1 Asymmetry in elastic $\vec{e}$ P scattering

1.1 Introduction

Due to the high mass of the Z^0, elastic eP scattering is dominated at low energy by photon exchange. In order to measure the neutral weak form factors in elastic electron proton scattering, one needs to be able to separate the electromagnetic $|\mathcal{M}_\gamma|^2$ contribution from the weak one $|\mathcal{M}_Z|^2$. One way would be to run at higher energy, but then the elastic eP cross section falls off to rapidly. Using Polarized electron enables to take benefit of the fact that the weak interaction does not conserves parity, thus a Left-Right asymmetry will gives access to

$$A_{PV} = \frac{d\sigma_R - d\sigma_L}{d\sigma_R + d\sigma_L} \propto \frac{\mathcal{M}_\gamma \mathcal{M}_Z}{|\mathcal{M}_\gamma|^2}$$

1.2 Why Parity Violation with Polarized electron

Using longitudinally polarized electrons, an asymmetry between left and right (longitudinal polarization) electron for elastic scattering on unpolarized proton is the manifestation of an interaction which is not invariant by reflexion wrt the scattering plane (x, y) $\mathcal{R}_{x,y}$. The parity is a product of this reflexion with a rotation of π along the axis perpendicular to the mirror plane $R_z(\pi)$

$$\mathcal{P} = \mathcal{R}_{x,y} R_z(\pi)$$

Since Physics is invariant under rotation, this is equivalent to an interaction not invariant under parity.

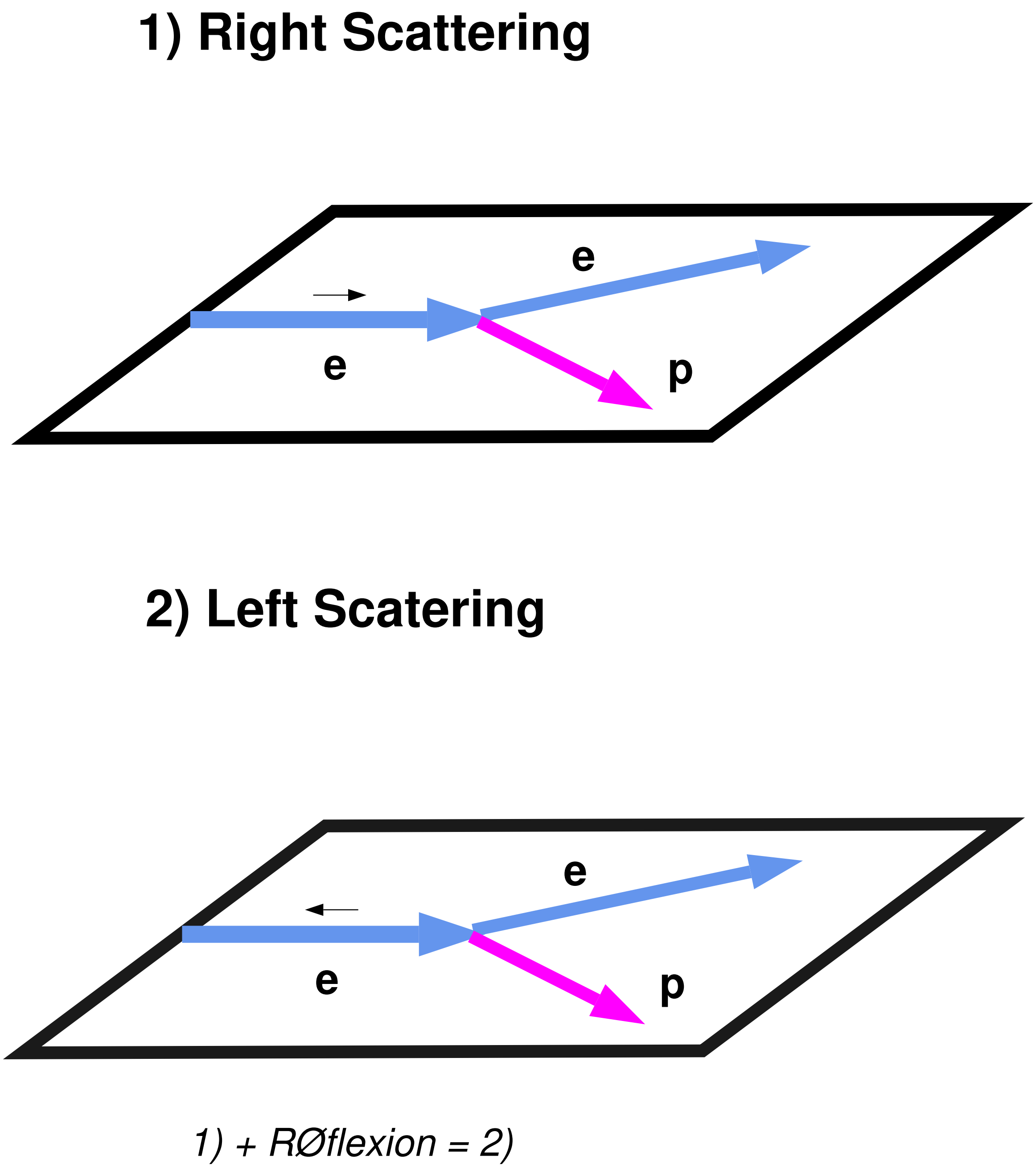

Figure 1: **A reflexion wrt to the scattering plane (x, y) $\mathcal{R}_{x,y}$., transform elastic right electron-proton scattering to left electron-proton scattering.**

1.3 Asymmetry versus Q^2

The asymmetry between scattering with Right and Left electron is[?]

$$A_{PV} = \frac{d\sigma_R - d\sigma_L}{d\sigma_R + d\sigma_L} = -\frac{GQ^2}{\sqrt{2}\pi\alpha}\frac{N}{D} \tag{1}$$

$$\begin{aligned} N = {} & 2\tau \tan^2\frac{\theta}{2} G_M^{(\gamma,p)} G_M^{(Z,p)} + \left(F_1^{(\gamma,p)} F_1^{(Z,p)} + \tau F_2^{(\gamma,p)} F_2^{(Z,p)}\right) \\ & -\frac{1}{2}\frac{E+E'}{M}\tan^2\frac{\theta}{2}\left(1 - 4\sin^2\theta_W\right) G_1^{(Z,P)} G_M^{(\gamma,p)} \end{aligned} \tag{2}$$

$$D = \left({F_1^{(\gamma)}}^2 + \tau {F_2^{(\gamma)}}^2\right) + 2\tau\tan^2\frac{\theta}{2}\left(F_1^{(\gamma)} + F_2^{(\gamma)}\right)^2 \tag{3}$$

This asymmetry is plotted on figure (2), assuming no strange quarks, no Q^2 evolution for $G_1^{(Z)}$and using the Simon's and Beise's fit for the nucleon EM form factors. Also given the relative extra asymetry with stange quark as predicted by jaffe ,Weigel and souder (figure 3). The asymmetry can also be written using Sachs Form factors :

$$\boxed{A_{PV} = -\frac{GQ^2}{\sqrt{2}\pi\alpha}\frac{\epsilon G_E^{(\gamma,p)} G_E^{(Z,p)} + \tau G_M^{(\gamma,p)} G_M^{(Z,p)} - \delta G_M^{(\gamma,p)} G_1^{(Z,P)}}{\epsilon {G_E^{(\gamma,p)}}^2 + \tau {G_M^{(\gamma,p)}}^2}} \tag{4}$$

with

$$\delta = \frac{1}{2}\left(1 - 4\sin^2\theta_W\right)\sqrt{1-\epsilon^2}\sqrt{\tau\left(1+\tau\right)} \tag{5}$$

The asymmetry is very little sensitive to the axial form factor $G_1^{(Z,p)}$, because of the axial coupling of the electron with quark is killed by the $\left(1 - 4\sin^2\theta_W\right)$ term. A better way to measure $G_1^{(Z,p)}$ is via neutrino proton scattering. In our case, the asymmetry is thus sensitive to $G_E^{(\gamma,p)} G_E^{(Z,p)}$ and $G_M^{(\gamma,p)} G_M^{(Z,p)}$.

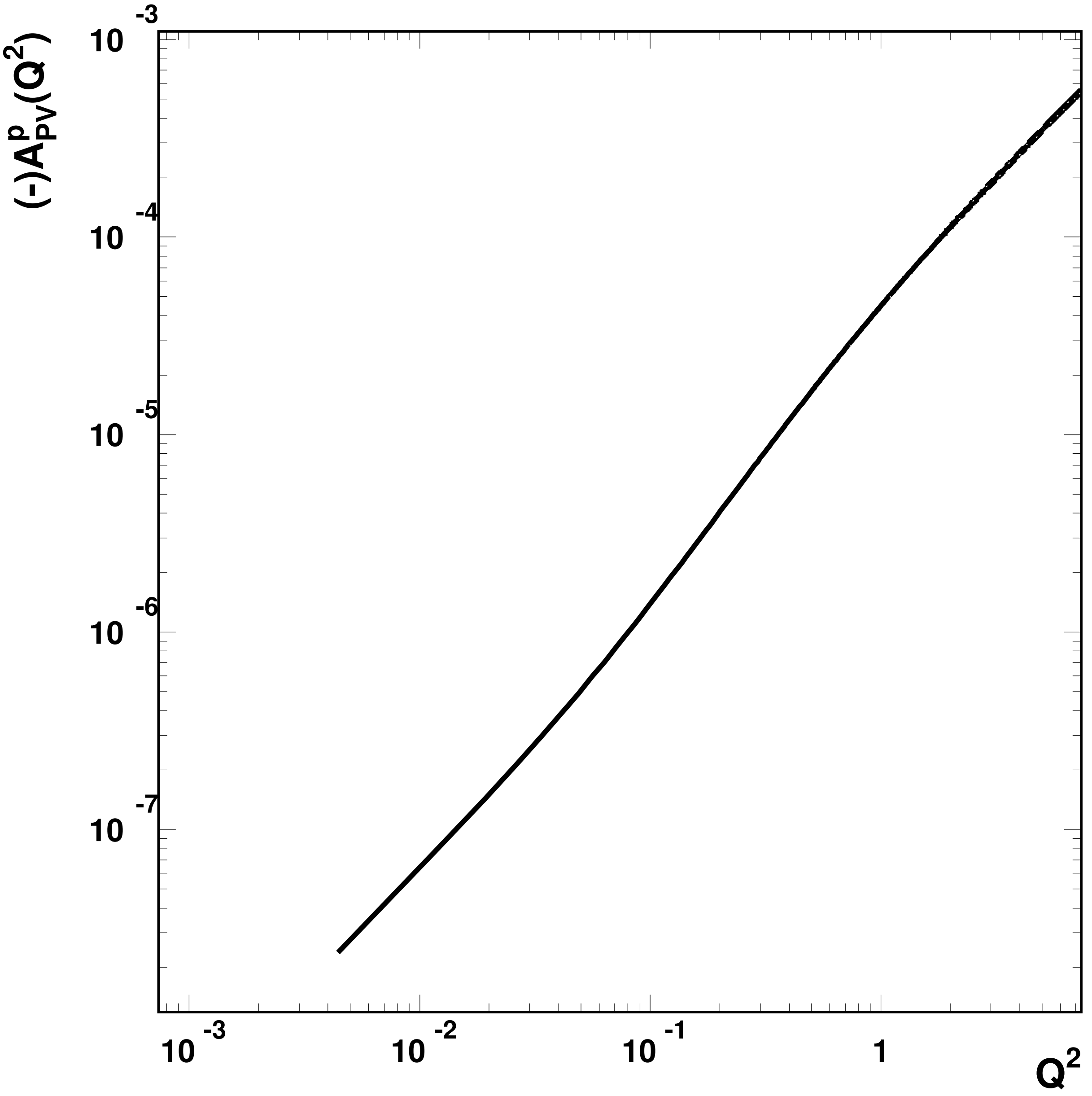

Figure 2: **The asymmetry for proton elastic scattering with Right and left electrons, assuming no strange quarks**, *for $E = 4.35 GeV$, with $\theta = 12.5^o$, using Beise parametrization.*

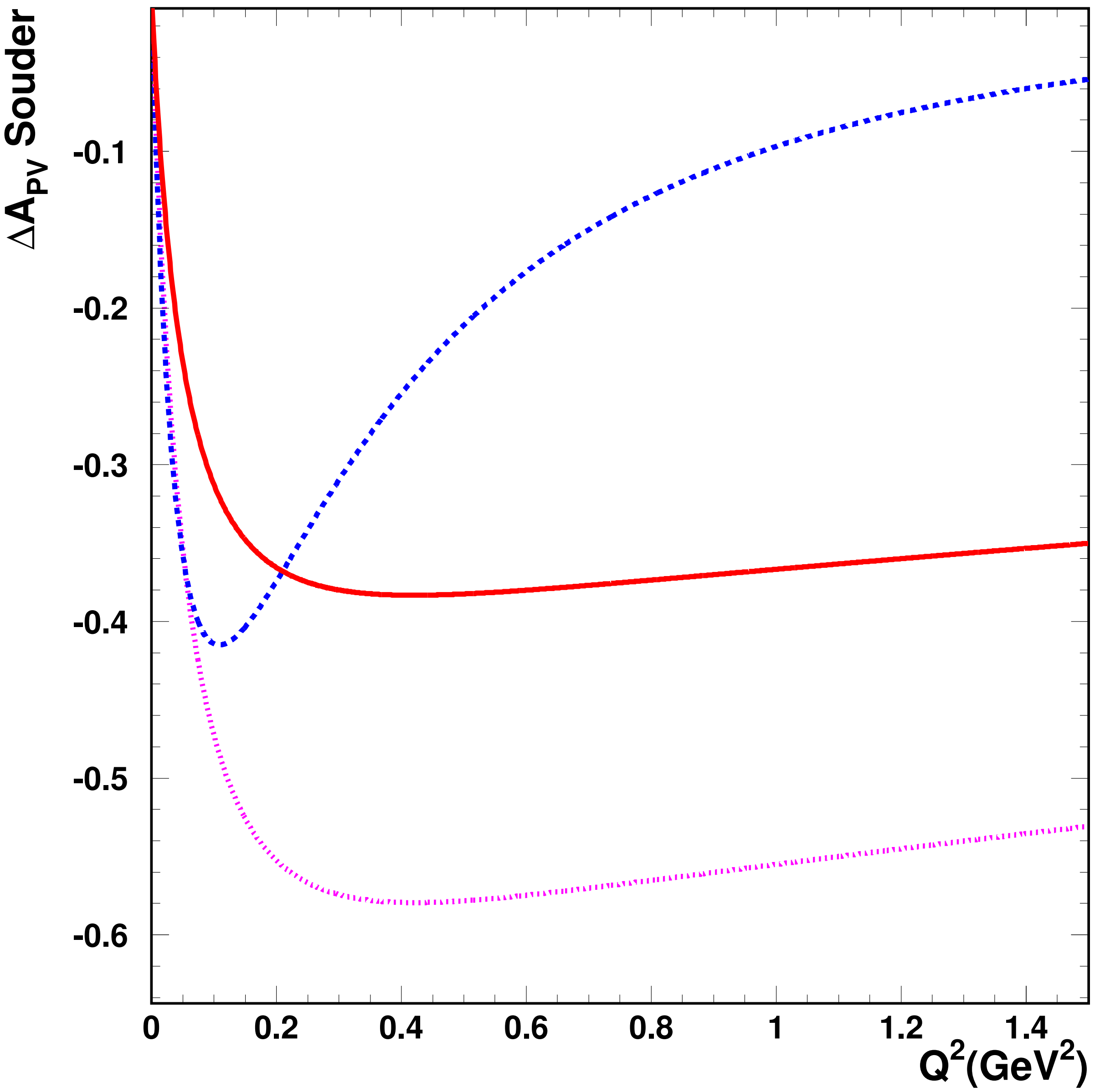

Figure 3: **The relative extra asymmetry for proton elastic scattering with Right and left electrons, with strange quarks using Jaffe/Souder predictions**

To see which combination of the form factors will be measured, let $A_{PV}^{(0)}$ be the asymmetry expected for no strange quark in the proton, using (see Eq. ??)

$$\boxed{G_{E,M}^{(Z,p)} = \frac{1}{4}\left[\left(1-4\sin^2\theta_W\right)G_{E,M}^{(\gamma,p)} - G_{E,M}^{(\gamma,n)}\right] - \frac{1}{4}G_{E,M}^{(s,p)}}, \tag{6}$$

(see Eq. ??)

$$\boxed{G_1^{(Z,p)} = -\frac{1}{2}g_a + \frac{1}{4}G_1^{(s)} = G_A + \frac{1}{4}G_1^{(s)}}, \tag{7}$$

one gets

$$\boxed{A_{PV} = A_{PV}^{(0)}\left(1-\Delta A\right)}, \tag{8}$$

with

$$A_{PV}^{(0)} = -\frac{GQ^2}{\sqrt{2}\pi\alpha}\left(A_E + A_M + A_A\right), \tag{9}$$

and

$$A_E = \frac{\epsilon G_E^{(\gamma,p)}\left[\left(1-4\sin^2\theta_W\right)G_E^{(\gamma,p)} - G_E^{(\gamma,n)}\right]}{4\left(\epsilon {G_E^{(\gamma,p)}}^2 + \tau {G_M^{(\gamma,p)}}^2\right)} \tag{10}$$

$$A_M = \frac{\tau G_M^{(\gamma,p)}\left[\left(1-4\sin^2\theta_W\right)G_M^{(\gamma,p)} - G_M^{(\gamma,n)}\right]}{4\left(\epsilon {G_E^{(\gamma,p)}}^2 + \tau {G_M^{(\gamma,p)}}^2\right)} \tag{11}$$

$$A_A = \frac{-4\delta G_M^{(\gamma,p)}G_A}{4\left(\epsilon {G_E^{(\gamma,p)}}^2 + \tau {G_M^{(\gamma,p)}}^2\right)} \tag{12}$$

The additional asymmetry due to strange quark is

$$\boxed{\Delta A = \frac{\epsilon G_E^{(\gamma,p)}G_E^{(s)} + \tau G_M^{(\gamma,p)}G_M^{(s)} + \delta G_M^{(\gamma,p)}G_1^{(s)}}{\epsilon G_E^{(\gamma,p)}\left[\left(1-4\sin^2\theta_W\right)G_E^{(\gamma,p)} - G_E^{(\gamma,n)}\right] + \tau G_M^{(\gamma,p)}\left[\left(1-4\sin^2\theta_W\right)G_M^{(\gamma,p)} - G_M^{(\gamma,n)}\right] - 4\delta G_M^{(\gamma,p)}G_A}} \tag{13}$$