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# Radiation Dose from Neutrino Decay at a Muon Collider

This note is a comment on the paper *A Characterization of the Neutrino-Induced Radiation Hazard at TeV-Scale Muon Colliders* by B.J. King of DESY (available only in draft form at present).

King's main conclusion can be stated as a limit on the closest distance from a circular muon-collider ring at which the radiation dose in the plane of the ring is less than 10 mrem/year. King's eq. (10) says

$$R_{min} = 1.2 \times 10^4 \text{ m} \times \left(\frac{E}{[1 \text{ TeV}]}\right)^{3/2}, \tag{1}$$

where $E$ is the energy of the muons in the ring. For 1-TeV muons $R_{\rm min} = 12$ km!

I agree with the details of the King's derivation, but note that it contains the interesting assumption that the object receiving the dose is immediately preceded by shielding thick enough to contain a TeV-scale hadronic shower.

If instead object is 'unshielded' the dose will be much less!

The paradox is that there is in effect no useful shielding against neutrino interactions, and any attempt at shielding makes things worse.

Some details follow.

If the object is, say, an unshielded person who presents perhaps only 30 cm of water to the neutrino flux, there is not sufficient mass to cause showering of the particles that emerge from the primary neutrino interaction. Then the only dose accumulated would be that due to ionization loss by the primary charged particles as they exit the person.

The charged-particle multiplicity in a neutrino interactions varies roughly as

$$N_{\rm charged} \approx 40 + 7 \ln E[\text{TeV}], \tag{2}$$

adapted from Fig. 36.1.4 of the *Review of Particle Physics* (*i.e.*, the 'wallet cards'). On average each particle traverse 15 cm, depositing about 30 MeV of energy. That is, only about 1 GeV of energy is deposited in a person per TeV neutrino interaction in that person.

King's model, however, assumed that the person was protected by shielding, so that person received dose not only from neutrino interactions in the his or her body, but from interactions in the shielding for which the hadronic shower leaked out of the shielding. For dense shielding as much energy passes into the person from upstream interactions as exits from interactions in the person. Hence we arrive at King's assumption that all of the neutrino's energy should be counted in the dose received by a person.

Thus for 1-TeV neutrinos the effect of 'shielding' is to increase the radiation dose by a factor of 1000 for a person behind the shielding!

It follows that if a 1-TeV muon collider had no shielding the minimum safe distance would be 1/30 of that of a shielded collider – taking into account only the dose due to neutrinos interactions!

In practice there must be some shielding against the hadrons, electrons and photons produced in and about the muon collider. In particular, kilometer-scale shielding will be required to range out TeV muons. However, beyond that it might be better to have no further shielding! More precisely, a chain link fence is better shielding against neutrinos than dirt or concrete!

A more detailed simulation of the hadronic showers following primary neutrino interactions in realistic shielding configurations will be required to judge the actual reduction in dose compared to King's estimate.