A novel sub-eV particle detection scheme using magnetic metrology of superconducting thin films using NV Centers

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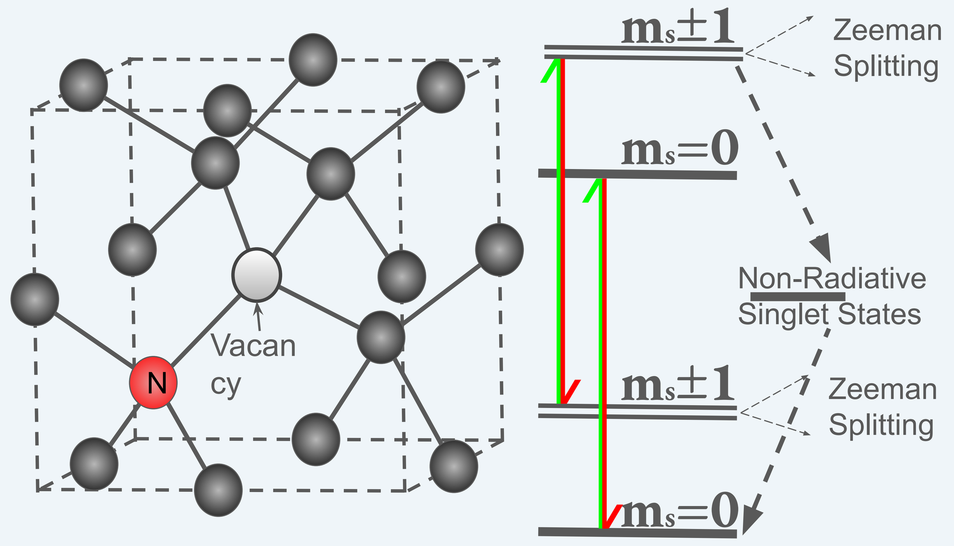
INTRODUCTION

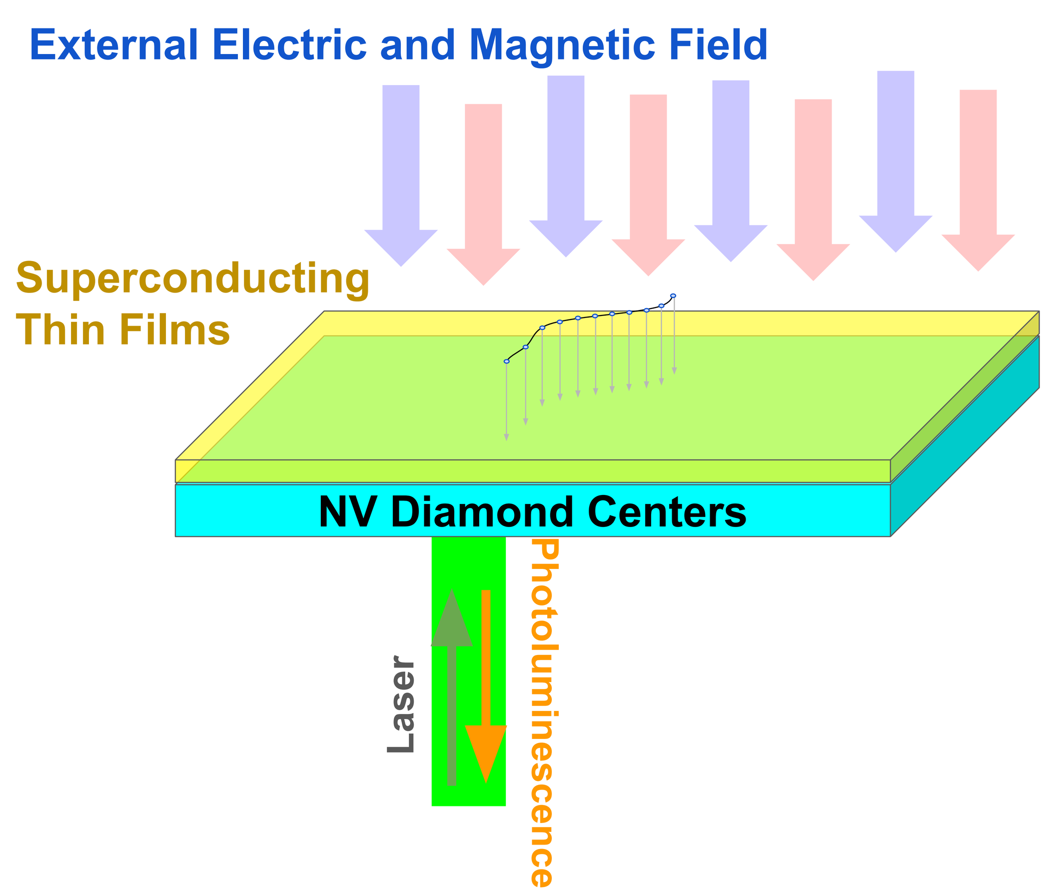
Superconducting Thin Films (STF):

- High Energy Resolution
- Detects energy from particles by measuring minute temperature increases.
- Low Noise Levels



Nitrogen-Vacancy(N-V) Centers:

- Offer high magnetic sensitivity at the nanoscale
- Ideal for detecting tiny changes in magnetic fields caused by particle interactions.
- Allows for improved energy and spatial resolution and sensitivity.

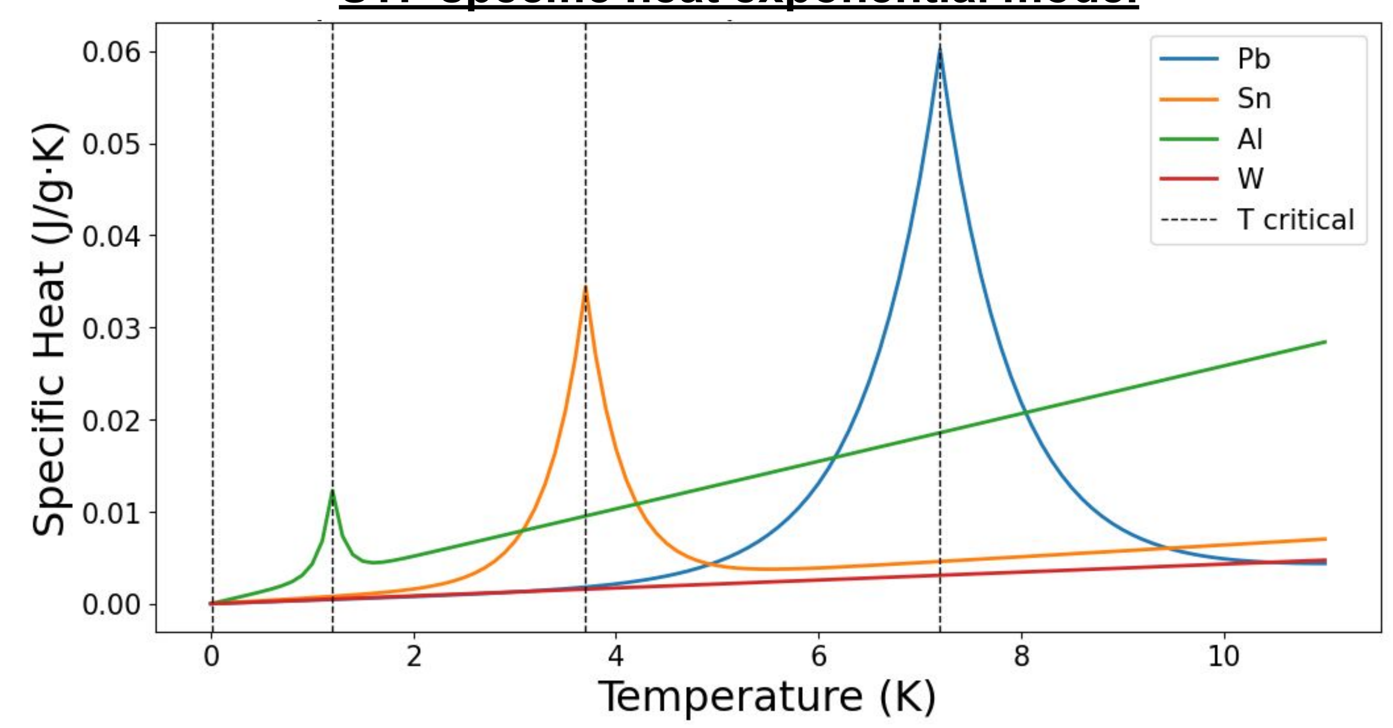


Motivation

Particle Physics Applications:

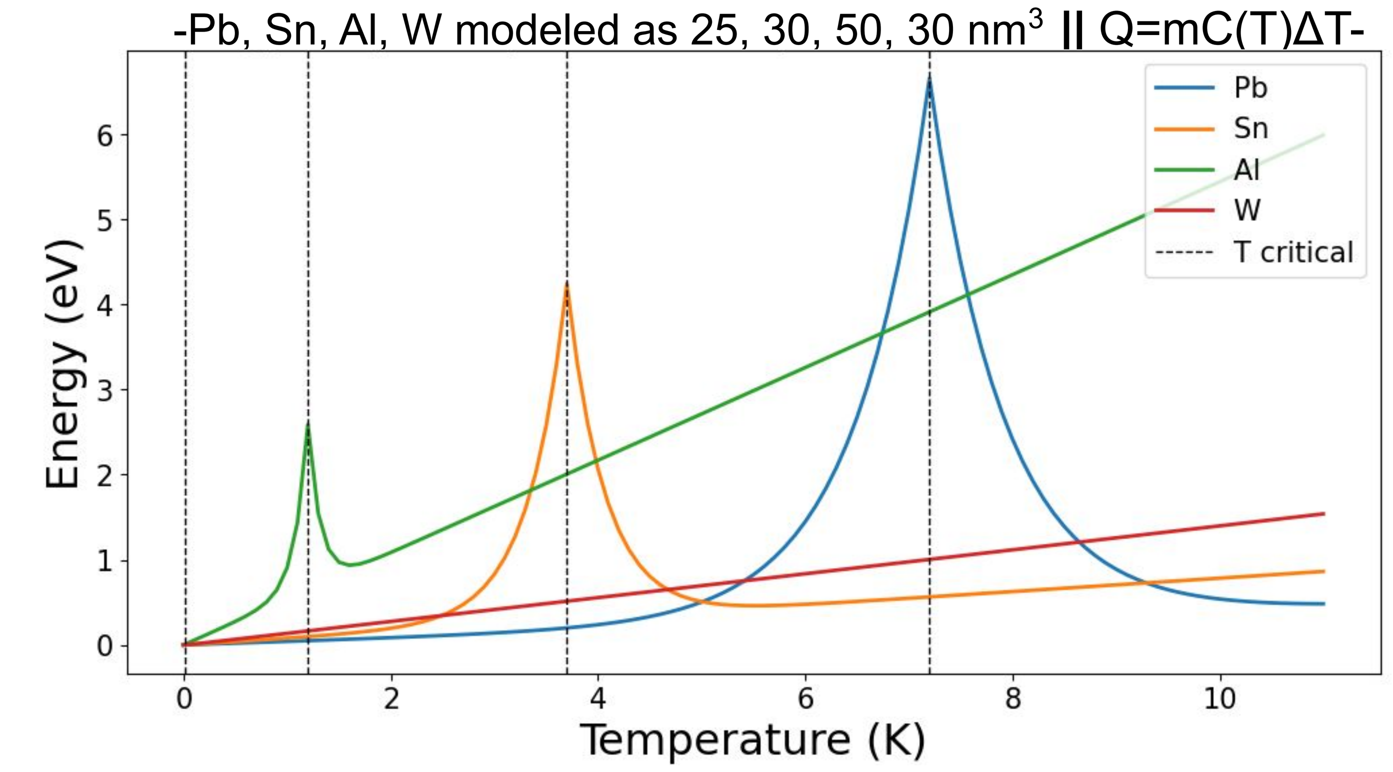
- Sensitivity to low energy particles
- Provides a compact, scalable solution for detecting particles that may interact weakly with matter, such as dark matter candidates.

STF specific heat exponential model

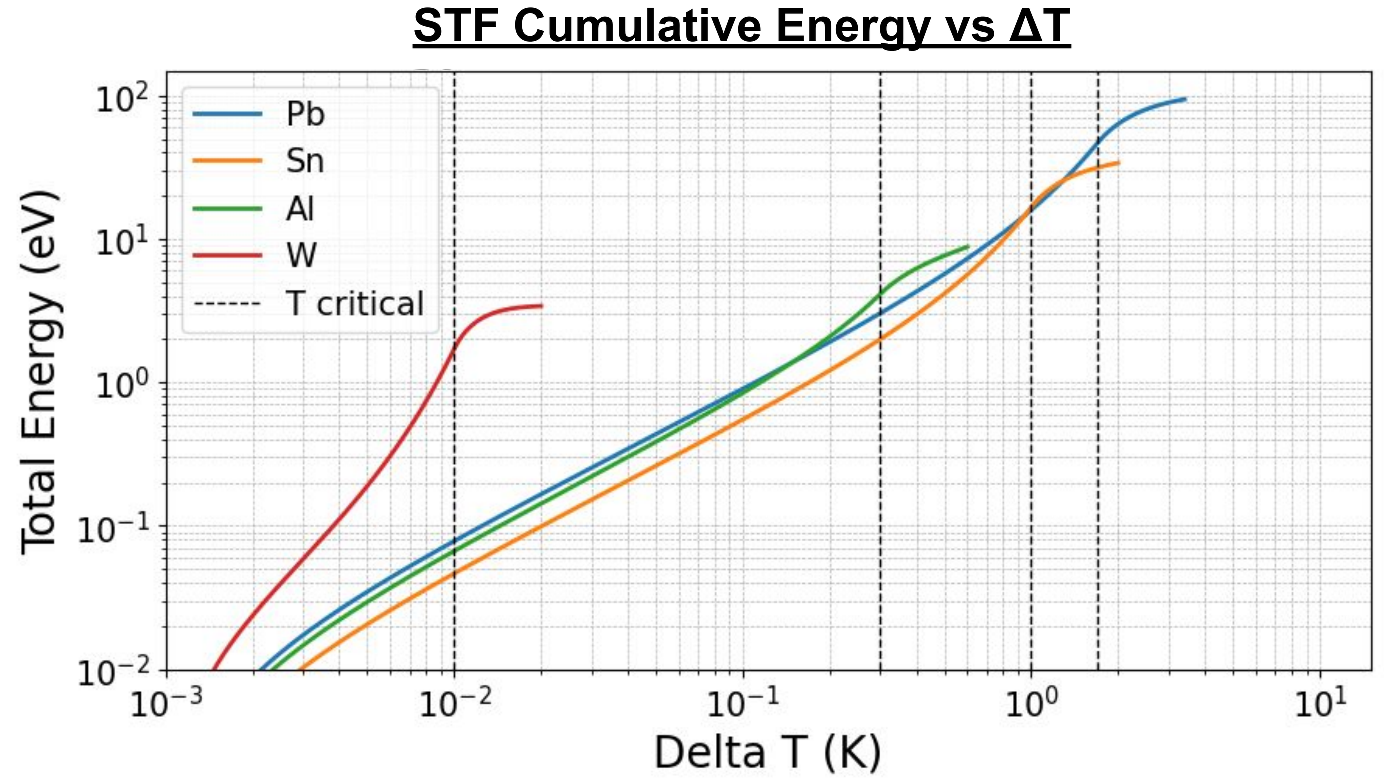


STF Temperature increase per energy deposited

-Pb, Sn, Al, W modeled as 25, 30, 50, 30 nm^3 || Q=mC(T)ΔT-



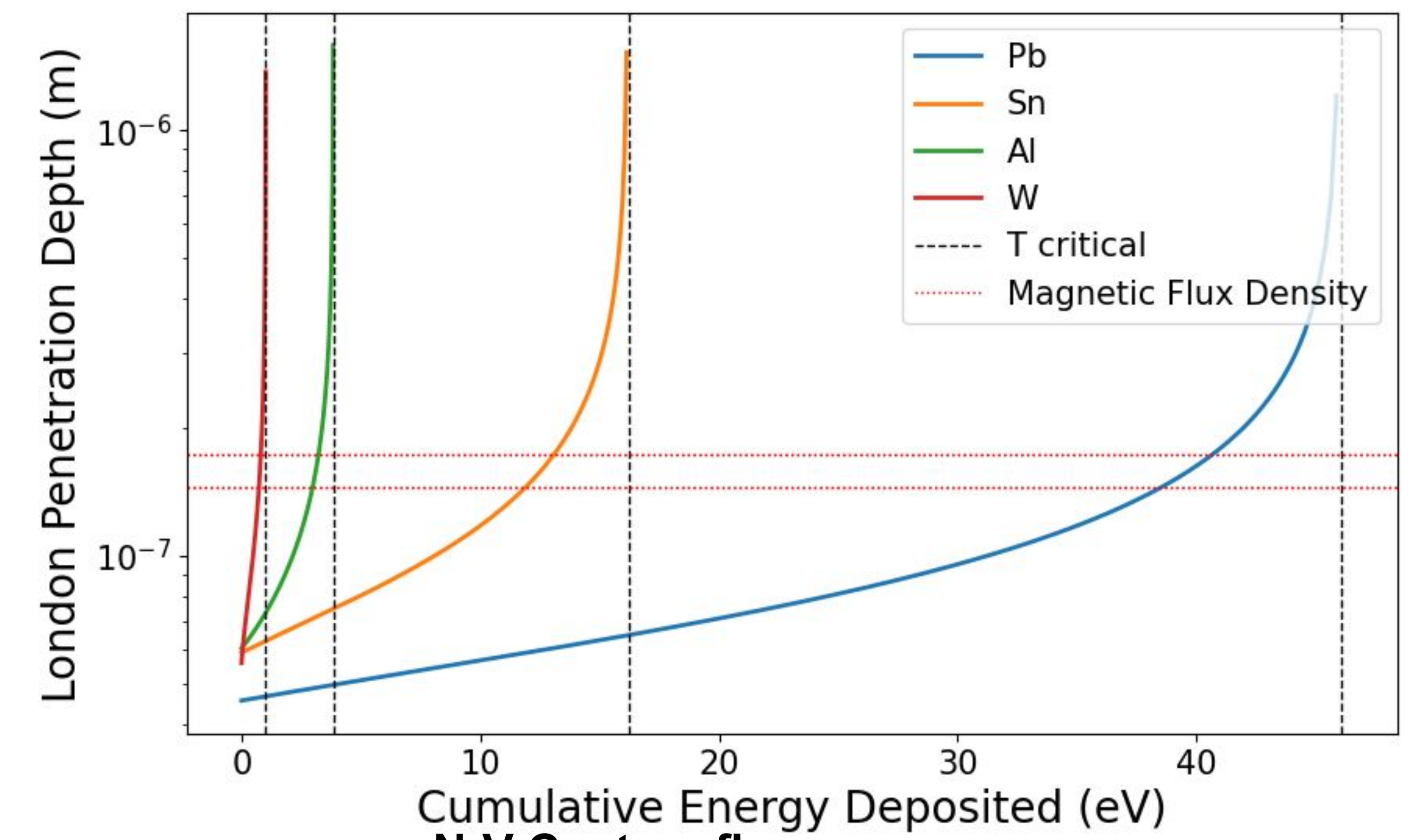
STF Cumulative Energy vs ΔT



Energy required to traverse critical temperature range			
Lead (Pb)	Tin (Sn)	Aluminum (Al)	Tungsten (W)
93.2 (eV)	33.3 (eV)	8.58 (eV)	2.09 (eV)

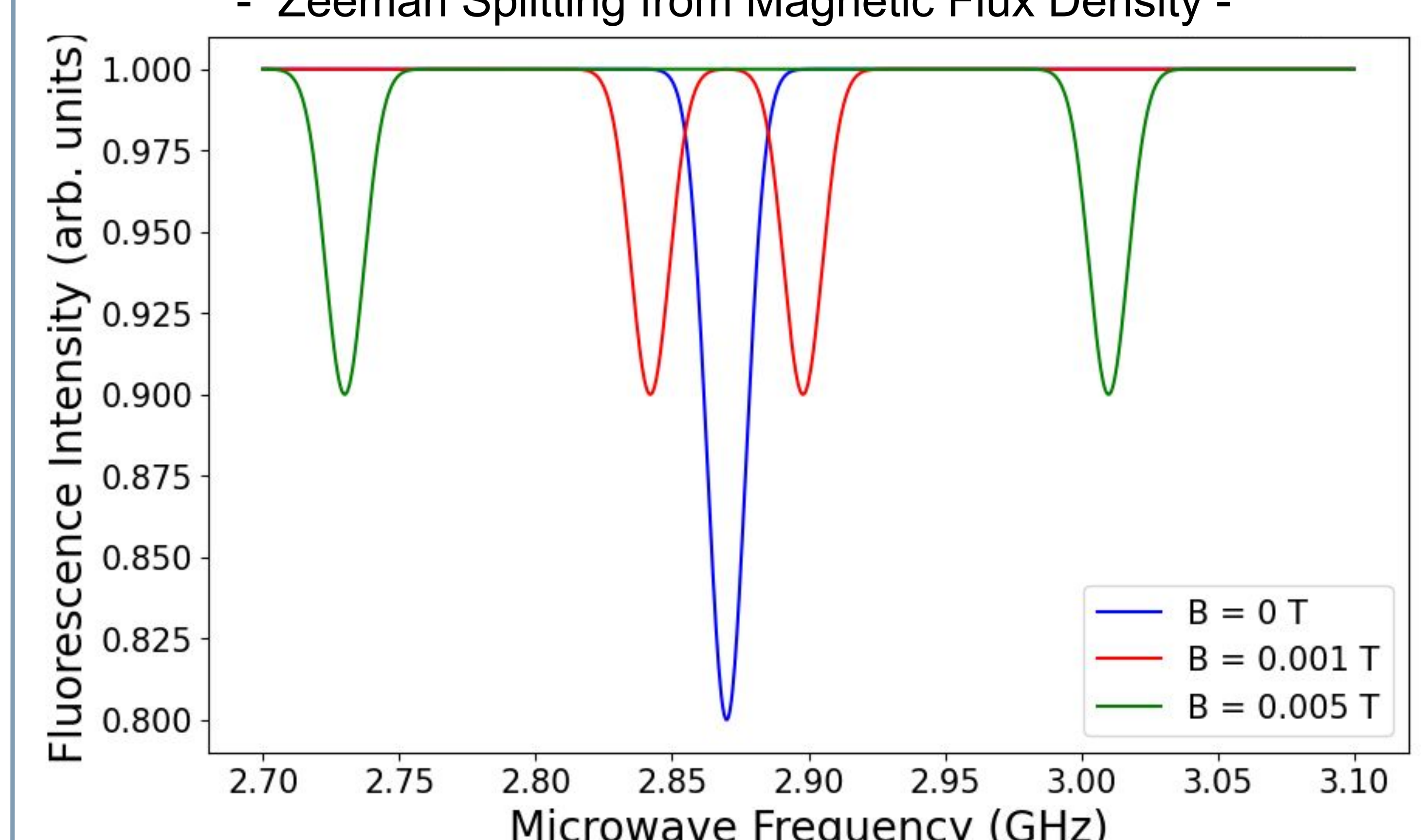
STF London Penetration Depth

-Magnetic Flux Density leading to Zeeman Splitting-



N-V Centers fluorescence

- Zeeman Splitting from Magnetic Flux Density -

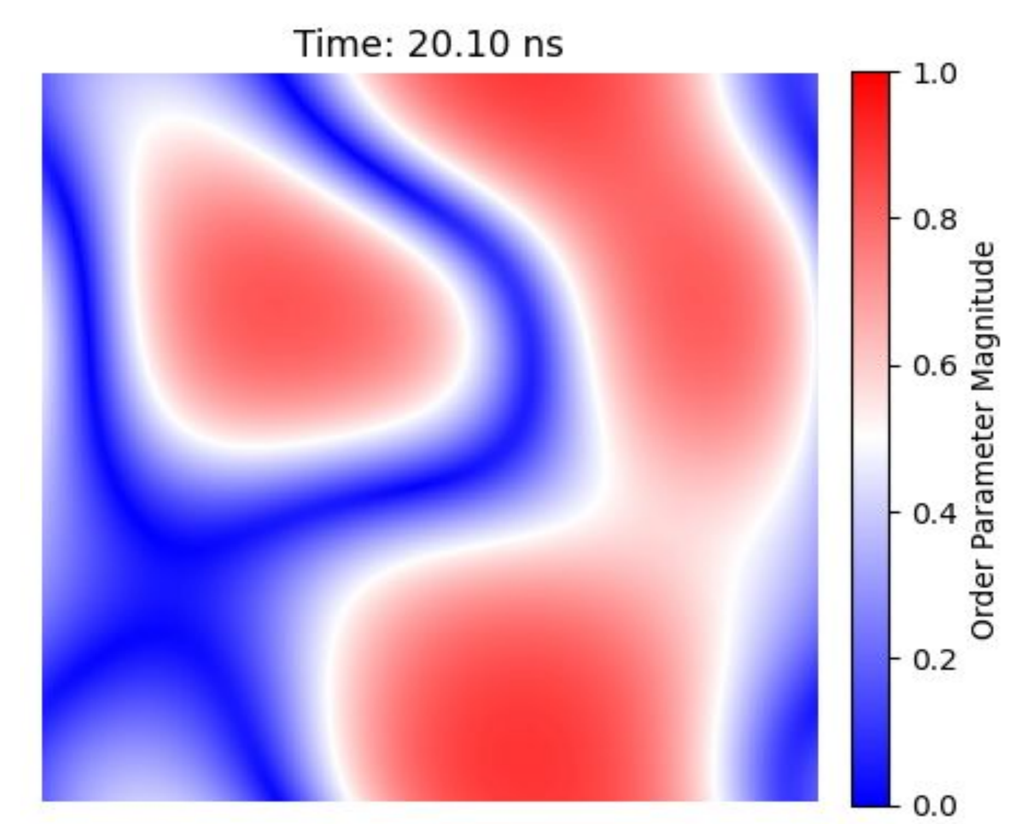


Conclusion

- NV-STF detector design shows potential for ultra-sensitive particle detection.
- Achieves sub-eV energy thresholds
- Combines NV centers' magnetic sensitivity with STF technology.
- Future experiments will optimize performance and develop compact, high-sensitivity detectors for fundamental physics.

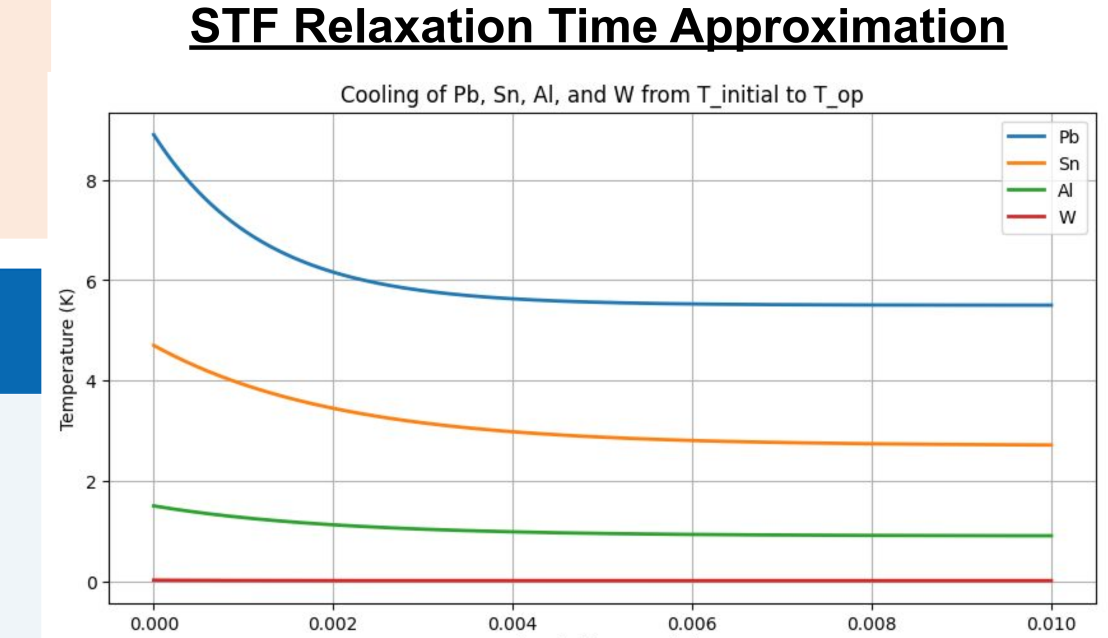
Future

1. Relaxation Simulation
   - Use COMSOL for modeling.
   - Incorporate Ginzburg-Landau (GL) theory and electron-phonon interactions to refine detector response predictions.
2. Experimental Validation
   - Develop and test prototypes to validate detection thresholds and spatial resolution.
3. On-Chip Detector Development
   - Aim for an integrated, on-chip detector with meV sensitivity.
   - Applications include fundamental physics, medical imaging, and quantum information processing, leveraging compact, high-sensitivity design for diverse fields.



Visualization of order parameter for lead mid transition calculated via Ginzburg Landau Theory

STF Relaxation Time Approximation



Sources

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