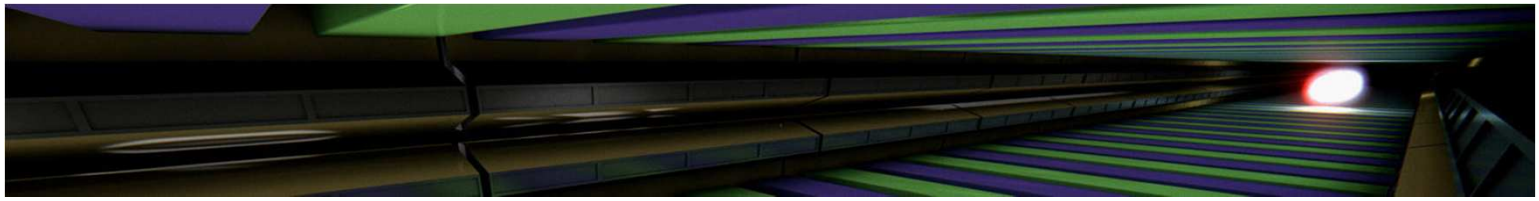


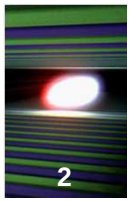
Two-color Resonant Photoionization Processes in Atoms

Tommaso Mazza
European XFEL, Hamburg (Germany)
Scientific Instrument SQS

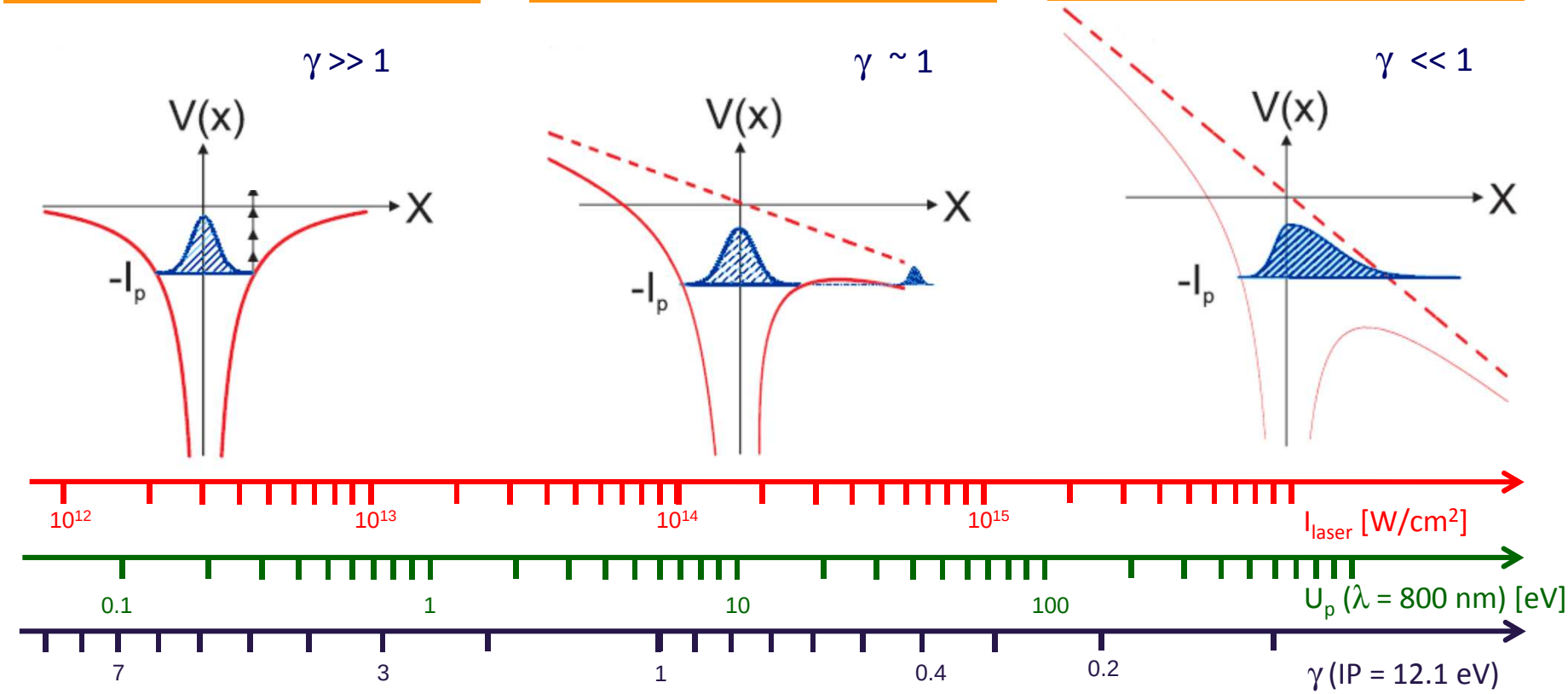
tommaso.mazza@xfel.eu

EMMI Workshop on Non-Linear Dynamics of Simple Quantum Systems at Extreme Temperatures and Intensities
GSI, Darmstadt, Germany

Introduction: Strong field ionization of atoms



Multiphoton Ionization | **Tunnel Ionization** | **Optical Field Ionization**



Keldysh parameter

$$\gamma = \sqrt{(IP / 2U_p)}$$

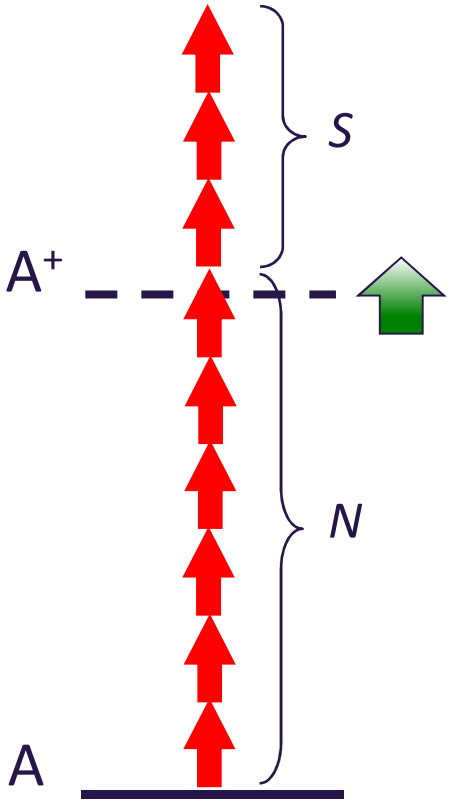
Ponderomotive potential

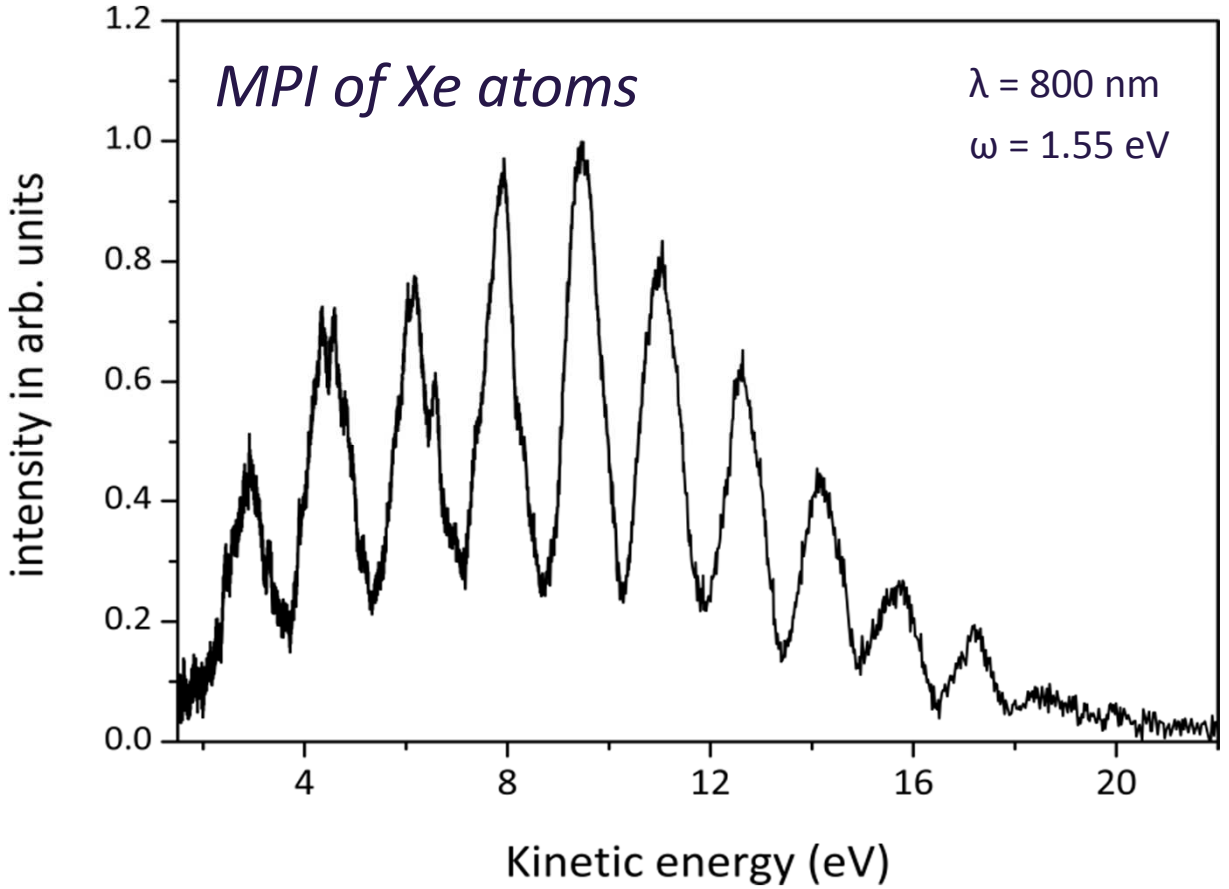
$$U_p = I / 4\omega^2$$

Quiver energy of a free electron in an oscillating electric field

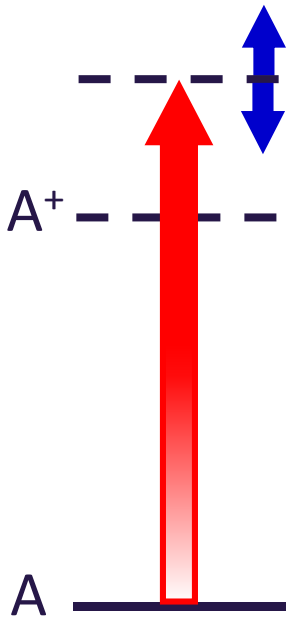
One-color above threshold ionization

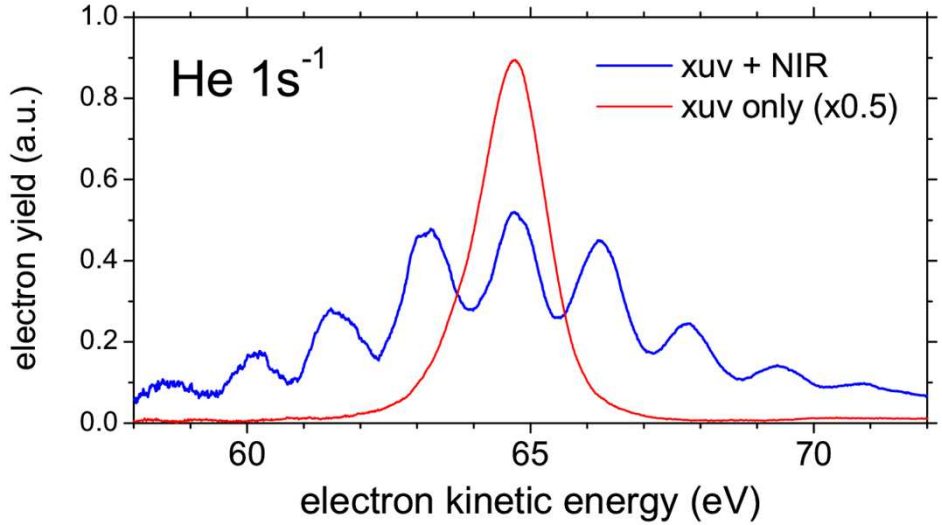
$$E_e = (n + s)\hbar\omega - (I_p + U_p)$$





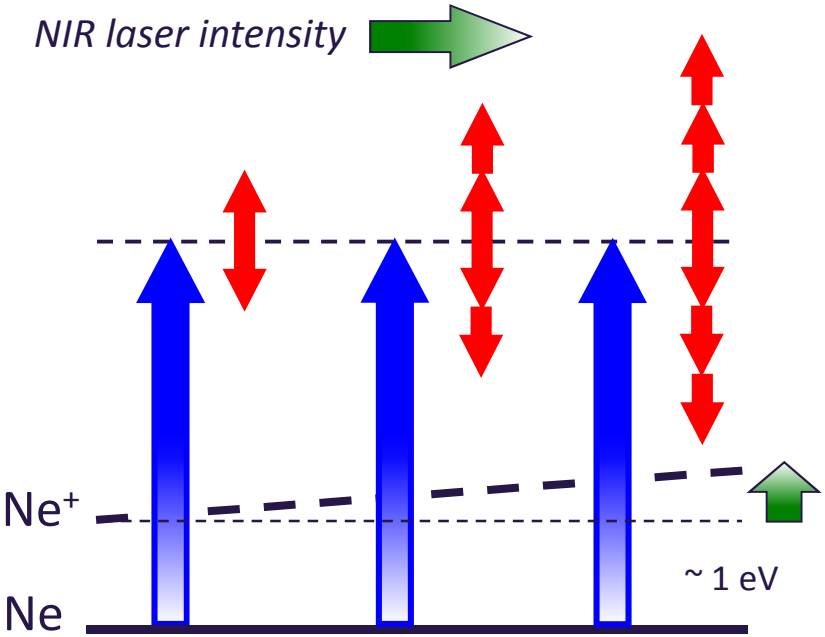
Two-color above threshold ionization

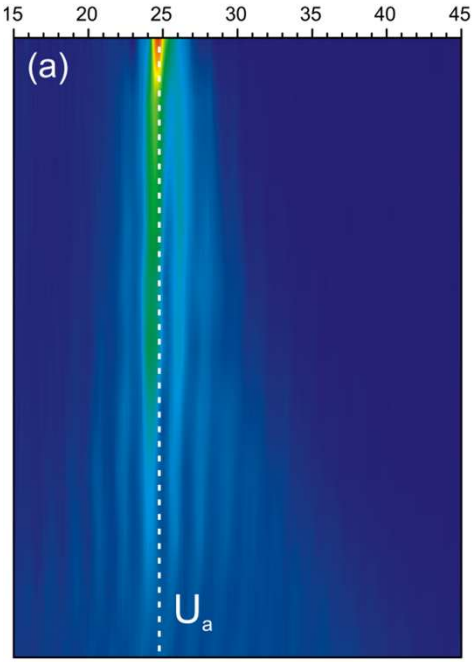




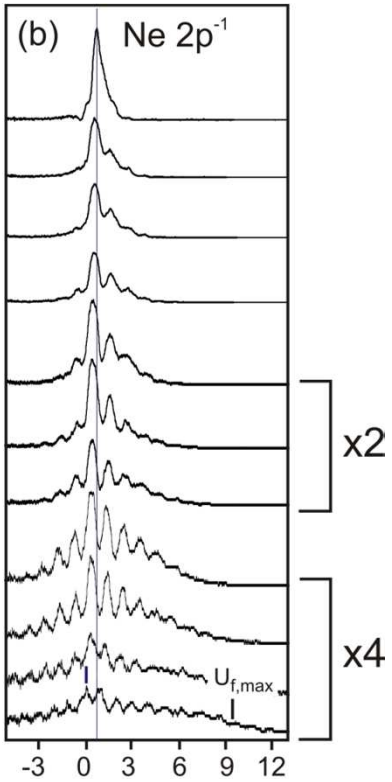
$I < 10^{12}$ W/cm^2
XUV ~ 89.5 eV
NIR = 1.55 eV

Two-color above threshold ionization



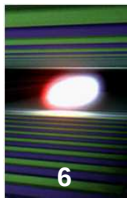


U_p

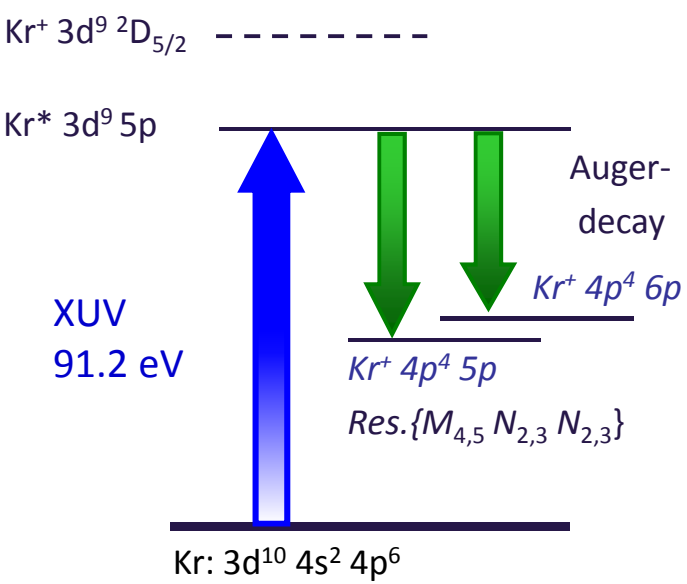


I = 10^{13} W/cm^2
XUV = 46 eV
NIR = 1.55 eV

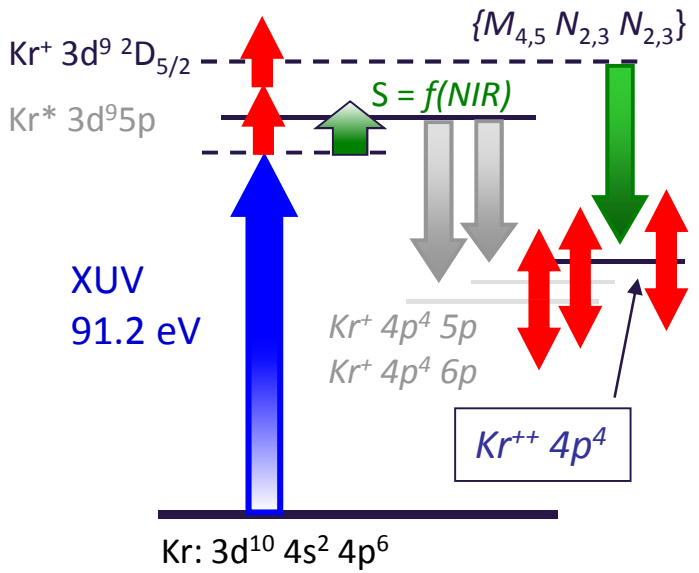
XUV resonance Kr* $3d^9$ 5p



XUV only



XUV & NIR

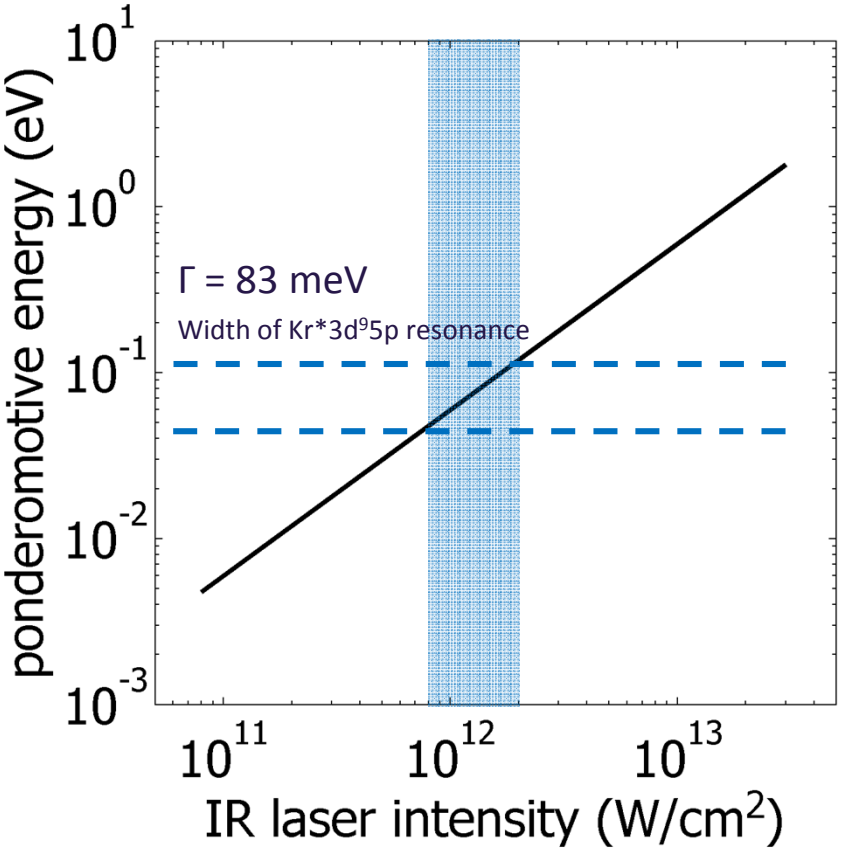


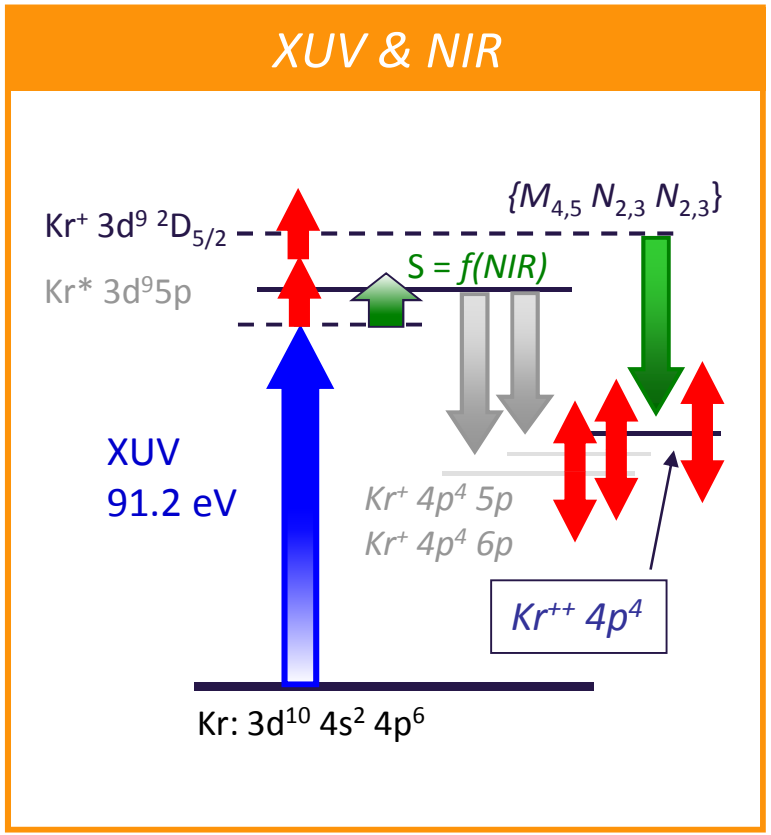
G. C. King et al., J. Phys. B 10, 2479 (1972)
H. Aksela et al., Phys. Rev. A 53, 290 (1996)

"Laser-assisted Auger decay"; Schins et al., Phys. Rev. Lett. 73, 2180 (1994)

XUV resonance Kr* $3d^9$ 5p

Ponderomotive shift "S"
of resonance positions





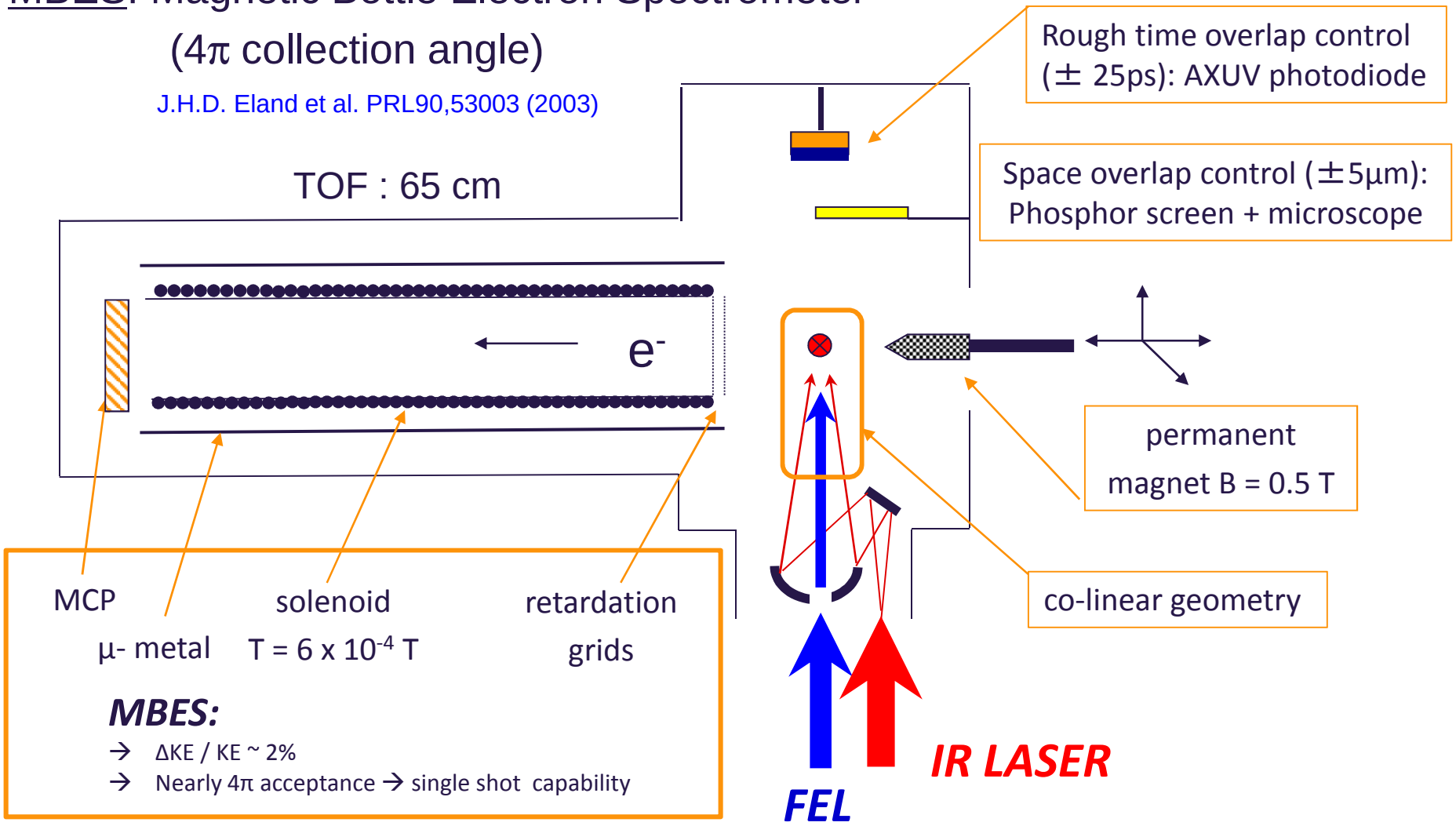
To get a shift comparable with Γ an intensity I(NIR) > 10^{12} W/cm² is needed

Two-Color Photoelectron Spectroscopy: Experimental apparatus

MBES: Magnetic Bottle Electron Spectrometer

(4π collection angle)

J.H.D. Eland et al. PRL90,53003 (2003)



Experimental parameters

FLASH :

91.2 eV, b.w. ≈ 1 eV;

energy ~ 50 µJ / pulse; focus ~ (70 µm)^2

PG-beamline:

ΔE ~ 60 meV, DT ~ 300 fs

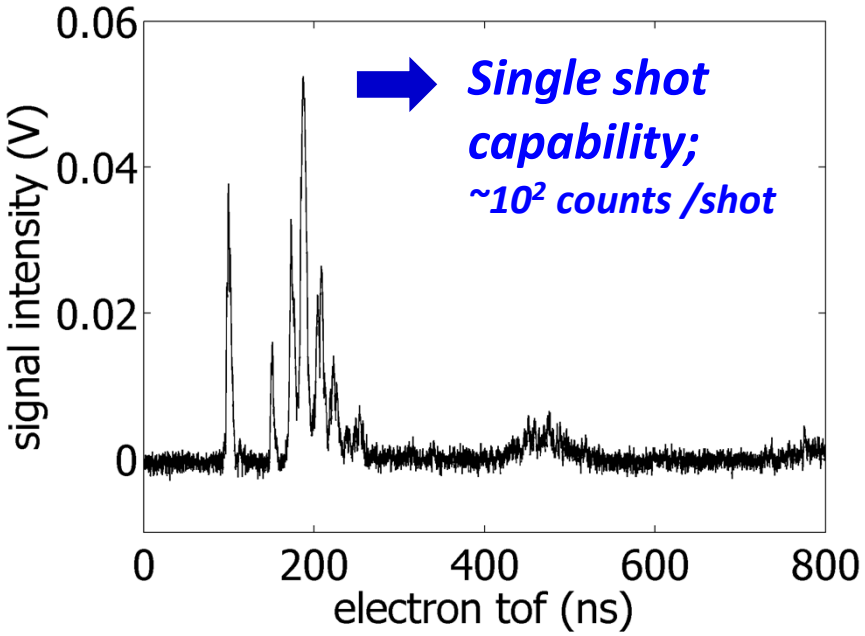
➡ ~ 10^{15} photons / shot/cm^2

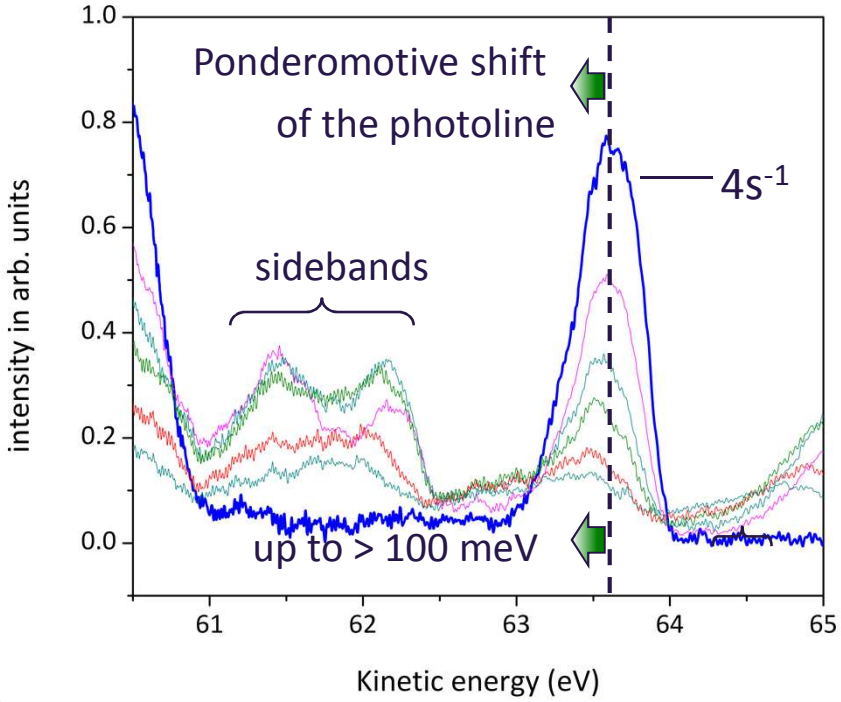
Optical laser :

Ti:sapphs 800 nm, 50 fs – 3 ps

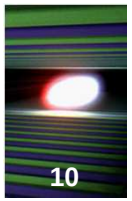
1 mJ / pulse; focus ~ (200 µm)^2

➡ I = 10^{11} – 10^{13} W/cm^2

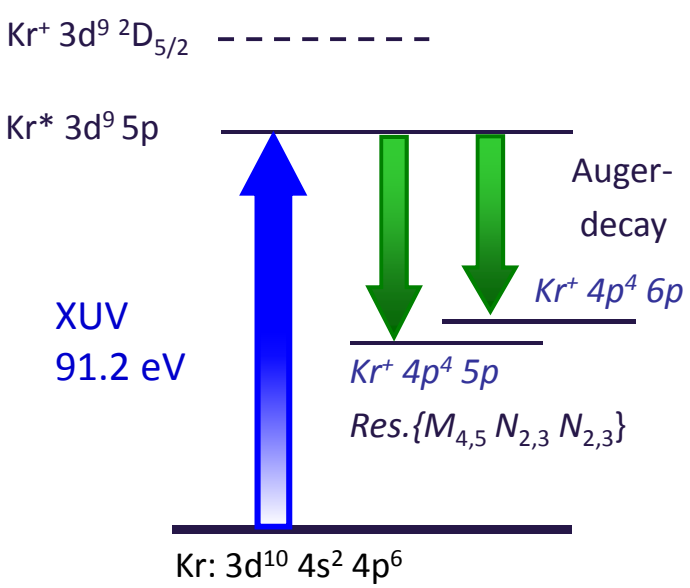


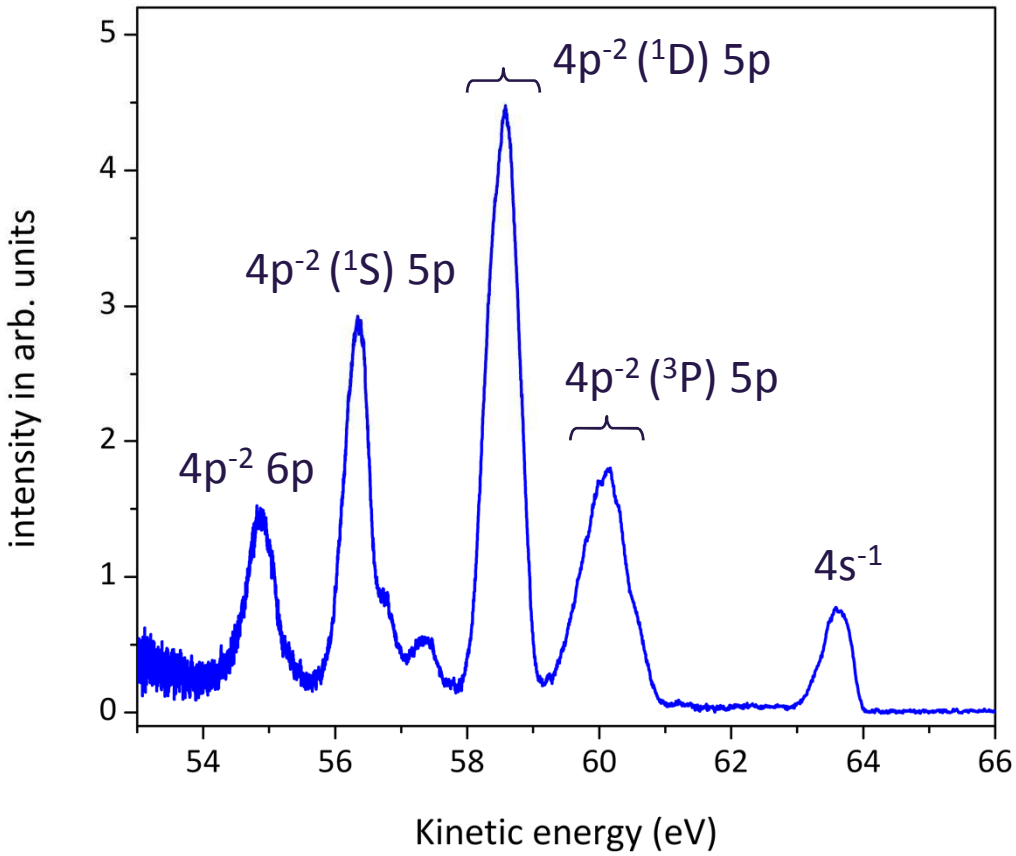


Auger decay of resonantly excited Kr $3d^{-1}$ 5p states

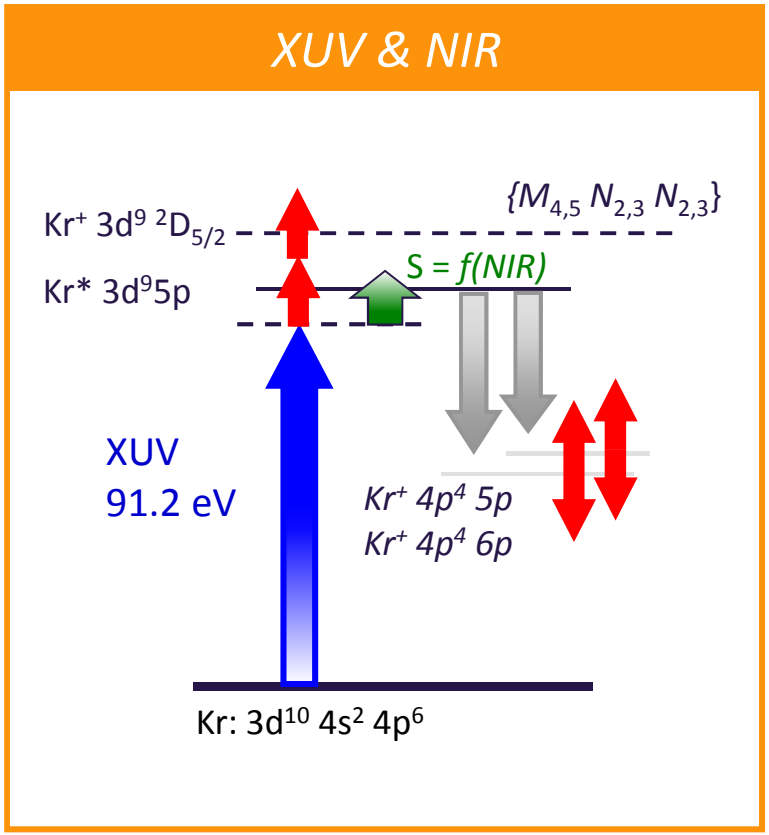


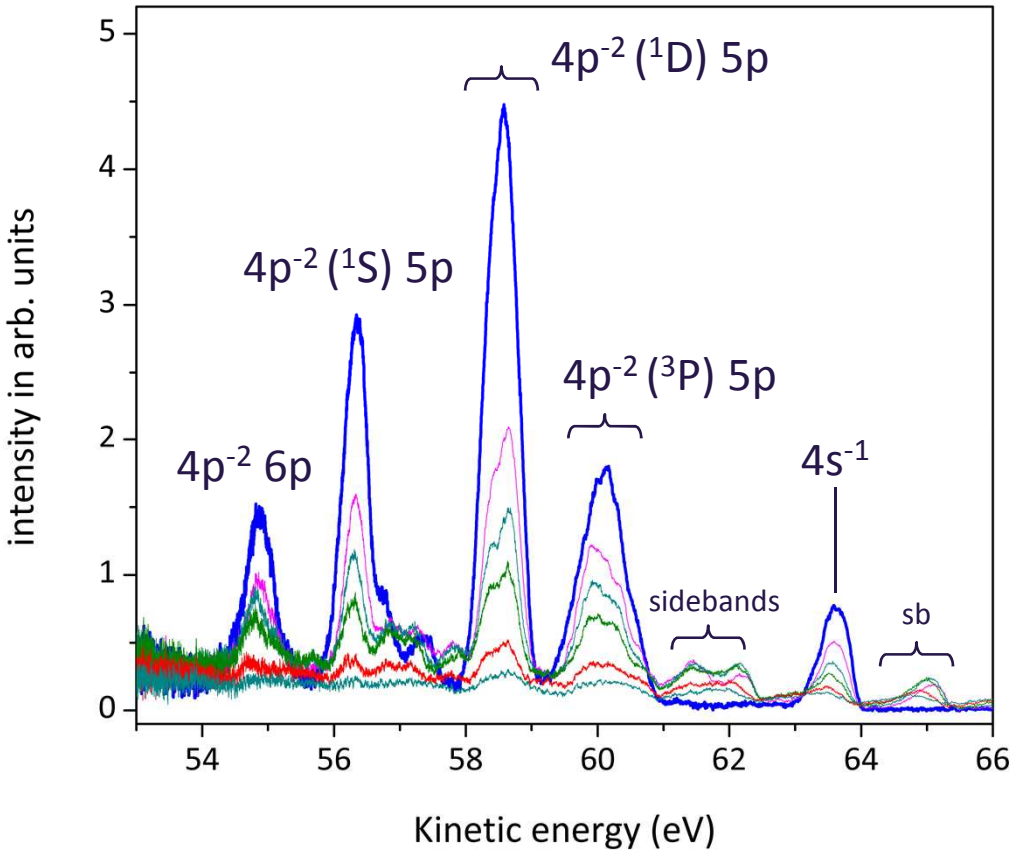
XUV only





Auger decay of Kr $3d^{-1}$ 5p states: ponderomotive suppression by dressing IR field



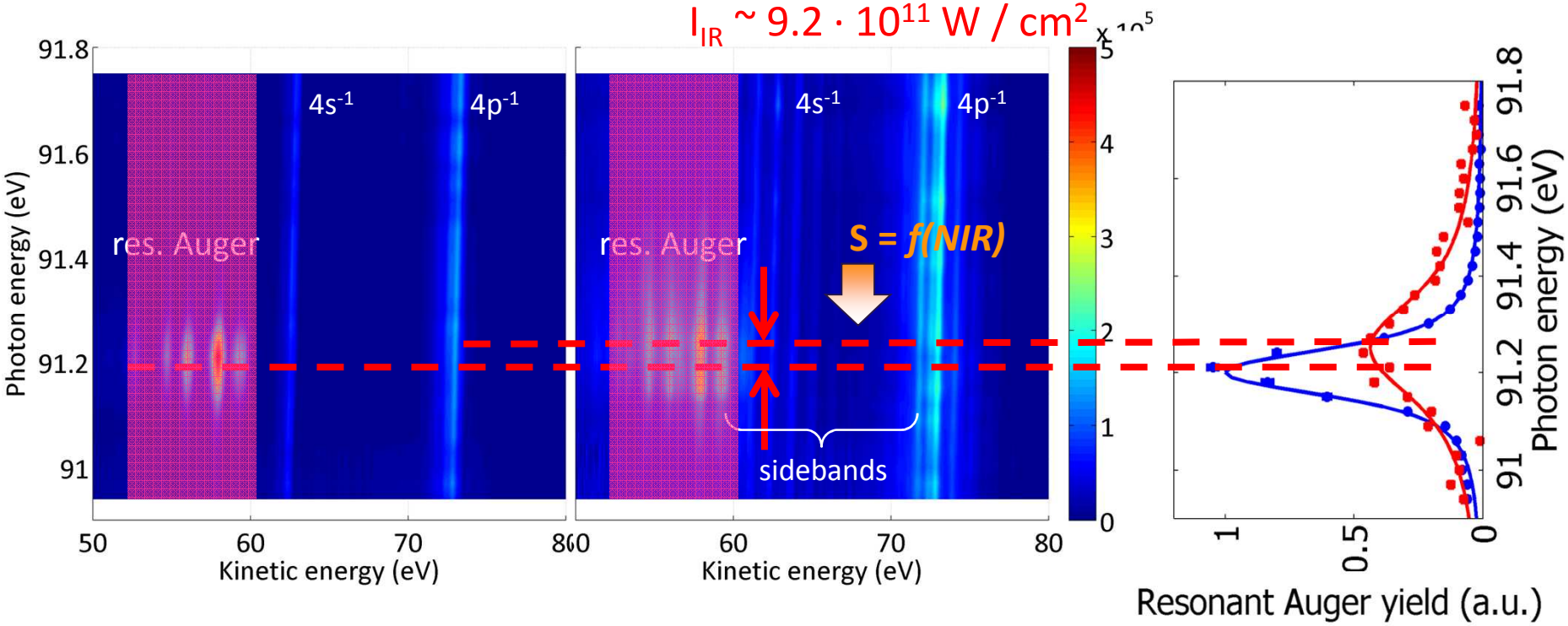


Suppression of the resonant Auger yield given by increased dressing IR laser intensity

Kr 3d - 5p excitation: ponderomotive shift by dressing IR field

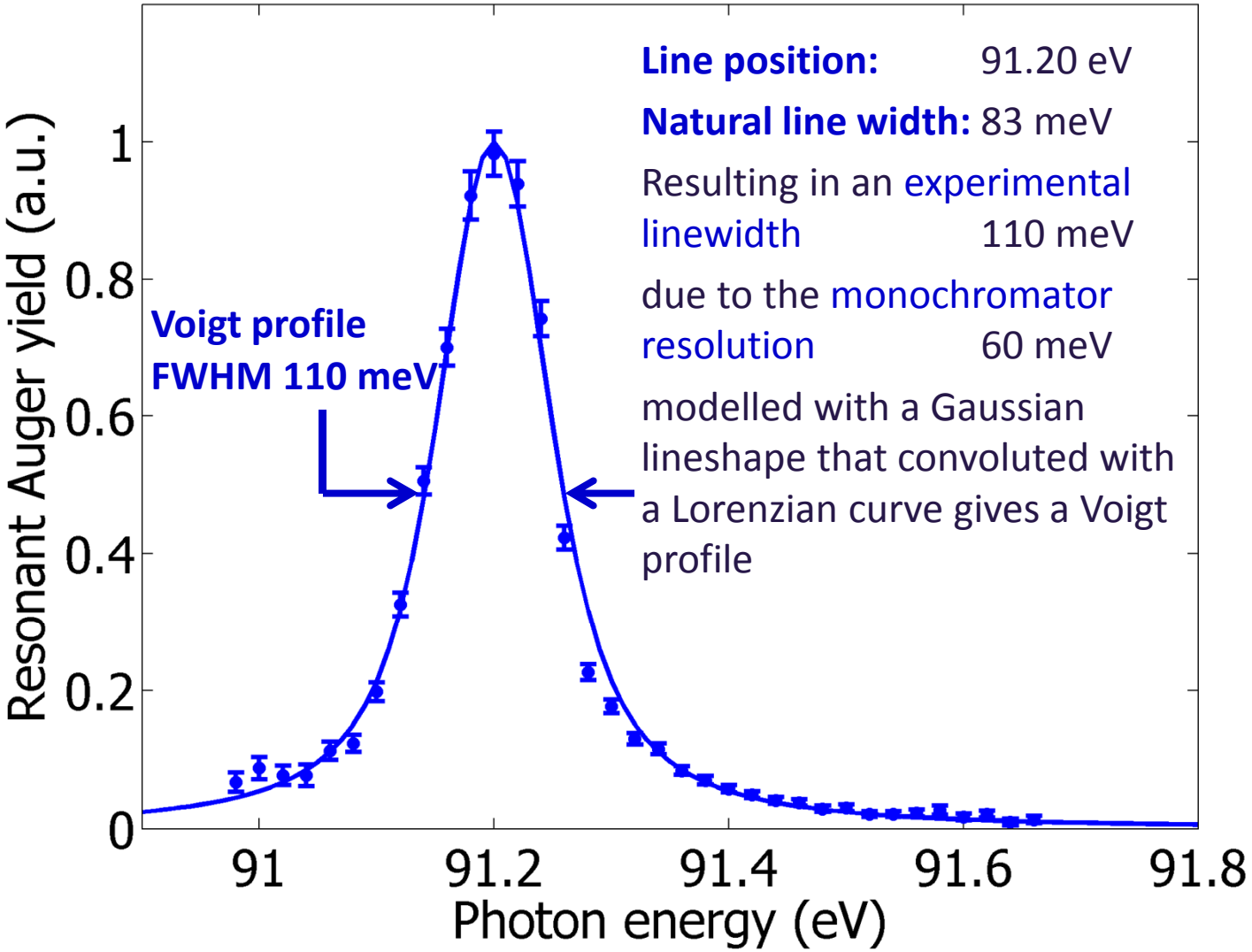
NIR laser OFF **NIR laser ON**

$I_{IR} \sim 9.2 \cdot 10^{11}$ W / cm^2

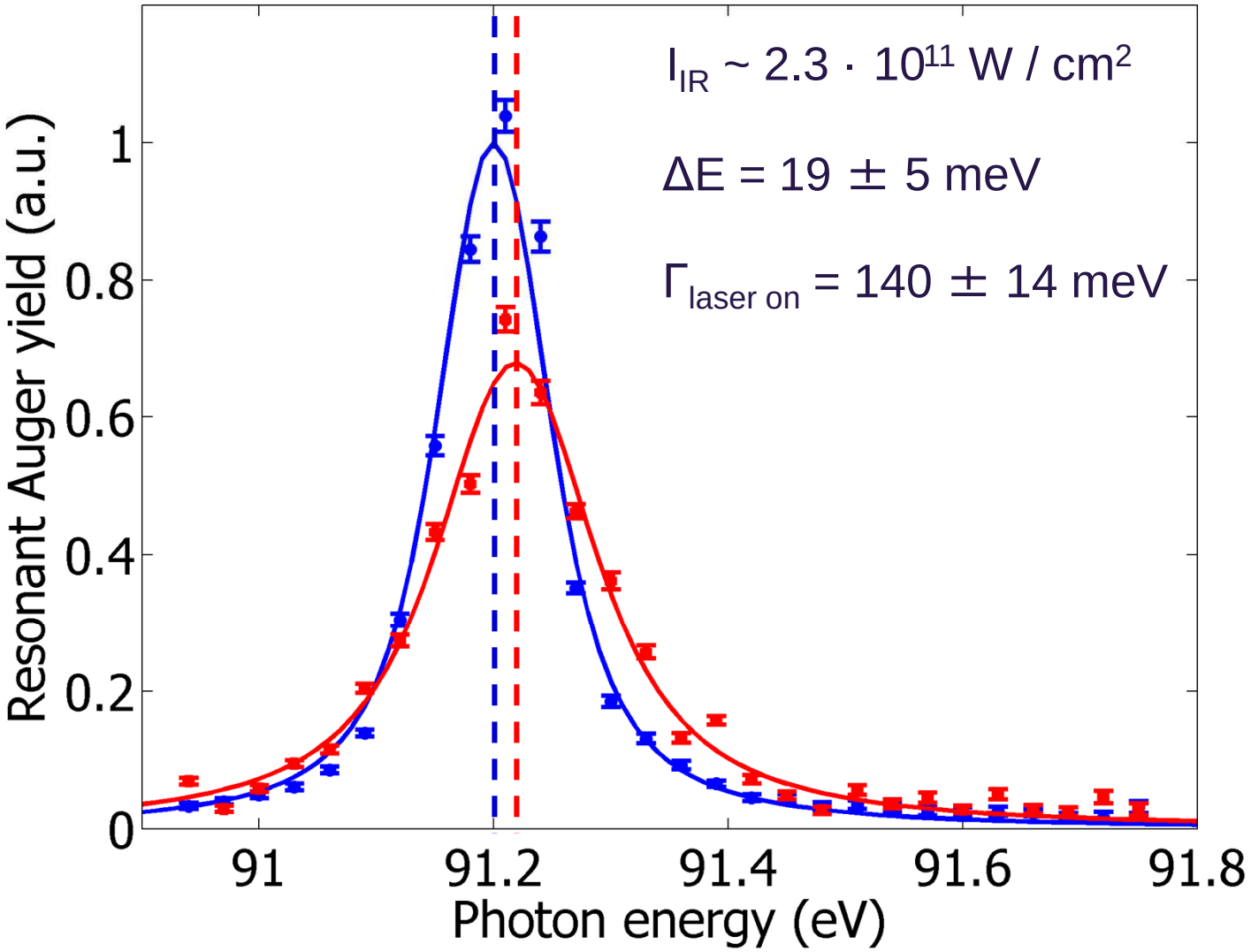


The resonance lineshape retrieved from the integrated resonant Auger electron yield ***normalized over the 4p PE line yield***

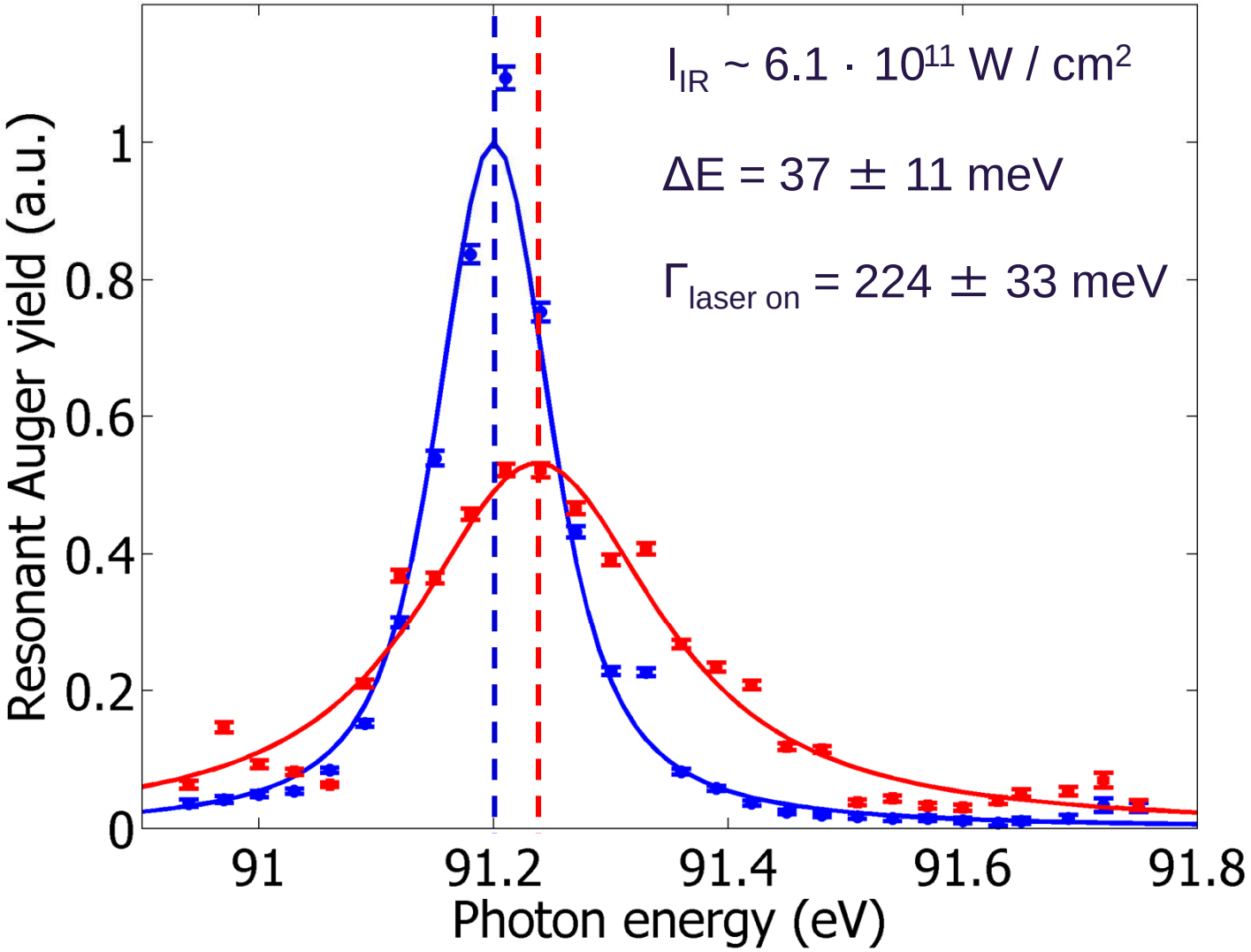
Kr 3d - 5p resonance lineshape



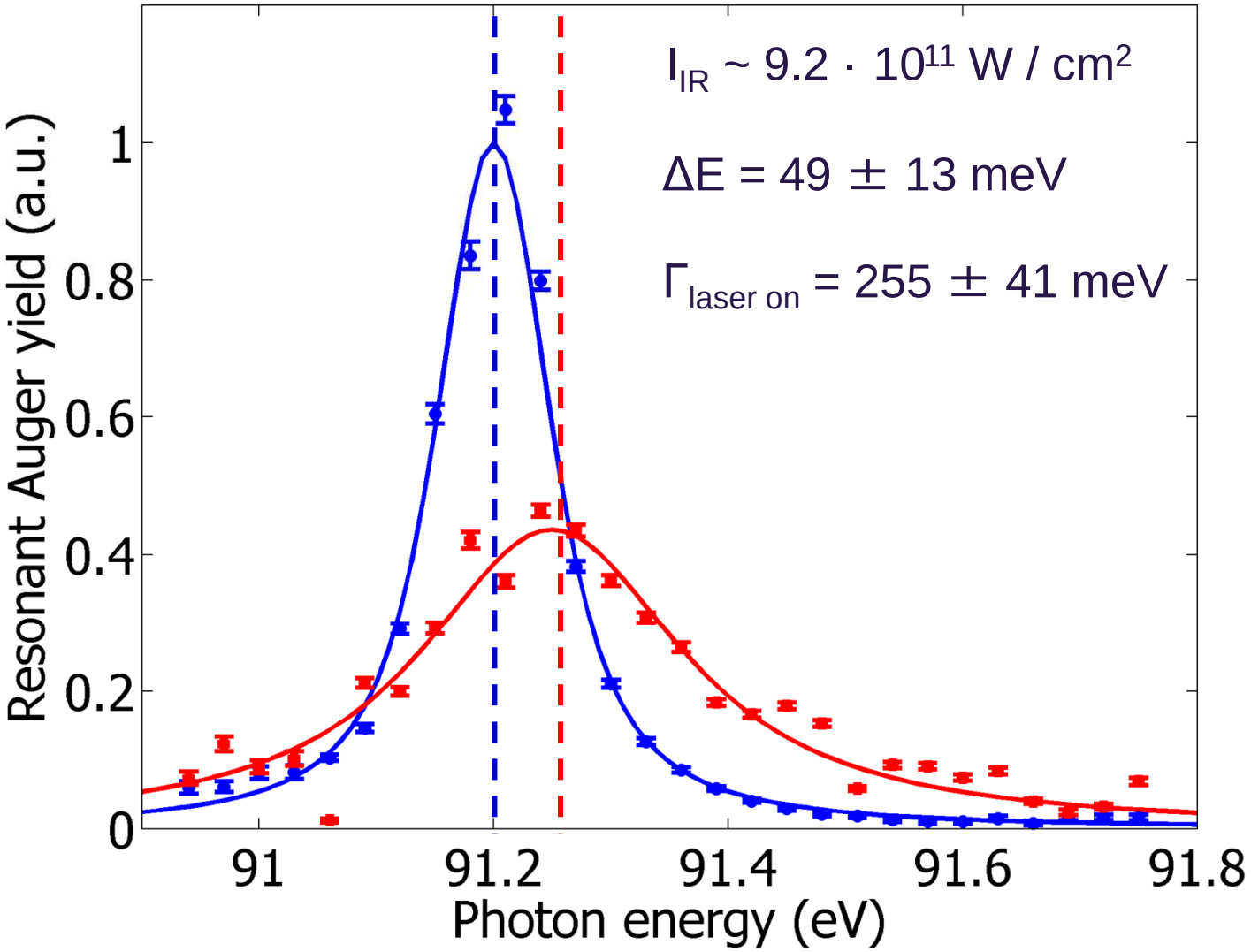
Kr 3d - 5p excitation: ponderomotive control by dressing IR field intensity



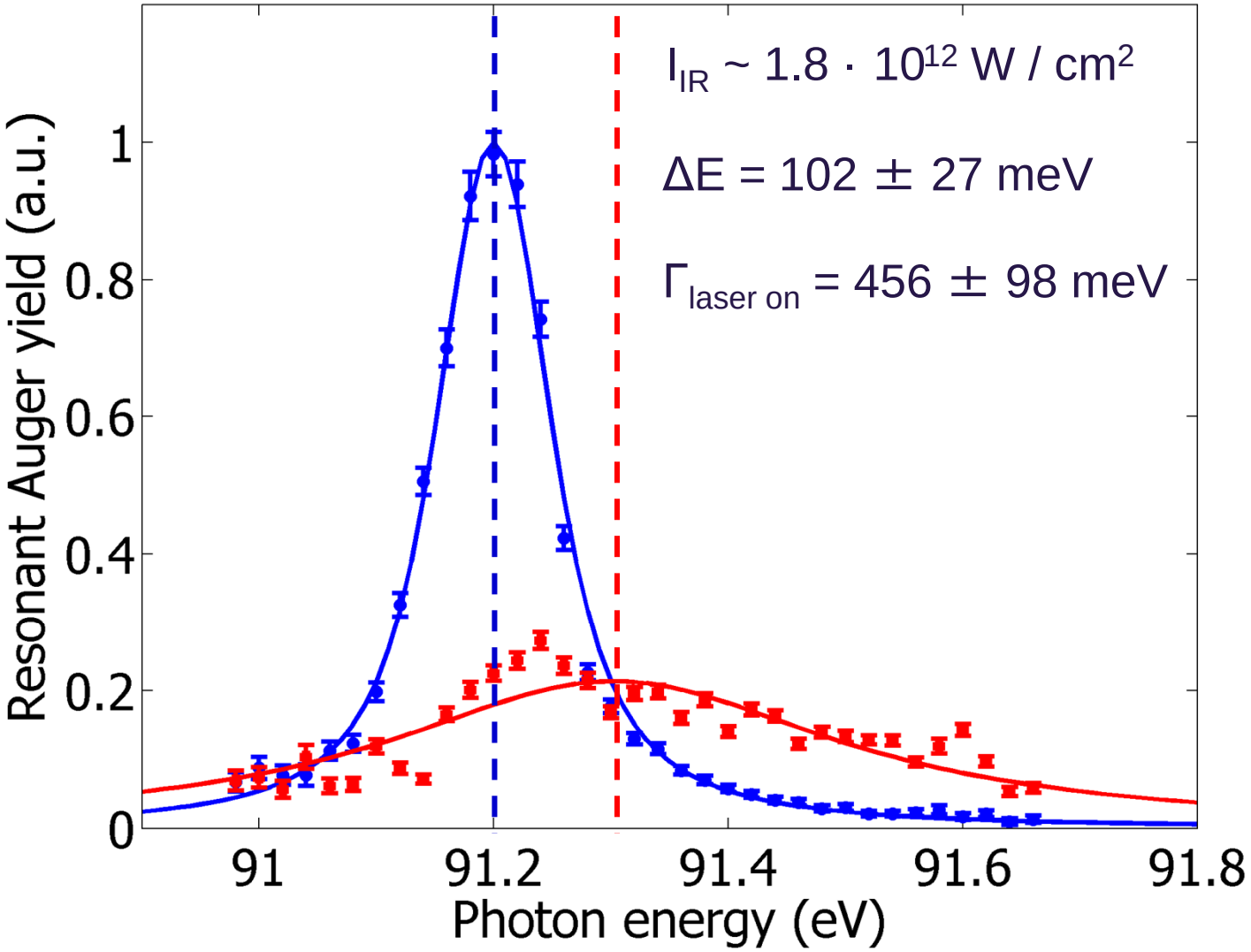
Kr 3d - 5p excitation: ponderomotive control by dressing IR field intensity



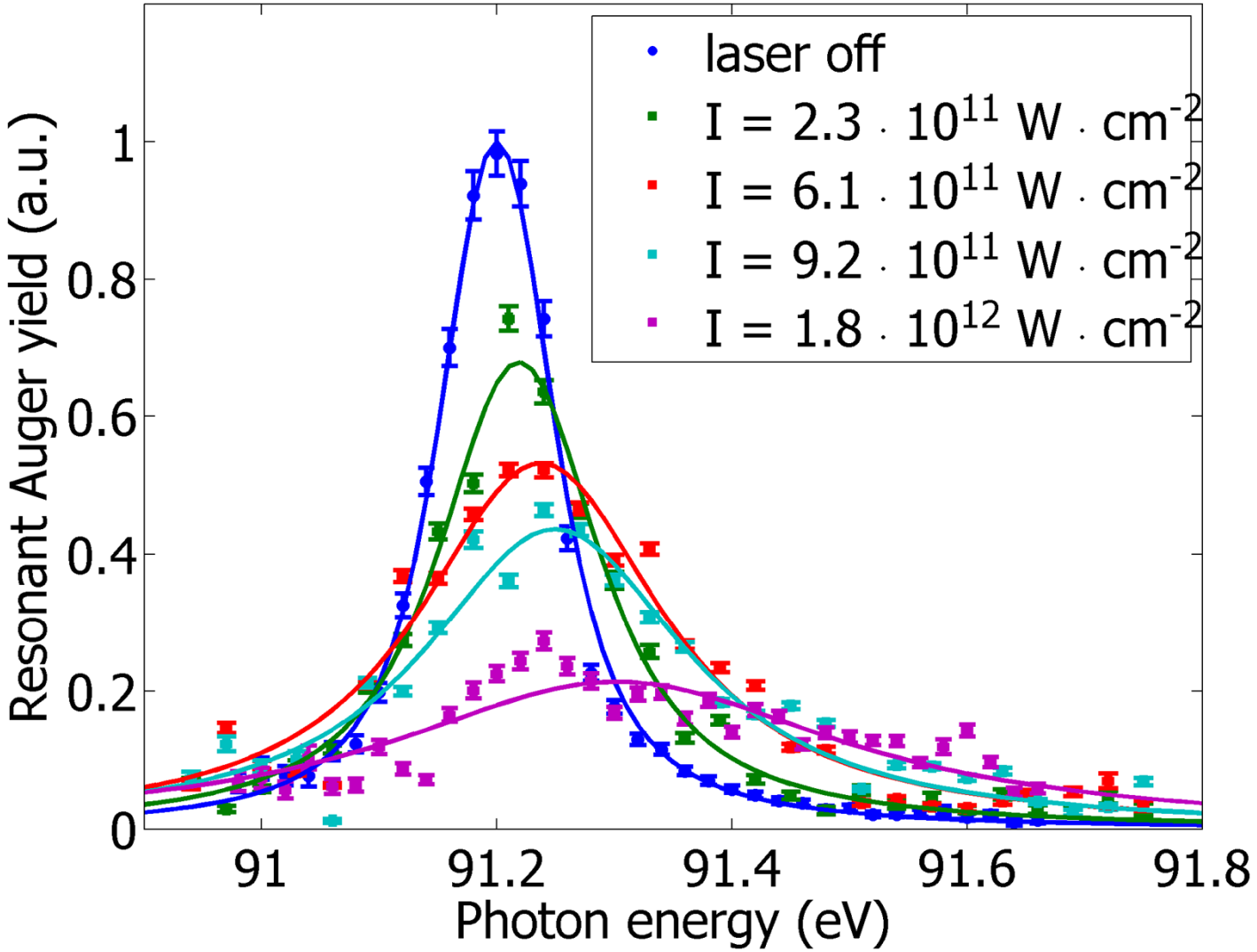
Kr 3d - 5p excitation: ponderomotive control by dressing IR field intensity



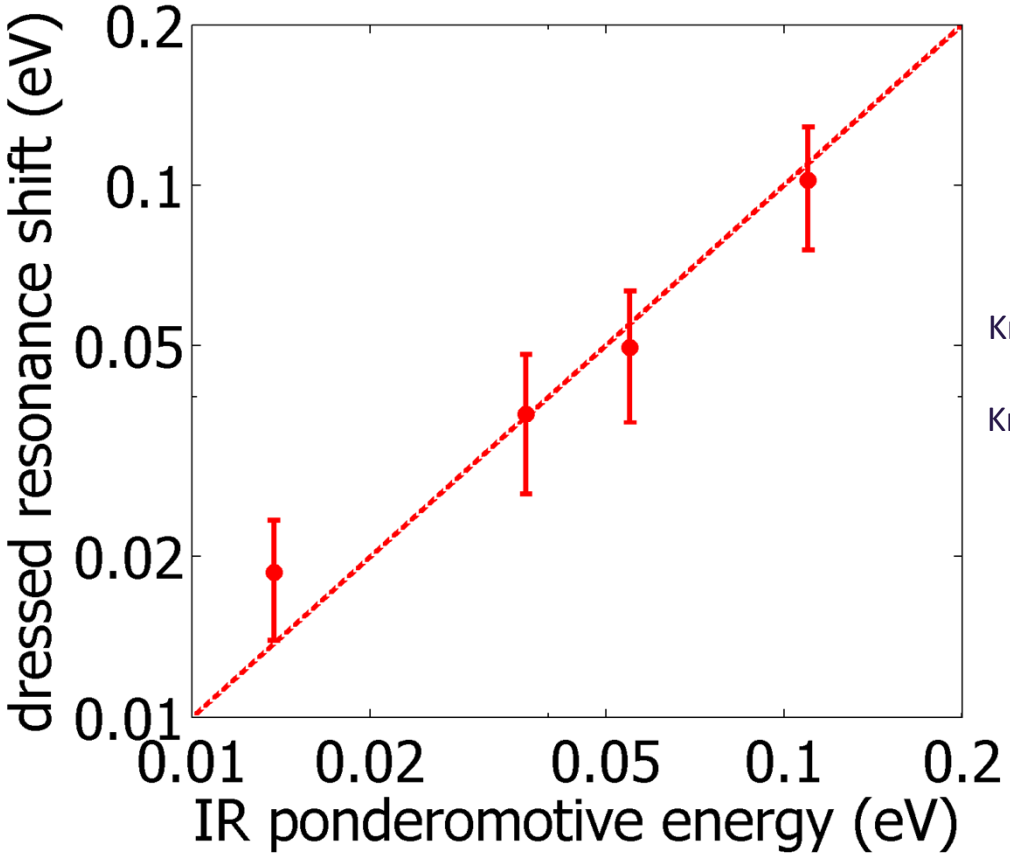
Kr 3d - 5p excitation: ponderomotive control by dressing IR field intensity



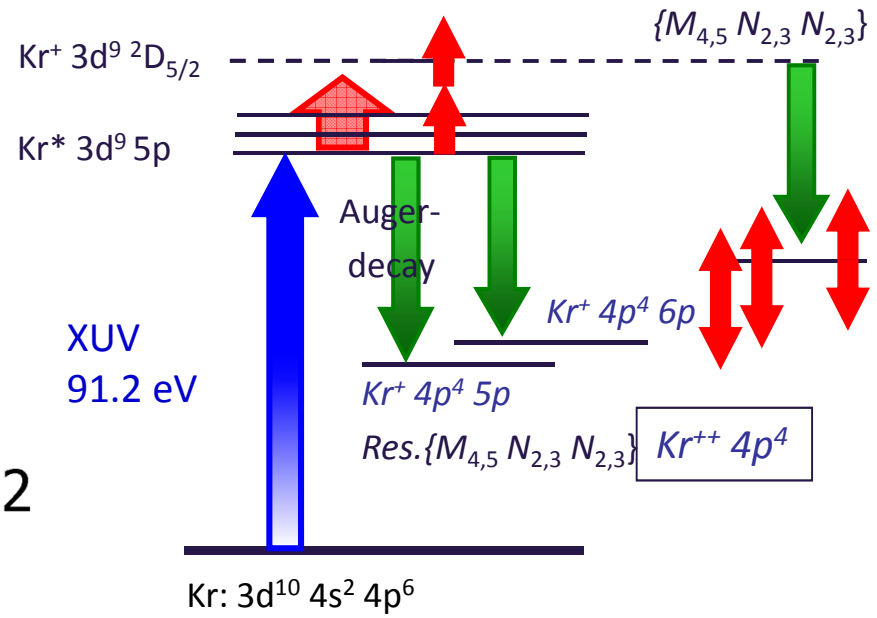
Kr 3d - 5p excitation: ponderomotive control by dressing IR field intensity



Resonance shift vs. IR ponderomotive energy



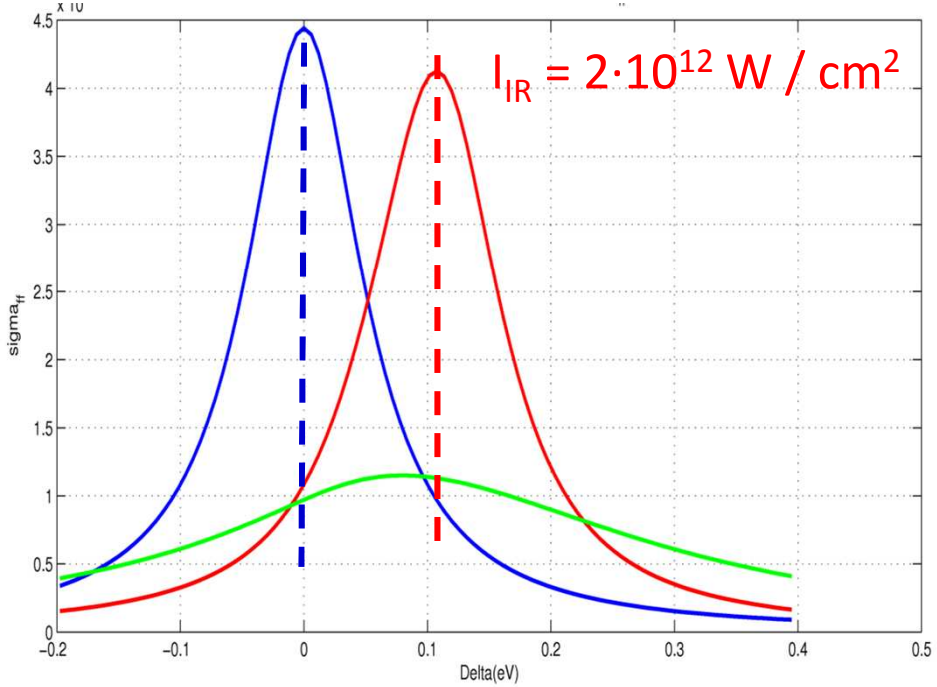
Resonance position shift is ponderomotive energy - driven

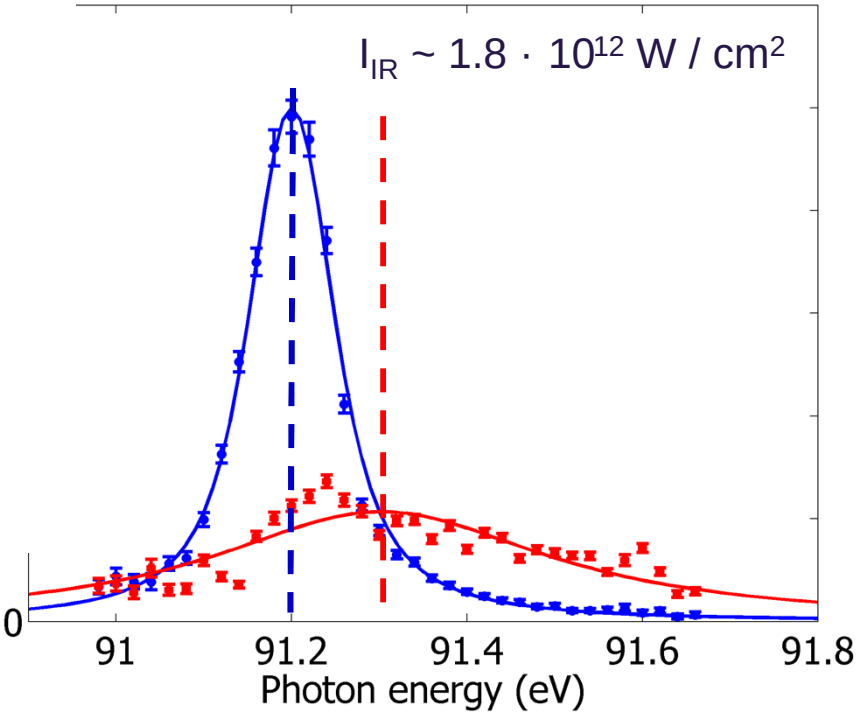


Ponderomotive control of Kr 3d - 5p excitation: theory

XUV only **XUV + NIR (ponderomotive shift)**

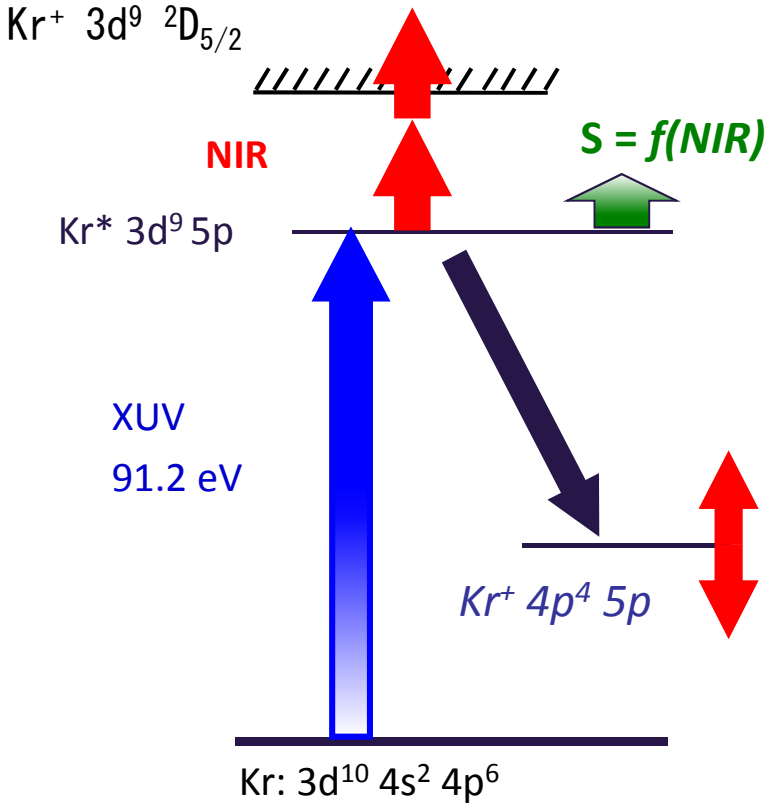
XUV + NIR (ponderomotive shift + two-photon ionization of 5p)

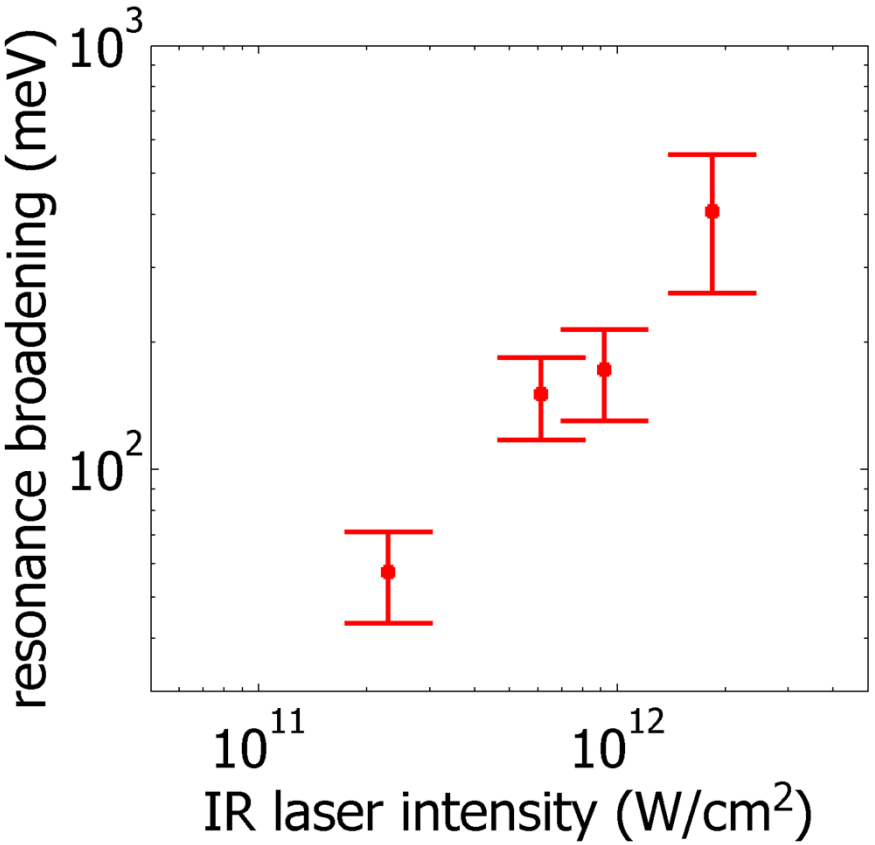




Theory: Peter Lambropoulos and Katerina Papamihail

Lineshape broadening vs. IR laser intensity

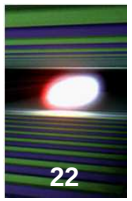




Intermediate states?
Broad laser band driven coupling?

Work in progress…

Summary



Two-color strong-field ionization

- Synchronized XUV and NIR pulses used at FLASH
- Single-shot capability of setup
- Observation of multiple sidebands and AC Stark Shift

Ponderomotive control of XUV atomic resonance

- Studied the impact of strong NIR fields on the Kr* $3d^9$ 5p resonance at 91.2 eV
- Using I(NIR) ~ 10^{12} W/cm^2 induced a ponderomotive shift of > 100 meV
- Idea: change an “opaque” to a transparent medium on a fs timescale
- Work-in-progress: Identify Auger lines from Kr^{2+} $4p^4$
- Work-in-progress: Comparison of exp. results with a sophisticated theoretical model
- Next: Measure Kr^+ / Kr^{++} ratio directly
- Next: tunable optical laser fields will allow further control, e.g. coupling of resonances

Acknowledgements

Experiment:

- European XFEL GmbH

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  Stefan Düsterer, Natalia Gerasimova and Harald Redlin

- School of Physical Sciences, Dublin City University

  Mossy Kelly and John Costello

- Department of Physics, Tongji University

  Wenbin Li

Theory:

- IESL-FORTH, University of Crete

  Peter Lambropoulos and Katerina Papamihail