FEYNMAN DIAGRAMS

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0.1 What is a Feynman diagram

A Feynman diagram is a graphical representations of the math describing the behavior of subatomic particles, as described by the quantum electrodynamics (QED) model. In the following notes, we will follow the convention that places time on the abscissas and space on the ordinates.

0.1.1 Electron

An electron e^- (Figure 1) is a subatomic particle of matter. It holds a negative charge, equals in module to the one of a positron. It is classified as fermion. It is represented as:

Feynman graph: ´

Figura 1: Representation of an Electron.

0.1.2 Positron

A positron e^+ (Figure 2), an anti-electron, is a subatomic particle of anti-matter. It holds a positive charge, equals in module to the one of an electron. It is classified as fermion. Note that a positron looks as an electron that travels back in time, according to the mathematics of QED. It is represented as:

Feynman graph: ˆ

Figura 2: Representation of a Positron.

0.1.3 Photon

A photon γ (Figure 3) is a subatomic particle representing a discrete packet of energy. It can produce a couple positron-electron and be produced by the annihilation of a couple of positron-electron. It can be transmitted by scattering between two particles. As the absence of arrows implies, to a photon the time direction is not important.

Feynman graph: ˜

Figura 3: Representation of a Photon.

0.1.4 Vertex

A vertex ν (Figure 4) is a point where three particles meet. In QED, only a vertex is allowed, one where a Positron e^+, an Electron e^- and a Photon γ meet. By rotating a vertex, its representation change. It can represent 6 different interactions.

Feynman graph:¨

Figura 4: A vertex of a Feynman diagram.

Feynman graph:″

Figura 5: Electron absorbs a photon.

Feynman graph:°

Figura 6: Positron absorbs photon.

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Feynman graph:ˇ

Figura 7: Electron emits a photon.

Feynman graph:˘

Figura 8: Positron emits a photon.

Feynman graph:¯

Figura 9: Photon produces an electron - positron pair.

Feynman graph:˙

Figura 10: Fermions annihilate and produce a photon.

0.2 First question

Draw the two-vertex diagrams for Bhabha scattering showing a single virtual photon interaction and describe what's happening at these vertices.

0.2.1 Answer

With time on the abscissas and space on the ordinates, we have the following two diagrams:

Feynman graph:´

Figura 11: Electron-Positron scattering.

Figure 11 denotes an electron-positron scattering by emission of a virtual photon. We can choose to view the graph either as the positron emitting the virtual photon in v_2 and the electron absorbing it in v_1 or vice versa, with no more correct interpretation.

Feynman graph:ˆ

Figura 12: Electron-Positron annihilation.

Figure 12 denotes an electron-positron annihilation by emission of a virtual photon. A couple positron-electron annihilates in v_1 and emits a virtual photon, that then produces a pair positron-electron in v_2.

The two graphs have the same on-shell particles, while the difference is found in what the virtual particles, in this case a single photon, does. Considering that by definition, the virtual particles mathematically speaking travel each and every possible path, the two graphs can be considered in this sense the same one.

0.3 Second question

Draw all possible four-vertex diagrams, ignoring self-energy diagrams (when a particle emits and then re-absorbs a virtual particle or a cople of virtual particles).

0.3.1 Answer

With time on the abscissas and space on the ordinates, we have the following diagrams:

Feynman graph:´

Figura 13: Electrons exchange photons.

Feynman graph:ˆ

Figura 14: Positrons exchange photons.

The graphs in figures 13 and 14 are the same, only with reversed time.

Feynman graph:˜

Figura 15: Electron and Positron exchange photons.

Feynman graph:¨

Figura 16: One of the possible interpretation is: a photon γ produces a virtual couple e^-, e^+ in v_1, then in v_2 an electron annihilates with the positron from v_1, producing a virtual photon γ_1. γ_1 then produces a couple e^-, e^+ in v_3 and in v_4 the previously produced fermions annihilates and produce a photon.

Feynman graph:″

Figura 17: One of the possible interpretation is: a photon γ produces a virtual couple e^-, e^+ in v_1, then in v_2 a positron annihilates with the electron from v_2, producing a virtual photon γ_1. γ_1 then produces a couple e^-, e^+ in v_3 and in v_4 the previously produced fermions annihilates and produce a photon.

The graphs in figures 16 and 17 are the same, only with reversed time.