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SNQ-MODERATOR OPTIMIZATION

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SNQ-Moderator Optimization

Fast moderators have to be optimized in their geometrical dimensions as well as in their structural material components. Experiments /1/ show in special cases that "grooved" moderators give higher responses for thermal neutrons than solid moderators.

In the design calculations for the SNQ-target-moderator-reflector system details like the surface structure of the fast moderator originally were not considered. Therefore, a study to optimize the moderator structure (size, surface, and material) was initiated.

A special fast running 3-D geometry model for HETC/MORSE Monte Carlo calculations was developed. The advantage of this geometry model is easy parameter variation for overall size of the moderator and description of grooves and fins including structural and moderator material. Point detector estimation of escaping neutron fluxes in energy, time and space with importance sampling is used.

Figure 1 represents the geometrical model for moderator optimization calculations which have been performed for an uranium target with 1100 MeV incident proton beam.

Figure 2 shows that variation of the H_2O-moderator width from 7 to 21 cm in the direction of the beam tubes (curve A) has no influence on the detector response at 6 m distance from moderator at the end of the beam tubes. A detector response curve for grooved moderators with 12 grooves (depths 1/3 of geometrical width) is plotted in the same figure as curve B. All curves represent theoretical values because in these calculations the grooves are without structural material. The maximum flux at detector positions is 5.7×10^{-7} n/cm^2 per proton compared to 2.90×10^{-7} n/cm^2 per proton in case of an ungrooved moderator shows a possible gain factor of nearly 2 for a grooved moderator. The optimum grooved moderator has an effective width of about 16 cm, i.e. geometrical width of 24 cm and groove depth of 8 cm. All other dimensions are not yet optimized. Variation of the groove depth at constant geometrical width of 18 cm (curve C) shows that the optimum response is obtained with 7 cm groove depth (11 cm effective moderator thickness). In the above calculations the distance between target material and moderator was taken as 5 cm. In case of 2.5 cm distance the gain factor is 1.25. Further calculations show that a 1 mm thick aluminium structure of the grooves reduces the detector response by 30 %. Therefore, the final detector response will be comparable to the case without grooves and without beam tubes.

The results of the calculations are summarized in Table I. The calculation for a moderator optimized in beam tube direction give a flux value of 4×10^{-7} n/cm^2 per incident proton at detector position B (see Figure 1) taking into account all losses in structural materials.

Also given in Table I are values for the "equivalent isotropic flux", denoted as "EIF". This is a commonly used basis for comparison in relating the neutrons measured at the end of a beam tube to the magnitude of the thermal neutron source.

Table I: Thermal neutron fluxes from fast moderator (uranium target, 1100 MeV proton beam energy)

Position	Thermal Neutron Fluxes		
	Φ_{th} (a) (n/cm^2 per proton)	Φ_{th} (b) (n/cm^2 s)	Φ_{th} (c) (n/cm^2 s)
A	2.80×10^{-2}	8.3×10^{14}	3.3×10^{16}
B (ungrooved)	2.75×10^{-7}	8.6×10^{9}	3.4×10^{11}
B (grooved)	4.0×10^{-7}	1.25×10^{10}	5.0×10^{11}
"EIF" (d)	4.6×10^{-2}	1.4×10^{15}	5.6×10^{16}

(a) Neutron fluence per beam proton
(b) Average neutron flux for $\bar{I} = 5$ milliamperes
(c) Peak neutron flux for $\hat{I} = 200$ milliamperes
(d) "EIF" = "Equivalent Isotropic Flux"

To make sure that the Monte Carlo models used are adequate for this problem a series of benchmark experiments was started. These experiments do not aim directly on the optimization of the SNQ fast moderator, but on validation of computational methods. These benchmark experiments were performed with 14 MeV neutrons.

Figure 3 shows a comparison of calculated neutron escape spectra from the fast moderator. Case a) represents the results of a calculation using the 1100 MeV proton beam induced neutron spectrum and source distribution of the SNQ design calculations. The moderated neutrons are transported to the end of flight path. This calculated neutron spectrum is compared with a spectrum originating from a 14 MeV point source (case b) in the same target-moderator-geometry.

No significant differences between the two cases can be recognized. Therefore, benchmark experiments investigating the neutronic behaviour of fast moderators of spallation sources can be performed using D-T-neutron generators.

The experimental arrangement of the experiments is shown in Figure 4. Ungrooved or grooved polyethylene moderators of various thickness are surrounded by lead reflectors of 20 cm x 60 cm x 60 cm dimension. The escape spectra of different fast moderators are measured at the end of the 5.4 m long flight path. Fixing the outer dimensions of the moderator the groove depth and the number of grooves and fins were varied. In Table II several results of the first experimental runs and the corresponding calculations are summarized. Figures 5 to 11 show the normalized measured and calculated neutron spectra of the different moderators. The calculations fit the experiments quite well. In the energy range below 0.02 eV a number of groups should be added to the used 53 group library. The integrated normalized fluxes show the same tendency in experiments and calculations, but in absolute numbers some minor differencies remain.

Table II: Benchmark Experiments and their Flux Yields

Groove Depth in cm	Number of Grooves	Thickness in mm	Normalized integrated flux 0.457E-2 – 1.0 eV	
			Experiment	Calculation
Reference	-	-	1.0	1.0
5	6	10	1.72	1.40
5	12	5	1.86	1.59
5	30	2	1.83	1.63
6	6	10	1.56	1.39
6	12	5	1.75	1.50
6	30	2	1.72	1.71
3	6	10	1.44	1.32
3	12	5	1.57	1.38
3	30	2	1.68	1.56

References

/1/ G. Bauer et al.
Realisierungsstudie zur Spallationsneutronenquelle, Teil B
Jül-Spez-113, June 1981

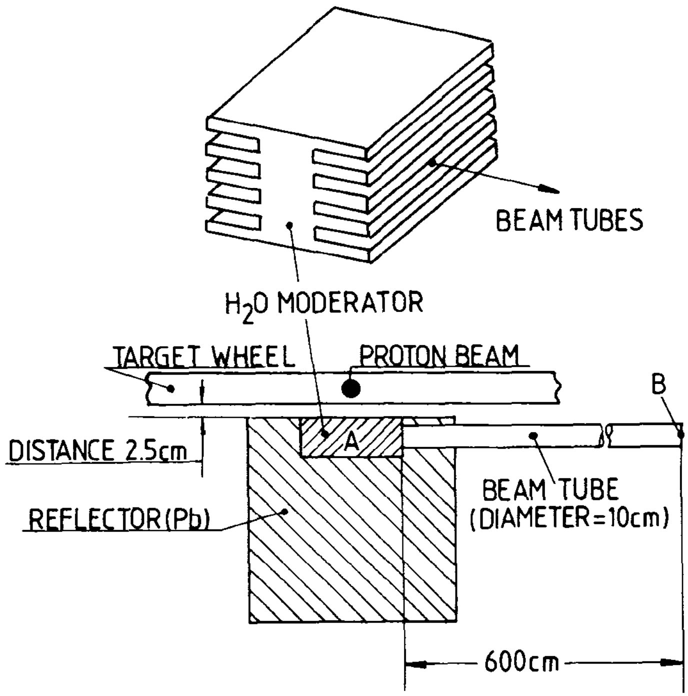

Fig. 1: Model for fast moderator design

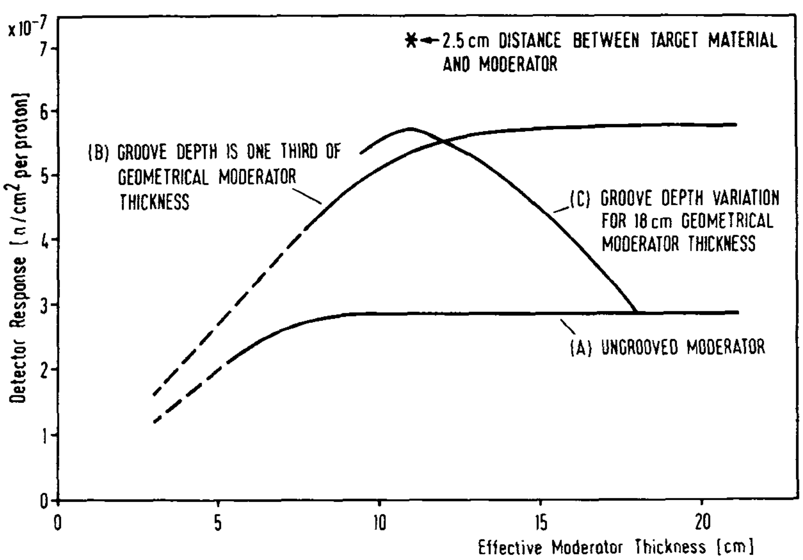

Fig. 2: Moderator optimization by Monte Carlo Calculation: Comparison of detector responses (thermal energy 10^{-5} - 0.4 eV) for solid and grooved moderators

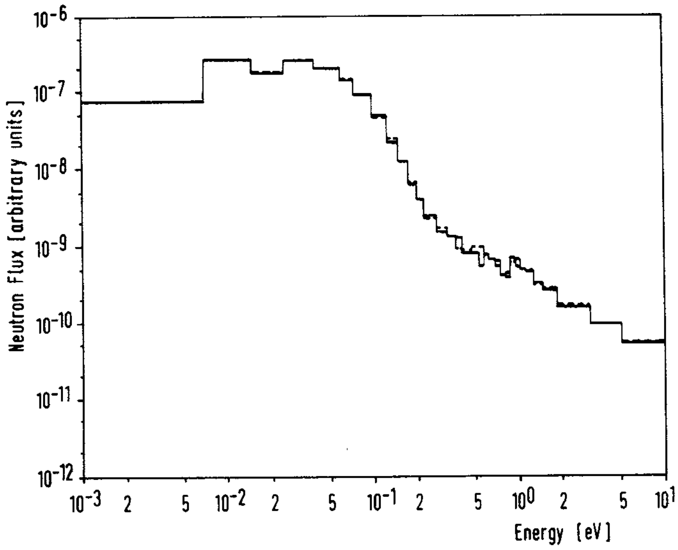

Fig. 3: Comparison of neutron flux spectra from fast moderator at the end of flight path (______) 14 MeV Neutron Source (-----) Spallation Source

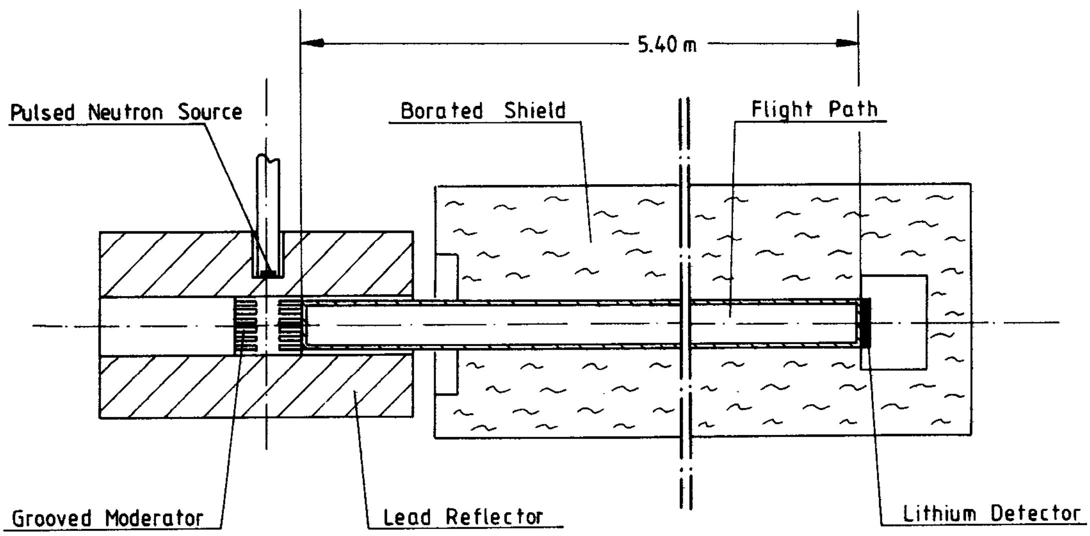

Fig. 4: Horizontal view of measurement assembly

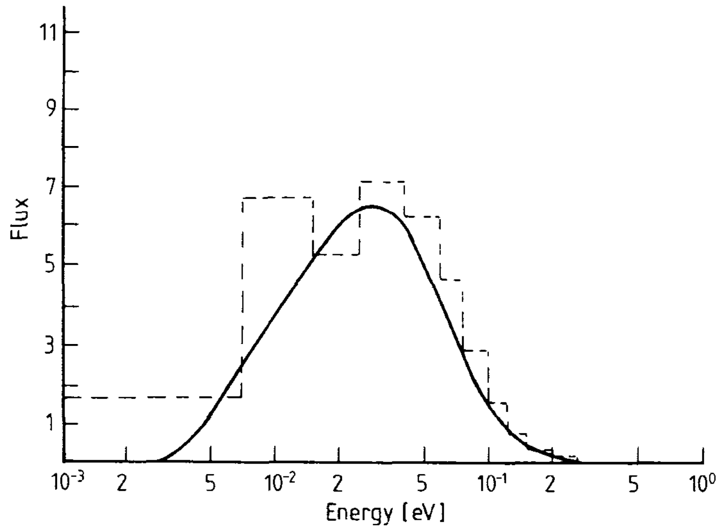

Fig. 5: Reference Moderator without Grooves

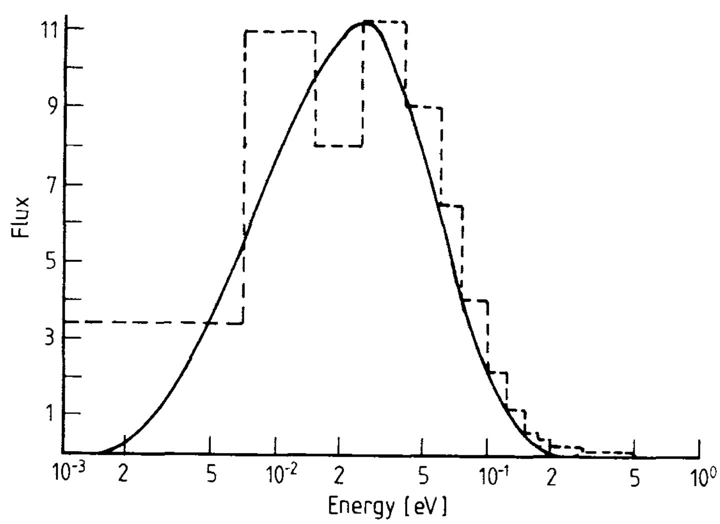

Fig. 6: 6 Grooves of 5 cm Depth

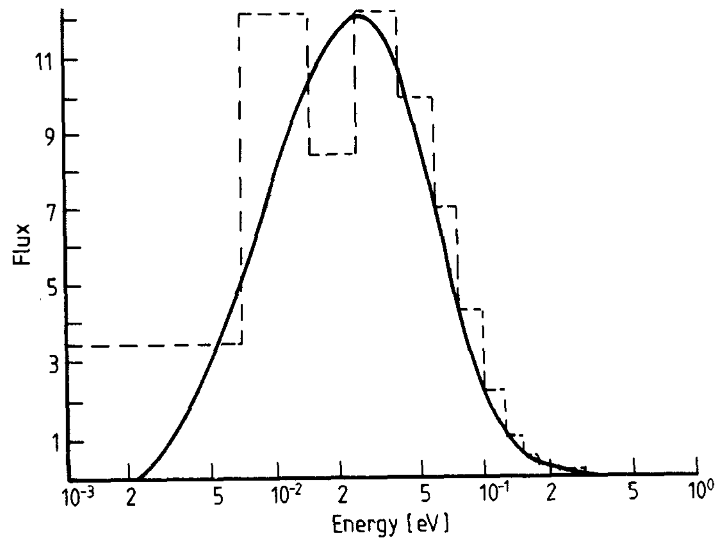

Fig. 7: 12 Grooves of 5 cm Depth

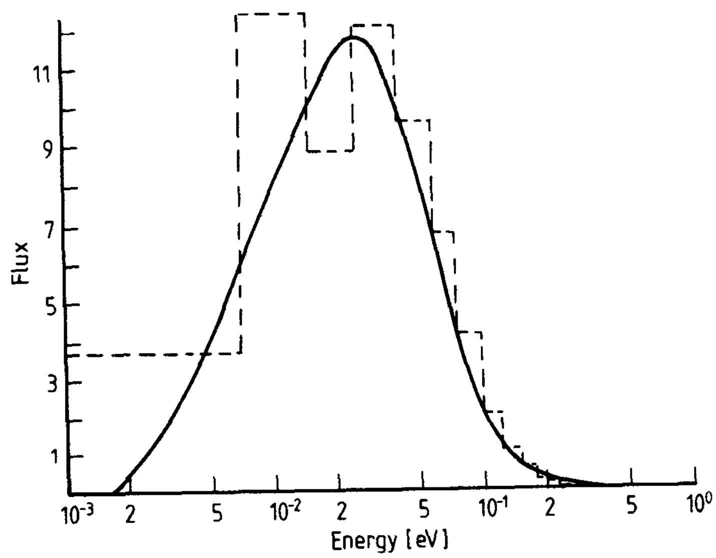

Fig. 8: 30 Grooves of 5 cm Depth

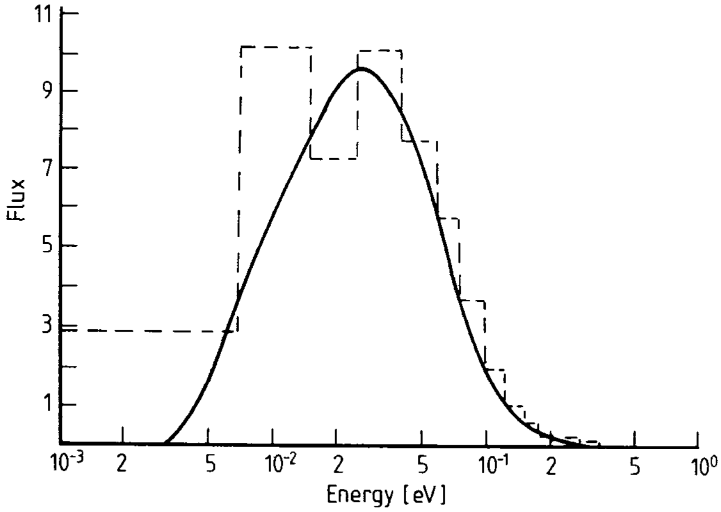

Fig. 9:

6 Grooves of 3 cm Depth

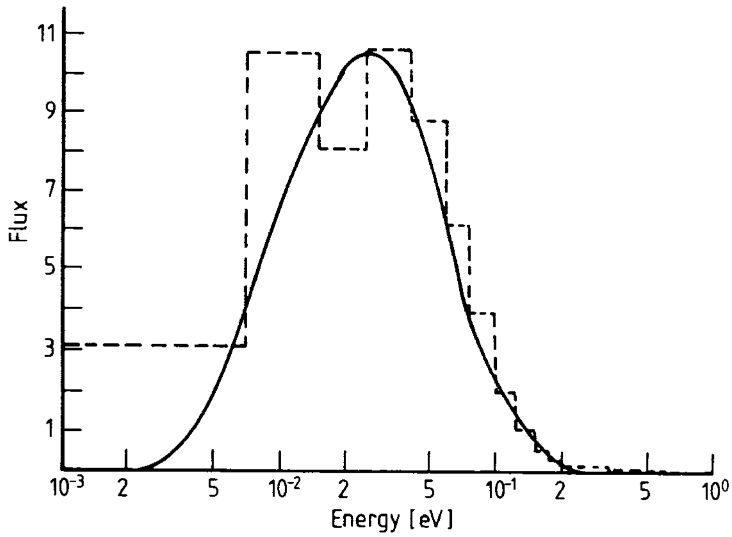

Fig. 10:

12 Grooves of 3 cm Depth

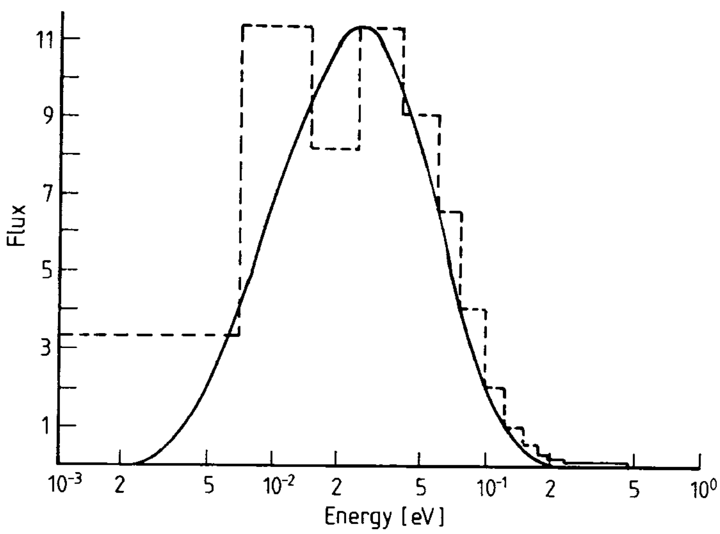

Fig. 11:

30 Grooves of 3 cm Depth