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SNO-STR-91-078

Mesurements of Li Foil in the Test Proportional Counter

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6/12/91

In a previous report (1) we have outlined the possible use of a 6Li foil counter as a detector of the neutral current neutrons in SNO. The basic idea is that 6Li has a large cross section (934b) for thermal neutron capture and this capture causes the production of an alpha particle and a triton to be emitted back to back. The alpha particle and the triton are emitted with 2.0 MeV and 2.7 MeV respectively. If one makes a thin foil (>25microns) and puts a detector on either side of the foil, one can measure these two particles in coincidence. This coincidence measurement can be used to reduce the backgrounds to a very low level. Also.the very high energy of these particle will allow them to be detected with relative ease and will make it easy to separate neutron signals from the natural backgrounds in the counter and the surroundings.

The Lithium Foil

A lithium foil was prepared for me at CRNL by Peter Dymtrenke through the efforts of Davis Earle. The foil was prepared by deposition of the 6Li on a foil of polypropylene with a thickness of 150 micrograms/cm**2 with a 90 Angstrom coating of Al on the foil. The 6Li was deposited by electron gun heating of the 6Li metal. The thickness of the 6Li deposited was 10 microns. The foil dimensions were 5x1 cm**2.

We have calculated the expected spectra of the two particles coming ıt of these foils and the calculations are shown in Fig. 1. Since the foil is asymmetric with a thin layer of polypropylene on one side of the 6Li and nothing on the other, the energy loss for the alpha particles on one side with be greater than on the other. The triton range is such that it will be almost unaffected by this thin layer of polypropylene. Thus in Fig. 1 we see that the spectrum of tritons for the two sides is almost almost the same while the maximum energy of the alphas on the foil side is reduced to about 1.8 MeV and the efficiency for detecting the alpha is correspondingly reduced. Peter Dymtrenko states that it is relatively easy to reduce the polypropylene foil thickness by a factor of two. This would increse the alpha particle efficiency significantly.

The Test Counter

The test counter was described in ref 1. It is a high pressure cylindrical chamber, Fig. 2, with a foil holder down the centre in which the foil is clamped. The particles emerging from the foil are detected by a single wires 100 microns in diameter on either side of the foil. The wires are 5 mm from the foil. The foil holders are quite thick about .5 mm and the Li foil comes up to the edge of the holder so that for a small fraction of the events with large angles and at positions close to the holder there will be a considerable amount of energy loss. This effect has not been taken into account in what follows.

The tests we describe in this note are all made with 6 bar of P10 gas. This is sufficient to make the range of the tritons shorter than the distance to the wall of the counter.

The linear signal processing electronics are standard low noise preamplifiers and amplifiers of the type usually detectors. The coincidence and control logic are standard LRS coincidence and discriminator units. The data from each wire is collected in LRS QVT pulse height analyzers. The data is read into a PC and analyzed in a VAX station 3100.

The Neutron Source

The neutrons are produced by an Am-Be neutron source provided for us by the IRS section of NRC by L. Vanderzwan. It produces 100K neutrons/sec. The counter and source are placed in a parawax castle to thermalize the neutrons. This source produced singles rates on the bare side of 5.1 Hz and on the polypropylene side of 3.908 Hz. It is assumed that the difference is due to the polypropylene foil.

RESULTS

Voltage Test

Tritons

A series of tests were made with the foil and counter. The first test measured the alpha-triton coincidence spectrum as a function of voltage on the wires of the counter. The pulse height spectra in coincidence for each of the wires for voltages of 1500,2000,2500,3000 are shown in Fig 3. All spectra are normalized to the same counting time. The right hand wire, which is the side with the polypropylene on it, is shown in the left hand column of the page and the Left hand wire, which has no polypropylene on it, is shown on the right hand column of the page. The voltages increase in going from bottom to top.

The most significant feature of these spectra is the distinct peak from tne tritons. One can use the position of this peak to see the gain change as a function of the voltage. It is seen that there is a relatively slow and linear increase in the peak position as the voltage increases until one gets to 3000 V. We assume that there is essentially no gain on the wires until after the 2500 V setting. The slow and linear rise is due to more efficient charge collection. However, at 3000 V gas gain starts to be significant. This demonstrates that the system works very well with little or no gain. This fact will make it relatively easy to operate the final system chosen at low gain with a reduced problem of applying and maintaining the HV.

Another fact which can be derived from these specra is that the resolution does not change significantly for the triton peak as a function of voltage on the wire. It is about 12% for all these spectra. This implies that the electrons is not contributing significantly to the resolution as expected.

The Alpha Spectrum

The alpha spectrum is the continuum below the triton peak. One can see that there is a significant difference between the left hand and right hand sides of the counter. The Left hand side is flat and goes from zero energy almost to the Triton peak. If one calibrates the energy using the upper edge of the triton peak and calculates the energy of the dip in the alpha continuum, one gets a maximum energy for it of 2.02 MeV to be compared with the expected energy of 2.05 MeV.

For the foil side spectra one can compare the measured energy of the end of the alpha spectrum with that extracted from the calculated spectrum. A value of 1.8 MeV is measured in good agreement with the expected value.

EFFICIENCY

In Fig. 4, we show the spectra for both sides in the same format used in Fig.3. There was 2000 V on the wires for all four cases. Again all spectra are normalized to the same counting time. Starting at the bottom and working up the first spectrum is the background without a coincidence requirement. The second is the source plus background again without a coincidence requirement. The third row is the source spectrum with the background subtracted and the top row has the spectra for the coincidence condition again normalized to the same counting time.

The rates for these eight spectra are shown in Table I. These rates are separated into alpha and triton rates for each side. From this data one can extract the coincidence counting efficiency of the system which is shown in the next to last row.

Finally, we have taken a set of background spectra with the two sides in coincidence and no source to measure the background rejection capabilities of the coincidence method. These data are shown in Fig. 5. The background spectra are taken for roughly 24 hours while the source date are for about 1/2 hour. It is our belief that these data are consistent with the cosmic ray neutron background data. The rates are summarized in Table I in the last row.

There are some interesting points in these numbers.

1. The singles rates for the two wires minus the background are quite different, i.e. 5.1 on the left hand and 3.9 on the right. This is accounted for by the polypropylene foil which is on the right.

2. The rates for the triton singles are almost identical with the left hand again being a little larger than the right consistent with the foil position.

3. The singles triton energy losses in escaping from the foil, assuming an infinite foil, are very small for a 10 micron foil, see Fig.6. Therefore the singles rates for the tritons on the left foil are assumed to be the full rate for this source and can be used to calculate the efficiency.

4. The singles to coincidence rates are consistent with the expectations for this geometry. The ability to look at the singles triton peak for neutrons in SNO from this data looks very promising. In which case, the overall efficiency of the system could be much higher.

4. The coincidence efficiencies are mostly greater than 50%. The calculated efficiency is 70% for the coincidences for a 10 micron foil. The calculations do not take into account edge effects which will be significant for this geometry. The best efficiency for this geometry would be for the case of an alpha out of the bare side and a triton out of the polypropylene side. The efficiency rate for the right wire triton is 59% to be compared with the calculated value of 75%. We assume that the difference is due to the edge effects and the foil. This deiscrpency will be studied further.

5. Ideally the coincidence alpha rate on the foil side should be equal to the coincidence triton rate on the bare side and vice versa for the complementary particle rates. The fact that this is not so, even though the total rates are equal is caused by the crude way in which the alpha and triton regions have been defined. More sophisticated analysis will

almost certainly rectify this problem.

6. The no neutron source rate in coincidence is very low. It is about 1000 times less than the singles. We don't know whether it is real or not and cannot tell that until we do a scatter plot of the energies on the two sides. It is quite possible that these data are randoms in coincidence with small pulses in the other side. The coincidence resolving time for this data is set at 2 microseconds. There is probably at least an order of magnitude in chance rate to be gained from improving this. It is possible, however, that the majority of the background is from cosmic ray neutrons.

CONCLUSIONS

1. The measurement of thermal neutrons using the CRNL 10 micron 6Li foil counter have shown that we are able to get the predicted spectra for the alpha and triton products of this capture process.
2. Further, the efficiencies calculated for these processes are respectible and close to what we would have calculated.
3. The rejection of the singles background by the use of the coincidence technique is >1000:1 and is consistent with infinity.
4. The counter works with essentially zero gain on the wires and this will make a realistic counter easier to use.

This technique of neutron detection appears to be very simple and easy to use once the foil is prepared. One therefore concludes that the technique has great potentialas a neutron counter for SNO.

Detection Probability as a Function of Li-6 Foil Thickness.

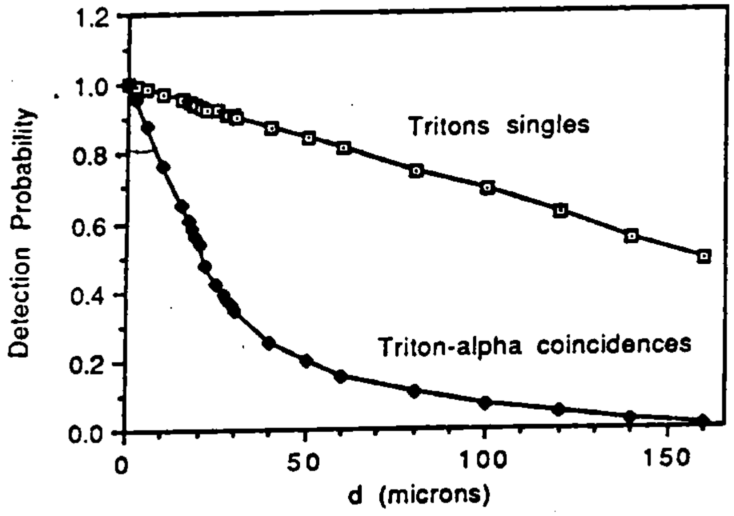

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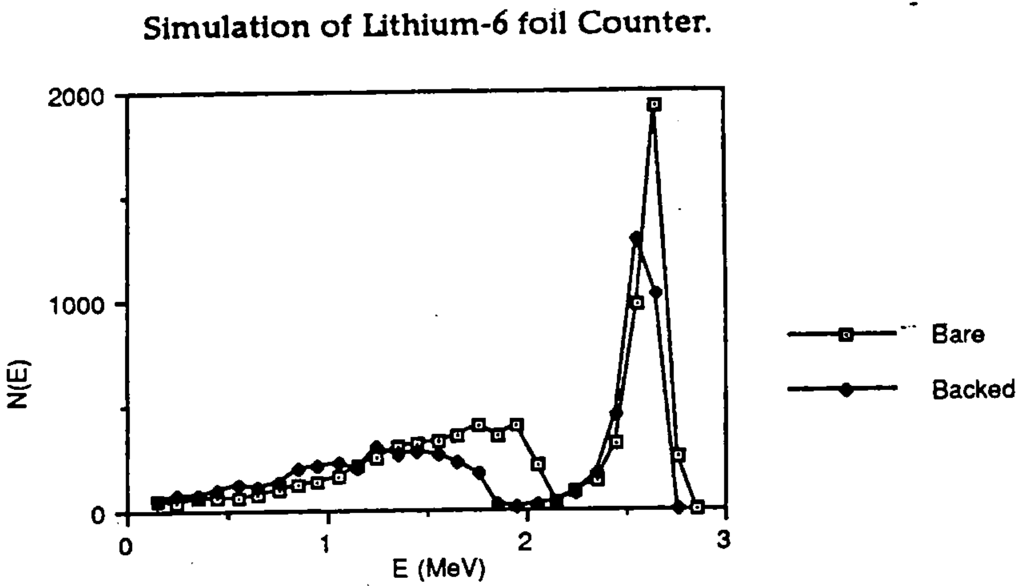
Table I

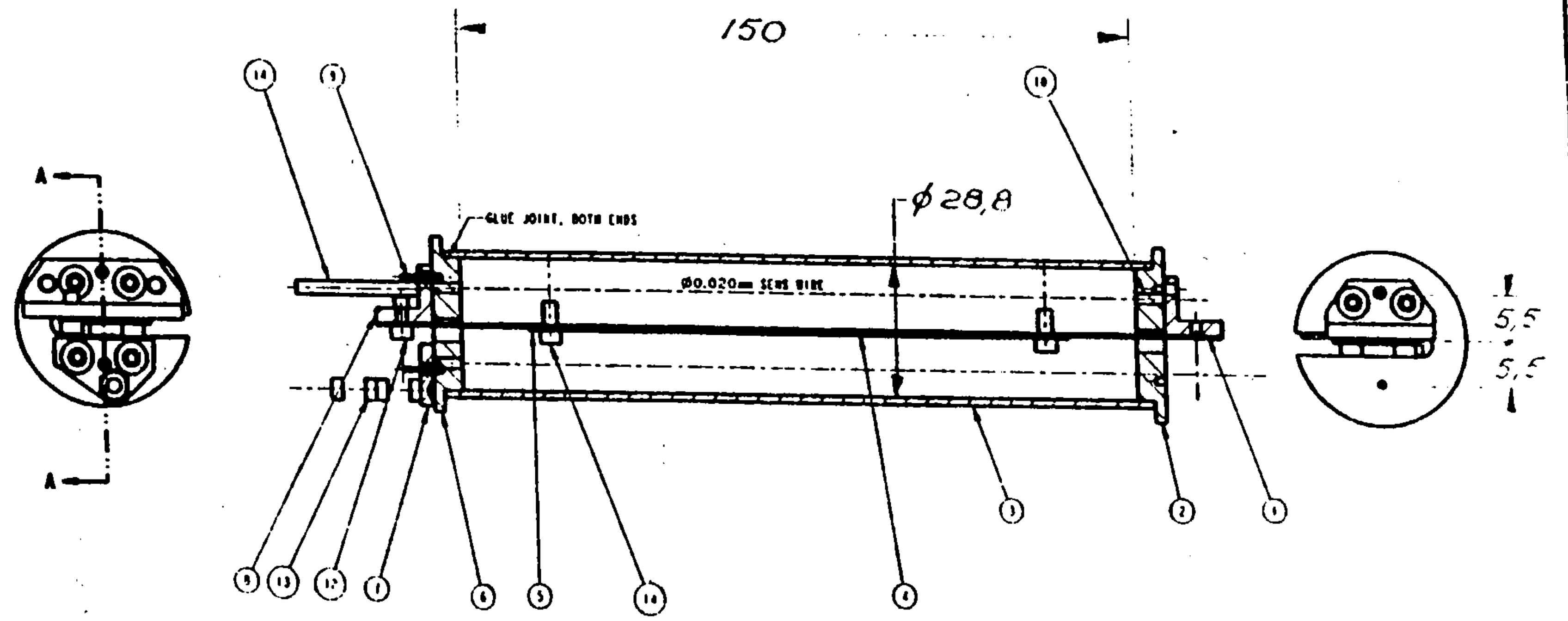
	Right Wire			Left Wire		
	Alpha	Triton	Sum	Alpha	Triton	Sum
Description	Hz	Hz	Hz	Hz	Hz	Hz
Bkgd Singles	0.970	0.045	1.01	0.459	0.20	0.48
Source + Bkgd	2.625	2.293	4.918	3.241	2.35	5.591
Source - Bkgd	1.755	2.248	3.908	2.782	2.32	5.111
Source-coinc.	1.140	1.362	2.502	1.644	.966	2.610
Effic-singles	.756	0.969		1.199	1.00	
Effic-coinc	0.491	0.587	0.640	0.708	0.416	0.511
Bkgd-coinc	0.00063	0.00015	0.00078	0.00058	0.00018	0.00075



Simulation for 10 µ Li-6 foil, either bare or backed with 150 µg/cm**2 polypropylene.
Coincidence assumed, no cut-offs.
(The "backed" calculation is rather crude and will have to be refined!)

D.K.
Nov. 30, 1991.

PRO DIR:	FILE NAME:
SCADP	CELL_ASSY_LITHIUM



SECTION A-A

NOTE: ALL 4 FEEDTHRU MUST BE ON SAME PLANE WITHIN .004"

14		4	4-40 X 3/16" LG SOC HD CAP SCREW	ST ST
13		3	4-40 X 1 1/4" LG FL HD SCREW	ST ST
12		12	4-40 HEX NUT	ST ST
11		4	4-40 X 1/4" LG SOC HD CAP SCREW	ST ST
10		6	4-40 X 1/4" LG FL HD SCREW	ST ST
9		4	⌀0.100 ⊙⊙ FEEDTHRU (OPAL)	
8	SNO-LPD-138	1	BRACKET, STRIP H.V.	
7	SNO-LPD-140	1	PLATE-STANDOFF	
6	SNO-LPD-139	1	ENDPLATE-CELL-TOP	
5	SNO-LPD-133	1	MASK-STRIP, LITHIUM	
4	SNO-LPD-129	1	SUPPORT STRIP, LITHIUM	
3	SNO-LPD-137	1	TUBE, PRESSURE VESSEL	
2	SNO-LPD-141	1	ENDPLATE-CELL-BOTTOM	
1	SNO-LPD-142	1	BRACKET, STRIP, GAS	

XENON DETECTOR

R Nicls
13 Feb. 91
ALL DIMENSIONS ARE IN MILLIMETERS
X +/- 1.0 X.XX +/- 0.1
X.X +/- 0.5 ANGLE +/- 30
1.5:1

CARLETON UNIVERSITY - INSTRUMENTATION GROUP

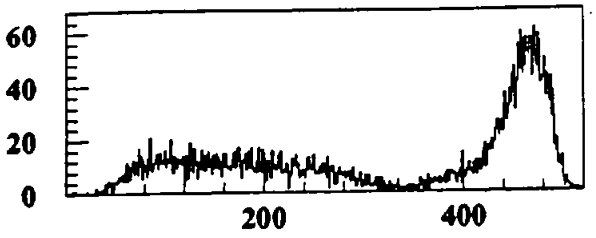
LITHIUM-CELL ASSEMBLY

SNO-LPD-145

A

FEB 1

Fig 12



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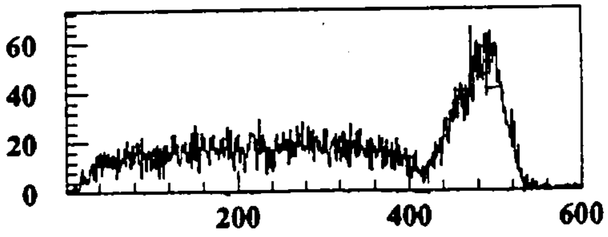

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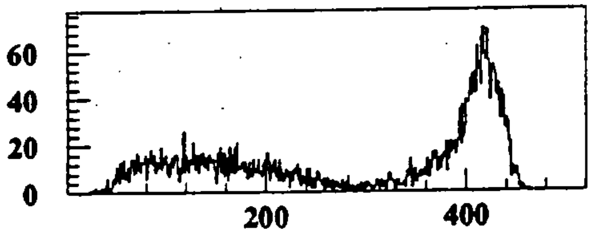

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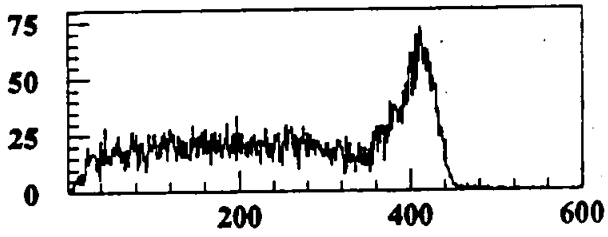

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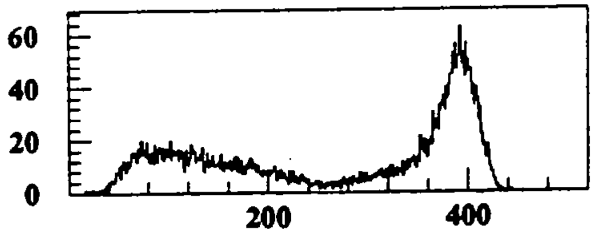

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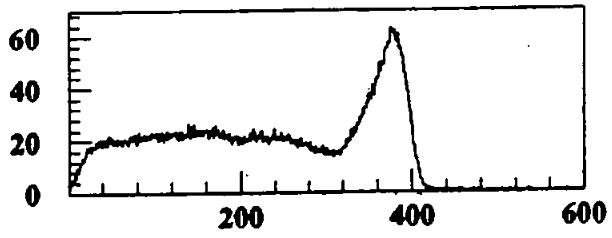

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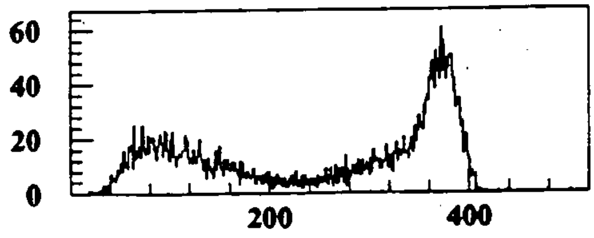

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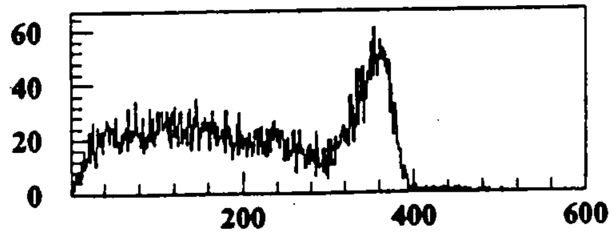

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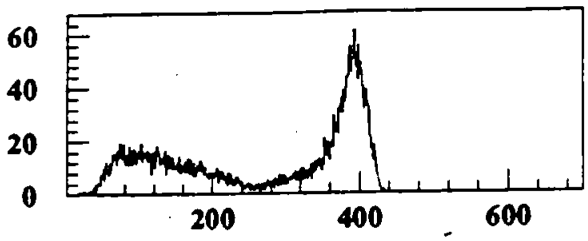

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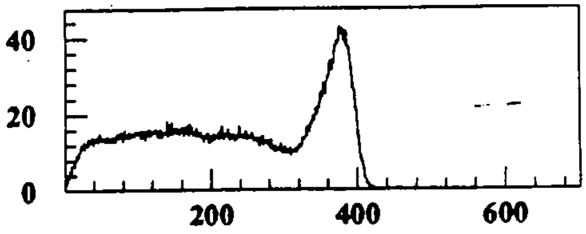

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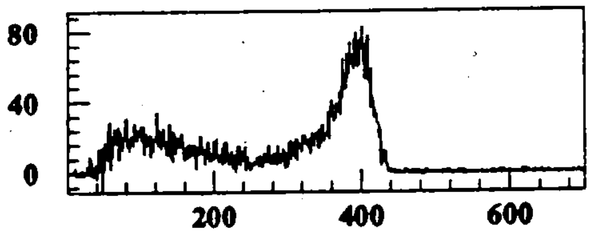
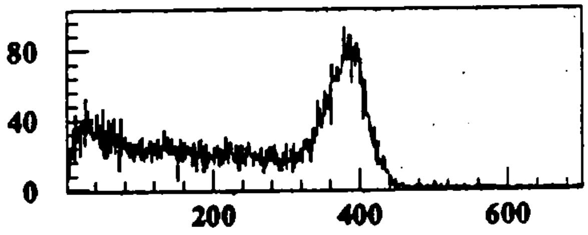
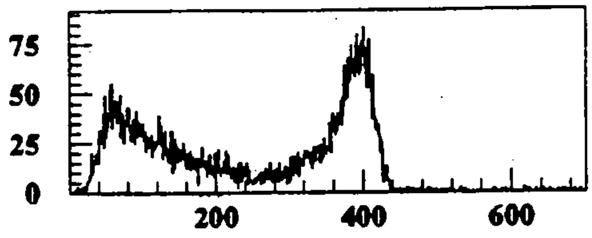


RUN21B



RUN20B



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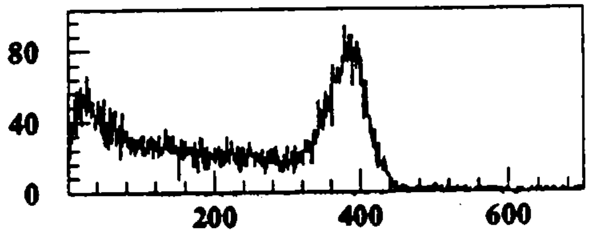
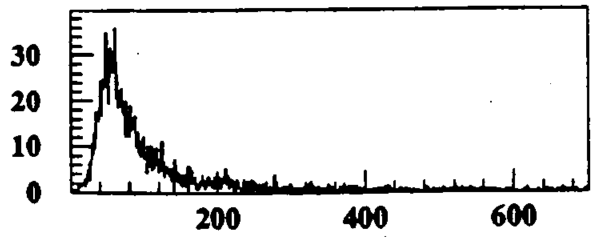
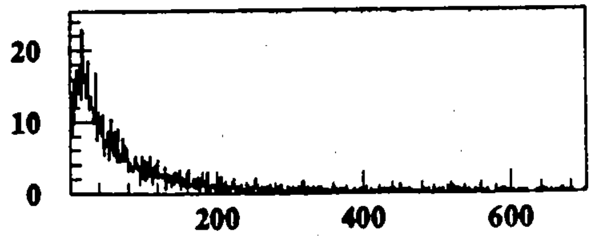


RUN20A

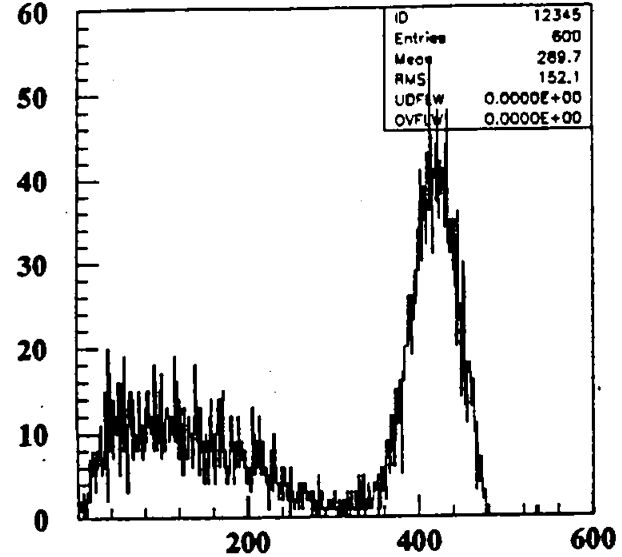


RUN22ASC



RUN23ASC

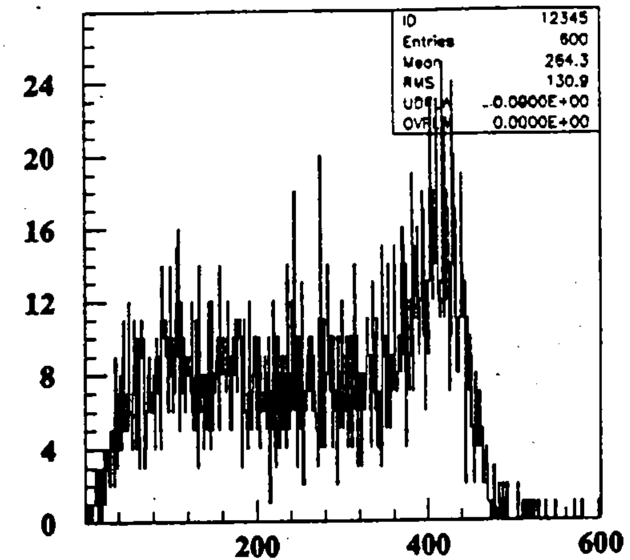
Foil Side



ΔT = 2,200 S.

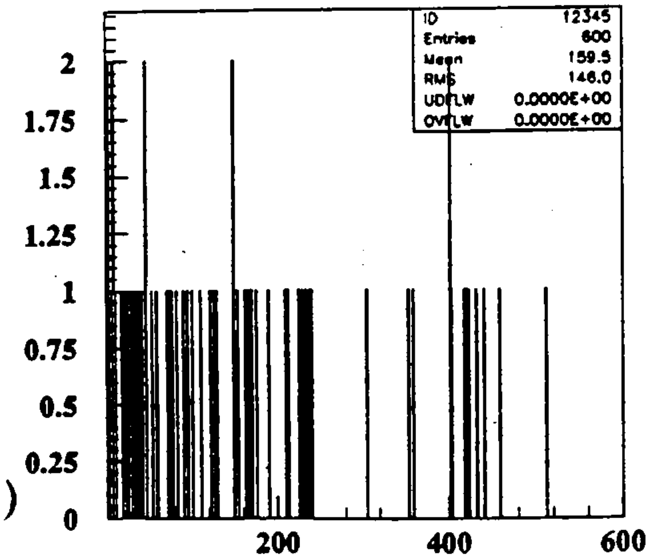
R45A

Bare Side



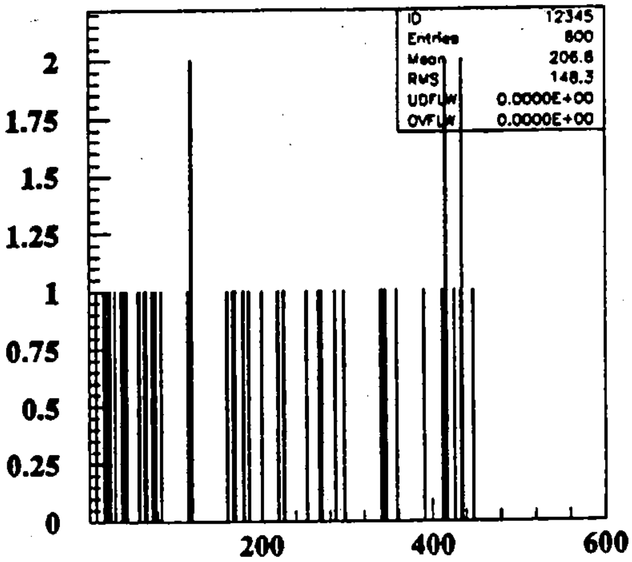
ΔT = 1,440 S.

R44A



ΔT = 81,280 S.

R46A



ΔT = 62,420 S.

R43A