Performance of plastic scintillator detectors with WLS/SiPM readout

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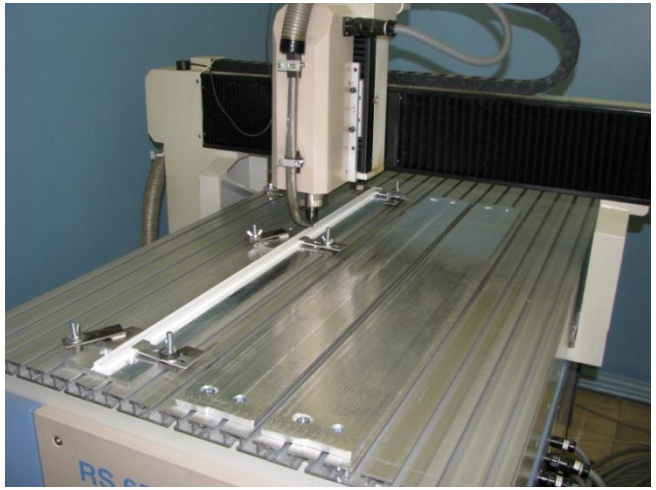
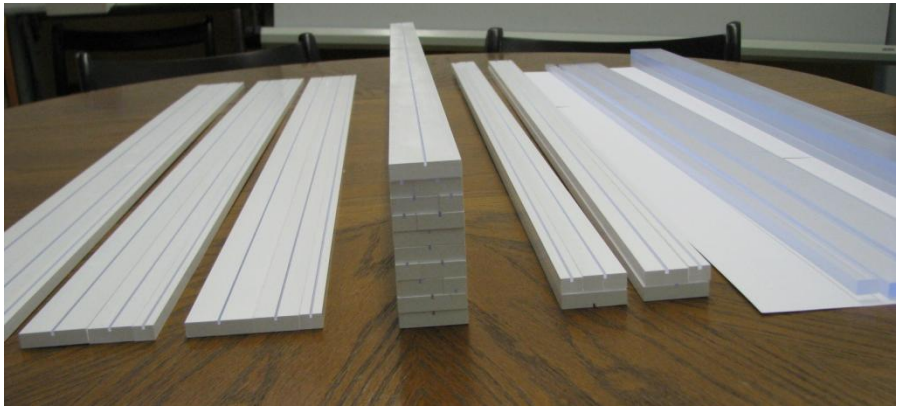
Extruded scintillators

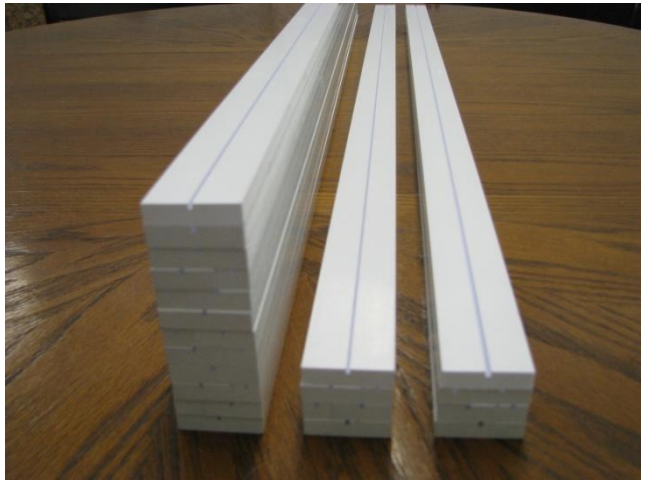
- Extruded scintillator slabs produced at Uniplast company, Vladimir, Russia polysterene based, 1.5% of paraterphenyl (PTP) and 0.01% of POPOP
- Plastics initially used for T2K SMRD detector counters production
- Counter surface is etched with a chemical agent (Uniplast) to create a 30-100 μm layer that works as diffusive reflector
- Counters of three different sizes:
  - $900 \times 7 \times 10$ mm^3
  - $900 \times 7 \times 20$ mm^3
  - $900 \times 7 \times 30$ mm^3
- 2 mm deep grooves for 1-mm WLS fibers

Scintillator bars (1)

Grooves milling with Woodpecker machine

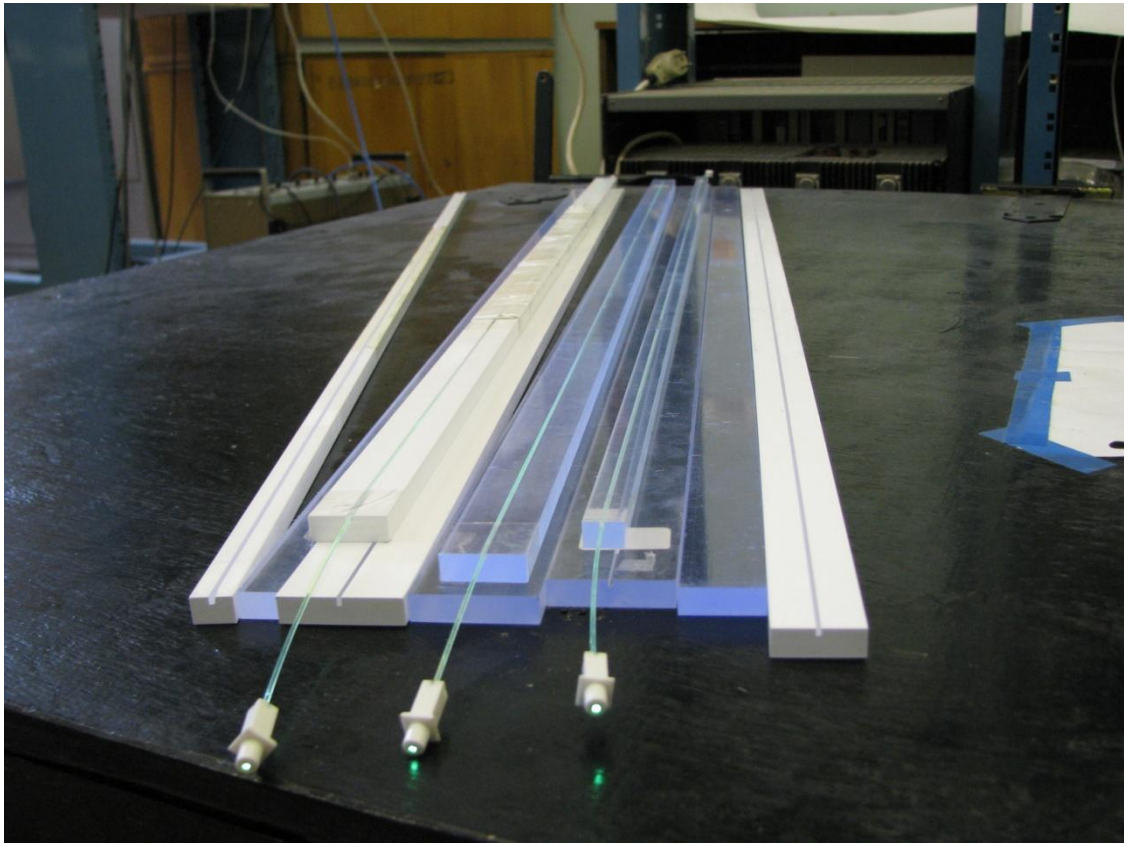






Counter prototypes at INR

Scintillator bars (2)



Tests with cosmic muons

Light collection: Kuraray WLS fiber (200 ppm, S-type) d = 1 mm

1 m long
5 m long
16 m long

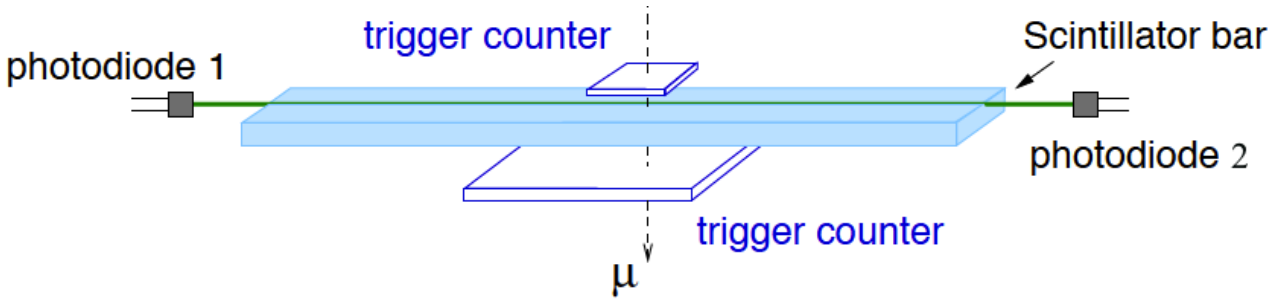
- Toshiba TSF451-50M silicone grease used to embed a fiber
  → improve optical contact between a fiber and a groove surface

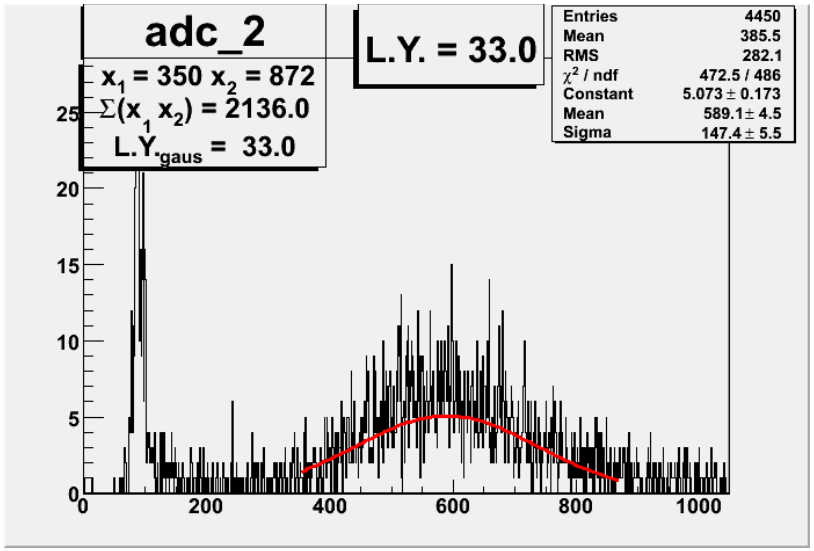
- Photosensors (two-end readout): 667-pixel Hamamatsu MPPC
  - HV from Hamamatsu, gain of 7.5×10^5 for 25 ^oC
  - note: no correction for cross-talk + after-pulses (~15% in total)

- Temperature: 25-28 ^oC

Cosmic telescope

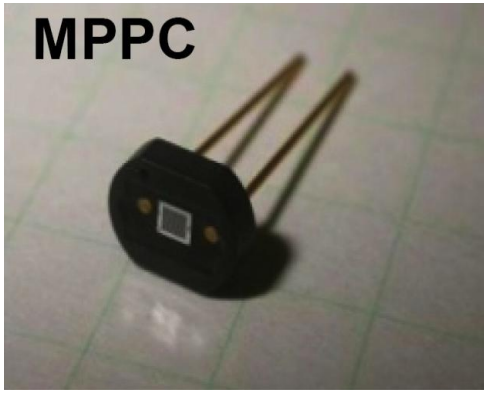
Test-bench design





MIP signal from one counter end

Hamamatsu MPPC photosensors



	MPPC
Number of pixels	667
Active area	1.3×1.3 mm^2
Pixel size	50×50 μm^2
Gain	0.7×10^6
PDE at 525 nm	30-35%
Dark rate, thr = 0.5 p.e.,22C	<500 kHz
Pulse width	<100 ns
Cross-talk	10-20%
After pulses	10-20%
Sensitivity to magnetic field	no

L.y. without chemical reflector

WLS fiber length = 1 m

Light attenuation length in scintillator bars 8-10 cm

Counter width	MPPC 1 L.Y., p.e.	MPPC 2 L.Y., p.e.	$\Sigma_{L.Y.}$, p.e.
10 mm	15.7	15.8	31.5
20 mm	15.5	13.6	29.1
30 mm	12.8	11.5	24.3
20 mm + Tyvek reflector (100-120 μm)	41.8	34.8	76.6

About ~2.5 effect with Tyvek paper reflector

T2K SMRD tests experience : L.Y. > 12 p.e. (sum of both ends) allows to achieve ~ 99% detection efficiency

L.y. with chemical reflector (1)

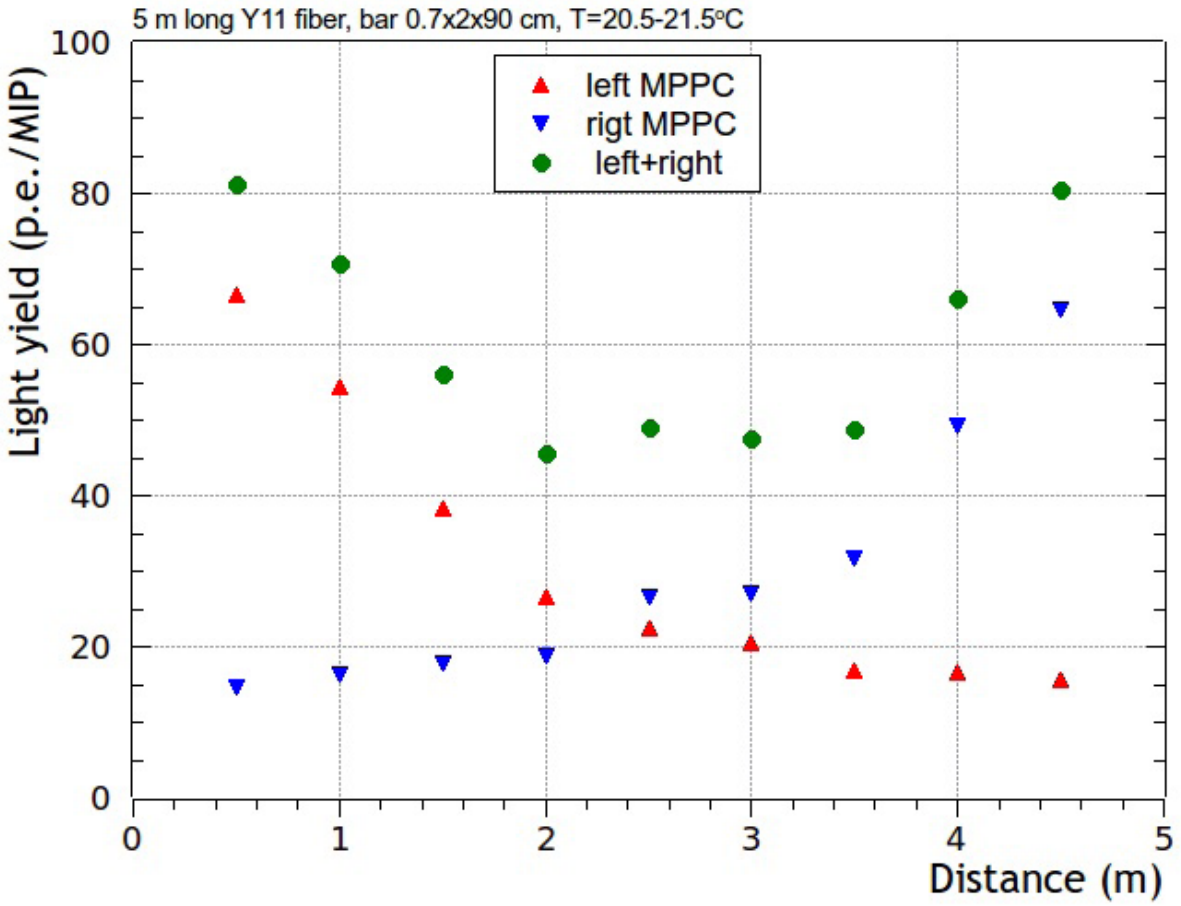
WLS fiber length = 1 m

Counter width	MPPC 1 L.Y., p.e.	MPPC 2 L.Y., p.e.	$\Sigma_{L.Y.,}$ p.e.
10 mm, grease	46.0	36.8	82.8
20 mm (1) w/o optical grease	25.7	22.1	47.8
20 mm (1),grease	39.7	35.7	75.4
20 mm (1), grease + Tyvek reflector	49.3	44	93.3
20 mm (2),grease	32.6	28.2	60.8
30 mm,grease	31.2	26.6	57.8

× 2.5 effect of chemical reflector
~ 60% effect of optical grease
~ 20% effect of additional Tyvek reflector

L.y. (2)

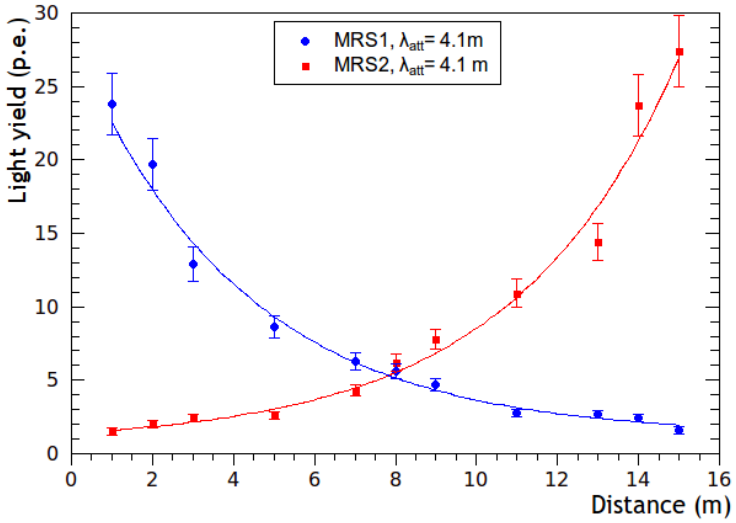
WLS fiber length = 5 m



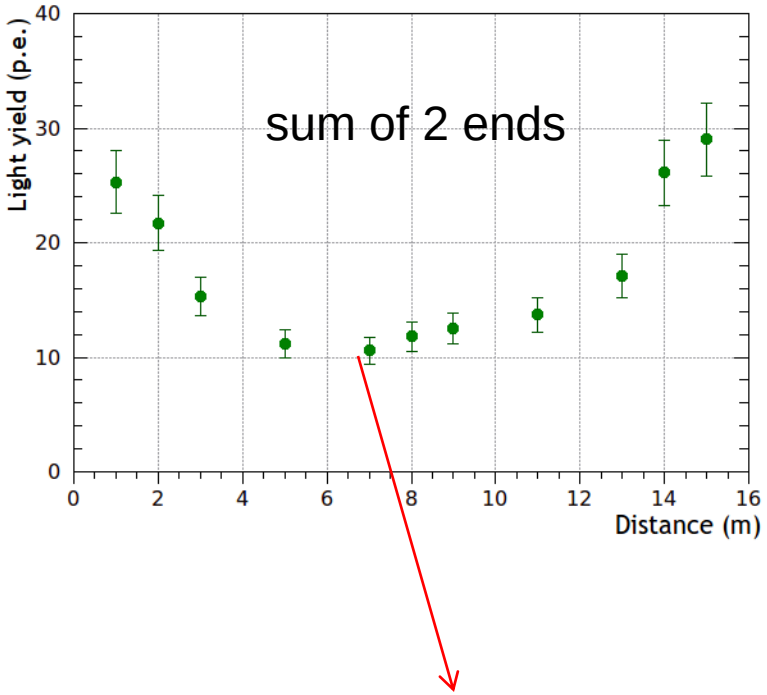
L.y. (3)

WLS fiber length = 16 m

Scintillator bar: 7 mm thick, 3 cm width
Photosensor: MRS APD
WLS fiber: Y11, 1mm diameter, double-clad, 16 m long



Cosmic muons
Temperature 19.5 – 20.5 C



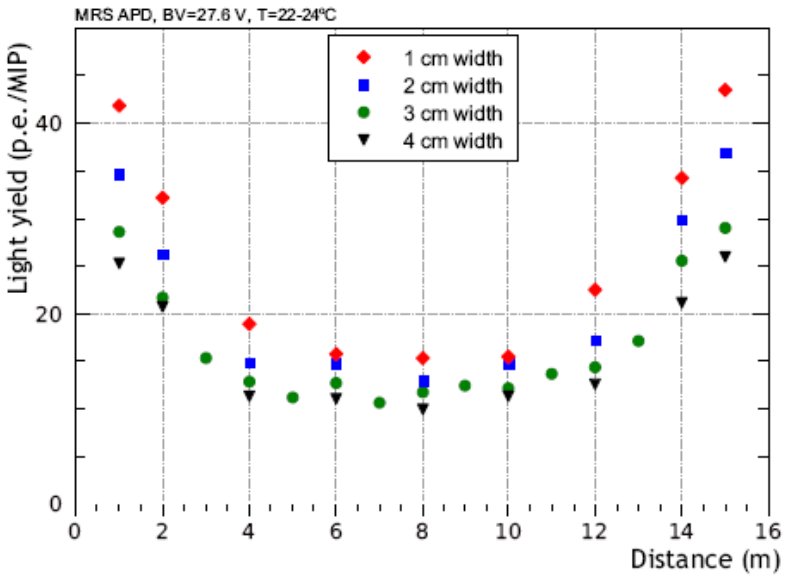
Minimum l.y. ~ 7-8 p.e./MeV

L.y. (4)

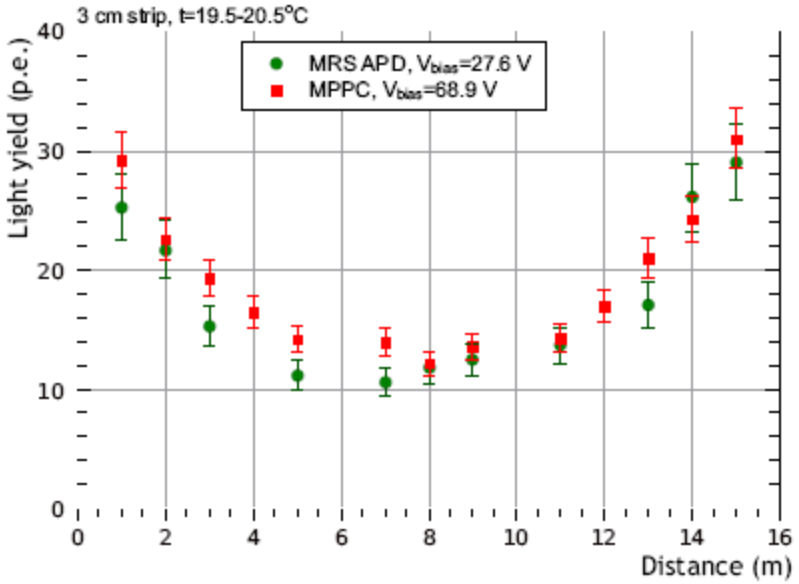
WLS fiber length = 16 m

Cosmic muons: sum of both ends

4 bars: 1, 2 3, 4 cm width
MRS APD 22-24 C

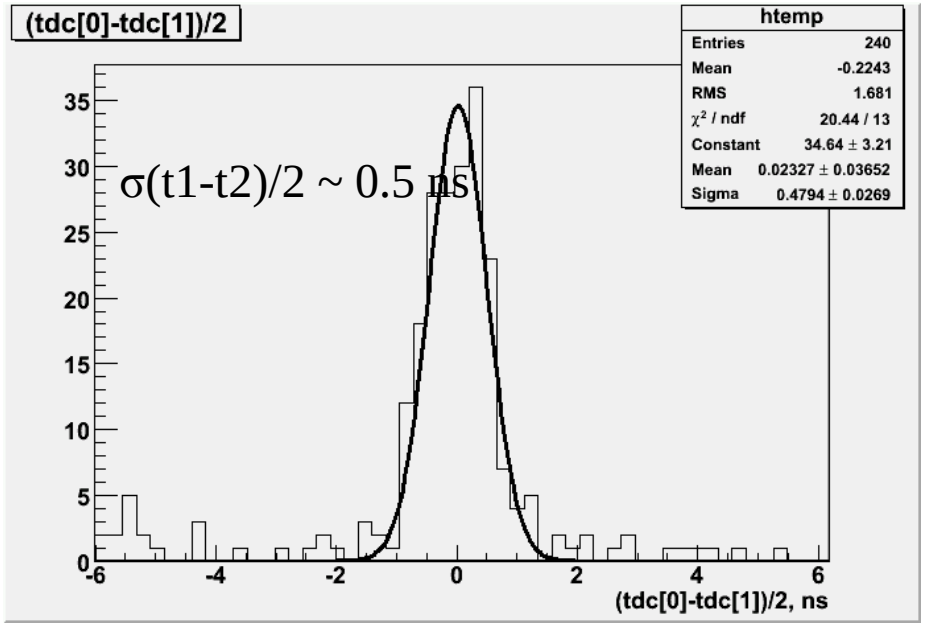


3 cm bar
MRS APD and MPPC at 22-24 C

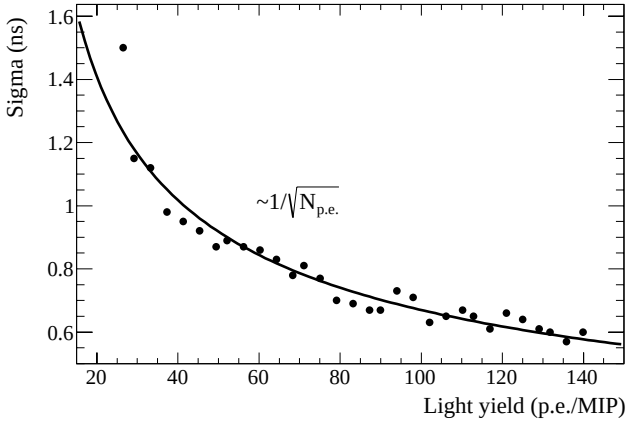


Timing

- Timing estimation with small 2 x 2 cm^2 upper trigger counter
- ~ 0.5 p.e. TDC threshold to suppress time-walk effects
- Two-sided readout → (t1-t2)/2 combination to estimate timing



σ(t1-t2)/2 vs L.Y. according to T2K SMRD test-bench results



Timing is mostly determined by fiber decay constant: τfiber~ 12 ns

Conclusion

- Extruded scintillators/WLS/SiPM → good performance

- 3000 bars (0.7 x 1.0 x 90 cm^3) ordered
  expected by 03.2013
- 6000 bars contract around 04.2013

- R&D on photosensors: high PDE for 500-700 nm
  low cross talk and after pulses
  gain ~ 10^6
  number of pixels ~1000