R&D of dark matter cryogenic detectors: study of impacts of an aluminium layer as a shield against magnetic fields

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The CRESST Experiment

- Cryogenic Rare Event Search with Superconducting Thermometers
- Scope: direct detection of dark matter particles through their scattering off nuclei in cryogenic calorimeters
- Situated at the Laboratori Nazionali del Gran Sasso, beneath 1400 meters of rock ~3600 m.w.e.
- The main part of the experimental • setup is composed by the shielding



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Gas-Tight Box

Thermal Shields

Polyethylen

Muon Veto External Lead Internal Lead

CRESST sensors



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Effects of the B-fields on the TESs

- working point
- phenomenon



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Effect of the B-fields at the LNGS

- B-fields measured through magnetometers external to the detector carousel
- Maximum B-field variation @LNGS = $0.5 \,\mu$ T
- System of coils is used to compensate for these effects
- Different detector orientation makes impossible to perform a compensation simultaneously for all of them

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New samples design

- The idea: exploiting the Meissner Effect of superconductors \bullet
- Insulation layer made of KMSF photoresist
- Sputtered Aluminium shield

6

The two configurations

 Two sputtered TESs on two different sapphire other with also the Al shield

 Two evaporated TESs on the same crystal: o and Al shield

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Two sputtered TESs on two different sapphire substrates: one with the dielectric layer only, the

Two evaporated TESs on the same crystal: one without additional layers, the other with photoresist

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Second configuration: Transition with increasing B-field CRESST

• This sample has neither the photoresist nor the Alu-Shield

Sweep Control TES B-Field [µT] 25 20 15 -10 5 1.2 -6 Heater Voltage [V]

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Spectra of the two detectors

- Due to its instability, the data cleaning greatly reduced the data set for the shielded sensor

BL Resolution Shield = $(28 \pm 2)eV$

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Goal: resolve the ⁵⁵Fe peaks to perform the calibration (two X-rays peaks at 5.89 keV and 6.49 keV)

Spectrum Control TES

Comparison between the performance of the two TESs: Test Pulses

• Variation of the magnetic field from 0 μ T to 27.3 μ T

Control TES 0 Field

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Comparison between the performance of the two TESs: Test Pulses

• Variation of the magnetic field from 0 μ T to 27.3 μ T

Shielded TES 0 Field

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Transition with fast variable field

- Field was swept from 0 to $27.3 \,\mu\text{T}$
- Both TESs show a dependence on this \bullet variation
- 1.5 Shielded TES has a weaker dependence \bullet on field variations
- Control TES has a broader transition \bullet

0.5

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Voltage [V]

Transitions with variable B-Field

Hypothesis

- Some parts of the sensor are not covered by the aluminium shield \bullet
- The same thing is also valid for the detector in the first \bullet configuration
- The same test was therefore performed also for the other detector: a very similar result was obtained

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Possible solution

Use of the phonon collectors with the dual function of shield and phonon collectors ullet

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Summary and outlook

- film to the standard detectors
- The response of the shielded sensor in the presence of external variable magnetic fields is much more stable than the non-shielded one
- In the second configuration it was not possible to make a definitive comparison between the two due to the instability of the shielded sensor

- New sensors need to be produced in order to accumulate statistics and understand if the shield actually reduces their stability
- Attempt to build the TES on top of the insulation layer to use the aluminium with the dual function of shield and phonon collector

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Attempt to build a magnetic shield, adding an insulation layer and an aluminium

THANKS FOR YOUR ATTENTION

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CRESST detectors

BACK UP SLIDES

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CRESST detectors

- Incident particles deposit energy in the crystal in the form of: \bullet
 - Lattice excitation
 - Scintillation light

Two detectors

- Phonon detector
 - CaWO₄ scintillating crystal
 - Detects the phonon signal (~90%)
- Light detector
 - Silicon on Sapphire substrate
 - Detects the light signal (few %)

Particle discrimination

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CRESST **Calibration of the two sensors: data cleaning**

- For the calibration of the sensors, a ⁵⁵Fe source is \bullet used (two X-rays peaks at 5.89 keV and 6.49 keV)
- To have a reliable energy estimation of the pulses, the dataset must be cleaned removing events with distortions
- The pulse amplitude is therefore estimated using \bullet appropriate analysis techniques (truncated fit)

Truncated fit

Transition

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Side Effects: shift in the transition temperature

- Sapphire A: sample with both layers
- Sapphire H: sample with insulation layer only

Transition Sapphires

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Transition Sapphire (after shield)

Silicon samples

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Transition Si Shield Voltage [V] 2.5 1.5 0.5 0 35 T [mK] 5 10 15 20 25 30

Comparison between the performance of the two TESs: Baseline

Baseline Control TES

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Baseline Control TES

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Comparison between the performance of the two TESs: Baseline

Baseline Shielded TES

المحالية والمحالية والمراجع المحالية والمحالية وا الألية سيديك والمطالبي أبدريد فالمحاد وإنتاب فالملين الكار مالمني بينيه فأسرار والتصفيح سعاديا وتبري والرابع -2 - المربعة المربعة المربعة المحالة المحالية المربعة المحالية ا والمستقد وأحجاز أسرطتها فالمقارب والمقارب والمتحاج والمتحاج والمتحاج والمتحاج والمحاج و المراجع المرجع والألوار المرقول والمنافع والمناجع والمراجع والمنافأة أحل والمعاد والمرجع ما المروانية والمرجب والمراطقة والمواجرة والملائن المراجعة ومساحر وأفريتهم ومالا والمرورية الترورية والمرزية ويرأنه ا المتحالين مصهد مرجدا والأطار مخرجا سألده سترجعه فالتجمير الأعلجية أسطر ومحمد فطلا وجحدائه والاستان والمزر والمزريان ياد المراب أن المربعة المربية الم ب والا و بالمربع المحافظ الأربع في فرا من ألب والمباد المعدية ، وو وأن أو تصليح بين بالمراجع المربع المربع أولا والم المربع المربع المربع والمنتخص والمحاج والمحاج والمحاج والعترو المحتج والمتألة المحاج والمتقل والمحاج المحاج والمحاج والمحاج والمحاج الوجام والمراجع والعادية والمراجع والمراجع فالمربط والمعادية أوجر والمعادية والمراجع و الجذام الإين المراجع والأردية والاستخدارة والمراجع والمتحاف المالية في ومن أوفل المكاورة ويدويا المردية والمحار والمراجع المارية المحمدة بالمرجوع والبي تربيق من المحمدة بالمرجوع والمرجبة والمارية من مع مانية المرأتين بن المنظر بين والمرجوع والم -10 3 9 5 6 8 Time [h]

Baseline[V]

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Deposition Techniques

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