



# Same-Shot X-Ray Thomson Scattering and Streaked Imaging of Xenon Radiative Shock Experiments



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## Creating Radiative Shocks

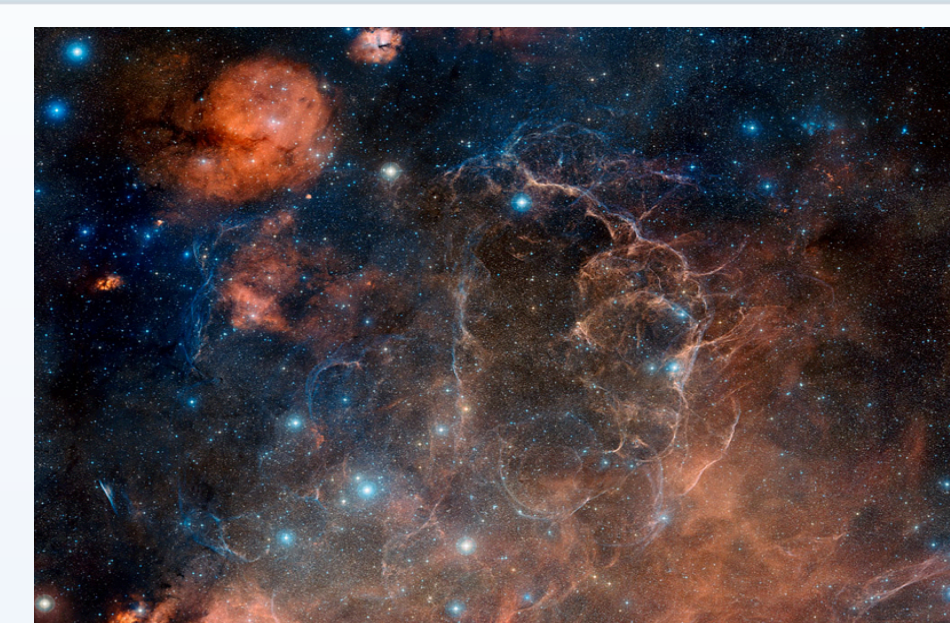
In a radiative shock the density and temperature structure of the shock have been altered by radiation transport from the shock-heated matter.

The radiative regime is reached when radiation fluxes exceed material fluxes, i.e.:

$$\sigma T_s^4 > \frac{\rho_o u_s^3}{2} \text{ or, for radiative shocks: } R_{rad} = \frac{\sigma T_s^4}{\rho_o u_s^3/2} > 1$$

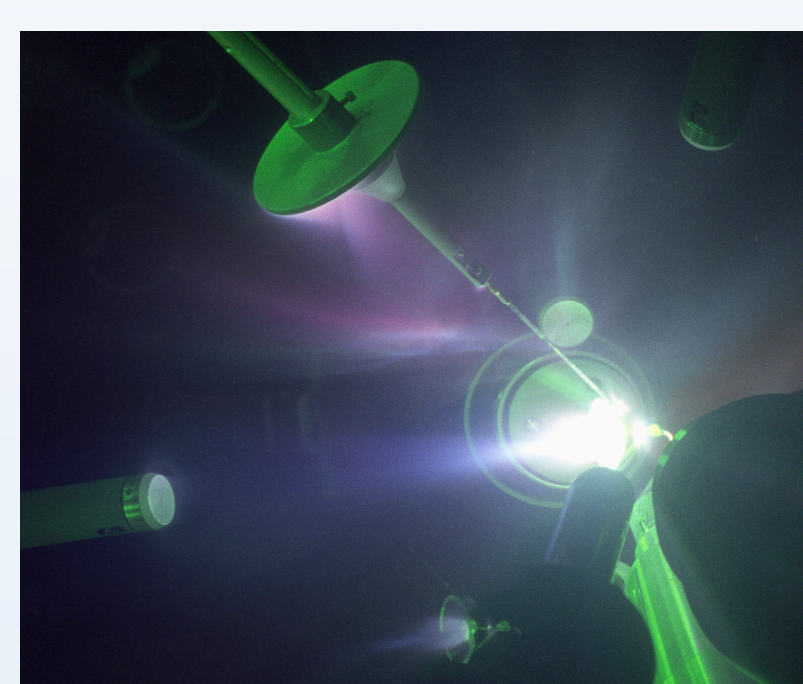
In the strong shock limit  $T \propto u_s^2$  so  $R_{rad} \propto \frac{u_s^5}{\rho_o}$

Systems with high velocities and low densities that can reach the radiative regime are ubiquitous in astrophysical systems, including supernovae, supernova remnants, and accretion disks.



The Vela Supernova remnant is an example of a radiative shock in astrophysics. Image from the NASA Astronomy Picture of the Day Collection

A time-integrated visible light image of the target in the chamber during laser irradiation. Plasma plumes are evident around the target and diagnostics.

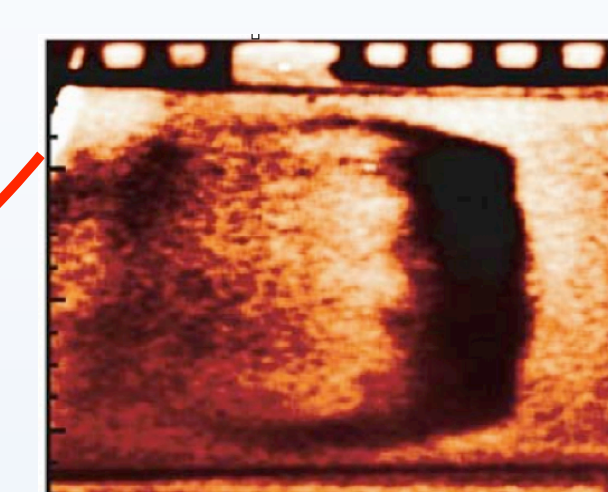
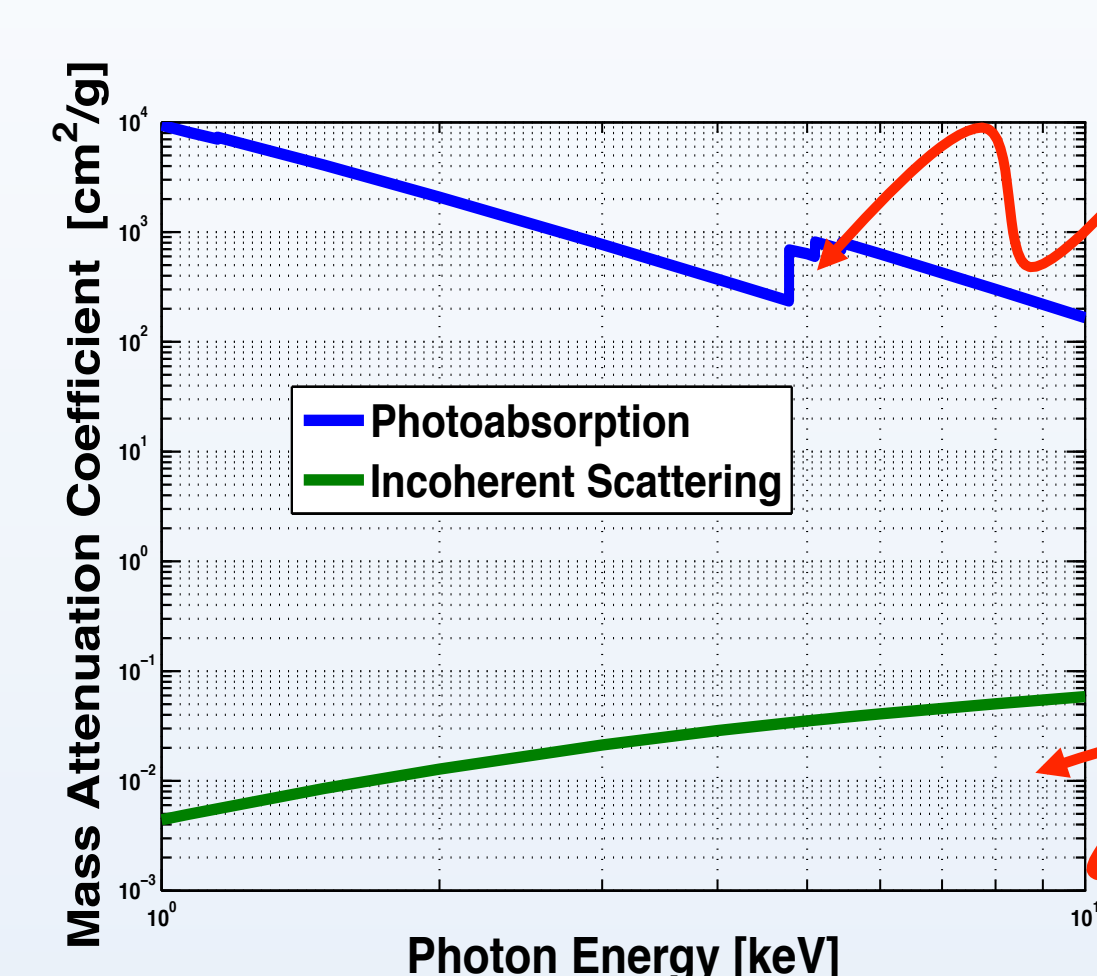


## Primary X-ray Diagnostics

Diagnostics are fielded to work in distinct modes:

- Passive detection: Henway spectrometer and Ross pair filters
- Transmission x-ray imaging: Streaked x-ray radiography
- Scattered x-ray spectroscopy: Zinc Thomson spectrometer
- Scattered x-ray imaging: Pinhole imaging of scattered photons
  - This is not fielded in the present experiments, but may prove to be a powerful means of measuring local electron density for dense targets and remains under develop.

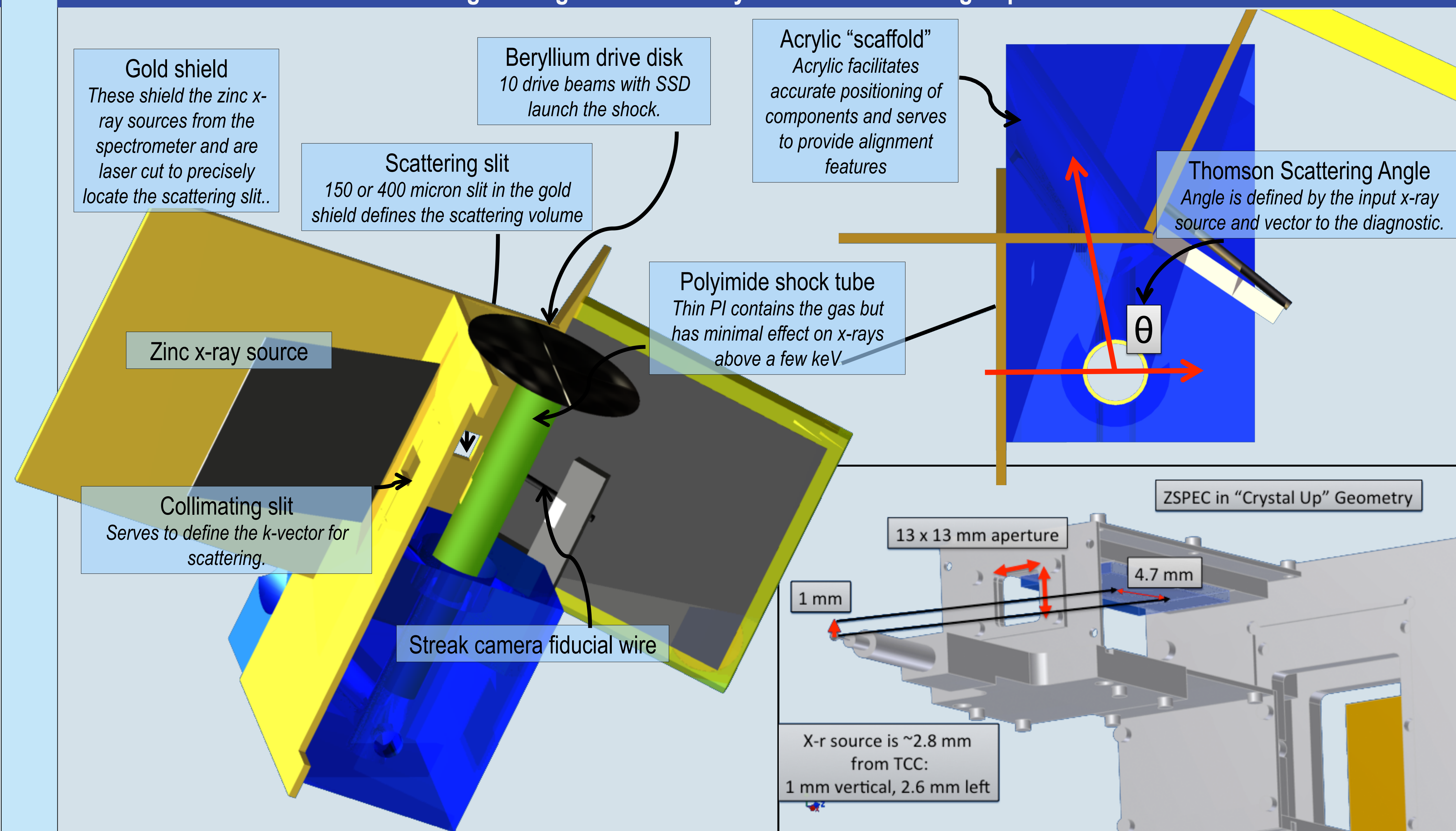
Contributions to the Xe Total Mass Attenuation Coefficient



Radiography with V (5.2 keV) Image courtesy of A. B. Reighard

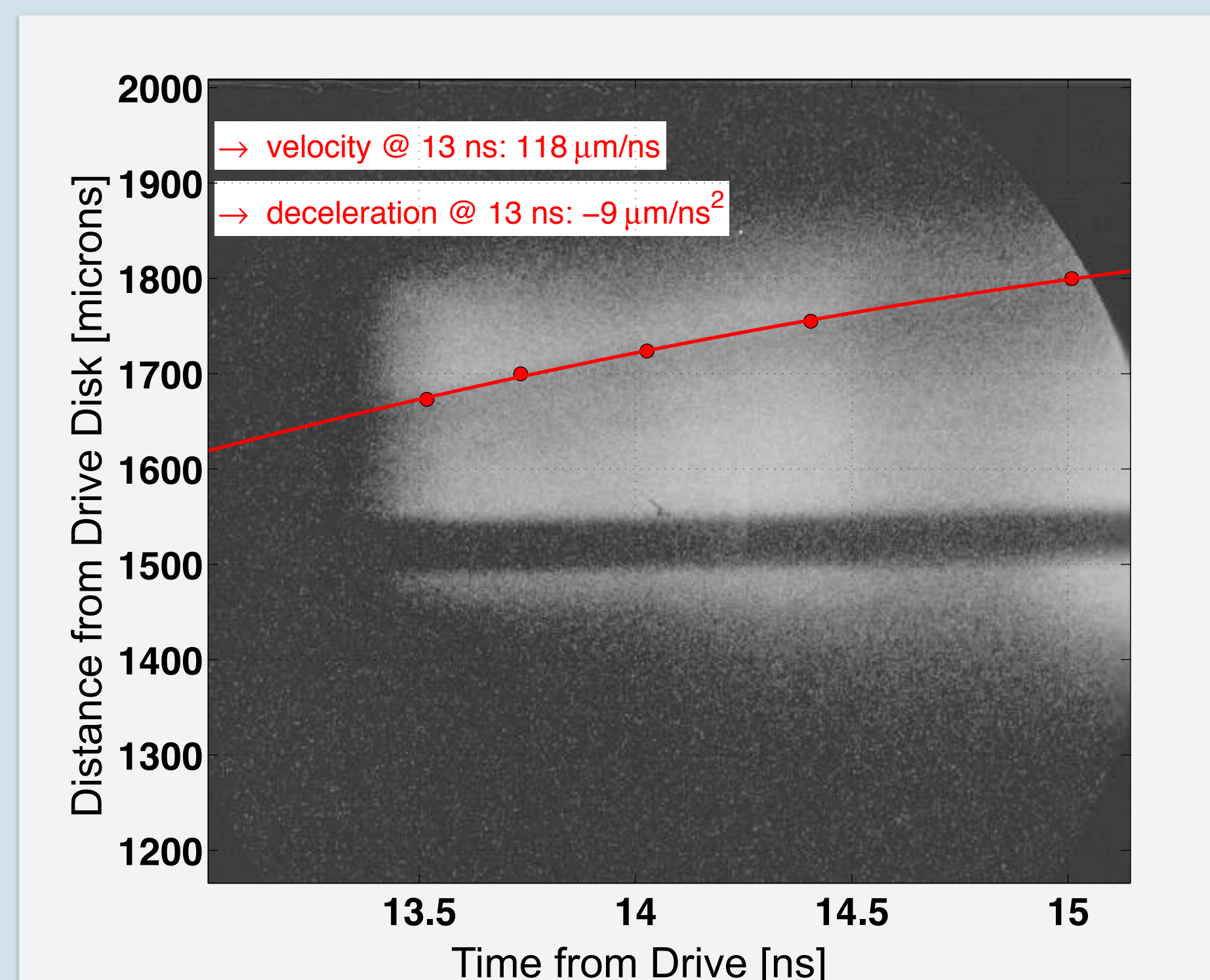
Scattering with Zn (9 keV) avoids attenuation

## Target Design for 2011 X-Ray Thomson Scattering Experiment



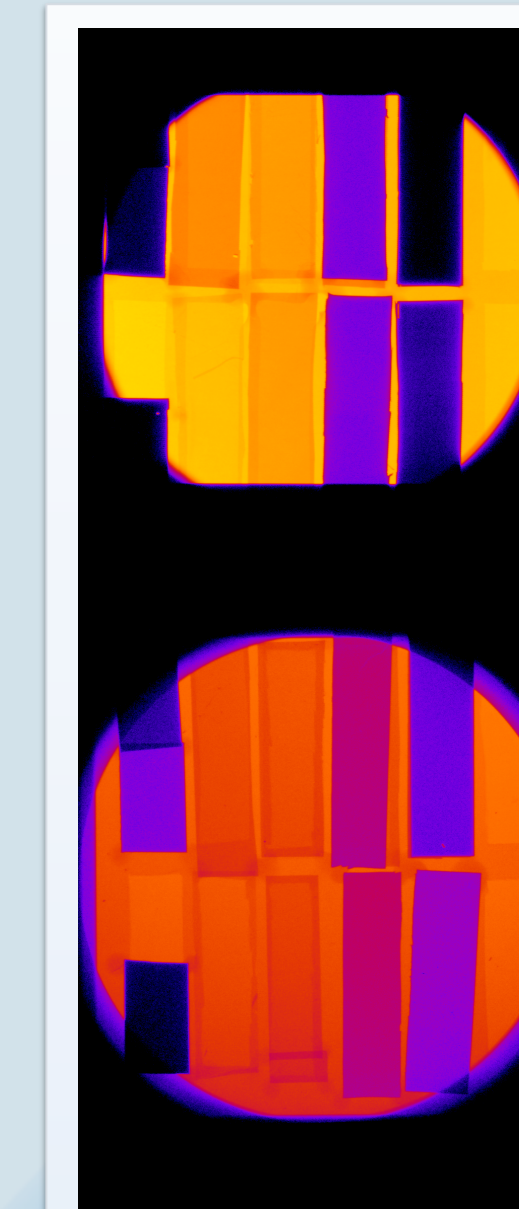
## X-Ray Streak Data

- Streak camera records shock front progression at sweep speeds of 2.5 ns and 5 ns, providing time resolution ~100 ps.
- A decelerating shock is clearly observed (2010 data).



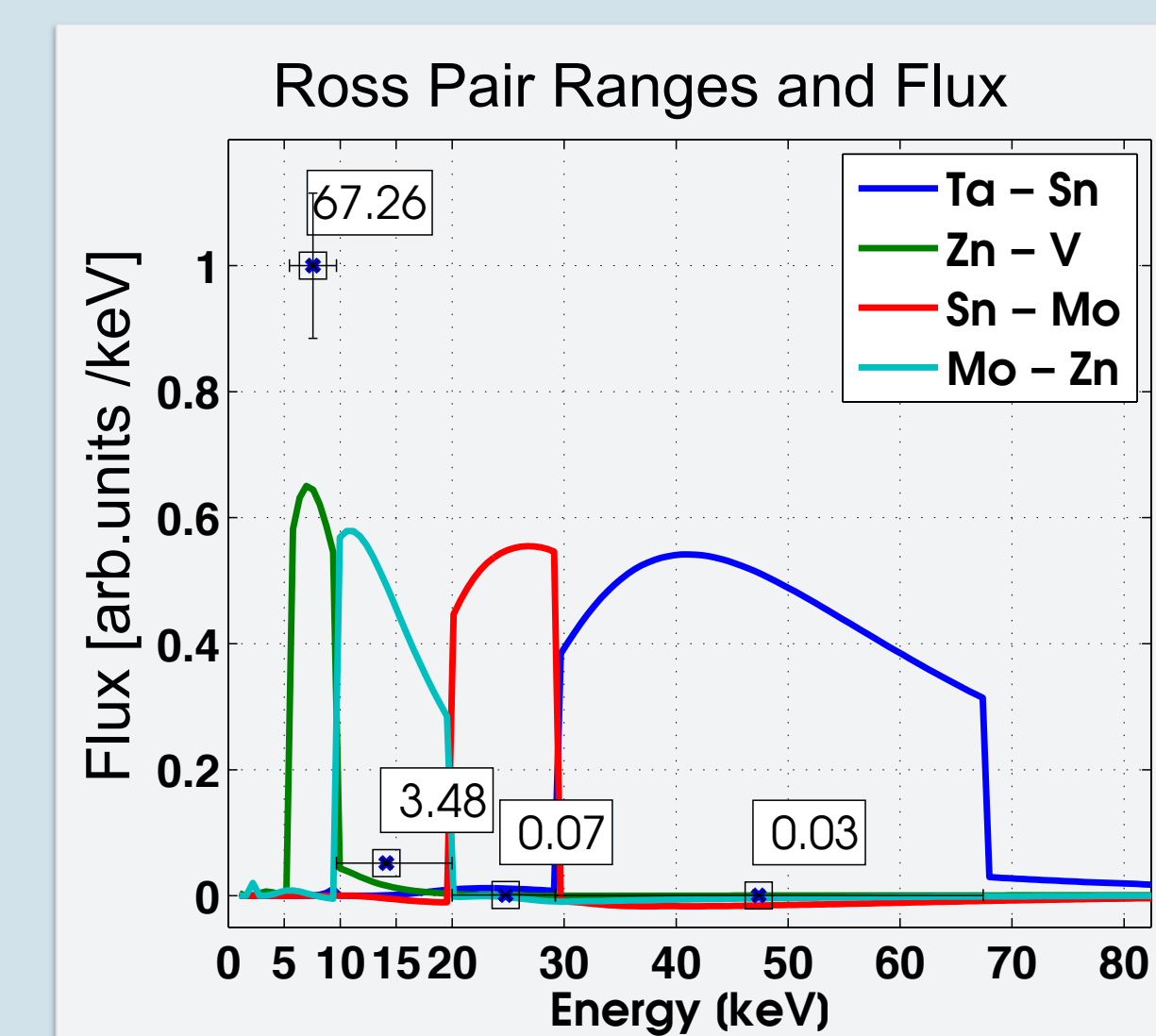
## Passive X-Ray Detectors

- Passive detectors confirm x-ray lines from expected diagnostic sources and inform our understanding of the x-ray background.
- Ross pairs serve as a simple, robust diagnostic to obtain absolute photon yields.
- The Henway x-ray spectrometer consists of four independently-filtered crystals covering 2-13 keV, monitoring x-ray sources and background in the range of the diagnostics.



(Above) Elemental filters are matched in thickness and transmission to form the Ross pair matrix.

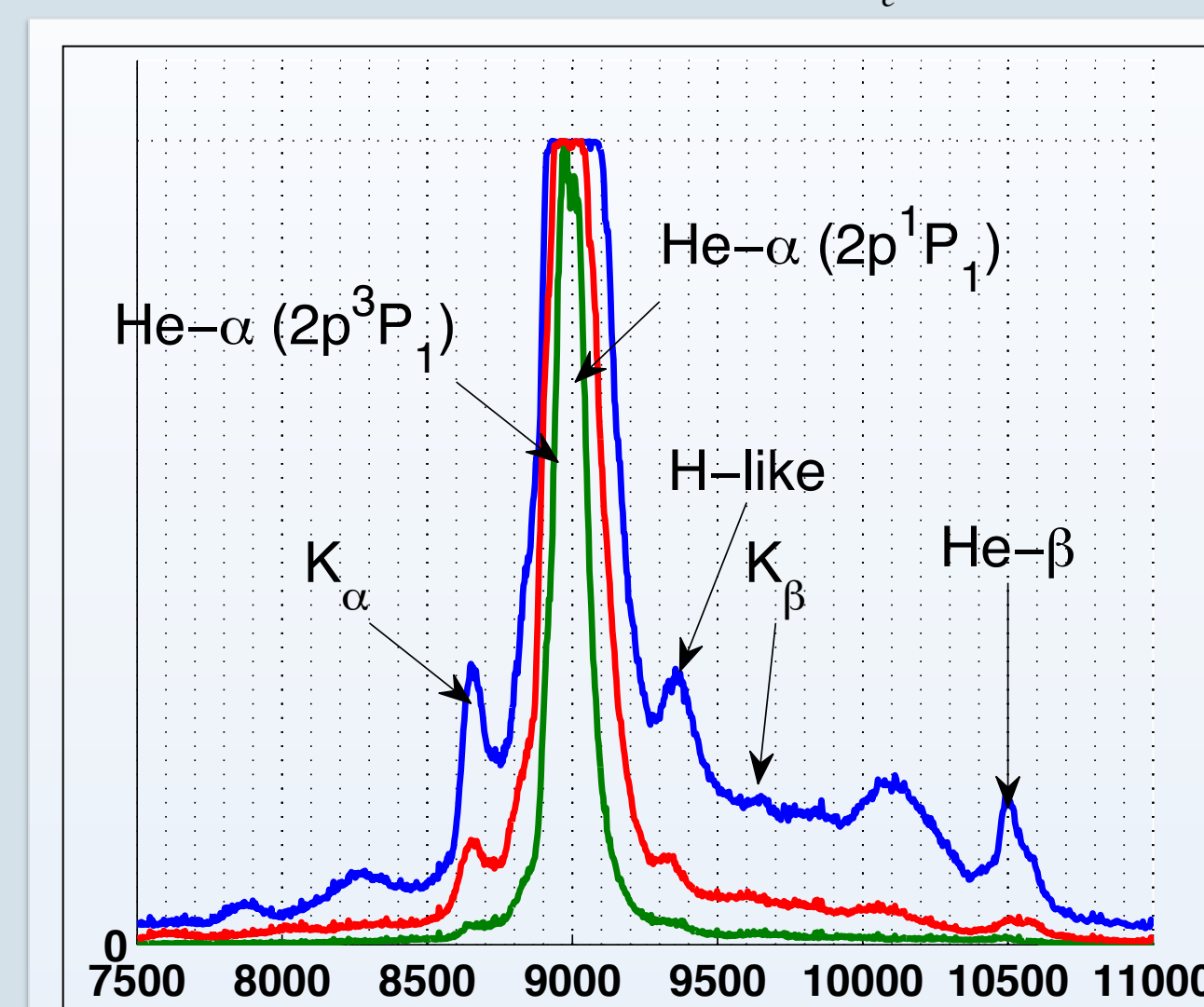
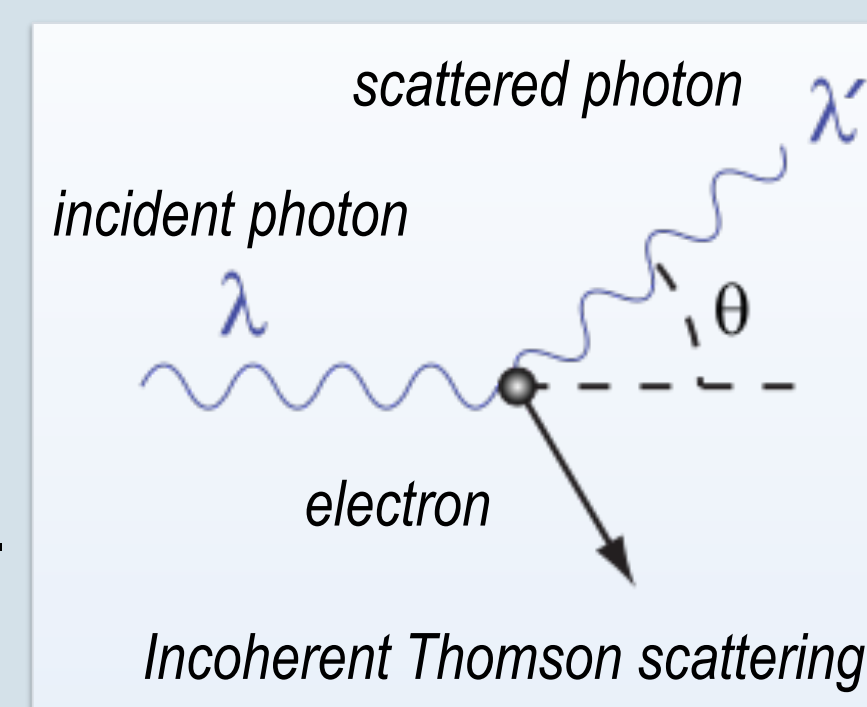
(Left) Ross pairs provide a simple, coarse spectrographic information about the x-rays present during the experiment.



## Diagnostic Principles

### Incoherent Thomson scattering

- Involves photon scattering from individual electrons.
- Recoil of free electrons leads to an energy downshift in the scattered spectrum.
- The shift is given by the Compton formula:  $\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos \theta)$



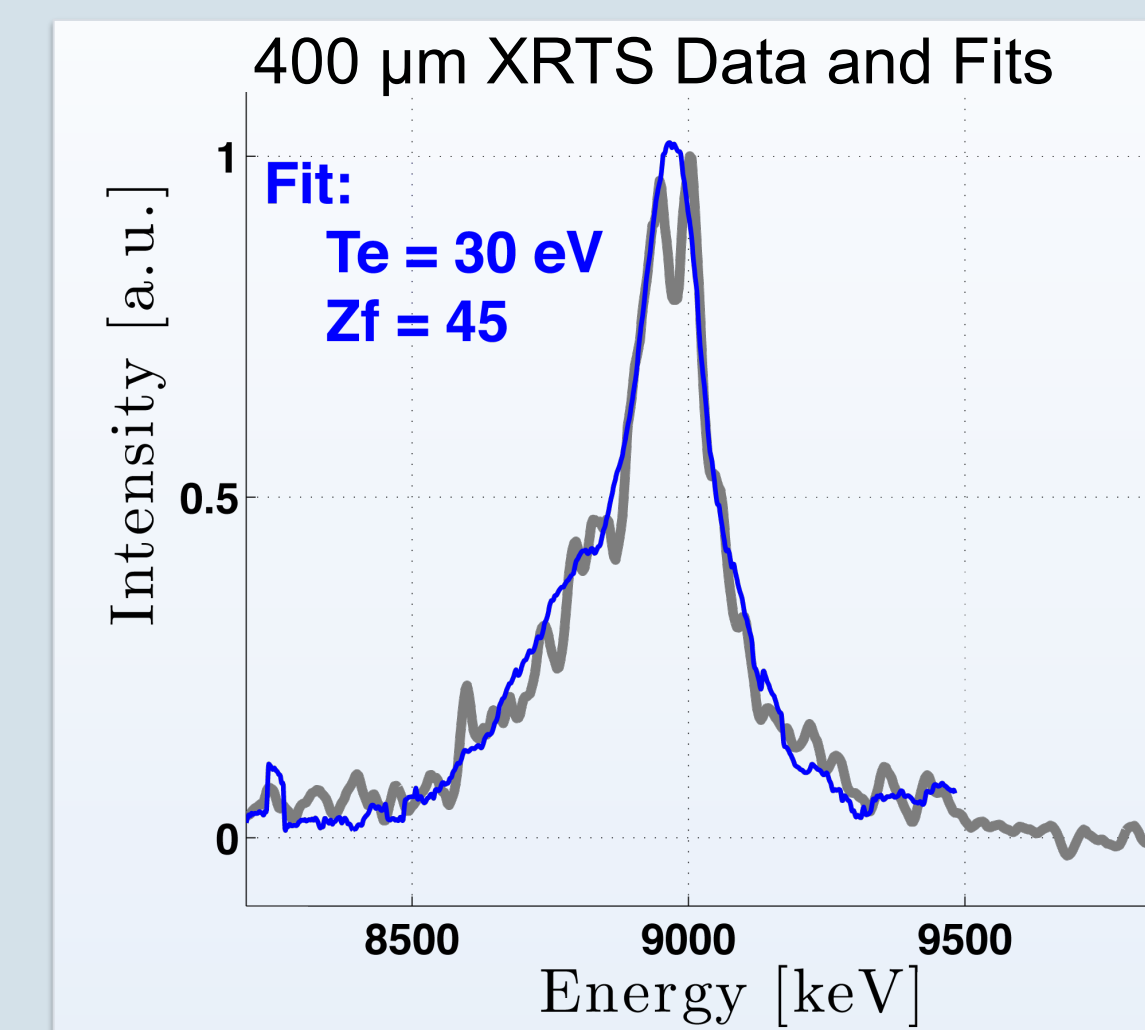
Input spectra for Compton scattering experiment shows several spectral lines. These must be accounted for in analysis of down-scattered signal.

### Streaked x-ray Radiography

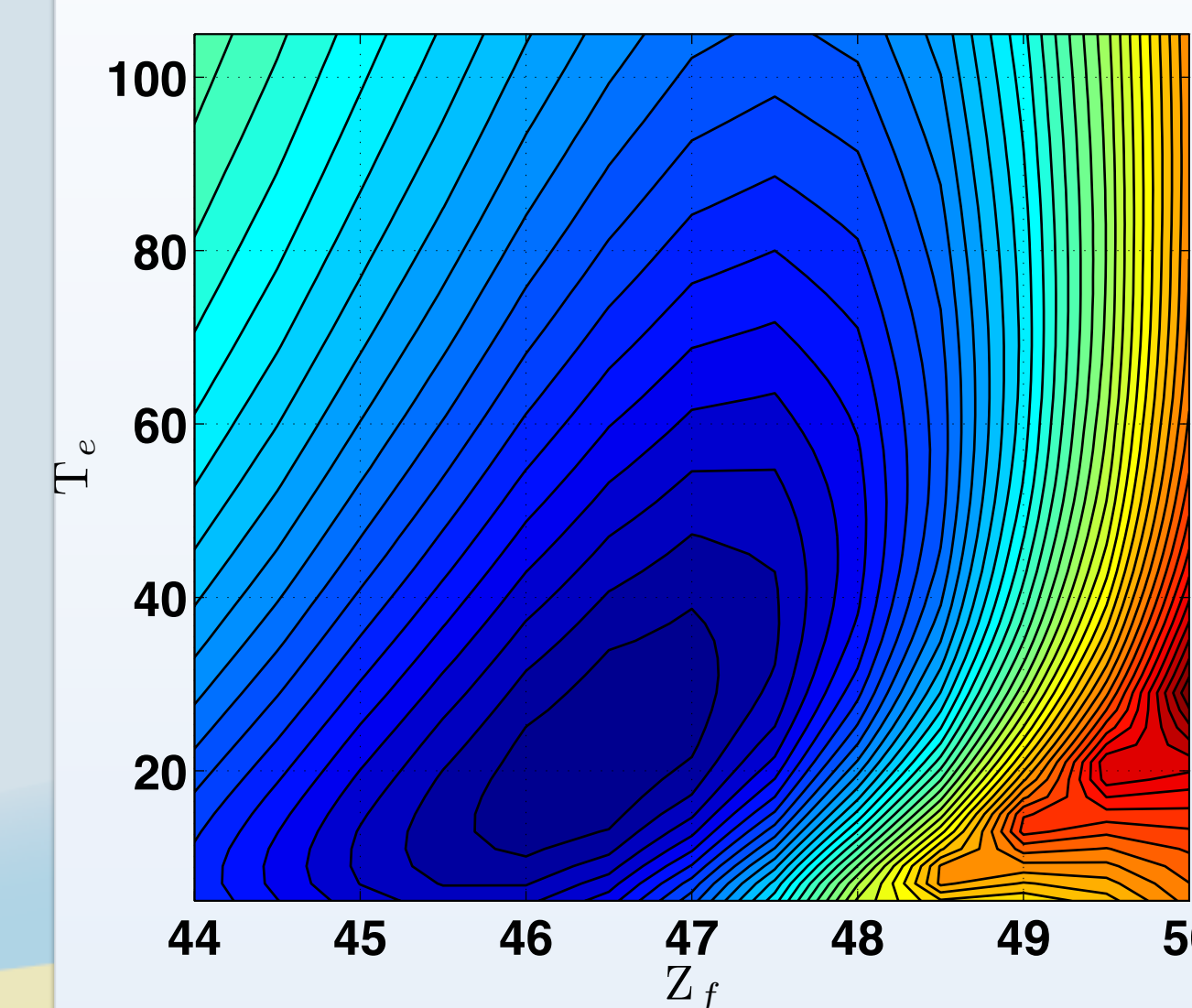
- Imaging a streak camera film with long-duration backlighting provides information about shock velocity and absolute position.

## XRTS results

- Scattered spectra shows a clear inelastic peak, which is fit for the 400 micron-slit target. Low signal-to-noise limits the use of data from the 150 micron case.
- Least-squares analysis yields an optimal single-plasma-state temperature of ~30 eV.



Temp and Z<sub>f</sub> Model Parameters Contour



- A more realistic multi-temperature plasma profile based on simulations is ongoing, and will be verified with future high resolution experiments.

## Acknowledgements

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