Probing Fields and Nuclei: Photorecombination and its Time-Reversed Process

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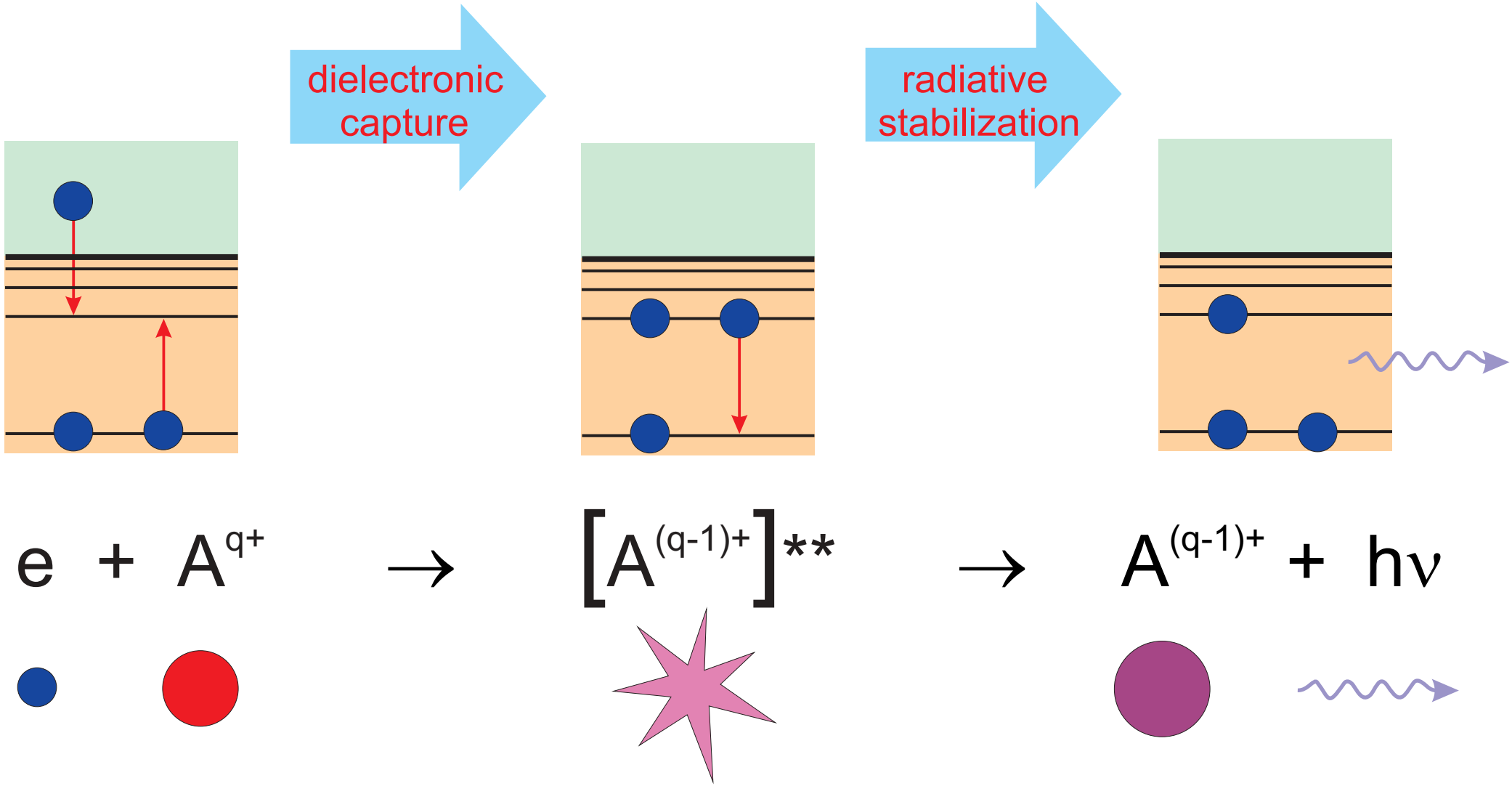
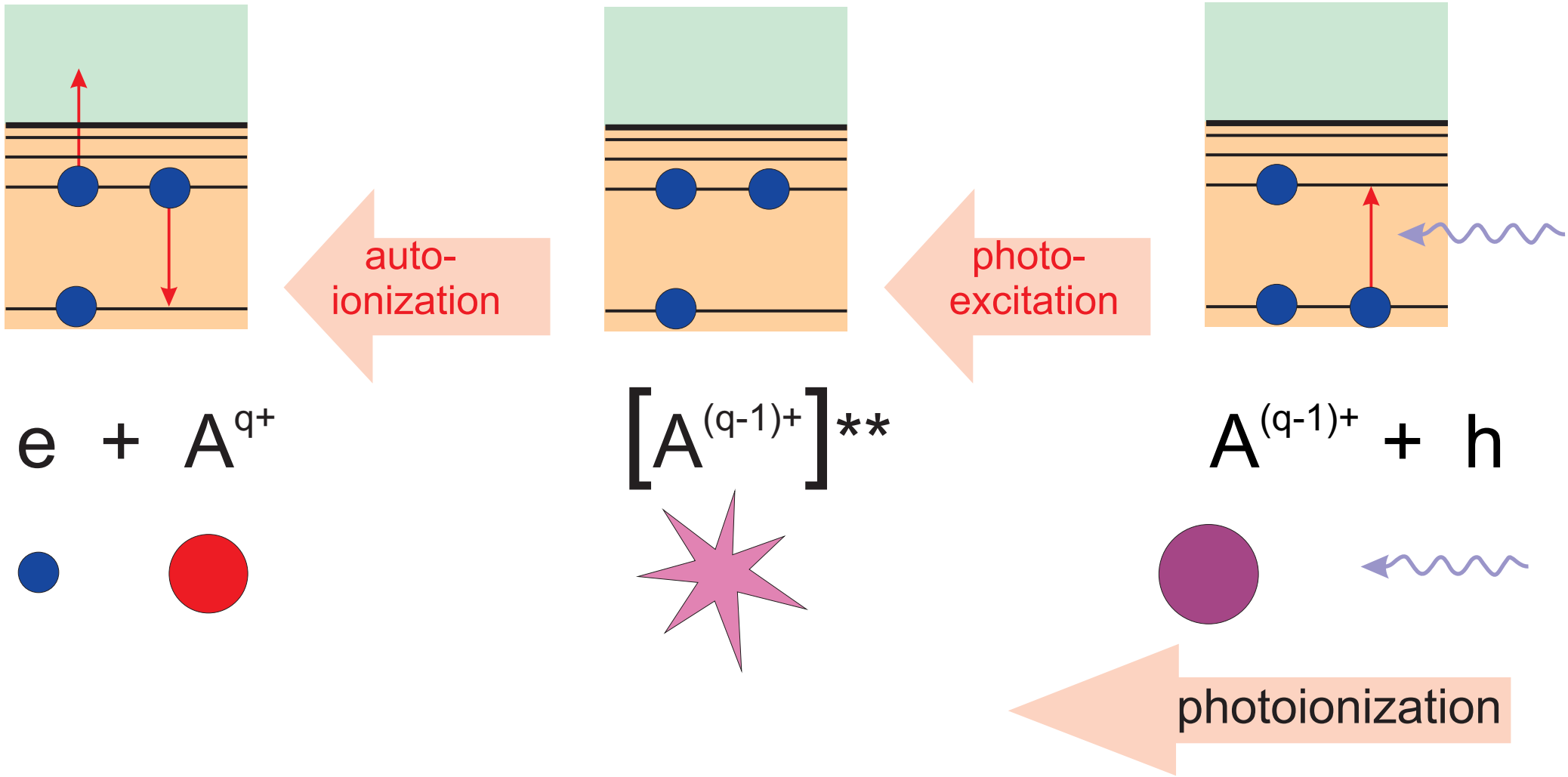
Recombination via Resonances



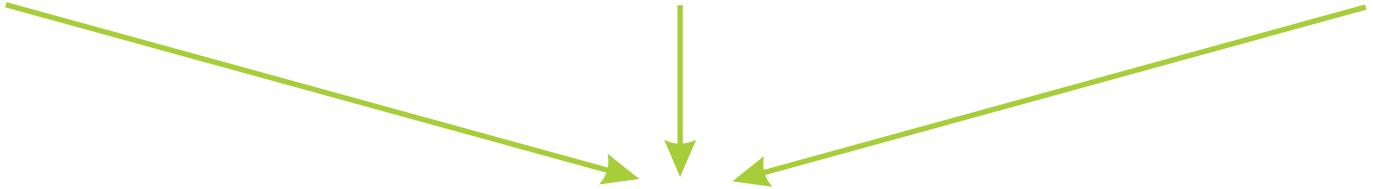
Photoionization via Resonances



Which goals do we have?

Understand elementary atomic collision processes

photo-recombination photo-excitation photo-ionization

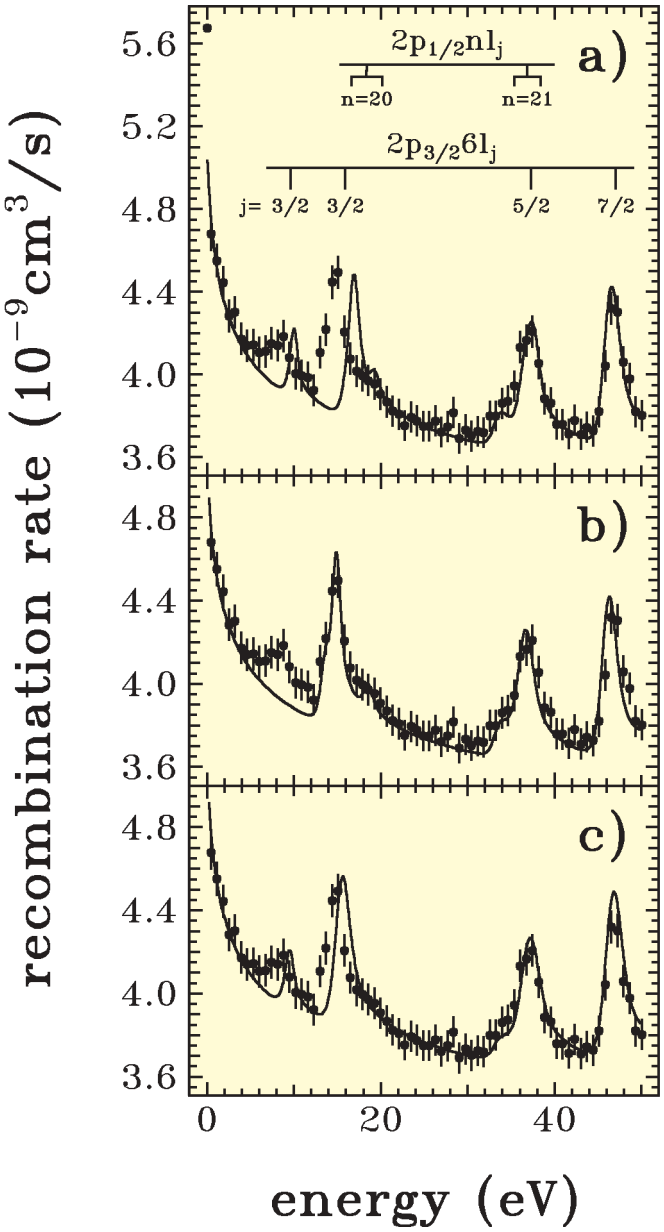


exploit high resolution of resonances

to study

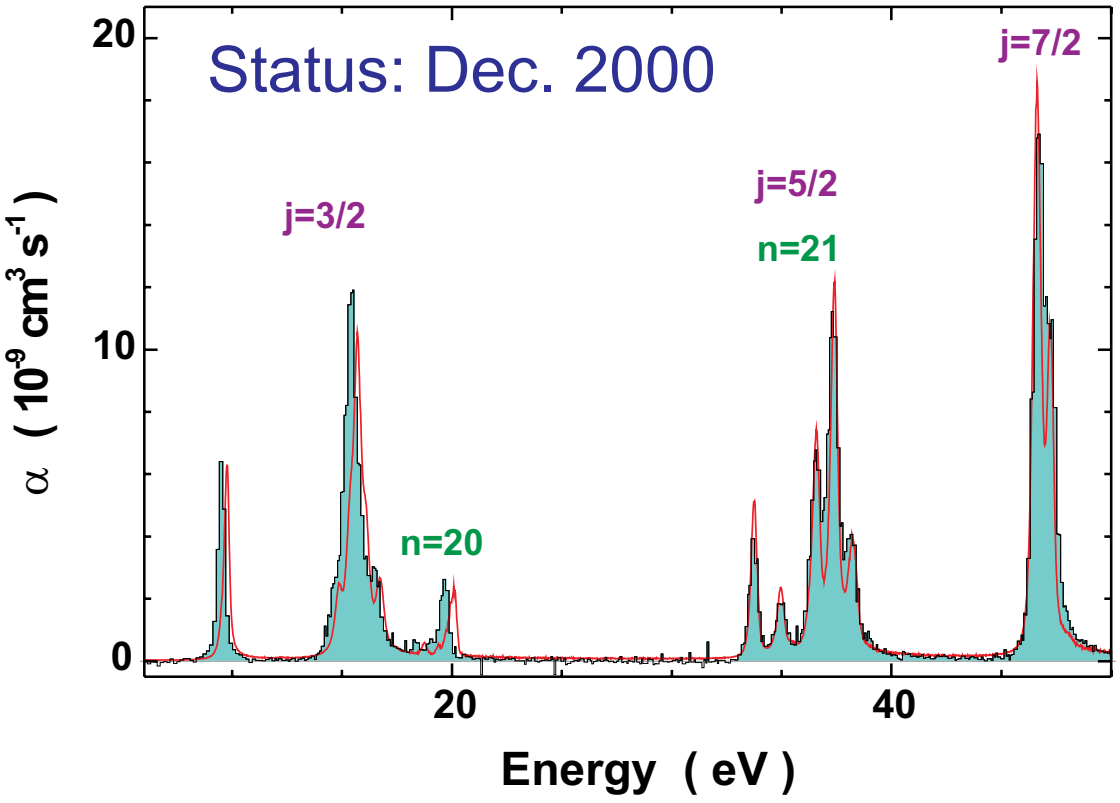
QED in strong fields hyperfine structure nuclear effects

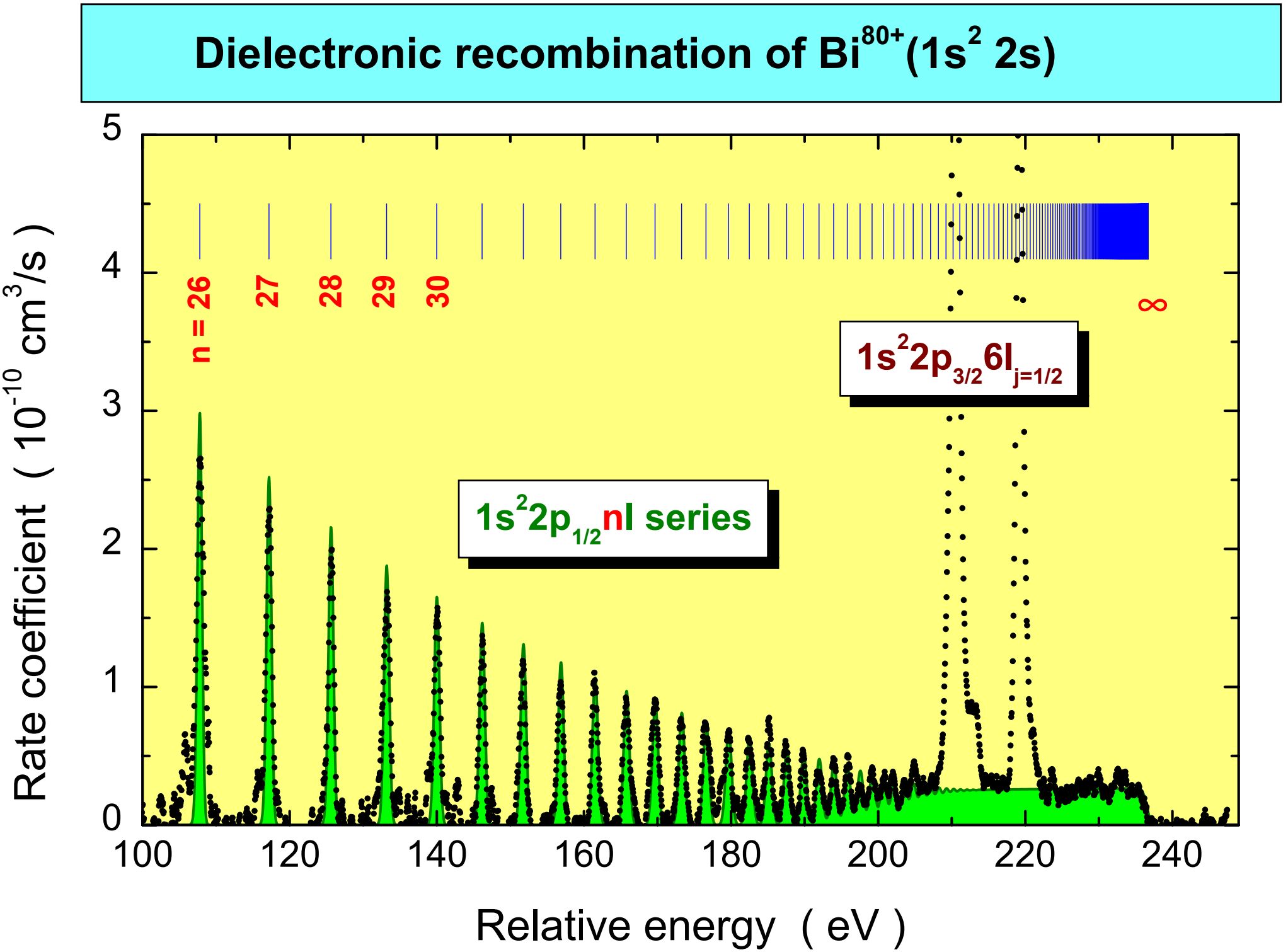
Progress of work at the ESR of GSI: Dielectronic recombination of Au^{76+}



Phys. Rev. Lett. 69, 2768 (1992)
Experiment-Collaboration Giessen-GSI

Giessen-GSI experiment and Giessen theory




Dielectronic recombination of Bi80+(1s2 2s)
Rate coefficient (10-10 cm3/s)
Relative energy (eV)
n = 26
27
28
29
30
∞
1s22p3/26lj=1/2
1s22p1/2nl series
0
1
2
3
4
5
100
120
140
160
180
200
220
240

$2s_{1/2}$ - $2p_{1/2}$ Lamb shift in Li-like ions

Status 2002 for $^{238}U^{89+}$

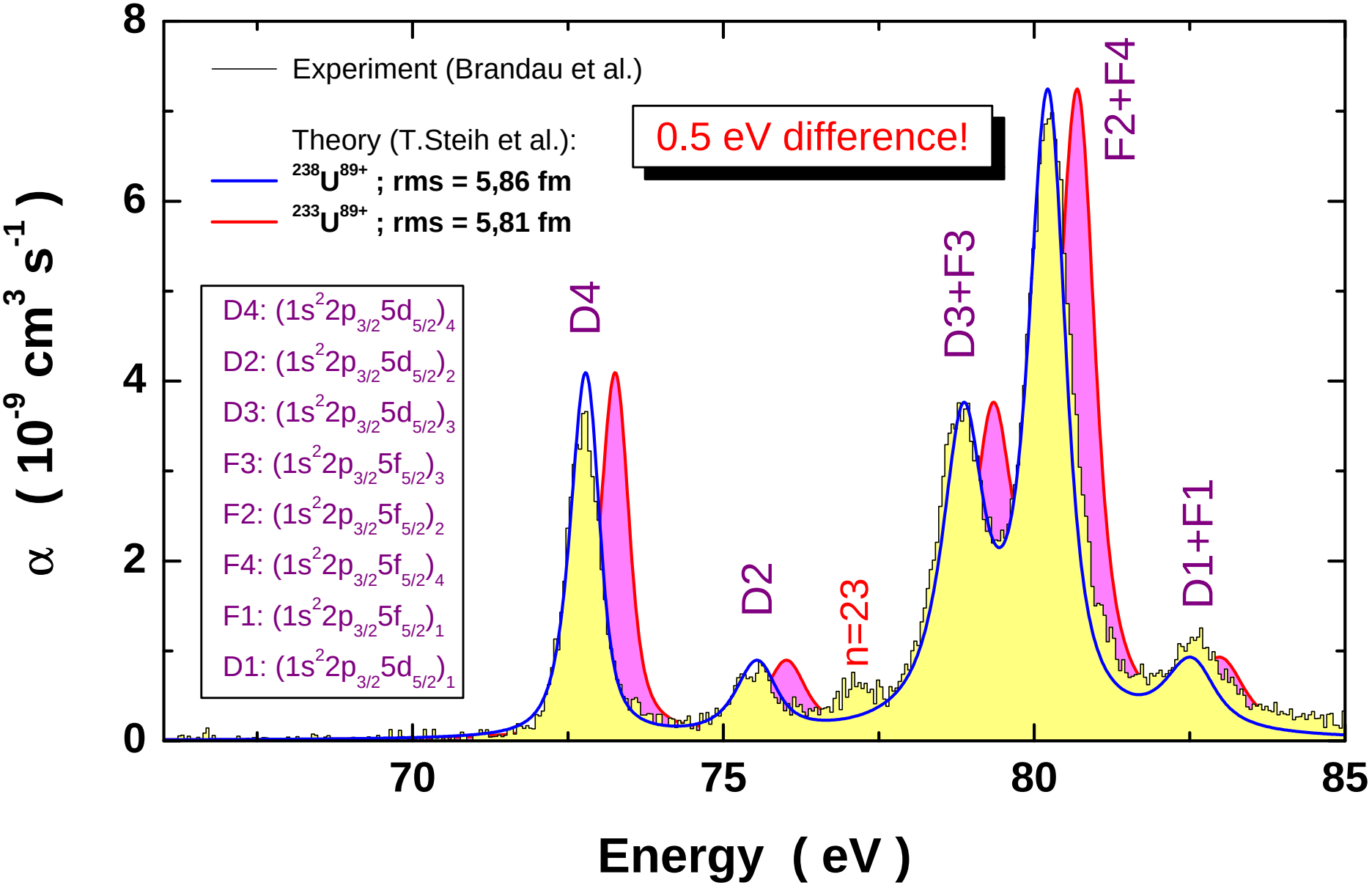
Theory: (Yerokhin et al.) — **280.64 eV ± 110 meV ± 210 meV**

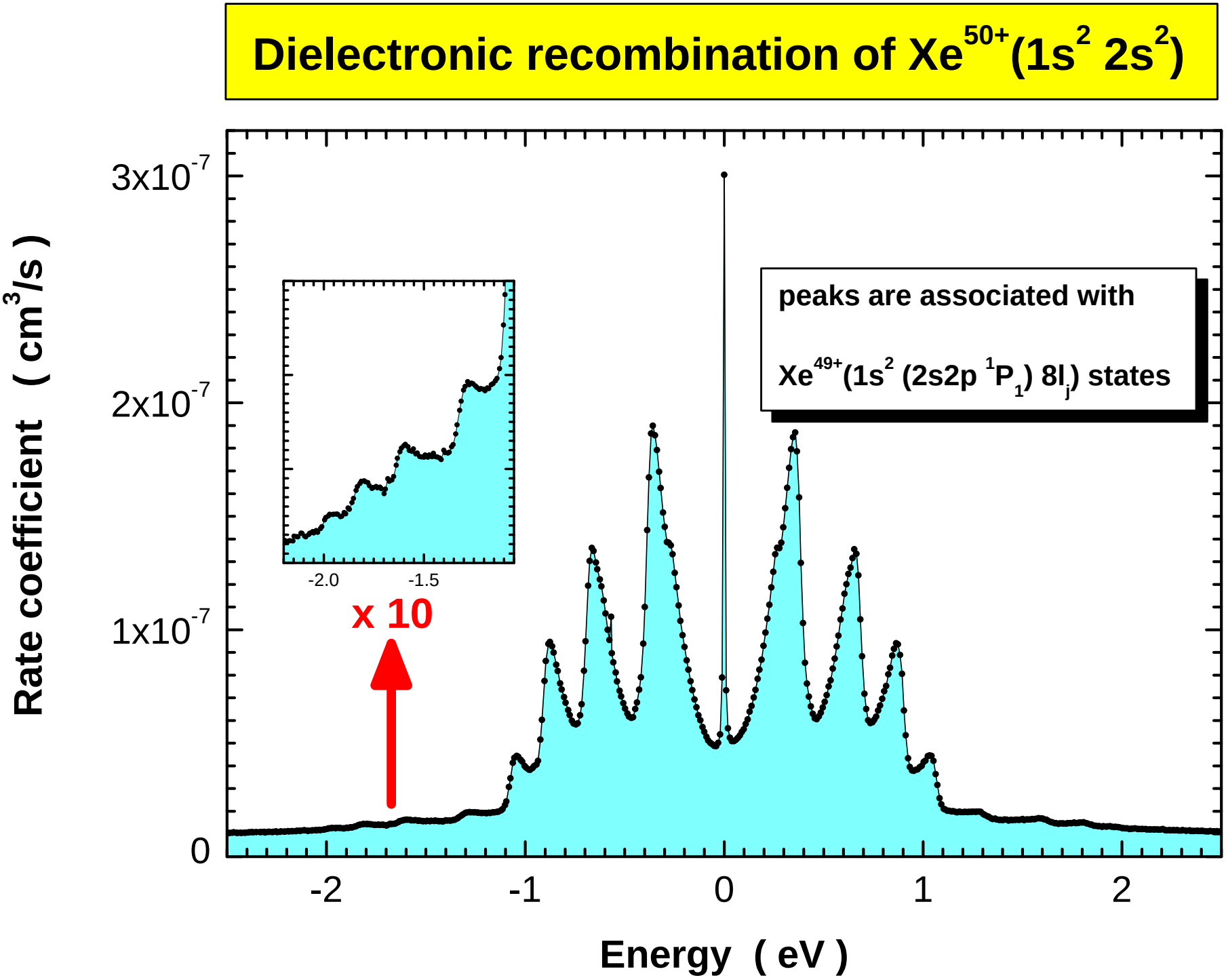
Experiment: (Schweppe et al. 1991) — **280.59 eV ± 90 meV**

ESR-DR-Experiment: (Brandau et al.): — **280.516 eV ± 34 meV ± 22 meV ± 43 meV**

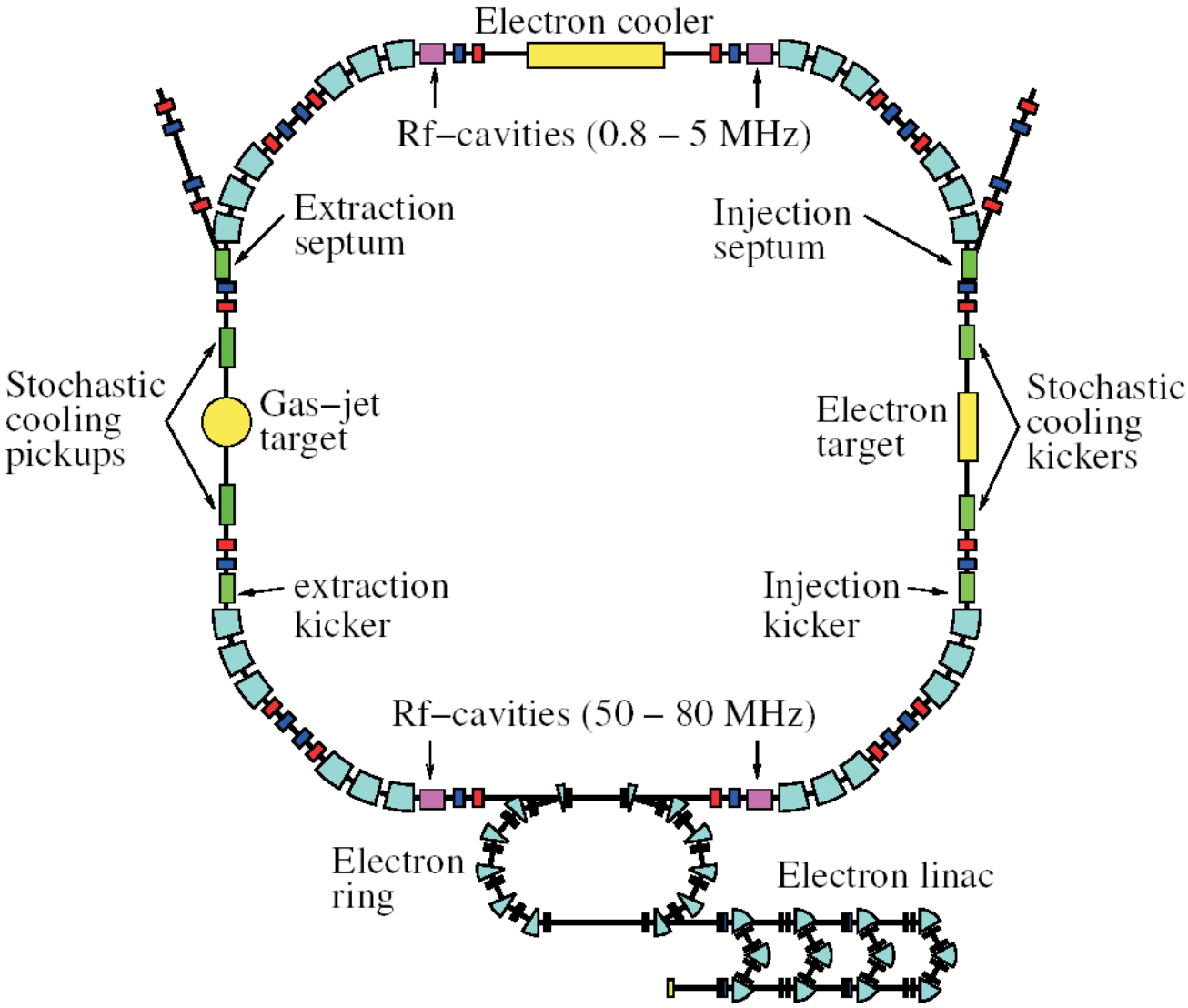
$$e + U^{89+}(1s^2 2s) \rightarrow U^{88+}(1s^2 2p_{3/2} 5l_{5/2})$$

$$e + U^{89+}(1s^2 2s) \rightarrow U^{88+}(1s^2 2p_{1/2} nl_j)$$




Dielectronic recombination of Xe50+(1s2 2s2)
Rate coefficient (cm3/s)
3x10-7
2x10-7
1x10-7
0
-2
-1
0
1
2
Energy (eV)
-2.0
-1.5
x 10
peaks are associated with
Xe49+(1s2 (2s2p 1P1) 8lj) states

The New Experimental Storage Ring NESR



Improvements expected:

simultaneous cooling (electron cooler) and measurement (electron target)

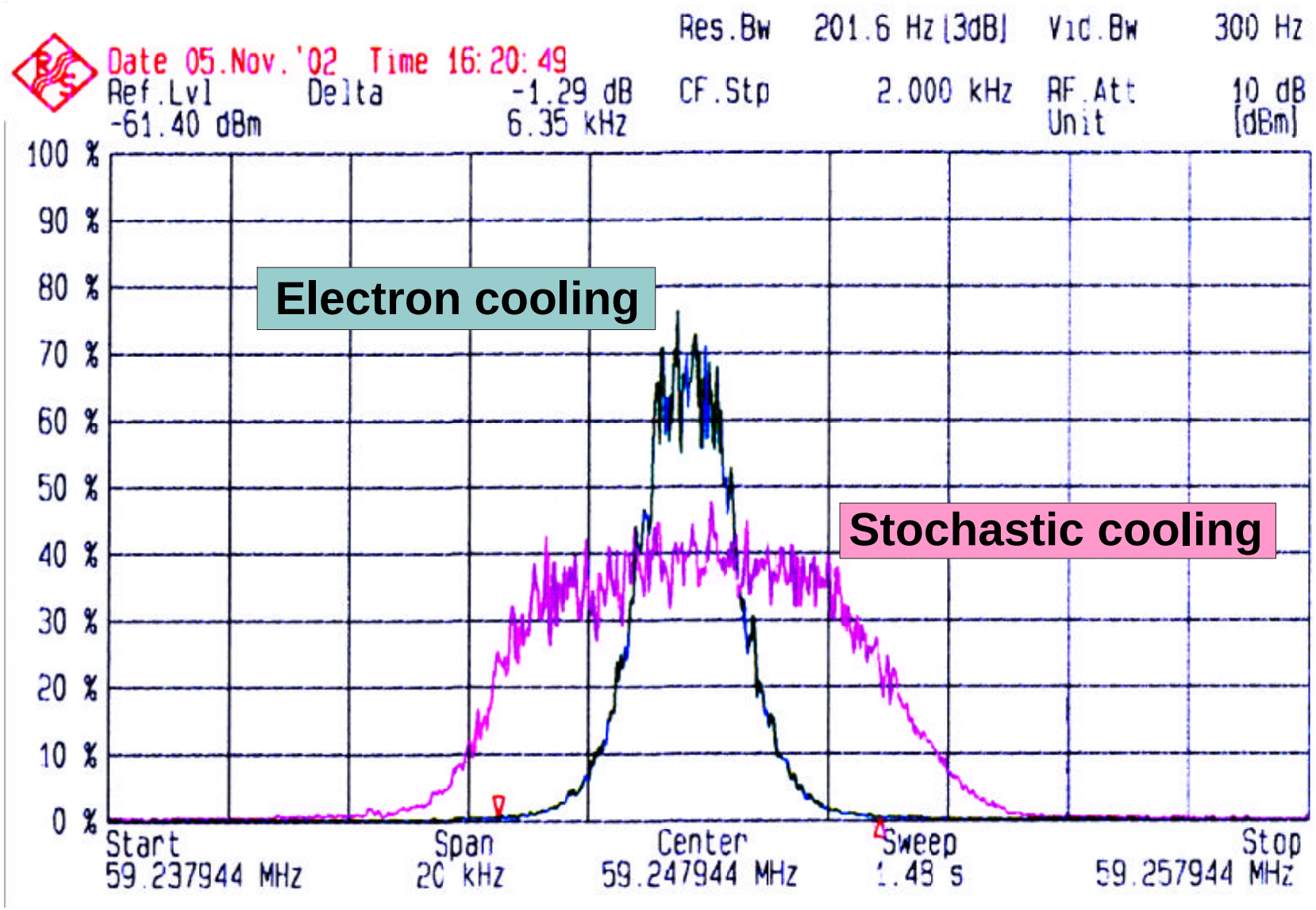
electron target with adiabatic beam expansion adiabatic acceleration of electrons flexibility of target setup

improved energy resolution

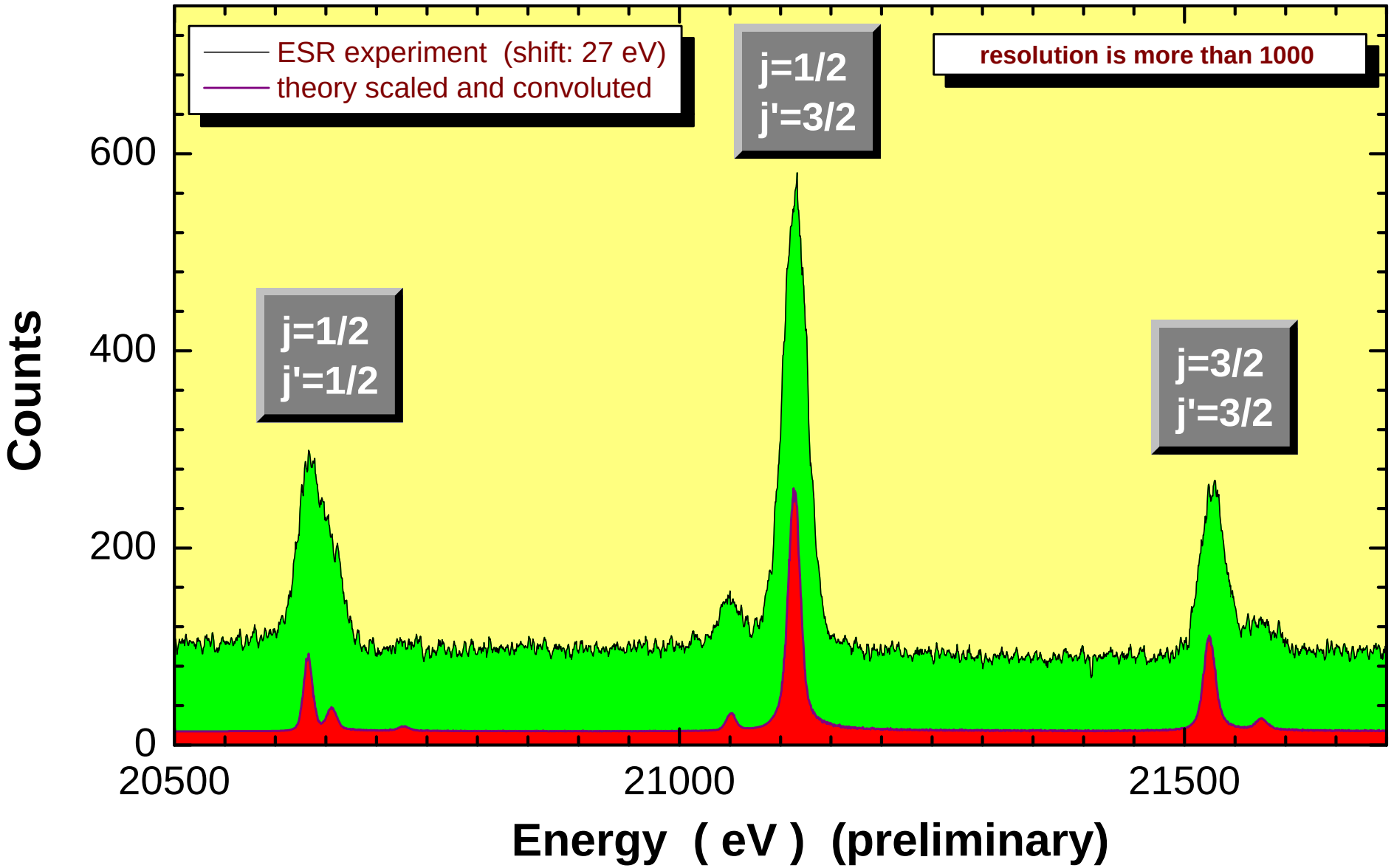
optimum access to high-energy resonances

Schottky Spectra of Xe^{53+} Ion Beam in the ESR

30^{th} harmonic, 400 μA

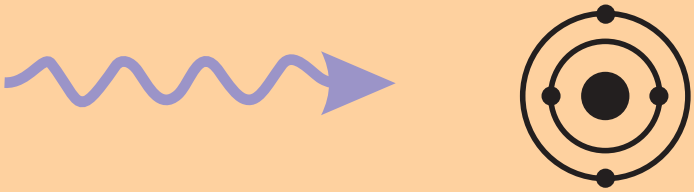


$$e + Xe^{53+}(1s) \rightarrow Xe^{52+}(2l_j\, 2l_{j'}') \rightarrow Xe^{52+}(1s^2) + K_\alpha \text{ photons}$$

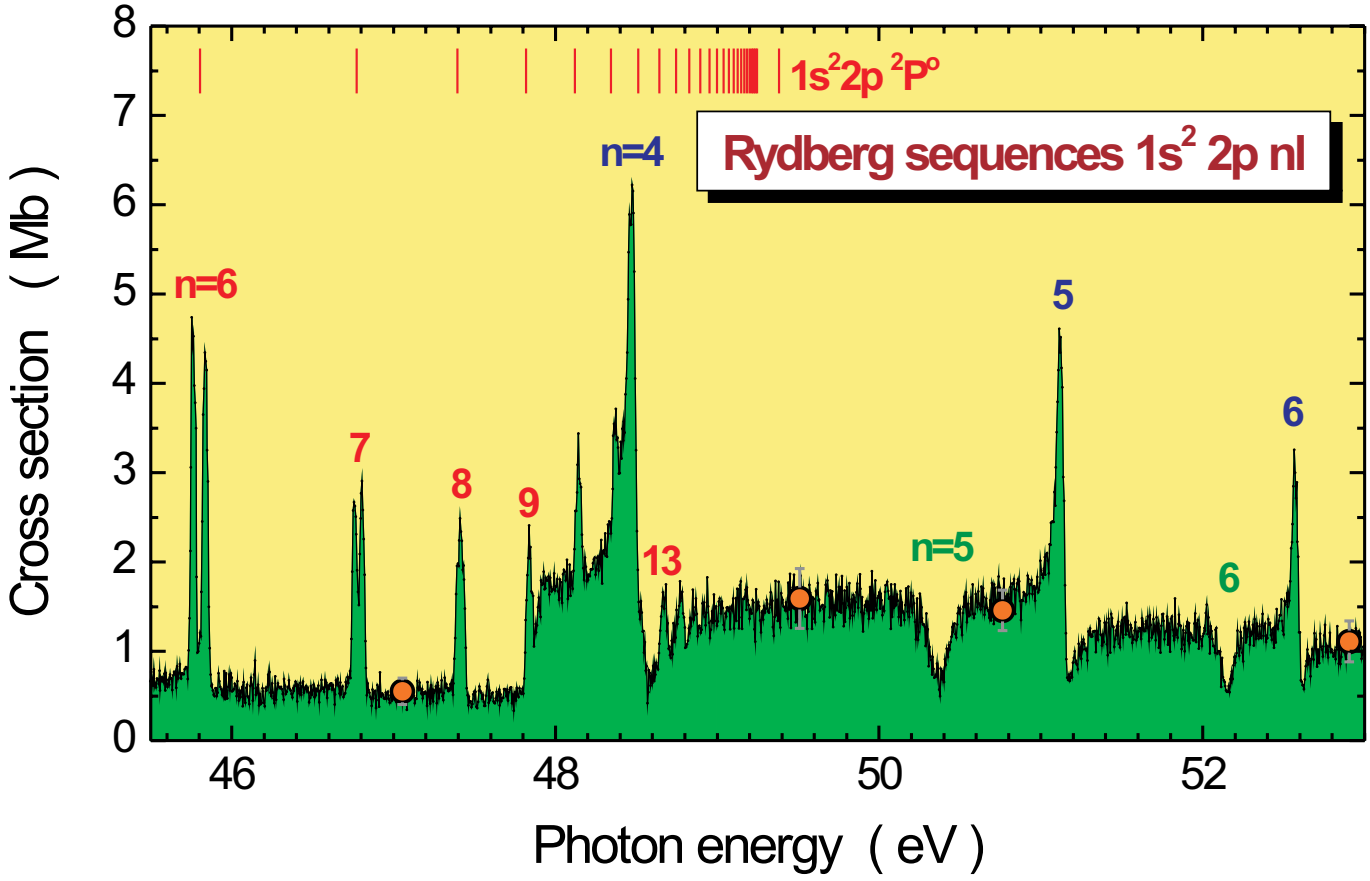


New Possibilities for Precision Spectroscopy of HCI

Interactions of energetic photons with ions



Example: photo-excitation of Be-like C^{2+} ions



ALS Collaboration

A. Müller, R. A. Phaneuf, A. Aguilar, M. F. Gharaibeh, A. S. Schlachter, I. Alvarez, C. Cisneros, G. Hinojosa, B. M. McLaughlin, J. Phys. B 35, L137 (2002)

Time-reversal studies

Dielectronic recombination: CRYRING Collaboration

$$e + C^{4+}(1s^2\ {}^1S_0) \rightarrow C^{3+}(1s2s2p\ {}^2P^o) \rightarrow C^{3+}(1s^2 2s\ {}^2S) + h\nu$$

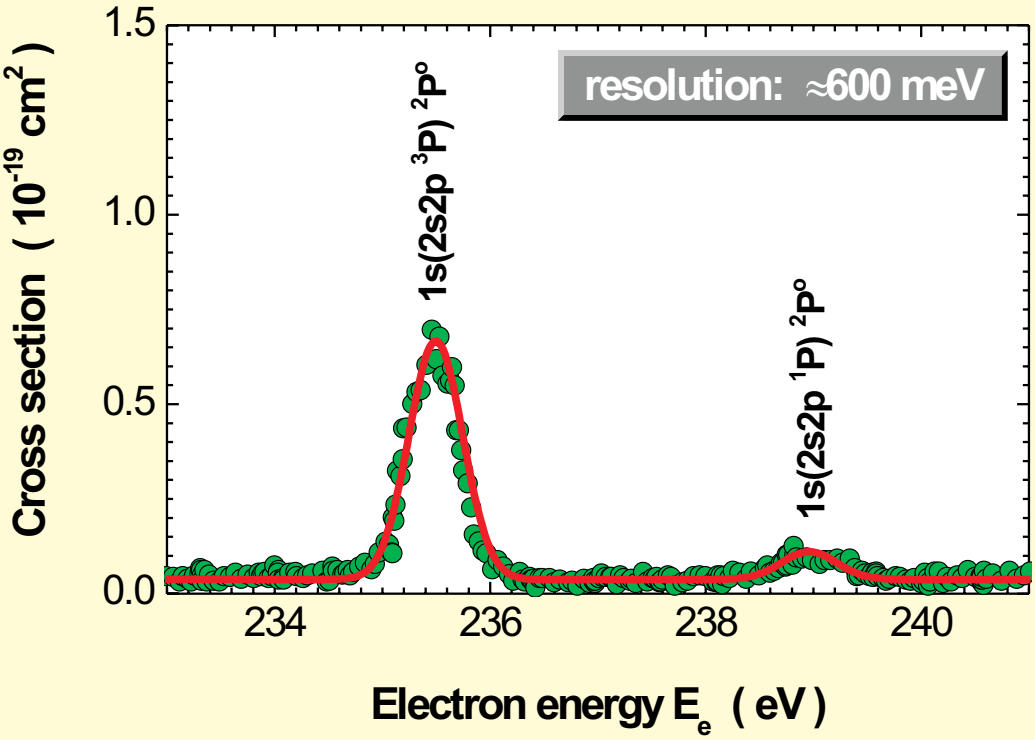


Photo-ionization: ALS Collaboration

$$h\nu + C^{3+}(1s^2 2s\ {}^2S) \rightarrow C^{3+}(1s2s2p\ {}^2P^o) \rightarrow C^{4+}(1s^2\ {}^1S) + e$$

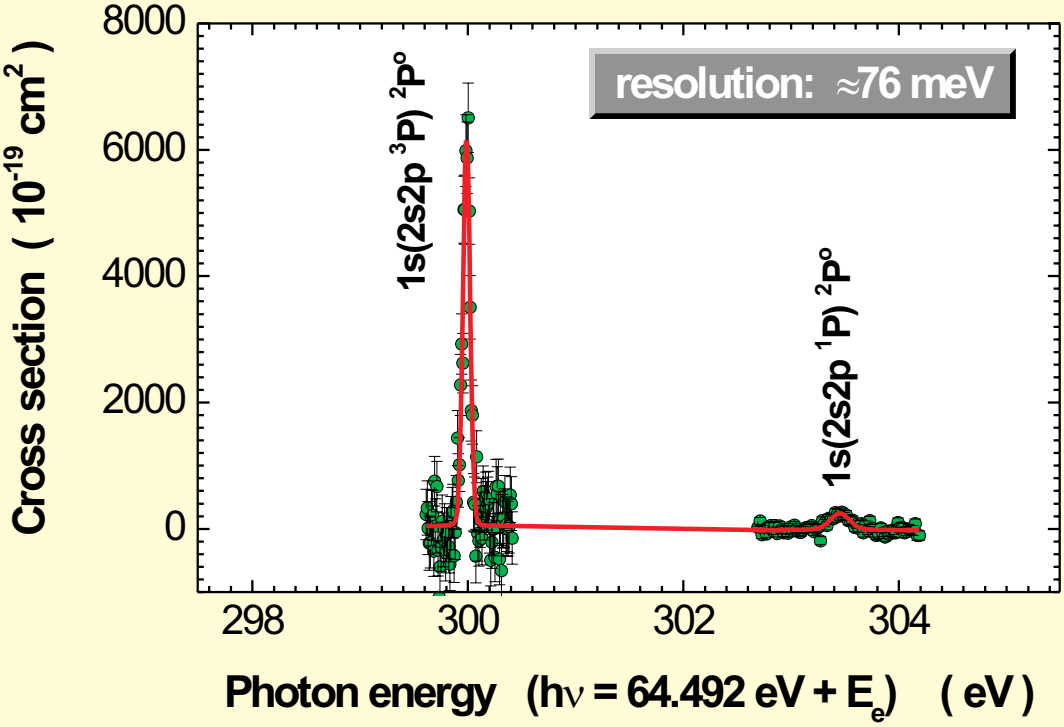


Photo-Excitation of the $2s_{1/2}$ - $2p_{1/2}$ Lamb Shift in Li-like U^{89+}

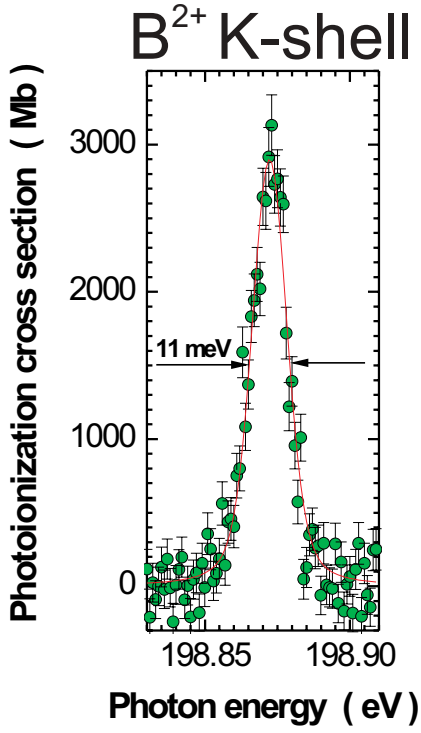
Trapped U^{89+} ions (e.g. in an EBIT) exposed to synchrotron radiation

demonstrated at ALS:

energy resolution up to 35 000
1.16 meV@ 40.2 eV, 10 meV @ 200 eV

absolute energies with $\Delta E/E = 3 \times 10^{-5}$
10 meV @ 300 eV

see also: Poster by S. Schippers et al.



Doppler-Boosted Laser Photons: