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A Study on UCN Source for a Spallation Facility

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Abstract

Results of pulsed UCN experiments with a supermirror turbine in KUR and some Monte Carlo calculations are reported. A turbine efficiency and the UCN output intensity satisfying designed values are obtained. Similar UCN experiments with a cold source at an electron linac are also carried out and compared. UCN gains by a cooled polyethylene converter are derived from the experiments. From these studies, a concept of a synchronized supermirror turbine is proposed for a spallation UCN source which can serve multi-loads uses of UCN experiments.

I. Possible Types of UCN Sources

There are several possibilities of approach to an efficient UCN source for a spallation facility. A superthermal liquid helium converter is expected to give the highest gain factor of UCN conversion, and such a device is proposed to be used for a pulsed spallation source in KENS.[1] However, the technical problem of the heat removal remains to be solved in a cryostat put near to a cold moderator to see the moderator in a large solid angle. Further, the pulsed UCN flux produced inside of a thick converter will be time-averaged when extracted because of the low velocity of UCN.

Next approach will be to use a mechanical velocity shifter, and experimental results using a Doppler shifter of a moving crystal were appeared in the previous meeting.[2] Another type of machine, a supermirror neutron turbine, was also constructed and reported in the meeting.[3] The former part of the present paper will describe the experimental results from the operation of this supermirror turbine.

Third method of UCN source is to extract UCN directly from the surface of a cold source or from a thin converter attached on the cold source. This kind of experiment by using an electron linac is also reported here for a comparison with the turbine results.

The method of a supermirror turbine presented here has advantages of giving a largely widened output of UCN beam which makes several experiments simultaneously possible, and further the use of supermirror blades makes it easy to fit for a higher velocity of incident neutrons than in the case of an ordinary mirror turbine.[4] As a result, it gives the possibility of utilizing the phase space density at the peak neutron flux from a pulsed spallation source with less broadening of the neutron density. From these studies, a concept of a synchronized supermirror turbine will be proposed as an efficient UCN source for a pulsed spallation facility.

II. Experimental Results of a Supermirror Turbine

The principle, design and construction of the present supermirror turbine was already reported in the previous meeting,[3] including the VCN feeding device for the turbine. For the measurements of UCN production in the turbine, as shown in Fig.1, a couple of reflecting supermirror blades (5) were attached at two symmetrical positions in 180^{o} directions around the wheel(4), and the remaining part around the wheel was shielded by cadmium plates(6). Thus, for a continuous feeding of VCN from a reactor (a phase space density being about 0.6×10^{-4} $n/cm^{2}sec(m/s)^{4}$ at the outlet of VCN-GT.), pulsed productions of UCN were performed and their distributions were analysed by a time-of-flight method through a short guide tube system(7 and 8), in which the distance from the output edge of the blades to a UCN detector(9) was about 13 cm.

The starting time of the time-analyser for detected neutrons was adjusted to the center of neutron bursts at the blade edge by using a pick-up system(11 and 12). Figure 2 shows one of the measured results with a gate opened during 10∿35 msec after the burst center. The "Ni-Al filtered" in Fig. 2 means the results of measurements with a filter of Ni-coated Al thin foil inserted in front of the detector window (i.e. between 7 and 8 in Fig. 1), which should consist of background and faster neutron countings. These non-UCN countings were essentially constant for the change of turbine speed, while the differences between two curves to be considered as UCN contribution becomes maximum at about 6 rps, i.e. the blade velocity of about 21 m/s.

Since the present measurements were performed for a continuous feeding of VCN, the non-UCN contribution in an actual condition of a pulsed source will be greatly decreased, and will be furthermore diminished by shielding the turbine vessel which was not done at all in the present study.

Further, Fig.3 gives the time-of-flight distribution of the UCN component for the optimum turbine speed of 6 rps. In this Figure, results of Monte Carlo calculations of UCN flights through the guide tube system were also shown for comparison.

From these measurements and analyses, the turbine efficiency of about 35 % expected in the present design is assured to be well attained in the present device of a simple and easy construction.

III. Direct Extraction of UCN from Pulsed Cold Source

Another time-of-flight experiment of UCN was carried out by using an electron linac and a cold source of solid mesitylene.[5] The experimental arrangement is shown in Fig. 4, where a bent guide tube of Ni-coated glass was used for the time-of-flight analyses. The effect of a polyethylene converter of 3 mm^t attached to the cold source was also studied, since the 3 mm^t Al wall of the cold pile (2) causes severe attenuation of UCN produced inside.

Figure 5 shows the result of the case with the polyethylene converter where the linac electrons were injected during a burst time of about 60 msec with the highest frequency of about 180 pps. The peak flux of cold neutrons at the cold moderator surface is estimated to be about $1\text{x}10^{10}$ n/cm^2sec.

As seen in Fig. 5, the present arrangement gives a larger contribution of non-UCN component comparing to the case of the turbine. In Fig. 6, a large gain factor of the cooled polyethylene converter for UCN intensity is illustrated as a result of these experiments.

IV. A Proposal of a Synchronized Supermirror Turbine

From these studies, it is proven that the neutron turbine gives a good elimination of non-UCN components and a high efficiency of UCN conversion. These advantages will be further multiplied by a possible utilization of the peak density of incident neutrons from a pulsed source by preparing appropriate UCN reflecting plates at remaining parts around the wheel, and also by a multi-loads uses of the wide UCN output from the turbine. Such a concept is illustrated in Fig. 7 as a possible combination of a synchronized supermirror turbine to a pulsed spallation source. The use of supermirror blades makes it easy to prepare the machine for faster incident neutrons, and this improves undesirable effect of neutron density broadening at the turbine inlet.

An example of the specifications resulted from these considerations is listed in Table 1. The construction of such a machine is a quite easy task within the present techniques.

Acknowledgements

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References

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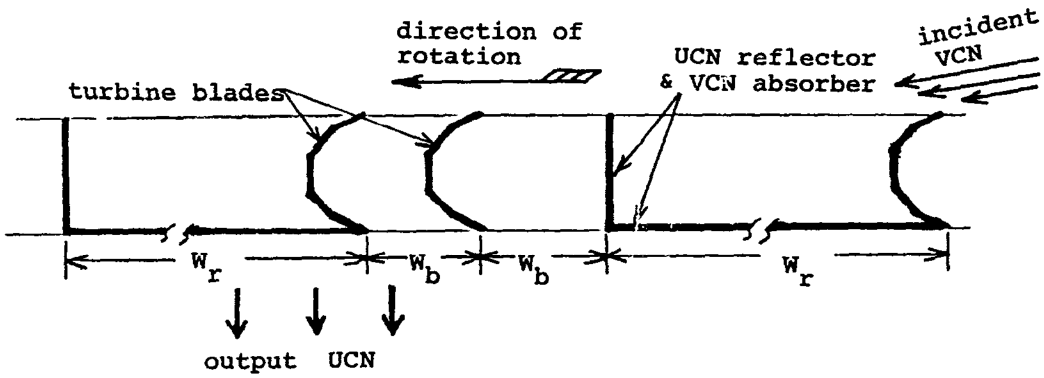
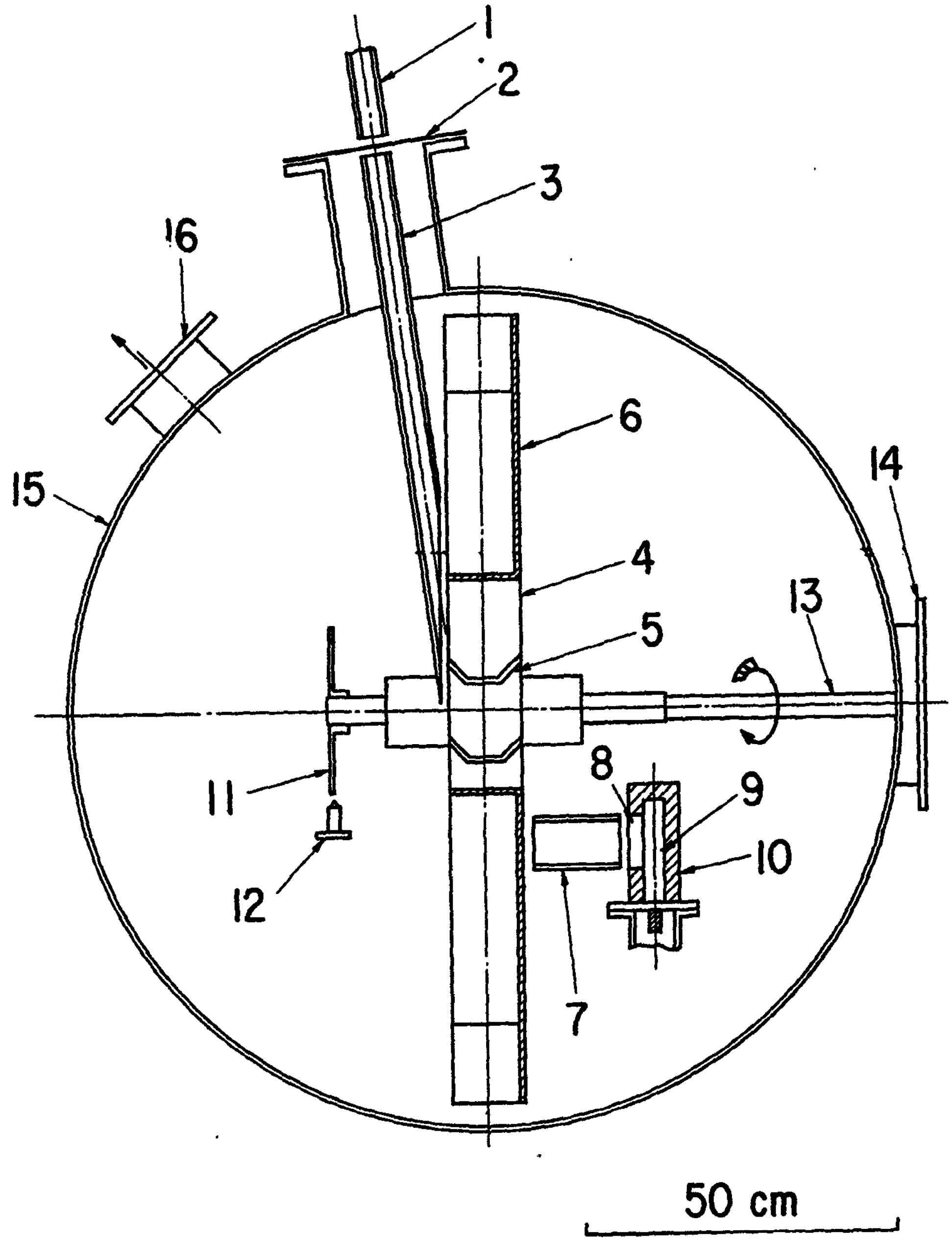
2) T.Dombeck: ibid.,p. 723 and p.732.
3) M.Utsuro et al.: ibid., p.743.
4) A.Steyerl: Nucl. Instr. Methods, 125, 461 (1975).
5) M.Utsuro et al.: J. Nucl. Sci. Technol. 14,390 (1977). Ann. Rep. Res. Reactor Inst., Kyoto Univ., 12, 12 (1979).

Table 1.
SPECIFICATIONS OF
A SYNCHRONIZED SUPERMIRROR TURBINE PROPOSED

Velocity Range of Incident Neutrons Used:	100 m/s ± 7 m/s,
Cross Section of VCN Feeding Guide Tube:	10 cm^H x 1.5 cm^W,
Length of VCN-GT:	$\sim$2.5 m from Cold Source,
Turbine:	
Diameter of turbine wheel;	300 cm,
Blade velocity;	50 m/s,
Blade shape;	Polygon of 5 flat supermirrors with 15cm^H,
Blade arrangement;	
a) For High Repetition Source ($\sim$ 100 pps);	Alternative arrangements of 2 blades(pitch $W_b \simeq 7.5$cm) and a reflector($W_r \simeq 35$ cm).
b) For Low Repetition Source ($\sim$ 10 pps);	Symmetrical 2 blade-groups in 180° directions around the wheel. Two blades in each group, and a wide reflector between the groups.
Cross Section of UCN Output:	$\sim$ 8 cm^H x $\sim$25 cm^W $\simeq$ 8 cm square x 3 loads





1:Double-curved VCN-GT from a Reactor, 2:Al window, 3:VCN feeding GT, 4:Turbine wheel, 5:Supermirror blades,6:Cd plates, 7:Ni-coated glass GT, 8:Guided window of Ni mirror, 9:UCN detector of He^3, 10:B_4C shielding, 11:Rotating disc with iron chips, 12:Magnetic pick-up, 13:Driving shaft, 14:Magnetic coupling, 15:Vacuum vessel, 16:Evacuation port.

Fig. 1 Experimental arrangement of UCN production with a supermirror turbine.

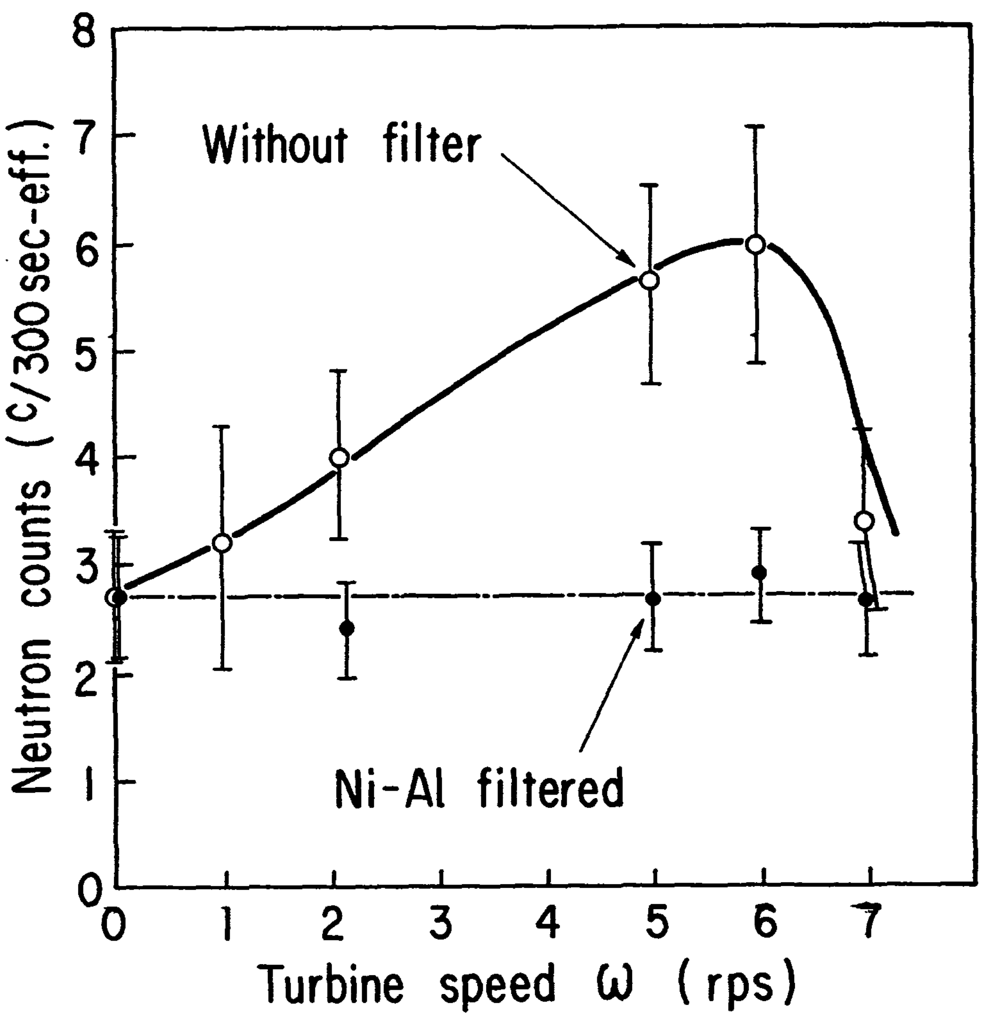


Fig. 2 Measured results of the turbine output for various rotation speed with a gate time of detected signals at 10∿35 msec. (Detector background subtracted.)

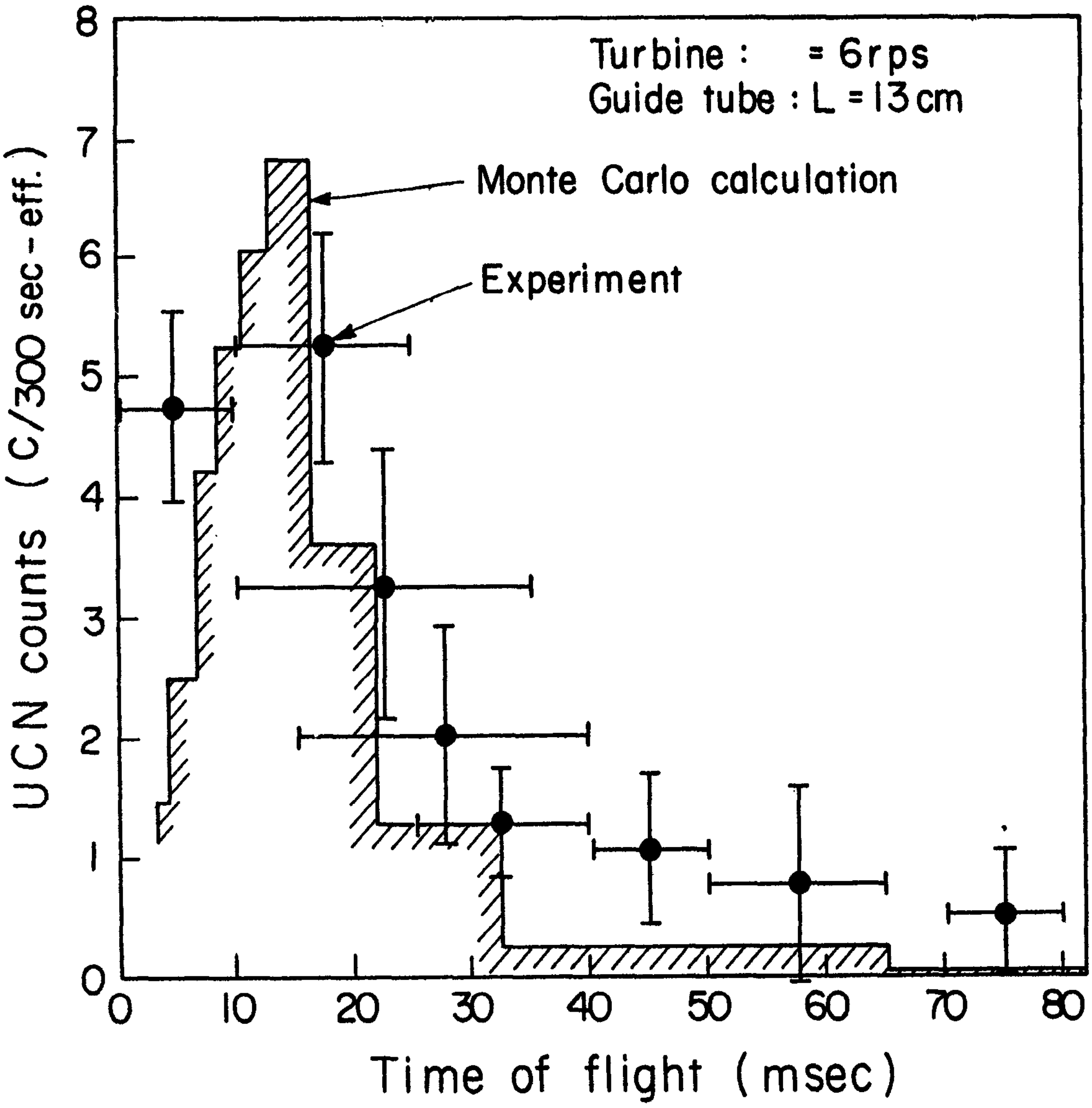
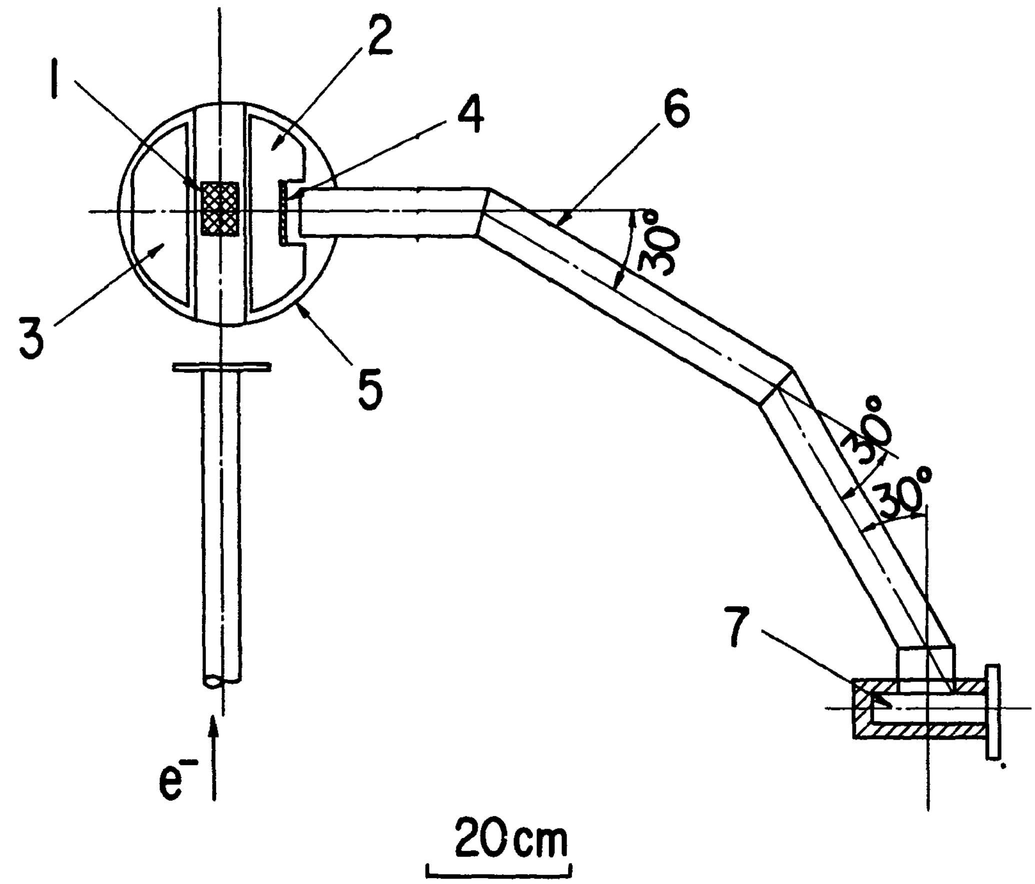


Fig. 3 Time-of-flight distribution of the difference between no-filter and filtered counting rates. Monte Carlo calculation was also shown for comparison.



1:Target, 2:Cold source, 3:Reflector, 4:UCN converter,
5:Vacuum vessel, 6:Evacuated guide tube, 7:UCN detector.

Fig. 4 Experimental arrangement of UCN production with a linac-cold source system.

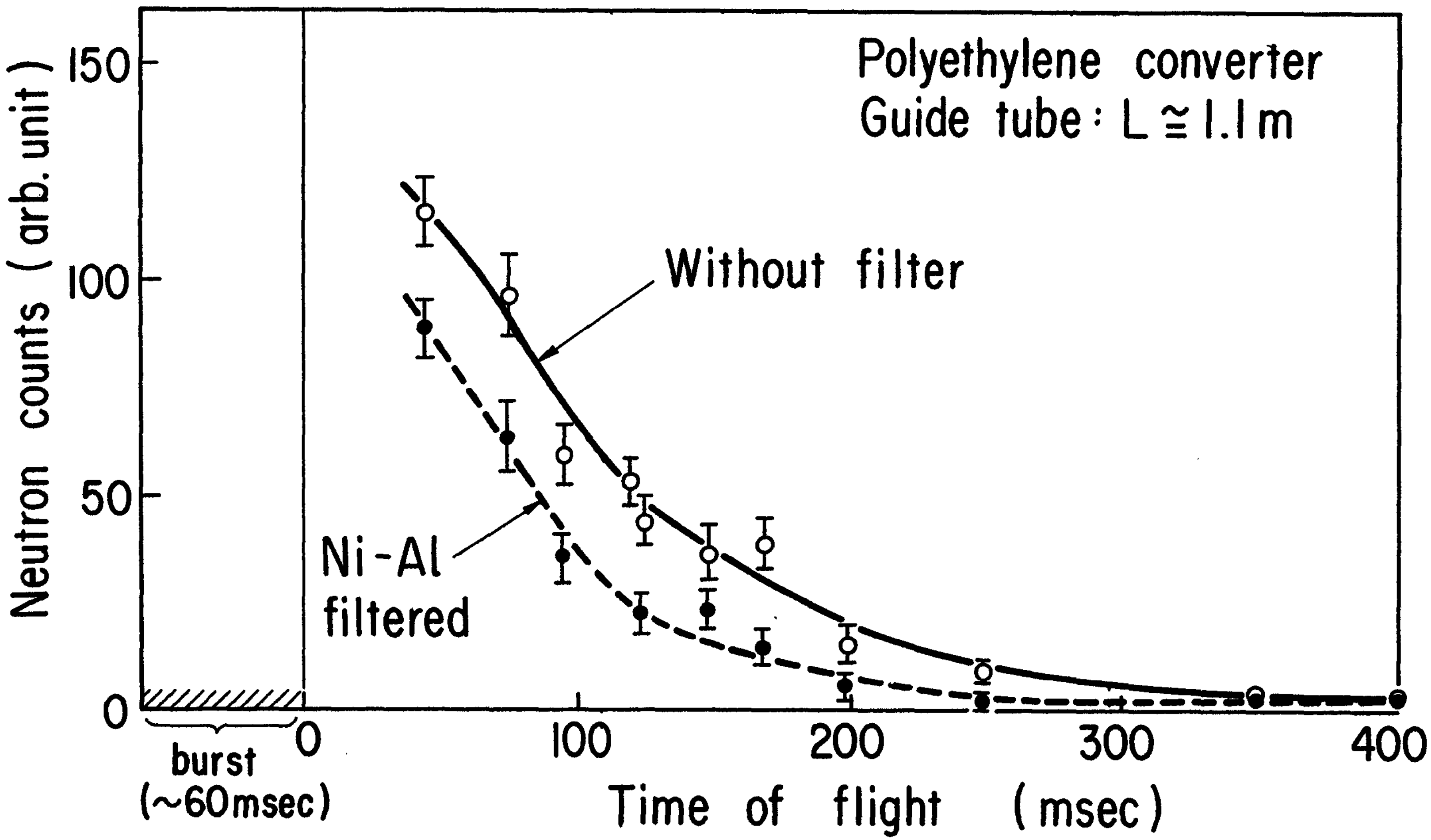


Fig. 5 Measured results with a polyethylene converter on the cold source.

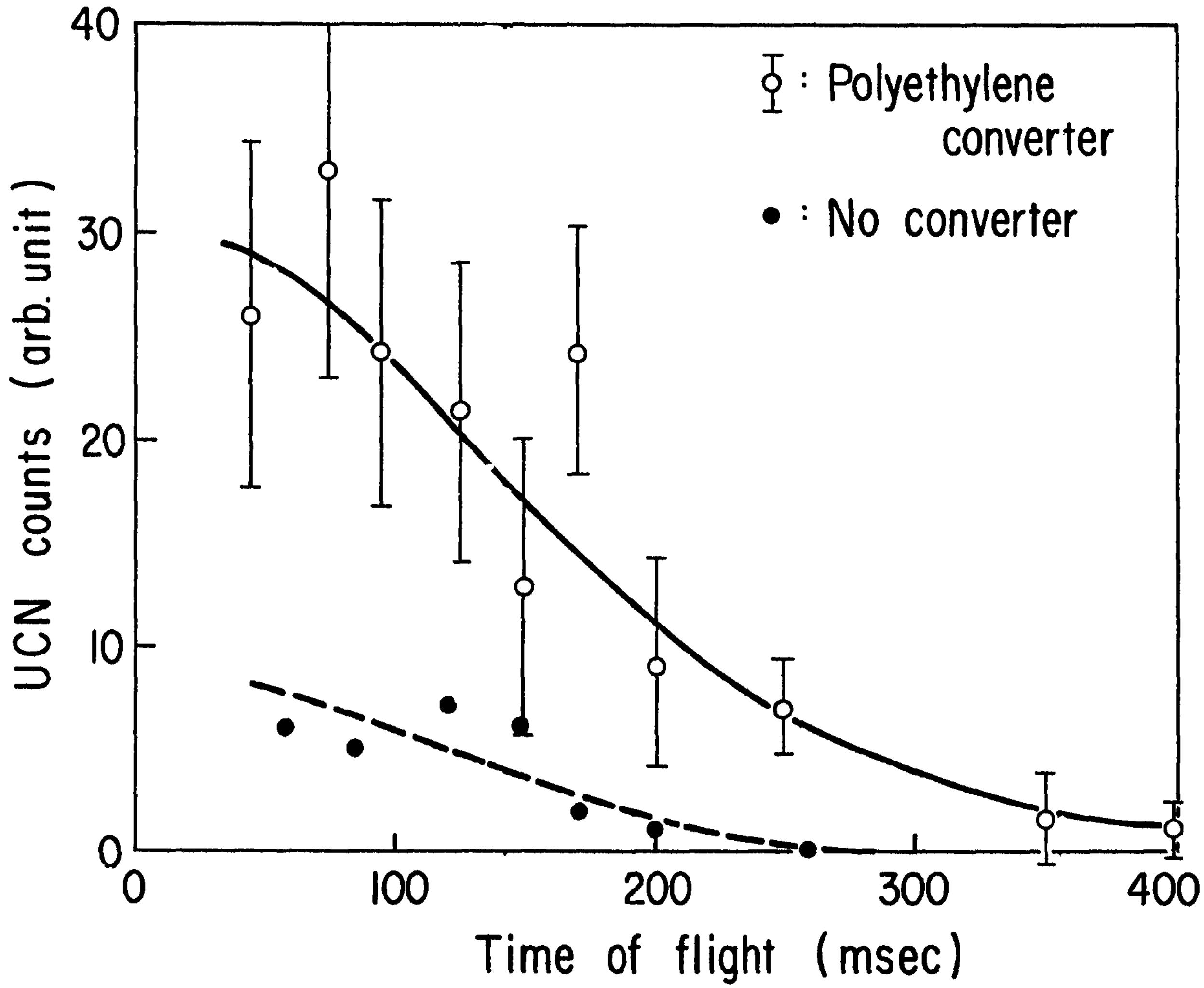
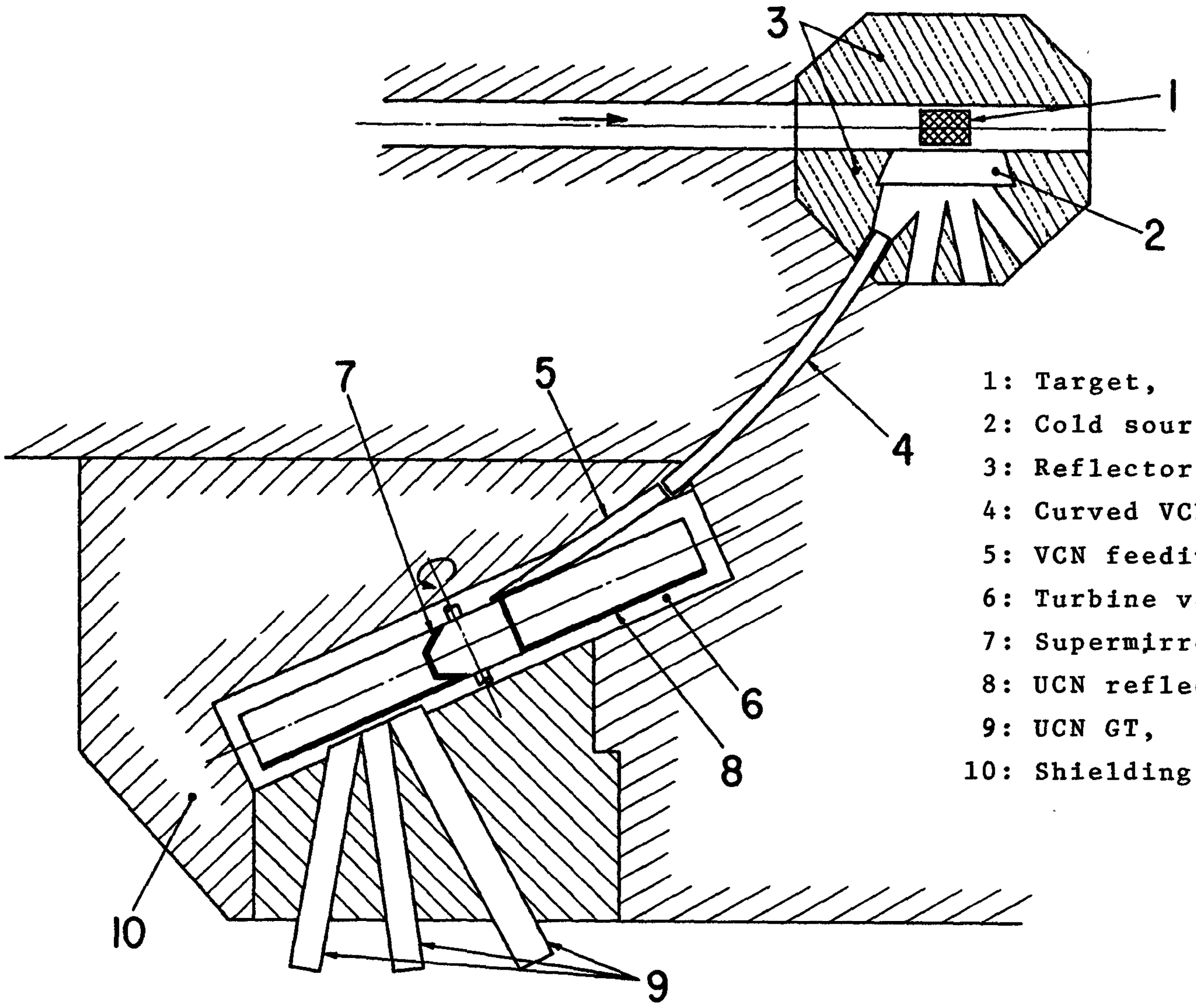


Fig. 6 Measured effects of the polyethylene converter to increase the difference between no-filter and filtered counting rates.



1: Target,
2: Cold source,
3: Reflector,
4: Curved VCN-GT,
5: VCN feeding GT,
6: Turbine vessel,
7: Supermirror blades,
8: UCN reflecting plates,
9: UCN GT,
10: Shielding.

Fig. 7 A conceptual drawing of a synchronized supermirror turbine combined to a pulsed spallation source.