A consistent set of atomic data for various elements in a fusion reactor (passive emissions / radiative losses)

T. Pütterich

MPI für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Thanks to: M. O'Mullane, R. Dux, A. Foster

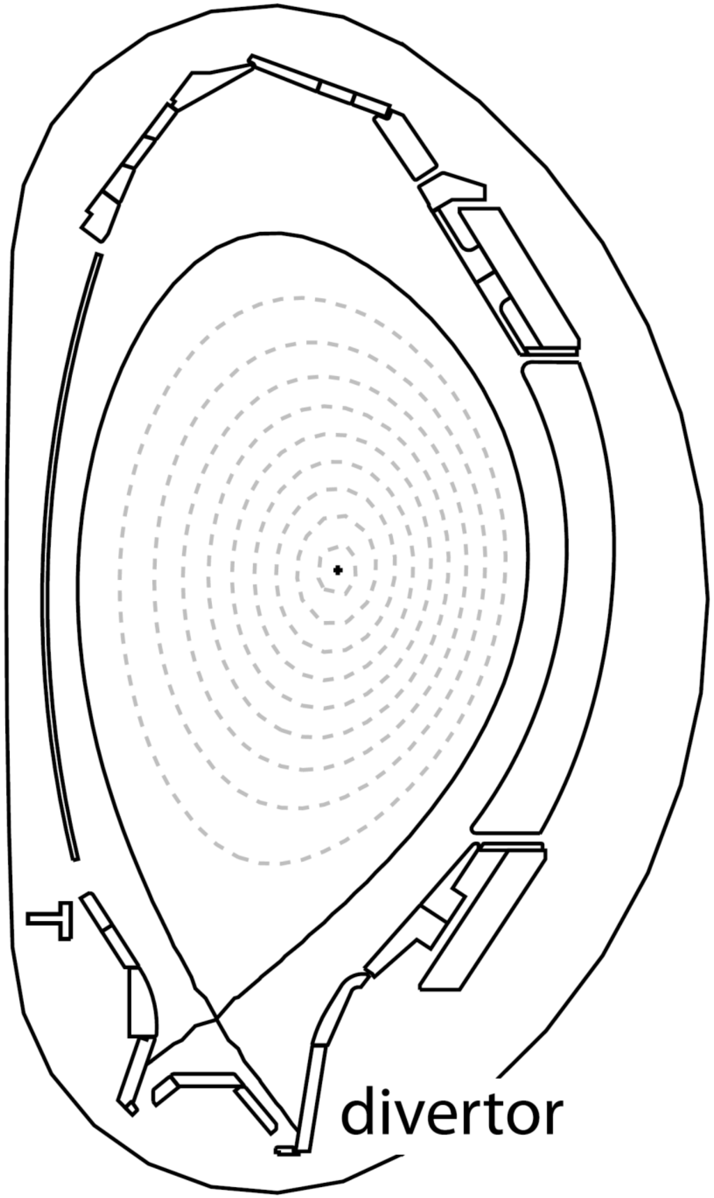
Overview

- Motivation
  - ⇨ Impurities in Fusion Plasmas
  - ⇨ Issues with existing data
- New Calculations using ADAS codes
  - ⇨ What quality has the new data?
  - ⇨ First tests with the new data
- First Applications of the new data
- Course of Action?

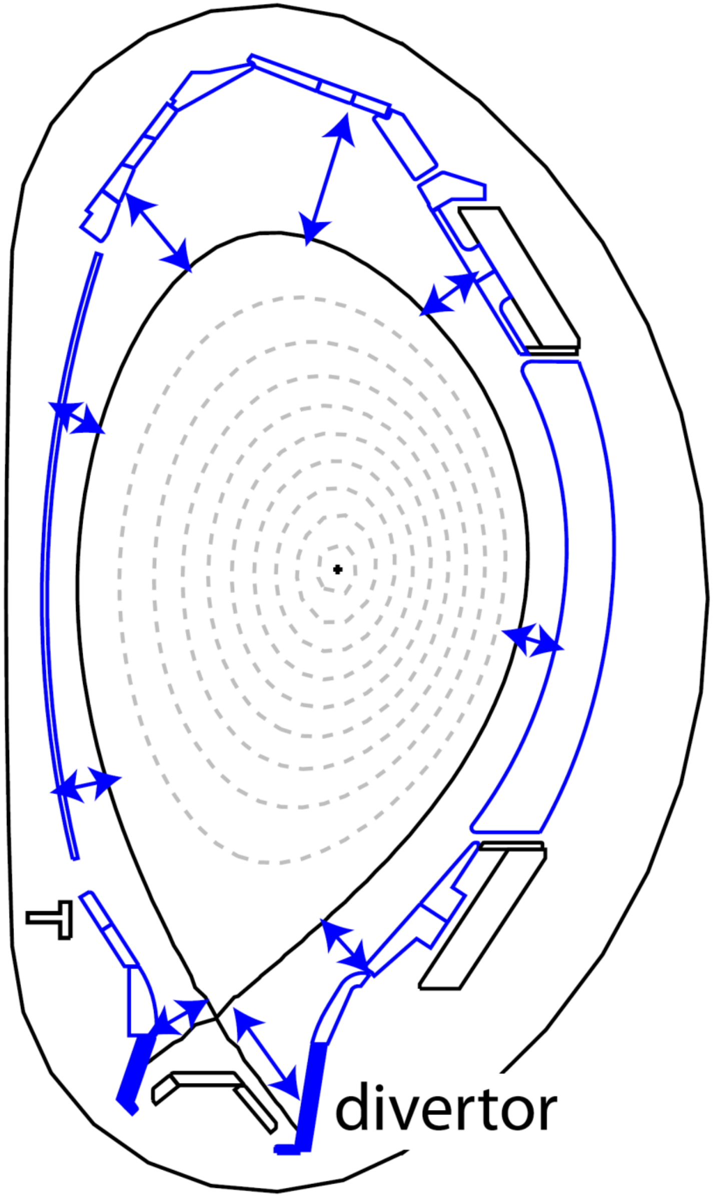
Overview

- Motivation
  - ⇨ Impurities in Fusion Plasmas
  - ⇨ Issues with existing data
- New Calculations using ADAS codes
  - ⇨ What quality has the new data?
  - ⇨ First tests with the new data
- First Applications of the new data
- Course of Action?

Impurity Sources

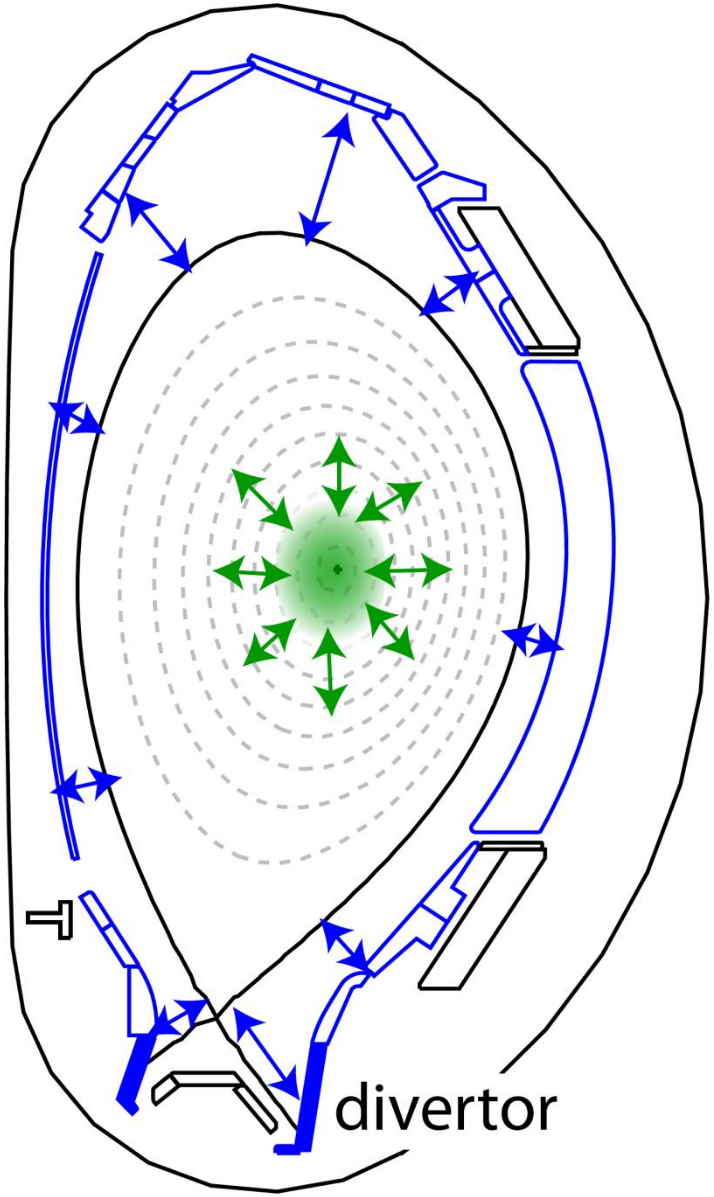


Impurity Sources



- Erosion from first wall
  (e.g. W, Be, C…..)

Impurity Sources



- Erosion from first wall (e.g. W, Be, C…..)

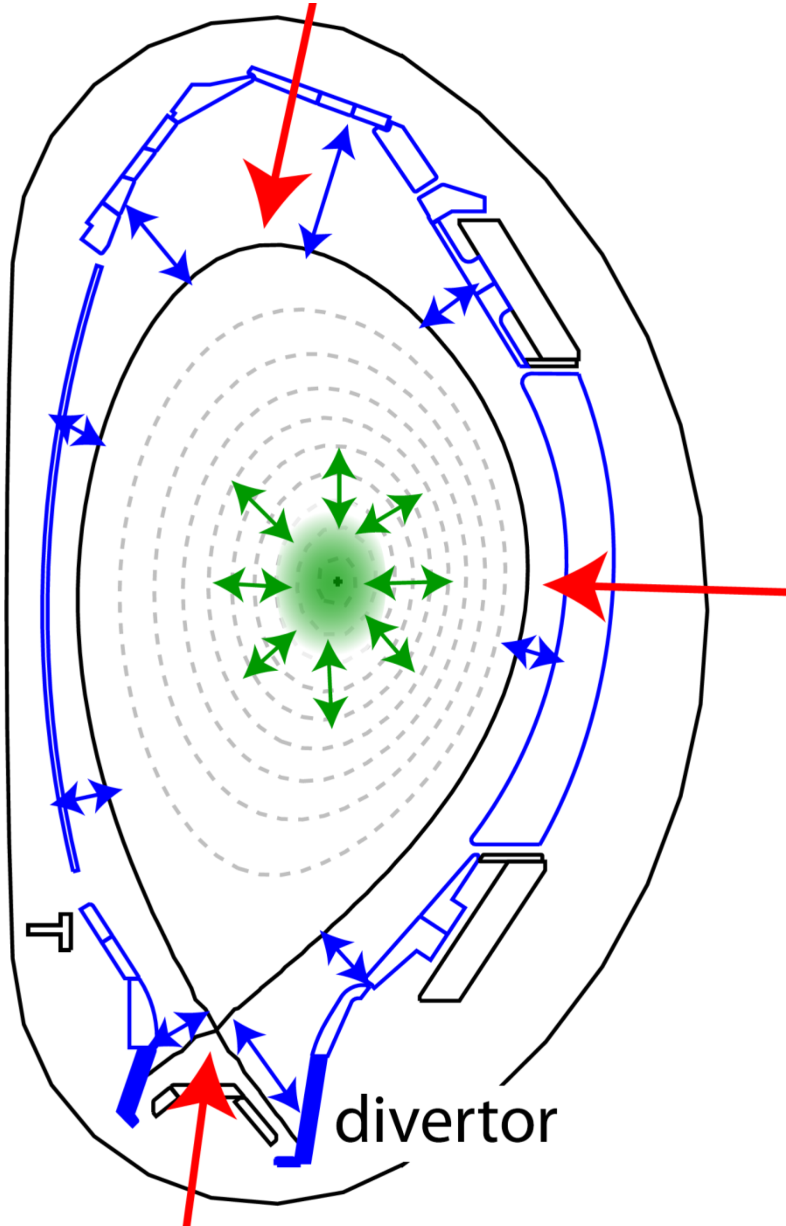
- Production of He in reactor core

$$ {}^{2}_{1}\mathrm{D} + {}^{3}_{1}\mathrm{T} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}\mathrm{n} $$

3.5MeV 14.1MeV

ASDEX Upgrade

Impurity Sources



- Erosion from first wall
  (e.g. W, Be, C…..)

- Production of He in reactor core

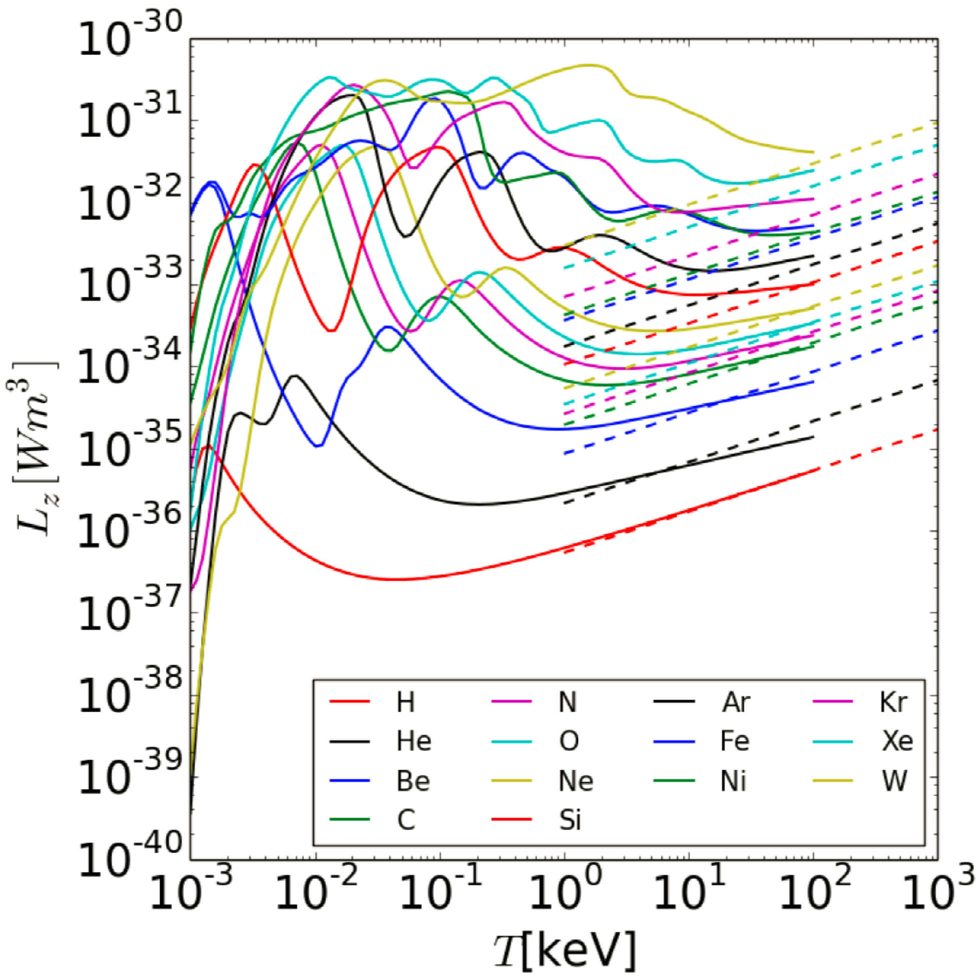
$$ {}^{2}_{1}\mathrm{D} + {}^{3}_{1}\mathrm{T} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}\mathrm{n} $$

3.5MeV 14.1MeV

- Intentionally injected impurities
  (e.g. N, Ne, Ar, Kr…)

Radiative Losses from Plasma: Need Atomic Data for Many Elements!

Cooling Factors (H. Lux, ADAS WS 2014)



- Strategy:

  Take what is available

  ⇨ Various calculation qualities

  ⇨ Systematic trends might be hidden

  ⇨ Not all data optimized for application in a reactor

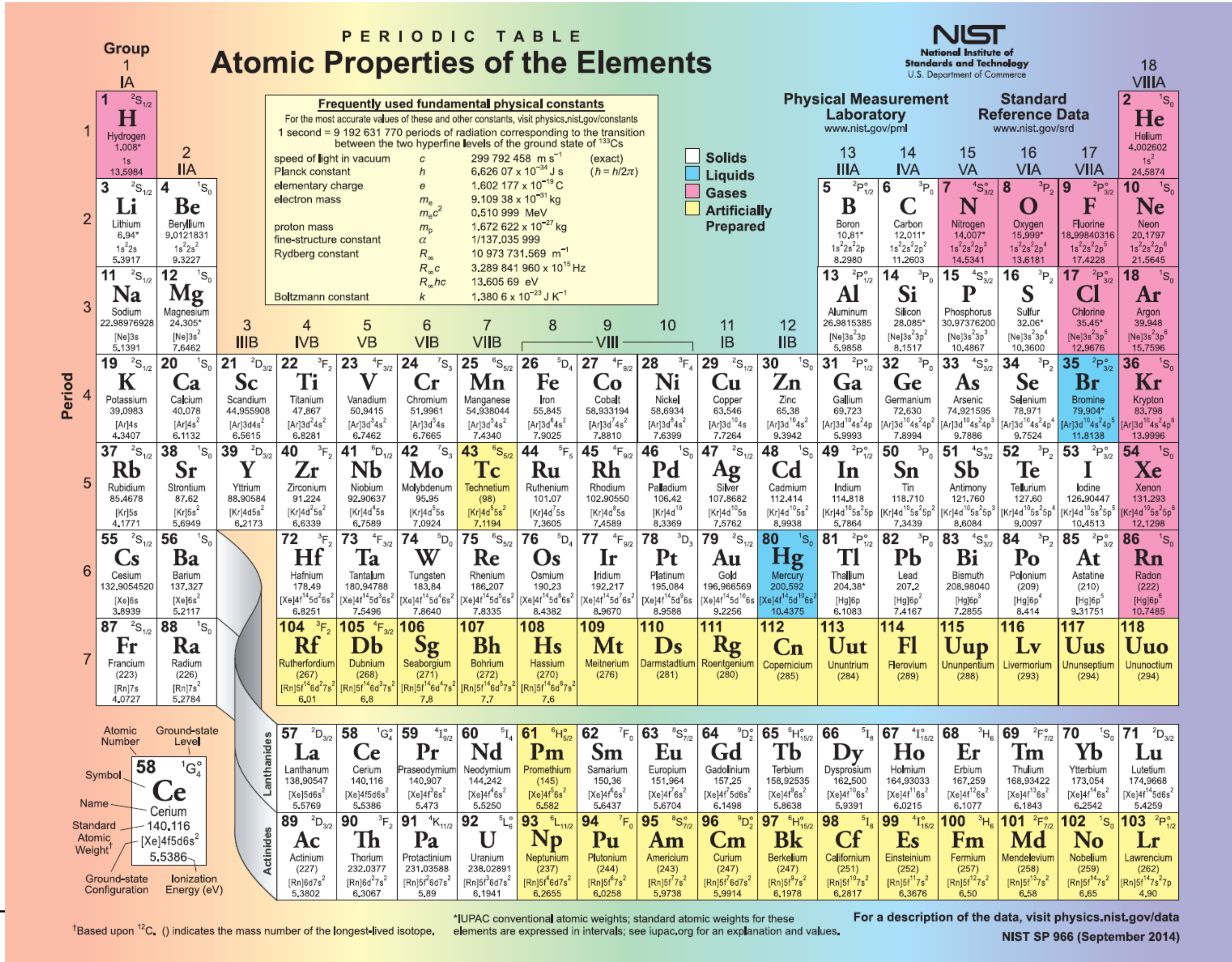
Overview

- Motivation
  - ⇨ Impurities in Fusion Plasmas
  - ⇨ Issues with existing data
- New Calculations using ADAS codes
  - ⇨ What quality has the new data?
  - ⇨ First tests with the new data
- First Applications of the new data
- Course of Action?

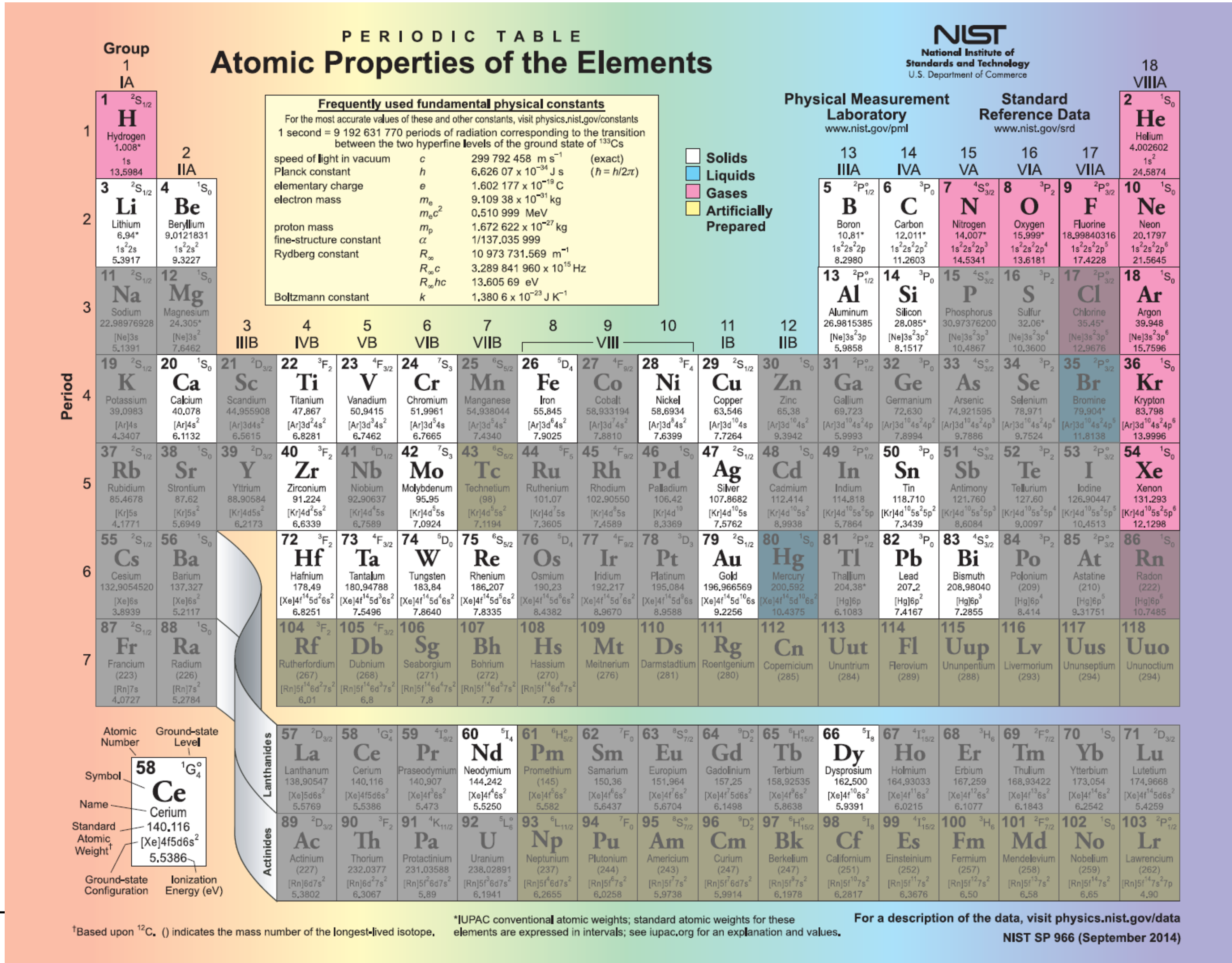
ASDEX Upgrade

What data was calculated I – What elements?

IPP



What data was calculated I – What elements?



What data was calculated II – What quality?

Baseline	elevated	high quality

New data has:

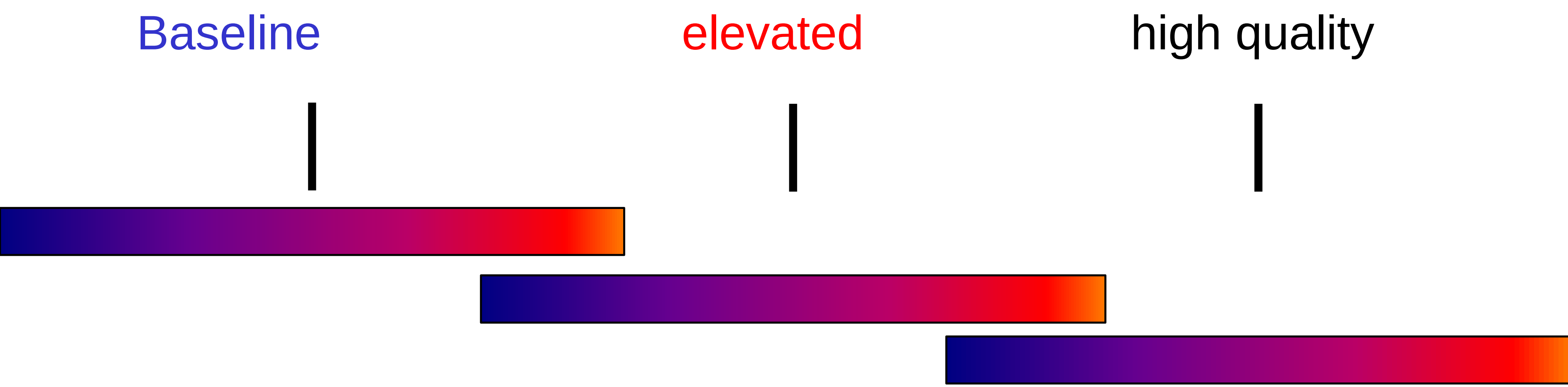
Excitation+population model: baseline

Recombination data: baseline

Ionisation data: elevated

But: baseline is not equal to baseline !

What data was calculated II – What quality?



New data has:

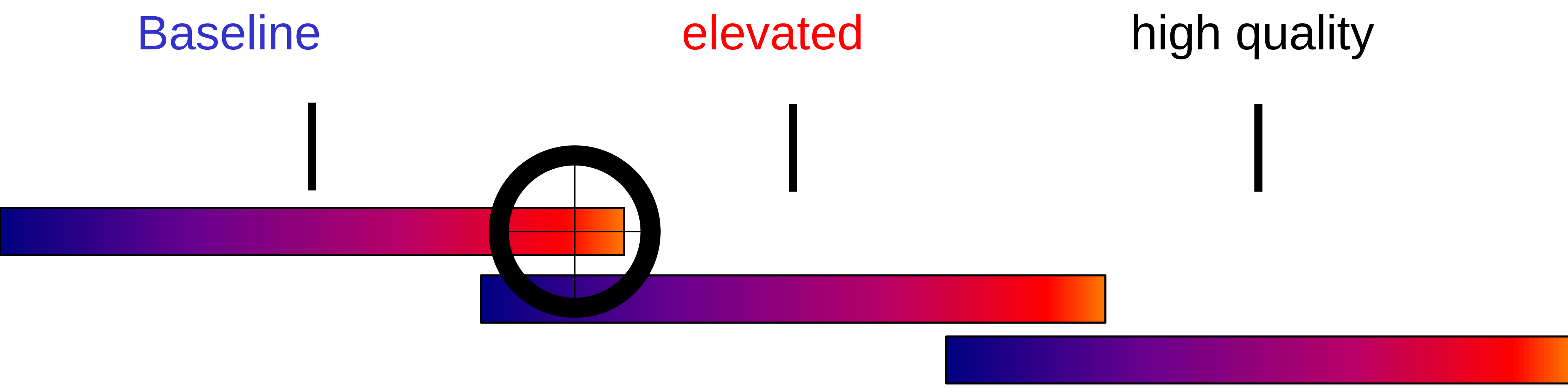
Excitation+population model: baseline

Recombination data: baseline

Ionisation data: elevated

But: baseline is not equal to baseline !

What data was calculated II – What quality?



New data has:

Excitation+population model: baseline (Cowan + p-w Born + basic CR)

Recombination data: baseline (ADAS407/408 type A, parametric forms)

Ionisation data: elevated (CADW, but in zero-density approx.)

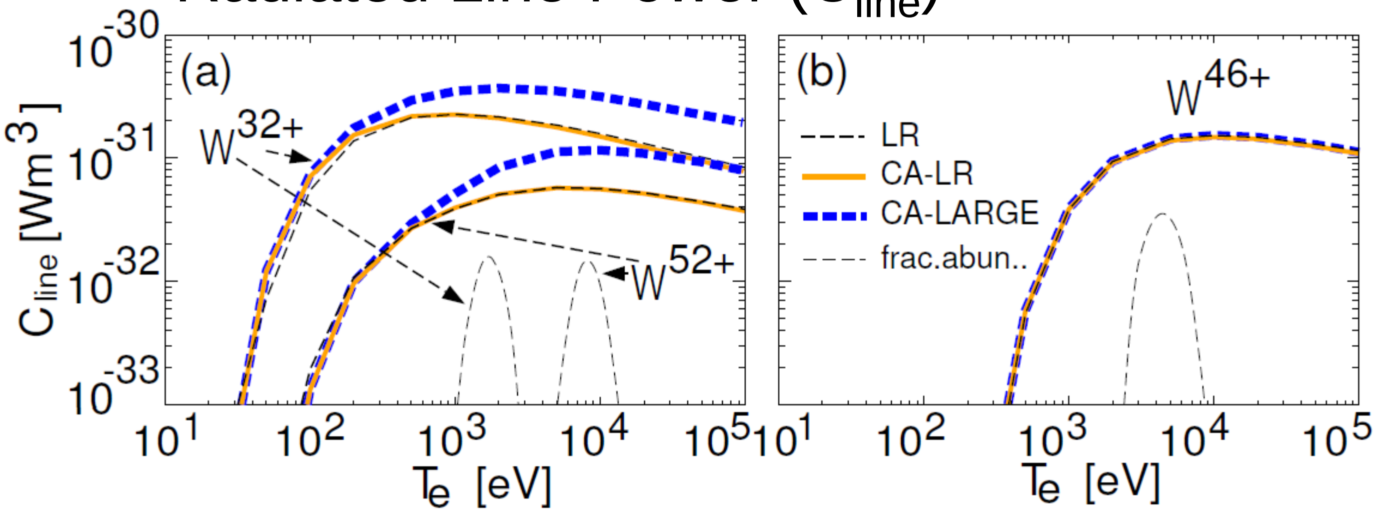
But: baseline is not equal to baseline !

What configurations have been included?

- Try to maximise number of configs
- Include the ‚important‘ configs
- Strategy:
  - ⇨ Use configurations as identified for W
    (PhD Pütterich, PPCF 2008, NF 2010)
  - ⇨ Level resolved calculations for
    - ⇨ Predicting spectra
    - ⇨ Running adas407/408
  - ⇨ Configuration averaged caluclations for cooling factors

Configuration Average is Good for Radiated Power

Radiated Line Power (C_{line})

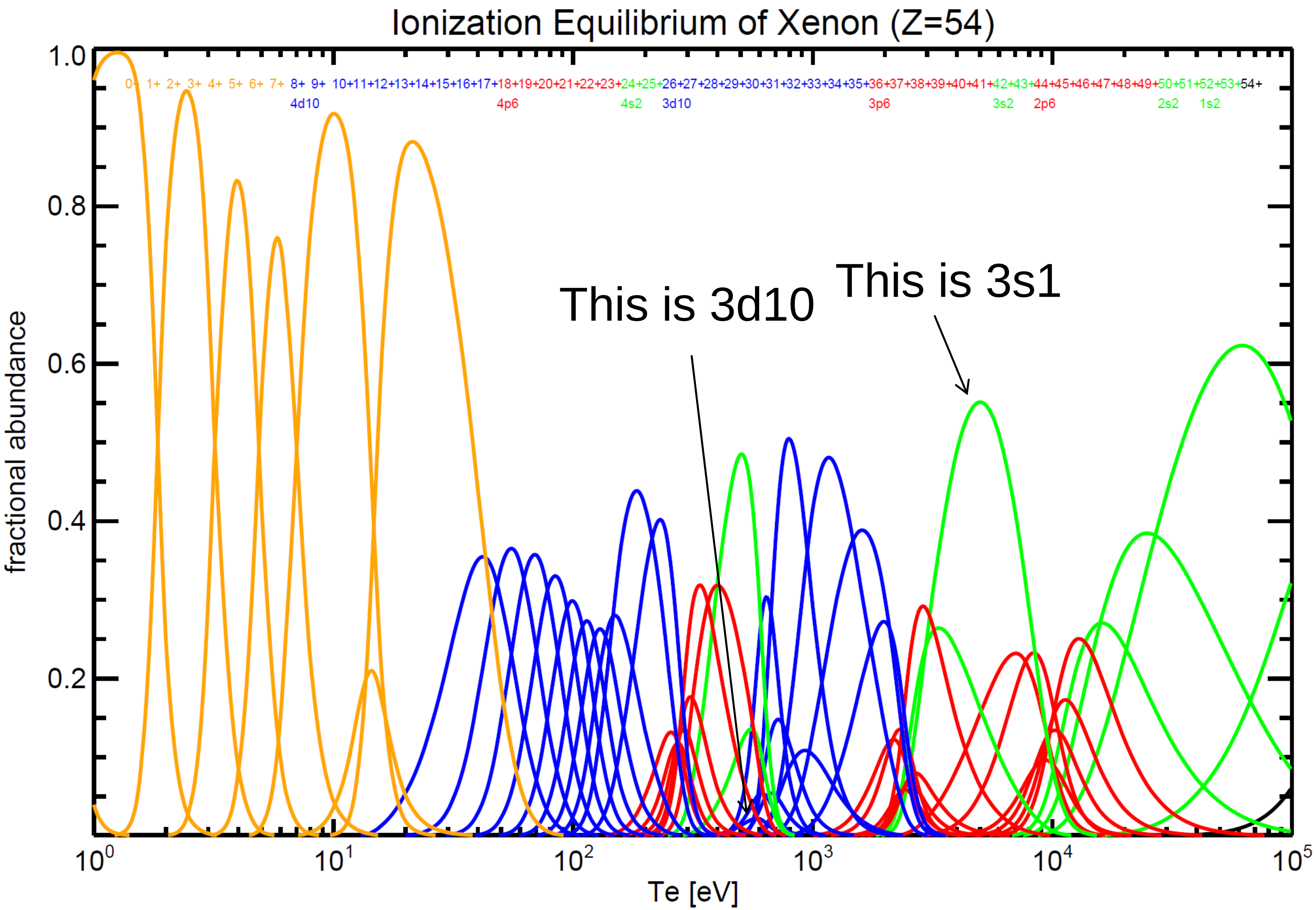


- Level-resolved LR
- Config.-average CA
  - ⇨ LR set of configs
  - ⇨ Large set of configs ~#30

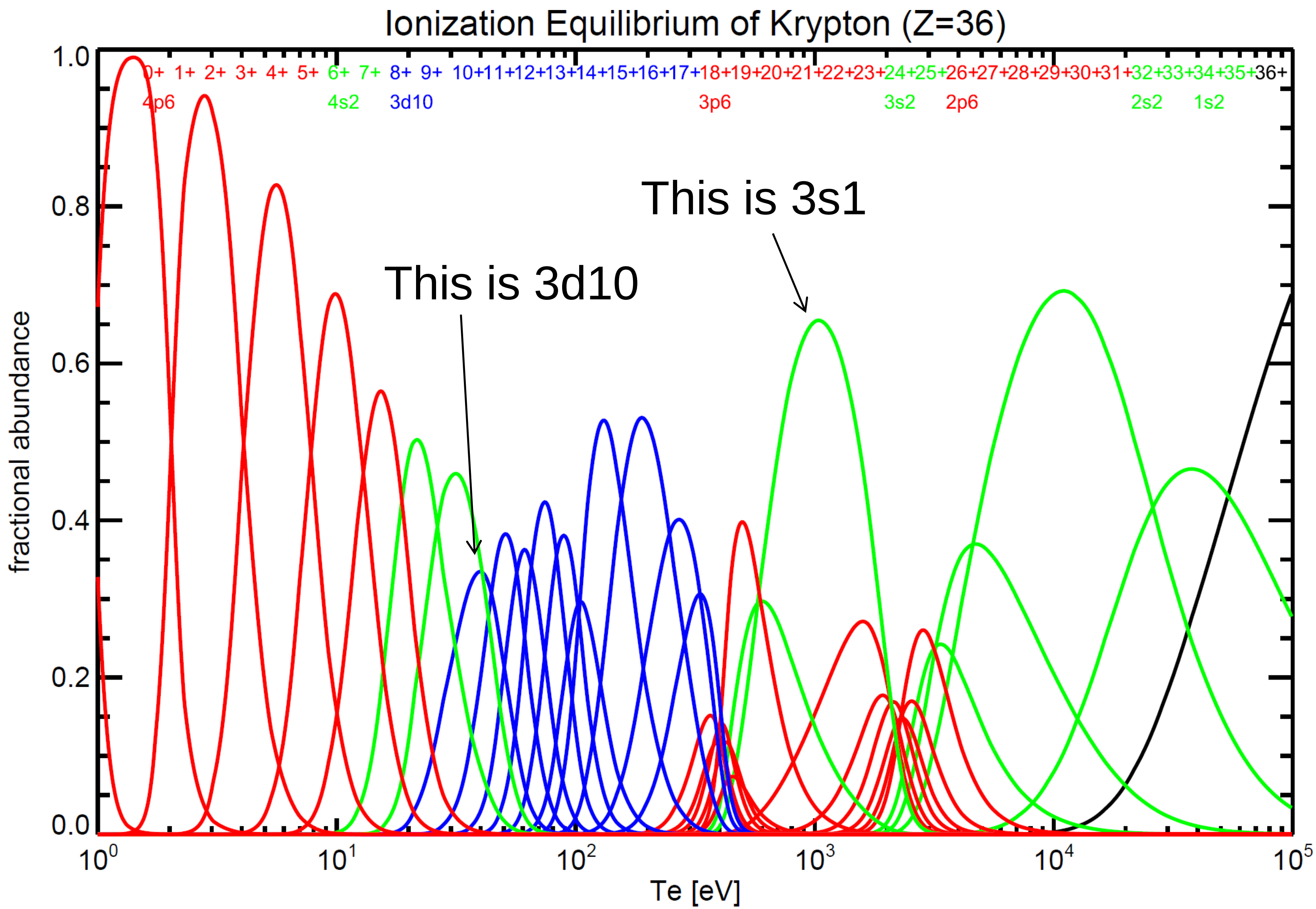
Pütterich NF 2010

	LR/CA-LR	CA-LARGE
Mo-like W^{32+}	$4d^6$, $4d^5 4f \rightarrow 4d^5\,5f$, $4p^5\,4d^7$, $\Sigma = 7$	$4d^6$, $4d^5 4f \rightarrow 4d^5 5g$, $4p^5 4d^7 \rightarrow 4p^5 4d^6 5g$, $4s4p^6 4d^7 \rightarrow 4s4p^6 4d^6 5g$, $3d^9 4s^2 4p^6 4d^7 \rightarrow 3d^9 4s^2 4p^6 4d^6 5g$; $\Sigma = 28$

Ionization Equilibrium for Old Data (Xe)

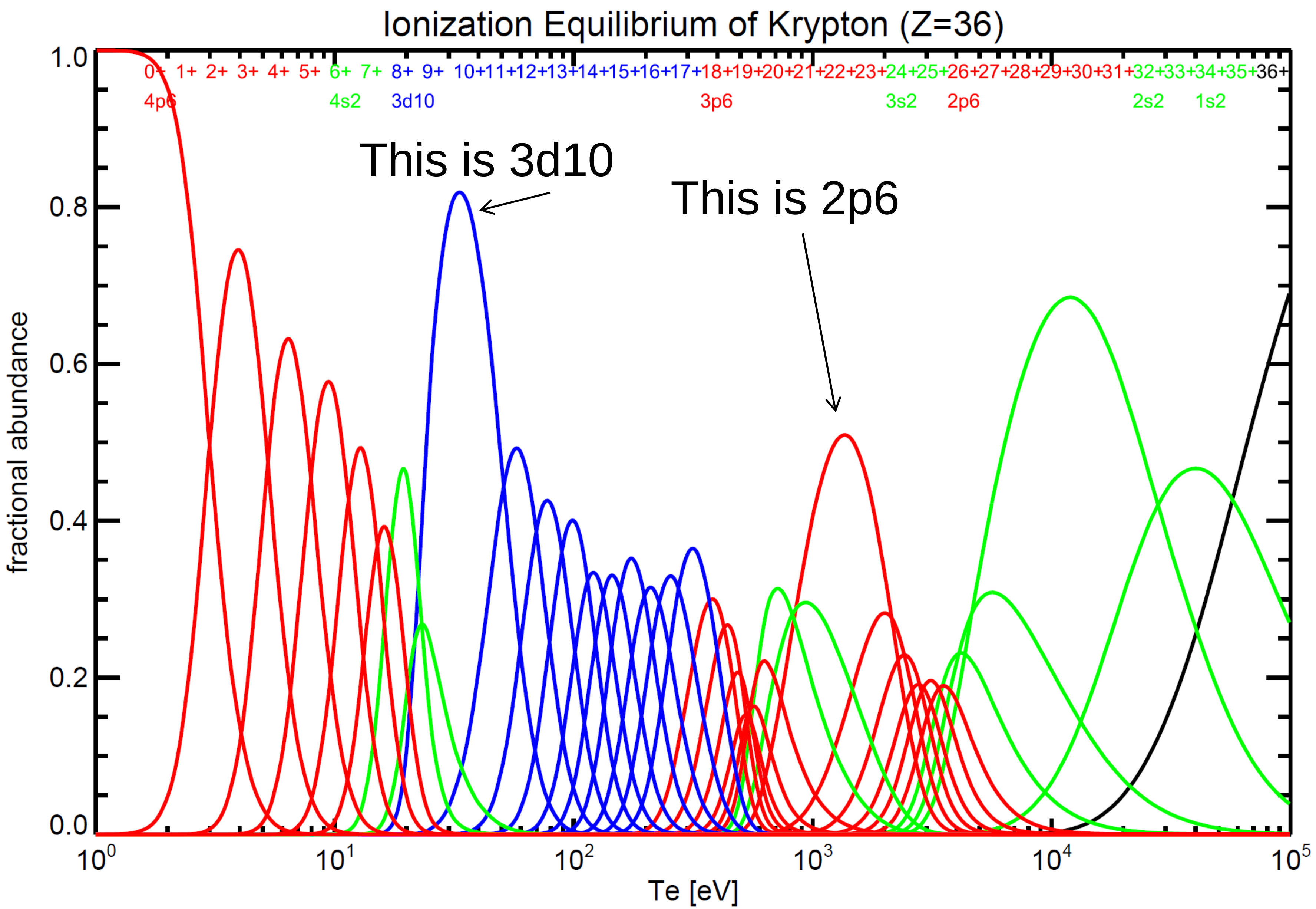


Ionization Equilibrium for Old Data (Kr)

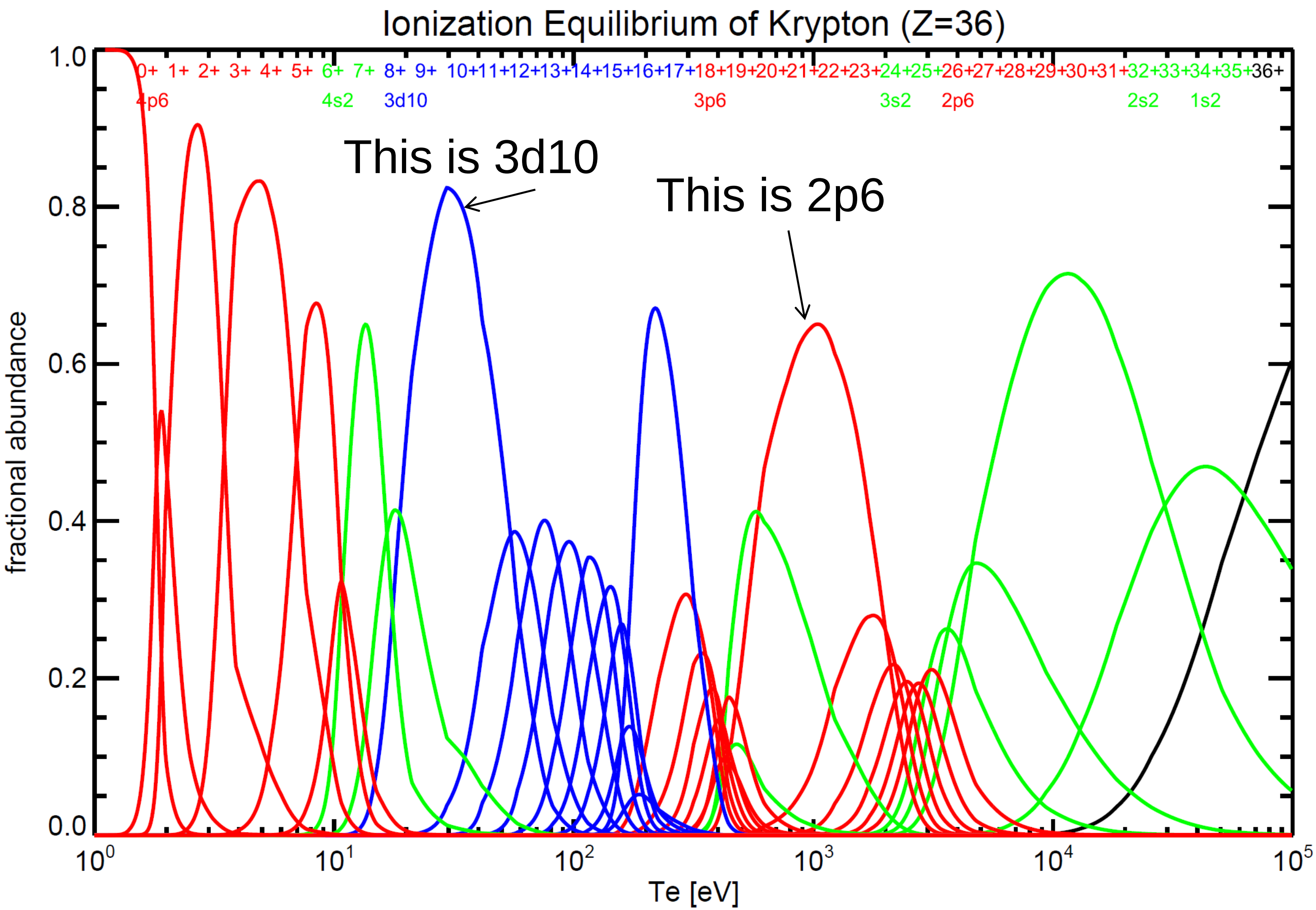


Ionization Equilibrium for Kr (Mattioli data)

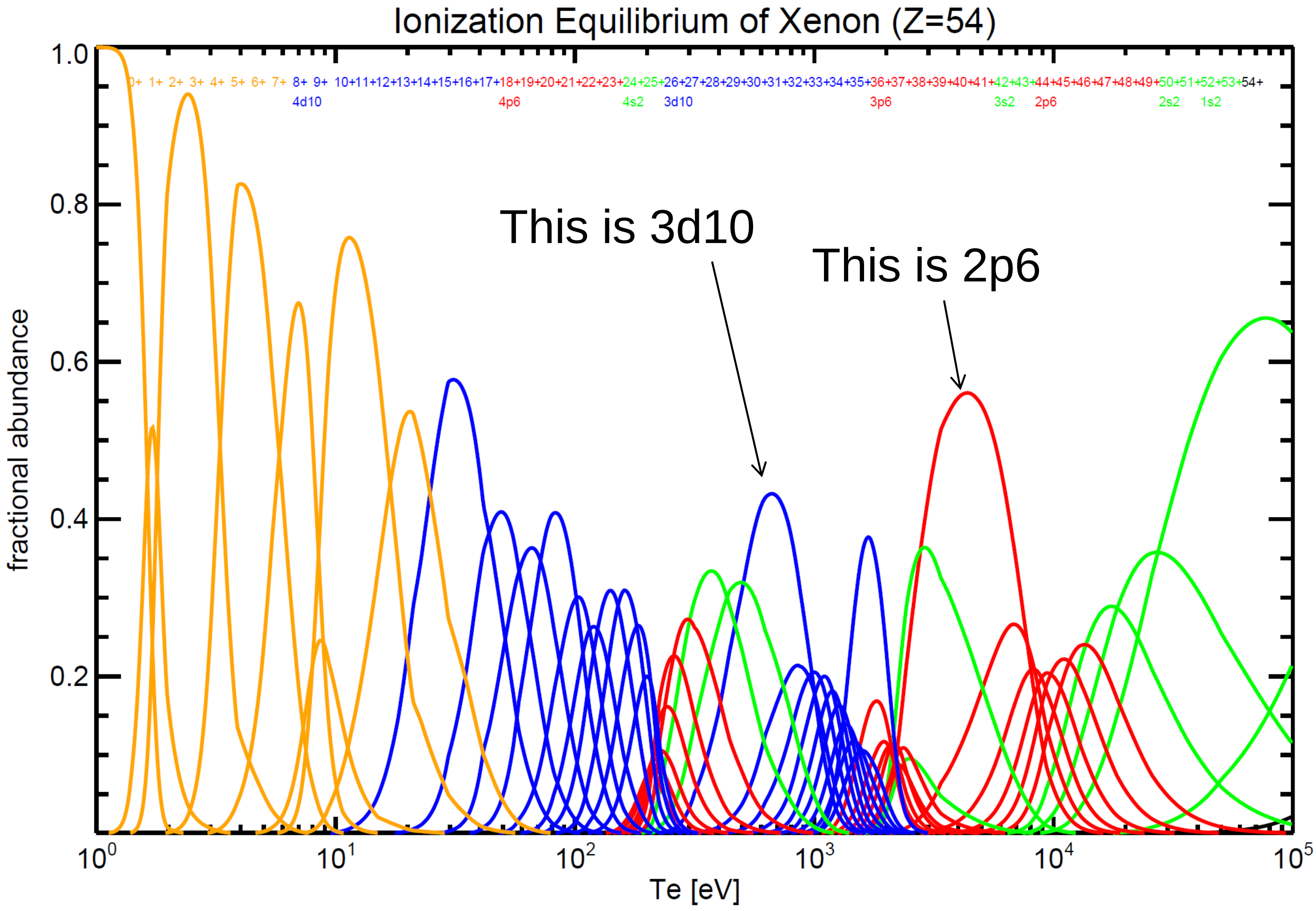
Mattioli JPB 2006



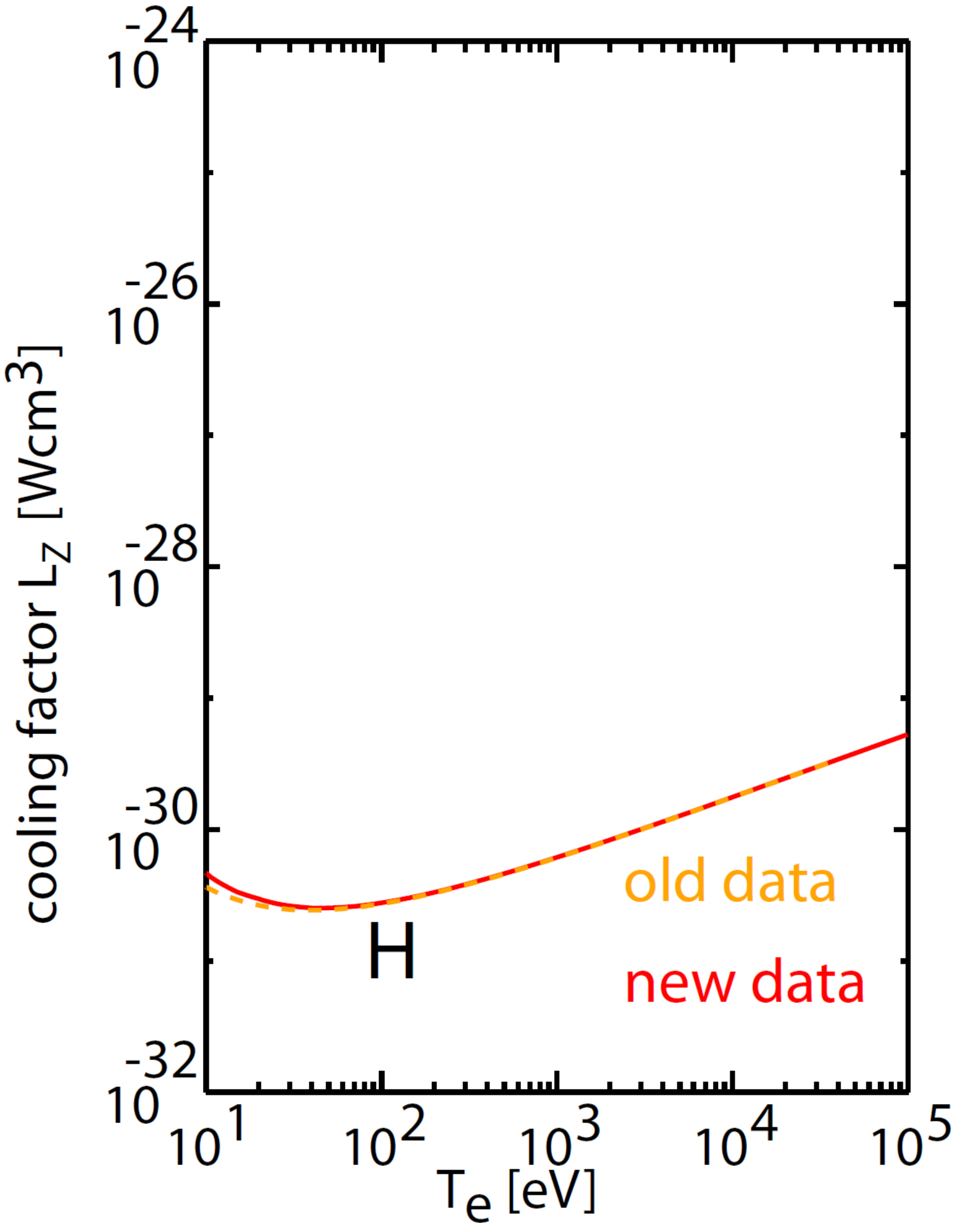
Ionization Equilibrium for New Data Credible (Kr)



Ionization Equilibrium for New Data Credible(Xe)

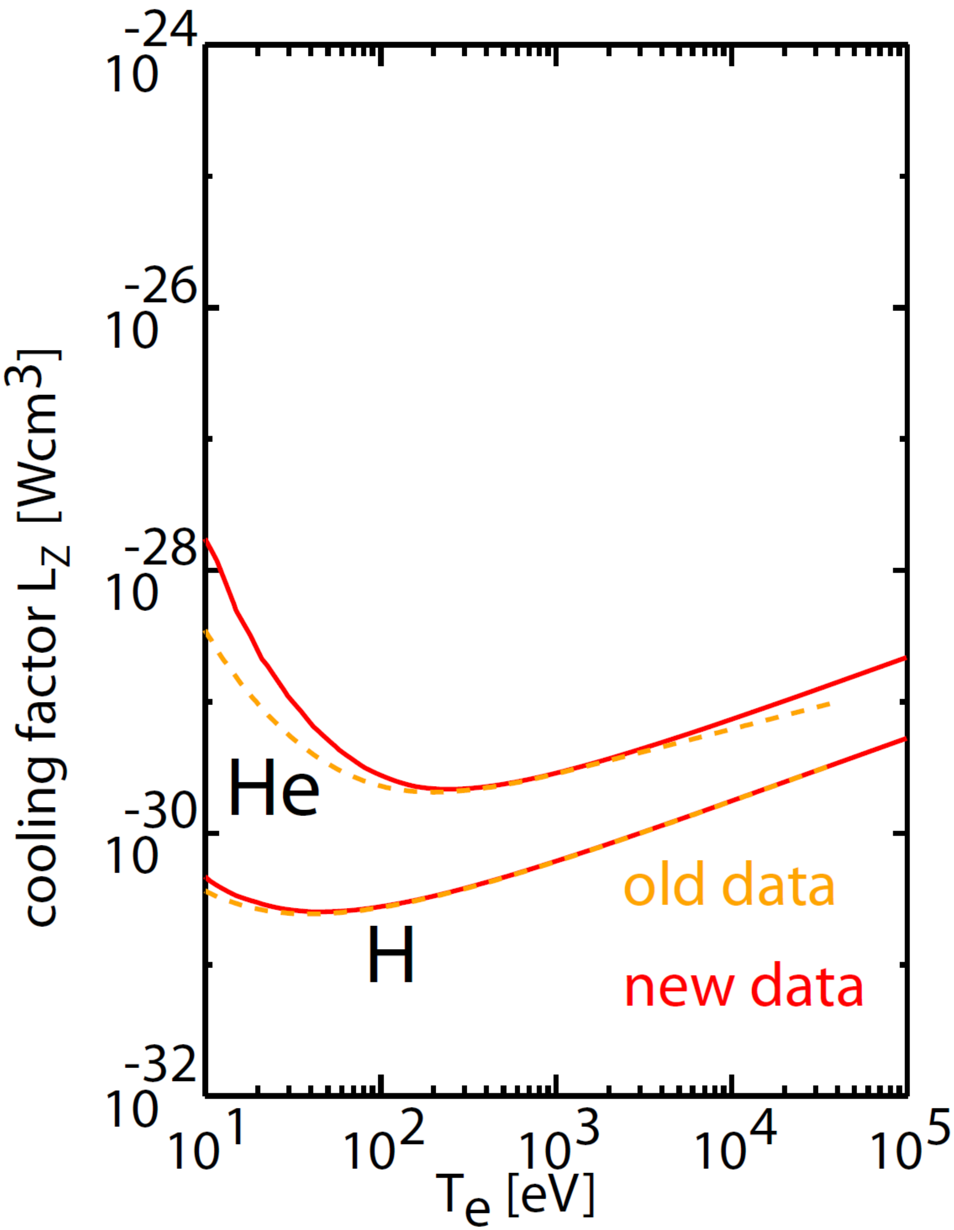


Old vs. New Data for H



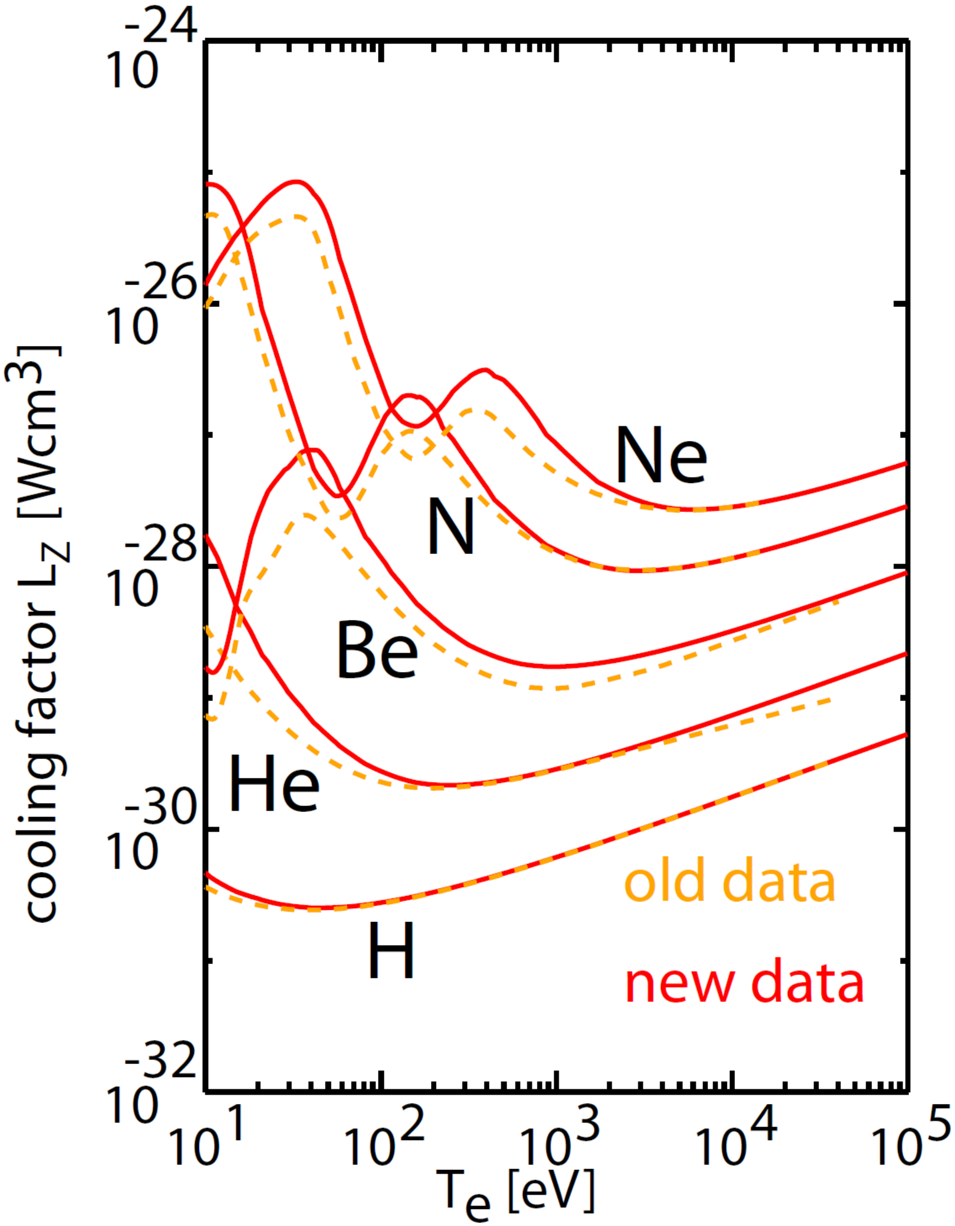
- Old data up to ~40keV available
- Continuum Radiation in agreement slight deviations for line radiation
- For low-Z, old data may be better for line rad. (or not?)

Old vs. New Data for He



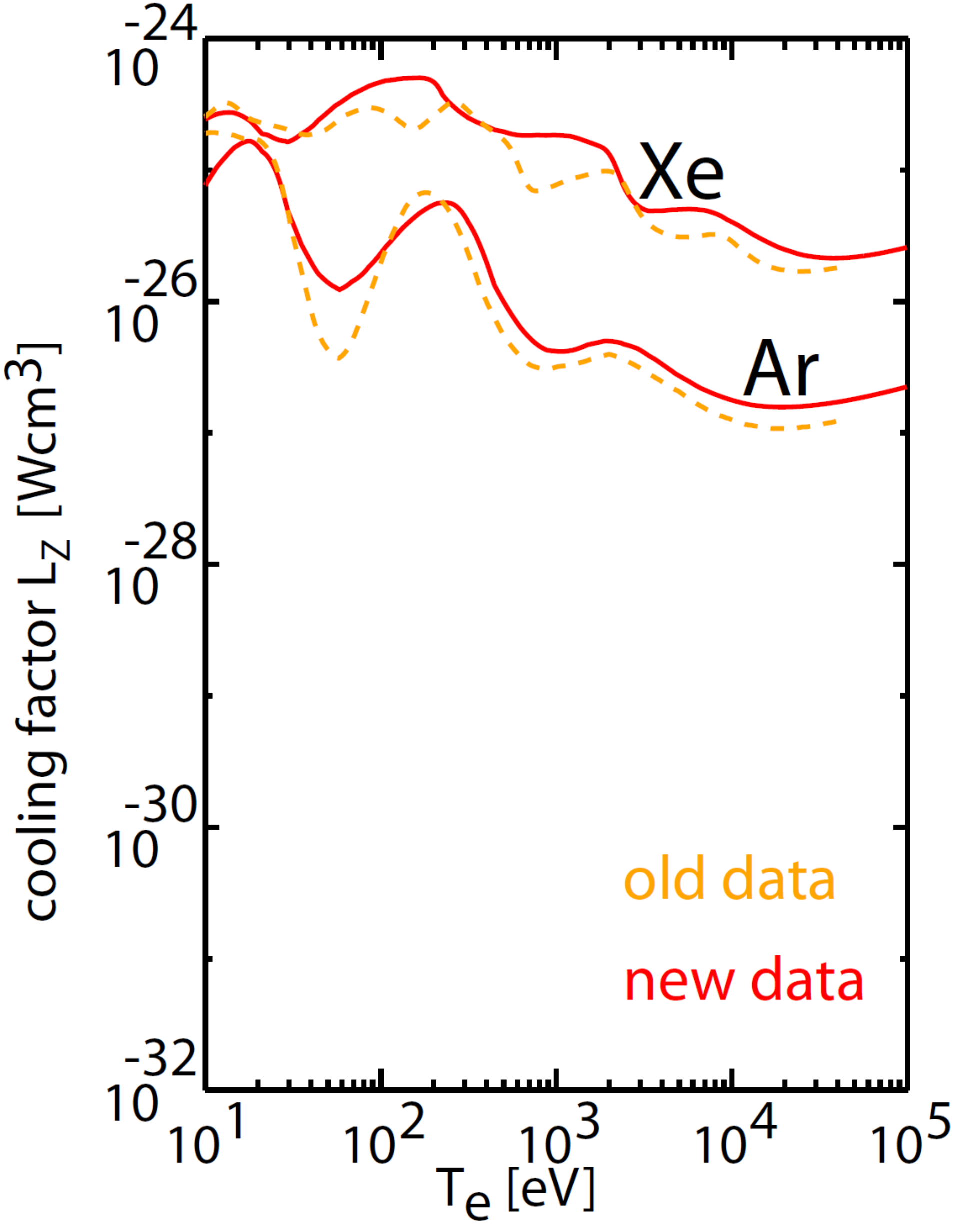
- Old data up to ~40keV available
- Continuum Radiation in agreement slight deviations for line radiation
- For low-Z, old data may be better for line rad. (or not?)
- Helium: Continuum rad. In old data has wrong T-dependence
  - extrapolation?

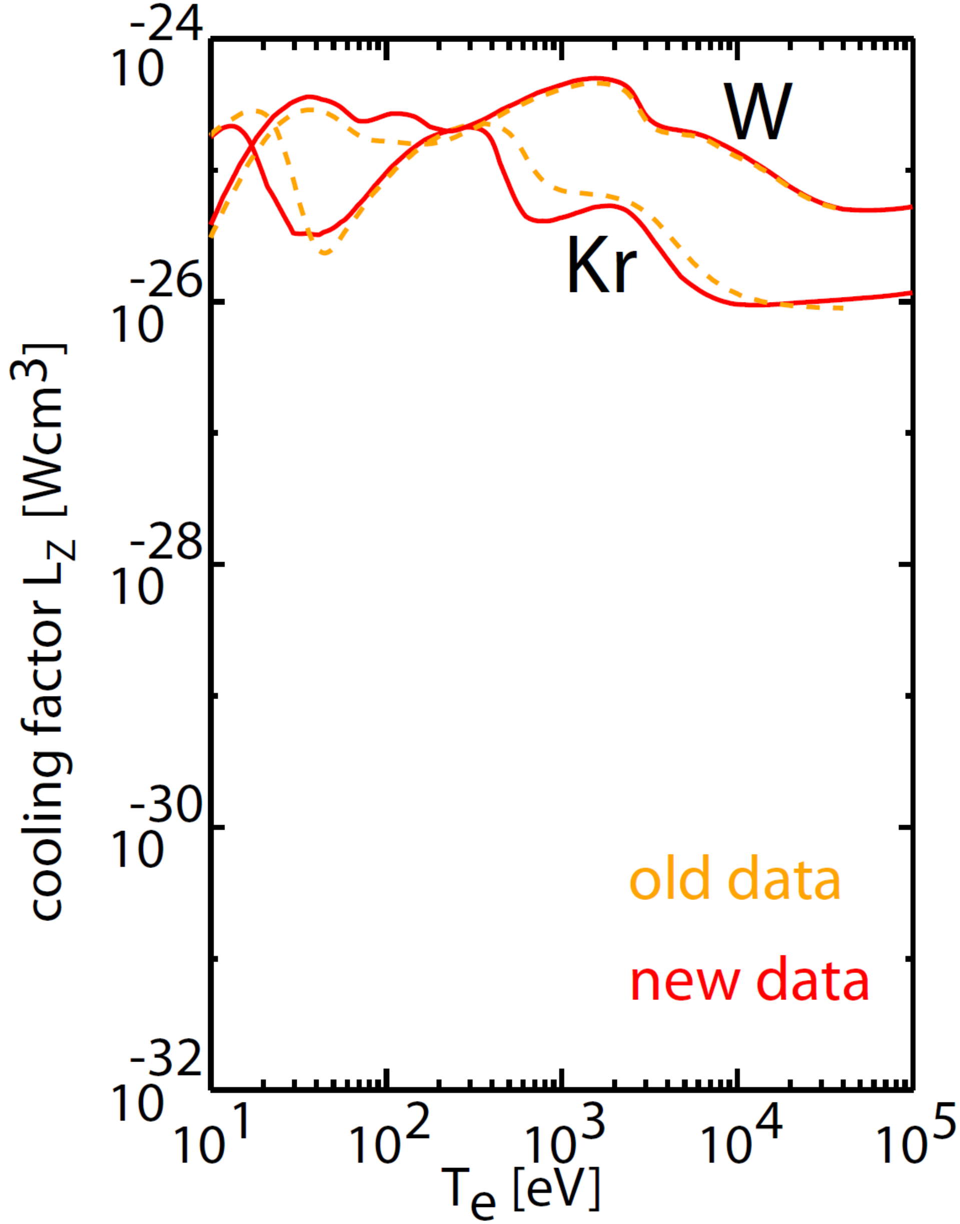
Old vs. New Data for H to Ne



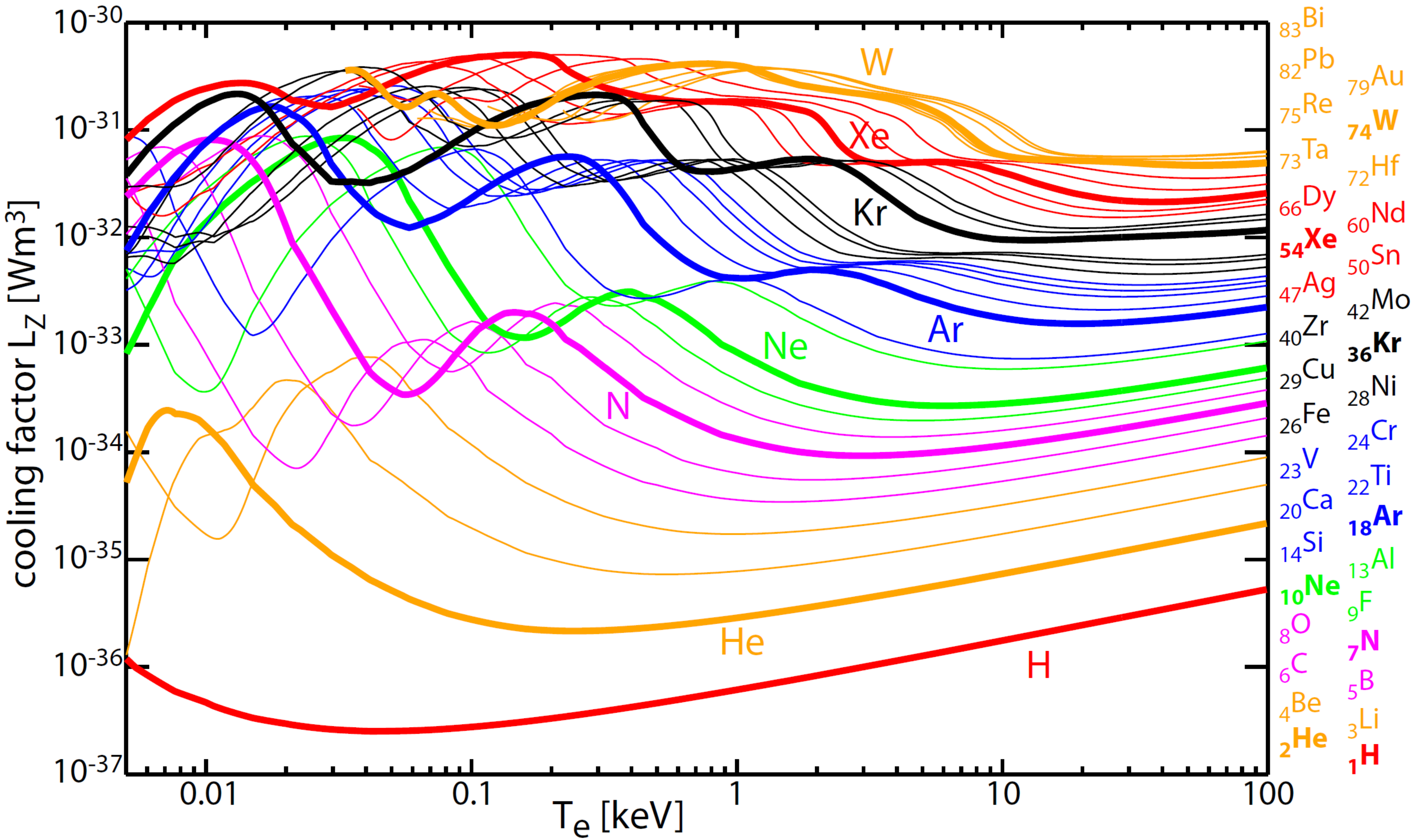
- Old data up to ~40keV available
- Continuum Radiation in agreement slight deviations for line radiation
- For low-Z, old data may be better for line rad. (or not?)
- Helium: Continuum rad. In old data has wrong T-dependence
  - extrapolation?

Old vs. New Data for Ar to W





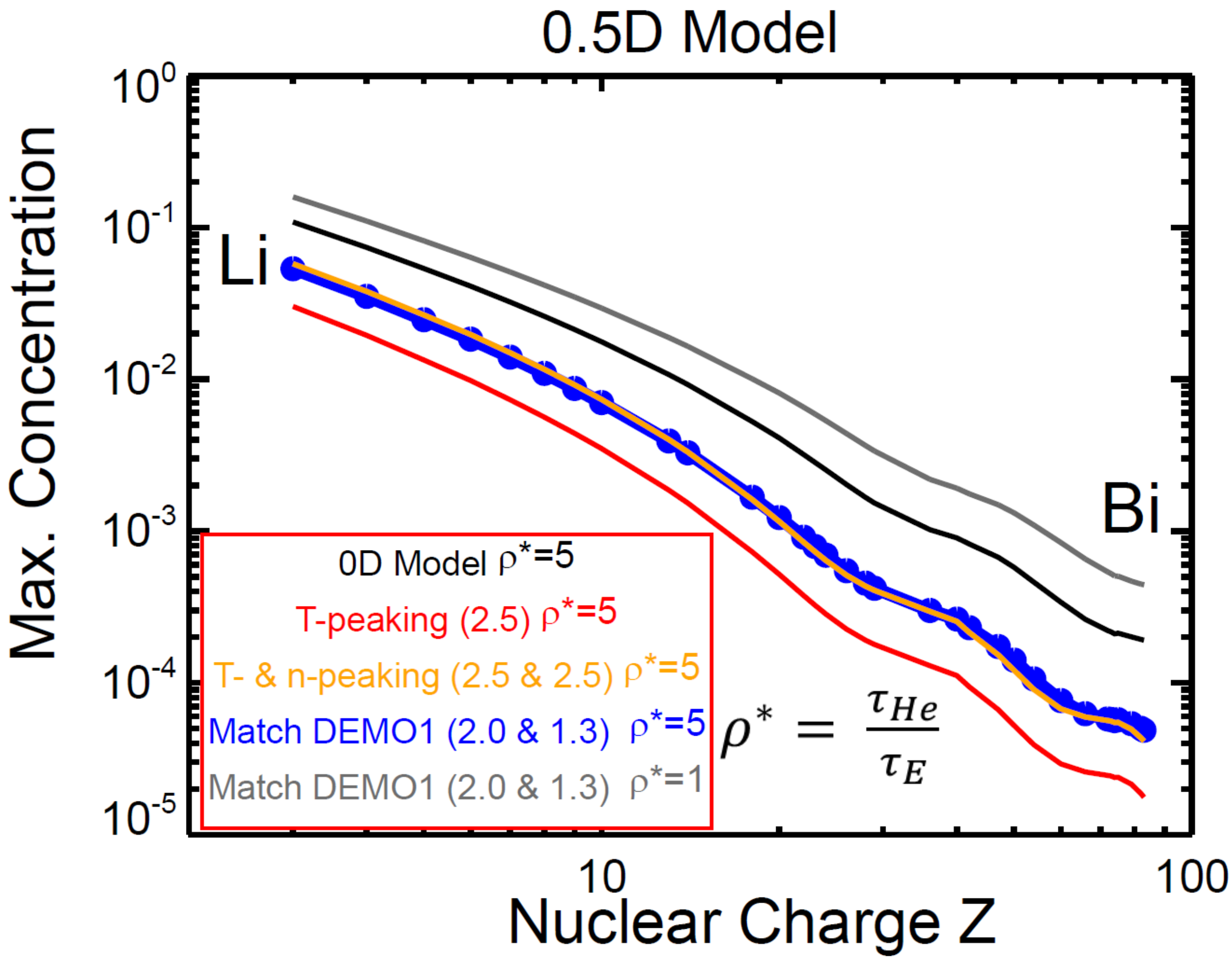
New Data Behaves Straight Forward



Overview

- Motivation
  - ⇨ Impurities in Fusion Plasmas
  - ⇨ Issues with existing data
- New Calculations using ADAS codes
  - ⇨ What quality has the new data?
  - ⇨ First tests with the new data
- First Applications of the new data
- Course of Action?

How Much of an Impurity is Tolerable in a Fusion Reactor?



- All reactor models require cooling factors to model impurity radiation
- Here, very simple 0.5D model is used to evaluate impurity limit for each element

Overview

- Motivation
  - ⇨ Impurities in Fusion Plasmas
  - ⇨ Issues with existing data
- New Calculations using ADAS codes
  - ⇨ What quality has the new data?
  - ⇨ First tests with the new data
- First Applications of the new data
- Course of Action?

Summary – Outlook

- Data for plasma emissions have been calculated for all ions of 35 elements
- The same procedure has been used for all elements, thus systematical trends in the data can be better observed
- The quality is good for baseline calculations
- For elements with Z higher than ~18 the new data is probably an improvement
- Include all data in ADAS? Dedicated benchmarking?