Estimating source strength needed to test MVD

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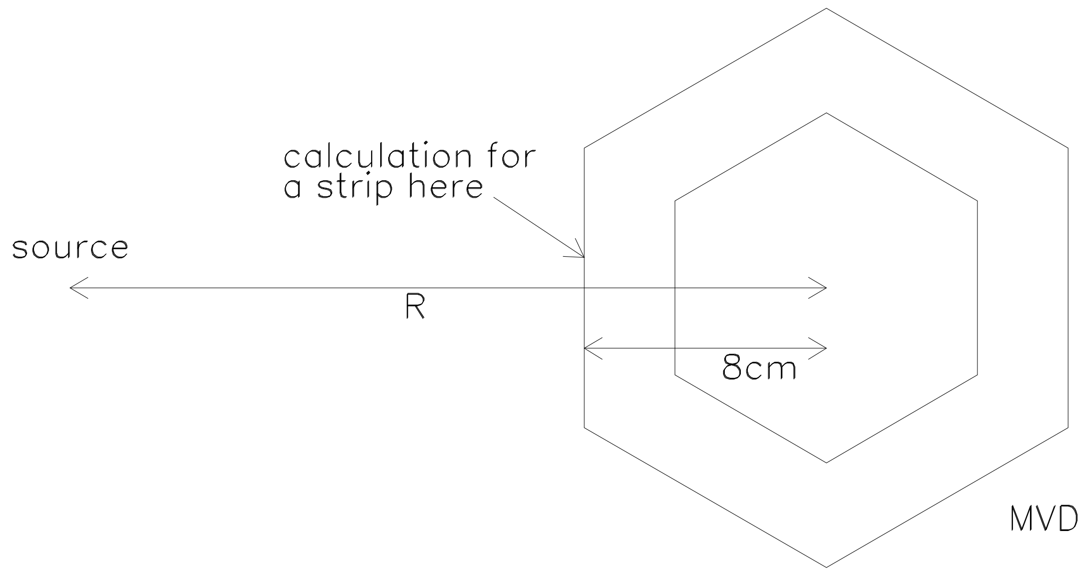
Assume:

- Source sits beside MVD, a distance R from the center of the MVD (i.e. from the beam line)
- The source is ^{57}Co, which has
  - $t_{1/2} = 0.745$ year
  - decay photons are 14keV (10%), 122keV (86%), 136keV (11%), plus Fe x-rays 55%:
  - This calculation is for the 122keV photons only
  - for 122 keV photons the attenuation length in Si is approximately $\lambda = 6$ gm/cm^2.



The attenuation of photons in Si is described by the following equation:

$$I = I_0 \exp(-t\rho/\lambda) \tag{1}$$

where ρ is the density of Si (2.33 gm/cm^3), I_0 is the original photon intensity, and I is the photon intensity at a depth t in the Si.

This calculation is for the strip having the highest rate, which means at the same z position as the source and on the outer Si layer closest to the source. The distance of the source

from this closest Si strip will then be $R - 8$cm. The area of a strip is
$dA = 0.02cm \times 8cm = 0.16cm^2$.
The solid angle covered by a strip is therefore
$d\omega = (4\pi) \times (0.16cm^2)/(4\pi(R - 8cm)^2)$.
The fraction of incident photons which will interact is
$P \approx 1 - \exp((t = 300\mu m) * (\rho = 2.33gm/cm^2)/(\lambda = 6gm/cm^2))$
which is approximately
$P \approx t\rho/\lambda$ (for $t\rho/\lambda << 1$).

So, the number of interactions in this strip per ^{57}Co decay is $\approx (d\omega/4\pi) \times (t\rho/\lambda)$. Assuming the source is at the outer surface of the enclosure (R=25cm) gives
$(dA/(4\pi(R - 8cm)^2) \times (t\rho/\lambda) = 5.1 \times 10^{-7}$ interactions/second.

If we want this to happen in say, f=1% of Δt=200ns sample periods (i.e. we have no trigger and have to hope for a hit in the appropriate period) we would need a rate of:
$f = 0.01/((200 \times 10^{-9}\text{sec}) \times (5.1 \times 10^{-7}\text{interactions/sec})) = 9.8 \times 10^{10}\text{decay/sec}$
$= 9.8 \times 10^{10}$ Becquerel = 2.65 Curie.

To get some sense of the size of this source, this would be depositing $\approx$ 122keV/interaction, with 0.01 interactions per 200 nsec (which is 50kHz) in a piece of Si of volume (0.03cm)(8cm)(0.02cm) and density ρ =2.33gm/cm^3. Every second the source would deposit
$(50000) \times (0.122\text{MeV})/((0.00233)(0.03)(0.02)(8)) = 5.45 \times 10^8$ MeV/kg.
A unit of absorbed dose is a gray, which is 1 gray = 6.24×10^{12} MeV/kg. The unit of dose equivalent (for biological damage) is the number of grays times a "quality factor" (Q), which is about 1 for photons. So, this source would deposit
$5.45 \times 10^8\text{MeV/kg}/6.24 \times 10^{12}\text{MeV/kg/gray} = 8.73 \times 10^{-5}\text{sievert/sec} = 0.315$ sievert/hour in the MVD Si. Comparing this to biological limits, the maximum permissible whole body dose per year is 50 mSv, which would be reached in about 10 minutes at this rate. A fatal dose is about 2.5-3.0 Gy. This limit would be reached in about 8 hours.

Another approach to the radiation safety problem with such a source is to assume a 100kg person is standing 1 meter from the source and that the person is 1.8cm tall and 40 cm wide with a density ρ = 1gm/cm^2 and is thick enough to fully attenuate the photons from the source. The solid angle covered by such a person would be
$d\omega = 4\pi \times ((40cm \times 180cm)/(4\pi(100cm)^2)) = 0.057 \times 4\pi$.
If the strength of the source is 9.8×10^{10}decays/sec, the person would absorb 5.61×10^9 photons per second, with each photon being 122 keV, or 6.85×10^8 MeV/sec, or 6.85×10^6MeV/(kg sec), or 1.10×10^6 Gy/sec into the person. At this distance, the maximum occupational dose would be received in about 12 hours and a fatal does in about 26 days.

Conclusion: We need a trigger since a source strong enough to use without a trigger is too strong to be safe (and is probably illegal).