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ILC Prototype Muon Scintillation Counter Tests

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Results are presented of source and cosmic ray tests of a prototype muon detector intended for use in ILC detectors. The detector is composed of strips of scintillator arranged diagonally across a panel, with wavelength-shifter fibers imbedded in grooves along the lengths of the strips.

1. DESCRIPTION OF TEST SETUP AND MODULES

The modules tested were built recently by Notre Dame University as quarter-size ILC prototype muon counters [Ref 1]. The modules are rectangular panels, 2.5m by 1.25m in size, and consisting of 64 strips of scintillator arranged diagonally across the modules. The central 22 strips are of equal length and run across the full width of the module. The other 42 strips are of varying lengths across the corners. Light produced in the scintillators is collected and transmitted to a cookie by wavelength-shifter fibers in grooves in the scintillator bars and clear fibers from the shifters to the cookie. Results of tests of a smaller pre-prototype counter were presented at the Stanford Linear Collider Workshop [Ref 2].

The test setup is shown in Fig. 1. The modules were stacked on a table in Fermilab Lab 6, to which were mounted four 20cmx20cm cosmic ray trigger counters and a source holder/collimator. The transport mechanism allowed motions of the trigger counters or source to cover different positions relative to the test counters. Two of the trigger counters are above the test counters and two are beneath. There is a 5cm thick Pb absorber below the upper trigger counters and one above the lower trigger counters to reduce triggers by the electromagnetic component of the cosmic rays. The source tests were made with a 1mCi Cs^{137} source that is mounted on the upper transporter with a 5cm thick Pb collimator.

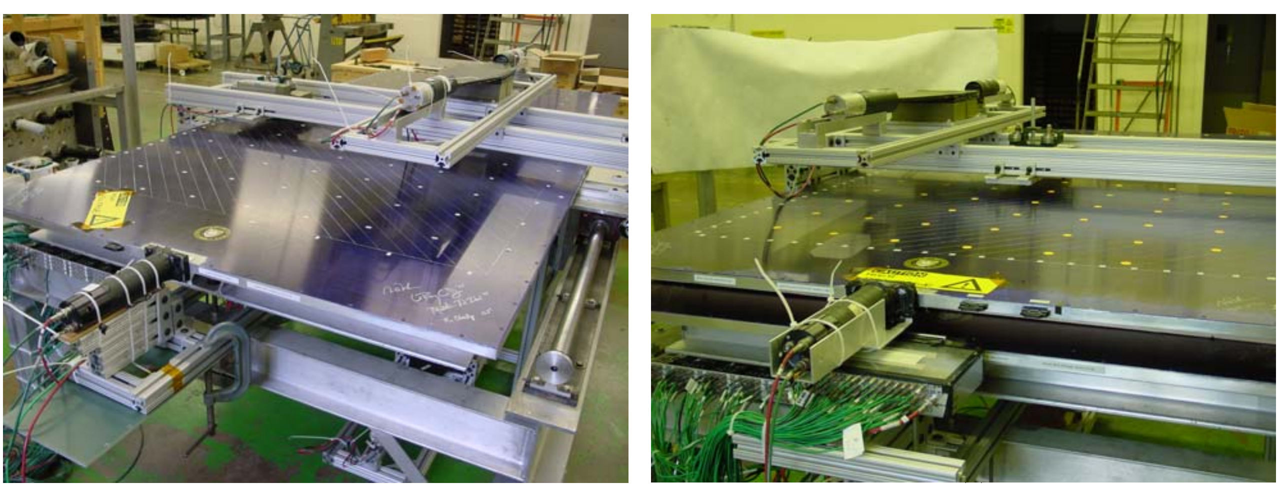
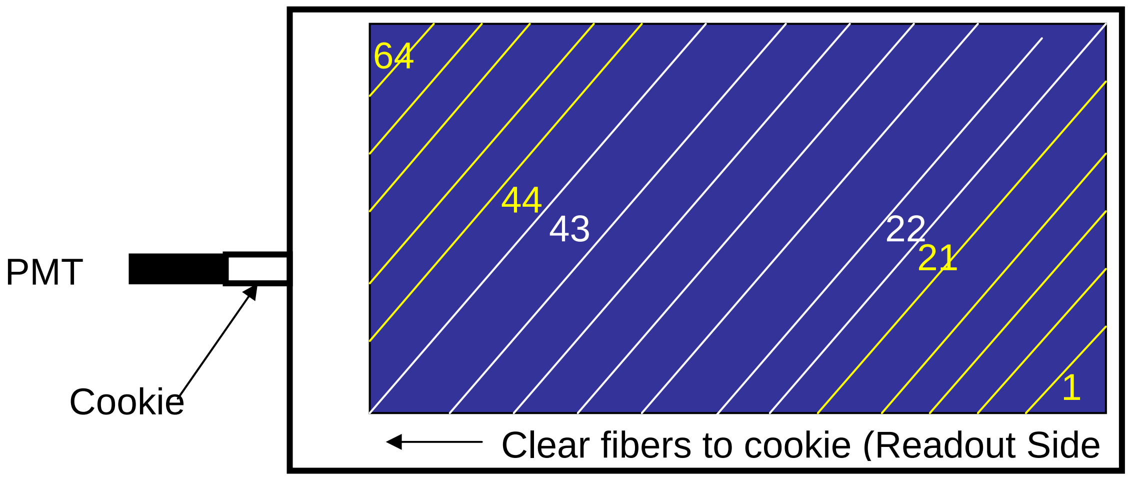


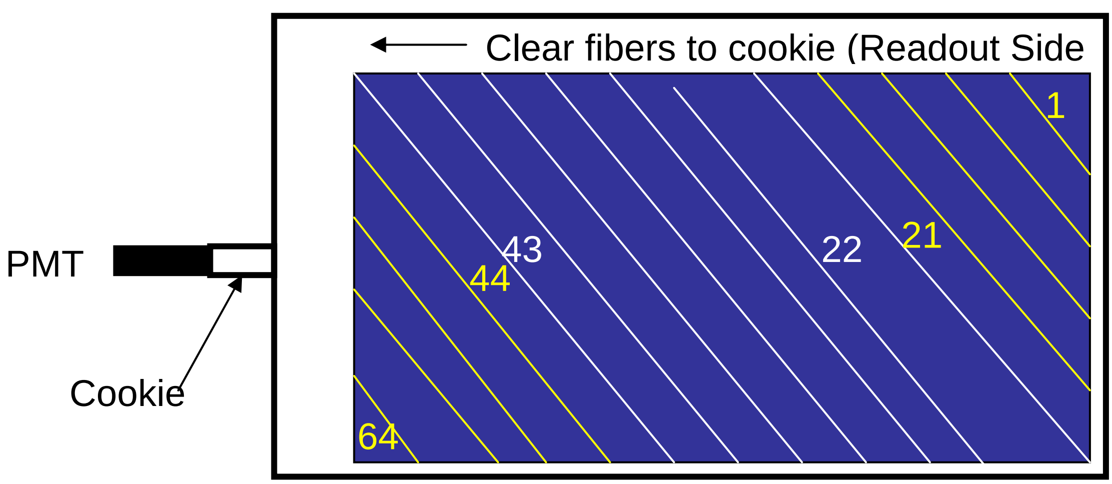
Figure 1: Test setup.

The test counters were tested with two types of of photomultiplier tubes: and single-anode Hamamatsu E-934-01 PMT (SAPMT) and a 64-element Hamamatsu H7546B multi-anode PMT (MAPMT). Counter S1 is shown in Fig 1(a), with the SAPMT, Counter S2 is in Fig 1(b) with a SAPMT, above S1, which is fitted with a MAPMT. The 64 signal cables are visible in Fig. 1(b). The upper trigger counters and the source holder can be seen in Fig.1 on the transporter. The counters were coated with toolmaker's dye and lines were scribed along the boundaries of the scintillator strips. Stickers were attached to the counters for positioning the source and trigger counters.

The strip arrangements and numbering schemes are shown in Fig. 2. The strips are at +45 and –45 degrees, respectively.



(a) Prototype Counter S1



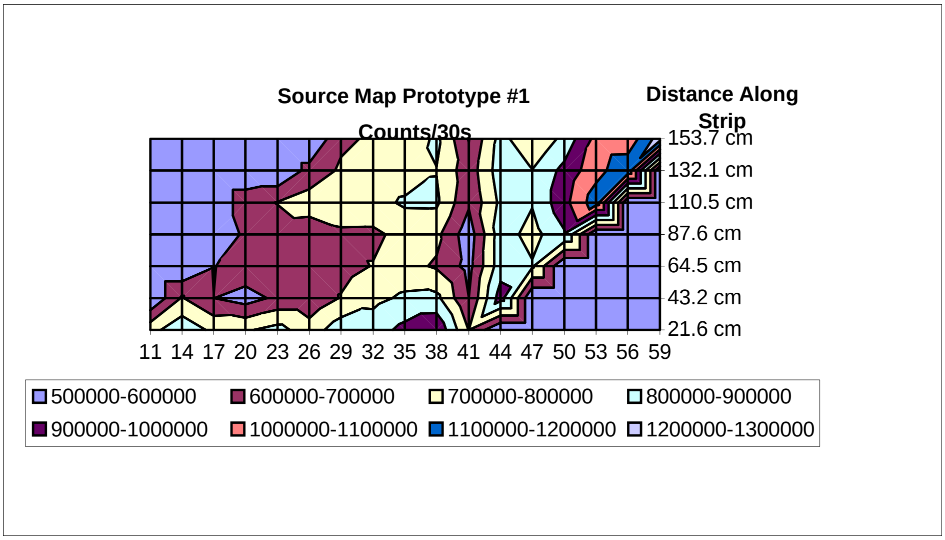
(b) Prototype Counter S2

Figure 2. Schematic arrangement of scintillator strips and numbering.

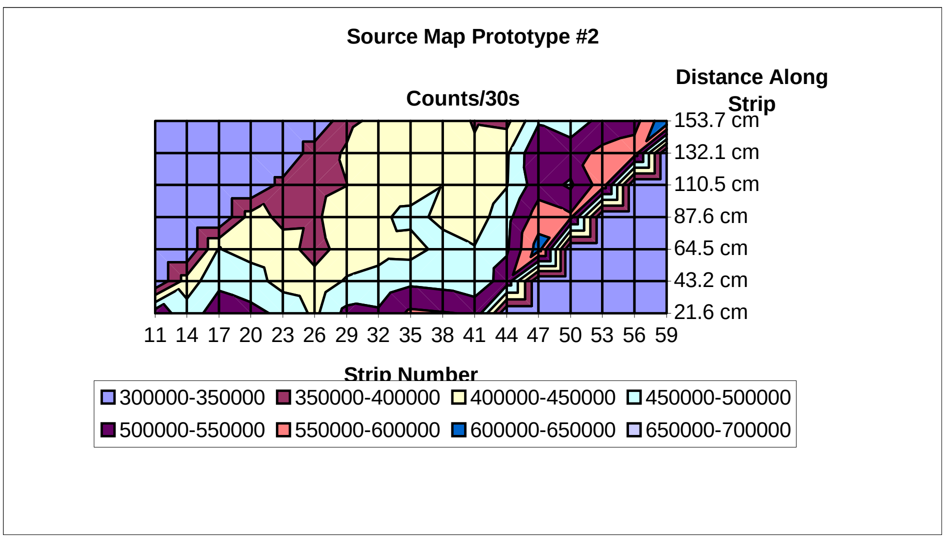
2. TEST RESULTS

2.1. Source Tests

Singles rates per 30 sec from the Cs source were measured at points on a grid along 7 longitudinal scans at approximately 22 cm intervals along every third scintillator strip as indicated by the stickers applied as shown in Fig.1. The results are shown as a 2-dimensonal contour plot in Fig. 3.



(a)



(b)

Fig. 3. Results of source tests

The map for S1 in Fig. 3 (a) shows a band of low count rate for strip #41, possibly due to a break in the splice between the wavelength shifter fiber and the clear fiber. One can see higher count rates for the higher-numbered strips, which are closer to the PMT (shorter clear fibers), and at smaller distances along the strips (shorter paths along the shifter fibers).

A more detailed display of the count rate vs. position along the strips is shown in Fig.4.

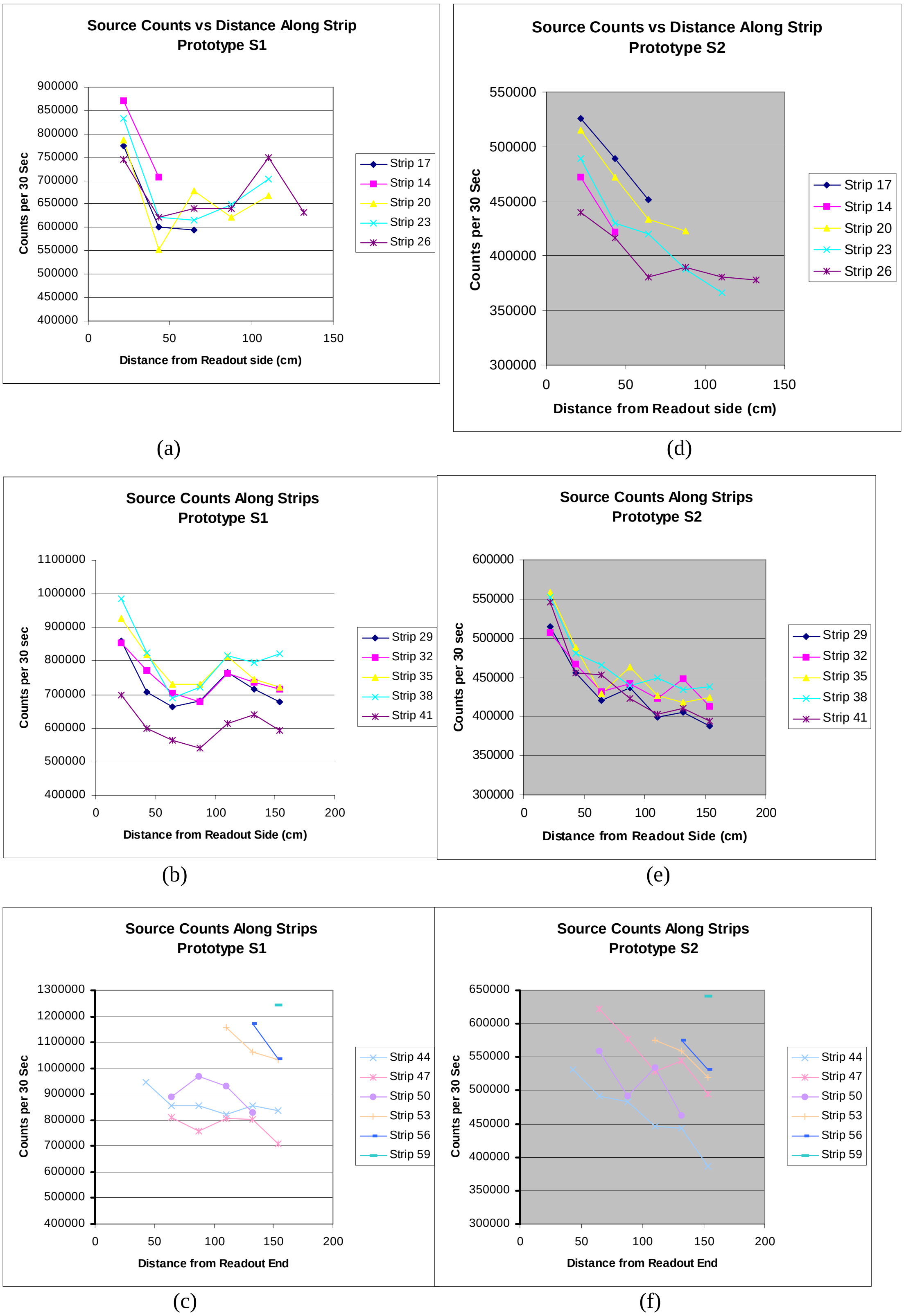


Fig. 4. Source tests results for prototypes S1 and S2. Count rates vs. position along strips.

Fig. 4(a) shows the count rate vs. distance along the strip for S1 for strips #14-26. Fig. 4(b) shows the count rate vs. distance along the strip for S1 for strips #29-41, the strips that are of equal length. Fig 4(c) shows the count rate vs. distance along the strip for S1 for strips #44-59. Figs. 4(d), 4(e), and 4(f) show the corresponding plots for counter S2. Both sets of data were taken with the same SAPMT. The counting rates for S1 show the lower values for strip #41 with the same response along the strip as the others in Fig. 4(b). There is approximately a 20-25% decrease in count rate along the longer strips, which corresponds to an attenuation length of 4m to 6m in the scintillator-wavelength shifter combination, if one assumes that the decrease in rates is due to attenuation of light.

Fig. 5(a) shows the count rates vs. strip number for S1 for the tested distances along the strips.

Fig. 5(b) shows the corresponding rates for S2. The rates decrease by 10-20% between strips 20 and 44 at constant distance along scintillator. This is probably due to loss in the clear fiber from end of the scintillator to the cookie. The lengths of clear fiber differ by about 1.25 m. For a 15% loss in 1.25m the attenuation length is about 7.7m. This is consistent with the data from the manufacturer.

2.2. Cosmic Ray and Other Tests

Using cosmic rays the mean number of photoelectrons detected by S1 was measured from the pulse height distributions from a LeCroy 2249 analog to digital converter (ADC). The results, a mean pulse height of 110 to 160 channels above pedestal at 0.25 pC per channel, correspond to 6 to 8 photoelectrons. This is an improvement of about a factor of 2 compared to the value for on our pre-prototype counter that was reported at the Stanford meeting [Ref 1]. A typical ADC spectrum had about 2% pedestals, which corresponds to about 4 photoelectrons, if one attributes the pedestal counts to be due to inefficiency.

Efficiencies were measured by comparing the coincidence rates for S1 and for S2 with the trigger counter rates. From these measurements the values obtained were 98% for S2 at a discriminator threshold of 30-35 mV. For S1 the efficiency was 90% at a 50 mV threshold. These measurements were done with the SAPMT.

Some preliminary tests were done with the MAPMT. The MAPMT produces separate signals for each strip, while the SAPMT collects light from all 64 strips. The effectiveness of the source collimator can be measured by recording the singles rates from the strips that are near the strip that has the source directly above it. This shown in Fig. 6, in which the rates for strips #27-32 are shown when the source is positioned over strip #28 and #30, respectively. The rates peak at the targeted strip, and the source profiles are 1 to strips wide, backgrounds subtracted. From the geometry, collimator size and distance above the counter, we expect about 25% of the source counts to result from adjacent strips.

Additional tests were performed using a single similar scintillator strip 1 m long, which had a wavelength shifter that extended ~15 cm past the end of the scintillator. The PMT was positioned near the end of the fiber.* Both source tests and cosmic ray tests were made on the strip. The results are shown in Fig. 7.

* The strip was provided by Northern Illinois University

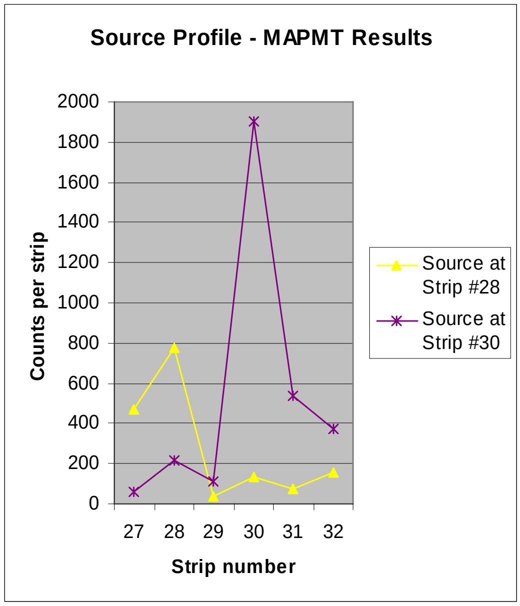


Fig. 6. Counts at various strips while the source is positioned above one strip.

Fig. 7(a) shows the source results. There is a decrease in count rate at the ends, which we attribute to spread of the source profile (poor collimation), and an attenuation of the rates along the strip. The observed attenuation length is about 4.6m, which is consistent with the expected value of 5m. Fig. 7(b) shows the cosmic ray results.

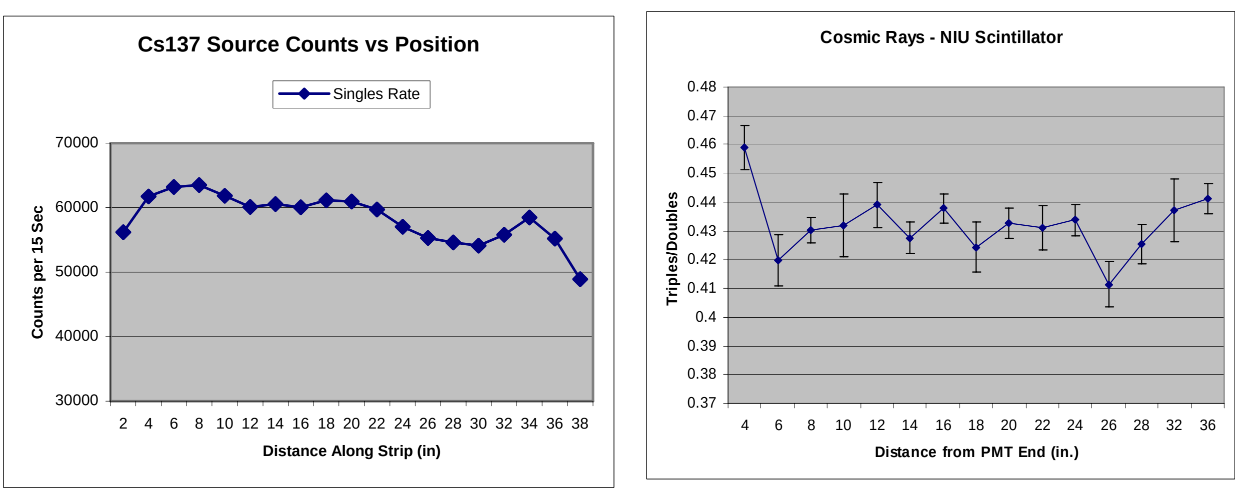


Fig. 7

The coincidence rates per counts in small trigger counters above and below the strip vs. position are shown. The trigger counters subtend a larger region across the strip and thus the triples rate is not near 100%. The falloff at the ends observed with the source is not present, and the rates are more constant than the sources rates, but the response is consistent with the source rates.

3. CONCLUSIONS AND FUTURE PLANS

We have shown progress in building and testing prototype ILC muon detectors and we have presented results of cosmic ray and source tests. Our next phase will include building and testing modules with readouts at both ends of each scintillator, improved mountings of the MAPMTs, continued cosmic ray an source testing, and beginning testing in a test beam.

Ackowledgments

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