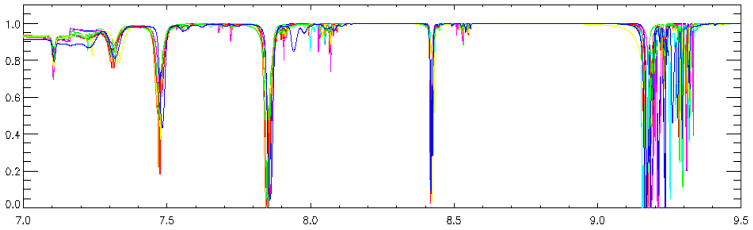
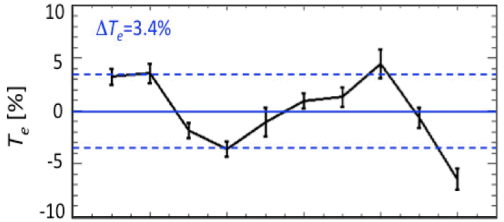
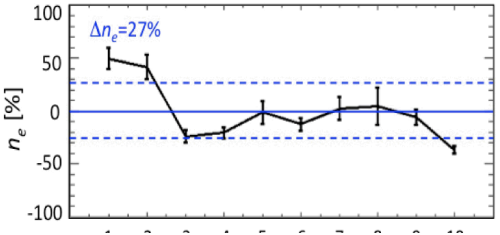
SAND2015-10207C

Exceptional service in the national interest

Sandia National Laboratories







K-shell spectroscopy uncertainty due to spectral models

Taisuke Nagayama

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

K-shell spectroscopy model inaccuracy investigation involves universities, national labs, and a private company

J.E. Bailey, S.B. Hansen, G. Loisel, G.A. Rochau
Sandia National Laboratories, Albuquerque, NM, 87185-1196

C.A. Iglesias
Lawrence Livermore National Laboratory, Livermore, CA, 94550

J. Colgan, C.J. Fontes, and D. Kilcrease
Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545

C. Blancard, Ph. Cosse, G. Faussurier, J.-C. Pain, and F. Gilleron
CEA, DAM, DIF, F-91297 Arpajon, France

J.J. MacFarlane and I. Golovkin
Prism Computational Sciences, Madison, WI

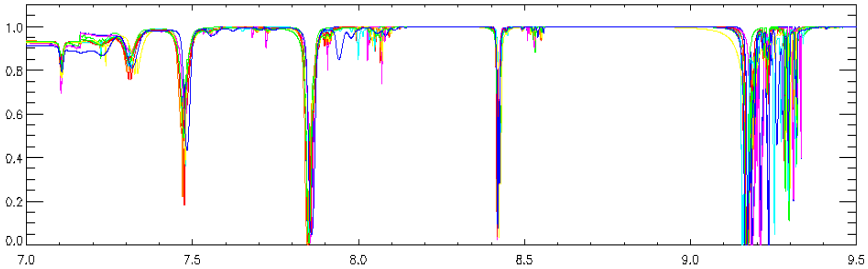
R.C. Mancini
University of Nevada, Reno, NV
s

R. Florido
Universidad de Las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain

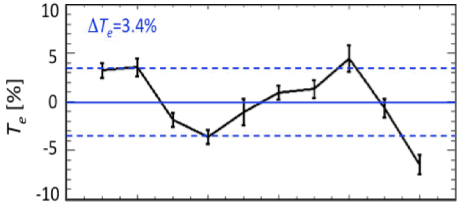
H.-K. Chung
International Atomic Energy Agency, A-1400 Vienna, Austria

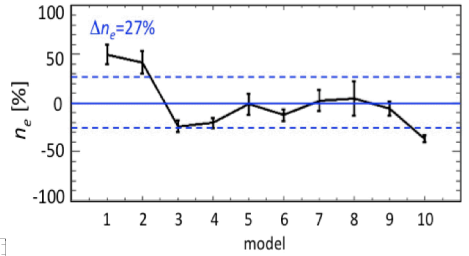
Summary: Model uncertainties in K-shell spectroscopy are 2-5% in T_e and 20-30% in n_e, primarily produced by line shape model differences

- Mg K-shell spectra are computed:
  - 10 different models
  - Same conditions

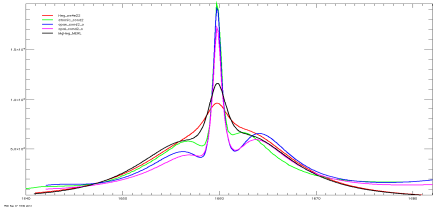


- The synthetic spectra are analyzed:
  - ΔT_e = 2-5 %
  - Δn_e = 20-30 %





- Major source of discrepancy:
  - Stark line shape models

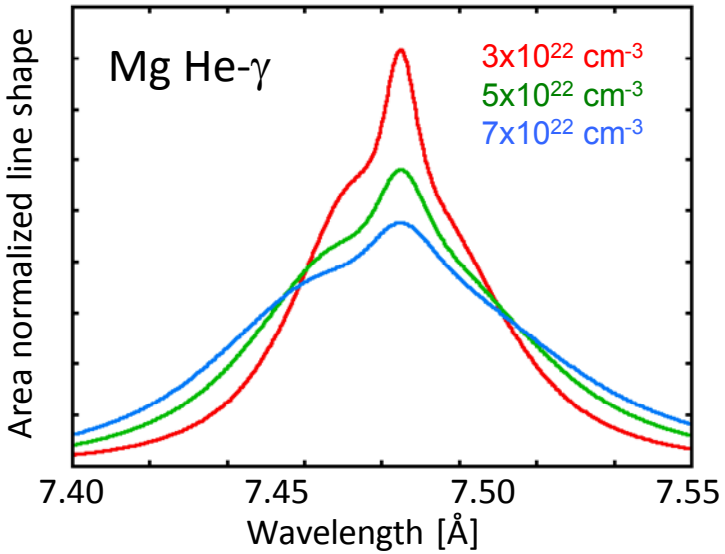


Line shape models should be scrutinized theoretically and experimentally

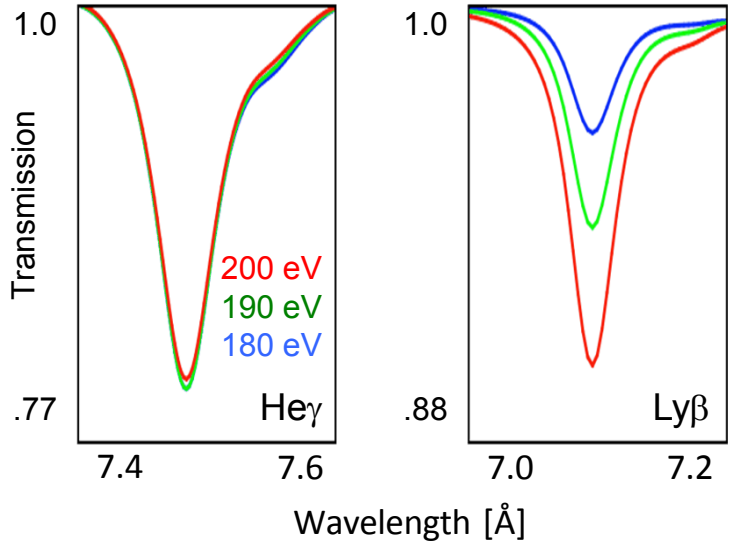
In high energy density plasmas, T_e and n_e can be precisely inferred from measured K-shell spectra1

Sandia National Laboratories

- Line shape: sensitive to electron density, n_e



- Line ratio: sensitive to electron temperature, T_e

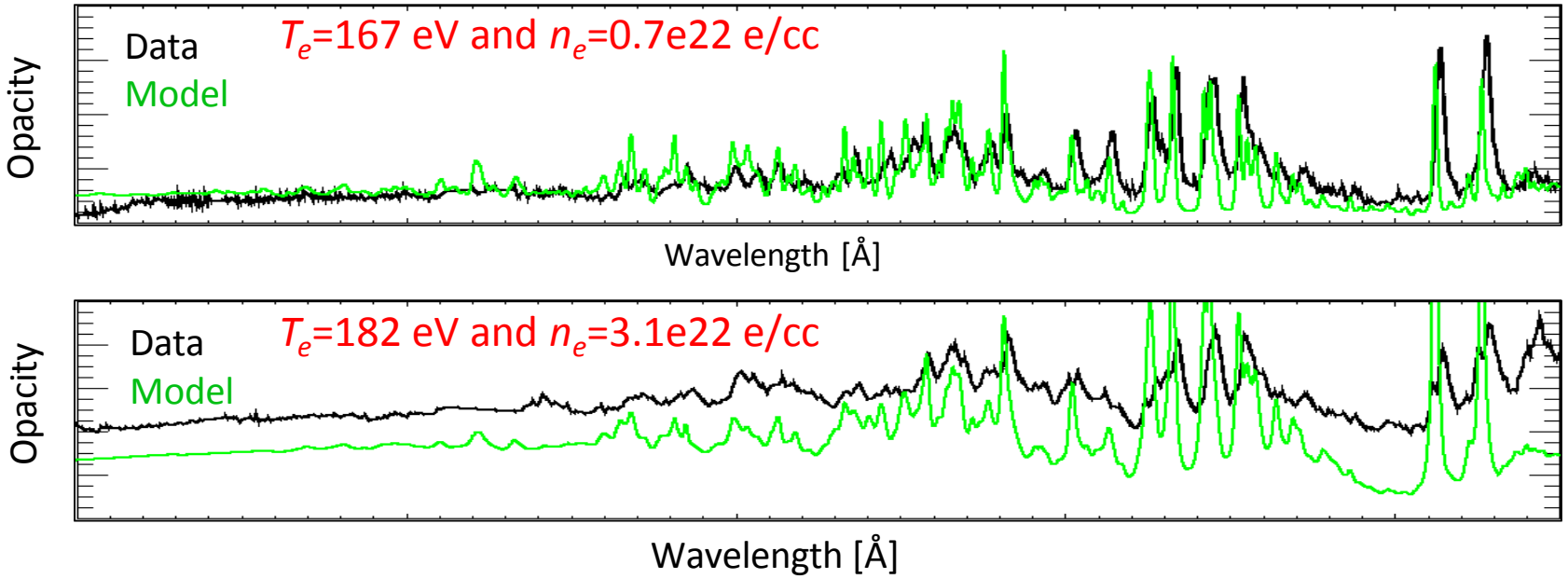


Plasma T_e and n_e can be extracted by fitting the data with detailed spectral model

Example: Mg K-shell spectroscopy is used to infer conditions for recent Fe opacity measurements

Sandia National Laboratories

- Recent opacity measurement reveals 30-400% opacity disagreement with models

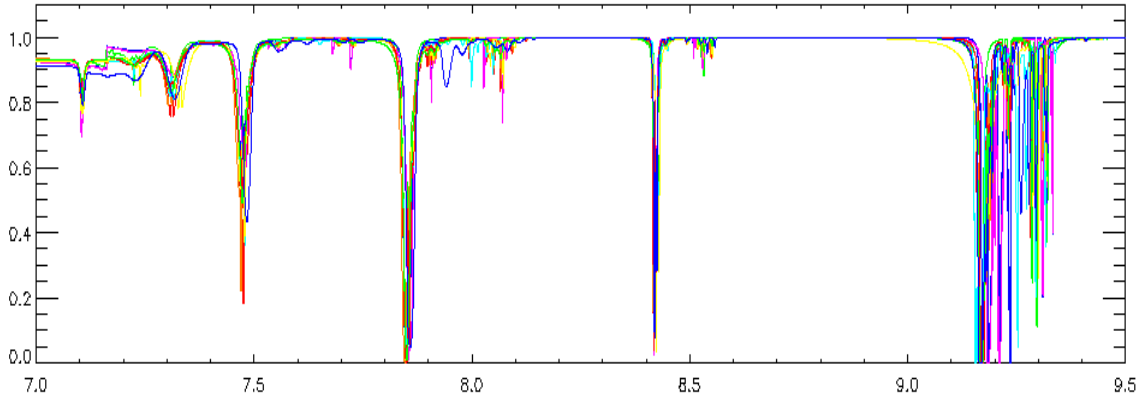


How accurate are the inferred T_e and n_e?

J. E. Bailey et al, Nature 517, 56 (2015).

K-shell spectroscopy model uncertainty is studied synthetically

- Compute Mg K-shell spectra with different models:



Participated models:

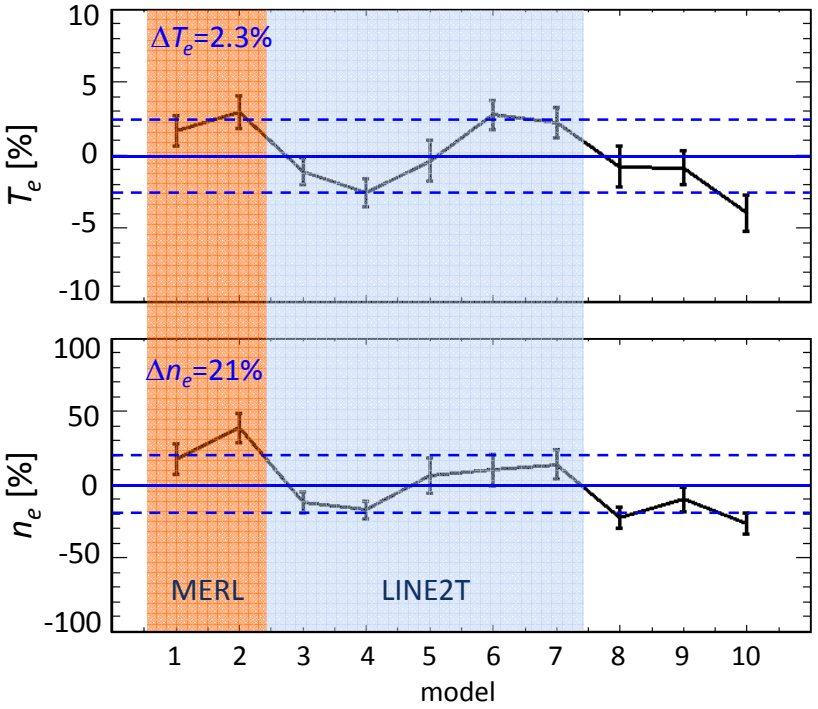
- ABAKO
- ATOMIC
- FLYCHK
- OPAL
- OPAS
- PrismSPECT
- SCRAM

- Synthetic spectra are analyzed using our tool (i.e., PrismSPECT with MERL)

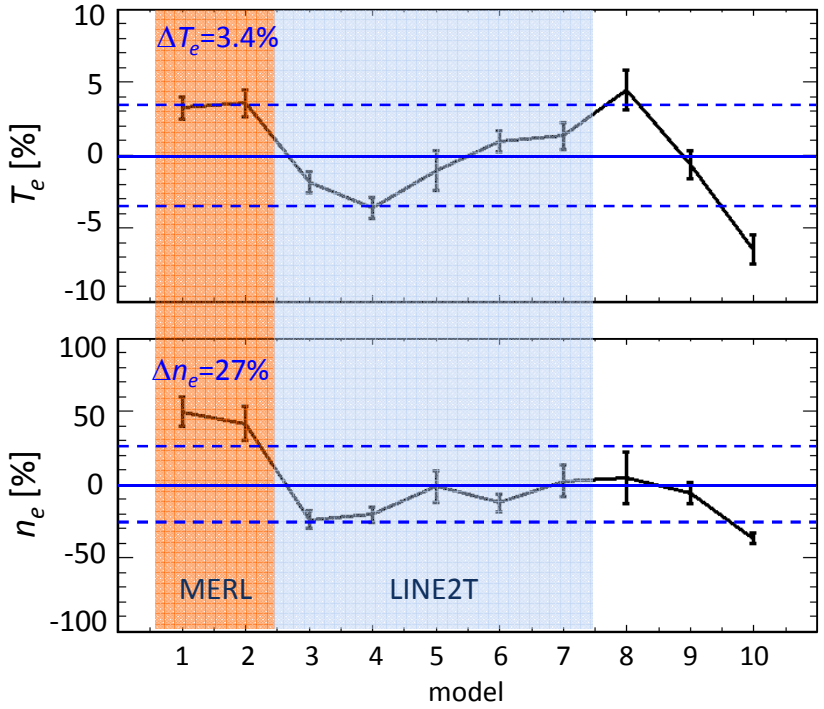
  → Do we get consistent results?

T_e and n_e model uncertainties are 2-5% and 20-30%, respectively

Case1: at T_e=165 eV, n_e=0.9e22 e/cc

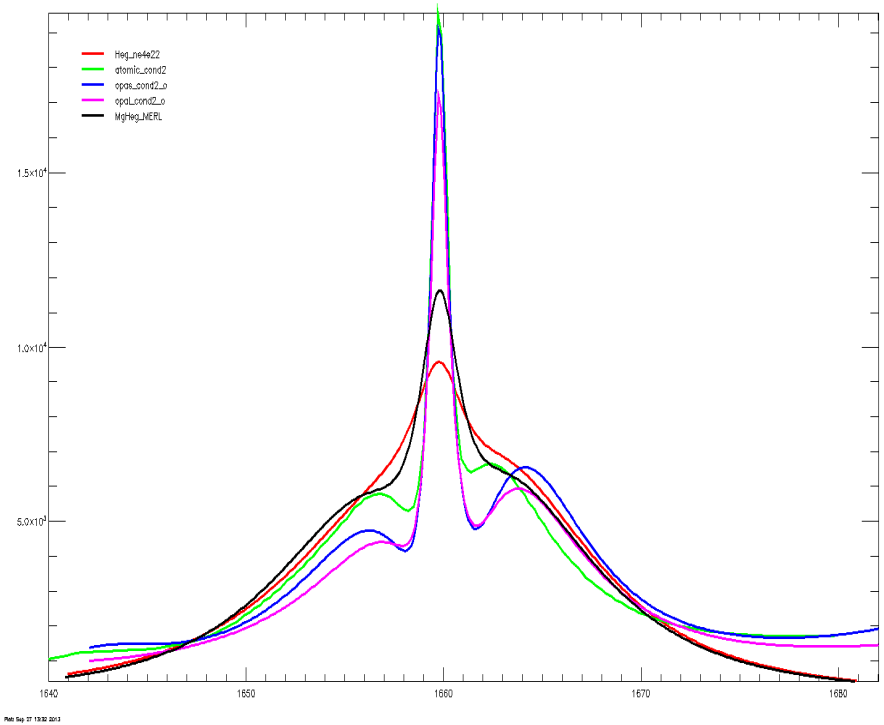


Case2: at T_e=195 eV, n_e=4.0e22 e/cc



Line shapes modeled by MERL and LINE2T produce roughly 30-50% difference in n_e

The discrepancy is primarily produced by Stark line model differences



Similarities: standard theory

- Static ion approximation
- Electron impact approximation

Differences:

	MERL	LINE2T
Extended basis set	YES	NO
Off-diagonal	YES	NO
G-function	Gaunt factor	Semi-classical

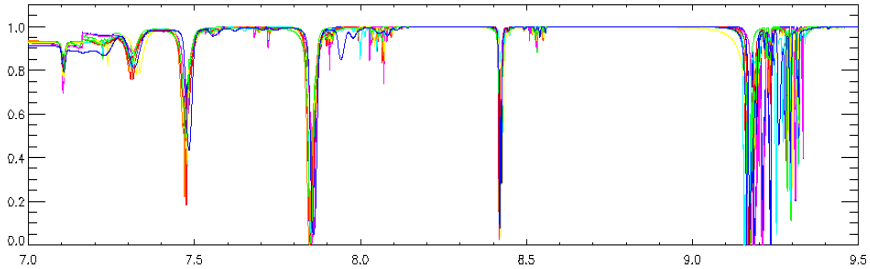
Line shape formalism should be experimentally validated!

MERL: R. C. Mancini et al, Comput. Phys. Commun. 63, 314 (1991).

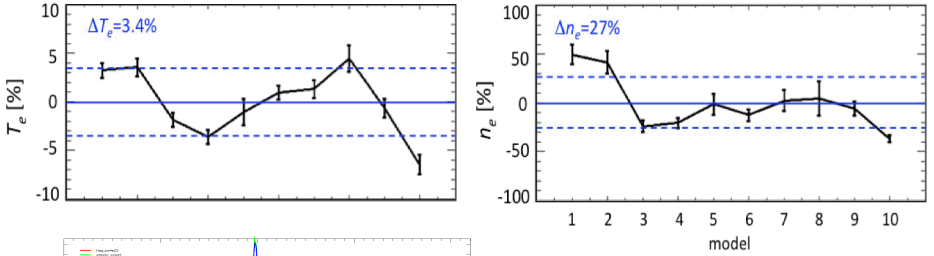
LINE2T: R. W. Lee, JQSRT 40, 561 (1988).

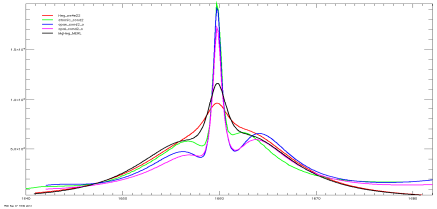
Summary: Model uncertainties in K-shell spectroscopy are 2-5% in T_e and 20-30% in n_e mostly due to line shape model differences

- Mg K-shell spectra are computed:
  - 10 different models
  - Same conditions



- The synthetic spectra are analyzed:
  - ΔT_e = 2-5 %
  - Δn_e = 20-30 %





- Major source of discrepancy:
  - Stark line shape models

Line shape models should be scrutinized theoretically and experimentally