SNO-STR-93-015

Neutral Current Detector Response and Calibration

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Two aspects of neutral current detector response have been investigated using our Monte Carlo neutron transport code[1-3]. The first deals with the radial neutron capture distribution of a proposed neutral current detector element. The second is the calculated response of all neutral current detector strings to a calibration source located at various positions in the acrylic vessel.

1. Radial capture dependence of neutrons.

Within a neutral current detector element the radial dependence of neutron capture will be a function of the abundance of neutron absorbing material. The higher the density of the absorbing material (^3He in our case) the more black the detector becomes and the closer the captures come to the detector wall. Knowledge of the capture distribution will be useful for predicting the detector relationship between alpha activity in the wall and the proton and triton tracks generated following ^3He neutron capture. Also important is the question of prototyping the detectors and measuring their intrinsic backgrounds. For these primarily electronic tests, ^3He is expensive and we would prefer to use a low concentration of the neutron capturing material.

For these studies we have placed a single detector element (taken to be made from 10 mil Ni, 2 m long and 2 inches in diameter) and placed vertically in the center of a modified version of the SNO acrylic vessel. The modification consisted of reducing the vessel radius from 6 m to 2 m. The other properties were held the same (99.92% D_2O, 2 inch acrylic walls, and the outside volume consisting of light water).

For this test detector, two gas fills were investigated. The first consisted of our proposed production gas mixture: 80%/20% $^3He/CF_4$ containing 3 atm of ^3He. The second was a diluted mixture of ^3He containing 6.9% ^3He, 76.4% ^4He, and 16.7% CF_4. For this case the total He pressure was 3 atm. For both gas fills two different spatial distributions of source neutrons were calculated: 1) a point source that emits neutrons in the forward hemisphere and is located in the central plane of the detector 10 cm from the center of the vessel (i.e. at the midpoint of the neutral current detector and 7.46 cm perpendicular from the detector tube wall), and 2) a distributed source that uniformly emits isotropic neutrons into the total vessel volume.

Figure 1 presents the results for a point source using the high concentration ^{3}He gas mixture. Also shown is the expected distribution for a uniform neutron capture probability per unit detector gas volume. (This distribution has been normalized to the same integral number of captures predicted by the Monte Carlo calculations.) It is clearly seen that at this relatively high ^{3}He pressure that the detectors have become fairly "black" to neutrons and the captures are concentrated toward the detector walls. Figure 2. is a similar presentation but for the case when diluted ^{3}He is used. In this case the detector is no longer "black" and the distribution closely follows the uniform capture distribution.

Figures 3. and 4. are analogous to Figures 1. and 2. except that the neutron source was taken to be isotropic emission throughout the 2 meter radius acrylic vessel. Though the Monte Carlo statistics are poorer, the results are similar to the point neutron source calculations. The high concentration ^{3}He case shows a distribution skewed toward the detector walls while the low concentration case closely follows the uniform distribution predication.

Figure 5. presents the vertical neutron capture distribution for the four cases studied. As expected, the point source (located 10 cm perpendicular to the mid plane of the detector) gives a vertical capture distribution peaked at the detector center and symmetric about the source location. The isotropic distributed source of neutrons produces a nearly flat vertical capture response with a very slight skewing toward the detector ends (an understandable geometric effect caused by the assumed orientation of this single detector in the 2 meter radius acrylic vessel).

2. Neutron Calibration

The ^{3}He detector strings are placed on a 100 cm x,y lattice. The central position (i.e. x=y=0) does not contain a counter string. The strings are located with $|x,y|$ = 50,150,...550 cm. A fission source of neutrons was placed at three coordinate locations: 1) x=y=z=0 cm, 2)x=y=400, z=0 cm, and 3) x=y=400, z=150 cm. 50,000 neutrons

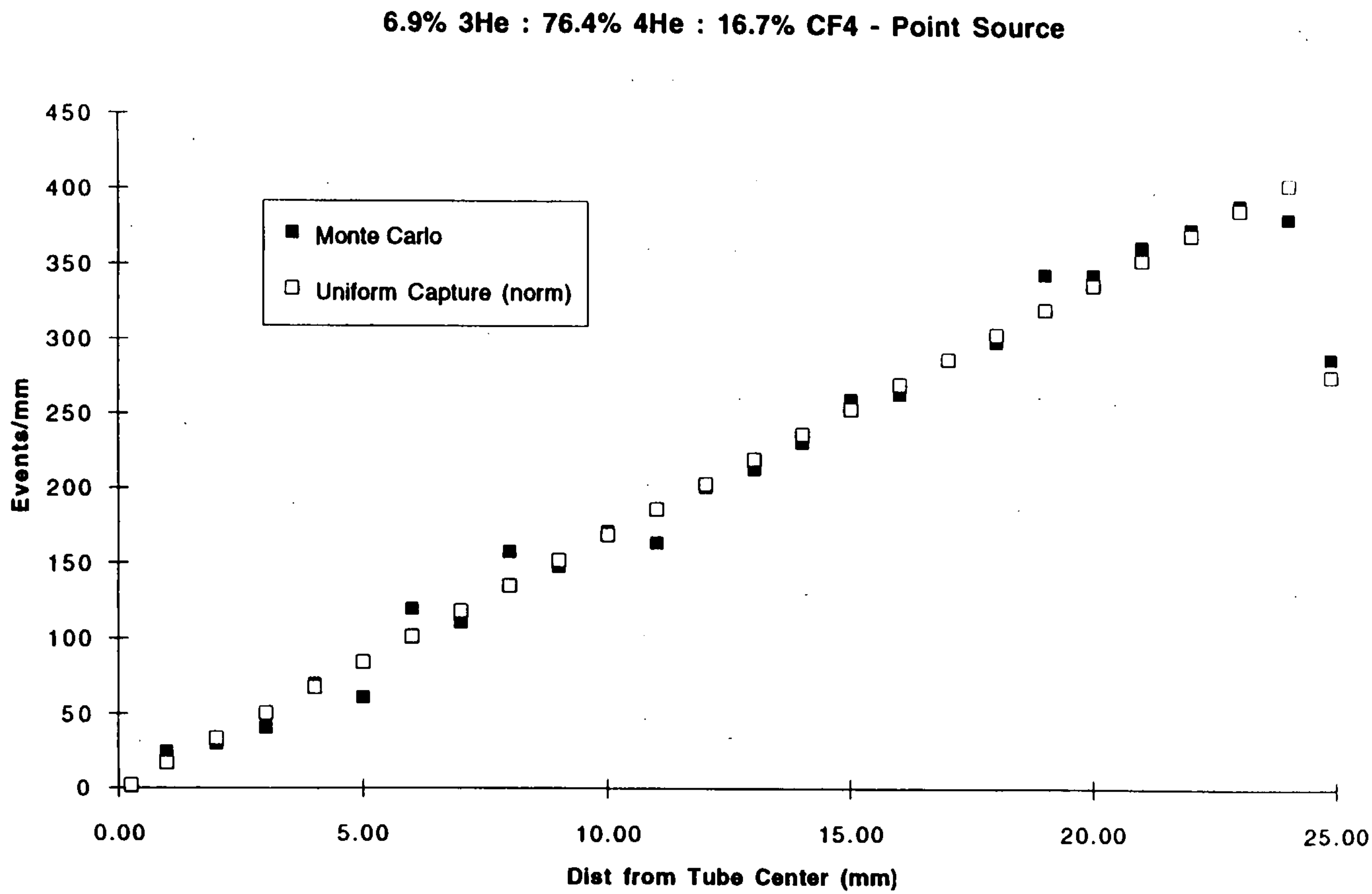

6.9% 3He : 76.4% 4He : 16.7% CF4 - Point Source
Monte Carlo
Uniform Capture (norm)
Events/mm
Dist from Tube Center (mm)
0
50
100
150
200
250
300
350
400
450
0.00
5.00
10.00
15.00
20.00
25.00

Figure 2

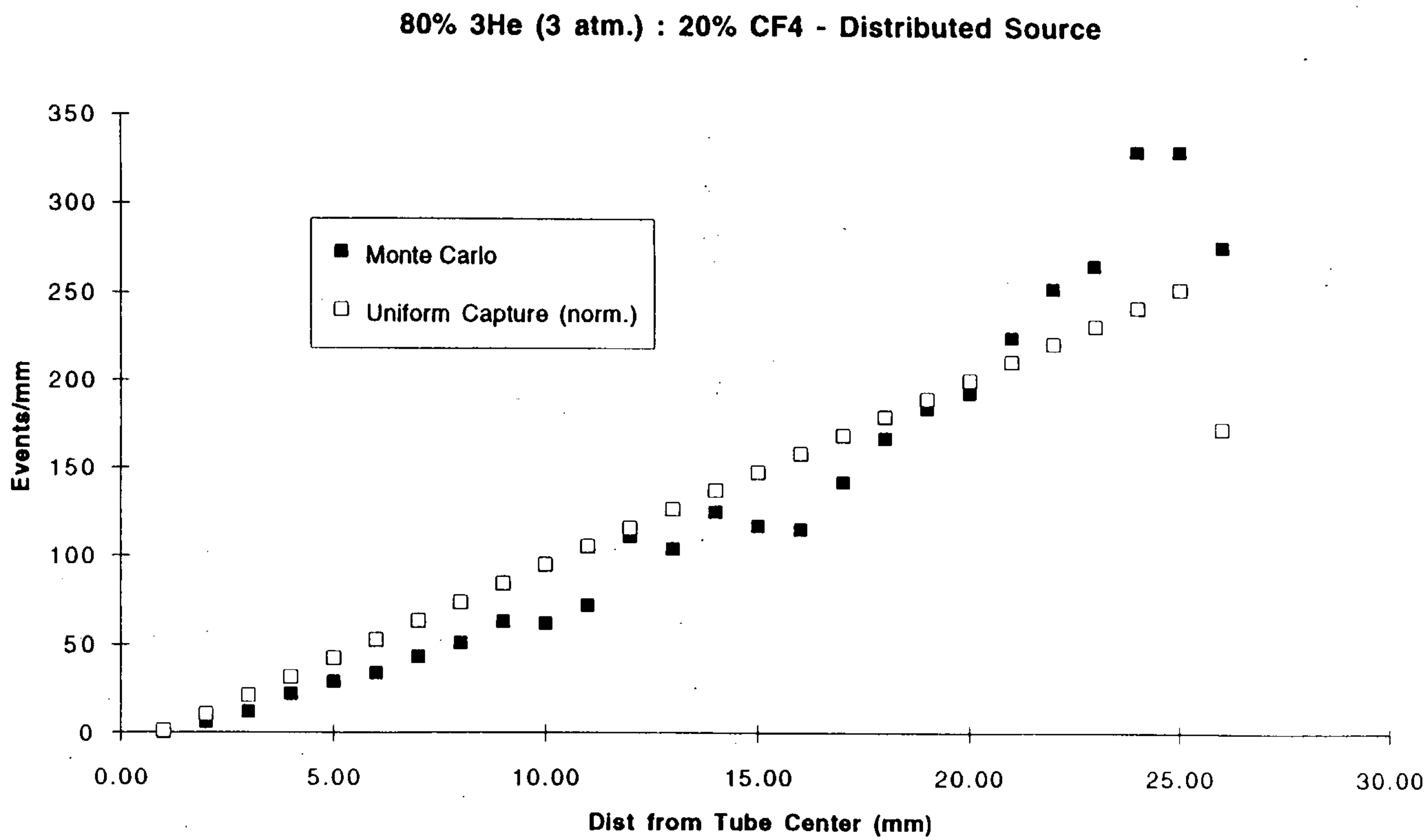

80% 3He (3 atm.) : 20% CF4 - Distributed Source
Monte Carlo
Uniform Capture (norm.)
Events/mm
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Dist from Tube Center (mm)

Figure 3.

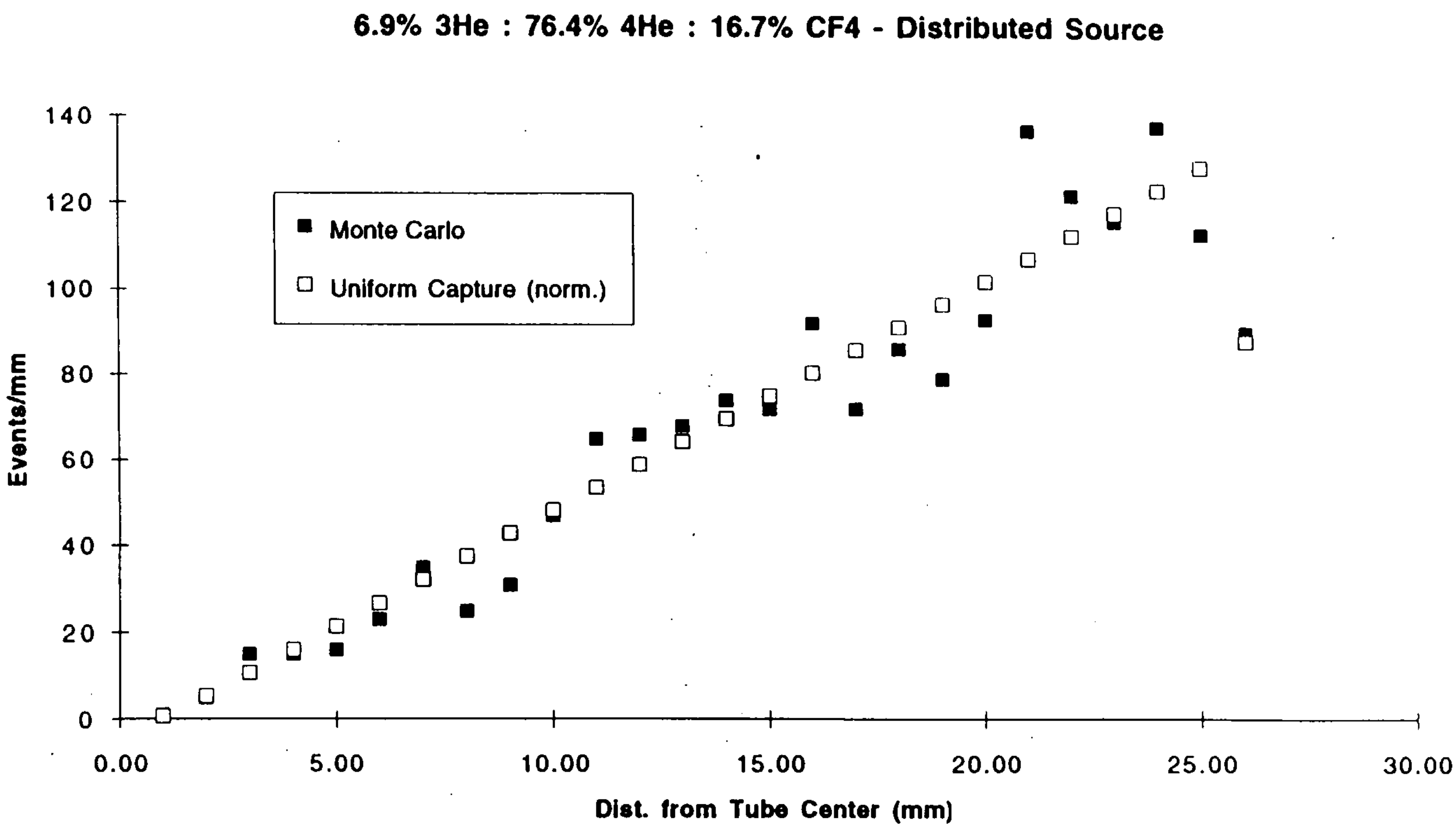

6.9% 3He : 76.4% 4He : 16.7% CF4 - Distributed Source
Monte Carlo
Uniform Capture (norm.)
Events/mm
0
20
40
60
80
100
120
140
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Dist. from Tube Center (mm)

Figure 4.

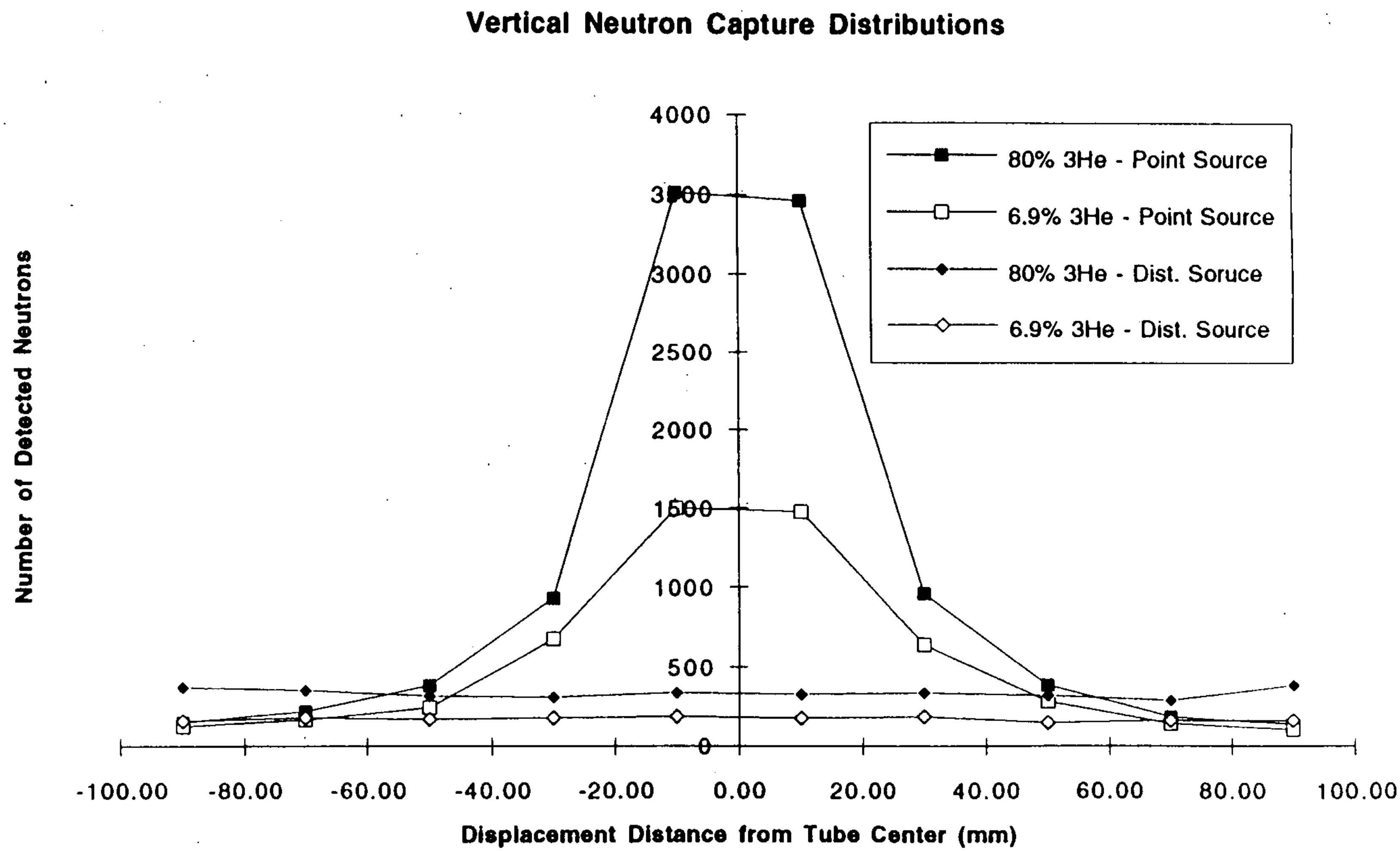

Vertical Neutron Capture Distributions
4000
3500
3000
2500
2000
1500
1000
500
0
Number of Detected Neutrons
80% 3He - Point Source
6.9% 3He - Point Source
80% 3He - Dist. Soruce
6.9% 3He - Dist. Source
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
Displacement Distance from Tube Center (mm)

Figure 5

CALIBRATION SOURCE: STARTS,CAP,X,Y,Z 50001 28093 0.0 0.0 0.0

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	0	3	1	0	0	0	0
0	0	0	1	4	10	0	10	4	3	0	0	0
0	0	4	13	52	92	0	106	46	8	2	0	0
0	0	5	34	192	675	0	681	216	42	7	0	0
0	0	14	80	723	5055	0	5118	702	83	13	1	0
0	0	0	0	0	0	X	0	0	0	0	0	0
0	2	13	83	696	5229	0	5060	706	81	13	1	0
0	0	12	56	209	722	0	677	189	36	12	1	0
0	0	2	16	31	86	0	78	34	6	2	0	0
0	0	1	2	2	5	0	11	8	2	0	0	0
0	0	0	0	1	1	0	1	4	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 6.
NEUTRON CALIBRATION
SOURCE LOCATED AT
X=Y=Z=0
(50,000 NEUTRONS)

CALIBRATION SOURCE: STARTS,CAP,X,Y,Z 50001 11091 400.0 400.0 0.0

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	1	2	3	7	6	3
0	0	0	0	0	0	0	1	15	21	58	44	4
0	0	0	0	1	1	0	2	28	147	502	393	0
0	0	0	1	0	0	0	5	53	527	4016	2453	0
0	0	0	0	0	0	0	5	31	379	2370	0	0
0	0	0	0	0	0	0	2	7	0	0	0	0

FIGURE 7.
NEUTRON CALIBRATION
SOURCE LOCATED AT
X=Y=Z=0
(50,000 NEUTRONS)

CALIBRATION SOURCE: STARTS.CAP.X.Y.Z 50001 5630 400.0 400.0 150.0

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	4	2	2	2
0	0	0	0	0	0	0	0	5	17	32	23	5
0	0	0	0	0	1	0	1	12	88	304	160	0
0	0	0	0	0	0	0	4	31	333	2725	836	0
0	0	0	0	0	0	0	4	26	174	830	0	0
0	0	0	0	0	2	0	0	5	0	0	0	0

FIGURE 8.
NEUTRON CALIBRATION
SOURCE LOCATED AT
X=Y=Z=0
(50,000 NEUTRONS)

were generated and the propagation and capture were determined. The results are presented in Figures 6-8. The overall capture efficiency for the three cases were: 56.2%, 22.2%, and 11.2%. From these calculations, a positionable neutron source on the order of 10 hz should be adequate to provide SNO neutron calibration.

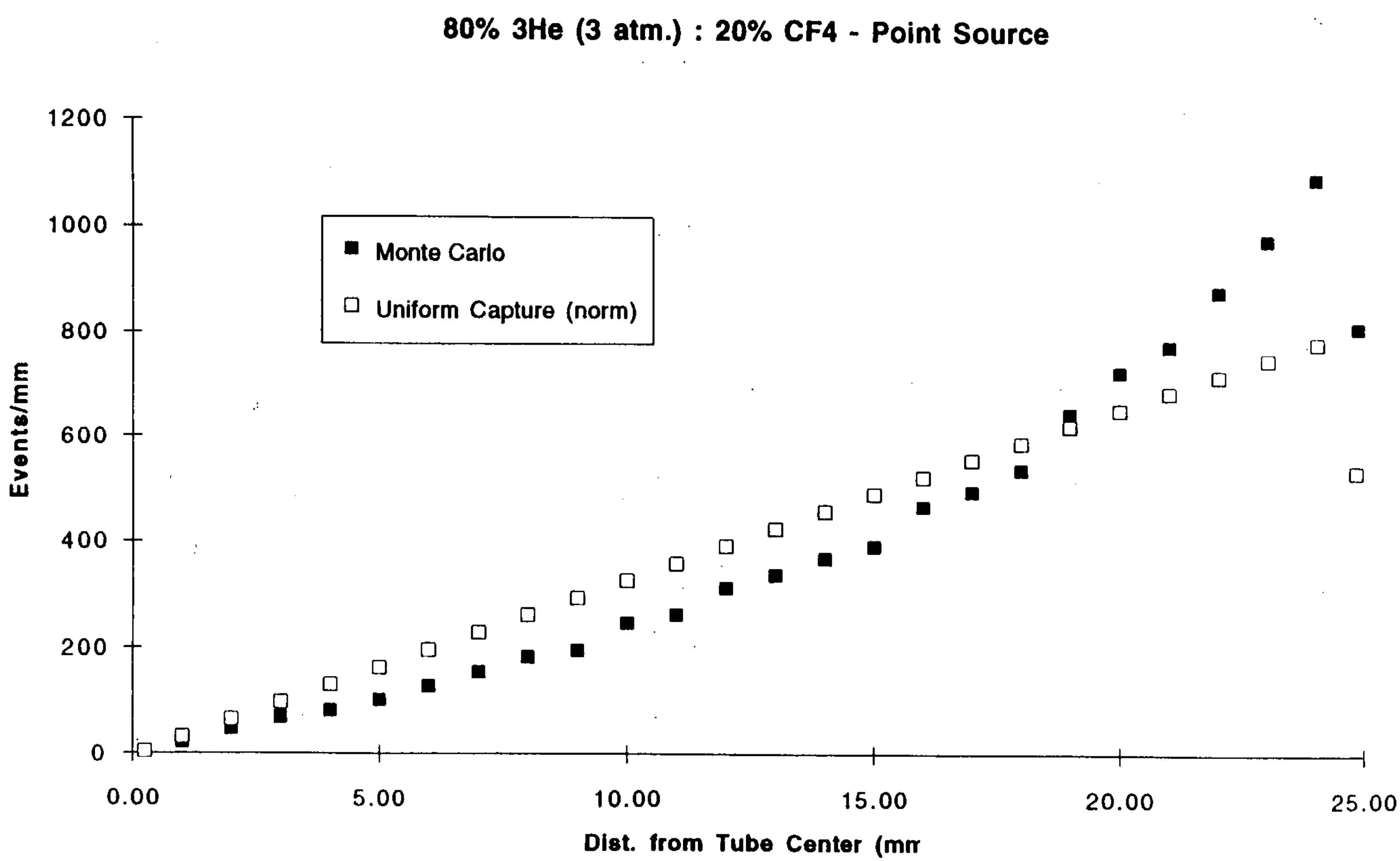
We are in the process of trying to design a self contained fission neutron source which will provide both neutrons and scintillation light. A ^{252}Cf source will be sandwiched between thin layers of scintillator and then encapsulated in acrylic. We estimate on the order of 20,000 photons will be generated per fission and along with the prompt neutrons. Both can be used to calibrate the total SNO detector system.

References

1) J.B. Wilhelmy and M.M. Fowler, SNO-STR 90-92 (1990).

2) J.B. Wilhelmy and M.M. Fowler, SNO-STR 91-035 (1991).

3) J.B. Wilhelmy, SNO-STR 92-058 (1992),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0
200
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600
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1000
1200
0.00
5.00
10.00
15.00
20.00
25.00
Dist. from Tube Center (mm

Figure 1