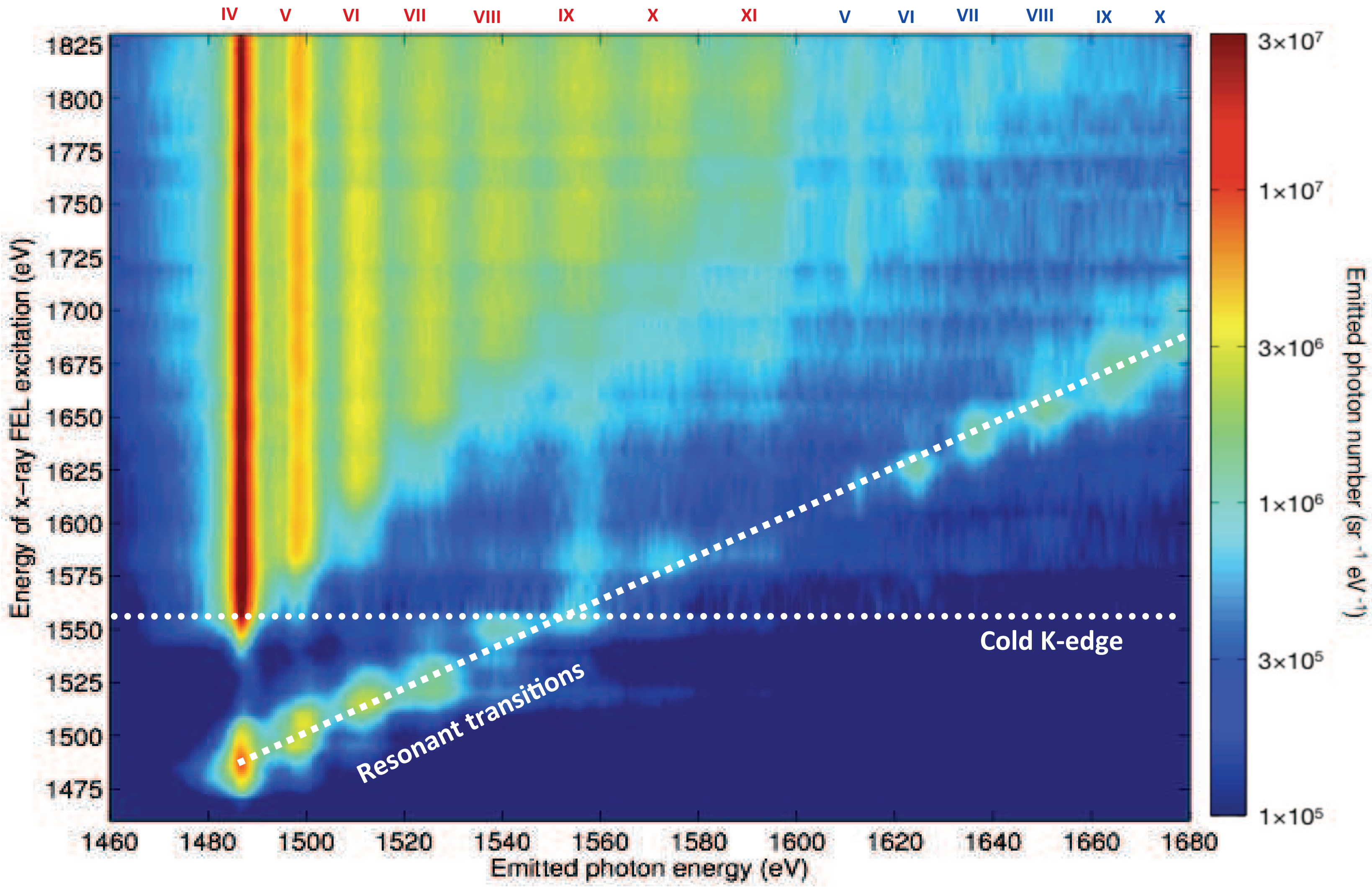
K-shell spectroscopy of Hot Dense Aluminium



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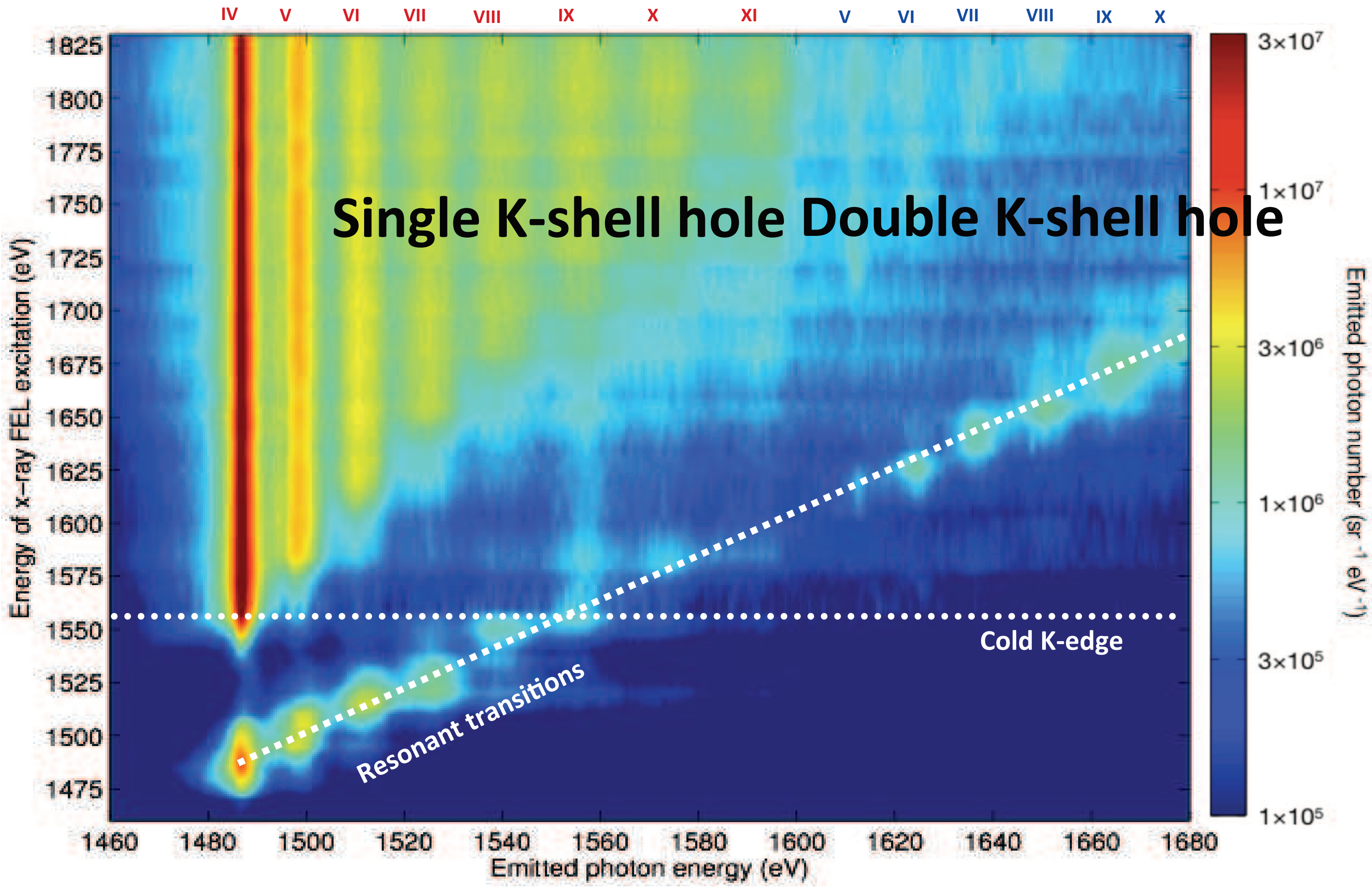
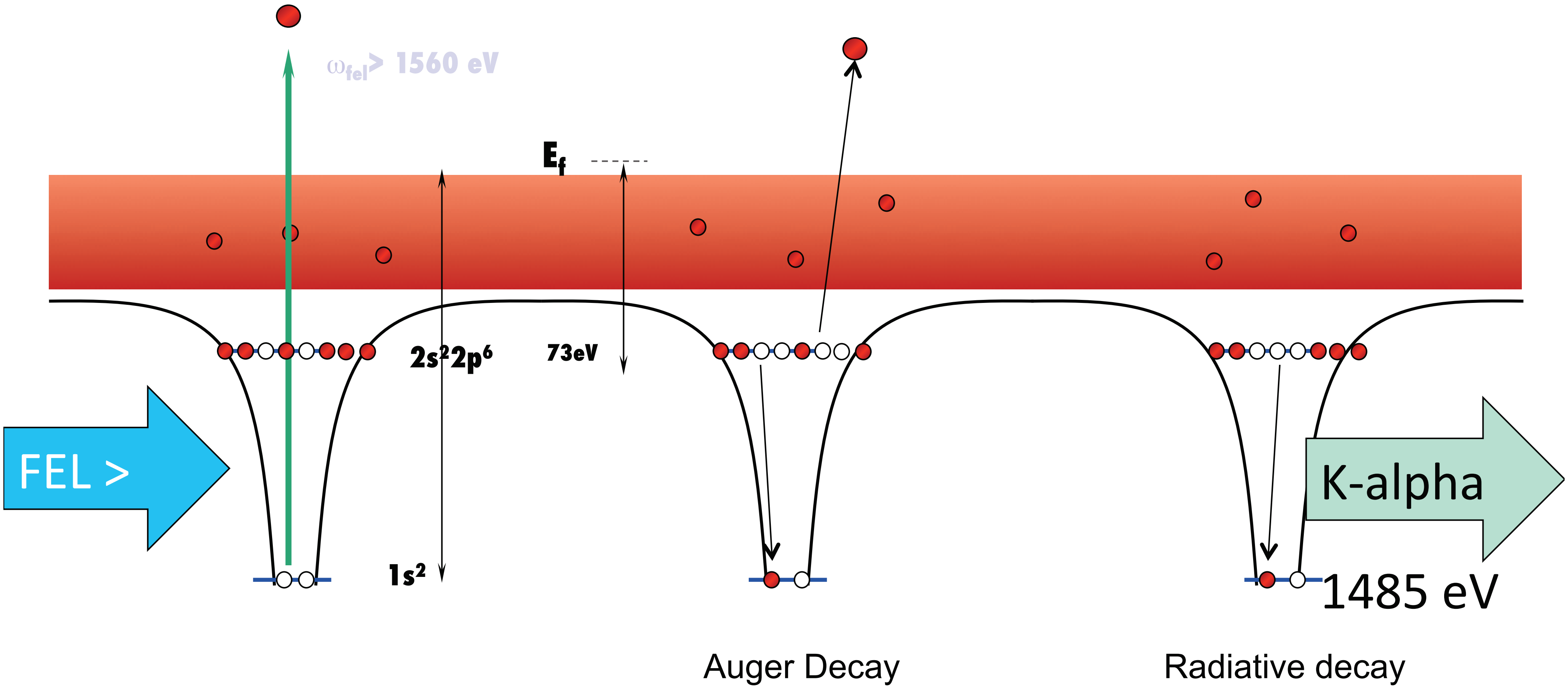


Hollow Atom Emission



Note: The dominant Auger decay ejects two L-shell electrons for each input photon – exactly as Linda Young showed for Neon gas-jet experiments at LCLS .

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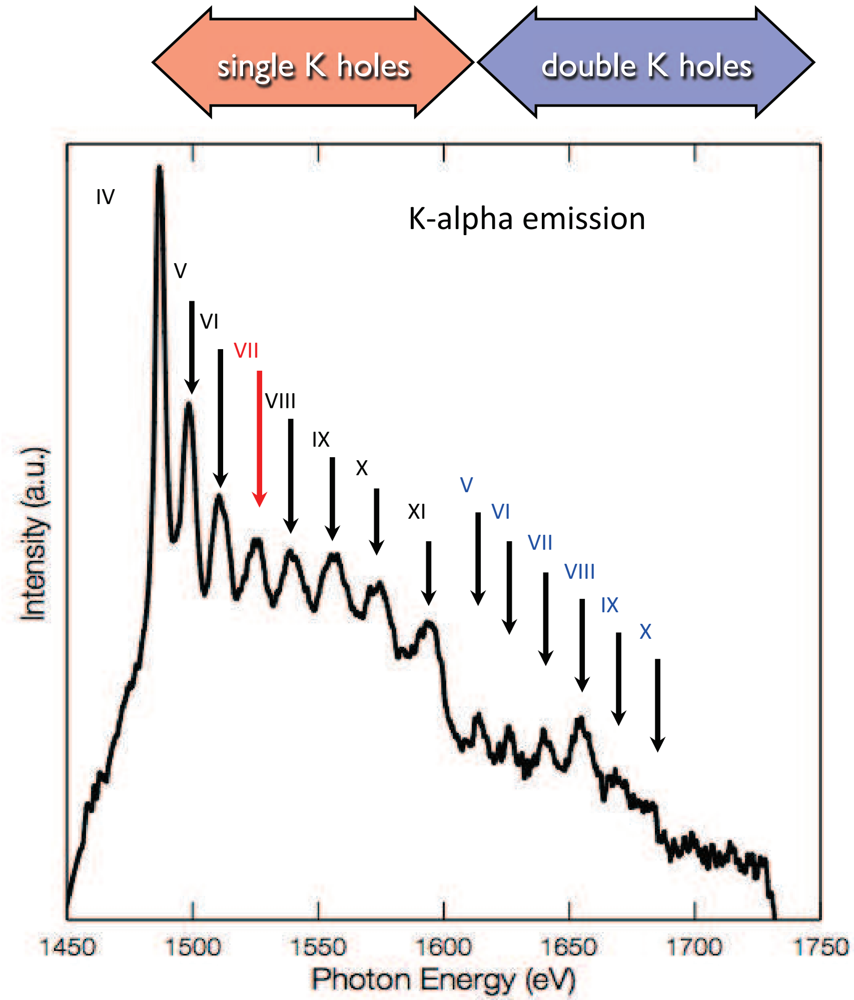
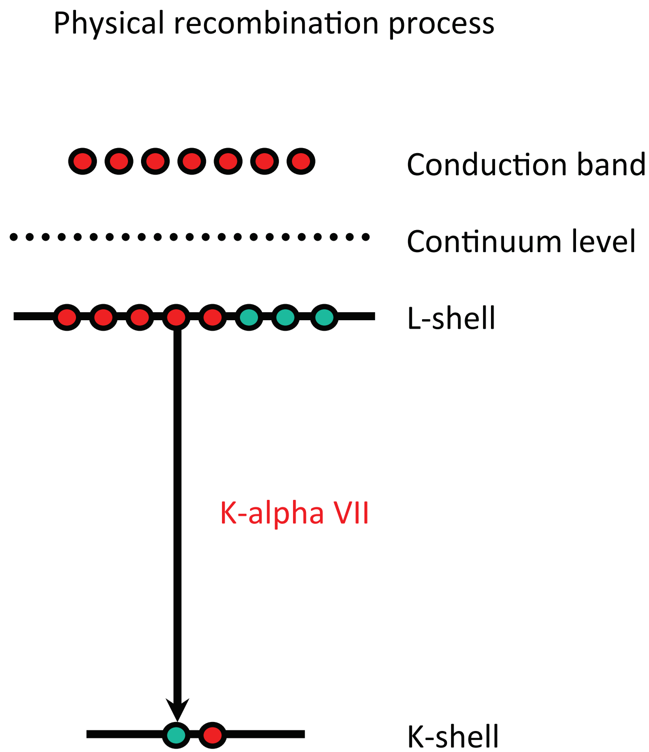
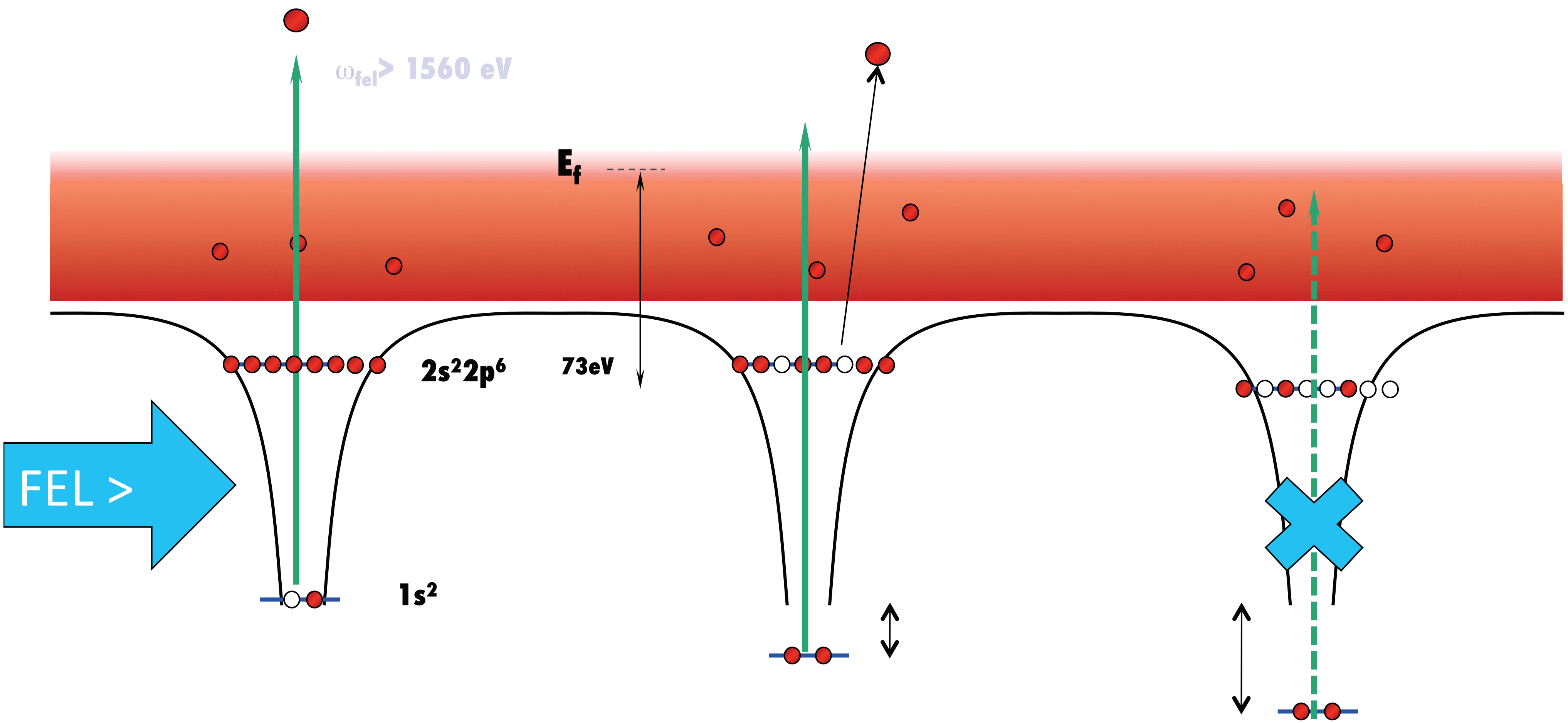




FEL photon energy: 1830 eV

K-edge/alpha shift



As the L-shell is ionized the K-electrons become more tightly bound. Eventually, if the FEL photon energy was initially only just greater than the original K-edge, it can no longer excite core holes in the highly ionized states. LCLS is a PUMP and a PROBE.

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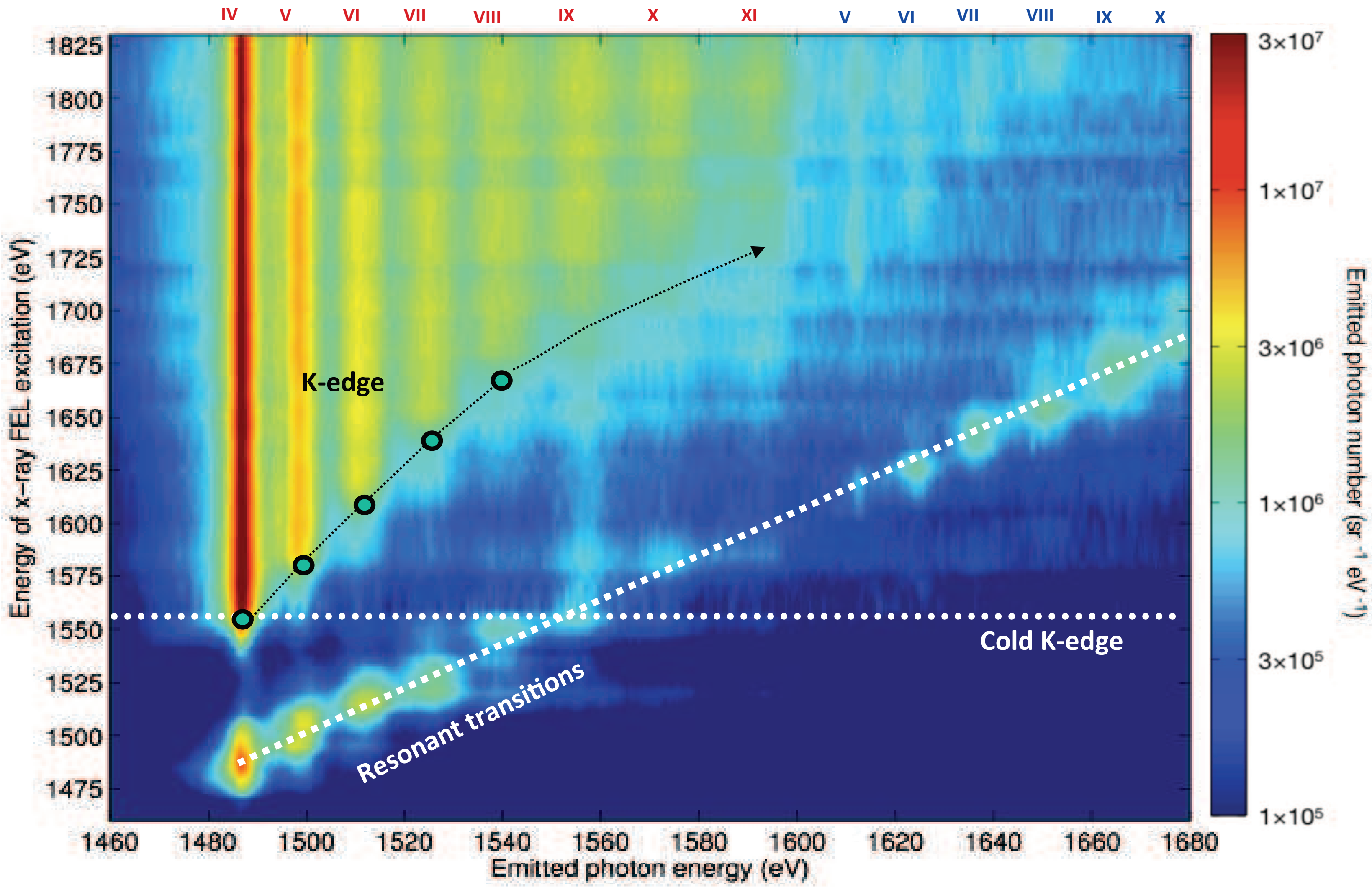


Modelling experiment with SCFLY (NAVI)

- SCFLY (NAVI) code: super-configuration collisional–radiative code, based on the FLYCHK package, freely available online (http://nlte.nist.gov/FLY/)
- 0-dimensional
- What does it calculate?
  - time dependent level populations, charge state distributions in a non-LTE plasma
  - self-consistent calculation of temperature determined by the X-ray absorption, assume instant electron thermalization.
  - emission spectra

- FEL experiment-specific improvements on FLYCHK
  - increased number of super-configurations
  - improved photo-absorption line profiles (off-peak line-wing pumping)
  - additional hollow-ion configurations added, double K-shell holes accounted for

From simulation to experiment …

Experimental data is integrated:

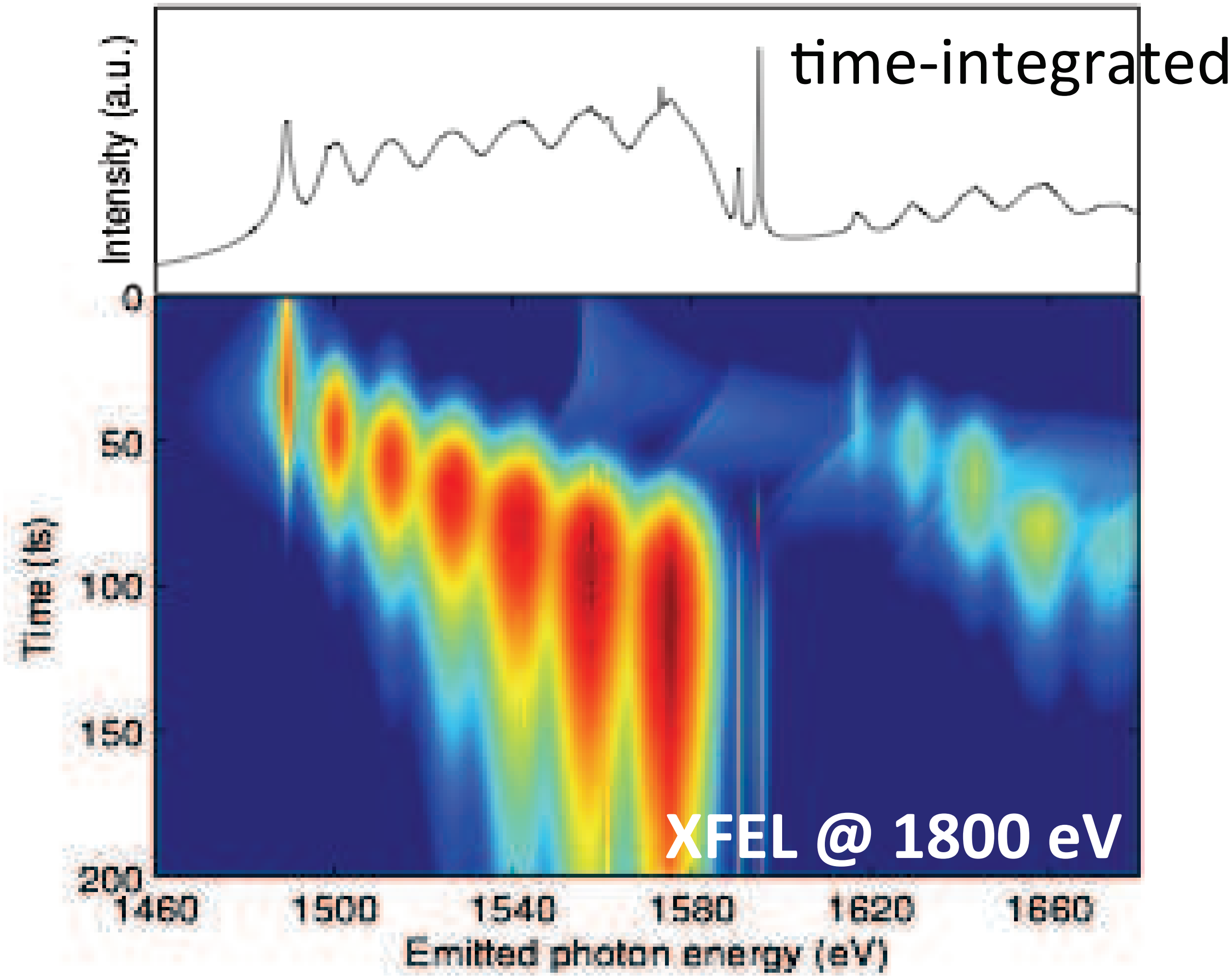
- **temporally** over duration of X-ray pulse: time-dependent simulation assume 80 fs Gaussian, ignore FEL profile, for a single-intensity calculation

- **spatially** over depth and 2D beam profile on target: treat depth as slab thickness in CR code, experimentally determine spot profile
- simulate effective intensity distribution on target by many single SCFLY calculations, weighted by measured profile on target

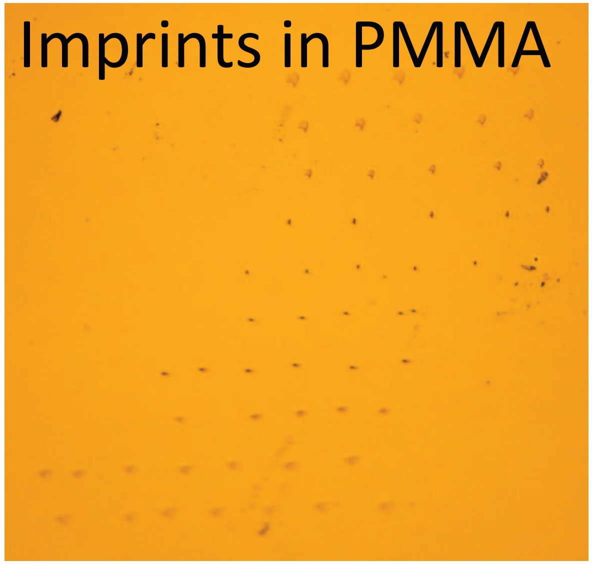
- We temporally integrate 24 different intensities to take into account the experimental spot.

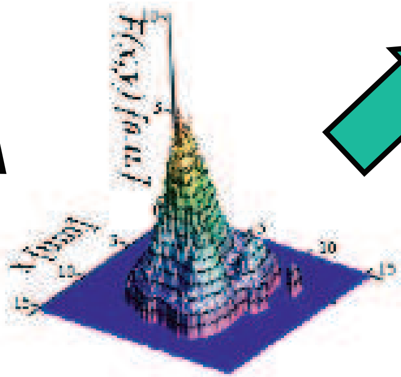
- NO adjusted parameters.

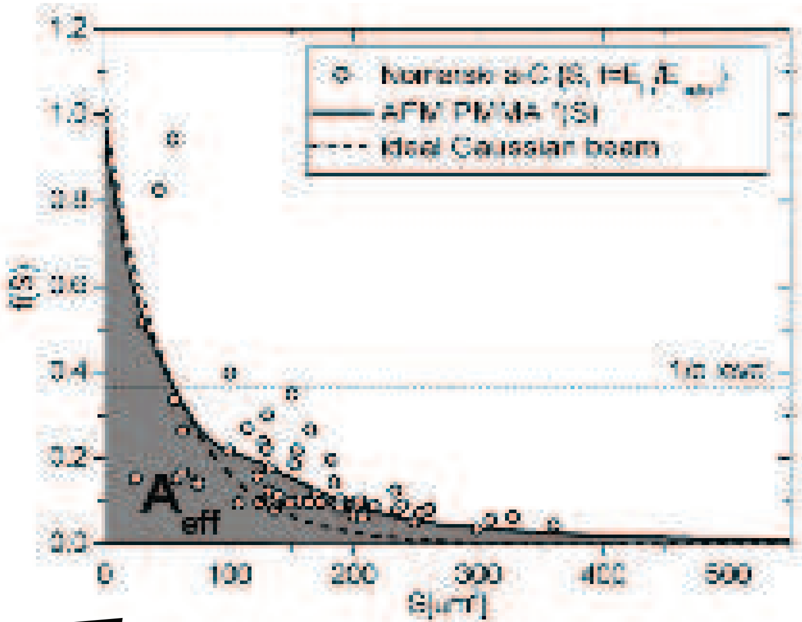
Time-dependent emission at single intensity



Spatial intensity profile on target

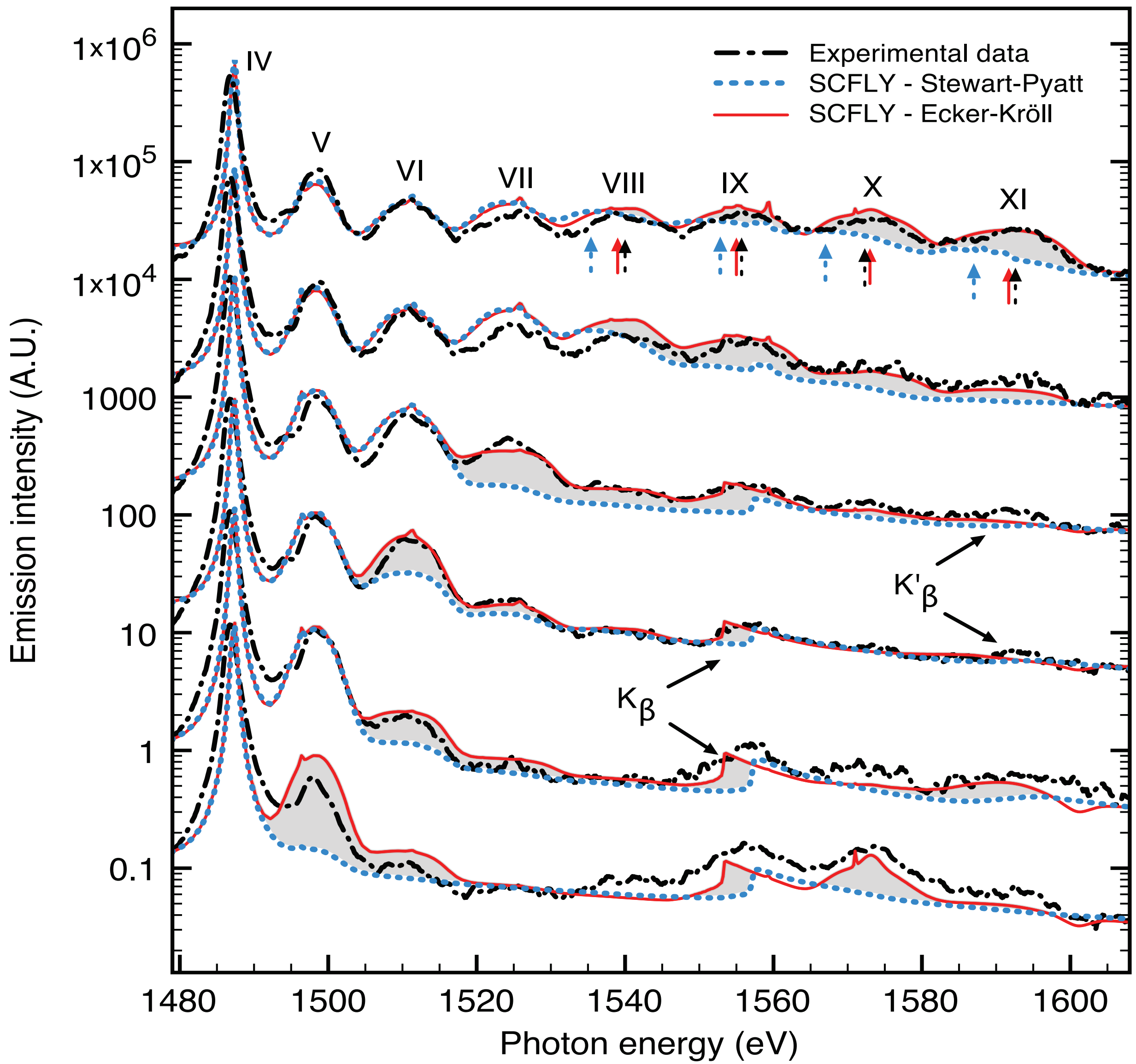




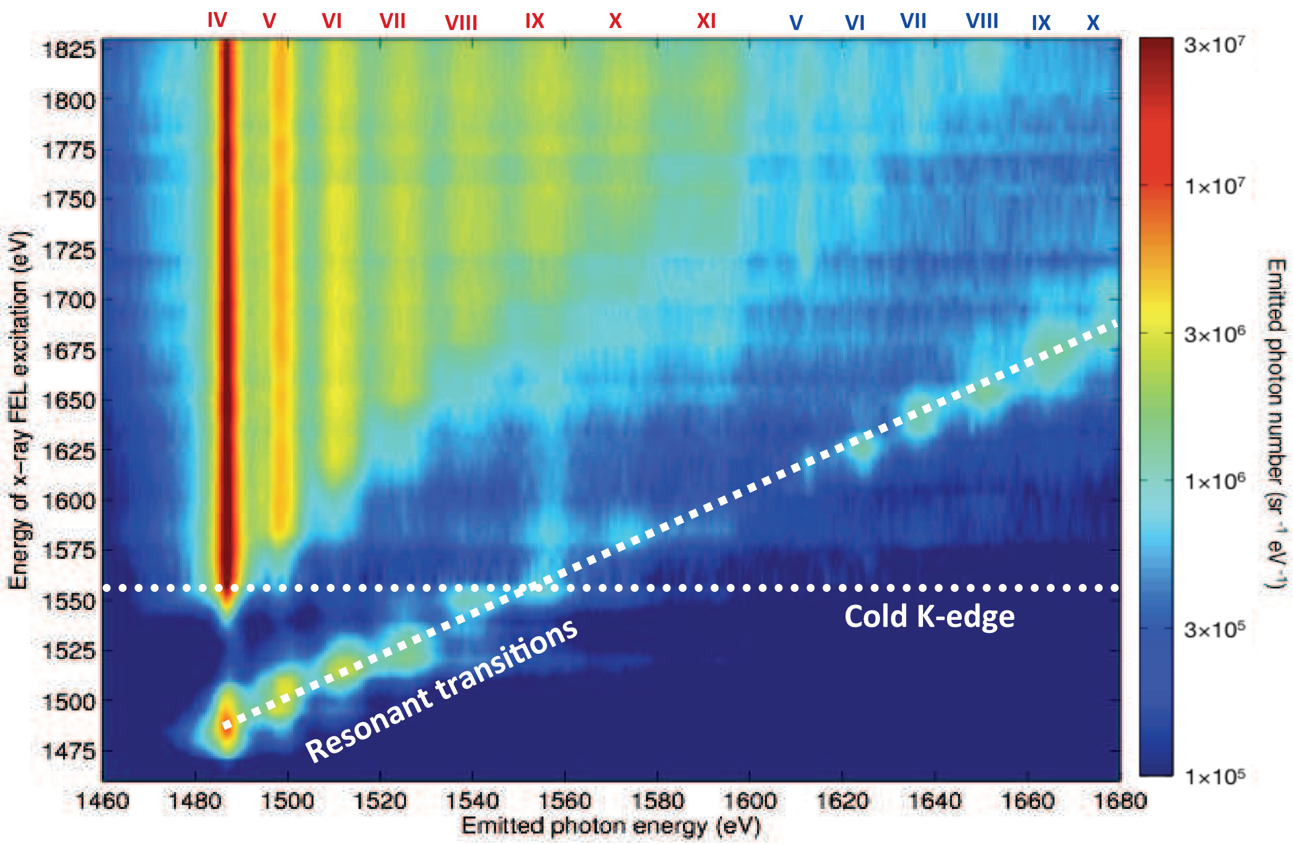


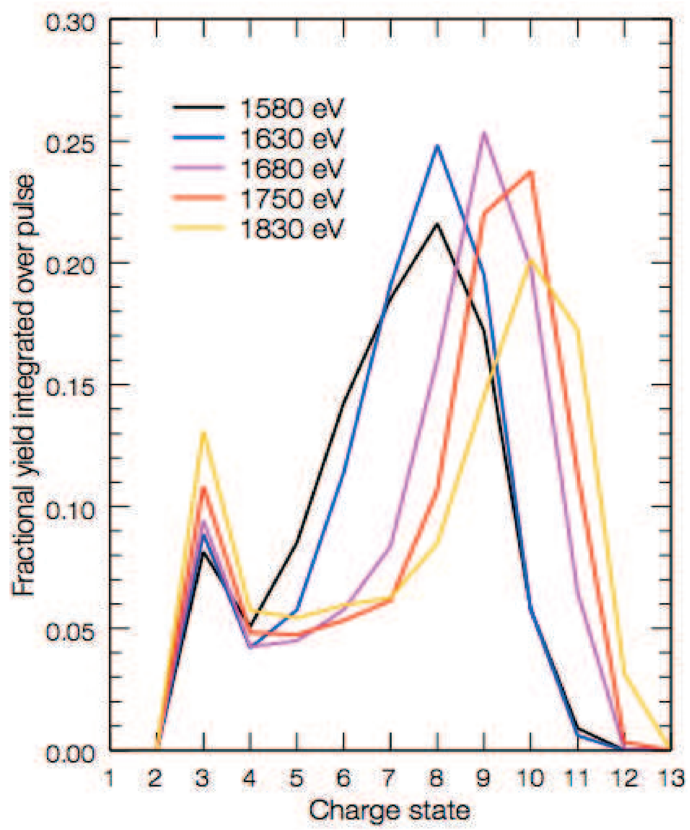
Chalupsky et al., Optics Express **18**, 27836 (2010)

Measured and Calculated Spectra



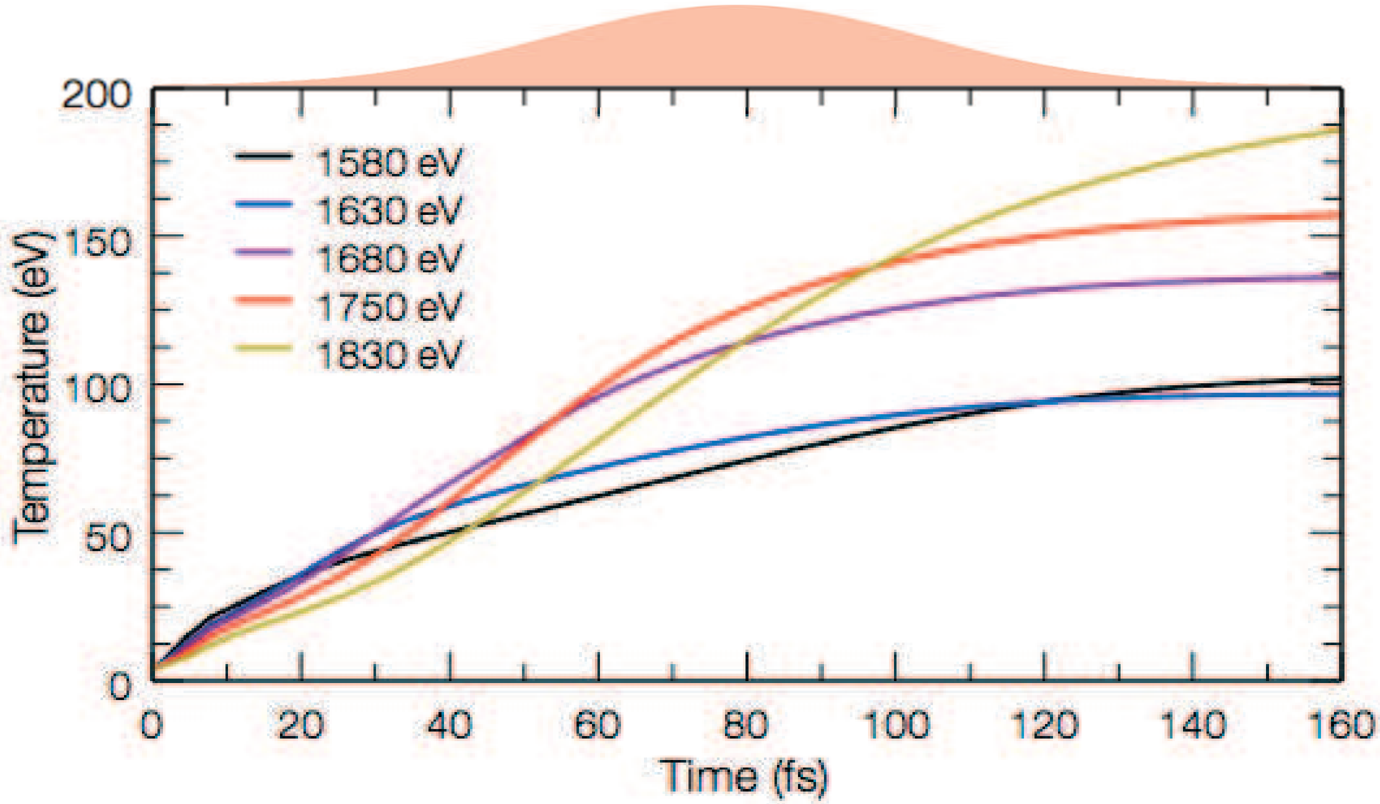
CSD and emission spectrum



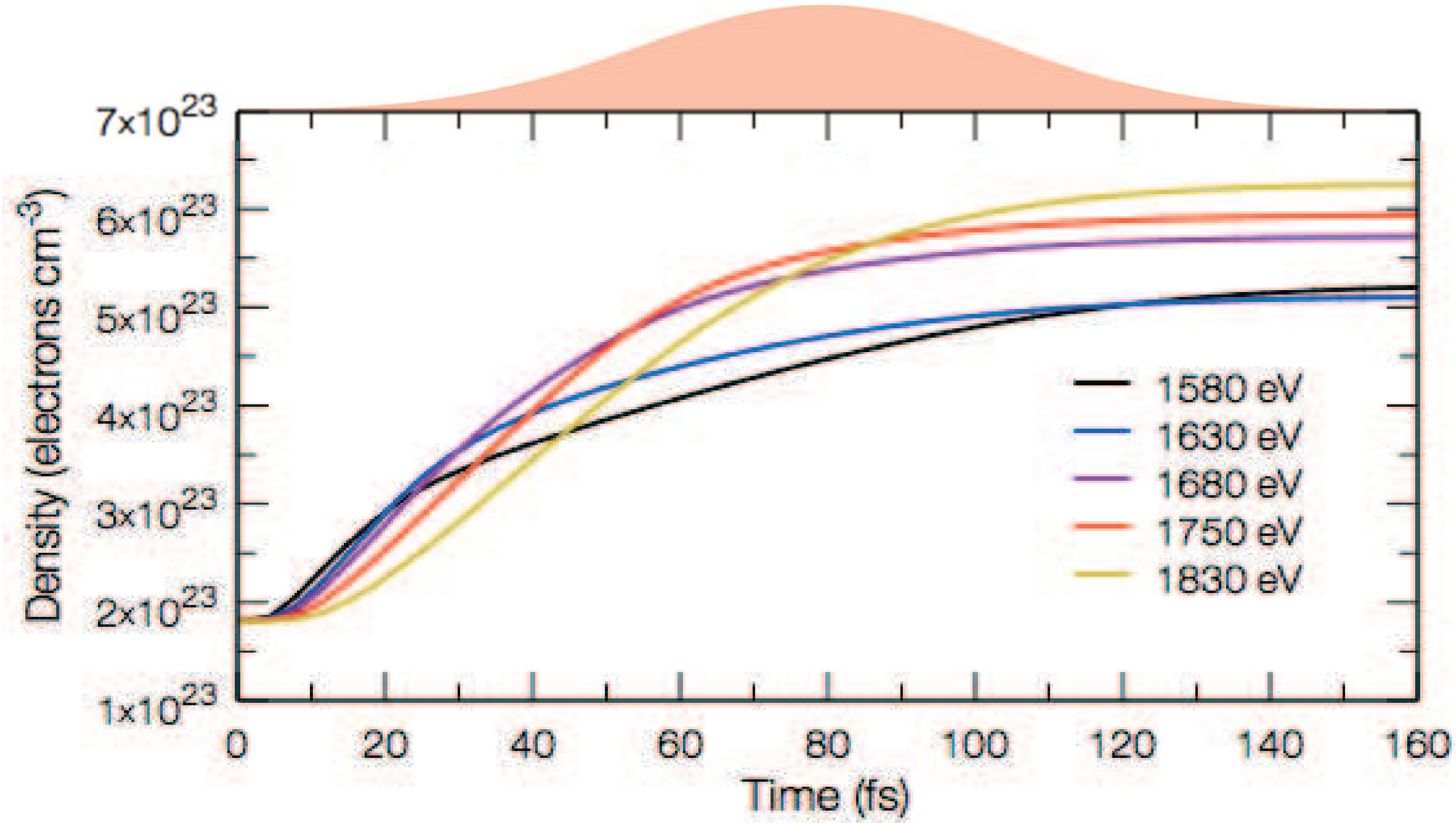


Plasma parameters: electron temperature

- Temperature is calculated self-consistently from the absorbed fraction of X-ray energy. **Instant equilibration is assumed** (justified by high density). No information inferred from spectra.
- Simulated FEL pulse peaks at 80 fs with a FWHM of 80 fs
- Ground state cross-sections largely irrelevant - excited/ionized states determine absorption



Plasma parameters: free-electron density

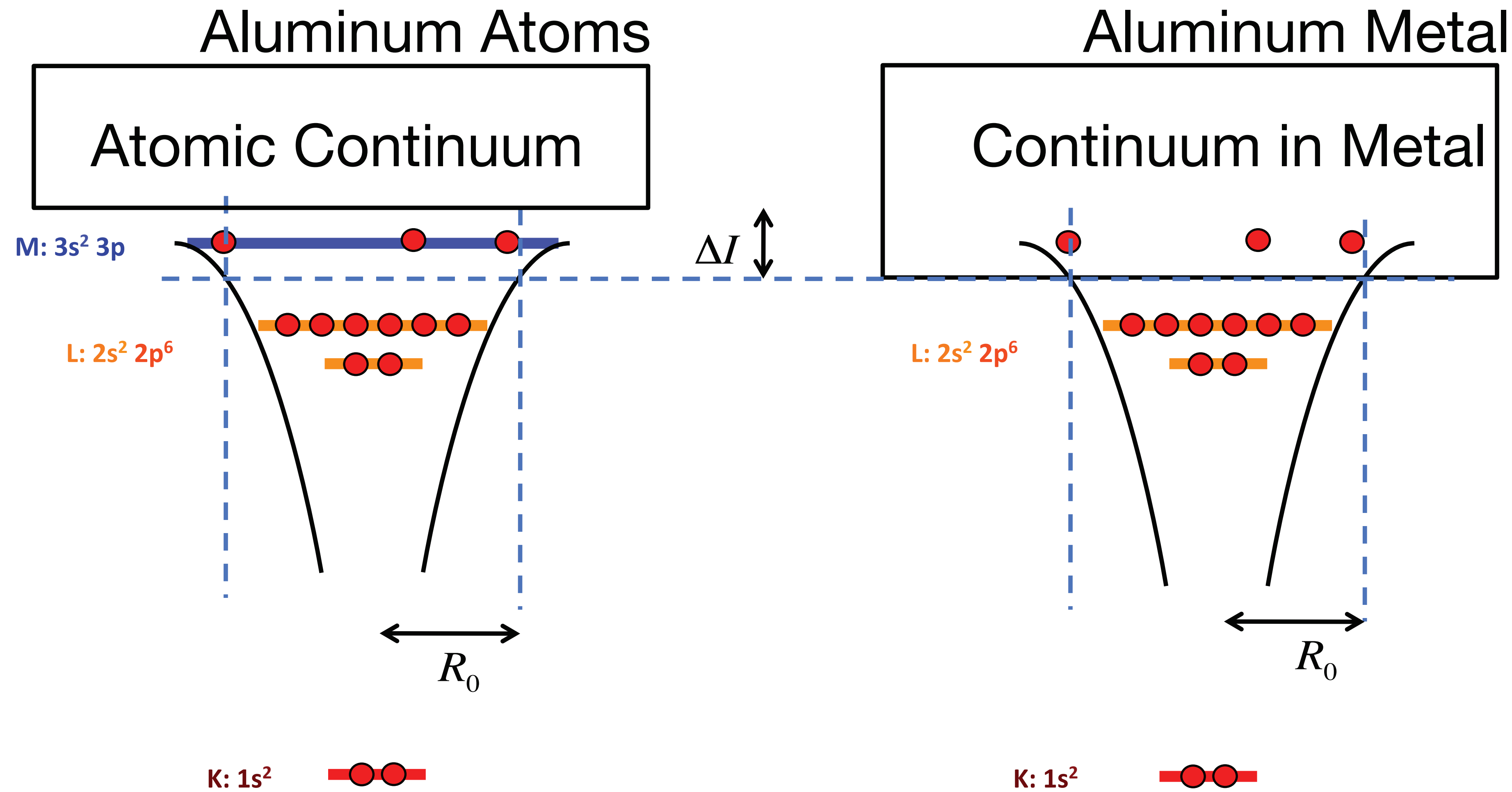


Ion density of solid-state Al (2.7 g cm^{-3})

The "Ion Sphere" Model of IPD

$$\frac{4\pi R_0^3}{3} = \frac{z^*}{n_e} = \frac{1}{n_i}$$

$$\Delta I = C\frac{z^* e^2}{4\pi\varepsilon_0 R_0}$$



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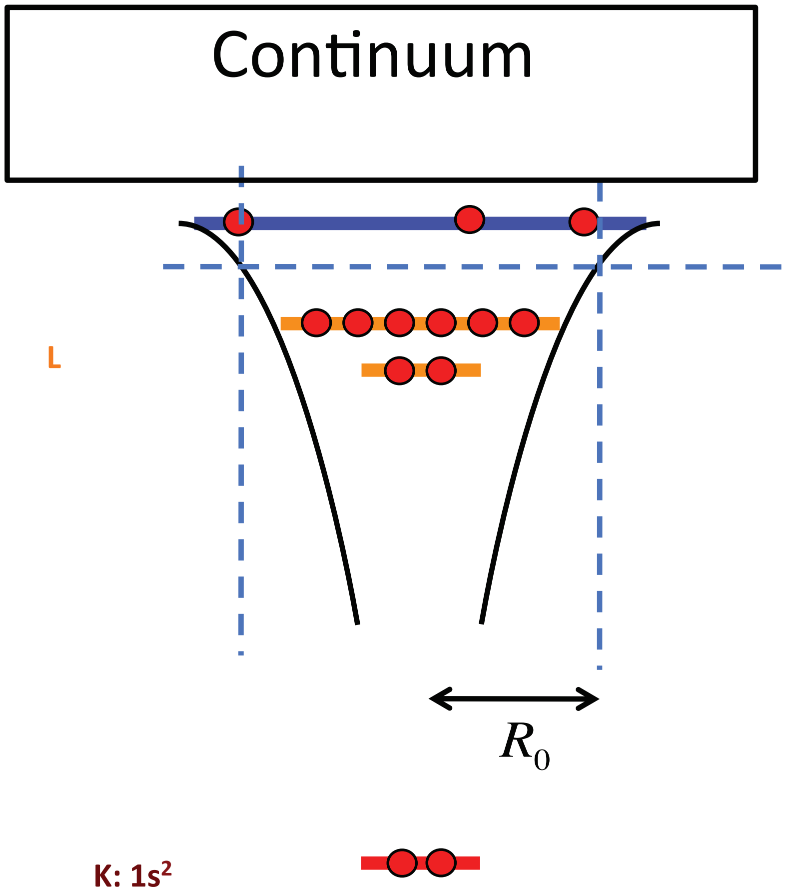

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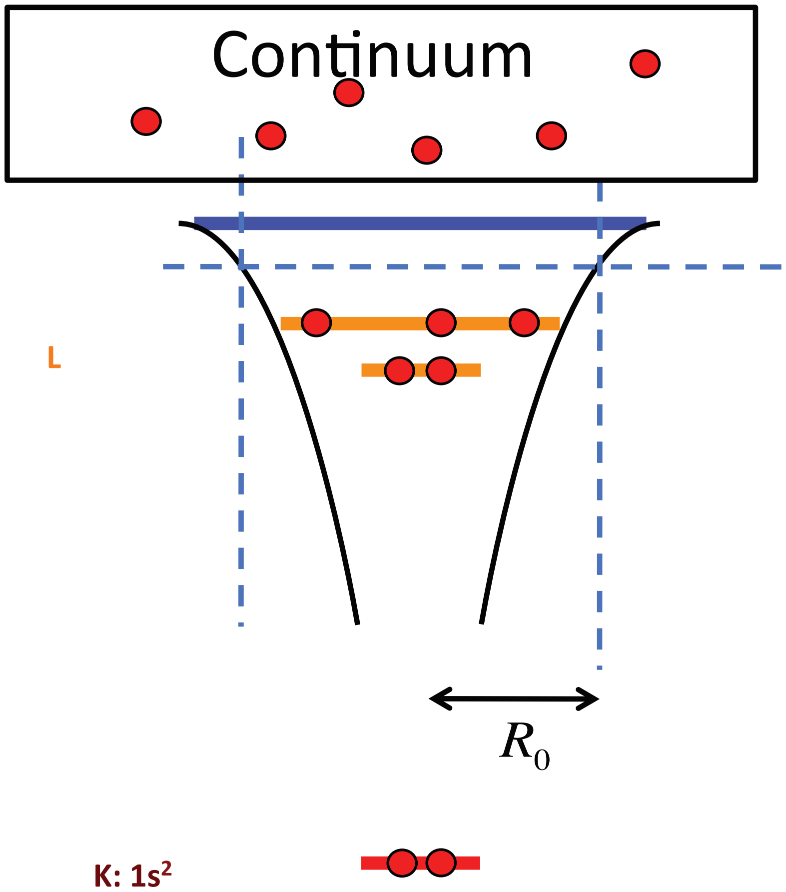

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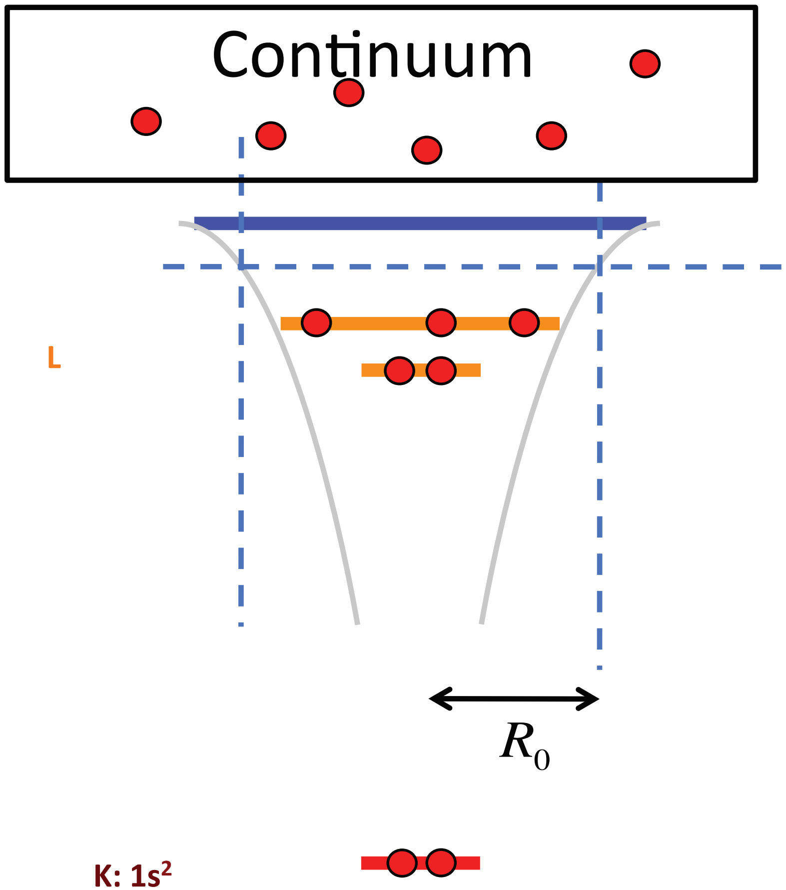

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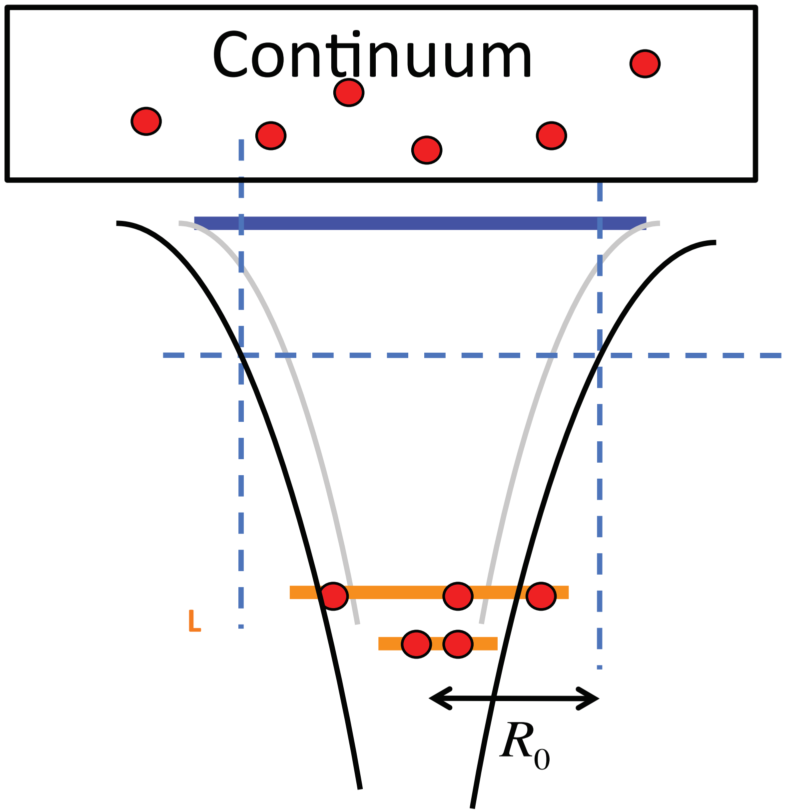

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