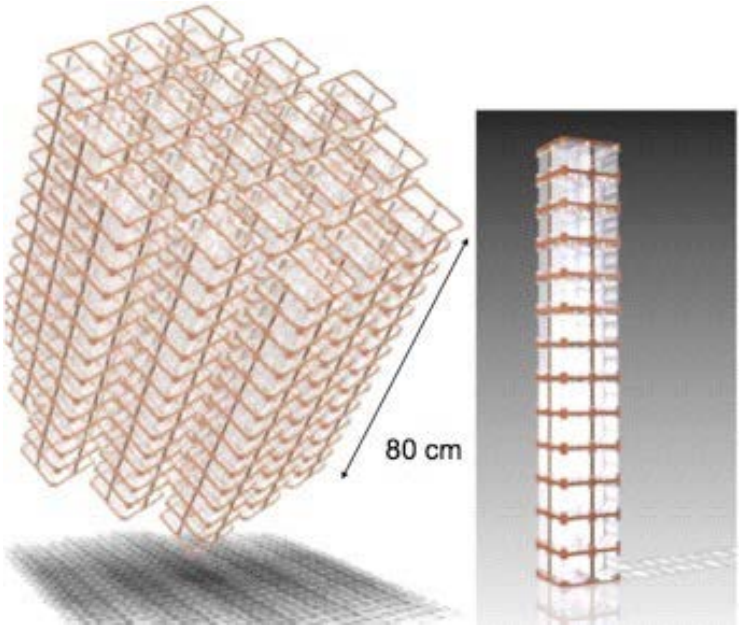
Phonon-mediated KIDs as light detectors for rare event search: the CALDER project

Angelo Cruciani
on behalf of the CALDER collaboration

Low Temperature Detectors 16 Grenoble 20-24 July 2015

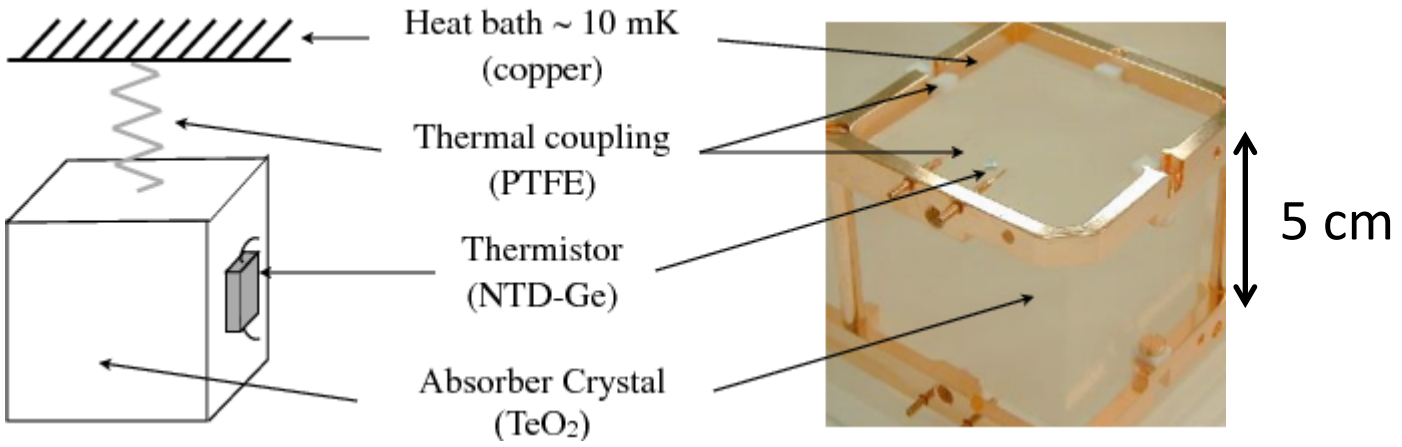
0νββ search with bolometers **TODAY**



CUORE at Gran Sasso

988 $^{nat}TeO_2$ bolometers
206 kg 130Te (0νββ candidate)
Start operations at the end of 2015

Sensitivity limited by natural α radioactivity



See L. Canonica and C. Ligi talks on friday

0νββ search with bolometers

TOMORROW

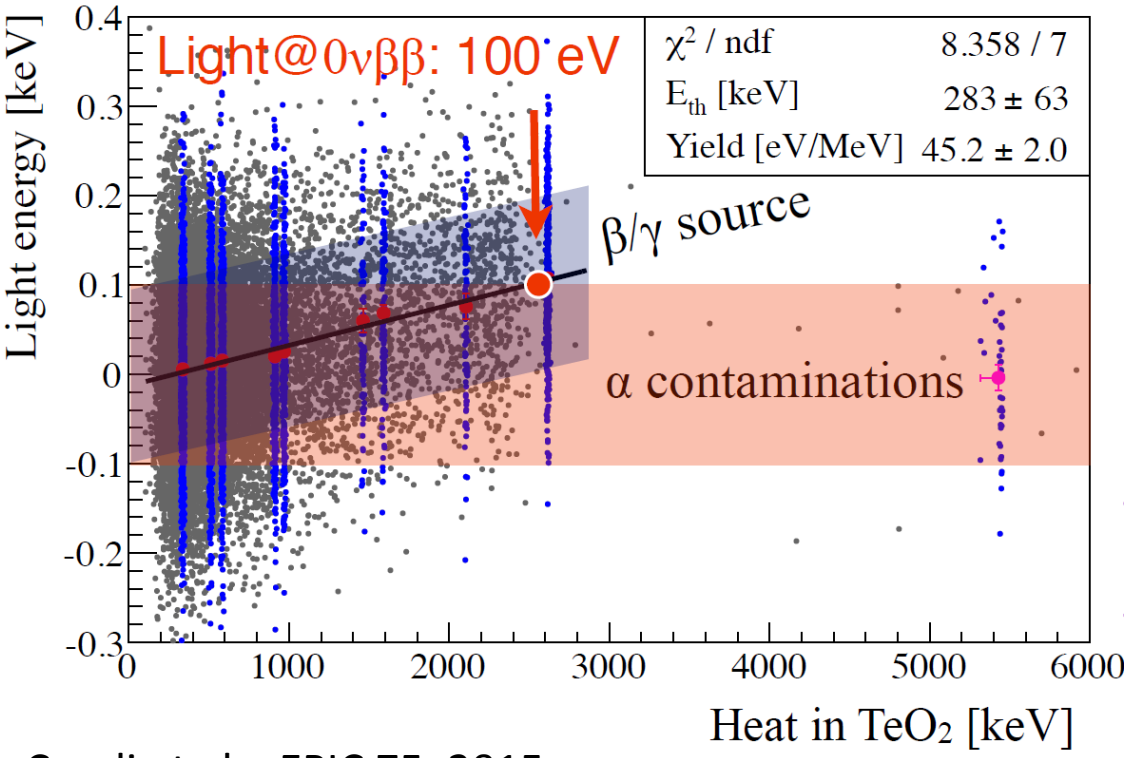
CUPID
CUORE Upgrade
with Particle IDentification

→

A possible way:
Cherenkov light
measurement

→

Need for
NEW LIGHT DETECTOR
with noise < 20 eV RMS



Casali et al. , EPJC 75, 2015

Candidate Detectors

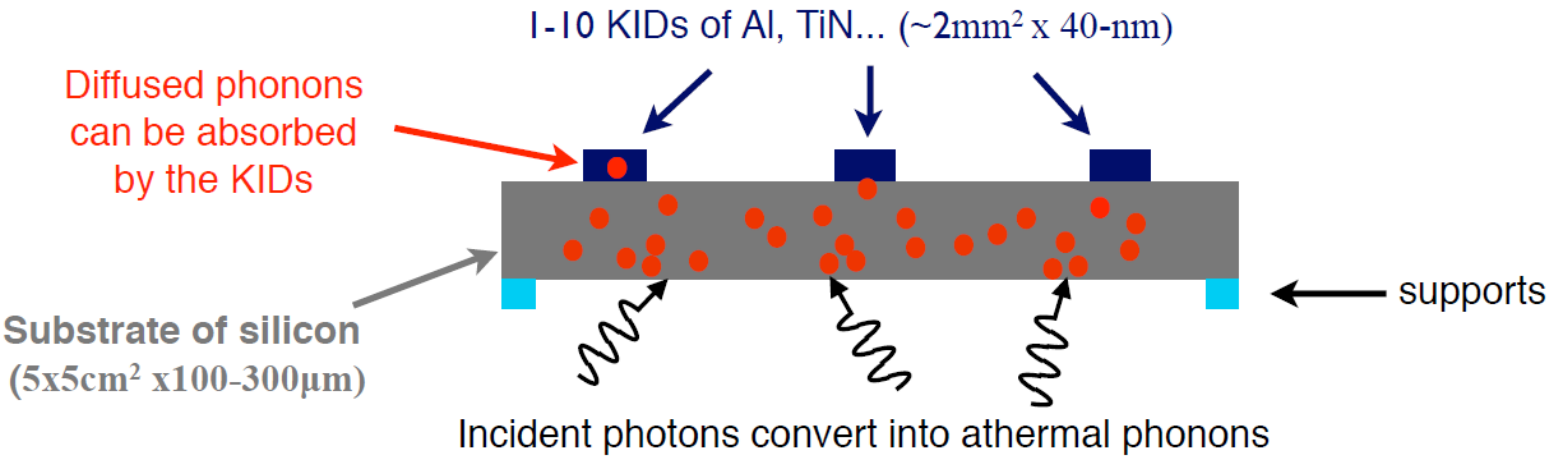
- ✓ NTD
- ✓ TES
- ✓ **KID**
- ✓ LUKE + …
- ✓ MMC
- ✓ …

About CUPID: arXiv: 1504.03599

The CALDER project

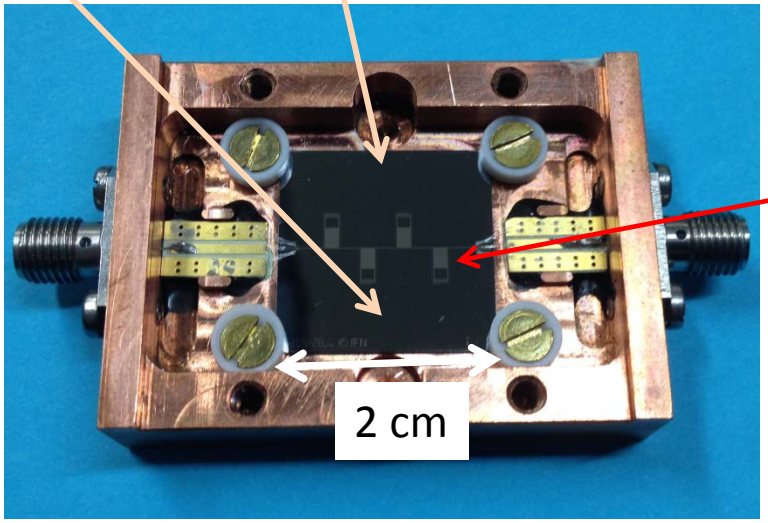
Requirements

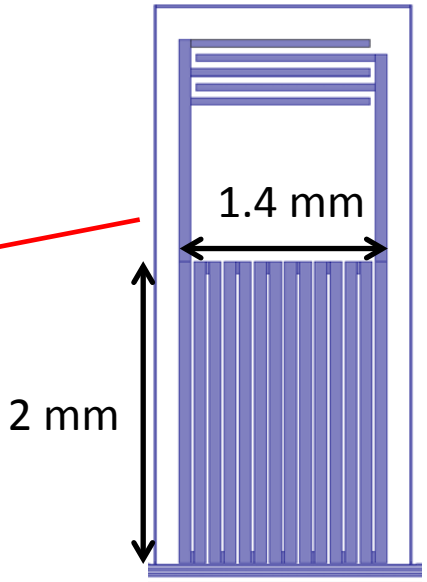
- Working T: 8-12 mK
- Noise < 20 eV RMS
- Size : 5 x 5 cm^2



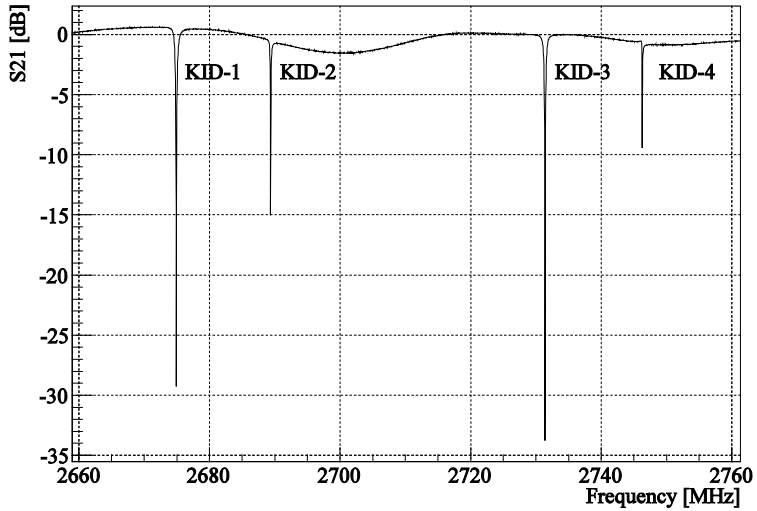
CALDER white paper: arXiv:1505.01318
EPJ C accepted

Low-Q prototype tests





40 nm Al
on
300 µm Si

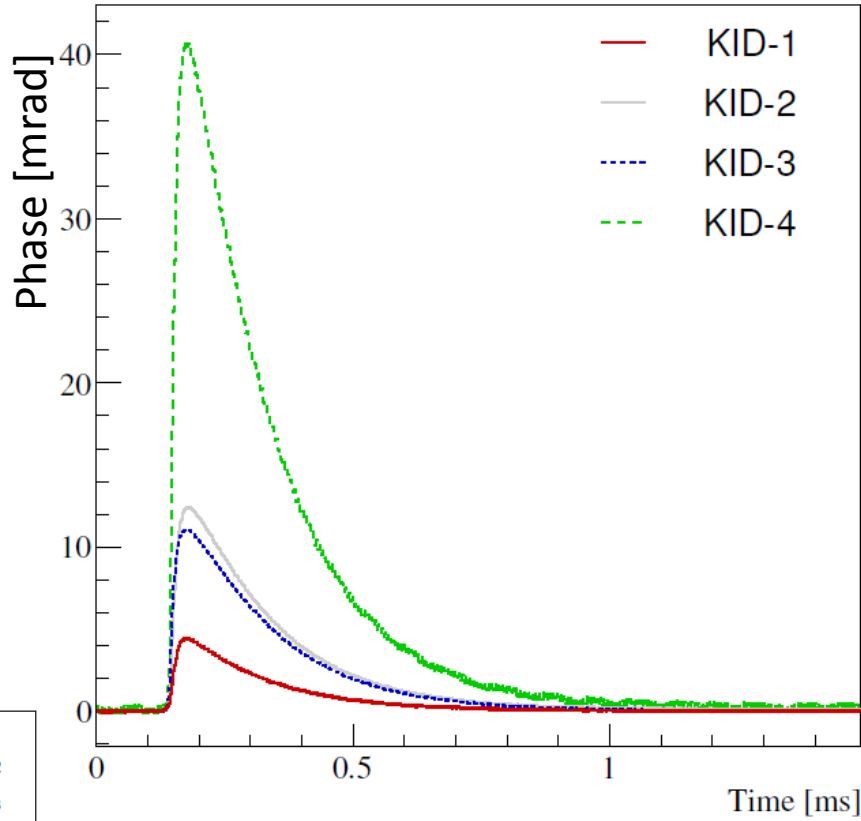


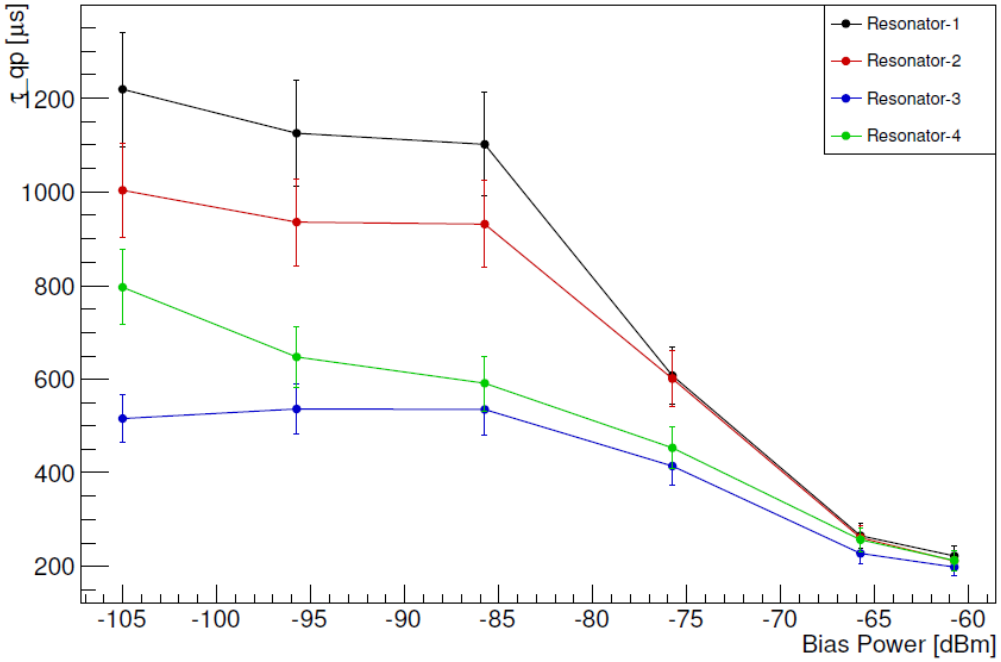
	f_0 [GHz]	Q [x10^3]
KID-1	2.675	6
KID-2	2.689	18
KID-3	2.731	8
KID-4	2.746	35

See also N. Casali (G1-29) and I. Colantoni (G1-30) posters

Phase Signal and Noise for ^{57}Co source

- Average phase signals at 14 keV.
- Rise time = 15-30 µs (arrival time of phonons)
- Decay time =180-200 µs (recombination of quasiparticles into Cooper pairs).





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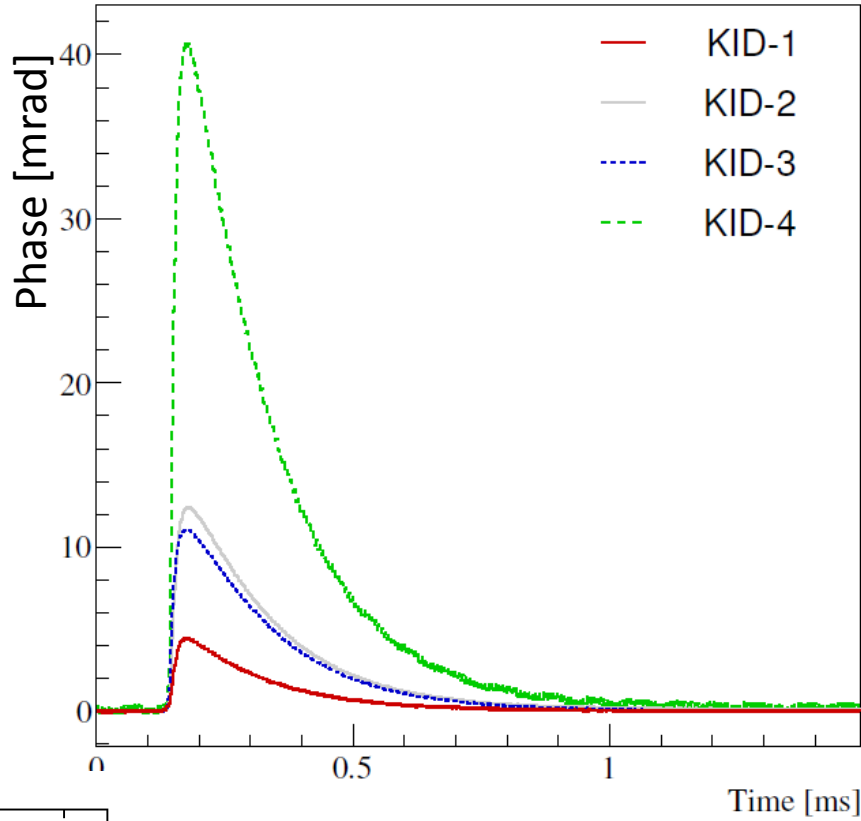
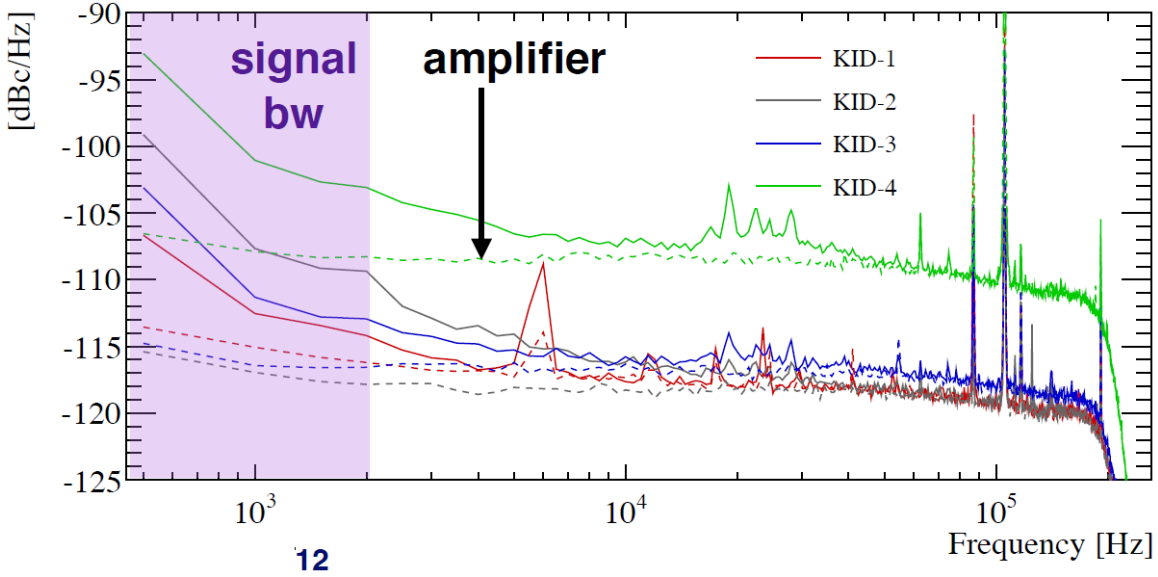
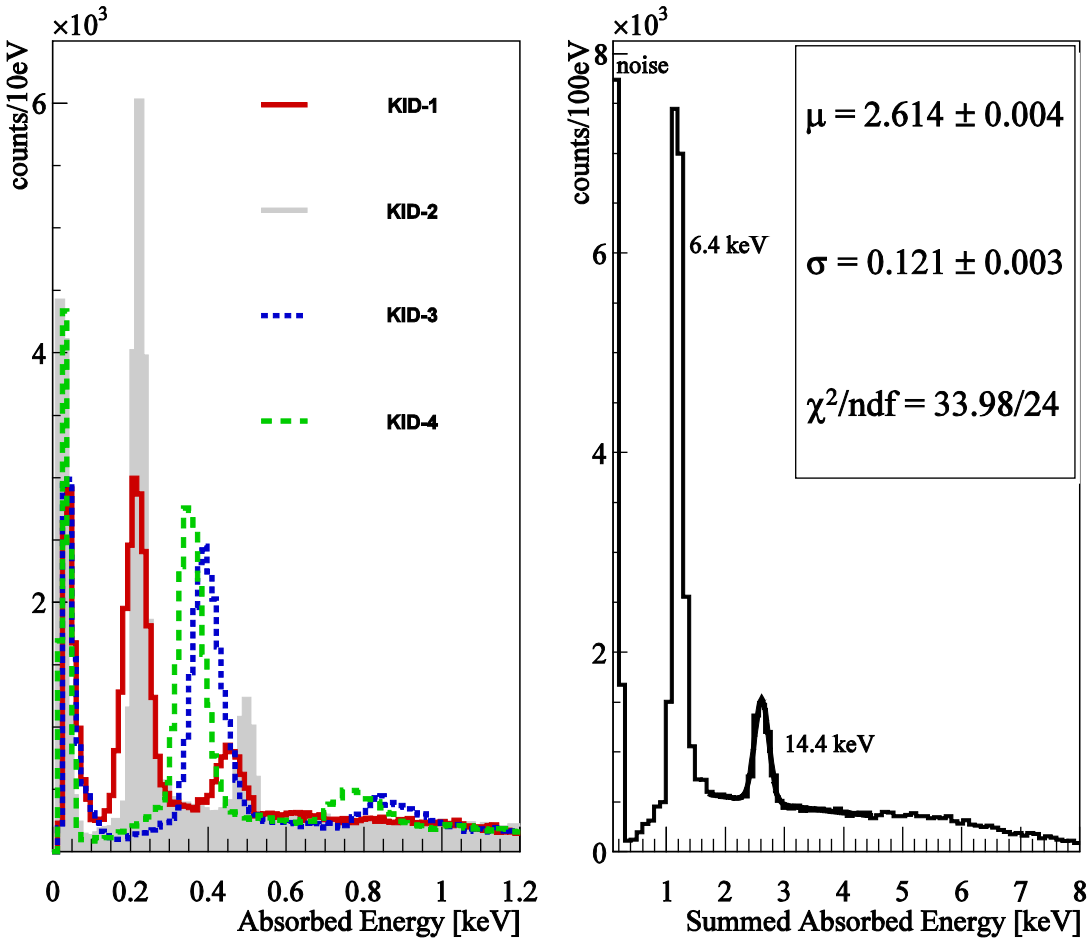




- Strongly limits the sensitivity (4x).
- Noise origin under investigation.

Energy Spectrum

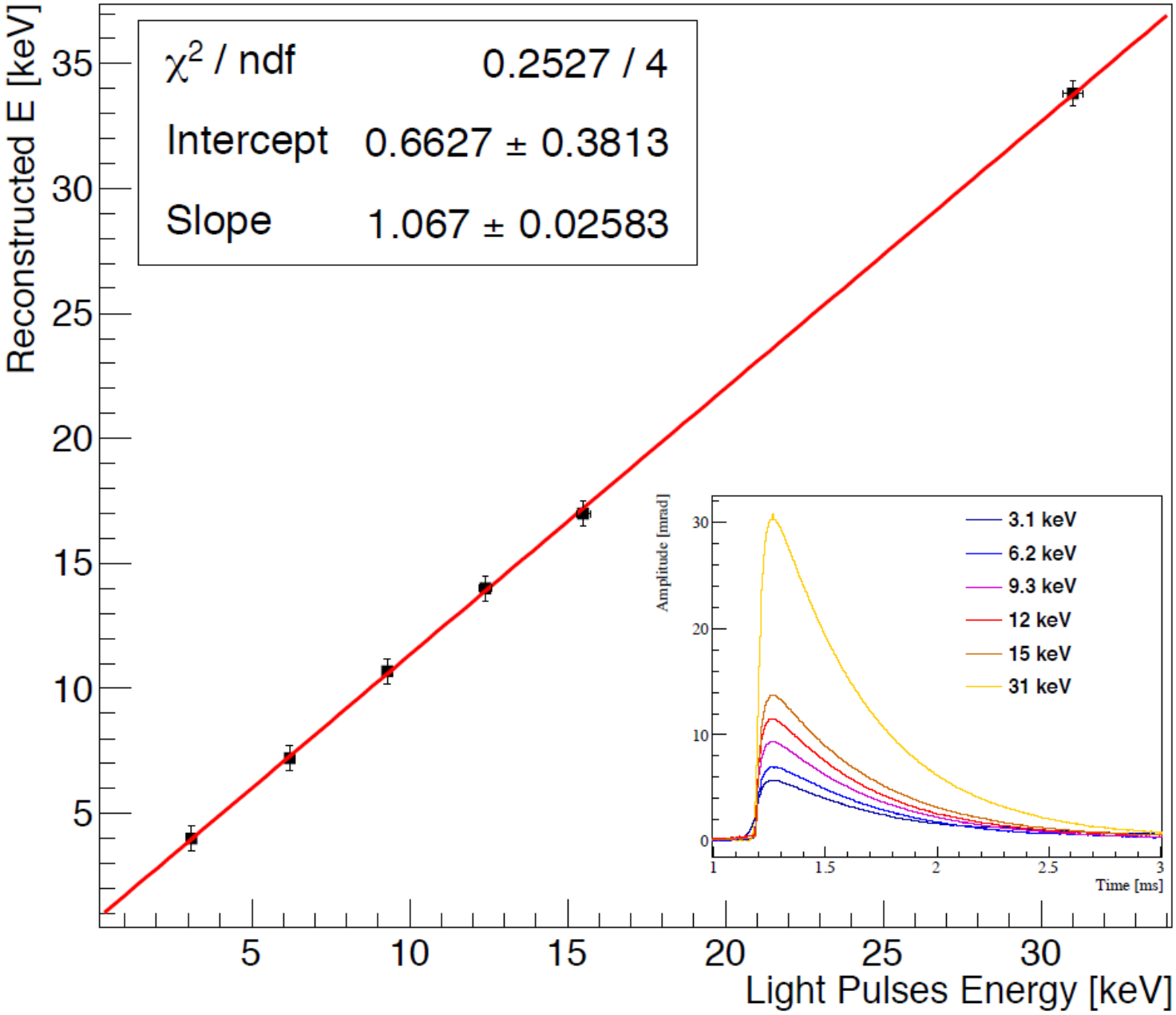


energy conversion efficiency to break cooper pairs η = 2.6/14.4 = 18%

baseline resolution (after calibration) σ_E = 154±7 eV

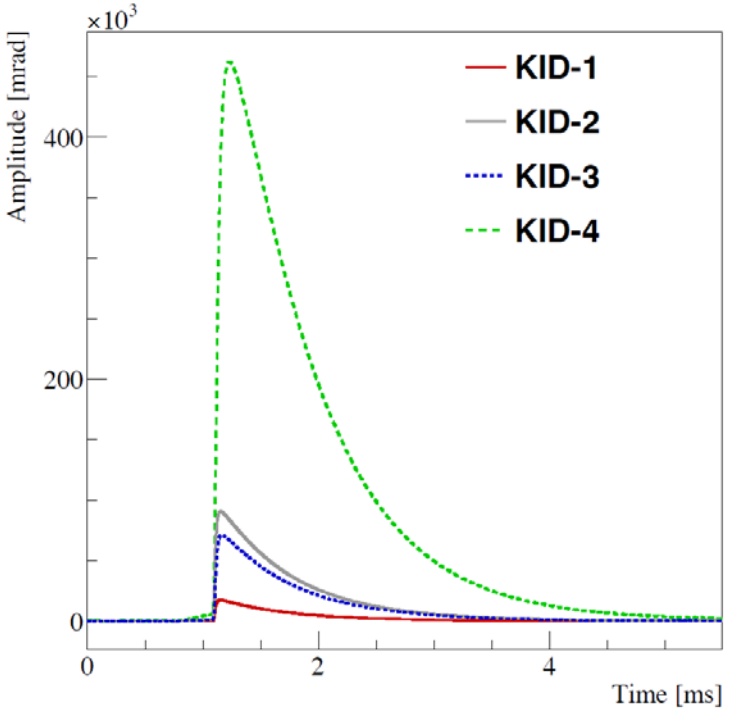
arXiv:1505.04666

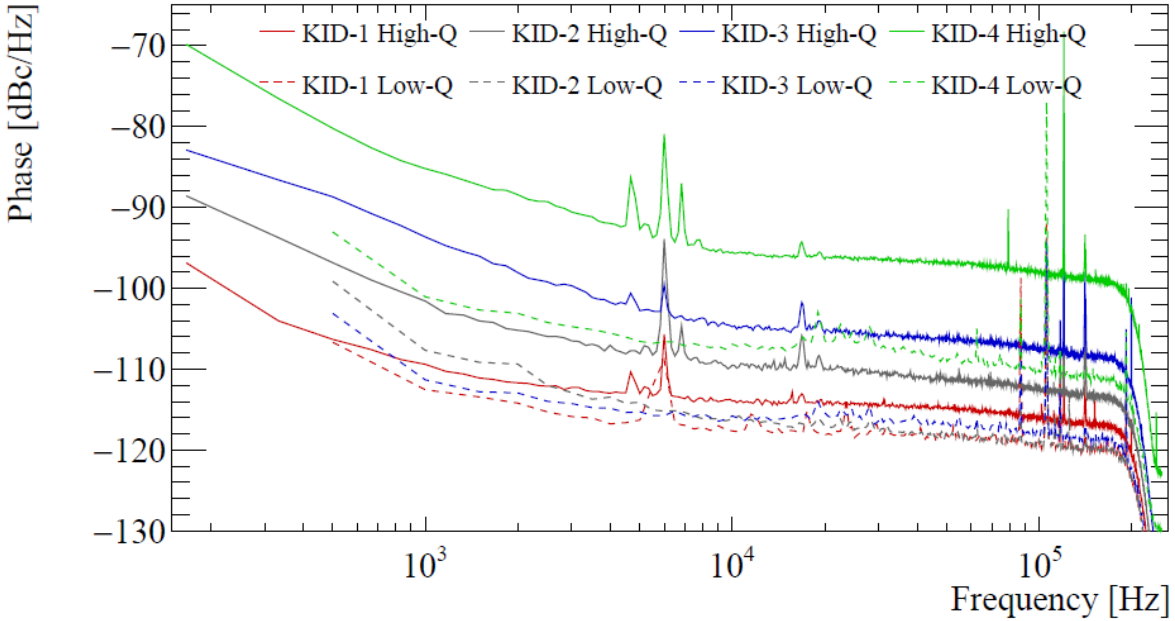
Detector response to optical pulses



High-Q prototype tests

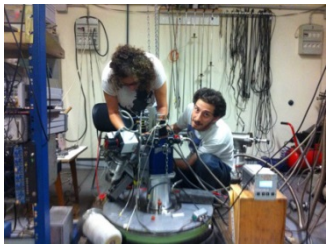
	f_0 [GHz]	Q [x10^3]
KID-1	2.675	18
KID-2	2.689	52
KID-3	2.731	82
KID-4	2.746	250





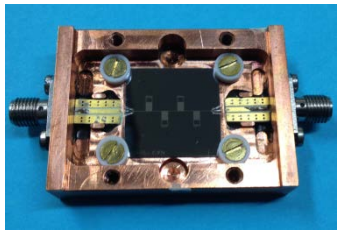
	Low Q	High Q
ε	18 %	19%
τ [μs]	200	700
σ [eV]	156	90
σ_{amp} [eV]	80	20

Timeline



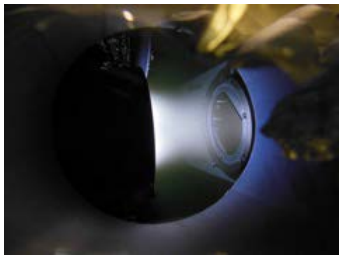
2013-2014

Cryostat setup (reached 10-15 mK), readout, data analysis, and first aluminum prototypes with low Q.



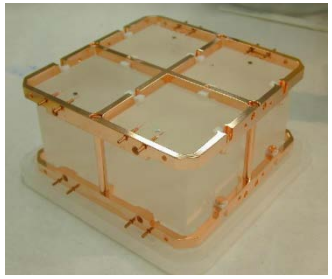
2014-2015

Reached 90 eV baseline noise. Finalize development and test of aluminum sensors, reach 50 eV noise.



2015-2016

Develop and test TiN - Ti/TiN sensors,
reach the goal of 20 eV noise.



2016-2017

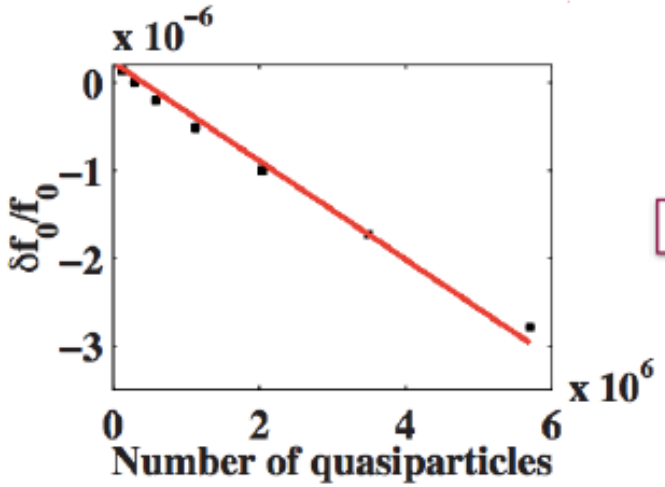
Build a demonstrator at LNGS: an array of TeO_2/ZnSe bolometers monitored by the new light detectors.

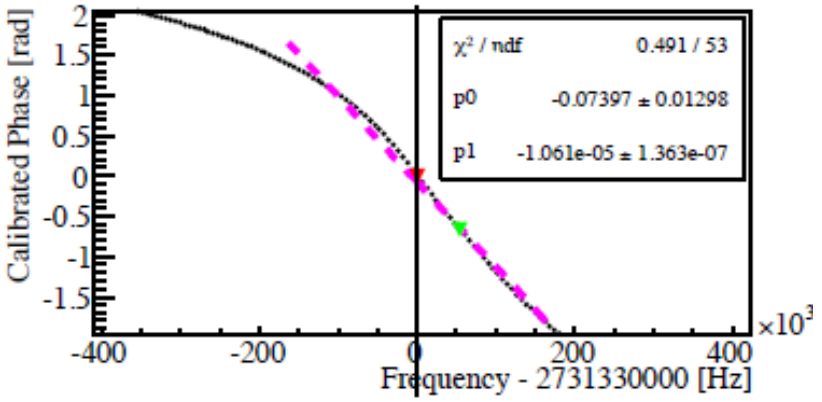
BACKUP SLIDES

Energy Absolute Calibration

$$E = n_{qp} \times \Delta_0$$

$$E = \frac{\delta f_0 / f_0}{p_0} \times \Delta_0$$

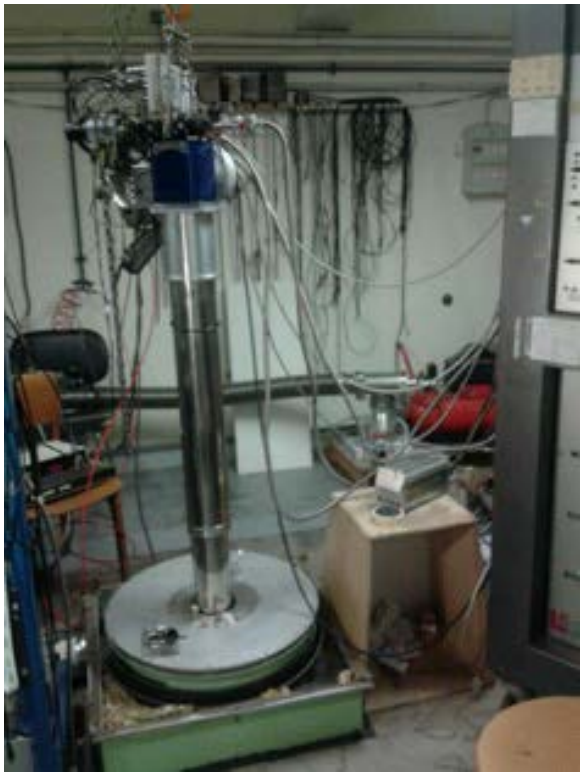




$$E = \frac{\delta\phi}{4Qp_0} \times \Delta_0 = \frac{\phi_{INTEGRAL}}{4Qp_0\tau_{qp}} \times \Delta_0$$

~8x10³ ~10⁻¹³ ~400 μs ~200 μeV

Our lab in Rome



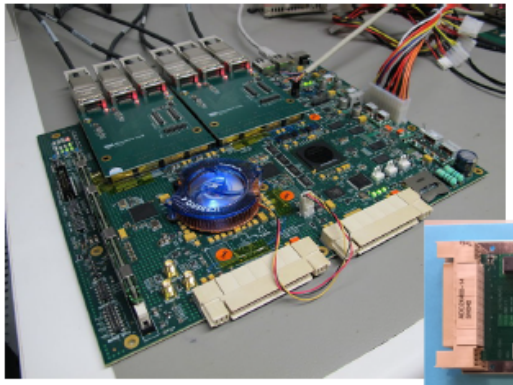
Nixa readout: electronics board developed at LPSC (Grenoble)

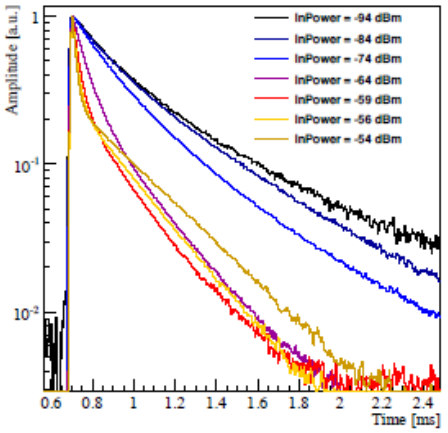
O. Bourrion et al., JINST 8 C12006 (2013)

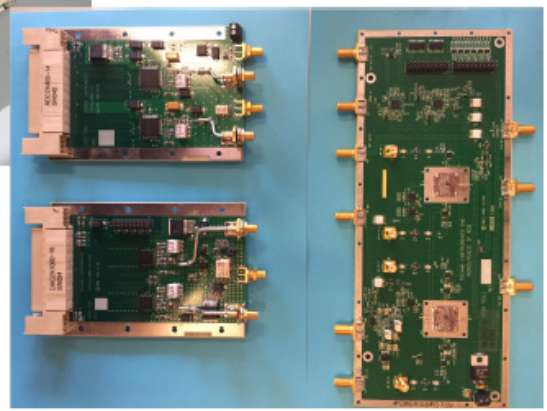
Next months…

DETECTOR:

- Define the final geometry of the pixels
- Test with new superconductors
- Test with 5x5 cm^2 substrate
- Improve model for pulses development







ELECTRONICS and ACQUISITION:

- Test of ROACH acq. board (replace NIXA)
- Integration of KIDs with "standard" bolometers
- Data synchronization, merging, from multiple readout systems

+ many other tasks like instrumentation of underground cryostats for KIDs readout, set-up of the final production and so on.

FINAL TEST: TeO2 + KIDs based LD

The CALDER research team

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C. Cosmelli, A. Cruciani, M. Martinez.

Consiglio Nazionale delle Ricerche:
Detector fabrication.
I. Colantoni and M.G. Castellano.

Università degli studi di Genova:
Electronics and DAQ.
S. Di Domizio.