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Another note on relativistic bound states and composite particles

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The question of bound states or composite particles made out of some constituents of a generic mass m consists in their forming of another particle of mass M, such that $-\varepsilon = Mc^2 - \sum mc^2 < 0$ is the binding energy. If $\varepsilon \ll mc^2$ the bound state is non-relativistic, and it has an extension $a \sim \hbar/p \sim (\hbar^2/m\varepsilon)^{1/2}$ and, correspondingly, an energetical structure arising from the boundary conditions of the (quantal) motion. If $\varepsilon \sim mc^2$, the constituents may lose their own identity, and the "bound state" or "composite particle" becomes meaningless; it may gets pure radiation. Moreover, the motion frequency is such that $\omega \sim c/a$, *i.e.* an energy $\varepsilon \sim \hbar c/a \sim mc^2$, hence the size of the order of the Compton length $a \sim \hbar/mc$. Below this length there is no sense to talk about a bound state or composite particle, without further hypotheses.

This is the content of the Bethe-Salpeter equation which amounts to Schrodinger's equation for two particles, and of Breit's equation, which includes relativistic corrections to Schrodinger's equation for two particles. They serve to illustrate the poles in the (infinitely summed, ladder-diagrams series) scattering amplitudes as bound states.