

Ultrafast carrier dynamics throughout the three-dimensional Brillouin zone of the Weyl semimetal PtBi₂



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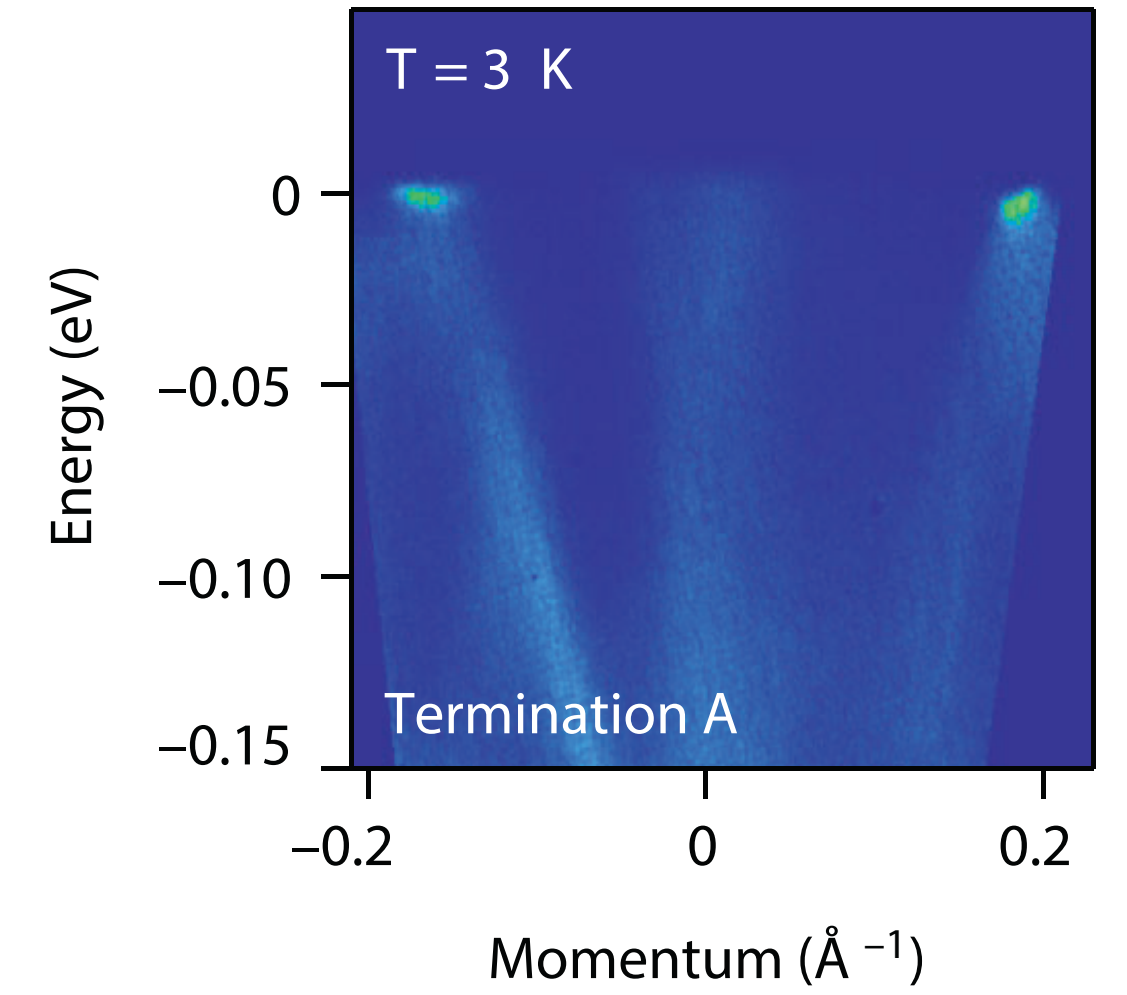
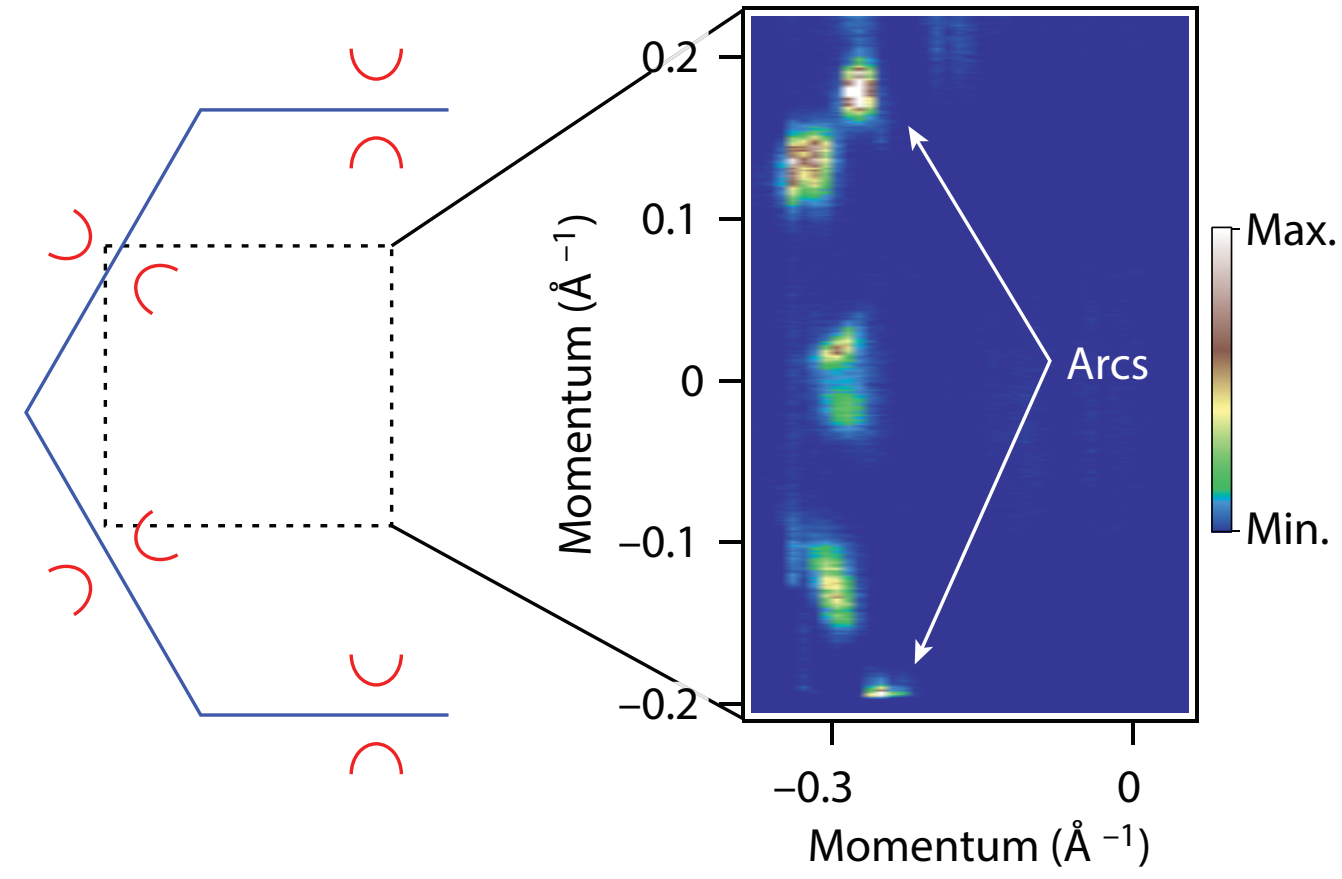
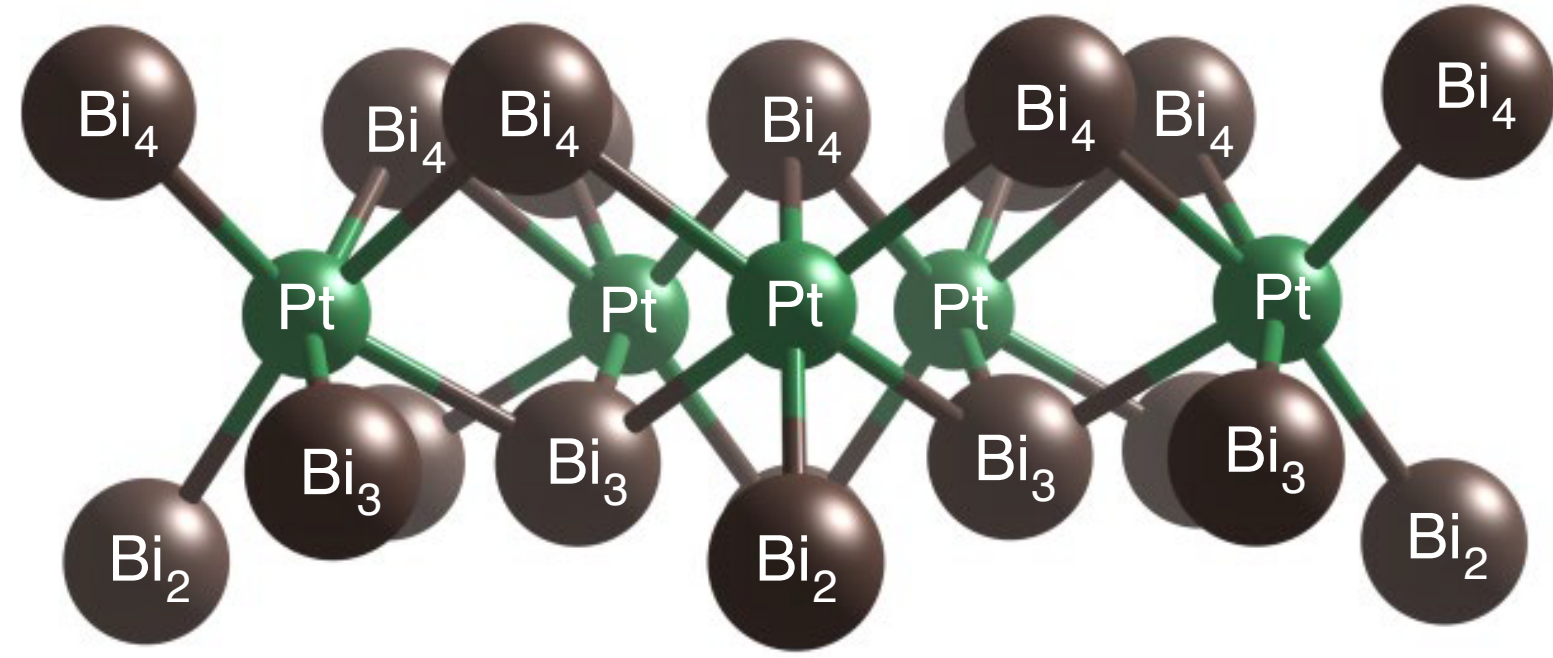
Saicharan Aswartham

Grigory Shipunov

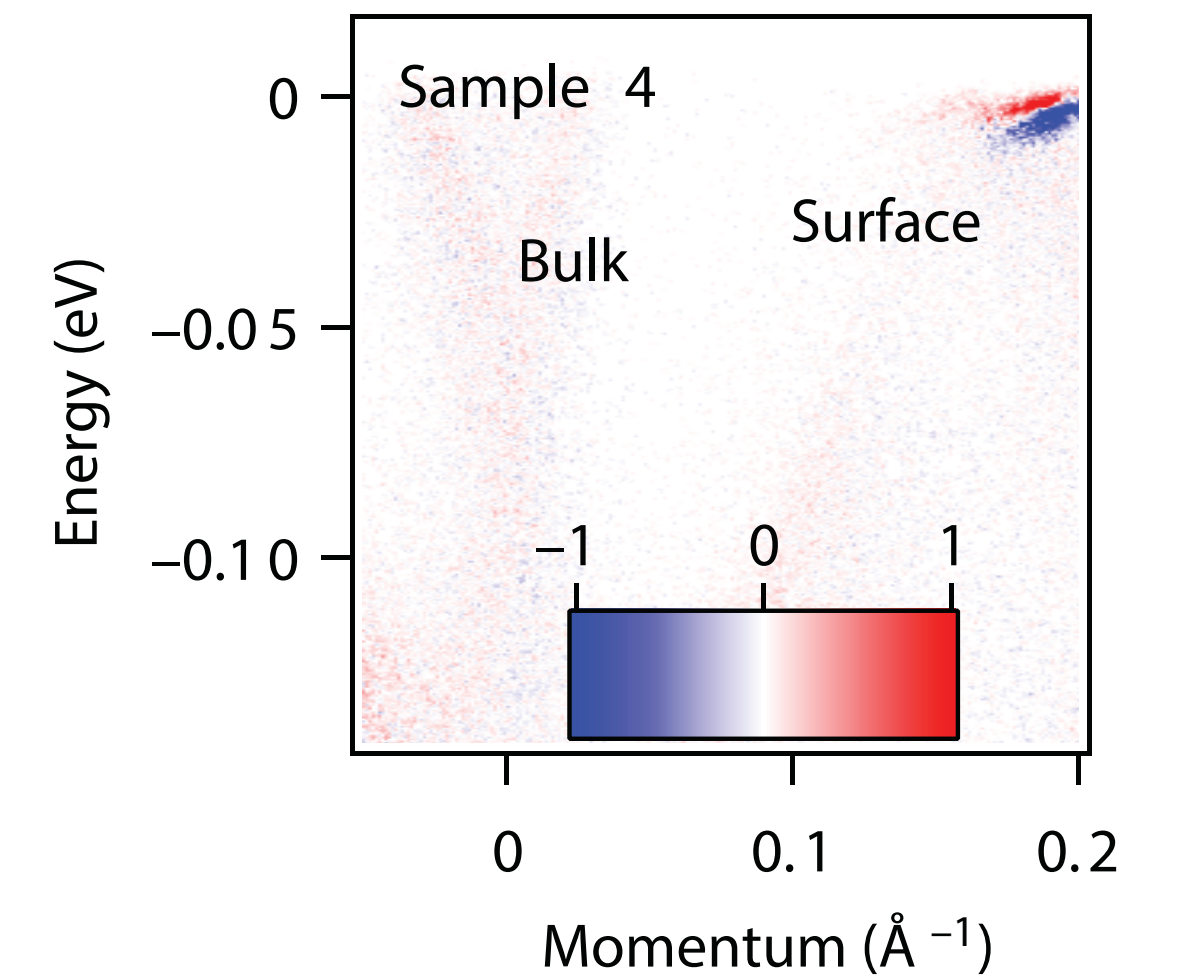
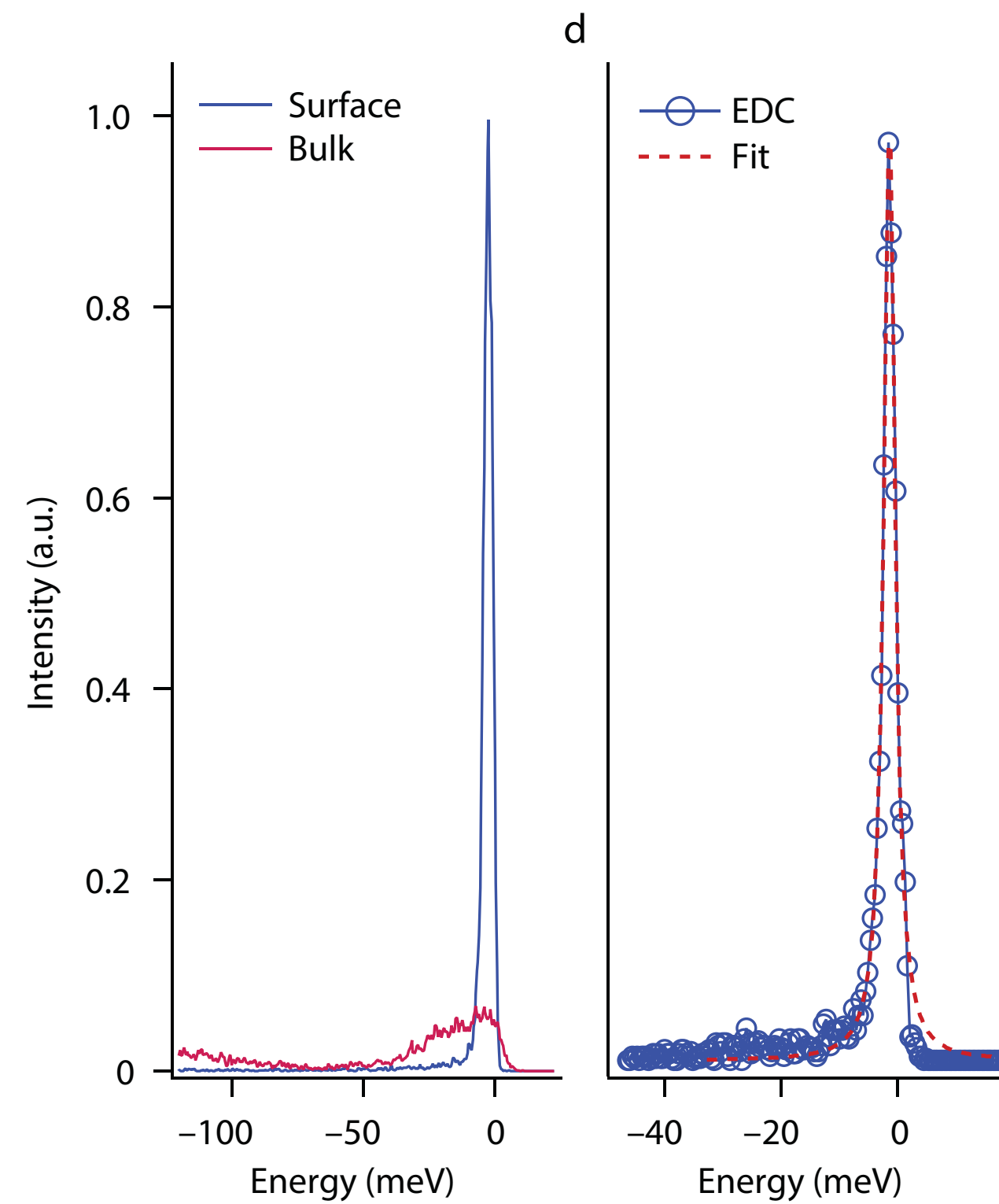
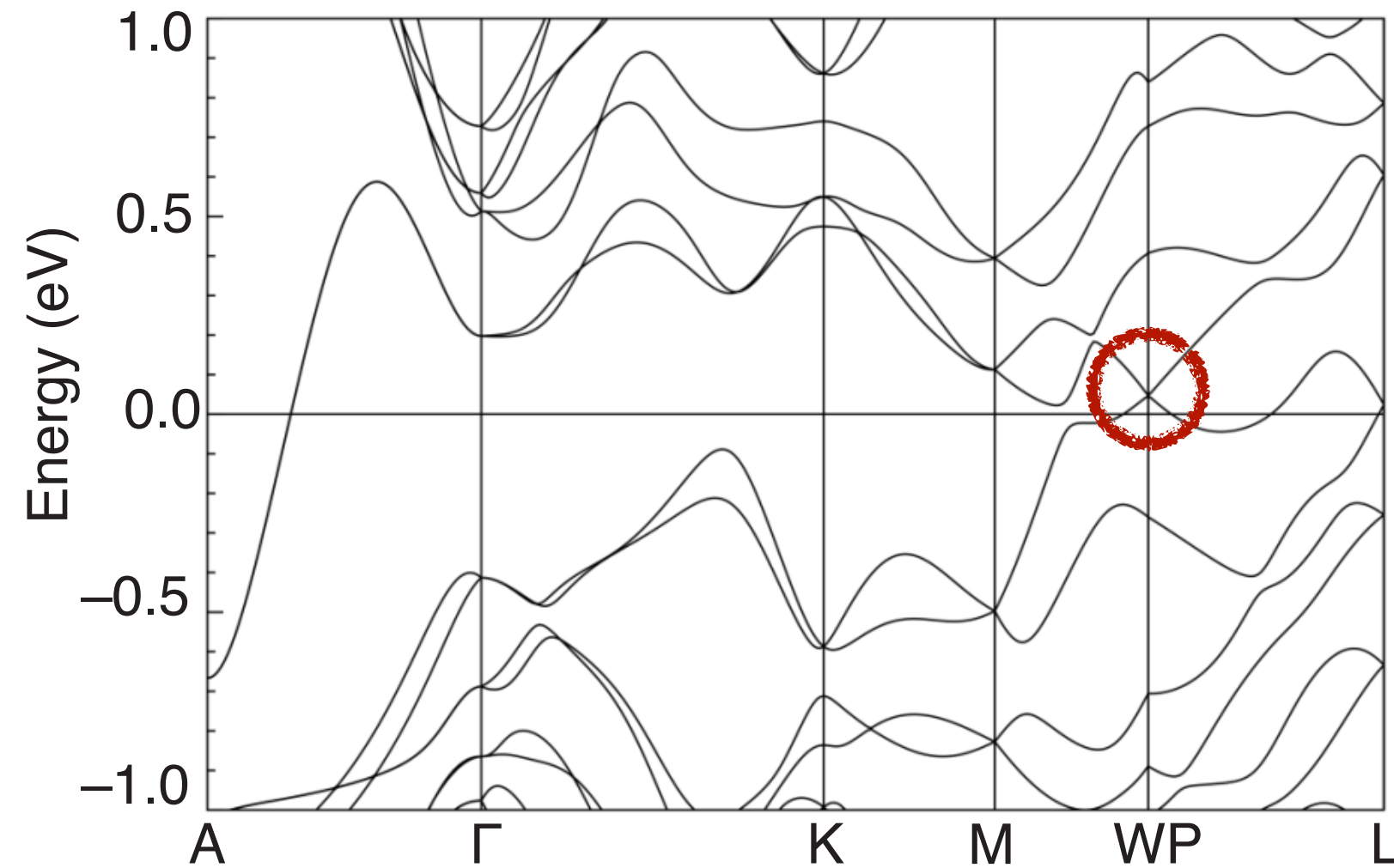
Bernd Büchner

Sergey Borisenko

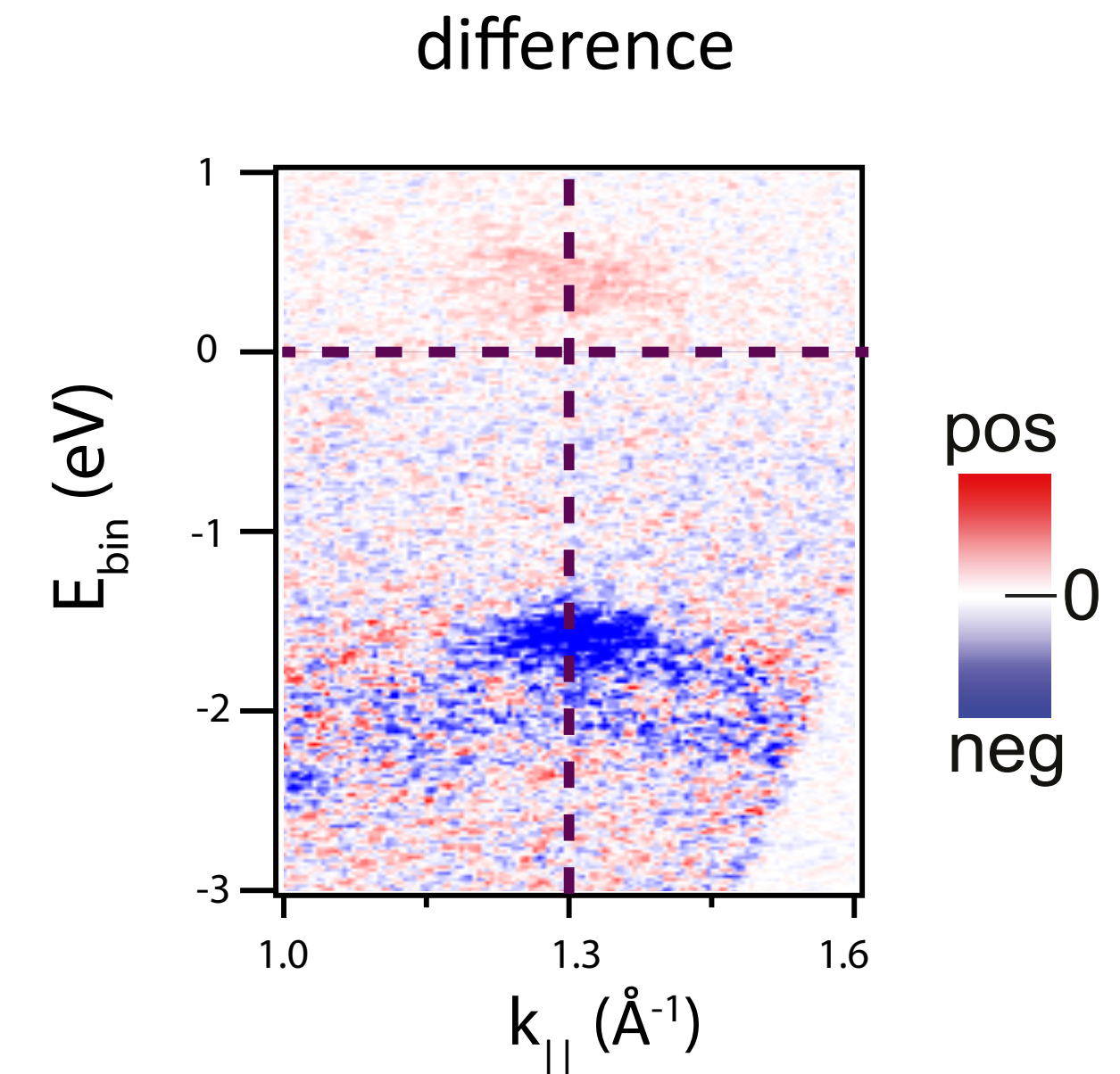
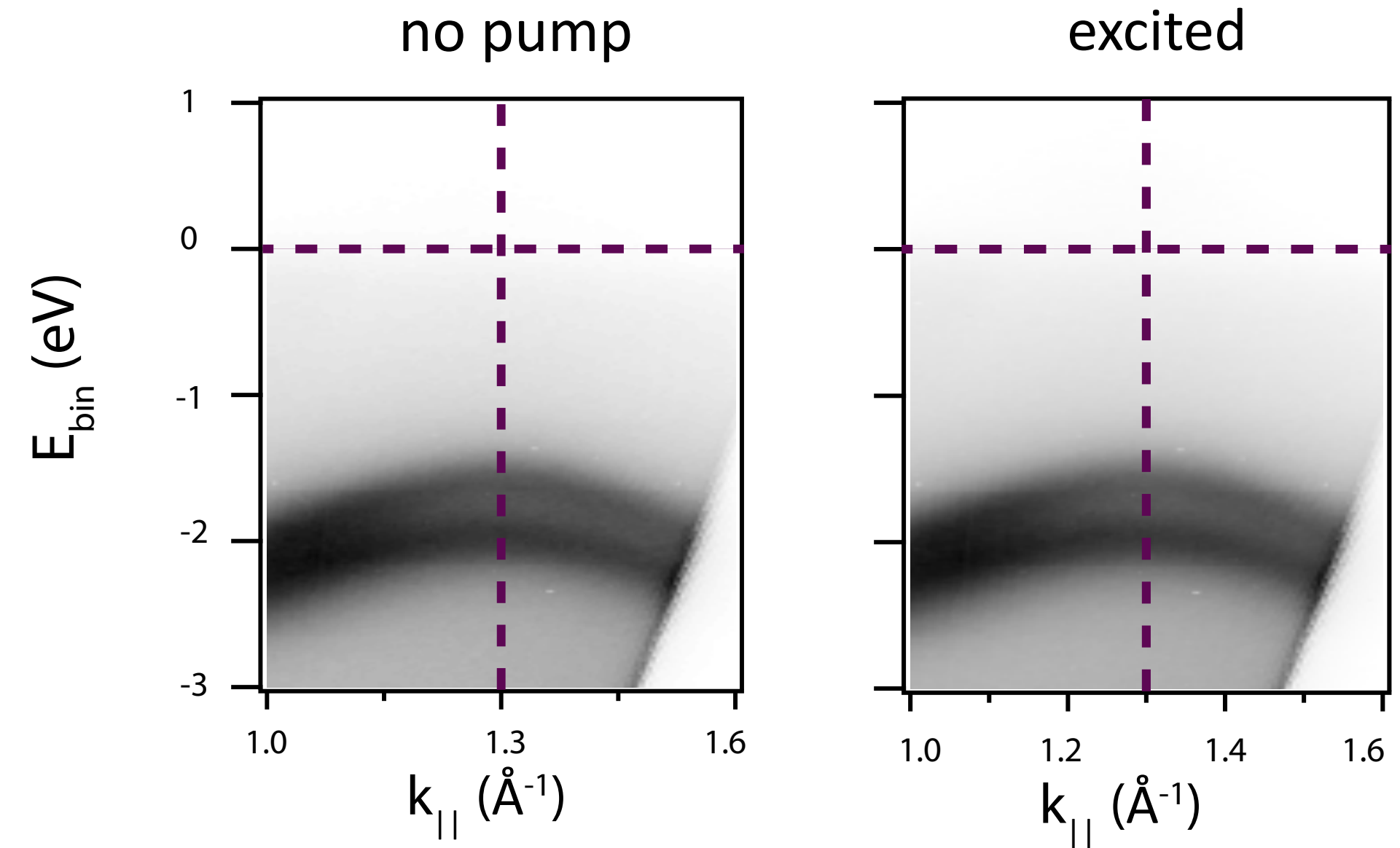
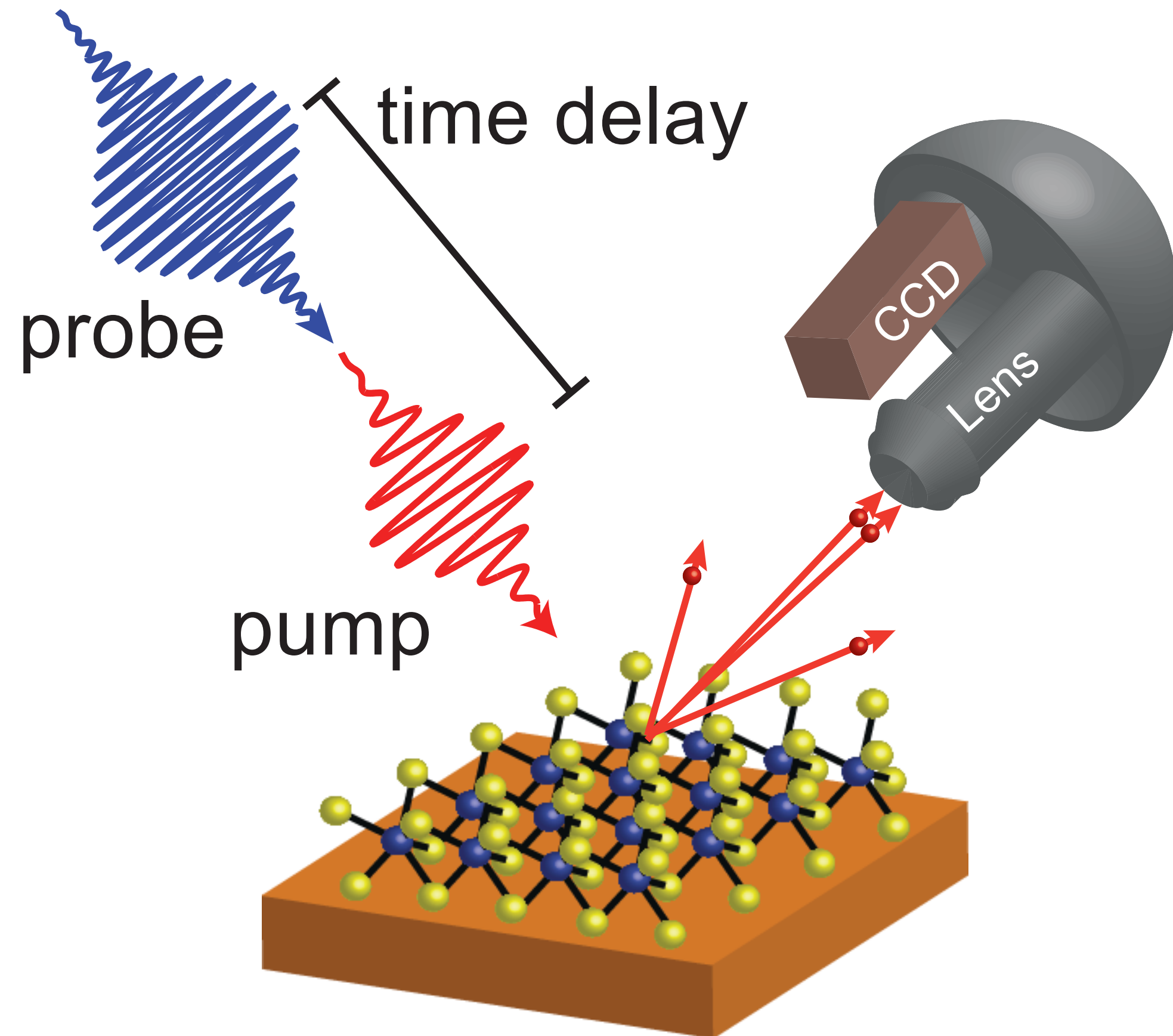
trigonal PtBi₂: superconducting Fermi arcs



Type-I Weyl semimetal:

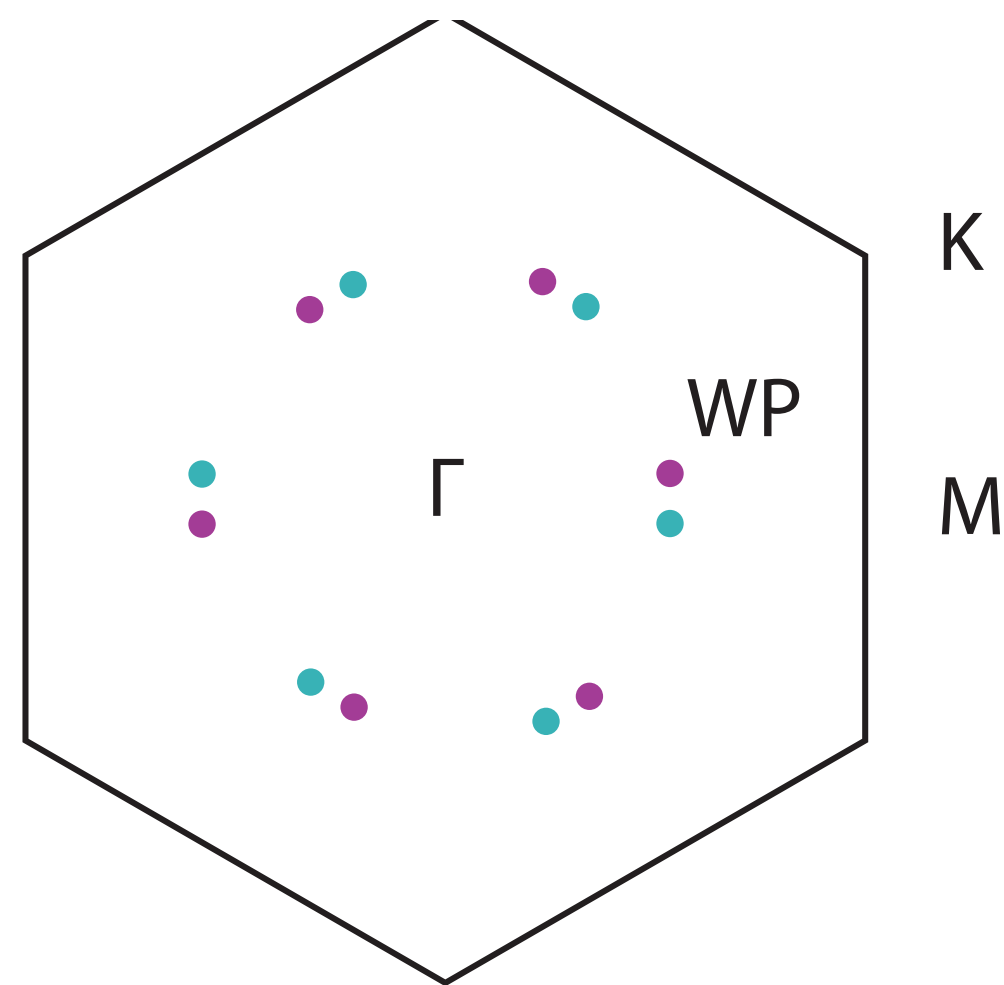
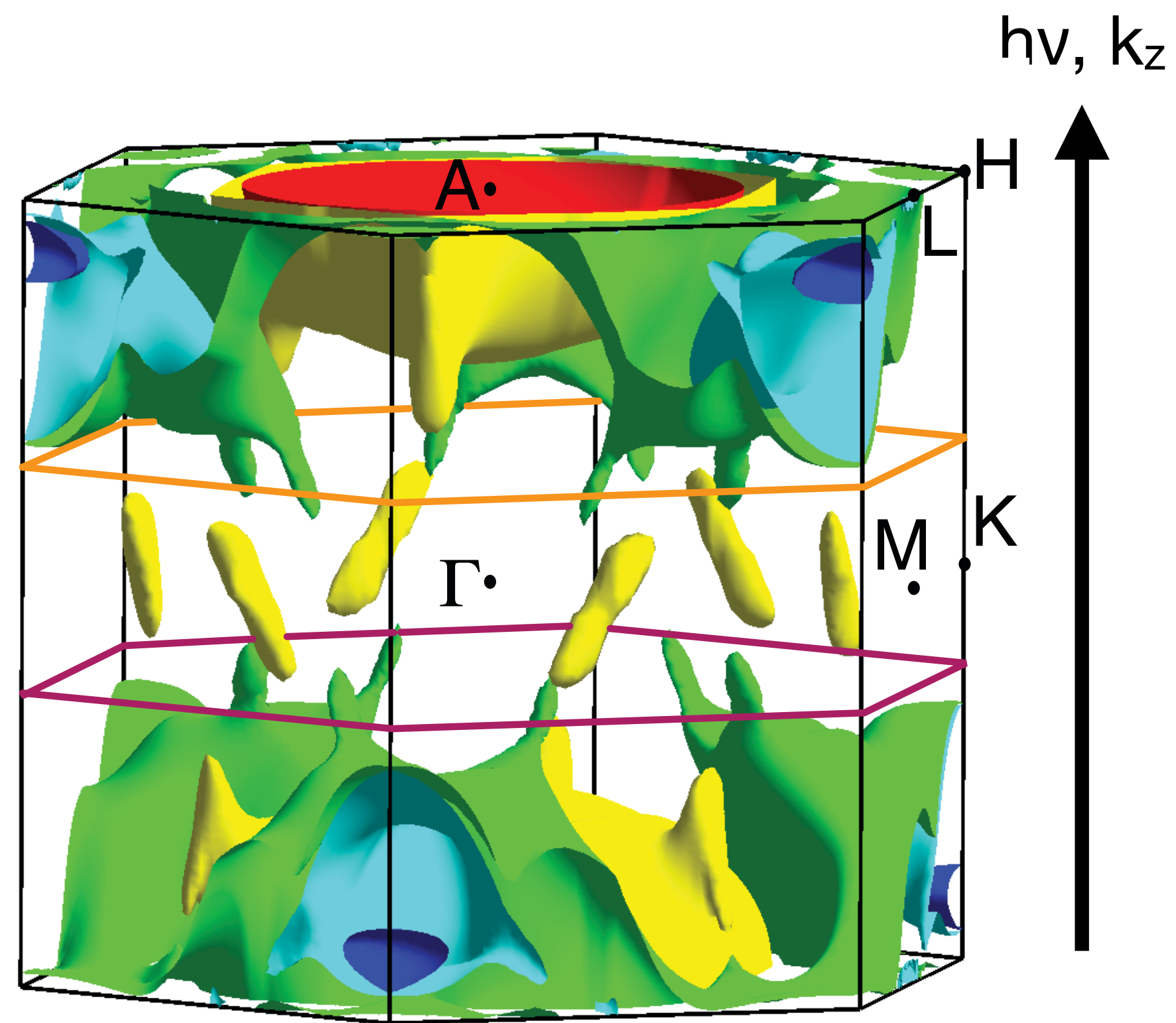


ARPES on unoccupied states

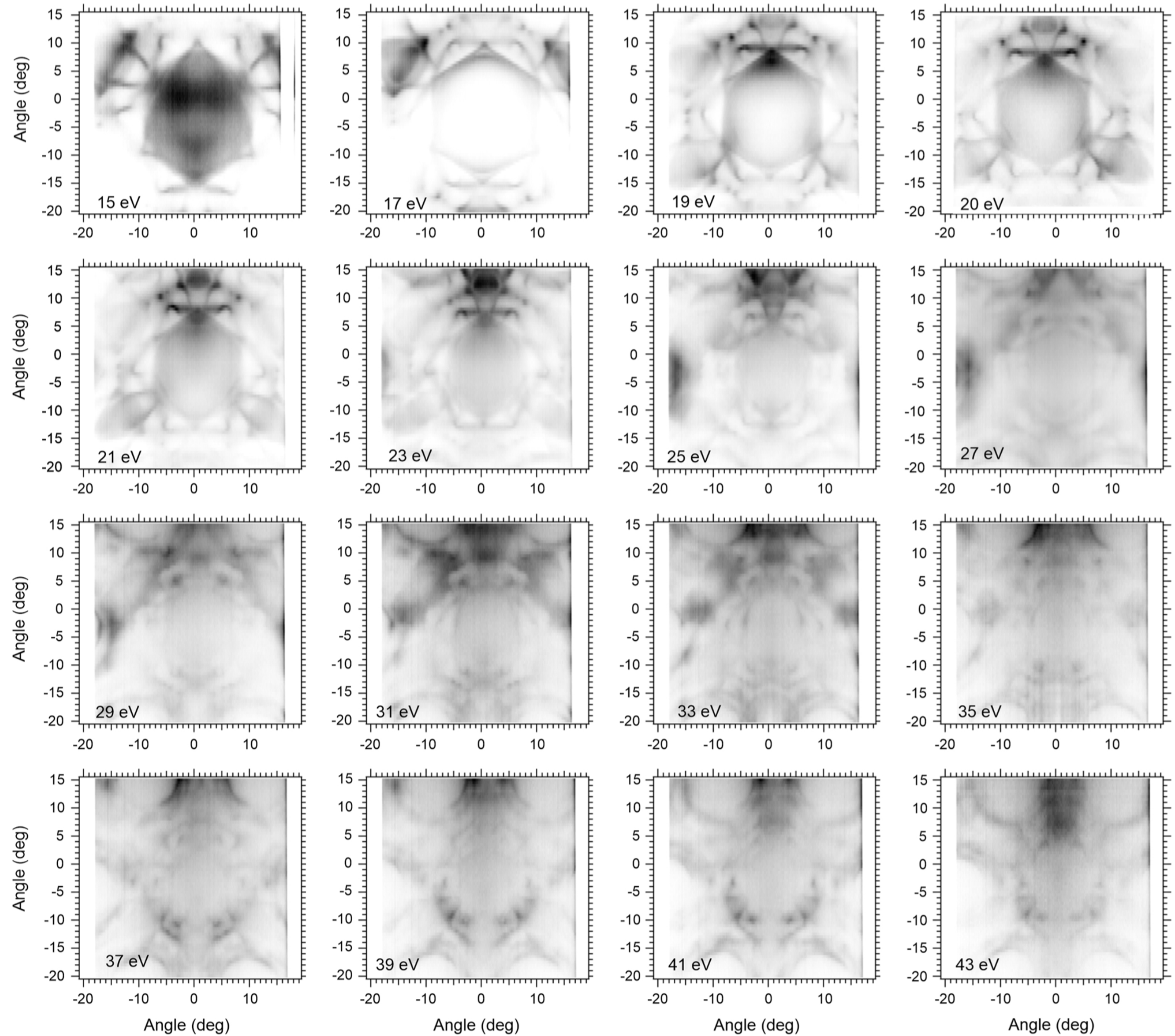


Antonija Grubisic Cabo *et al.*, Nano Letters, **15**, 5883 (2015).

Søren Ulstrup *et al.*, Physical Review B **95**, 041405(R) (2017).

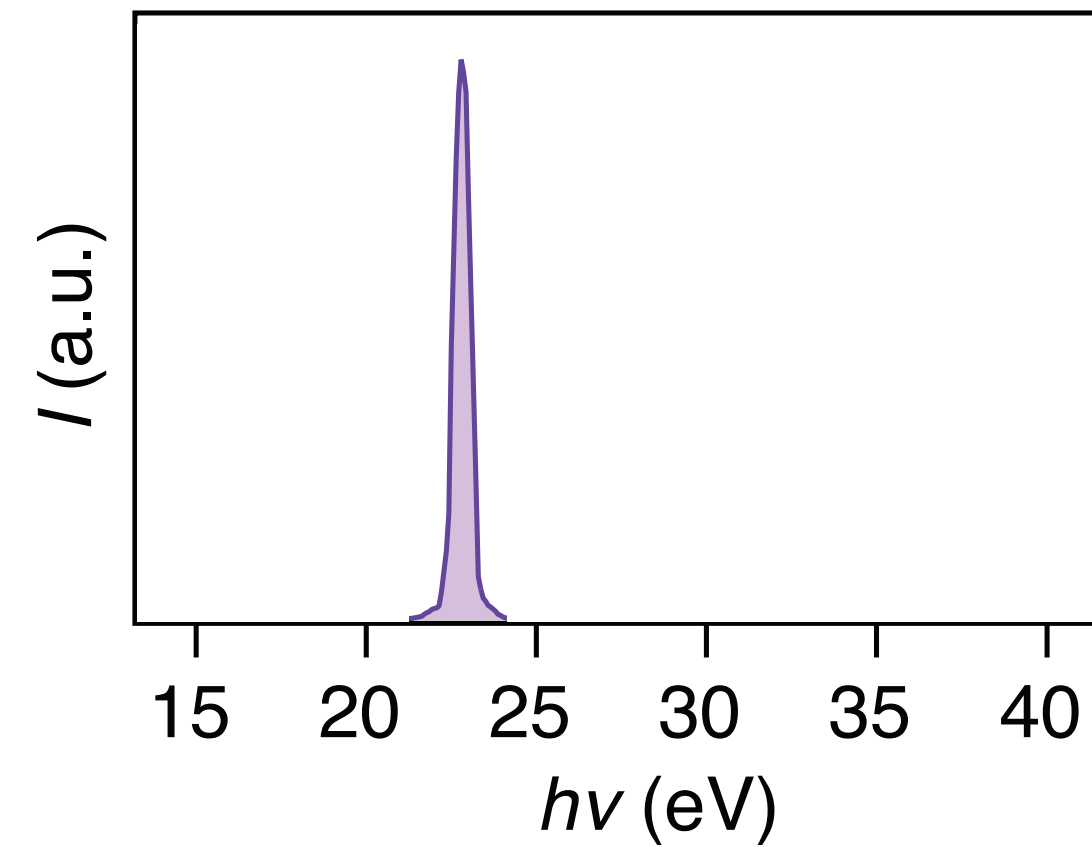


WPs in PtBi₂

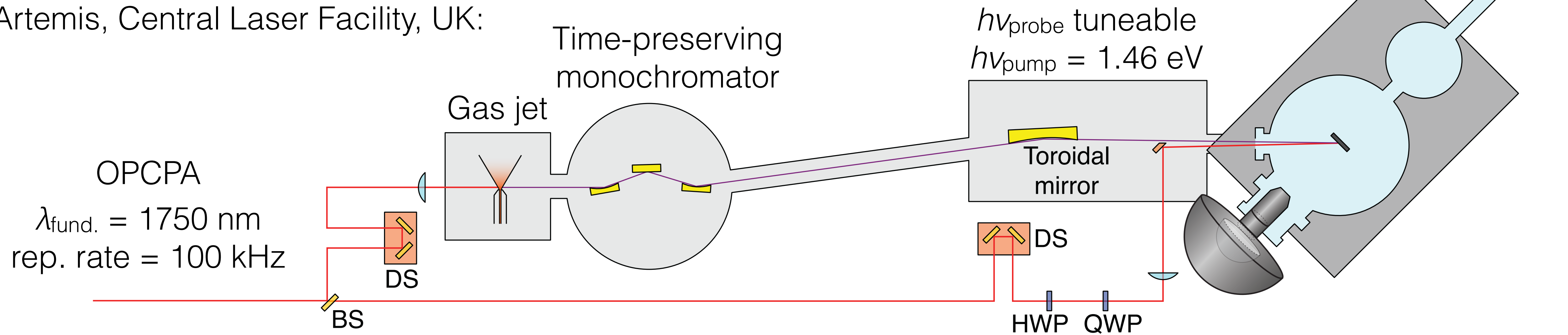


high harmonic laser source

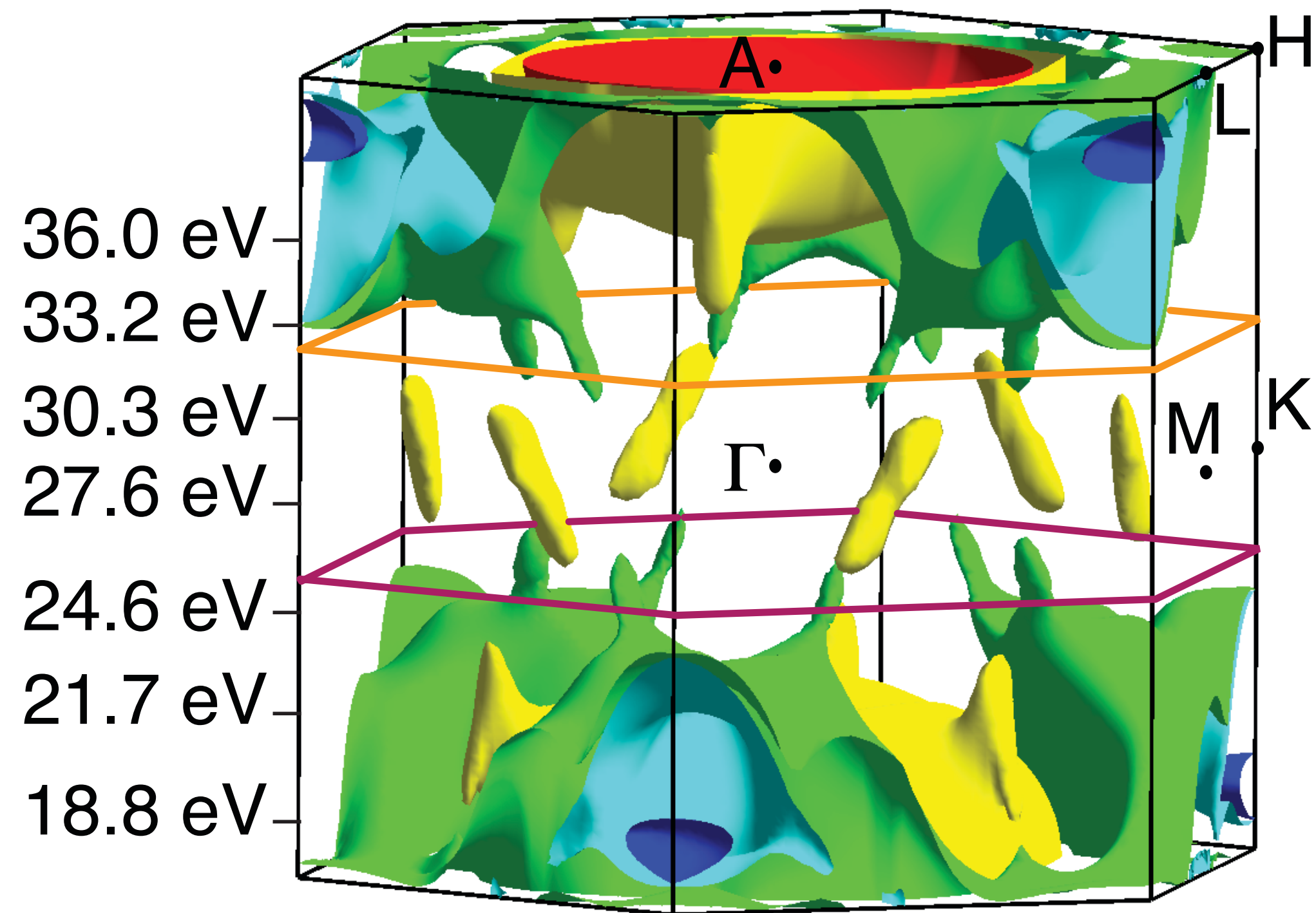
High-harmonic comb + monochromator



Artemis, Central Laser Facility, UK:



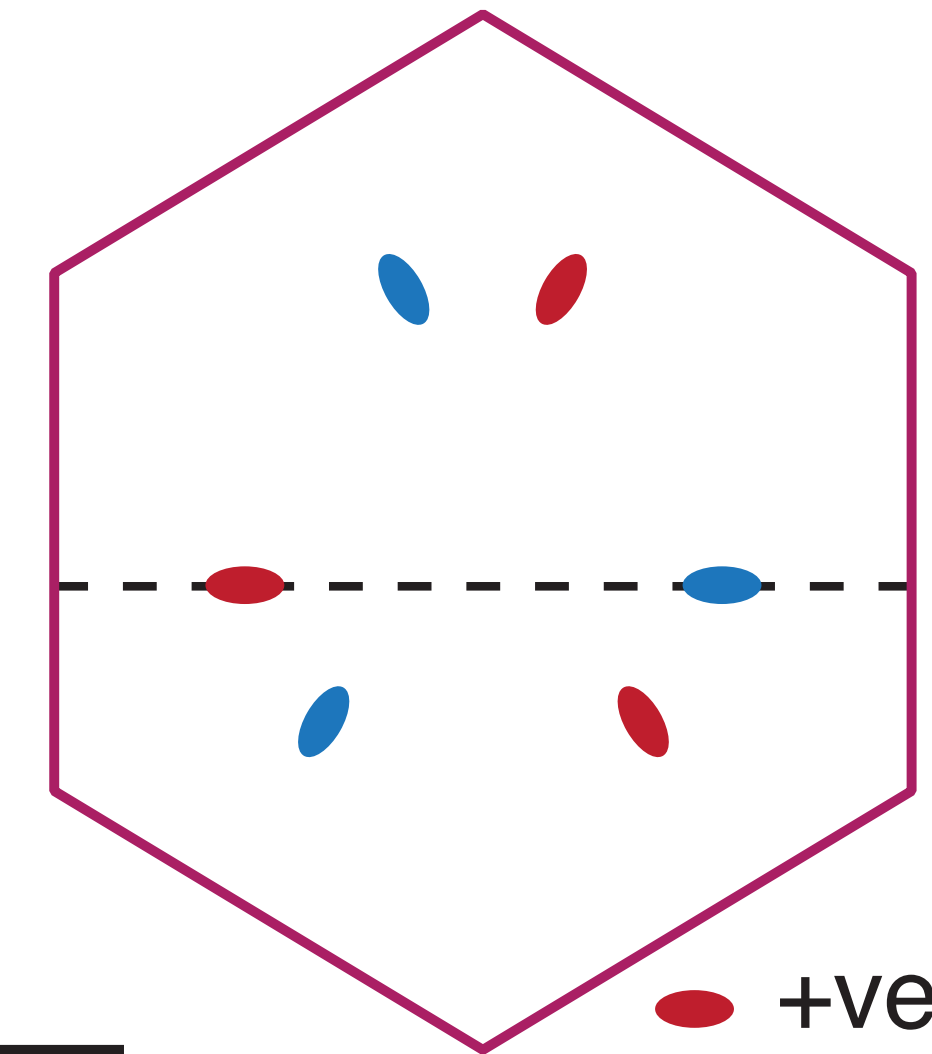
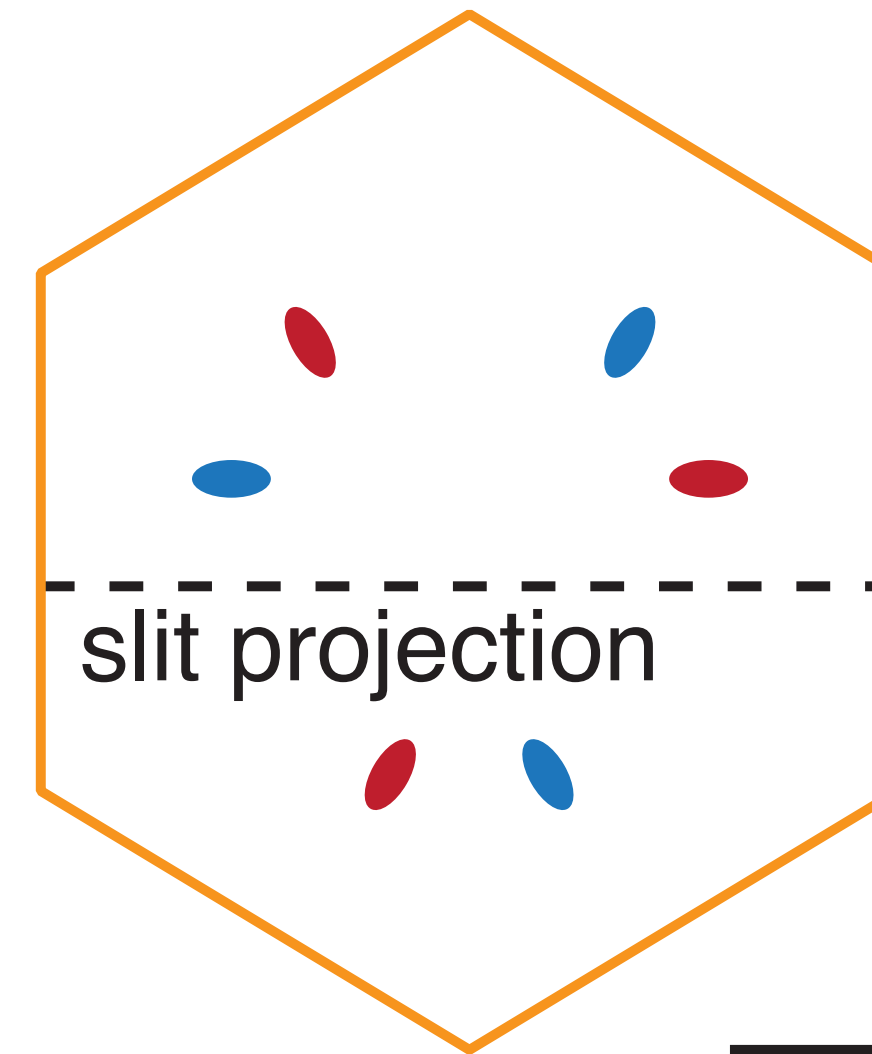
trigonal PtBi₂



2D const. energy contour, $E - E_F = 47$ meV

$$k_z = 0.15 c^*$$

$$k_z = -0.15 c^*$$

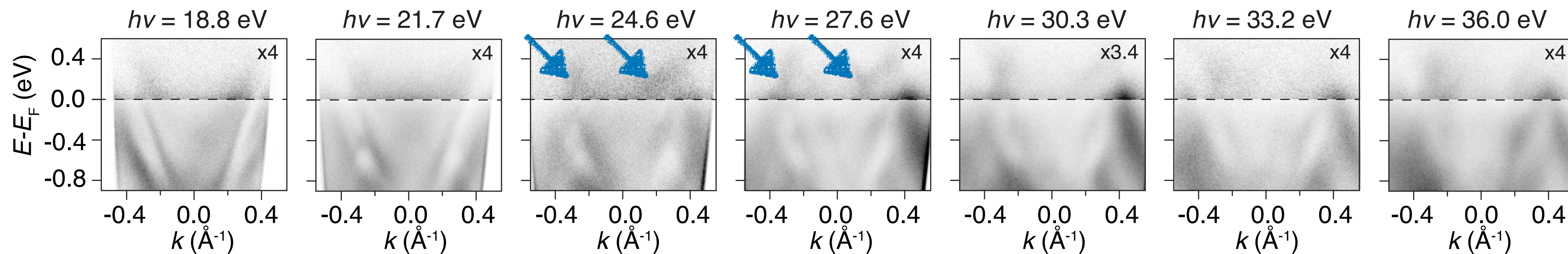


slit projection

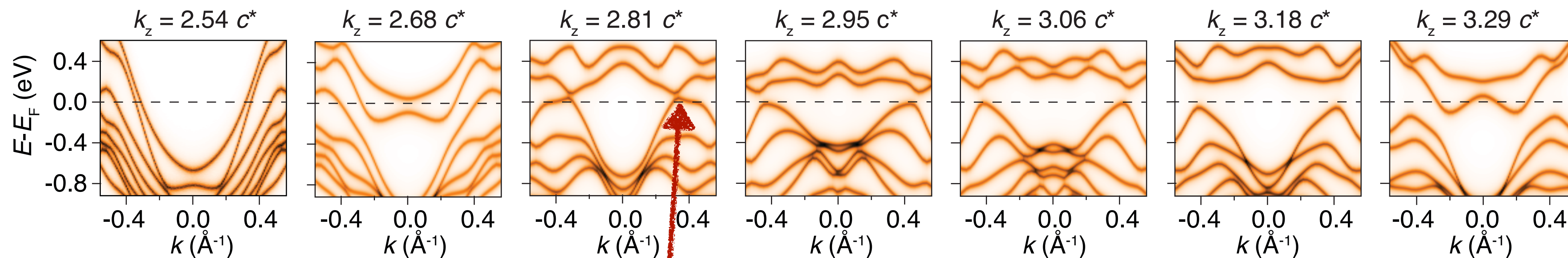
0.5 \AA^{-1}

● +ve chirality
● -ve chirality

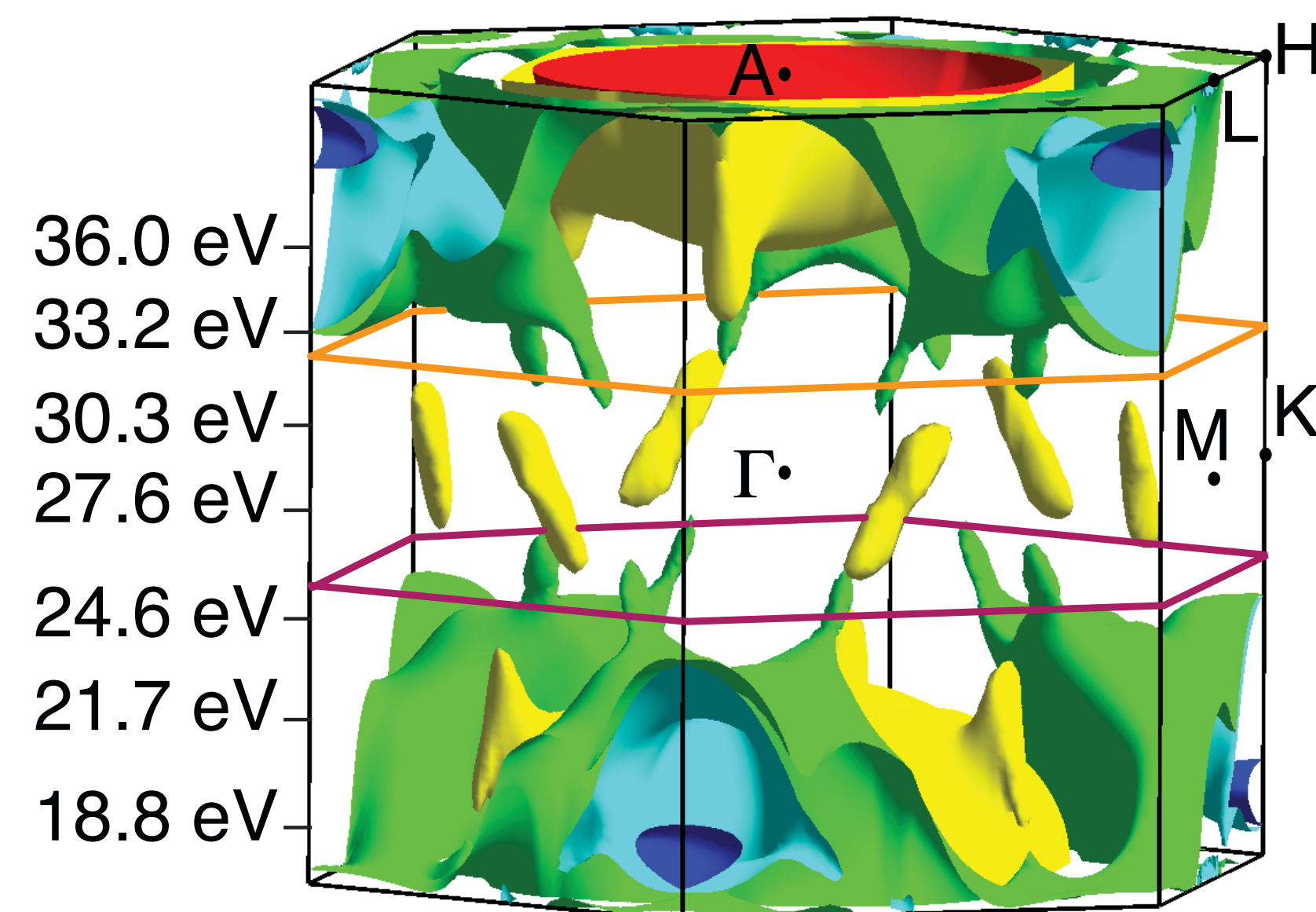
Data:



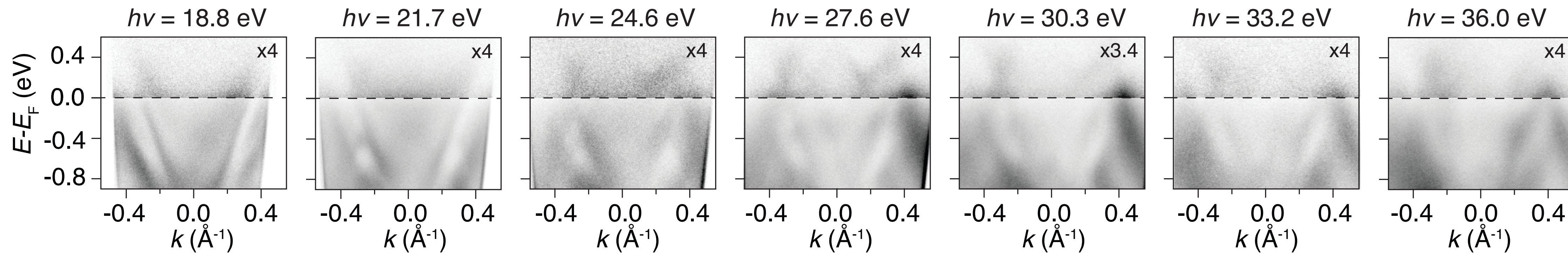
Theory:



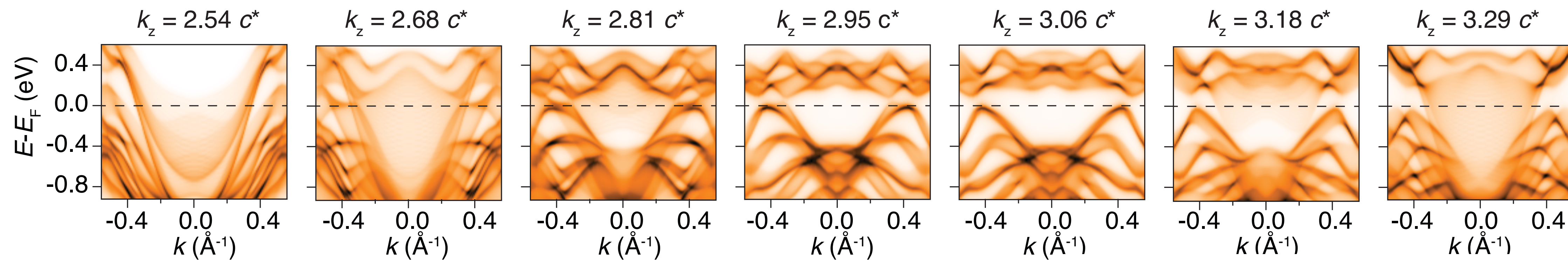
Weyl point



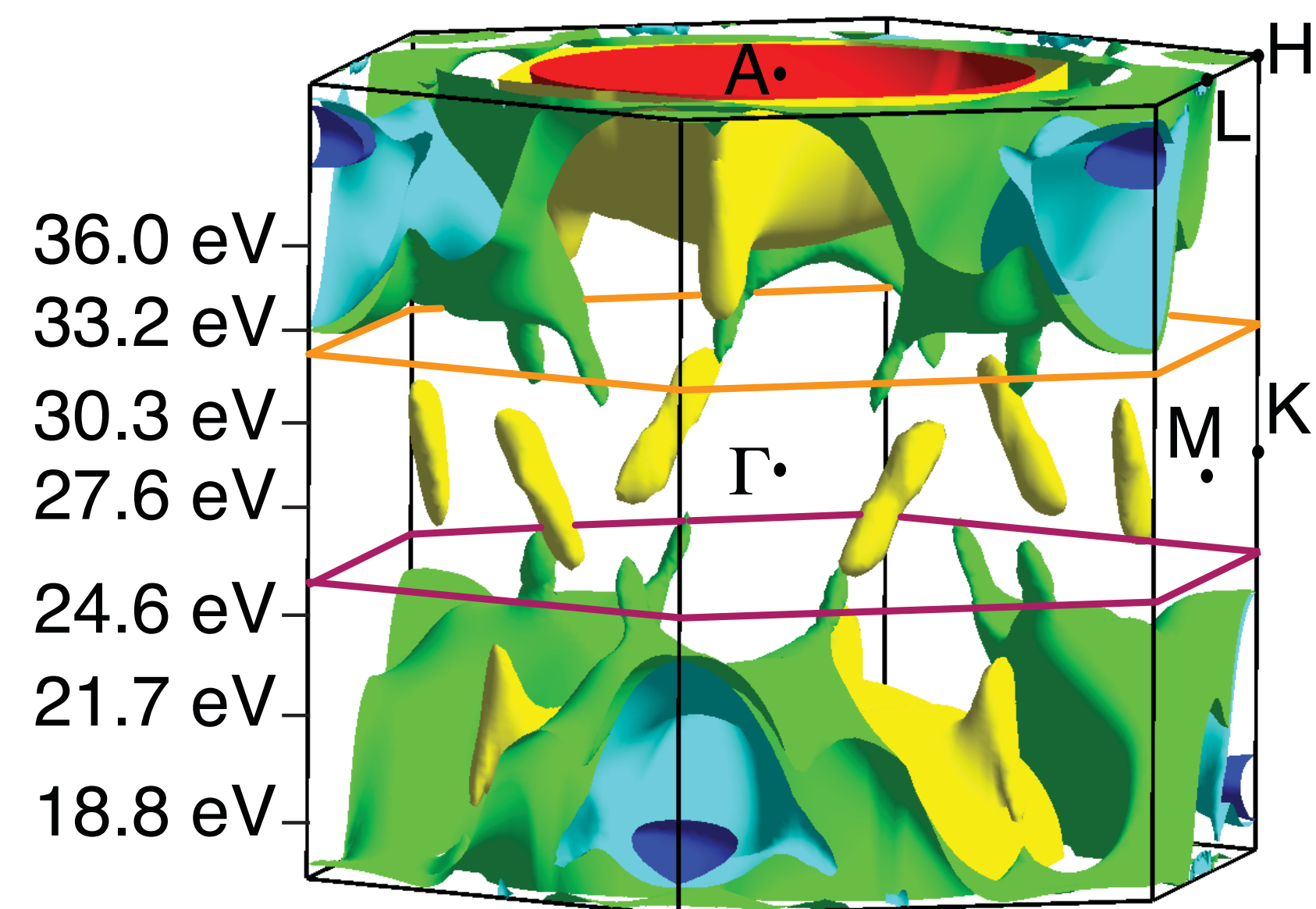
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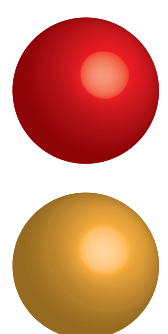
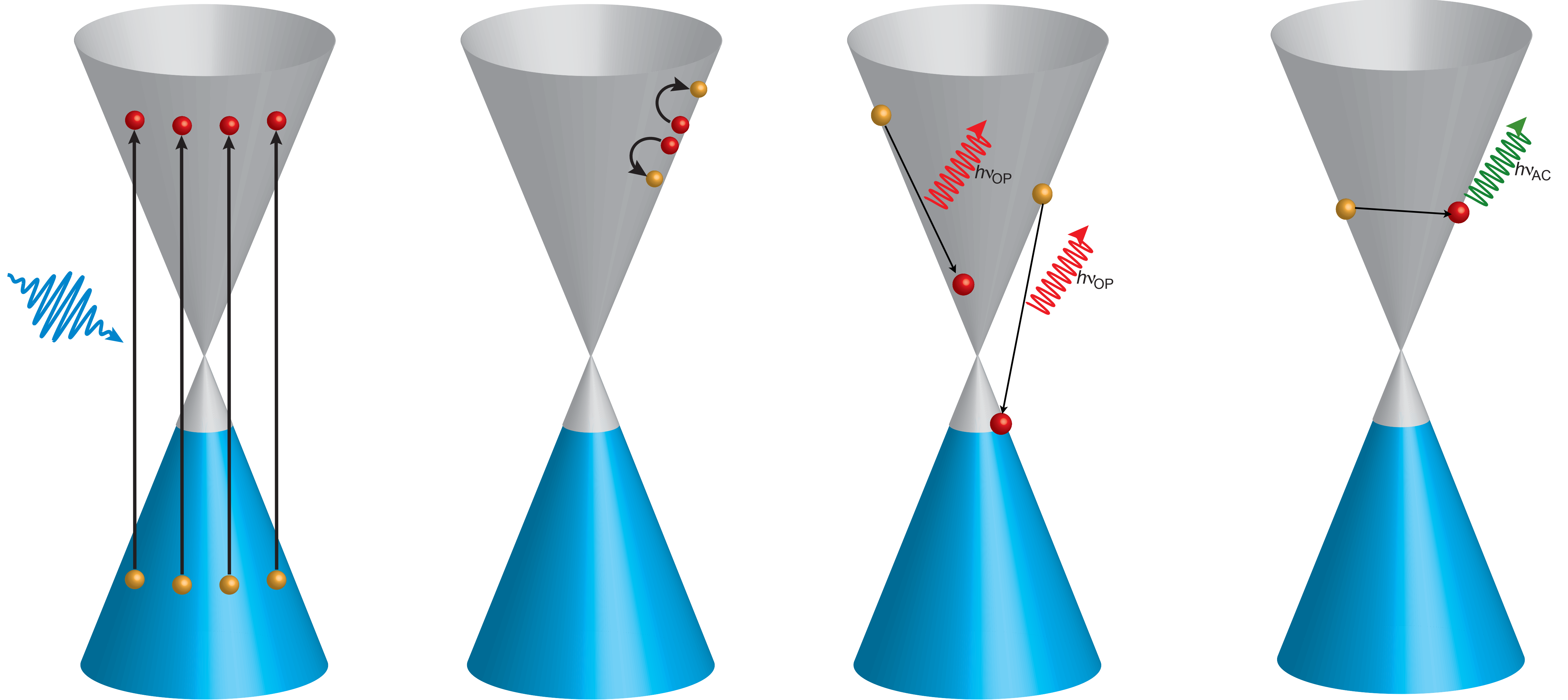
Theory:



k_z broadening $\sim 15\%$ of the Brillouin zone



ultrafast dynamics: why is this interesting?



electron

t = 0 fs

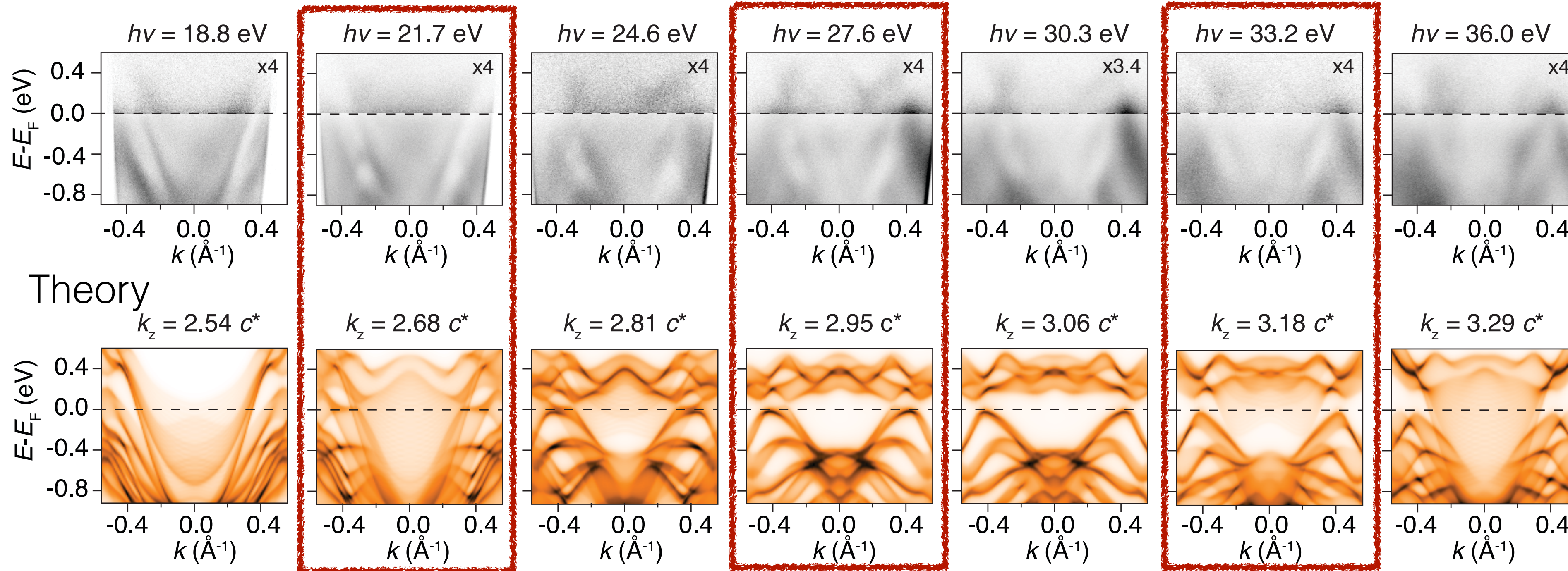
hole

t < 20 fs

t > 250 fs

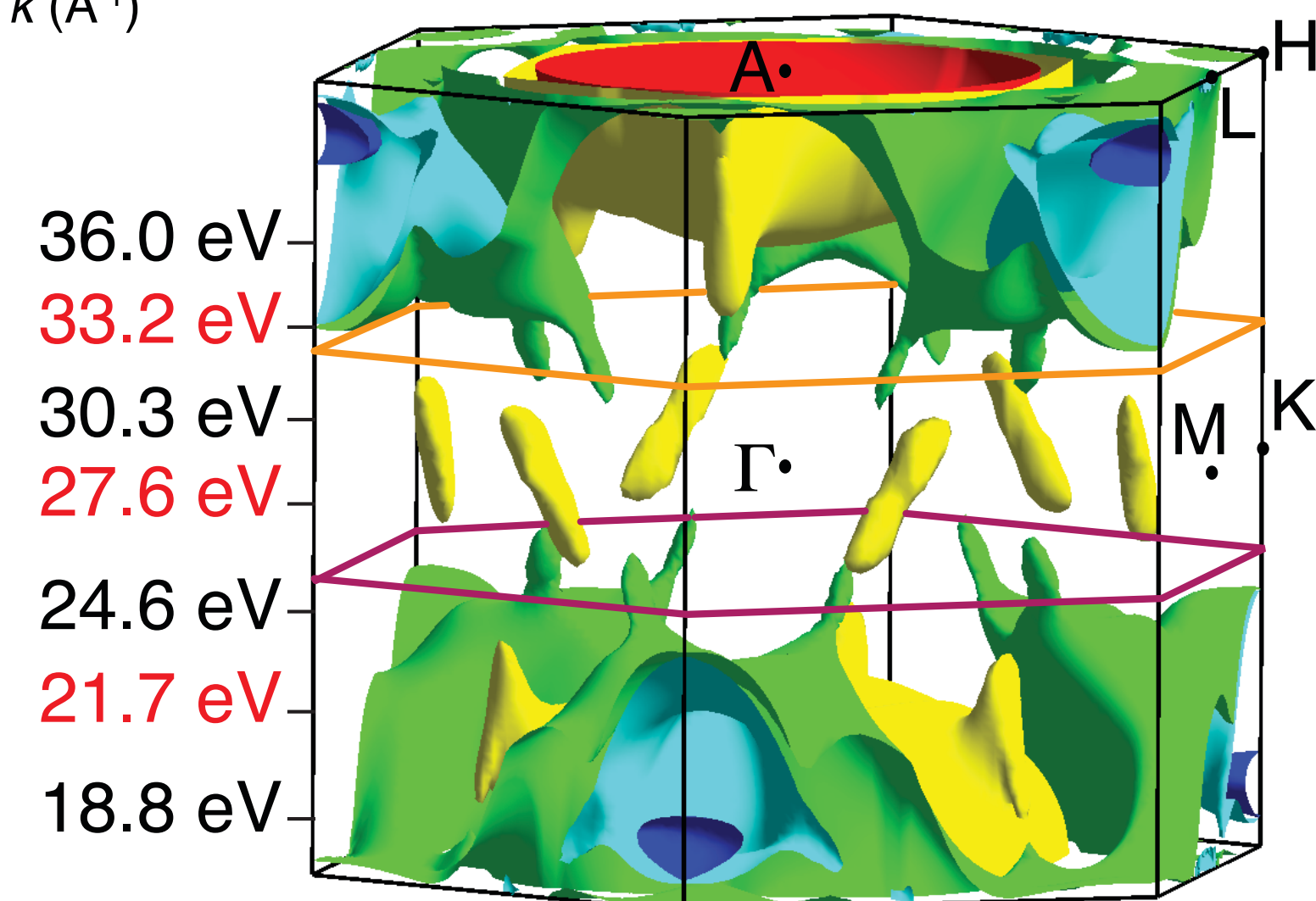
dynamics

Data

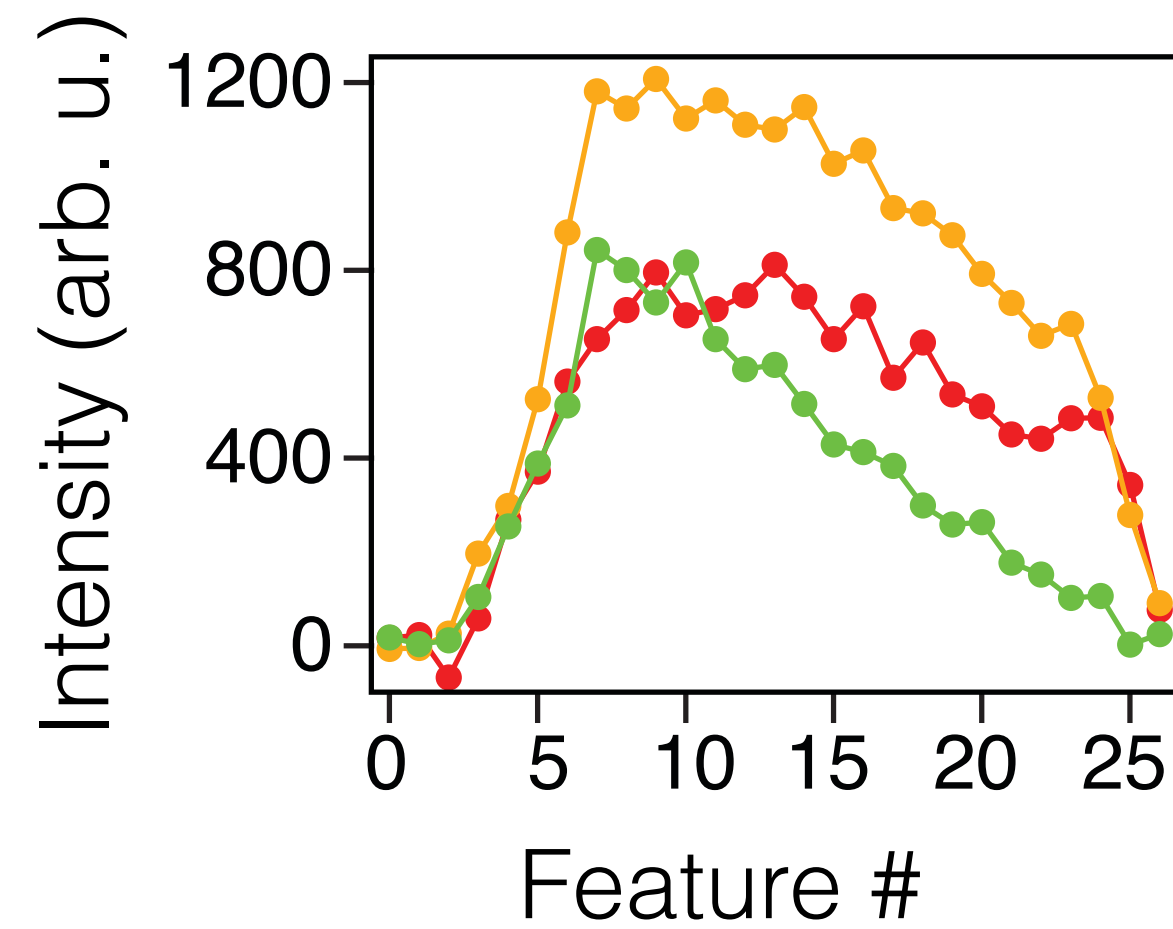
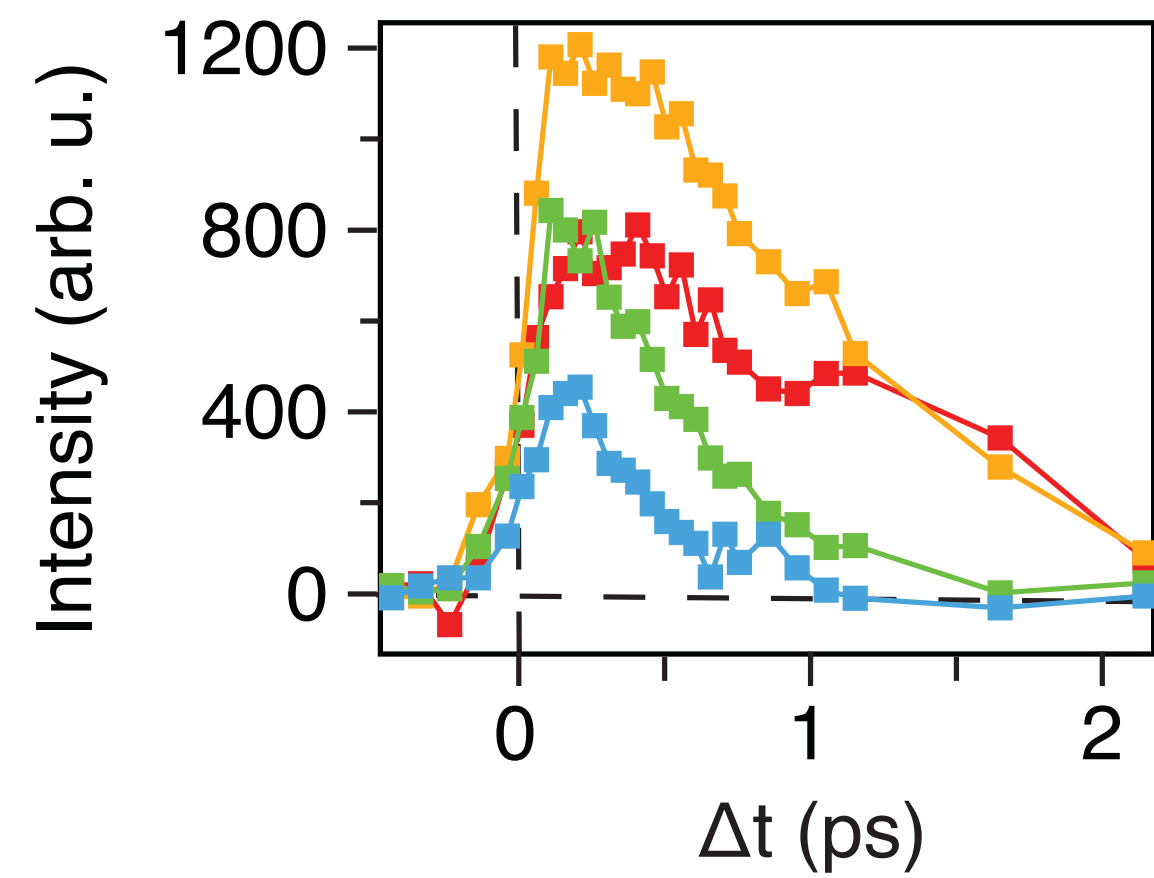
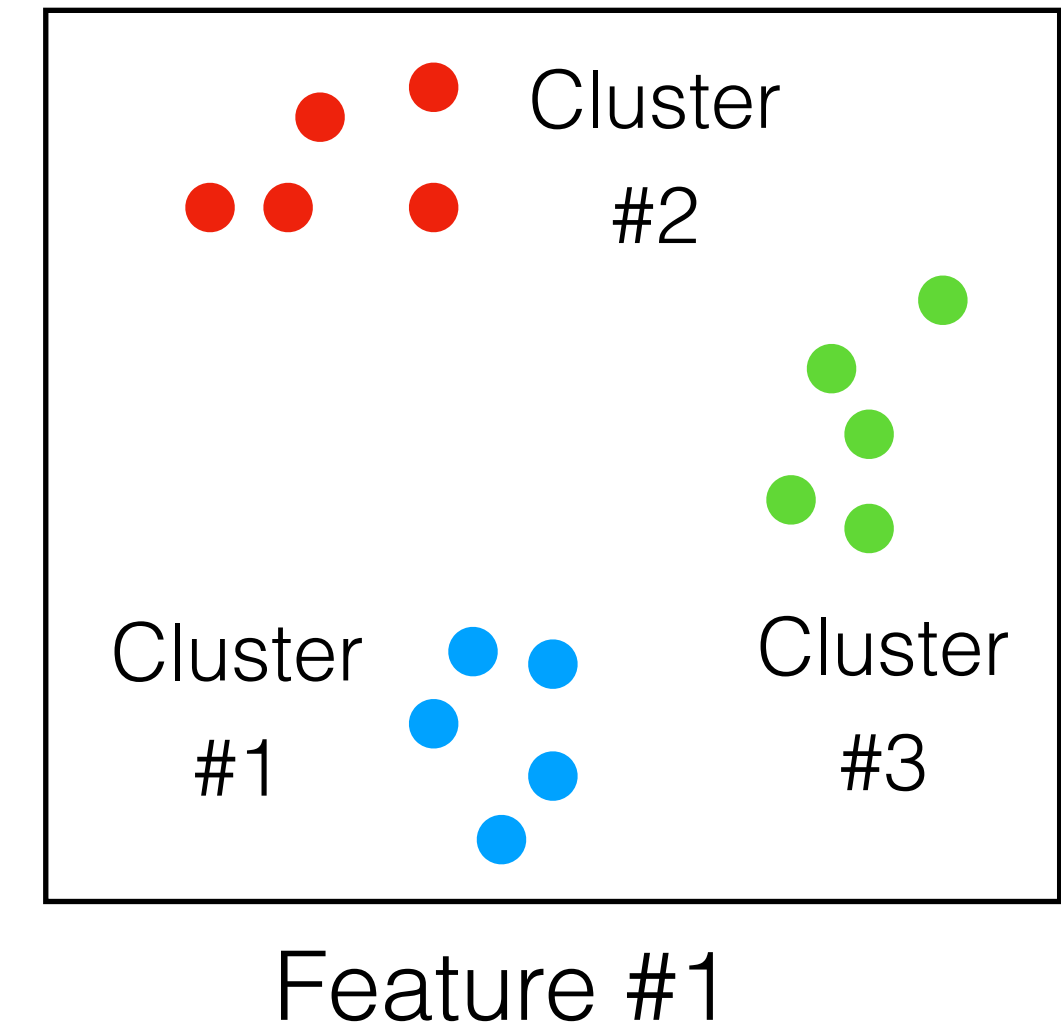
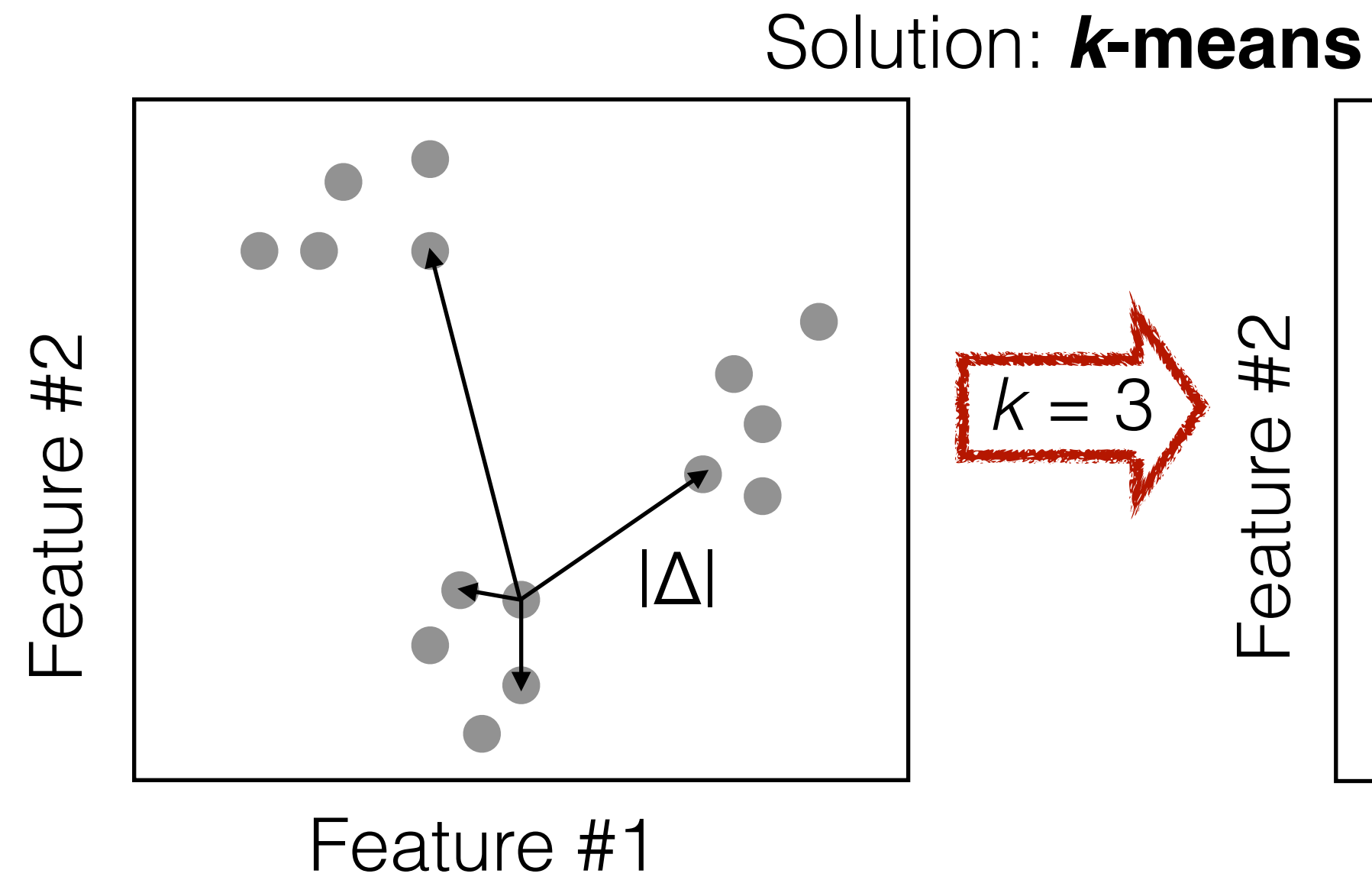
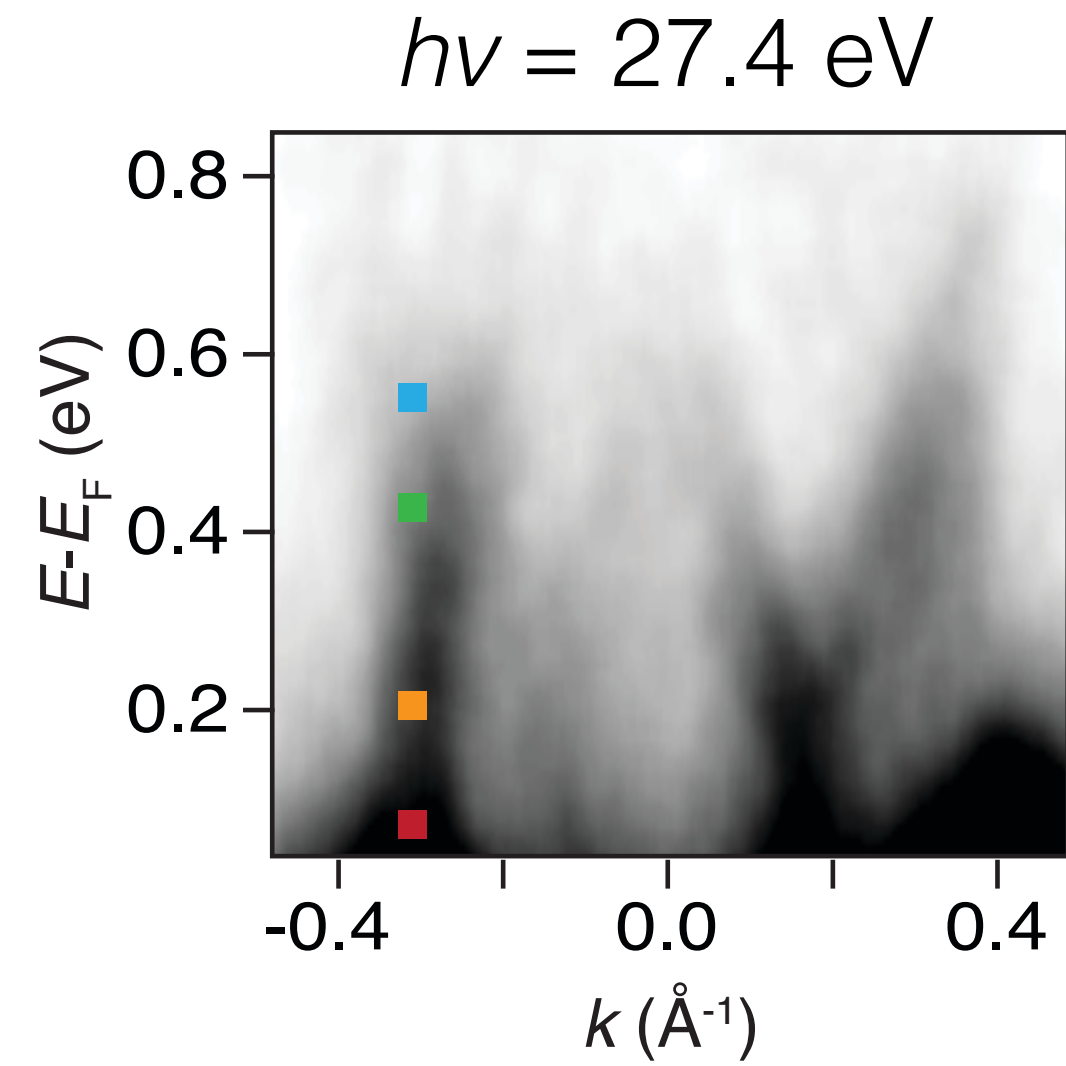


Theory

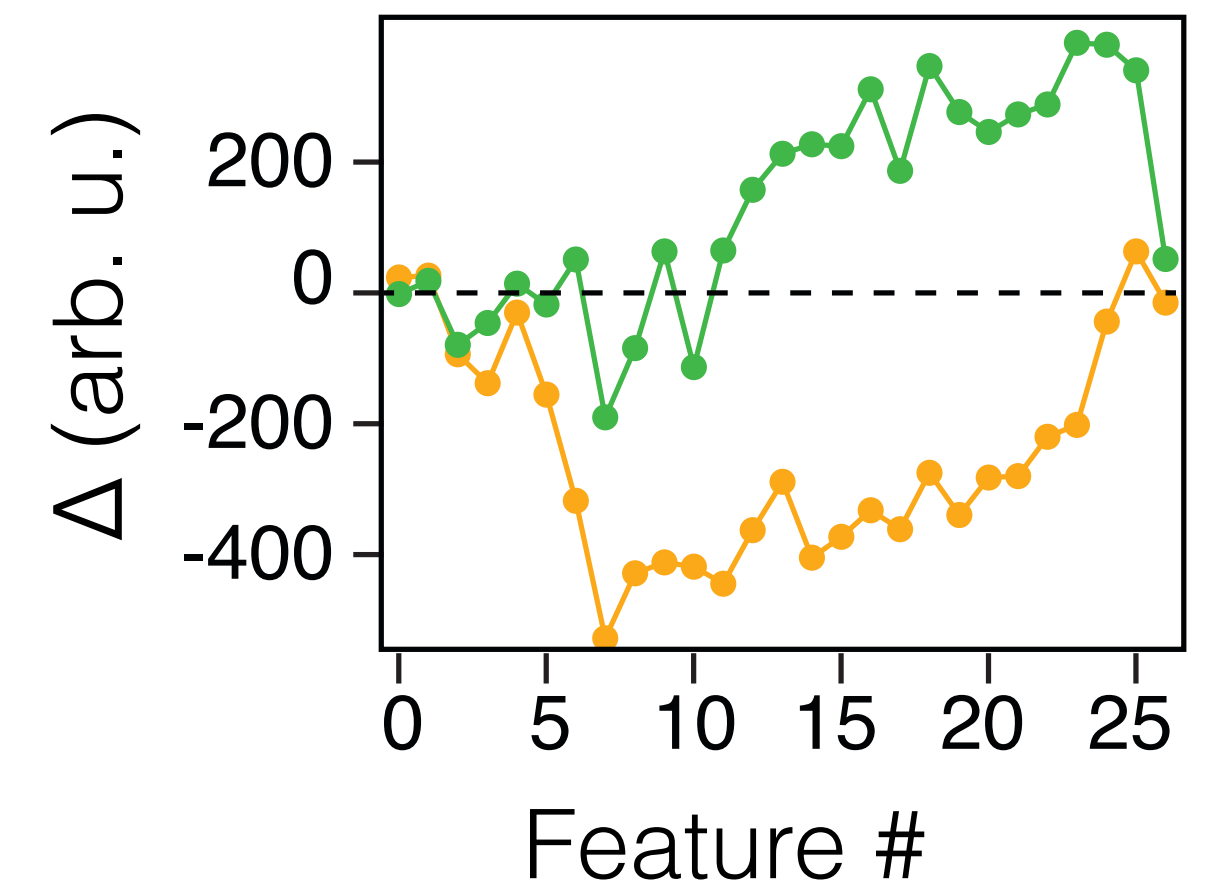
k_z broadening \sim 15% of the Brillouin zone



ultrafast dynamics: classification

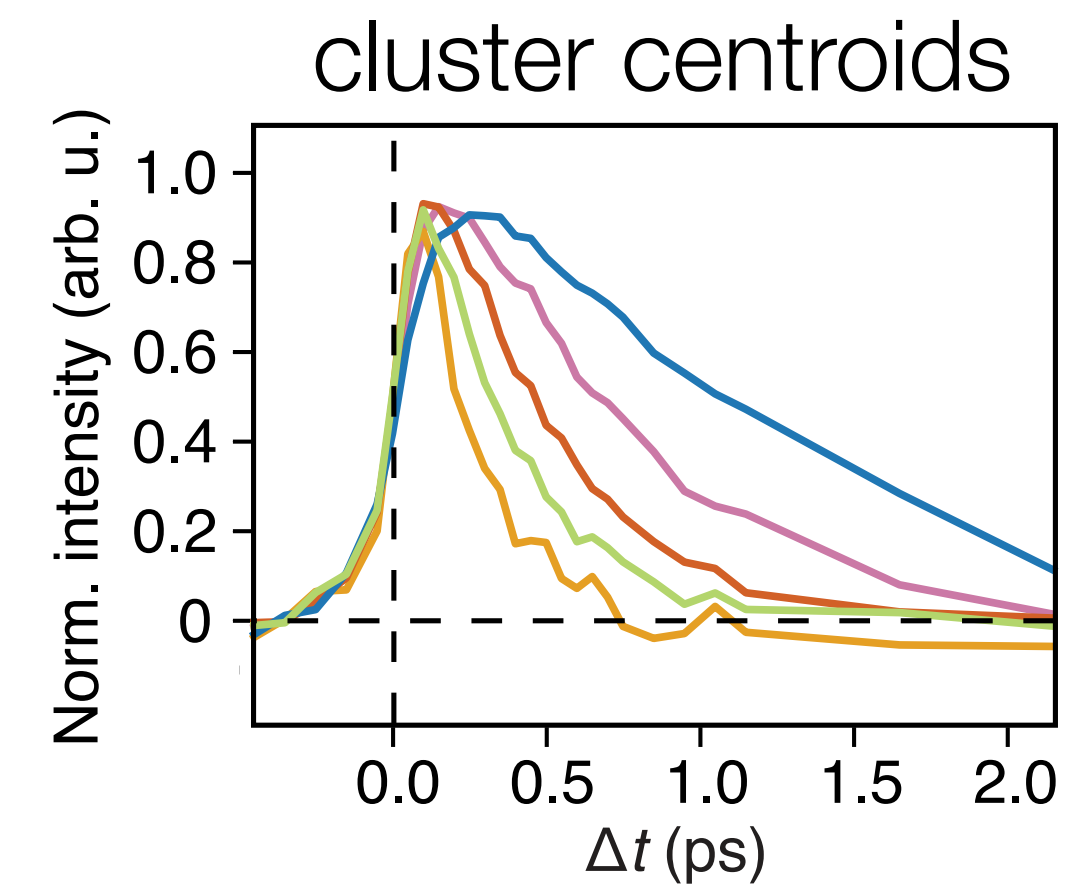
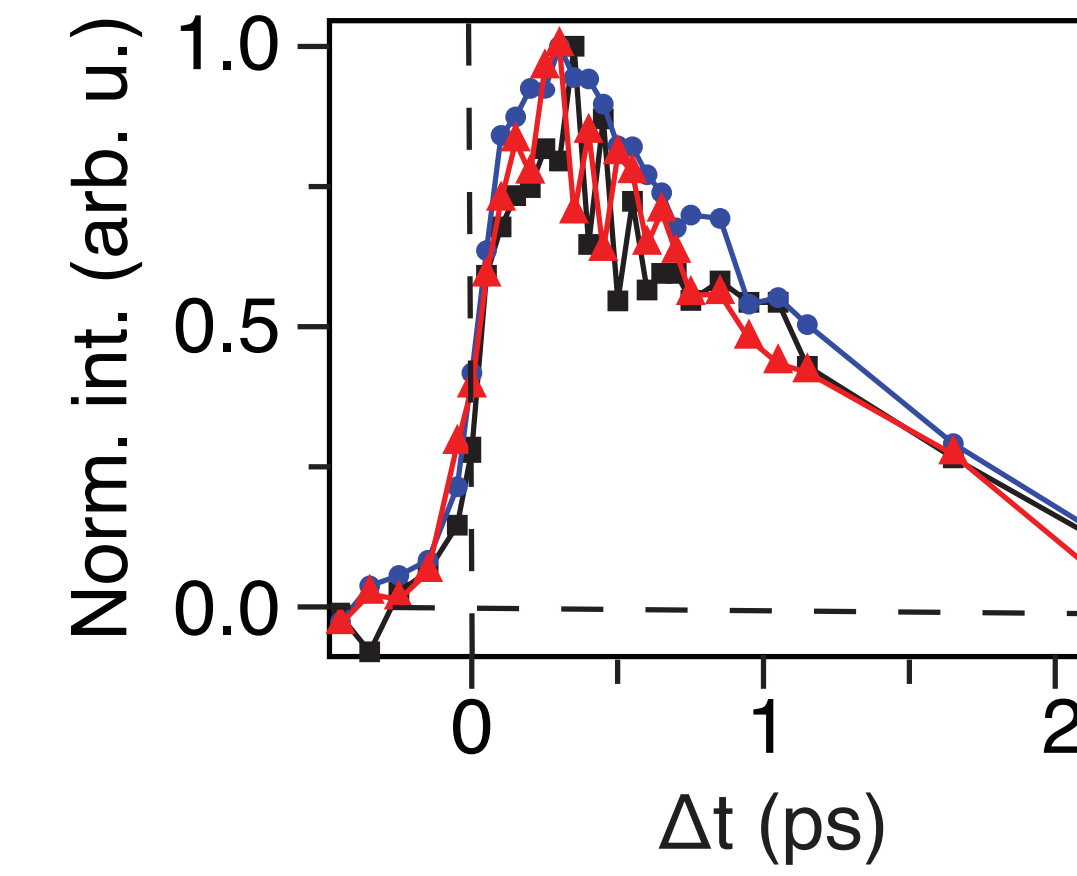
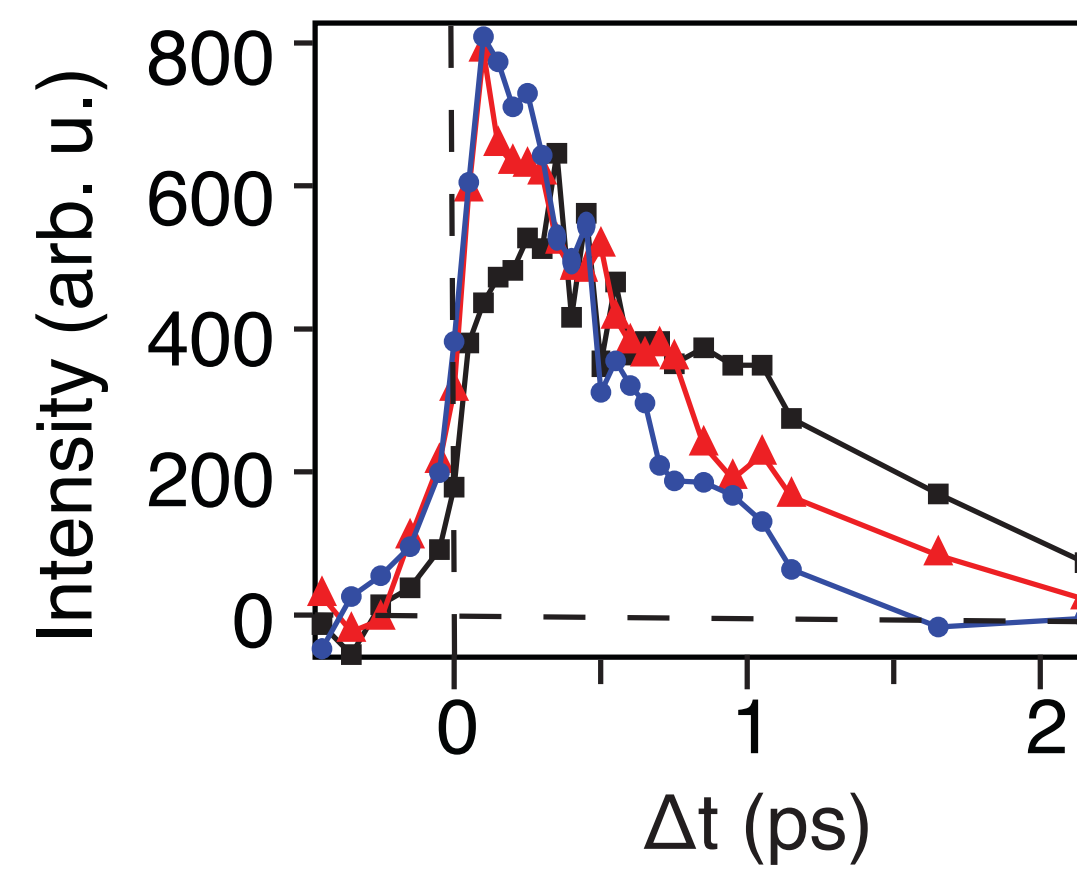
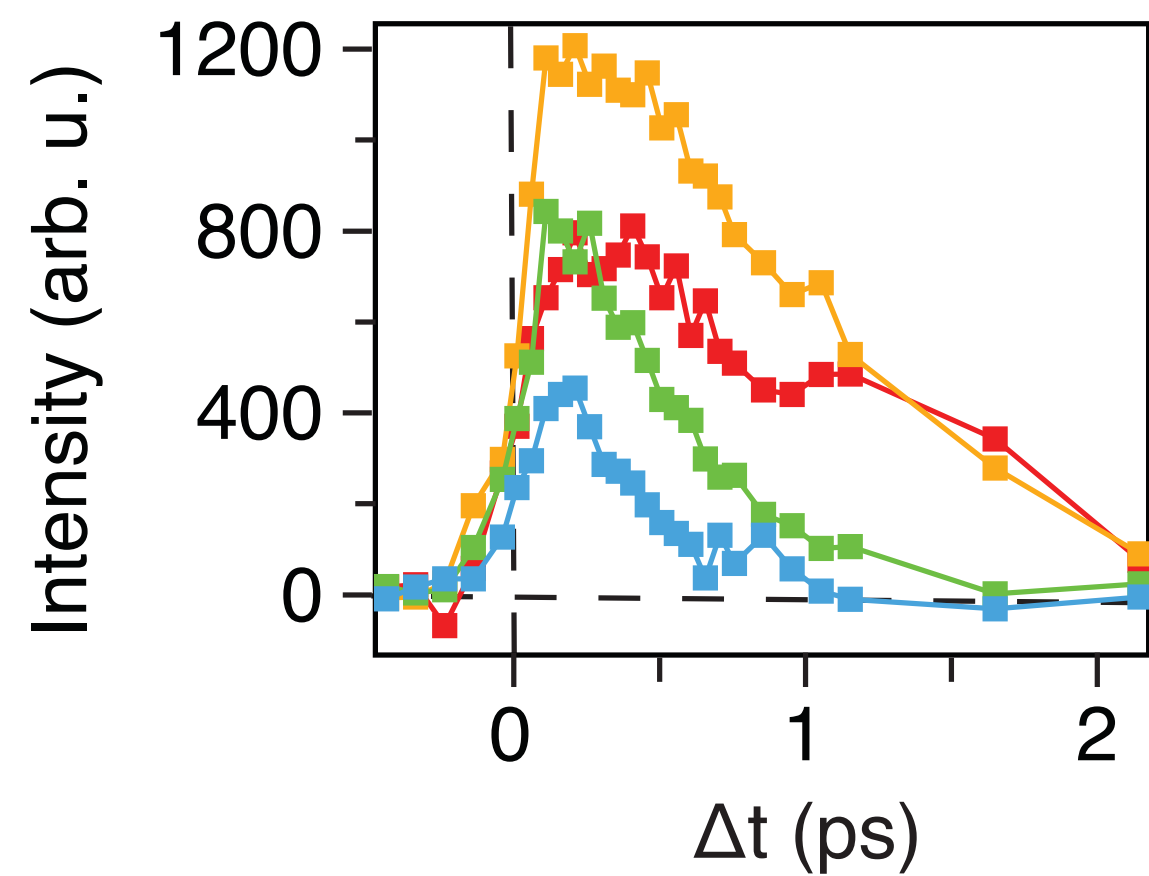
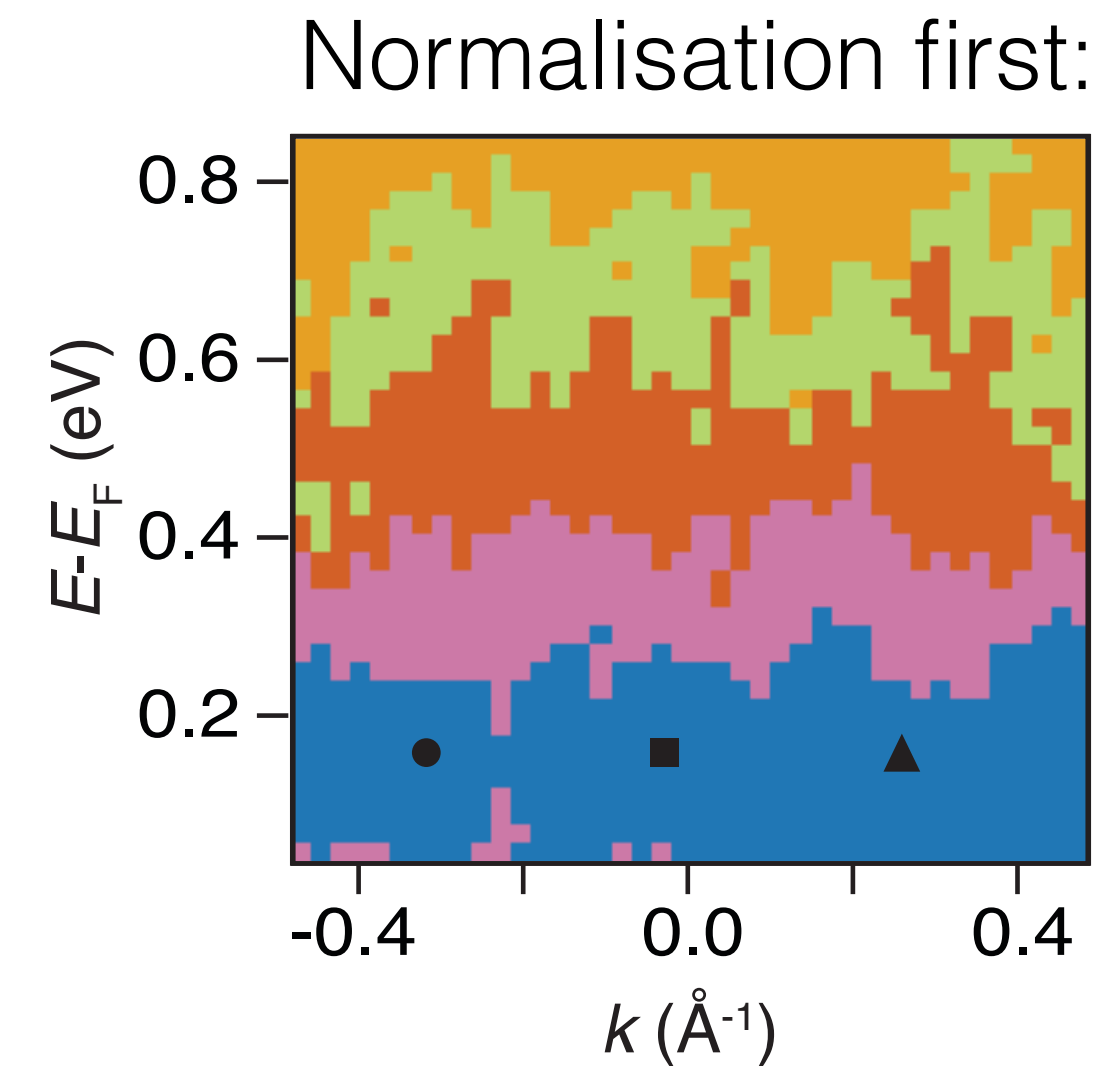
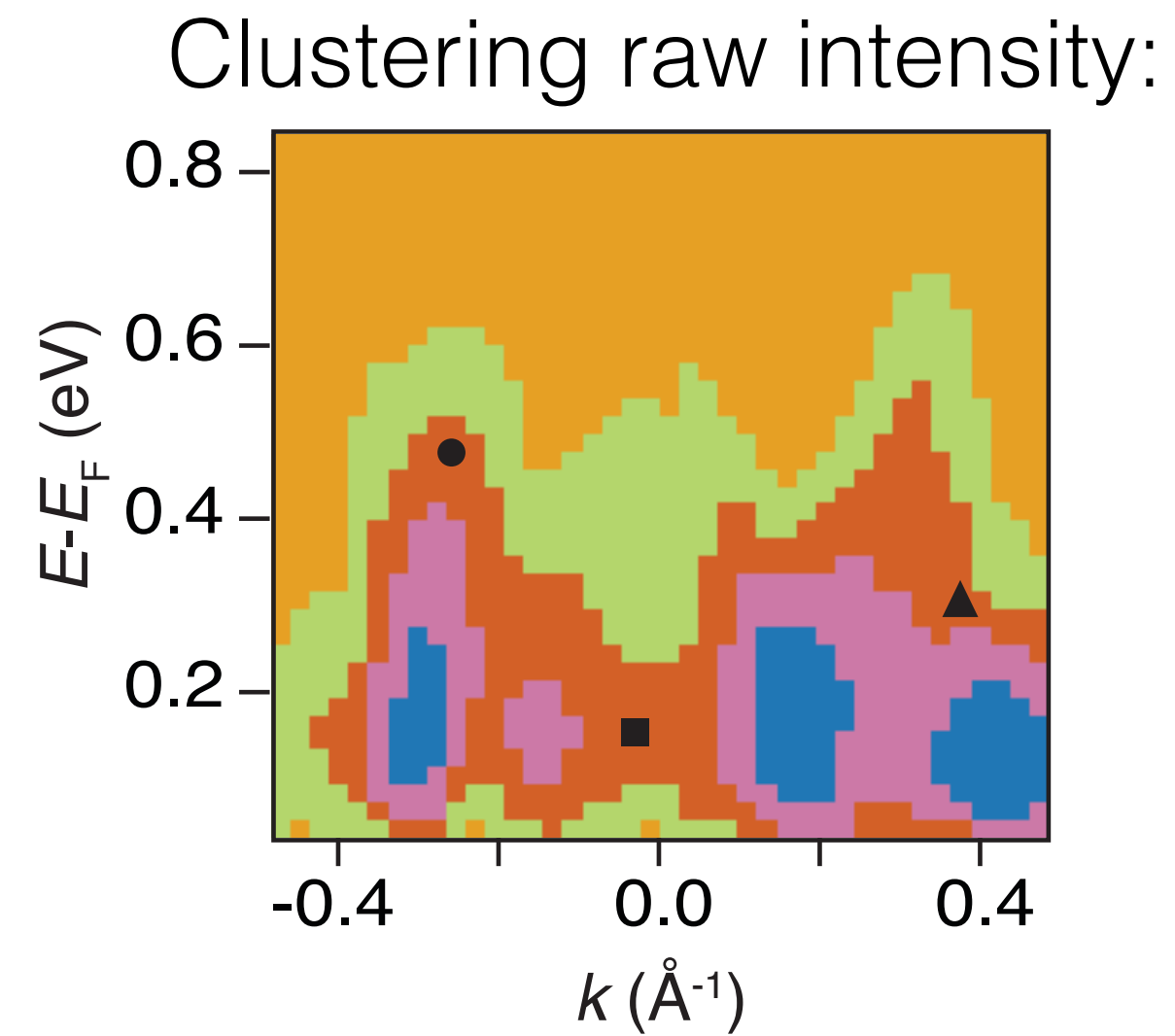
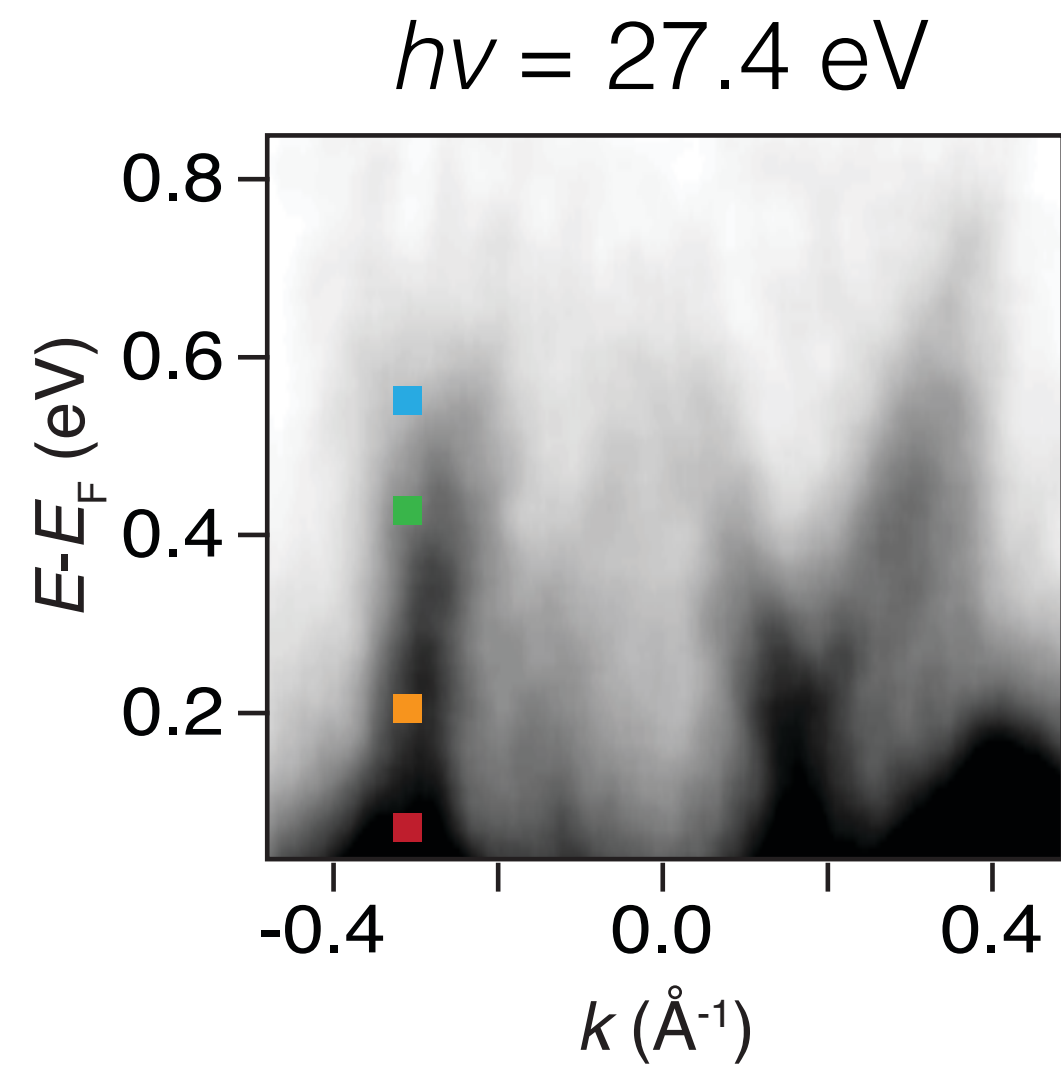


difference



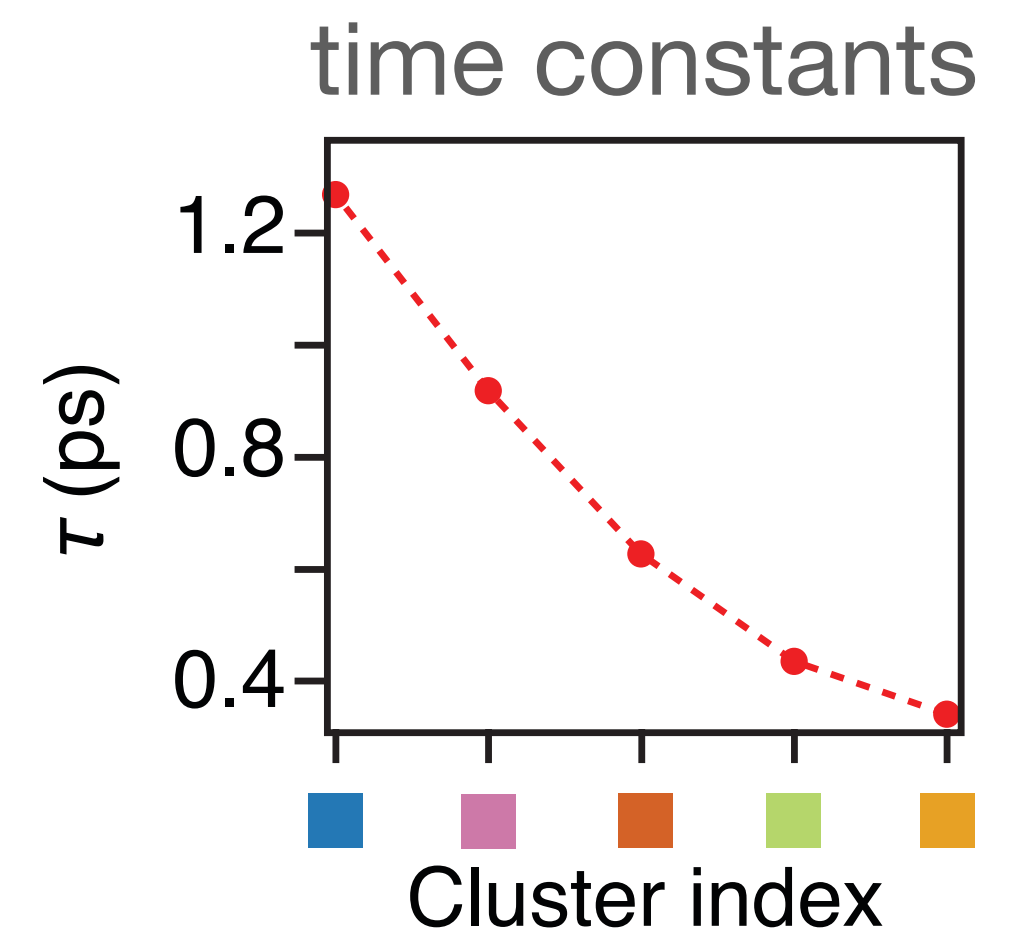
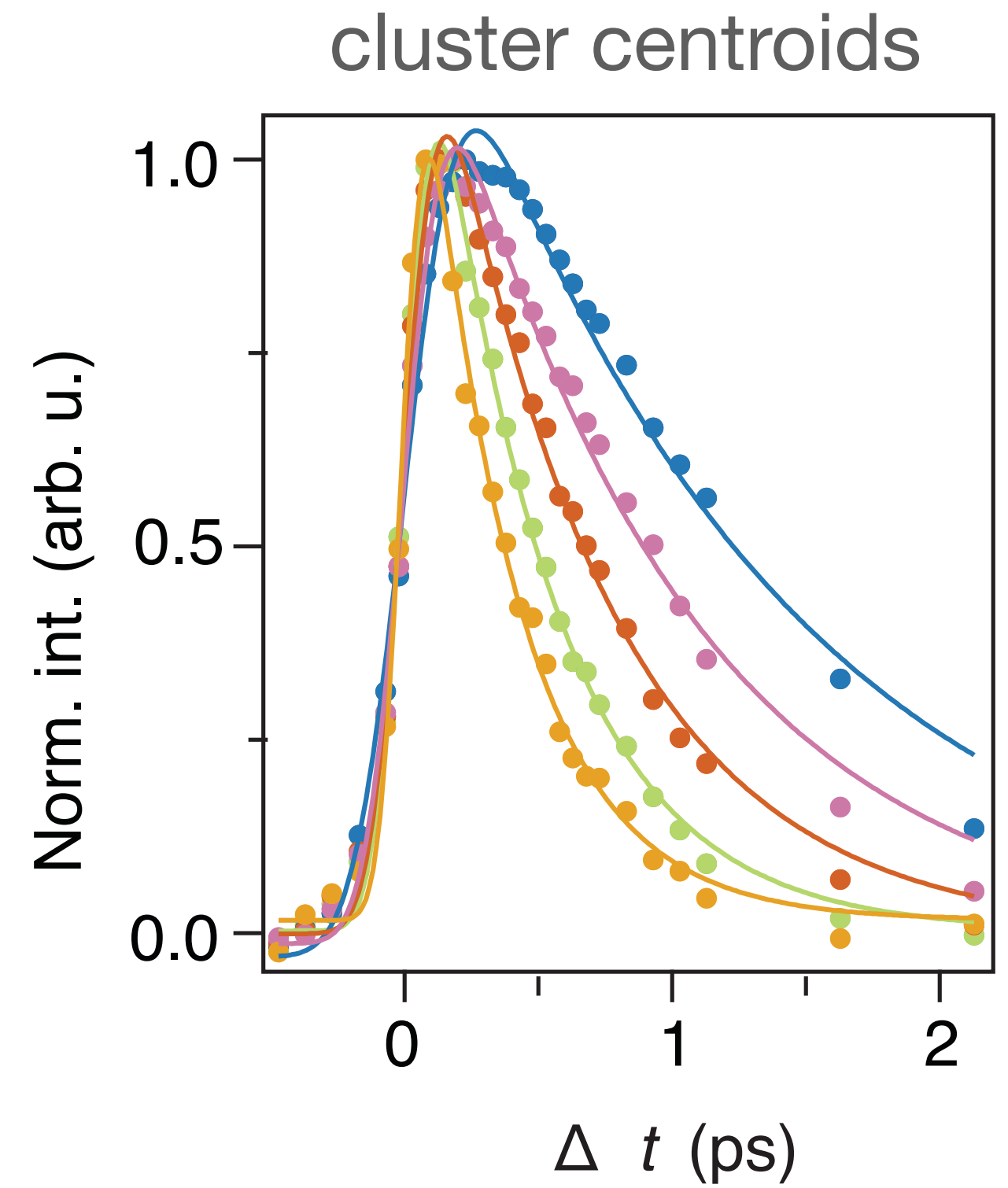
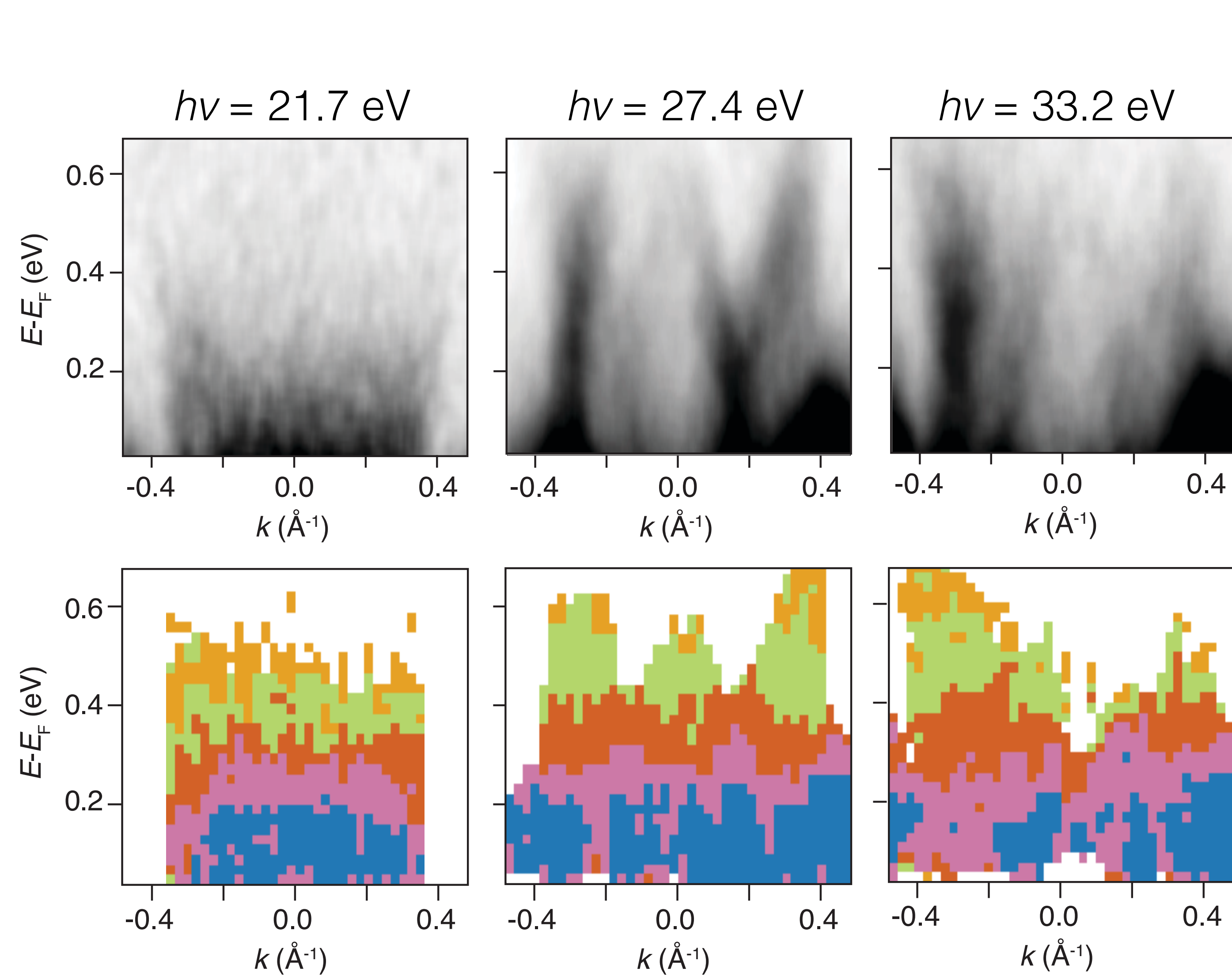
Time Distribution Curves (TDCs)

ultrafast dynamics: classification

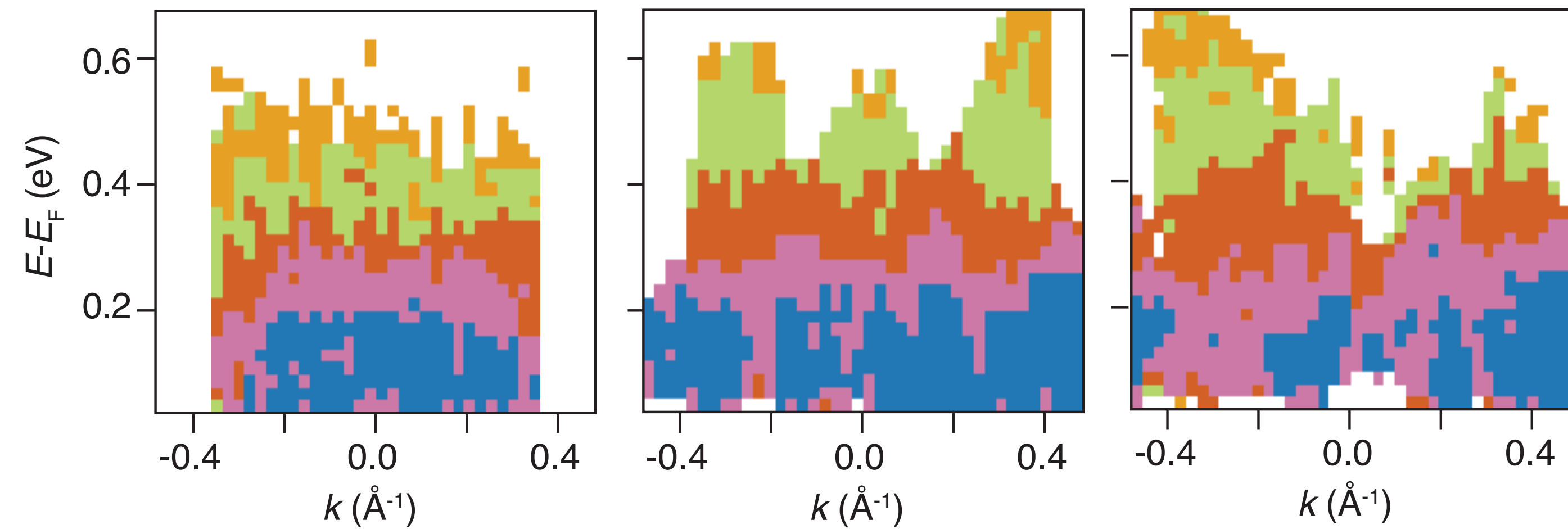
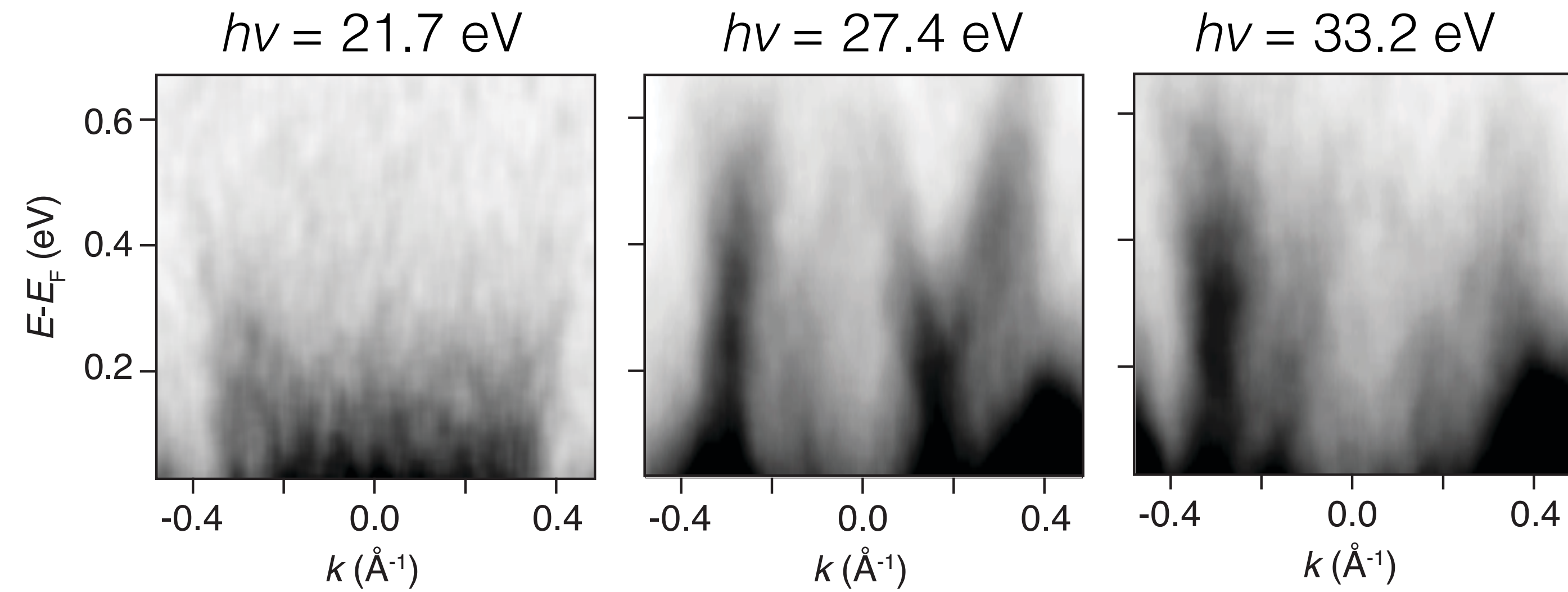


Time Distribution Curves (TDCs)

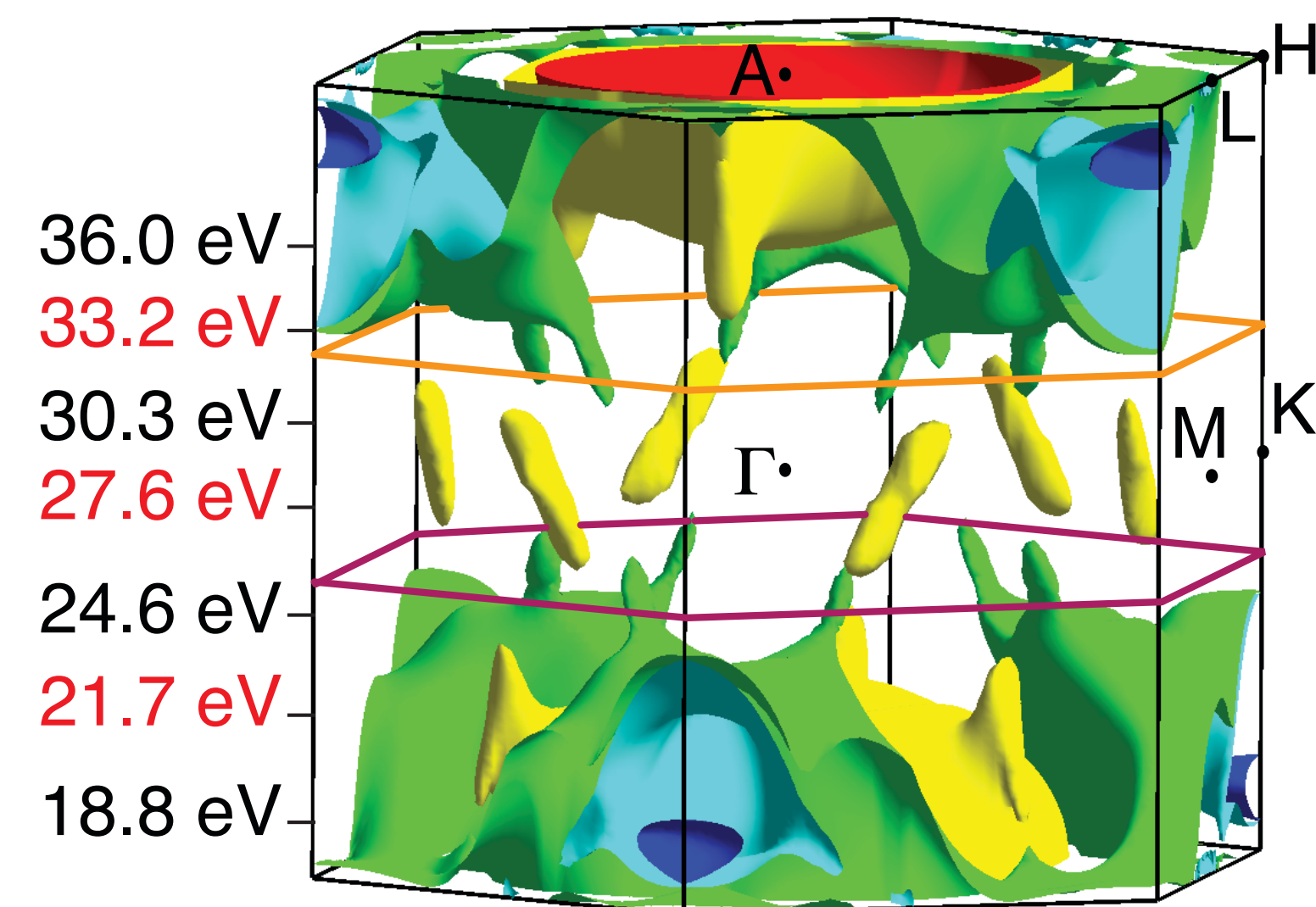
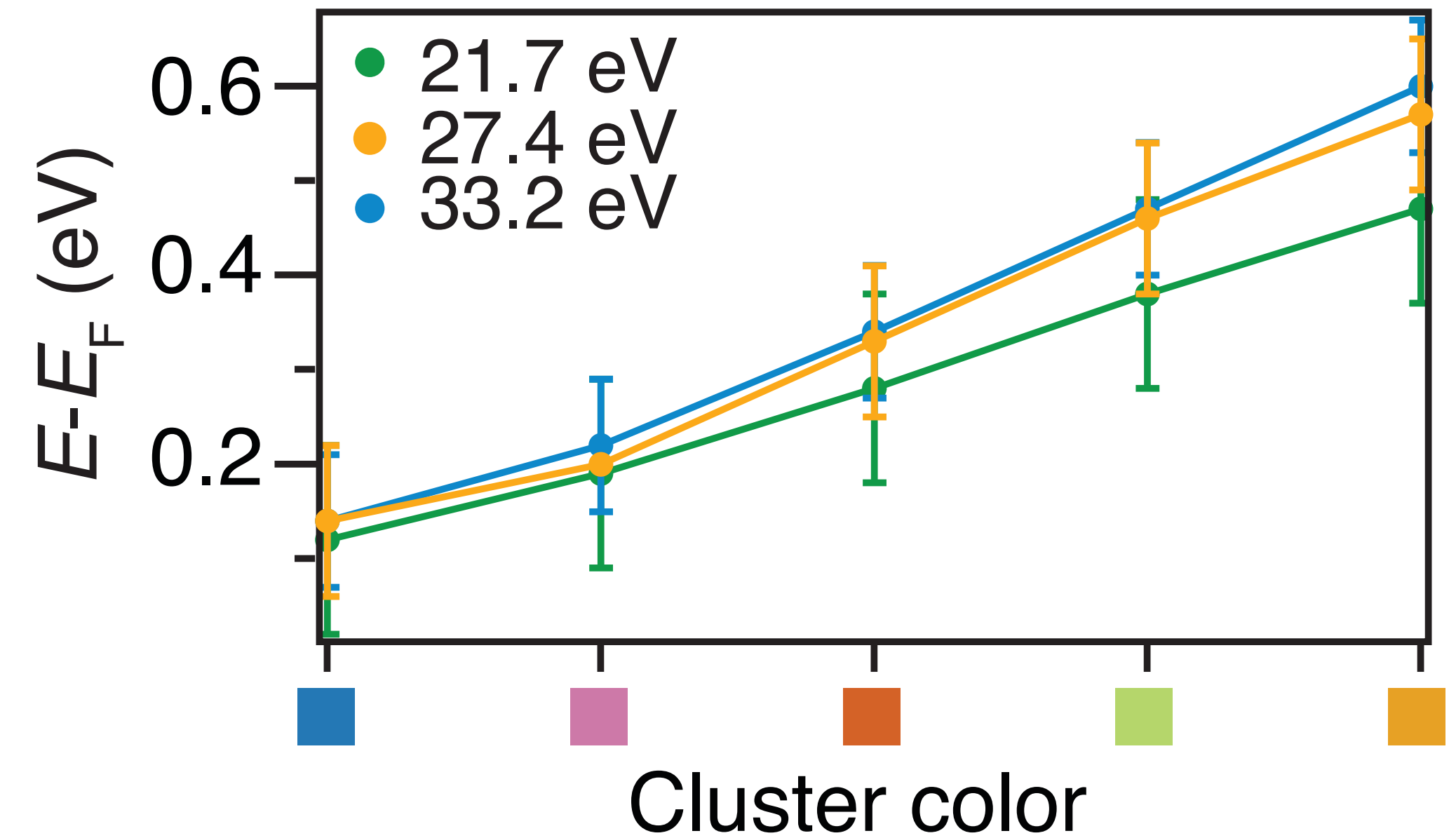
ultrafast dynamics: clustering everything together



ultrafast dynamics: clustering everything together

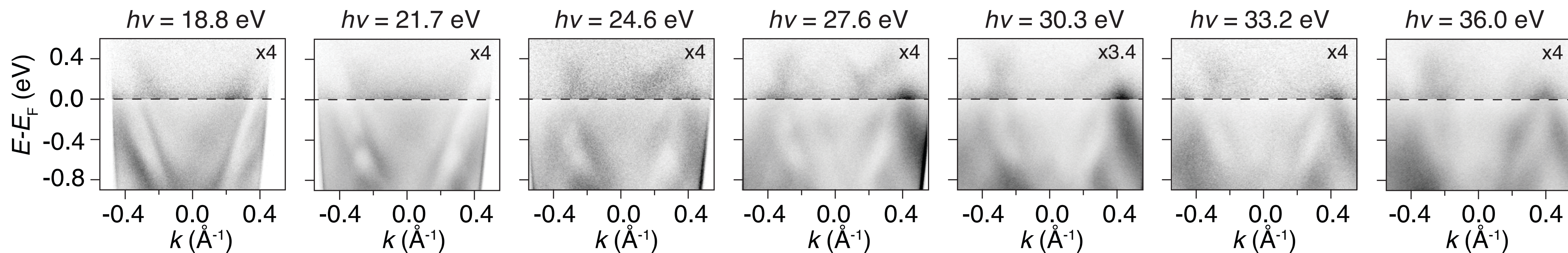


Faster dynamics at $h\nu = 21.7$ eV

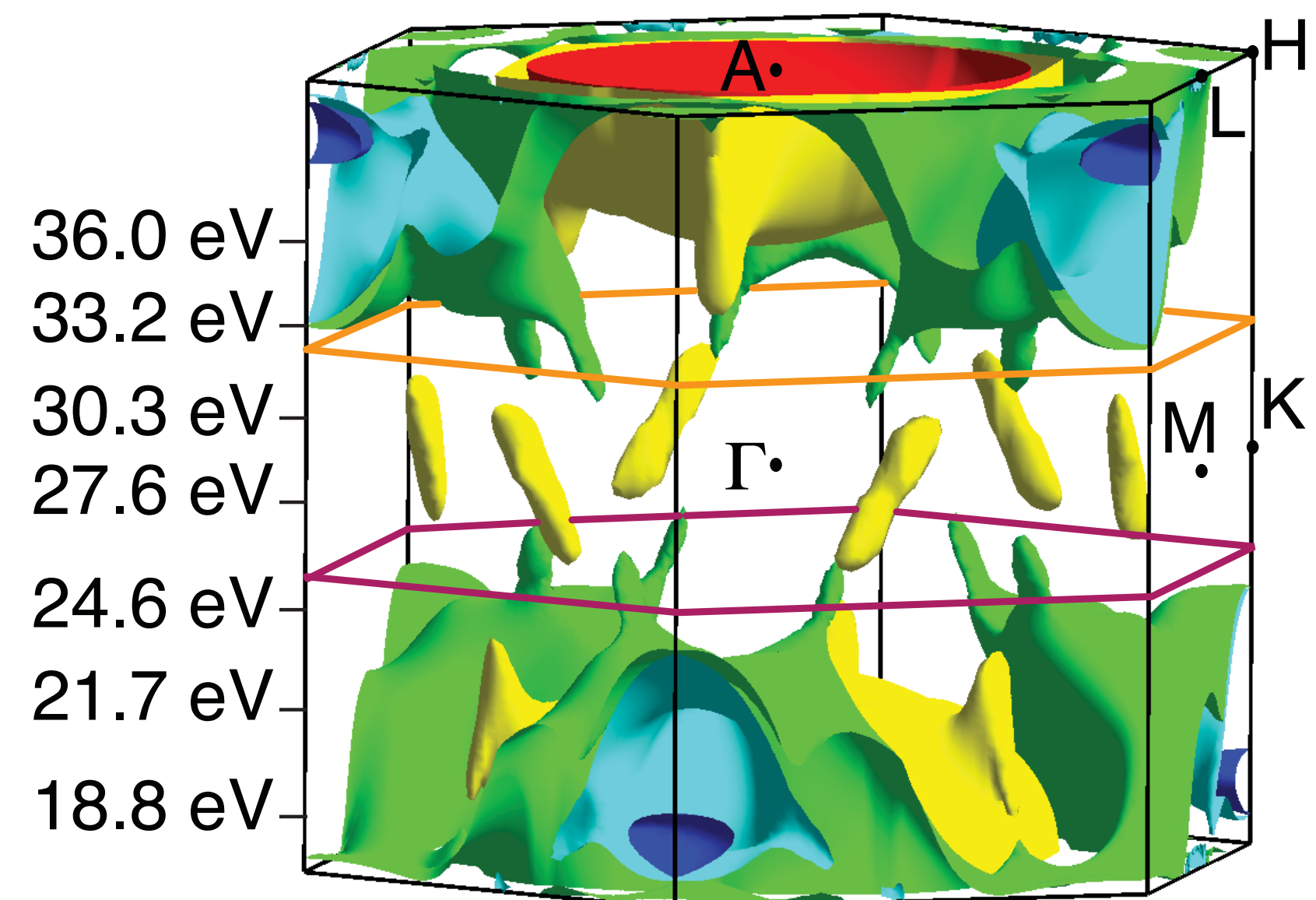
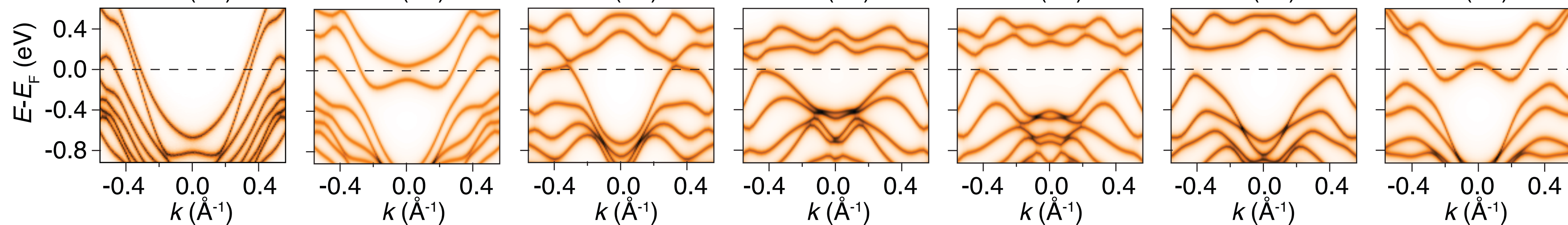


metallic / semiconducting character in the BZ

Data:



Theory:

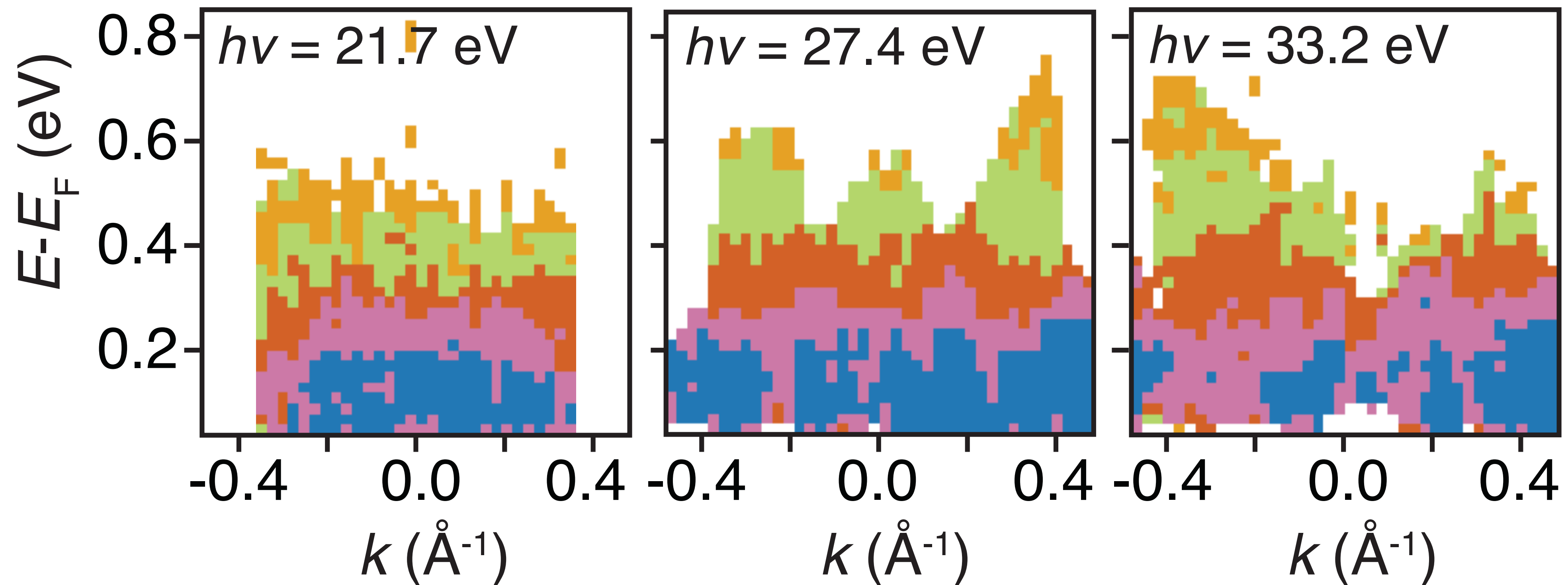


conclusions

- Using time-resolved ARPES, we can identify the Weyl points in the unoccupied band structure of trigonal PtBi₂.
- k_z is tuned using a high harmonic laser source with wide and fast tuneability between harmonics.
- The electron dynamics is faster in the parts of the Brillouin zone hosting metallic bands.
- Trends in high-dimensional data sets can be detected by k-means.

clustering by k-means

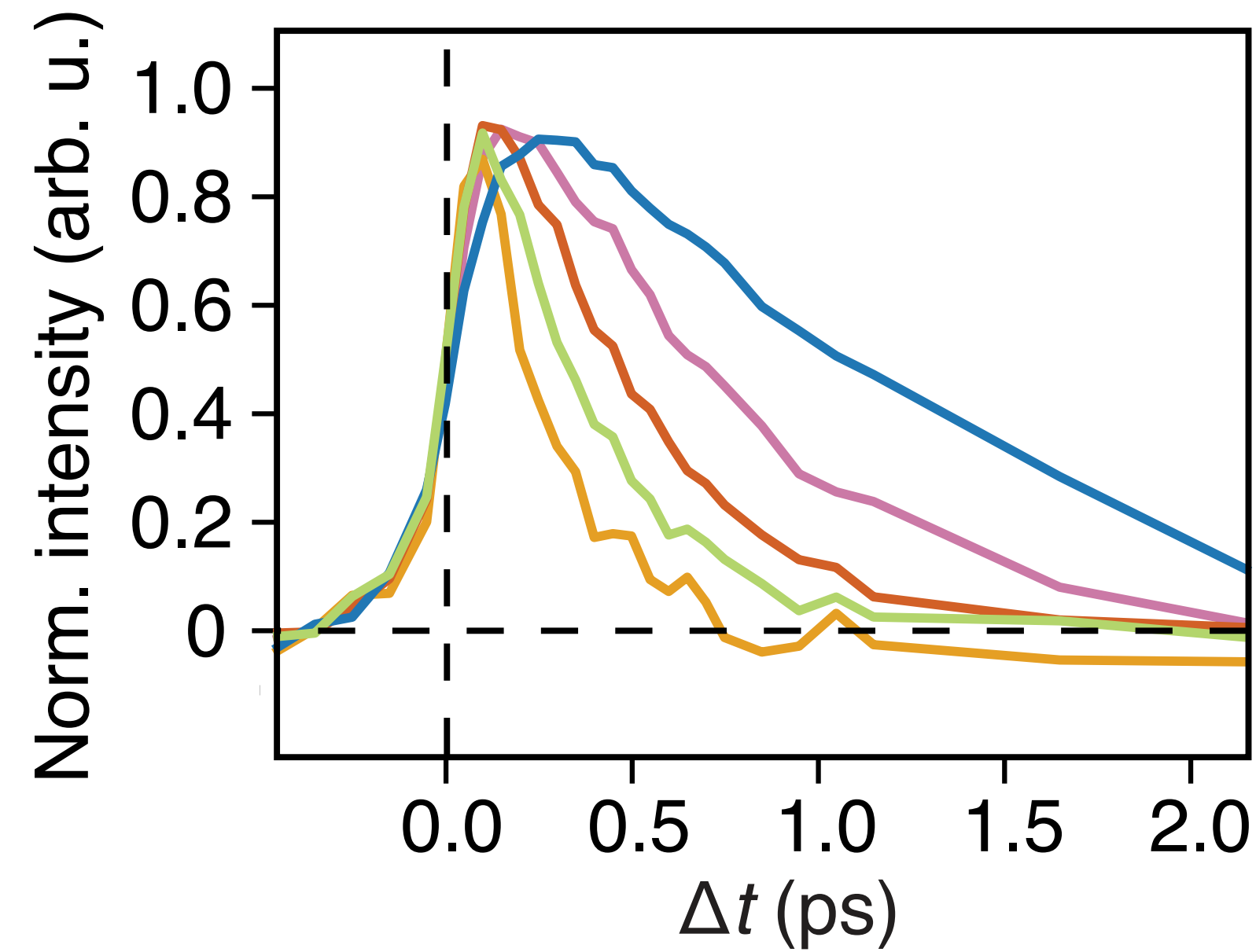
- clustering is agnostic about position in E-k space



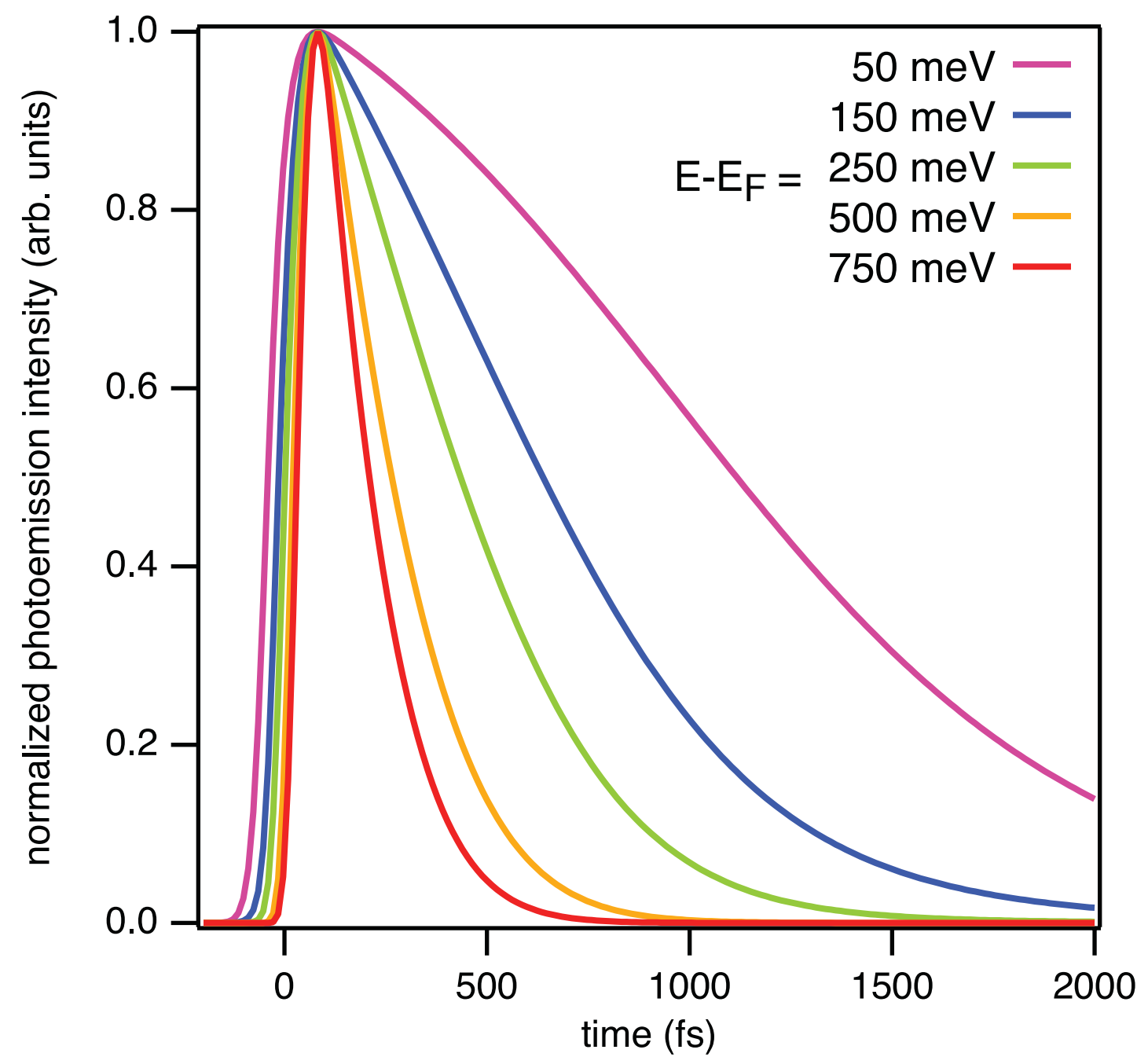
clustering by k-means

- Clustering is agnostic about line shape

present case



simulated data linear dispersion



coherent phonons

