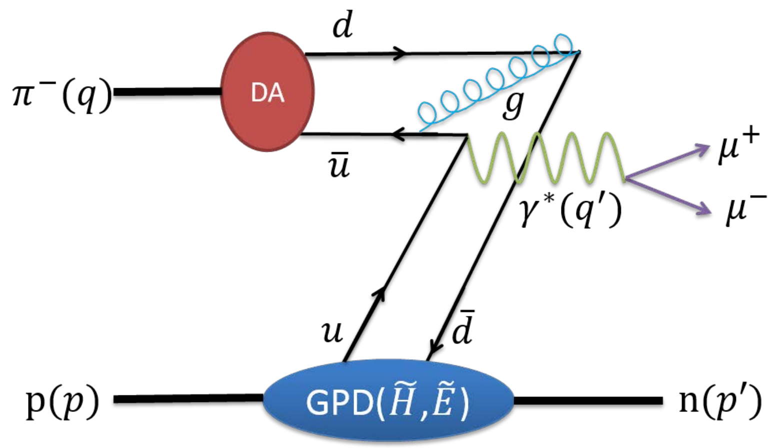
Benchmark Analyses of the π^0 Production off the ^{4}He Target

Chueng-Ryong Ji
North Carolina State University

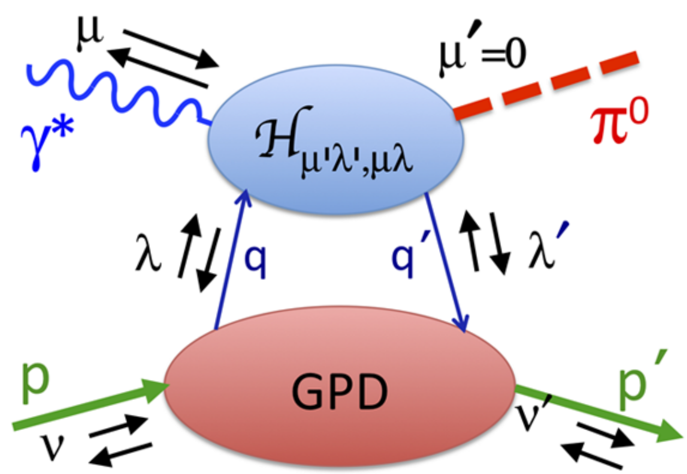
Reimei Symposium on
"Synergies in Hadron Physics between J-PARC and JLab"

November 5, 2019

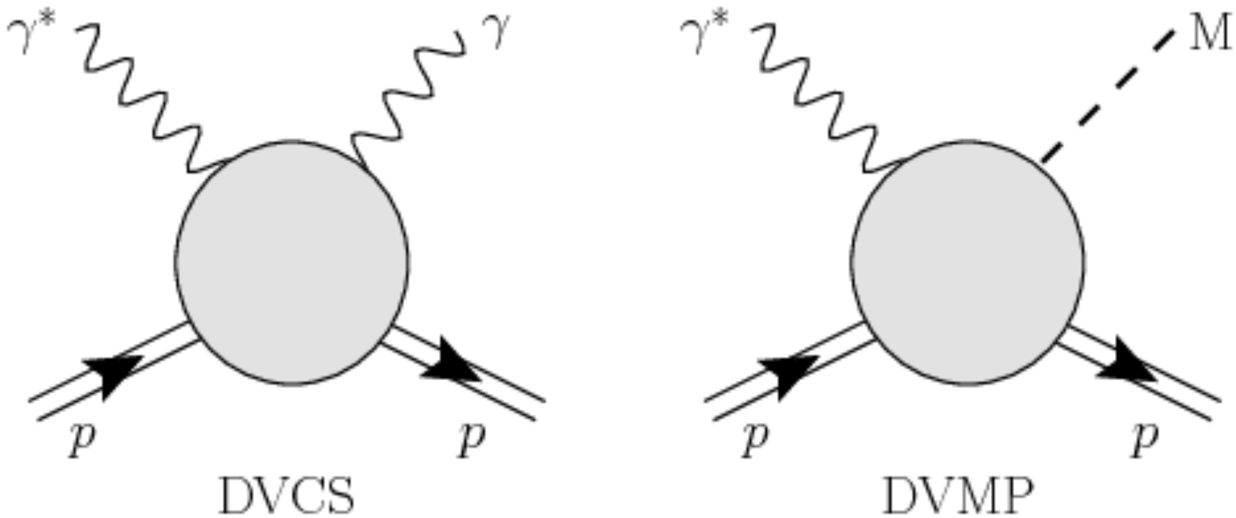
Exclusive pion-induced Drell-Yan process at J-PARC



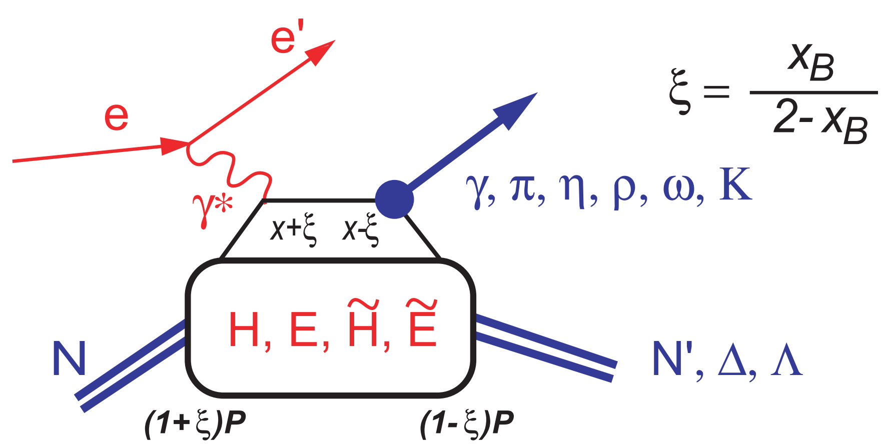
Measurement of Exclusive π^0 Electroproduction at JLab



CLAS Collab.PRL 109, 112001 (2012); PRC90,025205(2014)



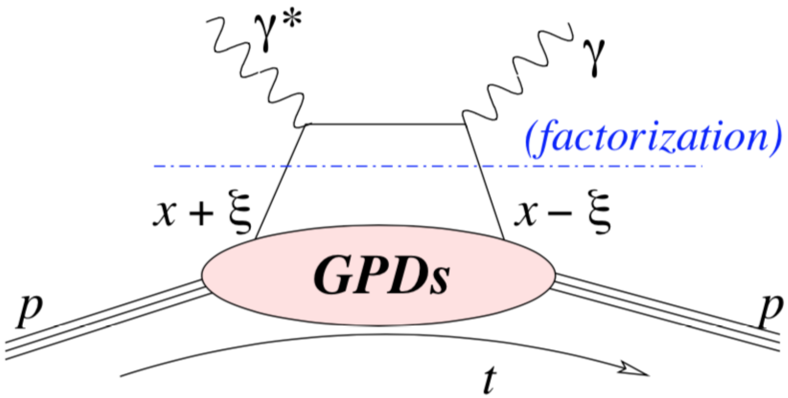
Q^2 >> M^2, |t|,..

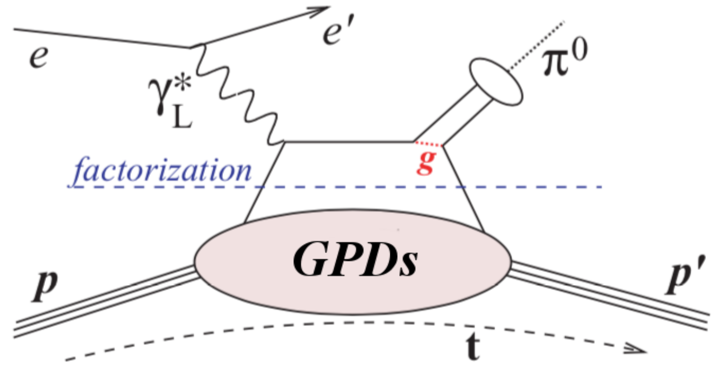


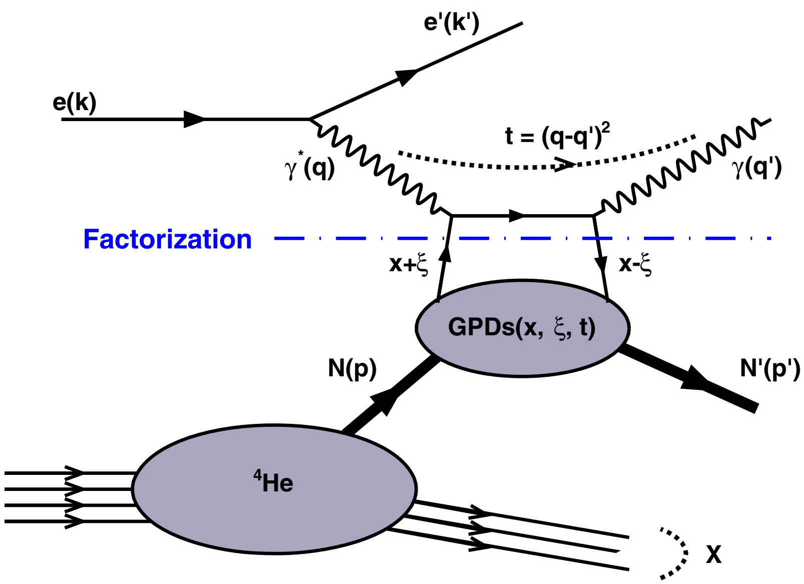
H, E - unpolarized, $\tilde{H}$, $\tilde{E}$ - polarized GPD

The GPDs Define Nucleon Structure

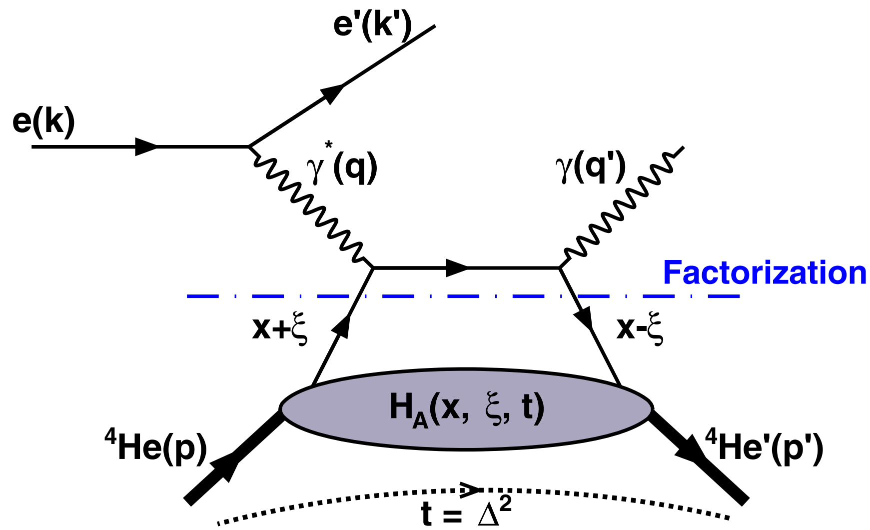
CLAS Collaboration



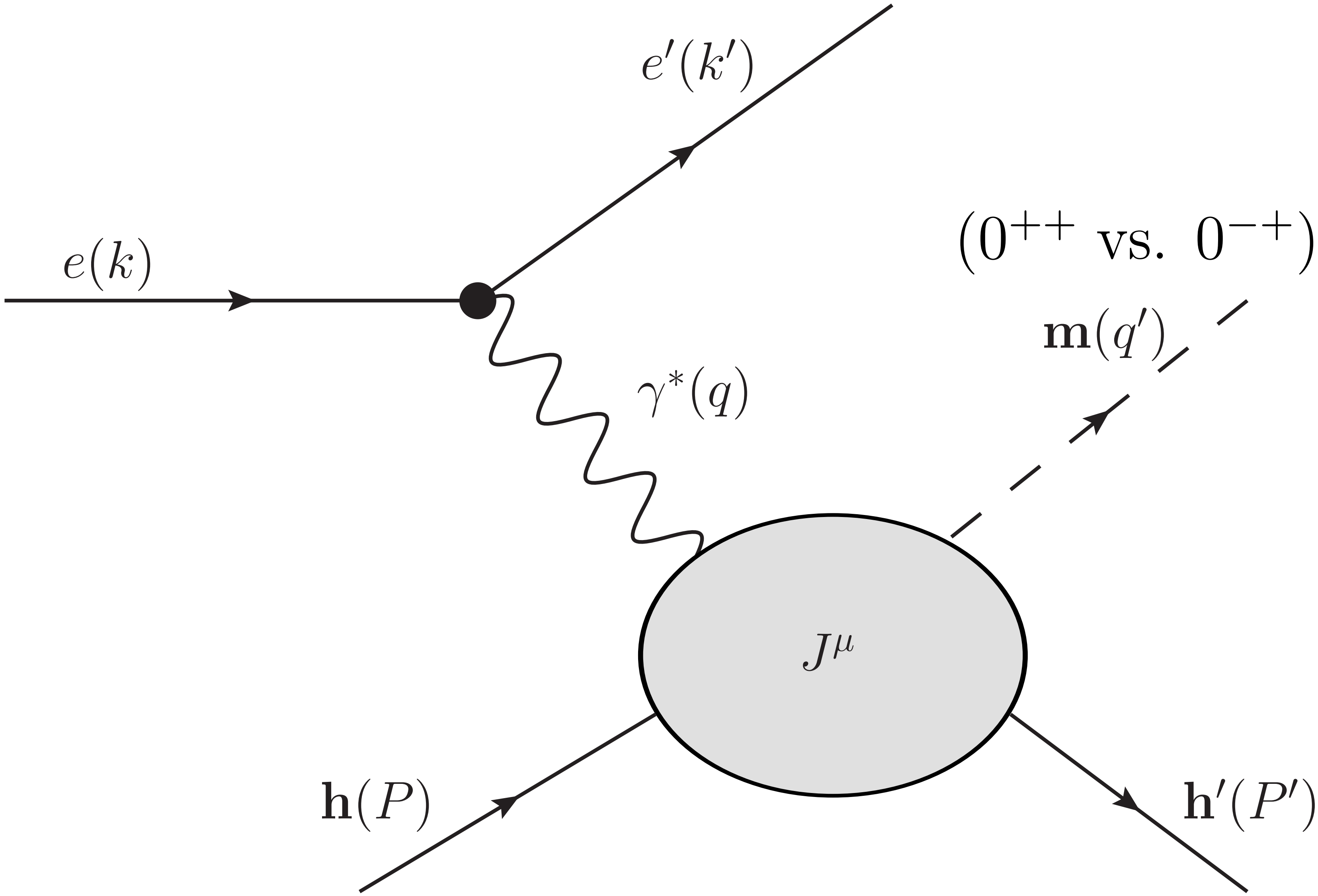




PRL123,032502(2019)



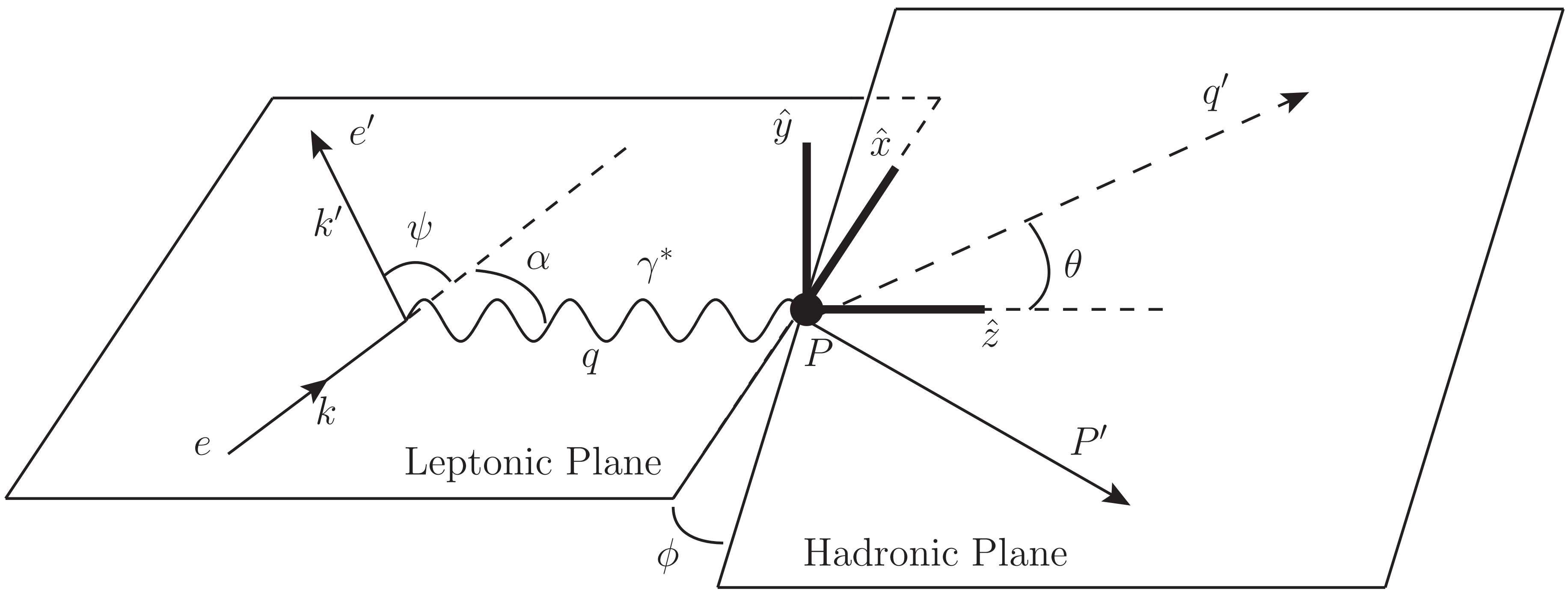
PRL119,202004(2017)



C.Ji, H.-M.Choi, A.Lundeen, B.Bakker
PRD99,116008(2019)

Salient Features

- No interference from Bethe-Heitler process
- BSA of exclusive coherent electroproduction of the π^0 off ^{4}He has been measured.
- Data appear consistent with our benchmark BSA prediction for 0^{-+} meson production off the scalar target.
- General formulation of hadronic amplitudes in Meson Production off the Scalar Target (0^{++} vs. 0^{-+})
- Comparison/Contrast with the leading twist GPD formulation.



e'
k'
ψ
α
γ^*
$\hat{y}$
$\hat{x}$
q'
θ
$\hat{z}$
q
P
k
e
Leptonic Plane
P'
ϕ
Hadronic Plane

5-Fold Differential Cross Section

for unpolarized target and without recoil polarization

The following notation of the coincidence cross section will be used in our calculations. Further details can be found in D. Drechsel and L. Tiator, J. Phys. G 18 (1992) 449-497. (scanned version) (click here for a larger image)

$$\frac{d\sigma}{d\Omega_f dE_f d\Omega} = \Gamma \frac{d\sigma_v}{d\Omega}, \quad \Gamma = \frac{\alpha}{2\pi^2} \frac{E_f}{E_i} \frac{k_\gamma}{Q^2} \frac{1}{1-\varepsilon}$$

$$\frac{d\sigma_v}{d\Omega} = \frac{d\sigma_T}{d\Omega} + \varepsilon \frac{d\sigma_L}{d\Omega} + \sqrt{2\varepsilon(1+\varepsilon)} \frac{d\sigma_{LT}}{d\Omega} \cos\phi$$

$$+ \varepsilon \frac{d\sigma_{TT}}{d\Omega} \cos 2\phi + h\sqrt{2\varepsilon(1-\varepsilon)} \frac{d\sigma_{LT'}}{d\Omega} \sin\phi$$

https://maid.kph.uni-mainz.de/maid2007/cross.html

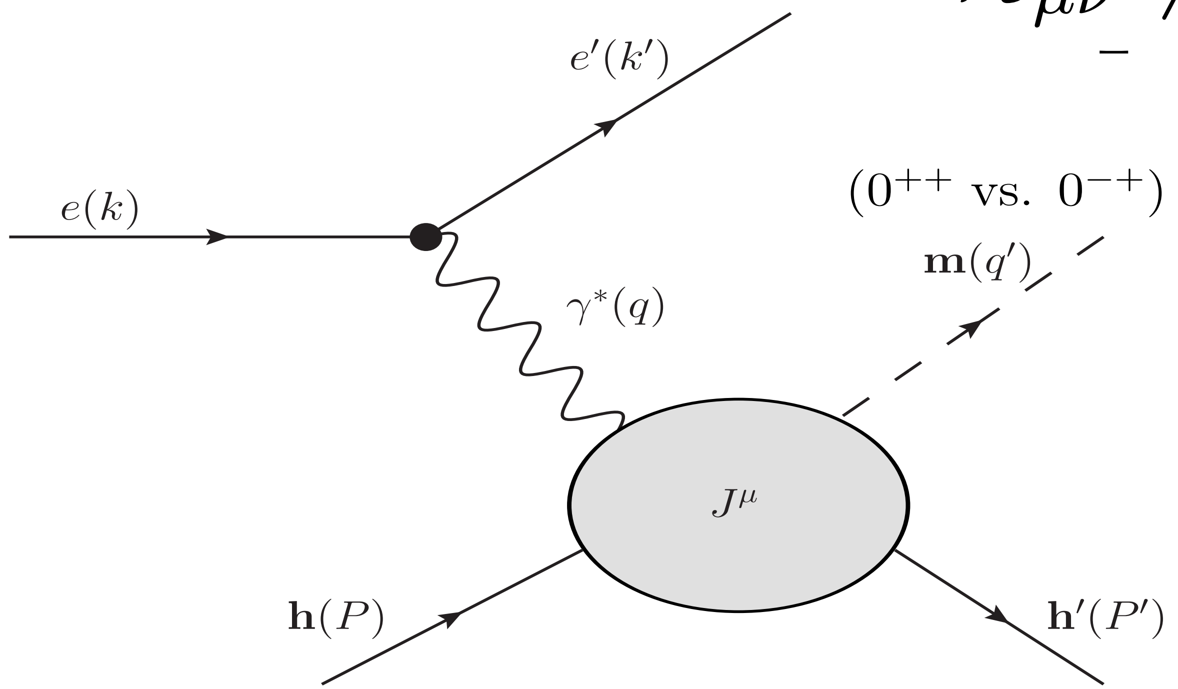
Mainz analysis interactive database (MAID)

$$\langle|\mathcal{M}|^2\rangle = \left(\frac{e^2}{q^2}\right)^2 \mathcal{L}^{\mu\nu}\mathcal{H}_{\mu\nu}$$

$$\mathcal{L}^{\mu\nu} = q^2\left[g^{\mu\nu} + \frac{2}{q^2}(k^\mu k'^\nu + k'^\mu k^\nu)\right] + 2ih\epsilon^{\mu\nu\alpha\beta}k_\alpha k'_\beta$$

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

$$\mathcal{H}_{\mu\nu} \neq \mathcal{H}_{\nu\mu}$$

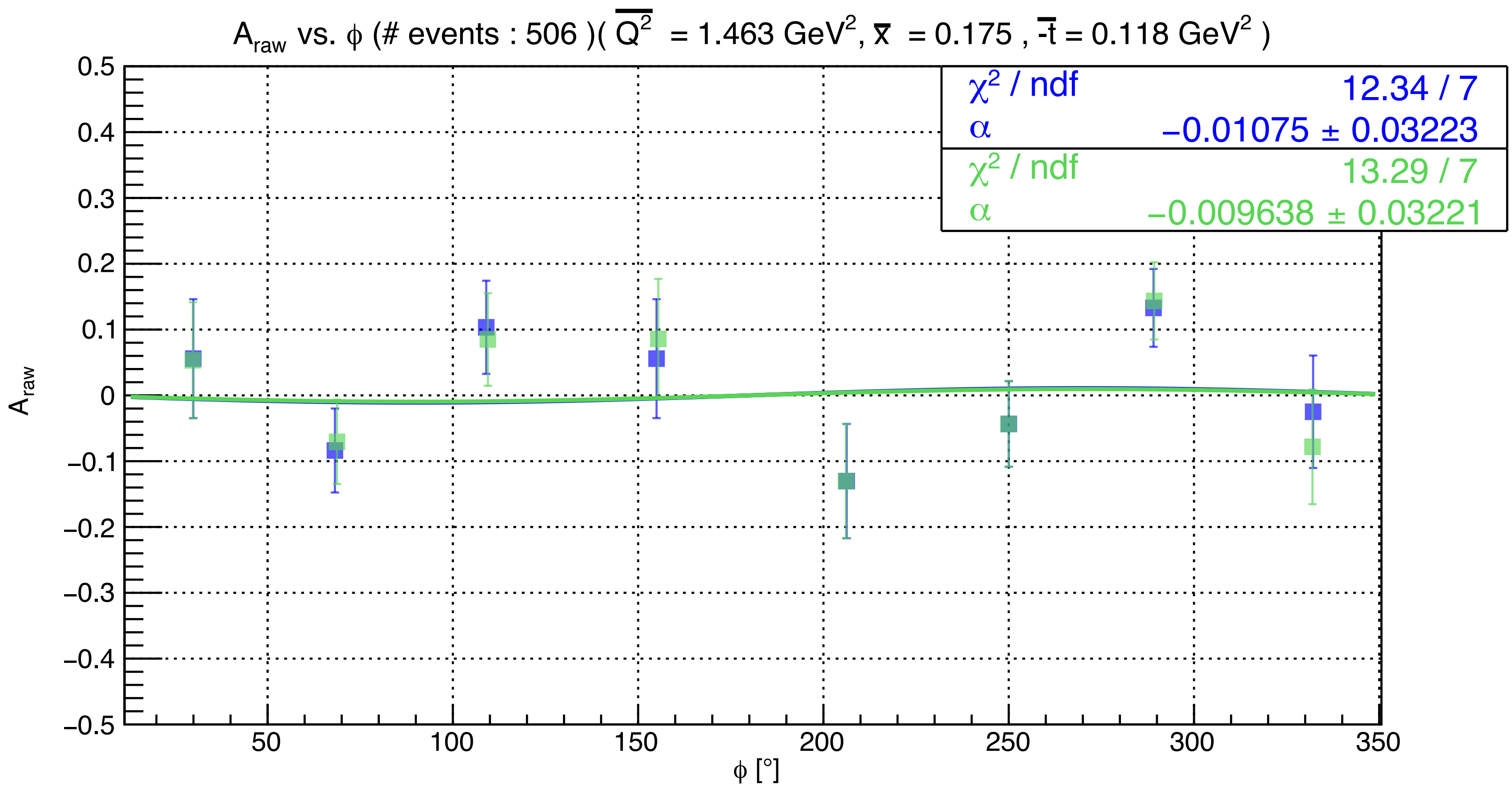


$$\boxed{J^{\mu}_{PS} = F_{PS}\epsilon^{\mu\nu\alpha\beta} q_\nu \bar{P}_\alpha \Delta_\beta}$$

$$\begin{aligned}\mathcal{H}_{\mu\nu} = J^{\dagger}_{\mu} J_\nu \\ &= |F_{PS}|^2 \epsilon_{\mu\alpha\beta\gamma}\epsilon_{\nu\alpha'\beta'\gamma'} q^\alpha \bar{P}^\beta \Delta^\gamma q^{\alpha'} \bar{P}^{\beta'} \Delta^{\gamma'} \\ &= \mathcal{H}_{\nu\mu}\end{aligned}$$

$$\boxed{\epsilon^{\mu\nu\alpha\beta} k_\alpha k'_\beta \mathcal{H}_{\mu\nu} = 0}$$

$$\frac{d\sigma^{PS}_{h=+1} - d\sigma^{PS}_{h=-1}}{d\sigma^{PS}_{h=+1} + d\sigma^{PS}_{h=-1}} = 0$$



$$A_{LU}(\phi) = A_{LU}^{90^\circ} \sin\phi$$

$$A_{LU}^{90^\circ} = -1.08 \pm 3.22\,(\text{stat.}) \pm 2.83\,(\text{sys.})\,\%$$

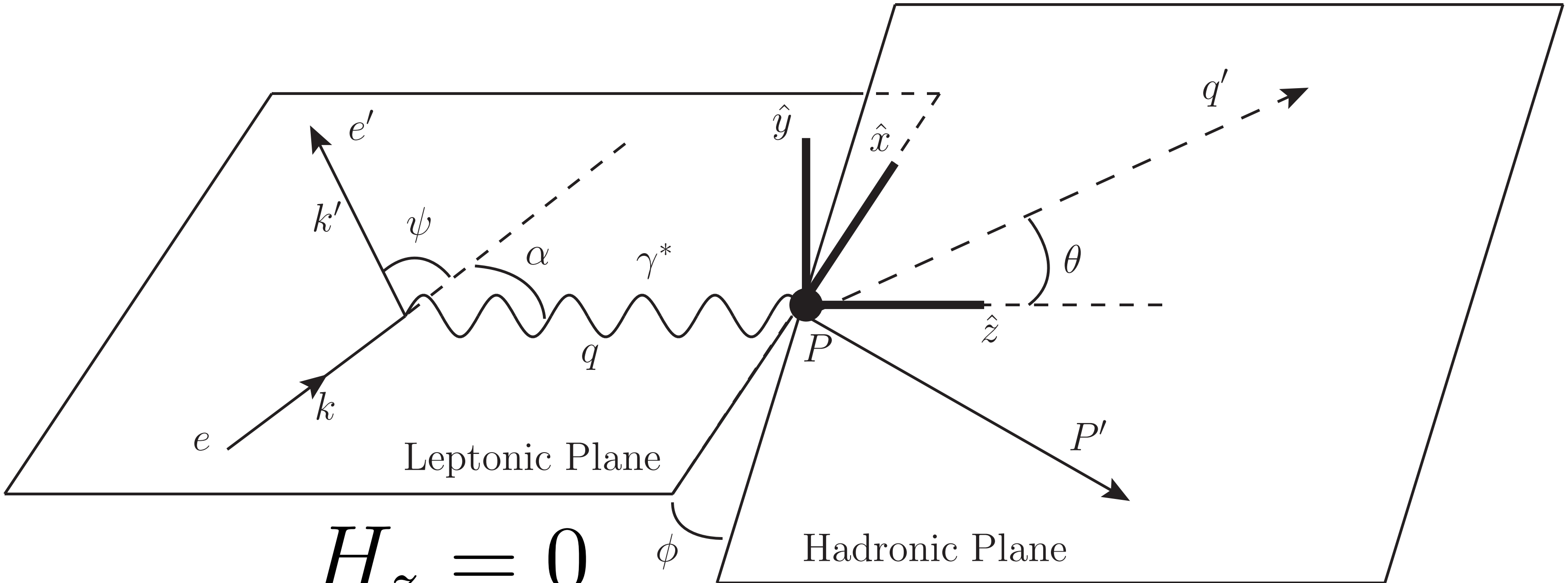
4-26-2019

Beam-Spin Asymmetry of Exclusive Coherent Electroproduction of the π0 Off 4He

Frank Thanh Cao

University of Connecticut - Storrs, franktcao@gmail.com

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



$$H_z = 0$$

$$\begin{aligned} d\sigma^{PS} &= d\sigma^{PS}_{T} + d\sigma^{PS}_{TT}\epsilon\cos 2\phi \\ &= d\sigma^{PS}_{T}(1 - \epsilon\cos 2\phi) \end{aligned}$$

$$d\sigma^{PS}_{T} = \kappa \frac{e^4 |F_{PS}(Q^2, t, x)|^2 \sin^2\theta}{4M^2 x^4 (1-\epsilon)} \left(4M^2 x^2 + Q^2\right) \left[x^2\left(t^2 - 4m^2 M^2\right) + Q^4 + 2Q^2 t x\right]$$

Equivalently general benchmark prediction is feasible to the reverse processes envisioned in JPARC experiments, e.g.

$\pi^- + {}^4He \rightarrow {}^4H\ e^+e^-$

Although the Hydrogen-4 is a highly unstable isotope, it may be still identifiable from its decay to tritium through neutron emission.

If the lepton spin polarizations can be measured, then the prediction of the zero spin asymmetry of the lepton pair may be testable.

Conclusion and Outlook

- The general formulation with the Rosenbluth-type separation of the differential cross section for the exclusive π^0 production off ^{4}He is provided.
- In particular, its BSA is predicted to be absent from the general symmetry ground and the data support this prediction.
- Equivalently general formulation is feasible for the reverse processes envisioned in JPARC experiments, e.g.

$$\pi^- + {}^4\mathrm{He} \rightarrow {}^4\mathrm{H}\, e^+e^-$$