EUV spectra of lanthanide ions observed with an EBIT

電子ビームイオントラップによるランタノイドイオンのEUVスペクトル測定

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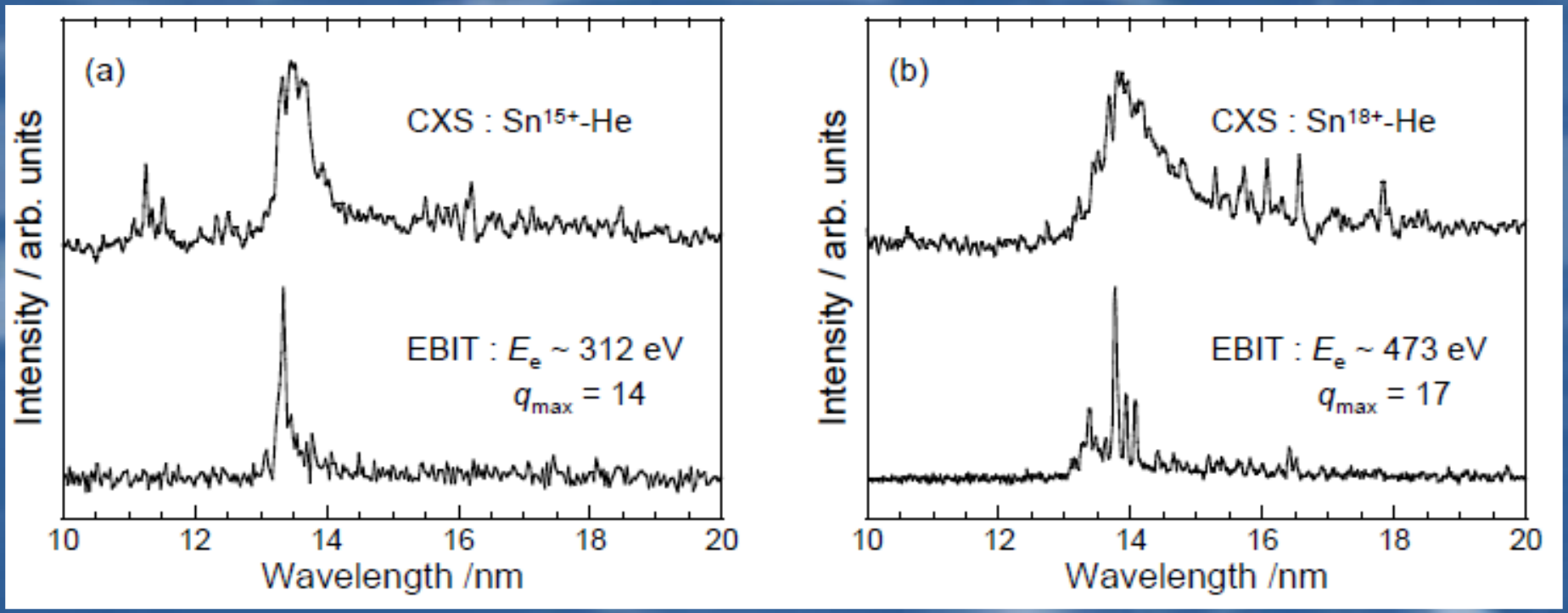
Our work on Sn spectra

14th International Conference on the Physics of Highly Charged Ions (HCI 2008) IOP Publishing
Journal of Physics: Conference Series **163** (2009) 012071 doi:10.1088/1742-6596/163/1/012071

Complementary spectroscopy of tin ions using ion and electron beams

H Ohashi[1], S Suda[1], H Tanuma[1], S Fujioka[2], H Nishimura[2], K Nishihara[2], T Kai[3], A Sasaki[3], H A Sakaue[4], N Nakamura[5] and S Ohtani[5]



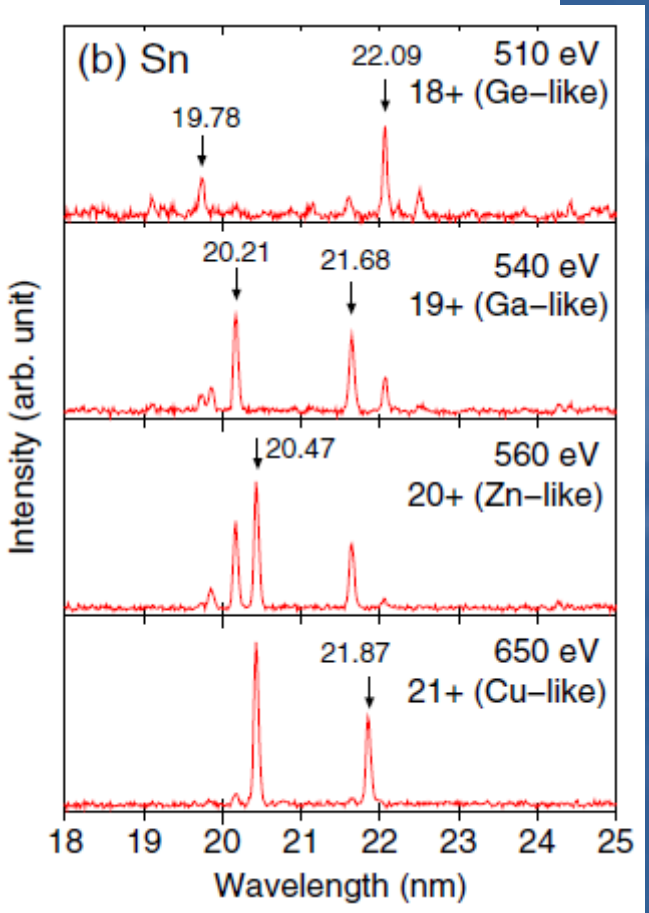
Our work on Sn spectra

IOP PUBLISHING PHYSICA SCRIPTA
Phys. Scr. T144 (2011) 014031 (3pp) doi:10.1088/0031-8949/2011/T144/014031

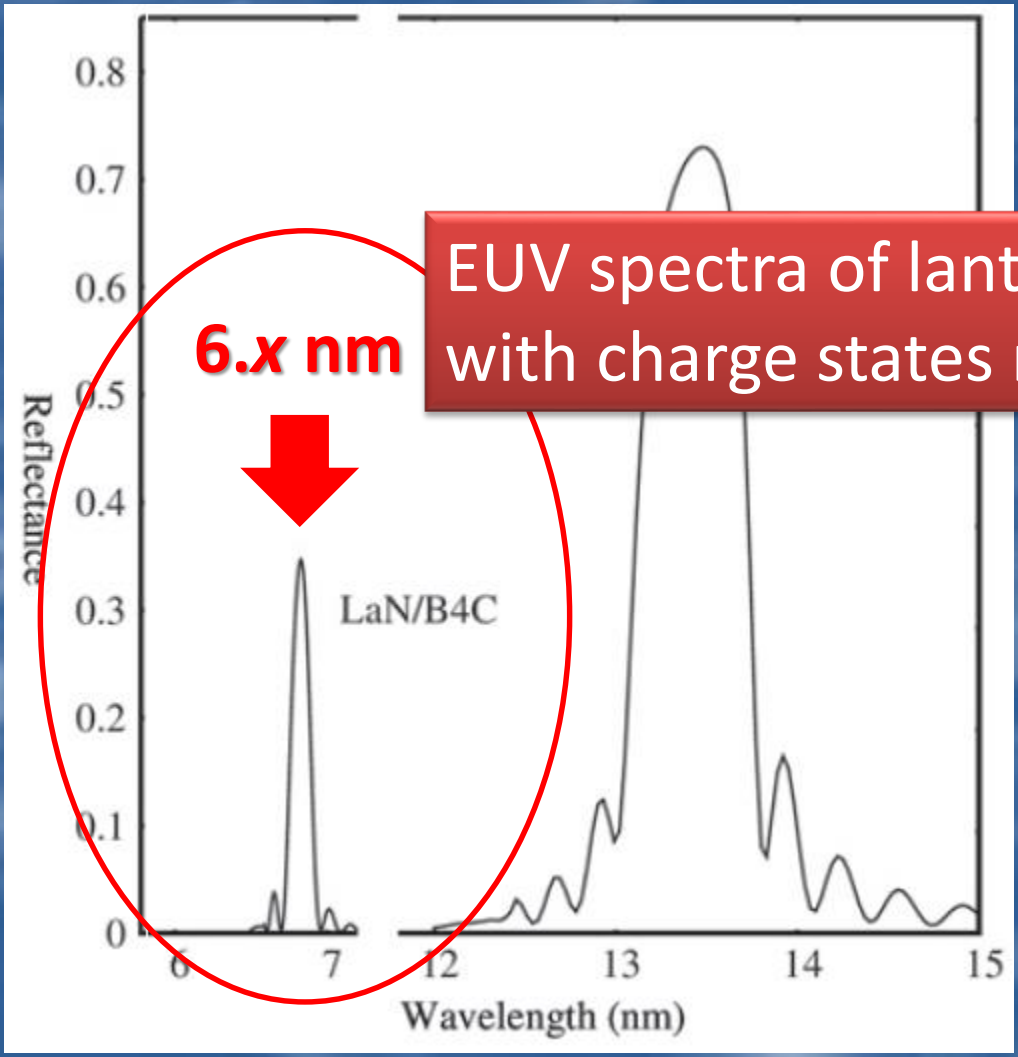
EUV spectroscopy of highly charged ions with high- and low-energy EBITs

Junji Yatsurugi[1], Etsushi Watanabe[1], Hayato Ohashi[1], Hiroyuki A Sakaue[2] and Nobuyuki Nakamura[1]

Ion	Transition	Present	[14, 15]
Sn^{18+}	$4s^2 4p_{1/2} 4p_{3/2}[2]–4s4p_{1/2}(1)4p_{3/2}^2[1]$	19.78	
	$4s^2 4p_{1/2}^2[0]–4s4p_{1/2}^2 4p_{3/2}[1]$	22.09	
Sn^{19+}	$4s^2 4p_{1/2}[1/2]–[4s4p_{1/2}(1)]4p_{3/2}[1/2]$	20.21	
	$4s^2 4p_{1/2}[1/2]–[4s4p_{1/2}(1)]4p_{3/2}[3/2]$	21.68	
Sn^{20+}	$4s^2\,{}^1S_0–4s4p\,{}^1P_1$	20.47	20.4798(10)
Sn^{21+}	$4s\,{}^2S_{1/2}–4p\,{}^2P_{3/2}$	21.87	21.8978(10)



Introduction



EUV spectra of lanthanide ions with charge states near Pd-like.

O'Sullivan et al.
Phys. Scr. 90, 054002

Electron beam ion trap (EBIT)

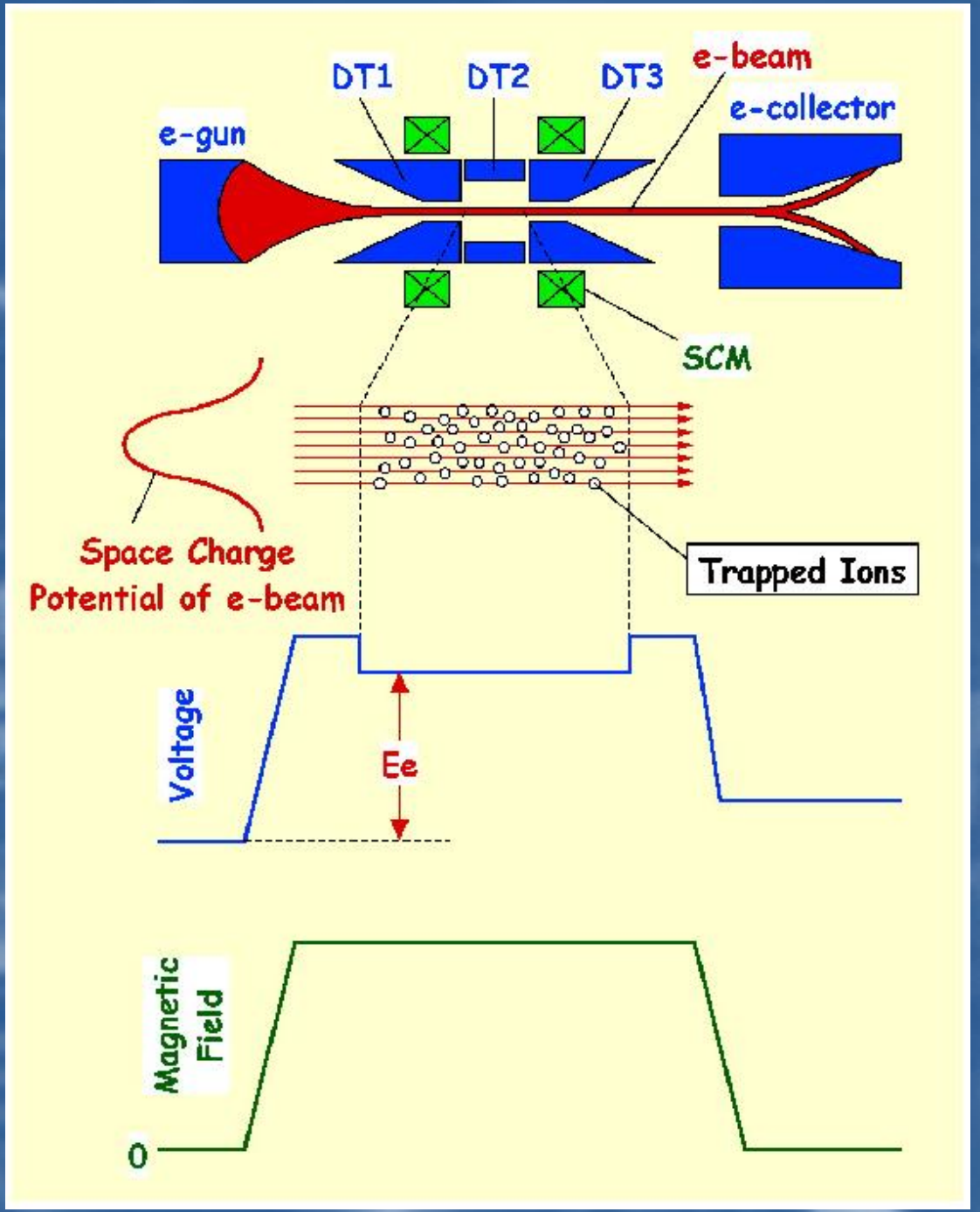
A Penning-like ion trap
+ a high energy,
high density e-beam.

Axial trap: well-like potential
Radial trap:
Axial B-field produced by SCM
e-beam space charge

Highly charged ions are produced through successive ionization by the e-beam.

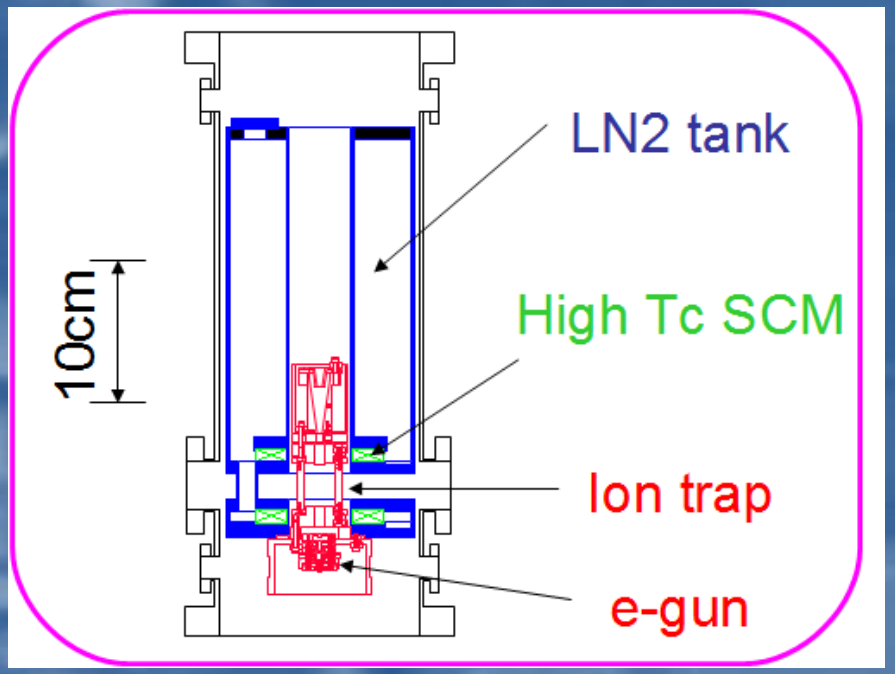
Electron energy limits the highest charge.

Emission from the trapped ions can be observed through the observation slits opened at the middle of the ion trap.



Compact EBIT (CoBIT)

Nakamura et al., Rev. Sci. Instrum. 79 (2008) 063104



Specifications

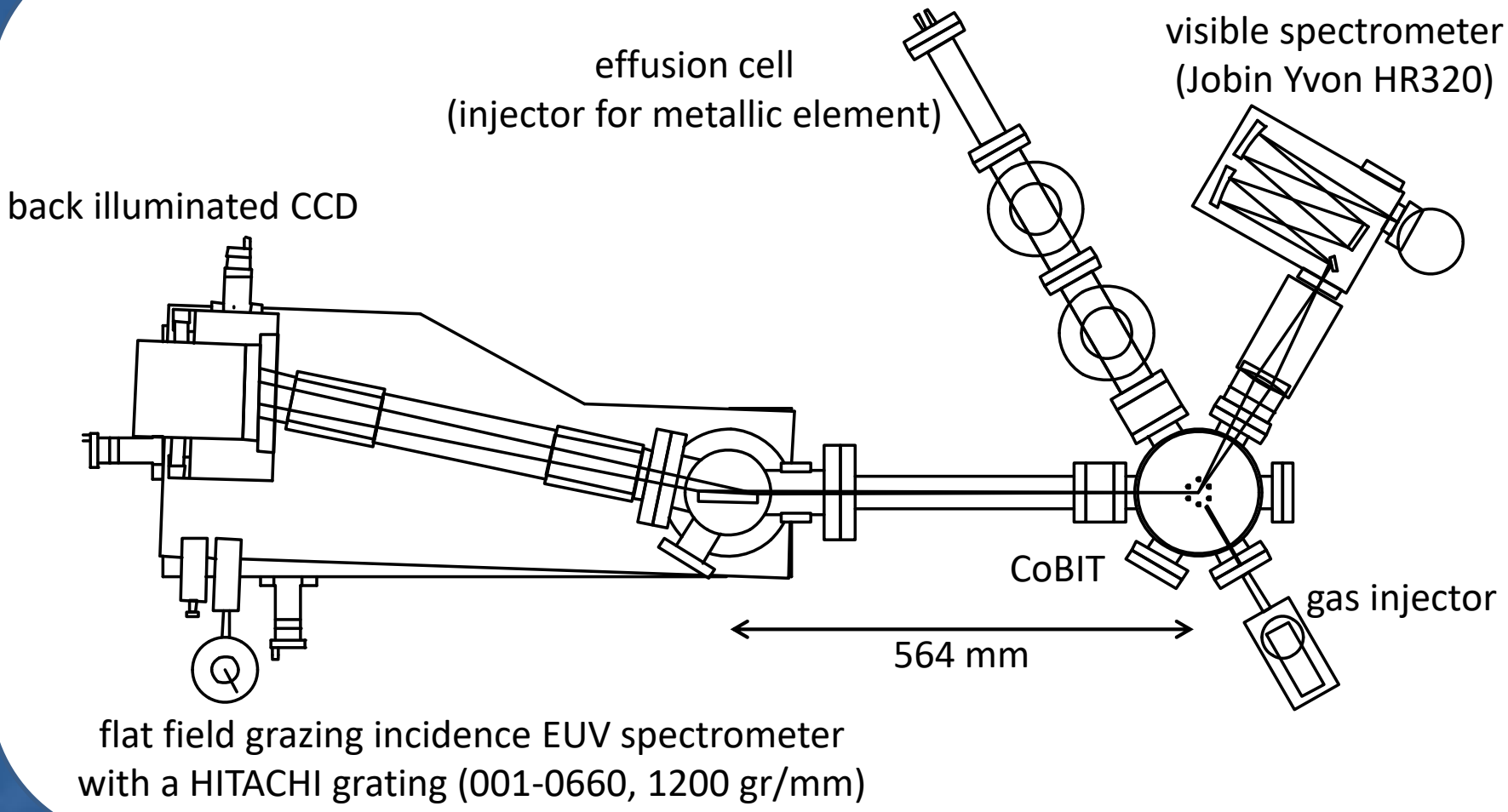
e-beam energy 0.1 – 2 keV

e-beam current 20 mA (max)

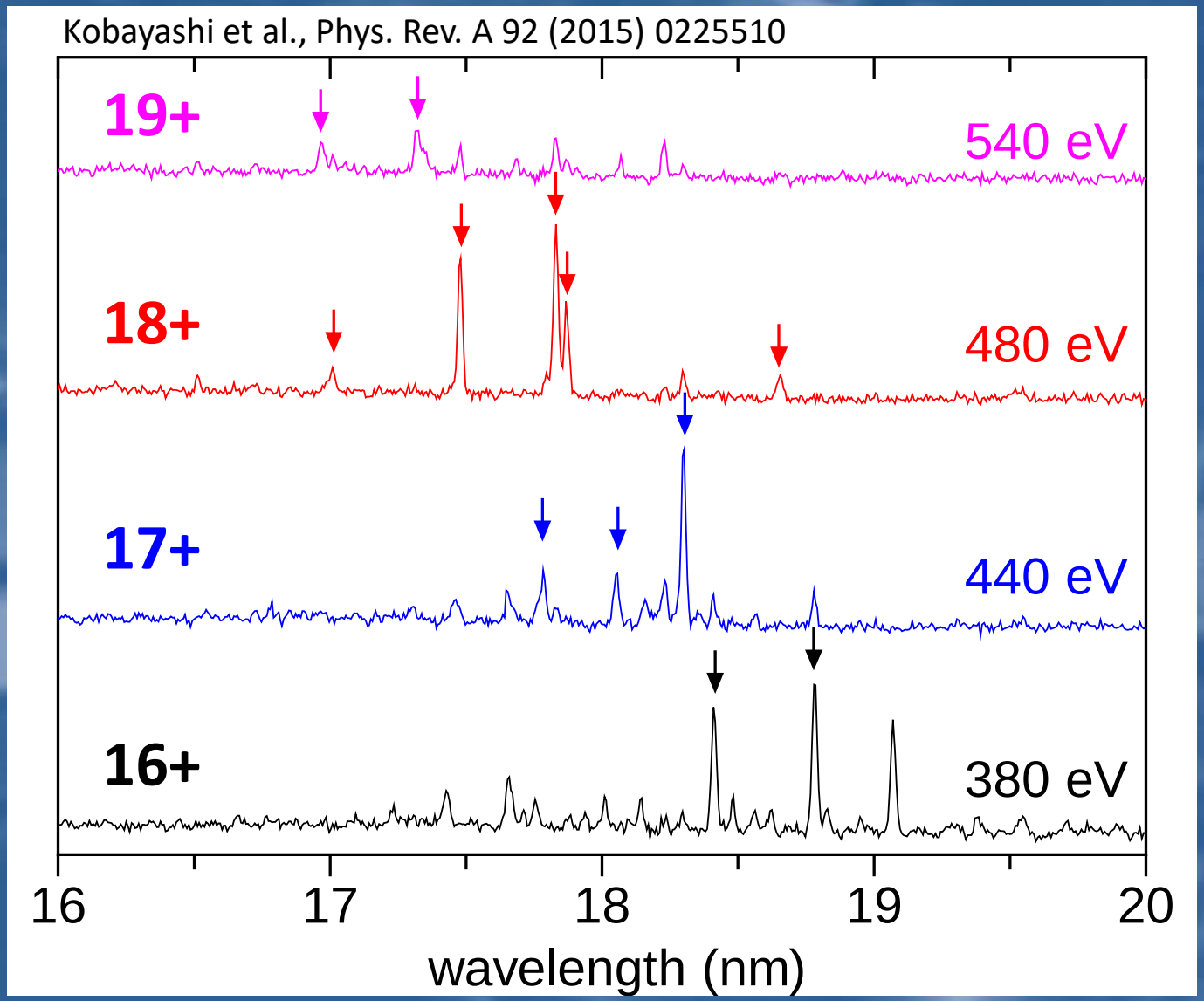
Magnetic field 0.2 T (max)

Temperature 77 K (High-Tc SCM)

Experimental setup



Electron energy dependence
- Typical spectra for Au -



I.P.

18+ → 19+
484 eV

17+ → 18+
457 eV

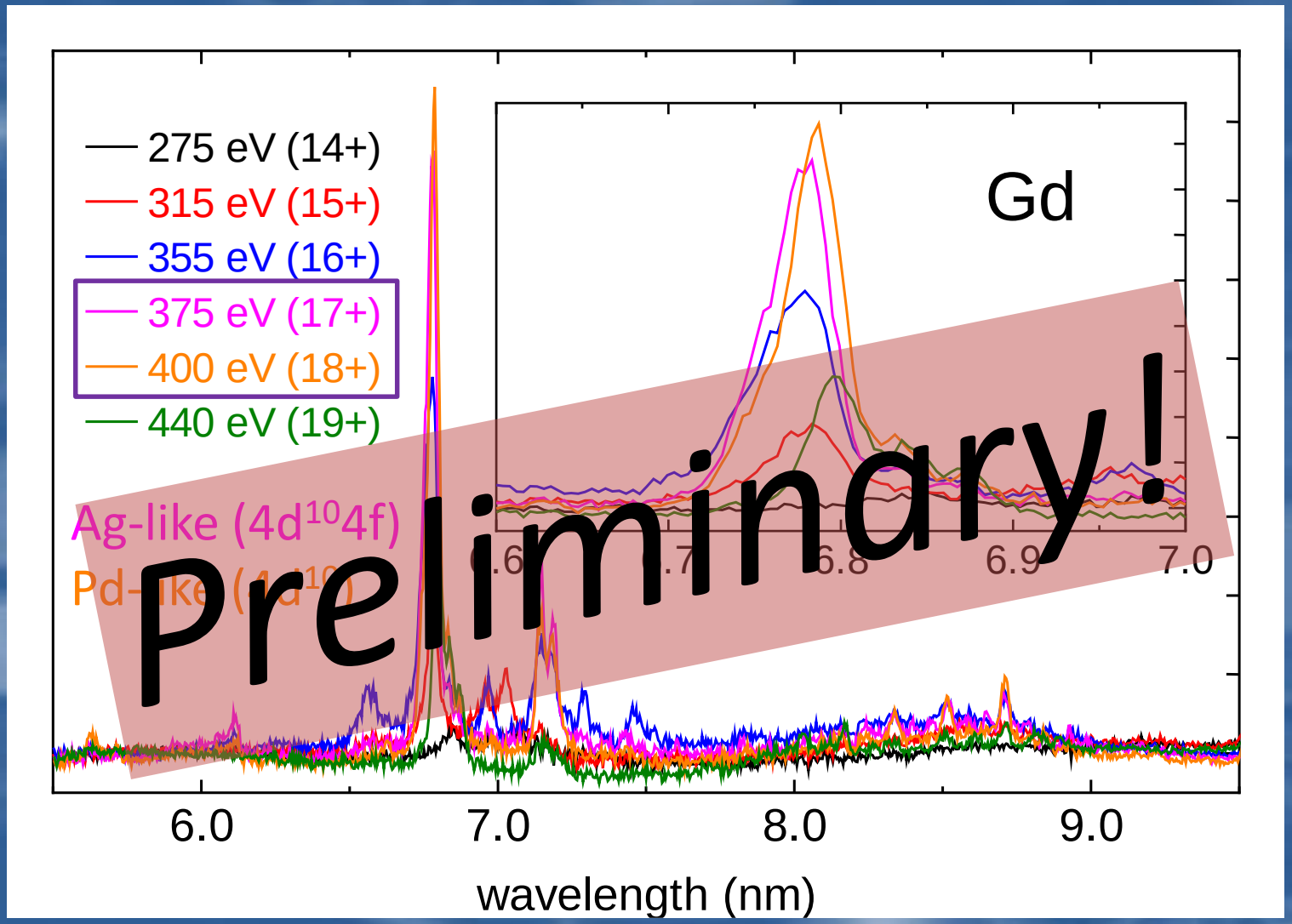
16+ → 17+
389 eV

15+ → 16+
364 eV

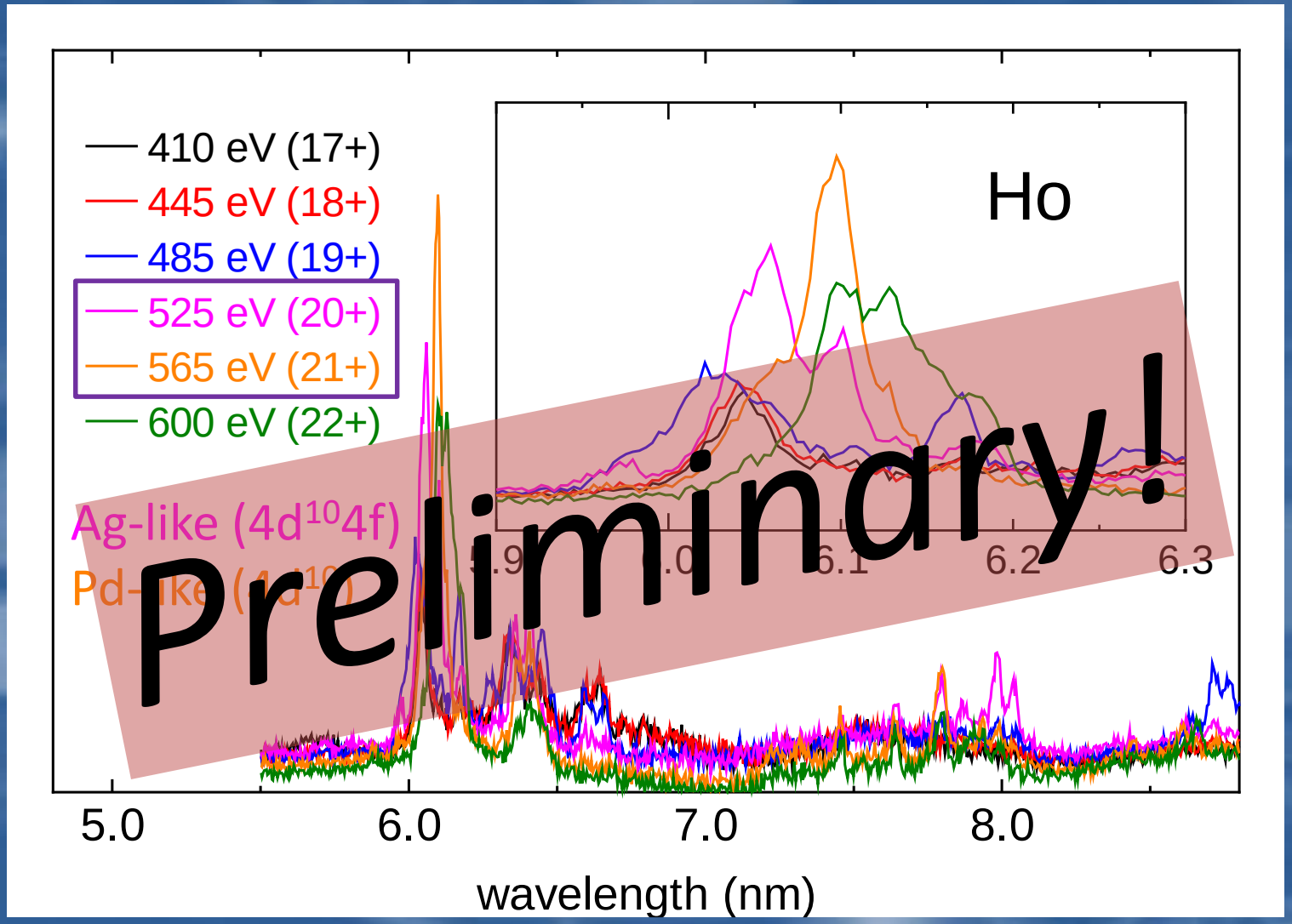
CoBIT spectroscopy

- Simple spectra
  - with a narrow charge distribution
  - dominated by transitions to the ground state
- Charge state that should be assigned for each emission line can be determined from electron energy dependence
- Good benchmark for models

EUV spectra of gadolinium (Z=64)



EUV spectra of holmium (Z=67)

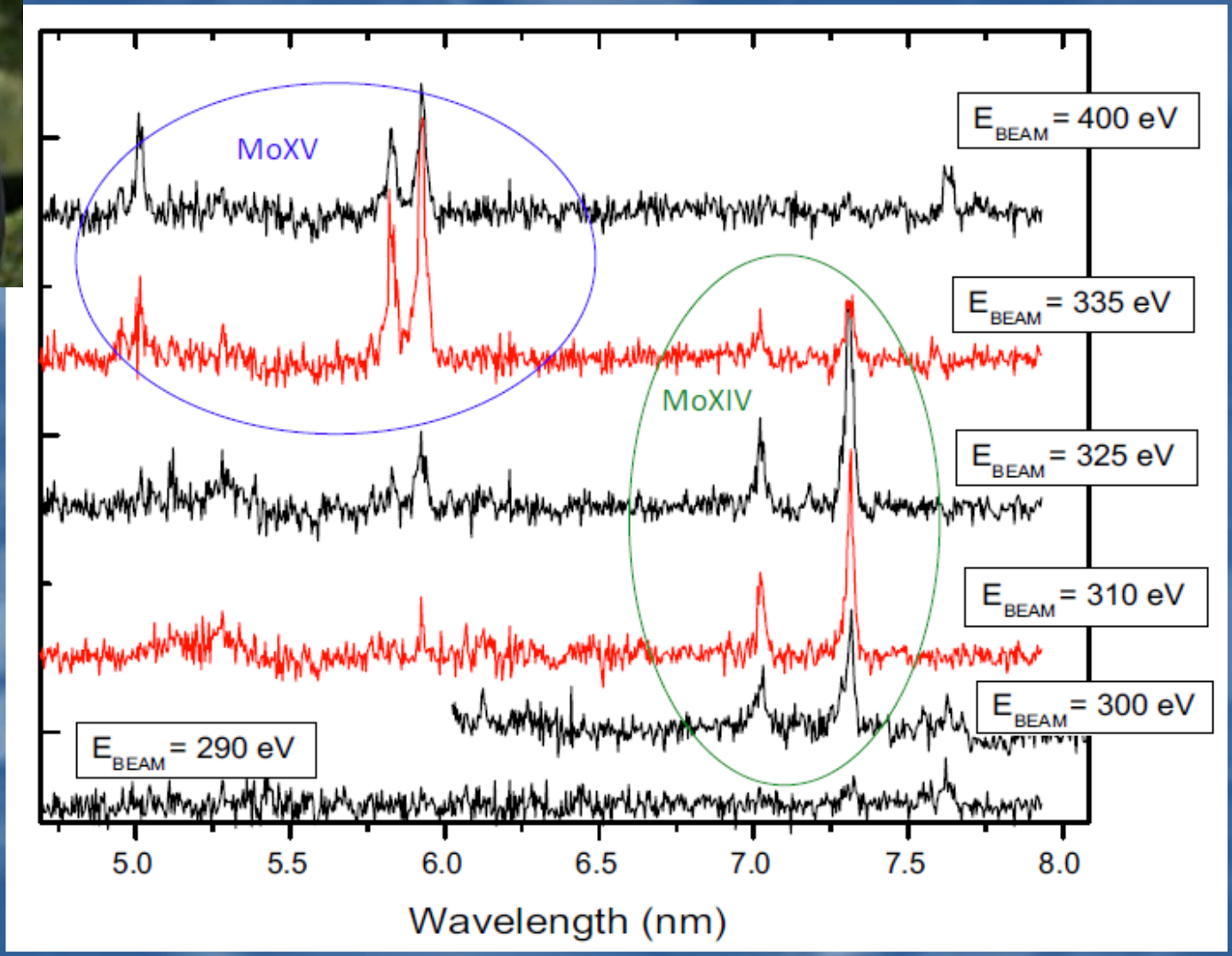


Summary and outlook

- CoBIT is a powerful device for studying spectra of highly charged ions relevant to EUVL.
- EUV spectra of Gd to Ho have been observed for studying the emission features near 6.*x* nm.
- Concentration of emission from adjacent charges has been confirmed for Gd at $x \sim 8$.
- CR model calculations are in progress for detailed understanding of the spectra.
- Observations for Mo are also in progress for the data relevant to BEUVL and water window.

EUV spectra of Mo

Emma Sokell (UCD)



E. Sokell et al., ICPEAC 2017 (July, Cairns)
J. Phys.: Conf. Ser. 875 (2017) 052045

Thank you