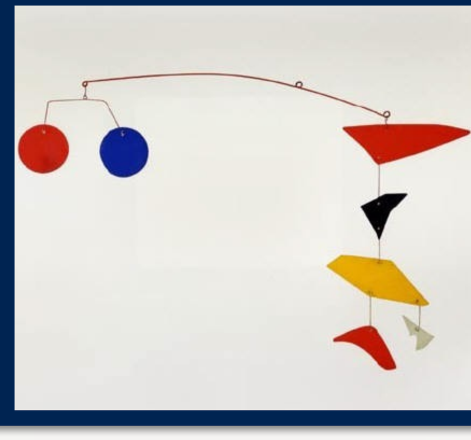


CALDER

Cryogenic Light Detectors for background free searches

PHYSICS MOTIVATION

Bolometers are primed to search for rare events, like Dark Matter (DM) interactions or neutrino-less double beta decay (0vDBD):

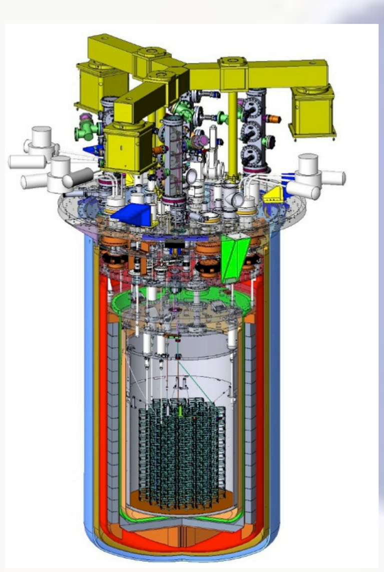
- superb energy resolution (0.1%) and efficiency;
- large variety of targets;
- low intrinsic background;

Moreover, IF EQUIPPED WITH **SENSITIVE LIGHT DETECTORS**, they can REJECT THE BACKGROUND due to α's (for 0vDBD) or to electrons (for DM interactions) exploiting the different light yield of different particles.

CUORE

[O.Cremonesi's talk and posters of L.Canonica, J.Cushman, K.Han and K.Lim]

1 ton of TeO_2 bolometers operated at ~10 mK to search the 0vDBD of ^{130}Te [1]



Detector features:

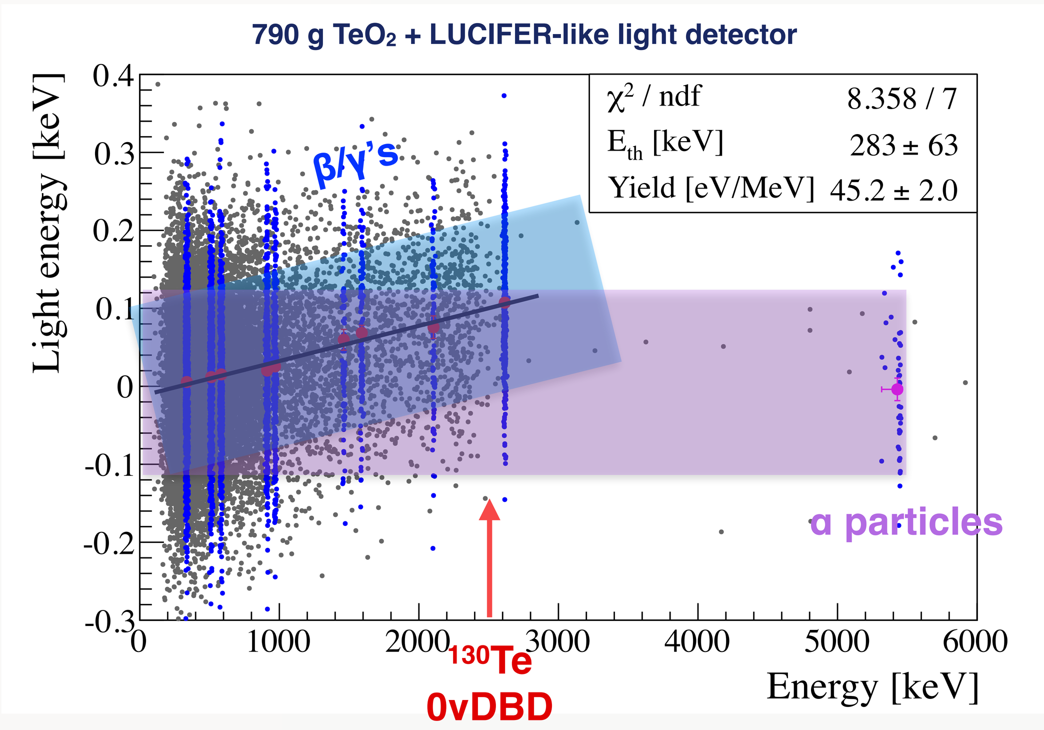
- 988 5x5x5 cm^3 TeO_2 arranged in 19 towers
- 206 kg of natural ^{130}Te
- Expected energy resolution of about 5 keV FWHM at 0vDBD energy
- Background target: 10^{-2} counts/keV/kg/y

Main source of background:
α contaminations of the detector materials

BUT
the experience gained in view of CUORE showed that we are reaching the ultimate level in the development of cleaning procedures for the detector materials

Why CALDER light detectors?

TeO_2 does not scintillate but electrons, in contrast to α's produce Cherenkov radiation [3]
(N.Casali's poster)



Light detectors with noise <20 eV would allow to reject α interactions and reach a background of 10^{-3} counts/keV/kg/y

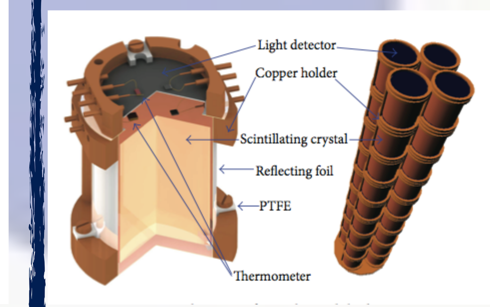
LUCIFER

[See K.Schaeffner's poster]

ZnSe scintillating bolometers to search the 0vDBD of ^{82}Se (but advanced R&D also on the search of ^{100}Mo using $ZnMoO_4$) [2]

GOALS:

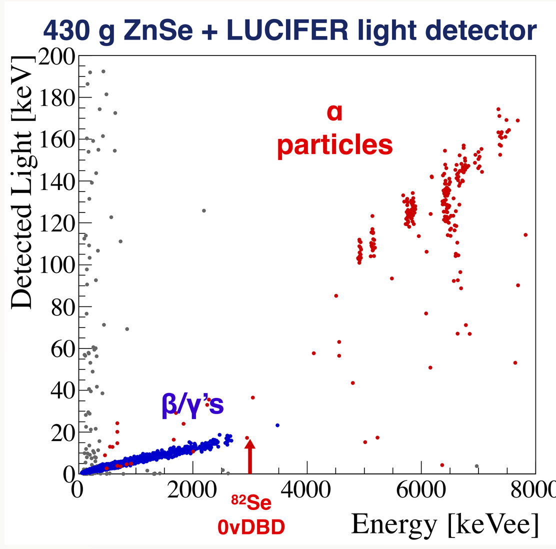
- Achieve ~zero background in the 0vDBD region (2997 keV)
- Reach 90% CL sensitivity on 0vDBD of the order of 10^{25} years



Detector features:

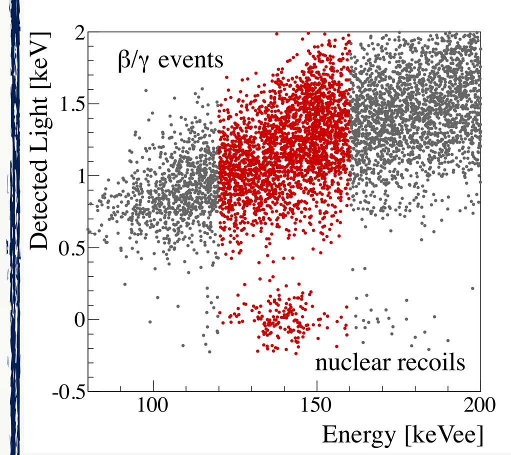
- 36 ZnSe crystals -coupled to light detectors- for a total mass of ~17 kg;
- almost 9 kg of 95% enriched ^{82}Se;
- expected resolution of 10 keV at 0vDBD energy FWHM

- LUCIFER light detectors are pure Ge slabs (∅ = 44 mm, h = 180 μm)
- They are equipped with NTD Ge thermistors and operated as bolometers
- Noise ~ 70 eV
- Excellent rejection of the α background



Why CALDER light detectors?

LUCIFER could become a multi-purpose detector:
0vDBD + Dark Matter searches

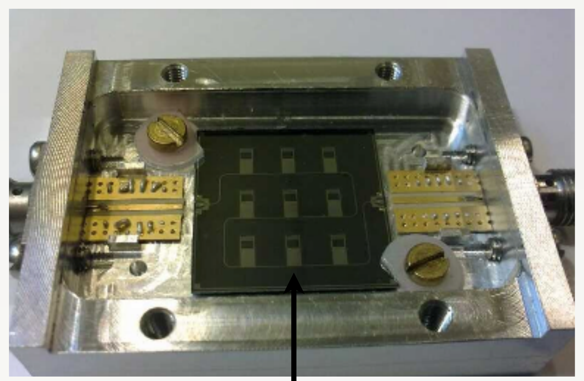


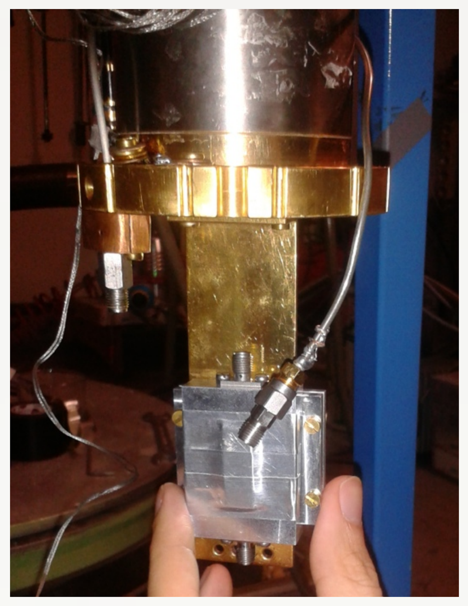
- Preliminary studies show that ZnSe has an energy threshold of ~ 2.4 keV
- The low threshold guarantees sensitivity in the WIMPs interaction region (<30 keV)

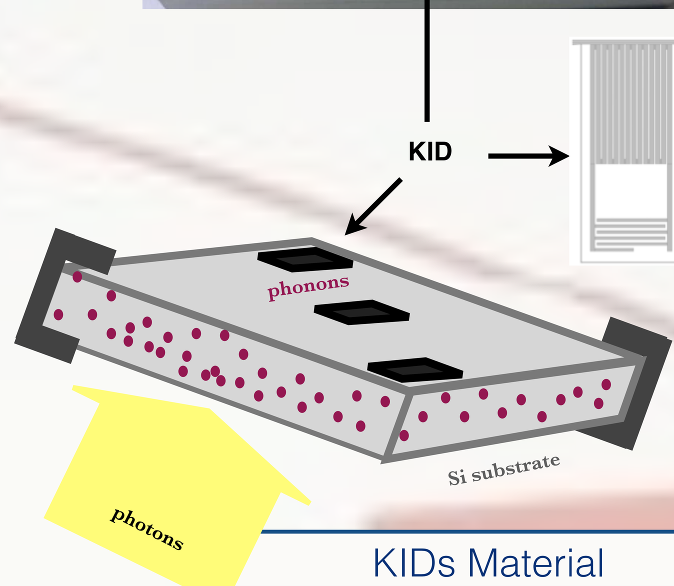
Light detectors with noise <20 eV would allow to reject the interactions due to electrons in the WIMPs region

PHONON MEDIATED KIDs

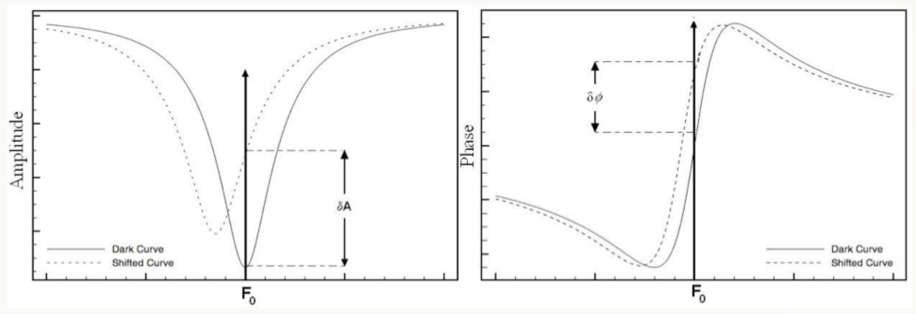
- Kinetic Inductance Detectors (KIDs) are single layers superconductors biased with AC current;
- KIDs can be sketched as LC circuits with proper resonant frequency;
- The interaction of a photon breaks the Cooper pairs, modifying the resonance amplitude and phase [4,5];







S.DOYLE'S THESIS



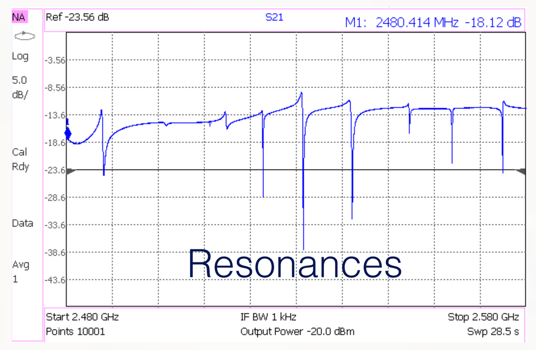
- Excellent sensitivity, wide operation range, multiplexing;
- The small active surface (1mm^2 x 40-200 nm) can be compensated by depositing the KIDs on a resistive substrate (5cm^2 x 100-300 μm) that convert photons into phonons, as done by Moore et al [6].

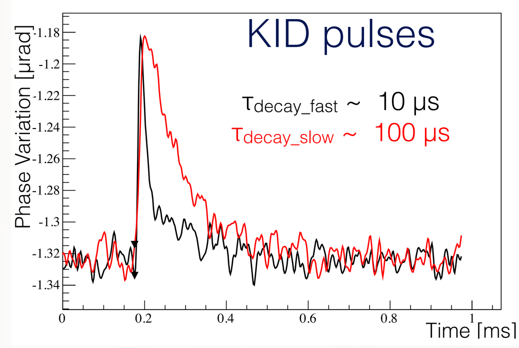
KIDs Material	Al
KIDs thickness	40 nm
Q	$(0.4-3)\times 10^5$
Resonant frequency	~2.5 GHz
Single pixel area	$2.9\ mm^2$
Substrate	300 μm Si wafer

CURRENT STATUS

CALDER (**C**ryogenic wide-**A**rea **L**ight **D**etectors with **E**xcellent **R**esolution) [7], began in **March 2013**

- Instrumentation of a ^{3}He/^{4}He cryostat in Sapienza University (Rome), lowering its base temperature from 60 to 15 mK and installation of an optical fiber for energy calibration;
- start prototypes fabrication at IFN-CNR (Rome) with 9 Al KIDs deposited on a 2x2 cm^2 Si substrate.
- acquisition of the first pulses and development of acquisition/analysis tools





GOALS:

- optimization of detector design and fabrication process in order to achieve energy resolution <80 eV;
- improve of electronics and data-acquisition (more sensitive trigger algorithm…);
- improve energy calibration system;
- study the position reconstruction capability.

NEXT STEP

Other materials, that will allow to reach better energy resolution ΔE, will be tested as soon as we will have a good control/understanding of the performances of Al KIDs.

	Al	TiN [non stoic.]	Ti+TiN [stoich]	Hf
Tc [K]	1.2	0.9	>0.4	0.12
L [pH/square]	0.05	3	30	3

$$\Delta E \propto \frac{T_C}{\epsilon\sqrt{QL}}$$

- Materials with lower Tc (better ΔE) can be investigated by working at 10 mK;
- Large Q and L can compensate the worsening of ΔE due to the loss of phonons in the PTFE holders of the Si substrate.

LIGHT DETECTORS REQUIREMENTS

Baseline noise	10-20 eV
Active area	$5\times 5\ cm^2$
Temperature range for detector operation	8-20 mK
Number of channels	order of 1000

+ excellent radio-purity and low heat load

None of existing light detectors fulfills all the requirements

PERSPECTIVES

- The LNGS R&D cryostat will be equipped for KIDs measurements;
- the CALDER light detectors will be coupled to CUORE and LUCIFER bolometers;
- the versatility of these light detectors will allow to use them in any other cryogenic experiment aiming at background suppression.

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