



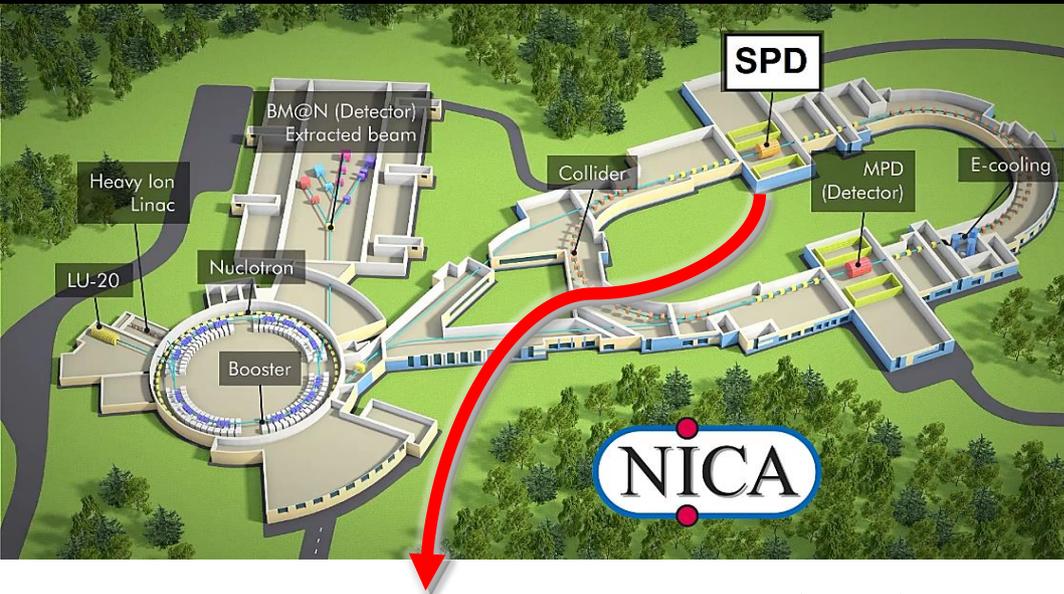
BBC status report

A.V.Tishevsky on behalf of JINR-MEPHI BBC

VIII SPD Collaboration Meeting

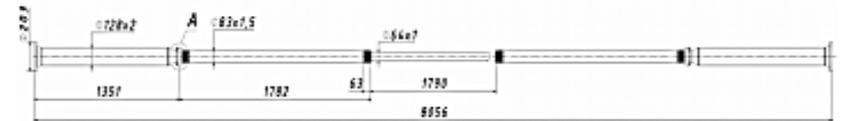
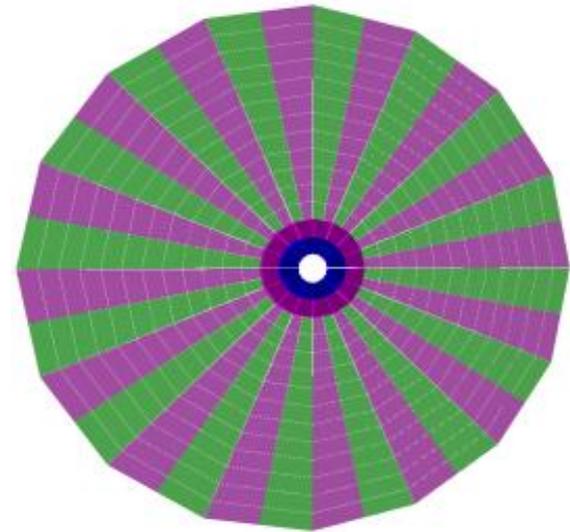
November 2024

- Introduction
- Mechanics
- Hardware
 - Tests porotype with CAEN FERS-5202
 - Application of DT5215 concentrator
 - New electronics (TDC based on FPGA)
- Methodical tests
 - Application of method for checking assembled sectors
 - X-ray tests
 - WLS- studies
- Results
- Simulation
- SPD Phase0 plans
- Conclusion



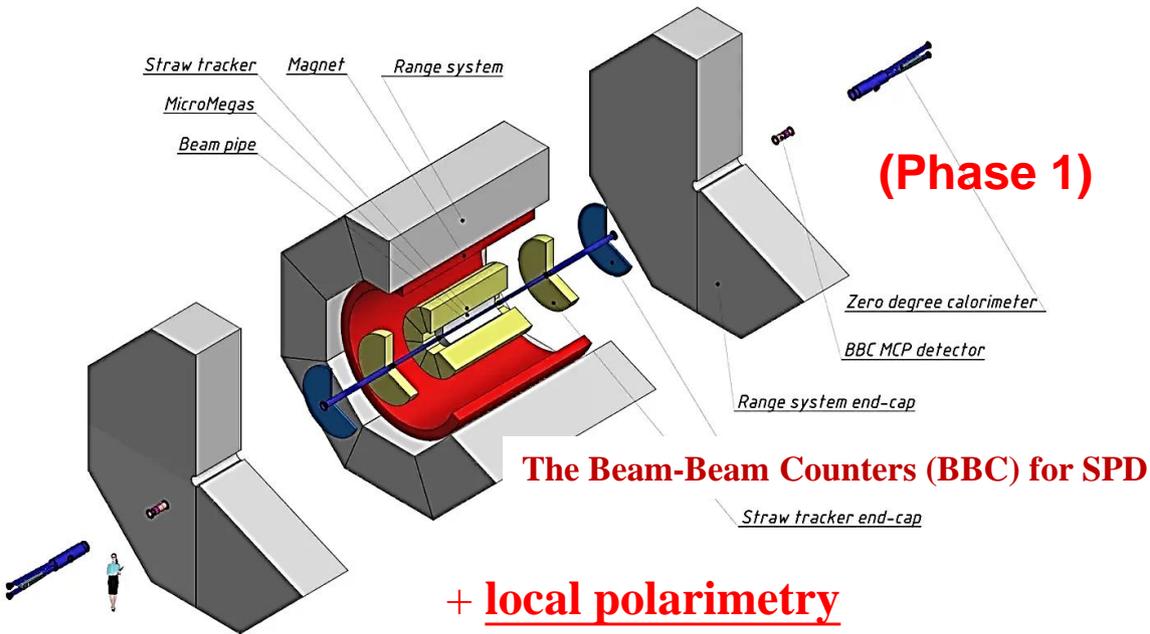
The Spin Physics Detector (SPD)

TDR 2023
 2 wheels with
 400 tiles each (416)



Now : 124 mm diameter
 Need: 83 mm diameter

We have the opportunity to use an additional tile due to the decreased diameter of the beam pipe.



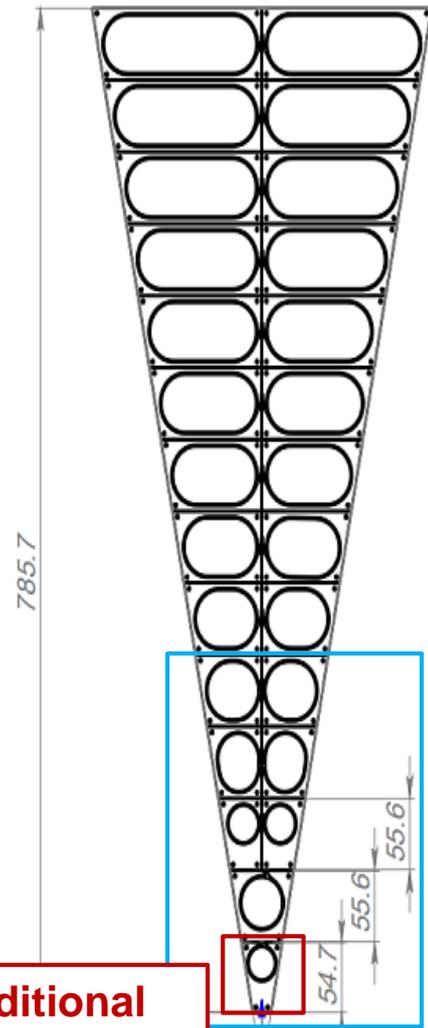
The Beam-Beam Counters (BBC) for SPD

- + local polarimetry
- + event plane detector for HI physics

- Scintillator tiles part at the distance ~1.7 m

BBC Sector (1/16 of wheel) design

26 tiles



8 channel prototype



Additional sector's tile

Grooved carbon backplate

Infrastructure layers (grooved)

Supporting

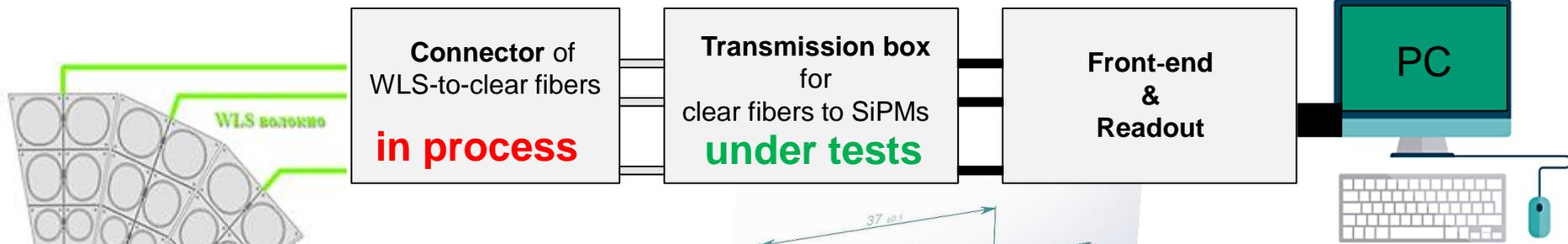


Plastic foam sandwich base (heavy)

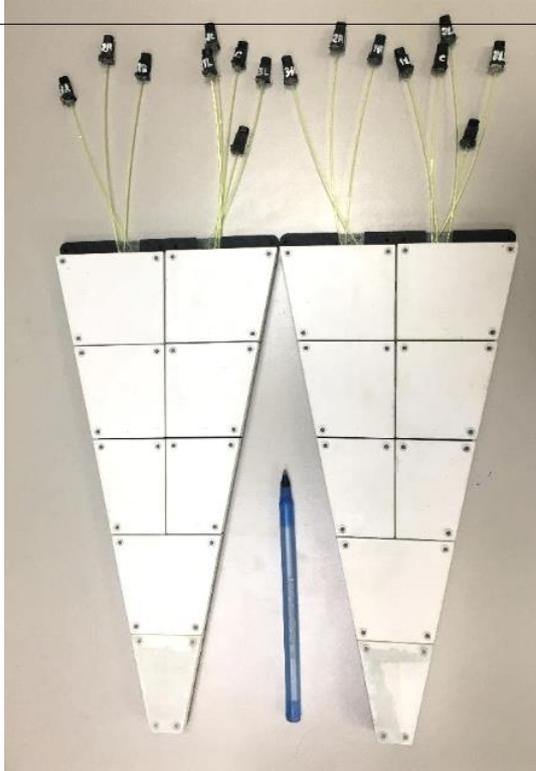


thickness ~ 30 mm

Honeycomb sandwich base (hardness under tests)



Readout system: ✓ CAEN FERS-5200



reduced sector prototype x2

REFERENCES [1-2]

- Selected options:**
- Scintillator: **Uniplast-Vladimir (chemical mating)**
 - Optical cement: **CKTN Med mark B**
 - WLS Fiber: **Saint-Gobain Crystals (SG92S)**
 - SiPM: **SensL 1x1 mm² (MicroFC-10035 SMTPA)**

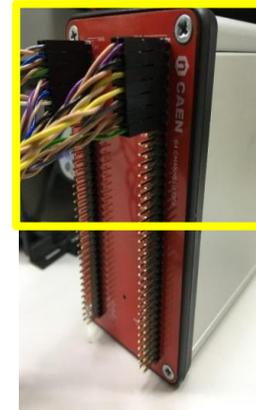
Final option is KURARAY (Y-11) for Phase 1 & 2

CAEN FERS 52XX is an extendable high speed front-end readout system

- DT5203 (picoTDC chip)
- DT5215 (Concentrator)
- **DT5202** (x2 Citiroc 1A chip)



- **DT5202** based on the 64-channel module for SiPM.



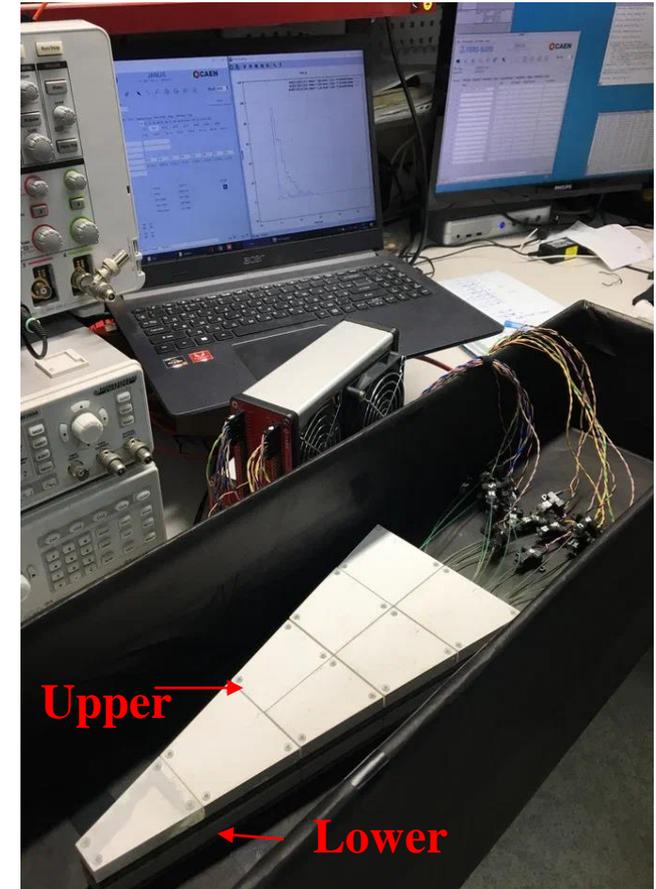
“AND2_OR32”
Trigger logic

Main Acquisition Modes:

- SPECTROSCOPY → for calibration
- **TIMING** → for future tests
- **SPECT_TIMING** → for current tests
(Spectroscopy + Timing)

The Timing mode will be used for testbeam and Phase 1 (perhaps) tests, because only this mode has access to the CAEN FERS system **for free-streaming mode.**

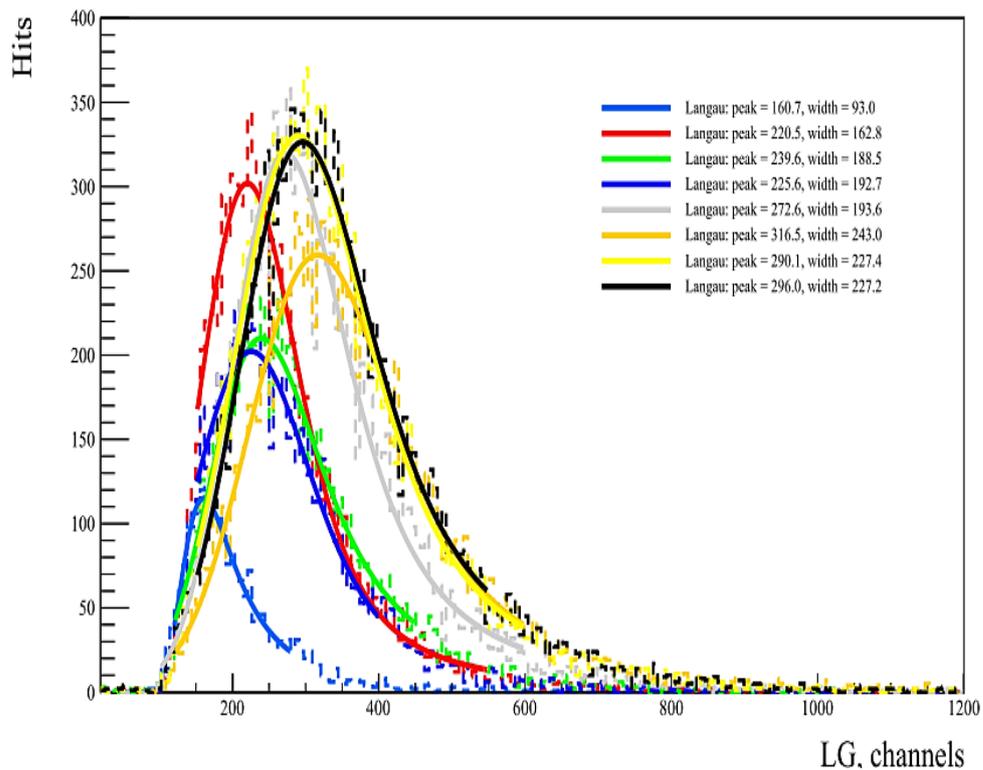
Stand for BBC measurements



The tests were performed for SPECT_TIMING mode (Hybrid) with **self-triggering** opportunity. Main tasks of Hybrid mode are:

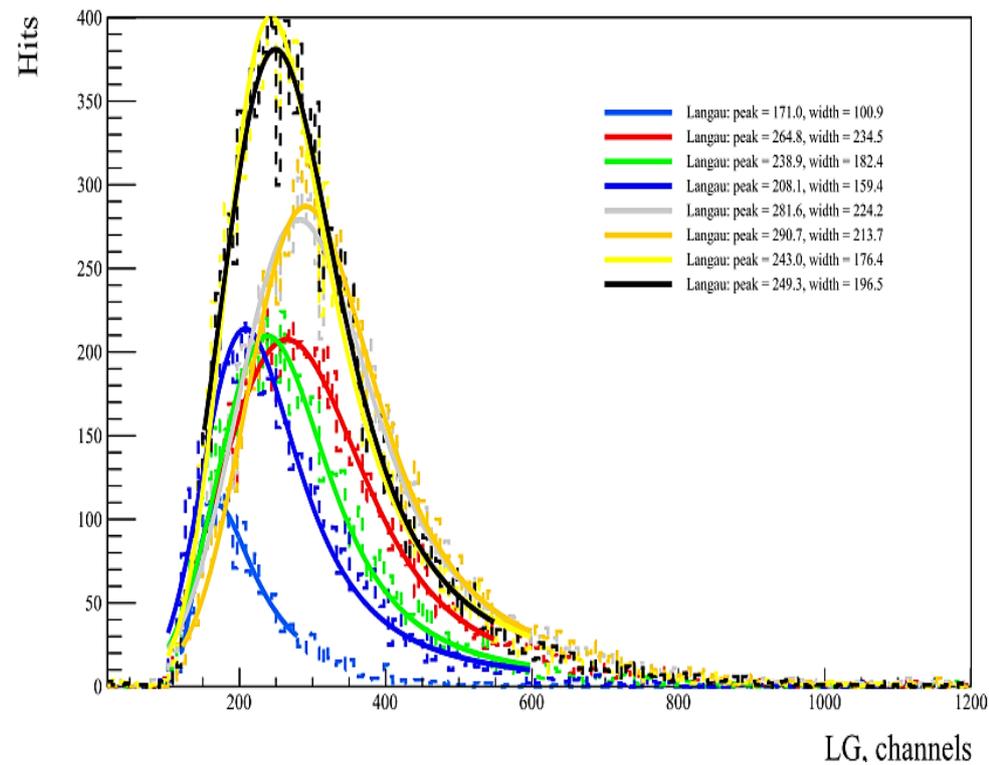
- test of the **self-triggering** option
- the signals analysis
- the **dependence** of the amplitude to the ToT

1-st sector prototype



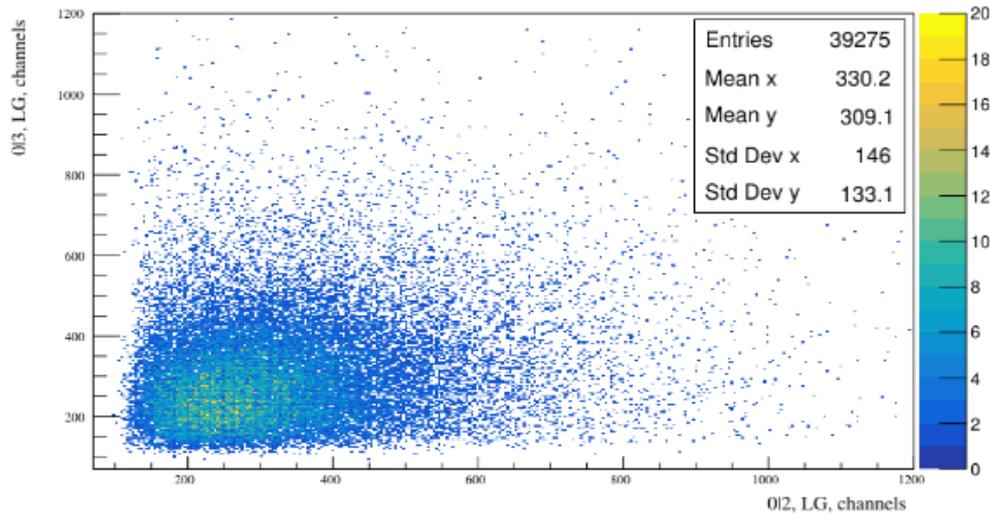
There are **2 specific channels**, but the debugging process of mass production continues.

2-nd sector prototype

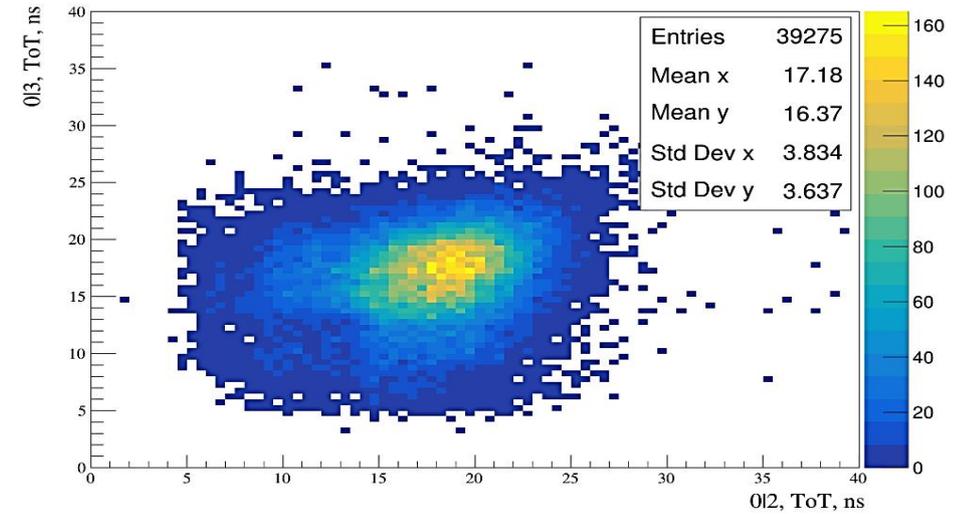


The stable tiles were taken for following tests

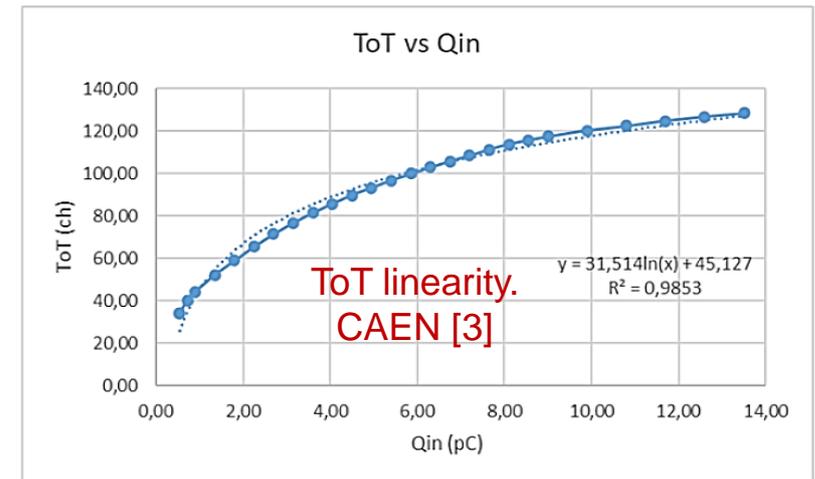
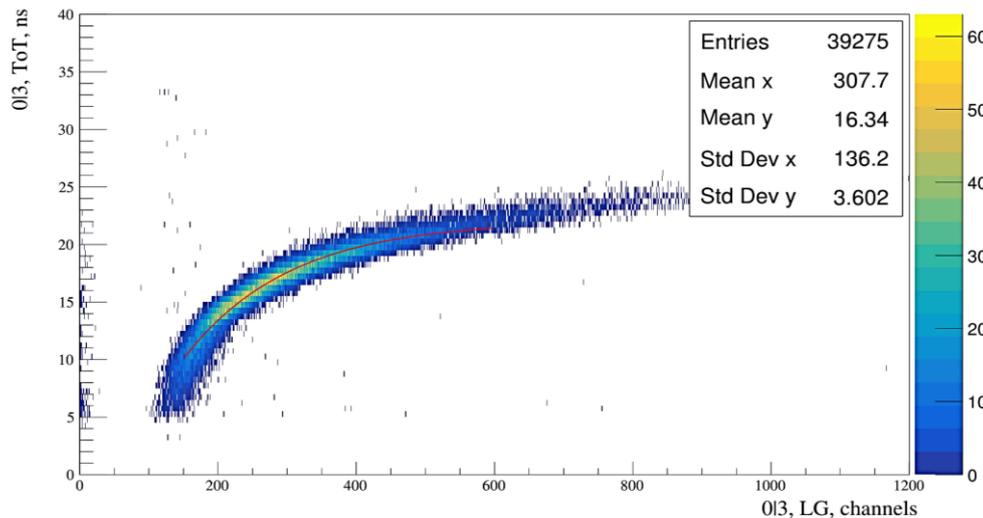
LG correlations



ToT correlations



LG vs ToT (channel №3)



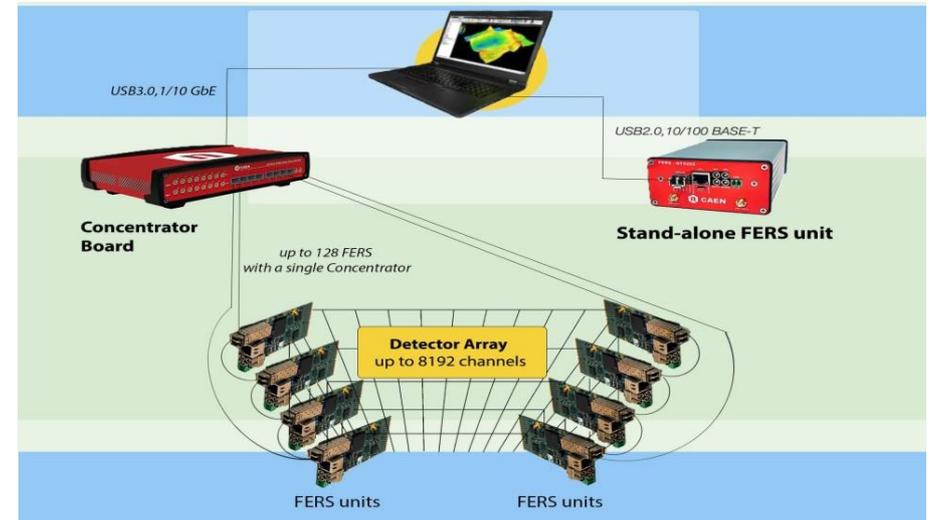
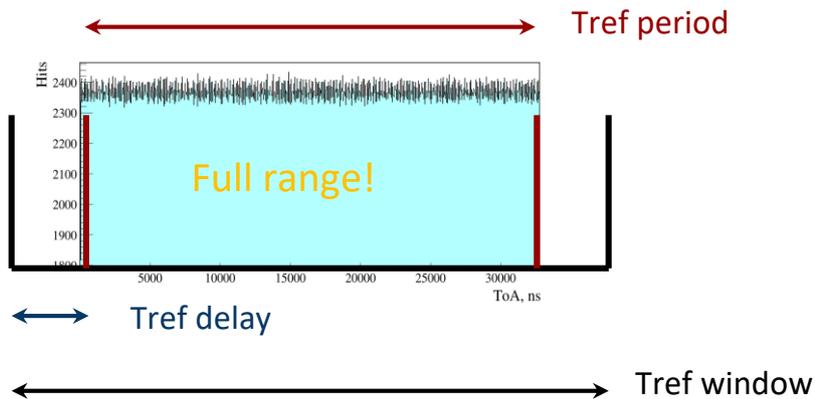
Correlation of energy deposition for 2 channels, as well as the time information for these channels.

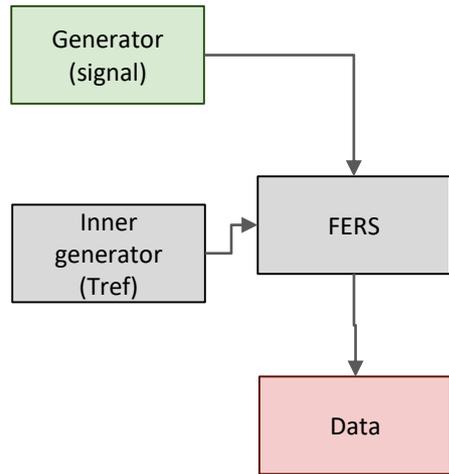
- The calibration of the charge scale is required

- **SPD** is planned to operate without **T0** (start) so we need to work with **free-streaming mode**.
- CAEN FERS 52XX gives us an opportunity to work in this mode.

Hits acquisition ranges

Tref may be provided by
- outer generator (T0)
- inner generator (PTRG)



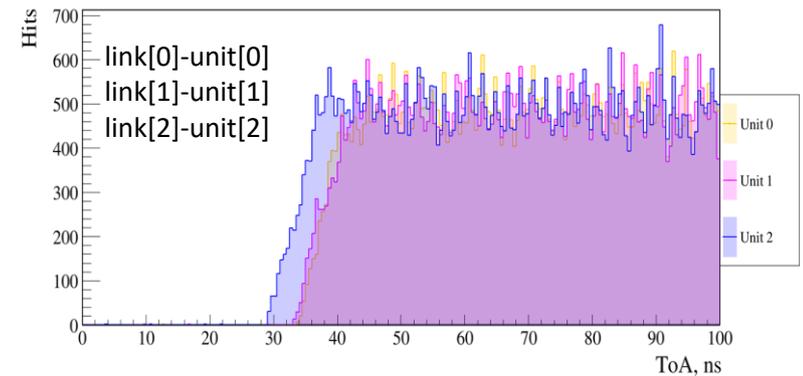
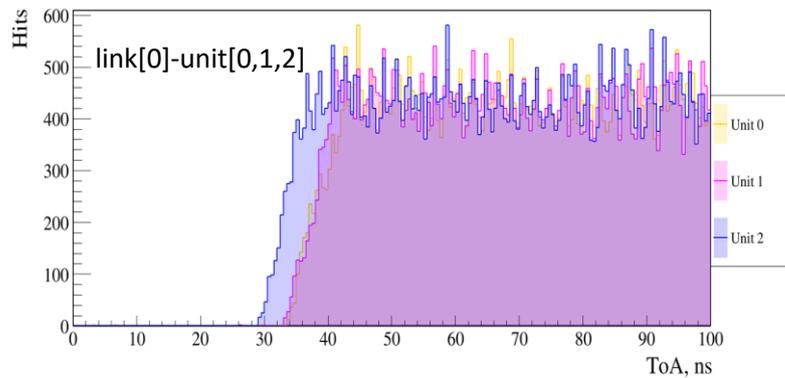


DT5215

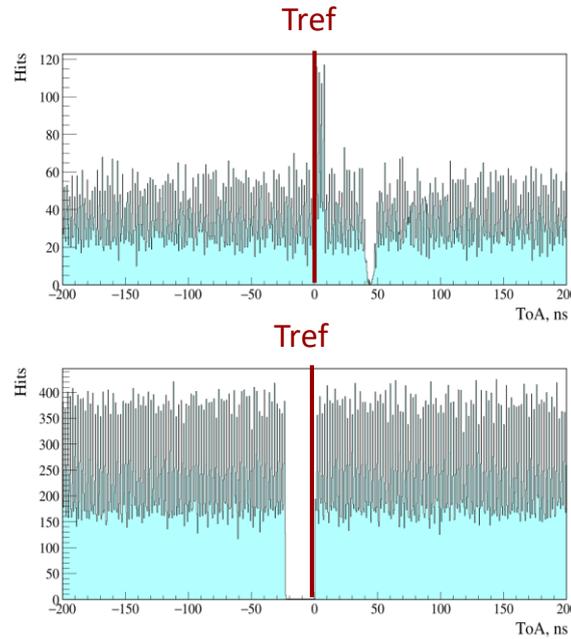
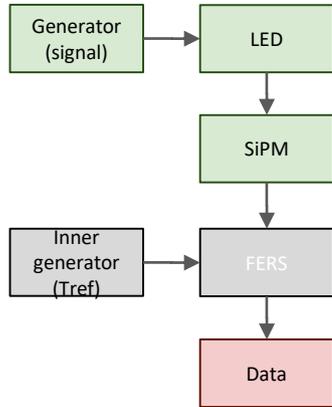


LINKS (0 & 1)

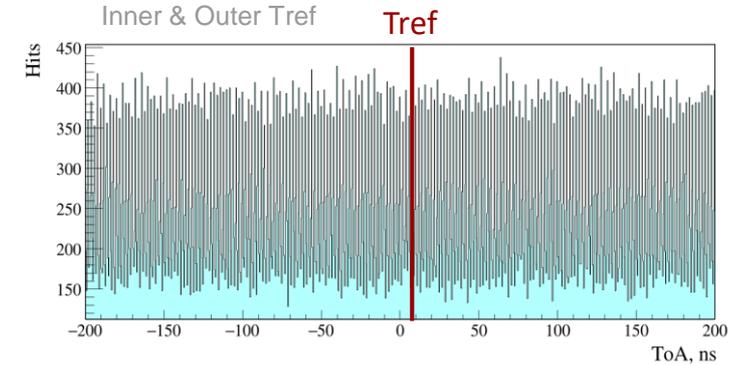
Concentrator to boards opto-fiber connection



(closest to reality)



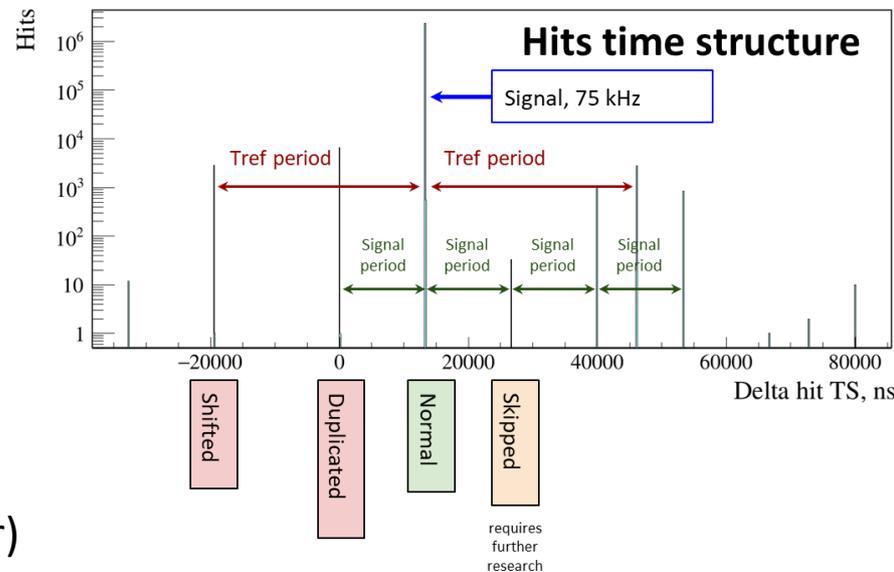
Hits around Tref signal



Tref delay = -68 ns

Tref window - Tref period = 100 ns

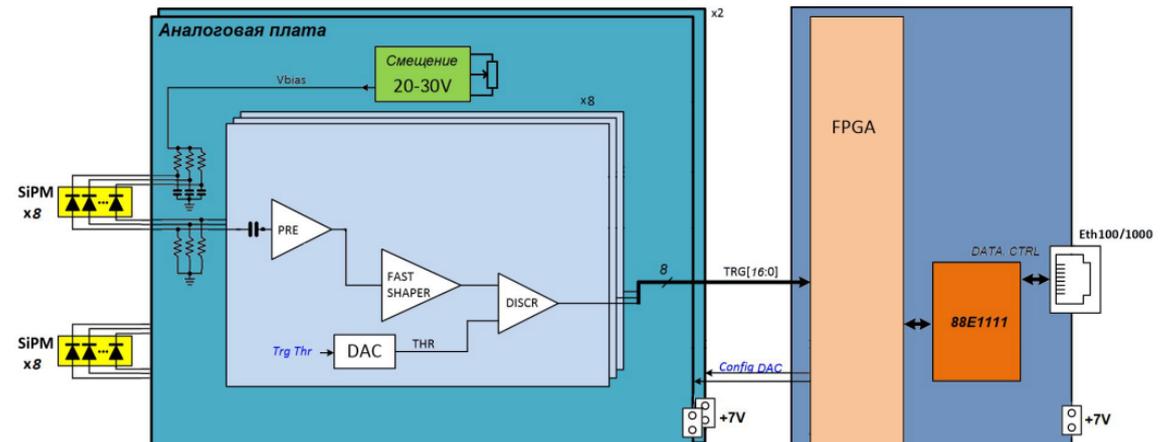
Any other



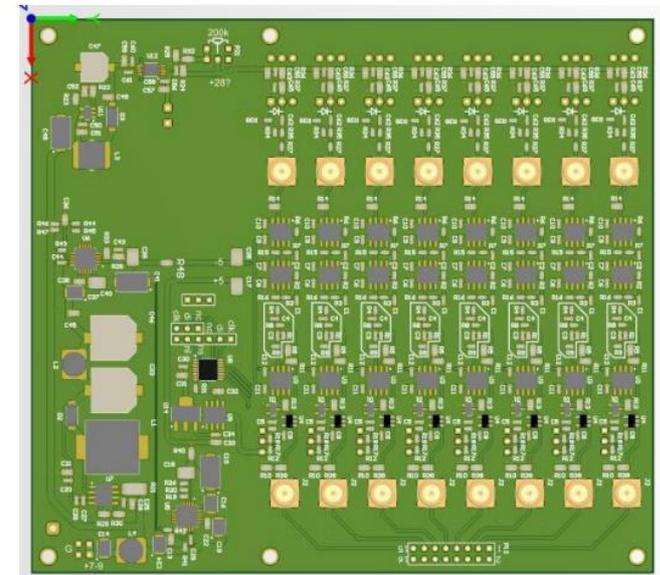
- **Continuous data reading** can be made only with **fine-tuning** of board parameters, poor data quality was observed

Simplified block diagram

Количество каналов	16 (до 20)
Полярность сигнала	положительная
Разрешение	18 пс
Порог дискриминации	программируемый 12-ти битный на каждый канал
Высоковольтный источник	20 - 30 В, ручная подстройка по 8 каналам
Режим работы	непрерывное считывание
Частота срабатываний	до 2 кГц
Время формирования (шейпирование)	20 нс, фиксированное
Временные метки	48-битный счетчик, шаг 3 нс
Интерфейс связи	Ethernet 100/1000

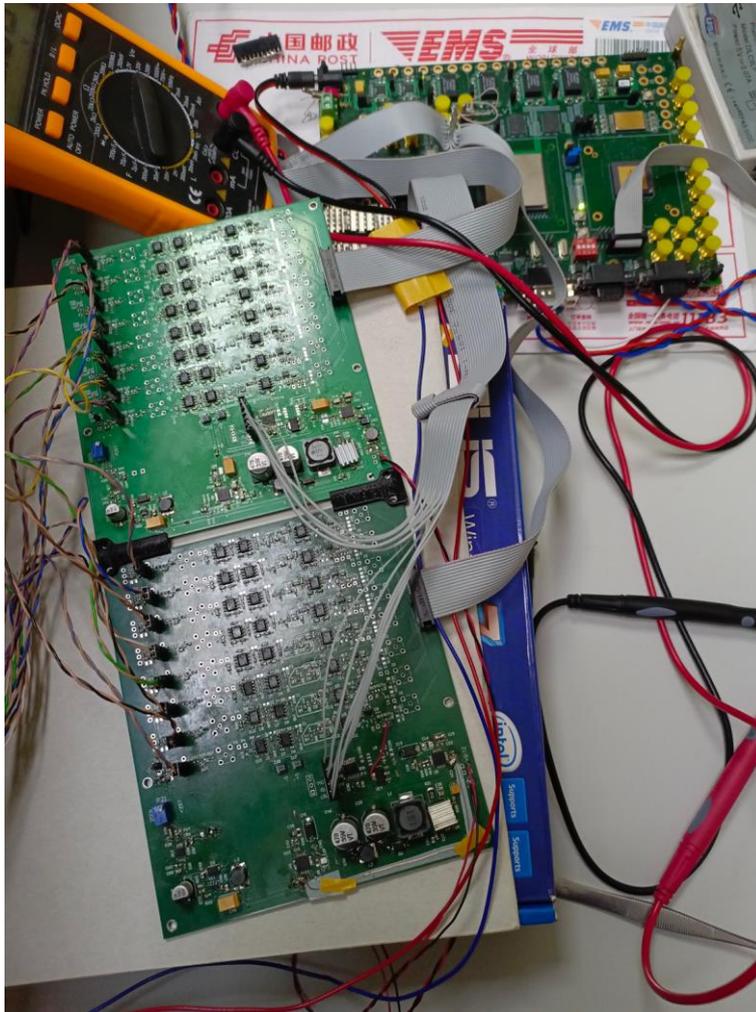


TDC based on FPGA

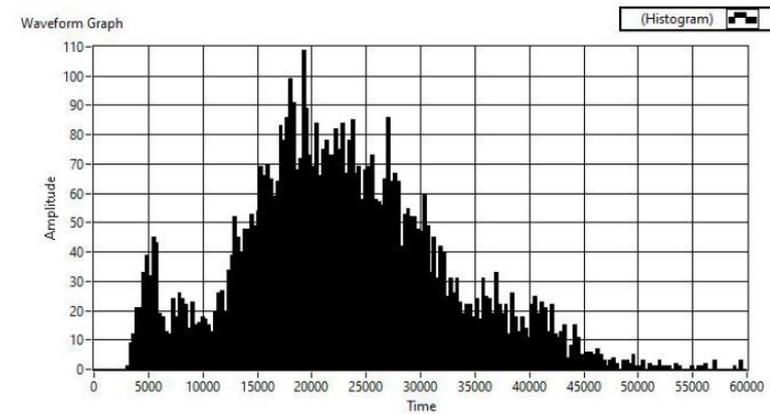


Front-end units
(SiPM supply, signal reading)

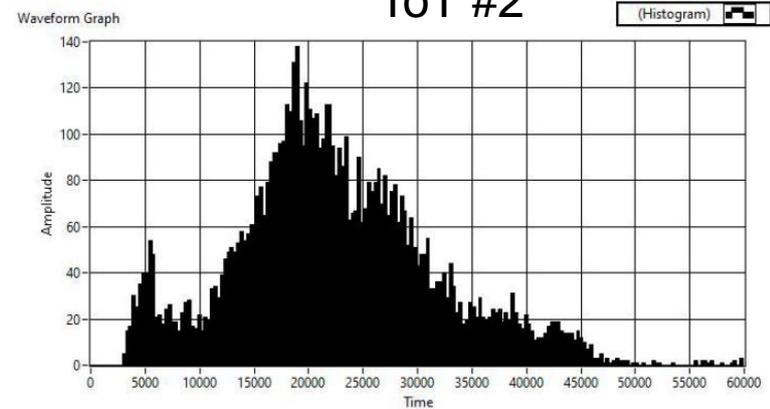
2 X 8 channels prototype



ToT #1



ToT #2

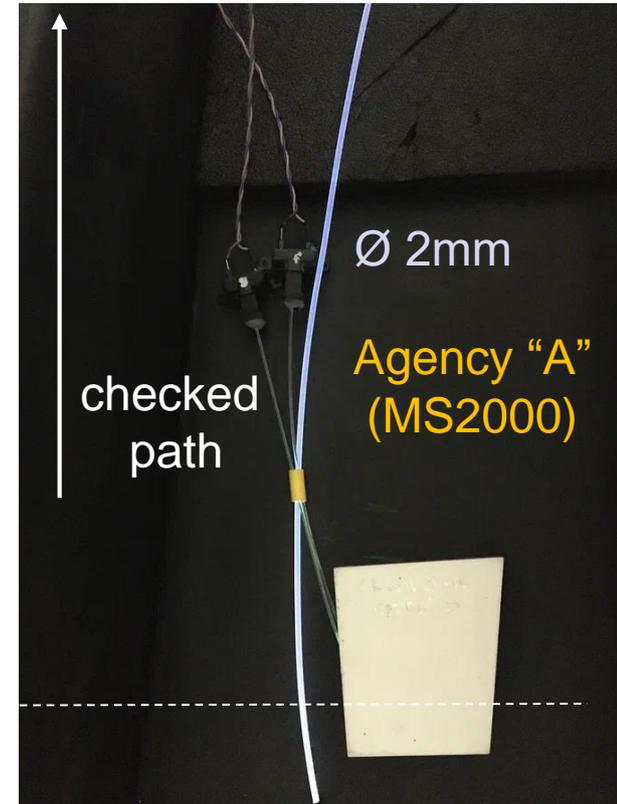
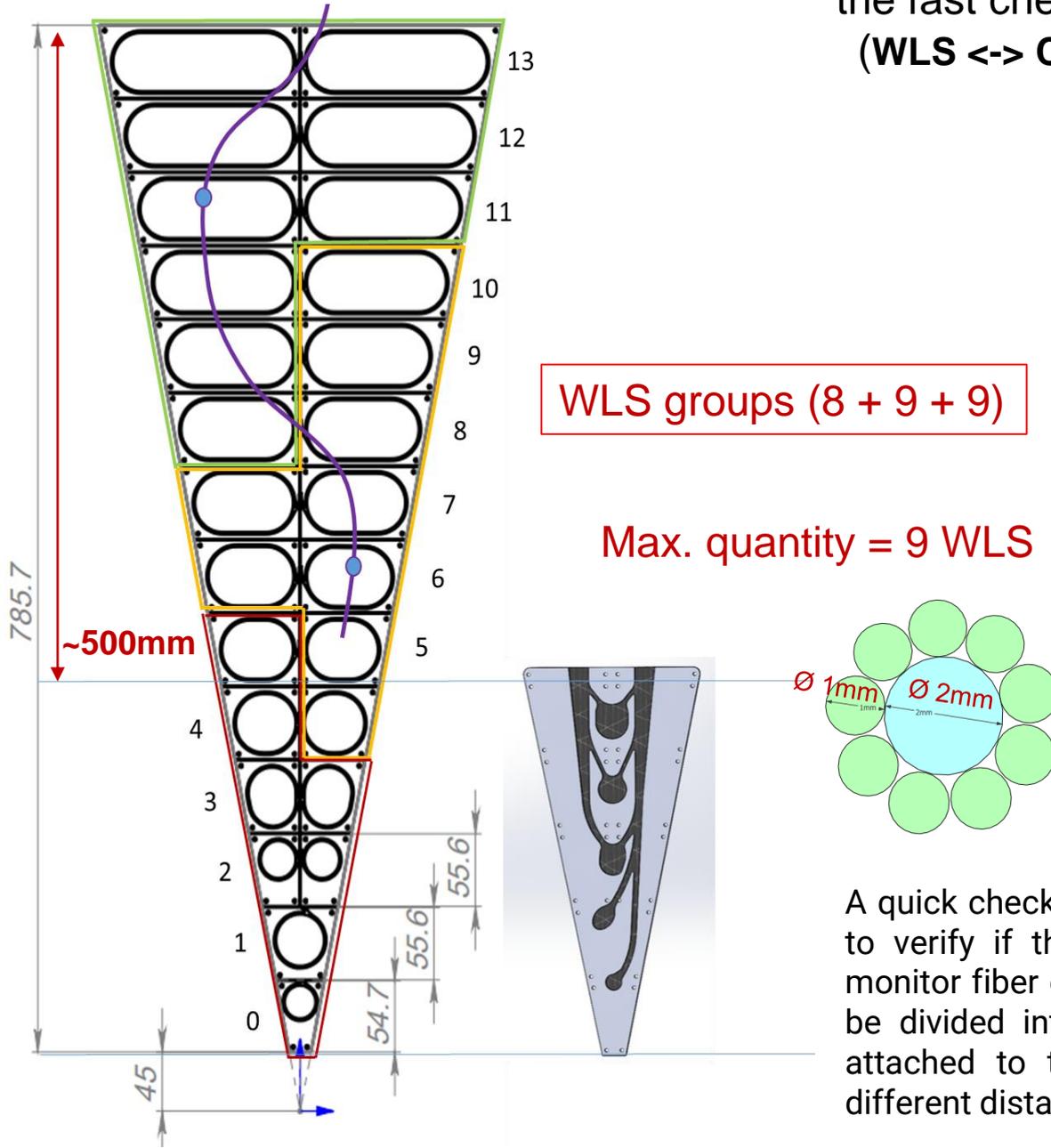


- The tests have started, optimization of the analog board
- Comparison of prototype results with DT5202 CAEN FERS unit

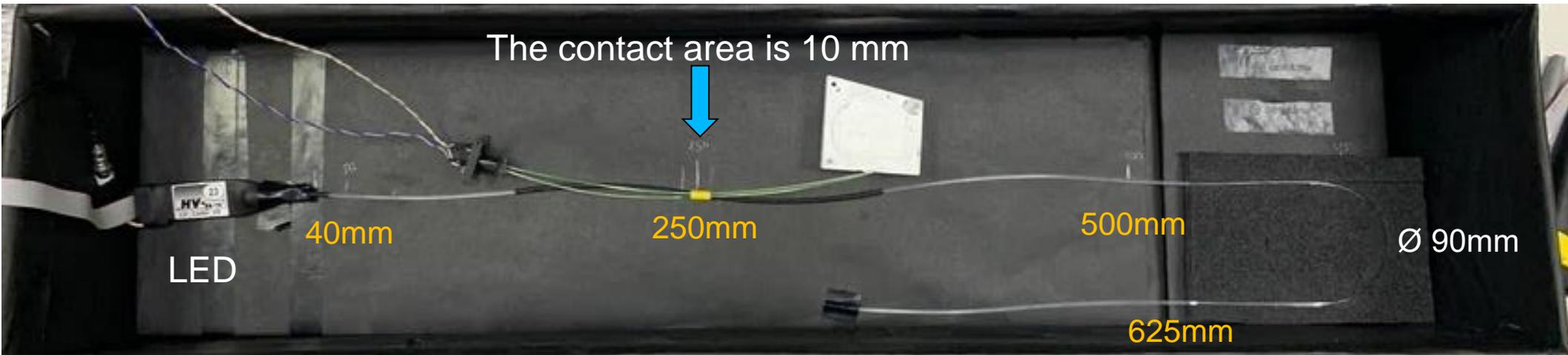
required

Optical connector (26 + 1)
WLS <-> Clear Fiber + SGF

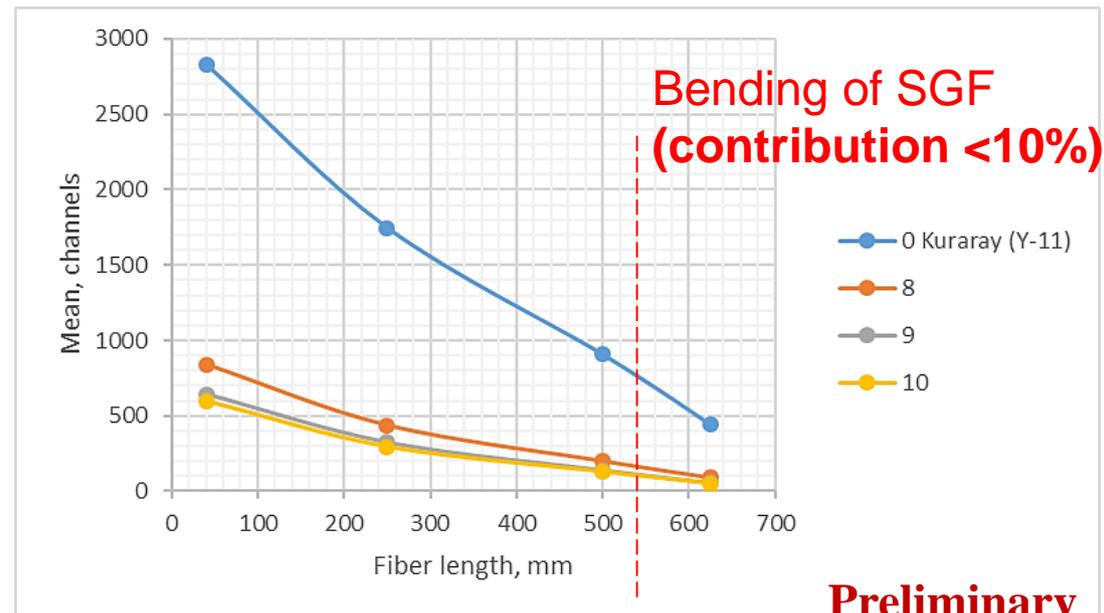
The side glow fiber (SGF) is one of the option for the fast check of a larger part of the signal path
(WLS <-> Clear Fiber <-> SiPM <-> DT5202 unit)



A quick check method for the assembled sector will allow us to verify if the fiber within the sector is undamaged and monitor fiber degradation over time. The complete sector will be divided into 3 groups of 8 or 9 tiles, and SGF will be attached to the fibers at different 3 spots, according to different distances to these spot locations.



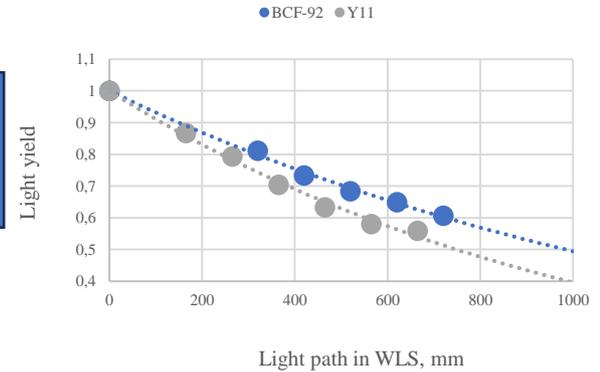
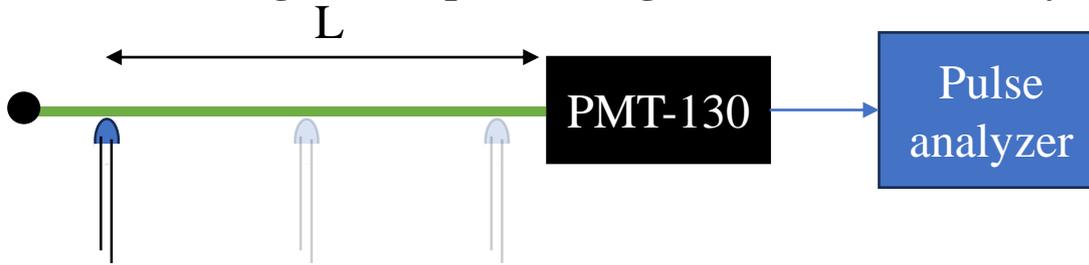
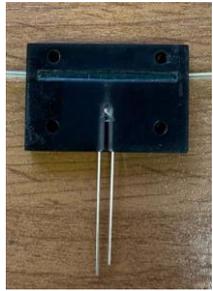
	Kuraray (Y-11)	Saint-Gobain Crystals (SG92S)		
mm\channel	0	8	9	10
40	2831	840	643	600
250	1747	438	325	295
500	906	200	140	128
625	441	90	55	50



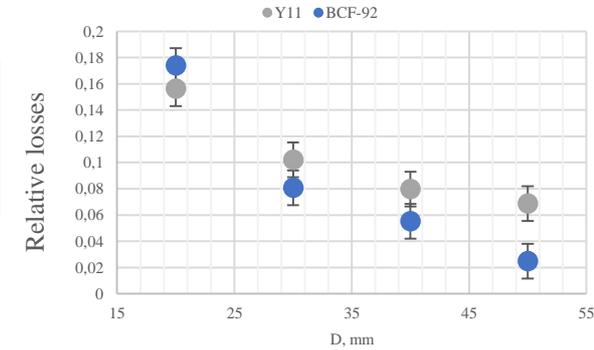
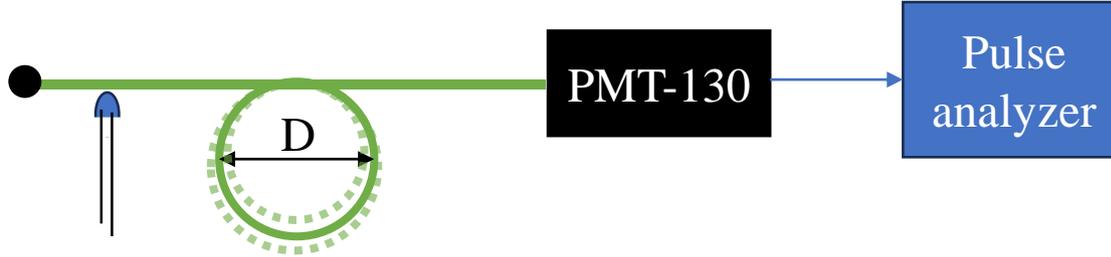
For the experiment we attached WLS fibers in several SGF spots: at 40-, 250-, 500- and 625-mm distance from LED, that was emitting light into the SGF end.

SGF loses ~75% of its light intensity at a length of 500 mm

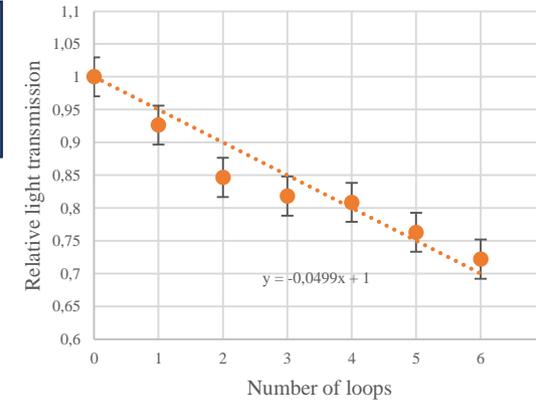
Relative light absorption & Light collection efficiency



Bending loss measurement

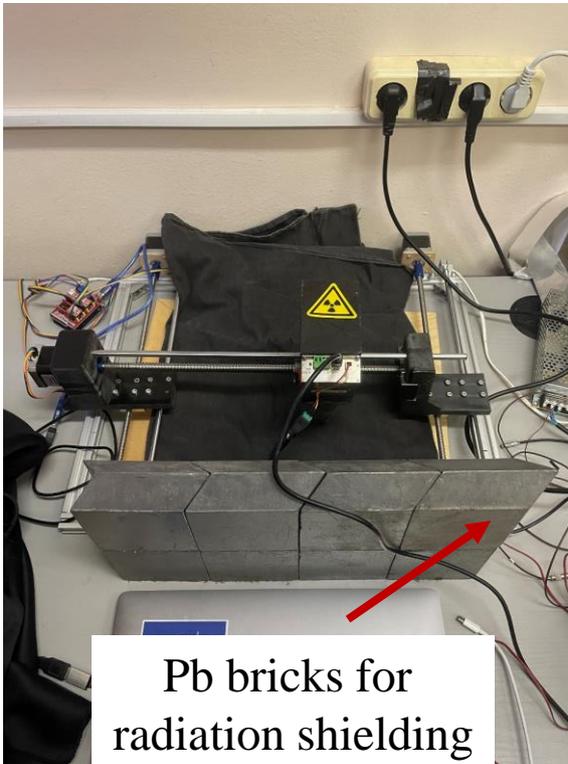


Dependence on the number of loops



	Y11, Ø1mm	BCF-92, Ø1mm
Light yield	1	0.33
Bending loss @ D30mm, %	10	8
Light absorption @ 1m, %	60%	50%
Trailing edge, ns	24	12

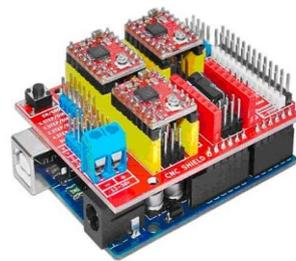
Experiment's setups and summary are presented at slide: the results justify our plans to use BCF92 fibers for prototypes and Y-11 fibers for the experiment.



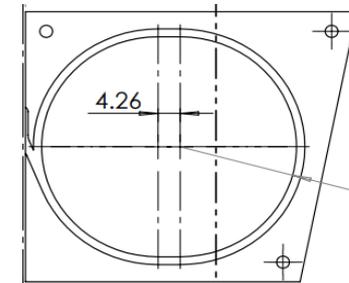
Pb bricks for radiation shielding



Mini-X X-ray tube

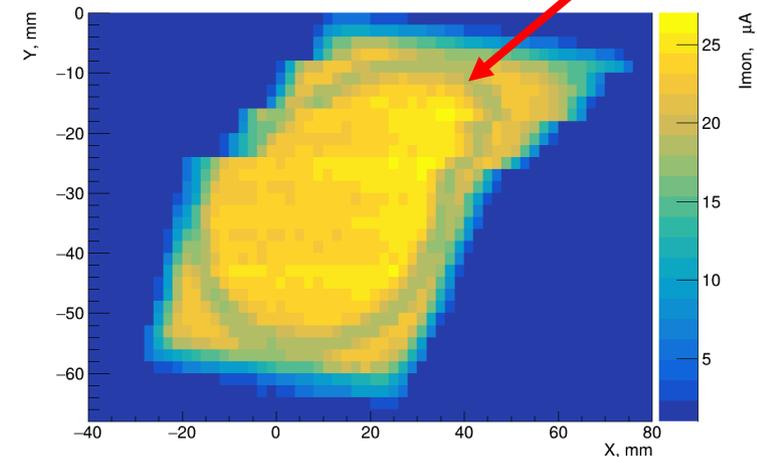


Arduino with CNC shield and drivers



Row 3 tile with SG BCF92

WLS fiber



Detector response VS. coordinate (preliminary)

For now, we assume that tile is homogeneous enough, so we could clearly see reduced detector response at points, where WLS fiber is glued into. More detailed research is required.

Coordinate table with X-ray tube:

- **AMPTEK Mini-X X-ray tube**
Ag target, 50 kV / 80 μ A, 2 mm collimator (5° X-ray cone) with ~ 2 cm from tile
- **NEMA 17 stepping motors**
Angular step 1.8° , 20 & 40 μ m resolution (X and Y axis correspondingly)
- **Arduino and CNC Shield**
Microcontroller board, enables movement automatization
- **CAEN DT5202**
A7585D power supply with 1 μ A resolution

- I. The 8-channel prototype has been **assembled**, the **self-triggering option** of CAEN FERS-52XX system has been **tested**. The work of the **ToT function** has been shown, the calibration of the charge scale for estimate of ToT linearity **is required**.
- II. FEE and digitizer option localized in RF has been developed. The comparison of new electronics with CAEN FERS-5202, and future upgrades (perhaps) **are required**.
- III. First tests with DT5215 and DT5202 **with free-streaming mode** has been **started**.
- IV. One of the possible methods of express sector checking has been **proposed**. The **loss of light** of **side glow fiber** has been **about 75%** at a length of 0.5m. Several fiber manufacturers needs to be considered.

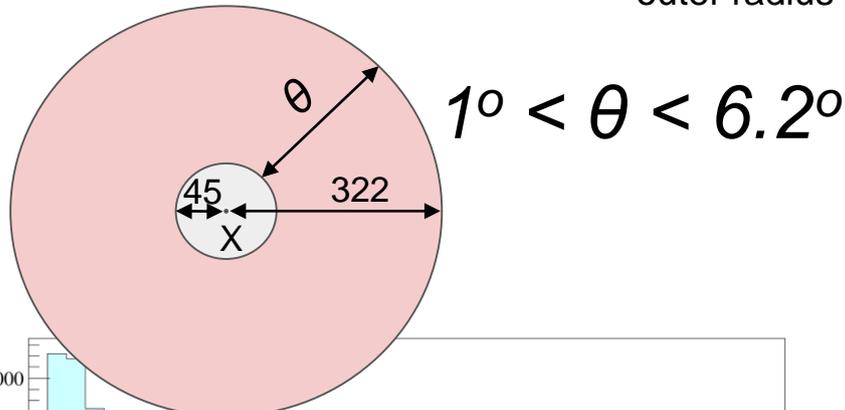
To do list

- Test of clear fiber (Saint-Gobain Crystals and Kuraray manufacturers) attenuation
- Test with new connector and transmission box
- Test of tiles and sector homogeneity

Beam ^{124}Xe with energy **3 GeV/n** collides with the **W** target.

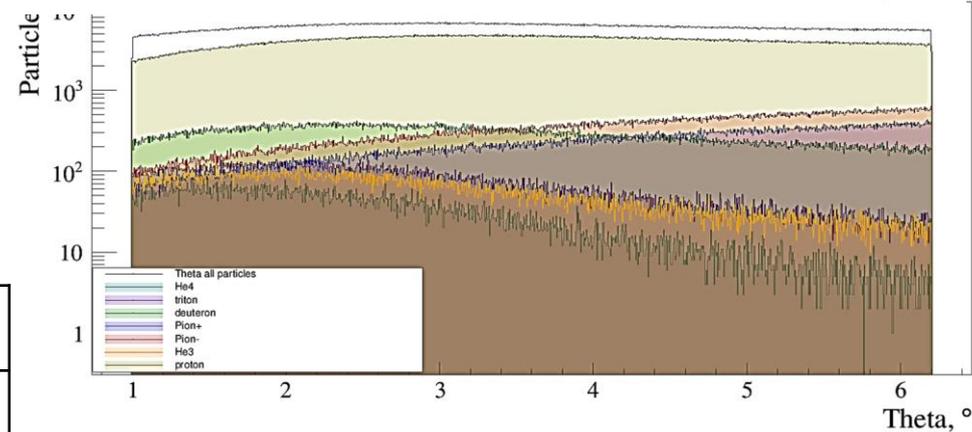
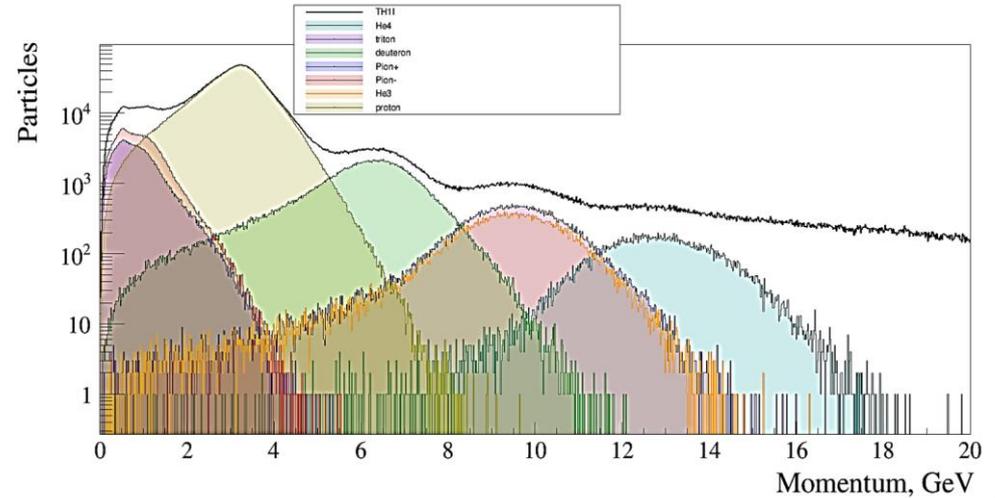
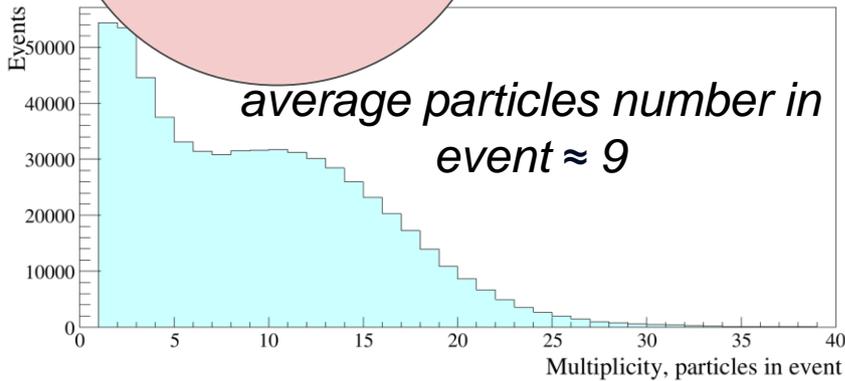
Condition of the simulation

The detector has the shape of a solid **disk** with an inner radius of **45 mm** and an outer radius of **322 mm**. Distance from target to detector \sim **3m**.



$$1^\circ < \theta < 6.2^\circ$$

average particles number in event ≈ 9



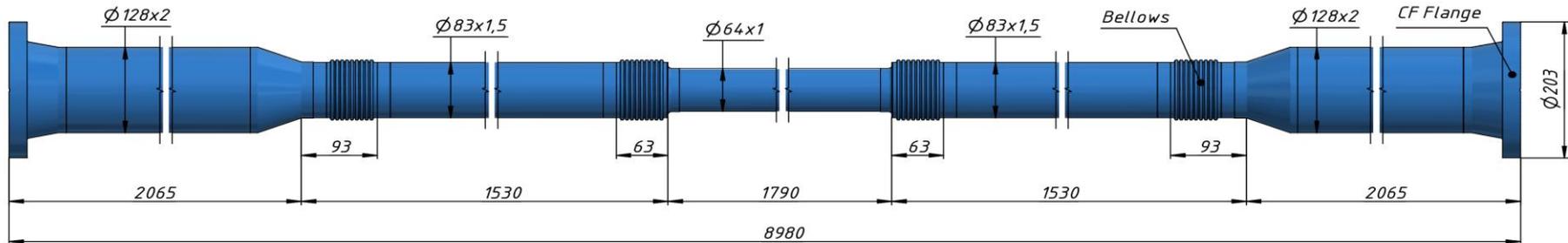
particles	p	π^+	π^-	^2H	^3H	^3He	^4He
%	74.26	4.03	6.18	5.16	1.26	0.98	0.52
average momentum GeV/n	3.02	0.90	0.93	2.96	3.12	3.10	3.19

As a result of the simulation, a distribution of the multiplicity of particles in events was obtained. It can be seen that the detector has a high multiplicity. The average particles number in the event is approximately 9.

- 1. Xe124+ W collisions (FT mode)
- 2. Being very optimistic:
Xe124 +Xe124 collisions (Collider mode)



D-120.000.000 Beam pipe MPD ver. 04.02.2021
Aluminium alloy 1201 GOST 4784-2019



Needs:

2 Wheels 128 scintillator tiles each

- scintillator -yes
- WLS – yes
- mechanic support -no
- SiPM – yes
- optical connectors – no
- optical cables -no
- transmission boxes -no



DT5202 -yes

DT5215 -yes

Conclusions

- I. The main task for 2024 to produce and to test the 8 tiles prototypes is almost finished.
- II. The R&D phase for optical and transmission connectors is continues.
- III. The manufacture of small BBC wheels (128 tiles each) for SPD Phase 0 is planned for the mid of 2025.

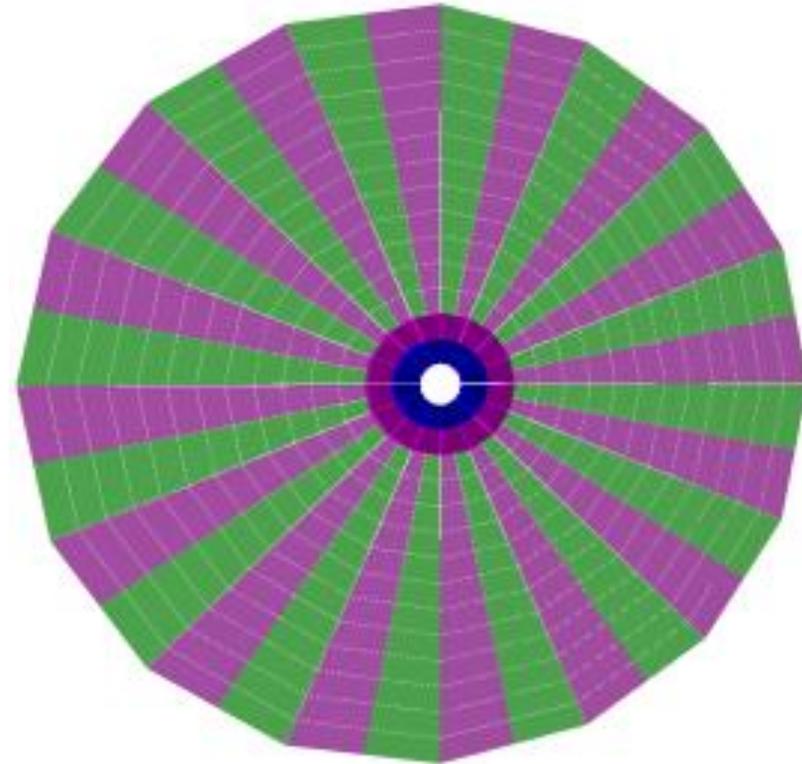
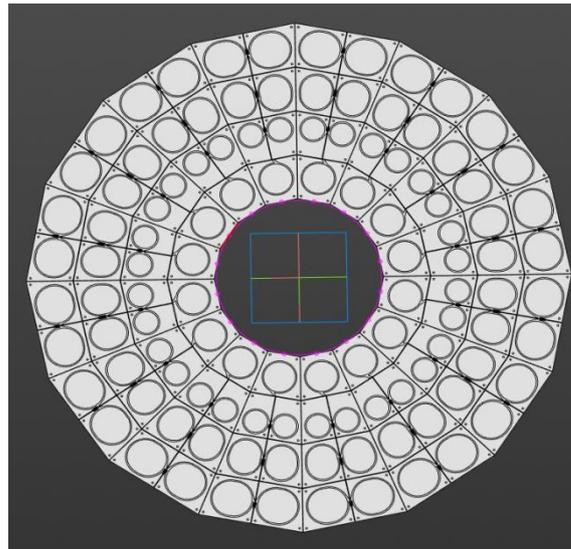
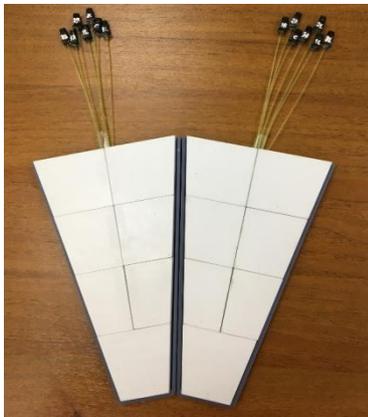
Thank you for the attention!

REFERENCES

1. Physics of Atomic Nuclei, 2024, Vol. 87, No. 4, pp. 450–457.
2. Phys.Part.Nucl. 55 (2024) 4, 1091-1098
3. www.caen.it/support-services/documentation-area/ (A5202/DT5202 User Manual)

Backup

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1-st Stage
16 tiles

2-nd Stage
2 wheels with 128 tiles each

3-rd Stage (final)
2 wheels with 400 tiles each (416?)

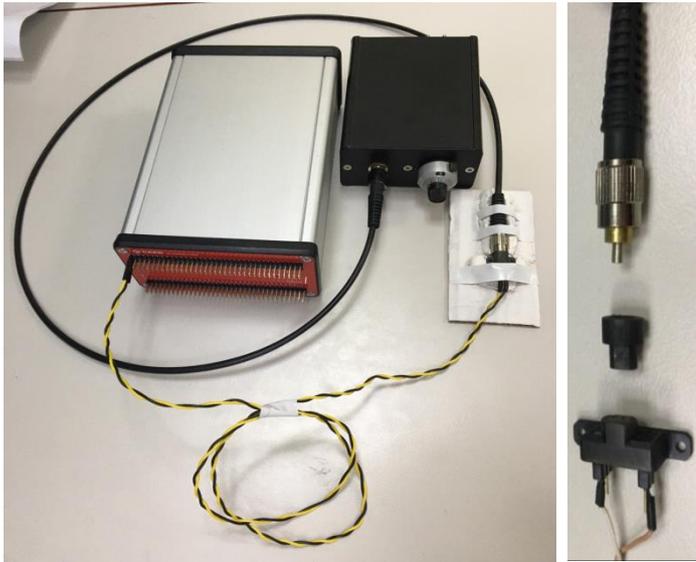
Phase 0

Phases: 1-st & 2-nd

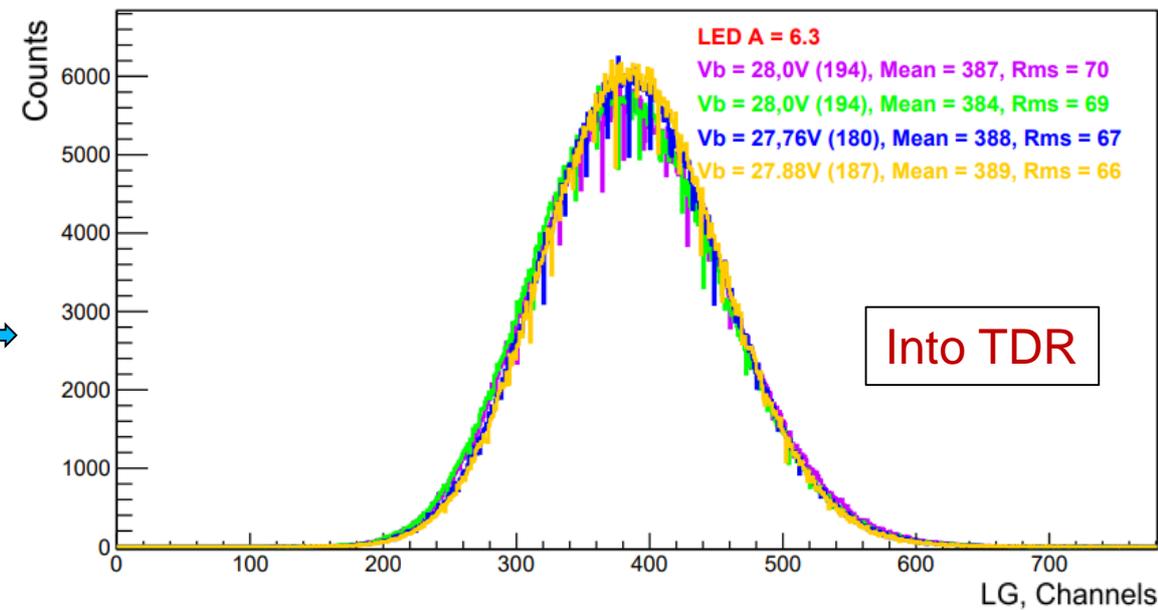
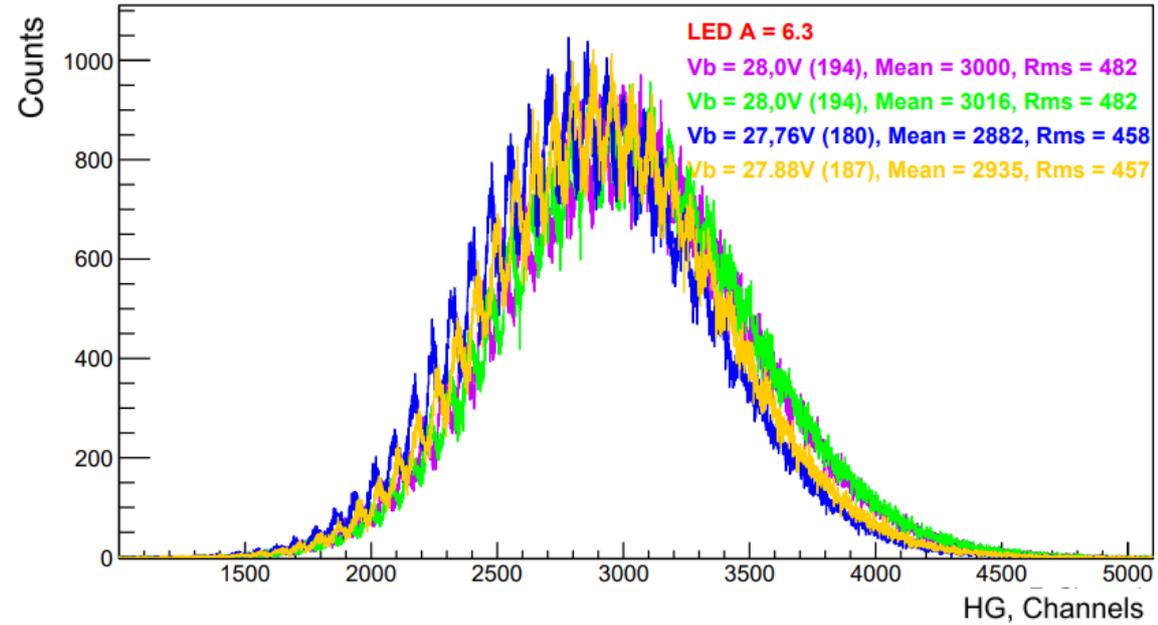
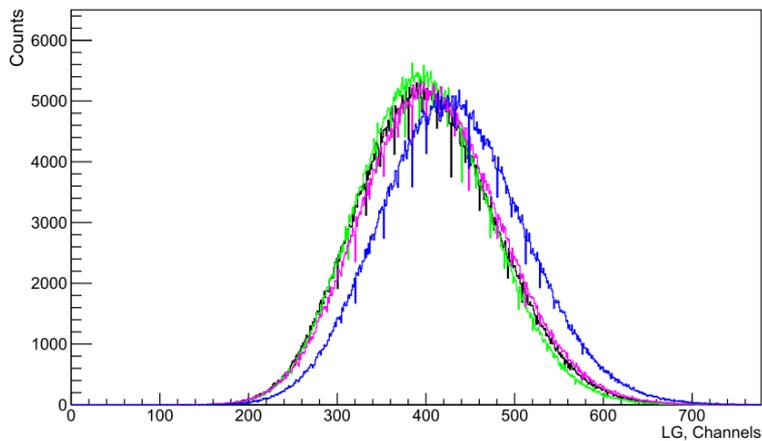
The hardware of BBC tests part

Calibration method (Led source)

DT5202 with CAEN LED Driver (SP5601)

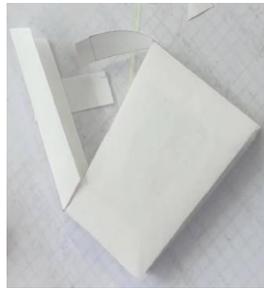


Not calibrated



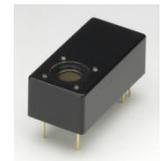
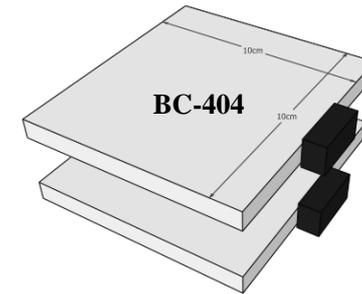
Materials selection test part

Scintillator cover



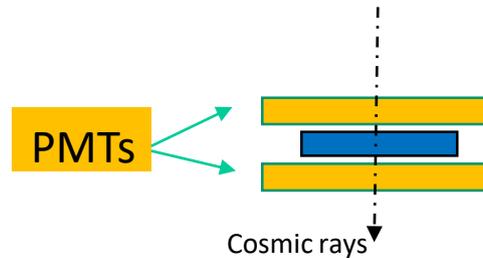
The amplitude spectra of the BBC prototype scintillation tile coated with **Mylar** or **Tyvek**, as well as covered with **Matted** options.

External trigger by coincidence of two scintillators with PMTs readout



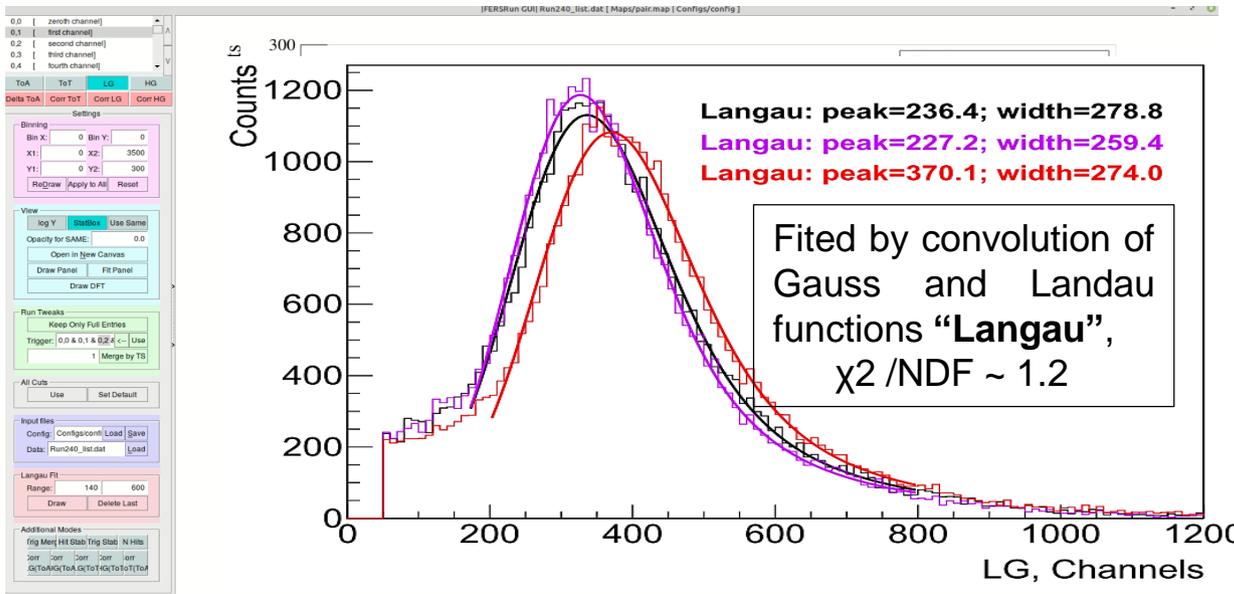
PMT
Hamamatsu
H10720-110

The “FersRun” framework has been designed.



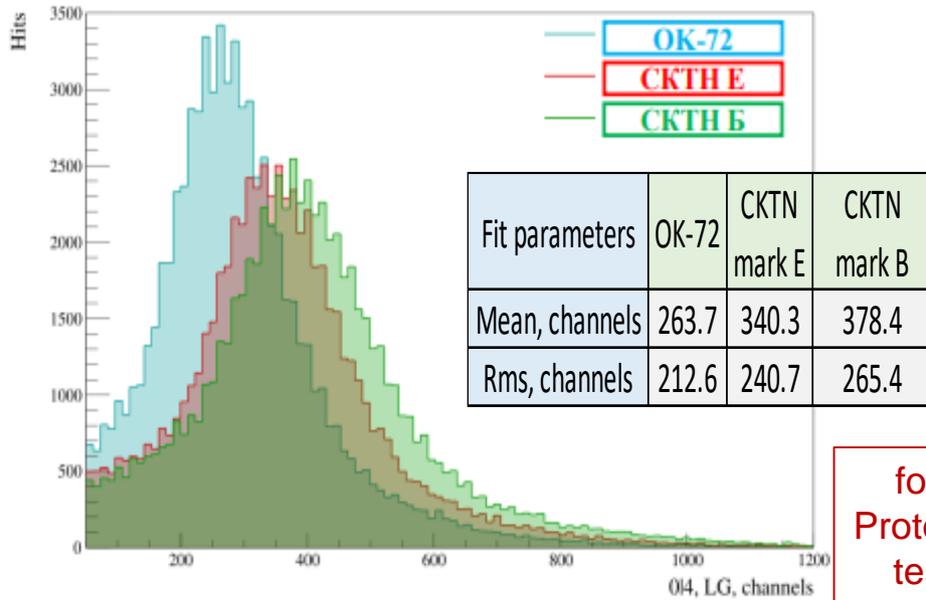
Matted
or
Mylar
or
Tyvek

SensL SiPM (27.34 V.)
S.G. (WLS)
CKTN (opt. cement)



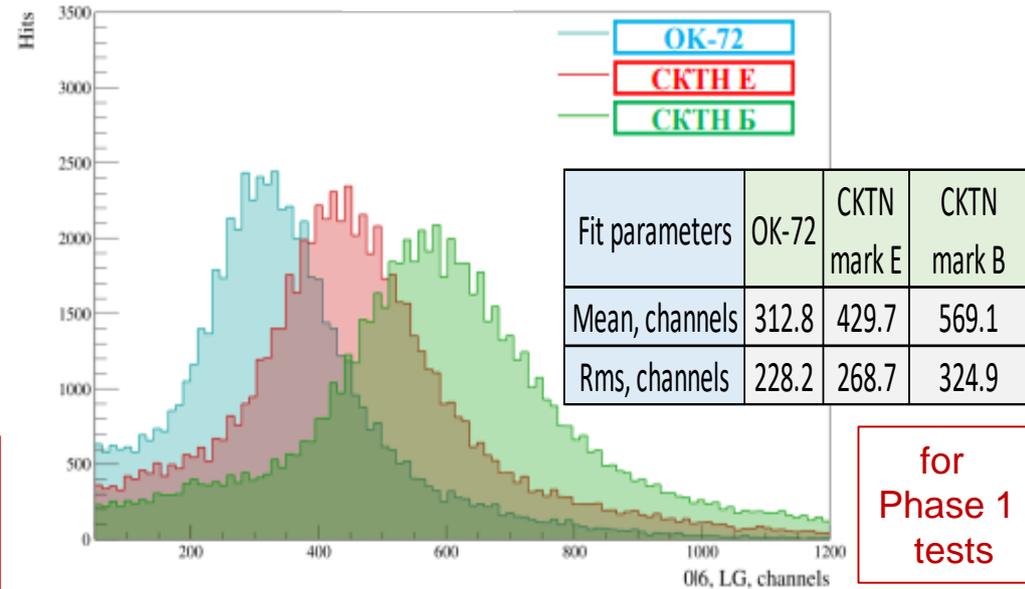
☐ The option with **matted tiles** is more priority for mass production.

SGC BCF92



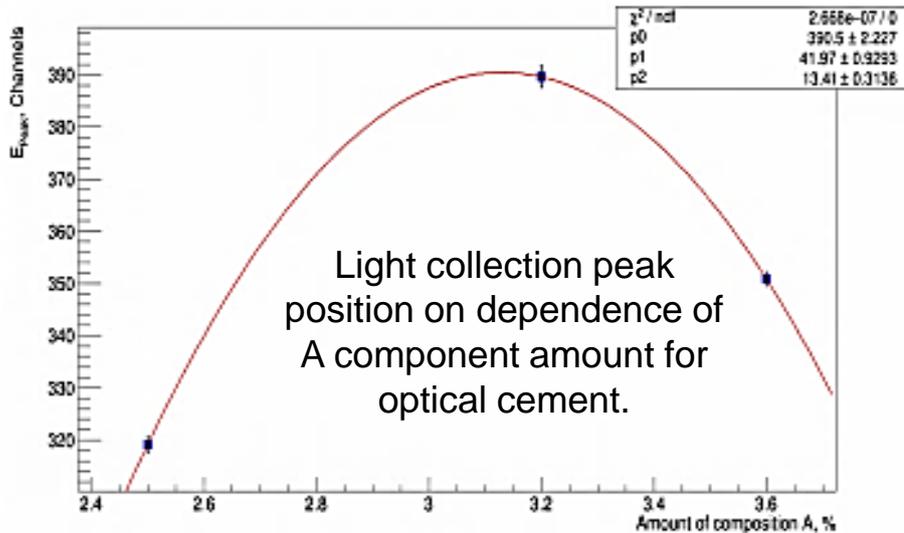
for
Prototype
tests

Kuraray Y-11



for
Phase 1
tests

CKTN

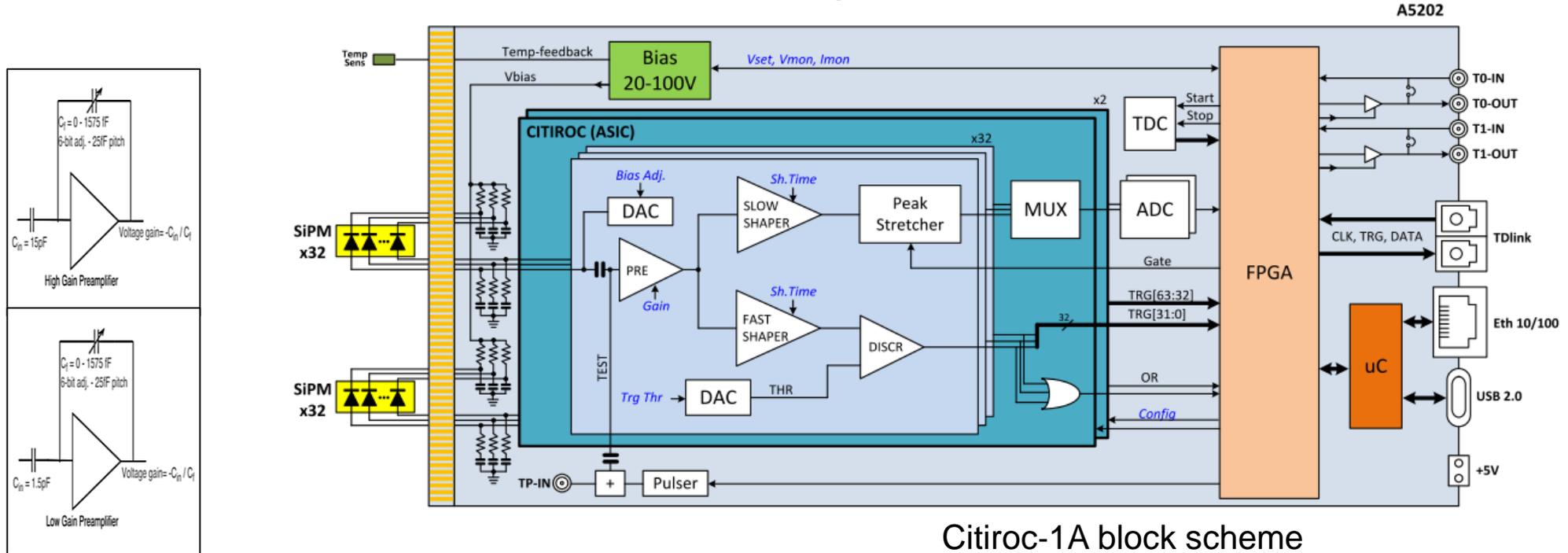


- ❑ Datasheet ratio will be used and closely monitored for mass production.

The results of tests of Kuraray WLS fiber and Saint-Gobain Crystals (SGC) WLS fiber with different types of cement are presented.

- ❑ **CKTN mark B** paired with SGC WLS fiber are the most appropriate candidates **for prototype** assembly tests.
- ❑ **CKTN mark B** paired with Kuraray WLS fiber are the most appropriate candidates for future **testbeam**.

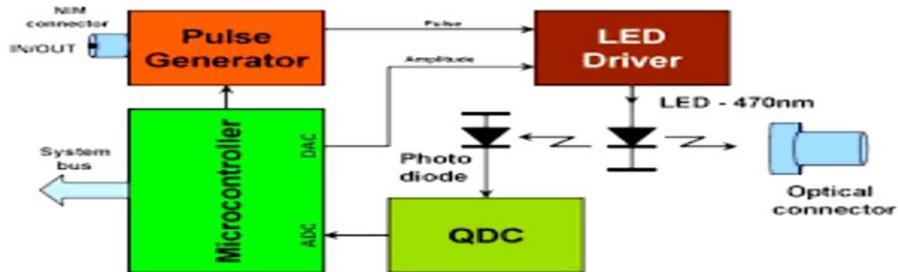
Simplified block diagram of the DT5202 FERS-5200 unit



Each channel has low (**LG**) and high (**HG**) gain preamplifiers providing a wide dynamic range.

- Triggers of consecutive channels are sent to an AND logic operator (e.g. CH0&CH1, CH2&CH3, etc.). The 32 outputs are then sent to an OR logic operator.

Schematic view of the LED



Citiroc-1A block scheme

