Nuclear energy research at Diamond Light Source

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1.
Facility introduction

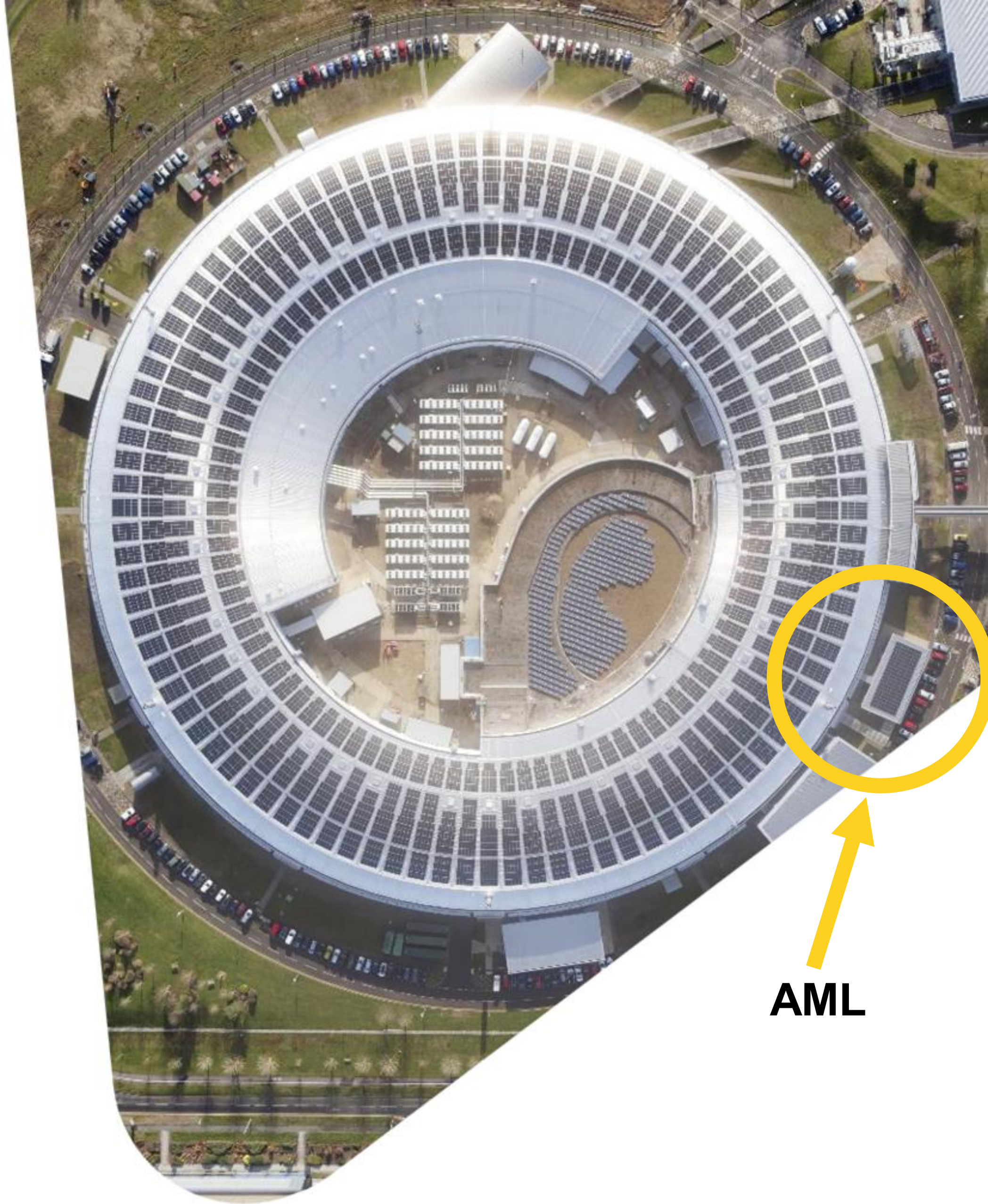
2.
Fission snapshot

3.
Fusion magnets

1.
Facility introduction

Nuclear studies at Diamond

- User research covers both fission and fusion
- Many studies make use of proxy systems for studies relevant to nuclear energy systems
- Beamline access for radioactive research supported by the **Active Materials Laboratory (AML)**



Active Materials Laboratory

- Supports documenting, handling, and manipulation of radioactive samples *on site*
- Central logistical hub for radioactive experiments
- Fully equipped dry and wet labs, and a counting room
- Accessible through Diamond beam time proposals and the Diamond offline laboratory access scheme
- Additional funding route for UK based researchers via the NNUF (now refunded through to 2030)

NNUF
National Nuclear User Facility

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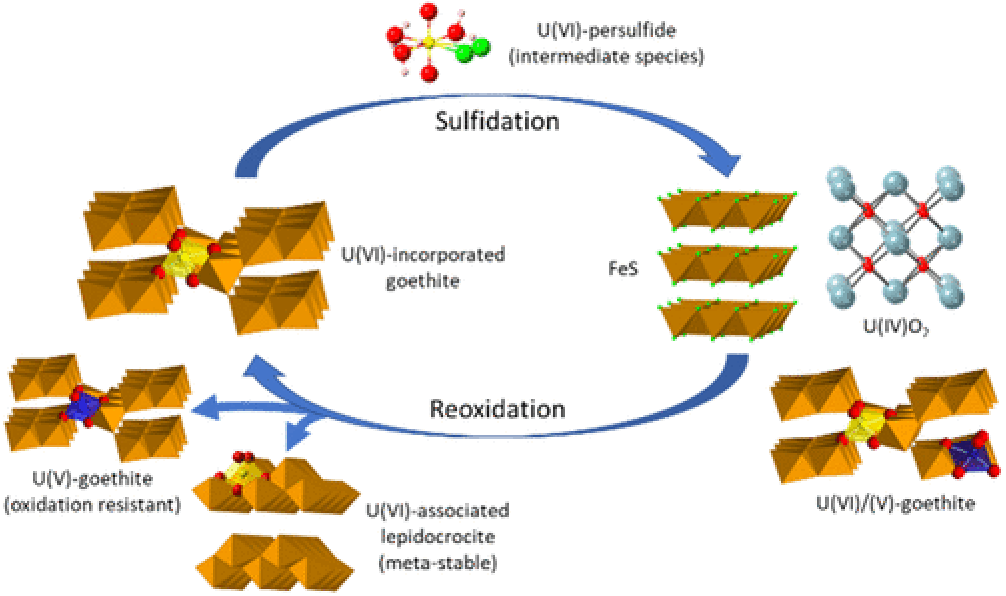
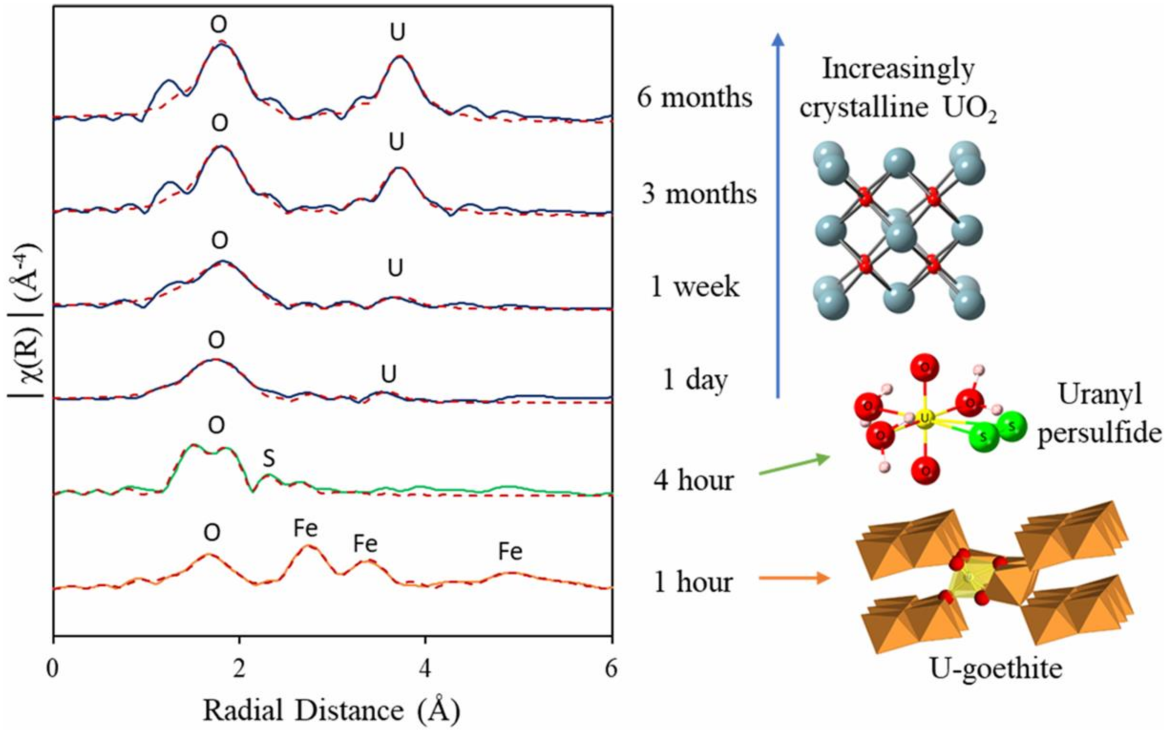
2.
Fission snapshot

Fission snapshot

- Established user community in the evolution of spent nuclear fuel under various conditions

- Evolution under simulated redox conditions, testing a potential waste disposal form, **B18**

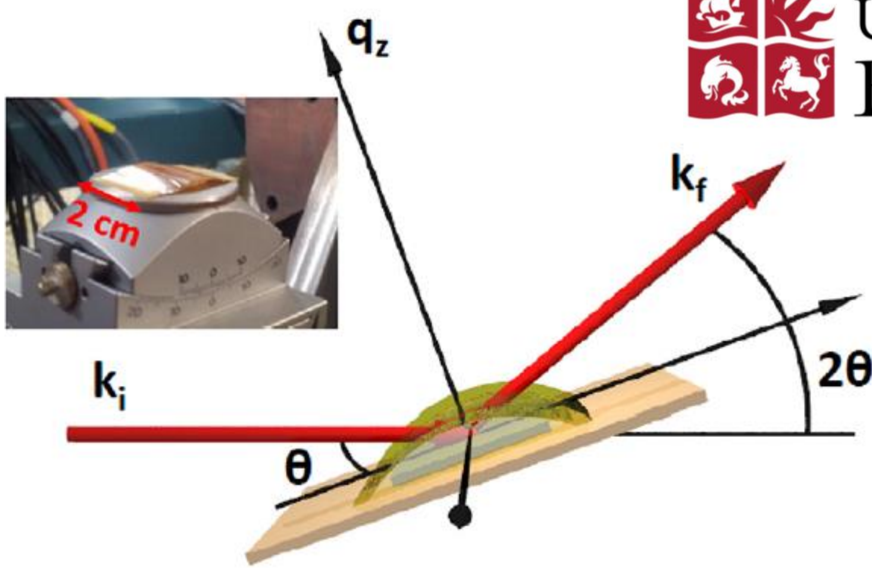


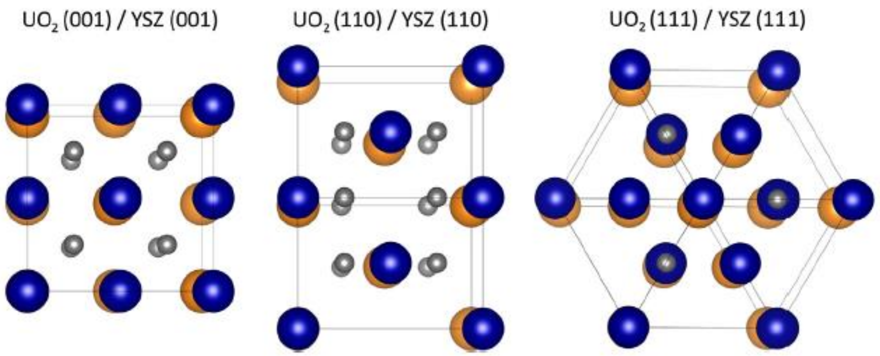


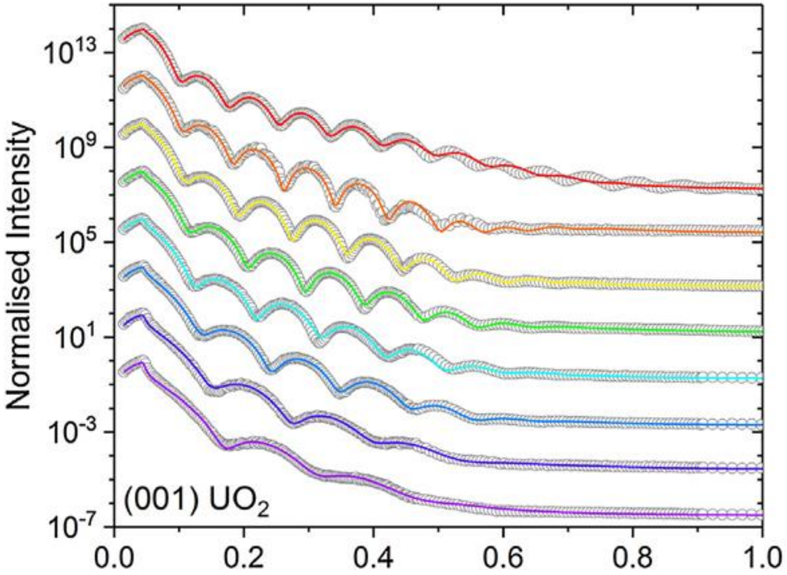
[1] – O. Stagg *et al.*, *Environ. Sci. & Technol.*, **56**(24), 2022.

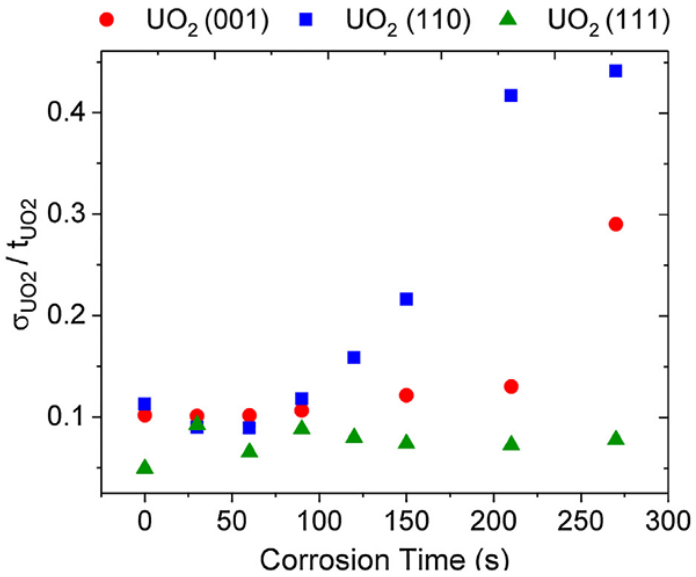
Fission snapshot

- Established user community in the evolution of spent nuclear fuel under various conditions
- Surface corrosion of uranium oxide surfaces, simulating spent nuclear fuel storage – **I07**





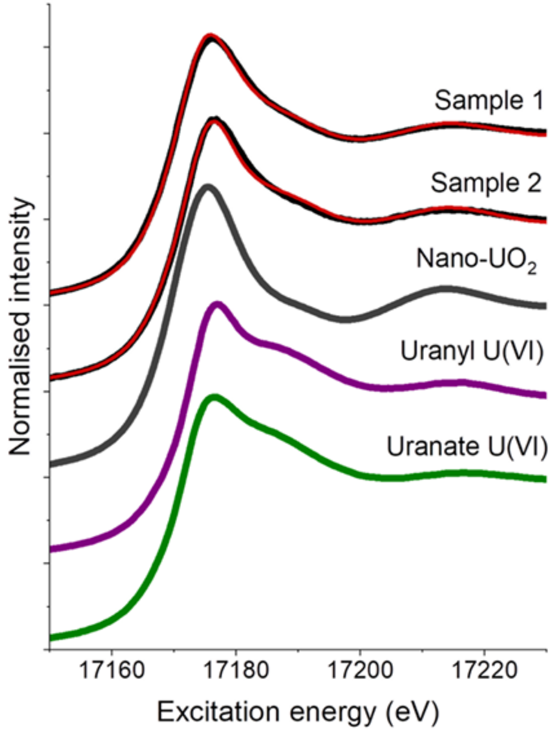


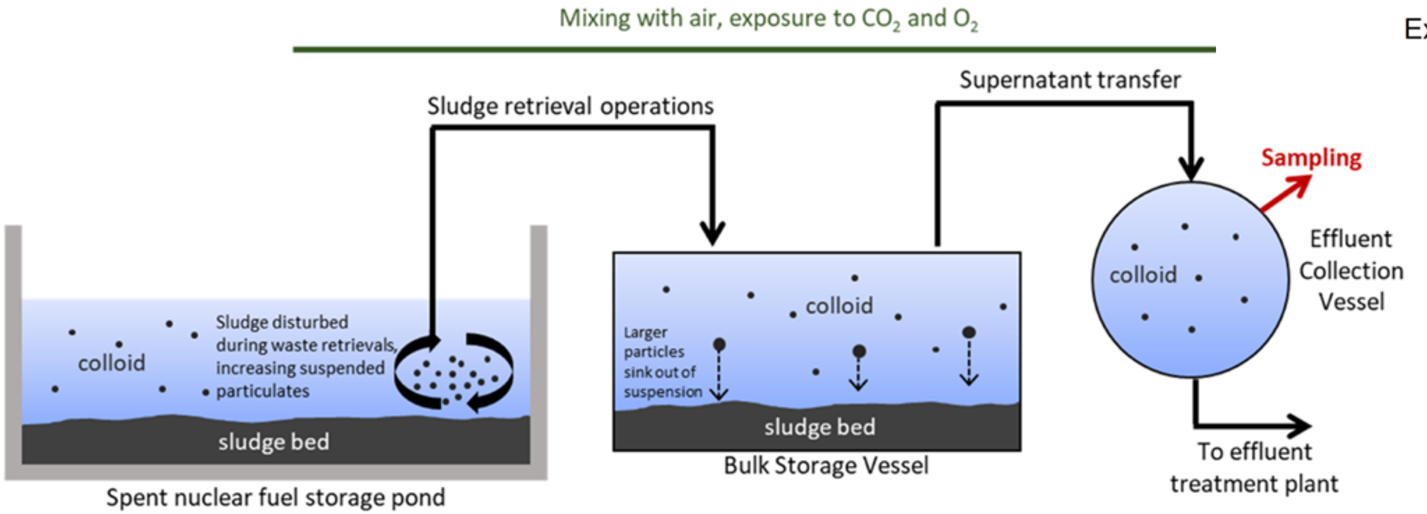


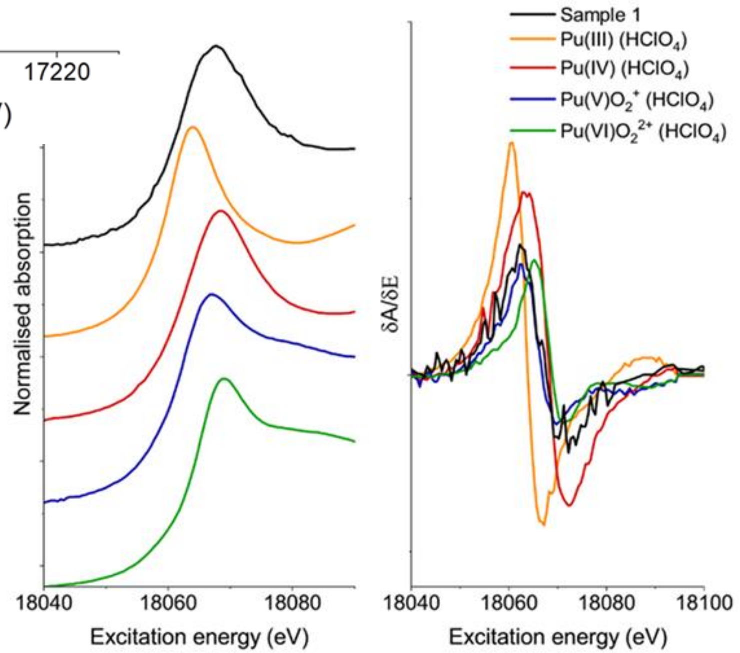
[3] – S. Rennie *et al.*, Corrosion Sci., **145**, 2018.

Fission snapshot

- Established user community in the evolution of spent nuclear fuel under various conditions
- Characterisation of nuclear "sludge" particles from Sellafield, **B18** and **I20-Scanning**





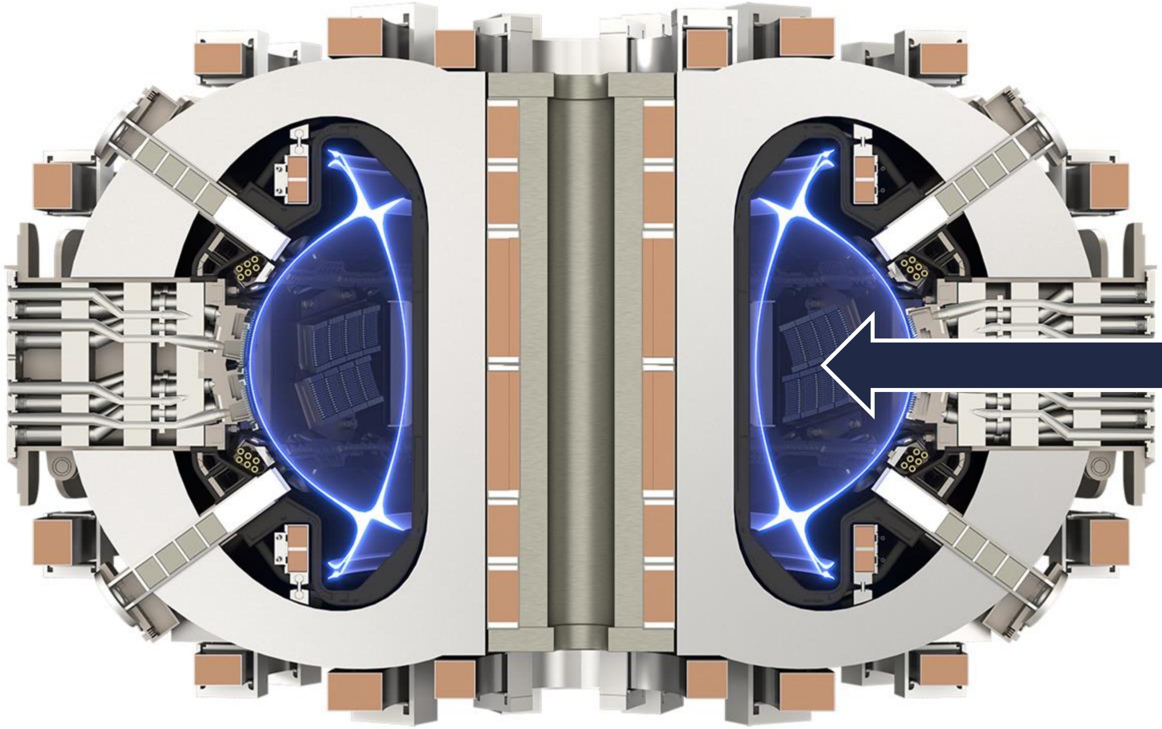


[2] – T. S. Neill *et al.*, J. Hazard. Mater., **489**, 2025.

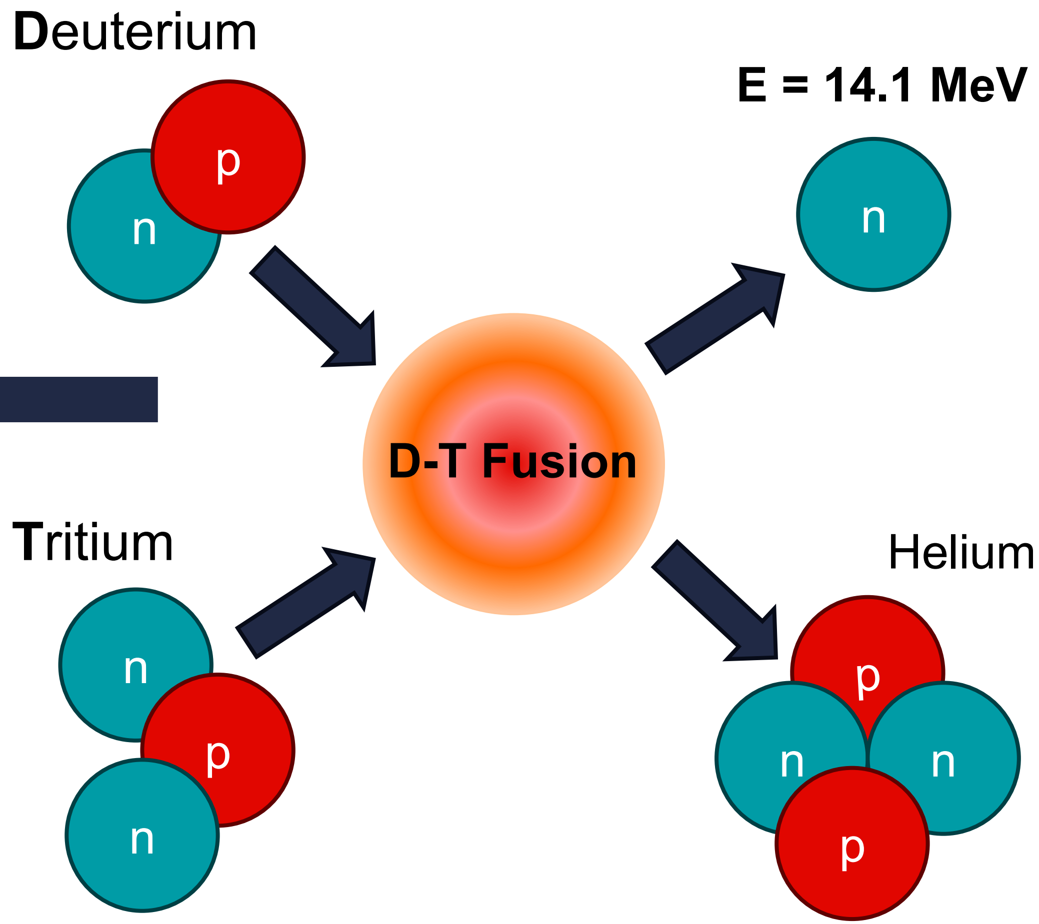
3.
Fusion magnets

Irradiation damage in Compact Spherical Tokamaks (CSTs)

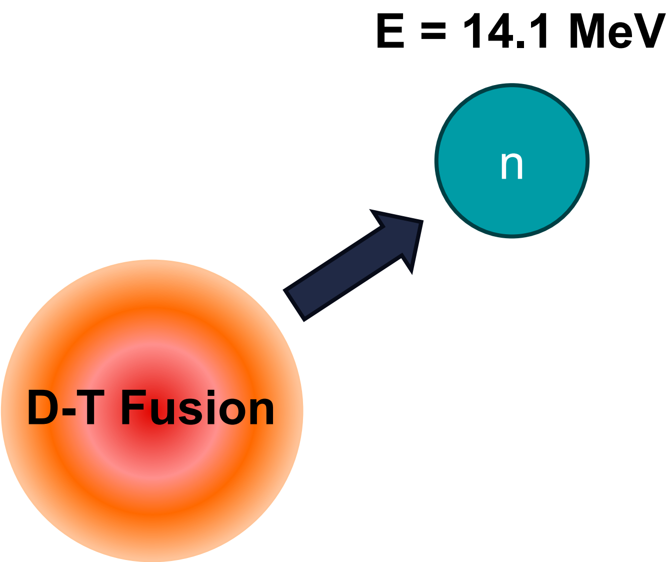
An example CST design cross-section



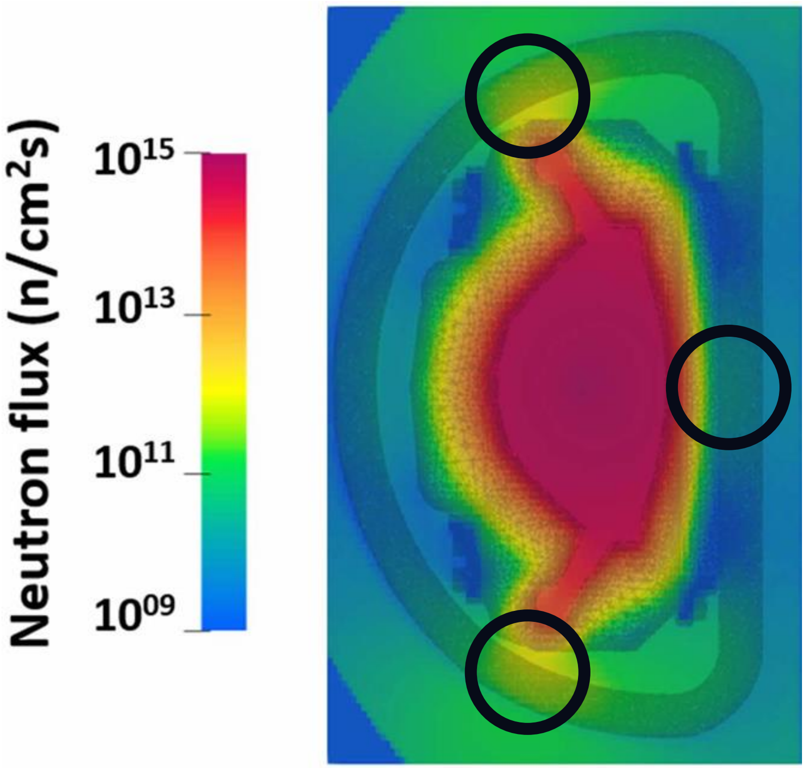
[4] - A. J. Creely *et al.*, *Phys. Plasmas* **30**(9), 2023.

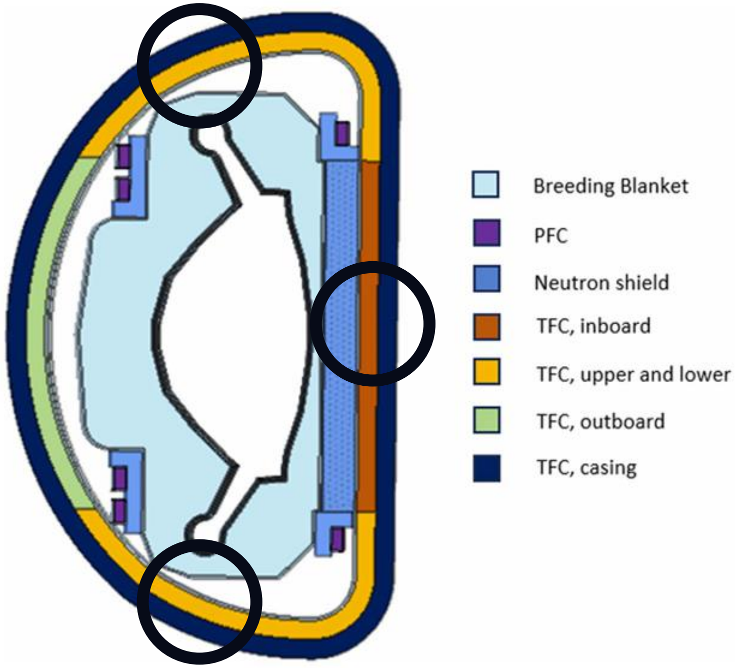


Irradiation damage in Compact Spherical Tokamaks (CSTs)



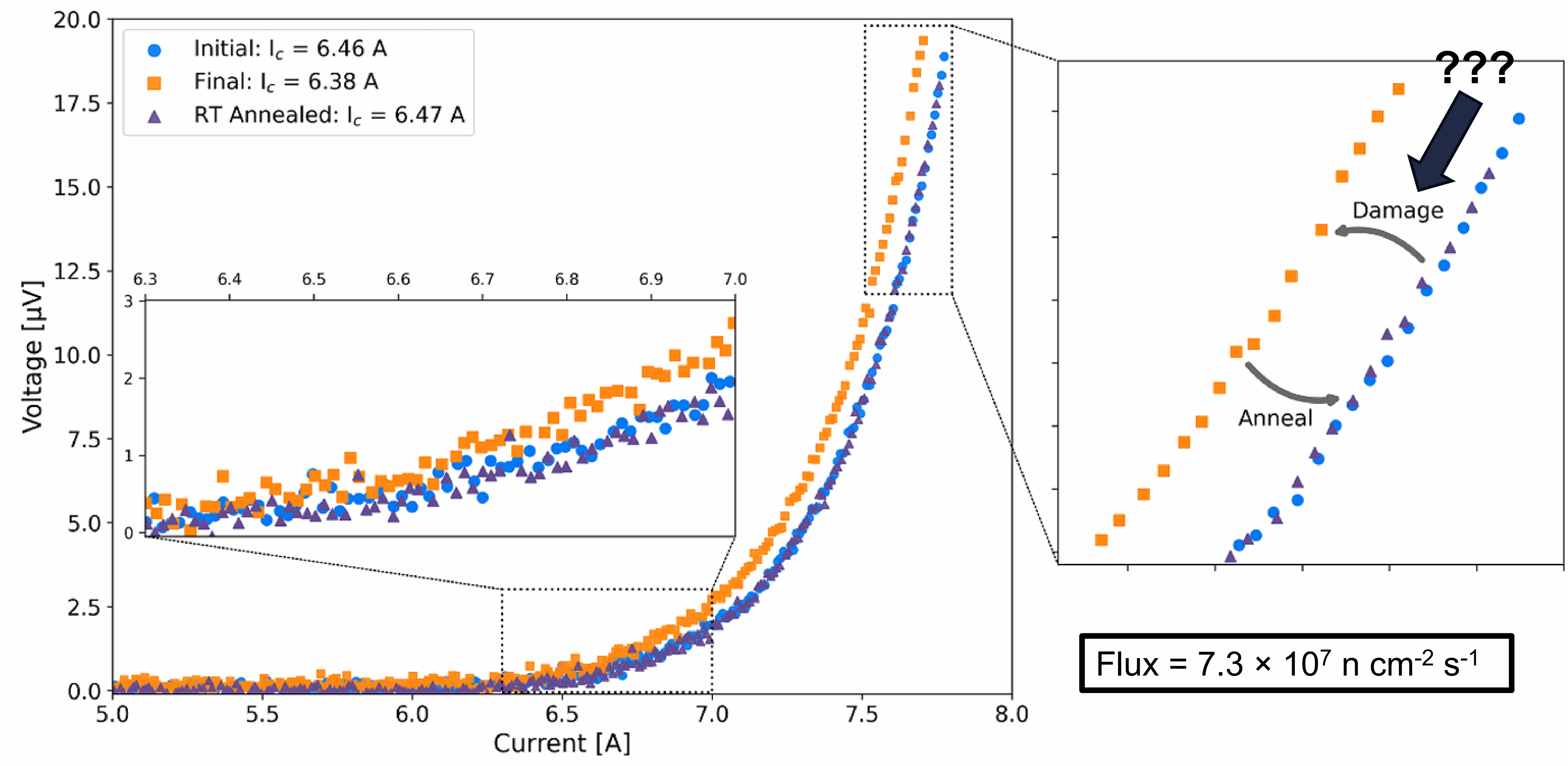
Simulated n flux distribution in a CST





[5] – D. Torsello *et al.*, *IEEE Trans. App. Supercon.* **35**(5), 2025.

Irradiation damage in Compact Spherical Tokamaks (CSTs)



Flux = 7.3×10^7 n cm^{-2} s^{-1}

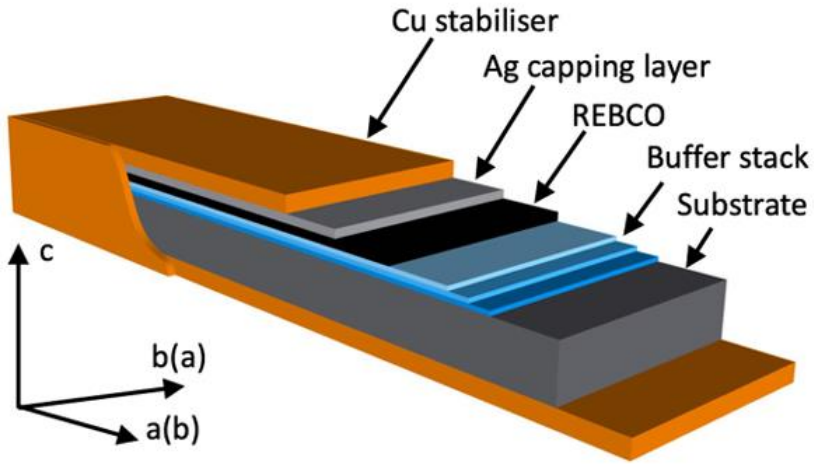
[6] – K. Adams *et al., Supercon. Sci. Technol.* **39**, (2026).

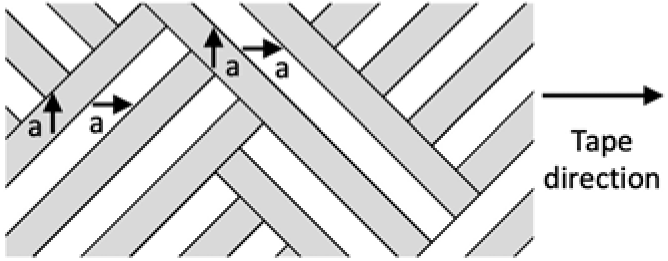
REBCO Coated Conductor

REBCO: (RE)$Ba_2Cu_3O_{7-\delta}$

RE = Y/Gd/Eu/etc

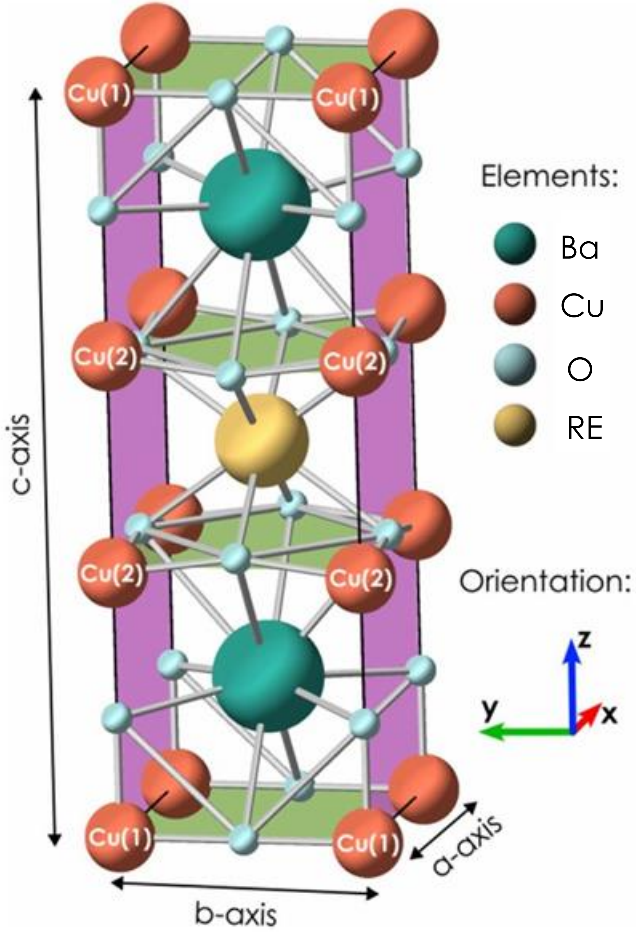
REBCO coated conductor (CC)





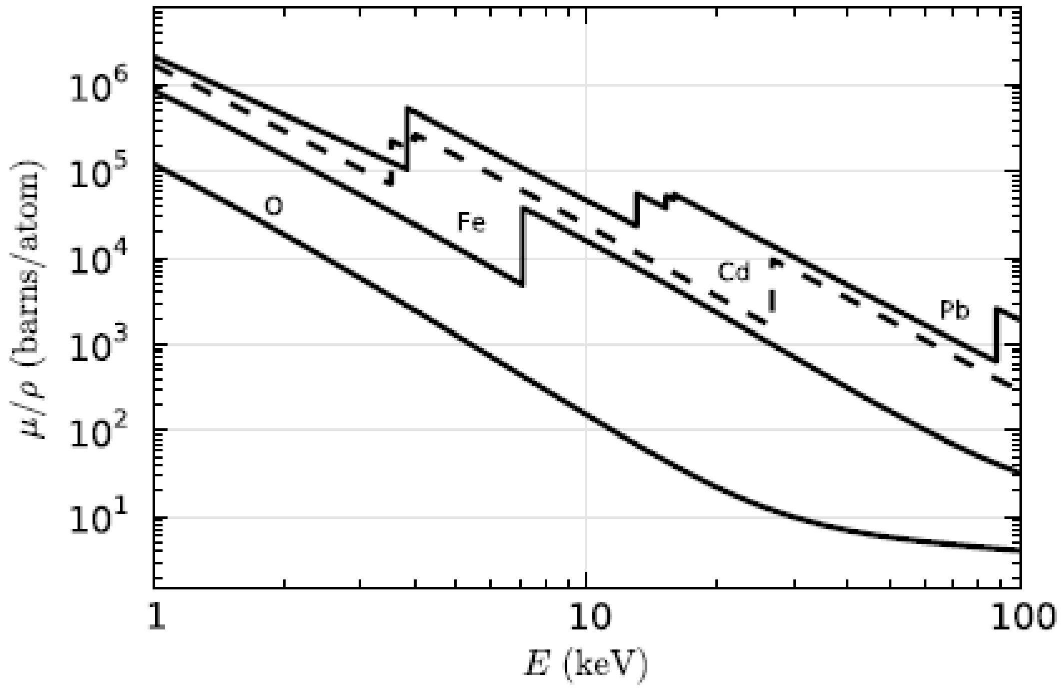
[7] – R.J. Nicholls *et al.*, *Comm. Mater.* **3**(22), 2022.

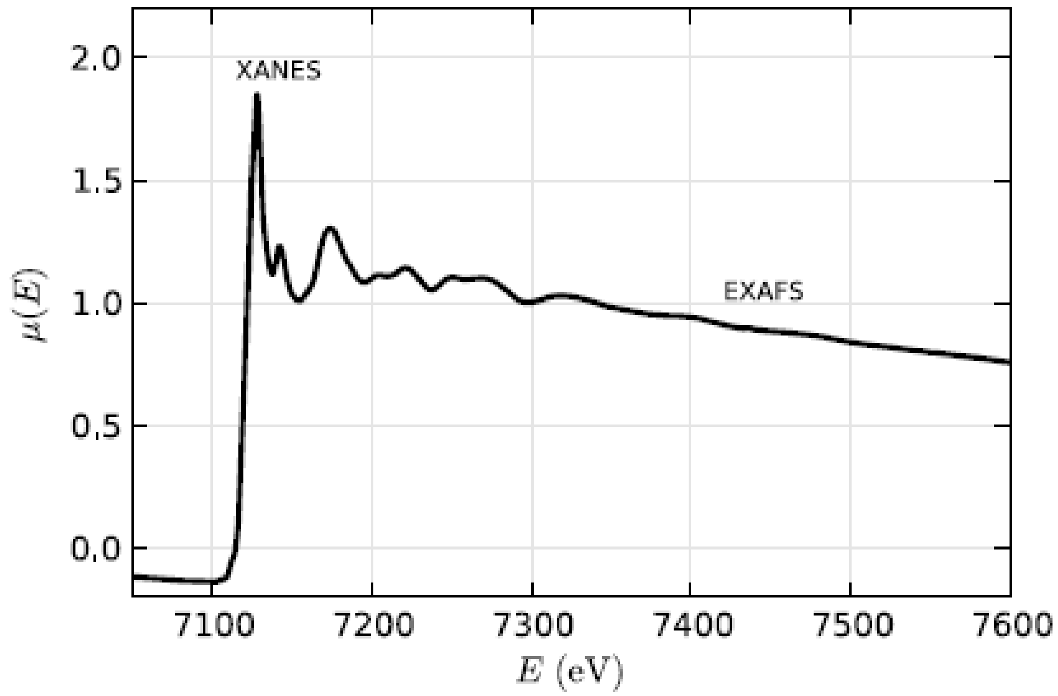
REBCO unit cell



[8] – J.C. Lewis *et al., Supercon. Sci. Technol.* **38**, 2025.

X-ray spectroscopy: emission and absorption





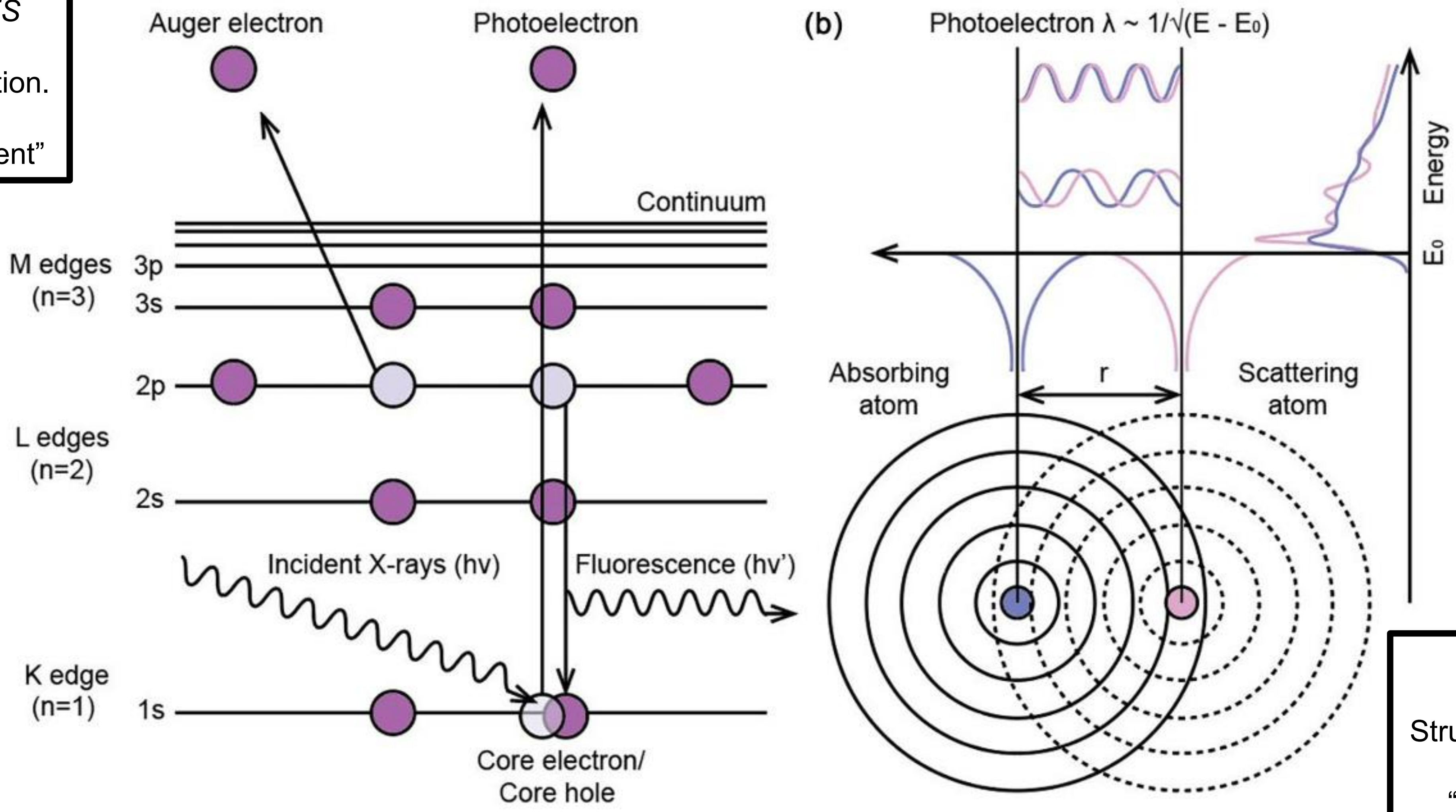
[9] – M. Newville, *Rev. Mineral. Geochem.*, **78**, 2014.

X-ray spectroscopy: emission and absorption

HERFD-XANES

Bonding information.

"Local environment"



EXAFS

Structural information.

"Local structure"

[10] – A. T. Baker *et al.*, *Metallomics*, **17**, 2025.

X-ray spectroscopy: emission and absorption

HERFD-XANES

Bonding information.

“Local environment”

X-ray spectroscopy: emission and absorption

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Structural information.

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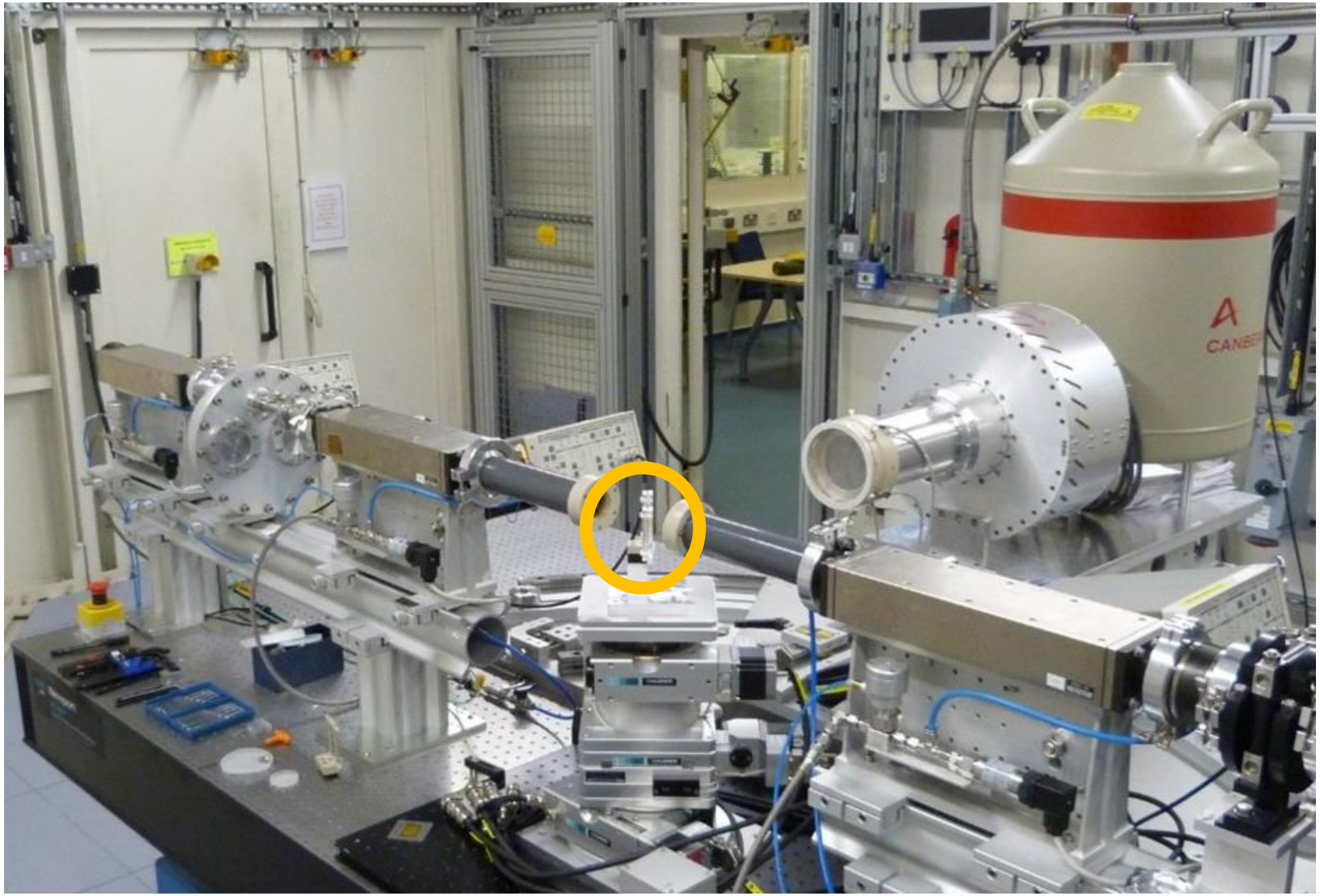
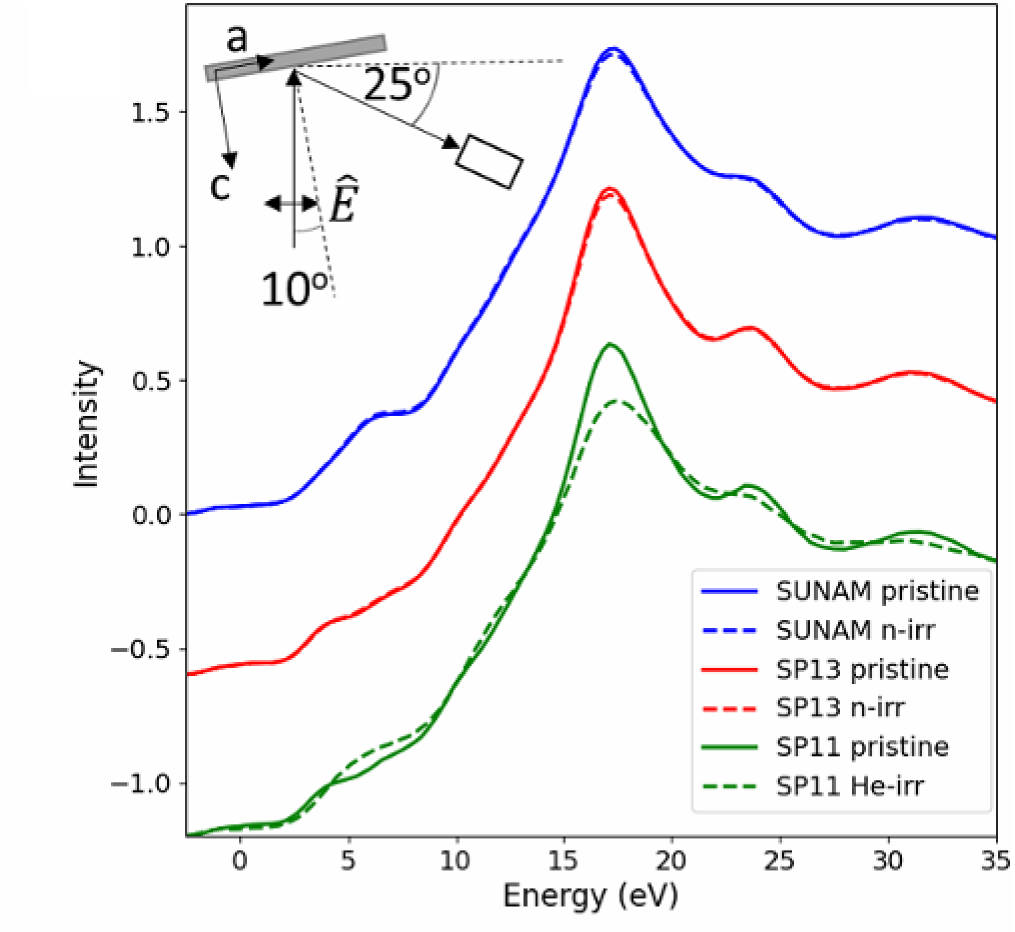
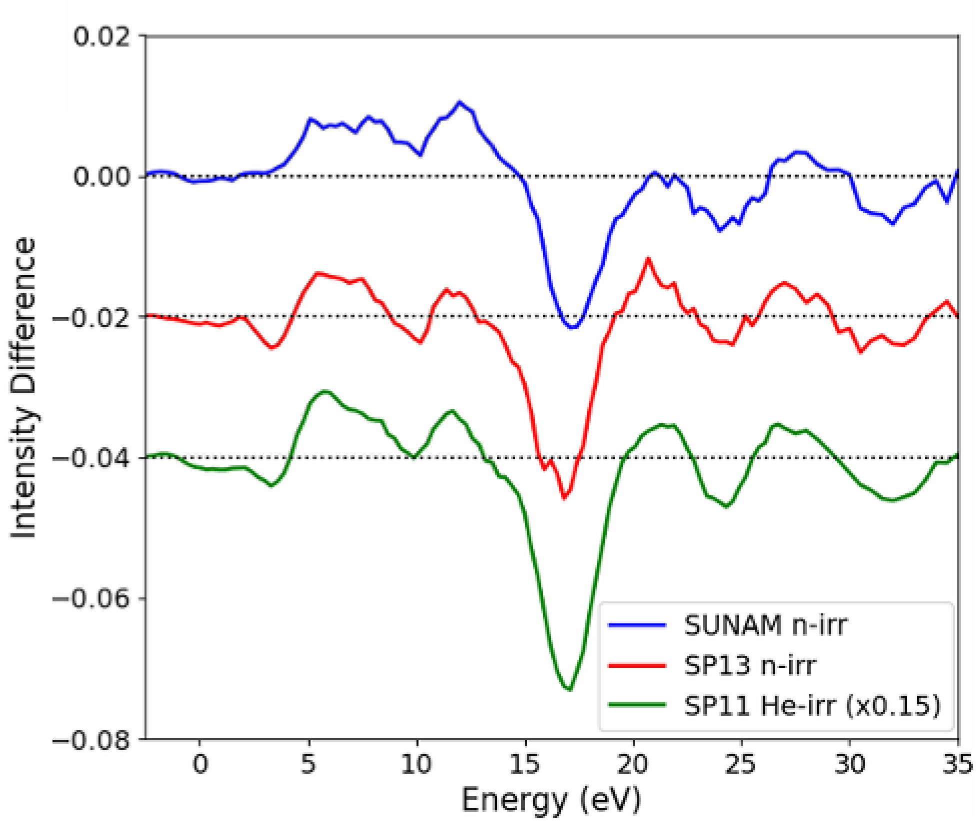


Are neutrons always needed?





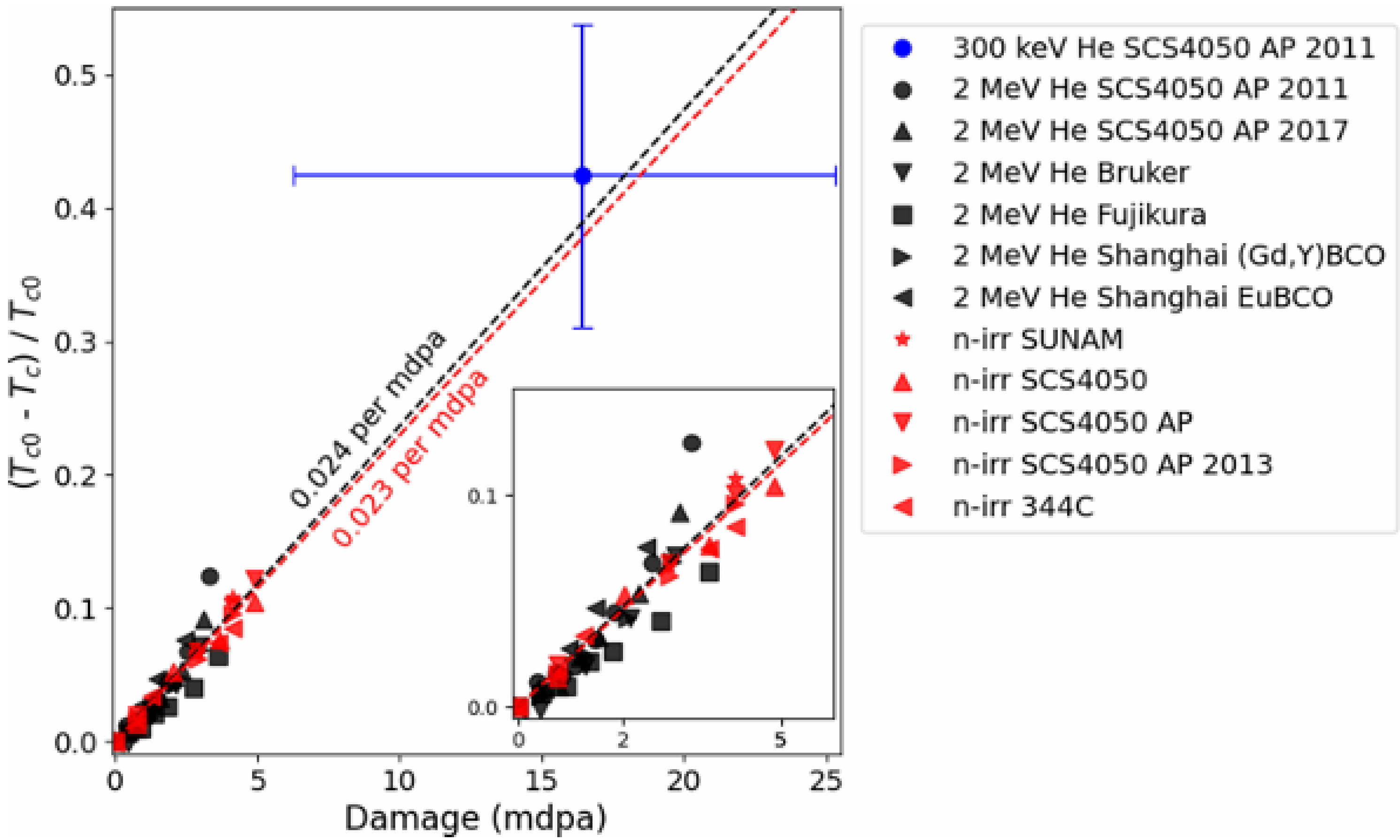
[11] – K. Adams *et al., Supercon. Sci. Technol.* **36**, (2023).

Are neutrons always needed?

- He^+ ions appear to be creating a similar change to fission spectrum neutrons

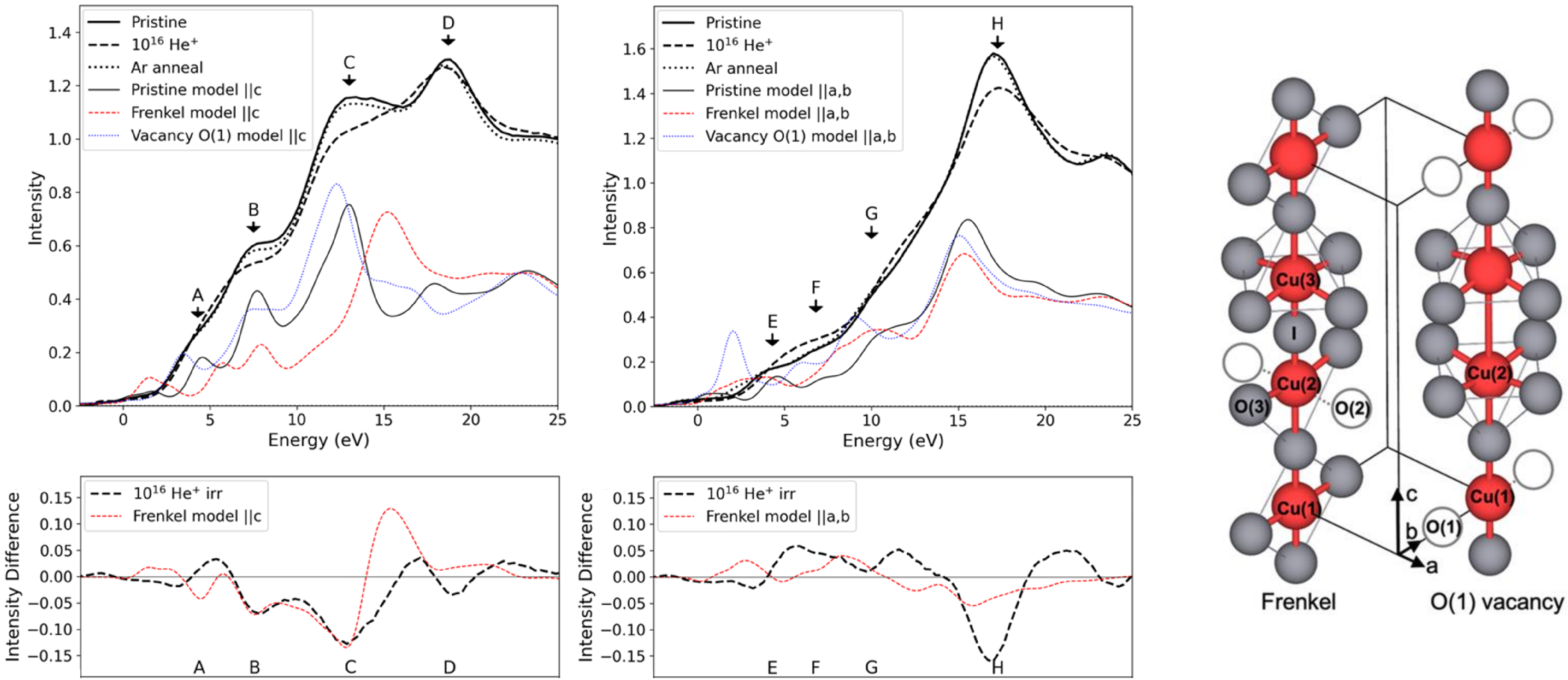
- But what are these changes?

Comparison of He^+ and neutron irradiation



[11] – K. Adams *et al.*, *Supercon. Sci. Technol.* **36**, (2023).

HERFD-XANES 300 keV He⁺ study



[7] – R.J. Nicholls *et al.*, *Comm. Mater.* **3**(22), 2022.

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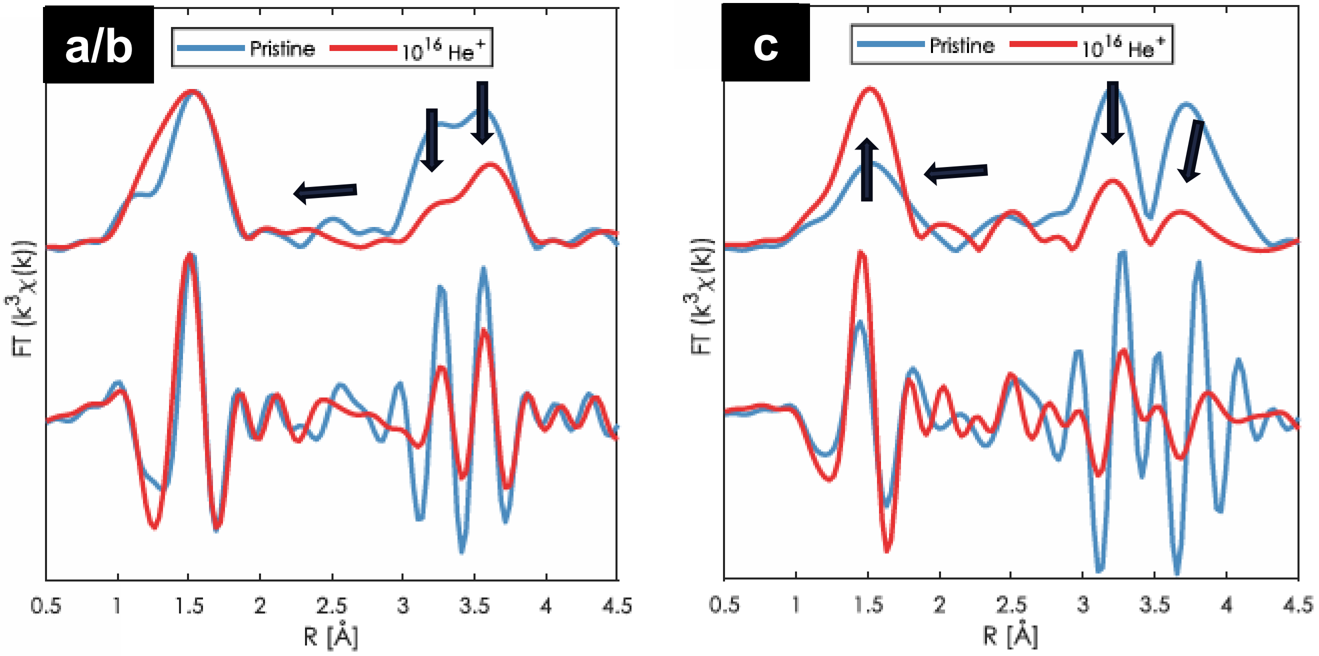
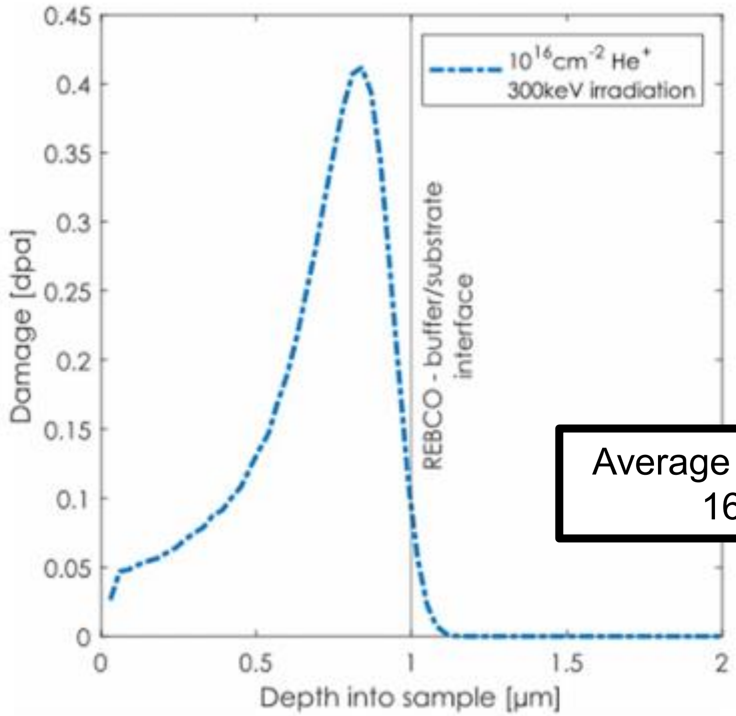
EXAFS 300 keV He^+ study

- Clear evidence of disorder in the unit cell after irradiation
- Trends in agreement with Frenkel model, but no obvious signature



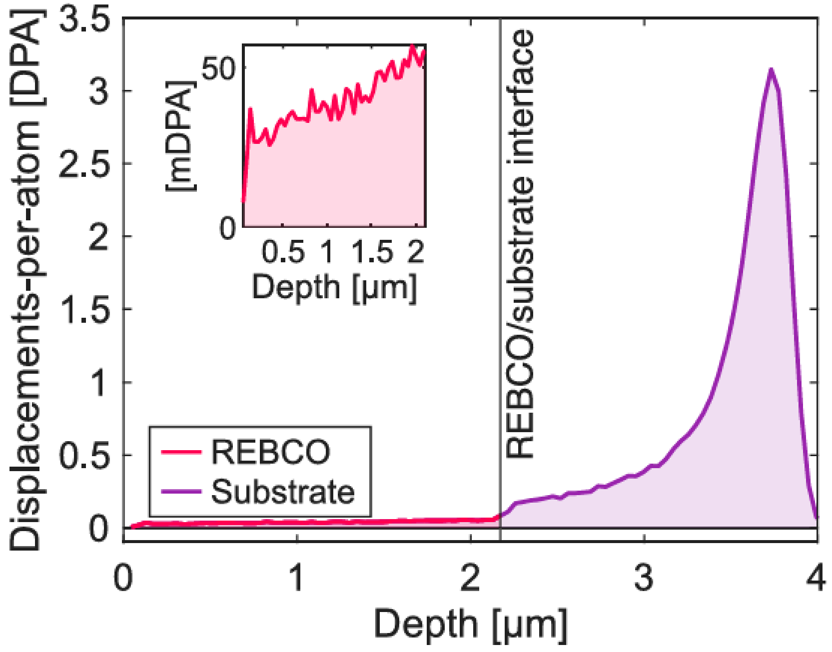


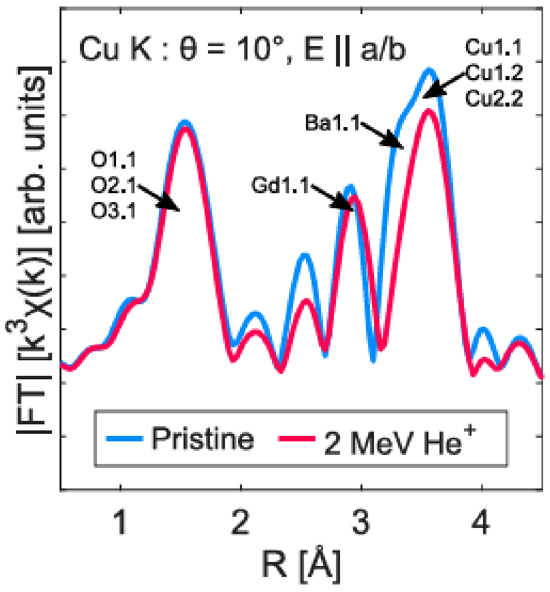
Average REBCO dose:
169 mdpa

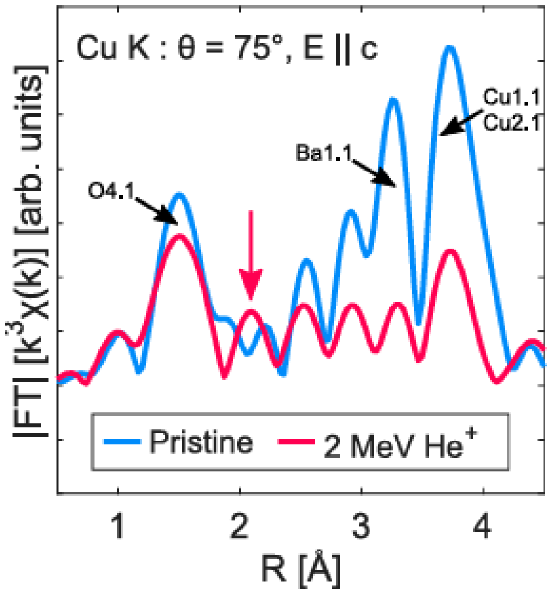
[8] – J.C. Lewis *et al., Supercon. Sci. Technol.* **38**, 2025.

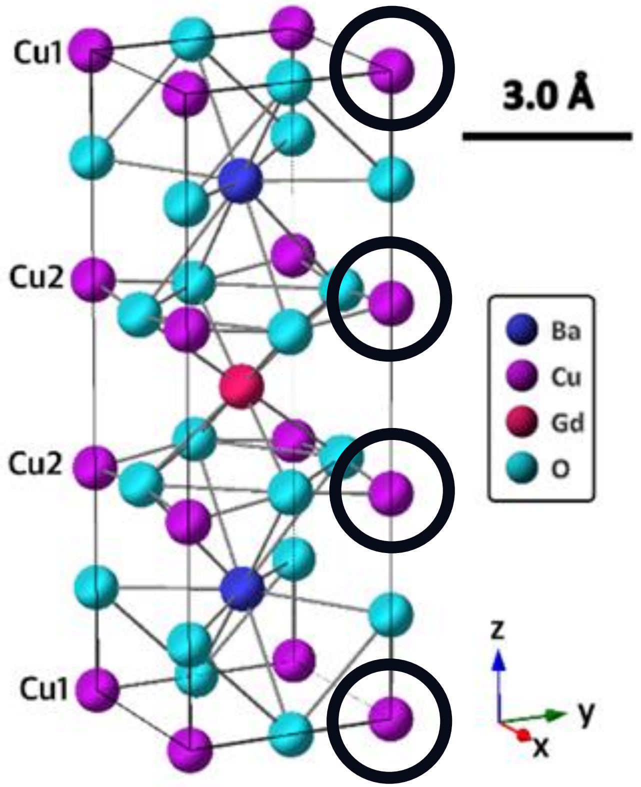
EXAFS 2 MeV He$^+$ study

REBCO dose = 39.9 ± 3.1 mDPA



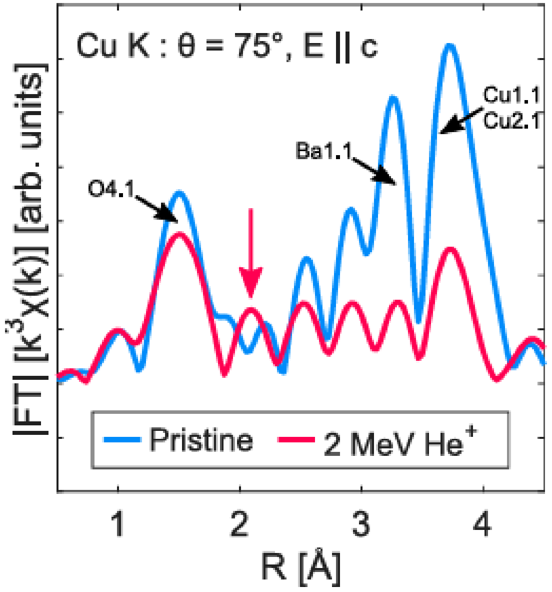


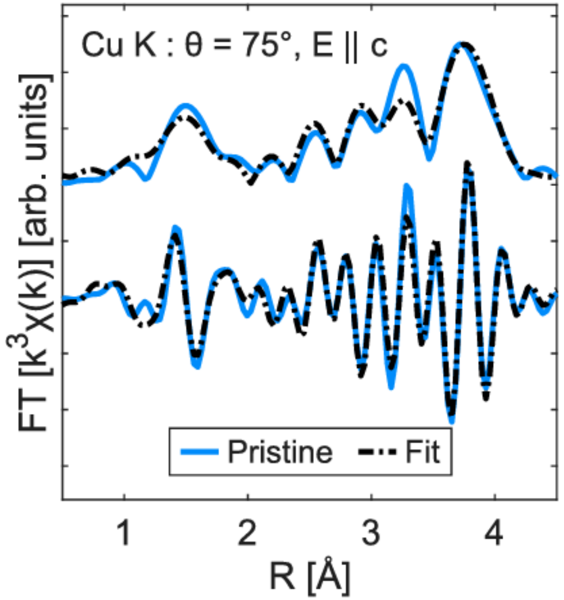


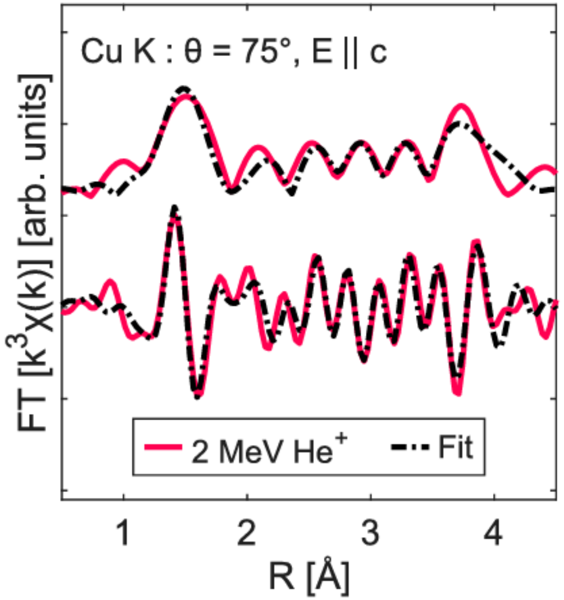


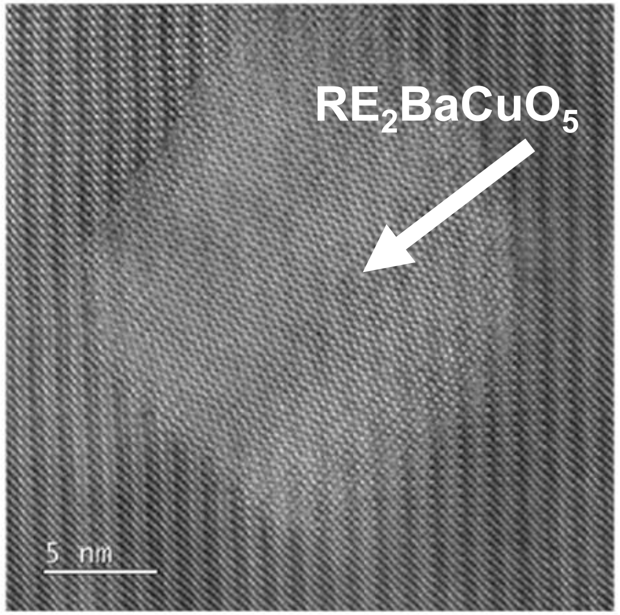
[12] – J.C. Lewis *et al.*, *Superconductivity* **18**, 2026.

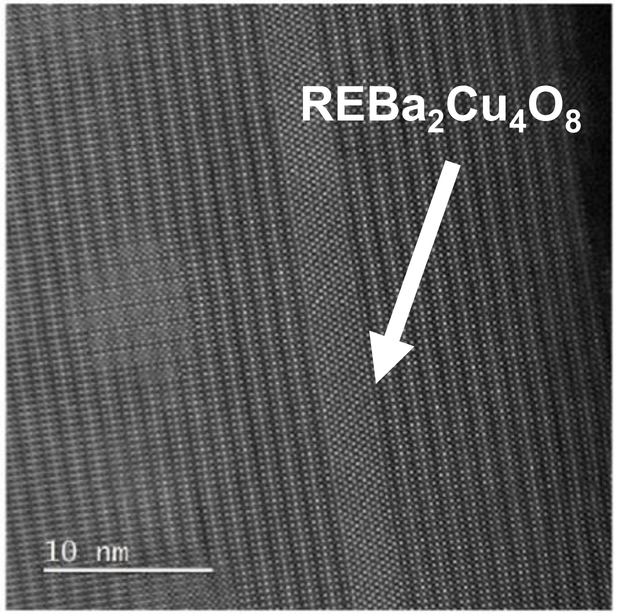
EXAFS 2 MeV He^+ study











- With as-grown defects accounted for, able to fit the local structure

- Suggests a new inter-atomic distance (↓) decorating the pre-irradiated local structure – tentatively in agreement with the Frenkel HERFD-XANES model

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[12] – J.C. Lewis *et al.*, *Superconductivity* **18**, 2026.

So, what next for REBCO at Diamond?

- HERFD-XANES of 2 MeV He^{+} irradiated samples (analysis pending)
- Ongoing microscopy studies at ePSIC
- Defect annealing studies – can we fix “broken” coated conductor and study this in situ?
- EXAFS and HERFD-XANES of D-T fusion spectrum neutron irradiated samples

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- Diamond beamtime proposals **SP23408, SP27236, SP28846, SP30309, SP33243**, **SP34258.**
- He^+ irradiation at University of Surrey through the EPSRC UK National Ion Beam Centre, **EP/X034577/1**.

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Talk summary

- Diamond has an established fission user community
- Growing nuclear fusion user community
- AML supports user access and facilitates on site radioactive work
- NNUF funding available for users to carry out multi-institutional projects, but access available as part of standard Diamond beam time proposals

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Thank you for your attention!

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