We thus obtain the potential

\[ V_{\text{FK}} = -\frac{\alpha}{\pi^2} (4\pi)^2 \frac{\sqrt{m_1} \sqrt{m_2}}{r} \frac{(\bar{\sigma}_1 \cdot \vec{r})(\bar{\sigma}_2 \cdot \vec{r})}{2\cos^2 \theta} \]

\[ V_{\text{FK}} = -\frac{e^2}{4\pi^2} \frac{1}{\Delta m} \frac{\sigma_1 \cdot \sigma_2}{r} \frac{(\bar{\sigma}_1 \cdot \vec{r})(\bar{\sigma}_2 \cdot \vec{r})}{2\cos^2 \theta} \]

\[ = \frac{F}{m_{\pi}} \frac{\sigma_1 \cdot \sigma_2}{r^2} \left[ \Sigma_{12} \left( \frac{1}{(m_{\pi})^2} + \frac{1}{(m_{\pi})^2} + \frac{1}{3m_{\pi}^2} \right) e^{-\frac{r}{r_{\pi}}} \right. \]

\[ + \left. \frac{\sigma_1 \cdot \sigma_2}{m_{\pi}^2} \left( e^{-\frac{2r}{m_{\pi}}} - \frac{6\pi}{m_{\pi}^2} \delta (\vec{r}) \right) \right] \]

\[ \Sigma_{12} = 3 \left( \sigma_1 \cdot \vec{r} \right) \left( \sigma_2 \cdot \vec{r} \right) - \frac{\sigma_1 \cdot \sigma_2}{r} \frac{r}{2} \]

7c) Short range repulsion

Short range range repulsion is due to the exchange of vector bosons. They are like massive photons. Because nucleons have the same charge for these bosons the interaction is repulsive. Because the vector bosons are much more massive \( m_{\pi} = 139 \text{ MeV} \), the interaction is short range.

This short range interaction also gives rise to a spin orbit force. For a Coulomb potential it is given by \( \frac{dV}{dr} = \frac{e^2}{r} \left( \frac{1}{r} \right) \]

We expect that the short range potential