4/26/17 Lecture 8 outline

• Continue from last time Feynman rules for quantum electrodynamics (QED). Draw diagrams for e.g $e^- + e^- \to e^- + e^-$ (draw both diagrams, t and u channel, with relative minus sign), $\gamma + e^- \to \gamma + e^-$ (again two channels, with relative + sign), $e^+ + e^- \to e^+ + e^-$ (now s and t channels with relative minus), $e^+ + e^- \to \mu^+ + \mu^-$.

• The diagrams are used to compute a quantum probability *amplitude*, $\mathcal{M}_{i \to f}$. Physical observables, like cross sections or lifetimes, are $\sim |\mathcal{M}|^2$, with some kinematic factors (phase space) to be discussed soon. The rules for relating the picture to $\mathcal{M}$ are as follows:

1. Draw every possible diagram with the given initial and final states. They are all added (sometimes with minus signs from exchanging fermions).

2. Internal lines contribute propagator factors. For scalar fields they are $i/(p^2 - m^2)$, for spin half it is $i/(\gamma^\mu k_\mu - m)$, for massless spin one, it is (in a particular gauge) $i\eta_{\mu\nu}/k^2$, for massive spin one it is $i(\eta_{\mu\nu} - k_\mu k_\nu / m^2)/(k^2 - m^2)$. (These propagators come from writing Greens functions for the field's linearized equations of motion, or equivalently from inverting the derivative factors in the field's quadratic $\mathcal{L}$.)

3. External Fermions give u or $\bar{u}$ if incoming or outgoing, while their anti-particles give $\bar{v}$ or v. Write these factors by following the arrows in the diagram starting at the head and working toward the tail. External spin 1 fields give polarization vectors ϵ_μ or ϵ^*_μ.

4. Gauge interaction vertices between spin 1/2 and spin 1 give $-iqg\gamma^\mu$. For weak interactions we'll see that this is modified a bit because only the left-handed chirality part of the fermion couples to the weak gauge bosons.

5. If the diagram has internal loops, their momentum is unconstrained and has to be integrated over. This generally requires much more work, because the integrals are apparently divergent. It took decades to sort out this issue – the resolution is that renormalization is required. I'll discuss it qualitatively a bit, but properly doing it is well beyond the scope of this class (see my class website for physics 215b for some info if you're interested).

• Examples.

• Often interested in averaging $|\mathcal{M}|^2$ over initial spins and summing over all final spins (inclusive cross sections). This simplifies things thanks to the $\bar{u}u$ and $\bar{v}v$ completeness relations.