The LVD experiment as a low background facility in the Gran Sasso Laboratory

Laboratori Nazionali del Gran Sasso

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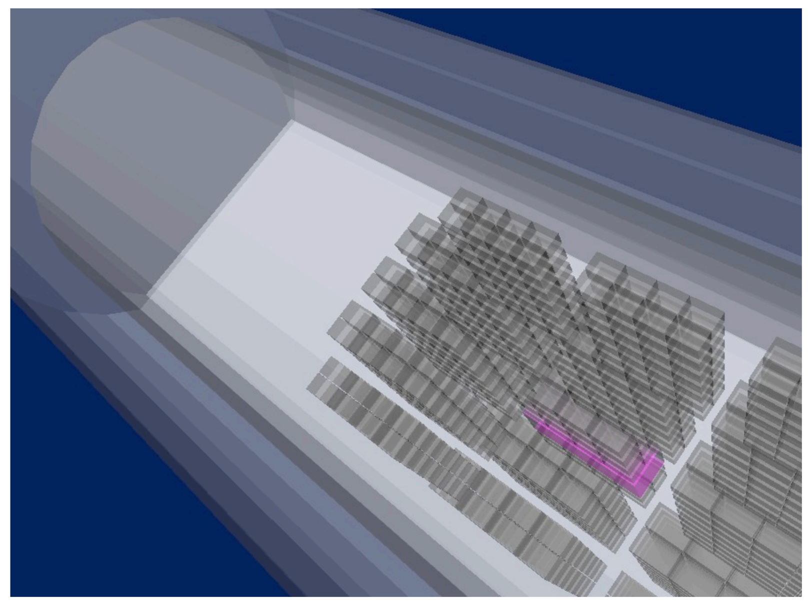
The LVD Core Facility



The LVD detector (1000 ton of liquid scintillator + 900 ton of Fe) has a highly modular structure: it is made by: 3 identical towers, each one composed by 35 active modules.

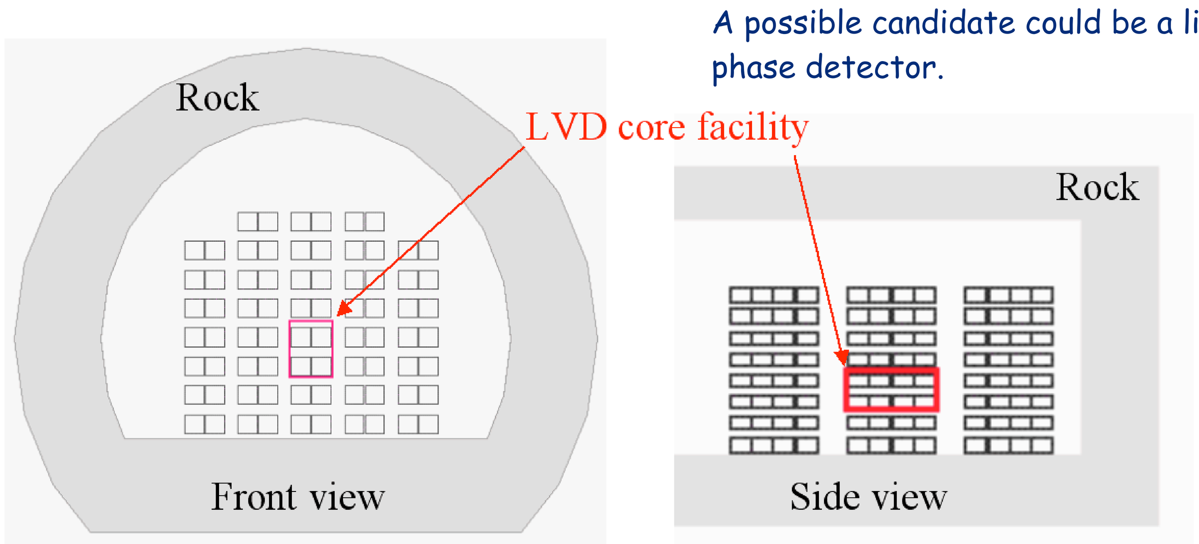
We are investigating the possibility to remove 2 modules from the most internal part of the detector and use that space to host an experiment dedicated to the search for rare phenomena. We call it "LVD Core Facility"

The available volume (~ 30 m^3) is:

2.1m x 6.2m x 2.8m

It can be realized with a negligible impact on the LVD operation and its sensitive mass.

The LVD_CF could be effectively exploited by a compact experiment for the search of rare events, such as double beta decay or dark matter. A possible candidate could be a liquid Xenon double phase detector.

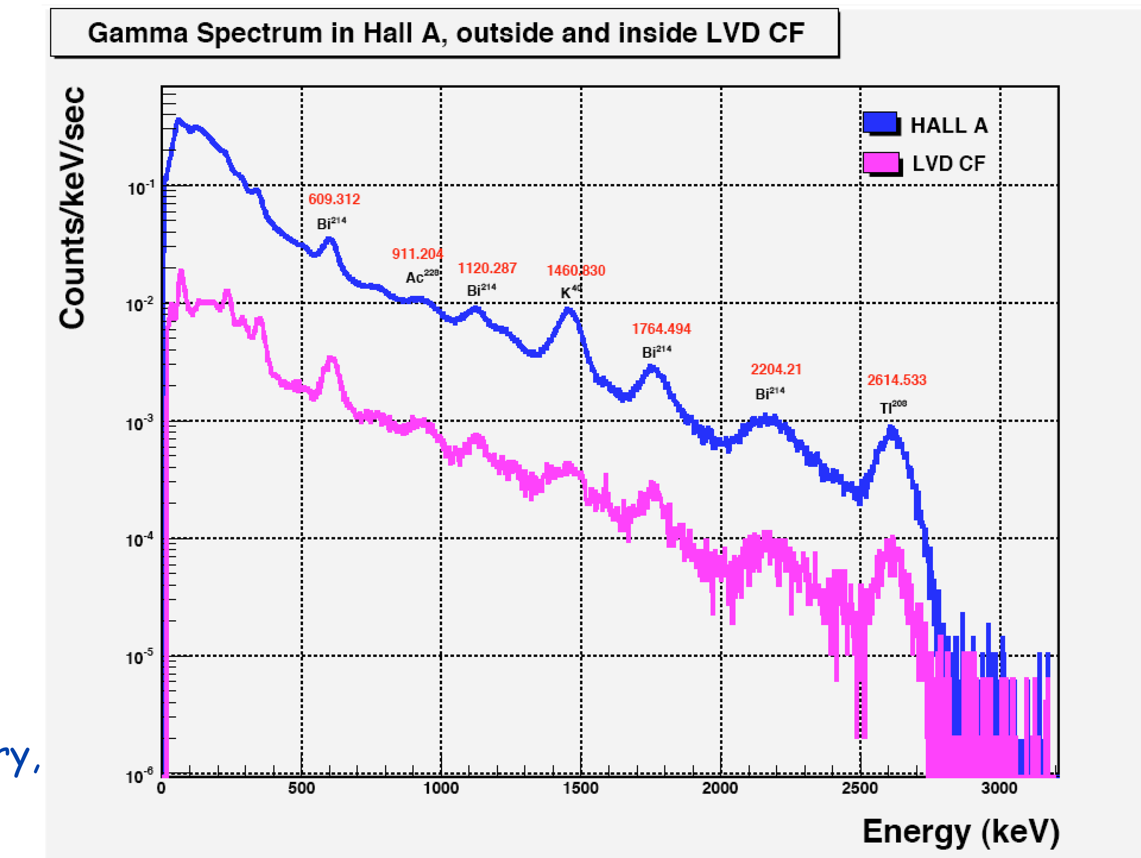


Front and side view of the LVD detector and its position relative to the rock around it. The red box represent the LVD core facility.

LVD as a γ ray shielding

We measured the intensity and spectrum of the gamma rays with a 2" sodium iodine detector.

As shown in the figure, the gamma ray intensity inside the LVD-CF is reduced by a factor >10 with respect to the one measured in the Hall A of the Gran Sasso Underground Laboratory, outside LVD.



The table shows the rate of counts in the areas of the main gamma peaks.

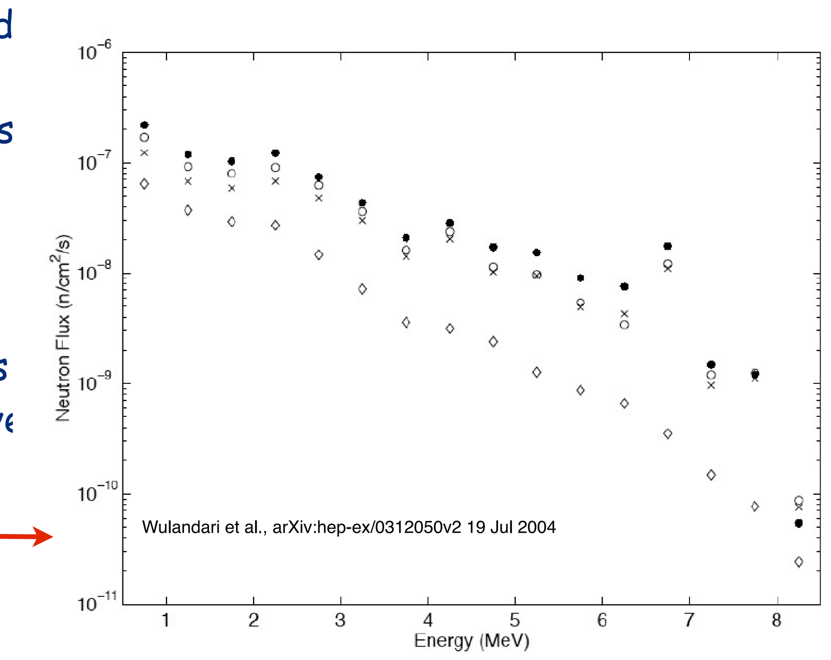
(after BG subtraction)	609.312 Bi214	911.204 Ac228	1120.287 Bi214	1460.830 K40	1764.494 Bi214	2204.21 Bi214	2614.533 Tl208
SALA A (240408 s)	0.189 +/- 0.011	0.014 +/- 0.002	0.042 +/- 0.003	0.164 +/- 0.008	0.040 +/- 0.002	0.0206 +/- 0.0016	0.0198 +/- 0.0015
LVD CF (236233 s)	0.025 +/- 0.003	0.0016 +/- 0.0008	0.0026 +/- 0.0007	0.0039 +/- 0.0008	0.0026 +/- 0.0005	0.0013 +/- 0.0004	0.0013 +/- 0.0004

neutrons from spontaneous fission and (α,n) reactions

For E_n < 10 MeV the neutron background is dominated by (α, n) reactions and spontaneous fission, mainly of ^{238}U. It is due to radio impurity in the rock surrounding the LVD array and in the LVD itself.

The component emerging from the walls of the hall A of the Gran Sasso Lab have been calculated and measured.

Neutrons below 4 MeV are mainly produced by spontaneous fission, while (α, n) reaction is the main contributor in the production of neutrons with higher energy.



These neutrons are propagated by the M.C. simulation inside the LVD array to evaluate the flux surviving at the LVD CF surface.

The work is still in progress, preliminary results and calculations show that the flux is attenuated by about a factor 100 by the presence of LVD.

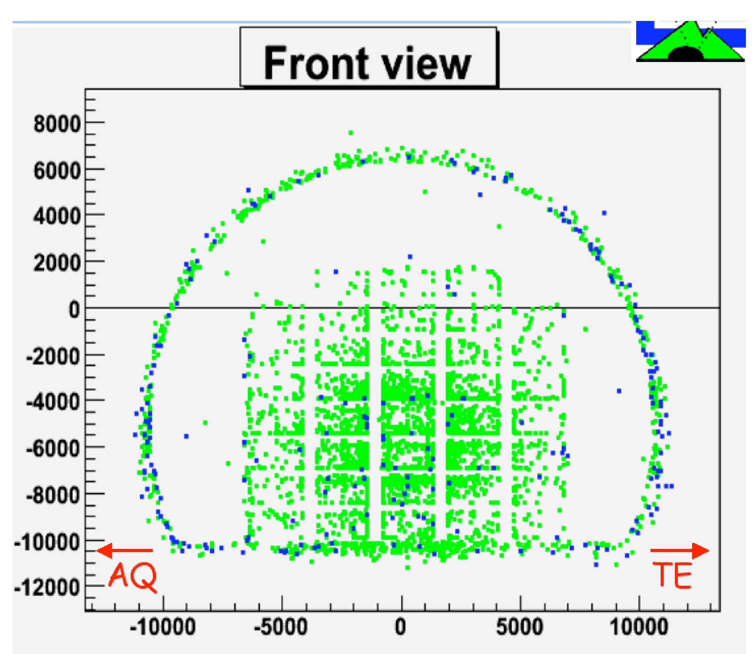
Thermal neutrons have been measured by using a ^3He detector. In the hall A, outside the LVD array, we measured: 0.3 n $\cdot$ $cm^{-2} \cdot s^{-1}$, in agreement with previous measurements, while, in the LVD CF, the thermal neutron flux is reduced by a factor 20.

muon induced neutrons

We set up a detailed MC simulation (with Geant4) of the LVD detector and the rock that surrounds it; we generated cosmic muons with energy spectrum and angular distribution sampled accordingly to what expected in the GS underground laboratory (<E>=280 GeV). Then we looked at the number and energy spectrum of the neutrons that enter the LVD-CF.

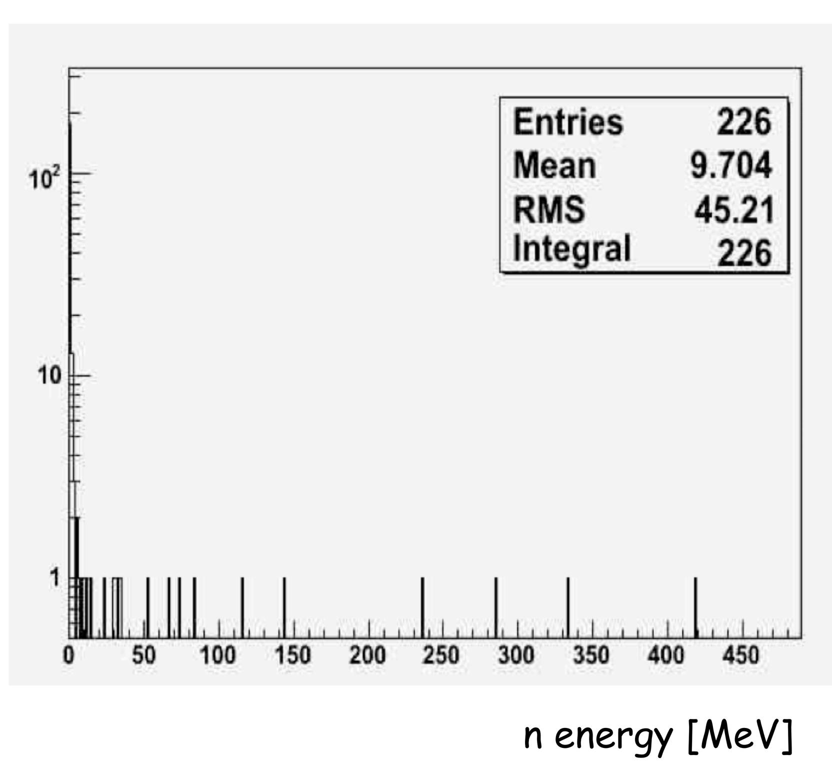
Because of its large volume LVD can detect muons even very far from the CF: the LVD external dimensions are 13m x 22.7m x 10m (LVDbox). Inside LVD there are gaps and corridors to allow easy access to the counters, thus some muons can cross LVDbox without being detected.

We recognize a muon when two scintillation counters are triggered in time coincidence: the events with a detected muon are called TAGGED (otherwise UNTAGGED). About 85% of the muons that hit the LVDbox are TAGGED.



Front view of the positions where the neutrons that enter the LVD-CF are produced. In green those neutrons whose parent muon is TAGGED, while in blue the UNTAGGED ones.

We generated 3 10^6 muons (corresponding to about 6 months of data acquisition): the number of neutrons that enter the LVD-CF when the muon is UNTAGGED is only 226. Only 25% of them comes from muons that cross the LVD external box and go through a corridor; the remaining 75% are neutrons produced in the rock around the detector that go inside the CF mainly through one of the gaps, as can be seen in the figure.

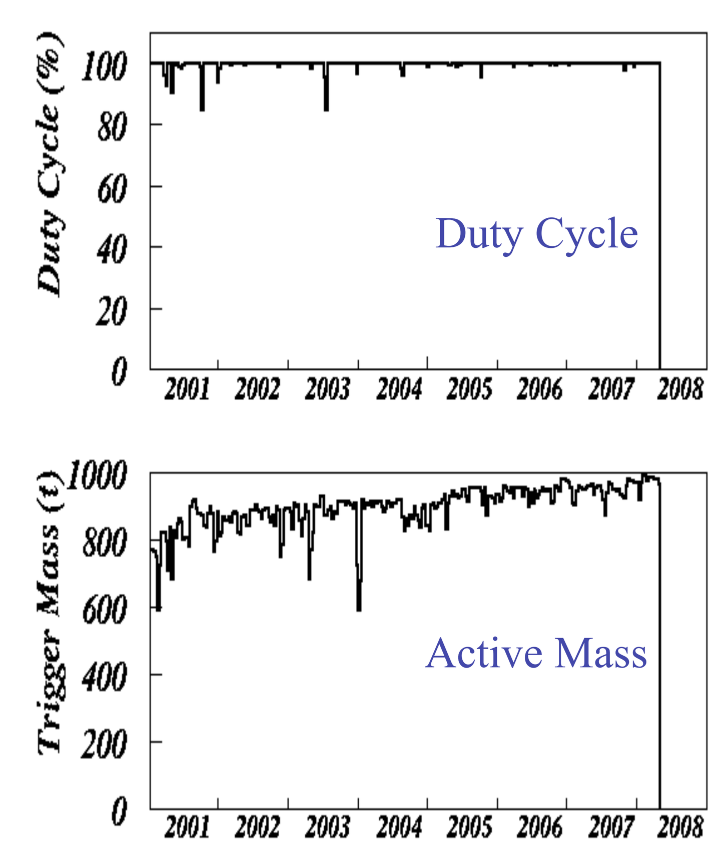


Looking at the energy spectrum, the number of neutrons with energy larger than 1 (10) MeV (the most dangerous for the dark matter search) is 51 (18), that is about one each 3 (10) days. In terms of flux this corresponds to 5.5 (1.9) 10^{-12} (cm^2 s)$^{-1}$.

The average (maximum) delay between the neutron arrival time and the parent muon for E_n > 10 MeV is 90 ns (400 ns).

LVD as a muon veto and background monitor

LVD is a neutrino observatory whose main purpose is to detect neutrino burst from gravitational collapse in the Galaxy. The detector duty cycle in the last 7 years was better than 99.6%

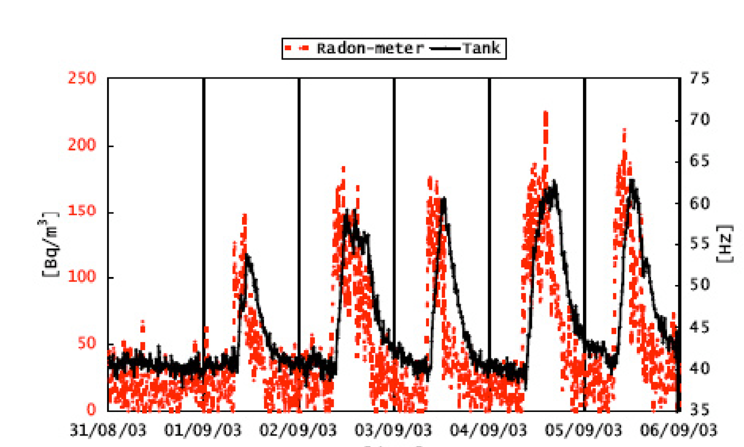


The counting rate of each of the 840 counters is continuously monitored. This gives the possibility to study periodicities or fluctuations in the background.

LVD can behave as a muon veto with respect to the LVD_CF. From our Monte Carlo we get a veto efficiency of 99.9% if we require a minimum energy release of 10 MeV in a single counter.

LVD is not a good shielding against Radon, nevertheless it is a very efficient Rd monitor: each counter behaves as a sensitive Rd-meter able to measure local variations of the Rd contamination.

In figure the response of a single counter is compared with the response of a radon-meter (ionization chamber which measures alpha particles with an air flow of 1 l/min) during a period characterized by large variations in the ^{222}Rd contamination in the Gran Sasso Lab due to failures in the ventilation systems.



Counting rate variations on a single LVD counter (black) compared with ^{222}Rd contamination monitored by an alpha radon meter (red).

conclusions

We are investigating the possibility to remove 2 modules from the most internal part of the LVD detector and use that space to host a compact experiment for the search of rare events, such as a liquid Xenon double phase detector.

The available volume is about 30 m^3 called LVD_CF

It can be realized with a negligible impact on the LVD operation and its sensitive mass.

The gamma ray intensity inside the LVD-CF is reduced by a factor >10 with respect to the one measured in the hall A of the Gran Sasso Laboratory, outside LVD.

The thermal neutron intensity inside the LVD-CF is reduced by a factor 20 with respect to the one measured in the hall A, outside LVD.

The rate of untagged muon induced neutrons with energy larger than 1 (10) MeV is one each 3 (10) days.

In terms of flux it corresponds to 5.5 (1.9) $10^{-12} cm^{-2} s^{-1}$ or an attenuation of the flux due to the presence of the huge LVD veto, of a factor 60.

This is the n-background typical of an underground laboratory placed at a much deeper site.

LVD behaves as a muon veto with efficiency 99.9% and a ^{222}Rd monitor with a sampling period of 10 min.

In general a monitor, with a duty cycle > 99.5%, able to detect any periodicity or fluctuation in the background.

Work is in progress: we are measuring the amount of radioactive nuclides (U, Th, K) present in the materials that compose LVD; the results will be used to estimate the γ and neutron contamination due to that source of background.