Joint Physics Analysis Center

Summer Workshop on the Reaction Theory
Exercise sheet 2

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June 12 – June 22 To be discussed on Friday of Week-I.

Classwork

Electromagnetic current matrix element for a nucleon in the Breit frame

Consider the electromagnetic current matrix element for a nucleon

$$\langle p', s'|J^\mu(0)|p, s\rangle = \bar{u}(p', s') \left\{ F_1(q^2)\gamma^\mu + F_2(q^2) i\sigma^{\mu\nu}\frac{q_\nu}{2M} \right\} u(p, s), \tag{1}$$

in the Breit frame, defined by

$$\begin{aligned} q^\mu &= (0, \vec{q}), \\ p^\mu &= (M\sqrt{1+\tau}, -\frac{\vec{q}}{2}), \\ p'^\mu &= (M\sqrt{1+\tau}, \frac{\vec{q}}{2}), \end{aligned} \tag{2}$$

with $Q \equiv |\vec{q}|$, and $\tau \equiv Q^2/(4M^2)$.

(1) By using the Gordon identity, rewrite this expression such that at most one gamma matrix appears between the nucleon spinors

(2) Show that the charge matrix element (J^0) in the Breit frame is given by

$$\langle p', s'|J^0(0)|p, s\rangle = \delta_{ss'}(2M)G_E(q^2), \tag{3}$$

with electric Sachs form factor G_E defined by

$$G_E(q^2) = F_1(q^2) - \tau F_2(q^2). \tag{4}$$

(3) Show that the current matrix element ($\vec{J}$) in the Breit frame is given by

$$\langle p', s'|\vec{J}(0)|p, s\rangle = G_M(q^2)\chi^\dagger_{s'} i(\vec{\sigma}\times\vec{q})\chi_s, \tag{5}$$

with χ_s a Pauli spinor, and with magnetic Sachs form factor G_M defined by

$$G_M(q^2) = F_1(q^2) + F_2(q^2). \tag{6}$$