

Scintillator detectors R&D

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Long scintillator detectors

Large volume segmented neutrino detectors:

Totally Active Scintillator Detectors

Magnetized Iron/Scintillator Sampling Detectors

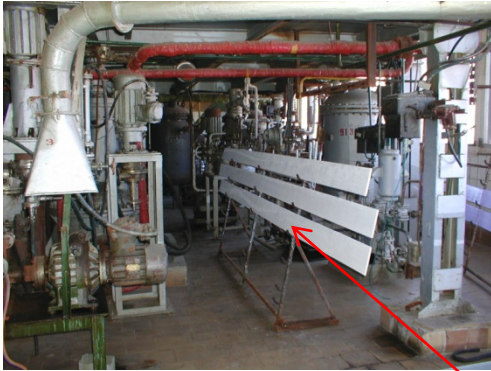


Scintillators of different shape and length, WLS fibers,
non-sensitive to magnetic field photosensors

Three main components of tested scintillator detectors:

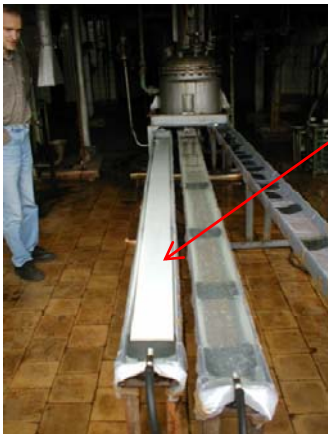
- extruded scintillator slabs and bars
- WLS fibers: double clad, 1-mm diameter Y11
- photosensors: avalanche photodiodes operating
in a limited Geiger mode
(MRS APD, CPTA, Moscow; MPPC, Hamamatsu)

Extruded scintillator slabs



- Extruded scintillator slabs 5-10 mm thick, 20 cm width, 3-5 m long
- Technique provided by Uniplast company Vladimir
- Polystyrene slabs + 1.5% PTP + 0.01% POPOP

20 cm width slabs



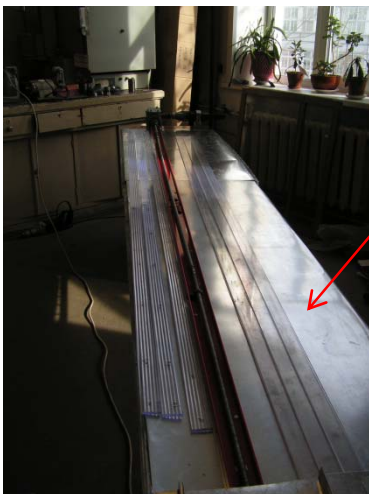
- Etching by a chemical reflector to enhance l.y.
- deposit thickness (30-100 μm) depends on etching time (a few minutes)
- almost ideal reflector – scintillator contact

Scintillator bars



Long wide slabs → cut into bars using cutting machine

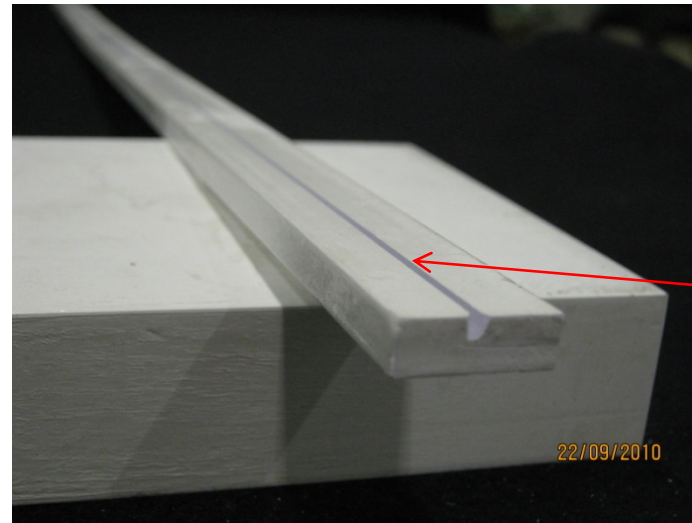
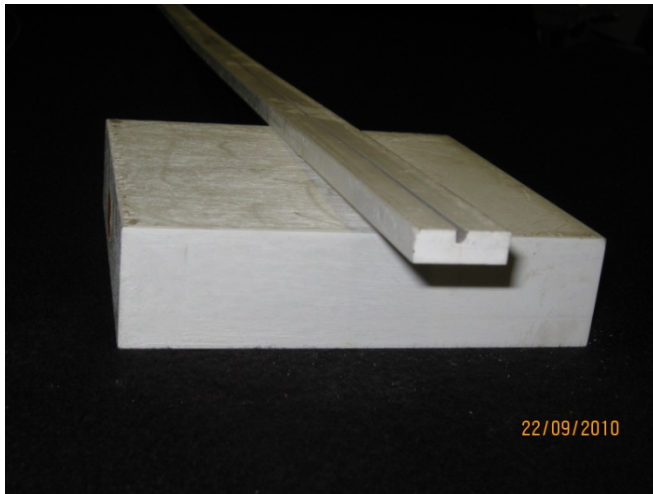
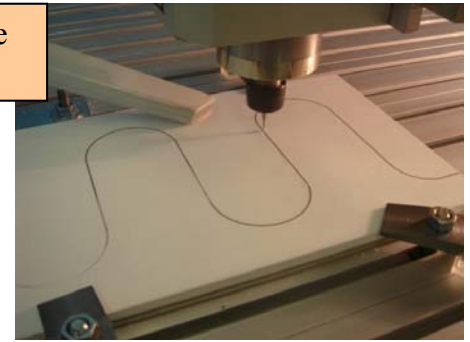
20 cm slab → 1-5 cm bars



Extruded bars

- Making grooves after etching procedure
- 3D engraving-milling machine

Length 1.0 - 3 m, width 1, 2, 3, 4 cm, thickness 7 mm

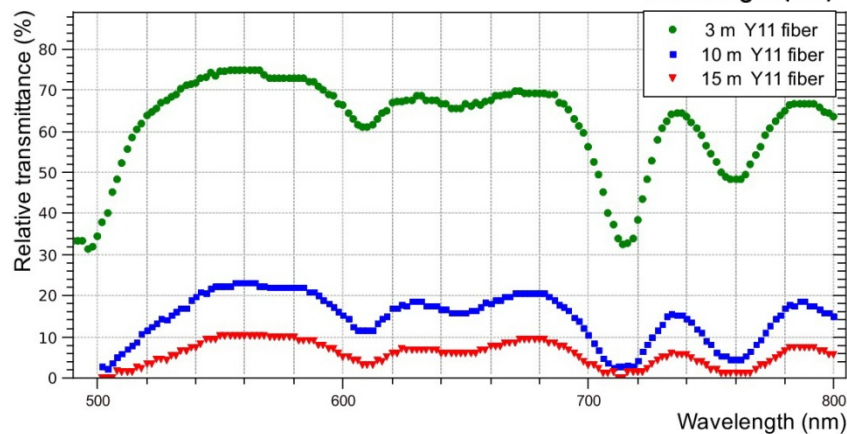
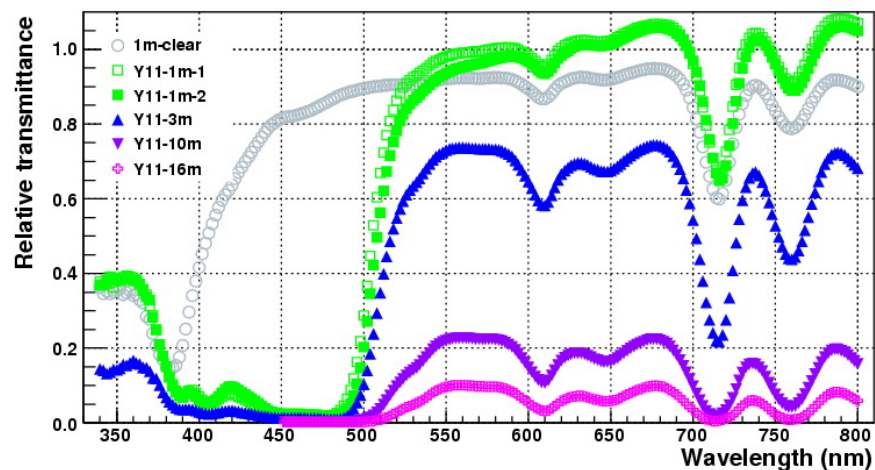
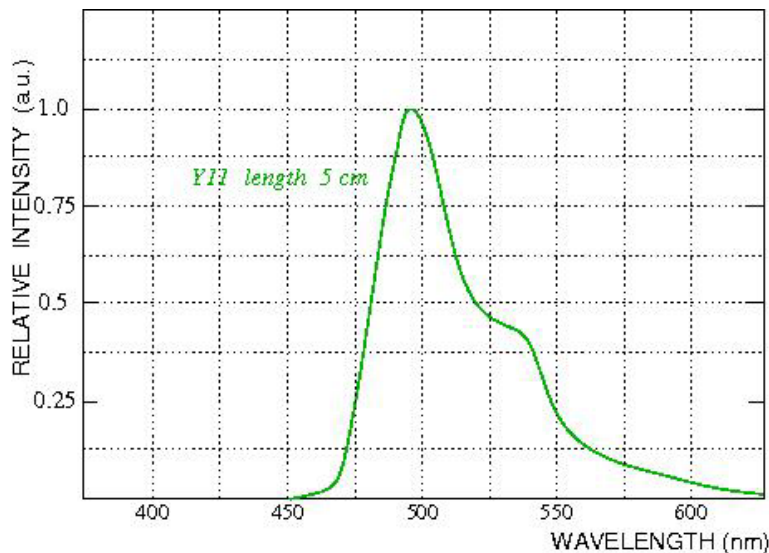


groove for Y11:
1.2 mm width
3.0 mm depth

Long fiber: signal attenuation

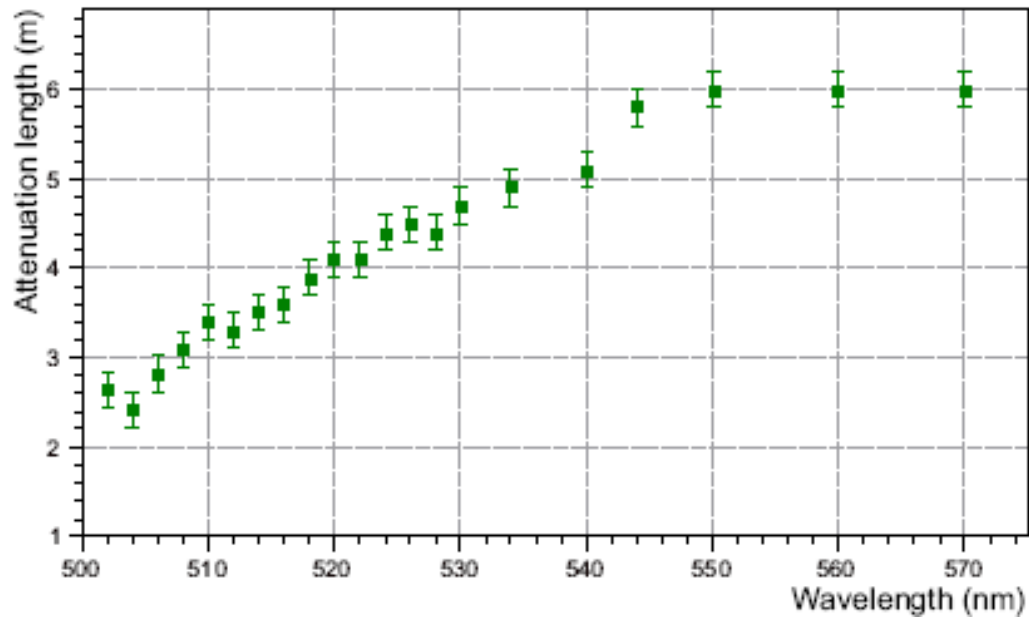
Y11: light absorption
as a function of wavelength

Emission spectra of Y11



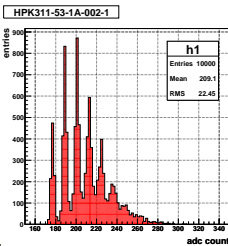
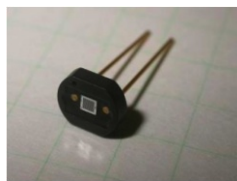
Attenuation was measured for
WLS lengths 1, 3, 10, 15 m

Attenuation length of Y11 vs wavelength

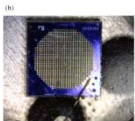
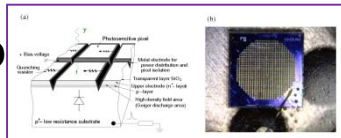


Geiger-Mode APD's

MPPC



MRS APD



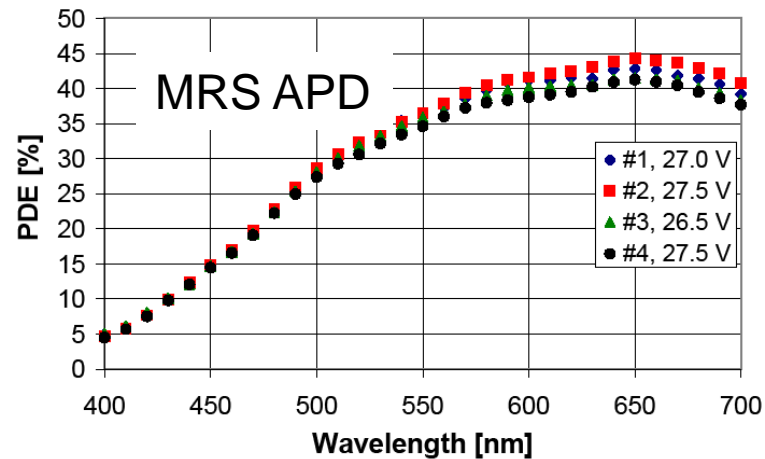
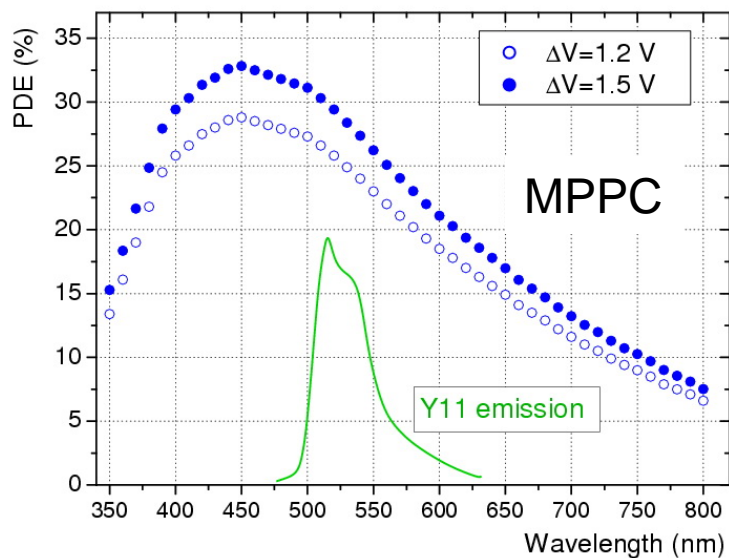
Number of pixels
Active area
Pixel size
Gain
PDE at 525 nm
Dark rate, $th = 0.5$ p.e., 22C
Pulse width
Cross-talk
After pulses
Sensitivity to magnetic field

MPPC

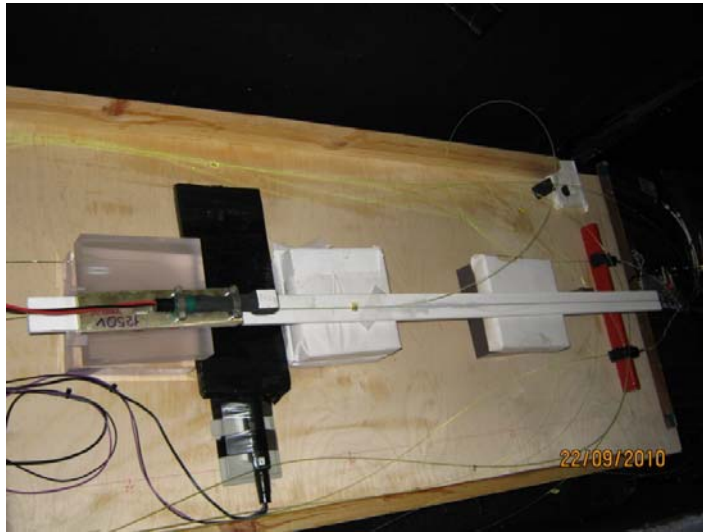
667
 1.3×1.3 mm²
 50×50 μ m
 0.7×10^6
30-35%
<500 kHz
<100 ns
10-20%
10-20%
no

MRS APD

556
 1.1×1.1 mm²
 40×40 μ m
 0.3×10^6
30%
<1MHz
tail ~ μ s
10%
1-2%
no



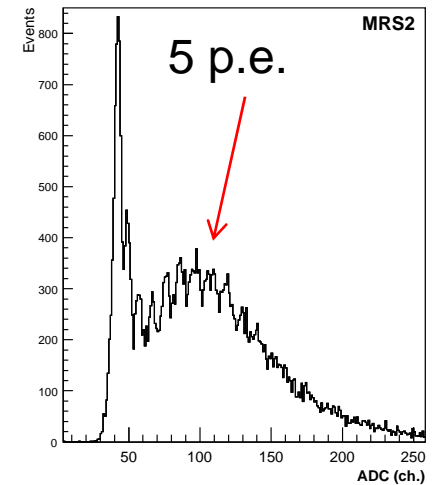
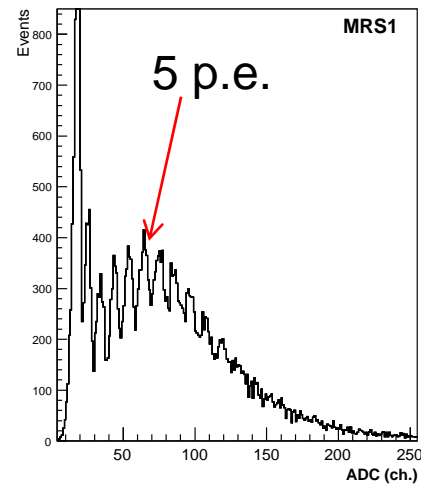
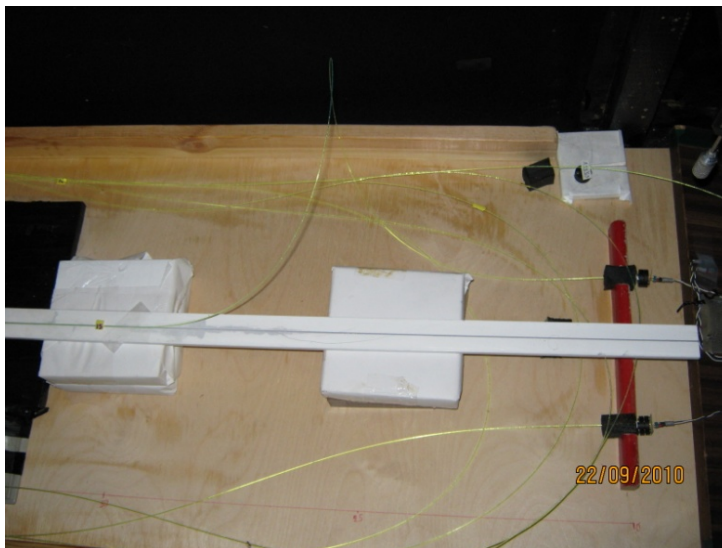
Cosmic muon test



Extruded scintillators:

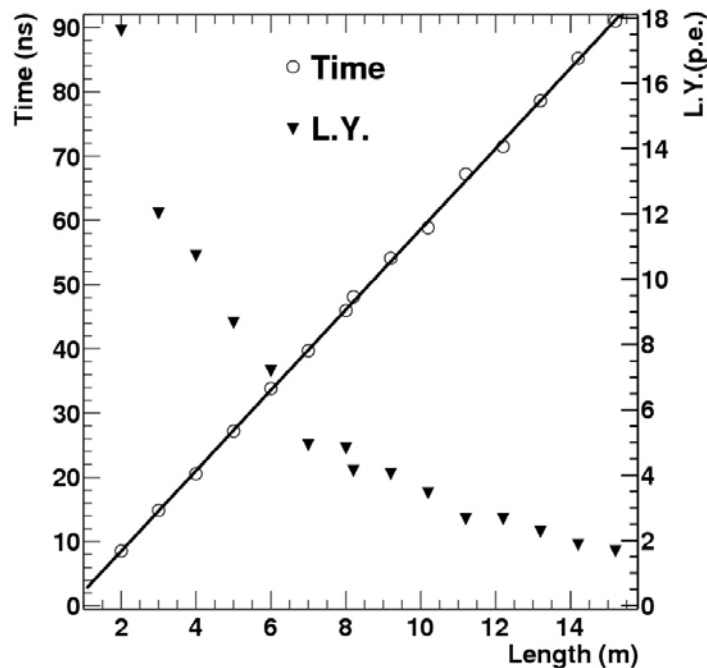
1 m long; 7 mm thick; 1,2,3,4 cm wide
Attenuation length of scintillator ~ 15 cm
1 mm diam, double clad Y11 16 m
Readout at both ends

Cosmic muon spectra for 3 cm scintillator
Distance 8 m from each photosensor



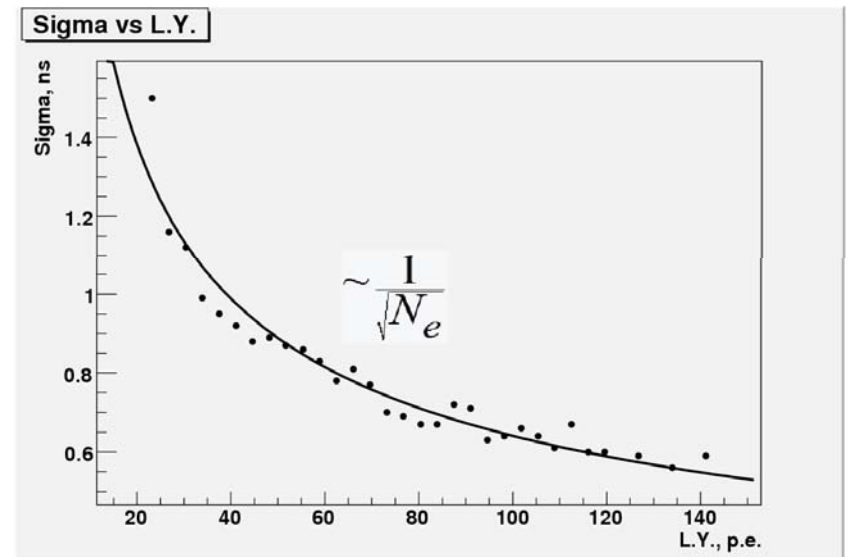
Timing

Measurement with a small plastic counter with a step ~ 1 m along the fiber



Speed of light in Y11
 16.0 ± 0.1 cm/ns

Time resolution, $\sigma \sim 1/\sqrt{N_{pe}}$



$\sigma \sim 1$ ns for MIP

Light yield/MIP

Scintillator bar:

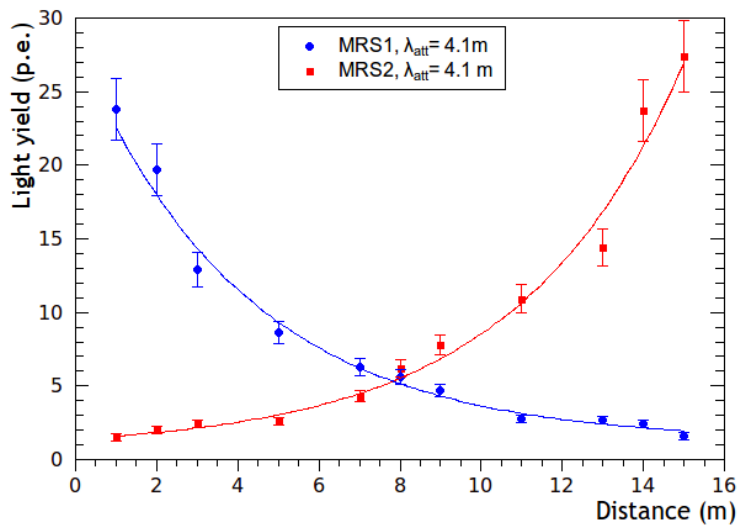
7 mm thick, 3 cm width

Photosensor:

MRS APD

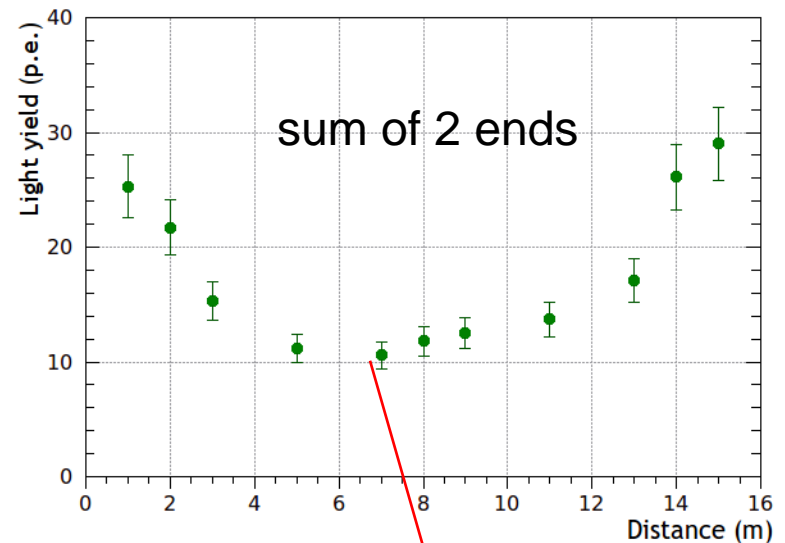
WLS fiber:

Y11, 1mm diameter, double-clad, 16 m long



Cosmic muons

Temperature 19.5 – 20.5 C

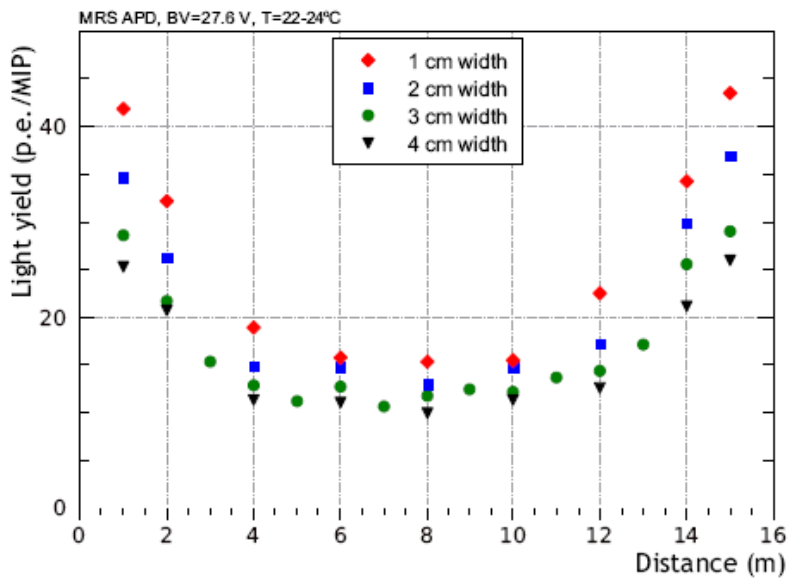


Minimum l.y. ~ 7-8 p.e./MeV

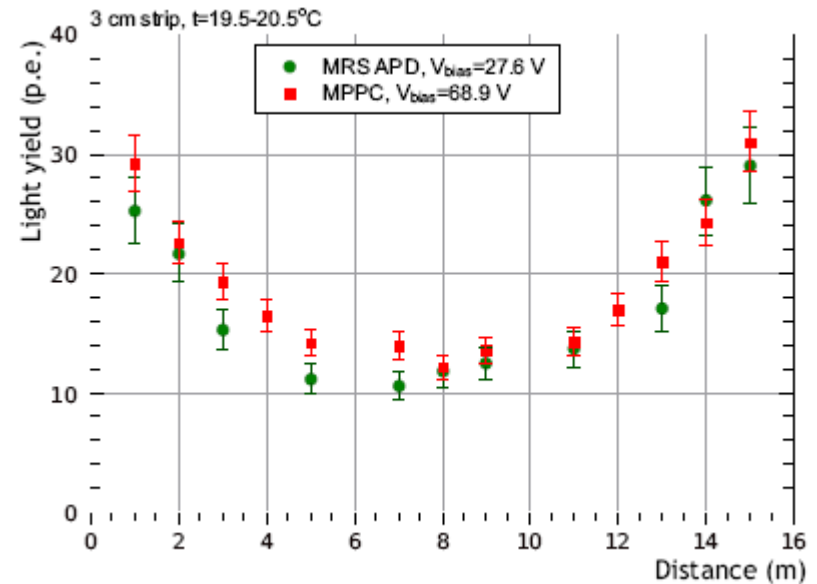
Light yield

Cosmic muons: sum of both ends

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

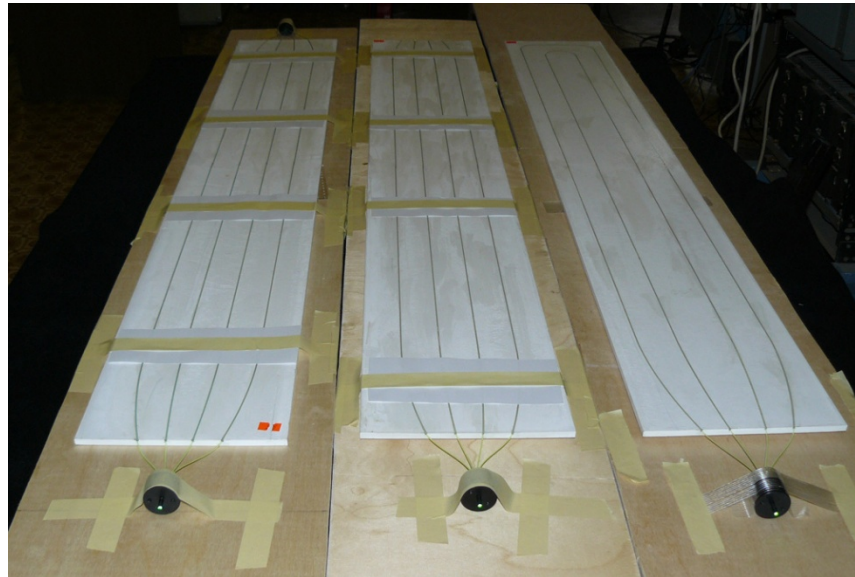


3 cm bar
MRS APD and MPPC at 22-24 C



Slabs for veto/trigger counters

~1200 x 200 x 7 mm³



- 2 U-shape Y11 fibers
- 4 straight Y11 fibers
- one-end and two-end readout using 3x3 mm² **MPPC**



Package	Plastic
Active Area	3 x 3 mm
Pixel Size	50 x 50 μm
Fill Factor	61.5 %
Spectral Response Range	320 - 900 nm
Peak Wavelength	440 nm
Operating Voltage	70±10 V
Dark Count	6000 kHz

One end readout

L.Y. ~ 56 p.e. at ~5 cm from MPPC
~ 45 p.e. at ~115 cm from MPPC

Conclusion

- Extruded scintillator detectors of rectangular cross-section $0.7 \times 1.0 \text{ cm}^2$ - $0.7 \times 4.0 \text{ cm}^2$ tested
- Scintillator detectors with long WLS fibers (up to 16 m) and Geiger mode APD's show:
 - high light yield for cosmic muons
 - S/N ratio ≥ 10 for minimum l.y.
 - good timing
 - high efficiency for MIP