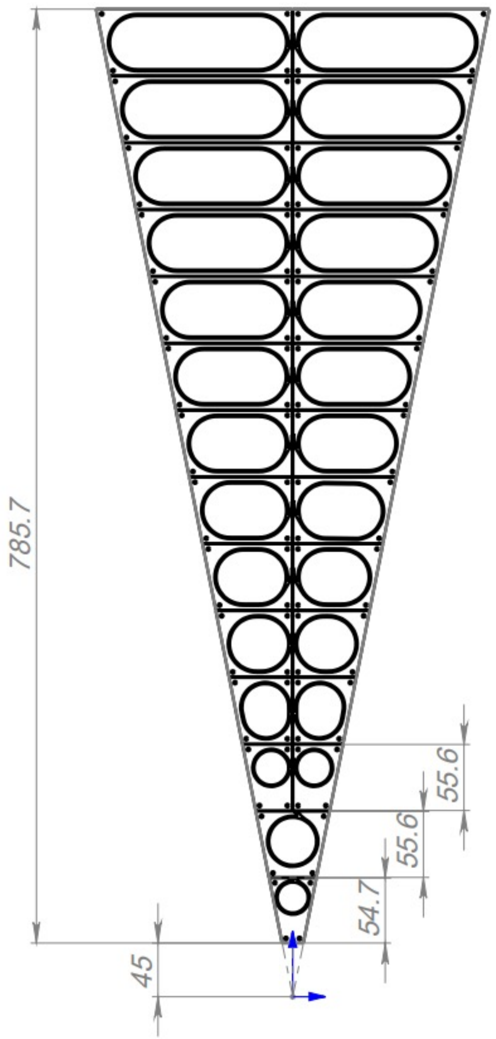
Study on the BBC improvement in MEPhI

Peter Teterin
on behalf of MEPhI group

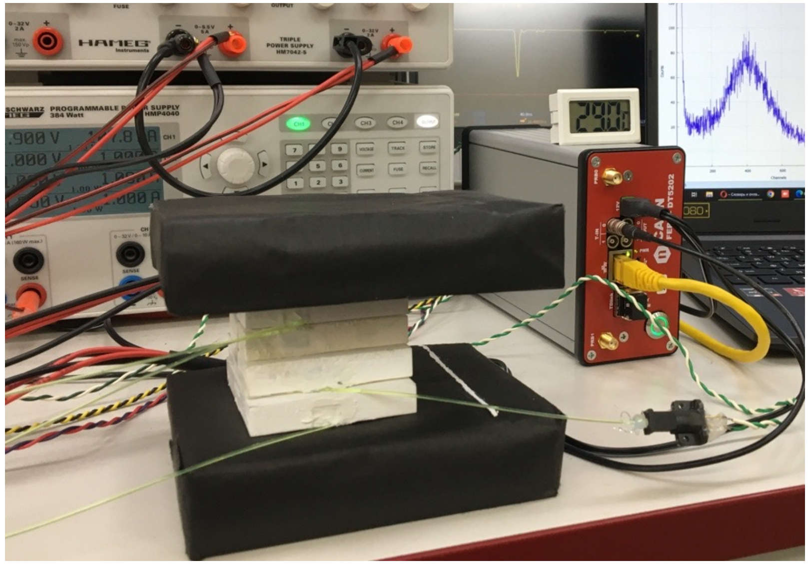
Almaty, 2024

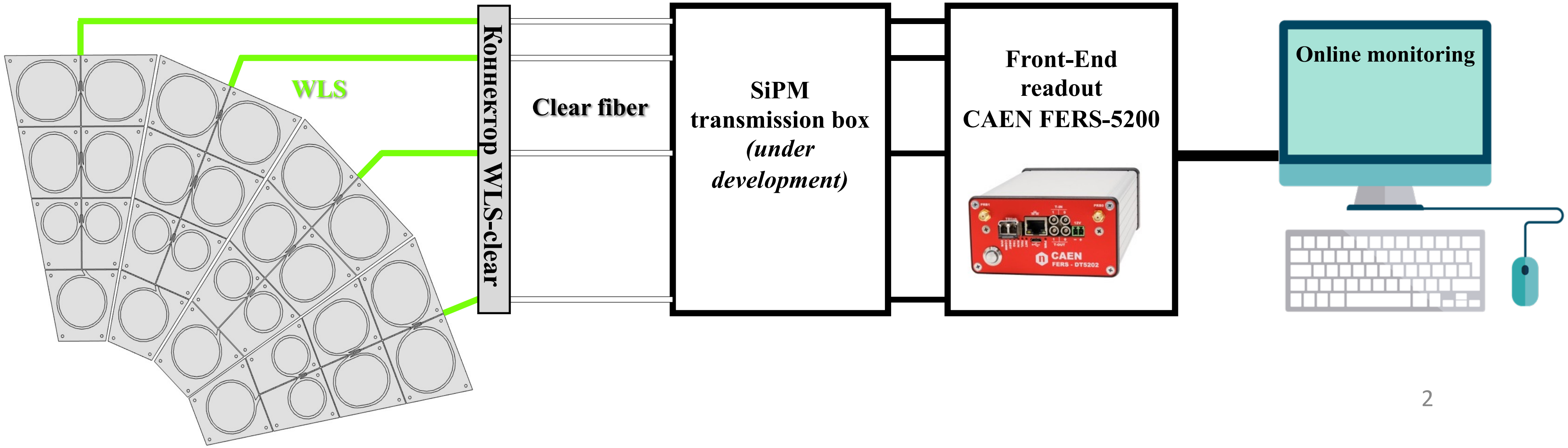
Tile cosmic testing setup



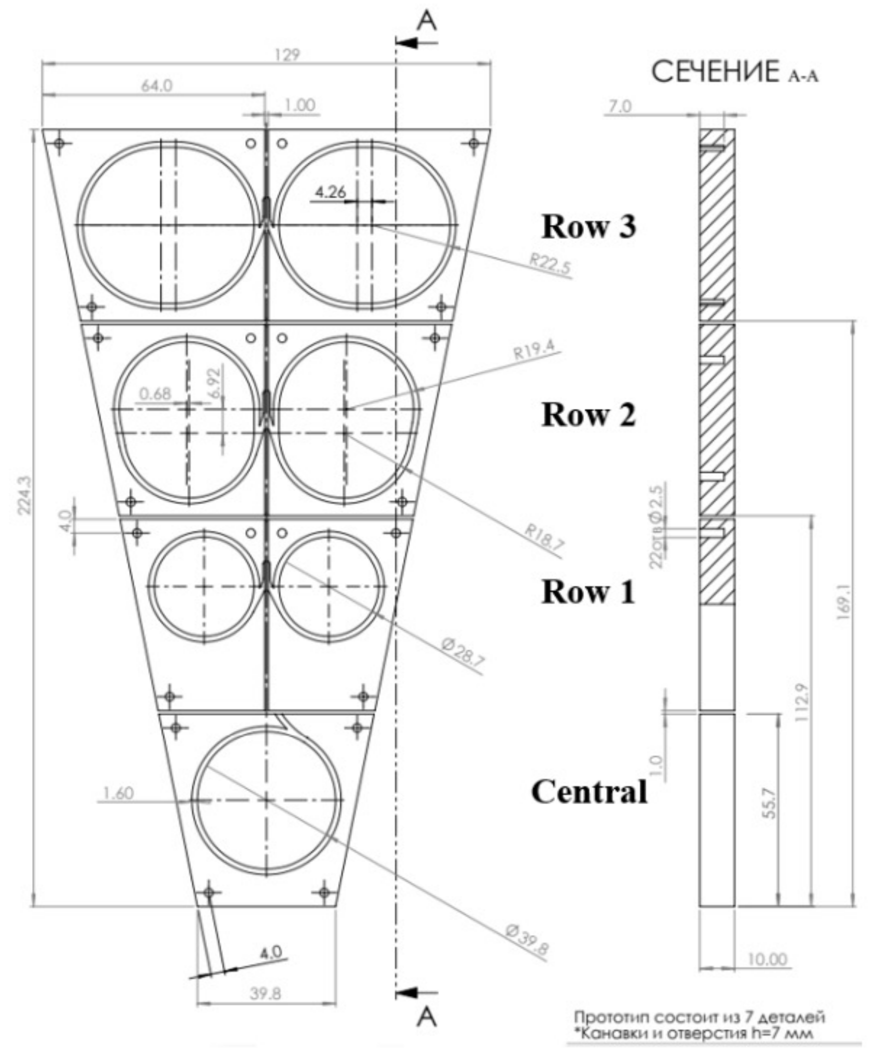
- SPD BBC: **16 sectors of 26 tiles each**

- FEE readout: **CAEN FERS-5200**
- For **cosmic tests**: external trigger with 2 10×10 cm^2 tiles and Hamamatsu H10720-110 PMTs, time resolution is ~650 pc
- The measurements were performed together with LHEP group. For measurement details, please see [slides of Alexey Tishevskiy]

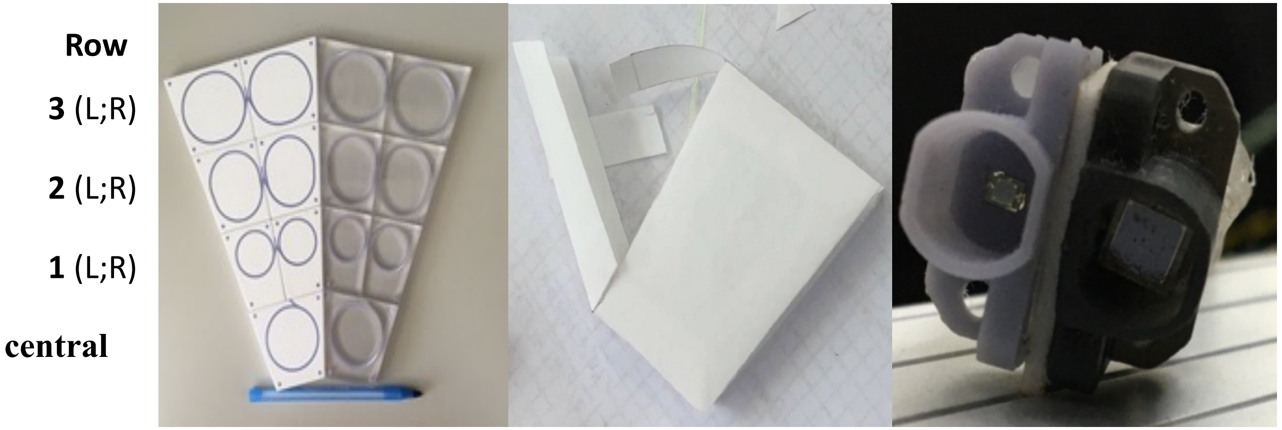




Material selection



Reduced-size 7-tile prototype of BBC sector



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 (Tver as an option)
- SiPMs: 3x3 vs 1x1 mm^2

Selection criteria:

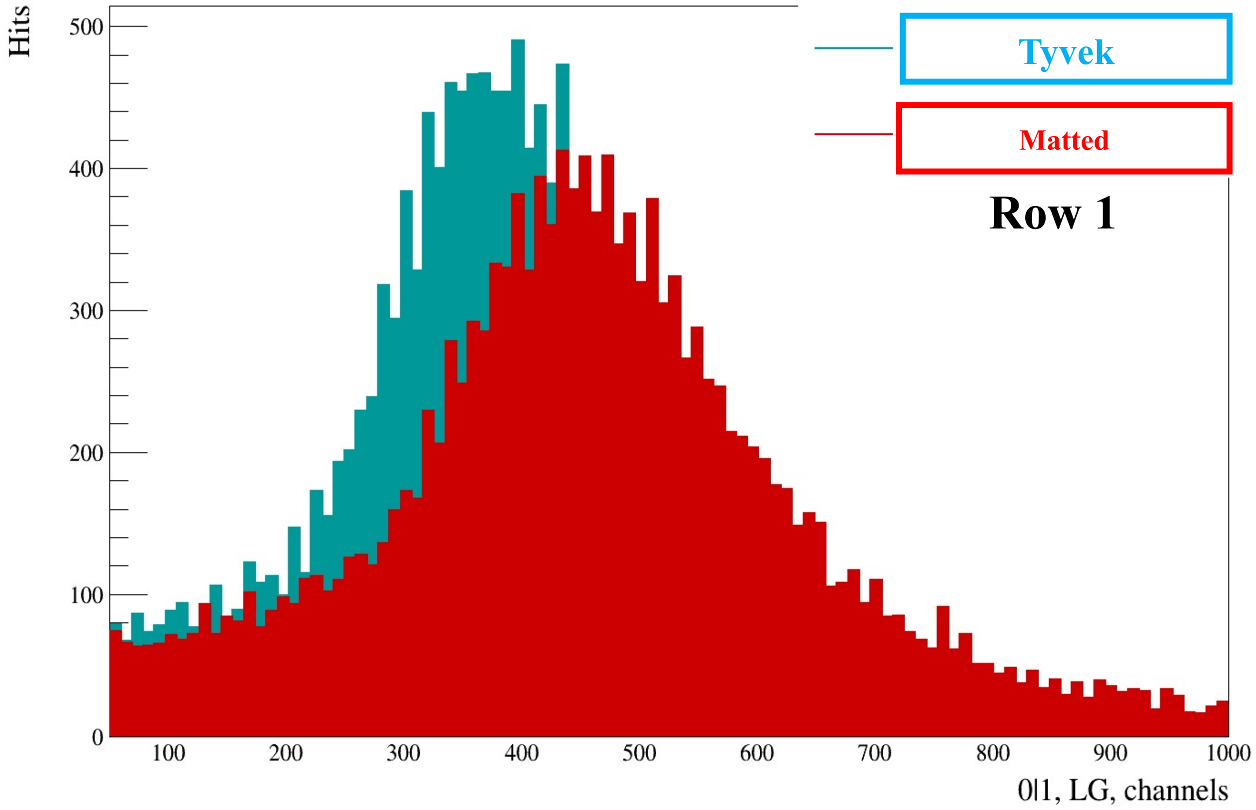
- Light collection
- Technological applicability
- Pricing
- Availability for purchase

} **Major factors**

- Radiation hardness
- Ageing etc

Material selection: scintillator cover material

Fit parameter	Matted Row 1	Tyvek Row 1	Matted Row 3	Tyvek Row3
Mean, Channels	444.9	382.3	409.1	384.7
FWHM, channels	290.1	268.6	306.0	279.9

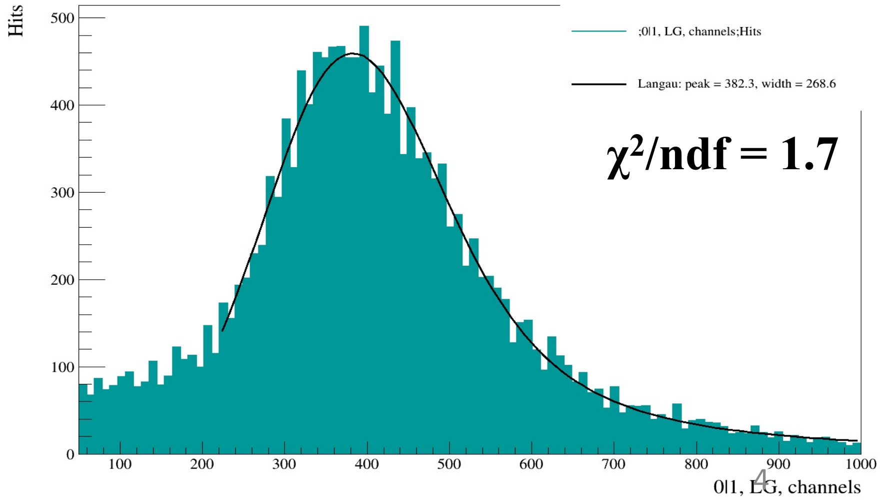


Tyvek envelope

Matted

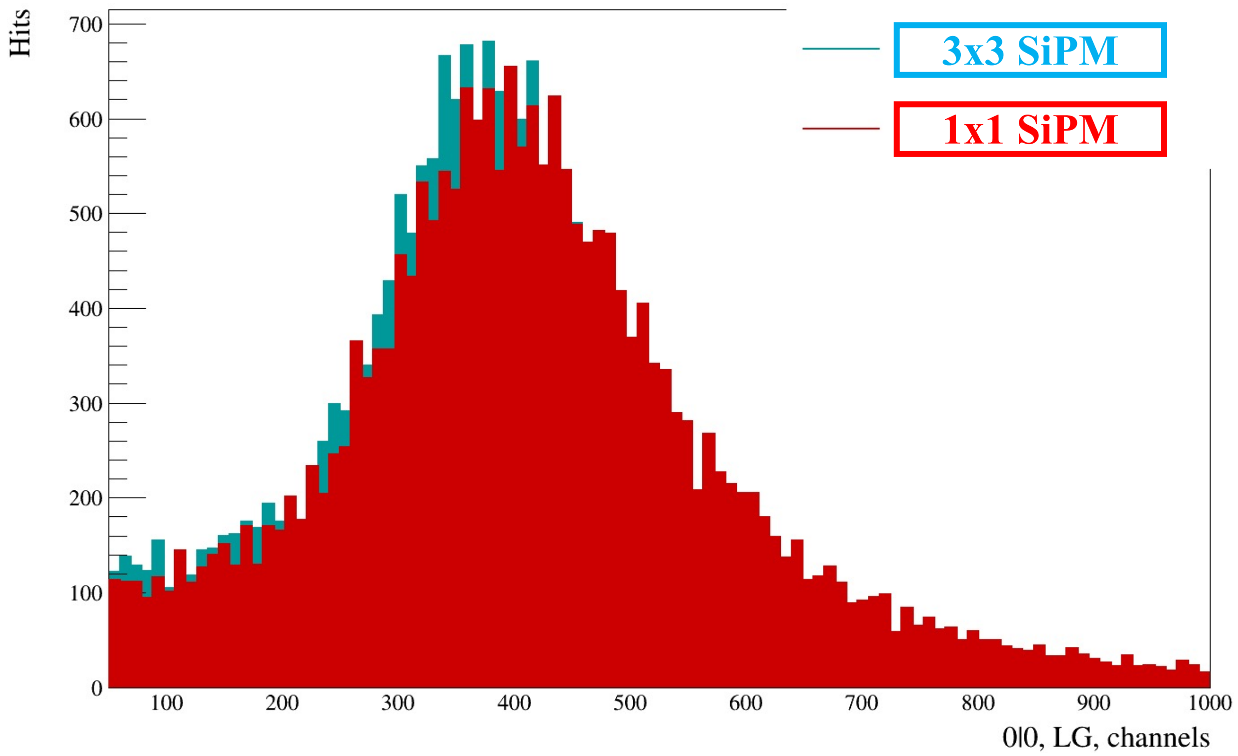
- Matted tiles collect more light (6% - 14%);
- Matted is better for mass-production and cheaper;
- Mating has no chemical difference to the scintillator material;
- Scintillator manufacturer (Uniplast Vladimir) supplies already matted tiles

Convolution of Gaussian and Landau (langauss) used as a fit function

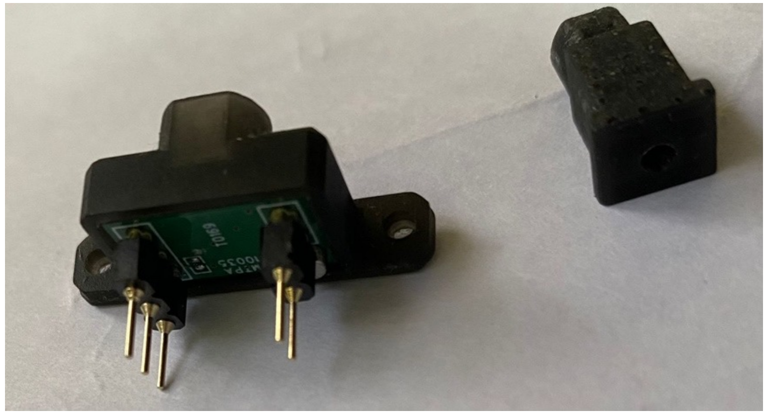


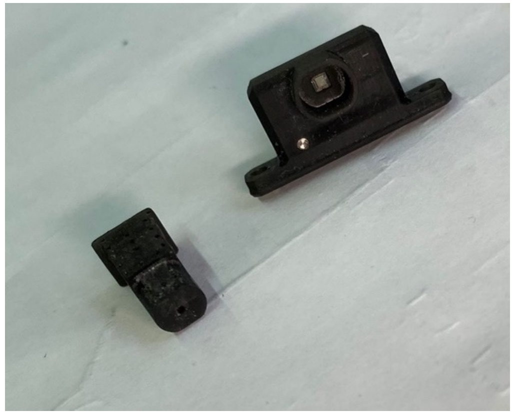
Onsemi (SensL) SiPMs

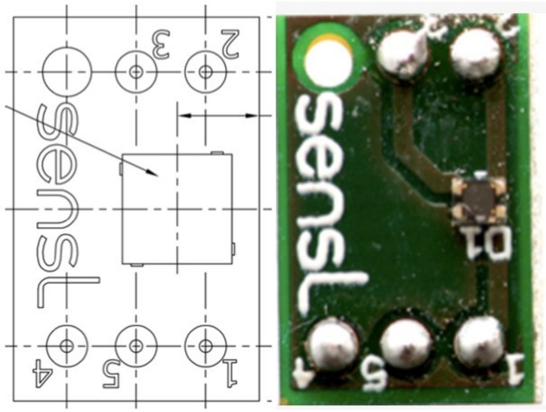
Fit parameter	1x1 mm^2	3x3 mm^2
Mean, Channels	388.9	369.0
FWHM, Channels	275.4	229.2



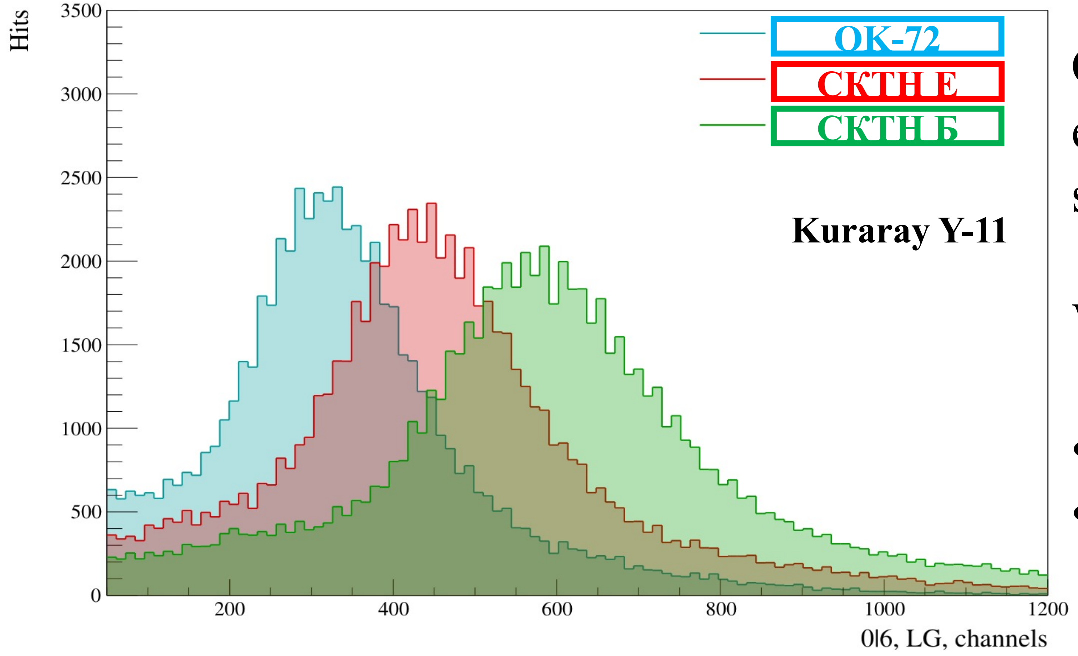
- SiPM 1x1 and 3x3 mm^2 distribution FWHM difference is about 5%
- SiPM 1x1 is better for compact PCB connector design
- SiPM 1x1 is cheaper

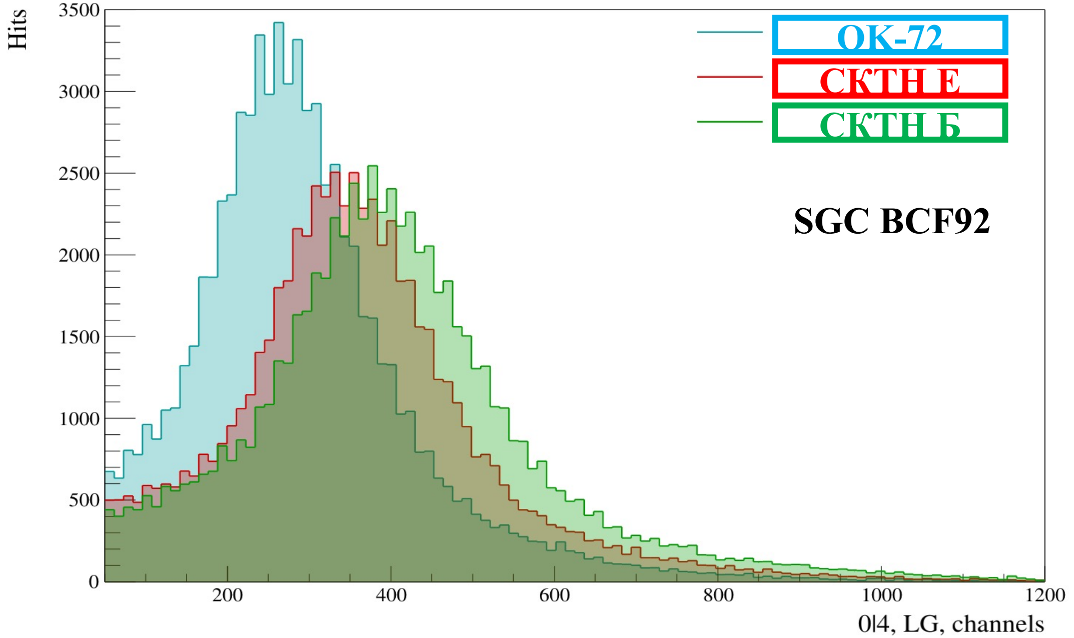






Material selection: optical cement





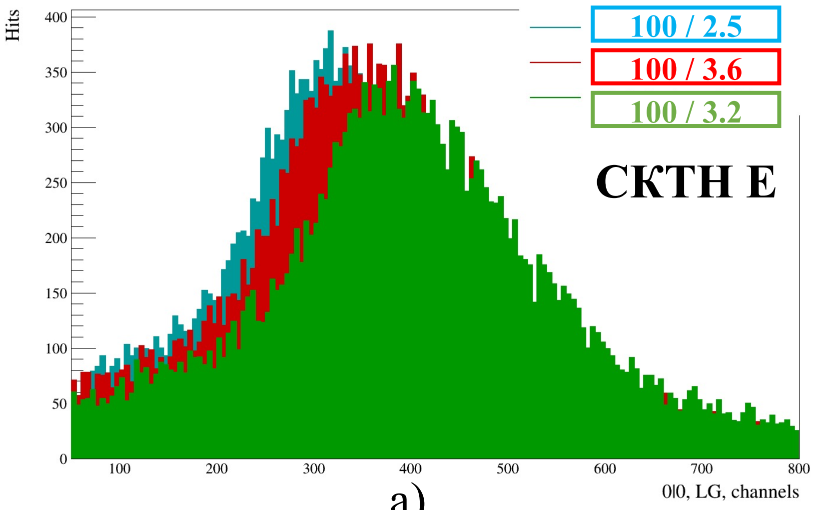
Optical cements for scintillator gluing are usually two-component epoxy resins. СКТНs are like silicone sealant, and OK-72 is similar to Araldite 2011

We tested СКТН Б, Е, OK-72 which are available for purchase

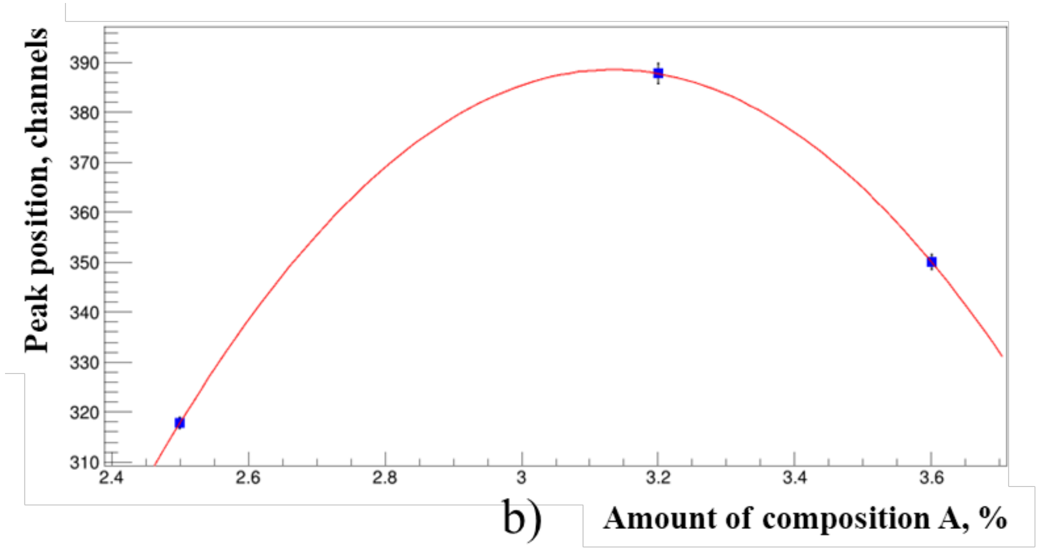
- СКТН Б and OK-72 has 50 times lower viscosity than СКТН Е
- СКТН Б transmits more light than the others, most likely, due to better adhesion and worse bubble formation

Fit parameters	СКТН МЕД Е	СКТН МЕД Б	OK-72	WLS
Mean, channels	429.7	569.1	312.8	Y-11 (top)
Width, channels	268.7	324.9	228.2	
Mean, channels	340.3	378.4	263.7	BCF92 (bottom)
Width, channels	240.7	265.4	212.6	

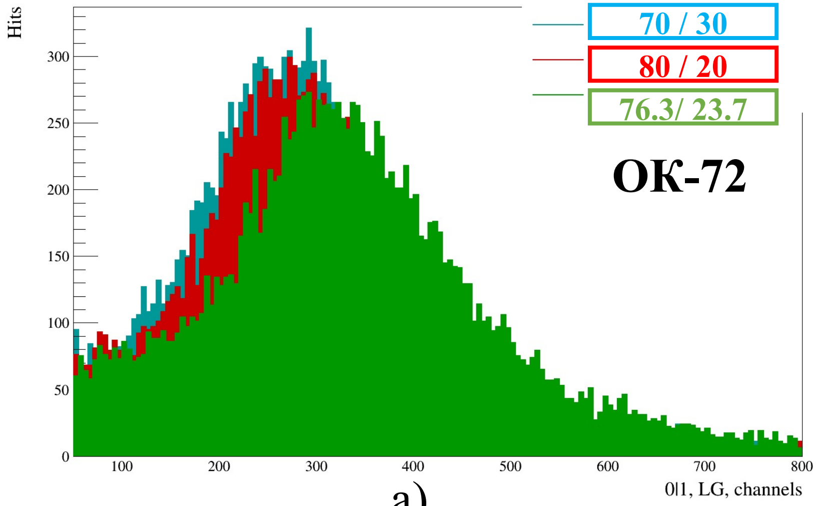
Material selection: optical cement composition



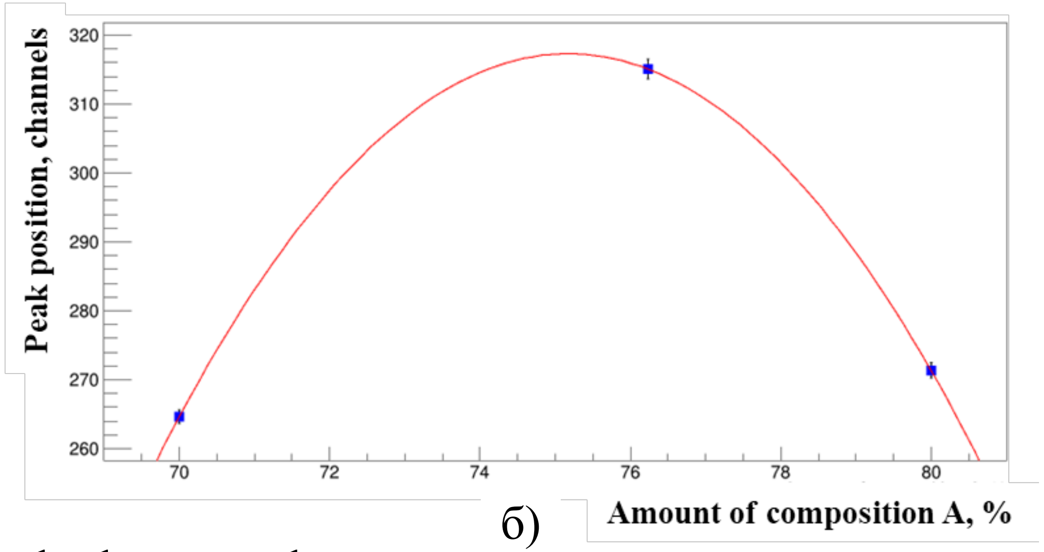
a)



b)



a)



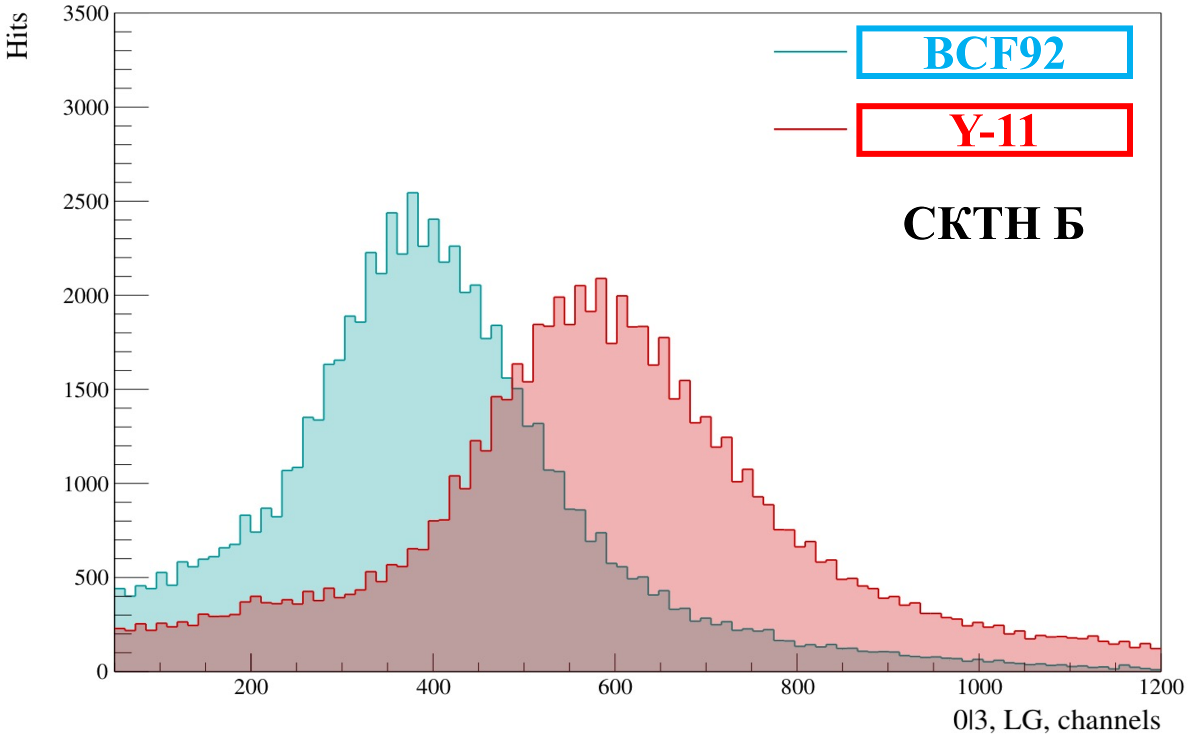
б)

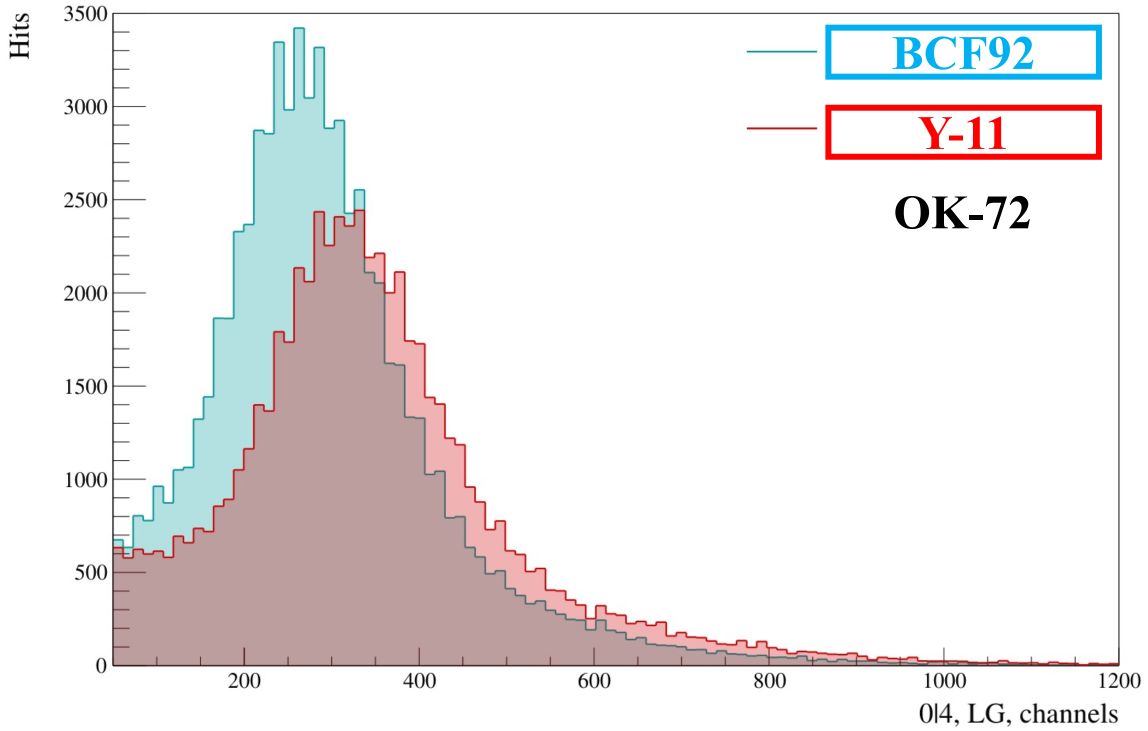
- Recommended by manufacturer compositions show the best results
- Violation of the composition leads to losses (up to 18%)
- СКТН Е is preferrable due to low viscosity

a) Optical cement compositions comparison

b) E peak vs A-component concentration

Material selection: WLS





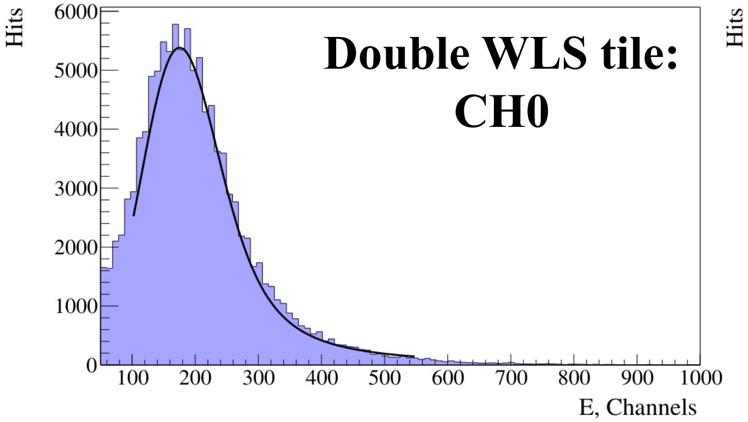
Fit parameters	BCF92	Y-11
Mean, channels	378.4	569.1
Width, channels	265.4	324.9

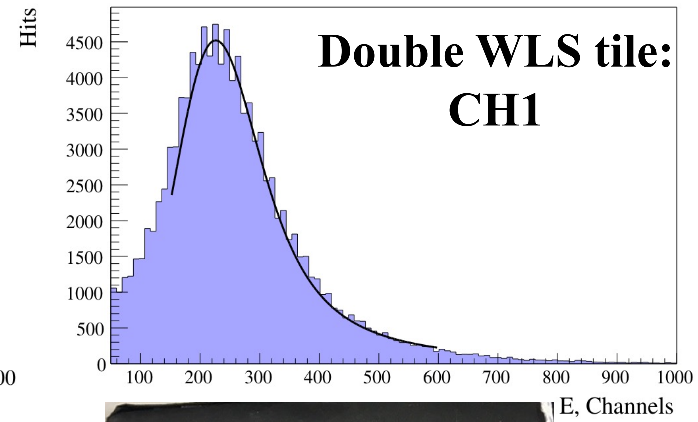
- Tiles with Y-11 collect more light
- For OK-72 tiles:
  - peaks are not well separated
  - peaks are in lower energy region

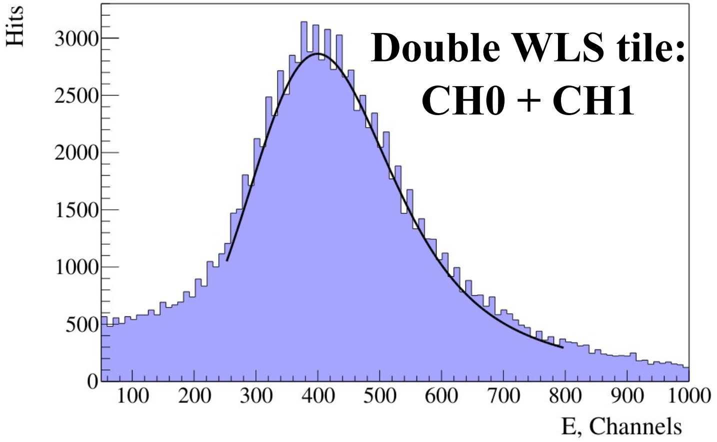
Seems, OK-72 absorbsUV photons

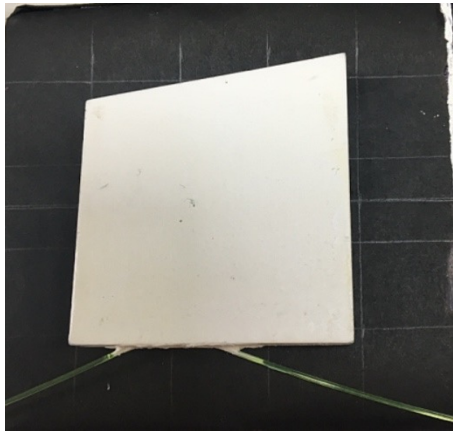
Fit parameters	BCF92	Y-11
Mean, channels	263.7	312.8
Width, channels	212.6	228.2

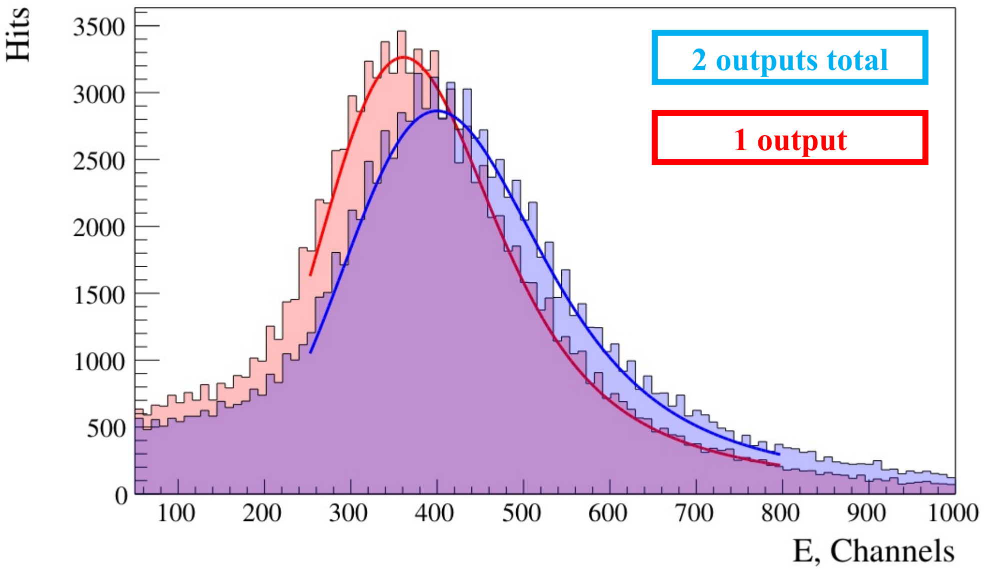
Optimization: light collection









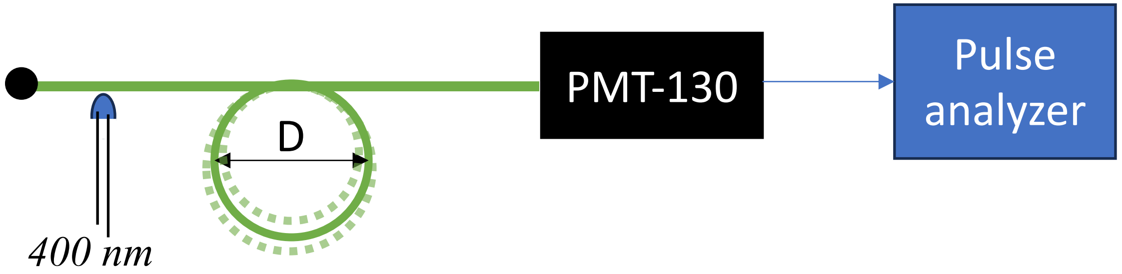


Fit parameters	One output tile	Two outputs tile (total)
Mean, channels	360.9	399.8
Width, channels	243.2	277.4

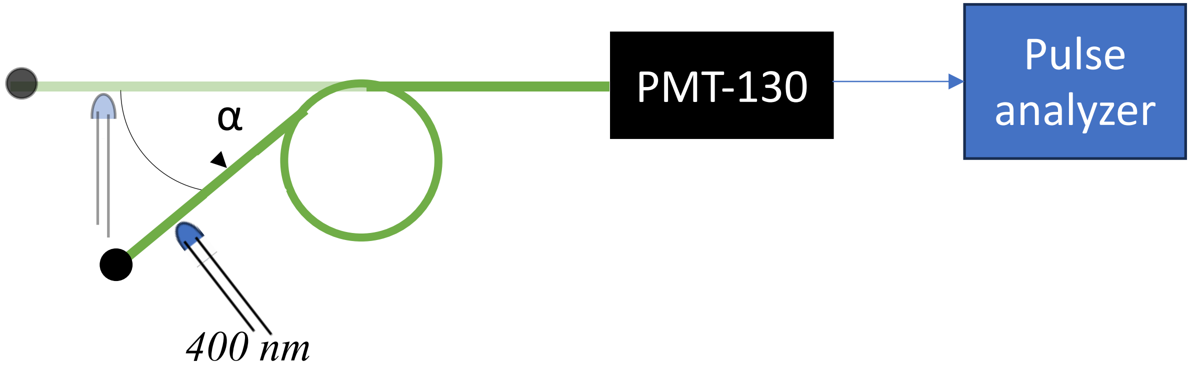
- Two tiles were used for data taking:
  - One output: one polished and painted end is embeded inside the tile with optical cement
  - Two outputs: data taking and summarization from both ends of the fiber
- Difference between the two tiles is up to ~10%

WLS extra tests: setups and measurements

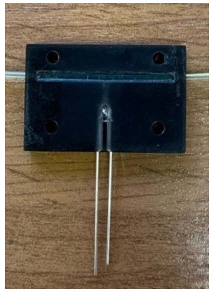
Bending loss measurement

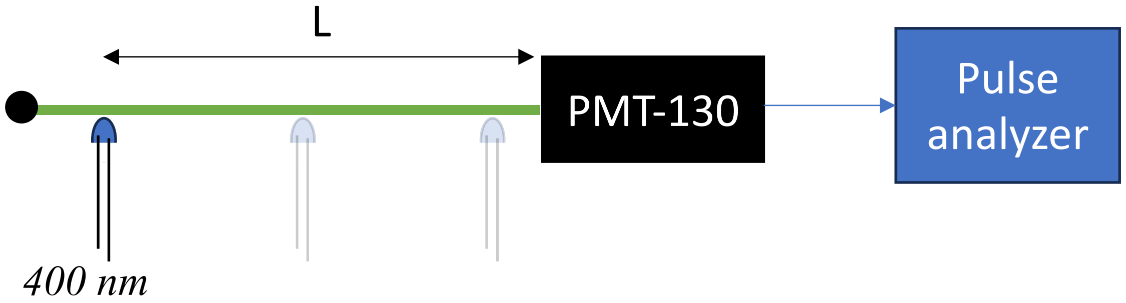


Bending loss vs Arc length



Relative light absorption & Light yield

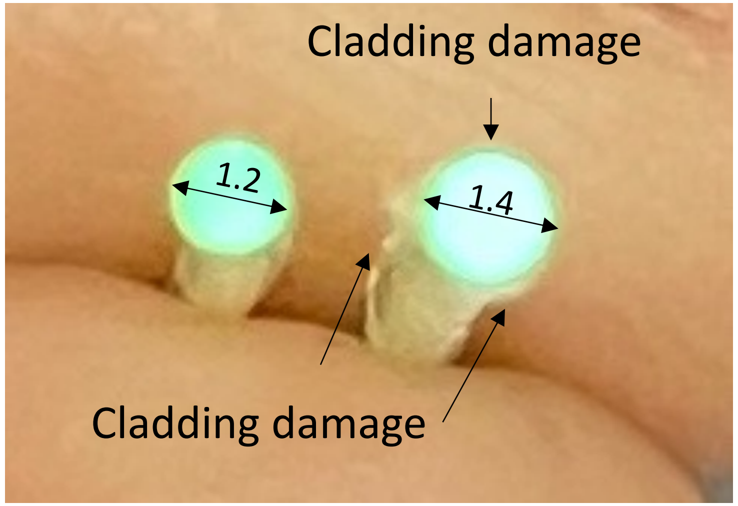




WLS tests: materials & equipment

Single cladding shifters:

- ❖ Kurarai Y11, Ø1mm
- ❖ Gaint Gobain BCF-92, Ø1mm
- ❖ 1st Tver shifter, Ø1.2mm – **mechanically weak cladding**
- ❖ 2nd Tver shifter, Ø1.2mm – **weak cladding, core D=1.2..1.4mm**

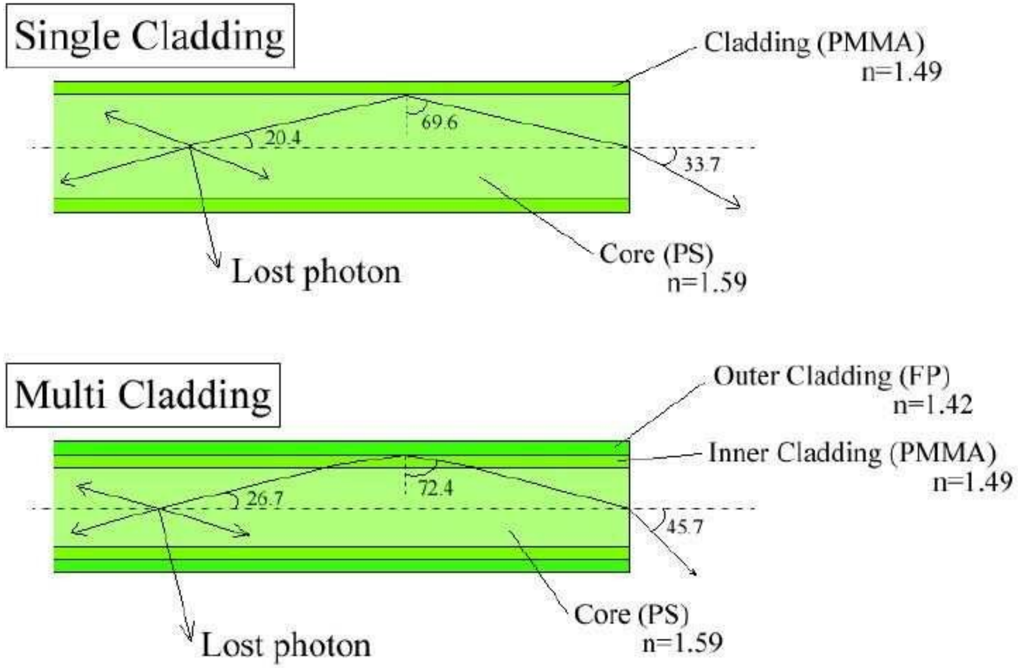


LED in pulse mode

- t_p = 20 ns (from pulse generator)
- LED wavelength = 400 nm

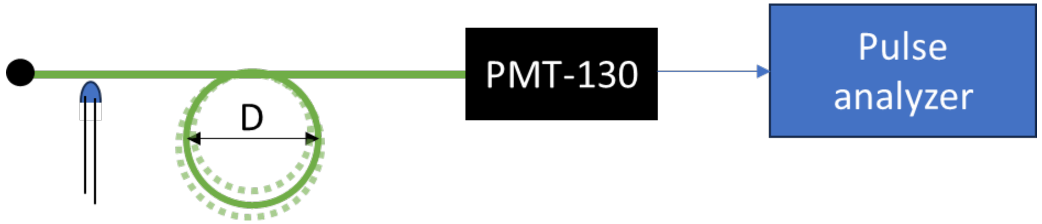
Photodetector – PMT-130 (1500V)

Pulse analyzer – Oscilloscope Lecroy 620Zi

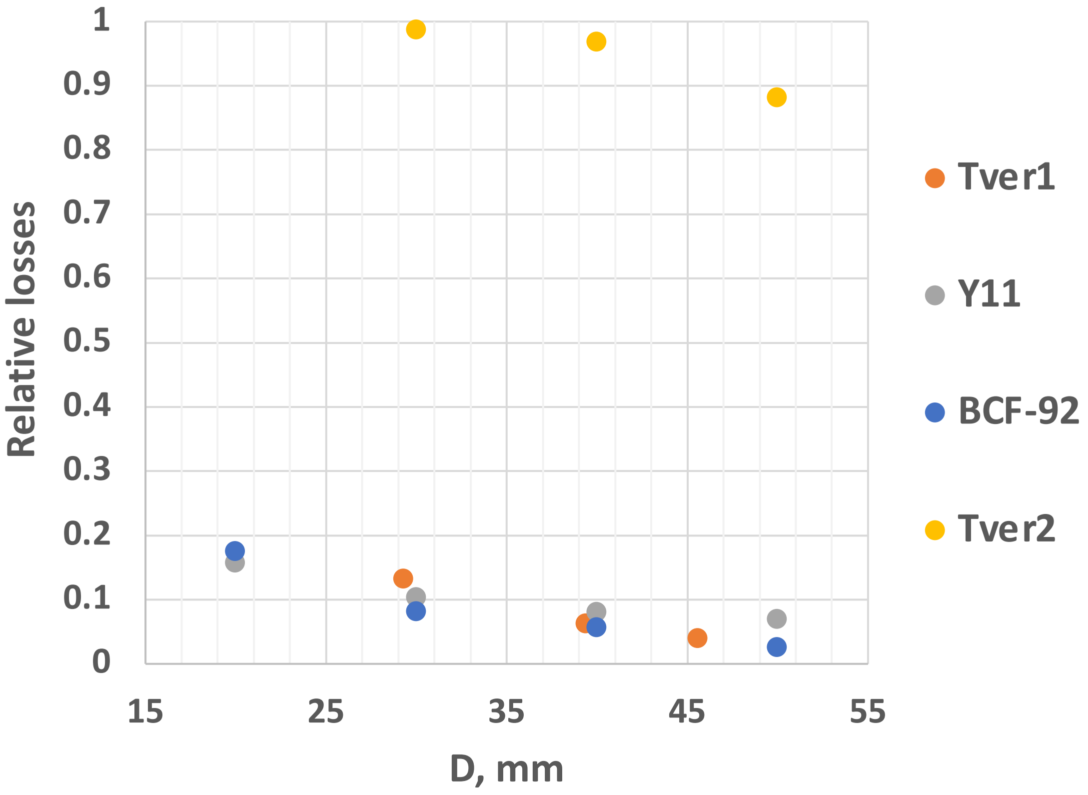


Source: arXiv:hep-ex/0607013v1

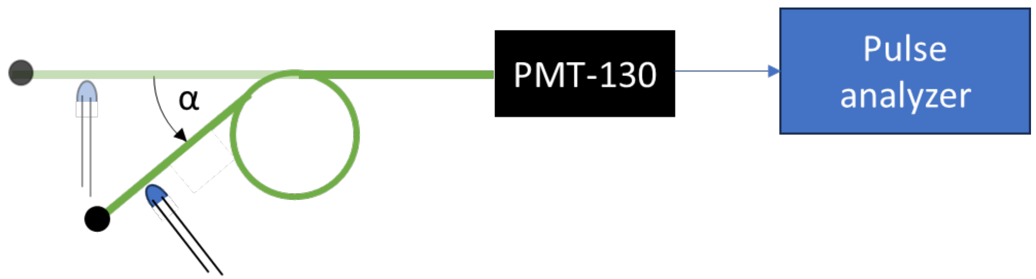
WLS tests: bending losses



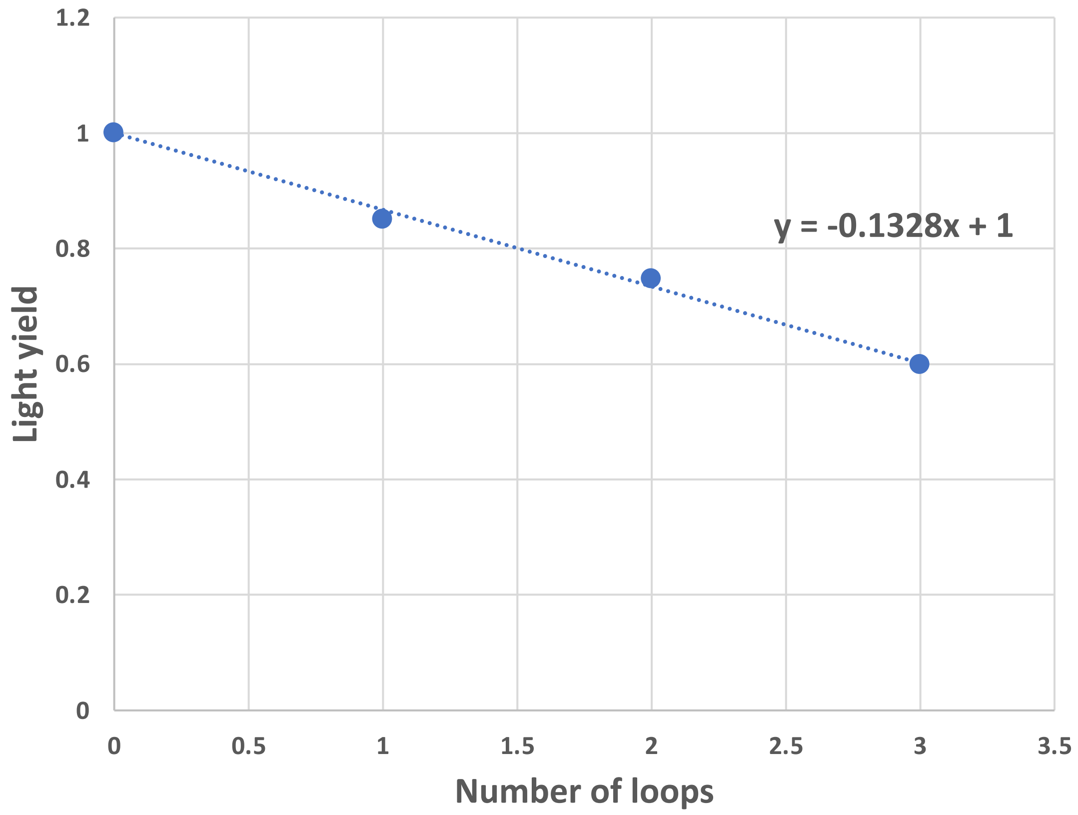
- **Single loop**
- **Fixed light path length**
- **30mm btw loop and PMT**



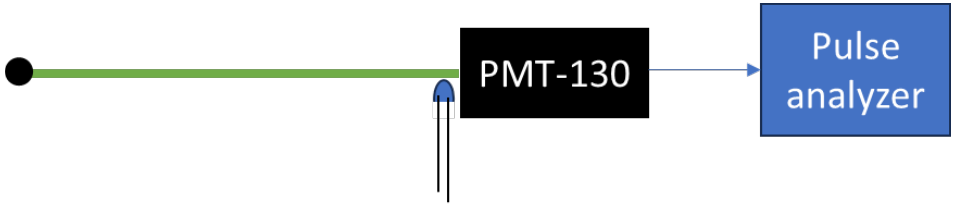
WLS tests: dependence on the number of loops



- WLS: Kyrarai Y11
- D = 30mm
- Base = 445mm
- 0, 1, 2, 3 loops tested



WLS tests: relative light yield



- **Closest LED position**
- **LED spot size: Ø1.5mm**

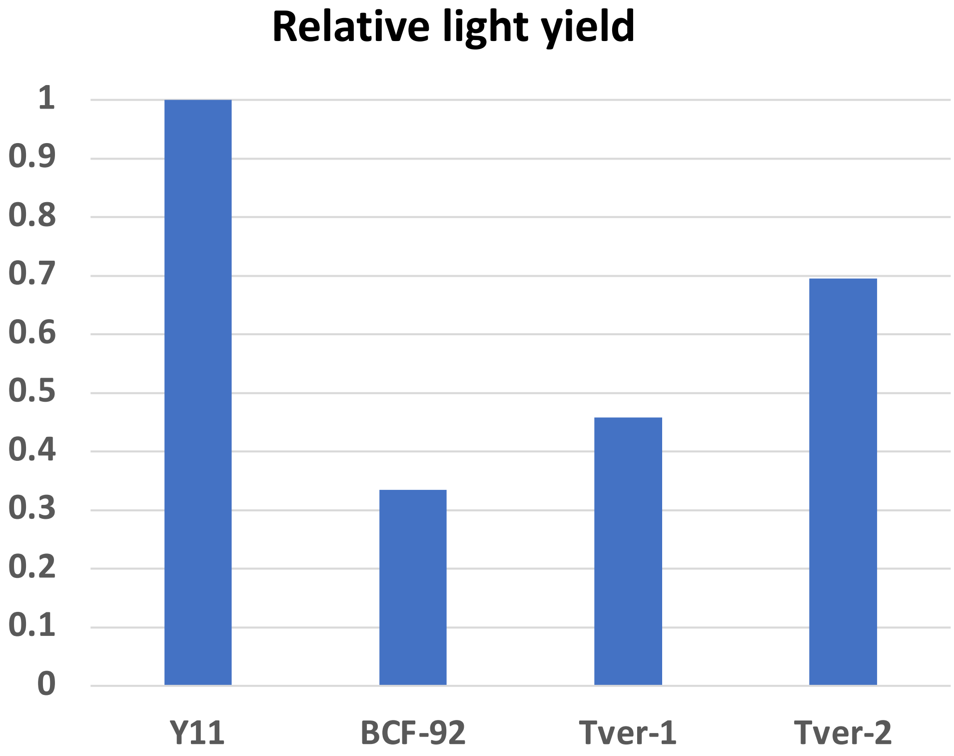
Shifters' diameters:

Y11 - Ø1mm

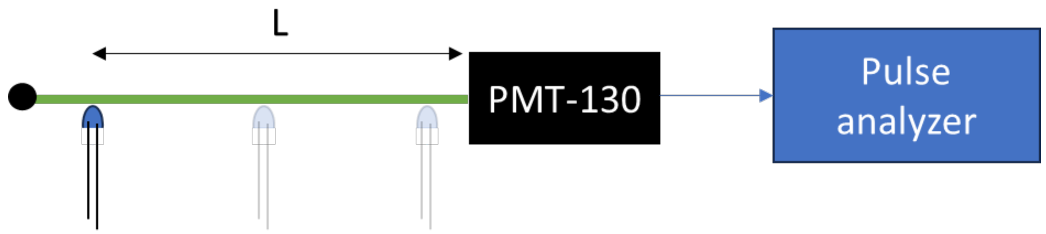
BCF-92 - Ø1mm

Tver1 - Ø1.2mm

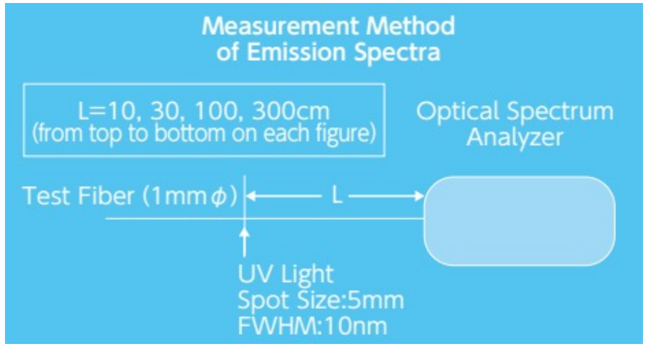
Tver2 - Ø1.2mm

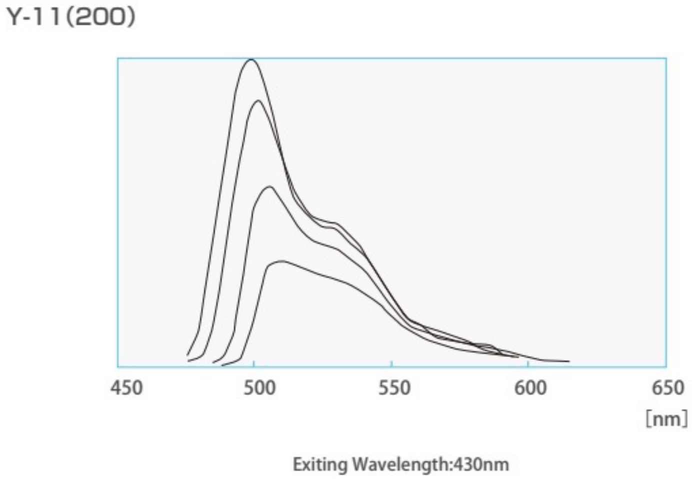


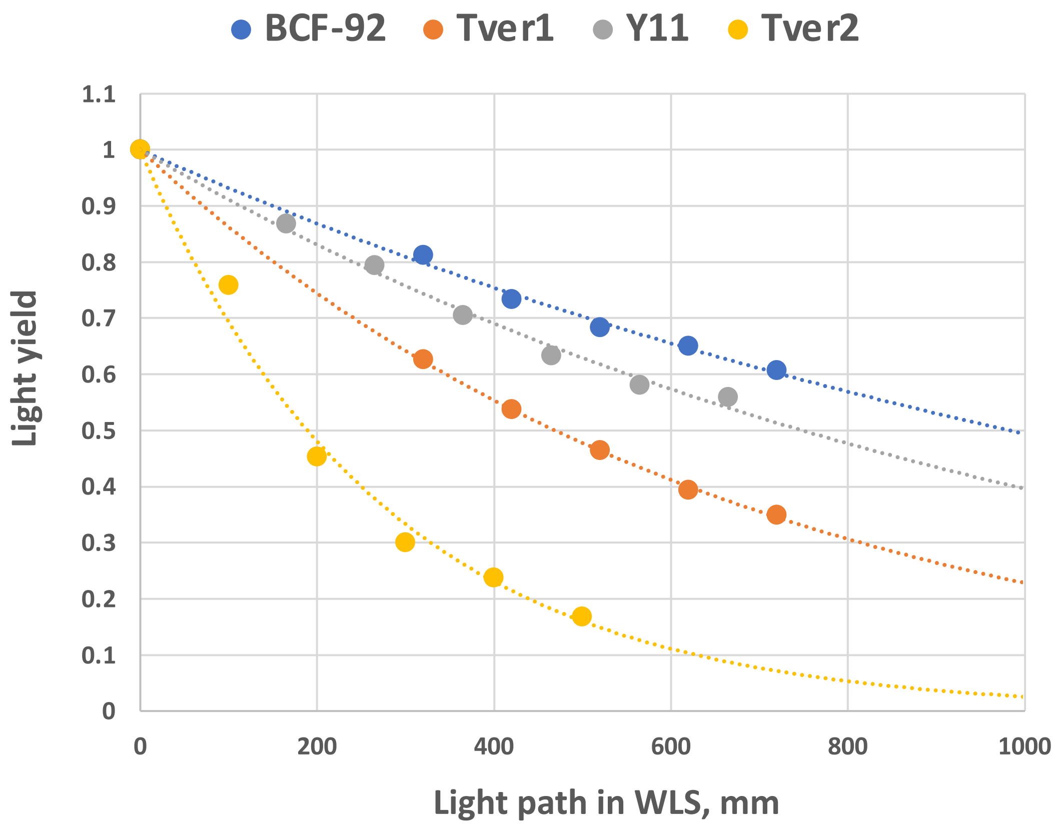
WLS tests: relative light absorption



Kurarai datasheet:



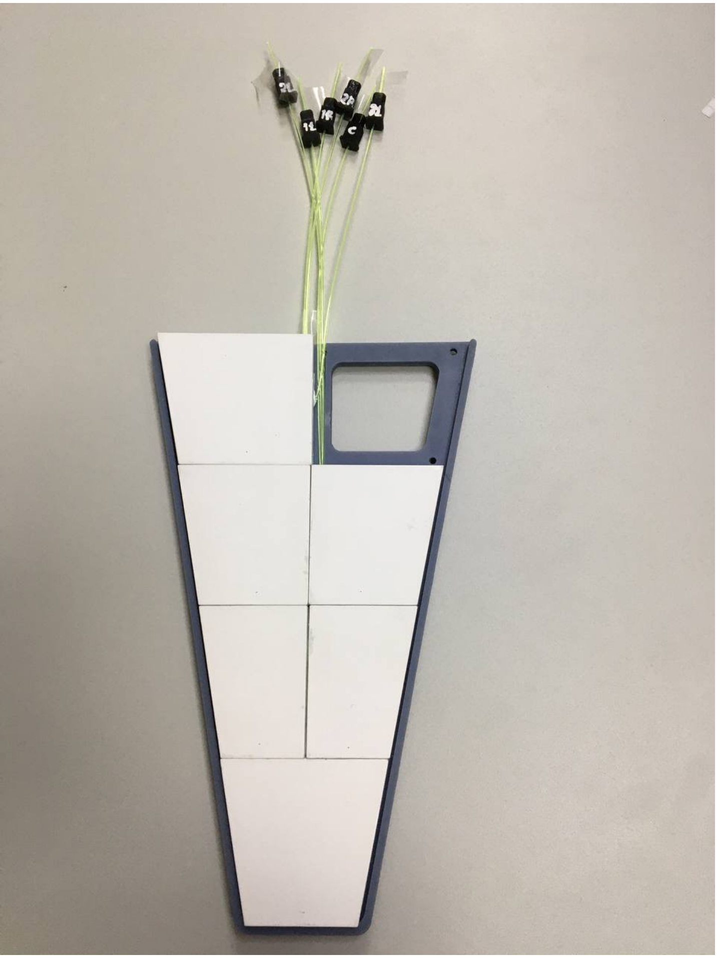




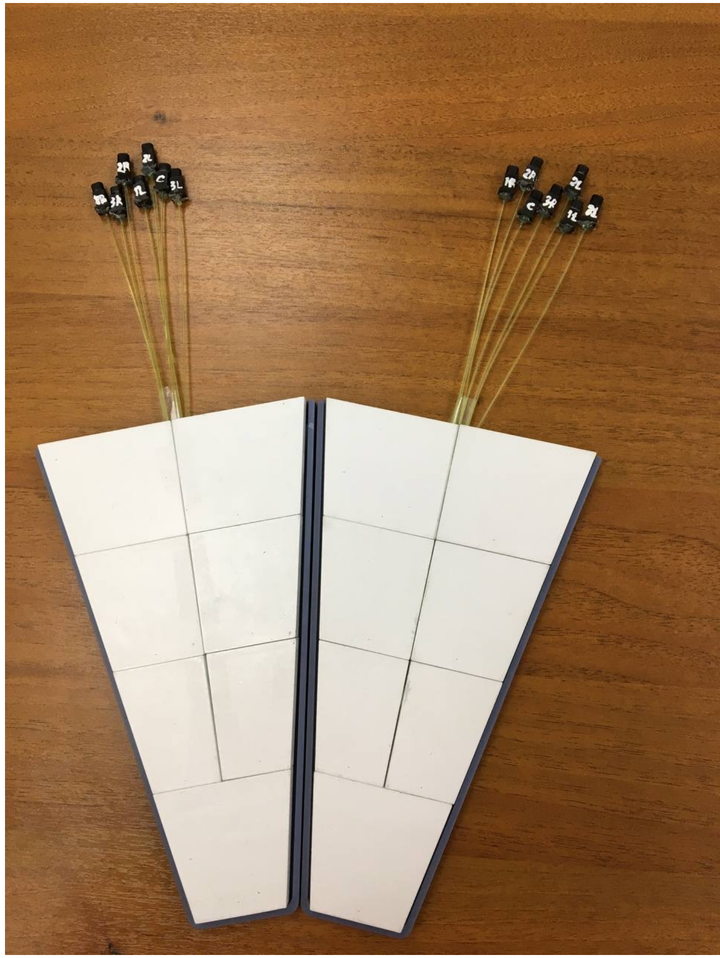
WLS tests: Summary for different types of WLS

	Y11, Ø1mm	BCF-92, Ø1mm	Tver1, Ø1.2mm	Tver2, Ø1.2mm
Light yield	1	0.33	0.45	0.69
Bending loss @ D30mm, %	10	8	12	99
Light absorption @ 50cm, %	35%	30%	50%	85%
Trailing edge, ns	24	12	16	20

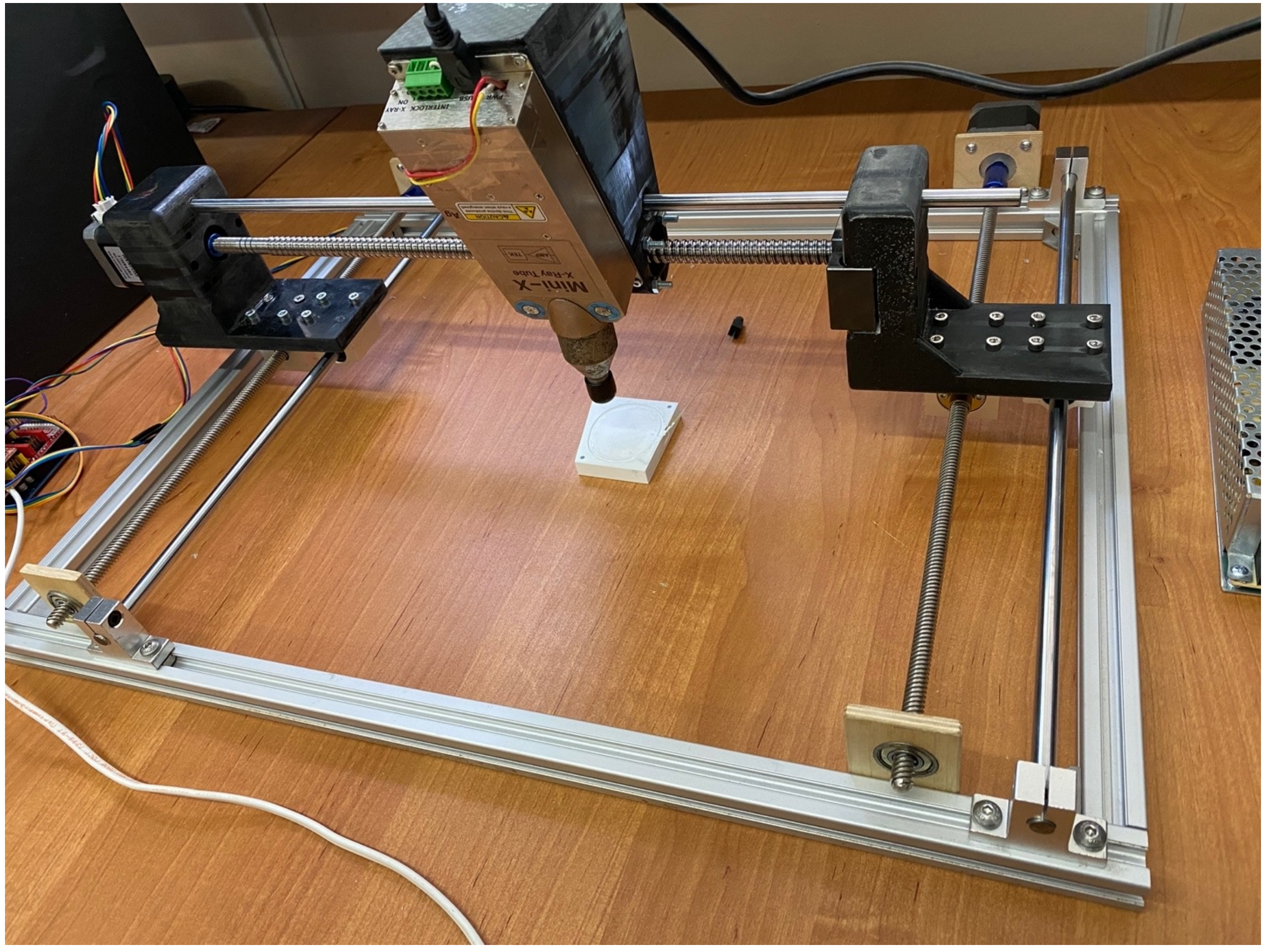
Prototyping and tests



- The material selection for BBC is complete, final configuration – matted surface, Y-11 fiber, СКТН Б optical cement
- Currently we have in hands 2 small sector prototypes of 7 tiles with СКТН Б and SG BCF92 fiber
- The mechanical frames for the prototype and final BBC are under development
- It is expected to have 1 more innermost tile in further prototypes

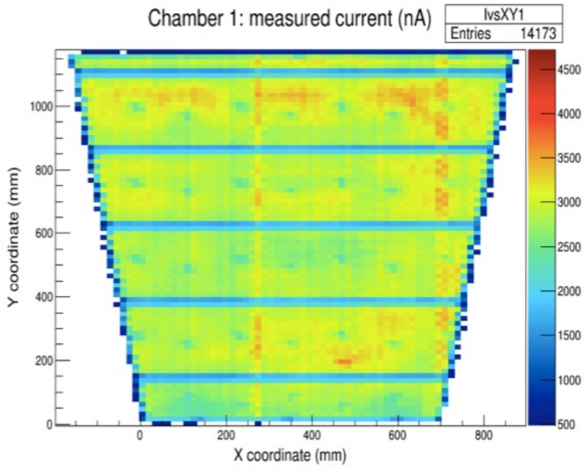


Setup for tiles uniformity test (future plans)



Plan:

- X-ray and radioactive source testing in integral signal mode. Similar method we used for gas detector uniformity testing



For the method, see P. Teterin *et al* 2020 *JINST* **15** C08008

Currently:

- A compact X-Y machine with Amptek Mini-X tube onboard is under testing
- Shifter measurements technique is a good background for the complete setup

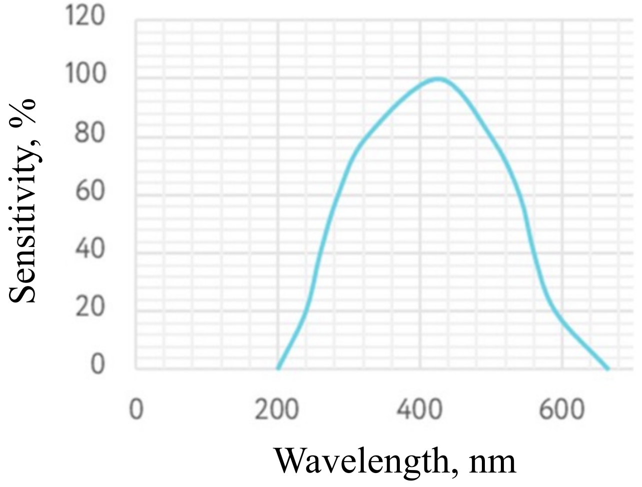
Summary

- The final configuration of materials for BBC – Uniplast Vldimir scintillator, matted surface, Y-11 fiber, СКТН Б optical cement
- Chemical mating is better than Tyvek (6 to 14%), and also better for mass-production
- 1x1 and 3x3 mm^2 SiPMs showed comparable signal but 1x1 is better from technological point of view
- Optical cement СКТН Б collects more light (10-25%) and has appropriate viscosity for the mass-production
- Tver's WLS have perspective light trapping and guiding parameters for HEP applications, but some improvements required: improvement of mechanical strength, and reduction of light loss @ first 50cm
- Y11 and BCF-92 gives acceptable for BBC results but Y11 is preferable due to high LY
- Two reduced BBC sectors of 7-tiles were built as a prototype for combined cosmic test

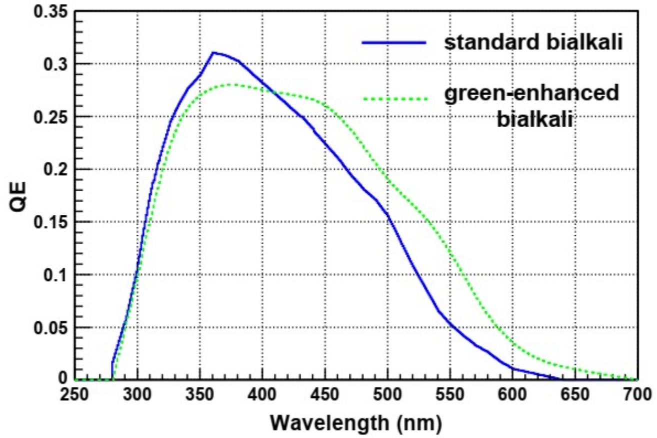
Backup

We used: ***Kuraray used for datasheet measurements:***

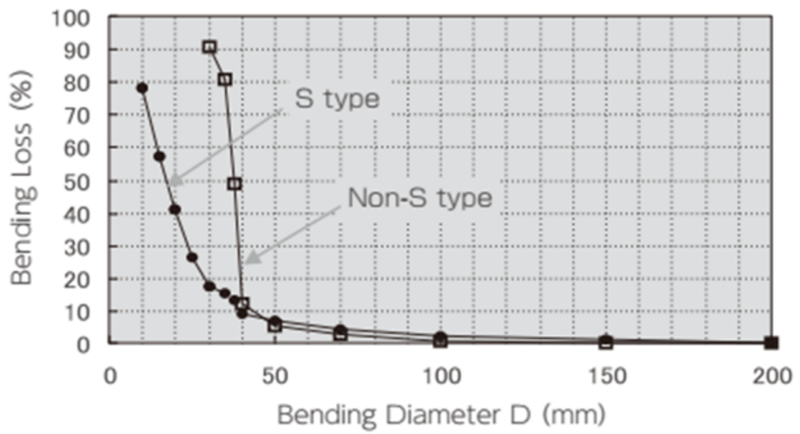
Sb-K-Cs photocathode



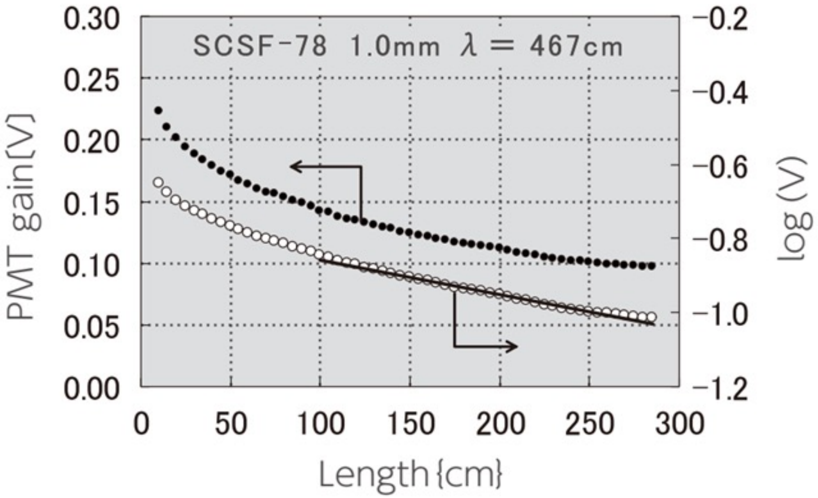
Bialkali photocathode



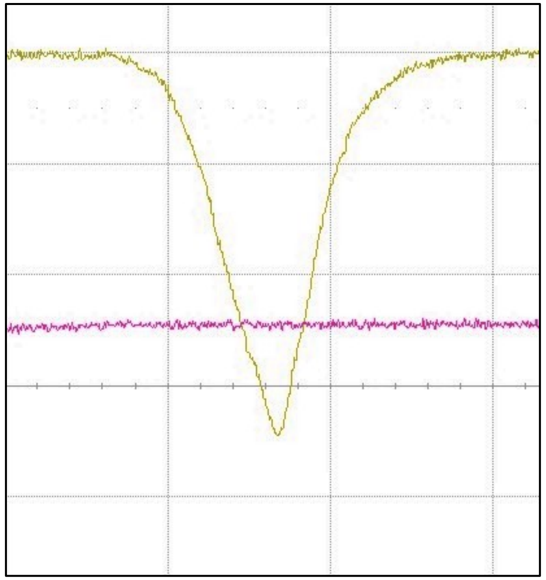
Multi-cladding Kurarai shifters:



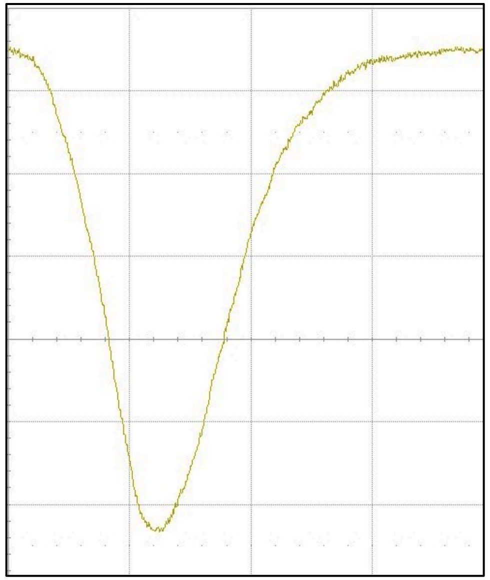
Kurarai data:



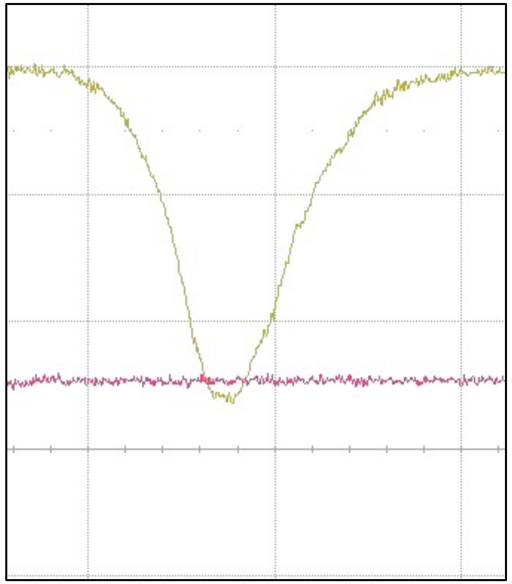
WLS tests: Pulse shape (Generator pulse = 20 ns)



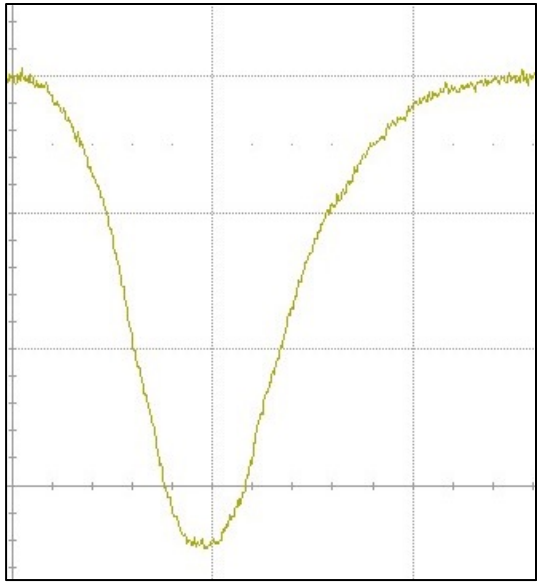
Saint Gobain BCF-92
trailing edge = 12 ns



Kurarai Y11
trailing edge = 24 ns



1st Tver
trailing edge = 16 ns



2nd Tver
trailing edge = 20 ns