BBC status report

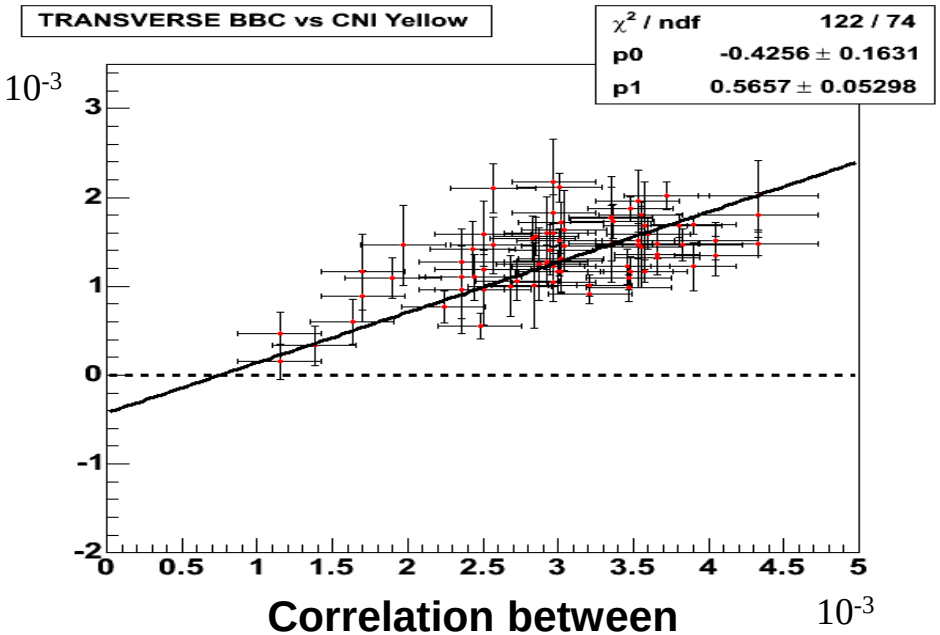
A.V.Tishevsky on behalf of JINR-MEPhI BBC

VI SPD Collaboration Meeting and Workshop on Information Technology

in Natural Sciences

24 October 2023

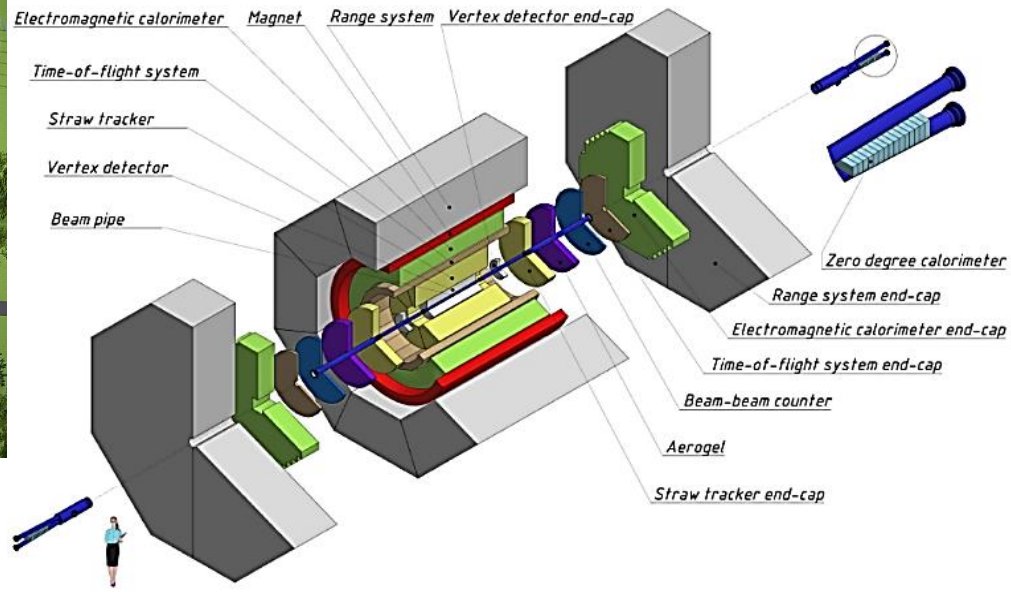
Introduction



Correlation between CNI polarimeter and STAR BBC asymmetries.

General

The Spin Physics Detector (SPD)



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.

TDR concept:

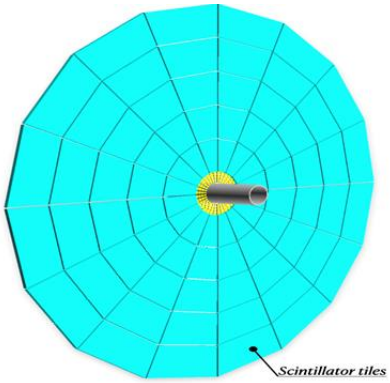
- **Scintillator tiles part at the distance ~1.7 m**
- **MCP part is at the distance ~4.0 – 4.5 m**

Introduction

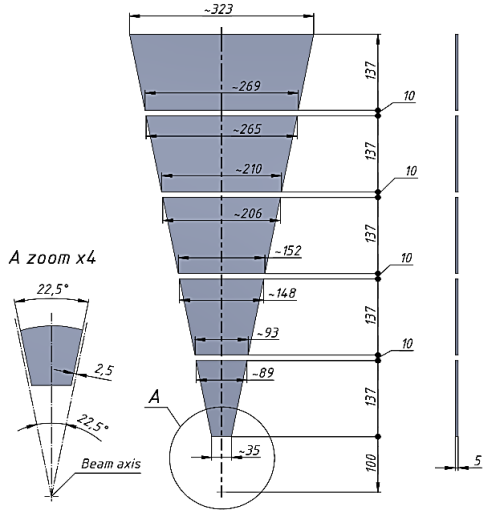
TDR version of BBC: scintillation tiles part

2 panels (z = ±171.6 cm.)
16 sectors by azimuth angle
6 sectors by polar angle
1.48 < η < 4.39

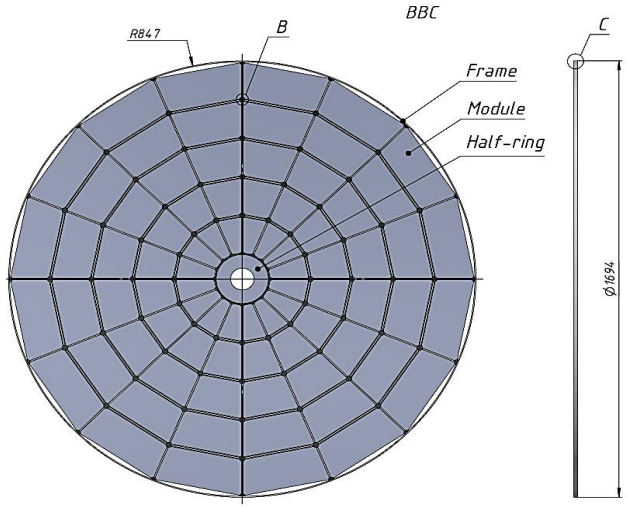
1 sector(extreme inner):
4.25 <r< 9.5 (cm.)
2-6 sector:
10.0 <r< 82.5 (cm.)



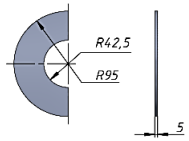
BBC Sector zoom x2



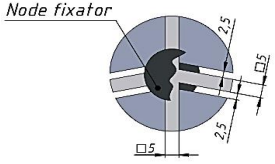
BBC



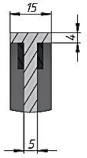
BBC Half-ring zoom x2



B zoom x10



C zoom x10

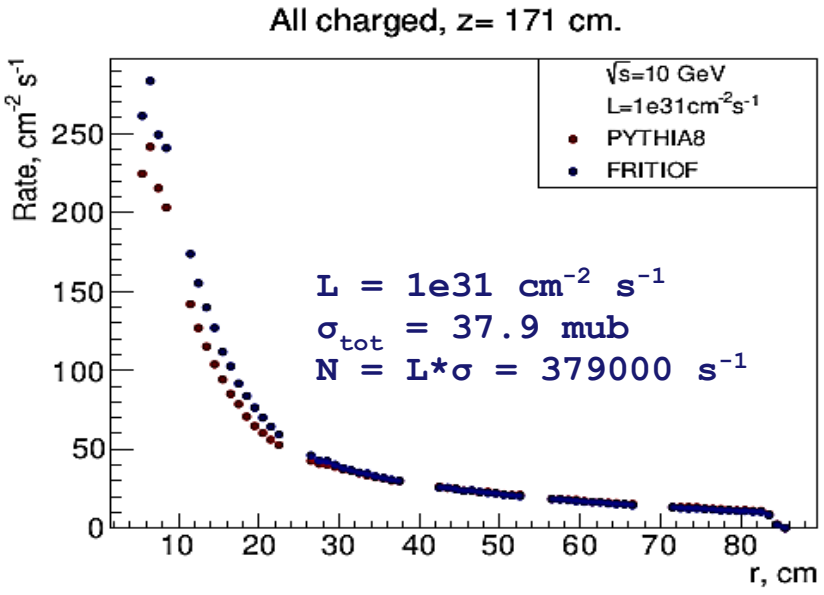


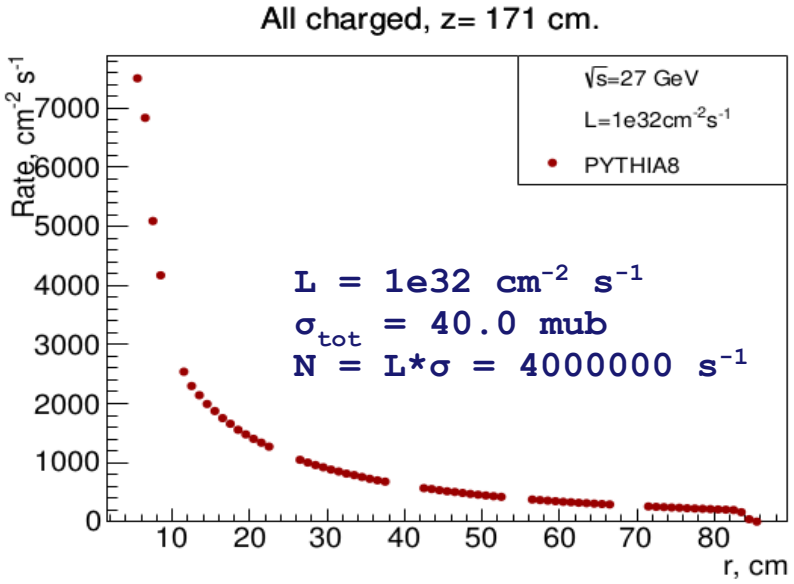
Inner part can be used for luminosity estimation and, possibly, for local polarimetry using pp- and dp- elastic scattering. Local polarimetry will be provided by the analysis of the azimuthal asymmetry in inclusive production of charged particles in forward direction.

Simulation (pp)

FTF and Py8 generators

$\sqrt{s}$ = 10 and 27 GeV





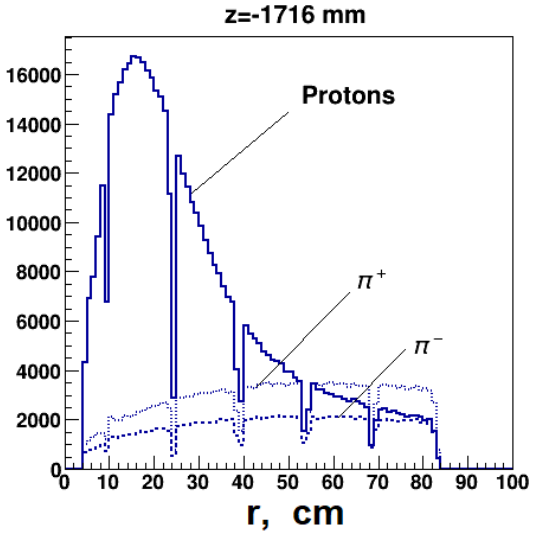
Z.Kurmanaliyev (JINR)

The result of this simulations shows that the in principle accepted for the internal part of this design works at the high luminosity of SPD.

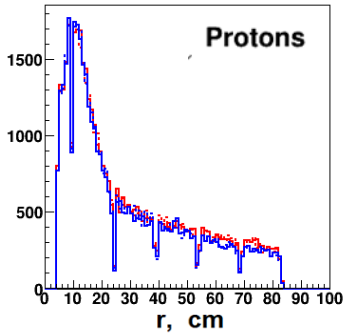
Simulation (pp)

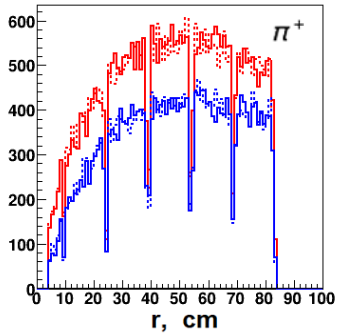
FTF and Py8 generators

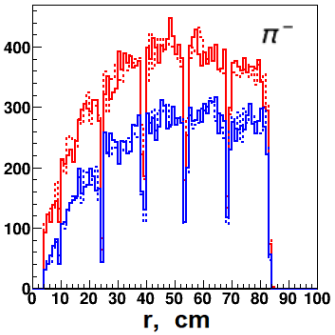
The dependence from the distance from IP



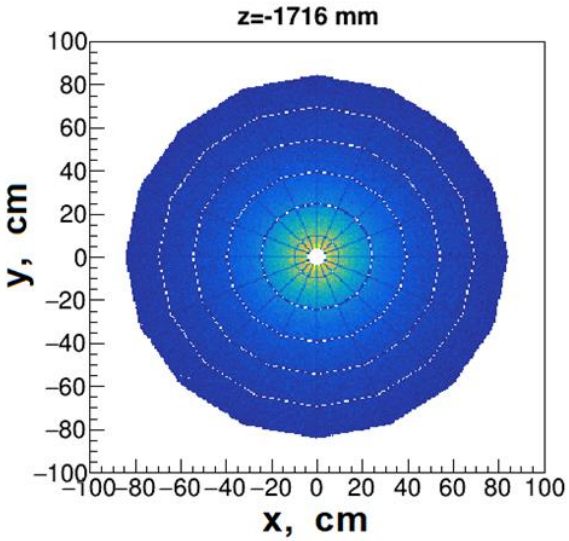
The influence of the magnetic field on detector loads

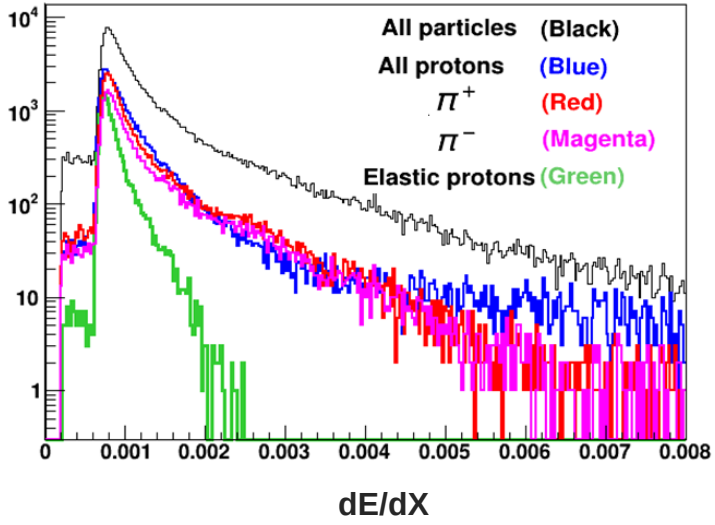






<u>The coordinate profiles of events in BBC</u>





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

A.Terekhin (JINR)

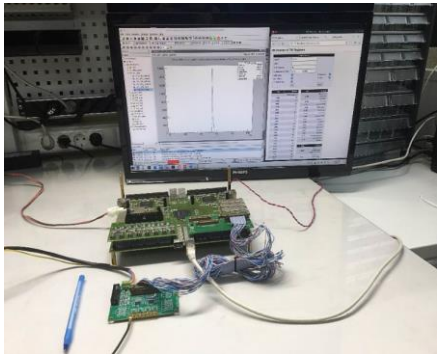
Simulation of the pp-scattering for the SPD BBC (**A.Terekhin**)

(see talk tomorrow)

The hardware of BBC tests part

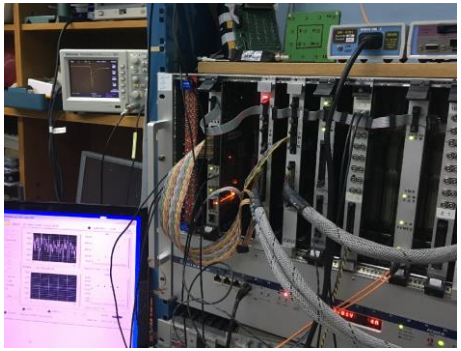
The stand for BBC measurements

TRB-3 (10 ps)



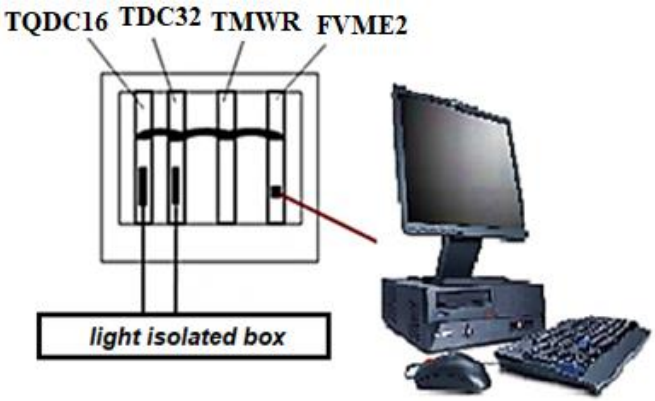
Together with **V.Chmil (JINR), S.Morozov, E.Usenko (INR)**

The VME based DAQ

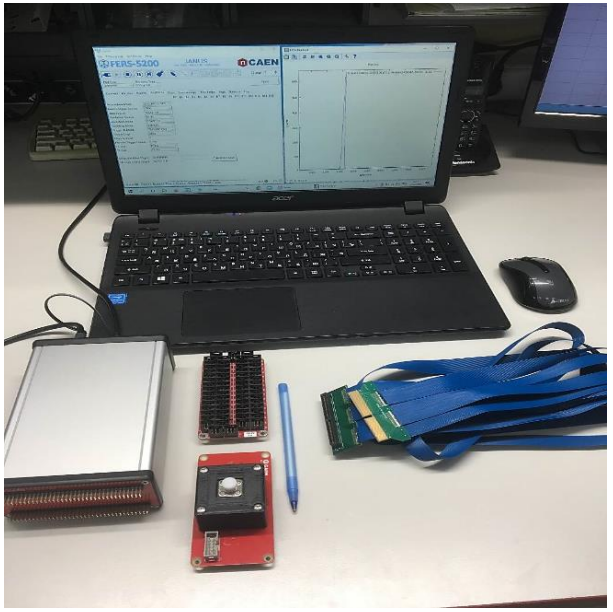


Isupov A.Yu. // EPJ Web Conf. 2019. V.10003. P.204

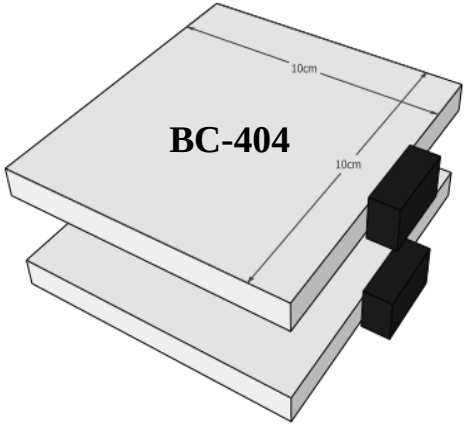
TQDC16

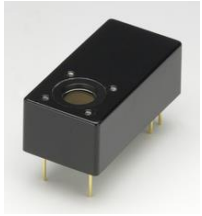


CAEN FERS 5200



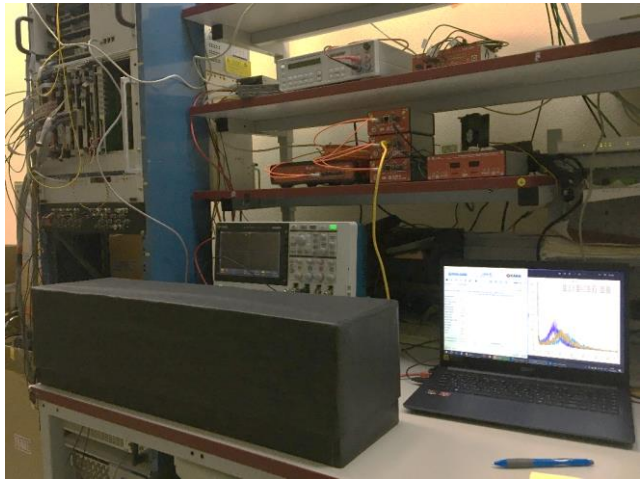
External trigger by coincidence of two scintillators with PMTs readout





PMT Hamamatsu H10720-110

The stand for BBC

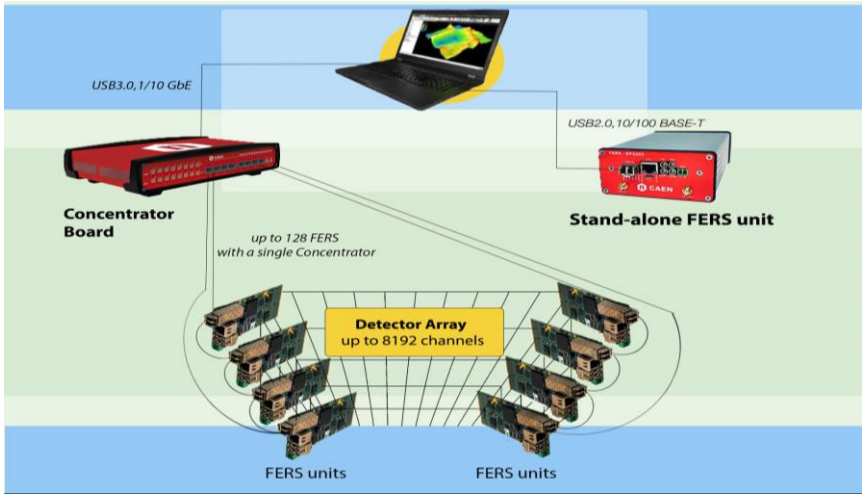


The hardware of BBC tests part

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).

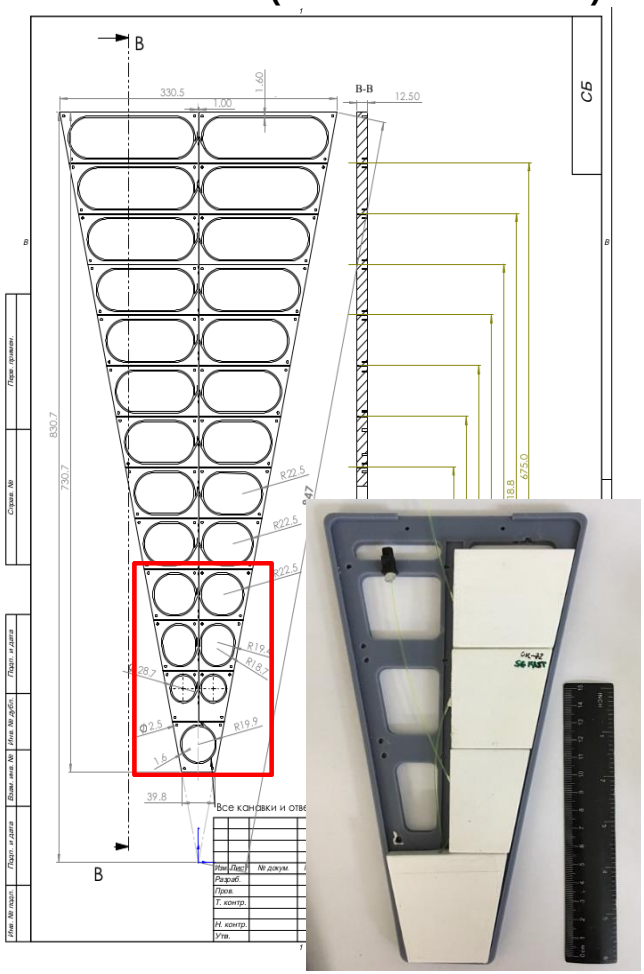
Each channel has low **(LG)** and high **(HG)** gain preamplifiers providing a wide dynamic range.

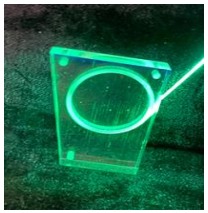
Main Acquisition Modes:

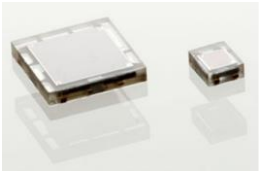
- SPECTROSCOPY.
- TIMING.
- SPECT_TIMING. The Spectroscopy + Timing

Proposal of 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
  - OK-72
- **SENSL SiPMs** (MicroFC-x0035-SMT)
  - 3x3 mm^2 (for tests)
  - **1x1 mm^2 (final option)**

Scintillation detector prototype materials

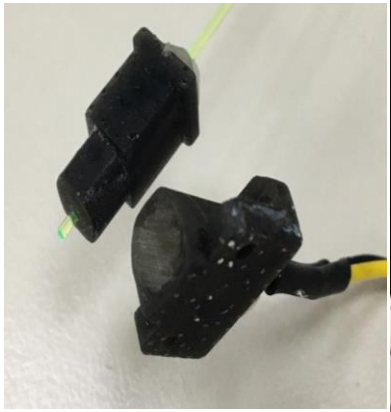
Line

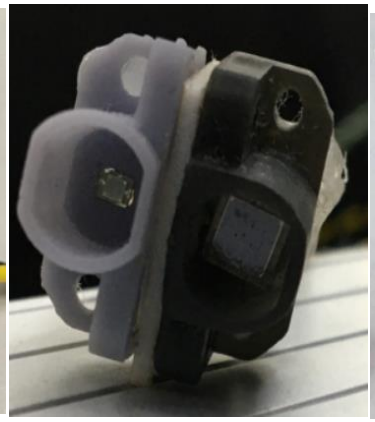
3 (L;R)

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

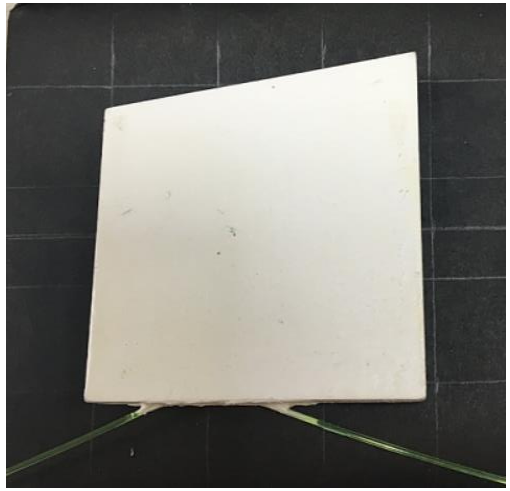
KURARAY (Y-11)

SiPMs: **3x3 mm^2 vs 1x1 mm^2 (final option)**

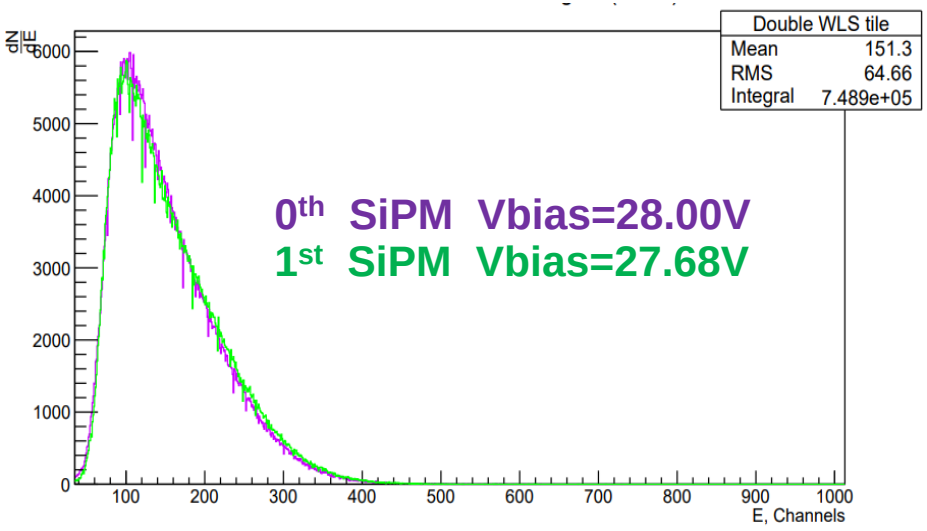
Table 1. Optical cements and their parameters

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

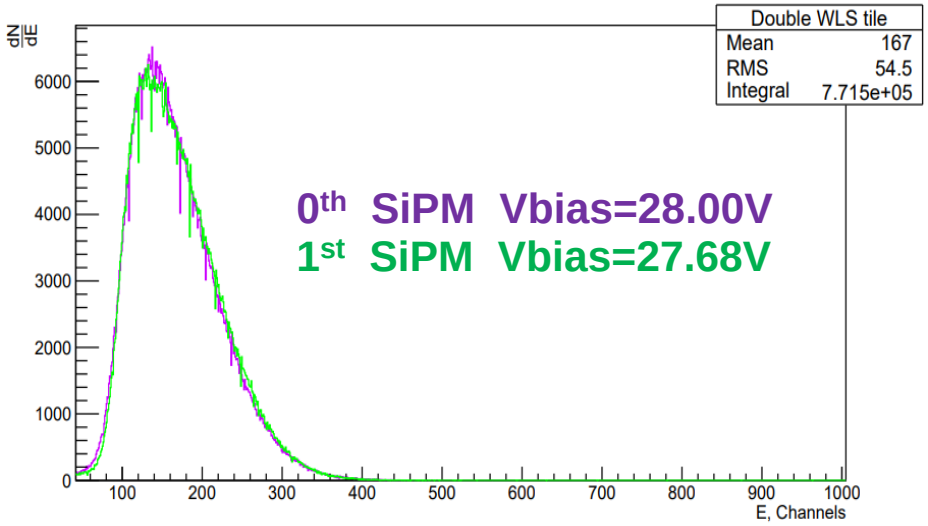
Tile with **two WLS outputs of single fiber** for tests and in particular for SiPM calibration with radioactive sources were used.



1x1 mm² SiPM



3x3 mm² SiPM

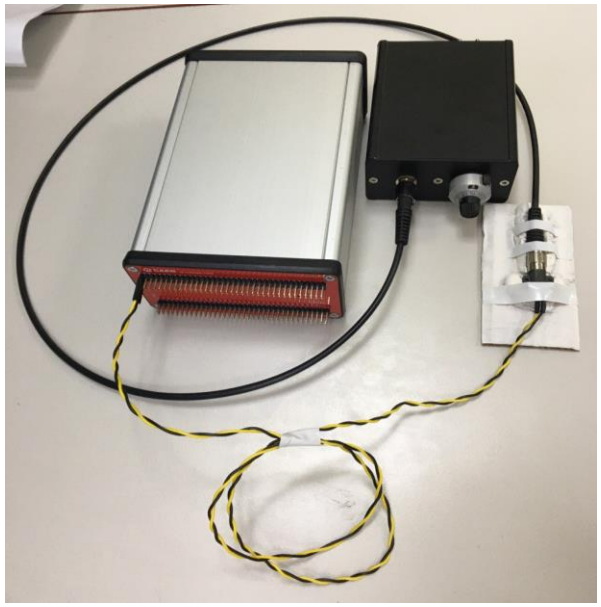


The amplitude histograms for both SiPM sizes with the chosen voltage are shown. This is not a bad result, but we preferred **another the way of calibration**.

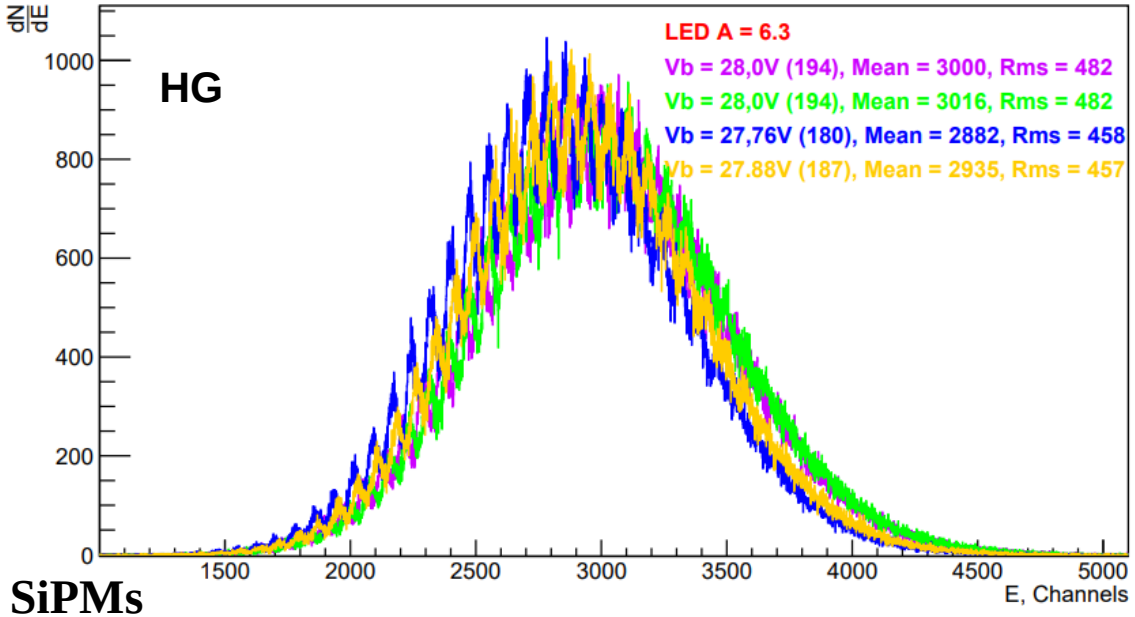
FEE studies results

Calibration method (Led source)

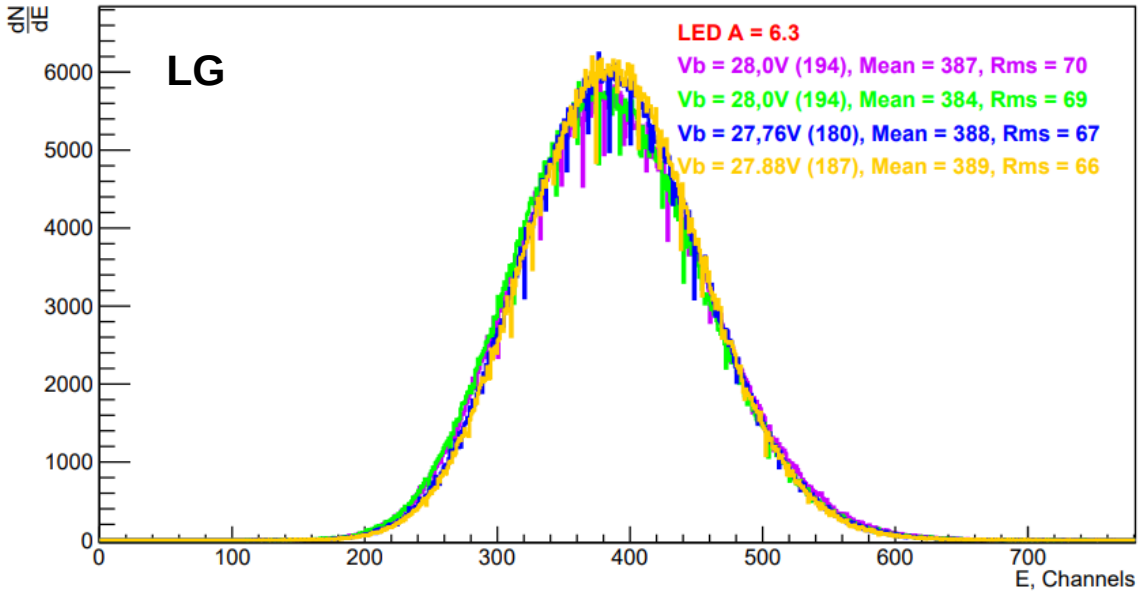
DT5202 with CAEN LED Driver (SP5601)



This voltages were used for the following tests with cosmic rays.

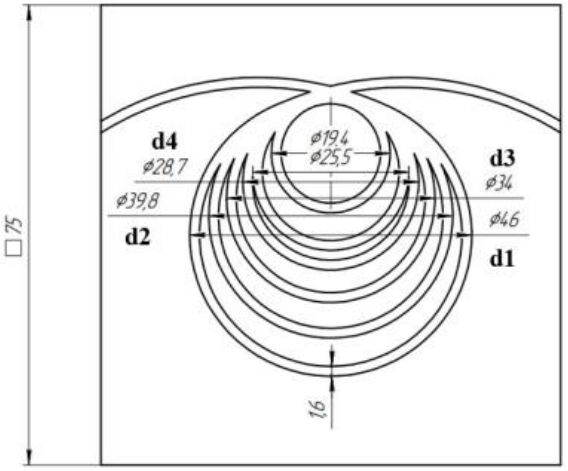


For 4 SiPMs

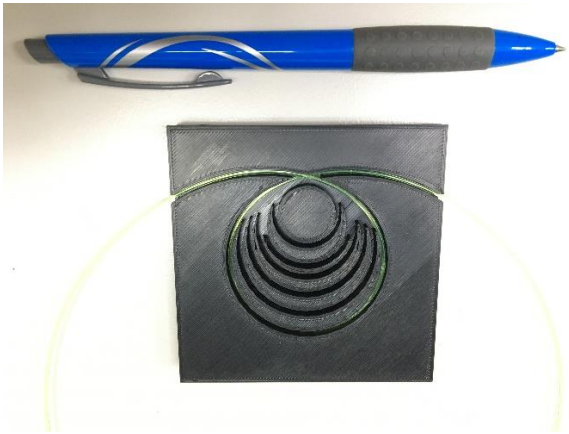


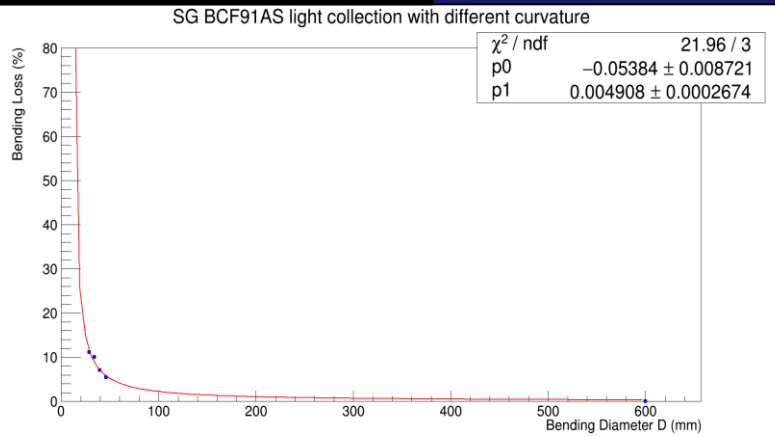
FEE studies results

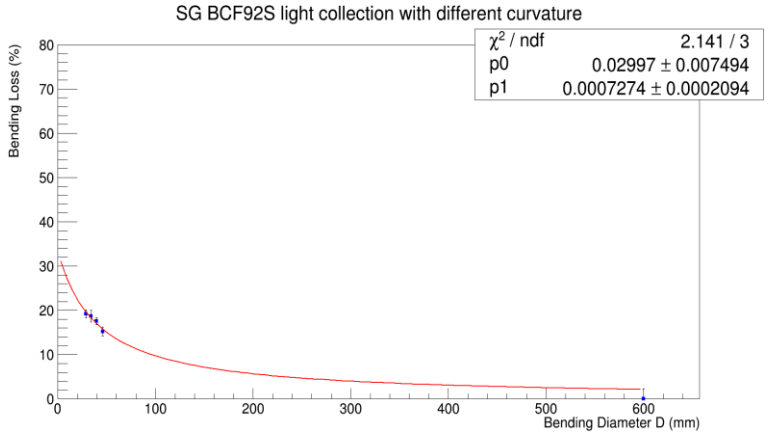
Fibers bending loss

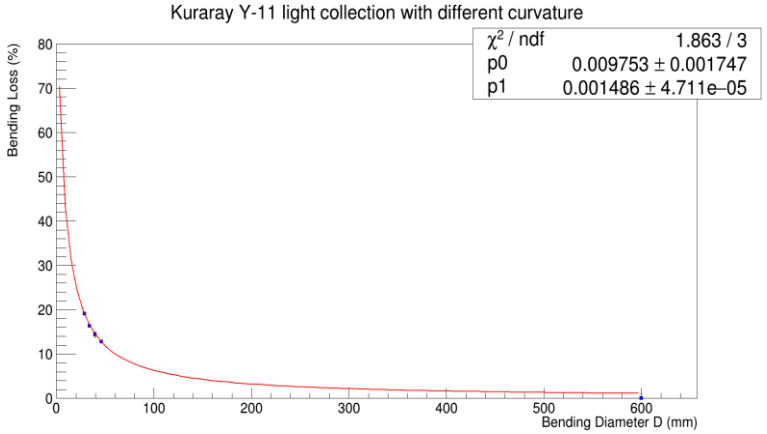


Tool for bending loss tests









Difference between d1 and d4 diameters:

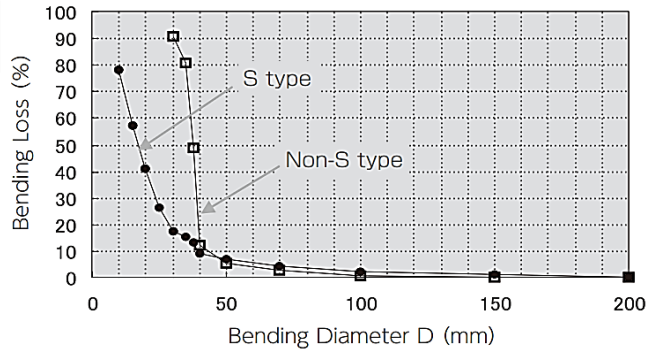
SG BCF91AS – 6.0%

SG BCF92S – 4.7%

Kuraray Y-11 – 8.5%

for 1 rotation (inside the tiles is 3)

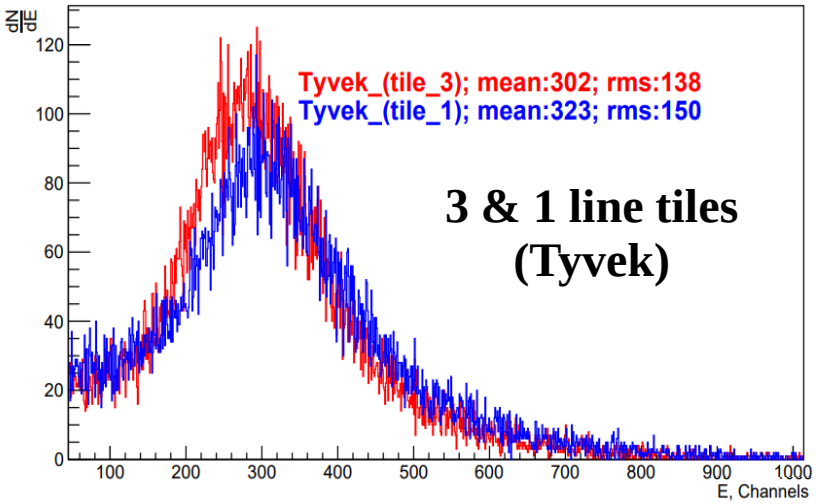
PRELIMINARY

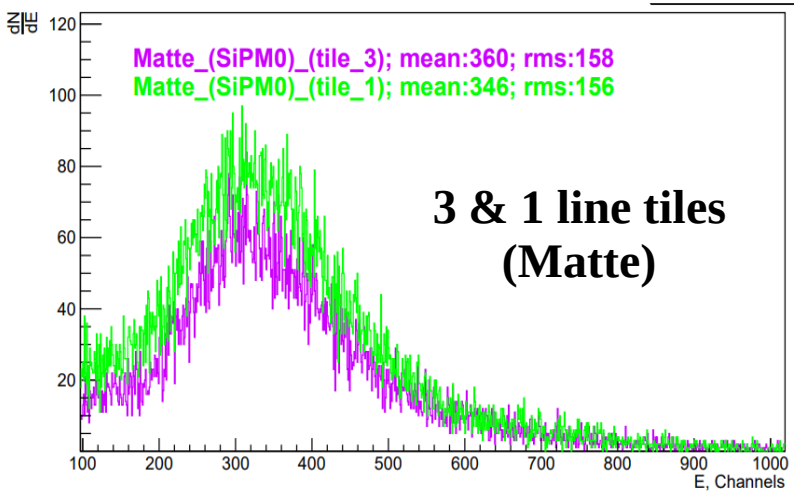


FEE studies results

Matte and Tyvek tiles (CKTN, SG92S)

Trigger time resolution ~650 ps

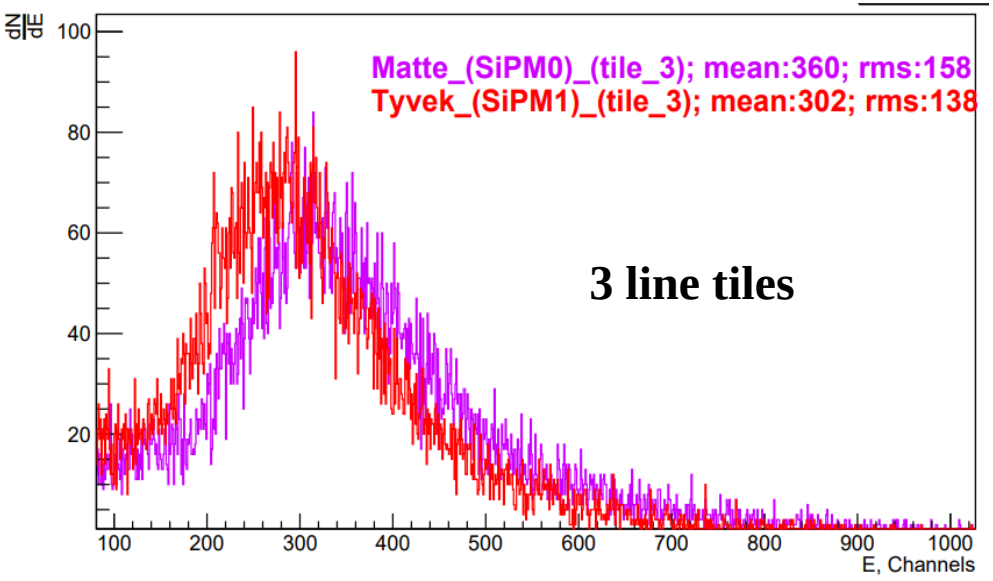


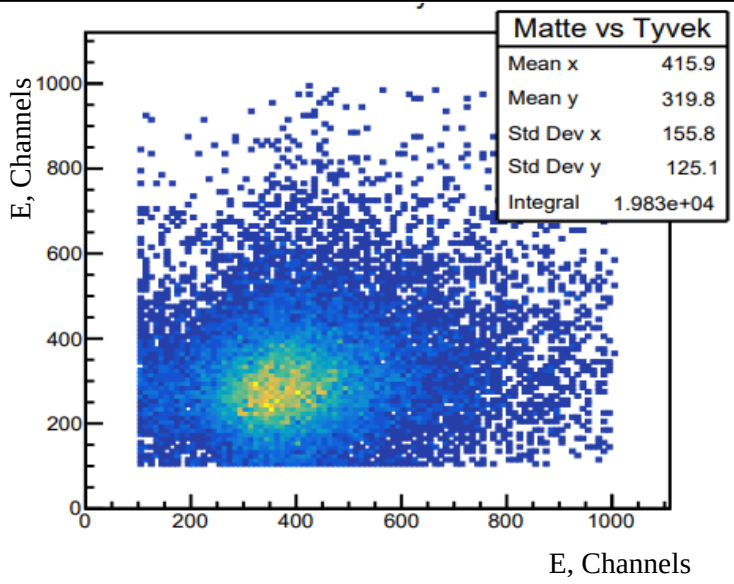


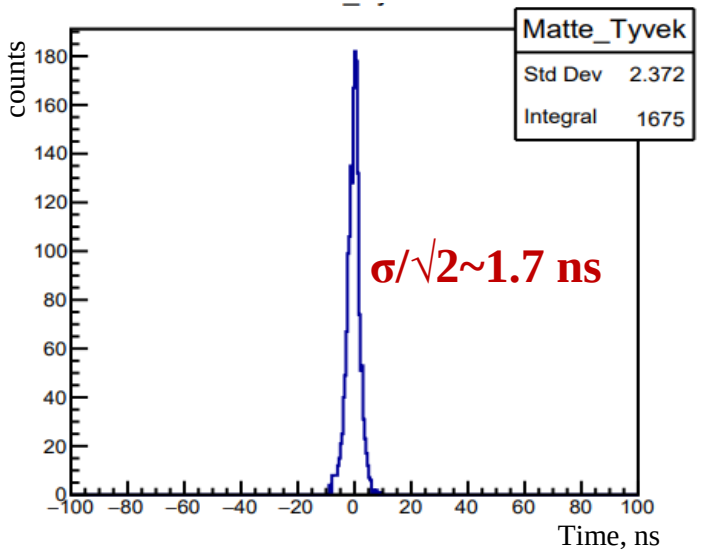
The result of comparison 1 and 3 line tiles. For Tyvek covered and matted tiles gives the same results.

FEE studies results

Matte and Tyvek difference



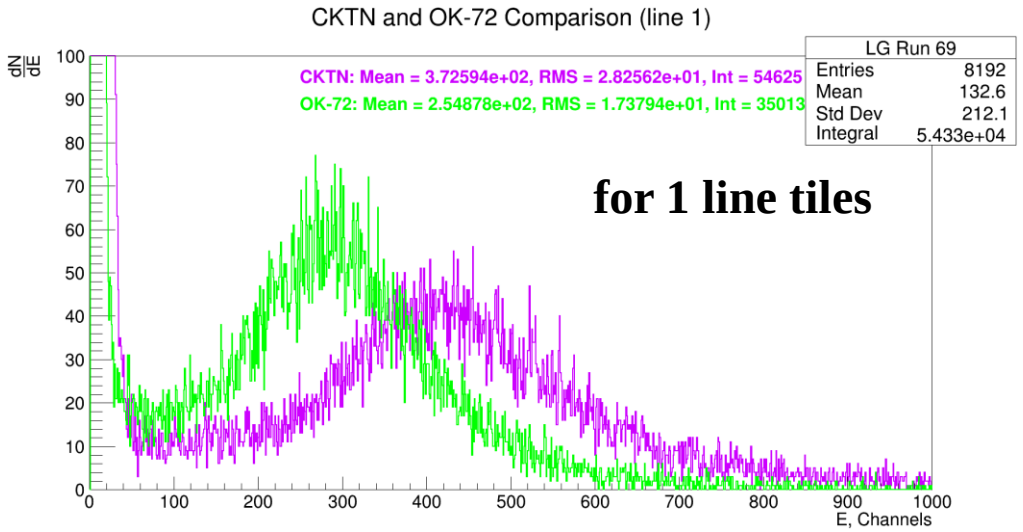


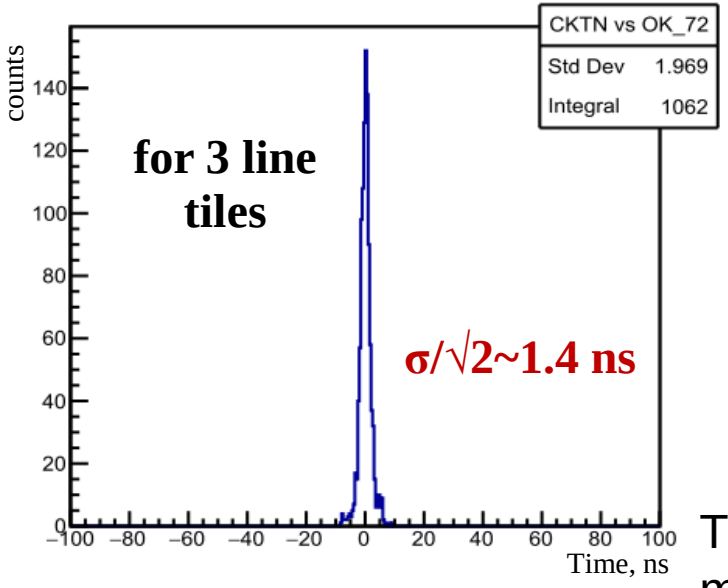


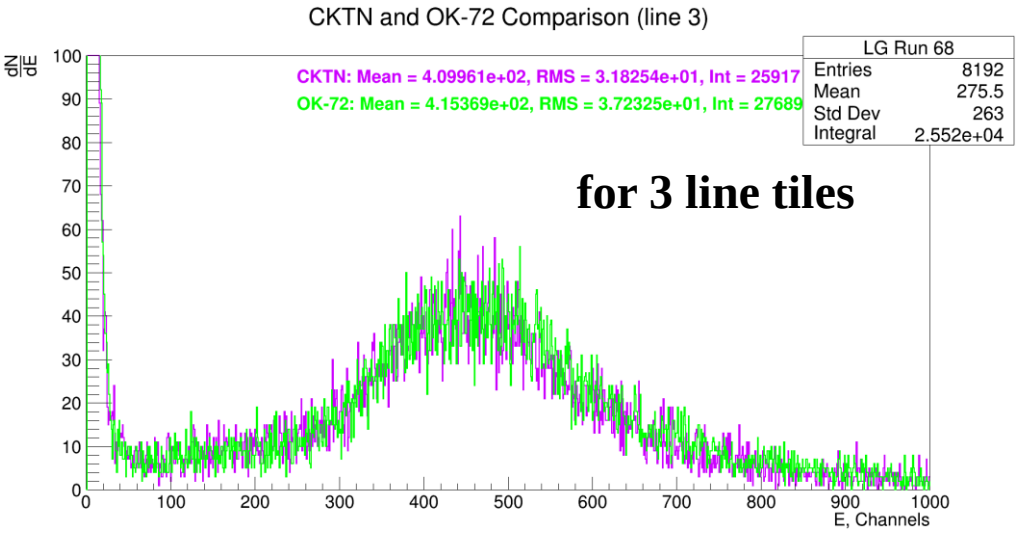
The result is similar, and due to the fact that the option with Tyvek coved tiles carries the technological complexity of mass production, the option with matted one is **more acceptable**.

FEE studies results

CKTN Med and OK-72 difference







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

FEE studies results

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

Saint-Gobain Crystals fibers

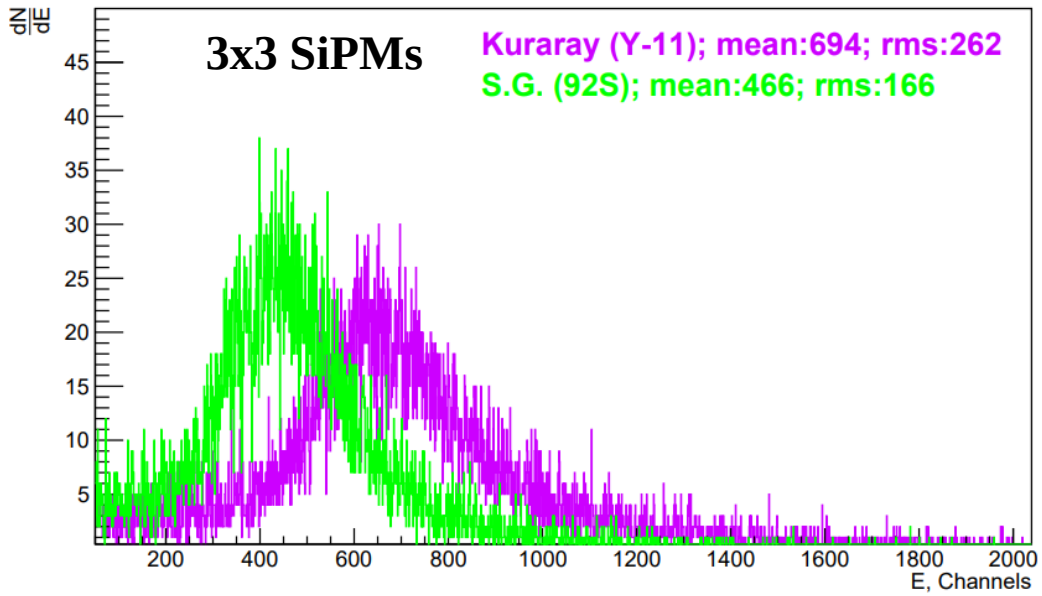
Specific Properties of Standard Formulations				
Fiber	**Emission Color**	**Emission Peak, nm**	**Decay Time, ns**	**# of Photons per MeV****
BCF-10	blue	432	2.7	~8000
BCF-12	blue	435	3.2	~8000
BCF-20	green	492	2.7	~8000
BCF-60	green	530	7	~7100
BCF-91A	green	494	12	n/a
BCF-92	green	492	2.7	n/a
BCF-98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

The difference is visible, but more tests are needed.



FEE studies results

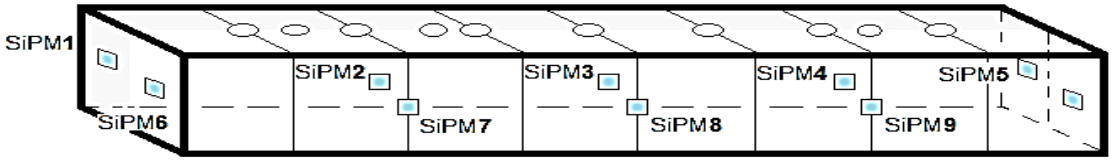
The first step of high granularity part of BBC development

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

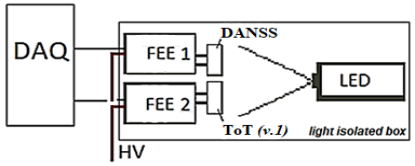
5 channels FEE of DANSS experiment (main option for ZDCs)

Plastic Scintillator
40 x 2 x 2 (cm³)

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

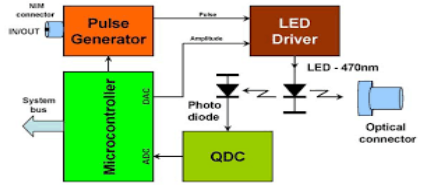


Schematic view of the test



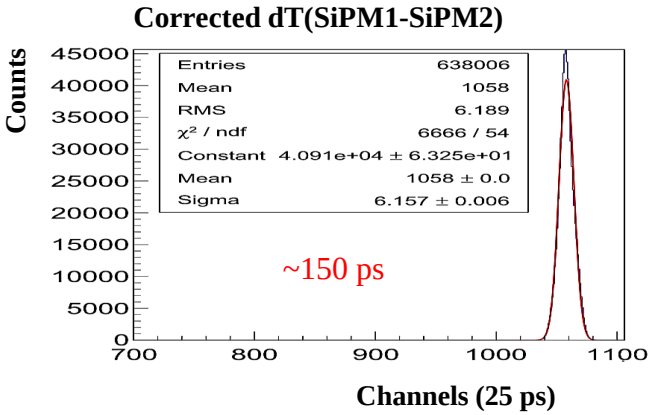
26.2 ± 0.3 °C

Schematic view of the LED

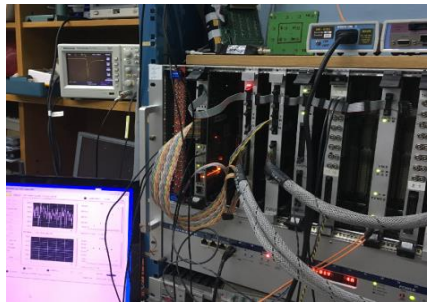


5 channels FEE of ToT (v03)

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

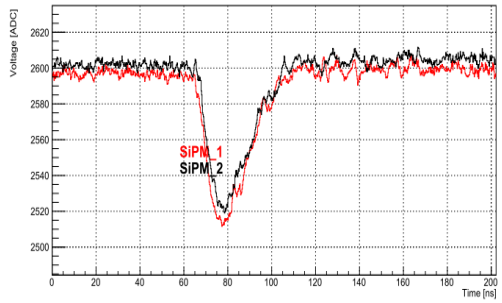


The VME based DAQ



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

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



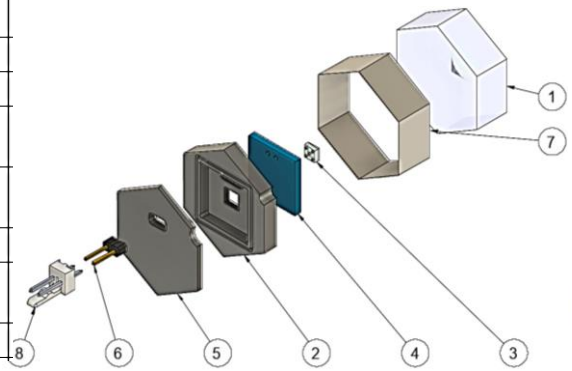
Phys.Atom.Nucl.
DOI:10.1134/S1063778822090381 (2022)

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

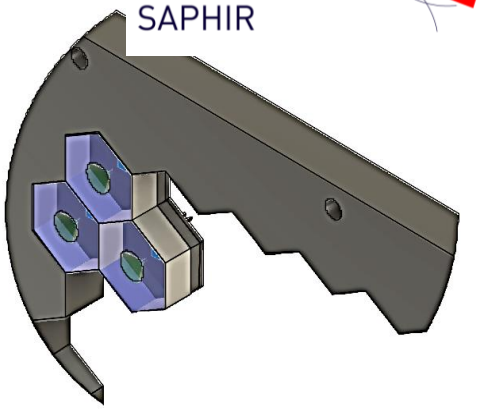
Tests at Lab201- VBLHEP

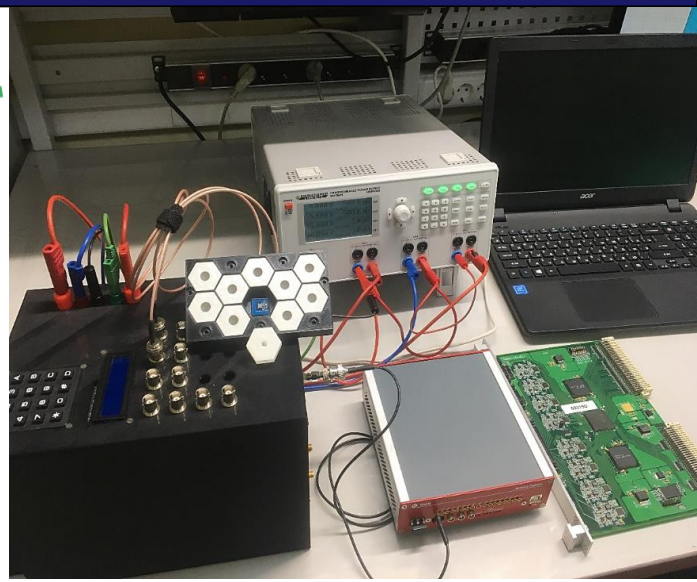
Hexagonal granularity detector

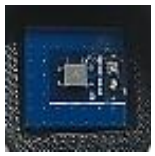
8	Male connector 0022272021
7	Mylar
6	RA conn
5	Tapa hexagon right cavity
4	MPPC PCB and support
3	S14160-3050HS
2	Housing mppc right cavity
1	Single Hexagon



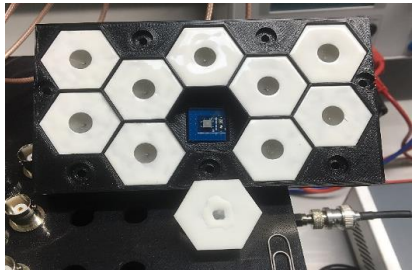
MILLENNIUM INSTITUTE
FOR SUBATOMIC PHYSICS
AT HIGH-ENERGY FRONTIER
SAPHIR





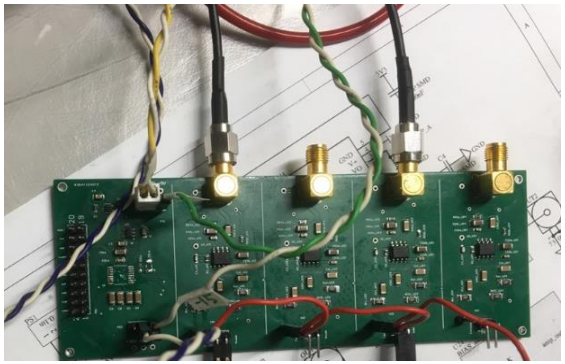


Hamamatsu
SiPM S14160-3050HS
(3x3 mm^2, 50 µm/cell)

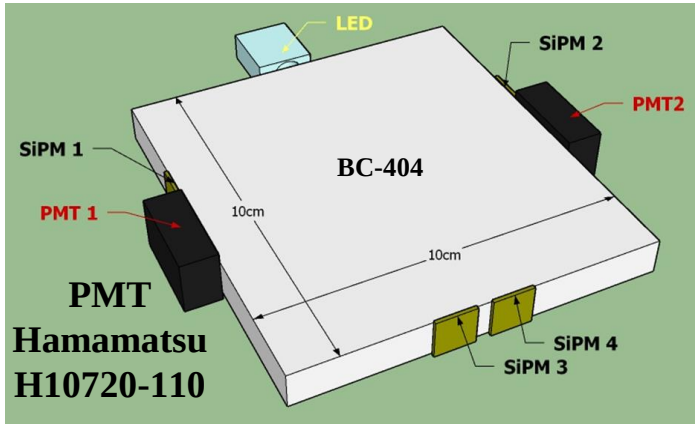


10 honey-comb scintillators
and SiPMs,
FEE boards,
micro PC control.

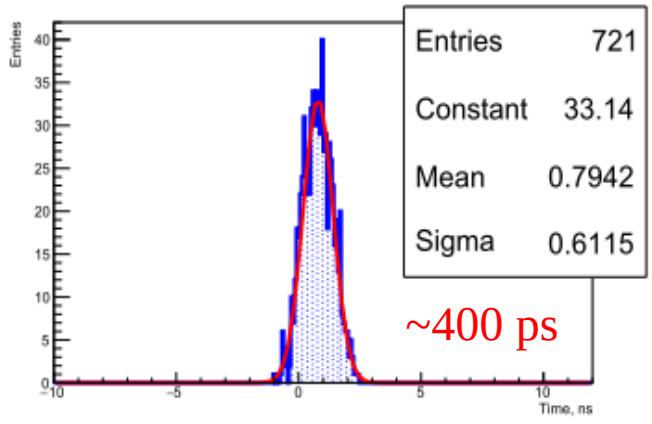
CAEN Digitizer DT5742
(16+1 Channel 12 bit 5 GS/s)



CTEPP-UNAB FEE (Chile) + SiPM



COSMIC RAYS



Together with **E.R. Rozas-Calderon (CTEPP-UNAB)**
M.A. Ayala-Torres (SAPHIR-UNAB)

Conclusions

Obtained results

I. The **tiles scintillation detector prototype tests** with CAEN FERS-5200 system has been started. The **calibration method** proved to be efficient. The **first result of time resolution** is obtained.

II. Comparison of **matted tiles and Tyvek covered** have been done. The result is generally similar, but the use of matted tiles is more technologically valid.

III. Comparison of **different types of optical cement** have been performed. OK-72 is technologically better. For the final choice of optical cement the tests with a large number of samples are required.

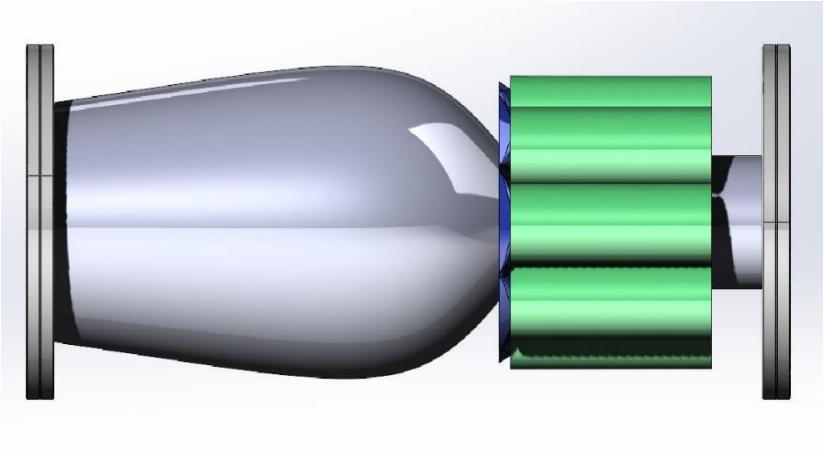
IV. The study **of fibers bending loss** were performed. The result for 3 turns of fiber in the progress.

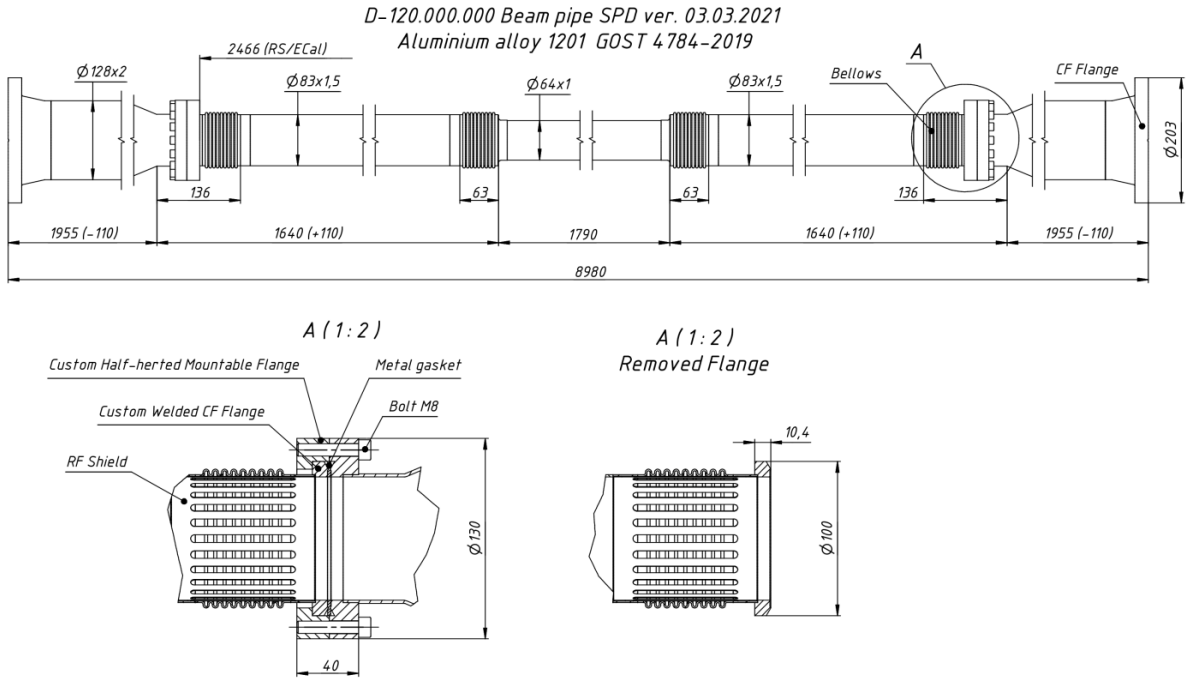
V. The tests with Kuraray WLS fibers, as well as **tests with 1x1 mm^2 SiPMs** are continued.

VI. The next step is assembly and tests of 7-tiles sector with selected materials.

Thank you for the attention!

Backup





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

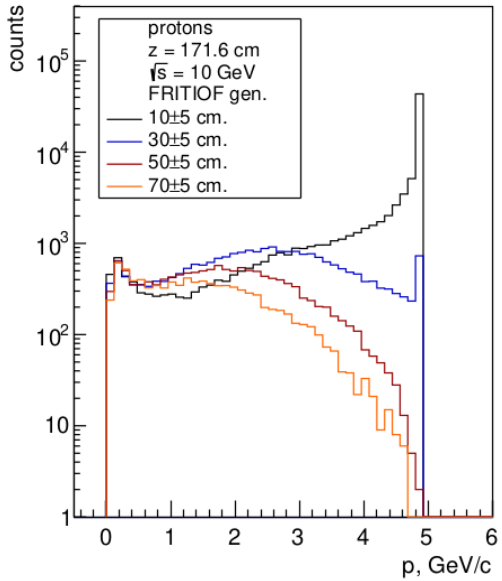
-MCP based TOPAZ PMTs
-Good time resolution 50ps
-Tests with laser and with 200 MeV electrons (LINAC-200) has been performed.
-Tests in SPD testzone and at ITS at Nuclotron are under preparation
-Combined detector (MCP+ Scintillators) for small angle scattering monitoring and physics

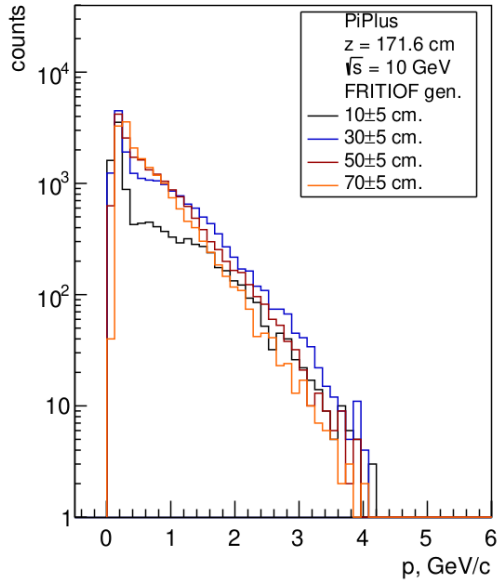
Team **A.Baldin et al.(JINR)**
G.Feofilov et al. (StPSU)
A.Kubankin et al. (BNRU)
…..

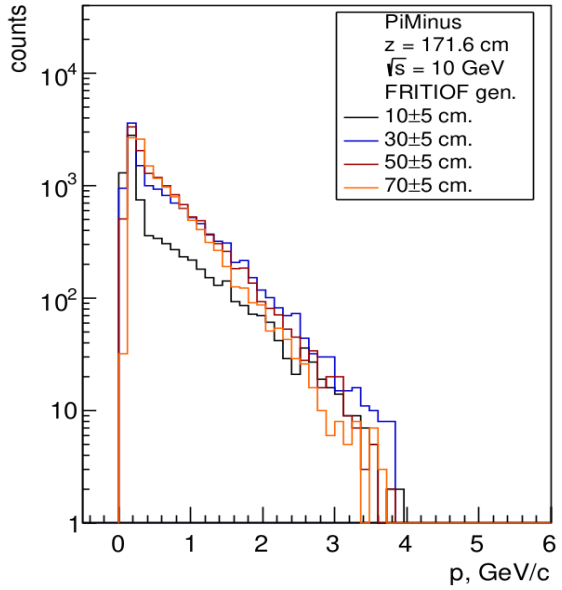
Simulation (pp)

Z.Kurmanaliyev

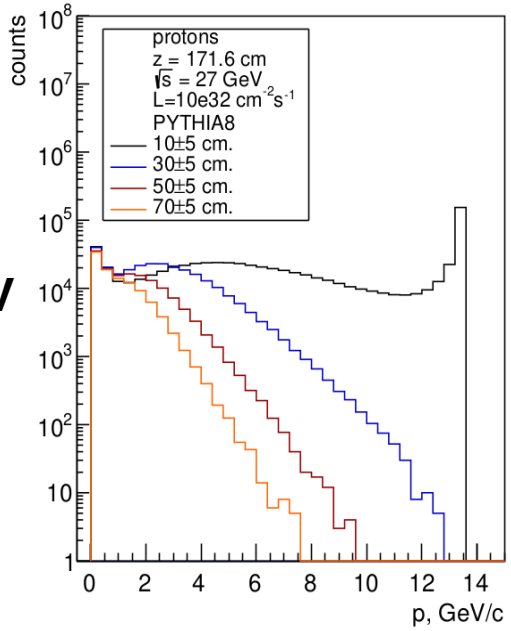
10 GeV

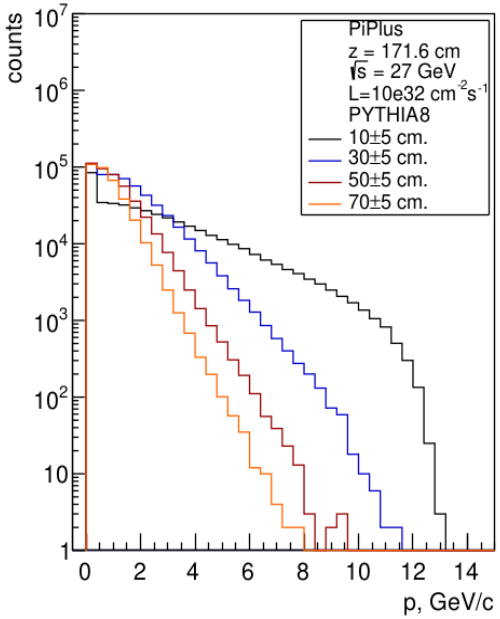


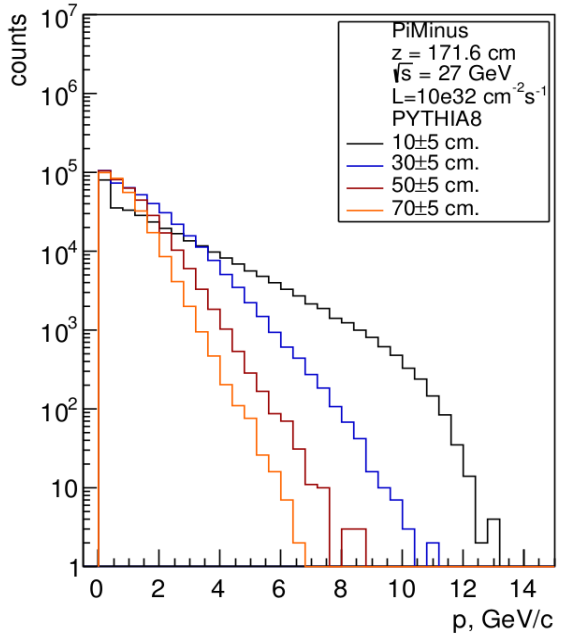




27 GeV



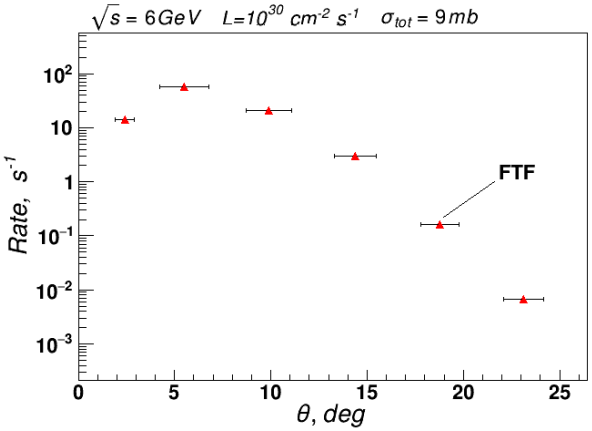


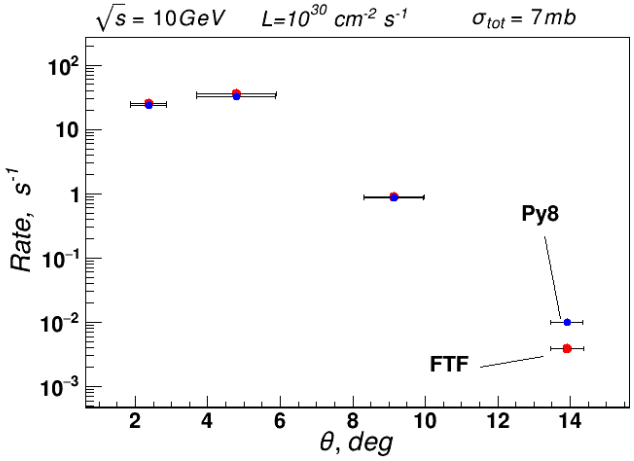


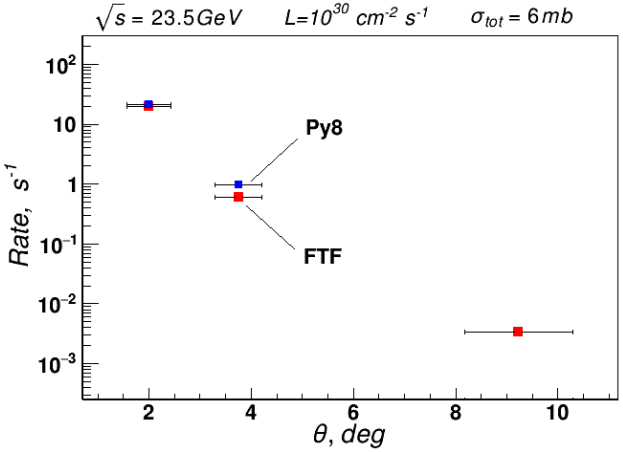
Simulation (pp)

FTF and Py8 generators

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





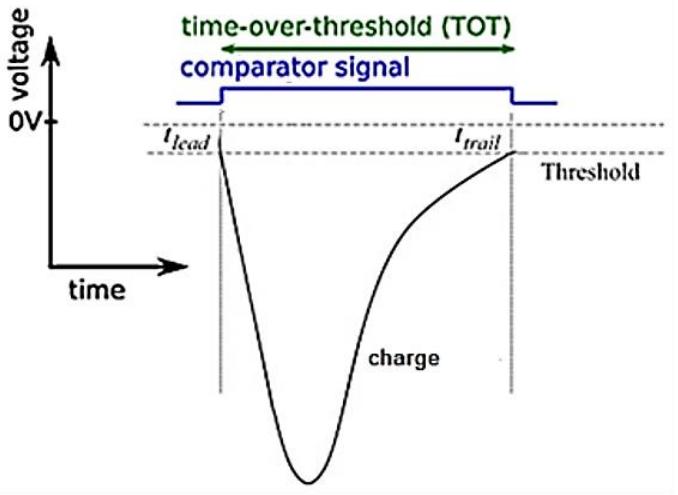


The pp-elastic scattering events have been selected for total energies equal 6.2, 10 and 23.5 GeV. The events rates as function from the angle scattering have been estimated for pp-elastic scattering by using the FTF and Py8 generators at Luminosity 10^{30} $cm^{-2}s^{-1}$ for 1/16 part of BBC.

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

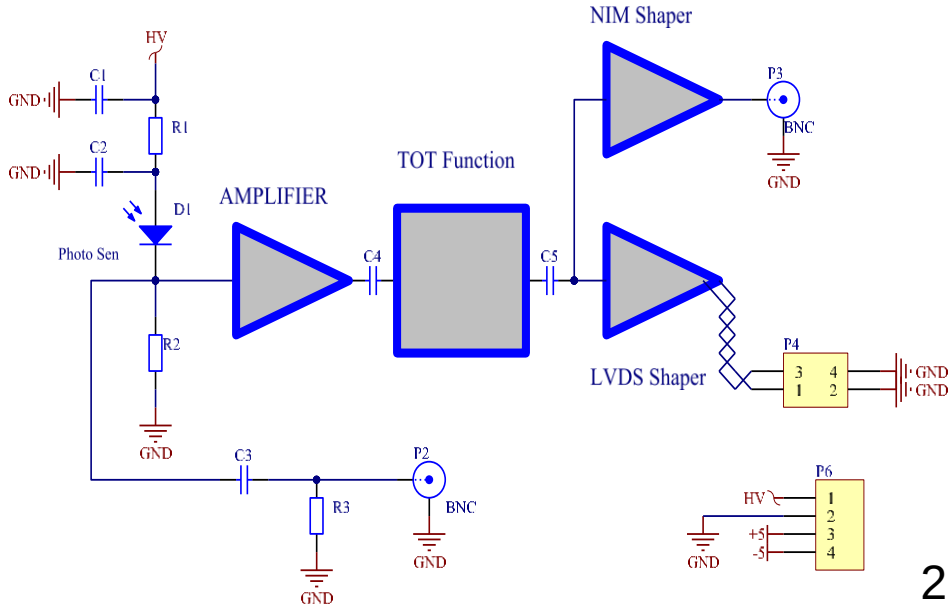
(see talk at this meeting)

The Time-over-Threshold (ToT) method



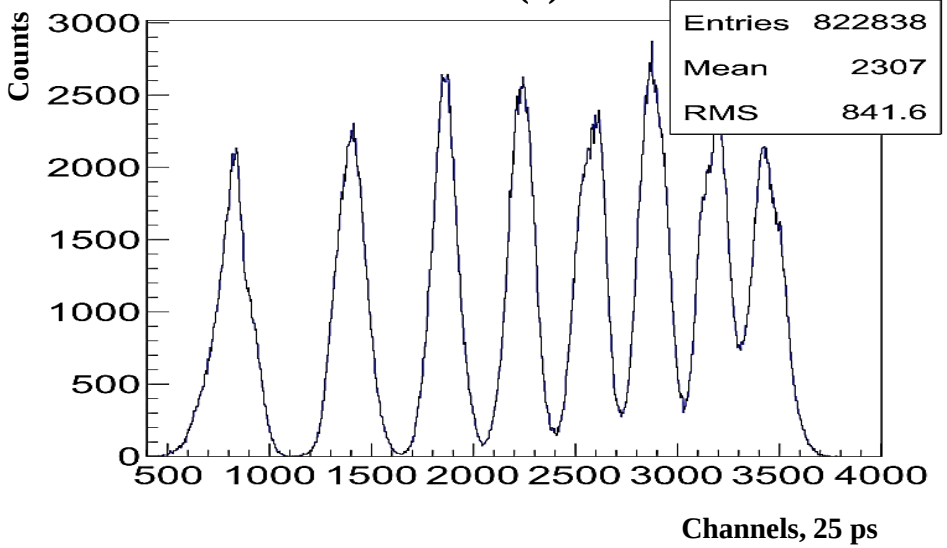
The ToT is a well-known method which allows to measure the energy deposited in the material.

Front-end electronics with ToT technique

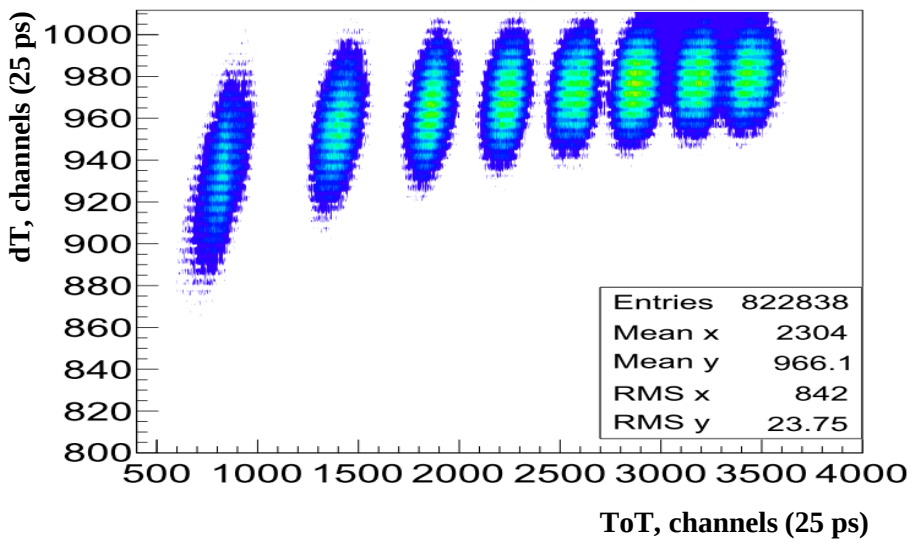


Extracting correction parameters FEE ToT (version №1)

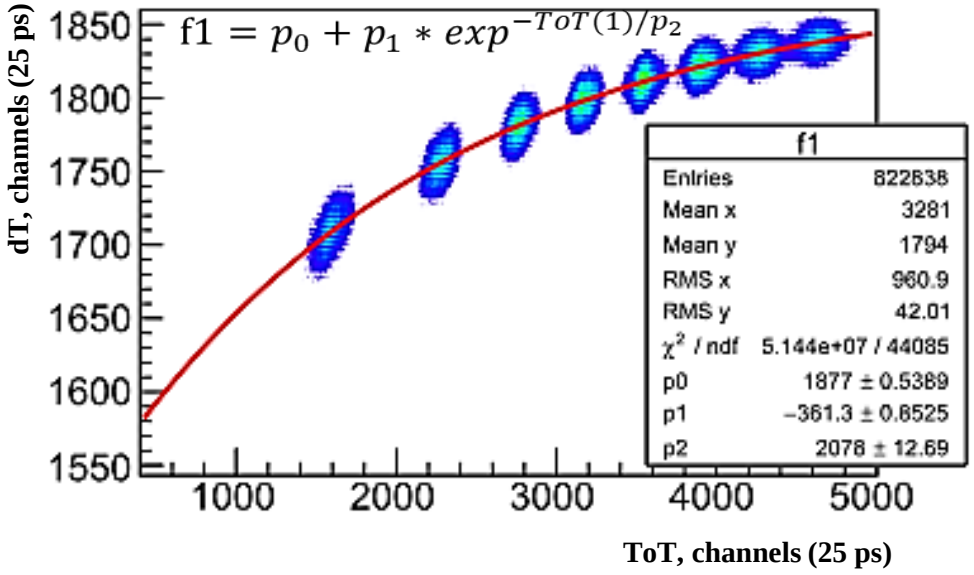
ToT(2)



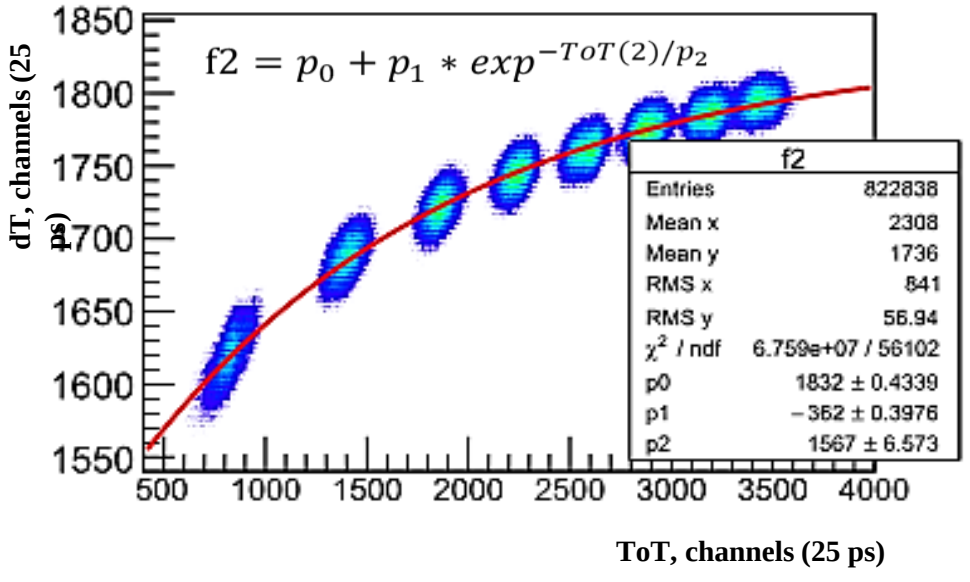
dT(SiPM1-SiPM2) vs ToT(2)



dT(trig-SiPM1) vs ToT(1)

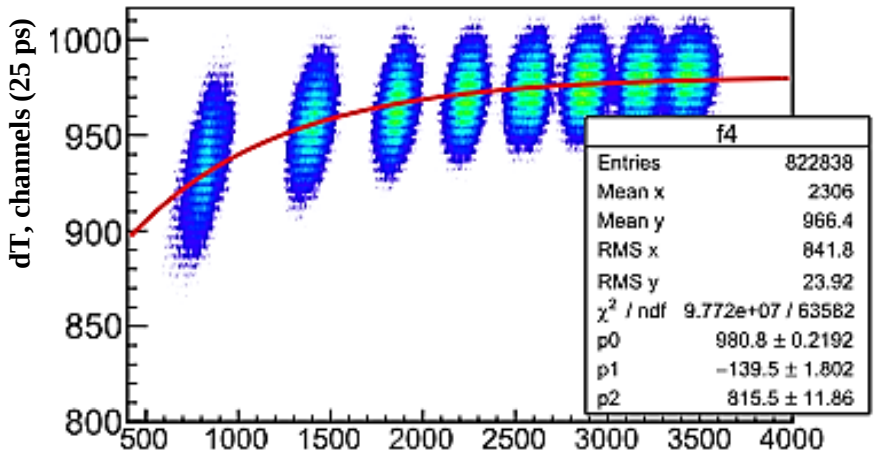


dT(trig-SiPM2) vs ToT(2)

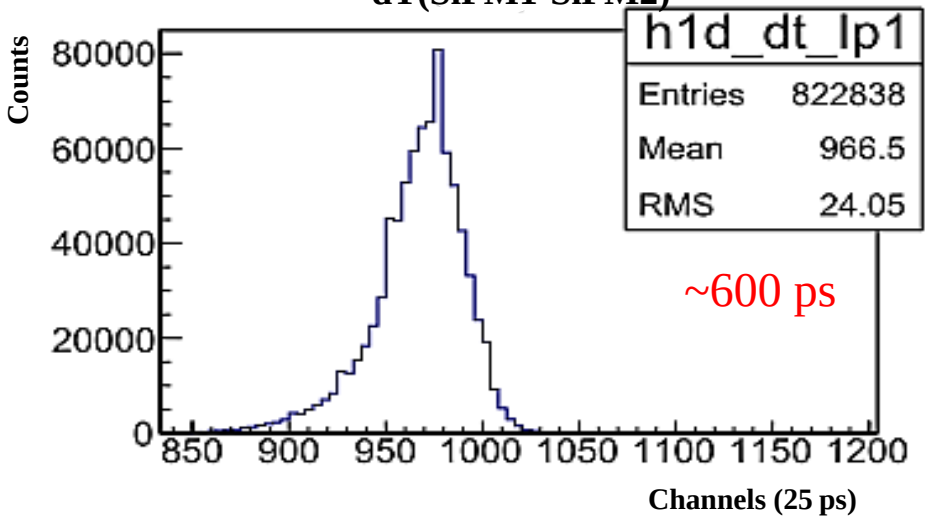


The time difference histogram FEE ToT (version №1)

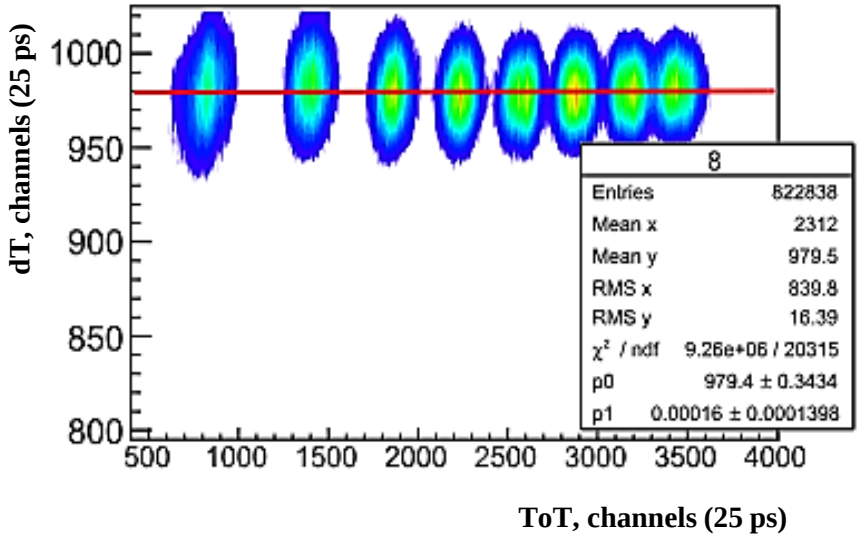
dT(SiPM1-SiPM2) vs ToT(2)



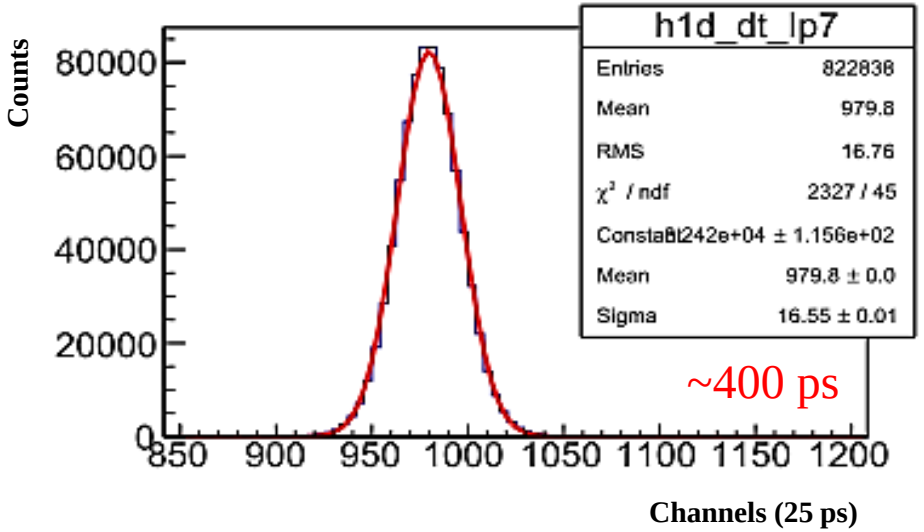
dT(SiPM1-SiPM2)



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



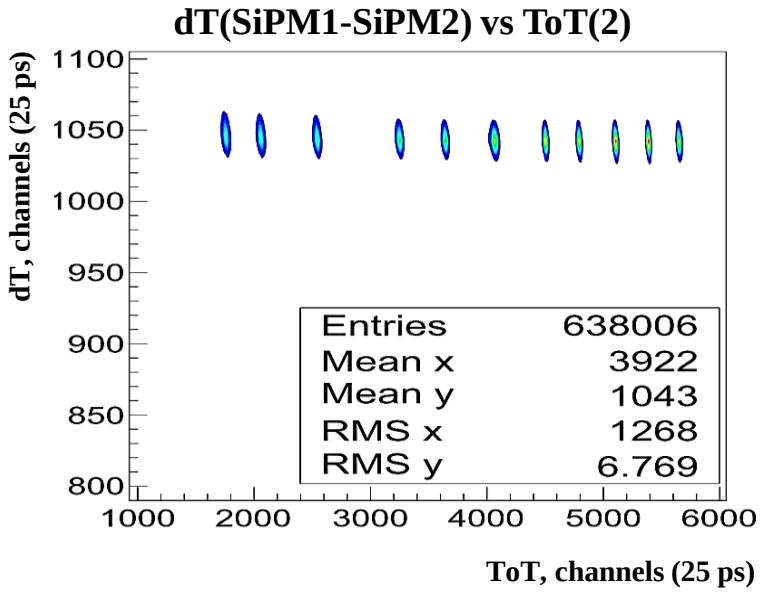
Corrected dT(SiPM1-SiPM2)

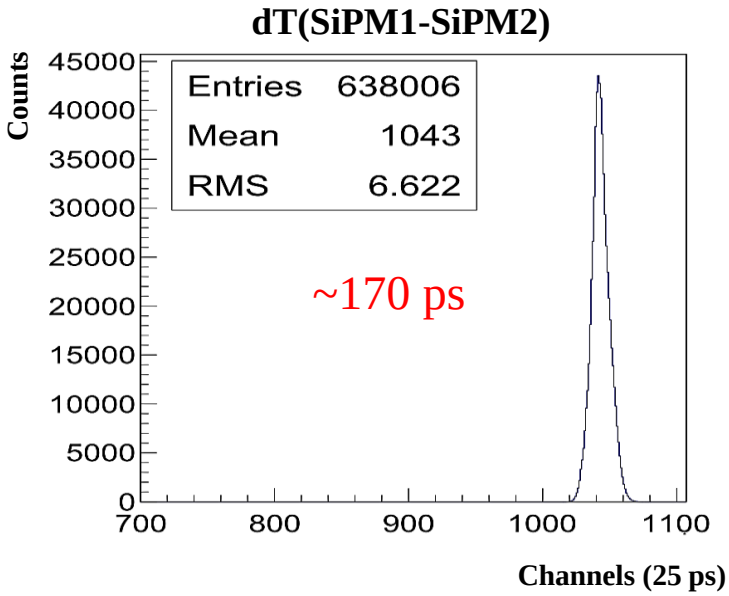


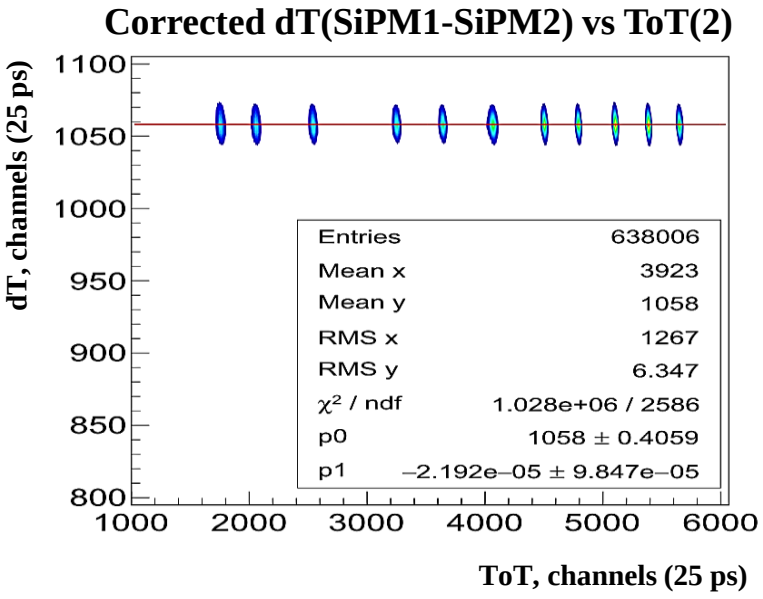
A.V. Tishevskiy et al., J.Phys.Conf.Ser, V.1690, 012051 (2020)

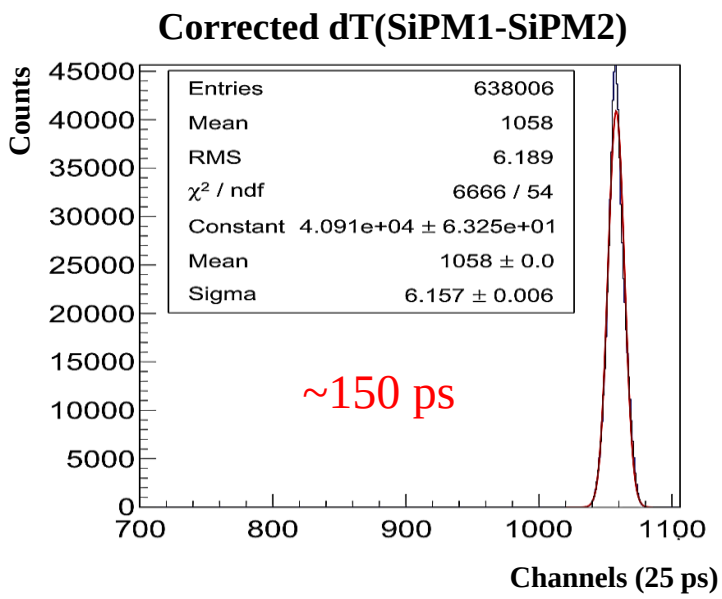
FEE studies results

The time difference histogram FEE ToT (version 03)



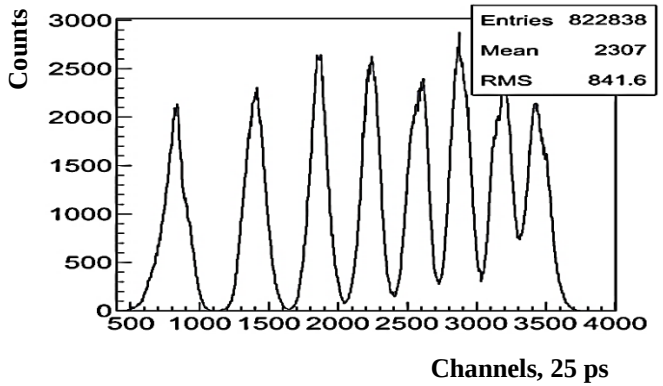




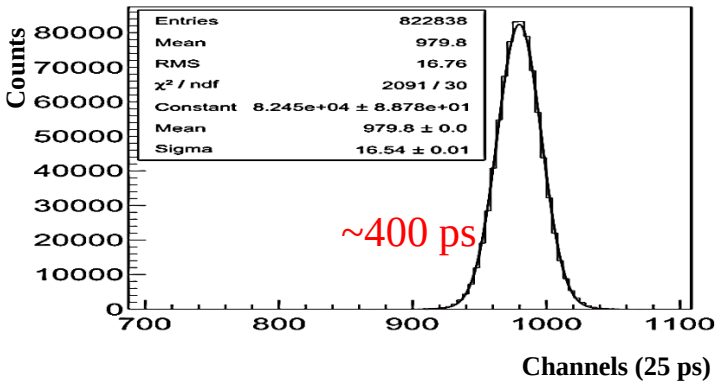


Comparison of FEE ToT versions

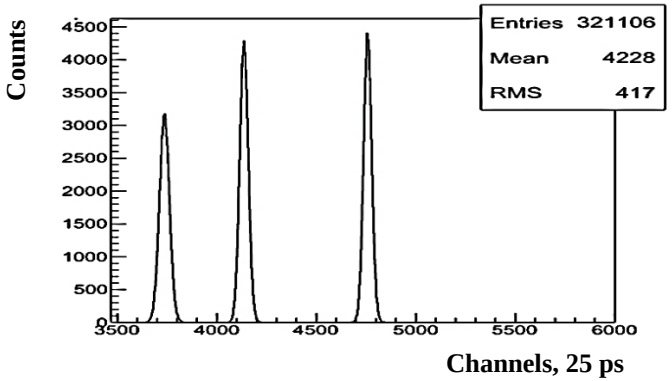
ToT



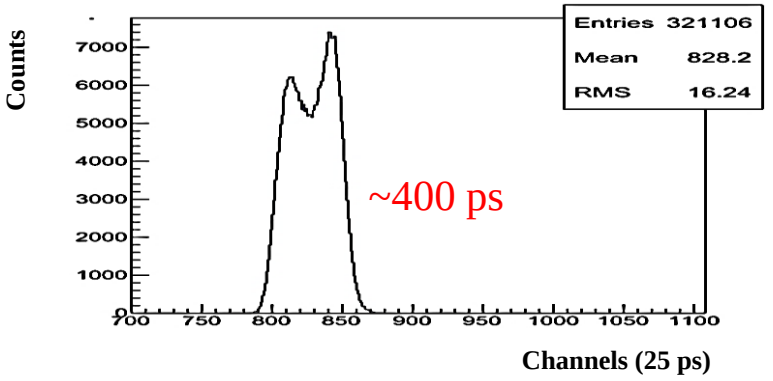
Corrected dT(SiPM1-SiPM2)



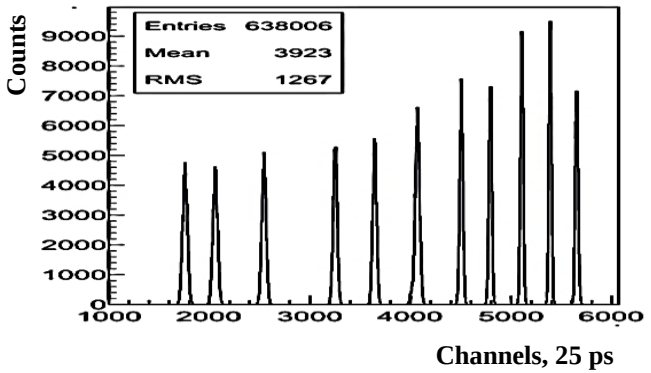
v.1

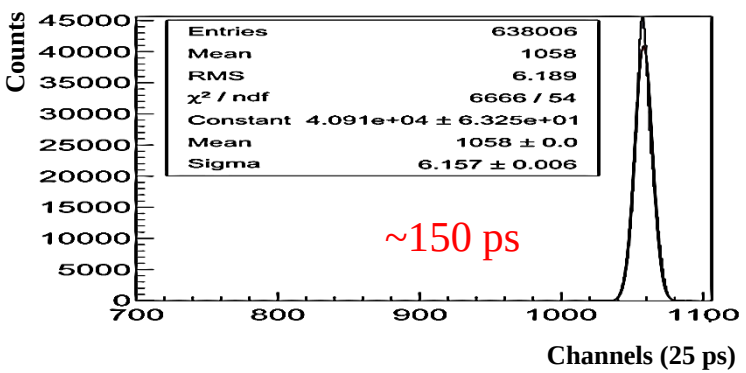


v.2



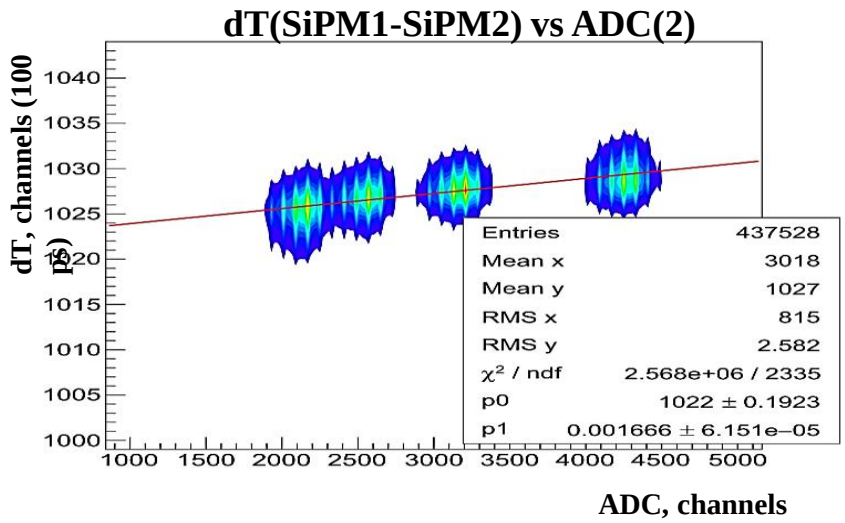
v.3

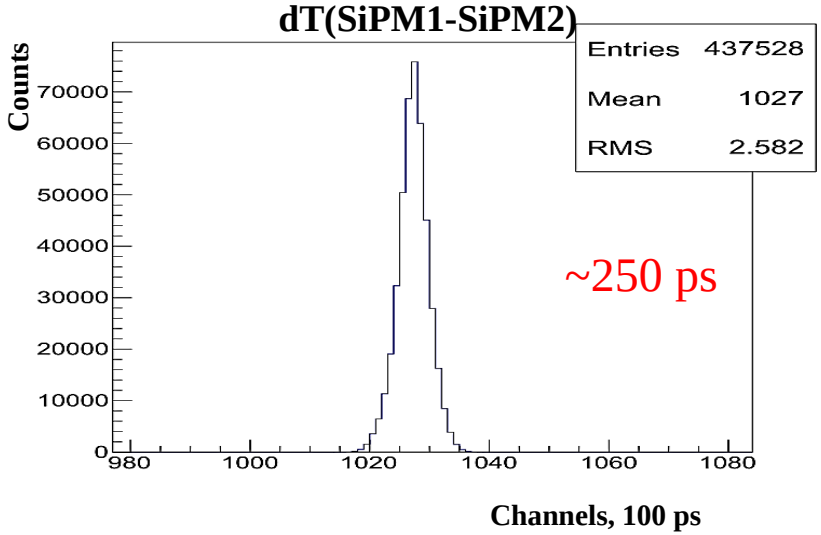


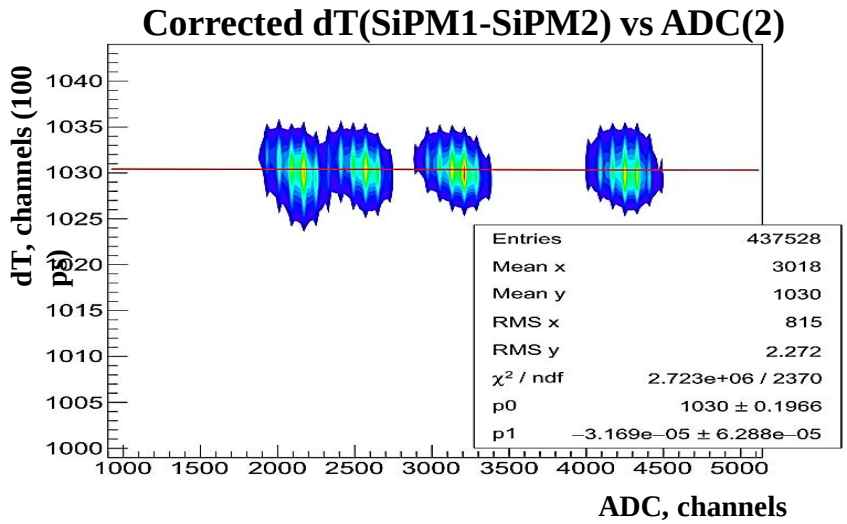


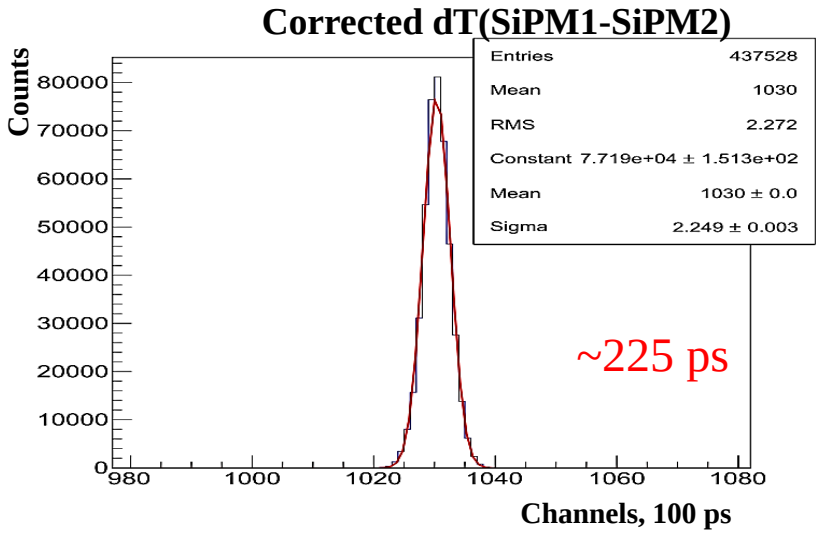
FEE studies results

The time difference histogram for FEE DANSS









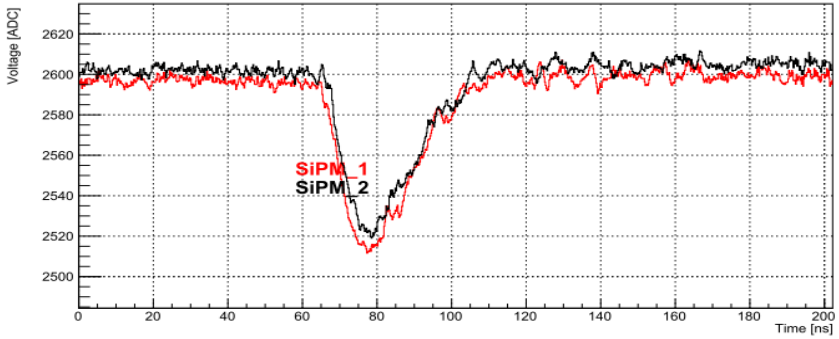
Phys.Atom.Nucl., DOI:10.1134/S1063778822090381 (2022)

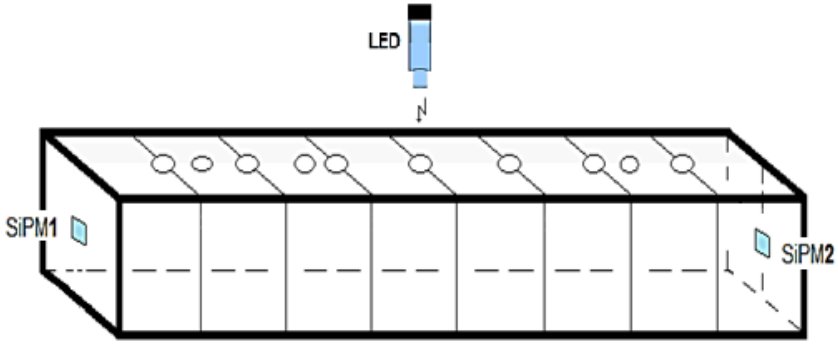
FEE studies results

CAEN digitizer DT5742 (16ch)

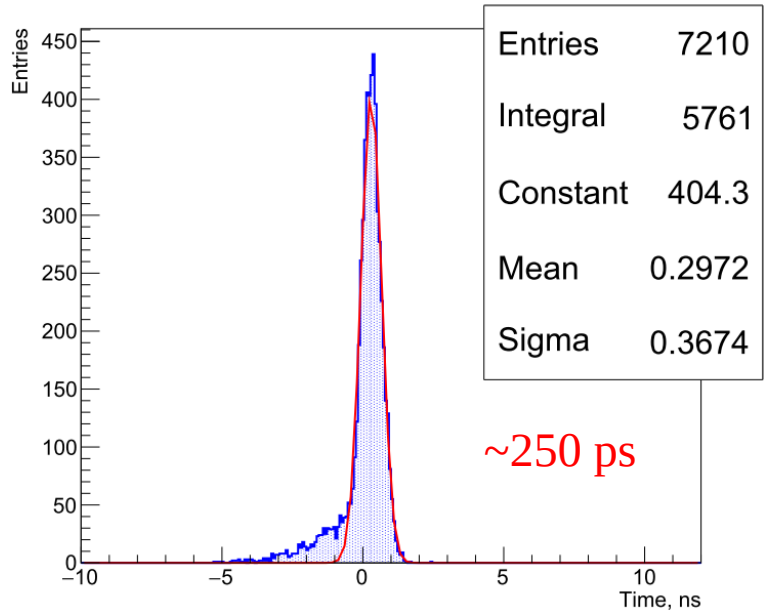
16+1 Channel 12 bit 5 GS/s
Switched Capacitor Digitizer

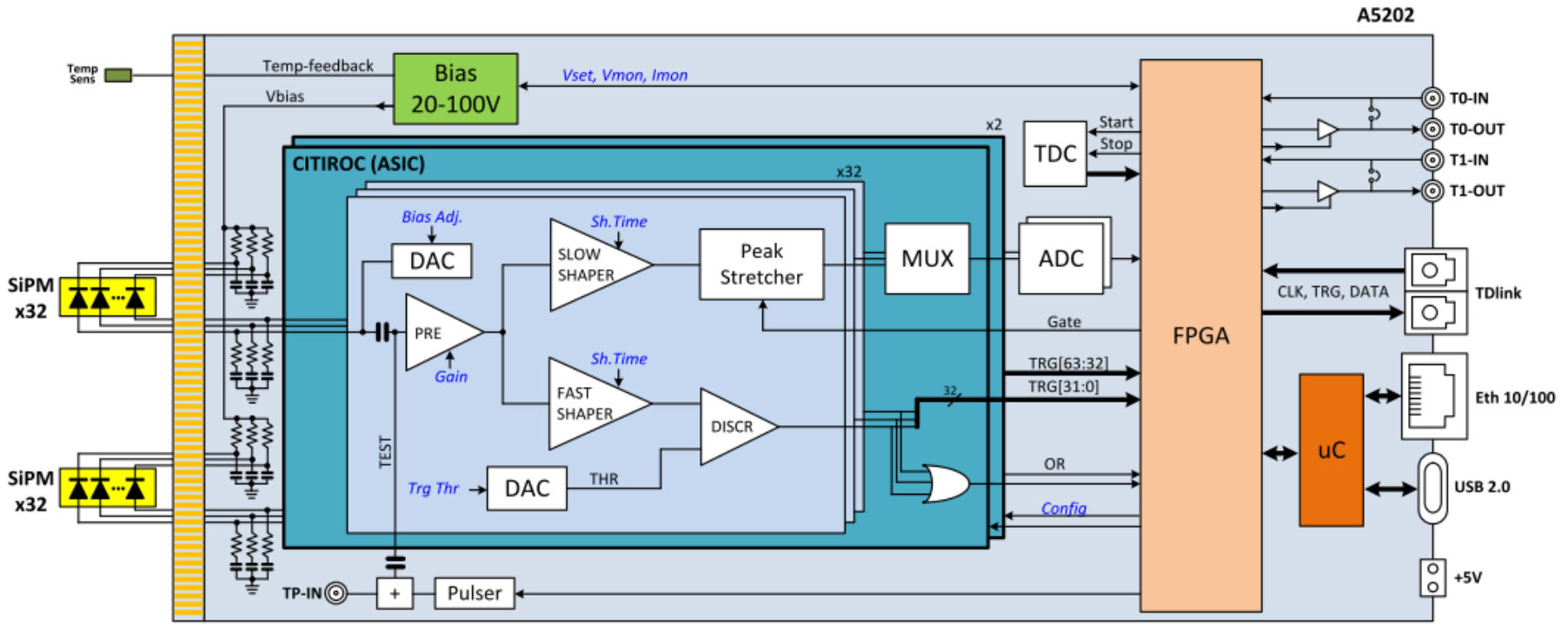
based on the DRS4 a Switched Capacitor Array. This technology relies on a set of capacitors that continuously sample the analog input signals. As soon as the trigger is issued, capacitors are decoupled from the input signals with a time interval from each other that is the sampling period.

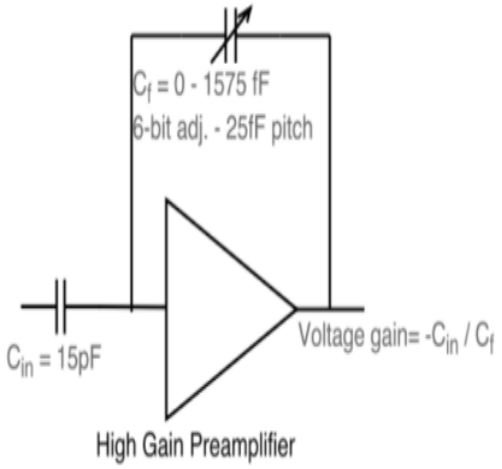


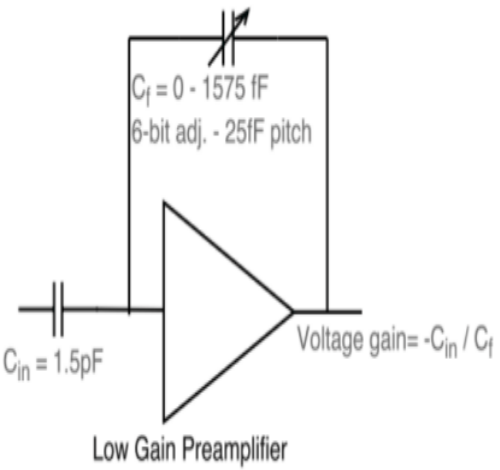


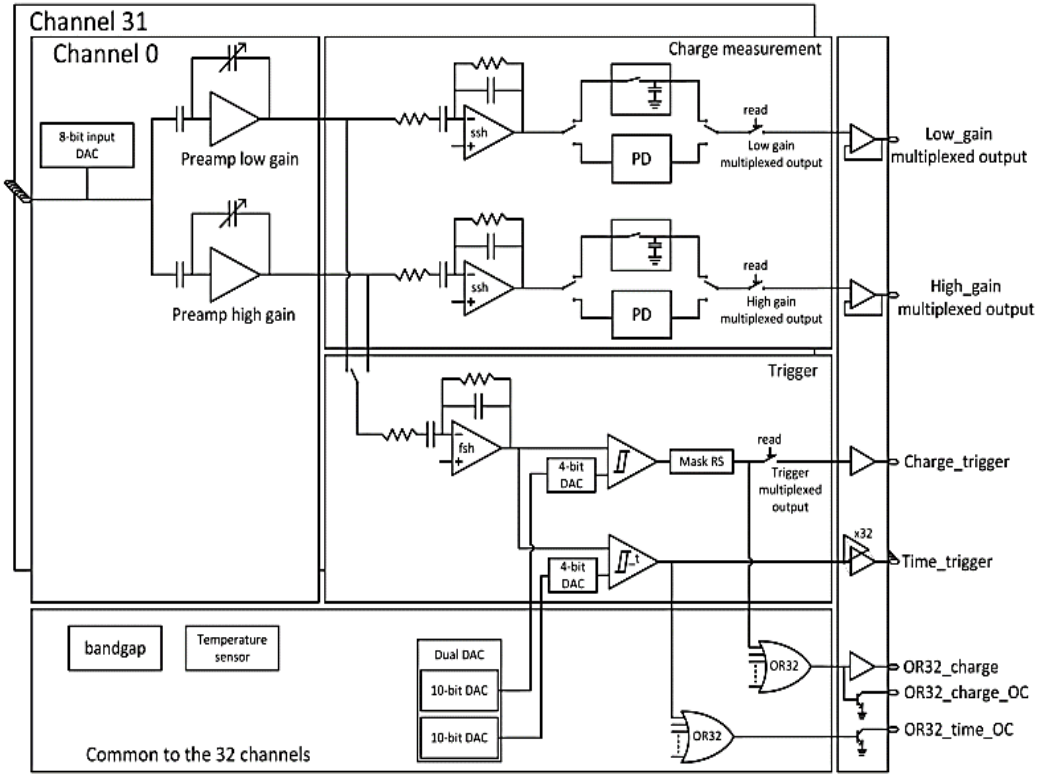
- Hamamatsu SiPM (S12572-010P)
- FEE of DANSS experiment




A5202
Temp Sens
Temp-feedback
Vbias
Bias
20-100V
Vset, Vmon, Imon
CITIROC (ASIC)
x2
x32
TDC
Start
Stop
Bias Adj.
DAC
Sh.Time
SLOW SHAPER
Peak Stretcher
MUX
ADC
SiPM x32
PRE
Gain
Sh.Time
FAST SHAPER
DISCR
TEST
Trg Thr
DAC
THR
Gate
TRG[63:32]
TRG[31:0]
32
OR
Config
FPGA
T0-IN
T0-OUT
T1-IN
T1-OUT
CLK, TRG, DATA
TDlink
Eth 10/100
uC
USB 2.0
+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
Charge measurement
8-bit input DAC
Preamp low gain
Preamp high gain
ssh
PD
read
Low gain multiplexed output
High gain multiplexed output
Low_gain multiplexed output
High_gain multiplexed output
Trigger
fsh
4-bit DAC
Mask RS
Trigger multiplexed output
Charge_trigger
Time_trigger
x32
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

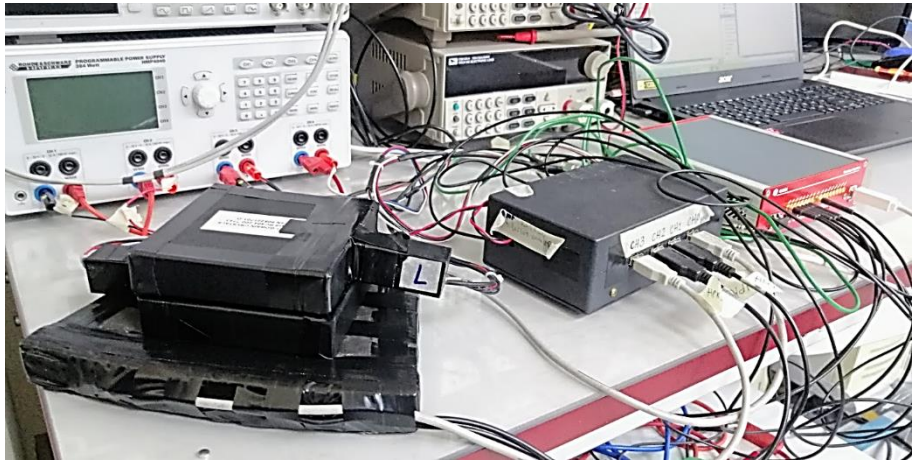
```
//*************************************************
// File Format Version 3.1
// Janus Release 2.2.10
// Acquisition Mode: Spect_Timing
// Energy Histogram Channels: 4096
// ToA/ToT LSB: 0.5 ns
// Run start time: Thu May 12 12:34:25 2022 UTC
//*************************************************
```

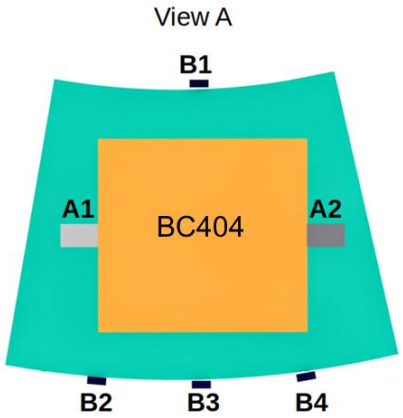
Tstamp_us	TrgID	Brd	Ch	LG	HG	ToA_ns	ToT_ns
2.080	0	00	00	39	39	-	-
		00	01	36	35	-	-
		00	02	36	20	919.0	8.0
		00	03	42	55	-	-
		00	04	30	9	-	-
		00	05	40	41	-	-
		00	06	36	12	-	-
		00	07	38	69	-	-
		00	08	33	13	-	-
		00	09	31	32766	955.0	5.5
		00	10	38	160	140.0	14.0
		00	11	37	282	74.0	20.0
		00	12	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.

Tests at Lab201- VBLHEP

SAPHIR-UNAB and Cinvestav Teams





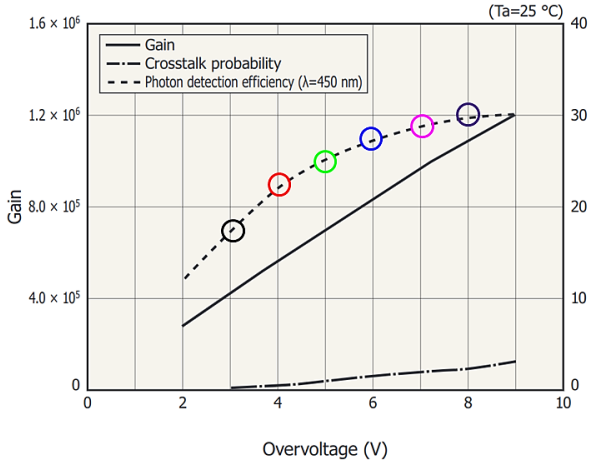
Light from prototype (BC404) is detected by four SiPM (B1-B4)

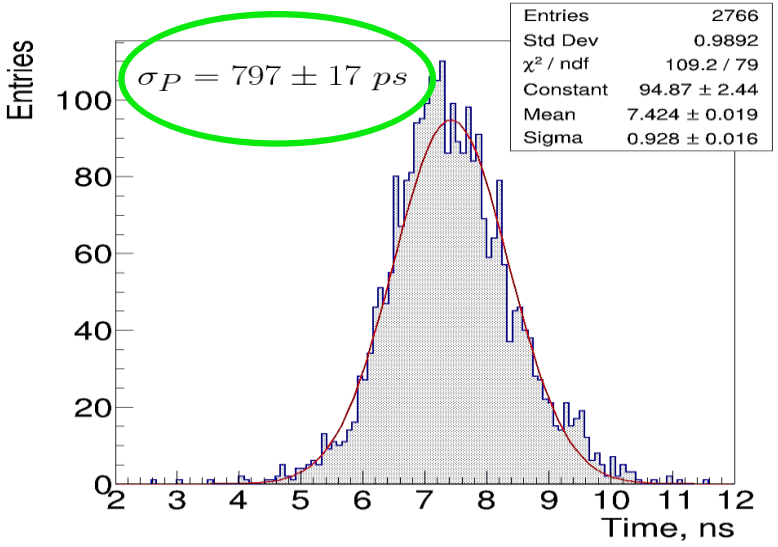
Different Vbias were explored (55.5, 56.5, 57.5, 58.5, 59.5, 60.5 V).

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

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

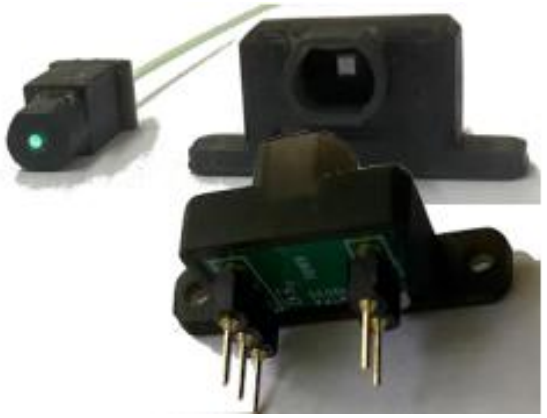
The prototype (in blue) was placed below the trigger counters (in yellow), which provided the start signal for data readout. Each trigger counter was made of a BC404 scintillator plate (10x10x2 cm^3) and one Hamamatsu (H5783) PMT (A1, A2).

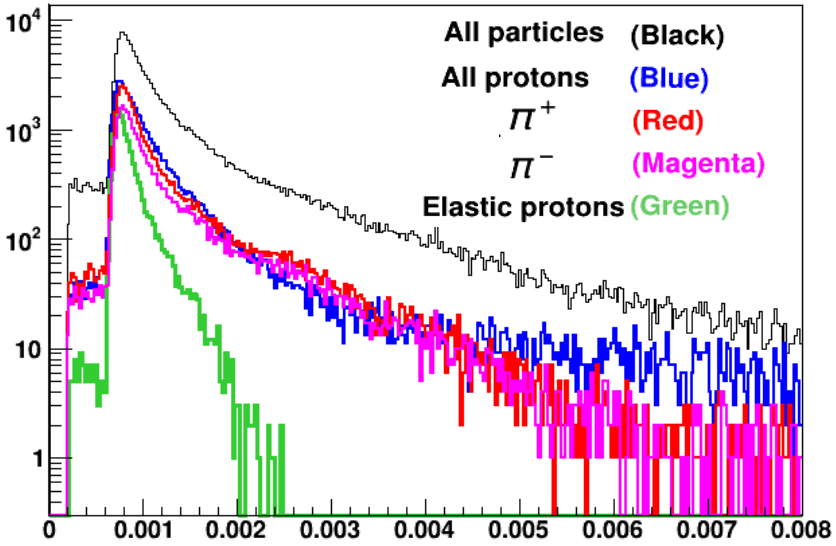




MILLENNIUM INSTITUTE FOR SUBATOMIC PHYSICS AT HIGH-ENERGY FRONTIER SAPHIR

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




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