The Strength of the Strong Cf-Source and the Efficiency for Detecting Neutrons

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The Cf-source run 14159 Nov. 23, 2000 was an approximately 8 hour run with the strong source at the centre of the AV. R. Tafirout made a frequency distribution of event rate (with Nhit $\geq$35) in 2 second intervals (fig. 1) which shows that, although the peak rate was about 18 events, mostly neutrons, in 2 seconds, the frequency distribution is not gaussian. The frequency distribution is complicated by the fact that the source emits several neutrons with every fission, and that every neutron is not detected because the detector efficiency for neutrons is less than one. This measured frequency distribution of neutron-capture rate, along with the known neutron-multiplicity distribution, can be used to determine the Cf-source strength and neutron detection efficiency.

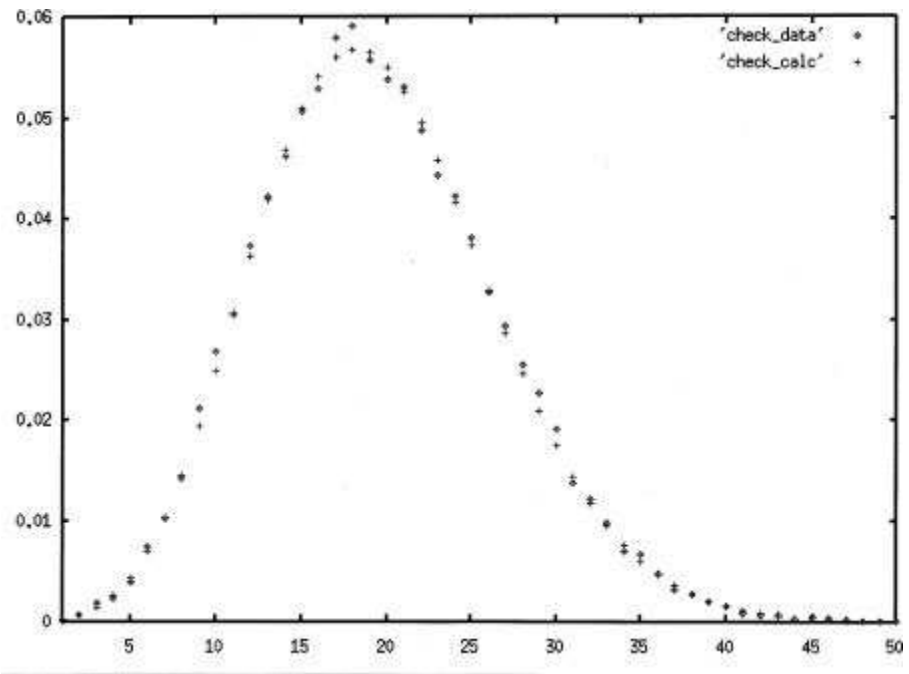

Figure 1 Neutron frequency distribution for the hot Cf source, run 14159. The ordinate is the probability of detecting d neutrons in 2 second intervals. The diamonds are the data (R. Tafirout), and the crosses are calculated with eqn. 1, with the best-fit parameters given in the text.

Call the source decay rate λ and the mean neutron multiplicity μ. It is known that μ = 3.767, and that it is distributed approximately as a normal distribution having σ^2 = 1.57 (J. Wilhelmy, private communication). The values of the multiplicity at integer values of neutron number sums to unity. If the efficiency for detecting a neutron is ϵ, then the probability of detecting d neutrons, given that r neutrons were produced when N Cf-nuclei decayed in unit time is given by

$$P(d) = \sum_{N=1}^{\infty} \sum_{r=d}^{\infty} \frac{r! \epsilon^d (1-\epsilon)^{r-d}}{d!(r-d)!} \cdot \frac{e^{\frac{-(r-N\mu)2}{2N\sigma^2}}}{\sqrt{2\pi N}\sigma} \cdot \frac{\lambda^N e^{-\lambda}}{N!} \qquad \textbf{(1)}$$

As an aside, note that this expression contains binomial, Poisson and normal probability distributions.

Fig. 1 shows a comparison of this functio n with the data. The ordinate P(d) is determined for the data by dividing the number of counts in each 2 second bin by the total number of counts in all bins. The parameters λ and ϵ in eq. (1) have been varied to achieve good agreement with the data. The result is that λ = 10.79 ± 0.15/2 seconds and ϵ = 0.485 ± 0.006 for Nhit ≥ 35. The χ^2 is 32.7 for 48 d.f.

Hence the decay rate is (5.38 ± 0.08)/s as of November 23, 2000, and is in reasonable agreement with that of Wilhelmy, 4.75/s (Wilhelmy, private communication) and Ewan, 5.15 ± 0.36/s, (G. Ewan, private communication) , although more precise. The neutron rate is 20.27 ± 0.28/s.

The neutron capture efficiency of 0.485 ± 0.006 for Nhit ≥ 35 needs to be corrected for the proportion of a 6.25 MeV γ-ray Nhit distribution which has Nhit < 35. Assuming a mean Nhit for 6.25 MeV γ-rays of 45.4 and a σ of 9.55 (Ph.D. thesis, Rushdie) then about 12.2% of the 6.25 MeV γ-ray is below Nhit of 35. Hence, the efficiency for neutrons to capture on a D for a central point source in SNO is 0.544 ± 0.007. The analytical value (SNO-STR-2000-029, eqn. 25) is 0.507 for a diffusion length of 1.23 m and a macroscopic cross-section of 6.347×10^{-5} cm^{-1}.

No cuts, other than an Nhit cut, were made to the data. Because of the high count rate I

expect that only marginal improvements at most would be achieved by cleaning the data.

I also tried to fit the neutron frequency distribution with Nhit $\geq$ 45. Although the mean decay rate was the same, the fit was very bad, the distribution being wider than the theoretical expression, eqn. 1. I suspect that this is because of the variation of mean Nhit/MeV as a function of the position in the D_2O . This would cause the efficiency for a particular Nhit threshold to vary quite a bit, so that the approximation of a single efficiency $\in$ might not be as valid.

In conclusion, the decay rate for the hot Cf source on November 23, 2000 was (5.38 ± 0.08/s, and the efficiency for n-capture on D for a n-source in the centre is 0.544 ± 0.007.

Thanks to J. Karn for doing the data fitting.