Polarized Target for Spectroscopy

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Joint Physics Analysis Center
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Workshop on Polarized Target Studies

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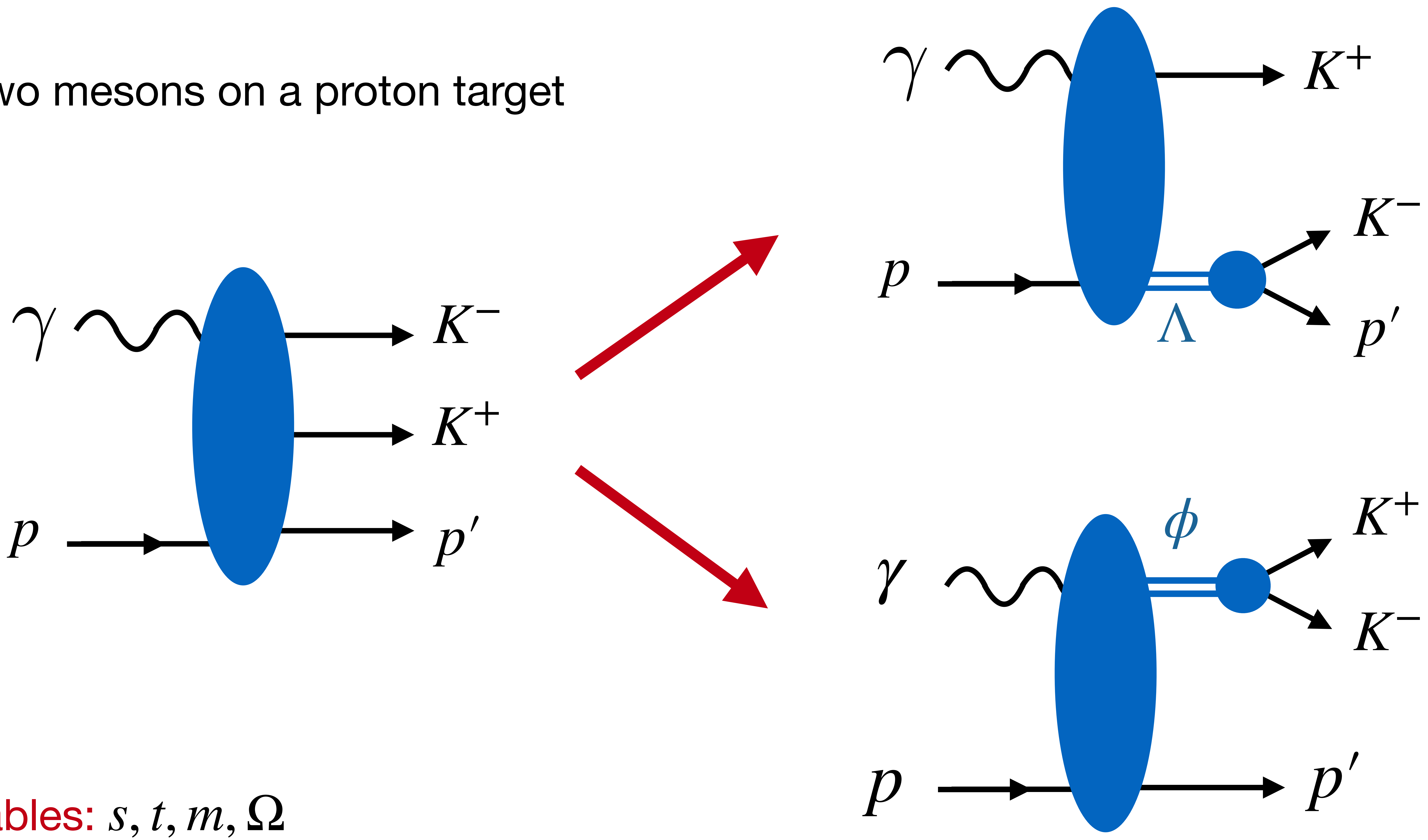
Introduction

Photoproduction of two mesons on a proton target



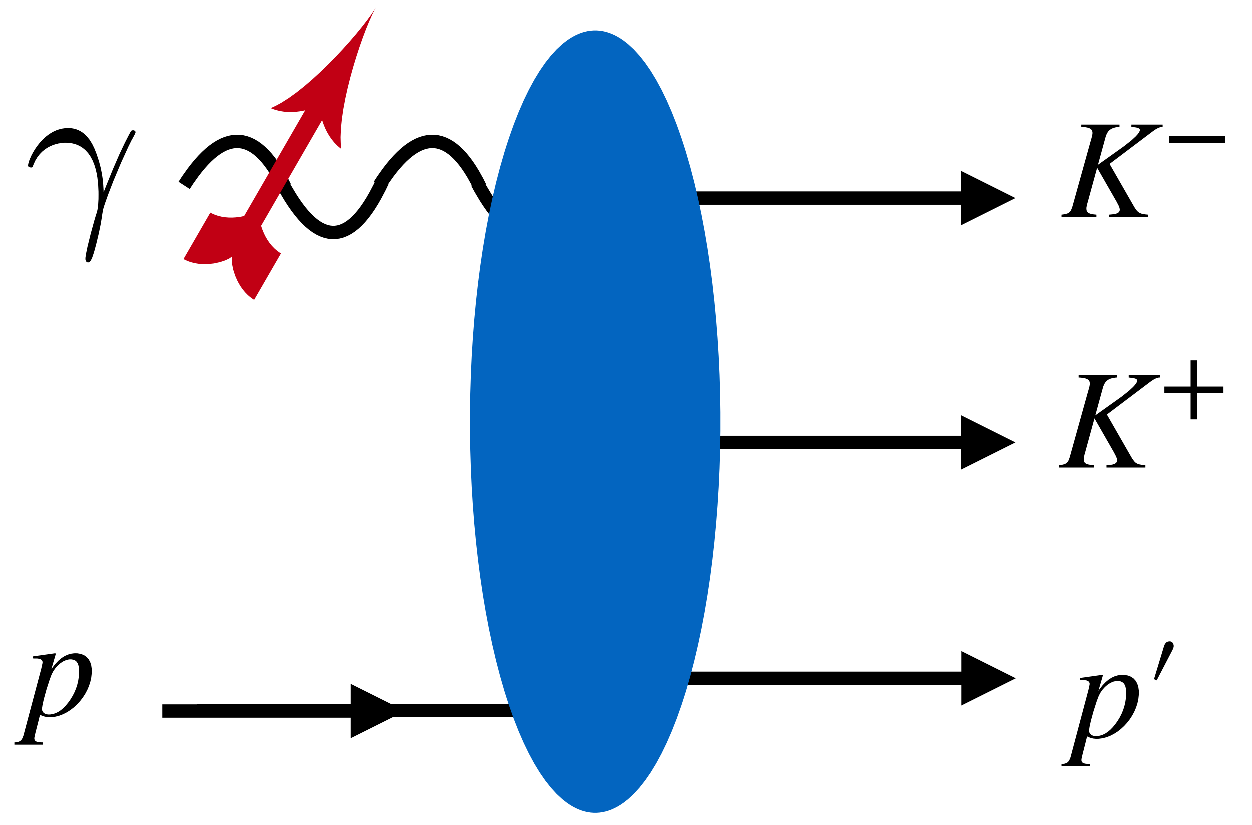
Five independent variables: s, t, m, Ω

Eight independent amplitudes: $\lambda_\gamma = \pm 1, \lambda_1 = \pm \frac{1}{2}, \lambda_2 = \pm \frac{1}{2}$

Intensities

Notations from Roberts and Oed Phys. Rev. C71 055201

With a linearly polarized beam:



$$I = \frac{d\sigma}{dt}\left[1 - \delta_\ell I^c \cos 2\Phi - \delta_\ell I^s \sin 2\Phi\right]$$

δ_ℓ is the degree of linear polarization

With both a linearly and circularly polarized beam:

$$I = \frac{d\sigma}{dt}\left[1 - \delta_\ell I^c \cos 2\Phi - \delta_\ell I^s \sin 2\Phi + \delta_\odot I^\odot\right]$$

$\delta_\odot$ is the degree of circular polarization

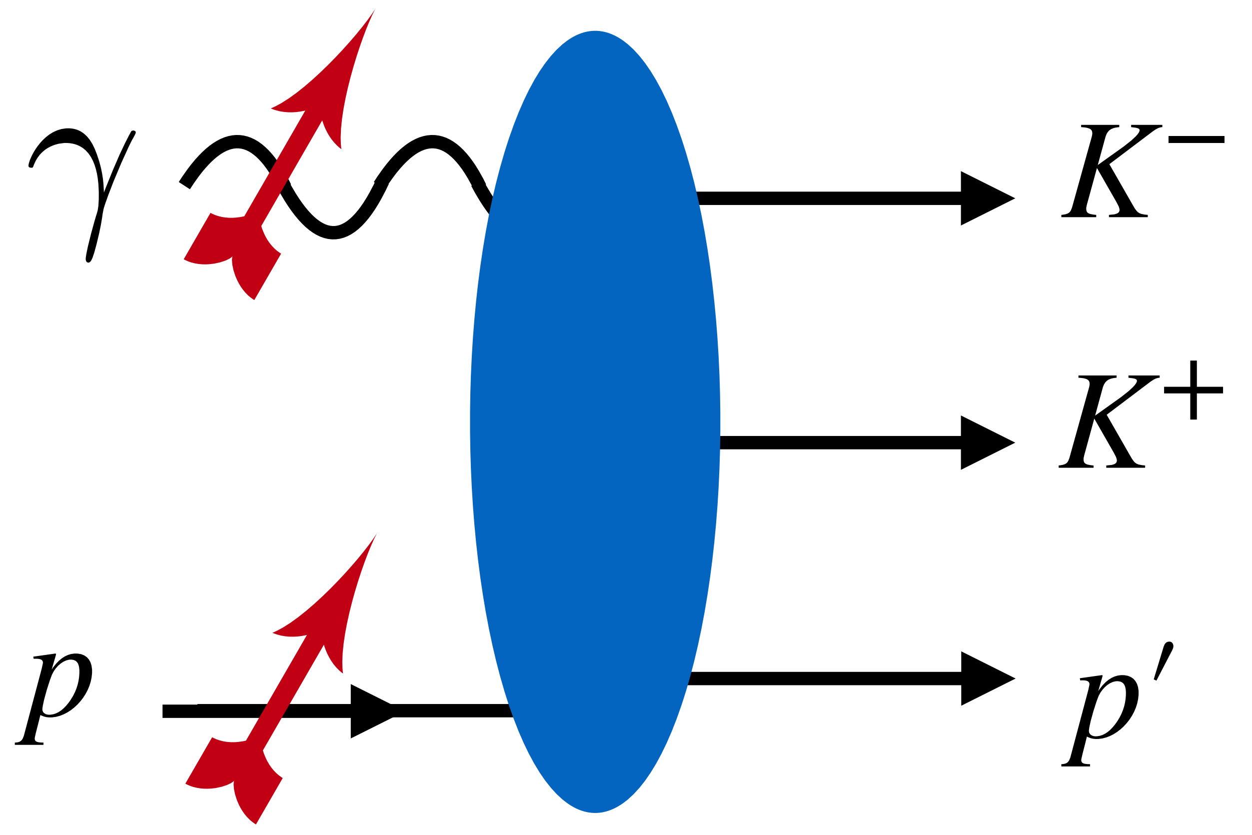
SDME of the beam $\rho^\gamma = \frac{1}{2} I + \frac{1}{2} \overrightarrow{P}_\gamma(\Phi) \cdot \vec{\sigma}$ With $\overrightarrow{P}_\gamma(\Phi) = (-\delta_\ell \cos 2\Phi, -\delta_\ell \sin 2\Phi, \delta_\odot)$

Intensities

With both a linearly and circularly polarized beam:

$$I = \frac{d\sigma}{dt}\left[1 - \delta_\ell I^c \cos 2\Phi - \delta_\ell I^s \sin 2\Phi + \delta_\odot I^\odot\right]$$

$\delta_\ell, \delta_\odot$ is the degree of linear and circular polarization



With a linearly polarized target:

$$I = \frac{d\sigma}{dt}\left[(1 + \delta_z P_z) - \delta_\ell (I^c + \delta_z P_z^c)\cos 2\Phi - \delta_\ell (I^s + \delta_z P_z^s)\sin 2\Phi + \delta_\odot (I^\odot + \delta_z P_z^\odot)\right]$$

SDME of the target $\rho^T = \frac{1}{2} I + \frac{1}{2}\overrightarrow{P}_T \cdot \vec{\sigma}$ With $\overrightarrow{P}_T = (0,0,\delta_z)$

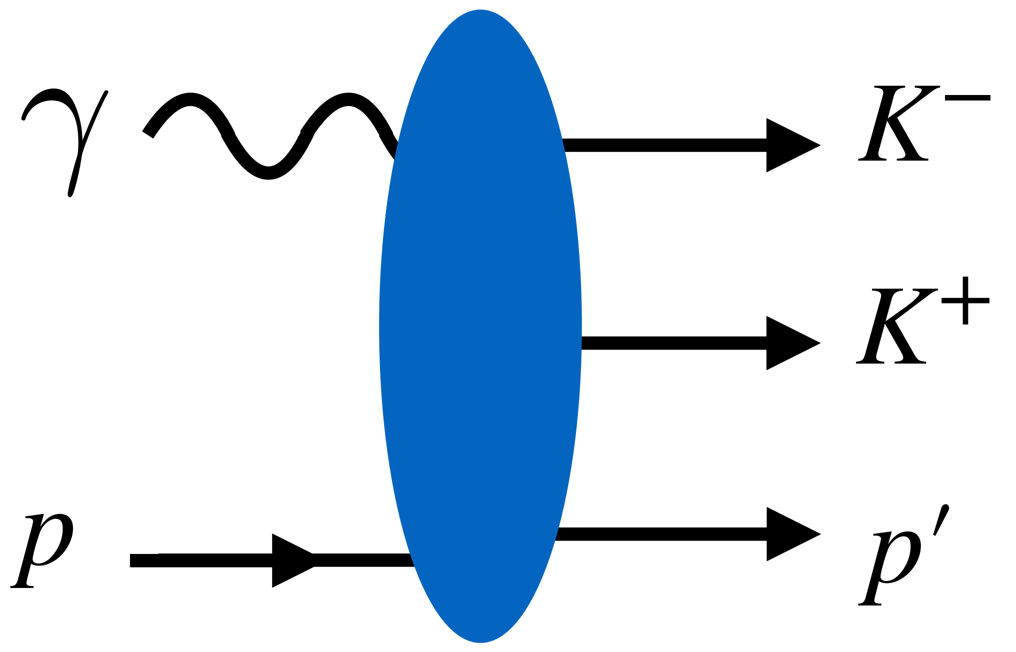
eight observables $d\sigma/dt, P_z, I^c, I^s, I^\odot, P_z^c, P_z^s, P_z^\odot$ depending on five variables

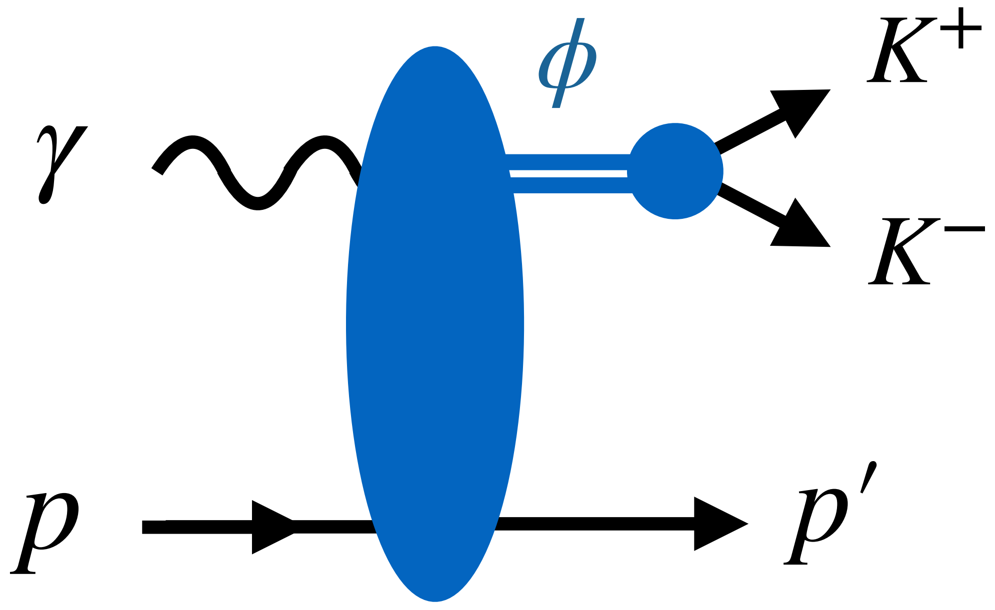
Intensities

With a linearly polarized target:

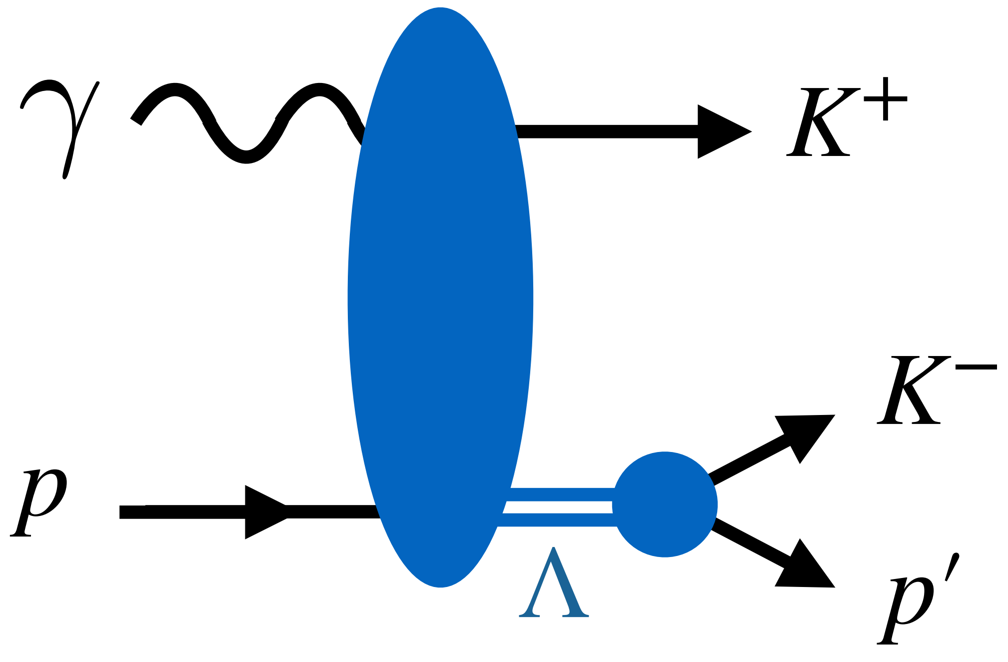
$$I = \frac{d\sigma}{dt}\left[(1 + \delta_z \cancel{P_z}) - \delta_\ell(I^c + \delta_z \cancel{P_z^c})\cos 2\Phi - \delta_\ell(I^s + \delta_z \cancel{P_z^s})\sin 2\Phi + \delta_\odot(\cancel{I^\odot} + \delta_z P_z^\odot)\right]$$

Reduction to $2 \to 2$ process, by integrating over decay angles



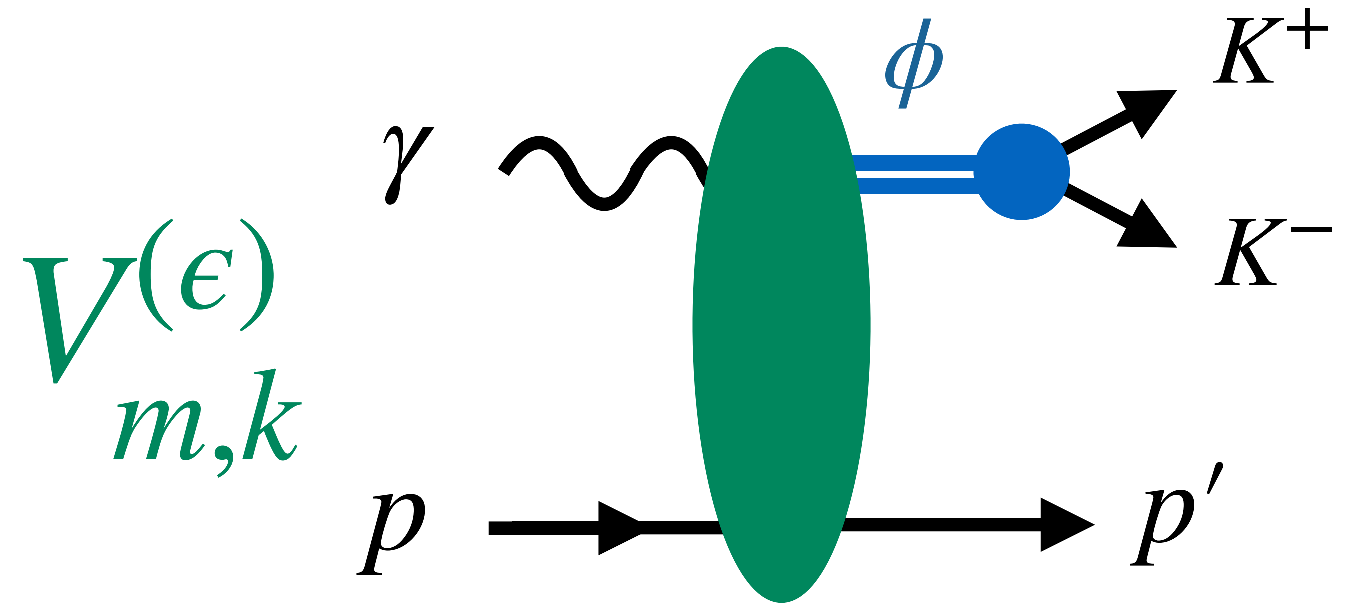


Or



Several observables vanishes by parity conservation

Meson Spectroscopy



$\epsilon = \pm 1$

$m = -J, \ldots, +J$

$k = 0,1$

With a linearly polarized target:

$$I = \frac{d\sigma}{dt}\left[1 - \delta_\ell I^c \cos 2\Phi - \delta_\ell I^s \sin 2\Phi + \delta_\odot \delta_z P_z^\odot\right]$$

Using the reflectivity basis and

Integrating over the decay angles: (omitting the phase space)

$$\frac{d\sigma}{dt} = \frac{1}{2}\sum_{m,k} |V^{(+)}_{m,k}|^2 + |V^{(-)}_{m,k}|^2$$

$$I^c \frac{d\sigma}{dt} = \sum_{m,k} (-1)^m \text{Re}\left[V^{(+)}_{m,k} V^{(+)*}_{-m,k} - V^{(-)}_{m,k} V^{(-)*}_{-m,k}\right]$$

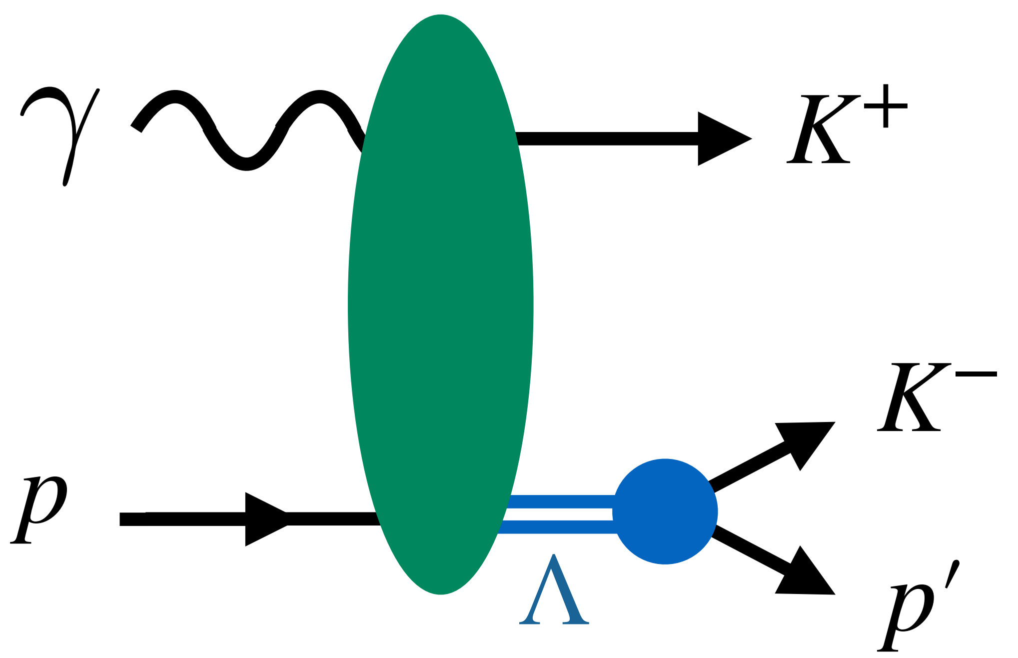
$$P_z^\odot \frac{d\sigma}{dt} = \sum_{m,k} \text{Re}\left[V^{(+)}_{m,k} V^{(-)*}_{m,k}\right]$$

$$I^s \frac{d\sigma}{dt} = \sum_{m,k} (-1)^m \text{Im}\left[V^{(+)}_{m,k} V^{(+)*}_{-m,k} - V^{(-)}_{m,k} V^{(-)*}_{-m,k}\right]$$

Meson Spectroscopy

With a linearly polarized target:

$$I = \frac{d\sigma}{dt}\left[1 - \delta_\ell I^c \cos 2\Phi - \delta_\ell I^s \sin 2\Phi + \delta_\odot \delta_z P_z^\odot\right]$$



$$\tilde{V}_k^{(\epsilon)}$$

$$\epsilon = \pm 1$$

$$k = 0,\ldots,2J+1$$

Using the reflectivity basis and

Integrating over the decay angles: (omitting the phase space)

$$\frac{d\sigma}{dt} = \frac{1}{2}\sum_k |\tilde{V}_k^{(+)}|^2 + |\tilde{V}_k^{(-)}|^2$$

$$I^c \frac{d\sigma}{dt} = \frac{1}{2}\sum_k |\tilde{V}_k^{(+)}|^2 - |\tilde{V}_k^{(-)}|^2$$

$$P_z^\odot \frac{d\sigma}{dt} = \sum_k \text{Re}\left[\tilde{V}_k^{(+)} \tilde{V}_k^{(-)*}\right]$$

Future directions

With a linearly polarized target and linear+circular beam polarization:

$$I = \frac{d\sigma}{dt}\left[(1+\delta_z P_z) - \delta_\ell (I^c + \delta_z P_z^c)\cos 2\Phi - \delta_\ell (I^s + \delta_z P_z^s)\sin 2\Phi + \delta_\odot (I^\odot + \delta_z P_z^\odot)\right]$$

What problems could a polarized target solve?
What questions could a polarized target answer?

How could we test those?

QNP2024

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Abstract submission and registration are open

https://indico.icc.ub.edu/event/180/

QNP 2024 BARCELONA

10th International Conference on Quarks and Nuclear Physics

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