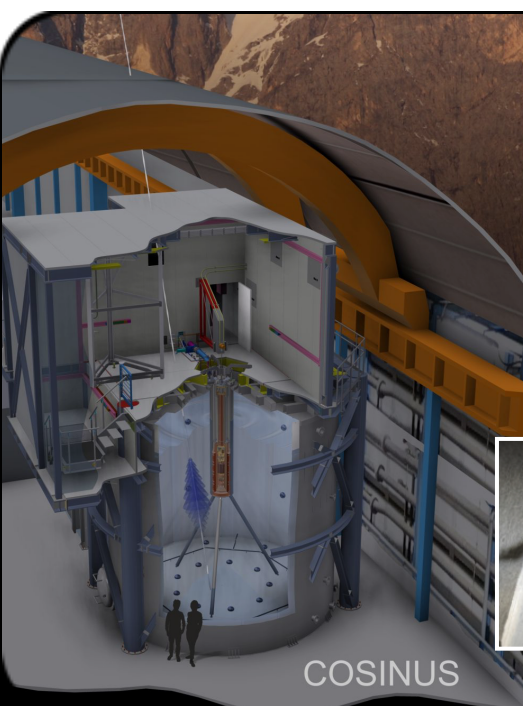
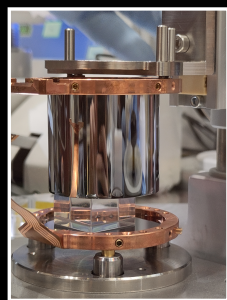
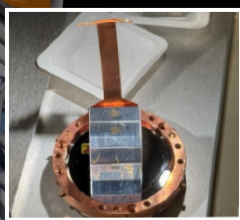




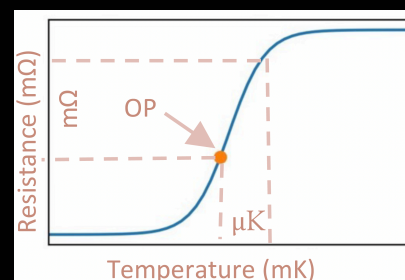
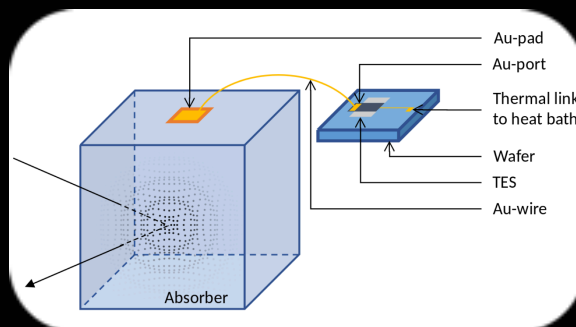
COSINUS (Cryogenic Observatory for Signatures seen in Next generation Underground Searches) features a modern low-background cryogenic facility aimed at direct dark matter (DM) search and located in hall B of Laboratori Nazionali del Gran Sasso (LNGS) in Italy.



COSINUS

The experiment operates ultrapure NaI crystals as scintillating calorimeters, enclosed with Si beakers serving as light detectors, where both channels are read out with TES sensors. The ratio of both signals ("Light Yield") can be used to separate nuclear recoils from e^-/γ events.

As instrumented detector material, NaI is challenging as it is hygroscopic, soft, and has a low melting point. In COSINUS, transition-edge-sensors (TES) are used to measure tiny temperature increases in the target crystal due to particle interactions. Fabricating a TES directly onto a NaI absorber crystal is difficult.



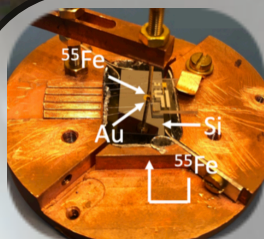
The solution for this problem is to place the sensor on a separate wafer, and then link it to the absorber using a gold wire and a pad for bonding. This design is called "remoTES". Its advantages include better reproducibility and reusability of the sensors, as well as an easier upscaling of the number of detectors.

In order to understand the properties and effects of different interface parts, prototypes with $20 \times 10 \times 5 \text{ mm}^3$ Si absorbers are produced and measured. In particular, we study the impact of

- Pad material & geometry
- Pad connection type
- Bond type between pad and link
- TES-side pad geometry

remoTES Design

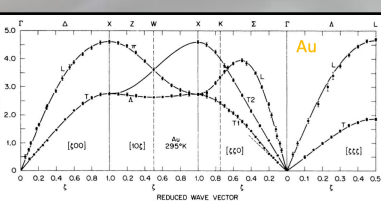
Studies with Si Absorbers - Different Pad Materials



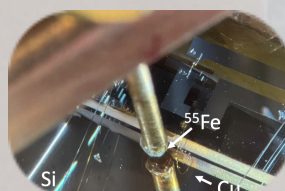
The phonon collector (PC) pad can be attached to the target crystal by glueing, sputtering or evaporation.

With Si targets and (sputtered or glued) Au pads, we achieve $\sigma \sim 100 \text{ eV}$ baseline resolution. This is more than an order of magnitude larger than for e.g. CRESST Si targets of similar mass.

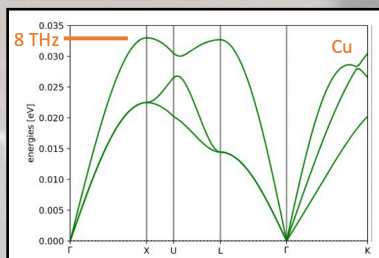
Au Pad; $\sigma = 267 \text{ eV}$



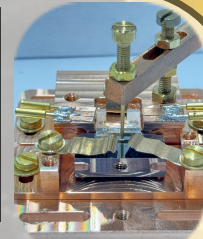
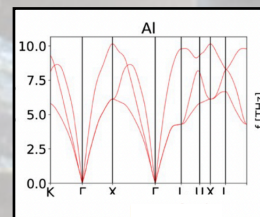
To improve performance, one strategy is to optimize for low thermal boundary resistance at the absorber/phonon collector interface. Acoustic matching of absorber and collector could improve the performance*: Cu features higher bands than Au, and should accommodate higher frequency phonons. Au has a high electron-phonon coupling, and should perform well with NaI.



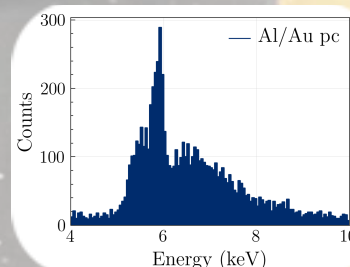
Cu pad; $\sigma = 95 \text{ eV}$



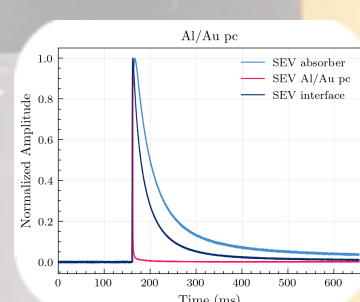
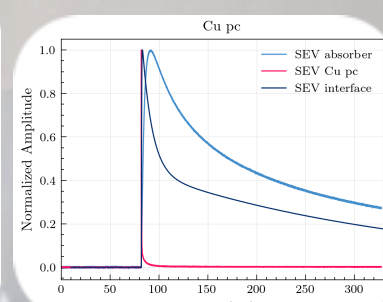
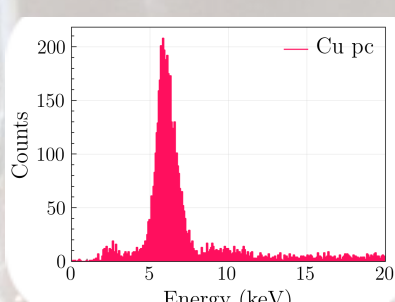
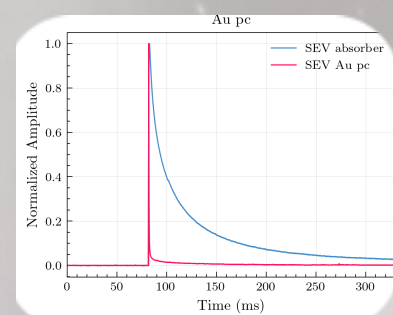
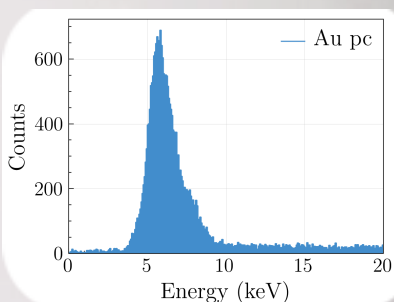
Detector prototypes are typically calibrated using the spectrum of a ^{55}Fe source. With improved detector resolution, more peaks from the source can be resolved.



Al/Au pad; $\sigma = 22 \text{ eV}$



Particle interactions in different parts of the detector (e.g. interface or target) are distinguishable by their pulse shape. We use averaged pulses (standard events, SEV) to describe the different event classes.

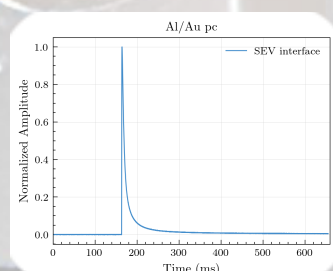
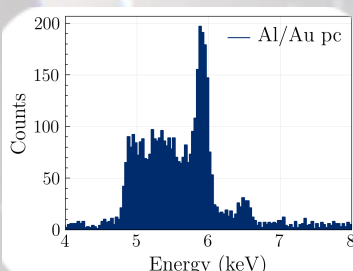


*Raya-Moreno, Martí, et al. "Phonon dynamics for light dark matter detection." *Physical Review D* 110.11 (2024): 112007.

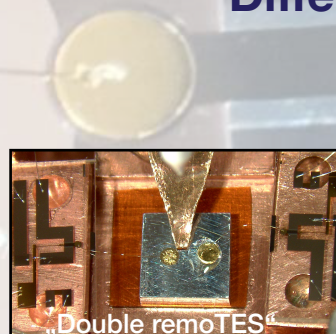
Recent Prototype Results & Performance



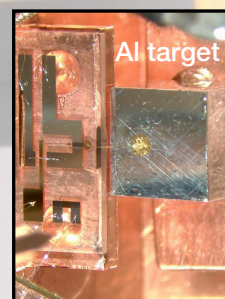
The latest Si remoTES prototype achieves a baseline resolution of 7 eV for absorber events. It features a Al/Au bilayer pad.



Different Materials & Multiple Sensors



The remoTES design allows the instrumentation of a wide range of materials. For example, operated targets include GaAs, Al, TeO₂, and Al₂SiO₄(F,OH)₂(Topaz). The first combination of two remoTES attached to the same absorber („double-remoTES“) is currently being tested.



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Successful application to NaI! Design for COSINUS Run1 prototype -> **Poster by K. Heim**
Description of pulse shapes & signal propagation -> **Poster by S. Braun**

Further Reading

Zema, Vanessa, et al. „Description and Performance of the COSINUS remoTES Design." *Journal of Low Temperature Physics* 217.3 (2024): 393-400.

Angloher, G., et al. "Particle discrimination in a NaI crystal using the COSINUS remote TES design." *Physical Review D* 109.8 (2024): 082003.

Angloher, G., et al. "First measurements of remoTES cryogenic calorimeters: Easy-to-fabricate particle detectors for a wide choice of target materials." *Nucl. Inst. Meth. Phys. Res. Sec. A* 1045 (2023): 167532.

Einfalt, Leonie, et al. "remoTES: A new design for the cryogenic NaI detectors of the COSINUS experiment." *SciPost Physics Proceedings* 12 (2023): 033.