Basic

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[2] The Standard Model asserts that the material in the Universe is made up of elementary fermions interacting through fields, of which they are the sources. The particles associated with the interaction fields are bosons. The quanta of the electromagnetic interaction field between electrically charged fermions are the massless photons. The quanta of the weak interaction fields between fermions are the charged W^+ and W^- bosons and the neutral Z boson. Since these carry mass, the weak interaction is short ranged. By the uncertainty principle, a particle of mass M can exist as part of an intermediate state for a time $\frac{\hbar}{Mc^2}$, and in this time the particle can travel a distance no greater than $\frac{\hbar c}{Mc^2}$. Since $M_w \approx 80$ GeV/c^2 and $M_z \approx 90$ GeV/c^2, the weak interaction has a range $\approx 10^{-3}$ fm. The quanta of the strong interaction field, the gluons, have zero mass like photons, might be expected to have infinite range. However, unlike the electromagnetic field, the gluon fields are confining. The elementary fermions of the Standard Model are of two types: leptons and quarks. All have spin $\frac{1}{2}$, in units of $\hbar$, and in isolation would be described by the Dirac equation. Leptons interact only through the electromagnetic interaction (if they

are charged) and the weak interaction. Quarks interact through the electromagnetic and weak interactions and also through the strong interaction.

References

[1] F. Halzen and A. D. Martin. *Quarks and leptons : an introductory course in modern particle physics*. 1984.

[2] W. N. Cottingham and D. A. Greenwood. *An introduction to the standard model of particle physics*. 2007.