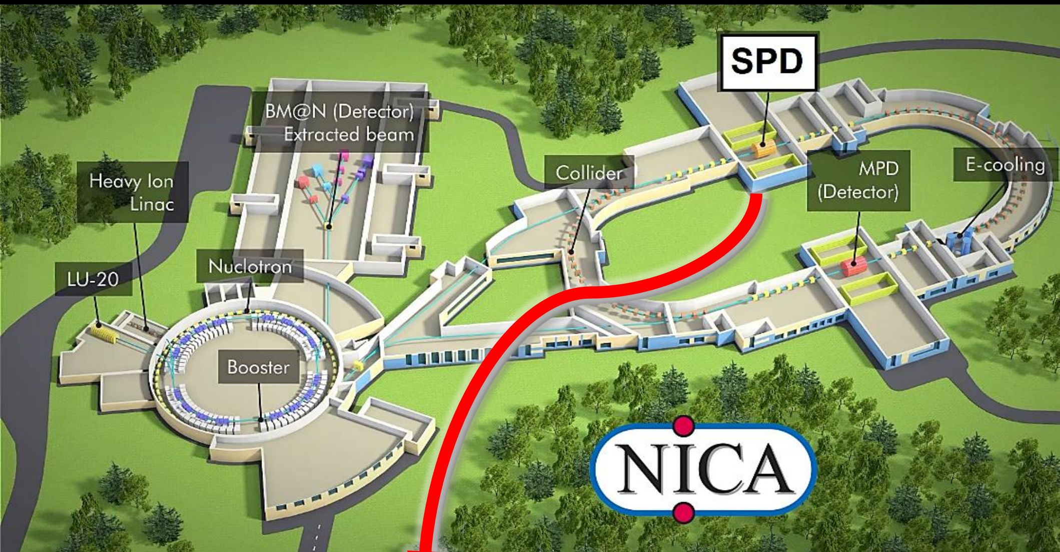
# Статус работ по BBC

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

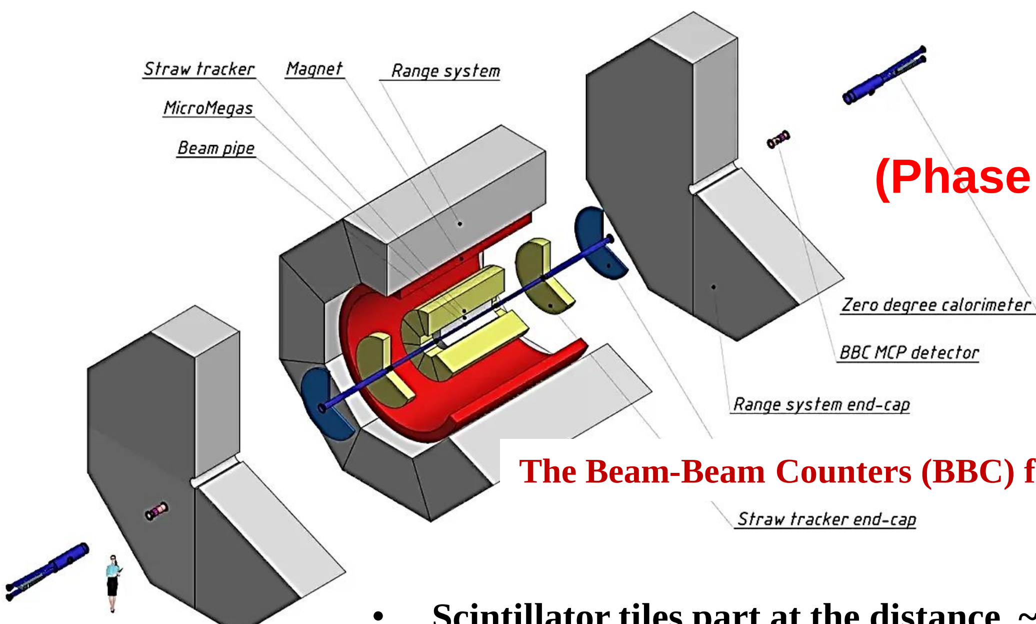
*Meeting WG Hardware SPD*

*March 2025*

## Introduction




The Spin Physics Detector (SPD)




**(Phase 1)**

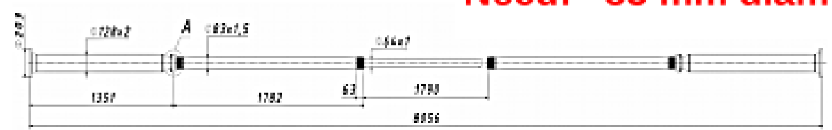
**The Beam-Beam Counters (BBC) for SPD**

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

## General

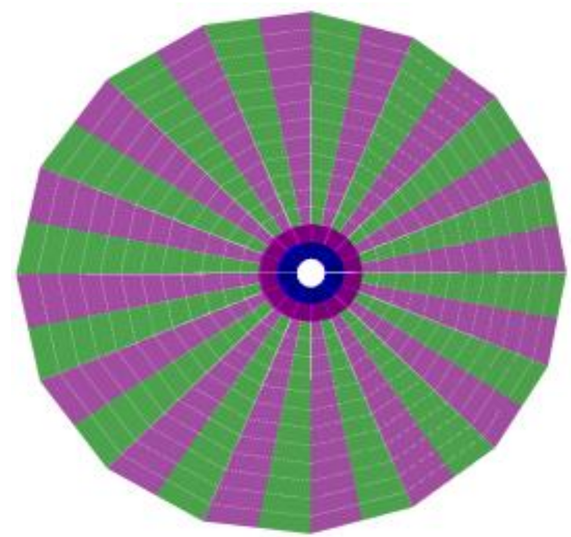
We have the opportunity to use an additional tile due to the decreased diameter of the beam pipe.

**Now : 124 mm diameter**
**Need: 83 mm diameter**



**TDR 2023**

**2 wheels** with
400 tiles each (416)

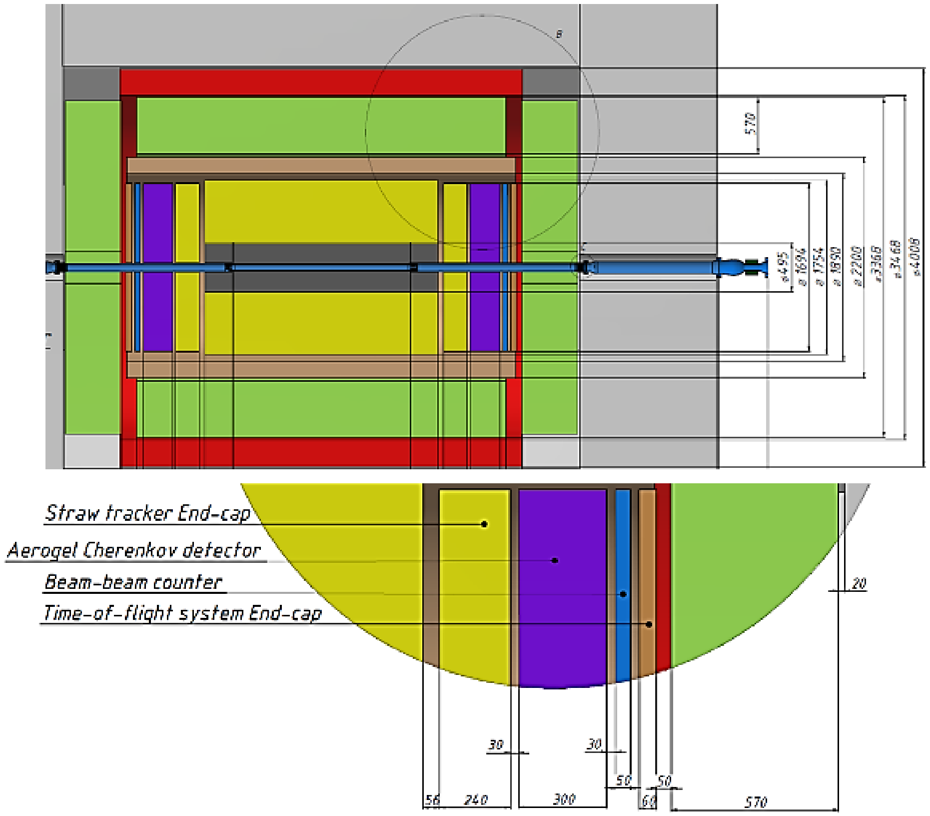


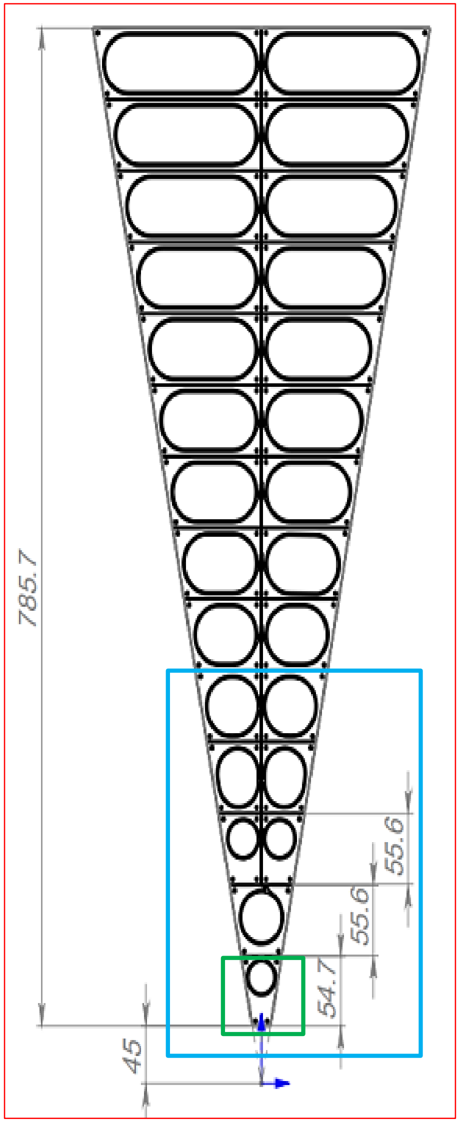
+ **local polarimetry**
+ event plane detector for HI physics

# Sandwich bases for BBC

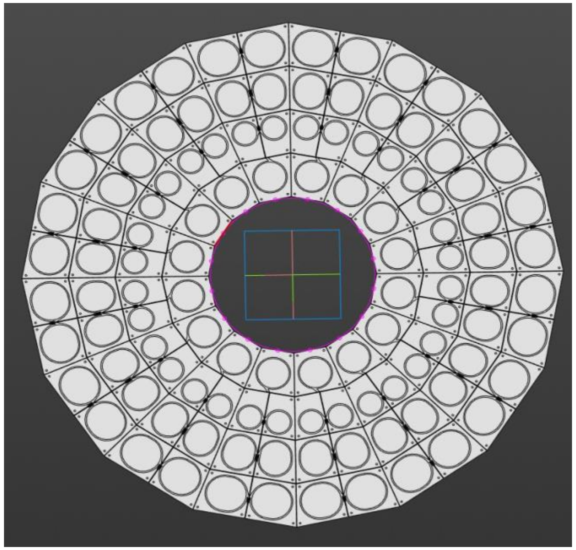
## BBC Sector (1/16 of wheel) design

**26 tiles**




**reduced prototype wheel (x2)**
**<u>(at the 1-st stage)</u>**



**due to the ambiguity of the cable output, the <u>final design is discussed</u>**

**Two full-scale sectors by the end of the year**
**<u>(at the 2-nd stage)</u>**

# Prototype assembling part

# Sandwich bases for BBC

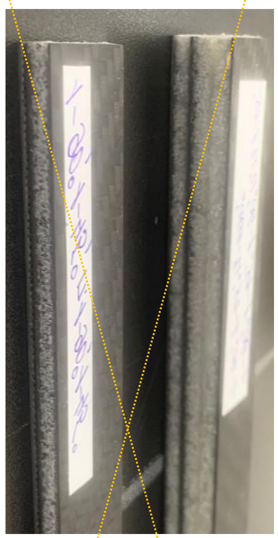
**Plastic foam sandwich base (comparable quantity of matter )**

**Honeycomb sandwich base (main option)**

**Parts:**

I. Infrastructure (grooved)
II. Main support

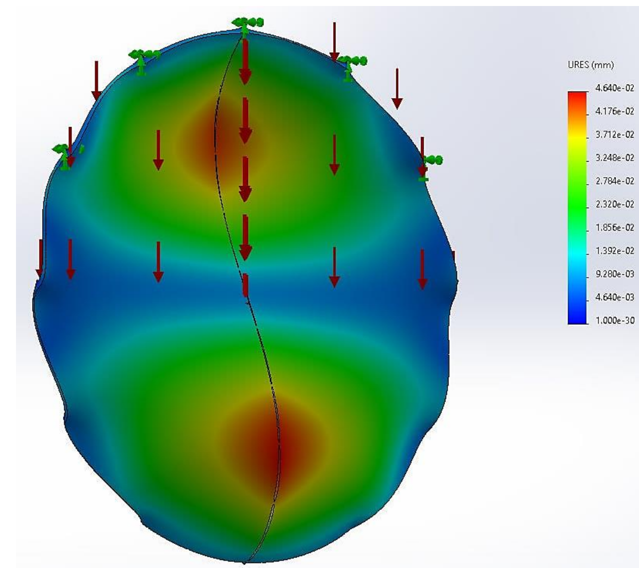
I. II.



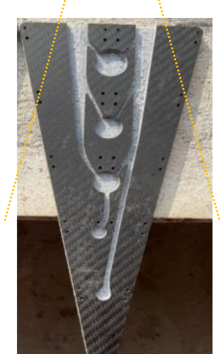
I. II.

total thickness ~ 30 mm

**Hardness modeling**



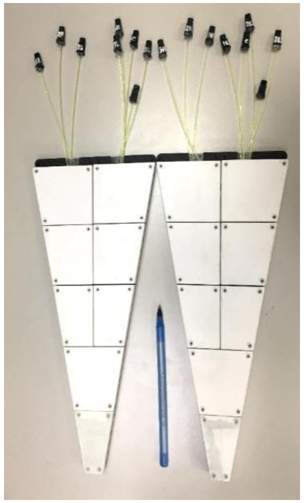

deformation = 0,046mm



**Grooved carbon backplate V1**

**3-options sandwich base with different number of carbon layers (at the middle of March)**

# Proposal for reduced wheel prototype



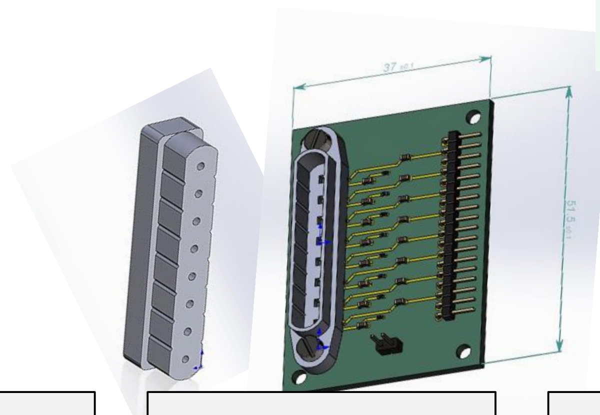
reduced sector prototype x2

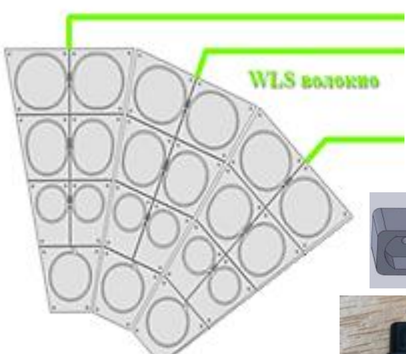
**Selected options (references [1-2]) :**

| | |
|---|---|
| **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) |

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

Hamamatsu (S14160-1315PS)

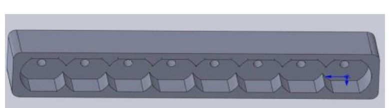




**Connector** of WLS-to-clear fibers
**in process**

**Transmission box** for clear fibers to SiPMs
**in process**

**Front-end & Readout**

## Readout system:

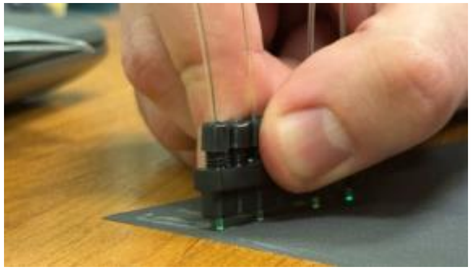
**CAEN FERS-5200** for Phase 0

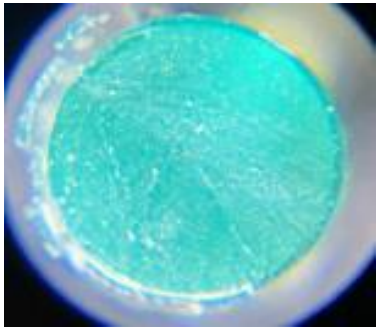
**NEW ELECTRONICS (?)** for Phase ≥1

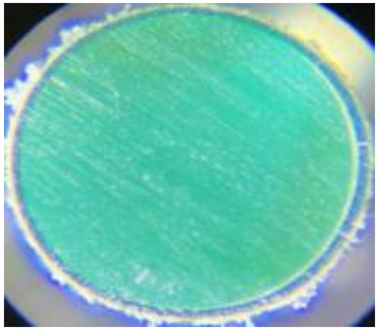
## Prototype assembling part


WLS-SiPM test connector couple

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





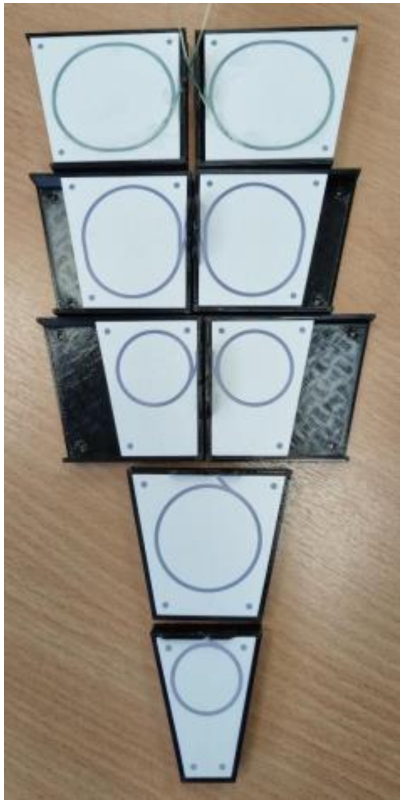


**Estimation of light loss for clear fibers**

## Mass production issues

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

Tiles and sectors: gluing frames



## 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)

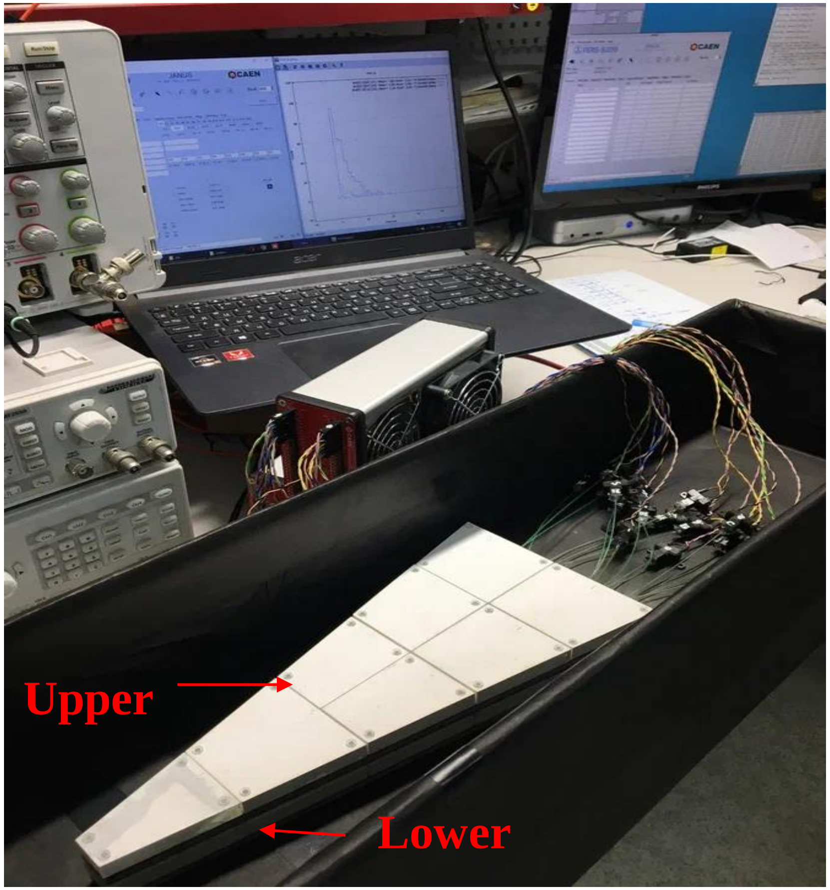
**Hybrid mode (LG+ToT+ToA)**

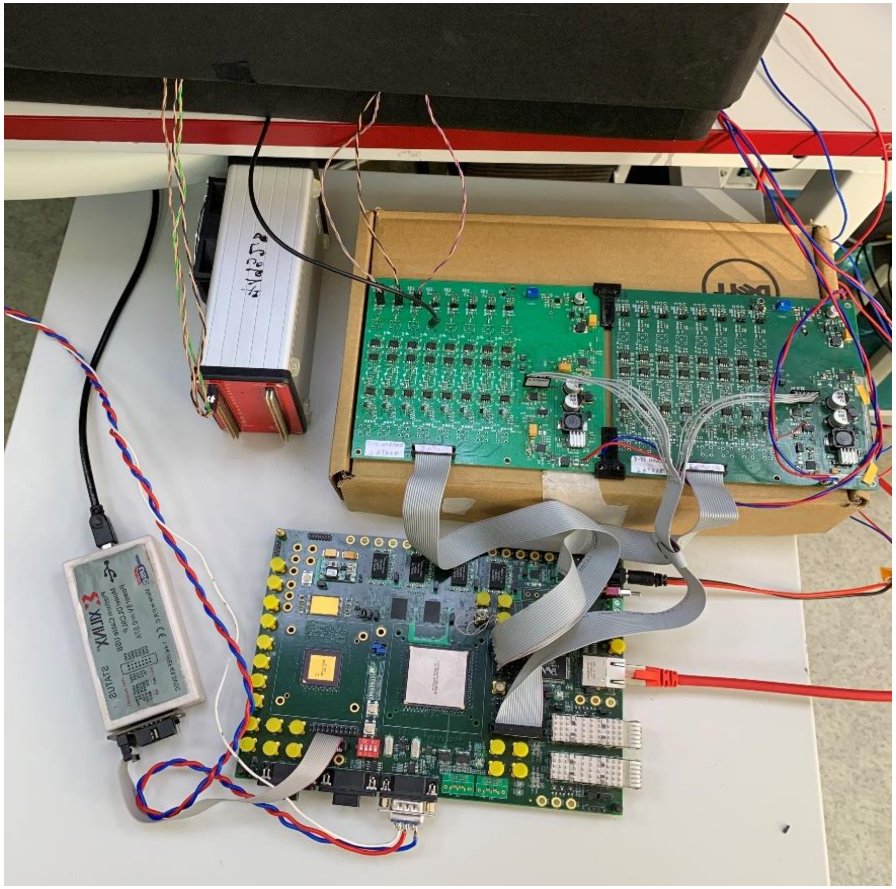
**The front-end readout system based on FPGA XILINX VIRTEX-5 <u>(new electronics; NE)</u>**

**The leader is P. V. Nekrasov (MEPhI)**

**ToT+ToA**

**free-streaming mode is possible**



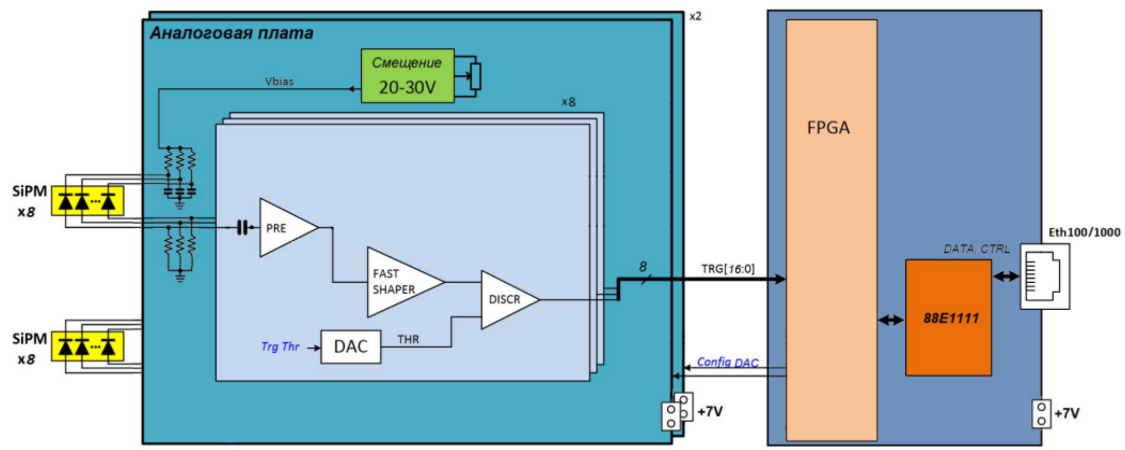



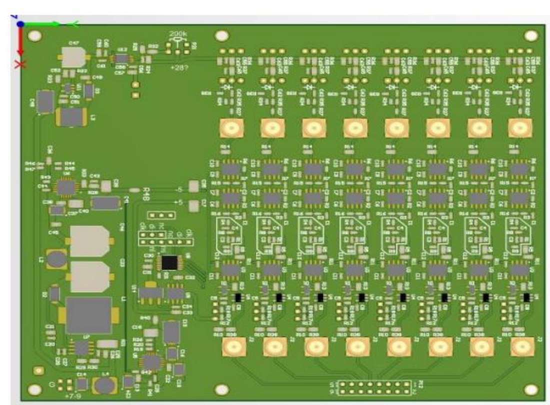
# The hardware for BBC

# New FEE & Readout electronic

## 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 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 |



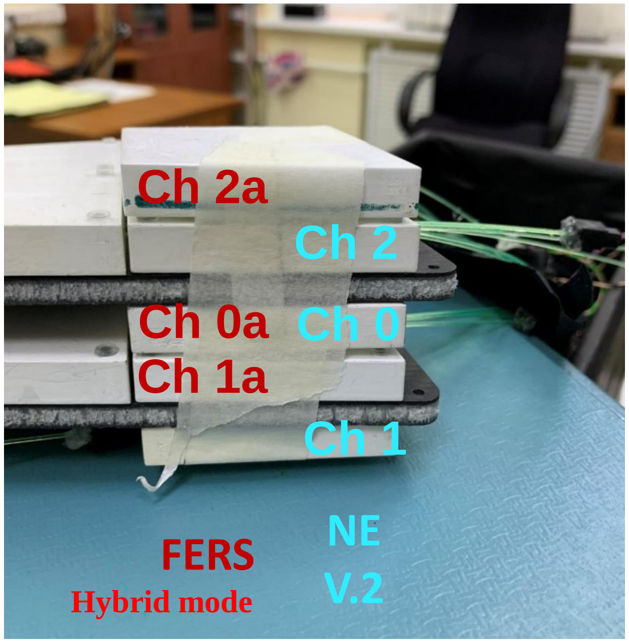



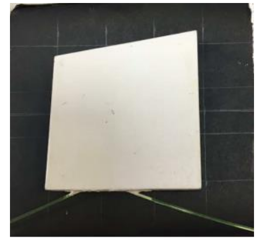
**Front-end units (SiPM supply, signal reading)**

**TDC based on FPGA (XILINX VIRTEX-5)**

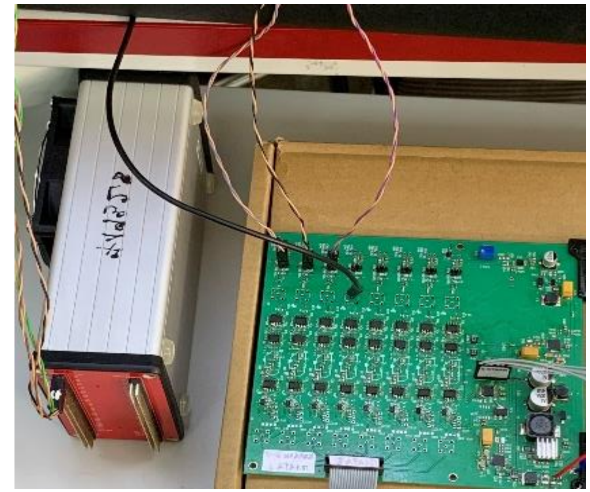
# The hardware tests

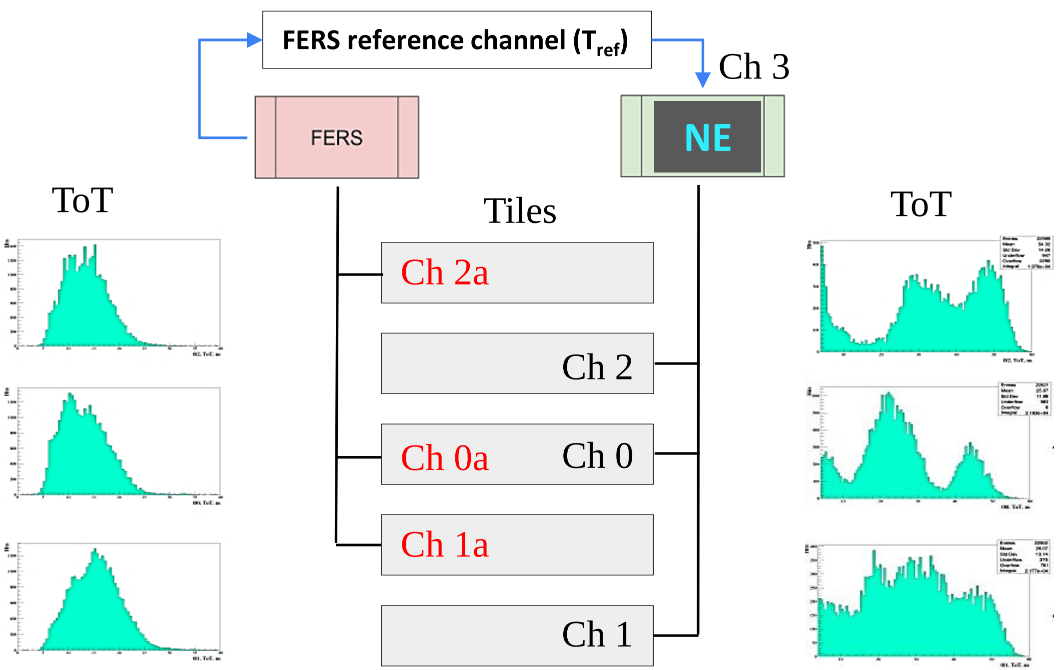
# The electronics test

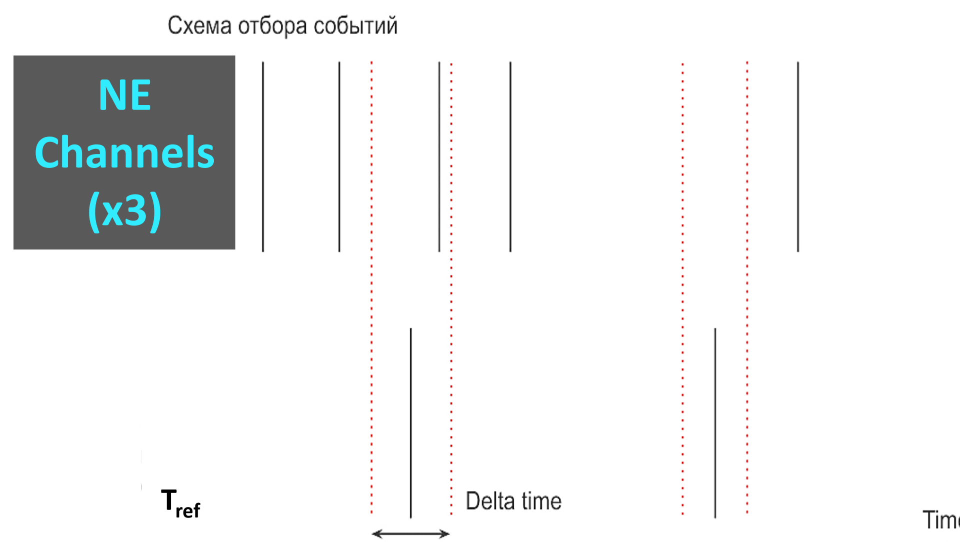


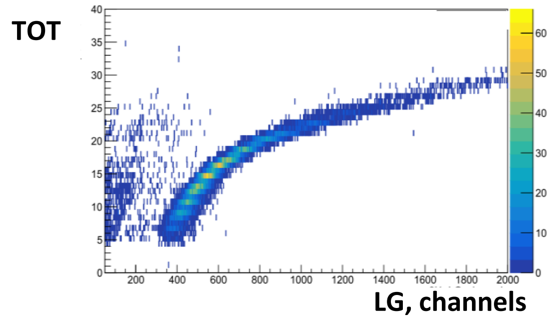
**"Majority (3ch) "**
Trigger logic



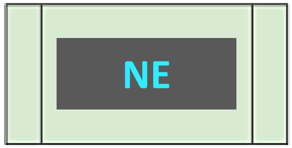


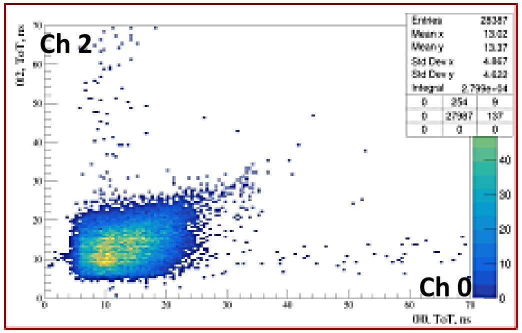



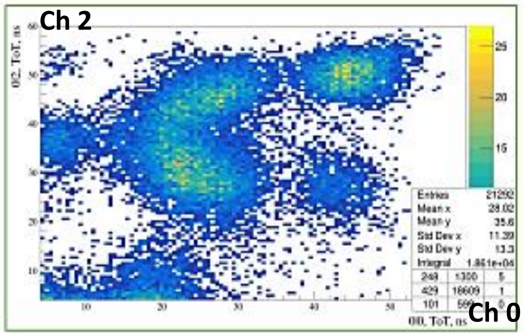
LG vs ToT (channel 1)

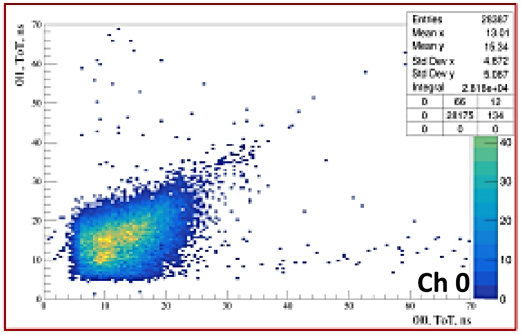


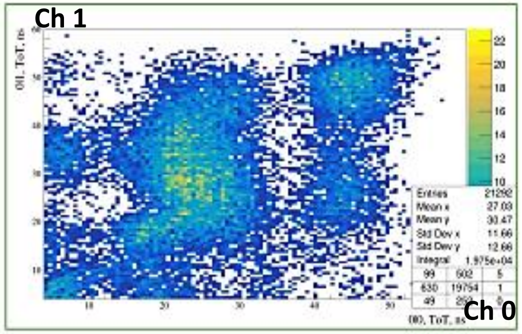





- **Improvement the "FersRun" framework for the correlations between different electronic channels**
- **Further research**
- **NE improvements**

**are required**

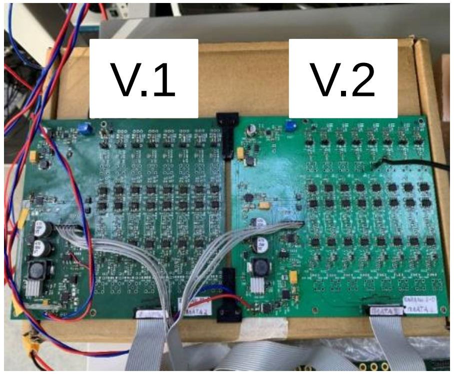
I. Preparation of infrastructure and development of methods of mass production are started.

II. FEE and digitizer option localized in RF has been developed.

III. The comparison of new electronics with CAEN FERS-5202 is started. The future upgrades are required.

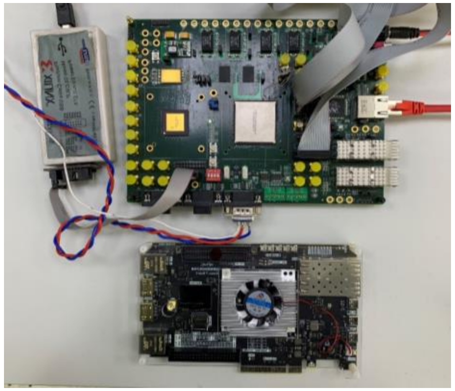
**To do list (for Yerevan meeting)**

- ❑ Test of clear fiber (Saint-Gobain Crystals and Kuraray manufacturers) attenuation
- ❑ Test with new optical connector and transmission box
- ❑ Development of quality control of connectors




**Analog part versions (next V.3)**

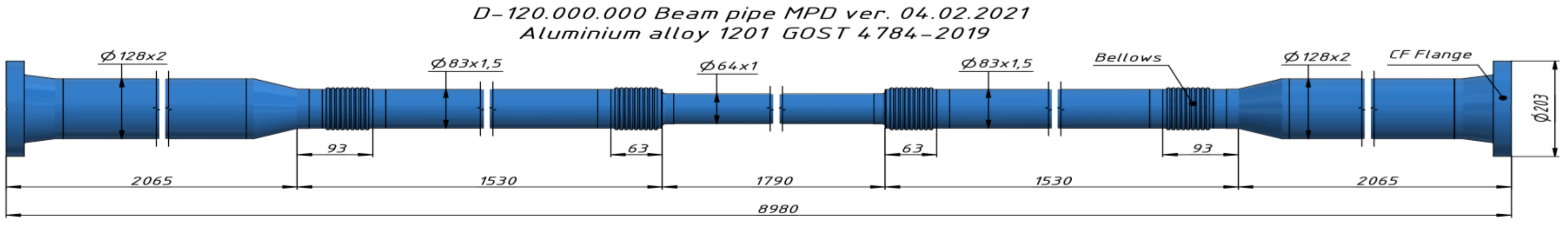
**FPGA XILINX VIRTEX-5**



**FPGA KINTEX-7**

# SPD Phase0

# BBC priority to 2025:




**1. Xe124+ W collisions (FT mode)**

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


**DT5202 -yes**
**DT5215 -yes**

## Needs:

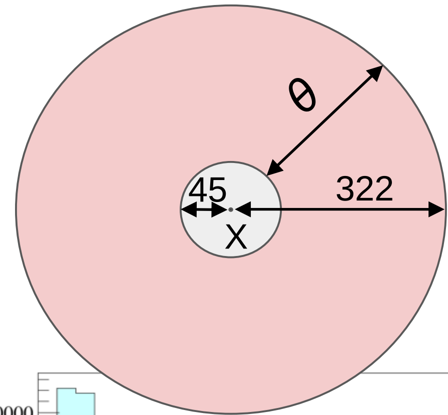
**2 Wheels 128 scintillator tiles each**
- **-scintillator -yes**
- **-WLS – yes**
- **- SiPM – yes**
- **- mechanic support -no**
- **- optical connectors – no**
- **- optical cables -no**
- **- transmission boxes -no**

# $^{124}$Xe+W **interactions for the SPD BBC detector prototype**

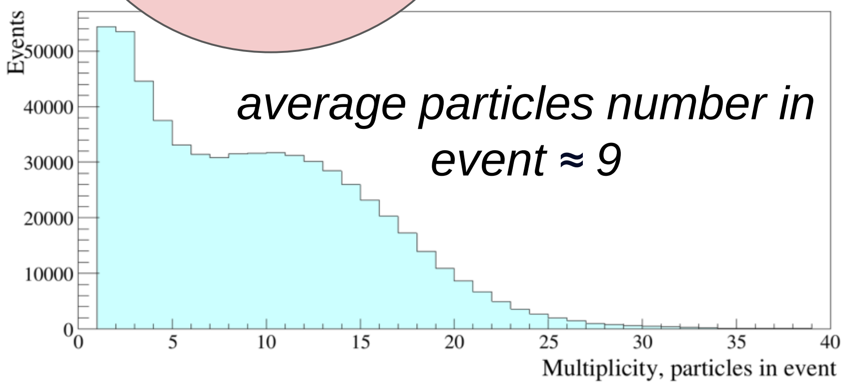
Beam $^{124}$**Xe** with energy **3 GeV/n** collides with the **W** target.

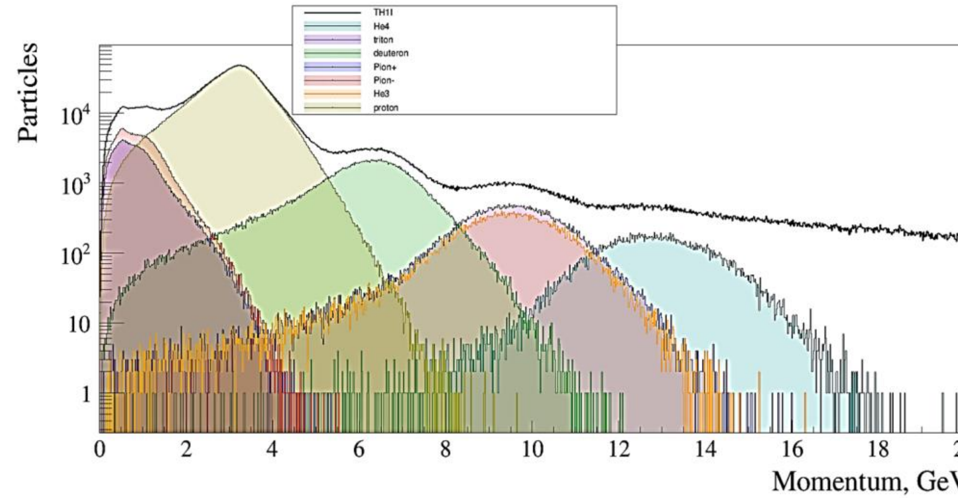
The detector has the shape of a solid **disk** with an inner radius of **45 mm** and an outer radius of **322 mm**. Distance from target to detector ~ **3m**.

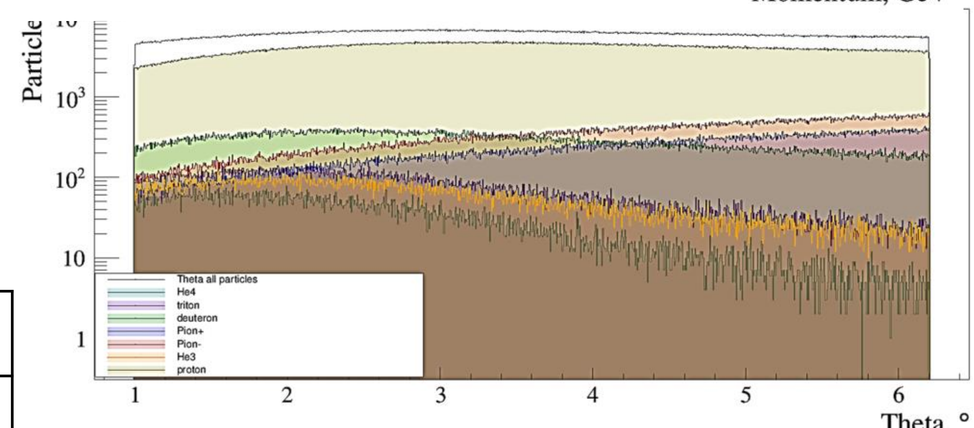
## Condition of the simulation




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



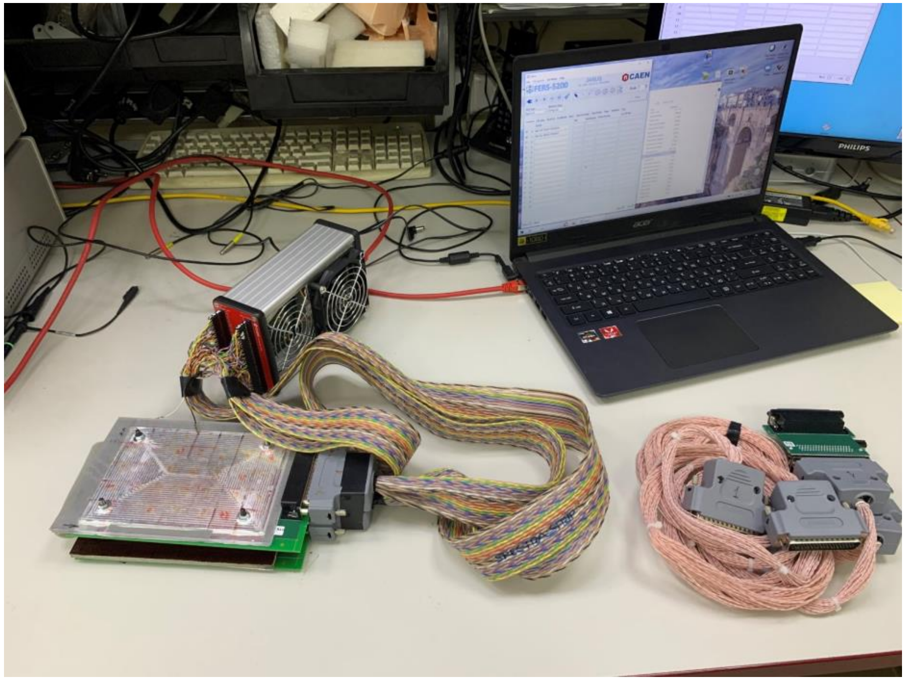

| particles | p | π+ | π− | $^2$H | $^3$H | $^3$He | $^4$He |
|---|---|---|---|---|---|---|---|
| % | 74.26 | 4.03 | 6.18 | 5.16 | 1.26 | 0.98 | 0.52 |
| average momentum GeV/n | 3.02 | 0.90 | 0.93 | 2.96 | 3.12 | 3.10 | 3.19 |

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.

**Volkova K. & Volkov I.**

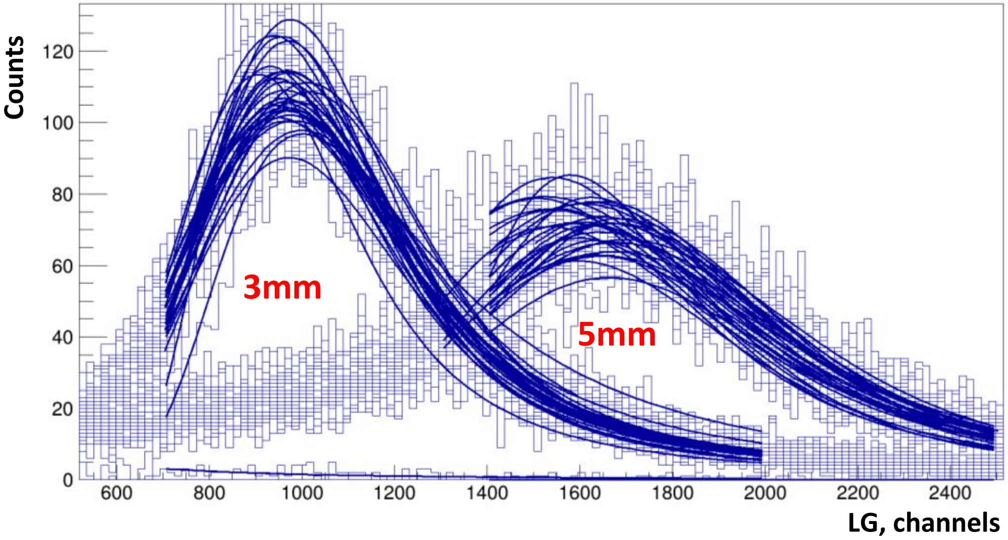
The first stage of ZDC was – 6 planes with trapezoid geometry and 320 mm thick copper radiator.

**2 test SiPM boards with 31 SiPM each**



20x20 mm^2 scintillator tiles with 3 and 5 mm thicknesses produced and connected to boards.
The tiles are wrapped in high reflecting film and have polished pit in the place where SiPM is attached. Sensitive area 140x100 mm^2 correspond to some middle part of ZDC.

**Long cable testing**




**Working on the beam BBC & ZDC (?)**

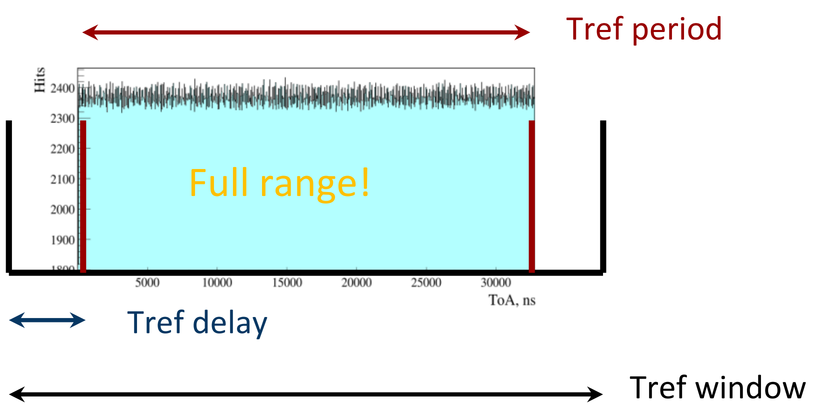
- **"FersRun" framework**
- **DT5215 concentrator**

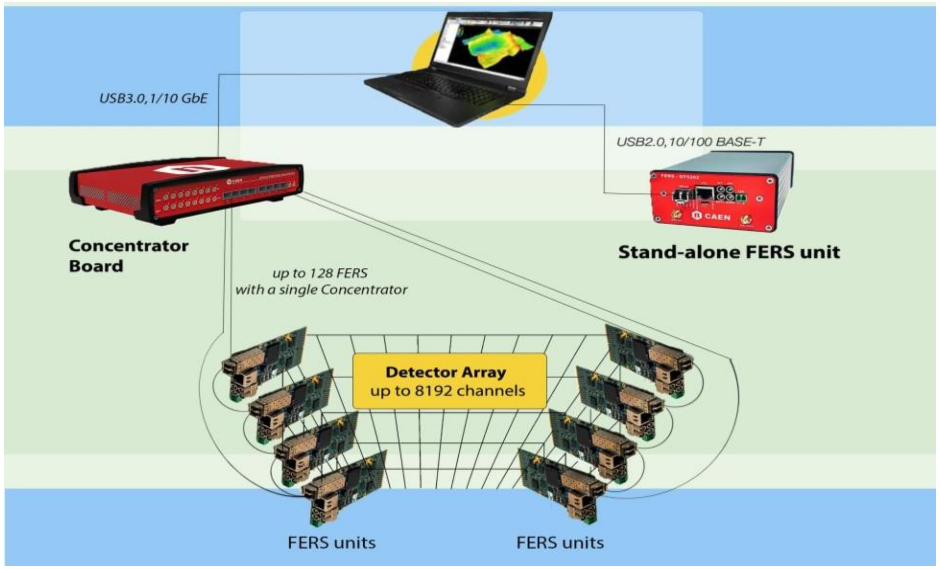
# Application of DT5215 concentrator

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

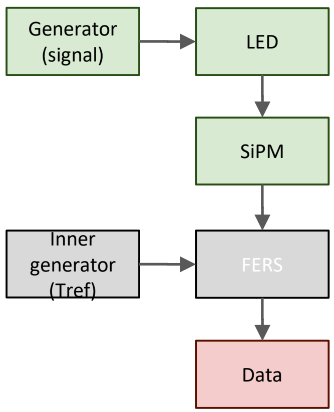
## Hits acquisition ranges

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

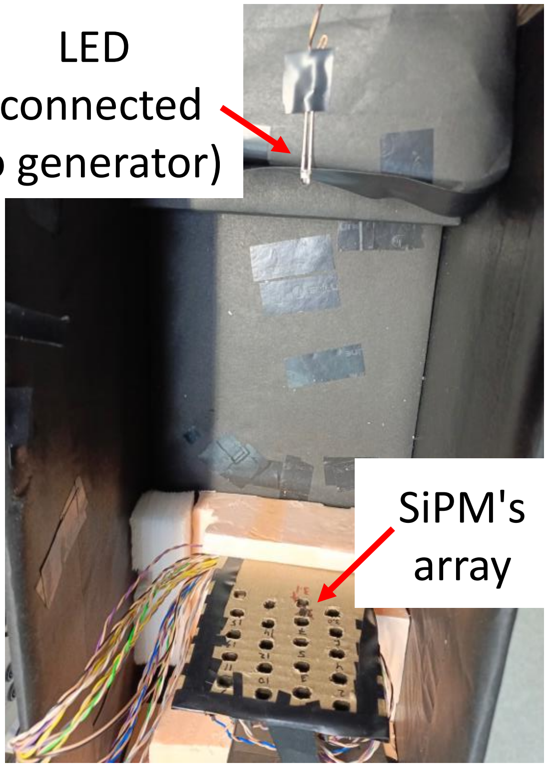


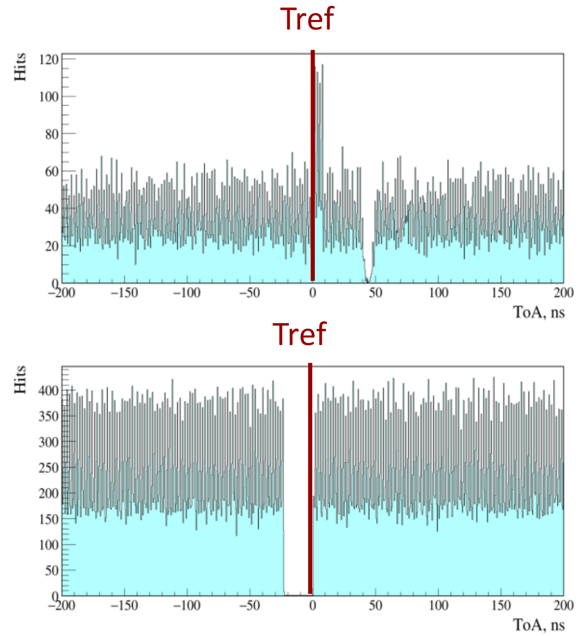



(closest to reality)



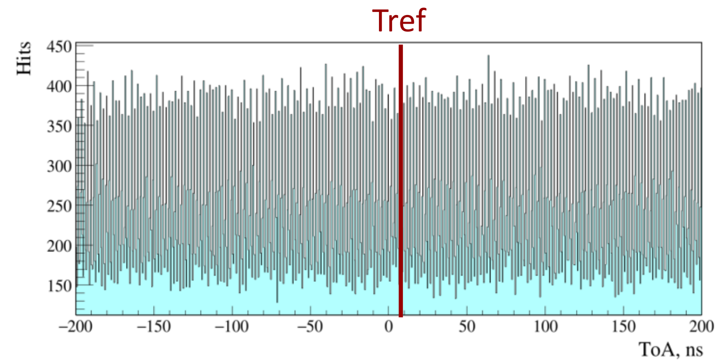

LED (connected to generator)




Any other

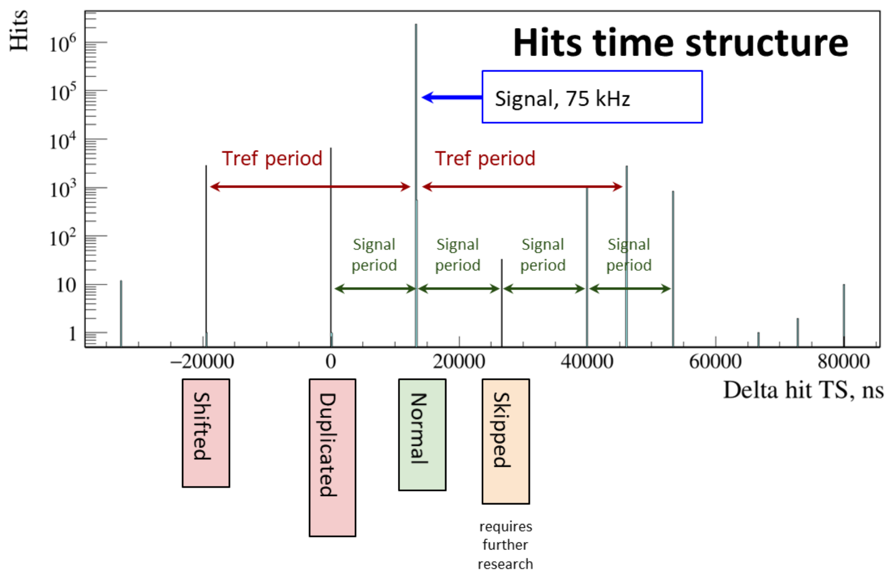
## Hits around Tref signal




Inner & Outer Tref

Tref delay = -68 ns

Tref window - Tref period = 100 ns



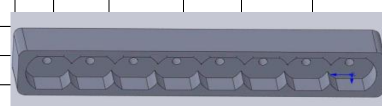

- **Continuous data reading** can be made only with **fine-tuning** of board parameters.

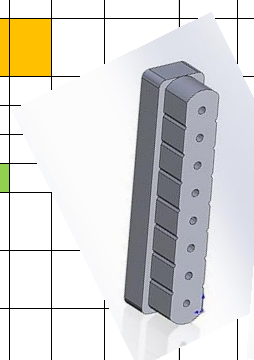
**Together with Volkov I.**

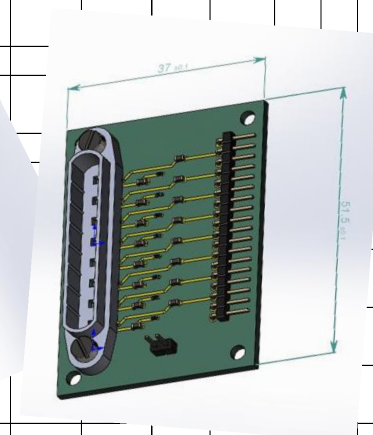
# Schedule of works

| № | 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

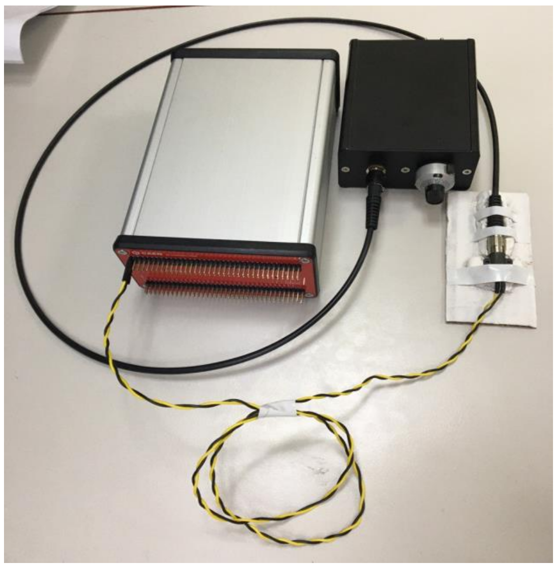
1. Physics of Atomic Nuclei, 2024, Vol. 87, No. 4, pp. 450–457
2. Phys.Part.Nucl. 55 (2024) 4, 1091-1098

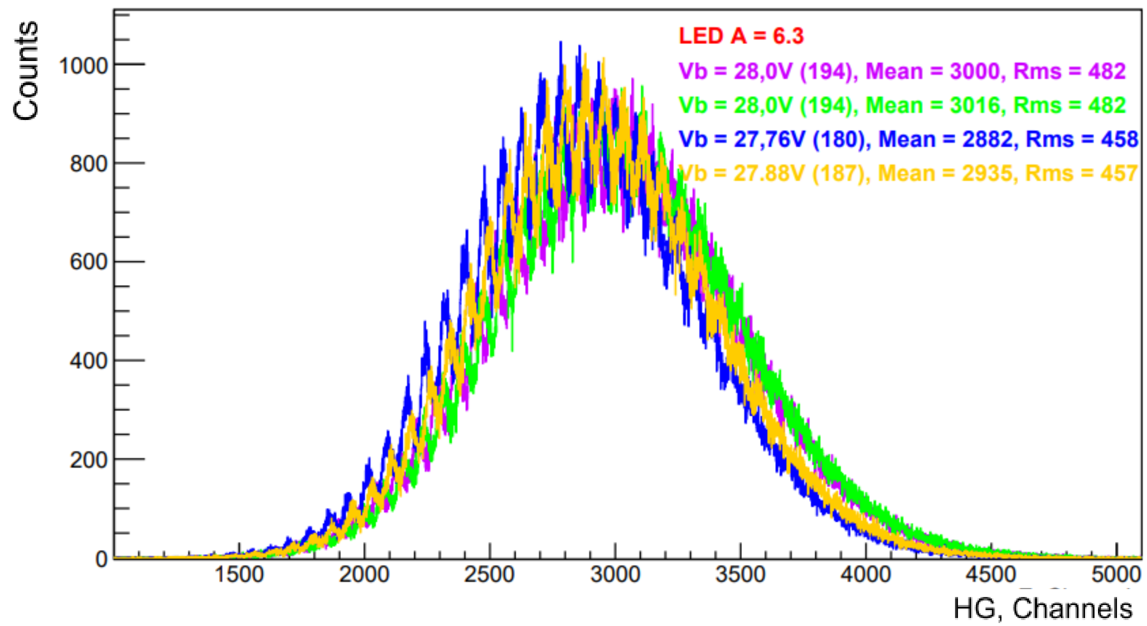
# Backup

# The hardware of BBC tests part

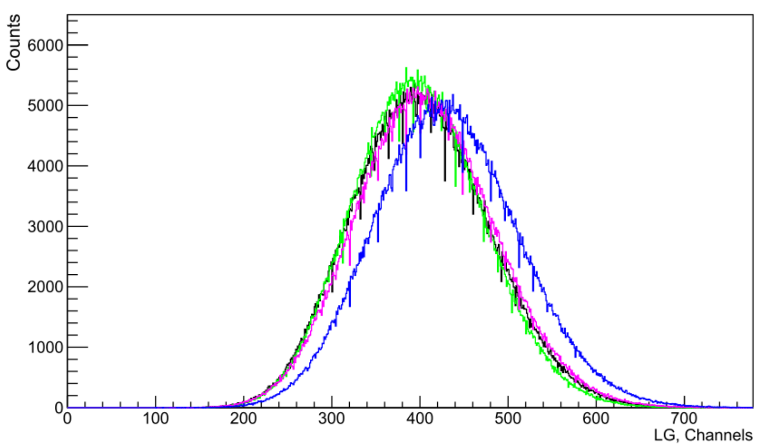
# Calibration method (Led source)

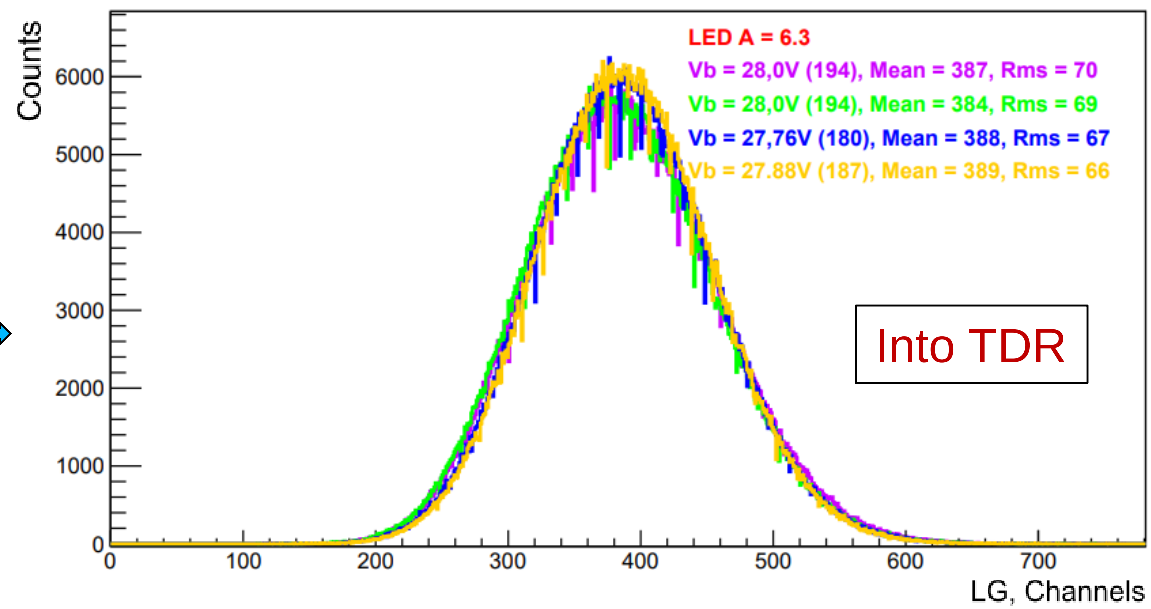
## DT5202 with CAEN LED Driver (SP5601)





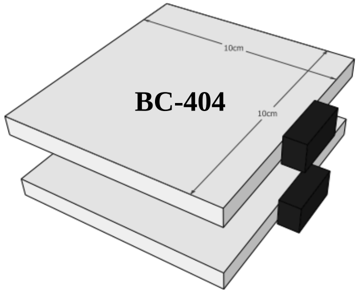

## Not calibrated

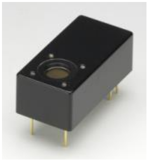


The amplitude spectra of the BBC prototype scintillation tile coated with **Mylar** or **Tyvek**, as well as covered with **Matted** options.

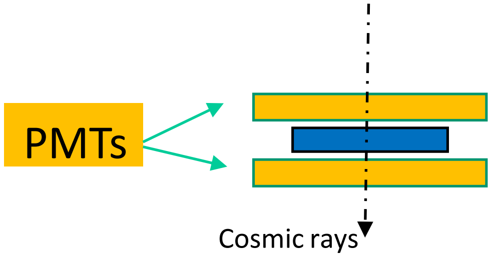
**External trigger by coincidence of two scintillators with PMTs readout**



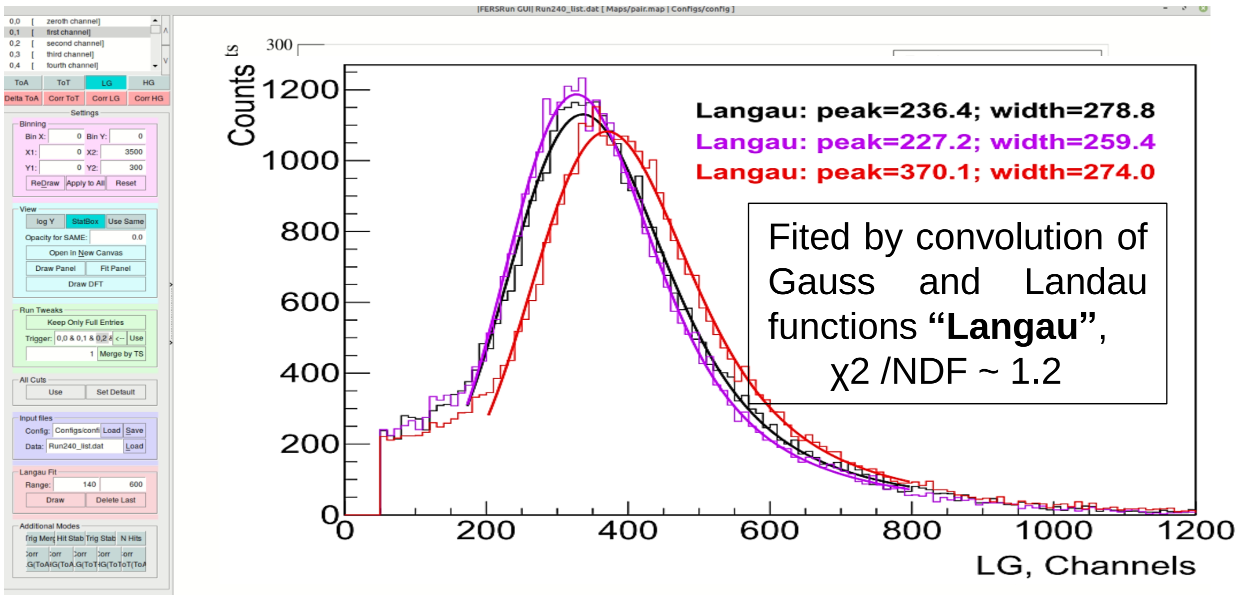
**PMT Hamamatsu H10720-110**

**The "FersRun" framework has been designed.**



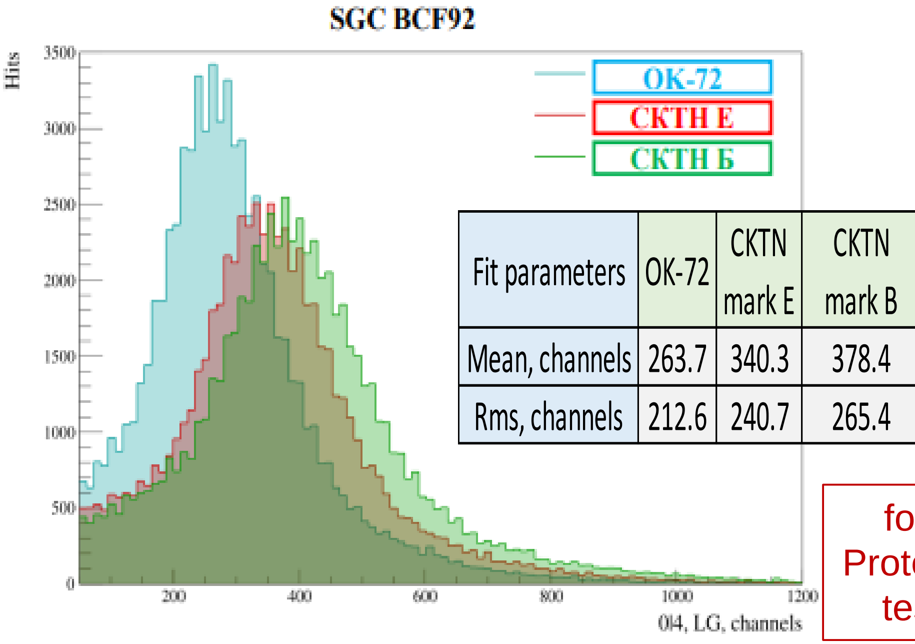

**Matted or Mylar or Tyvek**

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



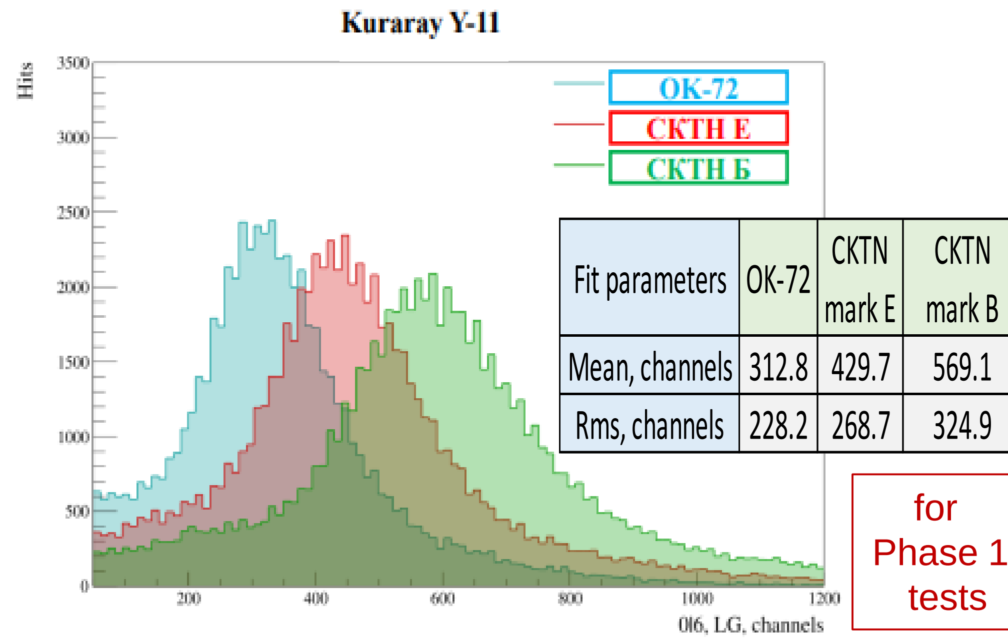

- The option with **matted tiles** is more priority for mass production.

# Optical cement and WLS



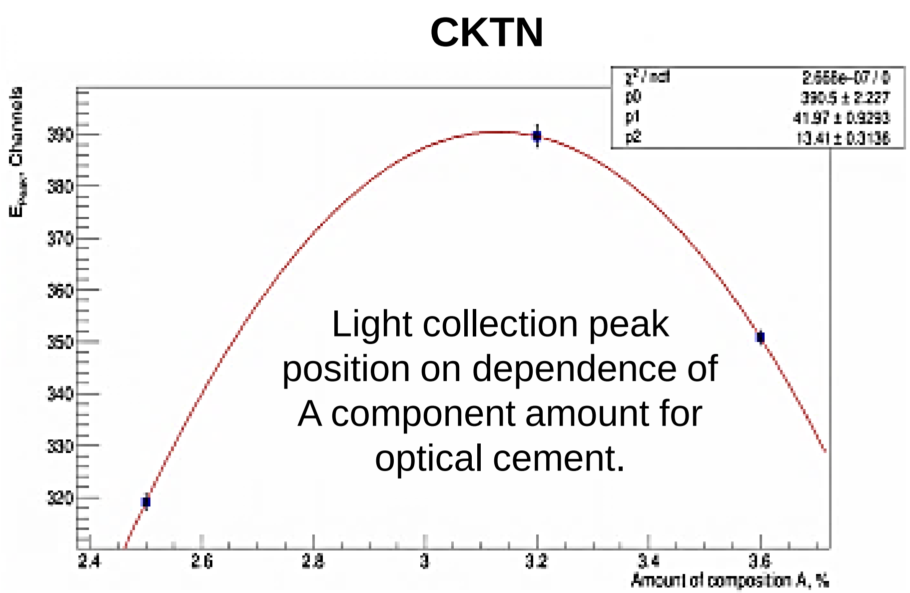

| Fit parameters | OK-72 | CKTN mark E | CKTN mark B |
|---|---|---|---|
| Mean, channels | 263.7 | 340.3 | 378.4 |
| Rms, channels | 212.6 | 240.7 | 265.4 |

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




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

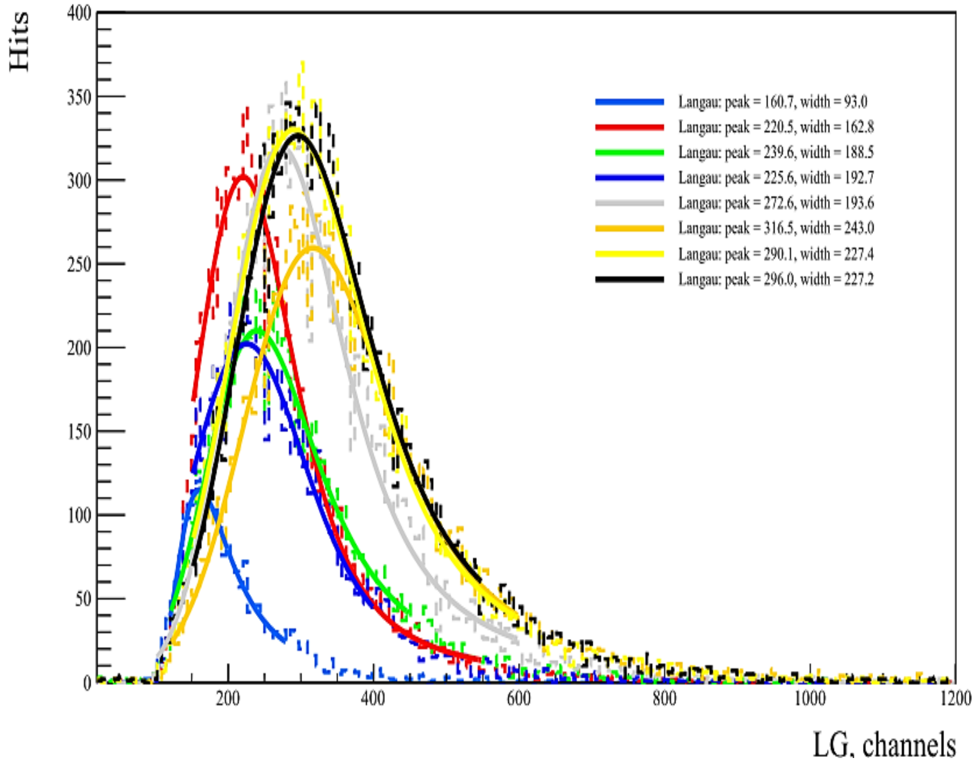
The results of tests of Kuraray WLS fiber and Saint-Gobain Crystals (SGC) WLS fiber with different types of cement are presented.

- ❑ **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**.

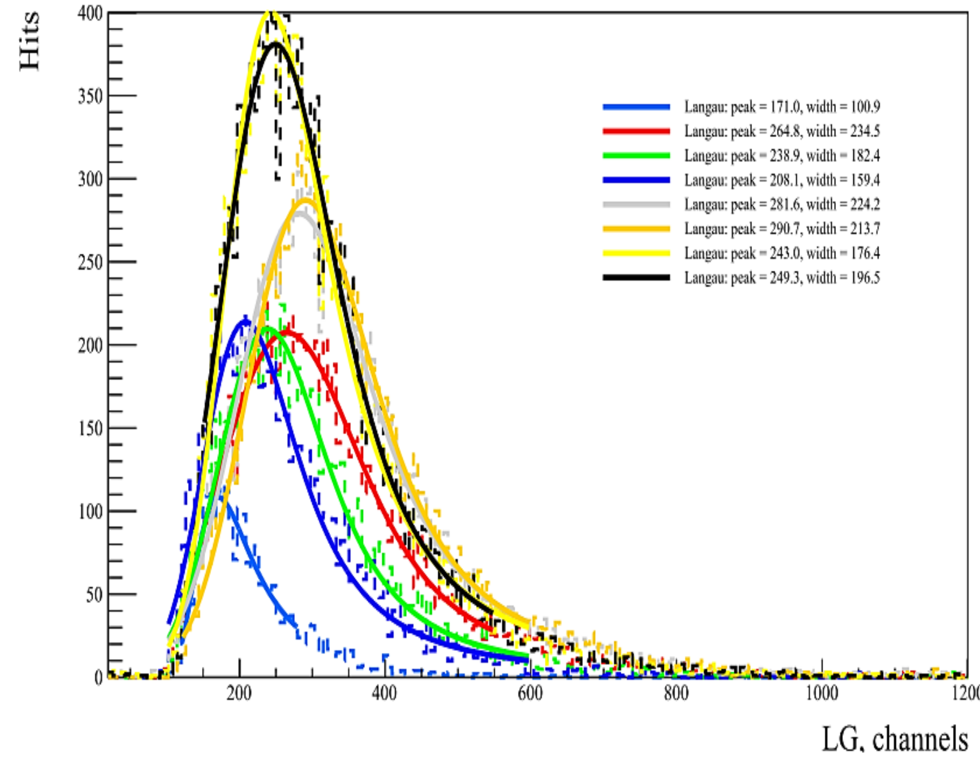
# Prototype assembling test

# Amplitude spectra of two sectors

### 1-st sector prototype




### 2-nd sector prototype



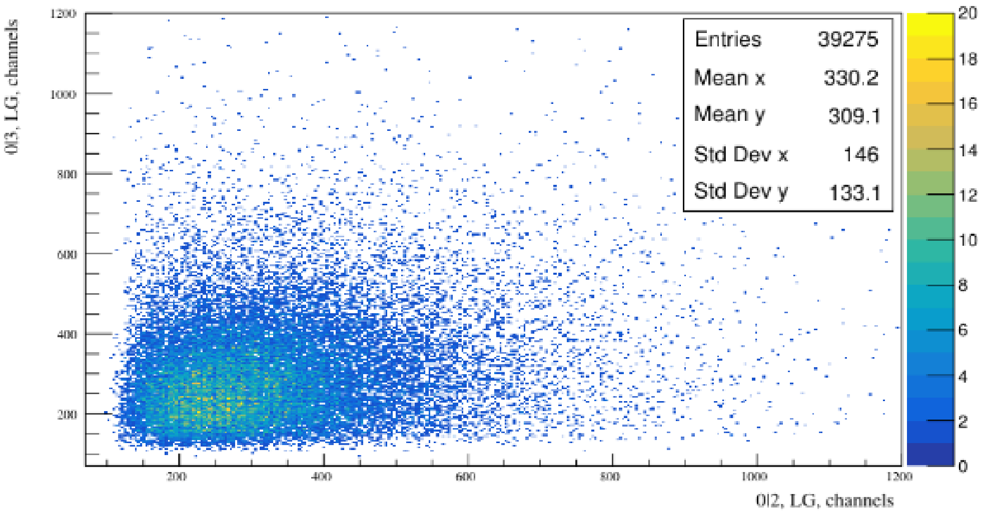

There are 2 specific channels, but the debugging process of mass production continues.

The stable tiles were taken for following tests

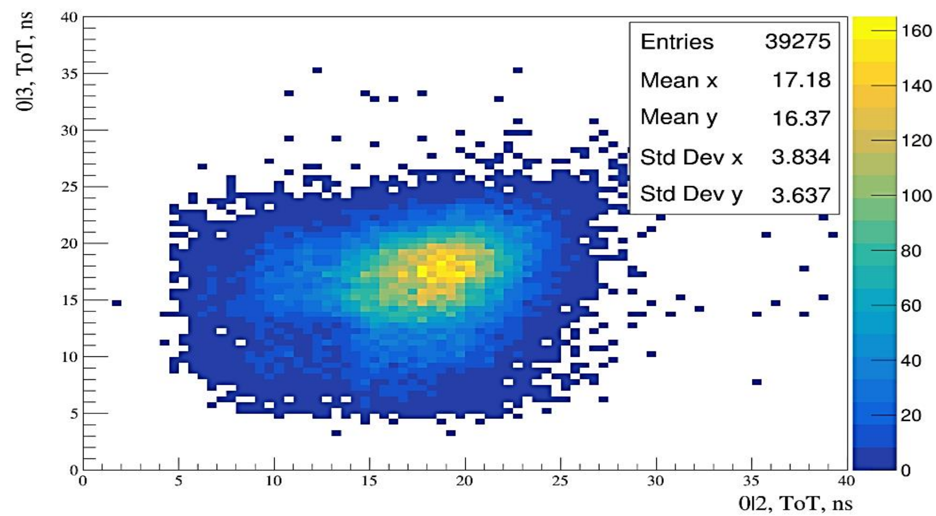
## Prototype assembling test

## The 1-st step for working with the timing mode

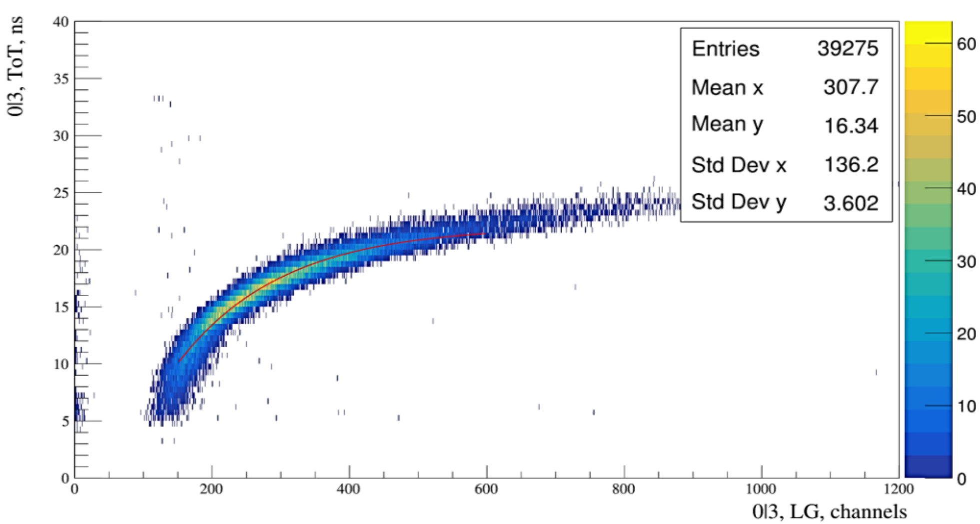
### LG correlations

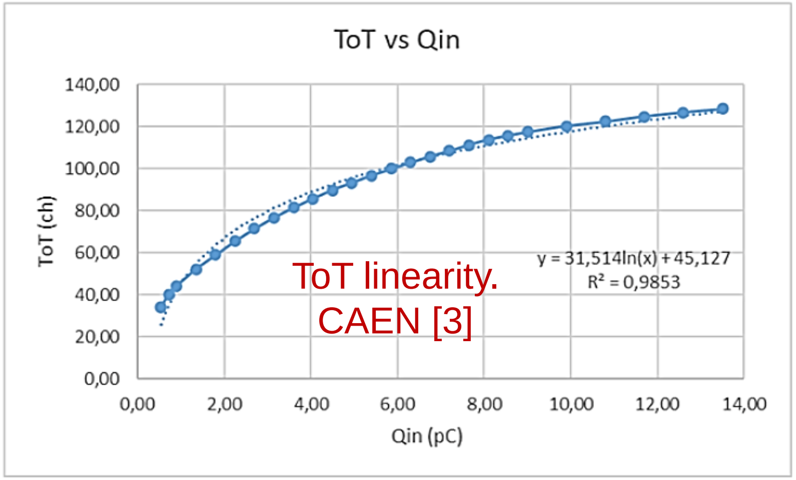



### ToT correlations




### LG vs ToT (channel №3)

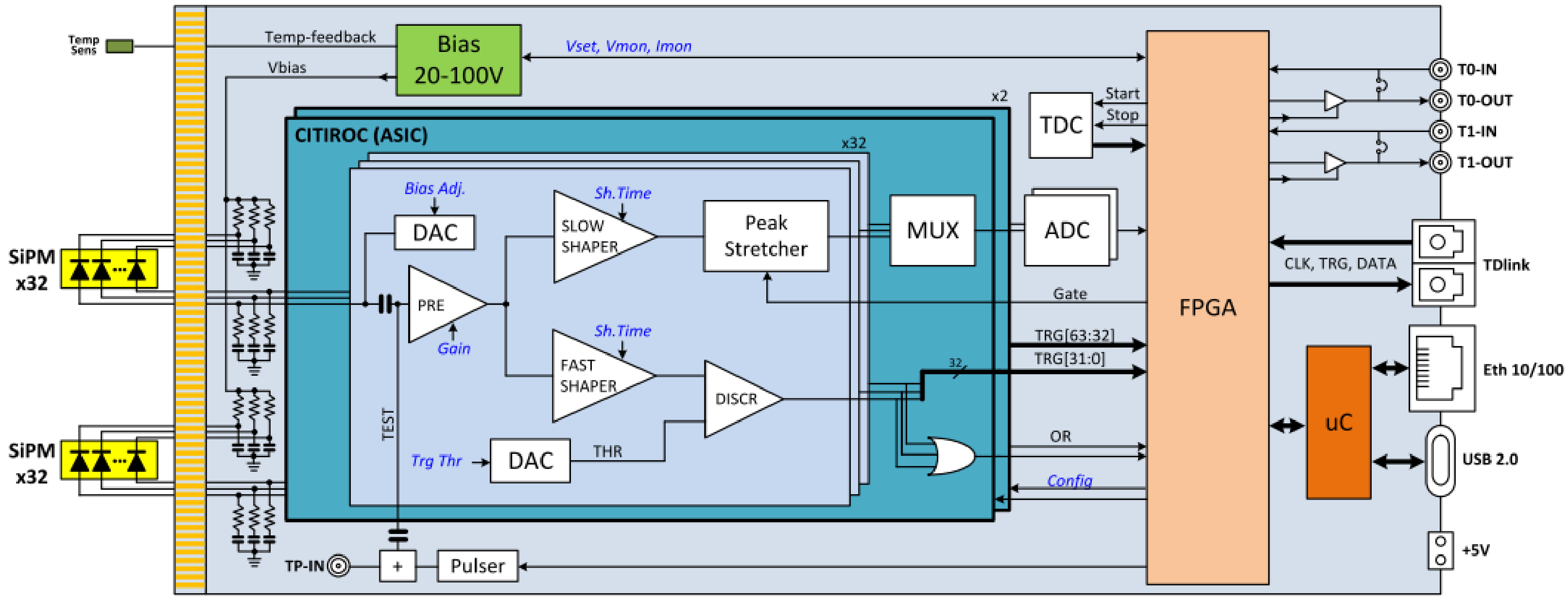


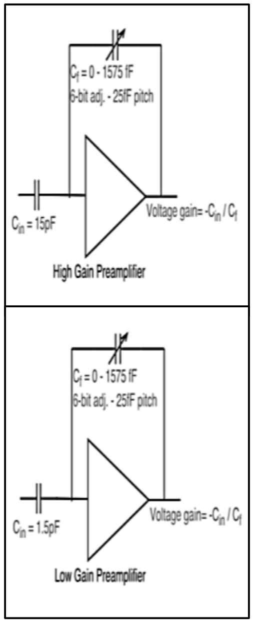




Correlation of energy deposition for 2 channels, as well as the time information for these channels.

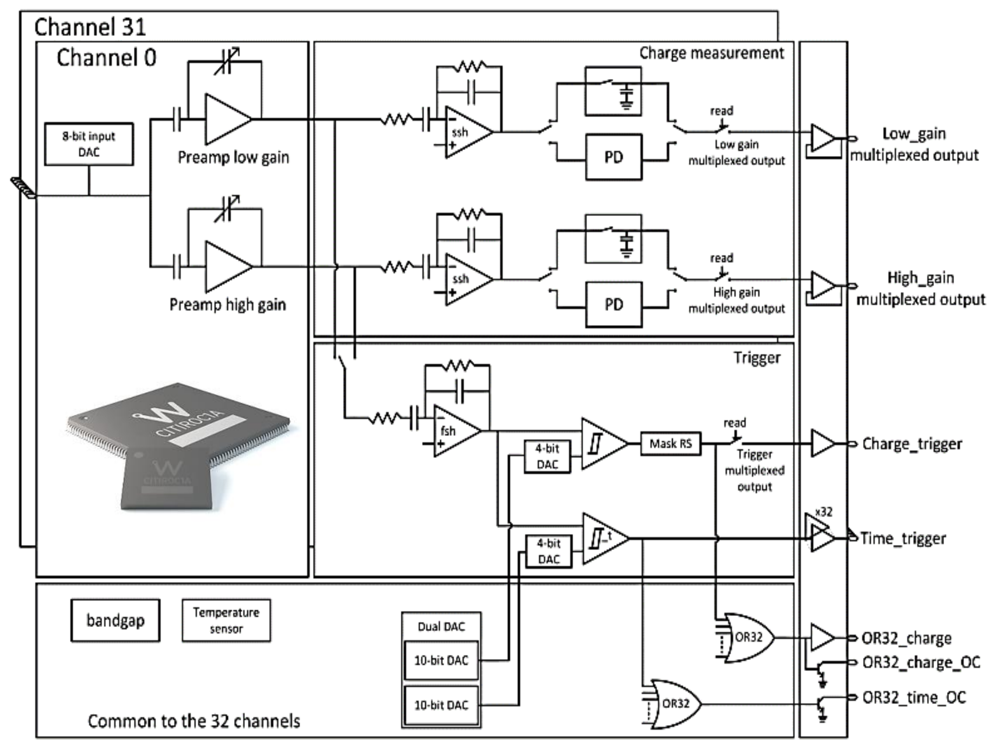
- The calibration of the charge scale is required

## Simplified block diagram of the DT5202 FERS-5200 unit



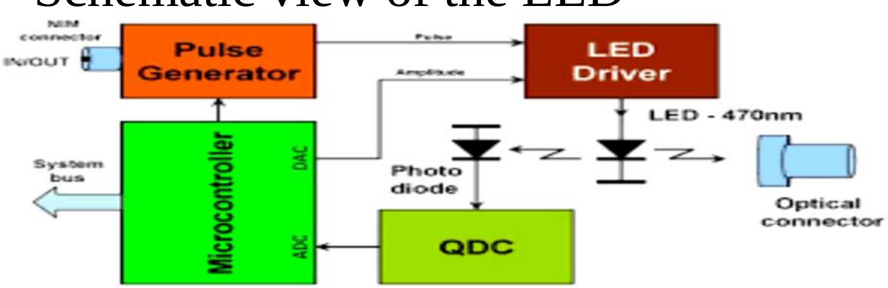

## Citiroc-1A block scheme




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

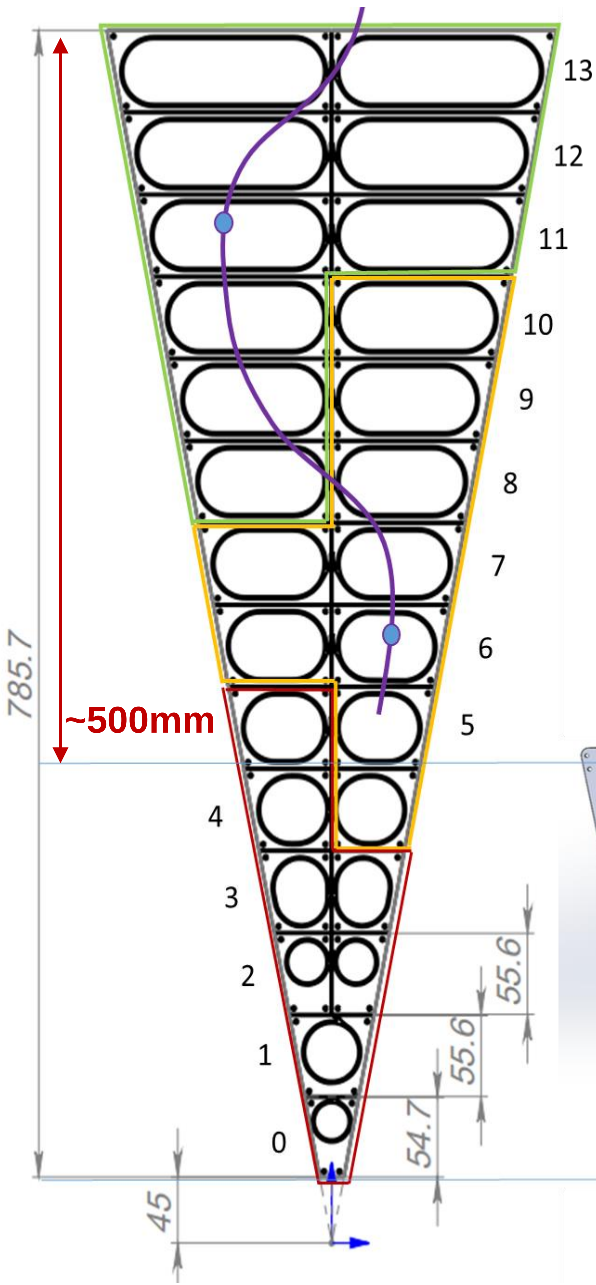
- Triggers of consecutive channels are sent to an AND logic operator (e.g. CH0&CH1, CH2&CH3, etc.). The 32 outputs are then sent to an OR logic operator.

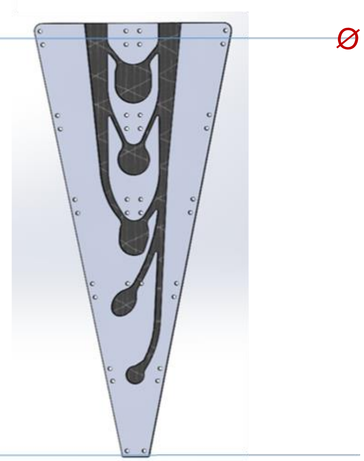
## Schematic view of the LED



# The method of assembled sector fast check

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

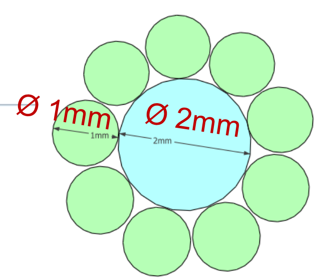


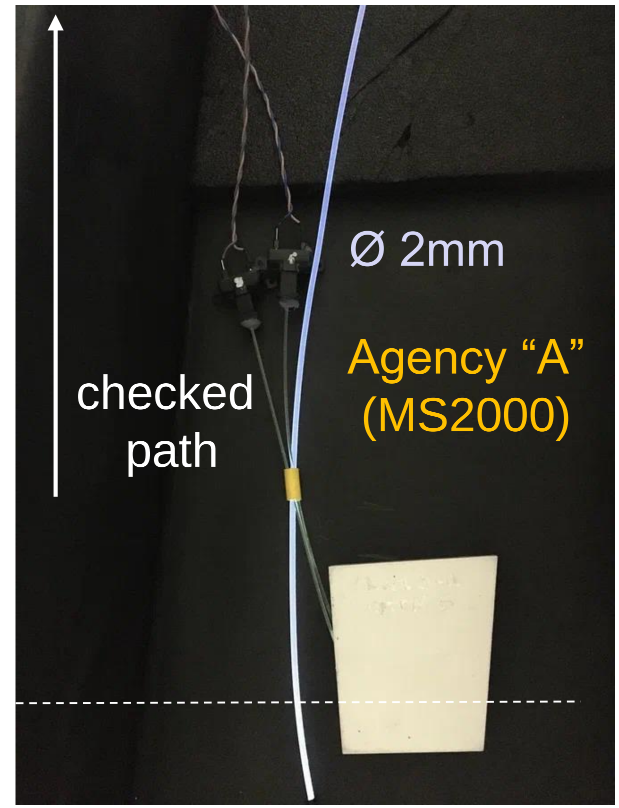



**The side glow fiber (SGF) is one of the option for** the fast check of a larger part of the signal **path** (**WLS <-> Clear Fiber <-> SiPM <-> DT5202 unit**)

WLS groups (8 + 9 + 9)

Max. quantity = 9 WLS

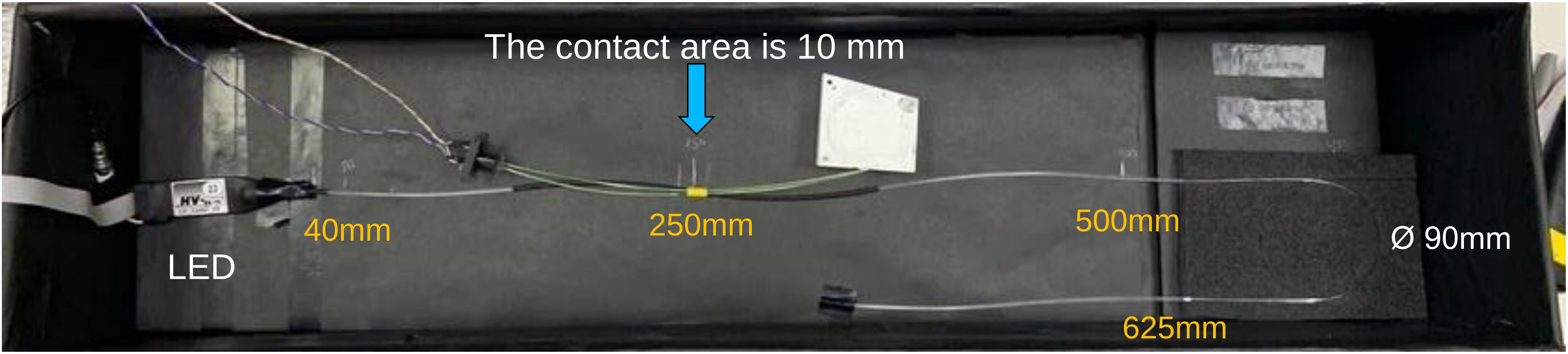


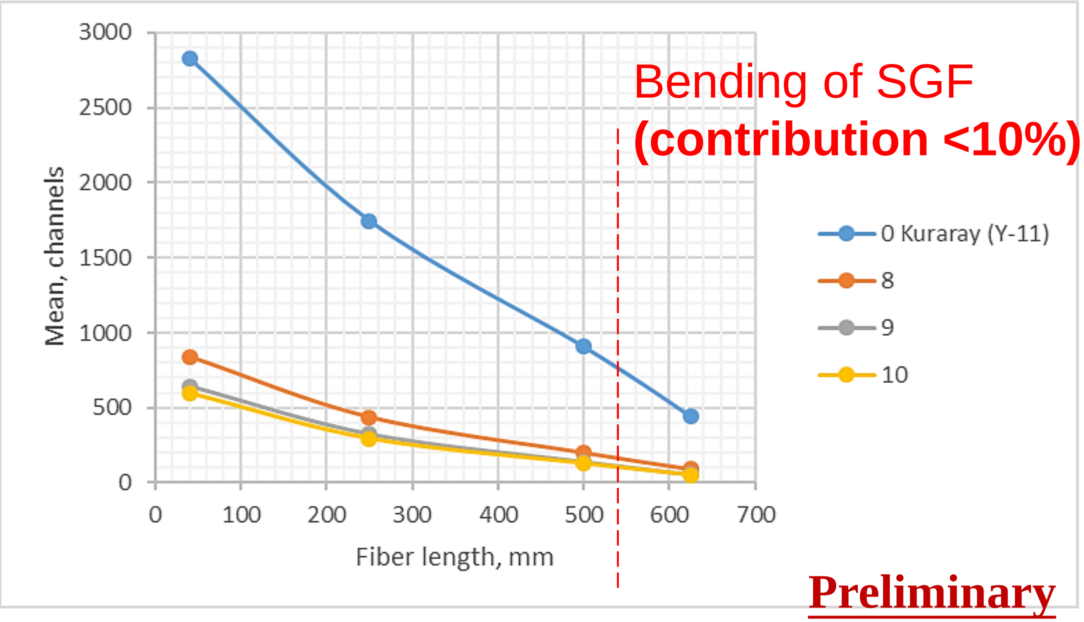

A quick check method for the assembled sector will allow us to verify if the fiber within the sector is undamaged and monitor fiber degradation over time. The complete sector will be divided into 3 groups of 8 or 9 tiles, and SGF will be attached to the fibers at different 3 spots, according to different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

Methodical tests

# The scan by SGF length




| | 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 |



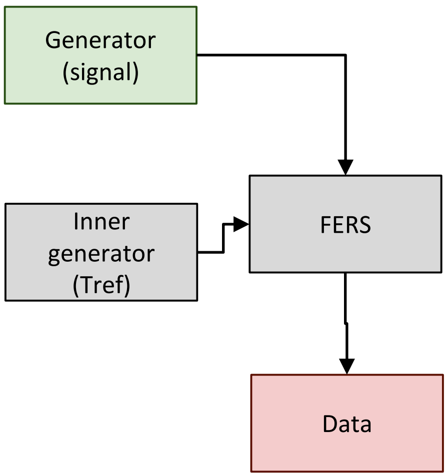

**Preliminary**

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.

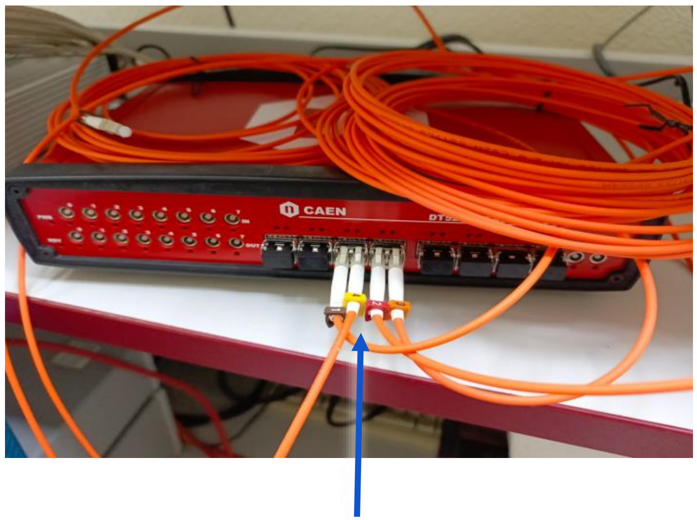
**SGF loses ~75% of its light intensity at a length of 500 mm**

# 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