Directional Detection of Dark Matter in Diamond

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Snowmass Quantum Sensors Meeting

08/19/2020

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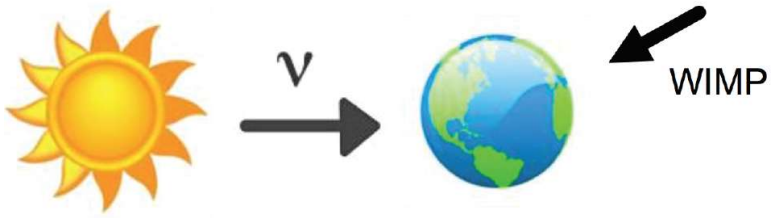
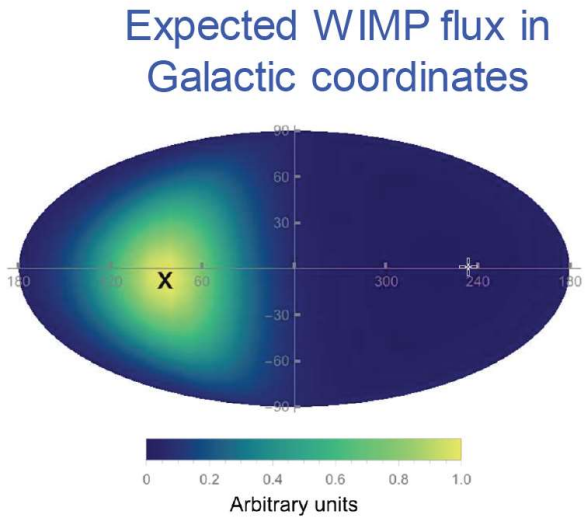
Directional detection allows direct WIMP searches below the neutrino floor



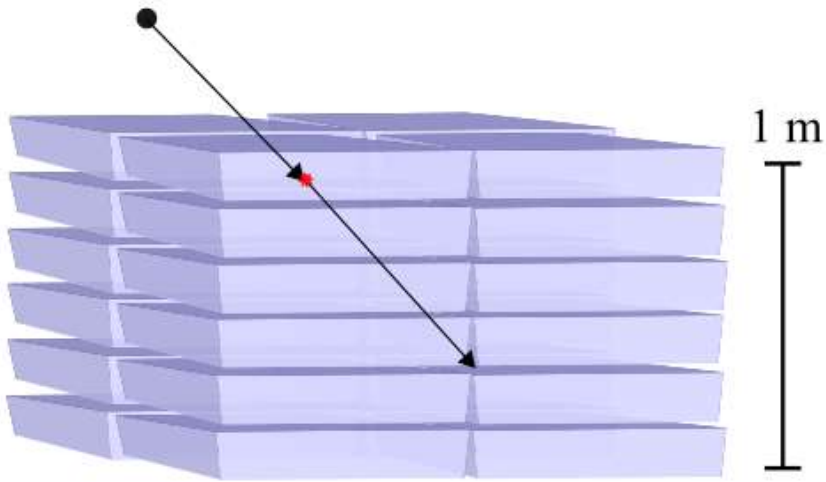


- Future WIMP searches will detect solar neutrinos
- WIMP discovery will require additional information
- Incident particle direction allows discrimination between WIMPs and neutrinos

Mayet et al, Physics Reports 627, 1-49

Direct detection in diamond

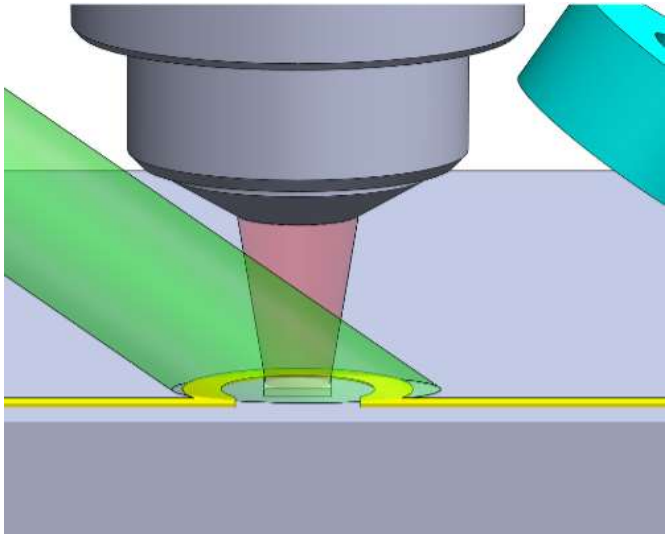
- Carbon – complementary sensitivity to existing detectors
- Dense
- High detection efficiency possible – phonons, charge, scintillation



Kurinsky et al, Phys. Rev. D **99**, 123005

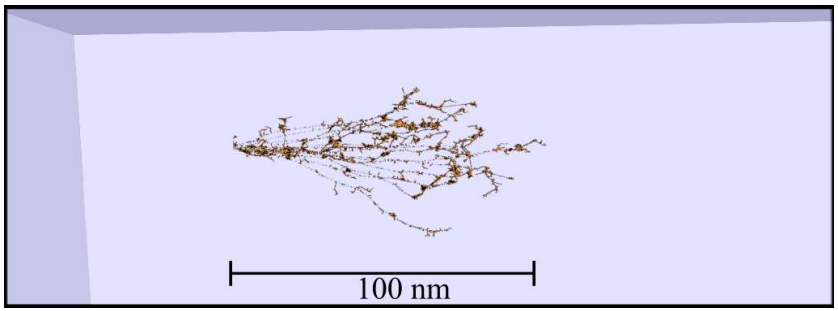
Directional detection principle

- WIMP event initiates recoil cascade
- Crystal damage track preserves particle direction



<u>Measure track direction with quantum defects:</u>

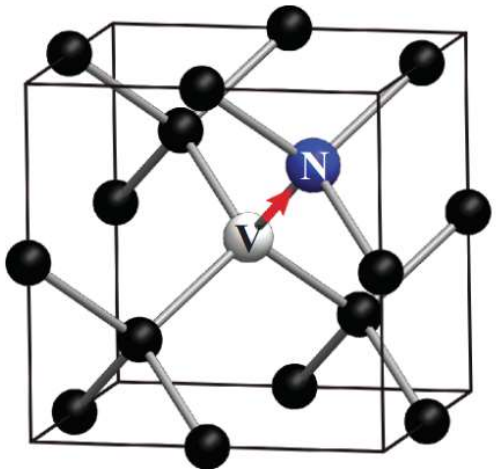
- "optical scale": NV center spectroscopy to resolve event to ~1um
- "atomic scale": 3-D mapping to determine incident direction

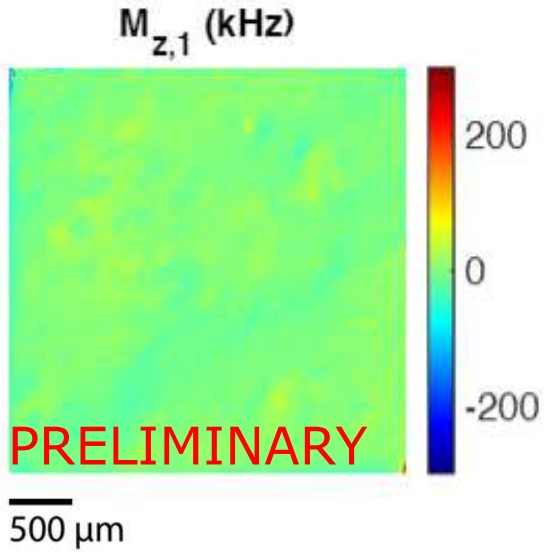


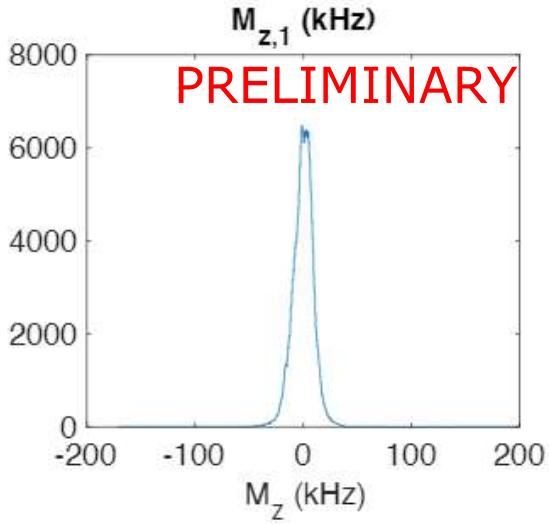
Techniques viable for other defects (SiV) or wide-bandgap crystals (SiC)

Rajendran et al, Phys. Rev. D **96**, 035009

Developing techniques for damage track detection

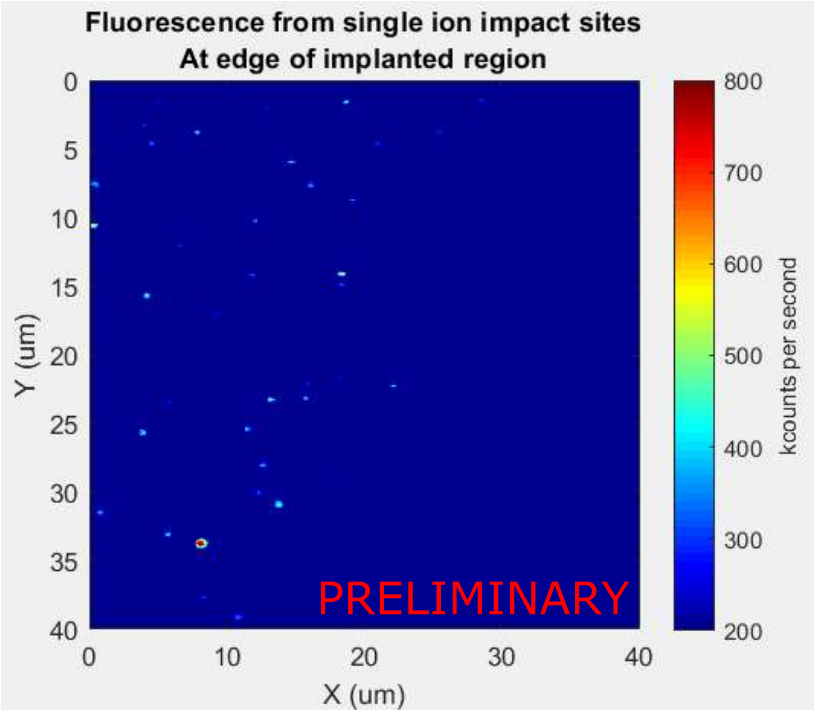






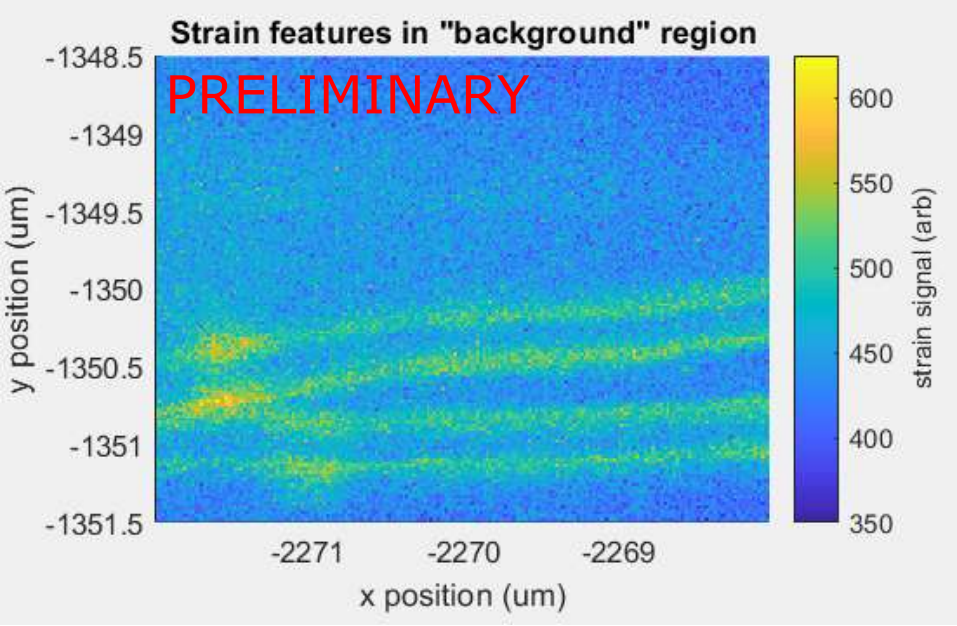
NV center strain spectroscopy – high sensitivity, uniform substrates, spatial resolution needs improvement

Developing techniques for damage track detection



Creation of NV centers from recoil-induced vacancies –
“background-free” measurement in high-N, low-NV diamond

Developing techniques for damage track detection



X-ray nanobeam diffraction – scanning probe of crystal strain with beam spot sizes below 10nm

Conclusions

- Crystal damage can allow directional detection with high-density WIMP targets
- Quantum defects like the NV center allow atomic-scale probes of crystal strain
- WIMP track detection is within or close to the capabilities of existing techniques
- Next steps: push spatial resolution, injected-signal measurements