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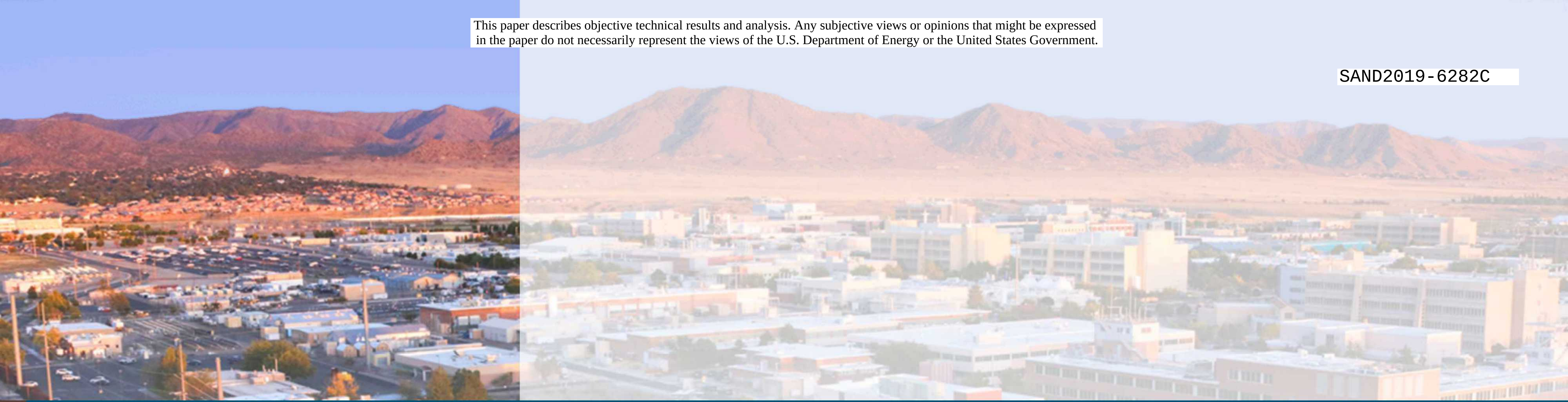

Shock Compression of Pre-Compressed H_2-He Mixtures

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Sandia National Laboratories
Albuquerque, NM
SCCM, 2019
Portland, Oregon

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Outline

- Pre-compression capability at the Sandia Z-facility and STAR
- Why pre-compressed samples of H_2-He?
- Pre-liminary data on H_2-He
- Summary

Pre-Compression Capability at Z and STAR

PROBE BODY (ALUMINUM)

COMPRESSION BOLTS

BELLEVILLE WASHERS

CYLINDER, HP CELL (17-4 PH STEEL)

CYLINDER WC SEAT

FLIGHT DISTANCE SPACER RODS

SAPPHIRE ANVIL

RUBY

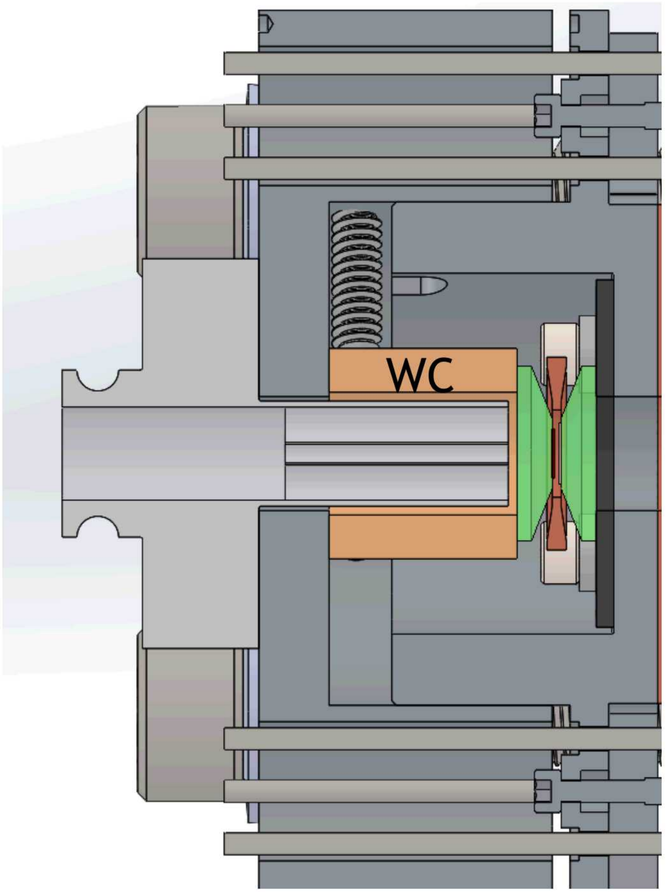
GASKET

SAPPHIRE ANVIL

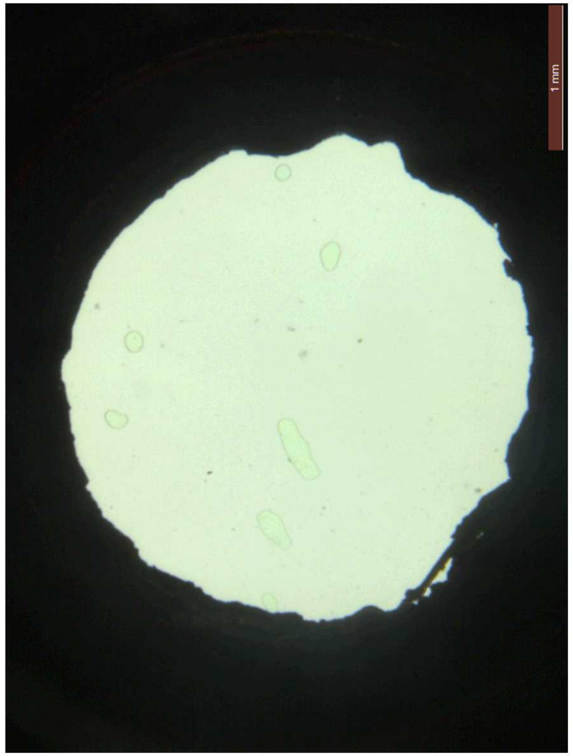
PISTON WC SEAT

PISTON (17-4 PH STEEL)

Components of pre-compression cell



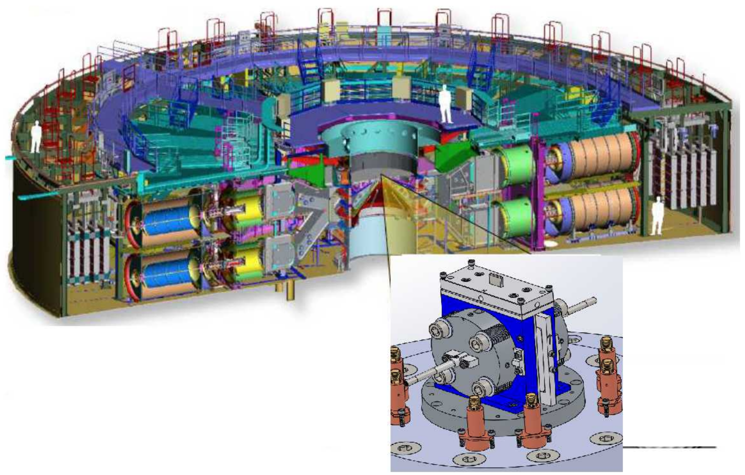
Side View of the closed DAC

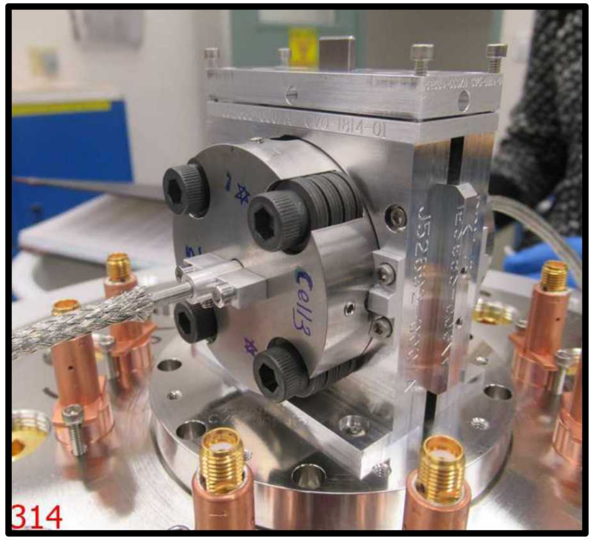


Sample thickness: 0.3728 mm
Sample diameter: 3.6 mm

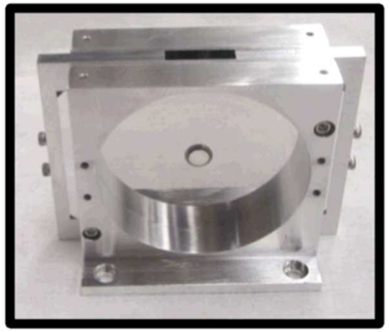
Micro-photograph of the fluid mix

Pre-Compression Capability at Z and STAR



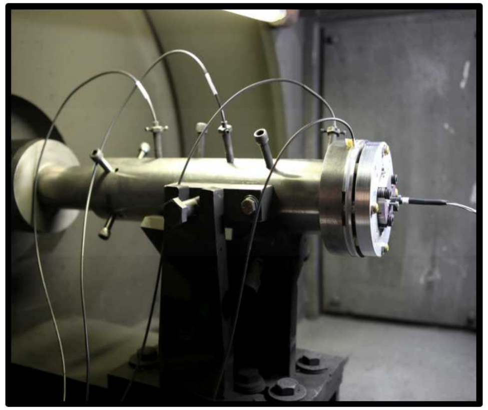


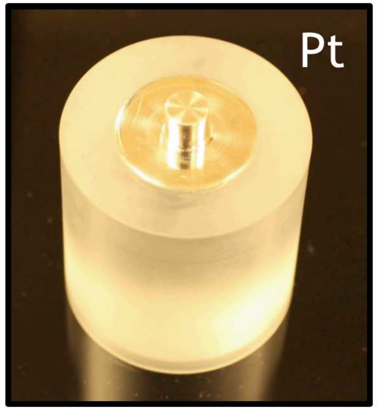
Al



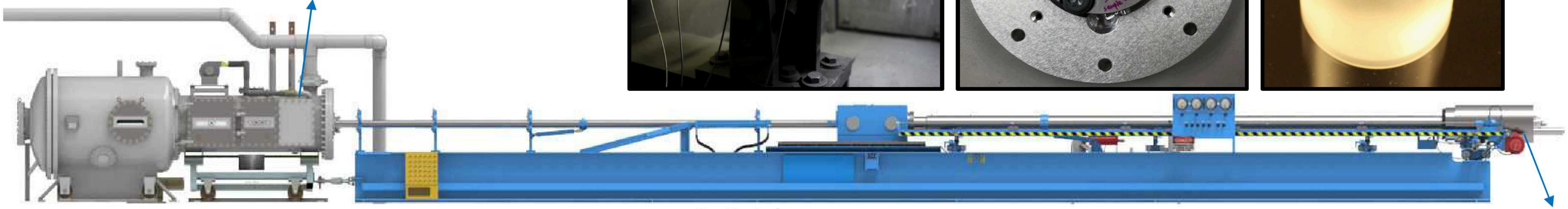
Target assembly for Z-experiment

Two stage light gas-gun at STAR





Impact chamber

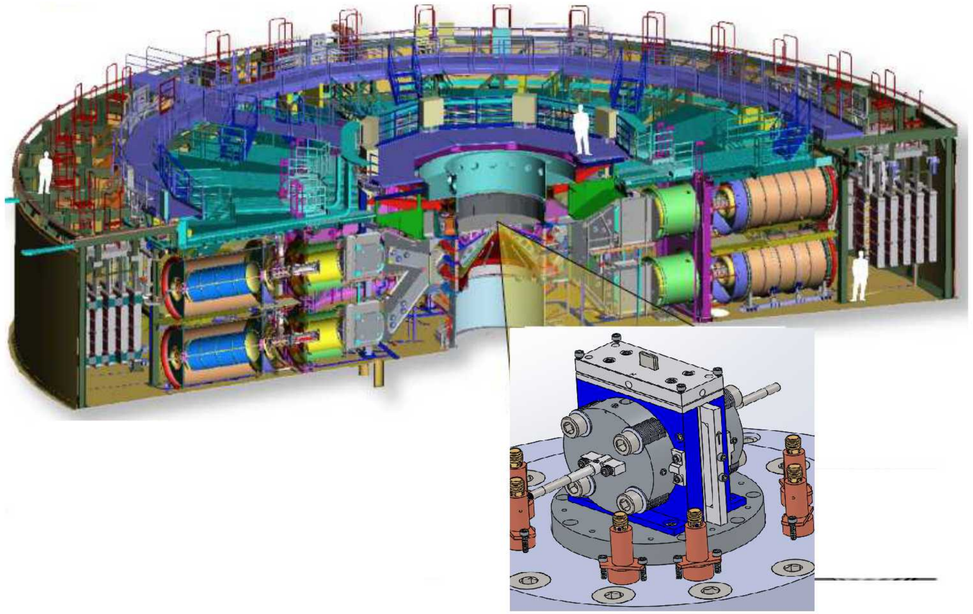


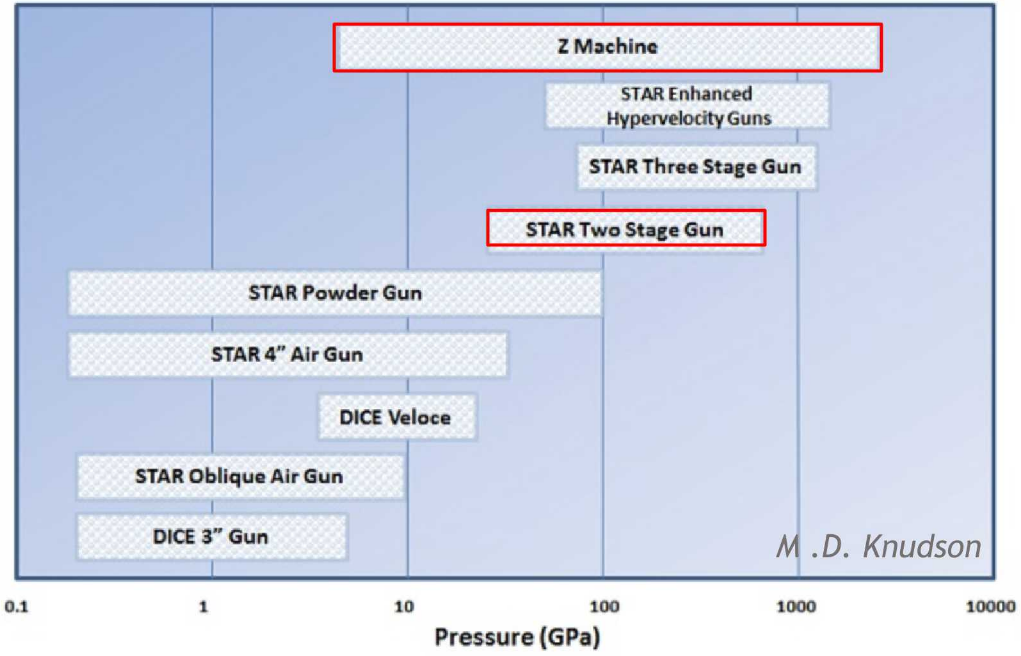
7 km/s max. velocity

B. Reinhart

Powder chamber

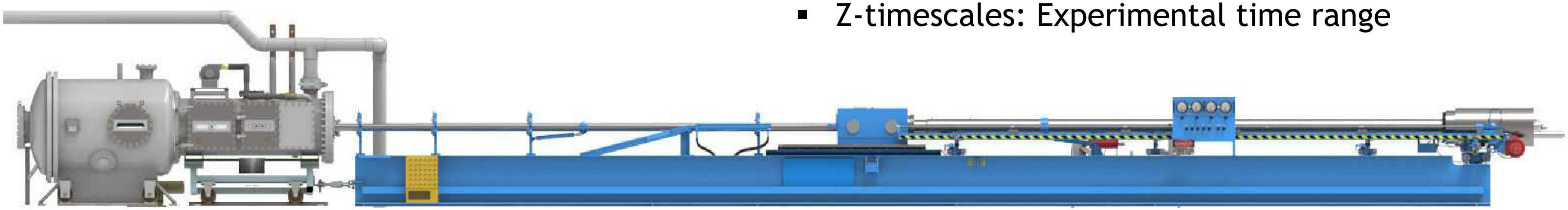
Planetary pressure range achieved using capabilities at Sandia





- Pressure range at STAR and Z ~10 to 1000 GPa
- Pre-compressed sample shocked at Z and STAR
- Z-timescales: Experimental time range

Two-stage-light-gas-gun at STAR



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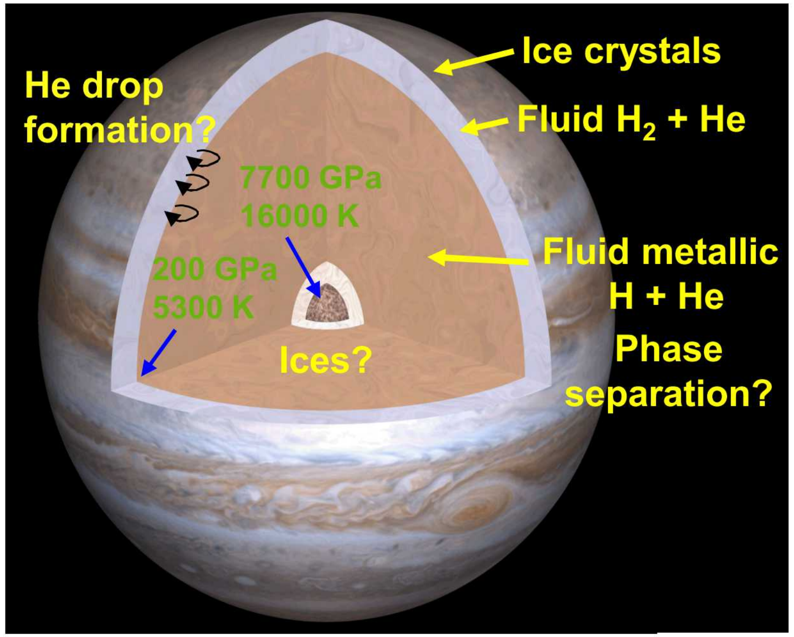
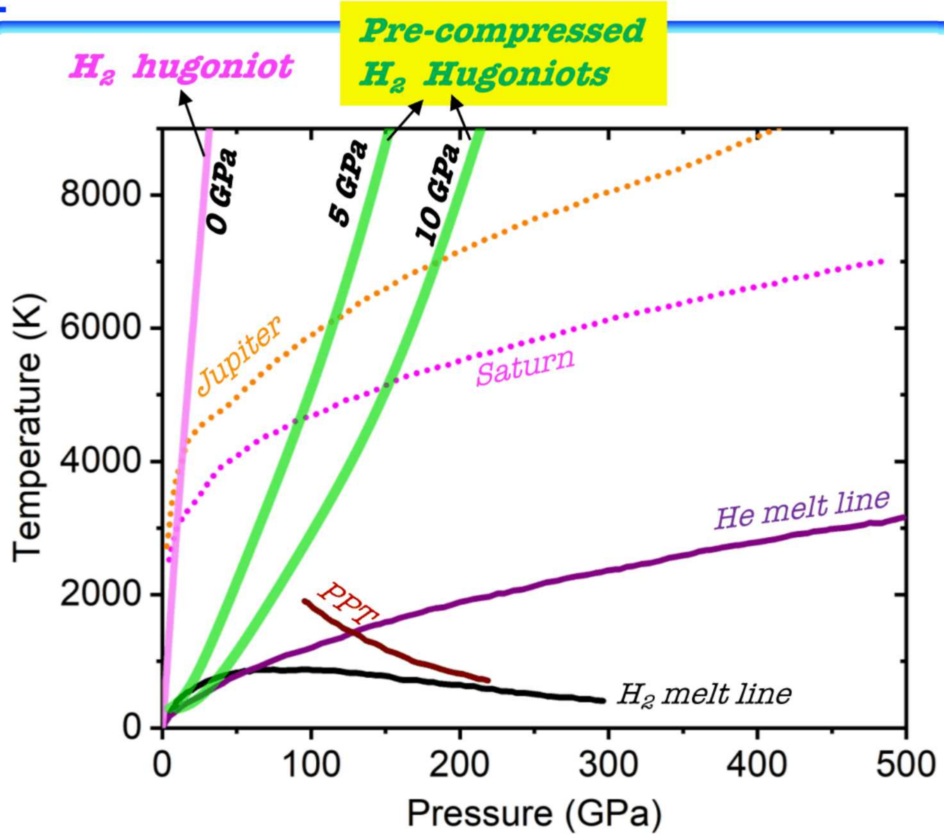
Why Study Pre-Compressed H_2-He Mixtures?



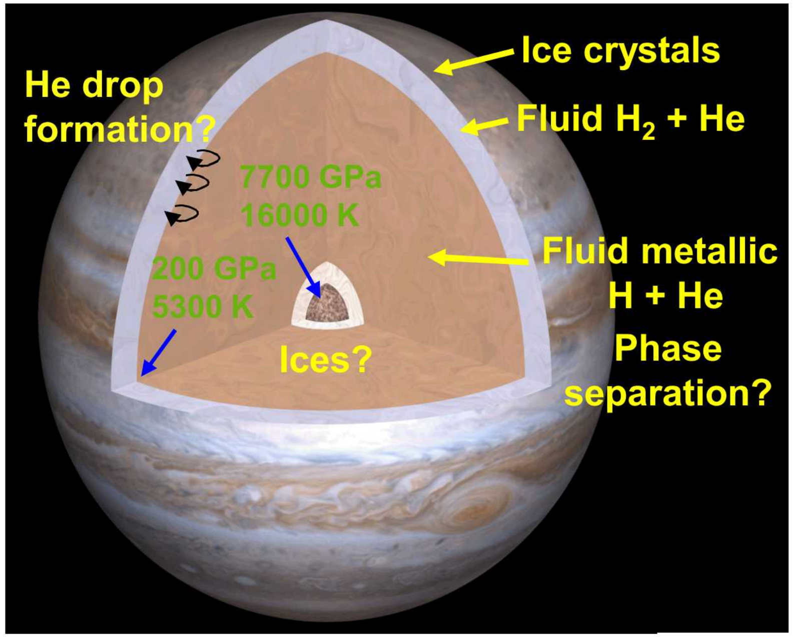


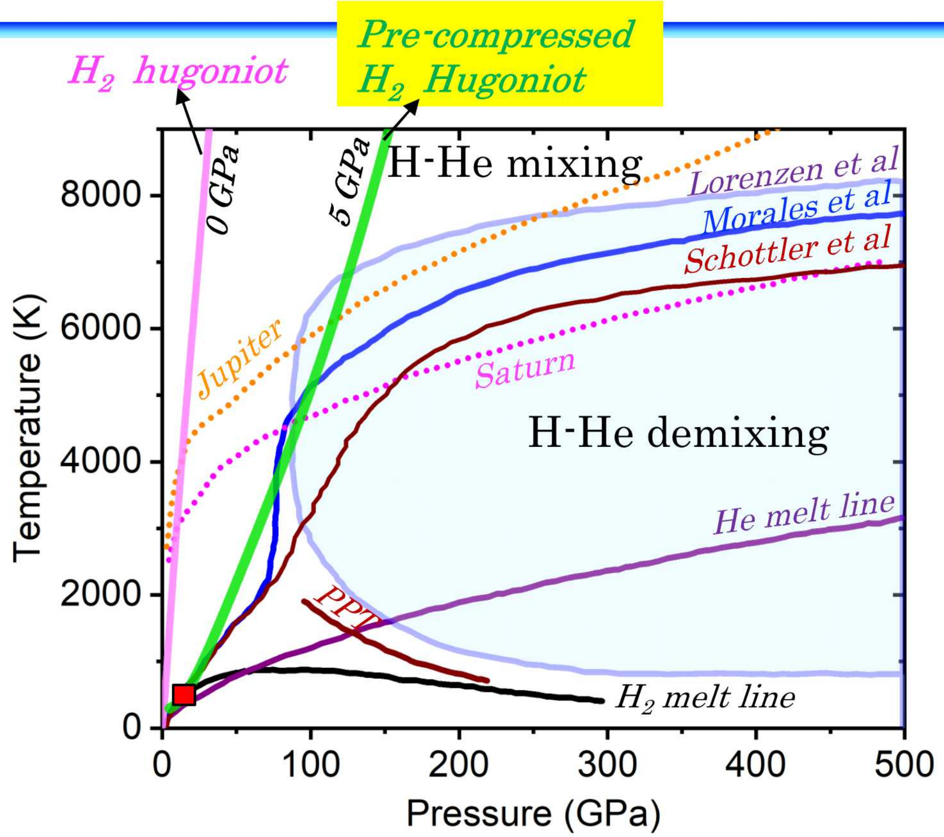
- H_2-He major component of planetary interiors
- Does He and H_2 phase separate in Jupiter/Saturn?

- Pre-compression allows to access unique state off of the Hugoniot.
- Probe planetary states

Pre-compression allows access to unique states off of the principle Hugoniot.

Why Study Pre-Compressed H_2-He Mixtures?



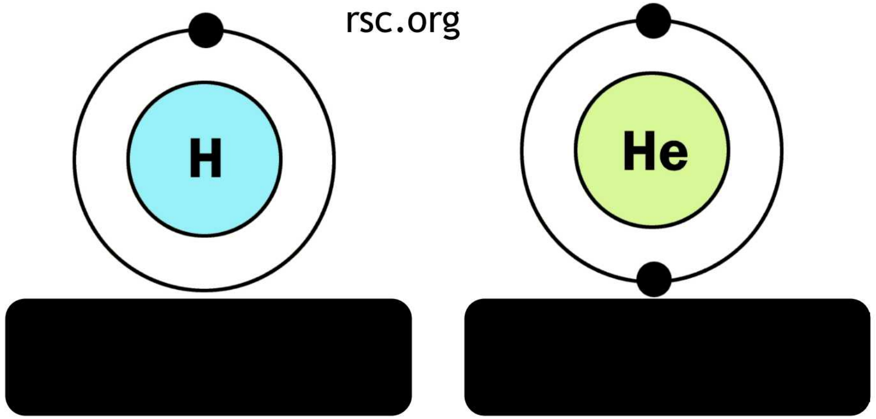


- H_2-He major component of planetary interiors
- Does He and H_2 phase separate in Jupiter/Saturn?

- Large deviation between theoretical mixture models
- Develop a capability to study H-He de/mixing using Z and STAR gas guns
- Pre-compression is the only way to study homogeneous fluid mixtures of H_2-He

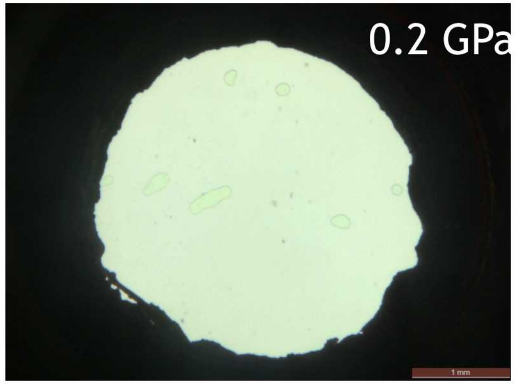
Pre-compression is the only method to achieve high density states of a homogeneous mixture initial condition

Pre-compression only method to achieve high density states

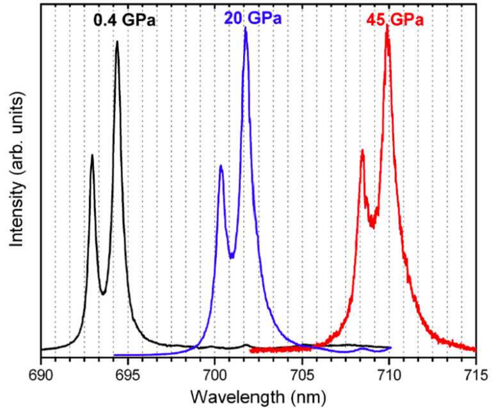


High-Pressure Gas Loader
~25,000 psi

DAC



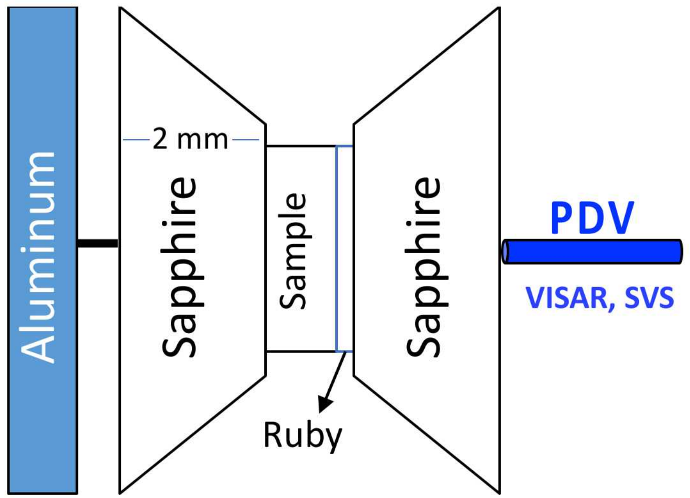
Micro-photograph of fluid mixture of H_2-He through the anvil window.

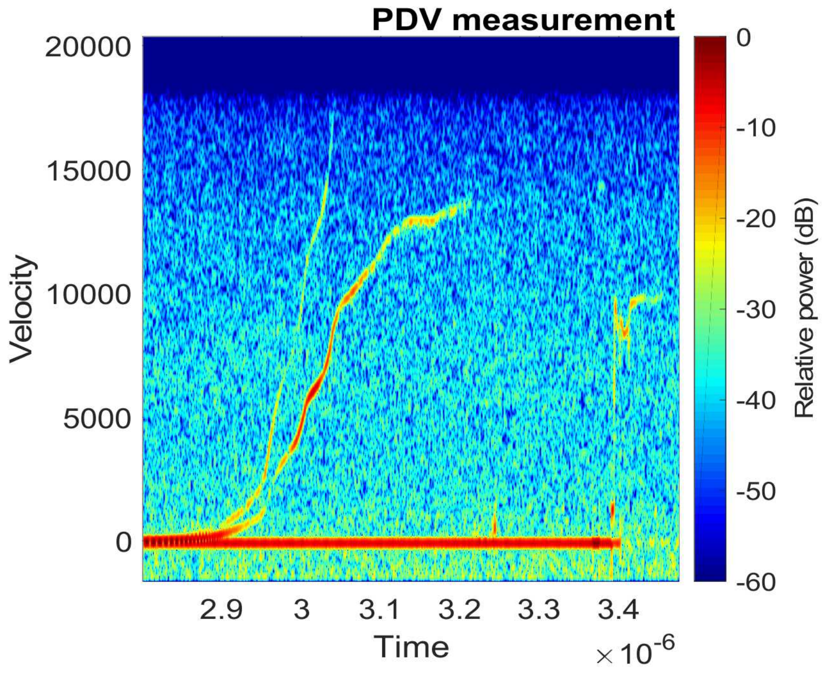


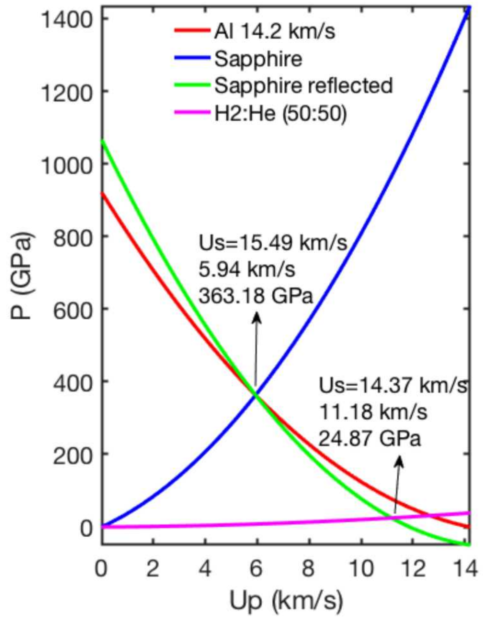
Ruby-shift with change in pressure

Pre-compression is the only method to achieve high density states of a homogeneous mixture initial condition

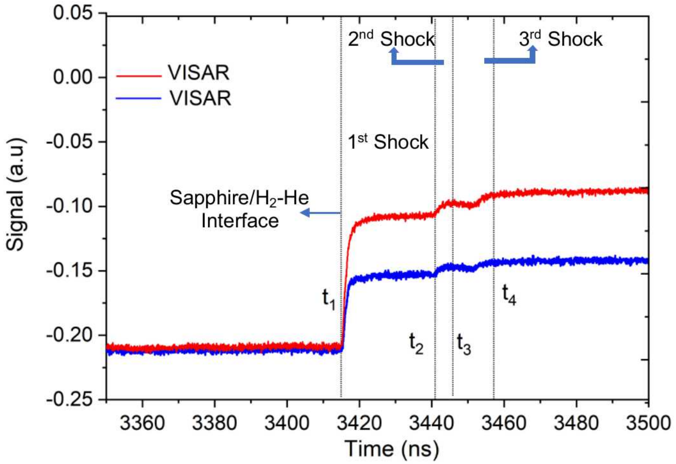
Velocimetry Measurements of Gas Mixtures (H_2:He)





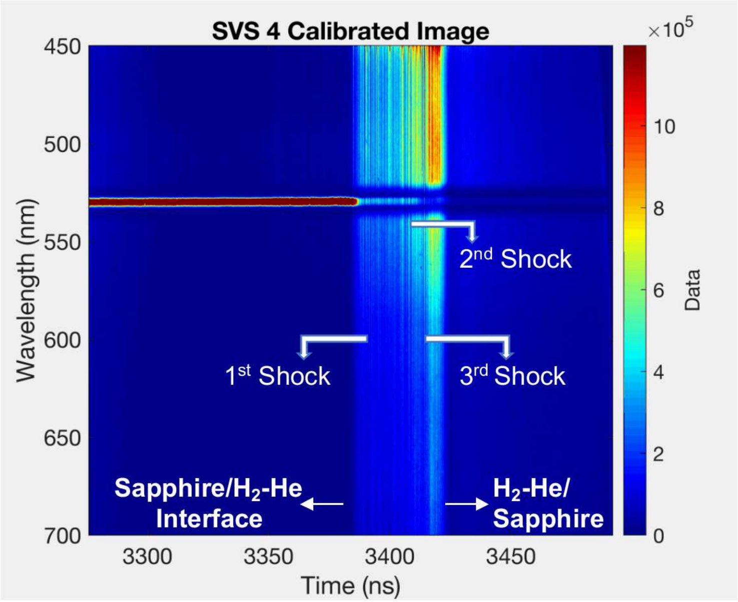


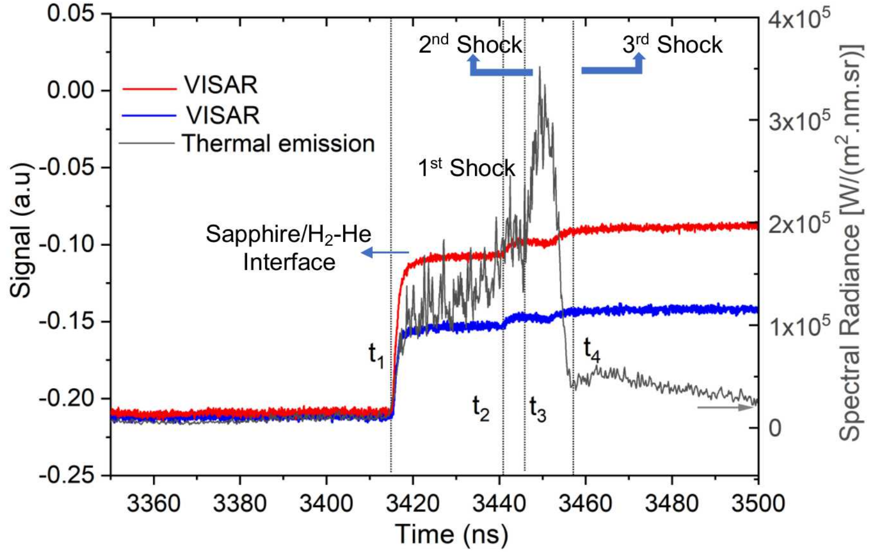
Impedance matching in the P-U_p plane.

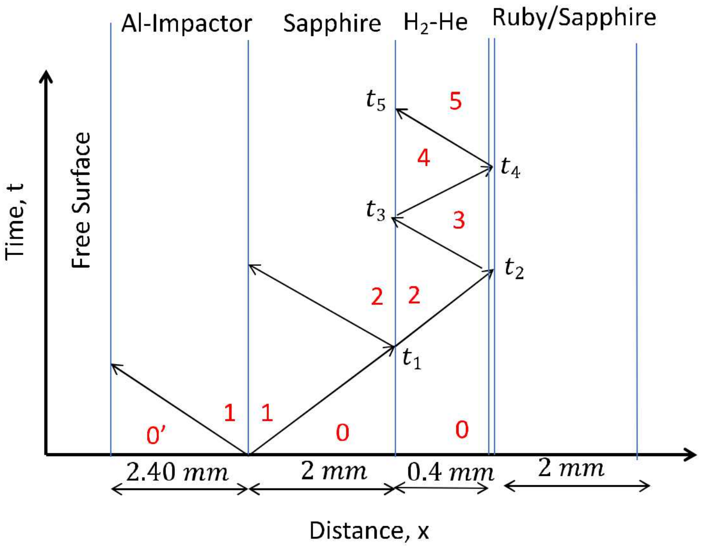


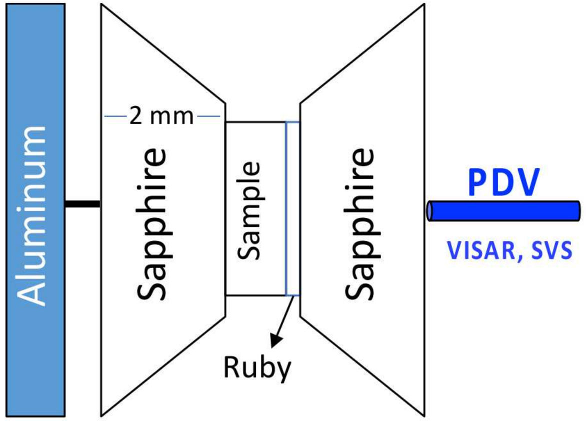
- Al flyer velocity of 14.2 km/s was obtained
- Shock front not reflective
- VISAR measurements
- Transit time measurement → Us

VISAR and Temperature Measurements of Gas Mixtures (H_2:He)



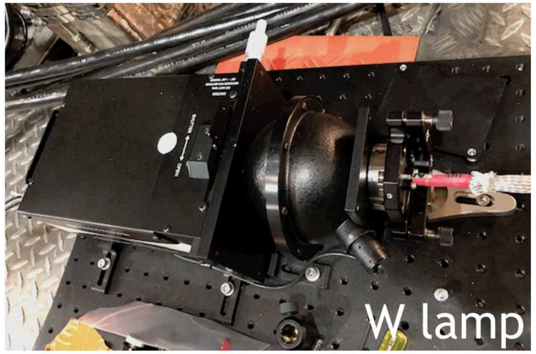


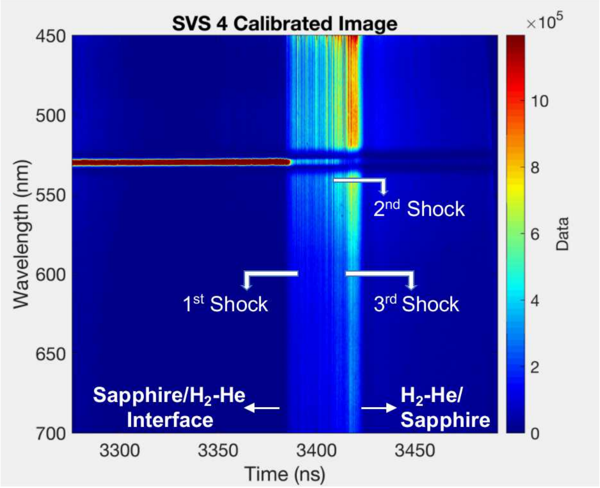




- Simultaneous VISAR and temperature measurements were performed
- The temperature at the sample after the first shock was estimated to be around 19,480 +- 603 K.
- Thermal emission data correlates well with the VISAR data.

Temperature Measurements of Gas Mixtures (H_2:He)

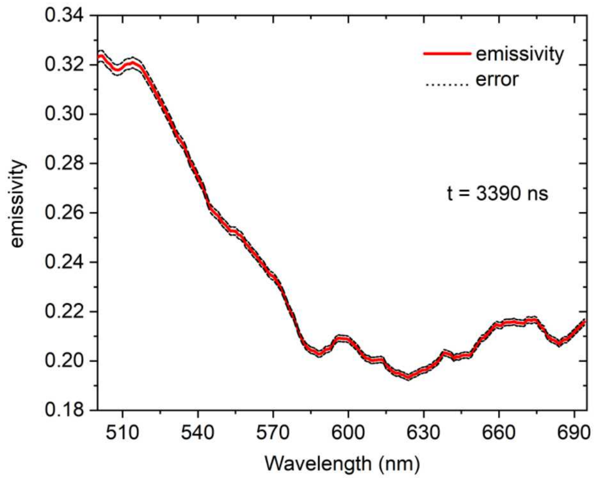


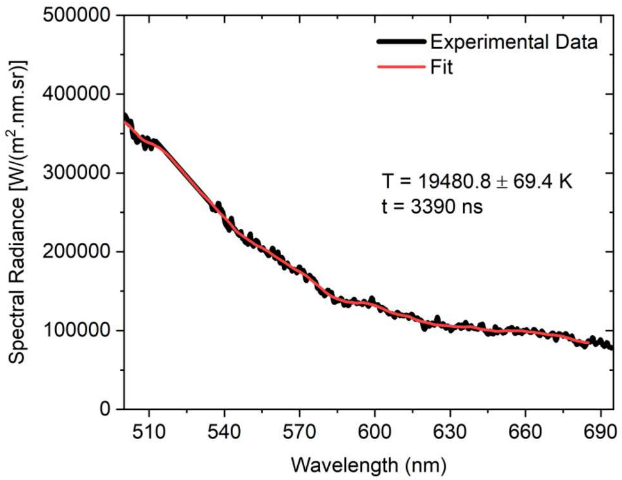


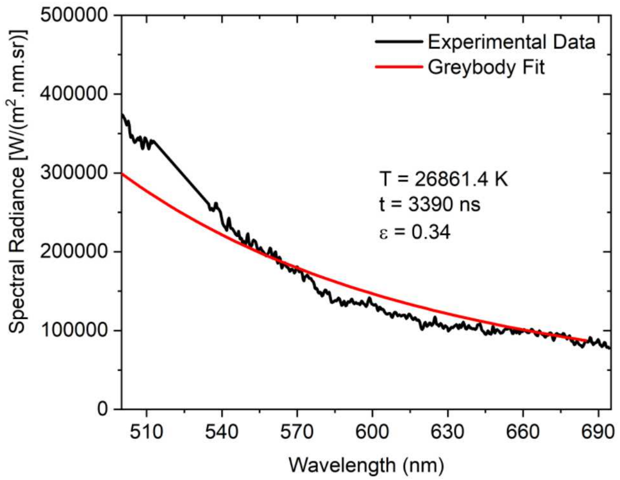
$$\frac{dL}{d\lambda} = \varepsilon \frac{2hc^2}{\lambda^5\left(e^{hc/\lambda kT} - 1\right)}$$

- Streaked Visible Spectroscopy
- Use W lamp for calibration
- Reducing spectral thermal emission data to spectral emissivity and temperature

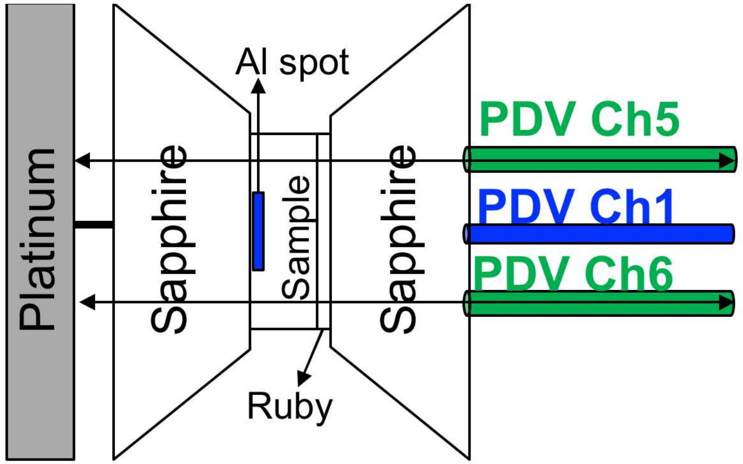
T at 1st Shock: 19480.8±69.4 K
T at 3rd Shock: 25548.4±100 K



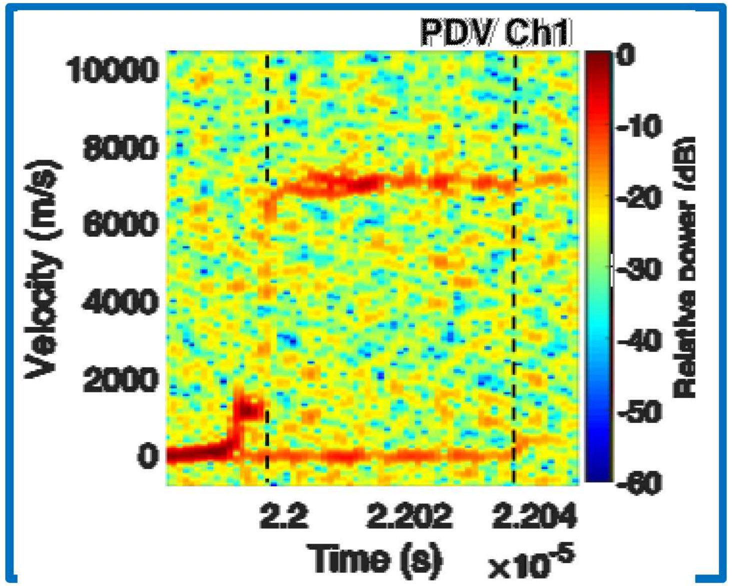


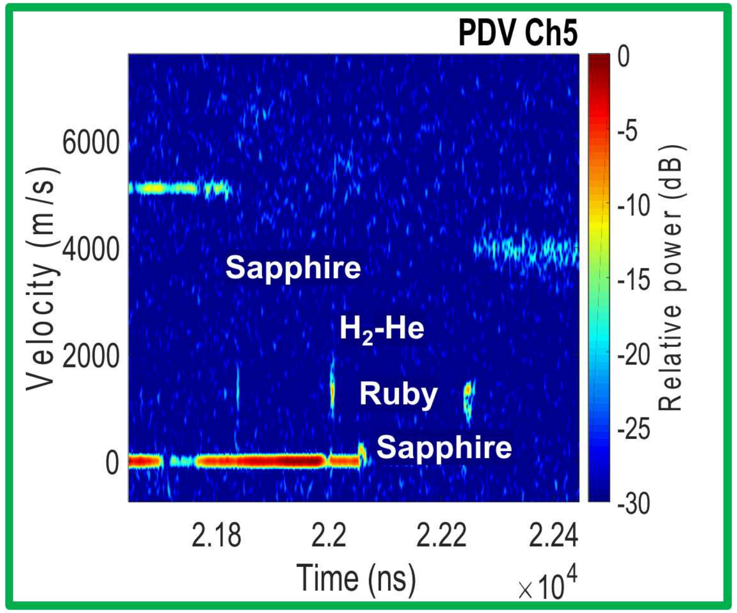


Velocimetry Showing Particle Velocity and Shock Transit Times



Schematic for shock loading pre-compressed H_2 -He mixture with a Pt flyer at STAR





	Pt Velocity (km/s)	U_s (km/s)	U_p (km/s)	P (GPa)
PC_20	5.01	9.52±0.24	7.02±0.03	9.69±0.76

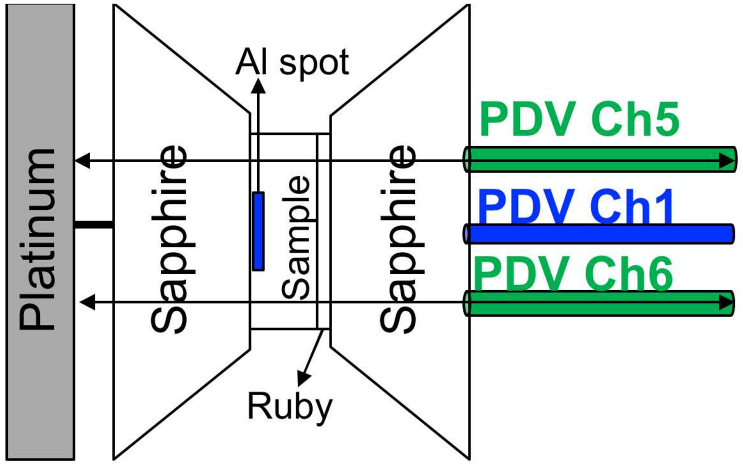
$$\rho_0(U_S - U_0) = \rho_1(U_S - U_1)$$

$$P_1 - P_0 = \rho_0(U_S - U_0)(U_1 - U_0)$$

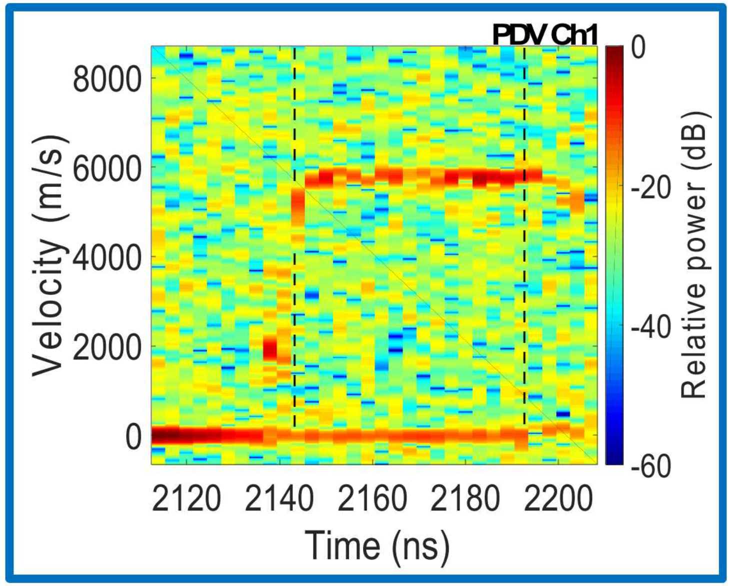
$$E_1 - E_0 = \frac{1}{2}(P_1 + P_0)(V_0 - V_1)$$

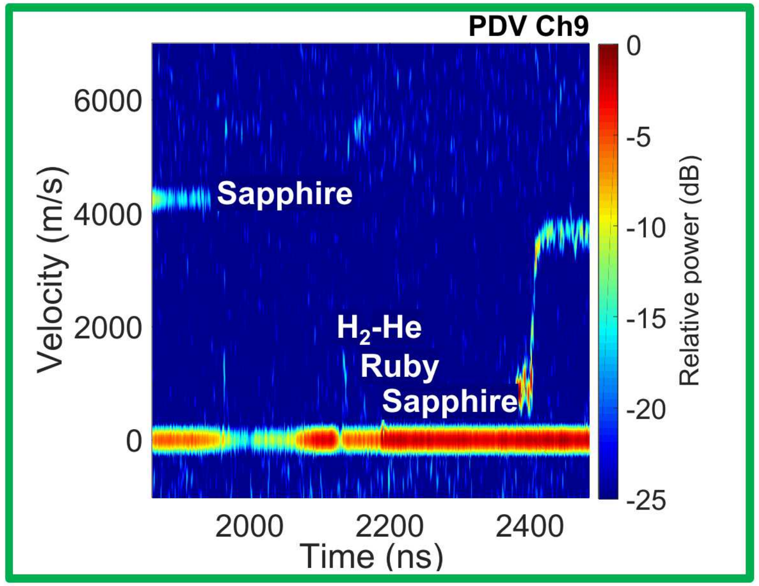
- Successfully measured the particle velocity, shock velocity, and transit times from PDV data.
- Uncertainties in initial density, shock velocity
- Quality of data; Hugoniot uncertainty

Velocimetry Showing Particle Velocity and Shock Transit Times



Schematic for shock loading pre-compressed H_2 -He mixture with a Pt flyer at STAR.





	Pt Velocity (km/s)	*U_s (km/s)*	*U_p (km/s)*	*P (GPa)*
PC_20	5.01	9.52±0.24	7.02±0.03	9.69±0.76
PC_24	4.25	7.86±0.31	5.76±0.05	6.64±0.49

$$\rho_0(U_S - U_0) = \rho_1(U_S - U_1)$$

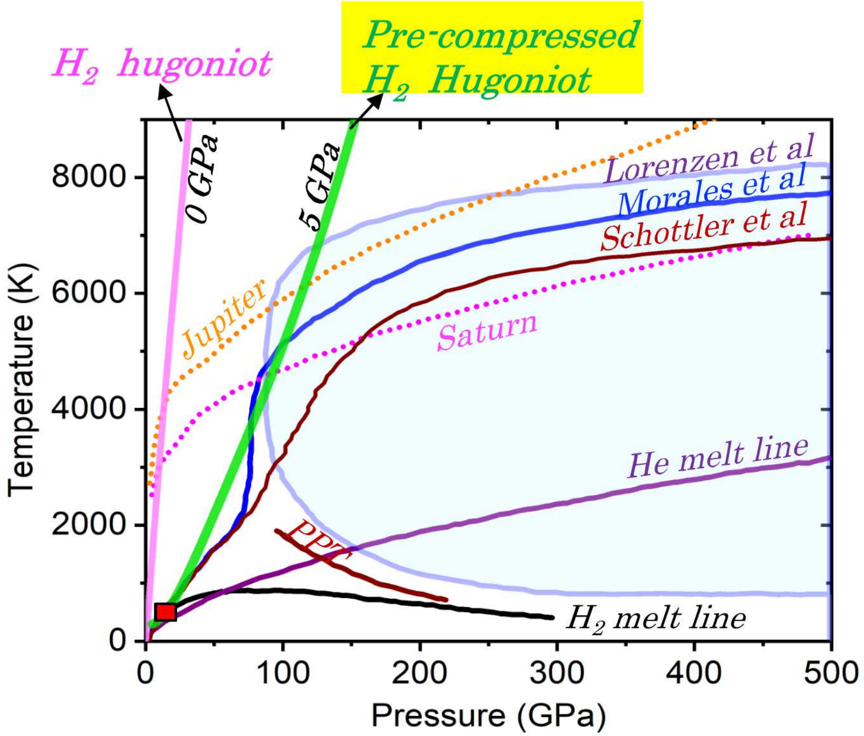
$$P_1 - P_0 = \rho_0(U_S - U_0)(U_1 - U_0)$$

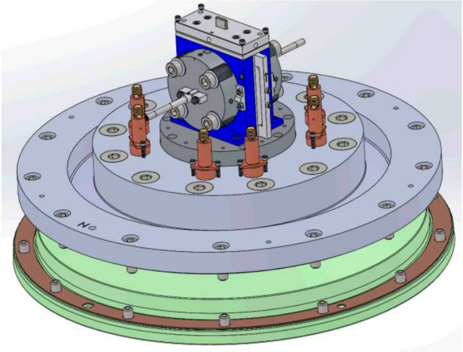
$$E_1 - E_0 = \frac{1}{2}(P_1 + P_0)(V_0 - V_1)$$

- Measured the particle velocity, shock velocity, and transit times from PDV data.
- Uncertainties in initial density, shock velocity, break-out times

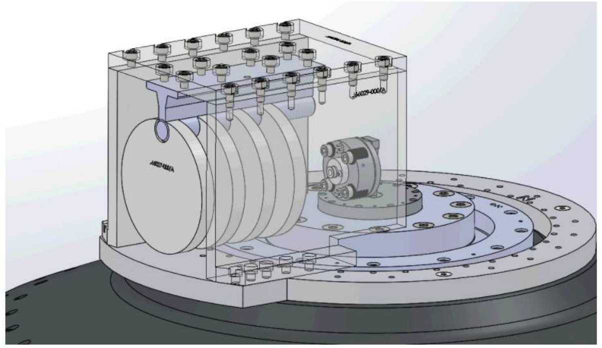
Summary and Path Forward

- **Pre-compression capability at Z and STAR**
- **Measured the particle velocity and transit times in H_2-He mixtures**
- **Simultaneous VISAR and temperature measurements were performed**
- **More experiments scheduled at Z and STAR to build an EOS for mixtures with quartz standard**
- **Design Change and Improvements**





Co-axial Load



Stripline Load

Acknowledgements

- Org. 1646: Dan Dolan, Tommy Ao, Seth Root, Chad McCoy, Justin Brown, Paul Specht, Sean Grant,
- DICE: Josh Usher, Keith Hodge, Randy Hickman, Lena Pacheco, Sheri Payne, Richard Hacking
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- Diagnostic Support Staff