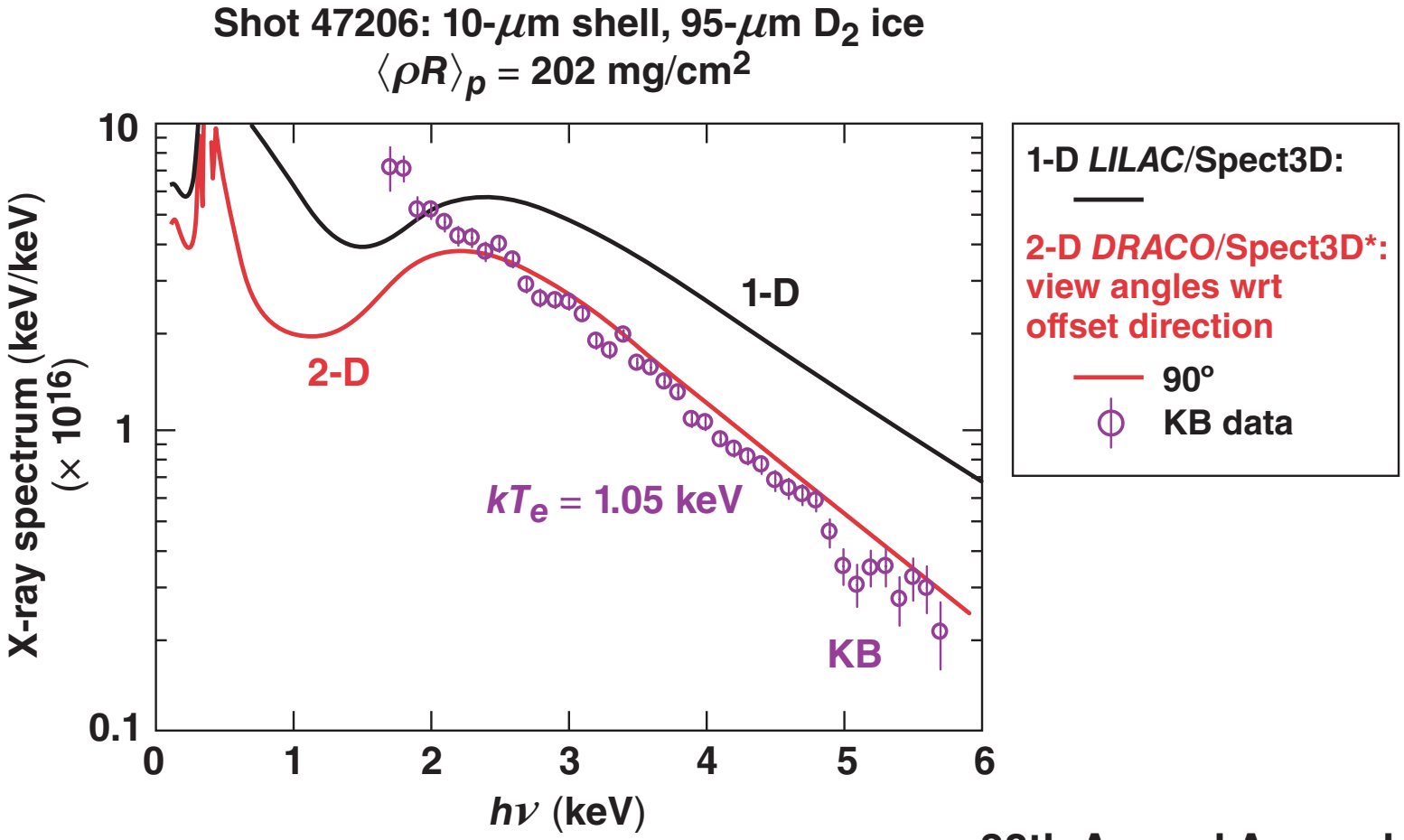
Radiative Transport Modeling Relevant to the Continuum Spectroscopy of Cryogenic Implosions



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University of Rochester
Laboratory for Laser Energetics

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Summary

The continuum x-ray spectra of cryogenic target implosions should provide T_e and ρR diagnostic information

UR LLE

- Spectra simulated with low-order-implosion nonuniformity display the observed continuum temperatures and intensities.

- Low-order-implosion nonuniformity alters the shell absorption at the soft end of continuum spectra, but not reliably enough to fully account for the low measured absorption.

- Accounting for the measured shell absorption requires accurate opacity models for imploded low-adiabat cryogenic hydrogen, including nuclear screening and strongly coupled plasma effects.

Collaborators

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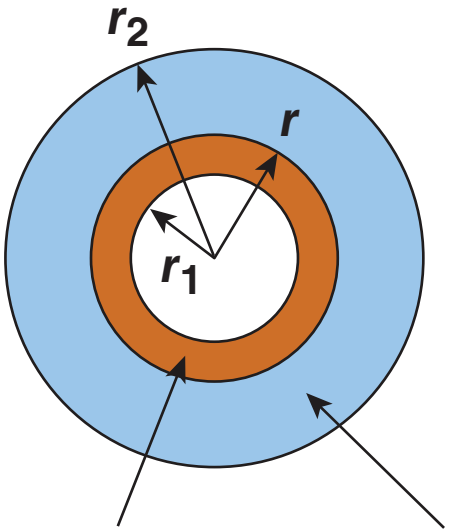
The continuum-spectrum peak shifts with shell areal density in a simple two-layer shell model

Cryo shell at peak compression with a variable source/absorber split (parameter f).

$\rho = 140$ g/cm^3

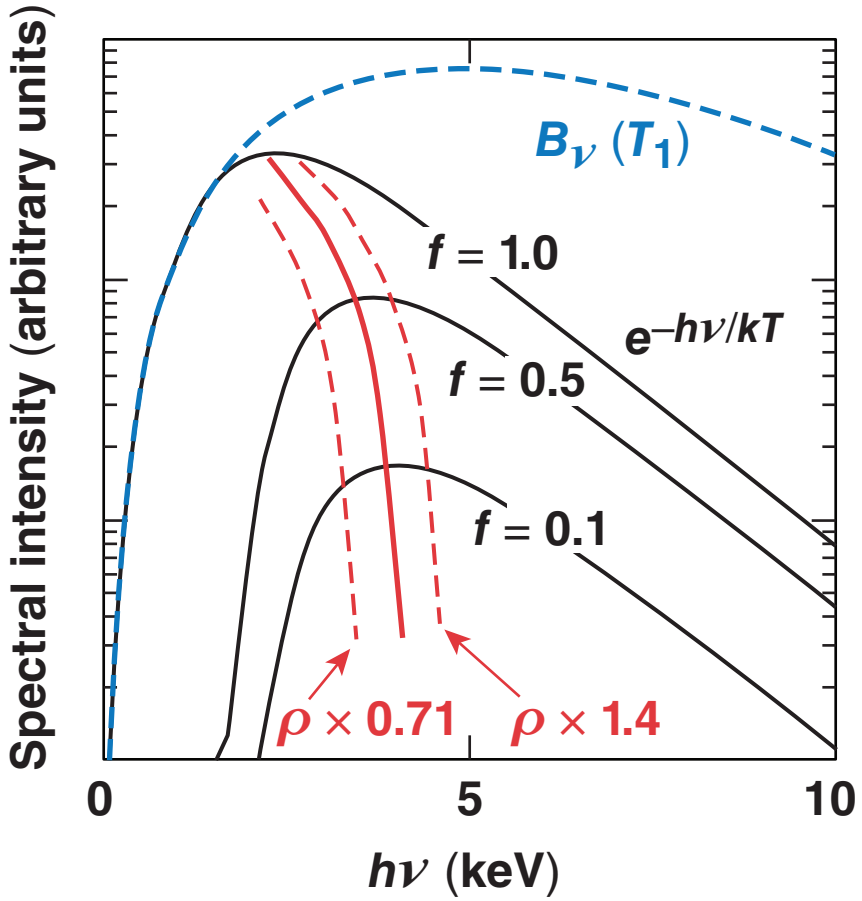


$r_1 = 15\ \mu$m
$r_2 = 30\ \mu$m

$r = r_1 + f(r_2 - r_1)$

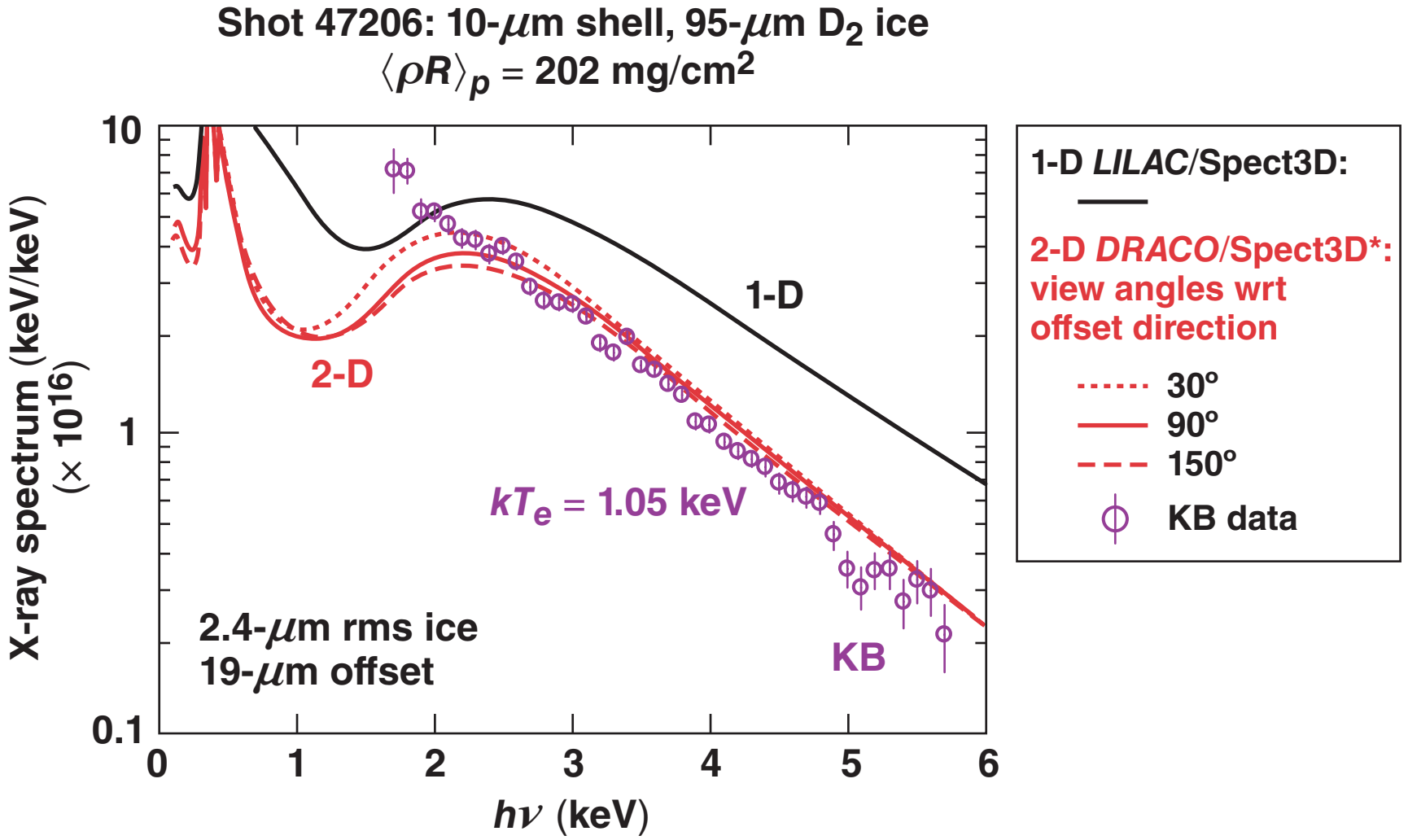
Hot source
$T_1 = 1.75$ keV

Cold shell
$\alpha_2 = 1.8$
$T_2 = 0.1$ keV



TC7948

The spectral temperature and hard x-ray intensity of the core of shot 47206 are simulated accurately



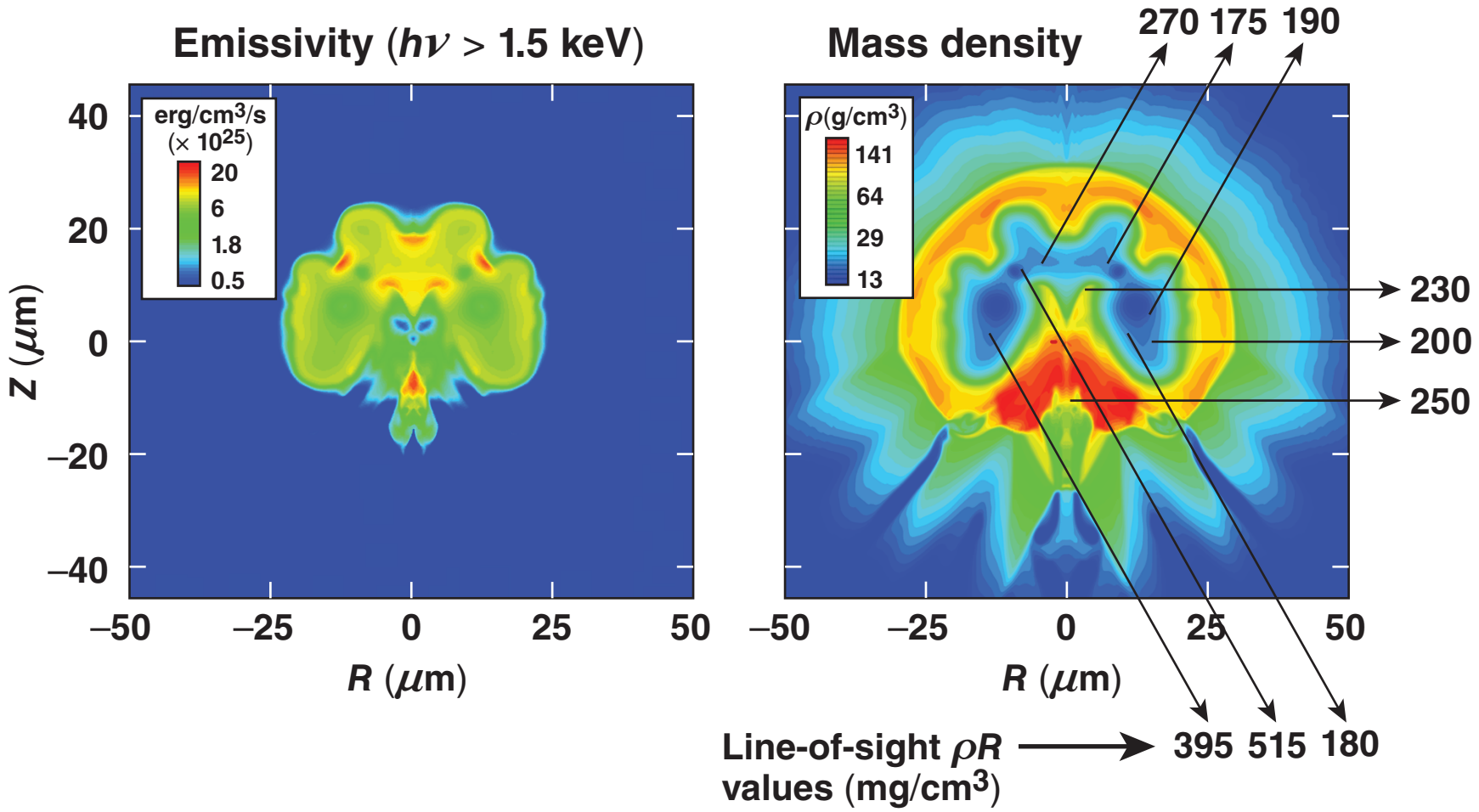
TC7949

*Spect3D: PRISM Computational Sciences, Inc., Madison, WI.

The simulated spectrum of the cryogenic high-ρR implosion is formed by a nonuniform source

UR LLE

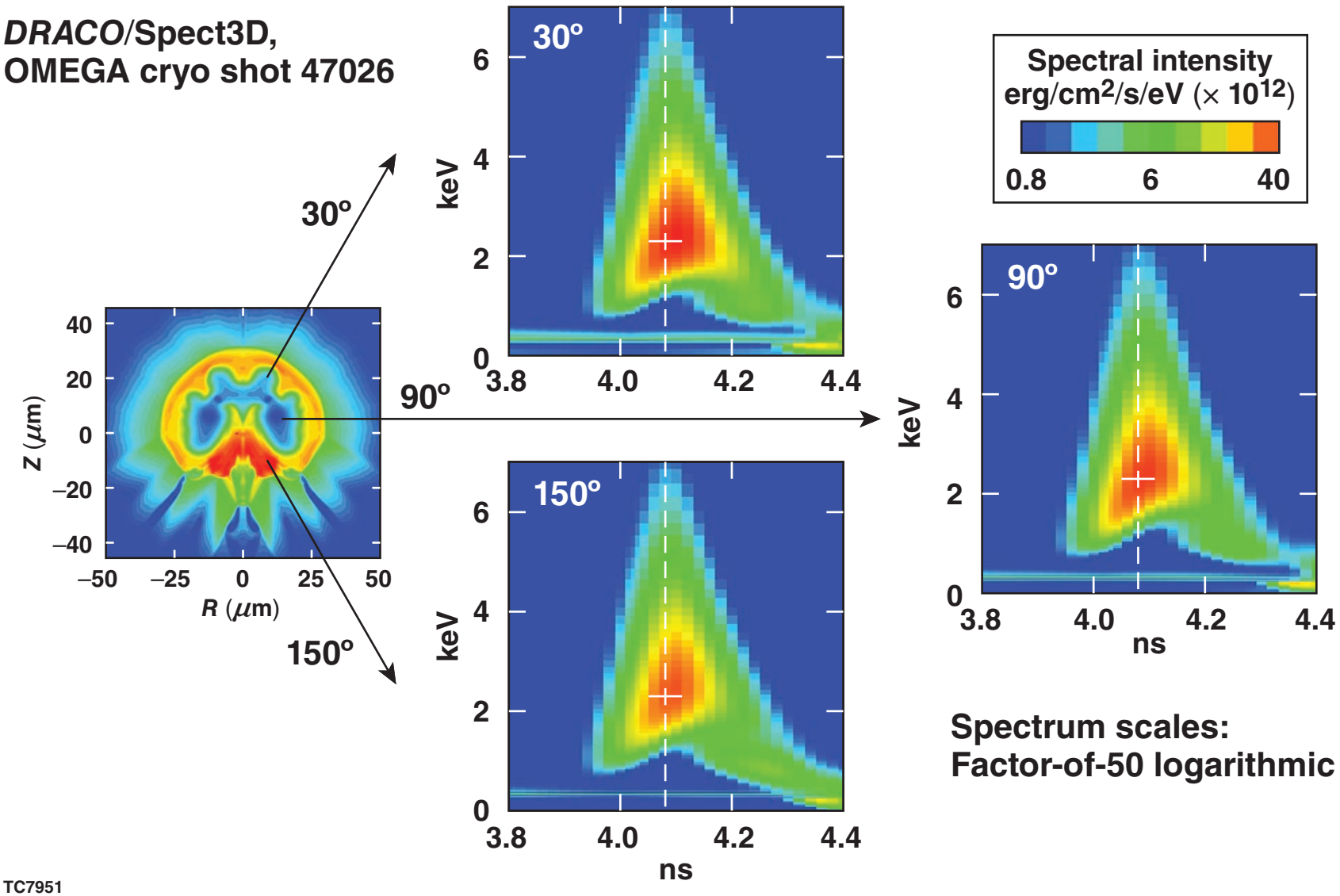
Cryo shot 47206 profiles at peak neutron emission, t = 4.08 ns



TC7950

DRACO/Spect3D time-resolved spectra of high-ρR implosions are very similar from all viewing angles

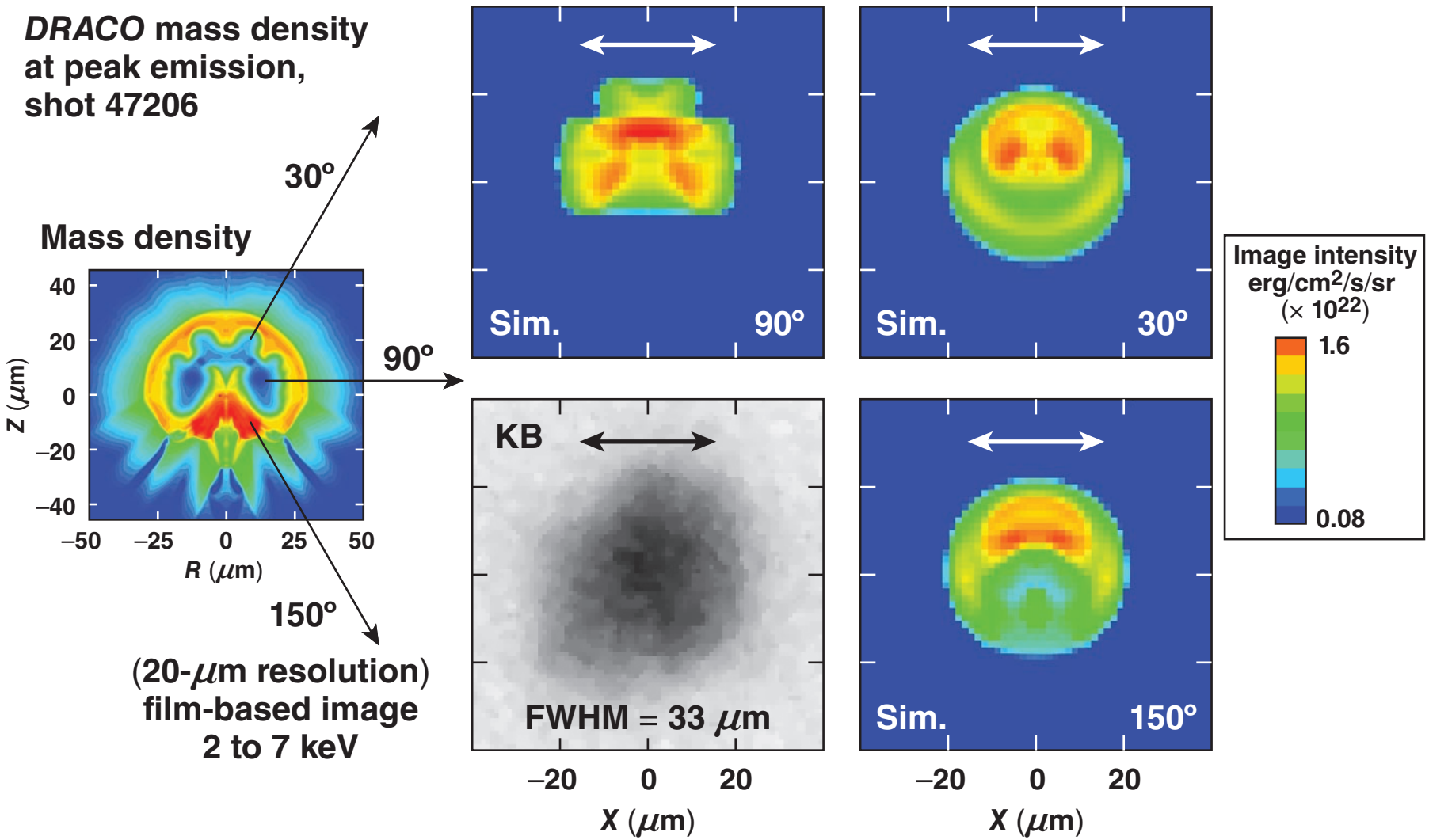
DRACO/Spect3D,
OMEGA cryo shot 47026



Spectrum scales:
Factor-of-50 logarithmic

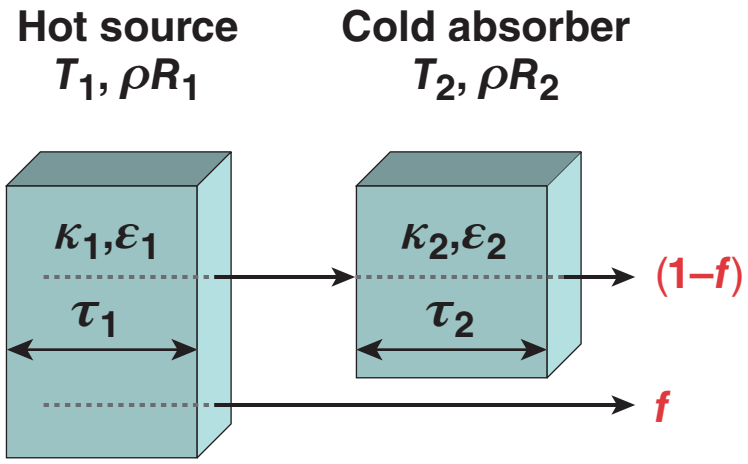
TC7951

DRACO/Spect3D x-ray images of high-ρR cores match the measured size of the of the spectral source



TC7952

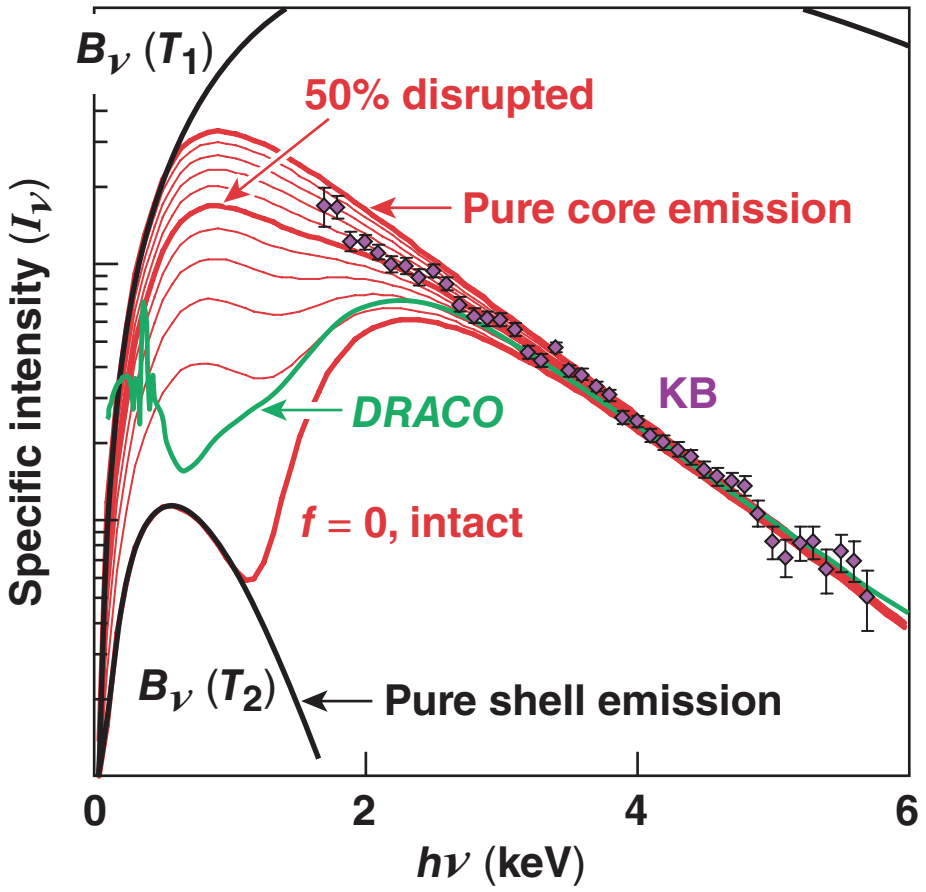
Cutting holes in a small fraction of the absorbing layer dilutes the diagnostic absorption effect



T_1 = 1.0 keV
ρR_1 = 70 g/cm^2

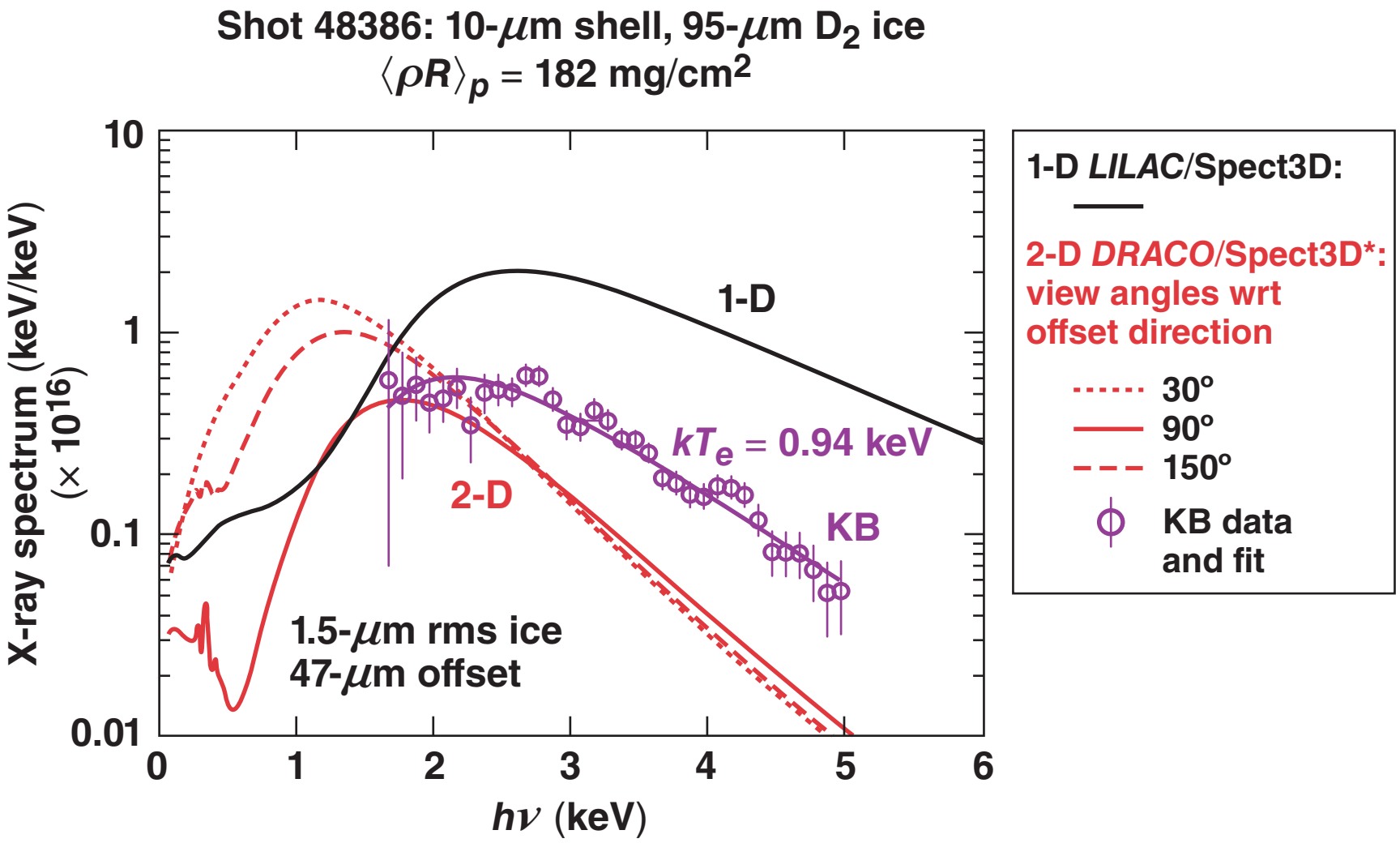
T_2 = 0.2 keV
ρR_2 = 180 g/cm^2

Conditions chosen to mimic shot 47206.



TC8139

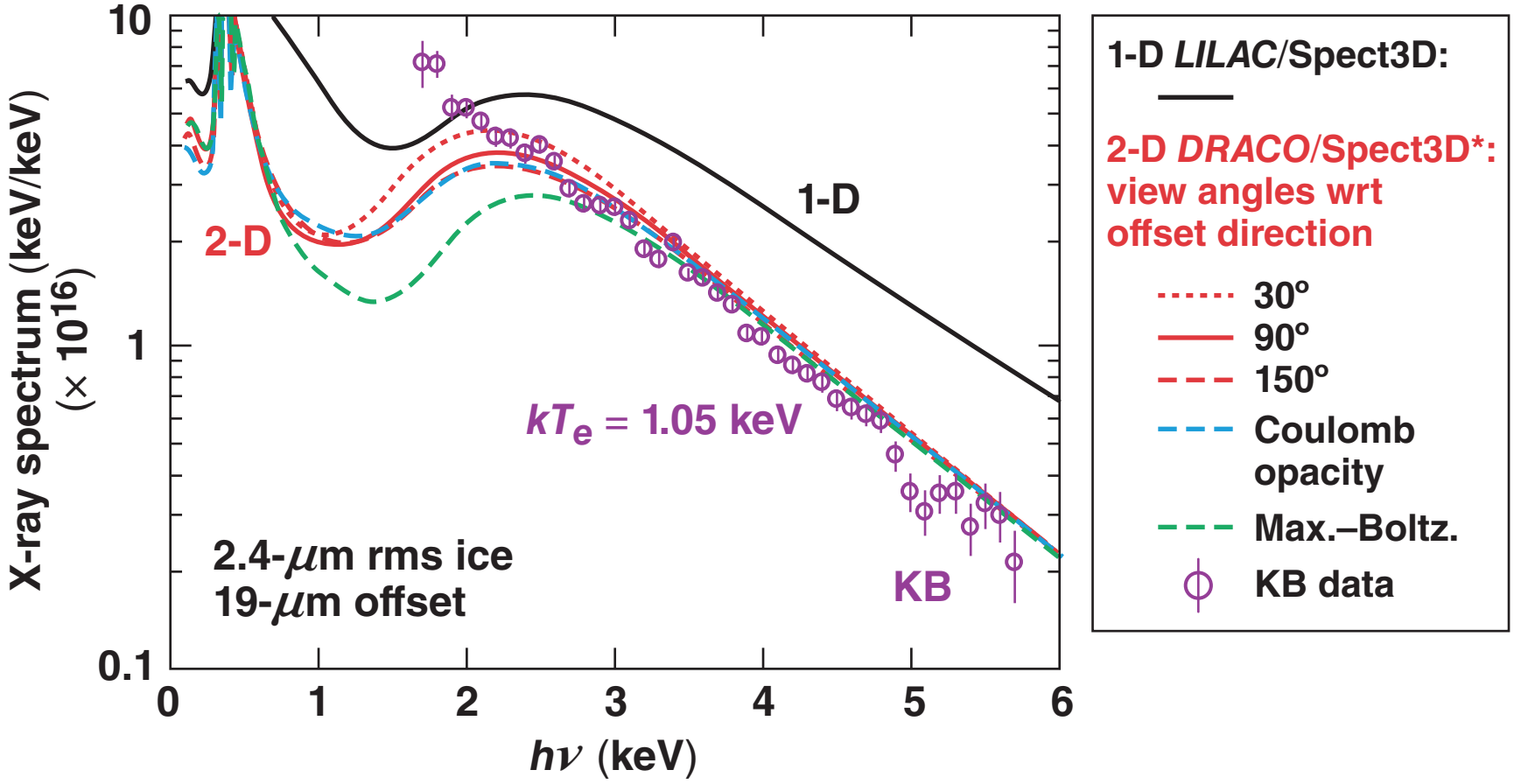
The measured continuum spectrum of shot 48386 is bracketed by 1-D and 2-D simulation results



TC8140

*Spect3D: PRISM Computational Sciences, Inc., Madison, WI.

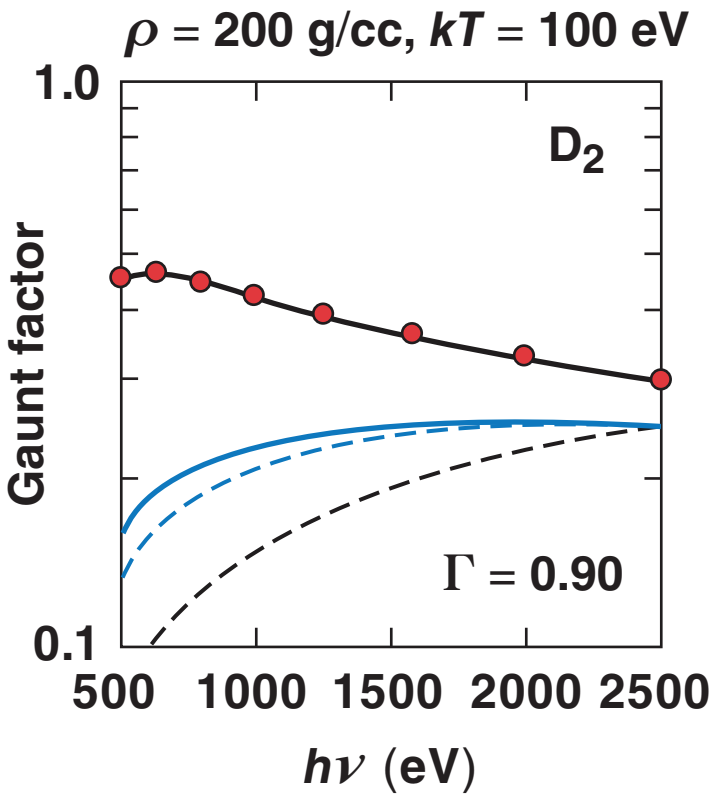
Accurate spectra require opacity models that include high-density effects



TC7949a

*Spect3D: PRISM Computational Sciences, Inc., Madison, WI.

The compressed-shell opacity model must include all relevant high-density strong-coupling effects



Opacity models

- Nakagawa *et al.** exact Coulomb degenerate
- Exact Coulomb
- Ion-sphere potential
- Stewart & Pyatt ion-sphere/ Debye–Hückel
- Include OCP** structure

- The Astrophysical Opacity Tables include the exact Coulomb Fermi–Dirac result of Nakagawa *et al.**
- The ion-sphere potential replaces the Coulomb potential in strongly coupled plasmas ($\Gamma > 1$).

Strongly coupled ion-sphere opacity reduction is potentially very significant.

* M. Nakagawa, Y. Kohyama, and N. Itoh, Ap. J. Suppl. 63, 661 (1987).
** J.-L. Bretonnet and A. Derouiche, Phys. Rev. B. 38, 9255 (1988).

TC7953

Summary/Conclusions

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UR LLE

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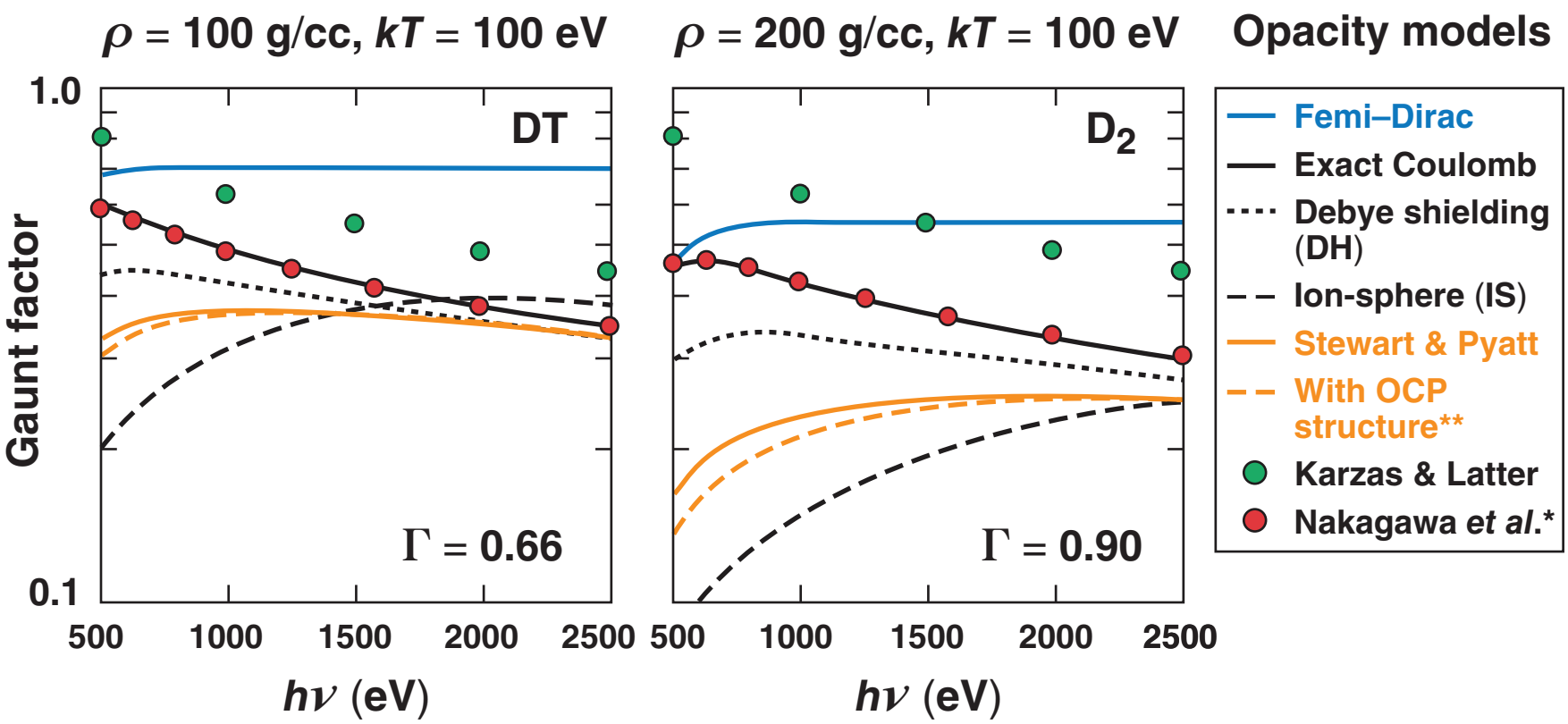
Well-known free-free opacity models diverge at low photon energy under warm high-density conditions



- The Astrophysical Opacity Tables include the exact Coulomb potential, Fermi–Dirac result of Nakagawa *et al*.*

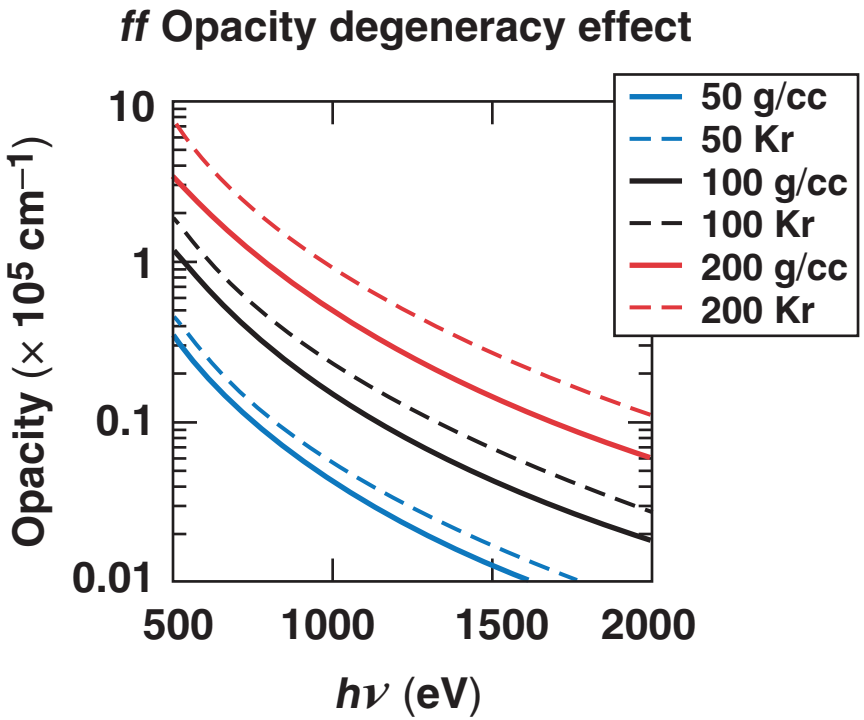
The Stewart & Pyatt potential interpolates between the DH and IS limits.

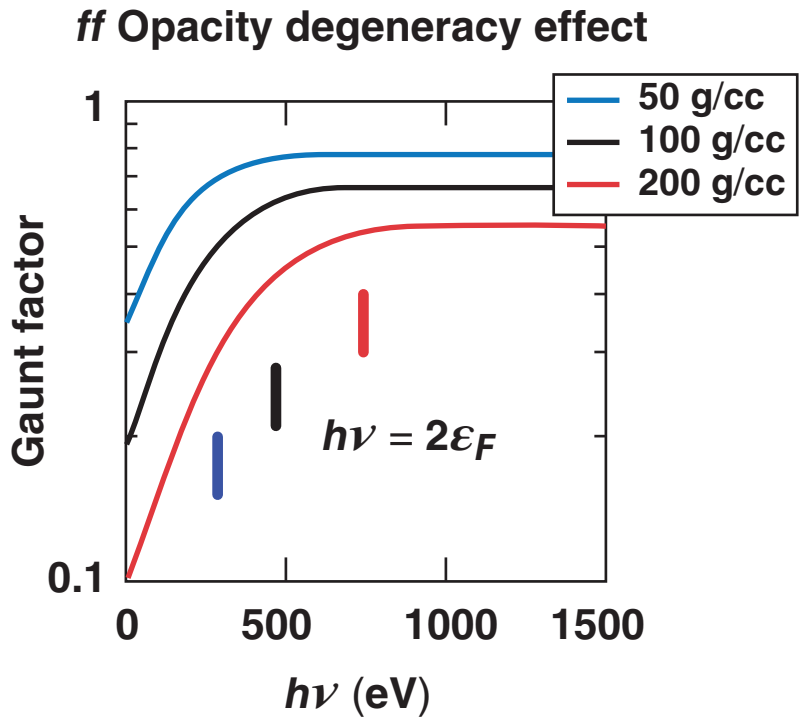
* M. Nakagawa, Y. Kohyama, and N. Itoh, Ap. J. Suppl. 63, 661 (1987).
** J.-L. Bretonnet and A. Derouiche, Phys. Rev. B. 38, 9255 (1988).

TC7954a

The degeneracy of compressed-shell electrons substantially reduces the free-free opacity

D_2 kT = 100 eV





- Above $h\nu = 2\varepsilon_F$, only the initial electron states are degenerate.

TC7955

It is possible for high-ρR implosions to form shells with poor coverage resulting in optically thin spectra

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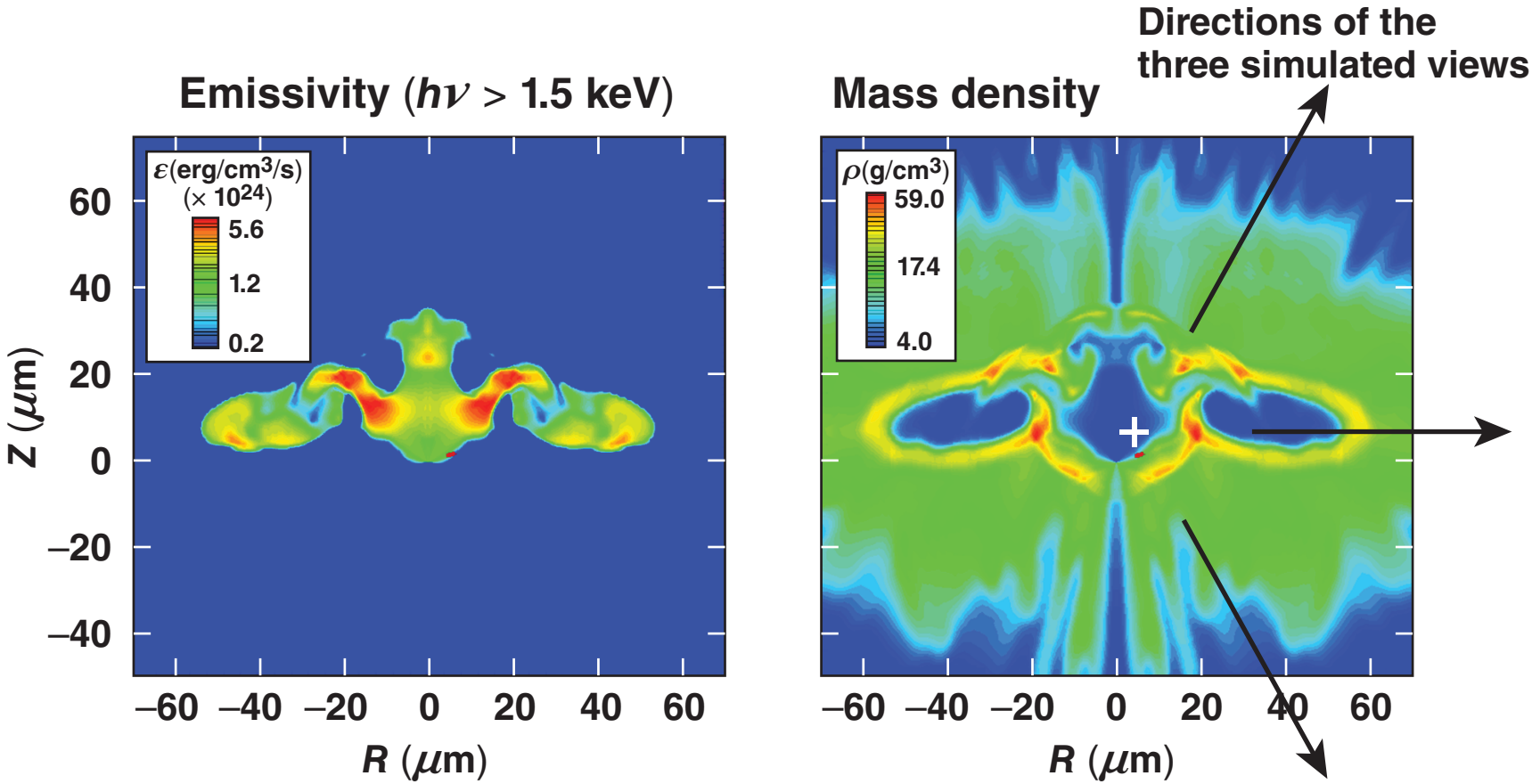
Cryo shot 48386 profiles at peak neutron emission, t = 4.1 ns



10-μm CD shell, 95-μm D_2 ice, $\langle \rho R \rangle_p$ = 182 mg/cm^2, σ_{ice} = 1.5 μm

TC8141