# Single Spin Asymmetry in Electroproduction of Scalar or Pseudoscalar Meson Production off the Scalar Target

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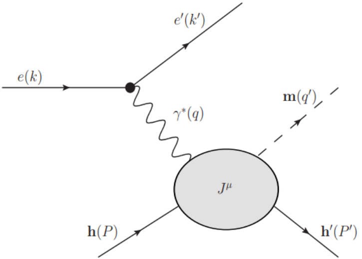
HUGS Student Seminar Session, June 2018

# Outline

# Background (Meson Production Diagram)




- A virtual photon impacts a scalar target which does not break apart, and a scalar or pseudoscalar meson is produced; there is no Bethe-Heitler process.

# Single Spin Asymmetry

$$A = \frac{d\sigma_{\lambda=+1} - d\sigma_{\lambda=-1}}{d\sigma_{\lambda=+1} + d\sigma_{\lambda=-1}} \tag{1}$$

- Meson production means no Bethe-Heitler process (which appears in DVCS), so any non-zero SSA is a direct measure of any asymmetry within the hadronic tensor
- A scalar target that does not break apart and a scalar or pseudoscalar meson production keeps the process simple, and the information that can be extracted is significant

# Background (Equations)

- Differential cross sections are proportional to the square amplitude:

$$\begin{aligned}\langle|\mathcal{M}|^2\rangle &= \left(\frac{e^2}{q^2}\right)^2 \mathcal{L}^{\mu\nu}\mathcal{H}_{\mu\nu} \\ &= \left(\frac{e^2}{q^2}\right)^2 \left[\frac{2q^2}{\epsilon - 1}\langle|\tau_{fi}|\rangle^2 + 2i\lambda\epsilon^{\mu\nu\alpha\beta}k_\alpha k'_\beta J^\dagger_\mu J_\nu\right]\end{aligned}$$

$$\mathcal{H}_{\mu\nu} = J^\dagger_\mu J_\nu$$

# Pseudoscalar Meson Production

$$\mathcal{H}_{\mu\nu} = |F_{PS}|^2 \, \epsilon_{\mu\alpha\beta\gamma}\epsilon_{\nu\alpha'\beta'\gamma'} q^{\alpha} \bar{P}^{\beta} \Delta^{\gamma} q^{\alpha'} \bar{P}^{\beta'} \Delta^{\gamma'} = H_{\nu\mu} \qquad (2)$$

- Contracted with the antisymmetric part of the leptonic tensor: vanishes.
- We predict for *all* kinematics that the SSA of pseudoscalar meson production off a *scalar* target vanishes.
- Can be used to ensure accurate experimental measurements

# Scalar Meson Production (1)

$$d\sigma_{\lambda}^{S} = d\sigma_{U}^{S} + d\sigma_{P}^{S}\epsilon\cos(2\phi) + d\sigma_{L}^{S}\epsilon_L + d\sigma_{I}^{S}\cos\phi\sqrt{\epsilon_L(1+\epsilon)} + \lambda\, d\sigma_{\mathrm{SSA}}^{S}$$

$$\frac{d\sigma_{\lambda=+1}^{S} - d\sigma_{\lambda=-1}^{S}}{d\sigma_{\lambda=+1}^{S} + d\sigma_{\lambda=-1}^{S}} = \frac{d\sigma_{\mathrm{SSA}}^{S}}{d\sigma_{U}^{S}(1+\epsilon\cos(2\phi)) + d\sigma_{L}^{S}\epsilon_L + d\sigma_{I}^{S}\cos\phi\sqrt{\epsilon_L(1+\epsilon)}}$$

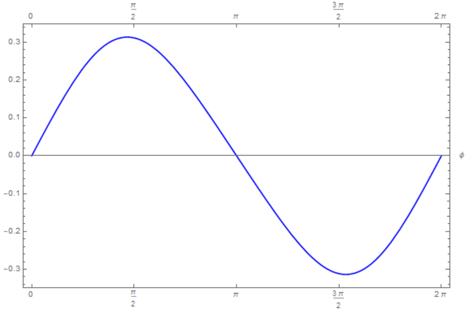
# Scalar Meson Production (2)

- The last expression is proportional to $F_1 F_2^* - F_2 F_1^*$, so for generally complex-valued form factors $F_1$ and $F_2$ we predict a non-zero SSA.
- Leading-twist GPDs have a single GPD and would predict a vanishing SSA.
- Measuring the SSA of the scalar meson is therefore an excellent test of whether leading-twist GPD formulations are valid in the corresponding kinematic regimes.

# SSA Pseudoscalar

Numerical check confirmed zero everywhere, used as a basis for some confidence for the scalar meson production numerical results.

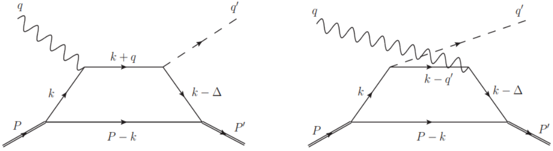
# SSA Scalar




$$F_1 = \frac{1}{\sqrt{2}}(1+i)\,, F_2 = \frac{1}{\sqrt{3}}(1+2i)$$

# SSA Scalar Notes

- A vanishing SSA for the scalar meson case is still possible: if both form factors are real
- Exactly solvable model for the form factors can provide insight into the kinematic regime needed to search for the non-vanishing SSA (work in progress)




(a) s − channel (b) u − channel

# SSA Scalar - General Formalism

$$\begin{bmatrix} d\sigma_U^S \\ d\sigma_L^S \\ d\sigma_I^S \\ d\sigma_{\text{SSA}}^S \end{bmatrix} = \begin{bmatrix} U_1 & U_2 & U_3 & 0 \\ L_1 & L_2 & L_3 & 0 \\ I_1 & I_2 & I_3 & 0 \\ 0 & 0 & 0 & S_A \end{bmatrix} \begin{bmatrix} |F_1|^2 \\ |F_2|^2 \\ F_{12}^+ \\ F_{12}^- \end{bmatrix}$$

$$F_{12}^{\pm} = F_1 F_2^* \pm F_2 F_1^*.$$

- Matrix elements are functions of $x$, $Q^2$, $m$, $M$, scattering angles, etc.
- Experimental measurement of LHS $\rightarrow$ measurement of form factors

# Summary

- Scalar (S) and pseudoscalar (PS) meson production off a scalar target has no Bethe-Heitler process and has only one (PS) or two (S) form factors.
- For pseudoscalar meson production off the scalar target, the SSA vanishes and can therefore be used as a basis of confidence for measurements.
- The SSA for scalar meson production is generally non-zero and can be used to extract information about the structure of the target.

- Future work
  - Toy model Feynman diagrams (box diagram, contact diagram) to find kinematics where the form factors take on complex values so SSA for the scalar is likely non-zero.
  - Use toy models to solve for explicit numerical values of the form factors

For full details, please see: https://arxiv.org/pdf/1806.01379.pdf

Thank you!