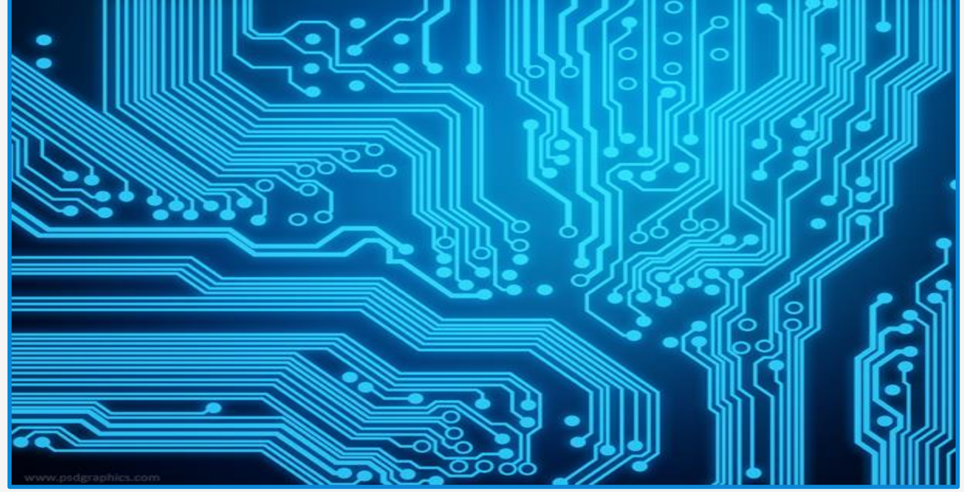

ADVANCED FPGA-BASED READOUT ELECTRONICS FOR STRIP DETECTORS

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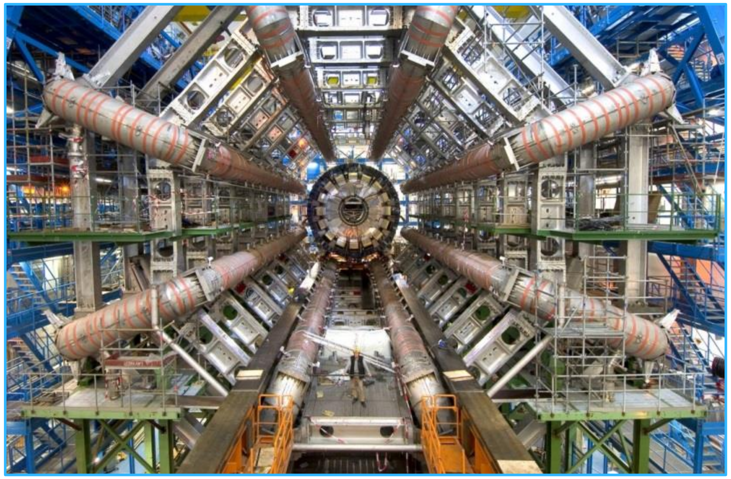
21st IWORID, Crete, Greece, July 7-12, 2019

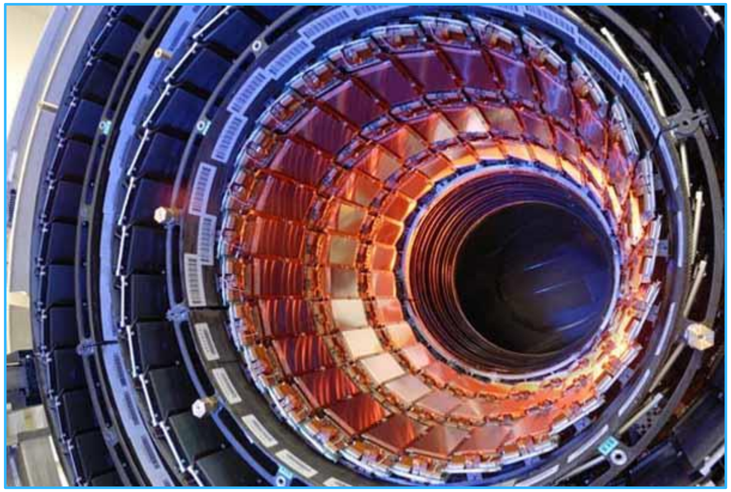
Outline

1. Motivation

- Strip detectors widely used in experimental physics (CERN, BNL, DESY)
- Need of cheaper and accurate detection systems.
- Applications using big area detectors.
- Strip detectors not only for tracking and counting (spectrometers).
- Minimize heat transfer to sensor from readout electronics.
- Minimize the irradiation of readout electronics.

ATLAS semiconductor tracker



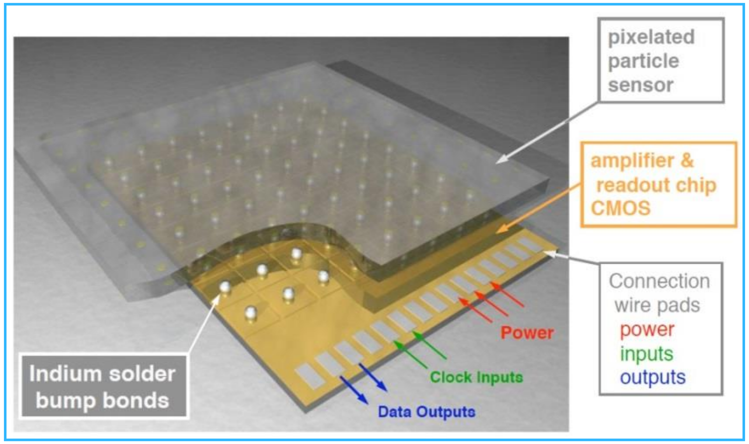


2. Pixel vs Strip Detectors

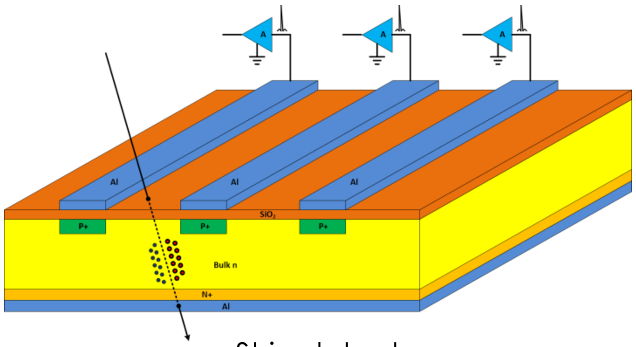
- Pixel detectors:

+ Excellent performance
+ Very good resolution
+ Track shape analysis in all directions
+ Produce unambiguous hits

– Cost per unit
– Small size (14 x 14 mm^2)
– Readout electronics interacts with the radiation being detected.
– Heat of the readout chip is transferred to the sensor.
– Bump-bonding needed to connect readout ASIC and sensor.



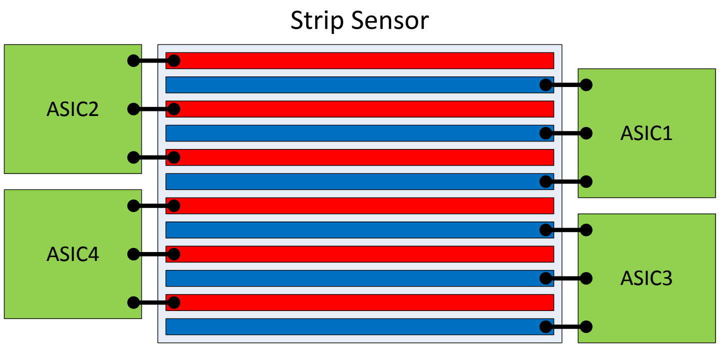
Mpix/Tpix hybrid assembly, CERN.



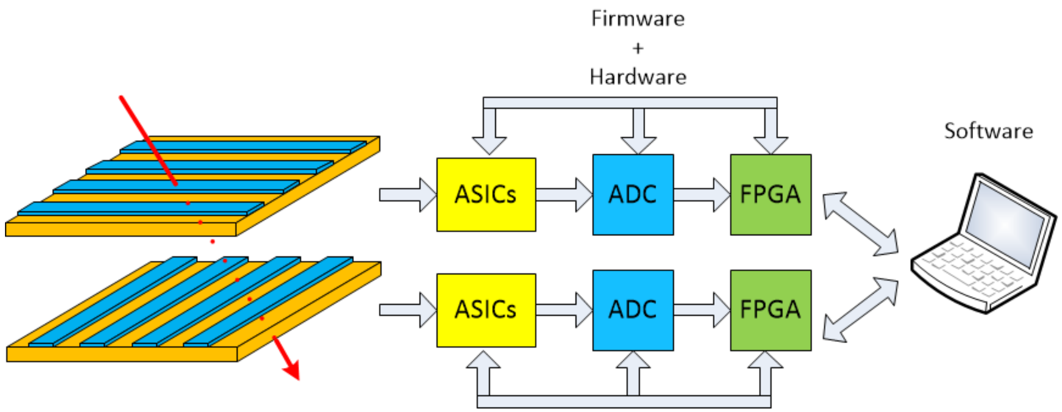
Strip detector.

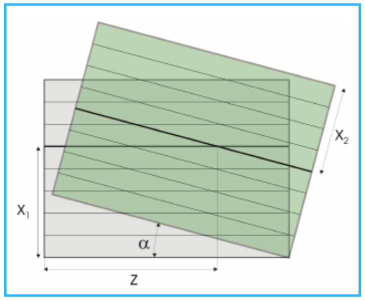
3. Approach

- Two-dimensional positioning:
  - Double sided strip detector (DSSD)
  - Two single strip detectors (SSD) needed for tracking.
- Right angle generates "Ghost" events. Stereo angle needed for high occupancies.

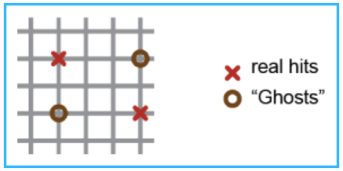


Interlaced configuration



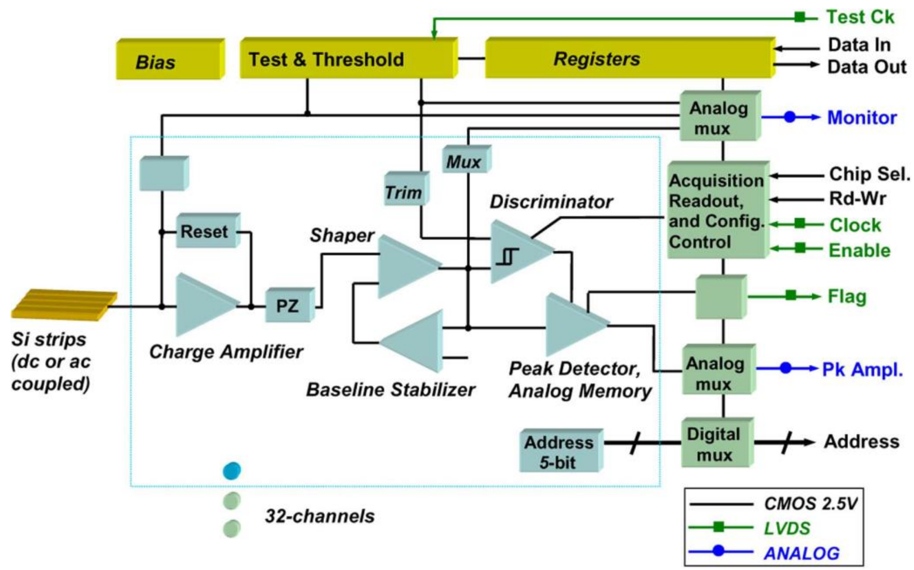


Stereo angle α:
40mrad SCT Endcap Module

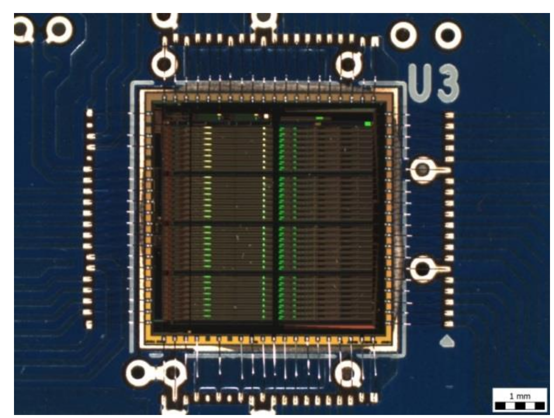


4. ASICs [BNL]

- Power: 166 mW (4mW/channel +38mW), 0.25 um technology.
- Front-End channels: 32
  - charge preamplifier, 5th order shaping amplifier with complex conjugate poles, peak detector, multiplexing.
  - charge preamplifier polarity : positive or negative.
  - integrated test capacitor: 200fF
  - shaping amplifier peaking time: 500ns, 1μs, 2μs, 4μs.
  - channel gain: selectable 14.25, 28.5, and 57 mV/fC (3.2 MeV, 1.57 MeV, 788 keV).
  - Baseline: 250mV.
  - Max. signal: 2V from baseline (≈3.2 MeV/channel)
- Output: Analog memory + addr.
- Events read in sparsified mode.



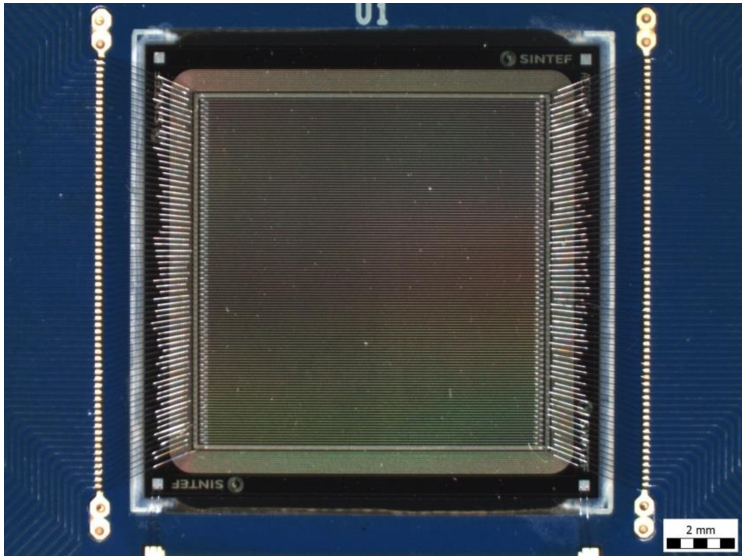
Courtesy of Gianluigi De Geronimo



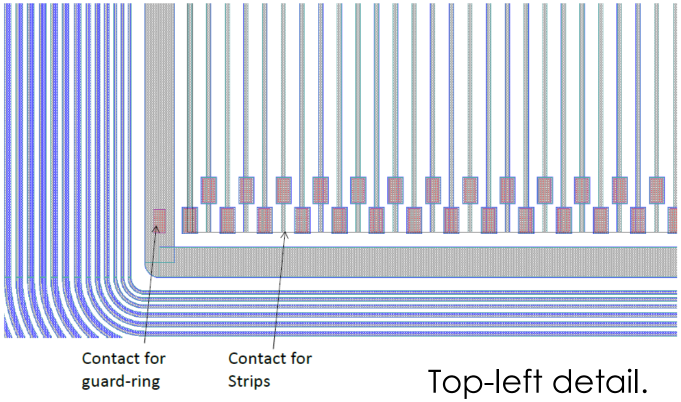
5x5 mm^2 NCIASIC3 die bonded to PCB.

5. Strip Detector [SINTEF]

- Silicon, AC-coupled.
- Physical dimension : 14 x 14 mm2
- Active area : 10 x 10 mm2
- Number of strips : 128
- Strip pitch : 90 μm
- Thickness : 300 μm frame, 200 μm active area
- Bias : Front side contact
- Bonding pad openings : 100 x 50 μm2

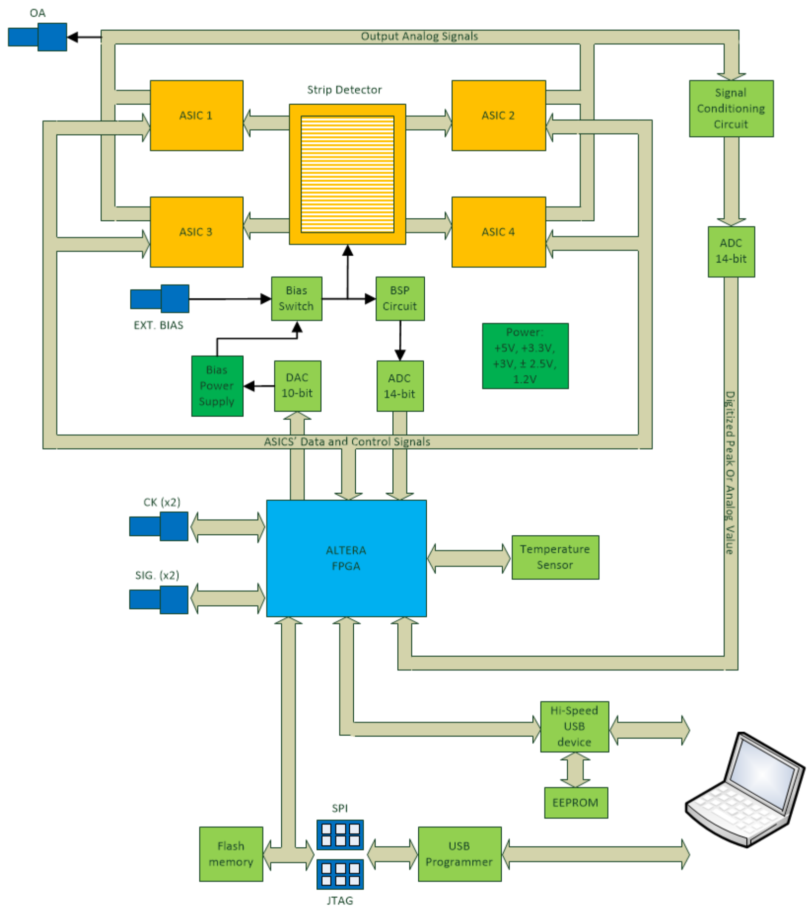


Strip detector bonded to PCB.

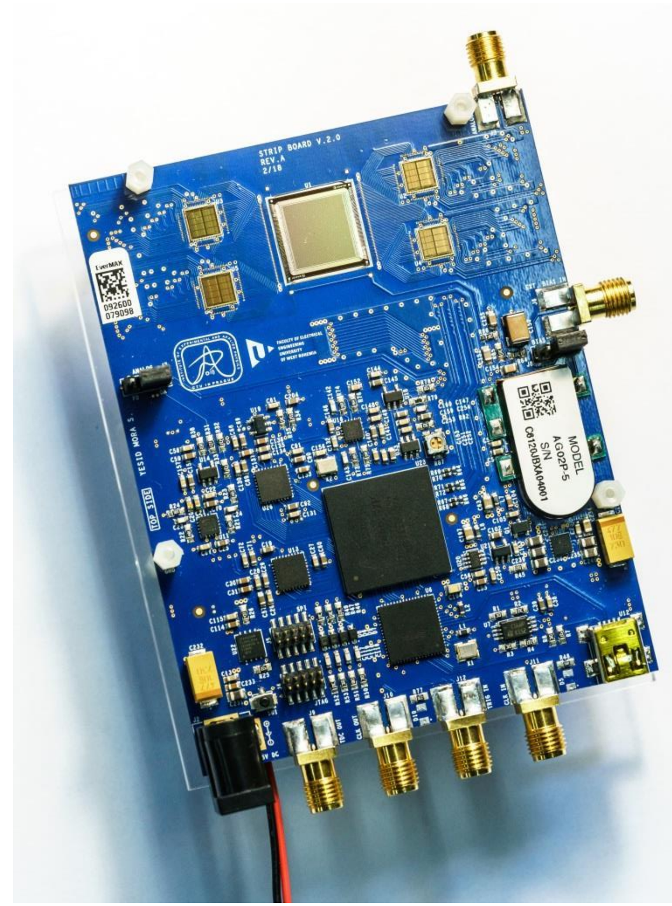


Top-left detail.

6. System overview

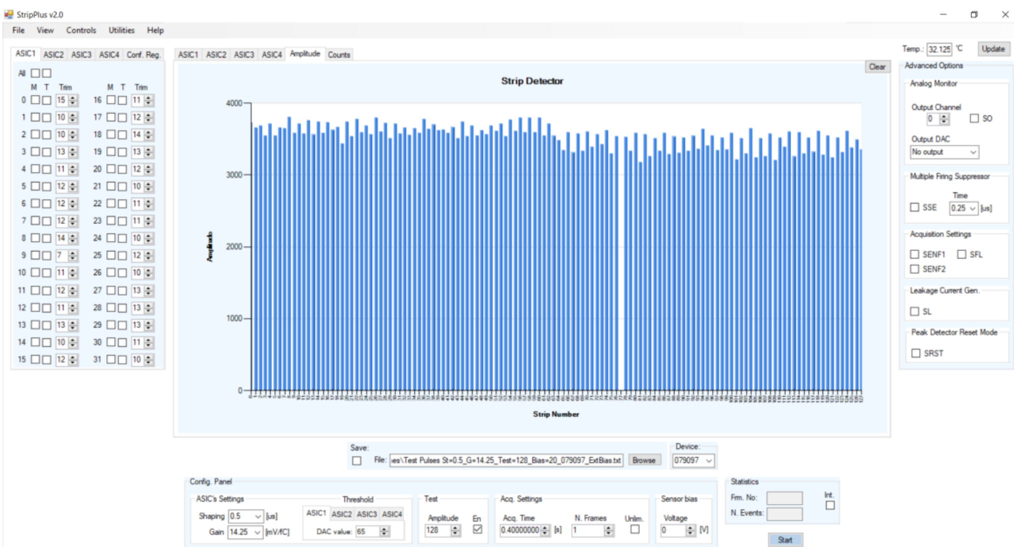


Block diagram of the system.



Top view of the device.

7. Software



GUI - StripPlus. Test pulse for an input charge = 17.5 fC (395 KeV) is shown.

- Features:
  - Data visualization: Amplitude and counting modes per ASIC and for the system.
  - Data saving
  - Masking channels
  - Test pulses
  - Generation and loading of configuration files.
  - Temperature monitoring
  - Baseline scan
  - Equalization
  - Calibration

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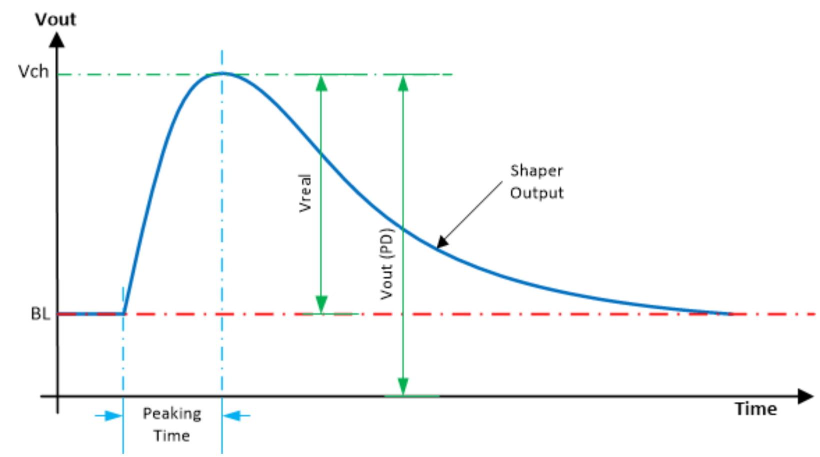
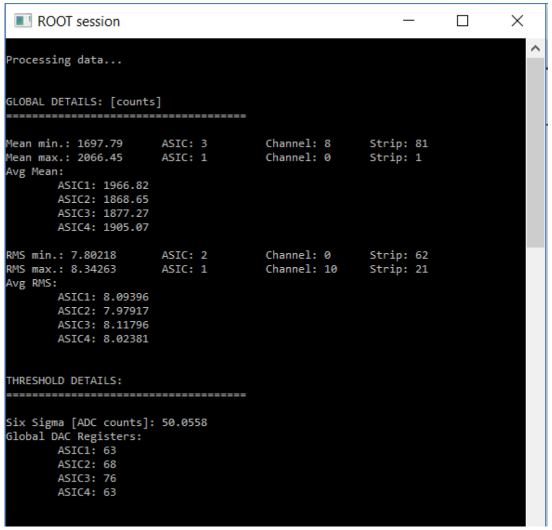
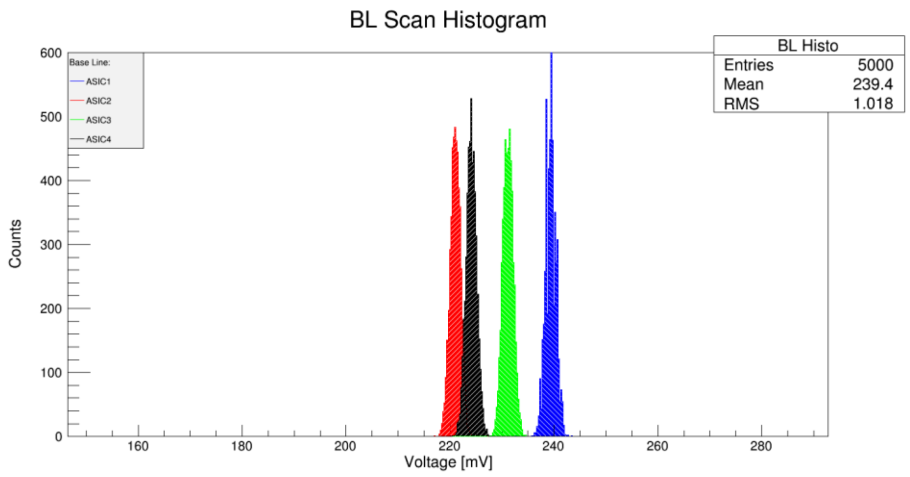
8. Base line scan

- Baseline (BL)= 250 mV
- Each channel has a slightly different BL.
- Each ASIC has a slightly different BL average.
- Baseline is a key parameter in energy calculation.

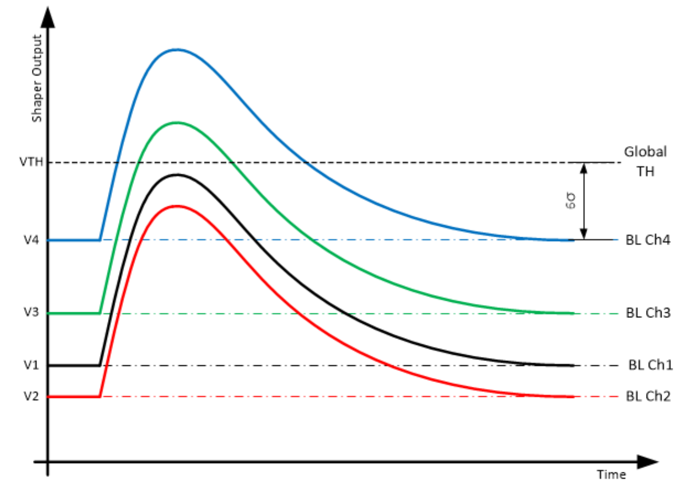


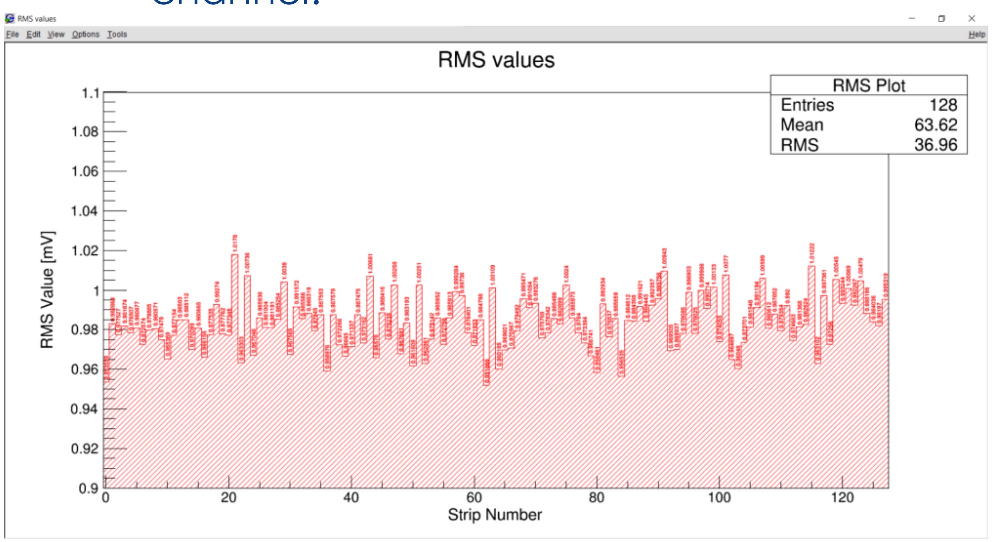


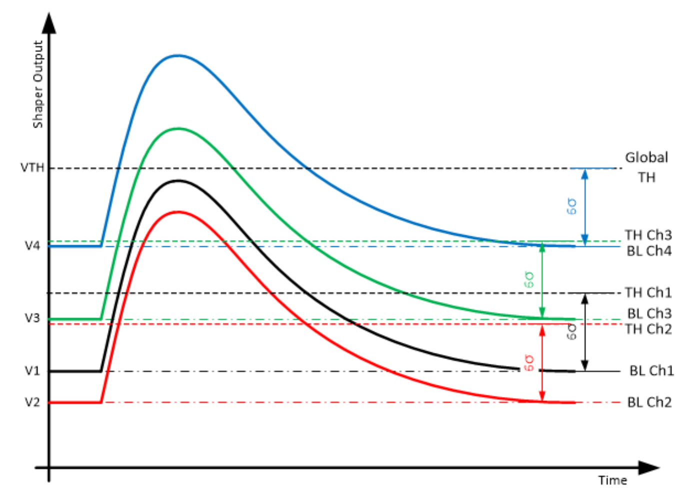


9. Equalization

- Different BL = different "sensitivity"
- Trimming DACs for threshold (step: 3.5mV)
- Detection of noisiest channel in the system.
- Calculation of the Global Threshold per ASIC: (3-6σ) from highest BL (step: 1.95mV, BL: 189mV).
- Calculation of trim value for each channel.







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10. Calibration (Gain)

- Calibration sources:
  - XRF: Zr (15.74 keV), Mo (17.44 keV), In (24.14 keV),
  - Gamma photons: 241Am (59.54 keV), 57Co (122.06 keV).

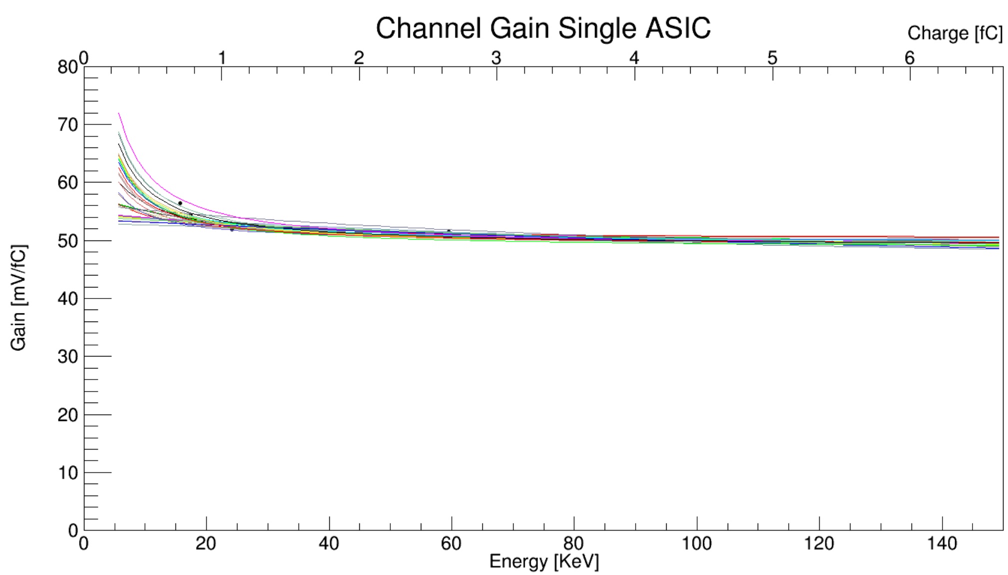
For each channel:

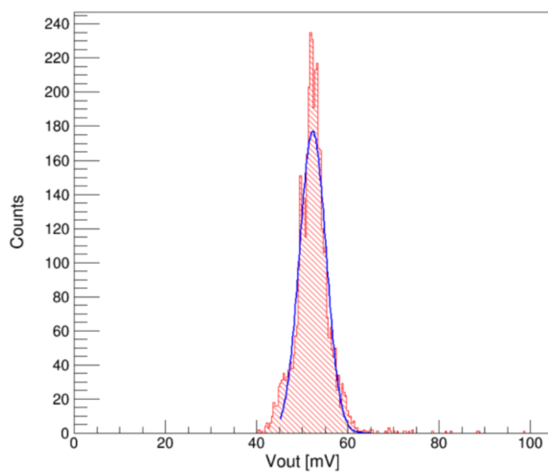
$$E = Vo_{[count]} * \frac{adcstep * ionSi}{G * e^{-} * 10^{15}}$$

$$G = a + \frac{b}{c + E}$$

$$E = \frac{R - b - a * c + \sqrt{(a * c + b - R)^2 + 4 * a * c * R}}{2 * a}$$

$$R = \frac{Vo_{[count]} * adcstep * ionSi}{e^{-} * 10^{15}}$$

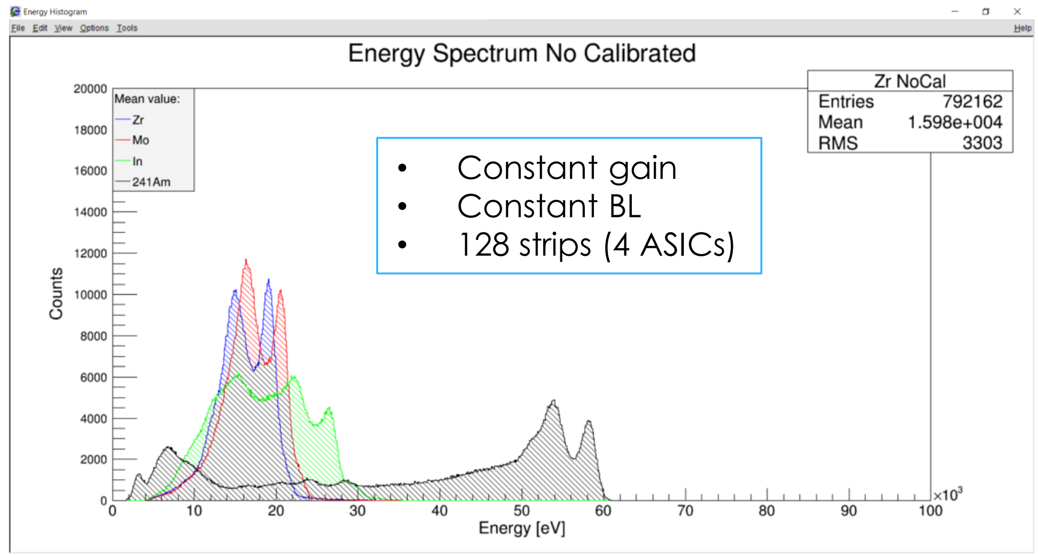


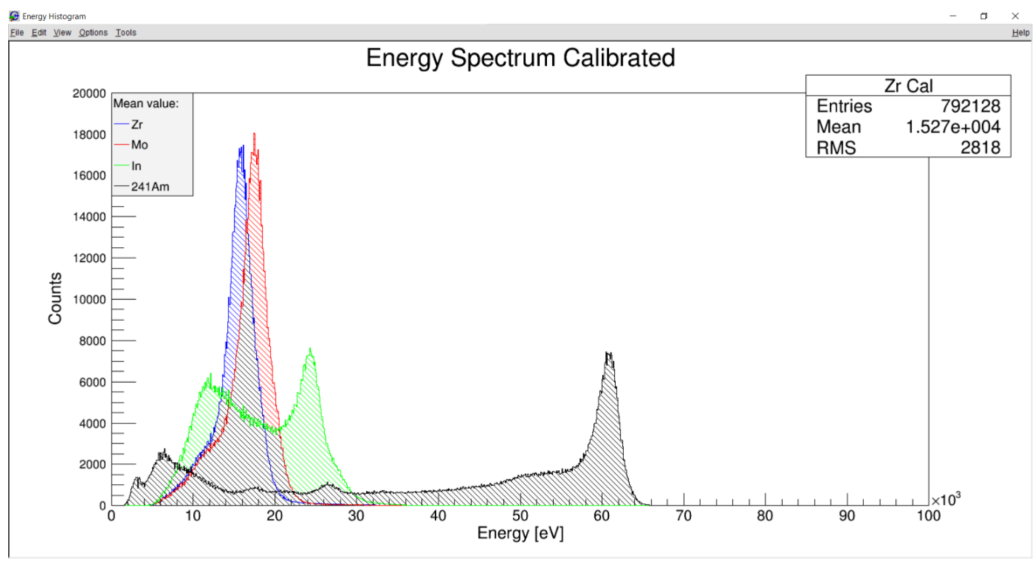


XRF-Mo (44.2 mV)

11. Results

- Improved resolution after calibration. (single peaks)
- Peaks centred at the right energy.
- Sigma calculated as about 1.6 keV in the range 15 to 60 KeV (G=57 mV/fC, ST=500 ns), ENC = 361 e- .
- Threshold level about 3 KeV.
- Data rate: 36,140 Frm/s – 14.17 MB/s.





12. Conclusions and Future Work

- The device showed good performance and energy resolution, becoming an interesting option for multiple applications: single event effect, tracking, dosimetry, and X-ray imaging, among others.
- Strip detectors can be used not only tracking and counting, but for energy spectroscopy.
- Equalization and calibration are essential in multi-chip configuration systems. (strip detectors)
- System shown here contains all the basic features for systems based on any size of strip detector.

- Bigger, thicker and different detector materials can be used in order to increase the efficiency of the system when measuring photons, betas or other type of particle requiring higher cross section materials to be detected.
- New approach using double-sided strip sensors can be fabricated and study in more detail.
- Calibration on wider energy range by means of tuneable protons at VdG.
- Neutron measurements using LiF converter.

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Thanks for your attention