



COSINUS: Direct dark matter detection using NaI as a cryogenic calorimeter

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Possible dark matter detection channels





Direct dark matter detection techniques





Direct dark matter detection techniques





Direct dark matter detection techniques





Direct detection dark matter techniques





Direct detection dark matter experiments





How to compare results?





How to compare results?





Status of direct dark matter search





• No DM signal observed by most of the experiment!

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Status of direct dark matter search





- No DM signal observed by most of the experiment!
- DAMA/LIBRA experiment claims to observe DM
- The DAMA/LIBRA signal has not entirely been cross-checked and excluded by experiments using the same target material

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Annual modulation of dark matter





Annual modulation of dark matter





The DAMA/LIBRA signal





- Period and phase match with DM expectation
- No convincing non-DM explanation

Decade long tension!!





Decade long tension!!







• DM event rate is material-dependent

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Decade long tension!!







- DM event rate is material-dependent
- APPEC Recommendation: "The long-standing claim from DAMA/LIBRA [...] needs to be independently verified using the same target material."
- Cryogenic Observatory for SIgnatures seen in Next-generation Underground Searches (COSINUS) aims to validate DAMA/LIBRA with a model-independent test: <u>Felix Kahlhoefer, FR,</u> <u>et al</u> <u>JCAP05(2018)074</u>

NaI based direct detection DM experiments





NaI based direct detection DM experiments









Rituparna Maji

Cryogenic detector







Cryogenic detector: TES

Heat Bath @10 mK

Phonon signal Resistance (mΩ) TES X ΔR ΔE $\Delta T \propto$ mm \sim 10 ΔΤ Temperature (mK) -50 50 100 150 200 250 Time (ms) Absorber

• Transition edge sensor (TES) can detect very small rise in temperature due to small energy deposition



But NaI is not so NaIce





- Direct deposition of TES on Nal is non-trivial
- First idea of **remoTES**: <u>M. Pyle et</u> <u>al. in 2015 arXiv:1503.01200</u>
- First successful operation of the working design of remoTES by COSINUS: <u>https://arxiv.org/abs/2111.00349</u>

Phonon detector: NaI + remoTES





- Phonon signal is readout by Nal + TES, independent of particle type
- precise measurement of the deposited energy





Phonon detector

Light detector: Si + TES



- Phonon signal is readout by Nal + TES, independent of particle type
- precise measurement of the deposited energy
- Scintillation light signal is readout by Si + TES, depends on particle type
- Dual channel read-out enables event discrimination



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Phonon detector



light detector



Light

 ΔE

250 Time (ms)

COSINUS

The COSINUS detector





- Phonon signal is readout by NaI + TES, independent of particle type
- precise measurement of the deposited energy
- Scintillation light signal is readout by Si + TES, depends on particle type
- Dual channel read-out enables event discrimination



Phonon detector



light detector



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Signal to background discrimination





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Signal to background discrimination





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Signal to background discrimination





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Physics reach of COSINUS 1π





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Event discrimination with NaI remoTES





- Underground run in June 2022 @ LNGS, Italy
- Calibration done with 57Co and 55Fe sources

Event discrimination with NaI remoTES





- Underground run in June 2022 @ LNGS, Italy
- Calibration done with 57Co and 55Fe sources
- Best achieved threshold with remoTES in underground run: < 2 keV





LNGS: Laboratori Nazionali del Gran Sasso

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COSINUS 1π time schedule





The **COSINUS** collaboration

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HELSINKI INSTITUTE OF PHYSICS







Thank You!

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Quenching factor mystery

COSINUS

- QF = The ratio of the scintillation light produced by nuclear recoil and electron recoil
- NR energy scale depends on QF
- Measurement of QF of Nal do not agree, especially in the low energy region
- QF measurement at room temperature required
- COSINUS would provide the first cryogenic measurement of quenching factor

Reported Quenching factor values for Na recoils



Quenching factor measurement



ollar 2013 (

Simon 2003

- **Room temperature** measurement
- Aim: study the effect of **TI** • dopant on QF
- Aim: Investigation in the low energy region
- **5** radio-pure **Nal(TI)** crystals • produced by SICCAS
- Energy calibration with **Am**, • **Ba**, **Cs** source and with **neutrons** (~1.5 MeV)
- Preliminary QF analysis • (Manuscript in preparation)



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25 E nr (keV)