On-line remote monitoring of radioactive waste repositories

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Abstract - A low-cost array of modular sensors for online monitoring of radioactive waste was developed at INFN-LNS. We implemented a new kind of gamma counter, based on Silicon PhotoMultipliers and scintillating fibers, that behaves like a cheap scintillating Geiger-Muller counter. It can be placed in shape of a fine grid around each single waste drum in a repository. Front-end electronics and an FPGA-based counting system were developed to handle the field data, also implementing data transmission, a graphical user interface and a data storage system. A test of four sensors in a real radwaste storage site was performed with promising results.

INTRODUCTION

Among the many issues associated to the disposal of short and medium term radioactive waste worldwide produced, there is the storage inside suitable sites where a high level of safety must be guaranteed. In order to detect possible leaks of radioactive material and to efficiently reduce the risks of contamination for the operators and for the environment. Detector Mesh for Nuclear Repositories (DMNR) is a project for a prototype demonstrator of the online monitoring of short-medium term radioactive waste, currently under development at INFN-LNS Catania. Such a system is planned to be distributed, fine-grained, robust, reliable, and based on low-cost components, providing a 3-dimensional map of the radioactivity produced by the waste inside the storage area. We have suggested to adopt a mesh of low cost radiation detectors, namely scintillating fibres, arranged as a grid of sensors around each waste drum (Fig. 1), readout by means of SiPM (Silicon PhotoMultiplier) photosensors capable of detecting the tiny light signals of few photons ([1], [2]). These allow to record continuously the measured activity, in order to check the instant rate and also the counting history around each drum. This system could also open new perspectives on the modality of waste packaging and storage.

Front-end electronics and an FPGA-based counting system were developed, in order to handle the data flow coming from the field sensors. Such a system also deals with the redundant data transmission toward a console with a graphical user interface and a data storage system (fig.2)

THE EXPERIMENTAL APPARATUS

The mesh of detectors has to be properly distributed, fine-grained, robust, reliable, and should be based on low-cost components. In addition, the sensors have to be operated in Geiger mode (on/off), since they are just needed to count the ionizing radiation events.

Each detector consists of a scintillating optical fibre, 1 m long. The fibre is a plastic one made of a scintillating core of polystyrene and a PMMA cladding, manufactured by Saint-Gobain Crystals.

The fibers are arranged around each drum in longitudinal and/or ring geometry, as in figure 1. Both geometries can be adopted, as the most likely leak position has to be determined. Each fibre can intercept radiation coming out of the drum wall, mostly gamma rays, so that the energy released inside its active volume is converted into scintillation light, that propagates to both ends of the fibre itself to be detected by the photosensor.

The output signal of a SiPM is generally small and needs further amplification. So we have used an innovative amplifier developed from our electronic department featuring a linear gain around 200 and a bandwidth of 4GHz. Each of the two SiPM outputs from a fiber is fed to an amplifier, whose output goes into a discriminator. The outputs of the two discriminators are combined by the coincidence unit, that will thus produce an output pulse only when a predefined amount of light is detected at both fiber ends.

The figure 3, shows a sketch of the front-end electronics architecture for one fiber. The digital output signals are represented near each component. It is worth to remark that a single FPGA can handle many fibers at once.
Several tests were performed with the fiber sensors on the bench with and without laboratory sources, in order to verify the capability of gamma detection, the sensitivity, the stability, to measure the noise level and the ambient radiation count rate. But the most important test, was to be performed in a real environment of radwaste. This is why we decided to perform a measurement inside a temporary storage site at a Sogin installation in Sessa Aurunca (CE) Italy.

For this purpose we installed four of our fiber sensors onto a trolley. The same trolley also hosted the front-end electronics, whereas the output digital pulses travelled on long cables towards the FPGA data acquisition system, placed outside, in order to be counted and recorded. The measurements were done in seven positions from the P0 position, outside the storage site, to the P6 positions inside the storage close to a rows of drums. On the left of the plot is shown how the counting rates change while the operator move the trolley inside the storage (Fig 4).

CONCLUSIONS

The DMNR project has shown that a real time online monitoring system for radioactive waste is feasible. The test performed inside a storage site has shown performance beyond the expectation. After the agreement between INFN and Sogin S.p.A signed on November 2012, was installed (June 2014) a pilot demonstrator system inside a Radwaste storage site (Garigliano Nuclear plant, Sessa Aurunca (CE)) for an extended period of time.

REFERENCES