Reply to "Comment on Testing Planck-Scale Gravity with Accelerators"

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In 2012 Letter Ref.[1] I have discussed a possibility to test Planck-scale space birefringence and refractivity for a leading order energy dependent photon dispersion model.

In a recent Comment [2] Kalaydzhyan questions correctness of Ref.[1] results, calling the method and conclusions wrong. Arguments in the Comment, however, are based on misunderstanding or incorrect assumptions making the claim invalid. Below I will address all concerns raised in the Comment.

1. According to the Comment, the experimental results in the Letter, obtained with HERA and SLC Compton beams, are excluded by previous non-observation of vacuum Cherenkov radiation at LEP. The statement, however, overlooks vacuum Cherenkov limits quoted in the Letter. New calculation suggested in the Comment is inaccurate since it ignores energy dependence of the Planck-scale refractive index

$$n = 1 + \zeta \frac{\omega}{M_P}, \tag{1}$$

with ω, M_P and ζ being the photon energy, the Planck mass and the scaling constant respectively (Eq.(1) is equivalent to the Letter's Eq.7 for $\mathcal{O}((\omega/M_P)^2)$) A correct approach is to substitute the n in the vacuum Cherenkov formula (e.g. in Eq.(1) of the Comment or Ref.[3]) by Eq.(1) and obtain limits on ζ. This has been done in the Letter where a tighter-than-LEP astrophysical bound $\zeta < 300$ is quoted for 3 TeV electrons (see section "Current limits"). Its easy to see that the HERA and SLC refractivities correspond to $\zeta = -1.6 \cdot 10^7$ and $\zeta = -2.2 \cdot 10^5$ values which are well below the limit exposed by non-observation of vacuum Cherenkov. These numbers are directly obtained from the measured refractivities, photon energies, Eq.(1) and the refractivity signs ($n < 1$) quoted in Ref. [1] and Ref. [3].

2. Next concern in the Comment is the electron's zero dispersion at the Planck-scale vacuum which is suggested to replace by something to reproduce a general relativistic term from the Comment's Eq.2, at classical limit $M_P \to \infty$. However, a closer look to this term

$$n = 1 + \frac{2GM}{c^2 R}, \tag{2}$$

with the gravitational constant G, reveals a real gravitational field origin from a spherical mass M and radius R. Obviously, the real field refractivity in Eq.(2) can not enter to description of any vacuum whether classical or quantum-gravitational since no vacuum can convert into real gravity (except at Big-Bang singularity). In case the refractivity in Eq.(2) is assigned to the Earth's field in the laboratory, the same term will have also the photon in the Eq.(1) which eventually will drop from the final result according to the equivalence principle. Thus, the suggested general relativistic field analogy is not applicable for the vacuum which, in contrast to real gravitational field, differently couples to photons and electrons because of charge and spin differences. Additional concerns in the Comment about possible quantum gravity signals mimicked by equivalence principle 1% violation could be handled by exploring energy dependence at the Planck-scale vacuum. In case the equivalence principle violation will persist to mimic also the energy dependence, the Planck vacuum could be separated from the real gravitational field by repeating the experiment at some (orbital) distance from the Earth. Thus, the Compton method has a potential to access the quantum Planck-scale even in case of broken equivalence principle.

3. The last critical remark in the Comment is a reference to competing electromagnetic effects such as electron-beam and electron-vacuum chamber interactions. In case the remark is addressing the HERA and SLC results, in Ref.[3] all the essential electromagnetic backgrounds are quantified and included in the systematic error. If, however, the criticism is concerning future Planck scale vacuum Compton tests, a possible bad influence of the beam or the vacuum chamber could be handled by experimental means - reducing the beam current or using non-conductive vacuum chamber.

In conclusion, the criticisms in the Comment are theoretically and experimentally unjustified and I confirm the original results and conclusions.

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[1] V. Gharibyan, Phys. Rev. Lett. **109**, 141103 (2012).
[2] T. Kalaydzhyan, arXiv:1604.04486 [hep-ph].
[3] V. Gharibyan, Phys. Lett. B **611**, 231 (2005).