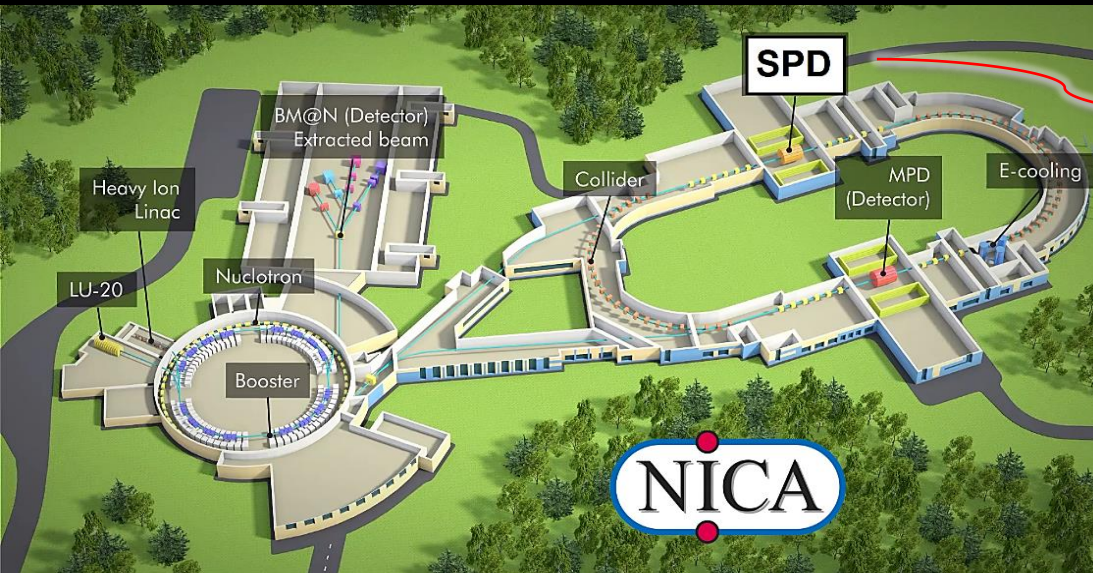




The first results of test of the SPD Beam-Beam Counter scintillation detector prototype

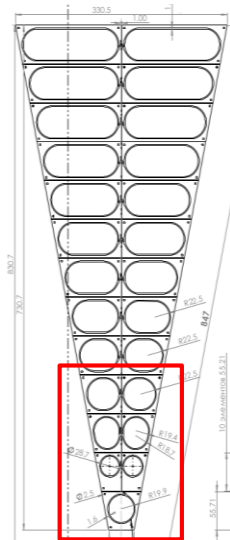
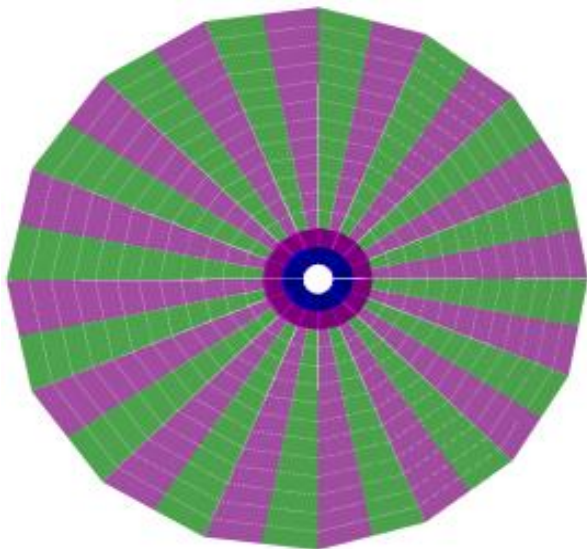
A.V.Tishevsky

Introduction



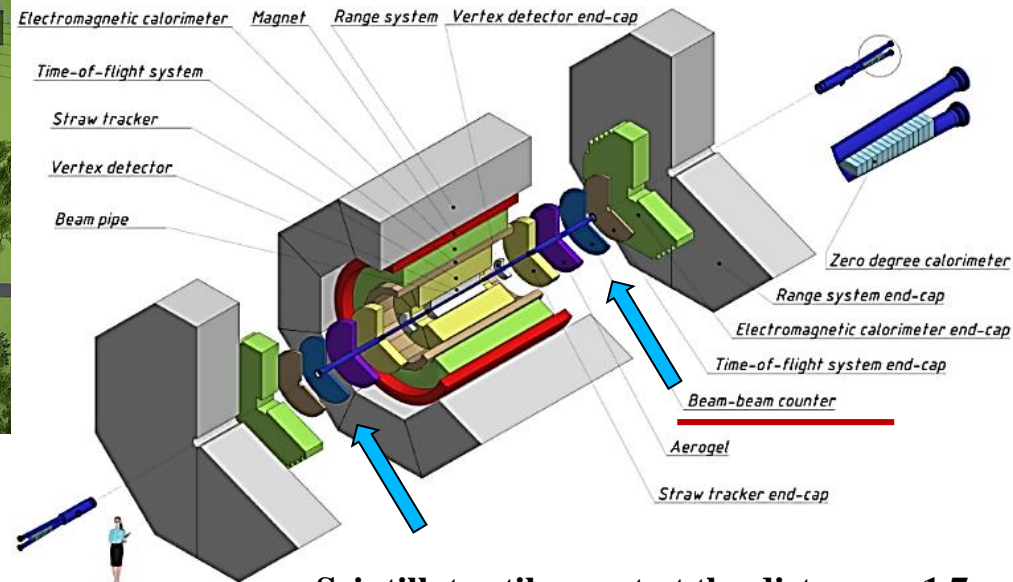
TDR 2023 (Phase 1)
2 wheels with
400 tiles each (416?)

25 tiles in sector (similar to STAR EPD)



General

The Spin Physics Detector (SPD)

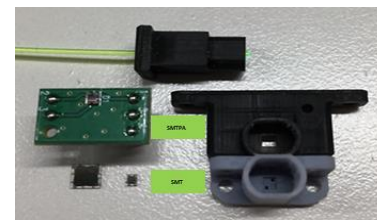
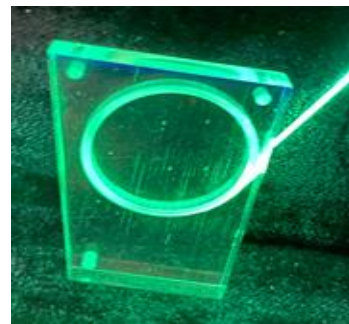
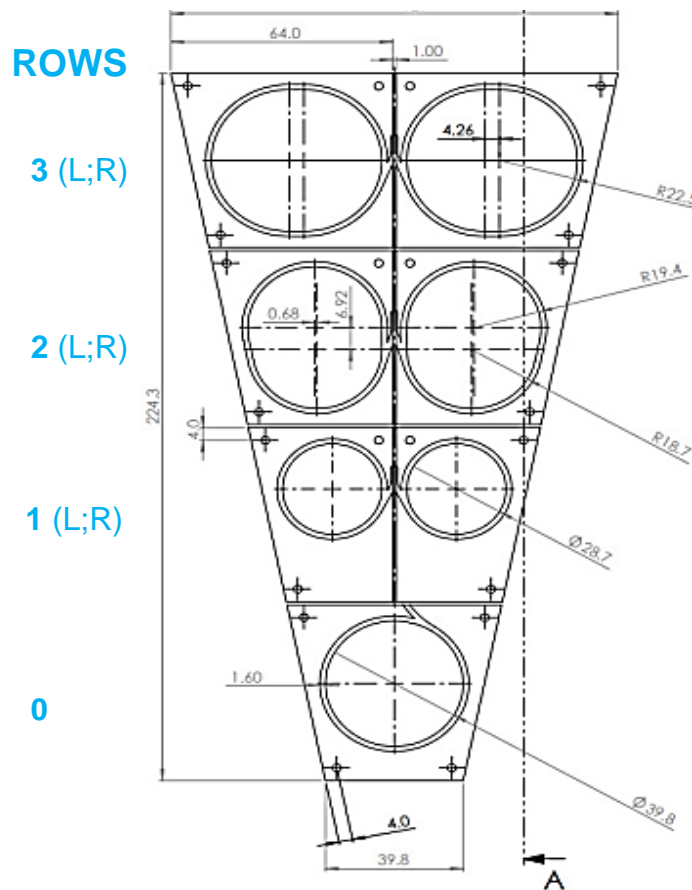
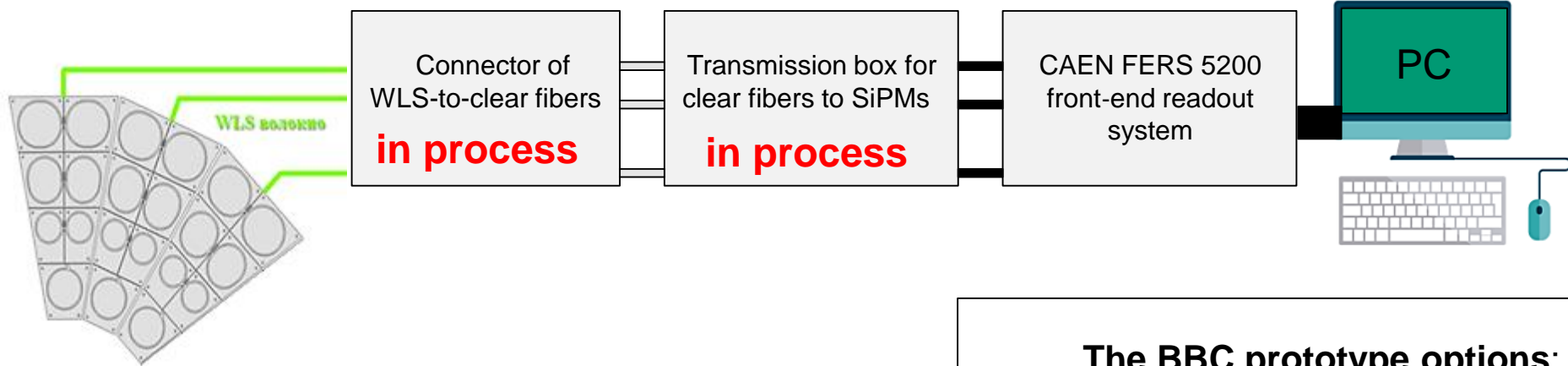


- Scintillator tiles part at the distance ~ 1.7 m

The Beam-Beam Counters (BBC) for SPD

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

The main purpose of BBC is the permanent monitoring of the beam polarization using the azimuthal asymmetry of the inclusive charged particles yield.

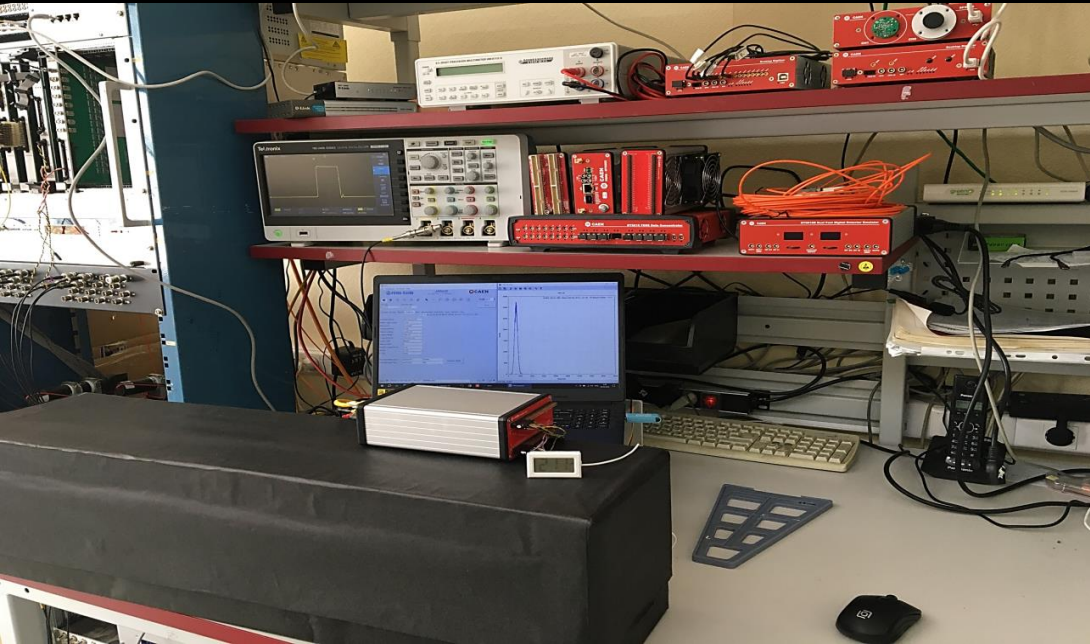


The BBC prototype options:

- Scintillator:** Uniplast (Vladimir)
 chemical mating vs polished
- Optical cement:** OK-72 vs CKTN Med
- Fibers:** Saint-Gobain Crystals
 vs
 KURARAY (Y-11)

- SiPMs:** ✓ SensL 1x1 mm² (main option of 2023)
- Readout system:** ✓ CAEN FERS-5200

The hardware of BBC tests part



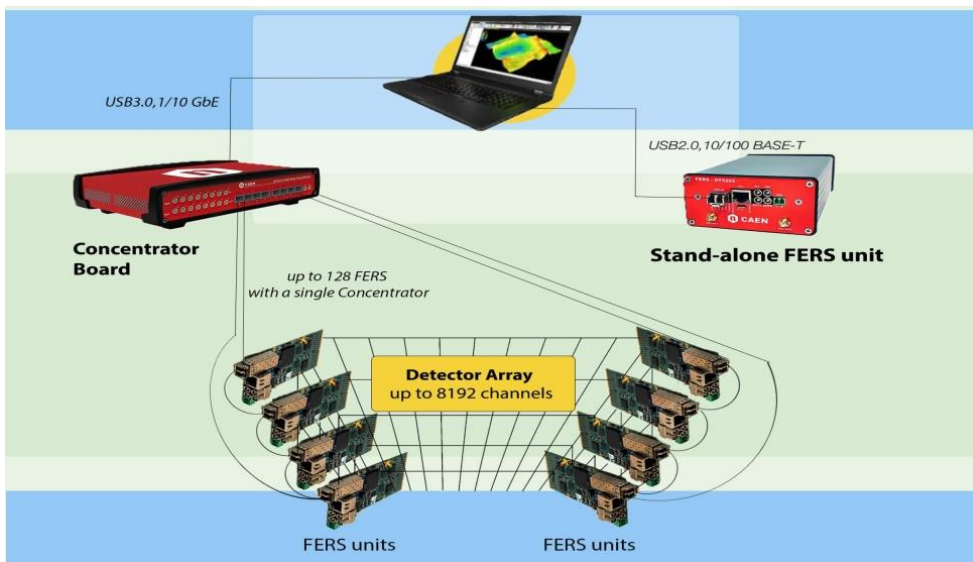
Stand for BBC measurements

CAEN FERS 5200 is an extendable high speed front-end readout system



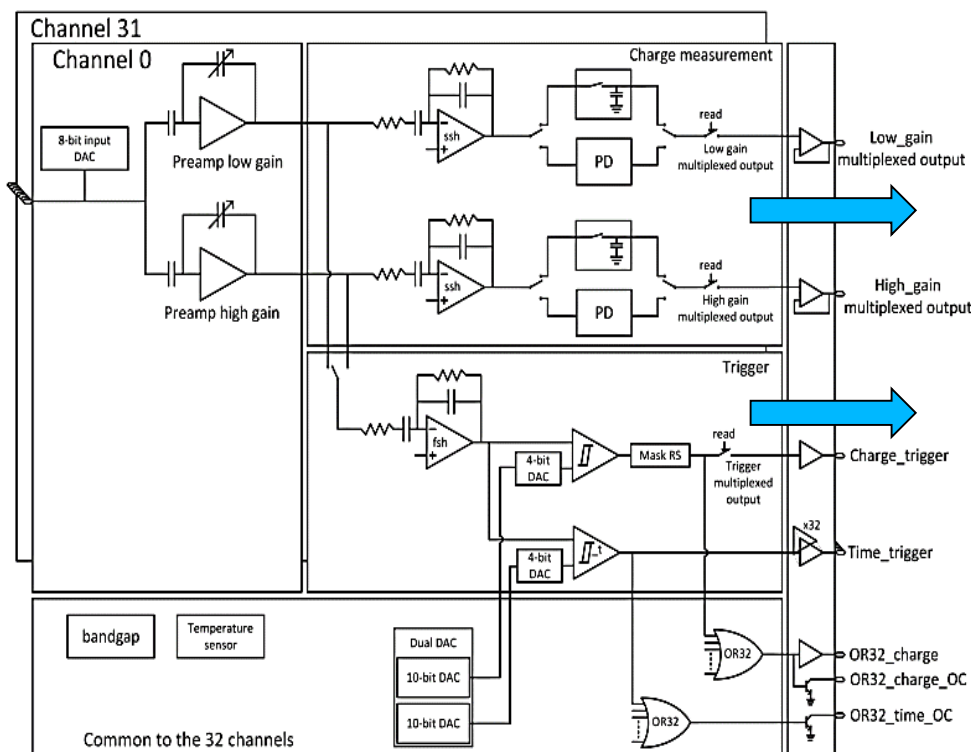
- DT5202 (citiroc 1A chip)
- DT5203 (picoTDC chip)
- DT5215 (Concentrator)

- Concentrator DT5215 for the possibility of expanding the number of channels to 8192.
- DT5203 (with picoTDC chip) for high-resolution multi-hit time measurements.
- **DT5202** (with two Citiroc 1A chips) based on the 64-channel module for SiPM.



Citiroc 1A allows triggering down to 1/3 p.e. and provides the charge measurement with a **good noise rejection**. Moreover, Citiroc 1A outputs the 32-channel triggers with a **high resolution timing** (better than **100 ps**).

Citiroc-1A block scheme



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

Time of Arrival (**ToA**) and Time over Threshold (**ToT**). **ToT** is giving a rough estimation of energy.

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

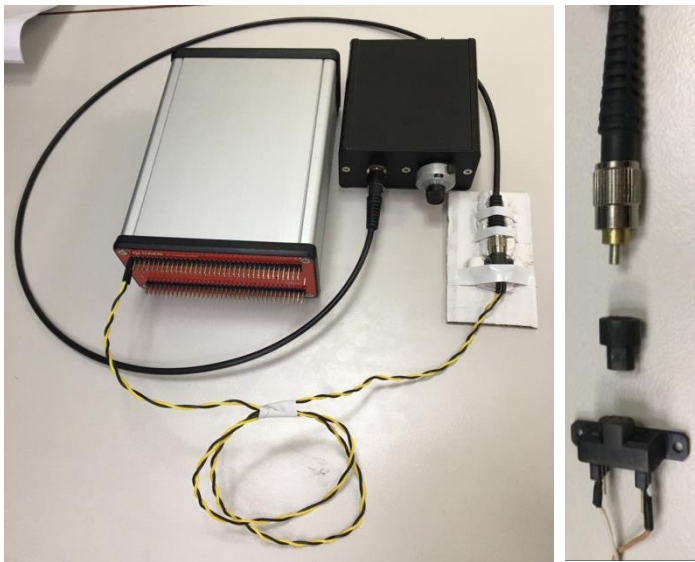
Main Acquisition Modes:

- SPECTROSCOPY → for collibration
- SPECT_TIMING (the Spectroscopy + Timing) → for tests
- **TIMING** → for testbeam and Phase 1 tests

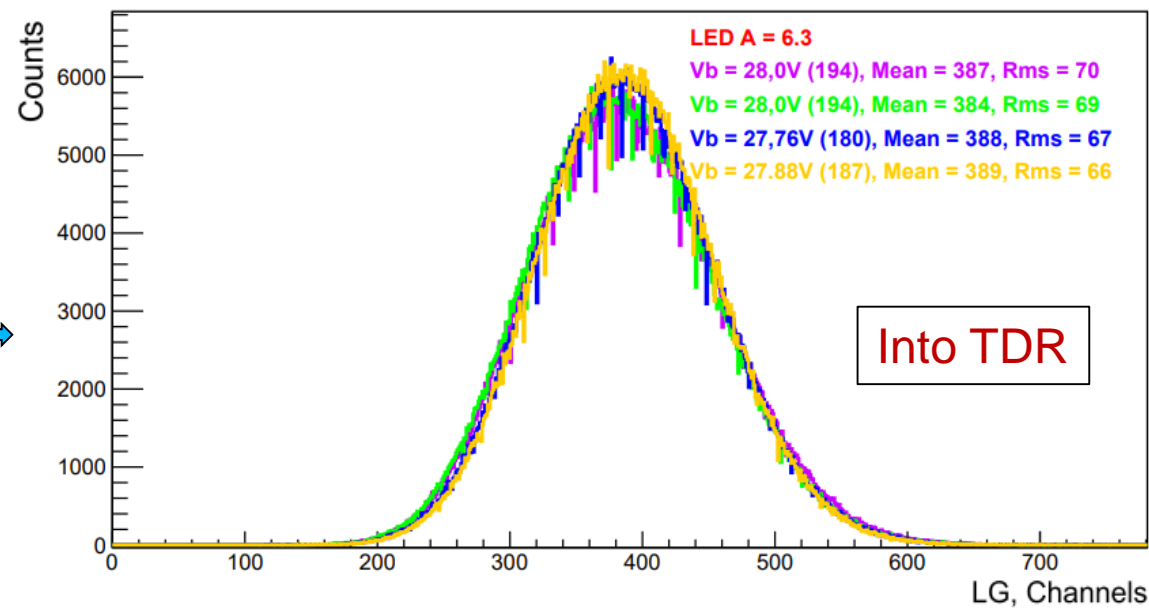
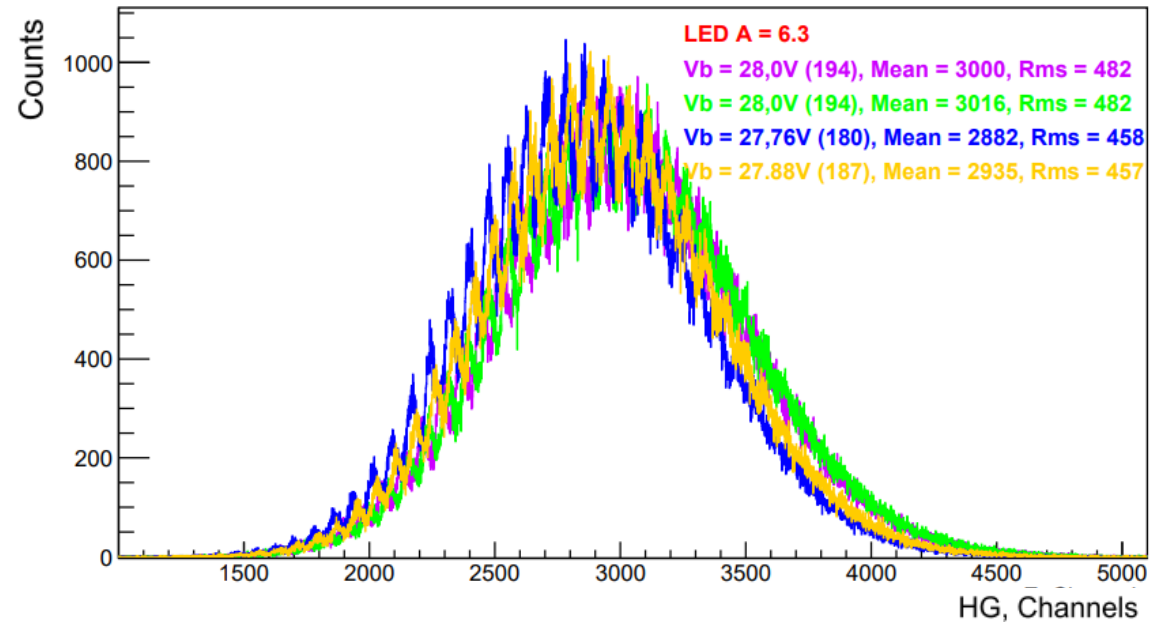
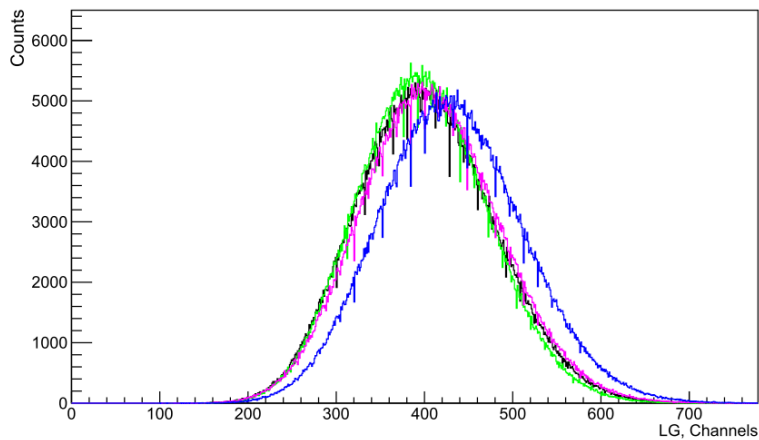
The hardware of BBC tests part

Calibration method (Led source)

DT5202 with CAEN LED Driver (SP5601)

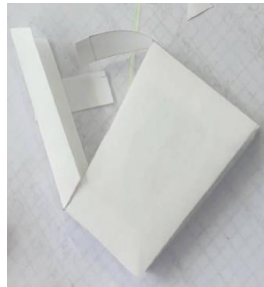


Not calibrated



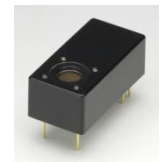
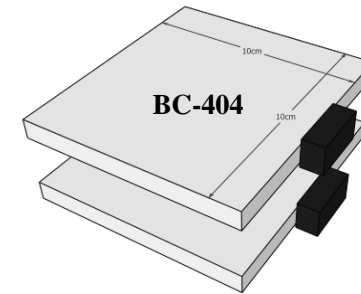
Materials selection test part

Scintillator cover



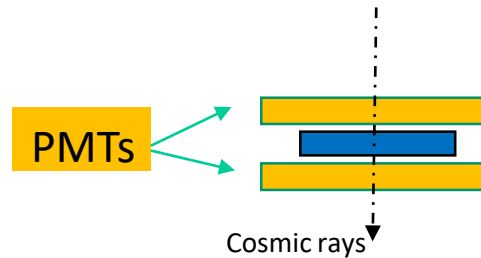
The amplitude spectra of the BBC prototype scintillation tile coated with **Mylar** or **Tyvek**, as well as covered with **Matted** options.

External trigger by coincidence of two scintillators with PMTs readout



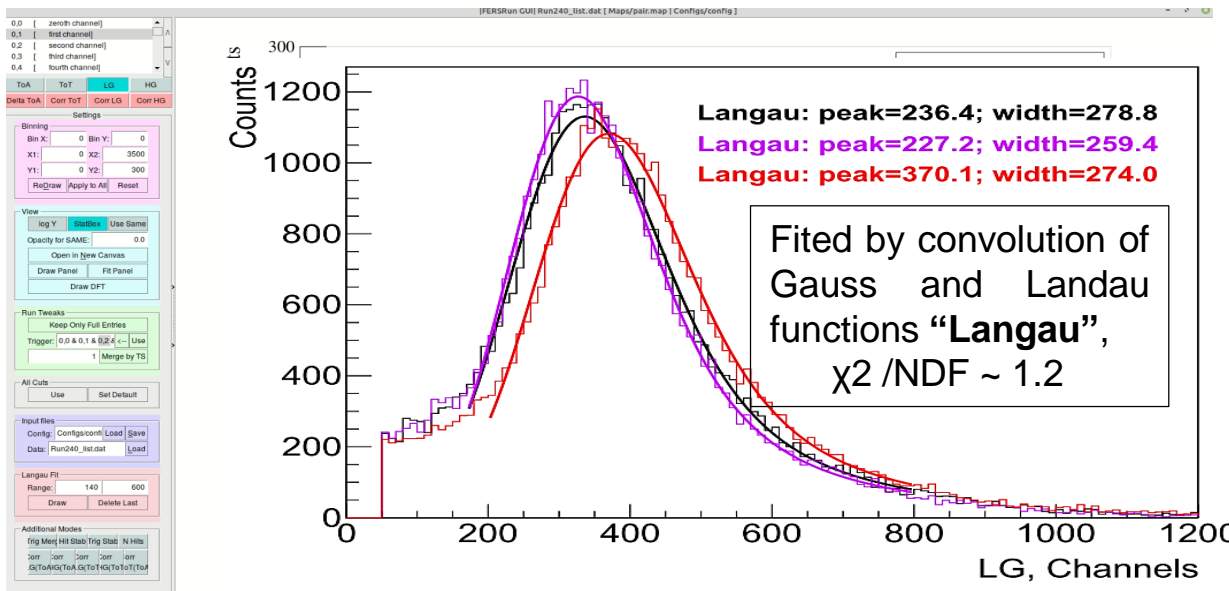
PMT
Hamamatsu
H10720-110

The “FersRun” framework has been designed.



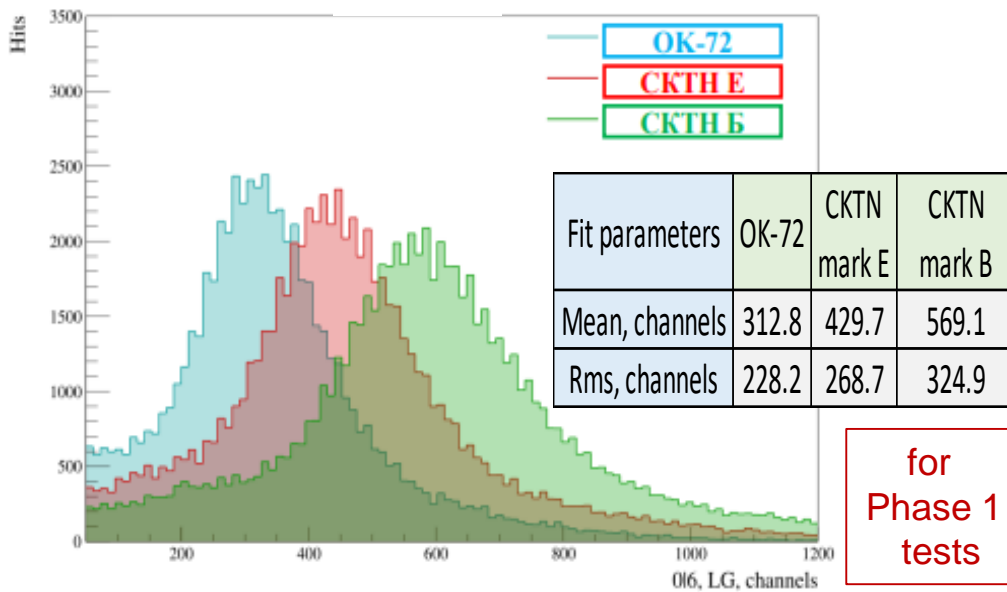
Matted
or
Mylar
or
Tyvek

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



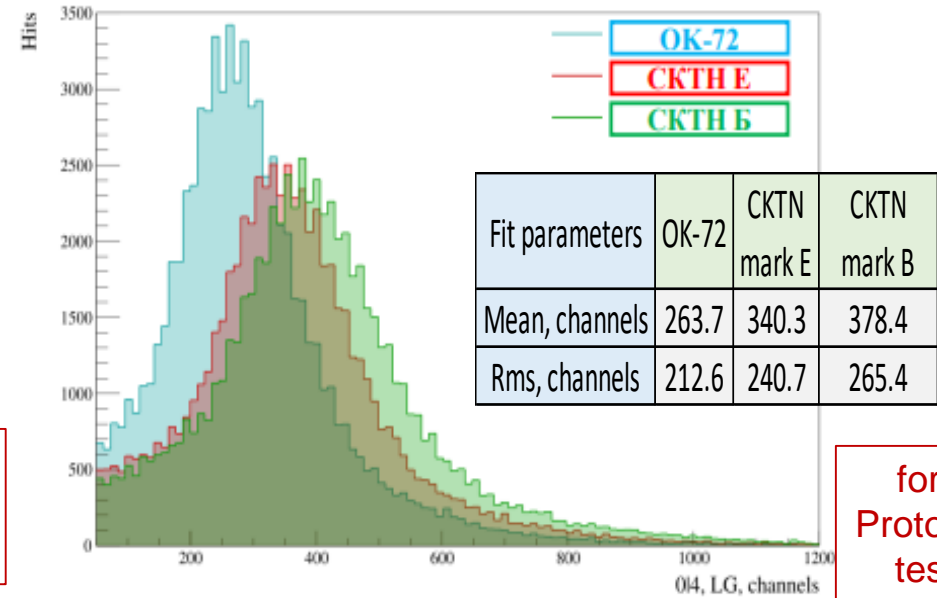
☐ The option with **matted tiles** is more priority for mass production.

Kuraray Y-11



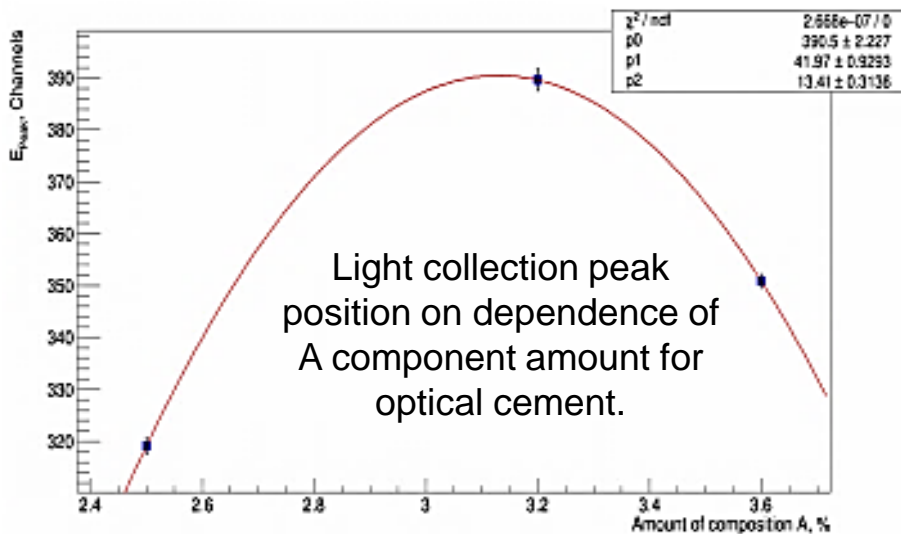
for Phase 1 tests

SGC BCF92



for Prototype tests

CKTN

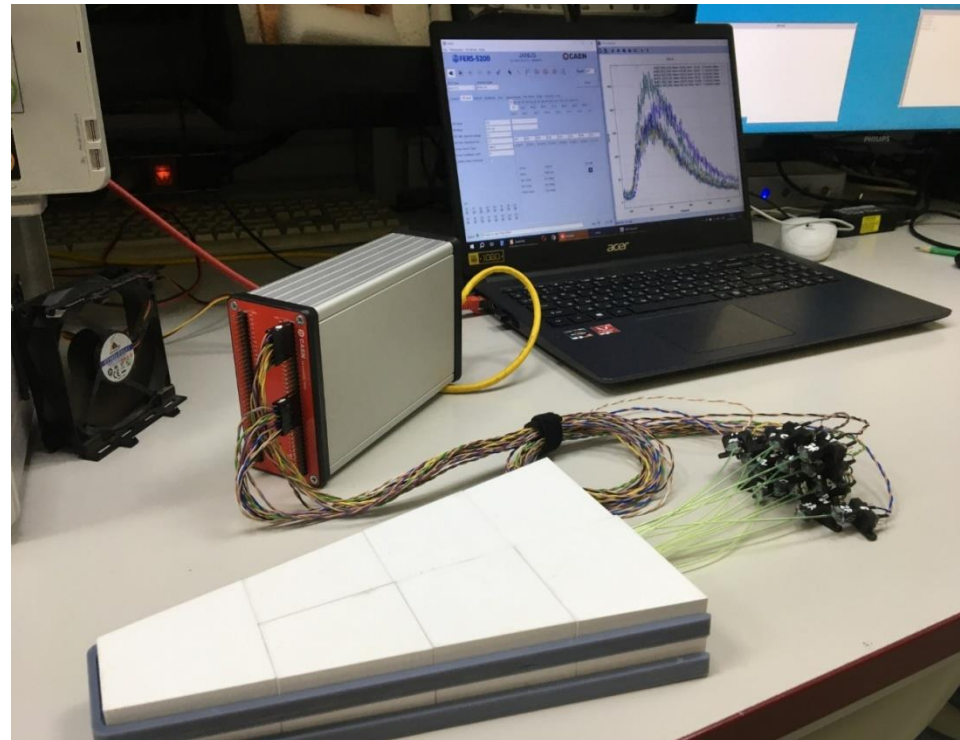


The results of tests of Kuraray WLS fiber and Saint-Gobain Crystals (SGC) WLS fiber with different types of cement are presented.

- ❑ **CKTN mark B** paired with Kuraray WLS fiber are the most appropriate candidates for future testbeam.
- ❑ **CKTN mark B** paired with SGC WLS fiber are the most appropriate candidates **for prototype** assembly tests.
- ❑ Datasheet ratio will be used and closely monitored for mass production.

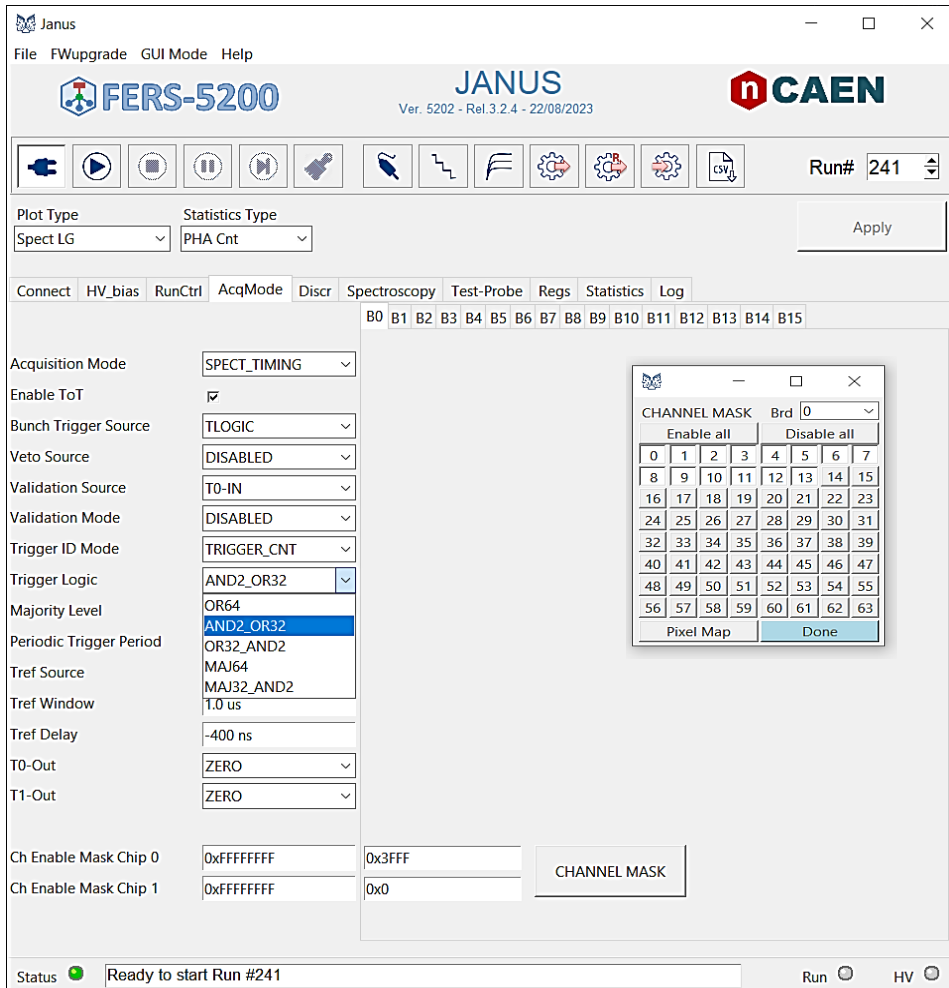
Selected options:

- Scintillator:** **Uniplast-Vladimir (chemical mating)**
- Optical cement:** **CKTN Med mark B**
- Fibers:** **Saint-Gobain Crystals (SG92S)**
- SiPMs:** **SensL 1x1 mm² (tests temperature ≤ 25.3 °C)**



Prototype assembling test part

Trigger logic parameters for DAQ

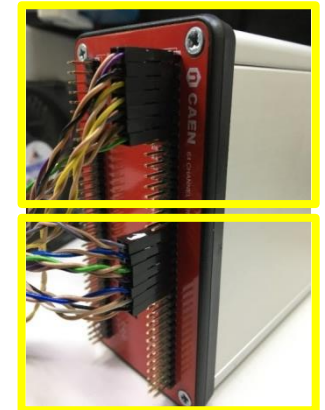


1-st Citiroc 1A was used



AND2_OR32 Parameter

Both Citiroc 1A were used



OR32_AND2 Parameter

One chip was used for the first case, for the other case the channels were allocated to two chips

1 out of working

Time Stamp	3600.860 s
Trigger-ID	6884
Trg Rate	2.717 cps
Trg Reject	0.51%
Tot Lost Trg	35
Event Build	0.00%
Readout Rat	245.409 B/s
T-OR Rate	0.000 cps

~3.8k counts/channel

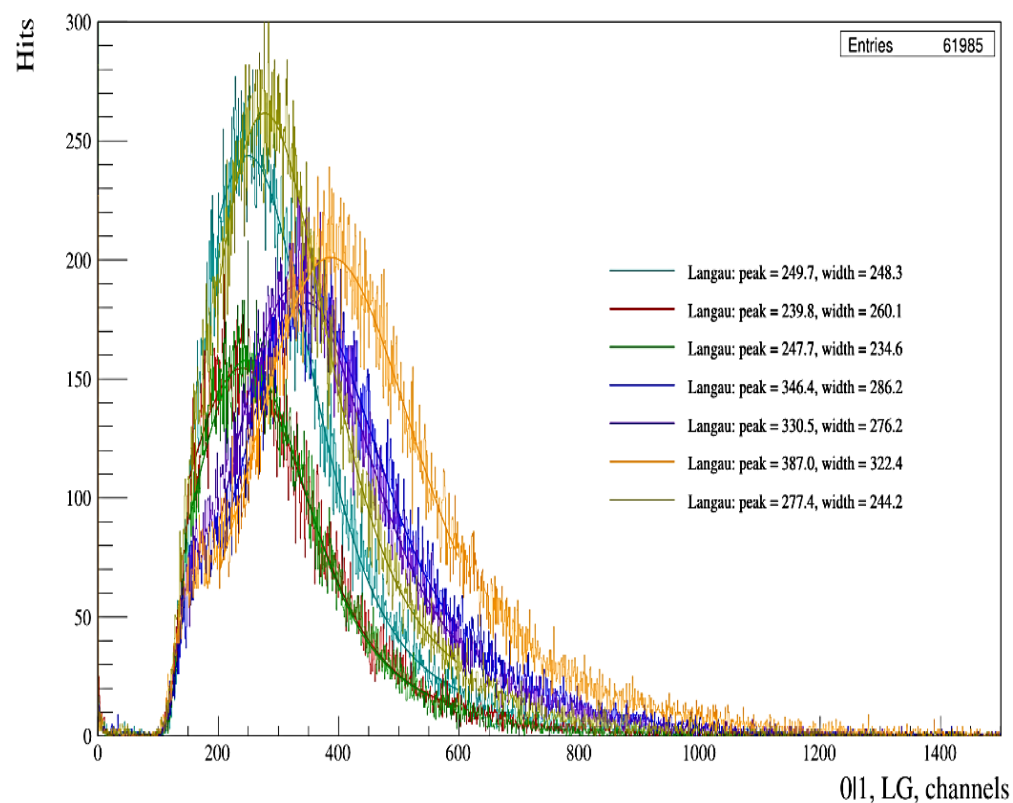
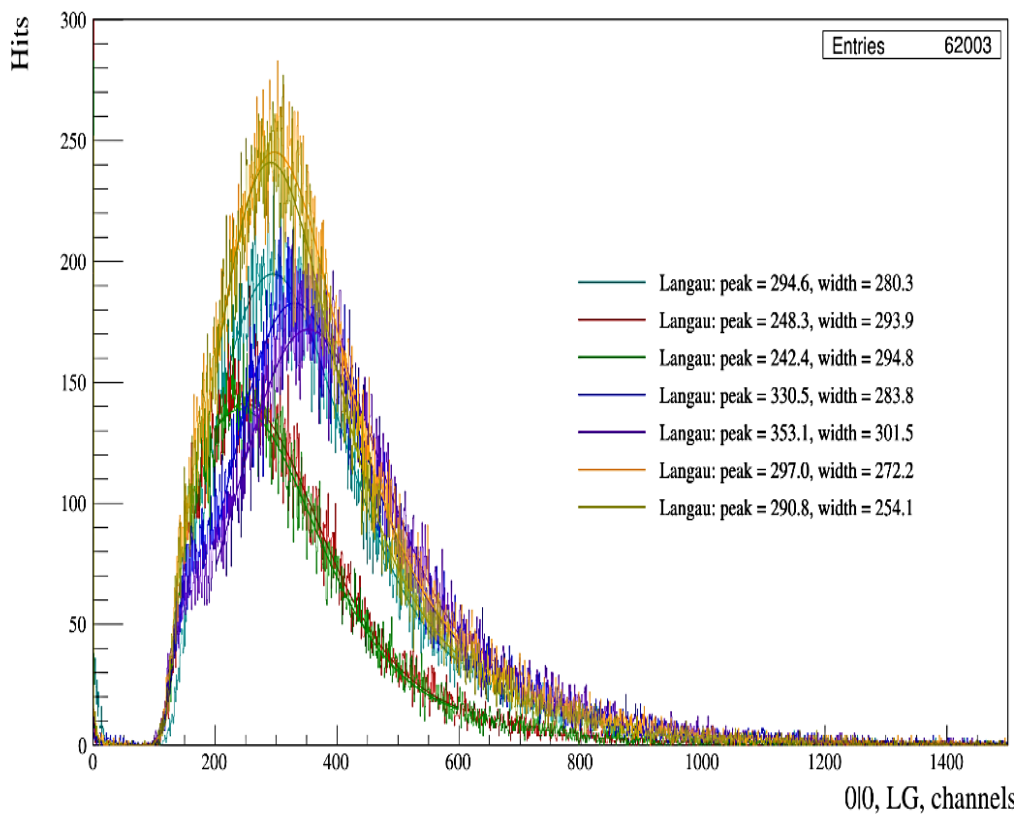
Time Stamp	3600.410 s
Trigger-ID	7332
Trg Rate	2.867 cps
Trg Reject	0.05%
Tot Lost Trg	4
Event Build	0.00%
Readout Rat	258.667 B/s
T-OR Rate	0.000 cps

~4.1k counts/channel

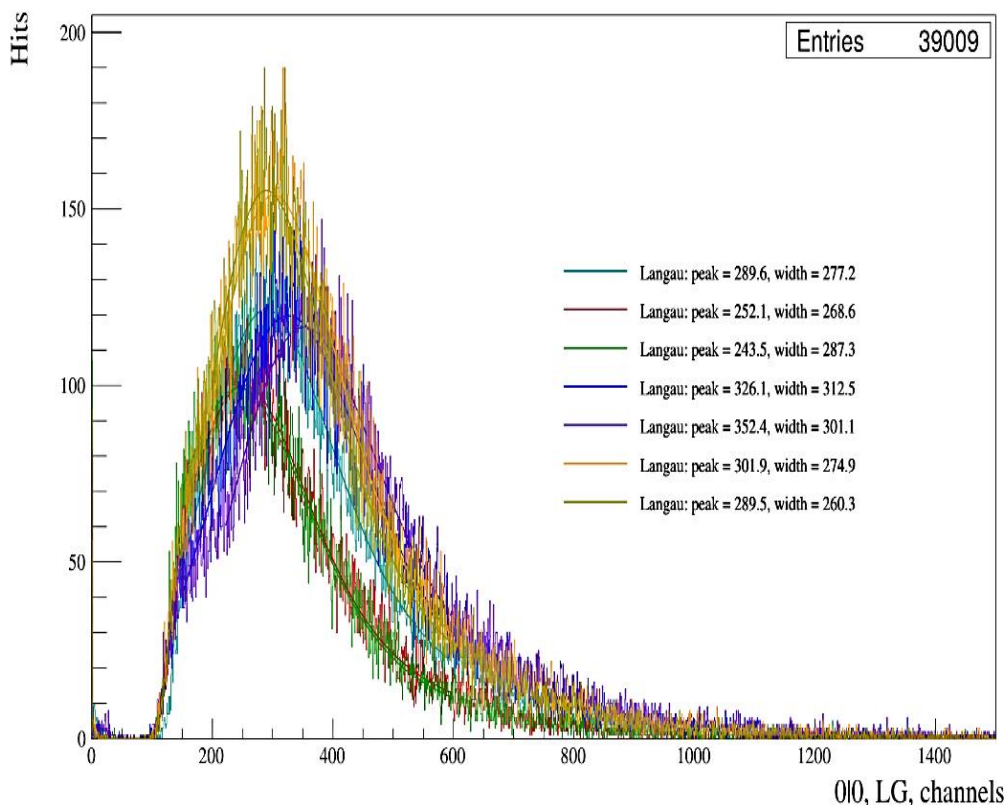
The tests were performed for Hybrid mode with **self-triggering** opportunity. The 2 trigger logic options were tested.

1-st sector

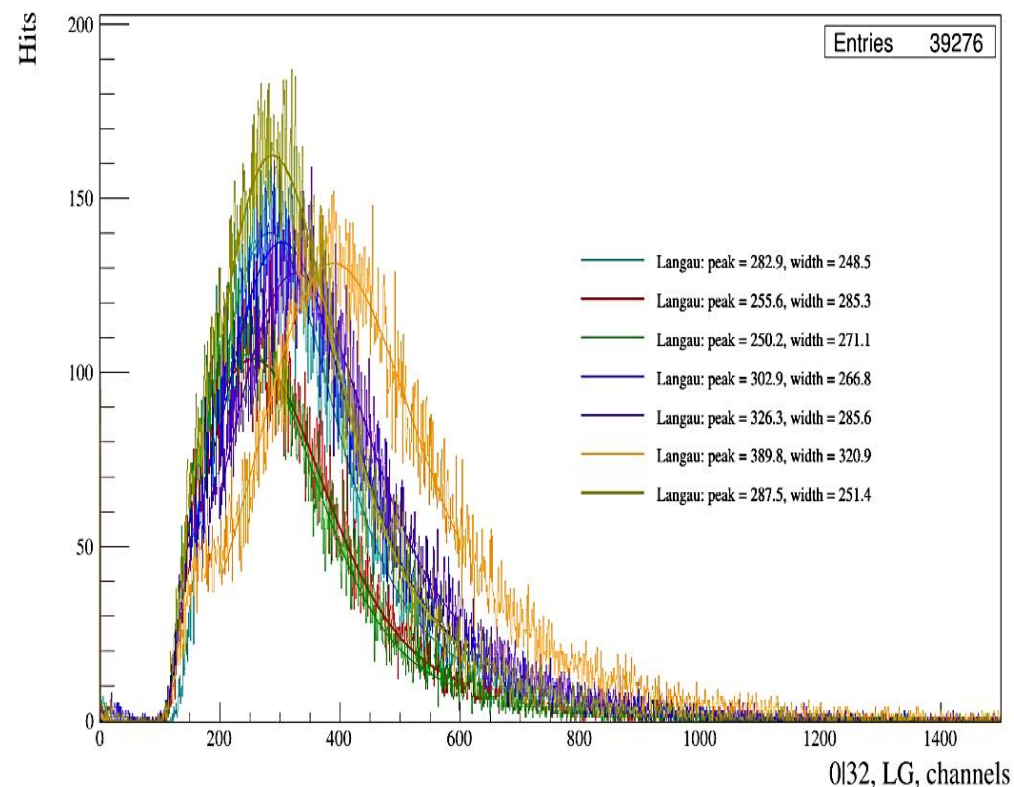
2-nd sector



1-st sector

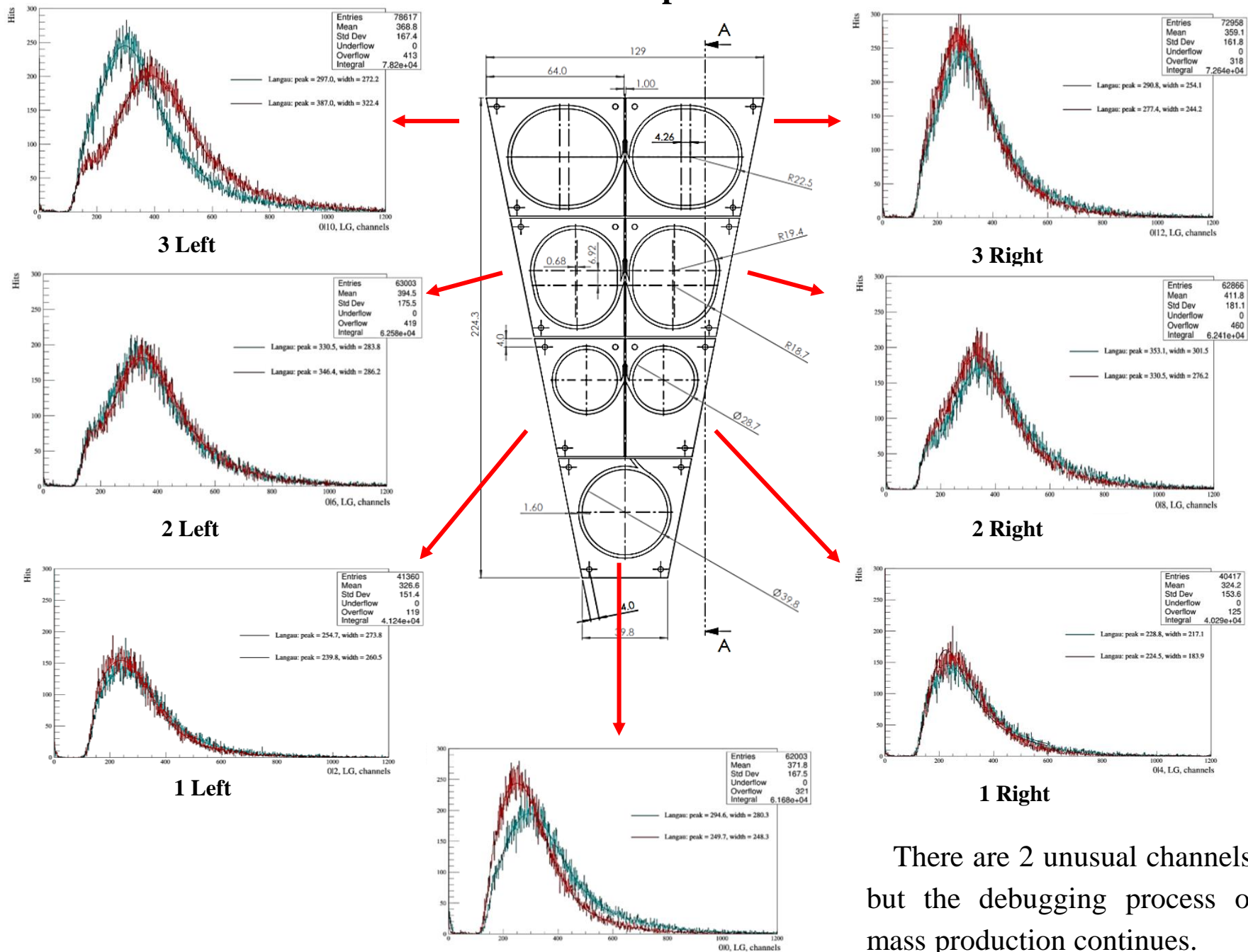


2-nd sector



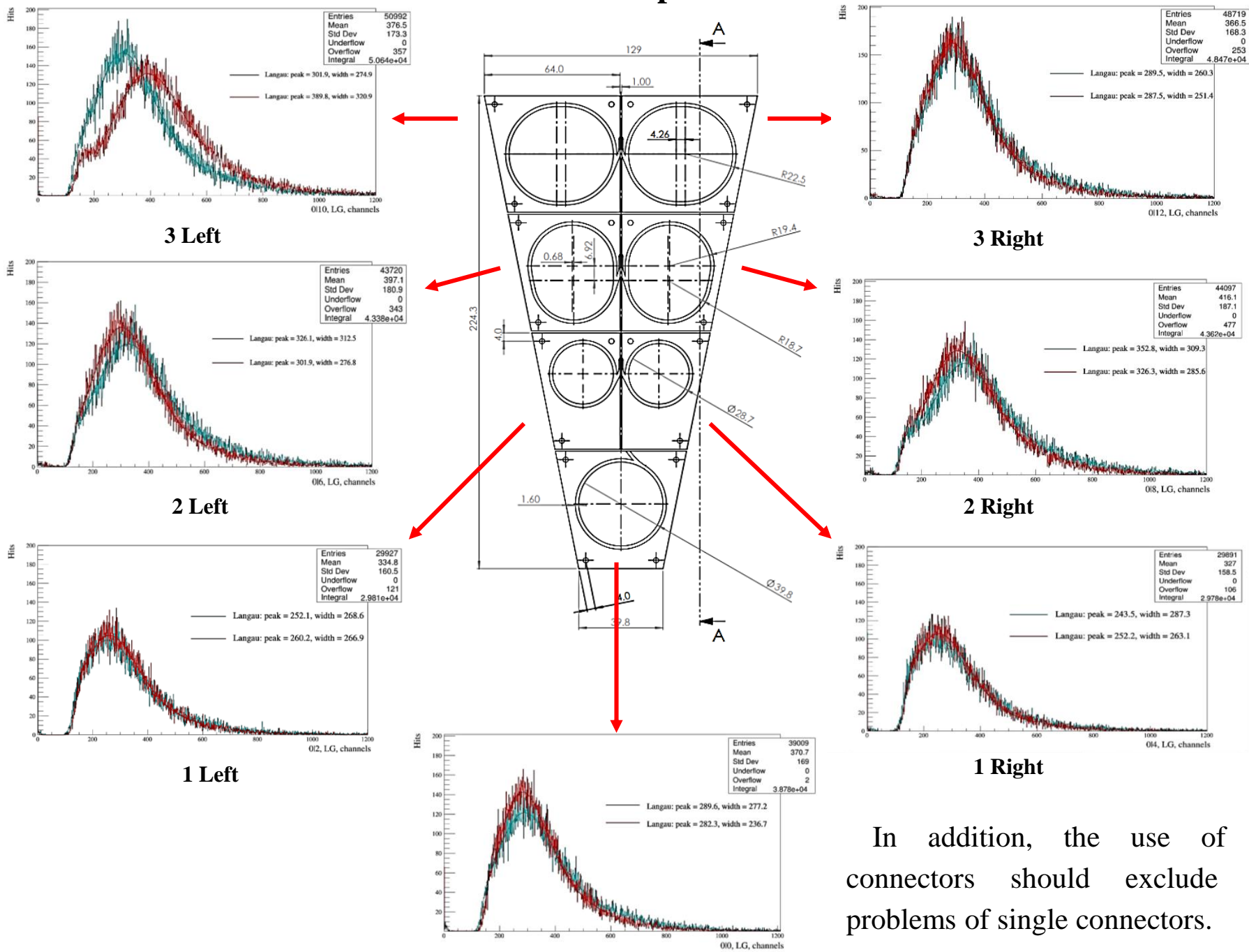
The same spectra are shown for 2-nd trigger logic. In both cases, the signals between the channels are different for each prototype. This is expected, but it is important to compare the pairs that worked.

The radius dependence



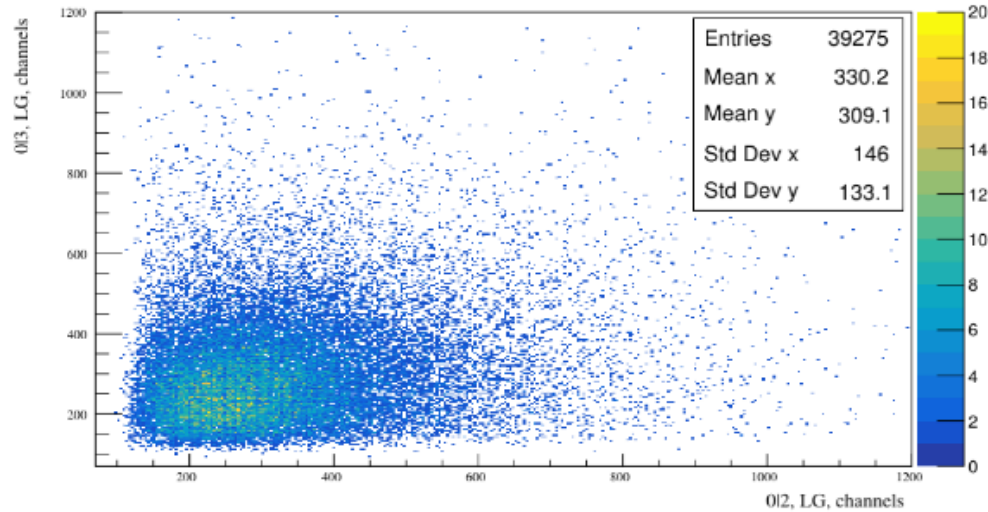
There are 2 unusual channels, but the debugging process of mass production continues.

The radius dependence

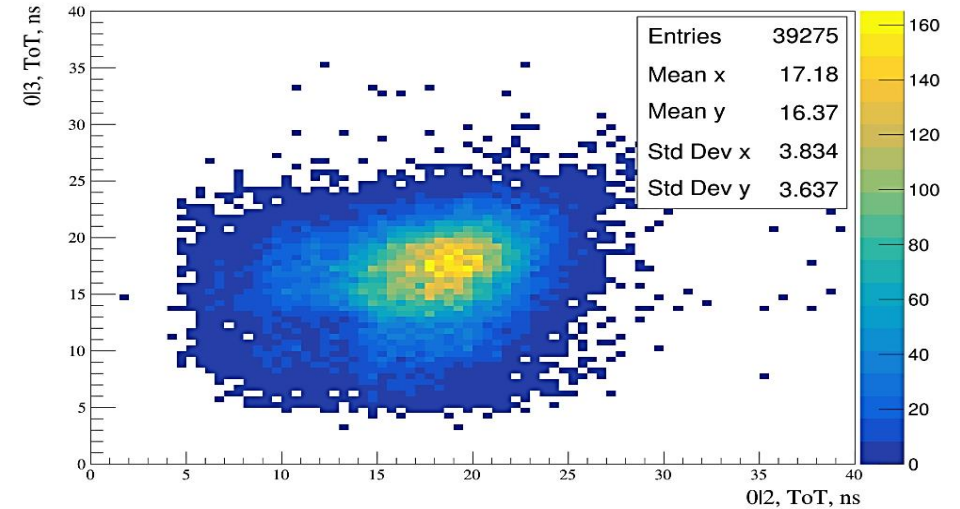


In addition, the use of multi-channel connectors should exclude the possible problems of single connectors.

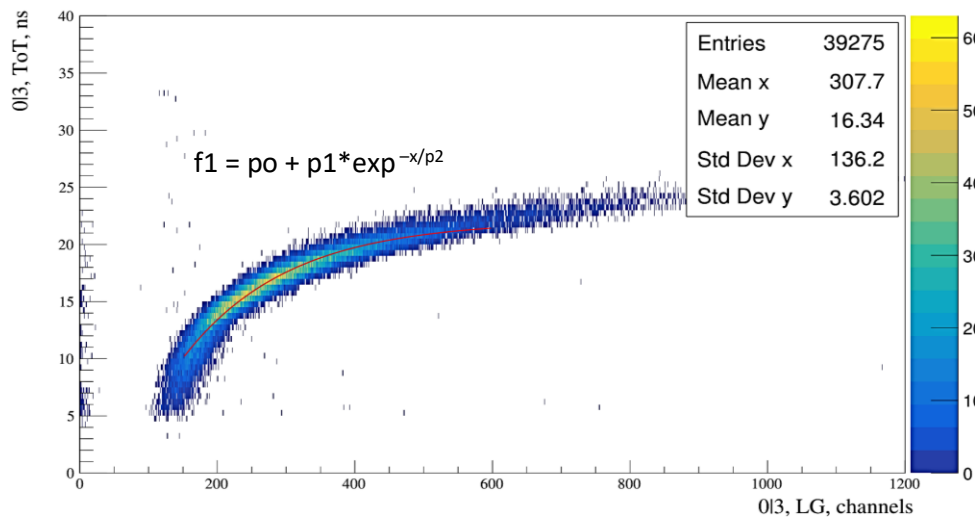
LG correlations



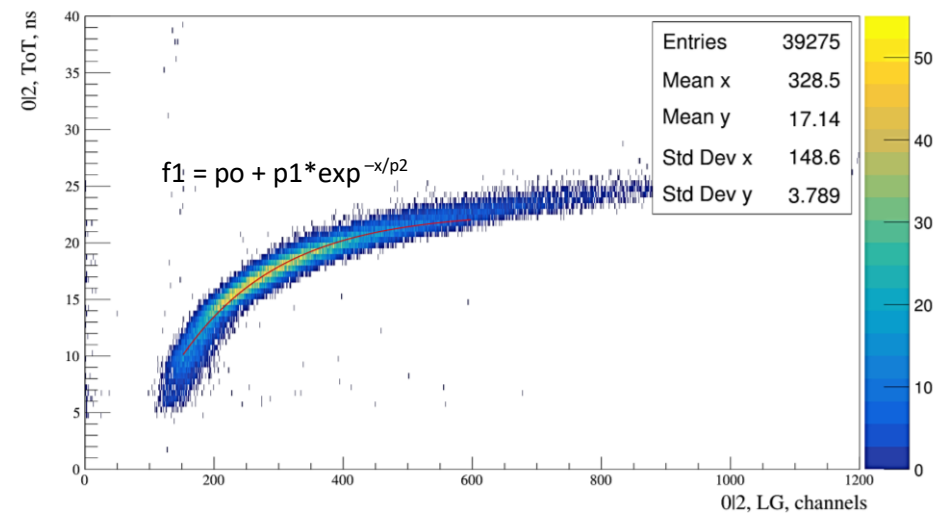
ToT correlations



LG vs ToT (channel №3)



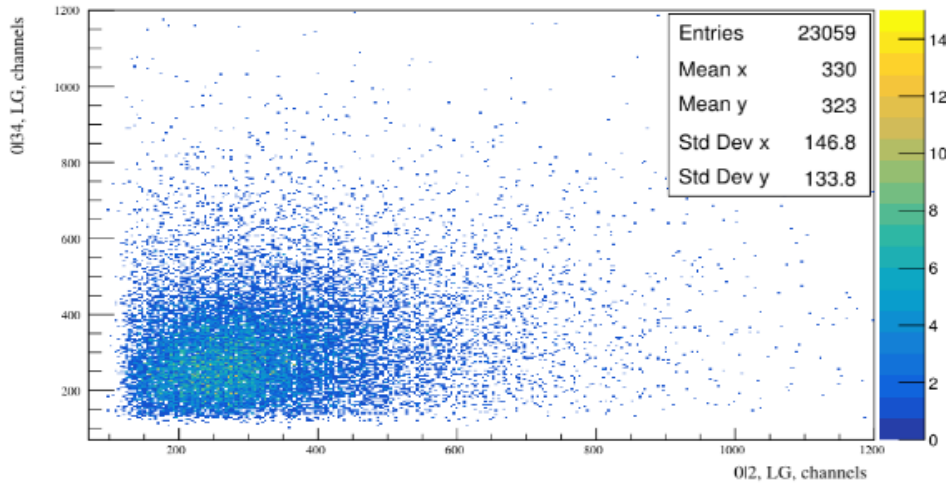
LG vs ToT (channel №2)



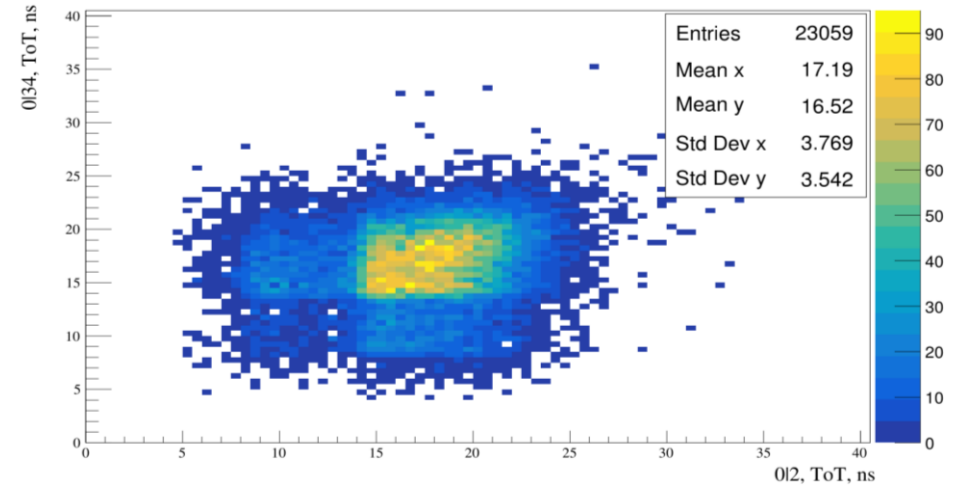
Correlation of energy deposition for 2 channels, as well as the time information for these channels.

- The correction of the ToT is required

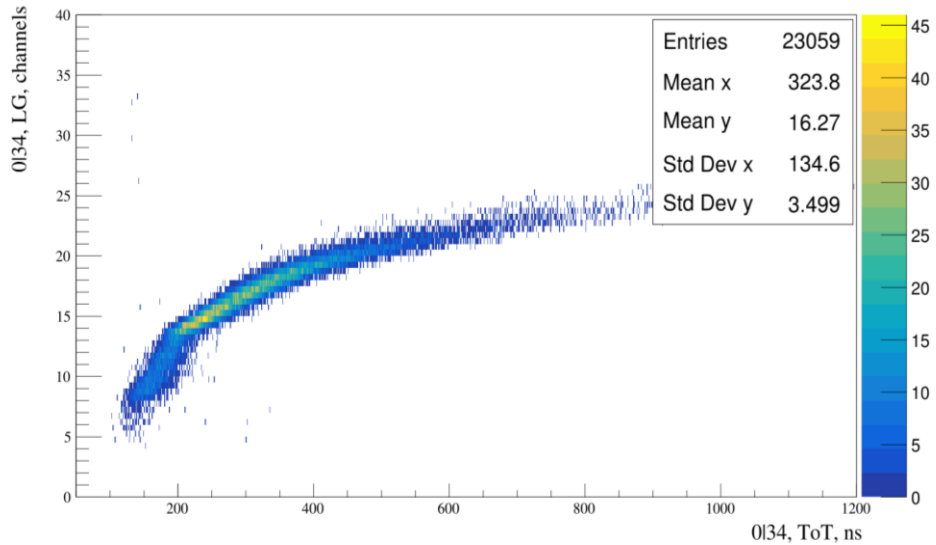
LG correlations



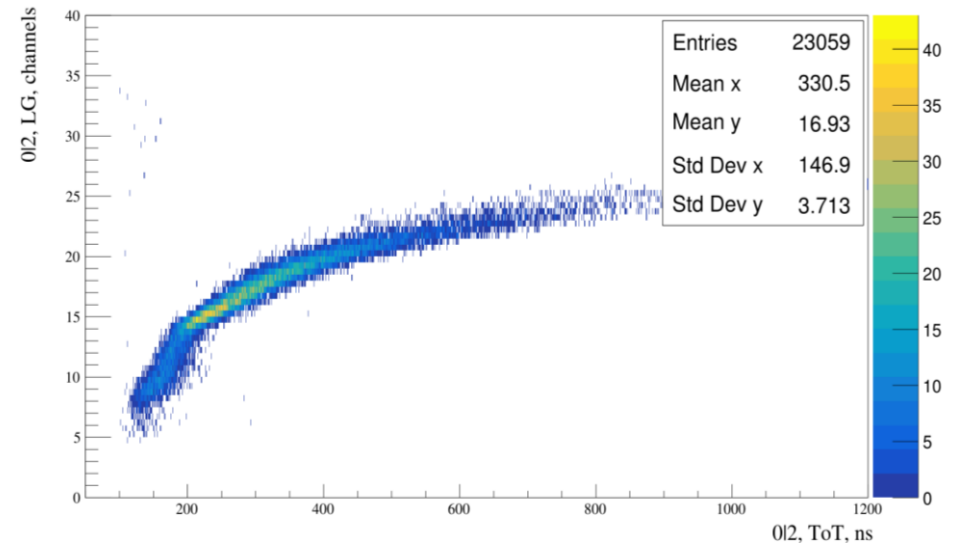
ToT correlations



LG vs ToT (channel №34)



LG vs ToT (channel №2)

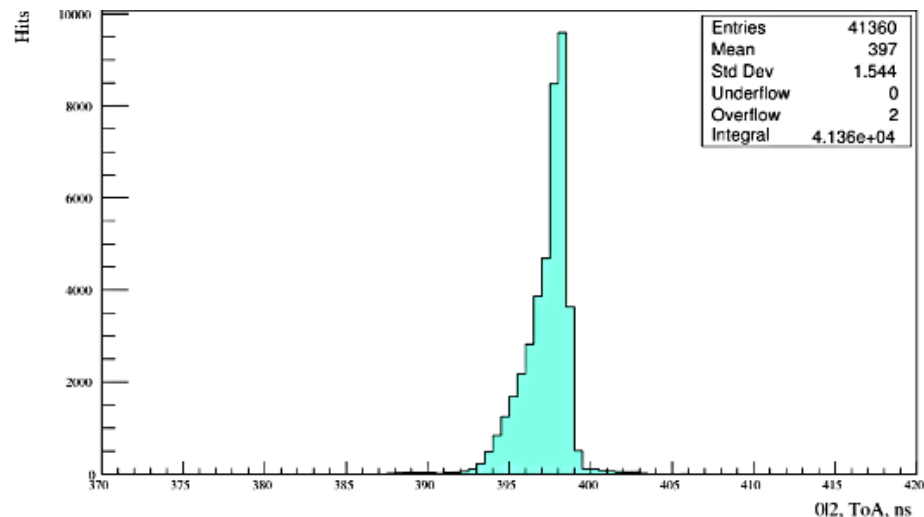


- The optimization of the thresholds is required

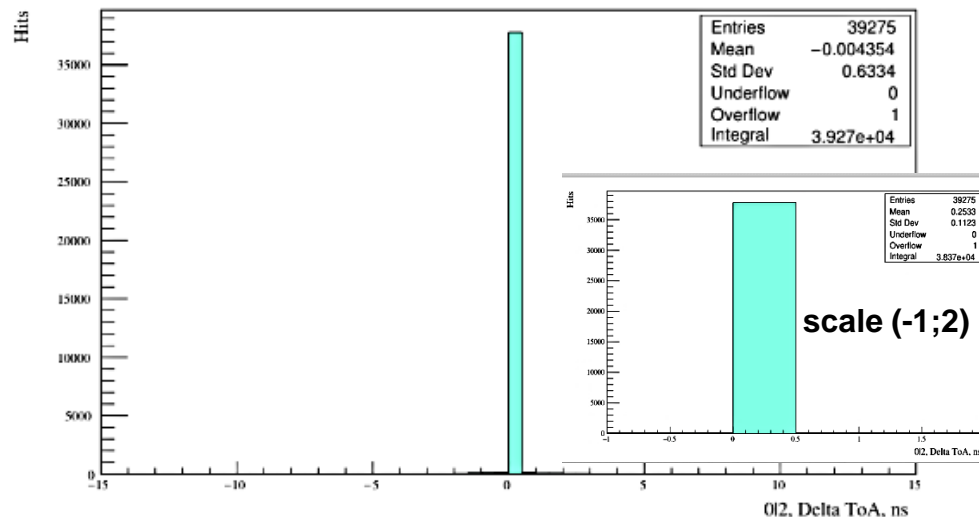
Prototype assembling test part

Time of Arrival (ToA) AND2_OR32

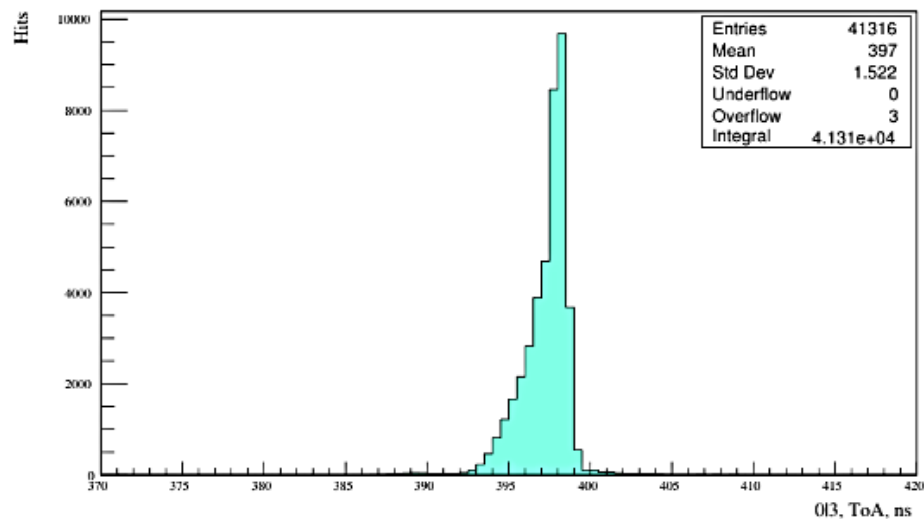
ToA 1 (between a reference signal and the 2-nd input pulses)



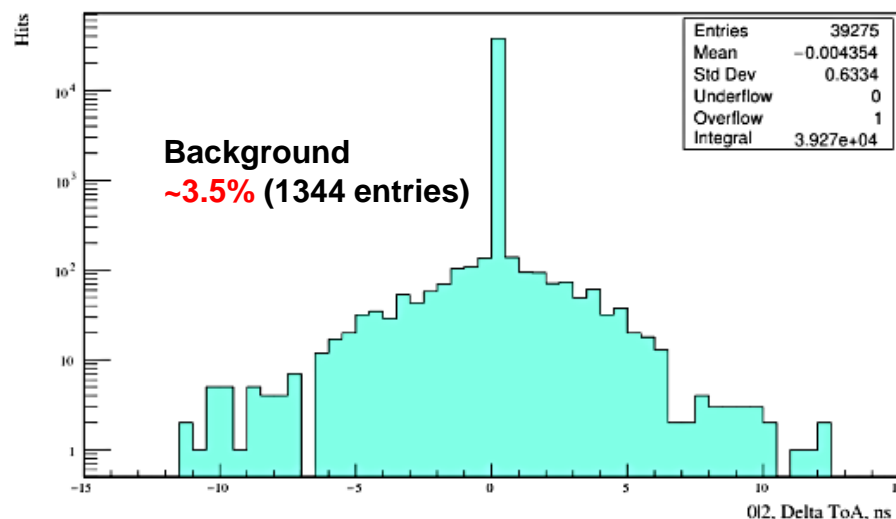
Δ (ToA 1 – ToA 2)



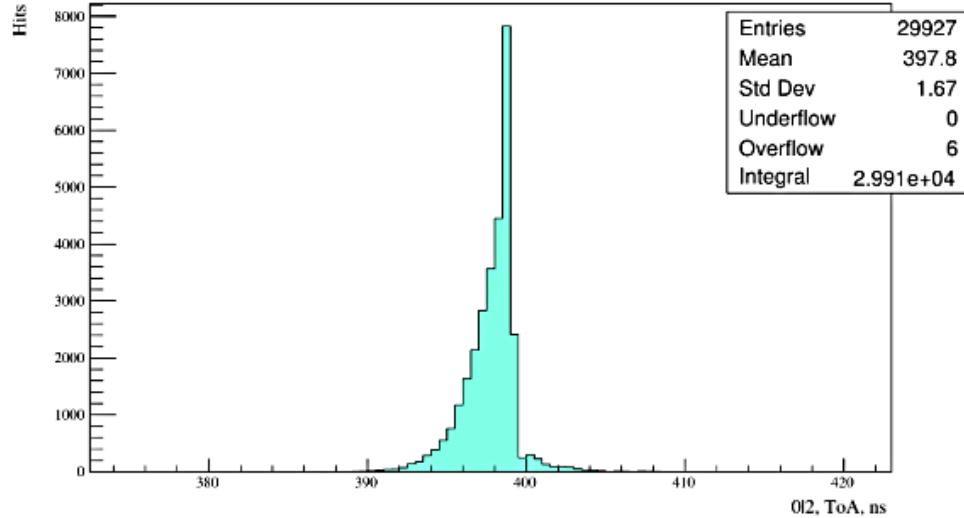
ToA 2 (between a reference signal and the 3-rd input pulses)



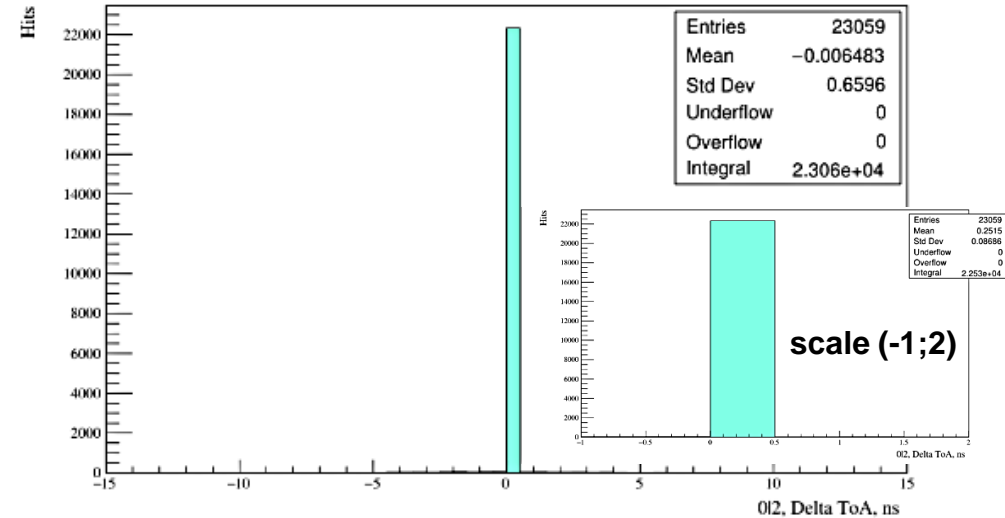
Logarithmic scale of Δ (ToA 1 – ToA 2)



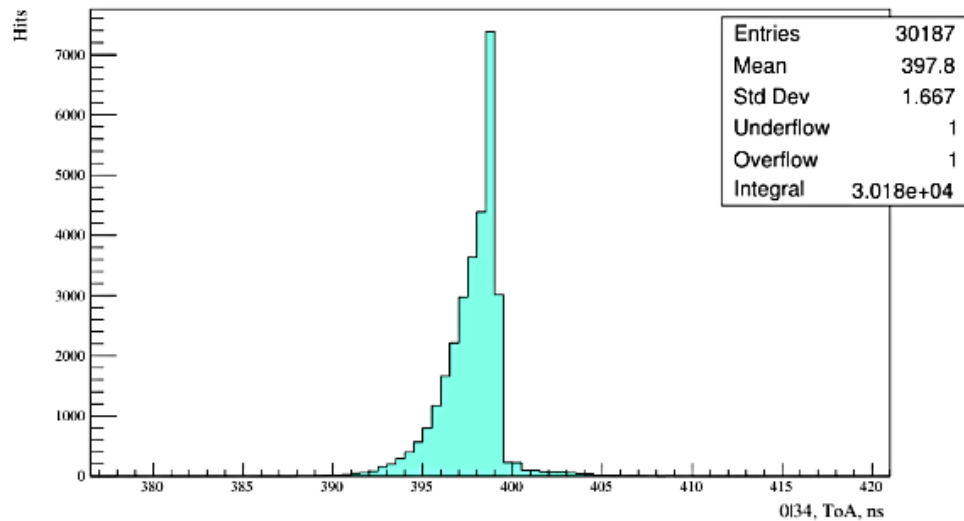
ToA 1 (between a reference signal and the 2-nd input pulses)



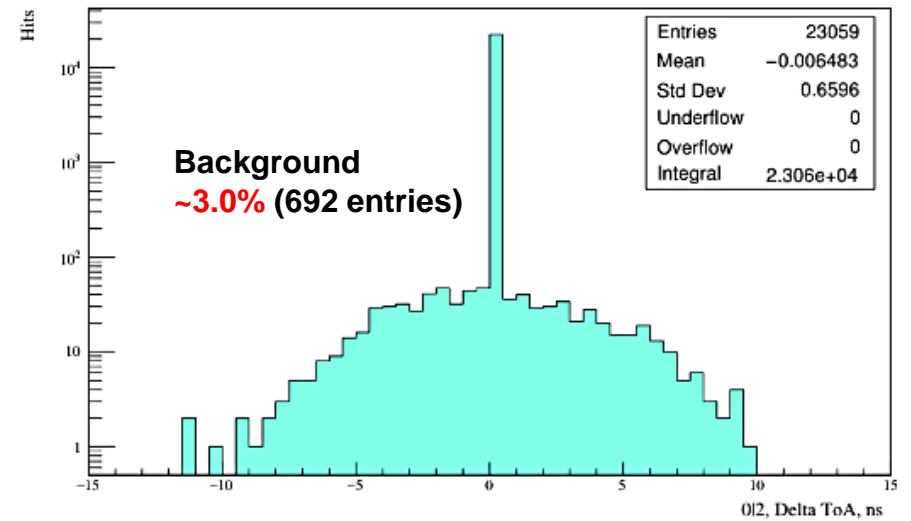
Δ (ToA 1 – ToA 2)



ToA 2 (between a reference signal and the 34-th input pulses)



Logarithmic scale of Δ (ToA 1 – ToA2)



- I. The scintillation detector prototype tests with CAEN FERS-5200 system has been started.
- II. The tests were performed for Hybrid mode with **self-triggering** opportunity. Several trigger logic options were tested. The first results of Citiroc 1A chips synchronization are promising. The tests with several DT5202 boards are in progress.
- III. The result for the ToT function has been presented. Correction of the ToT function and optimization of thresholds are required.

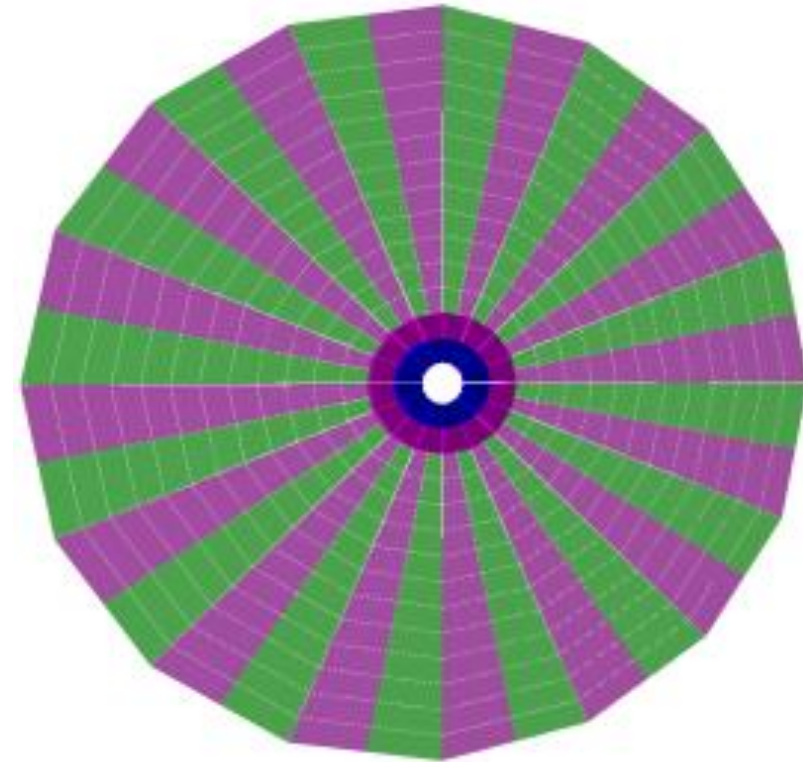
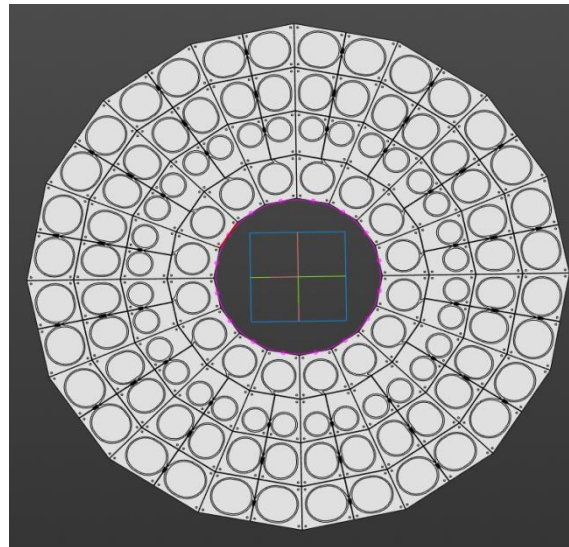
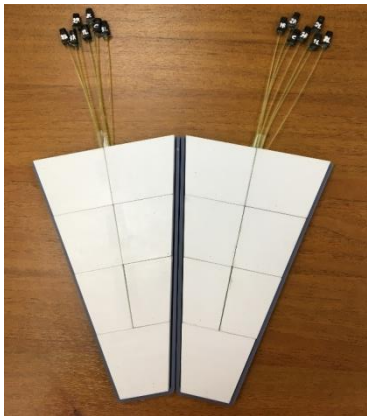
To do list

- Tests with several DT5202
- obtain the optimal thresholds
- obtain the temperature coefficient

Thank you for the attention!

Backup

M
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1-st Stage
14 tiles (16?)

2-nd Stage
2 wheels with 112 tiles each (128?)

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

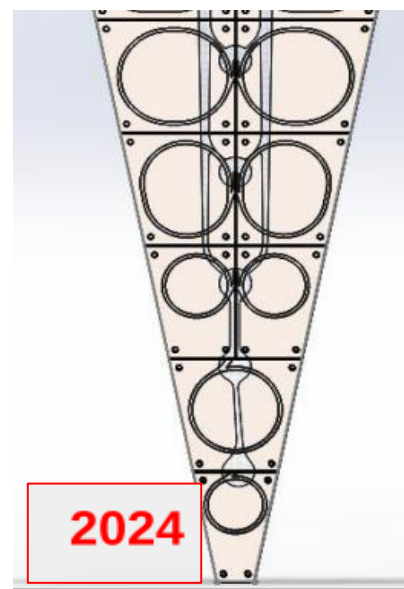
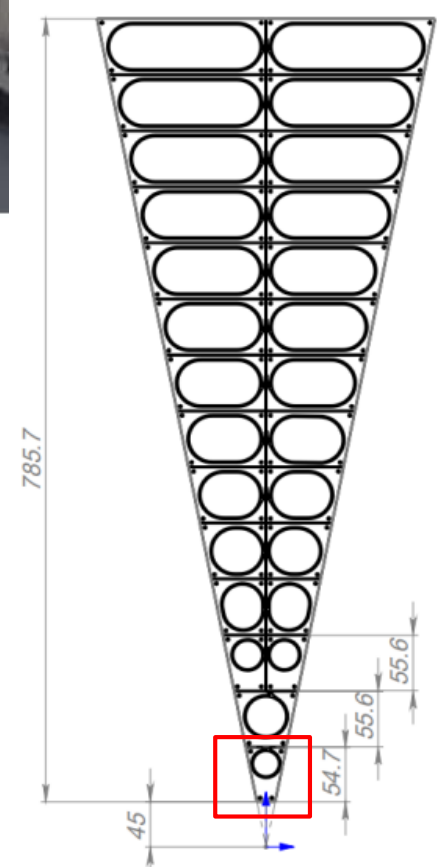
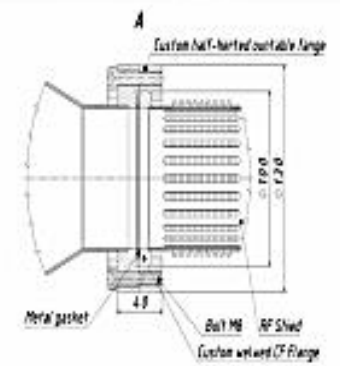
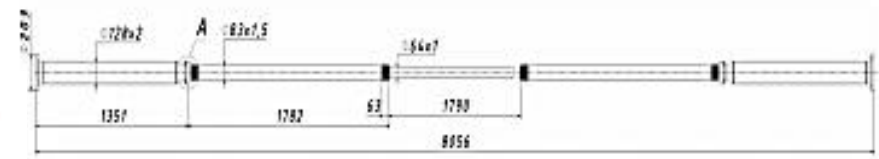
Phase 0

Phases: 1-st & 2-nd

Extended design

Additional tile for sector. The 8-tiles prototype.

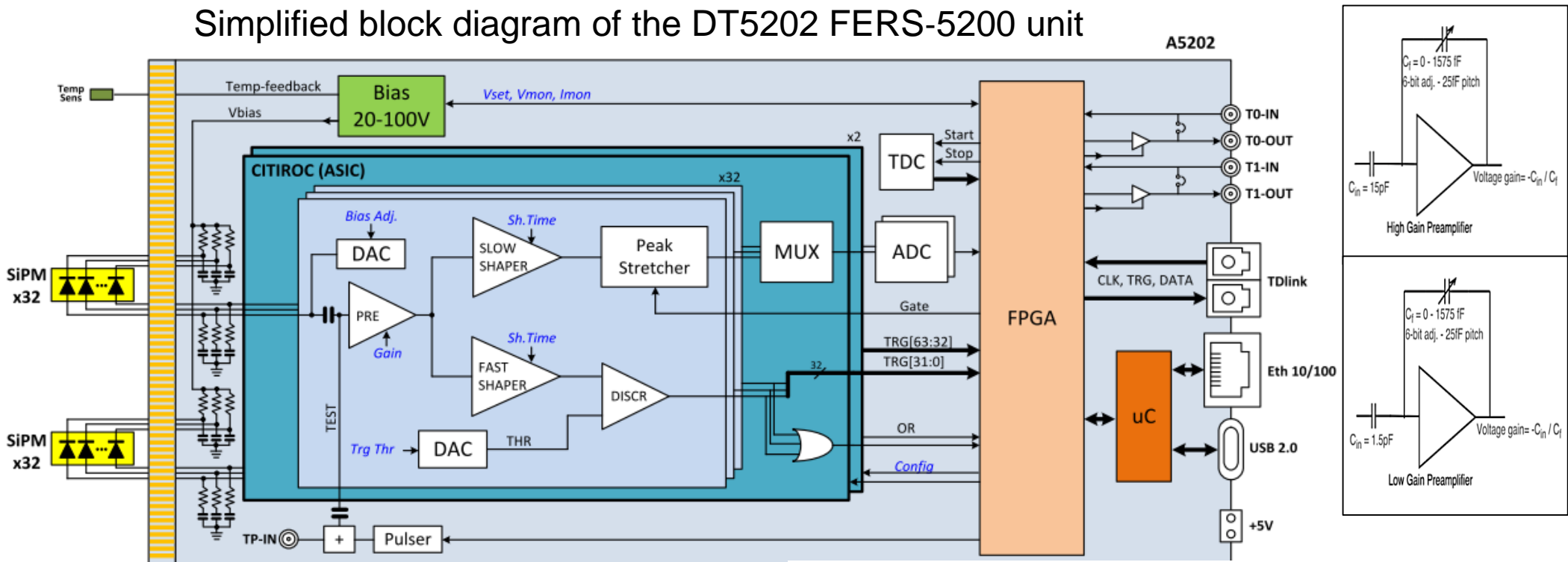
**Now : 124 mm diameter
Need: 83 mm diameter**



We get the opportunity to use an additional tile due to the diameter decreases of the beam pipe.

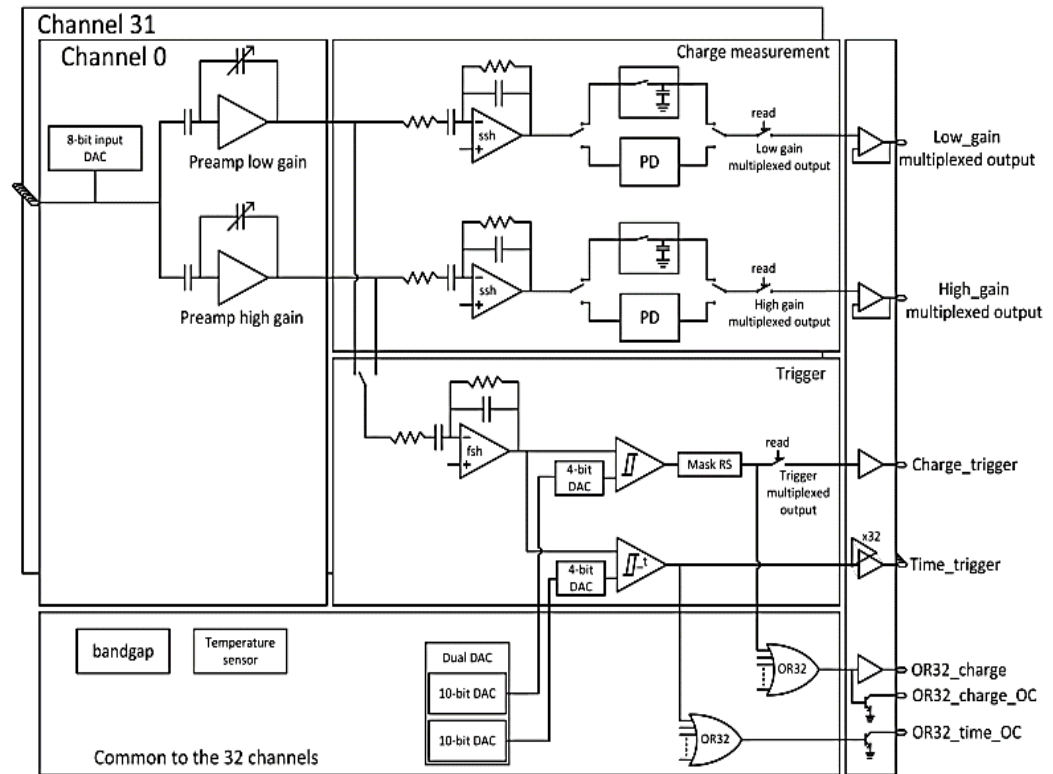
- ❑ One of the plans for this year is to assemble and test 8-channel prototypes with new mechanics.

Simplified block diagram of the DT5202 FERS-5200 unit



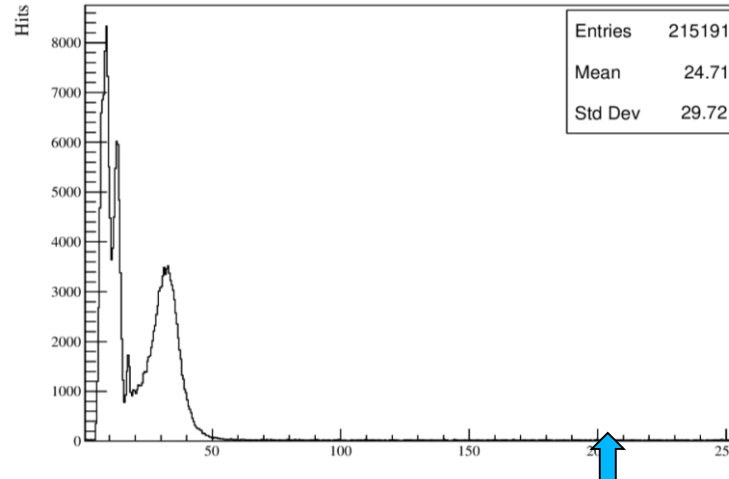
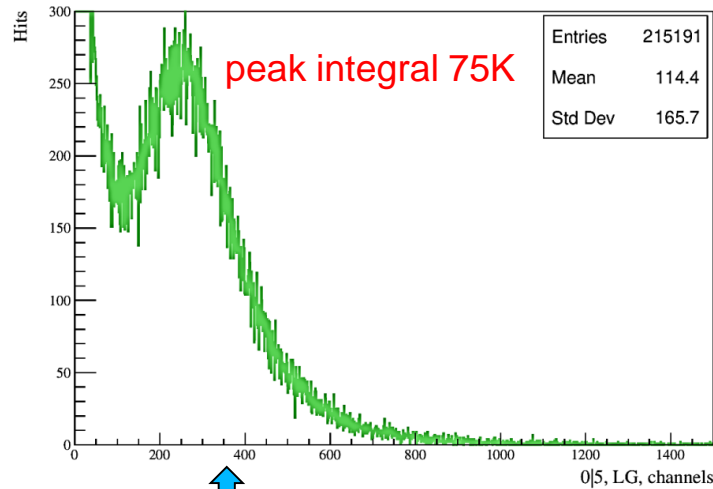
❑ Triggers of consecutive channels are sent to an AND logic operator (e.g. CH0&CH1, CH2&CH3, etc.). The 32 outputs are then sent to an OR logic operator.

❑ OR32_AND2: Triggers of each Citiroc-1A (32 channels each) are sent to an OR logic operator. The 2 output signals (one for each Citiroc-1A) are then sent to a logic AND operator.



T-Discriminator Threshold = 200 (for **HG**)

3.27 Gb/hour



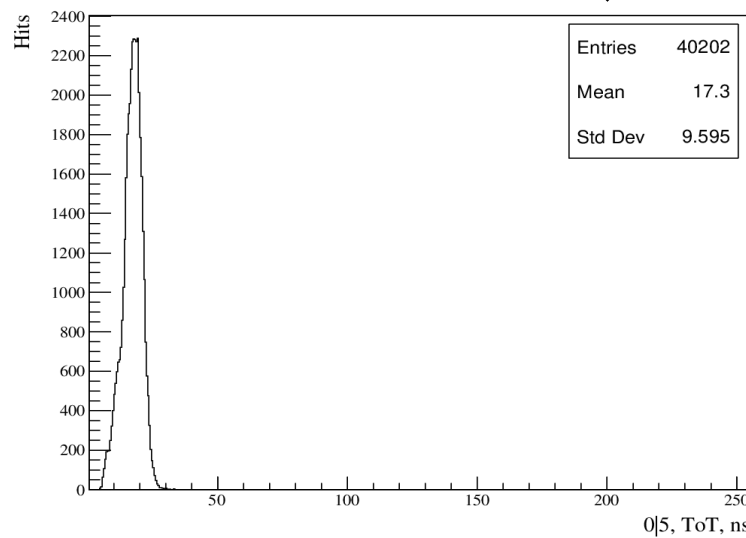
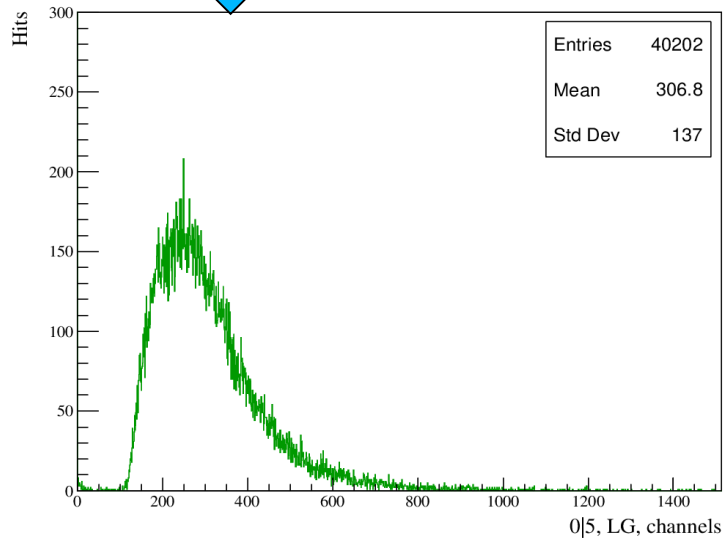
The comparison of the amplitudes and ToT histograms depending on the T-Discriminator thresholds.

↑
LG
↓

T-Discriminator Threshold = 200 (for **LG**)

↑
ToT
↓

<1 Mb/hour



FEE studies results

Saint-Gobain Crystals vs KURARAY fibers difference. (CKTN optical cement)

Saint-Gobain Crystals fibers

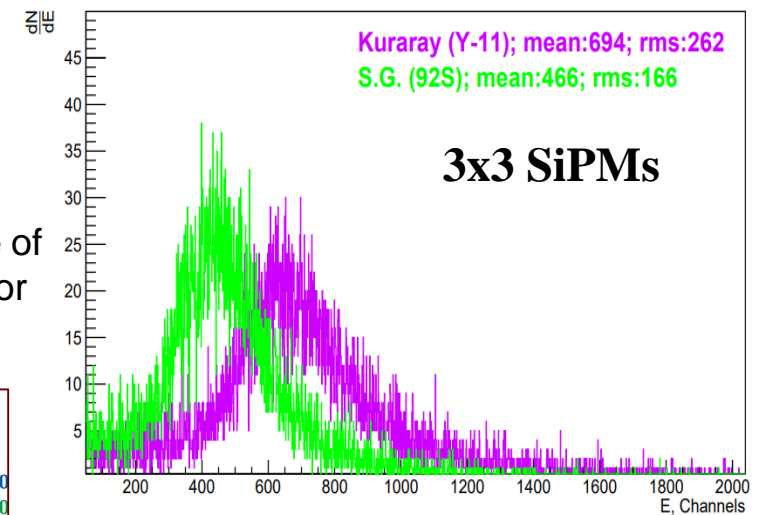
Specific Properties of Standard Formulations				
Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	# of Photons per MeV**
BCF-10	blue	432	2.7	-8000
BCF-12	blue	435	3.2	-8000
BCF-20	green	492	2.7	-8000
BCF-60	green	530	7	-7100
BCF-91A	green	494	12	n/a
BCF-92	green	492	2.7	n/a
BCF-98	n/a	n/a	n/a	n/a

** For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity

KURARAY fibers

Description	Emission			Absorption Peak[nm]	Att.Leng. ²⁾ [m]	Characteristics
	Color	Spectra	Peak[nm]			
Y-7(100)	green	See the following figure	490	439	>2.8	Blue to Green Shifter
Y-8(100)	green		511	455	>3.0	Blue to Green Shifter
Y-11(200)	green		476	430	>3.5	Blue to Green Shifter (K-27 formulation) Long Attenuation Length and High Light Yield
B-2(200)	blue		437	375	>3.5	UV to Blue shifter
B-3(200)	blue		450	351	>4.0	UV to Blue shifter

Kuraray Y-11 fiber collects more photons



Light collection peak position on dependence of A component amount for optical cement.

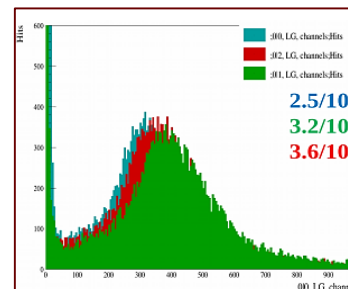


Table 1. Optical cements and their parameters

Brand	Viscosity, cPs	Operating temperature range	Spectral characteristics	Refractive index
EJ-500	800	From -65 to +105 °C	60-95% at 300-350 nm 95-100% at 350-600 nm	1.574
CKTN MED Mark E	15 · 10 ³	—	92-96% at 500 nm	1.606
OK-72	—	From -60 to +60 °C	99% at 400-2700 nm	1.587