**Questions & answers**

(Authorships and date are indicated in the table at the end of the document)

It is valuable to address several arguments related to radiation quality that are frequently discussed in professional settings. These topics often emerge during expert debates, peer review processes for scientific publications, and evaluations of grant proposals for research programs. Over time, they have become recurring themes within the field.

This chapter seeks to offer substantive insights that contribute to the ongoing dialogue. In certain cases, the discussion may revisit or build upon concepts introduced in earlier chapters, providing additional context or presenting alternative perspectives.

To enhance clarity and engagement of the readers, the topics are presented in a question-and-answer format. When contributors express differing opinions, these are explored through a point-counterpoint structure, allowing for a balanced and thoughtful examination of the issues.

**Q1: Are Radiation Quality and Beam Quality Expressing the Same Concept?**

**A1: No.** Radiation quality and beam quality may appear similar in terminology, but they represent fundamentally different concepts. Although they are sometimes used interchangeably in literature, this overlap can lead to confusion, especially in clinical and scientific discussions.

Beam quality is a metrological concept designed to uniquely characterize a beam of ionizing radiation. Its primary purpose is to standardize dosimetric measurements, allowing for accurate calibration of dosimeters across different radiation sources. The quantification of beam quality relies on physical indicators such as dose profiles and absorption characteristics within a medium. Depending on the radiation type, different metrics are applied: for photon beams, exponential attenuation is measured; for electron beams, the half-value layer (HVL) is commonly used; and for ion beams, indices like R10—marking the depth at which the dose falls to 10% of the Bragg peak—are referenced. Even with beams that are not monoenergetic, indices based on dose fall-off, such as the 50% dose range, can still be defined. TRS 398, which continues to be a global standard for defining beam quality in radiation therapy, discourages the use of beam-quality indices in proton therapy and deems them impractical for carbon ion therapy due to complex fragmentation phenomena. These indices are non-stochastic because they emerge from predictable, deterministic dose distributions. The beam-quality correction factor, denoted as kQ,Q₀, is used to adjust dosimeter readings based on this characterization.

Radiation quality, in contrast, pertains to the biological effectiveness of ionizing radiation. It emphasizes the impact on the target, especially in terms of biological responses such as cellular damage or the creation of lethal lesions. This concept plays a central role in fields like radiobiology, microdosimetry, and therapeutic efficacy, where understanding the biological consequences of radiation is critical.

Despite their distinct roles, mixed terminology is often used in scientific literature and this may create some confusion. For example, the IAEA TRS 398 guidelines, both the 2000 edition and the 2023 revision, use the phrase "radiation beam quality" in contexts that refer, according to what it is poined out above, to beam quality. Further complicating matters, the 2019 Annual Report of a National Cancer Institute (Durante et al., Med. Phys. 46(2)) describes beam quality in terms of biological effectiveness, essentially referring to what is, in our notes above, identified as radiation quality. Similarly, Endo et al. (2023) blurs the lines between these concepts by using both terms interchangeably in discussions about biological effects.

While beam quality addresses measurement and standardization and radiation quality focuses on biological outcomes, distinguishing between the two is important to prevent misinterpretation.

**Q2: Is LET a macroscopic quantity?**

**A2**: A preamble is necessary. In physics, a macroscopic quantity refers to a measurement that captures the overall behavior or characteristics of a system. These quantities emerge from the collective properties of countless individual components. For example, temperature, pressure, and volume are macroscopic quantities commonly used in thermodynamics and fluid mechanics. In contrast, microscopic quantities describe the behavior of individual molecules or atoms. To illustrate this distinction, let us consider a gas in thermal equilibrium. The temperature of the gas represents a macroscopic quantity since it reflects the average result of countless random collisions among individual particles moving within a given volume. Meanwhile, the instantaneous kinetic energy of each atom or molecule is a microscopic quantity. This individual behavior can be described using probability density distributions that show how many particles possess energy within a specific range.

When it comes to Linear Energy Transfer, the term “macroscopic” is used to indicate that unrestricted LET does not represent the random, statistical nature of energy deposition, but rather the average energy lost by particles with identical energies crossing the same distance.

Weighted averages like LETt or LETd, which are simplified ways to of representing LET, can be a;sp directly associable with the term macroscopic.

However, things become more complex when radiation field is the combination of particles of different energies and types. The representation of this heterogeneity is done using distributions of unrestricted LET values. Under those mixed conditions, unrestricted LET loses that neat analogy with other macroscopical quantity like temperature. Since it is spontaneous to argue that representing a quantity using a distribution contradicts the idea of macroscopic, some confusion has been created.

Finally, restricted LET is not accounting for the energies of secondary electrons whose energy exceeds a cutoff level. Excluding these electrons requires knowing the energy distribution of all electronic collisions, an information that is inherently microscopic. Therefore, restricted LET, no matter if it is represented in form of distribution or as average value and refers to monoenergetic beams, cannot truly be considered macroscopic.

In the end, continuing to label LET as a macroscopic quantity can create confusion and is often unnecessary. For unrestricted LET, it’s more accurate to use the alternative term “non-stochastic,” which avoids misinterpretation.

**Q3: When the vertical axis of microdosimetric distributions should be represented using y as additional multiplicative factor: y·f(y) , y·d(y)?**

**A3.** The area underneath the distribution between two values, when the co-ordinates are both represented in linear metric, is proportional to the fractional quantity represented by the distribution. For instance, the area under the distribution d(y) in the lineal-energy interval (y1,y2) is proportional to the partial dose imparted by events with lineal energies between those two values y1 and y2.

However, the microdosimetric spectra are often presented using the so-called semi-logarithmic graphs where the lineal energy y, in abscissa, is represented in logarithmic scale while the distributions, in ordinate, maintain the linear scale. In order to preserve the area normalization, a supplementary multiplicative factor y must be added to represent the distributions in ordinate obtaining y·f(y) or y·d(y). The same method is used for the semi-logarithmic representation of LET so that the ordinate axis shows an additional multiplicative factor LET: LET·f(LET) or LET·d(LET).

This multiplicative factor in front of the distributions should be used only in case of semi-logarithmic metrics. All other representation must avoid it, including the case in which both axes have a logarithmic representation, as the result would have no quantitative meaning. It is not uncommon, however, to see the notation y·d(y) used in other representations different from the semilogarithmic.

A short digression to recognize why such semi-logarithmic representation is the most used. The reasons are historical and are founded of the capability of compacting several decades of the spectrum to visually emphasize some important features. Highlighted in this representation is the presence of “edges” and spectra components. This refer to the maximum energy imparted by a charge particle of a specific type. These edges would not be clearly visible in the linear representation. Another typical case where the semi-logarithmic metric shows its advantage is the gamma-neutron spectrum where the two regions for the two particles can be clearly distinguished in semilogarithmic representation but would be blurred in other representation.

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