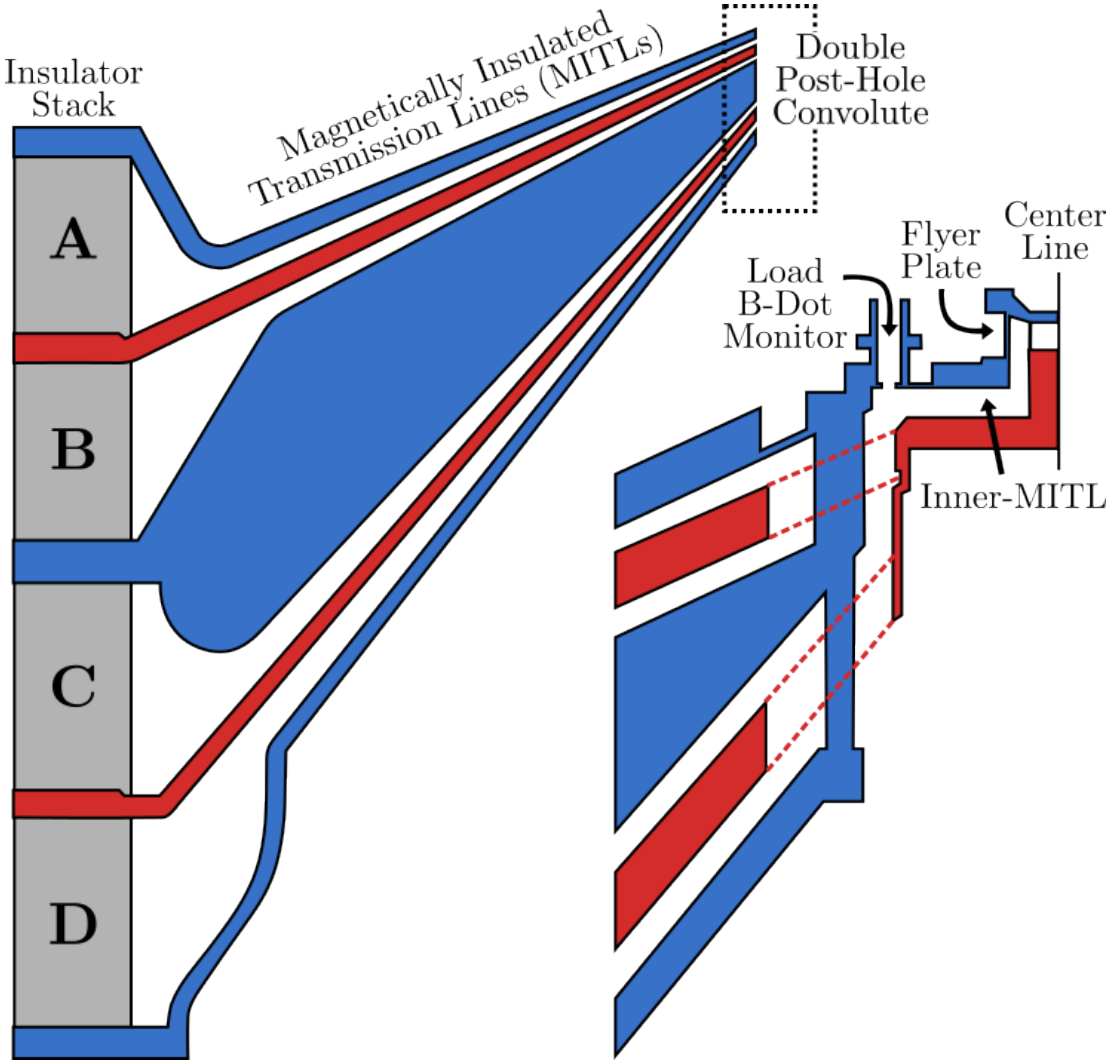
Multi-MA current losses occur near the load



CURRENT

Magnetically Insulated Transmission Lines (MITLs)

↓

Convolute

↓

Inner-MITL

↓

Load

Four transmission lines insulated by the J x B force

Combines current from four into one transmission line

Final transmission line

Wire array, MagLIF, etc.

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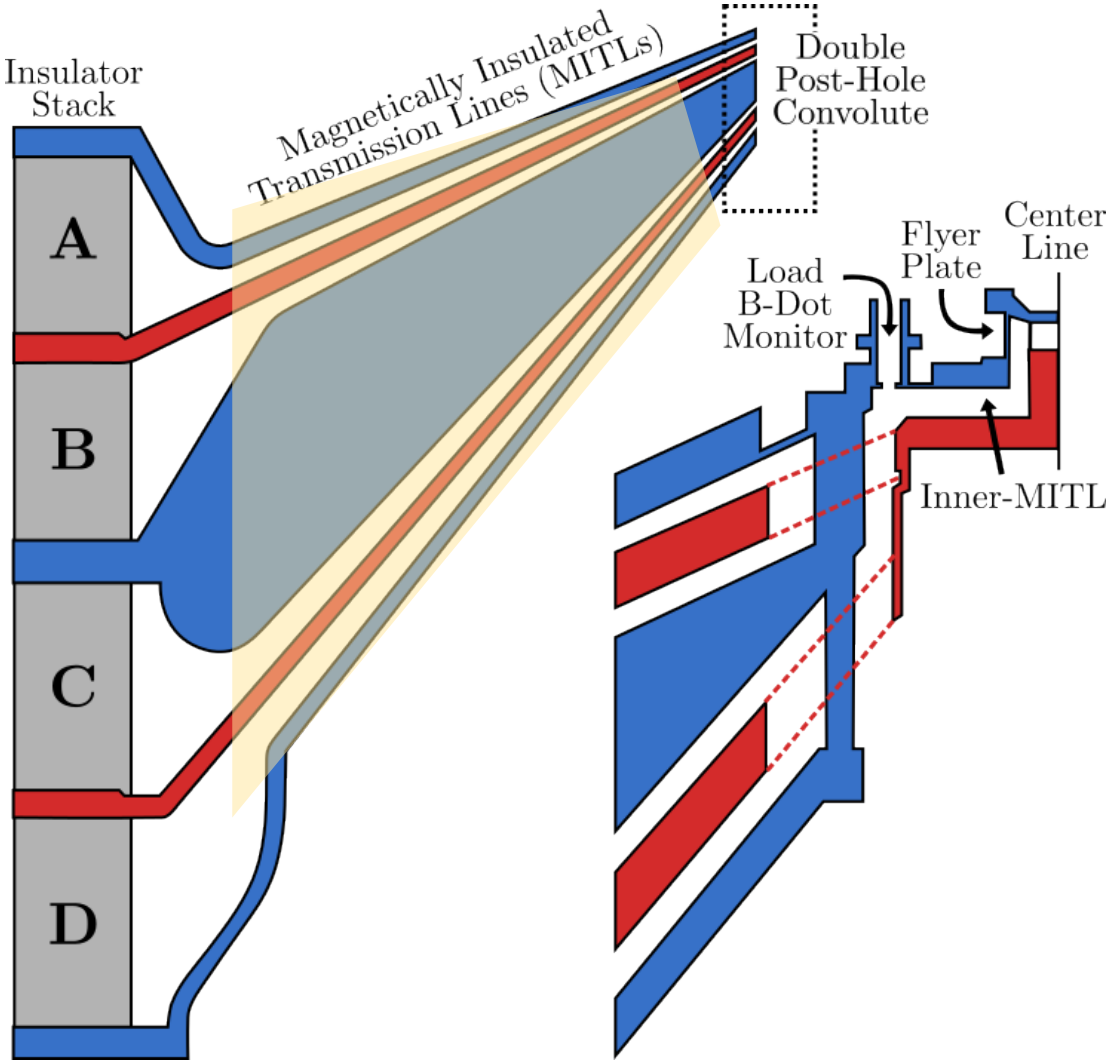

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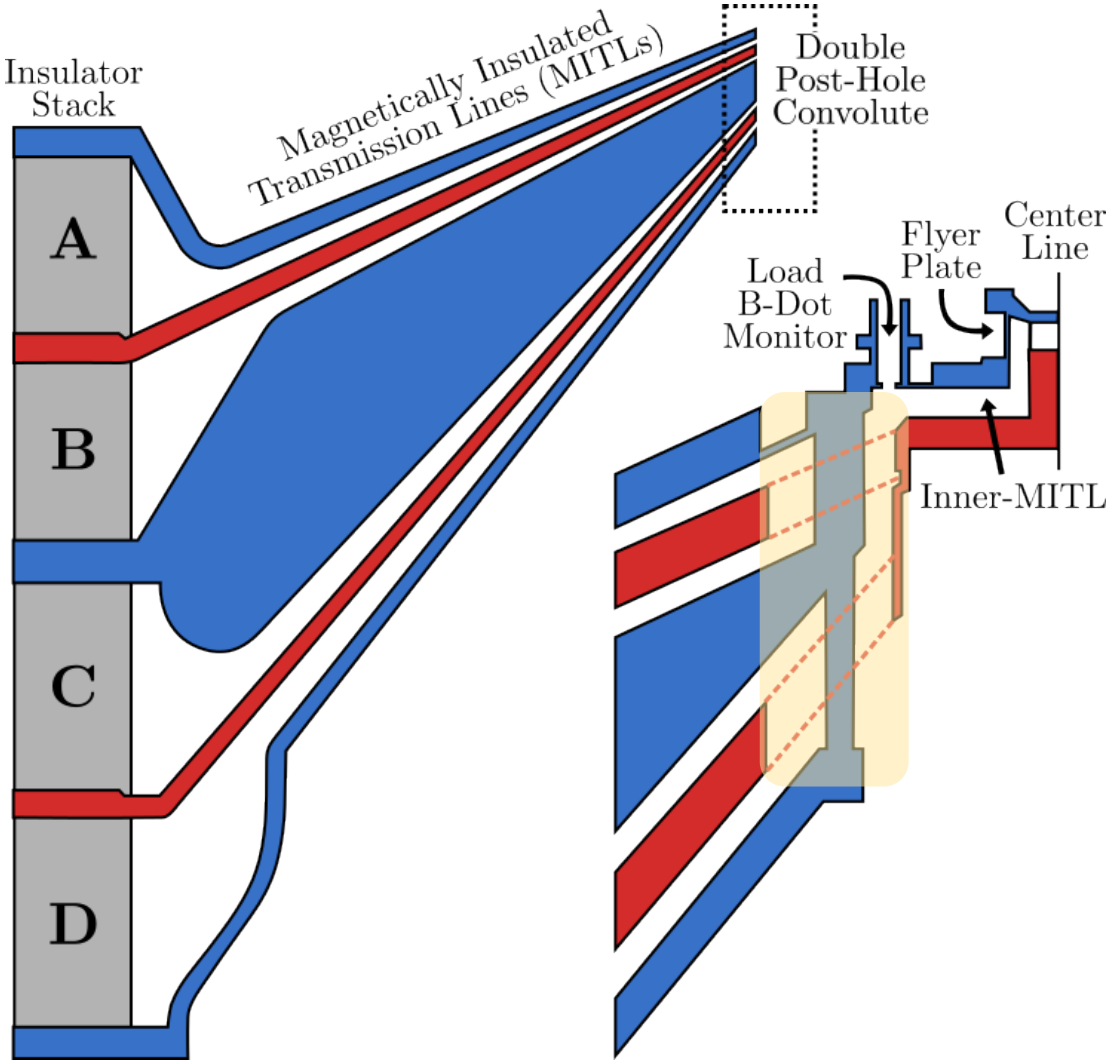

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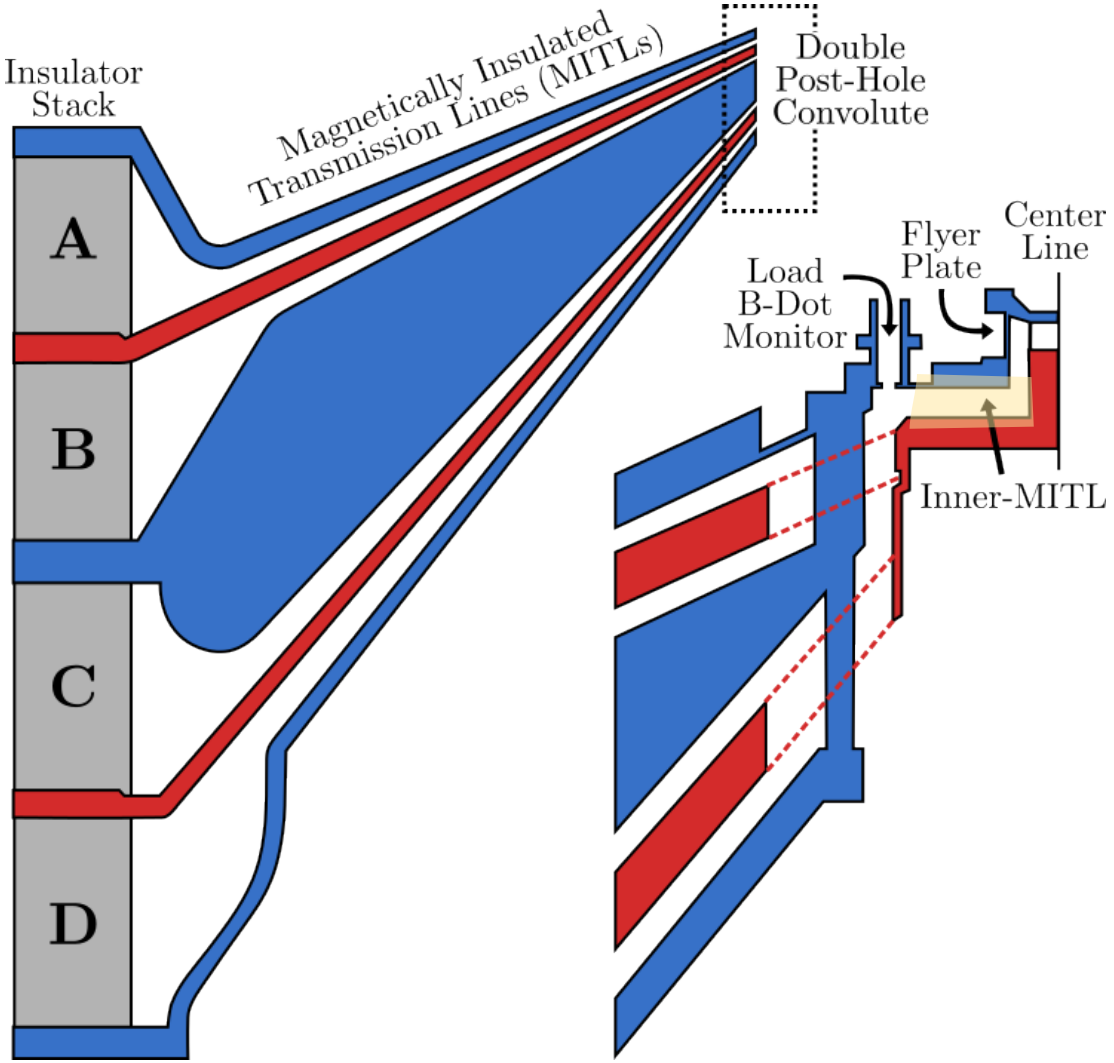

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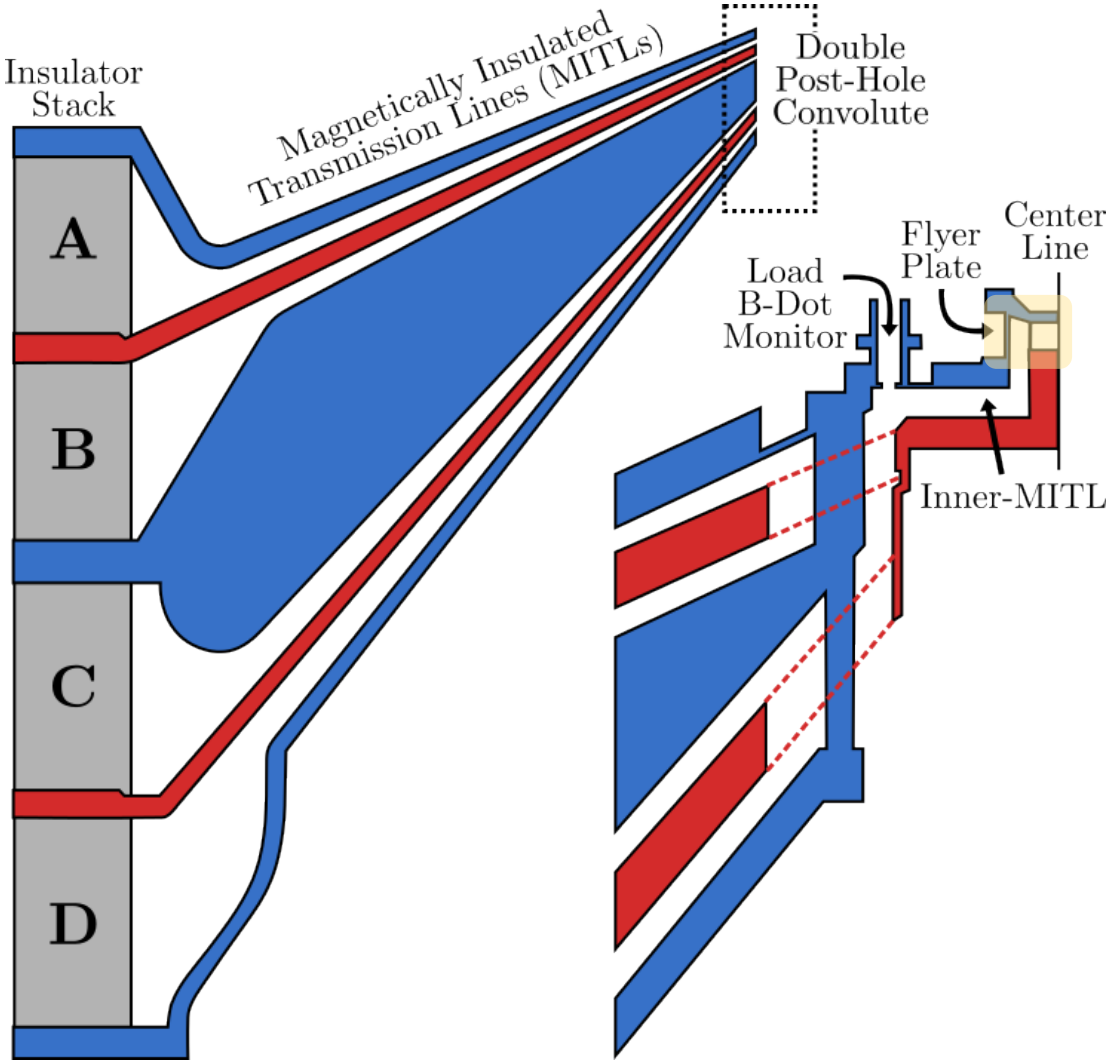

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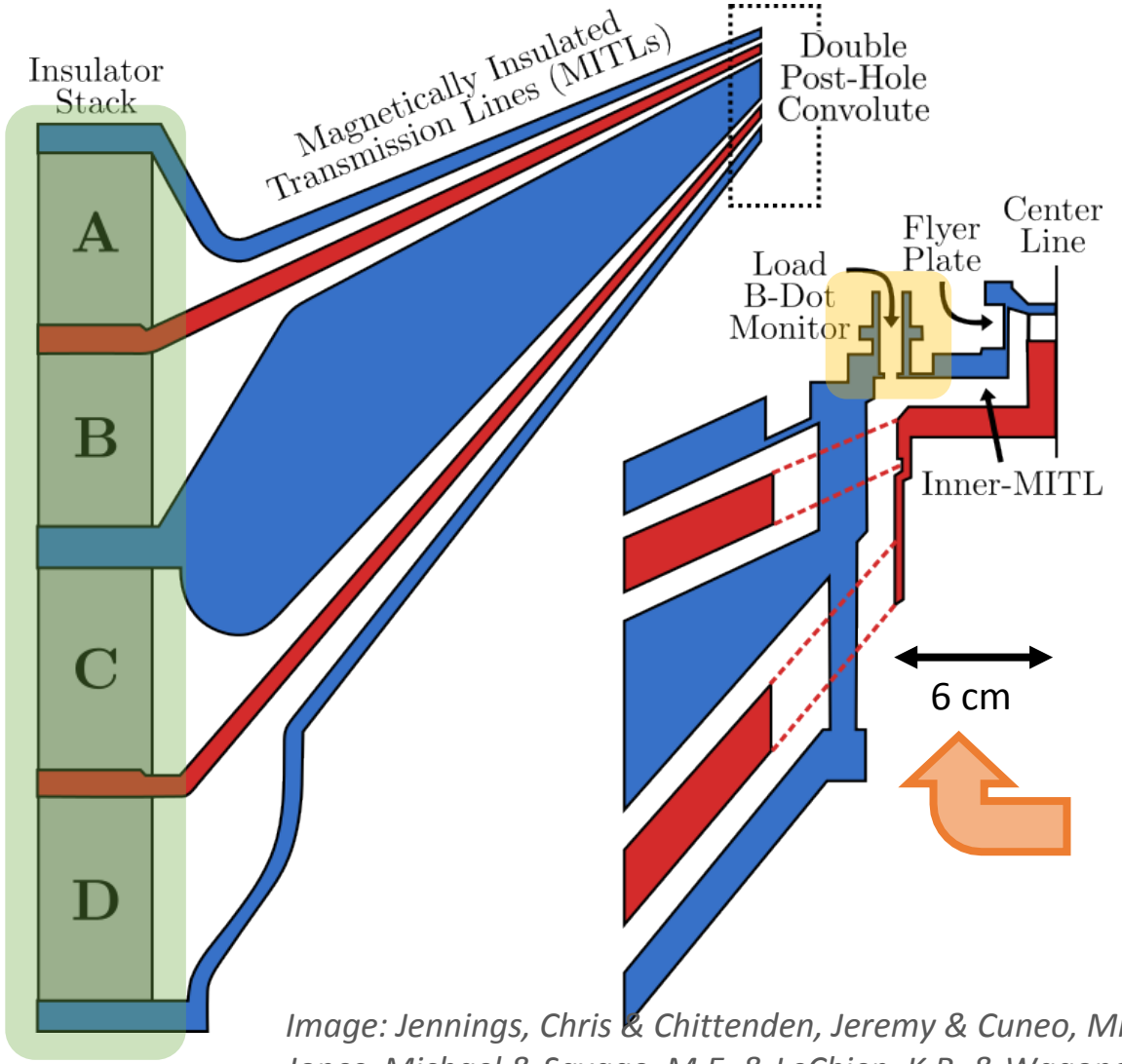
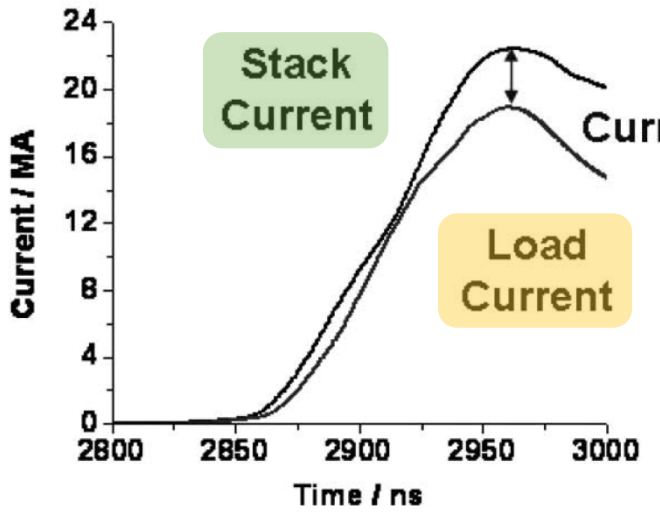




B-Dot Measure-ments

Previous work focused on current loss due to <u>plasma formation in the convolute</u>.

Image: Jennings, Chris & Chittenden, Jeremy & Cuneo, Michael & Stygar, W.A. & Ampleford, David & Waisman, Eduardo & Jones, Michael & Savage, M.E. & LeChien, K.R. & Wagoner, T.C.. (2010). Circuit Model for Driving Three-Dimensional Resistive MHD Wire Array Z-Pinch Calculations. Plasma Science, IEEE Transactions on. 38. 529 - 539. 10.1109/TPS.2010.2042971.

Mag*netized* ***L****iner* ***I****nertial* ***F****usion (MagLIF)*

Experimental fusion concept:

- Load region magnetized up to 30 T
- Preionization via laser heating
- Cylindrical, fuel-filled metal liner imploded

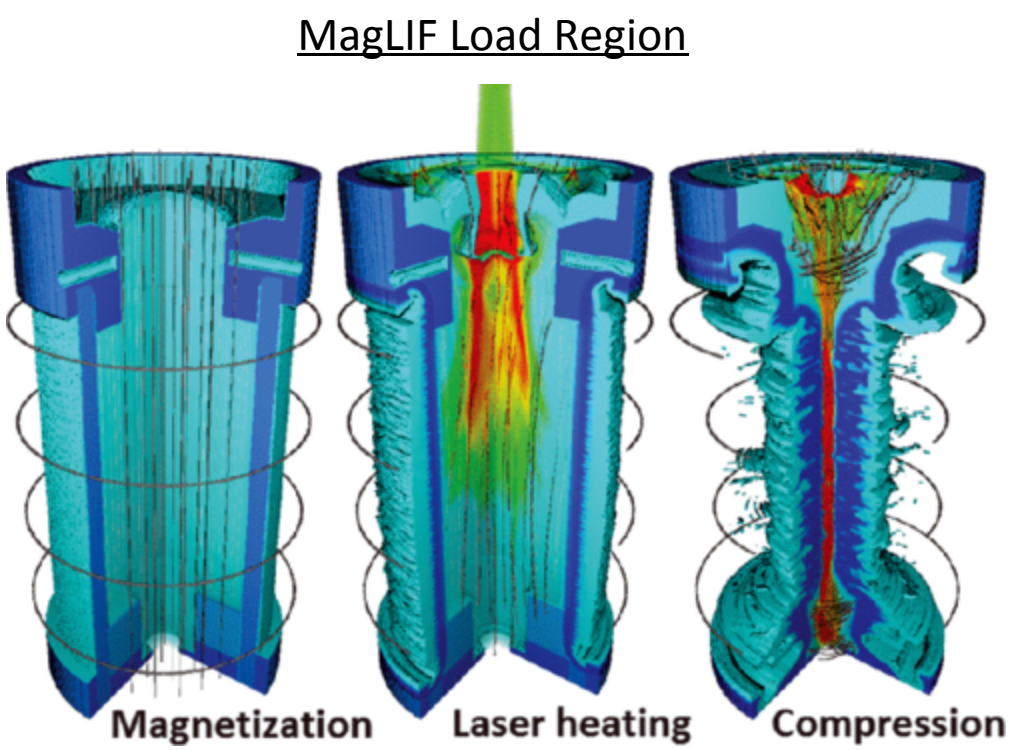
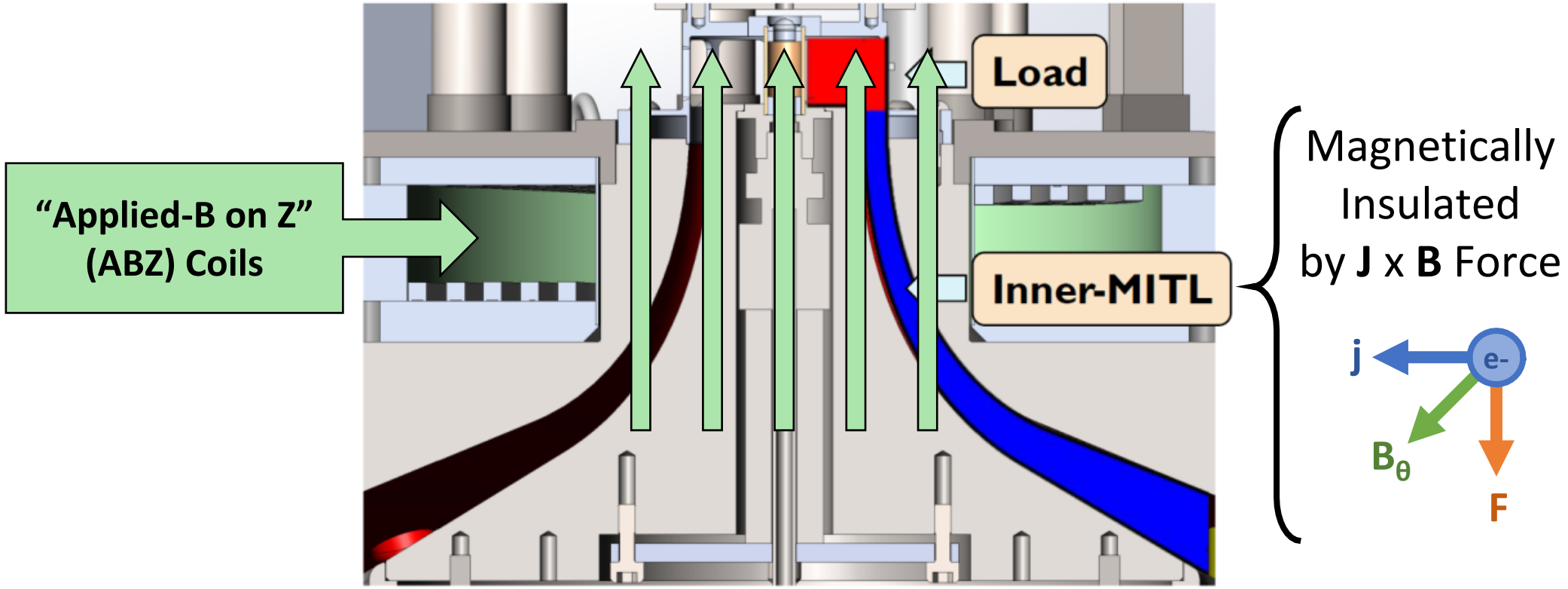


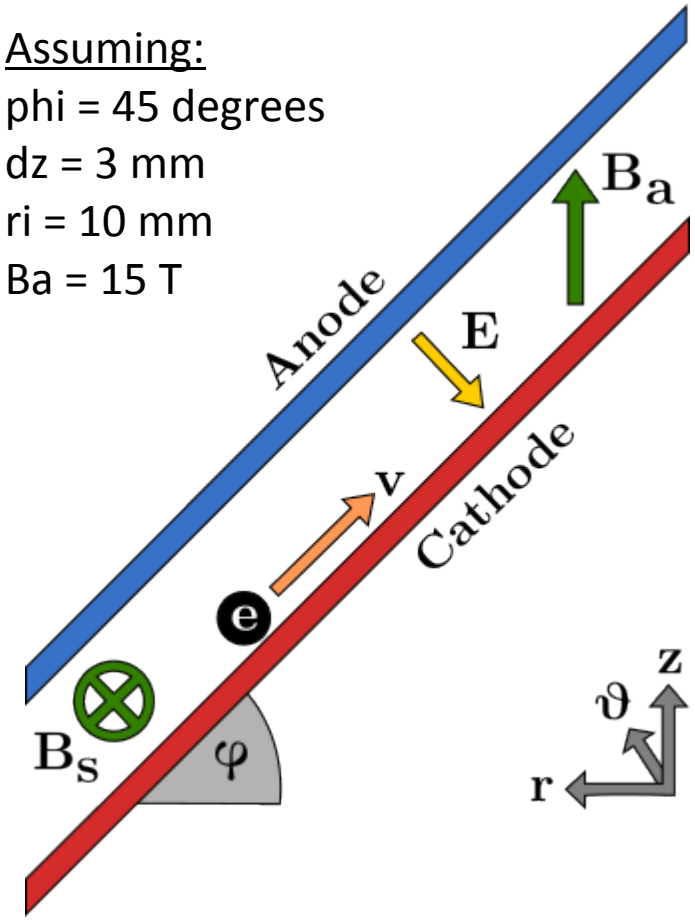
Image: M. R. Gomez, et al. (2014). Experimental Demonstration of Fusion-Relevant Conditions in Magnetized Liner Inertial Fusion. Phys. Rev. Lett. 113, 155003. 10.1103/PhysRevLett.113.155003.

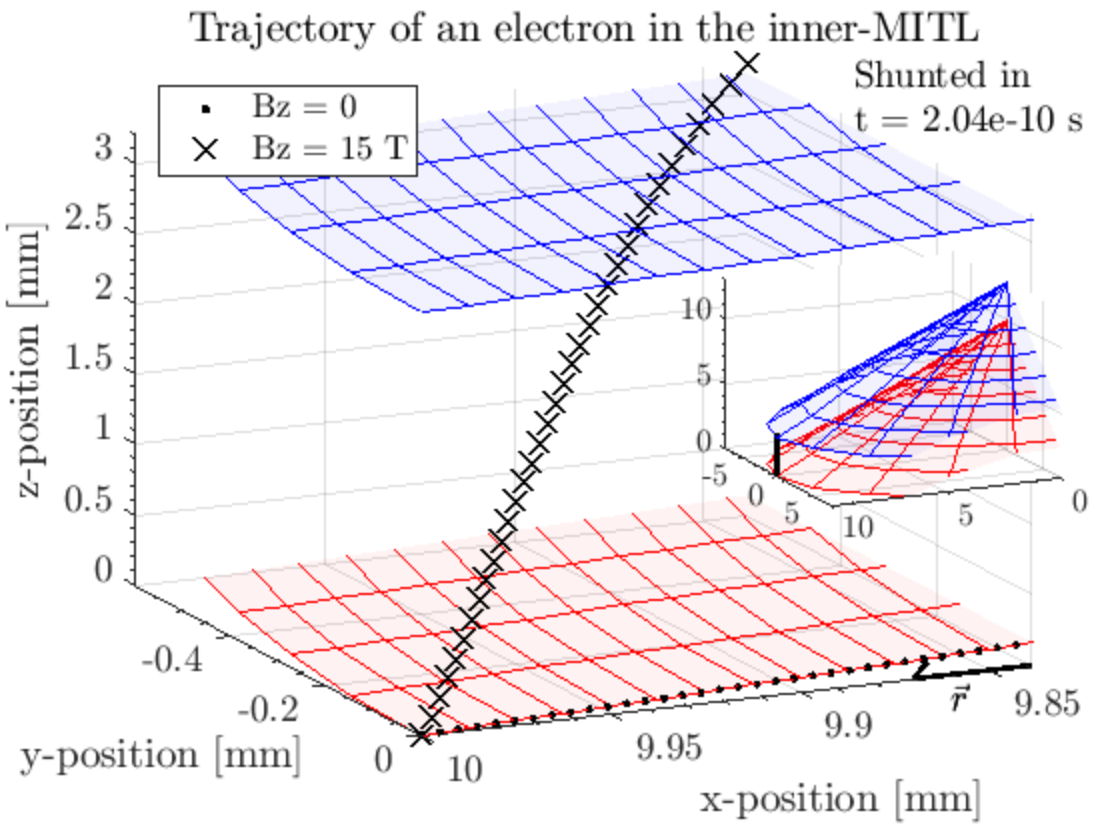
What effect does the applied axial magnetic field have on current coupling?



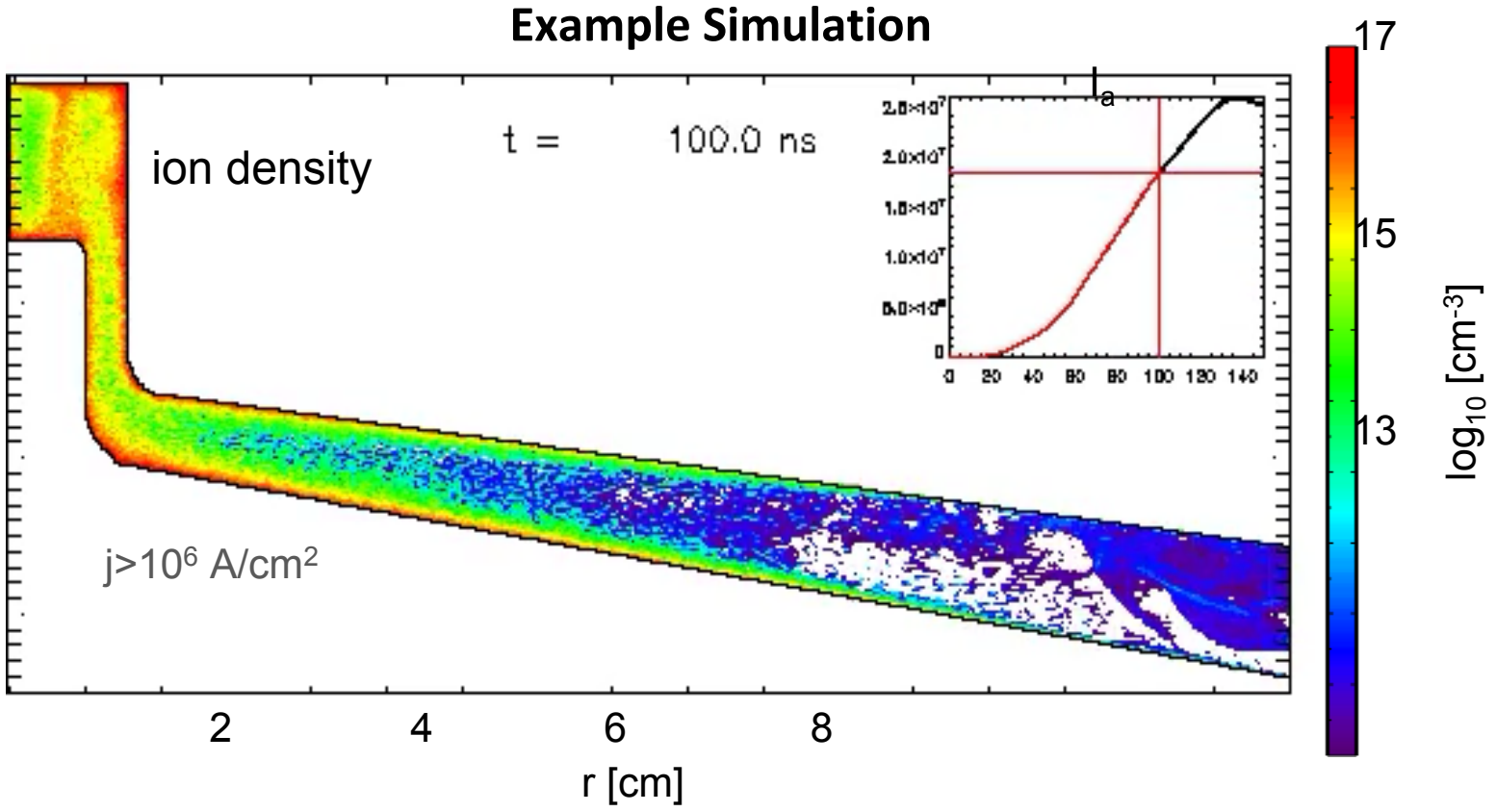
Simplified model of the trajectory of a free electron in the inner-MITL shows shunting in ~200 ps

Assuming:
phi = 45 degrees
dz = 3 mm
ri = 10 mm
Ba = 15 T





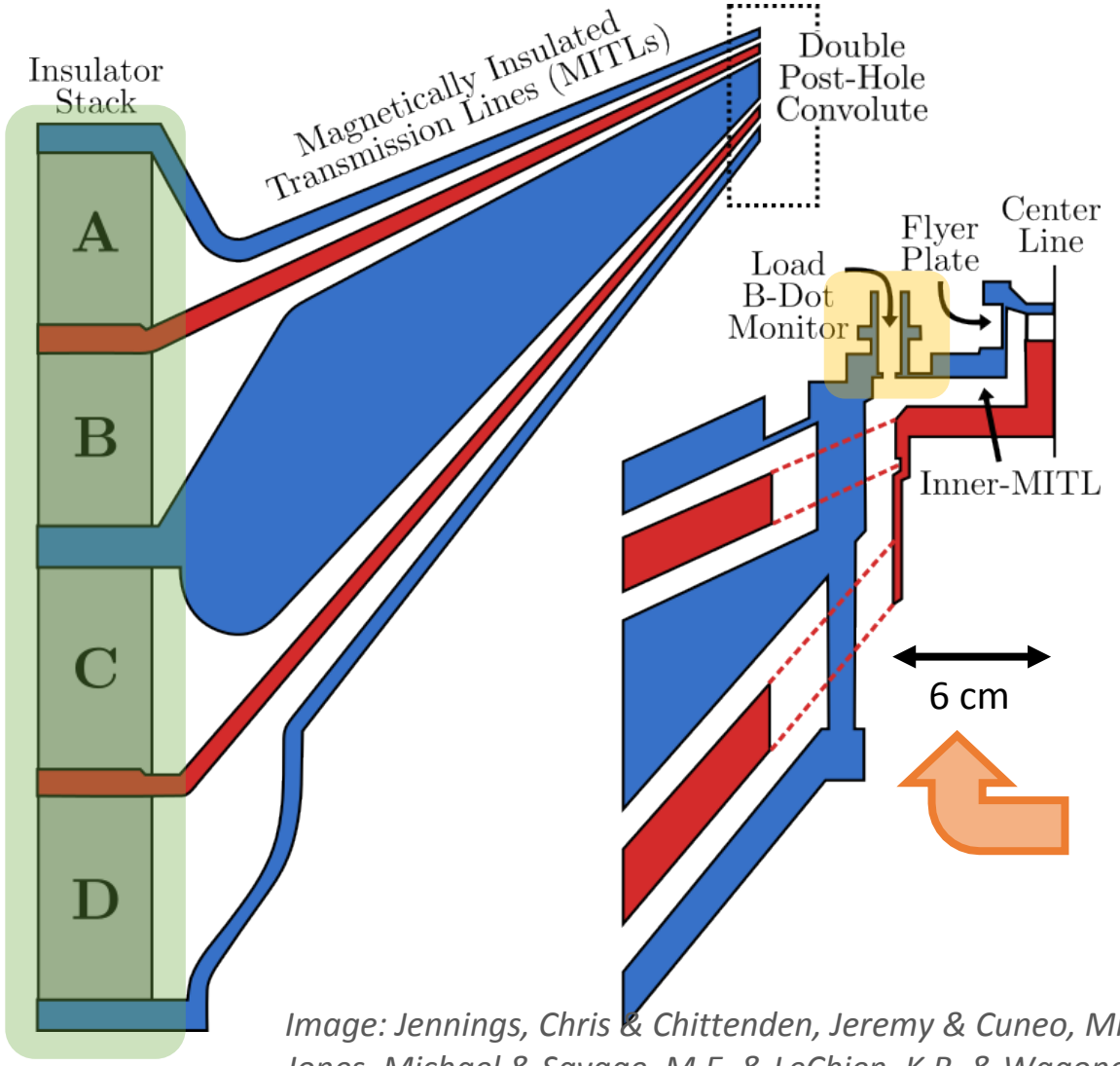
PIC Simulations Using LSP In Progress

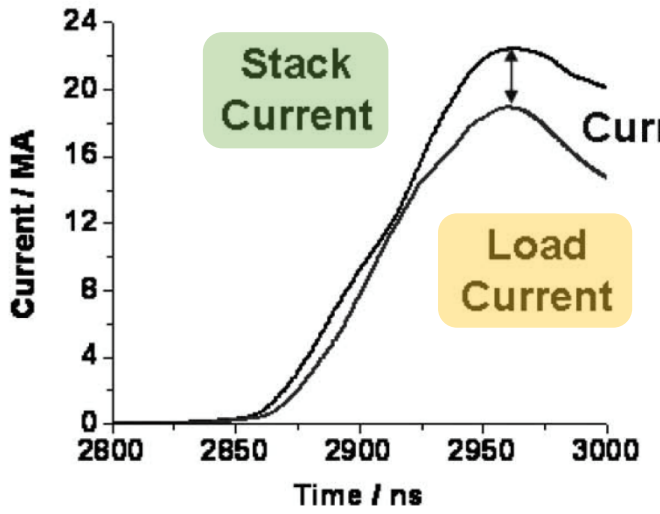


Simulations in progress by Nicki Bennett

$$B_z = \begin{cases} \mathbf{0\ T} \\ \mathbf{15\ T} \\ \mathbf{30\ T} \end{cases}$$

Multi-MA current losses occur near the load





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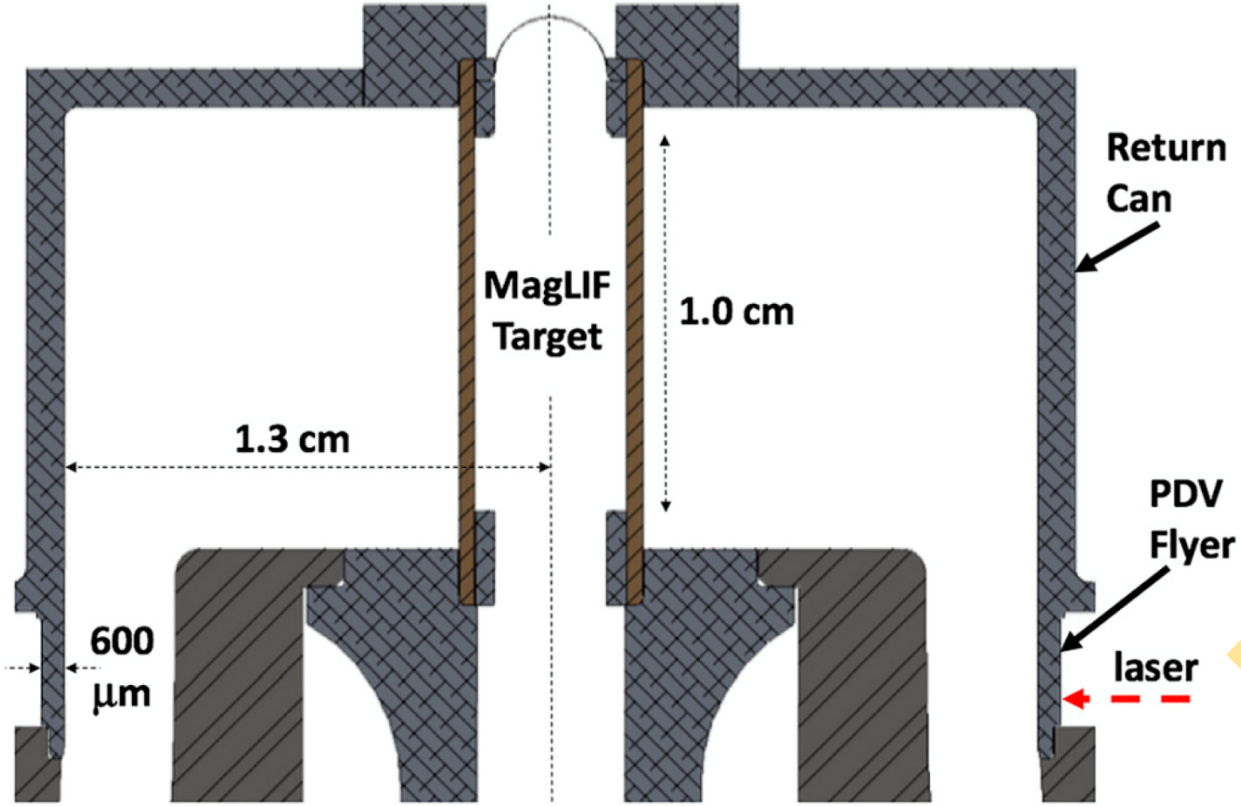
More accurate load current measurement with velocimetry



Two velocimetry diagnostics:

1. **PDV**: Photonic Displacement Velocimetry
2. **VISAR**: Velocity Interferometer System for Any Reflector

Measures Doppler-shifted light reflected from the flyer that is pushed outwards by magnetic pressure.

Image: M. H. Hess, K. J. Peterson, D. J. Ampleford, B. T. Hutsel, C. A. Jennings, M. R. Gomez, D. H. Dolan, G. K. Robertson, S. L. Payne, W. A. Stygar, M. R. Martin, and D. B. Sinars (2018). Design and testing of a magnetically driven implosion peak current diagnostic. Physics of Plasmas. 25. 042702.

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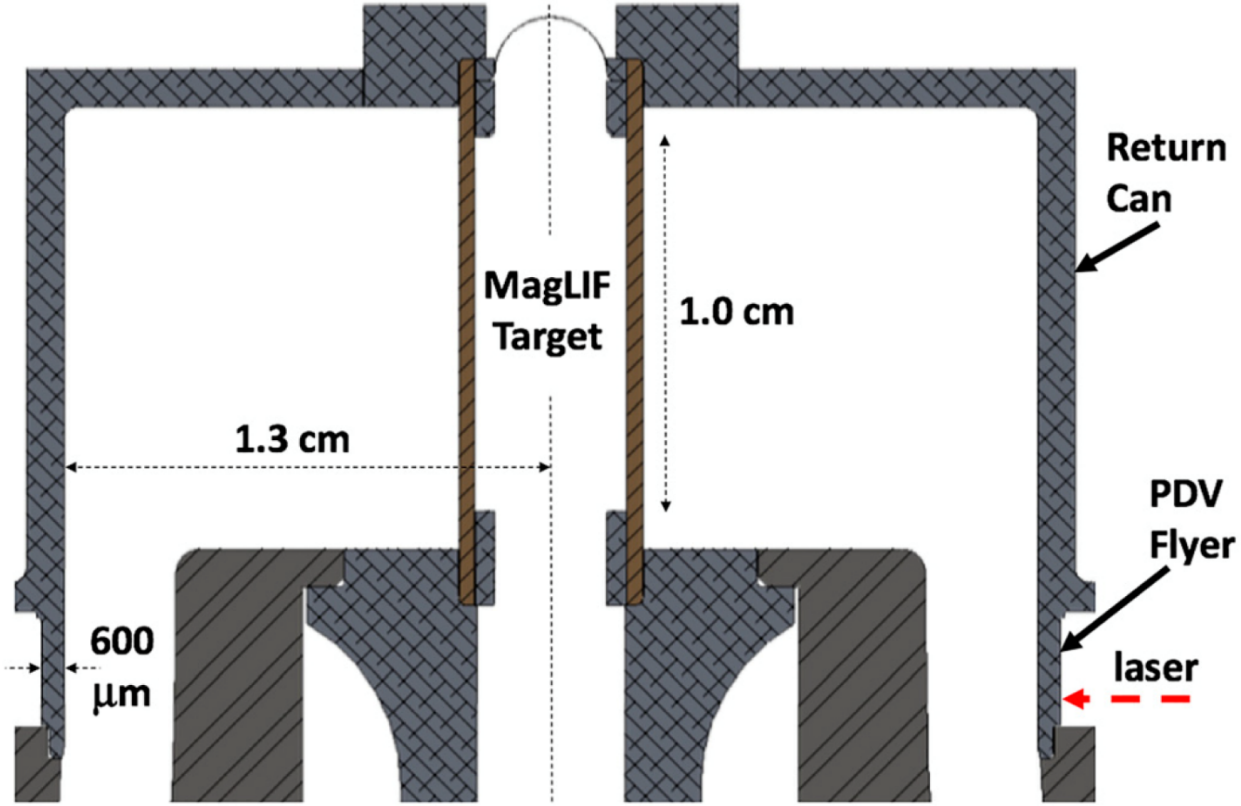

Measured velocity is input into a 1D MHD code to back calculate the current that produced that velocity history.

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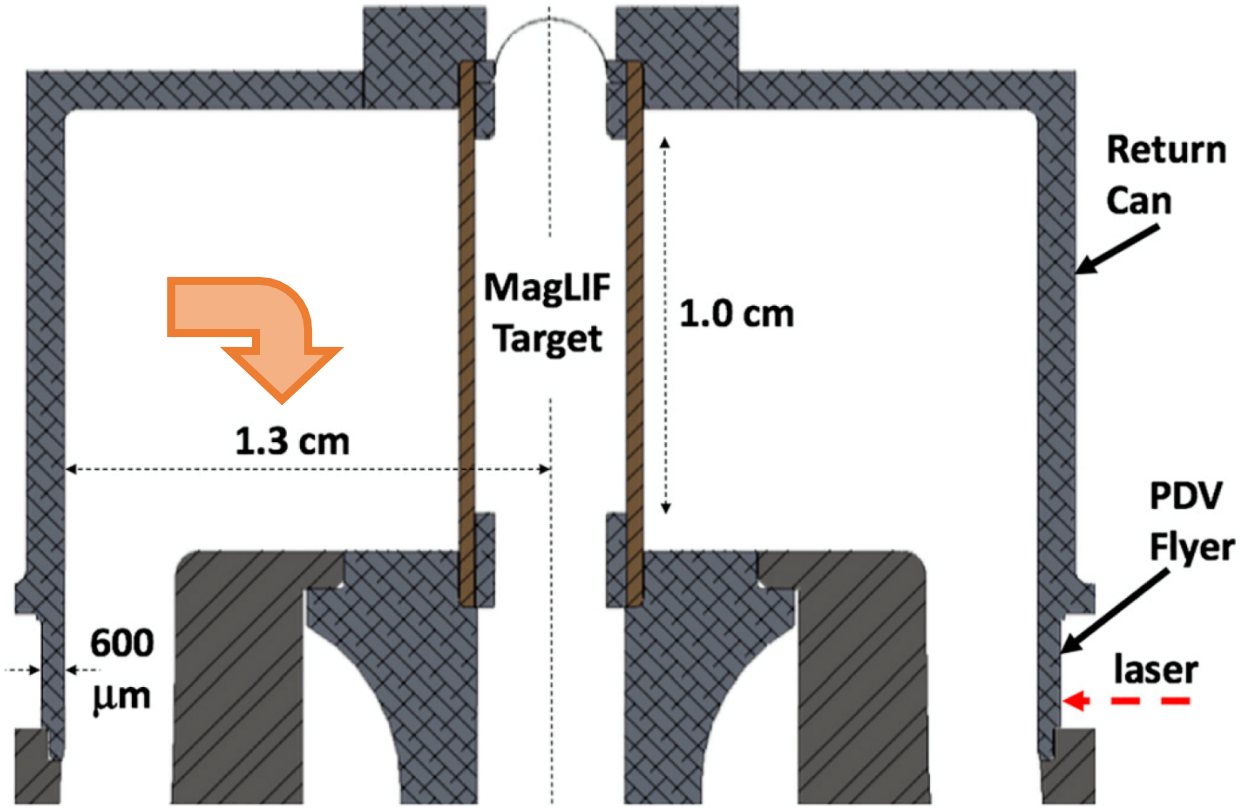

Key Point: Current measurement is much closer at

R = 1.3 cm *vs* 6 cm

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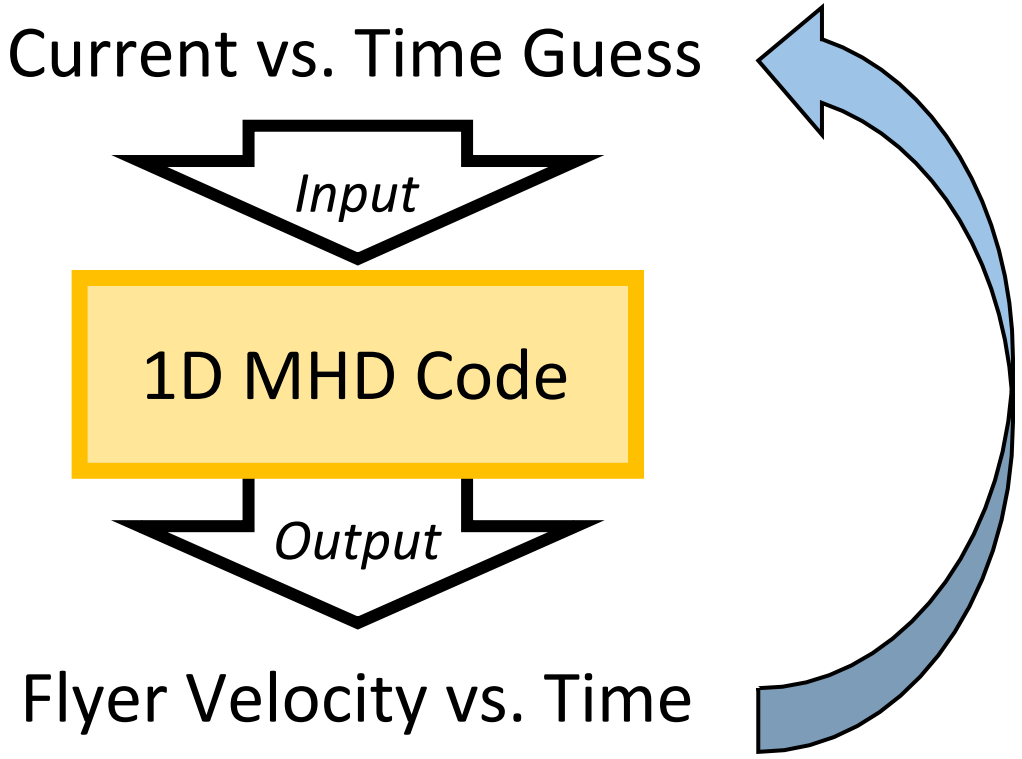
Unfold Process Overview



Compare output to measured velocity and iterate

*Use **stack current** as the initial guess*

Unfold Process Overview

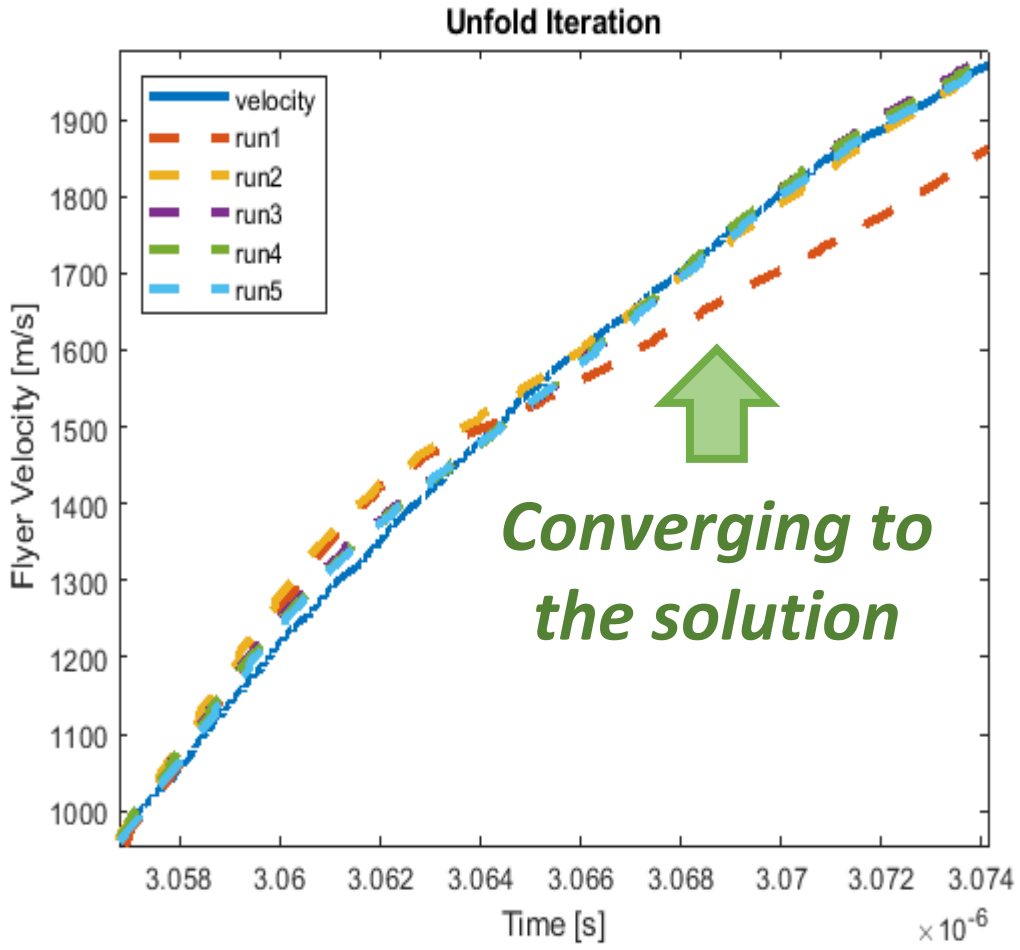
Current vs. Time Guess

Input

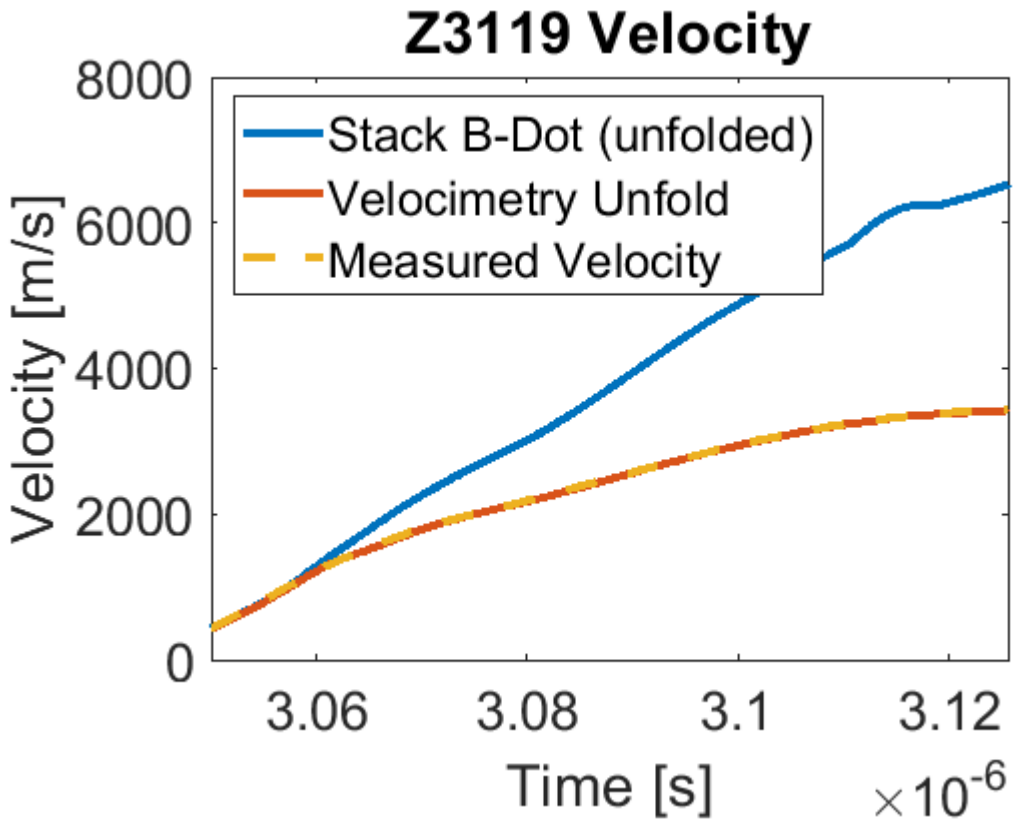
1D MHD Code

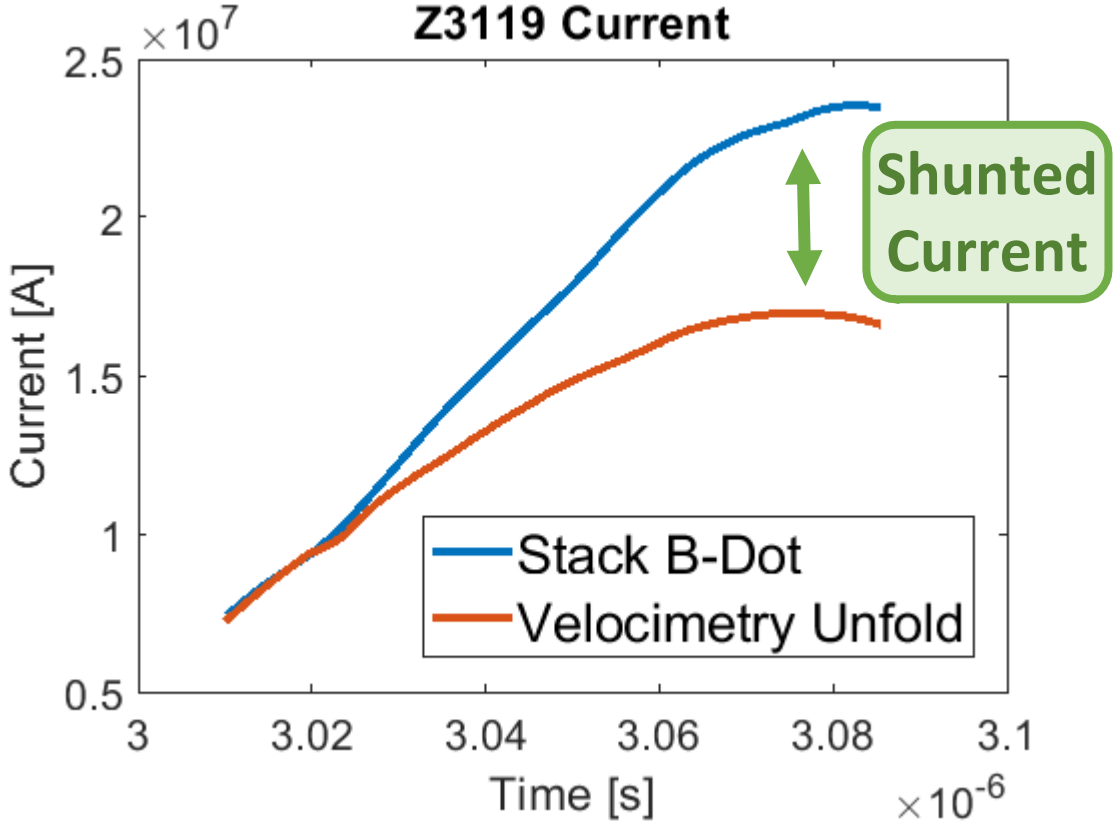
Output

Flyer Velocity vs. Time



Unfold Analysis Final Result





Measured Result Shows No Effect From Applied Field

“Current Loss”

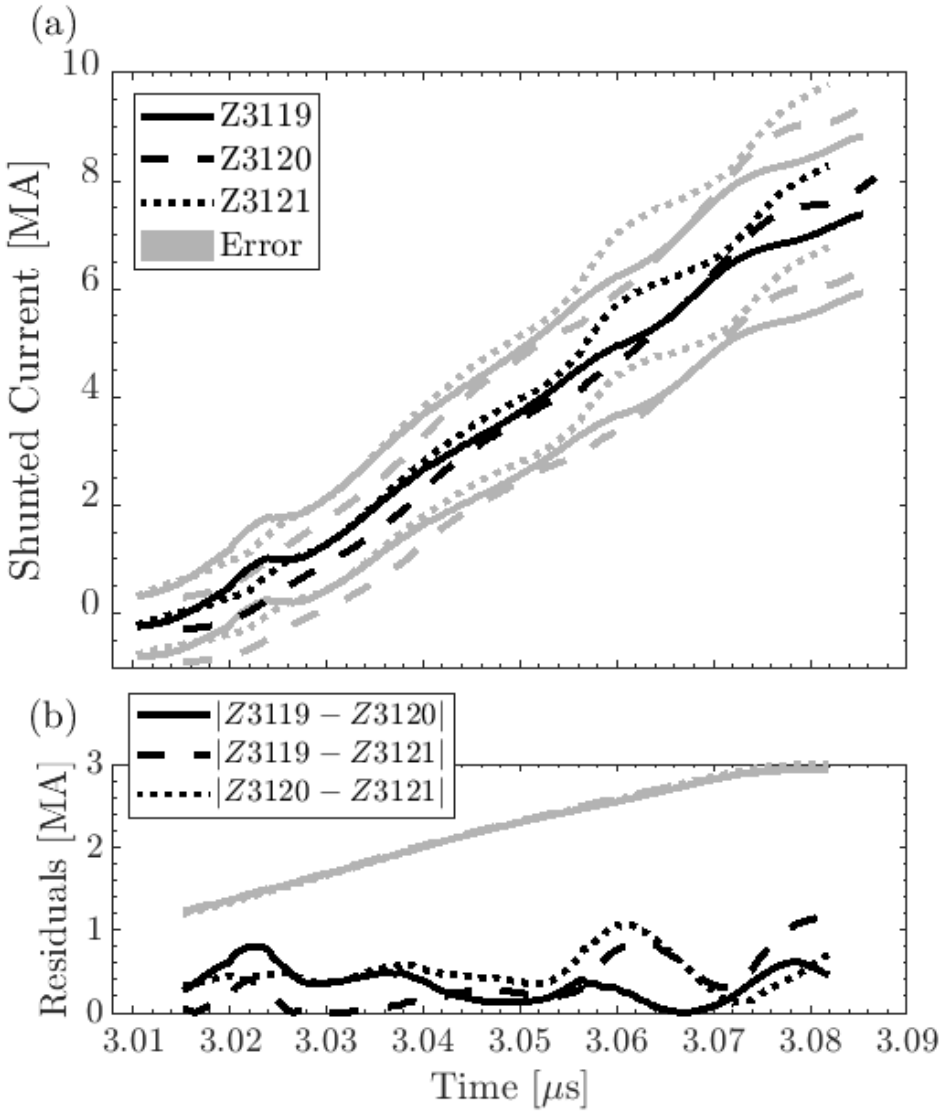
=

Translated Stack Current

−

Unfold Current

Residuals

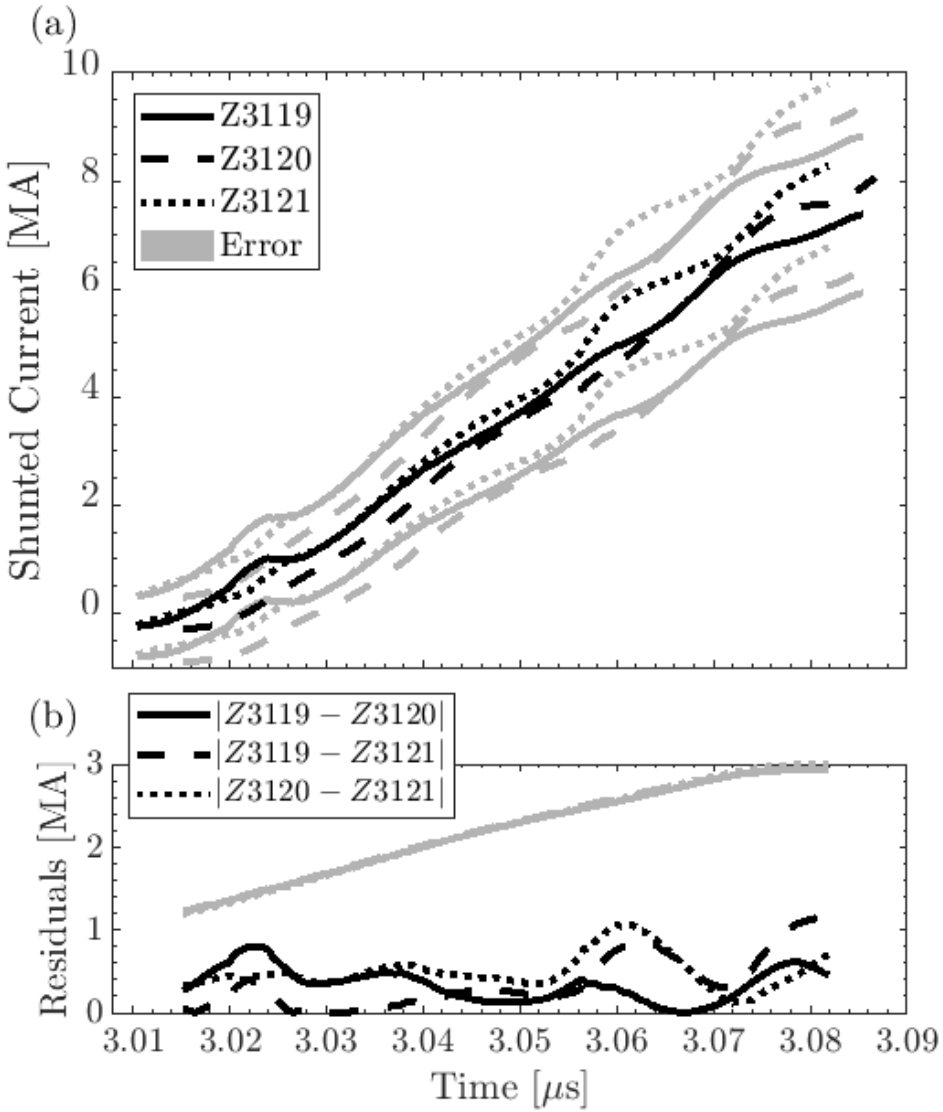


Measured Result Shows No Effect From Applied Field

Identical Set-up

	Applied B-Field
Z3119	**14 T**
Z3120	**15 T**
Z3121	**0 T**

Residuals are **below** the combined **error margins**



Conclusion

Unfold-velocimetry technique enables…

- **measurement** of current **closer to the load** than ever before on Z-machine (radius 1.3 cm vs 6 cm)
- **analysis** of current loss in the **inner-MITL region**

Upcoming paper on the **effect of axial magnetic fields** from MagLIF on current coupling.

- Results show that **performance is not affected** by the applied field

Thank you!

This work is supported by the DOE NNSA under Award Numbers DE-NA003842.

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