

Quantitative measurements of radiative shock properties on the National Ignition Facility

H. J. LeFevre^{1,a}, G. S. Ceasey², K. H. Ma², M. J. MacDonald³, T. Döppner³, M. A. Millot³, C. Huntington³, E. Johnsen², C. C. Kuranz¹

¹ Nuclear Engineering, University of Michigan Ann Arbor, MI

² Mechanical Engineering, University of Michigan Ann Arbor, MI

³ Lawrence Livermore National Laboratory Livermore, CA

Radiative shocks occur in astrophysics

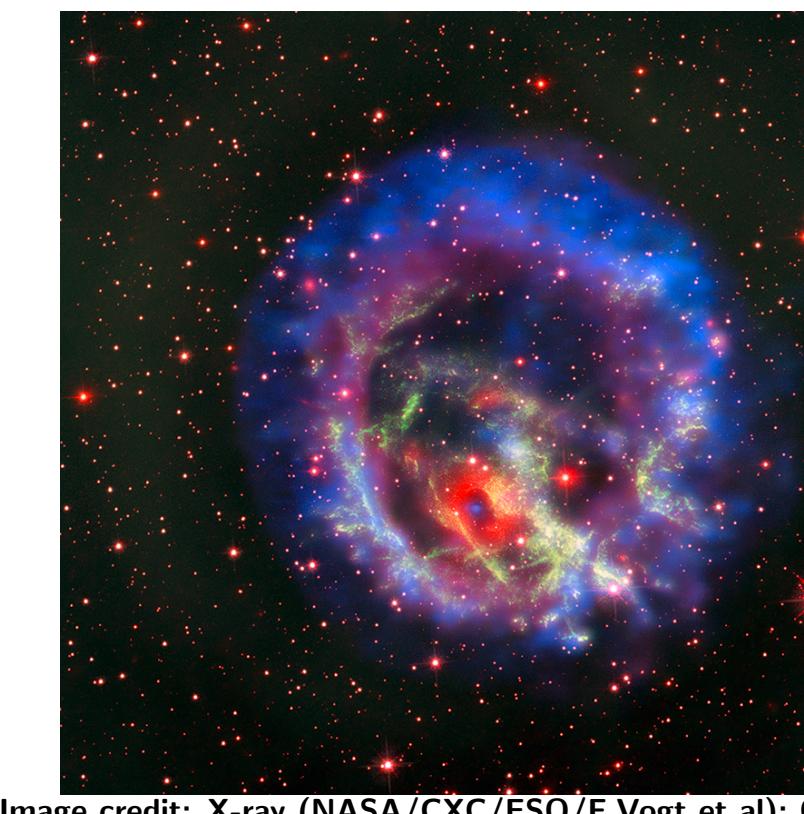


Image credit: X-ray (NASA/CXC/F. Vogt et al); Optical (ESO/VLT/MUSE and NASA/STScI)

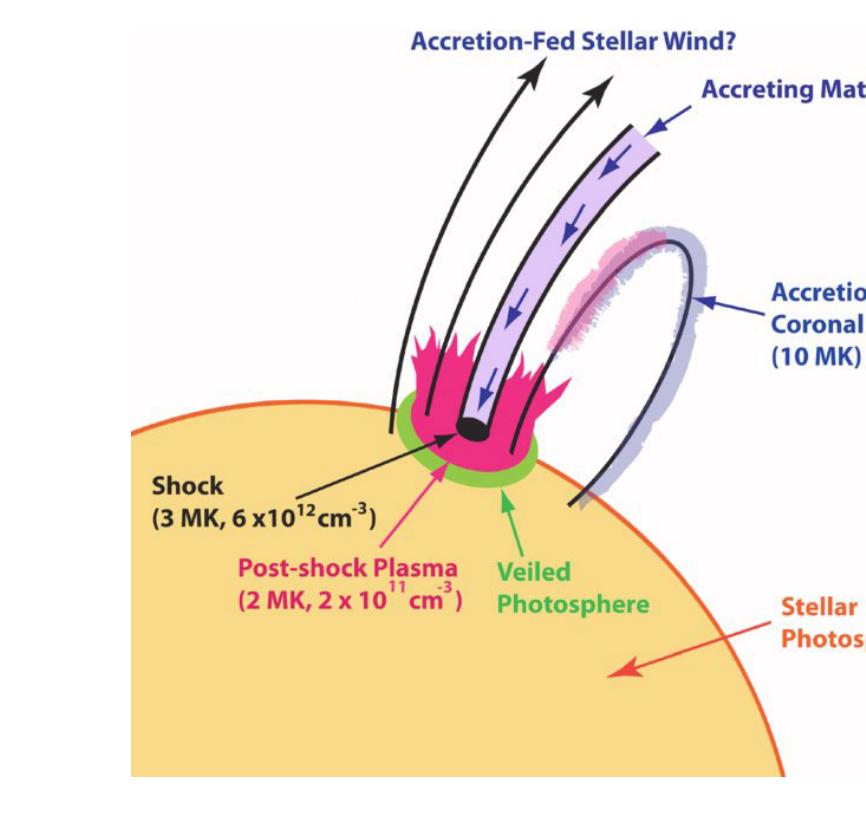
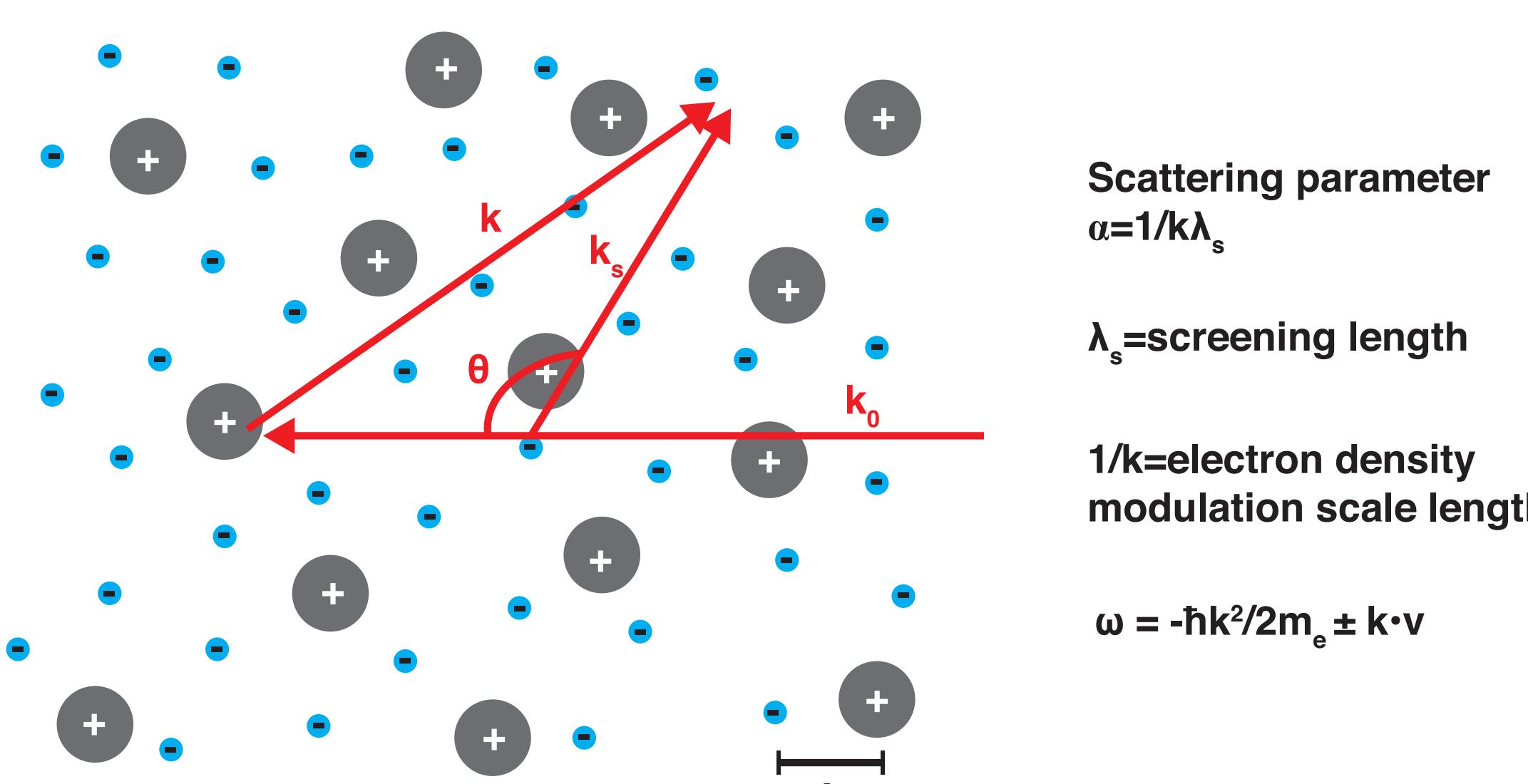


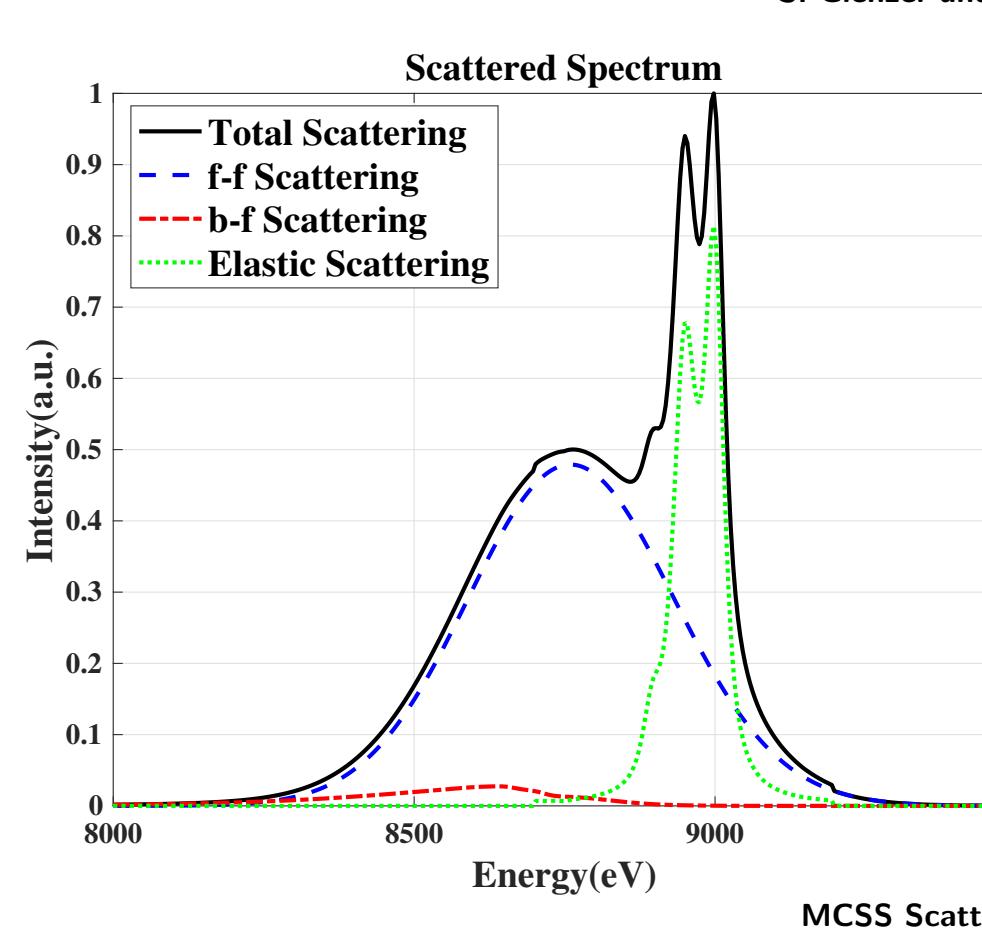
Image credit: Brickhouse et al., 2010

- Radiation energy fluxes exceed inflowing material energy fluxes changing the shock structure
- $Q = \frac{2\sigma u^5}{\rho R^4}$; Shock strength parameter
- $R_F = \frac{2\sigma T^4}{\rho u_s^3}$, Ratio of radiation to material energy flux

Non-collective x-ray Thomson scattering allows for a measurement of T_e



S. Glenzer and R. Redmer RMP 81 (2009)



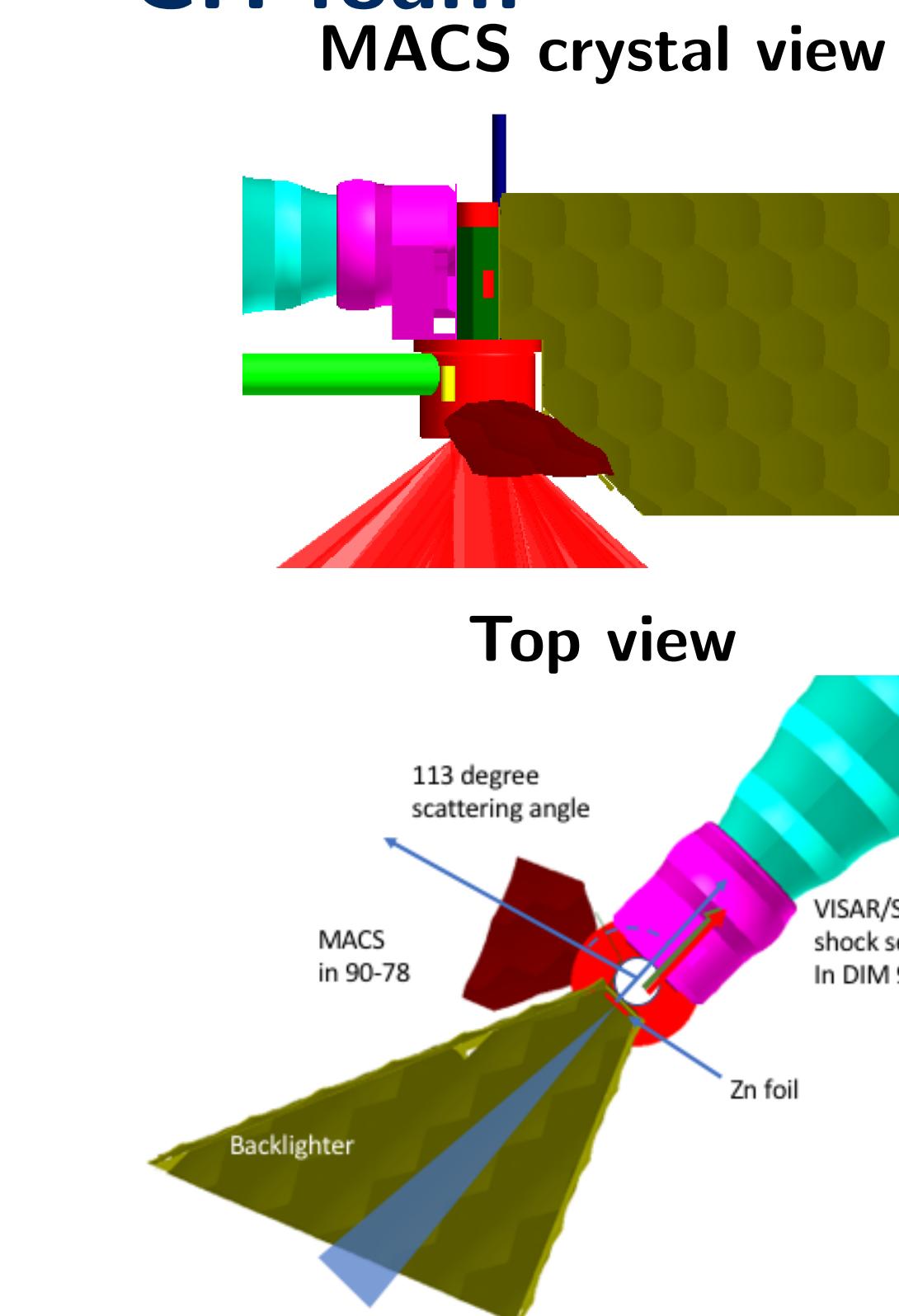
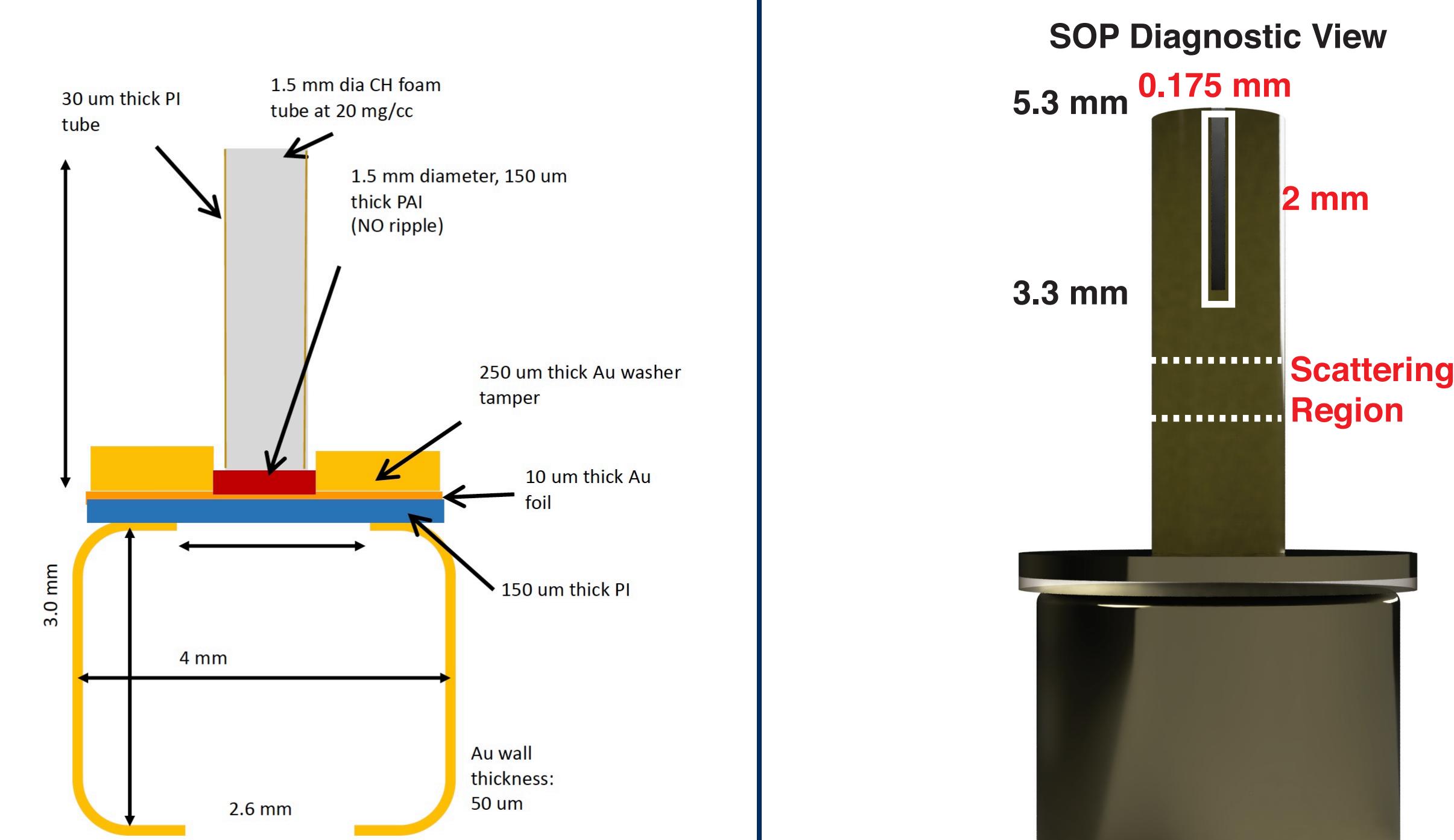
An existing NIF platform makes XRTS measurements of capsule implosions



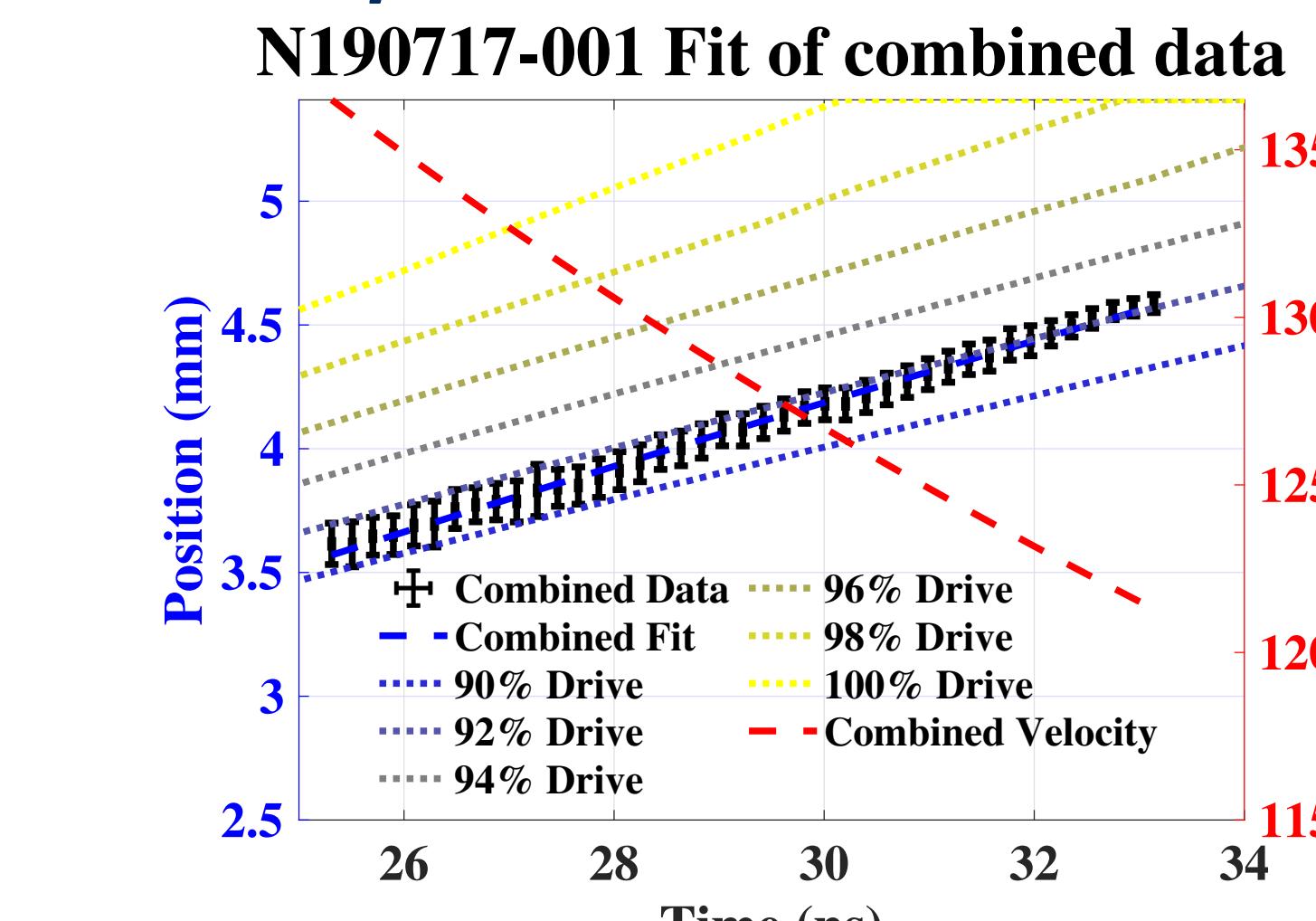
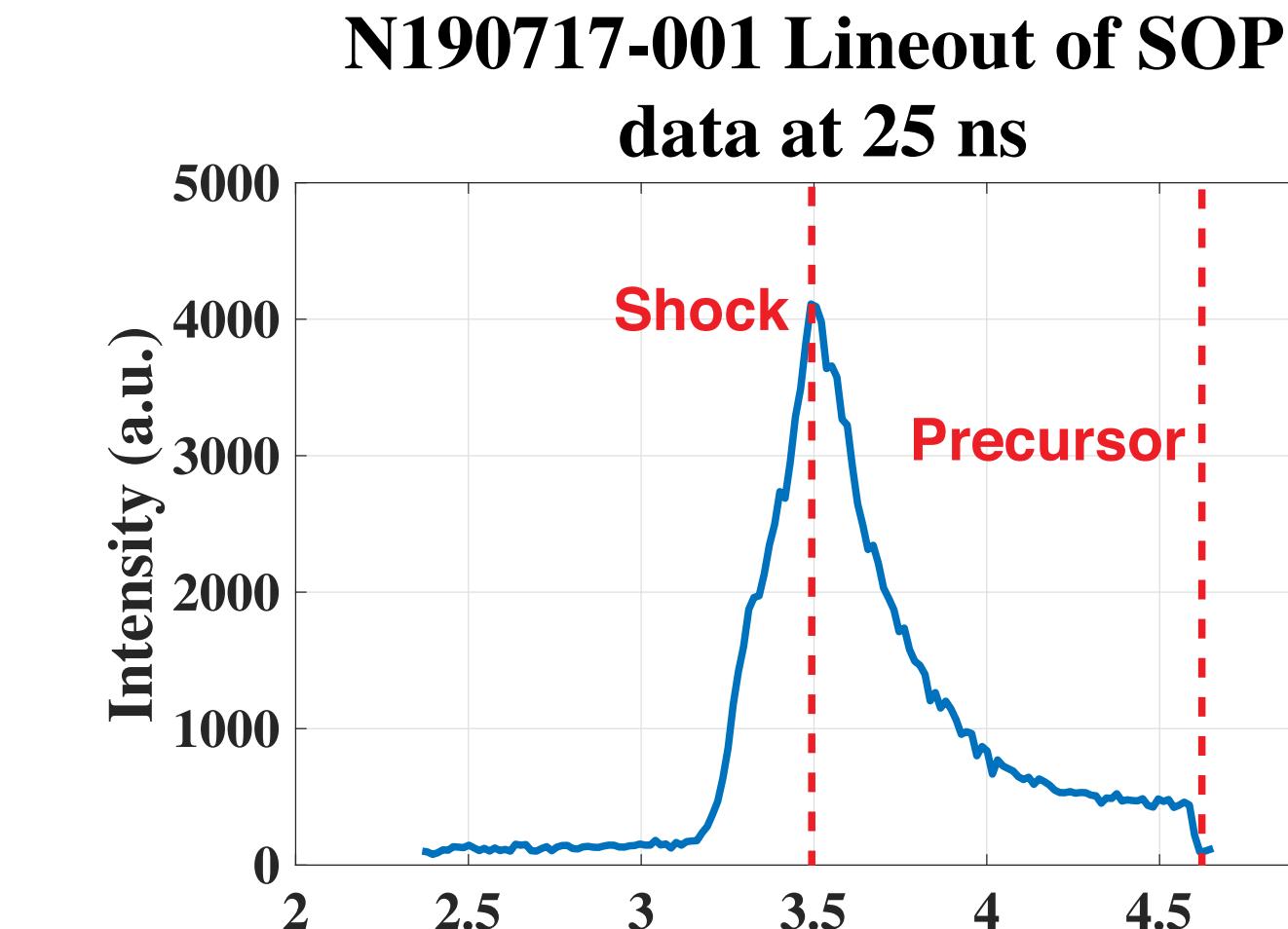
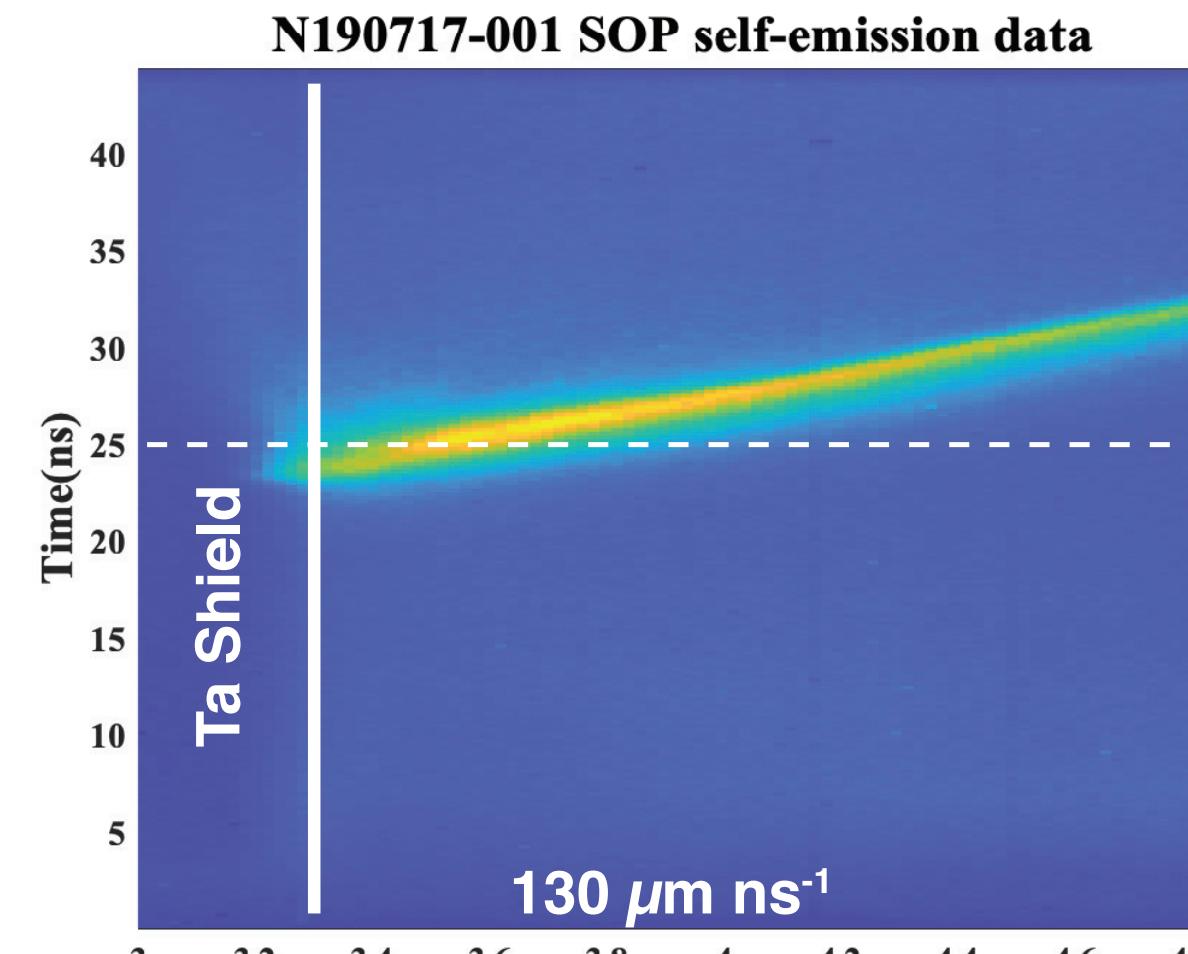
- Uses Zn He- α source at 9 keV to probe system
- Mono-angle Crystal Spectrometer uses a cylindrically curved HOPG crystal

Kraus et al. Journal of Physics: Conference Series 717 (2016) 012067
Döppner et al. Journal of Physics: Conference Series 500 (2014) 182019
Kraus et al. PHYSICAL REVIEW E 94, 011202(R) (2016)
Kraus et al. Review of Scientific Instruments 85, 110617 (2014)

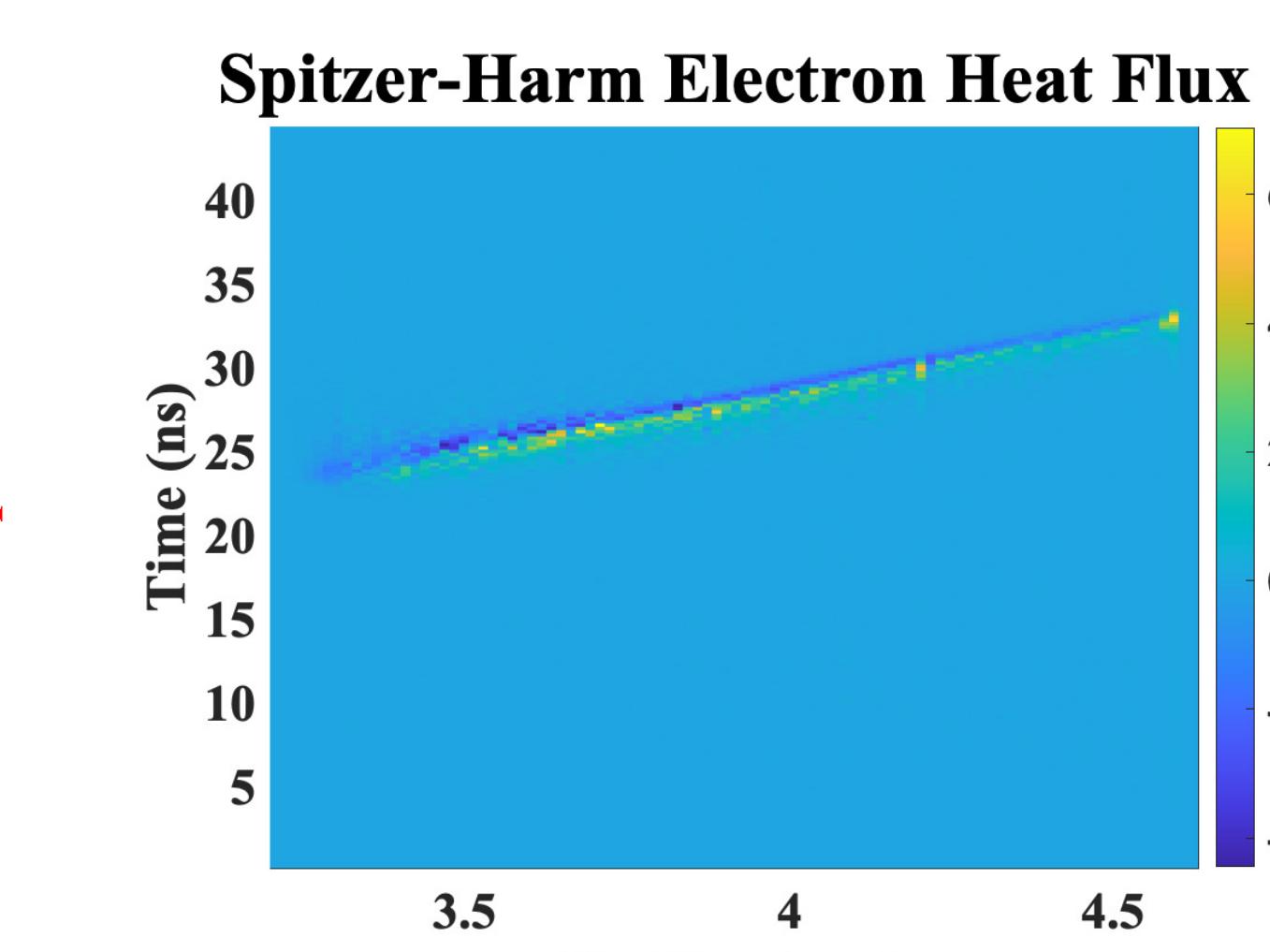
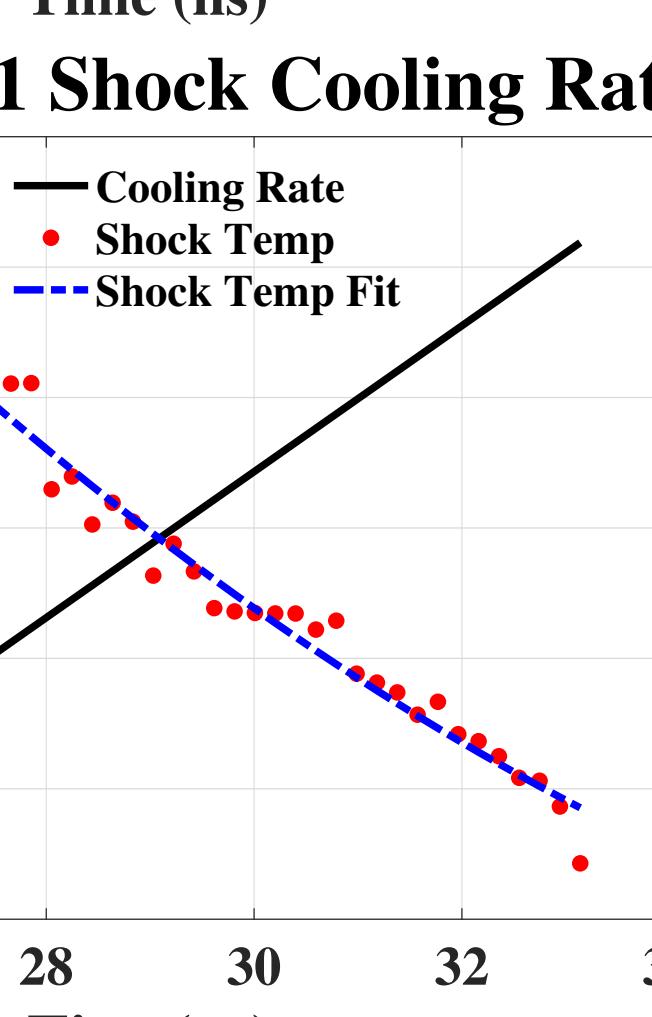
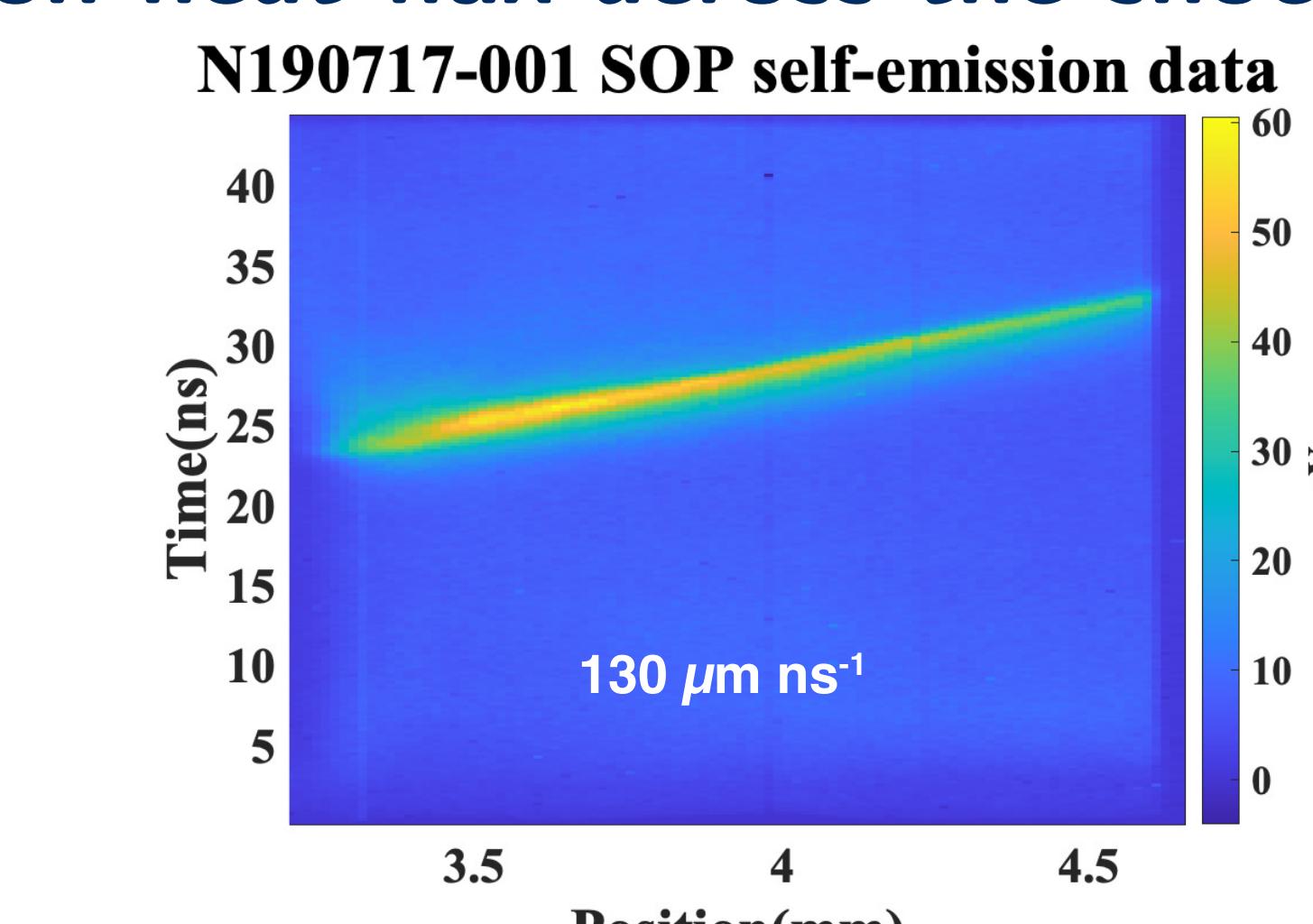
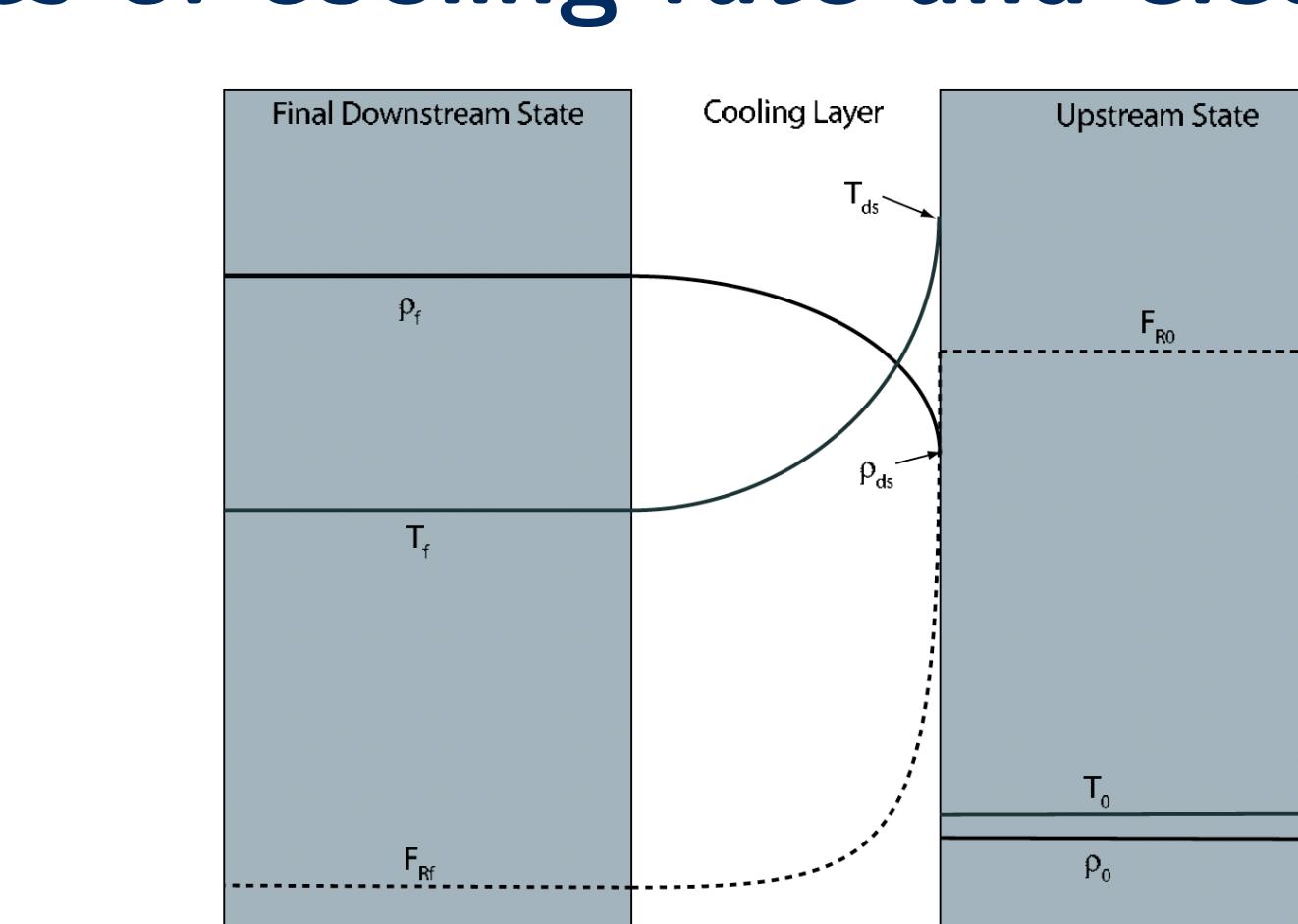
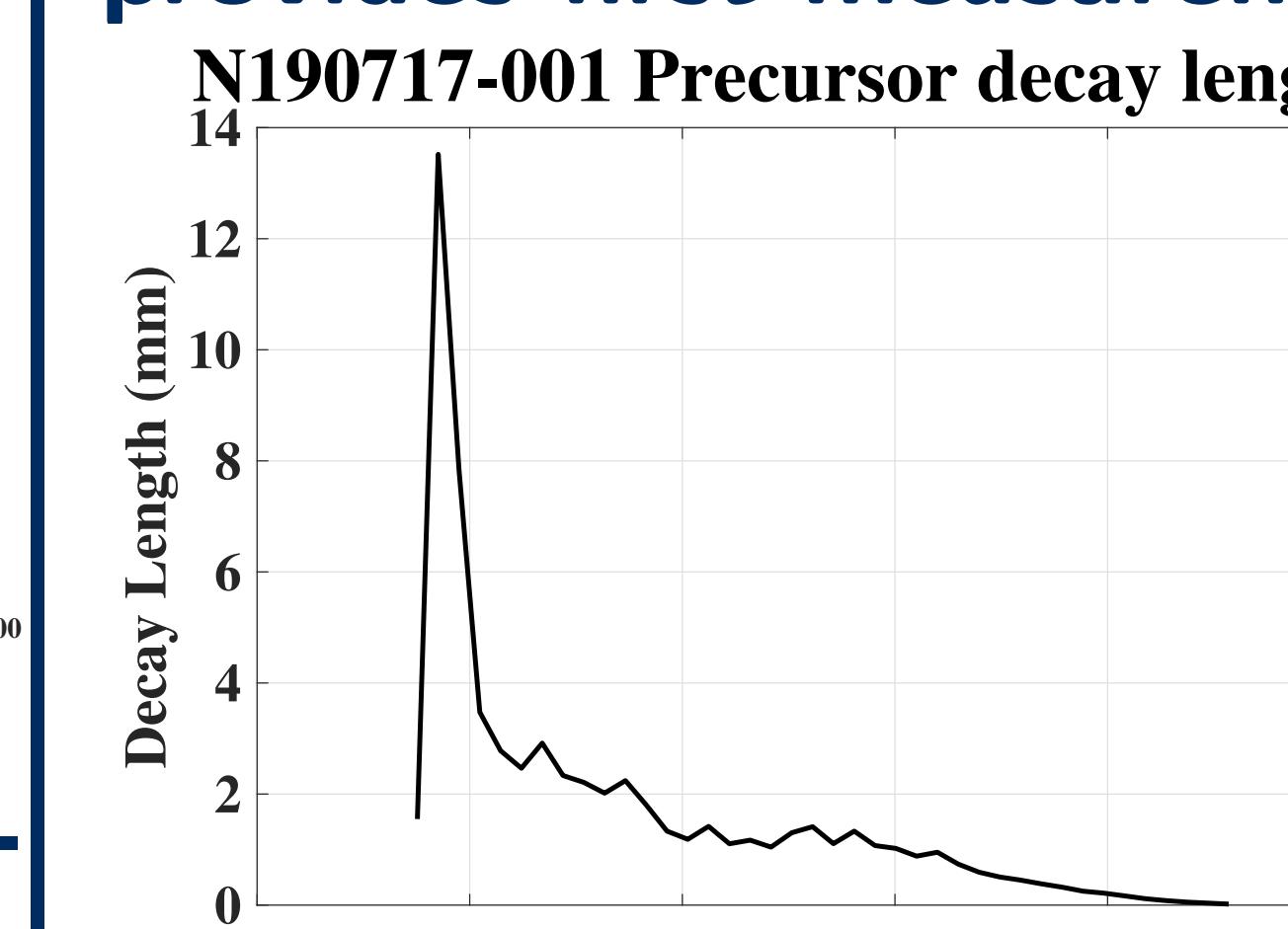
A DS campaign used XRTS and optical self-emission to measure a radiative shock in 20 mg cm^{-3} CH foam



The SOP data measures a shock velocity of $130 \mu\text{m ns}^{-1}$

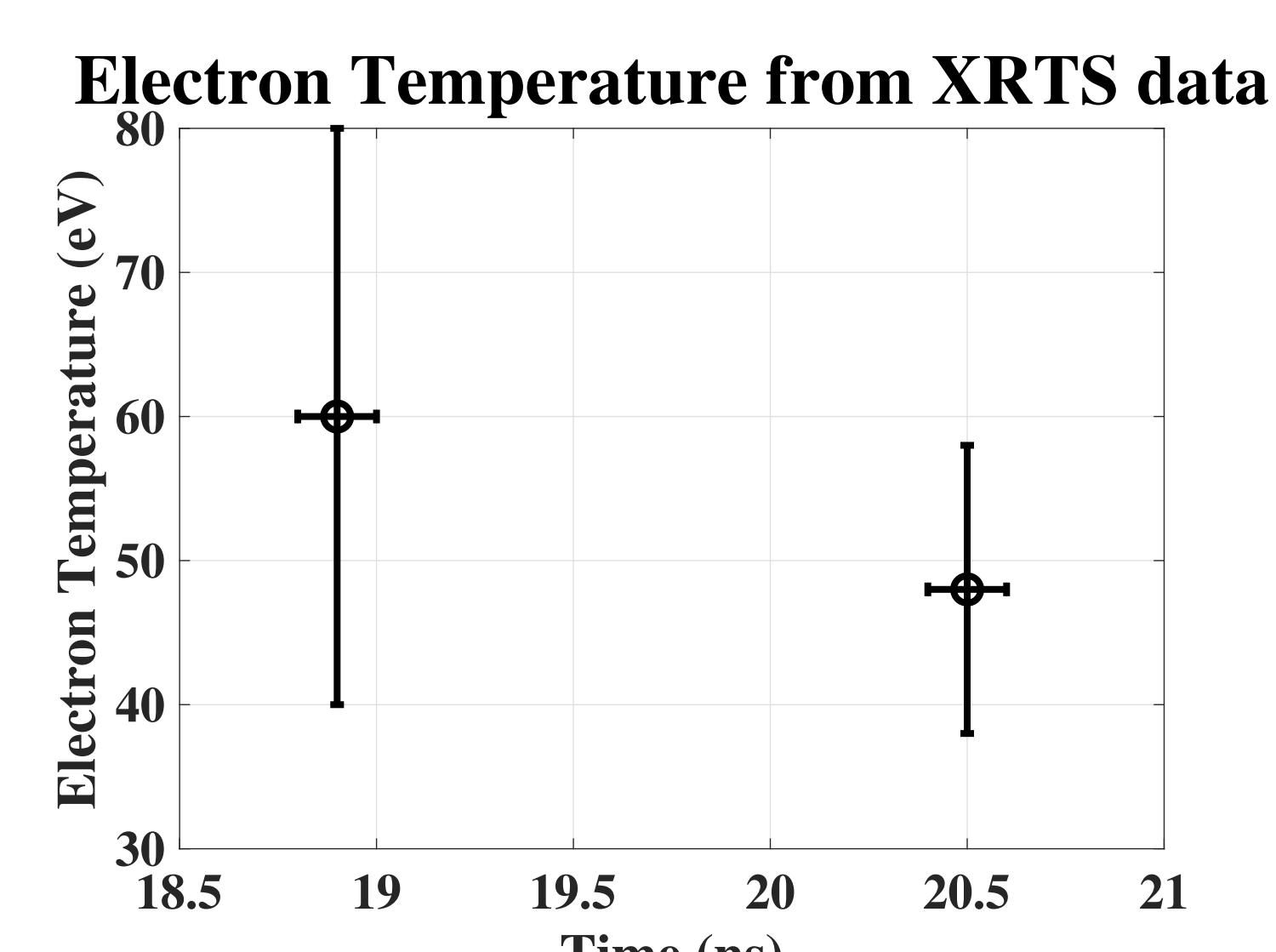
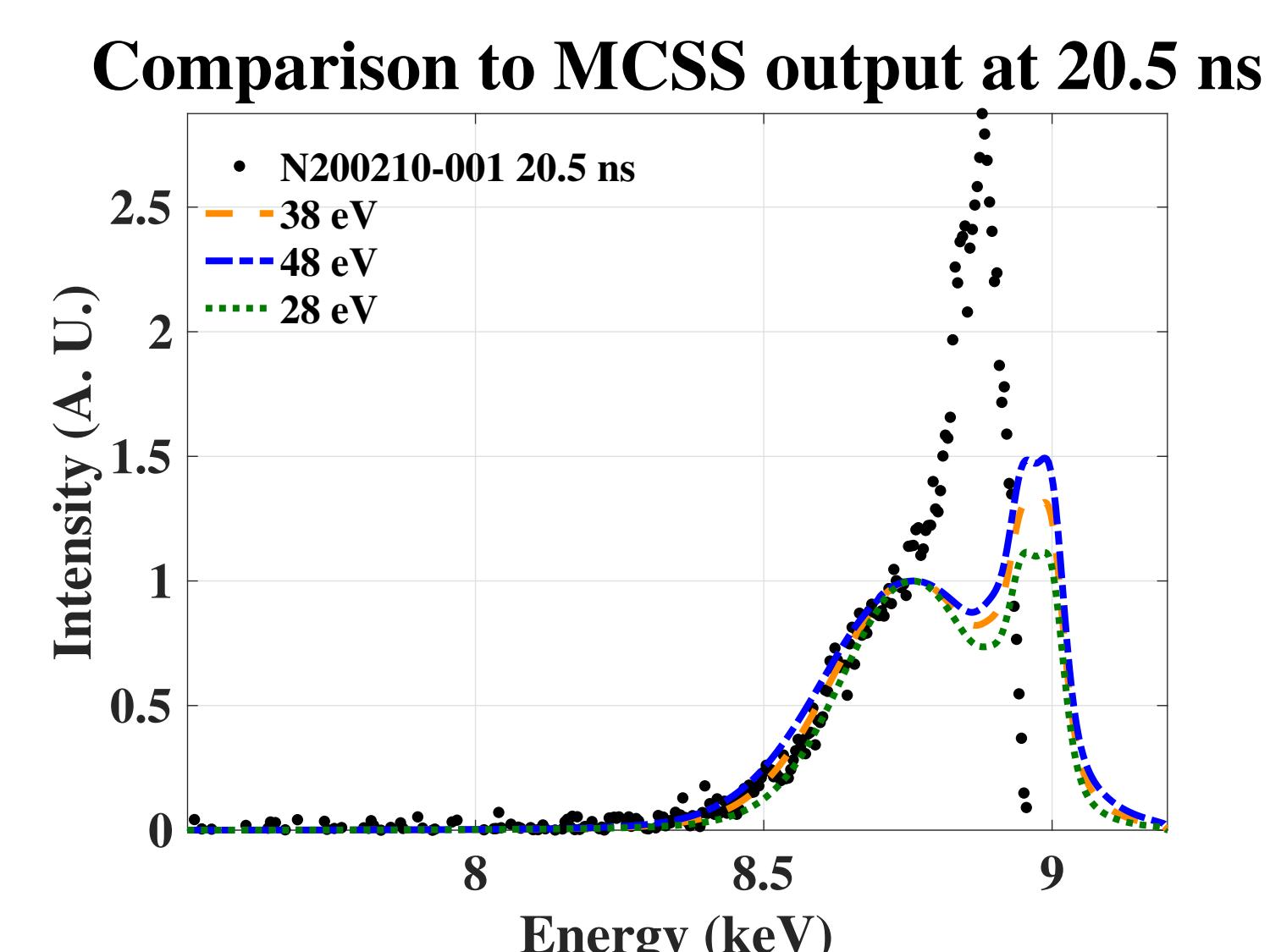
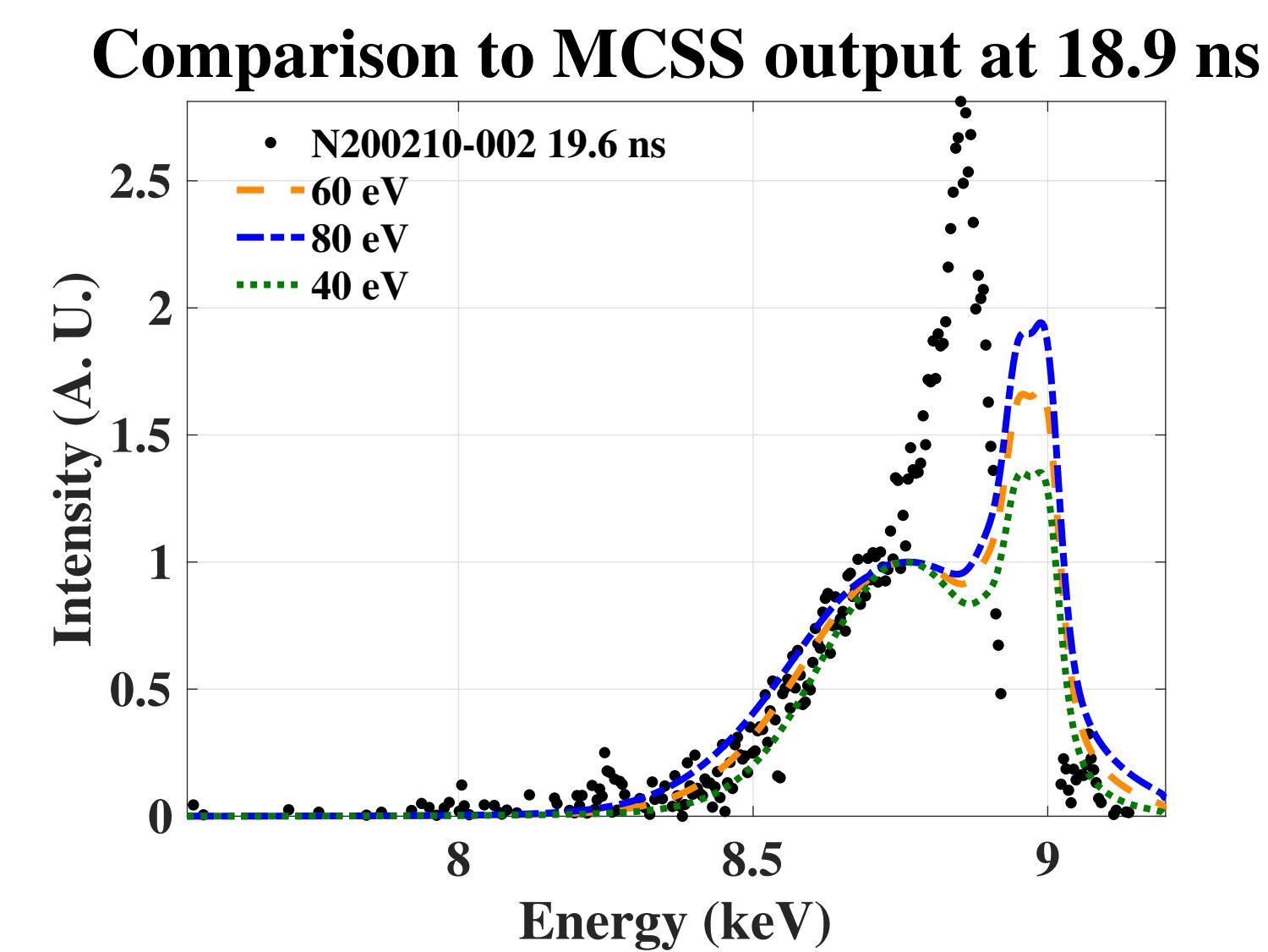


A three-layer radiative shock model maps the self-emission data to temperature and provides first measurements of cooling rate and electron heat flux across the shock



- $\frac{\rho}{\rho_0} = 9.1$, Compression
- $T_f = 48.8 \text{ eV}$, Final state temperature
- $Q = 2800$
- $T_{ds} = 96 \text{ eV}$, Initial post-shock temperature
- $R_F = 4$, Radiative
- Fit suggests a temperature of 8.1 eV and ionization of 1.3

The XRTS measurements generally agree with the self-emission data



- Probe beams use a 2.8 ns pulse with a 0.67 ns ramp
- Scattering from shocked foam and entrained ablator
- Background subtraction affects the elastic component
- Synthetic spectra use David Chapman's MCSS code
- Comparison only considers the inelastic component
- Error bars from integration time and synthetic spectra comparison

Funding Acknowledgements

This material is based upon work supported by the National Science Foundation MPS-Ascend Postdoctoral Research Fellowship under Grant No. 2138109. This work is funded by the U.S. Department of Energy NNSA Center of Excellence under grant number DE-NA0003869 and the National Science Foundation through the Basic Plasma Science and Engineering program NSF 16-564, grant number 1707260. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and supported by Laboratory Directed Research and Development (LDRD) Grant No. 18-ERD-033.