Ongoing BBC detector activities in MEPhI

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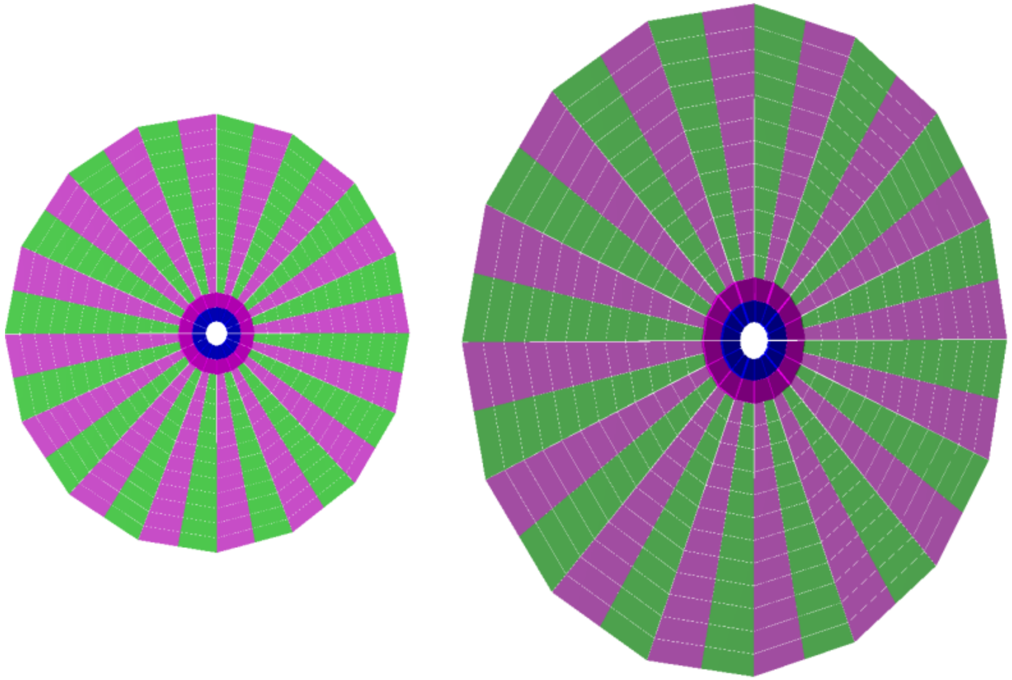
NRNU MEPhI

Beam-beam counter (BBC) detector

Two Beam-Beam Counters (BBC) are planned to be installed at the ends of the SPD setup, symmetrically with respect to the interaction point along the collision axis.

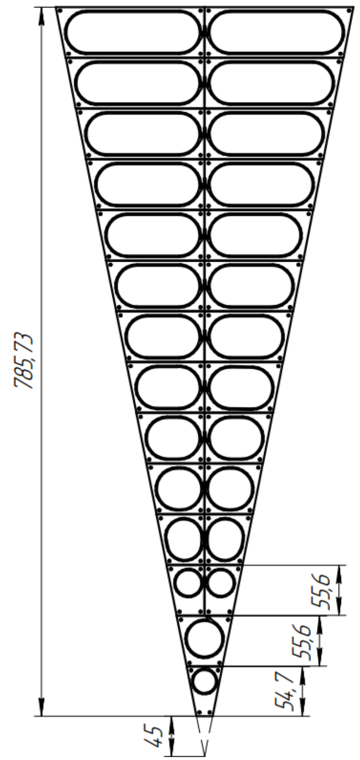
The main functions of the BBC are as follows:

- Local polarimetry within the SPD, based on the measurement of azimuthal asymmetries of polarized proton and heavy-ion beams
- Continuous monitoring of beam collision intensity (beam monitoring)



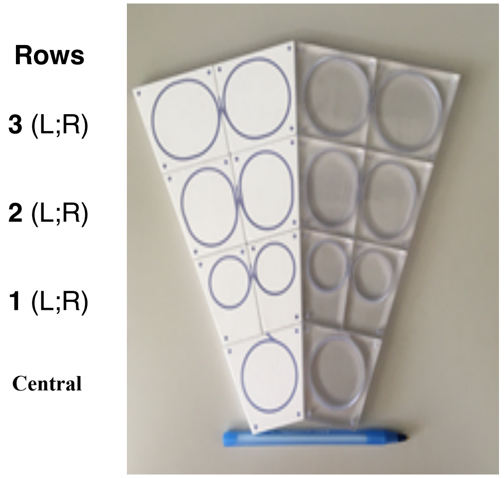
Pic. 1 - Beam-beam counter (BBC) detector (Geant4 model)

Beam-beam counter (BBC) detector



Pic. 2 – whole sector

The SPD BBC will consist of 16 sectors, each containing 26 tiles, arranged within a single detector wheel. Each tile serves as an individual signal source, read out via a silicon photomultiplier (SiPM) coupled to the end of a Wavelength-Shifting (WLS) optical fiber.
The total number of readout channels suggests the use of the CAEN FERS-5200 front-end electronics (FEE) system, specifically designed for large-scale detector arrays.

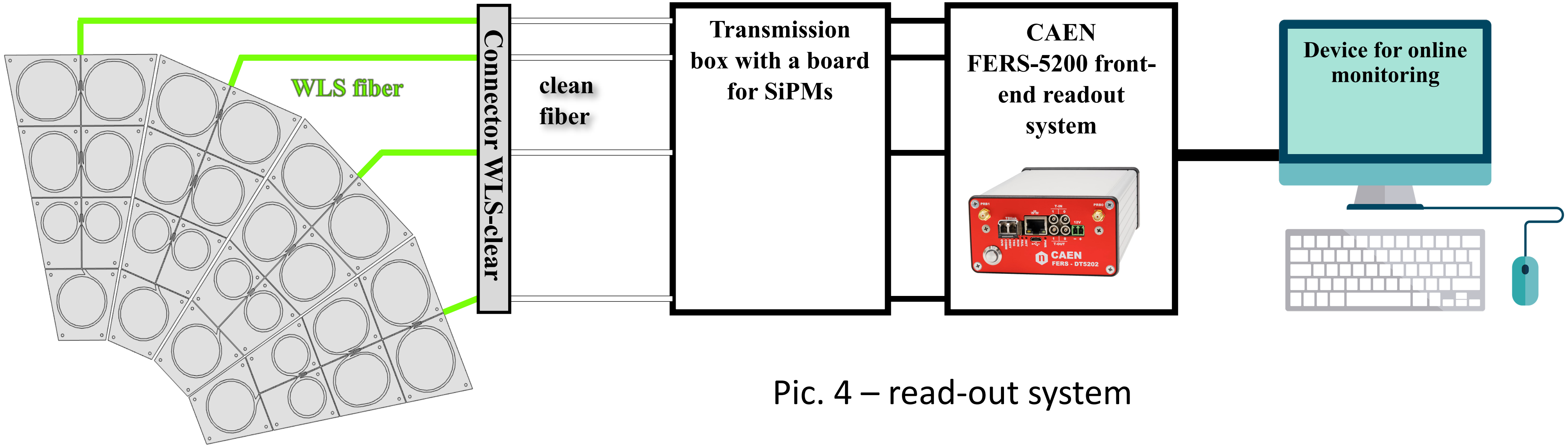


Pic. 3 – prototype sector

In operation, the following materials are used:

- Frosted (matte) surface coating
- **Saint-Gobain Crystals BCF92** Wavelength-Shifting (WLS) fiber
- **CKTN B** optical cement
- **Onsemi FC30035** SiPM

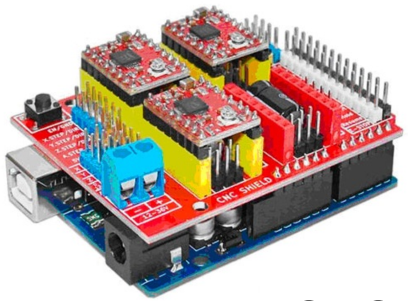
- The Wavelength-Shifting (WLS) fiber shifts the ultraviolet spectrum toward the green region of the visible light.
- The clear optical fiber features a long attenuation length.
- The monitoring device serves as a tool for preliminary analysis.



Pic. 4 – read-out system

X-ray scanning technique

Pic. 5 - AMPTEK Mini-X X-ray tube

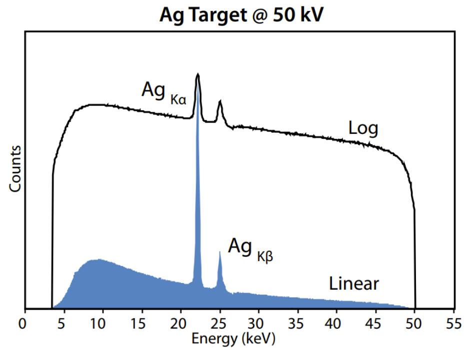


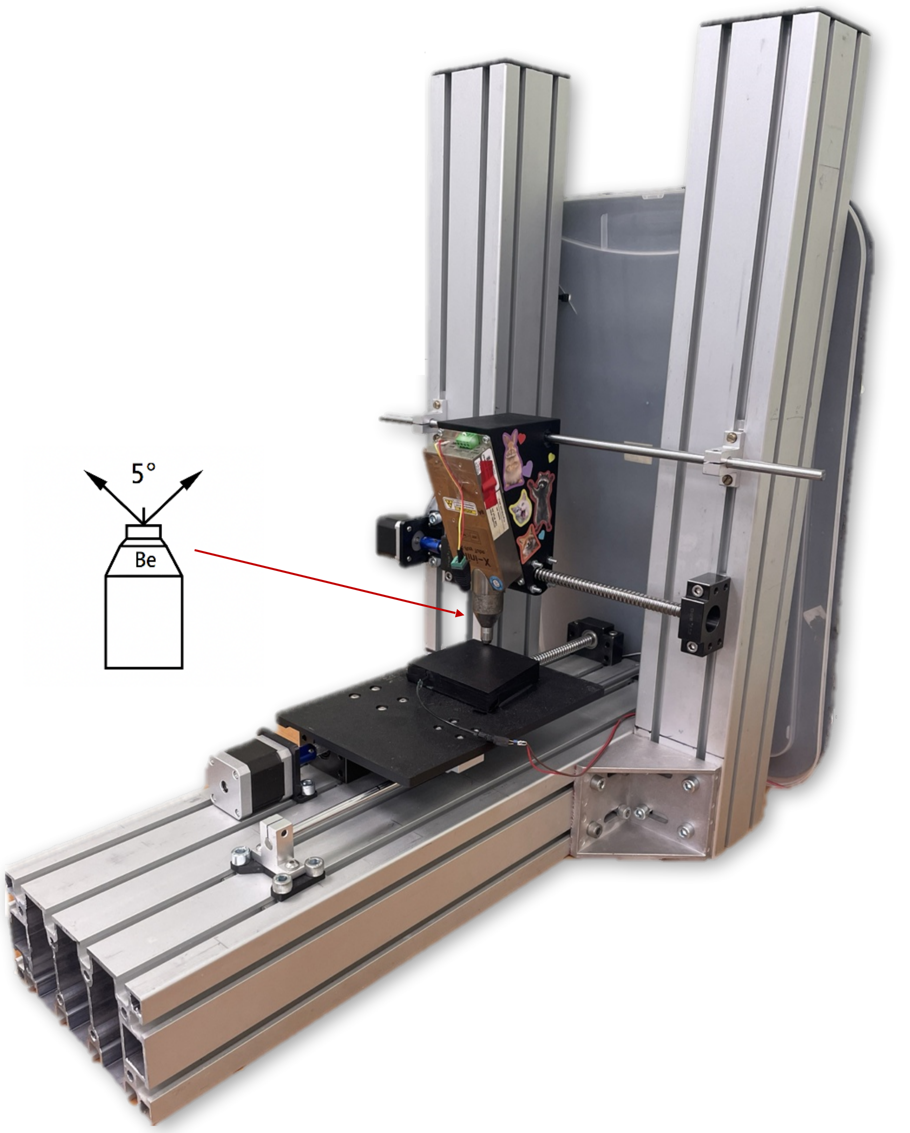
Pic. 6 - Arduino with CNC shield and stepper motor drivers

The coordinate positioning stage based on an X-ray tube includes the following components:

- **AMPTEK Mini-X X-ray tube**
  With a usage of a silver (Ag) target, operated at 50 kV / 80 µA, equipped with a 2 mm collimator (5° X-ray cone), positioned approximately 2 cm above the tile
- **NEMA 17 stepper motor**
  With a step angle of 1.8° and a mechanical resolution of approximately 20 µm along the X and Y axes
- **Arduino with CNC Shield**
  A microcontroller board enabling automated motion control
- **CAEN DT5202**
  A power supply unit A7585D with a resolution of 1 µA;
- **Light-isolating black box for tile shielding**
- **Lead sheets for radiation protection**

Pic. 7 - Mini–X Output X-Ray Spectra

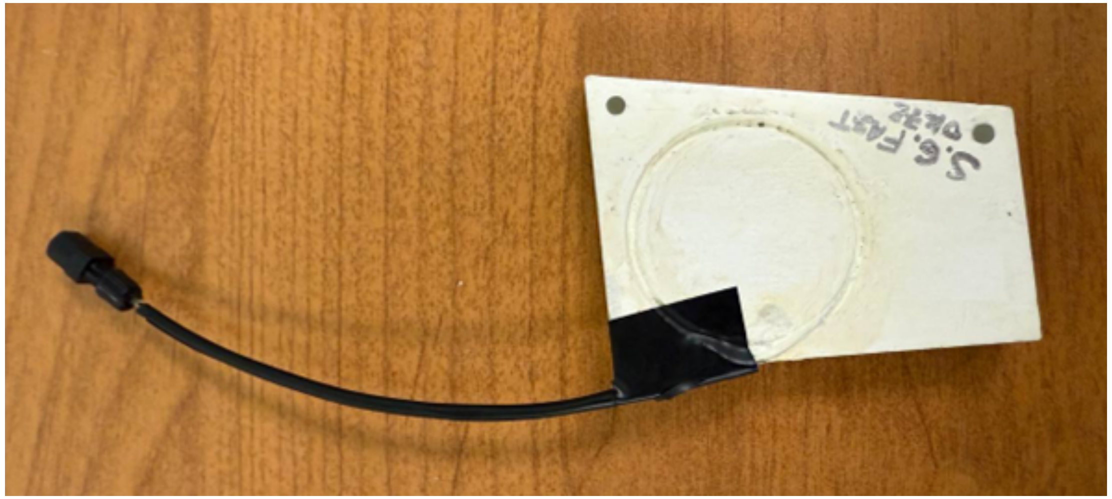




Pic. 8 – The experimental setup

Results 1 – full test (1st method)

Tile sizes: 42mm x 28mm x 36mm

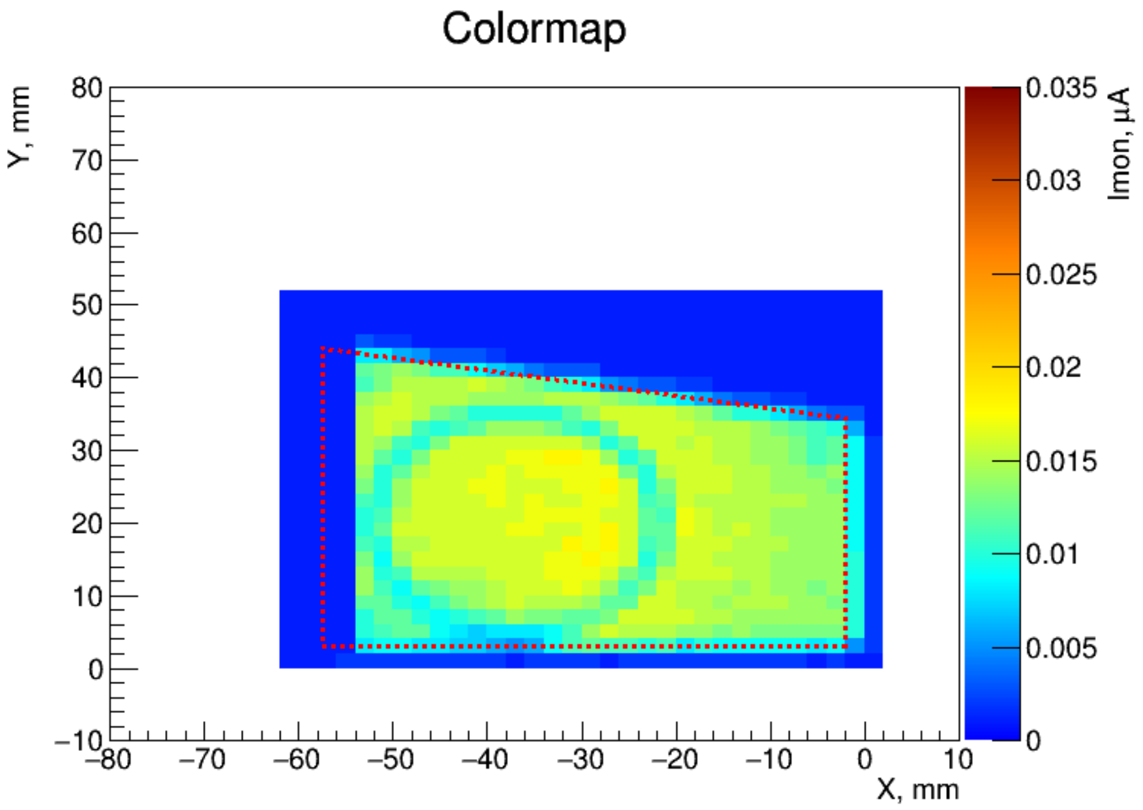


Pic. 9 – **Good** tile ✅
(correctly constructed and
prepared for installation)

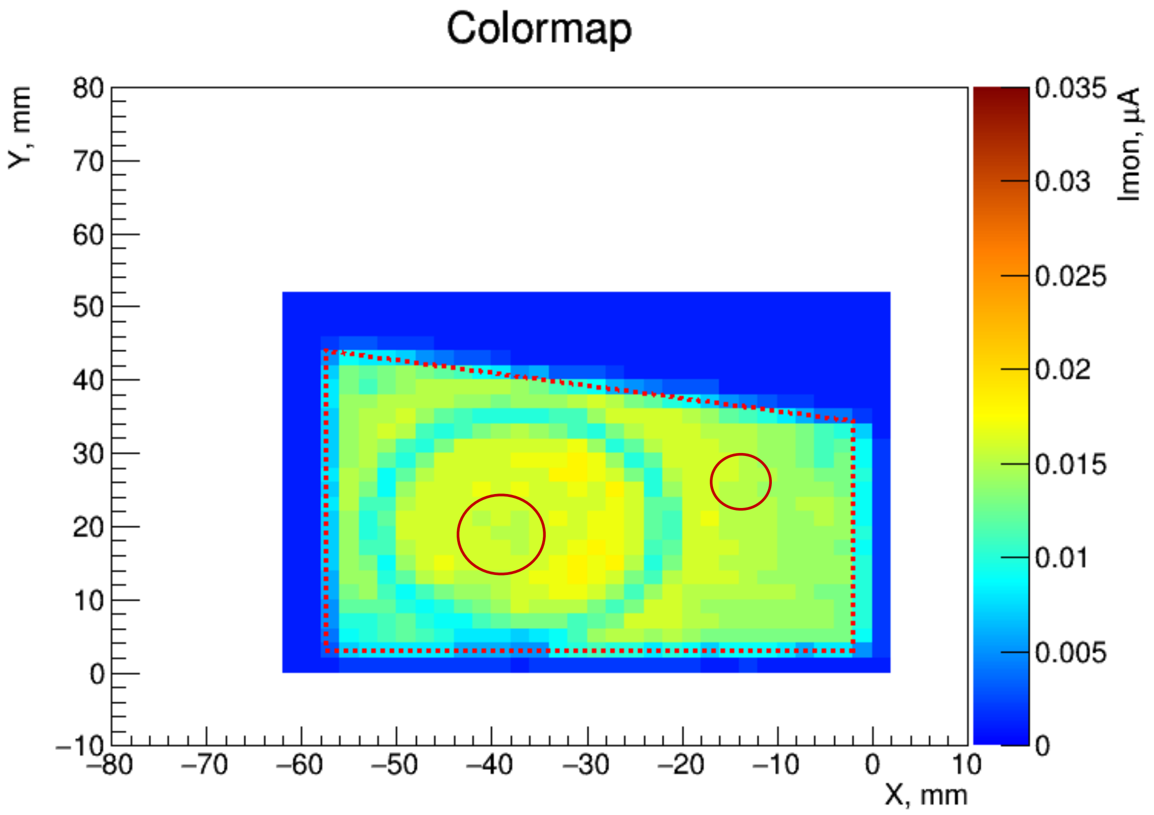
Pic. 10 – **Bad** tile ❌
(applied two different defects}
in x-crossed areas)

Results 1 – full test (1st method)

X & Y axis – coordinates of the measurement (in mms), Z axis – measured current in µA



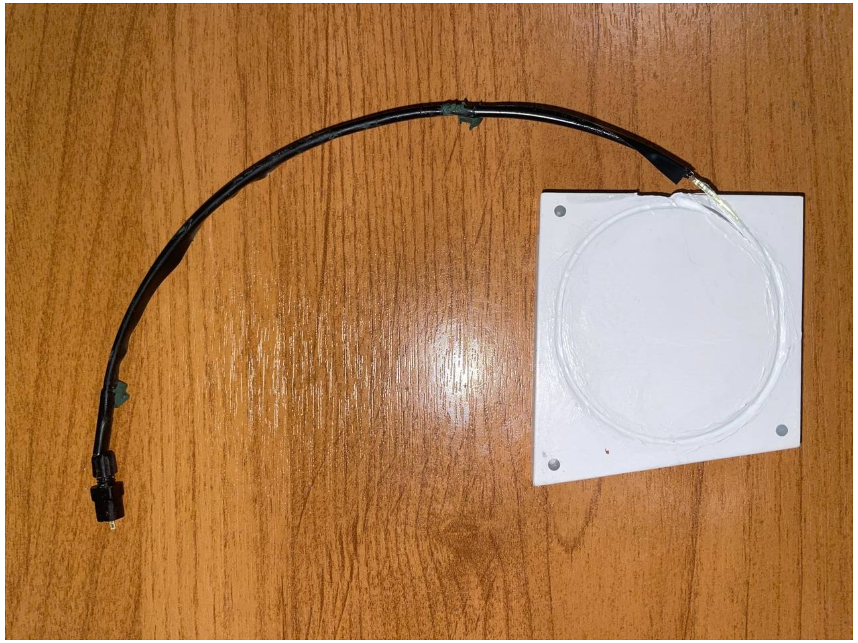
Pic. 11 – Color map of **good** tile ✅
(correctly constructed and
prepared for installation)



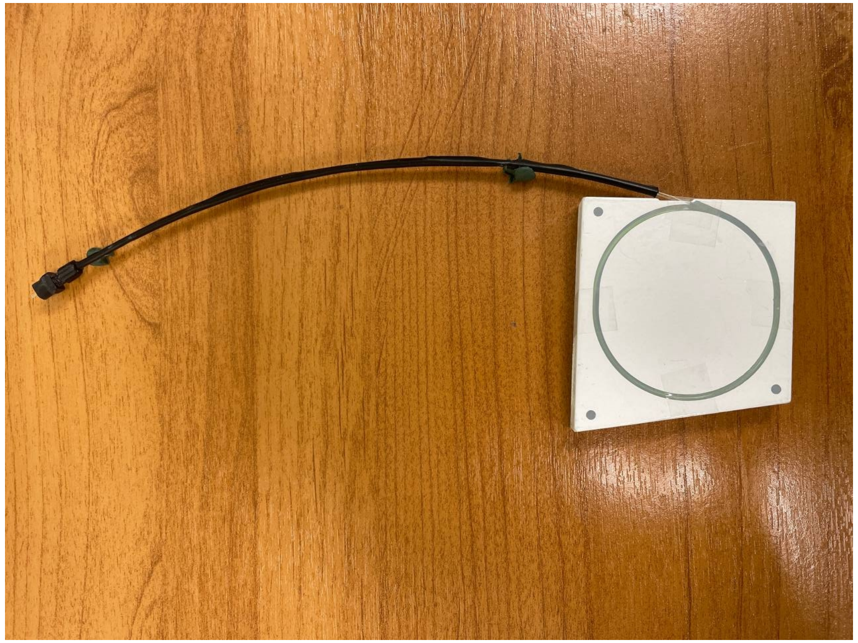
Pic. 12 – Color map of **bad** tile ❌
(applied two different defects}
in x-crossed areas)

Results 2 – grid test (2nd method)

Tile sizes: 64mm x 28mm x 59mm



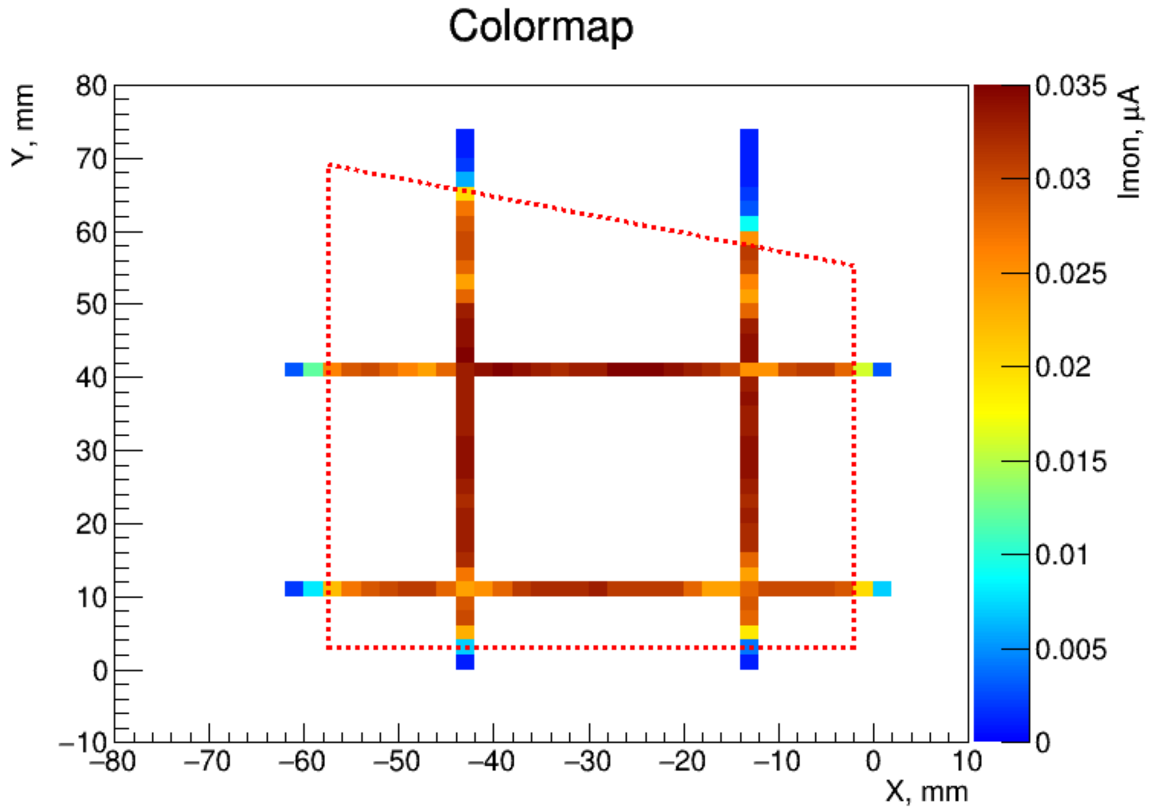
Pic. 13 – **Good** tile ✅
(correctly constructed and prepared for installation)



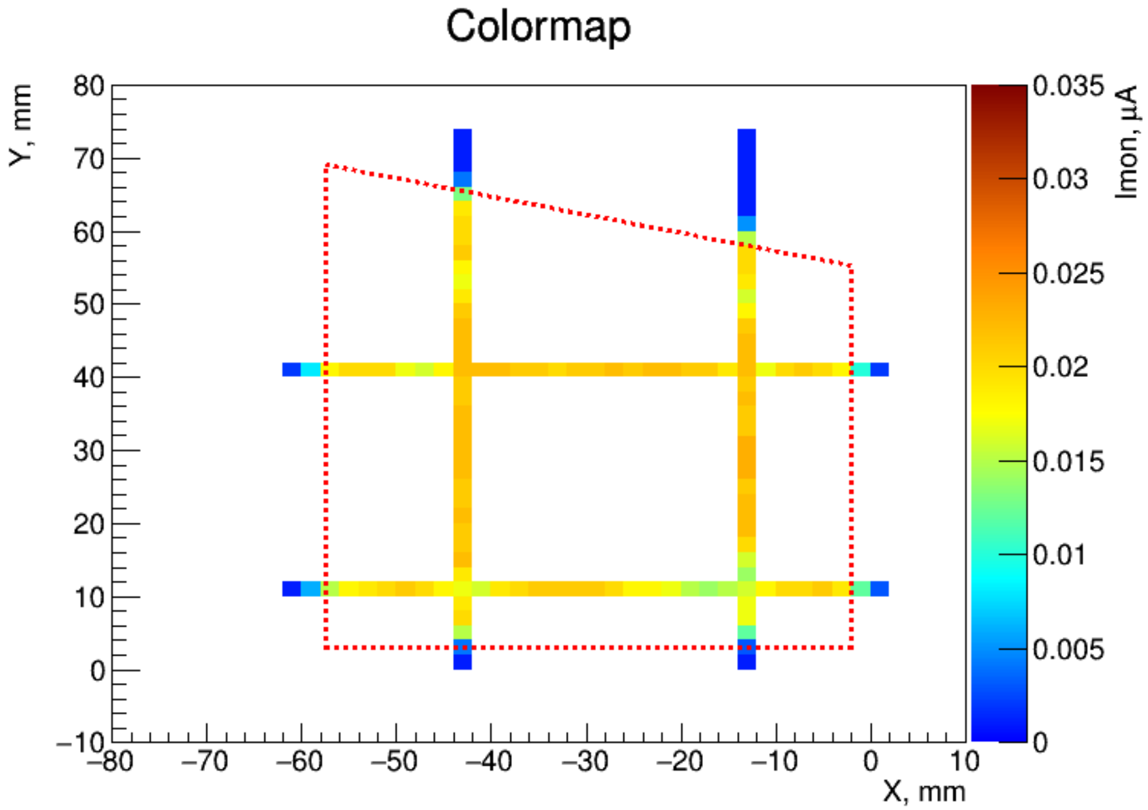
Pic. 14 – **Bad** tile ❌
(Tile assembled without filling grooves with optical cement)

Results 2 – grid test (2nd method)

X & Y axis – coordinates of the measurement (in mms), Z axis – measured current in µA



Pic. 15 – Color map of the **good** tile ✅
(correctly constructed and
prepared for installation)



Pic. 16 – Color map of the **bad** tile ❌
(Tile assembled without filling
grooves with optical cement)

Fiber polishing technique

WLS and clear fibers are the most critical parts of detectors for beam-beam counter because of:

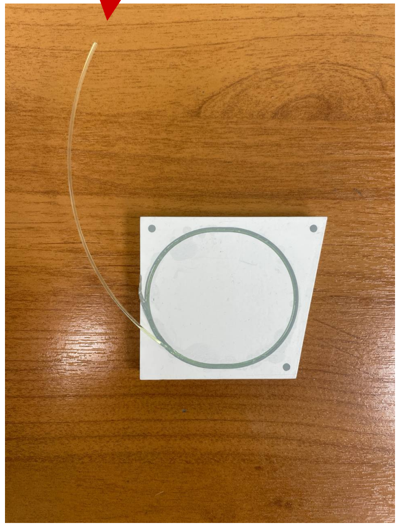
- ➢ light collection and transmission
- ➢ manual preparation of edges surface (minimal automatic processing)

Proposed technique:

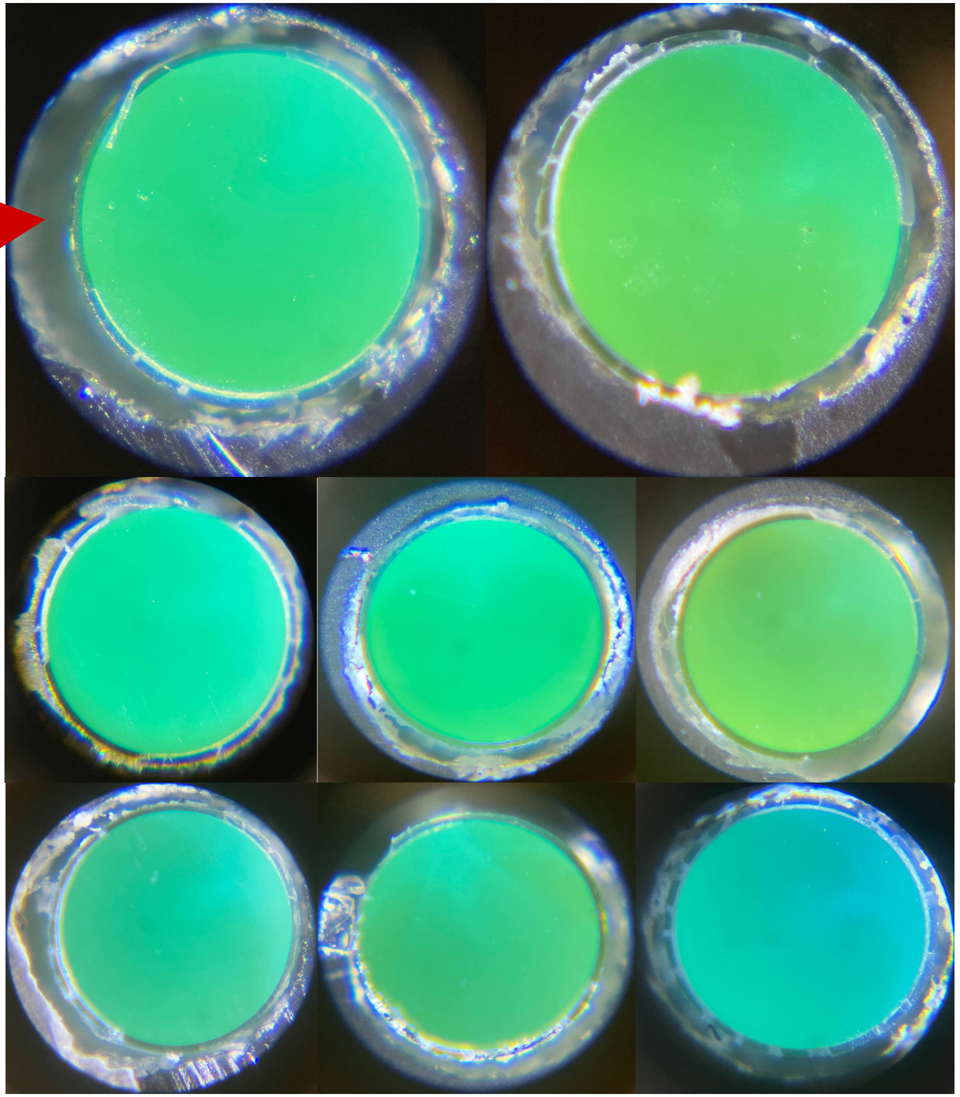
- Put a fiber into optical connector, then cut in <1mm away from connector
- The instrument for cutting must not crack the core
- Polish by sandpapers with grits 3k, 5k, 7k

The goal:

- Flat edge surface perpendicular to fiber axis
- No cracks and shears at the fiber core
- No white spots/areas at the edge surface (to reduce refraction)
- Avoid significant cladding damage
- Automation of polishing process



Pic. 17 – WLS edge ×100 magnification



8-Tile telescope

Main purpose is to confirm tiles response uniformity

8 similar detectors
- 4 left and 4 right tiles of 2nd row
- WLS fiber SG BCF-92
- 3 loops of WLS into tiles
- similar WLS length
- back edges of WLSs are covered with TiO_2 paint
- front edges of WLS polished simultaneously

- 8 SiPMs of matrix Hamamatsu S13361-3050AE-08
- CAEN FERS DT5202 readout system
- 4 tiles connected to 1st FE chip, 4 tile to 2nd FE chip

Trigger

External cosmic muon detectors supplied trigger signal with significant delay, so:
- Each tile can trigger the DAQ system
- The event accepted **only** if the external muon detectors confirm muon pass (external validation mode)

Pic. 18 – 8-tile telescope setup

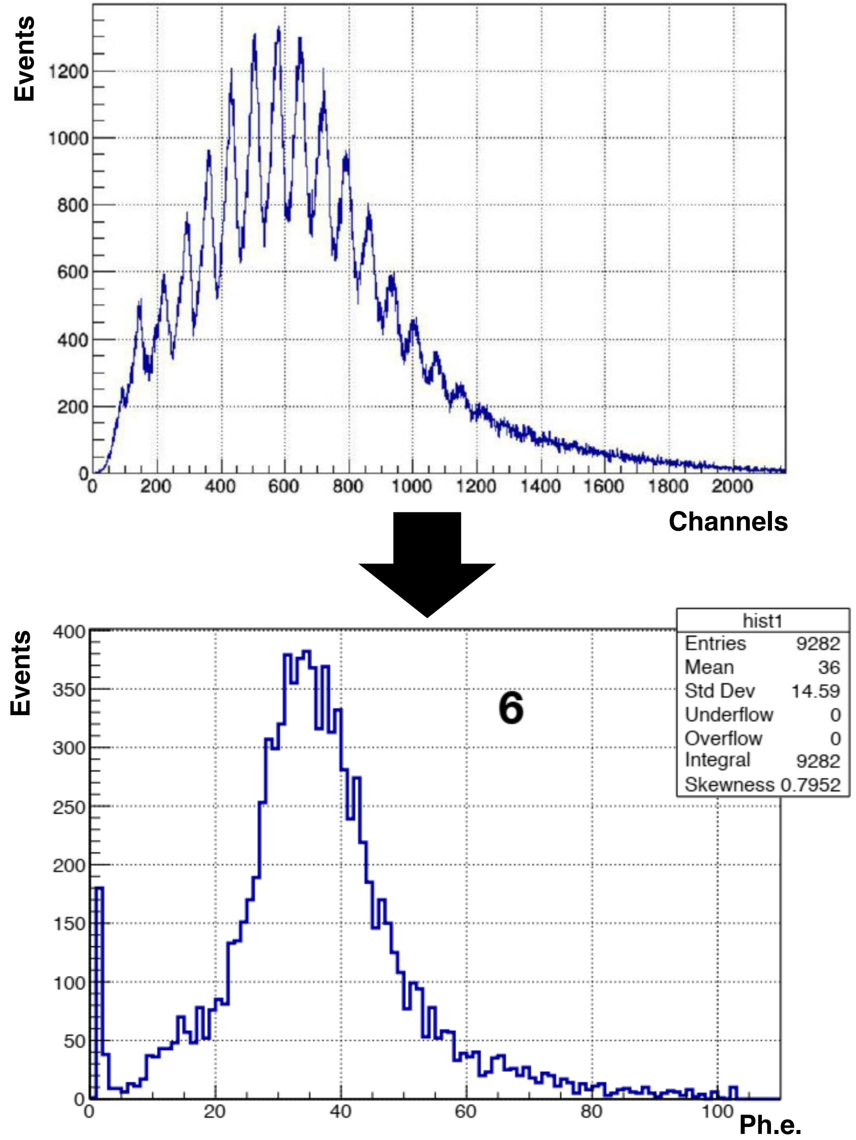
SiPMs calibration

Difference in breakdown voltage (V_{br}) that affects to photon detection efficiency

- V_{br} of each SiPM have been obtained
- Similar overvoltage (V_{set} - V_{br}) is set for each channel

For correct comparison of detectors response, signals from each detector calibrated by single photoelectron (1ph.e.) SiPM response

- 1ph.e. spectra obtained for each channel
- Distance between 2 neighboring peaks considered as 1ph.e. response

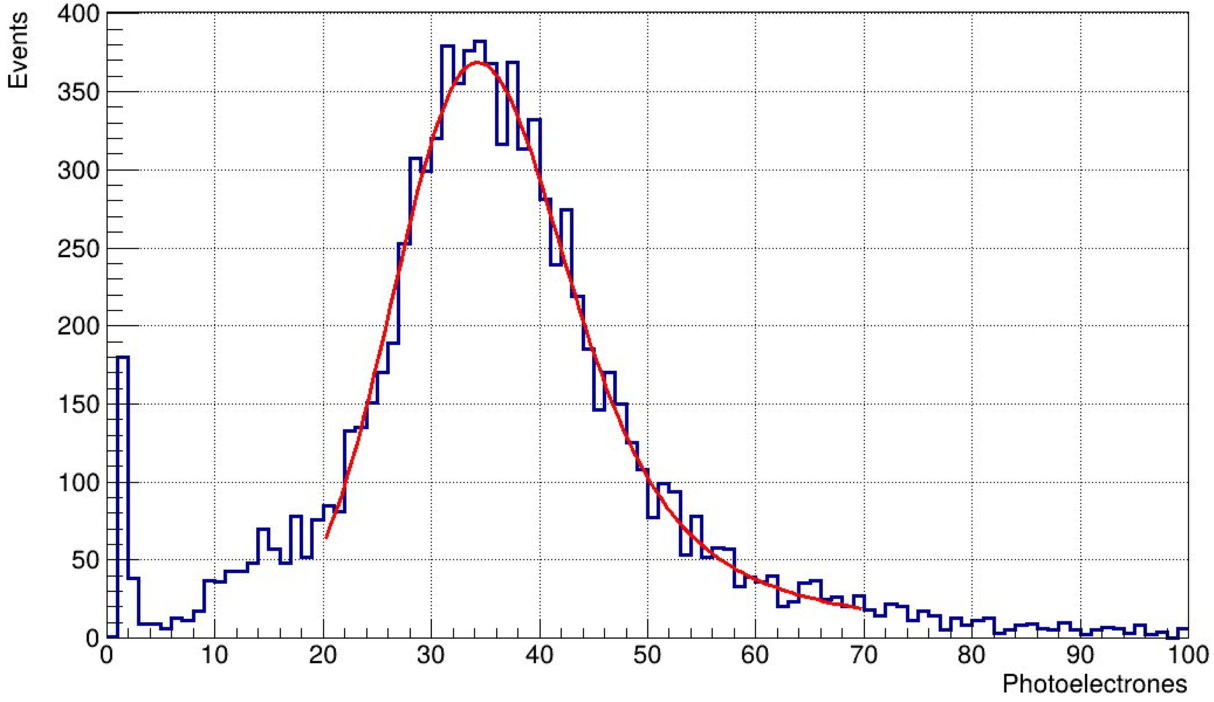


Pic. 19 – SiPM calibration results

The results of SiPM calibration

Spectra from each detector fitted with Landau-Gaussian convolution

- **Mean values** of 7 detectors responses lay between **27 and 35 ph.e.**
- Average of Means = 31 ph.e. – **acceptable**
- Max non-uniformity <13% – **acceptable**
- WLS of 4th tile was wrongly positioned – not taken into account
- Tiles connected to 2nd FE chip showed perfect uniformity → **non-uniformity related to readout electronics - ?**



Pic. 20 – Fitted spectrum from one of the SiPM

Efficiency of tiles is calculated as number of tile signals over 5ph.e. level w.r.t. total number of coincidence of top and bottom tile

- Average efficiency = 98,6% at 151 acquired events

Signal processing unit for silicon photomultipliers

Functions:

- 64 signal processing channels
- Bias voltage supply for photomultipliers
- Operation mode: timestamping of signal threshold crossing and time-over-threshold measurement

Operational features:

- Scalable and synchronizable modules via optical communication channels
- Hub board for integrating multiple modules into 16-unit rings

Pic. 21 – Signal processing unit

The tests have been already reported by Ivan Volkov in the previous talk

Technical specifications:

Inputs	64 channels
Signal polarity	Positive
Preamplification	×50
Shaping time	20 ns
Triggering	10-bit DAC for setting individual thresholds per channel
High-voltage supply	• Global adjustment range 20–30 V • per-channel fine adjustment range up to 3 V
Timing resolution	12 ps
Timestamping	48-bit counter with 2 ns step
Communication interfaces	• USB • Ethernet • SFP optical link

Conclusion

I. The X-ray scanning technique is almost ready for mass production as a validation of assembling quality

II. WLS polishing technique tested and confirmed. Further automation is intended

III. Tile response uniformity was performed via the 8-tile cosmic stand:
- Average detector response to cosmic muons = 31 ph.e.
- Detectors response non-uniformity <13%
- Detection efficiency by cosmic muons = 98,6% at 151 acquired events

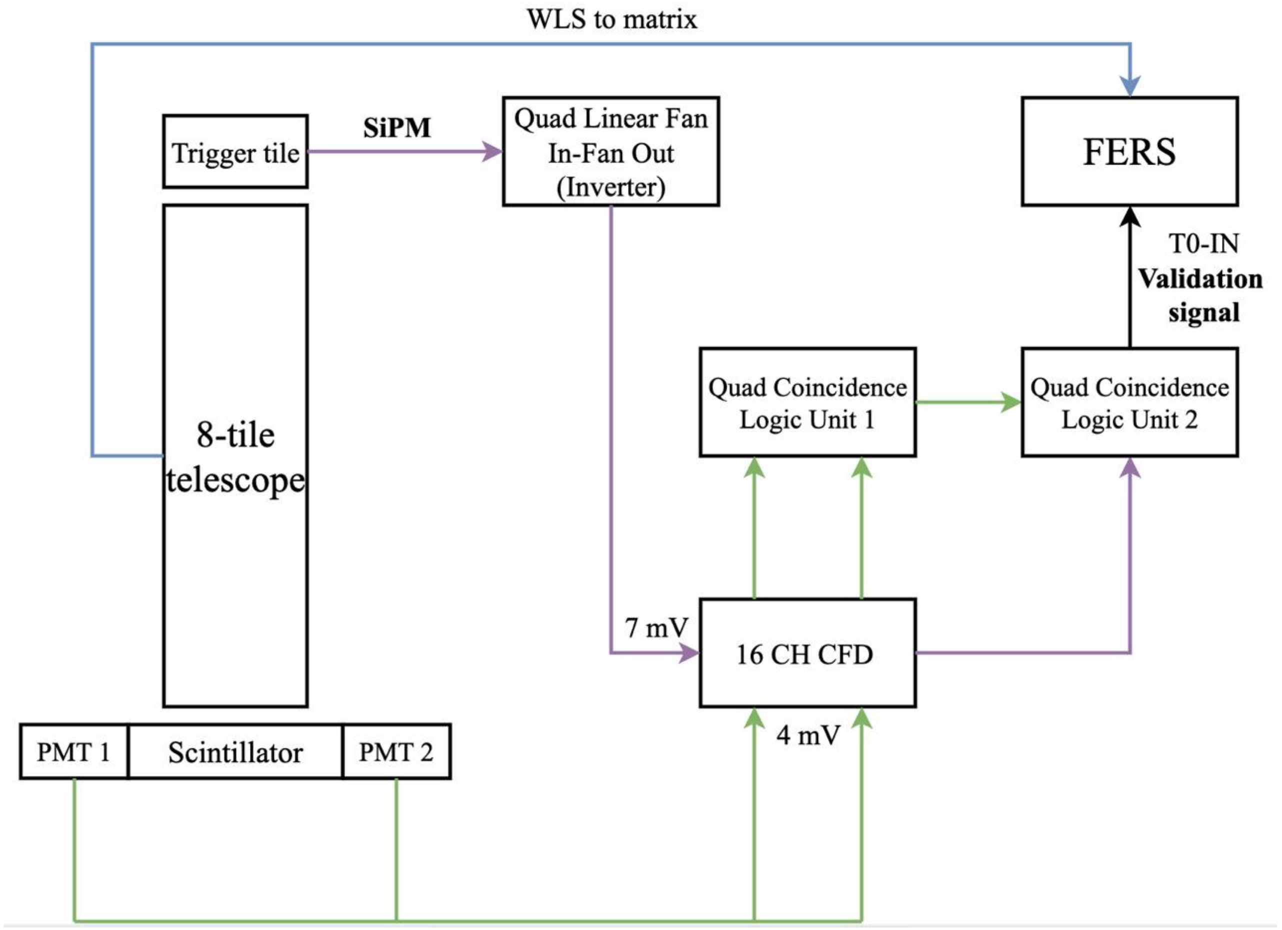
IV. Development of the alternative electronics for detectors readout is in progress

These were the final tests for the mass production of tiles for Module-0

Thank you for your attention!

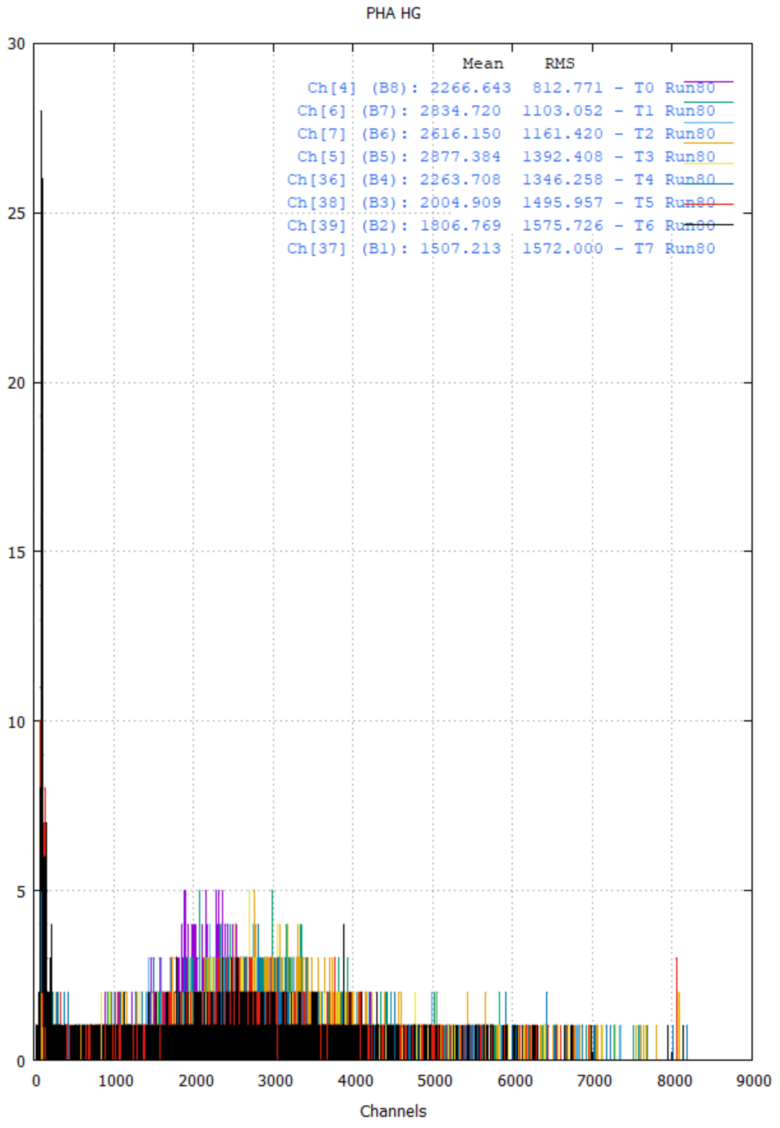
Back-up slides

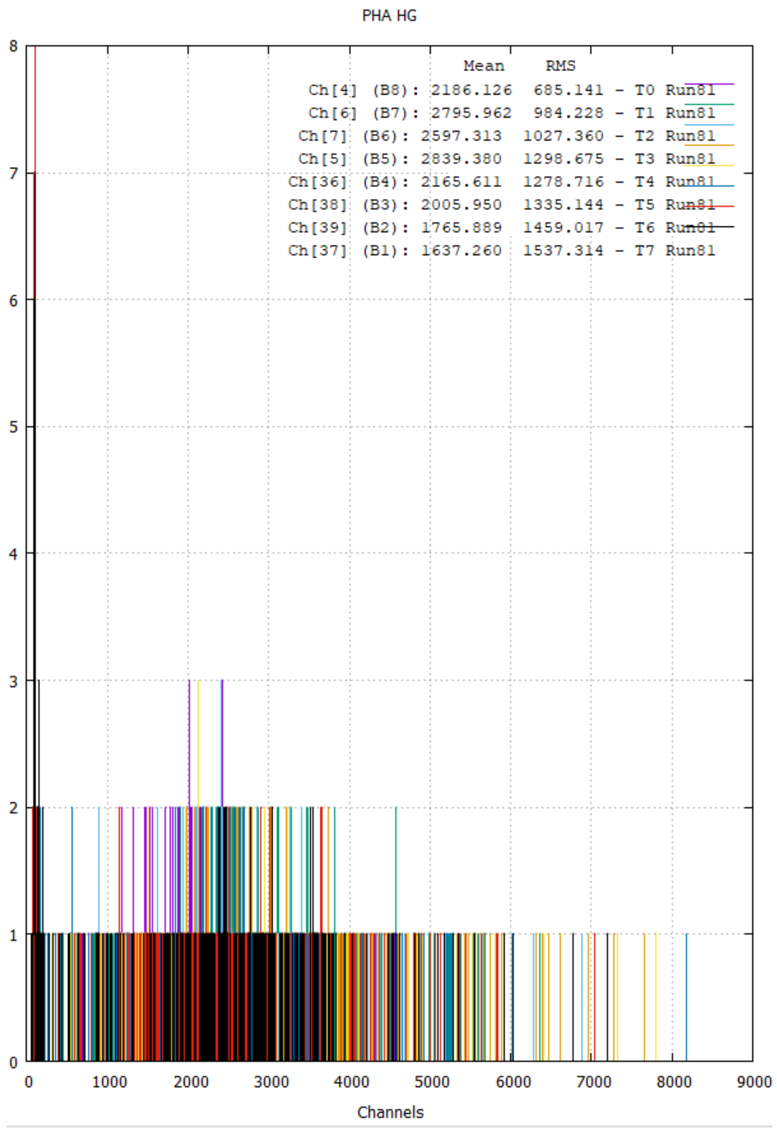
Back-up slides 1 (8-Tile telescope logic)

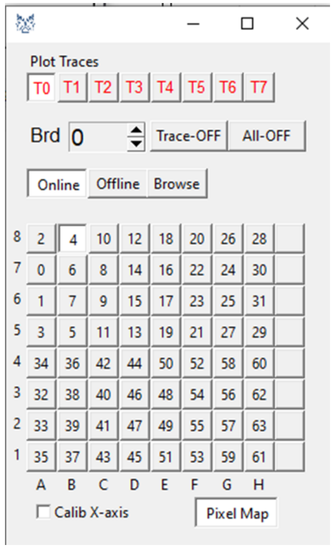


- Acquisition: Spectroscopy;
- Bunch Trigger Source: T-OR - The OR signal from the channel TDs is used as bunch trigger source;
- Validation Signal Accept;
- T Discriminator Thd: 550 parrots

Back-up slides 2







B2

Back-up slides 3 (SiPM calibration table)

Channel	Value
4	79
5	77
6	79
7	77
36	85
37	88
38	86
39	88

1st Citiroc-1A: 4, 5, 6, 7;
2nd Citiroc-1A: 36, 37, 38,39.

Back-up slides 4 (Tiles response)

Channel	Ph.e.
4	27
5	39
6	35
7	34
36	30
37	30
38	30
39	30