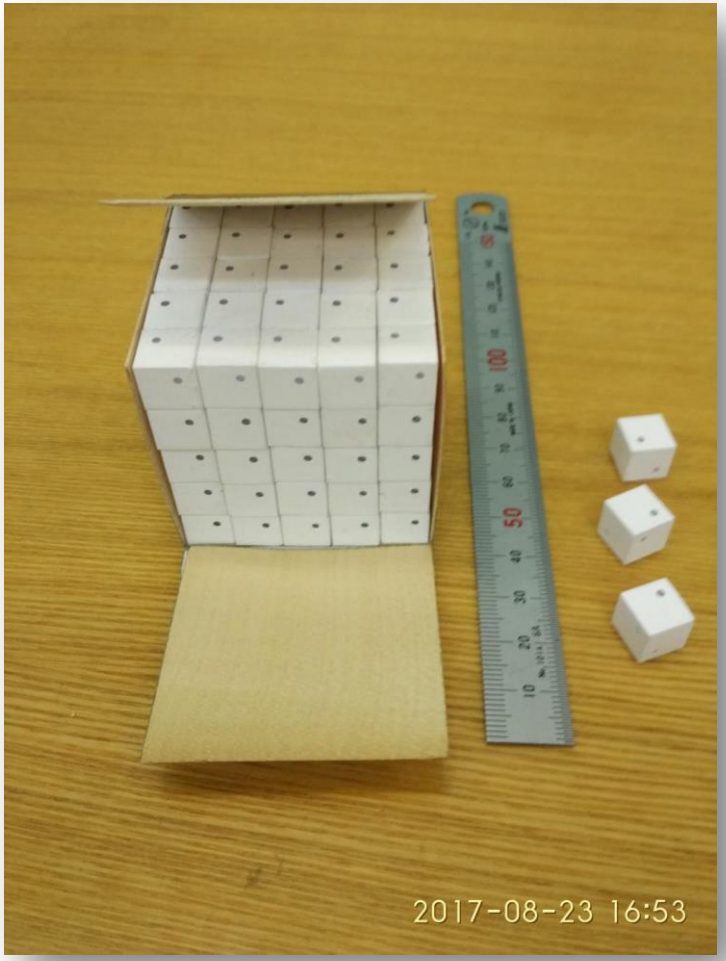
Preliminary results for beam test of a prototype of a segmented neutrino detector (SuperFGD) at CERN T10 in October 2017

Oleg Mineev, Alexey Khotjantsev

INR RAS

5x5 cube from the cubes

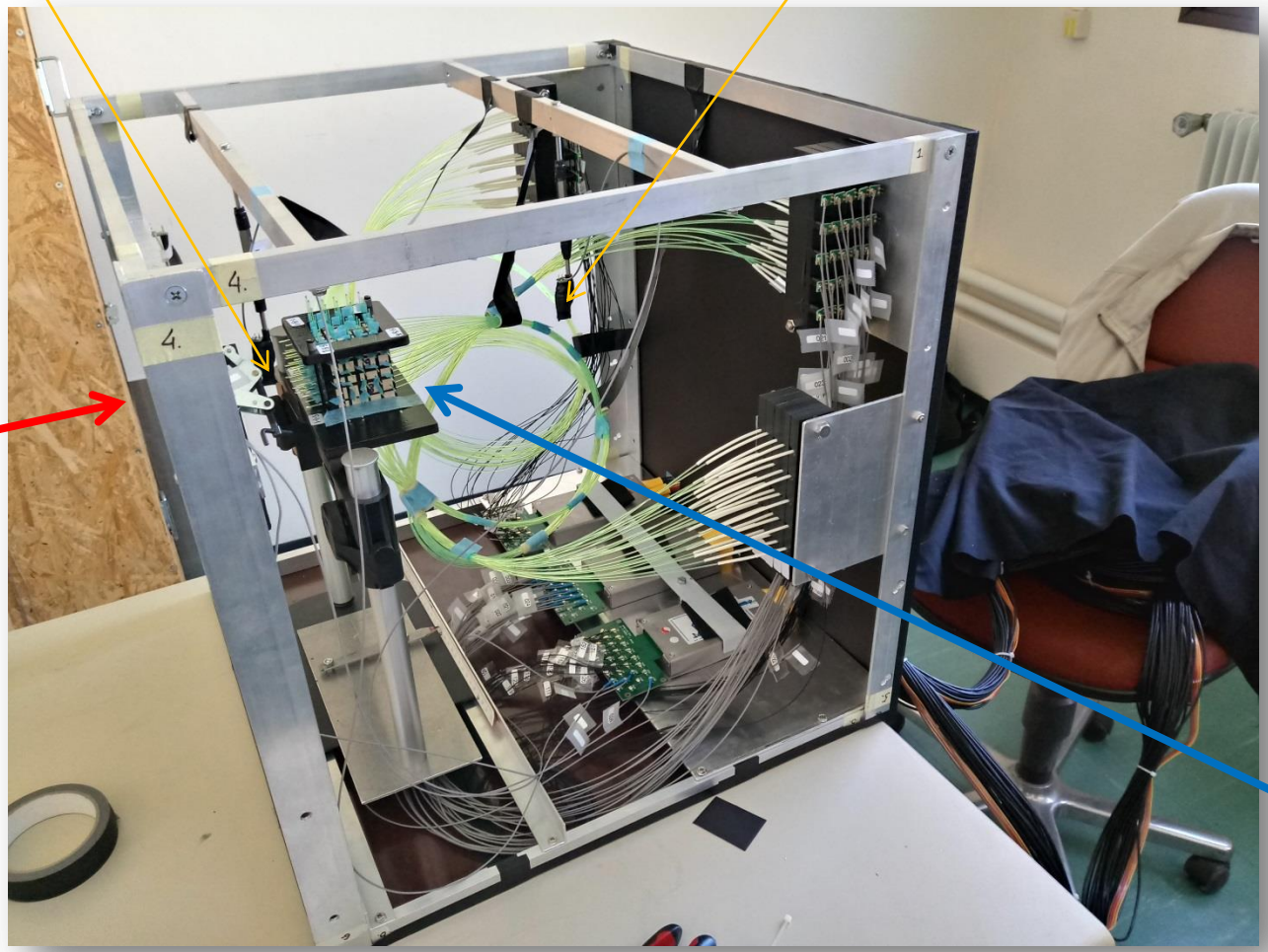


- Manufactured in Vladimir (Uniplast Co.)
- Cube size: 10x10x10 mm^3
- Material: extruded polystyrene doped with 1.5% of paraterphenyl (PTP) and 0.01% of POPOP
- White chemical reflector: thickness is about 50 μm
- Holes for WLS fibers: three of 1.5 mm diameter

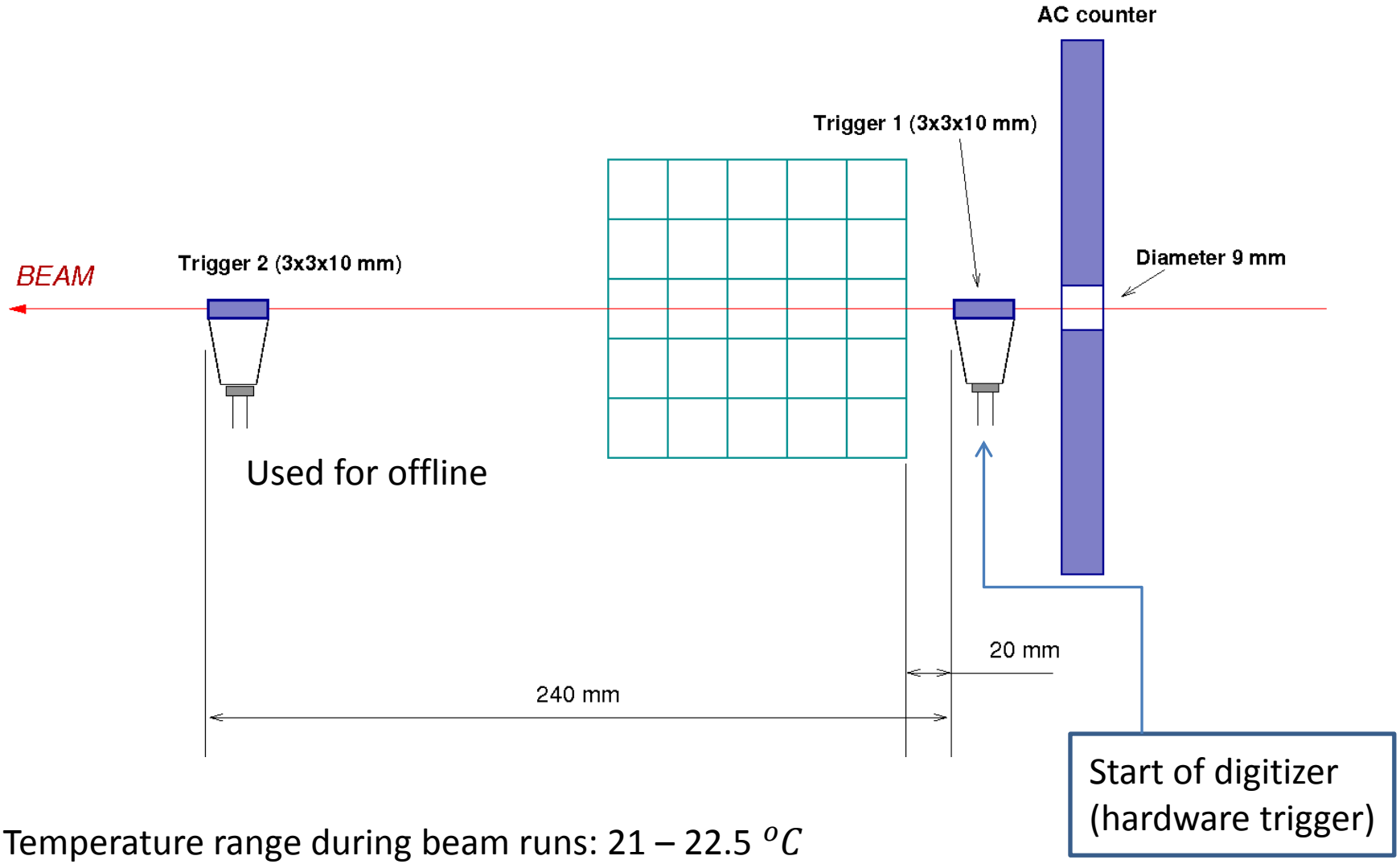
Cube assembling at INR RAS

- 125 cubes, 75 readout channels:
  - WLS fibers: Kuraray Y11(200) S-type, 1mm diameter, 1.3 m long
    - Reflector at far end of the fiber: Silvershine Al paint
  - MPPC: S12571-025C, 1x1 mm, PDE about 35% for green light at Ubias = 67.5 V
  - Digitizer CAEN DT5742: 200 ns time window at 5 GHz sampling rate

The cube inside support frame at CERN

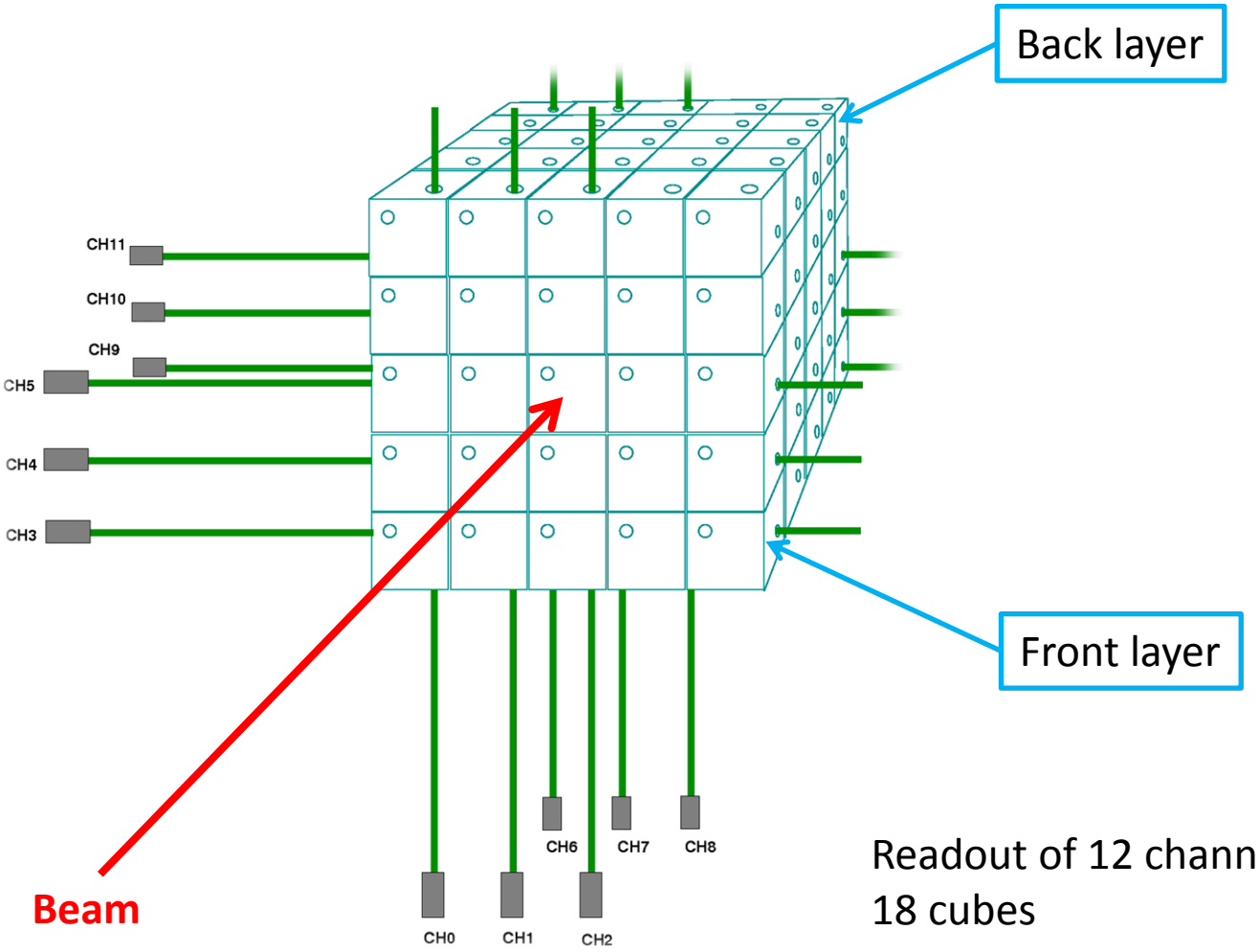


Beam test scheme (side view)



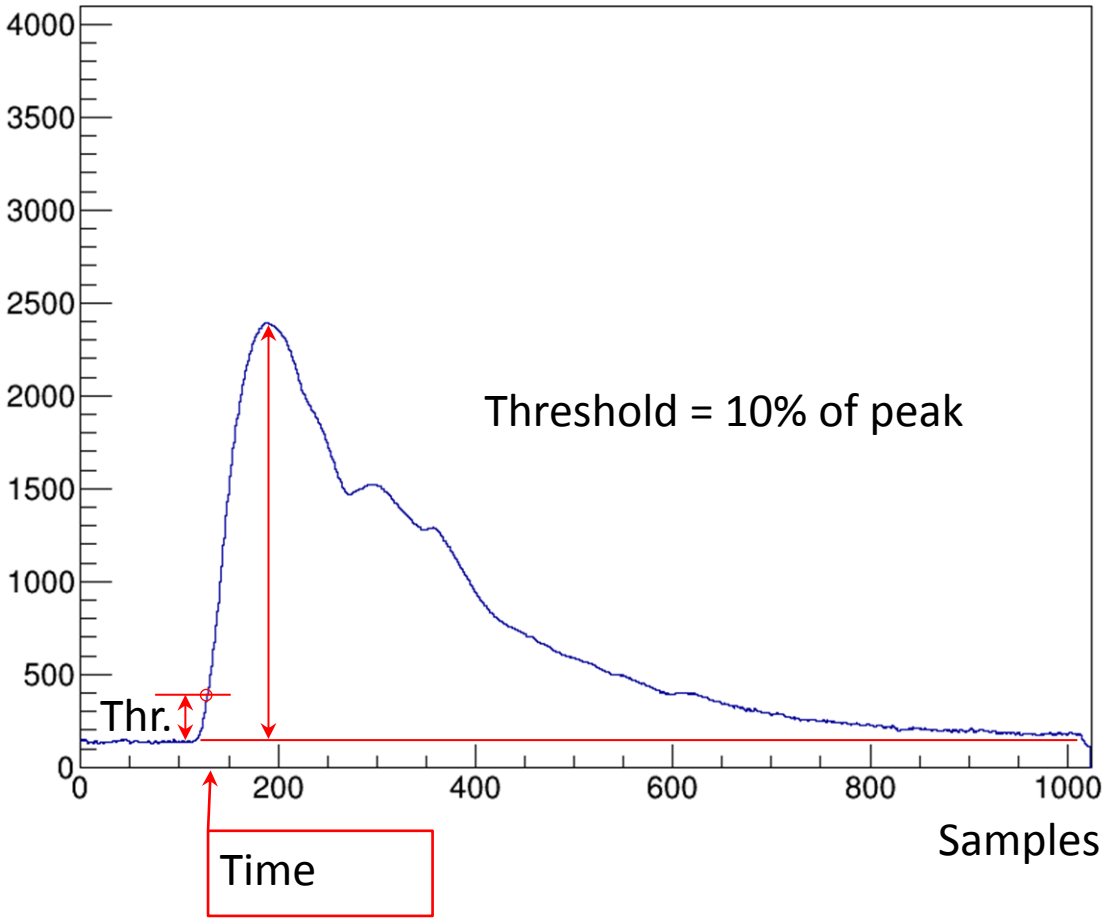
Temperature range during beam runs: 21 – 22.5 ^{o}C

Channel map for digitizer

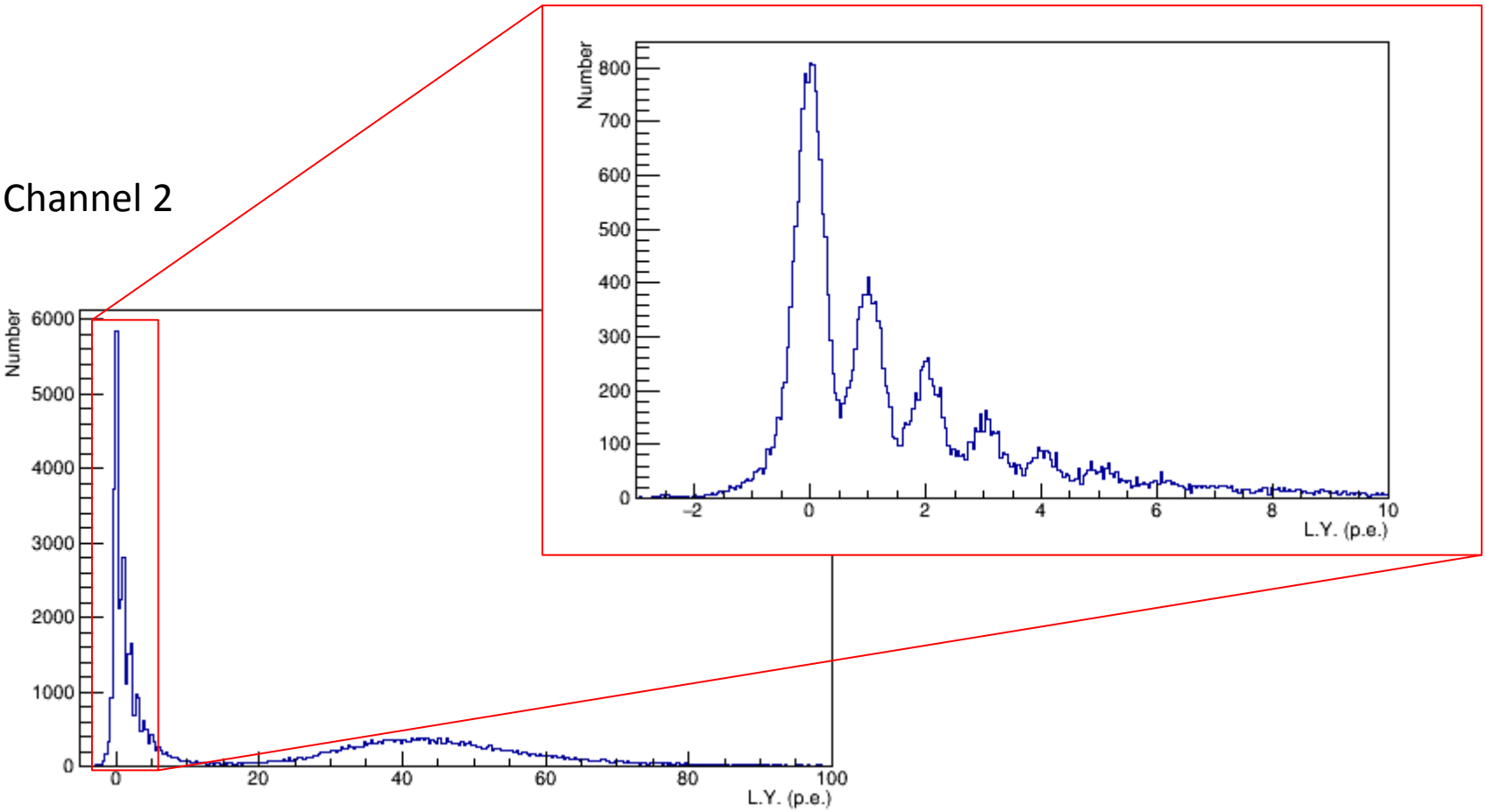


Readout of 12 channels,
18 cubes

Typical signal waveform, 200ns @ 5GS/s

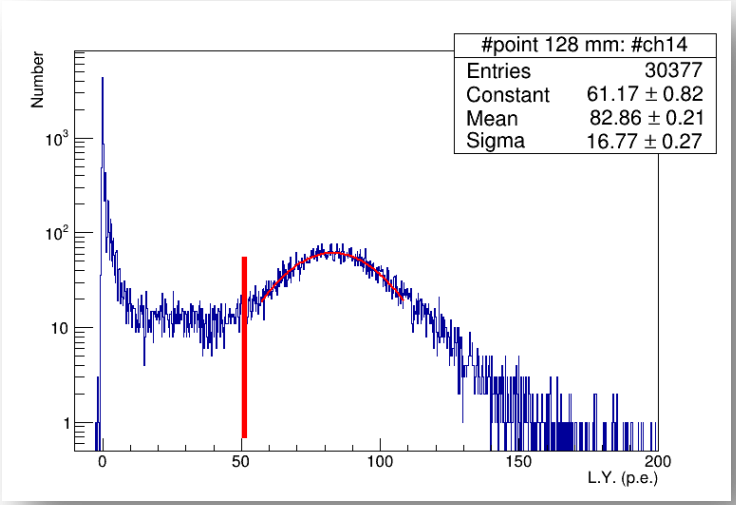


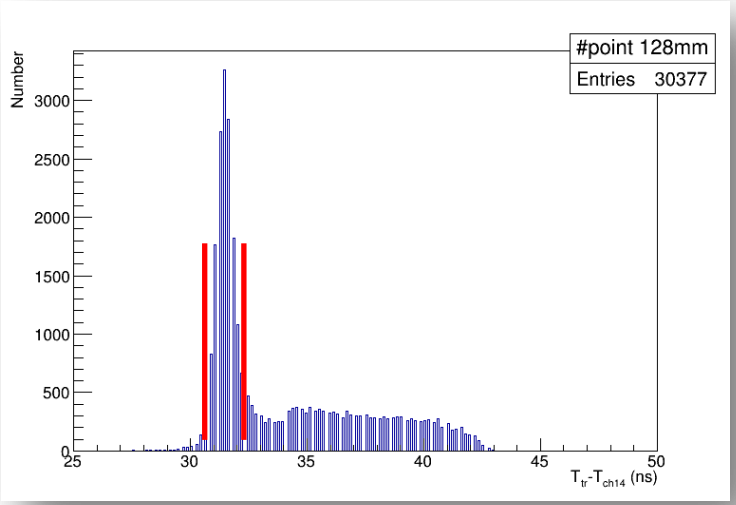
Single photoelectron peaks



Channels can be calibrated for each run

Event selection: Trigger counter #2

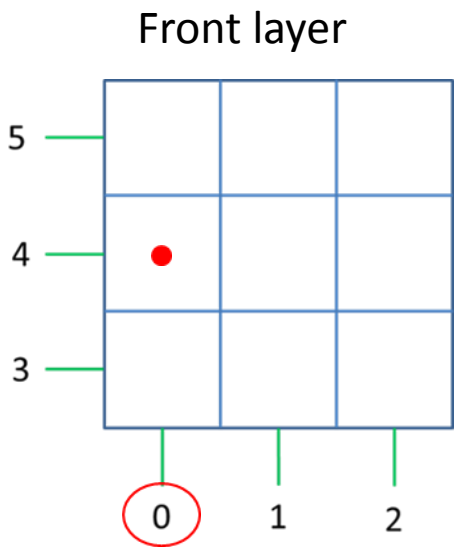


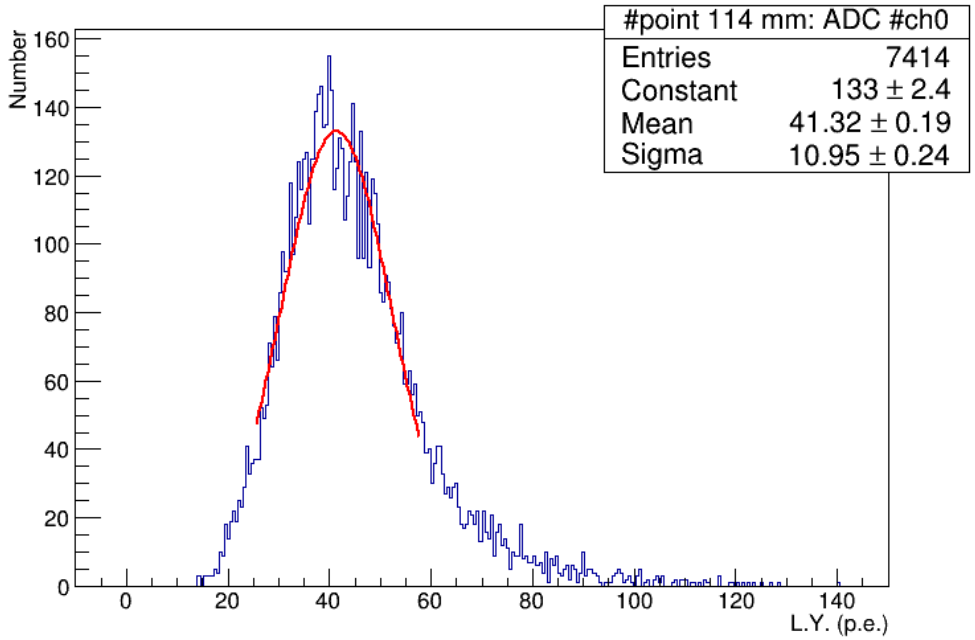


Cuts:

- $L.Y._{tr2} > 50\ p.e.$
- Window $|T_{tr1} - T_{tr2}| < 1\ ns$
- Anti-coincidence counter:
  - $L.Y._{AC1} < 10\ (\mathrm{p.e.})$
  - $L.Y._{AC2} < 10\ (\mathrm{p.e.})$

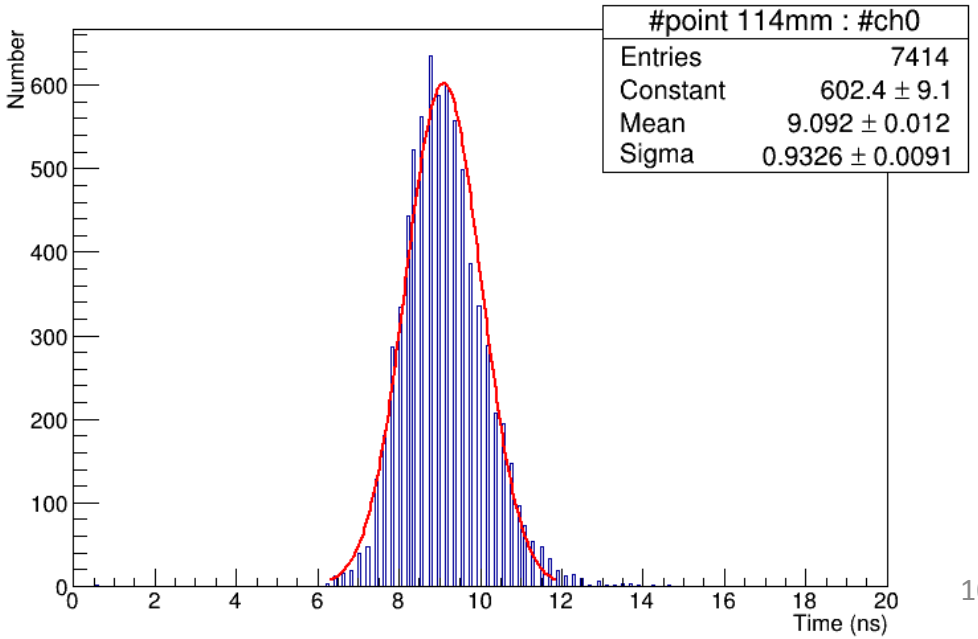
Beam position 114 mm , cube #121, ch0



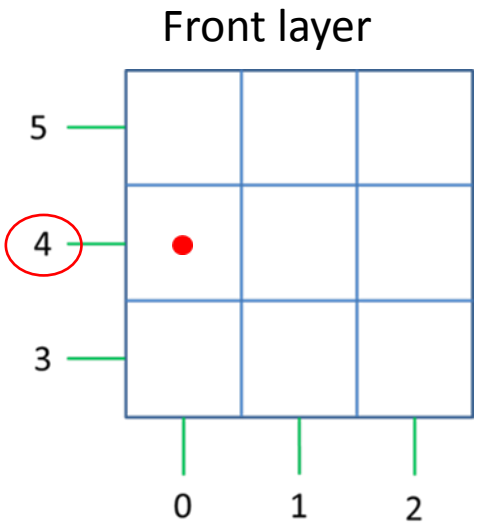


- L.Y. = 41.3 p.e.
- Time resolution = 0.93 ns

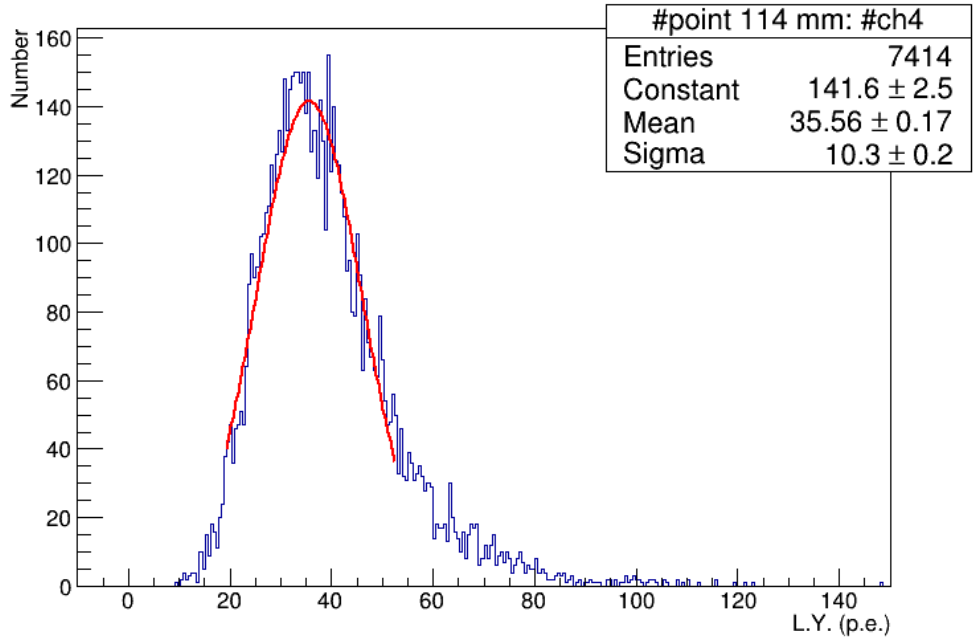
Time = $T_{ch0} - T_{tr2}$

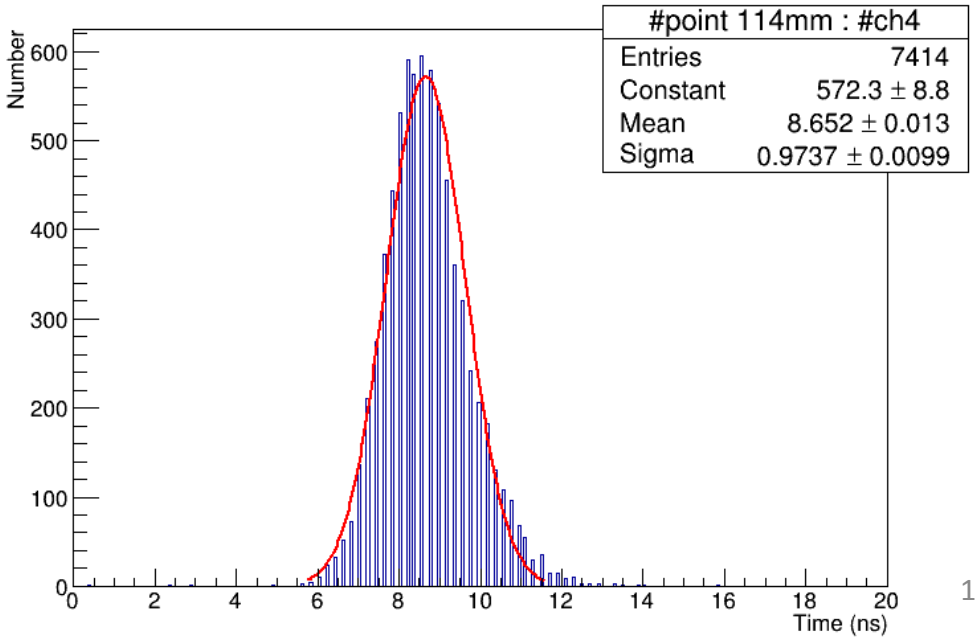


Beam position 114 mm , cube #121. ch4

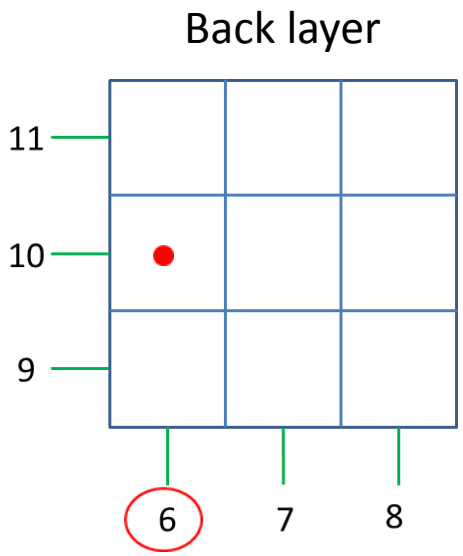


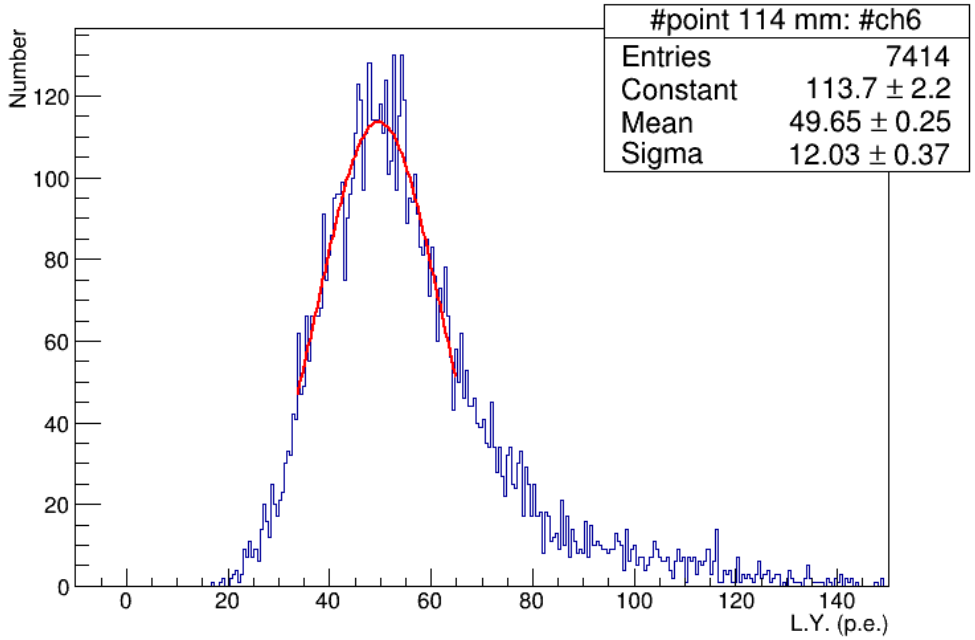
- L.Y. = 35.6 p.e.
- Time resolution = 0.97 ns

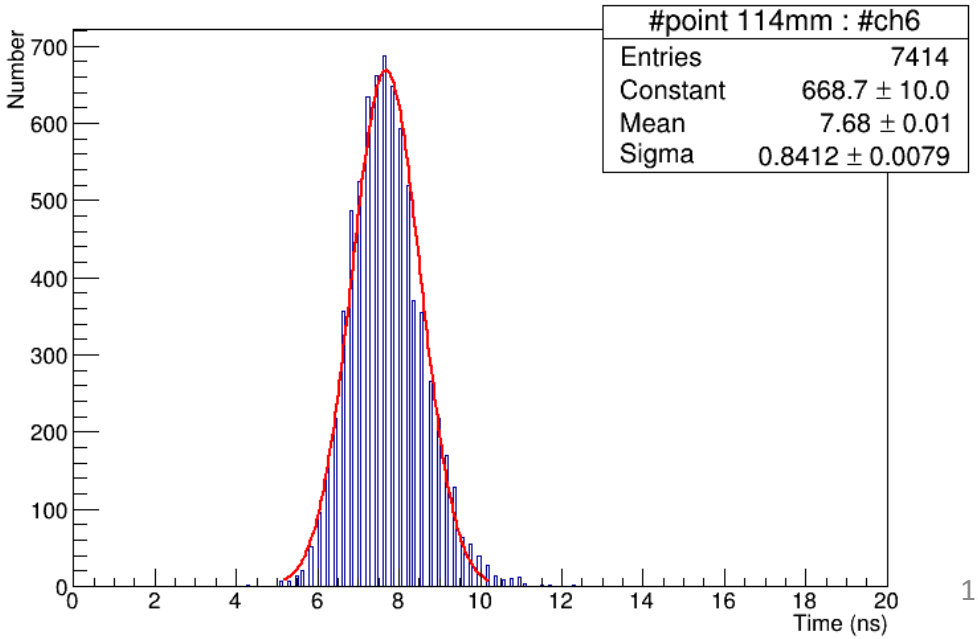




Beam position 114 mm , cube #125, ch6

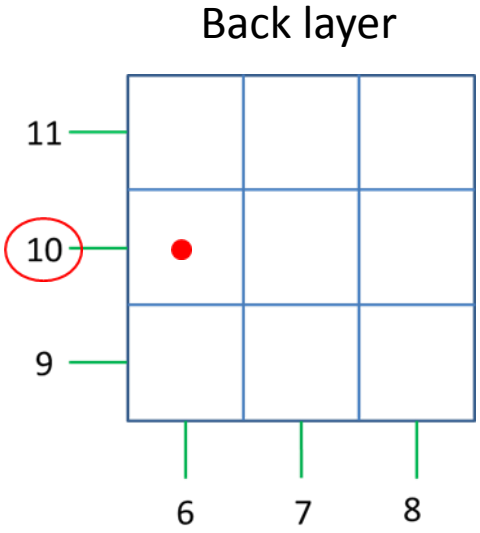


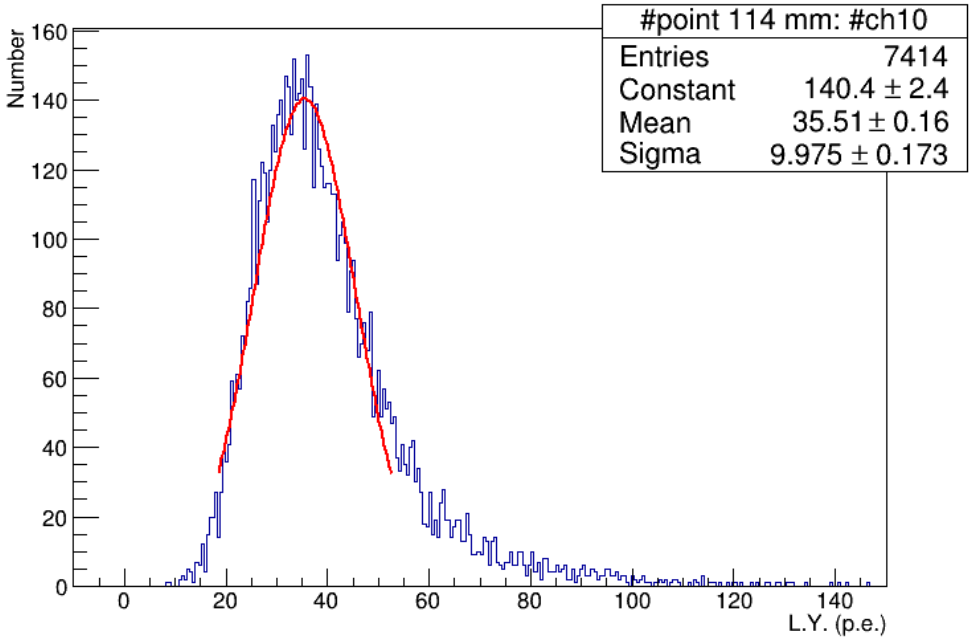




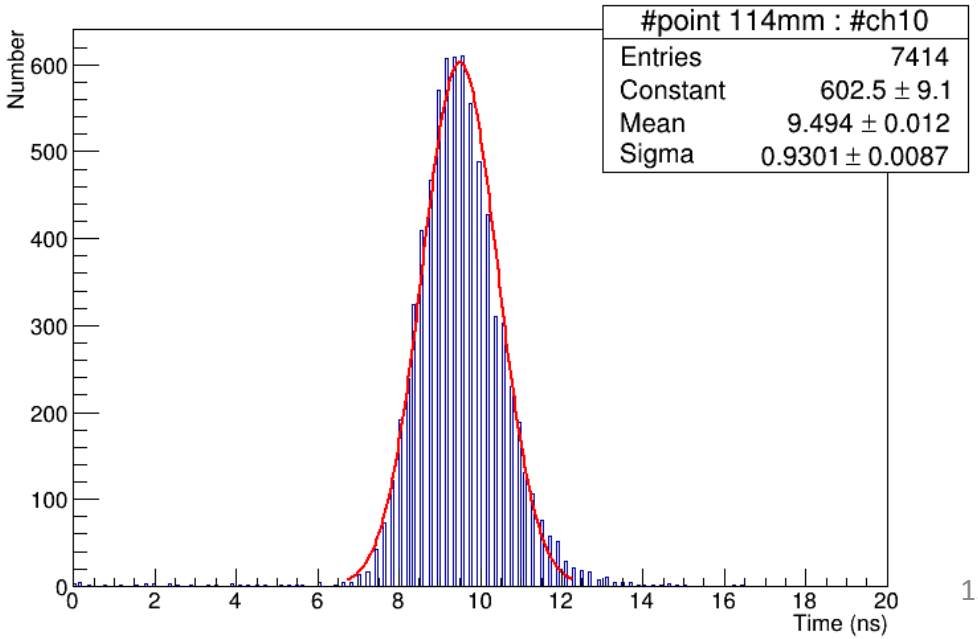
- L.Y. = 49.7 p.e.
- Time resolution = 0.84 ns

Beam position 114 mm , cube #125, ch10

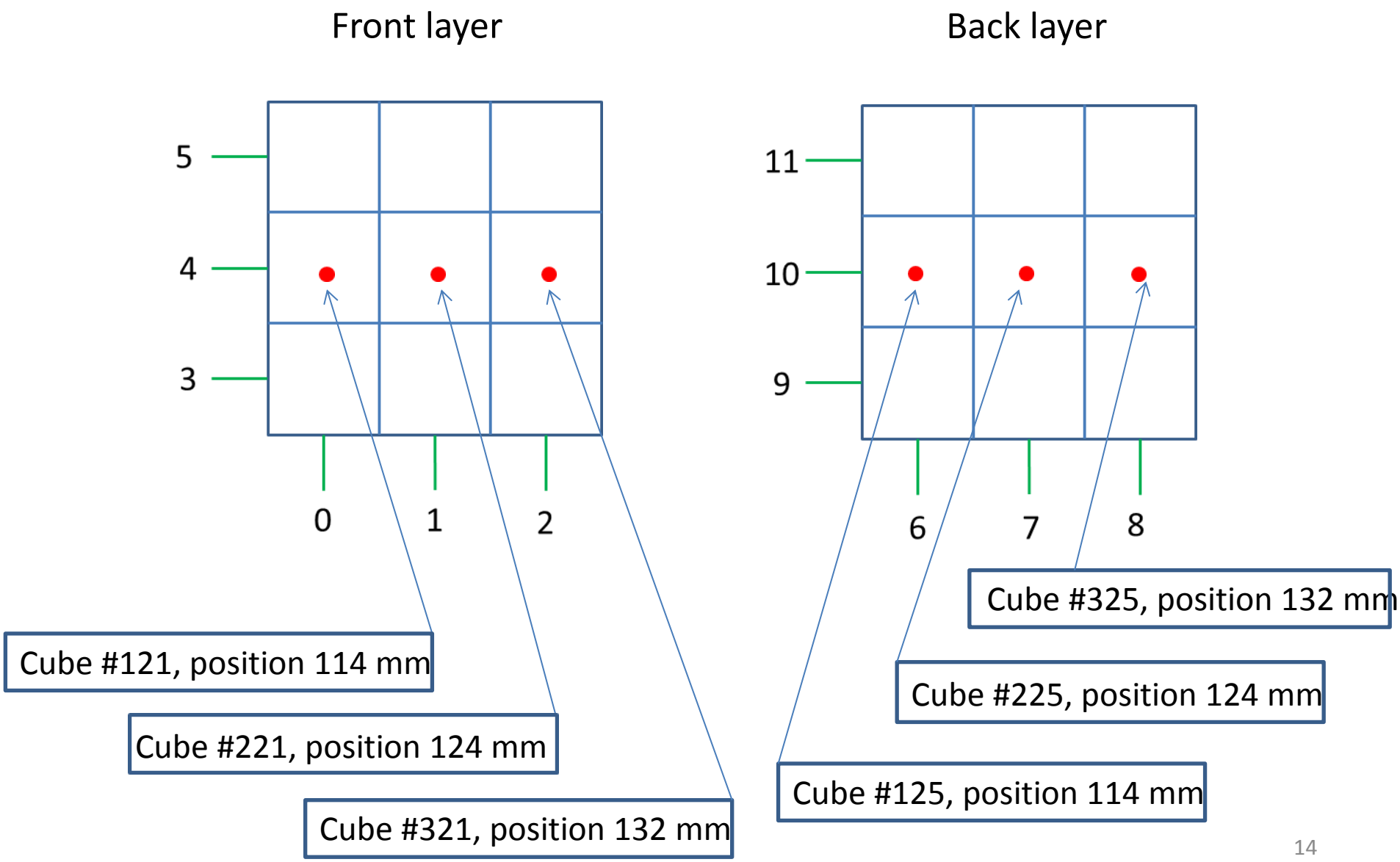




- L.Y. = 35.5 p.e.
- Time resolution = 0.93 ns



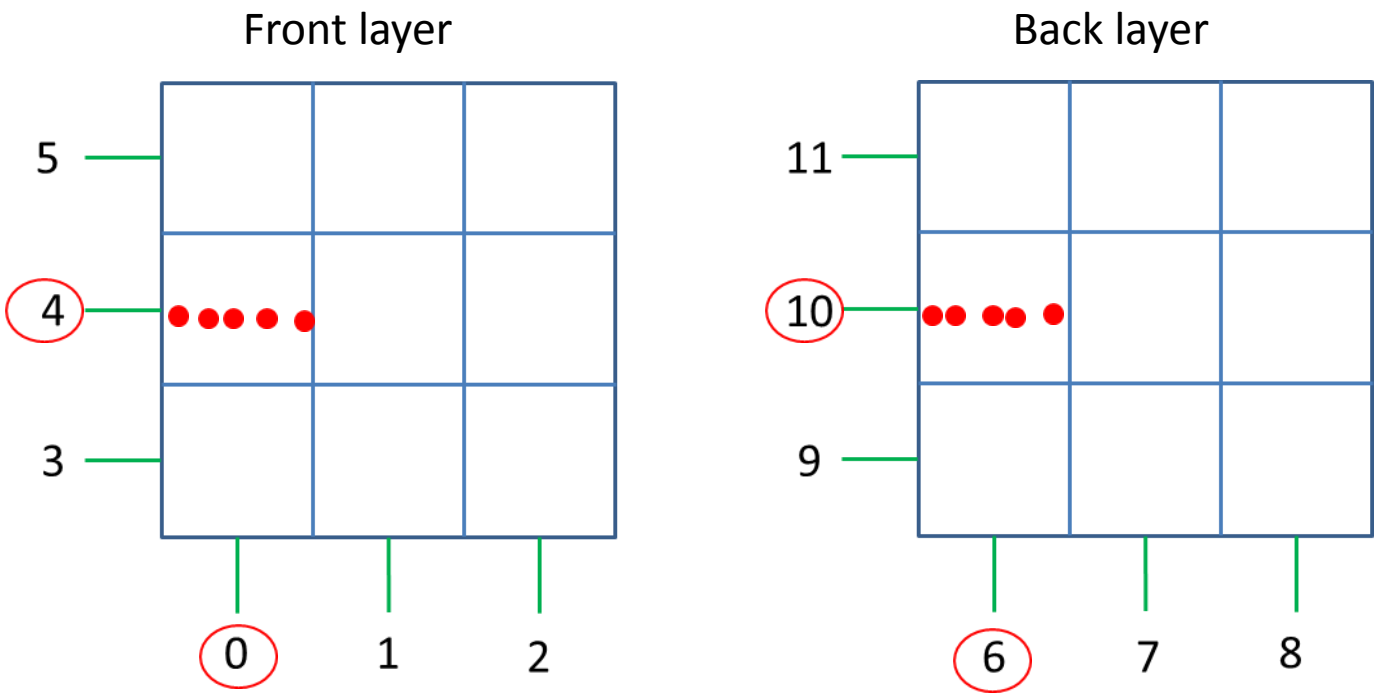
Measurement points



L.Y. and time resolution

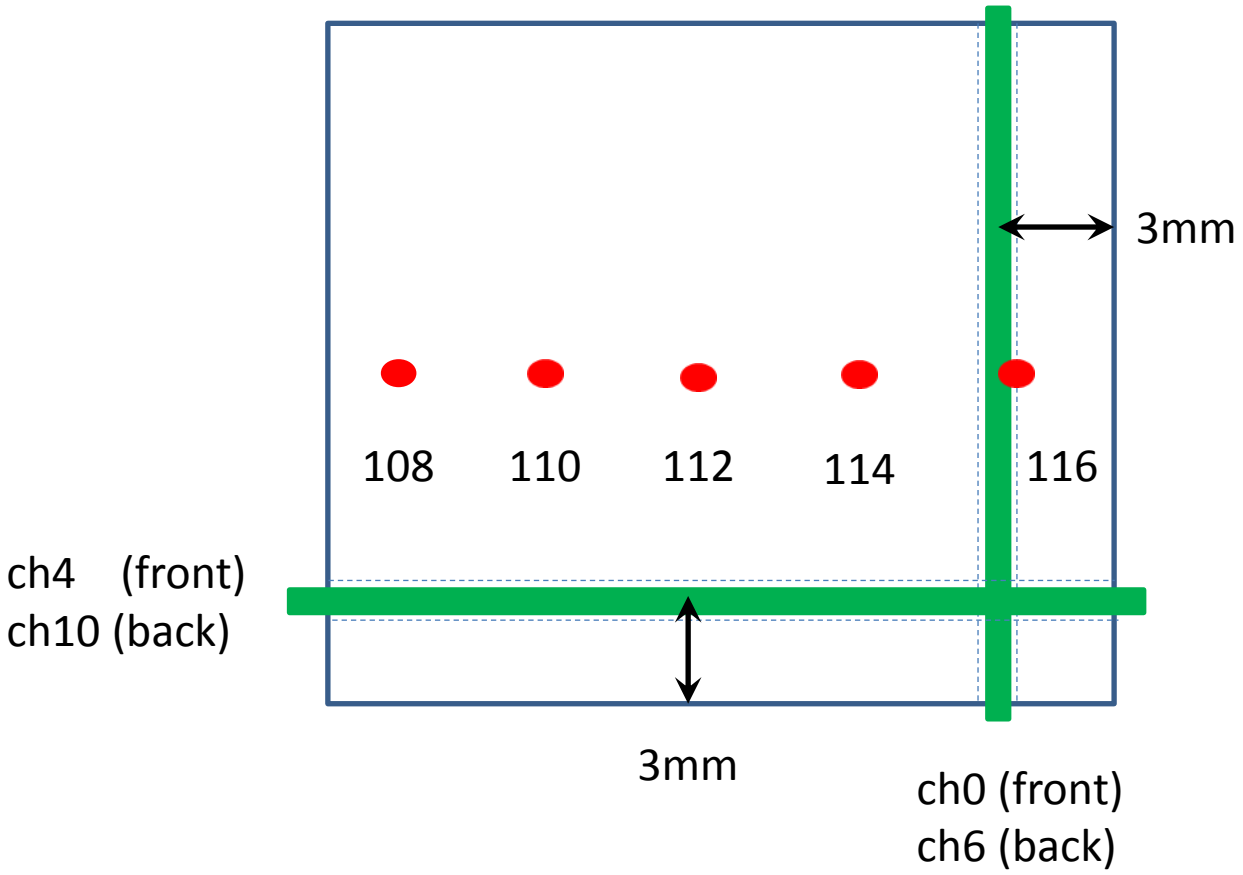
point(mm)	cube	channel	L.Y.(p.e.)	Time resolution(ns)
114	121	0	41.3	0.93
		4	35.6	0.97
	125	6	49.7	0.84
		10	35.5	0.93
124	221	1	41.5	0.90
		4	38.8	0.93
	225	7	46.2	0.86
		10	36.9	0.89
132	321	2	33.2	1.00
		4	40.3	0.92
	325	8	42.1	0.86
		10	38.6	0.89

Scan with step of 2 mm



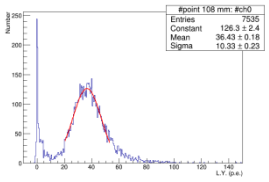
Point positions: 108, 110, 112, 114, 116 mm
For cube #121 (front layer) and cube #125 (back layer)

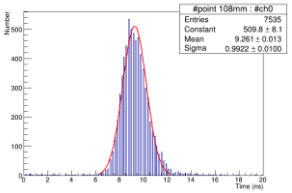
Fiber positions inside a cube



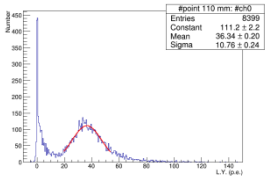
Scan for cube #121, ch0 (across fiber)

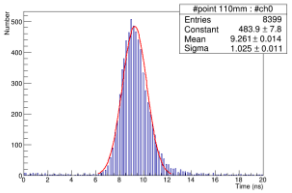
108



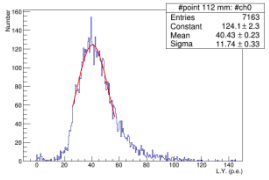


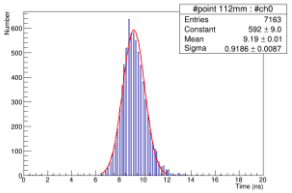
110



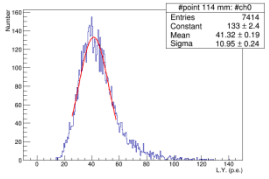


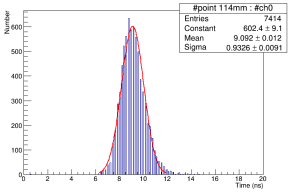
112



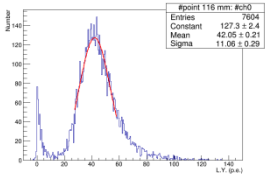


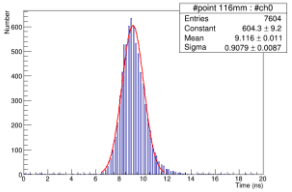
114





116

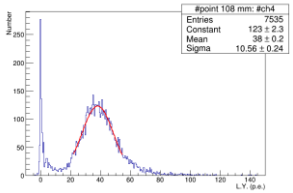


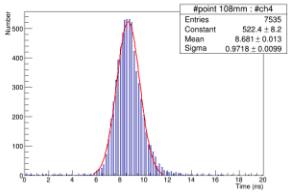


point (mm)	L.Y. (p.e.)	Time Resolution (ns)
108	36.4	0.99
110	36.3	1.03
112	40.4	0.92
114	41.3	0.93
116	42.1	0.91

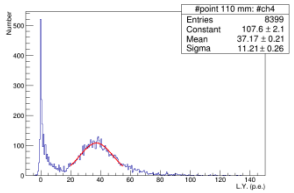
Scan for cube #121, ch4 (along fiber)

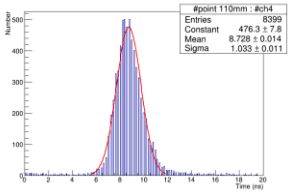
108



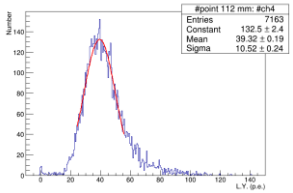


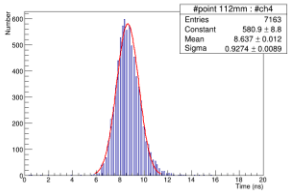
110



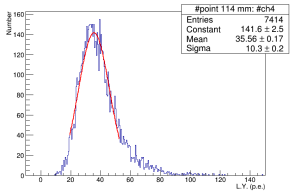


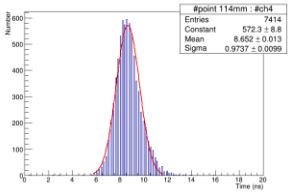
112



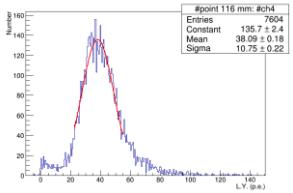


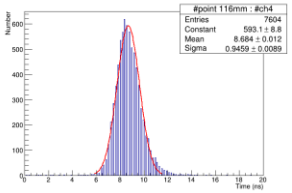
114





116

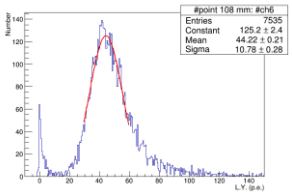


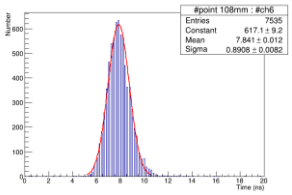


point (mm)	L.Y. (p.e.)	Time resolution (ns)
108	38.0	0.97
110	37.2	1.03
112	39.3	0.93
114	35.6	0.97
116	38.1	0.95

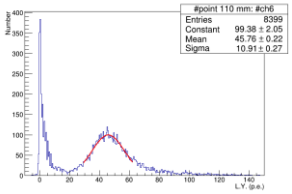
Scan for cube #125, ch6 (across fiber)

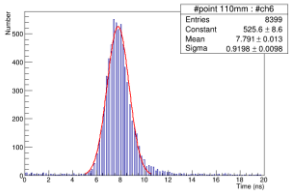
108



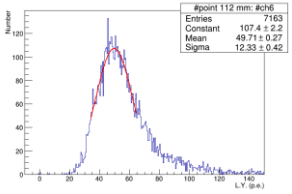


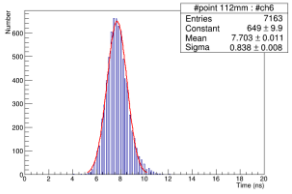
110



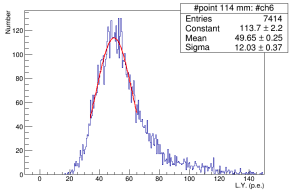


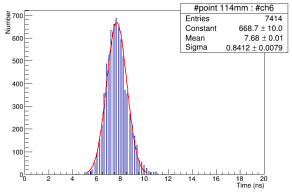
112



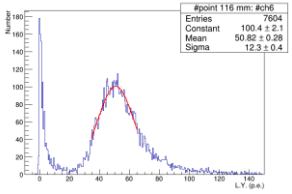


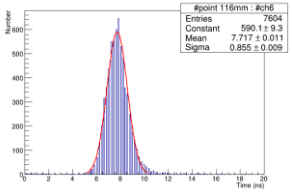
114





116

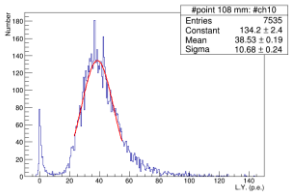


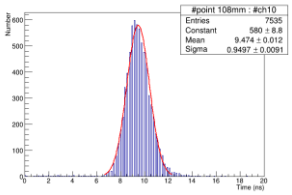


point (mm)	L.Y. (p.e.)	Time resolution (ns)
108	44.2	0.89
110	45.8	0.92
112	49.7	0.84
114	49.7	0.84
116	50.8	0.86

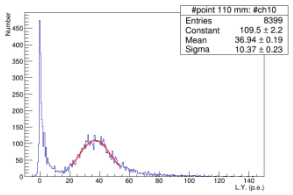
Scan for cube #125, ch10 (along fiber)

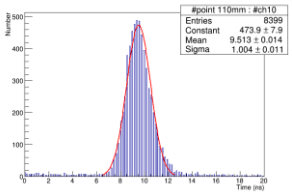
108



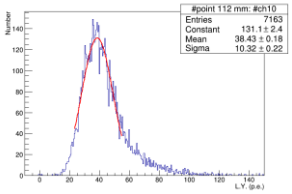


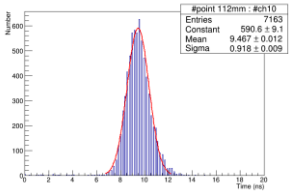
110



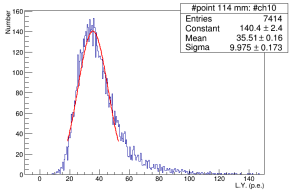


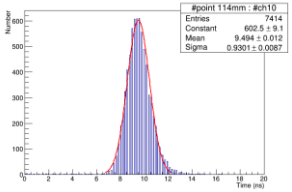
112



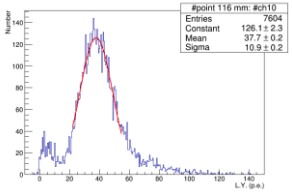


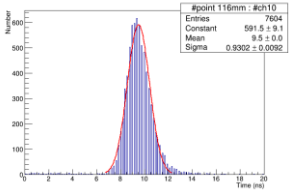
114





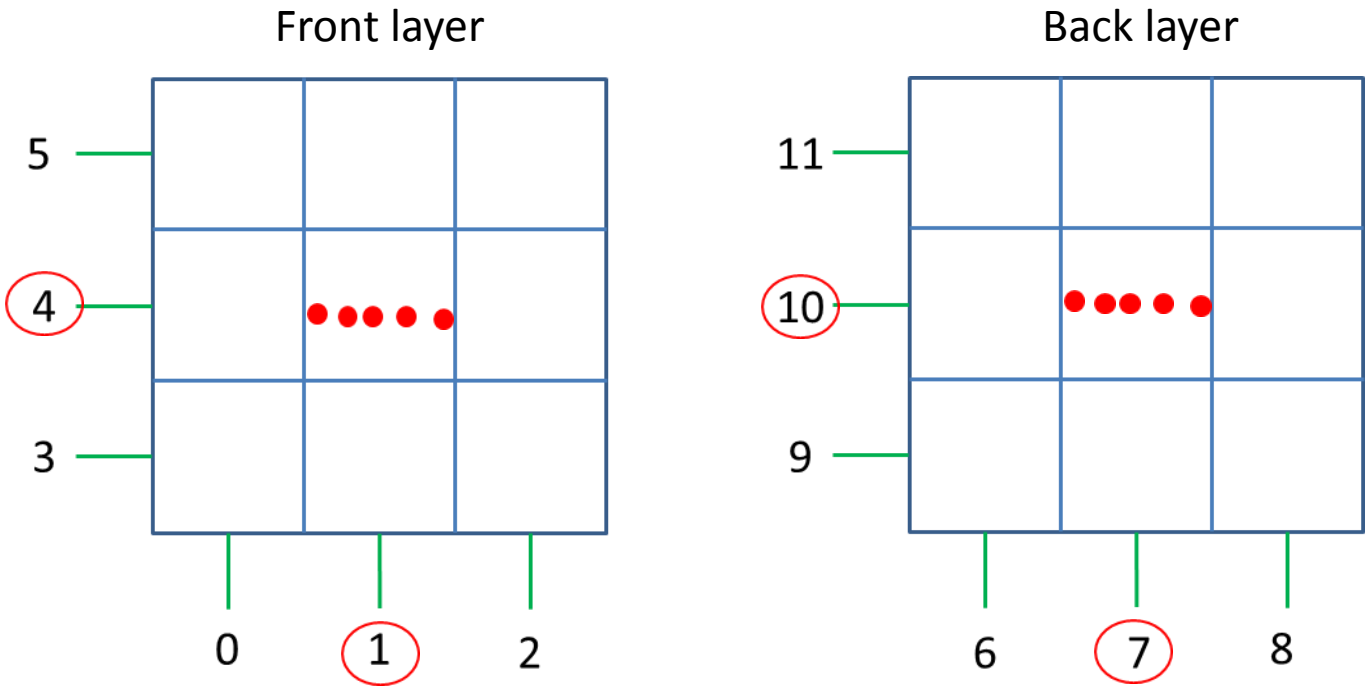
116





point (mm)	L.Y. (p.e.)	Time resolution (ns)
108	38.5	0.95
110	36.9	1.00
112	38.4	0.92
114	35.5	0.93
116	37.7	0.93

Scan with step of 2 mm

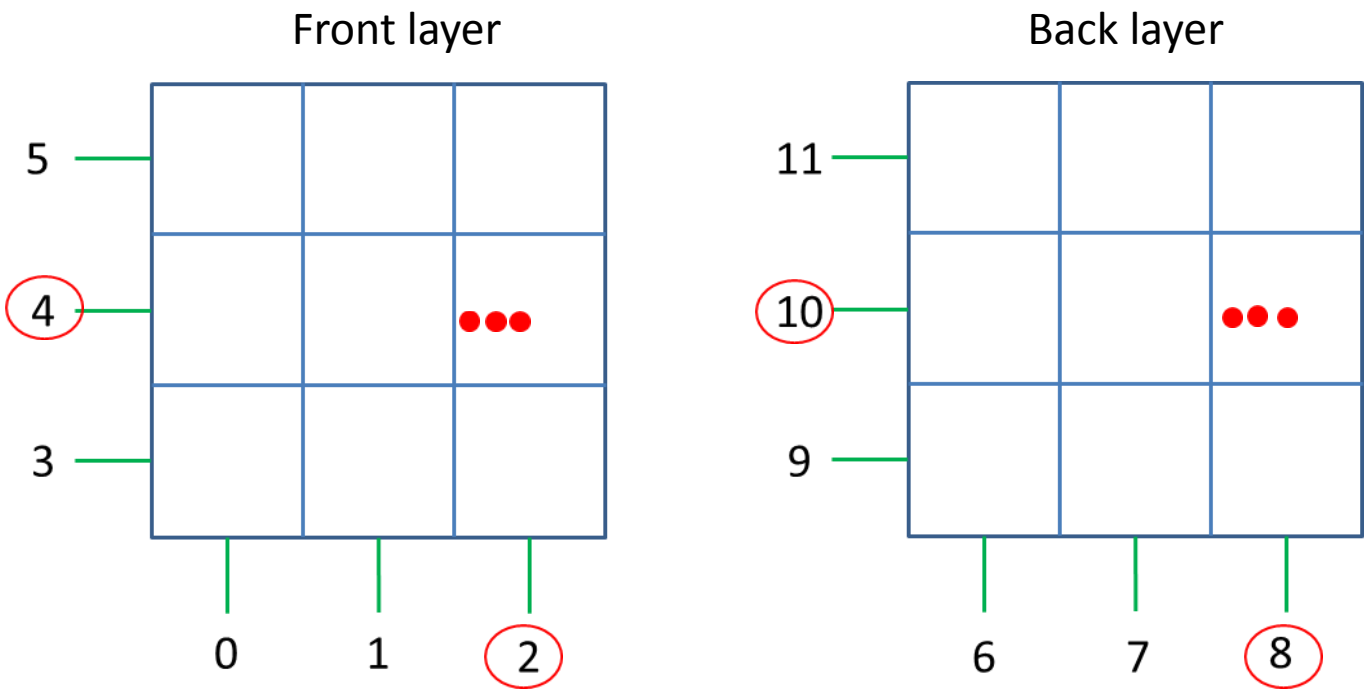


Point positions: 118, 120, 122, 124, 126 mm
For cube #221(front layer) and cube #225 (back layer)

Scan for cube #221 and cube #225:

point (mm)	cube #221				cube #225			
	ch #1		ch #4		ch #7		ch #10	
	L.Y. (p.e.)	σ_t (ns)	L.Y. (p.e.)	σ_t (ns)	L.Y. (p.e.)	σ_t (ns)	L.Y. (p.e.)	σ_t (ns)
118	37.8	0.96	40.7	0.95	42.4	0.91	40.0	0.91
120	38.4	0.96	40.3	0.96	43.3	0.94	38.7	0.95
122	40.5	0.91	40.9	0.93	46.8	0.85	40.3	0.88
124	41.5	0.90	38.8	0.93	46.2	0.86	36.9	0.89
126	42.7	0.88	40.1	0.94	47.6	0.87	38.8	0.90

Scan with step of 2 mm

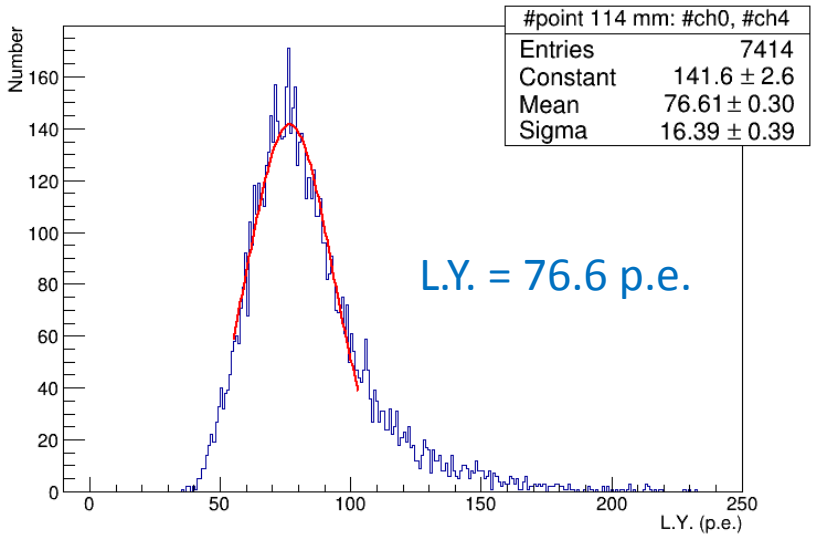


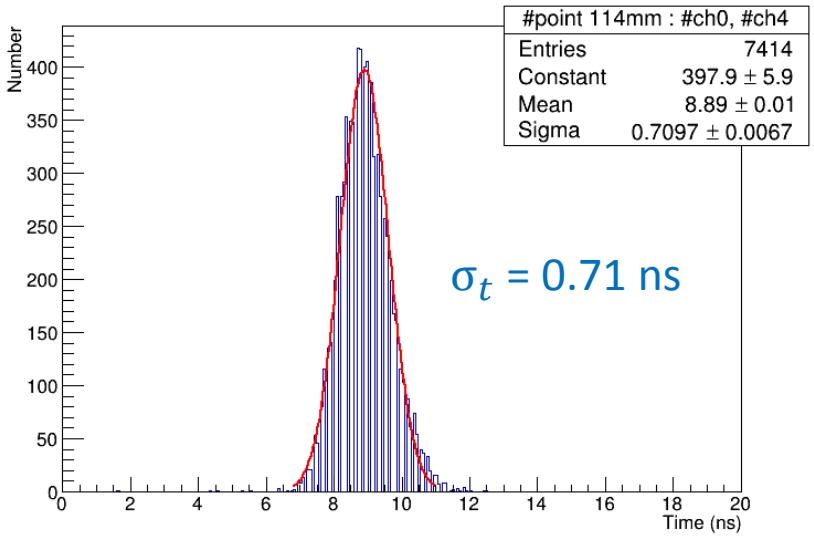
Point positions: 128, 130, 132 mm
For cube #321(front layer) and cube #325(back layer)

Scan for cube#321 and cube#325:

point (mm)	cube #321				cube #325			
	ch #2		ch #4		ch #8		ch #10	
	L.Y. (p.e.)	σ_t(ns)	L.Y. (p.e.)	σ_t (ns)	L.Y. (p.e.)	σ_t (ns)	L.Y. (p.e.)	σ_t (ns)
128	29.6	1.03	39.8	0.93	37.3	0.93	37.6	0.90
130	29.6	1.05	38.2	0.94	37.6	0.98	35.2	0.96
132	33.2	1.00	40.3	0.92	42.1	0.86	38.6	0.89

L.Y. and time resolution for cube#121, point 114 mm, ch0 and ch4 combined





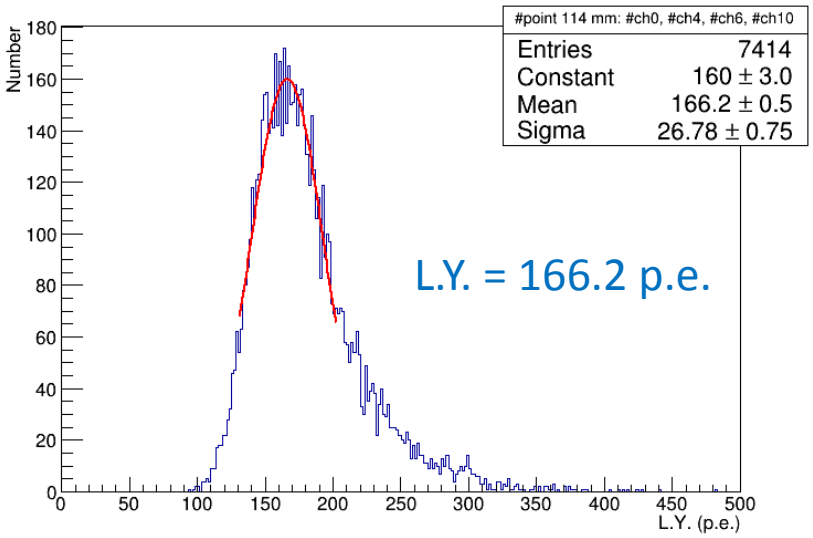
$$L.Y._{cube} = L.Y._{ch0} + L.Y._{ch4}$$

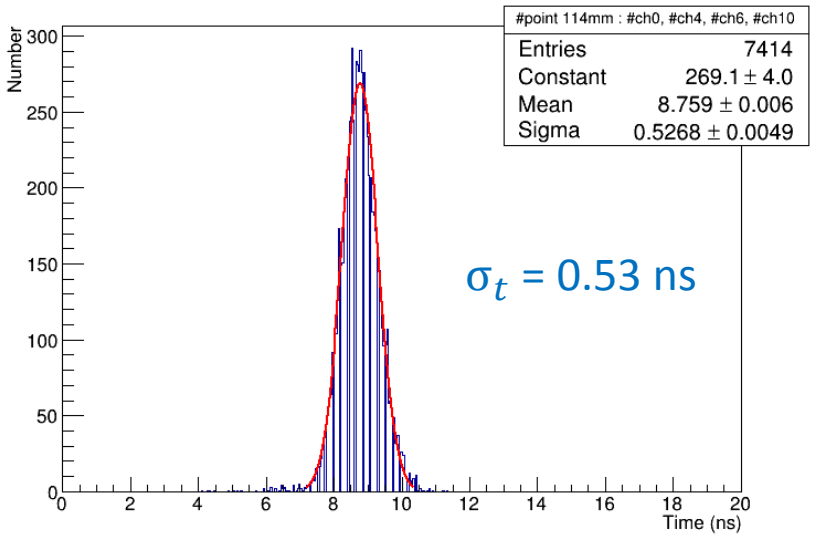
$$T_{cube} = \left((T_{ch0} - T_{tr2}) + (T_{ch4} - T_{tr2})\right)/2$$

L.Y. and time resolution for cubes (two fibers combined)

point (mm)	cube	L.Y. (p.e.)	Time resolution (ns)
114	121	76.6	0.71
	125	84.7	0.66
124	221	80.0	0.68
	225	83.1	0.65
132	321	73.5	0.72
	325	80.9	0.66

L.Y. and time resolution, point 114 mm, cube#121 + cube#125





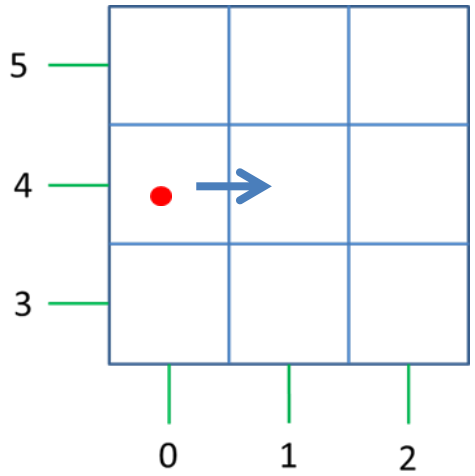
$L.Y._{track} = L.Y._{cube121} + L.Y._{cube125}$

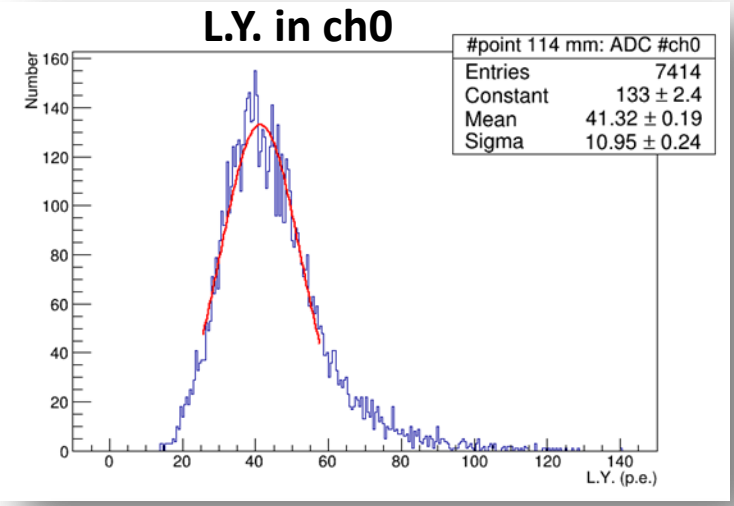
$T_{track} = (T_{cube121} + T_{cube125})/2$

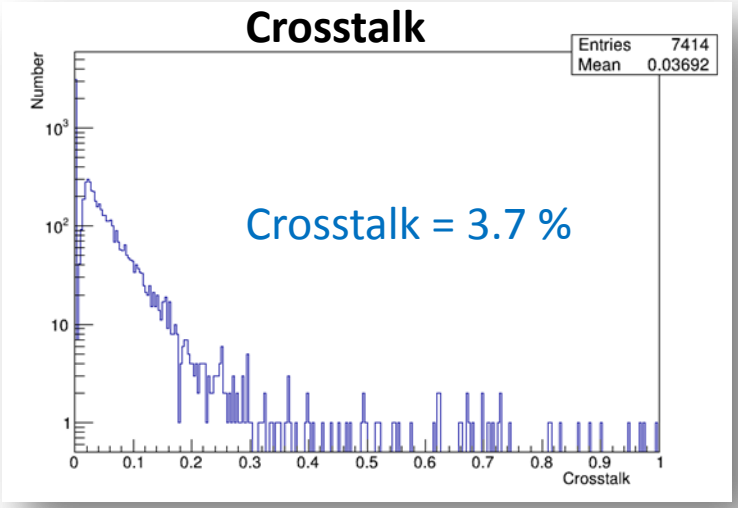
L.Y. and time resolution, front + back cubes

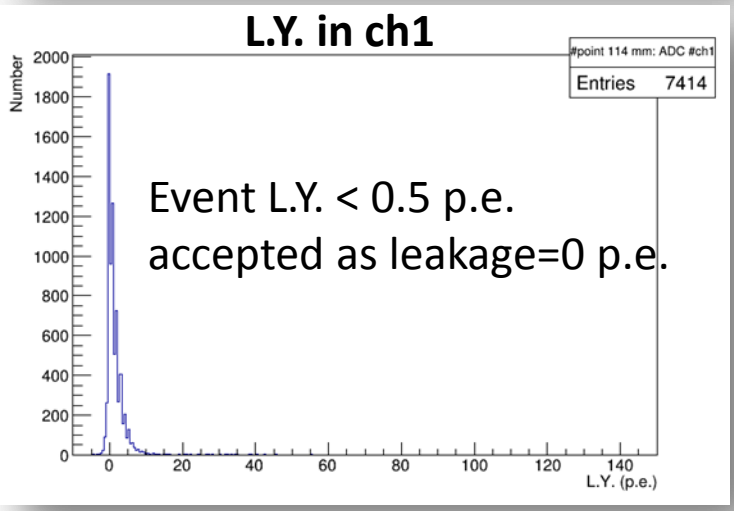
point (mm)	track	L.Y. (p.e.)	Time resolution (ns)
114	cube #121 cube #125	166.2	0.53
124	cube #221 cube #225	167.9	0.51
132	cube #321 cube #325	158.3	0.52

Crosstalk=$\left(\frac{LY_{ch1}}{LY_{ch0}}\right)$, point 114 mm



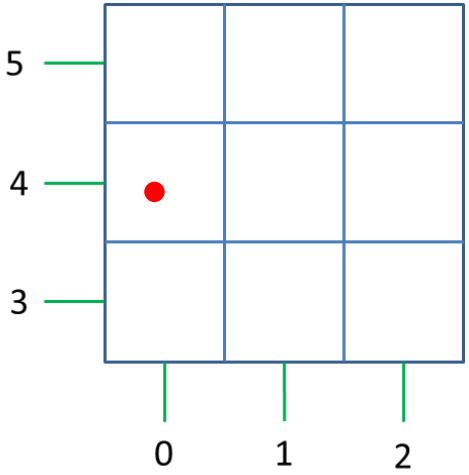






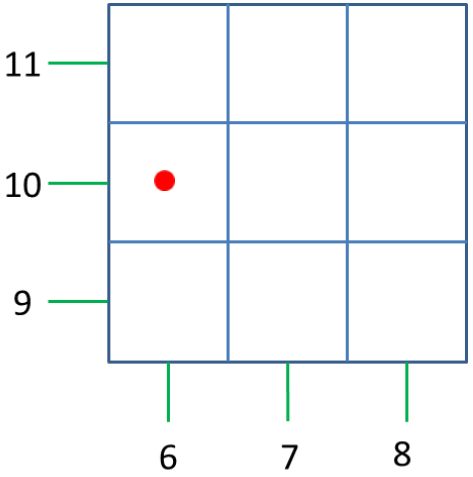
Crosstalk , point 114 mm

Front layer



Crosstalk	Value (%)
LY_{ch1}/LY_{ch0}	3.69
LY_{ch2}/LY_{ch0}	0.55
LY_{ch3}/LY_{ch4}	3.16
LY_{ch5}/LY_{ch4}	4.50

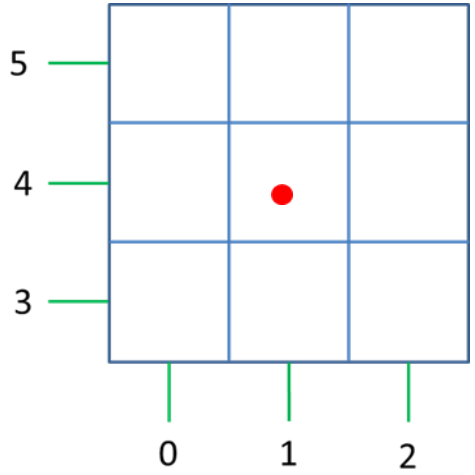
Back layer



Crosstalk	Value (%)
LY_{ch7}/LY_{ch6}	3.73
LY_{ch8}/LY_{ch6}	0.45
LY_{ch9}/LY_{ch10}	2.86
LY_{ch11}/LY_{ch10}	5.62

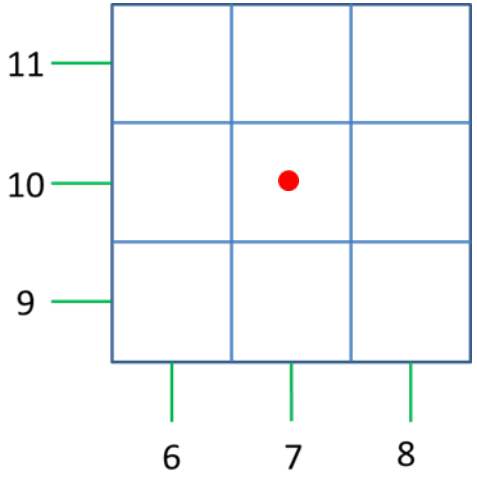
Crosstalk , point 124 mm

Front layer



Crosstalk	Value (%)
LY_{ch0}/LY_{ch1}	3.22
LY_{ch2}/LY_{ch1}	3.24
LY_{ch3}/LY_{ch4}	3.46
LY_{ch5}/LY_{ch4}	3.77

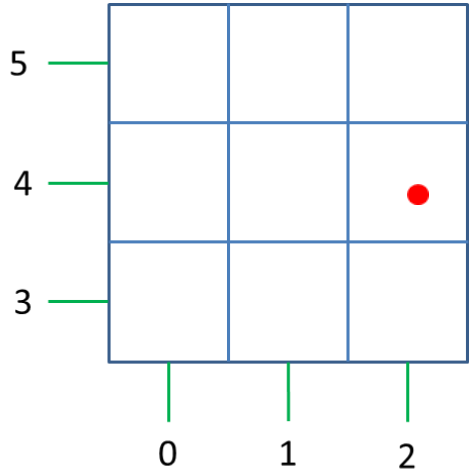
Back layer



Crosstalk	Value (%)
LY_{ch6}/LY_{ch7}	3.07
LY_{ch8}/LY_{ch7}	3.63
LY_{ch9}/LY_{ch10}	3.30
LY_{ch11}/LY_{ch10}	6.17

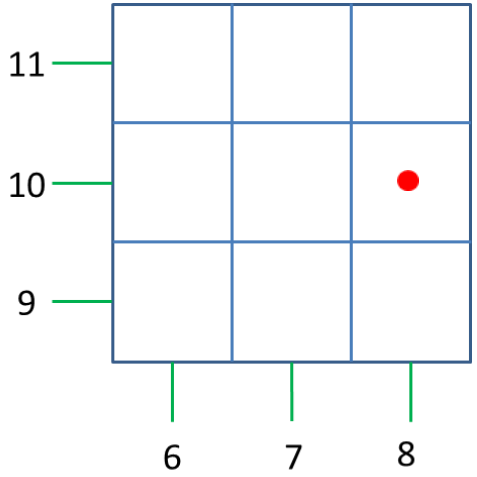
Crosstalk , point 132 mm

Front layer



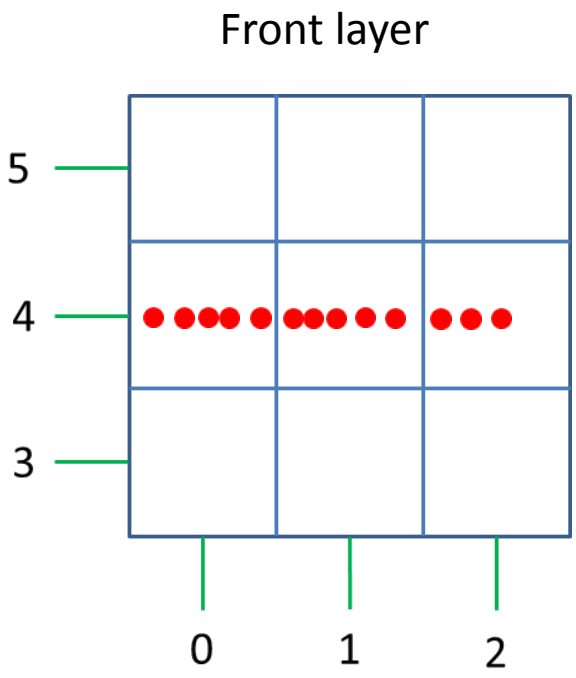
Crosstalk	Value (%)
LY_{ch1}/LY_{ch2}	4.98
LY_{ch0}/LY_{ch2}	0.56
LY_{ch3}/LY_{ch4}	3.52
LY_{ch5}/LY_{ch4}	4.85

Back layer



Crosstalk	Value (%)
LY_{ch7}/LY_{ch8}	3.91
LY_{ch6}/LY_{ch8}	0.44
LY_{ch9}/LY_{ch10}	3.72
LY_{ch11}/LY_{ch10}	6.33

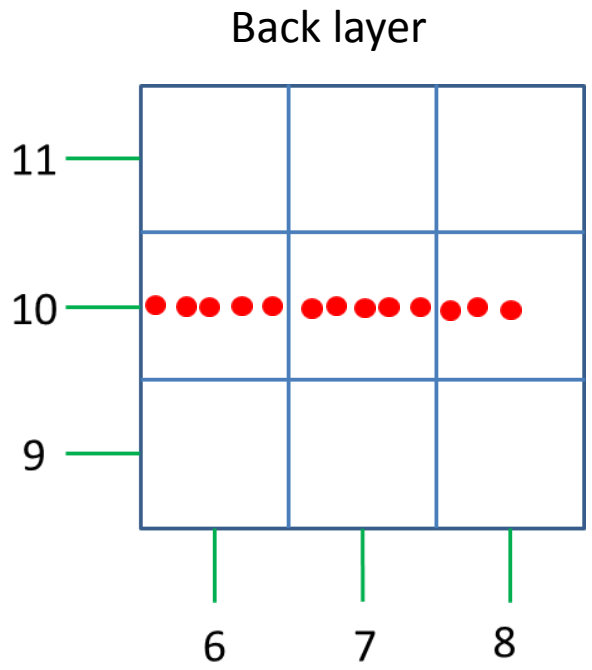
Crosstalk = $\frac{LY_{ch3}+LY_{ch5}}{LY_{ch4}}$ (front layer)



Average crosstalk = 7.36 (%)

#point (mm)	Crosstalk (%)
108	6.84
110	7.30
112	7.36
114	7.52
116	7.26
118	7.02
120	6.72
122	7.20
124	7.08
126	7.36
128	8.04
130	7.77
132	8.22

Crosstalk = $\frac{LY_{ch9}+LY_{ch11}}{LY_{ch10}}$ (back layer)

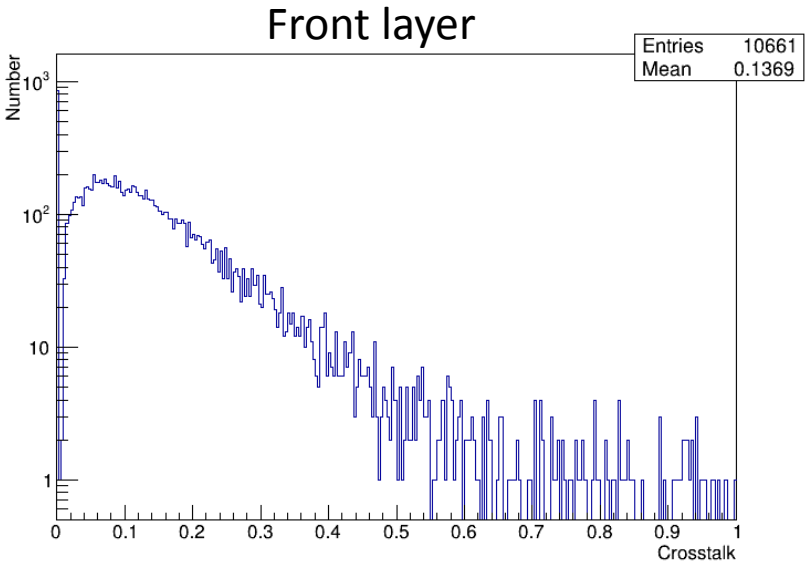


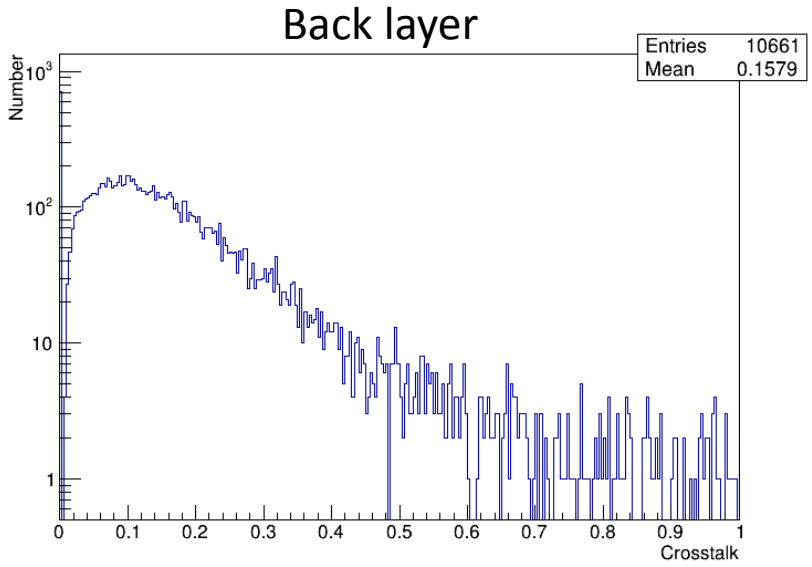
Average crosstalk = 8.64 (%)

Back layer has small angular misalignment relative to the beam.

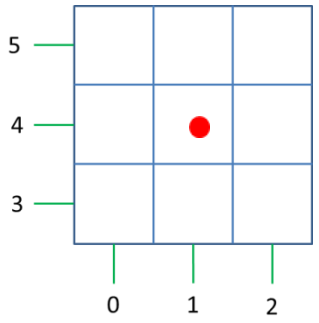
#point (mm)	Crosstalk (%)
108	7.46
110	6.99
112	7.78
114	8.31
116	8.00
118	9.16
120	8.13
122	8.98
124	9.31
126	9.54
128	9.81
130	8.93
132	9.87

Crosstalk leaked to four sides



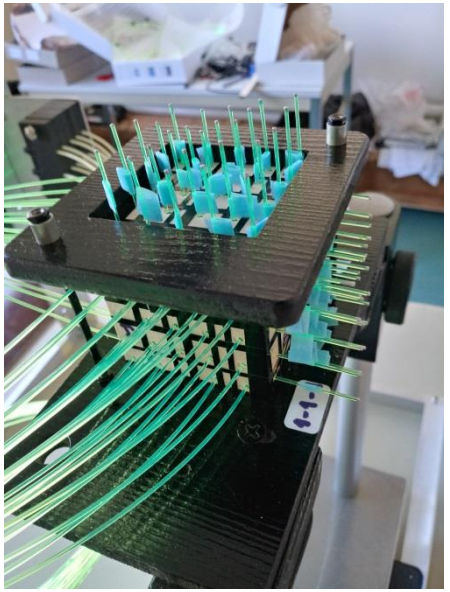


$$C_{front} = \frac{1}{2}\left(\frac{LY_{ch0}+LY_{ch2}+LY_{ch3}+LY_{ch5}}{LY_{ch1}-LY_{ch3}-LY_{ch5}} + \frac{LY_{ch3}+LY_{ch5}+LY_{ch0}+LY_{ch2}}{LY_{ch4}-LY_{ch0}-LY_{ch2}}\right) = \mathbf{13.69\ \%}$$



$$C_{back} = \frac{1}{2}\left(\frac{LY_{ch6}+LY_{ch8}+LY_{ch9}+LY_{ch11}}{LY_{ch7}-LY_{ch9}-LY_{ch11}} + \frac{LY_{ch6}+LY_{ch8}+LY_{ch9}+LY_{ch11}}{LY_{ch10}-LY_{ch6}-LY_{ch8}}\right) = \mathbf{15.79\ \%}$$

Summary



Preliminary results with the digitizer:

- Average L.Y. ≈ **41.0 p.e.** per a fiber
- Average L.Y. ≈ **79.8 p.e.** per two fibers (a cube)
- Average σ_t ≈ **0.92 ns** per a fiber
- Average σ_t ≈ **0.68 ns** per two fibers (a cube)
- Average σ_t ≈ **0.53 ns** per two cubes (four fibers)
- Average crosstalk per cube side: Crosstalk ≈ **3.7 %**

Data analysis with multichannel electronics is in progress.