BBC status report. Plans fo 2024.

V.P.Ladygin on the BBC SPD group

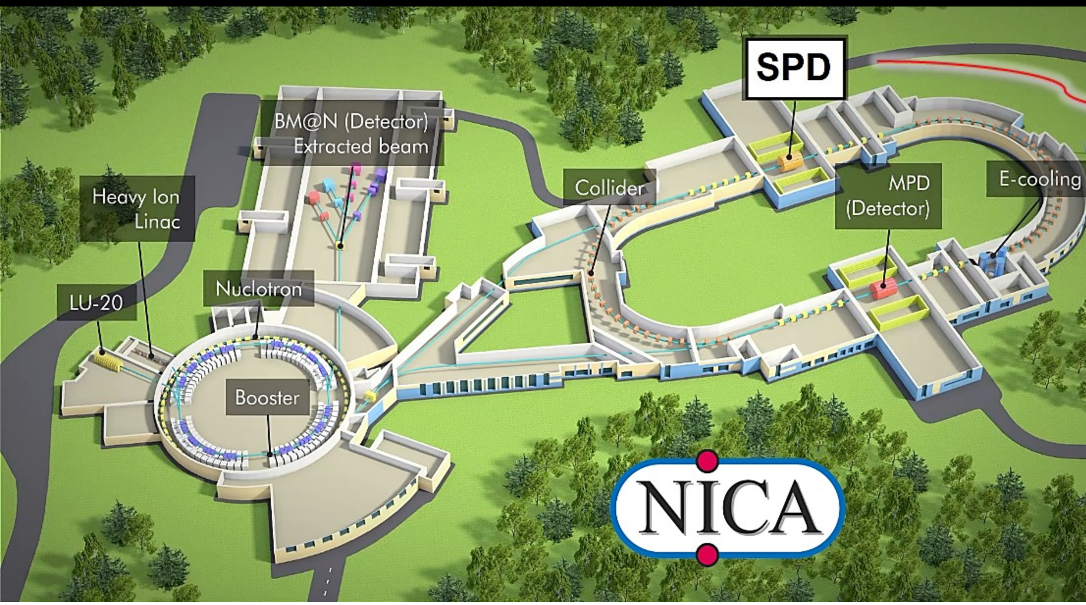
BBC group:
VBLHEP: 7 +1 (HI simulation?)
DLNP: (J.K., I.D.-simulation)
MEPhI: about 10

SPD WG Hardware Meeting

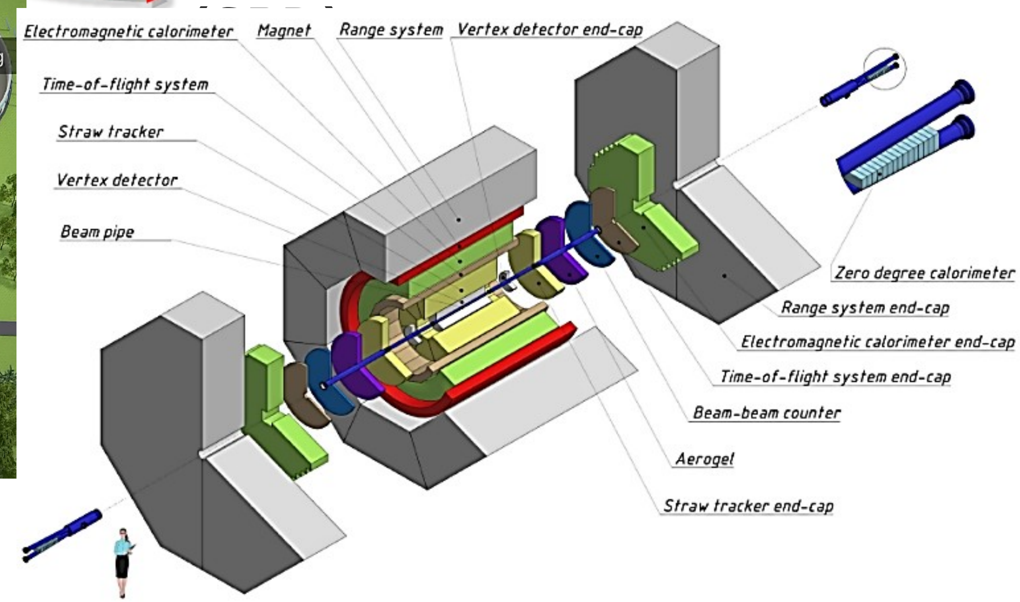
15 February 2024

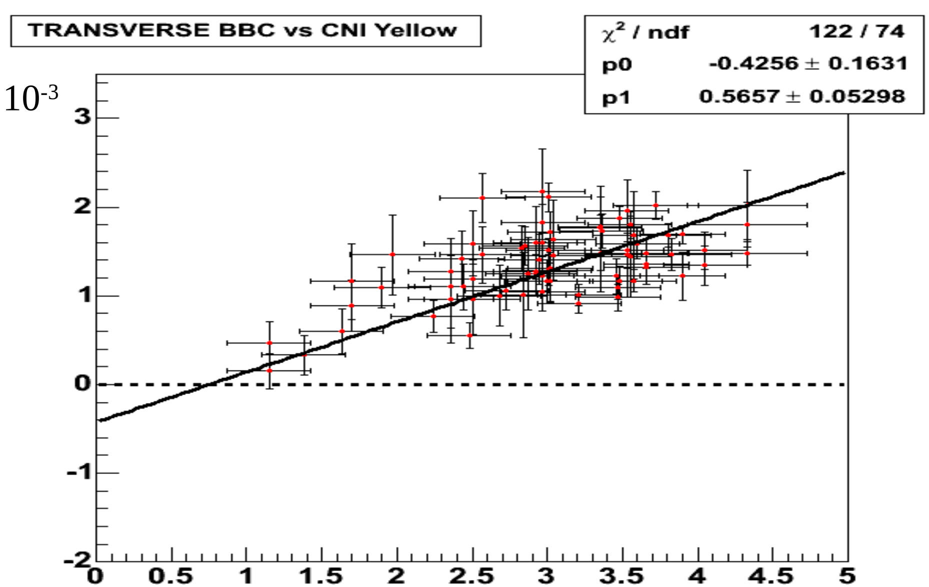
Introduction

General



The Spin Physics Detector





Correlation between CNI polarimeter and STAR BBC asymmetries.

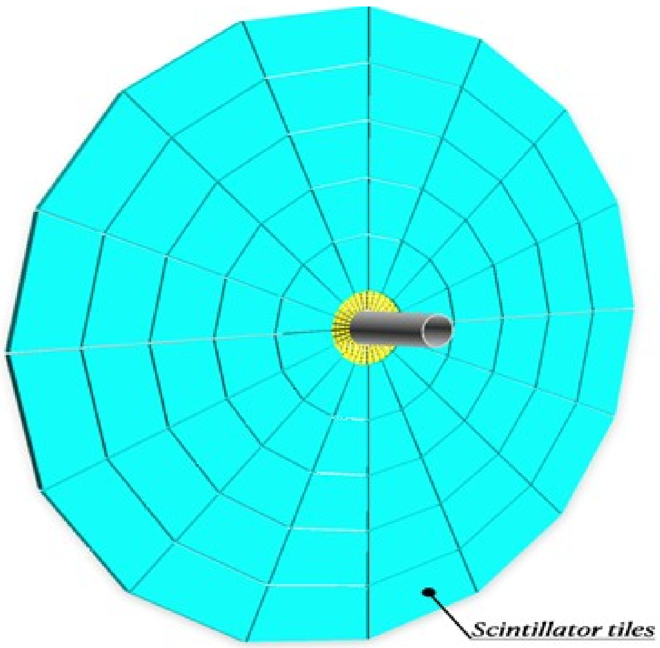
The Beam-Beam Counters (BBC) for SPD

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

+ event plane detector for HI physics.

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

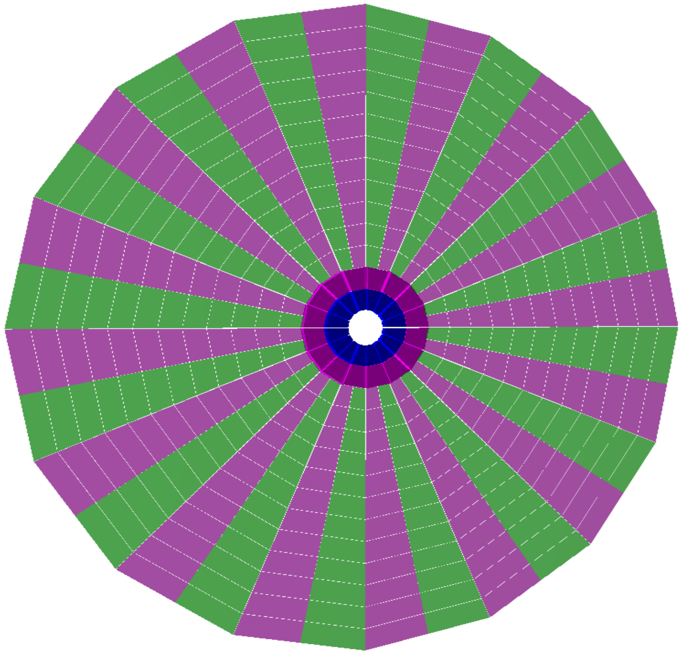
TDR versions of BBC



TDR 2022

96 tiles

local polarimetry



TDR 2023

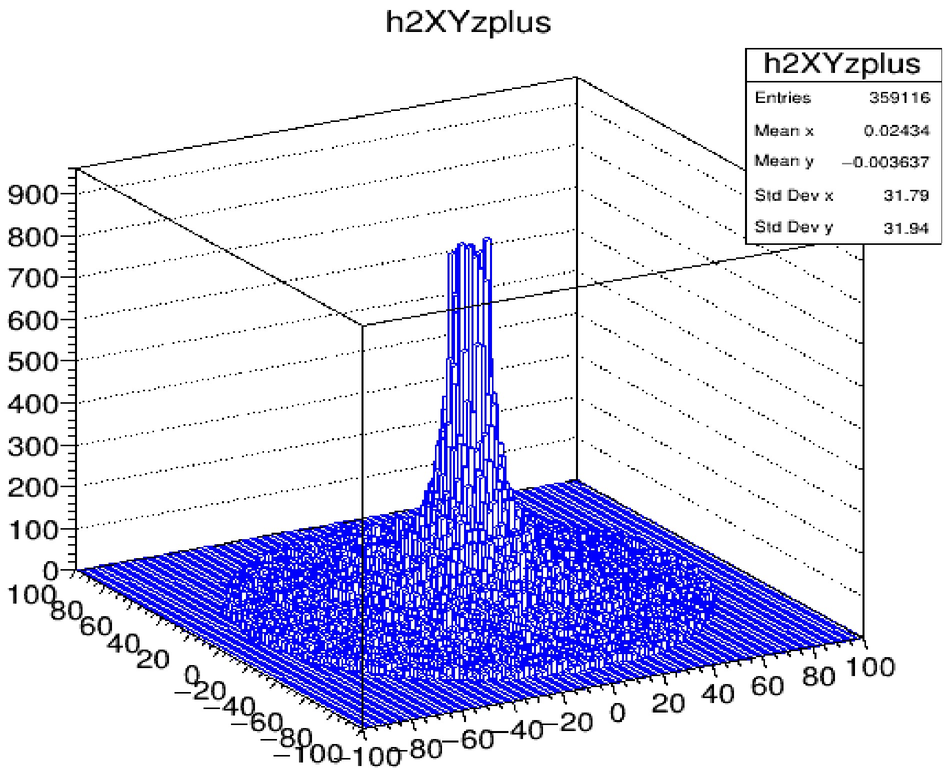
400 tiles

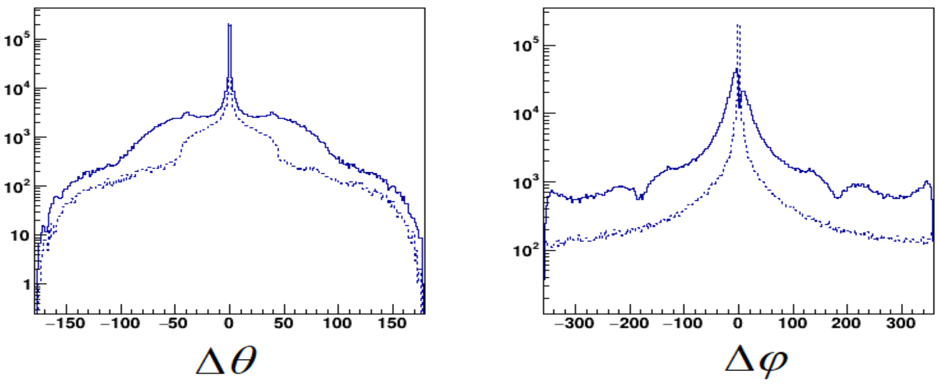
local polarimetry

Event plane determination

Simulation (pp)

New geometry and MF effect





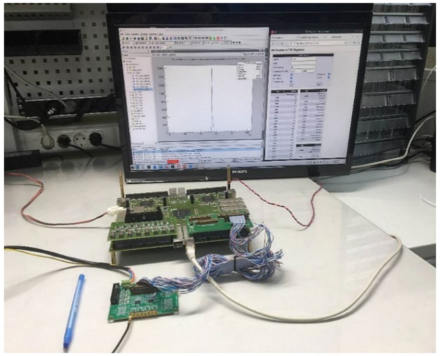
Magnetic Field effect is under study.

BBC software meeting
15-16 February 2024

Geometry in the SPDRoot

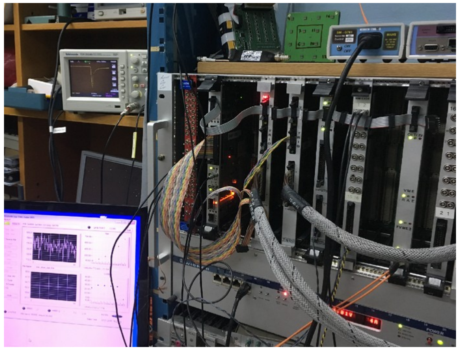
Stands for BBC measurements

TRB-3 (10 ps)



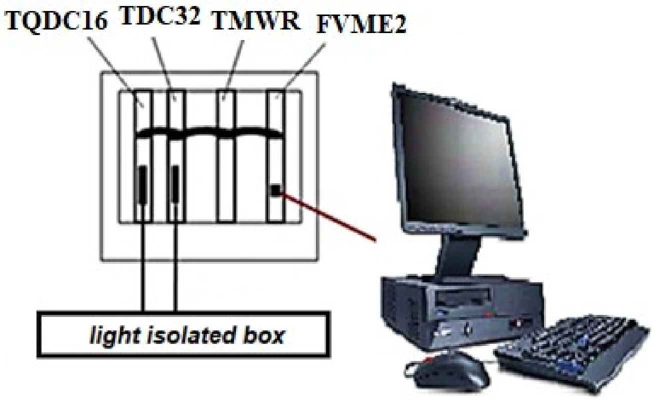
Together with **V.Chmil (JINR), S.Morozov, E.Usenko (INR)**

The VME based DAQ

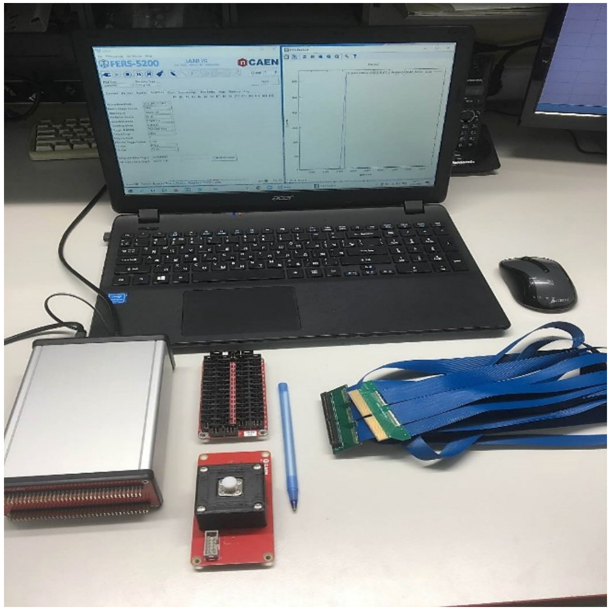


Isupov A.Yu. // EPJ Web Conf. 2019. V.10003. P.204

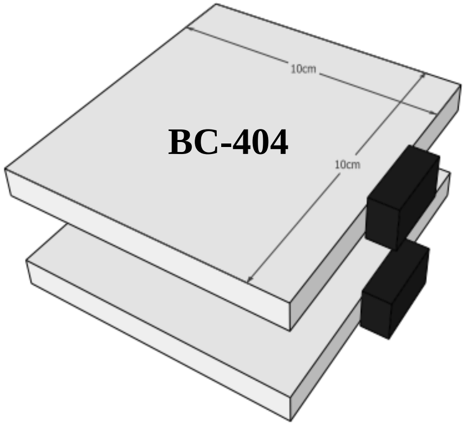
TQDC16



CAEN FERS 5200

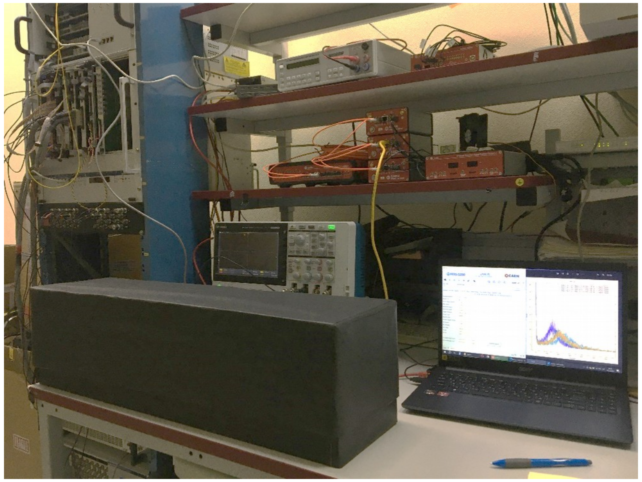


External trigger by coincidence of two scintillators with PMTs readout



PMT Hamamatsu H10720-110

The stand for BBC

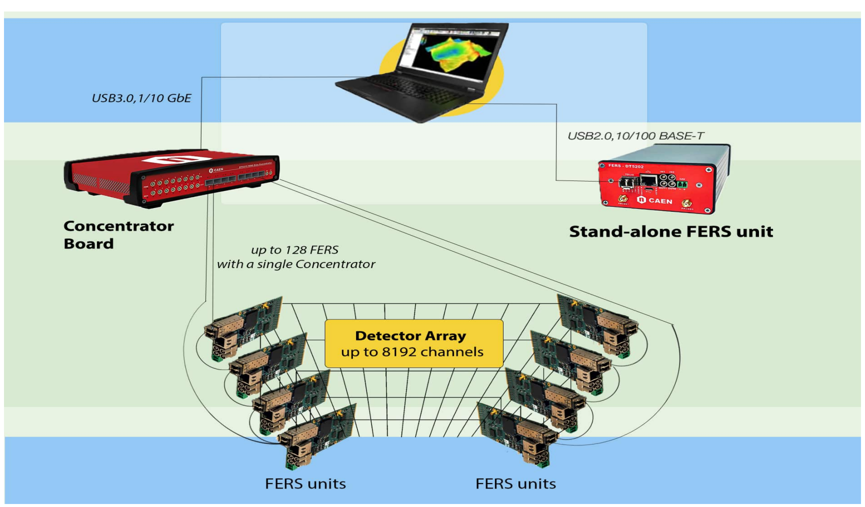


The hardware of BBC tests part

CAEN FERS-5200 readout system

FERS-5200 is an extendable high speed front-end readout system based on the **DT5202 64-channel module** for SiPM.

Concentrator **DT5215** for the possibility of expanding the number of channels to 8192.



Fine for testbeam and Phase0 experiments.

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).

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

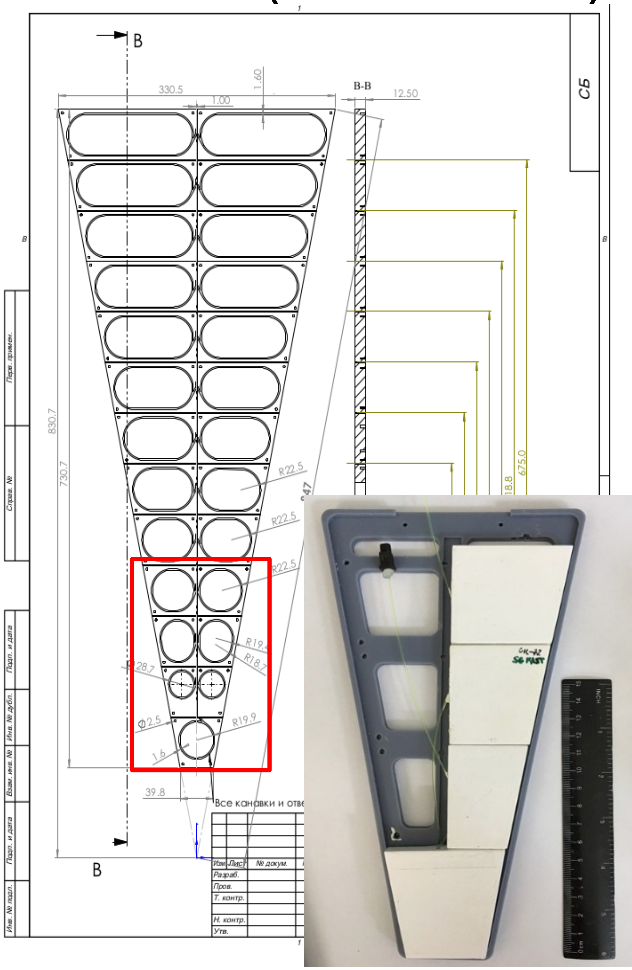
Main Acquisition Modes:

- SPECTROSCOPY.
- TIMING.

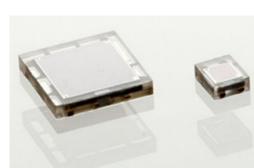
SPECT_TIMING. The Spectroscopy + Timing

Proposal for prototype BBC design

Tile height 55.7 mm
25 tiles in sector (similar to STAR EPD)



Currently, the selection of materials for the build of 7 detector prototype sector tiles is underway



The BBC prototype options:

- **CAEN FERS-5200 readout system**
- the sets of 7-tiles scintillator (**thickness 10 mm**)

prototypes were produced by Uniplast (Vladimir)

  - 6 sets with chemical **mating**
  - 6 sets polished (Tyvek covered)

- scintillation optical fibers (WLS and clear)
  - KURARAY
  - Saint-Gobain Crystals
- optical cements
  - CKTN Med E
  - OK-72

SENSL SiPMs (MicroFC-x0035-SMT)

  - **1x1 mm²**

Scintillation detector prototype materials

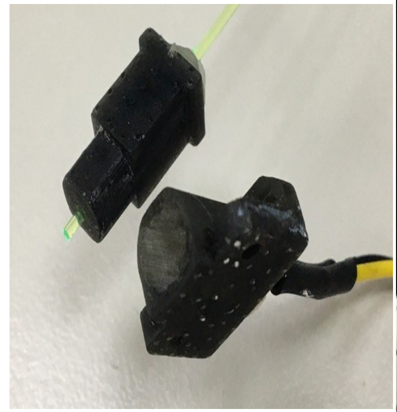
Line

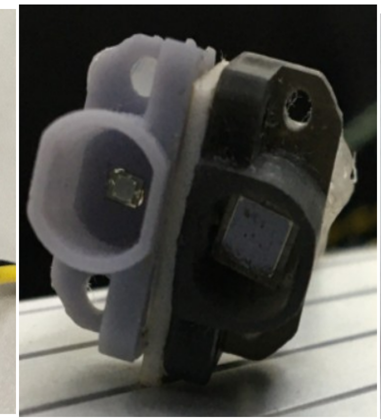
3 (L;R)

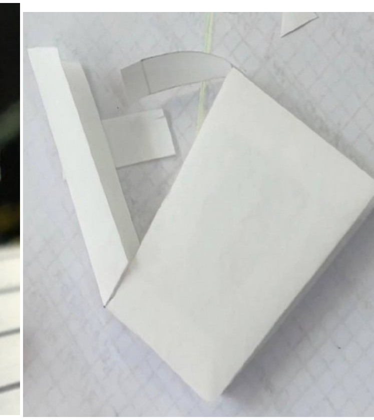
2 (L;R)

1 (L;R)

central







Materials selection (scintillator, optical cement, fibers, etc) and prototype tiles testing with material combinations.

Scintillator: **Matte vs Tyvek covered**

Optical cement: **CKTN Med vs OK-72**

Fibers: **Saint-Gobain Crystals (SG91AS, SG92S)**

vs

KURARAY (Y-11)

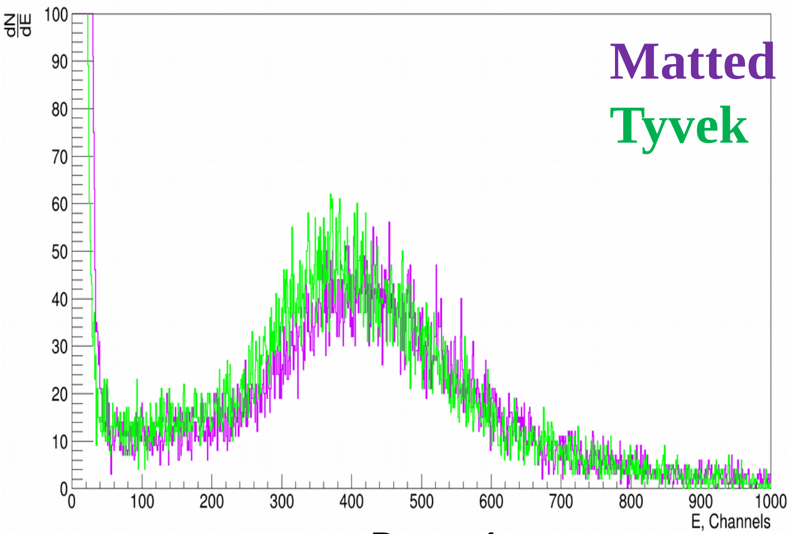
SiPMs: **SENSL 1x1 mm^2 (main option 2023)**

Table 1. Optical cements and their parameters

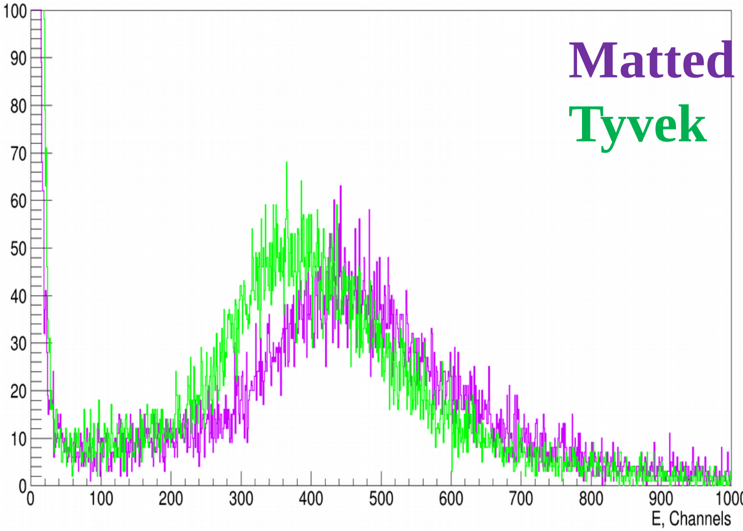
Brand	Viscosity, cPs	Operating temperature range	Spectral characteristics	Refractive index
EJ-500	800	From -65 to +105 °C	60-95% at 300-350 nm 95-100% at 350-600 nm	1.574
CKTN MED Mark E	$15 \cdot 10^3$	—	92-96% 500 nm	1.606
OK-72	—	From -60 to +60 °C	99% at 400-2700 nm	1.587

Material selection: Cover and WLS

Scintillator cover: **matted** vs Tyvek

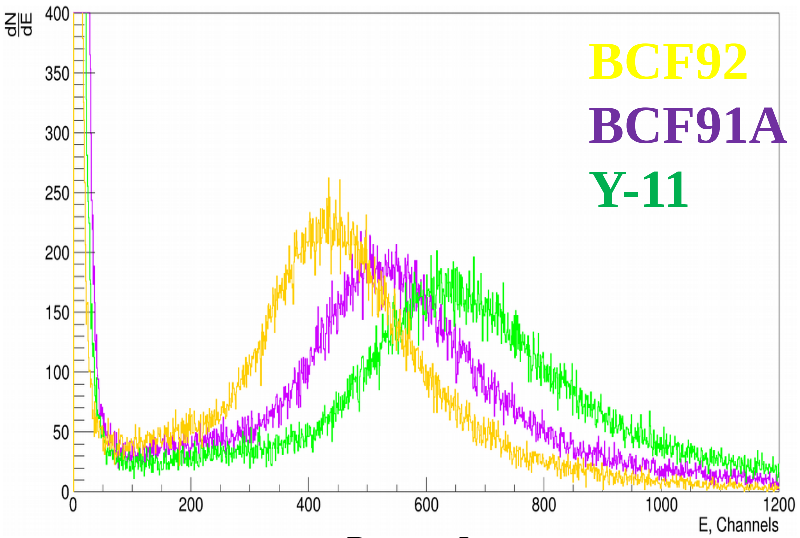


Row 1



Row3

Due to the higher peak position (from 7% and up to 15%) as well as the comparative simplicity in the context of mass production, the option with matted ones is more appropriate.

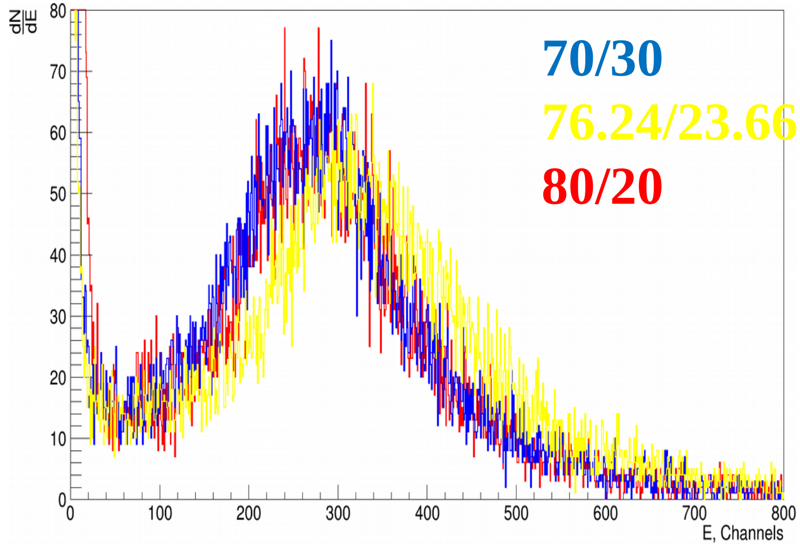


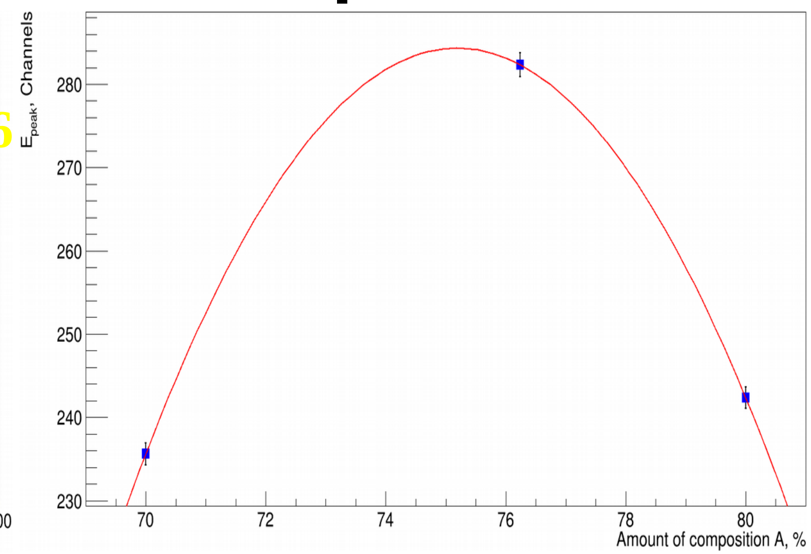
Row 3

Due to the fact that Kuraray Y-11 fiber collects more light these fibers looks more appropriate for our detector

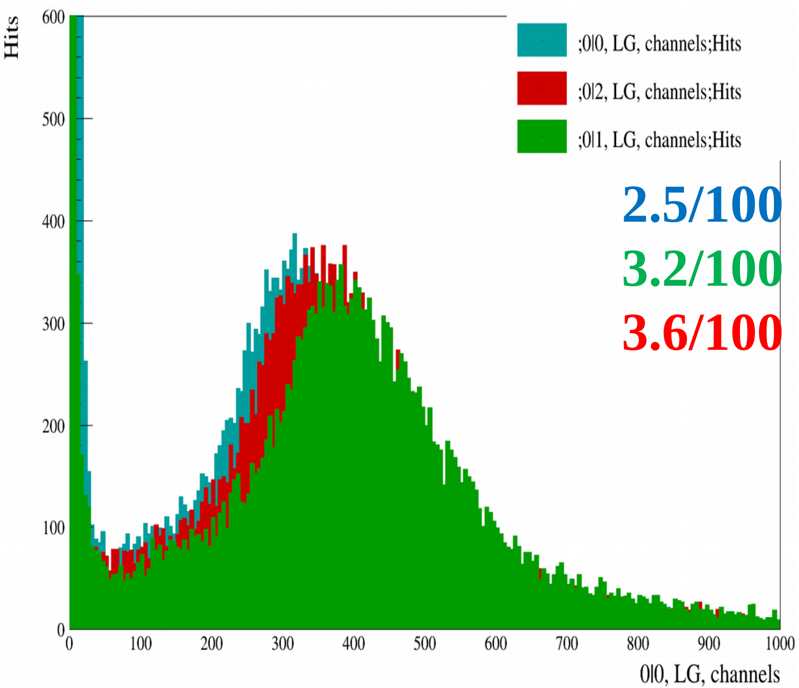
Into TDR

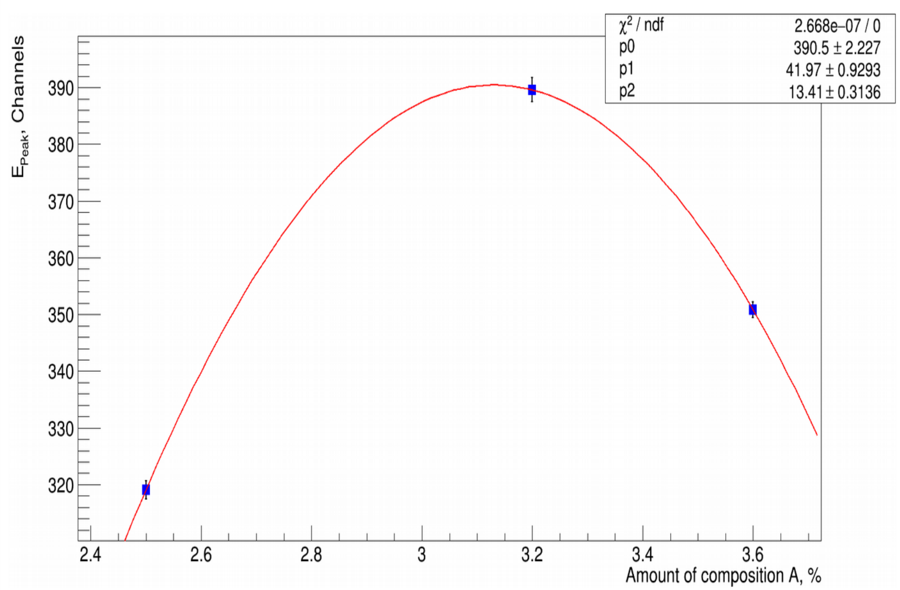
Material selection: Optical cement





Study: OK-72 70/30 (blue), 76.24/23.66 (yellow) and 80/20 (red) compositions comparison
On the right: Light collection peak position in dependence of A component amount for optical cement.
Same for CKTN, using 2.5 (blue), 3.2 (green), 3.6 (red) of A to 100 B.

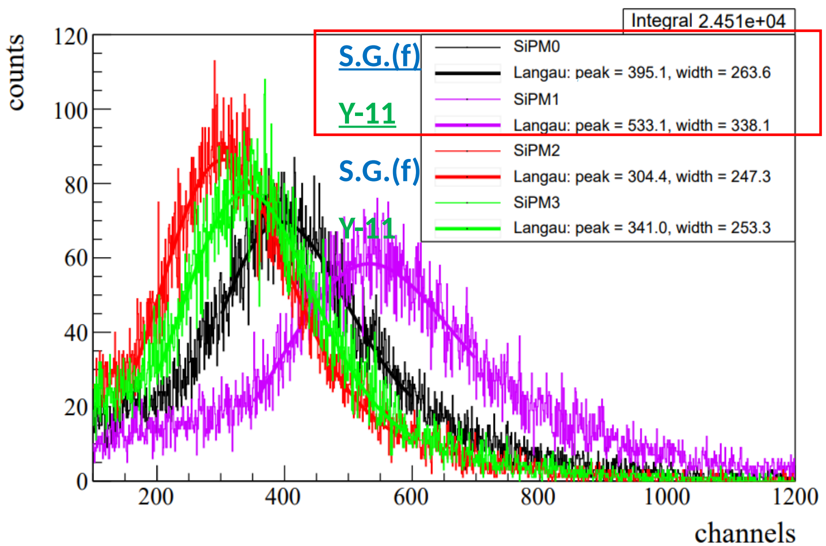




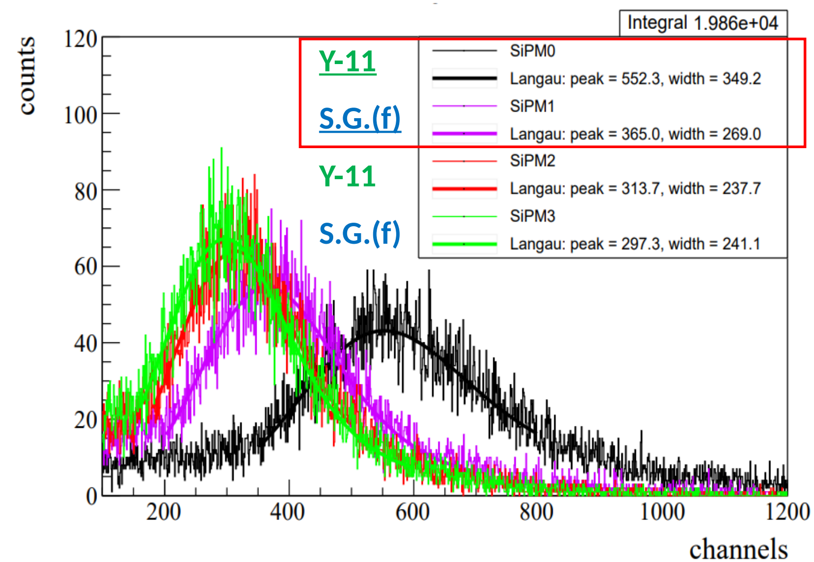
Study proved that A/B ratio affects the light collection, but not dramatically (questionable for CKTN). Also, datasheet ratio is the most effective we used so far.

Material selection: Optical cement

Run138



Run 139

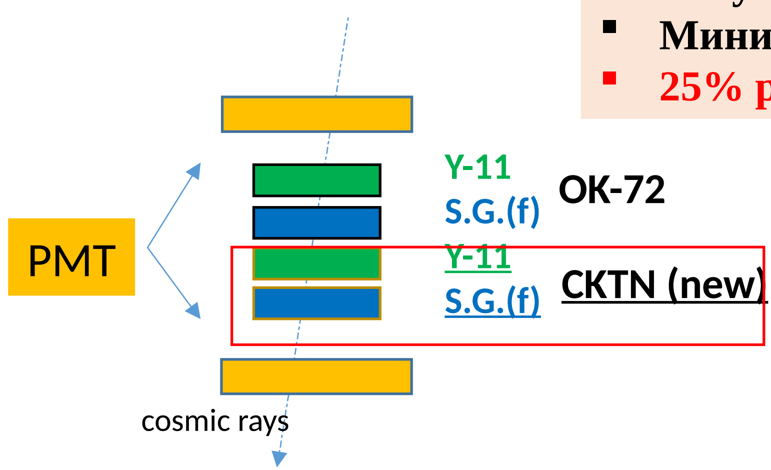


Row 2

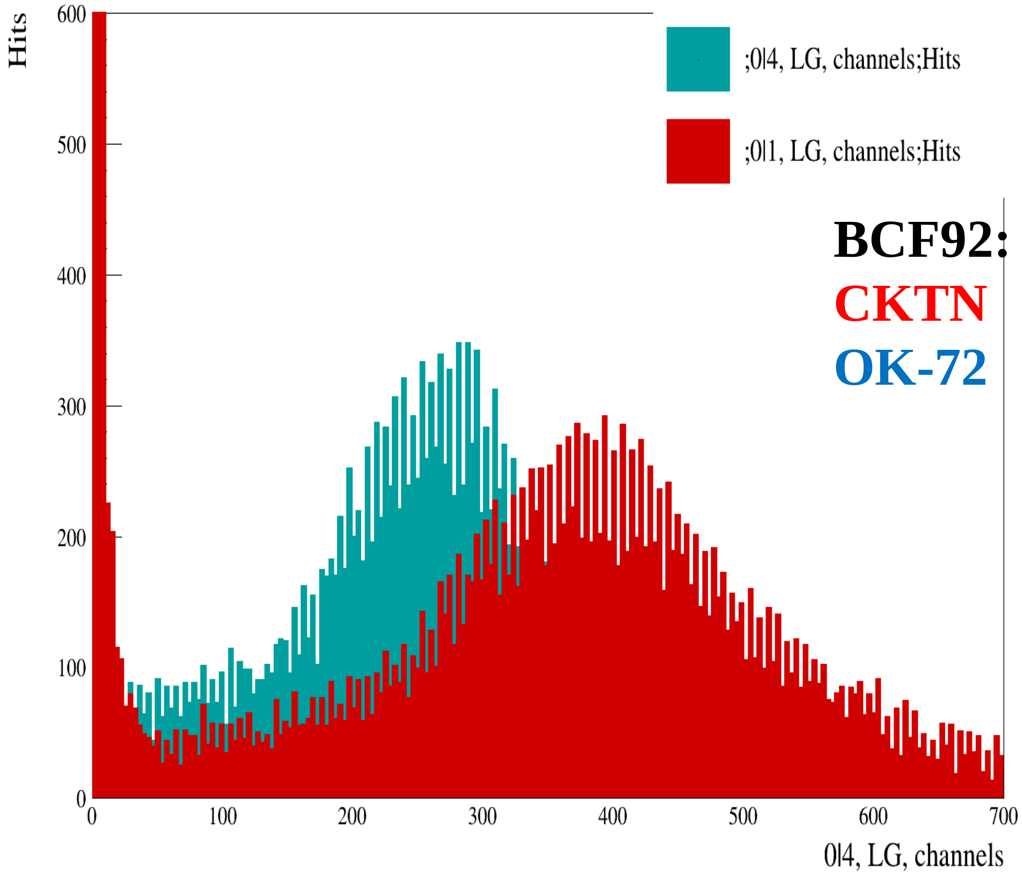
1x1 mm² SMTPA SiPM

Vbias~27,37V calibration for all

- **Отсутствие влияния SiPMs**
- **Минимальное различие сигнала для различного волокна (при ОК-72)**
- **25% различие сигнала для различного волокна (при СКТN)**



Material selection: Optical cement



Fit Params	CKTN	OK-72
Mean, Channels	389.6	202.6

Reason, why we still looking for the answer:

CKTN MED type E - Light collection ✔
Convenience in mass production ✕

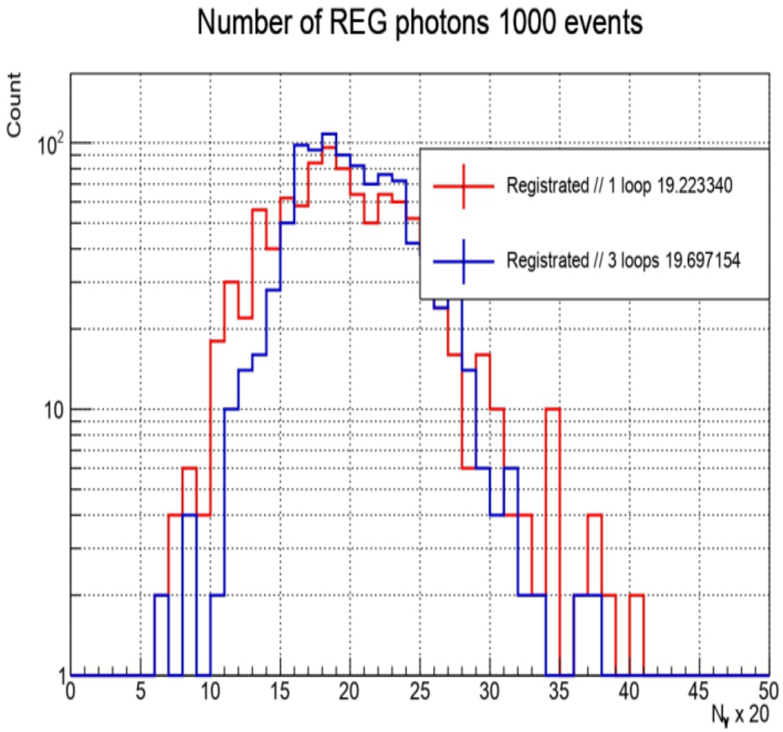
OK-72 - Light collection ✕
Convenience in mass production ✔

28.01.2024 Samples:

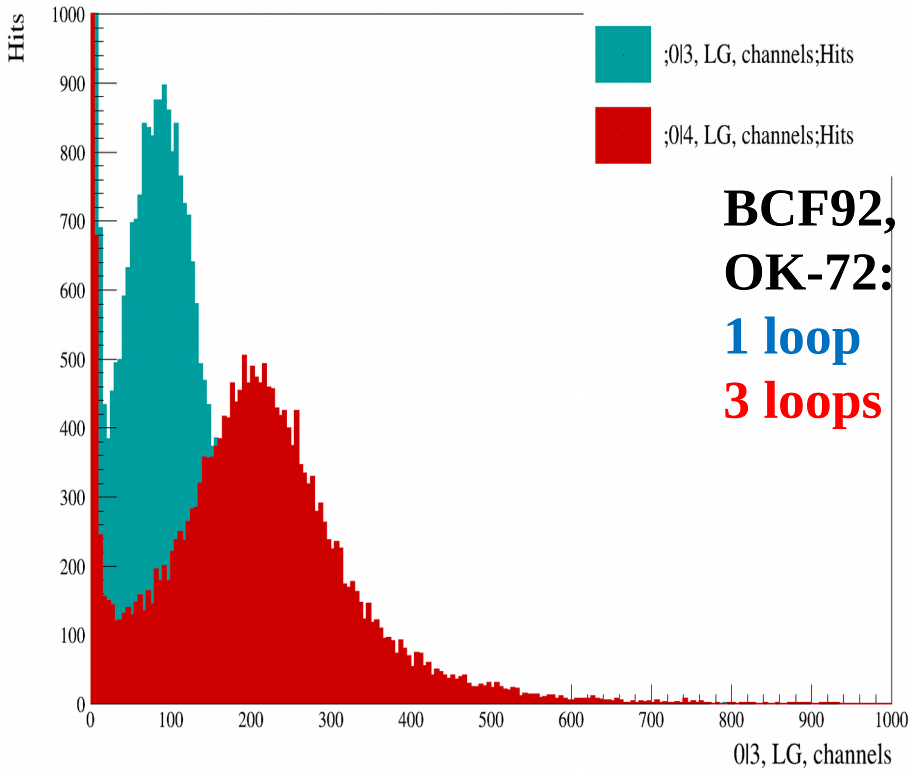
Comparison of row 2 tiles with SGC BCF92 and CKTN (red) VS OK-72 (blue)

There is a possibility that we will test a compromise variant – CKTN MED Type A - same light collection (as stated in the data sheet), but the viscosity is reduced by 10-100 times. Curing time might also increase

Material selection: Amount of fiber rows



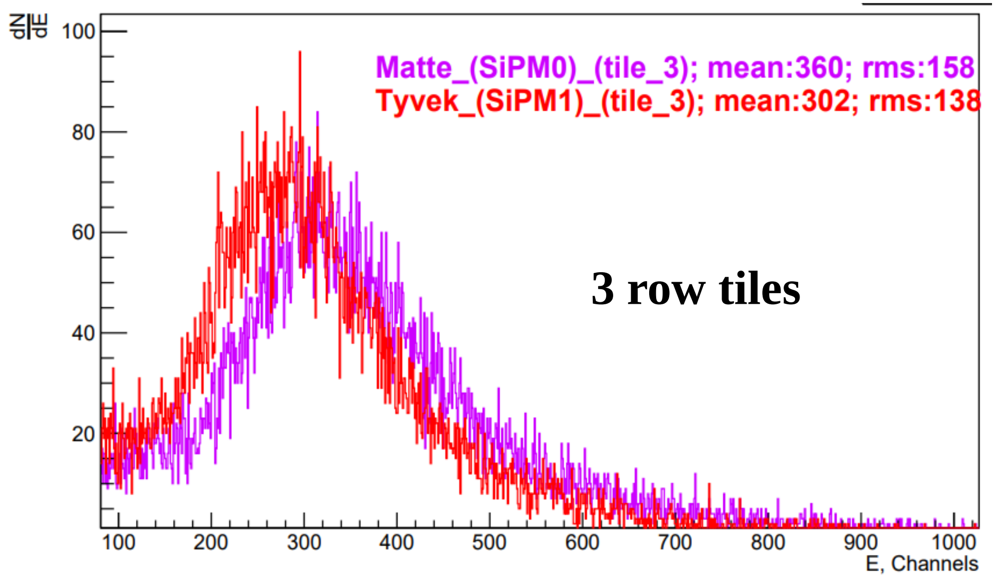
For more details, see https://indico.particle.mephi.ru/event/389/contributions/3829/attachments/2283/4212/-12--.pdf

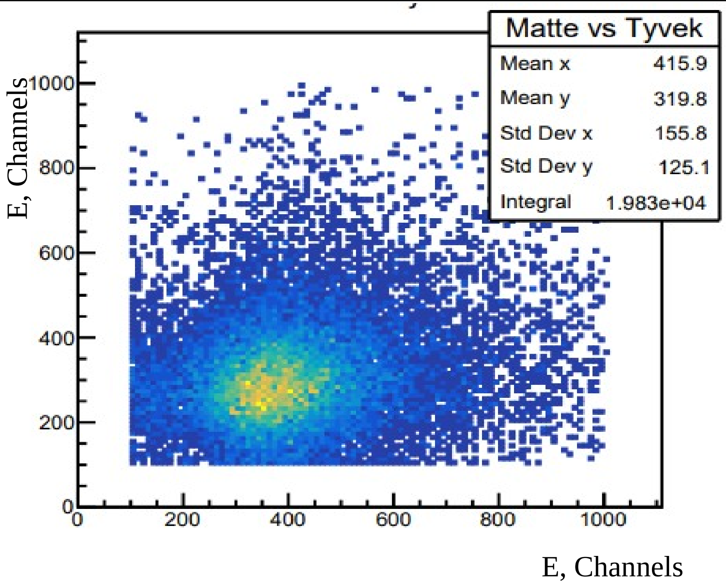


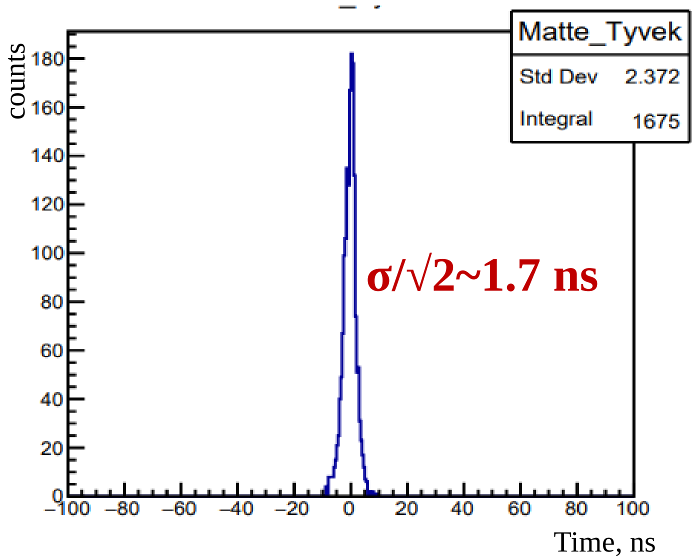
Experimental data: Light collection of second row tiles with SG BCF92 and OK-72, but: 1 (blue) and 3 (red) rows of WLS fiber, starting from the same depth

Fit Params	1 row	3 rows
Mean, Channels	86.7	202.6

Correlations and timing

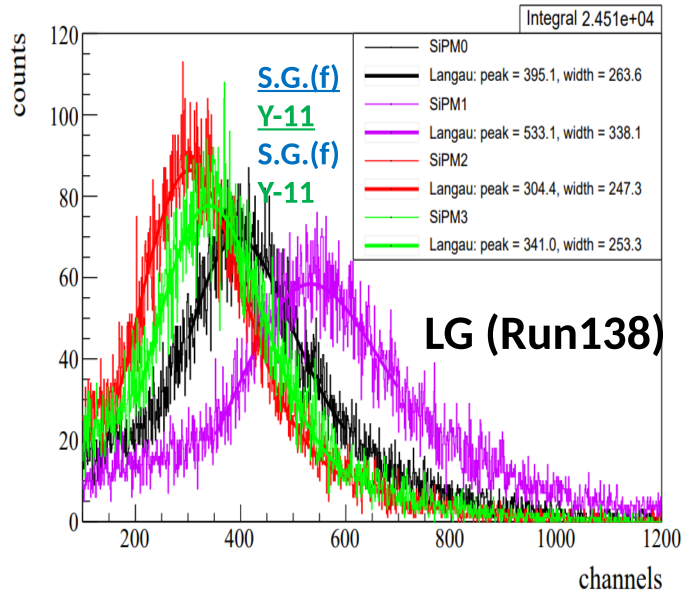


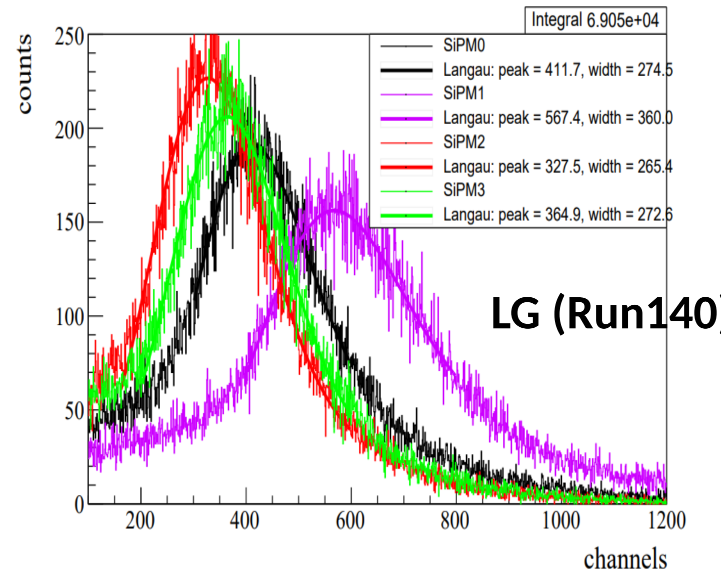




Off-line software for the data from FERS5200 (n*DT5202-->DT5215) is developped

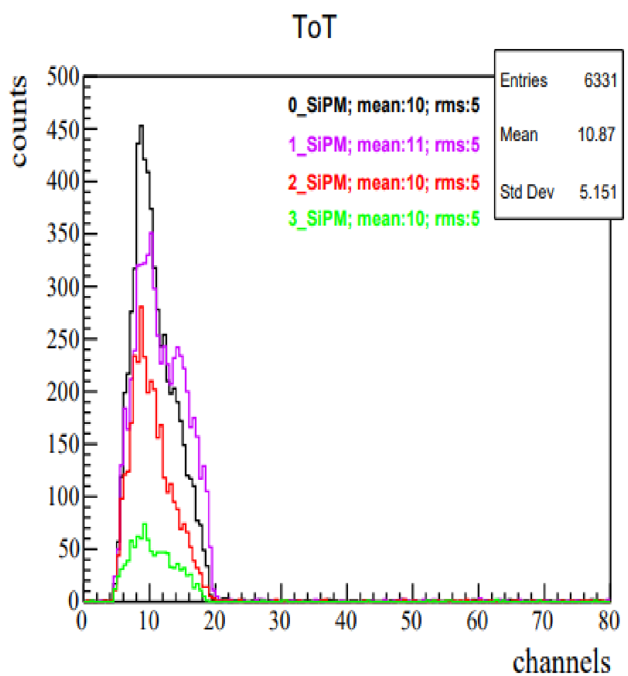
FERS DT5202 working options

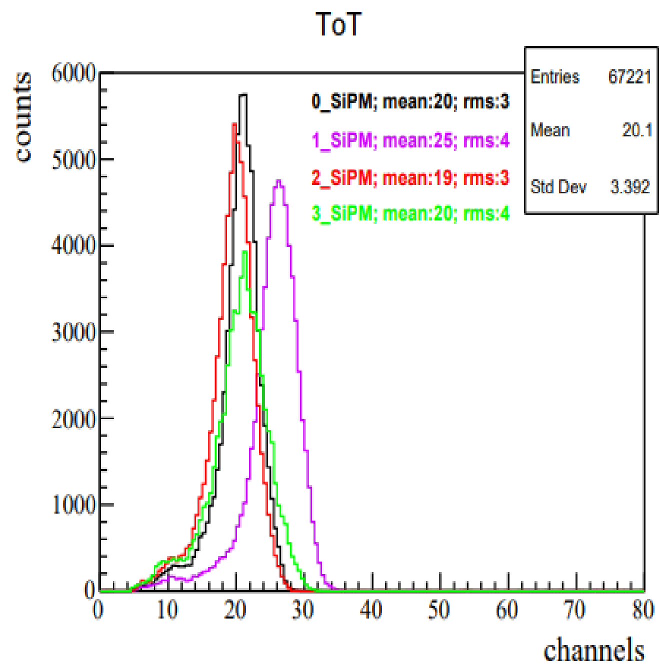




T-Threshold = **300**

T-Theshold = **200**





ToT for the free-streaming mode of DAQ

Results and plans 2024

Current status

1. New geometry of the outer part of BBC is defined.
2. Scintillators manufacturer is selected (Uniplast-Vladimir).
3. Scintillator cover and WLS types are selected.
4. FEE and digitizer option for Phase0 and Phase1 (possibly) is selected.
5. Software for the data analysis and simulation is developed.

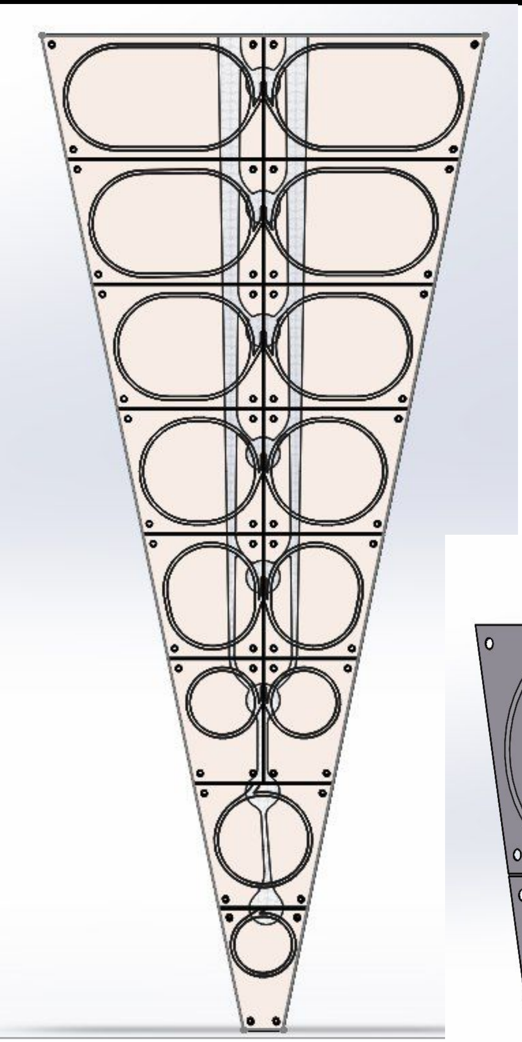
To do:

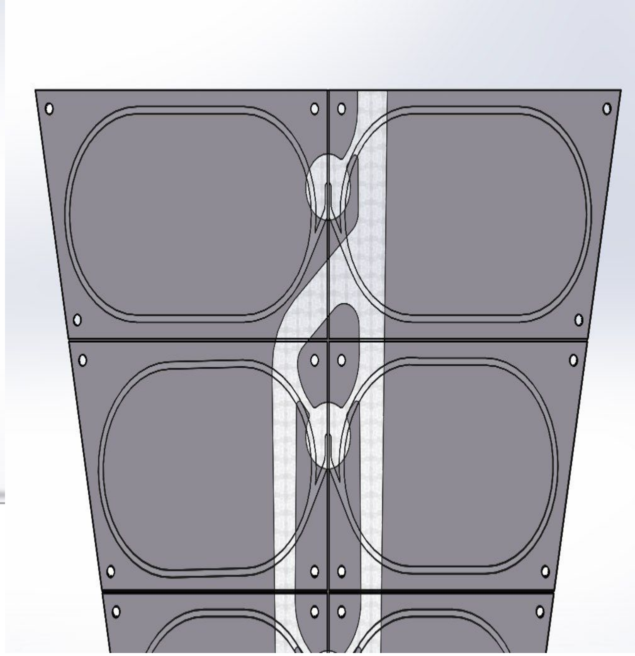
1. Optical cement studies- several tiles with CKTN MED type A:	March
2. Design of the carbon (sandwich type) support:	May
3. 2 7-tiles prototypes design, manufacture and testing:	July
4. Design of the transmission (optic cable -SiPMs-el.cable) box	October
5. Design of the optical cable&connectors	October
6. Tests with S14160-1315PS Hamamatsu SiPMs 1.3x1.3 mm^2	October

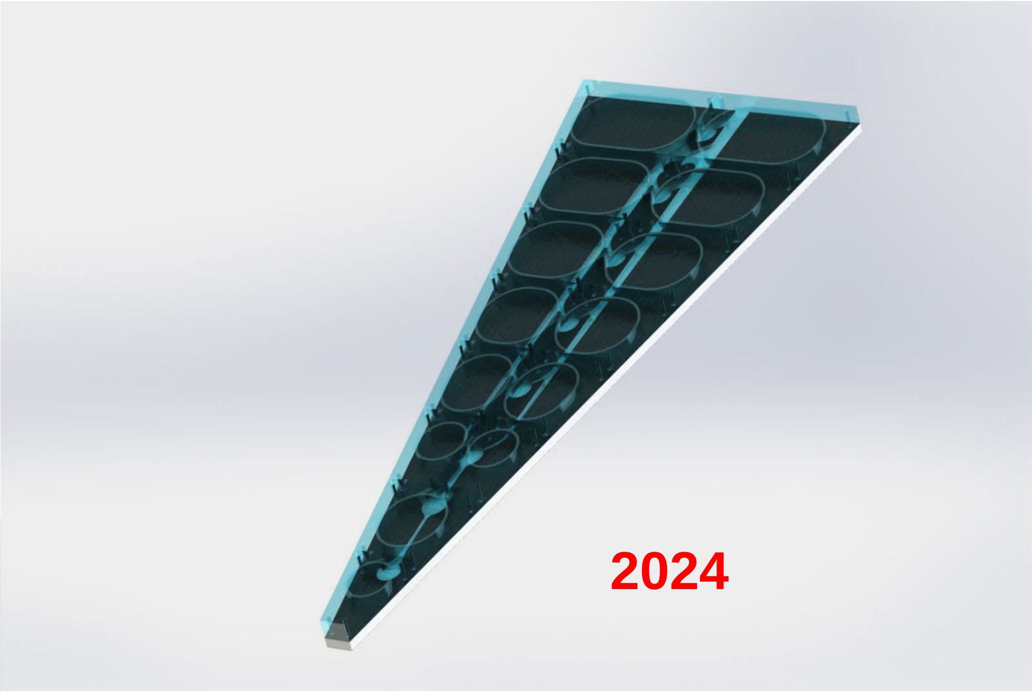
It is almost fully secured

Plans 2024

7-8 tiles prototype



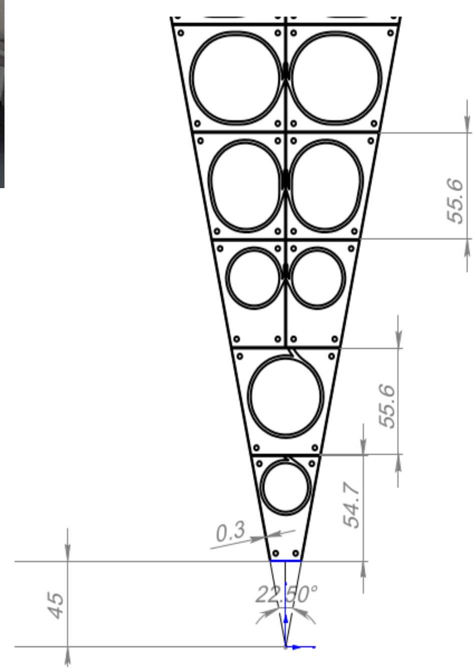


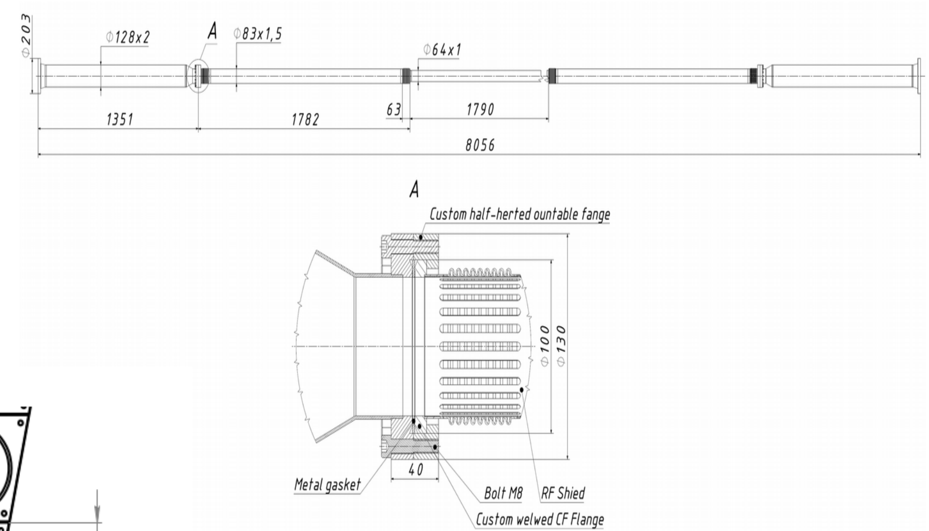


Sandwich support:
Carbon fiber+foam plastic
3 layers for prototypes
5 layers for detector

Plans 2024

Prototypes for NICA





Now : 124 mm diameter
Need: 83 mm diameter

Conclusions

Risks

I. The R&D phase for the scintillation tiles is almost finished. Tests with new optical cement will be performed in March-April.

II. The main task for 2024 is to produce and to test the 7-8 tiles prototypes.

III. The manufacture of 2 small BBC wheels (128 tiles each) for SPD-Phase_0 is planned for the end of 2024.

Risks 2024-2025:

FERS5200 CAEN availability. We have only 3 DT5202 boards.

Radiation conditions for HI collisions. Simulation for beam pipe& small BBCs& Bi+Bi is required.

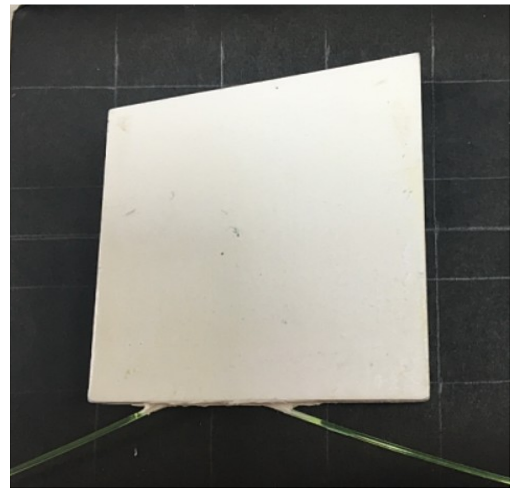
Risks >2024:

New electronics (localized in RF) is needed: FEE, digitization, L1.

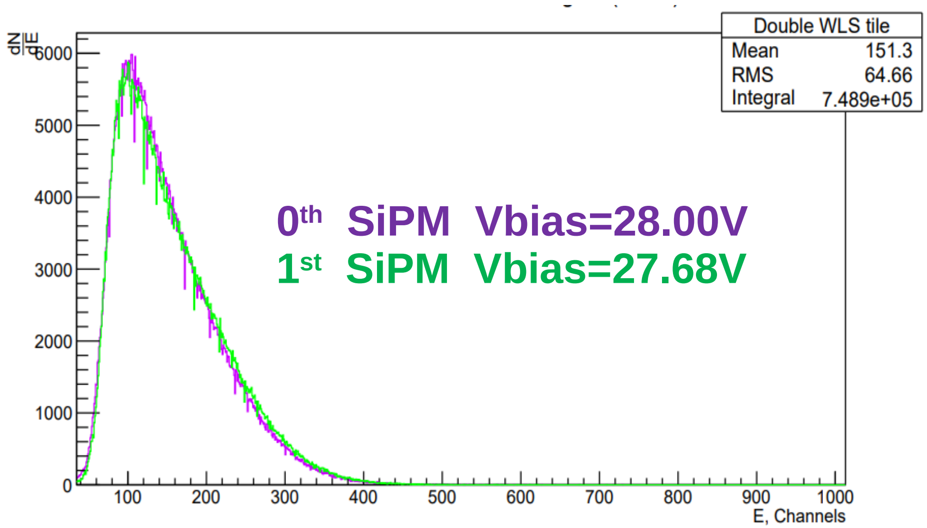
Backup

The first steps at the work with FERS and tiles tests

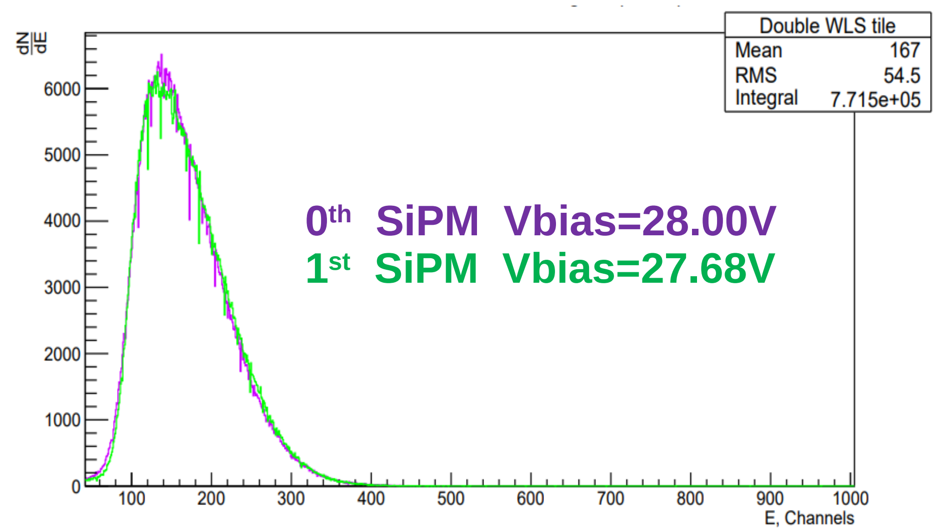
Tile with **two WLS outputs of single fiber** for tests and in particular for SiPM calibration with radioactive sources were used.



1x1 mm^2 SiPM

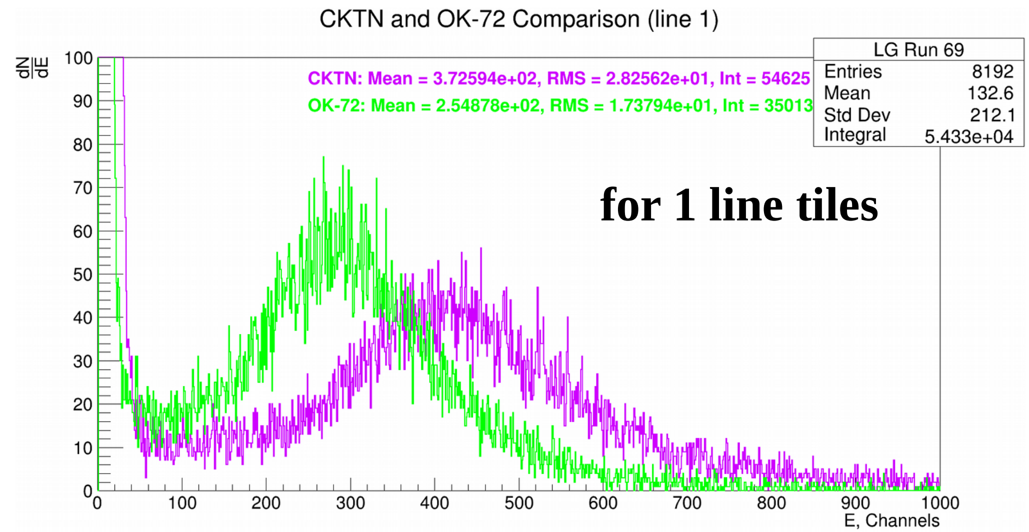


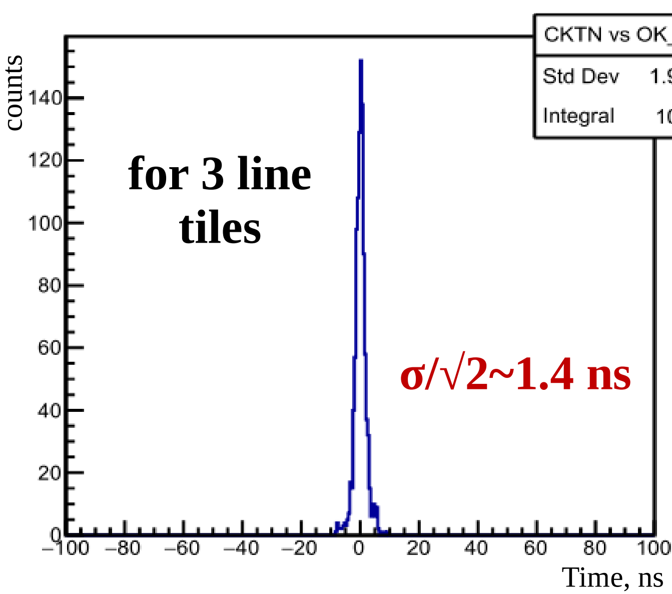
3x3 mm^2 SiPM

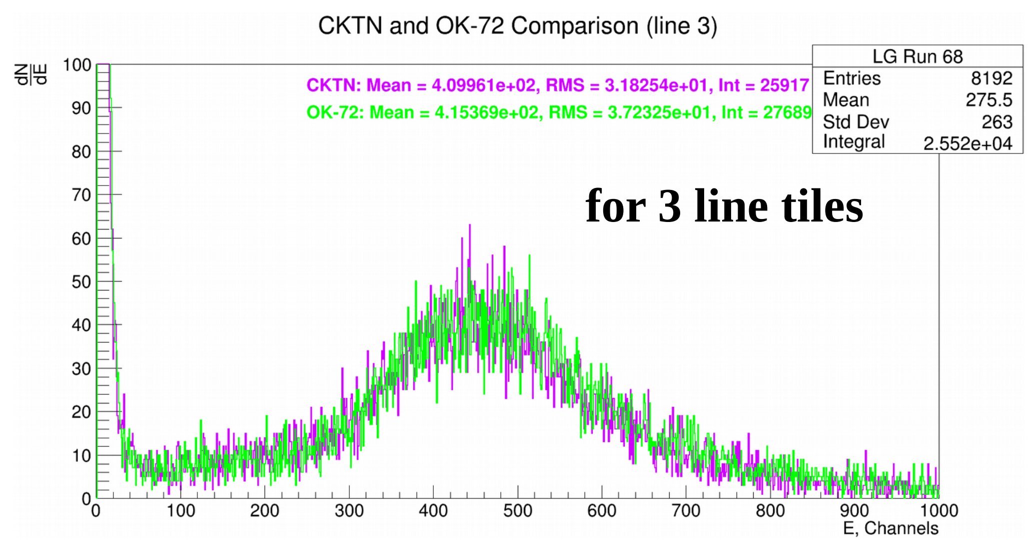


The amplitude histograms for both SiPM sizes with the chosen voltage are shown. This is not a bad result, but we preferred **another the way of calibration**.

CKTN Med and OK-72 difference





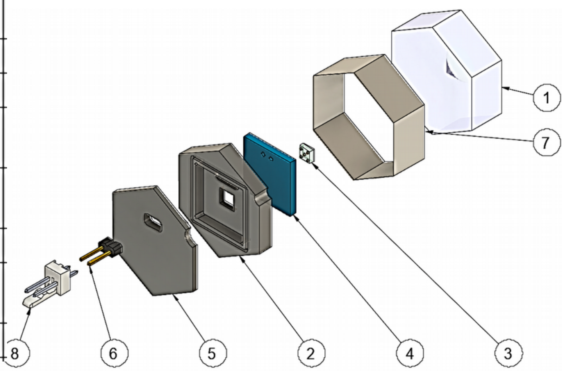


There is uncertainty with optical cement, so additional measurements are important.

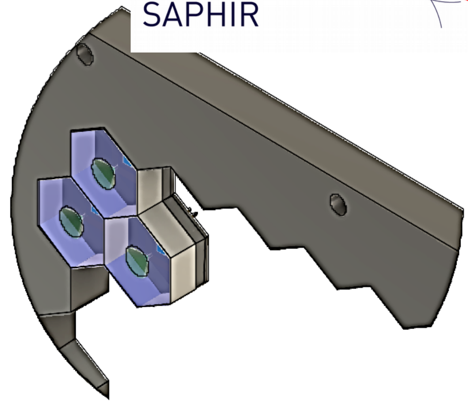
Tests at Lab201- VBLHEP

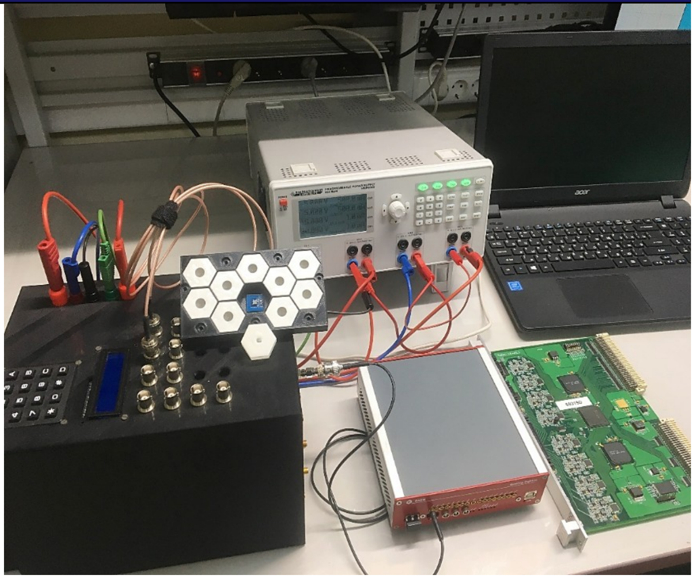
Hexagonal granularity detector

8	Male connector 0022272021
7	Mylar
6	RA conn
5	Tapa hexagon right cavity
4	MPPC PCB and support
3	S14160-3050HS
2	Housing mppc right cavity
1	Single Hexagon

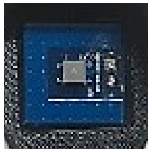


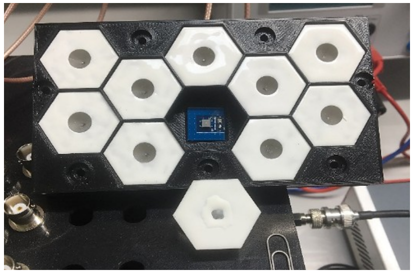
MILLENNIUM INSTITUTE FOR SUBATOMIC PHYSICS AT HIGH-ENERGY FRONTIER SAPHIR





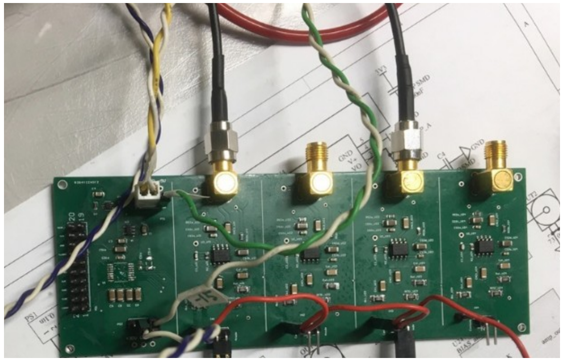
CAEN Digitizer DT5742
(16+1 Channel 12 bit 5 GS/s)



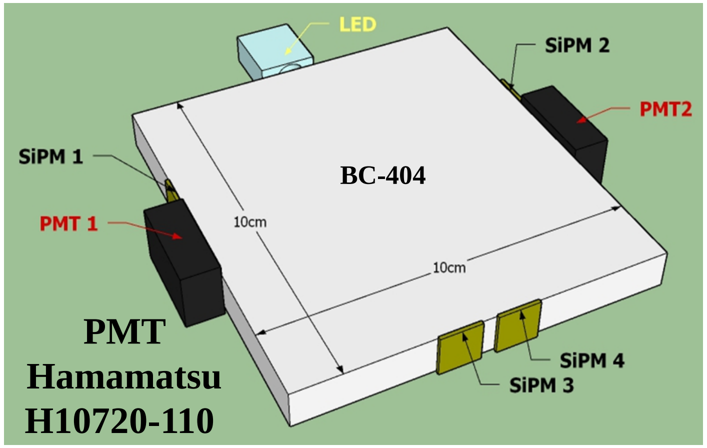


10 honey-comb scintillators and SiPMs,
FEE boards,
micro PC control.

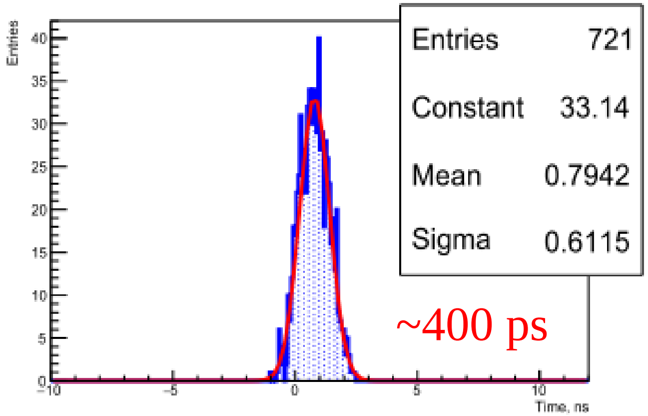
Hamamatsu SiPM S14160-3050HS
(3x3 mm^2, 50 µm/cell)



CTEPP-UNAB FEE (Chile) + SiPM



COSMIC RAYS



Together with E.R. Rozas-Calderon (CTEPP-UNAB)

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

Saint-Gobain Crystals fibers

Specific Properties of Standard Formulations

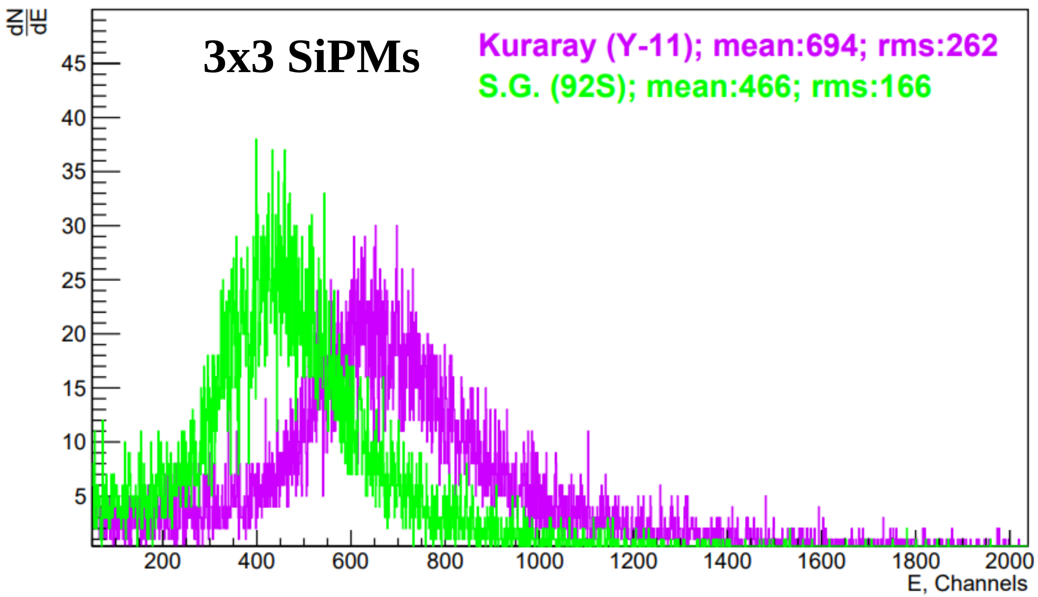
Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	# of Photons per MeV**
BCF-10	blue	432	2.7	~8000
BCF-12	blue	435	3.2	~8000
BCF-20	green	492	2.7	~8000
BCF-60	green	530	7	~7100
BCF-91A	green	494	12	n/a
BCF-92	green	492	2.7	n/a
BCF-98	n/a	n/a	n/a	n/a

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

KURARAY fibers

Description	Emission			Absorption	Att.Leng.[2]	Characteristics
	Color	Spectra	Peak[nm]	Peak[nm]	[m]	
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

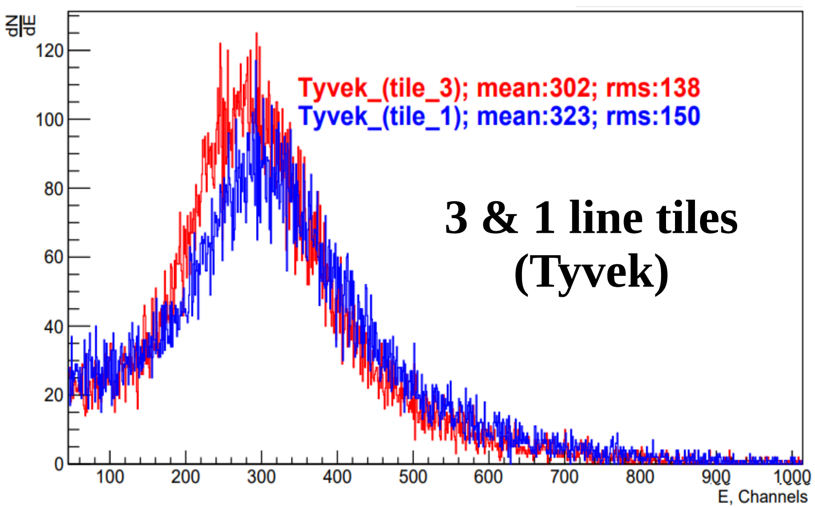
Kuraray Y-11 fiber collects more photons.

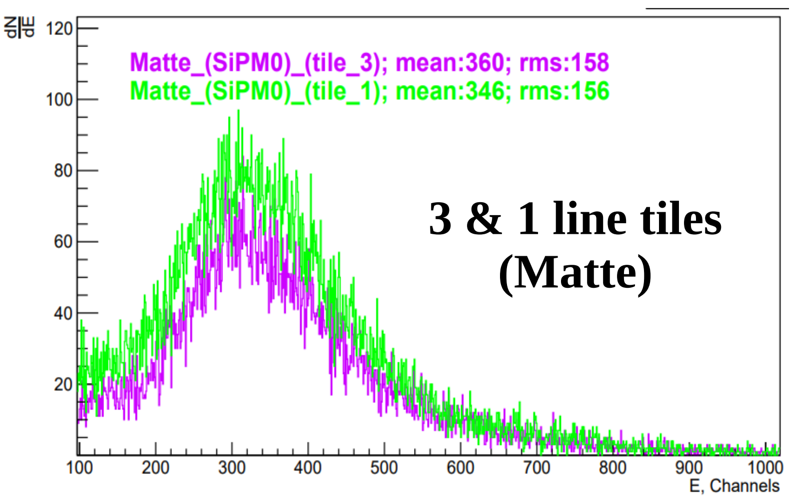


FEE studies results

Matte and Tyvek tiles (CKTN, SG92S)

Trigger time resolution ~650 ps

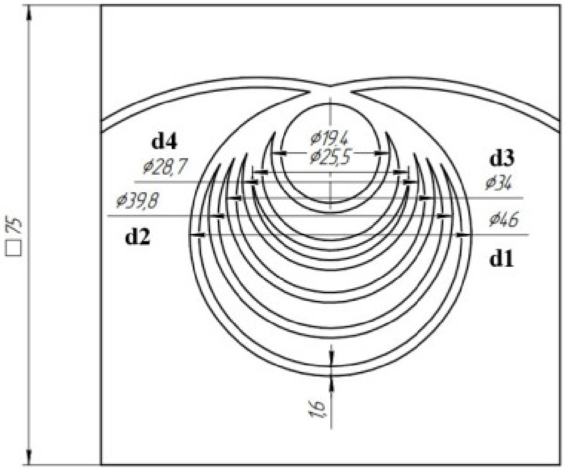




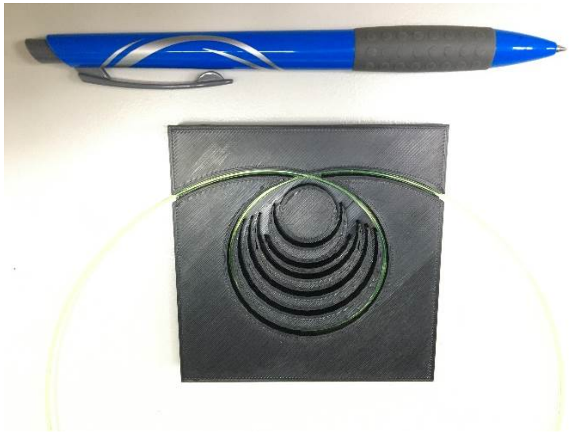
The result of comparison 1 and 3 line tiles. For Tyvek covered and matted tiles gives the same results.

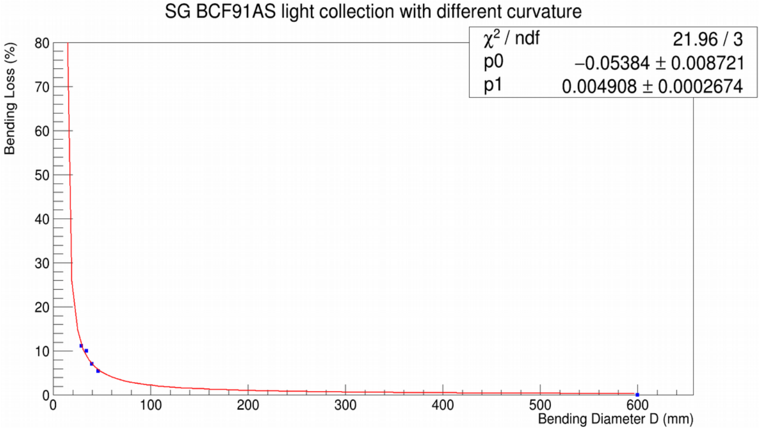
FEE studies results

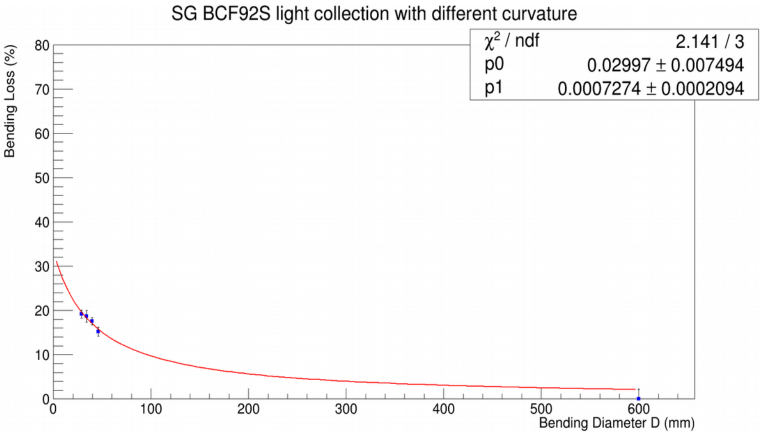
Fibers bending loss

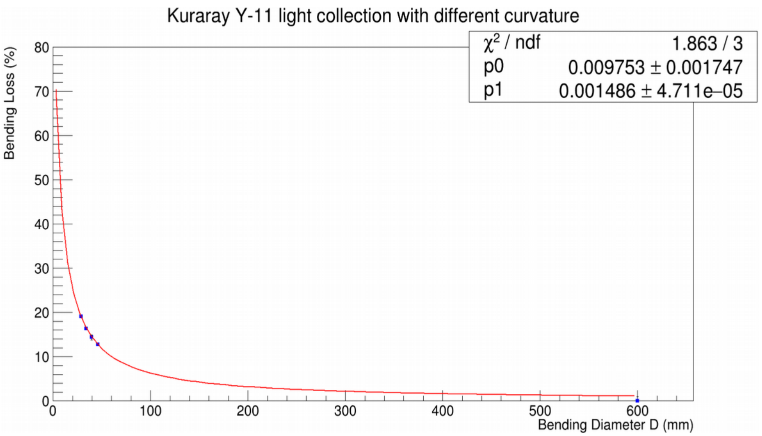


Tool for bending loss tests









<u>Difference between d1 and d4 diameters:</u>

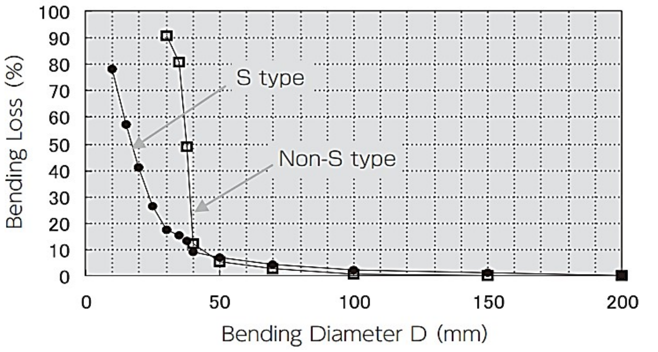
SG BCF91AS – 6.0%

SG BCF92S – 4.7%

Kuraray Y-11 – 8.5%

for 1 rotation (<u>inside the tiles is 3</u>)

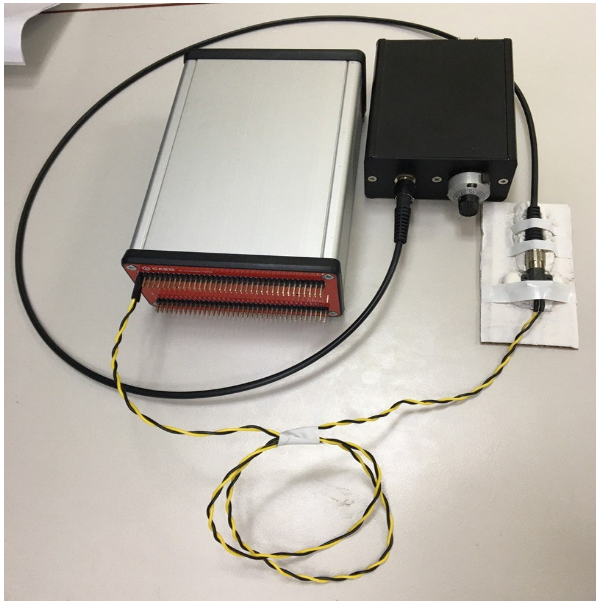
PRELIMINARY



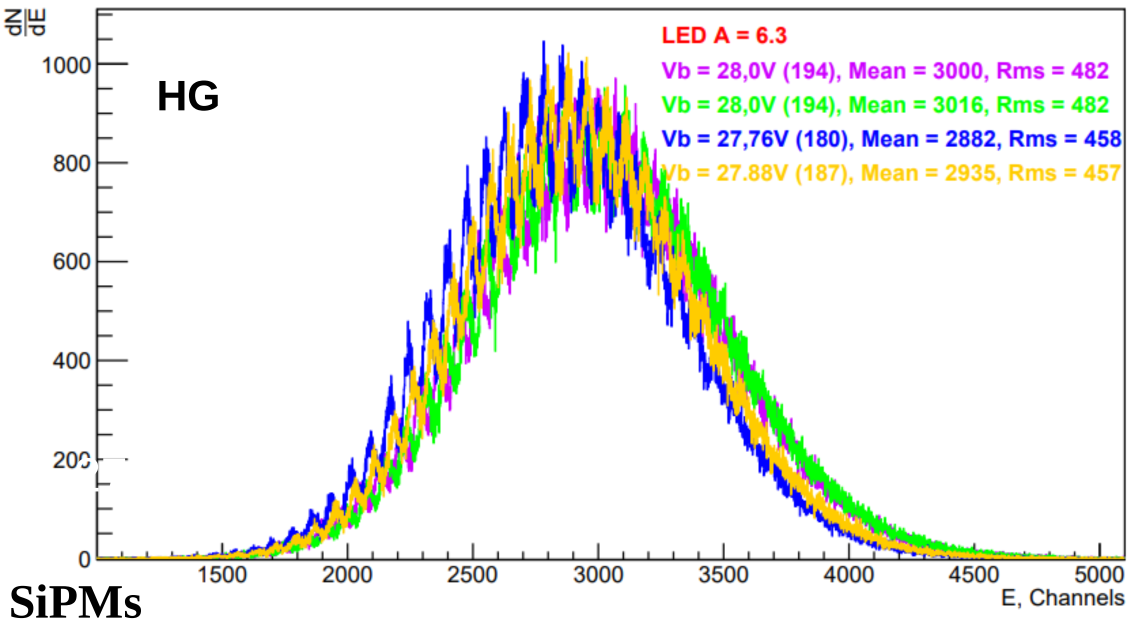
FEE studies results

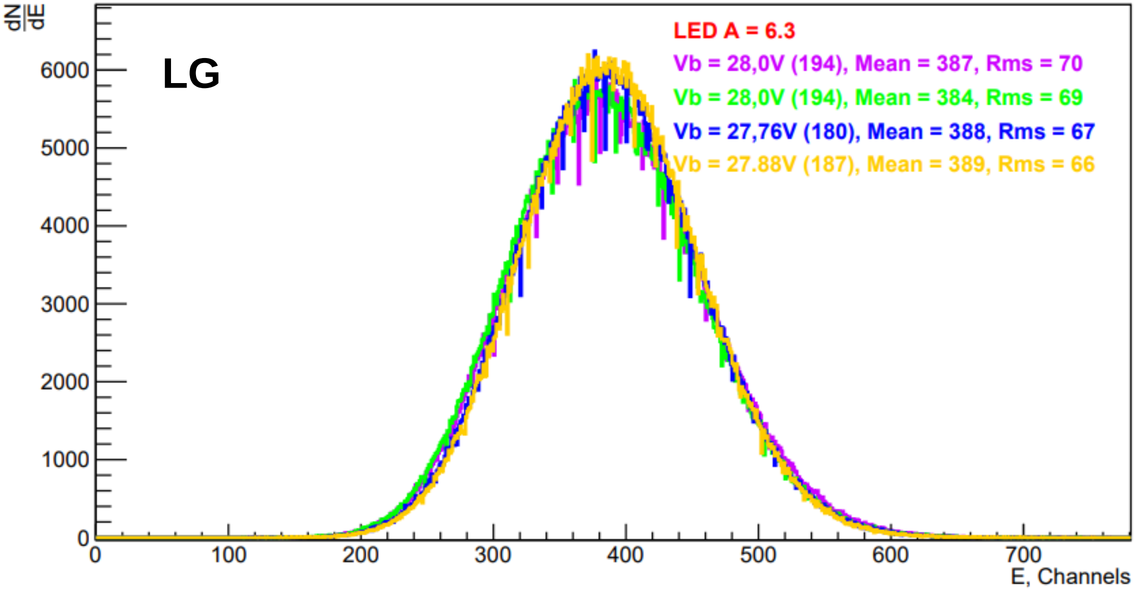
Calibration method (Led source)

DT5202 with CAEN LED Driver (SP5601)



For 4 SiPMs

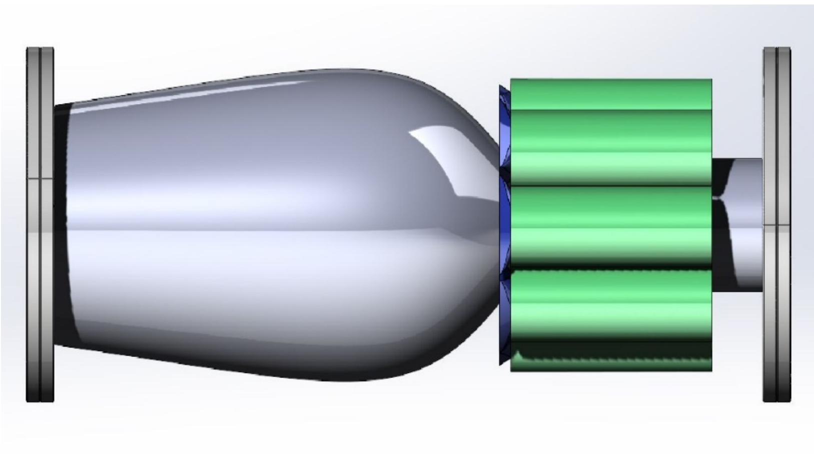


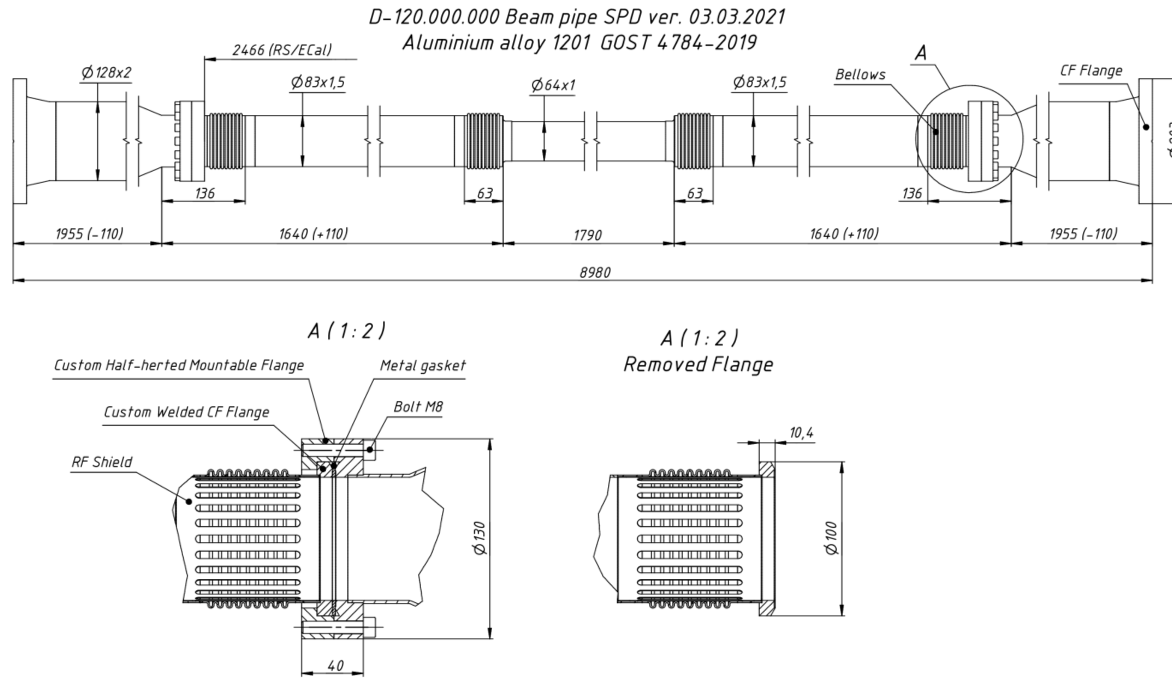


Thank you for the attention!

Introduction

MCP part





2-new high granularity detectors placed at about +/-4.5m from IP outside the beampipe. Option with the detector inside the beampipe is cancelled.

-MCP based TOPAZ PMTs
-Good time resolution 50ps
-Tests with laser and with 200 MeV electrons (LINAC-200) has been performed.
-Tests in SPD testzone and at ITS at Nuclotron are under preparation
-Combined detector (MCP+ Scintillators) for small angle scattering monitoring and physics

Team **A.Baldin et al.(JINR)**
G.Feofilov et al. (StPSU)
A.Kubankin et al. (BNRU)
…..

FEE studies results

The first step of high granularity part of BBC development

Together with **I.Alexeev, D.Svirida (KRI ITEP)**

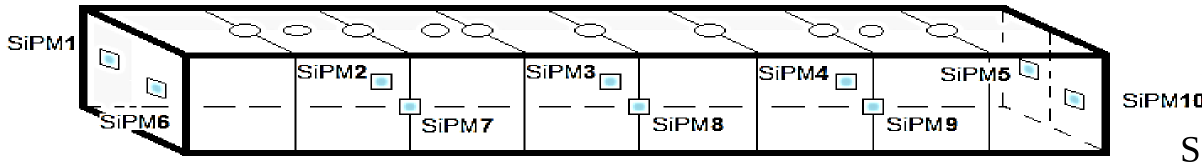
5 channels FEE of DANSS experiment (main option for ZDCs)

Plastic Scintillator

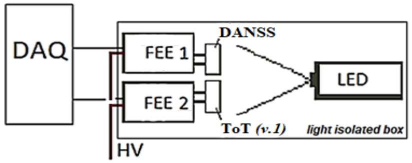
40 x 2 x 2 (cm³)

10 pcs

Hamamatsu SiPM (S12572-010P 3x3mm², 10 μm/cell)

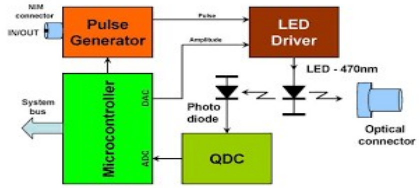


Schematic view of the test



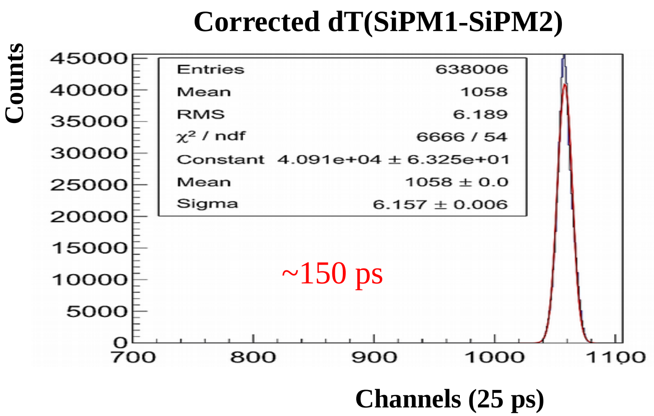
26.2 ± 0.3 °C

Schematic view of the LED



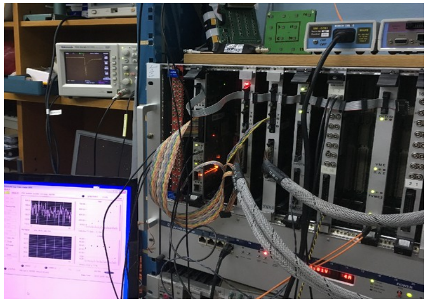
5 channels FEE of ToT (v03)

Together with **P.Polozov, T.Kulevoy (KRI ITEP)**



Phys.Atom.Nucl. DOI:10.1134/S1063778822090381 (2022)

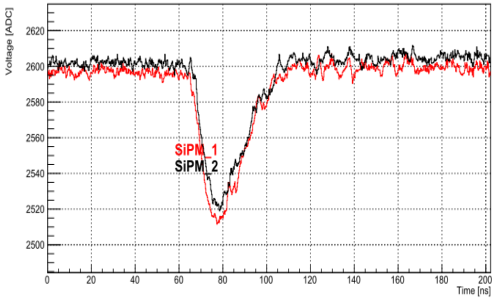
The VME based DAQ



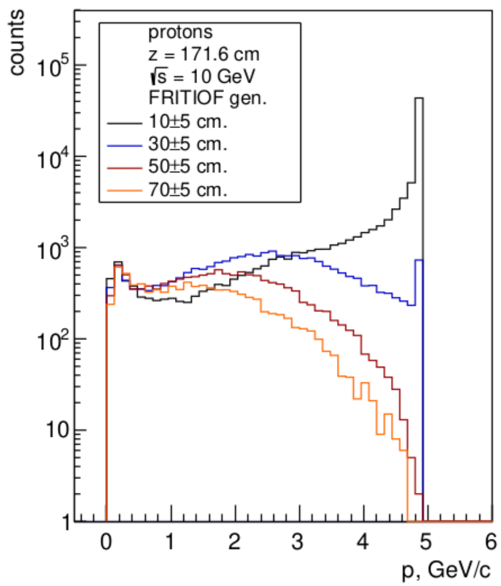
Isupov A.Yu. // EPJ Web Conf. 2019. V.10003. P.204

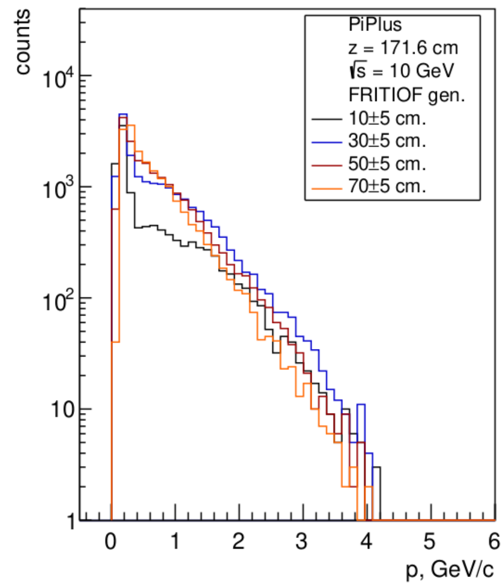
Yu.Gurchin, A.Isupov, V.Ladygin, S.Reznikov, A.Terekhin, I.Volkov (JINR)

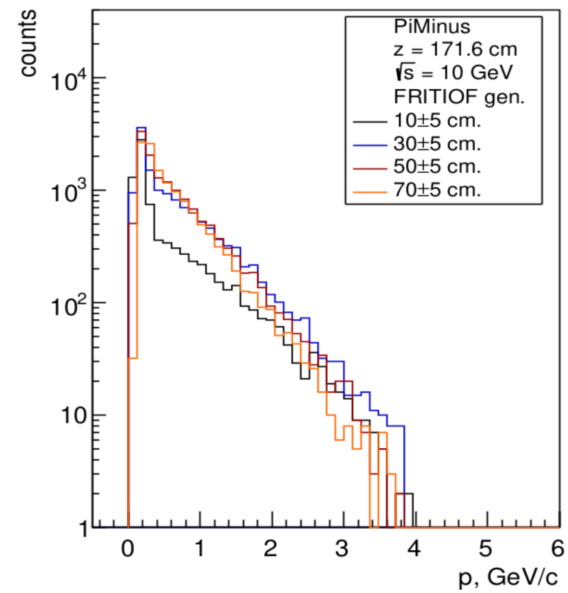
CAEN Digitizer DT5742 (16+1 Channel 12 bit 5 GS/s)



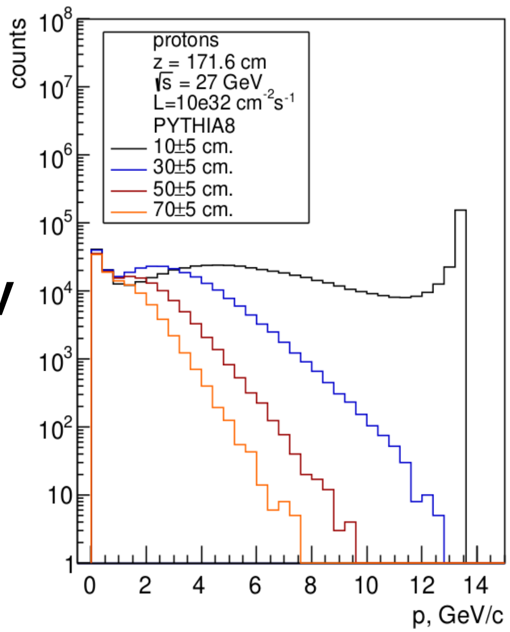
10 GeV

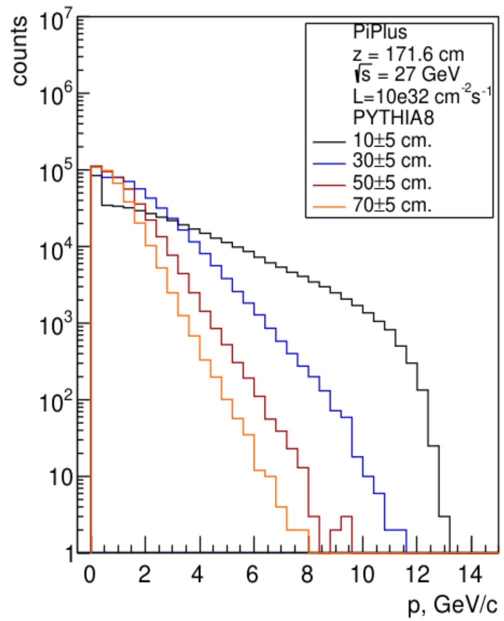

protons
z = 171.6 cm
$\sqrt{s}$ = 10 GeV
FRITIOF gen.
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c

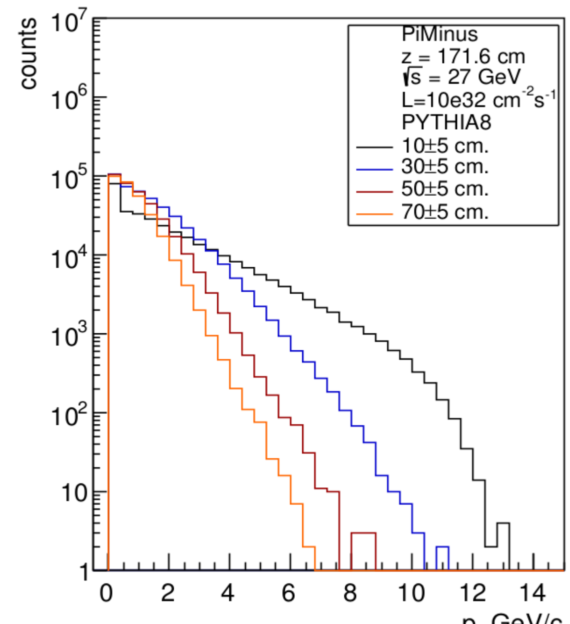

PiPlus
z = 171.6 cm
$\sqrt{s}$ = 10 GeV
FRITIOF gen.
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c


PiMinus
z = 171.6 cm
$\sqrt{s}$ = 10 GeV
FRITIOF gen.
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c

27 GeV


protons
z = 171.6 cm
$\sqrt{s}$ = 27 GeV
L=10e32 cm^{-2}s^{-1}
PYTHIA8
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c

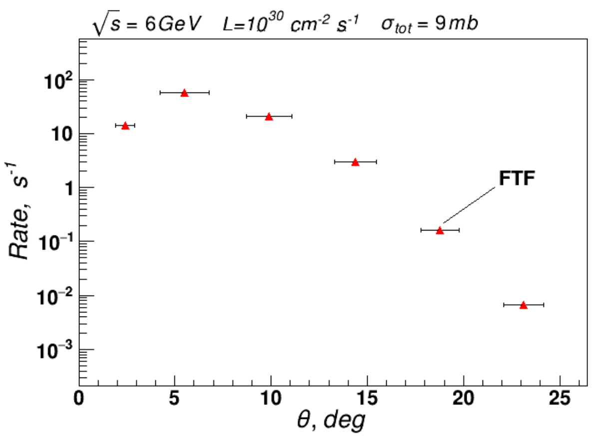

PiPlus
z = 171.6 cm
$\sqrt{s}$ = 27 GeV
L=10e32 cm^{-2}s^{-1}
PYTHIA8
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c

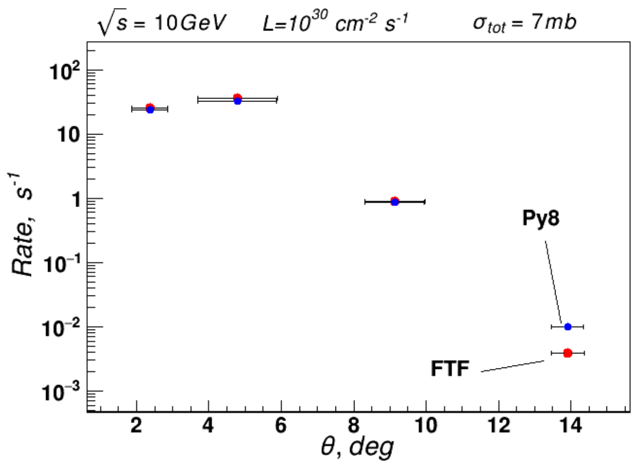

PiMinus
z = 171.6 cm
$\sqrt{s}$ = 27 GeV
L=10e32 cm^{-2}s^{-1}
PYTHIA8
10±5 cm.
30±5 cm.
50±5 cm.
70±5 cm.
counts
p, GeV/c

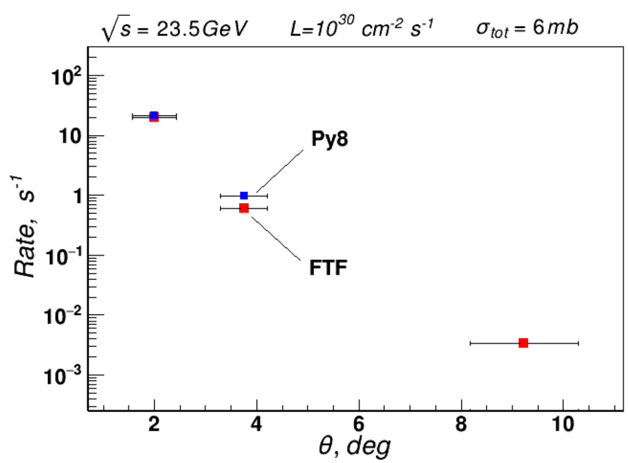
Simulation (pp)

FTF and Py8 generators

$\sqrt{s}$ = 6.2, 10 and 23.5 GeV,
N_{total} = 1*10^{6} events





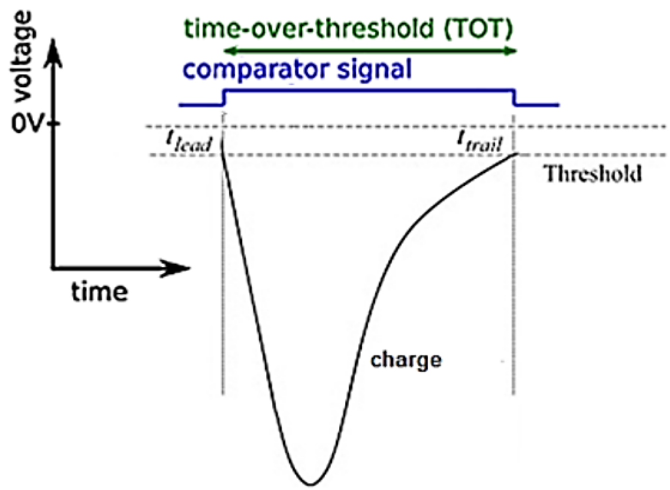


The pp-elastic scattering events have been selected for total energies equal 6.2, 10 and 23.5 GeV. The events rates as function from the angle scattering have been estimated for pp-elastic scattering by using the FTF and Py8 generators at Luminosity 10^{30} cm^{-2}s^{-1} for 1/16 part of BBC.

Z.Kurmanaliyev (JINR)
A.Terekhin (JINR)

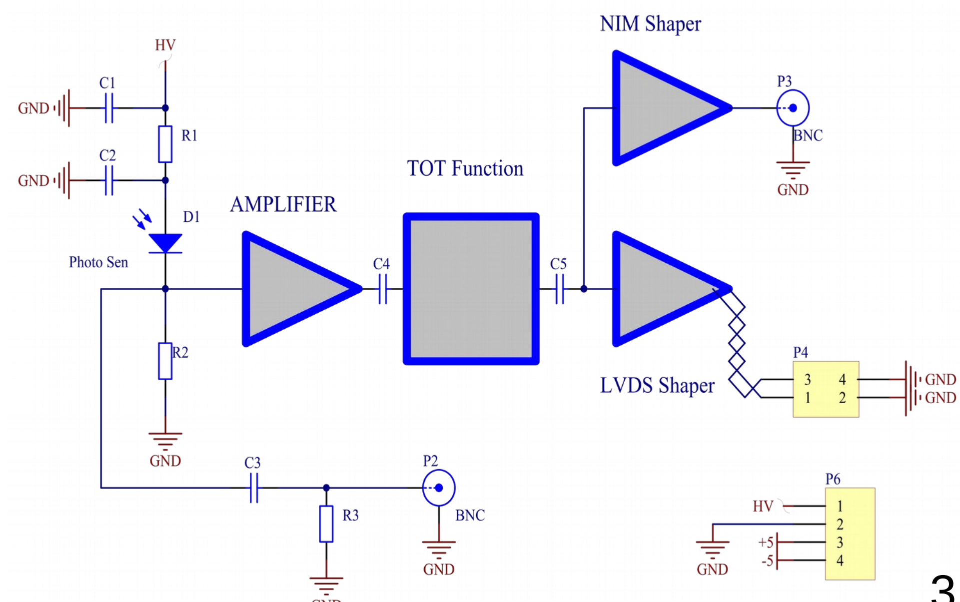
(see talk at this meeting)

The Time-over-Threshold (ToT) method

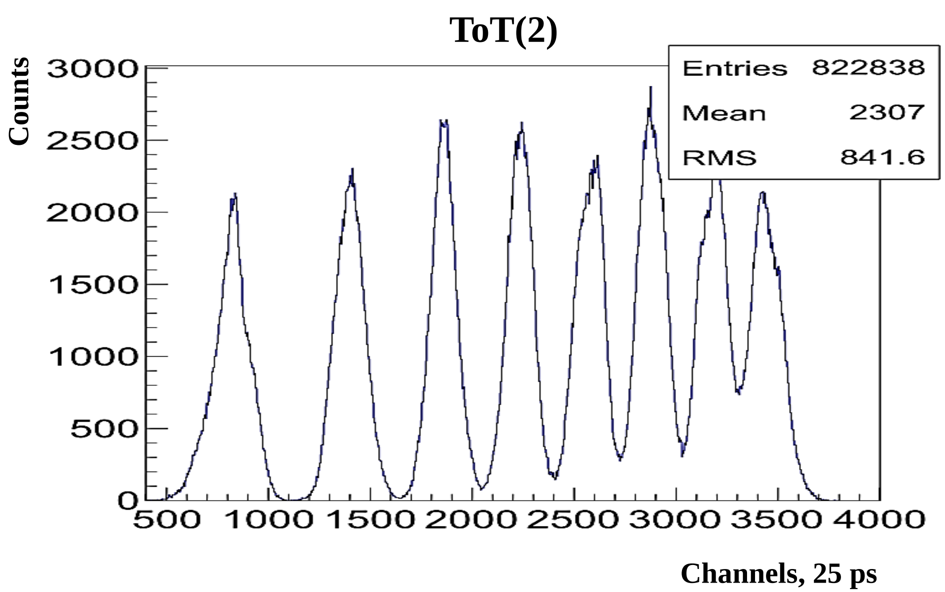


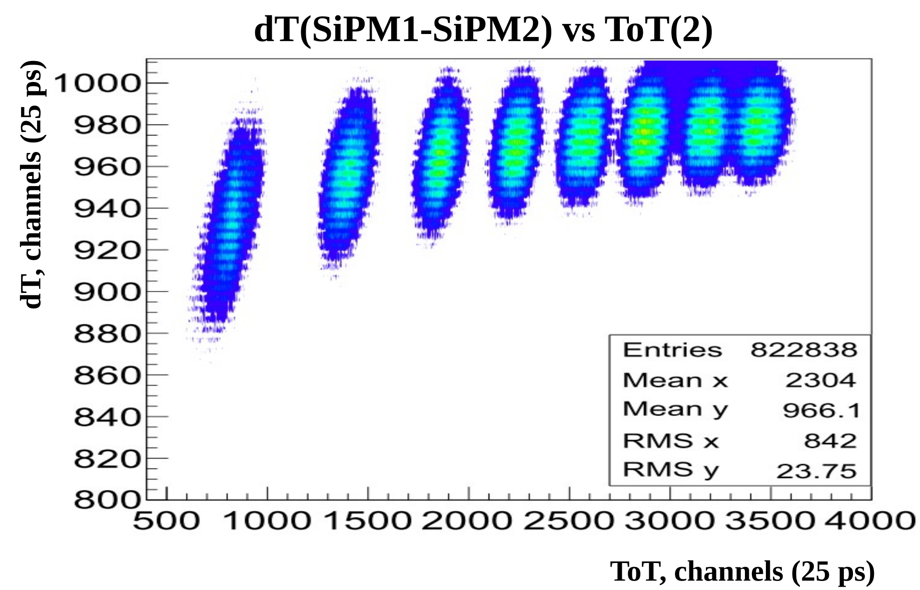
The ToT is a well-known method which allows to measure the energy deposited in the material.

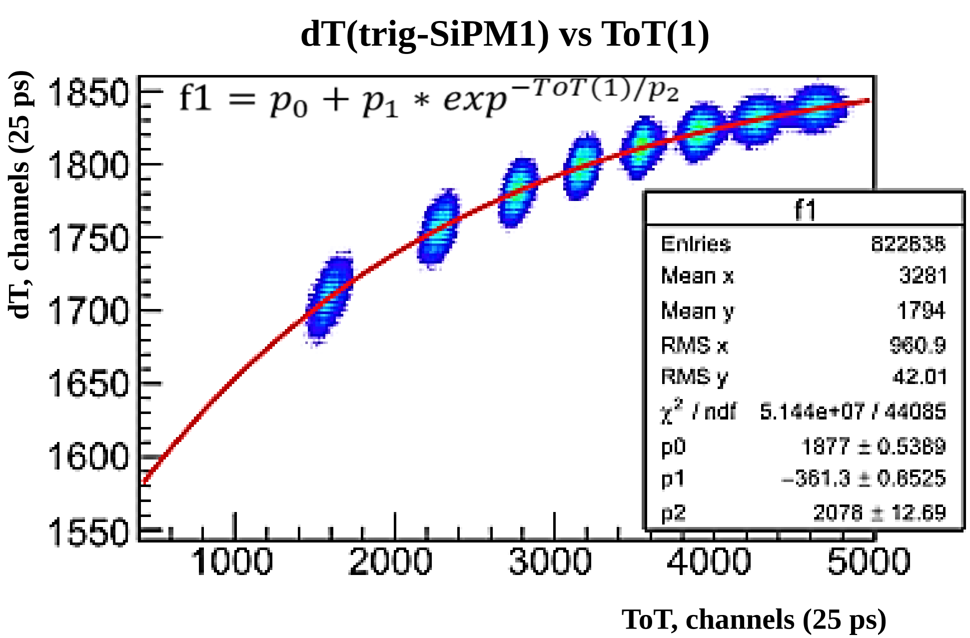
Front-end electronics with ToT technique

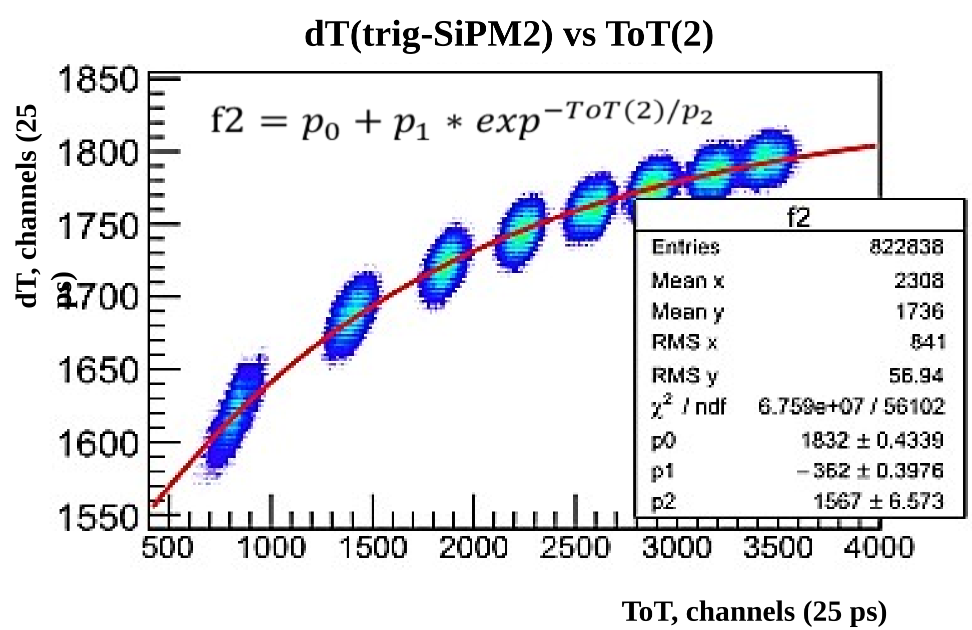


Extracting correction parameters FEE ToT (version №1)



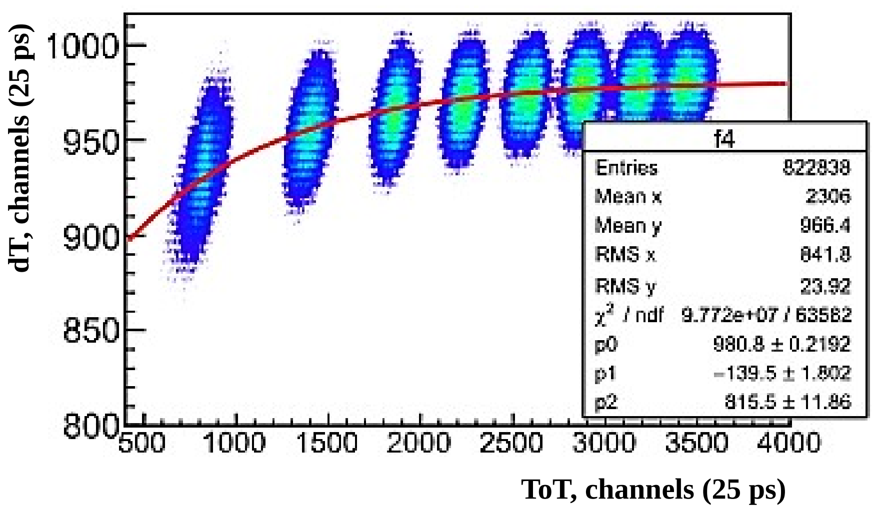




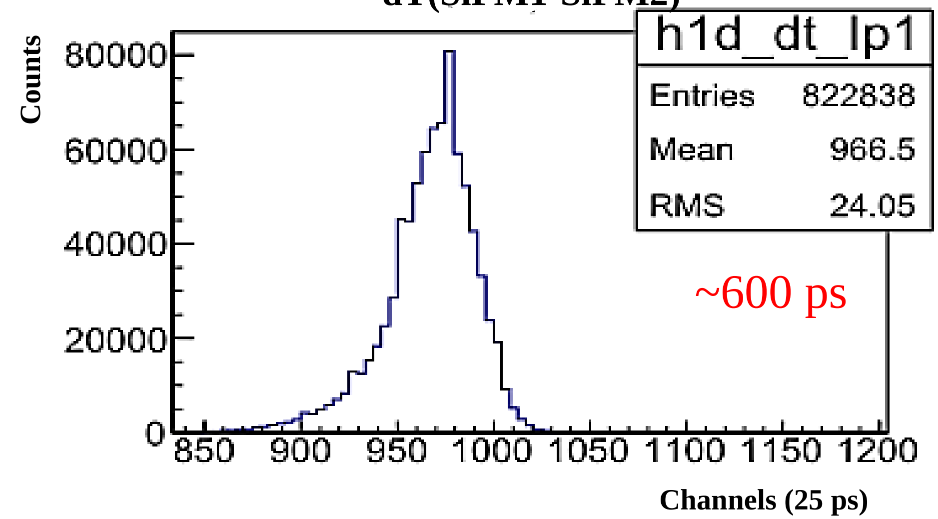


The time difference histogram FEE ToT (version №1)

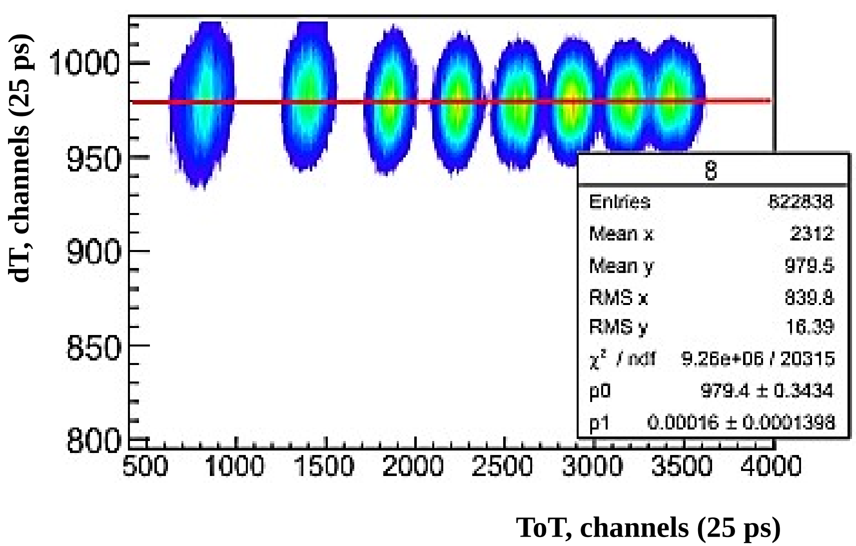
dT(SiPM1-SiPM2) vs ToT(2)



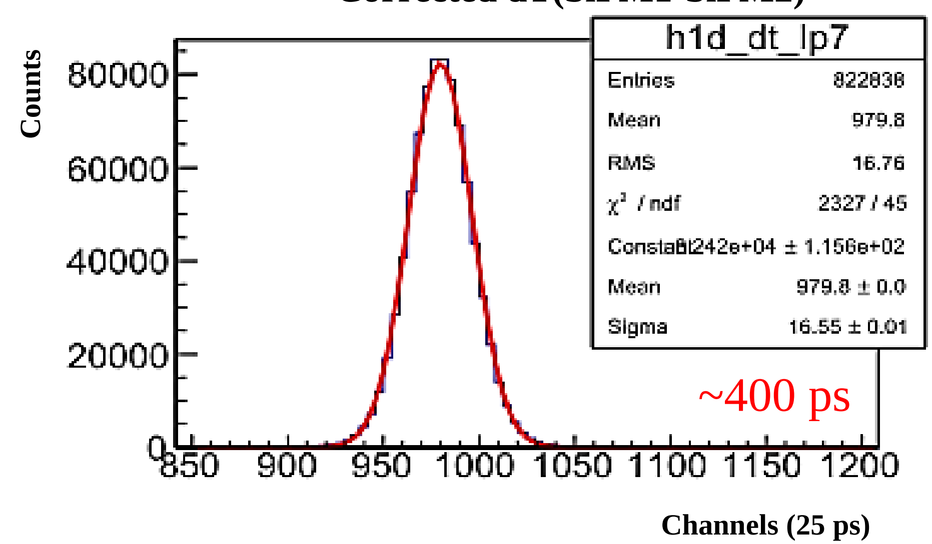
dT(SiPM1-SiPM2)



Corrected dT(SiPM1-SiPM2) vs ToT(2)



Corrected dT(SiPM1-SiPM2)

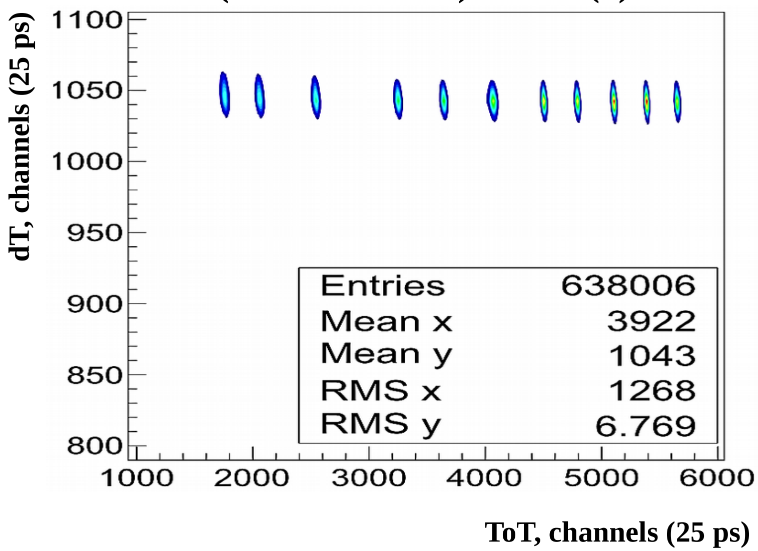


A.V. Tishevskiy et al., J.Phys.Conf.Ser, V.1690, 012051 (2020)

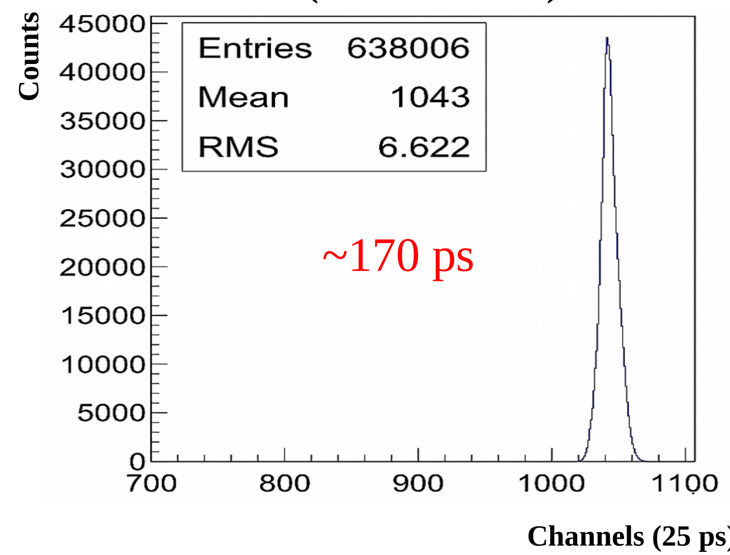
FEE studies results

The time difference histogram FEE ToT (version 03)

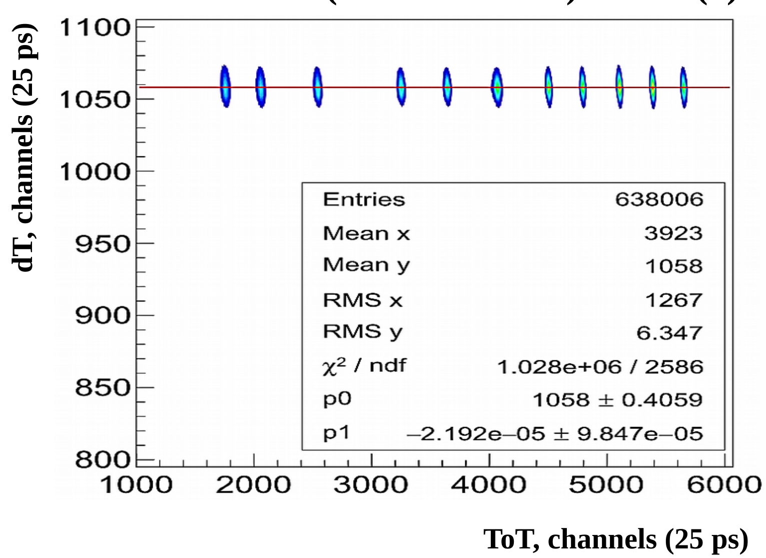
dT(SiPM1-SiPM2) vs ToT(2)



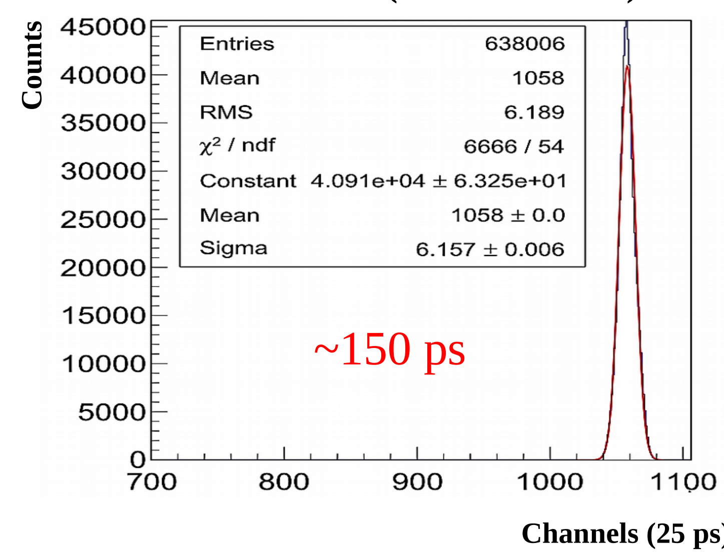
dT(SiPM1-SiPM2)



Corrected dT(SiPM1-SiPM2) vs ToT(2)



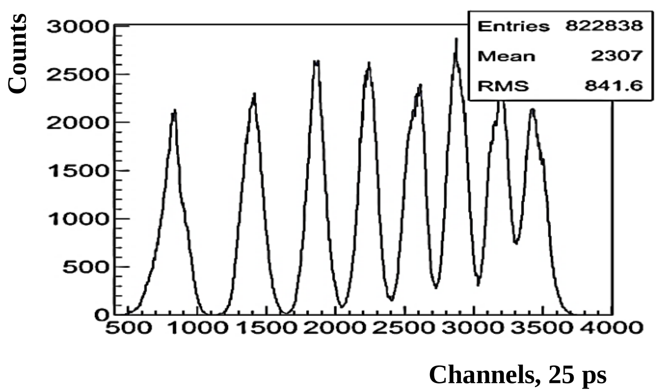
Corrected dT(SiPM1-SiPM2)

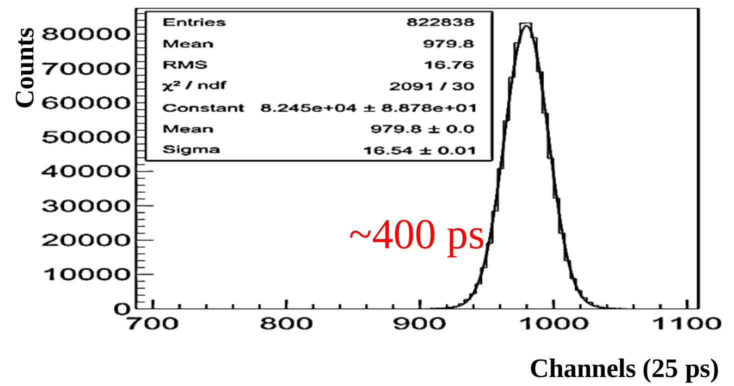


Comparison of FEE ToT versions

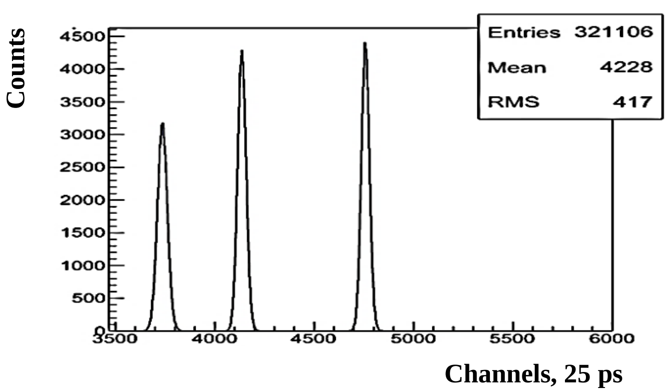
ToT | Corrected dT(SiPM1-SiPM2)

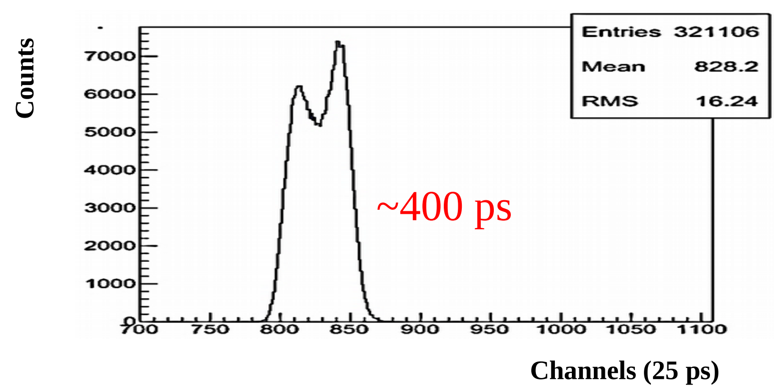
v.1



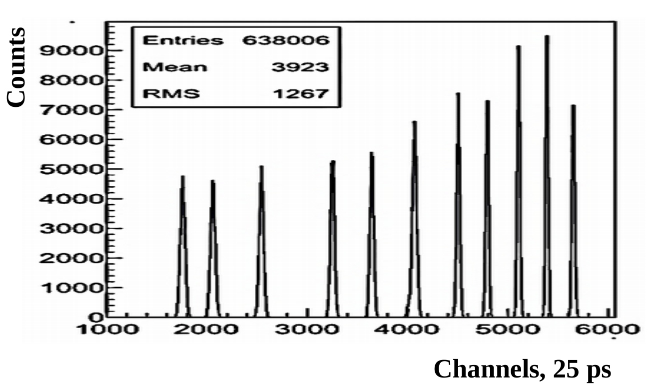


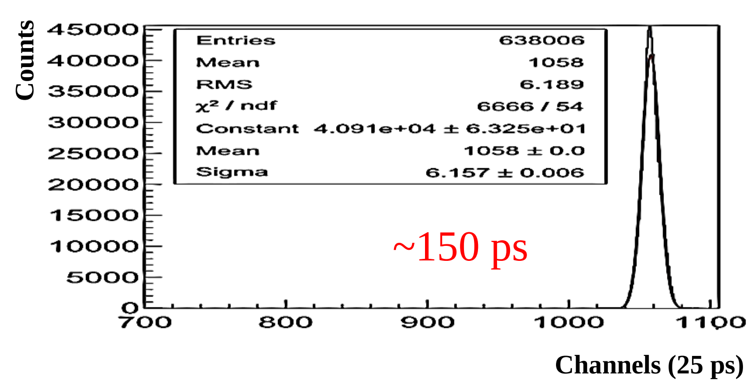
v.2





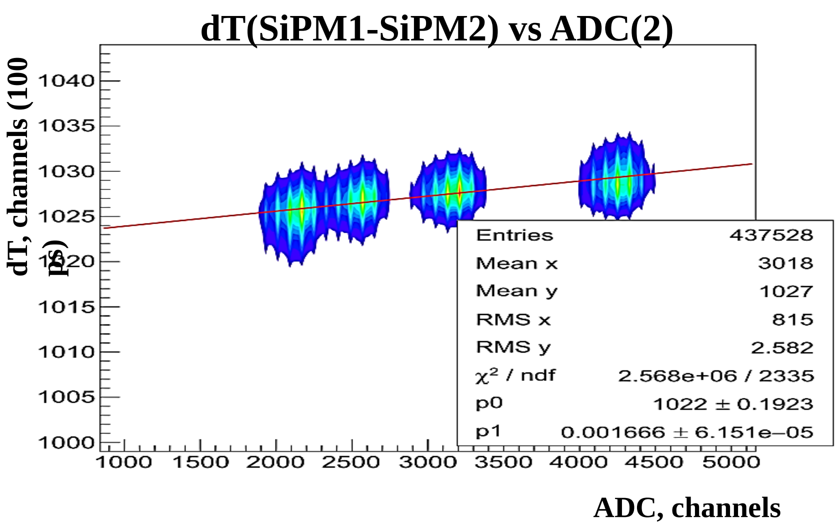
v.3

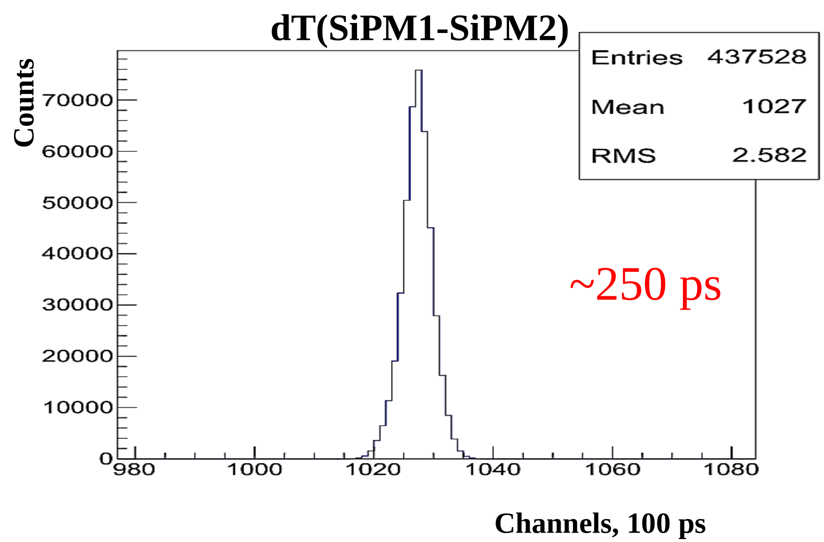


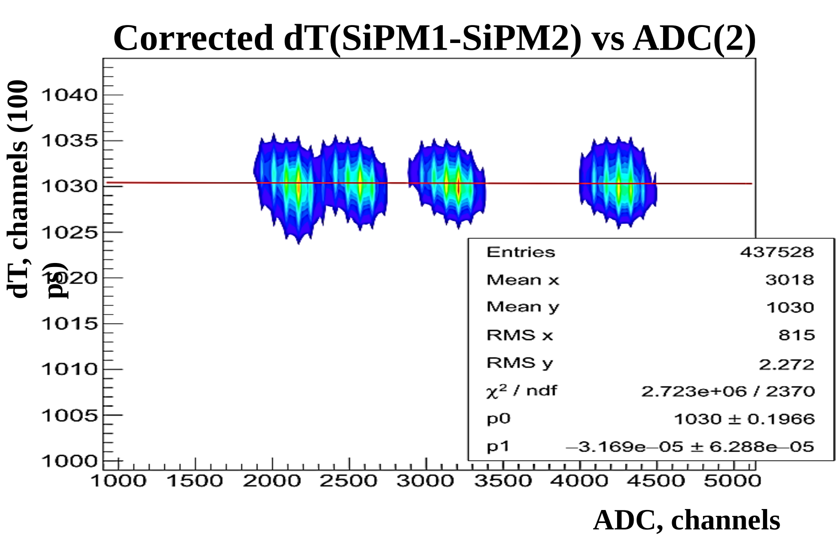


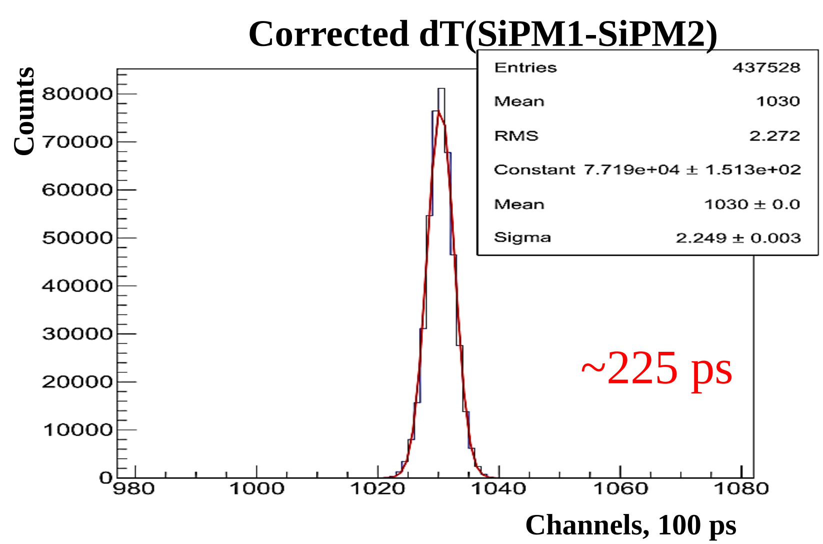
FEE studies results

The time difference histogram for FEE DANSS







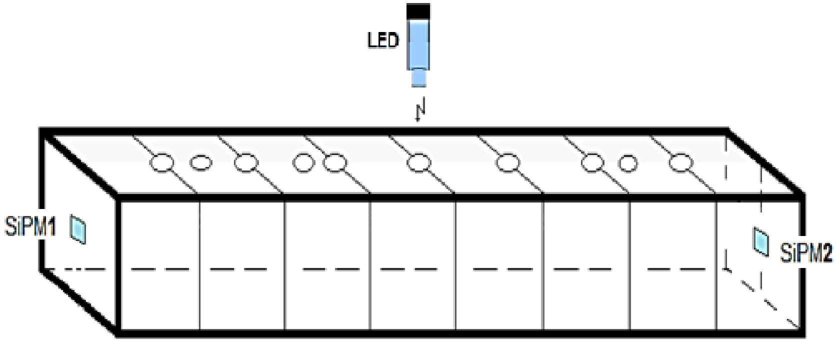


Phys.Atom.Nucl., DOI:10.1134/S1063778822090381 (2022)

FEE studies results

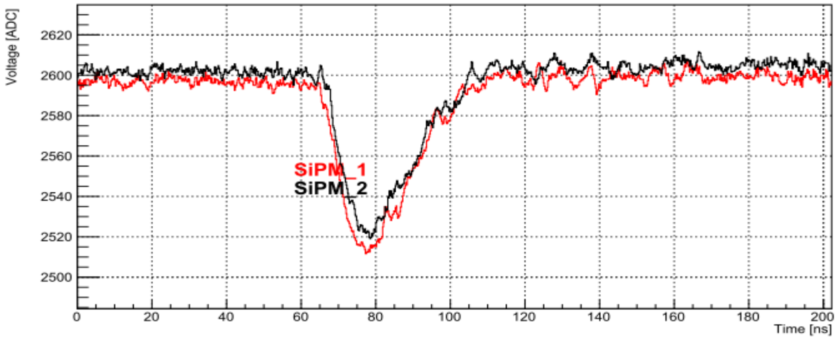
CAEN digitizer DT5742 (16ch)

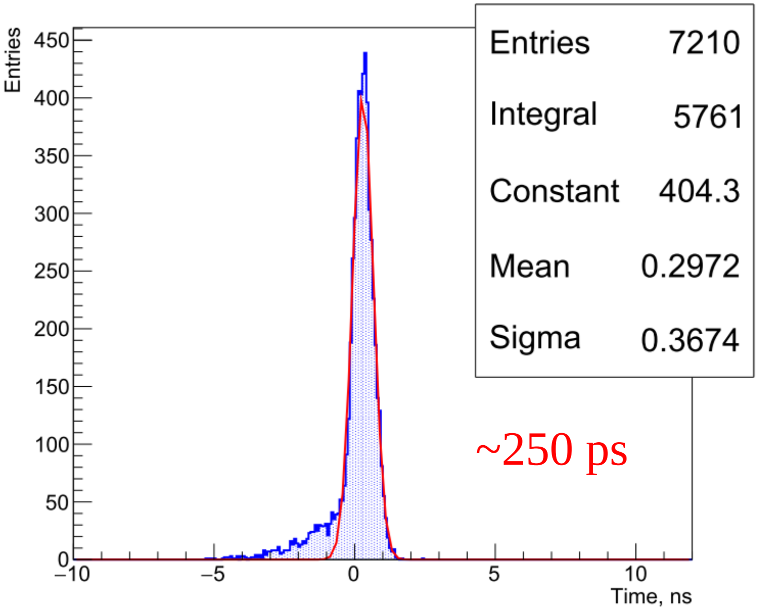
16+1 Channel 12 bit 5 GS/s
Switched Capacitor Digitizer

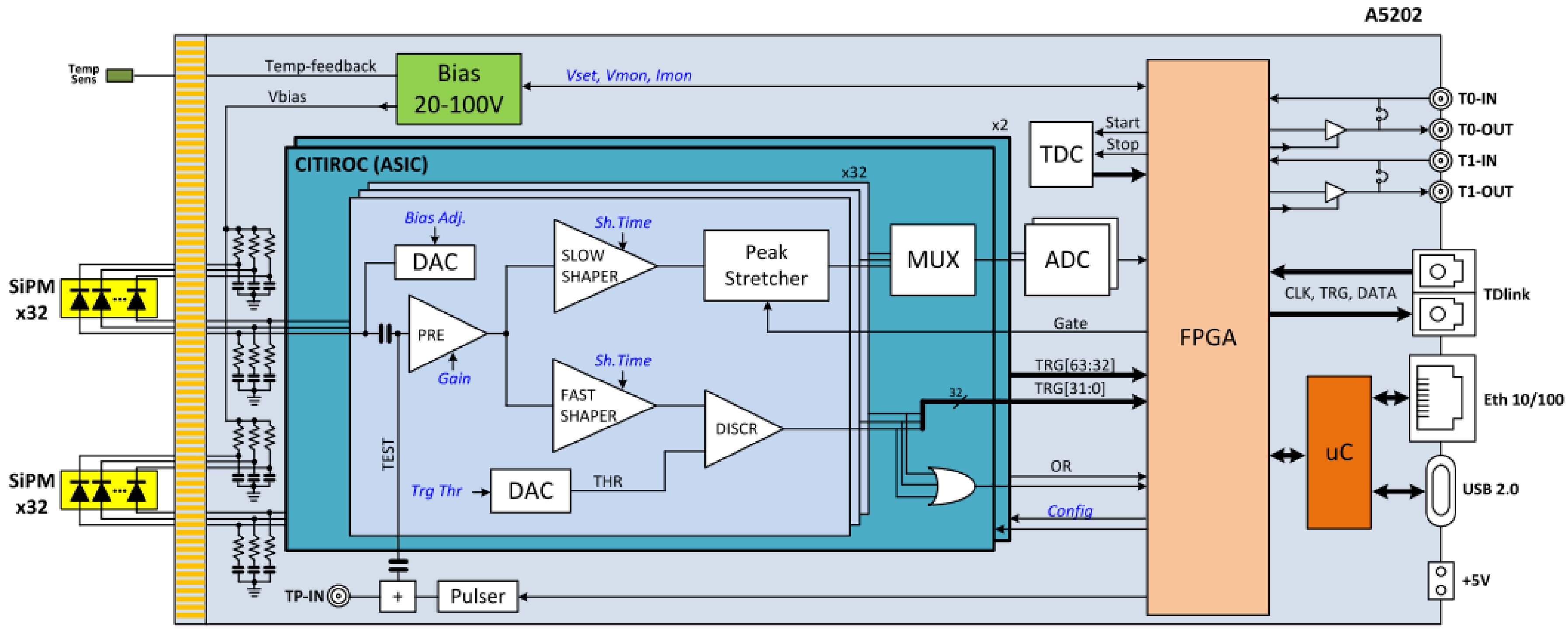


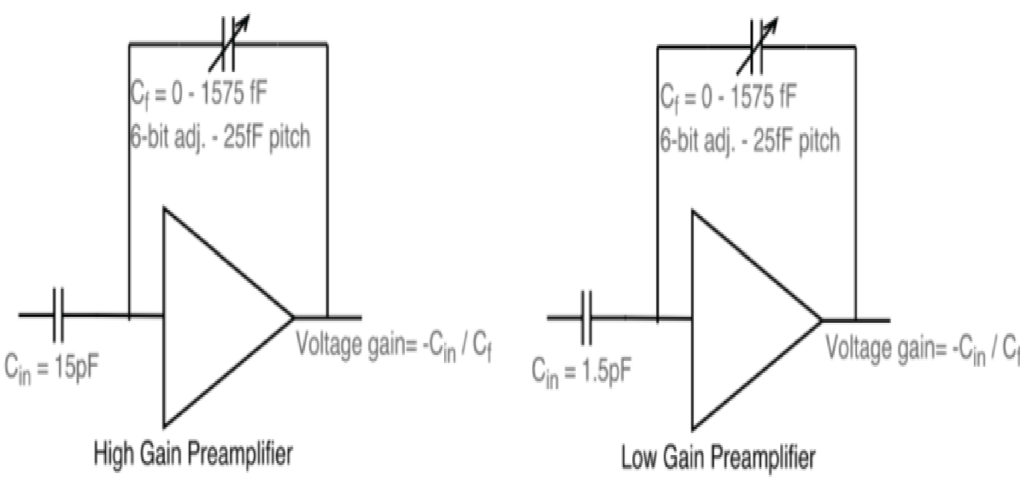
- Hamamatsu SiPM (S12572-010P)
- FEE of DANSS experiment

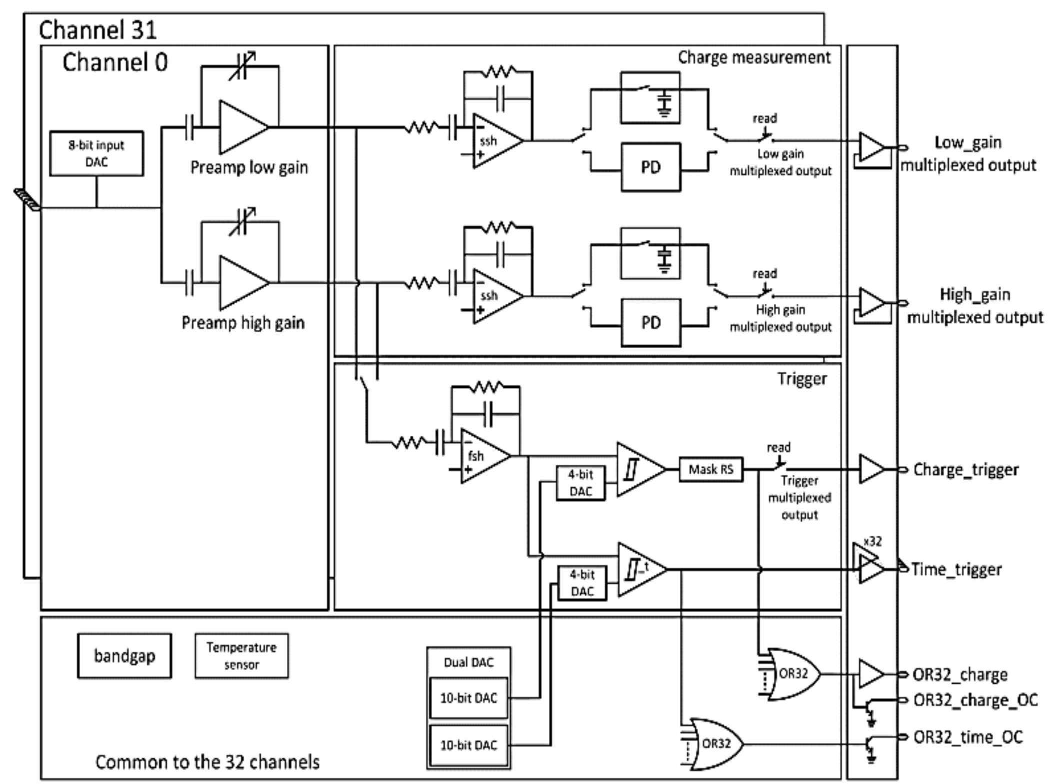
based on the DRS4 a Switched Capacitor Array. This technology relies on a set of capacitors that continuously sample the analog input signals. As soon as the trigger is issued, capacitors are decoupled from the input signals with a time interval from each other that is the sampling period.





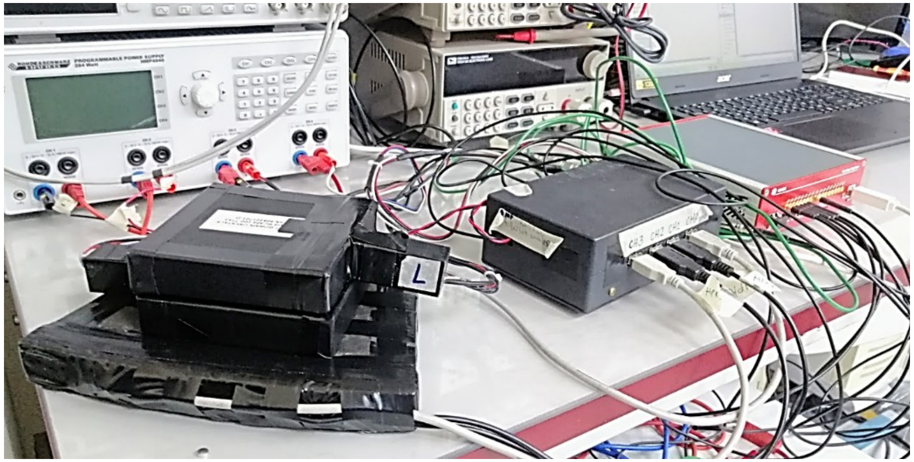

A5202
Temp Sens
Temp-feedback
Bias 20-100V
Vset, Vmon, Imon
Vbias
x2
CITIROC (ASIC)
x32
TDC
Start
Stop
T0-IN
T0-OUT
T1-IN
T1-OUT
Bias Adj.
DAC
Sh.Time
SLOW SHAPER
Peak Stretcher
MUX
ADC
TDlink
CLK, TRG, DATA
SiPM x32
PRE
Gain
Gate
FPGA
FAST SHAPER
TRG[63:32]
TRG[31:0]
32
DISCR
Eth 10/100
uC
TEST
Trg Thr
DAC
THR
OR
USB 2.0
Config
+5V
TP-IN
+
Pulser

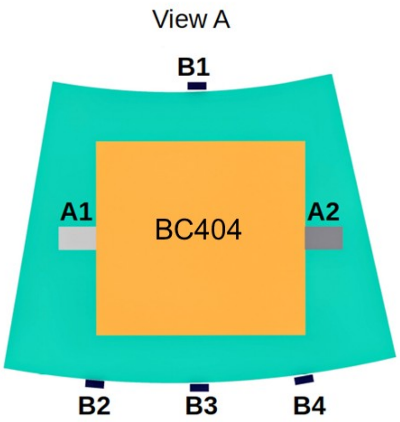

C_f = 0 - 1575 fF
6-bit adj. - 25fF pitch
C_{in} = 15pF
Voltage gain= $-C_{in} / C_f$
High Gain Preamplifier
C_f = 0 - 1575 fF
6-bit adj. - 25fF pitch
C_{in} = 1.5pF
Voltage gain= $-C_{in} / C_f$
Low Gain Preamplifier


Channel 31
Channel 0
8-bit input DAC
Preamp low gain
Preamp high gain
Charge measurement
ssh
PD
read
Low gain multiplexed output
Low_gain multiplexed output
High gain multiplexed output
High_gain multiplexed output
Trigger
fsh
4-bit DAC
Mask RS
Trigger multiplexed output
Charge_trigger
x32
Time_trigger
bandgap
Temperature sensor
Dual DAC
10-bit DAC
10-bit DAC
OR32
OR32_charge
OR32_charge_OC
OR32_time_OC
Common to the 32 channels

```
//**************************************************
// File Format Version 3.1
// Janus Release 2.2.10
// Acquisition Mode: Spect_Timing
// Energy Histogram Channels: 4096
// ToA/ToT LSB: 0.5 ns
// Run start time: Thu May 12 12:34:25 2022 UTC
//**************************************************
      Tstamp_us        TrgID   Brd  Ch        LG        HG   ToA_ns    ToT_ns
          2.880            0    00  00        39        39        -         -
                                00  01        36        35        -         -
                                00  02        36        20    919.0       8.0
                                00  03        42        55        -         -
                                00  04        30         9        -         -
                                00  05        40        41        -         -
                                00  06        36        12        -         -
                                00  07        38        69        -         -
                                00  08        33        13        -         -
                                00  09        31     32766    955.0       5.5
                                00  10        38       160    140.0      14.0
                                00  11        37       282     74.0      20.0
                                00  12        45       141        -         -
                                00  13       105       785     71.0      28.0
                                00  14        35        14        -         -
                                00  15       105       768     71.0      28.5
                                00  16        35        69        -         -
                                00  17        36       101    855.0       8.5
                                00  18        38       100        -         -
                                00  19       117       861     71.0      29.5
                                00  20        35        32        -         -
                                00  21        44       236     83.5       8.5
                                00  22        38        25        -         -
                                00  23        57       240     83.0       9.0
                                00  24        36     32767        -         -
                                00  25        32        12        -         -
                                00  26        39        53        -         -
                                00  27        33        49        -         -
```

Fig. 3.36: Event List example in Spectroscopy + Timing Mode (Ascii format), where ToA and ToT are expressed in ns.





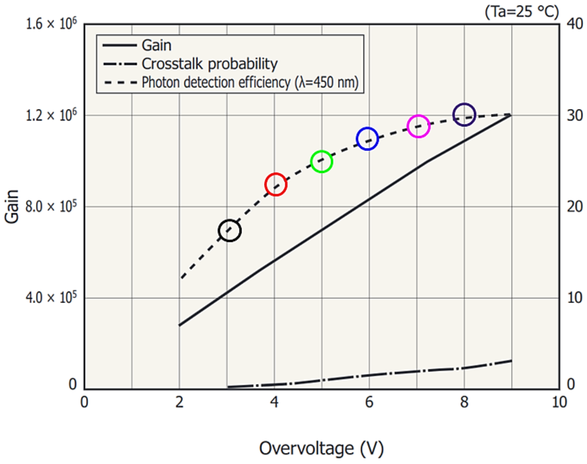
Light from prototype (BC404) is detected by four SiPM (B1-B4)

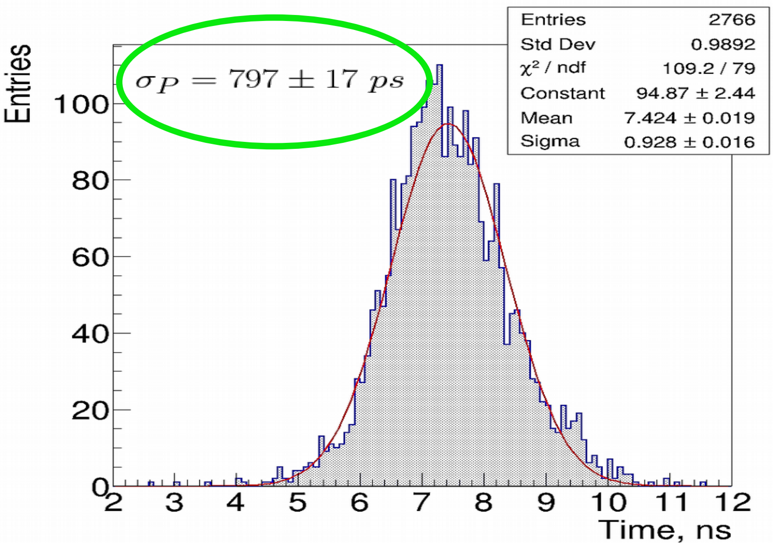
Different Vbias were explored (55.5, 56.5, 57.5, 58.5, 59.5, 60.5 V).

DAQ based on **(16 ch) CAEN digitizer DT5742** was launched

Hamamatsu SiPM (S13360-3050CS, 3x3 mm^2, 50 µm/cell)

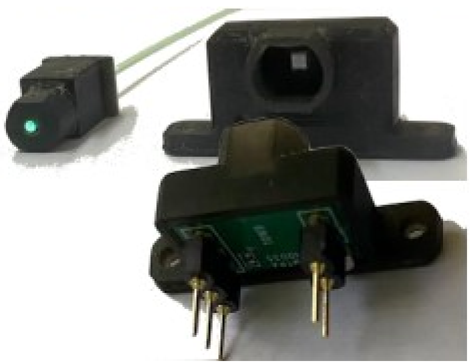
The prototype (in blue) was placed below the trigger counters (in yellow), which provided the start signal for data readout. Each trigger counter was made of a BC404 scintillator plate (10x10x2 cm^3) and one Hamamatsu (H5783) PMT (A1, A2).

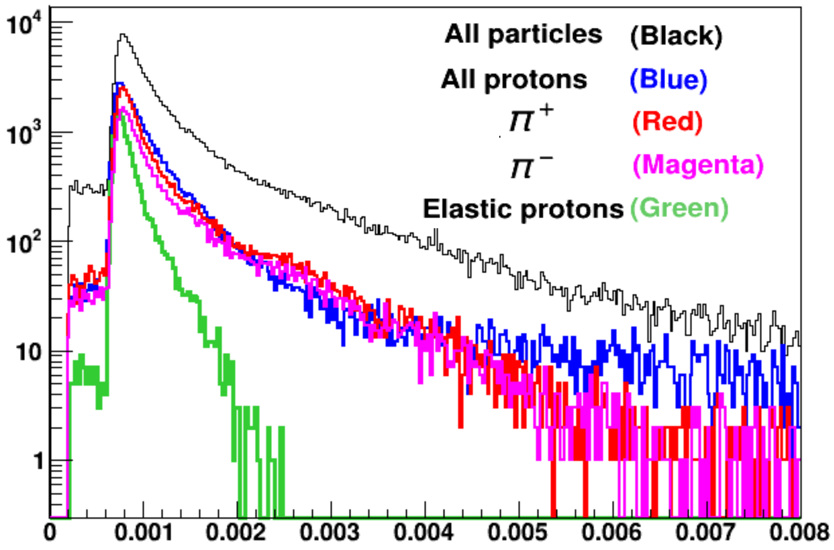


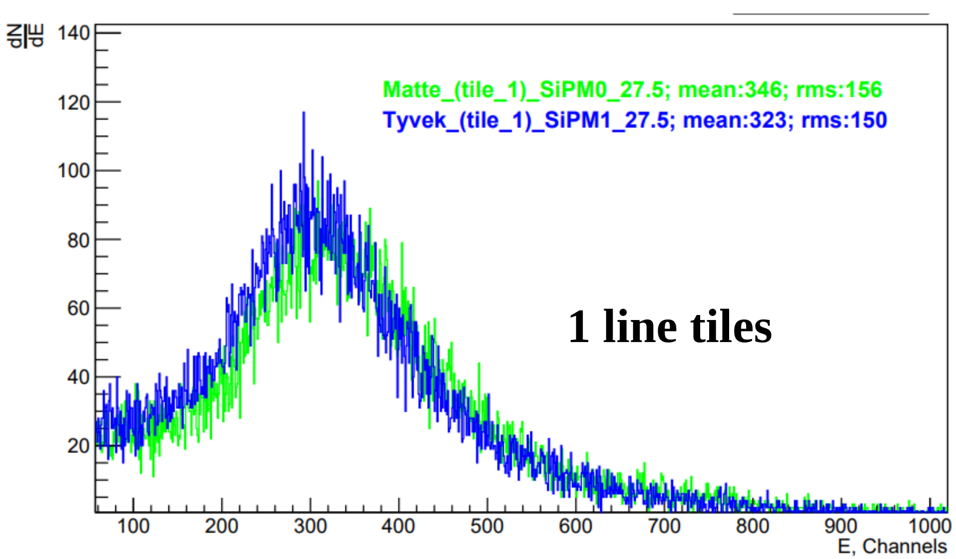


MILLENNIUM INSTITUTE FOR SUBATOMIC PHYSICS AT HIGH-ENERGY FRONTIER SAPHIR

Together with **M.A. Ayala-Torres (SAPHIR-UNAB)**




All particles (Black)
All protons (Blue)
π^+ (Red)
π^- (Magenta)
Elastic protons (Green)
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008
1 10 10^2 10^3 10^4


$\frac{dN}{dE}$
Matte_(tile_1)_SiPM0_27.5; mean:346; rms:156
Tyvek_(tile_1)_SiPM1_27.5; mean:323; rms:150
1 line tiles
E, Channels