Why Two Gamma Photons Can Produce Separated Electric Charge: An Operational Field-Reorganization Account of Pair Production

Independent Research Collaboration on Black Hole & Cosmology Concep

Article #122

MODE: Operational / Non-ontological

Abstract

We provide an operational, non-ontological explanation of how the collision of two high-energy gamma photons can lead to the emergence of electric charge in the form of an electron–positron pair. The analysis avoids particle-primitive assumptions and instead treats the process as a forced reorganization of an electromagnetic field configuration once kinematic and geometric constraints permit a localized rest frame. Charge separation is shown to be the minimal and energetically allowed structural outcome of such a confined electromagnetic state. The appendix clarifies the strict limits of classical Maxwell theory and situates charge emergence within standard QED and QED–PIC simulation practice.

1. The Question

When two gamma photons with sufficient energy collide at a nonzero angle, the reaction

$$\gamma + \gamma \to e^- + e^+$$

may occur. The operational question addressed here is not "what particles are made of," but rather: *what changes in the electromagnetic field configuration at the collision point that necessitates the appearance of separated electric charge?*

2. Pre-Collision State

Each photon individually:

- carries energy and momentum,
- has no invariant rest mass,
- has no electric charge and no Gauss flux.

Two photons prior to interaction therefore constitute a purely radiative electromagnetic system with zero net charge and no rest frame.

3. Kinematic Trigger: Formation of a Rest Frame

If the photons collide with a nonzero relative angle, the total four-momentum of the two-photon system becomes timelike. This permits the definition of a center-of-momentum frame in which:

- energy is spatially localized,
- the configuration is no longer freely propagating,
- the electromagnetic field becomes temporarily confined.

4. Instability of a Confined Neutral EM Configuration

A localized electromagnetic field configuration with sufficient energy cannot remain purely radiative. In the absence of a propagation channel, the field must reorganize. The neutral, zero-Gauss-flux configuration is structurally unstable under confinement.

Note (operational): Here “instability” denotes an operational incompatibility between localization and purely radiative propagation, not a classical electromagnetic theorem.

5. Minimal Structural Reorganization

Electromagnetic fields admit two qualitatively distinct modes:

- radiative modes with zero net Gauss flux,
- Coulomb-like modes with nonzero Gauss flux (electric charge).

The lowest-energy reorganization consistent with charge conservation is the splitting of the confined field into two regions with equal and opposite Gauss flux:

$$Q_{\text{total}} = 0 \quad \Rightarrow \quad (+e) + (-e).$$

This is not the creation of charge from nothing, but the emergence of a field structure in which charge becomes a well-defined operational quantity.

Clarification: Gauss flux is used here as an operational diagnostic of charge, without committing to a microscopic ontology.

6. Why Electron–Positron?

Among all possible charged configurations, the electron–positron pair represents the minimal-energy, stable realization of separated charge. Heavier charged states would require additional energy and are therefore disfavored at threshold.

7. Interpretation

Within this framework:

- no particles pre-exist the interaction,
- no charge is “extracted” from photons,
- charge appears as a consequence of enforced field localization.

Mass and charge arise simultaneously as bookkeeping features of a confined electromagnetic configuration.

Positioning: This account is complementary to standard QED; it addresses structural necessity rather than interaction amplitudes.

8. Conclusion

Pair production is best understood as a structural transition of the electromagnetic field once kinematics allow confinement. Electric charge separation is not an added assumption but the inevitable outcome of field reorganization under energy, symmetry, and conservation constraints.

Appendix A: On Asymmetric Field Breakdown, Charge Emergence, and the Limits of Maxwell Theory in Two-Photon Collisions

A.1. What Can and Cannot Happen Within Classical Maxwell Theory

We begin by stating a strict and non-negotiable result:

Within classical Maxwell electrodynamics in vacuum, starting from $\rho = 0$ *and* $\mathbf{J} = 0$*, no time evolution can generate a nonzero charge density.*

The relevant Maxwell equation is

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}.$$

If $\rho = 0$ initially everywhere, then $\nabla \cdot \mathbf{E} = 0$ holds identically at all later times under Maxwell evolution.

Therefore:

- Interference, focusing, caustics, or strong field gradients *can* produce highly asymmetric and localized field structures.
- However, such asymmetries *cannot* by themselves generate Gauss flux or electric charge.

Any claim of $\nabla \cdot \mathbf{E} \neq 0$ must therefore correspond to the activation of a degree of freedom *outside* classical vacuum Maxwell theory.

This statement is purely mathematical and does not depend on interpretation.

A.2. Where Charge Emergence Enters in Standard Physics (QED)

In the Standard Model, charge emergence in photon–photon collisions occurs via the Breit–Wheeler process:

$$\gamma + \gamma \to e^- + e^+.$$

This process is *not* derivable from Maxwell equations alone. It requires:

- quantized electromagnetic fields,
- charged fermionic fields,
- and relativistic energy–momentum conservation.

Operationally:

- the electromagnetic field transfers energy into fermionic degrees of freedom,
- electric charge appears because fermions carry conserved gauge charge,
- Maxwell equations remain valid *after* pair creation, with $\rho \neq 0$ supplied by the created particles.

Thus, in standard physics, the statement $\nabla \cdot \mathbf{E} \neq 0$ does not arise from a "failure" of Maxwell theory, but from the appearance of new source terms.

A.3. Numerical Evidence: QED–PIC Simulations

Numerical simulations that explicitly demonstrate this transition belong to the class of QED–PIC (Particle-In-Cell with Quantum Electrodynamics modules).

Their structure is:

1. Maxwell equations evolve the electromagnetic fields.
2. Particle equations of motion evolve charged particles.
3. QED modules stochastically introduce pair creation when invariant conditions are met.

In these simulations:

- $\nabla \cdot \mathbf{E}$ remains zero until pair creation events occur,
- once pairs are created, charge density appears explicitly,
- Gauss's law is then satisfied with $\rho \neq 0$.

No simulation based purely on vacuum Maxwell PDEs has ever produced charge.

A.4. The Critical Invariant Parameter for Two-Photon Collisions

The physically relevant threshold is controlled by the invariant center-of-mass energy. For two photons of energies E_1 and E_2 colliding at angle θ, the invariant is

$$s = 2E_1E_2(1 - \cos\theta).$$

Pair production becomes kinematically allowed when

$$\sqrt{s} \geq 2m_ec^2.$$

Key consequences:

- Head-on collisions ($\theta = \pi$) maximize s.
- Nearly parallel photons ($\theta \approx 0$) cannot produce pairs regardless of energy.
- Energy and angle enter only through this invariant combination.

Polarization states affect cross-sections but do not remove the threshold condition. Classical wave phase plays no direct role in the two-photon, few-quantum regime.

A.5. Model-Level Interpretation: Asymmetric Field Breakdown

Within the present project, we adopt a strictly operational, non-ontological language.

The phrase "asymmetric field breakdown" refers to the following:

- the electromagnetic field configuration near collision becomes highly localized,
- symmetric radiative modes cannot self-close under geometric constraints,
- the system reaches a point where energy cannot remain purely radiative.

At this point, an additional channel must be activated.

We do *not* claim that Maxwell equations dynamically generate charge. Instead, we introduce an effective source channel ρ_{eff} representing the activation of matter degrees of freedom.

A.6. Effective Source Activation (Model-Level Closure)

We define an effective Gauss law:

$$\nabla \cdot \mathbf{E} = \frac{\rho_{\text{eff}}}{\varepsilon_0},$$

where ρ_{eff} is activated only when invariant conditions exceed threshold:

$$\rho_{\text{eff}} = 0 \quad \text{for } \sqrt{s} < 2m_ec^2,$$
$$\rho_{\text{eff}} \neq 0 \quad \text{for } \sqrt{s} \geq 2m_ec^2.$$

This effective description is analogous in spirit to source activation terms used in QED–PIC simulations and does not claim independent predictive power beyond standard QED.

This prescription:

- preserves Maxwell equations structurally,
- respects energy–momentum conservation,
- avoids introducing ontological claims about field substance.

A.7. Interpretation of "Charge Separation"

Charge separation should be understood as:

- emergence of a Coulomb component ($1/r^2$ field),
- associated with fermionic degrees of freedom,
- not as a deformation of free electromagnetic waves.

The electromagnetic field remains divergence-free everywhere *except* where effective sources are present.

A.8. Summary of the Appendix

- Maxwell theory alone cannot generate charge from light.
- Pair production requires new degrees of freedom.
- The critical parameter is the invariant center-of-mass energy.
- Asymmetry refers to the failure of radiative mode closure, not violation of Maxwell equations.
- Charge emergence is modeled as effective source activation, not field self-divergence.

This closes the conceptual and mathematical gap between classical field evolution and observed charge creation in two-photon collisions.