

Summary of UCN Source Production Study

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Abstract

In this note, I summarize the UCN source production data in 2006 and 2007. The UCN production is up by a factor of 2 in 2007. Also included in this note is a systematic study of the cold neutron and UCN productions as a function of source volume and the poly temperature.

1 Summary of Data Runs to Study SD2 Source UCN Production

In Tables 1 and 2, the DAQ runs taken in 2006 and 2007 that were dedicated to the SD2 source production are summarized.

Run	T_{src} (K)	T_{poly} (K)	P_{SD2} (mbar)	cn/p 10^{-17}	monitor 2 (/uC)	description
4155/8441	5.2	62	944	9.5	9.6	volume scan, Nov 11, 2006
4156/8442	4.7	56	839	9.5	7.4	SAA
4158/8444	4.6	55	650	9.6	5.7	SAA
4160/8444	4.7	54	500	10.0	4.4	SAA
4163/8449	4.6	55	400	10.2	3.3	SAA
4164/8450	4.7	51	203	10.2	1.4	SAA
4165/8451	4.7	55	103	10.7	0.58	SAA
4167/8452	4.7	56	54	10.5	0.57	SAA
4169/8454	4.7	59	17	10.8	0.07	SAA
4170/8455	4.5	52	658	10.1	5.04	SAA
4171/8456	5.0	42	947	9.7	8.8	SAA
4181/8470	5.4	112	950	20.4	4.2	flapper open, Nov 22, 2006
4182/8471	5.0	107	950	19.2	0.7	flapper closed
4183/8472	5.0	106	950	20.7	15.0	flapping
4523/8808	9.0	53	950	39.0	4.9	flapper open, Dec 16, 2006
4531/8817	9.0	45	950	39.5	14.7	flapping
4533/8820	9.0	45	950	35.3	1.1	flapper closed
4552/8852	10	85	950	34.9	0.7	flapper open (broken), Dec. 17, 2006
4553/8853	10	89	950	34.9	0.7	flapper closed (broken)
4555/8855	8.5	92	950	34.9	0.7	flapper open (broken)
4556/8856	8.4	92	950	35.0	0.8	flapper closed (broken)

Table 1: *Source Production Data Taken in 2006. Note that T_{src} is the temperature reading from LHe #1, and T_{poly} is the “poly2” temperature.*

Run	T_{src} (K)	T_{poly} (K)	P_{SD2} (mbar)	cn/p 10^{-17}	monitor 2 (/uC)	description
4701/9046	5	84	986	13.5	2.9	volume scan, July 18, 2007
4708/9060	5	62	1049	18.5	2.7	SAA
4718/9071	5	80	104	15.1	0.25	SAA
4720/9073	5	78	303	16.0	0.93	SAA
4722/9075	5	75	503	16.6	1.57	SAA
4725/9078	5	73	702	17.7	2.26	SAA
4727/9080	5	73	775	17.7	2.42	SAA
5127/9279	297	270	160 (gas)	16.5	0.06	poly T scan, Aug 18, 2007
5131/9283	6.0	246	726	19.2	5.4	SAA
5132/9284	6.0	246	726	19.2	5.2	SAA
5133/9285	6.0	246	726	19.1	5.4	SAA
5134/9286	5.0	212	726	21.3	6.6	SAA
5135/9287	5.0	212	726	19.5	6.6	SAA
5136/9288	5.0	212	726	19.6	6.5	SAA
5137/9289	5.8	178	726	19.3	6.6	SAA
5140/9292	5.7	175	726	19.1	6.3	SAA
5141/9293	5.7	174	726	19.3	6.6	SAA
5142/9294	5.4	150	726	19.8	6.7	SAA
5143/9295	5.4	149	726	19.8	7.3	SAA
5144/9296	5.4	148	726	20.1	7.0	SAA
5145/9297	5.4	145	726	20.1	7.1	SAA
5146/9298	5.4	134	726	20.2	6.7	SAA
5147/9299	5.4	133	726	20.3	7.6	SAA
5148/9300	5.4	133	726	20.3	7.4	SAA
5149/9301	5.4	132	726	20.3	8.4	SAA
5150/9302	5.4	120	726	20.8	7.5	SAA
5151/9303	5.4	119	726	20.8	7.4	SAA
5152/9304	5.4	119	726	20.8	7.7	SAA
5153/9305	5.4	118	726	20.8	7.4	SAA
5154/9306	5.5	106	726	20.9	8.4	SAA
5155/9307	5.4	106	726	20.8	8.2	SAA
5156/9308	5.4	105	726	20.9	8.1	SAA
5157/9309	5.5	105	726	20.9	7.8	SAA
5158/9310	5.5	90	726	21.1	8.2	SAA
5159/9311	5.5	90	726	21.2	8.3	SAA
5160/9312	5.6	90	726	21.1	8.3	SAA
5161/9313	5.6	90	726	21.2	7.9	SAA
5162/9314	5.6	65	726	21.2	8.0	SAA
5163/9315	5.6	66	726	21.2	7.9	SAA
5164/9316	5.6	67	726	21.1	7.6	SAA
5165/9318	5.6	68	726	21.1	8.2	SAA

Table 2: *Source Production Data Taken in 2006.*

2 UCN Production Comparison between 2006 and 2007

It is difficult to extrapolate cn/p consistently for different run period due to two reasons. First, the cold neutron detector has been positioned at different places during the 2006 run. Its acceptance had also been obstructed by Chris’s detector before the flapper installation (mid Nov. 2006). Secondly, since the cold neutron is counted from the scope trace, a time scale change will also affect the integral. The monitor detector, “monitor 2”, was downstream of the gate valve in 2006, and was moved to upstream in 2007. Its yield also wondered “erratically”¹ particular in 2006. The main detector geometry, on the other hand, has not changed between the two years, which allows a meaningful comparison of the UCN production between 2006 and 2007. In Fig. 1, the UCN per μC of proton in 2006 and 2007 as a function of SD2 volume is plotted. The volume scan in 2006 was performed right after the first beta decay run (before the installation). The volume scan in 2007 was performed in mid/late July; the source situation was similar to that in 2006. From the figure, one clearly sees that the UCN production in this year is a factor of 2 of that of 2006.

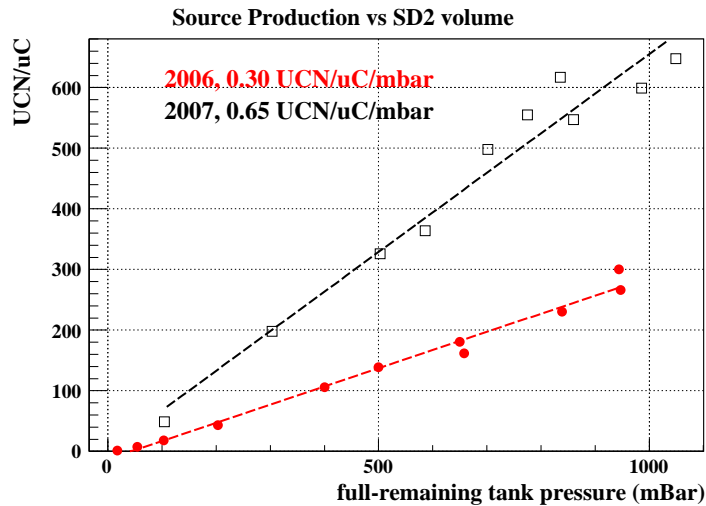


Figure 1: Number of detected UCN per μC of proton as a function of SD2 volume (in unit of mbar) in 2006 (red solid circles) and 2007 (black open squares). Note the data in 2006 volume scan were taken with “2-burst-per-pulse” beam. The yield shown here has corrected for this factor of 2.

One of the major source improvement made in 2007 is that an additional layer of polyethylene has been added to the bottom of the source. Simulation suggested that this would optimize the thermalization of the fast neutrons and boost the UCN production. This is very likely the explanation of the observed improvement. Confirming evidence comes from the scope data from the cold neutron detector. In Fig. 2, typical cold neutron scope traces (from Gary’s slow DAQ) from 2006 and 2007 are overlaid². The “prompt” fast neutrons and the “delayed” thermal and cold neutrons can be clearly separated in time. The integral of the prompt signals (indicated in the figure) from both traces are comparable, whereas the delayed integral is up by about 70% in 2007.

¹The inefficiency factor for multi-burst beam from Gary’s DAQ has been corrected.

²We took the CN trace from Dec. 16/17, 2007, where the detector position was identical to that of 2007.

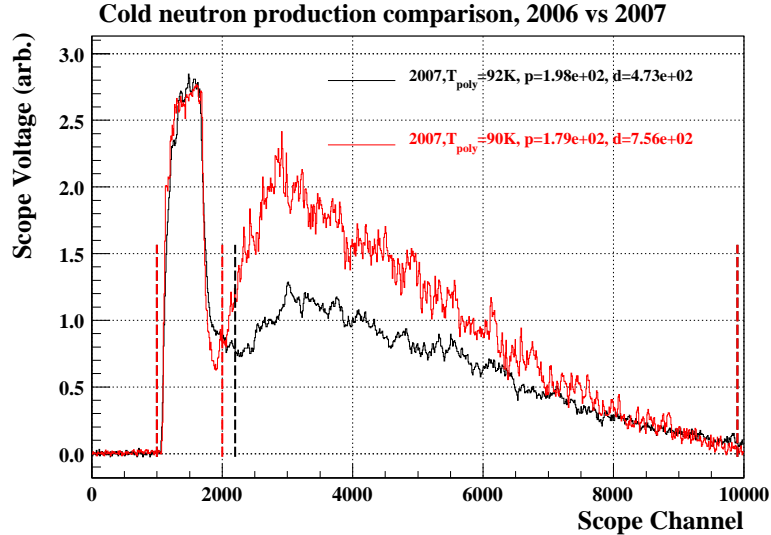


Figure 2: Scope traces (collected by Gary’s DAQ) for the cold neutron detector in 2006 and 2007. Due to different scope setting, the data from 2006 was shifted and rebinned in time. Vertical dashed lines indicate the timing cuts for the prompt and delayed signals. The integrals (in arbitrary units) of the prompt and delayed signals are indicated in the legend as “p” and “d”.

3 Dependence of the Cold Neutron and UCN Production on SD2 Volume and Poly Temperature

In this section, a more detailed examination of the cold neutron and UCN production as a function of SD2 volume and poly temperature will be made.

3.1 Volume Dependence

In Fig. 3, the cold neutron scope trace for an empty and full (726 mbar) source (both with warm poly) are overlaid. One clearly sees that the n-D scattering, though less efficient in thermalizing neutron than the poly, does have a significant effect (about 15%) in the delayed neutron peak. The cold neutron traces for different SD2 volumes (with more-or-less the same source and poly temperature) are overlaid in Fig. ???. The effect of the n-D scattering is obvious. In particular, the cold tail in the delayed peak is increasing with increasing SD2 volume. For completeness, the integral of the delayed neutron peak as a function of SD2 volume is plotted in Fig. 5.

3.2 Temperature Dependence

The same “flavor” of study was also performed by studying the cold neutron and UCN production while cooling the poly. For a glance of the data see Table 2. One sees that the UCN monitor detector yield has a rather strong dependence on the poly temperature, whereas the cold neutron integral does less so. In Fig. 6, the cold neutron scope traces are overlaid for a few different poly temperatures.

The UCN monitor 2 yield as well as the delayed cold neutron integral are plotted against

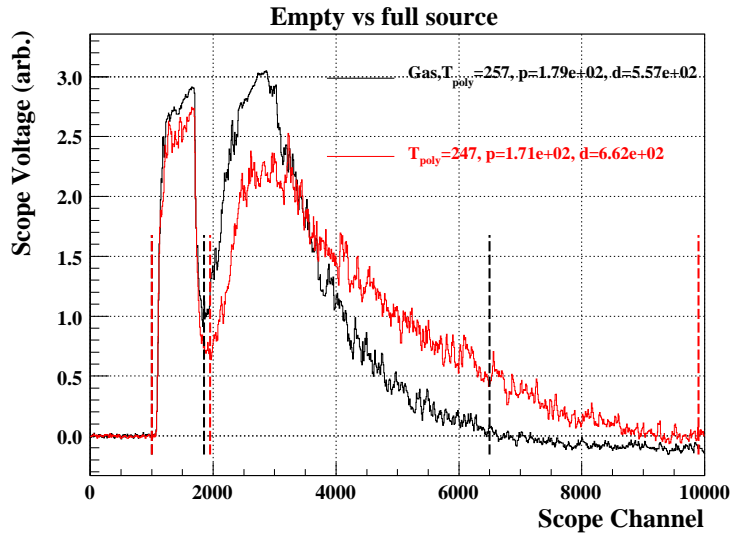


Figure 3: Cold neutron scope traces for an empty (black) and a 726 mbar (red) source, both with warm poly. Vertical dashed lines indicate the timing cuts for the prompt and delayed signals. The integrals (in arbitrary units) of the prompt and delayed signals are indicated in the legend as “p” and “d”.

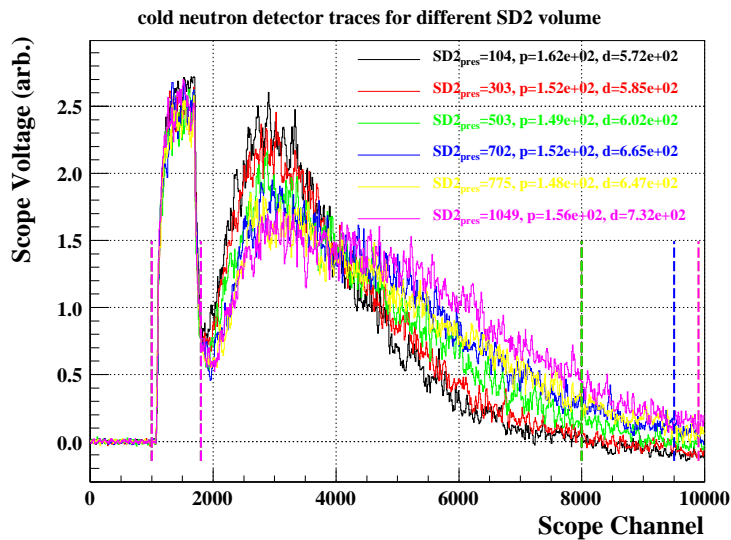


Figure 4: Cold neutron scope traces for different SD2 volume during the volume scan in 2007. Vertical dashed lines indicate the timing cuts for the prompt and delayed signals. The integrals (in arbitrary units) of the prompt and delayed signals are indicated in the legend as “p” and “d”.

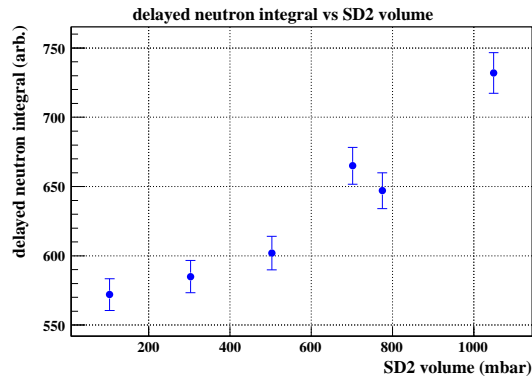


Figure 5: *Delayed cold integral integral (as indicated in Fig. 4) as a function of SD2 volume. The uncertainty of each data point is assigned as 2%, based on the run-by-run fluctuation of this integral under the same beam/source conditions.*

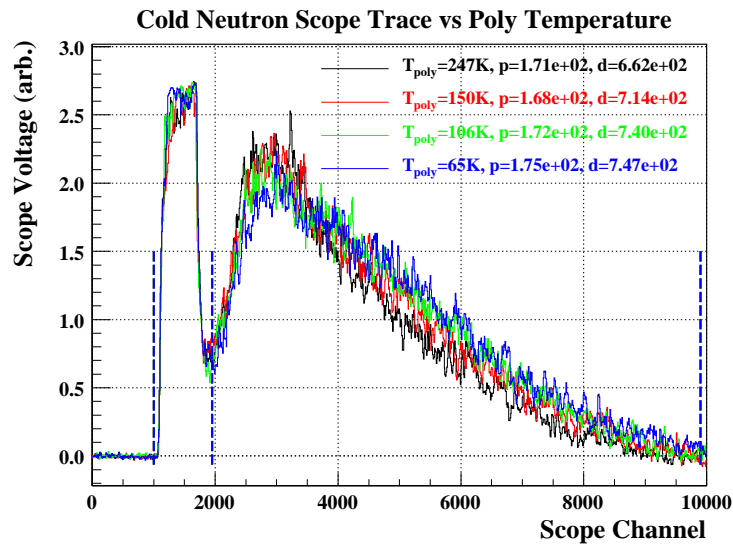


Figure 6: *Cold neutron detector scope traces for a few different poly temperatures (for color code see legend). Vertical dashed lines indicate the timing cuts for the prompt and delayed signals. The integrals (in arbitrary units) of the prompt and delayed signals are indicated in the legend as “p” and “d”.*

the poly temperature in Fig. 7. One observes, again, that monitor 2 yield has a stronger

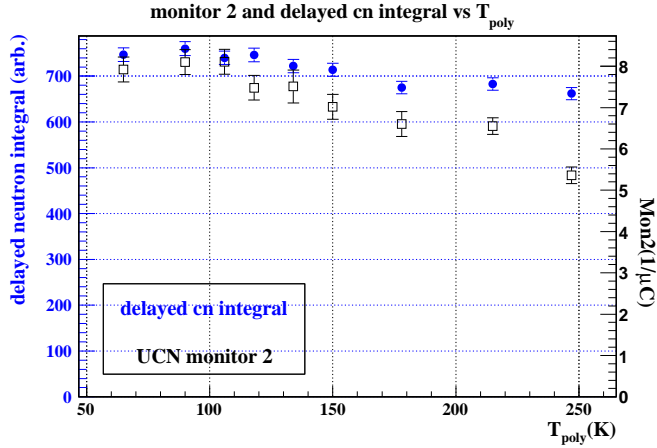


Figure 7: *UCN monitor 2 yield (black open squares, y axis on the right) and delayed cold neutron integral integral (blue closed circles, y axis on the left) as a function of the poly temperature. The uncertainties for both sets of data are assigned based on the run-by-run fluctuations under the same beam/source conditions.*

dependence on the poly temperature – increased by 40% from a warm poly to ~ 100 K. The same but a slighter trend is also observed in the delayed cold neutron integral, which is more sensitive than the gross cold neutron counts in Table 2. It is also noteworthy that for T_{poly} below 110 K, the cold neutron and UCN productions are practically constants.

4 Summary

A few conclusions can be drawn from this simple analysis:

- The UCN production is improved by about a factor of 2 in 2007, and there is evidence that this is due to the additional poly layer at the bottom of the source;
- Qualitatively the delayed peak in the cold neutron scope trace indicate the details of UCN productions in the source;
- So far with an up-to 1000 mbar source, the n-D scattering still helps the overall UCN production;
- The cool down of poly helps with the UCN production, although effects become negligible for temperature below 110 K.