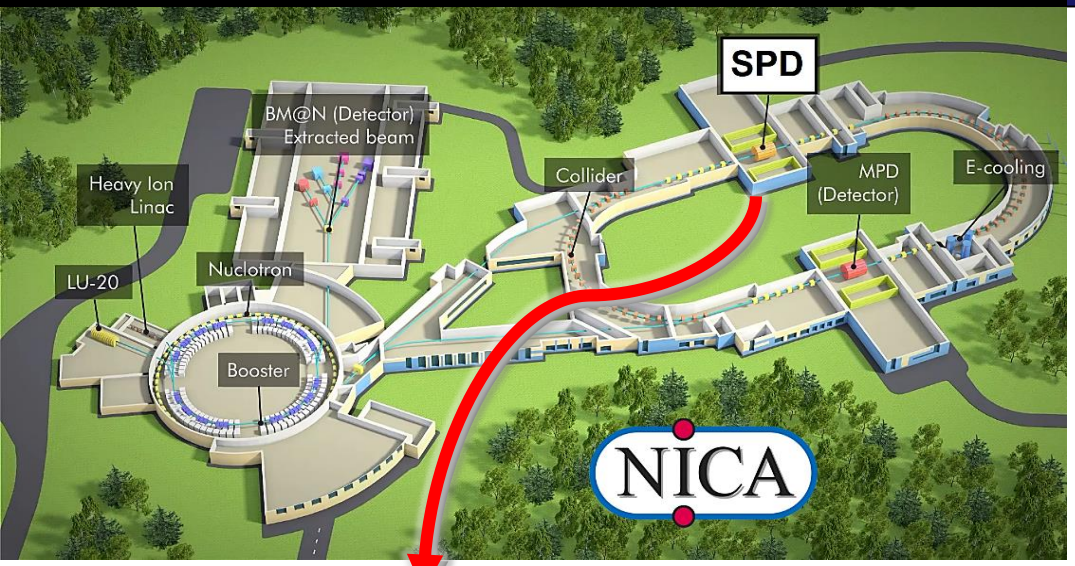
Статус работ по BBC

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

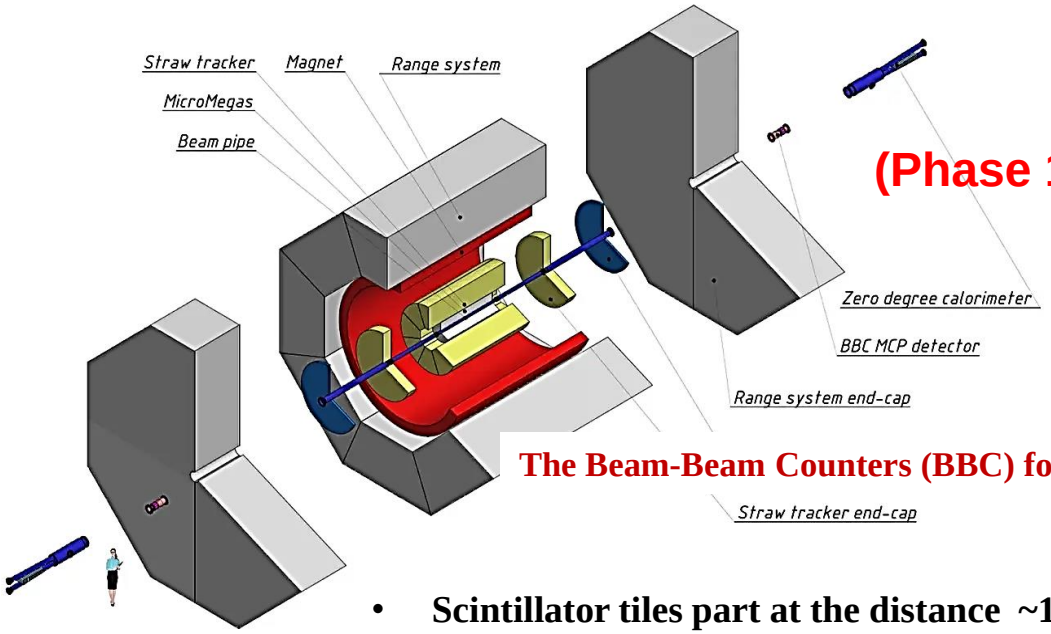
MEPhI-SPD weekly physics & detectors meeting

29 April 2025

Introduction



The Spin Physics Detector (SPD)



(Phase 1)

The Beam-Beam Counters (BBC) for SPD

- **Scintillator tiles part at the distance ~1.7 m**

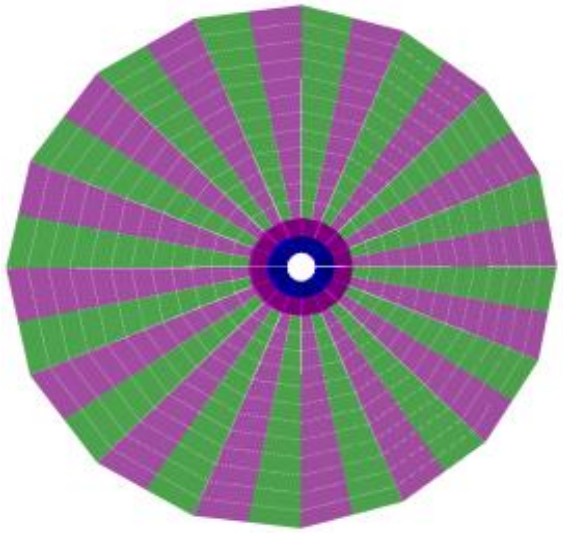
General

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

Now : 124 mm diameter
Need: 83 mm diameter

TDR 2023

2 wheels with
400 tiles each (416)

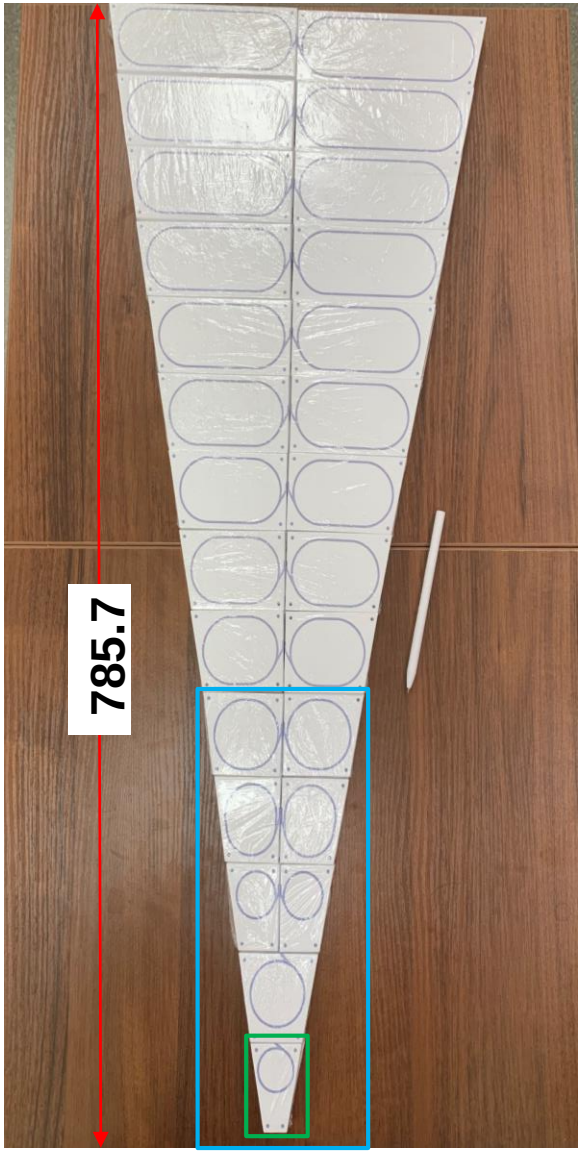


+ **local polarimetry**
+ event plane detector for HI physics

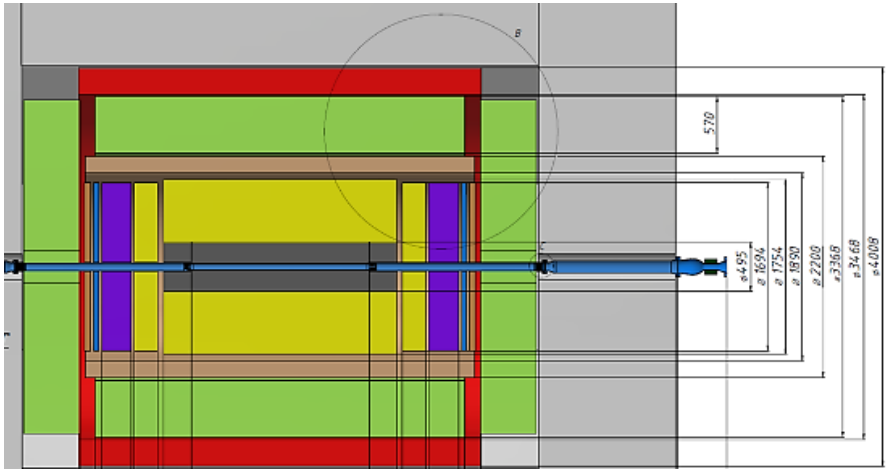
Sandwich bases for BBC

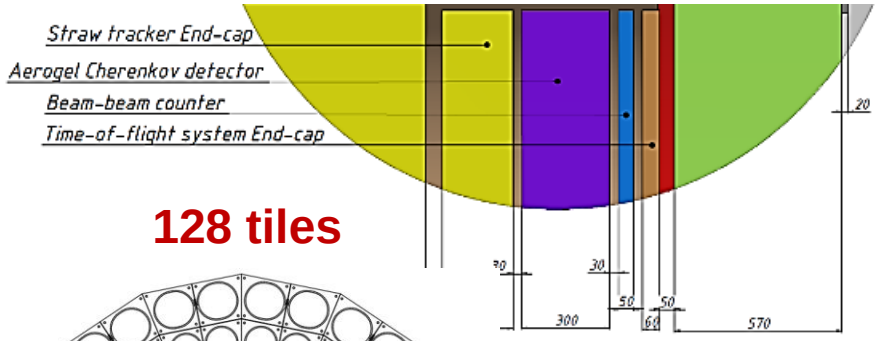
BBC Sector (1/16 of wheel) design

26 tiles

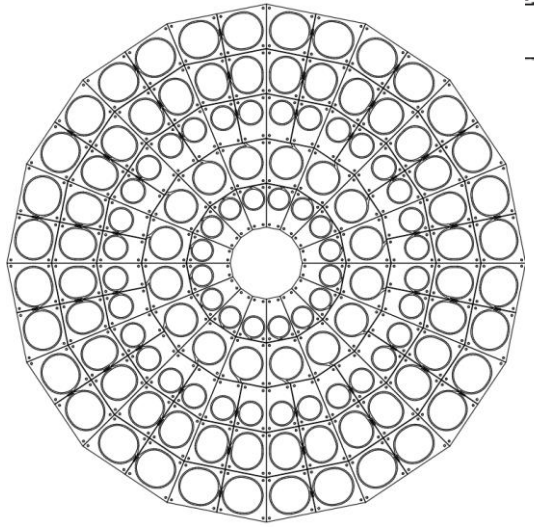


due to the ambiguity of the cable output, the final design is discussed





128 tiles



Two full-scale sectors by the end of the year (at the 2-nd stage)

reduced prototype wheel (x2) (at the 1-st stage)

Prototype assembling part

Sandwich bases for BBC

Plastic foam sandwich base (comparable quantity of matter)

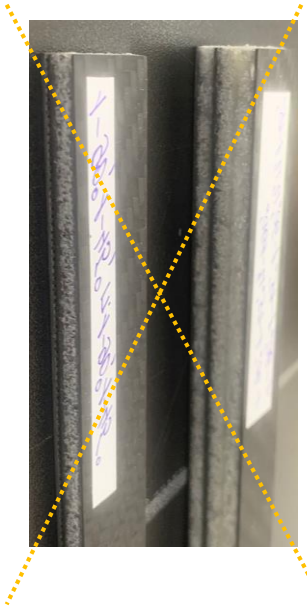
Honeycomb sandwich base (main option)

3-options sandwich base with different thickness of carbon layers

Parts:

I. Infrastructure (grooved)
II. Main support

I. II.



I. II.

total thickness ~ 25 mm

I. II. I. II. I. II.

thickness of each ~ 20 mm

Hardness modeling

deformation = 0,046mm

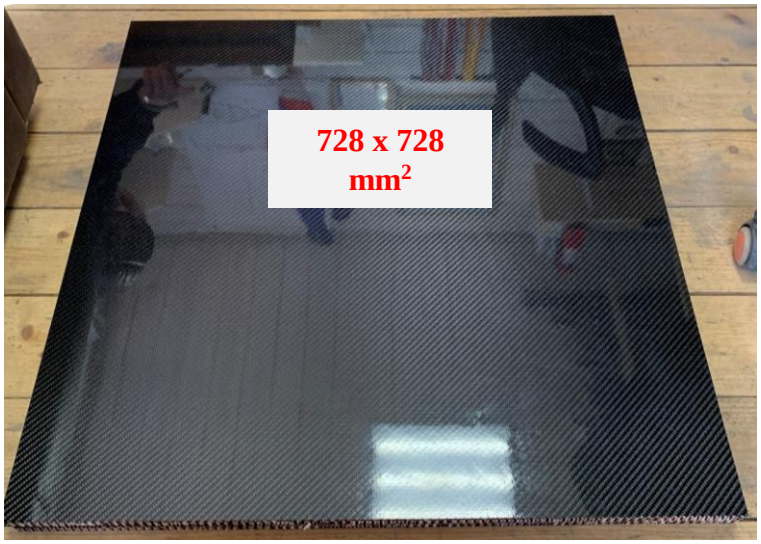
Hardness modeling is underway

Prototype assembling part

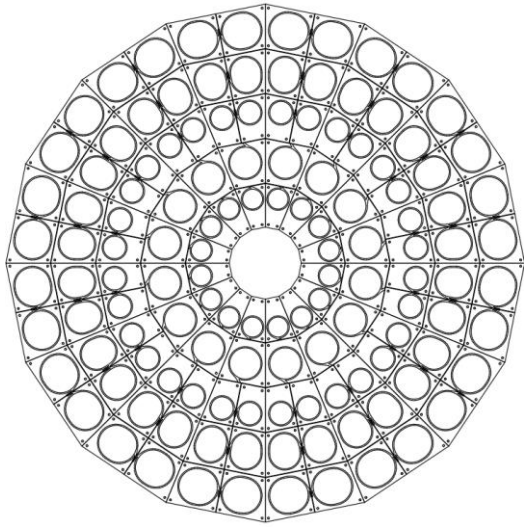
Sandwich bases for BBC

Grooved carbon backplate V1

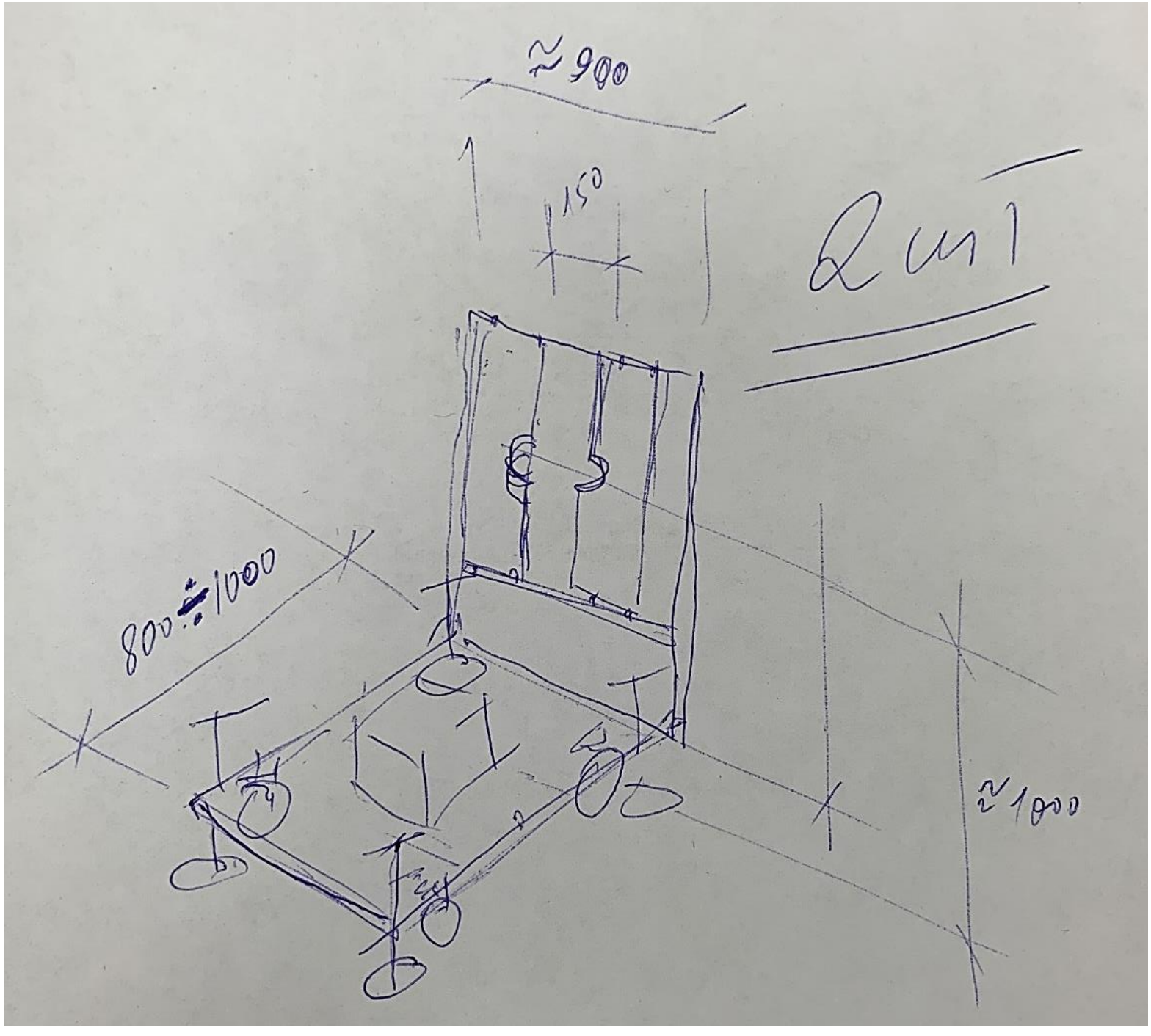
Grooved wood backplate V3



Grooved wood backplate is required (reduced prototype wheel)



The next step is developed of the basic mechanics


≈900
150
800÷1000
≈1000

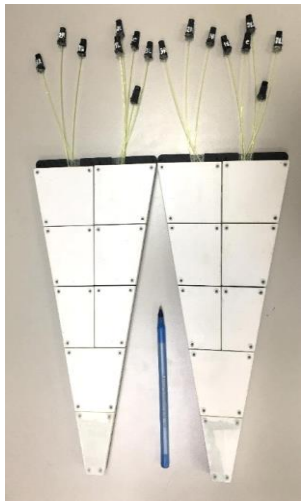
Prototype assembling part

To do list (for Yerevan meeting)

- ❑ Test of clear fiber (Saint-Gobain Crystals and Kuraray manufacturers) attenuation
- ❑ Test with new optical connector
- ❑ Development of quality control of connectors
- ❑ The comparison of new electronics (for phase1) with CAEN FERS-5202
- ~~❑ Test with DT5215 concentrator~~

Prototype assembling part

Proposal for reduced wheel prototype



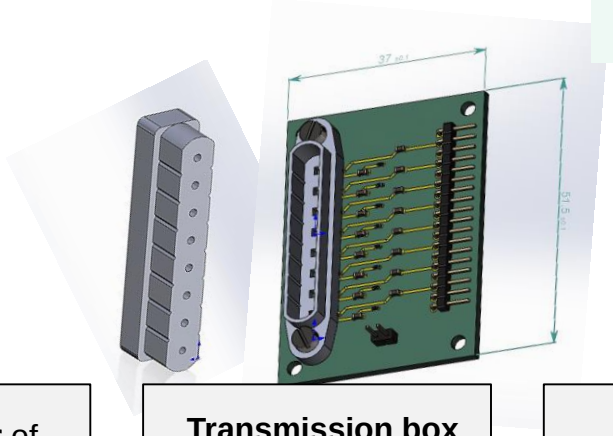
reduced sector prototype x2

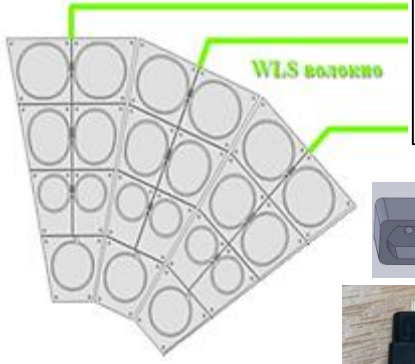
Selected options (references [1-2]) :

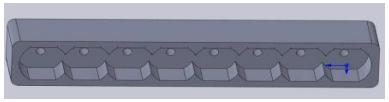
Scintillator:	**Uniplast-Vladimir (chemical mating)**
Optical cement:	**CKTN Med mark B**
WLS Fiber:	**Saint-Gobain Crystals (SG92S)**
SiPM:	**SensL 1x1 mm^2 (MicroFC-10035 SMTPA)**

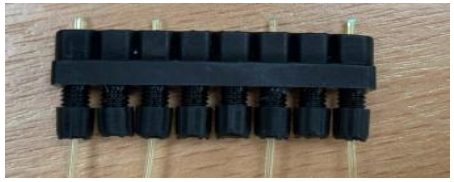
Hamamatsu (S14160-1315PS)

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





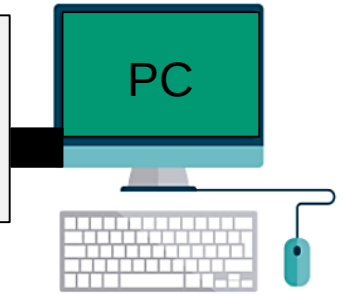




Connector of WLS-to-clear fibers **tested**

Transmission box for clear fibers to SiPMs **?**

Front-end & Readout



Readout system:

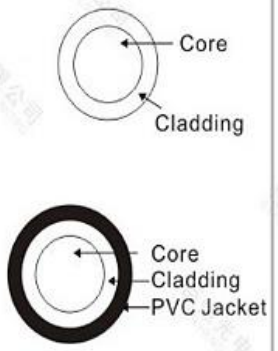
CAEN FERS-5200 for Phase 0

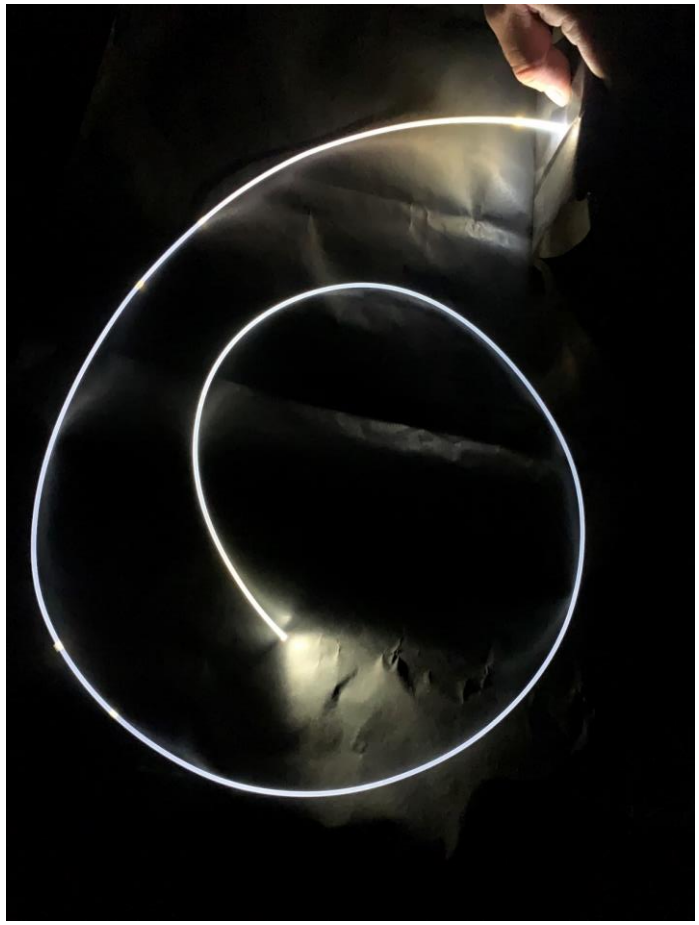
NEW ELECTRONICS (?) for Phase ≥1

The method of assembled sector fast check

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**)

Item no.	Diam-1.5, 2, 2.5, 3, 3.5, 4, 5, 6, 8, 10, 12, 14, 16, 18mm
Item name	Solid core Side glow Optic fiber
Fiber core material	Methyl Methacrylate (MMA)
Cladding material	Polytetrafluoroetylene(PTFE)(Telfon)
Jacket material	N
Core refractive index	1.55
Cladding refractive index	1.50
Refractive index Profile	Step
Wavelength range	350 -780nm
Max bending radius	5X diameter
Working temperature	-20 – 100°C
Storage temperature	10-50 °C

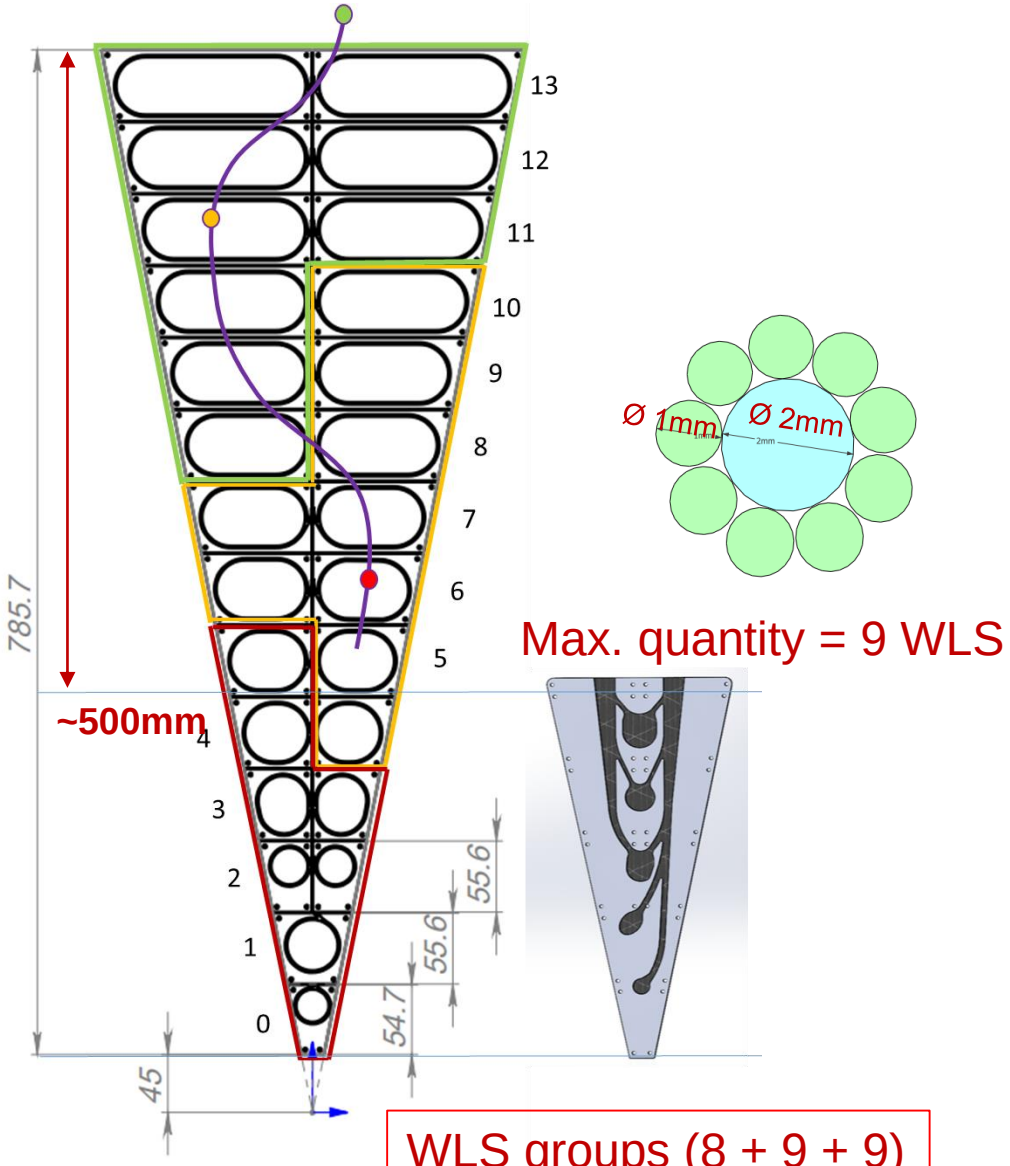




A quick check method for the assembled sector will allow us to verify if the fiber within the sector is undamaged and monitor fiber degradation over time.

Methodical tests

The method of assembled sector fast check

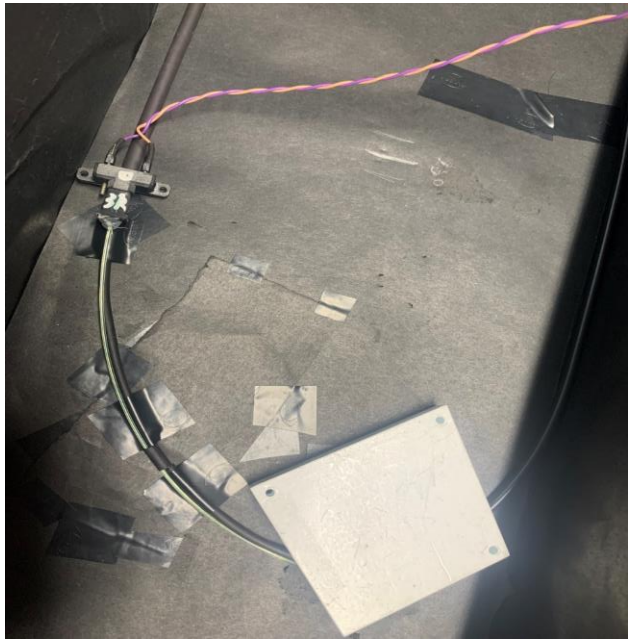


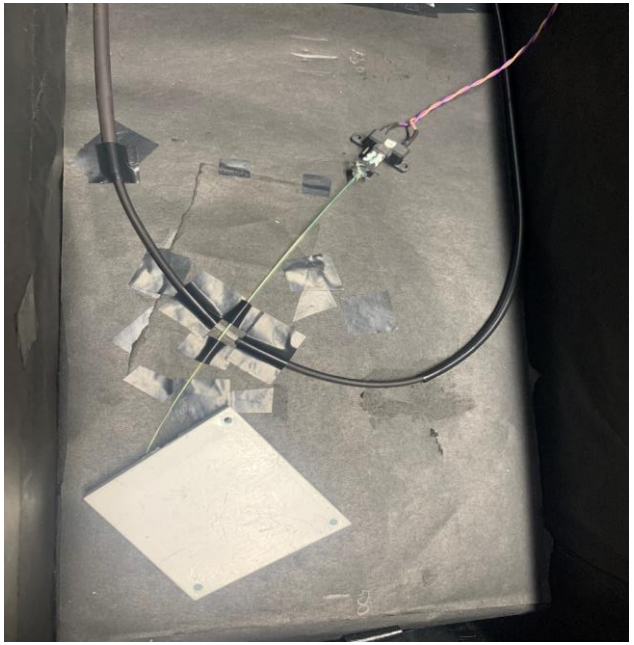
Max. quantity = 9 WLS

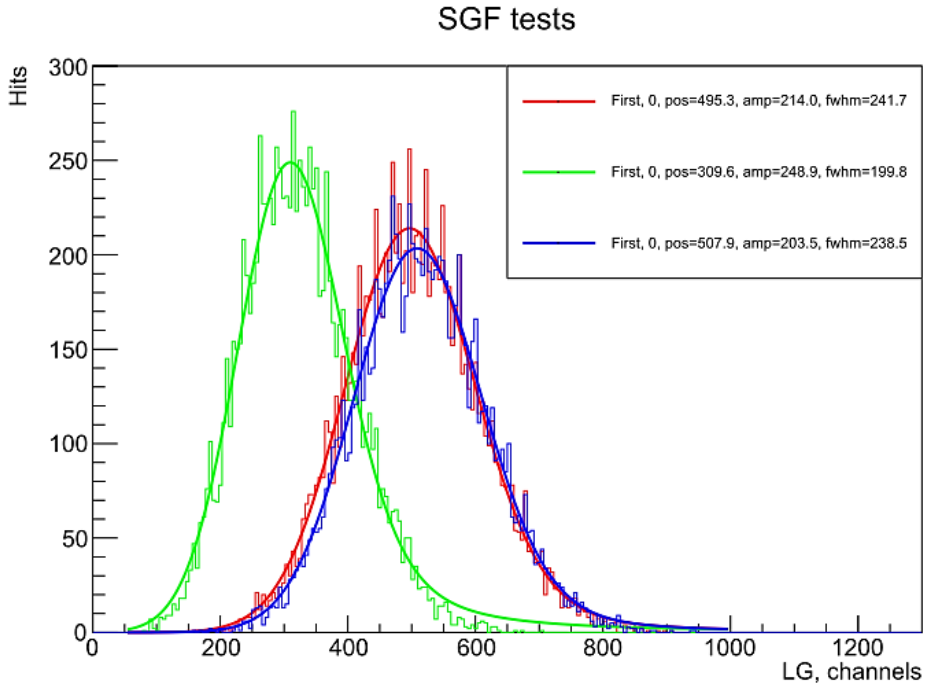
WLS groups (8 + 9 + 9)

Methodical tests

The method of assembled sector fast check

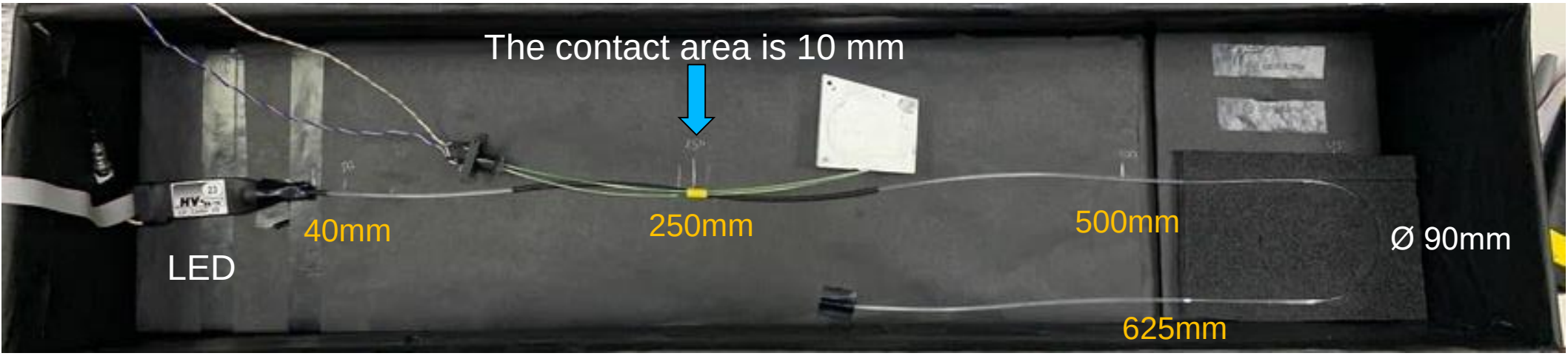


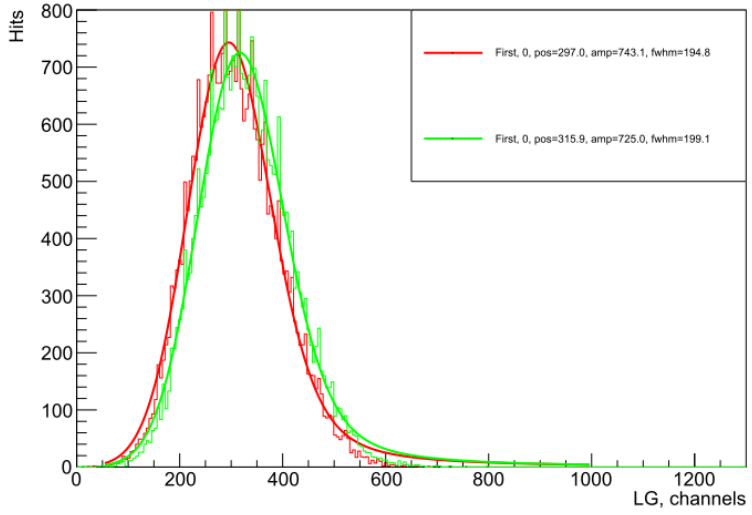


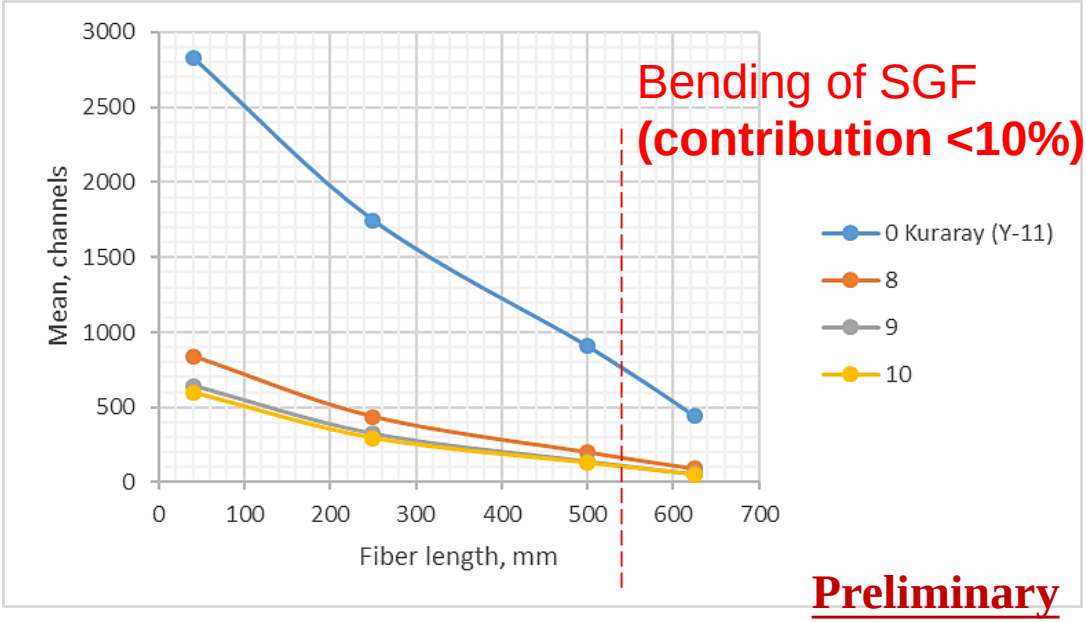


Methodical tests

The scan by SGF length



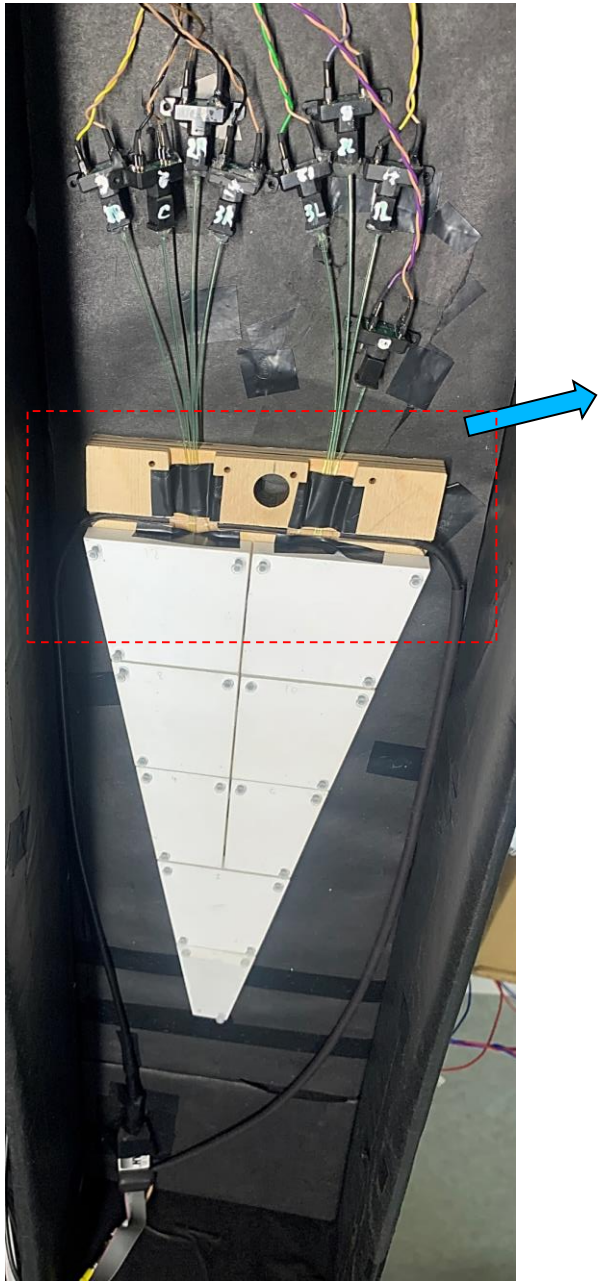




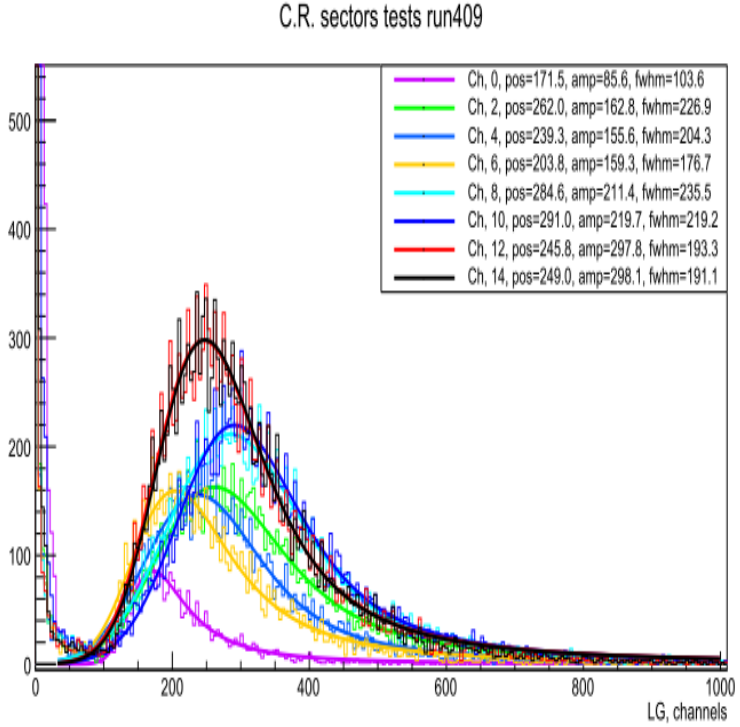
For the experiment we attached WLS fibers in several SGF spots: at 40-, 250-, 500- and 625-mm distance from LED, that was emitting light into the SGF end.

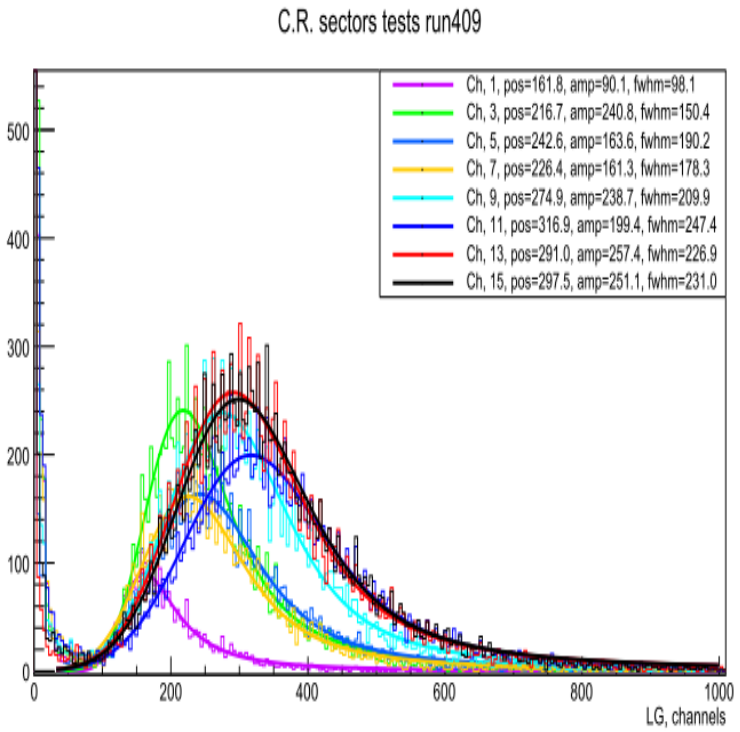
Methodical tests

The method of assembled sector fast check

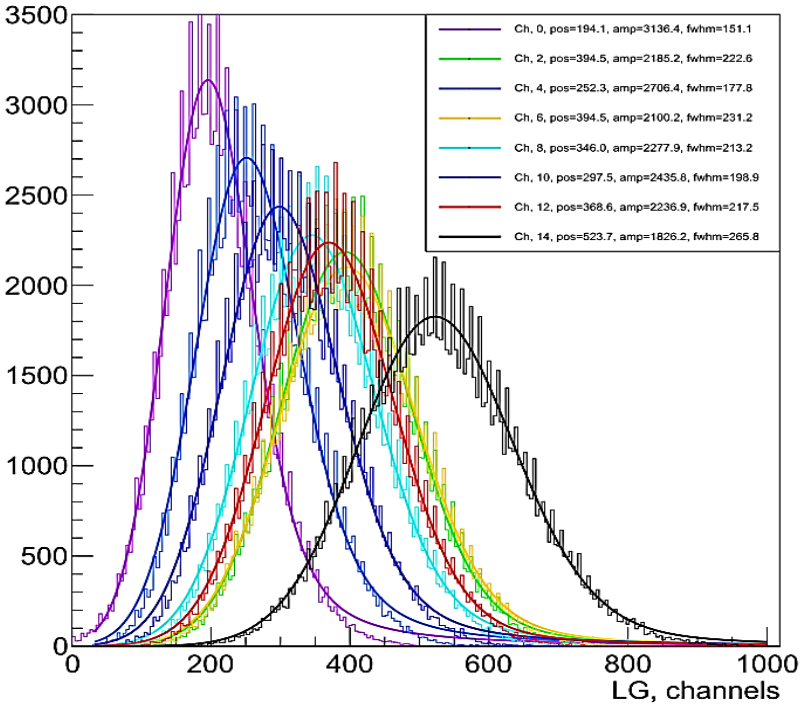


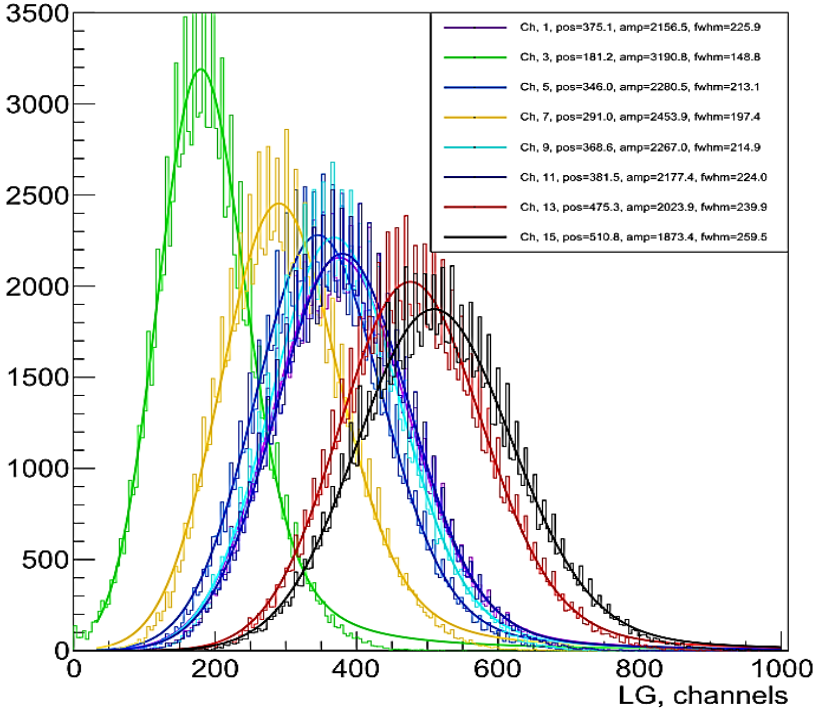
Cosmic rays



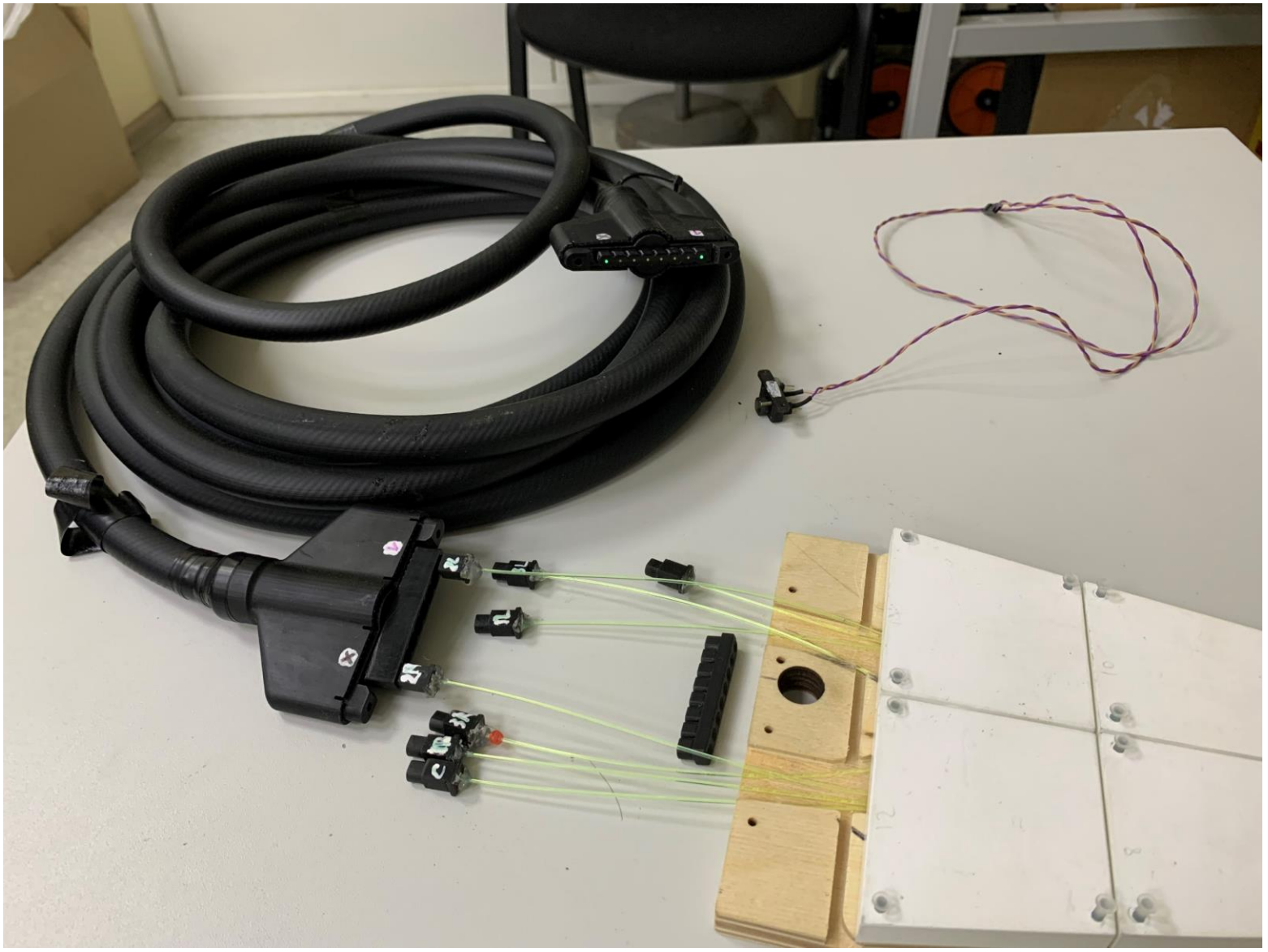


Test with SGF





Тесты



The hardware for BBC

Stand for BBC measurements with two types of electronics

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

DT5203 (picoTDC chip)

DT5215 (Concentrator)

- **DT5202** (x2 Citiroc 1A chip)

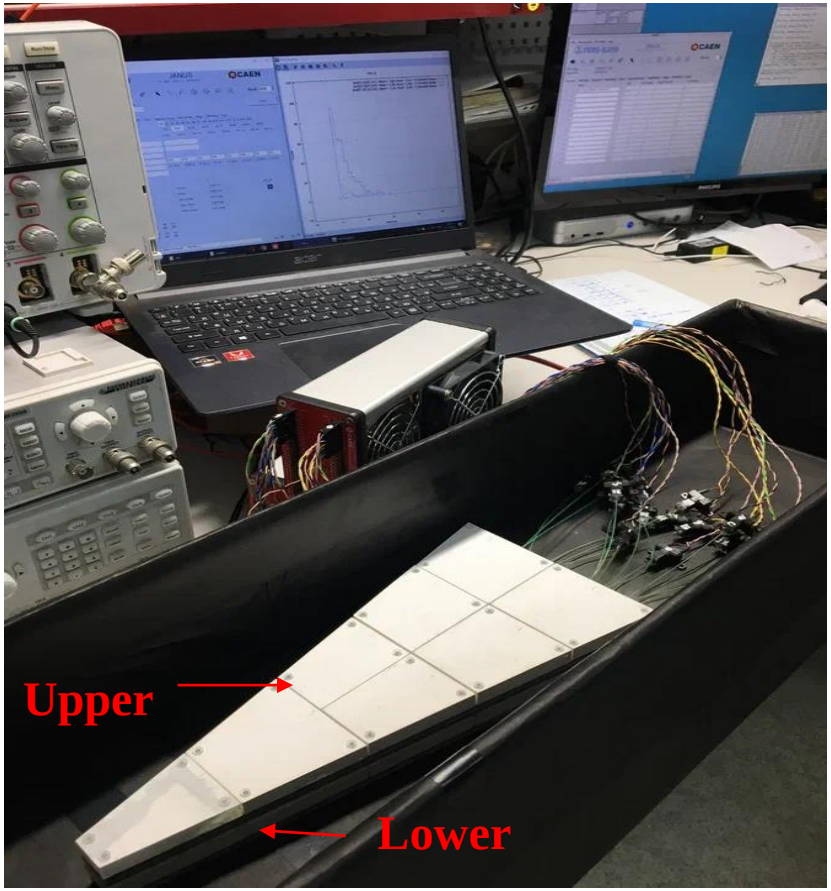
Hybrid mode (LG+ToT+ToA)

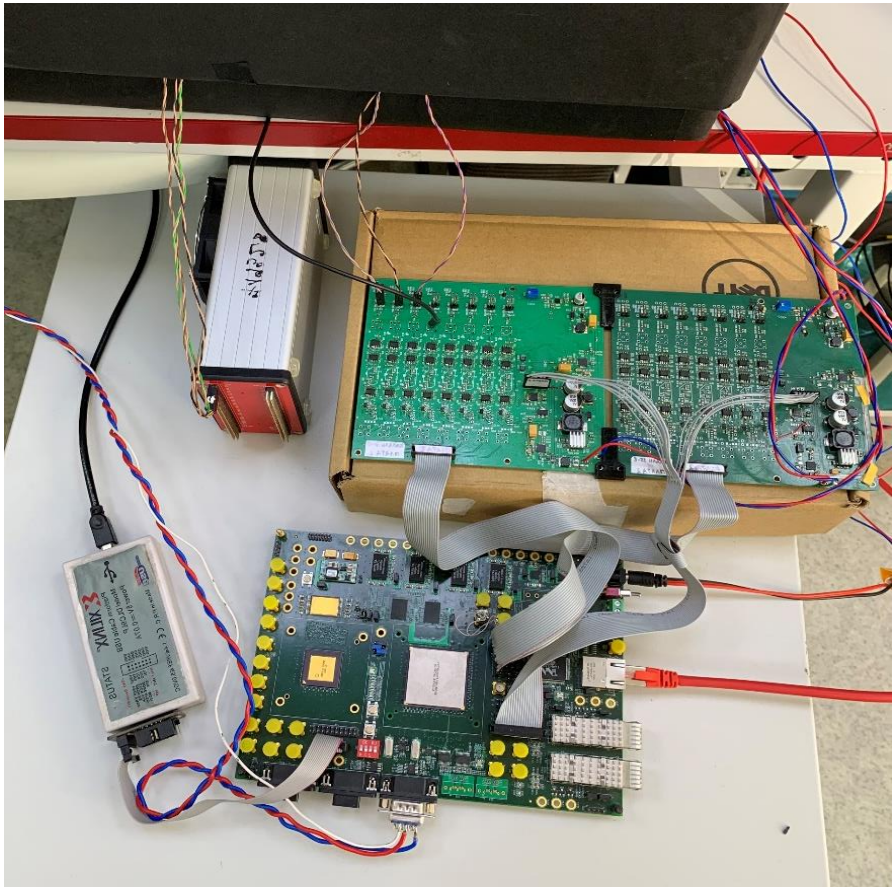
ToT+ToA

The front-end readout system based on FPGA XILINX VIRTEX-5 (new electronics; NE)

The leader is P. V. Nekrasov (MEPhI)

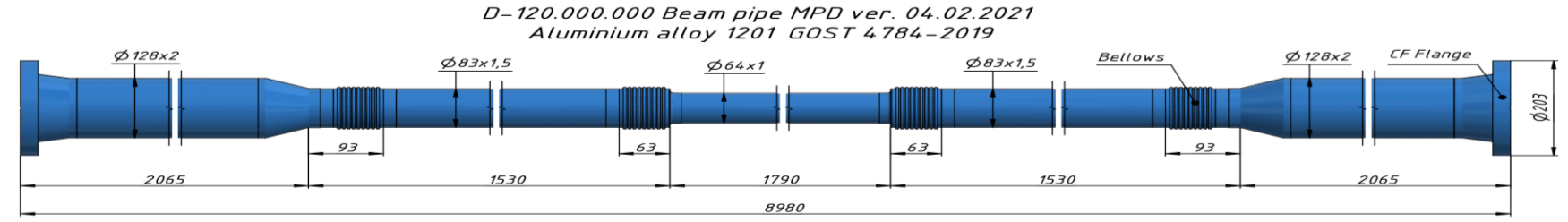
free-streaming mode is possible





report by Volkov I.

BBC priority to 2025:



1. Xe124+ W collisions (FT mode)

2. Being very optimistic:
Xe124 +Xe124 collisions (Collider mode)

DT5202 -yes
DT5215 –yes
Optic line –yes

Needs:

2 Wheels 128 scintillator tiles each
-scintillator -yes
-WLS – yes
- SiPM – yes
- optical connectors – yes(+-)
- optical cables – yes(+-)
- transmission boxes - ?
- mechanic support – no
- ready for mass production – no

Prototype assembling part

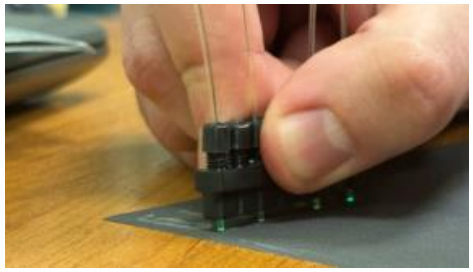
Mass production issues

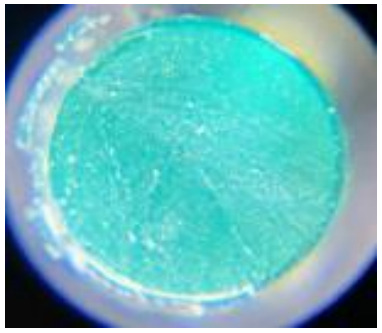
now

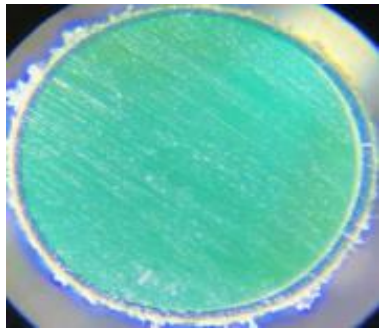
WLS-SiPM test connector couple

- Preparation of infrastructure for mass production (obtaining equipment, equipping rooms, etc.)
- Development of methods of mass production (algorithm + tools)

Estimation of light loss at the Interface of fibers (WLS-to-clear)

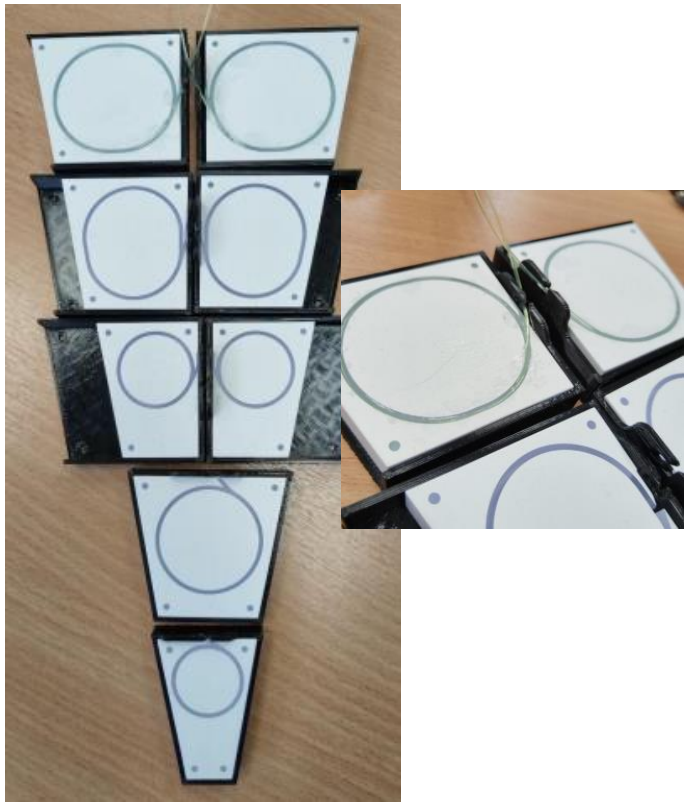






Estimation of light loss for clear fibers

Tiles and sectors: gluing frames



Final grooves mapping is required

Prototype assembling part

Mass production issues

Simulation (^{124}Xe+W interactions for the SPD BBC detector prototype)

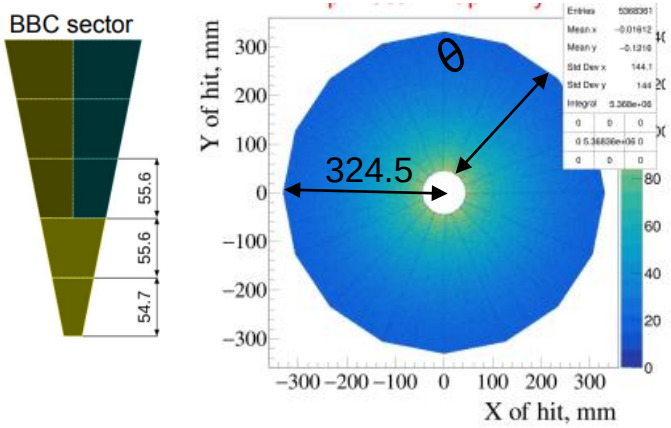
PHQMD generator+ Geant4

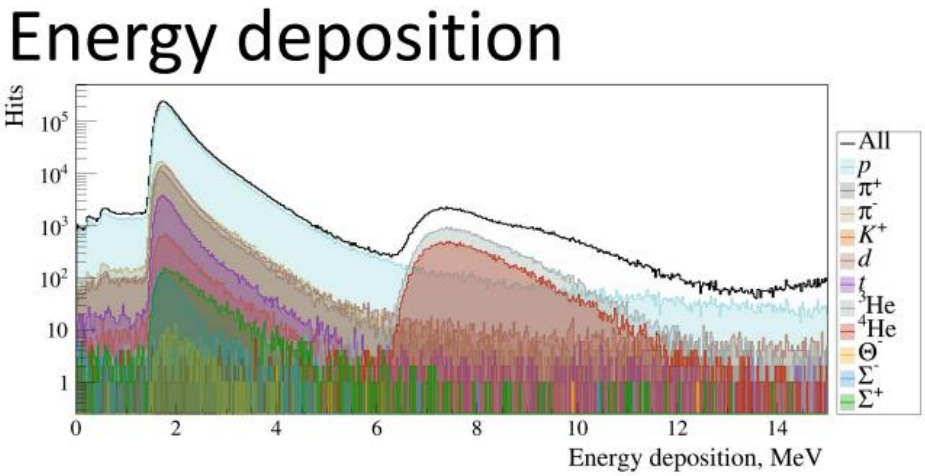
Condition of the simulation with Geant4

$1^o < \theta < 6.2^o$

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

The detector is a disk with an inner radius of **45 mm** and an outer radius of **324.5 mm**, which is divided into **16 sectors** and **5 rows**. A total of **128 scintillators**, the gap between scintillators is **0.6 mm**, thickness - **10 mm** Distance from target to detector ~ **3m**.

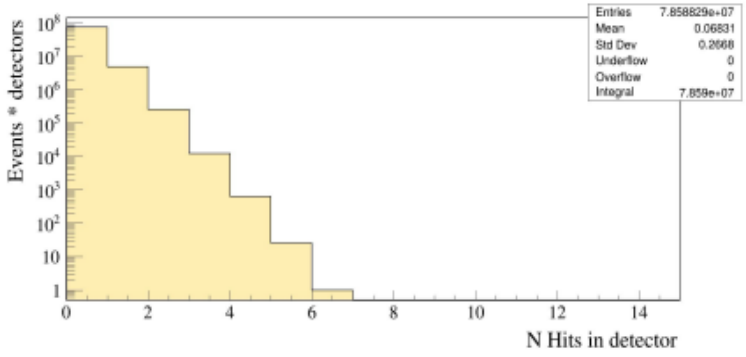




particles	%
p	76.38
π+	4.13
π−	6.34
d	5.35
t	1.31
^{3}He	1.03
^{4}He	0.55
K+	0.30
Sigma+	0.08
Sigma-	0.05
other	4.48

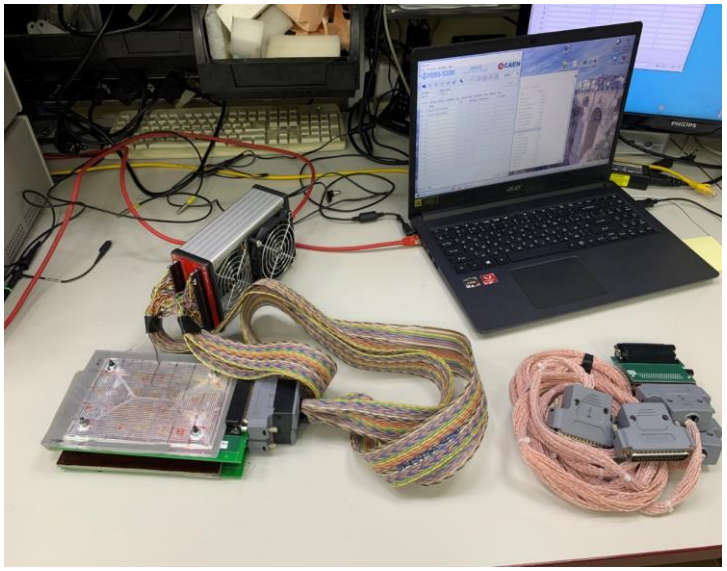
Multiplicity in detector

The number of particles that hit the tile in one event



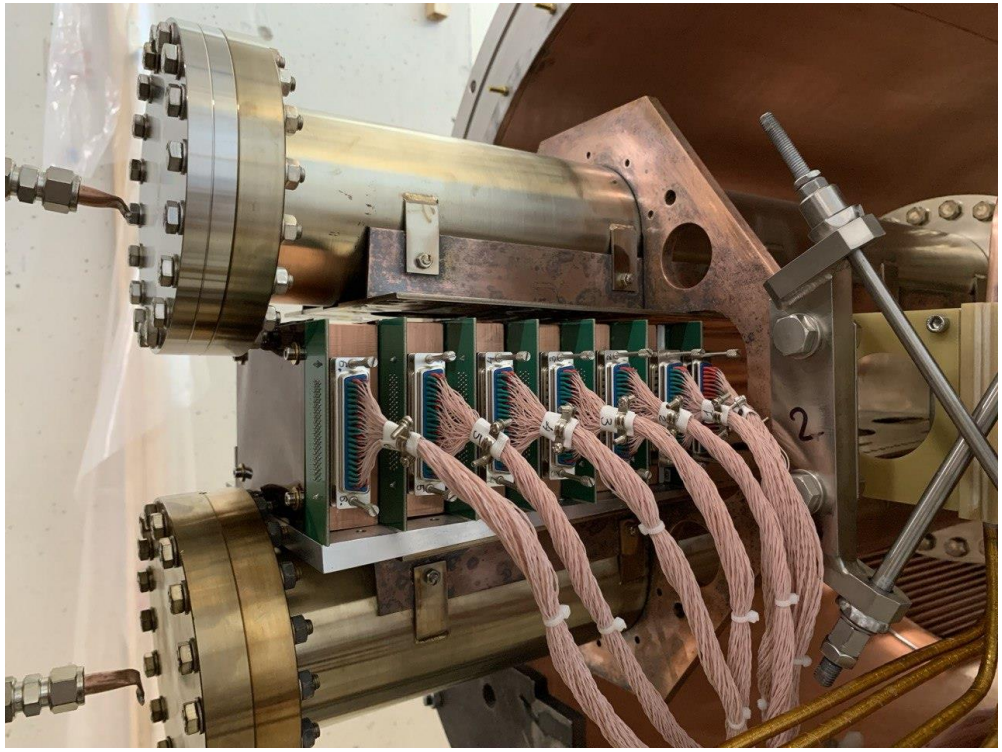
talk by Volkova K. & Volkov I.

test SiPM boards with 31



20x20 mm^2 scintillator tiles with 5 mm thickness was tested

The first stage of ZDC is – 6 planes + 1 veto with trapezoid geometry

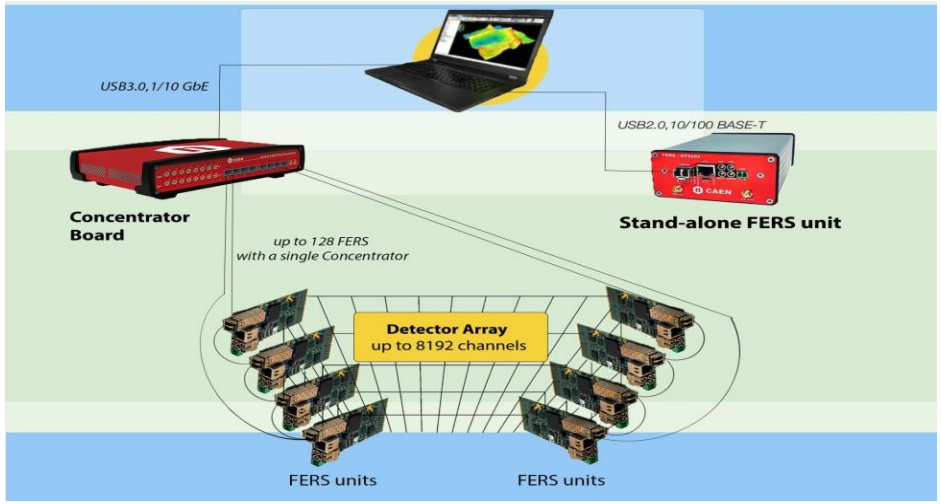


Working on the beam BBC & ZDC (?)

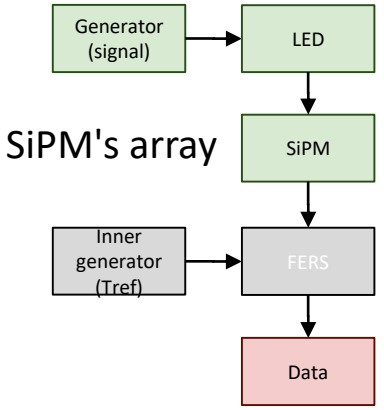
- **“FersRun” framework**
- **DT5215 concentrator**

Application of DT5215 concentrator

- **SPD** is planned to operate without **T0** (start) so we need to work with **free-streaming mode.** **(first step - Hybrid mode for DT5202)**

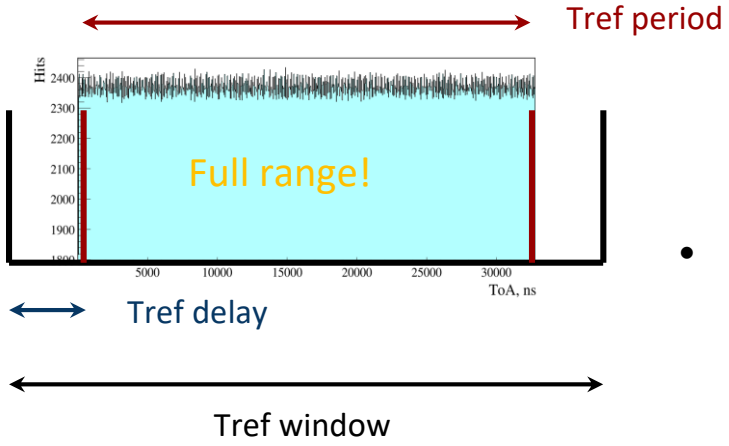


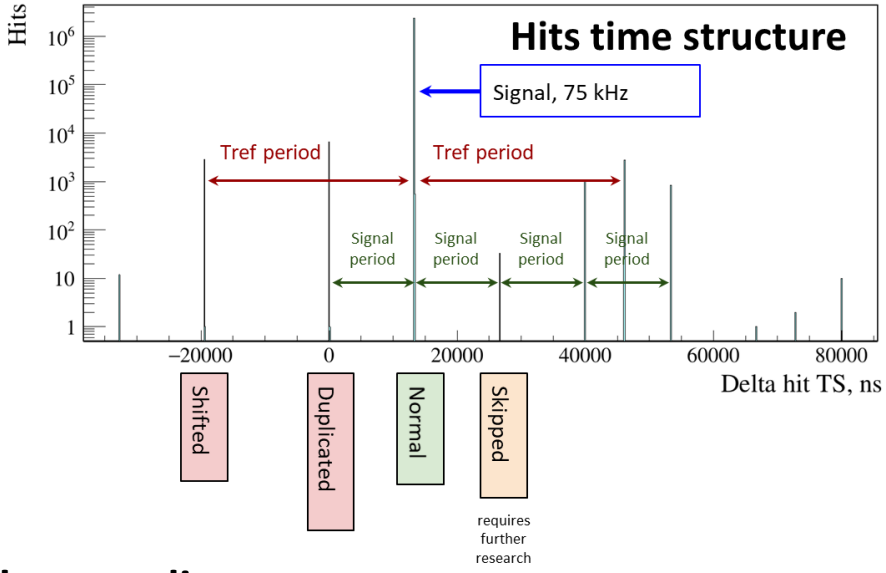
Tests with SiPM's array



Hits acquisition ranges

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





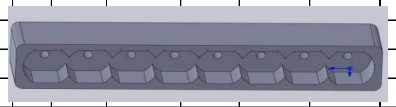
- **Continuous data reading** can be made only with **fine-tuning** of board parameters.

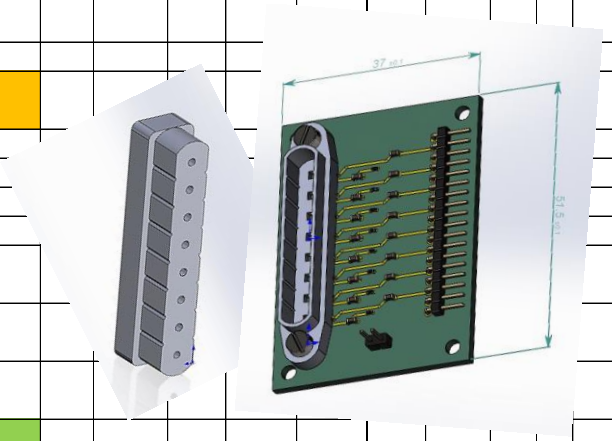
upgrade f/w and tests are recurred

Schedule of works

№	Наименование	2024 year											2025 year												2026 year					
		1-st quarter			2-nd quarter			3-rd quarter			4-th quarter			1-st quarter			2-nd quarter			3-rd quarter			4-th quarter			1-st quarter			2-nd quarter		
		March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June
1	Estimation of light loss on fiber bending																												
2	Manufacturing and testing of samples with various optical cement options																												
3	Selection of final assembly components																												
4	Production of a three-layer base for a prototype																												
5	Assessment of the strength of the base																												
6	**Development of 2 sector prototypes [2*7 tiles]**																												
6.1	Astimation tests																												
6.2	Calibration of the energy scale of DT5202																												
6.3	Determining the optimal thresholds for DT5202																												
6.4	Determination of temperature dependence and its consideration in tests																												
6.5	Prototype testing									1	2																		
6.6	Data processing and interpretation of results																												
7	Tests with Hamamatsu SiPM (1.3x1.3 mm^2)																												
8	Development of the inner part of the detector (the space between the tube and the proposed BBC concept)																												
9	Development of mapping_a for the BBC subsystem																												
10	**Development of 2 detector prototype wheels [2*(8*16) =256 tiles]**																												
10.1	Production of the prototype frame																												
10.2	Production of a five-layer base for a prototype																												
10.3	Implementation of composite sleeves for fixings, and milling																												
10.4	Installing the base into the frame																												
10.5	Development and manufacture of optical connector modules (WLS <-> transparent fiber)																												
10.6	Development and manufacture of connectors (transparent fiber <-> SiPM)																												
10.7	Development and manufacture of a printed circuit board (PCB) for SiPM																												
10.8	Checking the performance of connectors and PCB																												
10.9	Prototype testing (test beam)																												
10.10	Data processing and interpretation of results																												
11	Coordinating the output of detector cables to the BBC control room																												
12	**Assembly of 2 rings of a full-scale detector**																												
12.1	Manufacturing of the frame (2 parts)																												
12.2	Manufacturing of a five-layer base for the detector																												
12.3	Implementation of composite sleeves for fixings, and milling																												
12.4	Installing the base into the frame																												
12.5	Full camera testing																												
12.6	Data processing and interpretation of results																												
13	Dismounting of detectors																												
14	Transferring detectors to SPD																												
15	Installation of detectors																												
16	Cross check and tests																												

~ 5-7 months delay





★ Not JINR

Conclusions

I. The R&D phase for **optical and transmission connectors** is continue.

II. The manufacture of **reduced BBC wheels** (128 tiles each) for SPD Phase 0 is planned to the mid of 2025.

III. The development of full size **two BBC sectors** (26 tiles each) for SPD Phase 0 is planned to the end of 2025.

Thank you for the attention!

REFERENCES

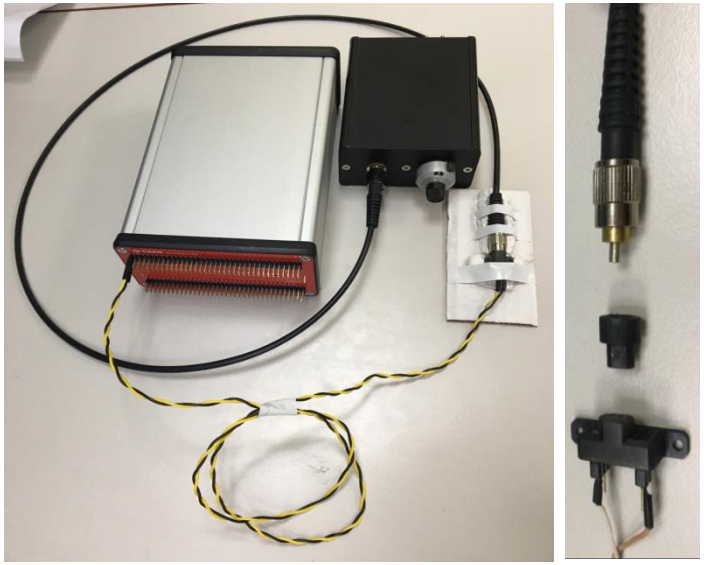
1. Physics of Atomic Nuclei, 2024, Vol. 87, No. 4, pp. 450–457
2. Phys.Part.Nucl. 55 (2024) 4, 1091-1098

Backup

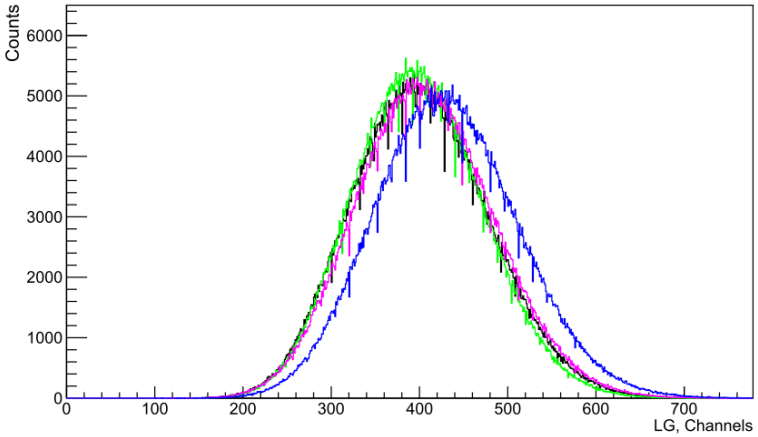
The hardware of BBC tests part

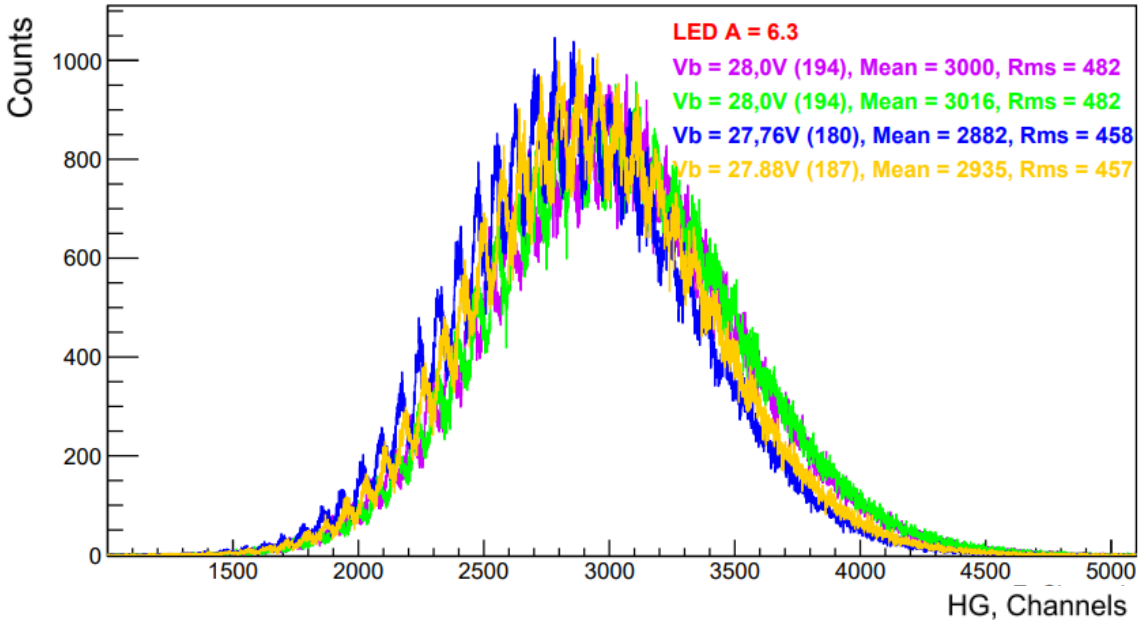
Calibration method (Led source)

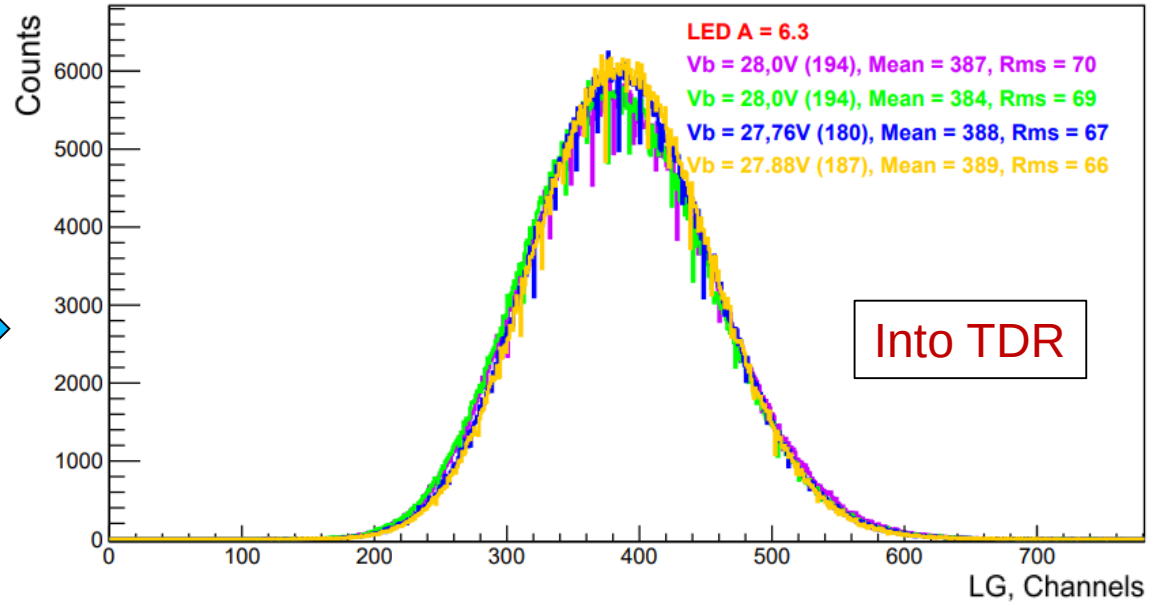
DT5202 with CAEN LED Driver (SP5601)



Not calibrated

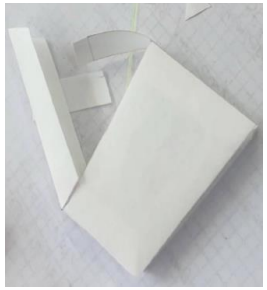






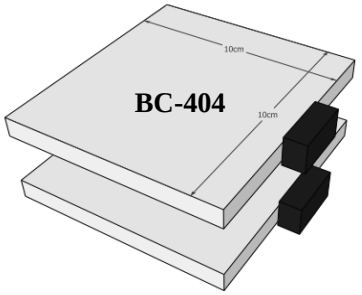
Materials selection test part

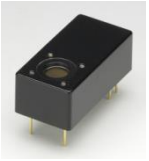
Scintillator cover



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

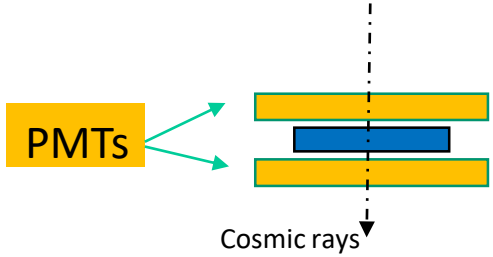
External trigger by coincidence of two scintillators with PMTs readout





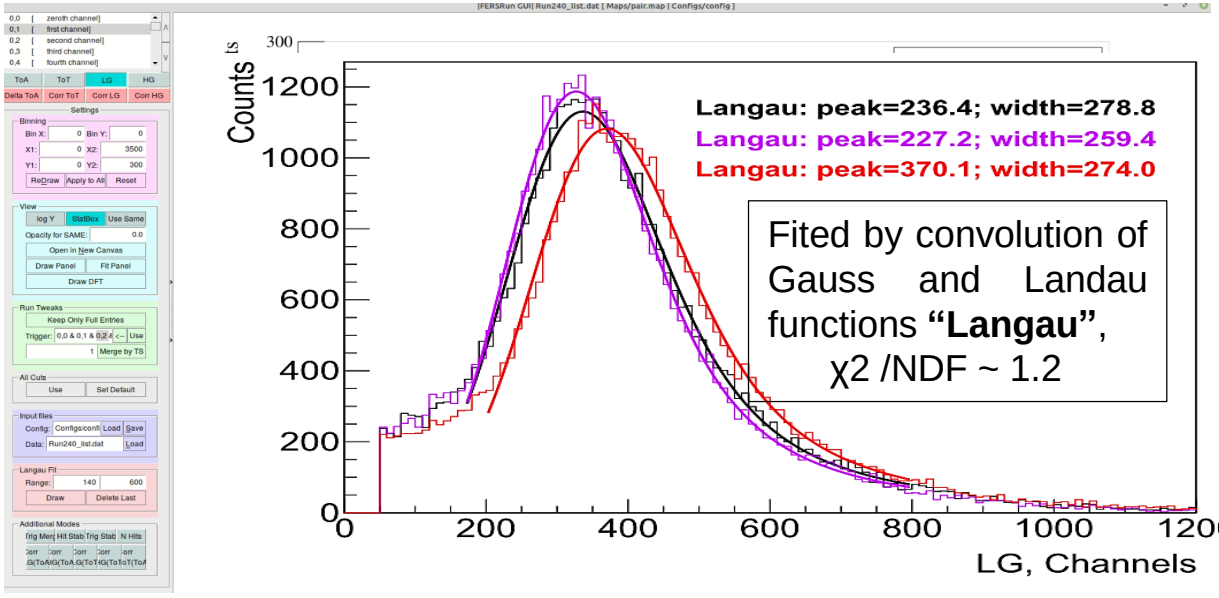
PMT Hamamatsu H10720-110

The "FersRun" framework has been designed.



Matted or Mylar or Tyvek

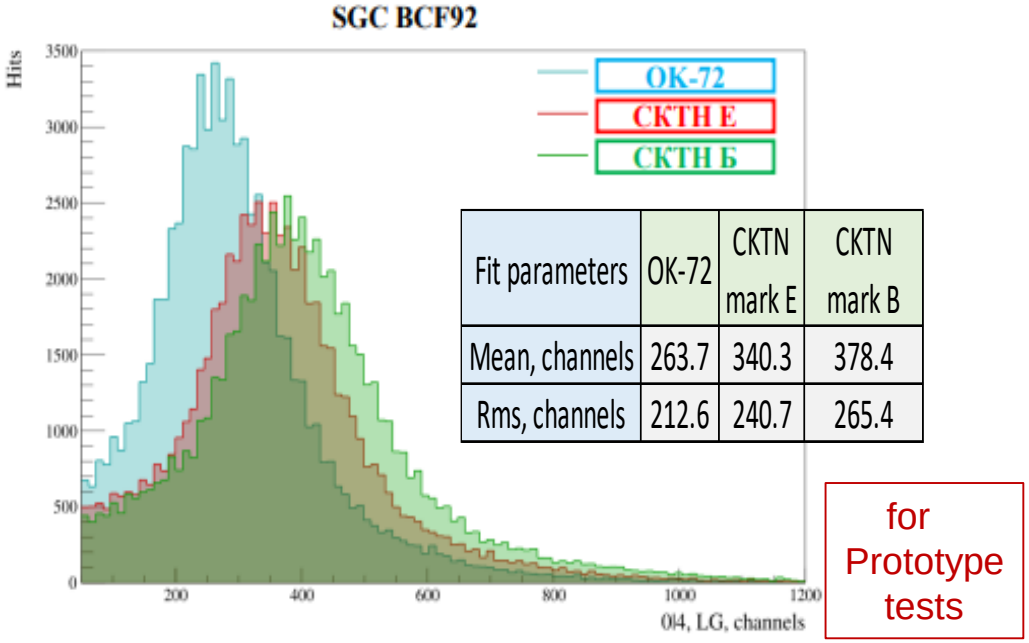
SensL SiPM (27.34 V.)
S.G. (WLS)
CKTN (opt. cement)



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

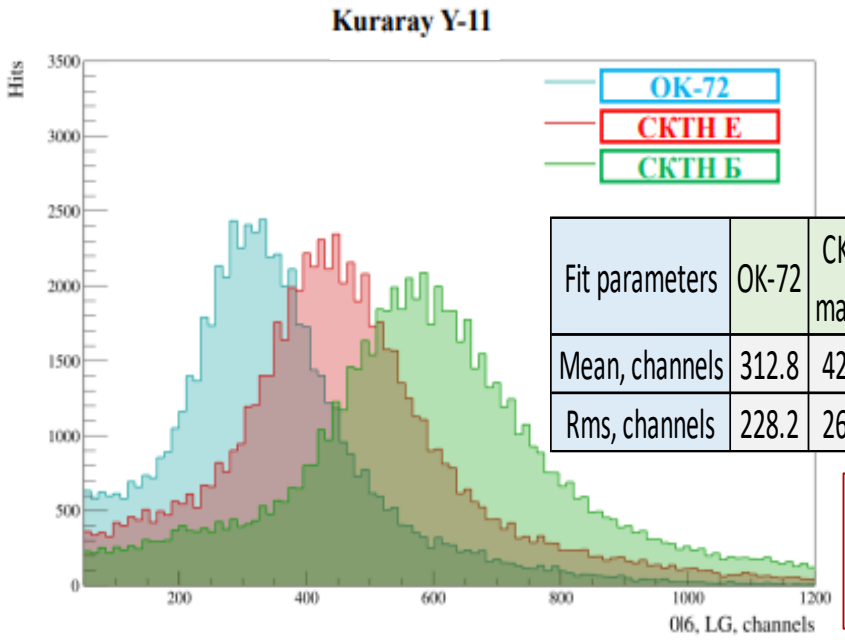
Materials selection test part

Optical cement and WLS



Fit parameters	OK-72	CKTN mark E	CKTN mark B
Mean, channels	263.7	340.3	378.4
Rms, channels	212.6	240.7	265.4

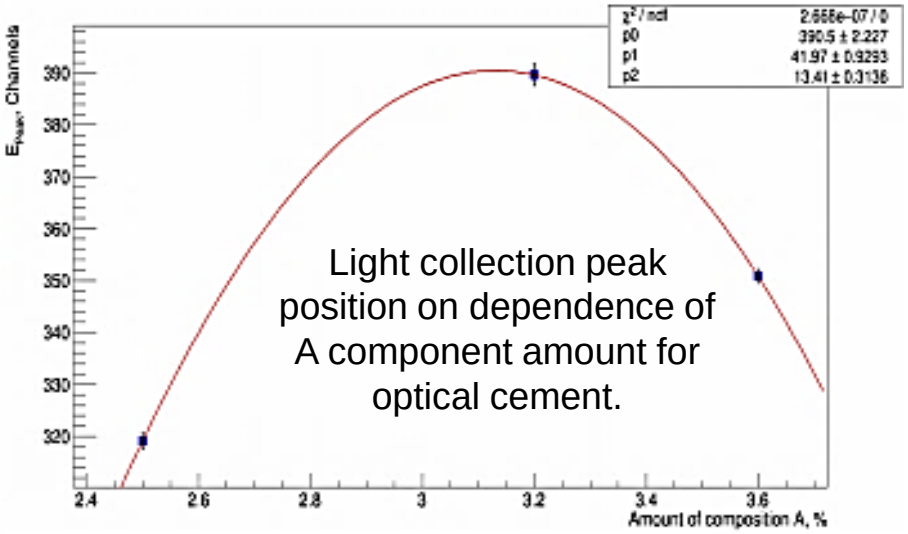
for Prototype tests



Fit parameters	OK-72	CKTN mark E	CKTN mark B
Mean, channels	312.8	429.7	569.1
Rms, channels	228.2	268.7	324.9

for Phase 1 tests

CKTN



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

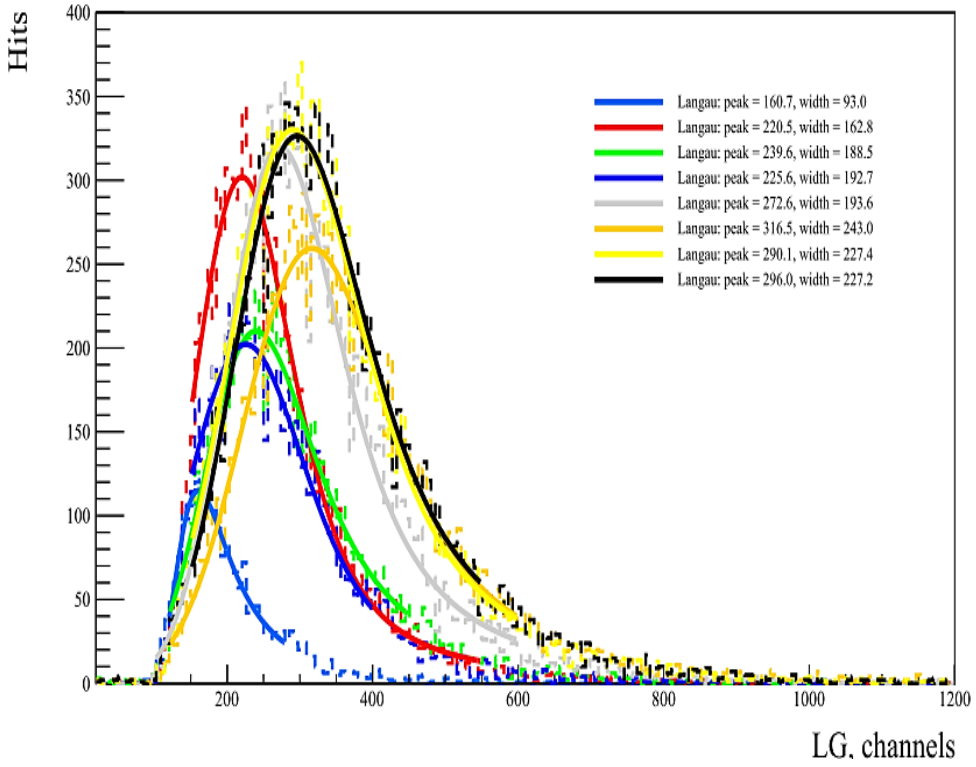
The results of tests of Kuraray WLS fiber and Saint-Gobain Crystals (SGC) WLS fiber with different types of cement are presented.

- **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**.

Prototype assembling test

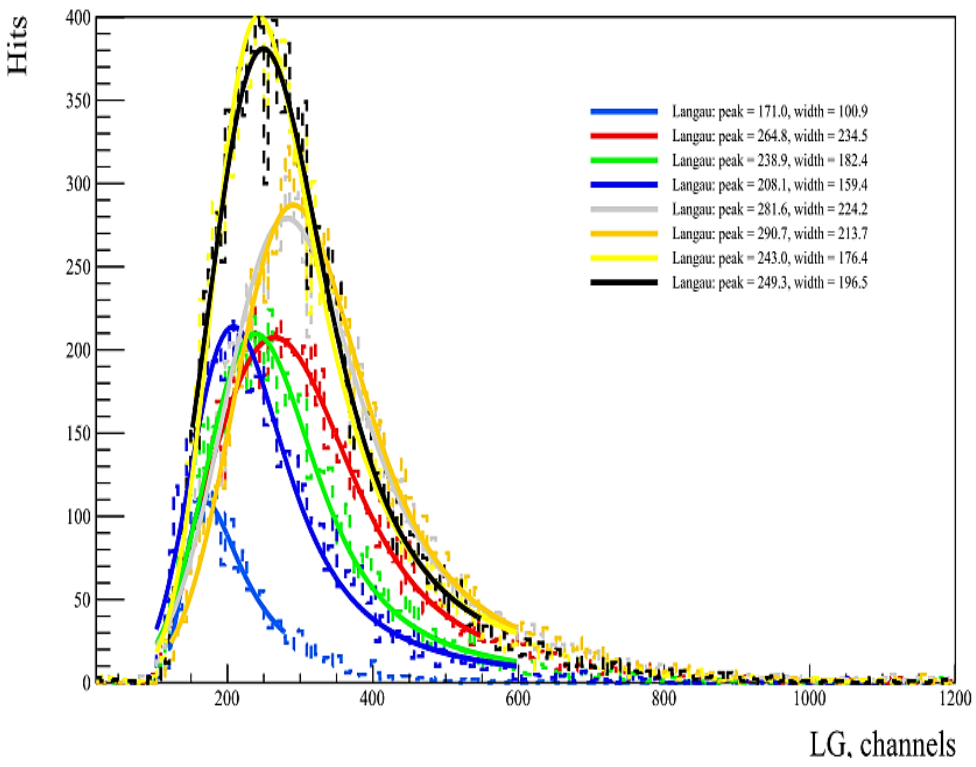
Amplitude spectra of two sectors

1-st sector prototype



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

2-nd sector prototype

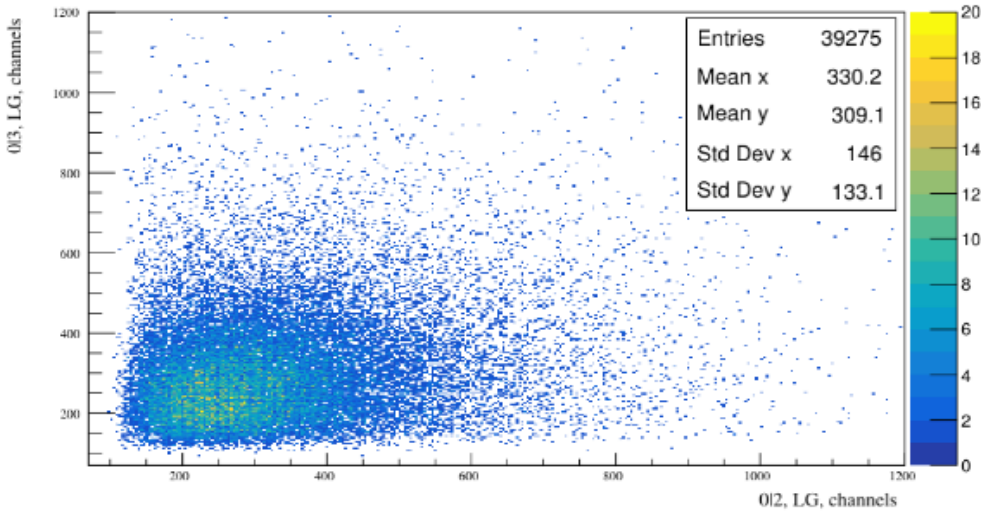


The stable tiles were taken for following tests

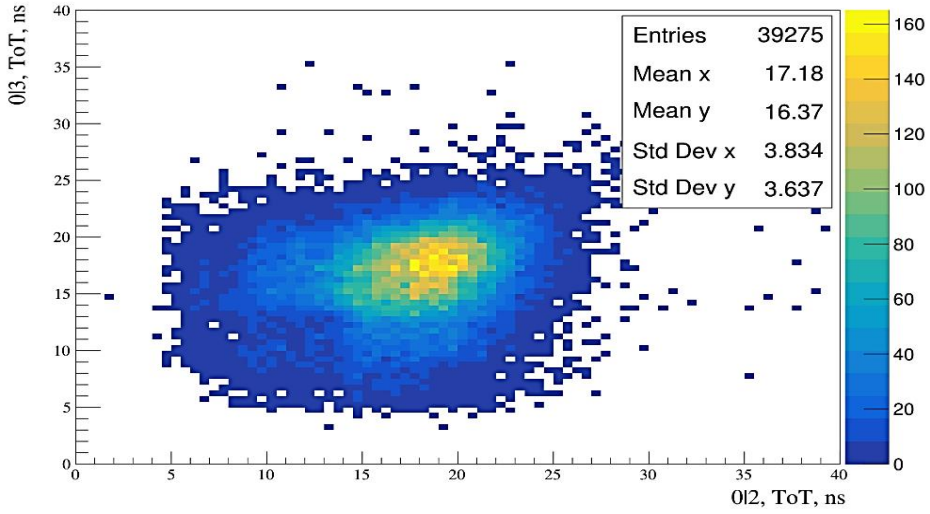
Prototype assembling test

The 1-st step for working with the timing mode

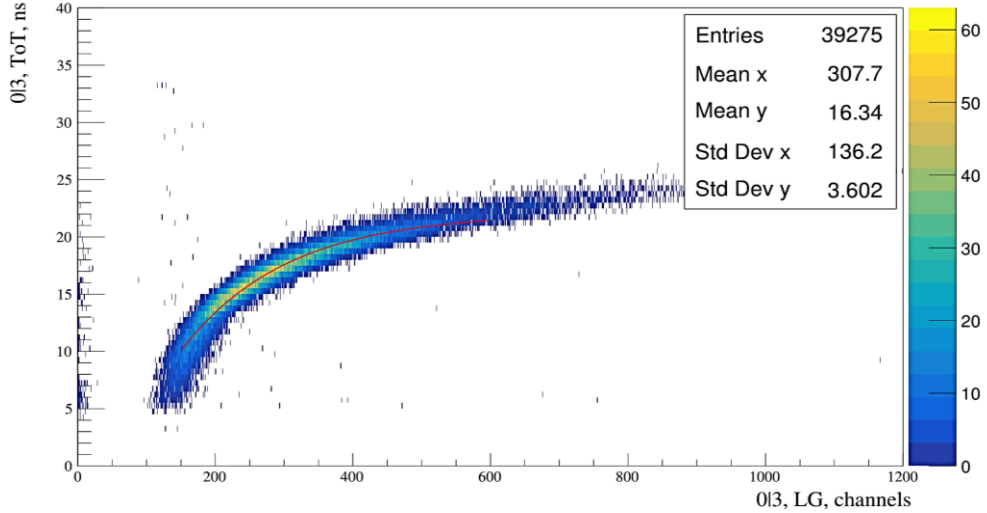
LG correlations

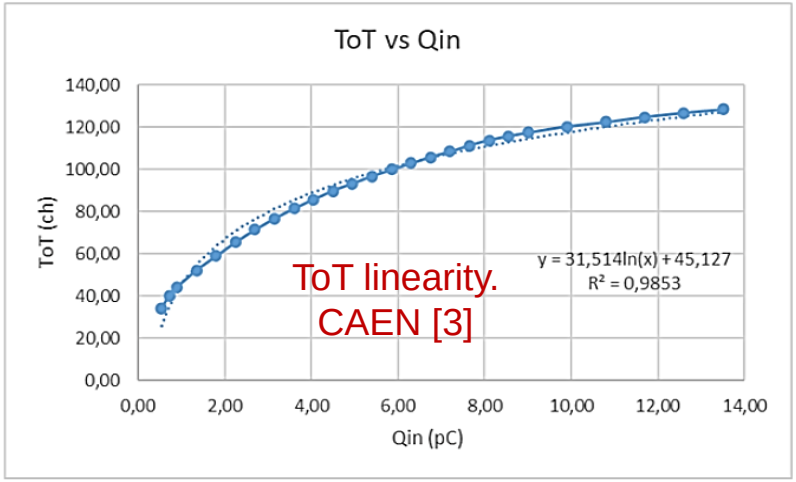


ToT correlations



LG vs ToT (channel №3)





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

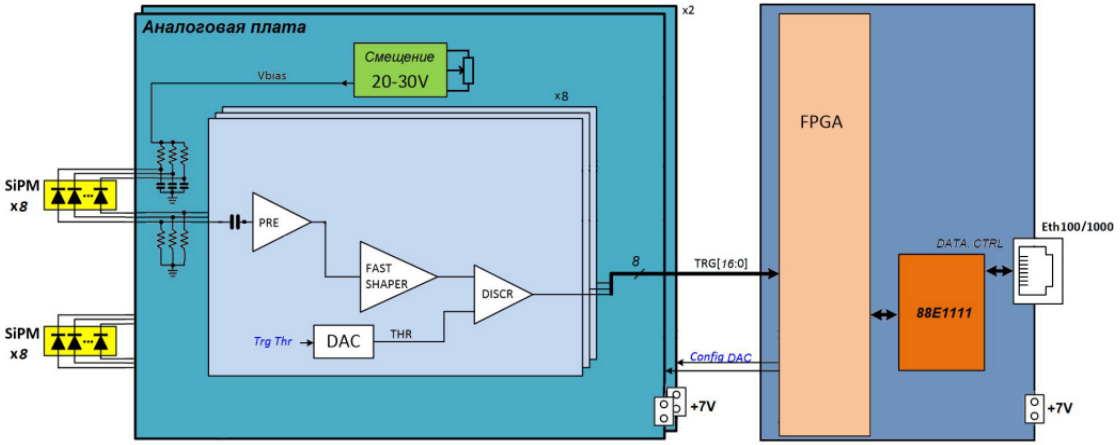
- The calibration of the charge scale is required

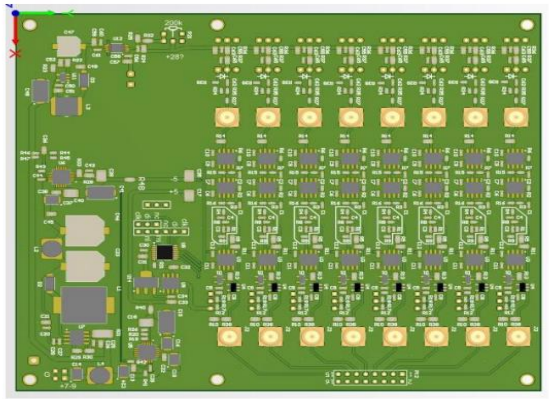
The hardware for BBC

New FEE & Readout electronic

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 каналов
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

Simplified block diagram



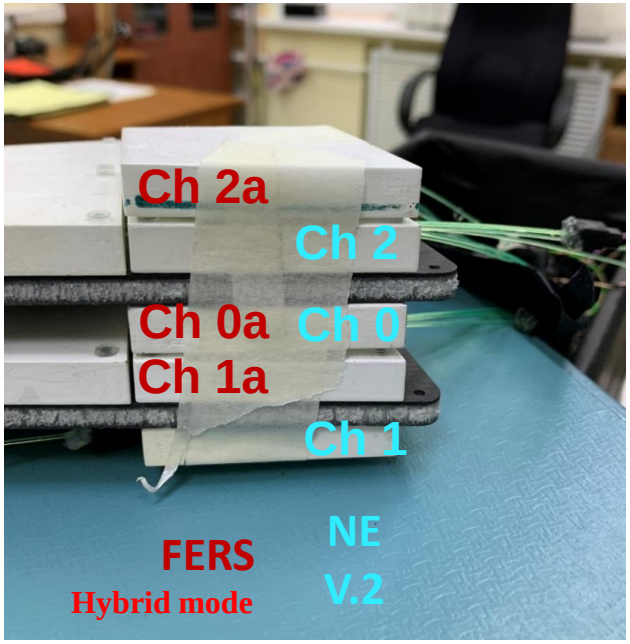


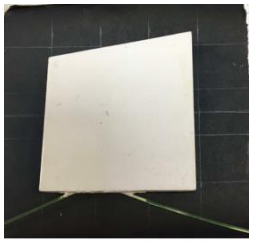
Front-end units
(SiPM supply, signal reading)

TDC based on FPGA
(XILINX VIRTEX-5)

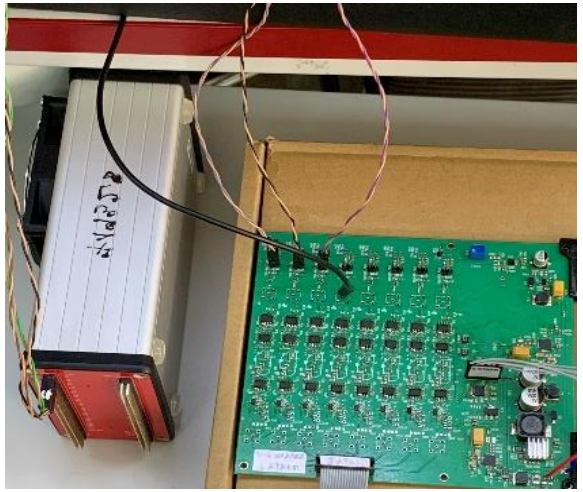
The hardware tests

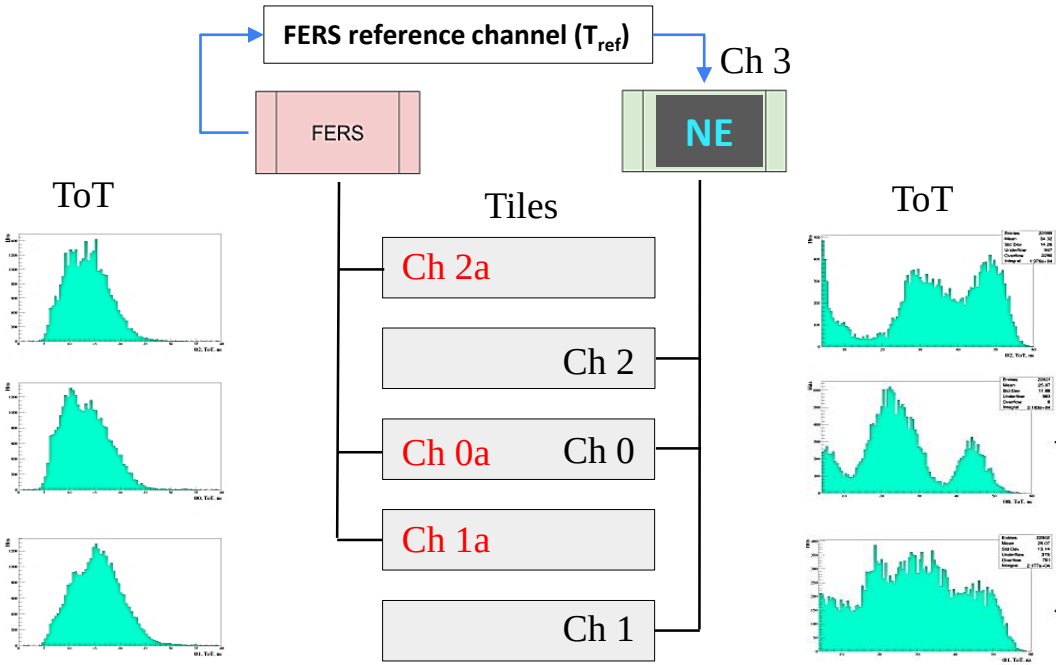
The electronics test

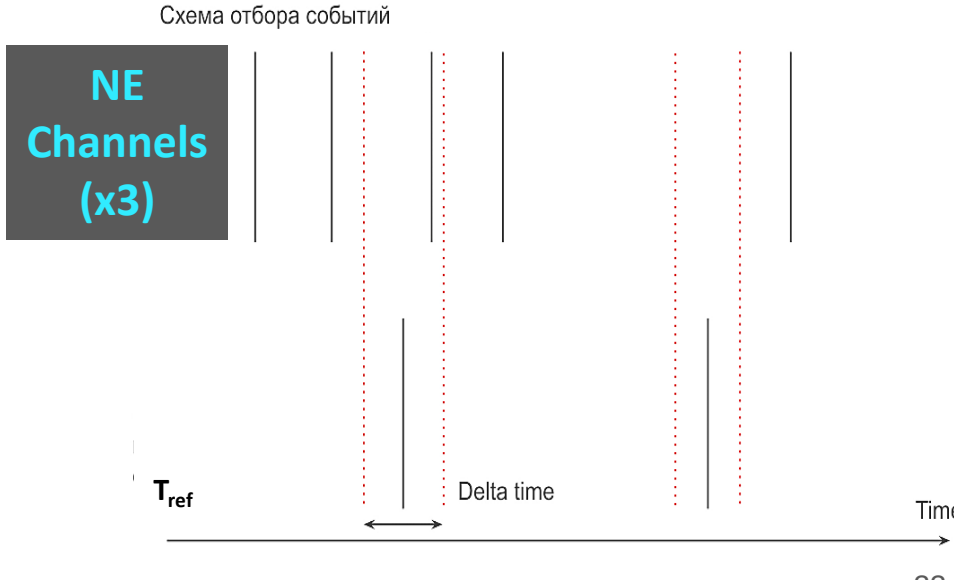




“Majority (3ch) ”
Trigger logic



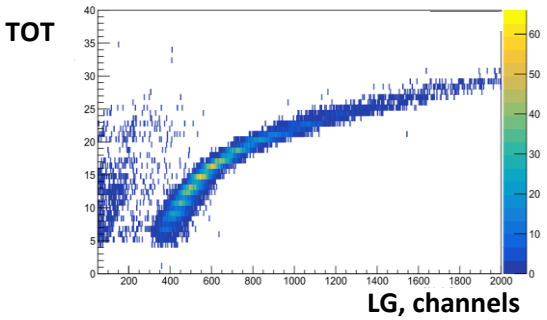


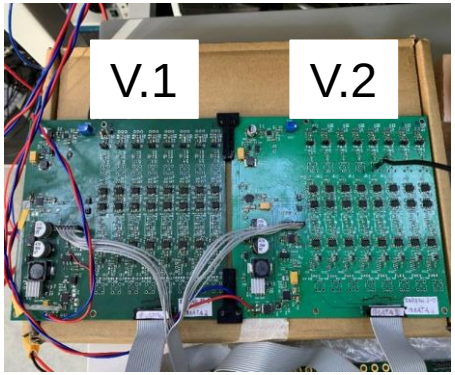


The hardware tests

Results

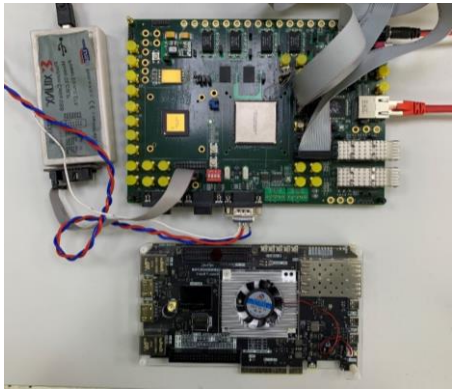
LG vs ToT (channel 1)



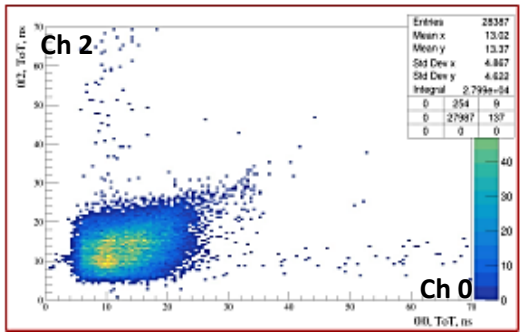


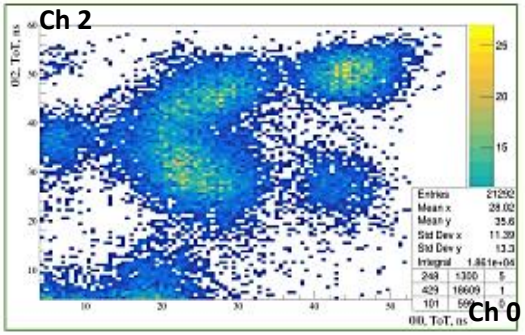
Analog part versions (next V.3)

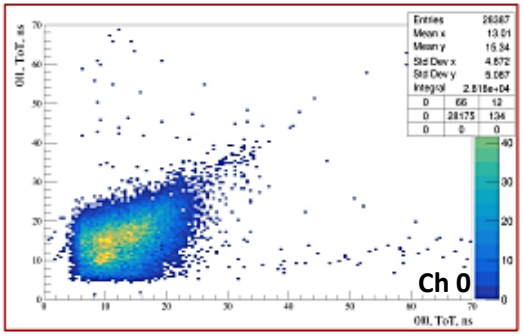
FPGA XILINX VIRTEX-5

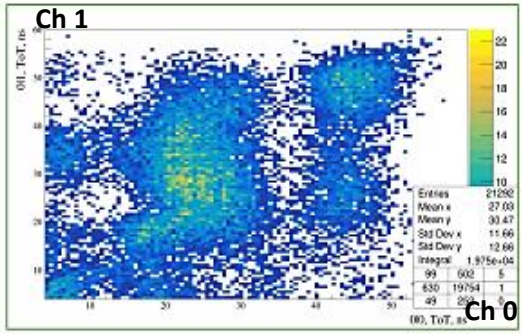


FPGA KINTEX-7





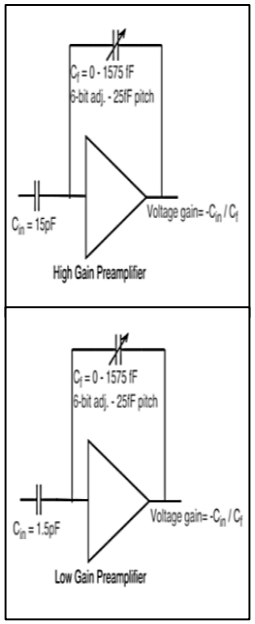


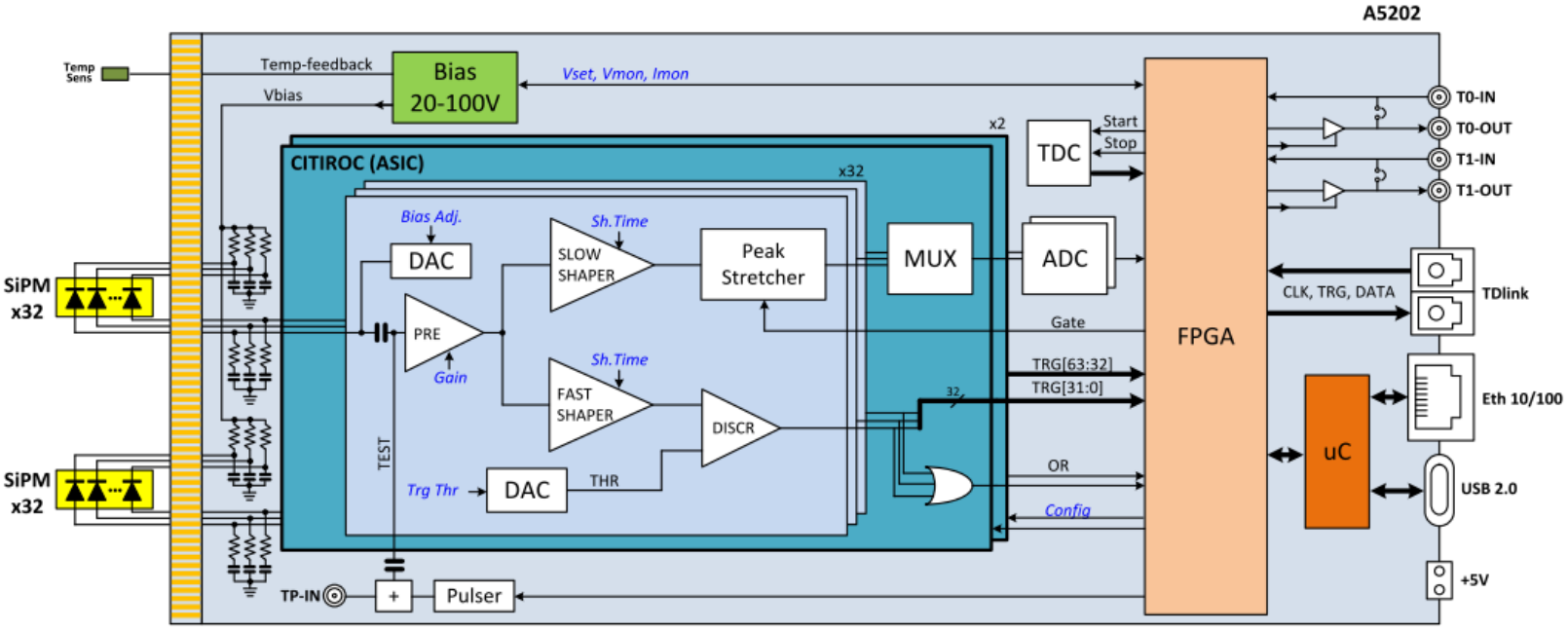


- Improvement the "FersRun" framework for the correlations between different electronic channels
- Further research
- NE improvements

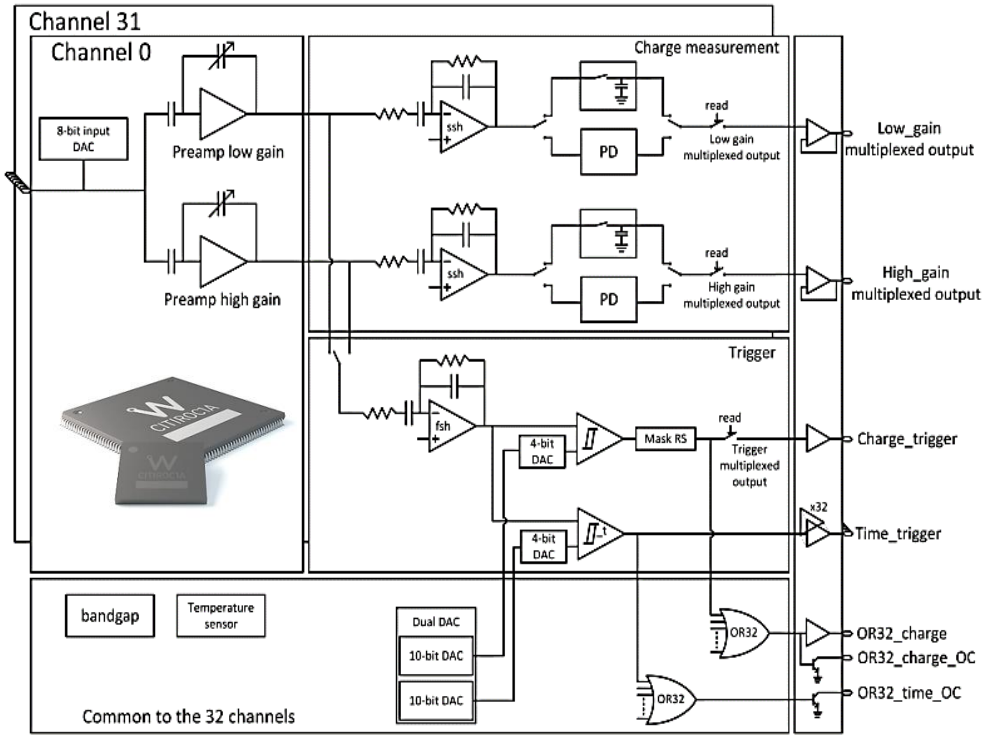
are required

Simplified block diagram of the DT5202 FERS-5200 unit





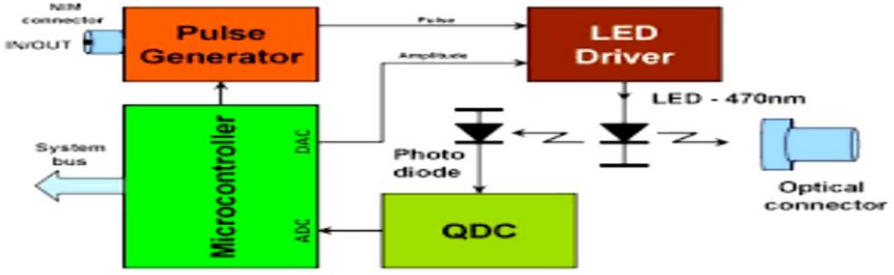
Citiroc-1A block scheme



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.

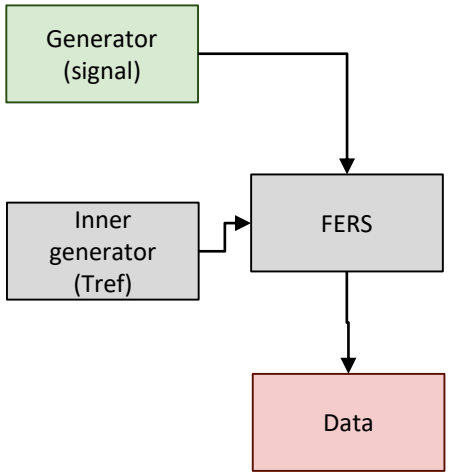
Schematic view of the LED

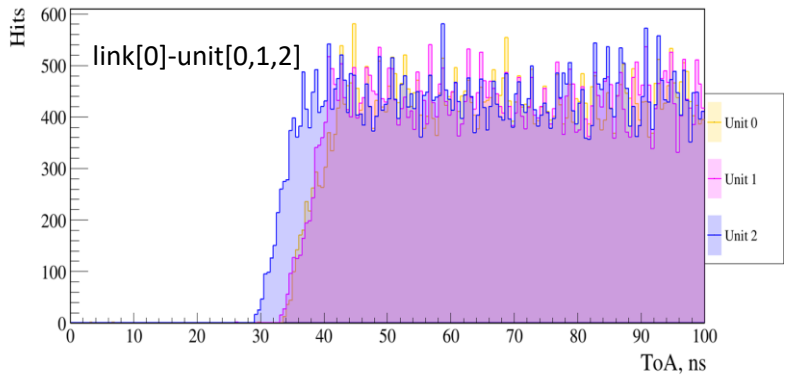


Application of DT5215 concentrator

Tests with different unit-concentrator links configurations

DT5215 (FW v. 6.0)





LINKS (1 & 0)

Concentrator to boards opto-fiber connection