

XUV spectroscopy and imaging of helium nanodroplets

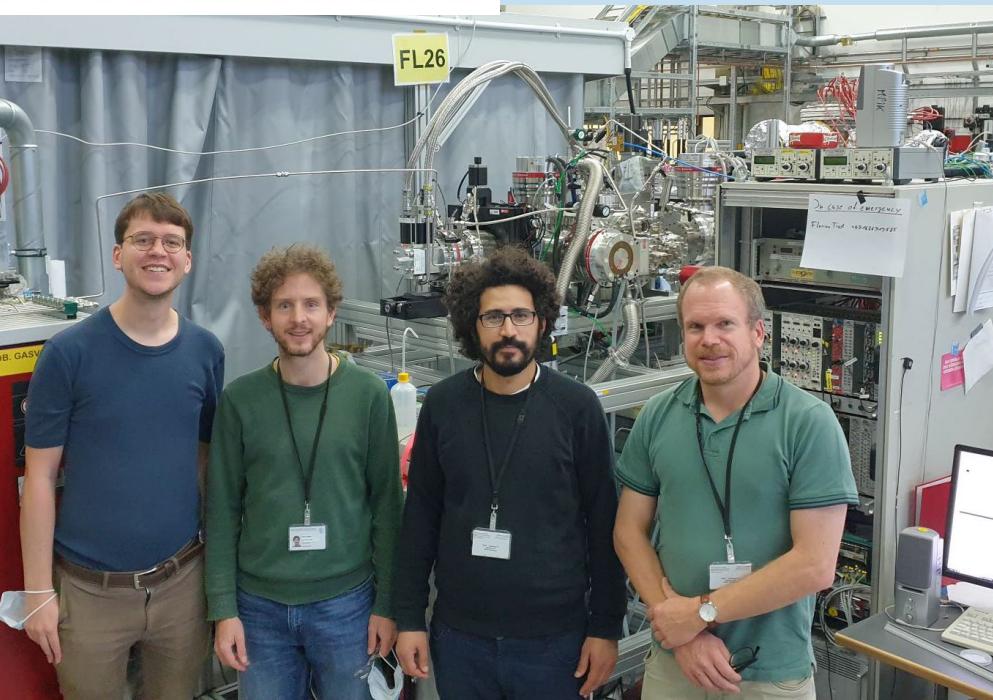
Marcel Mudrich

Department of Physics and Astronomy, Aarhus University, Denmark

- Correlated-decay dynamics of excited He nanodroplets
- XUV-enhanced ignition of a He nanoplasma
- X-ray diffraction imaging of He nanodroplets



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Thanks to...



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and the MAC team



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ETH Zürich: D. Rupp, L. Hecht, A. Colombo

IIT Madras: S. Krishnan, K. Sishodia

UConn: A. C. Laforge

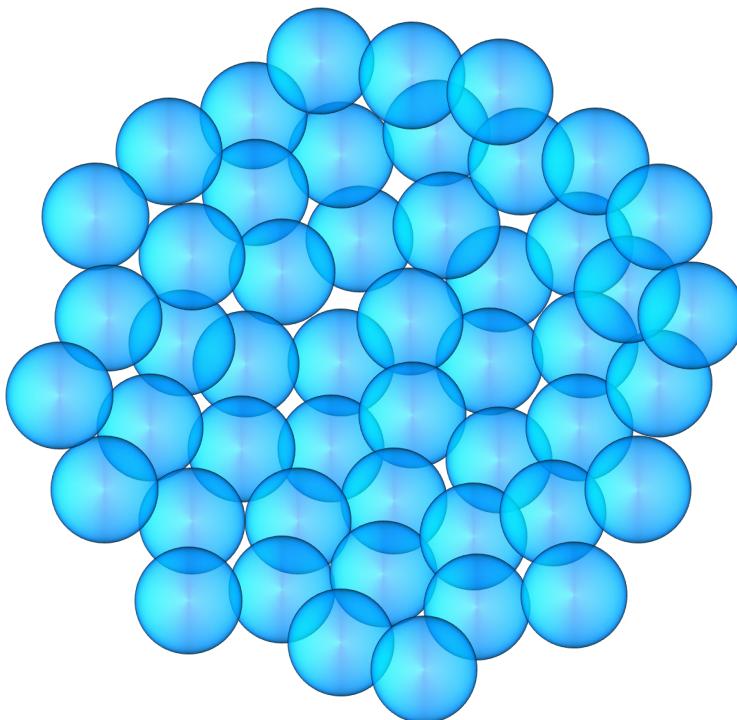
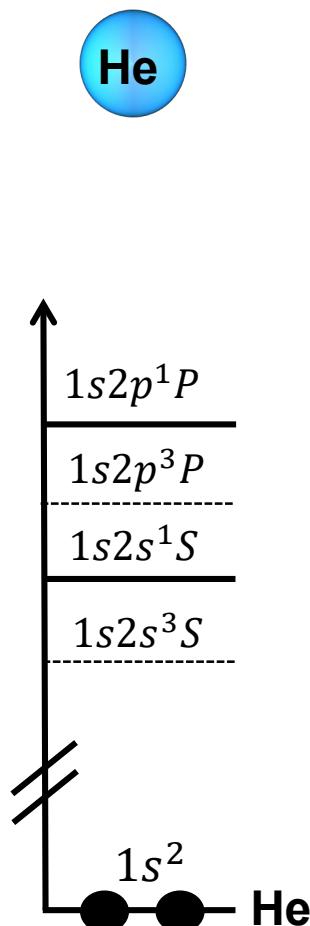
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MPIK Heidelberg: T. Pfeifer, R. Moshammer

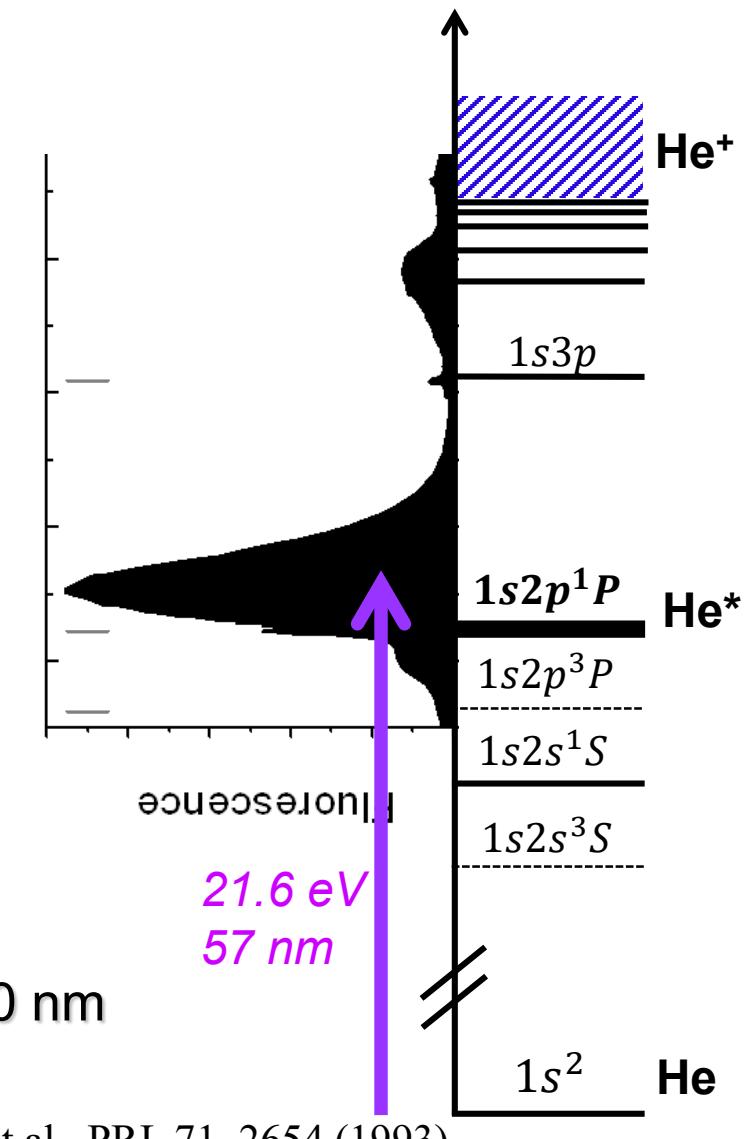
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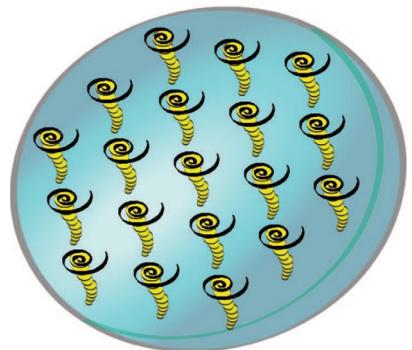
Helium nanodroplets – excitation & ionization



Weak binding: ~ 7 K per He atom
 $\rightarrow T = 0.37$ K \rightarrow superfluid
Size: $10^2 - 10^{10}$ He atoms $\rightarrow \varnothing 1 - 1000$ nm

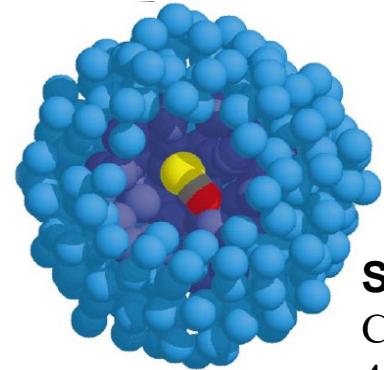


Aggregates in He drop



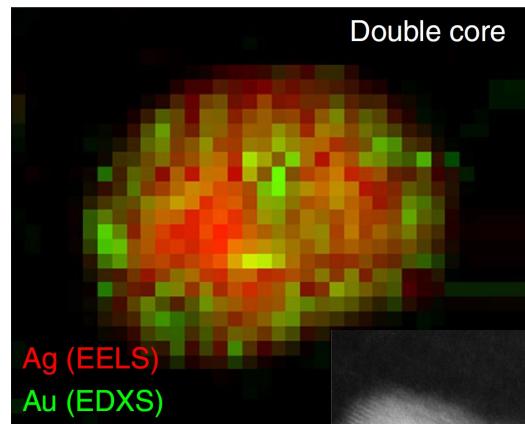
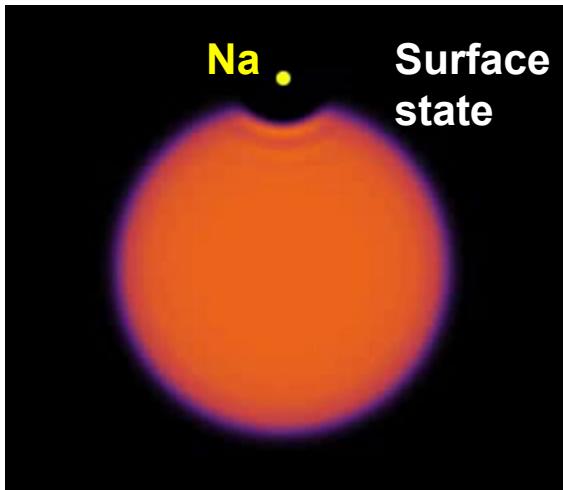
Vortex-aggregation

Science 345, 906-909 (2014)



Solvation

Chem. Angew. Int. Ed.
43, 2622 (2004)



**Core-shell
metal NP**

Nat. Commun. 6, 877

Nanorod

Phys. Rev. B 90, 1

Alkwin Slenczka
Jan Peter Toennies *Editors*

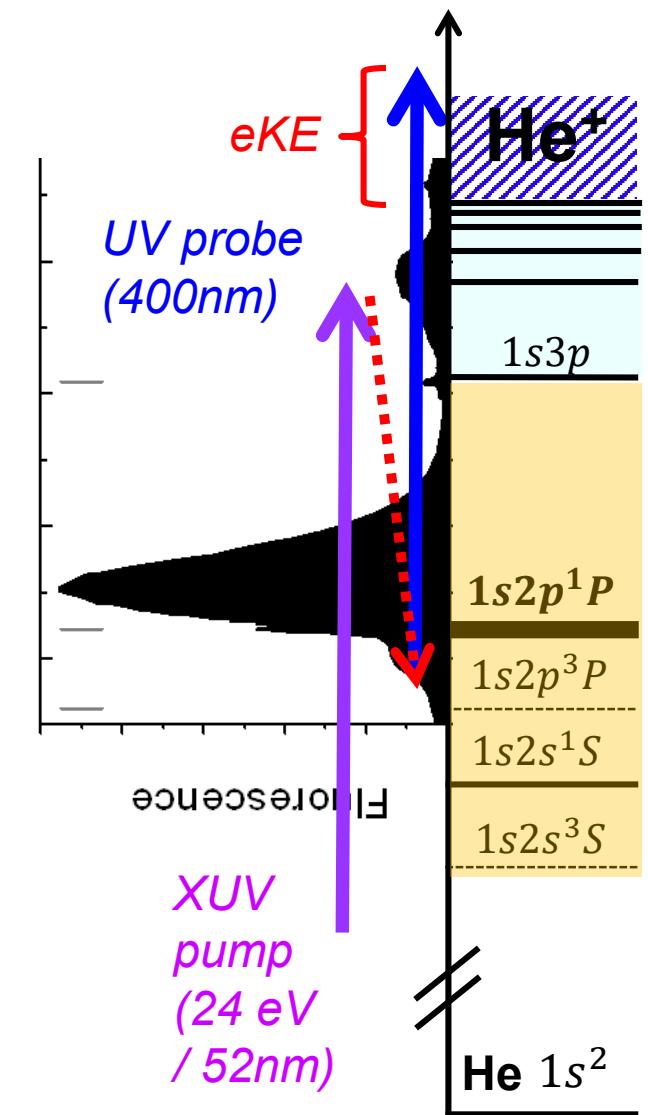
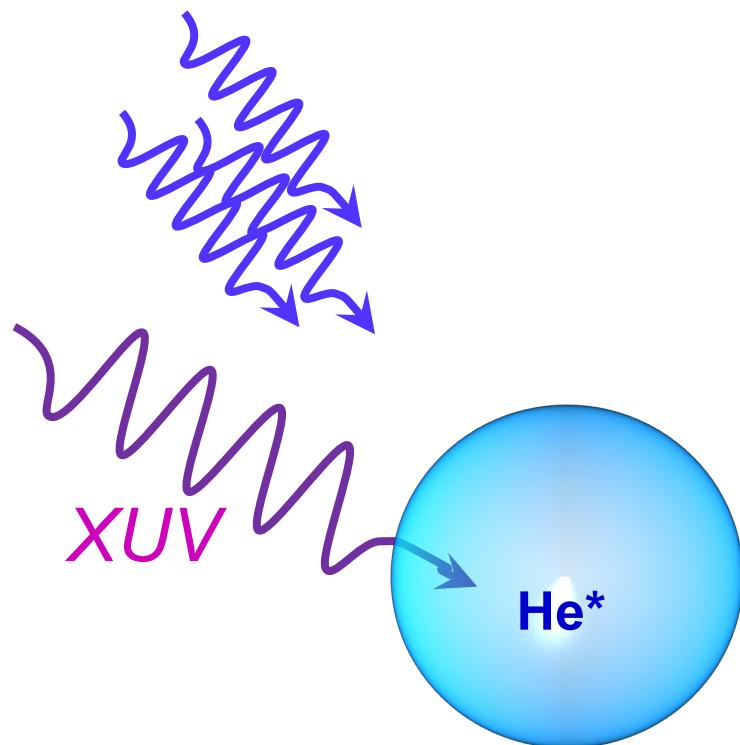
Molecules in Superfluid Helium Nanodroplets

Spectroscopy, Structure, and Dynamics

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Springer

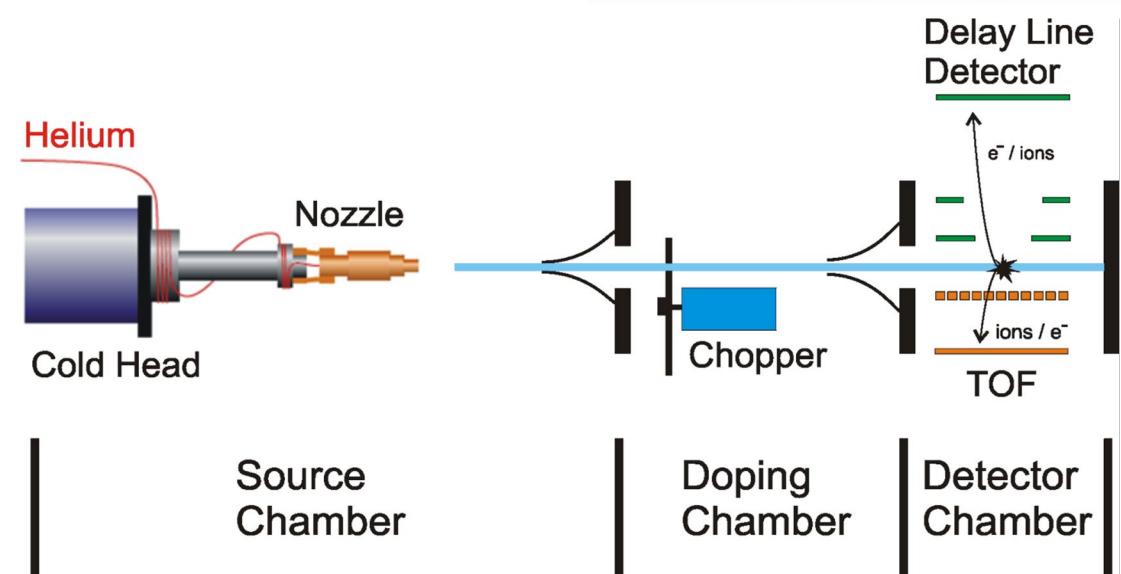
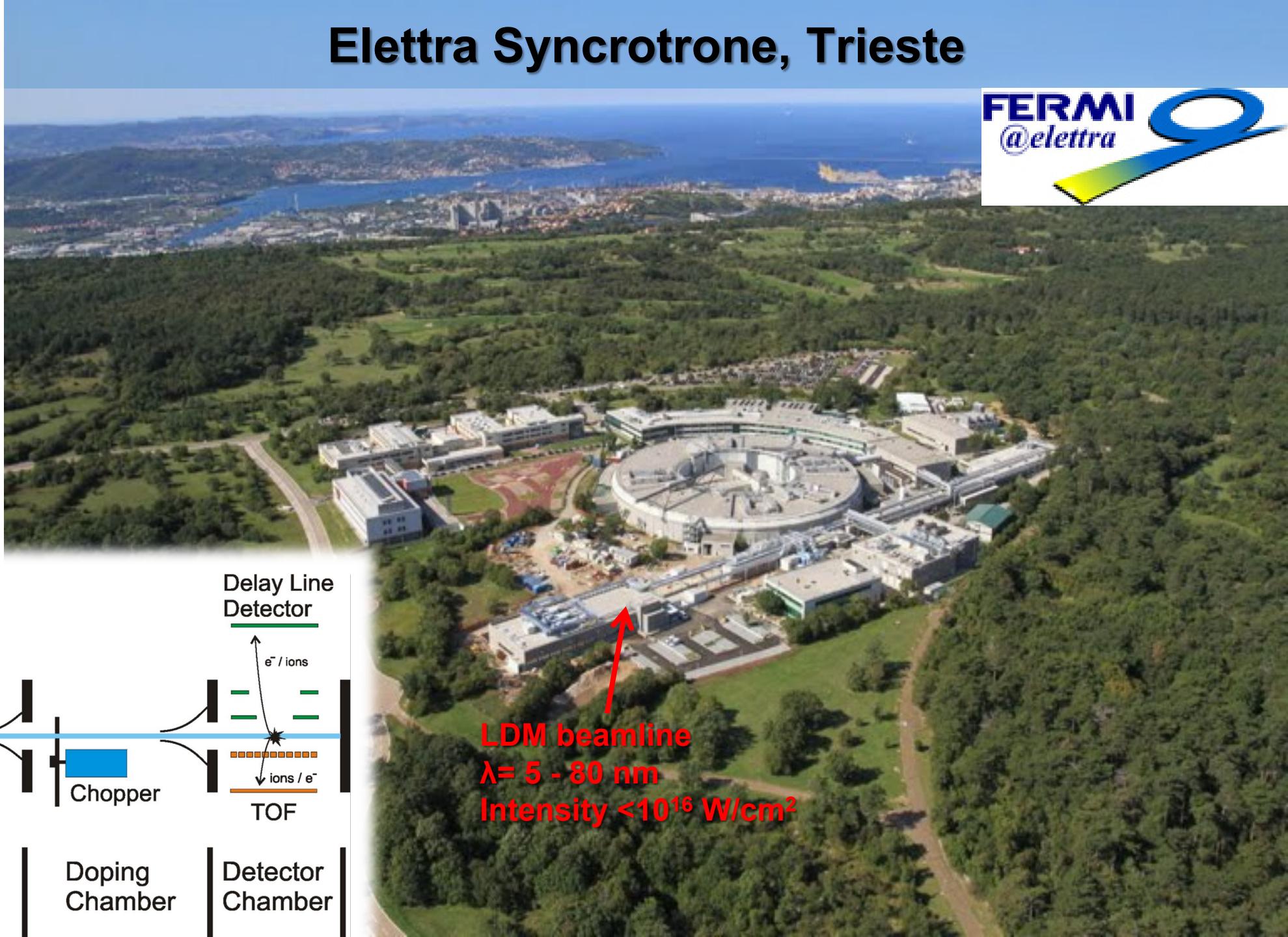
Relaxation of excited pure He nanodroplets





Elettra Sincrotrone Trieste

Elettra Sincrotrone, Trieste

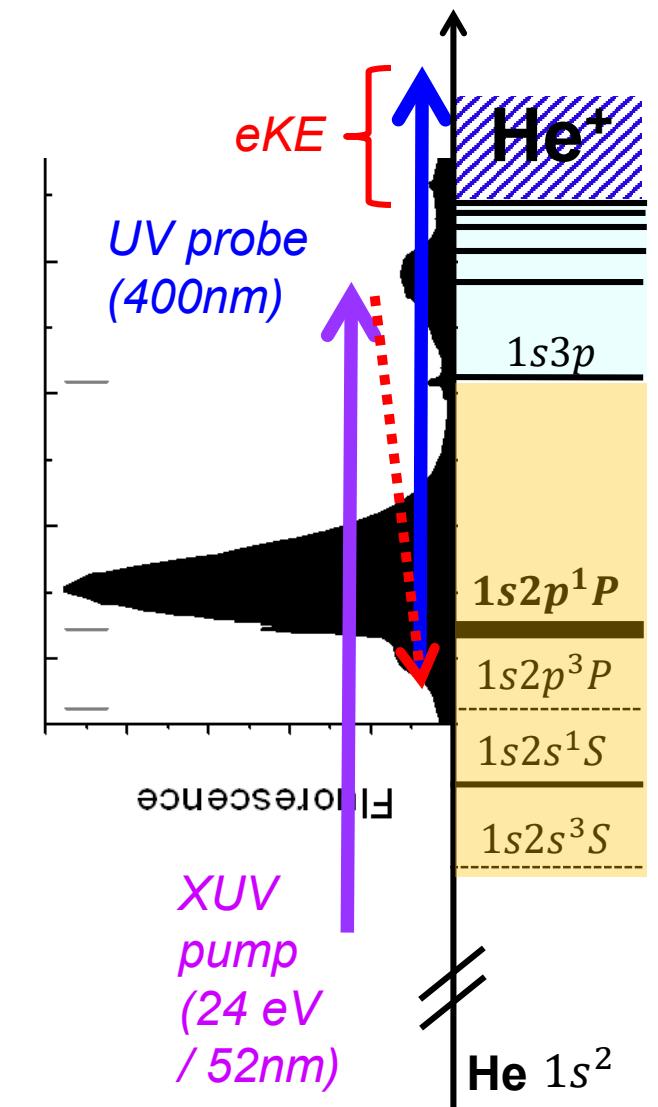
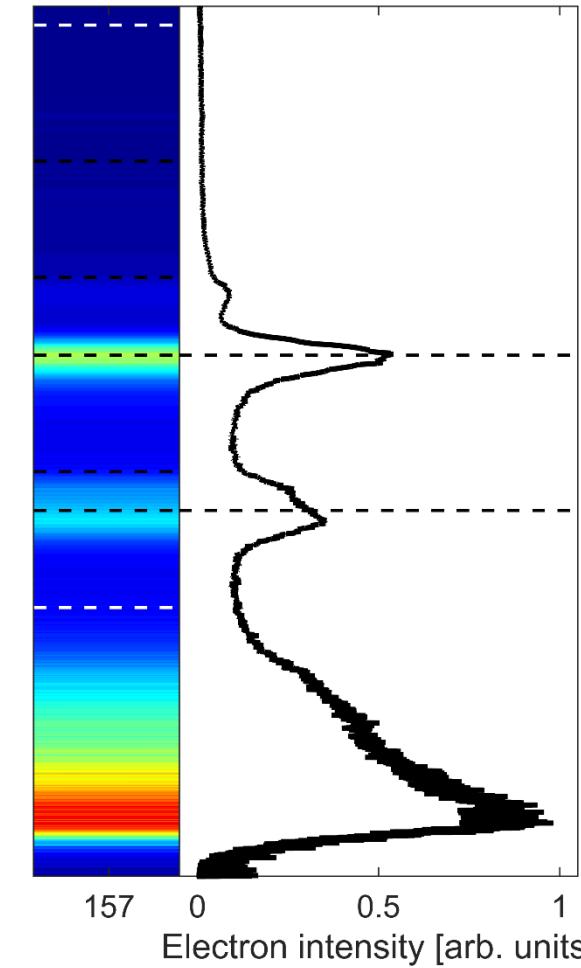
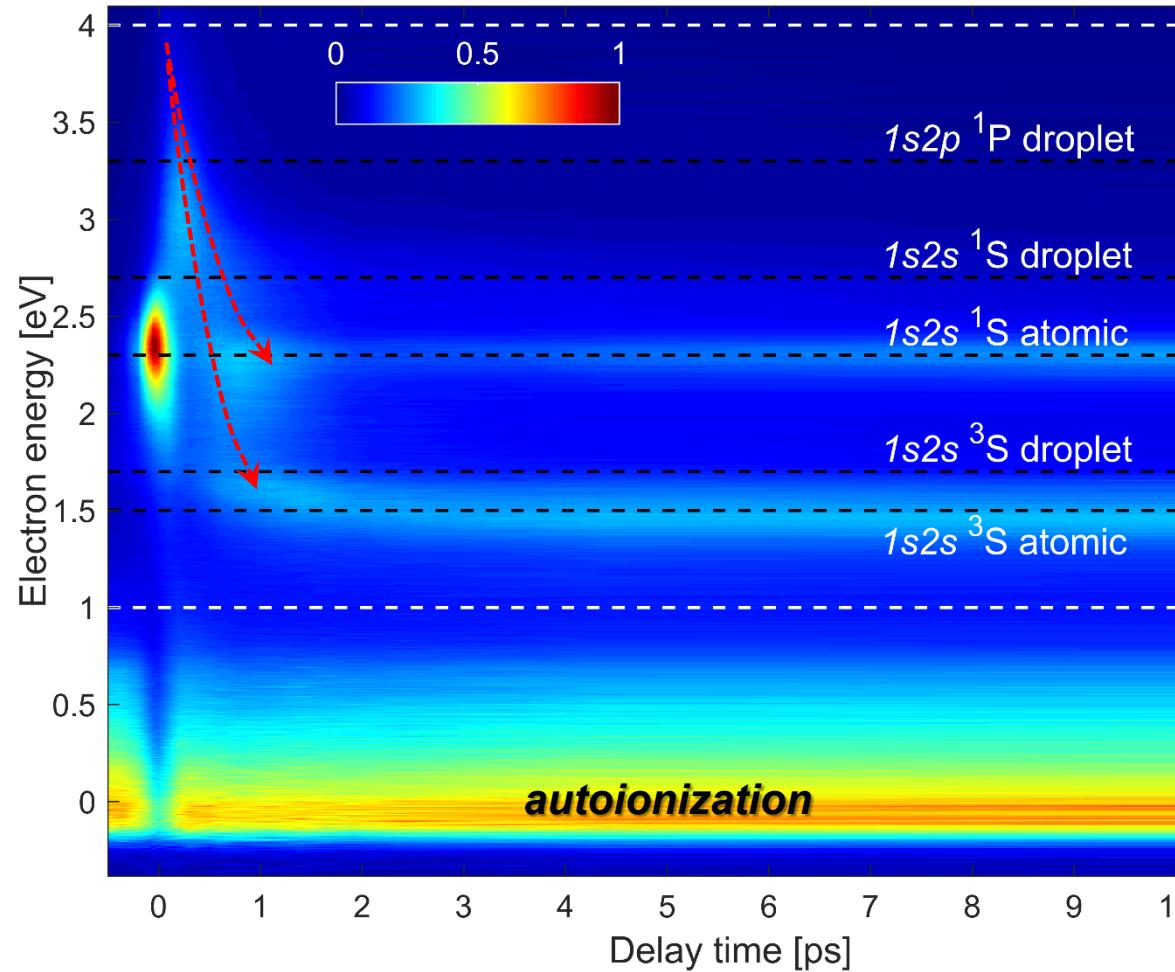


LDM beamline
 $\lambda = 5 - 80 \text{ nm}$
Intensity $< 10^{16} \text{ W/cm}^2$

Relaxation of *superexcited* He nanodroplets



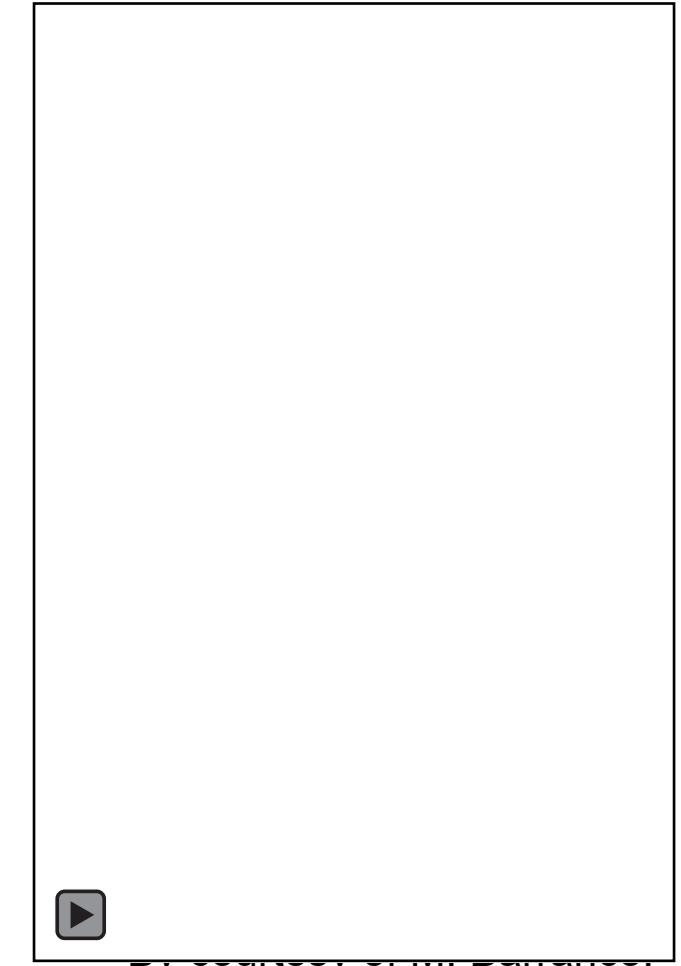
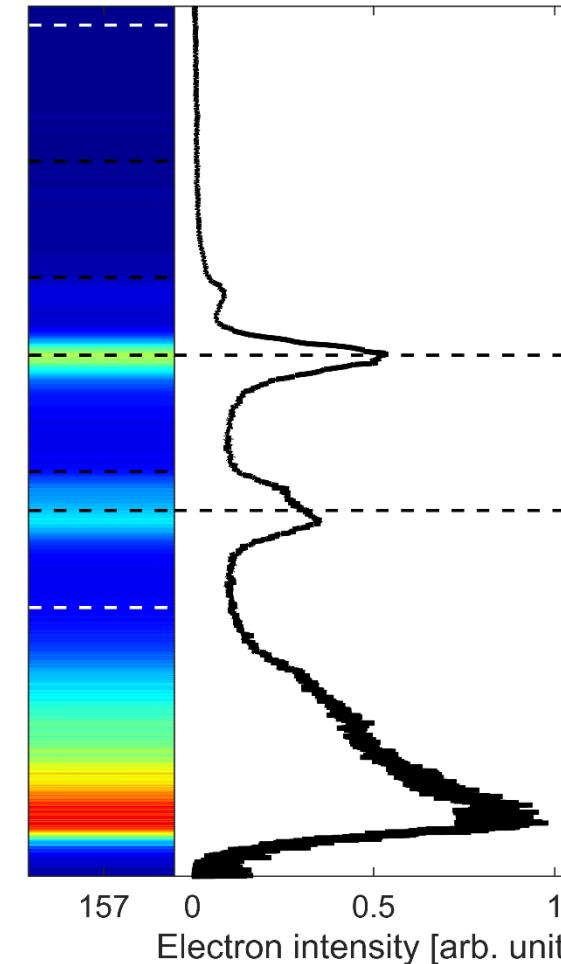
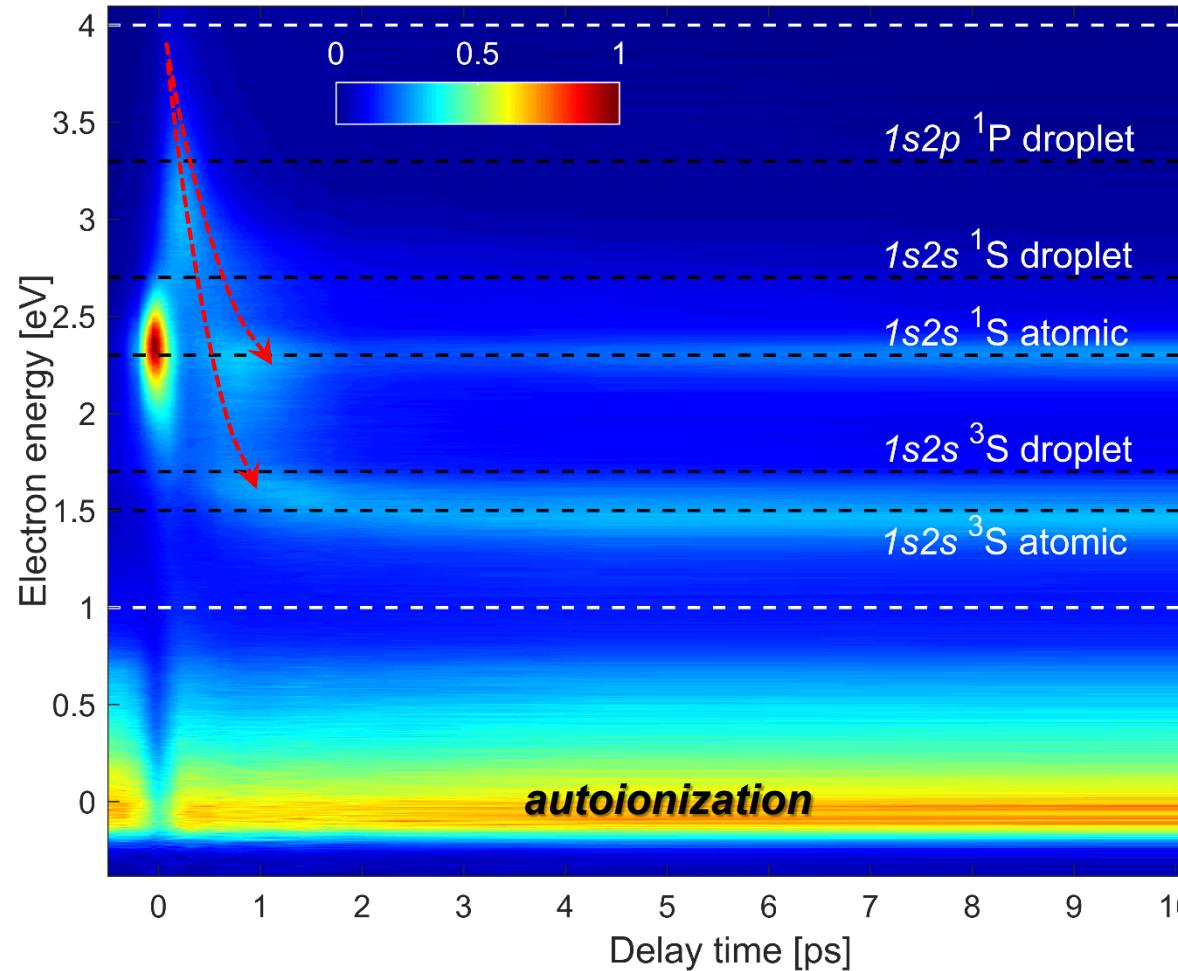
Measured with magnetic bottle spectrometer



Relaxation of *superexcited* He nanodroplets

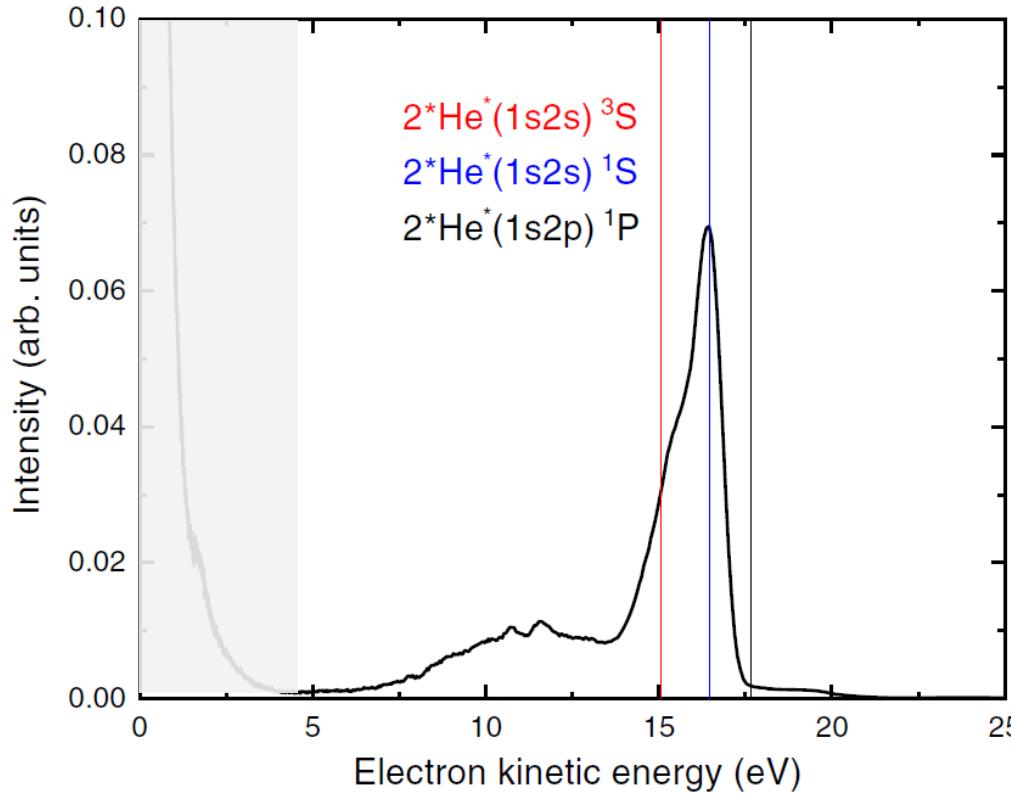


Measured with magnetic bottle spectrometer

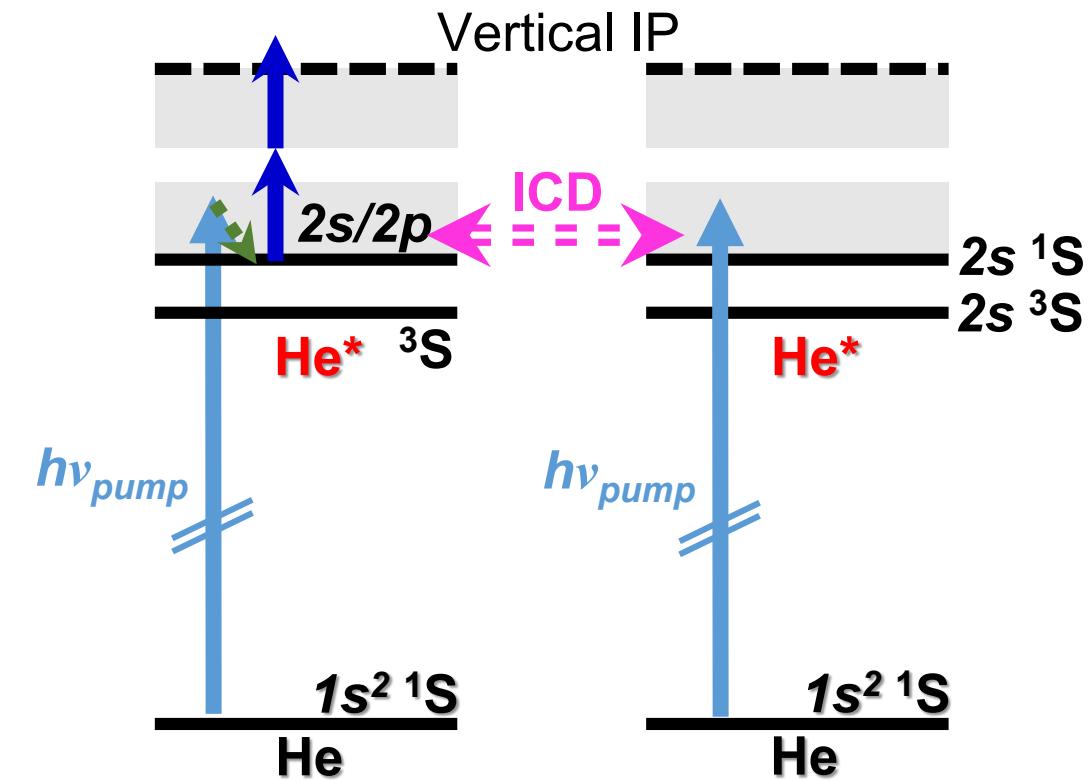


Barcelona

Multiply excited He nanodroplets

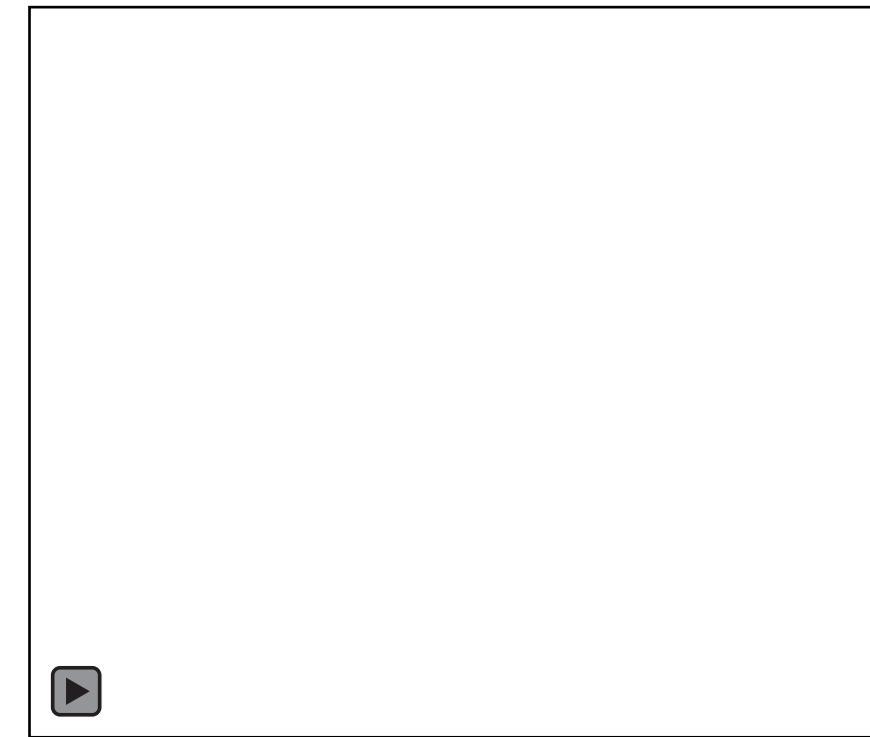
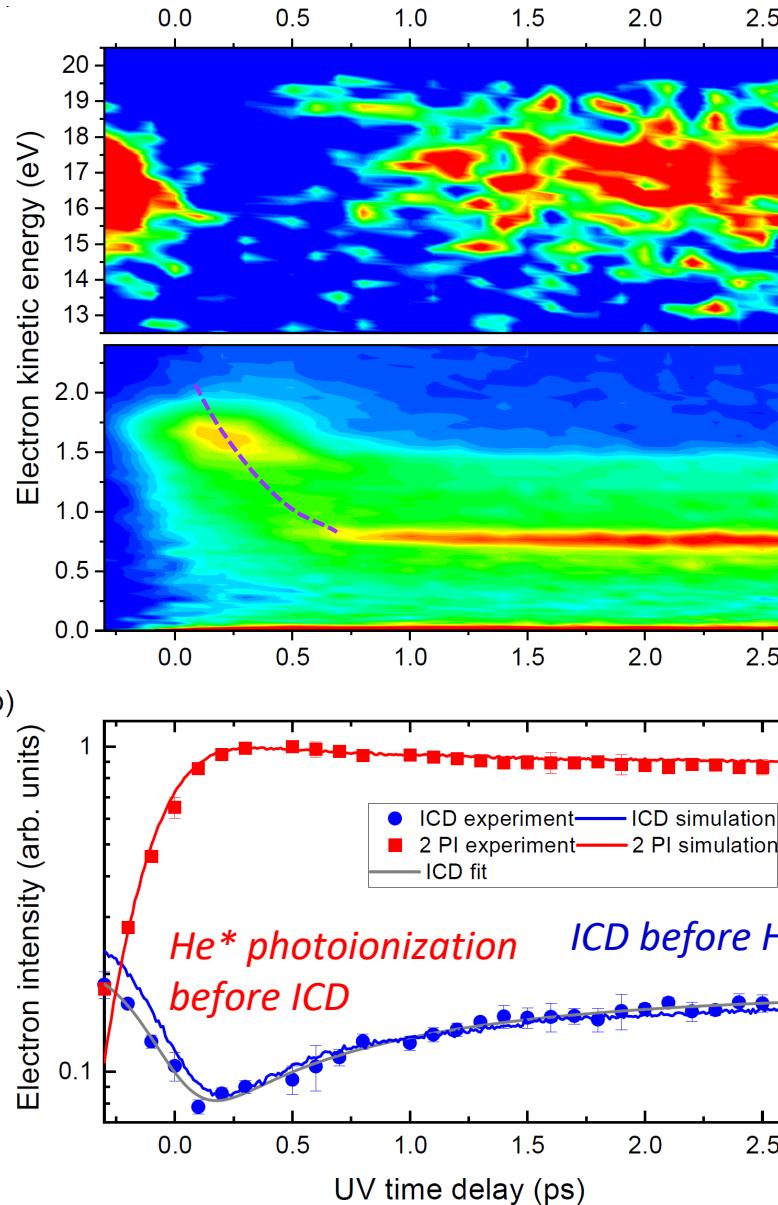


Interatomic Coulombic decay (ICD):

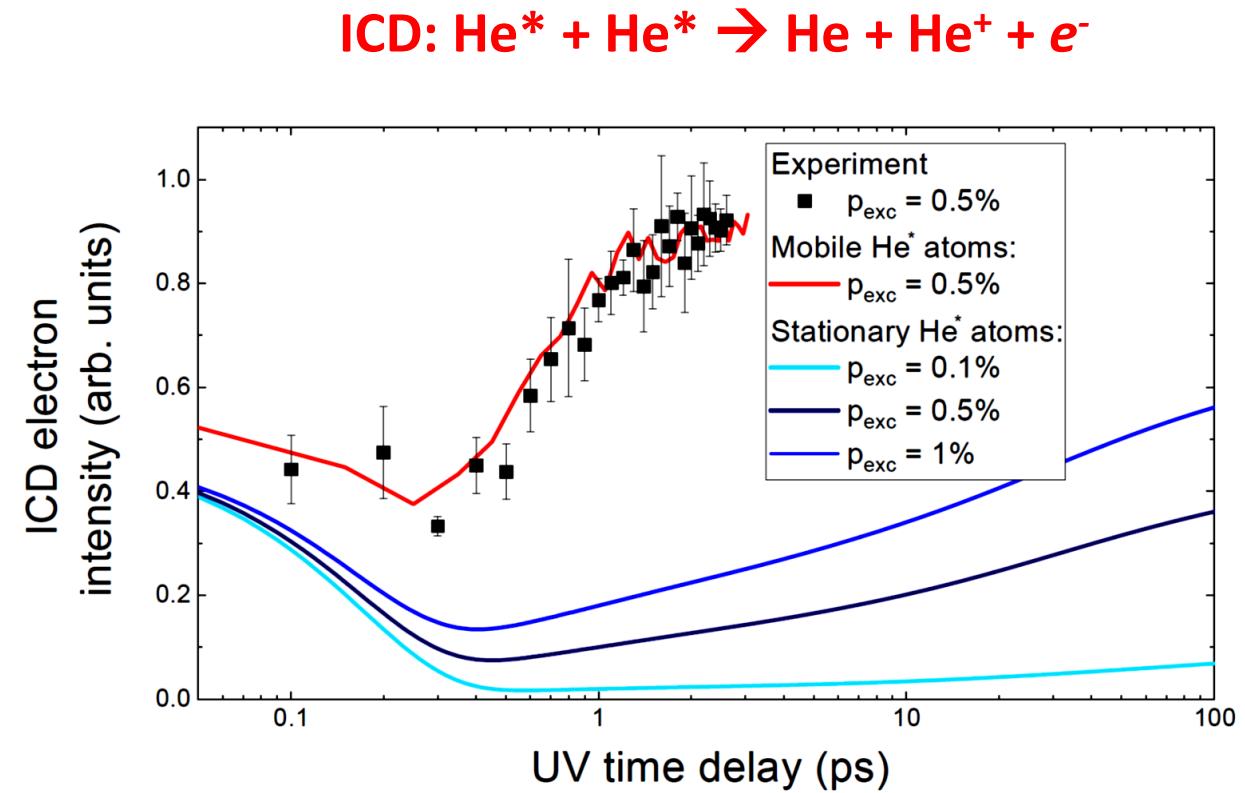
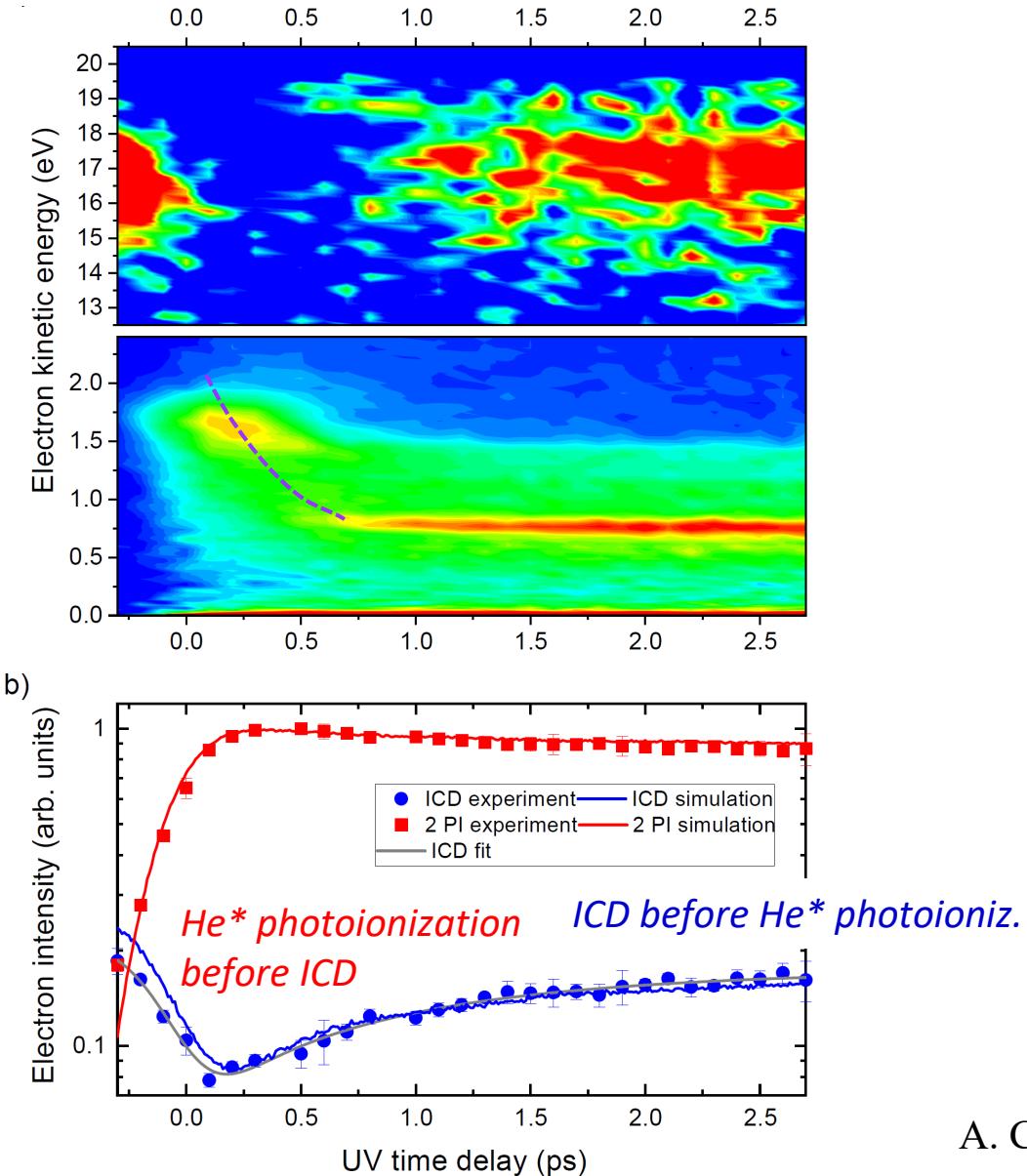


See also Kuleff et al., PRL 105, 043004 (2010)

Multiply excited He nanodroplets

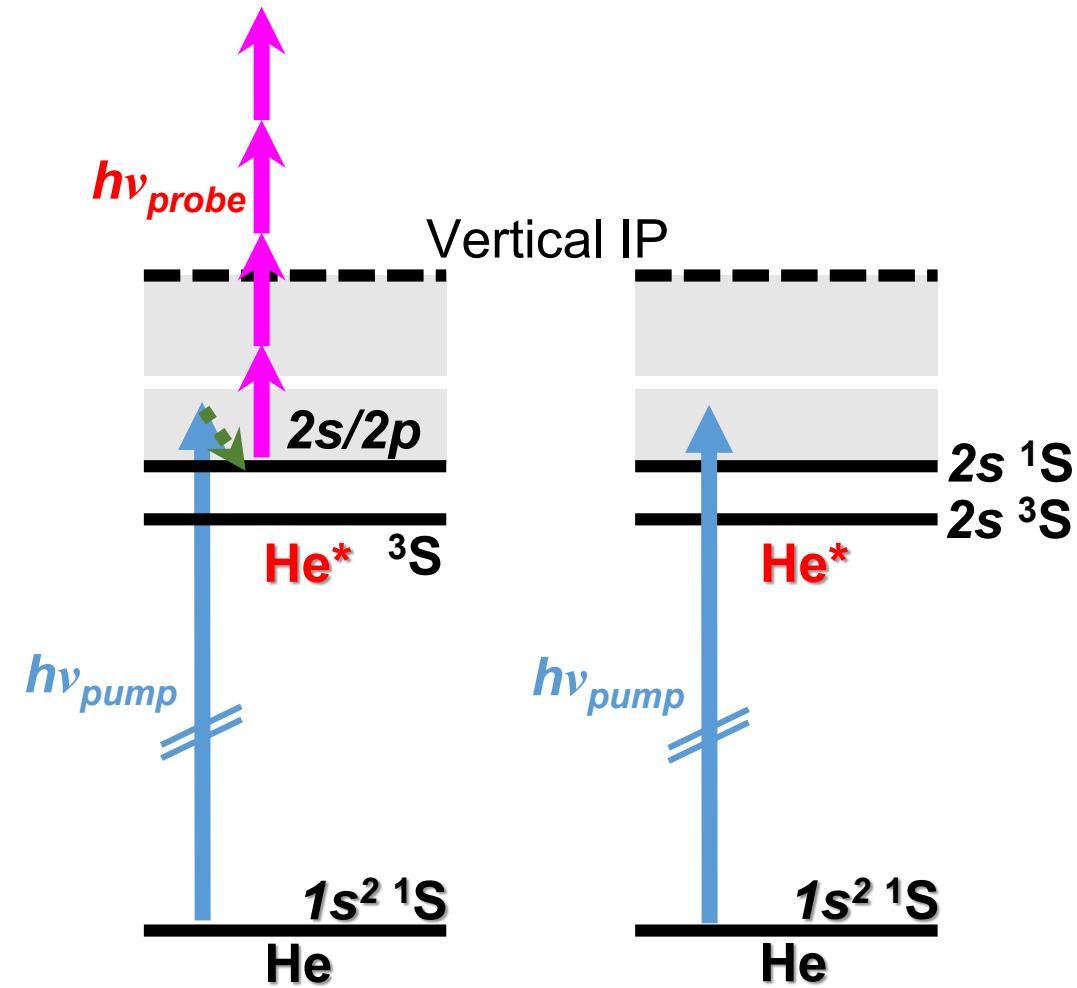
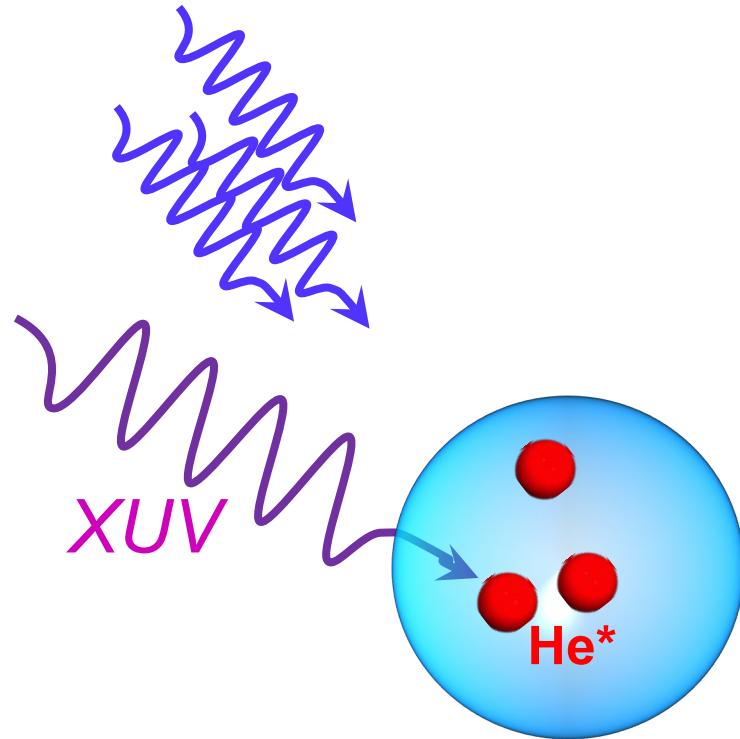


Multiply excited He nanodroplets



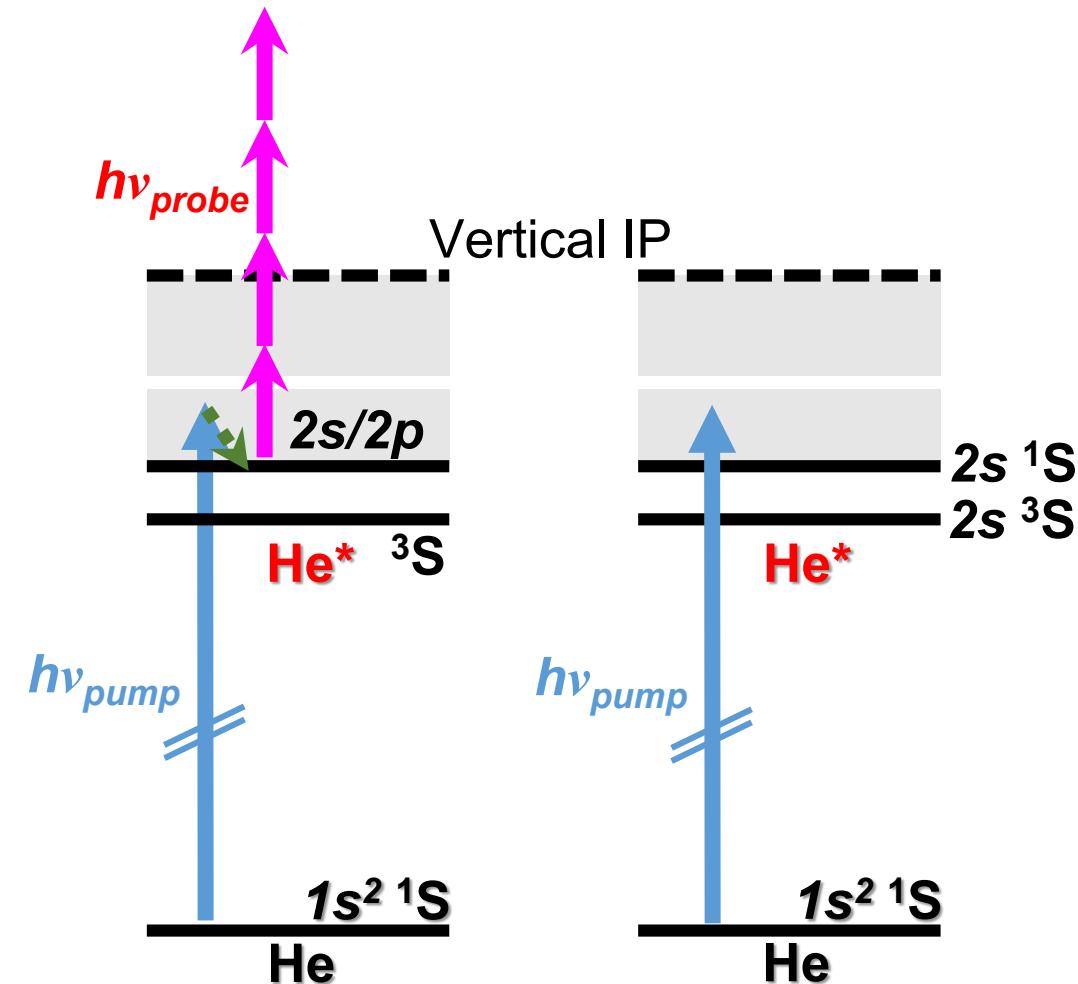
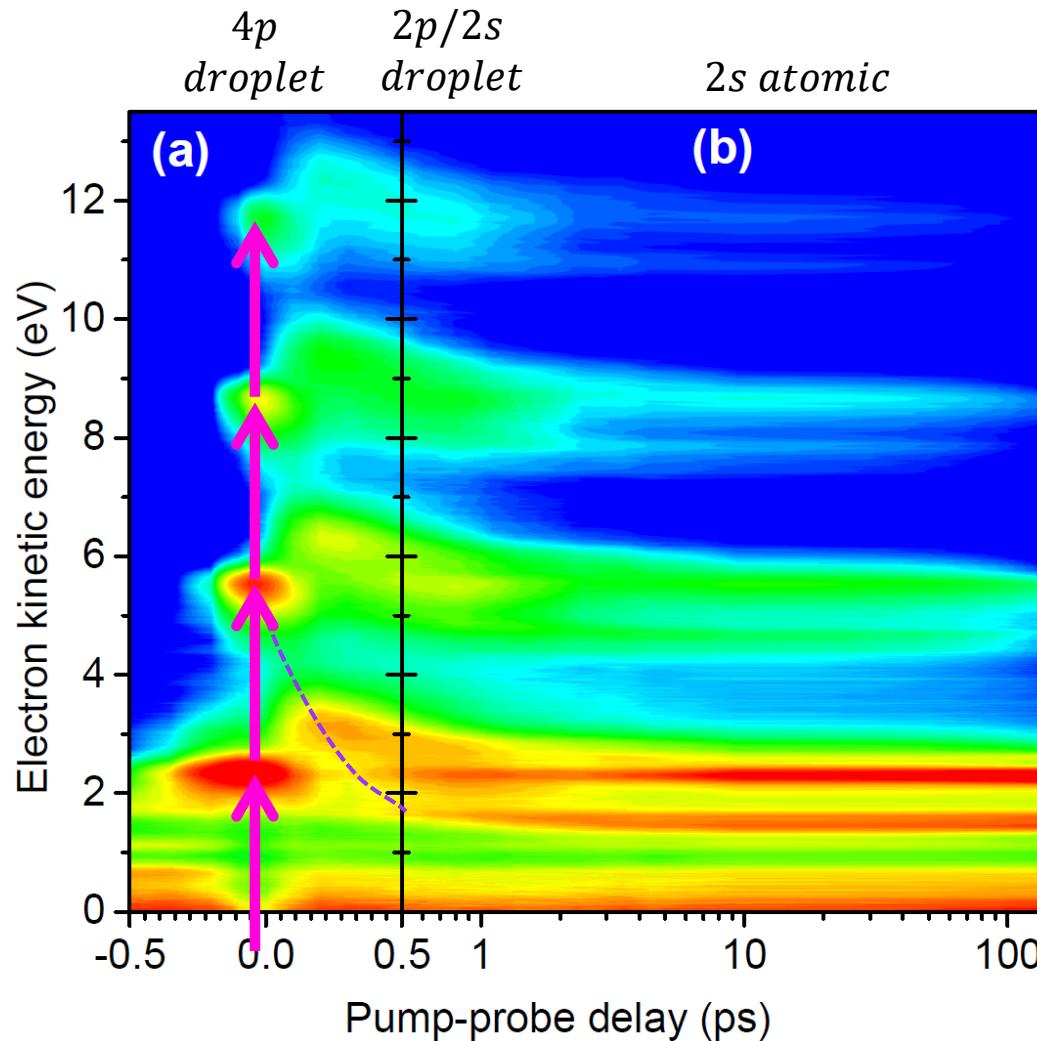
→ Bubble dynamics accelerates ICD,
No ICD at distances > 10 Å due to He^{*} ejection

Multiply excited He nanodroplets



Ionization of excited He nanodroplets

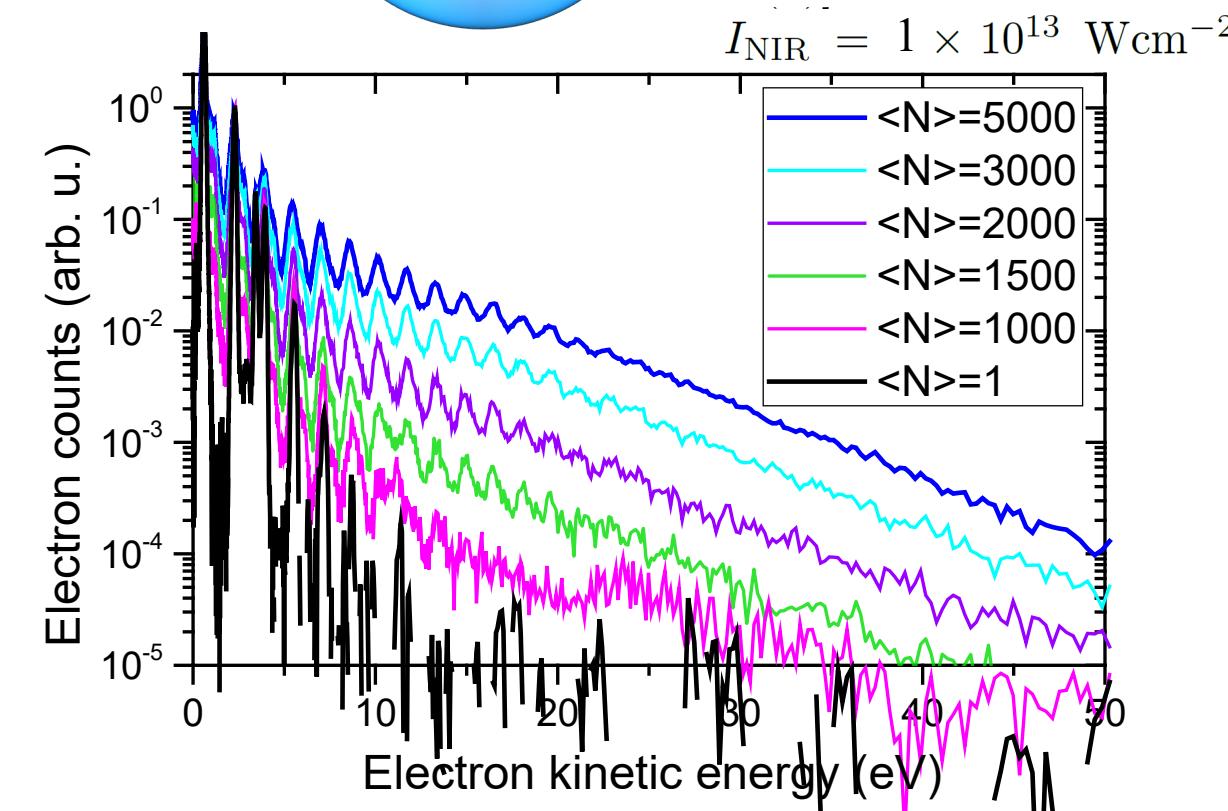
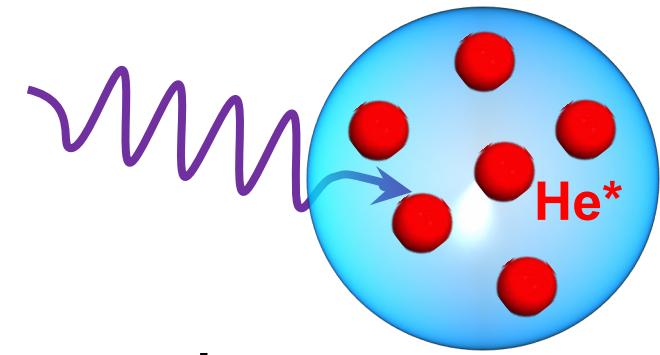
→ **Above threshold ionization (ATI)**



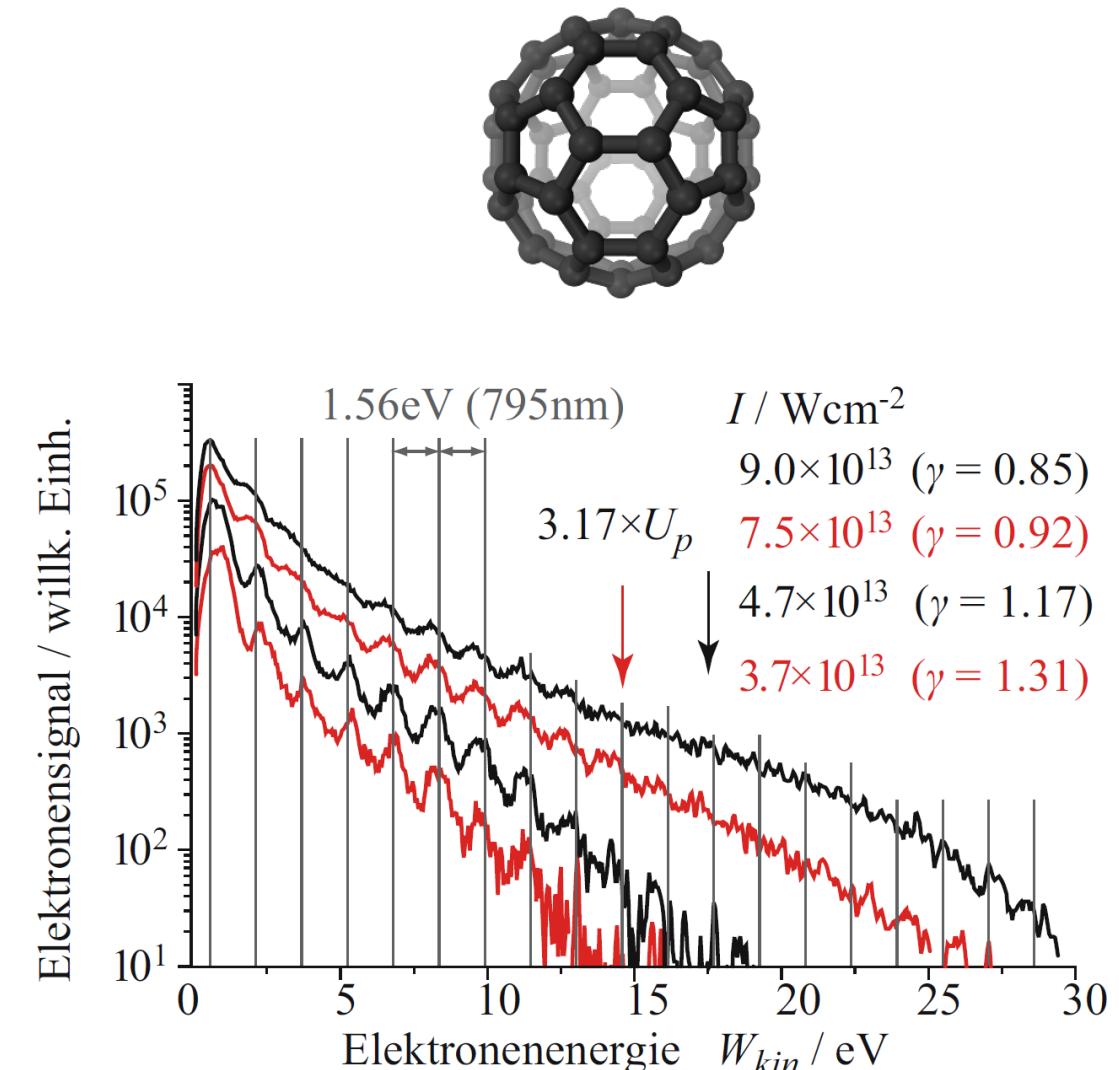
→ **Enhanced ATI in excited droplets**

R. Michiels, ..., M.M., PRL 127 093201 (2021)

Ionization of excited He nanodroplets → ATI

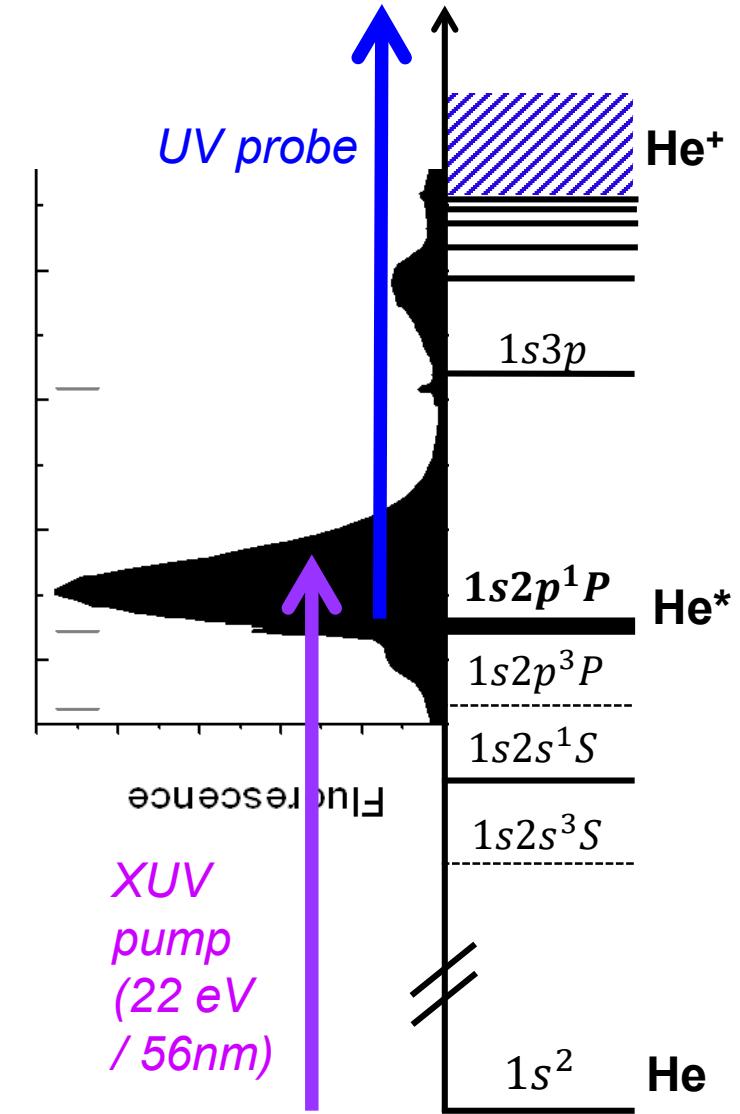
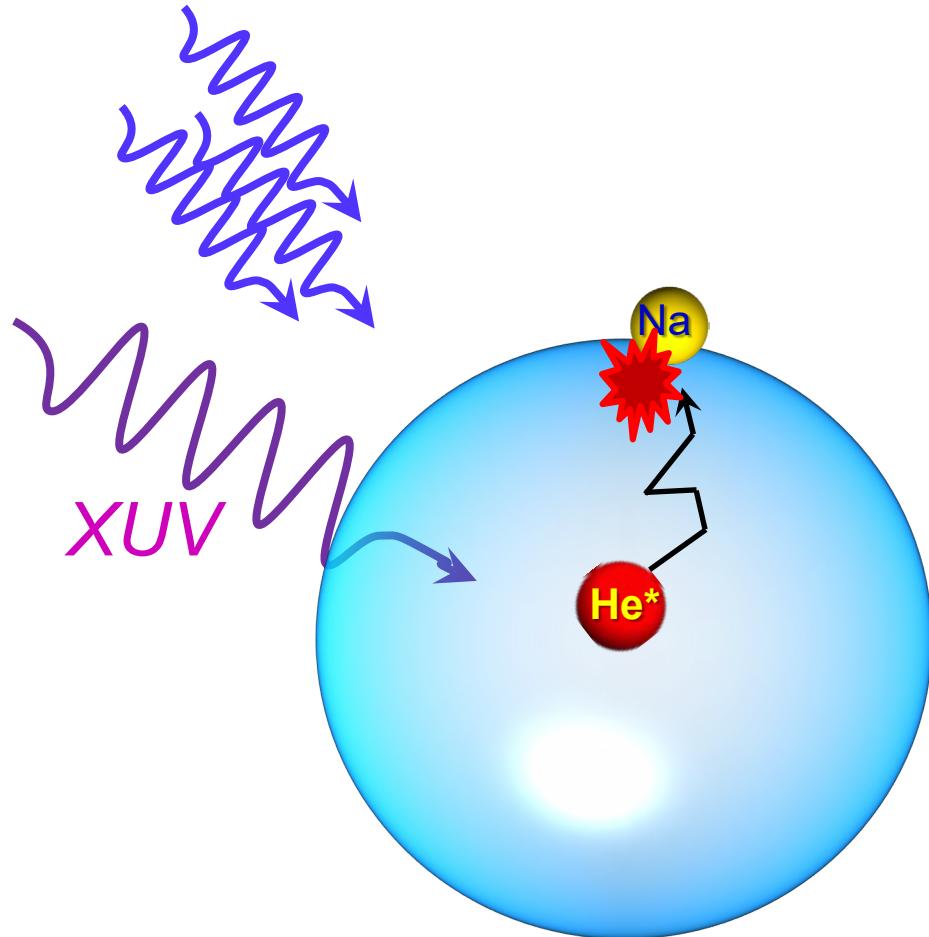


R. Michiels, ..., M.M., PRL 127 093201 (2021)

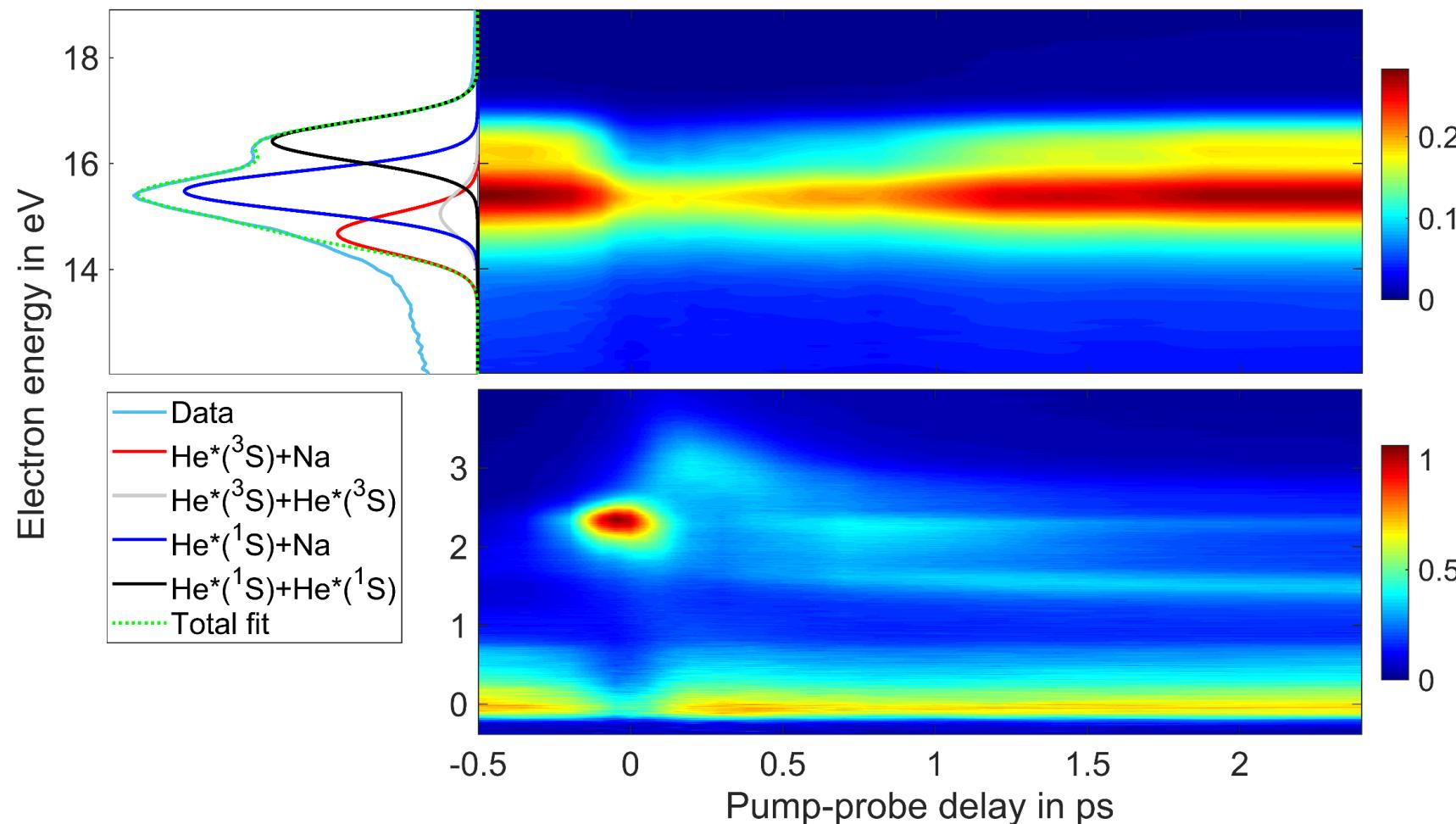


Campbell et al., PRL 84, 2128–2131 (2000)

ICD of doped He nanodroplets: $\text{He}^* + \text{Na} \rightarrow \text{He} + \text{Na}^+ + e_{\text{ICD}}$



ICD of doped He nanodroplets: $\text{He}^* + \text{Na} \rightarrow \text{He} + \text{Na}^+ + e_{\text{ICD}}$



→ Bubble dynamics determines both $\text{He}^* + \text{He}^*$ and $\text{He}^* + \text{Na}$ decay

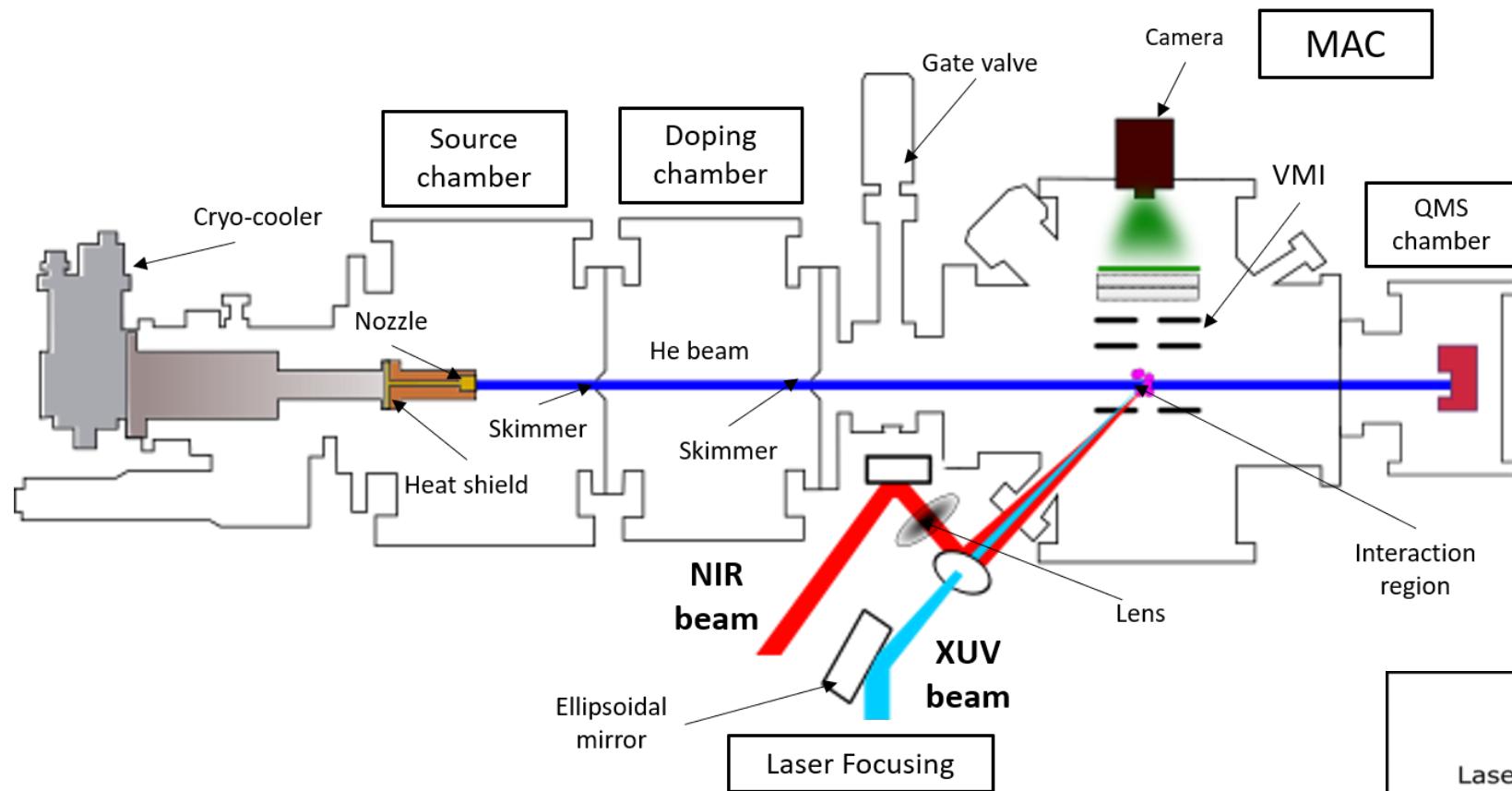
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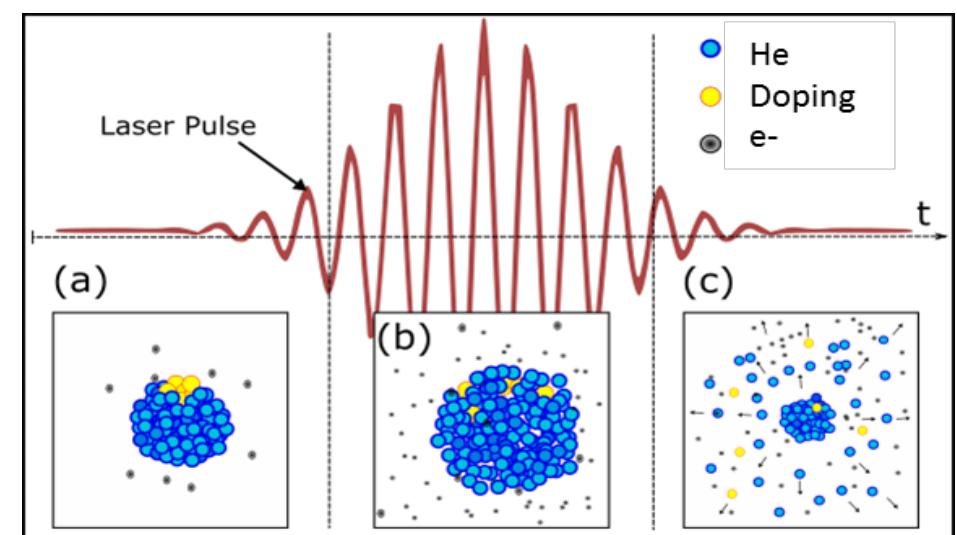
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XUV ignition of a laser-induced nanoplasma

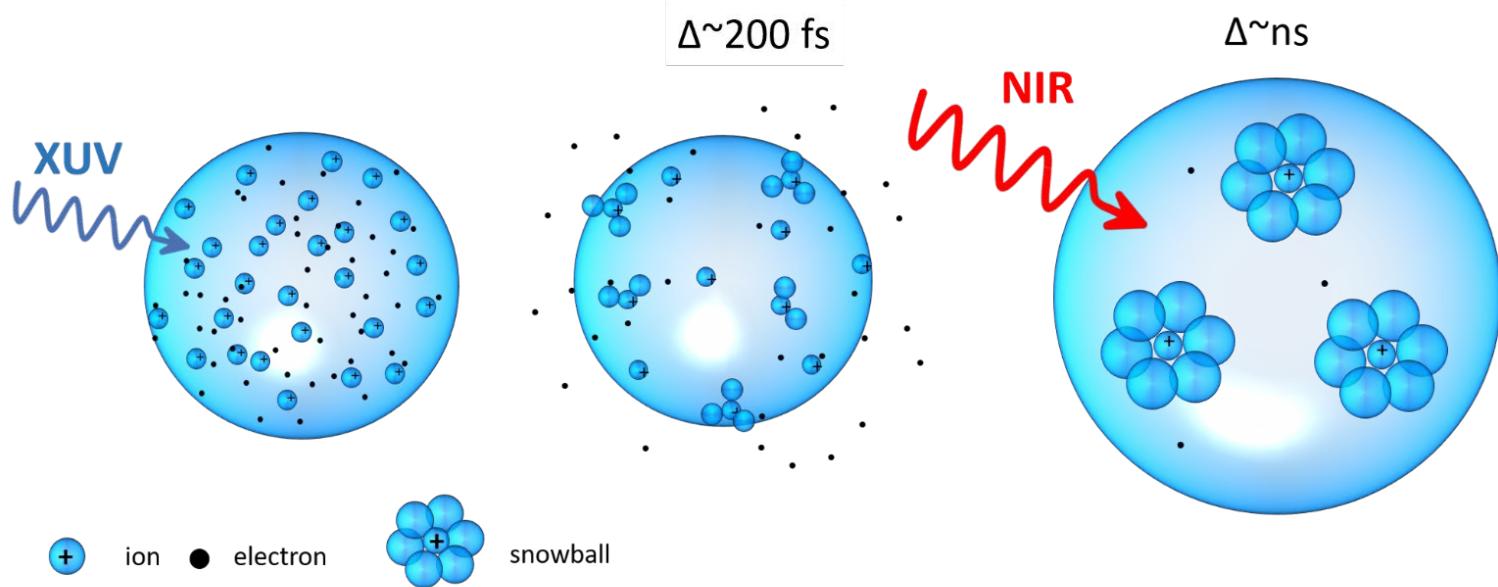
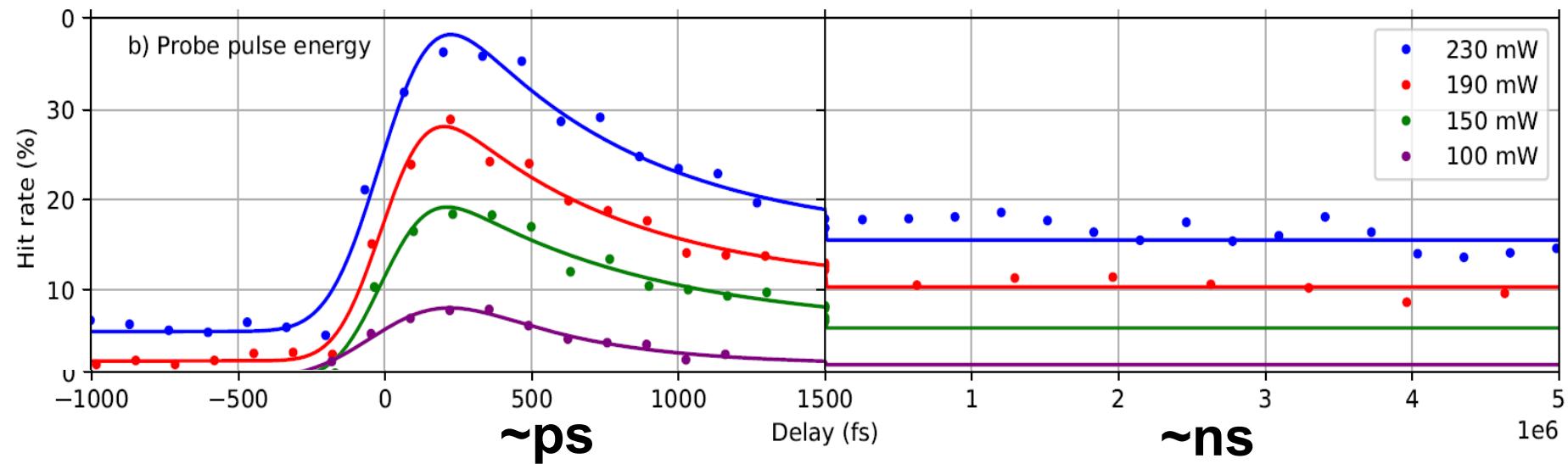


XUV: 29.6 eV (HH19), $5 \times 10^7 \text{ Wcm}^{-2}$

NIR: 800 nm, 10^{15} Wcm^{-2}



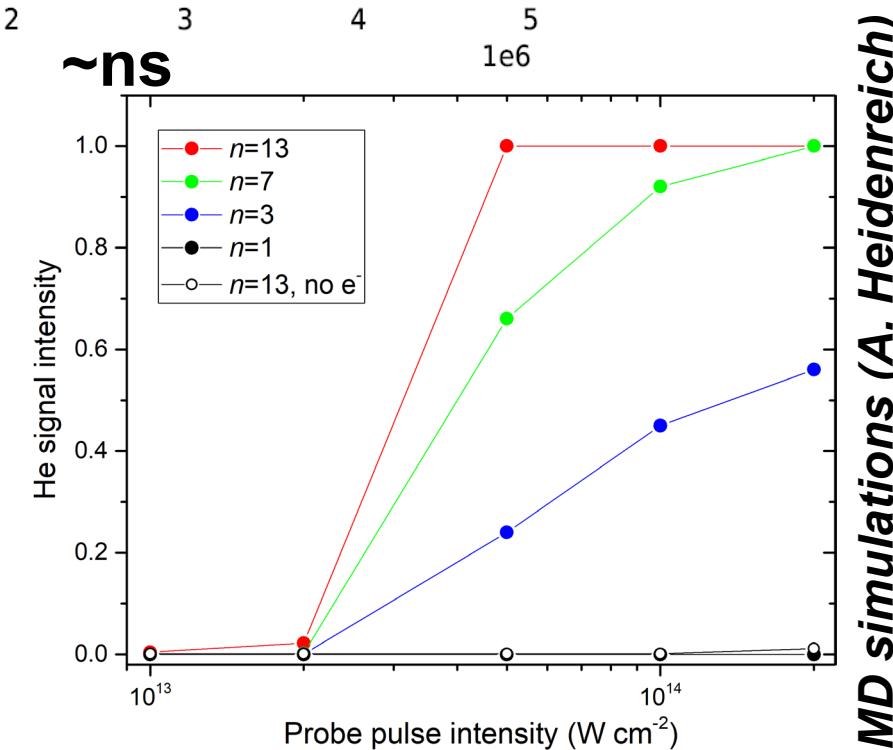
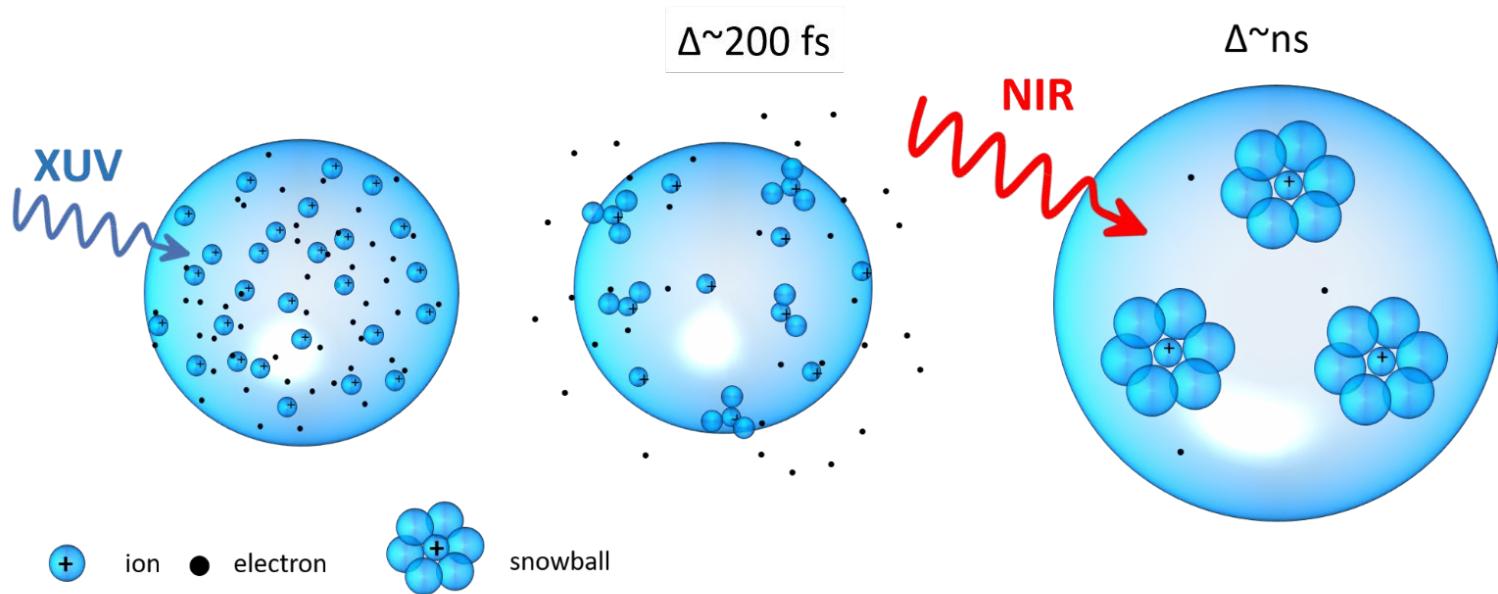
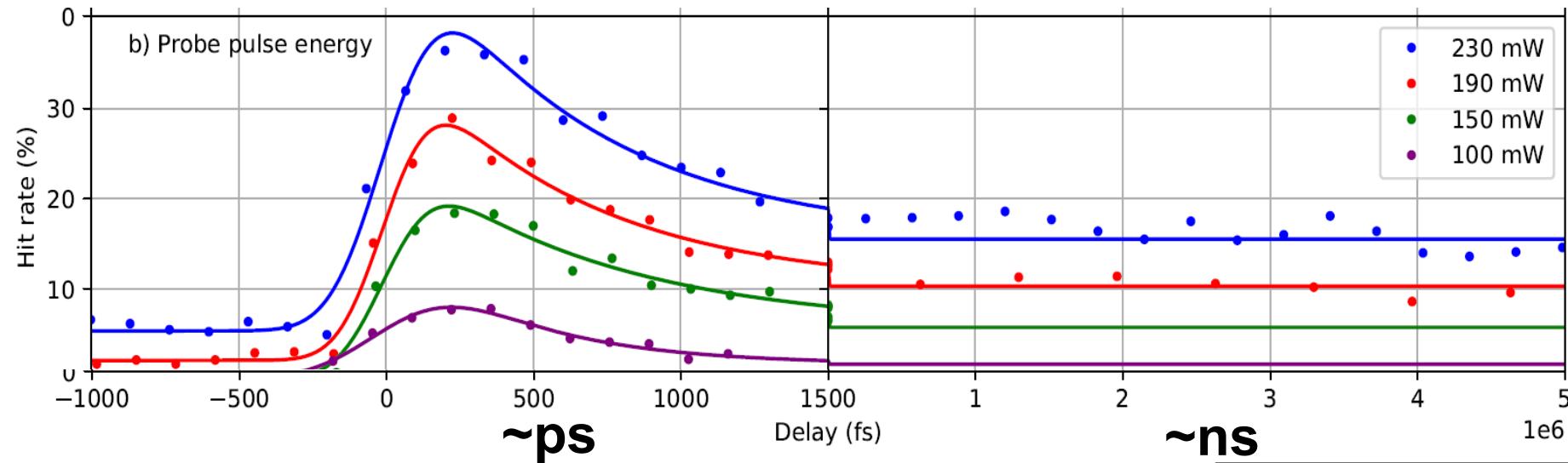
XUV ignition of a laser-induced nanoplasma



ps-delay: Photoelectrons act as seeds for NIR avalanche ionization

ns-delay: Formation of 'snowballs', trapping of electrons in quasibound states → delayed NIR ignition

XUV ignition of a laser-induced nanoplasma



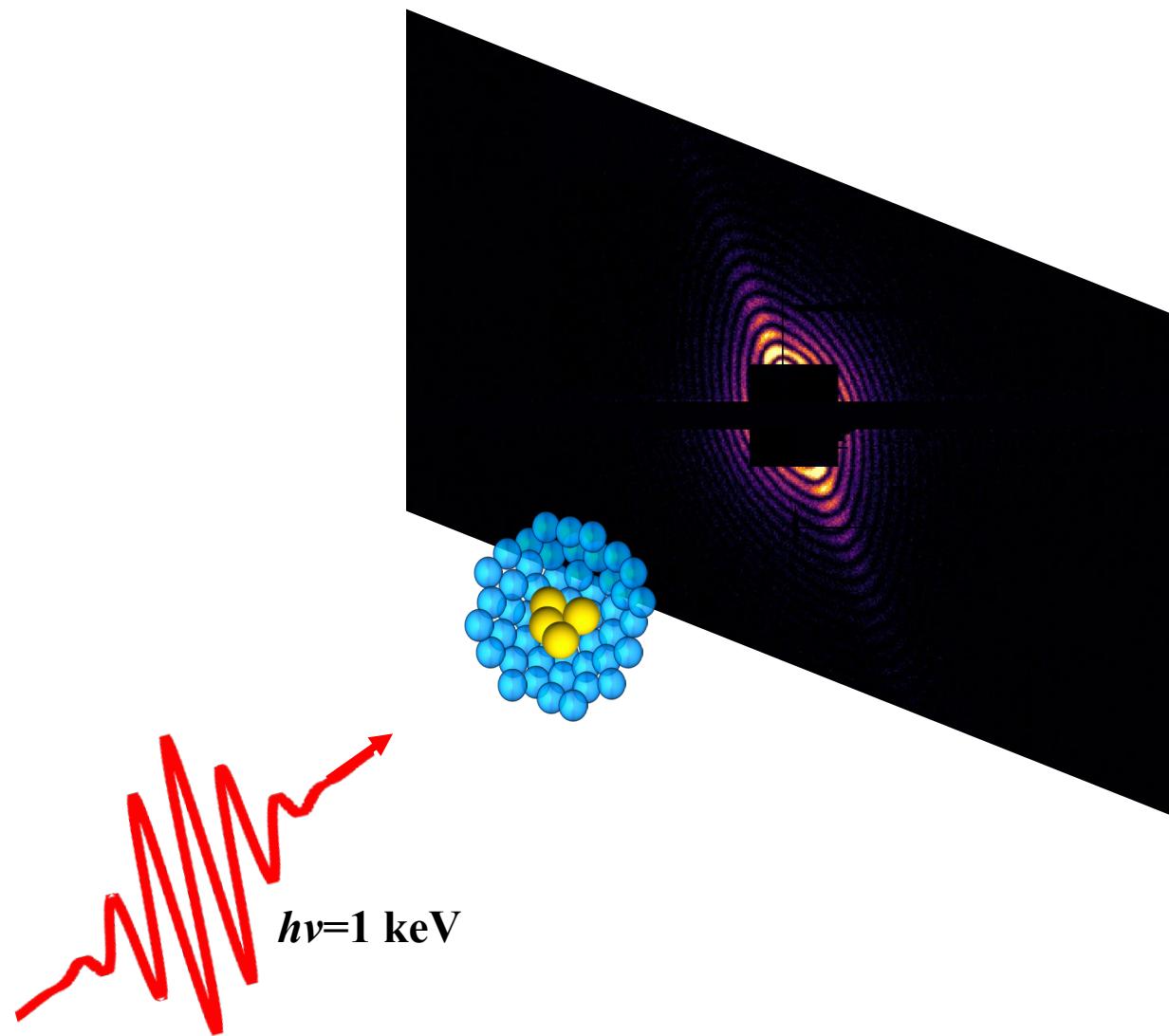
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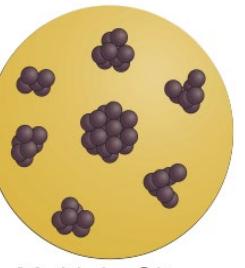
X-ray diffraction imaging of He droplets



Diffraction imaging of doped He nanodroplets



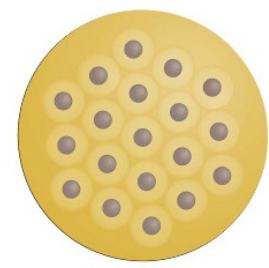
Compact Single-Site



Multiple Sites

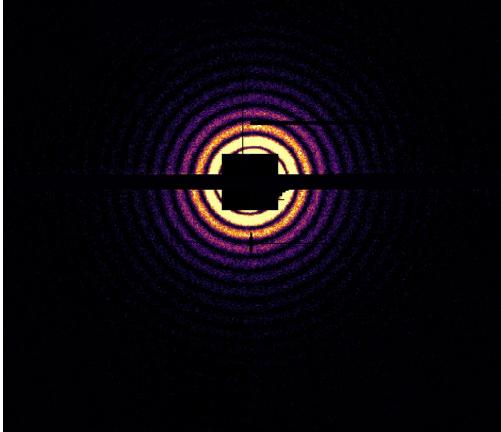


Open Structure

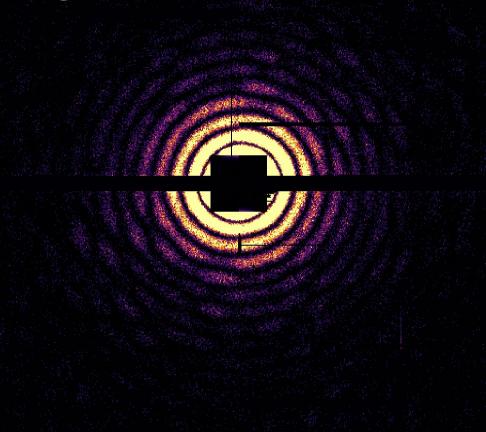


Foam Structure

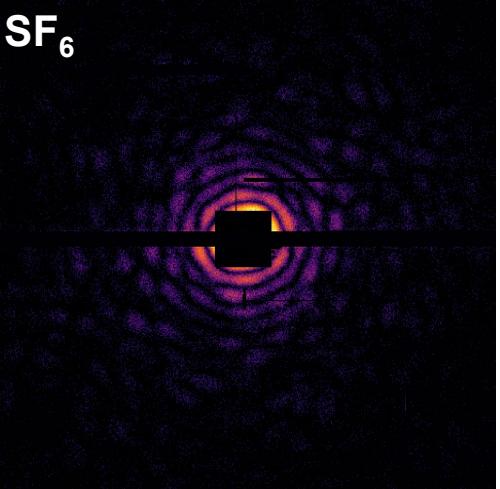
Pure He_N , spherical



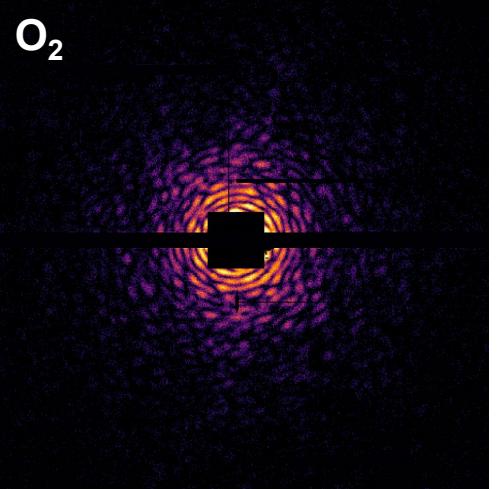
Mg



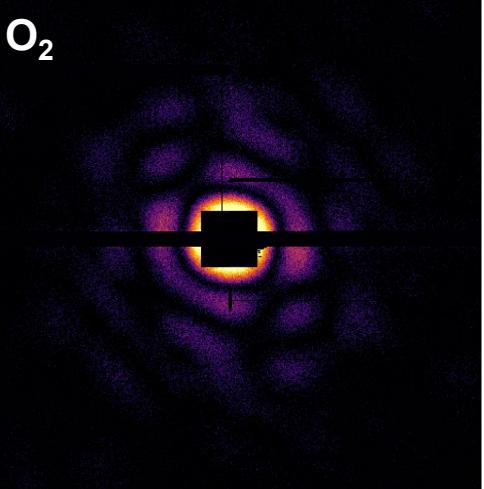
SF_6



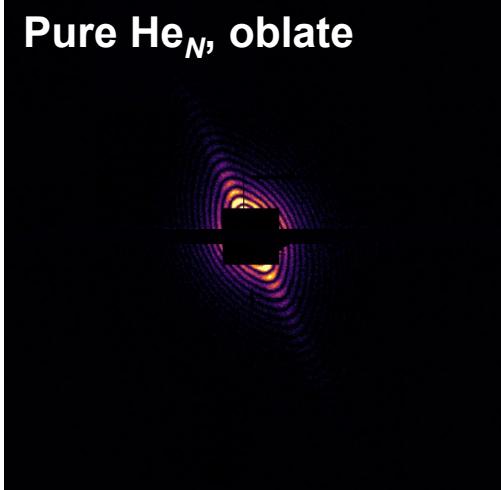
O_2



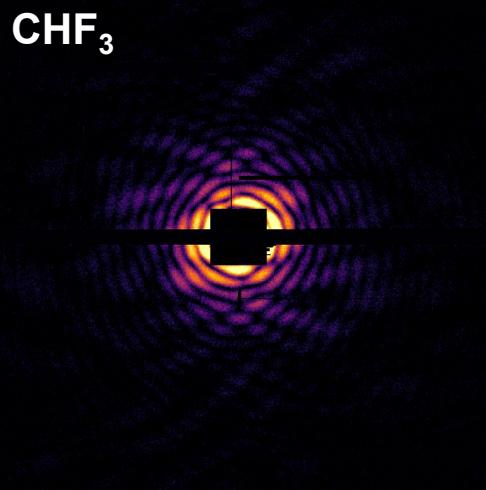
O_2



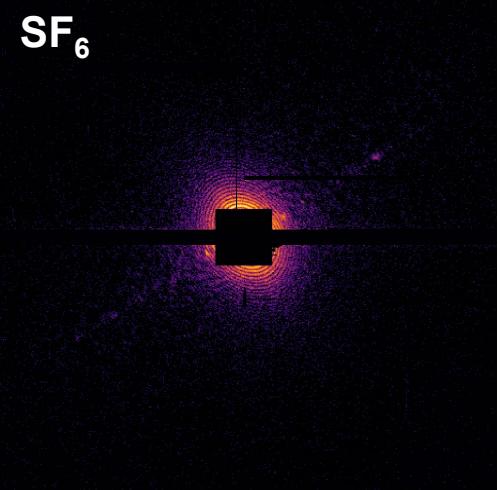
Pure He_N , oblate



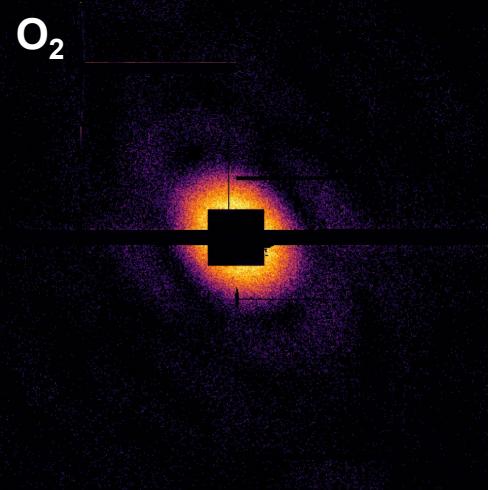
CHF_3



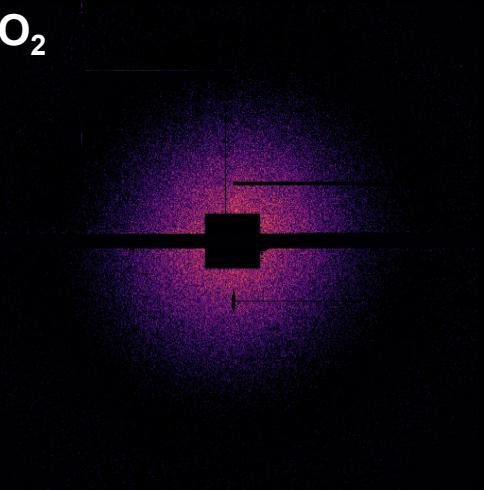
SF_6



O_2



O_2



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