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THE READ-OUT SYSTEM OF THE
MILANO AND GRAN SASSO EXPERIMENTS WITH
BOLOMERIC DETECTORS

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ABSTRACT

The improvement of the signal-to-noise ratio of the readout system used with
our bolometric detectors depends on many technical issues. Examples of detector
mounting and interconnection links as well as a description of a Faraday cage
containing the Gran Sasso di Monti refrigerator are given in the paper. A new
version of a GaAs voltage-sensitive preamplifier and new readout schemes are also
described.

1. Introduction

The characteristics of the Gran Sasso facilities have been
talked Conference [1]. This paper
signal-to-noise ratio of the over
We will briefly describe the cooling by reducing mechanical
electric capacitance and how to
to reduce the pick-up of electro-
new version of our GaAs preamplifier
configurations for signal readout
also be illustrated.

2. Detector mounting

The relatively large mass
Ga crystal) make it necessary
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low temperatures. The spring
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Fig 1 shows the crystal is supported by six conic bell
conductance to the harness.

A schematic diagram is shown in Fig 2. In this case
electrically isolated from the
1. Introduction

The characteristics of the bolometric detectors presently used at Milano and Gran Sasso facilities have been fully described in a separate paper presented to this Conference [1]. This paper reports on the measures taken to improve the signal-to-noise ratio of the overall system.

We will briefly describe the detector mountings designed to allow crystal cooling by reducing mechanical vibrations, the detector to preamplifier link of low electrical capacitance and low thermal conductance, and a Paradyne cage projected to reduce the pick-up of electromagnetic interference by the detector. Finally, the new version of our GaAs preamplifier will be presented in more detail. Alternative configurations for signal readout intended to improve the signal-to-noise ratio will also be illustrated.

2. Detector mounting

The relatively large masses of our detectors (up to 190 g for our larger Ge crystal) make it necessary to count with a mounting system which avoids mechanical vibration that induce microphonics noise and heat-up the crystals well above their optimum operating temperature. Different types have been designed but in all cases the crystal is supported by a number of low thermal conductance tips pressed by springs which absorb the mechanical contractions at low temperatures. The spring tension is limited by the maximum pressure that the crystal can support without being damaged. With non-negligible effort the spring tension may be adjusted so that the resonant frequency of the system is far away from the region where the signal has its maximum energy density.

Fig 1 shows the mounting used for the 200 g Ge detector. The crystal is supported by six cone bases supports which introduce a negligible thermal conductance to the base tank.

A schematic diagram of the mounting structure used with the Te detector is shown in Fig 2. In this case the detector is supported by two copper cylinders electrically isolated from the crystal by using a thin sheet of mylar.
Initially, we have indistinct or 100μm constantan wire the chamber and the 4K plate where was realized by means of a 4 cm by a sheet of mylar of 100μm the thermalizing pads. The total electrical capacitance mainly determined by the cap although the thermal contact by the elastic contacts introduce.

An alternative way, with through a 1mm teflon isolator using pads as is the latter car.

Fig 3: Internal view of the A front cover about 90 cm away

3. Detector-Preamplifier link

It is already very well known that the detector-preamplifier link must introduce a low electrical capacitance to avoid excessive signal integration, and low thermal conductance to reduce the amount of excess power injected into the detector.
Initially, we have indistinctly used either 50µm diameter manganine wire or 100µm constantan wire thermalised in different points in between the mixing chamber and the 4K plate where the preamplifier is located. The thermalisation was realised by means of 0.1 cm² copper pads electrically isolated from the cryostat by a sheet of mylar of 100µm. The wire was tightened by elastic contacts in the thermalising pads. The wire was freely “flying” from one pad to the next. A total electrical capacitance of about 20 pF was introduced by this mounting mainly determined by the capacitance of the pads. The results where acceptable although the thermal contraction of the cryostat could not be well compensated by the elastic contacts introducing microphonics noise.

An alternative way, which is presently used, consists in passing the wire through a 1mm thick isolation firmly attached to the cryostat and thermalised using pads as in the latter case.

The 2.1 g Te detector

Detector-preamplifier link must cover signal integration, and some power injected into the

Fig 3: Internal view of the Milano dilution refrigerator. Detector-preamplifier link must cover about 50 cm and is thermalised in the intermediate plates.
4. The Faraday cage

In order to minimize the pick-up of electromagnetic energy by the detector, a Faraday cage was specially designed by Belling Lee-Ray Proof. It measures 2m x 2m x 2.8m and the whole refrigerator and lead shields are allocated in it. The walls are made of galvanized steel 2mm thick welded in order to assure a high attenuation in a broad frequency range. The cage is sectioned through a 75cm x 75cm knife-edge hatch and the refrigerator can be extracted from the top 1m x 1m hatch.

All pipes traversing the cage walls pass through waveguides designed on purpose. The cage is galvanically isolated from the pumps and floor and is connected to ground at one point only.

A panel with 16 BNC feedthrough connectors and 6 N connectors is used for transmitting detector signals. A power line filter (52505TS) and a set of general purpose low frequency filters (2 x Y2590, 1 x Y2112, and 10 x Y2156) are used for the diagnostic and control signals of the refrigerator, as well as to provide standard NIM voltages. It is our intention to use rechargeable batteries for operation of the preamplifier and detector biasing during the long-term experiments, reducing still further the possibility of spurious interference pick-ups.

Attenuation measurements have been made using an HP 8566 Spectrum Analyzer. An antenna was located inside the cage and connected to the external spectrum analyzer via the BNC feedthrough connectors. At cage's door open an electromagnetic spectrum extending to about 2 GHz could be measured although the intensity was moderate. The instrument sensitivity -13 db was exceeded (including a welding in the inside of the cage. Mean through the filters. The cage is from 10 Hertz to 10 GHz with a Fig 4 shows a general view.

5. The Signal Readout System

To bias the bolometers thermally attached to the 4 increase of resistance compared (2.7 x 12.4mm²). Nominal noise contributed by the load compared to the bolometer, is

The bolometer signal is operates at 4K, is located very DC connection allows the readout condition in the detect
the intensity was moderate. At door closed no noise was measured, limited to
the instrument sensitivity -134 dBm. External, intense noise sources have been
excluded (including a welding machine) and again no signal was recorded from
the inside of the cage. Measurements have been done with no cables entering
through the filters. The cage was designed for an attenuation greater than 106 dB
from 10 kHz to 10 GHz with a maximum of 126 dB from 500 kHz to 500 MHz.
Fig 4 shows a general view of the Turbino cage.

5. The Signal Readout System

To bias the bolometers we have used LCR Eltec 102 thick film resistors
thermally attached to the 4K plate. These resistors present at 4K a 1/3
increase of resistance compared to its value at 300K, and are very small in area
(1.7 x 1.0 x 0.4 mm²). Nominal values of LCR resistors can be as large as 10¹²Ω.
The noise contributed by the lead resistors, which is operated at a higher temperature
compared to the bolometer, is kept small by choosing a large resistor value.
The bolometer signal is readout by a low-noise Gage preamplifier which
operates at 4K. It is located very close to the detector, and it is DC coupled to it. The
DC connection allows the measurement of bolometer V-I load lines keeping
the same conditions to the detector as when they are biased for detection.

We fit the pipes (left)

Fig 2. Room noise level at 1 K of the new voltage-sensitive preamplifier. The value
at 11 K is also given as a reference.
The GaAs preamplifier has the following characteristics: It is a voltage-sensitive type, with a gain of 51 and a bandwidth of 6 MHz. The input impedance is purely capacitive as the leakage current is negligible. The total input capacitance is about 8 pF, partially dominated by the parasitic capacitance of the input connections (which must be thermalized). The output impedance is 50 Ω. The input noise level has a 1/√f dependence and is about 9nV/√Hz at 100 Hz, decreasing to 0.3nV/√Hz at 1 MHz.

The present version incorporates several improvements with respect to our previous approaches. The circuit configuration is given in Fig 6.

Fig 6: Circuit configuration of the voltage-sensitive preamplifier. Q1 is actually a set of ten transistors in parallel.

The input stage is constructed by ten 2SK164 MESFETs in parallel to reduce the noise level of the individual devices by a factor √10. A double cascode (Q2, Q3) and a high-impedance dynamic load (Q5, Q6) make it possible to obtain a voltage gain in the first amplifying stage of about 1000. A following inverting-amplifying stage (Q7) increases the overall open-loop low-frequency gain to about 3500. The closed-loop voltage gain is determined by resistors R1 and R2.

The preamplifier prototype, still being used, and the following version surfaced mounted onto an Al₂O₃ substrate are shown below.

Fig 7: Prototype and surface.

For an exhaustive discussion, see [2].

A spectrum of a 320 keV beta-emitting detector using the new GaAs preamplifier has energy resolution limited by the n...
For an exhaustive description of this preamplifier we refer the reader to a separate paper[5].

A spectrum of a $^{60}$Co source obtained with our 15g Ge bolometric detector using the readout system described, is shown in Fig 8. The resolution is limited by the microphonic noise.

![Energy spectrum of a $^{60}$Co source obtained from a 15 g Ge bolometric detector using the new GaAs voltage-sensitive preamplifier](image)
We are at the moment concentrating our attention to reduce the microphonic noise which is still limiting the resolution of our spectra. We expect to get better performances by using a balanced differential readout instead of the single-ended used so far. In addition, the parasitic capacitance of the interconnecting link can be reduced by bootstrapping (Fig 9).

\[ T = 4K \]

\[
\begin{array}{c}
\text{Pad} \\
\hline \\
\text{Pad} \\
\hline \\
\text{Pad} \\
\hline \\
\text{Pad} \\
\hline \\
\end{array}
\]

\[
\begin{array}{c}
R_B \\
\hline \\
\times 50 \\
\hline \\
\times 1 \\
\hline \\
\div \\
\hline \\
\times 50 \\
\hline \\
- \text{Out} \\
\end{array}
\]

\[
\begin{array}{c}
\text{BOOMETER} \\
\hline \\
\text{LINK} \\
\hline \\
\text{BIAS} \\
\end{array}
\]

Fig 9: Scheme of the balanced configuration readout with parasitic capacitance compensation

The resolution of our bolometric detectors is limited by the inefficient conversion of the deposited energy into an electrical pulse [5]. Once this limit will be improved and microphonics and other external noise sources will be reduced, the amplifier noise will contribute to some extent to the total energy resolution [4].

As our preamplifiers present a series noise with a 1/f distribution, we consider the use of AC bias and synchronous demodulation using a lock-in amplifier (Fig 10). In this way the signal spectrum is shifted to higher frequencies where the noise level of the preamplifier is smaller [5][6].

All these new readout configuration have preliminary been tested and will be progressively installed.

Fig 10: The use of a lock-in amplifier 1/f noise

6. Conclusions

We have devoted a signiﬁcant effort to give the best at concentrating our attention to improve the low-noise performance of our detectors.

At the moment we are limited by external noise sources. The new version of GaAs detectors have improved in terms of stability.

7. Acknowledgments

We acknowledge the valued contributions of S. Parmeggiano and the help of R. Benedet.
ion to reduce the microphonic
noise. We expect to get better
st instead of the single-ended
if the interconnecting link can

\[ x_{50} \times +Out \]

\[ \times 50 \]

\[ -Out \]

BIAS

\[ \frac{x_{50}}{x_{50}} \times +Out \]

\[ \times 50 \]

\[ -Out \]

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pulse [5]. Once this limit will
noise sources will be reduced,
be total energy resolution [4].

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Fig 10: The use of a lock-in amplifier to reduce the signal-to-noise degradation by
the amplifier 1/f noise

S. Conclusions

We have devoted a significant effort in the realisation of a readout system
capable to give the best signal-to-noise ratio from our bolometric detectors
concentrating our attention in the detector mounting, in the interconnecting link,
in the low-noise amplifier and in the Faraday cage which contains the whole system.
At the moment we are limited by the microphonic noise which we expect to reduce
in the near future.

The new version of GaAs preamplifier presently used has incorporated many
improvements in terms of noise, power dissipation, bandwidth and long-term
stability.

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help of E. Benedet.
9. References


The research in the last year was focused on the detection of dark matter and the detection of neutrinos. Effective techniques for the detection of rare events have been developed, and the use of bolometric detectors has shown promising results.

1. Introduction

1.1. Motivations.

Low temperature bolometers are used to detect dark matter and neutrinos. The detection of these particles is crucial for understanding the universe and its fundamental laws. Neutrino detection is limited by the neutrino flux, which is very low, while dark matter detection is limited by the mass of the particles. The detection of both particles is crucial for understanding the universe.