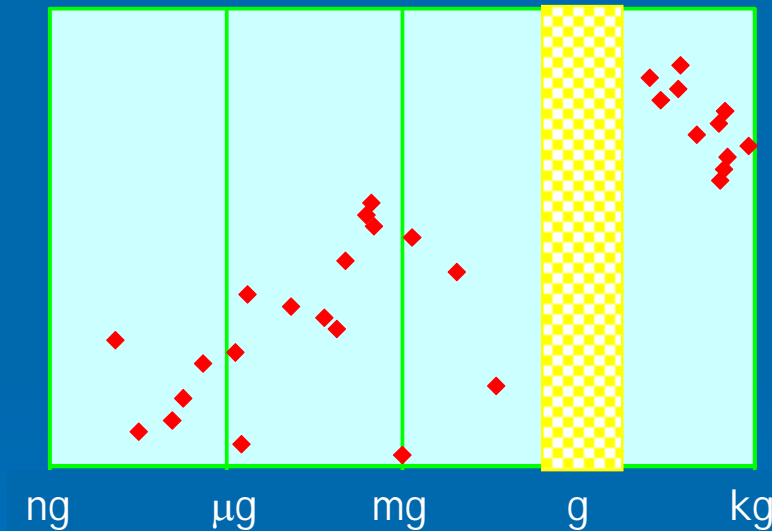


# Science and Technology of Large Mass Bolometer Arrays



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How to define Large Mass Bolometers



Arrays: more than 10 identical channels

Many differences, but also many common aspects

# Searches for Rare Events

(Double Beta Decay, Dark Matter, Axions)



## Main requirements:

- ☐ Large mass
- ☐ Low Background
- ☐ High energy resolution
- ☐ Low threshold
- ☐ High efficiency
- ☐ Long measuring time



LTD's

- + vast material choice
- + high energy sensitivity
- + calorimetric approach
- + possible double readout
- + **LARGE MASS (ARRAYS)**
- slowness (in some cases)
- cost
- operation difficulties
- dead time (duty cycle)

# Practical requirements

Technological aspects to be fulfilled



**Material selection and background reduction**  $\neq$  physics  $\rightarrow \neq$  goals

**Detector design** Optimizing it, taking care also of the other requirements

**Array design and assembly**

**Reproducibility** a MUST if you work with arrays

**Vibrational noise reduction** Cryostats are not a "silent world"

**Readout** for a big number of channels

**Cryogenics** Cooling down large masses

**Long term (years) stability and high duty-cycle**  
must compete with "standard techniques"

# Background reduction



## Where does it come from ?

- ❖ Cosmic ray interactions and induced activities
- ❖ Environmental radiation
- ❖ Residual impurities in the construction materials
- ❖ Radon and its progenies
- ❖ Neutrons from environmental radioactivity

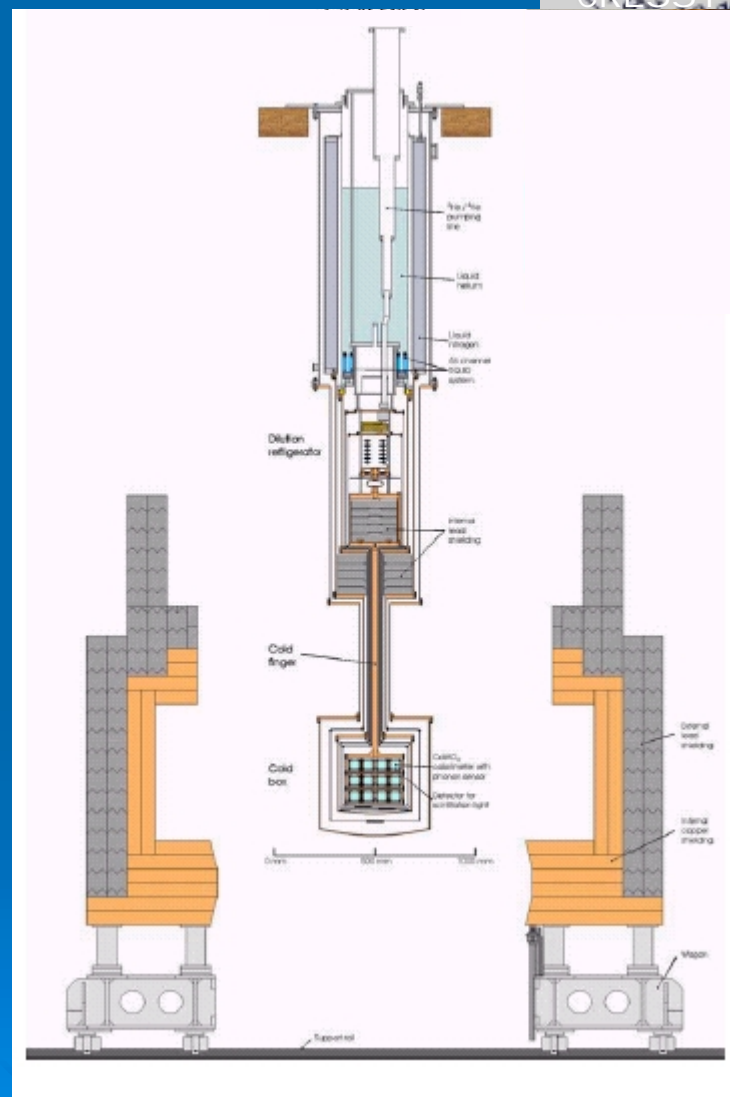
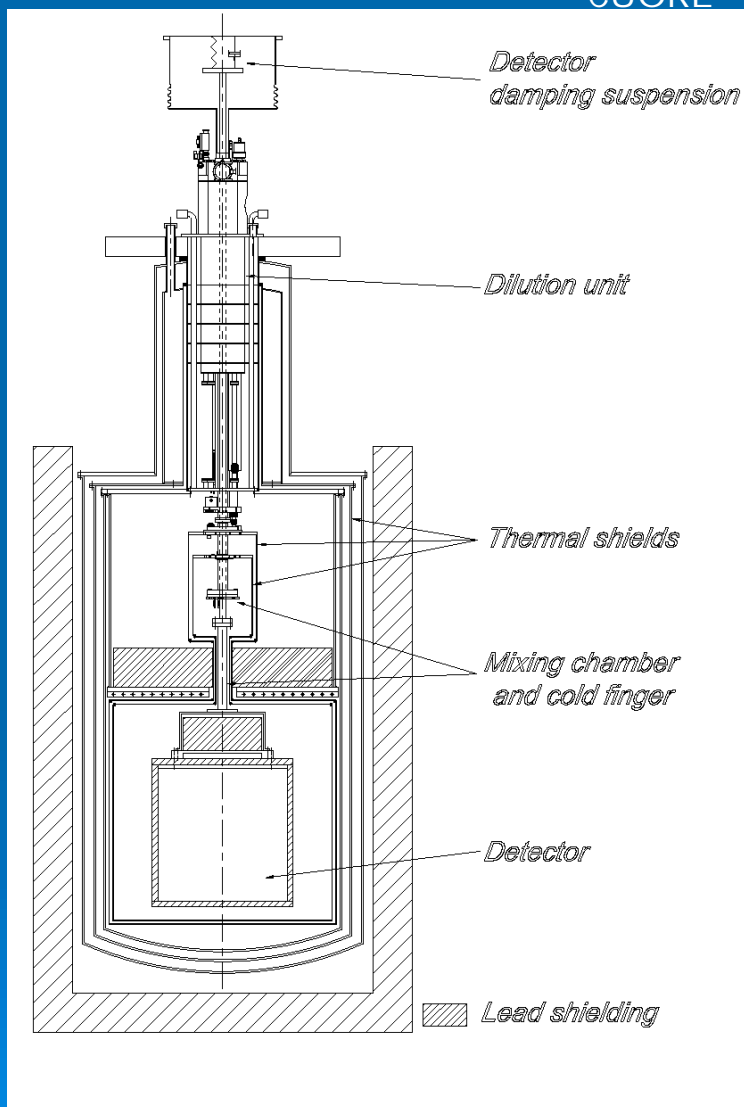
## How to get rid of it ?

- ☐ Deep underground laboratories      also to store materials!
- ☐ Passive and active shieldings
- ☐ Material choice and treatment (  $\alpha$  ! )
- ☐ Background identification      If different from the expected signal

# Cryostats and shieldings



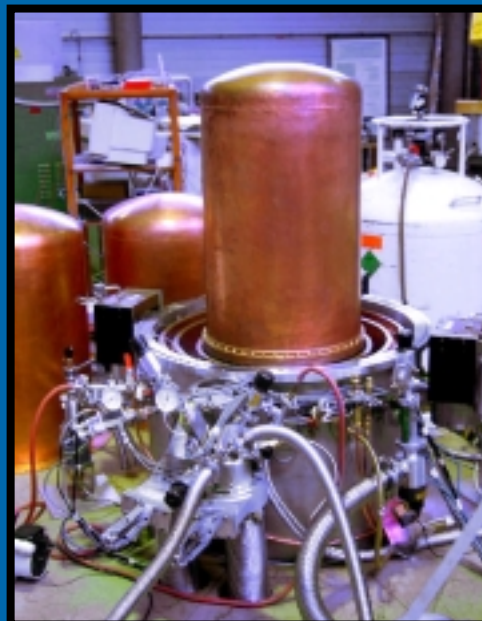
CUORE



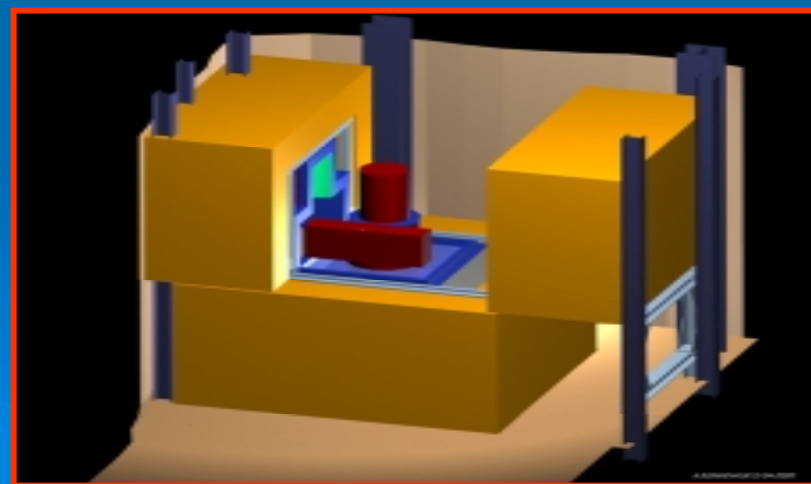
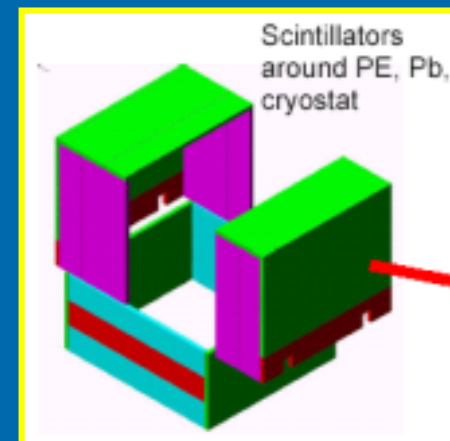
# Cryostats and shieldings



CDMS:  
a lateral ICE BOX



EDELWEISS  
A reverse cryostat





# Surface treatments



Tumbling

Electro-polishing

Chemical etching

Plasma sputtering

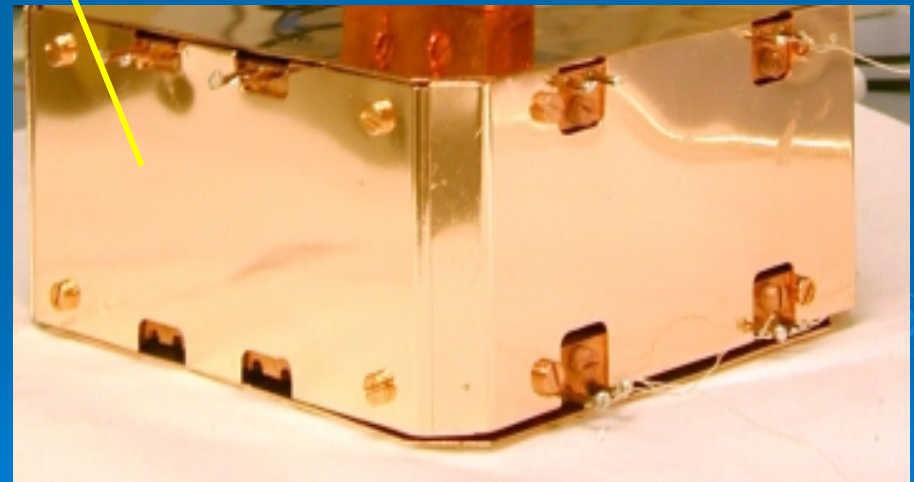
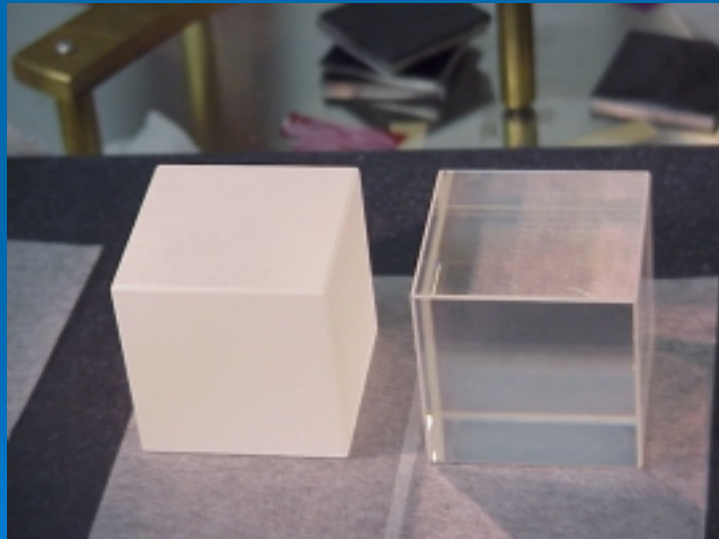
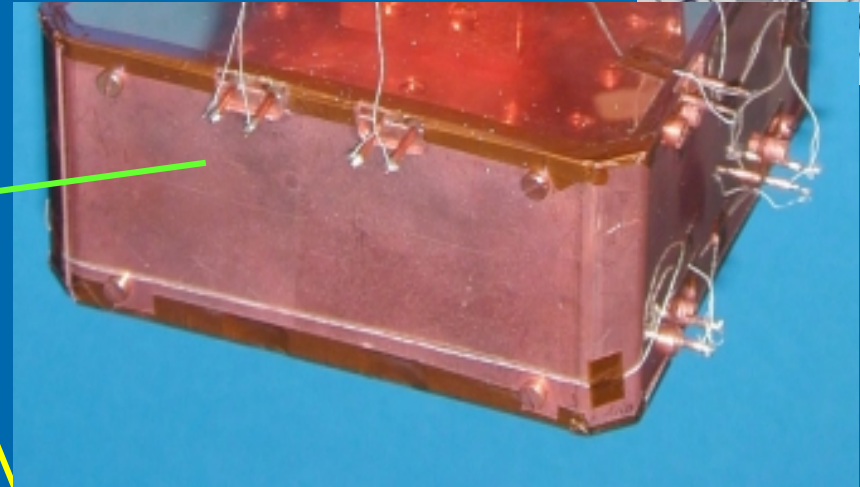
Ion-gun cleaning

He conditioning

Lapping and polishing

Chemical Etching

Ion-gun sputtering

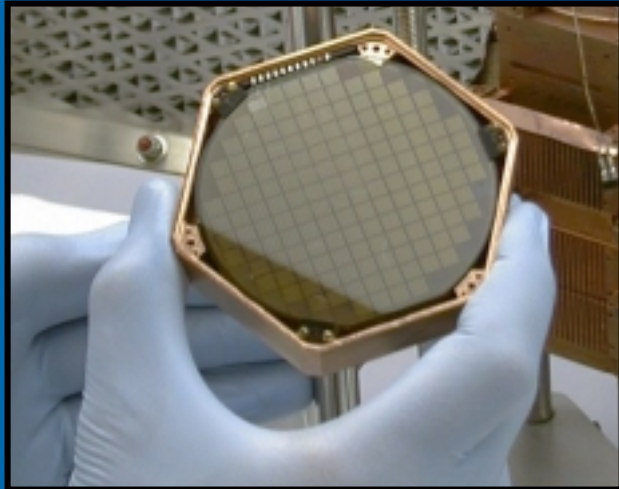


WHENEVER YOU USE SOME MATERIAL TO CLEAN, IT HAS TO BE EXTREMELY PURE

# Detector designs



CDMS

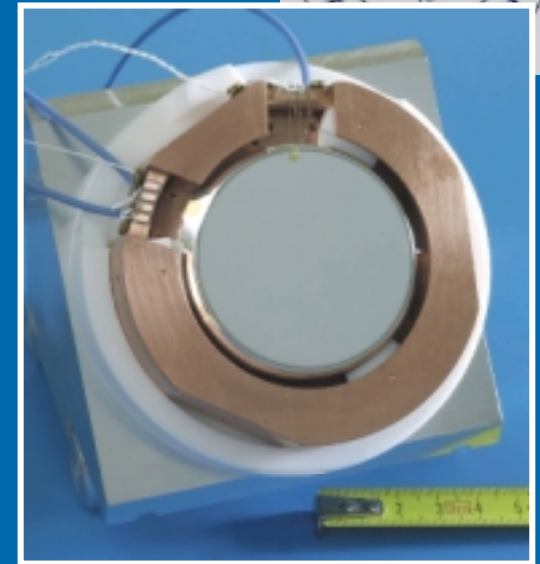


TES sensors  
or NTD thermistors

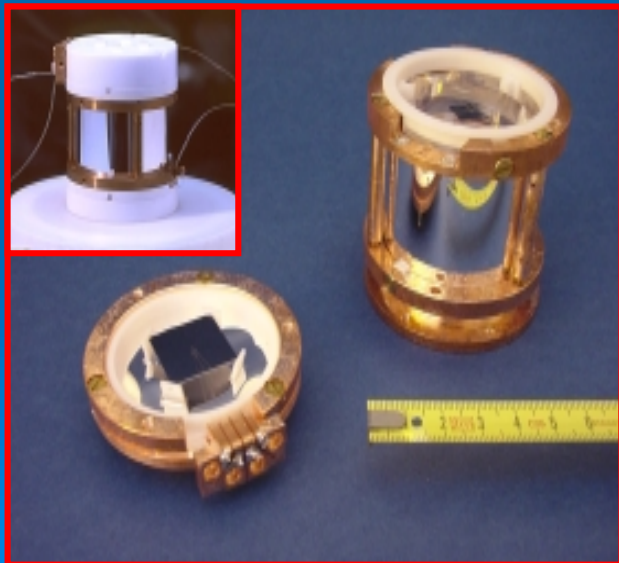
ionization or scintillation

stack of individual detectors  
or single segmented bolometer

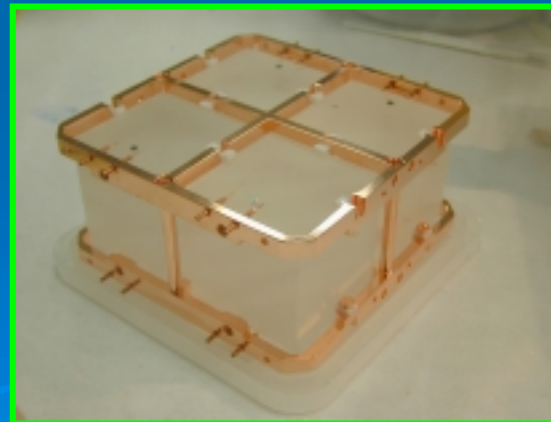
copper and teflon  
small conductance to heat sink  
good thermal contact S-A



CRESST



CUORICINO

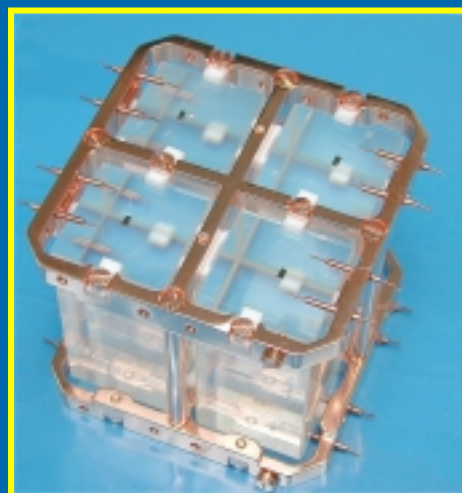
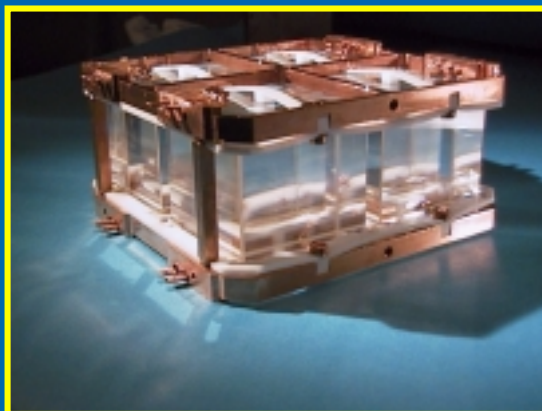




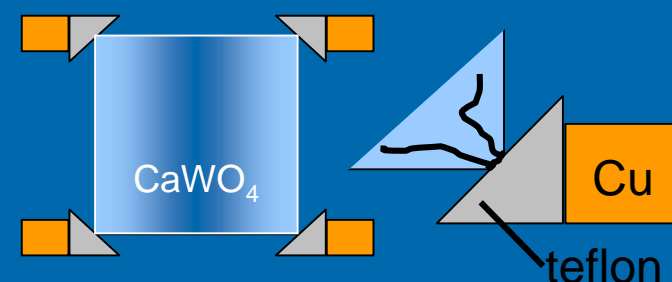
# Detector mounting evolution



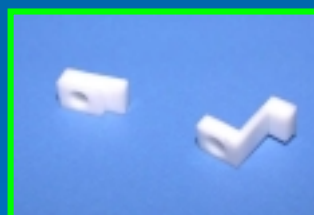
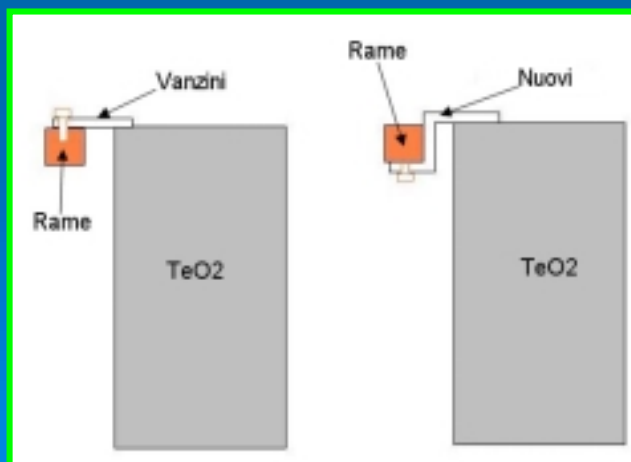
Even if the basic idea remains the same, there still are changes



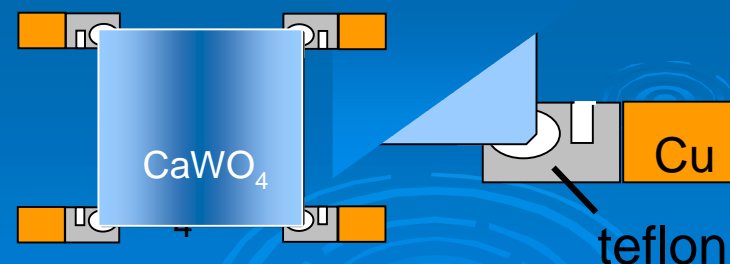
CRESST



CUORICINO



new design:



# Array structures (present)

MI BETA-II



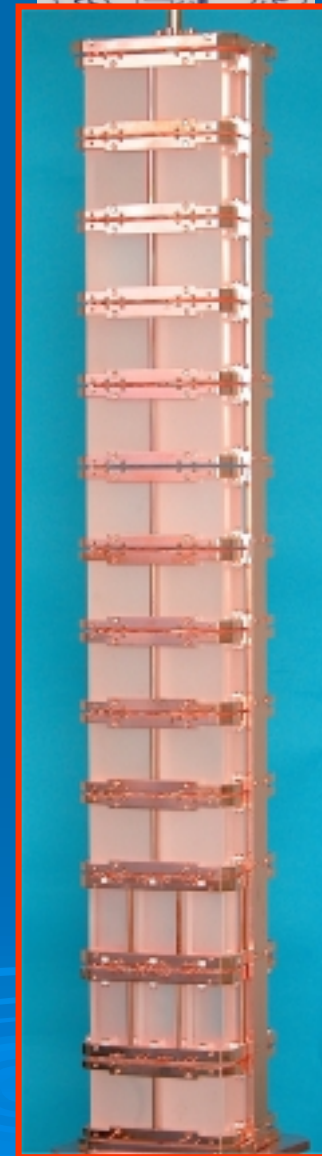
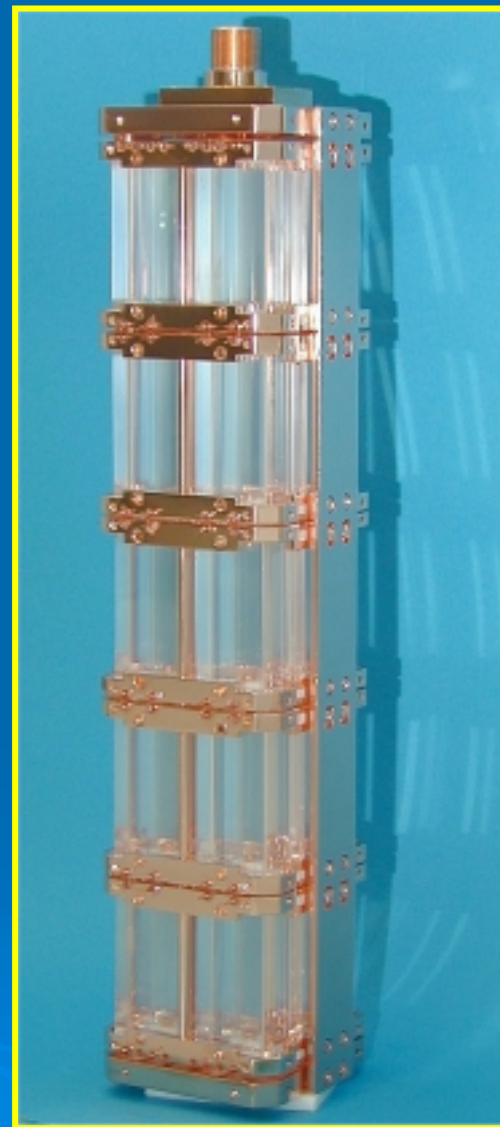
Modularity

Optimization for  
(anti)coincidence techniques

CDMS



Edelweiss

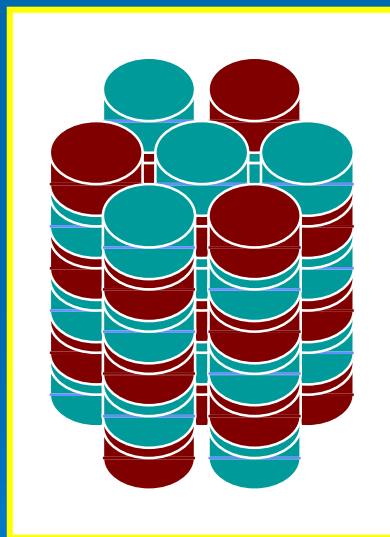


# Array structures (future)

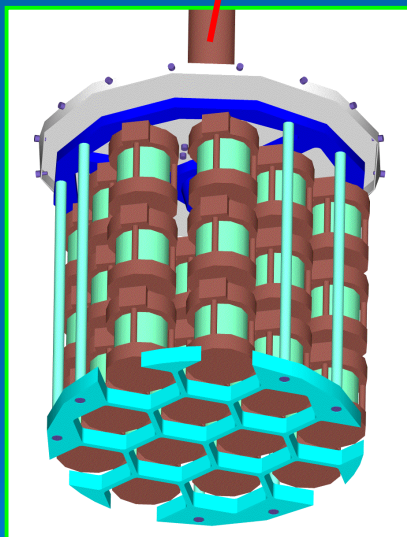


Hanging or standing structures

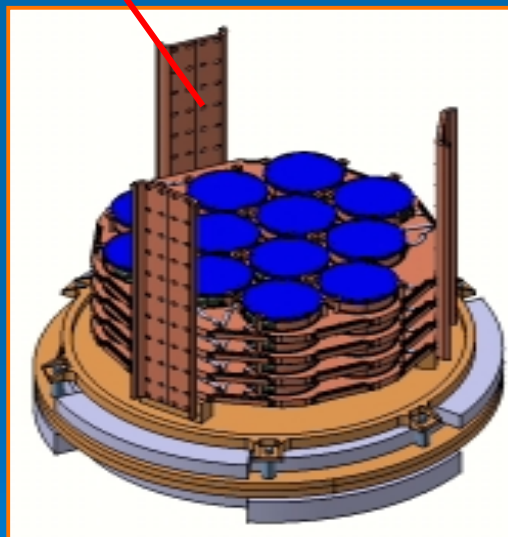
Compact designs



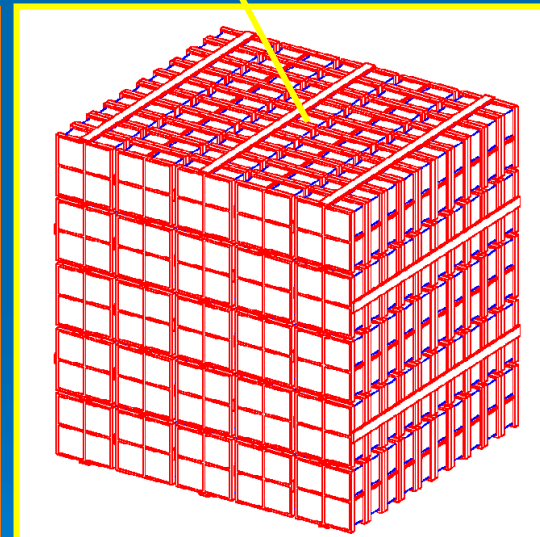
CDMS



CRESST



EDELWEISS



CUORE

A real single high-granularity segmented device!

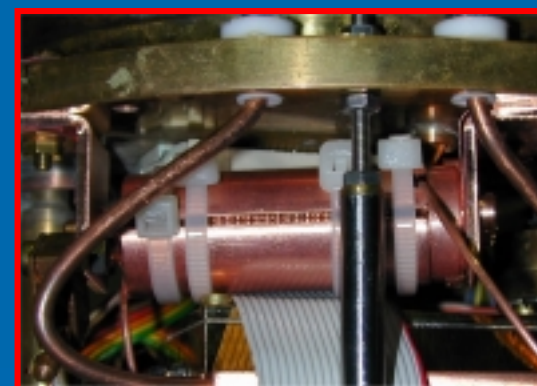
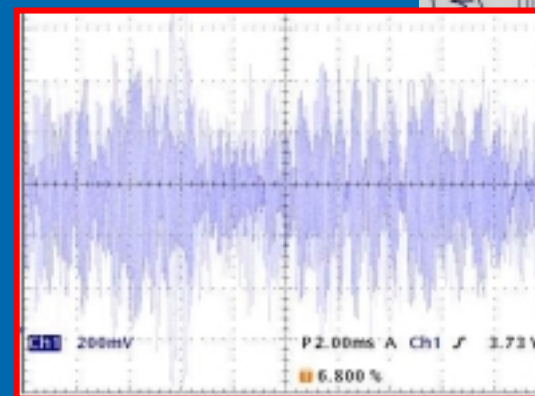
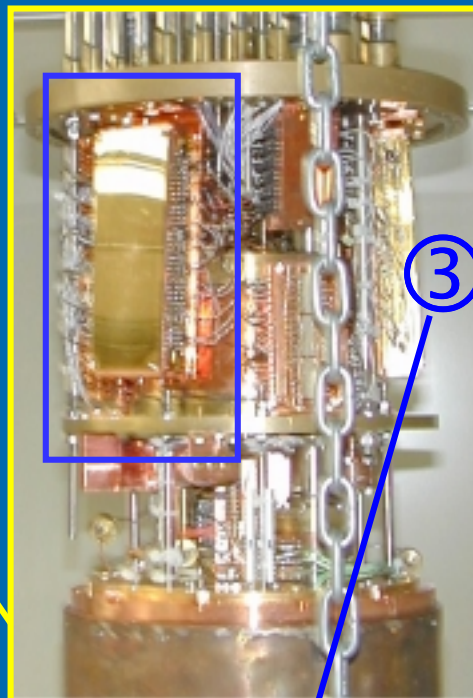
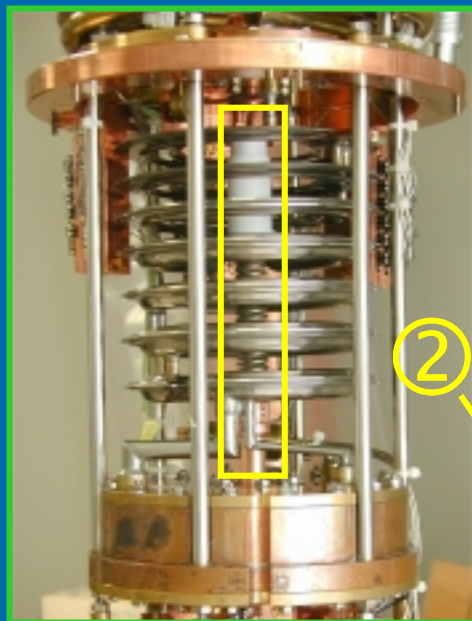


# Vibrational noise

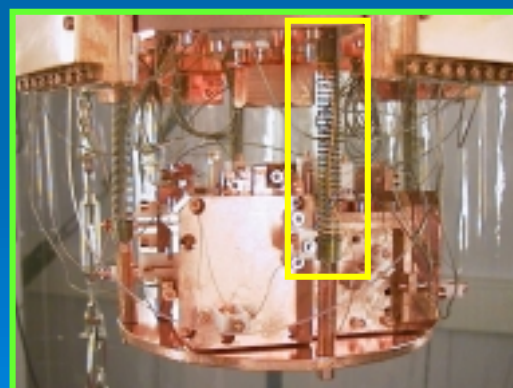
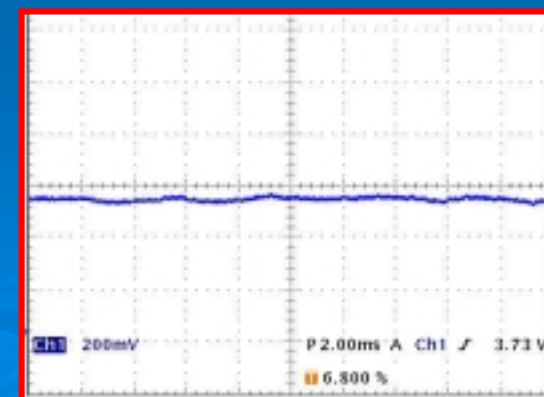
Poster G07



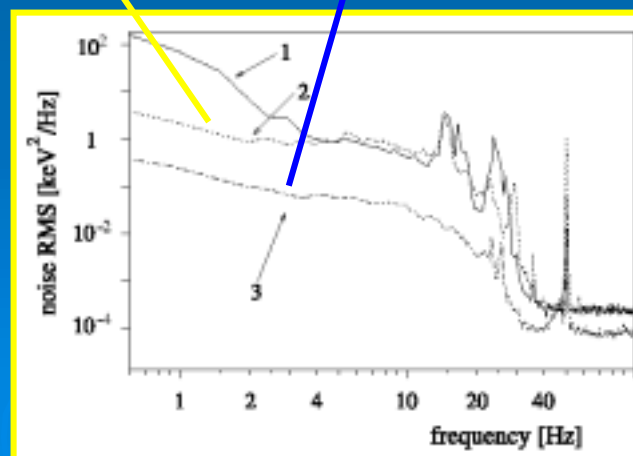
MI BETA-II



CUORICINO



CRESST



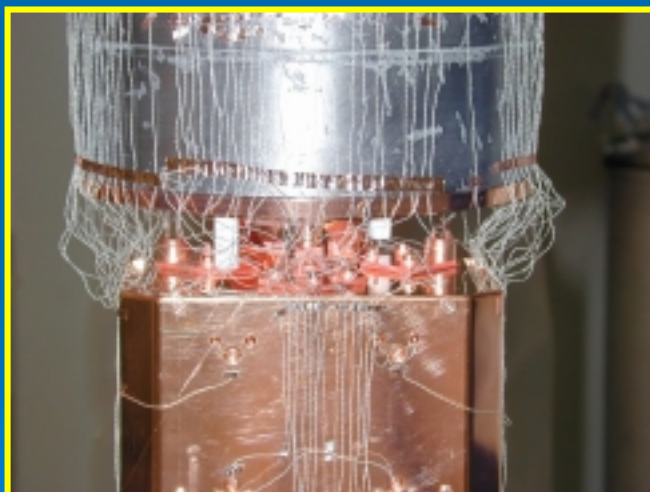
# Wiring

150 wires, 1500 solders...

Difficult to assemble so many wires in a clean environment!

Material choice always critical from a thermal and from a radioactive point of view

CUORICINO



CUORICINO



CRESST-II



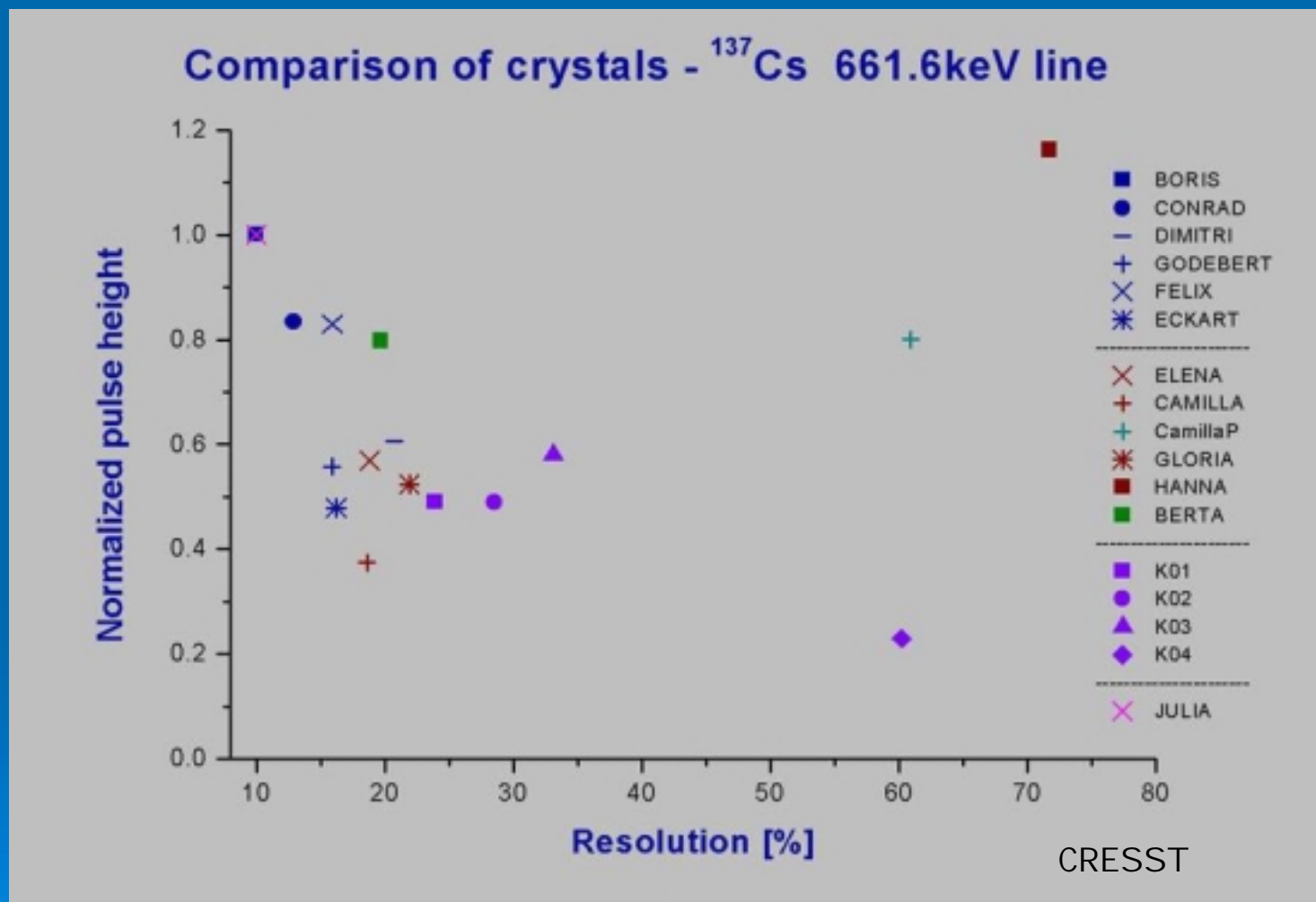
CDMS-II

Heat load, SQUIDS, multiplexing...



# Reproducibility

STILL FAR TO BE REALLY UNDER CONTROL



# 100-1000 kg COOLDOWN...



## MIBETA - II



## MIBETA-II

Cooling down of large Cu mass: H-problem

↳ 1 month drift before base temperature

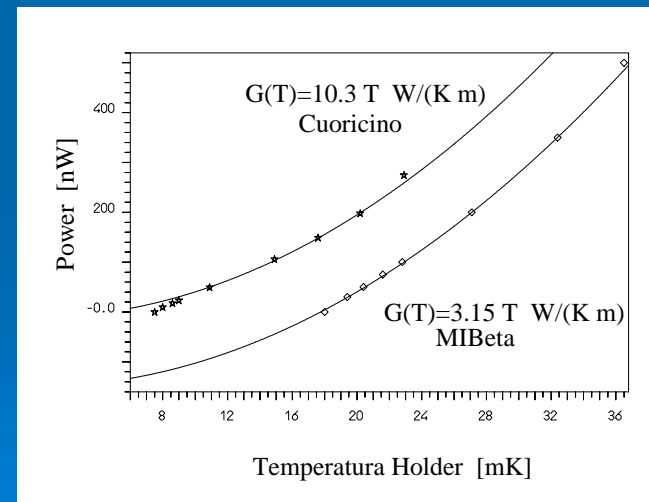
## CUORICINO

Better copper thermalization +

Cooldown stopped at around 20 Kelvin for 2 days.



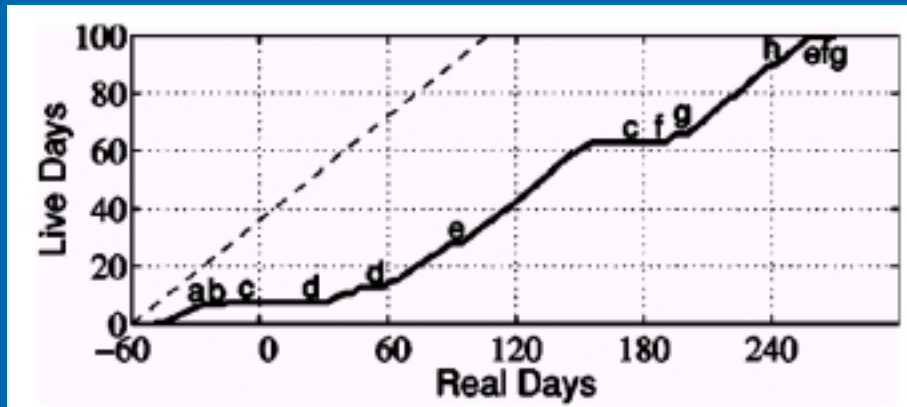
Detectors quickly at base temperature and no more annoying drift of the operating points.



TON MASSES WILL REQUIRE EVEN MORE STUDIES, ON THE BASIS OF G. A. KNOW-HOW

# Live Time vs Real Time

To be really competitive with the “conventional” techniques, L.T. must as high as possible



Best LT/RT = 60%, AVE = 30%

CDMS

## Cryogenic setup

- maintenance stops
- accidental stops

... long recovery times

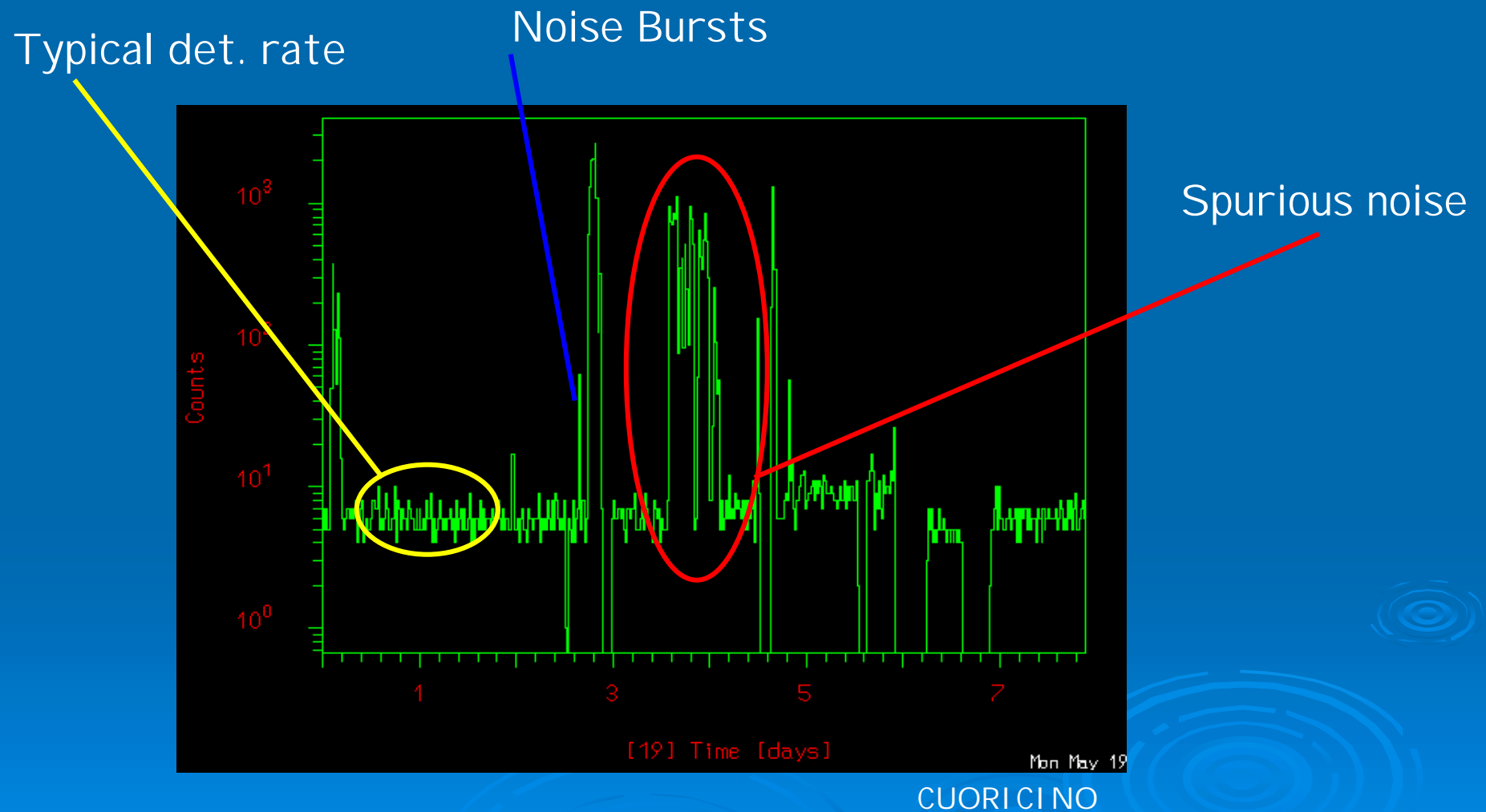
( 1-2 months if warmed up)

## To fight against all this

- ➔ Highly reliable electronics and data acquisition
- ➔ Cryogenic system regular maintenance
- ➔ System spares
- ➔ Avoid refillings
- ➔ Optimize calibration sources and efficiencies
- ➔ Eliminate spurious noises

# Noise

In many cases a stable trigger rate with bolometers is just a wonderful dream



# Response instabilities

Cryogenic apparatus exhibits intrinsic instabilities which affect detector behavior

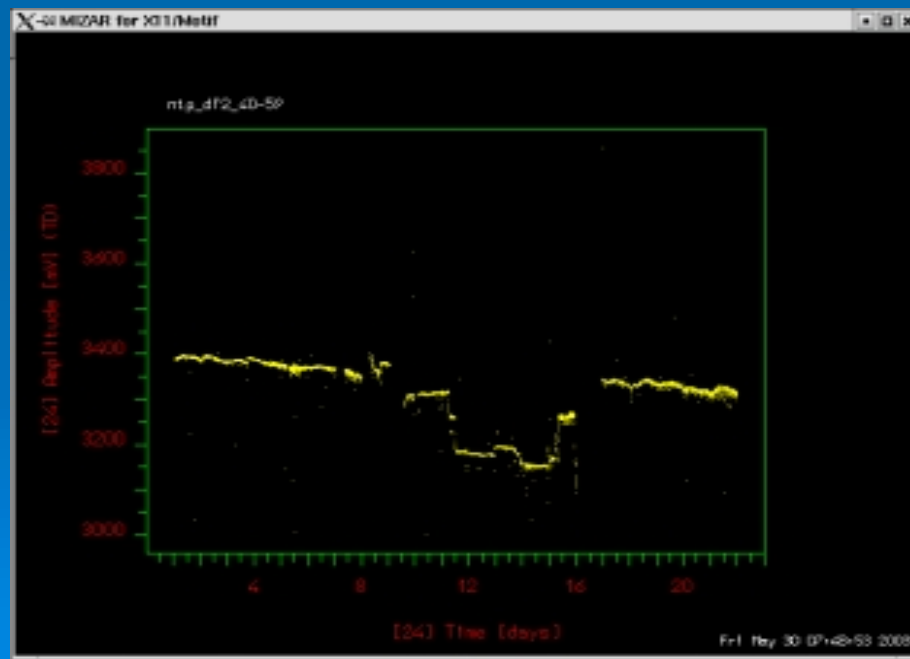


Different techniques foreseen

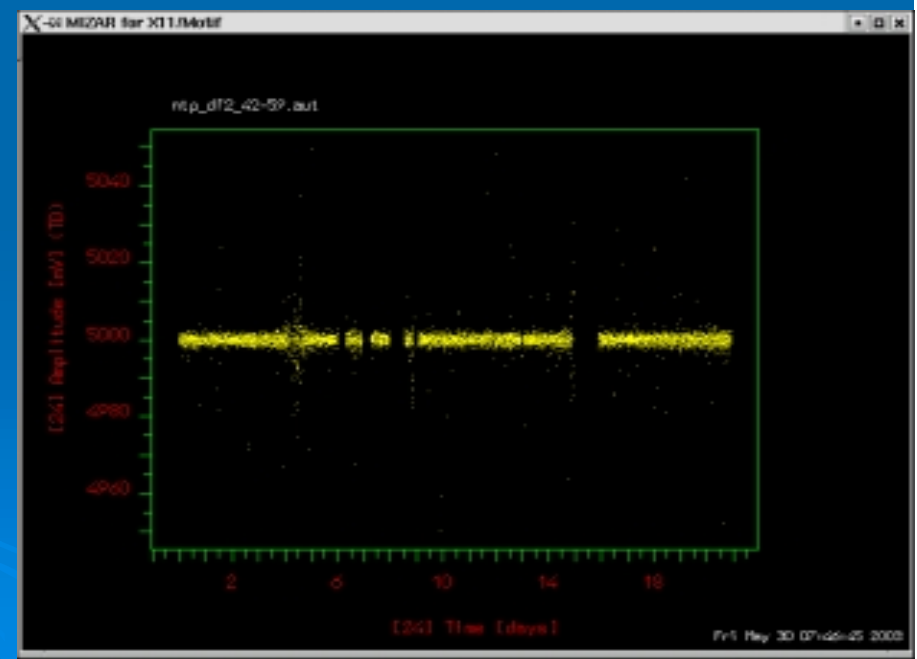
- ☐ heater
- ☐ optical fiber pulser
- ☐ radioactive sources

$\Delta V \sim 10 \%$

CUORICINO



$\Delta V \sim 0.1 \%$





MIZAR for X11/Motif

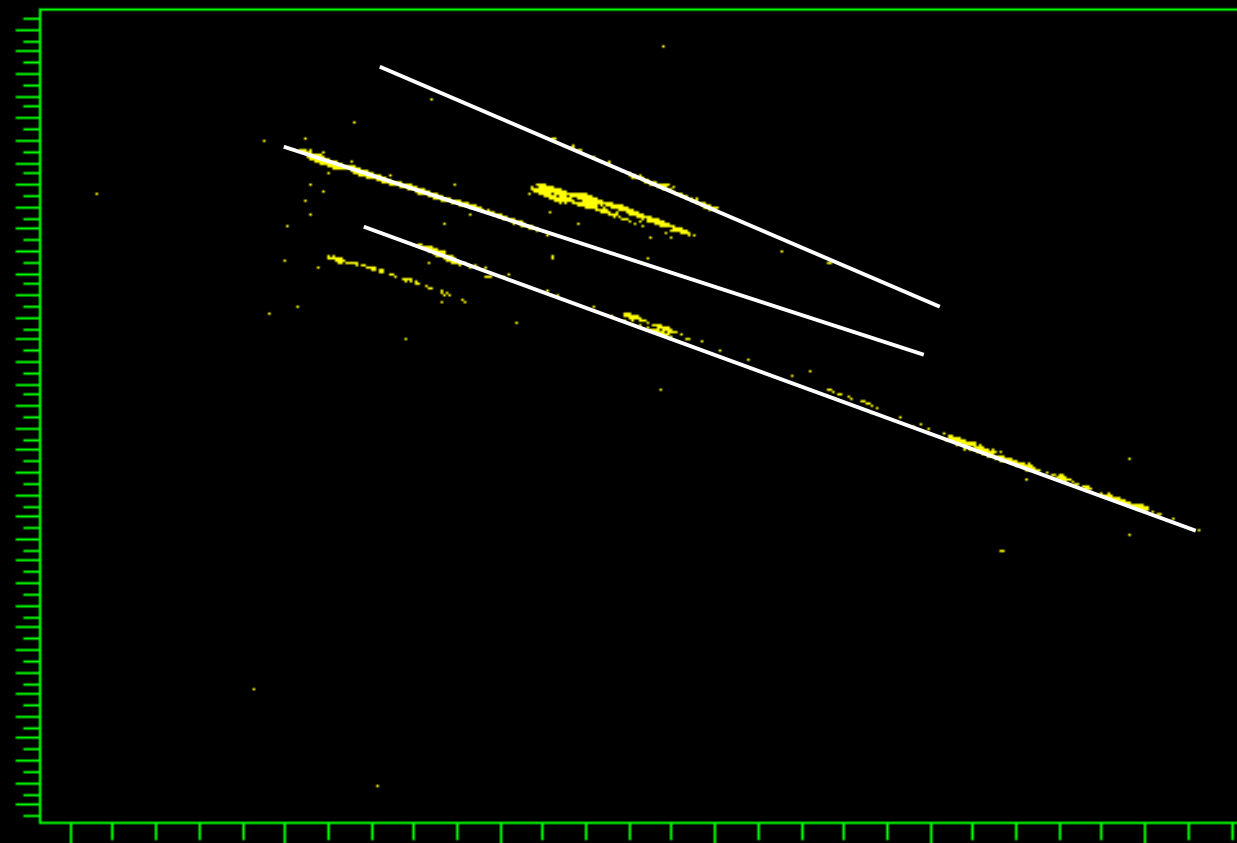
MIZAR for X11/Motif

Arbitrary Units  
0.10  
0.08  
0.06  
0.04  
0.02  
-0.0

[111] Amplitude [mV] (TD)

ntp\_df2\_40-59

4140  
4100  
4060  
4020  
3980  
3940  
3900  
3860  
3820



0.3

0.5

0.7

[111] Baseline value [V]

Fri May 30