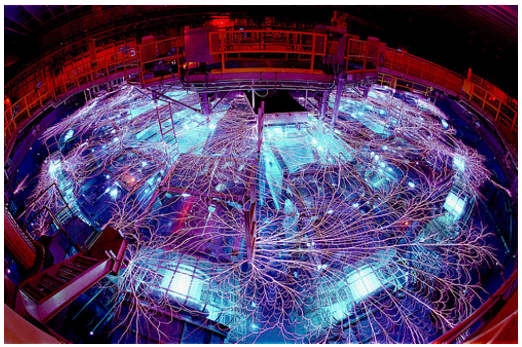
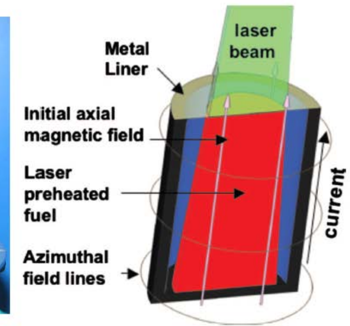
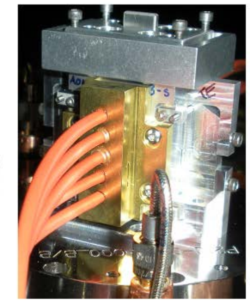
Exceptional service in the national interest

Sandia National Laboratories







High Energy Density Science on the Z facility at Sandia National Laboratories

M. R. Gomez and the entire Z team

Stewardship Science Graduate Fellowship Conference

6/25/2013

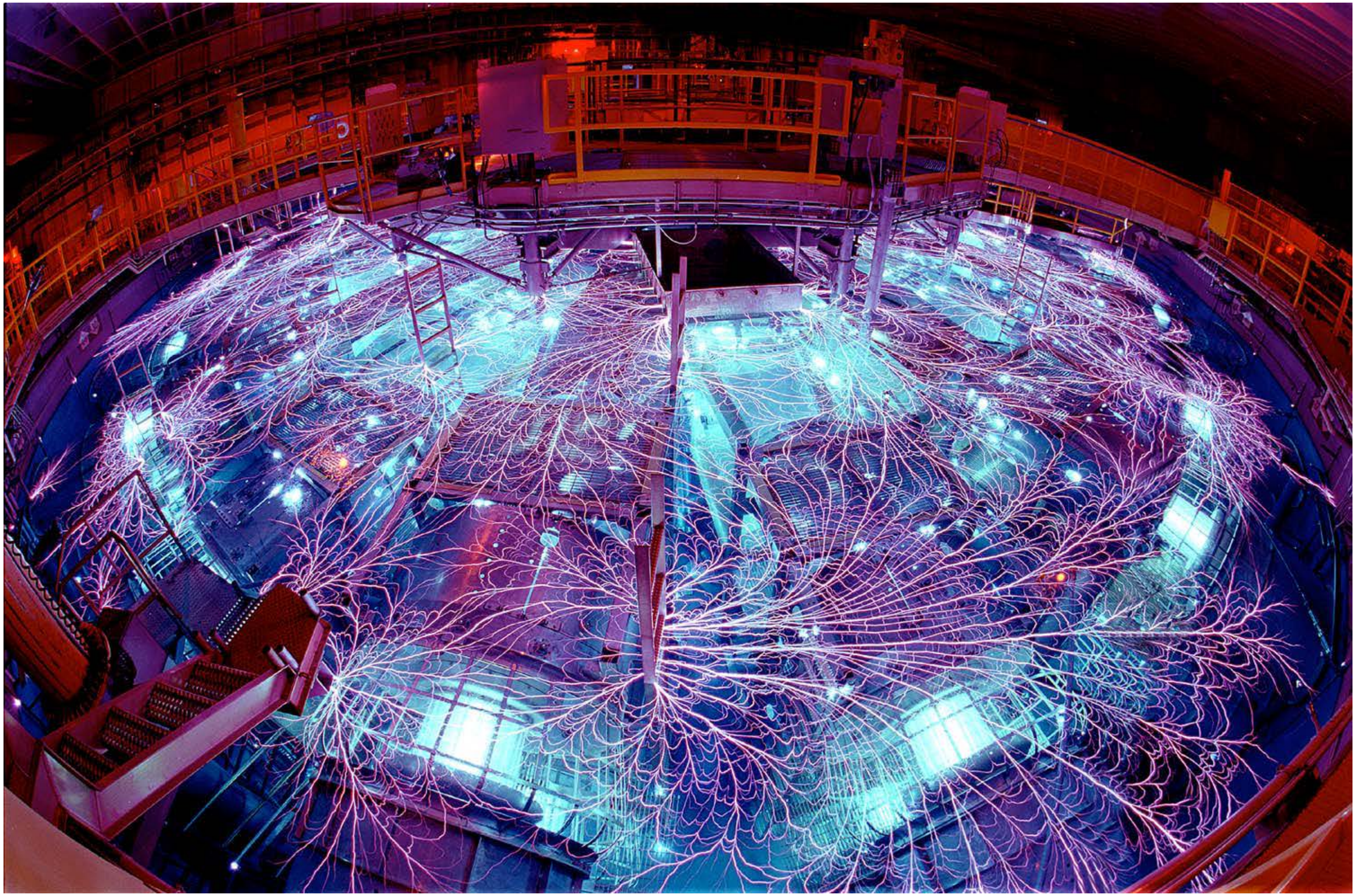
U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

HED Science is a key component of stockpile stewardship

- Certification of the stockpile in the absence of underground testing
  - Verifying functionality of non-nuclear components in harsh environments
  - Confirm that replacement components and new materials will not change the effectiveness of the nuclear components
- HED science is advanced through above-ground experiments on facilities like NIF, Z, and Omega
  - Key physics are difficult to accurately model
  - Experiments are used to benchmark simulations

Z is the premier facility for magnetically driven HED science

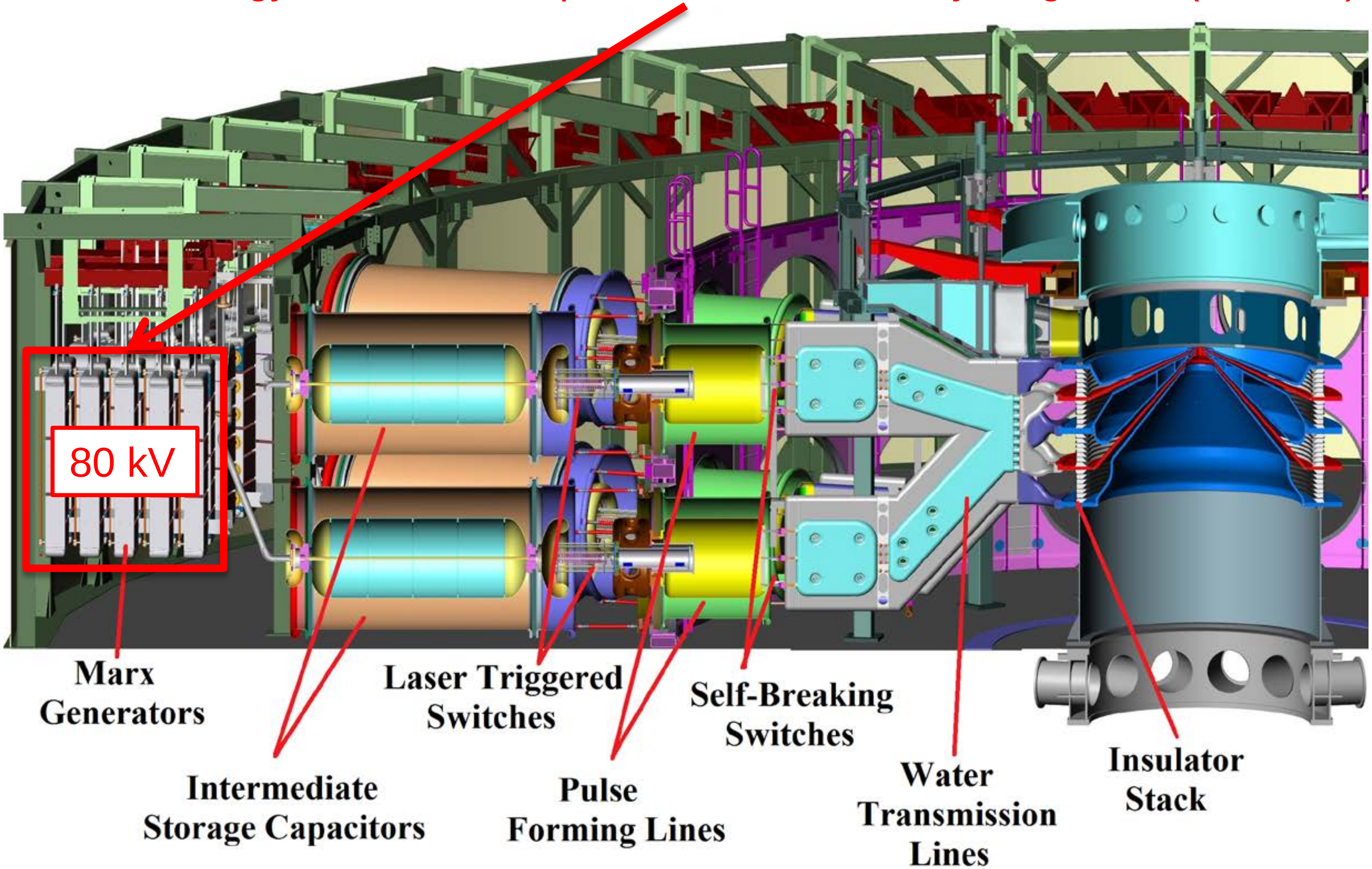


Magnetically-driven HED experiments use high currents to create extreme conditions

- Electrical energy is stored over relatively long times and discharged over relatively short times
- Pulses are added in parallel and series to increase current and voltage, respectively
- Electrical power ~ 10-100 TW
- Pressure ~ 10-100MBar, Temperature ~ 1-10 keV

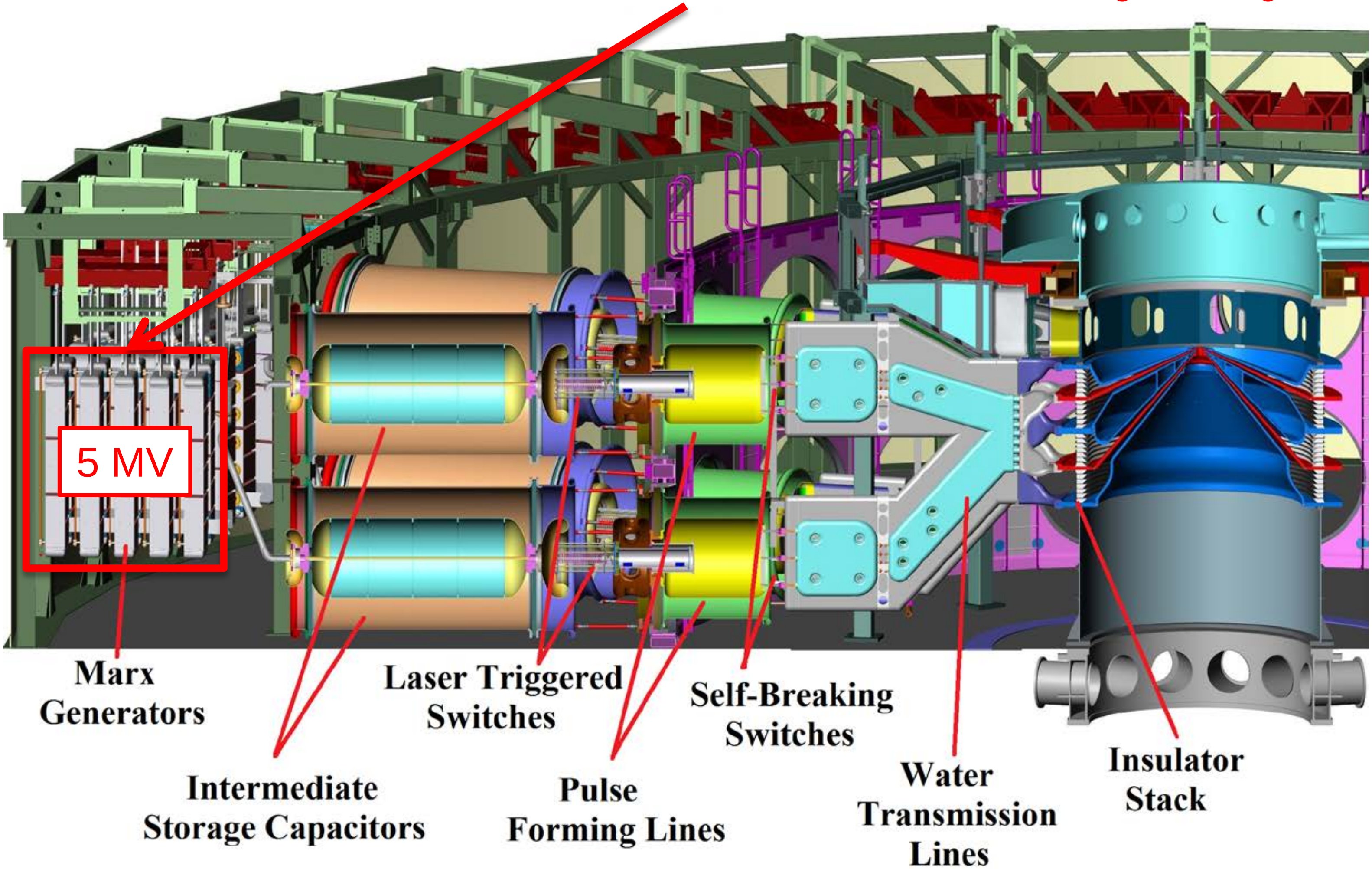
A quick review of Z's pulsed power

Electrical energy is stored in capacitors over relatively long times (minutes)



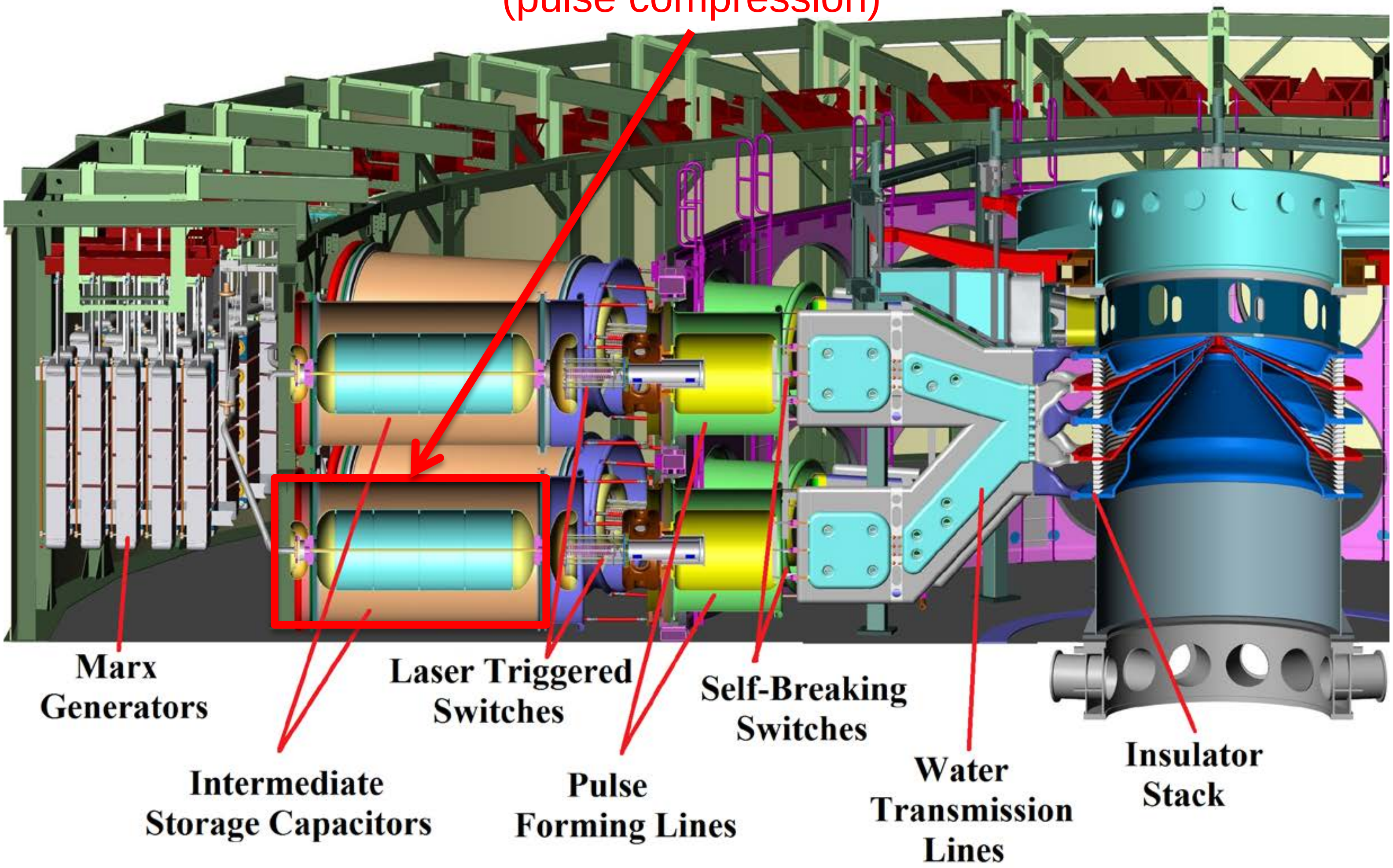
A quick review of Z's pulsed power

Switches within the Marx banks close to erect 60x the charge voltage



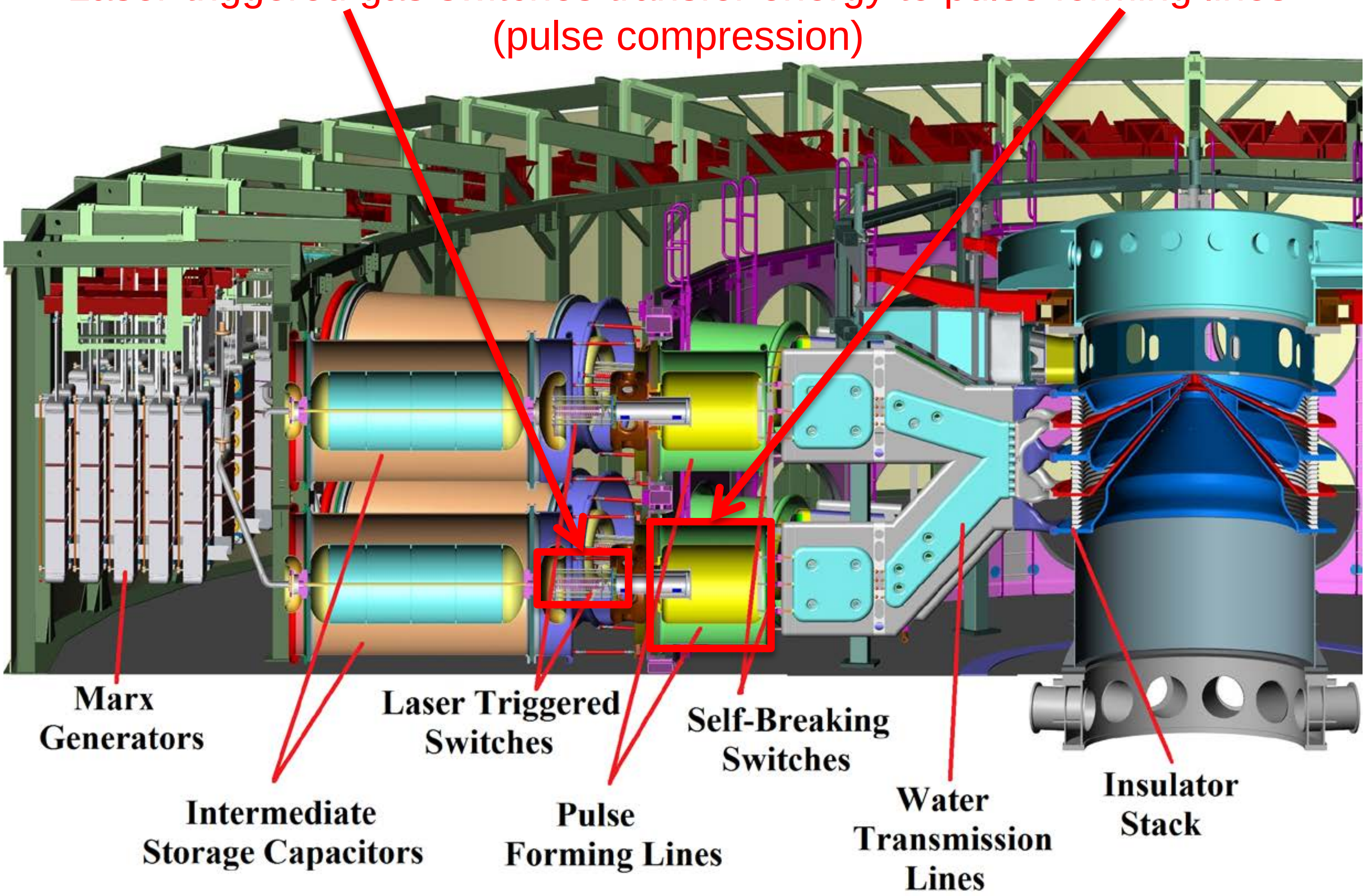
A quick review of Z's pulsed power

Marx banks discharge into intermediate storage capacitors (pulse compression)



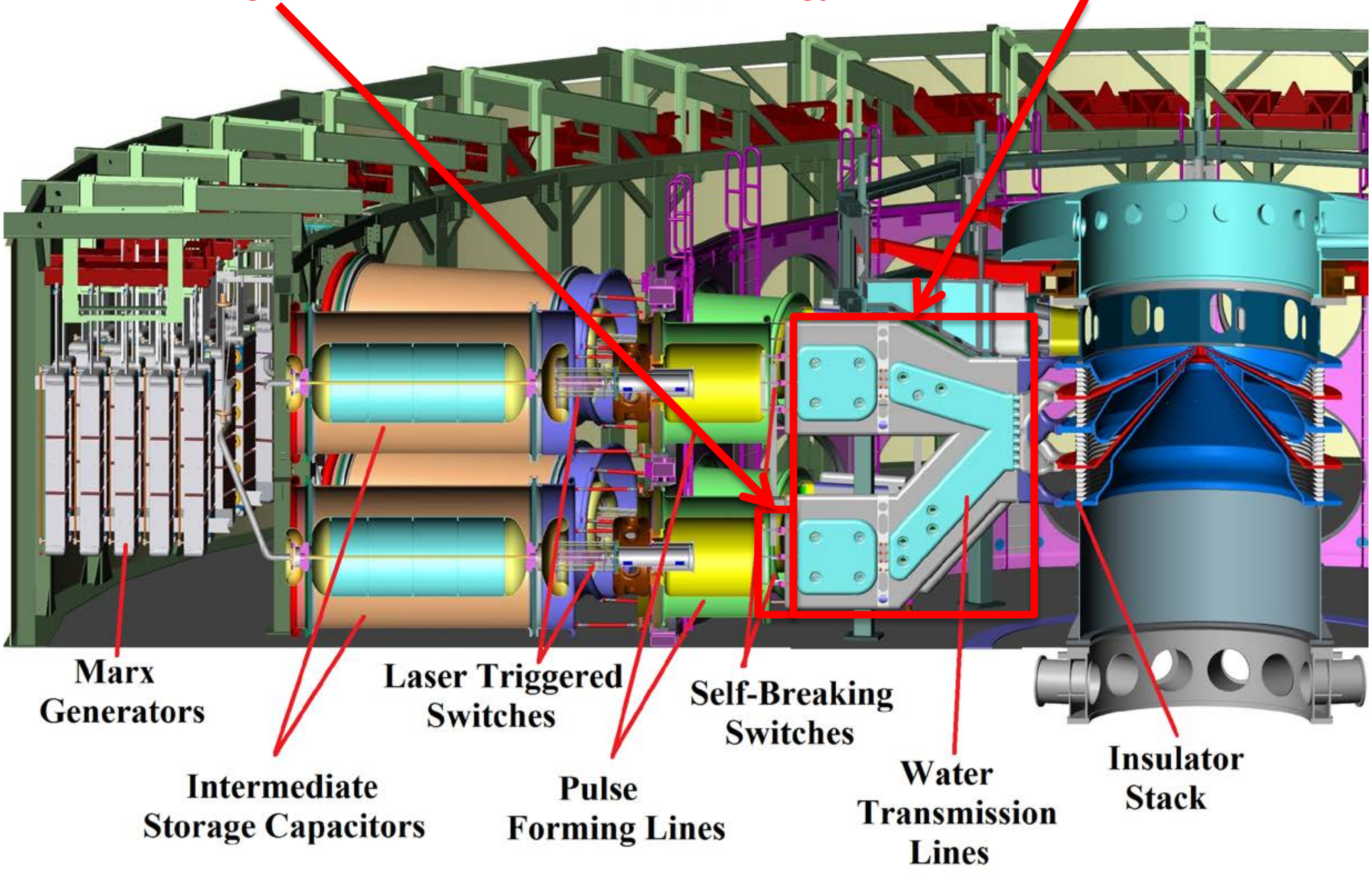
A quick review of Z's pulsed power

Laser-triggered gas switches transfer energy to pulse forming lines (pulse compression)



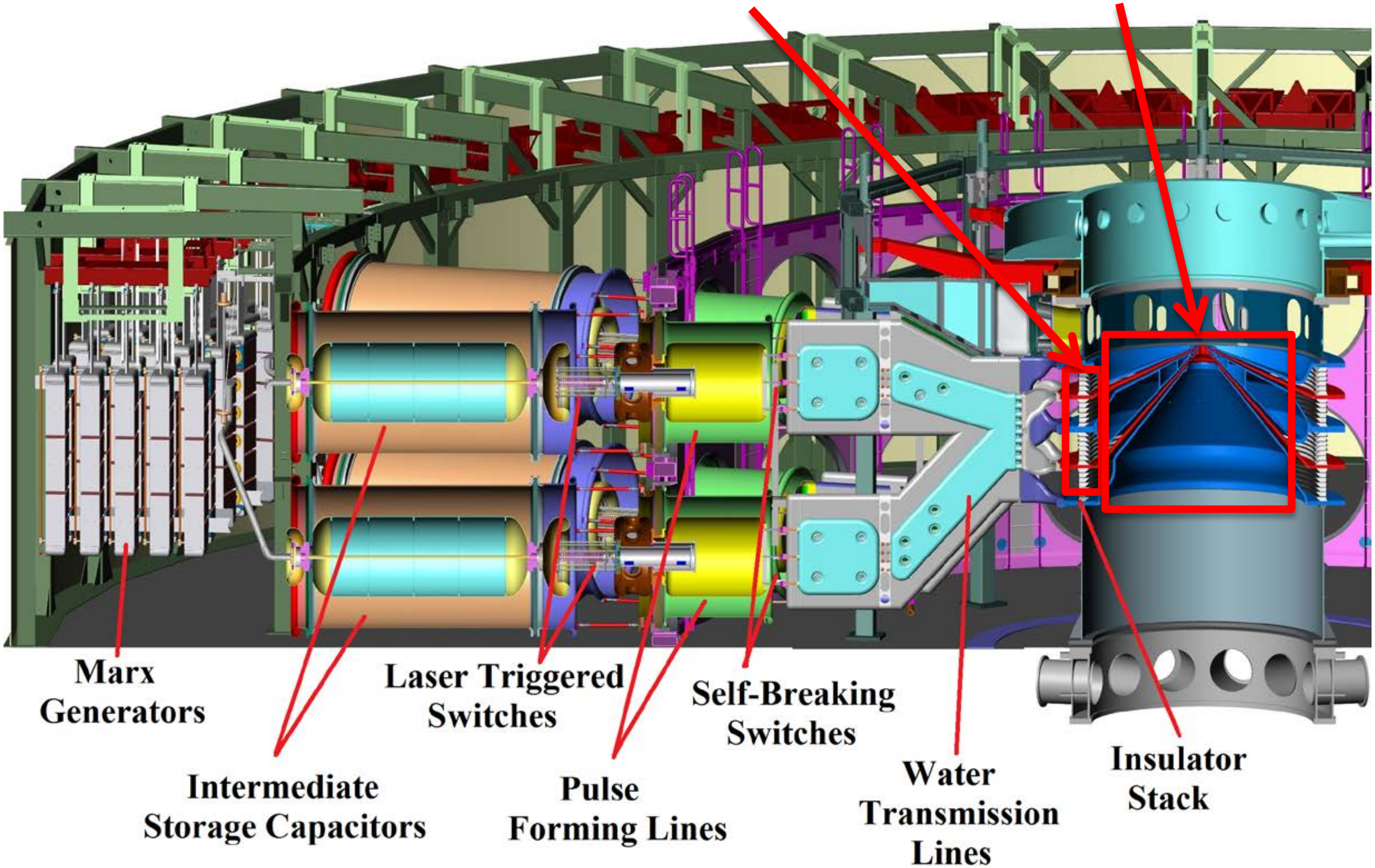
A quick review of Z's pulsed power

Self-breaking water switches transfer energy to water transmission lines



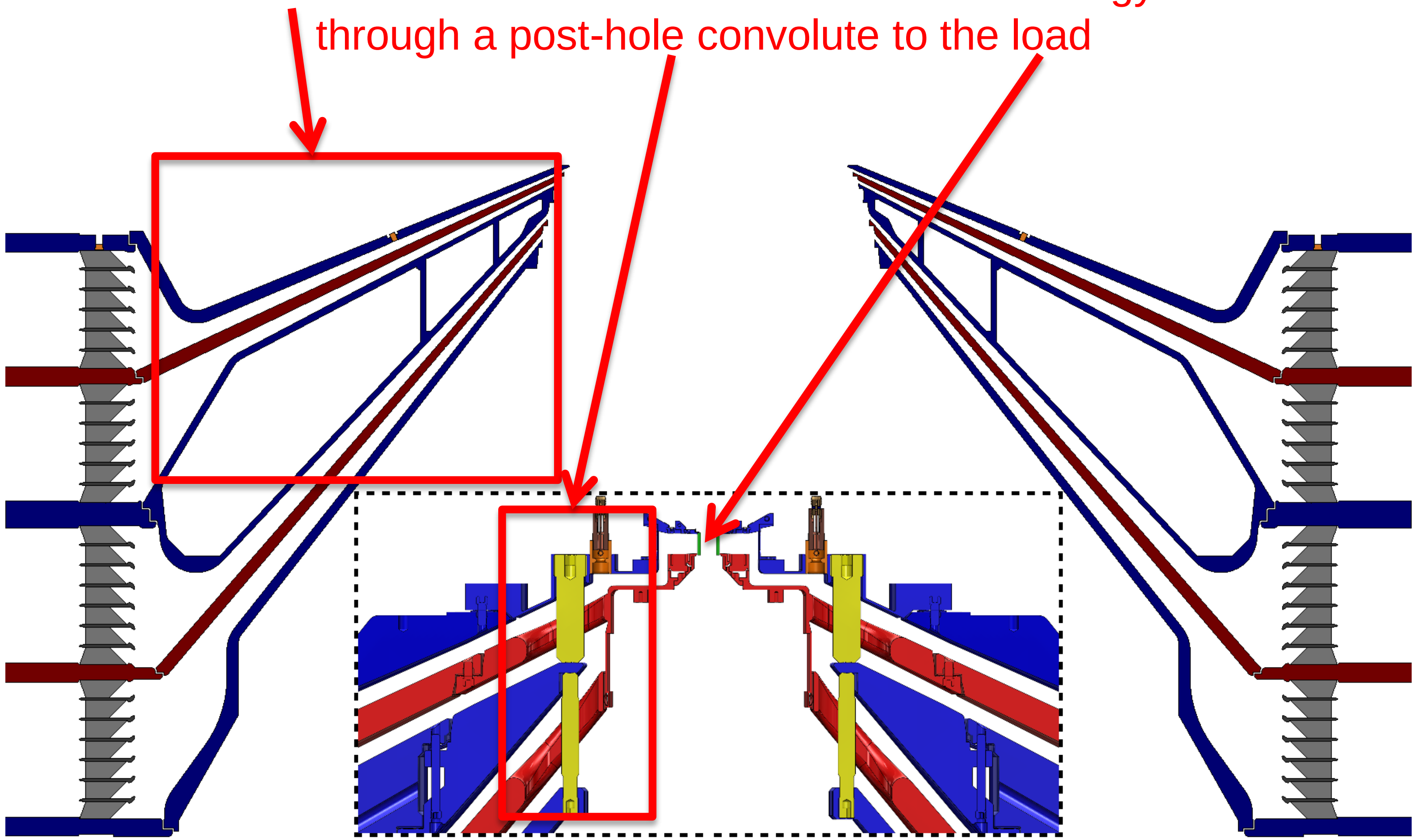
A quick review of Z's pulsed power

Energy is passed through insulating stack into vacuum section

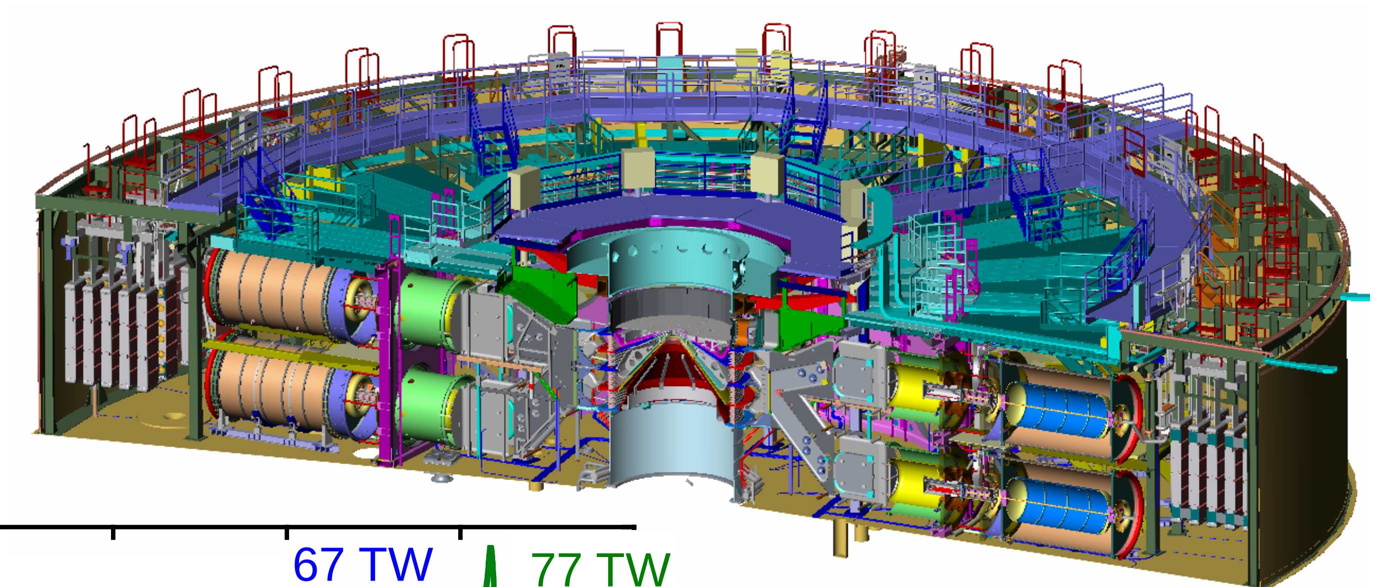


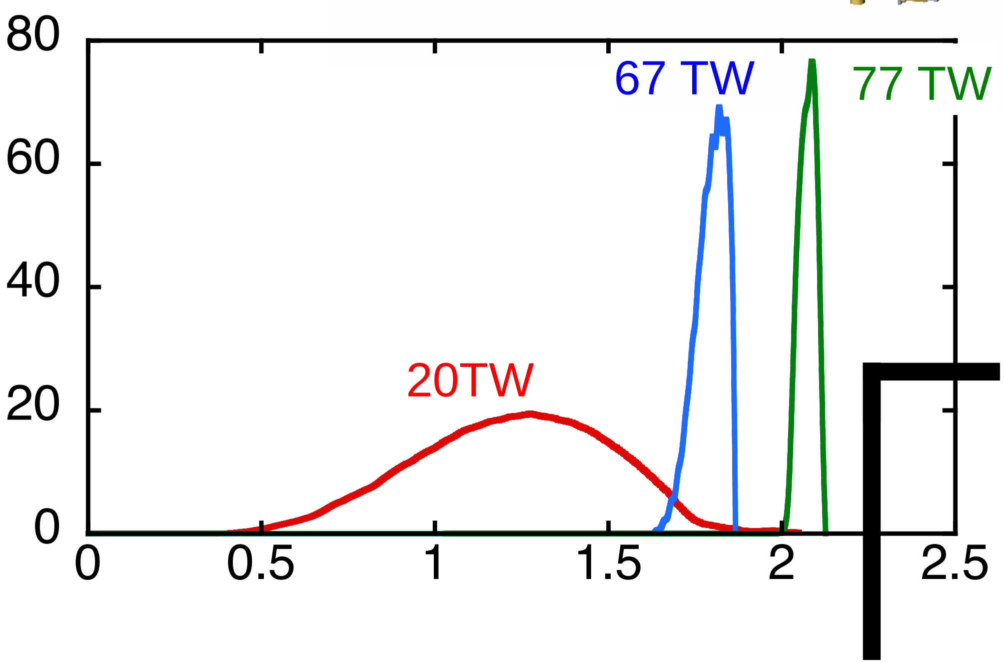
A quick review of Z's pulsed power

Four vacuum transmission lines transfer energy through a post-hole convolute to the load



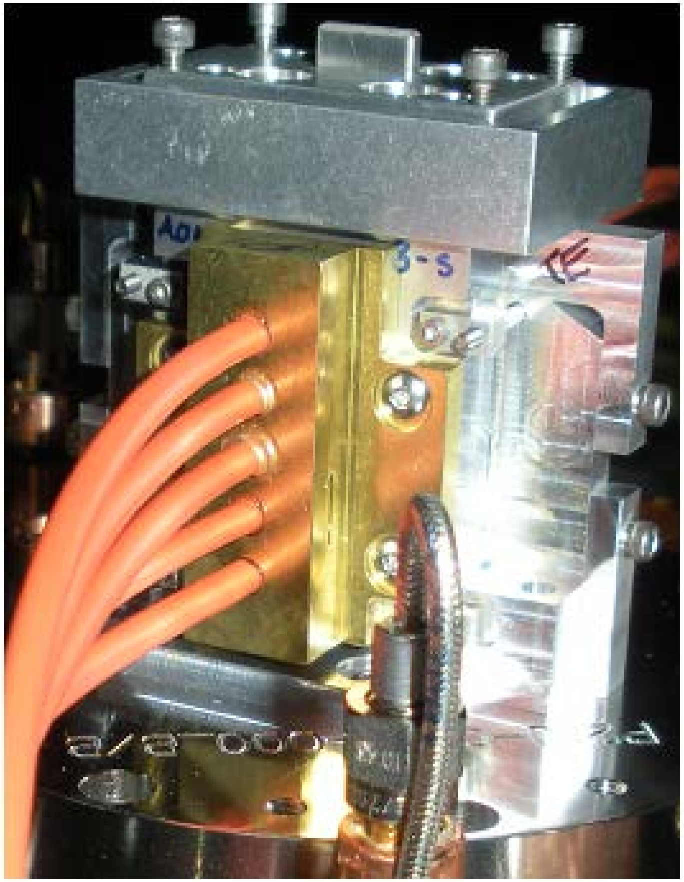
A quick review of Z's pulsed power



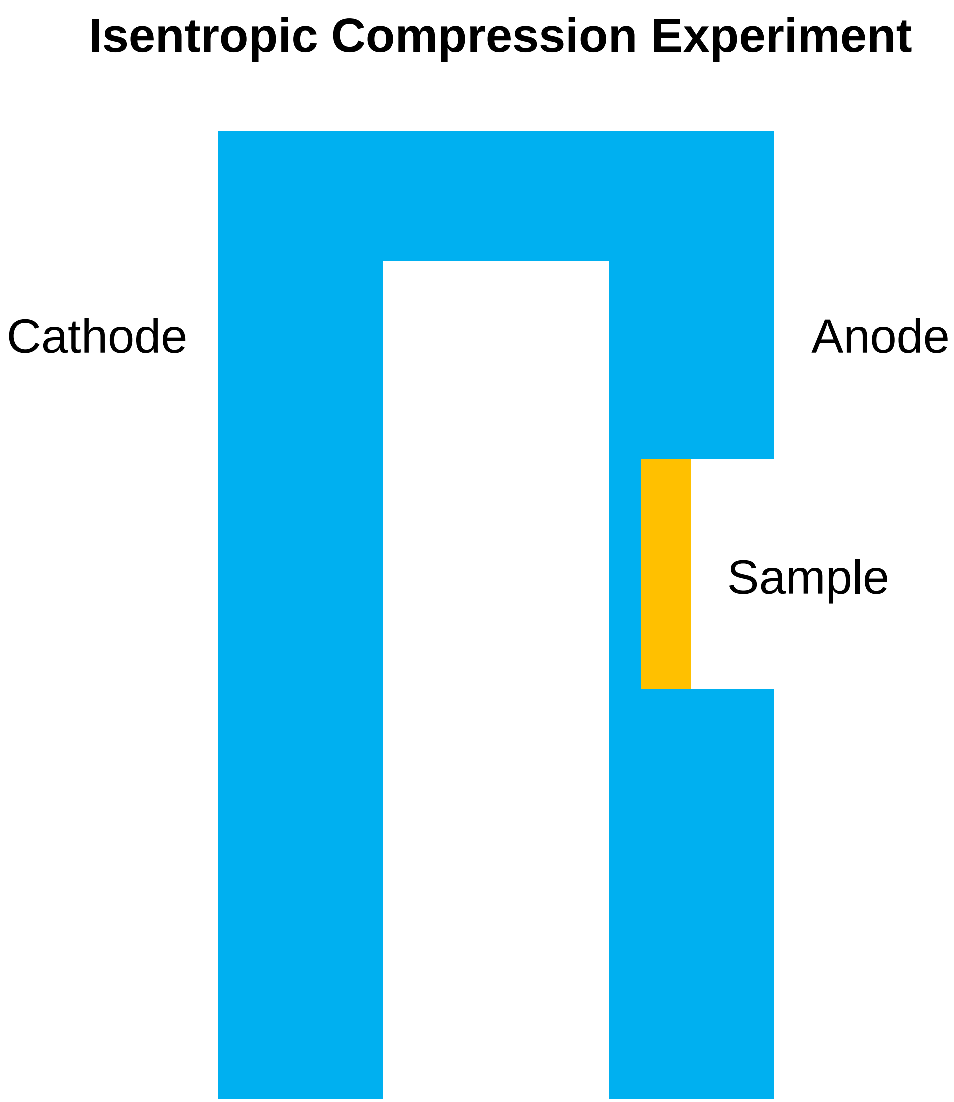


Many types of magnetically-driven HED experiments are conducted at the Z facility

- Dynamic material physics
- Radiation effects
- Inertial confinement fusion
- Basic science

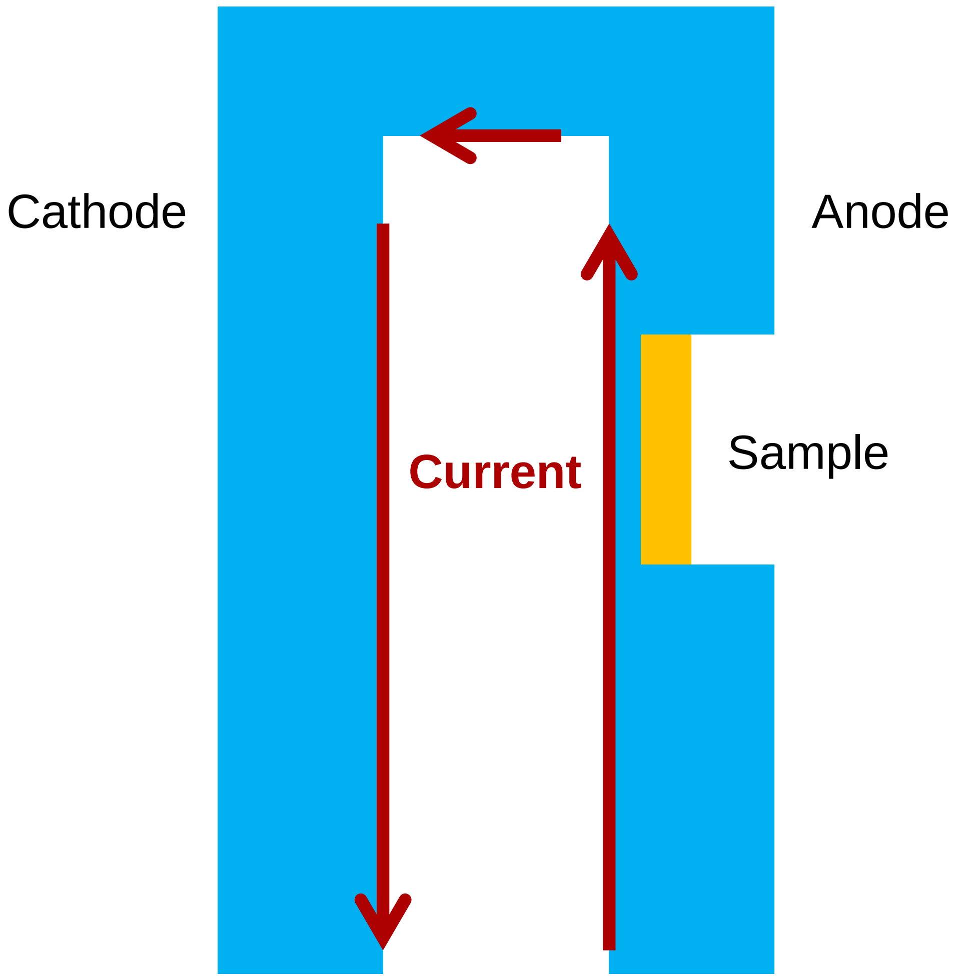


DMP experimental configurations



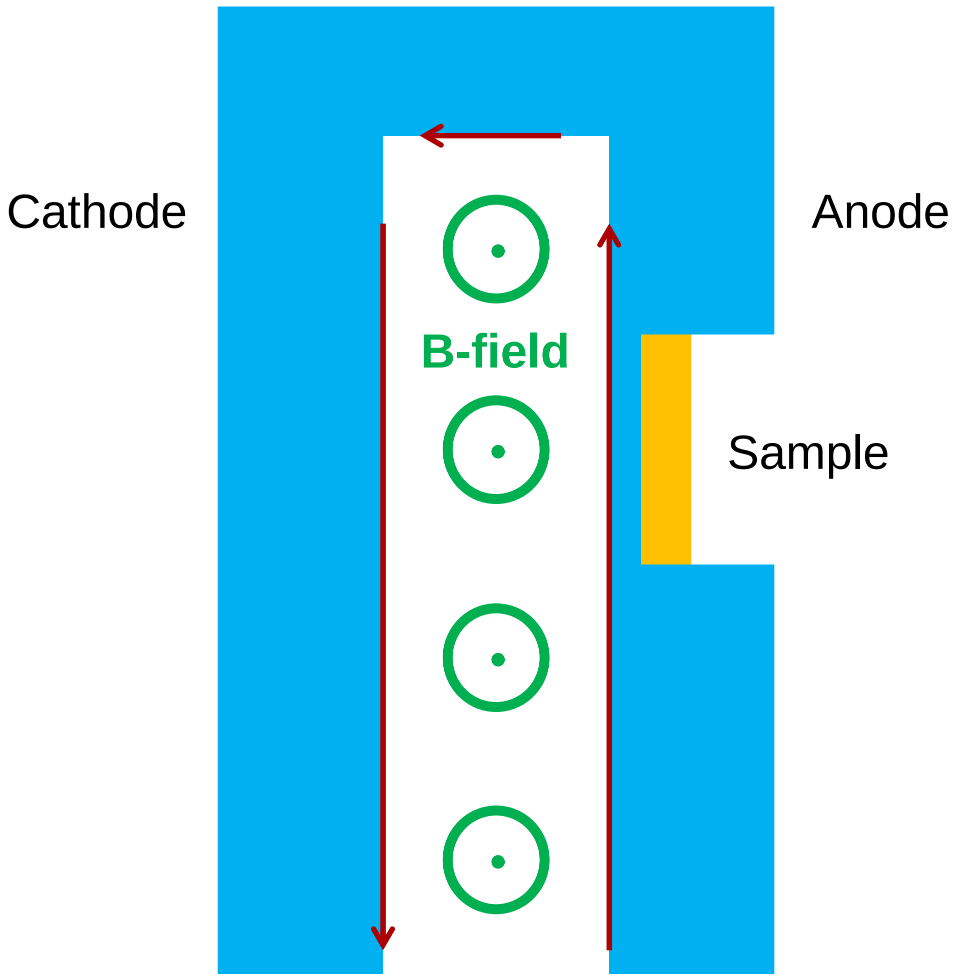
DMP experimental configurations

Isentropic Compression Experiment



DMP experimental configurations

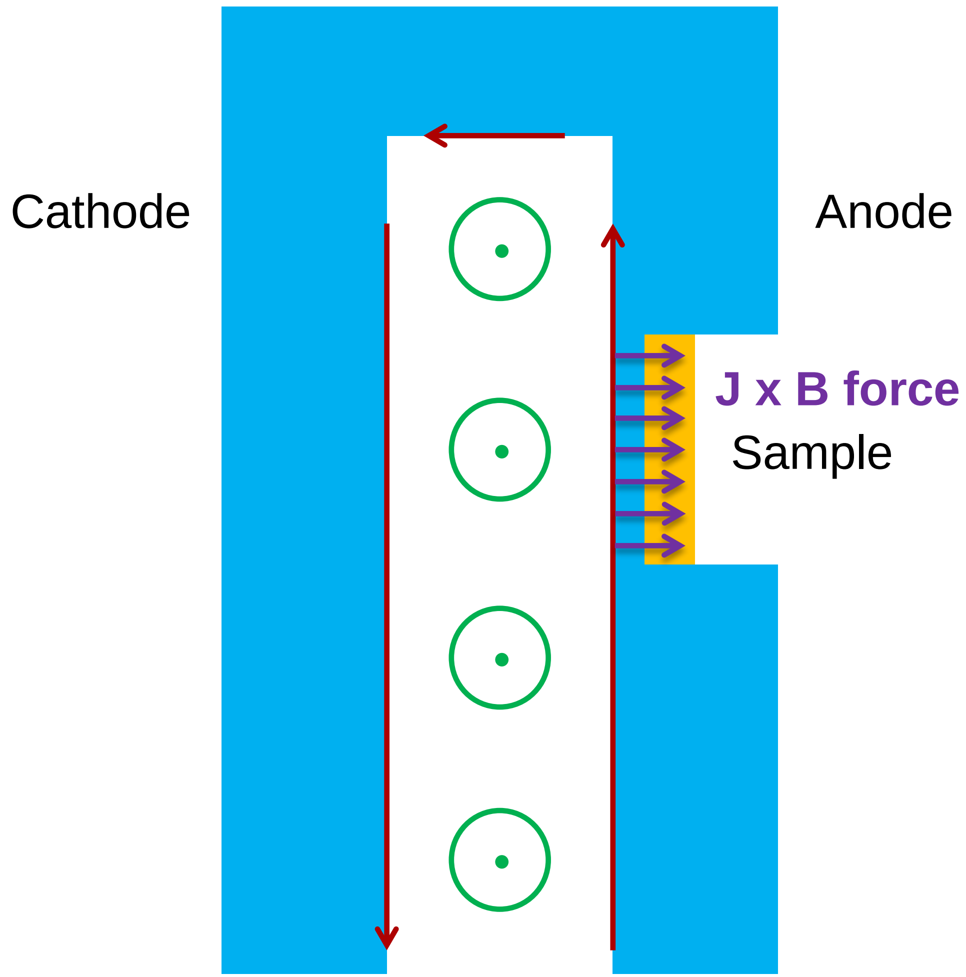
Isentropic Compression Experiment



DMP experimental configurations

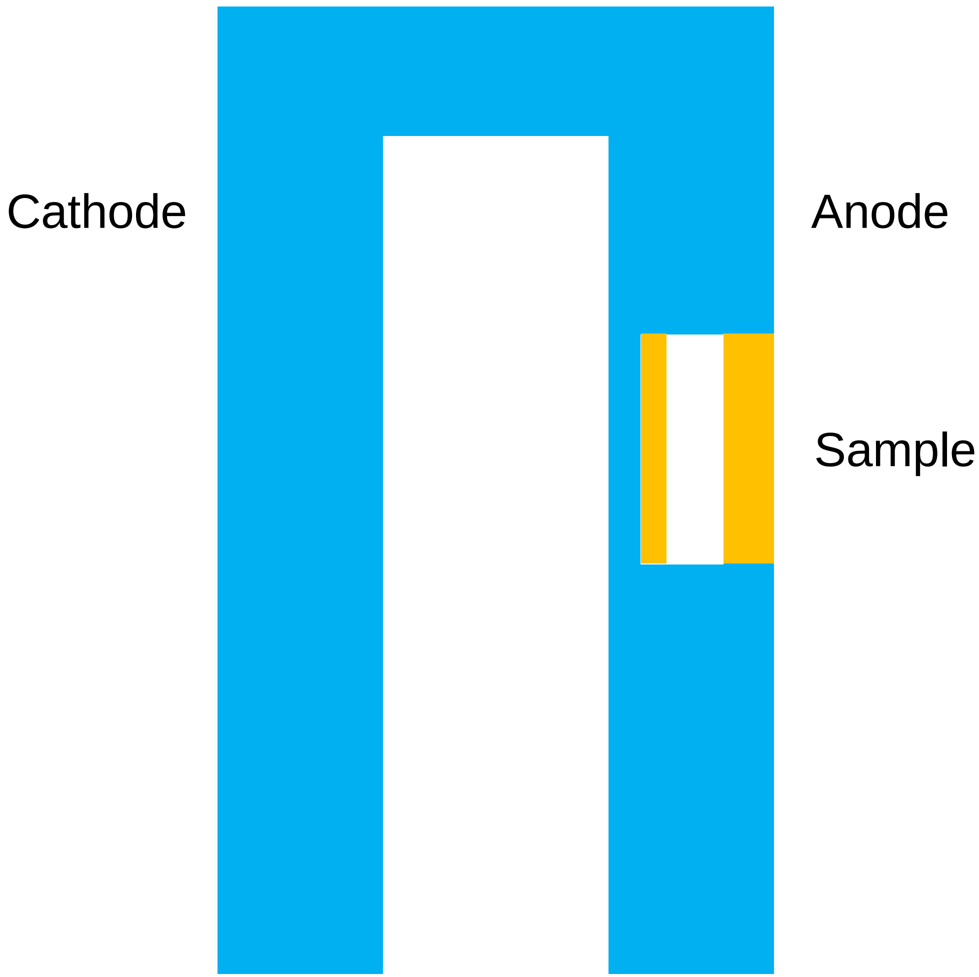
Sandia National Laboratories

Isentropic Compression Experiment



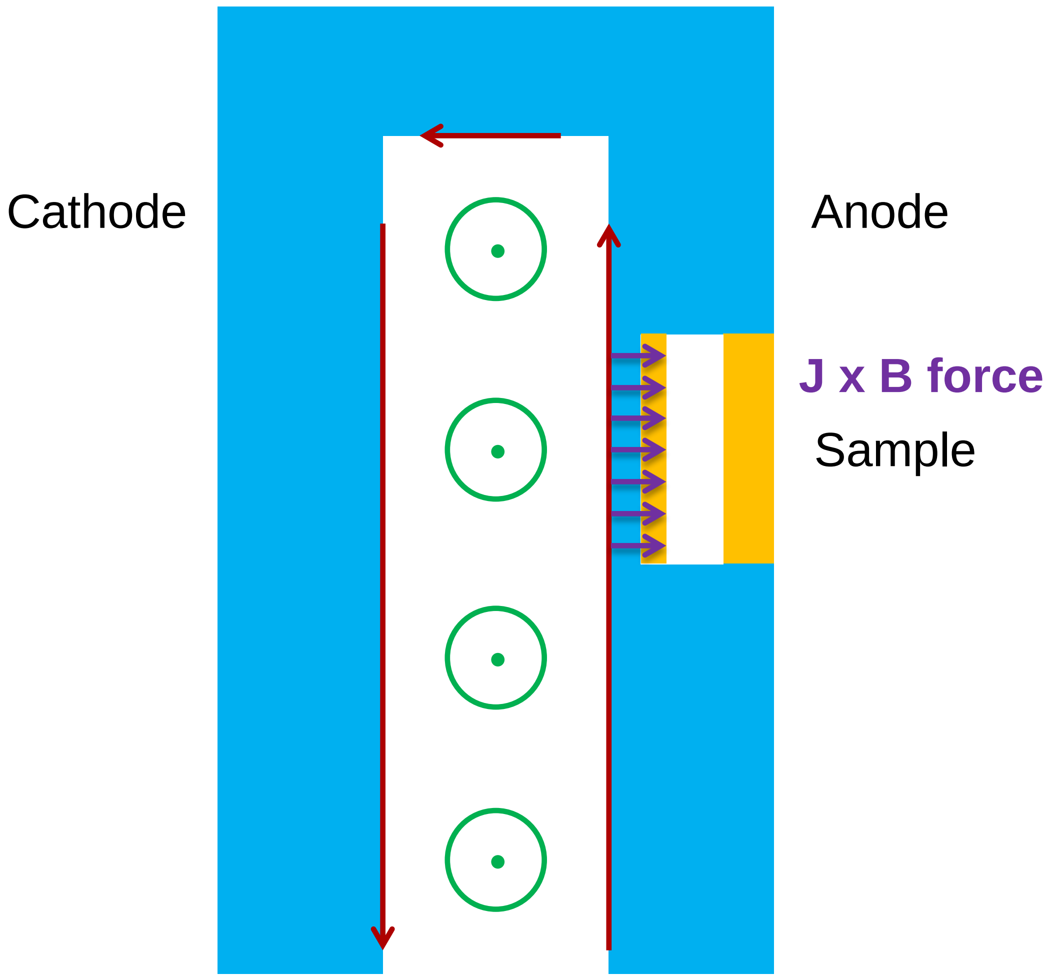
DMP experimental configurations

Flyer Plate Experiment

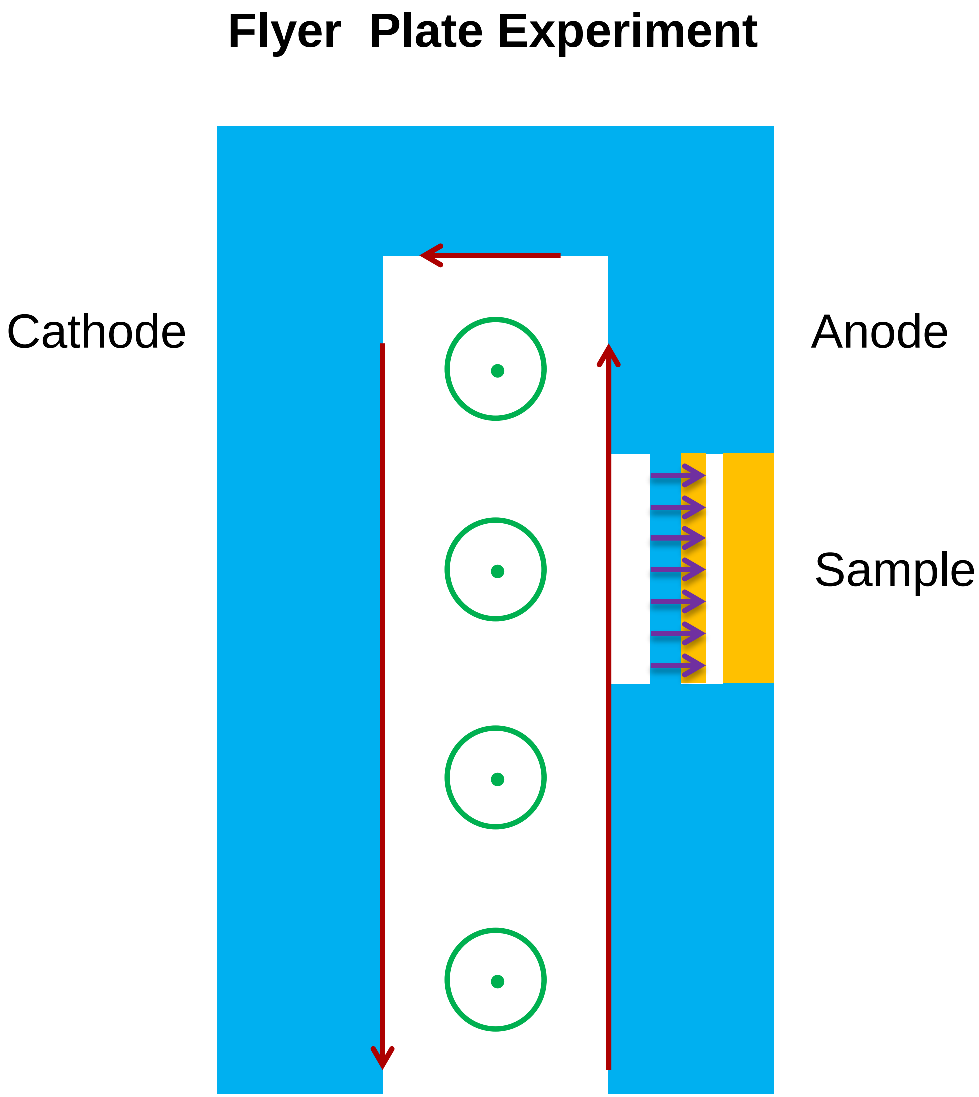


DMP experimental configurations

Flyer Plate Experiment

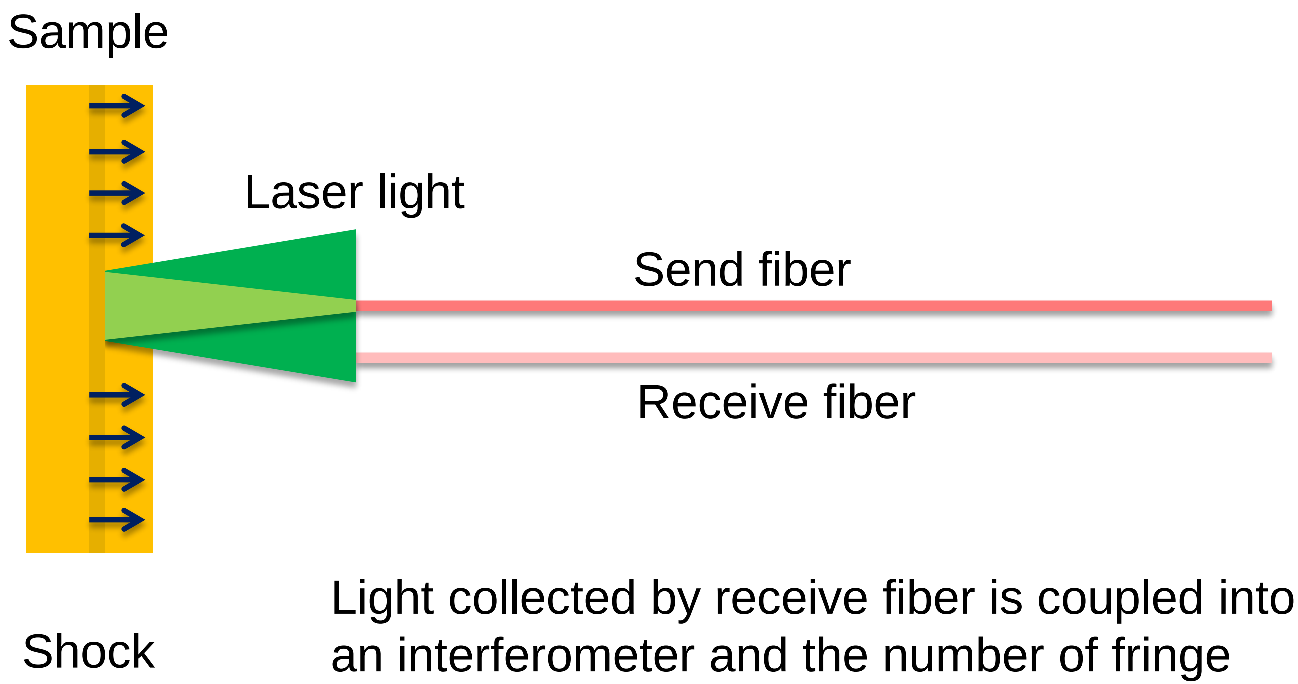


DMP experimental configurations



DMP diagnostics

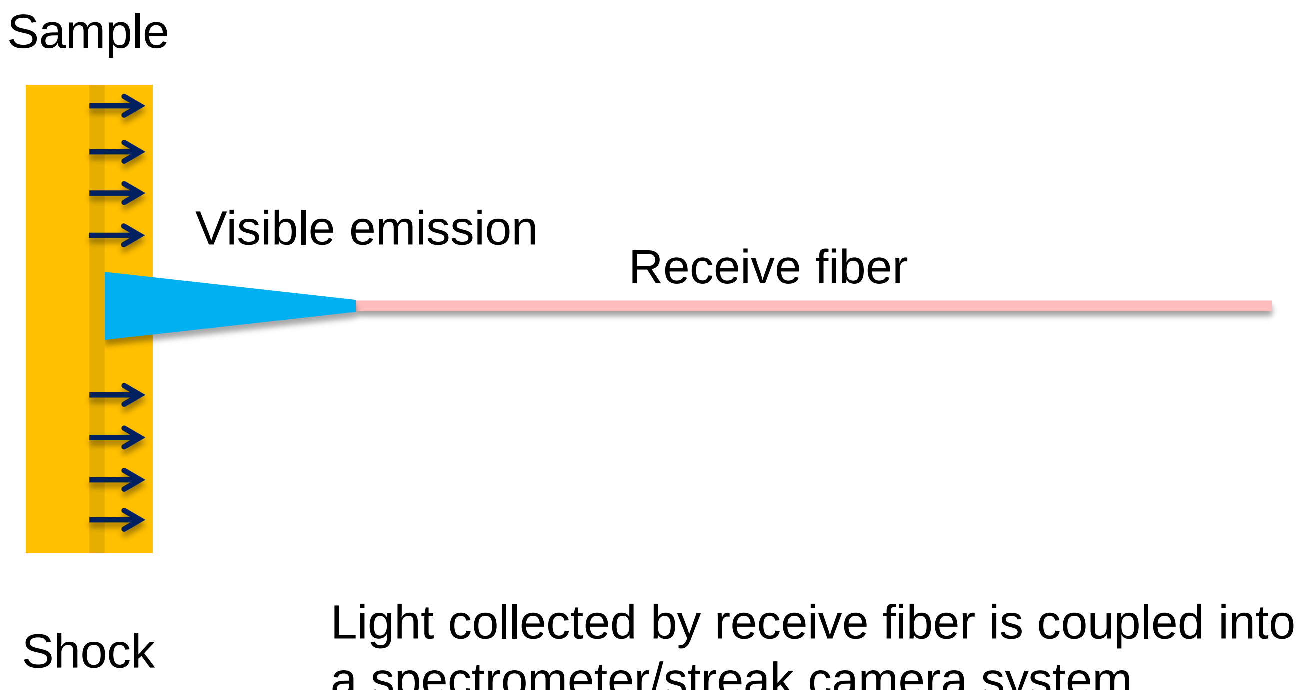
- VISAR – Velocity Interferometer System for Any Reflector



Light collected by receive fiber is coupled into an interferometer and the number of fringe shifts is used to unfold the shock velocity

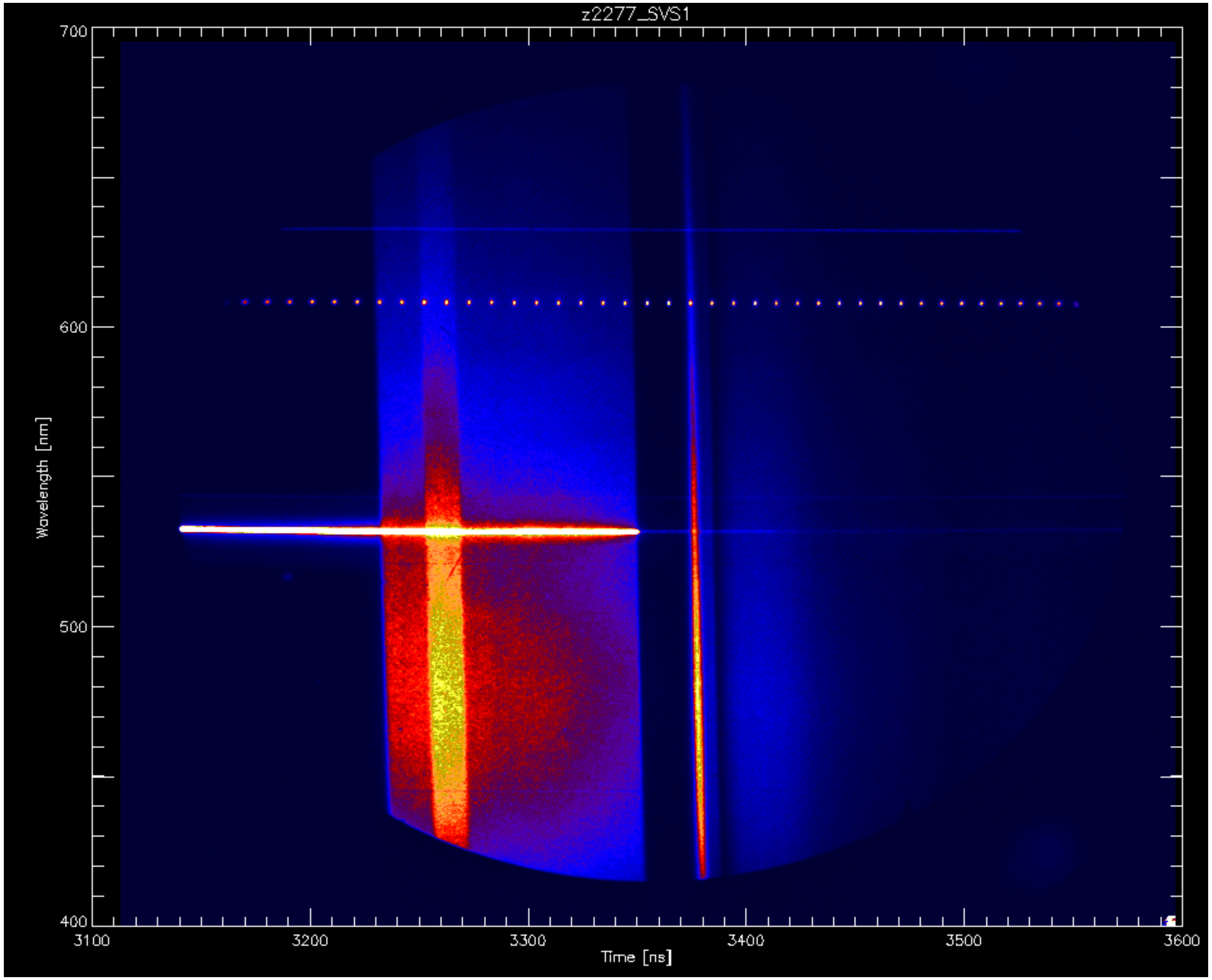
DMP diagnostics

- Optical pyrometry – Spectrally and temporally resolved visible emission

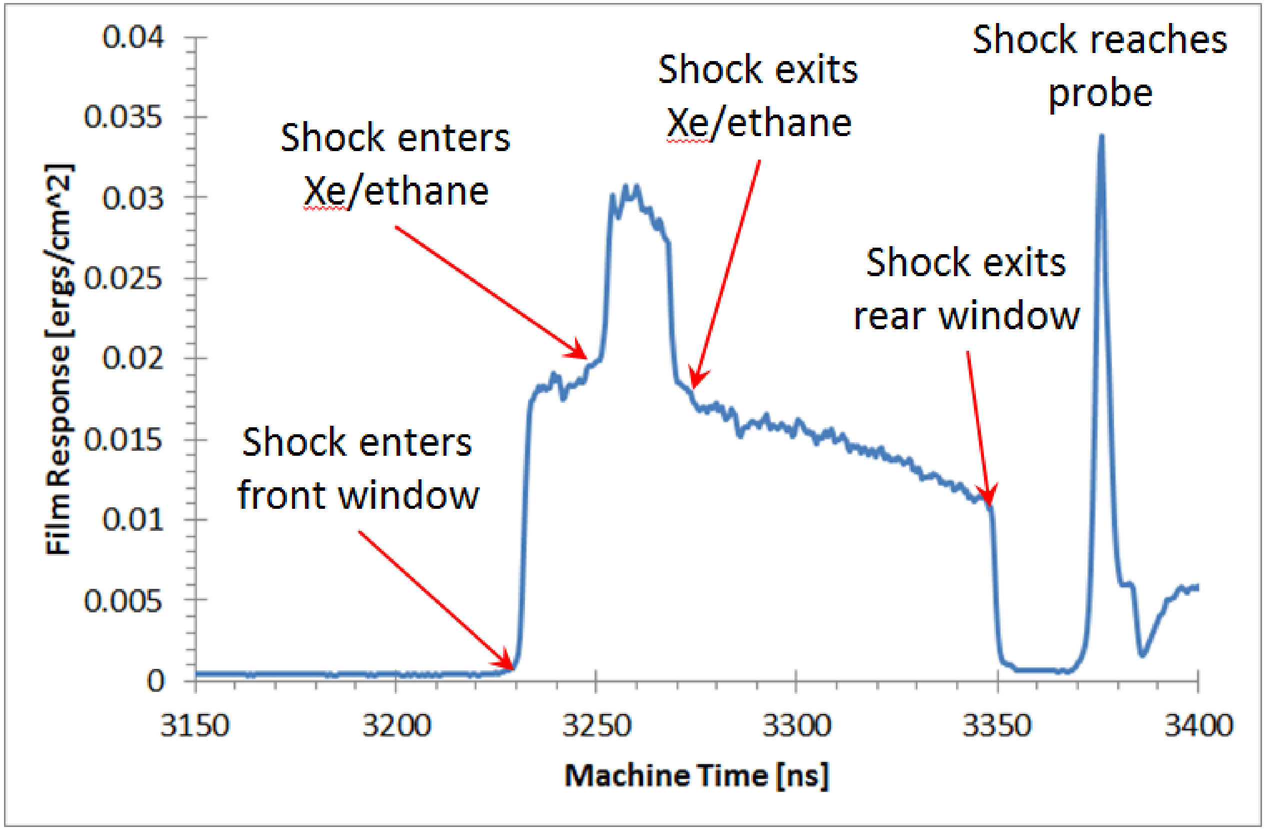


Light collected by receive fiber is coupled into a spectrometer/streak camera system

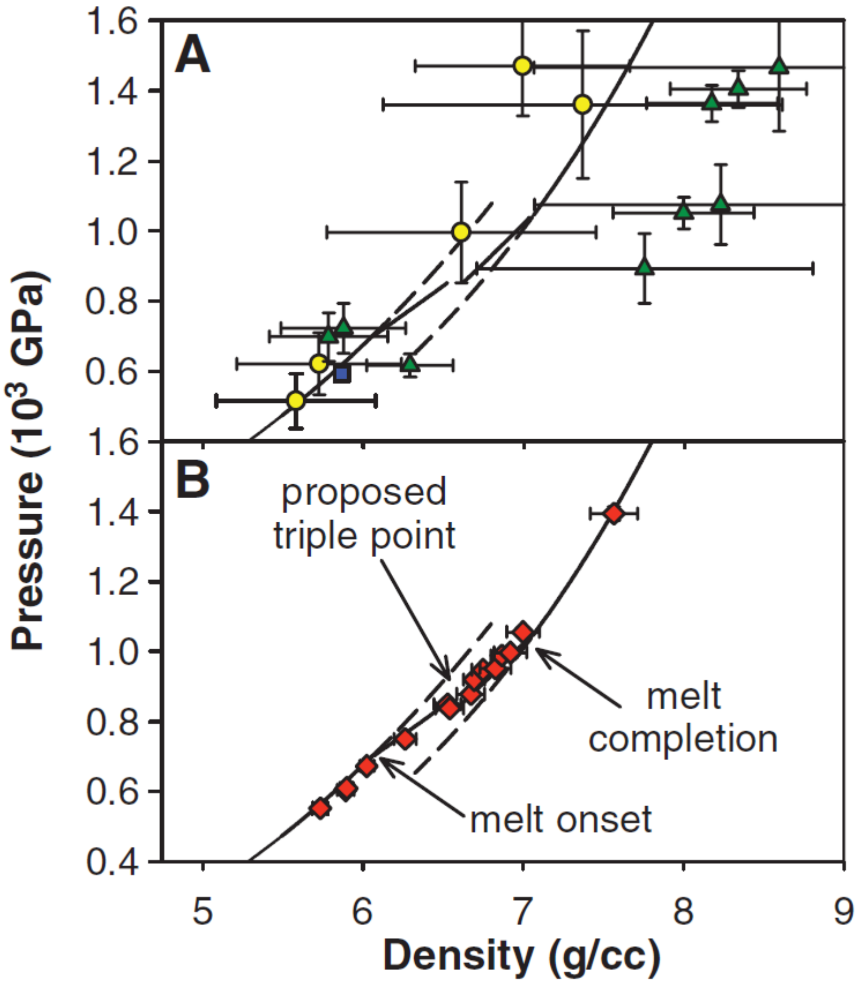
Sample Optical Pyrometry Data



Sample Optical Pyrometry Data



Notable result from DMP experiments on Z

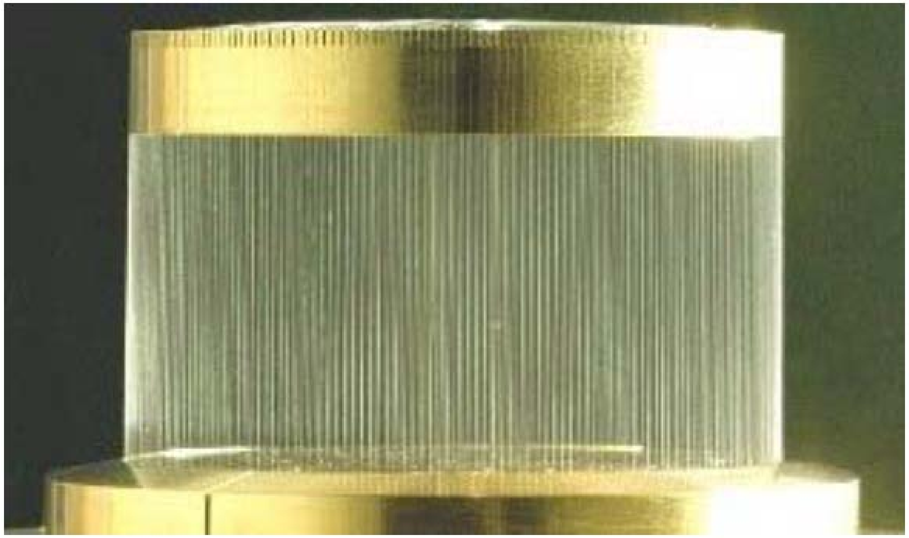


Carbon EOS measurements on Z confirmed the existence of a theoretically predicted diamond-BC8-liquid triple point

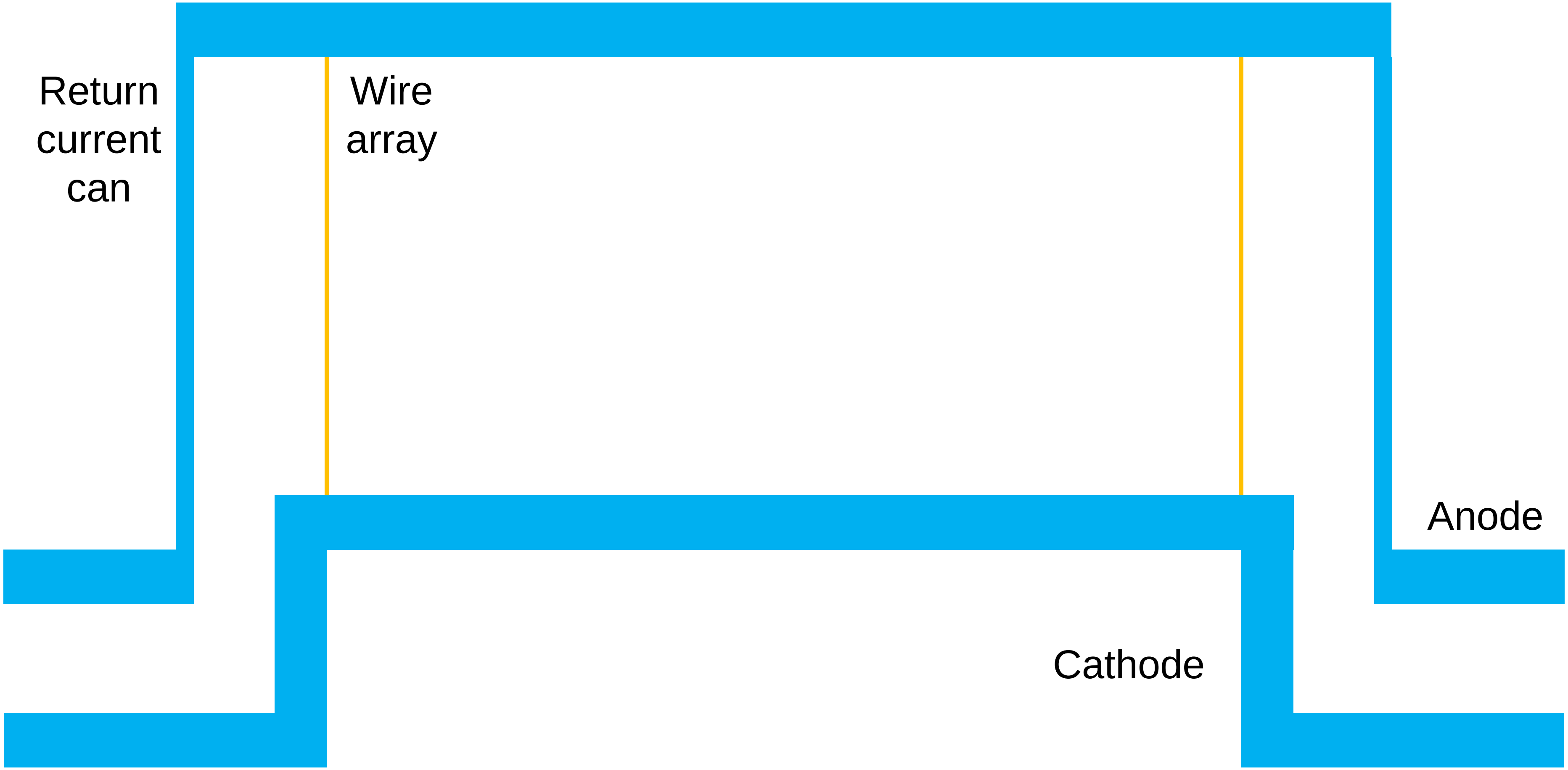
Previous measurements could not prove/disprove the existence of the triple point due to large uncertainties associated with small sample sizes

Many types of magnetically-driven HED experiments are conducted at the Z facility

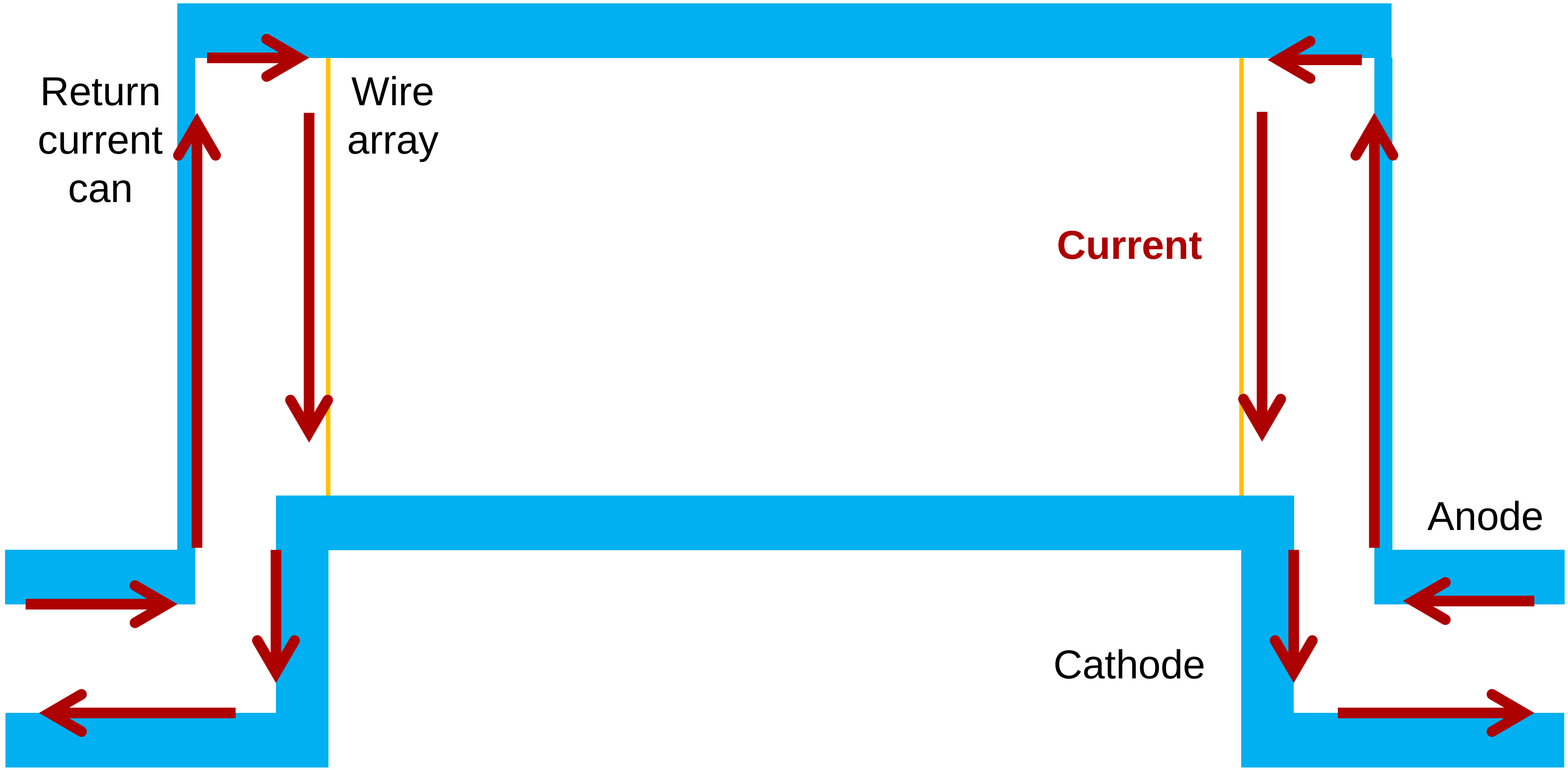
- Dynamic material physics
- Radiation effects
- Inertial confinement fusion
- Basic science



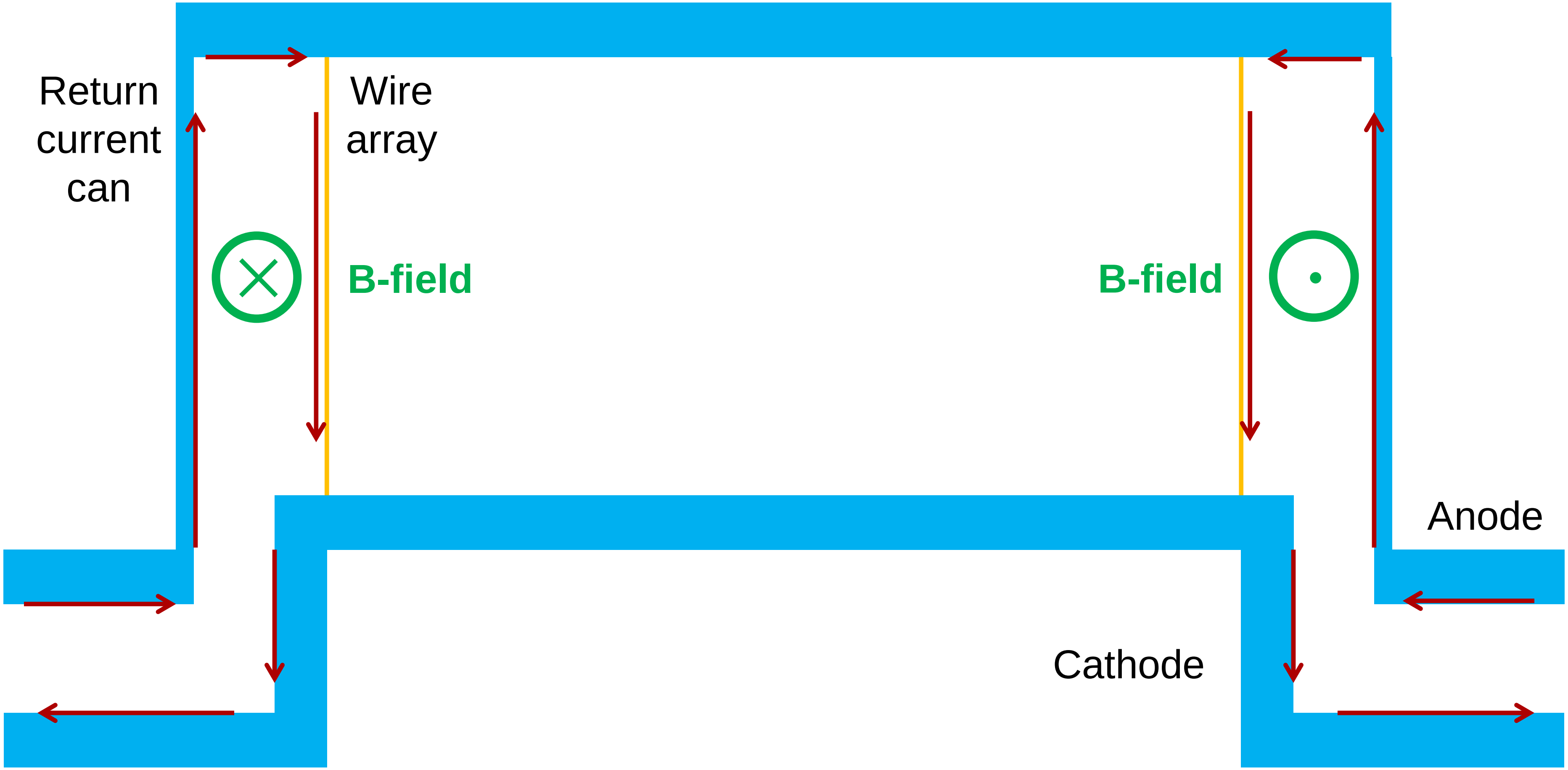
Radiation effects experimental configuration



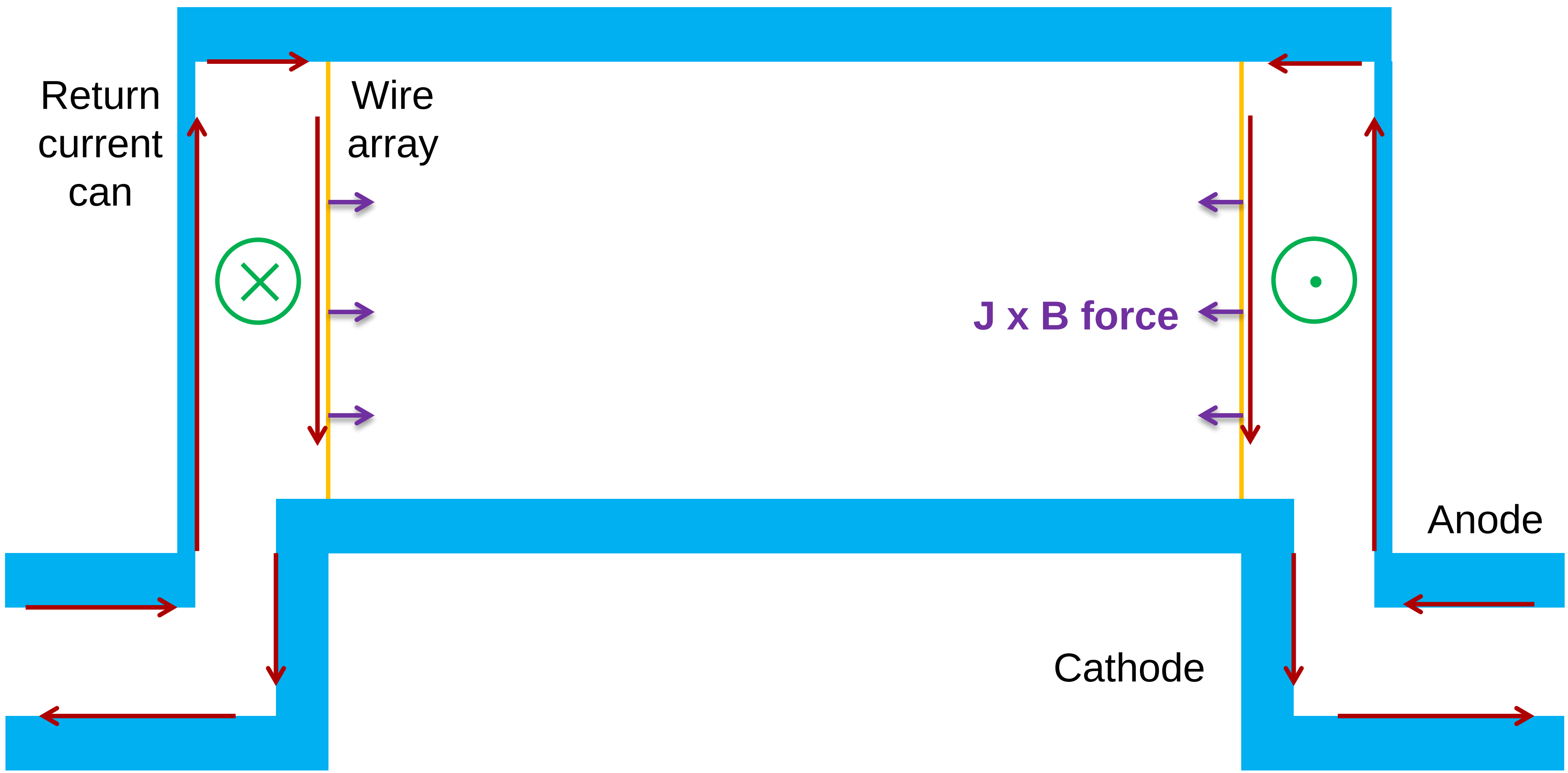
Radiation effects experimental configuration



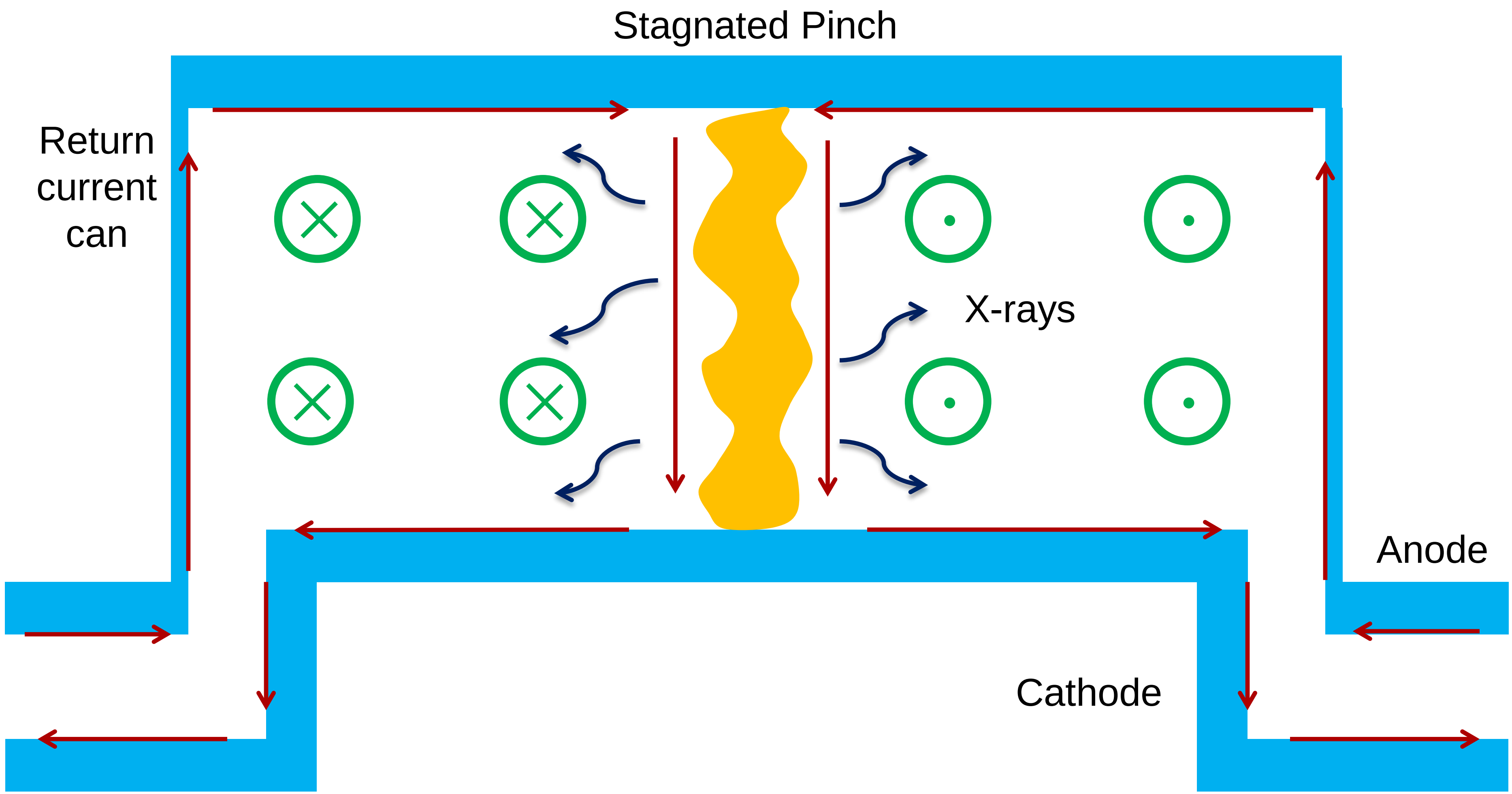
Radiation effects experimental configuration



Radiation effects experimental configuration

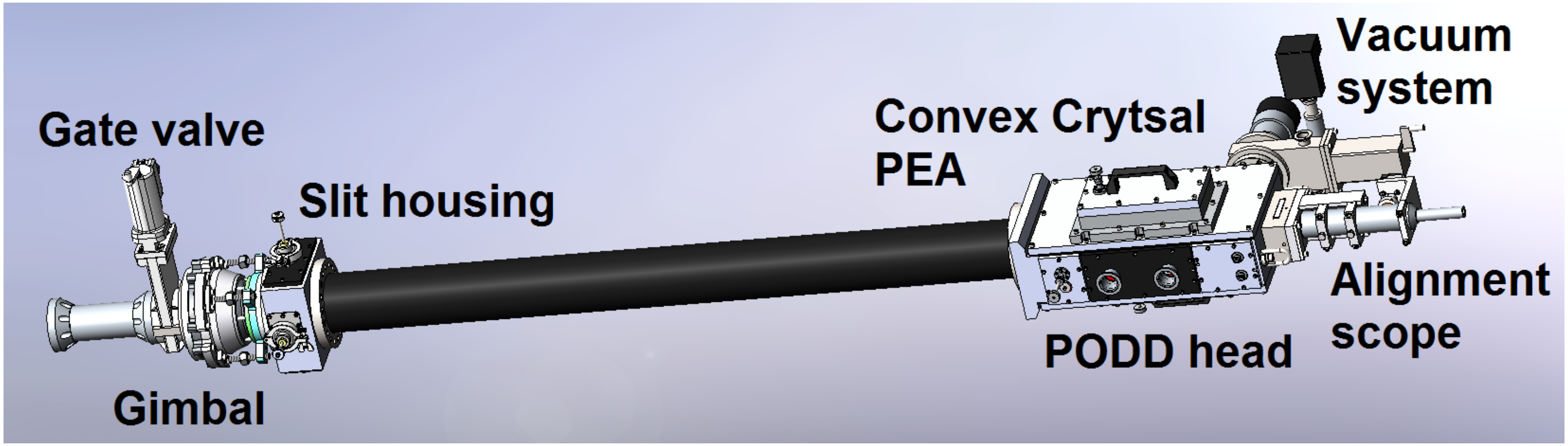


Radiation effects experimental configuration

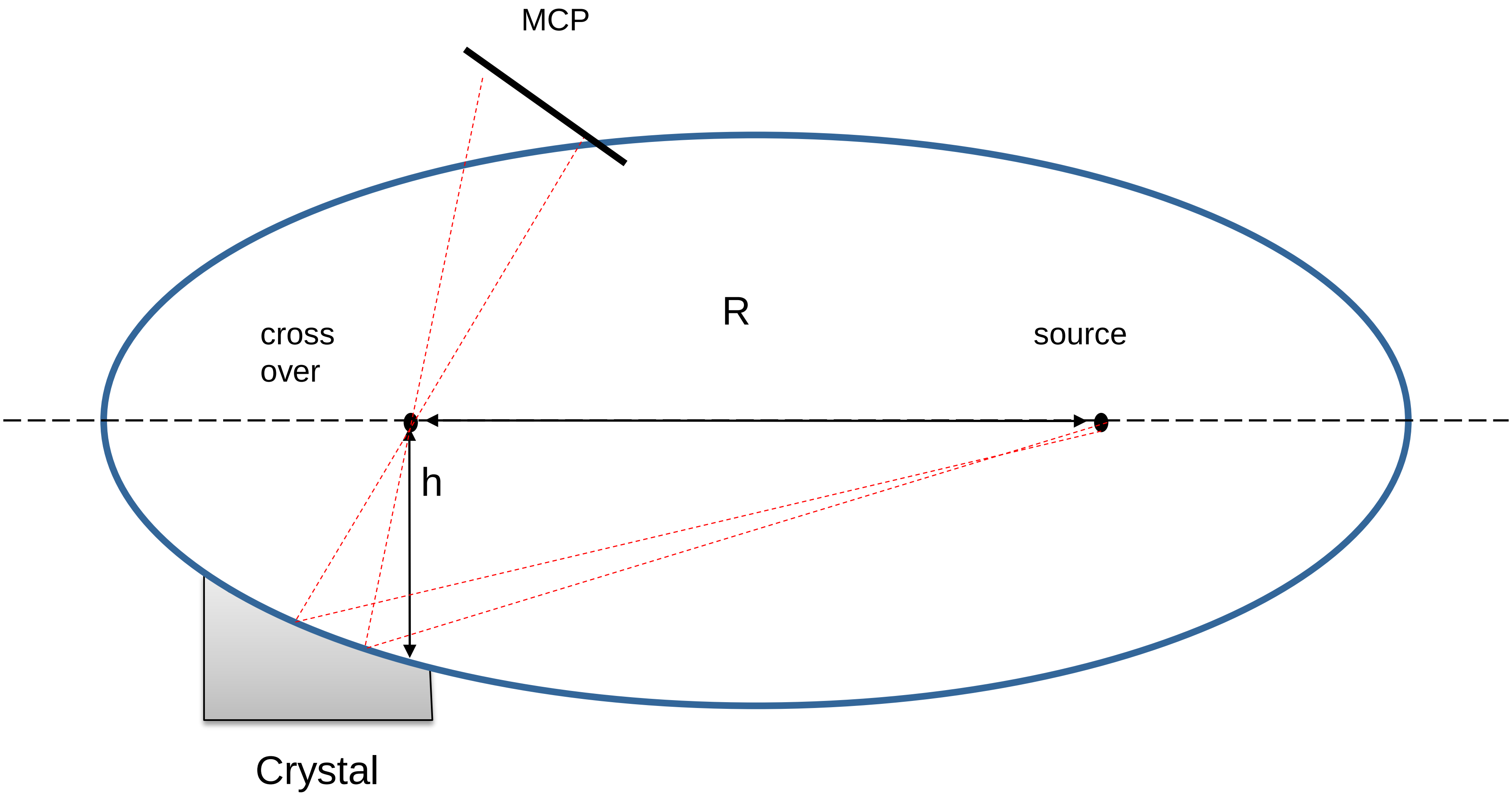


X-ray diagnostics

- Pinned Optically-aligned Diagnostic Dock
  - Monochromatic x-ray pinhole imaging (MLM)
  - Time-resolved x-ray spectroscopy (TREX)
  - High spectral resolution spectroscopy (TIXTL)

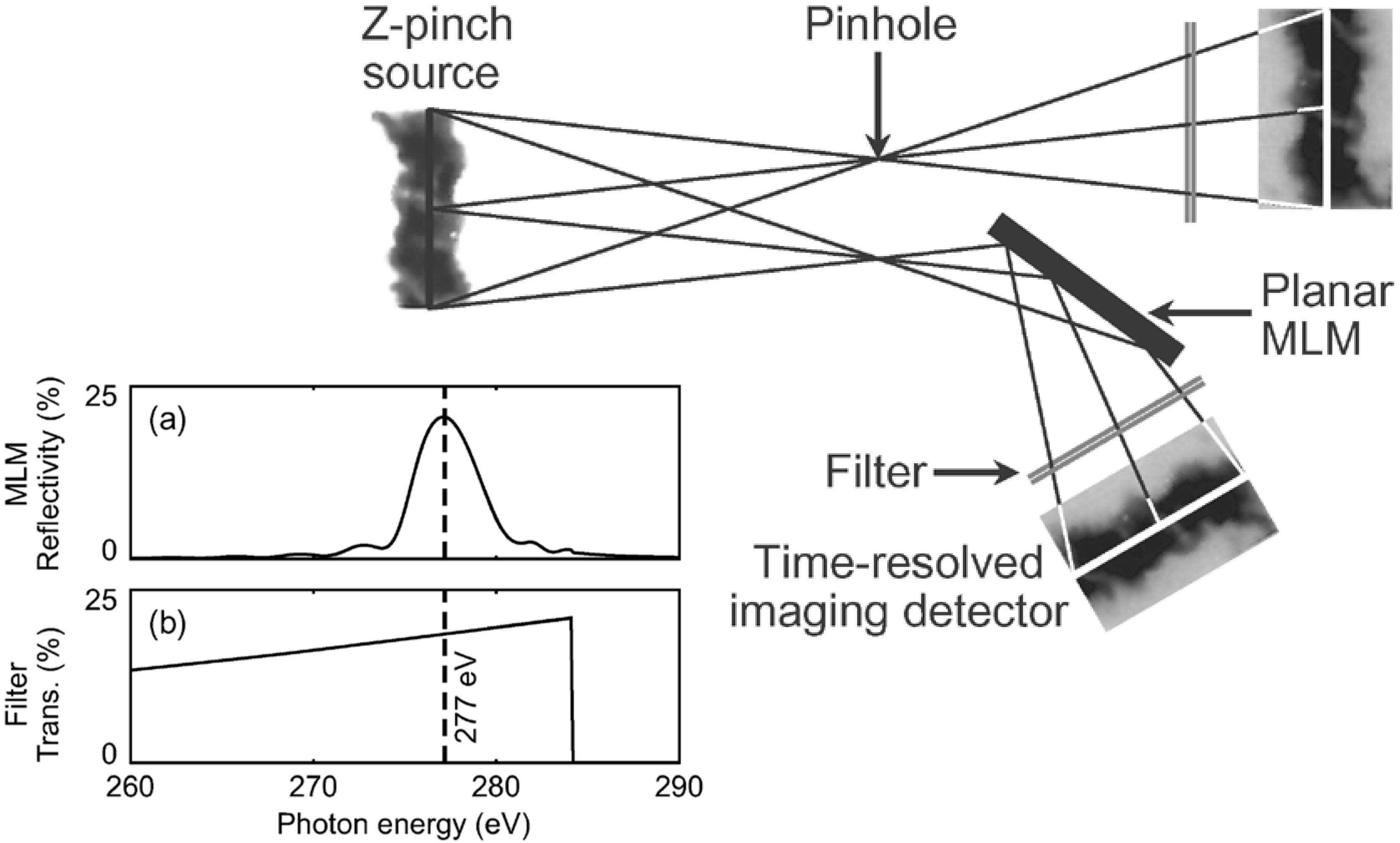


TREX diagnostic



Choice of ellipse dimensions and crystal material sets the wavelength range

MLM diagnostic



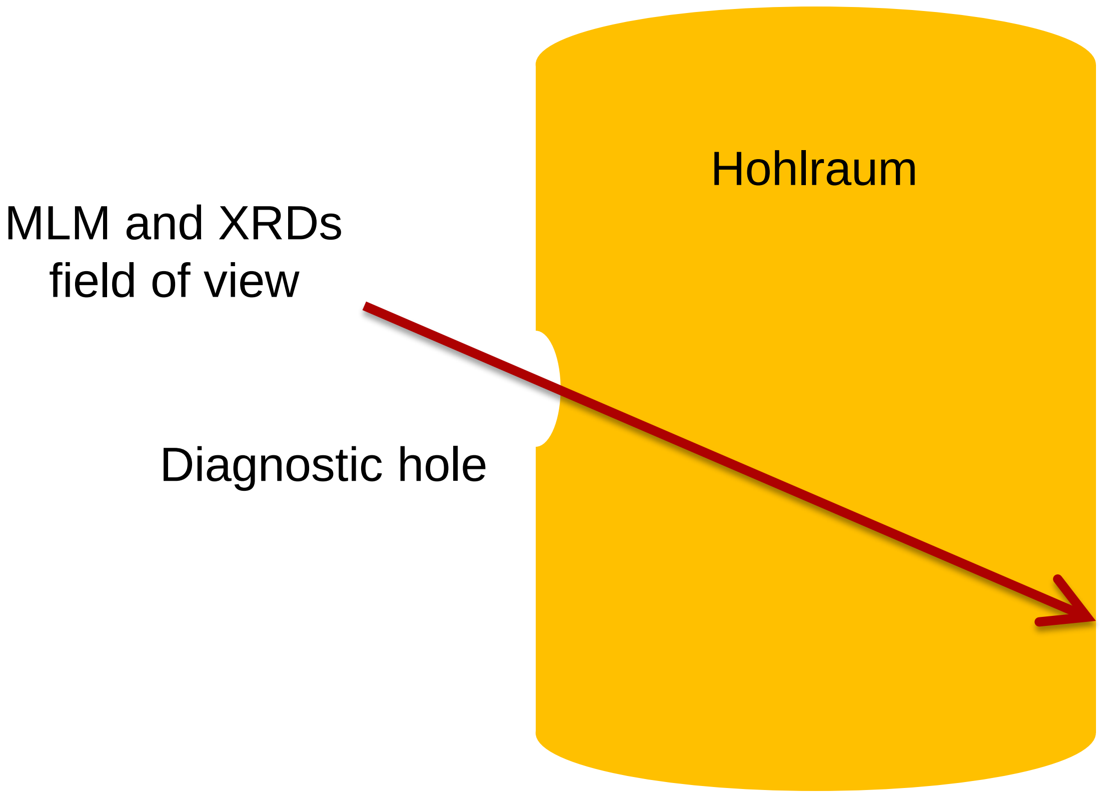
Hohlraum temperature measurements with MLM

MLM measures spatially- and temporally-resolved 277 eV emission

MLM also gives hole closure information

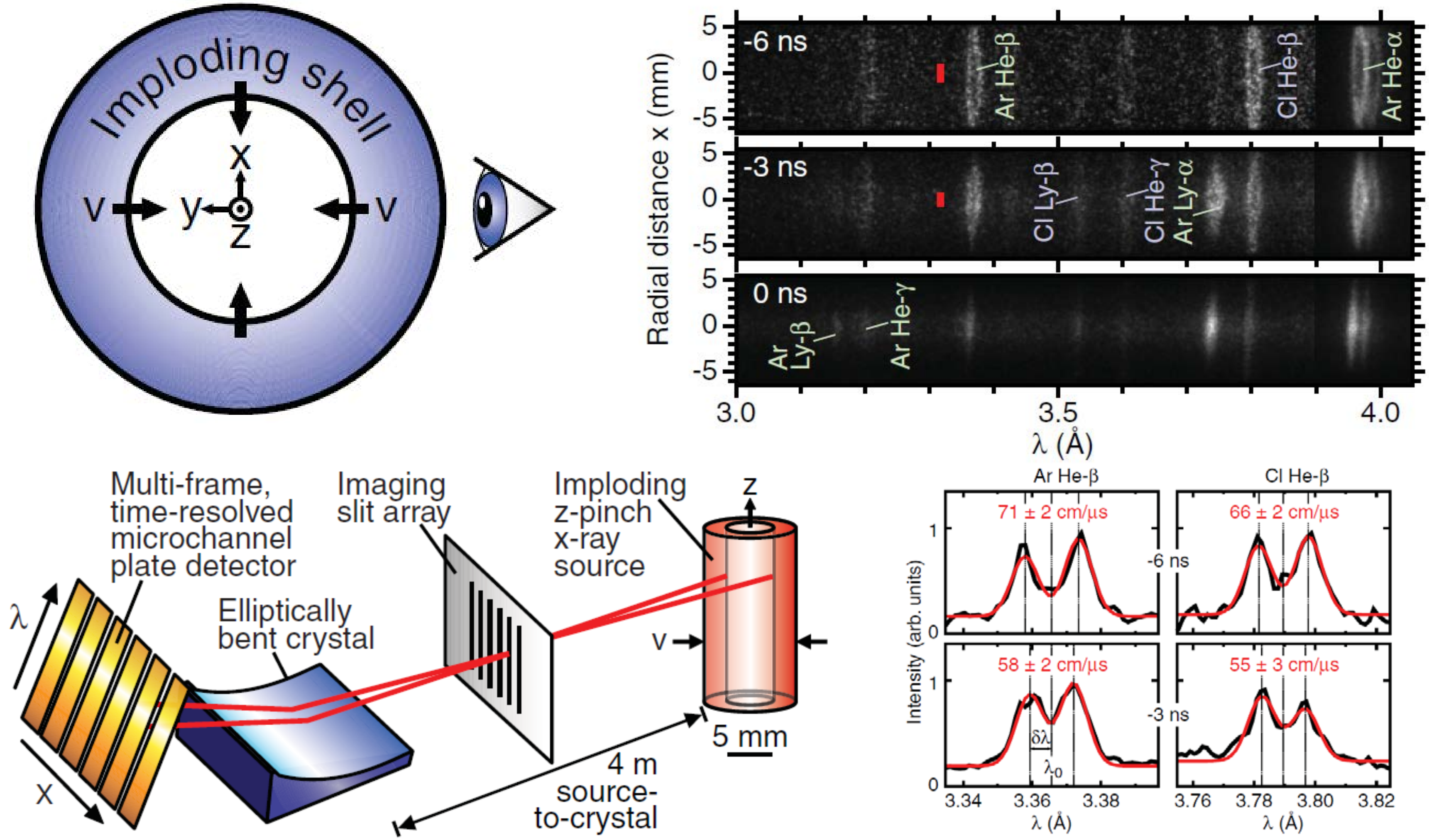
XRDs measure time-resolved, filtered x-ray emission

The information can be combined to determine hohlraum wall temperature



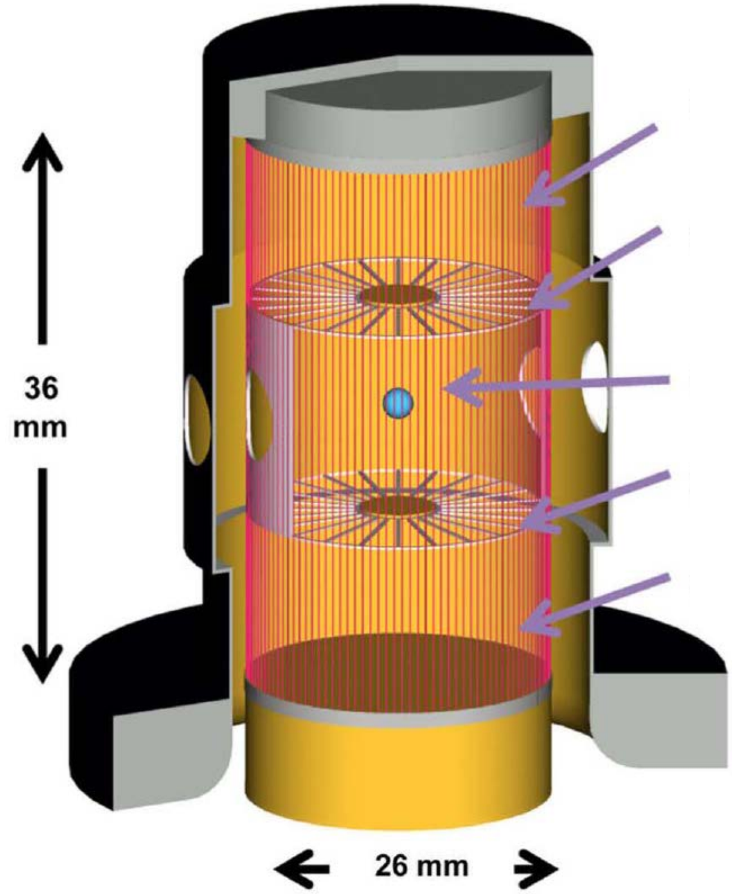
Temperature drive is important for constraining simulations

Interesting results from radiation effects experiments on Z

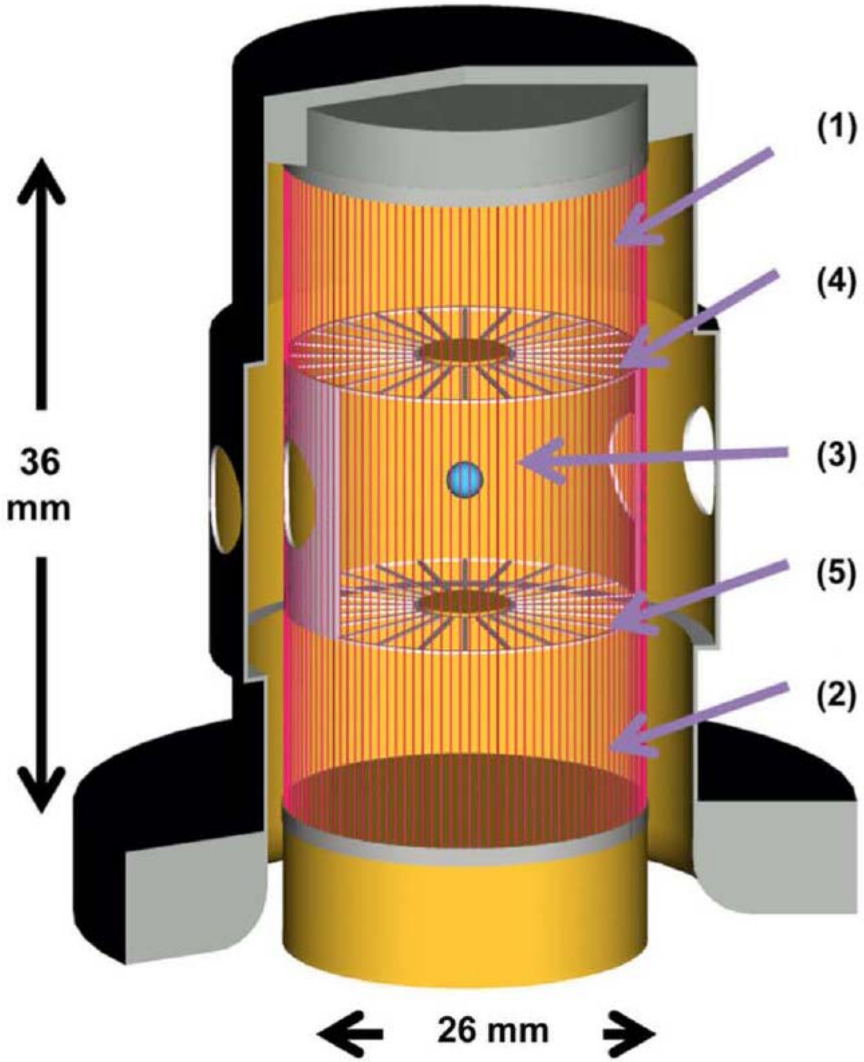


Many types of magnetically-driven HED experiments are conducted at the Z facility

- Dynamic material physics
- Radiation effects
- Inertial confinement fusion
- Basic science



ICF experimental configurations



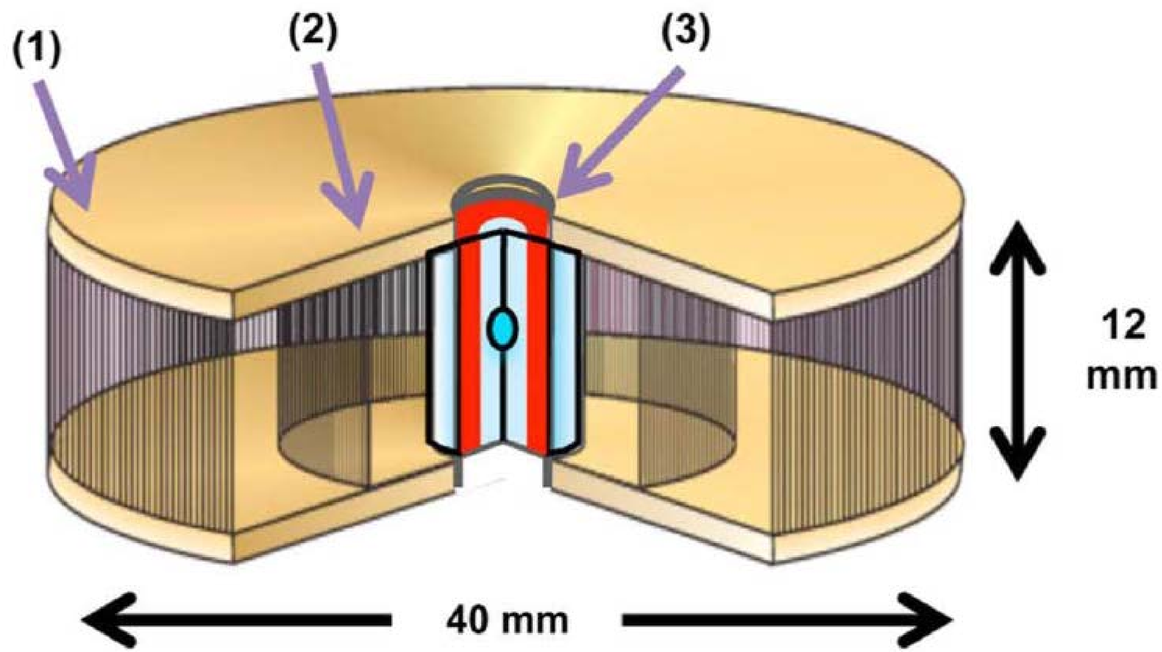
Double-Ended Hohlraum

1) Upper z pinch
2) Lower z pinch
3) Secondary hohlraum with capsule
4) Upper Be spokes
5) Lower Be spokes

ICF experimental configurations

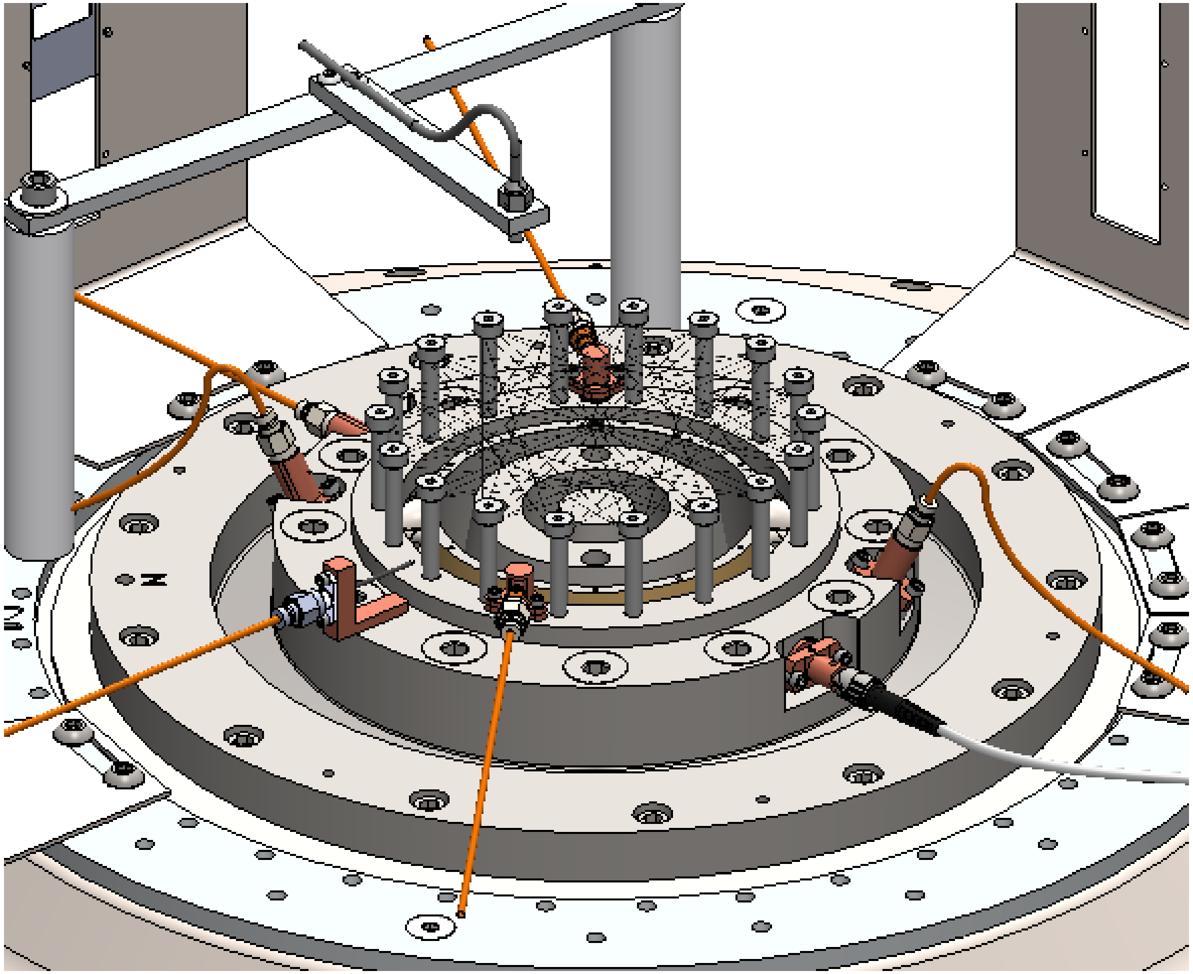
Dynamic Hohlraum

1) Outer z pinch array
2) Inner z pinch array
3) Foam target with capsule



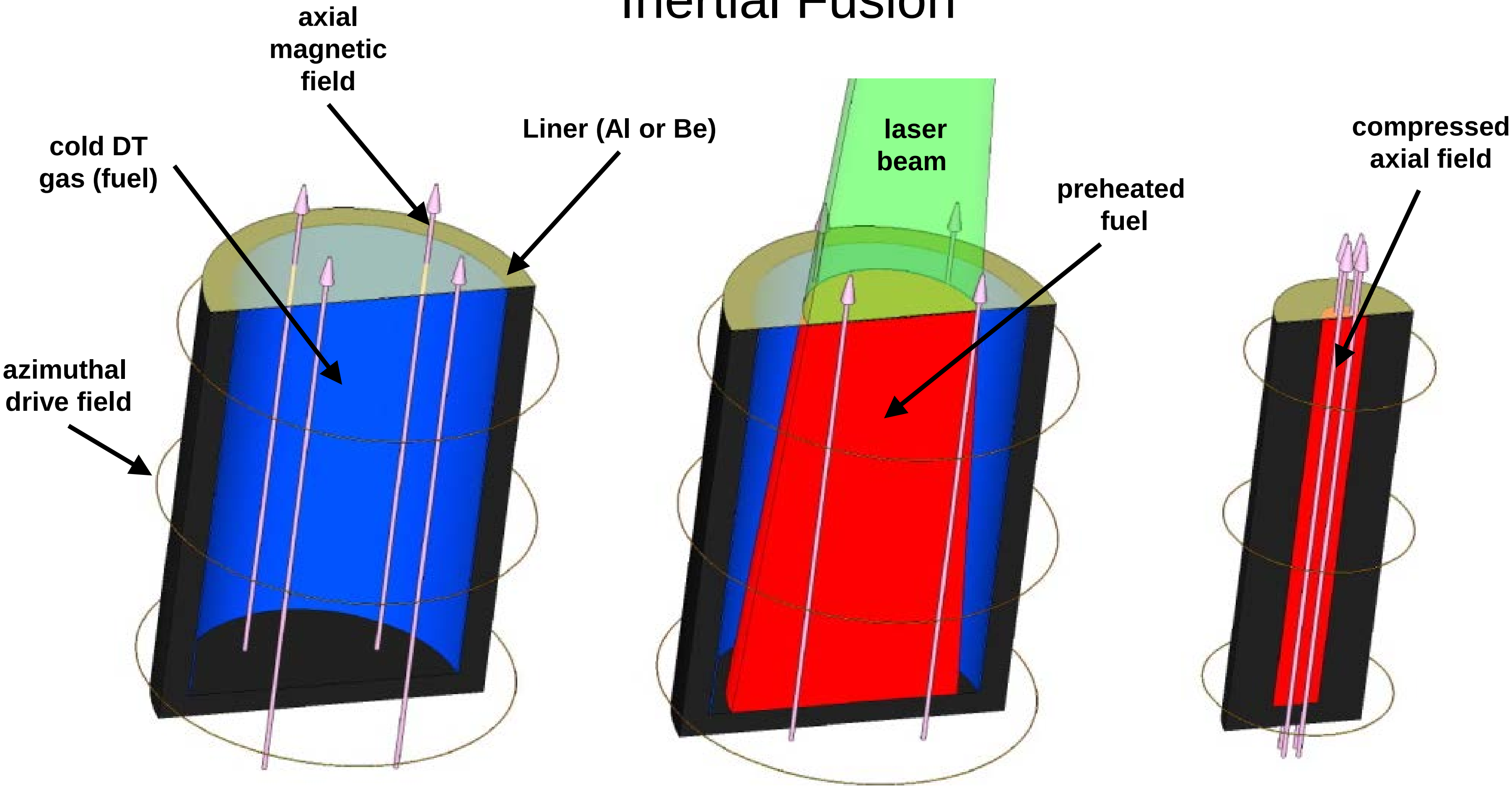
ICF experimental configurations

Deuterium Gas Puff



ICF experimental configurations

Magnetized Liner Inertial Fusion



Neutron diagnostics

- Activation samples – Indium and copper
- Neutron time of flight (nTOF) detectors
- Be Probe (yield)

Primary reactions

$$^{2}H + {}^{2}H \rightarrow {}^{3}H + {}^{1}H + 4.03\ MeV$$

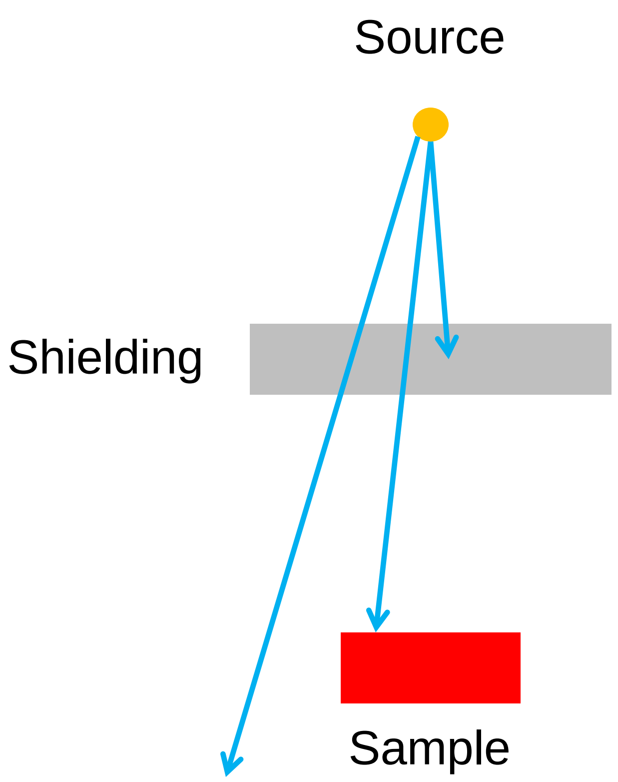
$$^{2}H + {}^{2}H \rightarrow {}^{3}He + {}^{0}n + 3.27\ MeV$$

Secondary reaction

$$^{2}H + {}^{3}H \rightarrow {}^{4}He + {}^{0}n + 17.6\ MeV$$

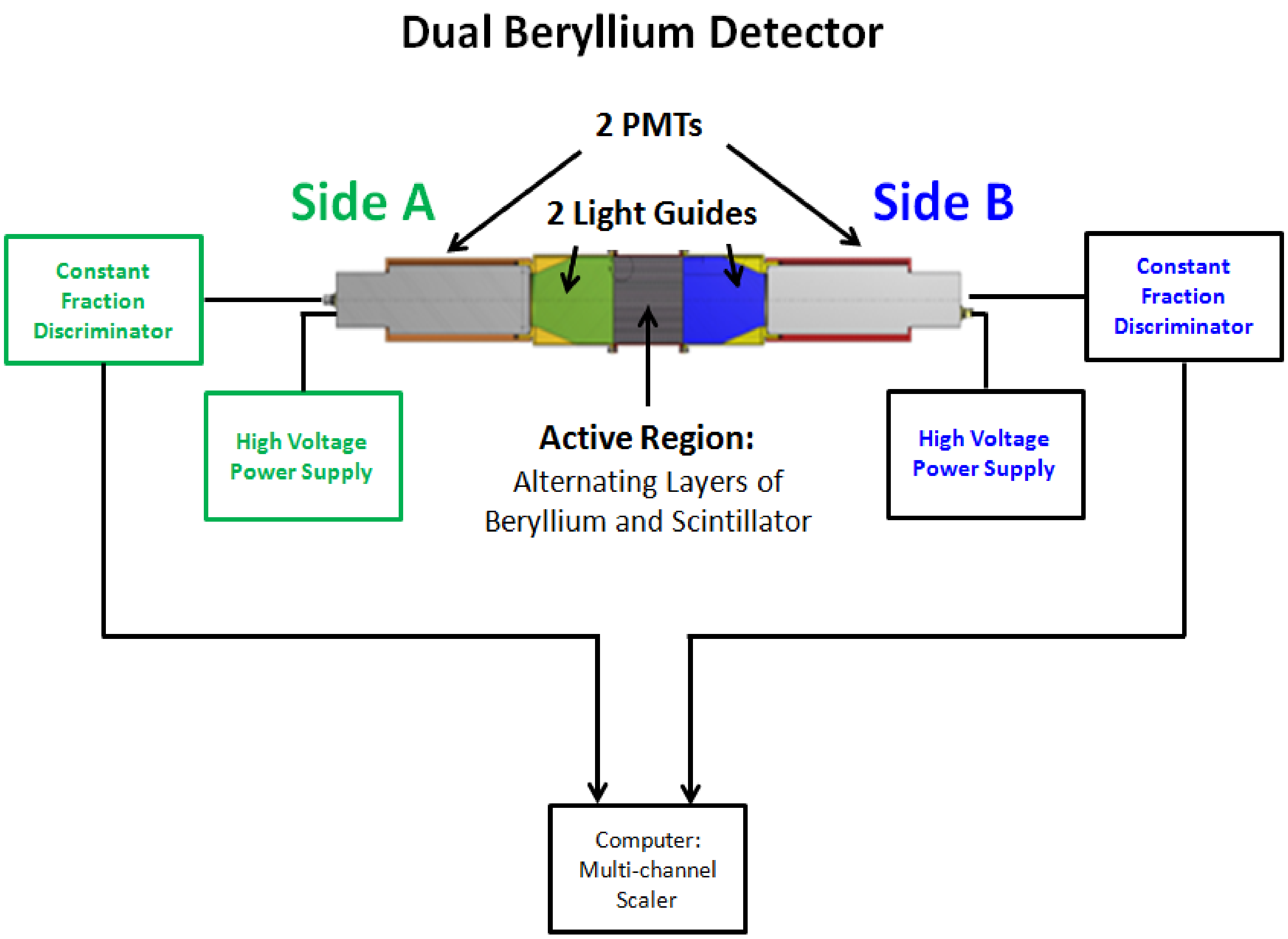
Activation Samples

- Indium activation samples
  - $^{115}In(n,n')^{115m}In$
  - 0.34 MeV threshold
  - 4.49 hour half-life
- Copper activation samples
  - $^{63}Cu(n,2n)^{62}Cu$
  - 11 MeV threshold
  - 9.67 minute half-life

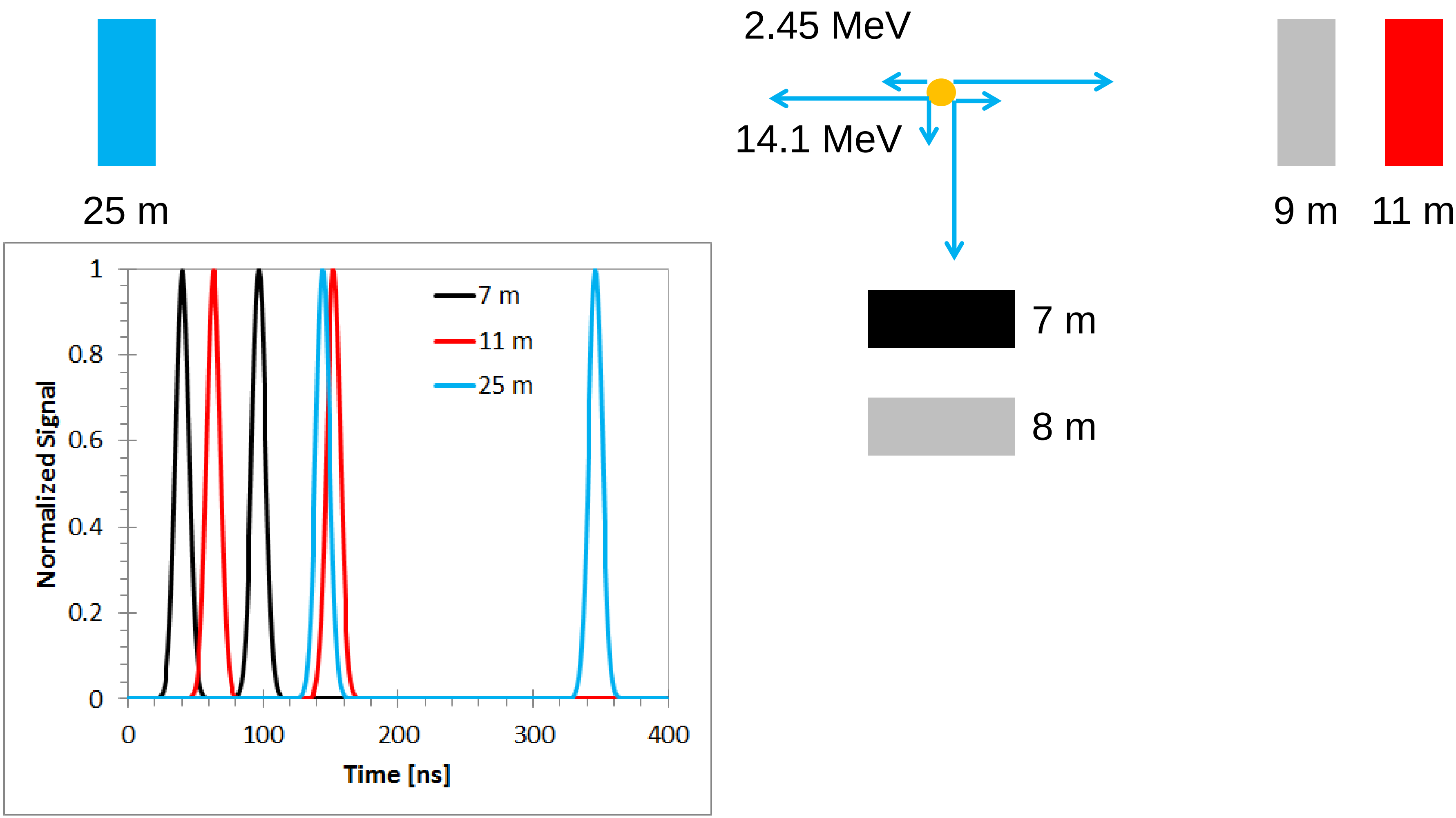


Be Detector

- $^{9}Be(n,\alpha)^{6}He$
- 0.67 MeV
- 0.8 second half-life
- ^{6}He emits a positron
- Coincidence counting

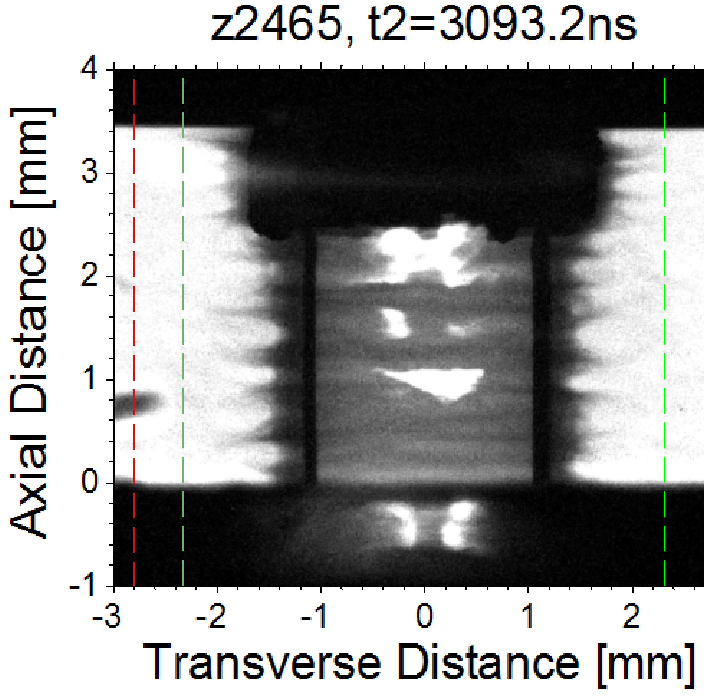


nTOF detectors

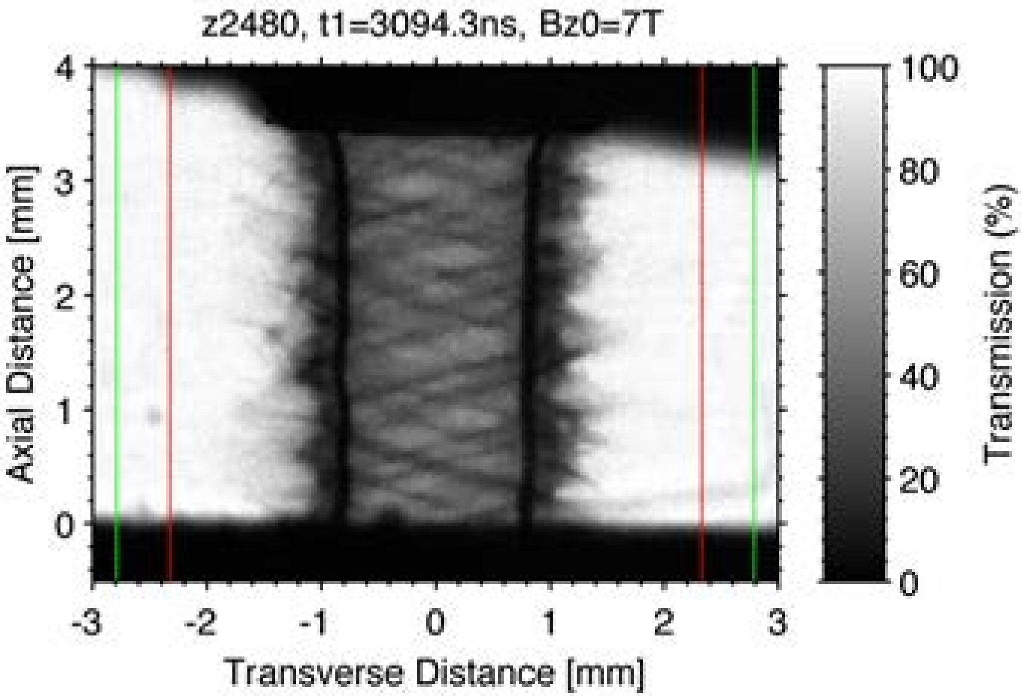


An unexpected result from the initial experiments in preparation for MagLIF

No axial B field



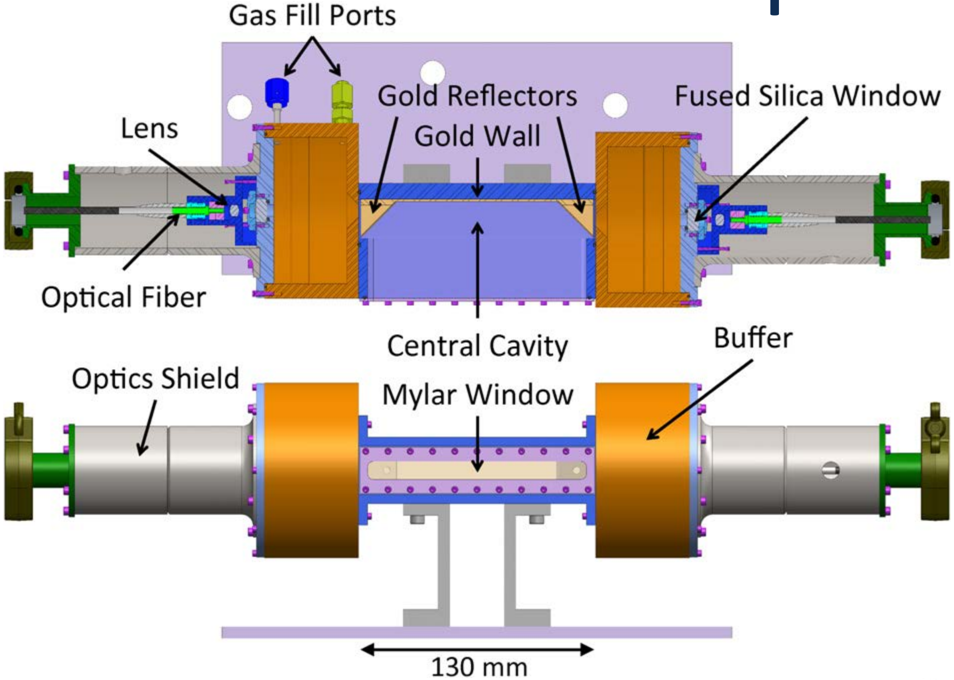
With applied axial B field

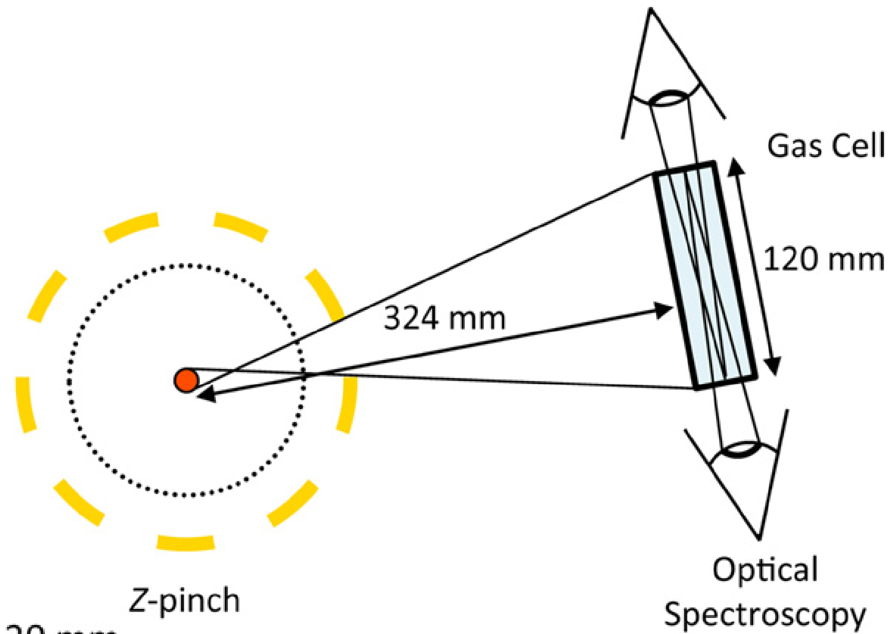


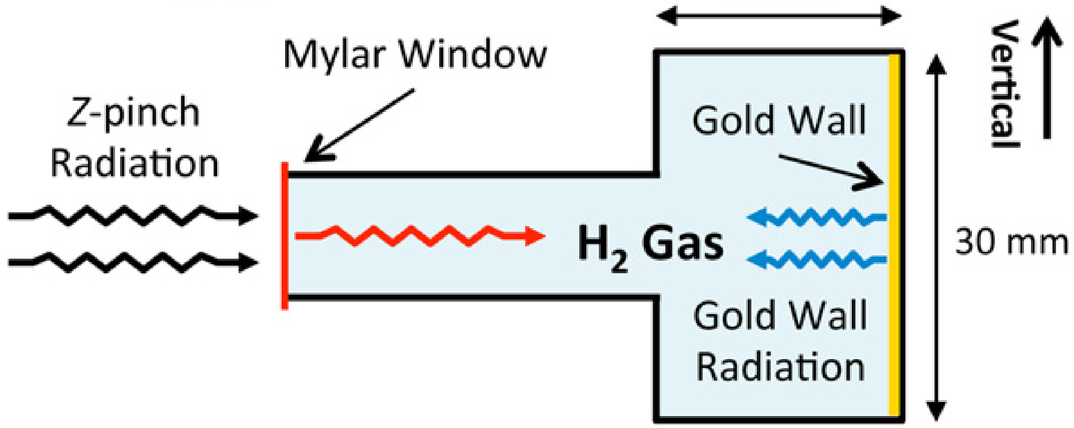
Many types of magnetically-driven HED experiments are conducted at the Z facility

- Dynamic material physics
- Radiation effects
- Inertial confinement fusion
- Basic science

White Dwarf Photosphere Experiments

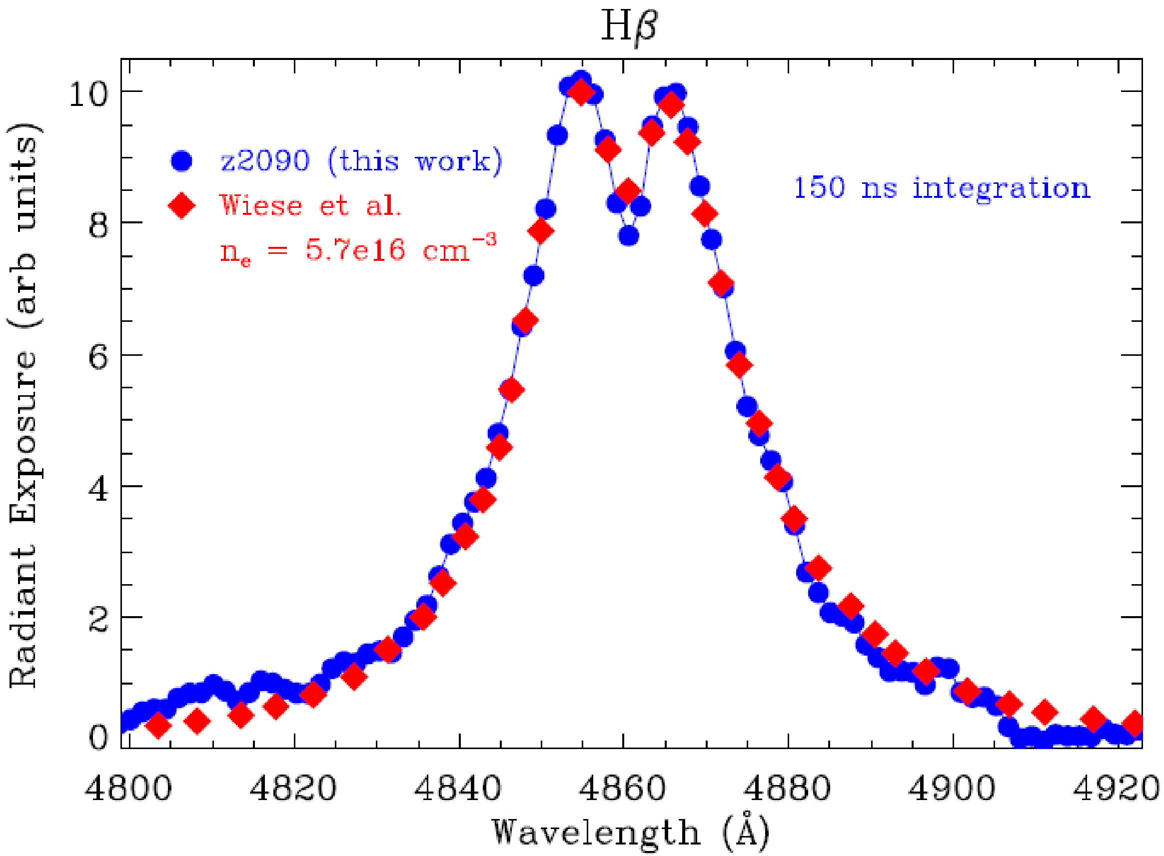




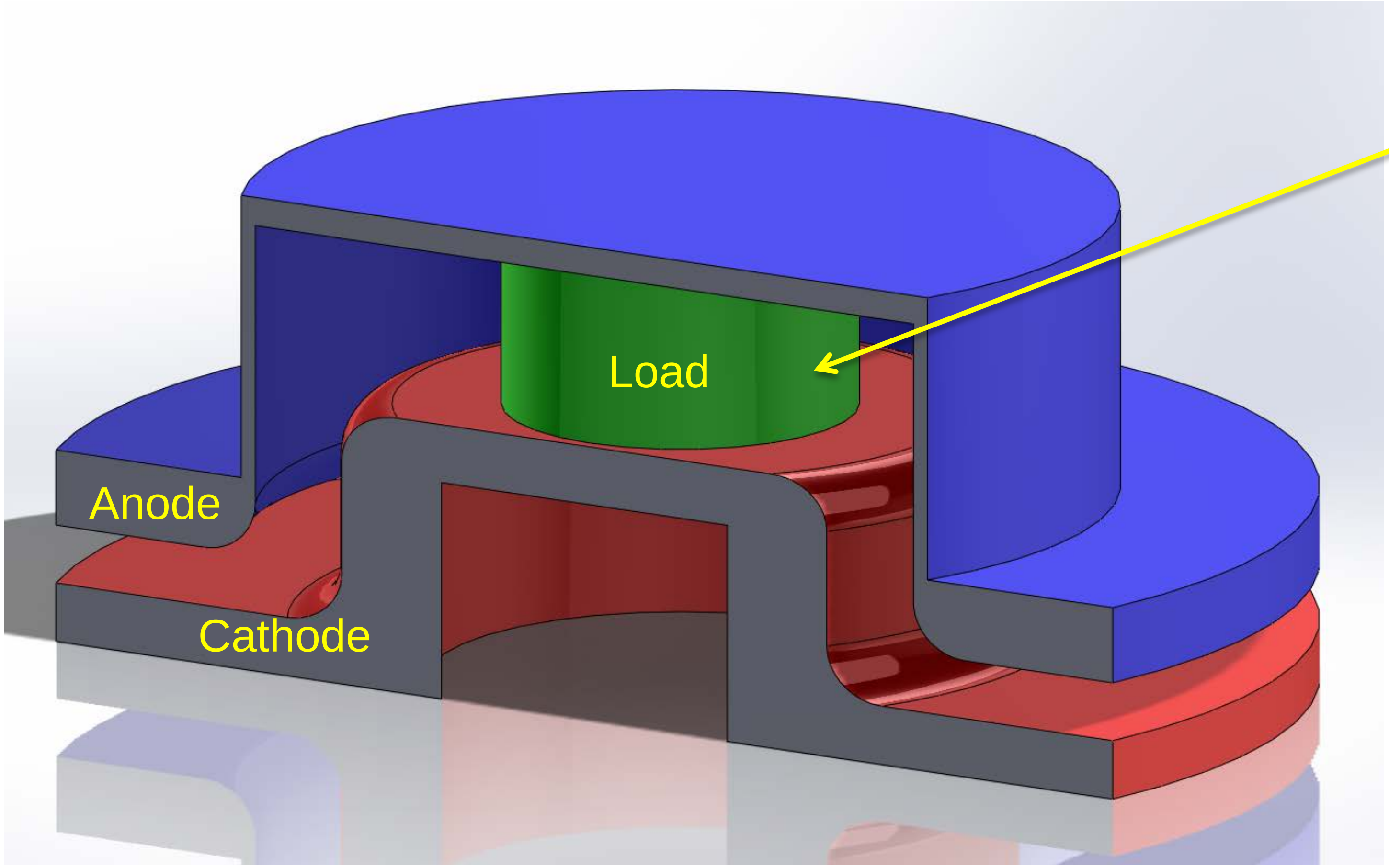


White Dwarf Photosphere Experiments

Comparing experimentally measured hydrogen Balmer series line shapes to those used in astrophysics to predict the conditions of White Dwarfs



Monitoring magnetic flux through Zeeman splitting of optical lines

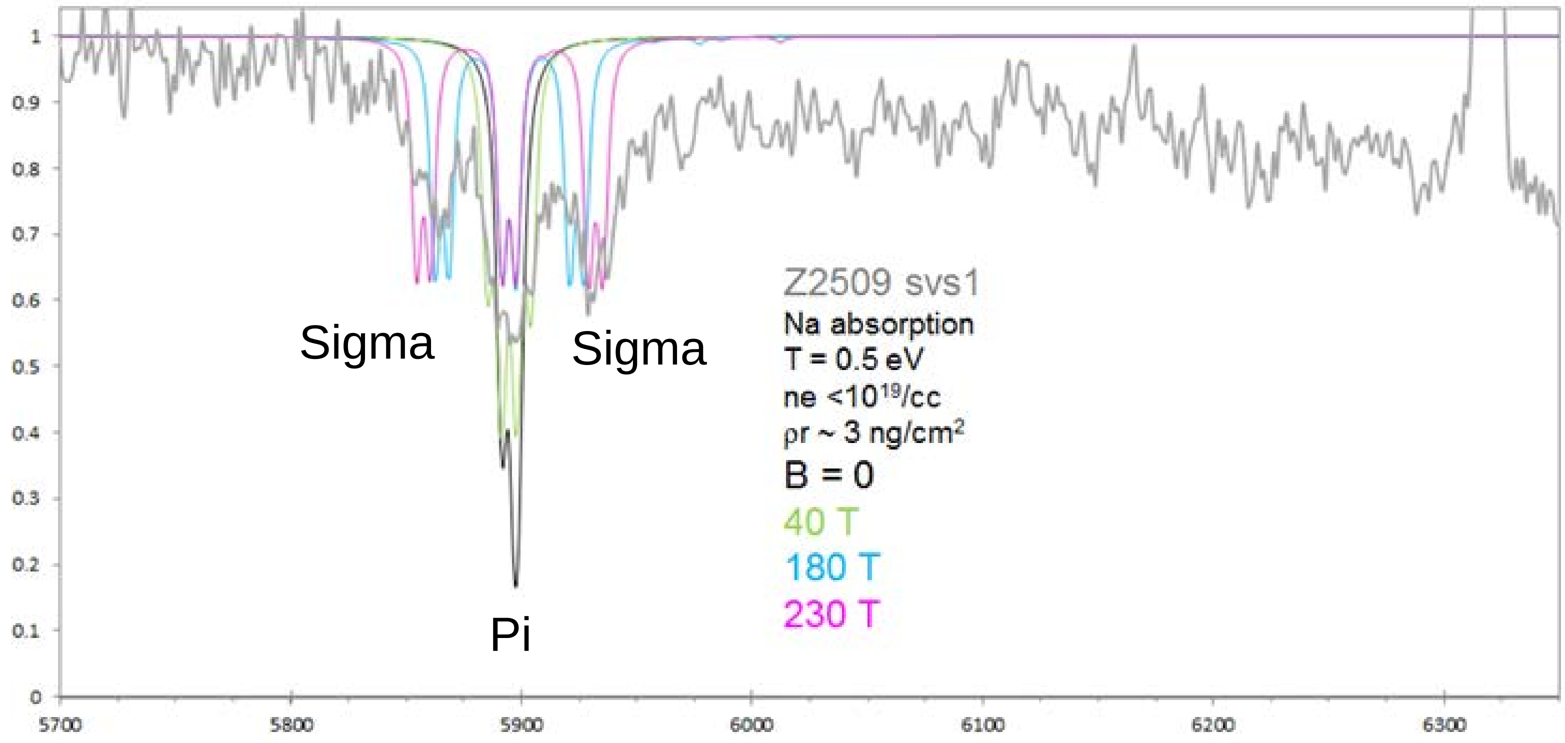


Spectroscopy probe views target surface radially

Magnetic field is in azimuthal direction

Pi and Sigma components of splitting expected

Monitoring magnetic flux through Zeeman splitting of optical lines



Spectroscopic measurement of magnetic flux may be useful for monitoring load current as well as magnetic flux compression in MagLIF

HED science on the Z facility supports the stockpile through many different avenues

- Dynamic materials physics experiments provide equations of state for weapons relevant materials
- Radiation effects experiments utilize the most powerful laboratory x-ray source for component testing
- Inertial confinement fusion experiments explore unique methods of neutron production

Questions?