Lecture 5

Master Particle Physics 1

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September19, 2011

Lectures PP1

L0 : Introduction

L1 : Particles and Fields (historical overview)
L2 : Wave Equations and Antiparticles
L3 : The Electromagnetic Field
L4 : Perturbation Theory and Fermi's Golden Rule
L5 : Electromagnetic Scattering of Spinless Particles

QED of Spinless Particles: Scattering Theory and Cross Sections

L6 : The Dirac Equation
L7 : Solutions of the Dirac Equation
L8 : Spin 1/2 Electrodynamics

QED for Fundamental Fermions

L9 : The Weak Interaction
(Fermi 4-point scattering: an analogy with QED)
L10: Local Gauge Invariance
(the role of symmetries in interactions)
L11: Electroweak Theory
L12: The Process: $e^+e^- \rightarrow \gamma, Z \rightarrow \mu^+\mu^-$

The Standard Model for massless particles $SU(2)_L \times U(1)_Y$

The Story Sofar...

1) Plane Waves

$$\text{Kinematics} \;:\; E^2 = \vec{p}^2 + m^2 \quad ; \quad E \to i\frac{\partial}{\partial t} \qquad \vec{p} \to -i\vec{\nabla}$$

$$\text{Klein}-\text{Gordon} \;:\; \left(\partial_\mu \partial^\mu + m^2\right)\phi(x) = 0 \quad ; \quad \phi(x) = N\, e^{-ip_\mu x^\mu}$$

$$\text{Current} \;:\; j^\mu = -ie\,\left[\phi^*\left(\partial^\mu\phi\right) - \left(\partial^\mu\phi^*\right)\phi\right] \quad ; \quad \partial_\mu j^\mu = 0$$

2) Electromagnetic Field

$$\text{Maxwell} \;:\; \partial_\mu\partial^\mu A^\nu - \partial^\nu\partial_\mu A^\mu = j^\nu \quad \text{or} \quad \partial_\mu F^{\mu\nu} = j^\nu$$

$$\text{GaugeFreedom} \;:\; A_\mu \to A'_\mu = A_\mu + \partial_\mu \lambda$$

$$\text{LorentzCondition} \;:\; \partial_\mu A^\mu = 0 \qquad \Rightarrow \text{Maxwell}: \; \partial_\mu\partial^\mu A^\nu = j^\nu$$

$$\text{PlaneWaves} \;:\; A^\mu = N\mathcal{E}^\mu(\vec{p})e^{-ip_\mu x^\mu} \qquad \Rightarrow 2 \text{ polarizations}$$

3) Scattering: $A_i+B_i \to C_f + D_f + \ldots$

$$d\sigma_{fi} = \frac{W_{fi}}{Flux}\, d\Phi$$

$$W_{fi} = \lim_{T,V\to\infty} \frac{|T_{fi}|^2}{TV} \quad ; \quad T_{fi} = -i\int d^4x\, \psi_f^*(x)\, V(x)\, \psi_i(x)$$

$$T_{fi} = -iN_A N_B N_C^* N_D^* (2\pi)^4\, \delta^4(p_A + p_B - p_C - p_D)\, \mathcal{M}$$

$$d\Phi = \sum_{i=1}^{N} \frac{V}{(2\pi)^3}\frac{d^3\vec{p}_i}{2E_i} \quad ; \quad Flux = 4\sqrt{(p_A\cdot p_B)^2 - m_A^2 m_B^2}\;/\;V^2$$

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Today: Electromagnetic Scattering

- A particle in a potential
- Spinless π−K scattering

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