Particle Physics - Problem Sheet 2

Discussion Questions

D1 What are the features of scattering processes that occur in the s, t and u channels? e.g. what initial and final state particles are involved, and what are the relative sizes of the cross sections? Which processes might be the most interesting?

D2 To measure a cross section experimentally we use the formula:

The experimentalists formula for a cross section is:

$$\sigma = \frac{N_{\text{selected}} - N_{\text{background}}}{\int \mathcal{L} dt \cdot \epsilon}$$

where:

- N_{selected} is the number of events passing some selection criteria.
- $N_{\text{background}}$ is the estimated number of background events that pass this selection criteria.
- $\int \mathcal{L} dt$ is the integrated luminosity collected by the experiment.
- ϵ is the efficiency of the selection criteria used to select the process under investigation.

What is the one standard deviation (1σ) on N_{selected} and $N_{\text{background}}$?
Discuss how you would observe a 5σ deviation between N_{selected} and $N_{\text{background}}$.

Standard Problems

S1 The normalisation condition for Dirac spinors is $u^\dagger u = 2E$. Show that the normalisation constant for a spinor is $1/\sqrt{E+m}$.

S2 For the Dirac spinors u^1 and u^2 show that the lower components are smaller than the upper ones by a factor of $\beta = v/c$ for a relativistic particle. What happens to the spinors for a non-relativistic particle?

S3 Consider the chiral projection operators:

$$P_L = \frac{1}{2}(1 - \gamma^5) \qquad P_R = \frac{1}{2}(1 + \gamma^5)$$

(a) Write out the operators as 4×4 matrices.

(b) Show that the operators satisfy the following relations:

$$P_L^2 = P_L \qquad P_R^2 = P_R \qquad P_L + P_R = 1 \qquad P_L P_R = 0$$

Explain why this makes them projection operators in quantum mechanics.

(c) In the ultrarelativistic limit $\beta \to 1$ show that the operators acting on the Dirac spinors have the following properties:

$$P_L u^1 = 0 \qquad P_L v^1 = v^1 \qquad P_L u^2 = u^2 \qquad P_L v^2 = 0$$
$$P_R u^1 = u^1 \qquad P_R v^1 = 0 \qquad P_R u^2 = 0 \qquad P_R v^2 = v^2$$

Hence explain what it is that they project out.