QFT Exam

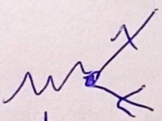
11/1/24

Presentation: 2 photon → electron-positron pair creation

ORal follow up part:

1) you have talked about ~~2 photo~~ ~~2~~ $\gamma + \gamma \to e^+ + e^-$
why not $\gamma \to e^+ + e^-$

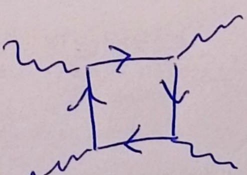
Answer: ~~E~~nergy momentum conservation:



No real proces!

2) In classical electro dynamics photon scatering does not exist. However it does in QED. Draw the feynman diagram + explain why this is consistent with the classical limit.

Answer: radiative correction:



As in the 4 homework
loops are of order $\hbar$ in the perturbation expansion series
⇒ the classical limit $\hbar \to 0$ ⇒ no 2 photon scattering is indeed the classical limit.

3) Some question like: Why is QFT consistent with SR? (But it was on a case (I don't know anymore)

4) what is helicity and ~~[illegible]~~ chirality? What do those two have in common?

Answer

- Helicity: the projection of the spin on the direction of movement: right handed $\Rightarrow$ or left handed $\rightleftarrows$
$\vec{\sigma} \cdot \vec{p}$
- chiral spinors are eigenstates of γ^5 i.e. $\gamma^5 \psi = \lambda \psi$

See ~~Sec~~ A. 6 in Mandl & Shaw.

5) Given is the following Lagrangian:

$\mathcal{L} = \mathcal{L}_0 + \mathcal{L}_I$ where $\mathcal{L}_0$ contains orders of 2 and $\mathcal{L}_I$ contains higher orders.

$\mathcal{L}_I$ is used to find the perturbations why is $\mathcal{L}_0$ used for

Answer: to ~~[illegible]~~ find the assymptotic solution ~~[illegible]~~ on which we can do the perturbation theory

6) Lets say $\mathcal{L}_0 = i\bar{\psi}_1 \not{\partial} \psi_1 + i\bar{\psi}_2 \not{\partial} \psi$
$- m\bar{\psi}_1\psi_1 - m\bar{\psi}_2\psi_2 - i\tilde{m}\bar{\psi}_1\psi_2 + i\tilde{m}\bar{\psi}_2\psi_1$

→ why is this last term needed for the Lagrangian?

<u>Answer</u>: the Lagrangian is Hermitian hence the hermitian part of $-i\tilde{m}\bar{\psi}_1\psi_2 \rightarrow i\tilde{m}\bar{\psi}_2\psi_1$ should be included.

Now you have 10 minutes to find the assymptotic eigen states of this $\mathcal{L}_0$. Use Linear Algebra to find them.

<u>Answer</u>: we will write this using matrix notation:

let $\Psi = \begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix}$ then $\overline{\Psi} = (\bar{\psi}_1 \;\; \bar{\psi}_2)$

and $\mathcal{L}_0 = \overline{\Psi}\not{\partial}\Psi - \overline{\Psi}\begin{pmatrix} m & +i\tilde{m} \\ -i\tilde{m} & m\end{pmatrix}\Psi = 0$

using linear transformations to switch bases with unitary transformation $U = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & i \\ 1 & -i\end{pmatrix}$

$\Rightarrow \tilde{\Psi} = U\Psi$ Hence

$\mathcal{L}_0 = \overline{\tilde{\Psi}}\not{\partial}\tilde{\Psi} - \tilde{\Psi}\begin{pmatrix} m+\tilde{m} & \\ & m-\tilde{m}\end{pmatrix}\tilde{\Psi} = 0$

→ dirac Lagrangian

so the asymptotic solutions are a dirac particle with mass $m+\tilde{m}$ and one with $m-\tilde{m}$

7) Up to now we have nothing assumed of $\tilde{m}$ in the previous question but what if $\tilde{m} > m$ thus $m - \tilde{m} < 0$ Thus such a particle obeys the same physics?

Answer: Yes. The EOM will also be the KG equations

In fact the Lagrangian $\mathcal{L} = \bar{\psi} \not{\partial} \psi - m \bar{\psi} \psi$ and $\mathcal{L}' = \bar{\psi} \not{\partial} \psi + m \bar{\psi} \psi$ are describing exactly the same as a linear transformation $\psi \to \gamma^5 \psi$ transforms them in one another $-\not{\partial} \gamma^5 \gamma^5 = -\not{\partial}$

$$\mathcal{L}(\cancel{\psi} \to \psi' = \gamma^5 \psi) = \bar{\psi} \underbrace{\gamma^5 \not{\partial} \gamma^5}_{[\gamma^5 \gamma^\nu] = 0} \psi - m \bar{\psi} \underbrace{\gamma^5 \gamma^5}_{= \mathbb{1}_{n \times n}} \psi$$

$$= -\bar{\psi} \not{\partial} \psi - m \bar{\psi} \psi = -\mathcal{L}.$$

Therefore they describe the same process!