

Light-By-Light Scattering as a Proof of at Least Incompleteness of the Perturbative Quantum Electrodynamics

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Abstract: Here, within the Scale-Symmetric Theory (SST), we described the mechanism of the light-by-light scattering and we calculated the cross-section: 76.5 ± 59.5 nb - it is independent of transverse momentum. This result is very close to the ATLAS data. The SST shows that in reality light is scattered on the central condensates in virtual electrons. The maximum width ± 59.5 nb follows from a natural phenomenon. The ATLAS background events decrease the observed maximum width to less than ± 44.4 nb (it does not concern uncertainties). On the other hand, the calculated within the Standard Model central value (too low) of the cross-section is inconsistent with the ATLAS data. We can say only that the ATLAS result is compatible with Standard-Model predictions only within experimental uncertainties. We answered as well following question: Why the perturbative Quantum Electrodynamics is at least an incomplete theory?

1. Introduction

The fiducial cross-section for light-by-light scattering ($\gamma\gamma \rightarrow \gamma\gamma$) obtained in Pb + Pb collisions with the ATLAS detector at the LHC is [1]

$$\sigma_{fiducial} = 70 \pm 24 \text{ (stat.)} \pm 17 \text{ (syst.) nb} = 70 \pm 41 \text{ nb} . \quad (1)$$

On the other hand, the Standard-Model (SM) predicted values are

$$45 \pm 9 \text{ nb [2] ,} \quad (2a)$$

$$49 \pm 10 \text{ nb [3] .} \quad (2b)$$

Here, within the Scale-Symmetric Theory (SST) [4], [5], we showed that central value is 76.5 nb whereas maximum width is ± 59.5 nb and it is the natural width that results from the mechanism of the light-by-light scattering. Moreover, obtained here result should not depend on diphoton transverse momentum i.e. the result $\sigma_{SST} = 76.5 \pm 59.5$ nb is an invariant. The observed maximum width can be lower due to a background. The central value

obtained within SST is very close to the central value obtained in the ATLAS experiment. We can see that the central values calculated within SM are inconsistent with experimental and SST result.

Here we suggest that the light-by-light scattering is a proof of at least incompleteness of the perturbative quantum electrodynamics.

Feynman in 1985 wrote: “I suspect that renormalization is not mathematically legitimate” [6]. We cannot prove that the cutoff is a real phenomenon. In our opinion, the cutoff follows from the fact that bare particles are not mathematical points or vibrating closed strings – SST shows that internal structure of bare particles is very rich [5]. Such structure leads to the very fruitful non-perturbative QED [7].

Next evidence that QED is incomplete is the fact that the measurement of the anomalous magnetic moment of the muon disagrees with the Standard Model by 3.4 standard deviations [8] – it suggests physics beyond SM. On the other hand, the anomalous magnetic moment of the muon calculated within the SST non-perturbative QED is consistent with experimental result [7].

According to SST, the phase transitions of the initial inflation field lead to five different energy/size scales in Nature and to the atom-like structure of baryons [4], [5].

2. Calculations

Within SST we calculated the radius of the central condensate in the bare electron [5]

$$r_{p(electron)} = 0.7354103 \cdot 10^{-18} \text{ m.} \quad (3)$$

Due to the Pb + Pb collisions, there are created the virtual electron-positron pairs (e^+e^- pairs). SST shows that there instead the light-by-light scattering, the light is scattered on the central condensates of electrons. Scattering is possible when spin of a group of virtual e^+e^- pairs is the same as a diphoton – total spin can be equal to zero but due to the four-object symmetry [5], quadrupoles of e^+e^- pairs are preferred (for example, there are preferred the alpha particles composed of 4 nucleons). It leads to conclusion that groups of 8 electron central condensates are preferred. They all can be placed on the same direction of transverse momentum (probability of such arrangement is lowest) – then cross-section for the light-by-light scattering on the 8 electron central condensates is $\sigma_{SST,minimum} = \pi r_{p(electron)}^2$. All the condensates can be placed on a plane perpendicular to transverse momentum in such a way that their cross-sections do not overlap (probability of such arrangement is lowest) – then cross-section for the light-by-light scattering on the 8 electron central condensates is $\sigma_{SST,maximum} = 8\pi r_{p(electron)}^2$. The arithmetic mean leads to the central value

$$\sigma_{SST,mean(central-value)} = (8\pi r_{p(electron)}^2 + \pi r_{p(electron)}^2) / 2 = 76.5 \text{ nb} . \quad (4)$$

The cross-sections of the condensates can overlap partially as well so we obtain

$$\sigma_{SST} = 76.5 \pm 59.5 \text{ nb} , \quad (5)$$

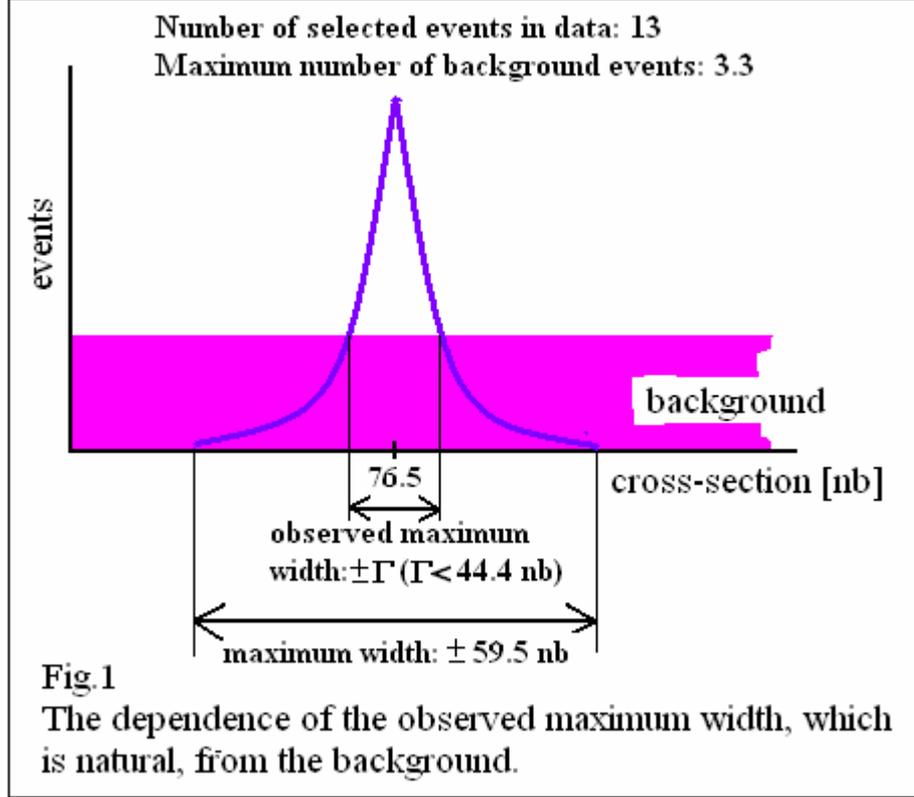
where $\Gamma_{max.} = \pm 59.5 \text{ nb}$ is the maximum width, which is natural, i.e. follows from the mechanism of the light-by-light scattering.

Due to a background, the observed maximum width, $\Gamma_{obs.,max.}$, is lower than the maximum width (Fig. 1). Probabilities for mean cross-section and cross-sections close to it are much

higher than for other cross-sections. To calculate the observed maximum width we can use the following approximate formula

$$\Gamma_{obs.,max.} < \Gamma_{max.} (N_{data} - N_{bkg,max.}) / N_{data} = \pm 44.4 \text{ nb} , \quad (6)$$

where N_{data} is the number of selected events in data ($N_{data} = 13$ [1]) and $N_{bkg,max}$ is the expected maximum number of background events ($N_{bkg,max.} = 3.3$ [1]).



When we take into account the number of selected events in data and the expected number of background events [1] then the final result obtained within SST for the light-by-light scattering in the presence of quadrupoles of the virtual electron-positron pairs is

$$\sigma_{SST,final,quadrupoles} = 76.5 \pm \Gamma_{obs.,max} (\Gamma_{obs.,max} < 44.4) \text{ nb} . \quad (7)$$

Obtained here the central value, contrary to the Standard Model, is very close to the ATLAS experimental result. We can say only that the ATLAS result is compatible with Standard-Model predictions only within experimental uncertainties.

Let us also emphasize that there may also be some slight admixture of events of light-by-light scattering in the presence of binary systems (instead of quadrupoles) of the virtual electron-positron pairs. Such scattering leads to

$$\sigma_{SST,final,binary-systems} = 42.5 \pm \Gamma_{obs.,max} (\Gamma_{obs.,max} < 19.0) \text{ nb} . \quad (8)$$

3. Summary

Here we showed that the QED is at least the incomplete theory because it is mathematically incoherent, the origin of the cutoff is unknown, the calculated anomalous magnetic moment of

muon is inconsistent with experimental result, and the calculated within the Standard Model central value (too low) of the cross-section for the light-by-light scattering is inconsistent with the ATLAS result. We can say only that the ATLAS result is compatible with Standard-Model predictions only within experimental uncertainties.

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