**Questions & answers**

It is useful to address several frequently asked questions related to radiation quality. These questions often arise in professional discussions or during the peer-review process of scientific publications. Over time, they have become recurring themes in the field. The responses provided here are intended as informed contributions to the ongoing discourse. In some cases, they may reference or reiterate content already discussed in other chapters.

**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. It’s important to note that this adjustment reflects beam quality alone—not radiation quality.

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 formation 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 definitions, confusion arises in scientific literature due to mixed terminology. 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 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 radiation quality. Similarly, Endo et al. (2023) blurs the lines between these concepts by using both terms interchangeably in discussions about biological effects.

Ultimately, 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, 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 LET does not represent the random, statistical nature of energy deposition, but rather the average energy lost per unit distance by particles with identical energies. This label works only for monoenergetic beams and for what is called unrestricted LET.

However, things become more complex when radiation from multiple particle beams with different energies overlap within the same space. Unlike temperature, which can still be described macroscopically under mixed conditions, LET loses that neat analogy. In this case, a proper macroscopic description must still specify the LET value for each distinct particle energy. This is done by a distribution of LET values. Some may argue that using a distribution contradicts the idea of a macroscopic quantity. To simplify matters, people sometimes refer to weighted averages like LETt or LETd, though this practice lacks precision and is often discouraged, those are quantities which are compatible with the term macroscopic used in thermodynamics.

Restricted LET, on the other hand, is based on the exclusion of secondary electrons whose energy exceeds a particular cutoff level. Accurately excluding these electrons requires knowing the energy distribution of electronic collisions, an information that is inherently microscopic. Therefore, restricted LET cannot truly be considered macroscopic even for monoenergetic beams.

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 term “non-stochastic,” which avoids misinterpretation. When dealing with complex radiation fields involving multiple particle types and energies, both unrestricted and restricted LET should be described using distributions rather than simplified averages.

**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 in that interval. 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.

However, the microdosimetric spectra are presented, in general, 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 in the distributions obtaining y·f(y) or y·d(y). The same condition is true for LET when the semi-logarithmic representation is used so the distributions should have the additional multiplicative value: LET·f(LET) or LET·d(LET)—or in an older notation as L·f(L) or L·f(L).

In conclusion, the 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. Nevertheless, it is not uncommon to see the multiplicative factors y in front of the distributions used in other representations in which abscissa and ordinate are represented both in linear or in logarithmic scale.

A short digression to understand 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 which refer to different particle types which are lost in the linear representation. A 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 but would be blurred in a linear representation.

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| Chapter GREY | | | |
| **Version** | **Date** | **Authors** | **Major changes and comments** |
| 0.1 | 28 July 2025 | Giulio Magrin | First version |
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