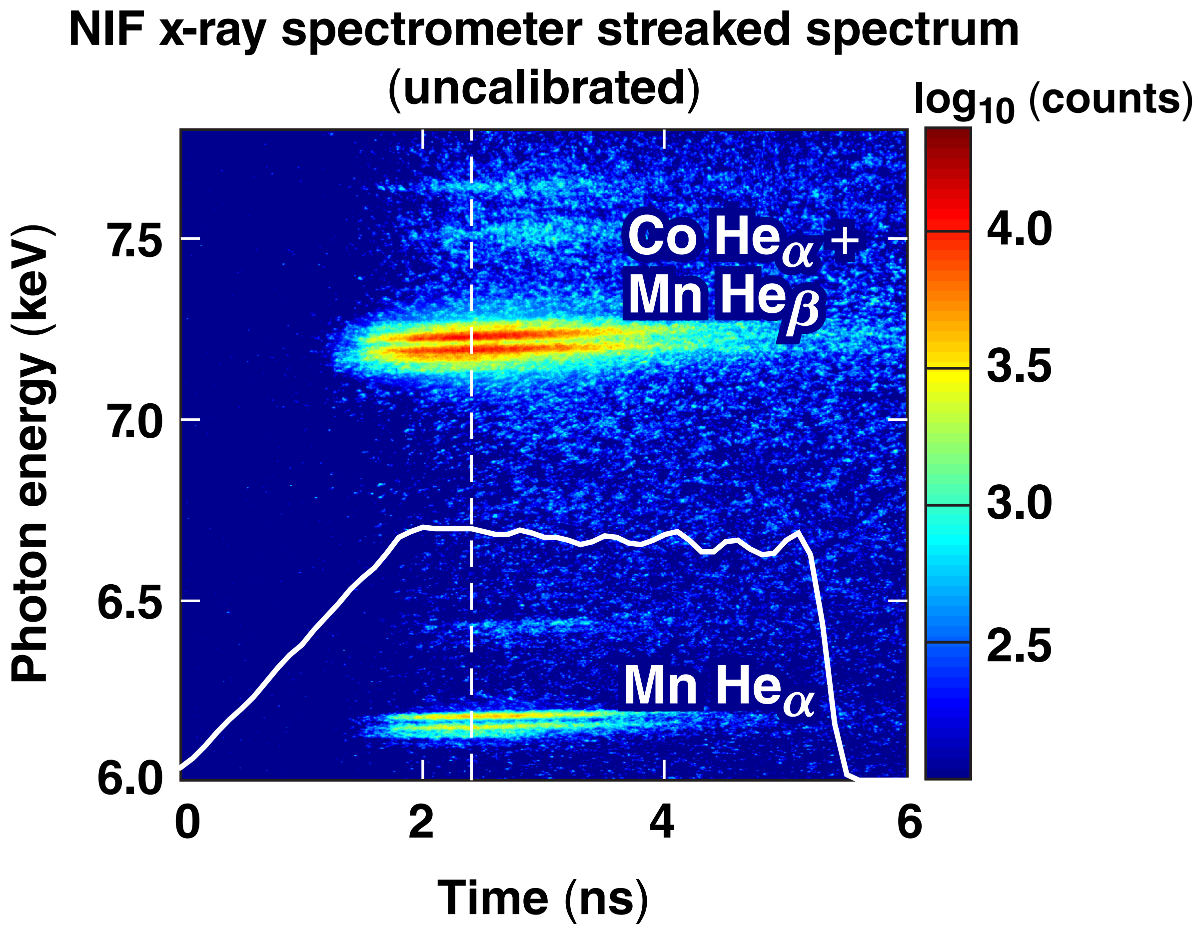
Application and Analysis of the Isoelectronic Line-Ratio Temperature Diagnostic in a Planar Ablating-Plasma Experiment at the National Ignition Facility

Shot N150520: 23° and 30° beams



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The isoelectronic Co/Mn He_{α} line ratio is a good temperature diagnostic for ablating plasmas

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- The Co/Mn He_{α} line ratio was used to measure the electron temperature in planar experiments performed to study the beam angle-of-incidence dependence of the two-plasmon–decay (TPD) instability
- The density sensitivity of this line ratio is a source of systematic error and a consideration in choosing microdot materials
- Spectrum simulations show that the He_{α} line ratio is only modestly affected by self-absorption

Collaborators

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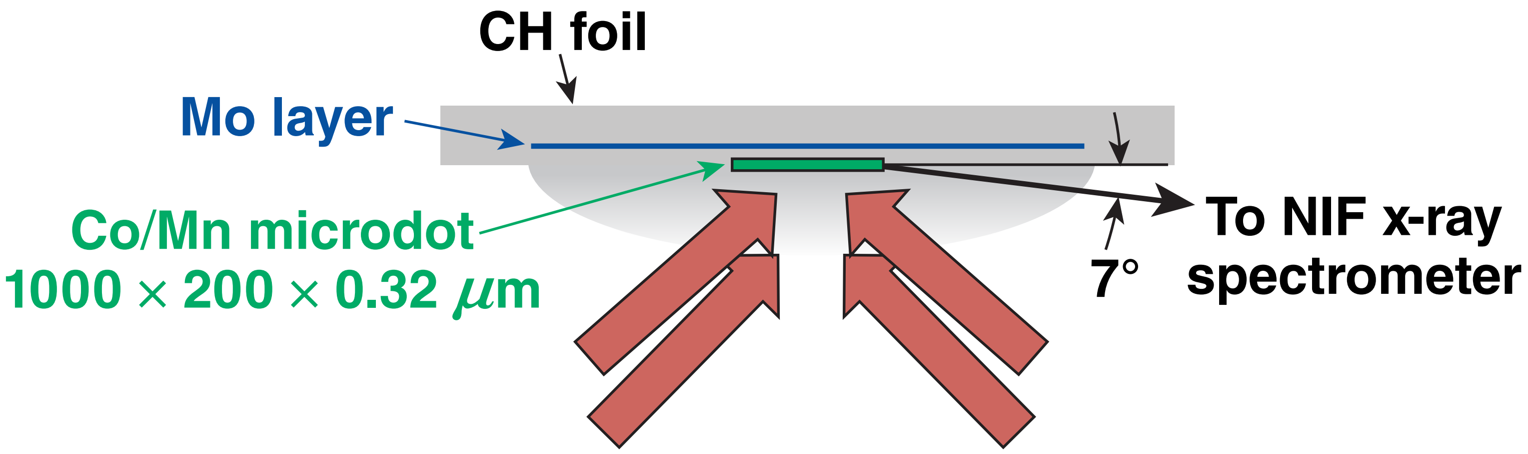
Temperatures in two planar experiments performed at the National Ignition Facility (NIF) were inferred from isoelectronic line ratios from embedded Co/Mn microdots

Shot N150520: 23° and 30° beams (32 beams total)

Shot N150521: 45° and 50° beams (60 beams total)



- *PrismSPECT** for parameter (T_e, ρ) surveys
  - detailed atomic modeling
  - self-absorption modeled as local photon-escape probabilities in spherical geometry
- *Spect3D** simulations include the same detailed atomic model plus
  - microdot conditions obtained from T_e, ρ histories from *DRACO* CH foil simulations
  - realistic microdot geometry with the actual 7° viewing angle
  - nonlocal coupling of radiation with atomic kinetics

*Prism Computational Sciences, Inc., Madison, WI 53711.

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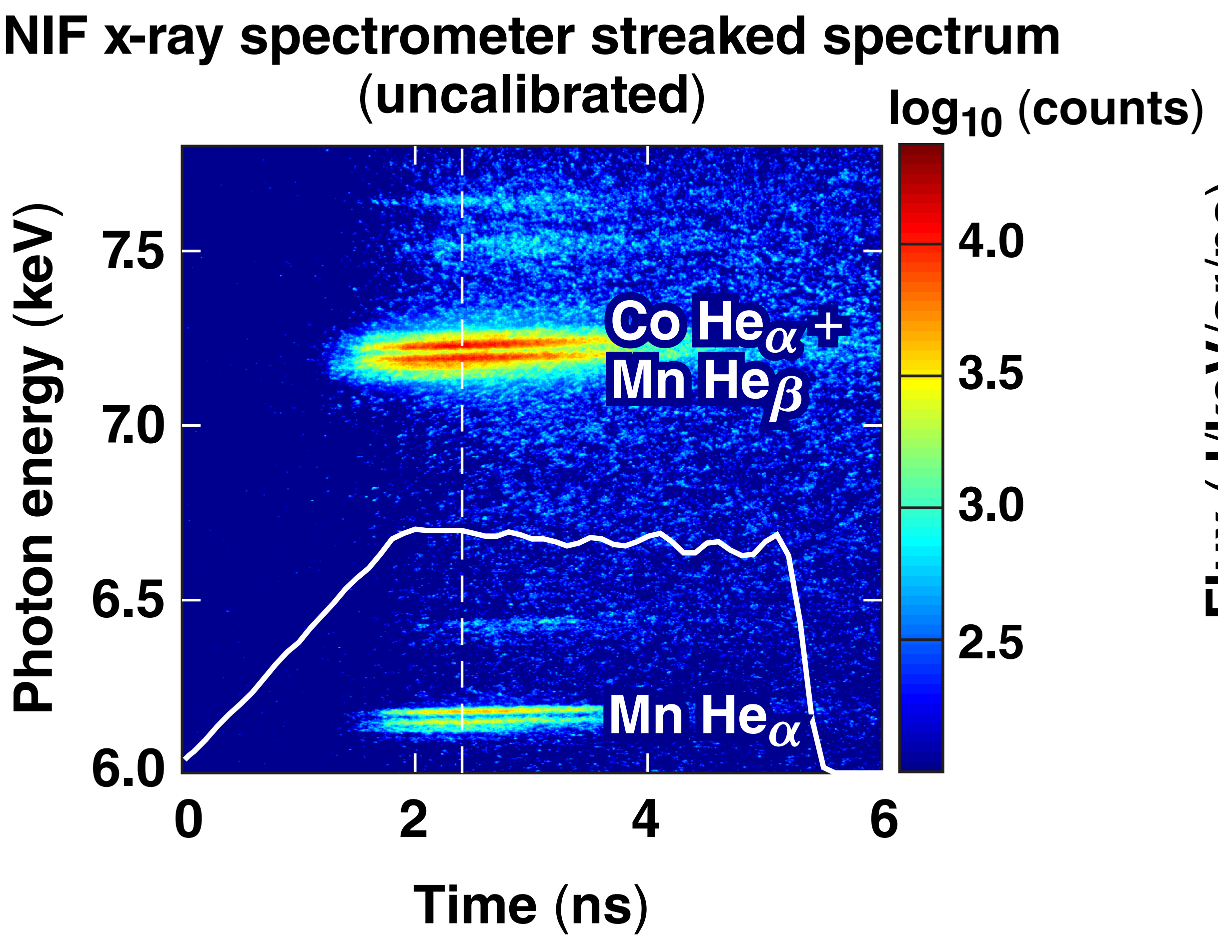
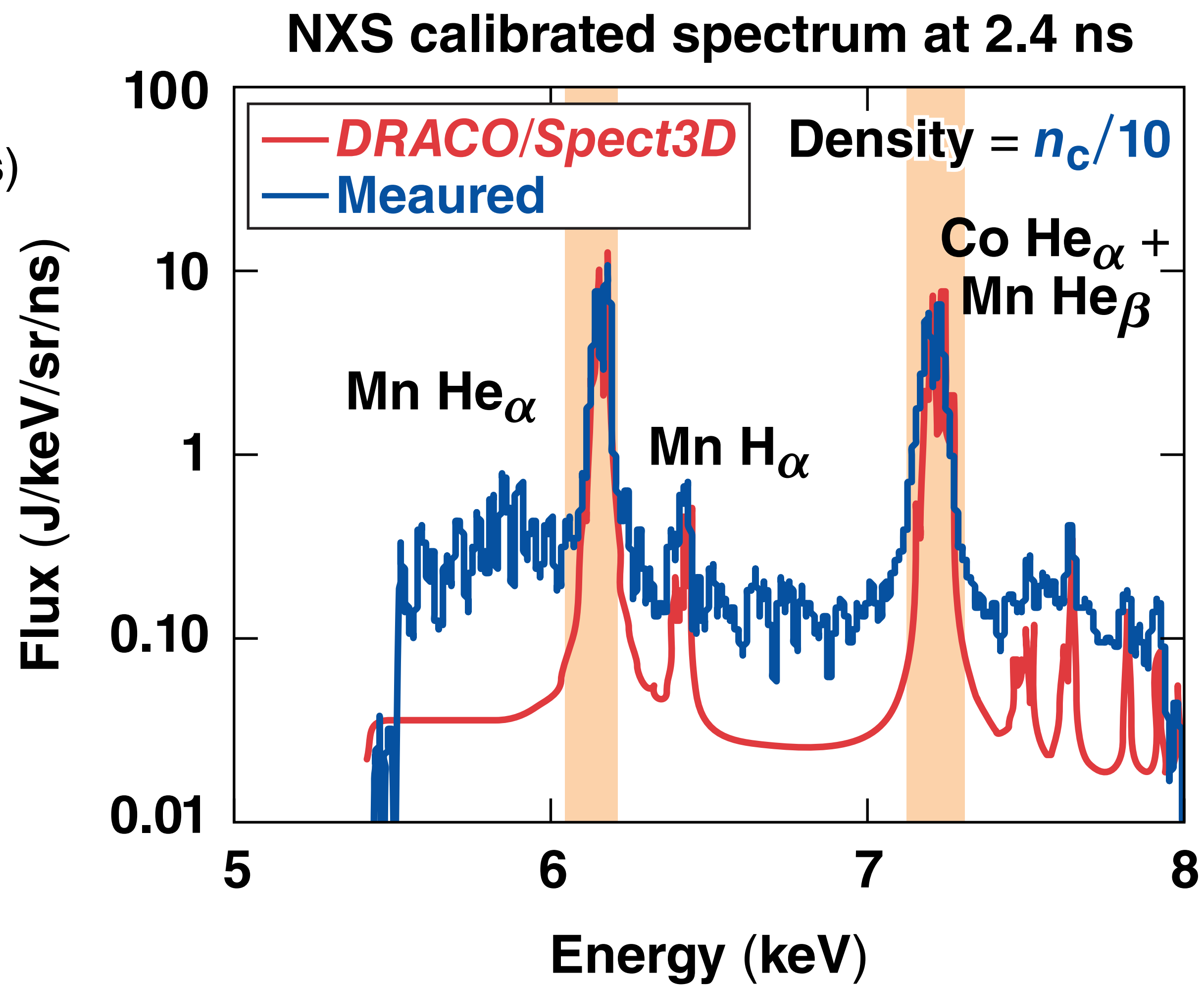
Spectra were measured through the entire duration of the laser pulse by the NXS spectrometer

Shot N150520: 23° and 30° beams





- Only the Mn and Co emission are simulated
- Line ratios are based on 200-eV spectral integrals

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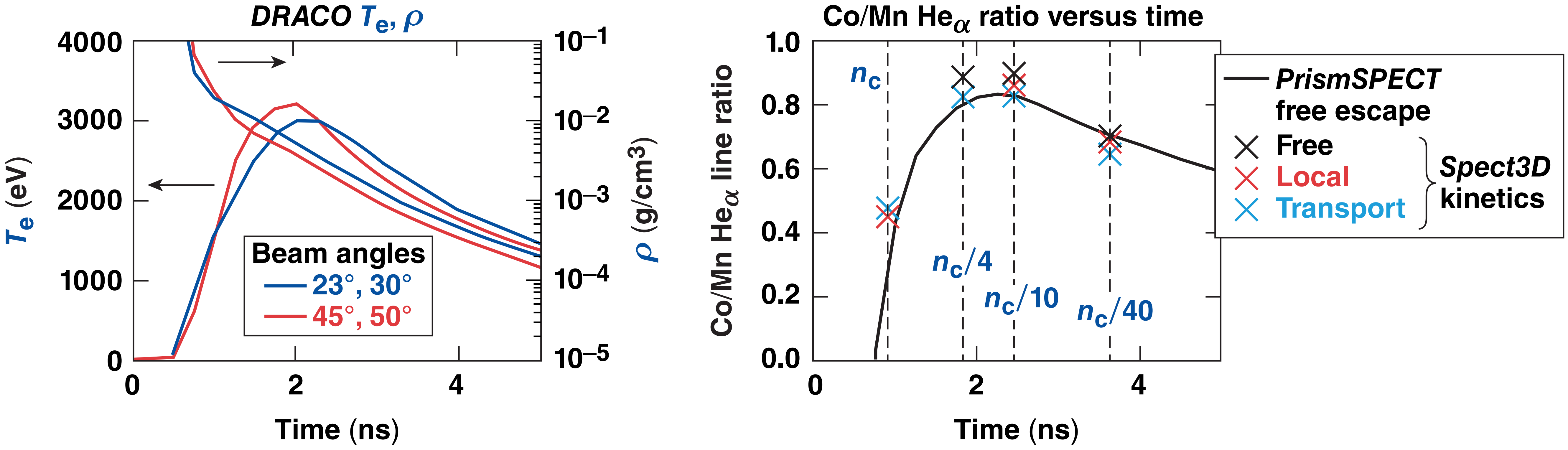
Consistent Co/Mn microdot line ratios have been obtained using *DRACO* T_e, ρ trajectories with *PrismSPECT* and *Spect3D* modeling



- *Spect3D* simulations, including nonlocal radiation transport, are based on the axially expanded microdot shape and the actual 7° viewing angle
- Very similar results are obtained for free-escape, local, and nonlocal photon-transport modeling

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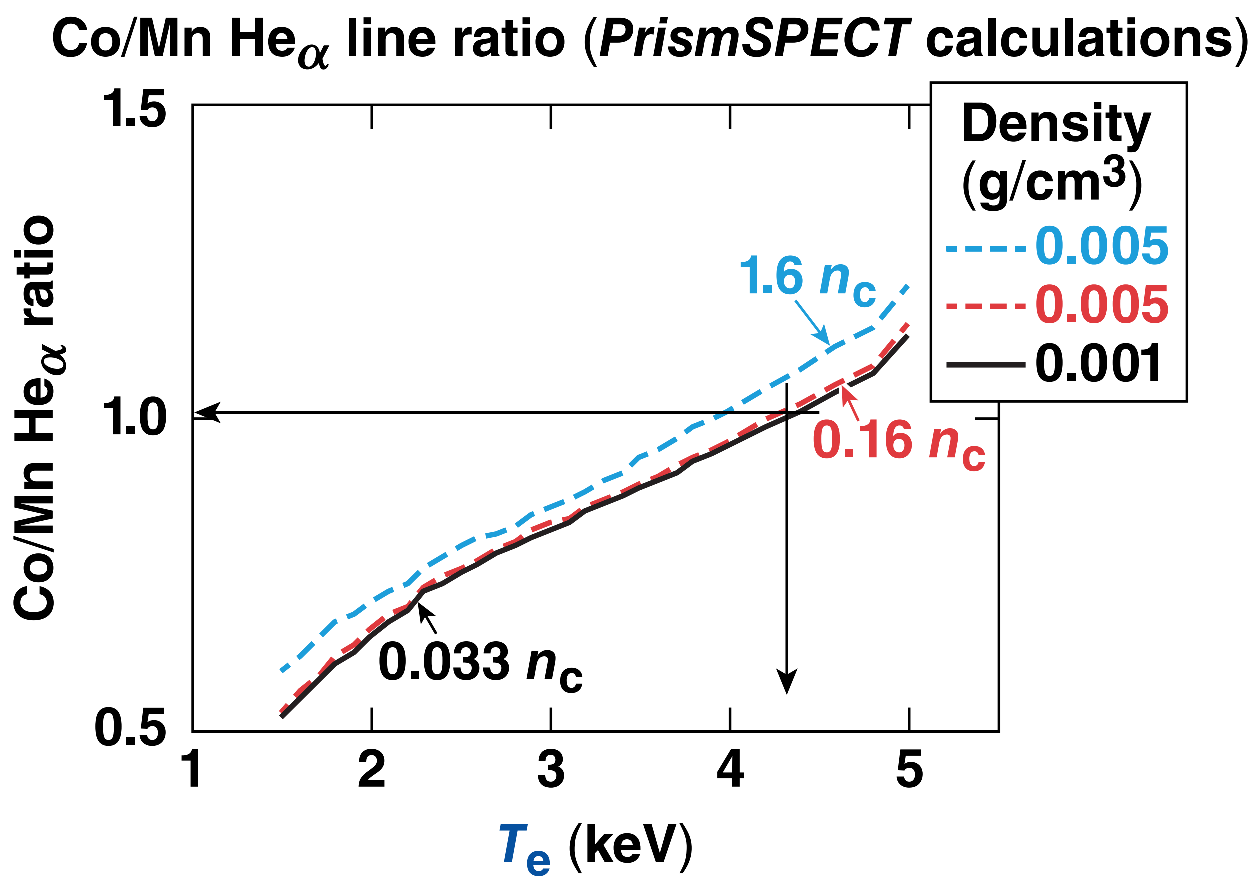
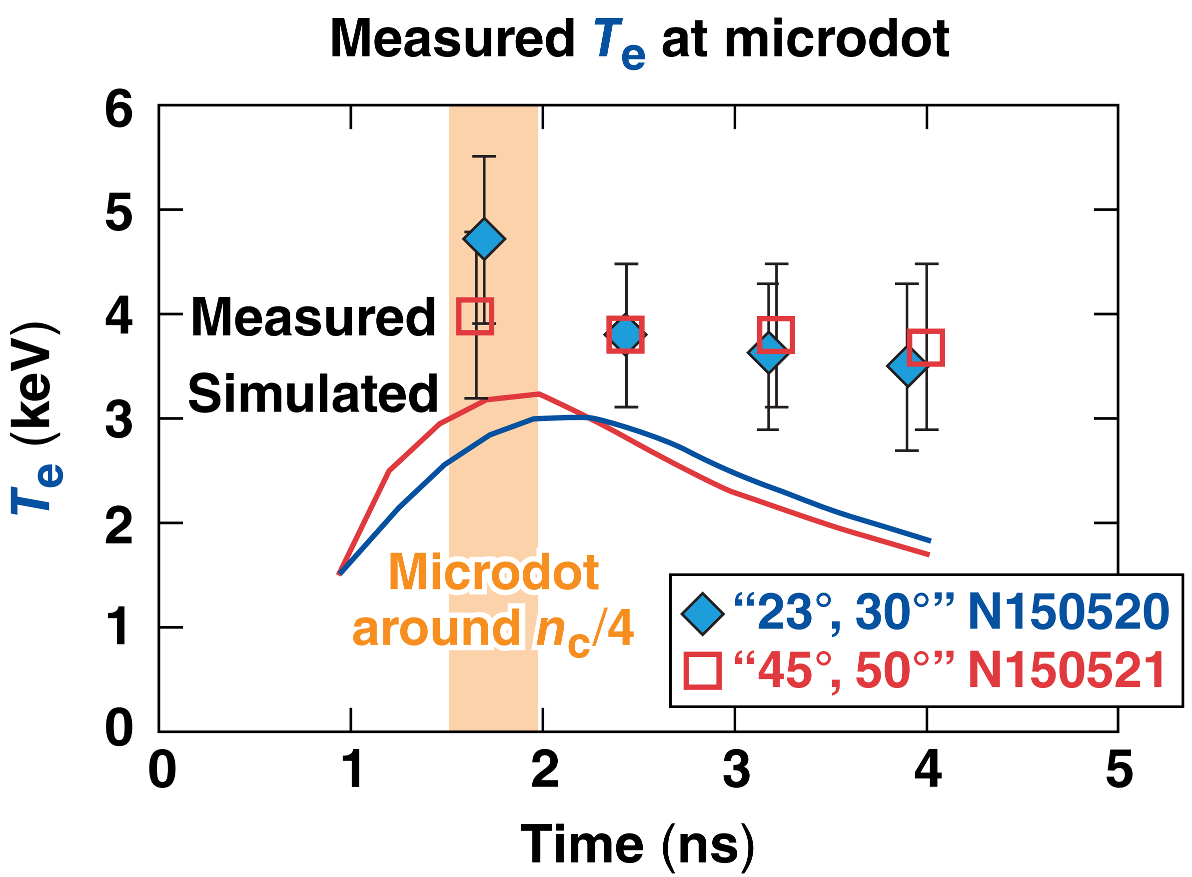
The isoelectronic He$_\alpha$ line ratio* is primarily a function of electron temperature T_e, depending weakly on n_e and optical thickness





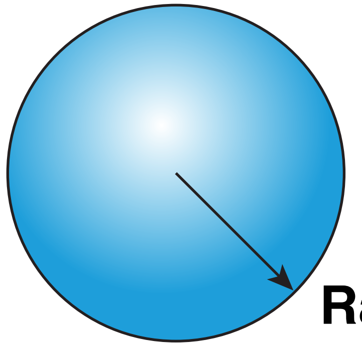
- The measured Co/Mn He$_\alpha$ line ratio indicates $T_e \approx 4$ keV at $n_c/4$, compared to $T_e \approx 3$ keV predicted by *DRACO* CH foil simulations

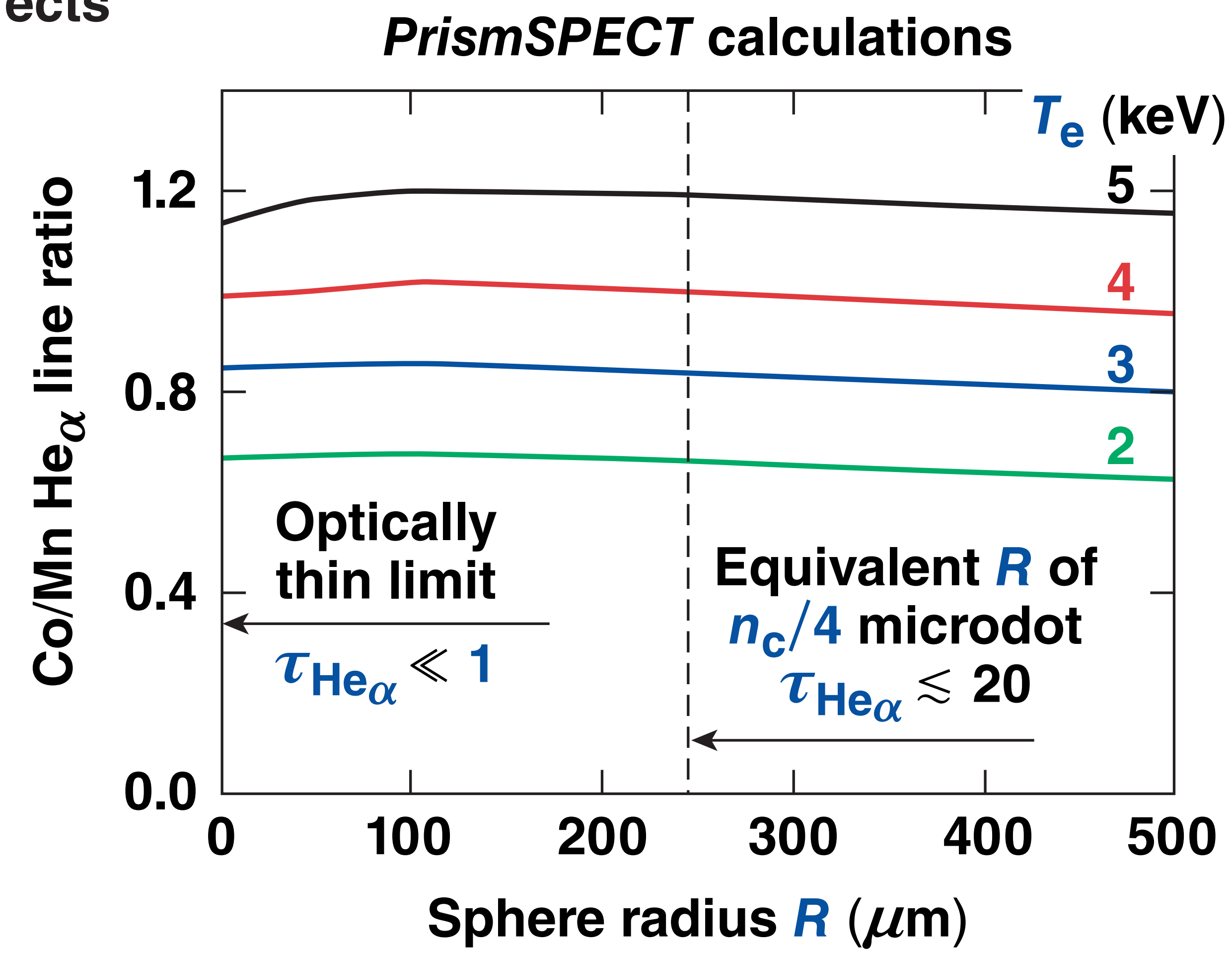
*R. Marjoribanks *et al*. Phys. Rev. A 46, 1747(R) (1992).

TC12491

There is little effect of self-absorption on the Co/Mn He$_\alpha$ ratio for quarter-critical microdot conditions

- Use microdot-scale spheres to test the effects of self-absorption on optically thick lines
  - line attenuation
  - pumping of the He$_\alpha$-emitting states

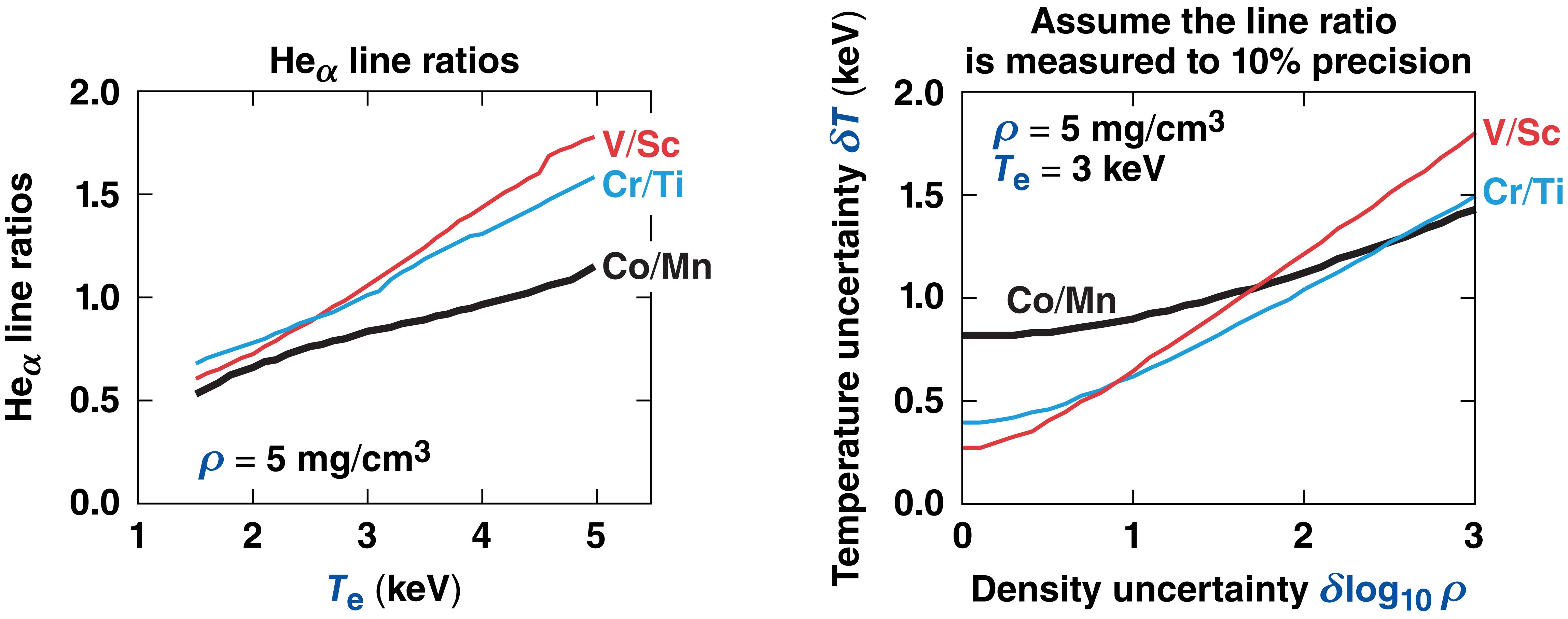




- The supply of emitted He$_\alpha$ photons is determined by the 1s–2p collisional excitation rate
- He$_\alpha$ photon absorption is followed by re-emission with near-certain probability

TC12492

Temperature measurement based on the Co/Mn line ratio does not require a stringent density constraint



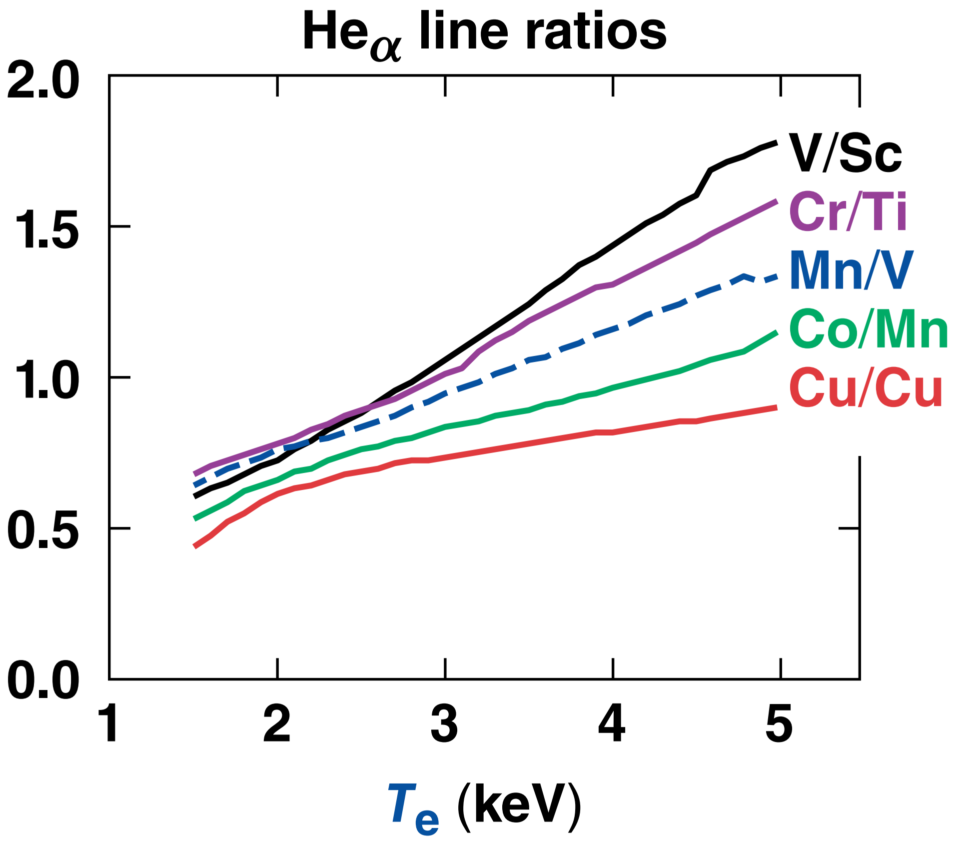
- Temperature measurement from density-dependent line ratios requires some prior knowledge of the density
- Alternative microdot materials offer higher temperature sensitivity at the expense of higher-density sensitivity

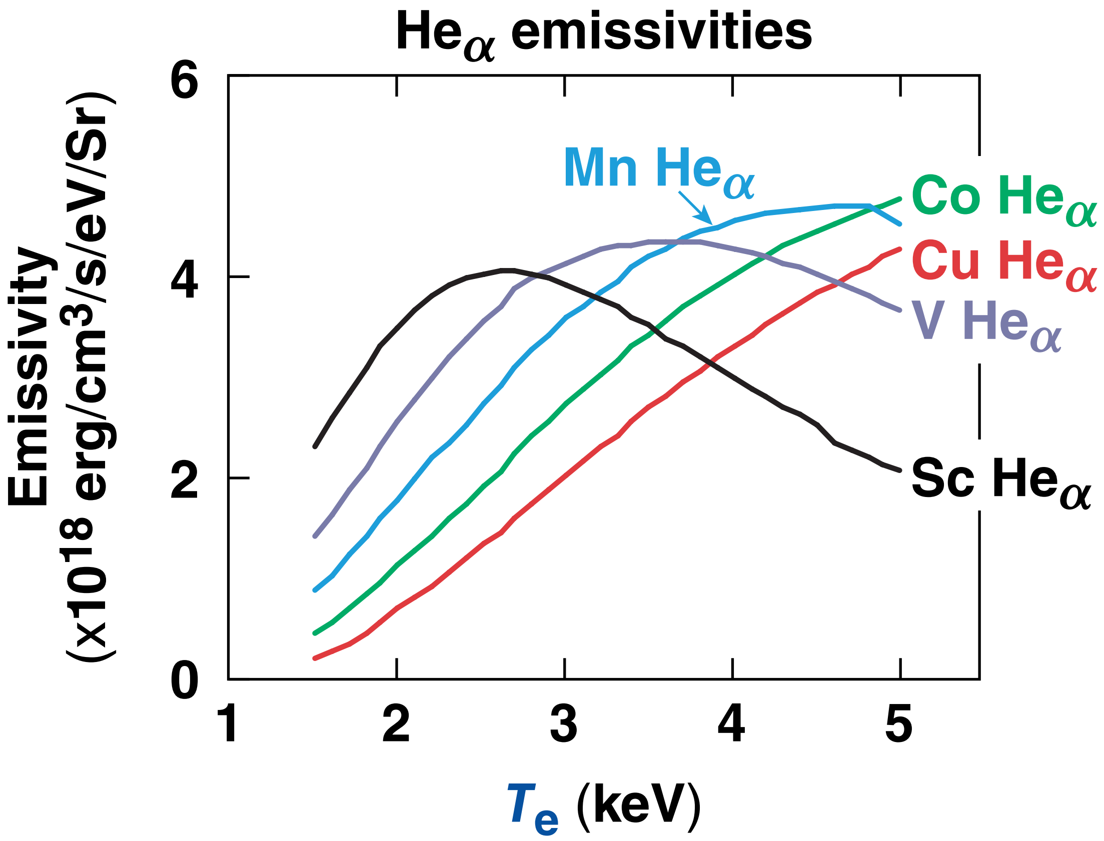
TC12493

The isoelectronic Co/Mn He$_\alpha$ line ratio is a good temperature diagnostic for ablating plasmas

- The Co/Mn He$_\alpha$ line ratio was used to measure the electron temperature in planar experiments performed to study the beam angle-of-incidence dependence of the two-plasmon–decay (TPD) instability
- The density sensitivity of this line ratio is a source of systematic error and a consideration in choosing microdot materials
- Spectrum simulations show that the He$_\alpha$ line ratio is only modestly affected by self-absorption

He$_\alpha$ line ratios from lower-Z elements, e.g., V/Sc, are more temperature sensitive than Co/Mn





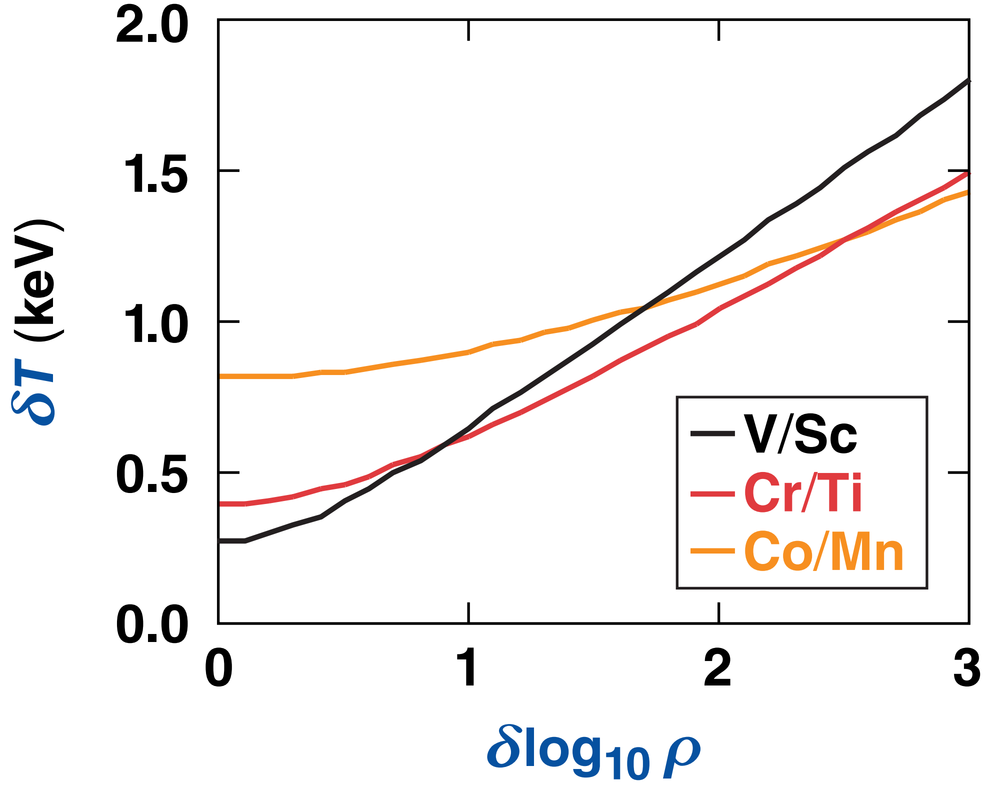
- Density 0.005 g/cm^3

- Temperature dependence is primarily from ionization balance and collisional 1*s*–2*p* excitation
- Mn and V He$_\alpha$ are not in the same NXS channel

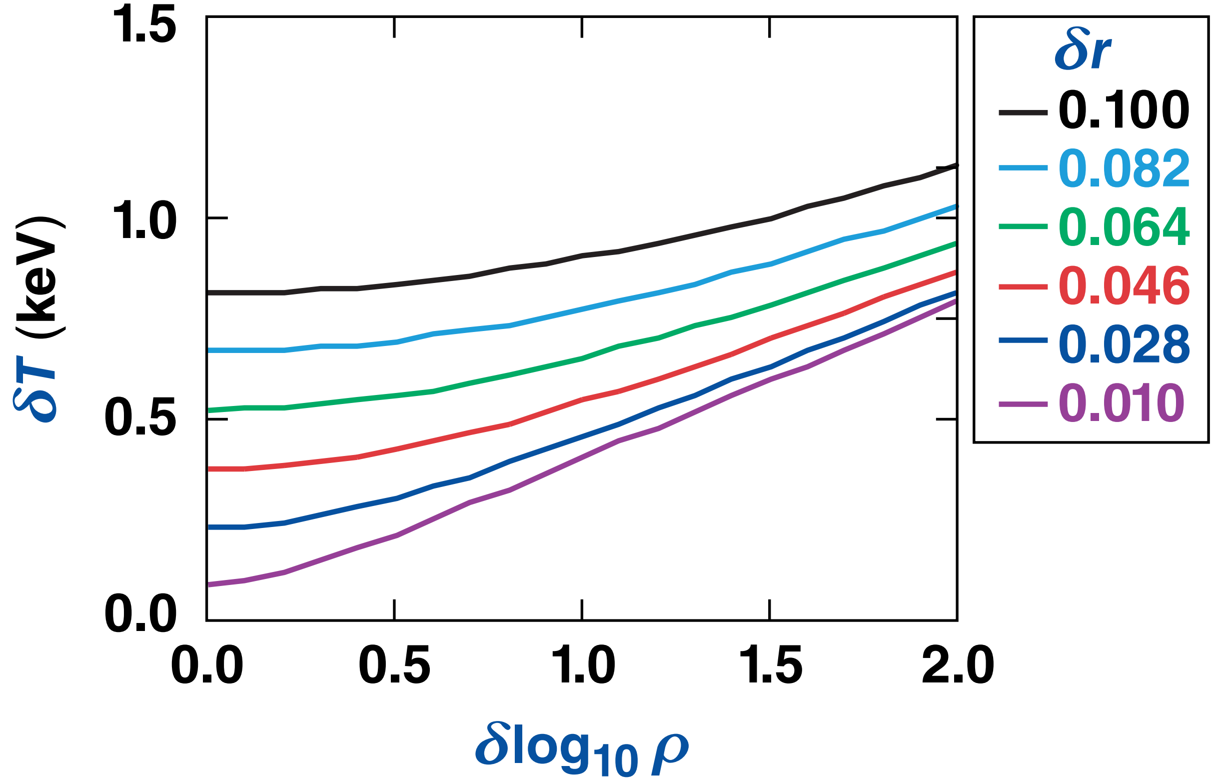
TC12494

The total δT temperature estimate uncertainty depends on the line ratio measurement uncertainty δr and also on a density constraint $\delta \log_{10} \rho$

Assume a line-ratio measurement precision: δr = 0.1



Select the Co/Mn isoelectronic line ratio



- Density 0.005 g/cm^3, temperature ≈ 3.0 keV

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