Development of the SPD Beam-Beam Counter scintillation detector prototype with FERS 5200 front-end readout system

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

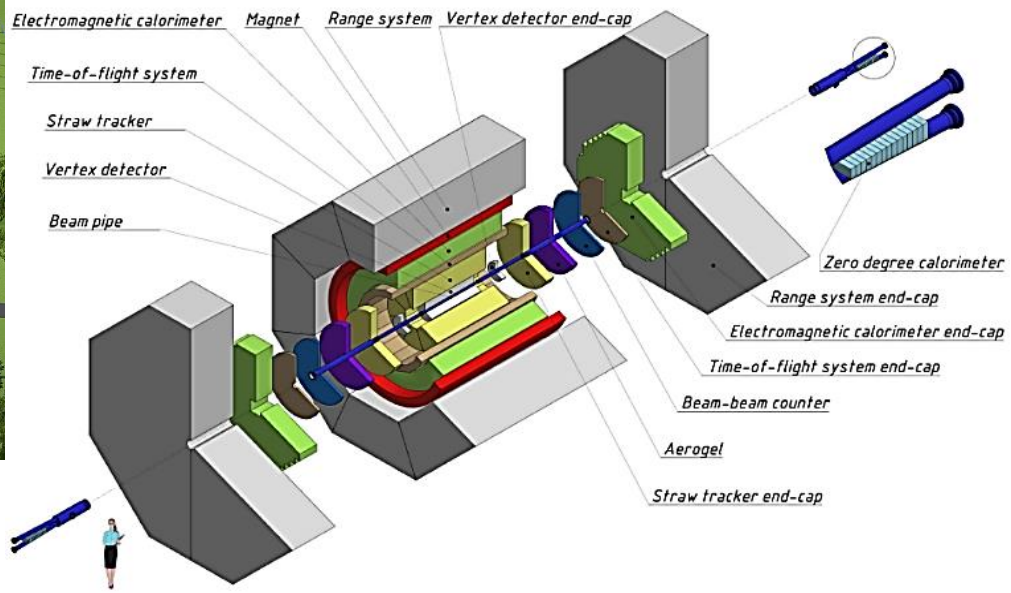
XIX Workshop on High Energy Spin Physics, DSPIN-23 (Efremov-90)

4 September 2023

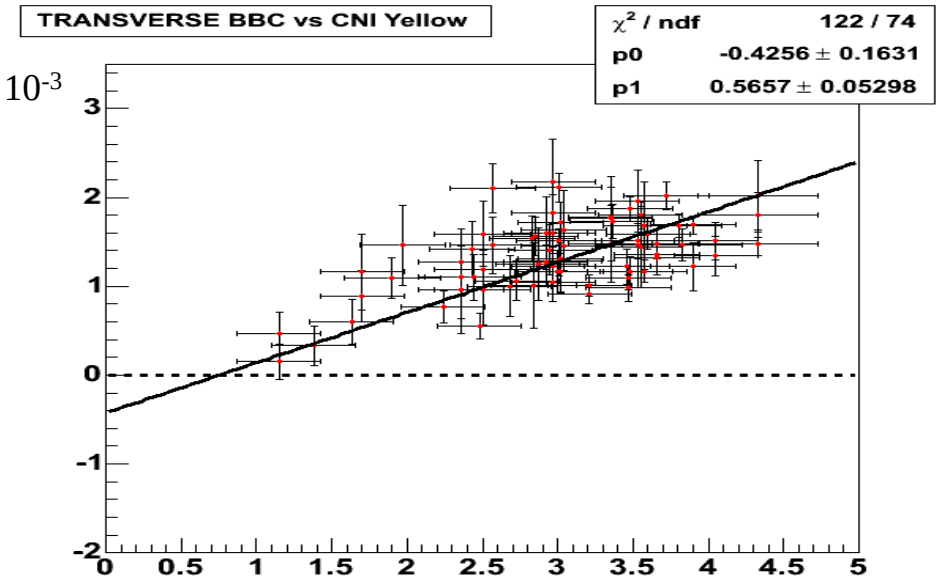
Introduction

General

The Spin Physics Detector (SPD)



The Beam-Beam Counters (BBC) for SPD



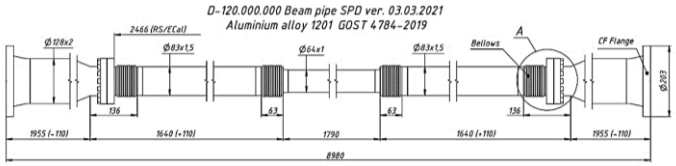
Correlation between CNI polarimeter and STAR BBC asymmetries.

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

Introduction

TDR version of BBC: scintillation tiles part

Two BBC, will be installed upstream and downstream the interaction point



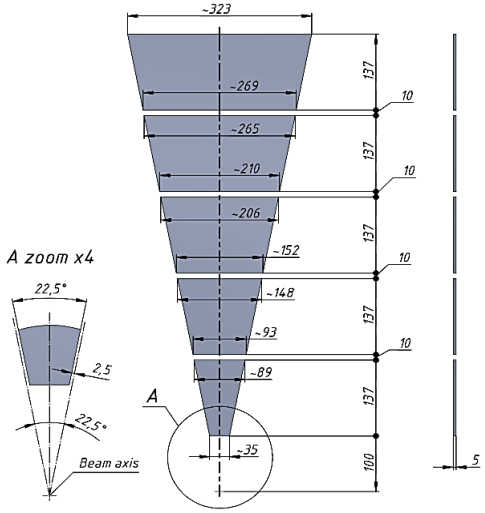
TDR concept:

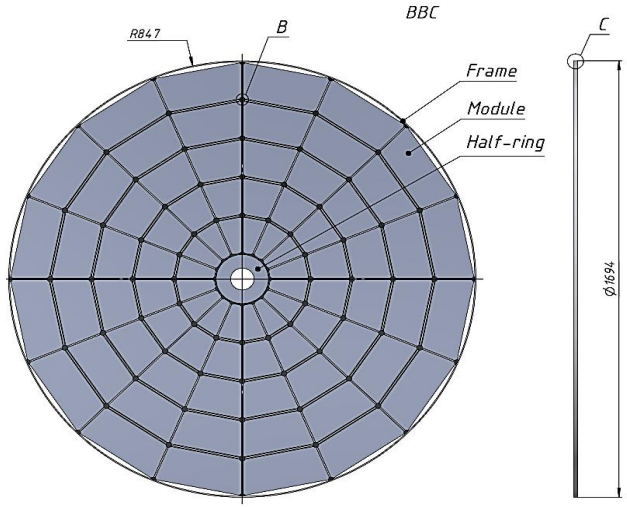
- **Scintillator tiles part at the distance ~1.7 m**
- **MCP part is at the distance ~4.0 – 4.5 m**

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

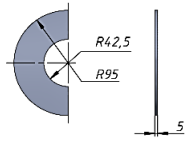
1 sector(extreme inner):
4.25 <r< 9.5 (cm.)
2-6 sector:
10.0 <r< 82.5 (cm.)

BBC Sector zoom x2

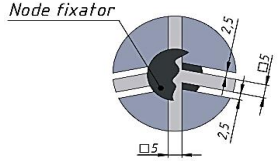




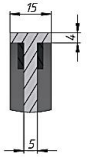
BBC Half-ring zoom x2



B zoom x10



C zoom x10

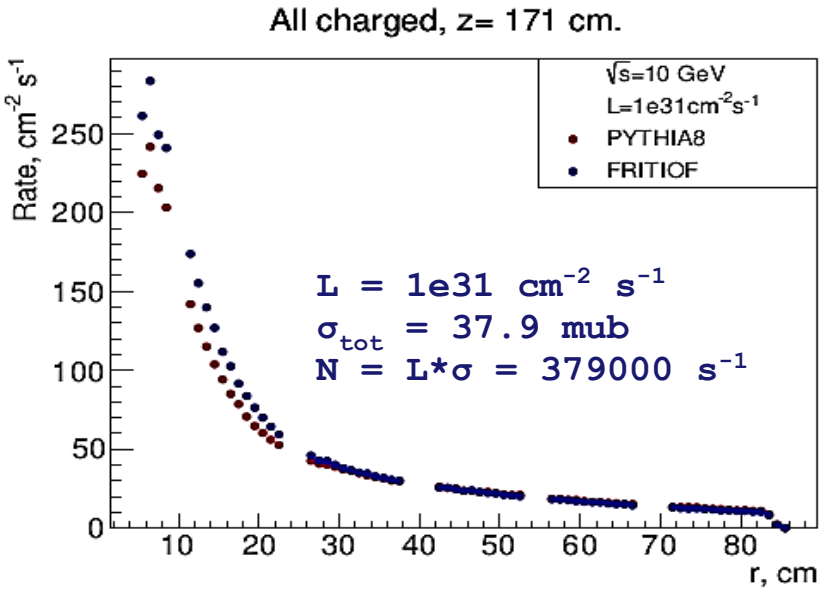


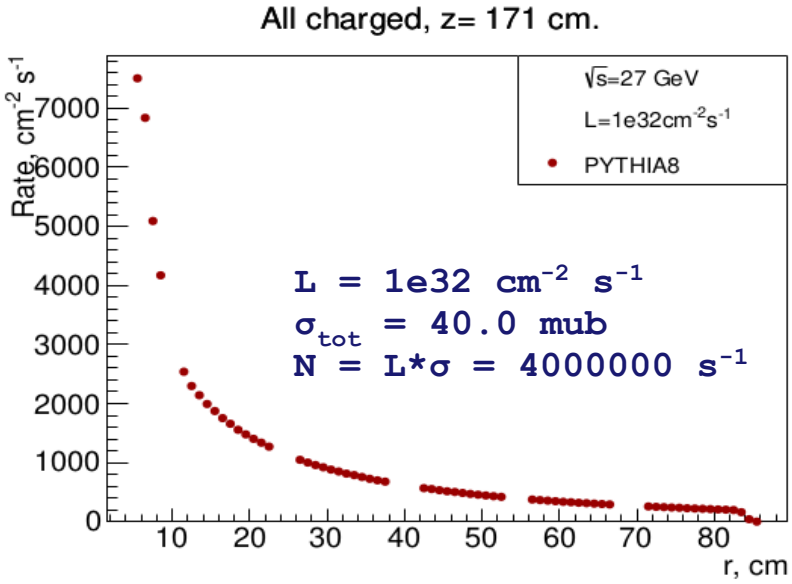
Inner part can be used for luminosity estimation and, possibly, for local polarimetry using pp- and dp- elastic scattering. Local polarimetry will be provided by the analysis of the azimuthal asymmetry in inclusive production of charged particles in forward direction.

Simulation (pp)

FTF and Py8 generators

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



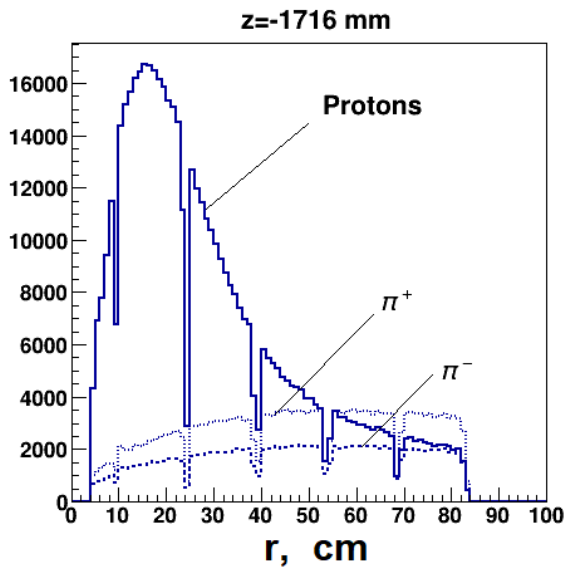


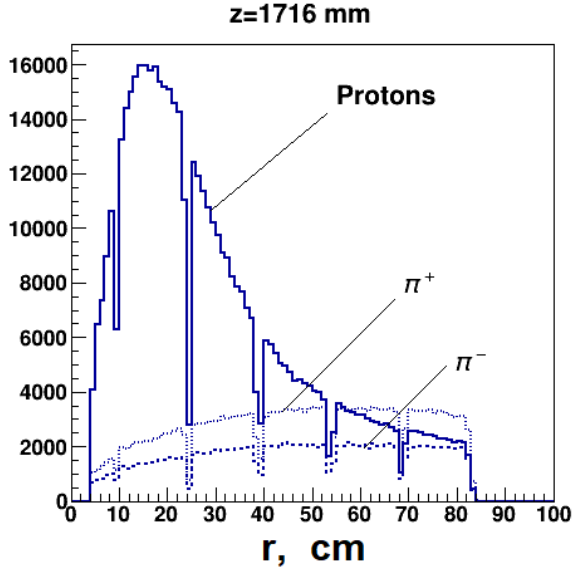
Z.Kurmanaliyev (JINR)

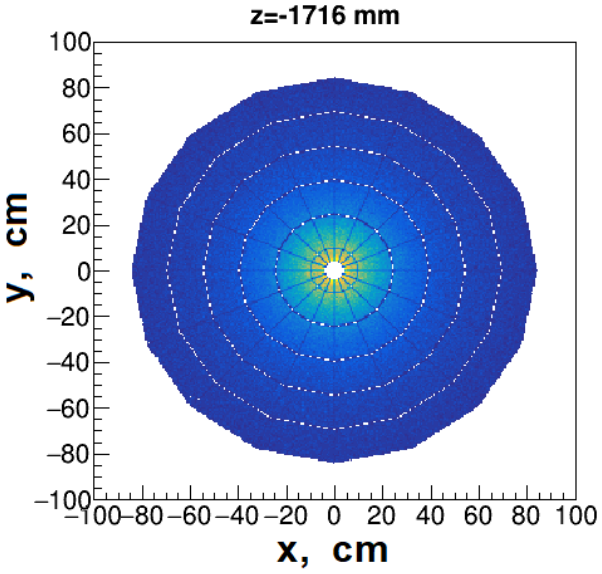
The result of this simulations shows that the in principle accepted for the internal part of this design works at the high luminosity of SPD

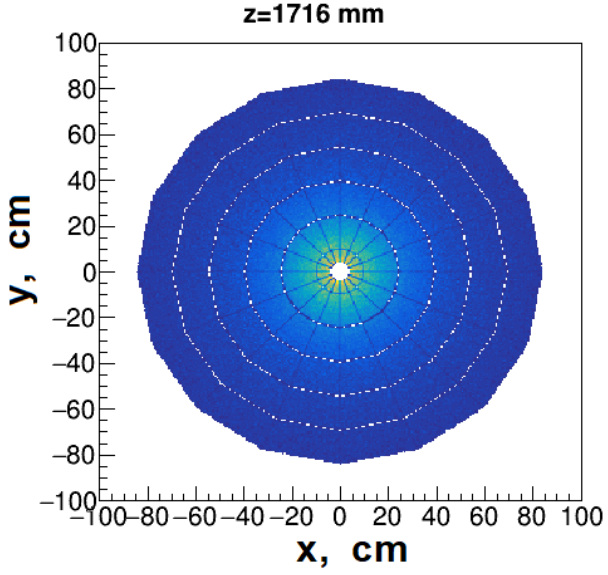
Simulation (pp)

FTF generator









$\sqrt{s} = 6.2$ GeV,

$N_{total} = 1*10^6$ events

Z.Kurmanaliyev (JINR)

A.Terekhin (JINR)

(see talk at this meeting)

FEE studies results

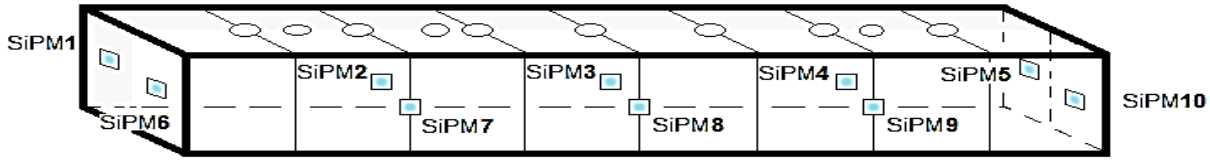
The first stage of BBC prototype development

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

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

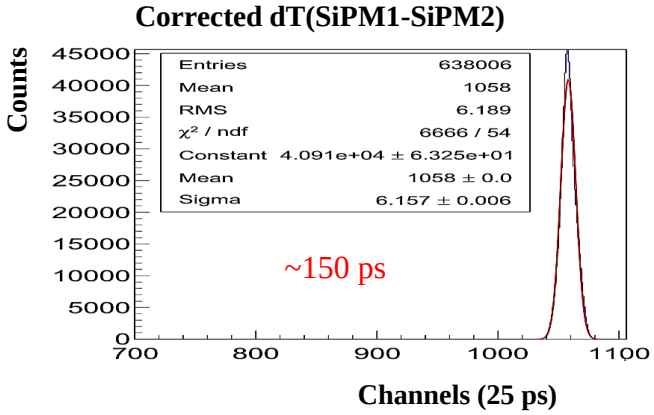
Plastic Scintillator
40 x 2 x 2 (cm³)

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

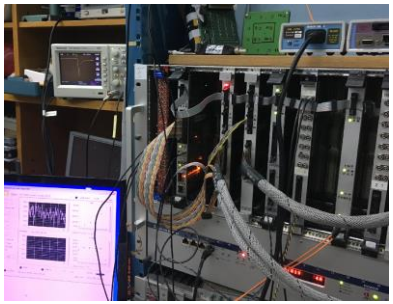


5 channels FEE of ToT (v03)

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

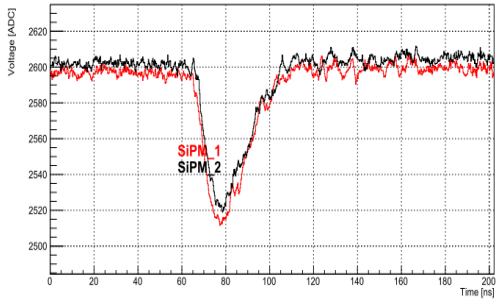


The VME based DAQ



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

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

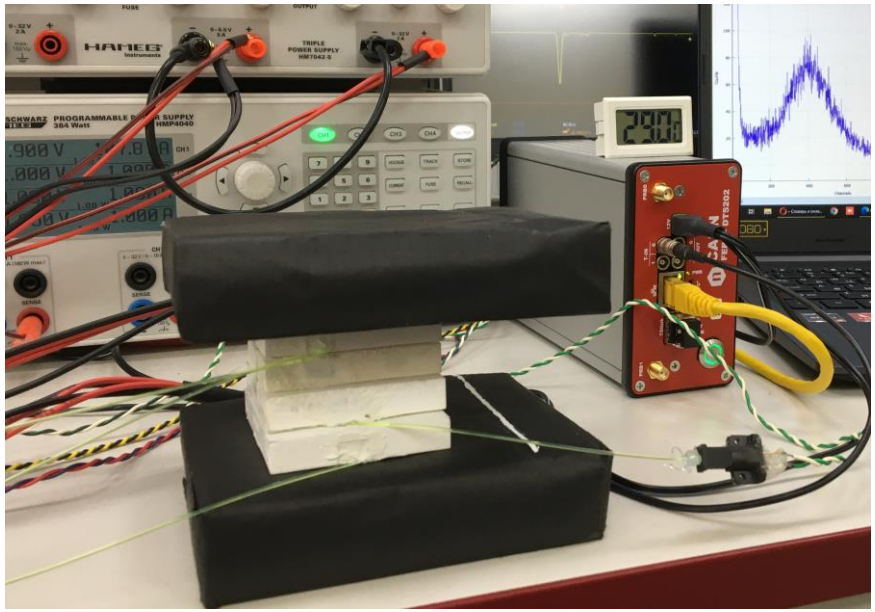


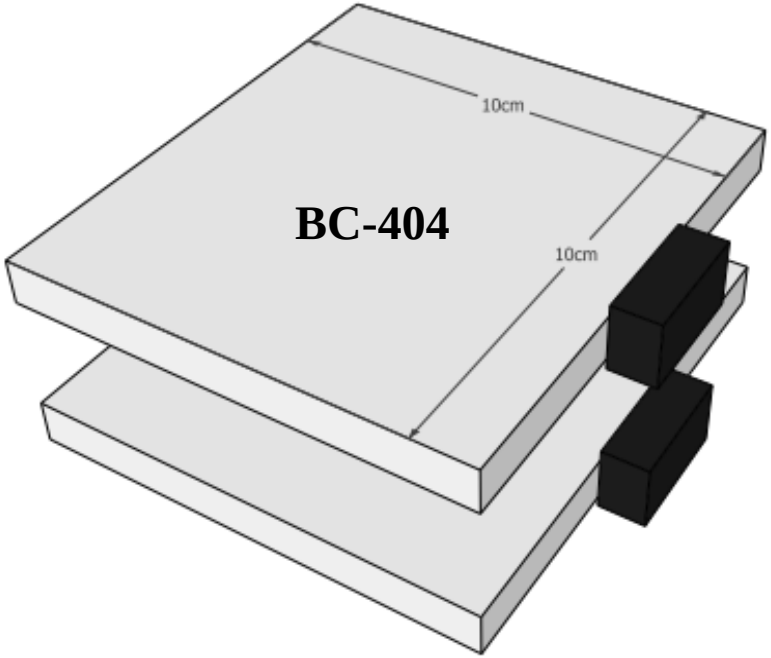
Phys.Atom.Nucl.
DOI:10.1134/S1063778822090381 (2022)

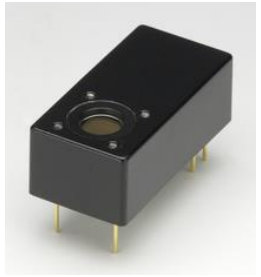
Yu.Gurchin, A.Isupov, V.Ladygin, S.Reznikov, A.Terekhin, I.Volkov (JINR)

FEE studies results

The stand for BBC tile tests







PMT
Hamamatsu
H10720-110

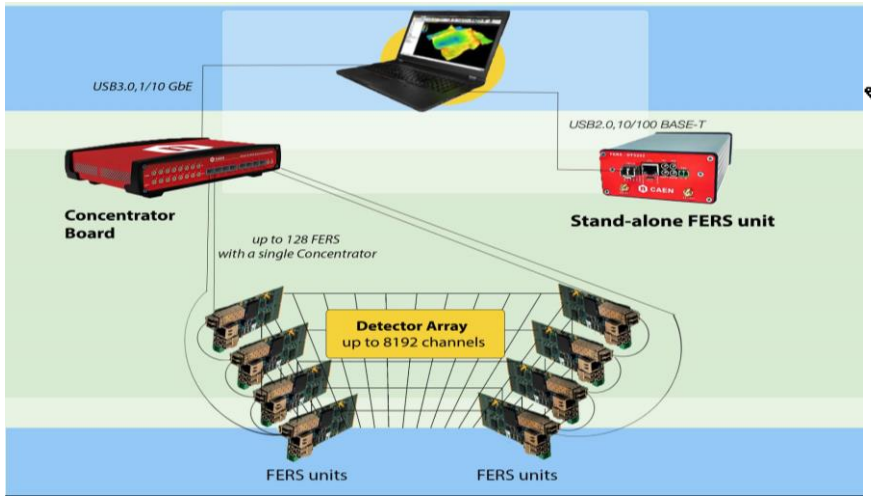
Trigger time resolution ~650 ps

FEE studies results

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.

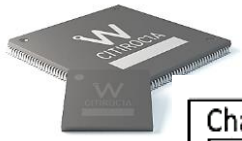
- Concentrator DT5215 for the possibility of expanding the number of channels to 8192.



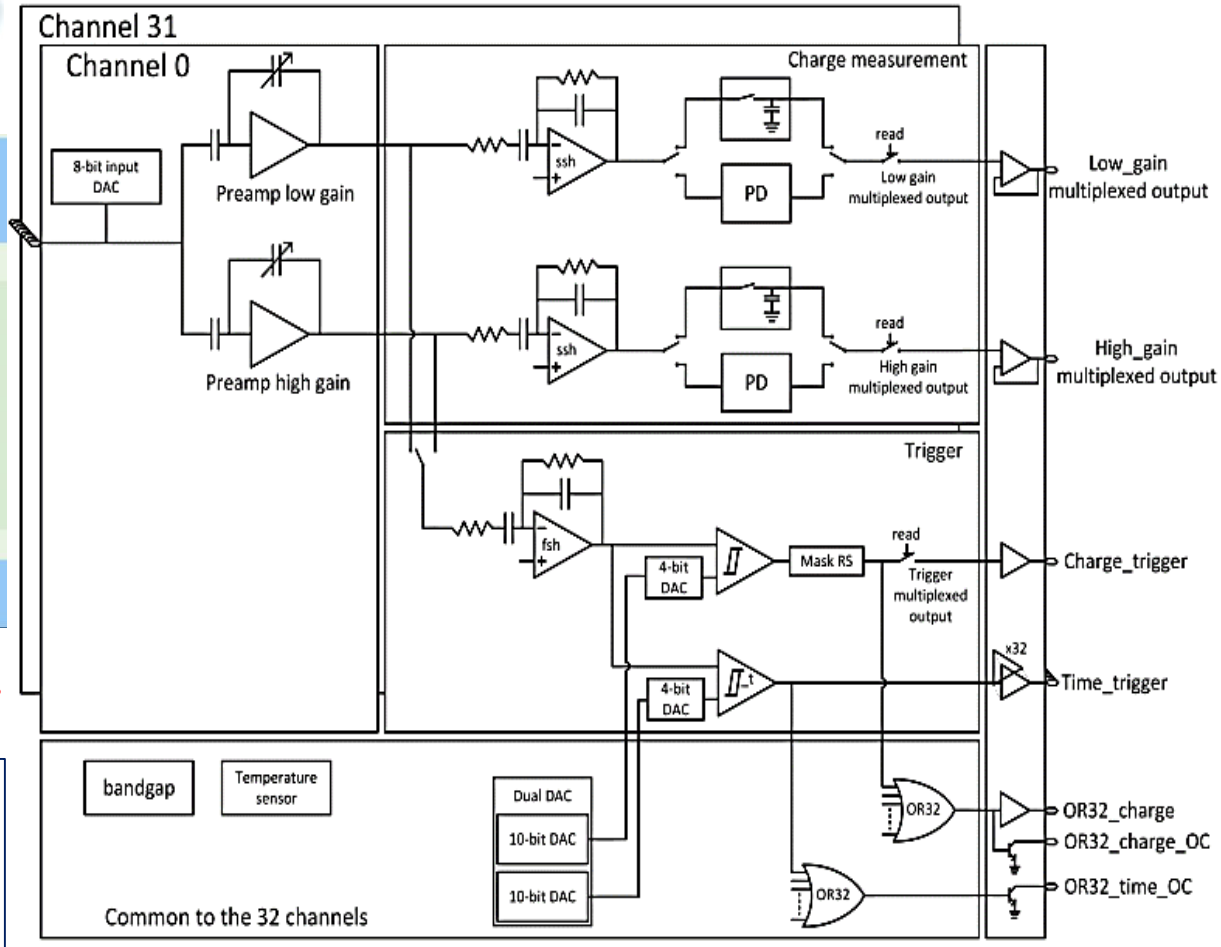
Fine for testbeam and Phase0 experiments.

Main Acquisition Modes:

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

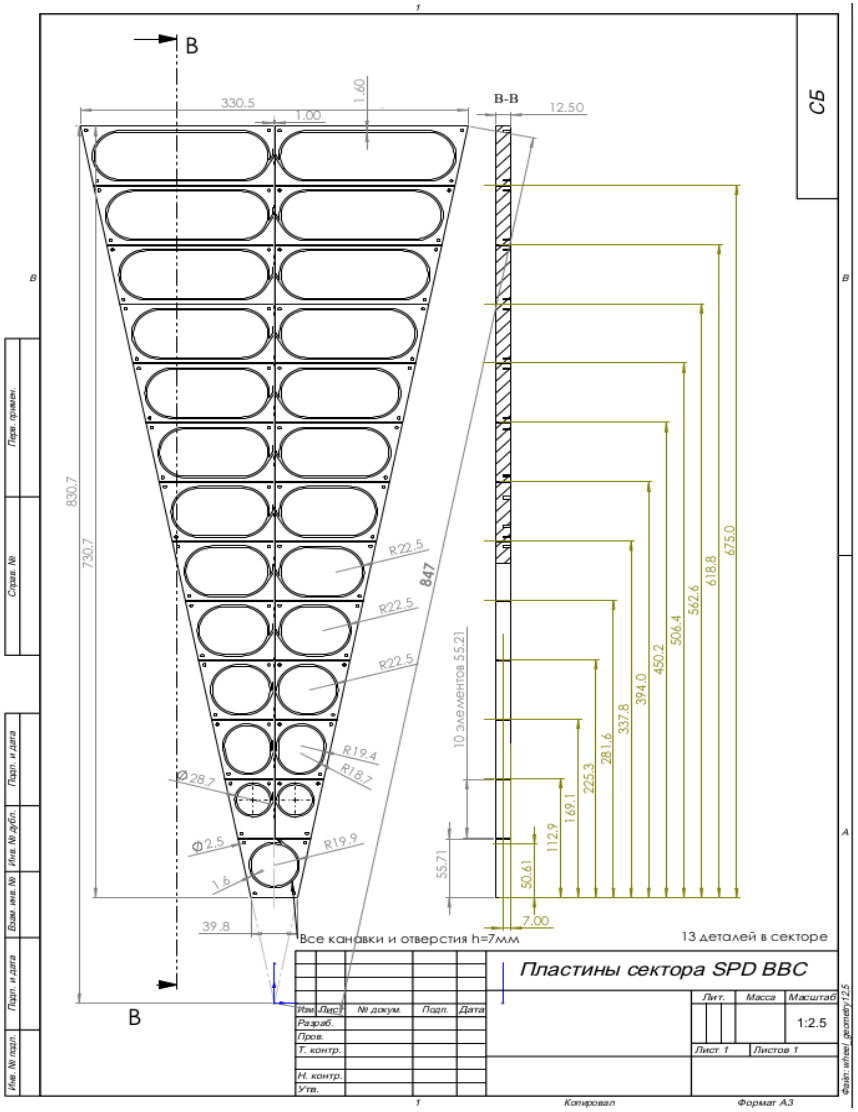


Citiroc 1A allows triggering down to 1/3 p.e. and provides the charge measurement with a **good noise rejection**. Moreover, Citiroc 1A outputs the 32-channel triggers with a **high resolution timing** (better than 100 ps).

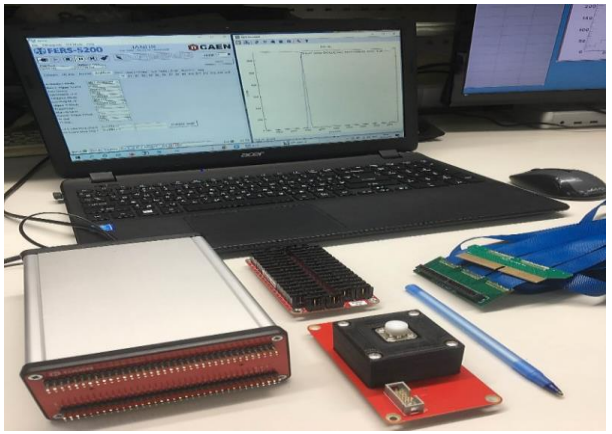


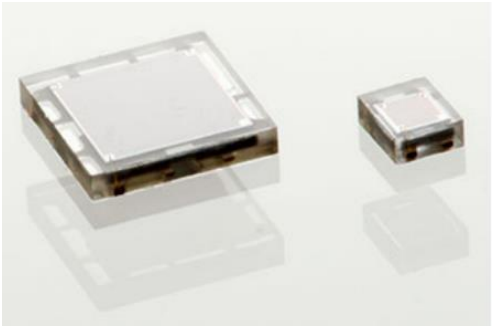
JINR and MEPhI Tests

Scintillation detector prototype



Together with MEPhI group (**G.Nigmatkulov et al.**)





The R&D stage continues and some problems arise related to dependence on the foreign technologies, as well as sanctions influence.

1. Equipment for BBC prototype:
   - **SENSL (MicroFC-x0035-SMT) SiPMs**
   - the **scintillator tiles** produced at Vladimir
   - **scintillation optical fibers** (WLS and clear)

   by KURARAY and Saint-Gobain Crystals

Scintillation detector prototype materials

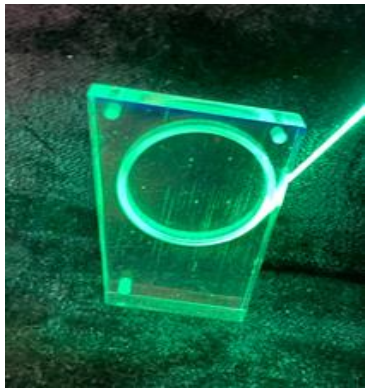
Line

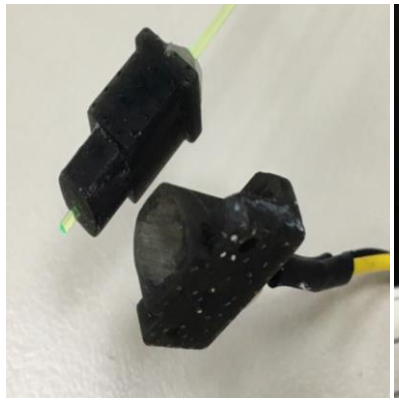
3 (L;R)

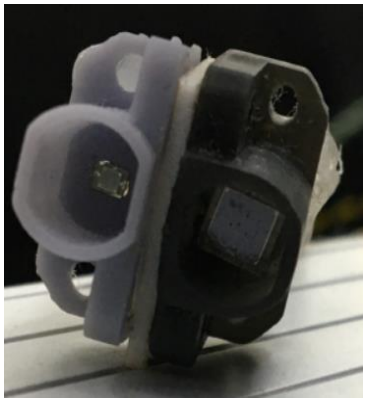
2 (L;R)

1 (L;R)

central





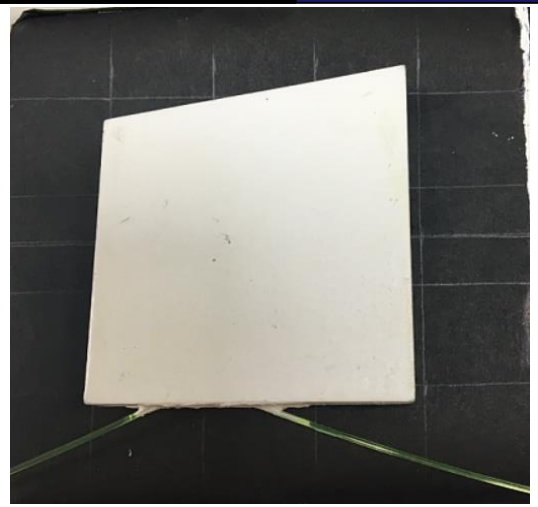


Materials selection (scintillator, optical cement, fibers, etc) and prototype tiles testing with material combinations.

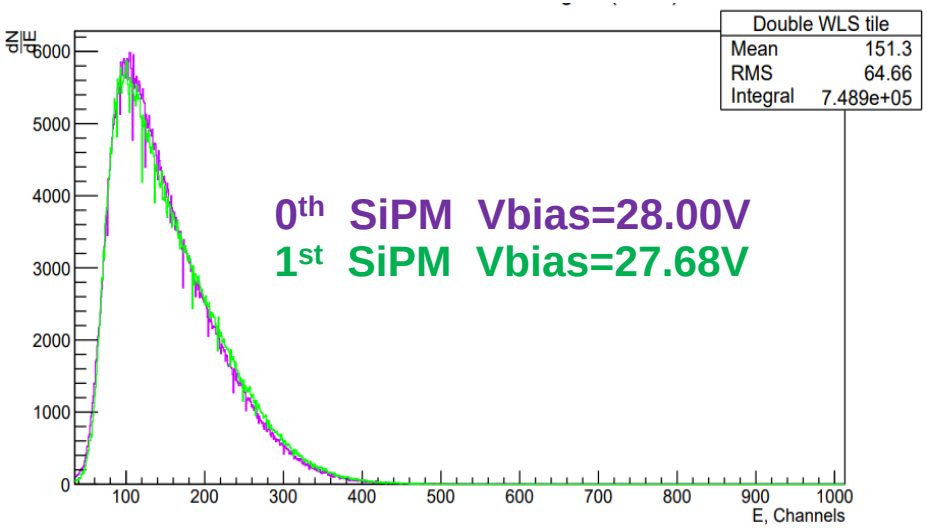
Scintillator:	**Matte vs Tyvek covered**
Optical cement:	**CKTN Med vs OK-72**
Fibers:	**Saint-Gobain Crystals vs KURARAY**
SiPMs:	**3x3 mm^2 ; 1x1 mm^2 (final option)**

FEE studies results

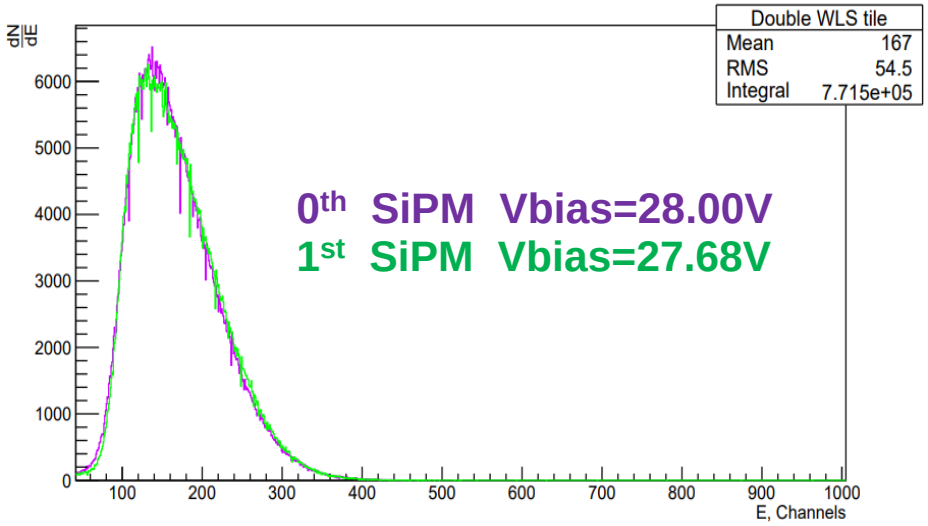
Calibration issue (beta source) SiPM comparison



1x1 mm² SiPM



3x3 mm² SiPM

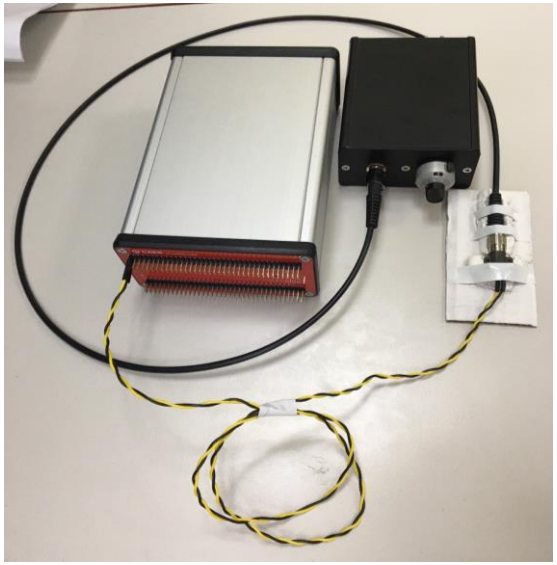


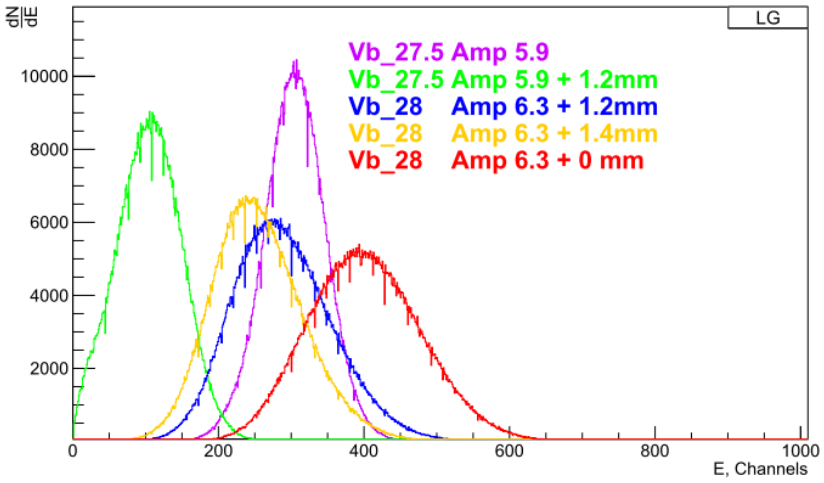
The amplitude histograms for both SiPM sizes with the chosen voltage. Difference at the same voltages for channels 0th and 1st are minimal, in both cases. **The main conclusion** is the signal difference between each WLS, that is not suitable for calibration.

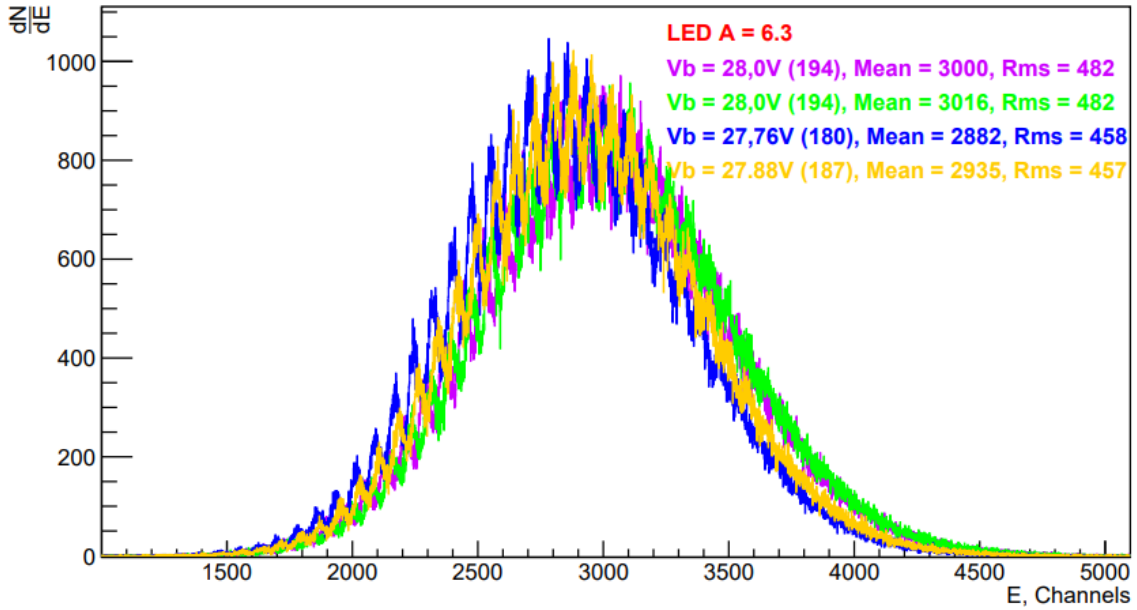
FEE studies results

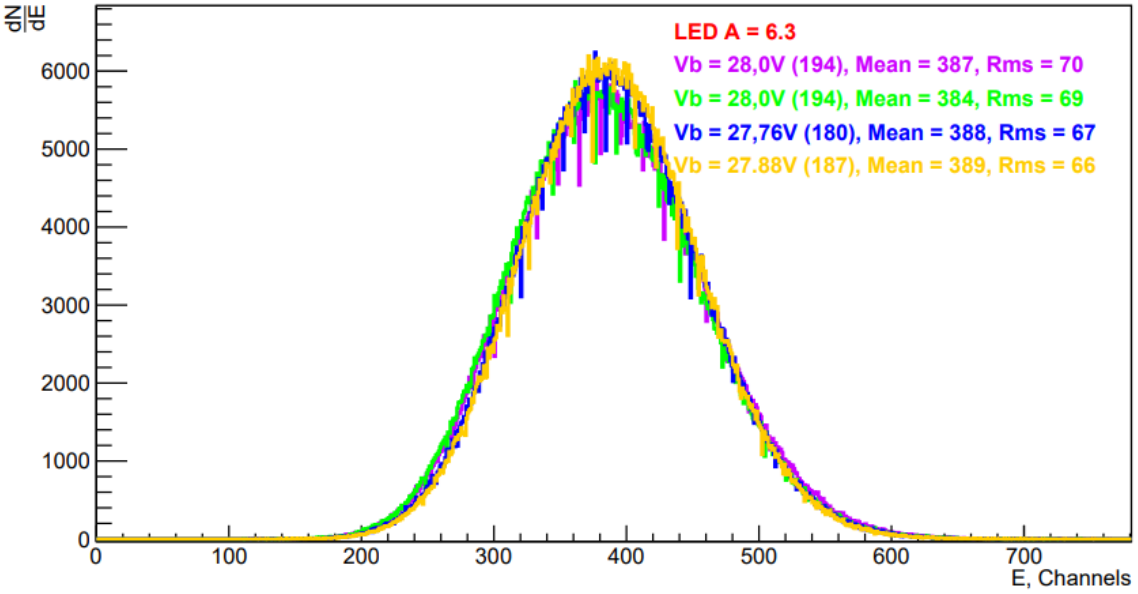
Calibration method (Led source)

DT5202 with CAEN LED Driver (SP5601)



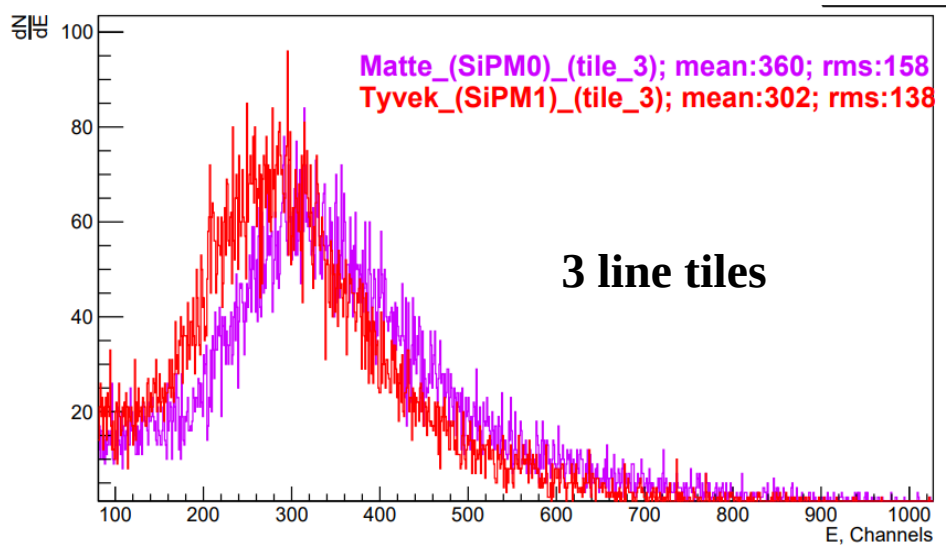


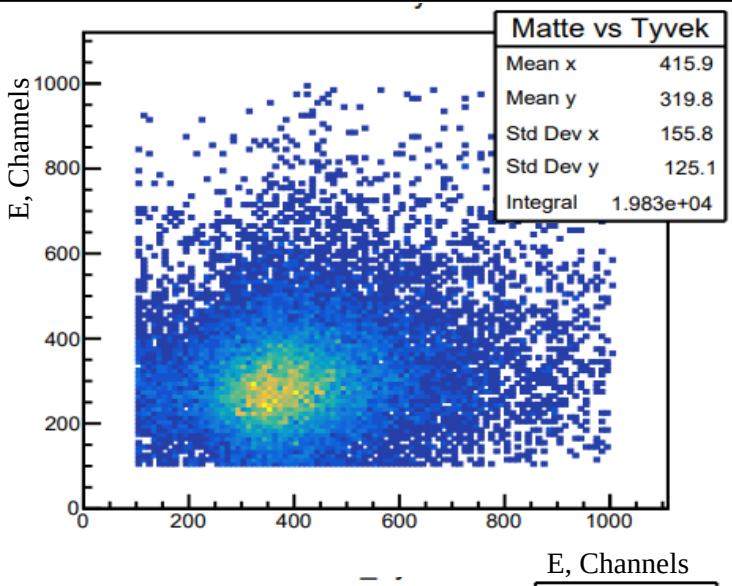


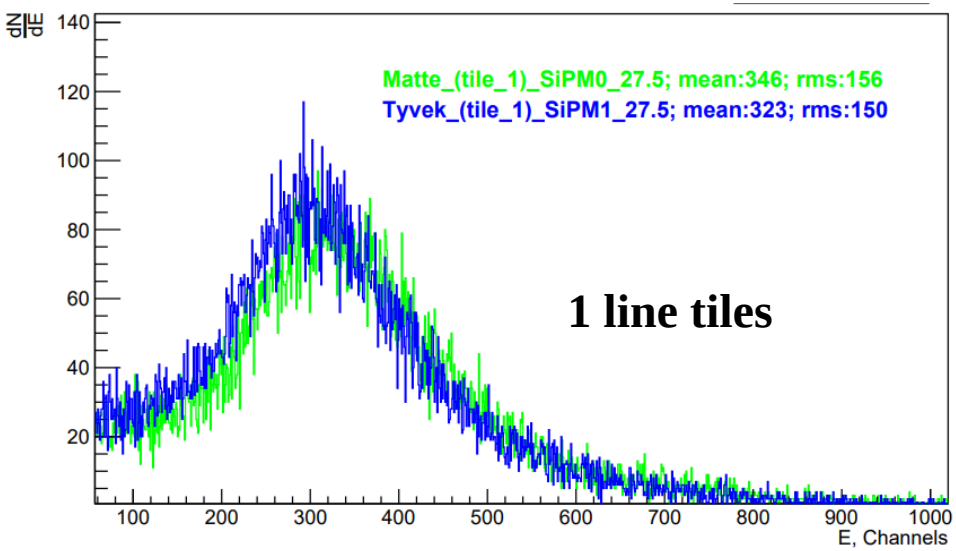


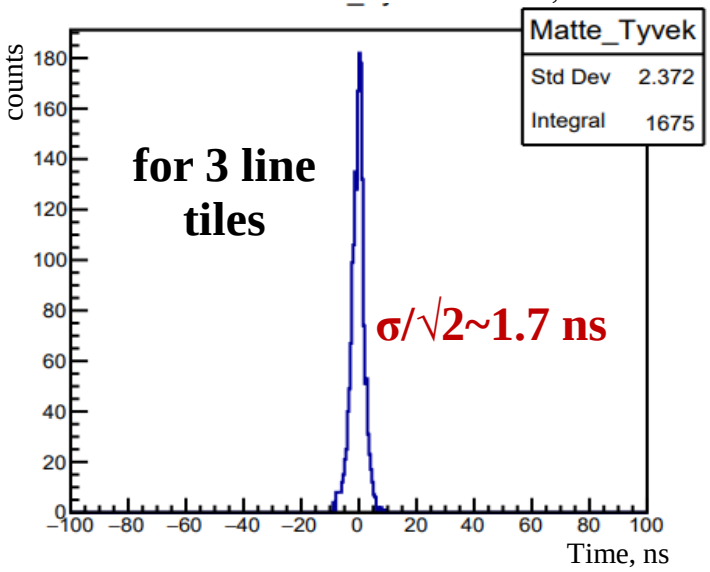
FEE studies results

Matte and Tyvek difference





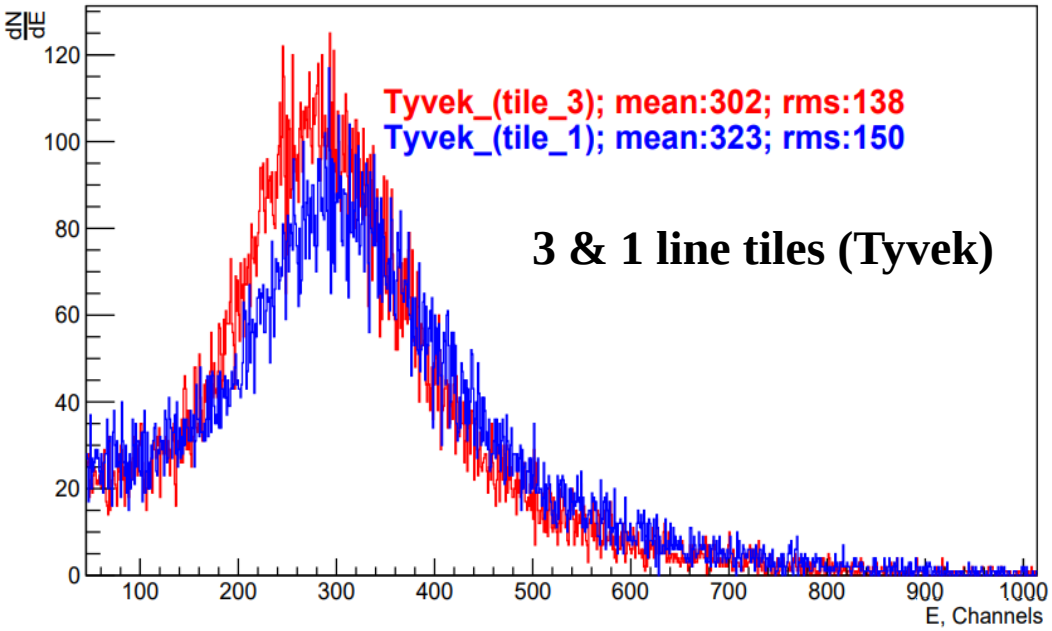


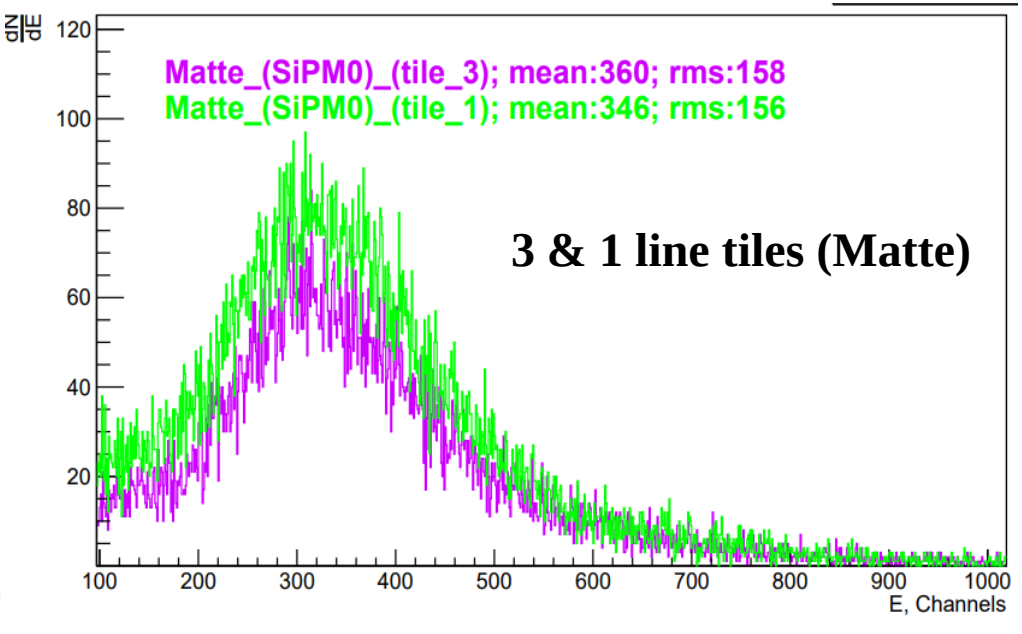


The result is similar, and due to the fact that the option with Tyvek carries the technological complexity of mass production, the option with matted one is **more acceptable**.

FEE studies results

Matte and Tyvek tiles

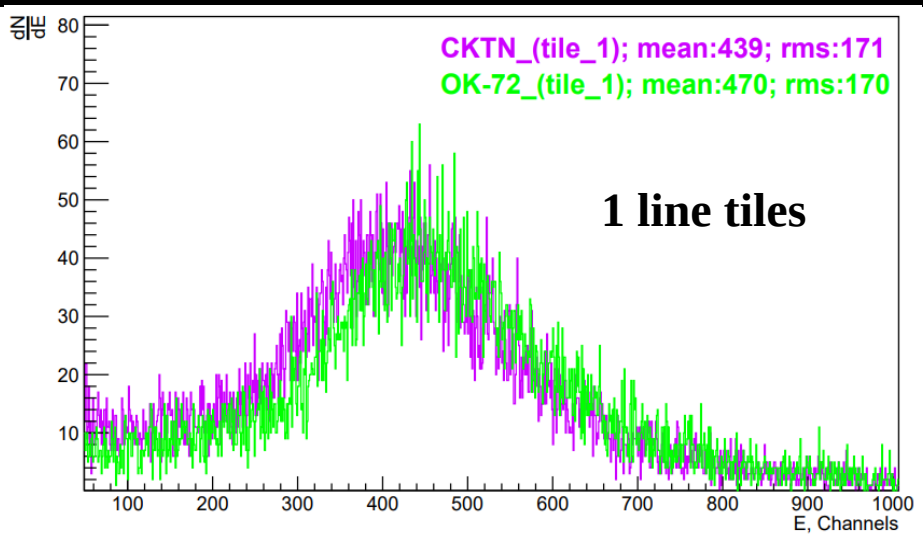


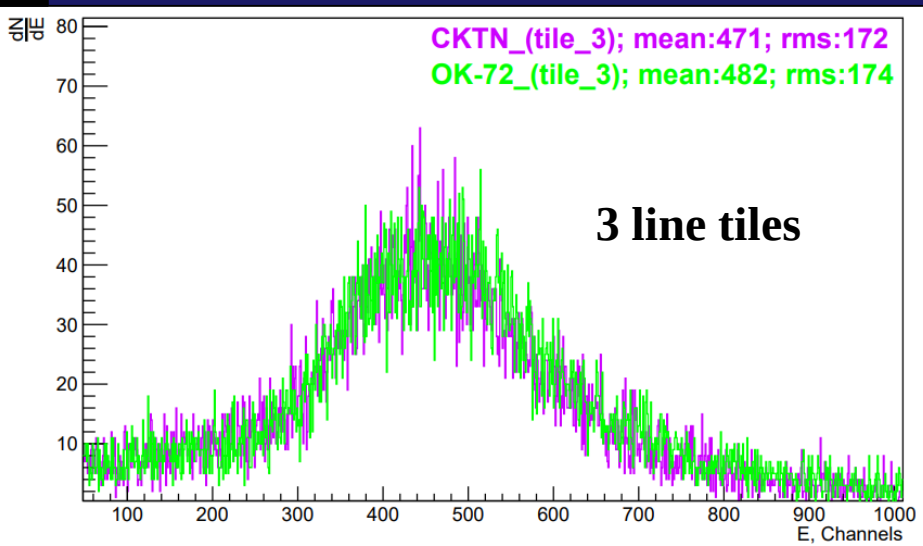


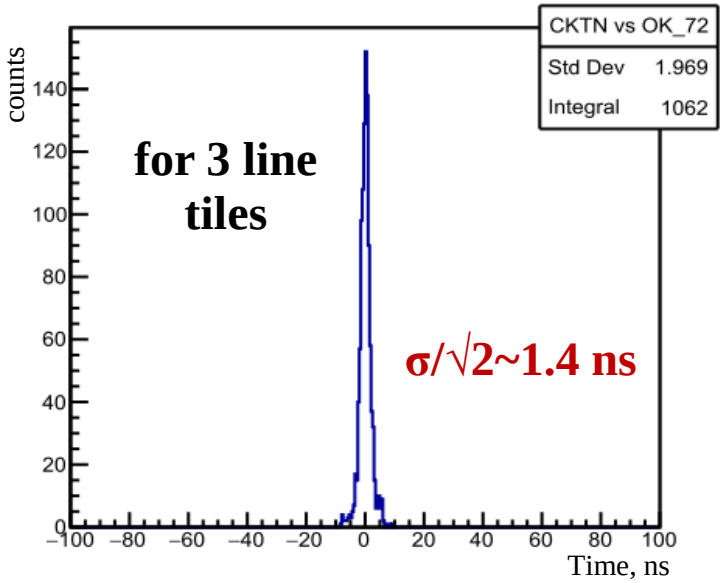
The result of comparison 1 and 3 line tiles. For Tyvek and matted tiles, the histograms are in the similar areas. The effect of fiber flexing requires a complex study.

FEE studies results

CKTN Med and OK-72 difference



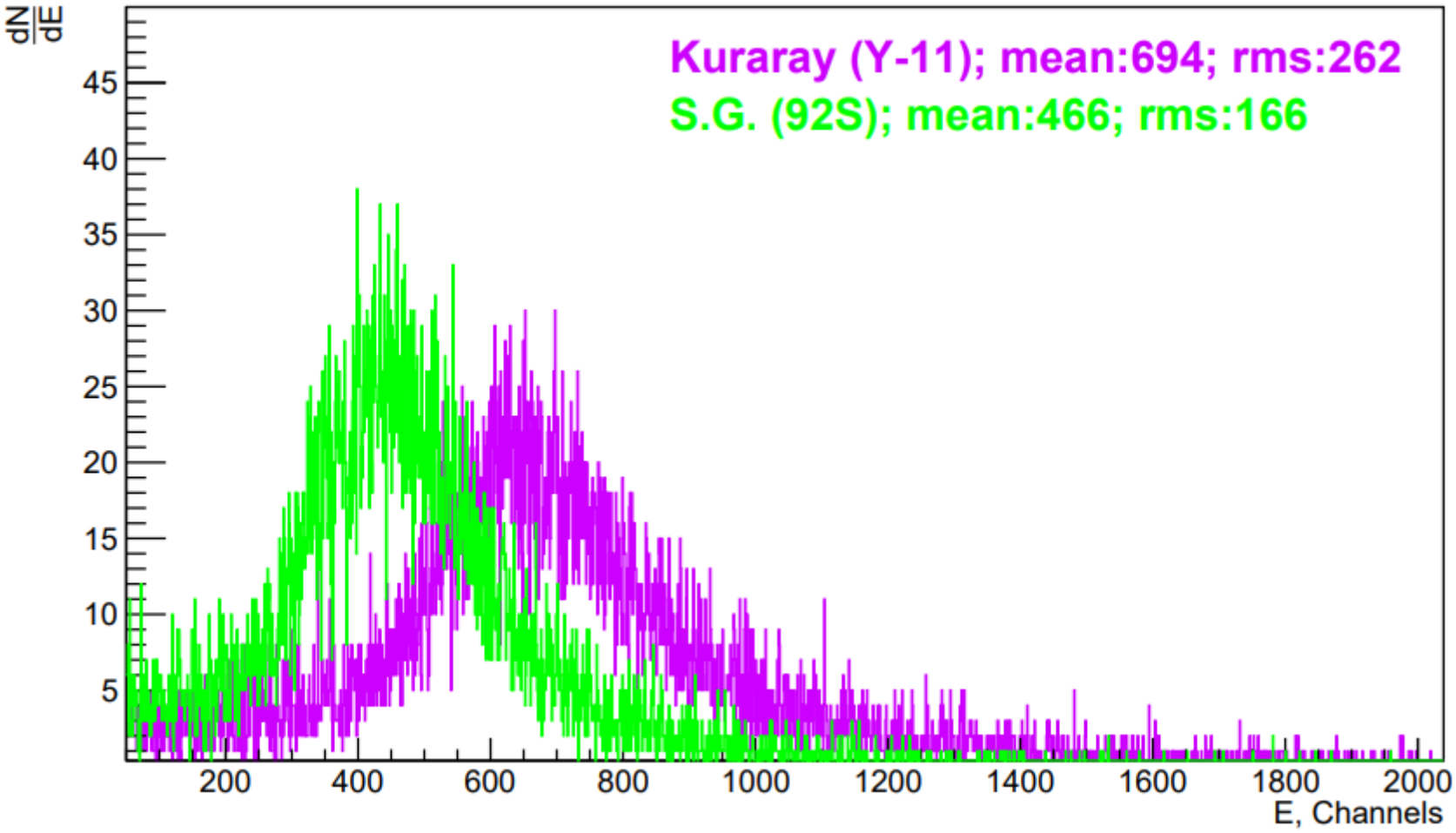




The time resolution is about 1.4ns, that is better then in matte and Tyvek covered tiles case.

FEE studies results

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



Conclusions

Obtained results

I. The **scintillation detector prototype tests** with CAEN FERS-5200 system has been started. The **method of determining** the operating voltage proved to be efficient. The **first result of time resolution** is promising. The upgrade of the data analysis tool is required.

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. The choice of optical cement is the situational decision.

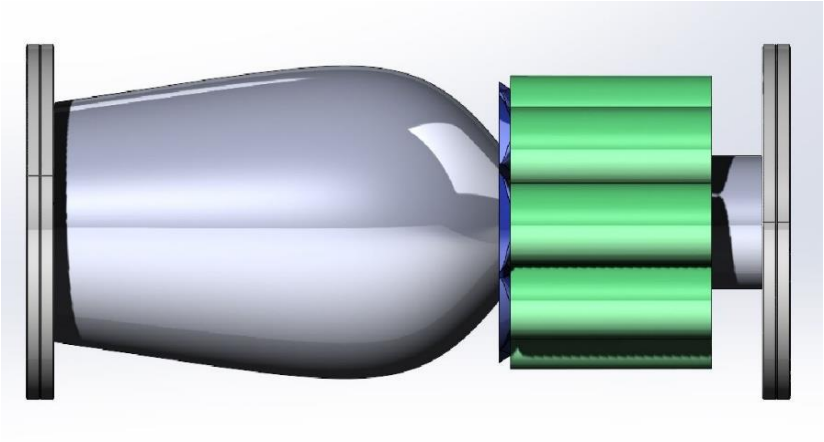
IV. The **study of a larger number** of samples and the effect of fiber flexures, as well as **tests with 1x1 mm^2 SiPMs** are required. Further is the build of 7 sector tiles.

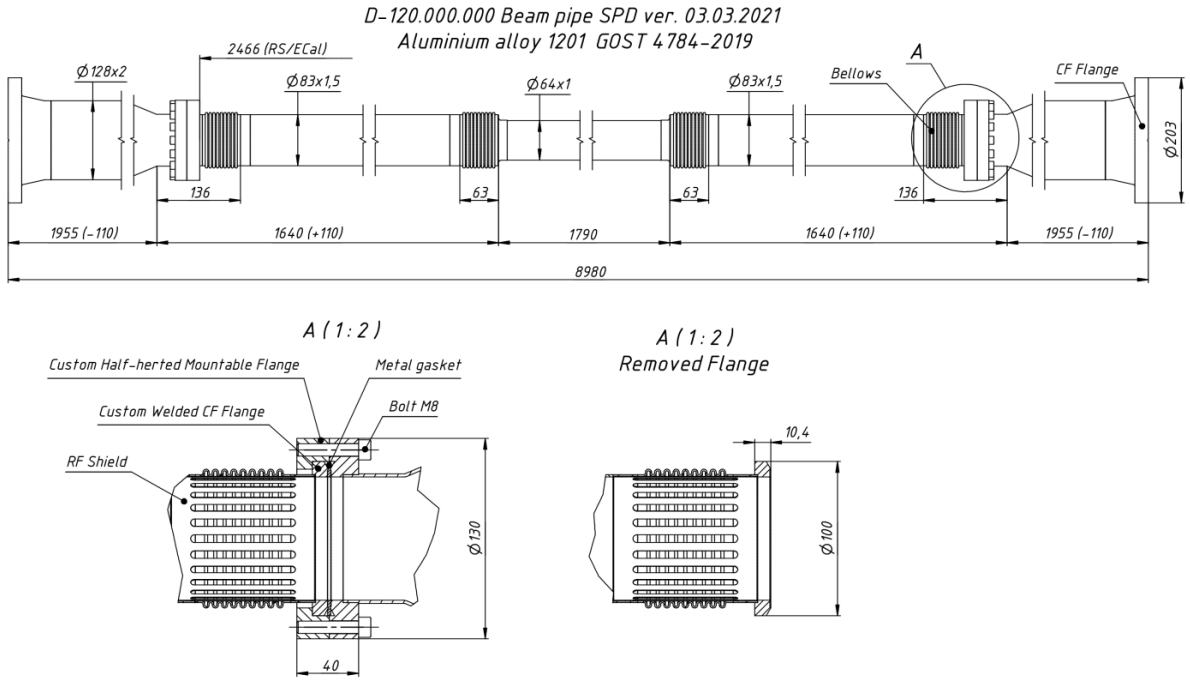
Thank you for the attention!

Backup

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.

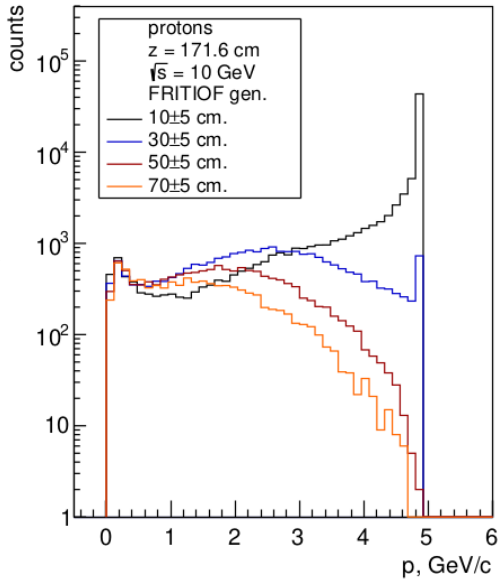
-MCP based TOPAZ PMTs
-Good time resolution 50ps
-Tests with laser and with 200 MeV electrons (LINAC-200) has been performed.
-Tests in SPD testzone and at ITS at Nuclotron are under preparation
-Combined detector (MCP+ Scintillators) for small angle scattering monitoring and physics

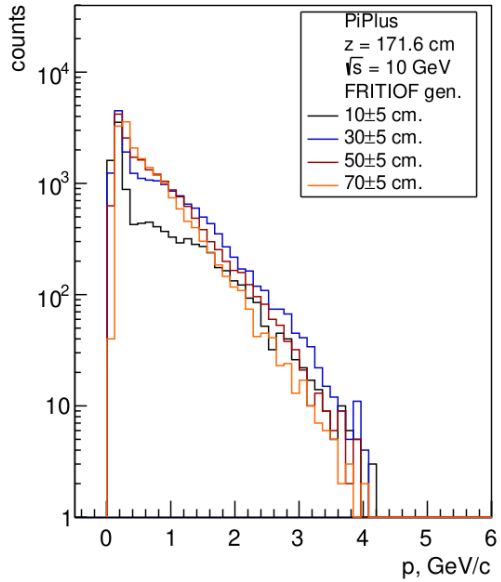
Team **A.Baldin et al.(JINR)**
G.Feofilov et al. (StPSU)
A.Kubankin et al. (BNRU)
…..

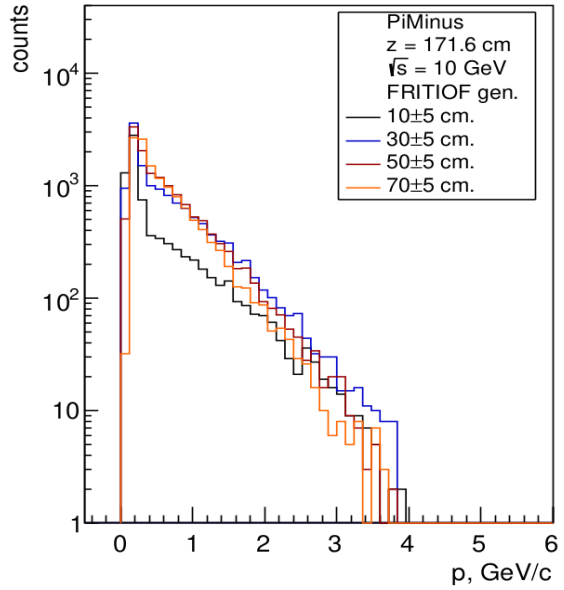
Simulation (pp)

Z.Kurmanaliyev

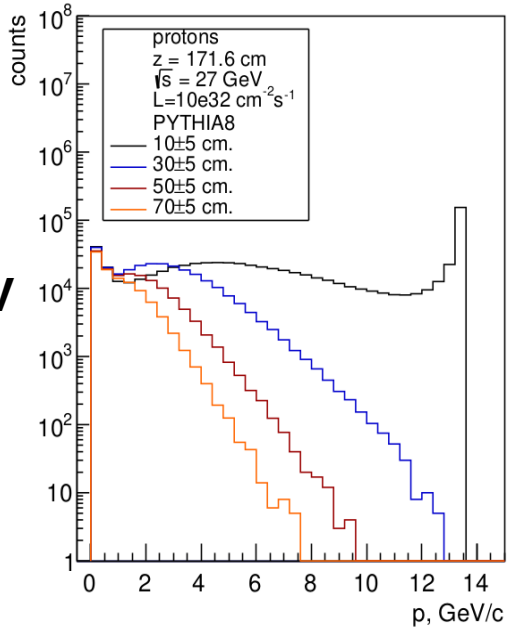
10 GeV

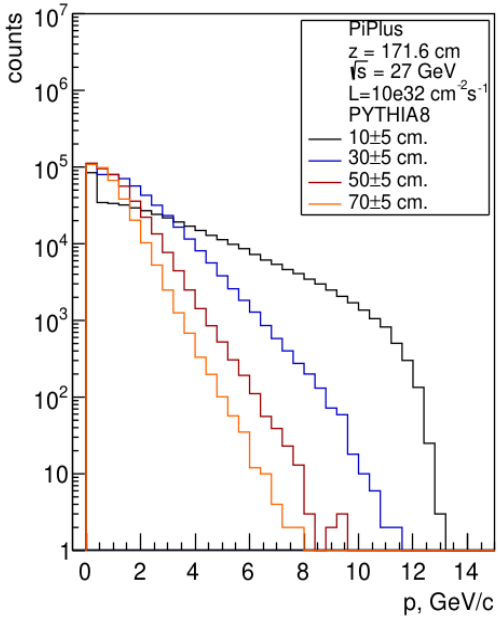


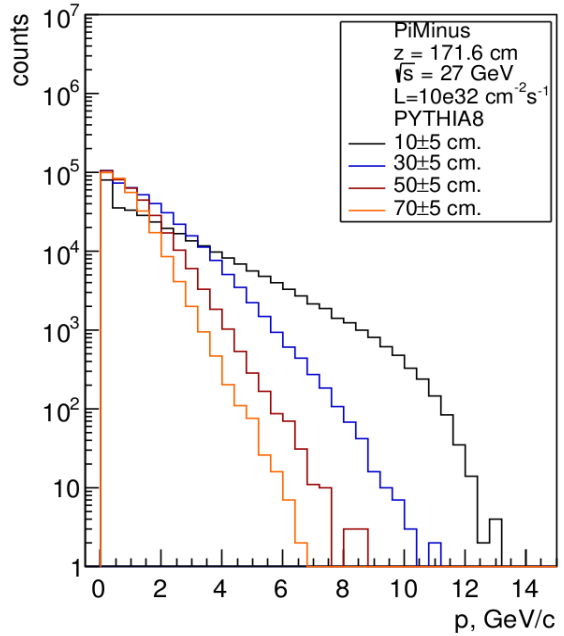




27 GeV



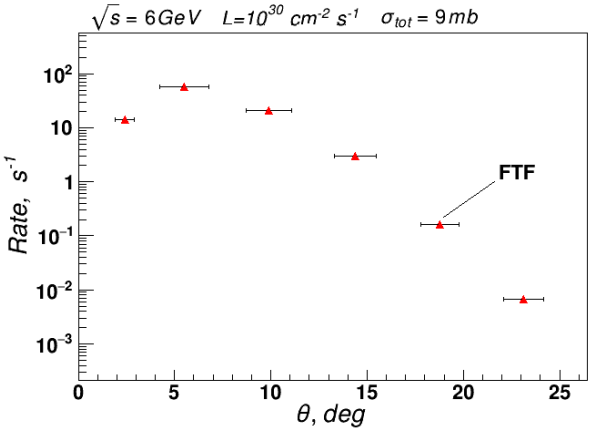


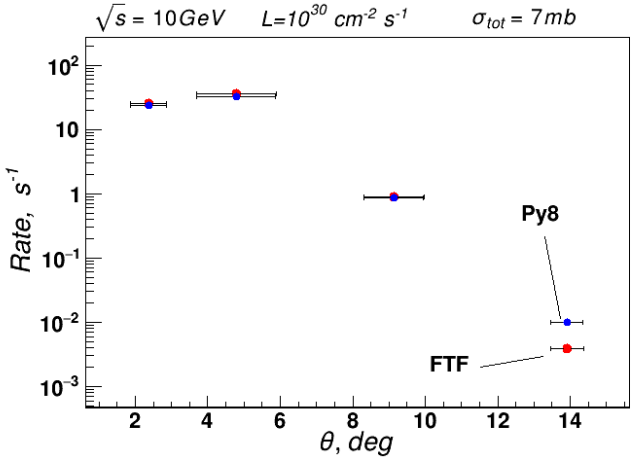


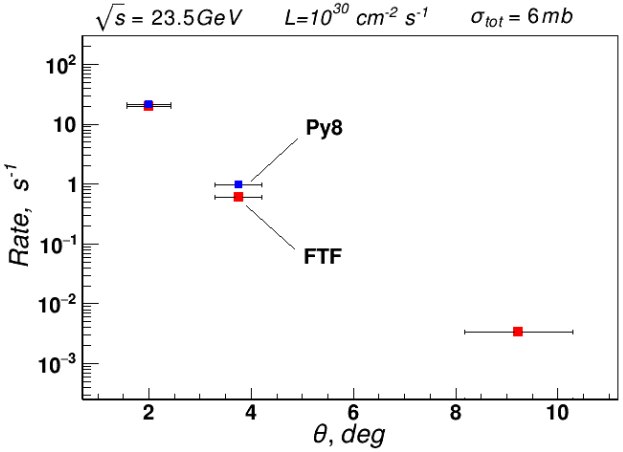
Simulation (pp)

FTF and Py8 generators

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







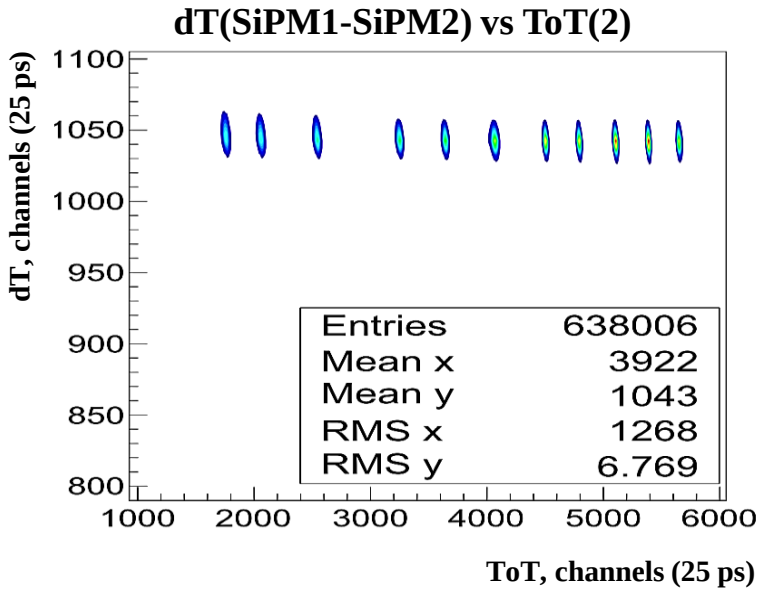
The pp-elastic scattering events have been selected for total energies equal 6.2, 10 and 23.5 GeV. The events rates as function from the angle scattering have been estimated for pp-elastic scattering by using the FTF and Py8 generators at Luminosity 10^{30} $cm^{-2}s^{-1}$ for 1/16 part of BBC.

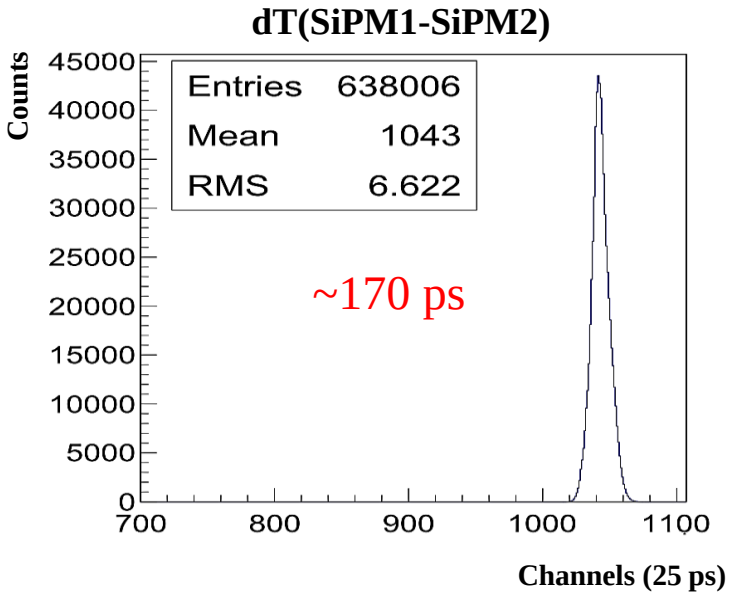
Z.Kurmanaliyev (JINR)
A.Terekhin (JINR)

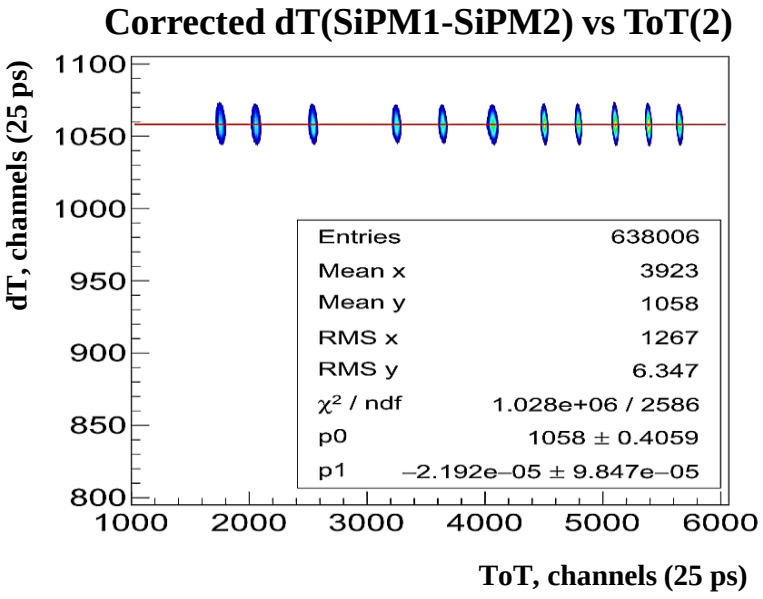
(see talk at this meeting)

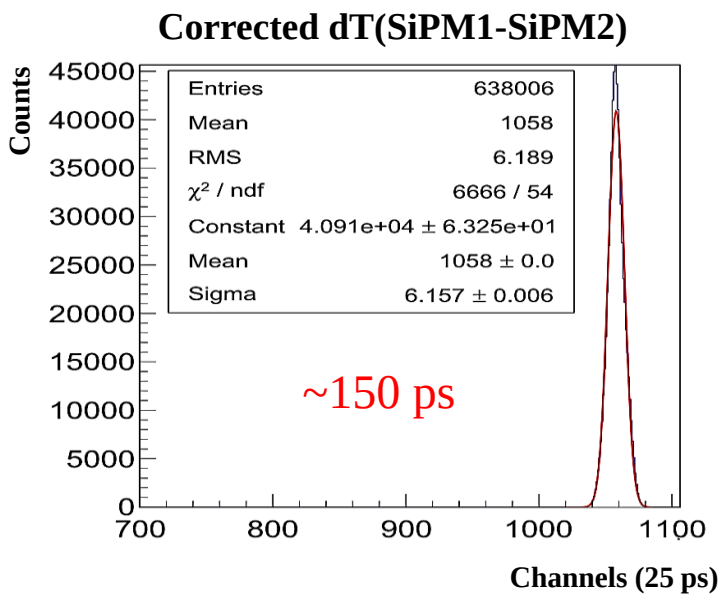
FEE studies results

The time difference histogram FEE ToT (version 03)



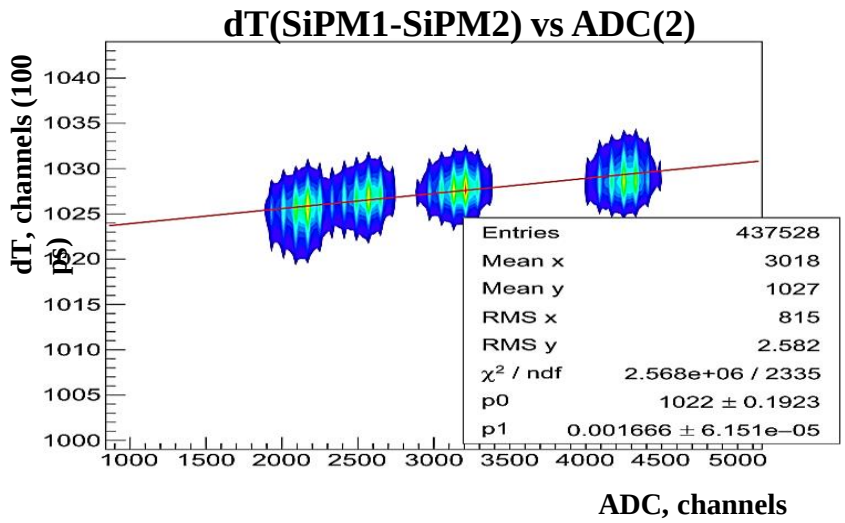


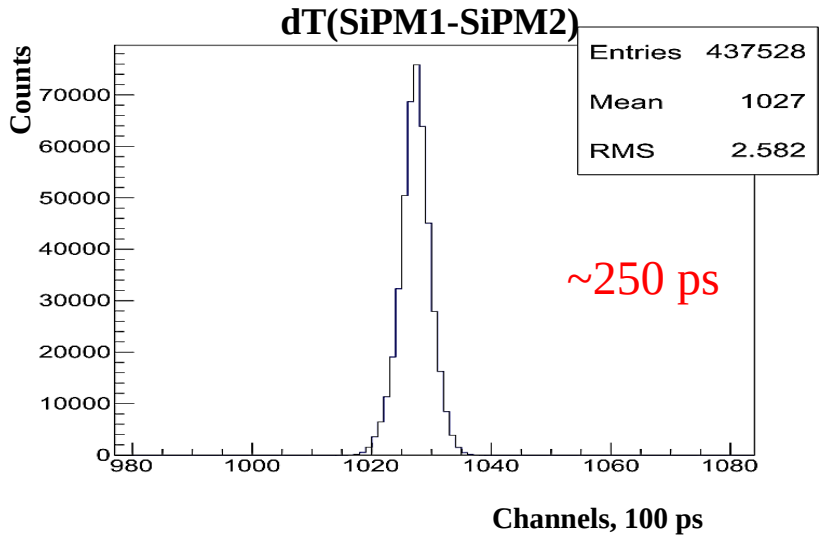


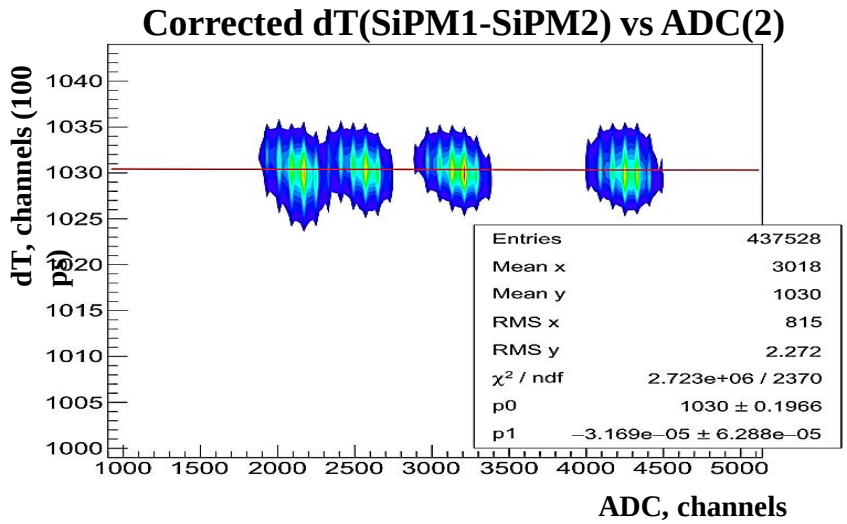


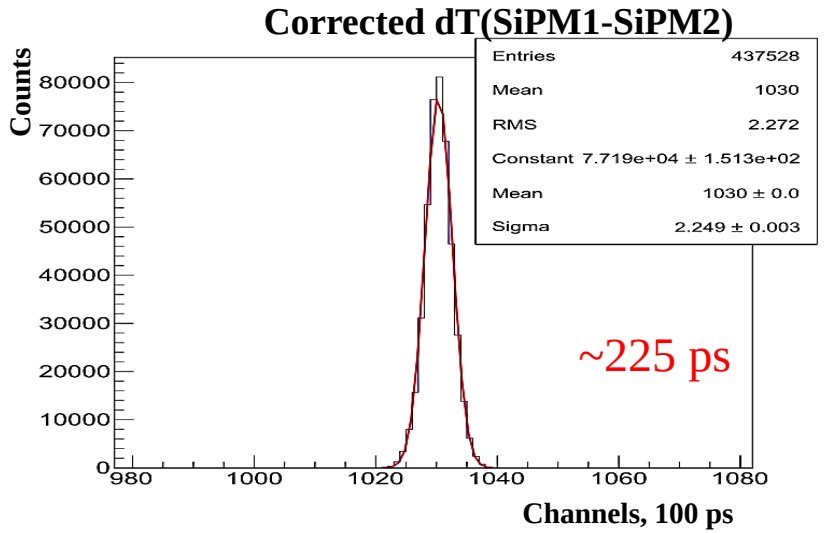
FEE studies results

The time difference histogram for FEE DANSS









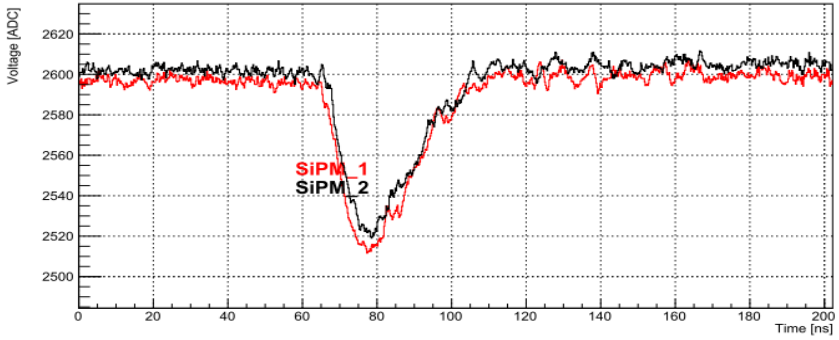
Phys.Atom.Nucl., DOI:10.1134/S1063778822090381 (2022)

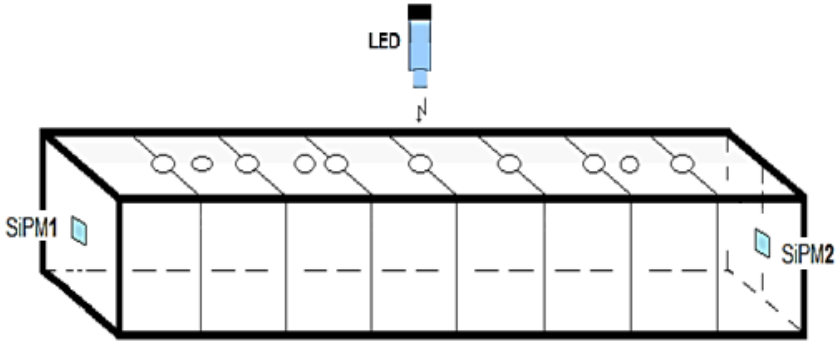
FEE studies results

CAEN digitizer DT5742 (16ch)

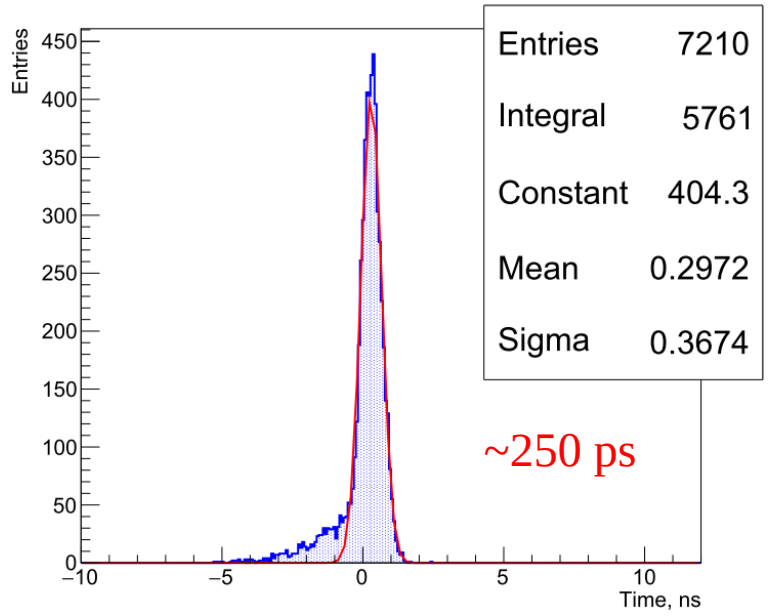
16+1 Channel 12 bit 5 GS/s
Switched Capacitor Digitizer

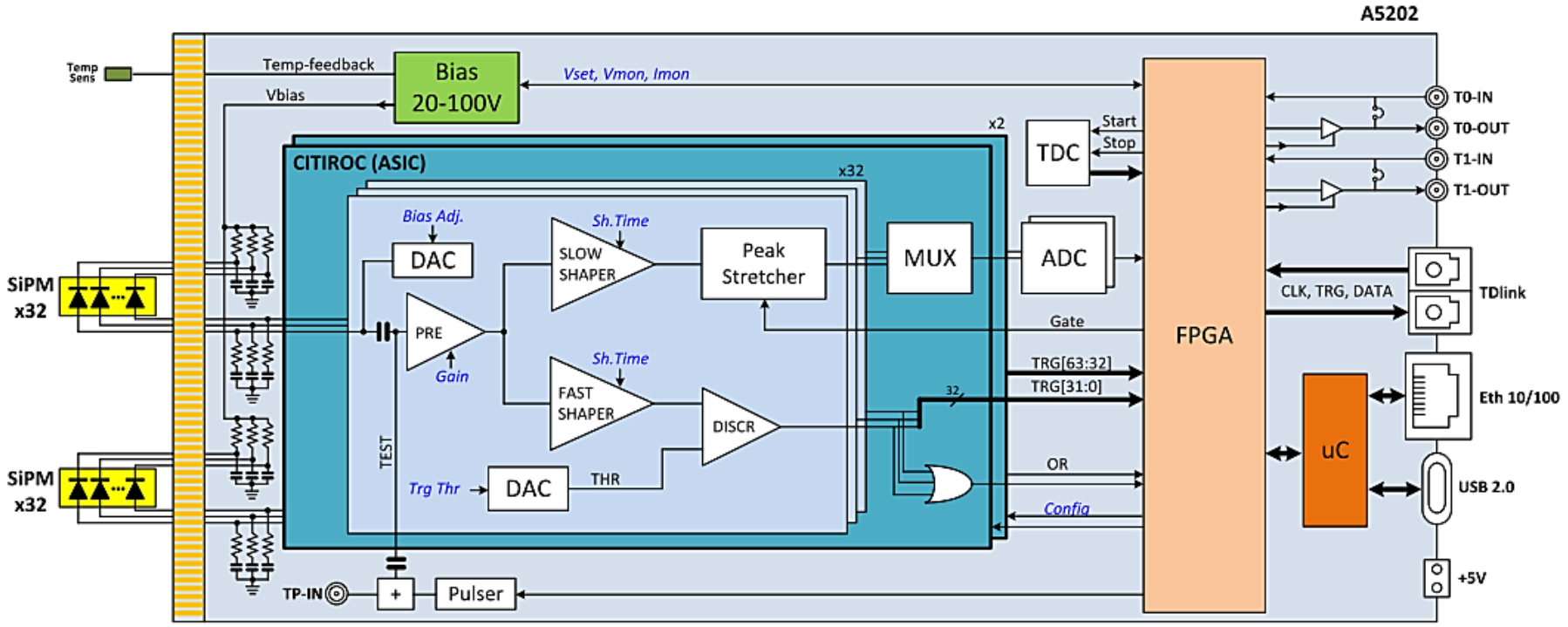
based on the DRS4 a Switched Capacitor Array. This technology relies on a set of capacitors that continuously sample the analog input signals. As soon as the trigger is issued, capacitors are decoupled from the input signals with a time interval from each other that is the sampling period.

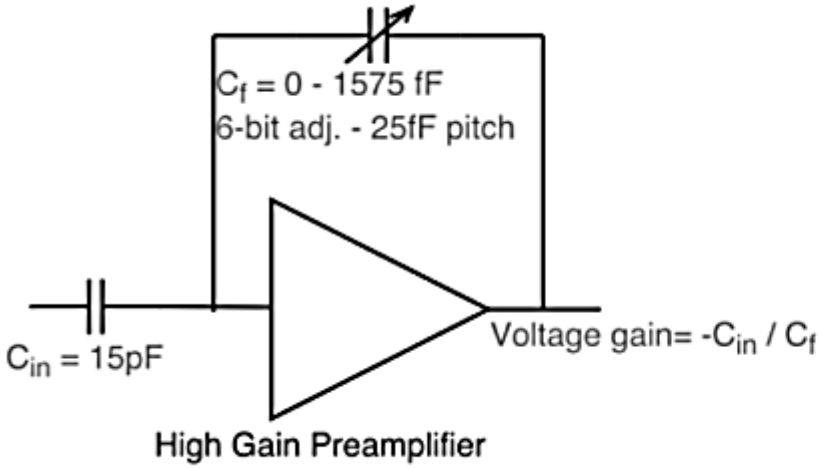


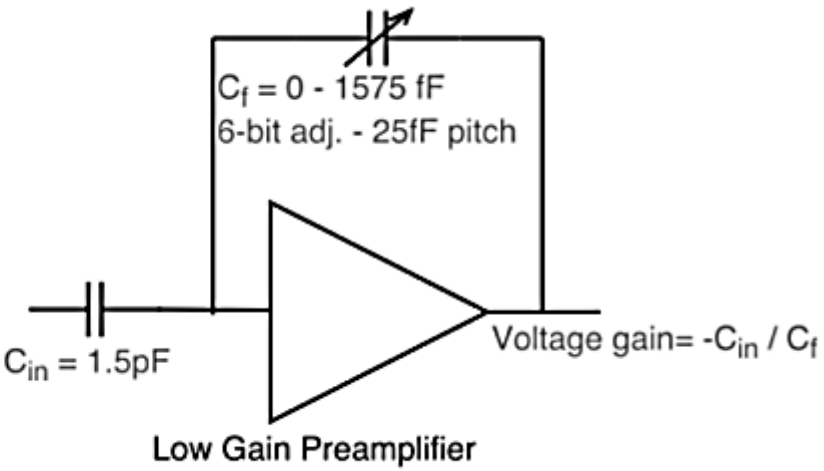


- Hamamatsu SiPM (S12572-010P)
- FEE of DANSS experiment




A5202
Temp Sens
Temp-feedback
Vbias
Bias 20-100V
Vset, Vmon, Imon
CITIROC (ASIC)
x2
x32
Bias Adj.
DAC
Sh.Time
SLOW SHAPER
Peak Stretcher
MUX
ADC
TDC
Start
Stop
PRE
Gain
Sh.Time
FAST SHAPER
DISCR
TEST
Trg Thr
DAC
THR
SiPM x32
SiPM x32
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

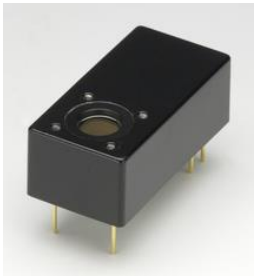
```
//************************************************
// File Format Version 3.1
// Janus Release 2.2.10
// Acquisition Mode: Spect_Timing
// Energy Histogram Channels: 4096
// ToA/ToT LSB: 0.5 ns
// Run start time: Thu May 12 12:34:25 2022 UTC
//************************************************
```

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	-	-

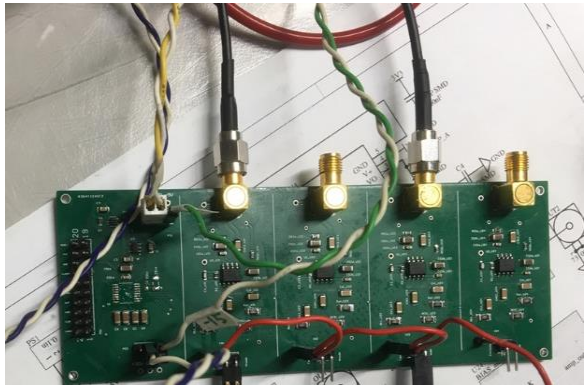
Fig. 3.36: Event List example in Spectroscopy + Timing Mode (Ascii format), where ToA and ToT are expressed in ns.

FEE studies results

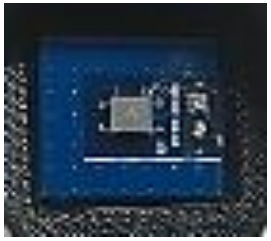
Prototype with Chile electronics



PMT Hamamatsu H10720-110

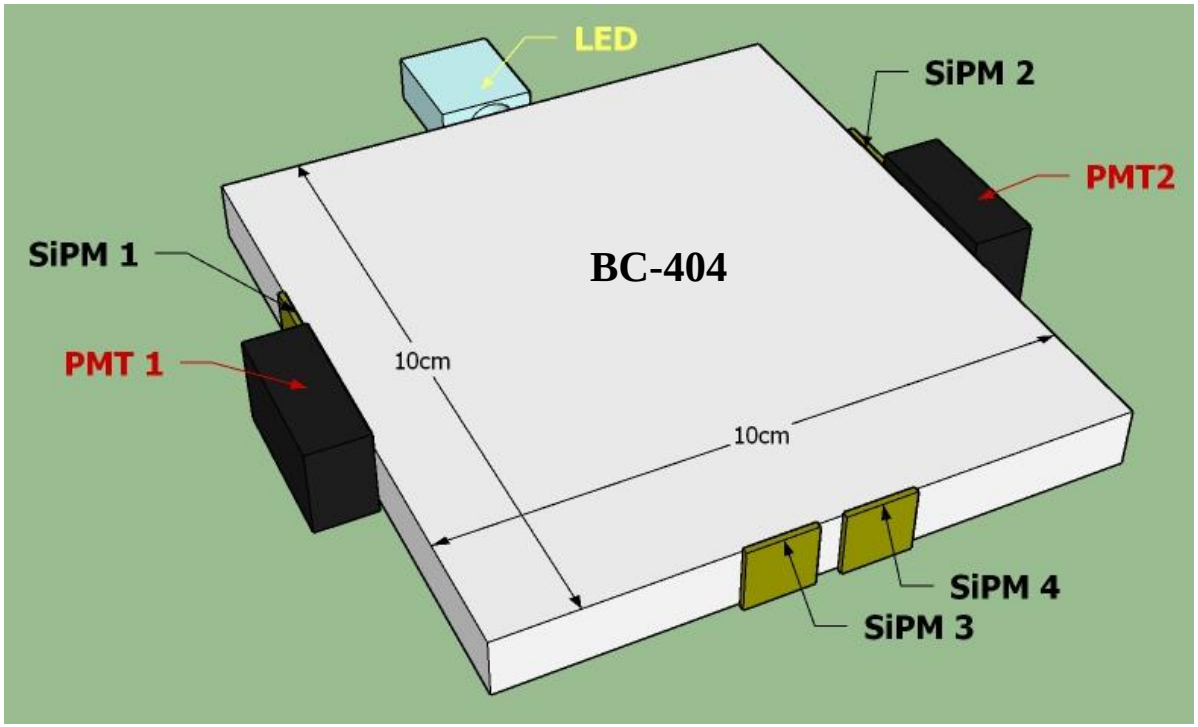


CTEPP-UNAB FEE (Chile) + SiPM

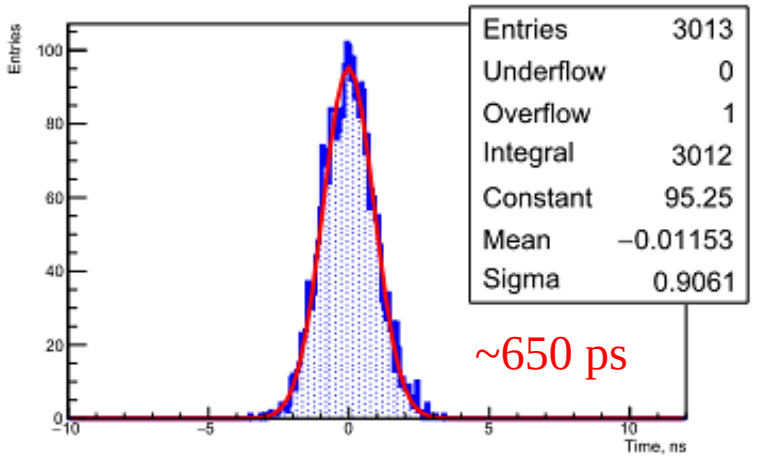


Hamamatsu SiPM S14160-3050HS

(3x3 mm^2, 50 µm/cell)



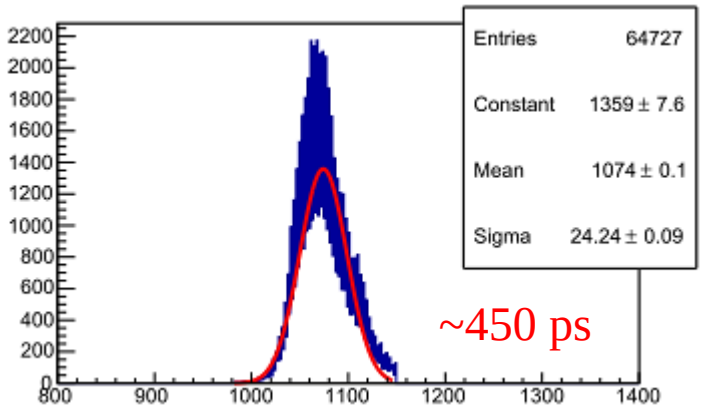
Trigger time resolution



FEE studies results

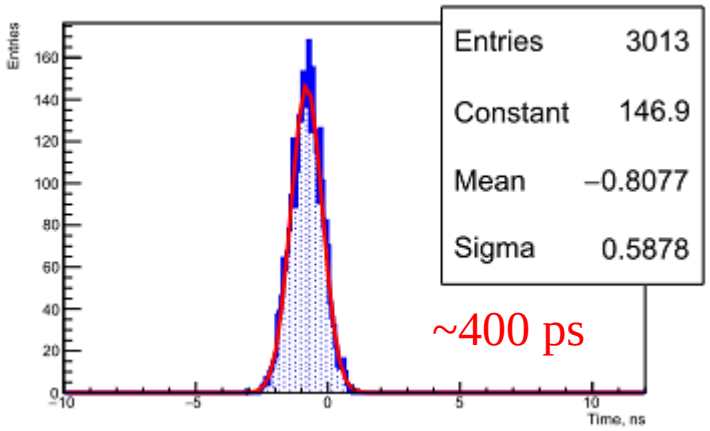
Prototype SiPM time resolution

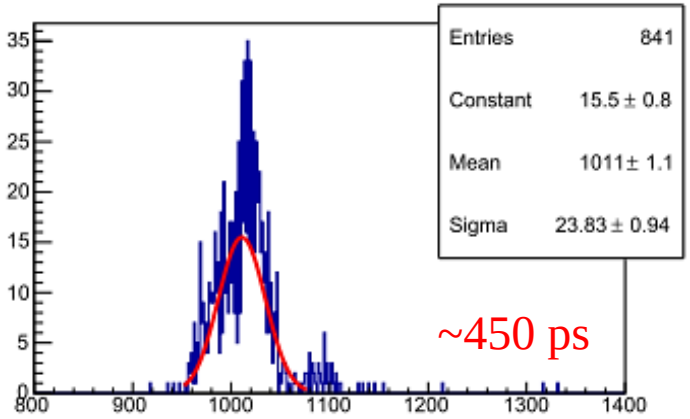
VME DAQ



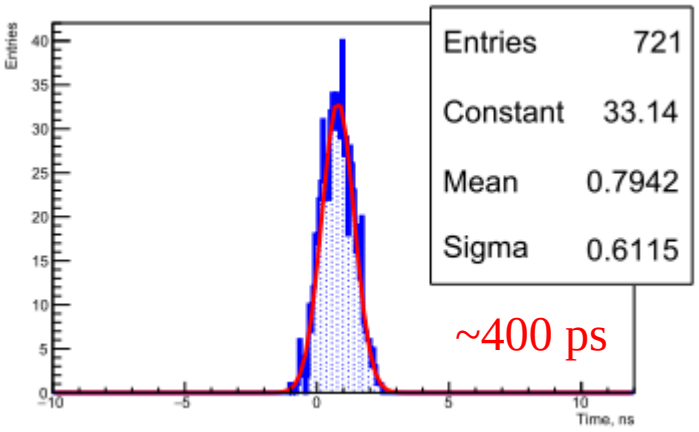
LED PULSER

Digitizer DT5742



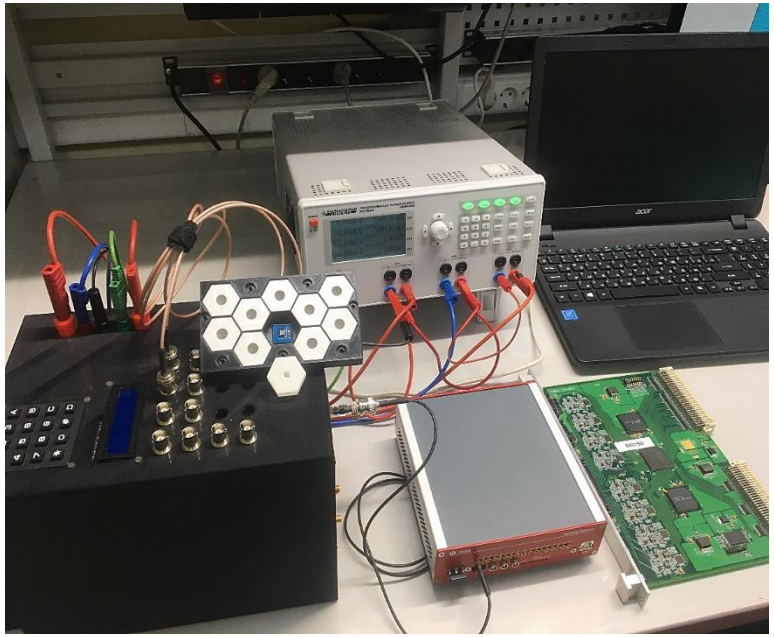


COSMIC RAYS

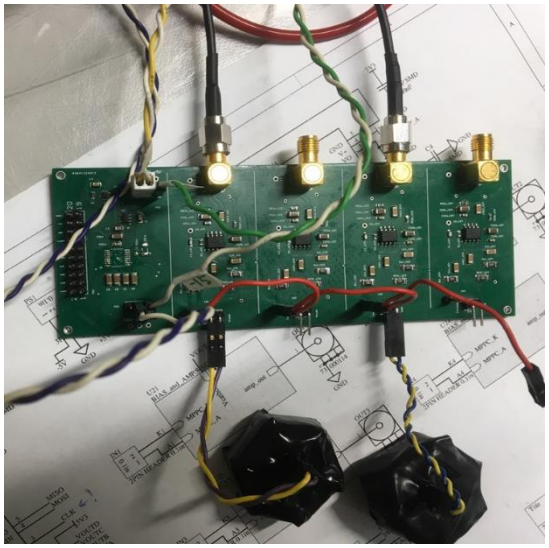


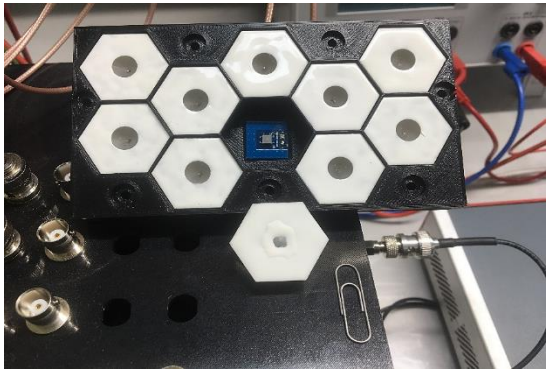
Tests at Lab201- VBLHEP

CTEPP-UNAB group, Chile



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





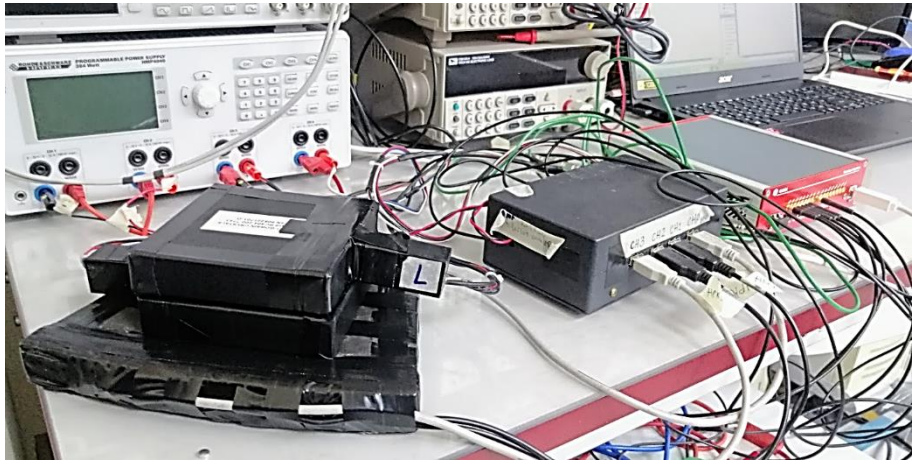
Hamamatsu SiPM S14160-3050HS

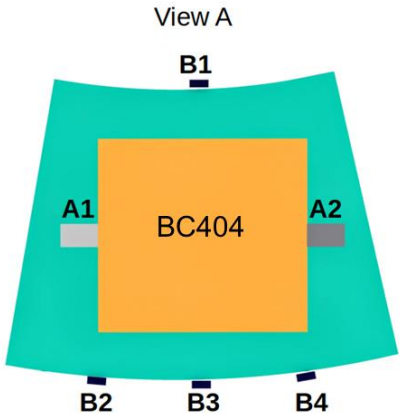
(3x3 mm^2, 50 µm/cell)

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

Tests at Lab201- VBLHEP

SAPHIR-UNAB and Cinvestav Teams





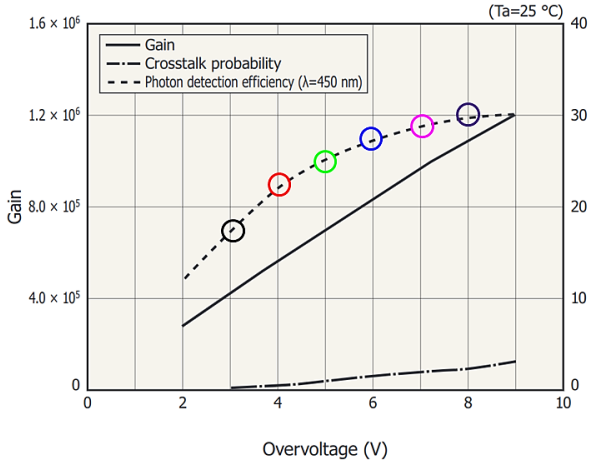
Light from prototype (BC404) is detected by four SiPM (B1-B4)

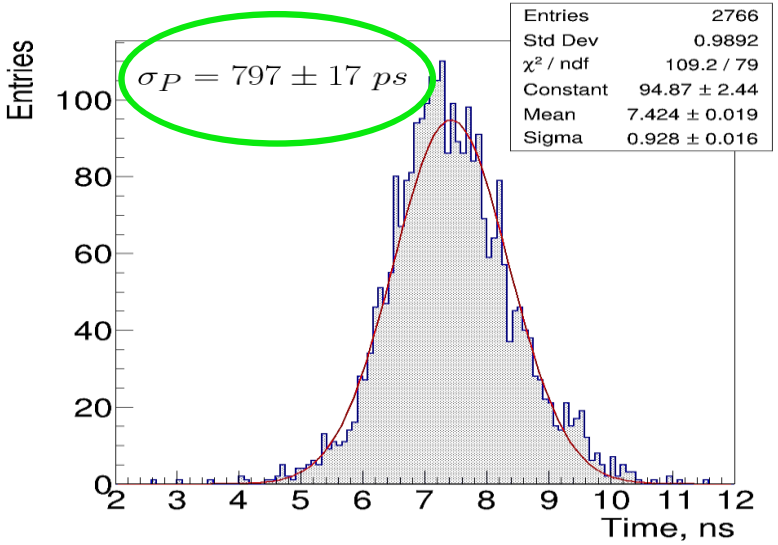
Different Vbias were explored (55.5, 56.5, 57.5, 58.5, 59.5, 60.5 V).

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).



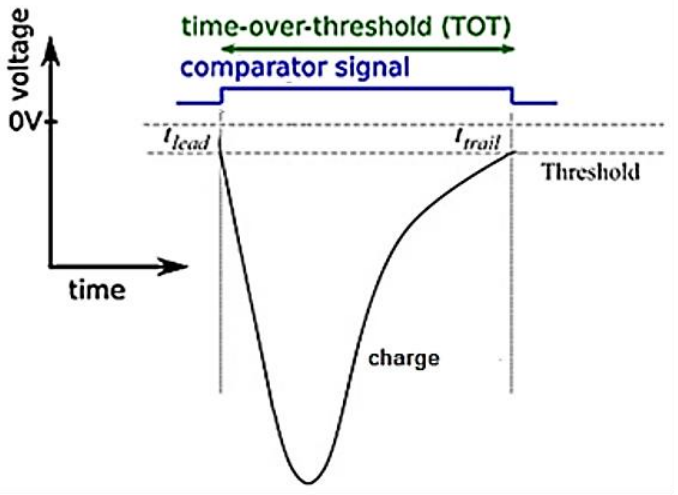


Together with **M.A. Ayala-Torres (SAPHIR-UNAB)**

First tests for SPD BBC prototypes

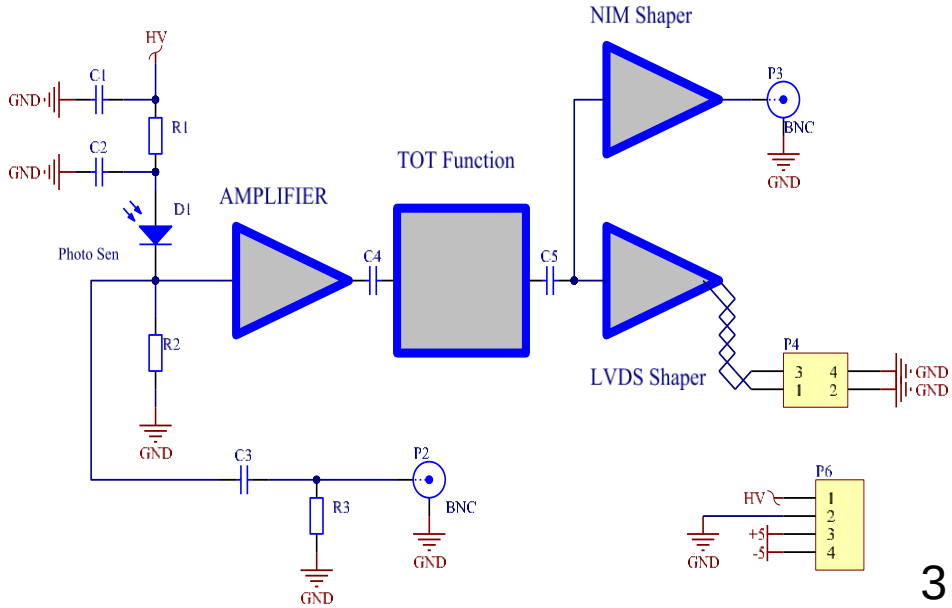
(talk at this meeting)

The Time-over-Threshold (ToT) method



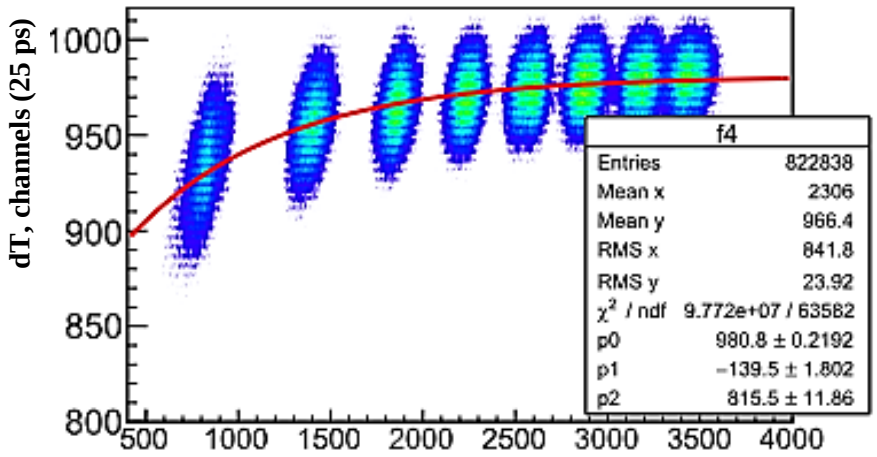
The ToT is a well-known method which allows to measure the energy deposited in the material.

Front-end electronics with ToT technique

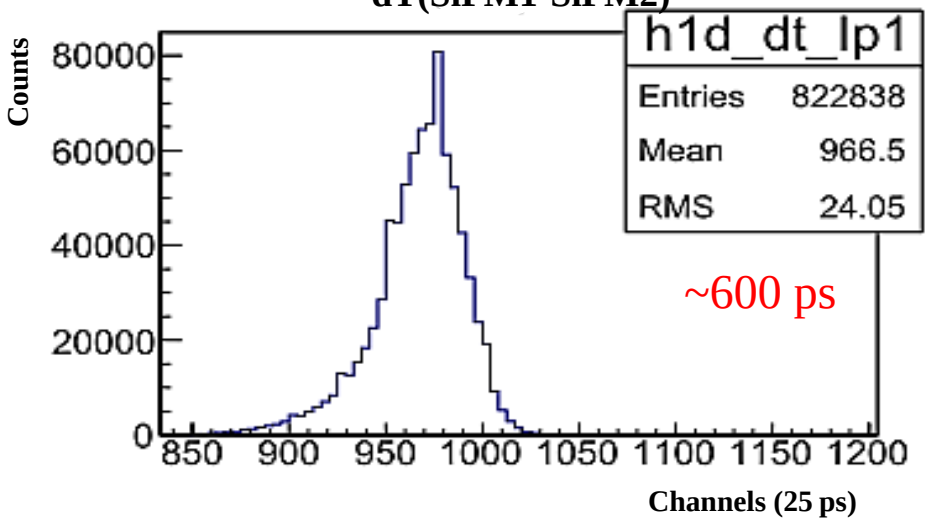


The time difference histogram FEE ToT (version №1)

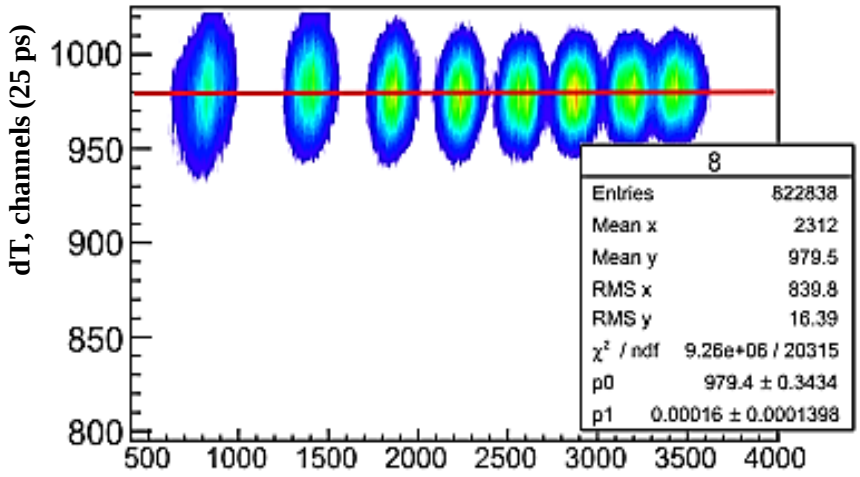
dT(SiPM1-SiPM2) vs ToT(2)



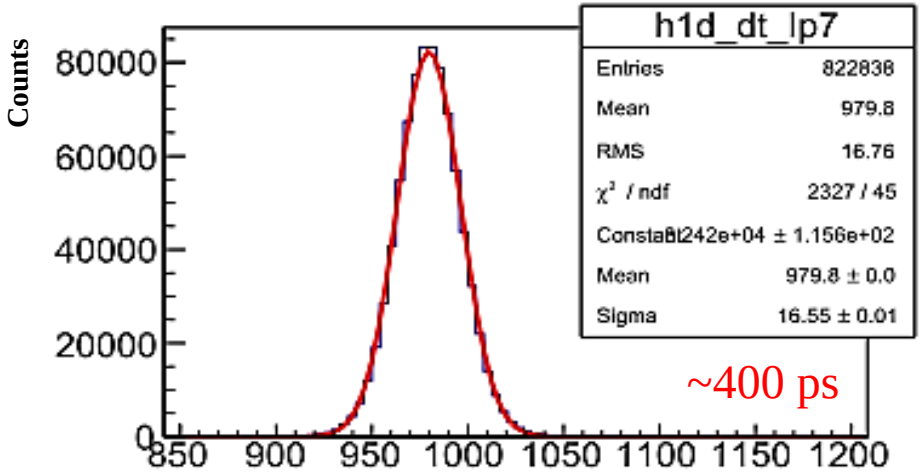
dT(SiPM1-SiPM2)



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



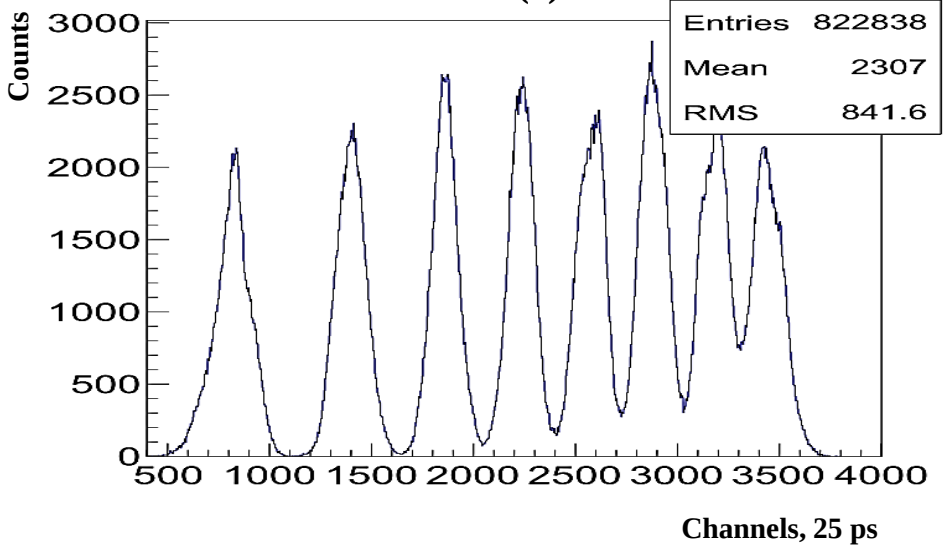
Corrected dT(SiPM1-SiPM2)



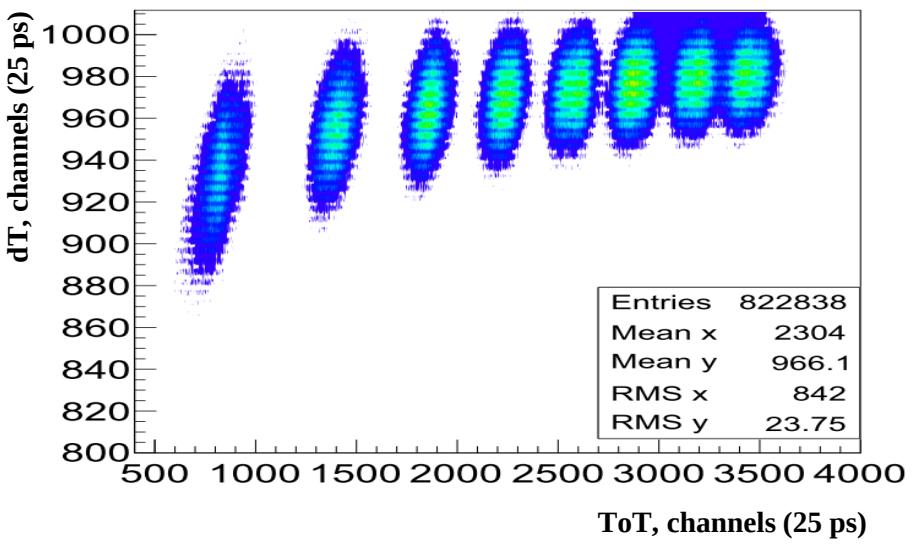
A.V. Tishevskiy et al., J.Phys.Conf.Ser, V.1690, 012051 (2020)

Extracting correction parameters FEE ToT (version №1)

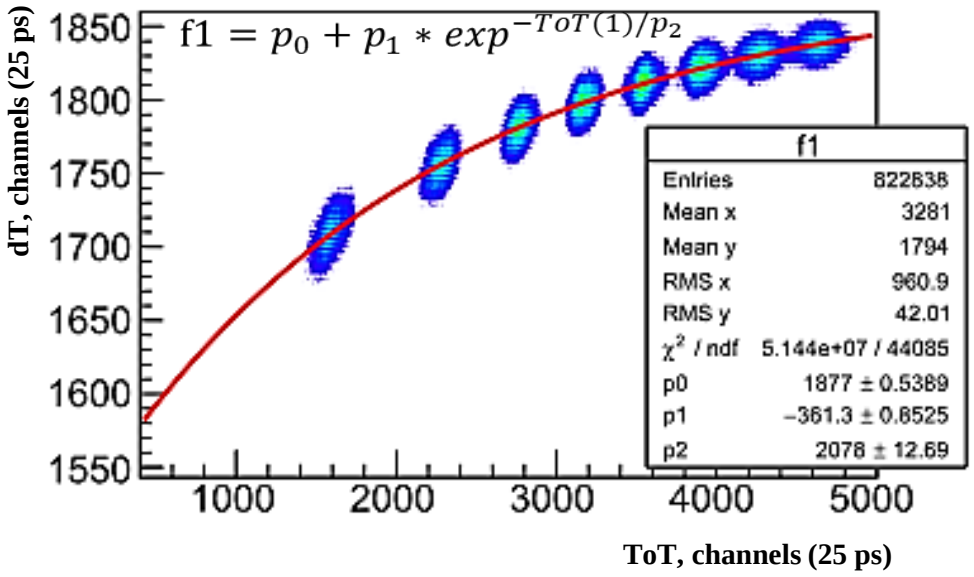
ToT(2)



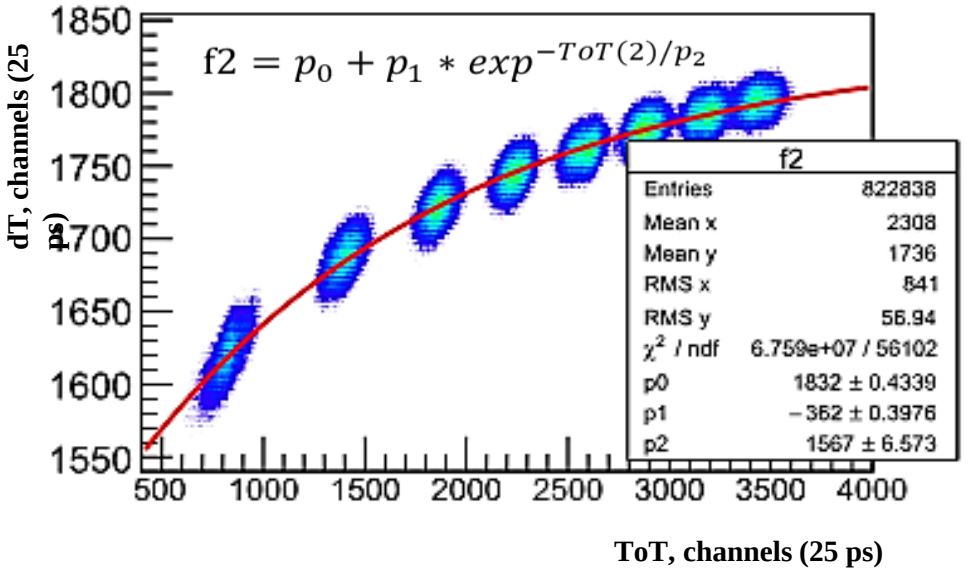
dT(SiPM1-SiPM2) vs ToT(2)



dT(trig-SiPM1) vs ToT(1)



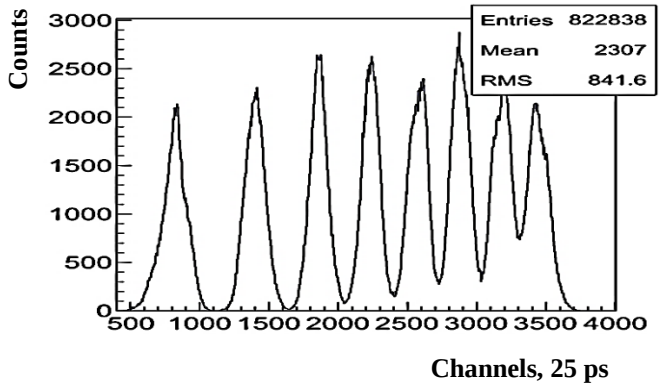
dT(trig-SiPM2) vs ToT(2)

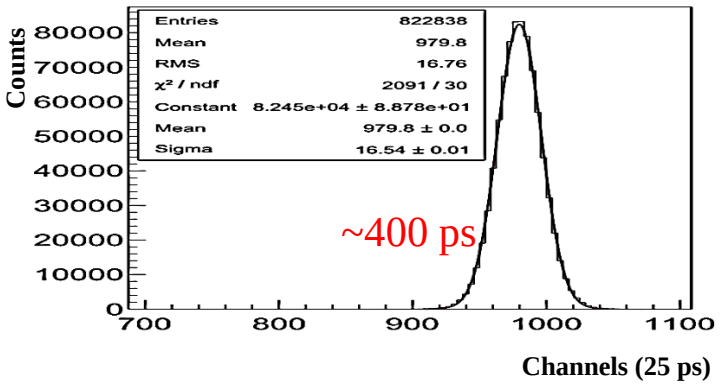


Comparison of FEE ToT versions

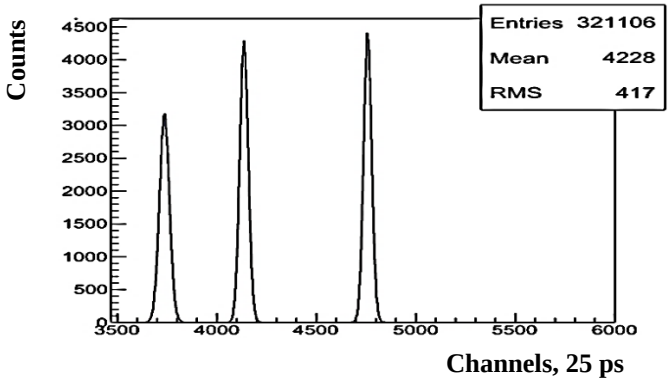
ToT | **Corrected dT(SiPM1-SiPM2)**

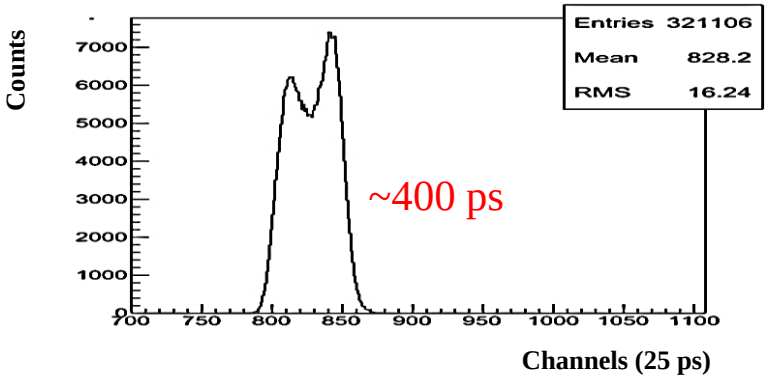
v.1





v.2





v.3