Probing atomic physics in partially ionized matter at extreme densities

D. Kraus[1,2], T. Doeppner[3], B. Borm[4], A. Yi[5], A. L. Kritcher[2], B. Bachmann[2], R. A. Baggot[6], D. A. Chapman[6], L. B. Fletcher[7], L. Divol[3], R. W. Falcone[2], S. H. Glenzer[7], O. L. Landen[3], M. J. MacDonald[2], A. M. Saunders[2], C. R. Weber[3], D. O. Gericke[6] and P. Neumayer[6]

[1]*Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany*

[2]*University of California, Berkeley, CA, USA*

[3]*Lawrence Livermore National Laboratory, Livermore, CA, USA*

[4]*GSI Helmholtzzentrum fuer Schwerionenforschung, Darmstadt, Germany*

[5]*Los Alamos National Laboratory, Los Alamos, NM, USA*

[6]*University of Warwick, Coventry, UK*

[7]*SLAC National Accelerator Laboratory, Menlo Park, CA, USA*

d.kraus@hzdr.de

The ionization balance plays a crucial role when modeling matter at extreme pressures. In dense matter, the bound states, and accordingly the ionization balance, are modified by the interaction with the surrounding medium. In particular, the influence of neighboring ions and screening due to continuum electrons results in reduced binding strength, which can be modeled by introducing effective (lower) ionization energies.

At the National Ignition Facility, we have compressed plastic (CH) and beryllium capsules to electron densities up to 10^{25} cm^{-3}, reaching pressures in the Gbar regime while the temperature remains on the order or below the Fermi temperature. Spectrally resolved X-ray scattering in combination with X-ray radiography measurements allows for directly accessing electron-ion correlations while at the same time constraining density and temperature. We find the electronic structure to be strongly affected by the extreme density and infer an ionization that is significantly larger than predicted by the Stewart-Pyatt interpolation between the Debye and ion sphere limits.

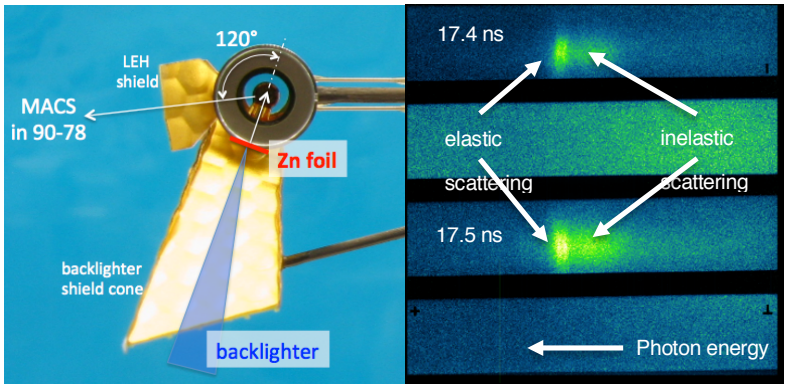

Figure 1: Target design of the experimental platform to perform spectrally resolved X-ray scattering on the National Ignition Facility and raw data of collected spectra. The elastic scattering is a direct measurement of the electron-ion correlations while the inelastic scattering allows for constraining density and temperature.