SDC-93-403

SDC
SOLENOIDAL DETECTOR NOTES

PROPOSED SDC MUON COUNTER CONFIGURATION

December 2, 1992

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2 Dec 92

1) Overview

We propose, as in the TDR, to identify the bunch crossing of muons traversing the barrel and intermediate regions of SDC with a single layer of scintillation counters. In this note we present a particularly attractive configuration and layout for these counters. This proposal is based on recent measurements of prototype counters and on a detailed evaluation of access requirements. We also present preliminary results from a study of neutron-induced backgrounds based on SDC Note SDC-92-361. We discuss a minor modification of the Intermediate and Forward counter configuration that will reduce backgrounds by an order of magnitude.

A muon counter task force charged with finding the optimal location of the single layer of counters has made a preliminary recommendation that this layer be located in the 1.0 m gap between the BW2/IW2 and BW3/IW3 chamber modules. This highly constrained space demands the implementation of compact counters with easily accessible photomultiplier tubes (PMTs) and bases. The only configuration which appears to satisfy these constraints is shown in figures 1 and 2.

As indicated in fig. 1, the light guides are folded back across the top of the counters so that all PMTs and bases are accessible without moving any counter. The total length of approximately 185 cm allows any counter to be removed from the detector should this be required sometime during the lifetime of SDC. (Counters with straight light guides would be about 300 cm long and would be difficult or impossible to move around the BW-IW corner.)

The task of reversing the path of photons is accomplished in two steps. The first consists of internal reflection at the counter ends whose edges are cut at 45 degrees. A quarter section of plastic cylinder then guides the photons adiabatically into a twisted-strip light guide. This configuration has been proposed by N. Christensen and K. Heller who determined experimentally that approximately 60-70% of photons transmitted by the scintillator are reflected by this geometry.

2. Performance of Prototype Counter

We have constructed and tested a counter at Michigan with the configuration and overall dimensions shown in fig. 1. The average number of detected photoelectrons (p.e.) from perpendicularly incident cosmic-rays is shown in fig. 3 as a function of distance from each end of the counter. The yields are essentially identical and more than adequate (>25) for SDC. This test was performed with Kuraray SCSN-81 scintillator. Based on previous experience, we would expect Bicron BC-408 to have a substantially (>50%) higher photon

yield. NE110 would show similar or slightly better and IHEP scintillator similar to slightly worse performance. We intend to construct counters with all these scintillators.

The signals from the two counter ends were processed with a mean timer whose output time relative to the signal from a small trigger counters is shown in fig. 4. The observed time resolution of about 1.4 nsec is dominated by the time jitter of the trigger counters which is measured to be of a similar magnitude. Even without unfolding this extraneous jitter, it is clear that the time resolution of the prototype counter is adequate for identifying the correct bunch crossing with very high probability. The small tails in the distributions towards early times are not understood but are consistent with multiple hits which can shift the mean-timer output by up to one half of the maximum light transit time (12/2=6 nsec) but only to earlier times. The tails are well contained within the 16 nsec time window. [Note: as shown in fig. 5, mean-timer mismeasurements at BS2 due to prompt multiple hits will be limited to less than 3.7 nsec.] The threshold for signals displayed in fig. 4 was approximately equal to 1.5 p.e. Raising the threshold to about 4.0 p.e. did not change the character of the time distributions.

We note that the mean timer also provides spatial information along the scintillator. For SDC, the mean timer output segments counters into four logical elements corresponding to 50 $\times$ 50 cm pixels in BS2 and IS2. This matches the hadronic calorimeter granularity of 0.1 $\times$ 0.1 in $\eta - \phi$ space.

3. Access

Figs. 6 and 7 show the platforms and ladders required for servicing the barrel counters described above. This design work is still in progress. As shown in fig. 8, full-scale models have been constructed to study the adequacy of the proposed 1.0 m gap between BW2 and BW3. Our initial impression is that this 1.0 m spacing is sufficient.

4. Neutron Backgrounds

L. S. Waters et al. (SDC Note SDC-92-361) have made a detailed study of neutron currents in SDC. Results pertinent to the muon trigger counters are summarized in fig. 9. The indicated number of neutrons correspond to an integrated luminosity of 10,000 pb^{-1}. It is clear that the region near the final-focus quadrupoles is a very intense source of neutrons. Rates in FW5 are an order of magnitude higher than in FW4. Surprisingly, the same is true for BW3 vs BW2. Rates increase dramatically with decreasing polar angle. It should be noted that this study is based on the TDR version of the forward SDC detector configuration (see fig. 10) with only minimal shielding near the quadrupoles. The actual SDC detector will be constructed with much more elaborate shielding schemes so that the rates calculated by Waters et al. will (hopefully) represent an upper limit on what will be experienced by SDC. A goal should be to reduce the Waters et al. rates by one order of magnitude.

The response of scintillator to fast neutrons is well documented. Some useful references (which all give very consistent results) include:

J. E. Hardy, Rev. Sci. Inst. 29 (1958) 705

S. T. Thornton and J. R. Smith, NIM 96 (1971) 551

M. Drosg, NIM 105 (1972) 573

R. A. Cecil et al., NIM 161 (1979) 439

Data from two of these references are shown in figs. 11 and 12. To summarize: 1.0 cm thick scintillator and a threshold of 0.1 minimum ionizing (0.2 MeV) yield a neutron detection efficiency which is zero below neutron energies of 1.0 MeV, rises to a maximum of 0.06 at 2 MeV, and falls linearly to 0.04 at 10 MeV. We have calculated the neutron-induced rates under the following simple assumption: the number of neutrons above 1 MeV is equal to half the number indicated in fig. 9 (which displays neutrons with $0.1 < E < 20$ MeV) and that the average scintillator detection efficiency is 0.050. The singles rates per counter from neutrons obtained in this manner are shown in fig. 13 for the standard SSC luminosity of 10^{33} cm^{-2} sec^{-1}.

Suppose a real muon trigger occurs and is correctly tagged by the muon counters. What is the probability of obtaining additional random taggings during the 1.0 usec drift chamber time window? This is shown in fig. 14 for the TDR muon counter configuration. The calculation for this figure ORs together all counters across an octant under the assumption that only the theta tubes are used in level 1. In BS2/IS2 this consists of the OR of 4 counters. In the forward region, 2 or 3 counters are ORed depending on theta. Except for the single layer of intermediate counters, the extra random tagging rate is reasonably low everywhere (typically 2% in the barrel and 10% in the forward system.) The random rate in the intermediate region equals the real rate and would increase the overall level-1 muon trigger rate by about 12%. (The random taggings would not survive level-2 and level-3 requirements). This increase presents no major problem.

It turns out that the random trigger rates from neutrons can be dramatically reduced in the intermediate and forward regions by a very simple change in configuration, one that adds essentially no extra cost. Basically, the IS2 and FS4 counters would be replaced with the design shown in fig. 15, and the FS5 layer would be eliminated entirely. Two close, optically isolated counters would yield a very low random coincidence rate because of the very short range of protons recoiling off the neutrons. Externally, the design in fig. 15 would be indistinguishable from the barrel counters. Using a high-yield scintillator such as Bicron BC-408 in IS2 would allow the use of 0.6 cm thick counters so that the total amount of scintillator material would be essentially the same as for the counter shown in fig. 1. The cost would be somewhat higher because the scintillator piece count is doubled. However, the cost increase would be compensated by the effective shift of FS5 to the FS4 location with its much smaller area. Recall that FS5 rates are nearly an order of magnitude higher than those in FS4. Shifting the layer to FS4 reduces the random tagging rate by twice this ratio of neutron rates since the FS4*FS5 trigger required the coincidence of one FS4 counter with the OR of two contiguous, overlapping FS5 counters. The double FS4 layer would be more vulnerable to electromagnetic debris than the FS4*FS5 combination but such debris is likely to be less severe than the neutron background. This should be studied

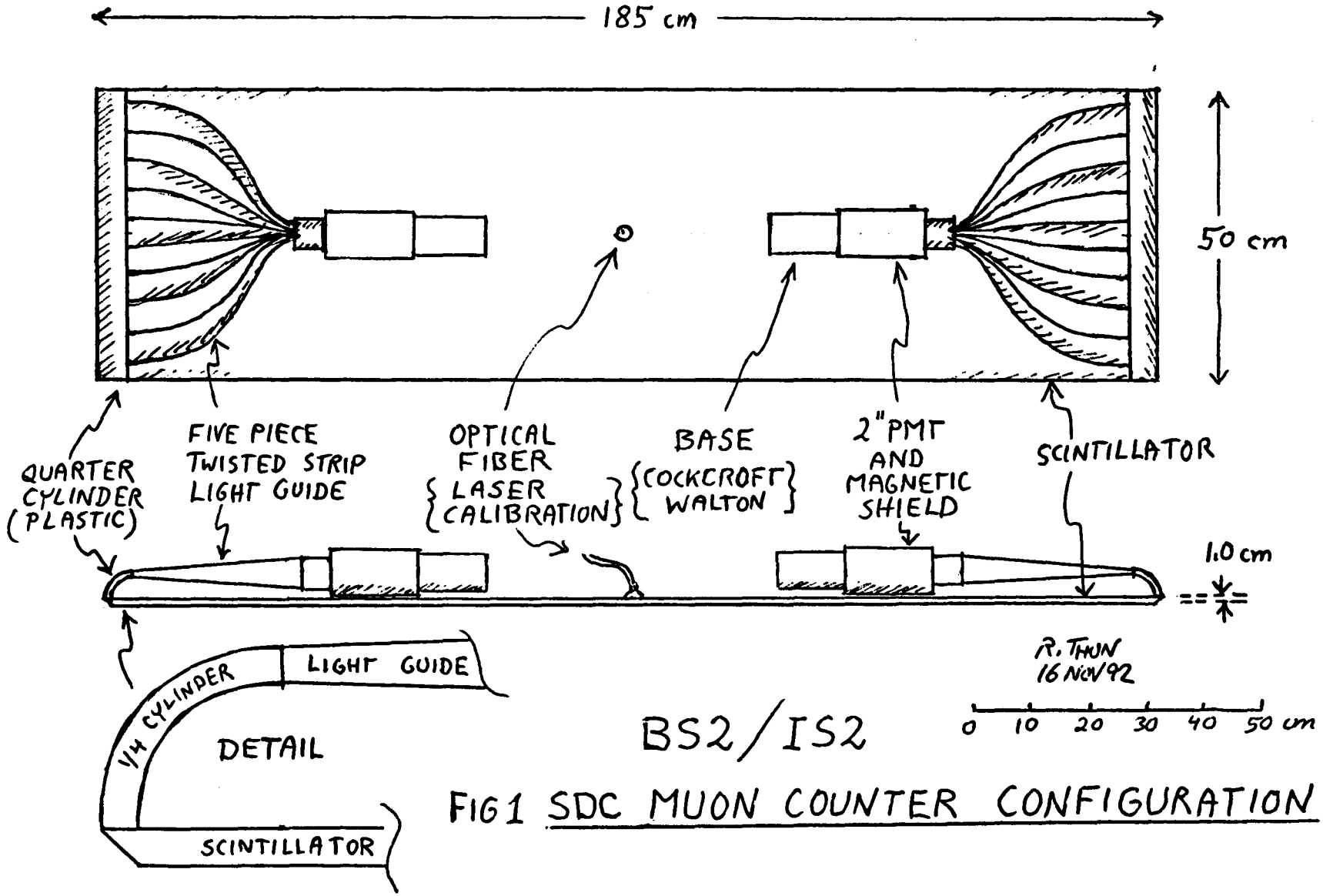
in greater detail. Figure 16 shows the expected random tagging rate from neutrons with this new, proposed IS2/FS4 layout at the SSC design luminosity. It is below 2% everywhere in IS2 and FS4.

5. The Next Step

We intend to produce and test several more counters according to the designs described in this note using various scintillator materials available to us. If the results continue to be encouraging, we would propose to have the Collaboration accept this design and then begin the detailed engineering required to implement it in the supertower prototype and in the SDC detector itself.

6. Summary

We propose to tag muons in SDC with a set of scintillators that provide excellent time resolution (better than 1.0 nsec), very good positional resolution (50 $\times$ 50 cm or better corresponding to 0.1 $\times$ 0.1 in $\eta - \phi$ space), and low neutron-induced random rates (typically less than 2% of the muon trigger rate at the SDC design luminosity). Scintillation counters represent a well-proven, low-risk technology which can be implemented by many groups working within the collaboration. The hazard associated with such counters is very low since no gas is required and the Cockcroft-Walton photomultiplier bases are powered by supplies operating at low voltage. The configuration of counters outlined in this note allows ready access to all photomultipliers and bases. Replacement of these active components in case of failure is a straight-forward matter.



BS2/IS2

FIG 1 SDC MUON COUNTER CONFIGURATION

FIG 2(a) SIDE VIEW: COUNTERS ARE SHINGLED FOR EASY REMOVAL AND GAPLESS COVERAGE

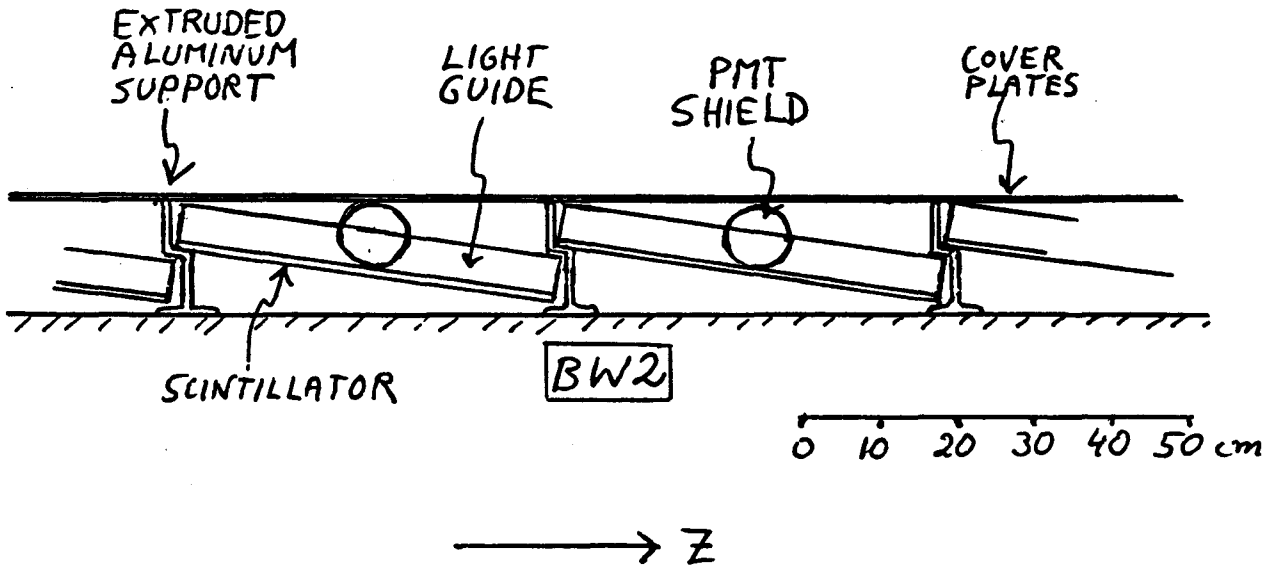
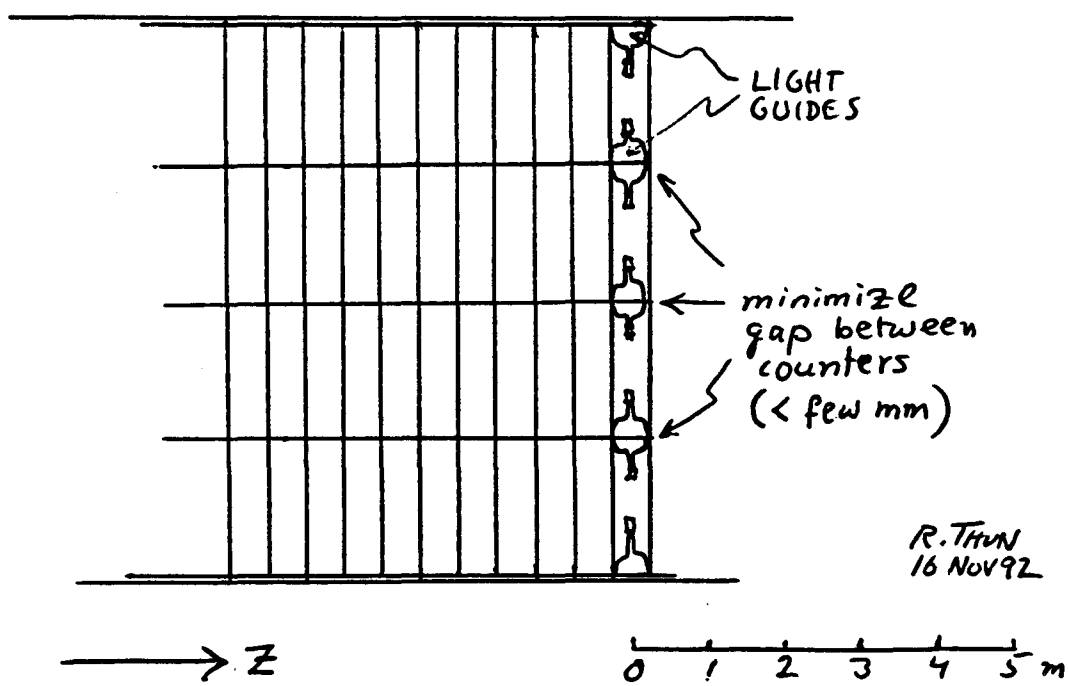


FIG 2(b) TOP VIEW: FOUR COUNTERS ACROSS OCTANT (NO OVERLAP IN DIRECTION ACROSS OCTANT)



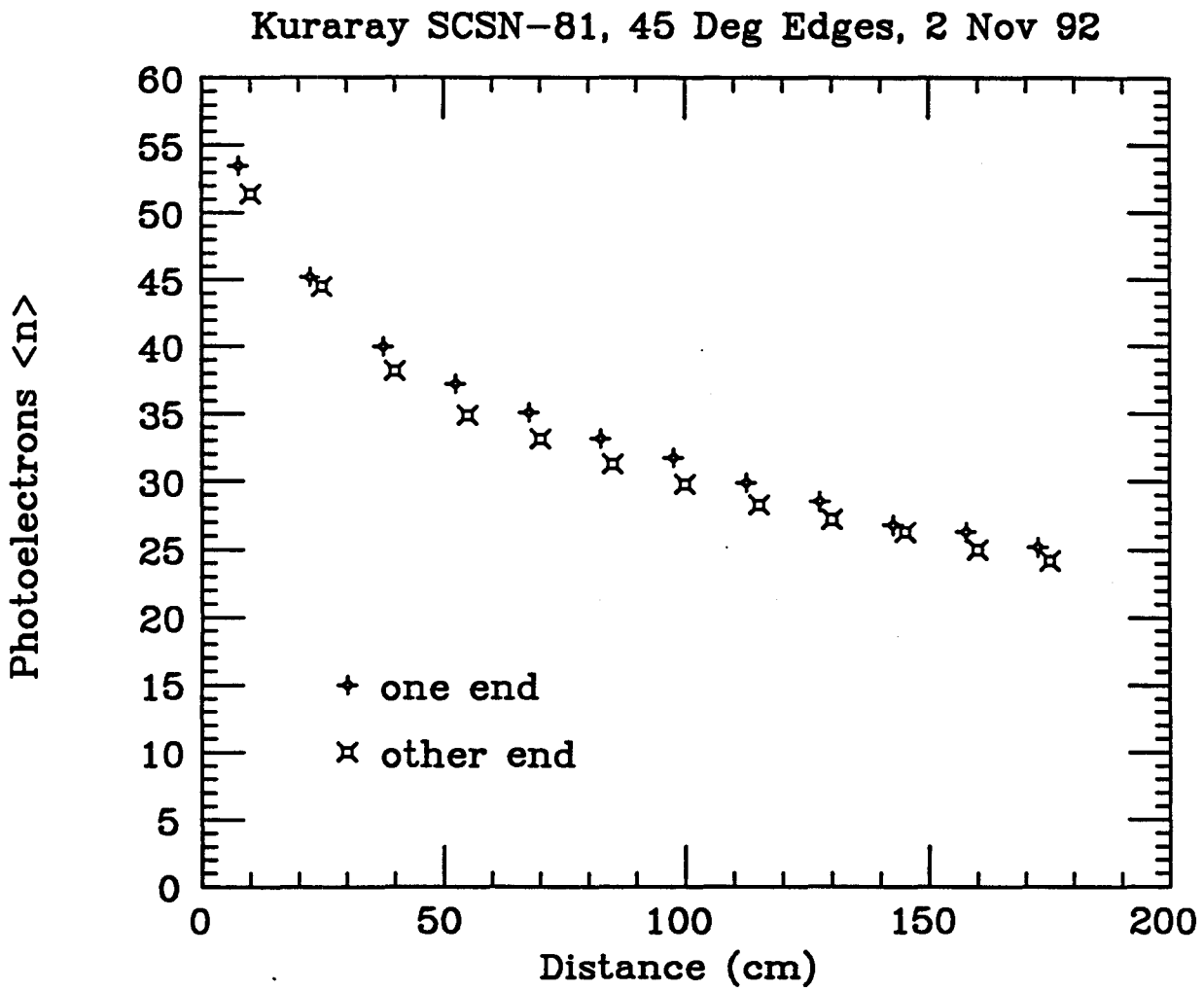
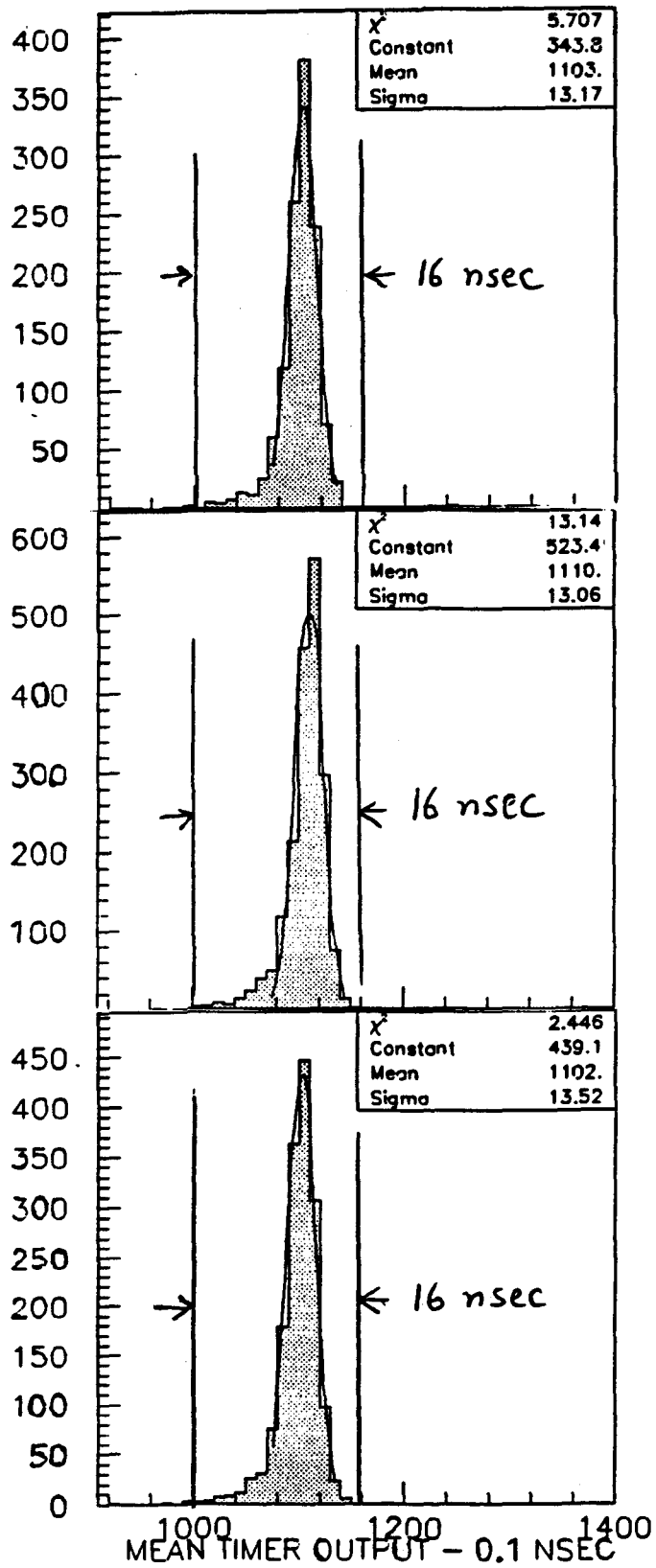


FIG 3 PHOTOELECTRON YIELD VS DISTANCE FROM COUNTER END FOR COSMIC-RAY MUONS

FIG 4

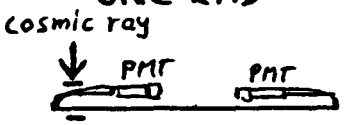
MEAN-TIMER SPECTRA

RESOLUTION IS DOMINT BY JITTER OF START TIME PROVIDED BY SMALL TRIGGER COUNTERS.



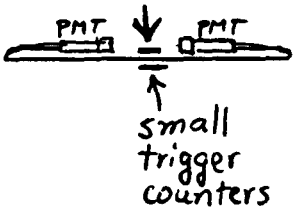
-0.825m

ONE END



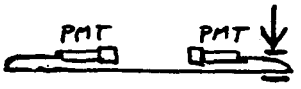
0.0m

CENTER

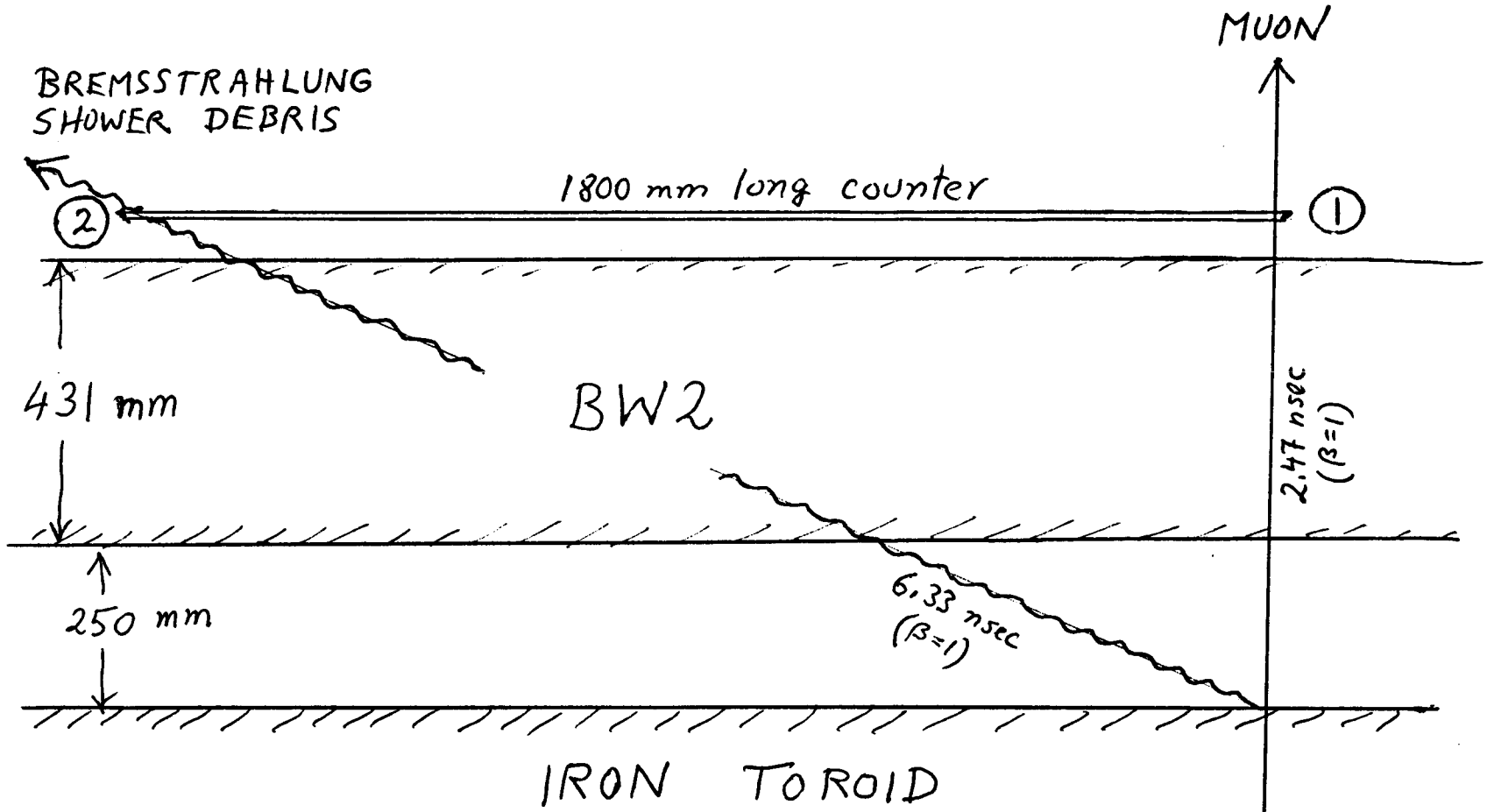


+0.825m

OTHER END



SCSN81 45 Degree Cut 2500V



SCALE

0 100 200 300 400 500 mm

LIGHT ARRIVAL TIMES (nsec)

$T1\,(\text{MUON}) \equiv 0$

$T2\,(\text{MUON}) = 11.3 = \frac{1800}{160} = \frac{\text{LENGTH}}{C_{eff}}$

$T2\,(\text{DEBRIS}) = 3.9 = 6.33 - 2.47$

MEAN-TIMER MISMEASUREMENT $= \frac{1}{2}\left[T2\,(\text{MUON}) - T2\,(\text{DEBRIS})\right] = 3.7$

FIG. 5

R. THUN
28 NOV 92

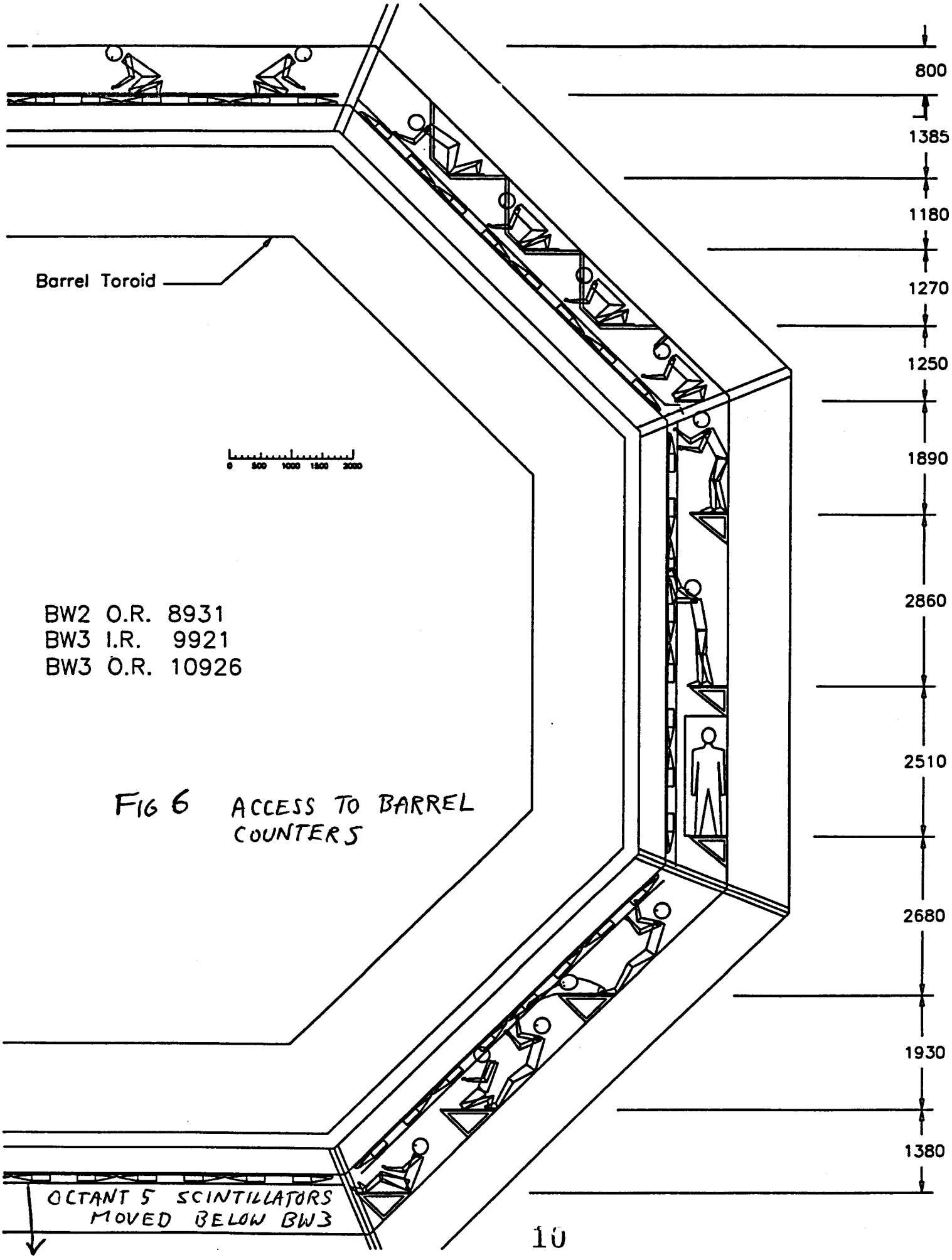


FIG 6 ACCESS TO BARREL COUNTERS

Barrel Scintillator 2

Access Ladders and Walks

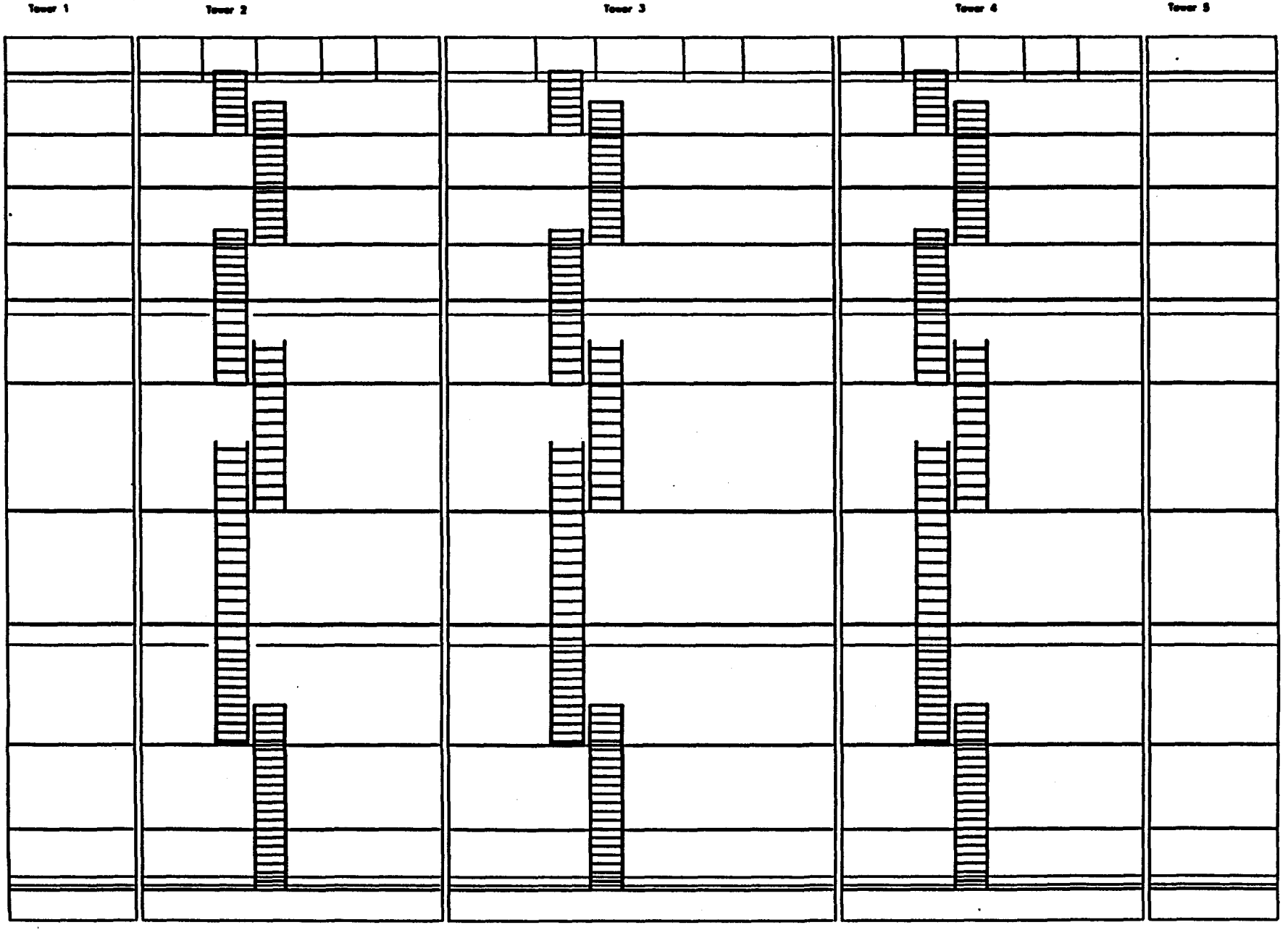


FIG 7 LAYOUT OF LADDERS IN BARREL

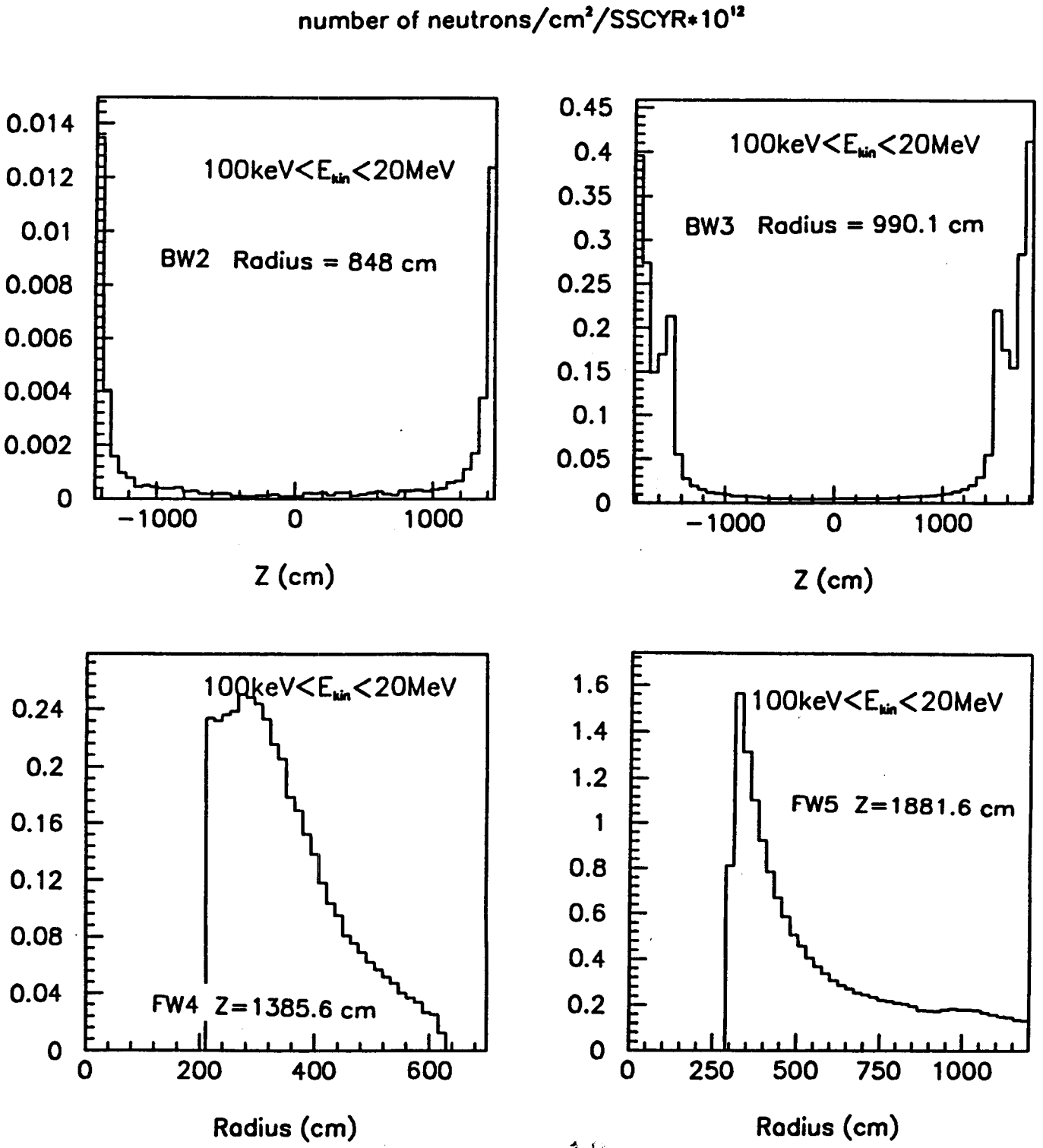
FIG 8 FULL-SCALE MODEL OF BW2 - BW3 GAP IN OCTANT 2

SDC Note SDC-92-361
November 12, 1992

Neutron Currents in the SDC

L. S. Waters, A. P. T. Palounek, H. G. Hughes,
H. Lichtenstein, R. E. Prael, and H. J. Ziock
Los Alamos National Laboratory

FIG 9



SDC-92-361

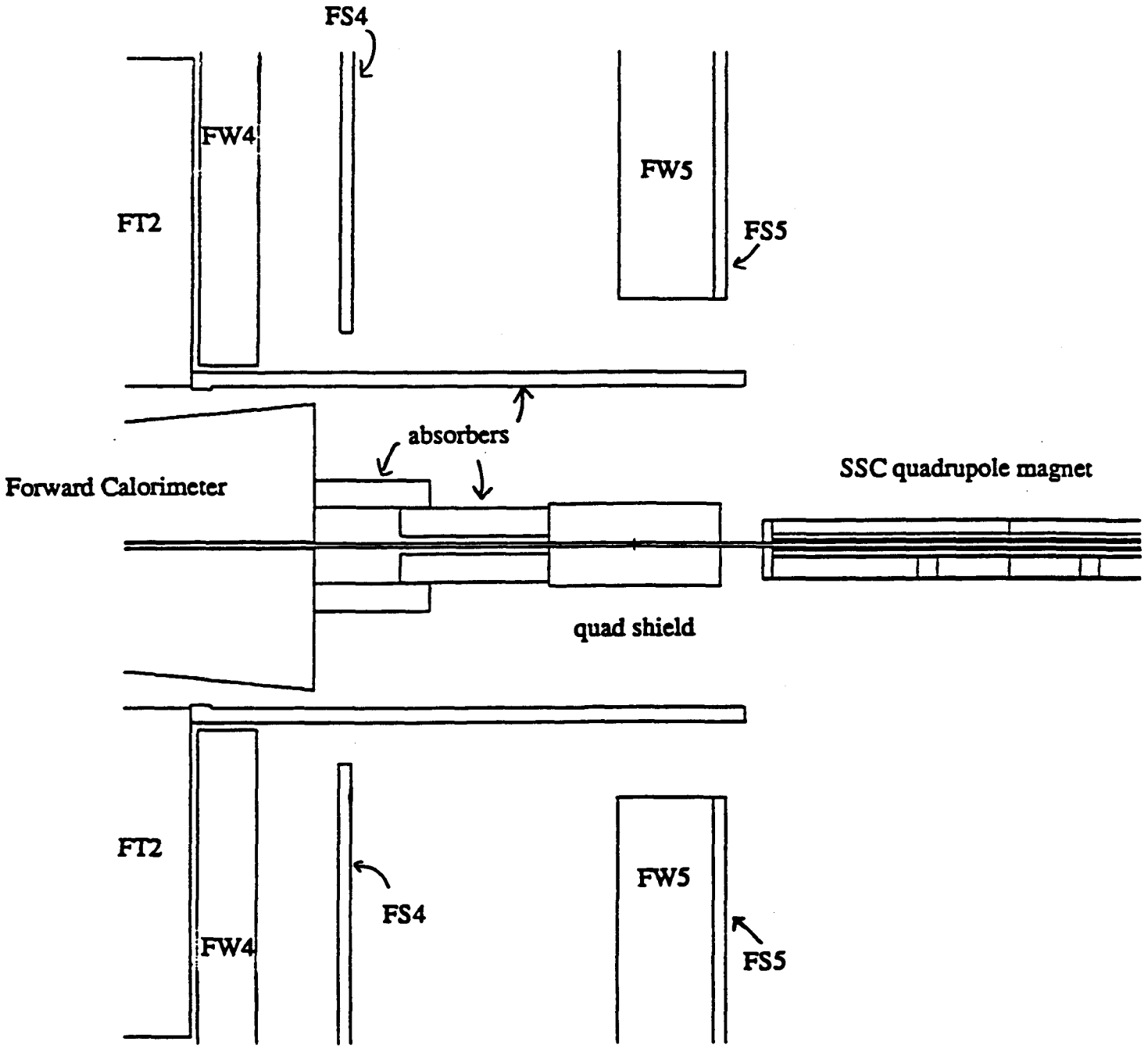


Figure 2: A close-up of the region around z=19m. This shows the end of the quadrupole magnet, the magnet collimators, part of the forward calorimeter, and edges of several muon chambers.

FIG 10

NUCLEAR INSTRUMENTS AND METHODS 96 (1971) 551–555; © NORTH-HOLLAND PUBLISHING CO.

MEASUREMENTS AND CALCULATIONS OF NEUTRON DETECTOR EFFICIENCIES*

S. T. THORNTON and J. R. SMITH

Department of Physics, University of Virginia, Charlottesville, Virginia, U.S.A.

Received 19 May 1971

Neutron detector absolute efficiencies measured in our laboratory for several organic scintillators are reported. A substantially revised version of Kurz's neutron detector efficiency computer program has been used to calculate efficiencies for new and previous measurements. Good agreement has been obtained for various scintillators.

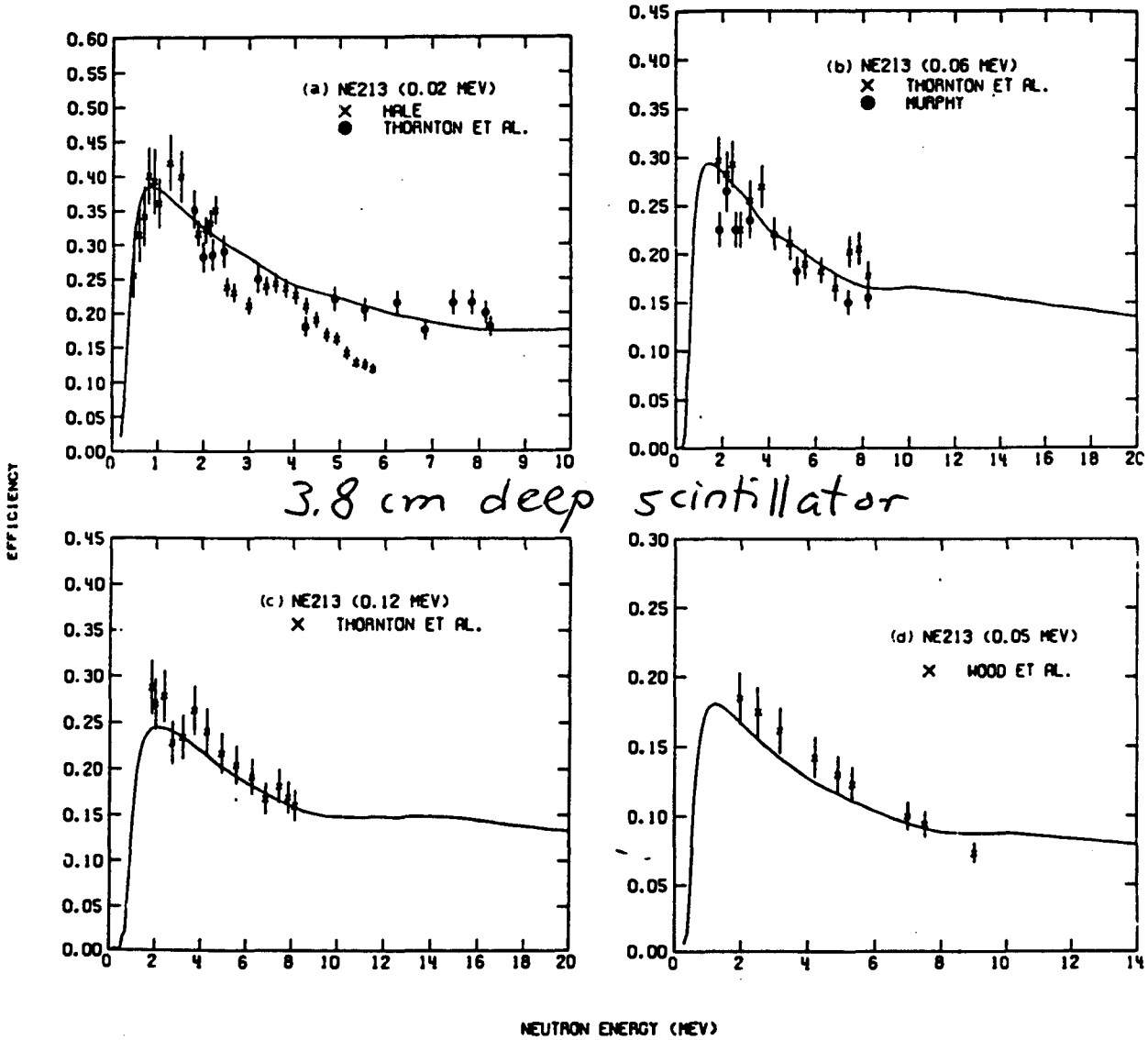


Fig. 1. Comparison of experimentally measured neutron detector efficiencies and calculations by DETEFF (solid line). The calculations were made for an equivalent electron energy bias as indicated in the parenthesis. The measurements were by (a) Hale[15]) and Thornton et al.[12]), (b) Thornton et al.[12]) and Murphy[13]), (c) Thornton et al.[12]), and (d) Wood et al.[18]).

* Work supported in part by the National Science Foundation through the University of Virginia Center for Advanced Studies.

SDC: 1.0 cm scintillator Threshold ~ 0.2 MeV

FIG 11

NUCLEAR INSTRUMENTS AND METHODS 105 (1972) 573–584; © NORTH-HOLLAND PUBLISHING CO.

ACCURATE MEASUREMENT OF THE COUNTING EFFICIENCY OF A NE-213 NEUTRON DETECTOR BETWEEN 2 AND 26 MeV*

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Received 4 July 1972

The neutron detection efficiency of a liquid scintillator (NE-213, 12 cm diam. × 5.7 cm) was measured with various bias settings corresponding to proton energies from 1 MeV to 6 MeV. For neutron energies below about 12 MeV a simplified calculation fits the data very well and the uncertainty in the shape is less than 2%. The importance of contributions from the reaction $^{12}C(n,n')3\alpha$ above that energy is shown. An extensive survey of publications dealing with the efficiency of organic scintillators is also presented.

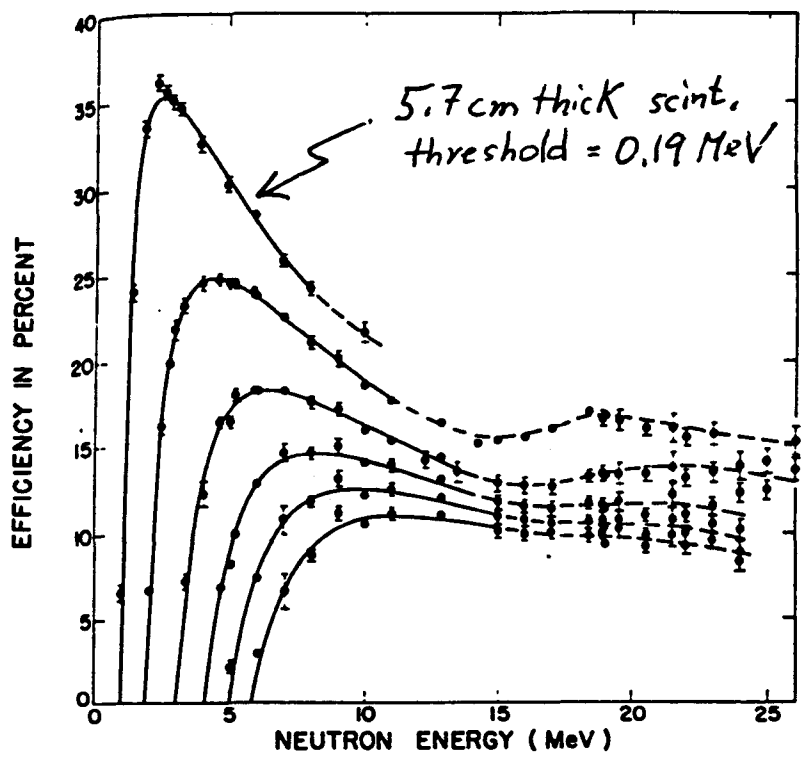


Fig. 4. Measured efficiency points for biases at 0.4, 1.0, 2.0, 3.0, 4.0 and 5.0 times Cs and calculated fits (solid lines). The dashed lines are handfitted.

SDC: 1.0 cm thick scintillator Threshold ~ 0.2 MeV

FIG 12

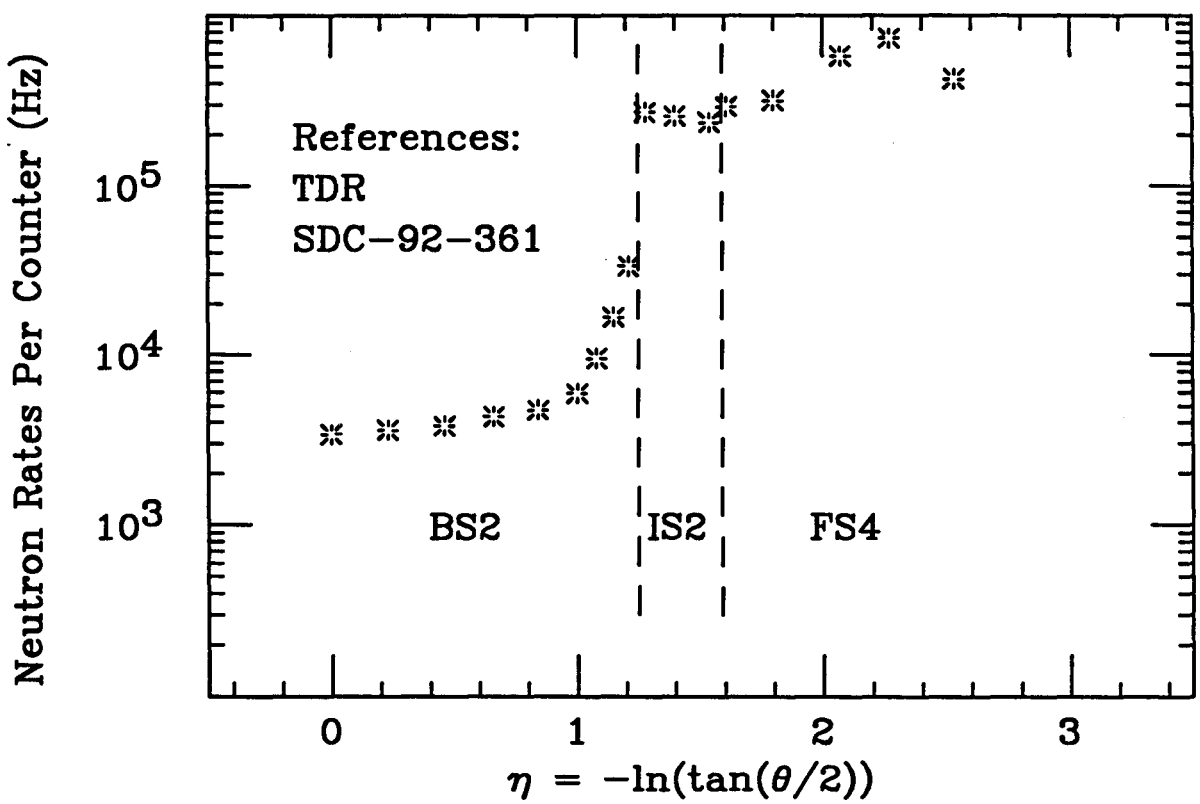


FIG 13 NEUTRON-INDUCED SINGLES RATES FOR $\mathcal{L} = 10^{33}\ cm^{-2} sec^{-1}$

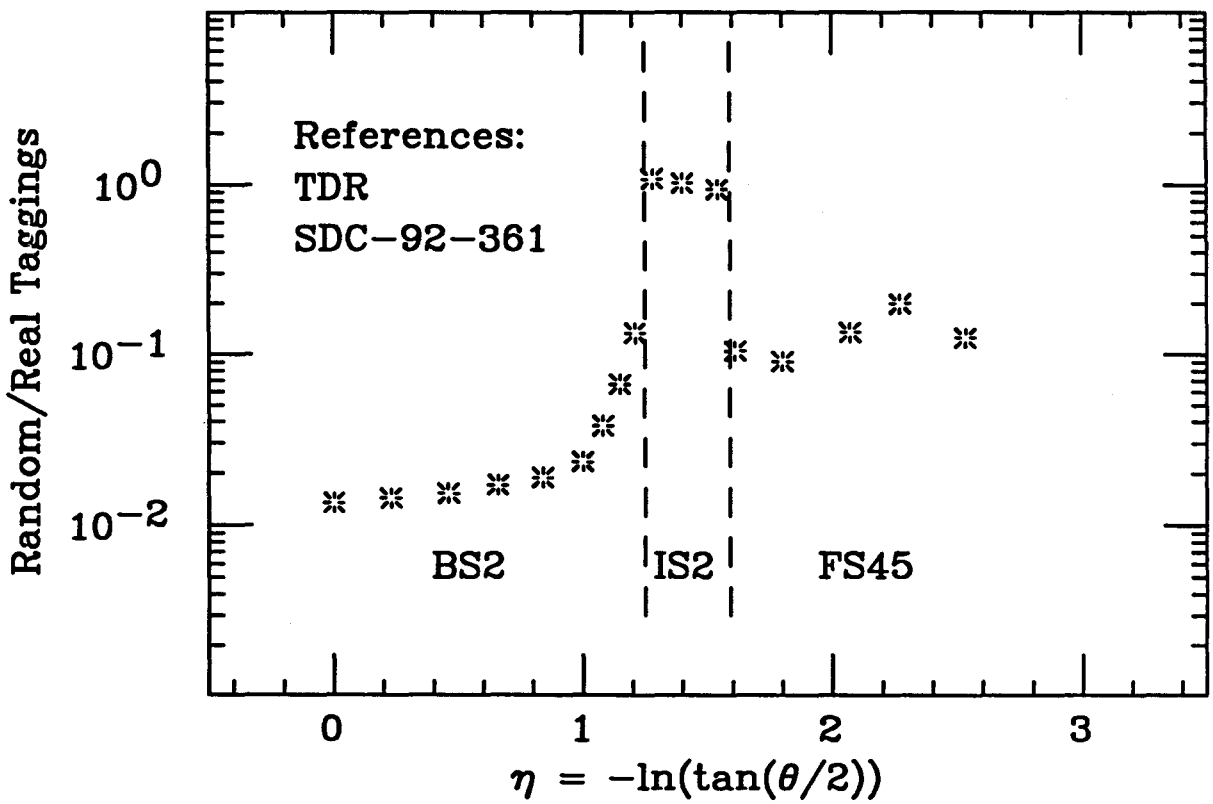
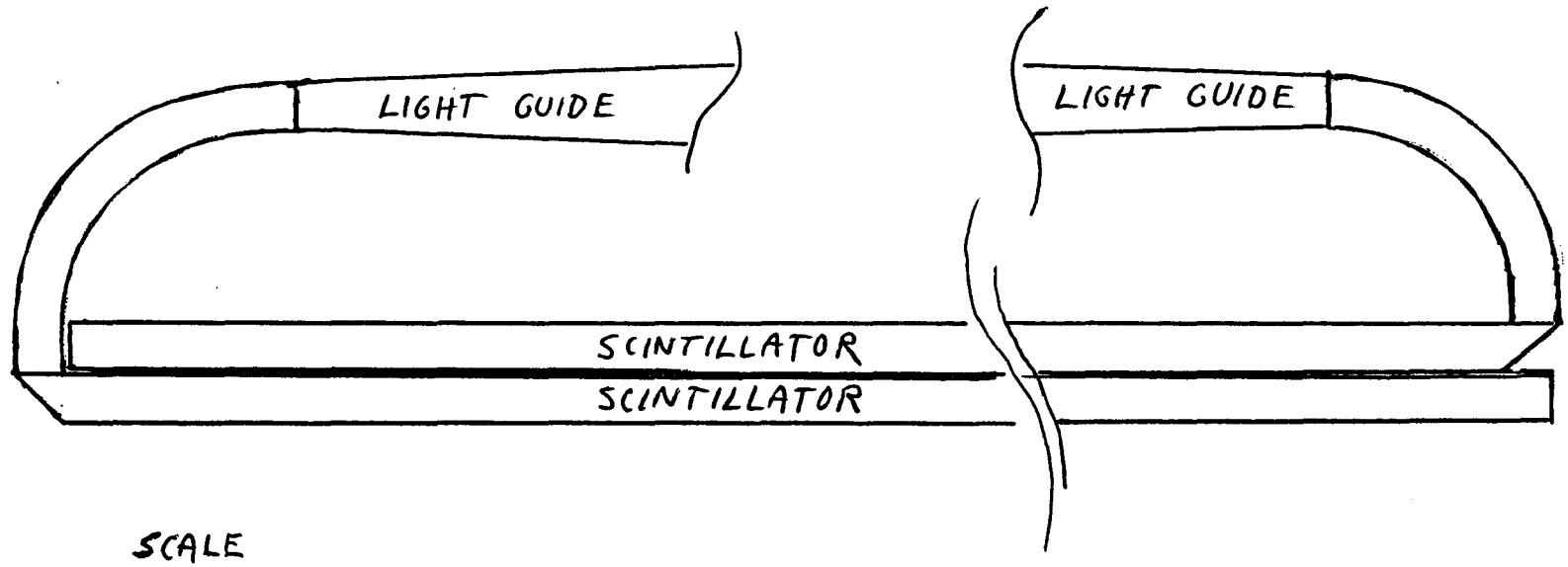


FIG 14 NEUTRON-INDUCED RANDOM TAGGING NORMALIZED TO REAL MUON RATE FOR $\mathcal{L} = 10^{33}\,cm^{-2}\,sec^{-1}$



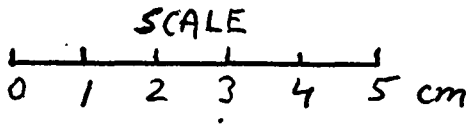


FIG 15 PROPOSED CONFIGURATION FOR IS2 AND FS4

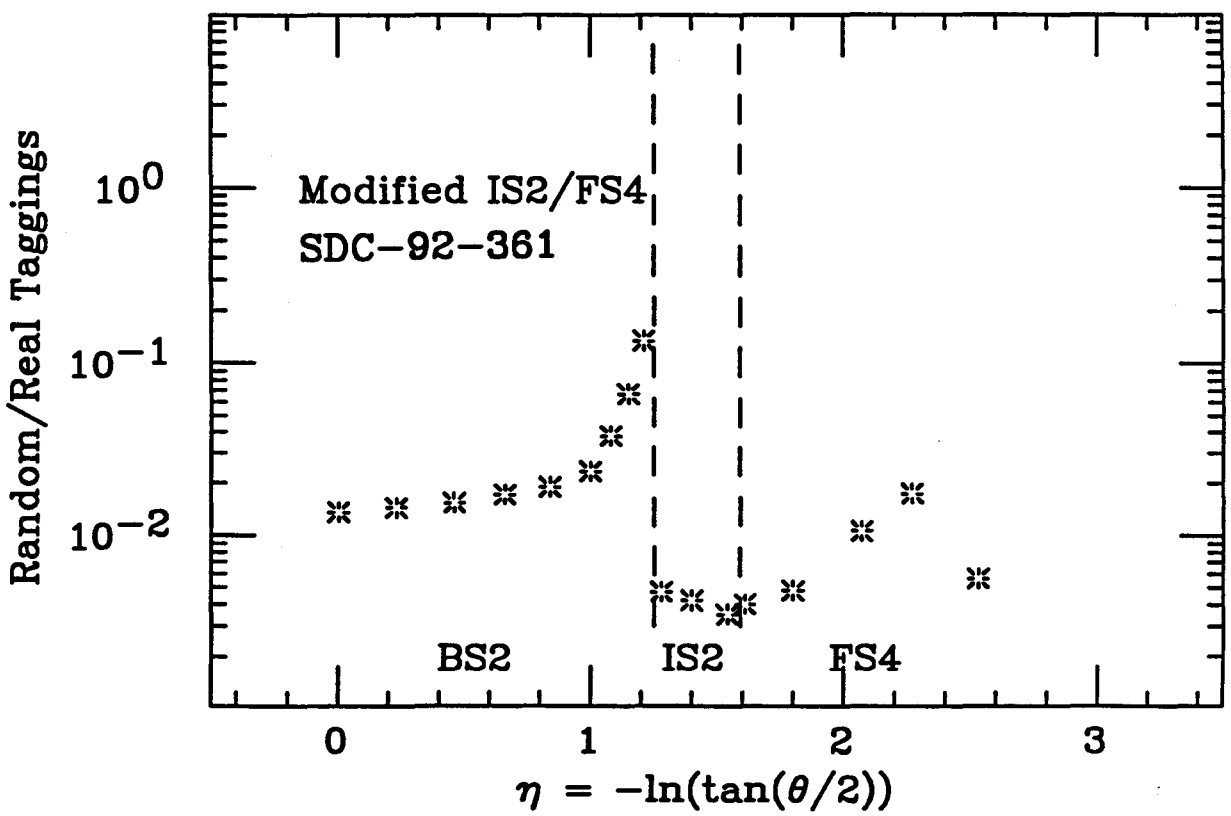


FIG 16 NEUTRON-INDUCED RANDOM TAGGING NORMALIZED TO REAL MUON RATE FOR $\mathcal{L} = 10^{33}\ cm^{-2} sec^{-1}$ AND WITH IS2/FS4 ACCORDING TO FIG. 15