MoBiKID
Kinetic Inductance Detectors
for up-coming B-mode satellite experiments

TIPP'17 - BEIJING

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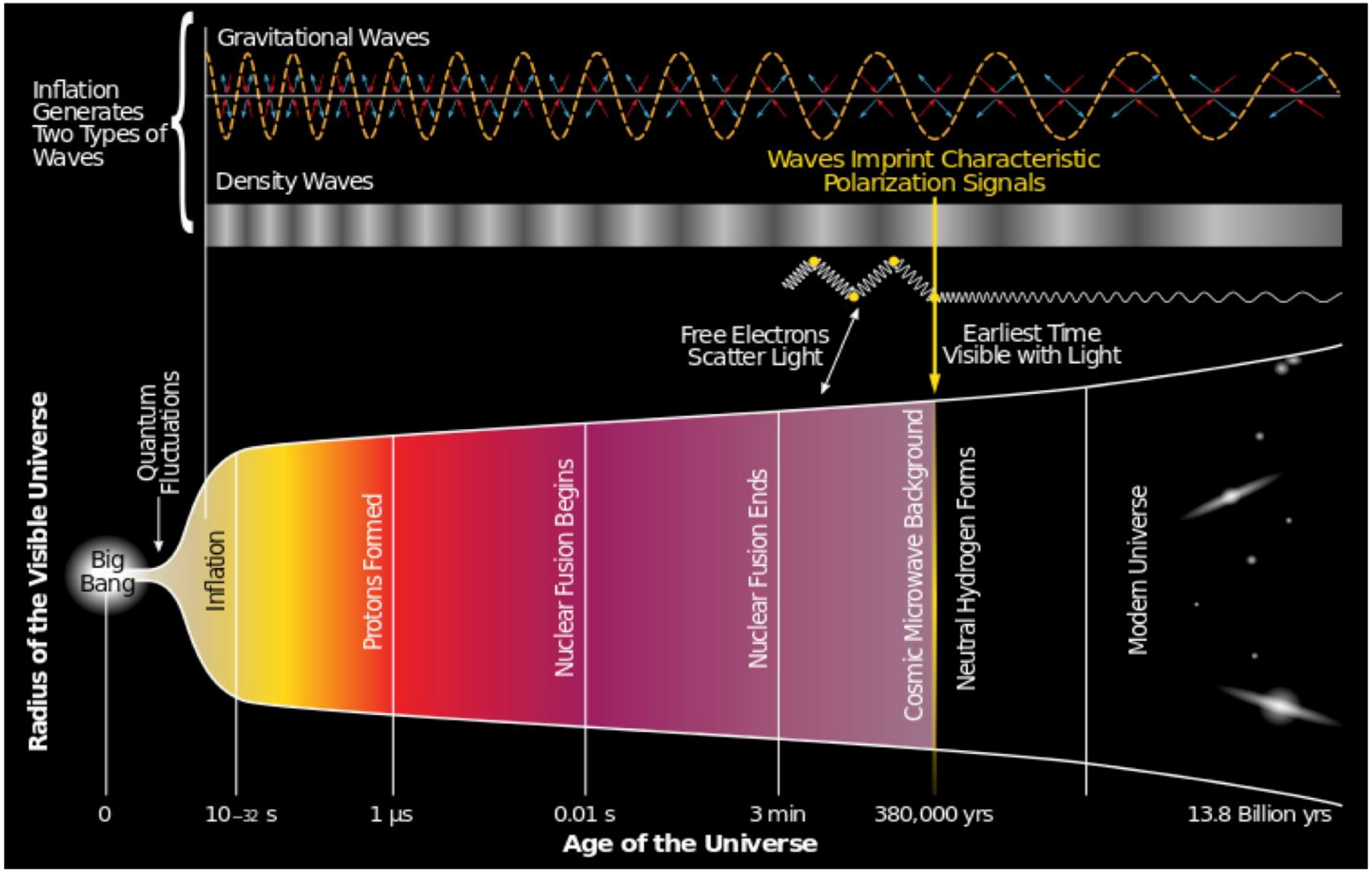
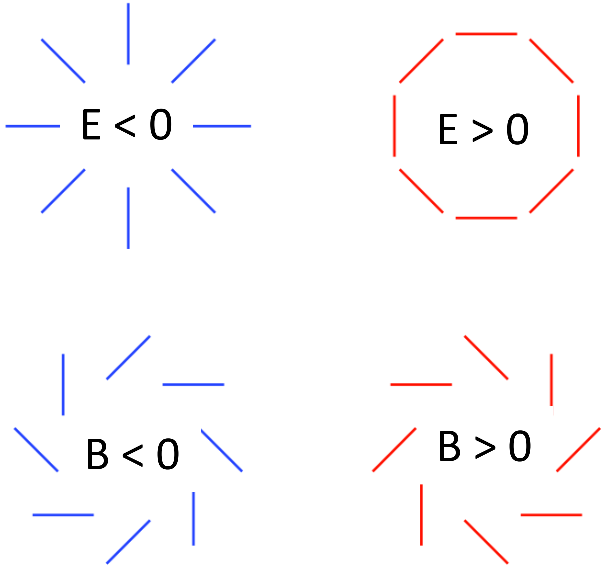
Dawn of the universe: where are we?

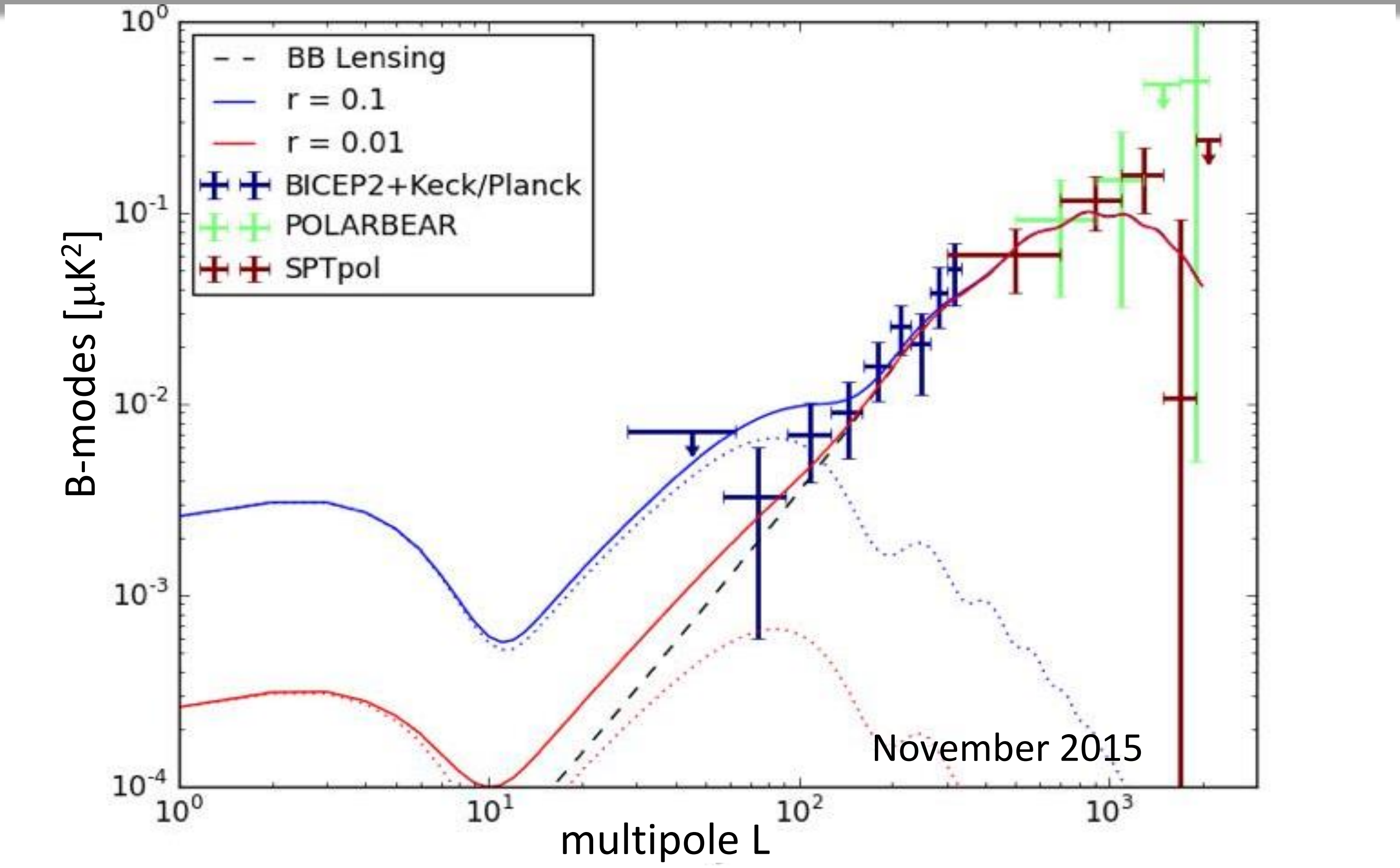


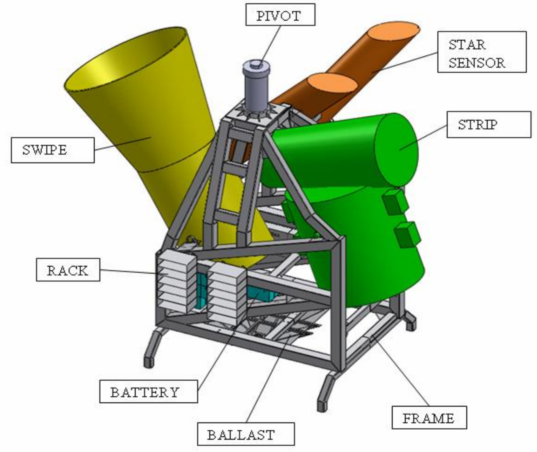
Looking into the CMB for a proof of the Inflation ....

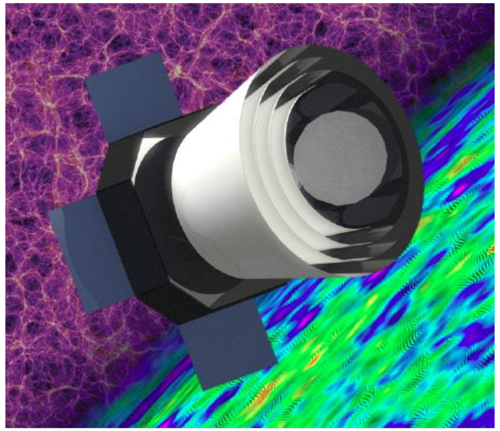


... B-mode polarization anisotropies are THE KEY!

Primordial B-mode polarization anisotropies







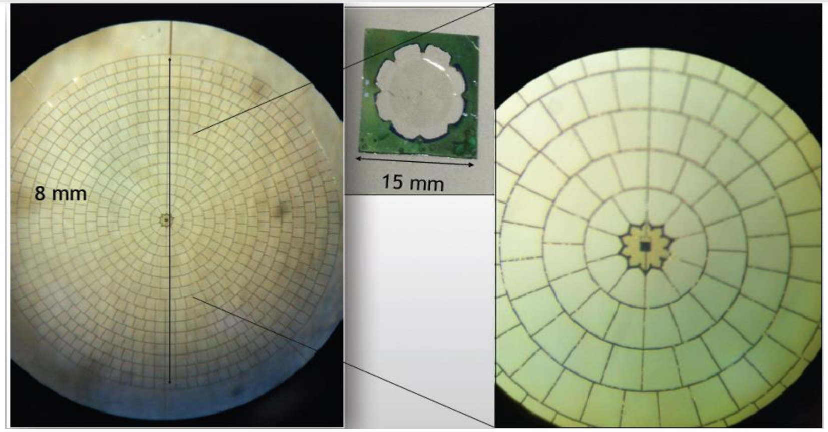
Interest in CMB is growing in paritcle physics community….

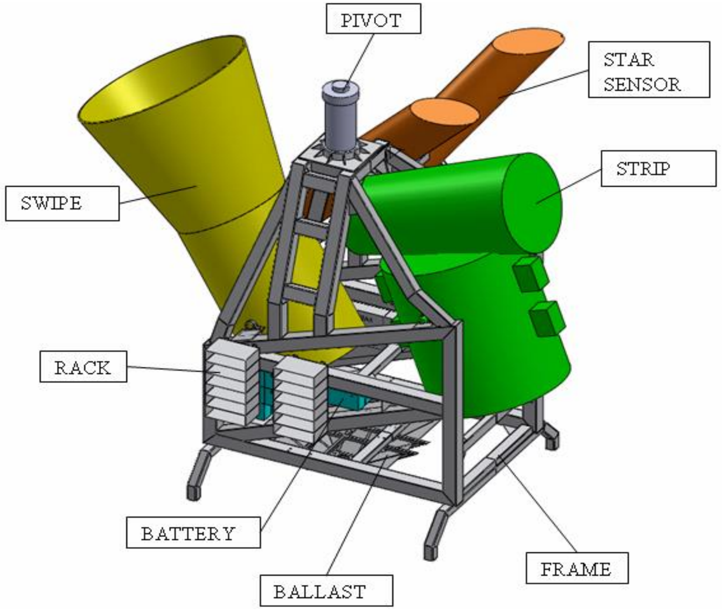
Large Scales Polarization Explorer

- PI: P. de Bernardis (Sapienza & INFN)
  CO-I: F. Gatti (Università di Genova & INFN)

- Goal: Reionization peak down to r=0.03

- Method:
  - Polar night flight (balloon)
  - Large angular scales (25% sky)
  - Frequency coverage 40-250GHz
  - Multimoded TES bolometers





Aiola, et al. Proc of SPIE (2012)

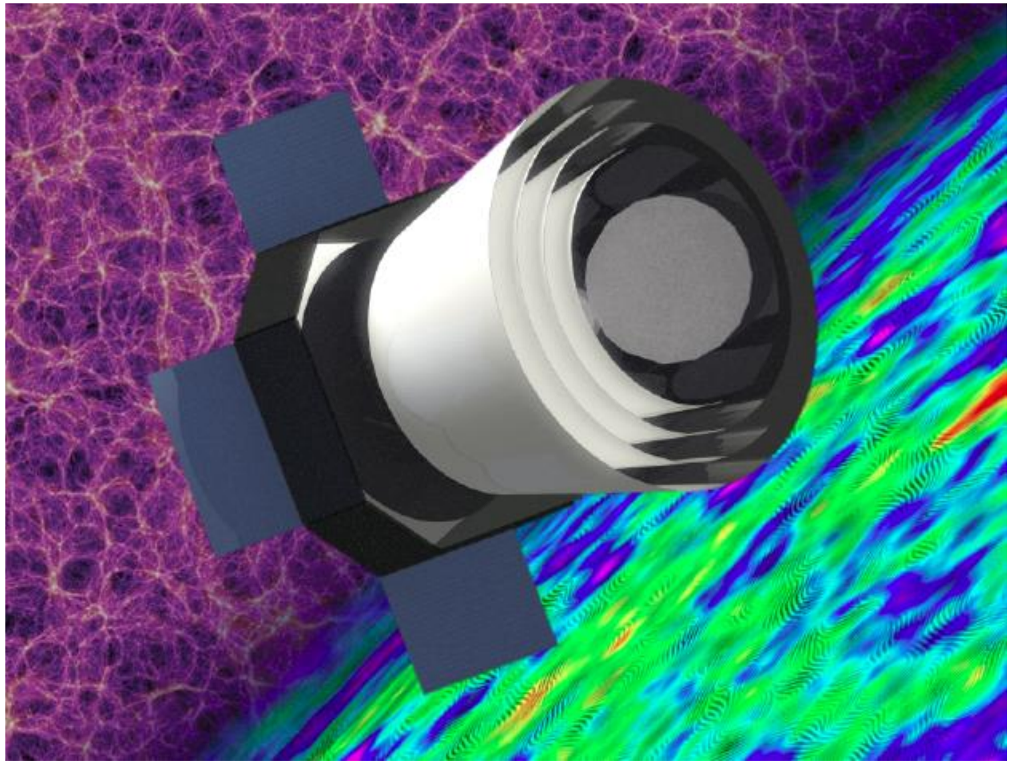
GE
FE
PI
RM1
RM2

COrE : Cosmic Origin Explorer

A satellite mission for B-modes proposed to last ESA M calls (from Lagrangian point L2)

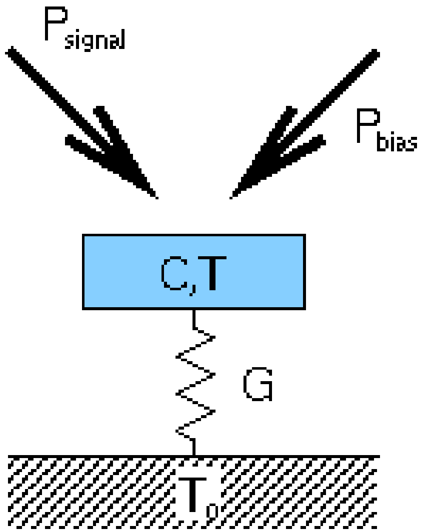
Scientific motivation was recognized as very strong.

On the other hand the maturity of detectors was considered not sufficient.

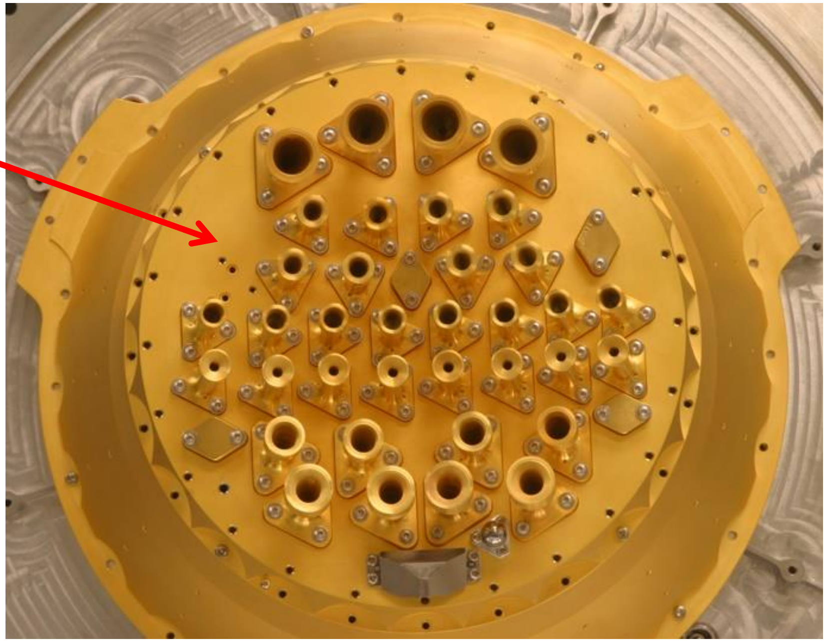


Space detector state of the art: PLANCK Bolometers

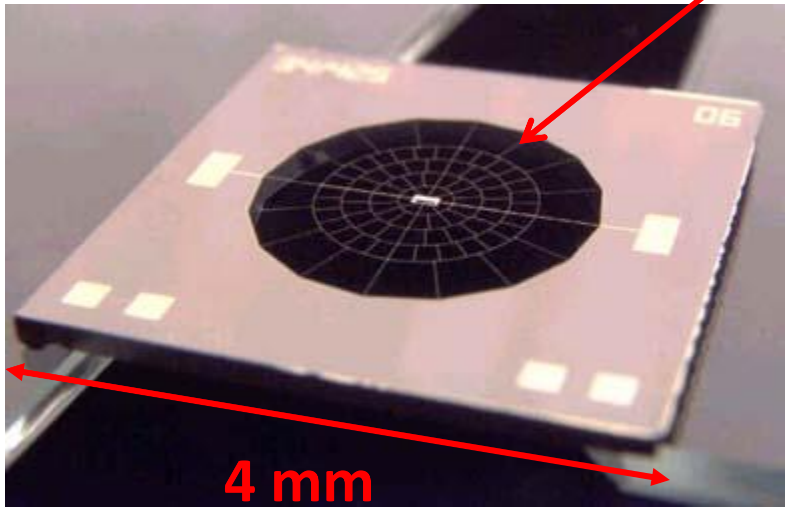
- Spiderweb bolometers
- Germanium termistor
- Excellent sensitivity
- NOT multiplexable!



PLANCK focal plane ~ 40 pixels

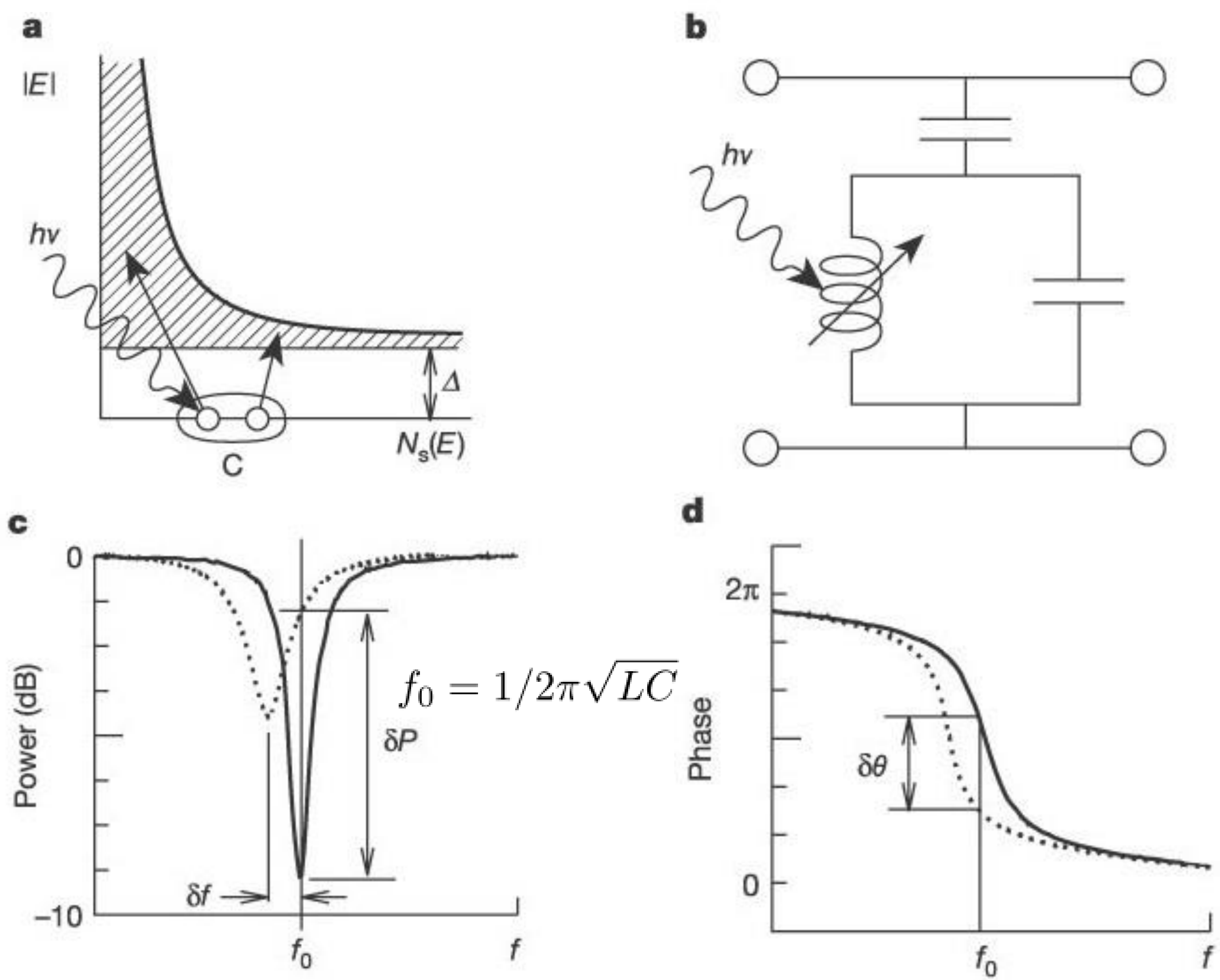


Spiderweb absorber



Kinetic Inductance Detectors (KIDs)

Day et al., Nature 425 (2003) 817

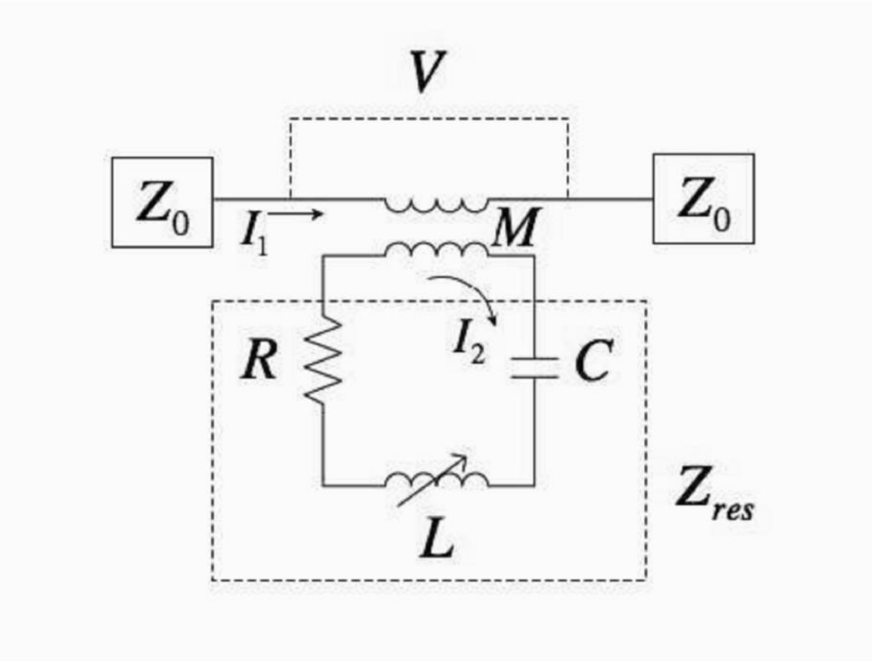


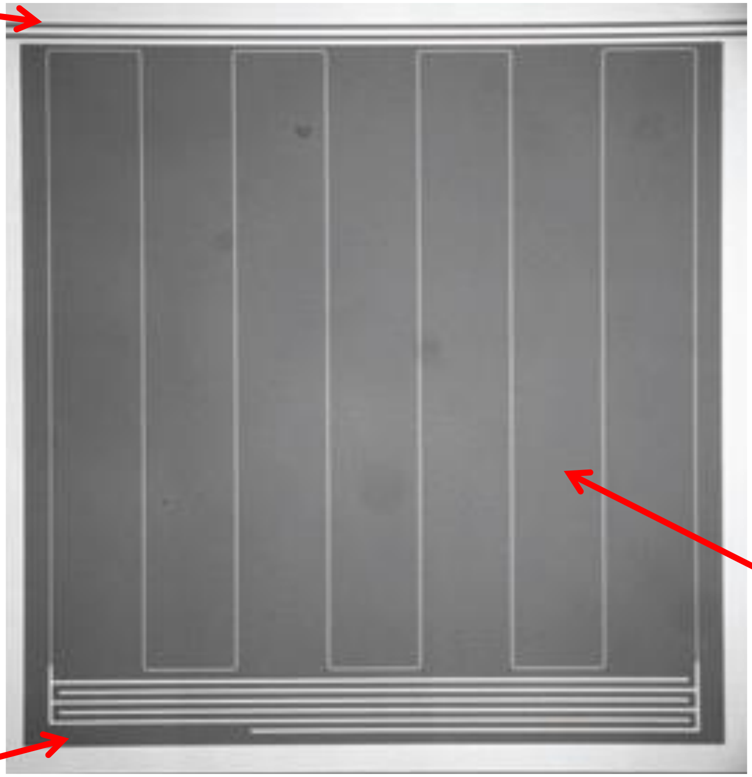
Cooper pairs (CP) in a superconductor act as an inductance (*L*).
Absorbed photons change cp density and *L*.

High quality factor (*Q*) resonating circuit biased with a microwave (GHz):
Signal from amplitude and phase shift.

LeKID: a « 3 in 1 » detector

Feedline





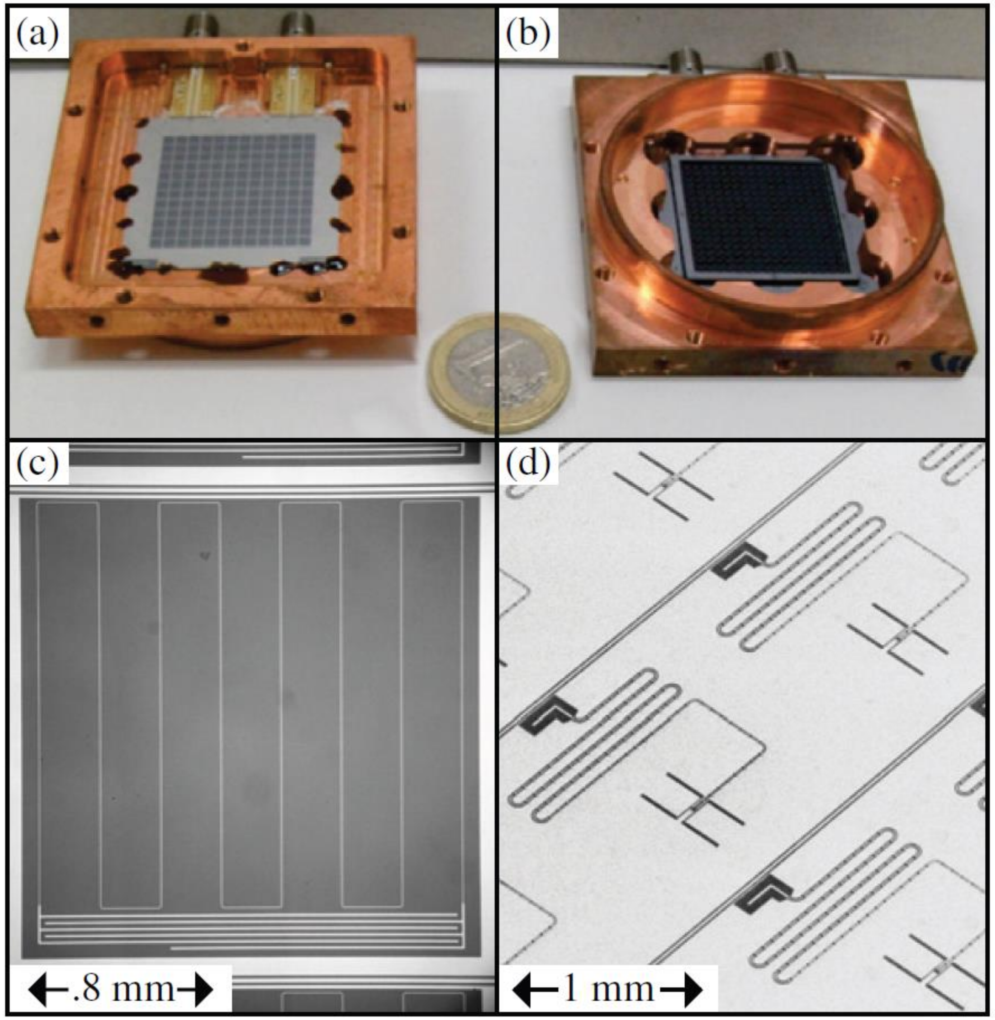
Capacitor

Inductor

- Absorber
- Sensor
- Multiplexer

S. Doyle et al., JLTP 151 (2008)

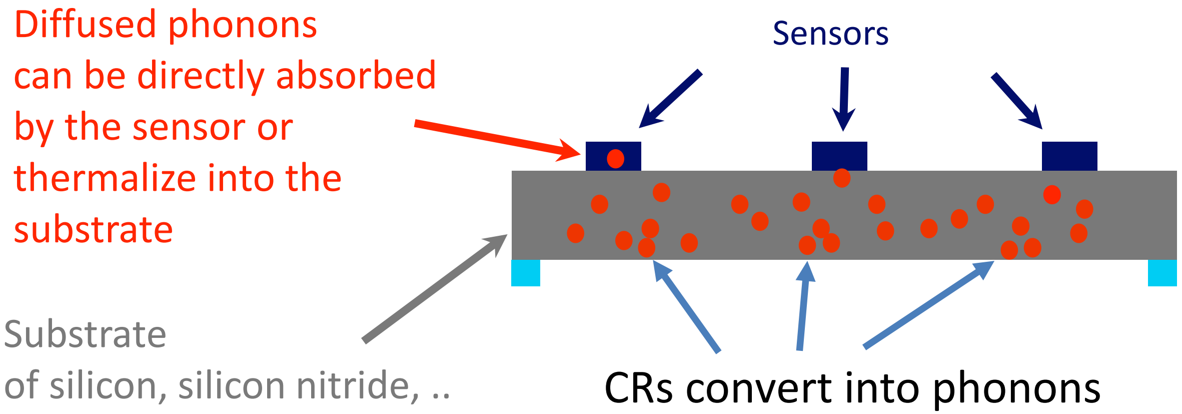
KID's evolution



- Detector concept and its demonstration in 2003 (Caltech)
- NIKA realized first observations on sky with KIDs in 2010 (Neel / CNRS)
- Different experiments are developing KIDs for balloon-borne telescope (e.g. BLAST, OLIMPO, …)
- Further tests are needed to demonstrate the suitability for space missions

Pictures from New IRAM KID Array (NIKA)
Monfardini, et al., APJS 194 (2011)

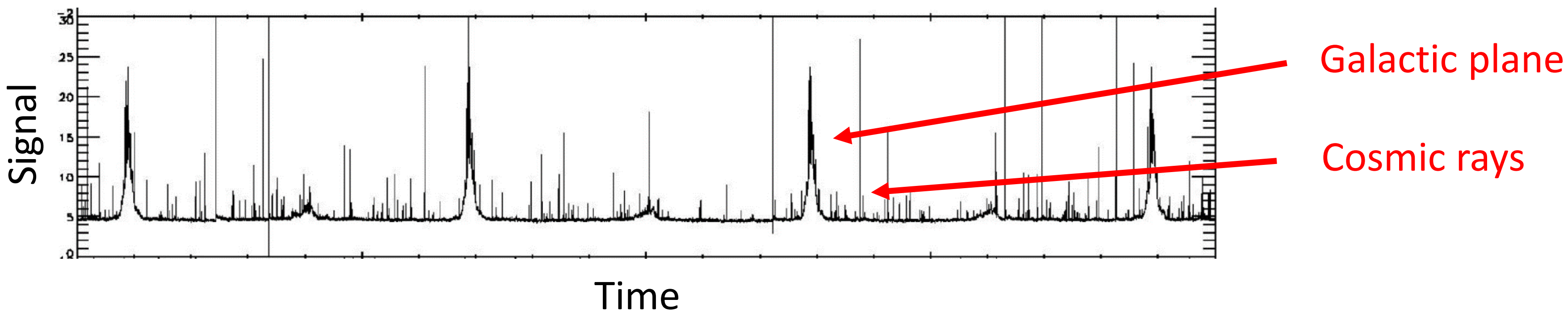
The challenge: Comsic Rays sensitivity



- CRs at L2 are mainly 200 MeV protons
- Rate about 5 cm^{-2} s^{-1}
- Their energy deposit into the substrate is 150 keV

Issues:

1. **Dead time (high energy release)**
2. **Data contamination (low energy release)**



Planck data from Catalano et al. 2014

Cosmic Rays sensitivity (2)

$$\sigma = \frac{NEP\sqrt{\tau}}{\eta} = \frac{5\ 10^{-18}\ \mathrm{W}/\sqrt{Hz} * \sqrt{2\ ms}}{\eta} = \frac{1.5\ eV}{\eta}\ !!!$$

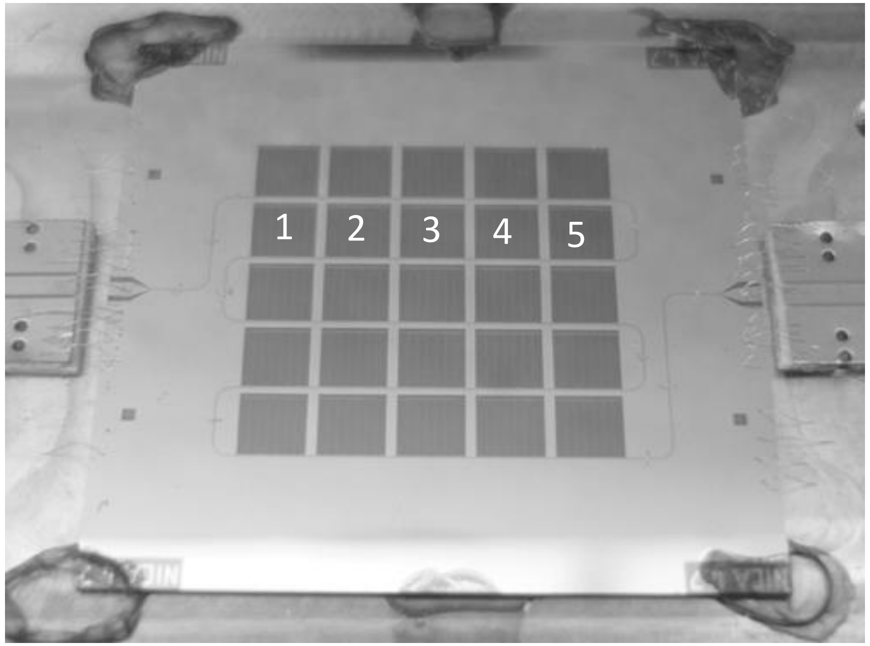
LEKID could be more severely affected due to the size of the sensor, that corresponds with the whole absorber

Typical efficiency η could range between 0.05 % and 3-4 %, depending on incident position and geometry of the device

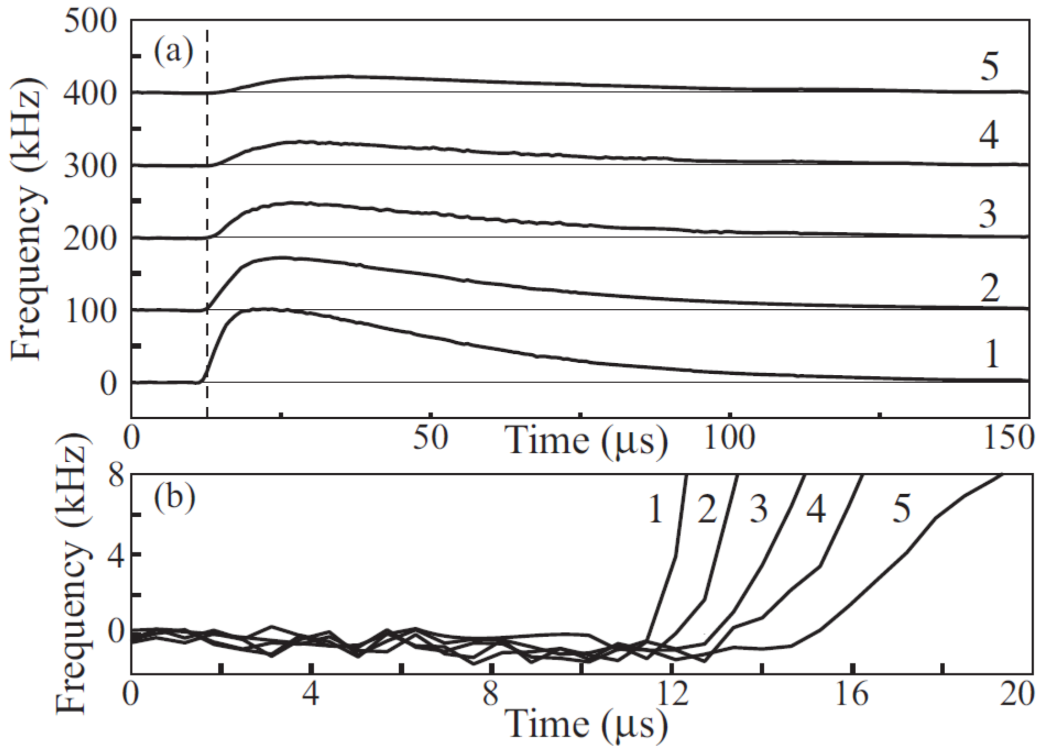
POSSIBLE COINCIDENCES BETWEEN MANY PIXELS

LEKID DESIGN
S. Doyle et al., JLTP 151 (2008)

First measurements



(Swenson, Cruciani, et al. APL , 2010 ;
Cruciani et al., JLTP 167, 2012)



This issue could be extremely significant

$$Dead\ time = r \cdot S \cdot (5\tau) \approx 25\ \%$$

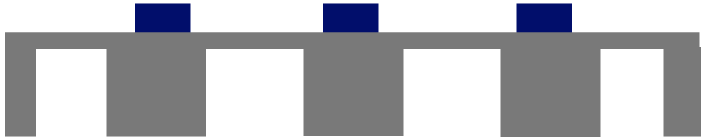
How to tackle the issue?

1. Definition of a solid methodology to quantify the problem

   Realisation of a testbed and a dedicated pipeline to characterize particle sensitivity of KIDs

2. Identification and test of solutions

Membranes



Pixel isolation

Low Tc Ground plane

MoBiKID

MoBiKID is a small R&D project (2.5 years, 150 k€), supported by INFN in collaboration with IFN-CNR

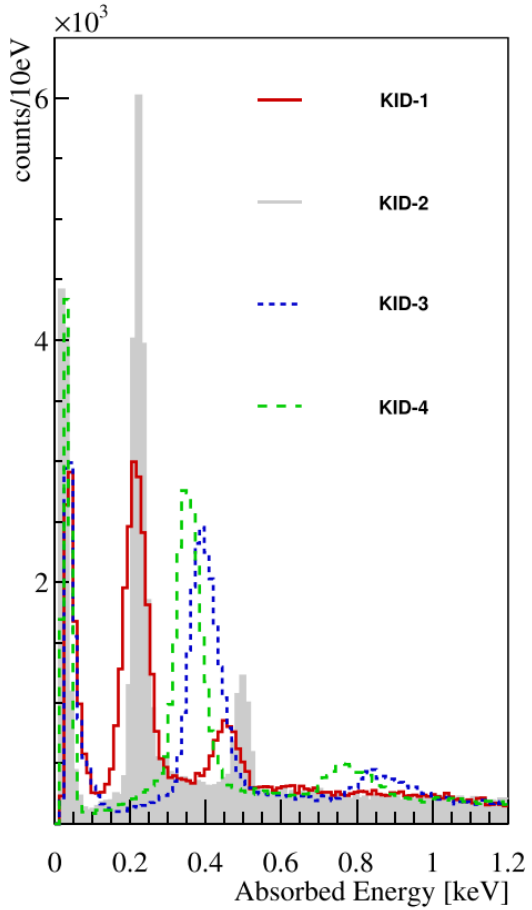
The project started in April 2016

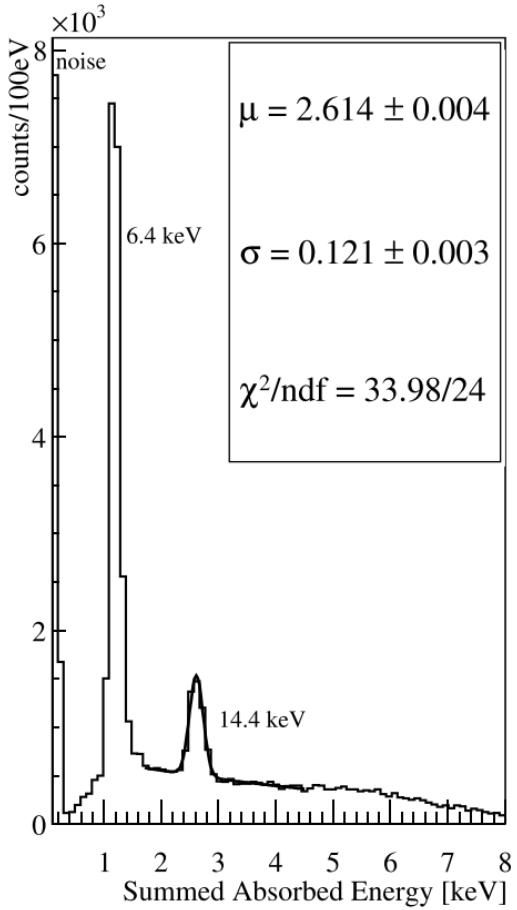
Main goals:

- Realization of a low background (0.1-1 pW) testbed for mm-wave KIDs for space
- Study of the effect of Cosmic Rays on KIDs in «space» conditions

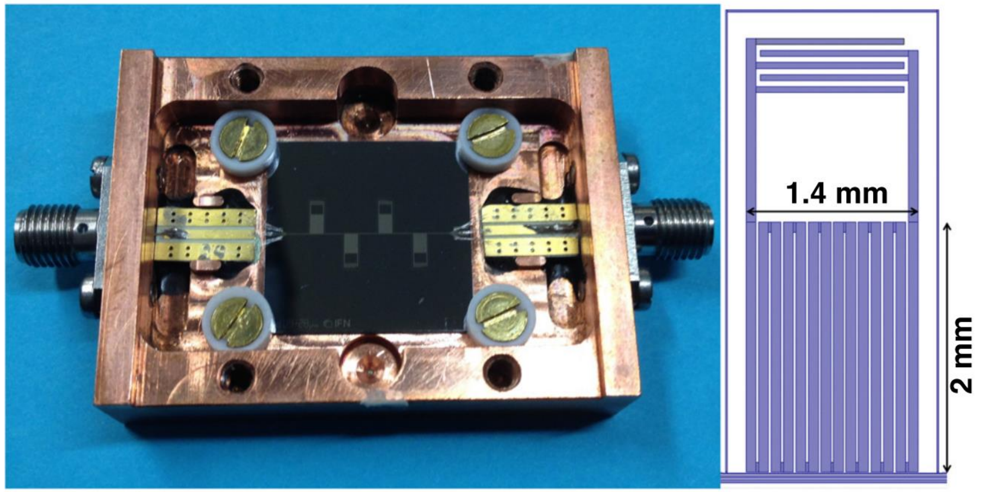
CALDER synergy (1)

The status and results of CALDER will be shown by N. Casali tomorrow.



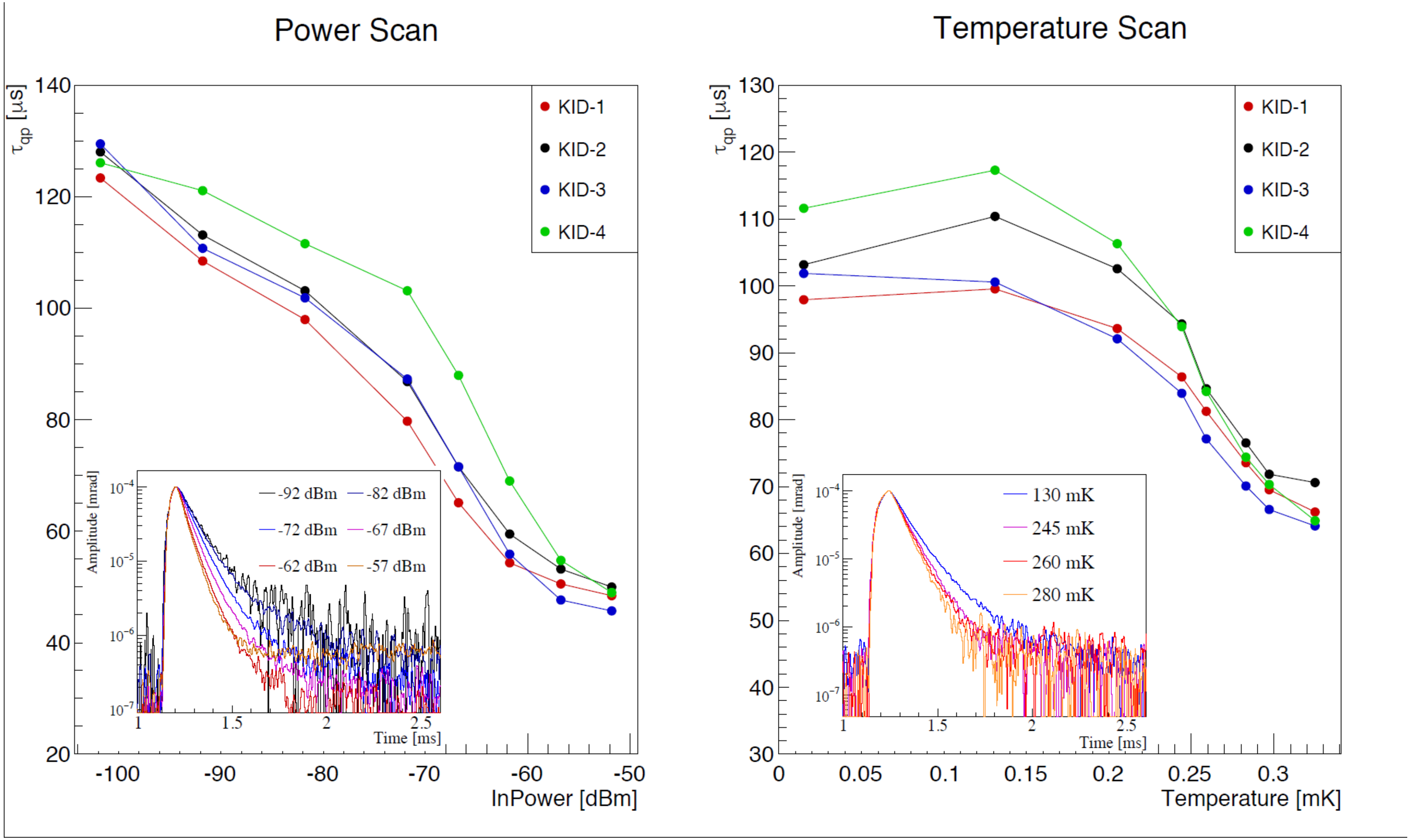


Cardani et al. , APL 107 (2015)



Capability to estimate absorbed energy and to measure efficiency with accuracy better than 20 %

CALDER synergy (2)



Study of the different time-scales:

Lifetime of QPs is interpreted as the main decay time of the pulse

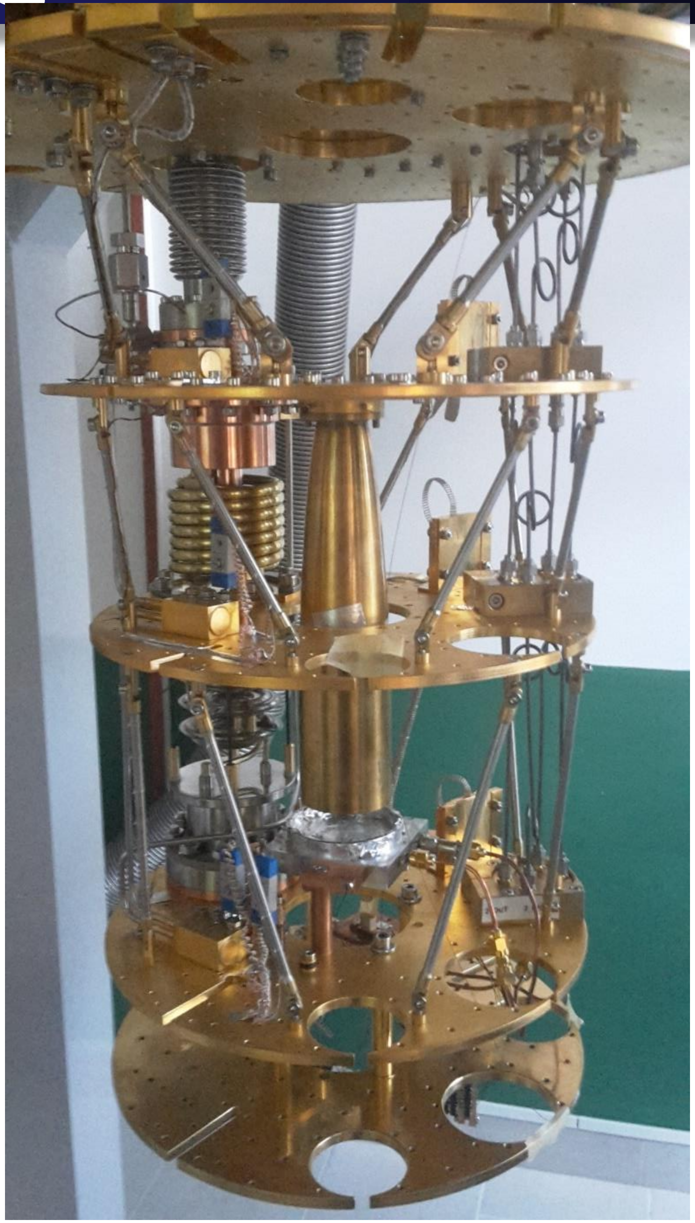
Cruciani et al, JLTP (2016)

KIDs cryogenic facility @ Roma

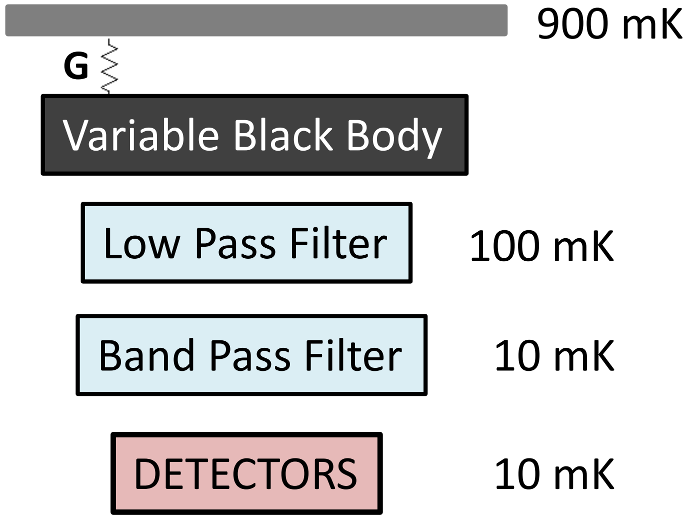
A new TRITON 200 dilution refrigerator, dedicated to mm-wave and UV-VIS KIDs (10 mK, exp. room: 24 x 40 cm)
Installed in October 2016

4 RF lines

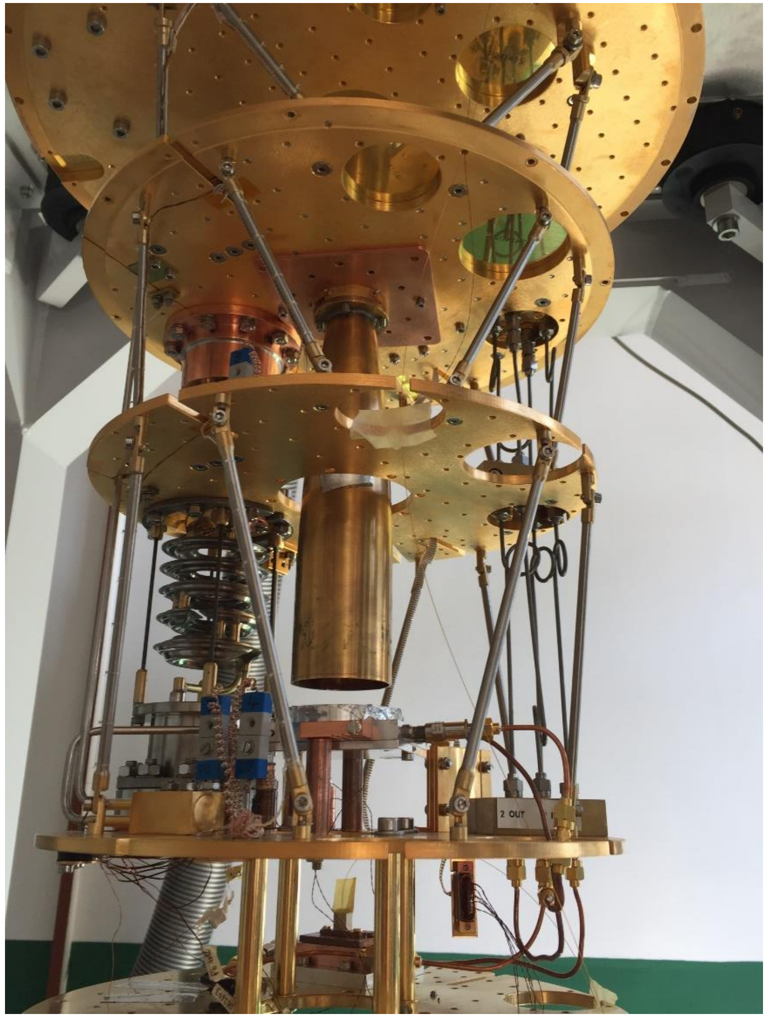
2 cryogenic amplifiers (CITLF3 and ASU)

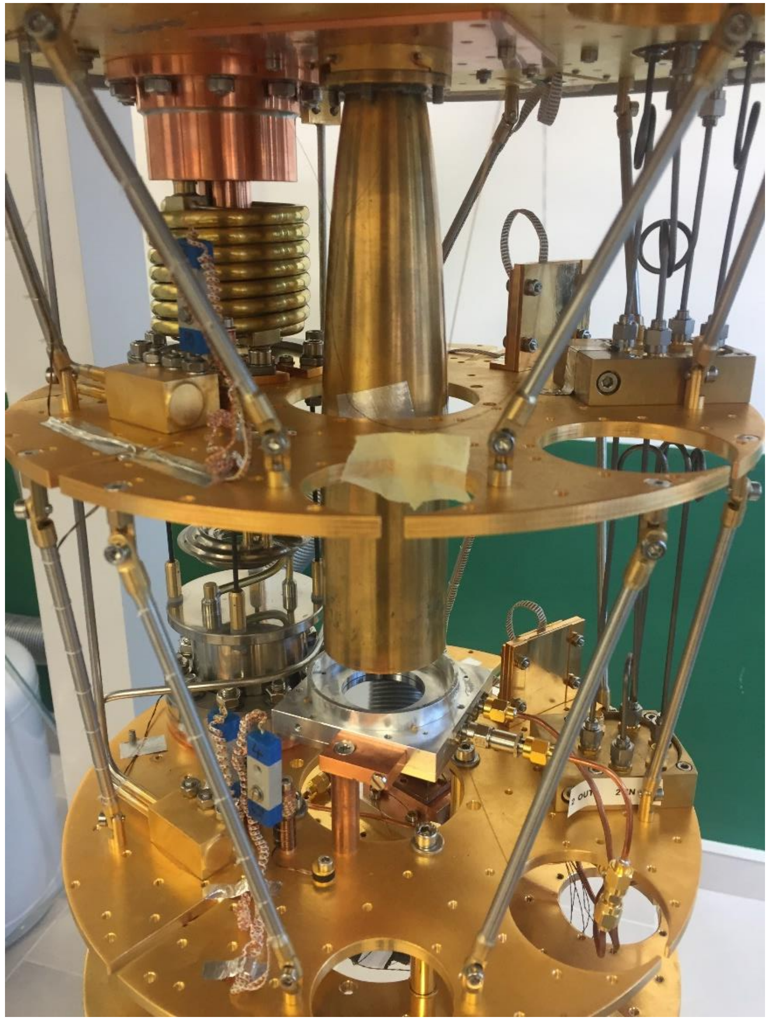


Sky simulator

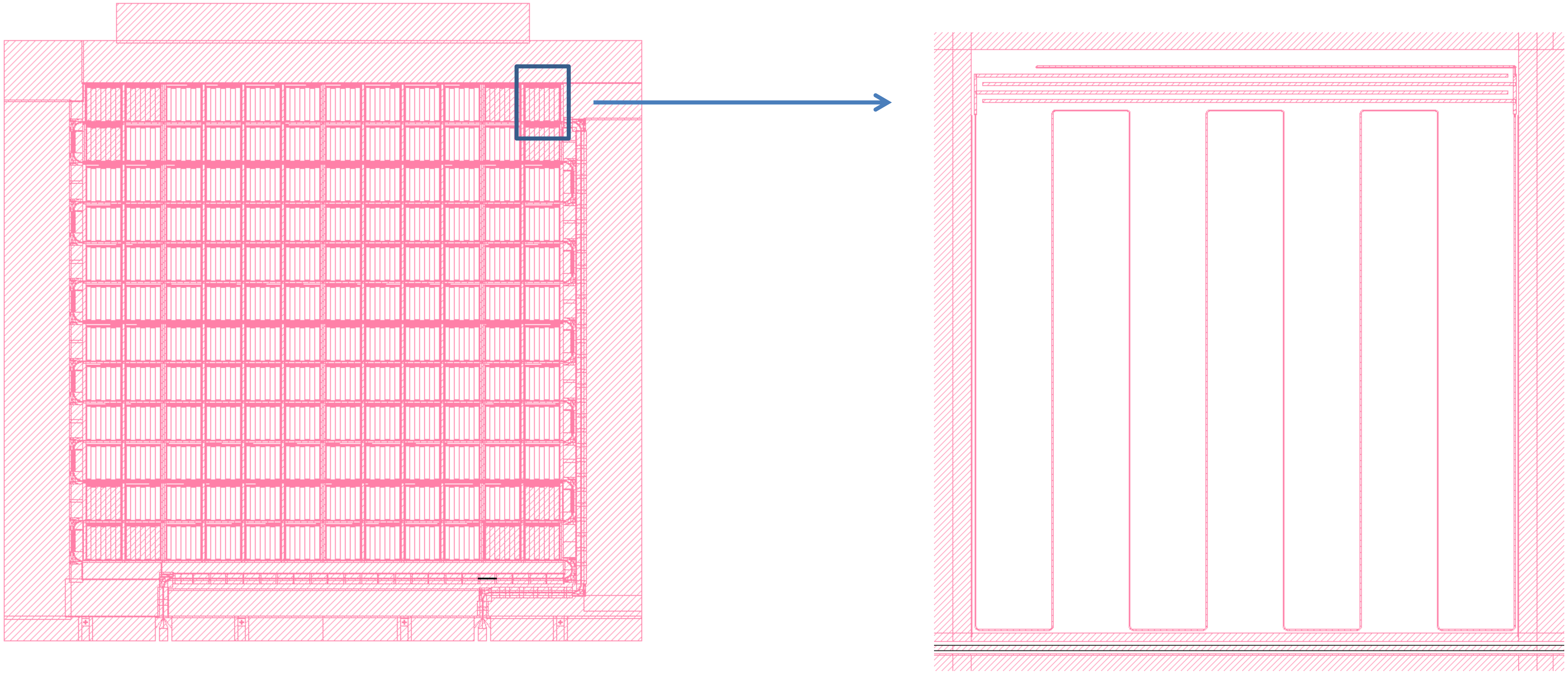


We realized a test-bed to simulate mm-wave optical signals in low-background conditions

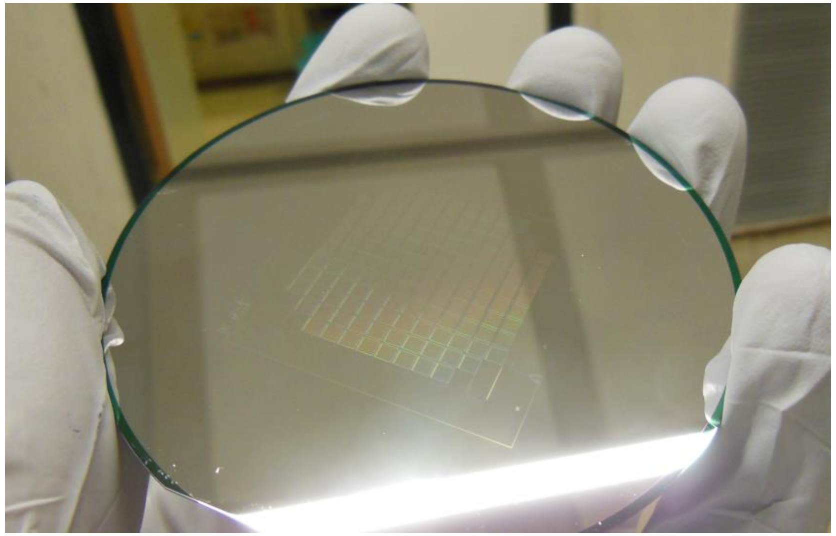


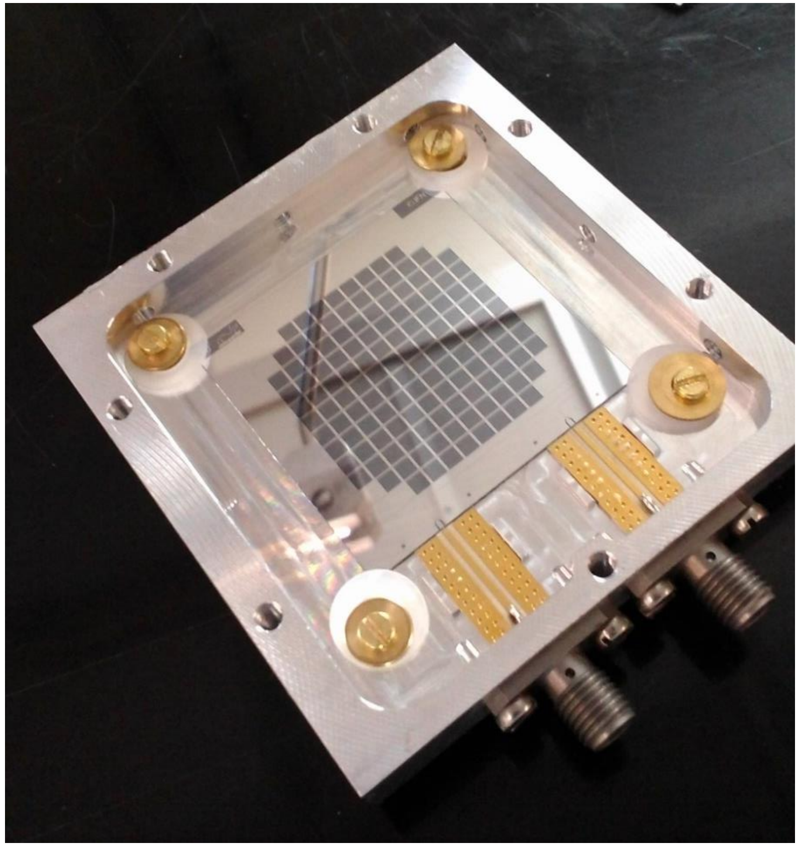


Design and fabrication of the first array (1)



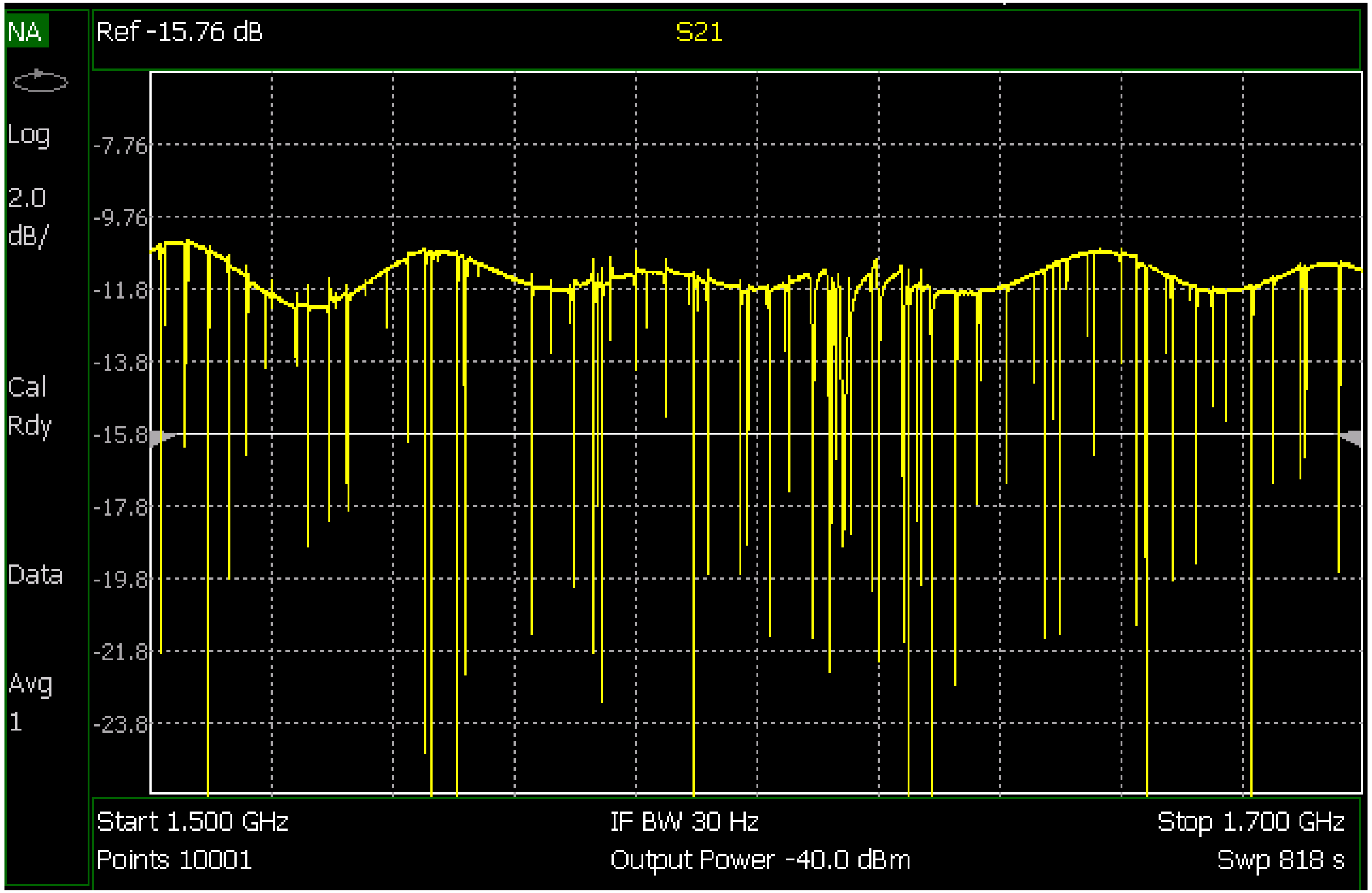
Design and fabrication of the first array (2)





150 GHz array
(132 pixels)

Array characterisation

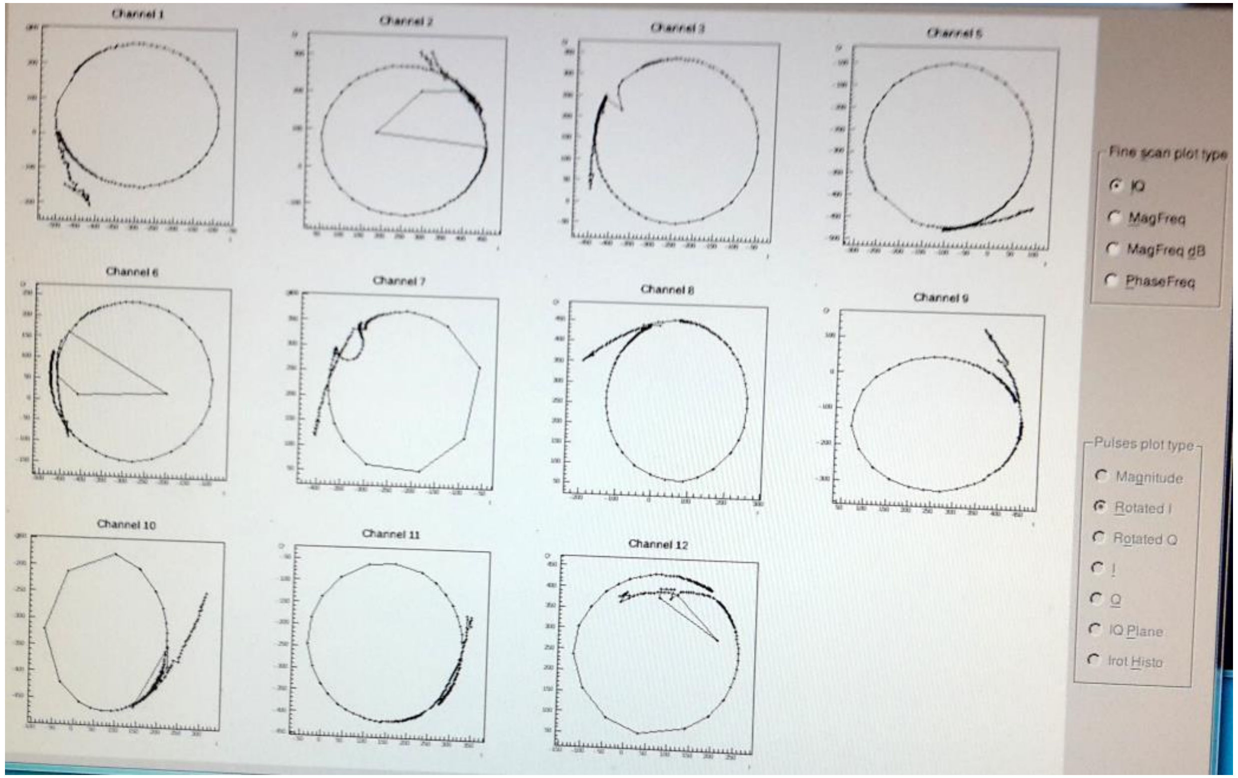


80 % of detectors inside the bandwodth

Q = (70 +/- 20) k

simulated Q_c= 90 k

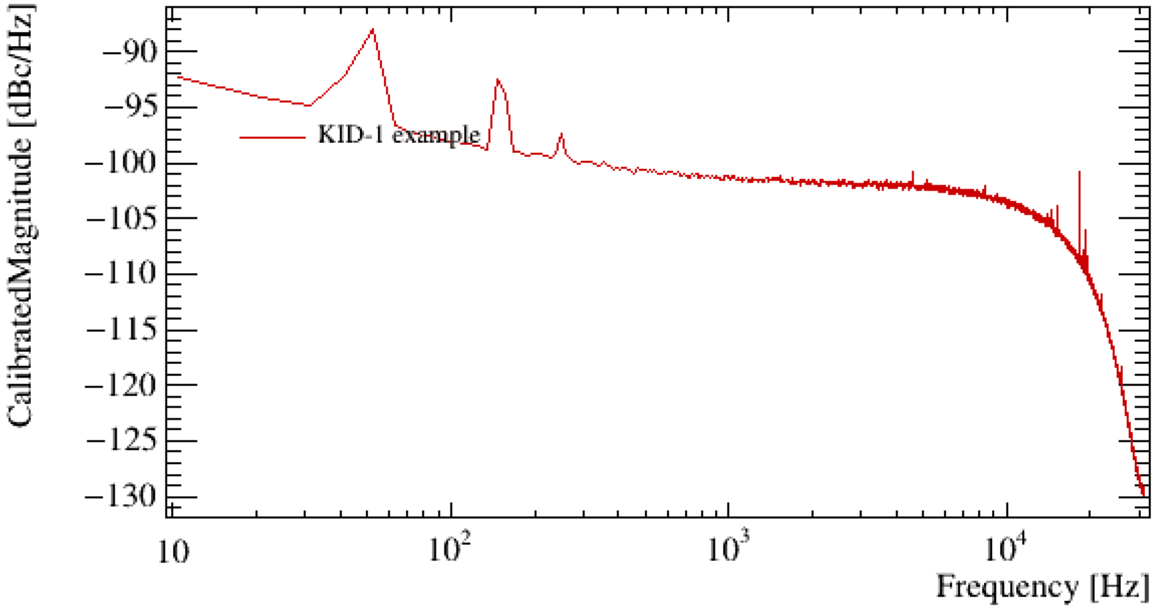
Array characterisation (2)

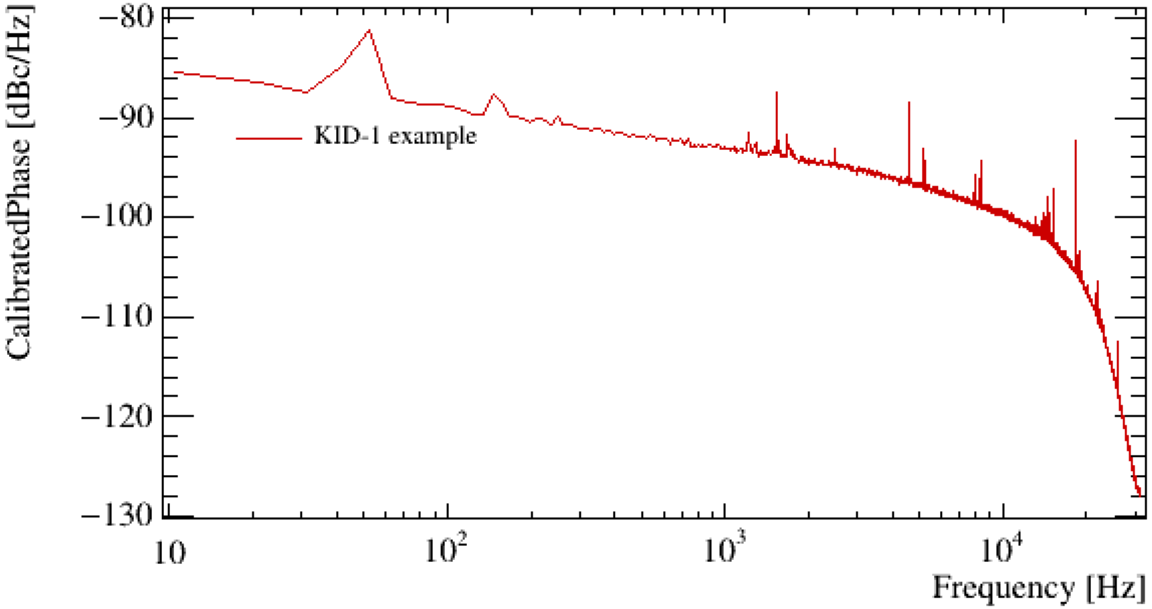


NIXA readout:
electronics board developed at LPSC (Grenoble)
100 MHz bandwidth, 80 channels @ 1kHz
12 channels @ 0.5-2 MHz

Bourrion, … Cruciani, et al, JINST 6 (2011) P06012

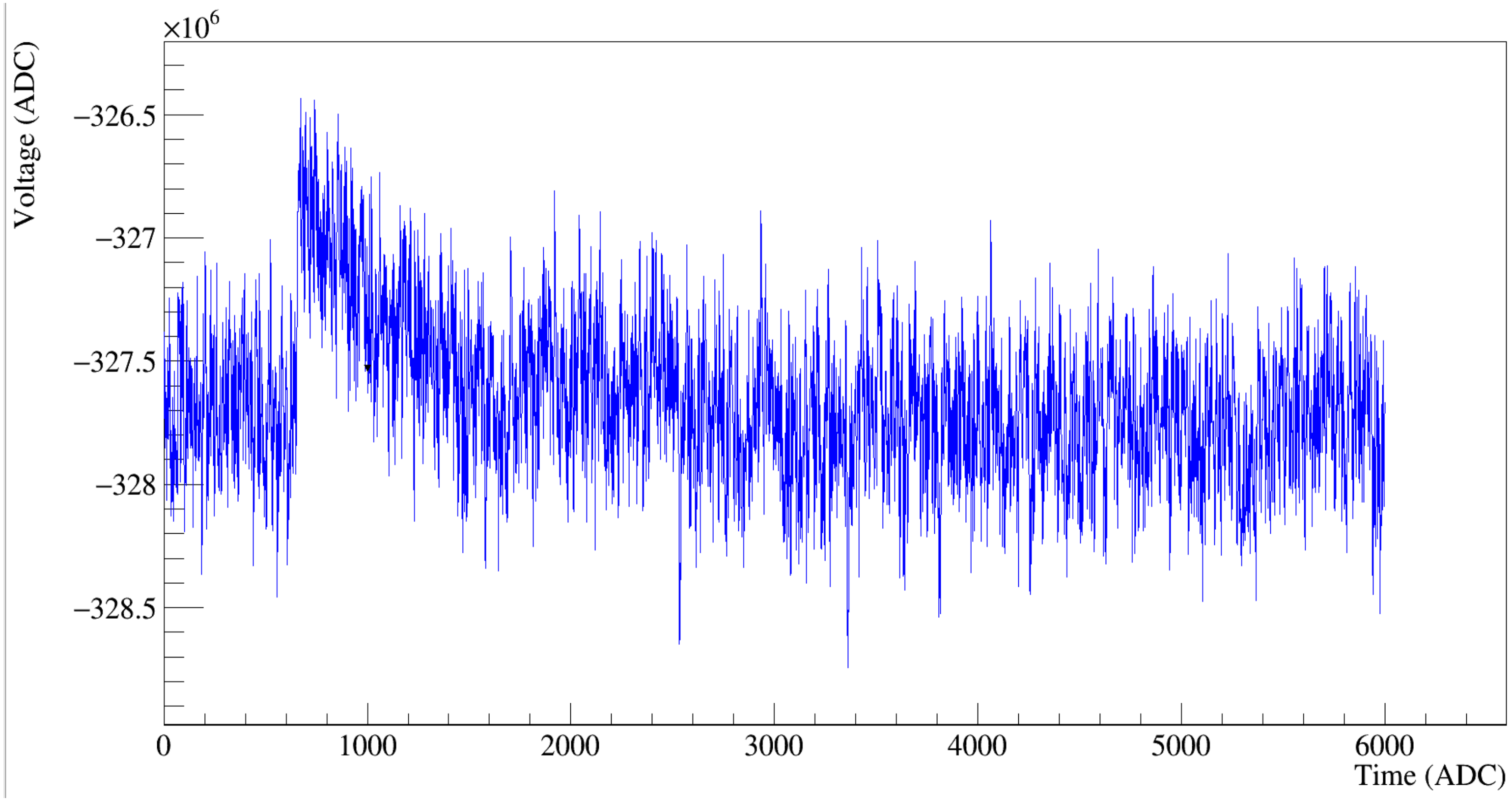
Array characterisation (3) Noise spectrum





Hints of the presence of TLS NOISE

Mm-wave signal



About 50 fW signal

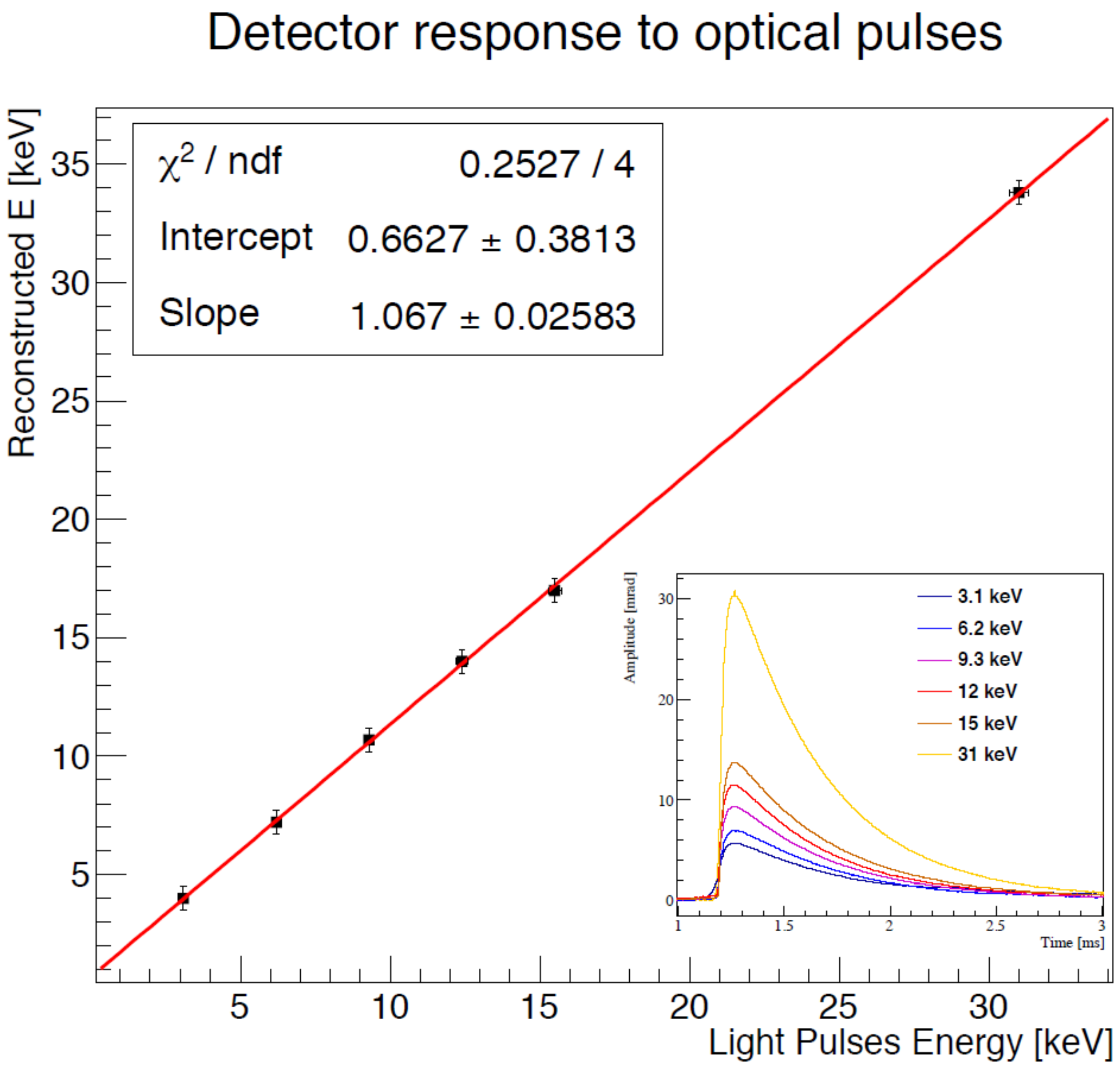
NEP is of the order of 10^{-17} W/Hz$^{0.5}$

Next steps

- Array improvements (better resonance spacing and Q dispersion)
- Cosmic ray test
- Realization of detectors using membranes and different GPs

BACK-UP SLIDES

CALDER synergy (3)



Detectors are illuminated using a 400 nm fast LED at 293 K, coupled with an optical fiber.

Pulses can be generated with energies down to few tens eV and duration < us

Cruciani et al, JLTP (2016)