Exclusive Meson Electroproduction off the Scalar Target

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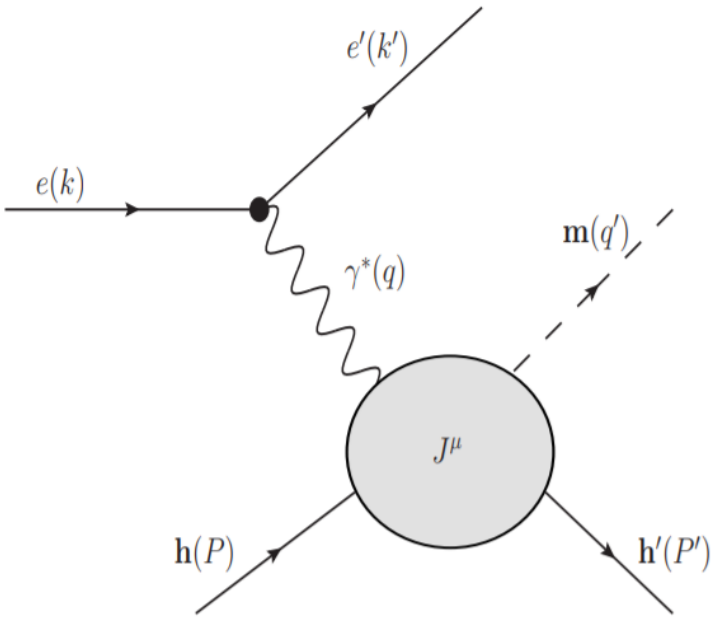
Exclusive Meson Electroproduction

$$e(k) + \mathbf{h}(P) \rightarrow e'(k') + \mathbf{h}'(P') + \mathbf{m}(q')$$



$$Q^2 = -q^2$$

Energy/distance scale of virtual photon probe

$$t = (P - P')^2$$

Momentum transfer to target

$$x = \frac{Q^2}{2P \cdot q}$$

In the forward limit, momentum fraction of interacting particle

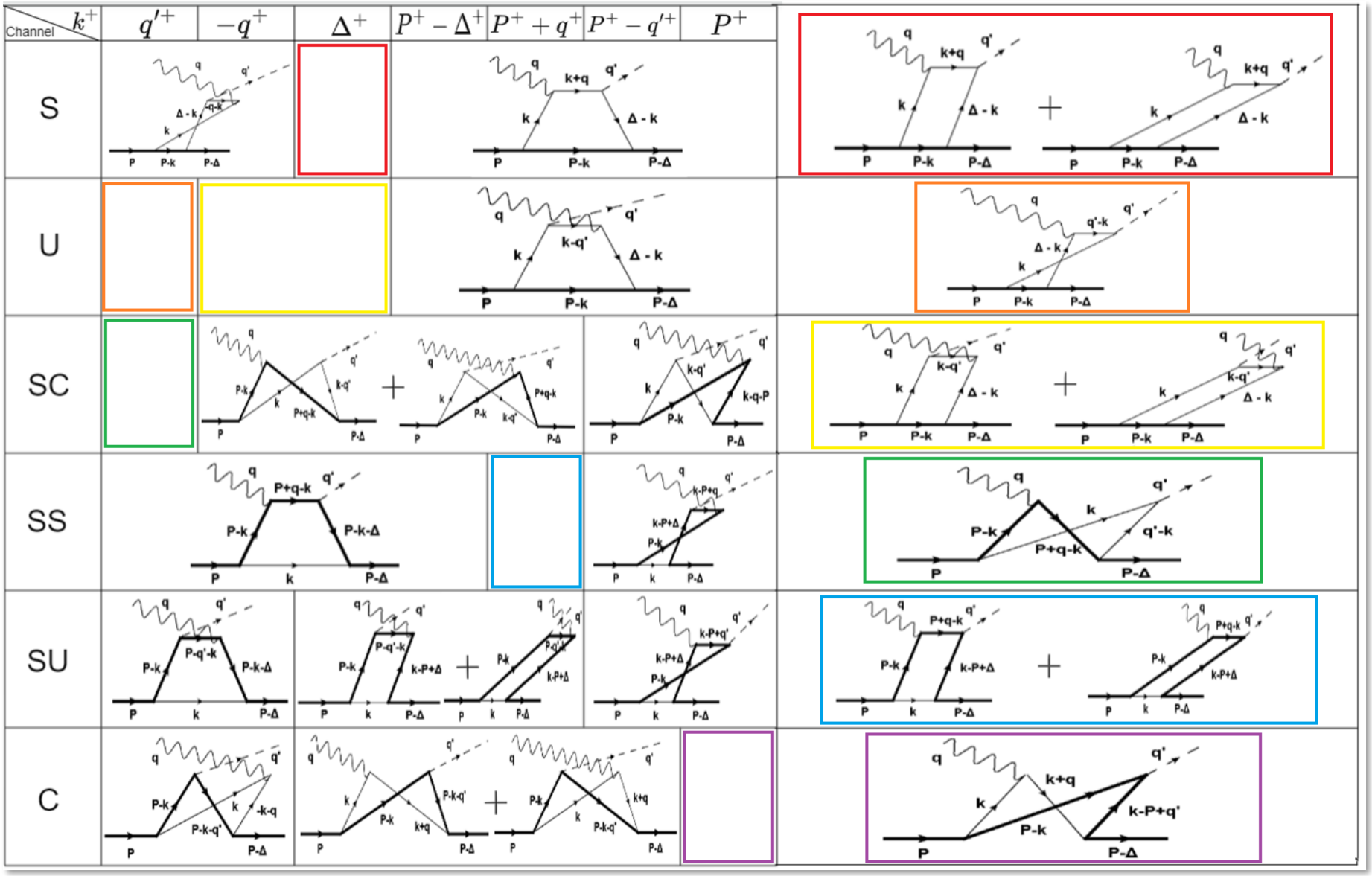
Compton Form Factors Analysis

$$J^{\mu} = \langle p',\ q' |\, \Gamma^{\mu}\, | p, q \rangle$$

- Form factors: coefficient functions of Q^2, x, t. Getting their analytic expressions would fully map the internal structure of the hadrons

$$J^{\mu}_{PS} = F_{PS} \epsilon^{\mu\nu\alpha\beta} q_{\nu} \bar{P}_{\alpha} \Delta_{\beta}$$

$$\begin{aligned} J^{\mu}_{S} \;=\; & F_1 (q^2 \Delta^{\mu} - q \cdot \Delta\, q^{\mu}) \\ & + F_2 [(\bar{P} \cdot q + q^2) \Delta^{\mu} - q \cdot \Delta\, (\bar{P}^{\mu} + q^{\mu})] \end{aligned}$$


Channel
k^+
q'^+
$-q^+$
Δ^+
$P^+ - \Delta^+$
$P^+ + q^+$
$P^+ - q'^+$
P^+
S
U
SC
SS
SU
C

DVMP Limit

$$Q^2 \gg (M_T^2, M_S^2, -t)$$

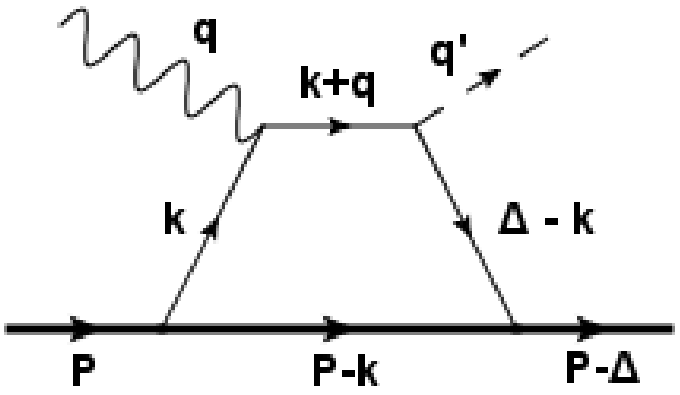
$$\mathscr{M}^{+\text{DVMP}}_{s,\text{hand}} = \frac{e_{Q_1}\mathcal{N}}{4\pi q^-}\int_{\Delta^+}^{P^+} dk^+ \frac{-2k^+ + \Delta^+}{C_s(k_b^- - k_i^-)(k_b^- - k_f^-)}$$

$$\mathscr{M}^{+\text{DVMP}}_{s,\text{twist}} = \frac{e_{Q_1}\mathcal{N}}{4\pi q^-}\int_{0}^{\Delta^+} dk^+ \frac{2k^+ - \Delta^+}{C_s(k_i^- - k_b^-)(k_i^- - k_f^-)}$$

Only a few diagrams carry a significant contribution to the scattering amplitude.
Namely, none of the C-Channel and none of the Effectively-Tree-level diagrams (for the charged target case) contribute.

Model Calculation of Compton Form Factors

- "Bare bones" model calculation
- 1-loop diagrams with simple rules:
  - Hadronic vertices: constant
  - Produced meson: phenomenological vertex
  - Scalar propagator loop (strong convergence); derivative coupling for virtual photon vertex



1+1D Calculation

I am working with Yongwoo Choi on reproducing the 1+1D results with code that readily extends to 3+1D and can quickly cross-check my other 3+1D code (2 different integration methods.)

Analysis of virtual meson production in solvable (1+1) dimensional scalar field theory

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Two *Mathematica* Notebooks

- Analytic contour integration over dk- (by hand)
- Analytic integration over ‘polar’-coordinate-like magnitude of perpendicular momentum
- Numerical integration over dk+ and the remaining ‘angular’ perpendicular momentum
- Gauge invariance satisfied, difficulty getting precision needed to compare to boosted frame (‘E1 boost’) effectively

- Analytic contour integration over dk- (by hand)
- Analytic integration over dk+
- Numerical integration over perpendicular momentum degrees of freedom, once 1+1D check is complete
- Currently trying to find a typo that is preventing gauge invariance from being satisfied
- Yongwoo and I compared one diagram and found agreement at least!

We are close!

Once the gauge invariance is satisfied and the 1+1D calculations are complete, I can also compare numerically to my other 3+1D Notebook, and we should be ready to get numerical data and write a paper very similar to the 1+1D paper already written!

The advantage of the 3+1D calculation however will give us much more to discuss. In particular it will be interesting to see the calculation of the Beam Spin Asymmetry.

Summary

- 1+1D code that I am writing seems close to matching Yongwoo. As it is written as 3+1D code, it will be very easy to extend to 3+1D at the click of a button (or return it to 1+1D). [CTRL+F, replace all of the '/.{lperp->0}' with '/.{lperp->lperp}'!]
- With 3+1D code, investigate the BSA for various kinematics and consider the DVMP limit, compute GPDs directly.

- Extension to more complicated couplings at the meson vertex and more realistic fermion-photon coupling and fermion loop may be readily possible.