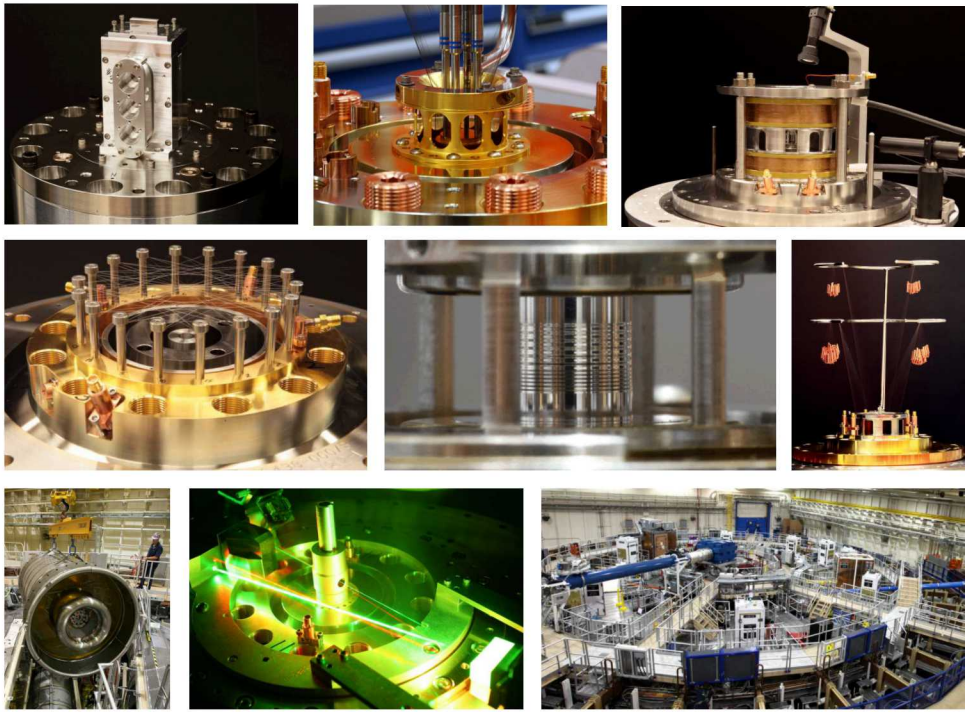
Line VISAR Development and Commissioning on the Z Machine

Michael Jones

On behalf of the Z Line VISAR Team

May 21st, 2019

SAND2019-5570PE



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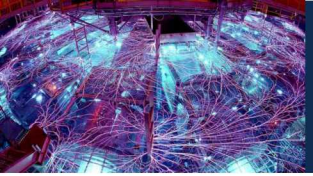
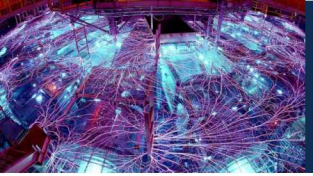


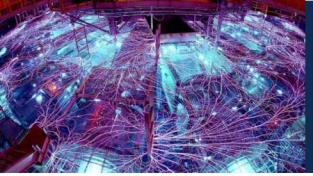
The Z Line VISAR (ZLV) team is extensive and multi-institutional

ZLV diagnostic scientists (SNL):	Clayton Myers and Dave Bliss
ZLV instrument team (LLNL):	Phil Datte, Gene Frieders, Gene Vergel de Dios, Tom McCarville, Michael Crosley, Neil Butler, and many more
ZLV instrument team (SNL):	Michael Jones, Dave Bliss, Drew Johnson, Decker Spencer, Grafton Robertson, and many more
ZLV physics team (LLNL):	Peter Celliers, Dave Erskine, Dayne Fratanduono, Kumar Raman, Paul Springer, Jim Hammer, and many more
Commissioning target modeling:	Mark Hess (HYDRA 2D & ALEGRA 1D) Chris Jennings (GORGON) Kumar Raman and Keith LeChien (ARES)

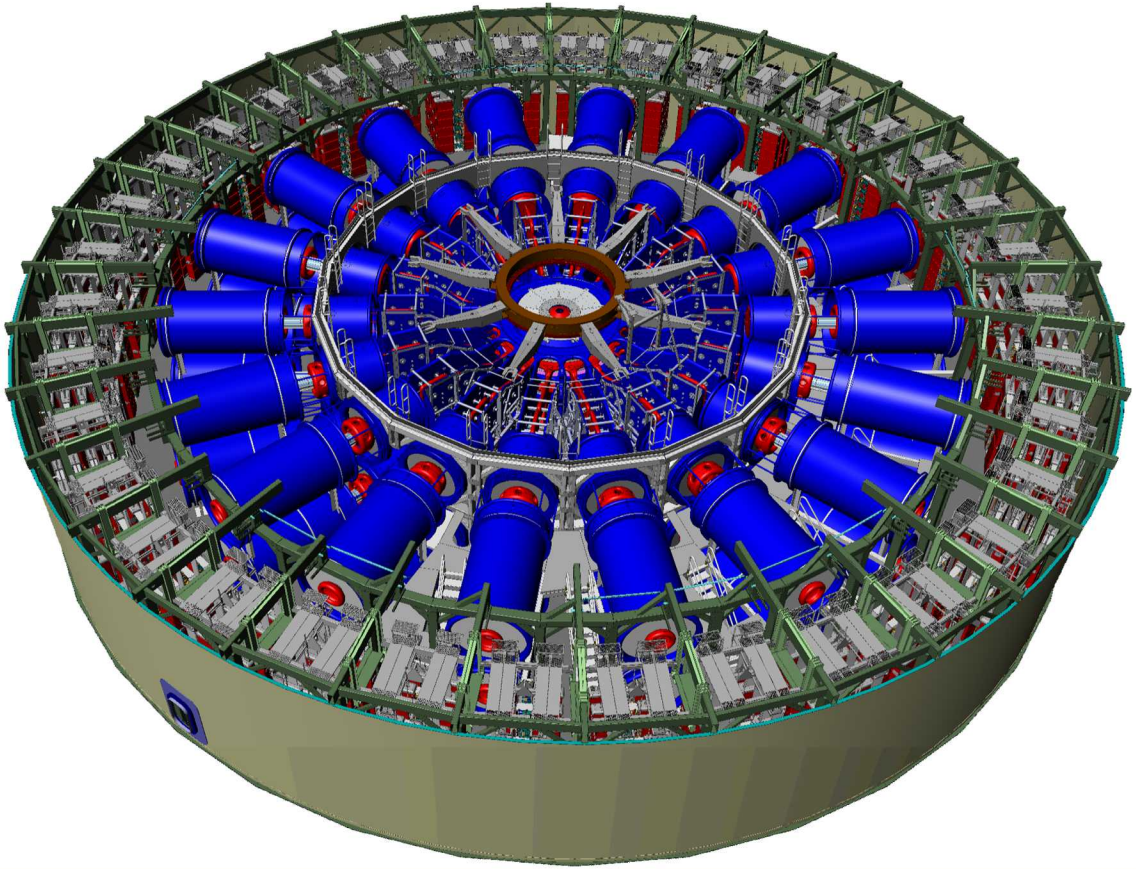


Agenda

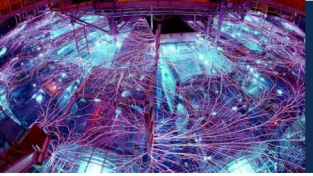
- Description of the Z Machine
- Objectives of a Line VISAR diagnostic at the Z Machine
- Physical Layout
- Commissioning Experiment - Design & Results



Z Compresses Energy in Space and Time to Create Extreme States of Matter



- Over several minutes 36 Marx Banks are charged up to 95 kilovolts.
- This results in a stored energy around 25 million Joules
- This energy is directed inward from a distance of 16 meters to a ~1 cm radius.



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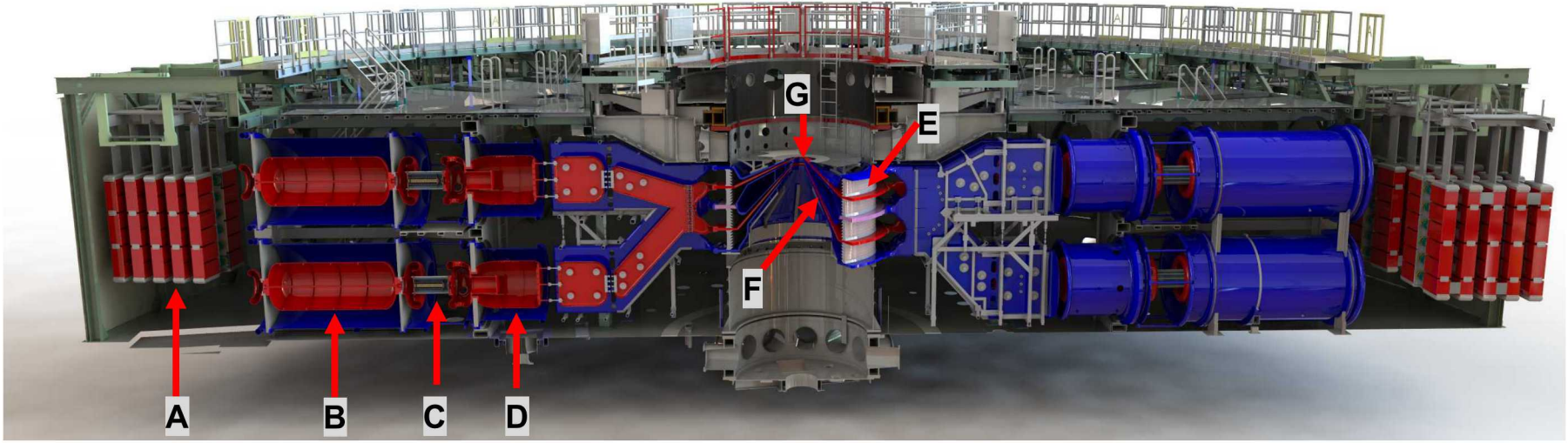
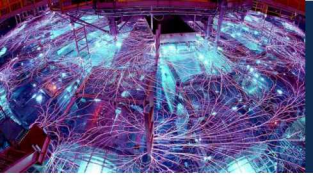
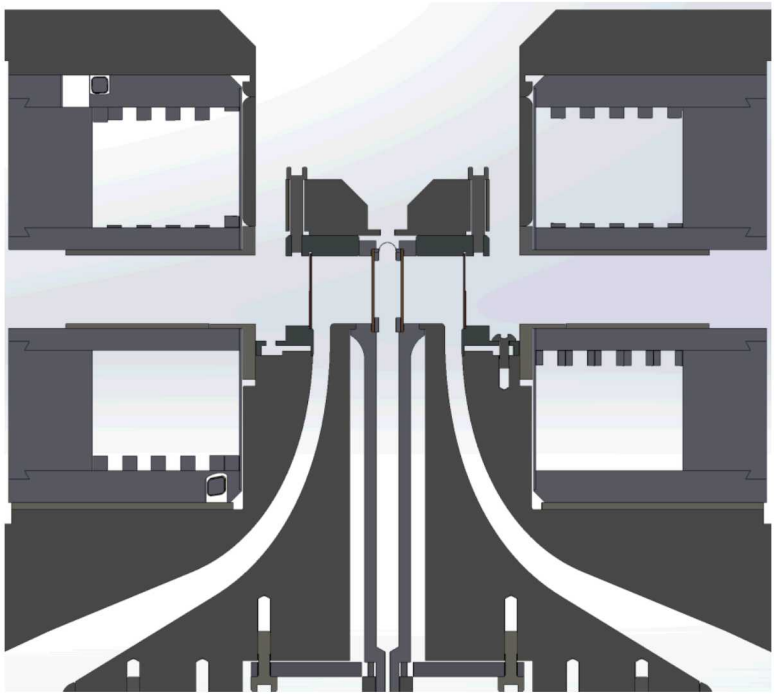


- As the energy travels towards the center there are several stages of pulse compression.
- The electrical pulse-length is compressed from 1.5us to 100ns
- X-ray outputs occur over a 3-10 ns timescale

A	Marx Capacitors
B	Intermediate Storage Capacitors
C	Laser Trigger Gas Switches
D	Pulse Forming Lines
E	Insulator Stack
F	Magnetically Insulated Transmission Lines
G	Load

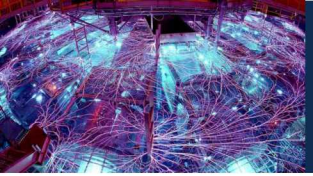


Understanding Current Delivery and Current Loss near the Experimental Load is Vital



- As the energy travels towards the experimental load – upwards of 30 million Amps, and 4 million Volts – it becomes more challenging to diagnose current delivery.

- The main objective for implementing a Line VISAR diagnostic at Z is to help infer where current loss is occurring at small radii.

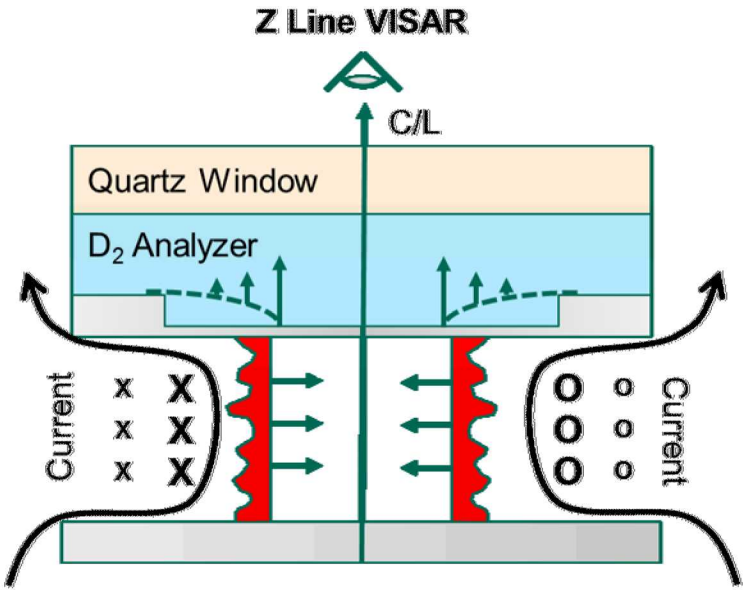


Line VISAR will provide spatially and temporally resolved measurements of current delivered to a target on Z

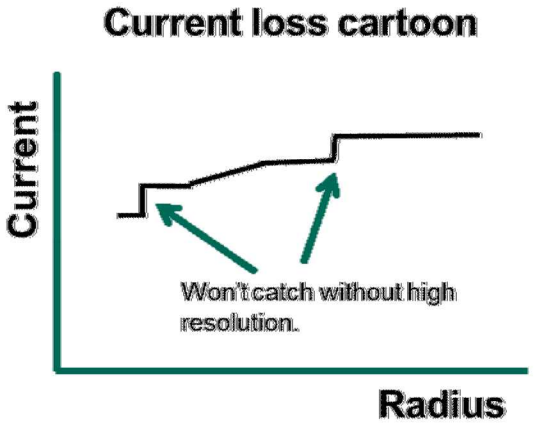
$$P = \frac{B^2}{8\pi} \sim \frac{I^2}{R^2}$$

$$U_s \sim \sqrt{\frac{P}{\rho}} \sim \frac{I}{R}$$

P – Pressure
B – Magnetic Field
I – Current
R – Radius
U_s – Shock Velocity

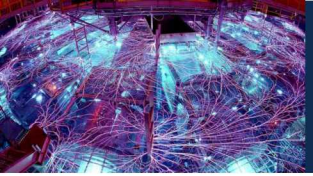


By measuring velocity as a function of position in a D_2 analyzer, we can infer the current delivery



Measuring the loss profile requires high spatial and temporal resolution

Slide courtesy of Dayne Fratanduono (LLNL)



Z Line VISAR is a high-performance instrument designed to meet the demands of the Z environment

Physics needs

- Measure high shock velocities
- Measure velocity as a function of radius to identify current loss locations
- High f-number to account for titling of the shock front
- Multiple fields of view to examine velocity at large and small radii
- 2D images of shocked surface to assess centering and symmetry

ZLV diagnostic requirements

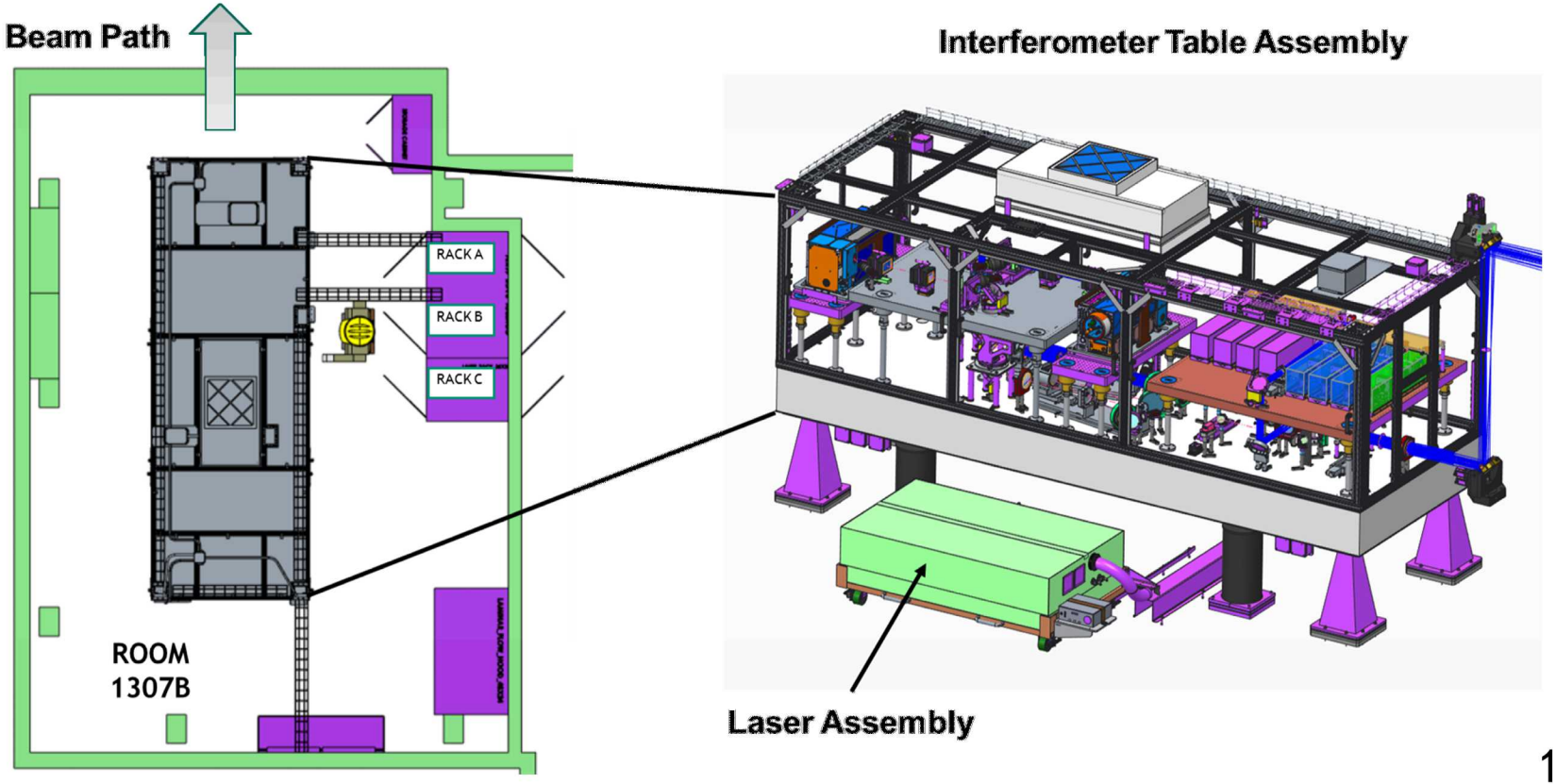
Velocity interferometer

- Spatial resolution better than 10-20 μm
- Timing accuracy better than 20 ps
- 1, 2 and 4 mm FOV
- f/2 (!)
- Two interferometer legs for fringe ambiguities

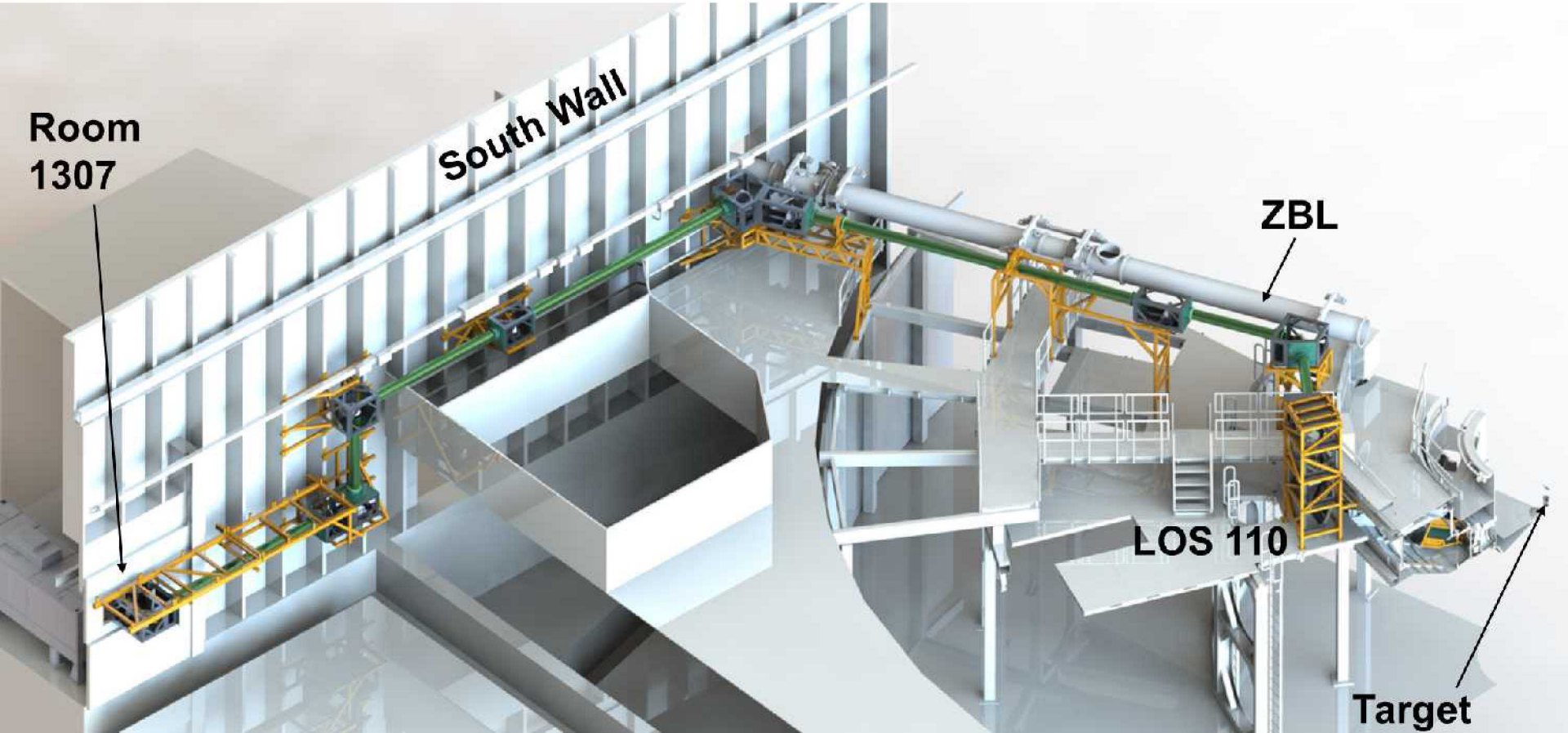
Gated Optical Imager (GOI)

- Spatial resolution of ~100 μm
- Multiple images (8) to account for physics and facility jitter

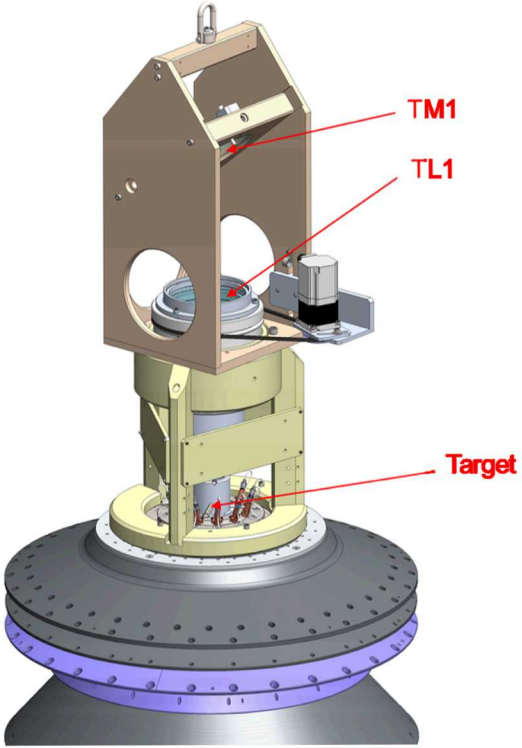
The ZLV optics table and laser system have been installed and brought online

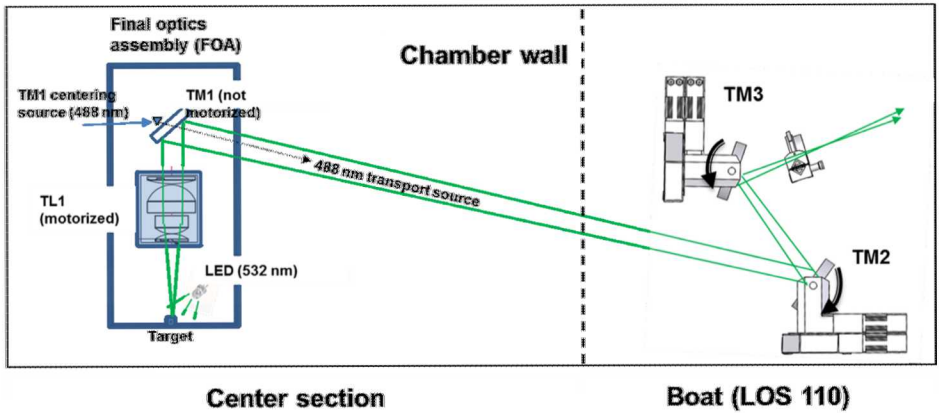


The ZLV beam transport system (9 lenses, 12 mirrors) is 50 meters long



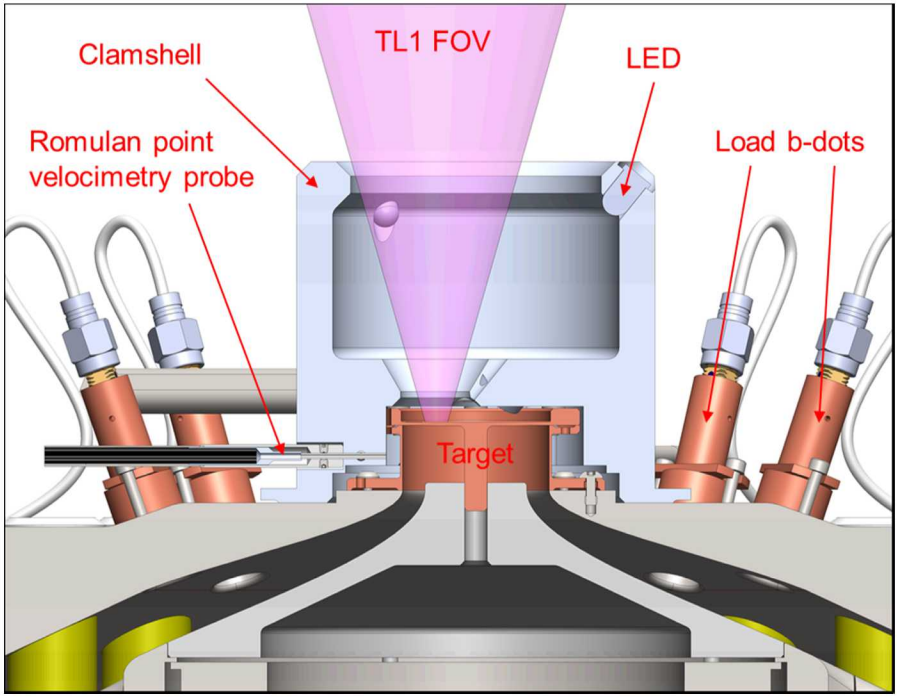
Each Z Line VISAR experiment must field a consumable final optics assembly that precisely images the top of the target

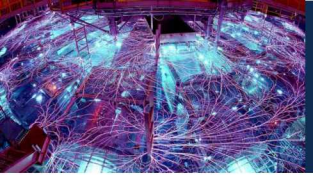




ZLV commissioning load hardware (A0817)

- An experiment was designed to commission the diagnostic and validate with a suite of existing diagnostics.
- Ten load B-dots and nine Romulan point velocimetry probes were fielded to assess the current delivered to the inner MITL





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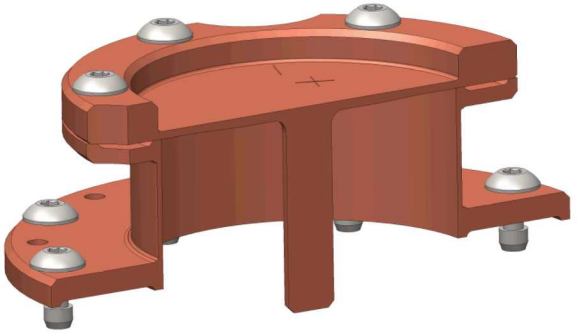

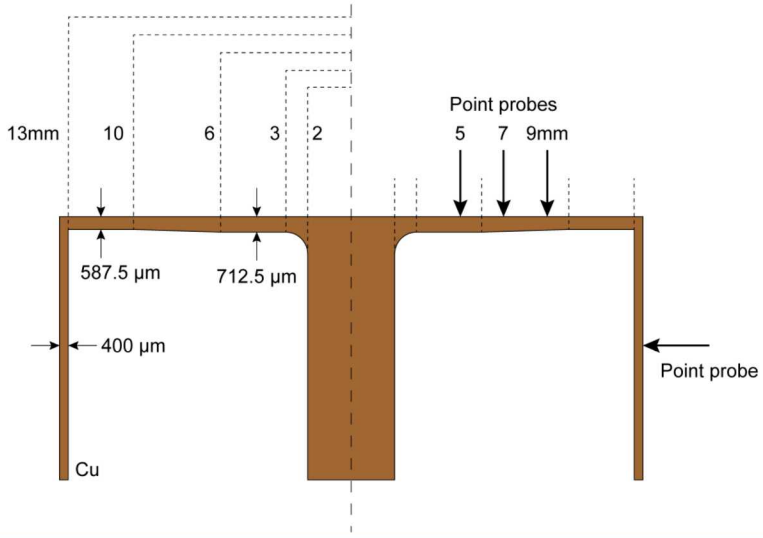

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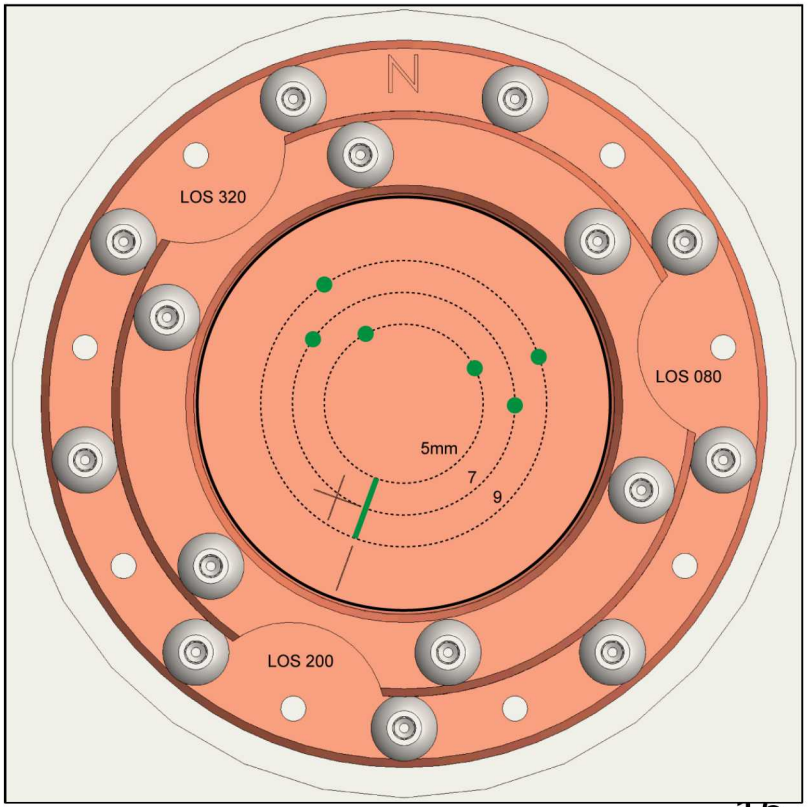
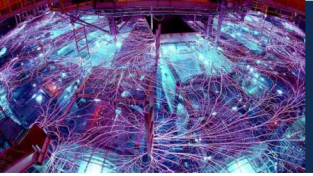
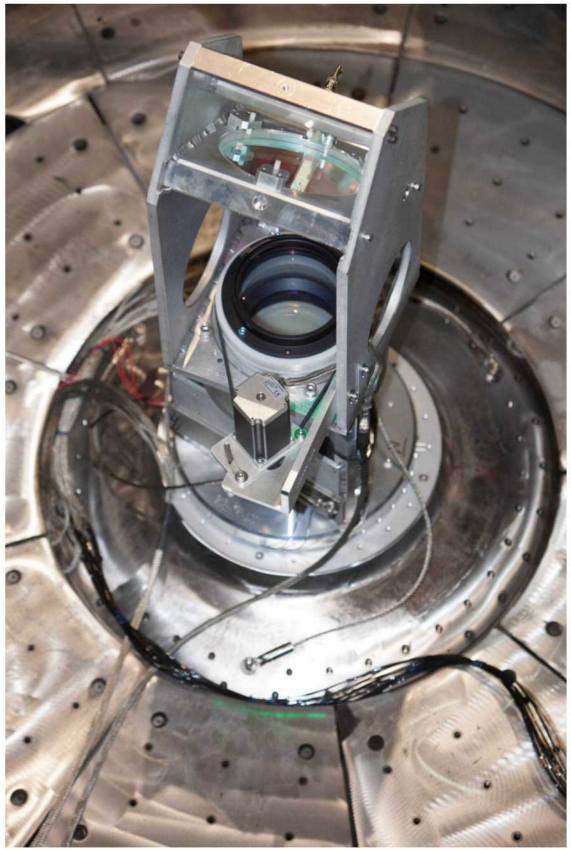
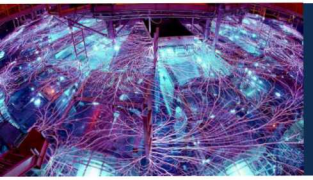
- The commissioning target is a non-imploding copper target with a shimmed top cap that thins linearly between r = 6 mm and r = 10 mm
- The Line VISAR is offset from machine center by 7 mm to enable six point probes to view the same radial distance at a different azimuth



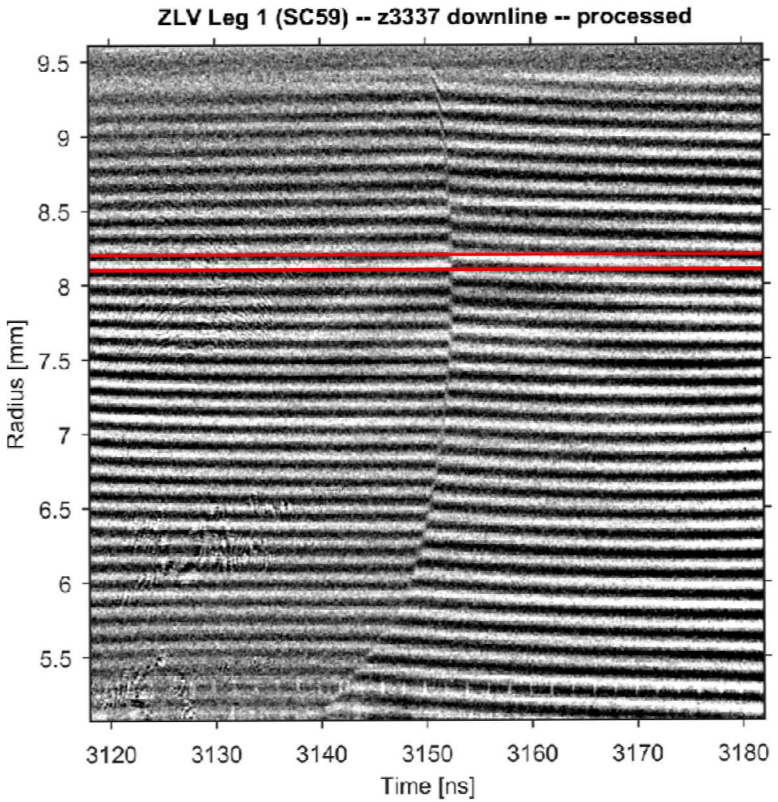


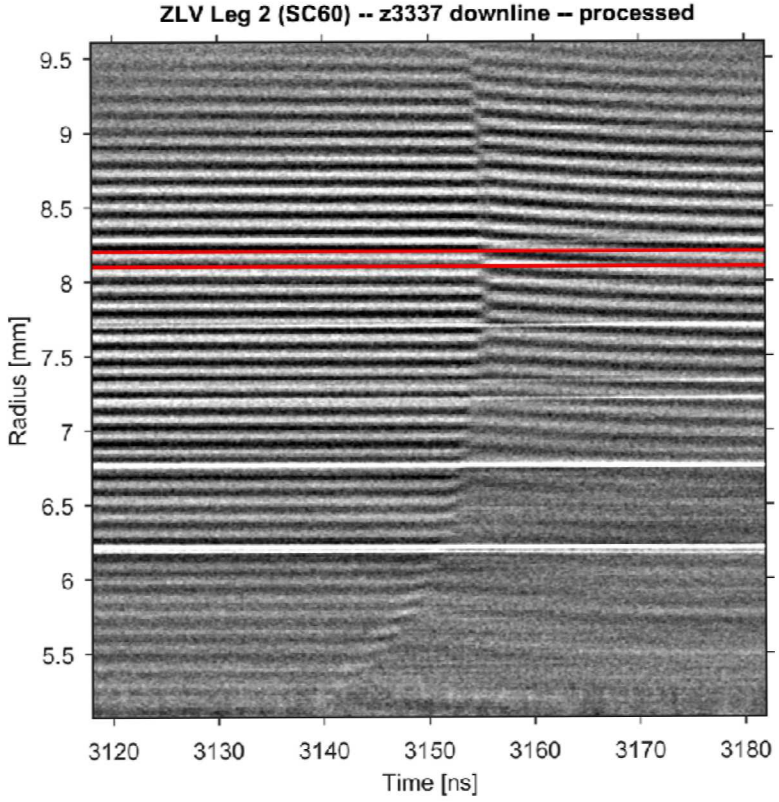
At 4:52p on December 17th, the first ZLV shot went downline (z3337)



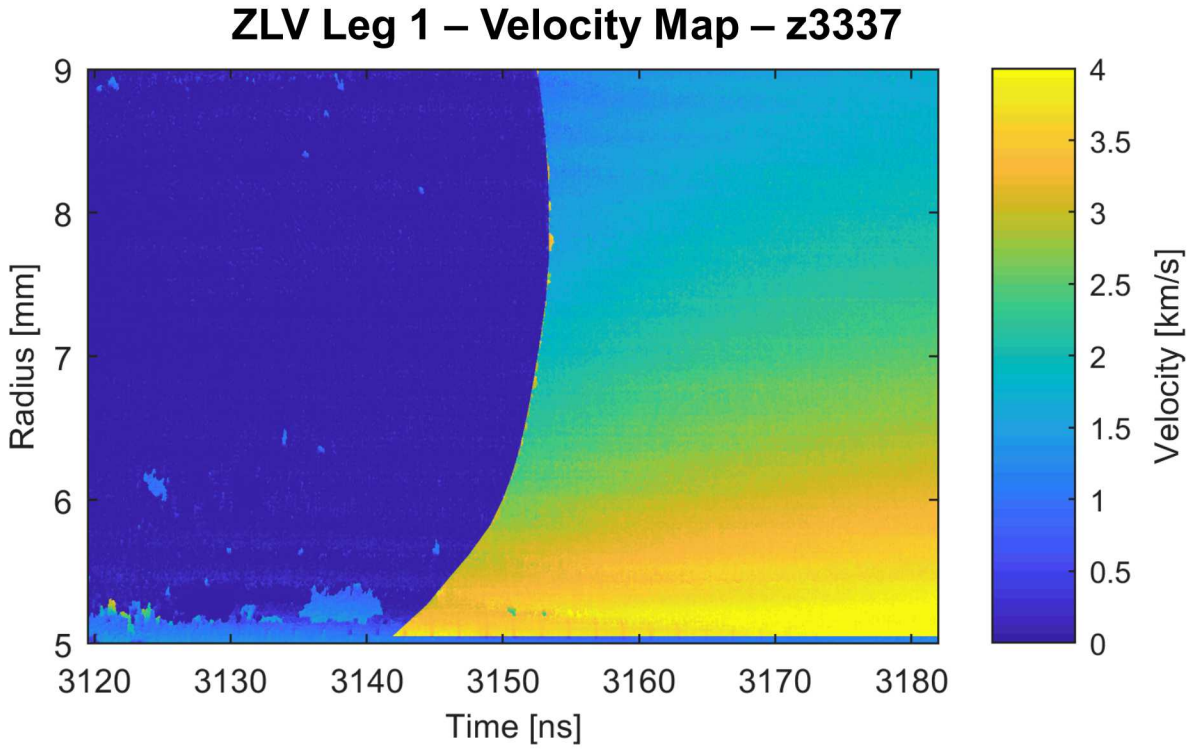


A curved shock breakout on both ZLV legs was observed at the expected time on the first experiment!





The resulting unfolded ZLV velocity map is a remarkable achievement after a single commissioning shot!

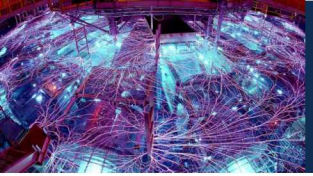


Line VISAR unfolds:

Peter Celliers and Dave Erskine

Streak image registration:

Dave Bliss, Peter Celliers, Gene Vergel de Dios, and the ZLV instrument team



Summary

- This project was extremely successful due primarily to the partnership between Lawrence Livermore National Laboratory and Sandia National Laboratories.
- The Line VISAR diagnostic is installed and commissioned on Z. The first commissioning experiment occurred in December, 2018
- Line VISAR will enable load current measurements that have never been possible on Z before.
- The first physics experiments using Line VISAR are occurring later this month.