A new method for background rejection with surface sensitive bolometers

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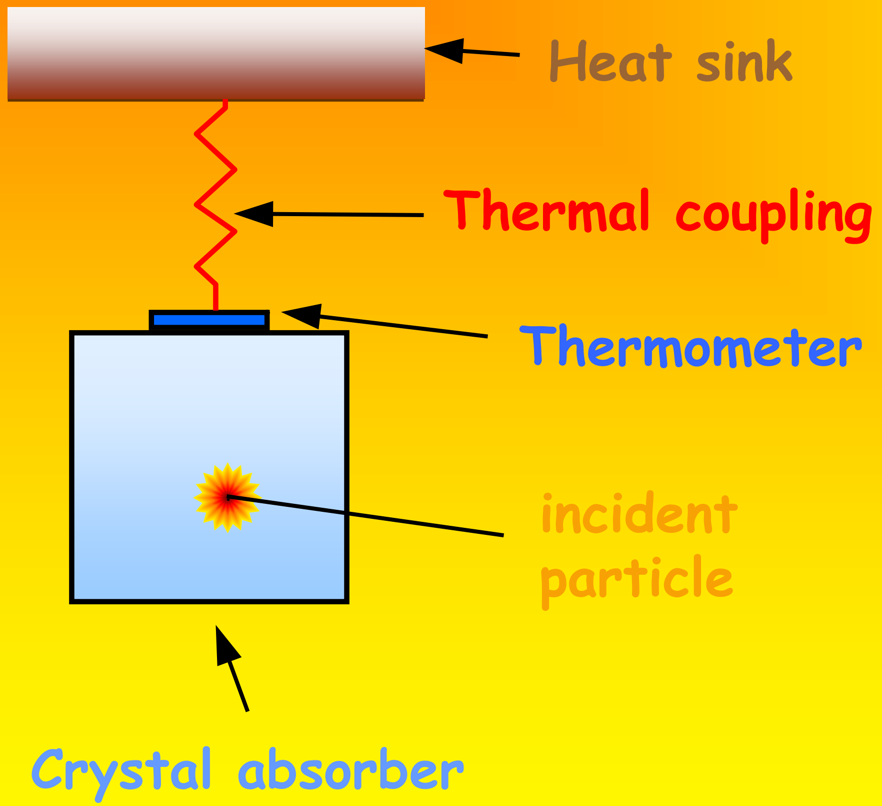
On behalf of the CUORE Collaboration

Basic principle of bolometric technique

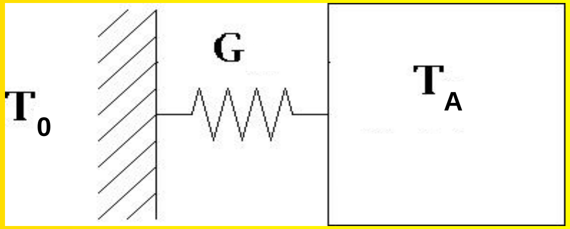
The original idea is very simple:



This technique measures **all** the energy deposited by particle in form of increase of temperature in the absorber

↓

Absorber ≡ DBD source



Signal: $\Delta T = E/C$

Time constant $= C/G$

Low heat capacity
- Low temperatures
- Dielectric diamagnetic materials

Basic principle of bolometric technique

BUT…

Drawback of the calorimetric mode:

- ✓ Only the deposited energy is measured
- ✓ No additional information on the nature of the event

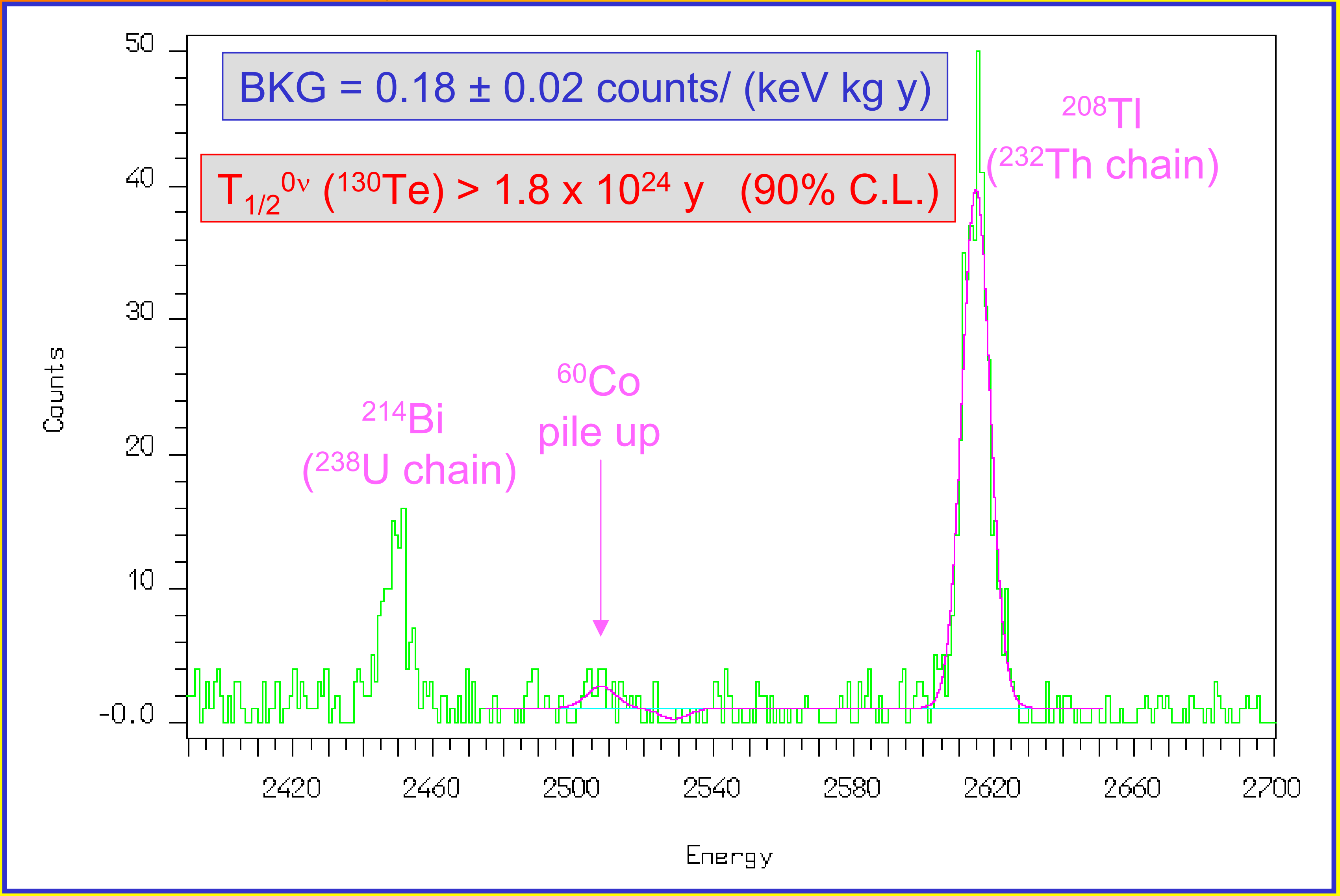
Studying the **dynamics of the heat flow** in the detector:

Information on the particle impact point

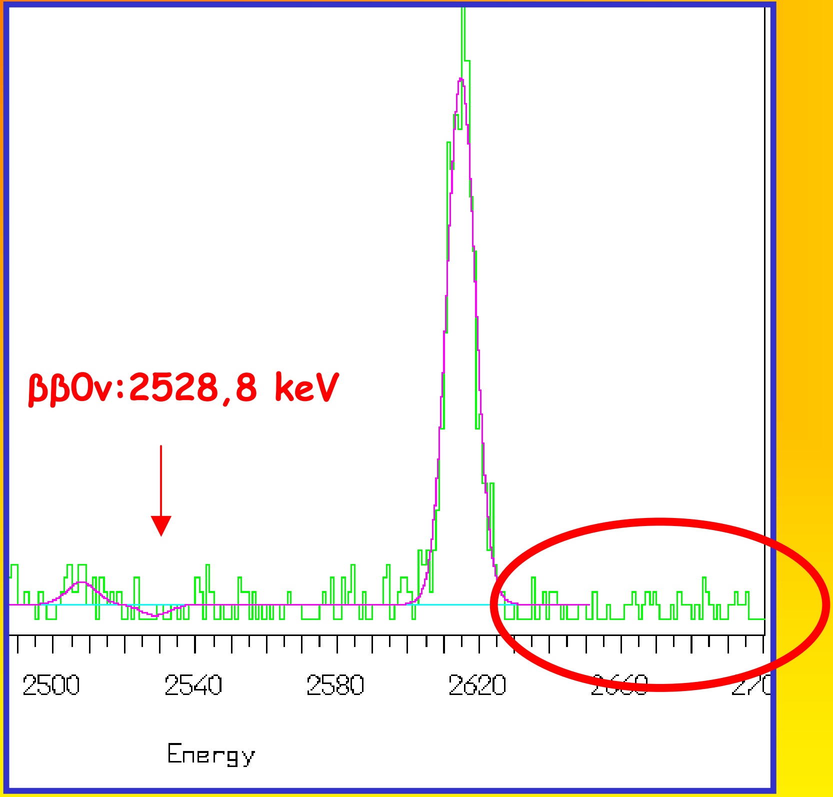
a new technique for an active background discrimination

Cuoricino results

Background sum spectrum of all the detectors in the DBD region



Cuoricino results



50% of bkg in ββ region

^{238}U e ^{232}Th on Cu surface

The continuum above the natural radioactivity region can extend down to the region relevant for ββ search of ^{130}Te

Main warning: surface contaminations of Th or U that emit degraded α and β particles releasing their energy on the detectors

Surface sensitive bolometers

Main goal: understand the origin of the events

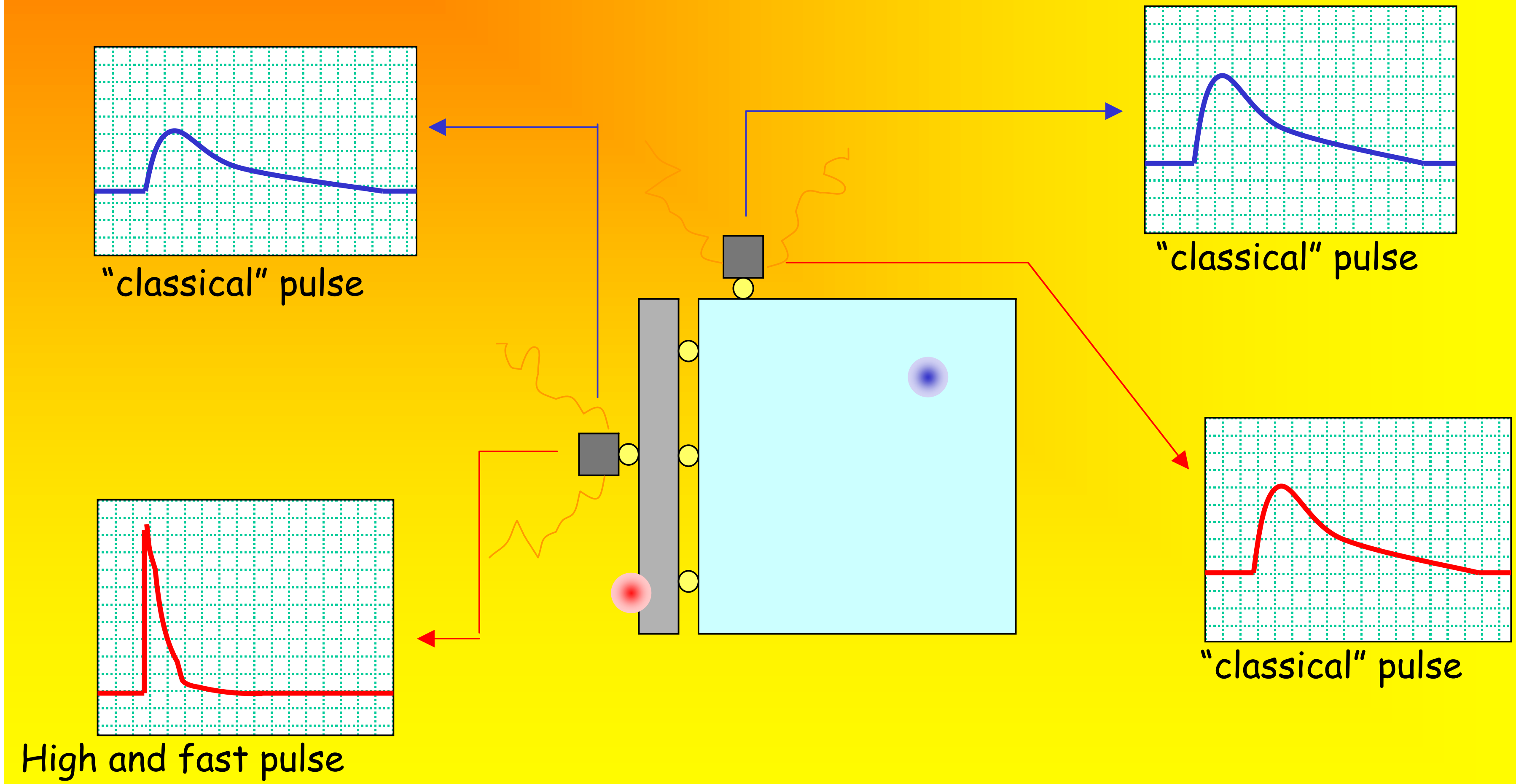
We know that other groups, such as the CDMS collaboration, have achieved this goal using **athermal phonons**

Given the structure of the CUORE experiment this approach is not possible.

We want to maintain the calorimetric read-out with **thermal phonons**

Surface sensitive bolometers

The main idea is to use an auxiliary bolometer to check the surface contamination.

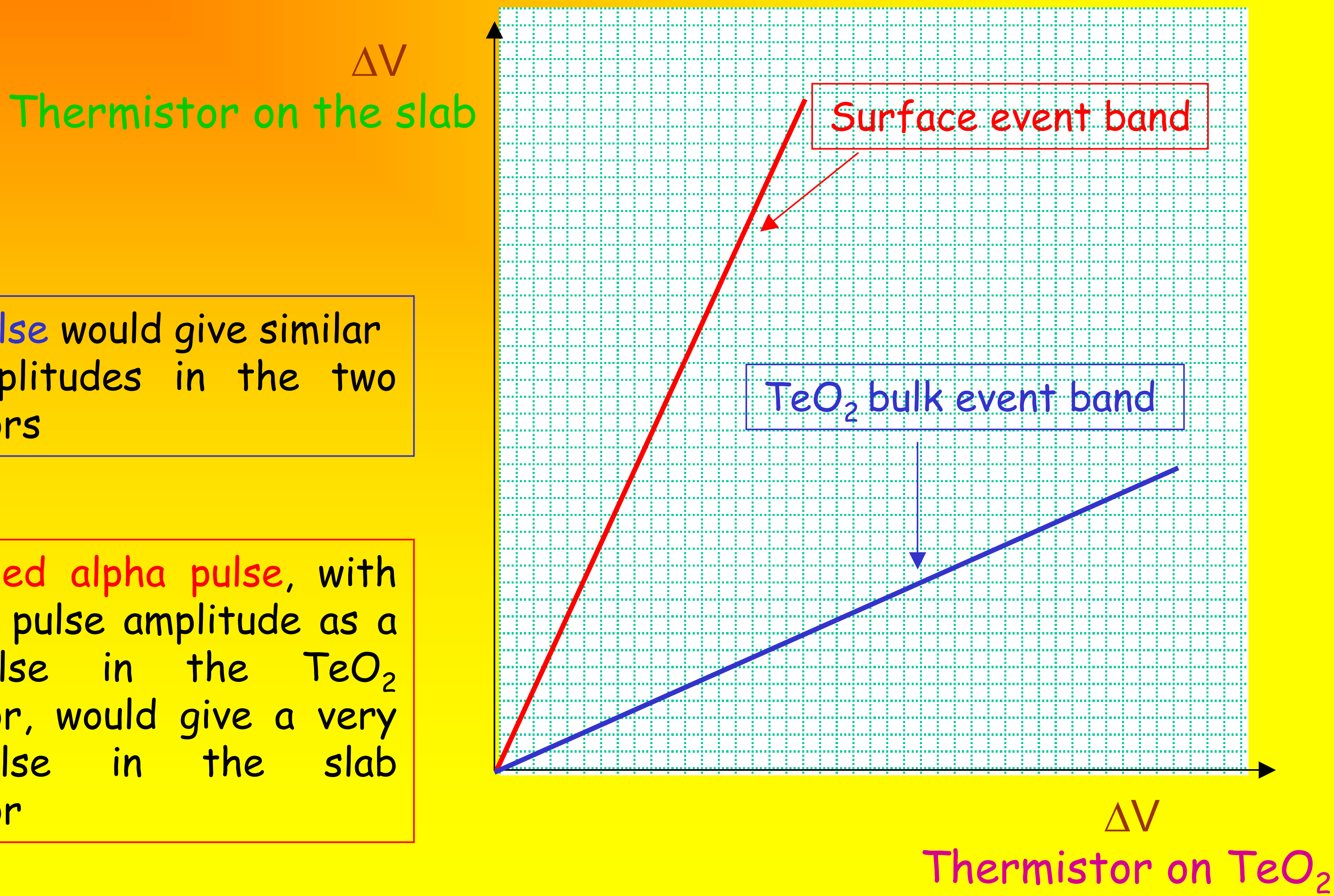


How surface events are identified (scatter plot)

Plotting pulse amplitude from the slab thermistor vs pulse amplitude from TeO_2 thermistor:

A DBD pulse would give similar pulse amplitudes in the two thermistors

A degraded alpha pulse, with the same pulse amplitude as a DBD pulse in the TeO_2 thermistor, would give a very high pulse in the slab thermistor



Surface Sensitive Bolometers at Insubria University

We have realized some prototype detectors using three different materials as active shields

High ultrapure germanium

Main absorber: $2x2x0.5\ cm^3$ TeO_2 crystal

Ge slab: $15x15x0.5\ mm^3$

NTDs: $3x1.5x1\ mm^3$, R_0= 2.65 Ω ; T_0= 7.8 K

High ultrapure silicon

Main absorber: $2x2x0.5\ cm^3$ TeO_2 crystal

Si slab: $15x15x0.3\ mm^3$

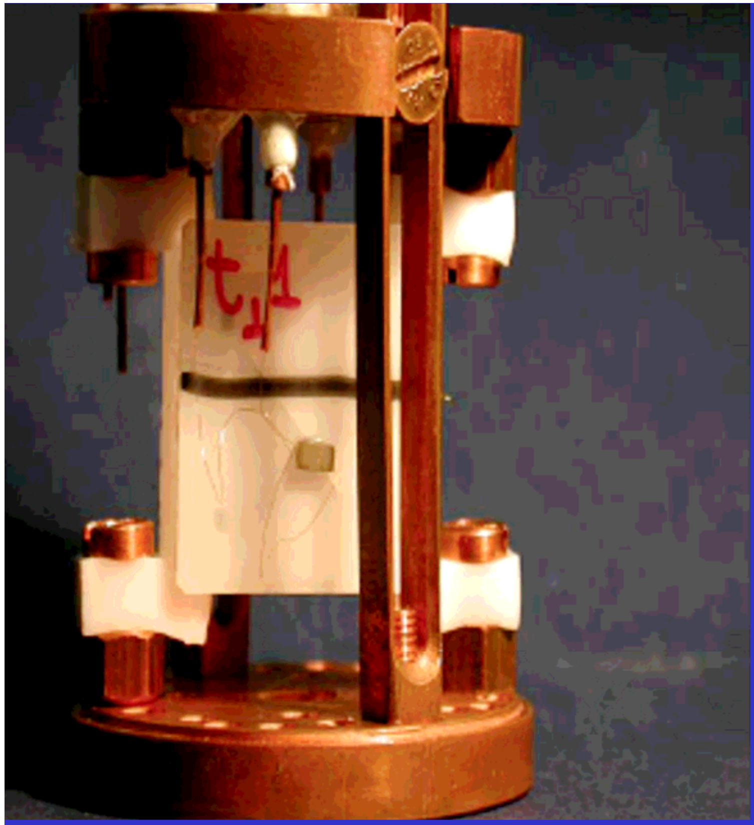
NTDs: $3x1.5x1\ mm^3$, R_0= 2.65 Ω ; T_0= 7.8 K

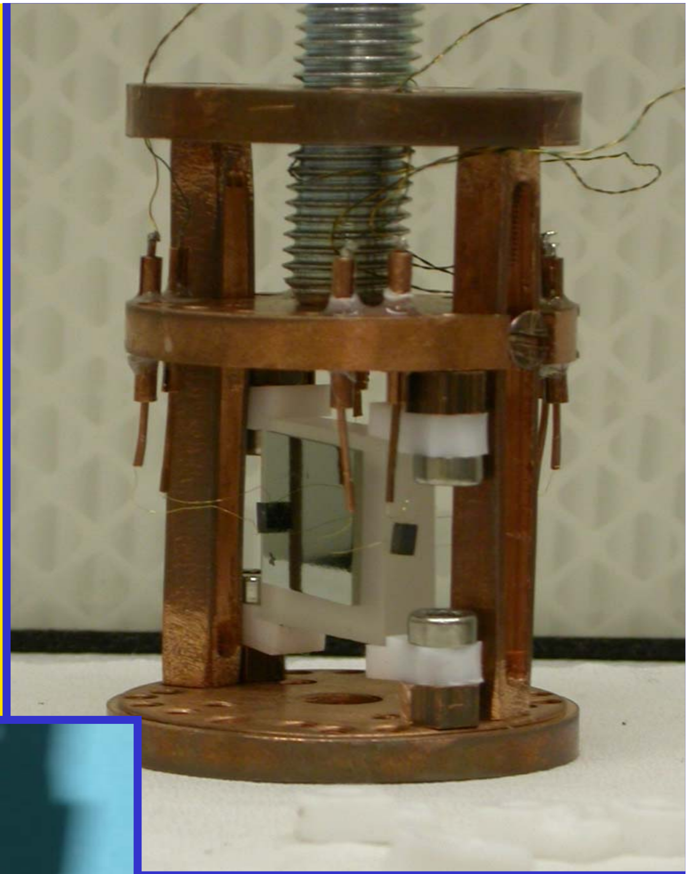
TeO_2

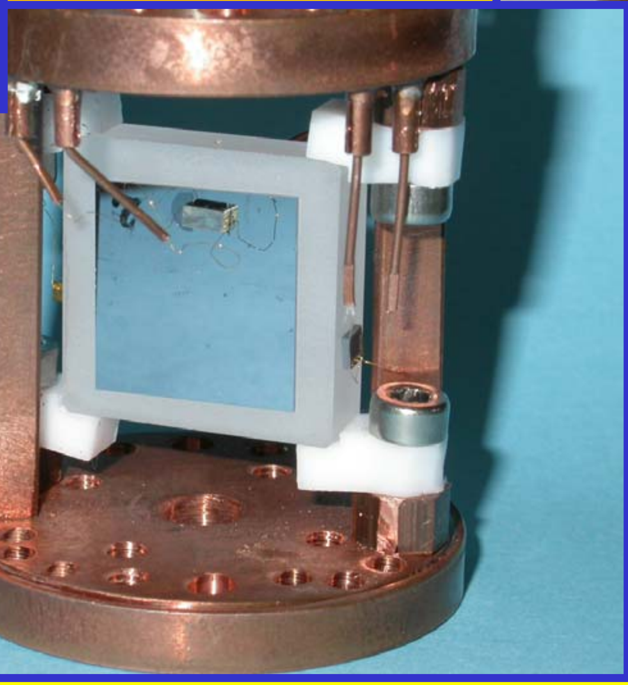
Main absorber: $2x2x0.5\ cm^3$ TeO_2 crystal

TeO_2 slab: $20x20x0.5\ mm^3$

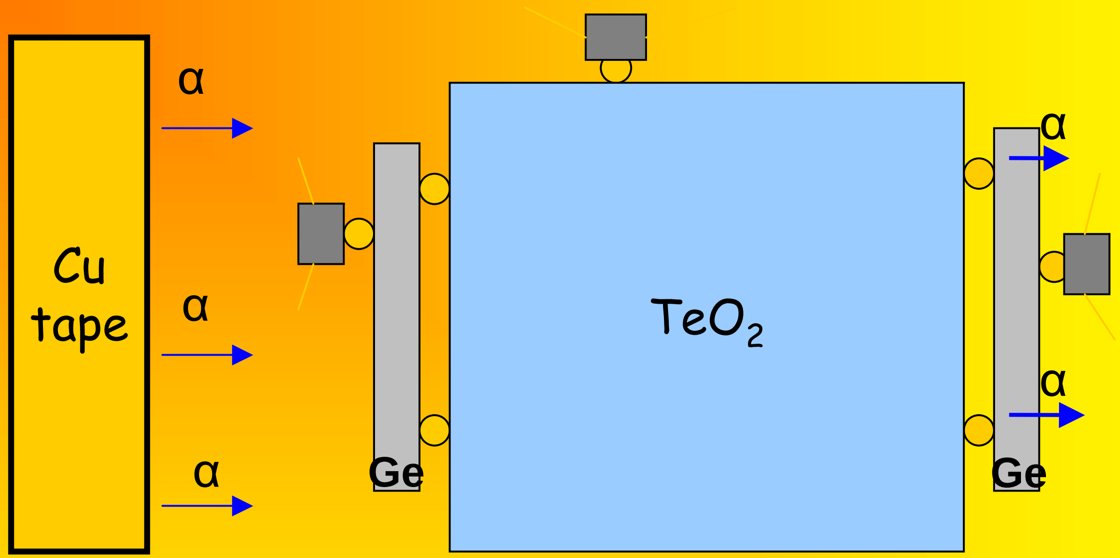
NTDs: $3x1.5x1\ mm^3$, R_0= 3.1 Ω ; T_0= 5.8 K







The α source



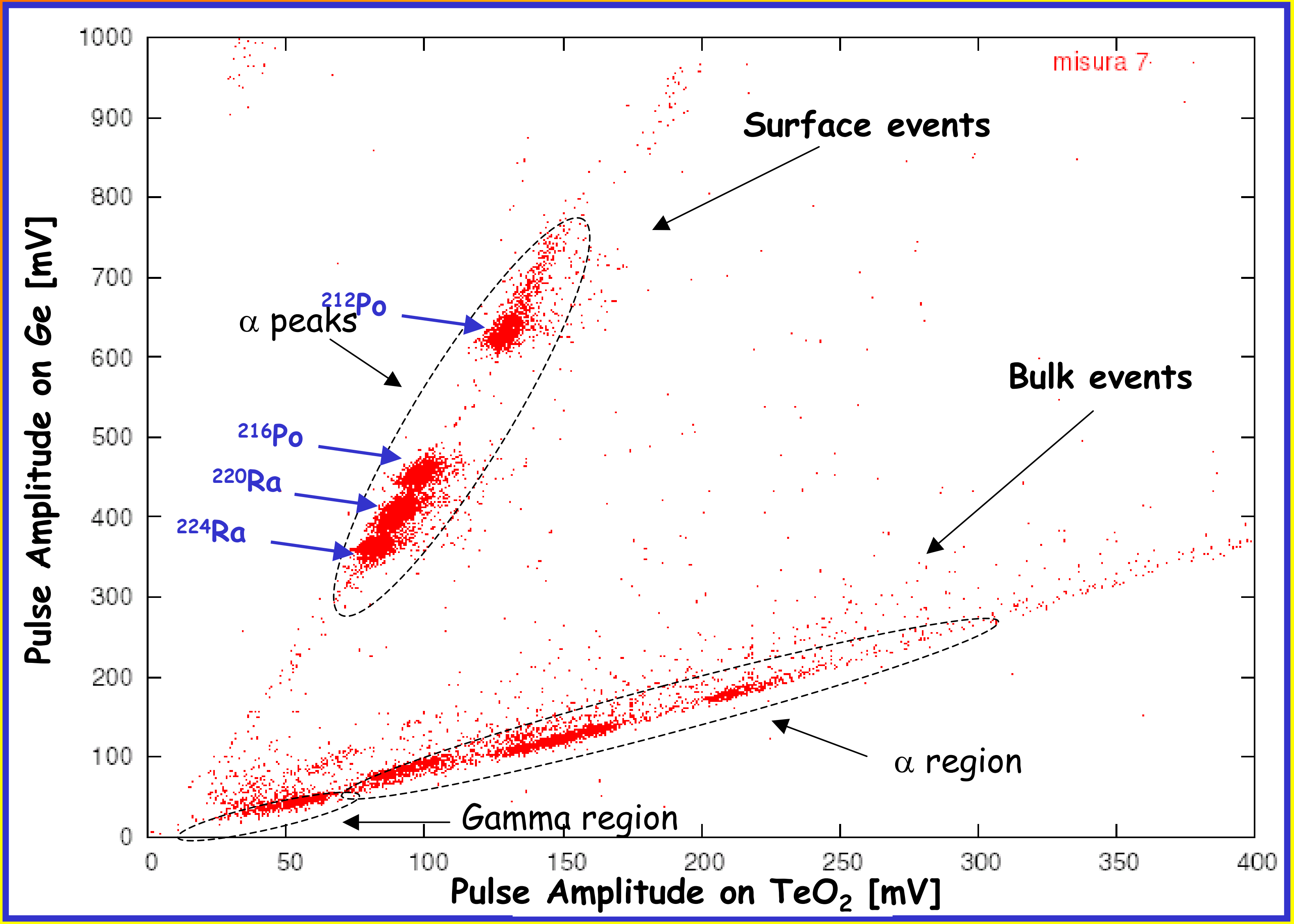
The source was obtained by a shallow implant of ^{224}Ra nuclides onto a piece of copper tape, facing the Ge layer. ^{224}Ra is an emitter with a half life of 3.66 d in equilibrium with its and emitting daughters.

Main lines:

- ^{224}Ra – 5685.5 keV
- ^{220}Rn – 6288.3 keV
- ^{216}Po – 6778.5 keV
- ^{212}Po– 8784.4 keV

Experimental results

scatter plot with Ge shields

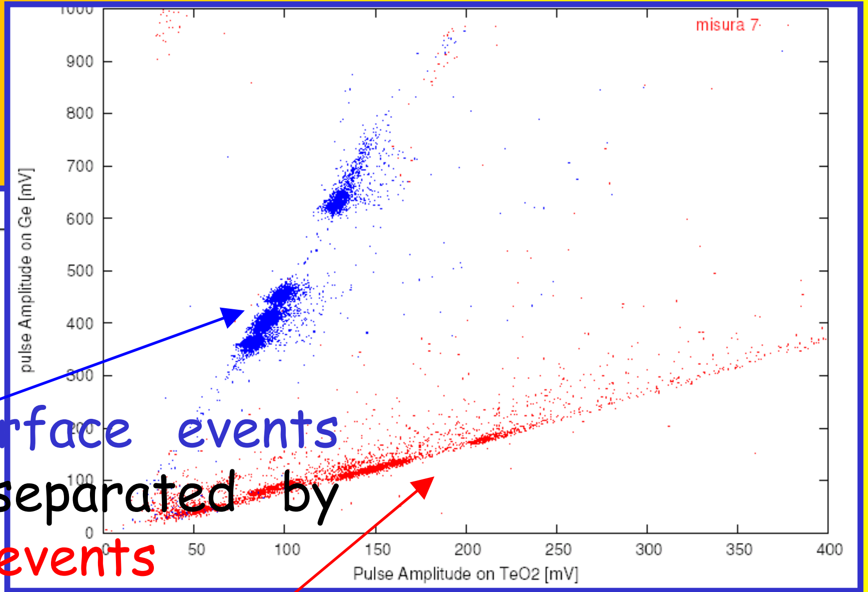


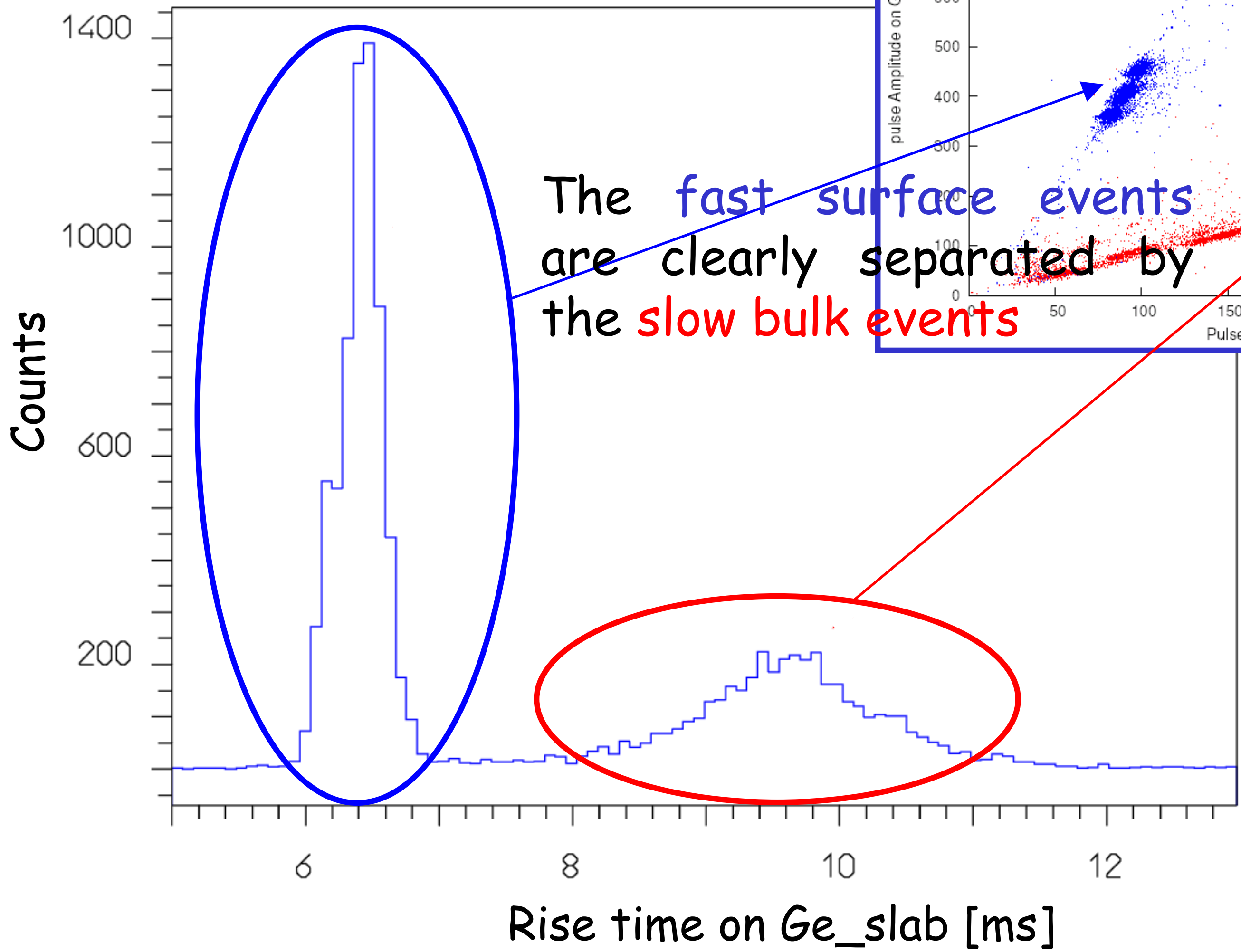
A second powerful separation between the two event types can be achieved also by **pulse shape analysis**

Rise time spectrum for pulses read by the NTD on Ge_slab

• τ ~ 6.4 ms: events on Ge bolometer

✓ τ ~ 9.6 ms: events on TeO2 bolometer

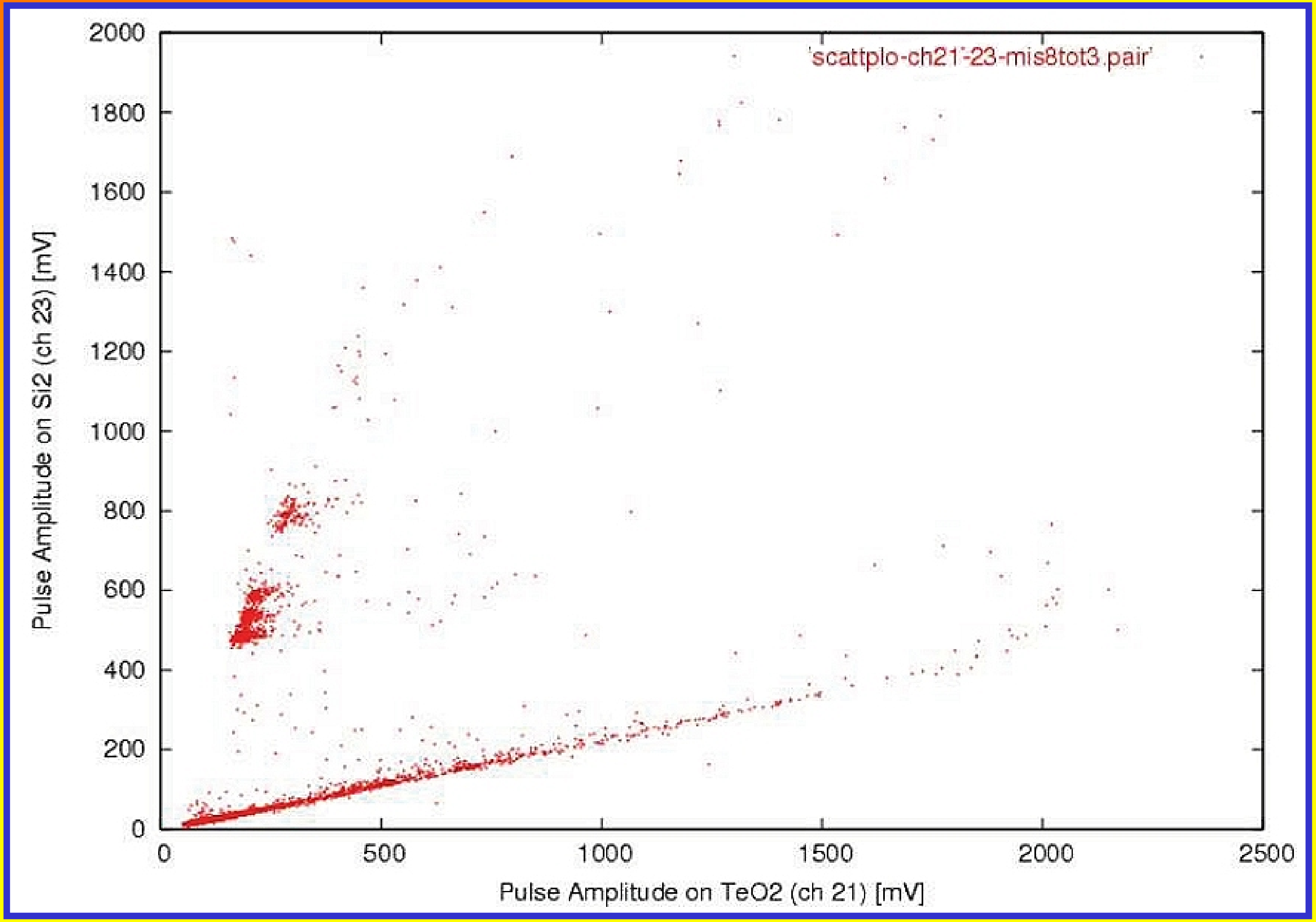




The fast surface events are clearly separated by the slow bulk events

A selection of the events by their rise time clearly identifies the two event bands

Experimental results
scatter plot with Si shields



In view of the CUORE experiment one could be scared of too many read-out channels

1 crystal: 7 thermistors (1 for the main absorber + 6 for the shields)

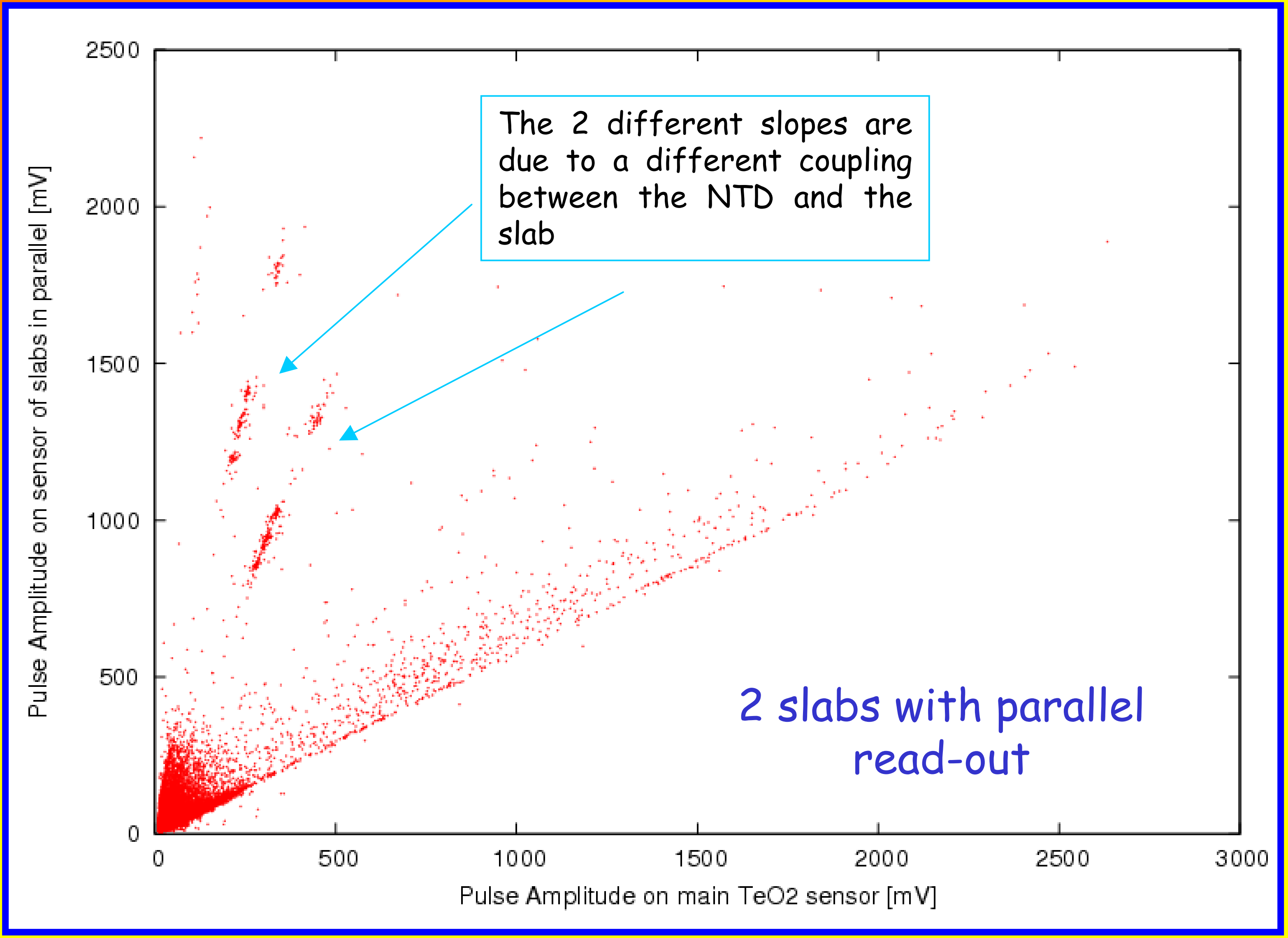
CUORE → **~ 1000** crystals

→ **~ 7000** channels

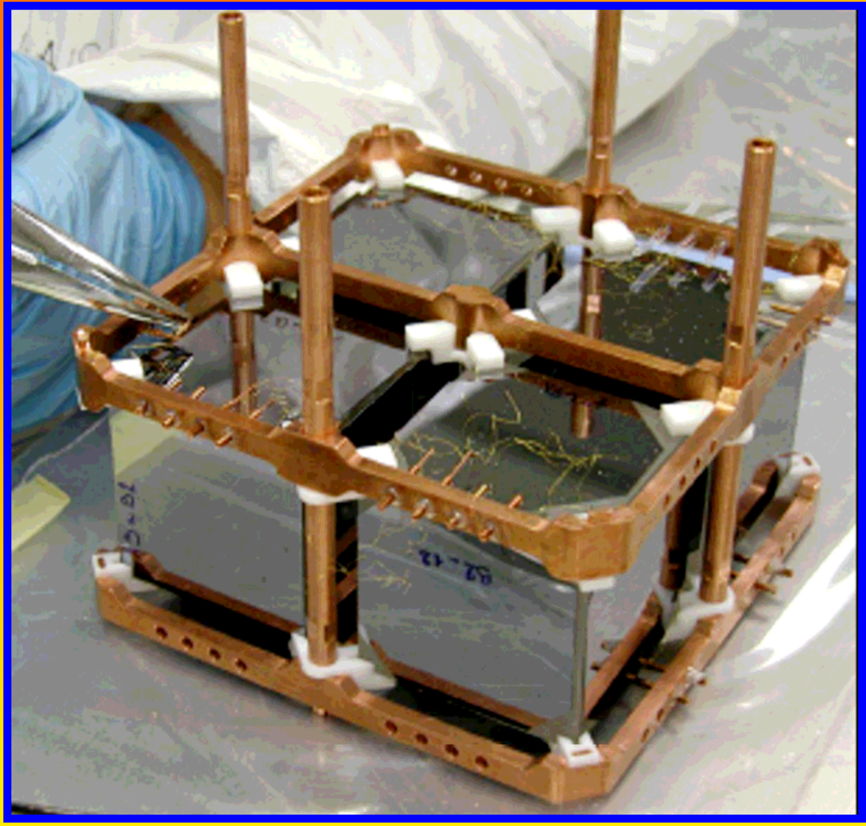
→ We can connect the thermistors on the slabs in parallel…"only" two read-out channels for each crystal

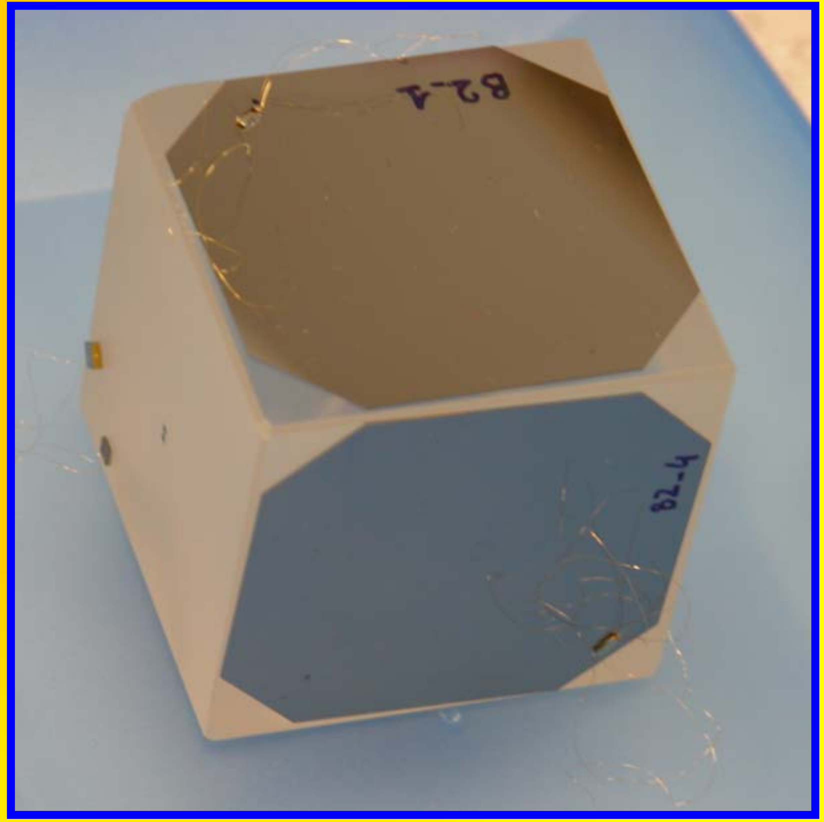
→ **~ 2000** channels

Experimental results
scatter plot with TeO_2 shields



Test @ LNGS (hall C) with 4 SSB





From VERY PRELIMINARY results their behaviour looks promising

Conclusions

- Composite structures overcome an intrinsic limitation of monolithic low temperature calorimeters, e.g., the impossibility to give information about event position;

- we can use this technique as a 'reserve weapon' for an active background reduction for the CUORE experiment.