Max-Planck-Institut für Plasmaphysik

Humboldt-Universität zu Berlin

X-ray and EUV spectroscopy of highly-charged tungsten ions relevant to fusion plasmas

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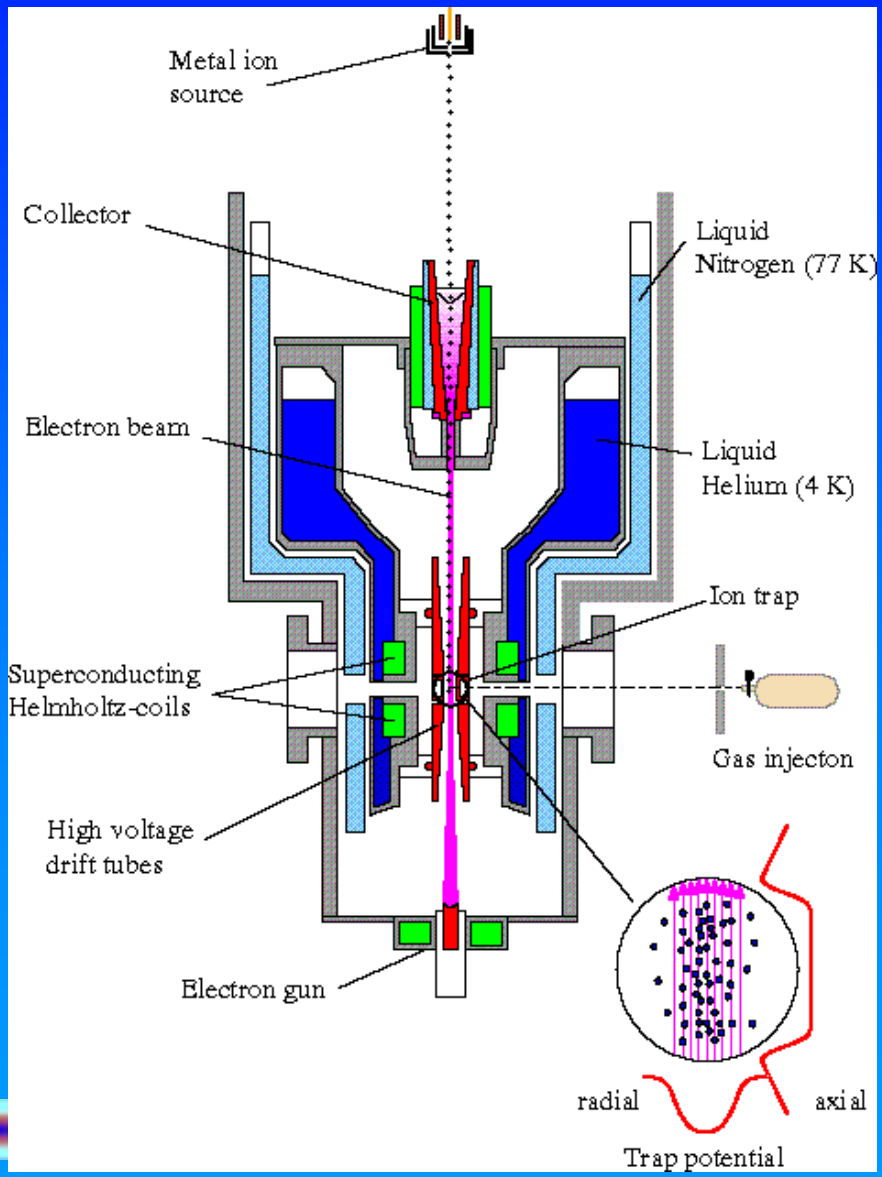
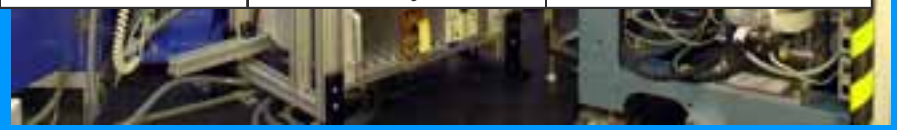
17491 Greifswald

14th ADAS Workshop 4-7 October 2009, Ringberg Castle, Tegernsee, Germany

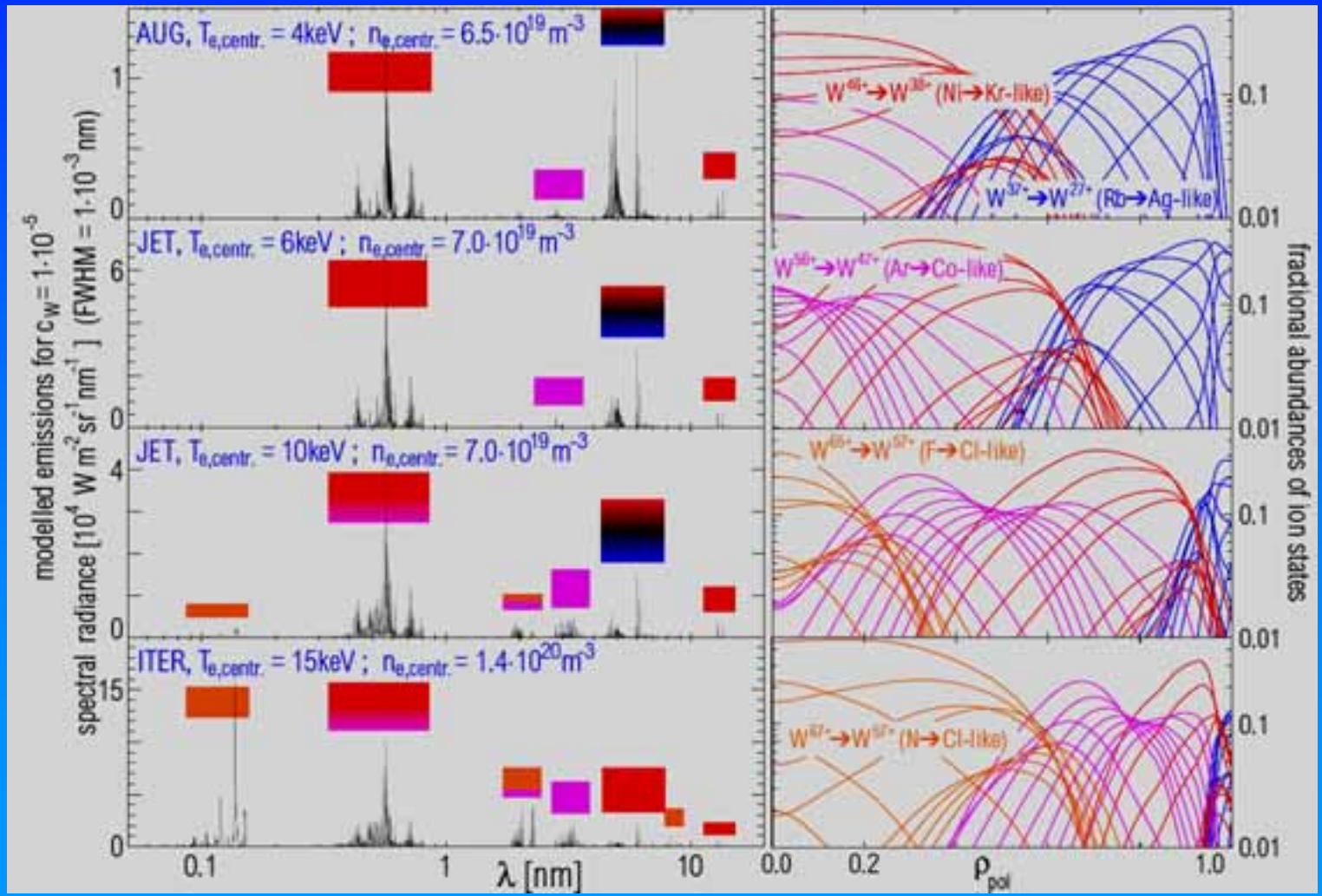
The Berlin Electron Beam Ion Trap



Electron beam	Energy	**30 000 eV**
	Energy spread	50 eV
	Sweep rate	1000 V/ms
	Current	150 mA
Focusing	Magnetic field	**3 Tesla**
	Beam radius	35 µm
	Current density	4000 A/cm^2
	Electron density	5•10^{12} cm^{-3}
Ionisation data	Highest charge state	W^{70+} (Be-like)
	Confinement time	20 s (Kr^{34+}, Mo^{40+})
	Trapped ions	50 000
	Ion density	10^8 cm^{-3}



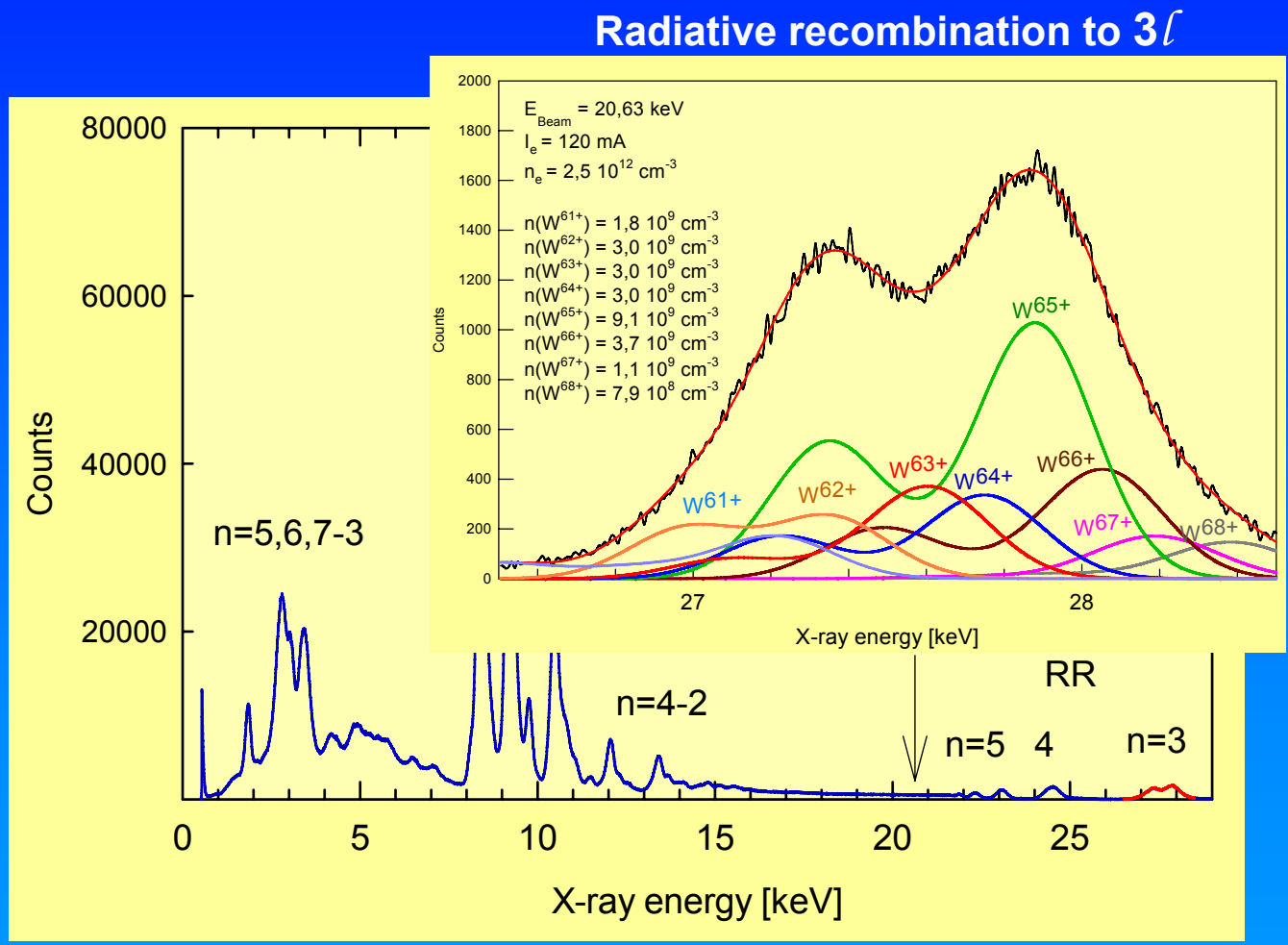
Tokamak prediction of tungsten emission



Modeled with ADAS

T. Pütterich, PhD thesis, IPP-report 10/29, 2006

Wide range x-ray spectra of tungsten

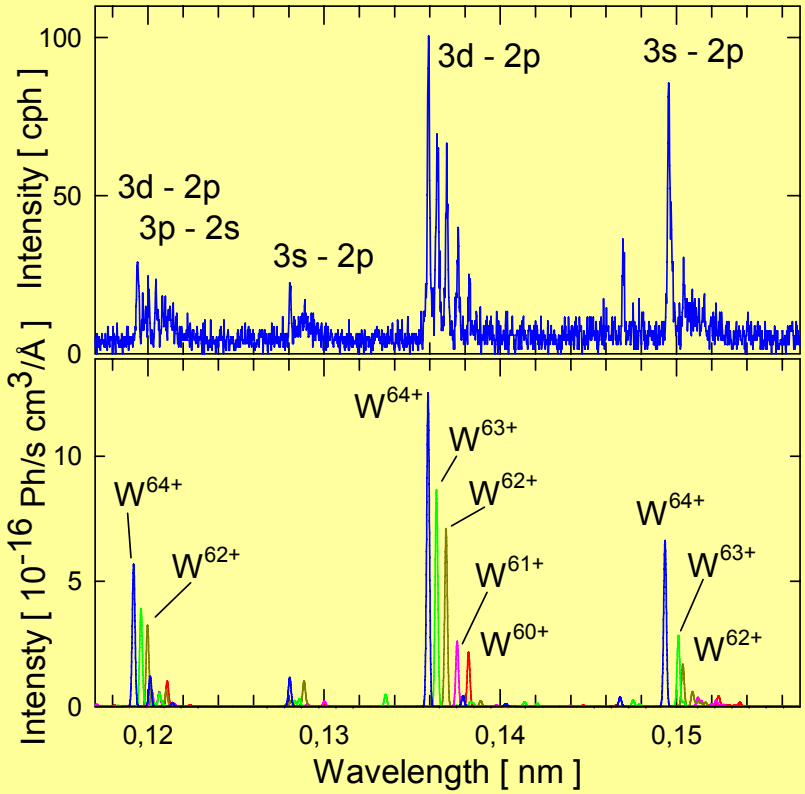


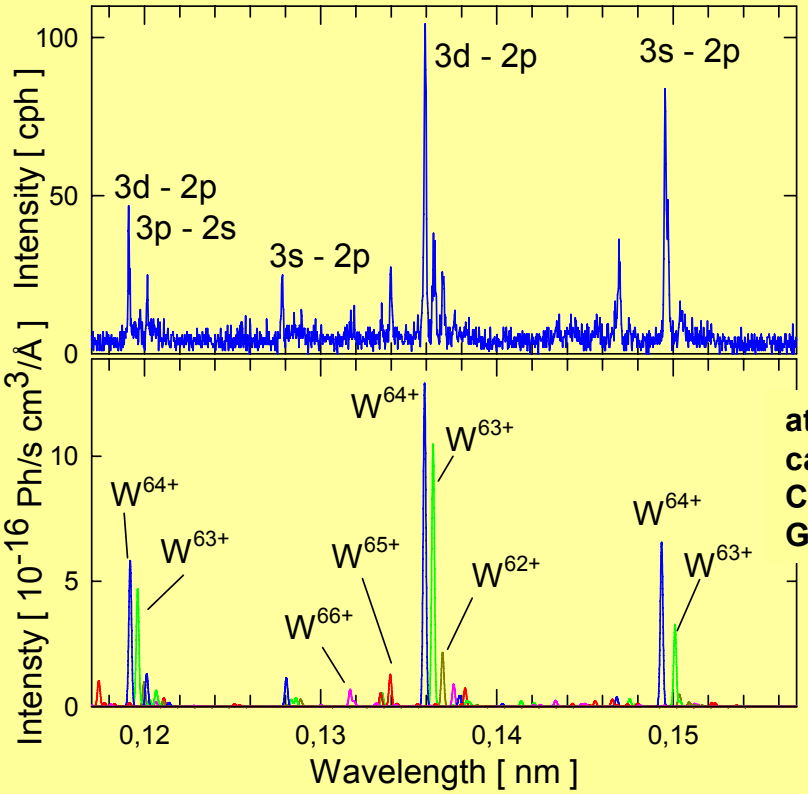
E_{beam} =20.63 keV

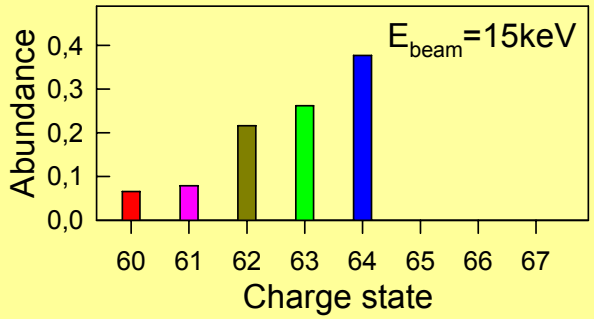
I_e = 120 mA

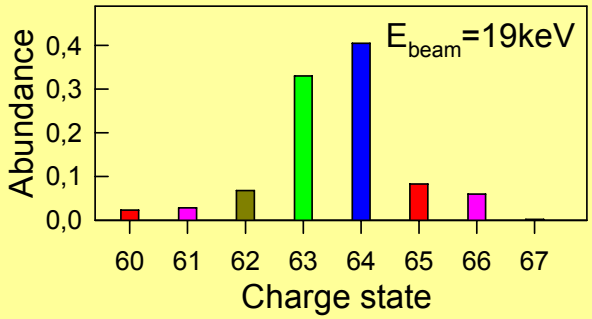
Tungsten density in EBIT

L-shell spectra of W^{q+} (q≤70)





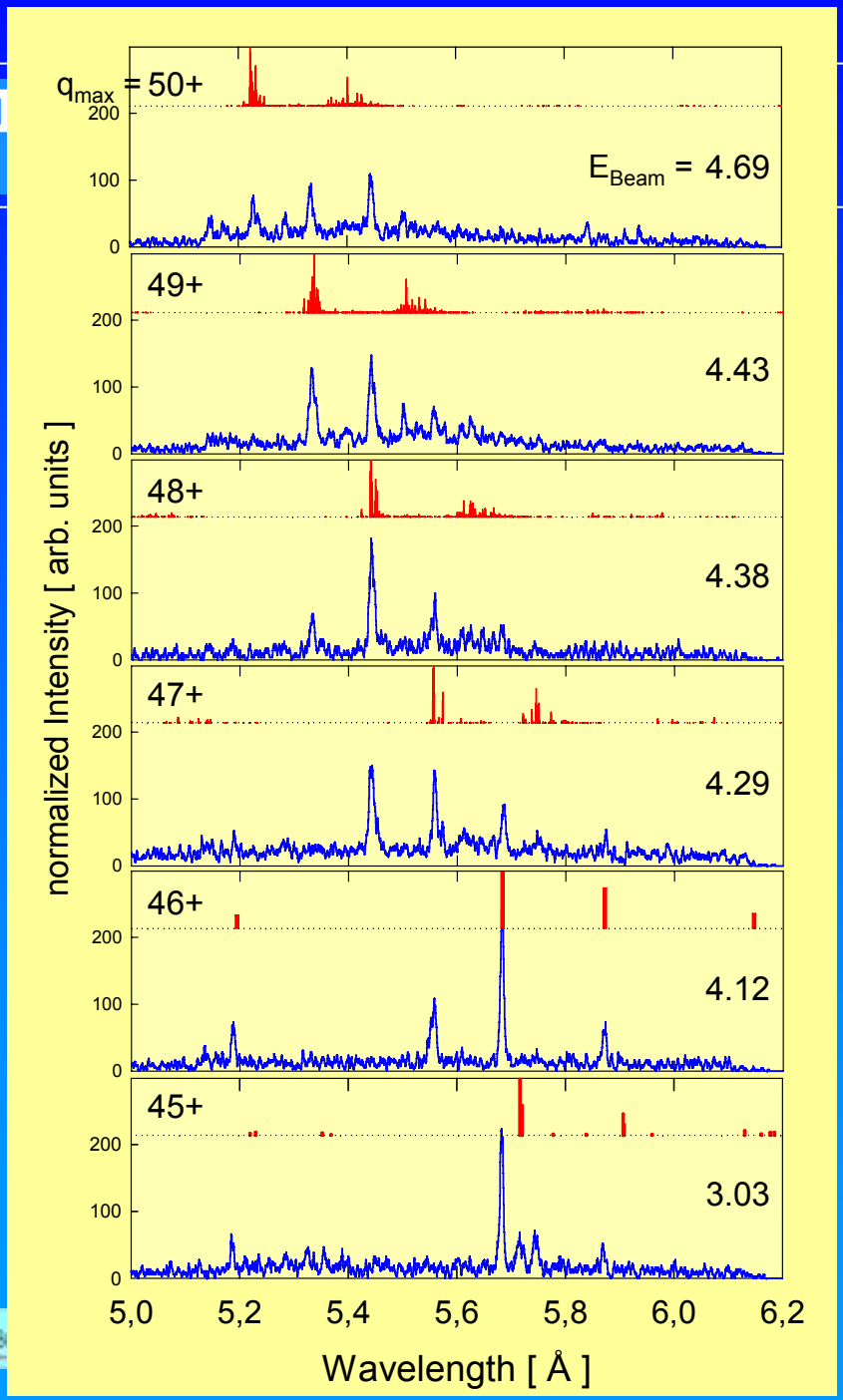


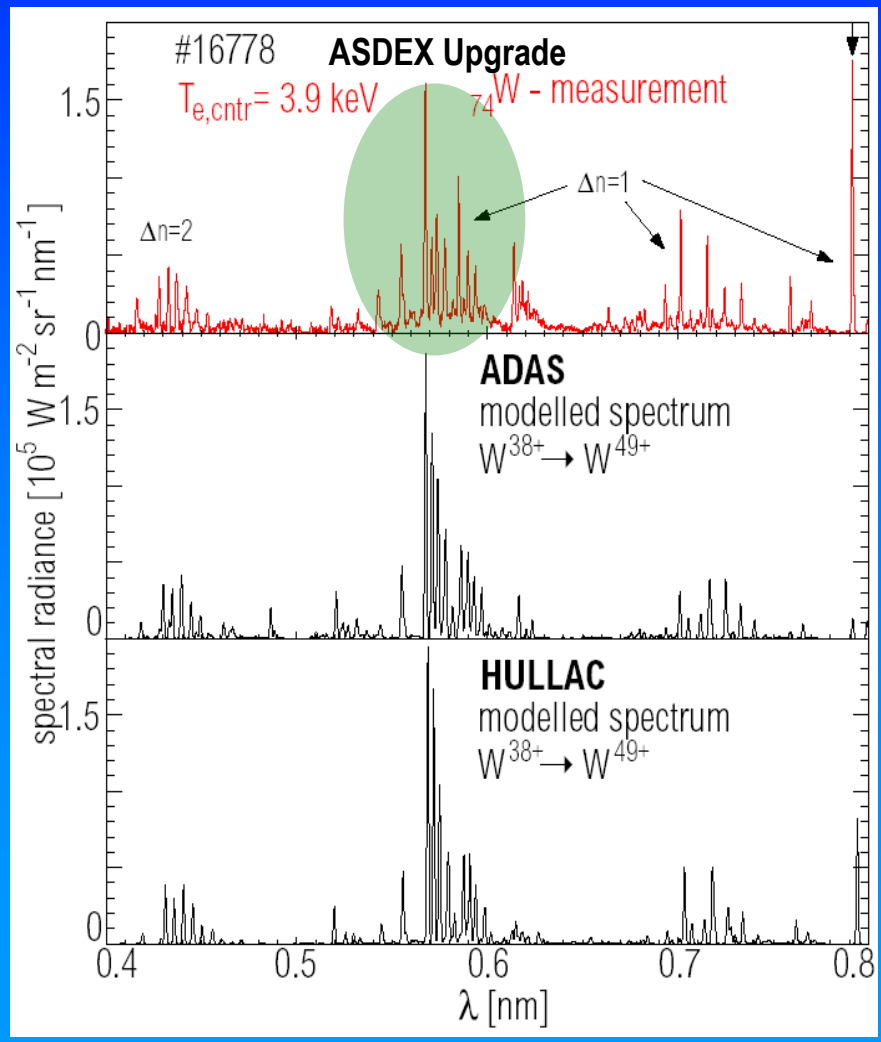


atomic structure calculations Cowan-code , GRASP + ADAS

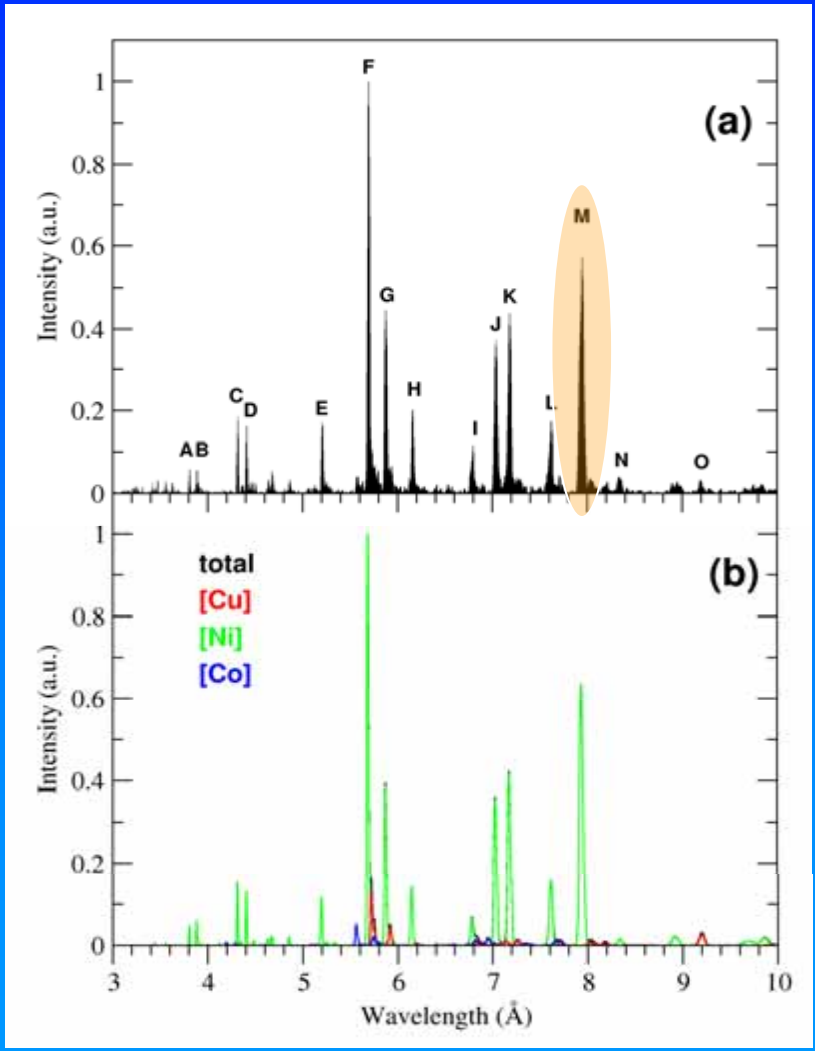
ate distribution ative ıation spectrum

M-shell spectra



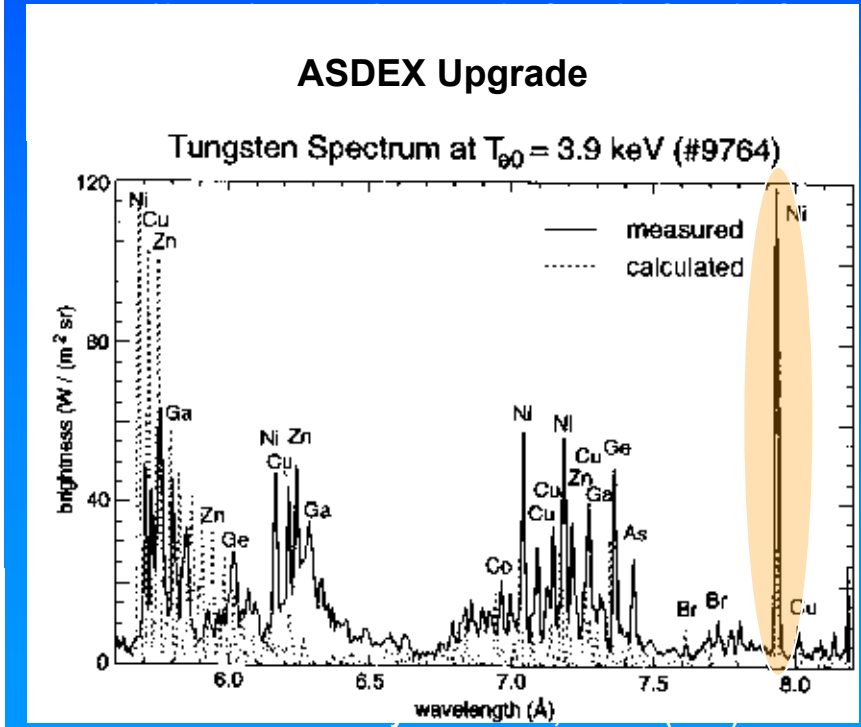


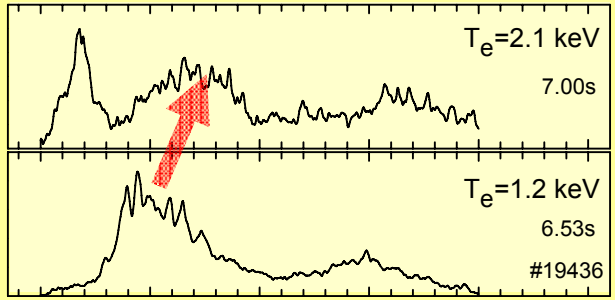
Broad-band high-resolution measurement



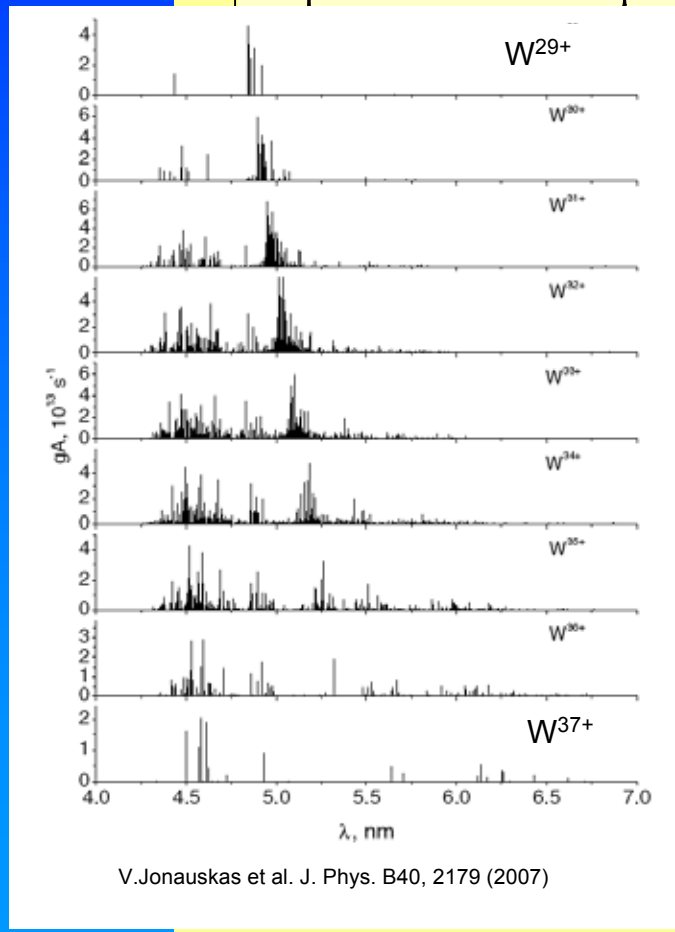
Microcalorimeter detector at NIST EBIT

E_{beam} =4.06 keV



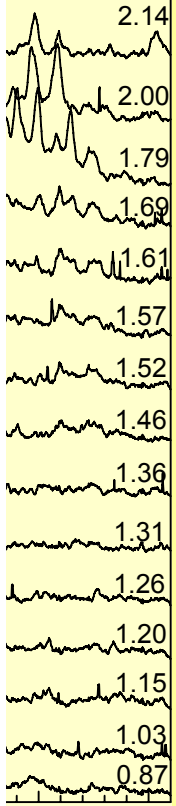


ASDEX Upgrade tokamak



V.Jonauskas et al. J. Phys. B40, 2179 (2007)

Electron-beam energy [keV]



high char

42
41
39
38
37
36
35
34
33
32
31
30
29+
28+
27+

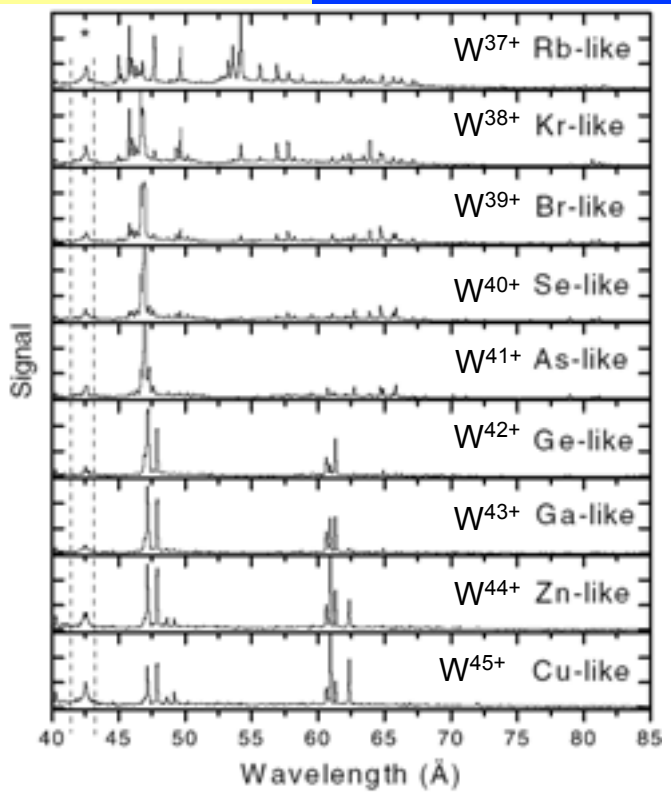
Ag-like W

Cd-like W^{26+}

In-like W^{25+}

45 50 55 60 65 70

Wavelength [Å]

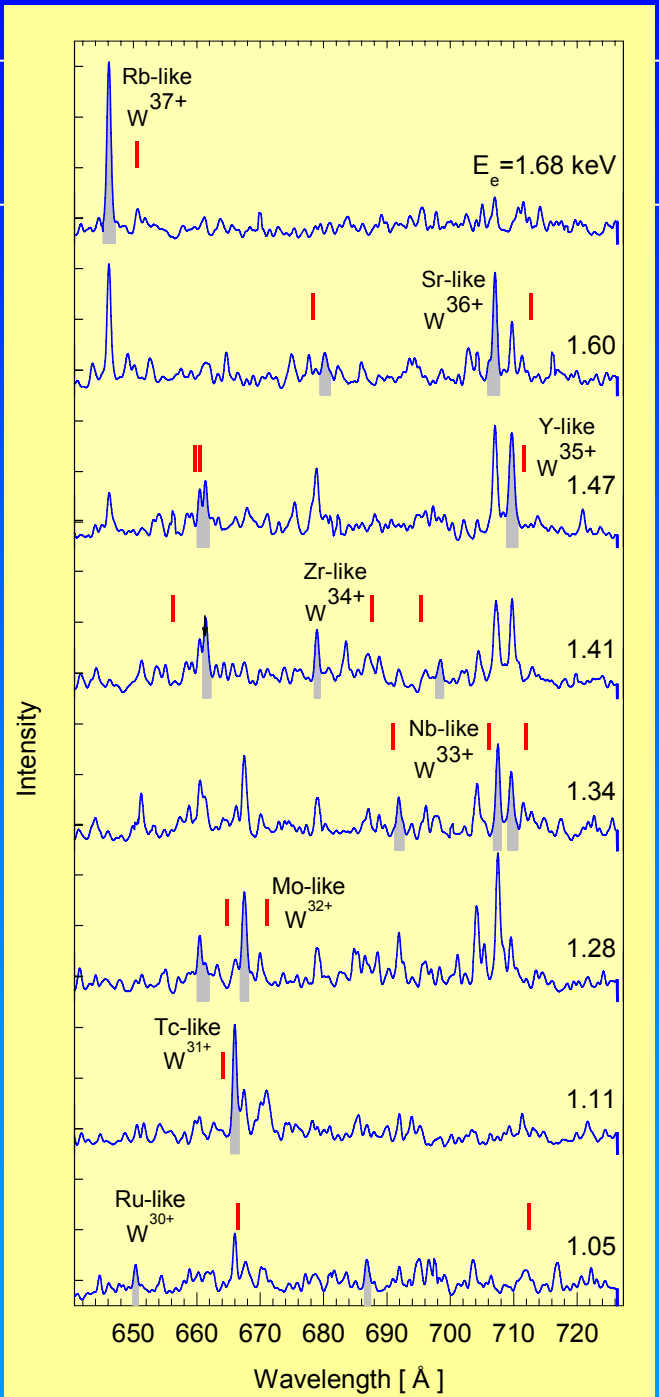


LLNL EBIT
SB Utter et al. Can. J. Phys. 80, 1503 (2002)

R. Radtke et al., PRA 64 (2001) 012720

T. Pütterich et al. J.Phys. B38 (2005) 3071

M1-lines

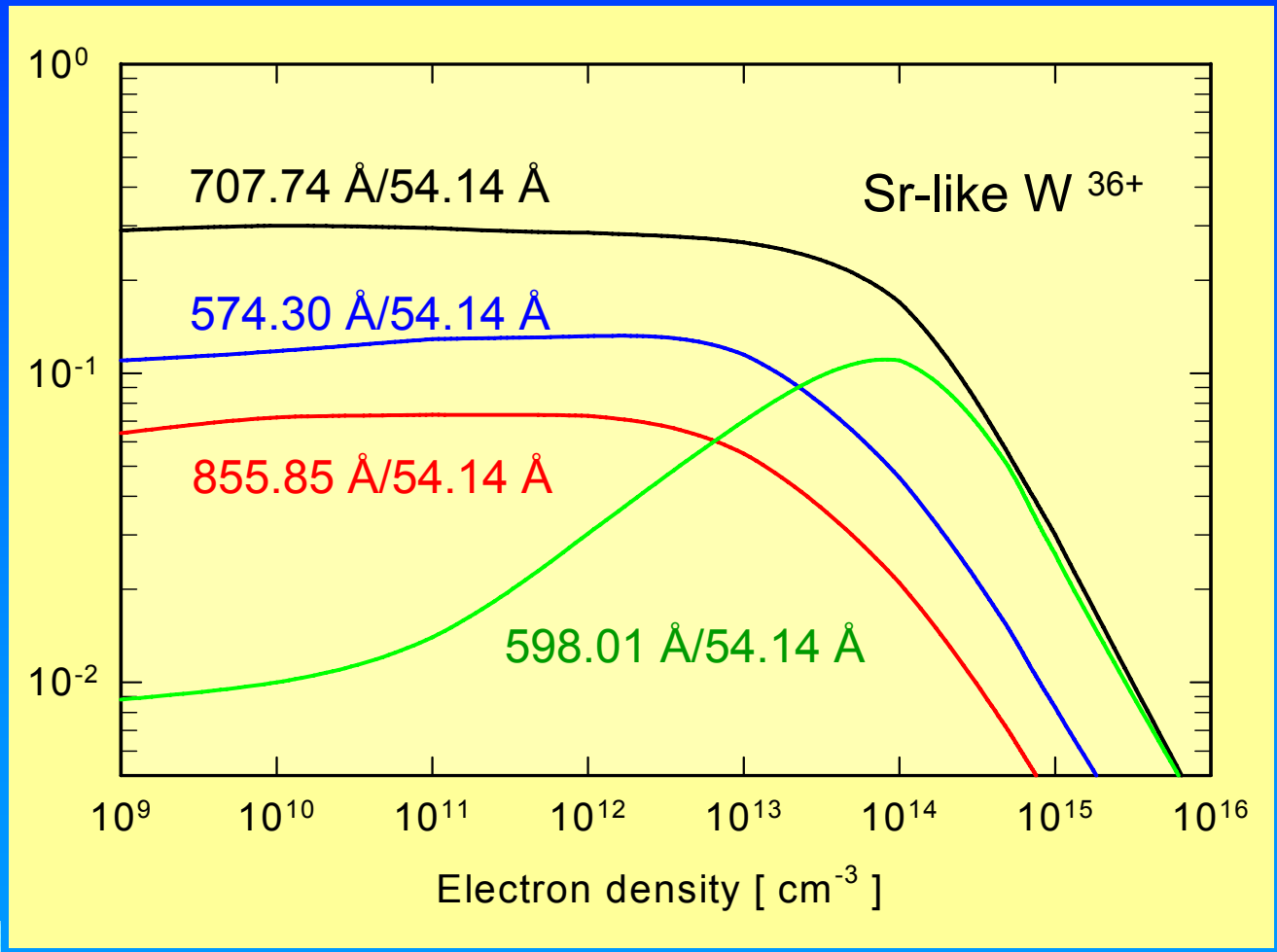


Ground-term fine structure transitions
$4p^5$ 4d – 4d, 4f

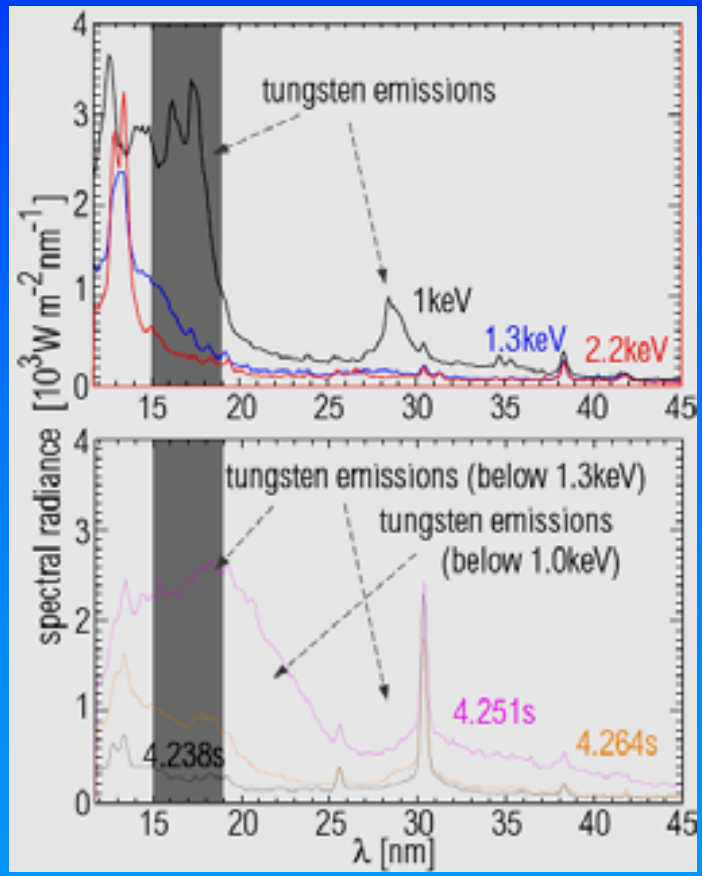
strong isolated lines
sensitive to electron collisional excitation

M1 to E1 line ratios

electron density diagnostic



N-shell transitions; lower q W emission



T. Pütterich, IPP-Garching

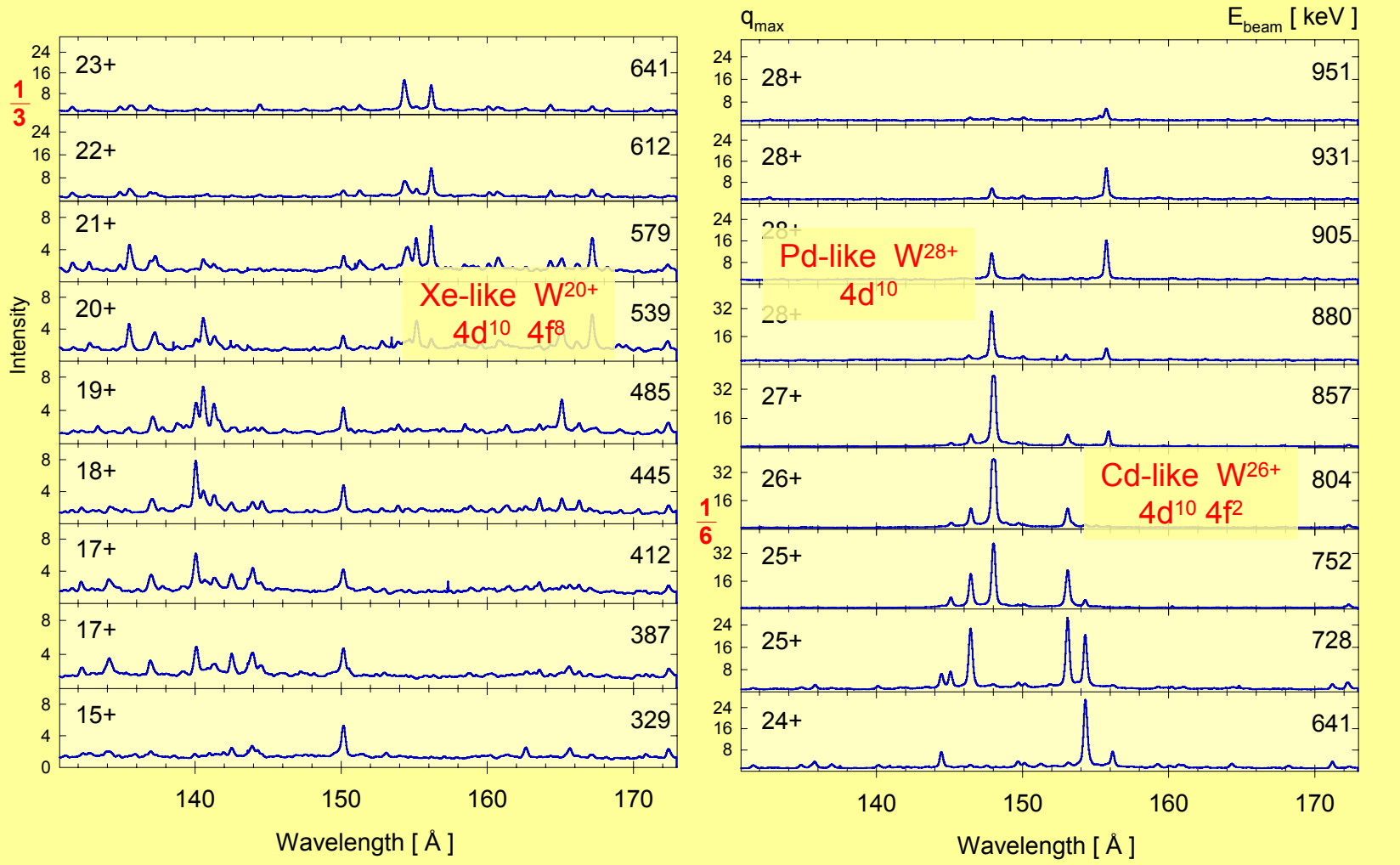
Impurity accumulation
in ASDEX Upgrade
at different electron temperatures

4f – 5l transitions

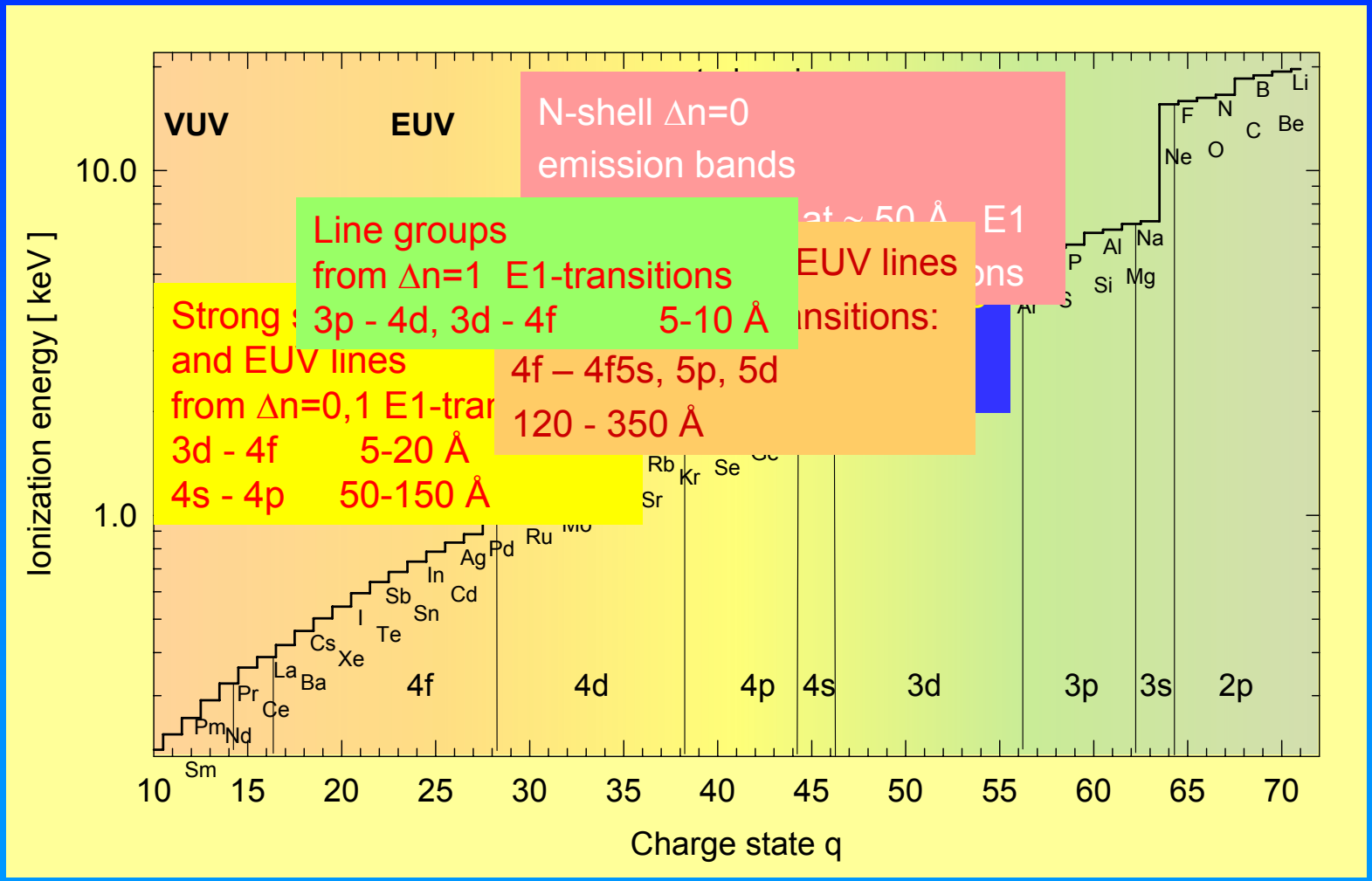
W laser blow off at 4.25s

- Atomic structure calculations challenging
- transport at the plasma edge

Pr to Pd-like W^{q+} emission



Summary: tungsten radiation



Ionization energies from A.E. Kramida, J. Reader, At.Data Nucl. Data Tables 92 (2006)457

Co workers

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