CRAB: A novel approach to the calibration of cryogenic particle detectors

Sebastian Dorer[1] for the CRAB collaboration

[1]Technische Universität Wien, Austria

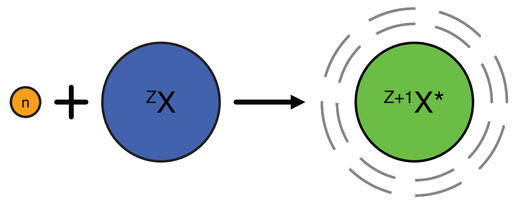
Introduction

Cryogenic particle detectors have found widespread usage in many current experiments, including the investigation of coherent elastic neutrino-nucleus scattering and the search for dark matter candidates. Despite their common deployment for investigating interactions in the sub-keV region, there is currently no method for the calibration of nuclear recoils in this energy regime.

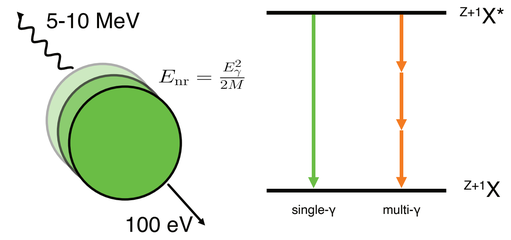
The **CRAB** experiment (**C**alibrated **R**ecoils for **A**ccurate **B**olometry) aims to provide a novel approach to the calibration of cryogenic particle detectors in the 100 eV energy regime via (n, γ) induced nuclear recoils [1].

Following a successful proof of concept at TU München in phase I of the experiment [2], phase II consists of a new and improved setup at the TRIGA Mk II research reactor at the Atominstitut of TU Wien that marks the collaboration's next step towards a high statistics, low background calibration measurement.

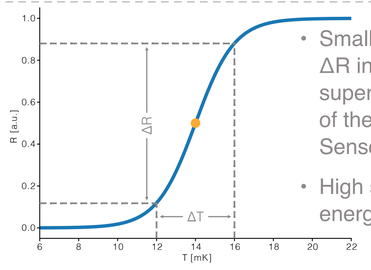
CRAB Principle



- Thermal neutron capture of target nucleus
- Resulting compound nucleus is in an excited energy state



- De-excitation to ground state via MeV gamma emission
- Nuclear recoil in the order of 100 eV



- Small ΔT results in large ΔR in the region of the superconducting transition of the Transition Edge Sensor (TES)
- High sensitivity for low energy nuclear recoils

- Nuclear recoil energy deposited in the target crystal leads to ΔT
- TES mounted on crystal changes its resistance with respect to temperature
- SQUID signal readout electronics

Calibration requirements for calibration candidates

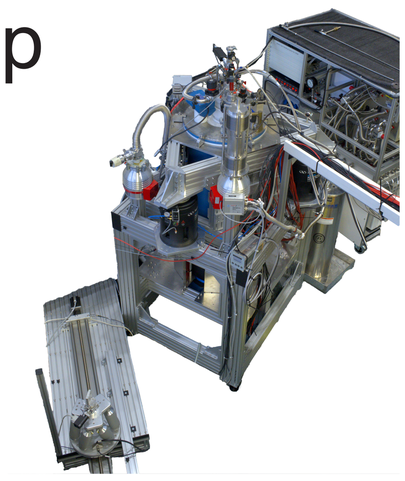
- High natural abundance
- Large thermal neutron capture cross section
- Broad single-γ branching ratio

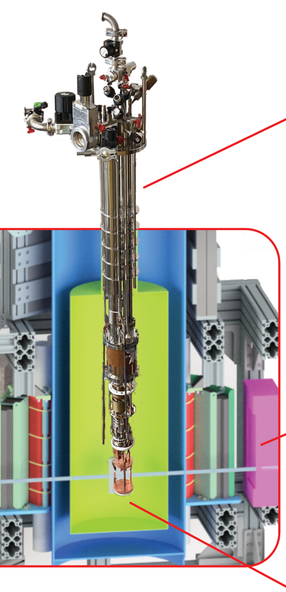
Examples for suitable bolometers:
$CaWO_4$, Al_2O_3, Si, Ge

Experimental Setup

Phase II upgrades

- Neutron source
- Neutron beam optics
- Cryogenic infrastructure
- γ detectors
- 2D neutron imaging
- Detector holder





Kelvinox wet dilution cryostat

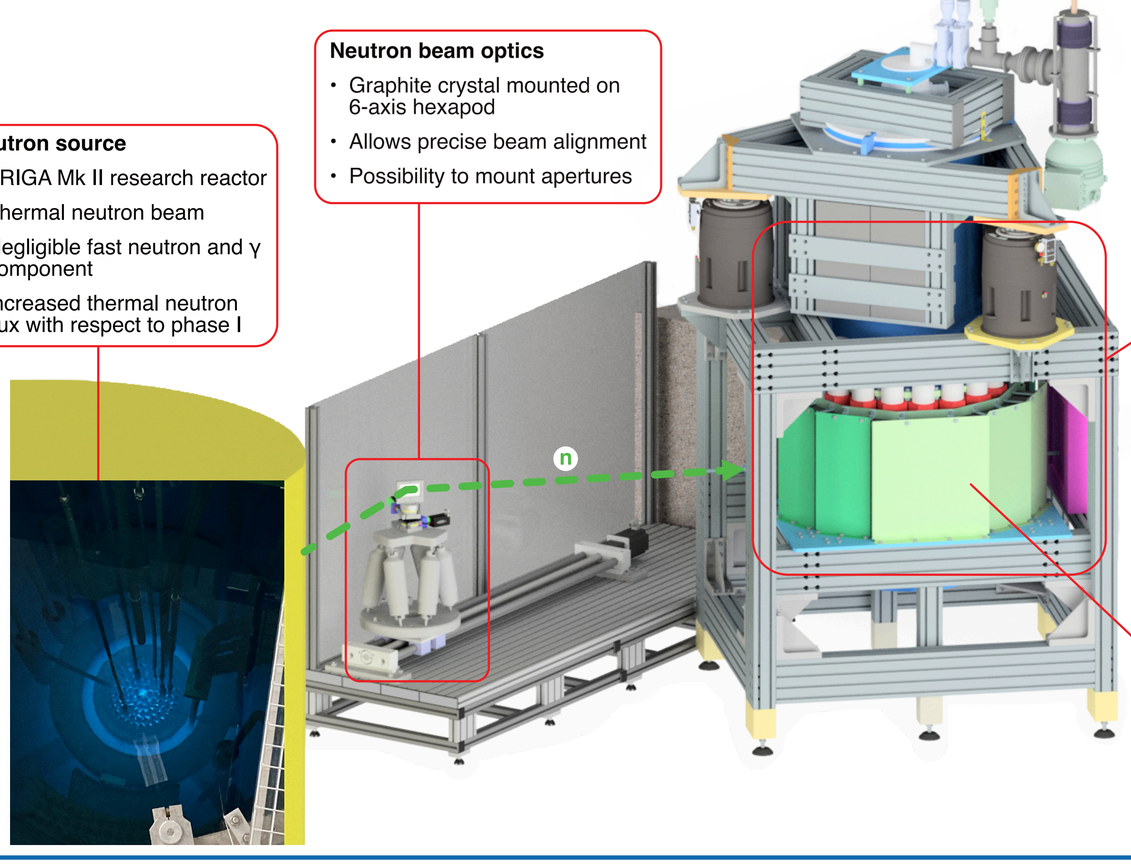
- Base temperature < 10 mK
- Custom gas handling system

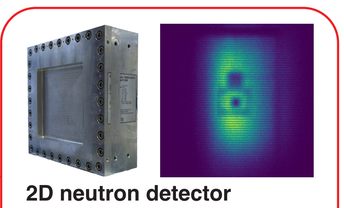
Neutron source

- TRIGA Mk II research reactor
- Thermal neutron beam
- Negligible fast neutron and γ component
- Increased thermal neutron flux with respect to phase I

Neutron beam optics

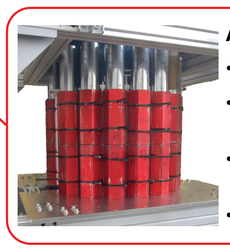
- Graphite crystal mounted on 6-axis hexapod
- Allows precise beam alignment
- Possibility to mount apertures





2D neutron detector

- Position sensitive ^{3}He neutron detector
- Beam alignment and monitoring



Array of 28 BaF_2 γ detectors

- Surrounding the cryostat
- Investigation of single- and multi-γ transitions
- Enables γ-tagging to improve the signal-to-noise ratio
- Study timing effects [3]

Double detector holder

- New lightweight detector holder design
- Aluminium PCB
- $CaWO_4$ equipped with Transition Edge Sensor
- SQUID readout

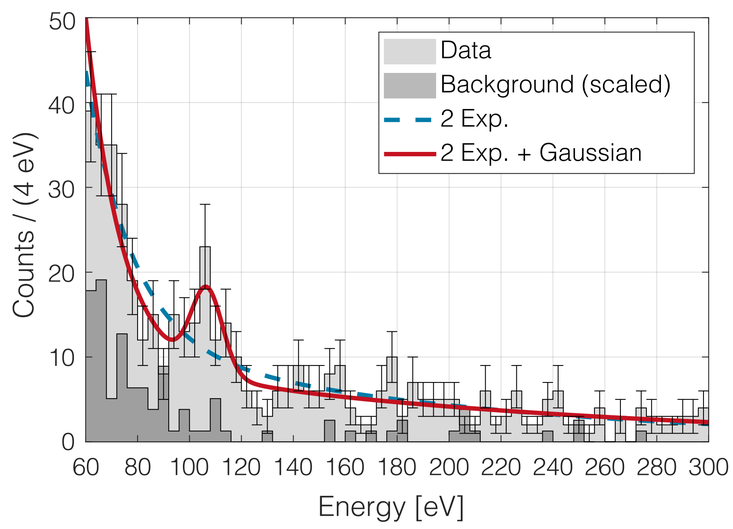
Results and Outlook

Phase I

- First observation of (n, γ) induced nuclear recoil in the 100 eV regime
- Publication of successful proof of concept using a NUCLEUS $CaWO_4$ crystal and ^{252}Cf neutron source [2]

Phase II

- Finished planning and construction of new and improved experimental setup at the Atominstitut of TU Wien
- Successful cryostat cooldown to a base temperature below 10 mK and observation of TES transitions and first signals in September 2024
- Start of first high statistics, low background measurement run at TU Wien scheduled for autumn 2024
- Implementation of updates in the following months (LED cross calibration system, γ coincidence tagging, read-out electronics)
- Extensive physics campaign including different detector materials scheduled beyond 2024



Collaborators

Acknowledgments

References

[1] L. Thulliez et al 2021 JINST 16 P07032, https://doi.org/10.1088/1748-0221/16/07/P07032

[2] H. Abele et al. (CRAB Collaboration, NUCLEUS Collaboration), Phys. Rev. Lett. 130, 211802, https://doi.org/10.1103/PhysRevLett.130.211802

[3] G. Soum-Sidikov et al. (CRAB Collaboration), Phys. Rev. D 108, 072009 https://doi.org/10.1103/PhysRevD.108.072009