Contribution of Triangle Diagrams in Muon-Proton Scattering via Two-Photon Exchange

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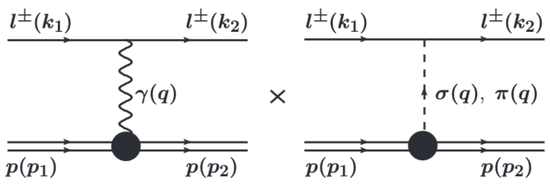
Introduction/Previous Calculations



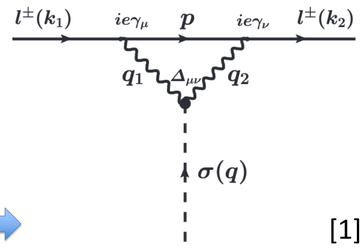
One-γ and one σ (π) exchange in elastic lepton-proton scattering

$$|\mathcal{M}|^2 = |\mathcal{M}^v + \mathcal{M}^s + \mathcal{M}^p|^2$$
$$\approx |\mathcal{M}|^2_{1\gamma} + 2\,\mathrm{Re}[\mathcal{M}^v\mathcal{M}^{s*}] + 2\,\mathrm{Re}[\mathcal{M}^v\mathcal{M}^{p*}]$$

$$2\,\mathrm{Re}\left[\overline{\mathcal{M}^v\mathcal{M}^{s*}}\right] = \mp\frac{8mM(s-u)e^2}{Q^2\left(Q^2+m_\sigma^2\right)}G_E\left(Q^2\right)g_{\sigma pp}\,\mathrm{Re}[f_s]$$

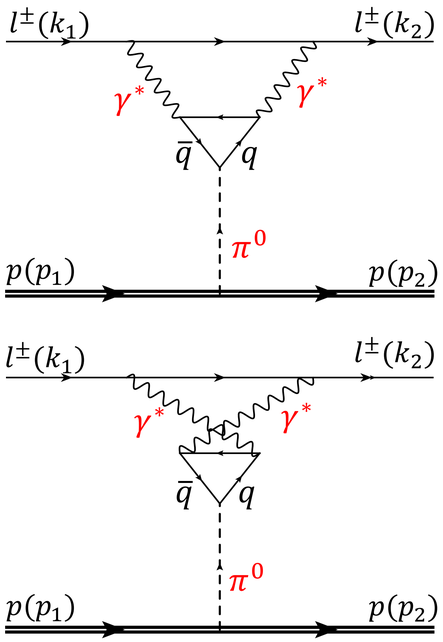
Term that causes interference between the σ and the γ diagrams

For unpolarized leptons, the **single pion exchange doesn't contribute** and the dominant σ contribution comes from



[1]

Triangle Diagrams

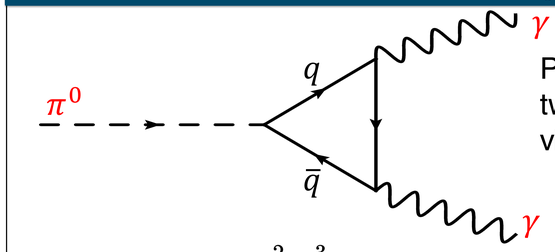


Higher order processes involving pions that do contribute?

I am studying the **axial anomaly diagram's** contribution to the two-photon exchange in elastic muon-proton scattering.

I am examining the role of **lepton and proton polarization** in the scattering process.

Neutral Pion Decay

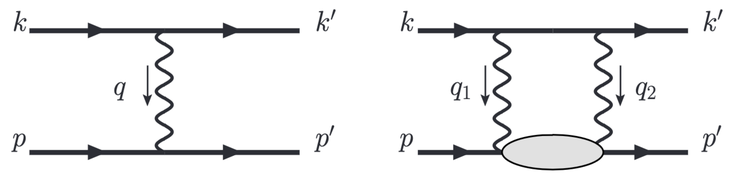


Pion decay into two photons via a virtual quark loop.

Insert this diagram into lepton-proton interaction

$$\Gamma\left(\pi^0\to\gamma\gamma\right) = \frac{\alpha^2 m_\pi^3}{576\pi^3 F_\pi^2}N_C^2 = 7.73\mathrm{eV}$$

Two-Photon Exchange (TPE)



Measurements so accurate that we must go beyond **One-Photon Approximation.** Generally, for two photons:

[2]

$$\mathcal{M}^{\mathrm{box}}_{\gamma\gamma} = -ie^4\int\frac{d^4q_1}{(2\pi)^4}\frac{L_{\mu\nu}H_R^{\mu\nu}}{\left(q_1^2-\lambda^2\right)\left(q_2^2-\lambda^2\right)}$$

Goals

- Study the axial anomaly's contribution in the context of Generalized Parton Distributions (GPDs).
- Study the charge asymmetry due to the higher order corrections.
- Focus on improving the TPE estimates in the kinematic region of MUSE.

References

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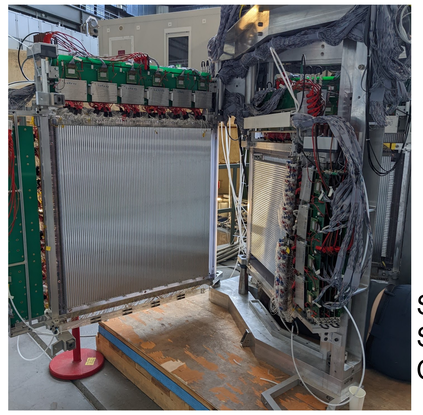
[2] A. Afanasev, P.G. Blunden, D. Hasell, B.A. Raue, Prog. Part. Nucl.Phys. **95**, 245 (2017).
[3] R. Gilman et al, 2017, arXiv:1709.09753
[4] S. Strauch 2018, doi.org/10.22323/1.341.0136

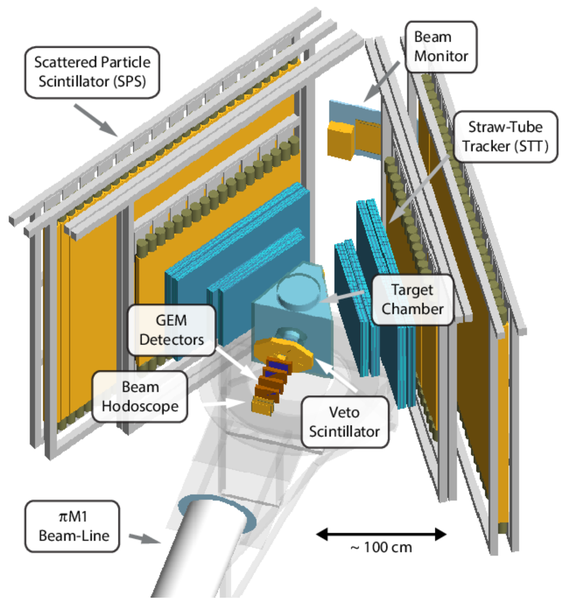
MUSE Experiment at PSI



Scattered Particle Scintillators at MUSE
Credit: Rachel Ratvasky[1]

MUon Proton **S**cattering **E**xperiment at Paul Scherrer Institute in Switzerland

- MUSE will directly test TPE in ep and μp scattering at **low Q^2**
- First low energy muon-proton elastic scattering experiment to determine the proton charge radius. [3]
- Use mixed meson/muon/electron beam at E_{beam} = 115, 160, 210 MeV
  Idea: to **simultaneously** measure *ep* and μ*p* and π*p* scattering.



Geant4-based schematic view of the detector setup for the MUSE experiment. [4]