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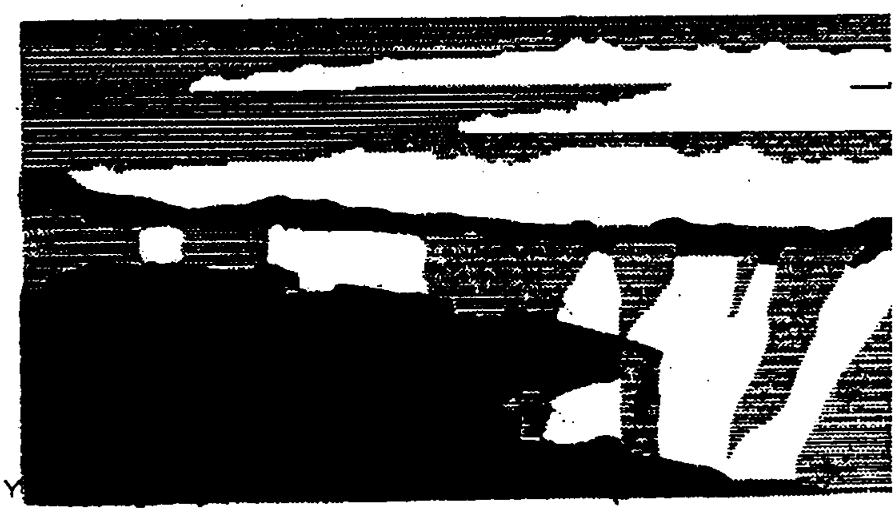

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Neutral Current Detection with Polyvinylidene Chloride Rods

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1 Introduction

John Simpson has proposed using rods of polyvinylidene chloride (PVDC) for neutron capture in the SNO vessel. There are several advantages in using this material:

1. It has a high Cl content ($C_2H_2Cl_2$) and, therefore, a high probability for neutron capture.
2. It is a plastic material which implies it probably can be made in high radiopurity.
3. The complication of putting in and removing a salt solution (NaCl or $MgCl_2$) is avoided.
4. It is a passive neutron detector which utilizes the existing PMT array.
5. It should be lower cost than the proposed ^{3}He counters.
6. Half length rods could be used that would allow simultaneous neutral current and charged current detection in the vessel.

The purpose of the present calculation is to determine the neutral current neutron capture efficiencies for these rods. These calculations only explicitly account for the neutron capture efficiency and do not determine the detection efficiency (which is dependent on the probability for identification of the Čerenkov radiation by the PMTs following photoelectric interaction with the cascade γ-rays). Some crude estimates of these effects are included in the current presentation.

Table 1: Neutron Captures (%/neutral current event)

$TubeRad$ (cm)	$Full$ ($Sausage$)	$TopHalf$ ($Sausage$)	^3He ($Sausage$)	$Full$ ($Continuous$)	$TopHalf$ ($Continuous$)
0.5	20.6 ± 0.5	10.7 ± 0.3			
1.0	30.6 ± 0.6	16.5 ± 0.4			
1.5	35.9 ± 0.6	19.7 ± 0.4			
2.0	39.6 ± 0.6	21.1 ± 0.5			
2.5	42.4 ± 0.7	22.9 ± 0.5			
2.52	42.7 ± 0.7	22.7 ± 0.5	41.8 ± 0.2	43.6 ± 0.7	23.7 ± 0.5

2 Geometries

For ease of calculation and for direct comparison with the ^{3}He simulations, the geometry was restricted to PVDC rods located on a 100 cm lattice grid. Several specific cases were calculated:

1. Identical geometrical configuration with the ^{3}He rods[1]. (An active detector radius of 2.5156 cm and a configuration made up of 1, 2, and 3 meter segments with 5 cm "dead" regions between segments.)
2. Radius of the rod was varied in 0.5 cm steps between 0.5 and 2.5 cm.
3. Cases where each rod was assumed to be continuous in length between the inside top and bottom of the vessel. (This removes the "sausage" effect encountered with the discrete ^{3}He counters.)
4. Calculations, as above, but for the rods only extending in the top half of the vessel. The bottom half is D_2O.

3 Results

Each PVDC case was calculated for 10K neutral current generated neutron events. (The ^{3}He case was for 100K neutral current neutron events.) The results are presented in Table 1 and in Figures 1 and 2 for capture on the Cl (in PVDC rods 99% of the neutron captures occur on Cl).

The results show the PVDC has a very comparable neutron capture probability to that obtained with the ^{3}He counters (42.7 vs 41.8%). The efficiency lost by having the "sausage" effect of the counter segments is relatively minor (0.9 ± 1.0 %). Deploying rods in only half of the vessel results in a loss of slightly less than half of the events (22.7 vs. 42.7%). This would, of course, lower the efficiency, but would allow real time comparisons between neutral current and charged current events.

Table 2: Neutron Detection Efficiency (%/neutral current event)

TubeRad (*cm*)	*Full* (*Sausage*)	*TopHalf* (*Sausage*)	^3He (*Sausage*)	*Full* (*Continuous*)	*TopHalf* (*Continuous*)
0.5	8.9 ± 0.3	4.6 ± 0.2			
1.0	13.2 ± 0.4	7.1 ± 0.3			
1.5	15.4 ± 0.4	8.4 ± 0.3			
2.0	17.0 ± 0.4	9.1 ± 0.3			
2.5	18.2 ± 0.4	9.9 ± 0.3			
2.52	18.4 ± 0.4	9.7 ± 0.3	41.8 ± 0.2	18.8 ± 0.4	10.2 ± 0.3

However, for SNO the real issue is not the neutron capture efficiency, but the efficiency of detecting the captures. With the ^{3}He counters this can approach 100% of the captures. In the PVDC rods the captures must be identified using the PMT array. The efficiency of detecting the generated Čerenkov light from the Cl deexcitation cascade is **not** determined in this report. It is, however, possible to make some estimates of this effect.

1. Skensved[2] has estimated that the ^{3}He neutral current array would block ≈ 20% of the light. This results in the background wall extending to ≈ 6 MeV. Assuming that the PVDC rods have the same geometrical effects then the detection efficiency for PVDC rods can be estimated. Using the White Book[3] values, the number of Cl captures leading to detected events with E≥6 MeV is ≈ 43%. The results of applying this 43% identification efficiency are presented in Table 2 and Figures 3 and 4.

2. If the rods are non transparent there will be an additional loss due to EM radiation interacting within the rod and, therefore, not yielding Čerenkov light visible to the PMTs. Since the Cl capture results in substantial high energy photon emission, this effect will not be too large but should be accurately estimated using SNOMAN and/or the Queens code.

3. Another issue effecting the precision of NC identification will be associated with the ability to subtract the background and CC events from the signal. The statistical accuracy (again using White Book values) is ≈ 4% for a kt-yr of data. The statistical accuracy assumes that the background and CC events are well known and not varying from whenever they were independently measured. This may not be an easy assumption to verify in the experimental run.

4. The effect on the structural integrity of hanging rods with density greater than the heavy water ($\rho = 1.7$ g/cm^3 for PVDC) has not been evaluated.

4 Conclusions

PVDC does offer some attractive features for neutral current detection. However, it is a very preliminary idea which would require substantial effort before implementation. Purely on the neutral current measurement capability, it has a detection efficiency which is over a factor of two smaller than either the salt or ^{3}He option.

5 Figure Captions

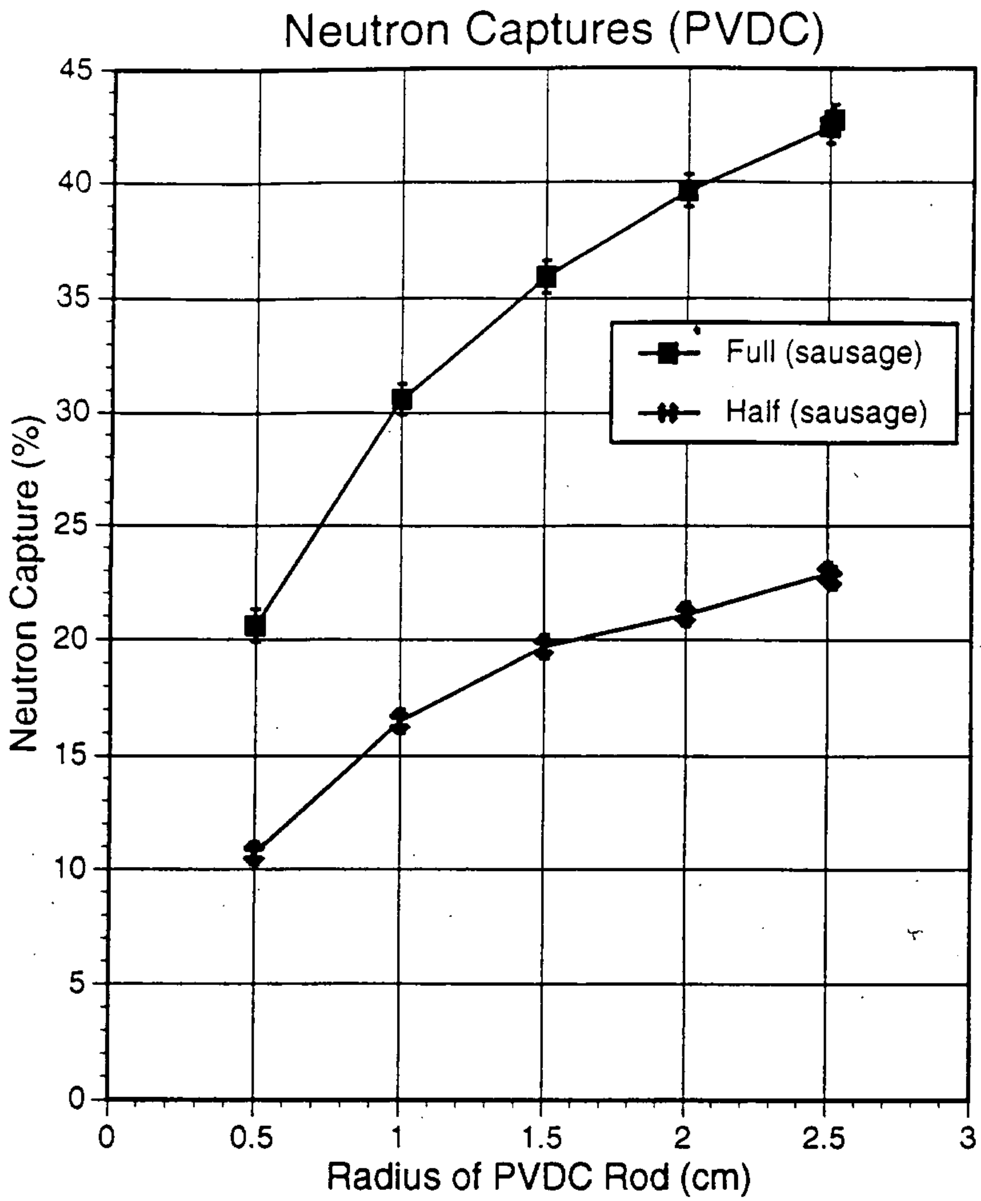
1. PVDC neutron capture as a function of rod radius
2. Neutron capture in PVDC and ^{3}He rods
3. PVDC neutron detection efficiency as a function of rod radius
4. Neutron detection efficiency in PVDC and ^{3}He rods.

References

[1] New Monte Carlo Calculations for Neutron Detection in SNO, J.B. Wilhelmy, SNO-STR 92-058 (1992).

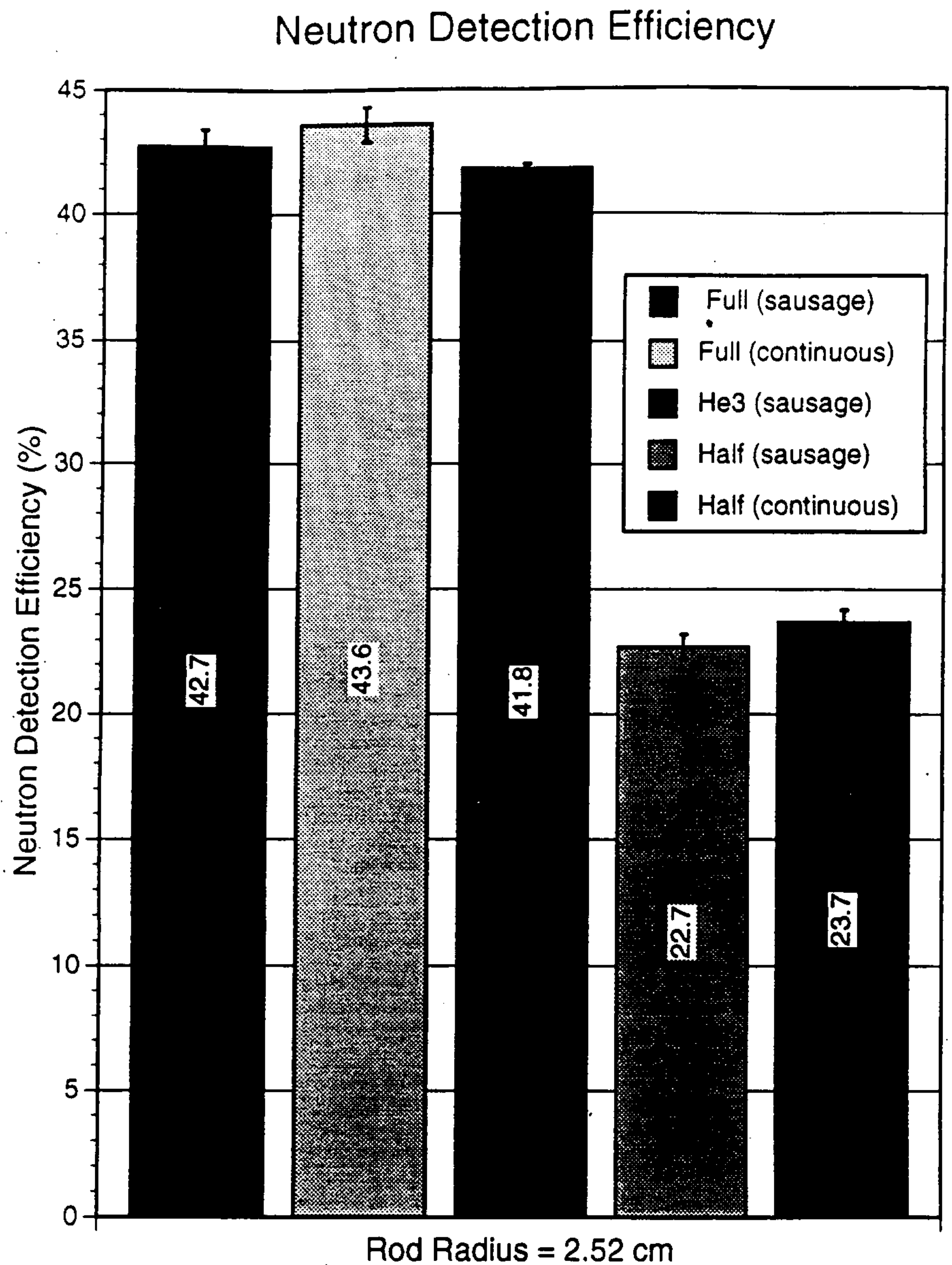
[2] Identifying Point Sources in the D_2O, P. Skensved, SNO-STR 94-036 (1994).

[3] Sudbury Neutrino Observatory Proposal, SNO-87-12 (1987).



Neutron Captures (PVDC)
Full (sausage)
Half (sausage)
Neutron Capture (%)
Radius of PVDC Rod (cm)
0
5
10
15
20
25
30
35
40
45
0
0.5
1
1.5
2
2.5
3

Figure 1



Neutron Detection Efficiency
Neutron Detection Efficiency (%)
45
40
35
30
25
20
15
10
5
0
42.7
43.6
41.8
22.7
23.7
Full (sausage)
Full (continuous)
He3 (sausage)
Half (sausage)
Half (continuous)
Rod Radius = 2.52 cm

Figure 2

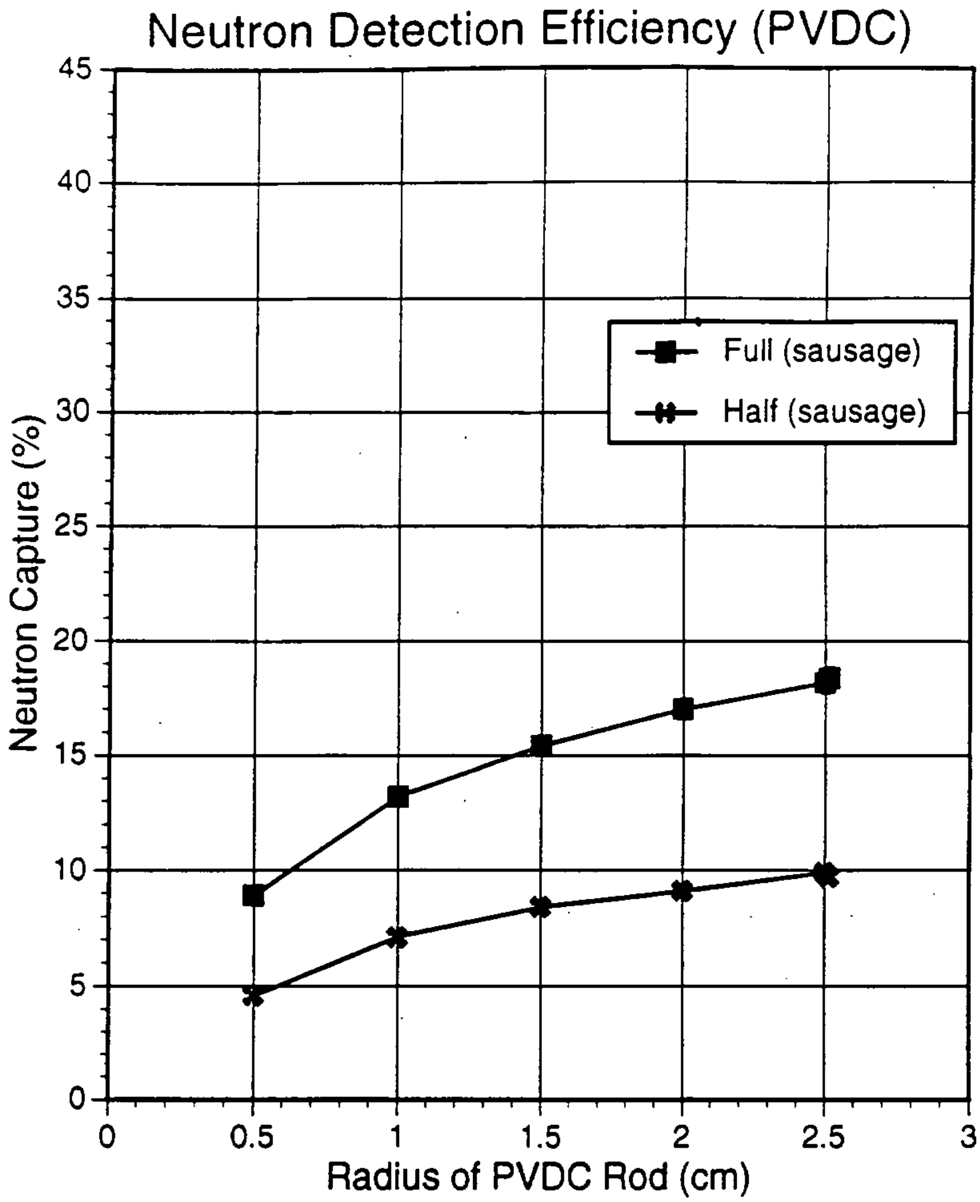
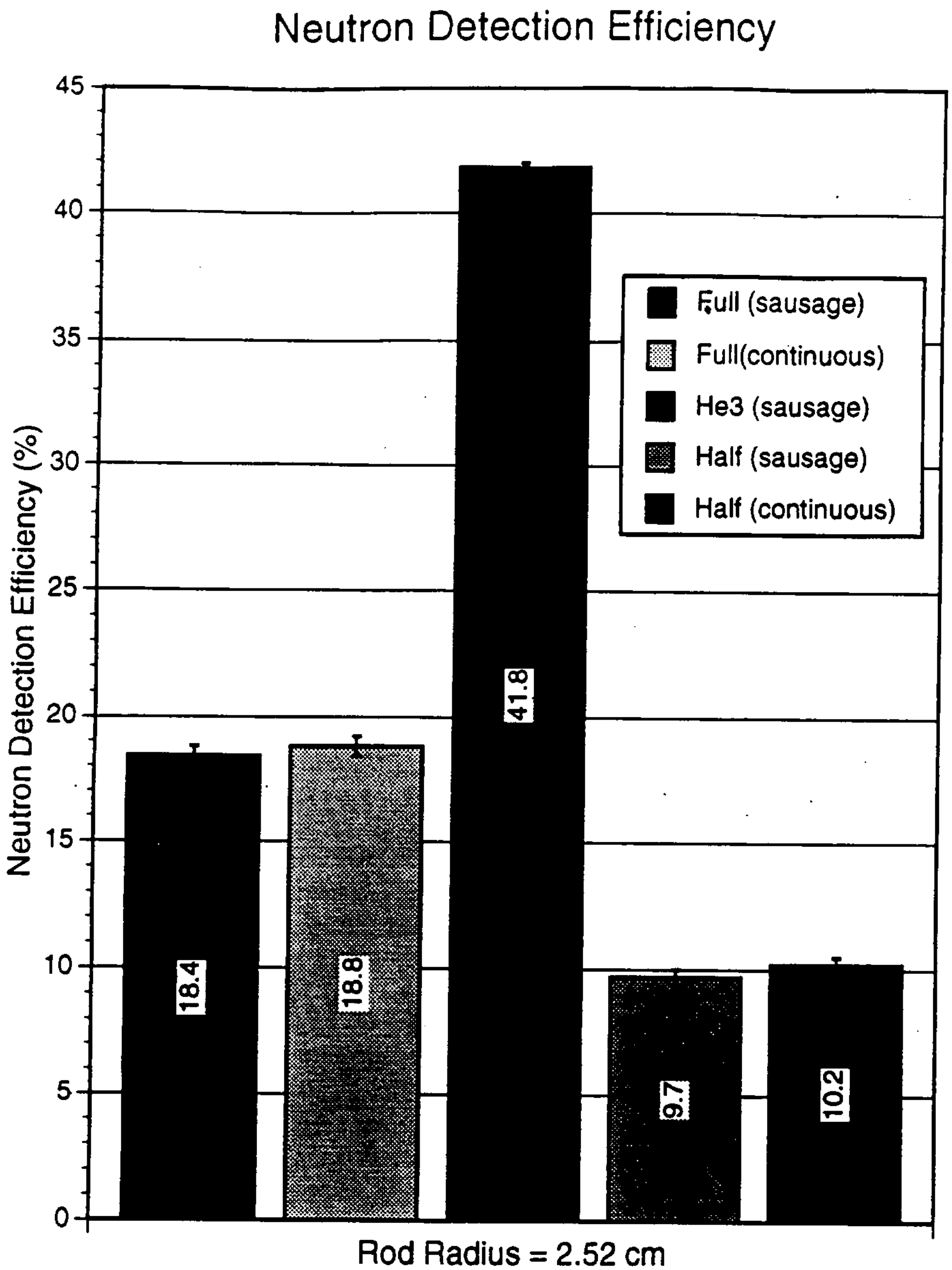

Neutron Detection Efficiency (PVDC)
Neutron Capture (%)
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
Radius of PVDC Rod (cm)
Full (sausage)
Half (sausage)

Figure 3



Neutron Detection Efficiency
Neutron Detection Efficiency (%)
45
40
35
30
25
20
15
10
5
0
Full (sausage)
Full(continuous)
He3 (sausage)
Half (sausage)
Half (continuous)
18.4
18.8
41.8
9.7
10.2
Rod Radius = 2.52 cm

Figure 4