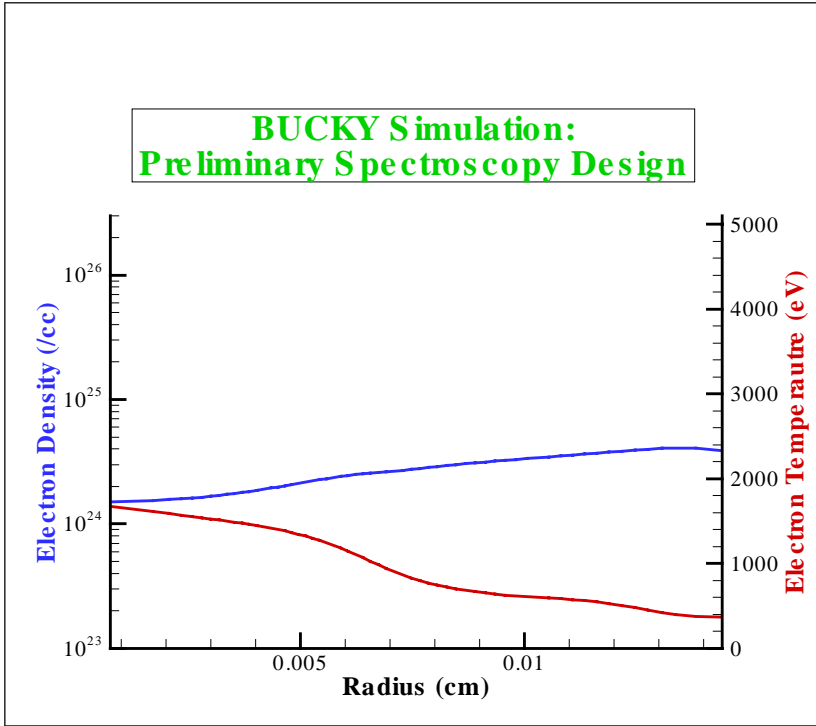
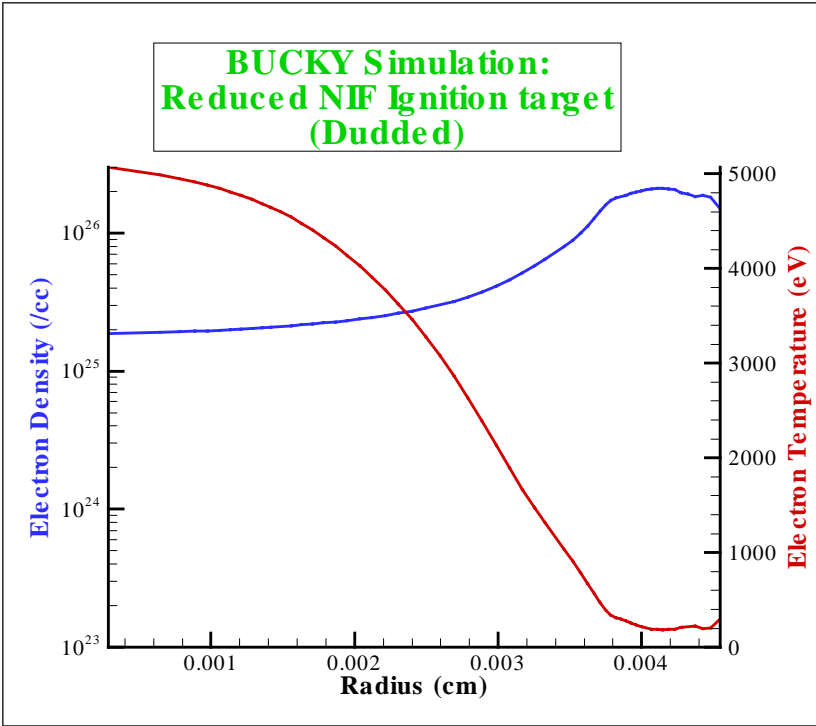


# Radiative Properties of Hot, Dense, and Homogeneous Matter




Don Haynes

Fusion Technology Institute

University of Wisconsin, Madison

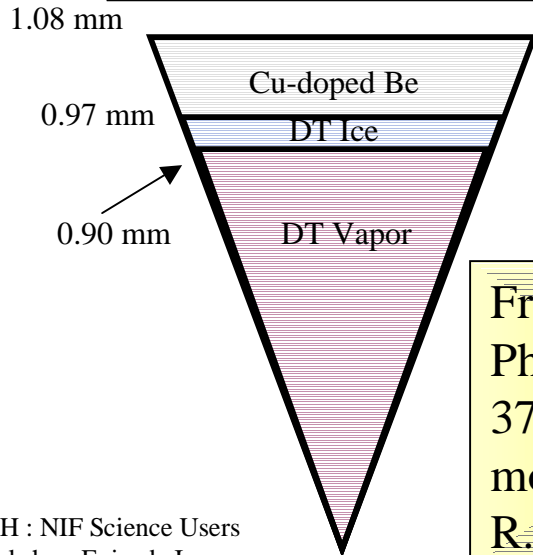
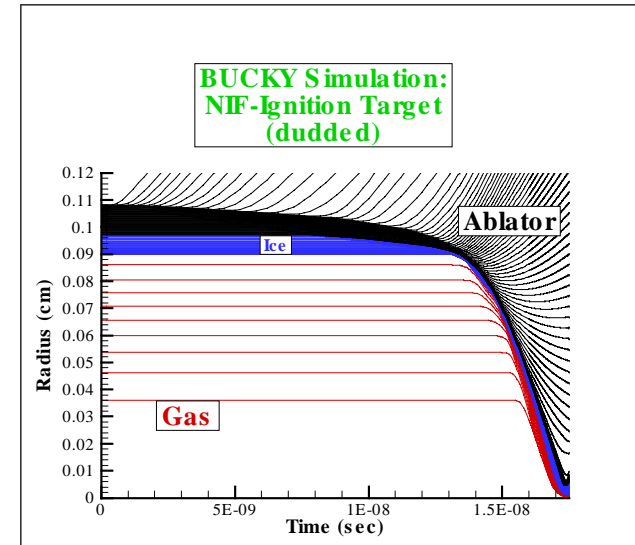
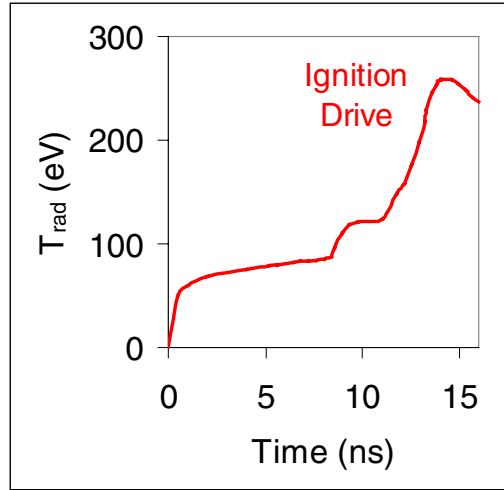
# Summary and Outline



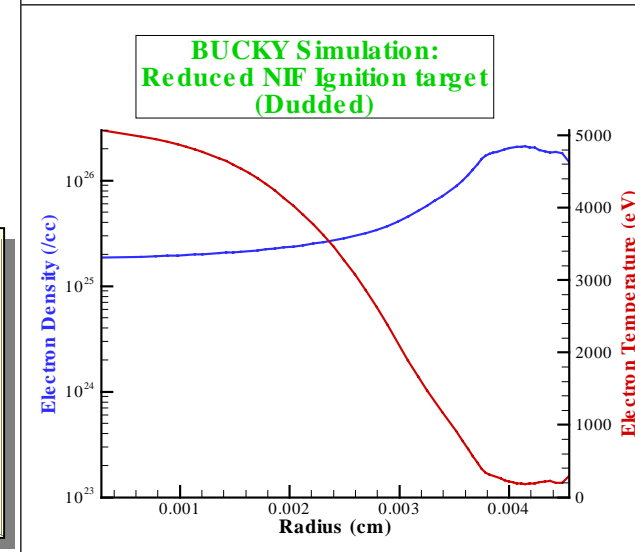
A slight modification to a published reduced-NIF ignition design leads to hot ( $kT_e \sim 1\text{keV}$ ), dense ( $n_e \sim 10^{24}/\text{cc}$ ) cores with substantially reduced core gradients, appropriate for spectroscopic investigation of several outstanding issues.

- Ignition design and gradients
- Deleterious effects of gradients on studies of:
  - Ion dynamics
  - Plasma induced line shifts
  - Continuum lowering
- Spectroscopy design with reduced core gradients.
- Target fabrication and diagnostic requirements.

# Ignition designs can lead to highly structured cores with multiple shocks and large spatial gradients of temperature and density



From Dittrich, *et al.*  
Phys. Plasmas **5**  
3708 (1998), with  
modifications by R.  
R. Peterson



While the effect of gradients on spectra are of both fundamental and programmatic interest, gradients must be reduced to study several outstanding fundamental issues.



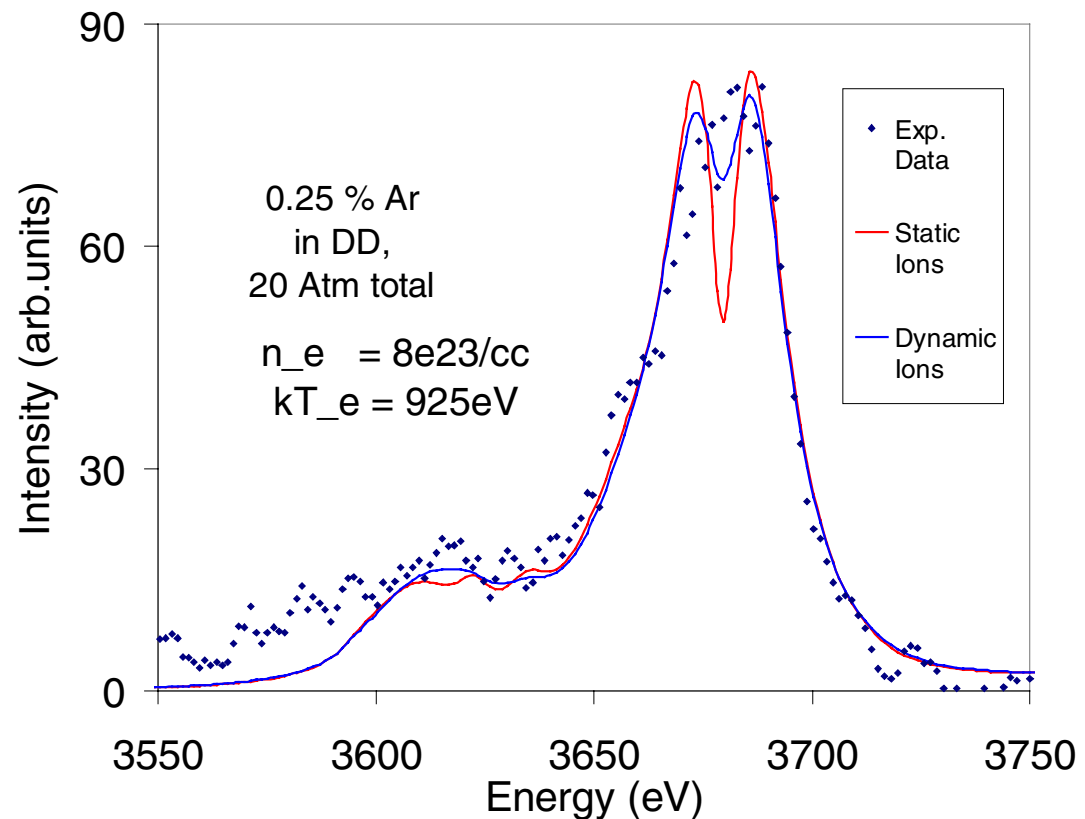
To illustrate the deleterious effects of spatial gradients in temperature or density, let us consider three issues of current interest:

- The effects of ion dynamics on lineshapes, especially at the dips of  $\beta$  lines.
- Plasma induced line shifts.
- Continuum lowering effects on relative intensities of isoelectronic lines.

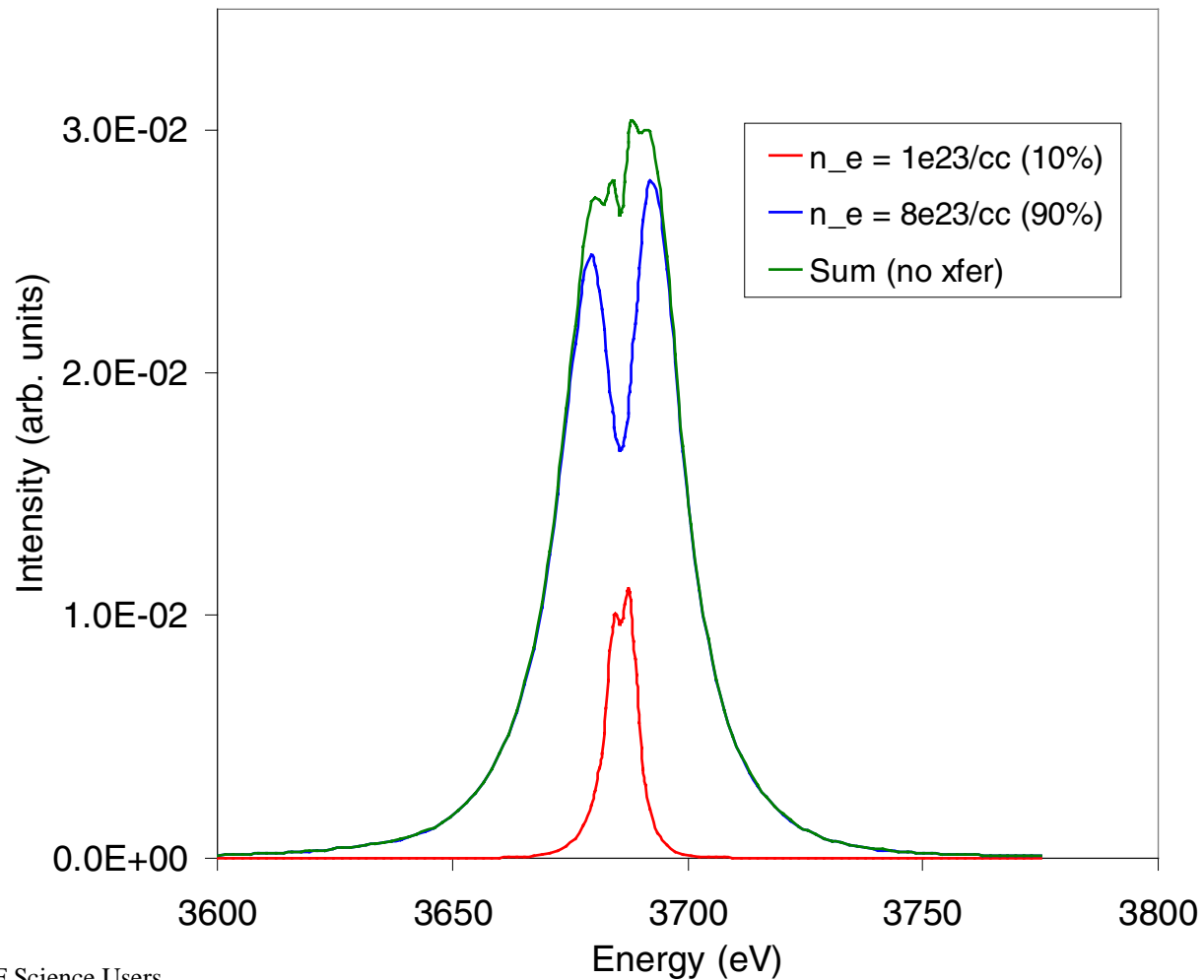
# Ion dynamics effects on $\beta$ lines

Two experimental campaigns were conducted to examine ion dynamics effects in spectra from spherical implosions.

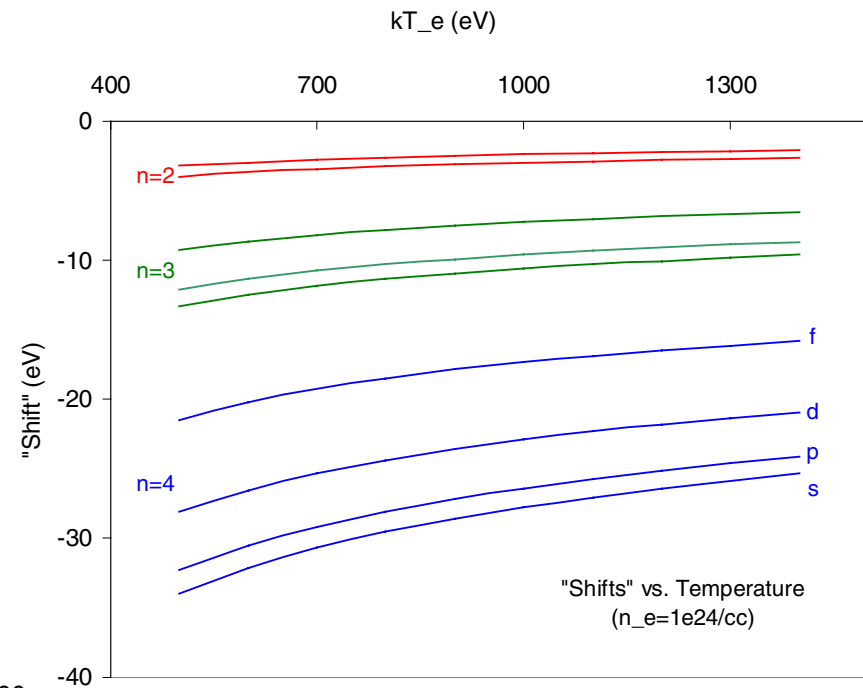
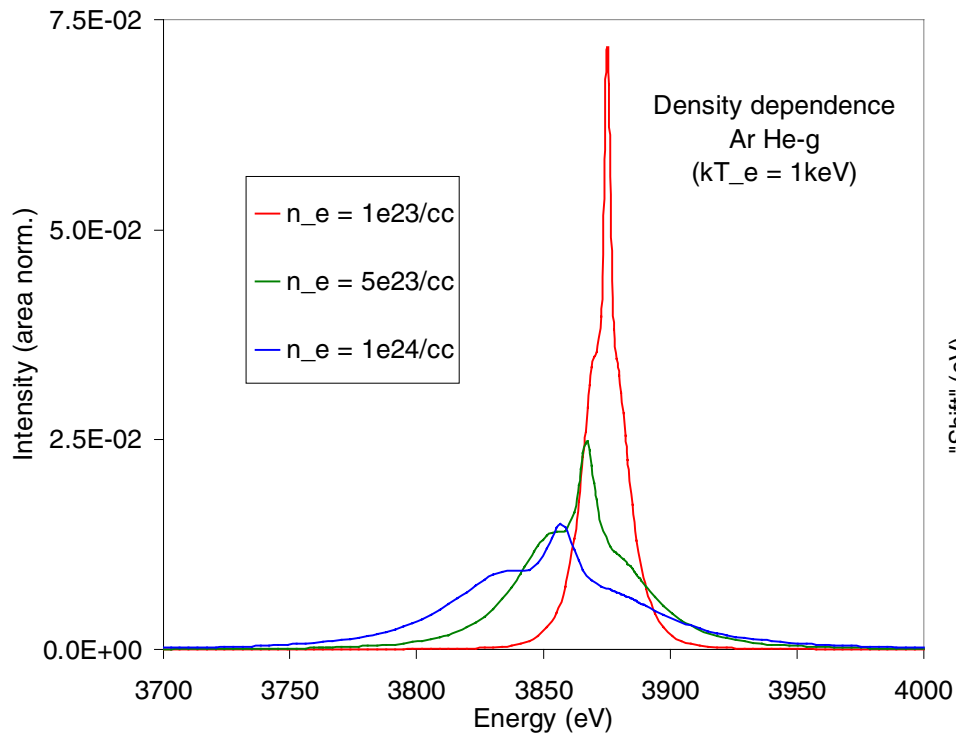
- Nova: Woolsey, et al. (held Ar concentration fixed, varied fill gas to vary  $v$ .)
- Omega: Haynes, et al. (held “fuel” constant, varied Ar concentration).



# Even a 10% “contamination” by lower density material can be detrimental to ion dynamics studies

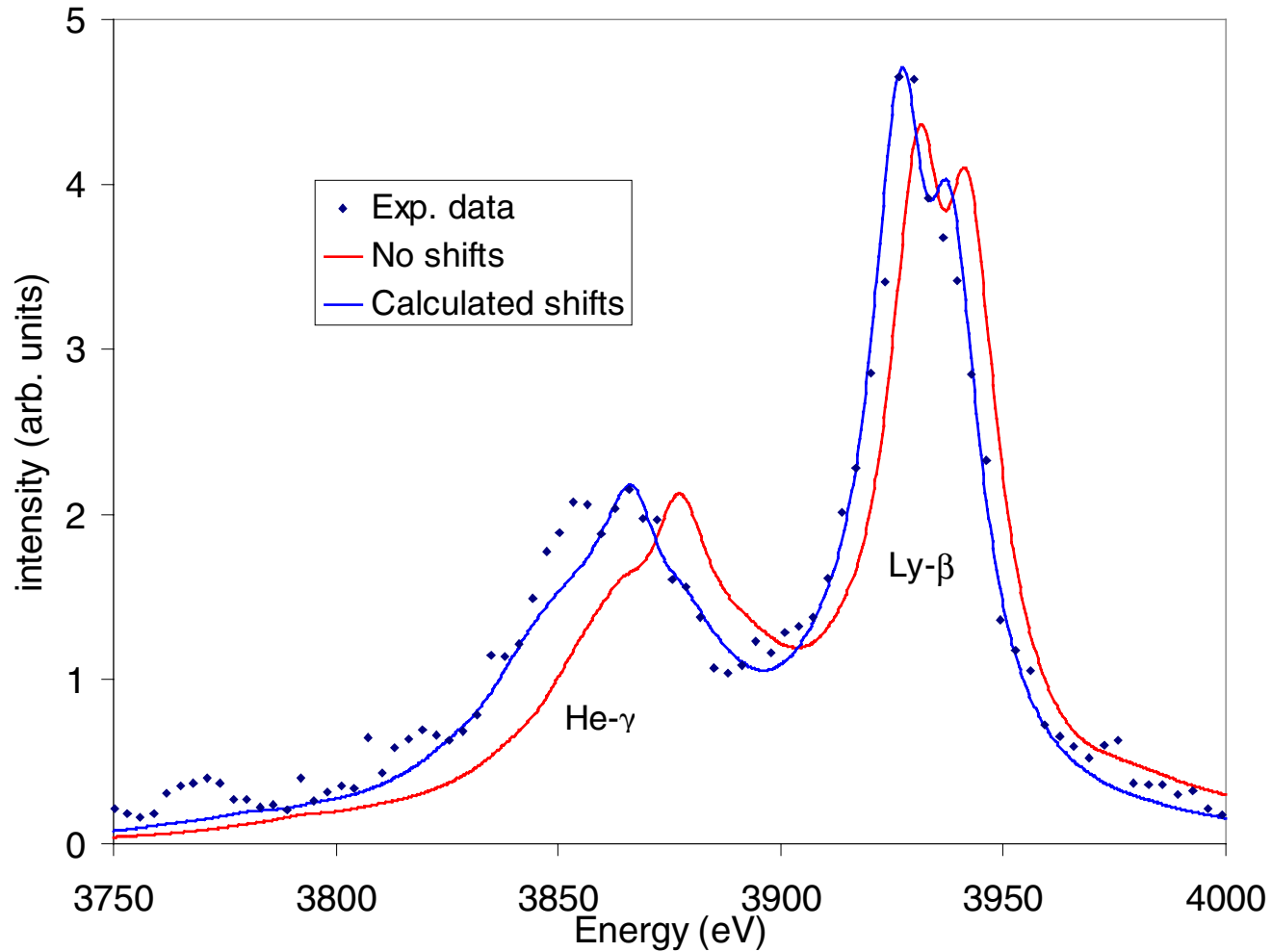


# Plasma induced line shifts



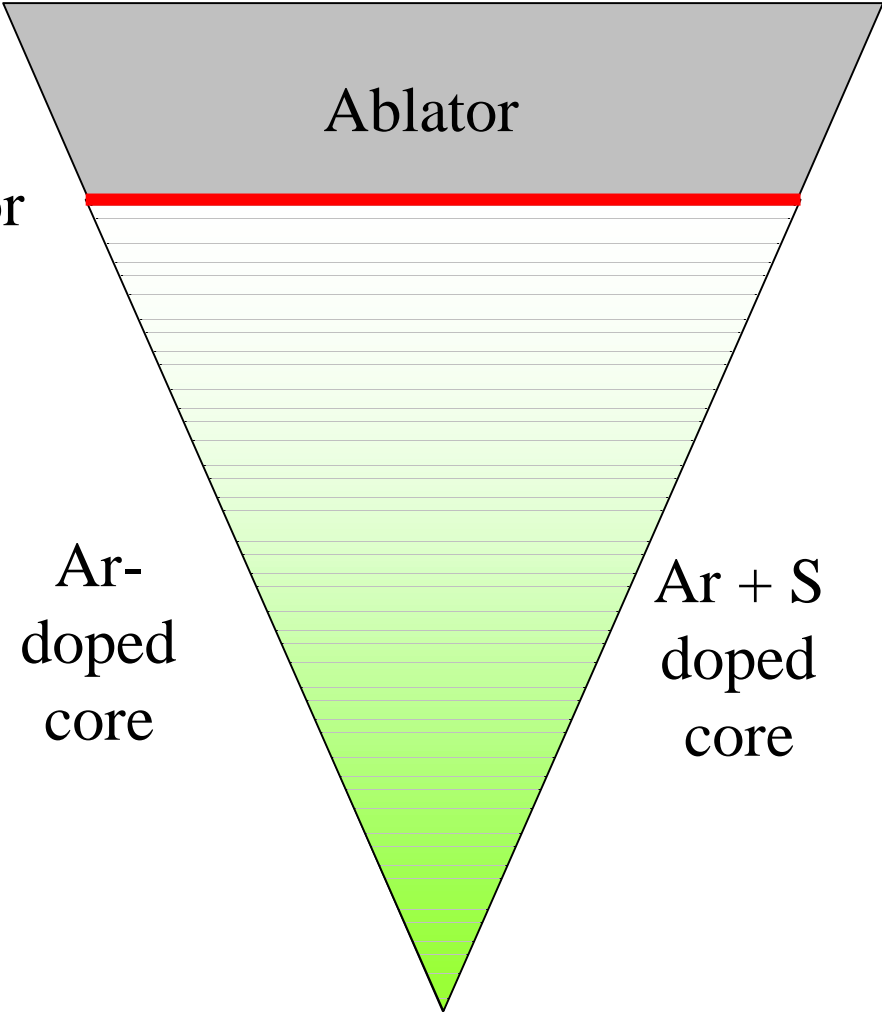
Calculations from Hooper's UF group  
(Hooper, Junkel, Gunderson)

# Plasma induced line shifts





# Continuum lowering effects on isoelectronic line ratios

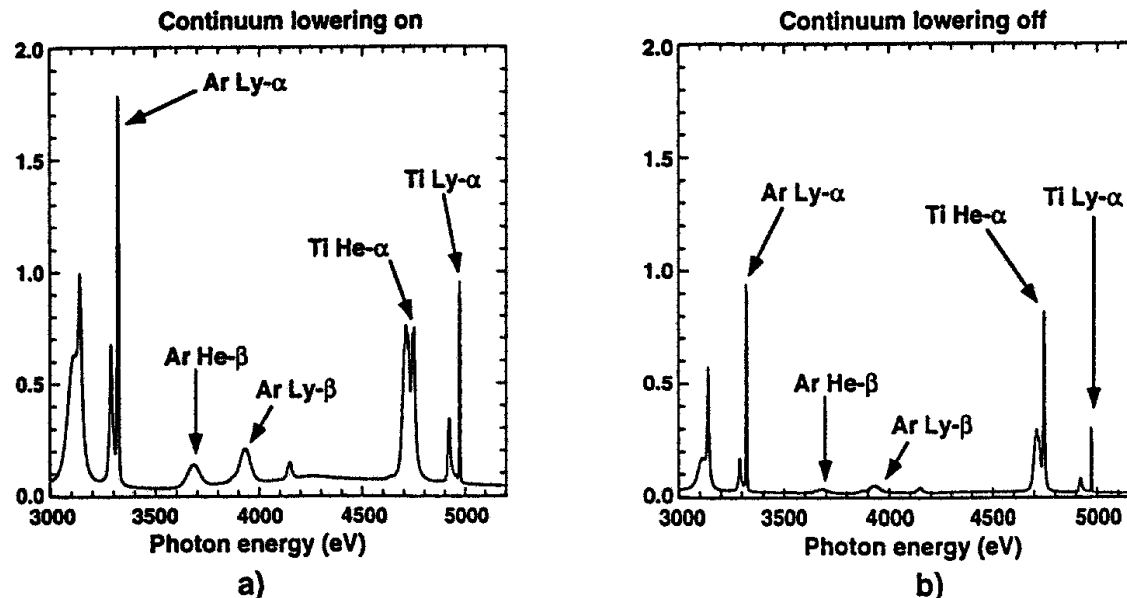


TiCH or  
Ti+V

Previous  
experiments

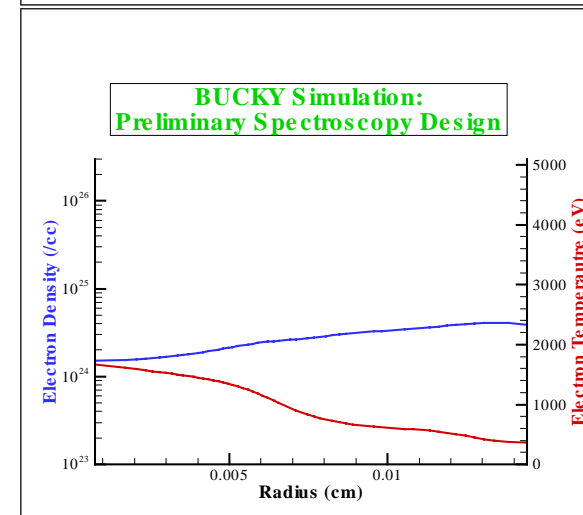
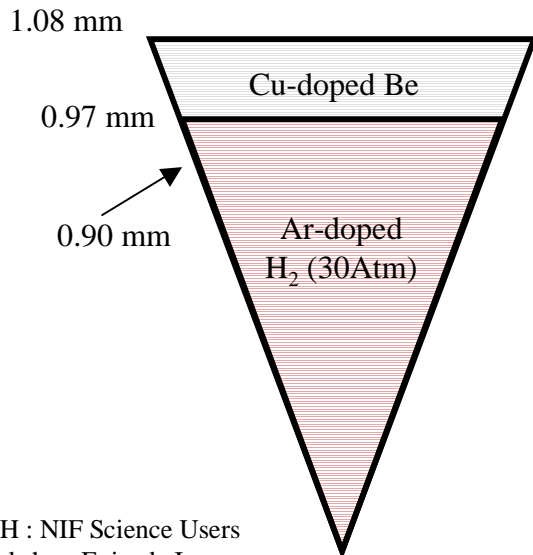
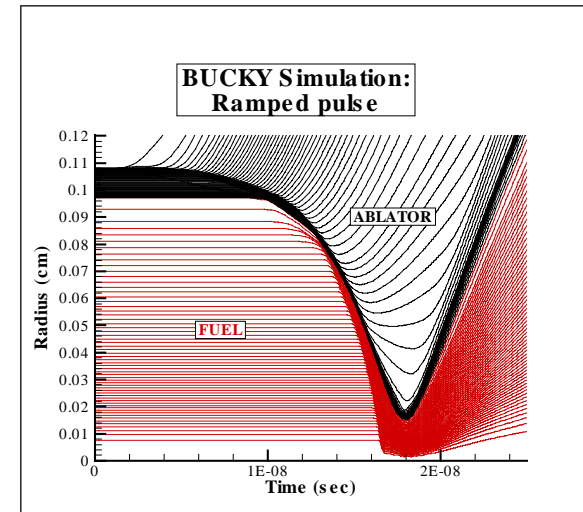
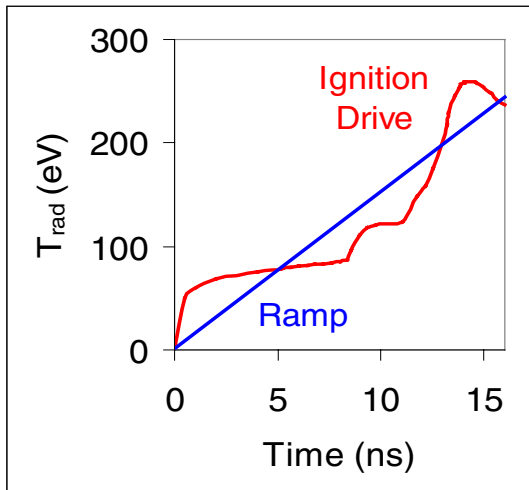
Proposed  
experiments

# Continuum lowering has a large effect on isoelectronic line ratios

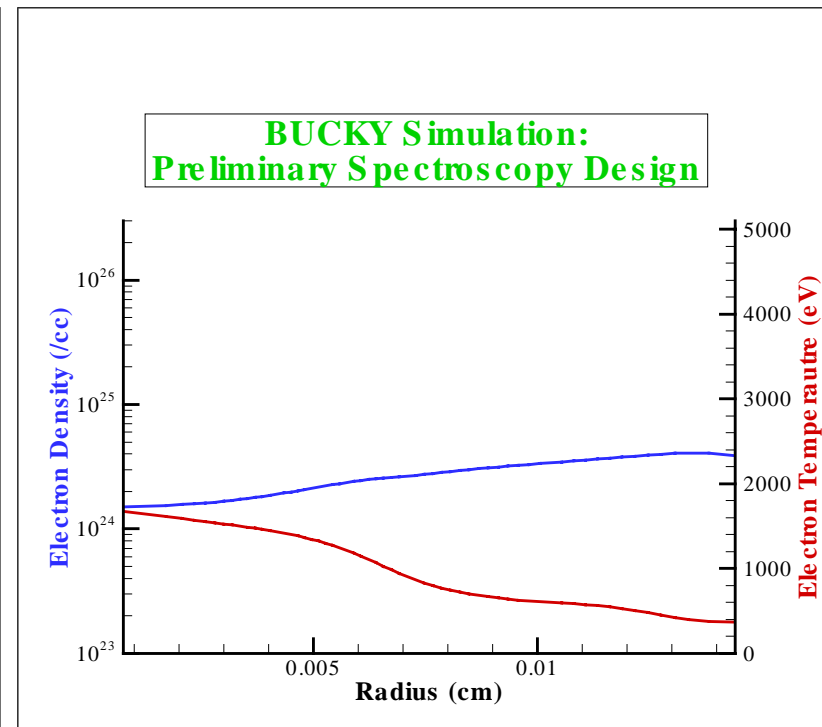
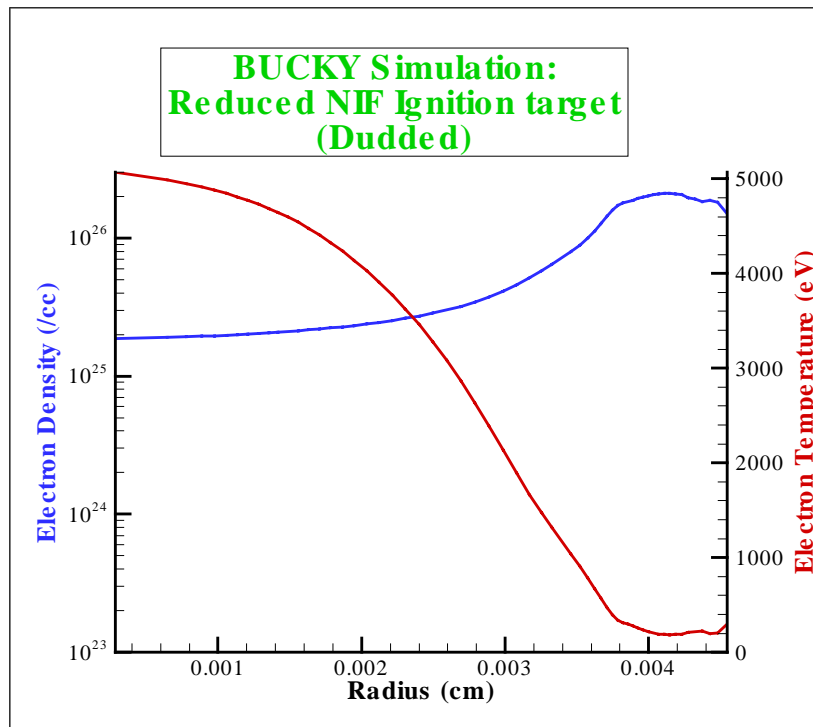


An example of continuum lowering effects on the relative intensities of lines originating from ions of differing nuclear charge. This figure is Figure 12 of Keane, *et al.*, RSI, 66, 689 (1995) and was reproduced with the kind permission of Dr. Keane. The original figure caption reads, “Computed Ar-Ti spectrum from a moderate growth factor implosion with 0.07% Ti seeded into the polystyrene. (a) Continuum lowering considered. (b) Continuum lowering not included.” Analysis of data from such an experiment would need to consider the possibility that the Ar and Ti emission may well be coming from regions of different temperature and density. We propose to introduce two mid-Z emitters into the core, and design the target/laser conditions to minimize spatial inhomogeneities during at least part of the time the *K*-shell lines from both radiating species are recorded by a single time-resolved spectrometer.

By modifying the drive, and not using cryo, the ignition design can yield smoother cores and is amenable to dopants in the core.



# A significantly smoother core results from these modifications




# Target fabrication and diagnostic requirements



In addition to target fabrication and diagnostics which can be reasonably expected to be present at NIF, we would require:

- The ability to add mid-Z dopants to H-isotope fuel
  - Smaller uncertainties in relative and absolute concentrations than are currently available.
- Reliable, synchronized monochromatic imaging at at least two different wavelengths.
- In the best of all possible worlds, temporally **and** spatially resolved spectrometers

# Summary and Conclusions



A slight modification to a published reduced-NIF ignition design leads to hot ( $kT_e \sim 1\text{keV}$ ), dense ( $n_e \sim 10^{24}/\text{cc}$ ) cores with substantially reduced core gradients, appropriate for spectroscopic investigation of several outstanding issues.

- Deleterious effects of gradients on studies of:
  - Ion dynamics
  - Plasma induced line shifts
  - Continuum lowering
- Target fabrication and diagnostic requirements.

**NIF's power and time scale will allow us to achieve hot, dense plasma conditions without violently shocking the core and causing gradients which would interfere with the goal of basic spectroscopic studies.**