MATERIALS SELECTION OF THE SPD BEAM-BEAM COUNTER SCINTILLATION DETECTOR PROTOTYPE

The XXVth International Baldin Seminar on High Energy Physics Problems

Relativistic Nuclear Physics and Quantum Chromodynamics

National Research Nuclear University MEPhI

Zakharov A.M on behalf of the SPD Collaboration

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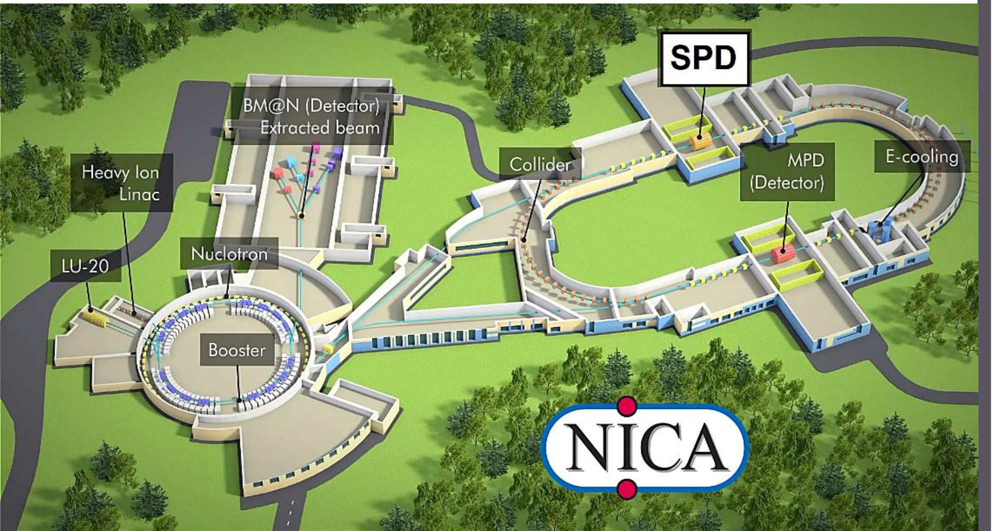
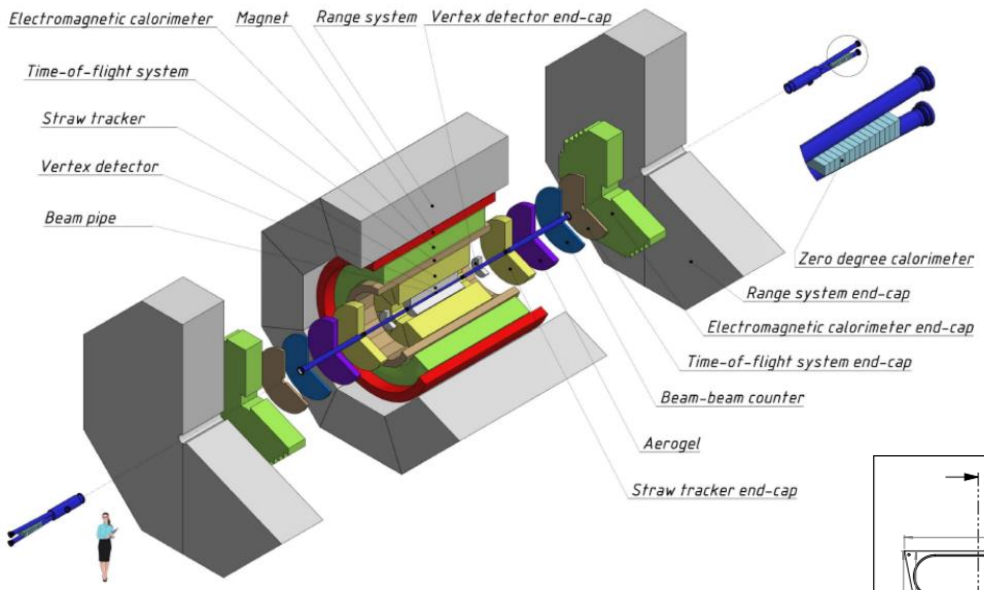
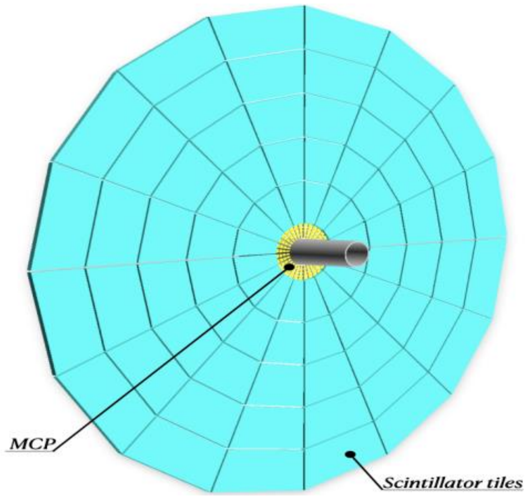
NICA SPD: General

The Spin Physics Detector collaboration proposes to install a universal detector in the second interaction point of the NICA collider under construction (JINR, Dubna) to study the spin structure of the proton and deuteron and the other spin-related phenomena with polarized proton and deuteron beams at a collision energy up to 27 GeV and a luminosity up to 10^{32} cm^{-2} s^{-1}

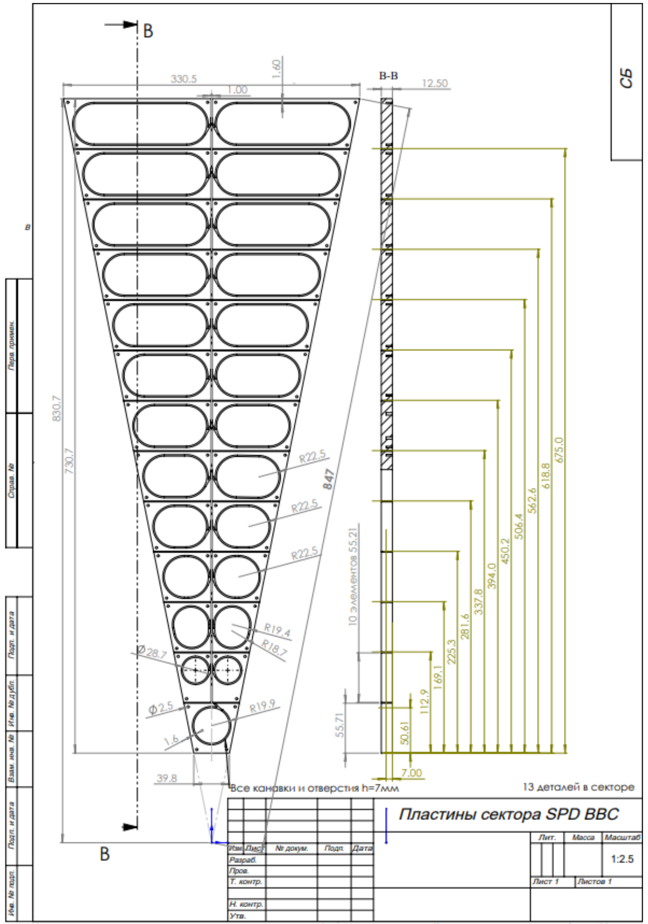






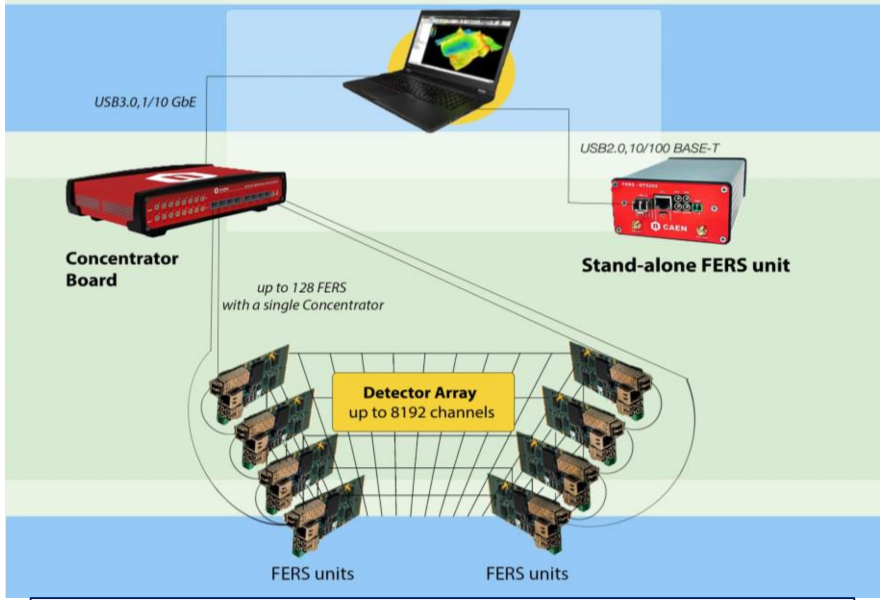
The main goals of the Beam-Beam Counters are:

- the local polarimetry at SPD basing on the measurements of the azimuthal asymmetries of polarized proton beams;
- the monitoring of beam collisions;
- participation in the precise determination of the collision time.



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.

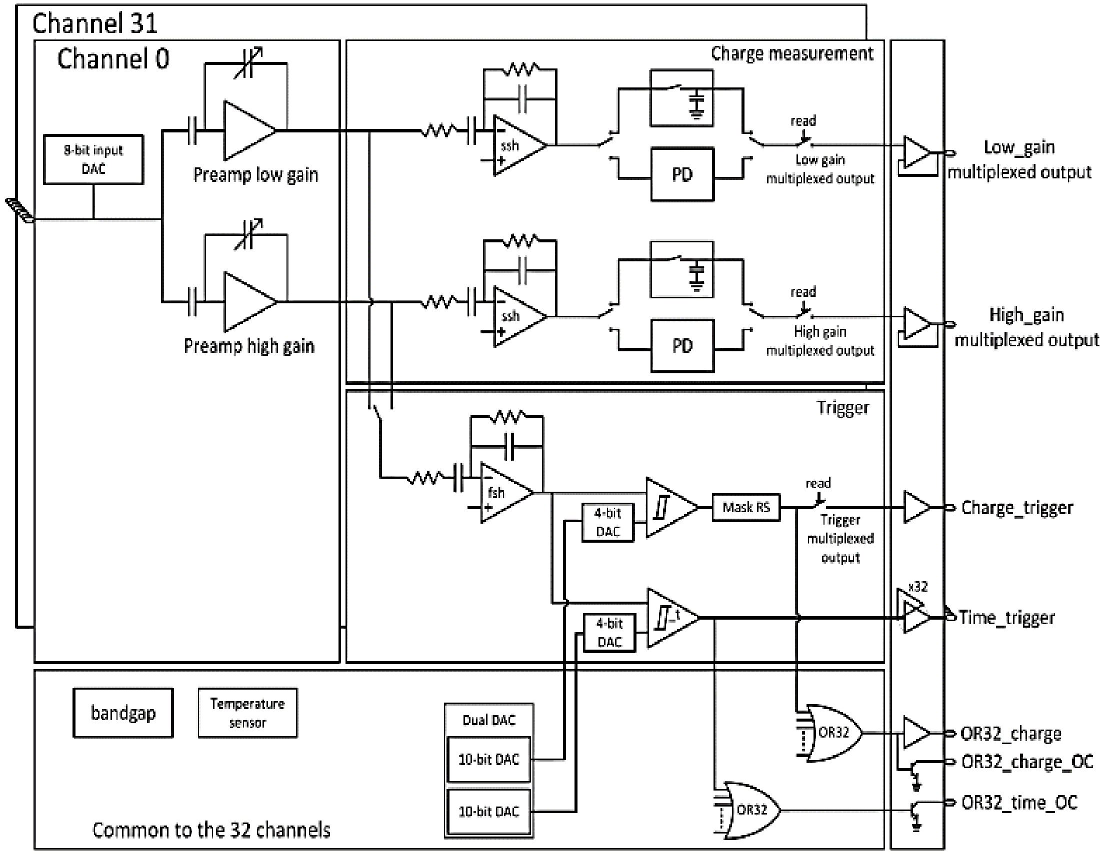


Main Acquisition Modes:

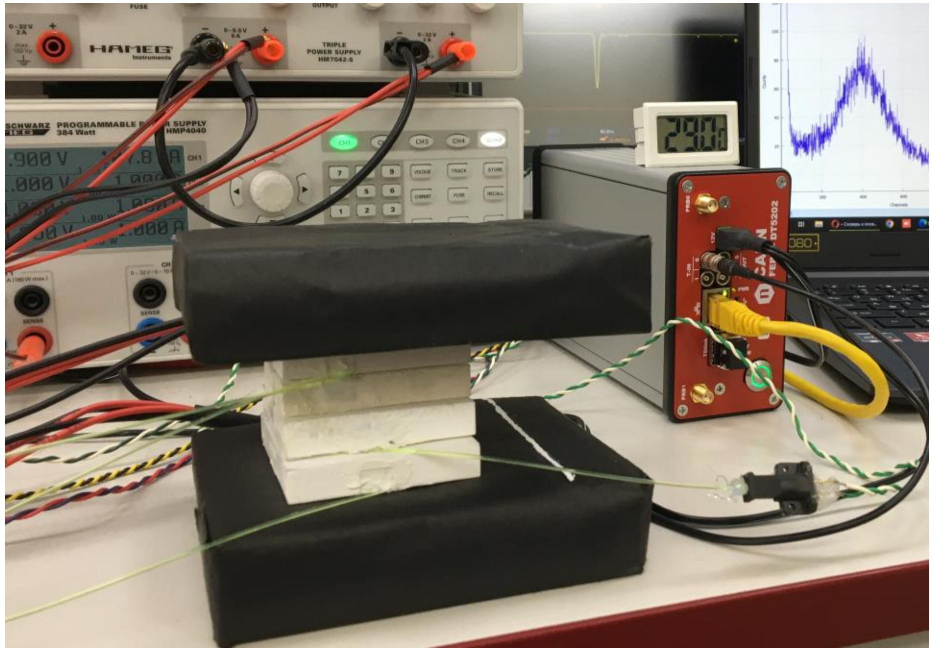
- SPECTROSCOPY.
- TIMING.
- SPECT_TIMING. The Spectroscopy + Timing

The A5202/DT5202 is based on the functions and readout chains of the Citiroc-1A ASIC.

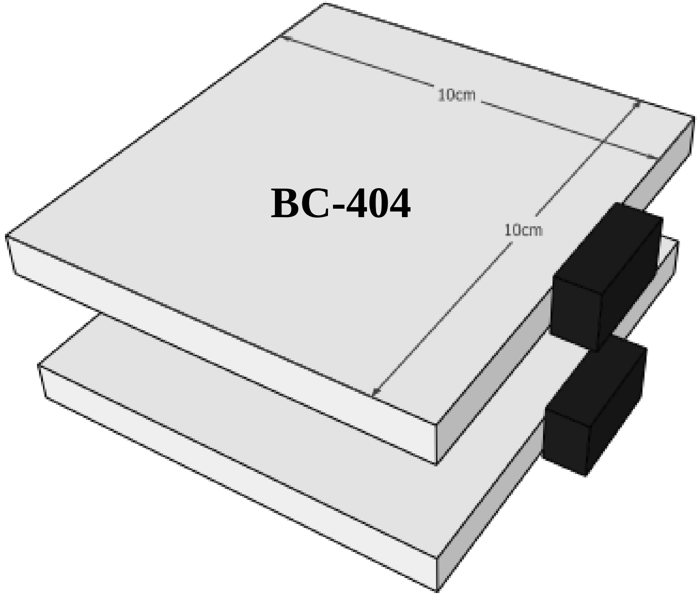
Citiroc 1A allows triggering down to 1/3 p.e. and provides the charge measurement with a <u>good noise rejection</u>. Moreover, Citiroc 1A outputs the 32-channel triggers with a <u>high resolution timing</u> (better than 100 ps).



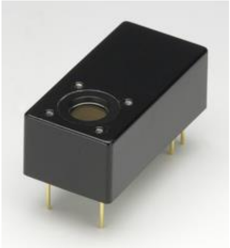
Stand for prototype tests



Tile system with external trigger – two scintillators with PMTs readout, covered in black paper



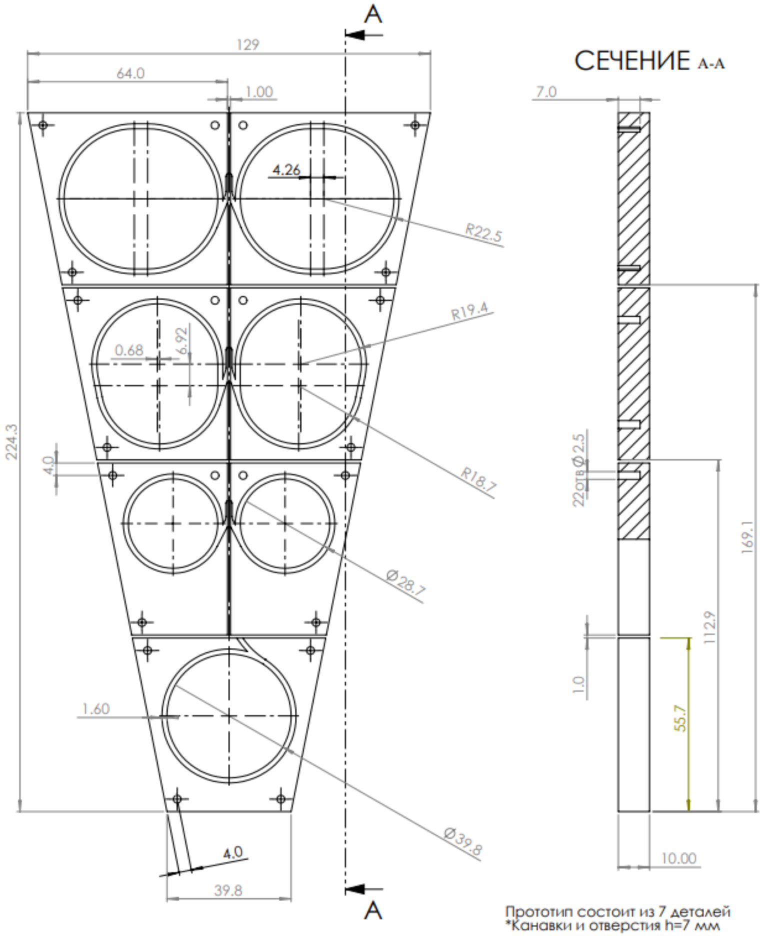
Trigger time resolution ~650 ps



PMT
Hamamatsu
H10720-110

Although CAEN FERS-5200 has an internal coincidence circuit, an external trigger proved to be more efficient for measurements on cosmic rays. Internal CC is used for radioactive source measurements.

Scintillation detector prototype materials



Geometry of tiles, used in this work (4 lines)

Similar to STAR EPD, but higher polar angle granularity

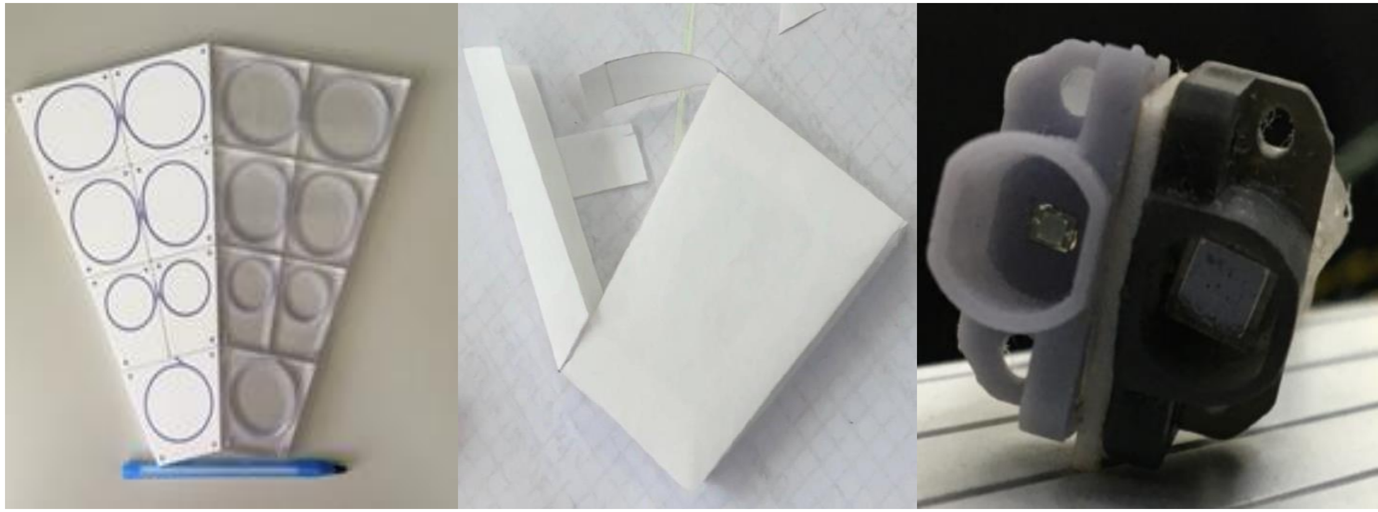
Line

3 (L;R)

2 (L;R)

1 (L;R)

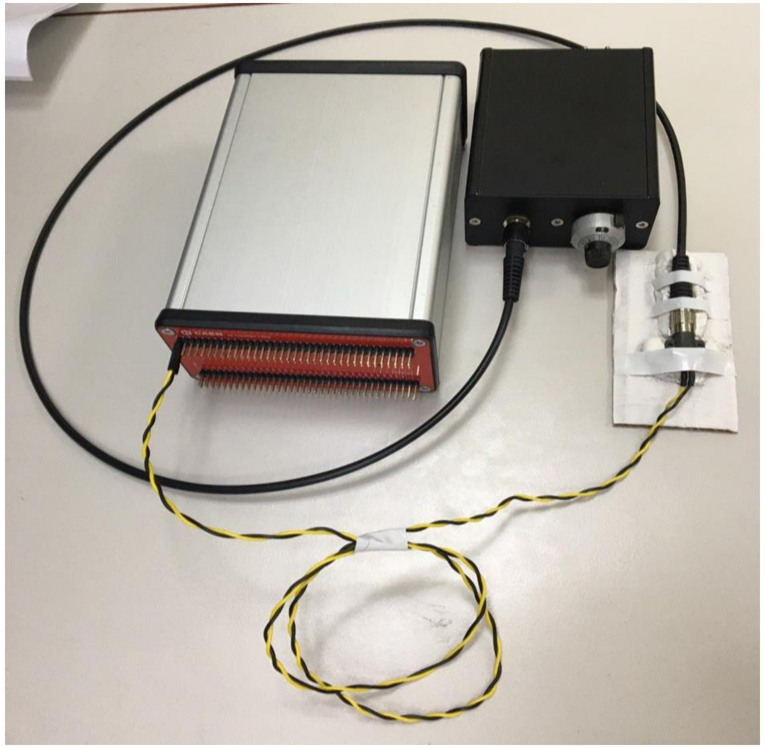
central



Materials selection and tests with different material combinations of tile prototype includes:

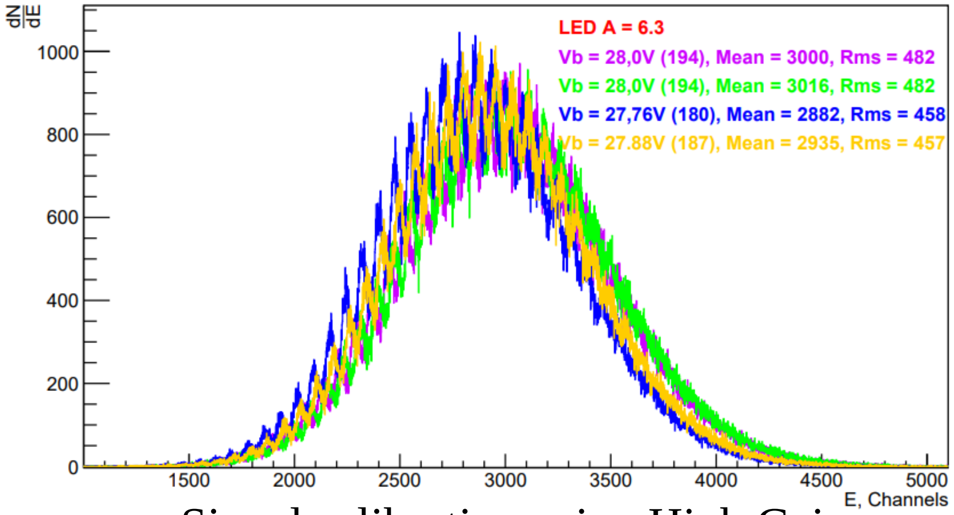
- **Scintillator:** **Matted or Tyvek covered**
- **Optical cement:** **CKTN MED vs OK-72**
- **Fiber:** **Saint-Gobain Crystals vs Kuraray**
- **SiPMs:** **3x3 vs 1x1 mm^2**

SiPMs Calibration

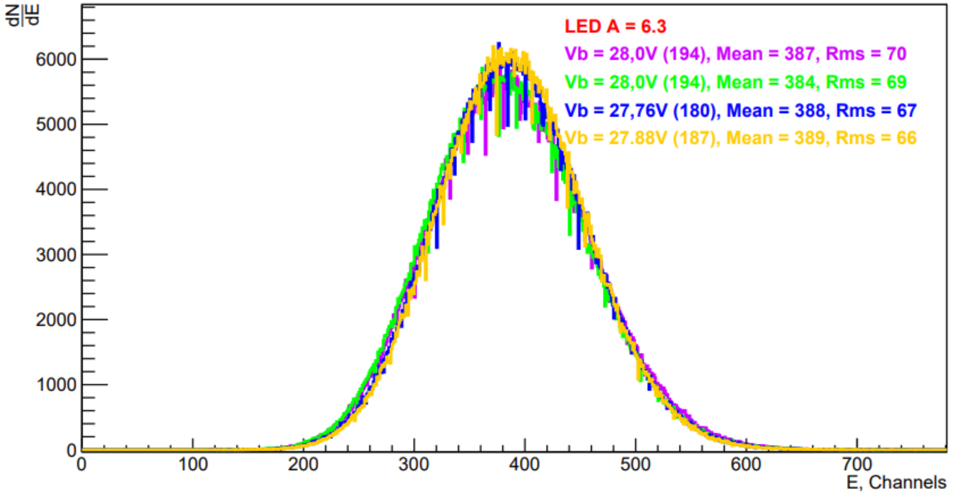


DT5202 with CAEN LED Driver (SP5601)

No cryocooler or any other temperature stabilizing technologies were used (future plans)



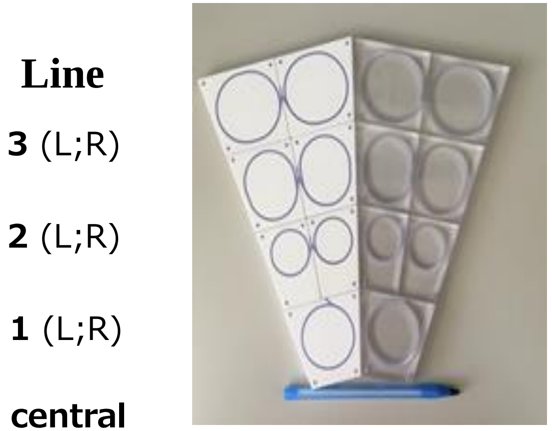
Signal calibration using High Gain



Signal calibration using Low Gain

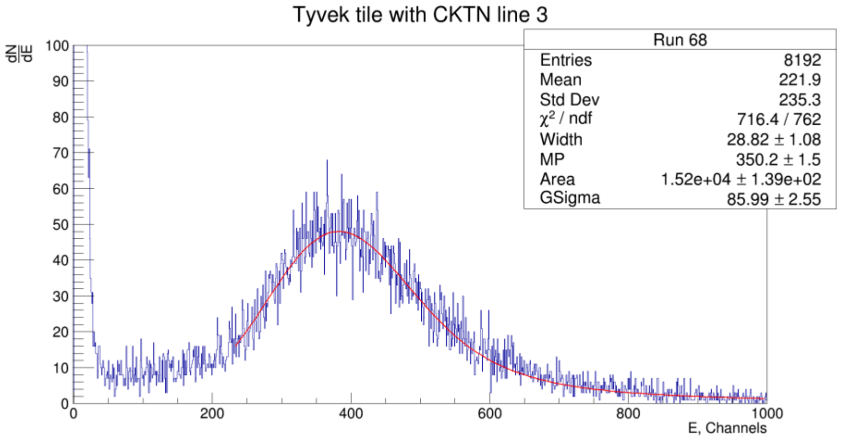
First attempts of calibration using radioactive source showed that we need a stable signal for calibration – the reason why led driver is the choice

Matte and Tyvek tiles comparison

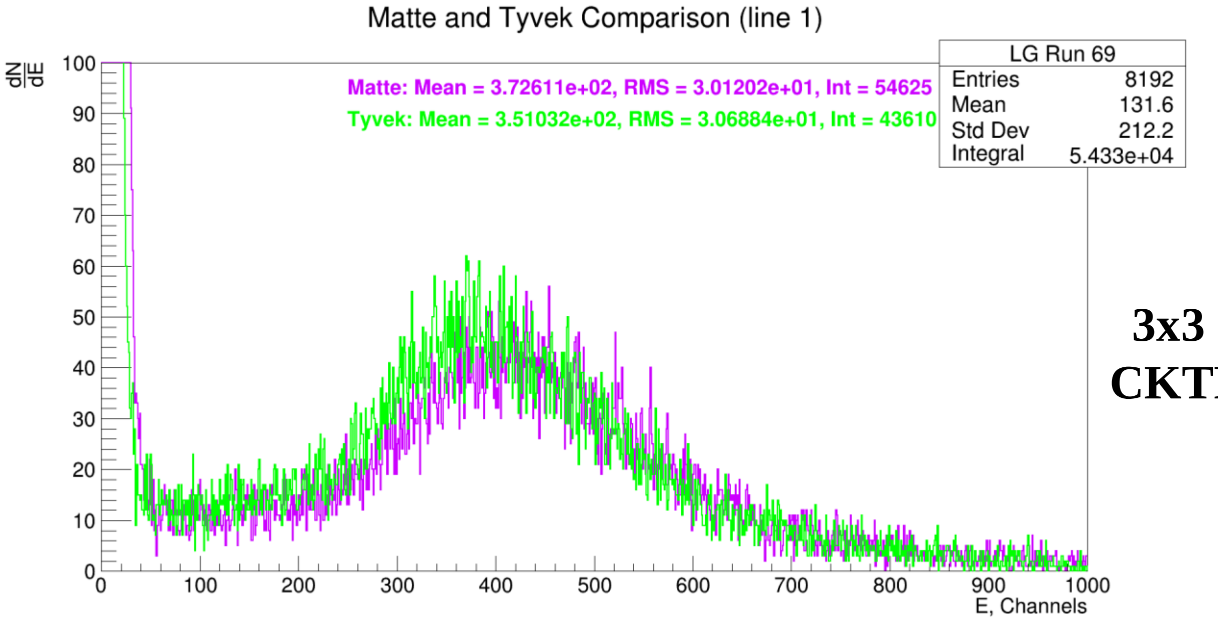


Matte – tile, covered with white acrylic paint, so called "belil" (picture above)

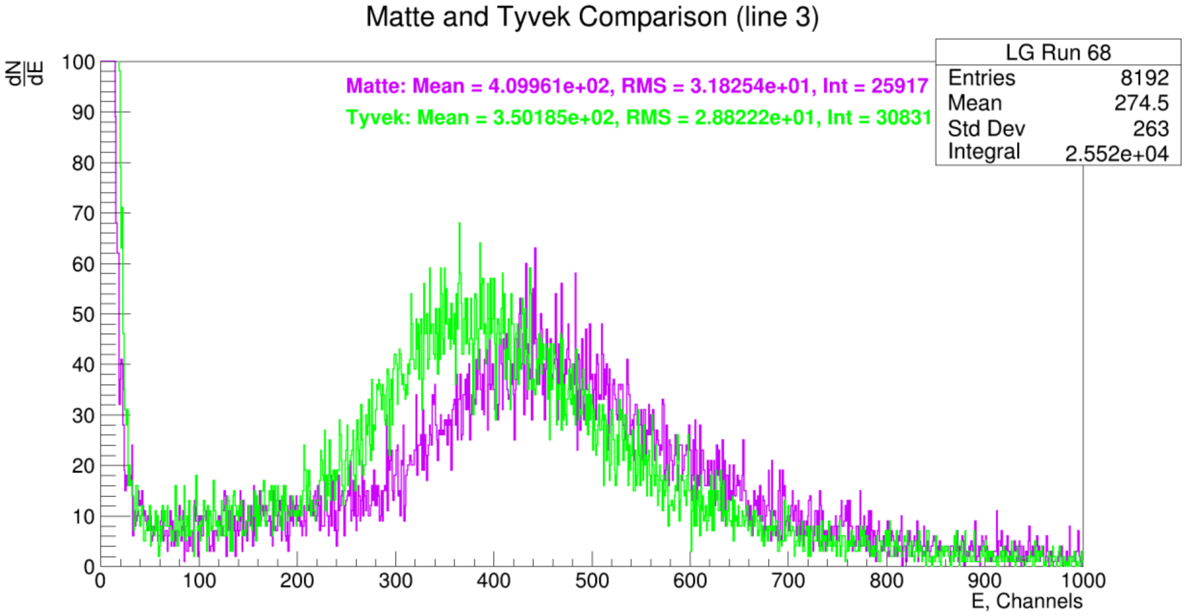
Tyvek – tile, double covered with a unique non-woven material made from high-density polyethylene continuous filaments (white paper)



Convolution of Gaussian and Landau (langaus) used as fit function



3x3 SiPMs CKTN MED



Due to higher peak position (from 6% and up to 15% difference) and technological complexity of mass production for Tyvek covers, the option with matted one is more appropriate

CKTN and OK-72 comparison (various compositions of OK-72)

Line

3 (L;R)

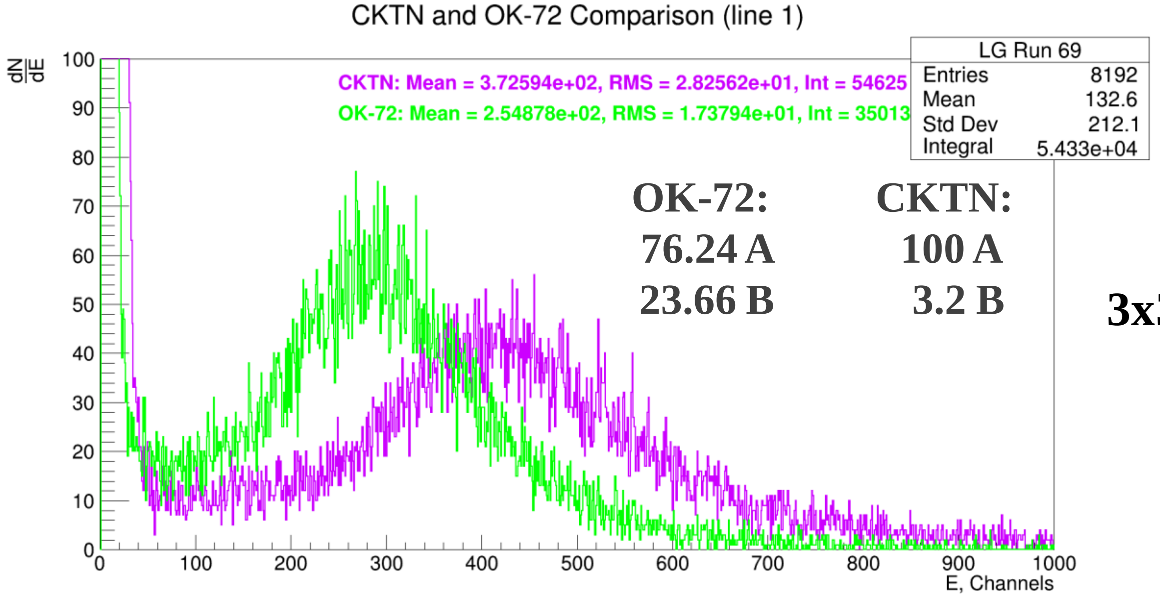
2 (L;R)

1 (L;R)

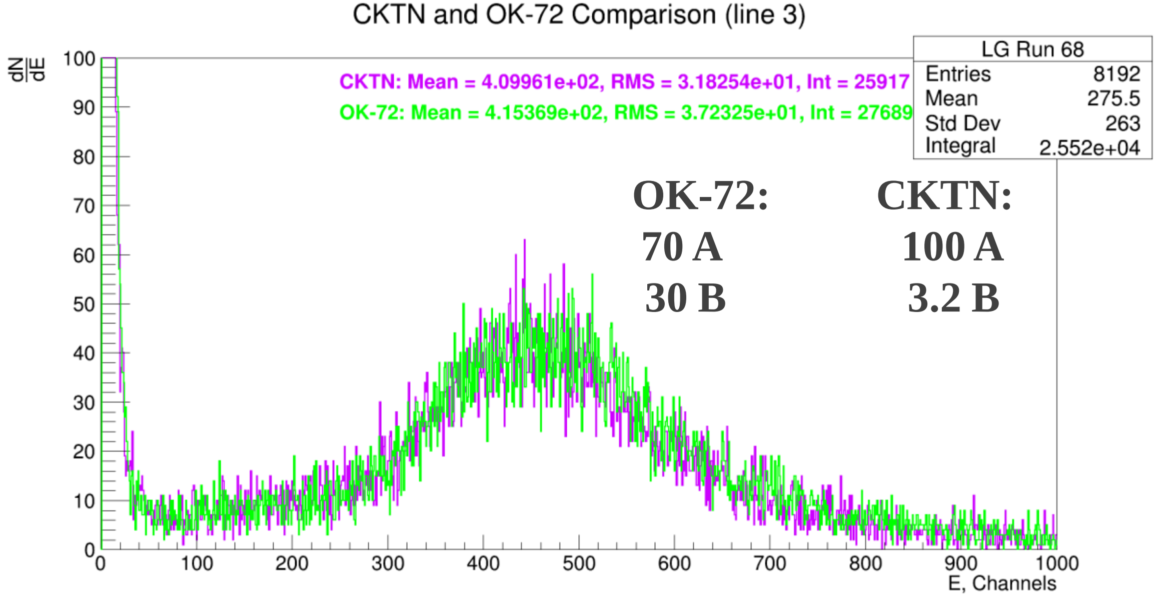
central

Brand	Viscosity, cPs	Operating temperature range	Spectral characteristics	Refractive index
EJ-500	800	From -65 to +105 °C	60-95% 300-350 nm, 95-100% 350-600 nm	1.574
EPO-TEK 301-2	225 - 425	Room temperature - +65 °C	94% 320 nm, 99% 400-1200 nm, 98% 1200-1600 nm	1.5318 589 nm
EPO-TEK 301	100 - 200	Room temperature - +65 °C	99% 382-980 nm, 97% 980-1640 nm, 95% 1640-2040 nm	1.519 589 nm
CKTN MED Mark E	$15 \cdot 10^3$	—	92-96% 500 nm	1.606
OK-72	—	From -60 to +60 °C	99% 400-2700 nm	1.587

Optical cements and their characteristics



3x3 SiPMs



Although OK-72 is easier to use due to its low viscosity, different compositions of A to B components effect on light collection. More research required

Fibers (SG91AS, SG92S, Y-11) comparison

3x3 SiPMs

Line

3 (L;R)

2 (L;R)

1 (L;R)

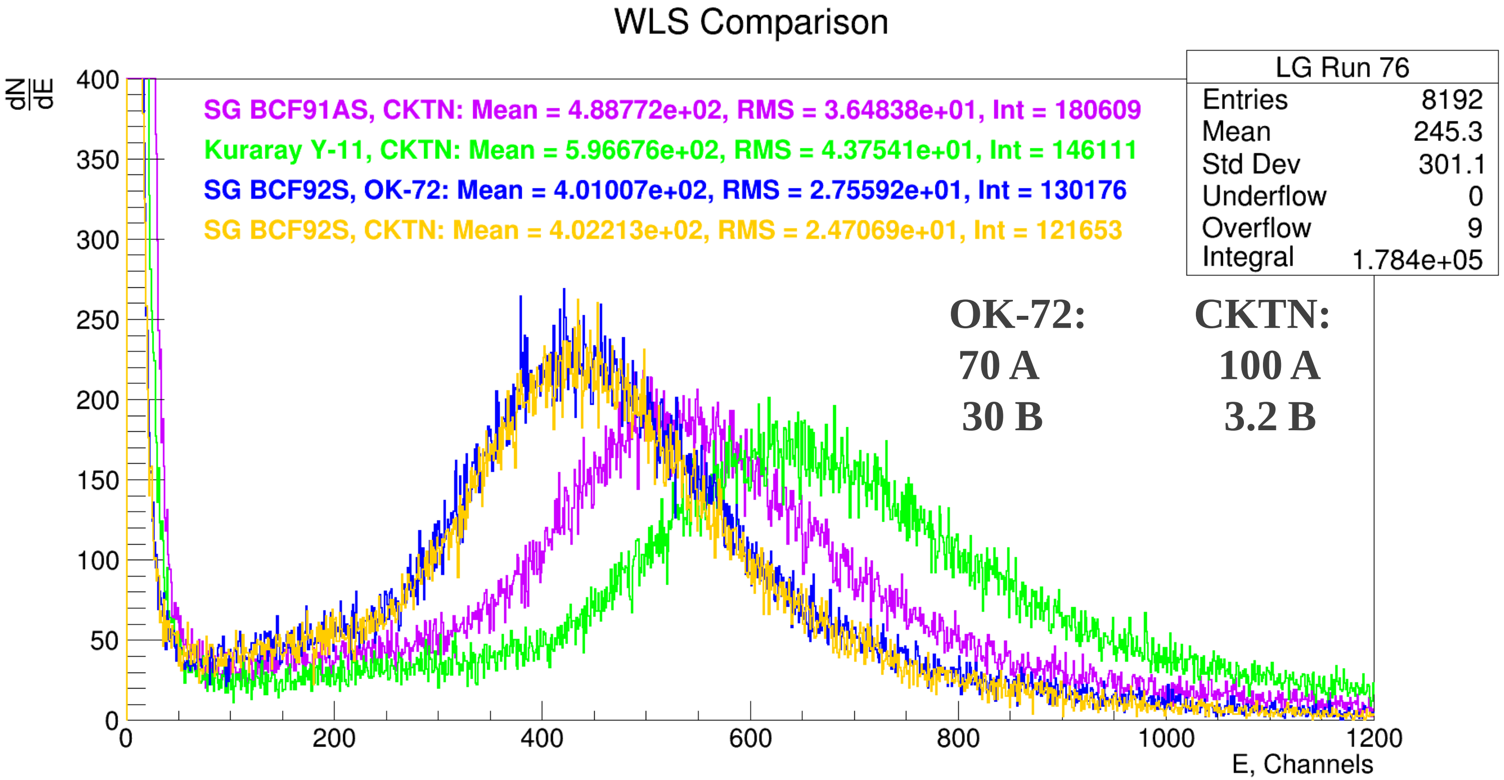
central

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

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



Due to fact, that Kuraray Y-11 fiber collects photons with higher energy (higher peak position), the choice of Y-11 fibers is more appropriate

Central tiles signal

3x3 SiPMs

Line

3 (L;R)

2 (L;R)

1 (L;R)

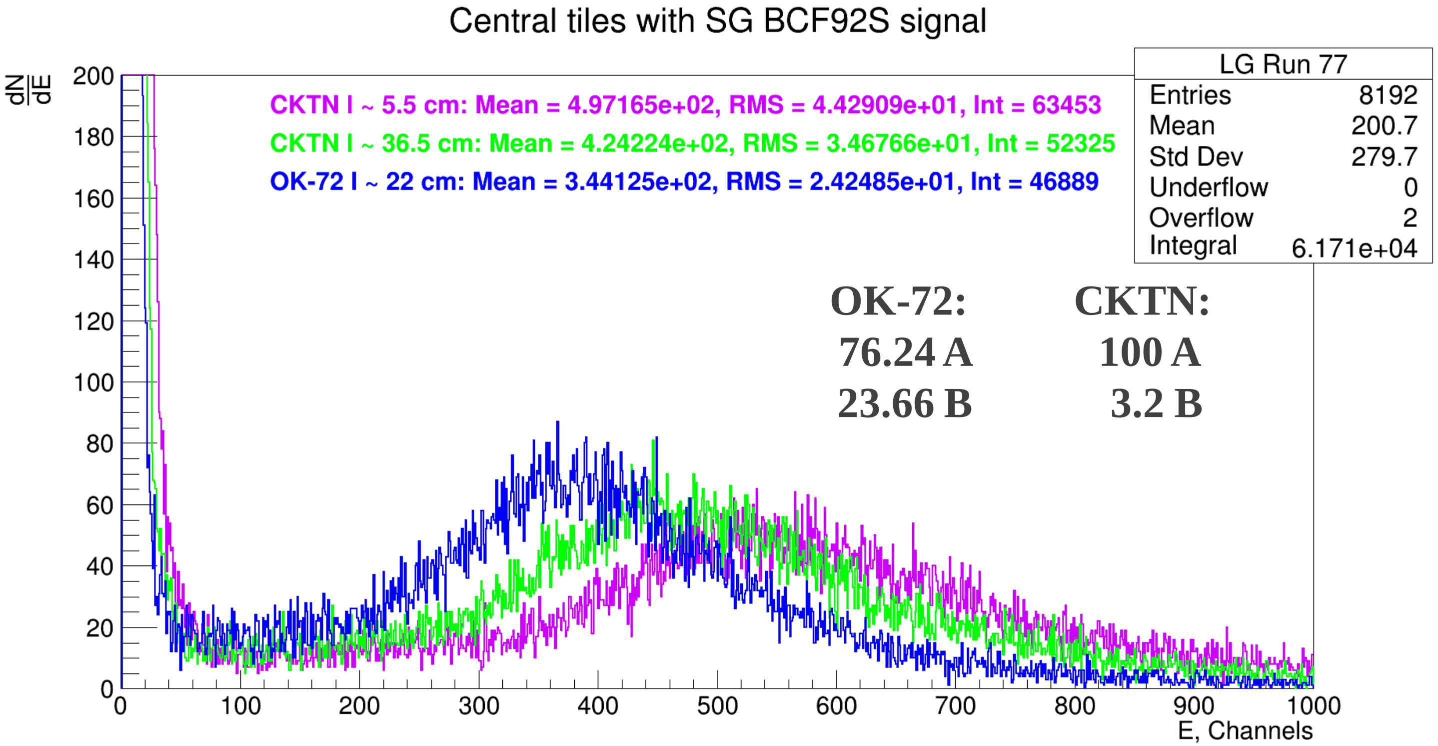
central

$$I = I_0 \times e^{-\frac{x}{350}}$$ - attenuation law

$$\frac{I_1}{I_2} = \frac{e^{-\frac{x_1}{350}}}{e^{-\frac{x_2}{350}}} = e^{\frac{x_2 - x_1}{350}}$$

$$x_2 - x_1 = 36.5 - 5.5 = 31\ (\pm\ 2)\ cm$$

$I_1 = I_2 \times e^{\frac{31 \pm 2}{350}} = 52325 \times 1.0926 = 57170.9 \pm 4546.1$, that is almost identical to 63453 within the error



Signal from central tiles is the step to move towards measuring an assembled system of tiles with 4 or more lines

Different geometries comparison

Line

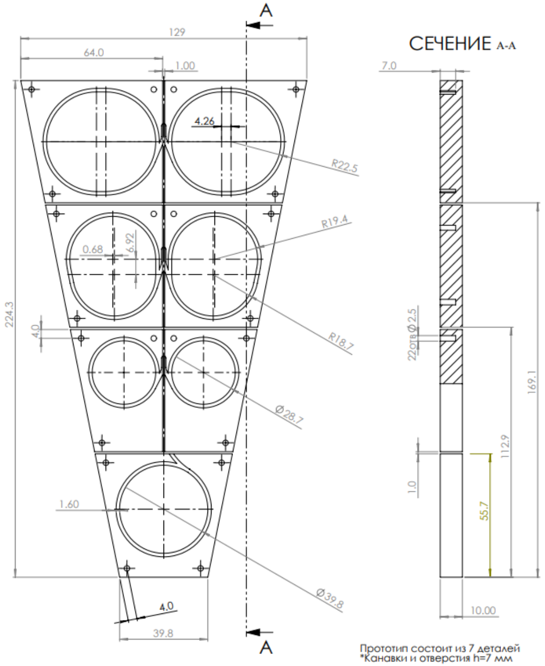
3 (L;R)

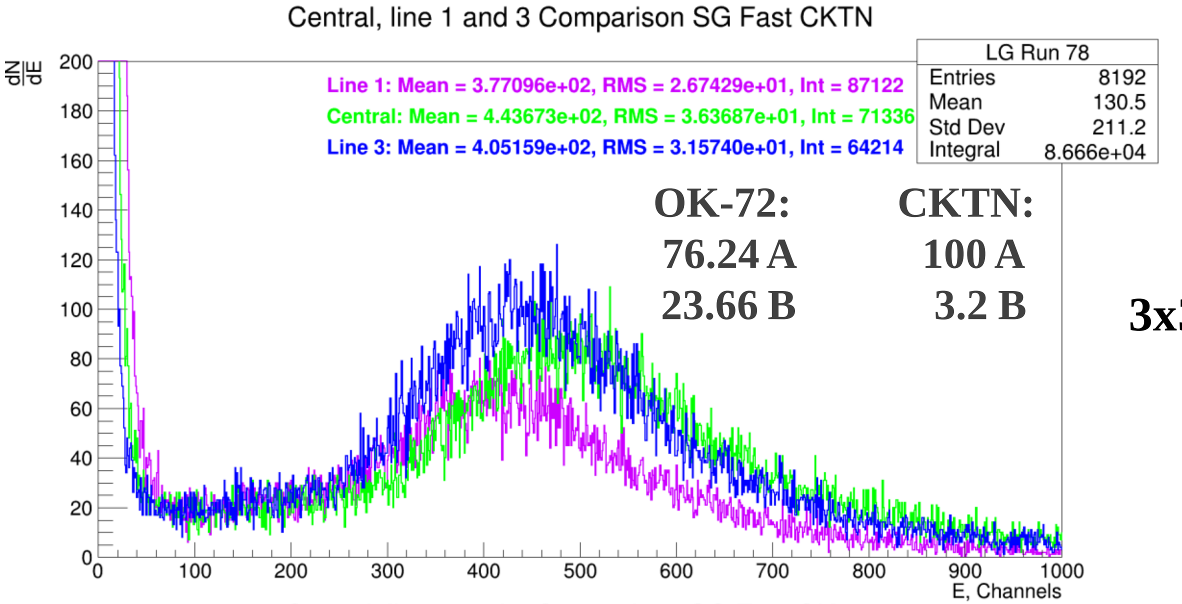
2 (L;R)

1 (L;R)

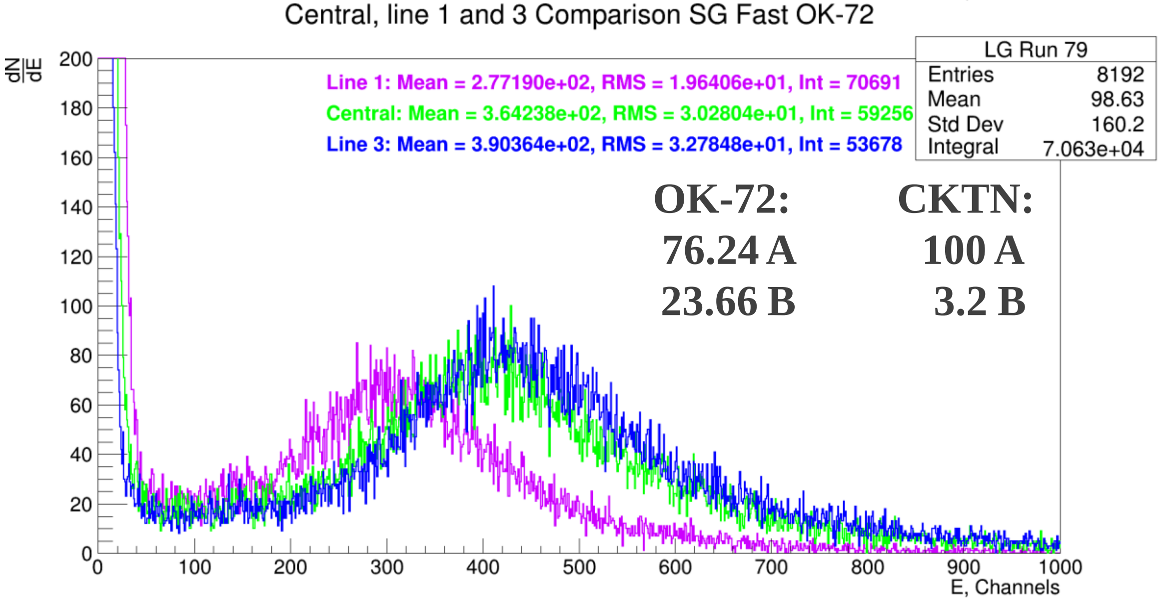
central

Central, line 1 and 3 tiles are participants for comparison



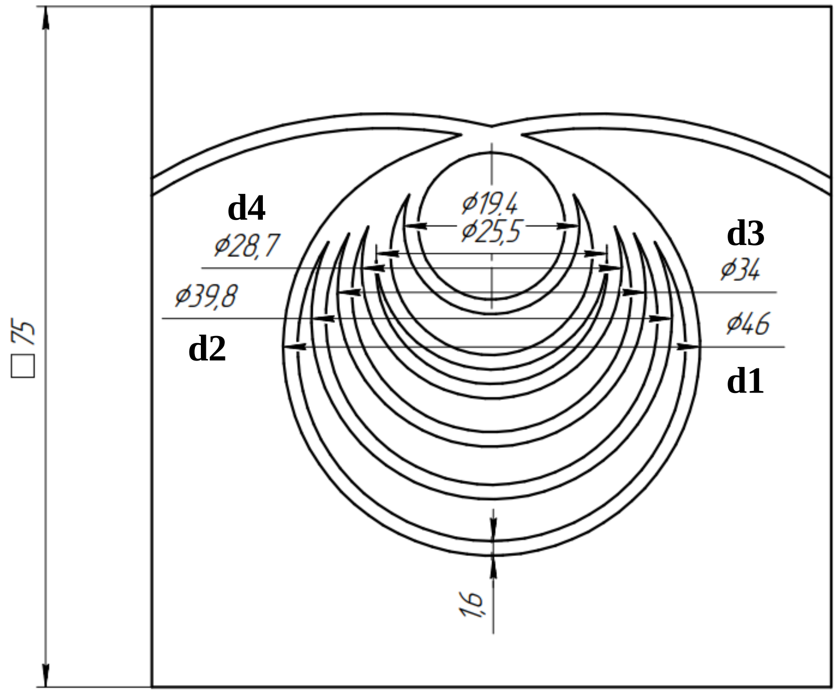


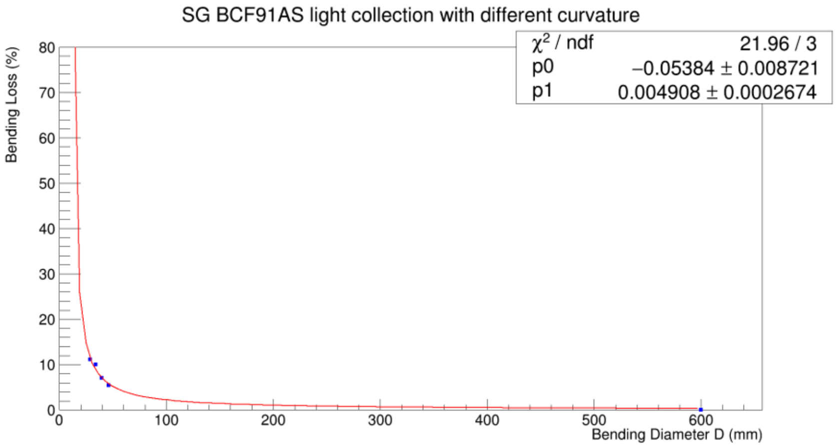
3x3 SiPMs

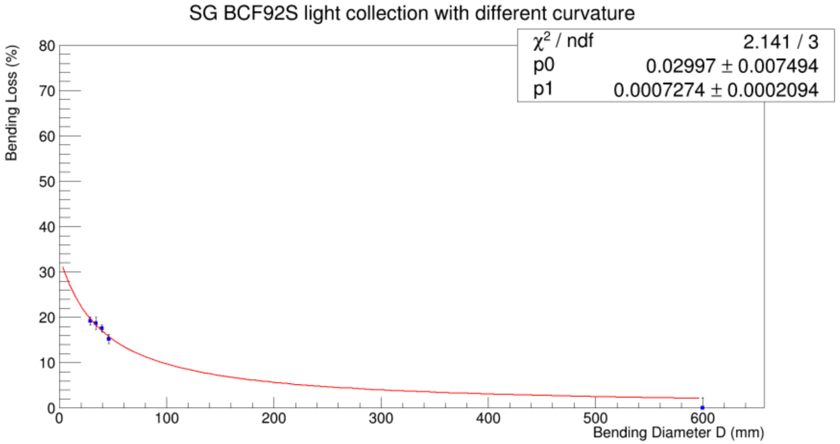


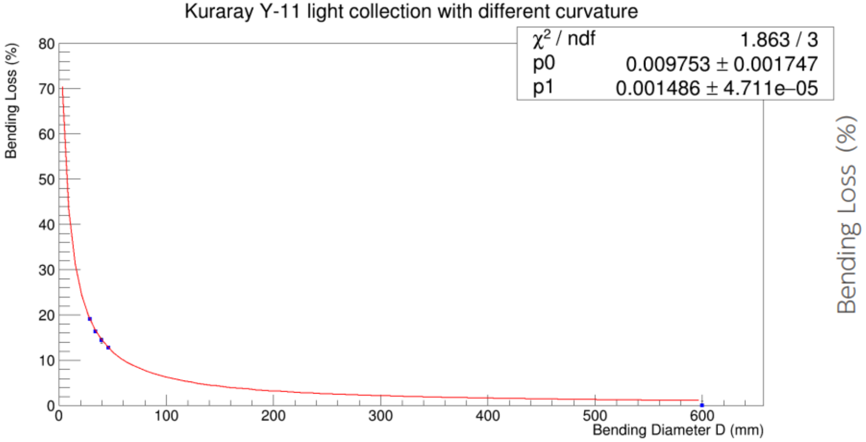
Signals from central, line 1 and line 3 tiles seem to be different because of different fiber curvature (see tile system scheme on the left)

Fibers bending loss









Difference in peak position between d1 and d4:

For SG BCF91AS – 6.01%

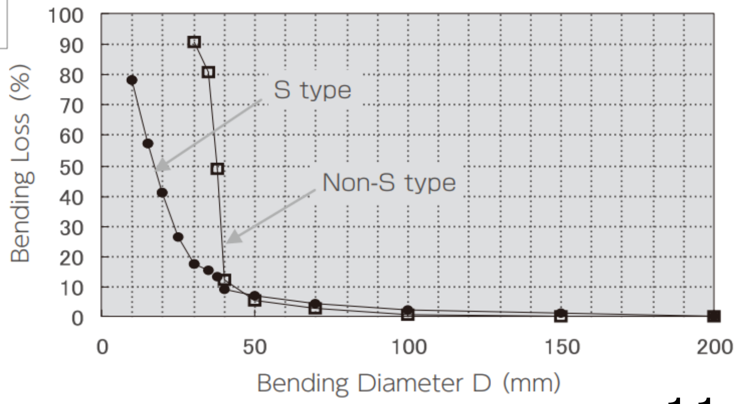
For SG BCF92S – 4.69%

For Kuraray Y-11 – 8.46%

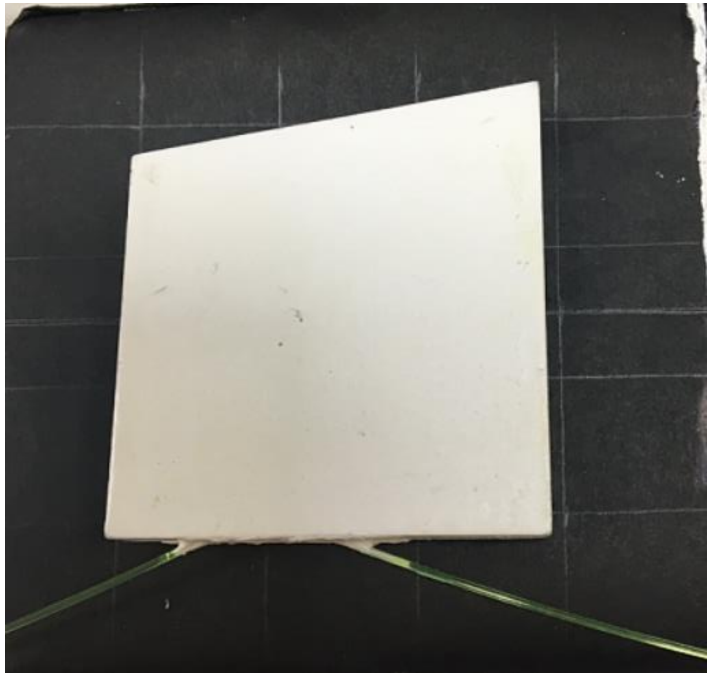
for 1 rotation (3 inside the tile)

3x3 SiPMs

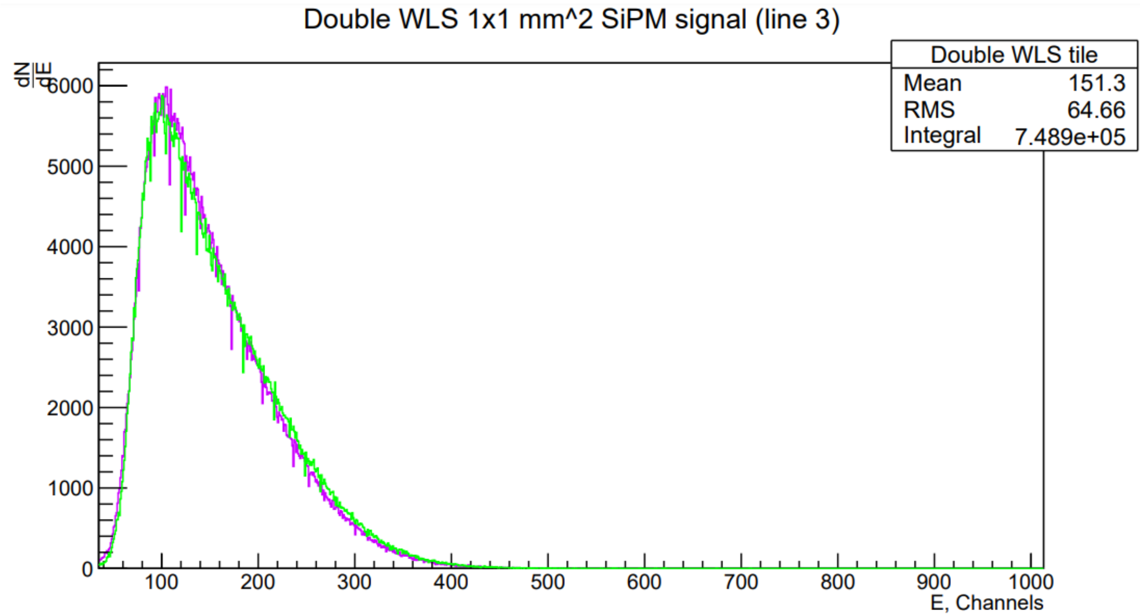
Experimental data doesn't fit the theory

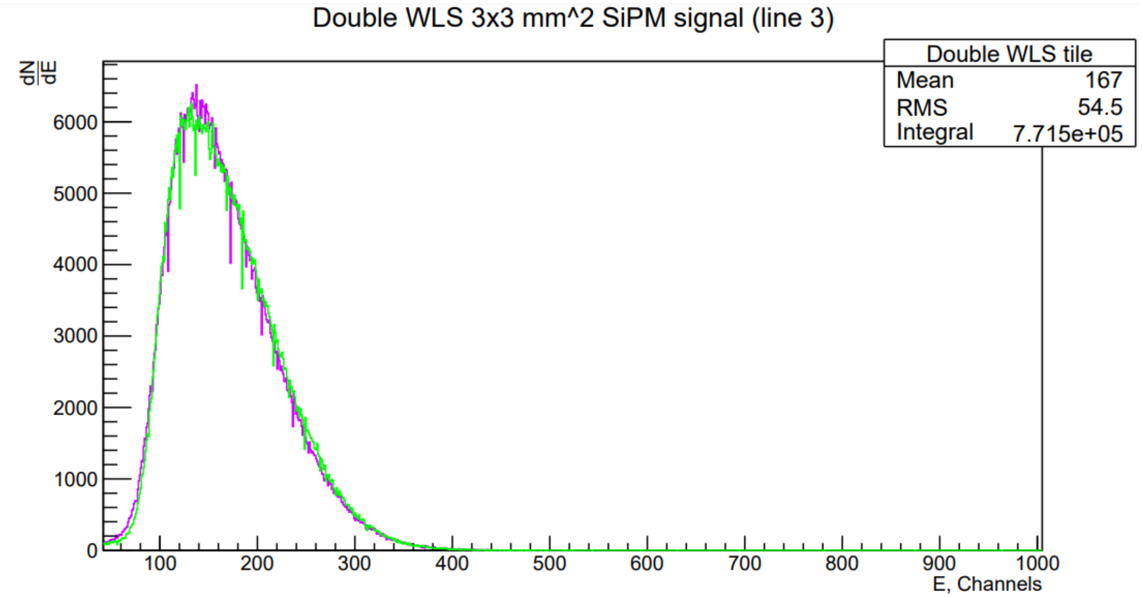


Additional: 1x1 SiPM callibration



Tile with two WLS outputs of single fiber with radioactive source are used





Conclusion

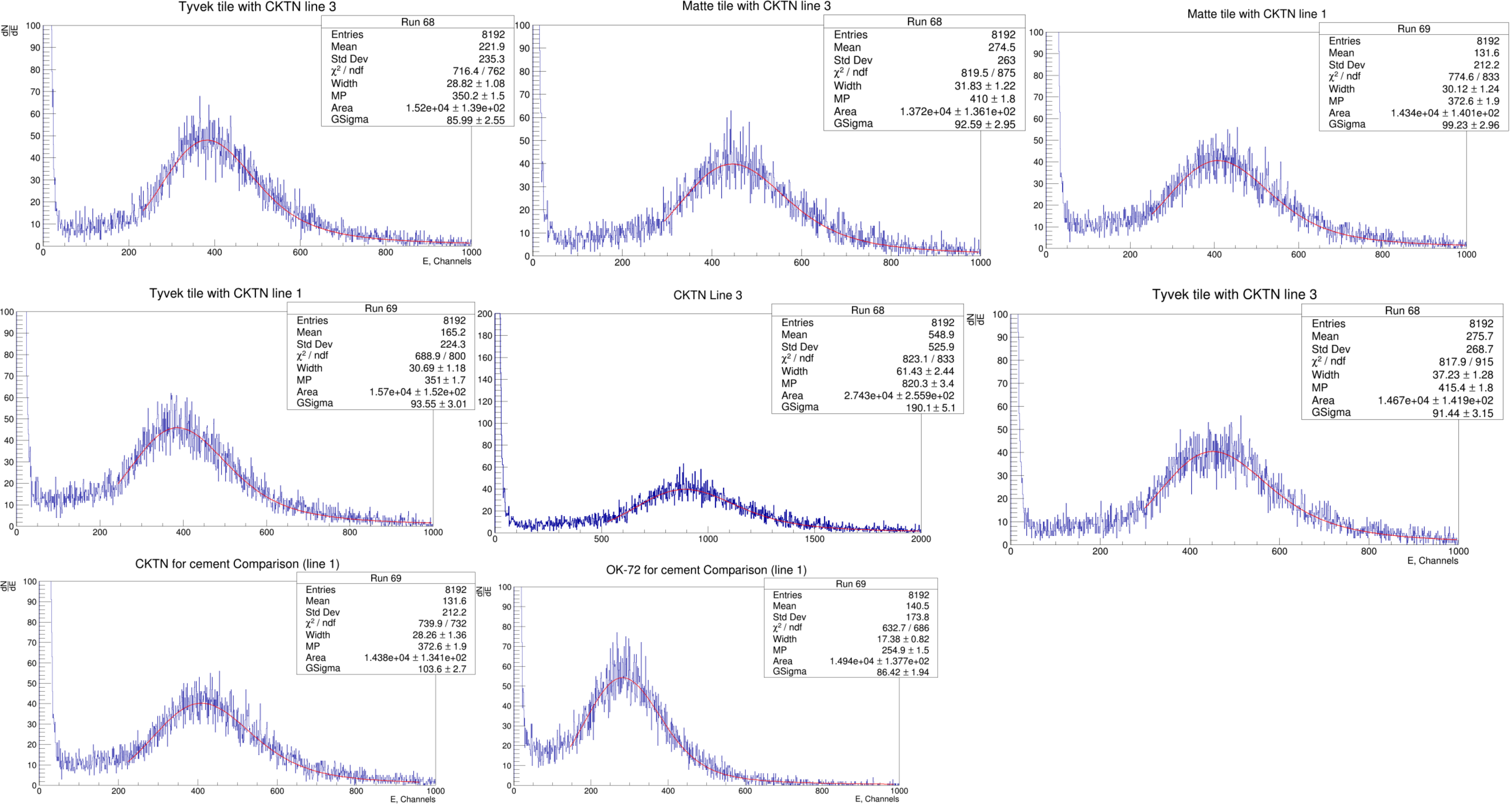
1. The **scintillator detector prototype tests** with CAEN FERS-5200 readout system has been started.
2. The comparison of **matted and Tyvek covered** tiles have been done. Matted one proved to be more efficient in both ways: amount of reflected light and convenience.
3. The comparison of **CKTN MED and OK-72 optical cements** have been done. Since different compositions highly effect on light collection, more research is required.
4. The comparison of **SG BCF91AS, BCF92S and Kuraray Y-11 WLS fibers** have been done. Due to fact, that Y-11 fiber collects photons with higher energy than SG fibers, it proved to be more efficient for our goals.
5. The study of **fibers bending loss** and verification of attenuation law were performed. Integral difference between tiles with various fiber lengths fits the theory. Bending loss study doesn’t fit the theory in case of Y-11 fiber – more research is required.
6. First **1x1 mm^2 SiPMs** performance tests are obtained. The work has shown that it is necessary to modernize SiPMs connectors.

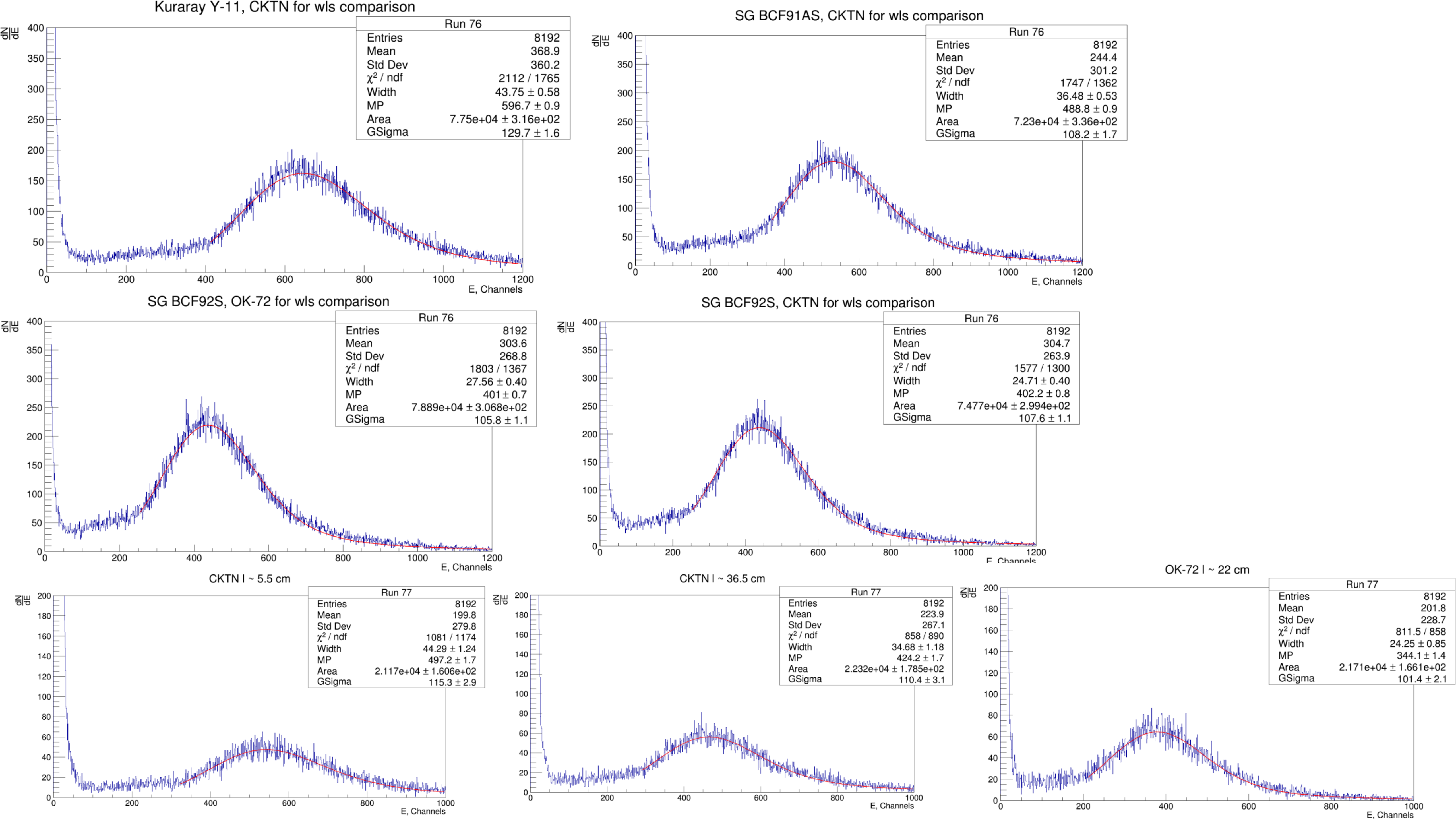
Future plans

- Temperature stabilizing technologies
- Complete transition to 1x1 SiPMs
- Selection of A to B composition for optical cements
- Tests with 4 lines sector
- Following studies of fiber bending influence on light collection
- Obtaining tiles time resolution

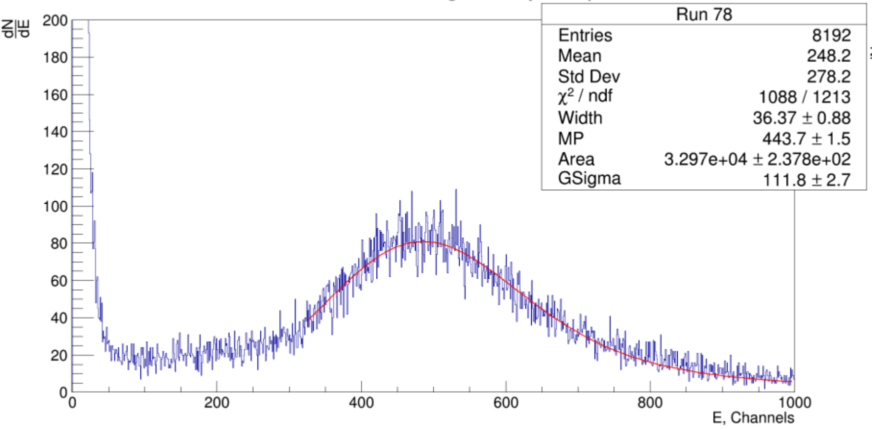
THANK YOU FOR YOUR ATTENTION

BACKUP

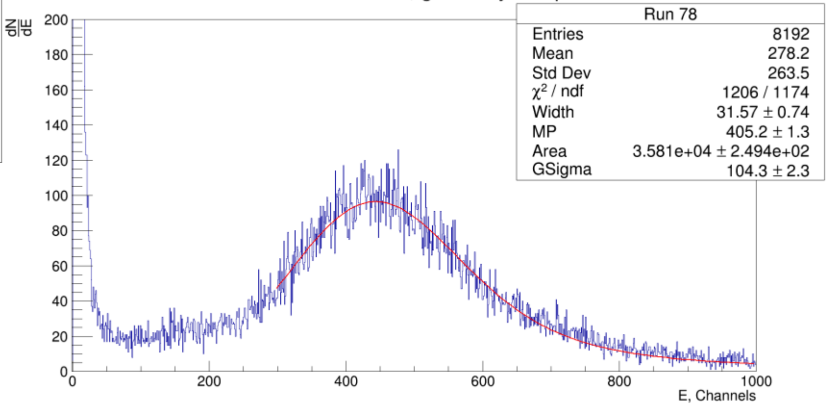

Tyvek tile with CKTN line 3
Run 68
Entries 8192
Mean 221.9
Std Dev 235.3
χ2 / ndf 716.4 / 762
Width 28.82 ± 1.08
MP 350.2 ± 1.5
Area 1.52e+04 ± 1.39e+02
GSigma 85.99 ± 2.55
dN/dE
E, Channels
Matte tile with CKTN line 3
Run 68
Entries 8192
Mean 274.5
Std Dev 263
χ2 / ndf 819.5 / 875
Width 31.83 ± 1.22
MP 410 ± 1.8
Area 1.372e+04 ± 1.361e+02
GSigma 92.59 ± 2.95
Matte tile with CKTN line 1
Run 69
Entries 8192
Mean 131.6
Std Dev 212.2
χ2 / ndf 774.6 / 833
Width 30.12 ± 1.24
MP 372.6 ± 1.9
Area 1.434e+04 ± 1.401e+02
GSigma 99.23 ± 2.96
Tyvek tile with CKTN line 1
Run 69
Entries 8192
Mean 165.2
Std Dev 224.3
χ2 / ndf 688.9 / 800
Width 30.69 ± 1.18
MP 351 ± 1.7
Area 1.57e+04 ± 1.52e+02
GSigma 93.55 ± 3.01
CKTN Line 3
Run 68
Entries 8192
Mean 548.9
Std Dev 525.9
χ2 / ndf 823.1 / 833
Width 61.43 ± 2.44
MP 820.3 ± 3.4
Area 2.743e+04 ± 2.559e+02
GSigma 190.1 ± 5.1
Tyvek tile with CKTN line 3
Run 68
Entries 8192
Mean 275.7
Std Dev 268.7
χ2 / ndf 817.9 / 915
Width 37.23 ± 1.28
MP 415.4 ± 1.8
Area 1.467e+04 ± 1.419e+02
GSigma 91.44 ± 3.15
dN/dE
E, Channels
CKTN for cement Comparison (line 1)
Run 69
Entries 8192
Mean 131.6
Std Dev 212.2
χ2 / ndf 739.9 / 732
Width 28.26 ± 1.36
MP 372.6 ± 1.9
Area 1.438e+04 ± 1.341e+02
GSigma 103.6 ± 2.7
dN/dE
E, Channels
OK-72 for cement Comparison (line 1)
Run 69
Entries 8192
Mean 140.5
Std Dev 173.8
χ2 / ndf 632.7 / 686
Width 17.38 ± 0.82
MP 254.9 ± 1.5
Area 1.494e+04 ± 1.377e+02
GSigma 86.42 ± 1.94
dN/dE
E, Channels


Kuraray Y-11, CKTN for wls comparison
Run 76
Entries 8192
Mean 368.9
Std Dev 360.2
χ² / ndf 2112 / 1765
Width 43.75 ± 0.58
MP 596.7 ± 0.9
Area 7.75e+04 ± 3.16e+02
GSigma 129.7 ± 1.6
dN/dE
E, Channels
SG BCF91AS, CKTN for wls comparison
Run 76
Entries 8192
Mean 244.4
Std Dev 301.2
χ² / ndf 1747 / 1362
Width 36.48 ± 0.53
MP 488.8 ± 0.9
Area 7.23e+04 ± 3.36e+02
GSigma 108.2 ± 1.7
SG BCF92S, OK-72 for wls comparison
Run 76
Entries 8192
Mean 303.6
Std Dev 268.8
χ² / ndf 1803 / 1367
Width 27.56 ± 0.40
MP 401 ± 0.7
Area 7.889e+04 ± 3.068e+02
GSigma 105.8 ± 1.1
SG BCF92S, CKTN for wls comparison
Run 76
Entries 8192
Mean 304.7
Std Dev 263.9
χ² / ndf 1577 / 1300
Width 24.71 ± 0.40
MP 402.2 ± 0.8
Area 7.477e+04 ± 2.994e+02
GSigma 107.6 ± 1.1
CKTN l ~ 5.5 cm
Run 77
Entries 8192
Mean 199.8
Std Dev 279.8
χ² / ndf 1081 / 1174
Width 44.29 ± 1.24
MP 497.2 ± 1.7
Area 2.117e+04 ± 1.606e+02
GSigma 115.3 ± 2.9
CKTN l ~ 36.5 cm
Run 77
Entries 8192
Mean 223.9
Std Dev 267.1
χ² / ndf 858 / 890
Width 34.68 ± 1.18
MP 424.2 ± 1.7
Area 2.232e+04 ± 1.785e+02
GSigma 110.4 ± 3.1
OK-72 l ~ 22 cm
Run 77
Entries 8192
Mean 201.8
Std Dev 228.7
χ² / ndf 811.5 / 858
Width 24.25 ± 0.85
MP 344.1 ± 1.4
Area 2.171e+04 ± 1.661e+02
GSigma 101.4 ± 2.1

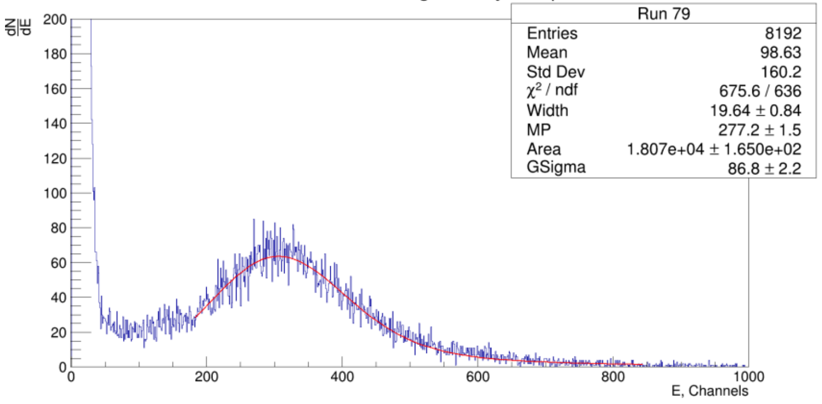
SG Fast CKTN Central, geometry comparison



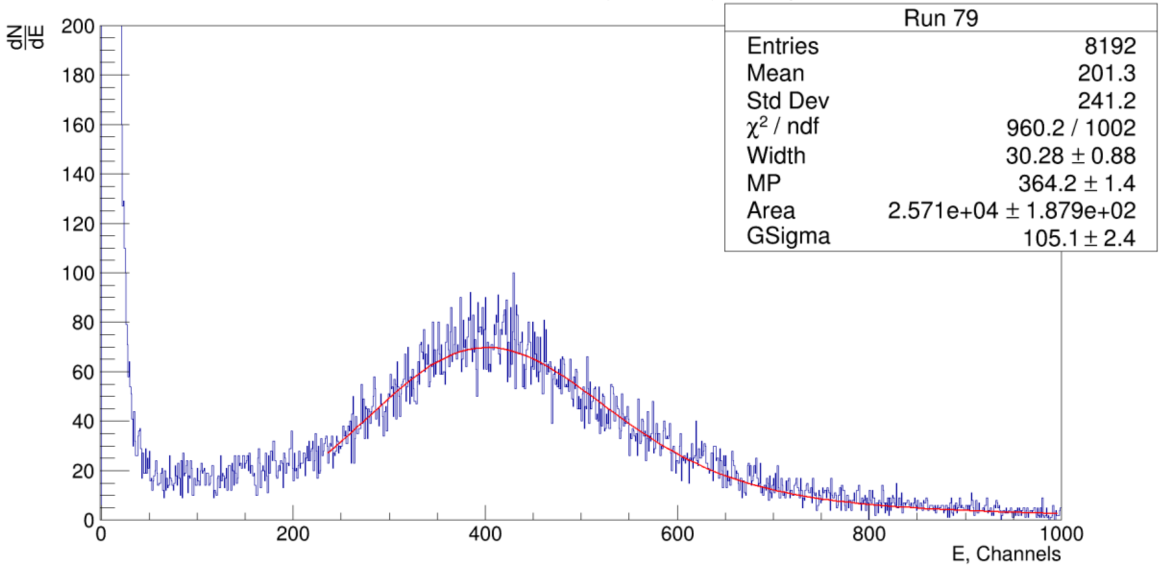
SG Fast CKTN Line 3, geometry comparison



SG Fast OK-72 Line 1, geometry comparison



SG Fast OK-72 Central, geometry comparison



SG Fast OK-72 Line 3, geometry comparison