Improving Light Collection Efficiency by Filling a Scintillation Strip with an Optical Filler

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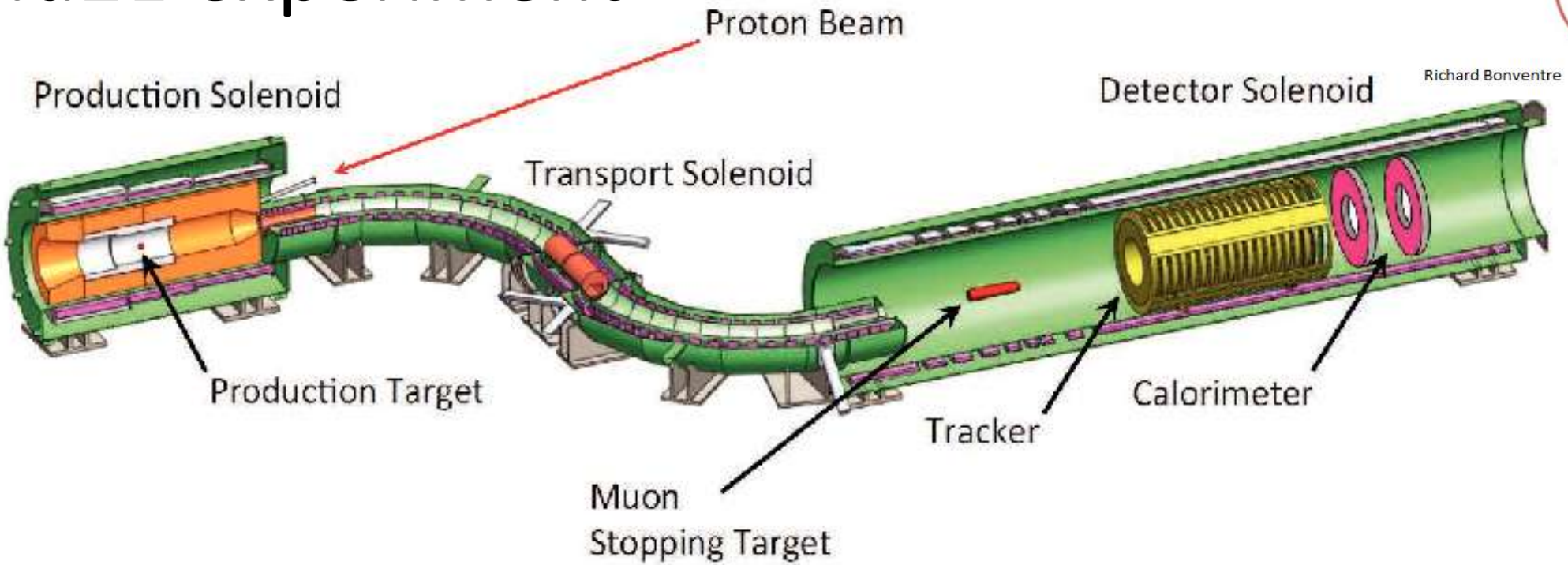
Scientific advisor: Chokheli Davit, JINR DLNP

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Outline

- The necessity to increase the light collection
- Experiments with optical liquid pouring into the short strips
- Radiation degradation of optical liquids
- Experiments with optical liquid pouring into the long strips
- Conclusion

Mu2E experiment



The Mu2e experiment will search for unambiguous evidence of charged lepton flavor violation through observation of the coherent, neutrino-less conversion in the presence of an aluminum nucleus ($\mu^- + N \rightarrow e^- + N$; monoenergetic electron: $E_e \approx m_\mu - E_b - E_{recoil} \approx 104.97 MeV$) with expected single-event sensitivity of 2.9×10^{-17} for a single-event (10000 times better than the current limit). It requires keeping the cosmic background below 0.25 events over the course of the three-year run. An overall veto efficiency of 99.99% must be achieved by Cosmic Ray Veto (CRV) system enclosing the Mu2e detectors in order to suppress background caused by the cosmic rays.

The necessity of enhancing light collection

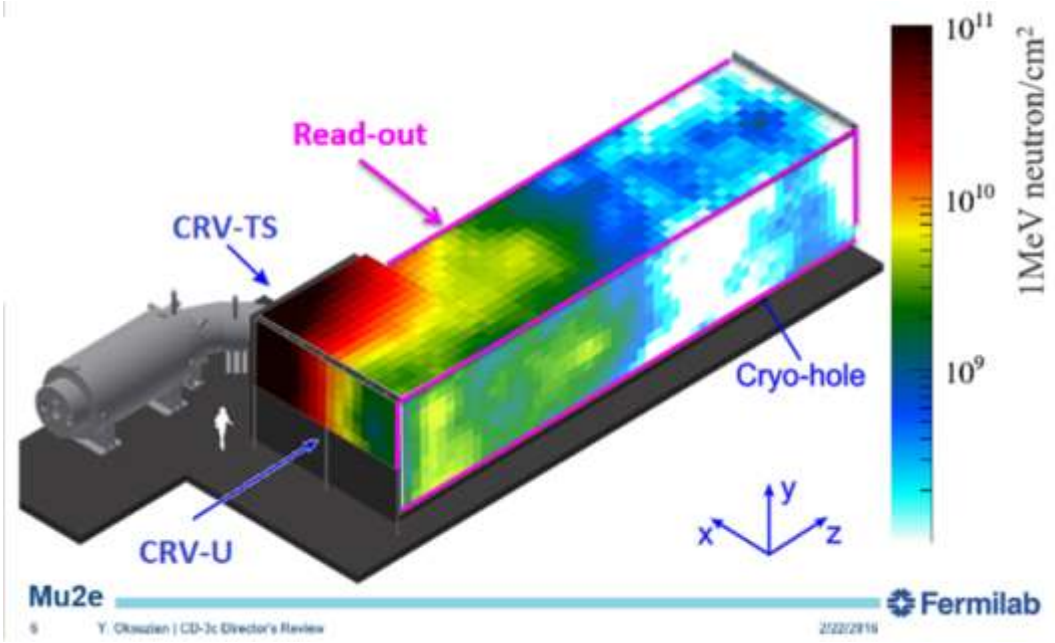


Fig. 2. Expected background level of neutrons at the Mu2e experimental setup.

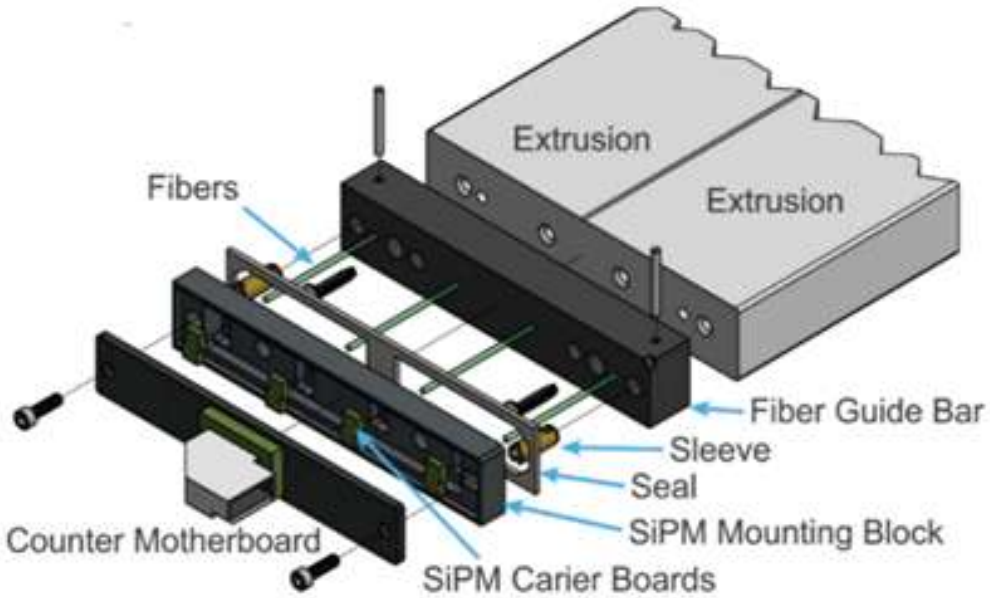


Fig. 3. Main element of the CRV system in the Mu2e project, consisting of a scintillator, a WLS fiber, and a light-readout adapter

Due to the high background radiation level in the region of one end , the Mu2e collaboration decided to use a single SiPM at the end where the background radiation is at an acceptable level. Thus, there is a need to increase light collection from the end of the fiber farthest from the SiPM. In our view, the most attractive and low-cost approach appears to be the method we proposed of injecting optical liquid into the hole with the WLS fiber.

Experiments with optical liquid pouring into the short strips

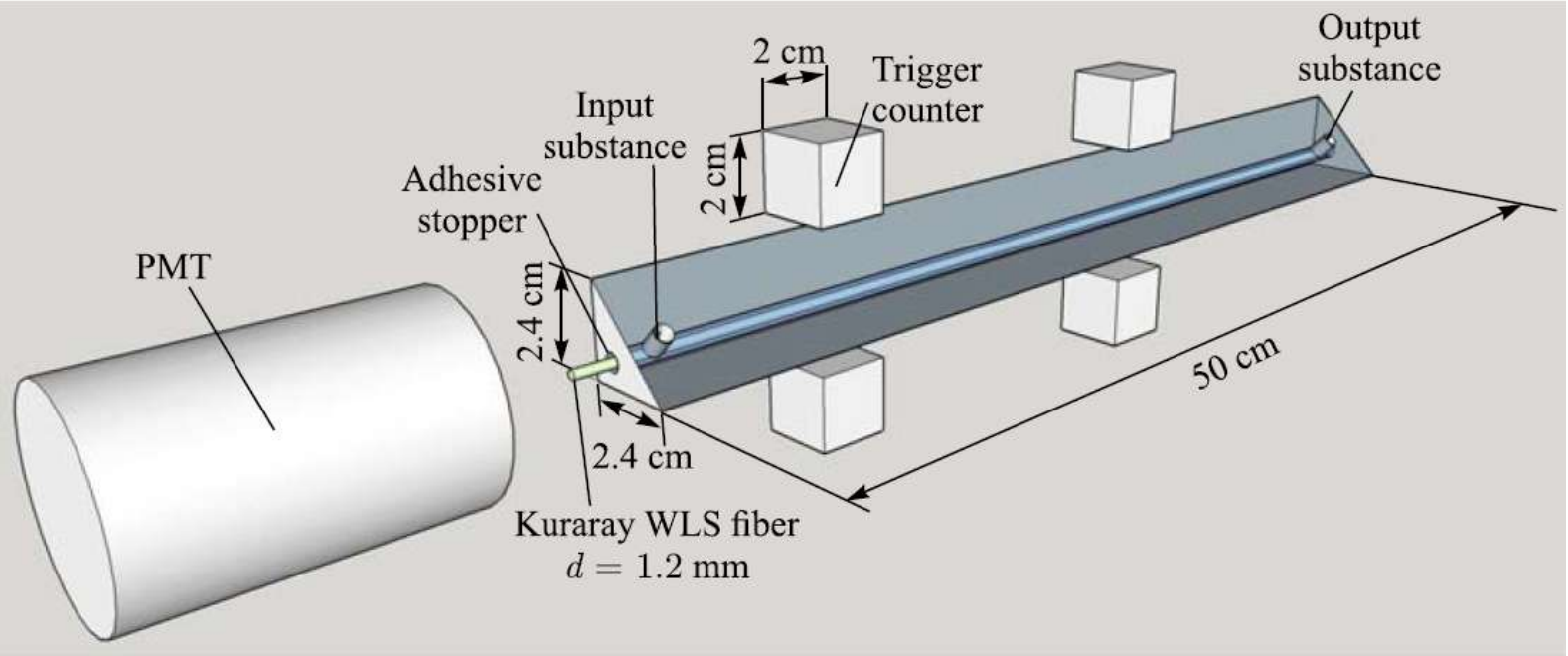


Fig. 4. Setup for measurement of light collection I 50-cm strip.

Parameter	Filler			
	Distilled water	Glycerin aqueous solution	SKTN-MED	UV glue "Spectrum"
Light collection increase, %	38 ± 6	43 ± 6	50 ± 5	36 ± 6

Table 1. Increase of light collection in 50-cm long strips with different liquids.

Experiments with optical liquid pouring into the short strips

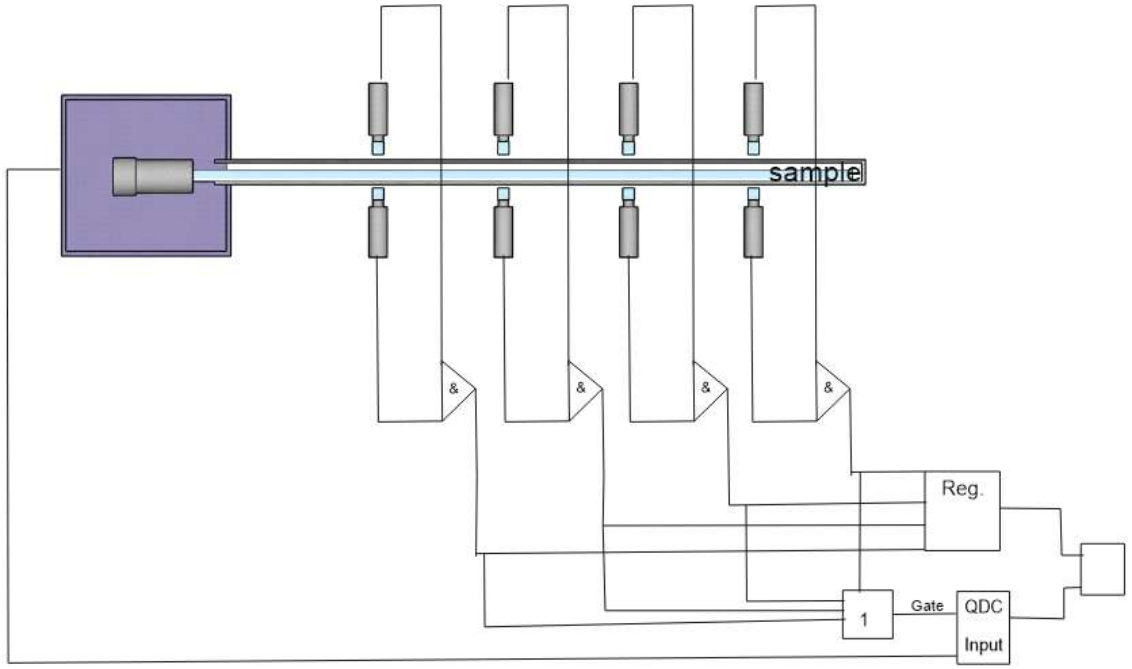


Fig. 5a. Schematic of the experimental setup for studying light collection of strips up to 2 m long

Filler/WLS fiber diameter	BC600 & 1mm WLS fiber	SKTN-MED(E) & 1 mm WLS fiber
Light collection increase, %	60%	70%

Table 2.Increase of light collection in 2 m long strips with different glues.

Radiation degradation of optical liquids

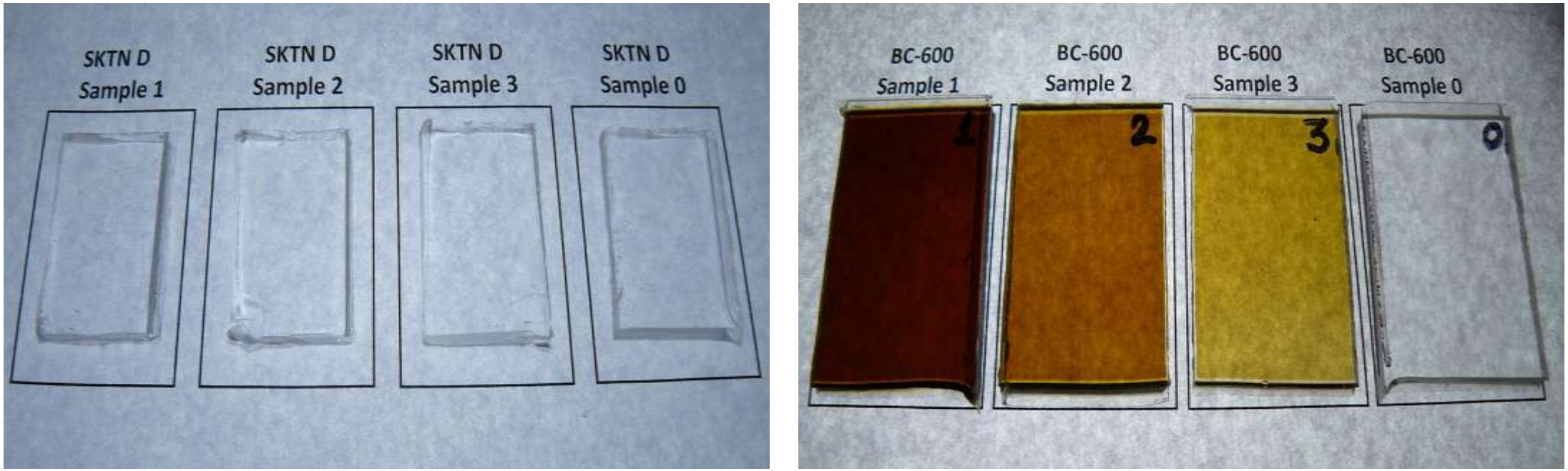


Fig. 6. Samples irradiated with neutron fluxes (16×10^{15}, 3.8×10^{14}, and 1.2×10^{14}) neutrons/cm^2. Left – polymerized SKTN rubber samples; right – polymerized BC-600 epoxy adhesive samples.

Measurements with optical liquid pouring in long strips

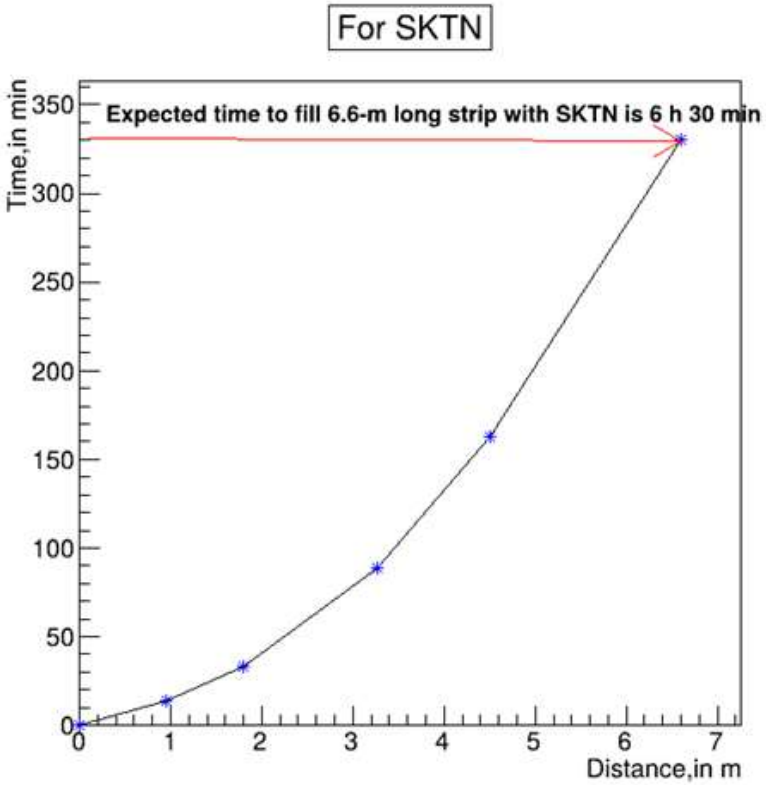


Fig. 7. Time required for pumping SKTNMED into a 6.6-m long strip(1000cst.).

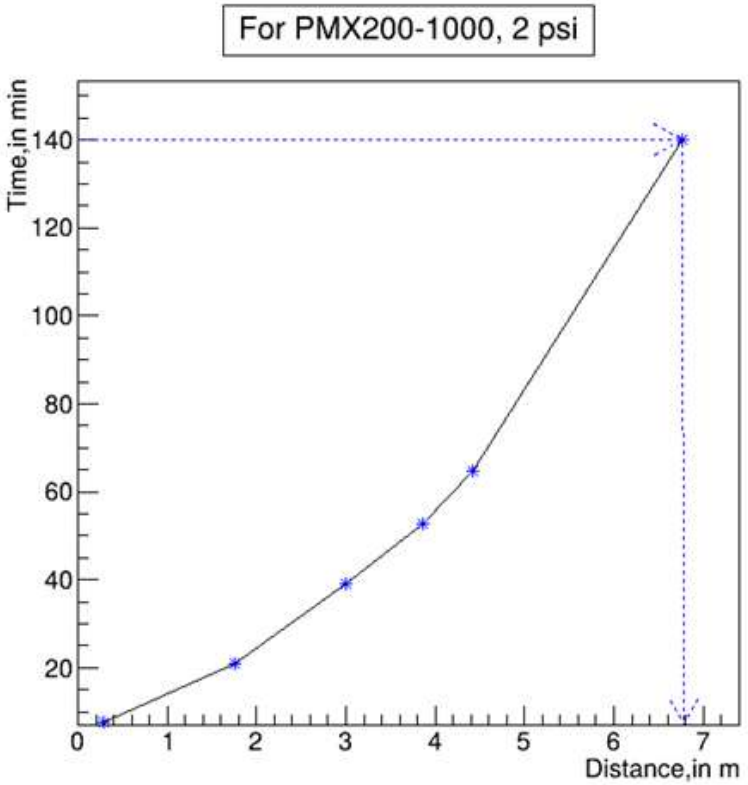


Fig. 8. Pumping time of PMX-200 with a viscosity of 1000 cst at 2 psi into a 6.6-m long strip;

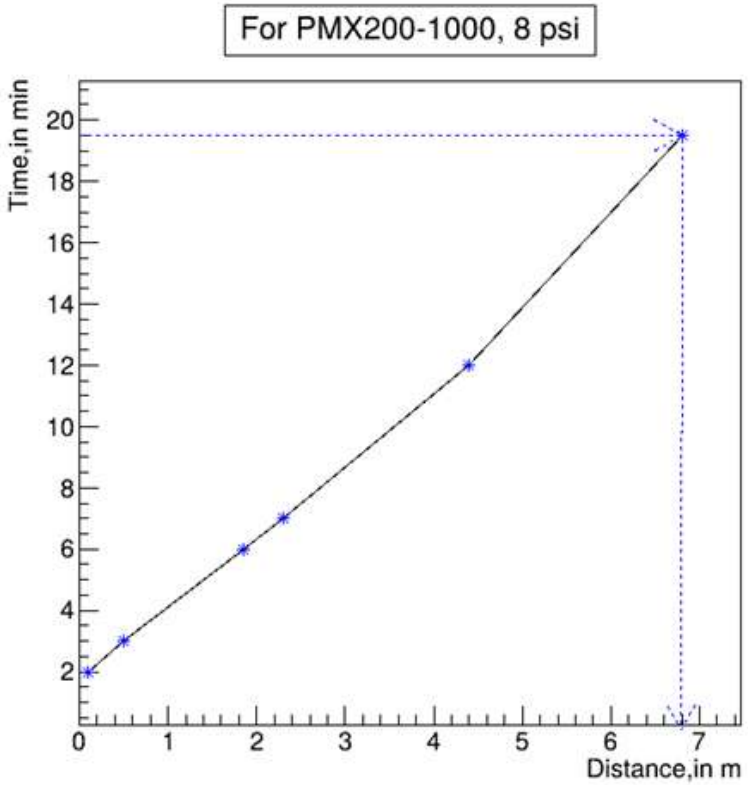


Fig. 9. Pumping time of PMX-200 with a viscosity of 1000 cst at 8 psi into a 6.6-m long strip;

Measurements with optical liquid pouring in long strips

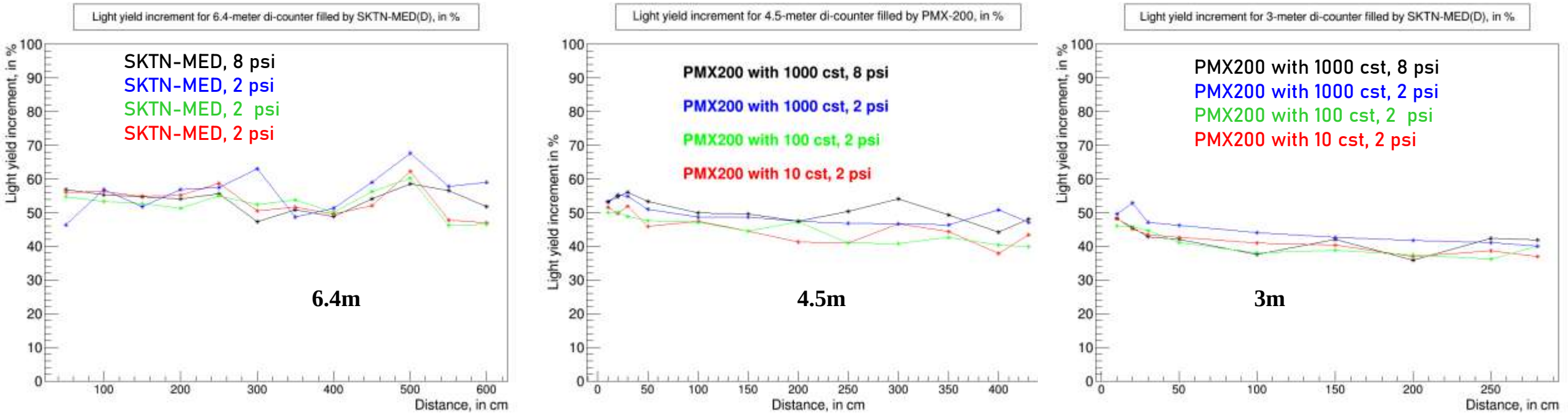


Fig. 10. Increase in light collection after filling with optical liquid relative to a counter with a "dry" hole. Strips ages before pouring: left – 2 months old, center – 1 year old, right – 3 years old.

Measurements with optical liquid pouring in long strips

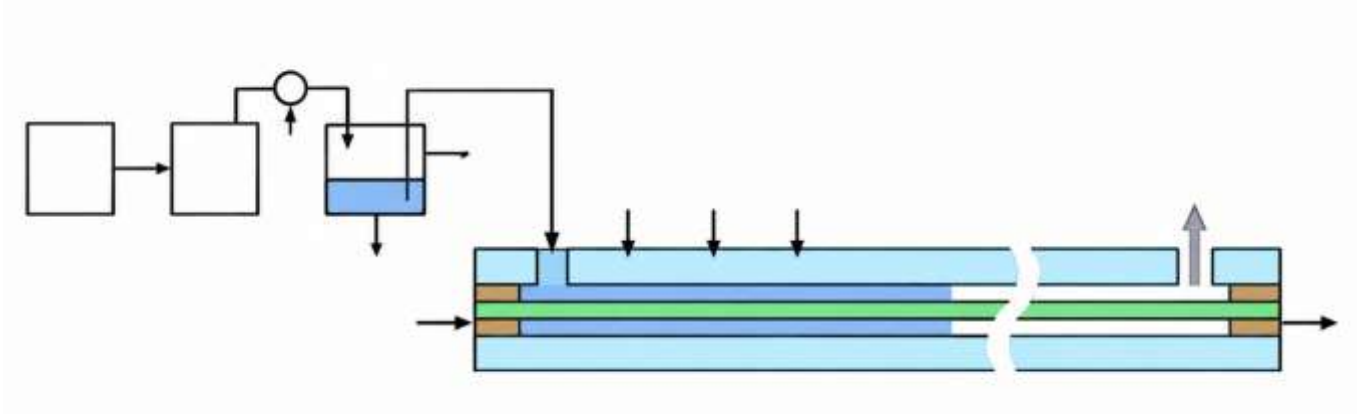


Fig. 11. Schematic view of a scintillating strip with an embedded WLS fiber and the hole filled with optical liquid.



Fig. 12. Setup for simultaneous filling of 32 holes in scintillation strips comprising 1 layer of the module.

Double-Sided SiPM Readout Test Results

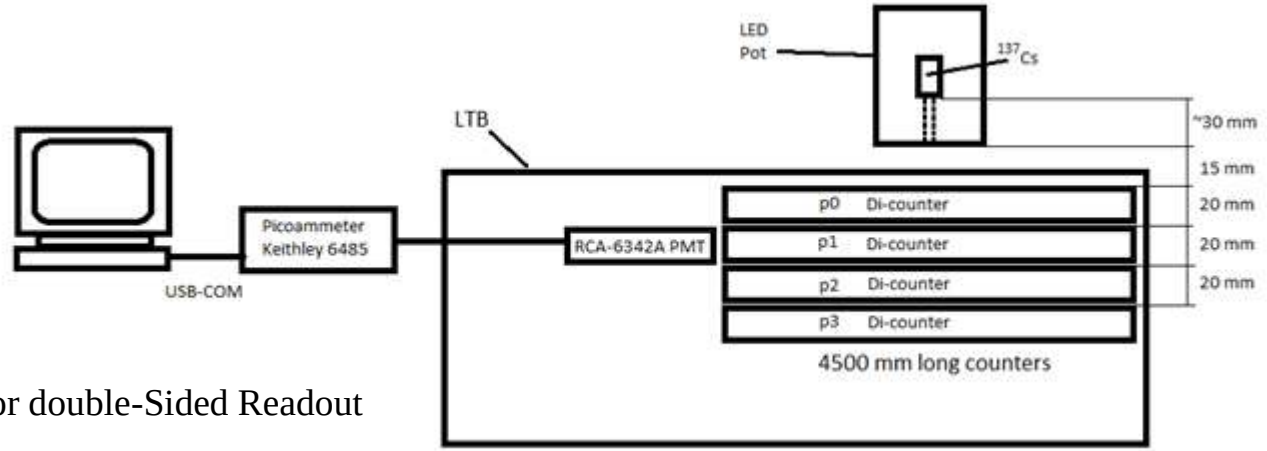


Fig.13 Setup for double-Sided Readout

The plots show the SiPM output current as a function of the radiation source position along a long scintillator strip. Individual responses from Side A and Side B exhibit a symmetrical exponential attenuation as the source moves away from the sensors. The combined signal, represented by the Summ(A+B) curves, remains flat and uniform across the entire scanning distance. Using SKTN optical glue (blue lines) increases the light collection efficiency by approximately 40% compared to a DRY contact (red lines).

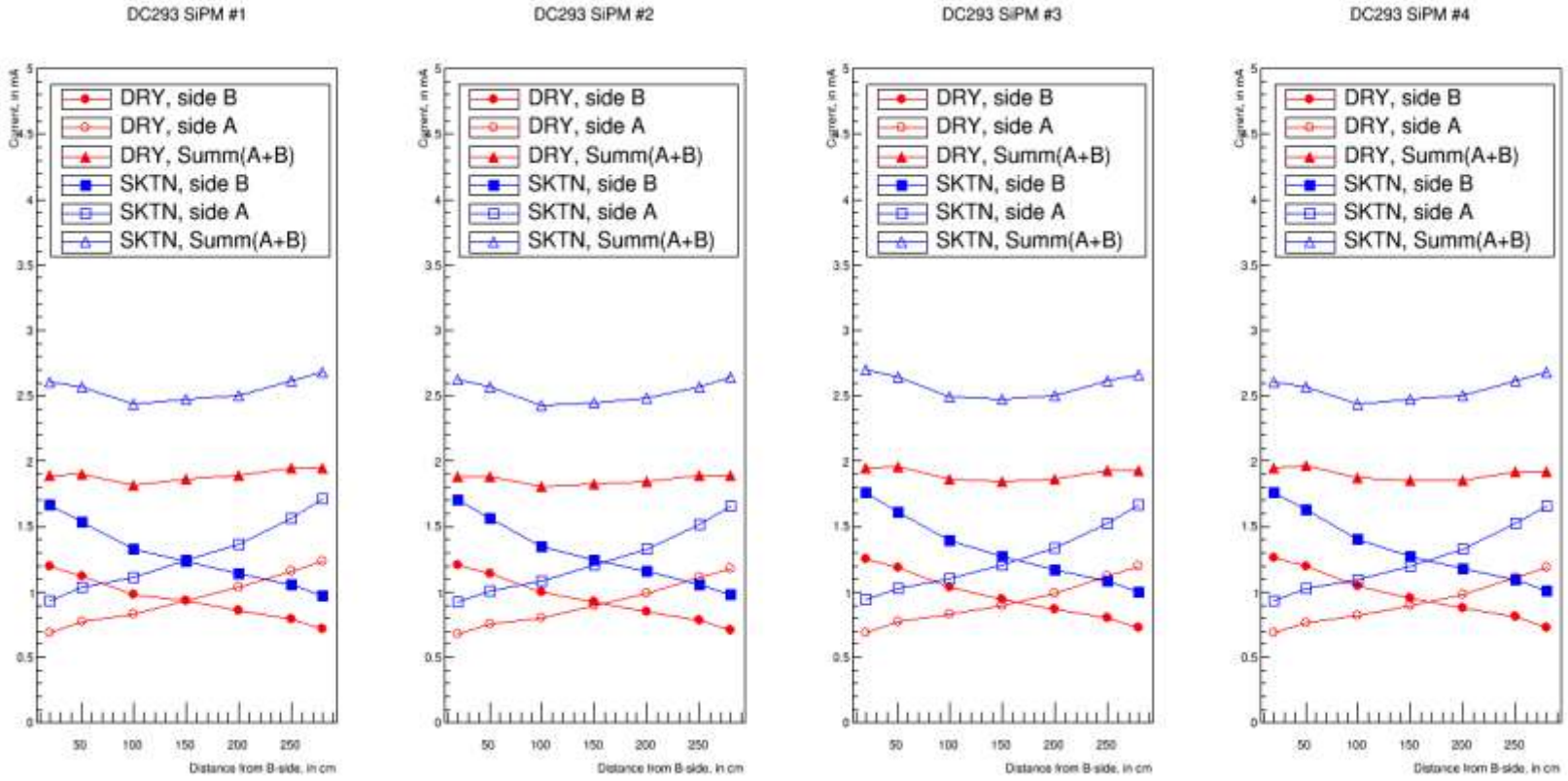


Fig. 14 Signal dependence on length of the strip from both sides of the strip

Conclusion

- We observed an increase in light collection from 30% to 60% with different manufacturing date.
- An optical liquid with an optimal filling time for the fibre-optic aperture in a counter up to 7 metres in length has been selected.
- A system has been developed for the simultaneous, controlled filling of 32 holes in strips with fiber in the centre, in the CRV module.
- The increase in light collection is due to the difference between the refractive index of the optical fluid and that of air, and to the optical fluid wetting the cracks that form on the surface of the fibre-optic hole as a result of residual tension in the extruded scintillators.

Thank you for your attention

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