Picture gallery for the ESS reference moderators version 4.12.00.

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1. Scope

The present collection of figures illustrates various features of the approximate expressions for the ESS reference moderator characteristics defined in document "ESS reference moderator characteristics for generic instrument performance evaluation", F. Mezei, 4.12.00. (in what follows referred to as ESS-Instr.-4.12.00. or [1]) In addition, explicit analytic expressions are also given for the long pulse moderator fluxes by the analytic integration of the equations under 3.c1) and 3.c2) in [1]. The present notice concludes with a summary of the main uncertainties concerning the expected ESS moderator performances, in particular in view of future revisions of [1], and some observations on comparing various types of moderators.

2. Analytic long pulse moderator spectra.

The time **t** dependence of the pulses is approximated in [1] by combinations of the generic function **F(t,t,n)**. The relevant "long pulse" integral **I** of this function is given below.

$$\mathbf{iexp(t,t,d)} = \begin{cases} \mathbf{0}, & \mathbf{if\ t<0} \\ \mathbf{t[1 - exp(-t/t)]}, & \mathbf{if\ 0\ £t\ £d} \\ \mathbf{t[exp(d/t) - 1]\ exp(-t/t)}, & \mathbf{if\ t>d} \end{cases}$$

defines the long pulse response of the exponential decay with time constant **t**, where **d** is the duration of the long pulse. The long pulse shape function **I(t,t,n,d)** is then defined as

$$\mathbf{I(t,t,n,d) = [iexp(t,t,d) - iexp(t,t/n,d)]\ n\ /(n\text{-}1)\ /\ t\ /\ d}$$

where the line shape parameter **n** is defined in [1]. Finally, the long pulse line shapes are obtained by replacing in the equations in 3.a3) and 3.b3) of [1] the function **F** by the function **I,** and taking into account the assumptions that d = 2 ms and the integrated intensity per long pulse is 3 times that per short pulse. Thus:

Long pulse coupled ambient H_2O moderator spectrum:

$$\Phi_7(t,\lambda) = 13.5*10^{11}M(\lambda,325)[I(t,80*10^{-6},20,2*10^{-3}) + I(t,400*10^{-6},20,2*10^{-3})] +$$

$$+ 27.6*10^{10}[1+ \exp(2.5\lambda-2.2)]^{-1}\lambda^{-1}I(t,12*10^{-6}\lambda,2*10^{-3})$$

Long pulse couples liquid H_2 moderator spectrum:

$$\Phi_8(t,\lambda) = 6.9*10^{11}M(\lambda,50)I(t,287*10^{-6},20,2*10^{-3}) +$$
$$+ 27.6*10^{10}[1+ \exp(0.9\lambda-2.2)]^{-1}\lambda^{-1}I(t,20*10^{-6}\lambda,5,2*10^{-3})$$

The figures in the next chapters show examples of these and the short pulse spectra defined in [1] and the wavelength λ dependence of several properties of these spectra.

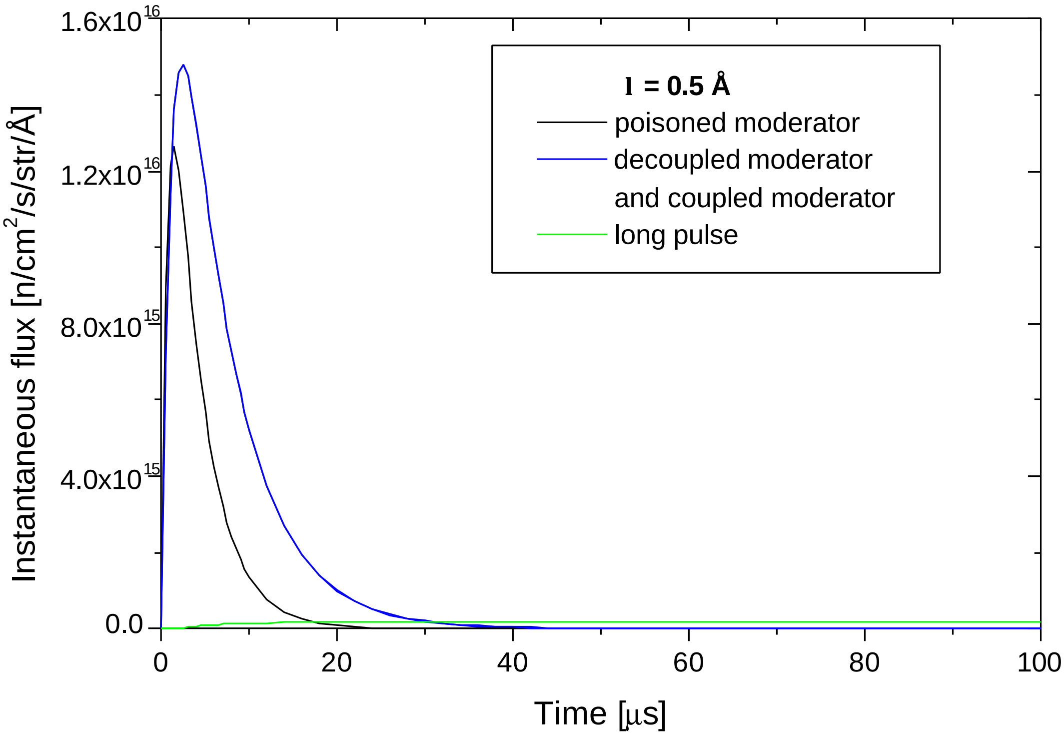
In what follows, the various moderator options are referred to according to the following definitions:

"Thermal moderators":	ambient H_20 moderators
"Cold moderators":	liquid H_2 moderators
"Poisoned moderators":	short pulse de-coupled poisoned moderators
"Decoupled moderators":	short pulse de-coupled un-poisoned moderators
"Coupled moderators":	short pulse coupled moderators
"Long pulse":	long pulse coupled moderators

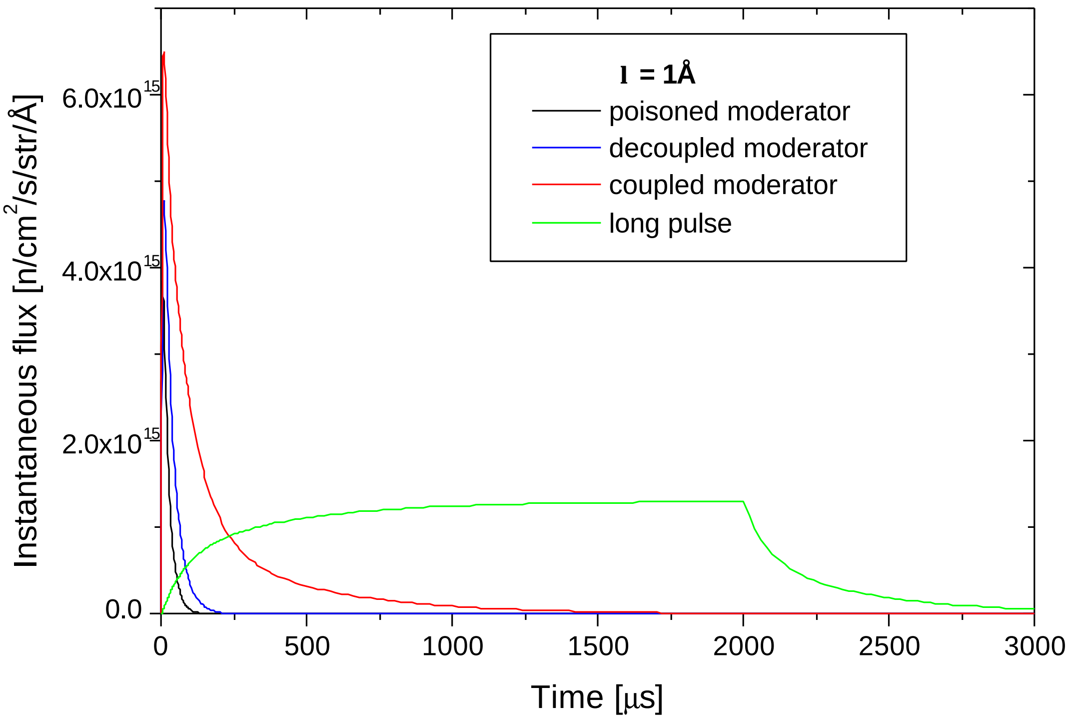
The assumed short pulse proton beam energy is 100 kjoule per pulse, and the long pulse power is 300 kjoule per pulse

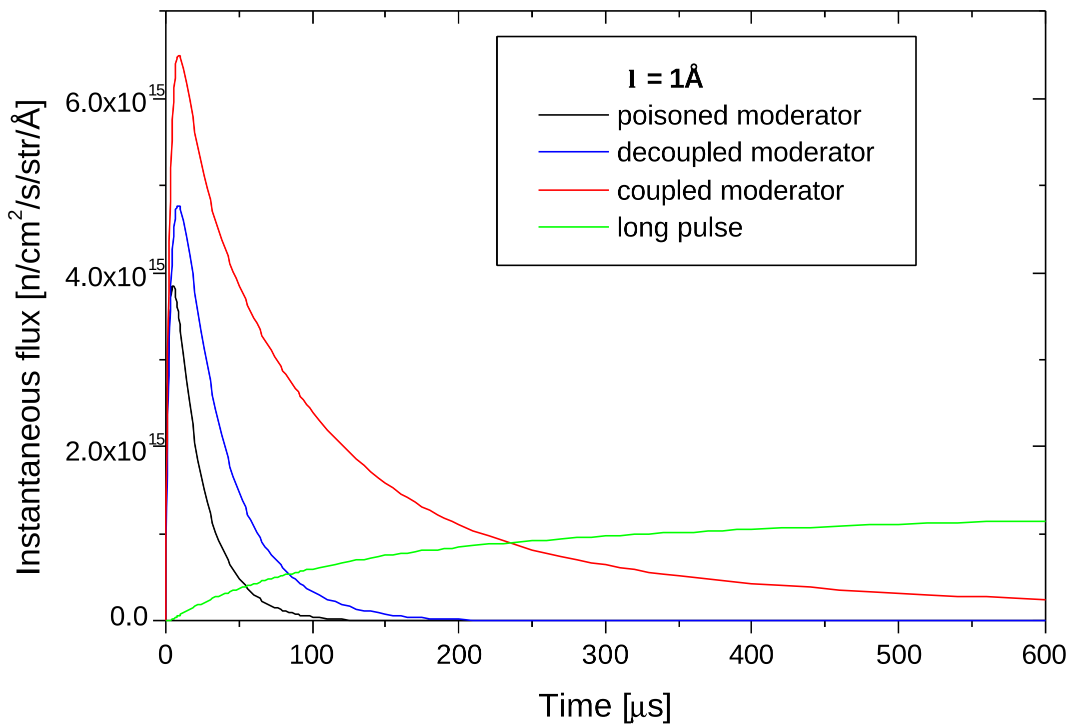
3. Line shapes at various wavelengths

Thermal moderators:



Thermal moderators:





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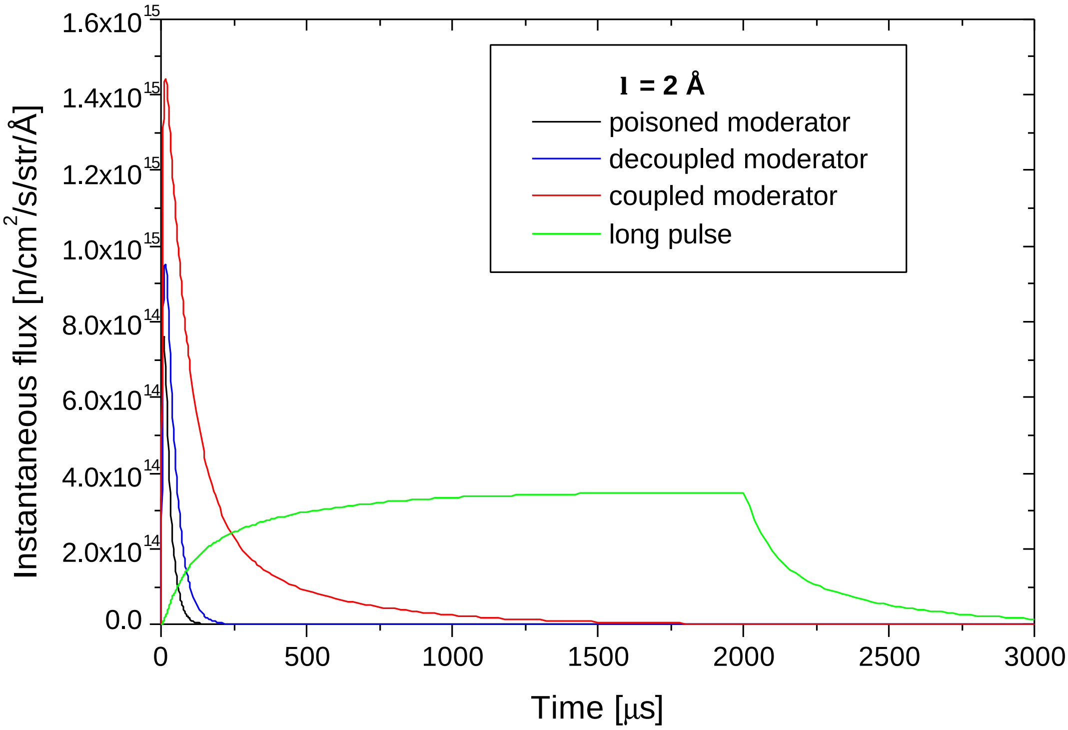

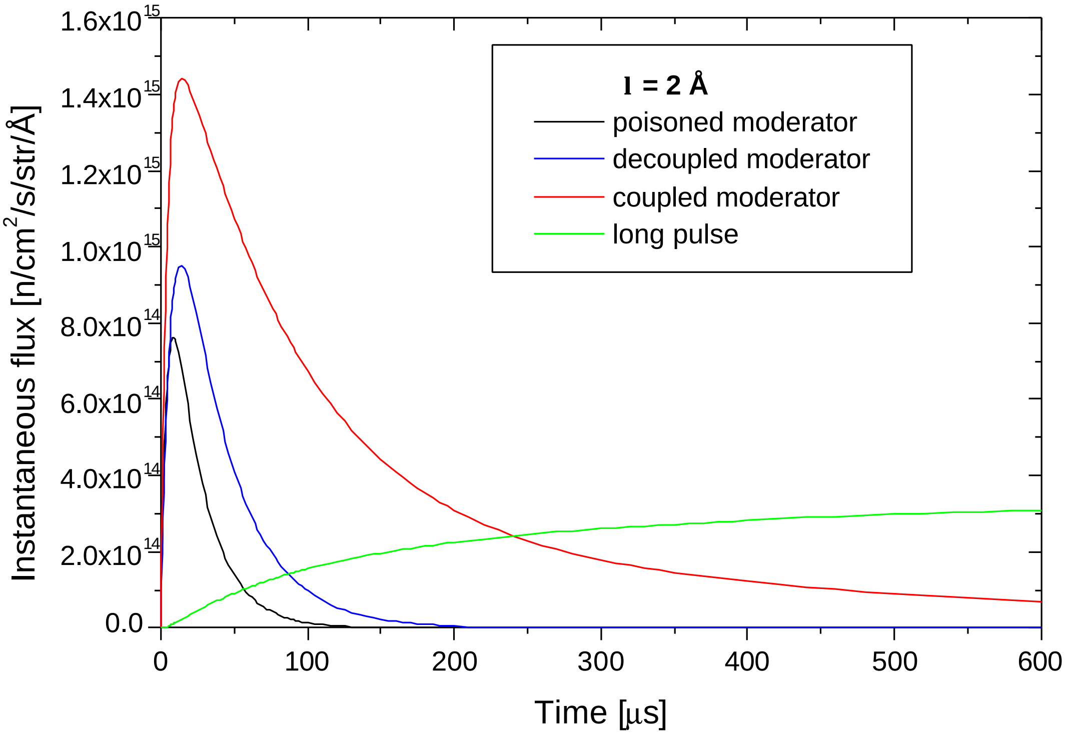

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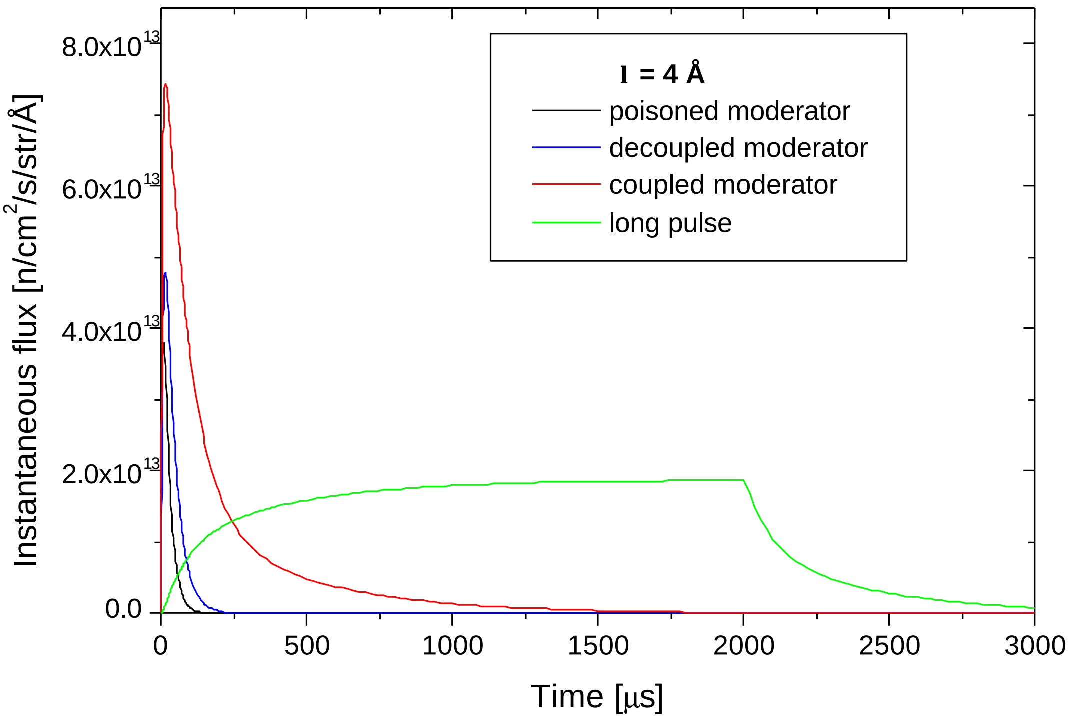

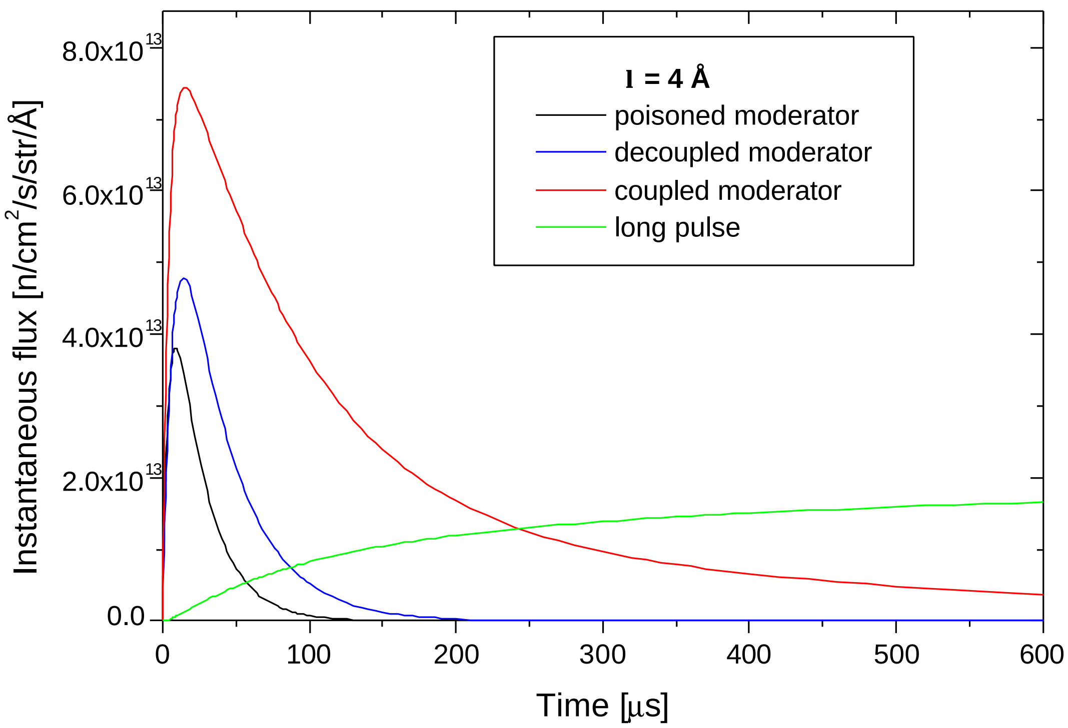

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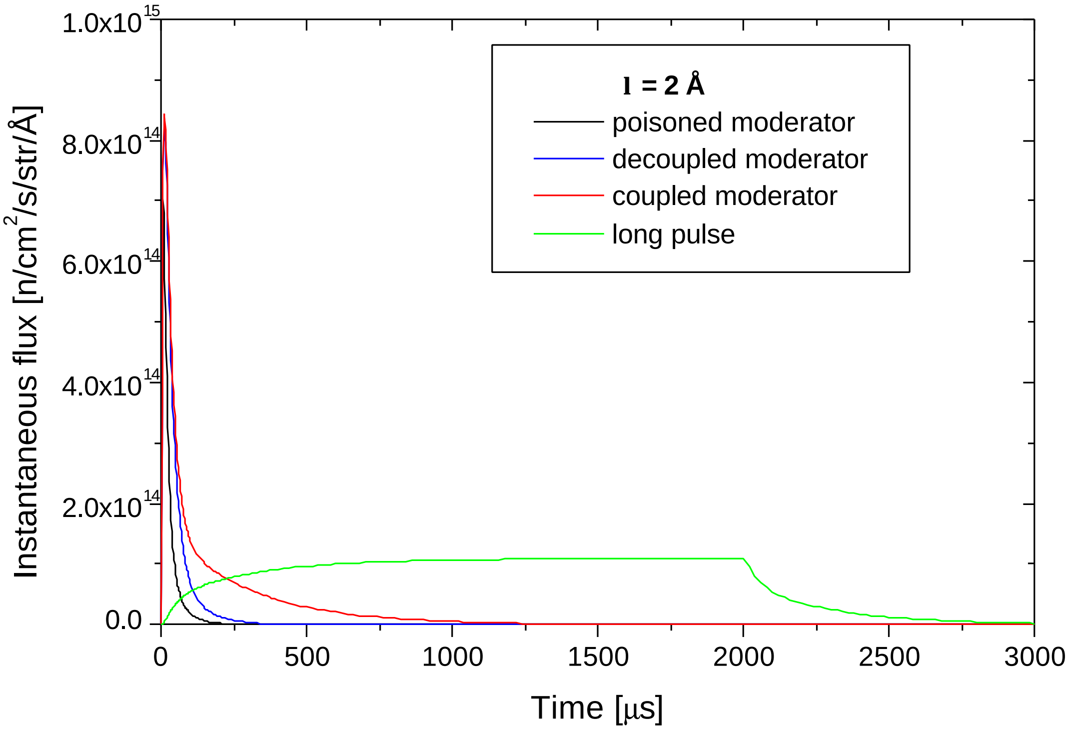

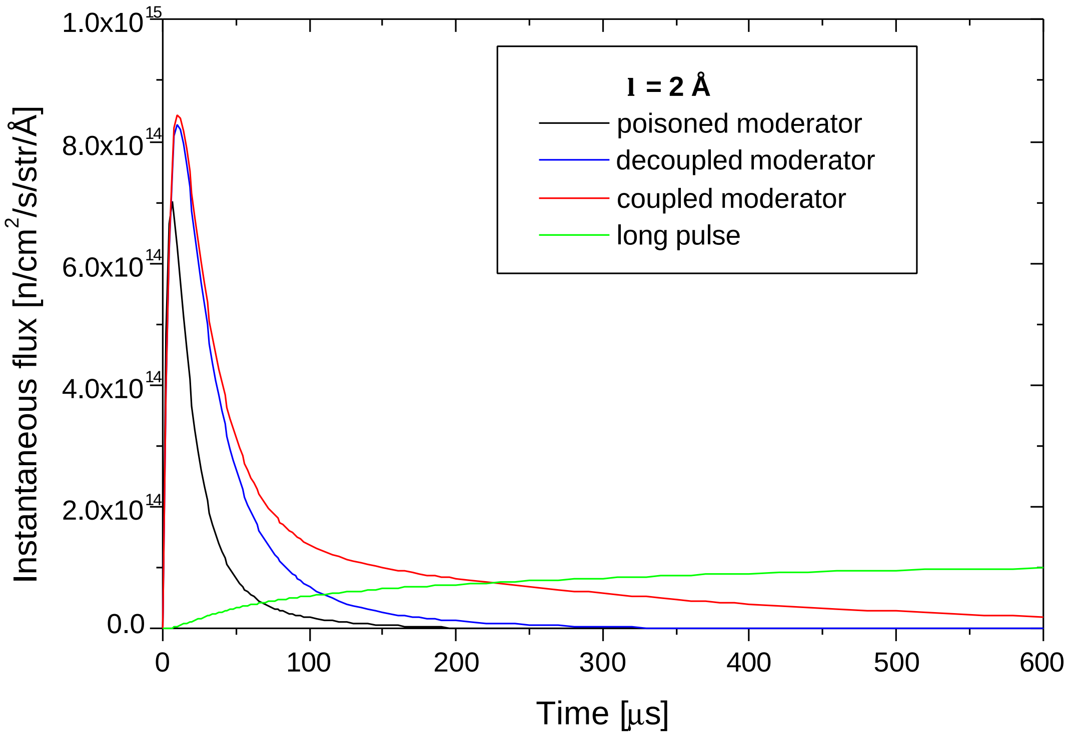

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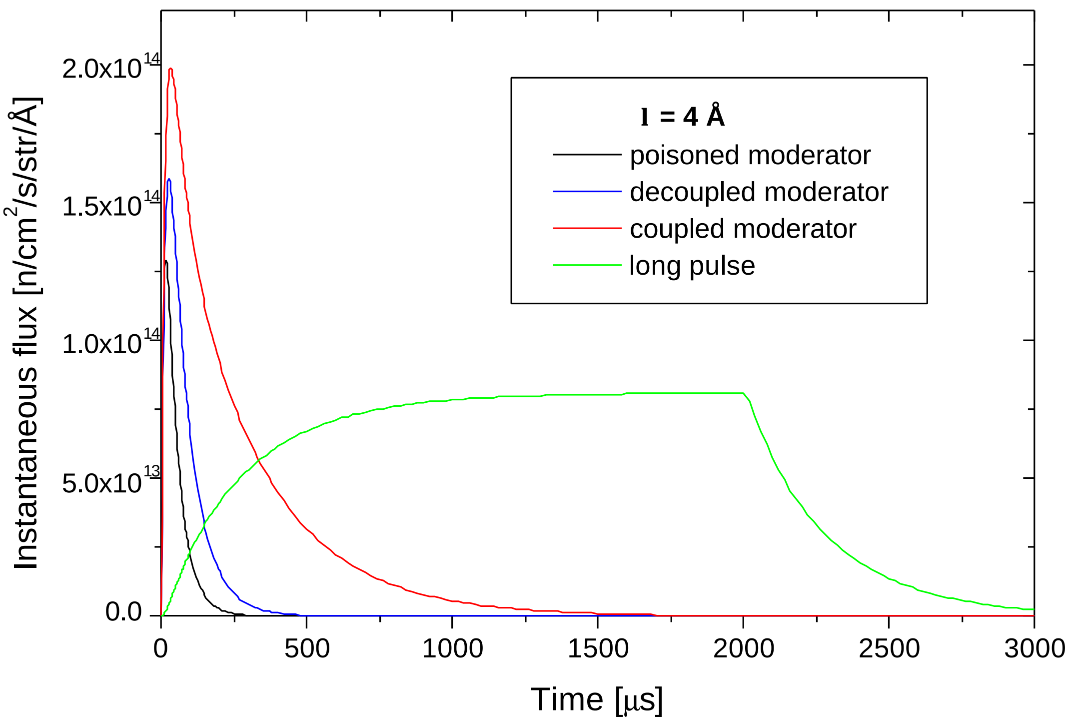

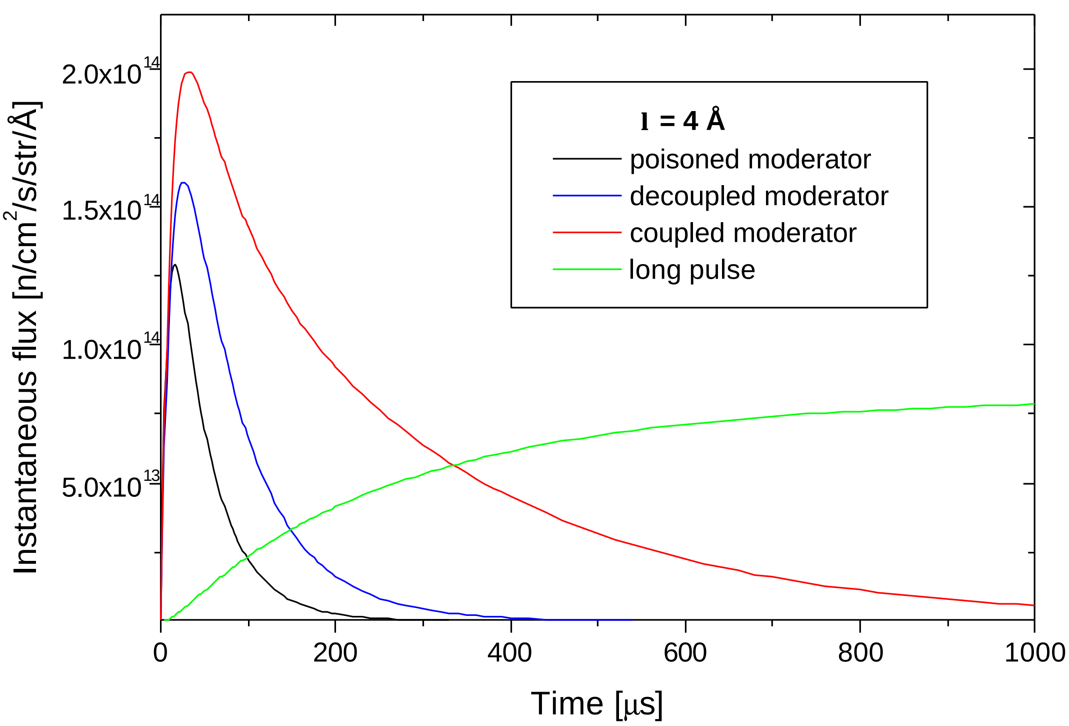

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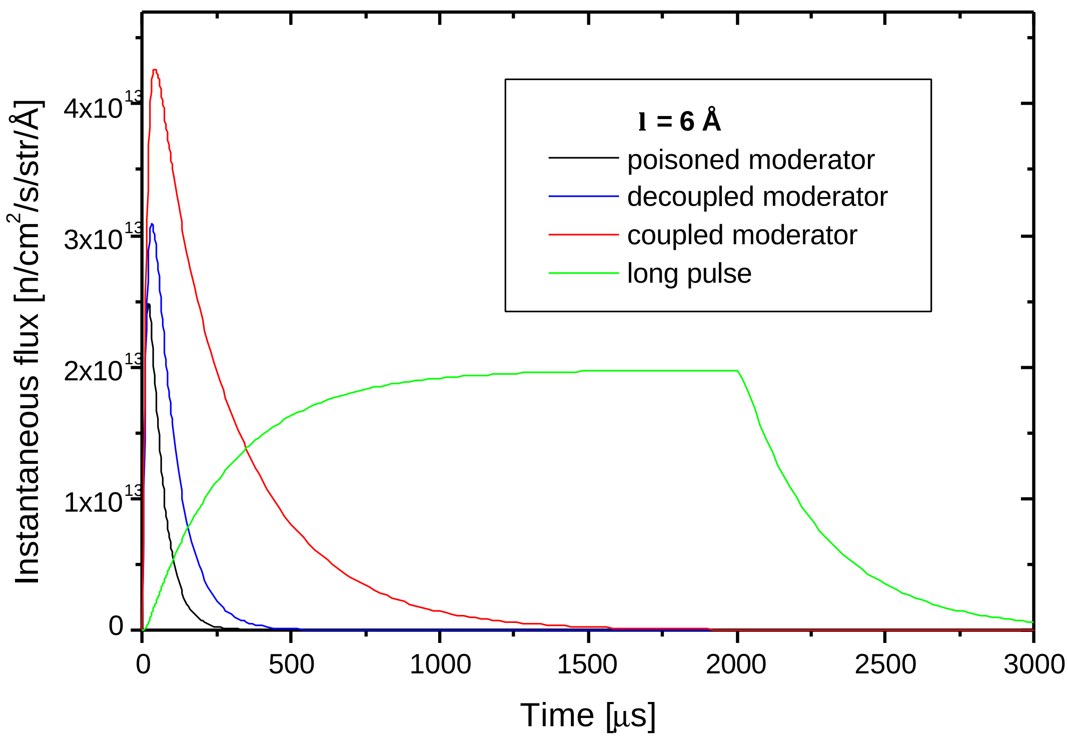

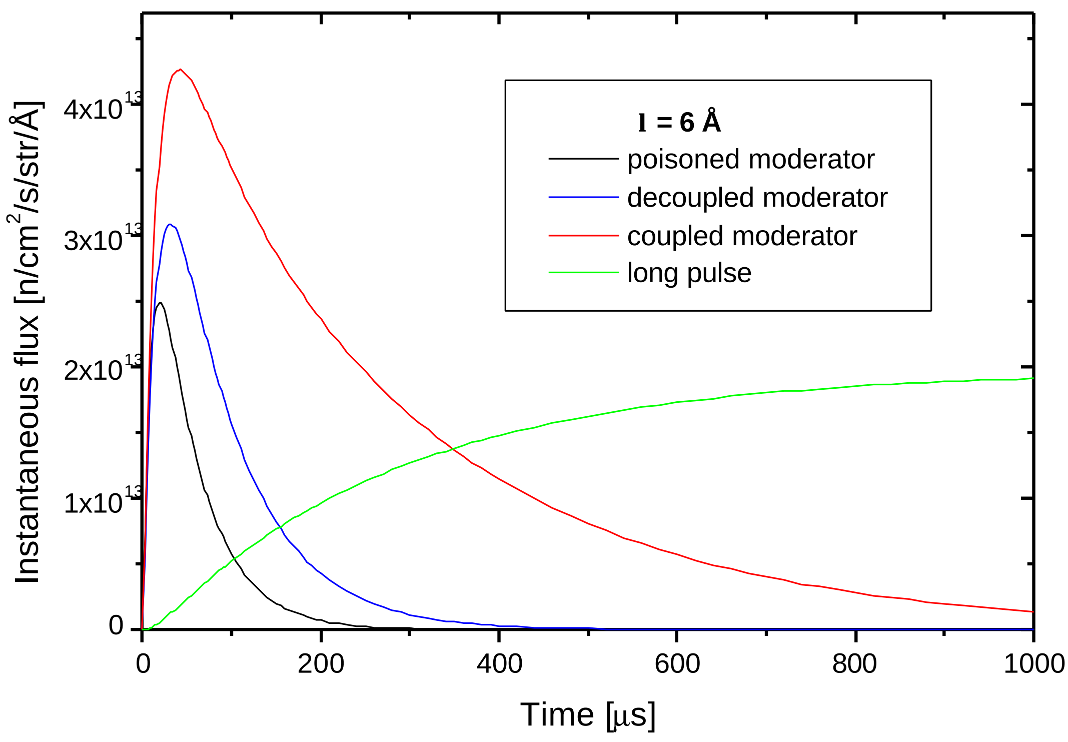

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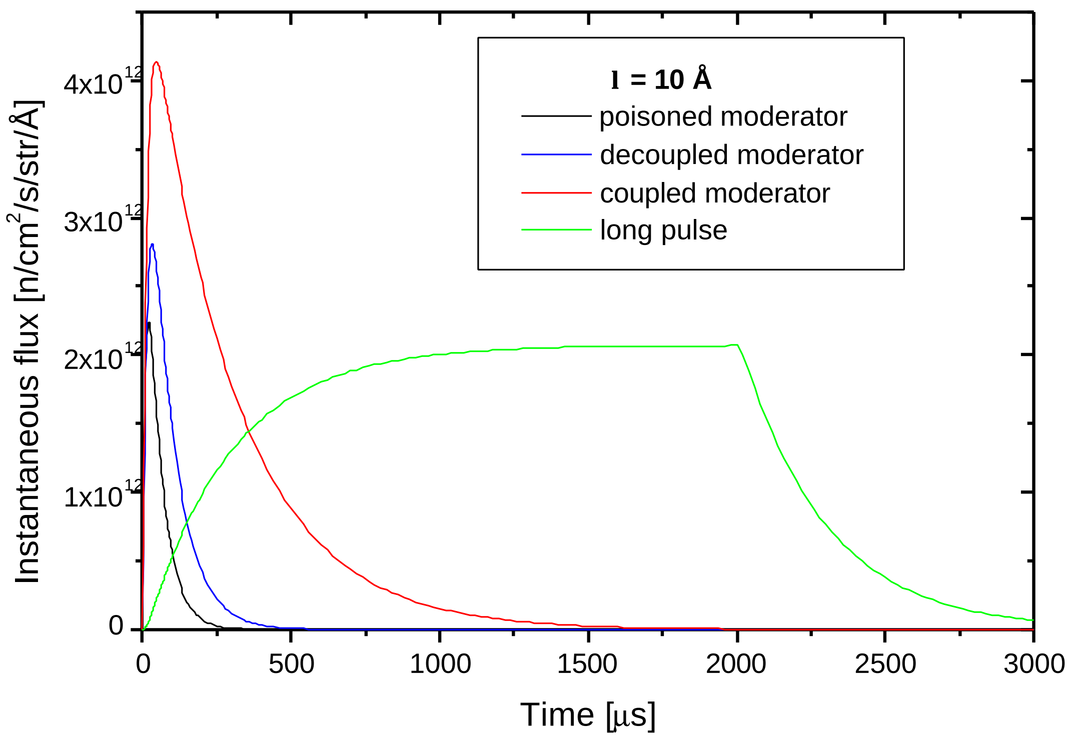

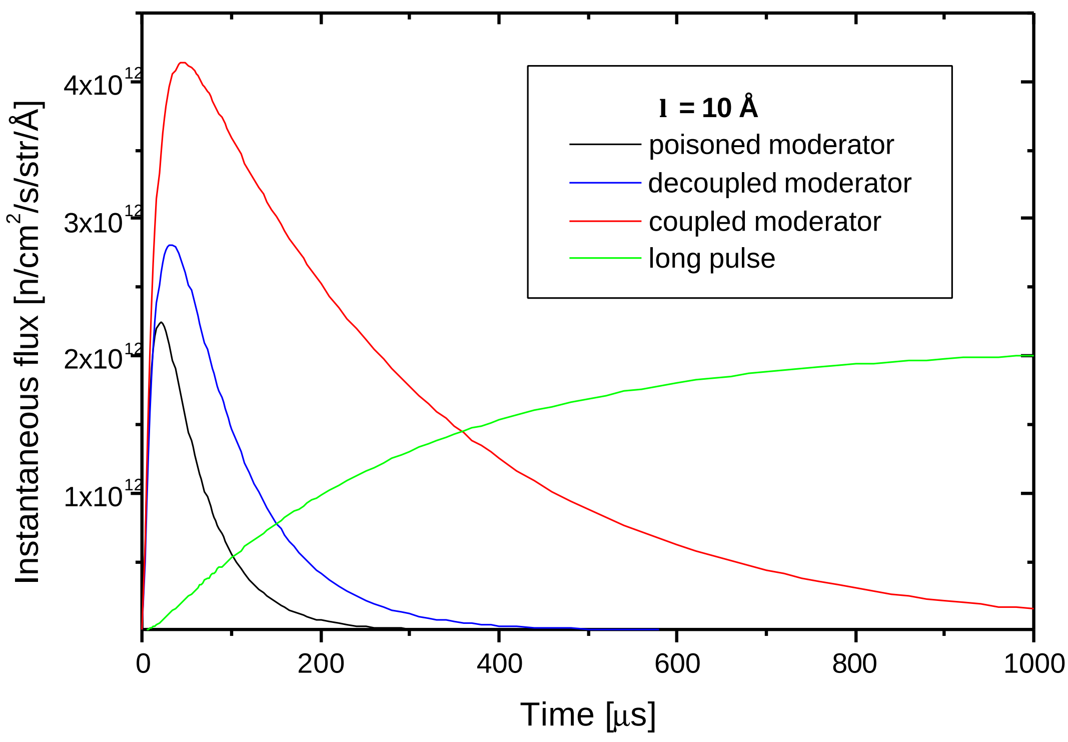

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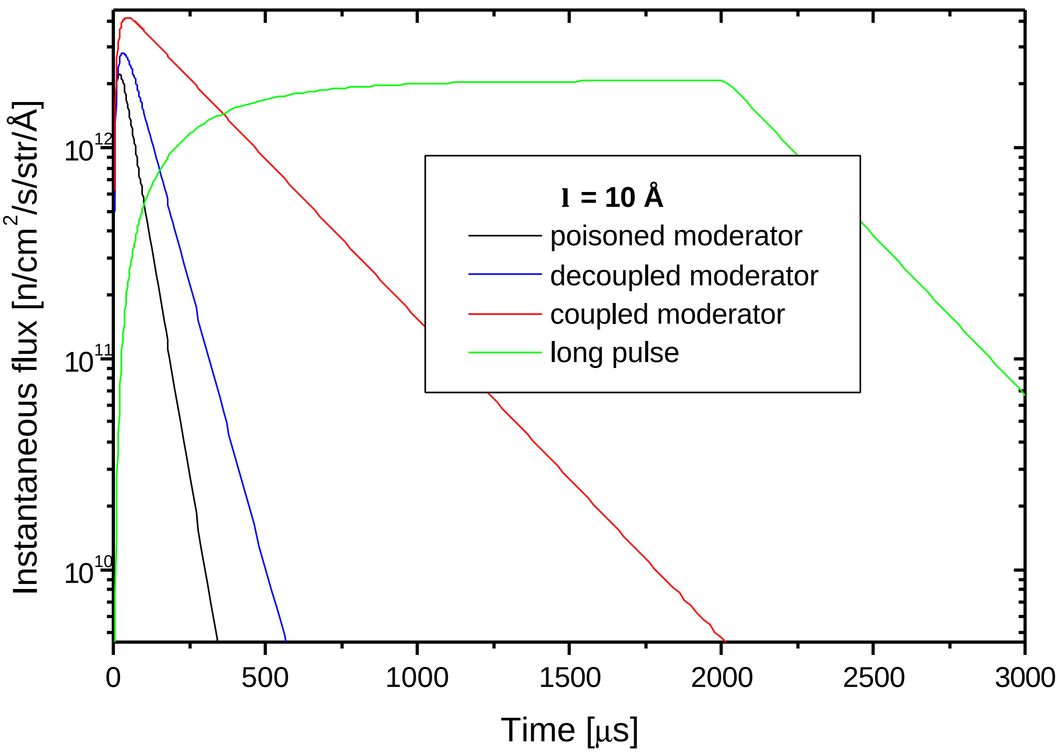
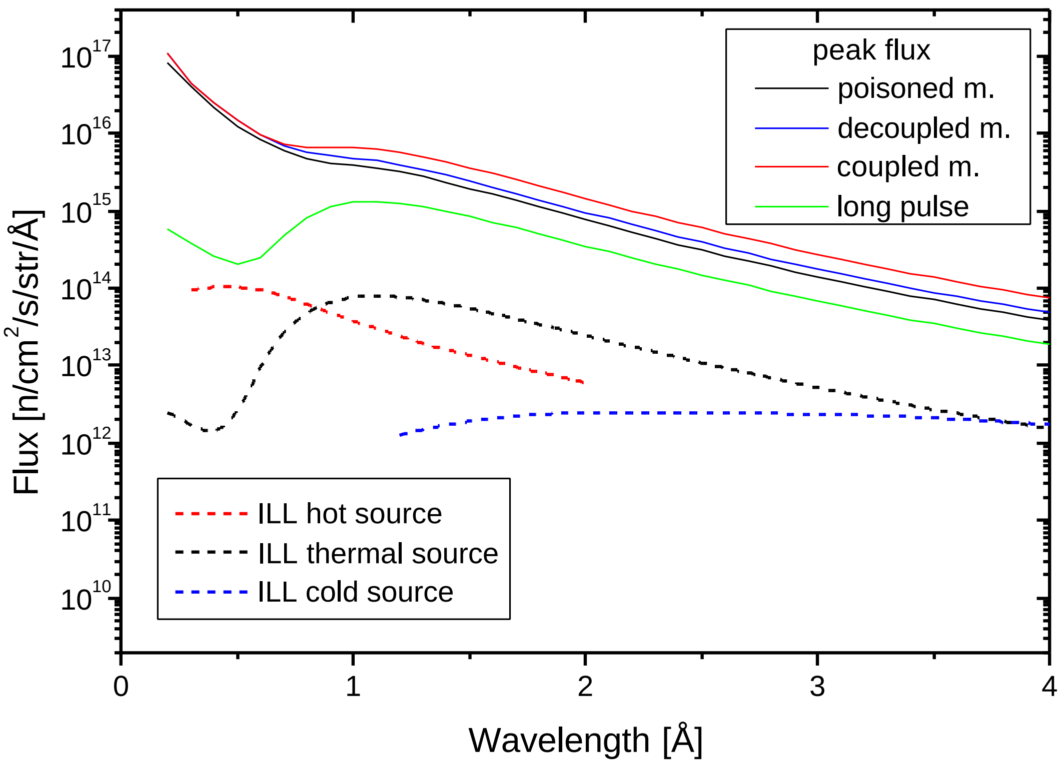
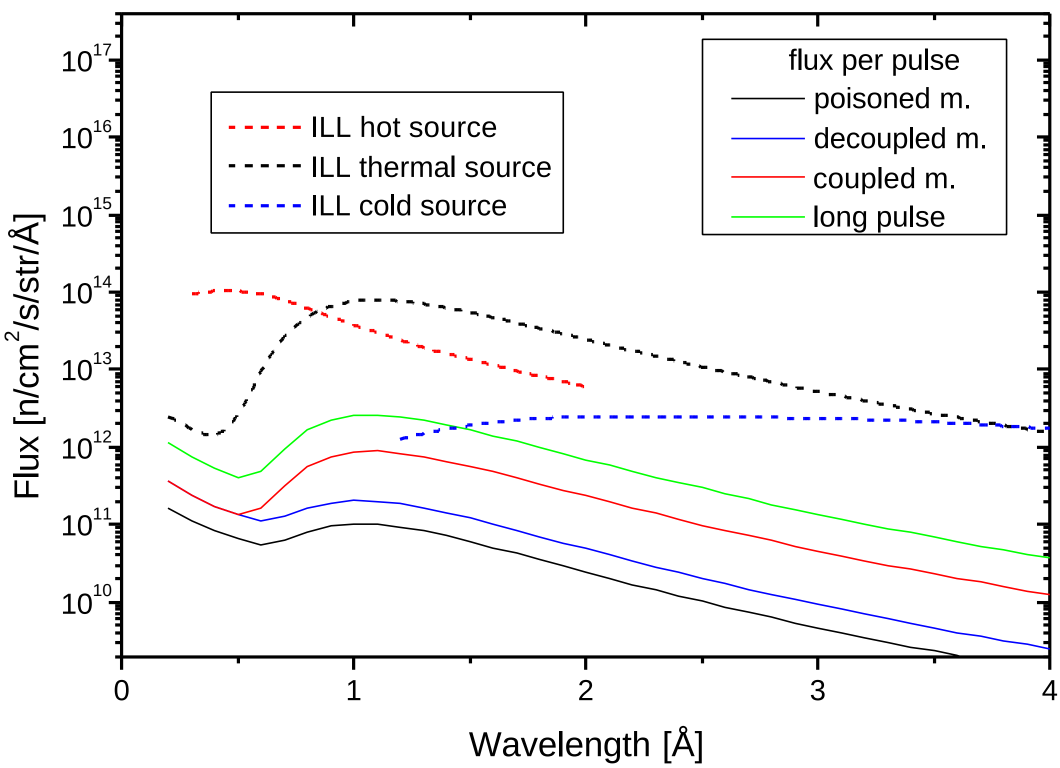


4. Peak, per pulse and time average fluxes

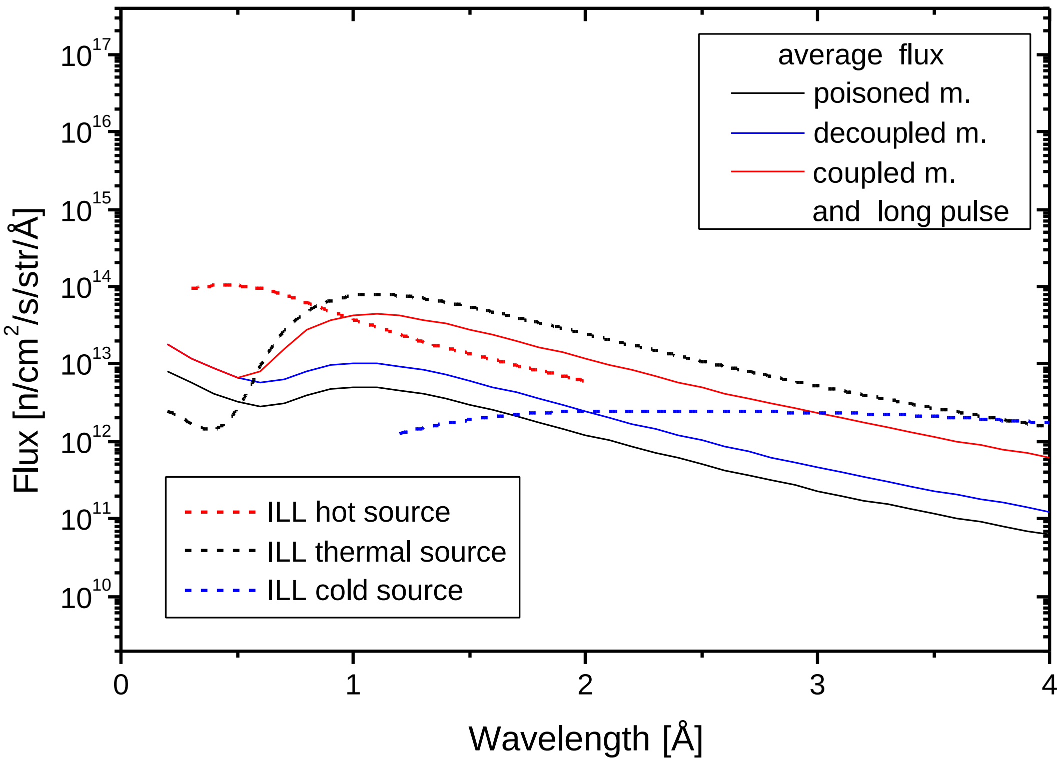
Thermal moderators:



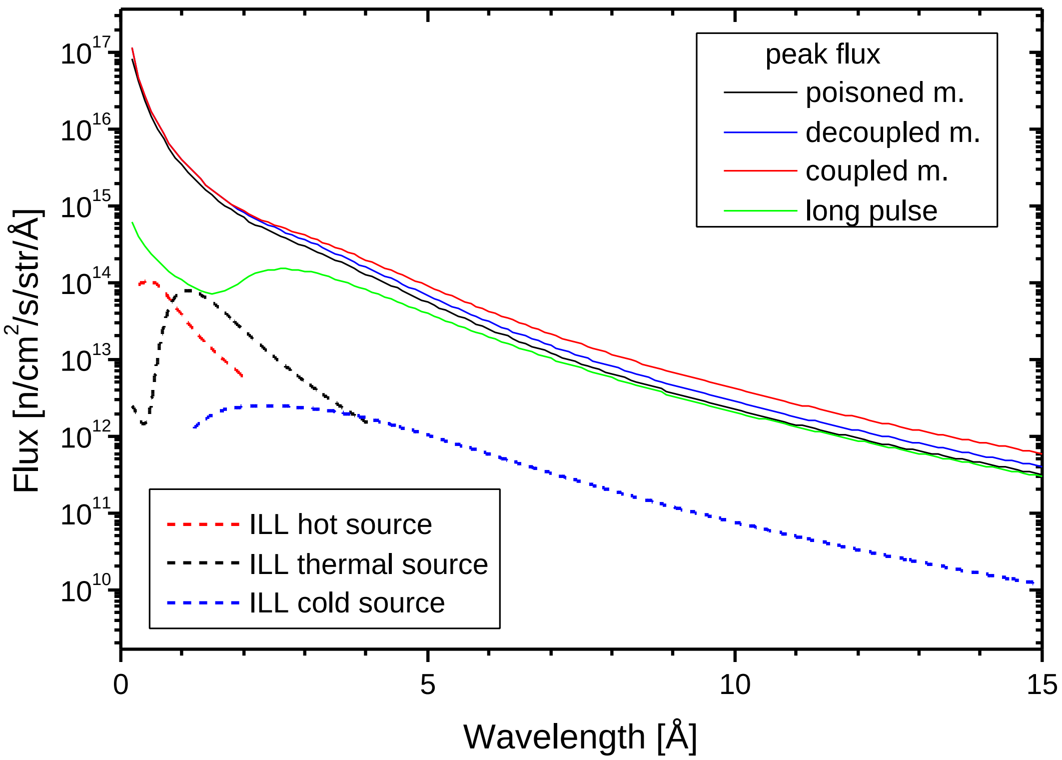


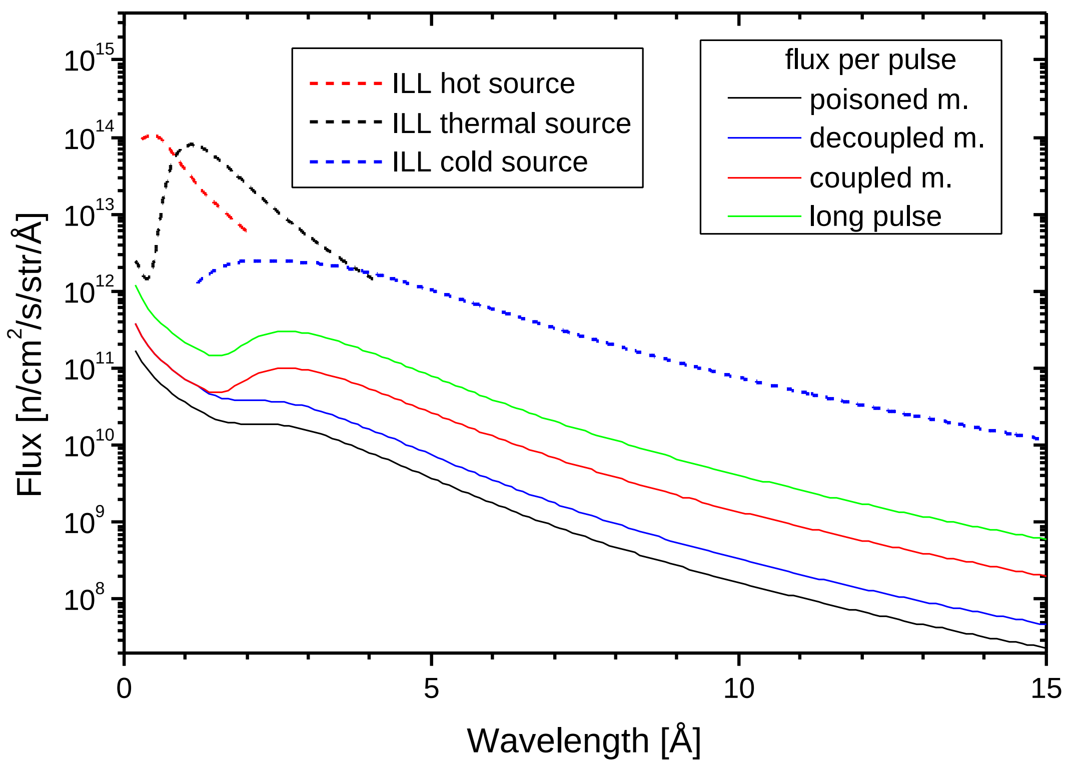
Thermal moderators:

The time average flux is defined for 50 Hz (5 MW total power) operation for the short pulse moderators and 16.667 Hz operation (also 5 MW total power) for the long pulse.



Cold moderators:





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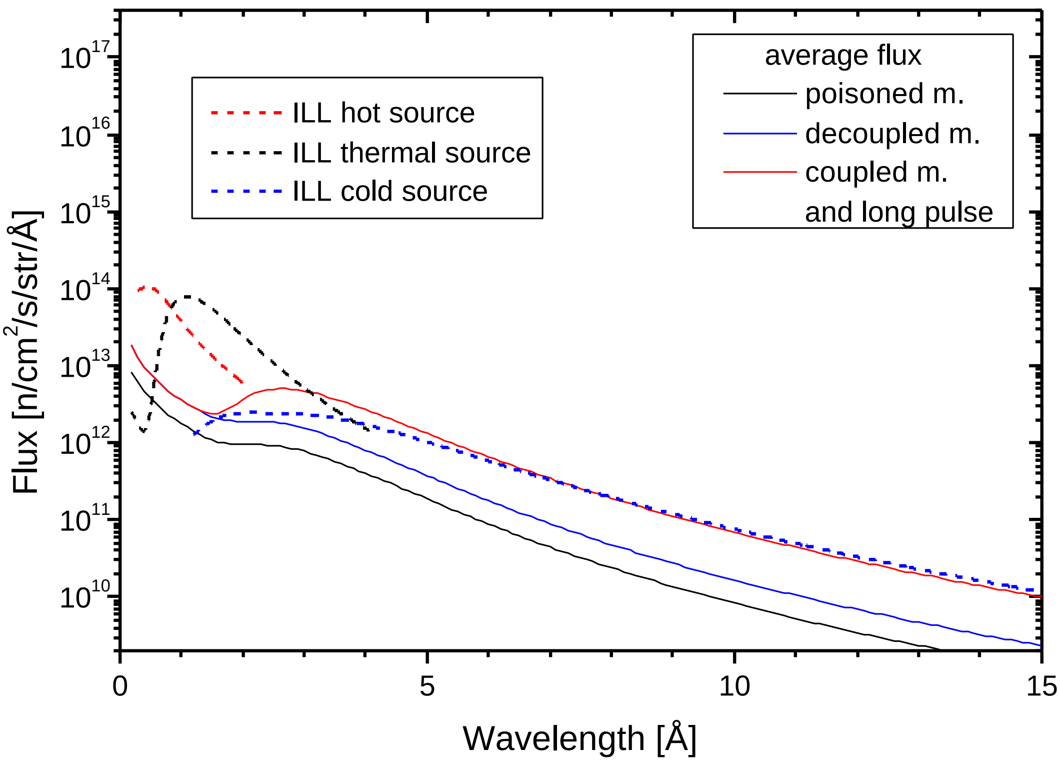
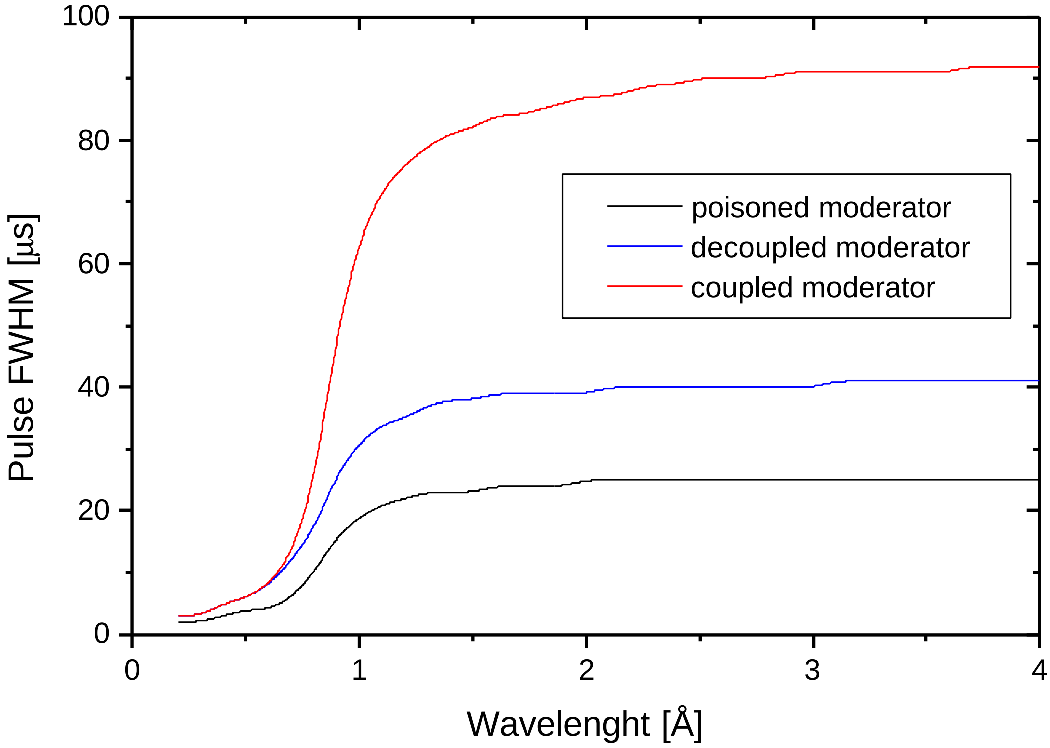
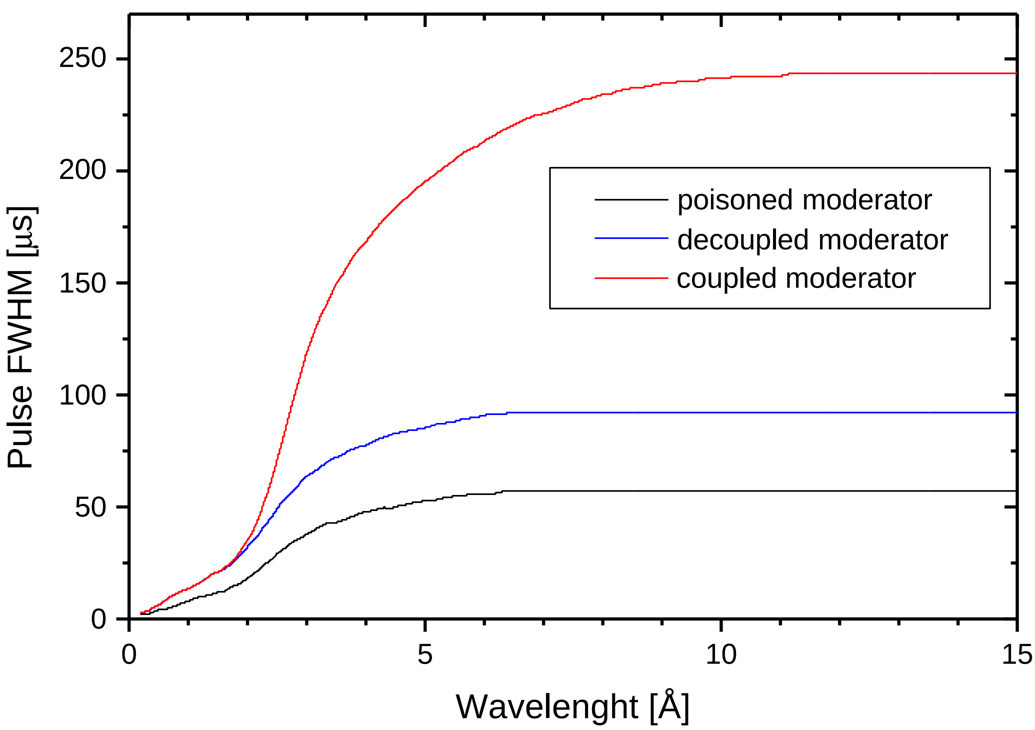


5. Pulse lengths

Thermal moderators:



Cold moderators



6. Observations, uncertainties, revision

A flagrant anomaly of our source data is the far from Maxwellian shape of the ILL cold moderator spectrum in the wavelength range of 2 – 5 Å, i.e. it is too flat around its maximum. Actually this coincides with another inconsistency of the source (the ILL "yellow book"), namely that in this wavelength range one of the two published cold spectra, that of IH1 with direct view of the cold sources, is up to two times superior to that of the other one, the cold neutron guide H13. In the figures above the published spectrum of IH13 was used. An explanation might be, that below 5 Å the guides are not fully illuminated, and the flux measurements were made in a way that below 2 Å only the direct view mattered for the guide too (and the solid angle was erroneously evaluated for IH1 above 5 Å). In any case, since we adopted here the representative, measured spectra of the effectively used ILL neutron guides, the comparison should be correct.

The line shapes and widths of all spectra is probably quite close to the ones which will be obtained at the end, although there are a number of source optimization questions outstanding, which will influence these properties. These questions include the choice of the reflector materials (e.g. Pb only, Be combined with Pb, Ni, or Fe, just to give a few examples of choices considered and/or implemented by now) and many engineering details. The big discrepancies in the literature concern the absolute neutron intensities from the various moderators. For example, the ratio between the average fluxes of coupled and poisoned moderators adopted here (on the basis of the latest calculations at SNS) is about 8.5:1, while the Los Alamos calculations suggest more like 14:1 and recent Japanese results on cold moderators 24:1 (at very similar pulse lengths). This question needs the most urgent attention by the neutronics specialists. In any case, revision of neutron intensity values only will be easily taken into account for the instrument performances by simply scaling. The same will apply to deviations from the here assumed total proton beam energy per pulse, either for the long pulse or the short pulse case.

The major new factor in conceiving instrumentation for future sources is the fact that coupled moderators provide both higher peak flux (about a conservative factor of 2 herein) and an order of magnitude higher average flux. The first coupled moderators ever have just become operational at Los Alamos, and the first instrument to use one of them received the first neutrons exactly 3 weeks ago. While ISIS, IPNS and KENS have achieved outstanding experience with de-coupled moderators, the use of coupled ones is an uncharted territory. The flux advantages of the coupled moderators (which actually can turn out to be much more than assumed here, cf. previous paragraph) puts into question the sense of using de-coupled moderators in many applications at wavelengths above 1 – 1.5 Å.

This lower wavelength limit is determined by the use of supermirror coated neutron guides for beam extraction. On spallation sources the typical closest distances between moderator and sample are 7 – 10 m, which – in view of the practical moderator sizes of some 12 cm x 12 cm – limits the incoming beam solid angle to $(0.7°\text{-}1°)^2$, i.e. to the acceptance angle of commercially available supermirror neutron guides at 1 – 1.5 Å wavelength. Thus for longer wavelengths the moderator to sample distance can be made substantially longer without high intensity penalty and therefore the same resolution can be achieved at the higher flux of coupled moderators. (This happens to the expense of the width of the accessible wavelength band though, but this band is on many current spallation source instruments much to wide anyway.)

A particular consequence is that the peak flux of the long pulse is comparable to the peak flux from poisoned moderator. The shortest pulse width one can achieve with fast disc choppers (eventually using "eye-of-the-needle" geometry, cf. F. Mezei, Proc. ICANS XII, U. Steigenberger et. al. ed. p. I-377) or Fermi choppers is less (especially for cold neutrons) than the pulse width of the poisoned moderators. In addition, the tail free, symmetric pulse shape of choppers translates into an additional gain in data collection rates. Thus for the highest wavelength resolution applications (except for $\lambda \leq 1$ Å) the long pulse or coupled moderator plus chopper combination can open up superior or by now inaccessible opportunities.