The SAMPA-SRS integrated readout for gaseous radiation detectors.

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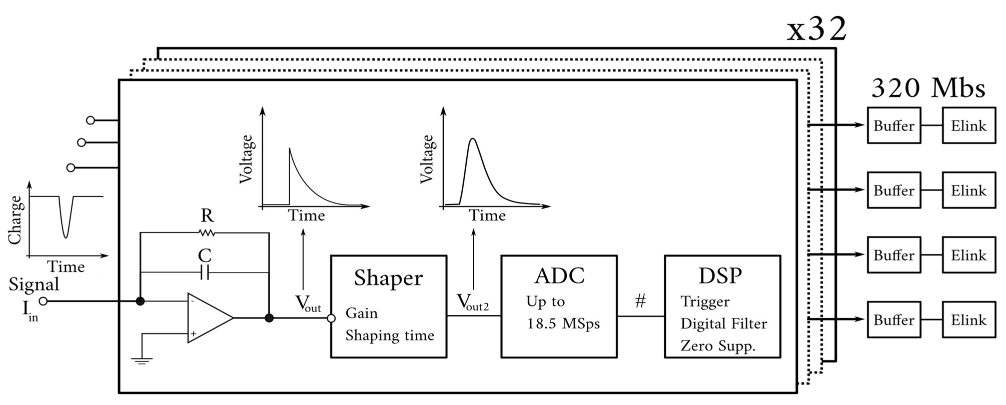
Introduction

SAMPA chip [1] was designed to work as the new front-end ASIC of the ALICE experiment TPC and Muon Chamber, however, its integration to the Scalable Readout System [2] has shown promising results in the lower energy physics studies. In this work we present the latest developments in the SAMPA-SRS integration. A software in charge of the acquisition configuration, acquisition, and decoding of the data was developed. To test the complete acquisition framework two different detectors were mounted: an X-ray position sensitive detector and a small Time Projection Chamber (TPC).

The SAMPA chip and the Scalable Readout System



SAMPA overview:

- TSMC CMOS 130nm, 1.25V technology.
- 32 Channels per chip with CSA + ADC + DSP.
- Positive and negative polarities with 2 analog front-end modes:
  - 20 or 30 mV/fC with 160 ns shaping time (target sensor cap: 12 - 25 pF).
  - 4 mV/fC with 300 ns shaping time (target sensor cap: 40 - 80 pF).
- ADC: 10-bit resolution, up to 18.5 MSPS.

The Scalable Readout System:

The Scalable Readout System (SRS) is an multi purpose acquisition system that can operate with different front-end ASICs such as the AVP25, VMM and now SAMPA, depending only on the chip availability and the user detection system/application.

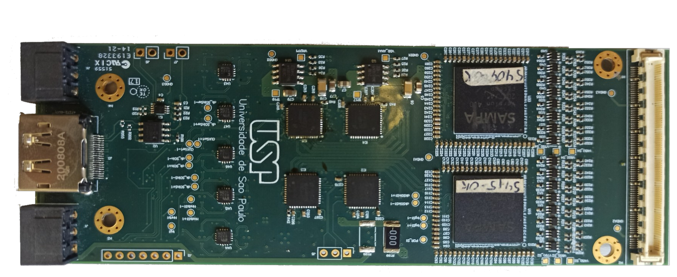
It supports and integrates systems with up to few thousand electronic channels and was developed within the RD51 collaboration at CERN.

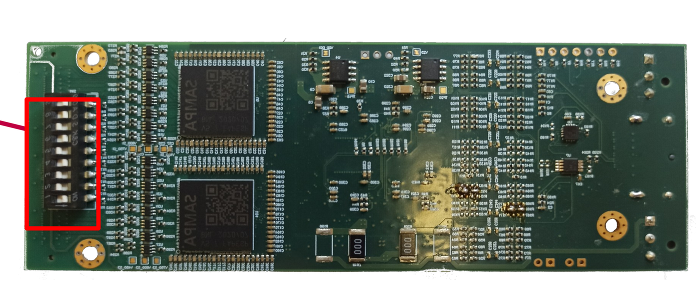
The Front-End Card:

- FPGA Xilinx Virtex 6
- Up to 20 LVDS I/O and 40 LVCMOS I/O
- Ethernet 1Gbps
- External input/output trigger
- Extensible firmware to new digital systems

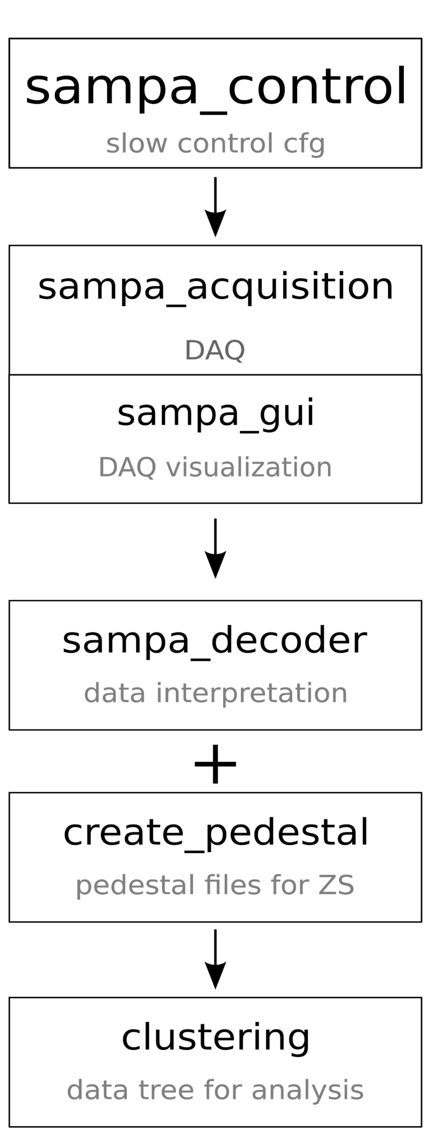
The hybrid board

- Four SAMPA chips operating at 300 MHz main clock. Each one is connected to one high speed serializer
- Each hybrid can read up to 128 channels
- A single DisplayPort cable is used to connect the hybrid to the adapter card at the FEC
- Use of external switches to change between gain configurations, shaping time, sampling rate and polarities.
- The number of channels and the physical dimensions of the hybrid are compatible with the standard readout plane developed by the RD51 collaboration





The SampaSRS software



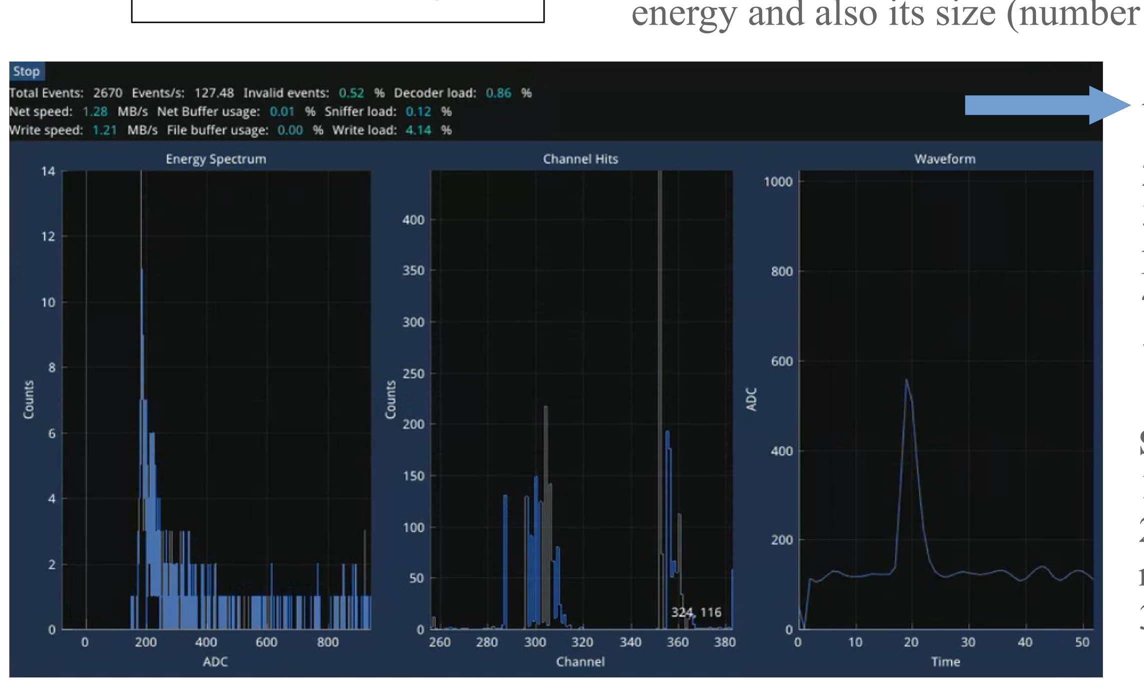
sampa_control: request/reply protocol communication between the computer and the FEC/SAMPAs to configure the acquisition (start/stop, internal/external trigger, waveform length, latency, zero suppression threshold)

sampa_acquisition/sampa_gui: a tool that capture the packages from the network. If the user wants to have a real time preview of the acquisition a graphic user interface process and decodes a small amount of data to create few histograms.

sampa_decoder: transform the raw data produced by SAMPA (unordered hexadecimal) into a human readable root file TTree. The event built contains information of time, channel and the complete waveform produced after a trigger.

create_pedestal: process and produces a pedestal file containing information of the baseline levels and noise for each channel. Can be used for offline zero suppression or as input for the online zero suppression of SAMPA (work in progress).

clustering: using a pedestal file build the clusters using a clustering algorithm that is going to be explained in details ahead. The new file contains information regarding the center of mass position of the cluster, energy and also its size (number of strips).

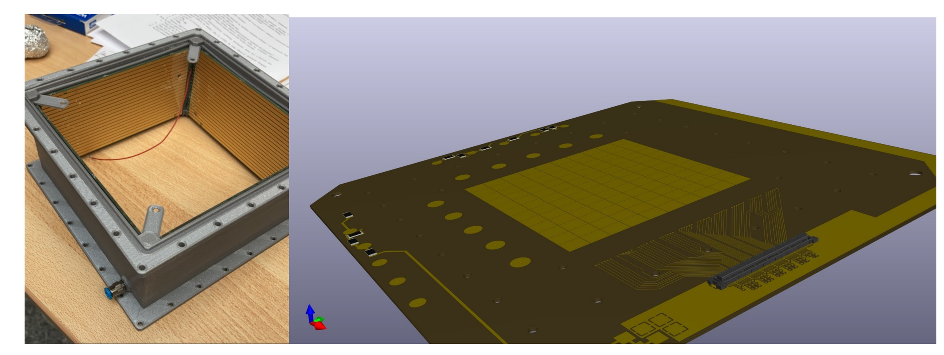


Acquisition details:
1. total number of events
2. trigger rate
3. valid events (check SAMPA's validation bits and package integrity)
4. network usage
5. writing speed and load

SampaGUI window (from left to right):
1. Energy spectrum
2. Channel (position) of the strip with the maximum energy value
3. Waveform of the channel with maximum energy

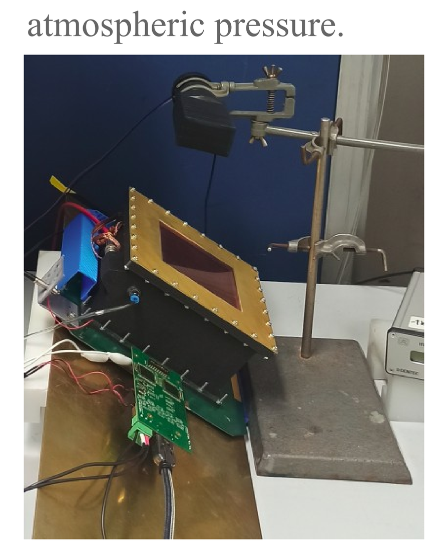
The TPC prototype

To test the SAMPA chip integrated with the SRS a small TPC prototype was built.

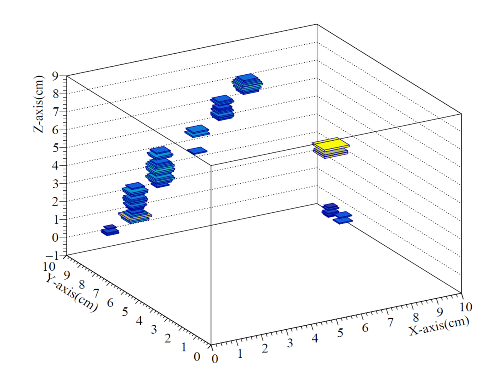


- 80 mm drift region.
- 3D printed PLA chamber.
- Field cage made of standard PCB strips with SMD resistors.
- The readout of the detector is made of 120 pads, covering a total of 10 cm x 10 cm.

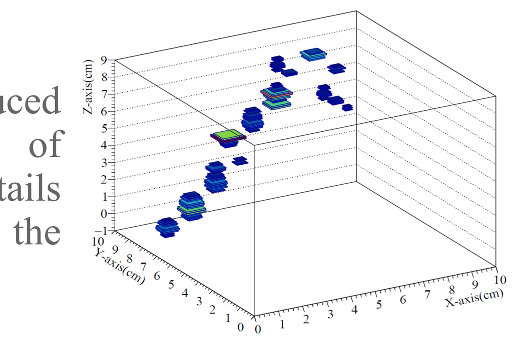
Detector setup:
- A standard triple-GEM detector (2mm gap between GEM foils and 1.5mm induction gap) is operated with a mixture of Ar/CO_2 (70/30) in open and continuous flow at a rate of 15 liters per hour at atmospheric pressure.



- Two photo-multipliers, above and below the detector, were placed to create the trigger.
- The detector is tilted in order to obtain longer tracks from cosmic rays.

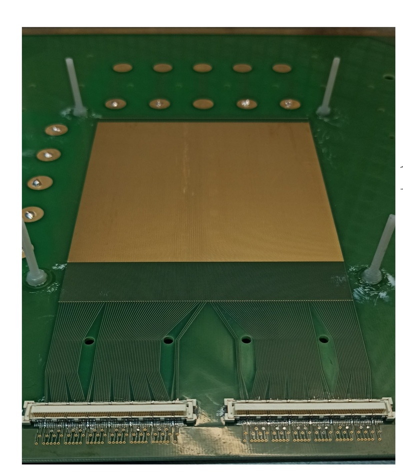


Muon tracks detected by this system.

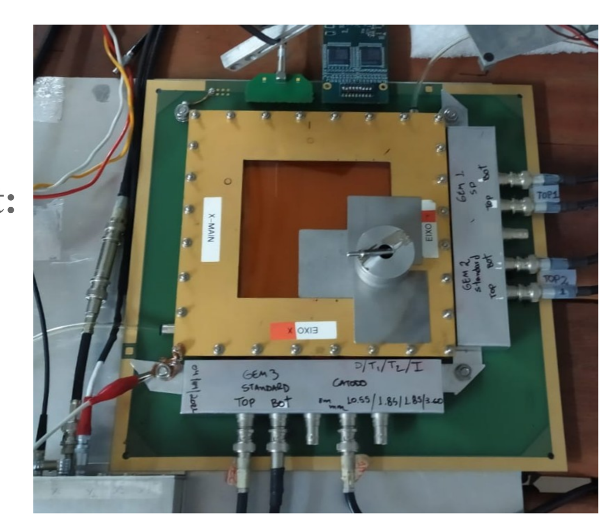


Example of tracks produced after several steps of processing. For more details regarding this system and the reconstruction check [3].

The 1D strip readout detector



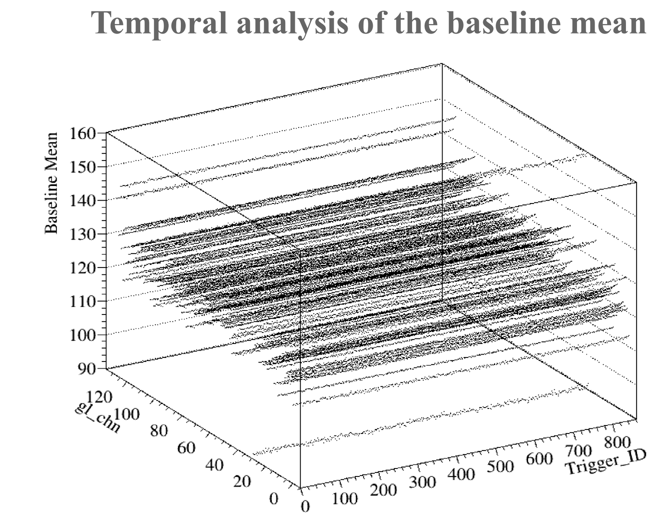
1D segmented readout:
- Strip width: 0.2 mm.
- Pitch: 0.4 mm.
- HRS connector.



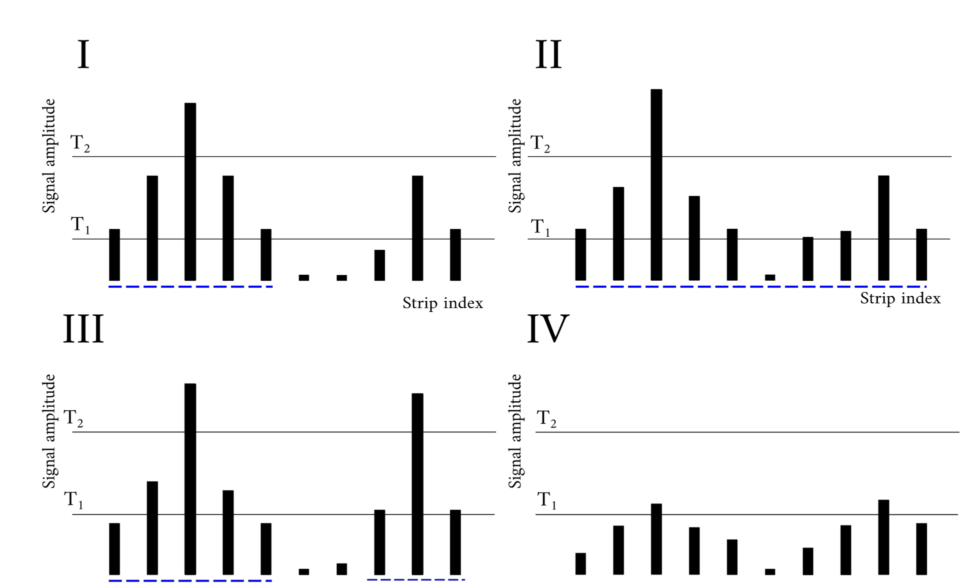
Detector:
- Triple-GEM operating at atmospheric pressure.
- Ar/CO_2 (70/30) 6 L/h flow.
- Trigger for the FEC is generated using the signal collected from the bottom of the last GEM.

Data processing and clustering

Temporal analysis of the baseline mean

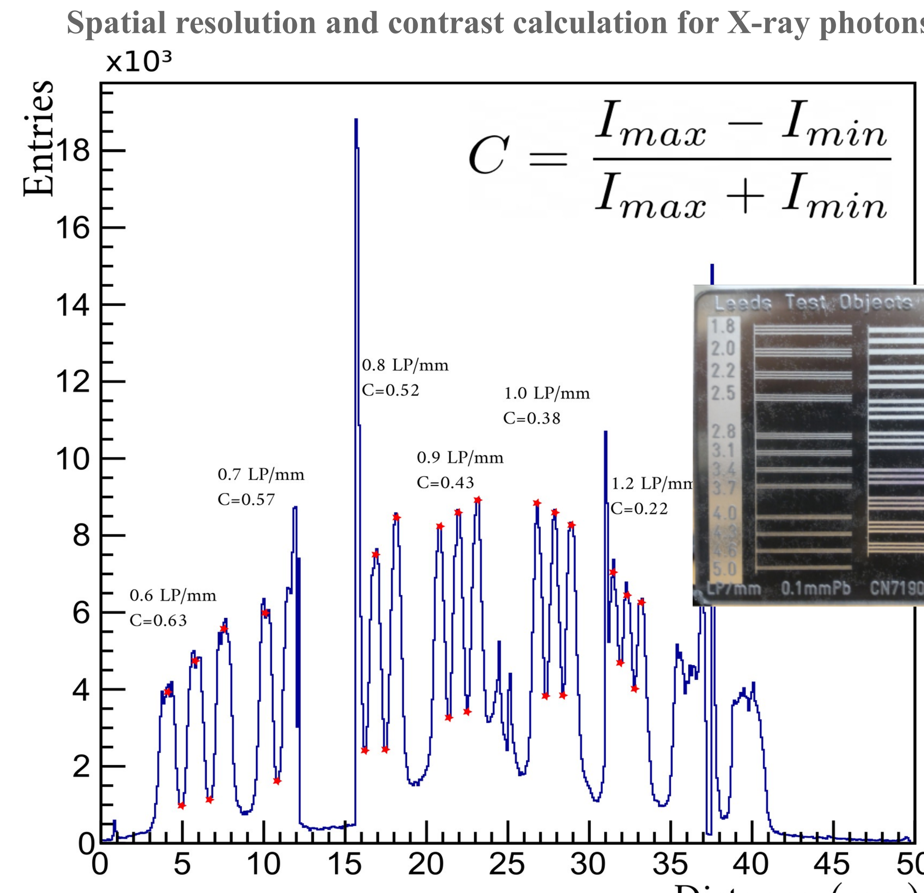


1. No common-mode signal was observed. Noise seems to be stable in time.
2. Baseline mean calculated using the waveform values thorough time.



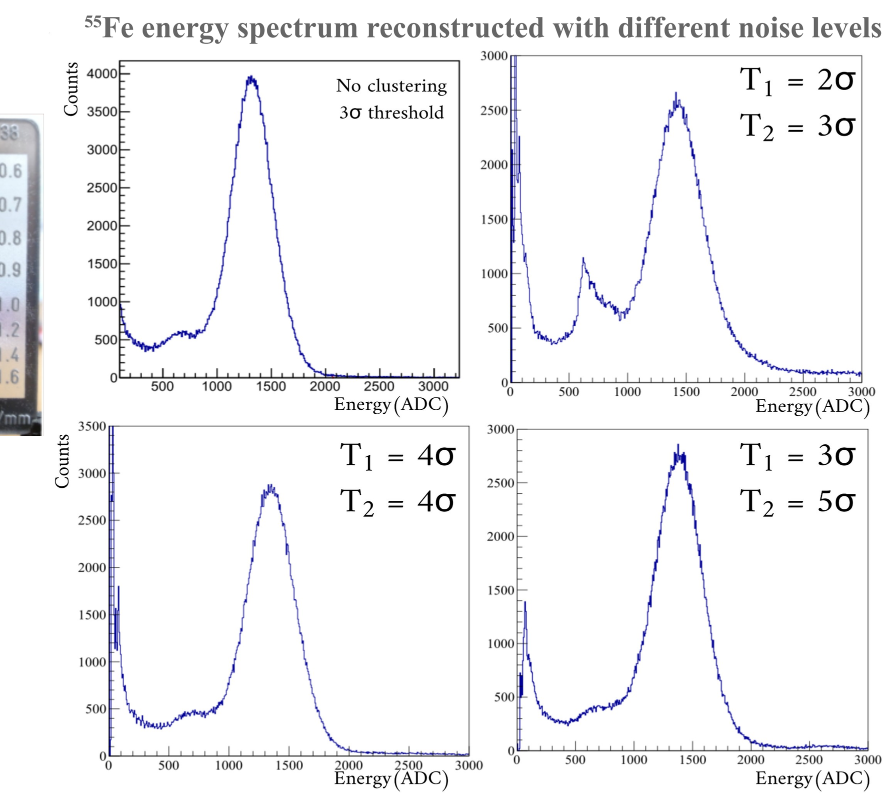
The clustering algorithm is based on checking two threshold levels T_1 and T_2. These value are calculated channel by channel, however, for simplicity in the drowning above they are all the same.
I) Valid cluster in the left. The signals in the right are in a distance greater than two strip pitches (could lead to a cluster split), however no signal is above T_2.
II) All signals are close neighbors and one of them validates the cluster ($>T_2$).
III) Two clusters are created and they are both valid.
IV) No valid cluster ($<T_2$).

Spatial resolution and contrast calculation for X-ray photons



The spatial resolution can be estimated using a lead mask. The red dots represent the points used to calculate the contrast values for the different spatial frequencies and usually the position resolution is equivalent to the contrast at 10%. In our case better than 833µm (1.2LP/mm).

^{55}Fe energy spectrum reconstructed with different noise levels



References

[1] – "SAMPA chip: the new 32 channels ASIC for the ALICE TPC and MCH upgrades", J. Adolfsson et. al. *Journal of Instrumentation*, vol. 12, pp.

[2] – S. Martoiu, H. Muller and J. Toledo, "Front-end electronics for the Scalable Readout System of RD51," *2011 IEEE Nuclear Science Symposium Conference Record*, 2011, pp. 2036-2038, doi: 10.1109/NSSMIC.2011.6154414.C04008–C04008, Apr 2017.

[3] – G.G.A. de Souza et al., "Operation of a TPC using the SAMPA chip integrated in the SRS", NIM-A, Vol. 1045 (2023), doi: https://doi.org/10.1016/j.nima.2022.167577

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