VIP Technical Note IR - 5

Background measurements for VIP with a 2-CCD test setup

(in the DEAR laboratory and at LNGS)

26 April 2005

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1. Introduction

The goal of the VIP experiment [1] is to push the limit on the probability of the violation of the Pauli Exclusion Principle (PEP) for electrons by four orders of magnitude with respect to the presently published value of $\beta^2/2 < 1.7 \times 10^{-26}$[2]. The 4 orders of magnitude to be achieved ($\beta^2/2 < 10^{-30}$) should arise both from detector design considerations and from a substantial reduction of the background.. A factor of 100 with respect to the test measurement performed at Neuchatel in 1998 by the DEAR group [3] was assumed in the VIP proposal by performing the experiment at LNGS.

This note summarizes the results of the measurements performed at LNGS to verify the proposal assumptions and to fulfill the recommendation of the LNGS Scientific Committee, which in the meeting of October 2004 stated: "***This experiment is interesting but the SC recommends that the collaboration better understands potential detector backgrounds and the real motivations to perform the experiment in the underground Laboratory, before a final installation occurs."***

Consequently, in the period November 2004 – April 2005 an intense activity was dedicated to measurements of the background in the DEAR Laboratory at Frascati and at the LNGS Laboratories. A 2 CCD test setup was used, having the same type of CCDs (CCD55) as those used in the VIP setup. Moreover, the materials of the setup are of the same quality and purity as those from the setup.

The results of the measurements was a factor about 50 in the background reduction, by using a preliminary shielding, showing the feasibility of a factor of 100 or more, which was assumed in the Proposal, by refining the shielding (geometry and materials).

In Section 2 the 2 CCD test setup is briefly presented; Section 3 is dedicated to the results of the measurements performed in the laboratory in the last months of 2004, while Section 4 to those obtained at LNGS laboratories in the first months of 2005. Section 5 contains a summary of the results and the conclusions.

2. The 2 CCD test setup

The 2 CCD test setup used for the VIP background measurements contains 2 CCD55 – of the same type as those used in the VIP setup. The CCDs are contained in an aluminium cillinder, with a quality (purity) very similar to the one of the VIP setup. In Fig. 1 and Fig. 2 details of the test setup are shown, while in Fig. 3 the 2 CCD test setup, as installed in the Laboratory in Frascati, is shown.

Fig. 1: The 2 CCDs used in the test setup, together with part of electronics.

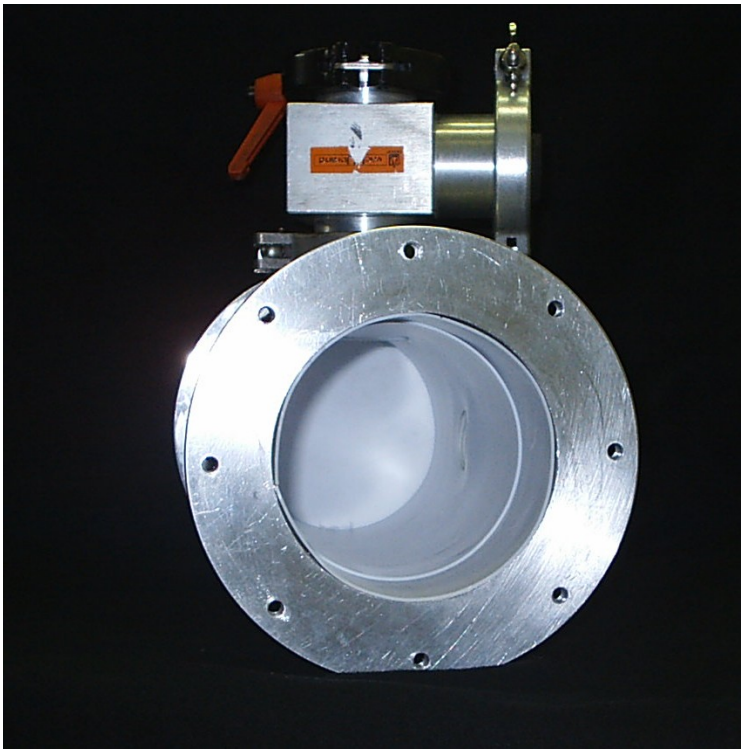

Fig. 2: The 2 CCD housing in aluminium with teflon shielding inside.

Fig. 3: The 2-CCD test setup installed in the laboratory.

One of the 2 CCDs started to work badly in December (most probably some electronic component got broken); we decided to go on with only one CCD – the correctly working one – instead of losing time to recover the badly functioning one. So, the results reported below refer to the single CCD setup.

3. Results of the background measurements performed in the DEAR laboratory

In the period November-December 2004, a series of background measurements with the 2 CCD test setup was performed in the laboratory. The measurements were done without and with shielding, and were preceded by a calibration measurement. The results are reported below.

3.1. Calibration measurement

The calibration measurement was done with an Fe source, and the resulting spectrum, calibrated in energy, is shown in Fig. 4.

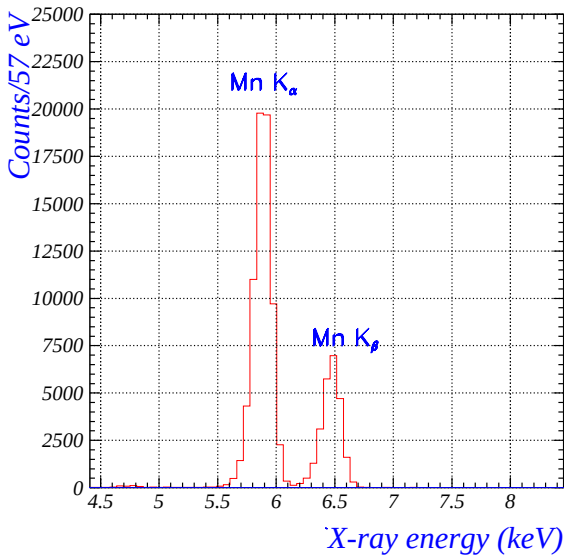

Fig. 4: Energy calibration – measurement with an Iron source performed in the DEAR laboratory.

A second calibration measurement was performed at the end of the measurements in the laboratory, and the rewsult was the same as the one reported in Fig. 4, checking in this way the stability of the energy calibration.

The energy resolution was of 180 eV (FWHM) at about 6 keV.

3.2. Results of the measurements performed in the laboratory without shielding

The measurement performed with the 2 CCD setup in the laboratory, without shielding, lasted 65 hours. The obtained spectrum is shown in Fig. 5.

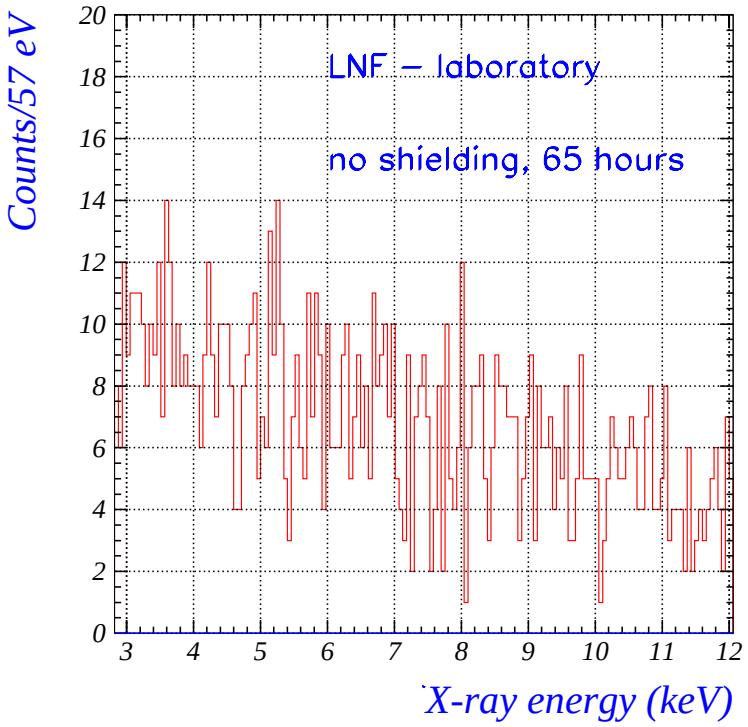

Fig. 5: X-ray spectrum obtained in the laboratory without shielding

The analysis of the spectrum shows a background reduction in the region of interest (7.4 – 7.9 keV) **a factor about 1.5 better than in Neuchatel**. This reduction is a compound consequence of the lack of the Copper line from the spectrum; and a better energy resolution compared to the Neuchatel case. (~500 eV in Neuchatel vs 160 eV in the current setup)

3.3. Results of the measurements performed in the laboratory with shielding

Soon after a measurement with an optimized shielding in the lab conditions was performed. The shielding was composed of an external layer of Lead (10 cm thick) and an internal layer of Copper (5 cm). The setup was enclosed in a plastic housing flushed with nitrogen, in order to remove possible Radon contaminations. The measurement lasted 325 hours, and the spectrum is shown in Fig. 6.

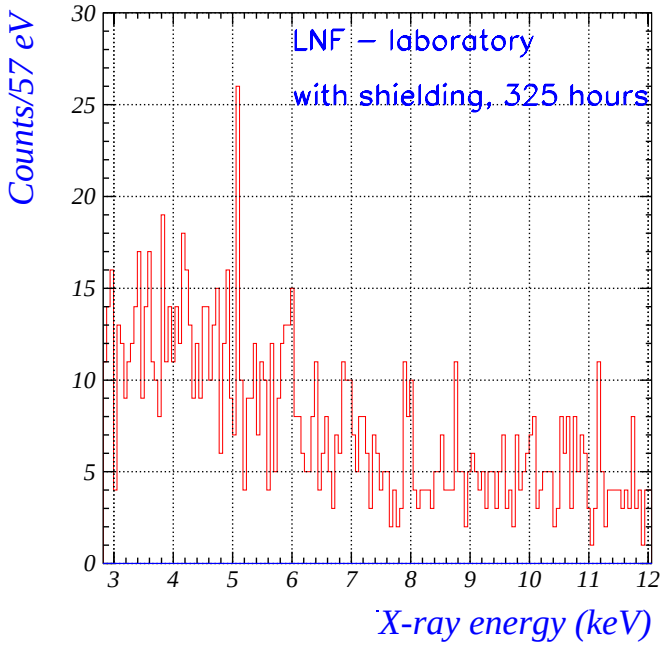

Fig 6: X-ray energy spectrum obtained in the laboratory, with shielding

A background reduction **factor of about 5.2 with respect to no-shielding** situation was obtained. The calibration measurement was done with an Fe source, and the resulting spectrum, calibrated in energy, is shown in Fig. 4. Indications of the presence of Mn, Co, Cu and Pb electronic transition lines are seen in the spectrum (5.9, 6.9, 8.05 and 10.5 keV).

4. Results of the background measurements performed at the LNGS laboratories

In December 2004 the 2 CCD test setup was transported to the LNGS and installed in the barrack allocated to VIP (ex-HDMS). A picture of the place is shown in Fig. 7.

Fig. 7: the VIP barrack at LNGS, when the test setup started to be installed

The installation was followed by a 3-days period of DAQ – performed without shielding. In the first months of 2005, a measurement with a preliminary shielding was done. The results of these measurements are reported below.

4.1. Results of the measurements performed at LNGS without shielding

A picture of the setup installed at LNGS without shielding is shown in Fig. 8.

Fig. 8: The 2 CCD test setup, without shielding, installed at LNGS.

The measurement, performed in the period 20-23 December, gave **a background reduction factor of about 4.5 with respect to the situation in the laboratory without shielding**.

4.2. Results of the measurements performed at LNGS with shielding

In the period 21 February – 28 March, a measurement of the background at LNGS with a preliminary shielding was performed. The shielding was done in an external layer of lead and an internal one of copper., 5 cm thickness each.

In Fig. 9 and Fig. 10 some pictures of the shielded 2 CCD test setup are shown.

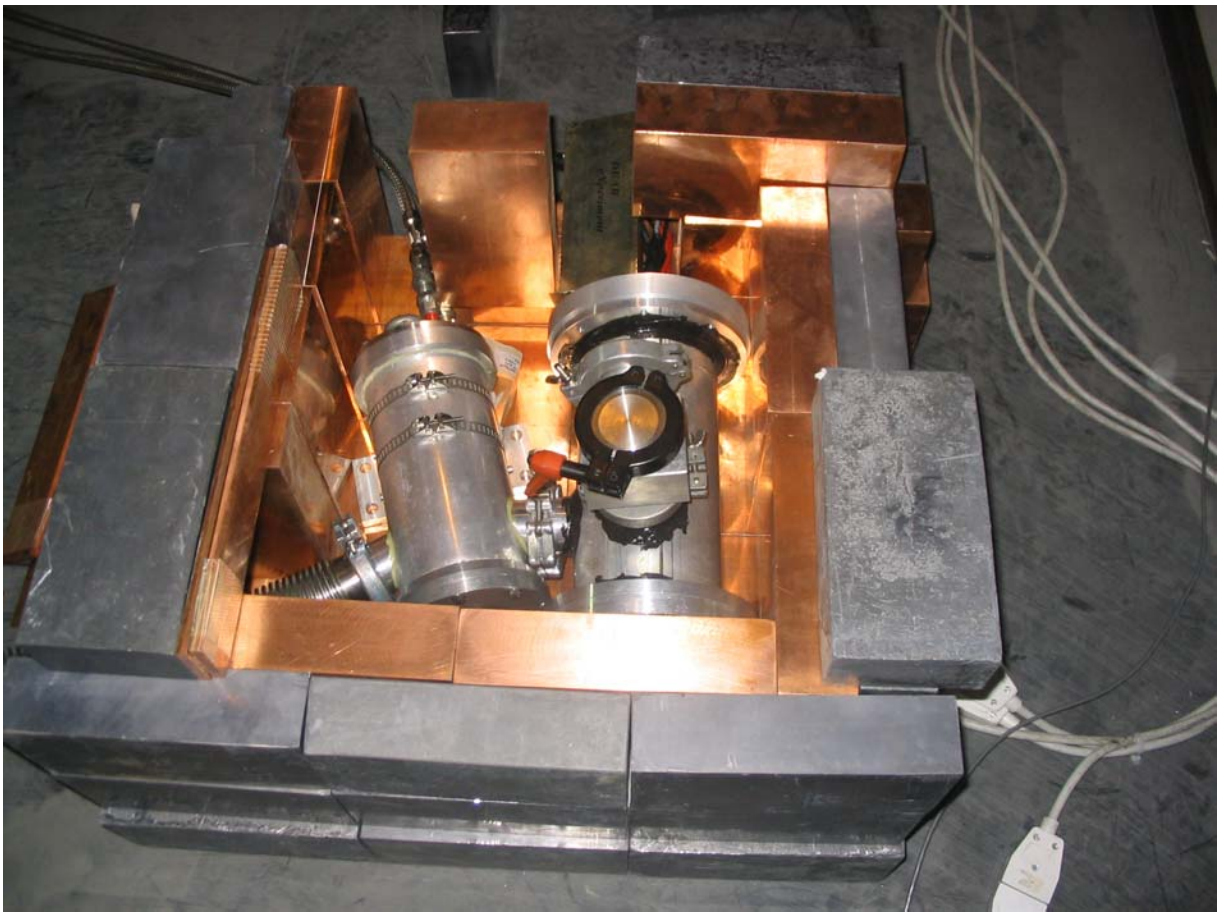

Fig. 9: The 2 CCD test setup with shielding at LNGS – detail during construction.

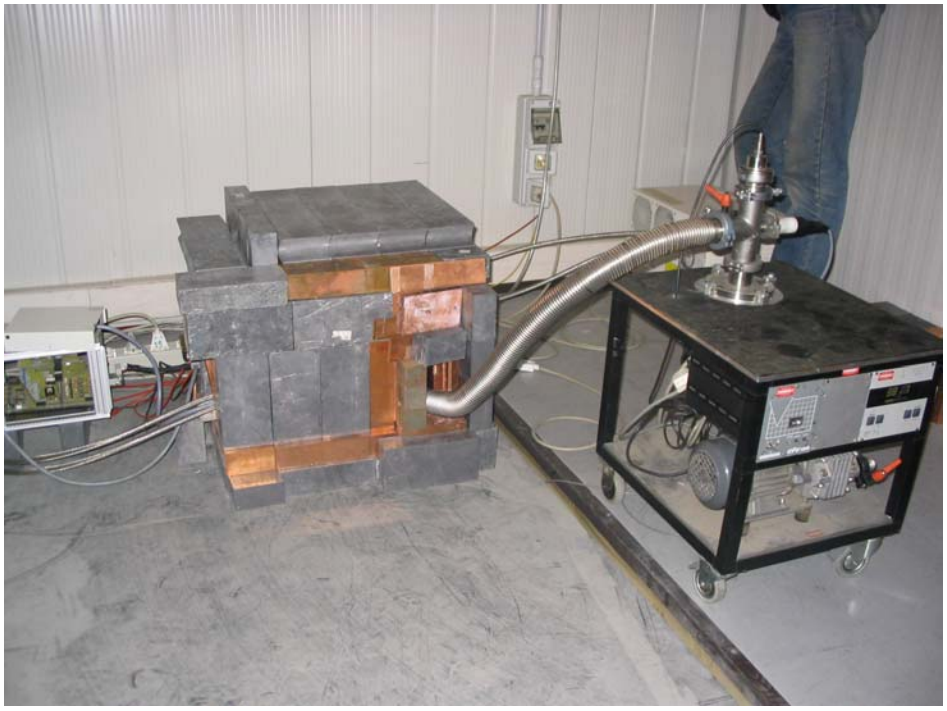

Fig. 10: The 2 CCD test setup with shielding taking data at LNGS.

The measurement lasted 832 hours, and the obtained spectrum is shown in Fig. 11.

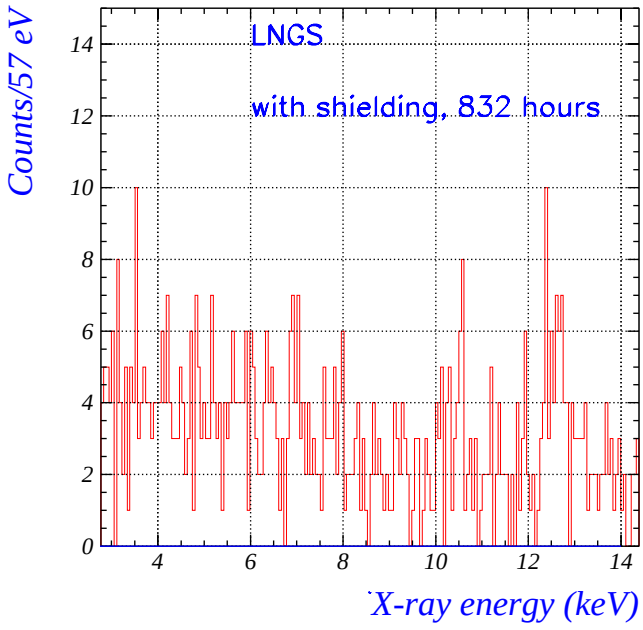

Fig. 11: X-ray spectrum obtained at LNGS with shielding.

The results of this measurement are:

- **a background reduction factor of about 6.3 with respect to LNGS without shielding;**
- **a background reduction factor of about 30 w.r.t laboratory without shielding;**
- **a background reduction factor of about 45 w.r.t. Neuchatel measurement.**

5. Summary and Conclusions

Background measurements with a 2 CCD test setup were performed in the DEAR laboratory at Frascati and at the LNGS laboratories, without and with shielding. A comparison between the normalized spectra such obtained is realized in Fig. 12.

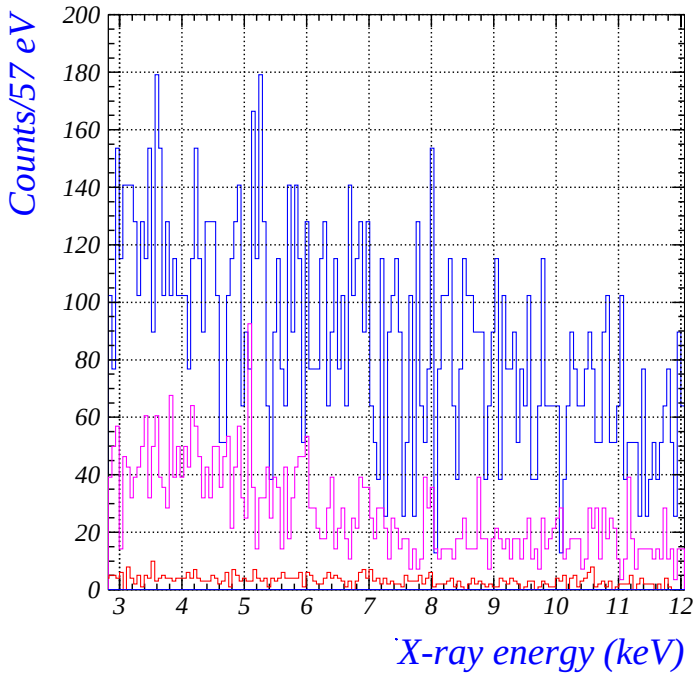

Fig 12: Comparison between normalized background spectra obtained with the 2 CCD setup: in blu the result obtained in the laboratory without shielding; in violet the results obtained in the laboratory with shielding; in red the results obtained with a preliminary shielding at LNGS.

A background reduction factor of about 50 was obtained at LNGS with respect to the Neuchatel measurement (as reported in Section 4), by using a preliminary shielding.

An increase of the background reduction factor to the value of 100 or more is feasible, by:

- design of a special VIP shielding geometry, which better covers all the solid angle;
- use of specially treated shielding materials (lead and copper);
- flushing with nitrogen

Moreover, by working at LNGS an improved background quality is obtainable: day/night and seasonal stability, not obtainable when working in the laboratory.

In conclusion, the measurements indicate that at LNGS a background reduction of a factor of 100 with respect to the Neuchat is feasible, thus fulfilling also the request of the LNGS SC Committee

Acknowledgements

The VIP Collaboration expresses special thanks to Dr. Matthias Laubenstein of LNGS for his precious help, permanent support and advice in preparing and performing the background measurements.

We also acknowledge the LNGS management and staff for their effective and kind support.

Bibliography

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