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INFN-CHNET RADIATION DATA STORING AND VISUALIZING SYSTEM FOR THE LABEC TANDEM ACCELERATOR

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Abstract

In the INFN section of Firenze, a TANDEM accelerator (3MV TANDETRON by HVE) is installed at the LABEC laboratory. The environmental radiation monitoring is guaranteed by a set of gamma and neutron dosimeters placed around the accelerator and in the adjacent rooms and by three gamma-neutron dose rate monitors placed inside the accelerator hall for real-time measuring. In the context of the INFN-CHNet (INFN network for Cultural Heritage) development activities, we set up a home-made, low-cost system for the remote acquisition, storing and visualization of dose rate measurements from radiation monitors. The system was built using Arduino boards which communicate with the three monitors and send data over a internal network. A main PC is used for remote data collection and display, while Raspberry mini-PCs serve as backup devices. The software was designed and implemented in modules for a future service-oriented application on cloud. In this note, a brief description of the system is reported.

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1 Introduction

In accordance with current Italian regulations[1], the use of accelerators requires:

- the installation of dedicated systems to ensure adequate protection against any radioactive exposure or contamination, that may affect areas around the accelerator;
- the adoption of measures aimed at preventing access to the installation by unauthorized personnel;
- the identification and analysis of any potential scenarios involving potential exposures, and the specific intervention methods to prevent radiation exposures or limit their consequences on workers and the population.

For this reason, in all laboratories hosting accelerators, a radiation safety system is installed to protect individuals from risks associated with radiation exposure [2]. An important component of a radiation safety system is the radiation containment system, to protect people from potential prompt radiation hazards in the areas around the accelerator, under both normal and abnormal accelerator operation conditions. Typically, radiation containment involves a combination of passive systems, such as shielding and protective collimators, that reduce or block radiation, as well as active systems, such as electronic monitors, that halt radiation hazards when abnormal conditions are detected. The primary components of the radiation containment system include active radiation monitoring devices. A system for real-time acquisition of radiation monitor read-out, radiation data storing, and visualizing is essential to control the proper functioning of the accelerator and to evaluate the status of the machine over time, particularly concerning radio-safety issues. In INFN Firenze, a TANDEM accelerator manufactured by High Voltage Engineering Europe [3] is installed at LABEC, a laboratory for the development of new technologies based on particle accelerators and ionizing radiations, and for their applications in environmental contexts and in heritage science[4]. The environmental radiation monitoring in the accelerator area is guaranteed by a set of gamma and neutron dosimeters around the accelerator and in the adjacent rooms. It is based on Thermo Scientific equipment[5] for real-time measuring in the accelerator hall and consists of 3 radiation monitors with neutron and gamma probes connected to a display unit (FHT 6020). The FHT 6020 unit has audible and visible alarms and allows for remote data acquisition via serial interface. The figure 1 shows a photo of the Thermo Scientific equipment. LABEC is also the coordinator node of the INFN-CHNet, the INFN network devoted to the study and diagnostics of Cultural Heritage [<https://chnet.infn.it>], and in the context of CHNet development activities we set up a home-made, low-cost system allowing for storing and visualizing dose rates coming from radiation monitors. Hereafter a description of the system is reported.

2 CHNet radiation data storing and visualizing system for LABEC accelerator

The basic structure of the system consists in (see figure 2):



Figure 1: Photo of a Thermo Scientific monitor used at LABEC.

- 1) acquiring dose rate measures from the three monitors (M1, M2 and M3) and sending them over the accelerator internal Local Area Network (LAN1);
- 2) data saving and real-time visualizing;
- 3) saved data remote retrieval and visualisation.

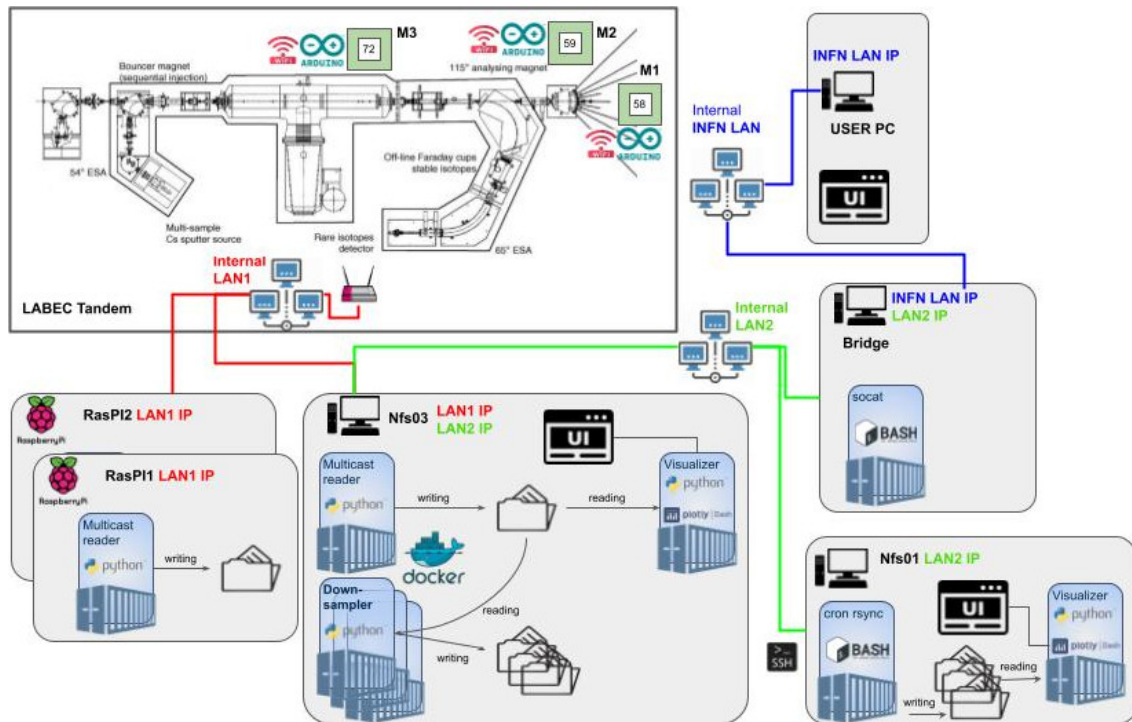


Figure 2: Scheme of the CHNet radiation data storing and visualisation system for the LABEC accelerator with three sections: 1) acquiring dose rates measures from the three monitors (M1, M2 and M3) and sending them over the accelerator internal Local Area Network (LAN1); 2) data saving and real-time visualizing; 3) saved data remote reloading and visualizing.

The full code can be found on the INFN remote versioning tool baltig, at the URL: https://baltig.infn.it/bombini/labec_radiosafety

2.1 Dose rates acquiring

The FHT 6020 control unit of the monitors allows a serial connection based on the RS485 standard protocol to communicate the measured dose rate values (in $\mu\text{Sv/h}$). For acquiring the dose rates from the 3 radiation monitors (M1, M2 and M3 in section 1 of the figure 2) an Arduino UNO microcontroller[6] with an RS485 adapter is installed close to the monitor and connected to the unit. The microcontrollers are programmed by using the Arduino IDE (Integrated Development Environment)[7] to extract dose rates measures from FHT 6020 unit (with a rate of 1 measure per second) and send data over the accelerator internal LAN1 by using the Arduino onboard WiFi module. The Arduino sketch can be found in the Baltig project in the path: *master/Arduino_sketches/Original_Reader_code*

The arduino sketch spawns three co-routines:

1. The first (read485), is dedicated to the real-time reading of the RS485 communication of the Radiation Monitor, with 9600 baud rate NoParity 1 stop bit. Data are sent by each detector once every second. The first bits represent the UniqueID of the monitor detector, then follows the radiation level as double precision number.
2. The second co-routine (recvUdp) reads the data from buffer
3. The third-co-routine (sendMcast) performs a broadcast communication of each monitor reading, adding the ISO standard timestamp to the data.

Any number of pc on the same local network can listen to the multicast address and display the realtime radiation levels or collect and save them.

2.2 Data storing and real-time visualizing

The entire software of the system was written in Python[8], whose architectural design follows the microservices approach, in order to be modular for a future service-oriented application. Some of those microservices can be hosted on cloud by using container technology[9]. Python was chosen because it is a highly flexible and easy to read language. With Python it is possible to write, in a few lines of code, a single-page web application for real time visualization, and a daemon to read a broadcast and store data. The program named “Multicast Reader” was implemented to collect the data sent by the Arduino boards over LAN1 and to locally save them. “Multicast Reader” programs run in background on a second industrial PC (named NFS03) and 2 Raspberry mini-PCs, used as back-up devices of the NFS03 PC, which are connected to the accelerator internal LAN1 (see section 2 of figure 2). Data are saved in local folders in CSV (Comma-Separated Values) format files to be easily opened and read by the most common computing programs. The average csv file, containing the daily per second measurement data of all monitors, has a size (without binary compression) of about 4Mb, i.e., there is a rate of less than 1.5 Gb/yr. NFS03 has a 1Tb SSD, while the Raspberry has a 128Gb MicroSD. So, at least, we have disk space for decades of data acquisitions. Another Python program named “Down-sampler” is executed on NFS03 (see the box of NFS03 PC in section 2 of figure

2) with a frequency of once per day to create data file copies with lower data sampling level, from one measure per second of original files to:

- one per minute, by averaging on 1-minute intervals;
- once every 10 minutes, by averaging on 10' intervals;
- one per hour, by averaging on 1 h intervals.

In this way, it is possible to select the right sampling frequency depending on the required time range of saved data to be reloaded and displayed (see the next section). A third program, named "Visualizer", running in background on NFS03, is implemented in Plotly Dash for Python[10] for real-time data displaying. It spawns a web server offering a reactive web page. With any browser it is possible to connect to the web-server set up by the program and to visualize in real-time the dose rates from all the radiation monitors for gamma rays and neutrons, plotted in function of the time in 2 graphs: one in the interval of the last 30 minutes and the other of the last 24 hours (see figure 3).



Figure 3: Screenshot of the page for real-time visualization of dose rates from all monitors for gamma rays and neutrons. Top: trending graph in the past 30 minutes; bottom: in the past 24 hours.

2.3 File re-loading and data post-visualizing

A second PC (NFS01, see section 3 of figure 2) is used to back-up all CSV files saved on NFS03 via SSH (Secure Shell Protocol) over the internal LAN of the lab (LAN2)¹, by means of RSYNC Linux tool[11]. By using Linux Cron utility[12] the file synchronization with RSYNC is programmed for daily execution. The program "Static-Visualizer", also developed in Plotly Dash, runs in background on NFS01 (see box related to NFS01

¹Two ethernet cards are installed on NFS03 for the connection to both LAN1 and LAN2.

PC in section 3 of figure 2) for data remote displaying and downloading from any client PC connected to the internal network of INFN Firenze. Any browser can be used to connect to the server set up on NFS01 by the program, through a TCP port forwarder created with the Socat Linux utility[13] running on the PC named "Bridge". The following figure shows the web page of the program with the mask for data selection by the user.

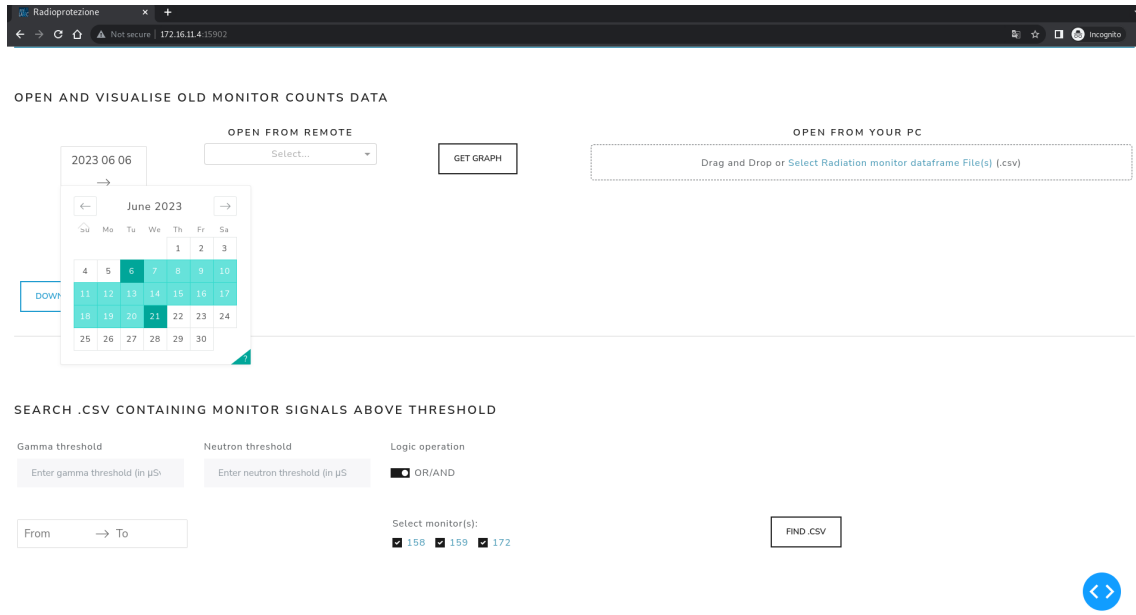


Figure 4: Screenshot of the software web page showing the mask for saved file reload. Top: section for trending graph in the user-specified time interval; bottom: section for file searching in a user-specified date range with gamma and neutron dose rates over user-specified thresholds.

The user who needs to reload saved data from the radiation monitors can select the desired time interval from the corresponding drop-down menu (see figure 4, top) and choose the data sampling level most suited for the selected time interval from the corresponding drop-down menu that offers the following options:

- original csv_files: one measure per second;
- 1min: data averaged per minute;
- 10min: data averaged every 10 minutes;
- 1day: data averaged per day.

Data are plotted in the time interval selected by the user for all monitors for gamma rays and neutrons (see an example in the figure below).

The data, in CSV format, can be downloaded by clicking on the button at the bottom left (see figure 5). The program also allows for file searching in a user-specified date range with gamma and neutron dose rates over user-specified thresholds (see figure 4, bottom).

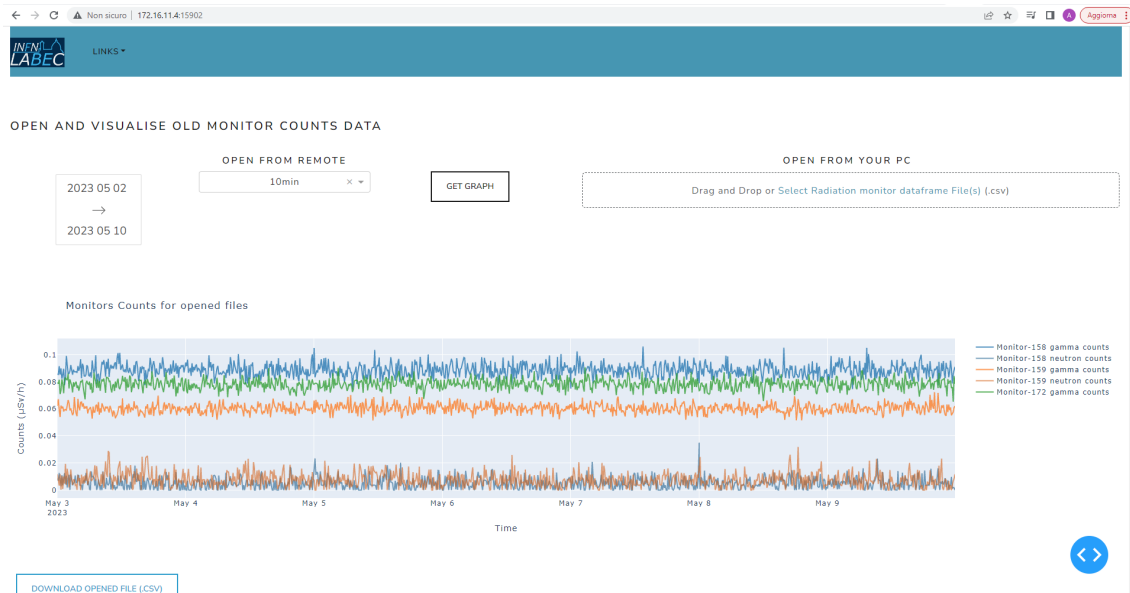


Figure 5: Screenshot of the software web page showing data plots

3 Conclusions

The system above described was developed within INFN-CHNet inspiring to open-design principles: open and free software and open hardware are used. Low-cost and easily obtainable components of recognized quality and robustness were chosen. During usage tests, the system has proven to be highly reliable. The use of well-established Arduino microcontrollers, combined with the noise immunity of the RS485 serial communication standard, allows for extraction of data from radiation monitors without interruptions, slowdowns, or data loss. The inclusion of redundant elements such as Raspberry Pi mini-PCs and multiple PCs ensures extremely secure data storage. Regarding the software, Python was chosen for its increased code readability and modifiability, and a web-based interface architecture was implemented to facilitate remote access and user-friendly data visualization. Furthermore, the software system is characterized by a modular architecture, allowing it to be easily configured as a cloud service.

References

- [1] DECRETO LEGISLATIVO 31 luglio 2020, **101**, Art. 50
- [2] J. C. Liu and others, Radiation Safety Systems for Accelerator Facilities, Radiation Protection Dosimetry, **96**, Issue 4, 1 August 2001, Pages 429–439, <https://doi.org/10.1093/oxfordjournals.rpd.a006630>
- [3] https://www.highvolteng.com/Ion_Accelerator_Systems_en.html (visited on June 2023)

- [4] Chiari, M., Barone, S., Bombini, A. et al. LABEC, the INFN ion beam laboratory of nuclear techniques for environment and cultural heritage. *Eur. Phys. J. Plus* **136**, 472 (2021), <https://doi.org/10.1140/epjp/s13360-021-01411-1>
- [5] <https://www.thermofisher.com/order/catalog/product/4255909> (visited on June 2023)
- [6] <https://store.arduino.cc/products/arduino-uno-rev3> (visited on June 2023)
- [7] <https://www.arduino.cc/en/software> (visited on June 2023)
- [8] [Van Rossum G, Drake FL. Python 3 Reference Manual. Scotts Valley, CA: CreateSpace; 2009
- [9] Merkel, D. (2014). Docker: lightweight Linux containers for consistent development and deployment. *Linux Journal*, 2014(239), 2
- [10] Plotly Technologies Inc., Collaborative data science Publisher: Plotly Technologies Inc., Montréal, QC, 2015, URL: <https://plot.ly>
- [11] <https://linux.die.net/man/1/rsync> (visited on June 2023)
- [12] Reznick L. Using cron and crontab. *Sys Admin*. 1993;2(4):29–32
- [13] <https://linux.die.net/man/1/socat> (visited on June 2023)