

PSI Center for Neutron and
Muon Sciences

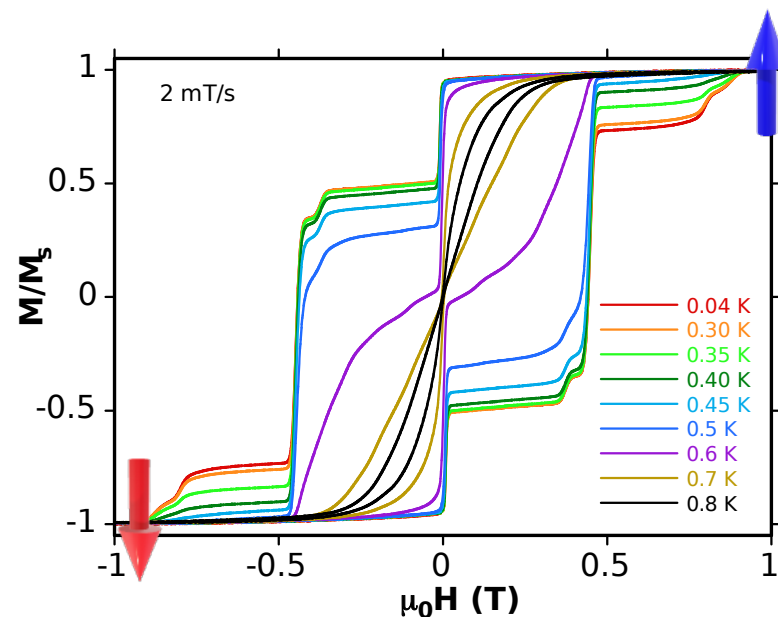
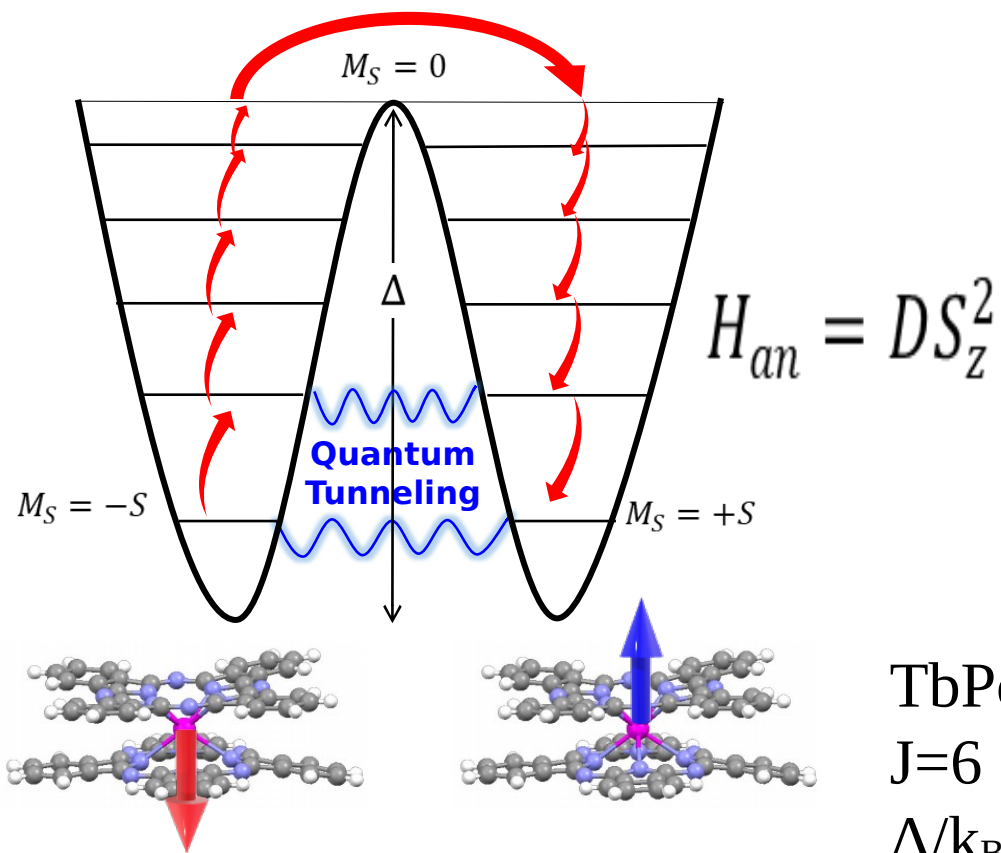
Interfaces of Molecular Magnets and Superconductors



Zaher Salman
MuSR2025, St. John's, 24 July 2025

- **Single Molecule Magnets (SMMs)**
 - SMMs on surfaces
 - μ SR perspective of SMMs
- **SMMs on Superconductors**
 - Sample preparation
 - LE- μ SR results
- **Conclusions and Outlook**

Single Molecule Magnets (SMMs)



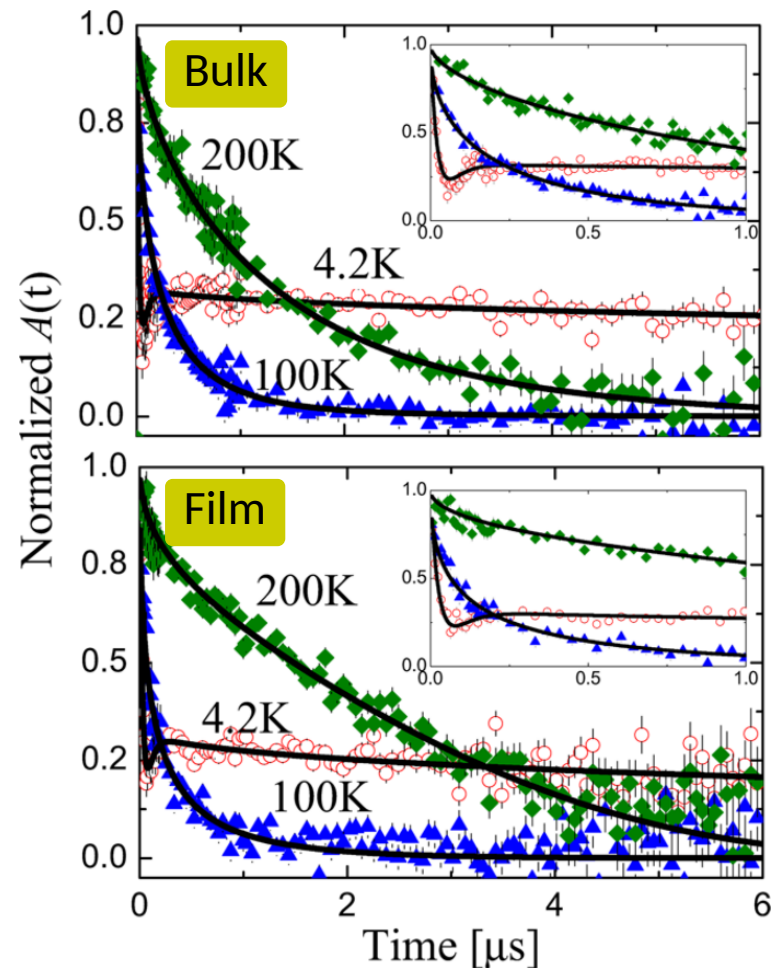
TbPc₂

J=6

$\Delta/k_B \sim 600K$

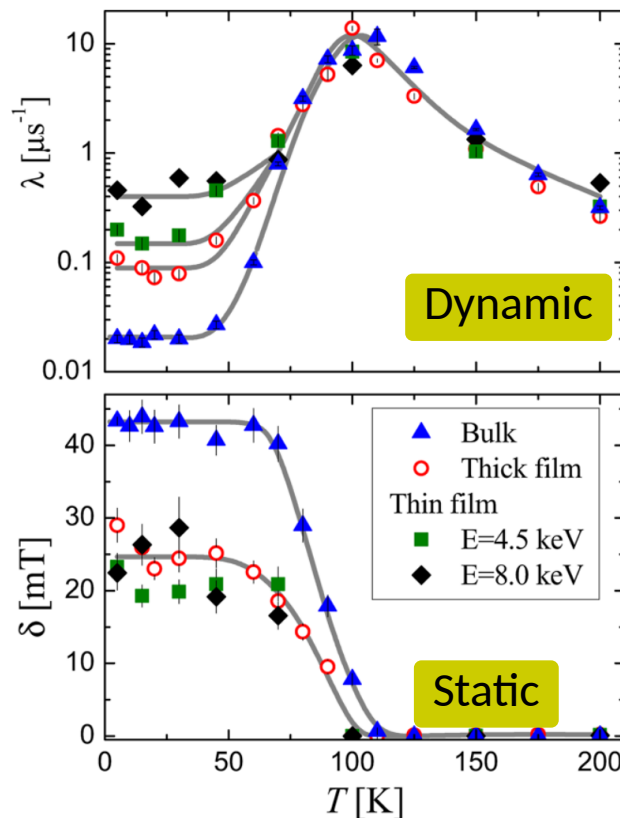
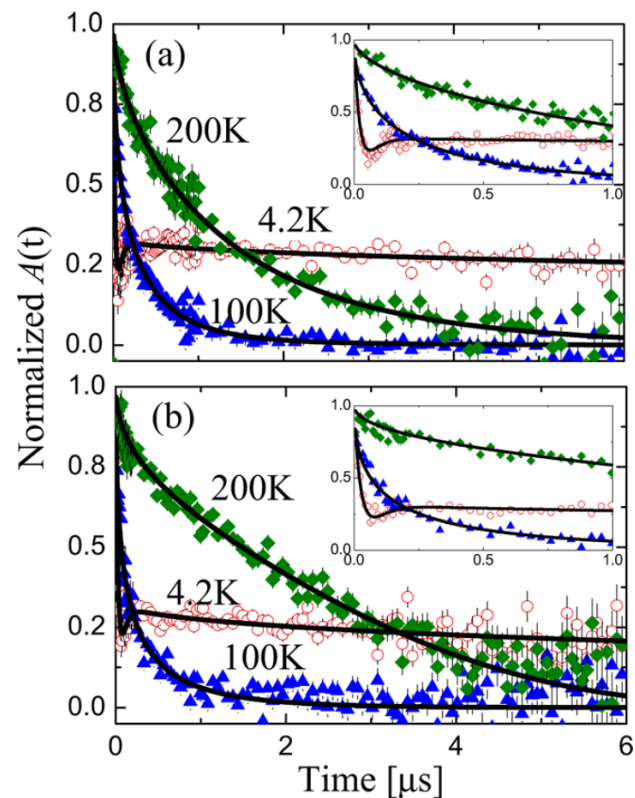
Typical zero field μ SR measurements in TbPc_2

- Dynamic relaxation at high temperatures (exponential)
- Slowing down of the dynamics (down to 100K)
- Freezing – appearance of static magnetic fields ($T < 100$ K)



A. Hoffmann *et al.*, ACS Nano 6, 8390 (2012).

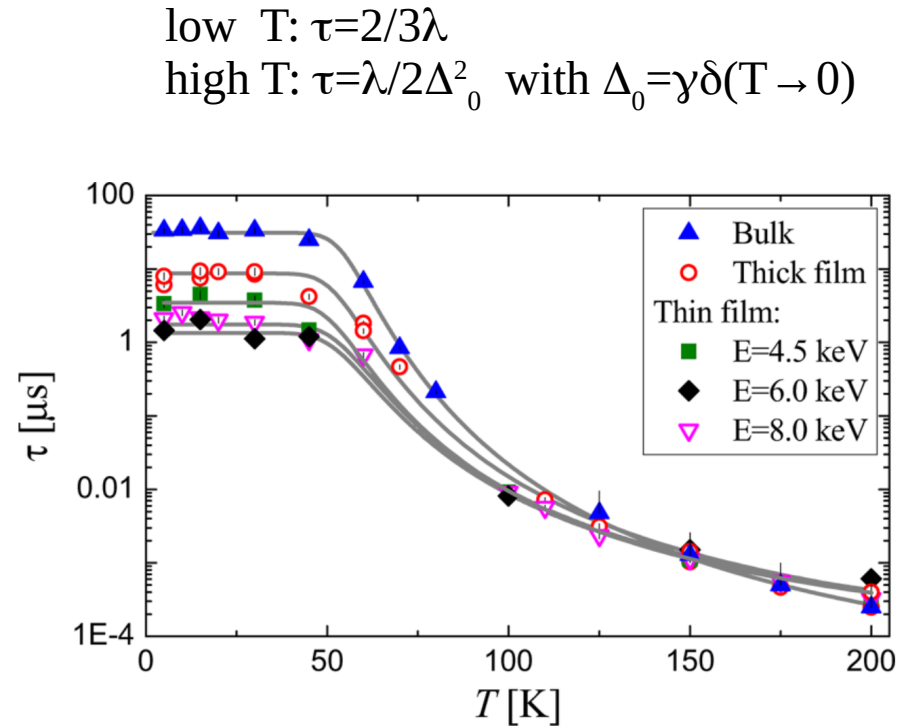
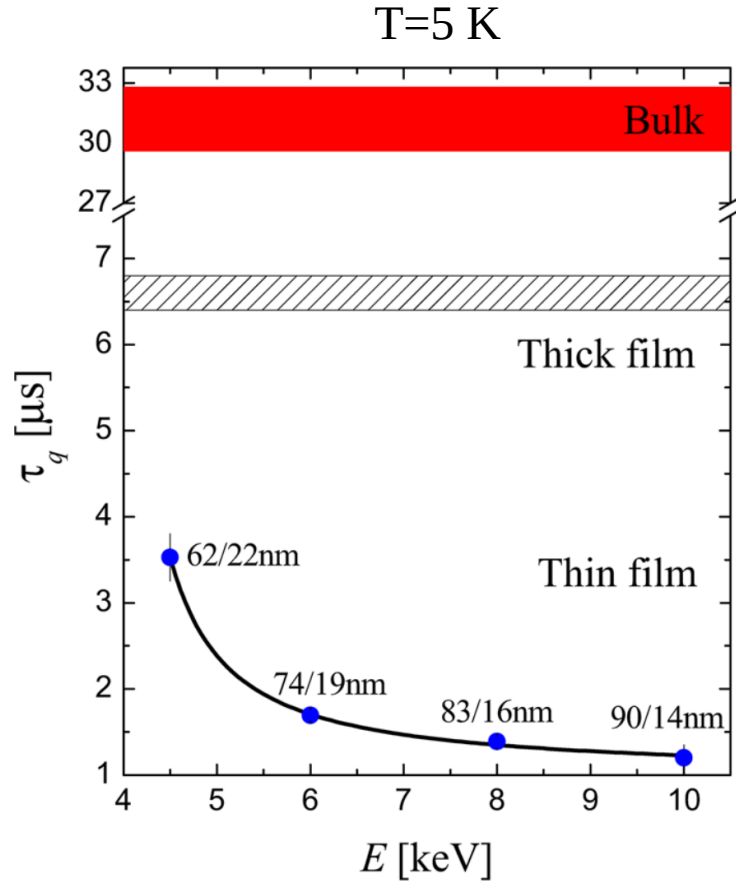
Typical zero field μ SR measurements in TbPc_2



low T :
 $\tau = 2/3\lambda$
 high T :
 $\tau = \lambda/2\Delta_0^2$
 $\Delta_0 = \gamma\delta(T \rightarrow 0)$

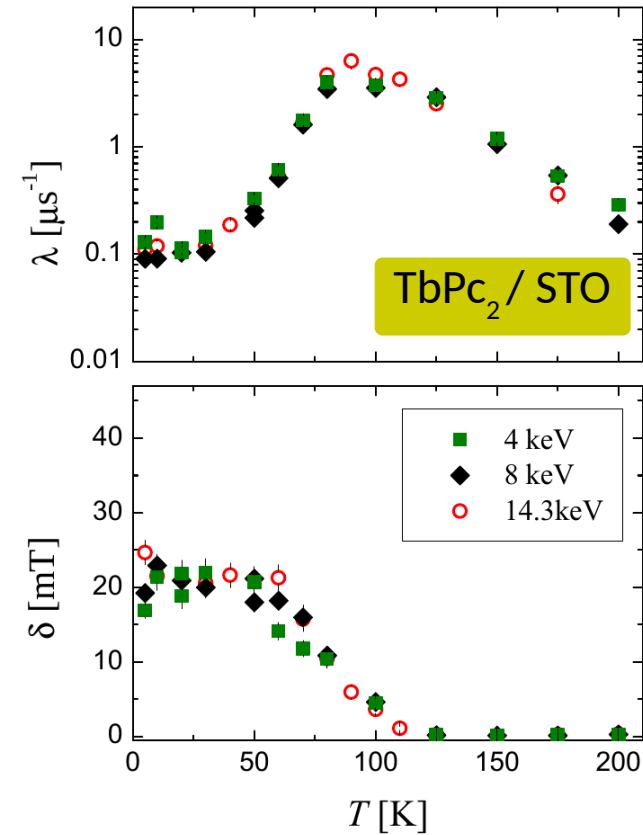
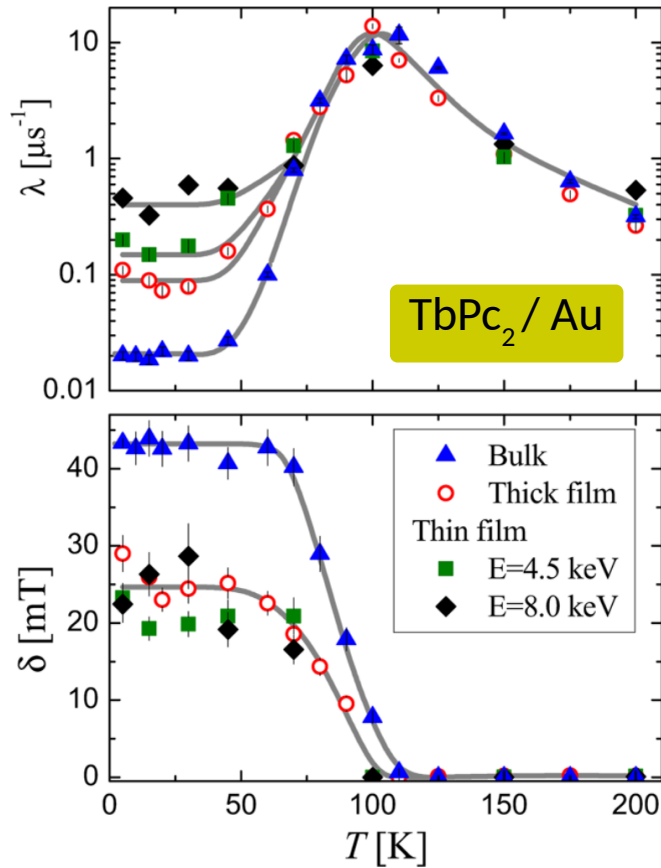
A. Hoffmanl et al., ACS Nano 6, 8390 (2012).

Spin Dynamics as a Function of Depth - TbPc2/Au



A. Hoffmann *et al.*, ACS Nano 6, 8390 (2012).

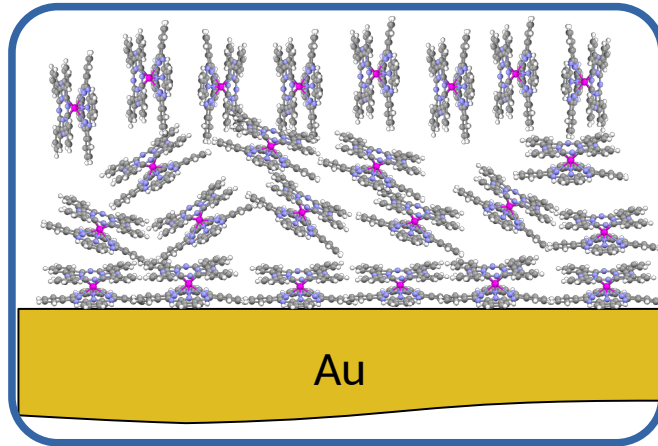
Comparison - TbPc₂/Au vs. TbPc₂/STO



Substrate Effect on Packing and Spin Dynamics

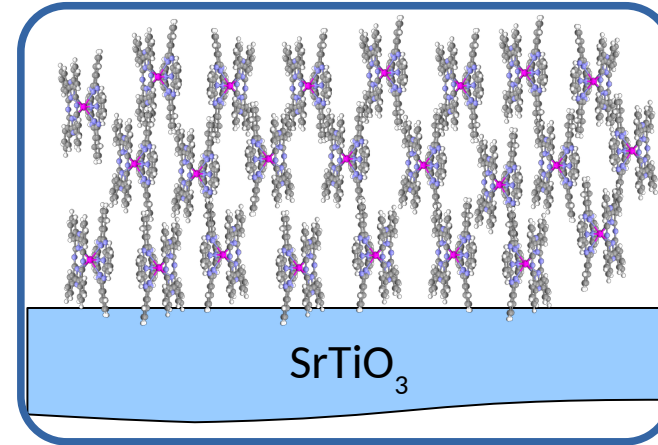
On Au:

- Molecules are lying down at the surface
- Gradually change to standing away from the substrate



On SrTiO_3 :

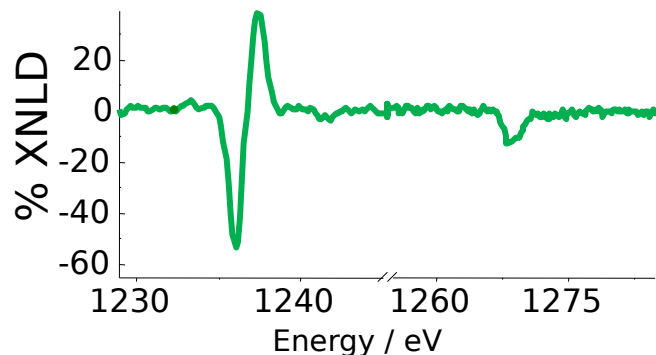
- Molecules are standing at the surface
- No dramatic change as we go away from the substrate



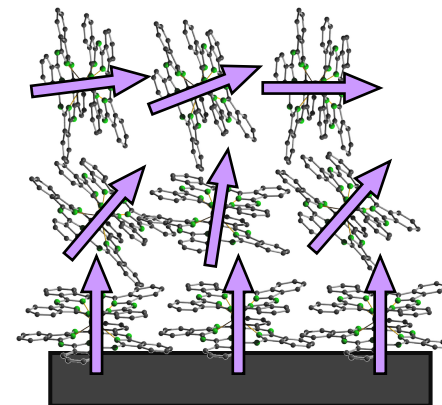
Control of TbPc₂ Orientation on Surfaces



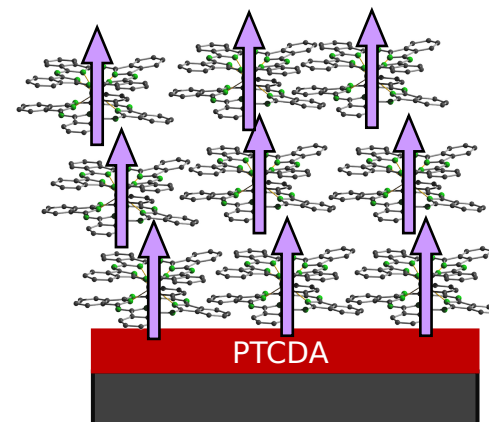
X-ray natural linear dichroism



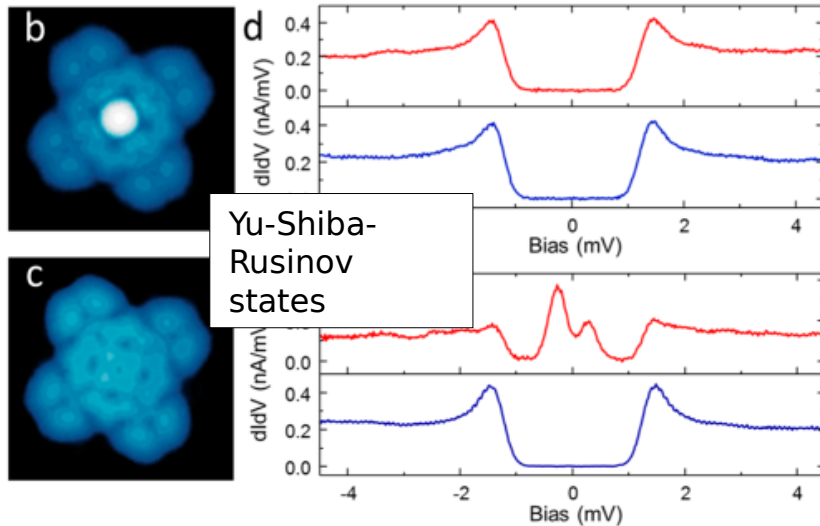
Standing
configuration



Lying-down
configuration

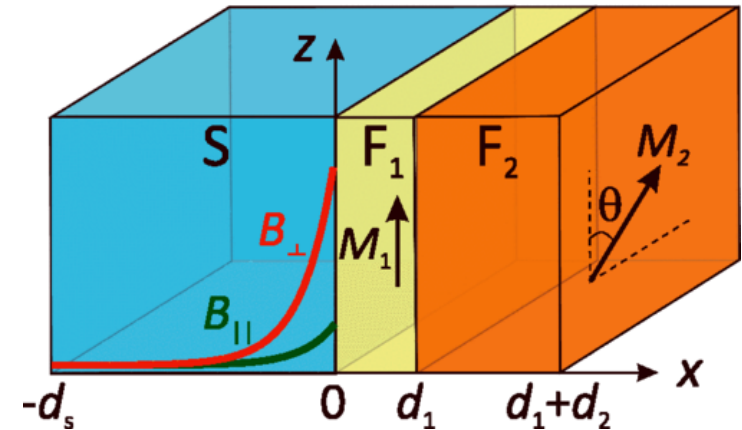


Formation of local bound states



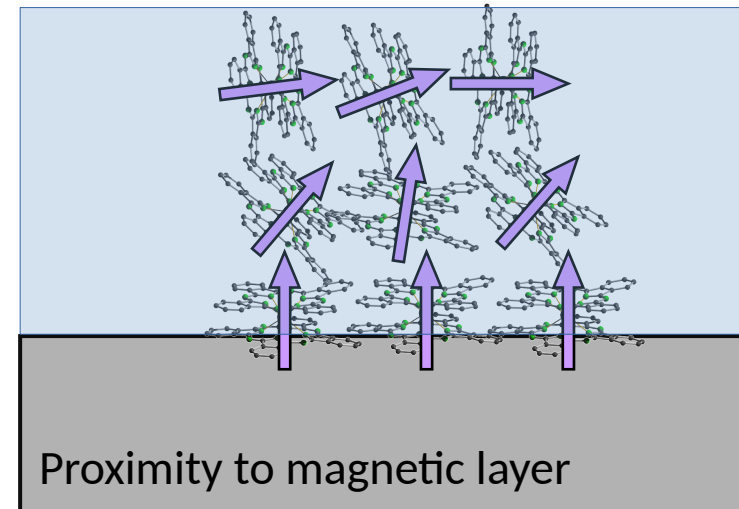
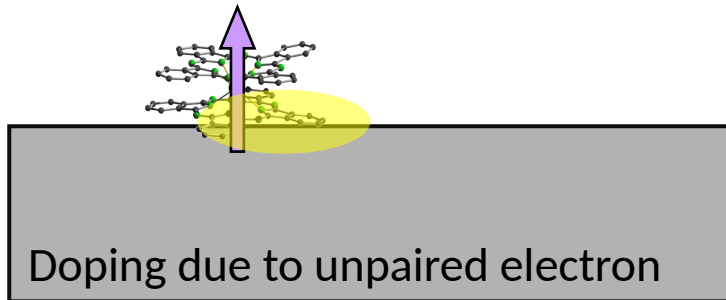
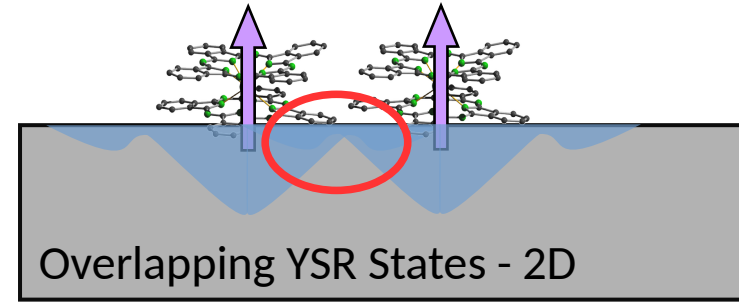
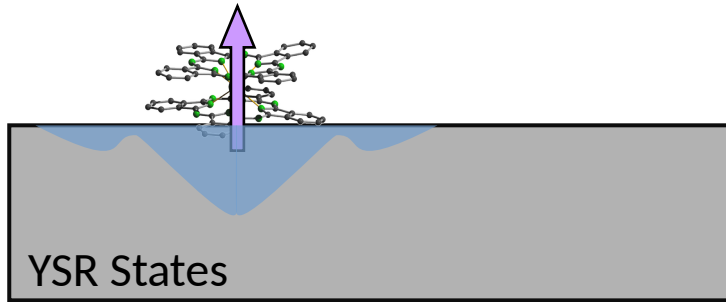
Malavolti *et al.* *Nano Lett.* 18, 12, 7955–7961 (2018)

Electromagnetic proximity effect

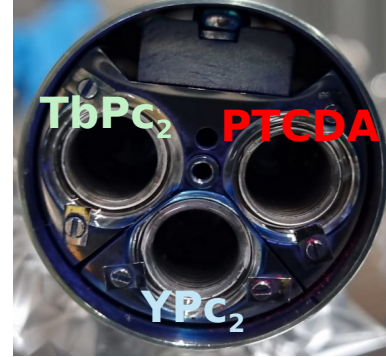
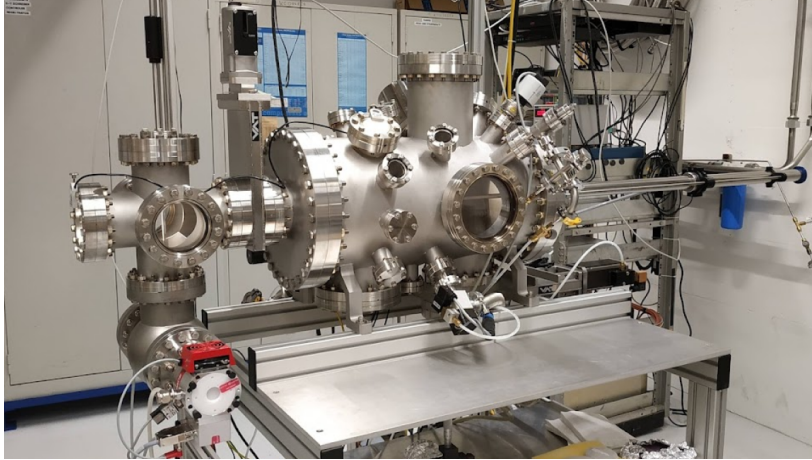


Devizorova *et al.* *Phys. Rev. B* 99, 104519 (2019)

SMMs (TbPc_2) on Superconductors

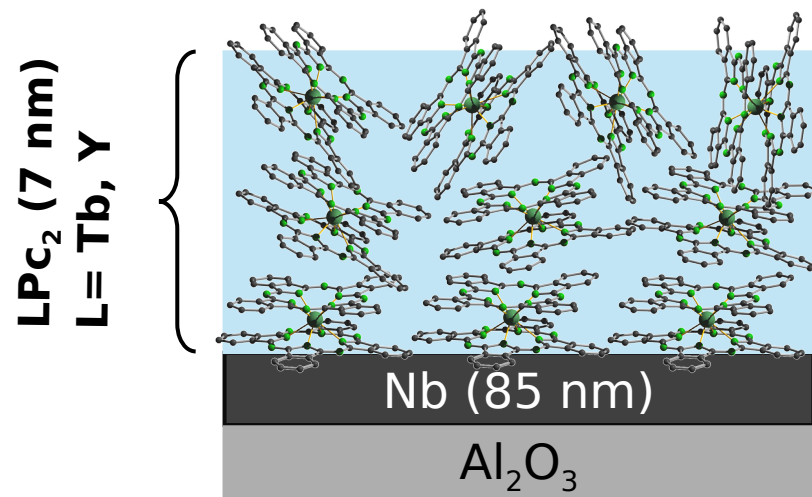


Sample Preparation Chamber - Leyla

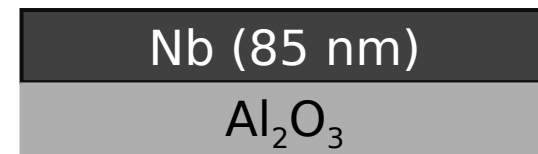
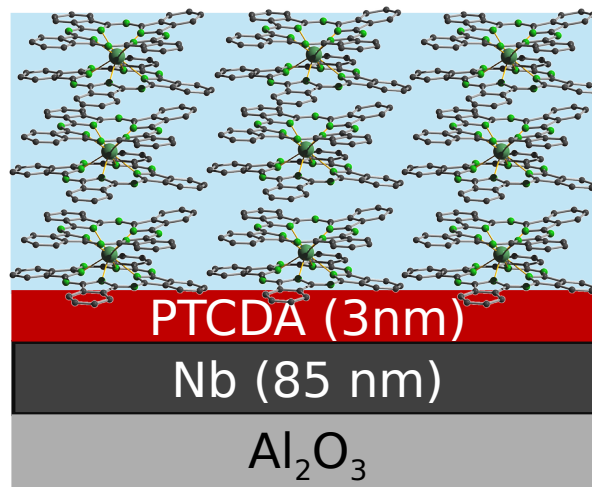


- $\sim 10^{-9}$ mbar
- Supports large area substrates
- Kentax 3-cell evaporator
- QCM and thickness monitor

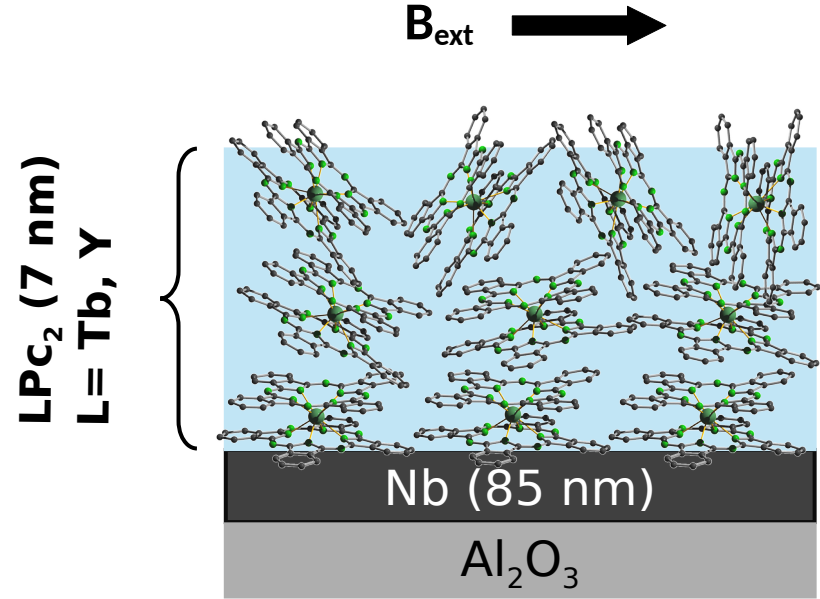
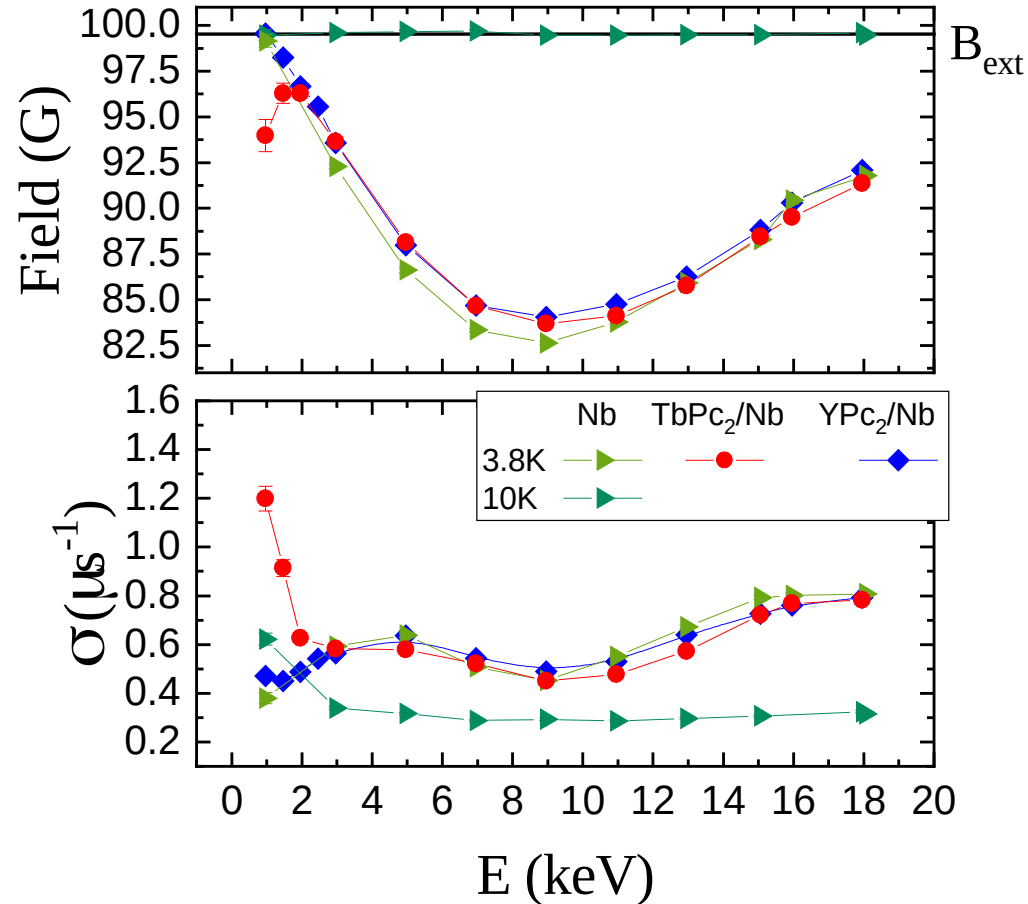
H. Teuschl et al. *Journal of physics: conference series*, vol. 2462 (2023)



Measured samples



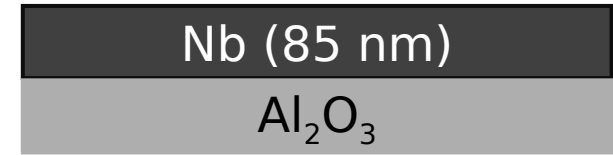
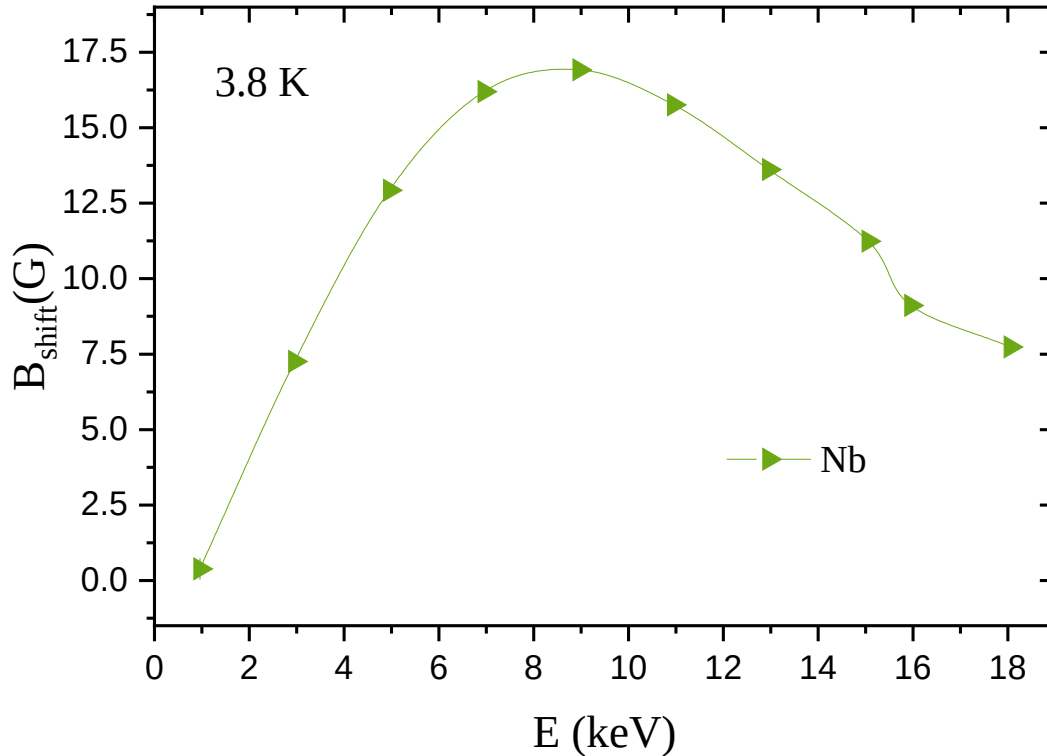
Meissner Screening in Hybrid Interfaces



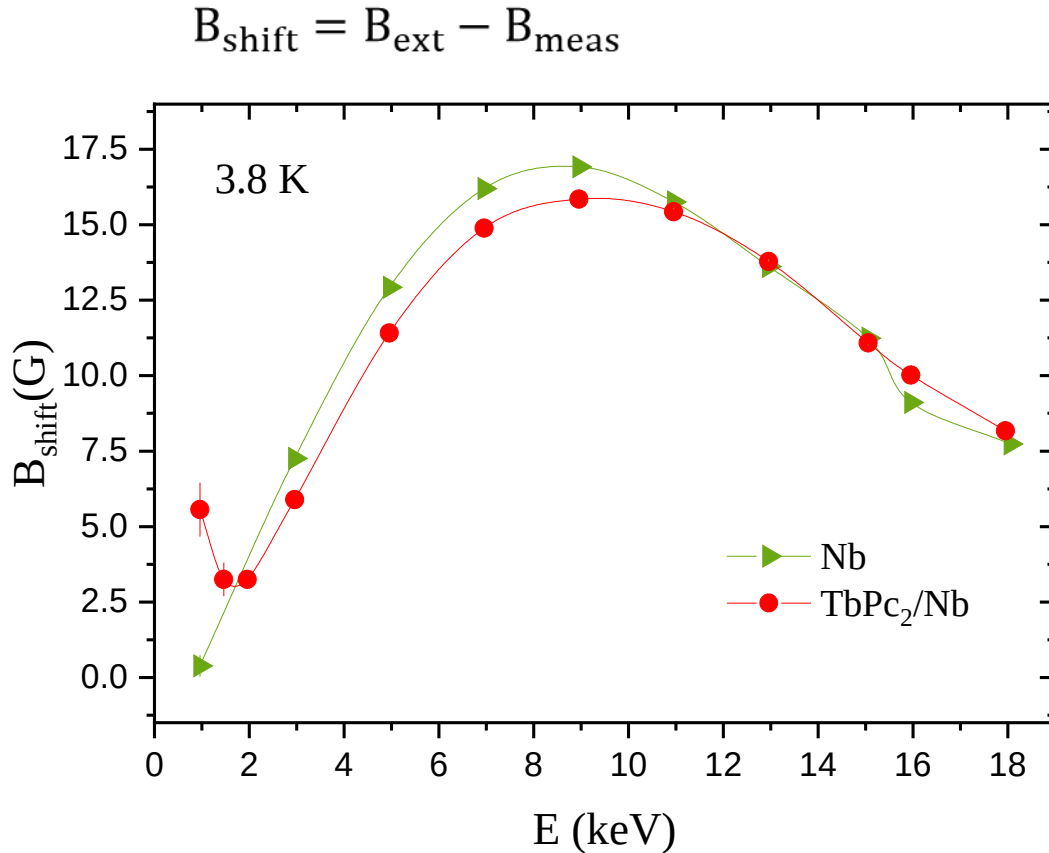
Meissner Screening in Hybrid Interfaces

B_{ext} 

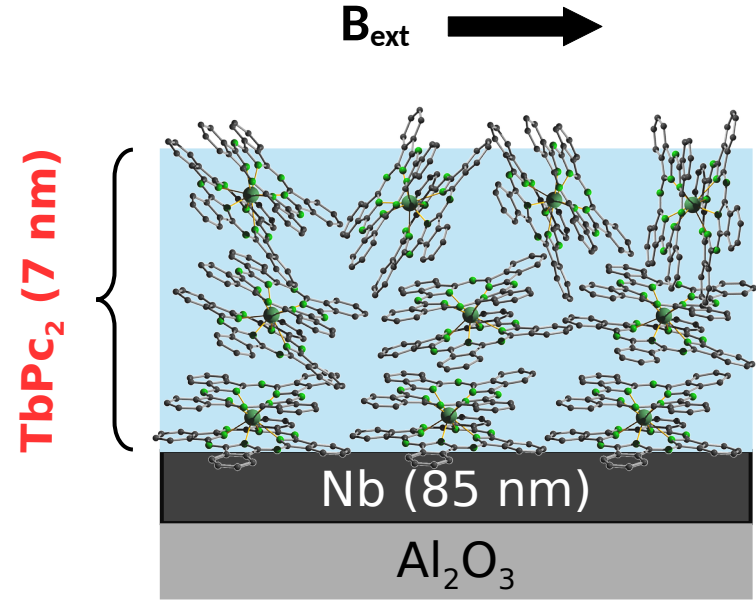
$$B_{\text{shift}} = B_{\text{ext}} - B_{\text{meas}}$$



Meissner Screening in Hybrid Interfaces

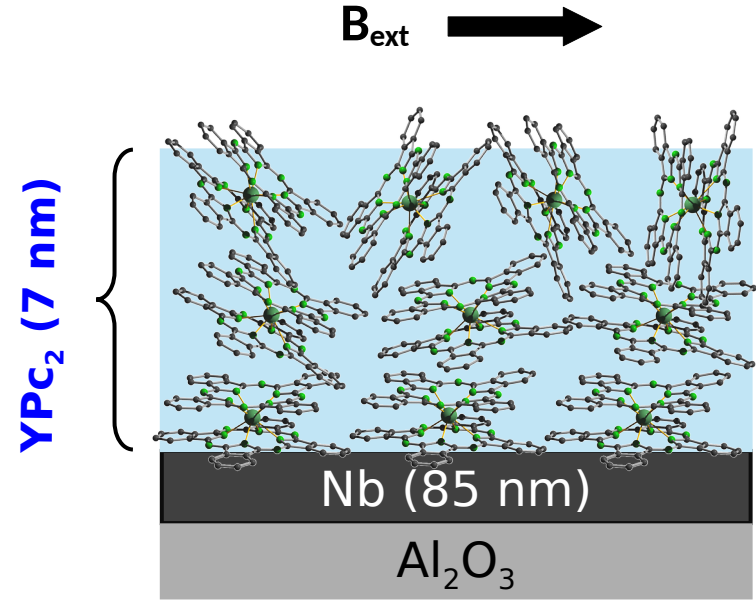
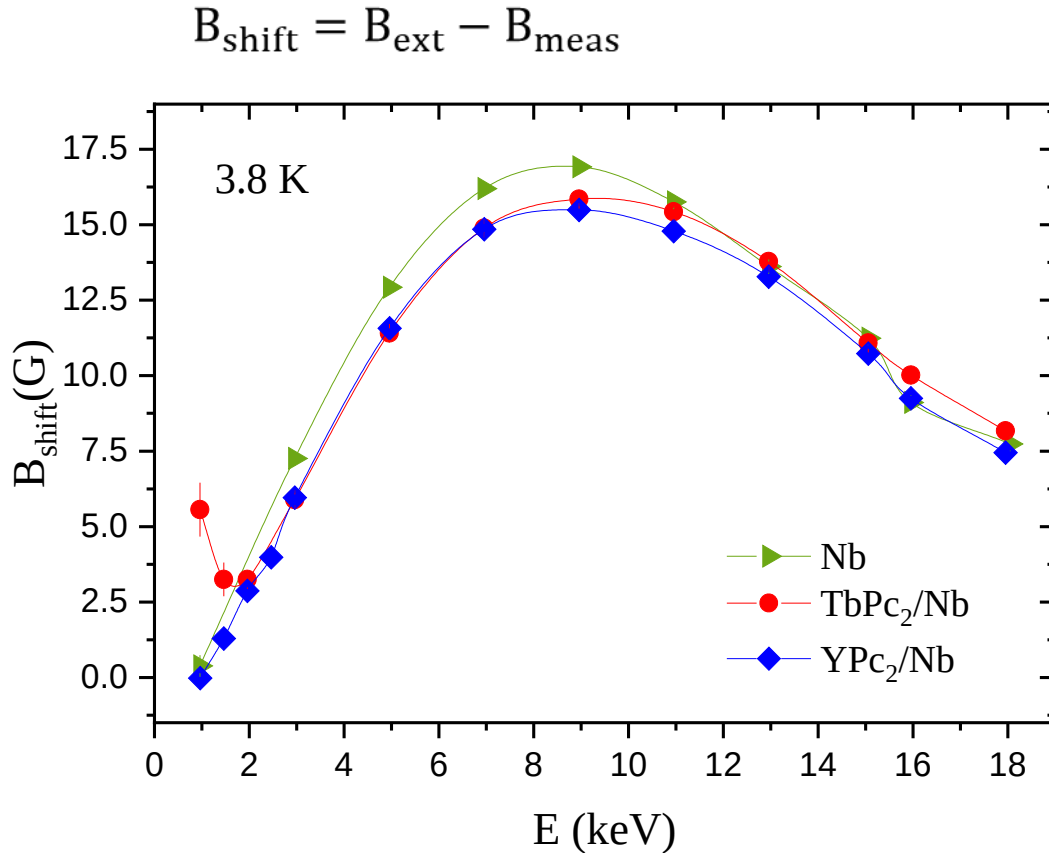


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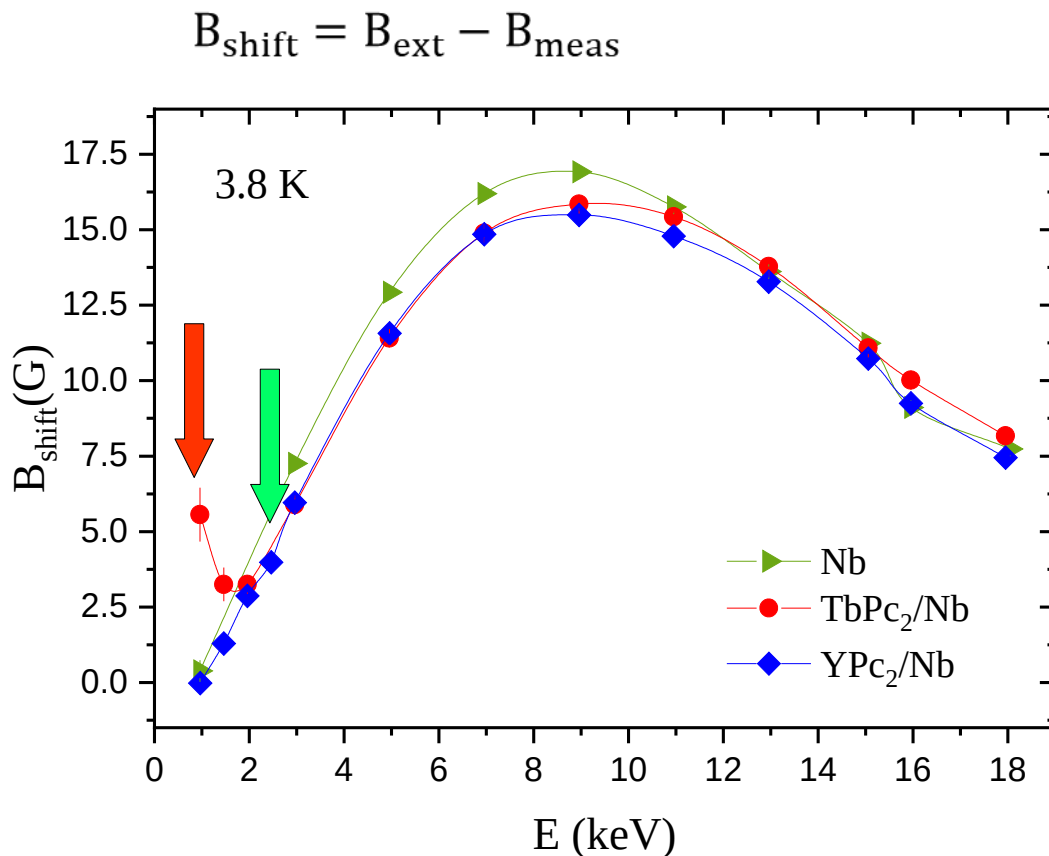


25.07.2025

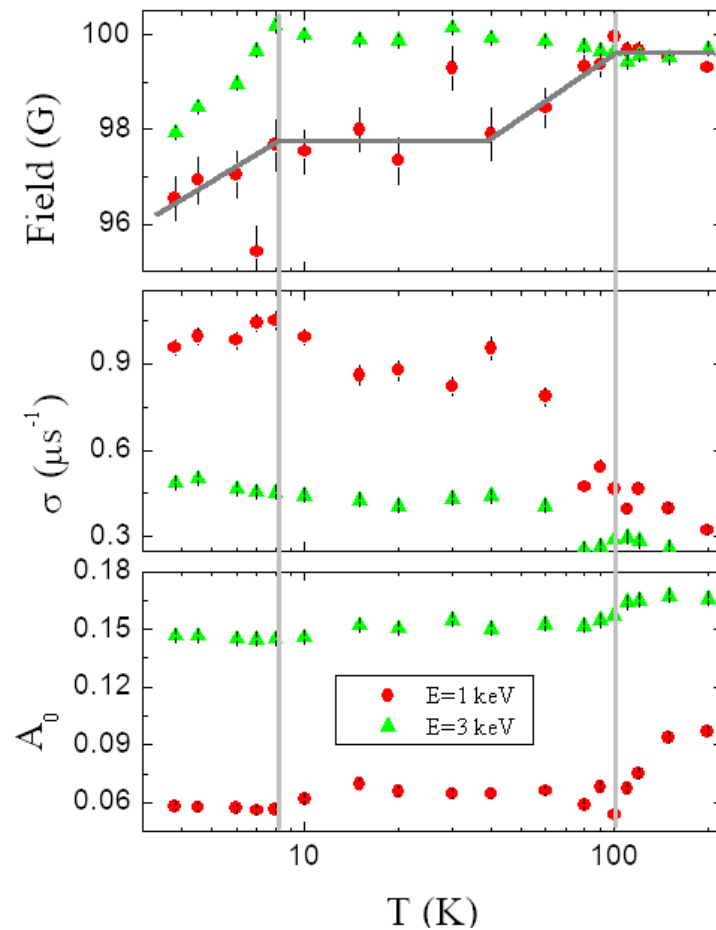
Meissner Screening in Hybrid Interfaces



Temperature Dependence in 7nm TbPc₂/Nb

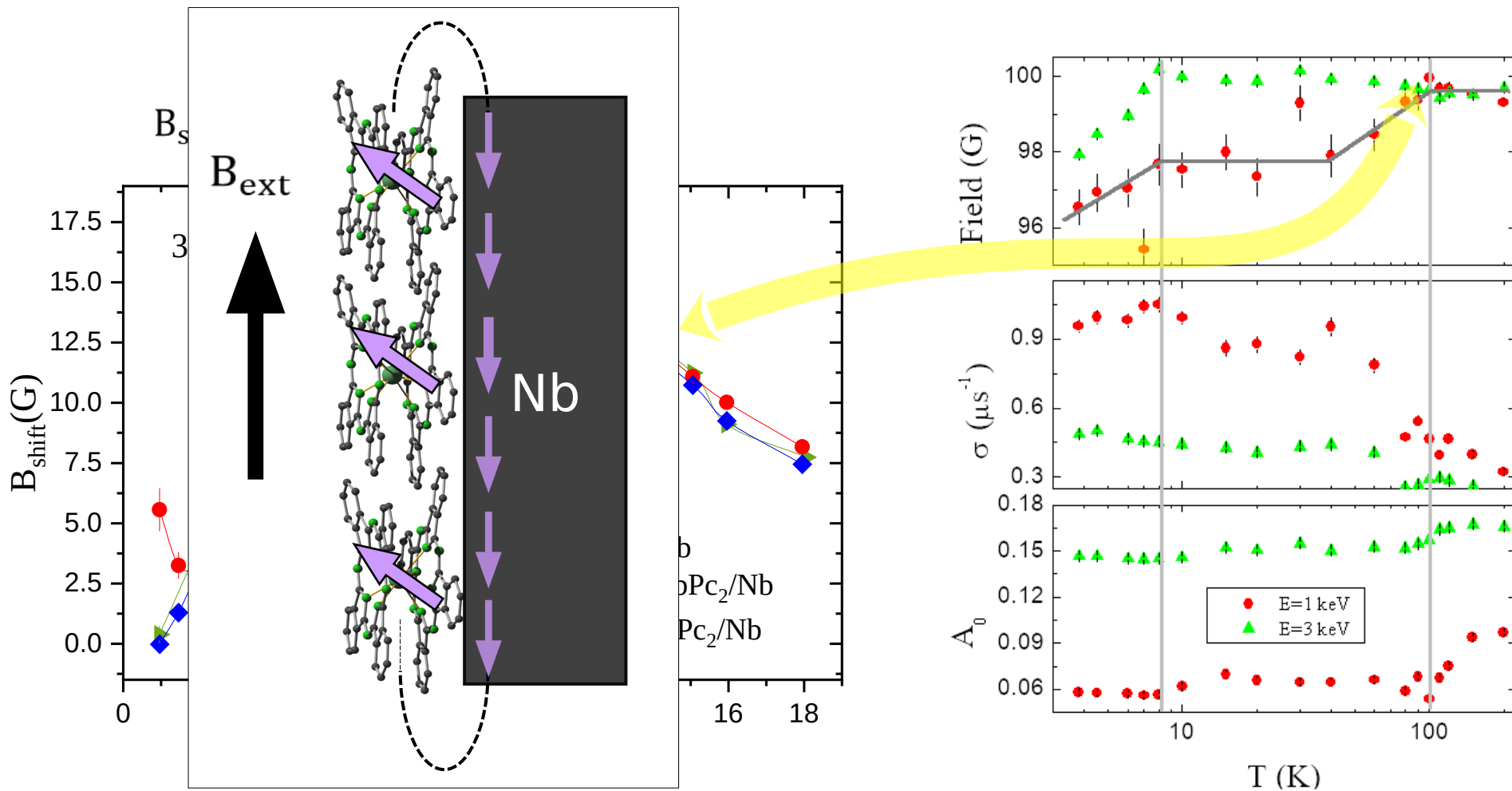


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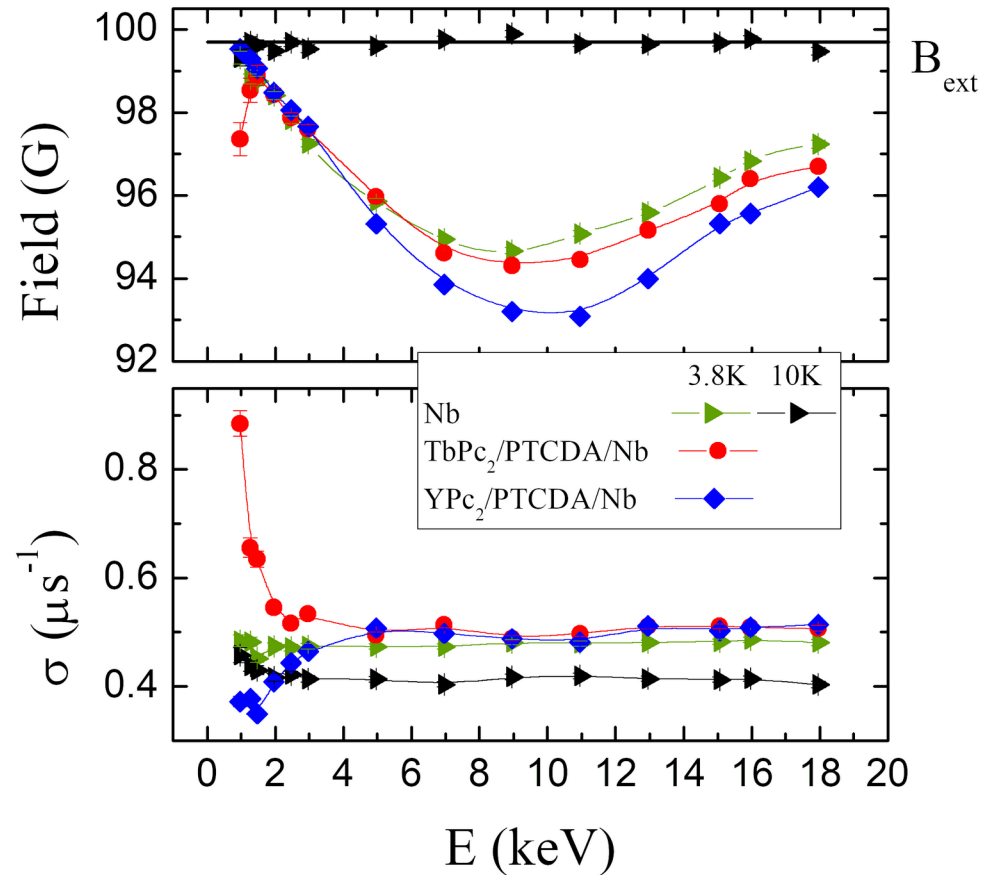


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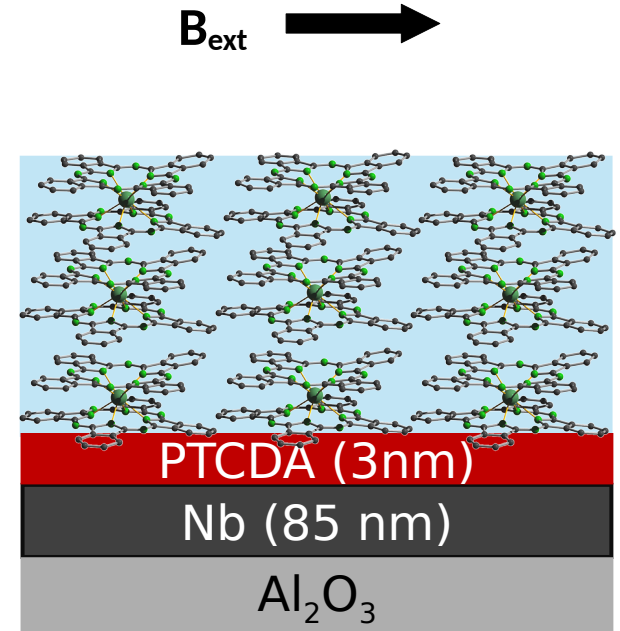
Temperature Dependence in 7nm TbPc₂/Nb



Meissner Screening in Hybrid Interfaces

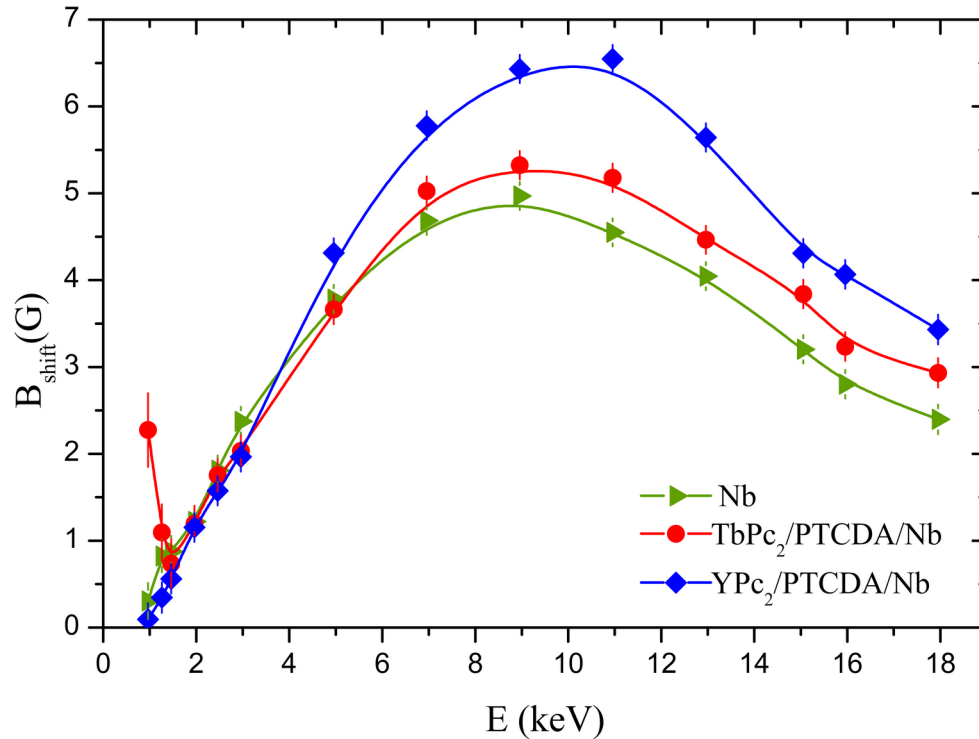


LPc_2 (7 nm)
 $L = \text{Tb, Y}$

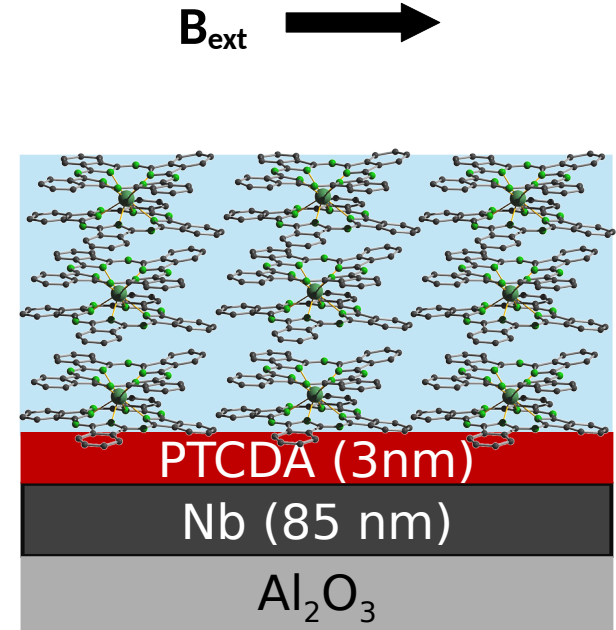


Meissner Screening in Hybrid Interfaces

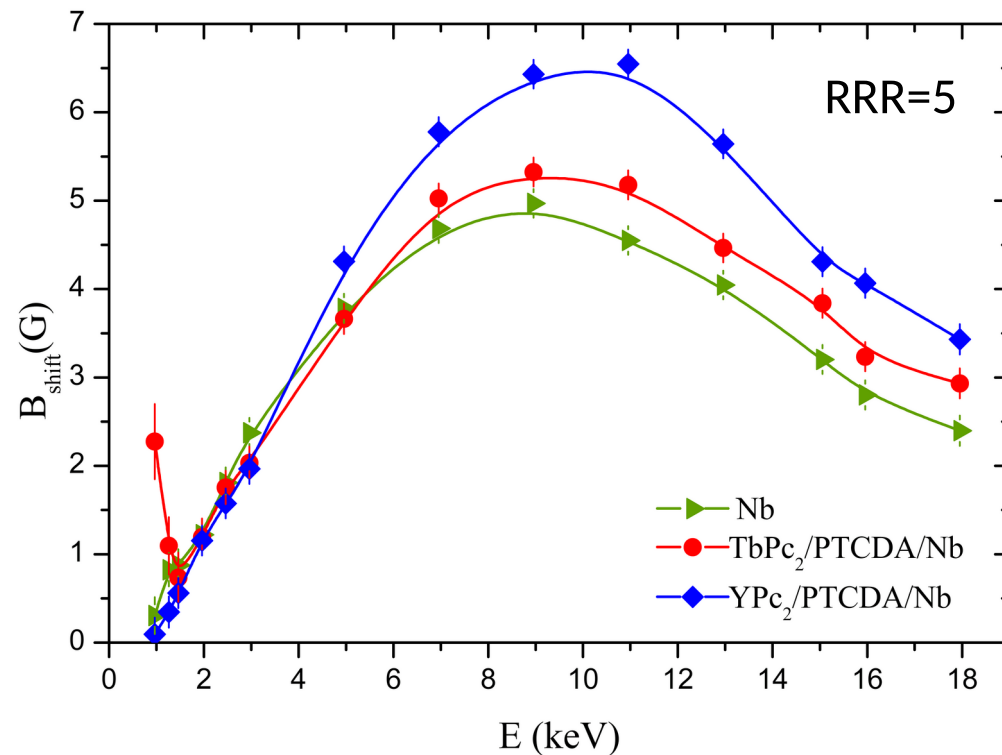
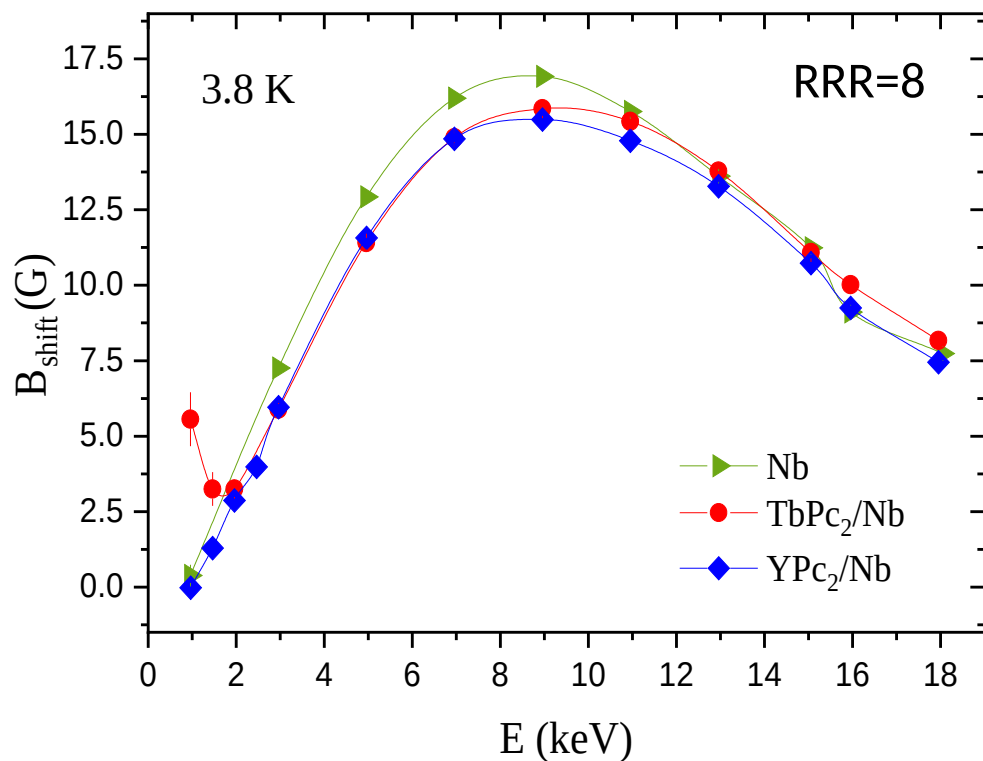
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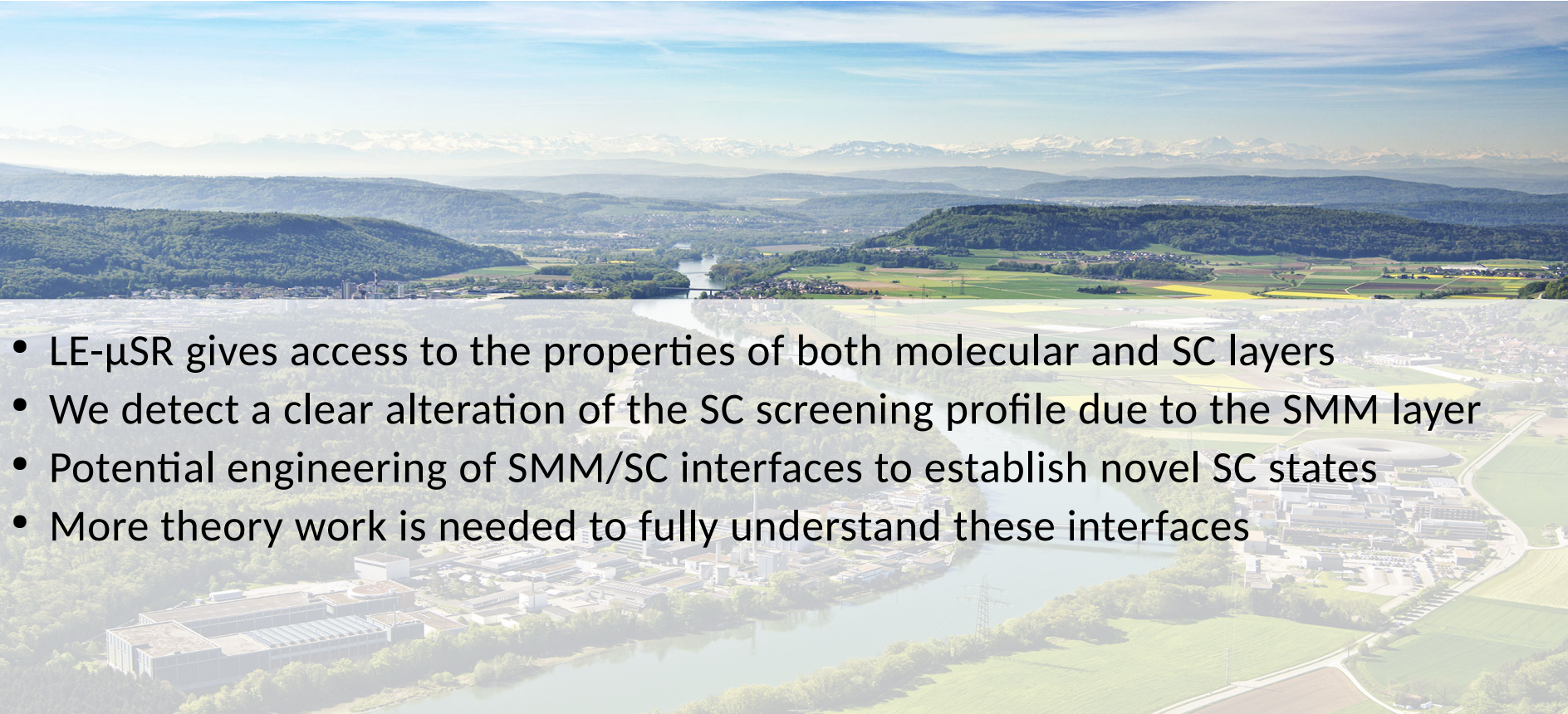


LPc_2 (7 nm)
 $L = \text{Tb, Y}$



Comparisons with and without PTCDA





- LE- μ SR gives access to the properties of both molecular and SC layers
- We detect a clear alteration of the SC screening profile due to the SMM layer
- Potential engineering of SMM/SC interfaces to establish novel SC states
- More theory work is needed to fully understand these interfaces

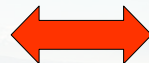
Thanks to ...



PSI

Marta Albanesi (Guest PhD / Florence)

Gianluca Janka
Thomas Prokscha
Andreas Suter



University of Florence

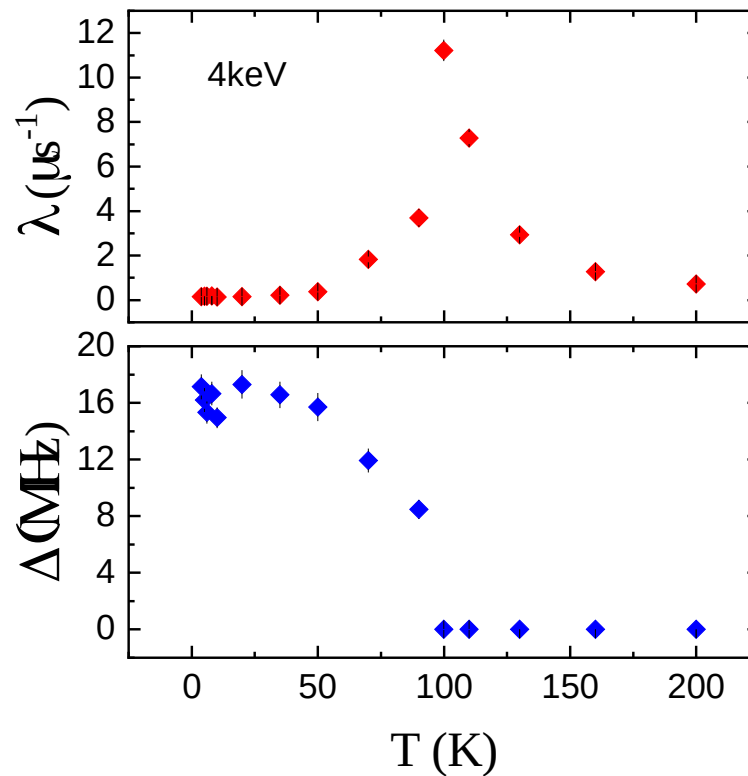
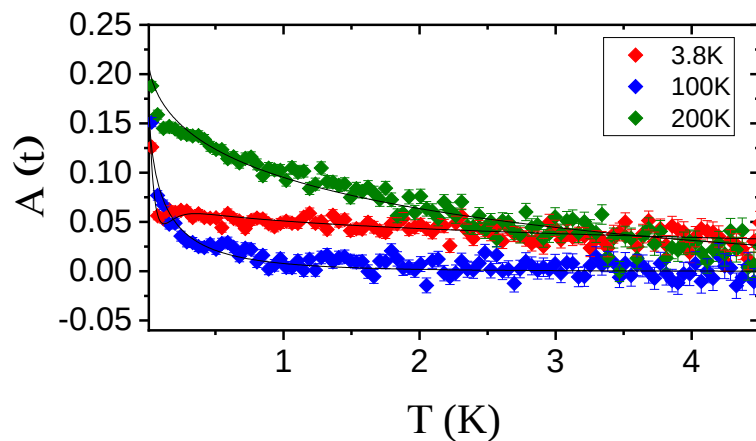
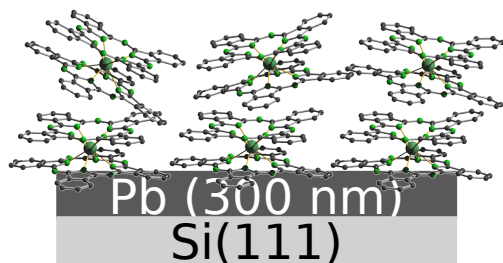
Matteo Mannini
Giulia Serrano

University of Konstanz

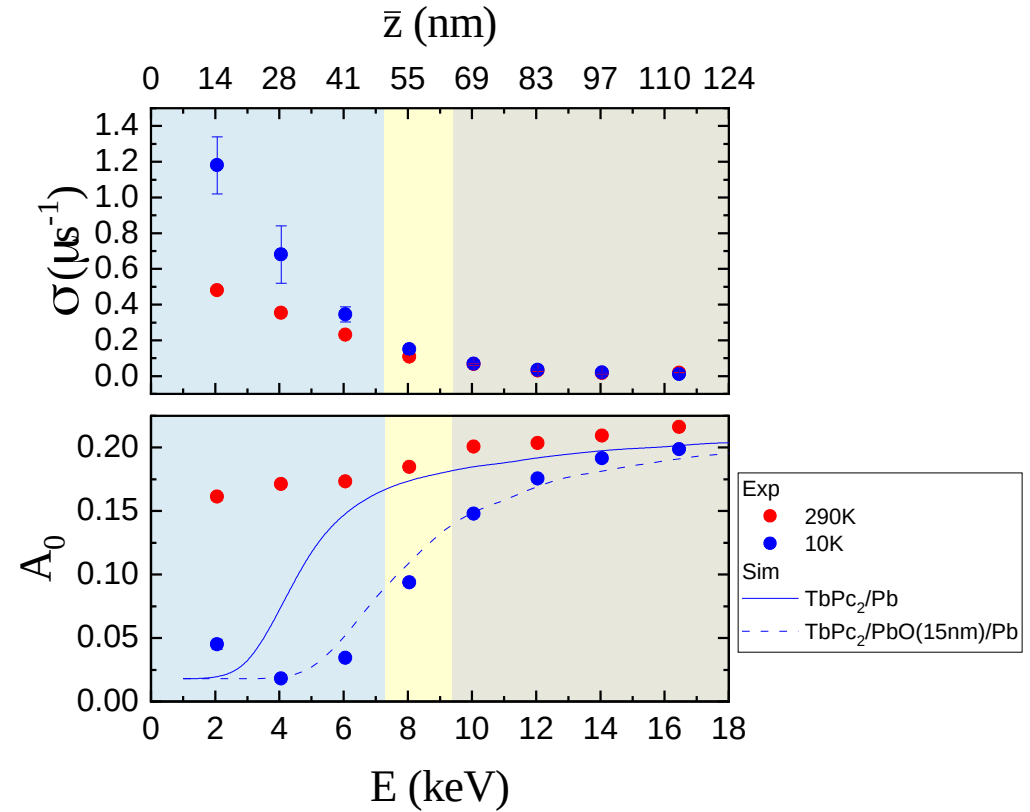
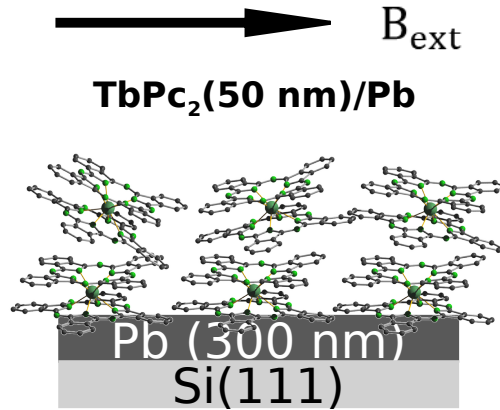
Angelo Di Bernardo
Elke Scheer
Jeniffer Koch

ZF LE- μ SR Results TbPc₂

TbPc₂(50 nm)/Pb



ZF LE- μ SR Results TbPc_2



ZF LE- μ SR Results YPc_2

$\text{YPc}_2(100 \text{ nm})/\text{Au}$

