

Off-line data quality monitoring for the GERDA experiment

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Abstract. GERDA is an experiment searching for the neutrinoless $\beta\beta$ decay of ^{76}Ge . The experiment uses an array of high-purity germanium detectors, enriched in ^{76}Ge , directly immersed in liquid argon. GERDA recently started the physics data taking using eight enriched coaxial detectors. The status of the experiment has to be closely monitored in order to promptly identify possible instabilities or problems. The on-line slow control system is complemented by a regular off-line monitoring of data quality. This ensures that data are qualified to be used in the physics analysis and allows to reject data sets which do not meet the minimum quality standards. The off-line data monitoring is entirely performed within the software framework GELATIO. In addition, a relational database, complemented by a web-based interface, was developed to support the off-line monitoring and to automatically provide information to daily assess data quality. The concept and the performance of the off-line monitoring tools were tested and validated during the one-year commissioning phase.

1. Introduction

GERDA is a low-background experiment which searches for the neutrinoless $\beta\beta$ decay of ^{76}Ge , using an array of high-purity germanium (HPGe) detectors isotopically enriched in ^{76}Ge [1]. The detectors are operated naked in ultra radio-pure liquid argon, which acts as the cooling medium and as a passive shielding against the external γ radiation. This innovative design – complemented by a strict material selection for radio-purity – allows to achieve an unprecedented background level in the region of the $Q_{\beta\beta}$ -value of ^{76}Ge at 2039 keV. The experiment is located in the underground Laboratori Nazionali del Gran Sasso of the INFN (Italy). The Phase I of GERDA recently started using eight enriched coaxial detectors (totaling approximately 15 kg of ^{76}Ge). The Phase I comes after a one-year-long commissioning, in which natural and enriched HPGe detectors were successfully operated in the GERDA set-up.

GERDA has an advanced slow control system to monitor the main parameters characterizing the operational status of the sub-systems, as temperature, pressure, detector currents, and to handle alarms. A different kind of monitoring – the “data quality” monitoring – is also crucial to check the overall performance of the experiment and to certify the validity of the data for physics analysis. A key difference between the slow control system and the data quality monitoring

is that the latter is not performed in real-time, but relies on an off-line data analysis. Both approaches are needed to ensure that every sub-system in GERDA is running in the intended way and that the data produced by the experiment are qualified for physics analysis.

2. The GERDA data flow

The data collected by the main GERDA acquisition system (DAQ) consist of charge signals from the HPGe detectors, digitized at 100 MHz sampling rate. Raw data files are automatically copied once per day, at night-time, from the DAQ server located in the underground laboratory to the main GERDA file server, which is located in the above-ground facilities of the Gran Sasso Laboratory. New files are automatically processed using the framework GELATIO, which was developed for the GERDA experiment [2]. Data are analyzed within GELATIO with a modular approach, according to the procedure described in Ref. [3]. The analysis modules implemented in GELATIO are tailored to extract physics information from the signals, like rise time and amplitude. The parameters produced as output by GELATIO are also imported in a relational database system, based on MySQL [4]. The database is fully integrated with GELATIO, in the sense that it allows for a two-way relationship, i.e. in both input and output. For instance it is possible to create a GELATIO-compliant file from a selection of events made by the database using SQL. An advanced web interface was developed to allow an easy and user-friendly interaction with the database. It can be used to send queries and to generate a set of standardized reports, which contain diagnostic information to assess the data quality. Reports are issued in the form either of numbers (e.g. counting rates) or of graphs (1-dimensional histograms, scatter plots). More details are presented in the following sections.

3. Duty cycle monitoring

A key diagnostic parameter is the duty cycle of the experiment within a given set of “Runs”. A “Run” is defined by the geometrical configuration (number and position of the HPGe detectors) and the bias high voltage applied to the detector electrodes. If everything is working properly, data acquisition during a Run is interrupted only when a calibration of the system has to be performed. A calibration consists in the irradiation of the detectors by ^{228}Th radioactive sources. It is typically performed once per week and the procedure requires less than two hours in total. Being GERDA a low-rate experiment, the amount of data is largely dominated by calibrations. Interruptions of the normal data taking may happen because either of scheduled operations (maintenance, upgrade, ancillary measurements) or of hardware problems (e.g. electrical power spikes or instabilities, failure of a sub-system). The overall duty cycle achieved during the last six months of the GERDA commissioning, excluding the interruptions due to system upgrades, is larger than 90%, consistently with the expectations. Given the low counting rate, no loss in duty cycle is expected from the dead time of electronics.

4. Rate monitoring

The counting rates for different classes of events, as physical events in the HPGe detectors and “test pulses”, are also important parameters to be monitored. During the data taking a pulse of fixed amplitude (test pulse) is automatically produced by a pulser and fed to all DAQ channels, in order to monitor the stability of the electronics. Test pulses are issued at the rate of 0.1 Hz, which is much higher than the typical rate of physical events observed in GERDA (about 2 mHz per detector in the full energy spectrum¹). More than 80% of the events collected in an ordinary GERDA run are test pulses.

The total event rate in the HPGe detectors is expected to be approximately constant in time. The possible occurrence of noise bursts which trigger the DAQ system can cause a substantial

¹ The energy threshold of the HPGe detectors during the commissioning was typically between 50 and 100 keV.

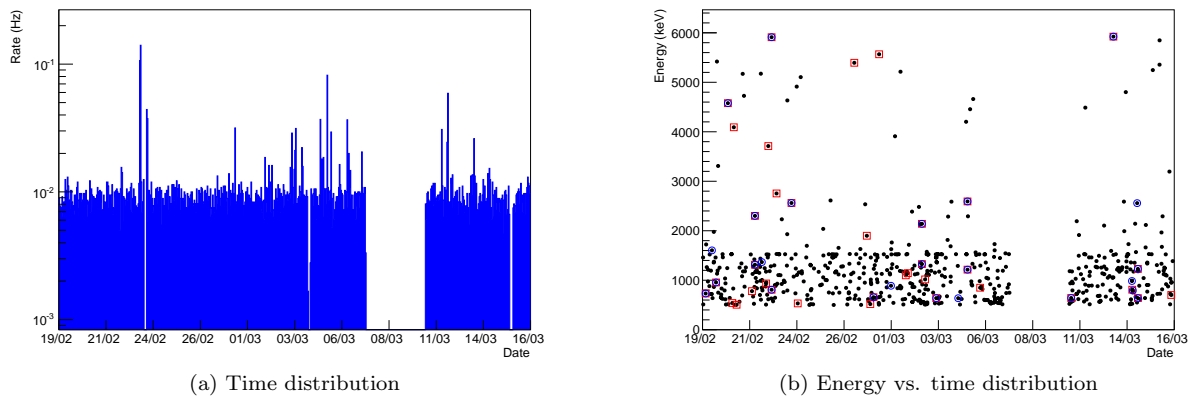


Figure 1. Illustrative plots from the database daily report. (a) Counting rate of physical events vs. time. A few noise bursts are clearly visible, in which the counting rate is increased by a factor > 2 . (b) Energy vs. time scatter plot for physical events above 500 keV. Events with more than one HPGe detector fired are marked by a red square, while events that are in coincidence with the muon veto system are marked by a blue circle. The 3-day empty region is due to an instability of the electronic system, which caused the data to fail the quality checks. The plots refer to an early GERDA commissioning Run performed on February-March 2011 with three non-enriched detectors.

increase of the event rate with respect to the normal value. The characteristic signature of noise bursts in the event rate distribution can be observed in the Fig. 1a.

In order to tag and reject events in the HPGe detectors due to muon-induced interactions GERDA features a muon veto system [5]. The general trigger of the muon veto system (which is a $1 \mu\text{s}$ -long NIM logical signal) is fed to the data acquisition of the HPGe detectors. For each interaction in the germanium array, the logical muon veto signal is hence encoded in the data stream. This permits the evaluation of the rate of muon-induced events in the HPGe detectors: the typical rate measured in the most recent Runs is about 0.5 counts/day per detector. It is in agreement with the expectations based on the Monte Carlo simulation performed with the framework MAGE [6] according to the procedure of Ref. [7]. Figure 1b shows the energy vs. time scatter plot for physical events detected in an early GERDA commissioning run with three non-enriched detectors. The occurrence of noise bursts and of interruptions due to poor data quality was significantly reduced in the most recent commissioning runs.

5. Monitoring of the read-out electronics performance

To monitor the read-out electronic chain and DAQ system stability, the database analyzes several parameters including:

- (i) Amplitude of the baseline vs. time (Fig. 2a). Fluctuations or drifts in the position of the baseline may indicate changes in the leakage current of the HPGe detectors or in the gain of the electronic chain.
- (ii) Root-mean-square (rms) of the baseline vs. time. The fluctuations of the baseline position with respect to the average value are a direct measurement of the noise of the electronic chain. Variations or sudden shifts of the baseline rms are symptoms of changes in the operation of the electronic chain.
- (iii) Test pulse amplitude vs. time. Since the signal injected in the electronic chain is constant, a time variation of its amplitude indicates a change in the global response of the electronic

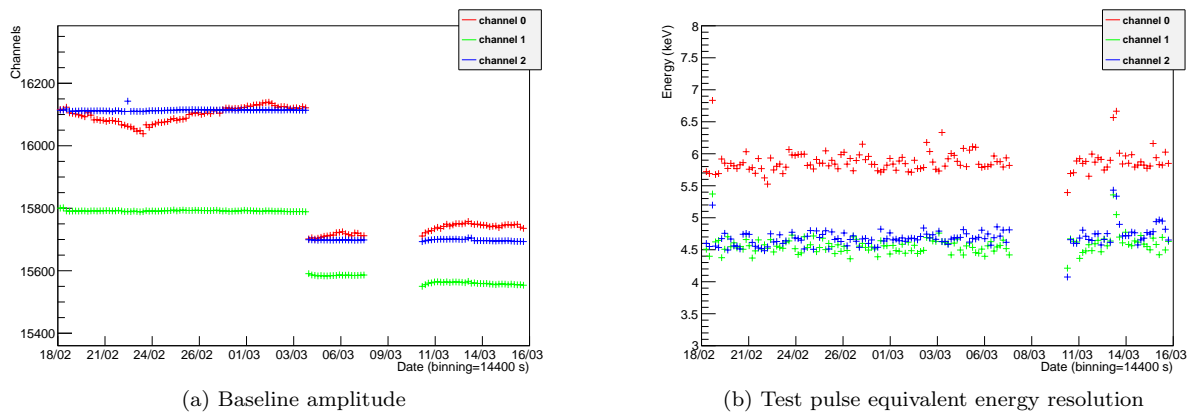


Figure 2. Monitoring of the stability in time of the electronic chain. (a) Baseline amplitude vs time. (b) Energy resolution of the test pulse line (FWHM) vs. time.

chain, e.g. gain drift, change in the system capacitance, etc.

- (iv) Width of the test pulse line vs. time (Fig. 2b). Fluctuations of the width of test pulse line are related to the electronic noise of the chain. They are quoted as full width at half maximum (FWHM) of the peak, as customary in γ -ray spectroscopy.

When an anomalous behavior is observed in one of these indicators, the corresponding data are marked as invalid and not included in the reference set for the subsequent analysis.

6. Conclusions

A complete system has been developed for the off-line monitoring of the data quality of the GERDA experiment. A standard set of daily reports and graphs to assess the stability of the system, which complements the information coming from the slow control, can be obtained by the combined use of GELATIO and of the dedicated GERDA database system. The concept and the performance of the off-line monitoring tools have been tested and validated during the one-year commissioning phase. All tools were found to be properly working and will be routinely used in the Phase I of the experiment.

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