JLab Hypernuclear Collaboration Meeting 2022

η' production (E12-17-003)

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INTRODUCTION

◆ What's the η' meson?

A member of the pseudoscalar meson nonet

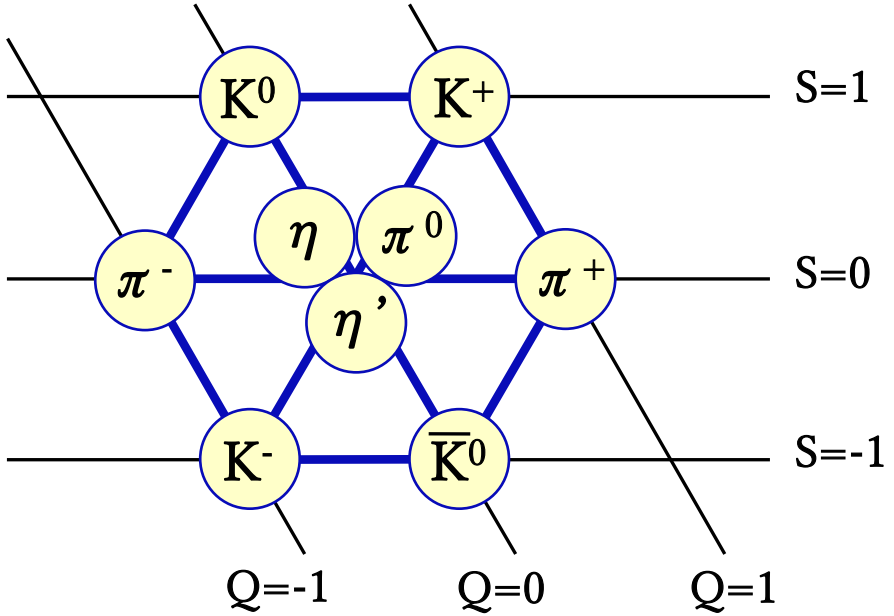
Mass: 958 MeV/c^2 Strangeness: 0 Isospin: 0

The $q\bar{q}$ composition in $SU_f(3)$: $3 \otimes \bar{3} = 8 \oplus 1$

$$\pi^0 = \frac{1}{\sqrt{2}}\left(u\bar{u} - d\bar{d}\right) \quad : \quad I = 1,\ I_3 = 0$$

$$\eta_8 = \frac{1}{\sqrt{6}}\left(u\bar{u} + d\bar{d} - 2s\bar{s}\right) \approx \eta \quad : \quad I = 0$$

$$\eta_1 = \frac{1}{\sqrt{3}}\left(u\bar{u} + d\bar{d} + s\bar{s}\right) \approx \eta' \quad : \quad I = 0$$



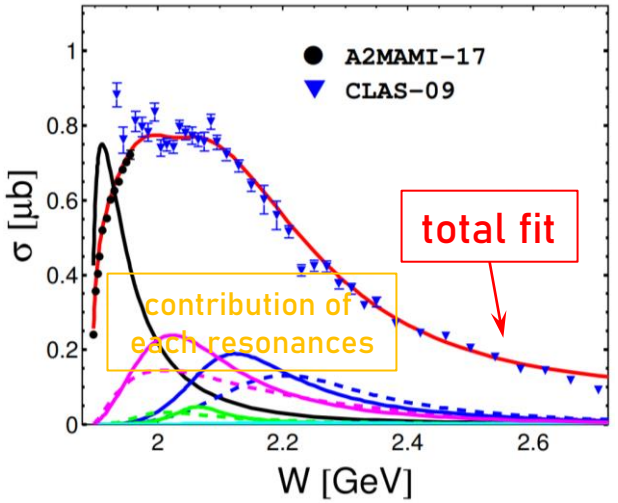
It has much larger mass by $U_A(1)$ anomaly in QCD.

INTRODUCTION

◆ η '-production off a nucleon (A=1)

- Couples to the nucleon resonances only with isospin I = 1/2
- Photoproduction data ($Q^2 = 0$) : CLAS, A2MAMI, CBELSA/TAPS
- Theories to fit and reproduce the photo-pro. data (EtaMAID, etc.)
- Scarce electroproduction data ($Q^2 > 0$): accessible (in backward angle) as a by-product in the hypernuclear spectroscopy.

L. Tiator et.al., Eur.Phys.. A 54 (2018), 210.



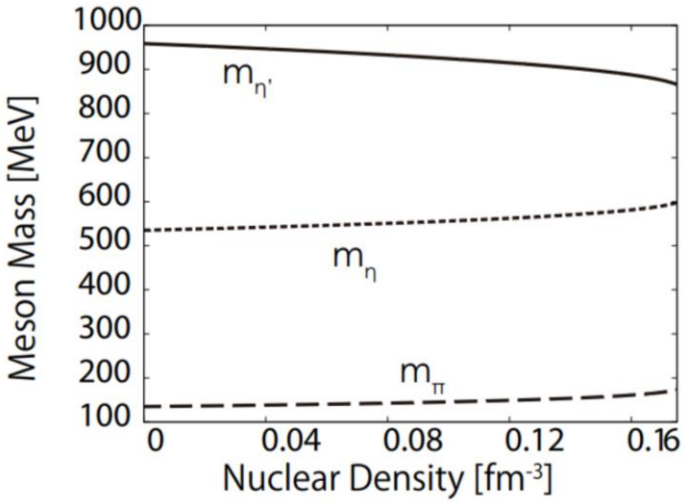
◆ off nuclei (A≧2)

- Mass reduction in the nuclear density (-40 MeV/c^2 ~ -150 MeV/c^2, model dependent) due to partial restoration of the chiral symmetry

→ Strong attractive interaction between η ' and nuclei (??)

- Searching for the η ' mesic nuclei at GSI and SPring-8

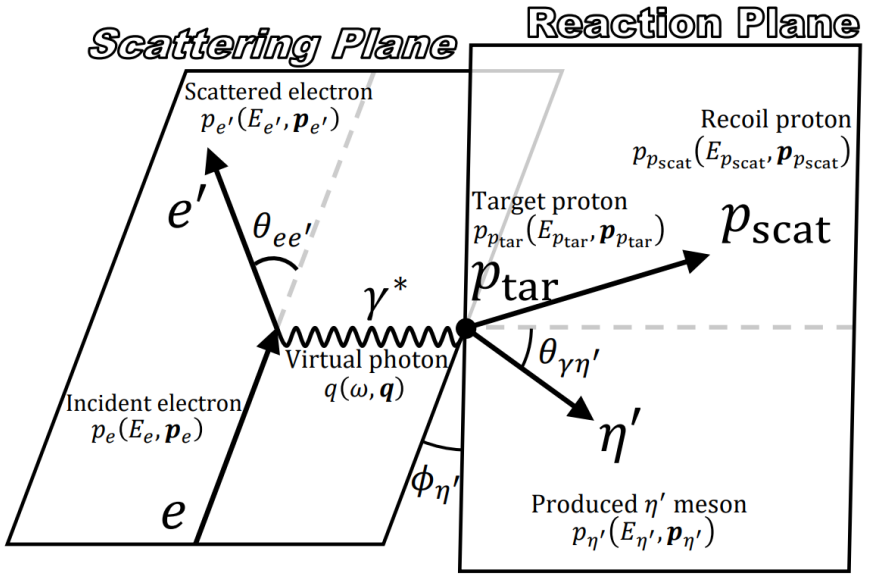
S. Sakai and D. Jido, PRC 88 (2013), 064906.



INTRODUCTION

◆ η '-electroproduction in the JLab hypernuclear experiment

- The $e^- + p \rightarrow e^- + p + \eta'$ reaction (besides the $e^- + p \rightarrow e^- + \Lambda + K^+$) in the same dataset.
- Understandable by extension from the real photon reaction:



The triple differential cross section of the electroproduction:

$$\frac{\mathrm{d}^3\sigma}{\mathrm{d}E_{e'}\mathrm{d}\Omega_{e'}\mathrm{d}\Omega^{\rm CM}_{\eta'}} = \Gamma\left(\frac{\mathrm{d}\sigma_{\gamma^*}}{\mathrm{d}\Omega^{\rm CM}_{\eta'}}\right)$$

flux of virtual photons with the electron scattering

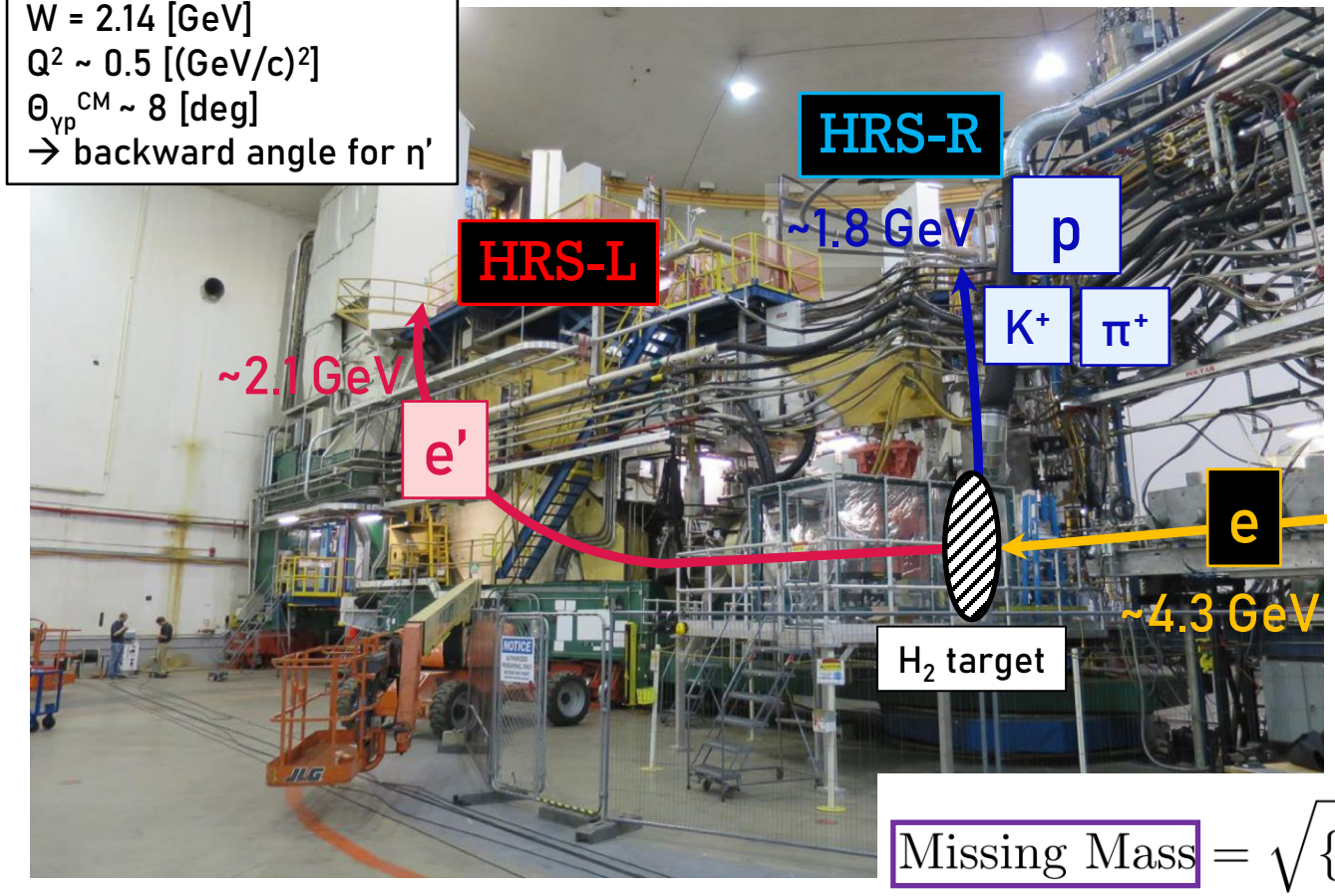
η' production by the virtual photon (γ^*)

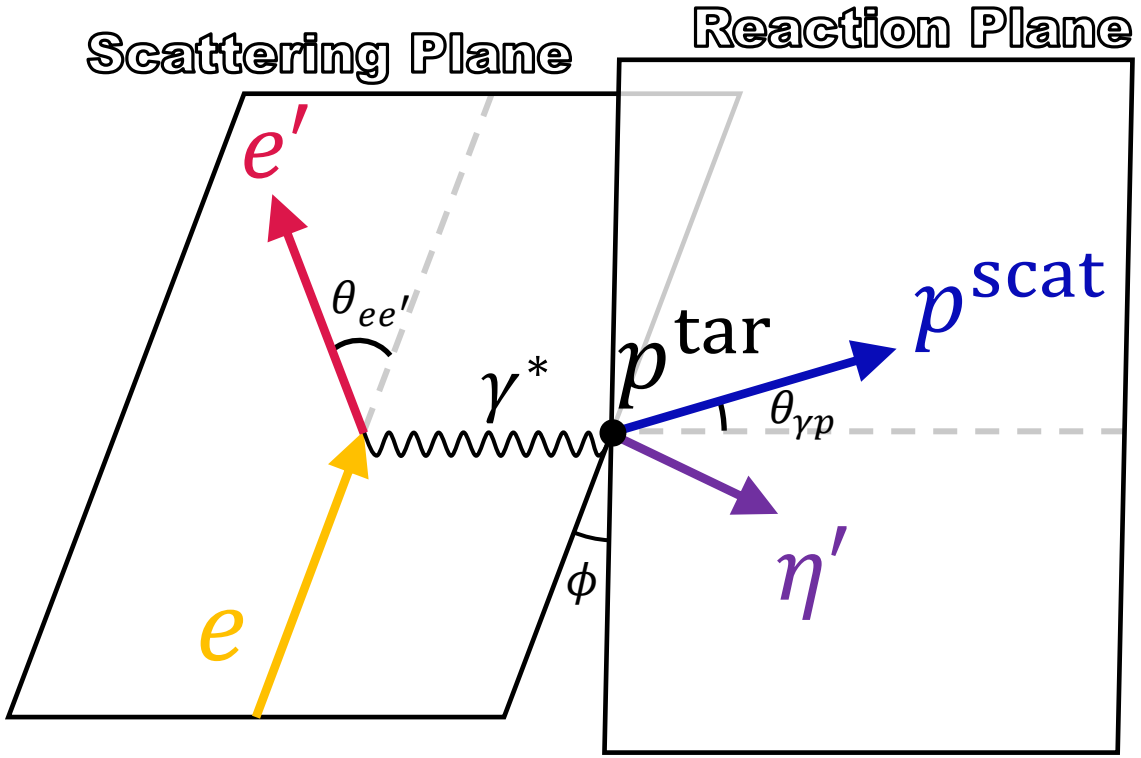
- Measuring the η' generated at a backward angle (almost 180 deg.) relative to the photon in the CM frame (= we can see slower η')

◆JLab E12-17-003 (the nnΛ state search in 2018)

↳ the $e^- + p \rightarrow e^- + p + \eta'$ reaction in the same dataset

W = 2.14 [GeV]
Q^2 ~ 0.5 [$(GeV/c)^2$]
$\Theta_{\gamma p}^{CM}$ ~ 8 [deg]
→ backward angle for η'



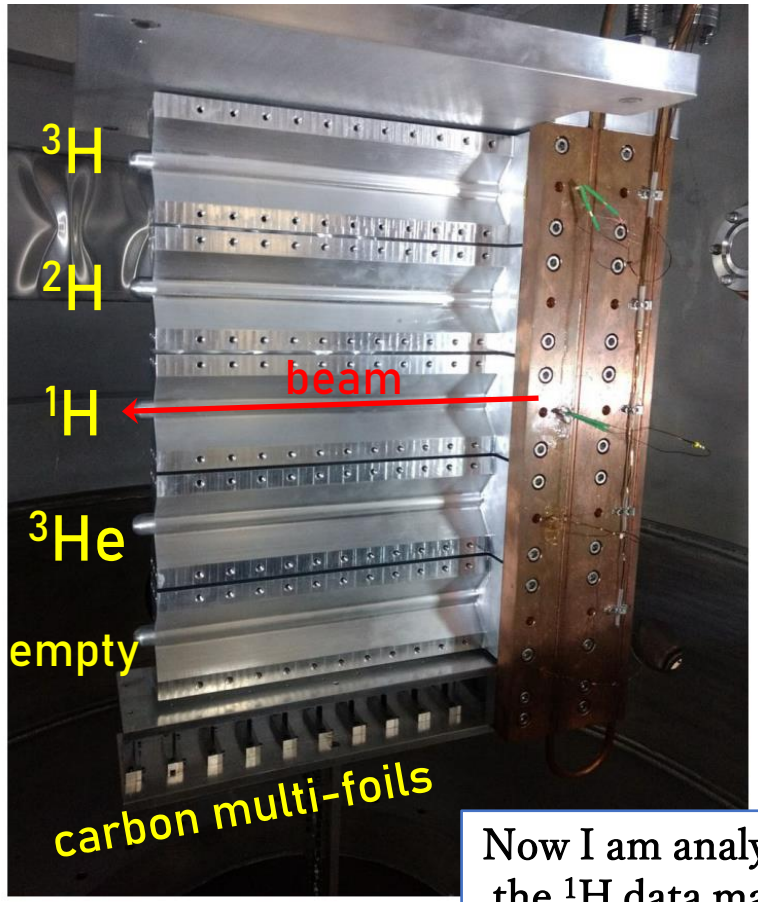


$$\text{Missing Mass} = \sqrt{\{(E_e - E_{e'}) + M_p - E_{p_{\text{scat}}}\}^2 - \{(\boldsymbol{p}_e - \boldsymbol{p}_{e'}) - \boldsymbol{p}_{p_{\text{scat}}}\}^2}$$

ANALYSIS STATUS

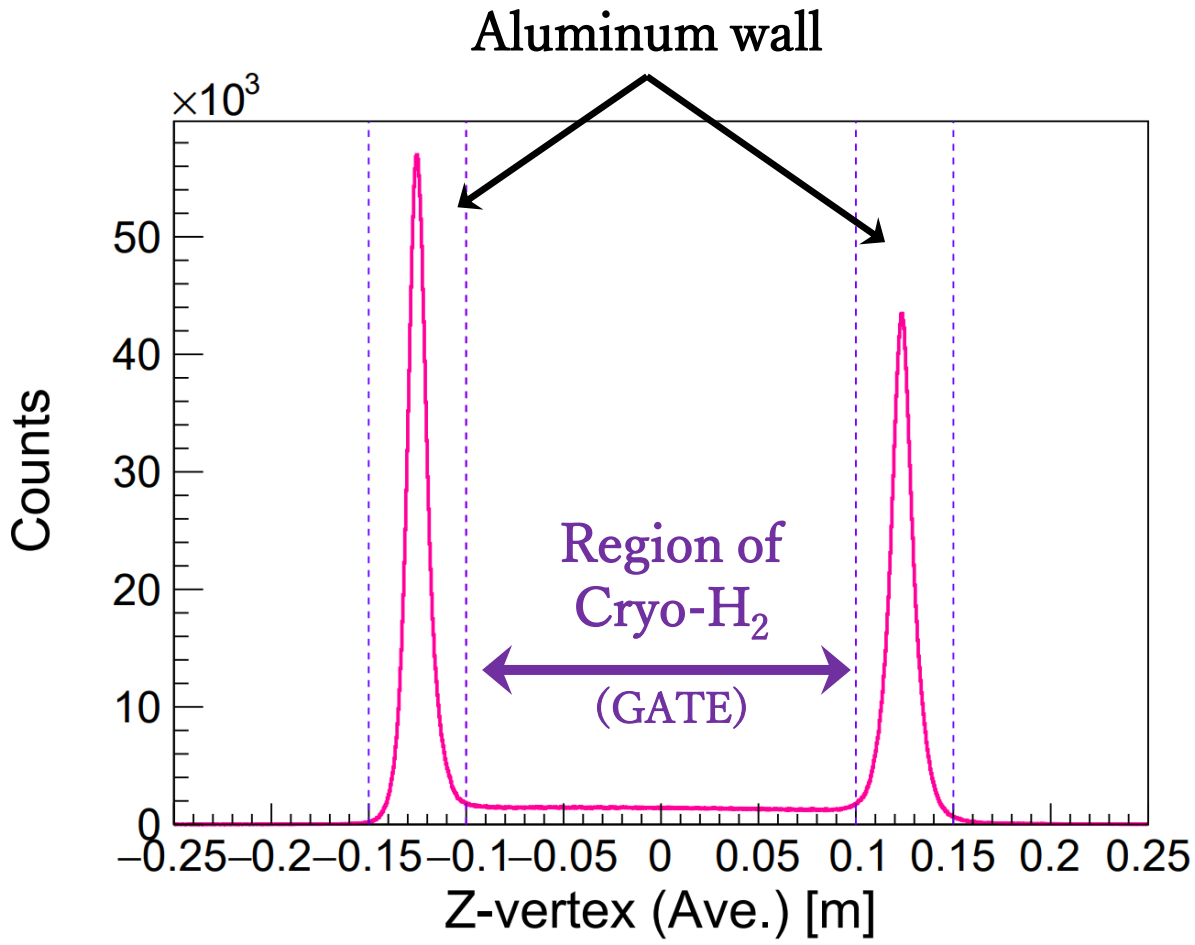
◆Target system

S.N. Santiesteban et.al., NIMA 940 (2019), 351-358.



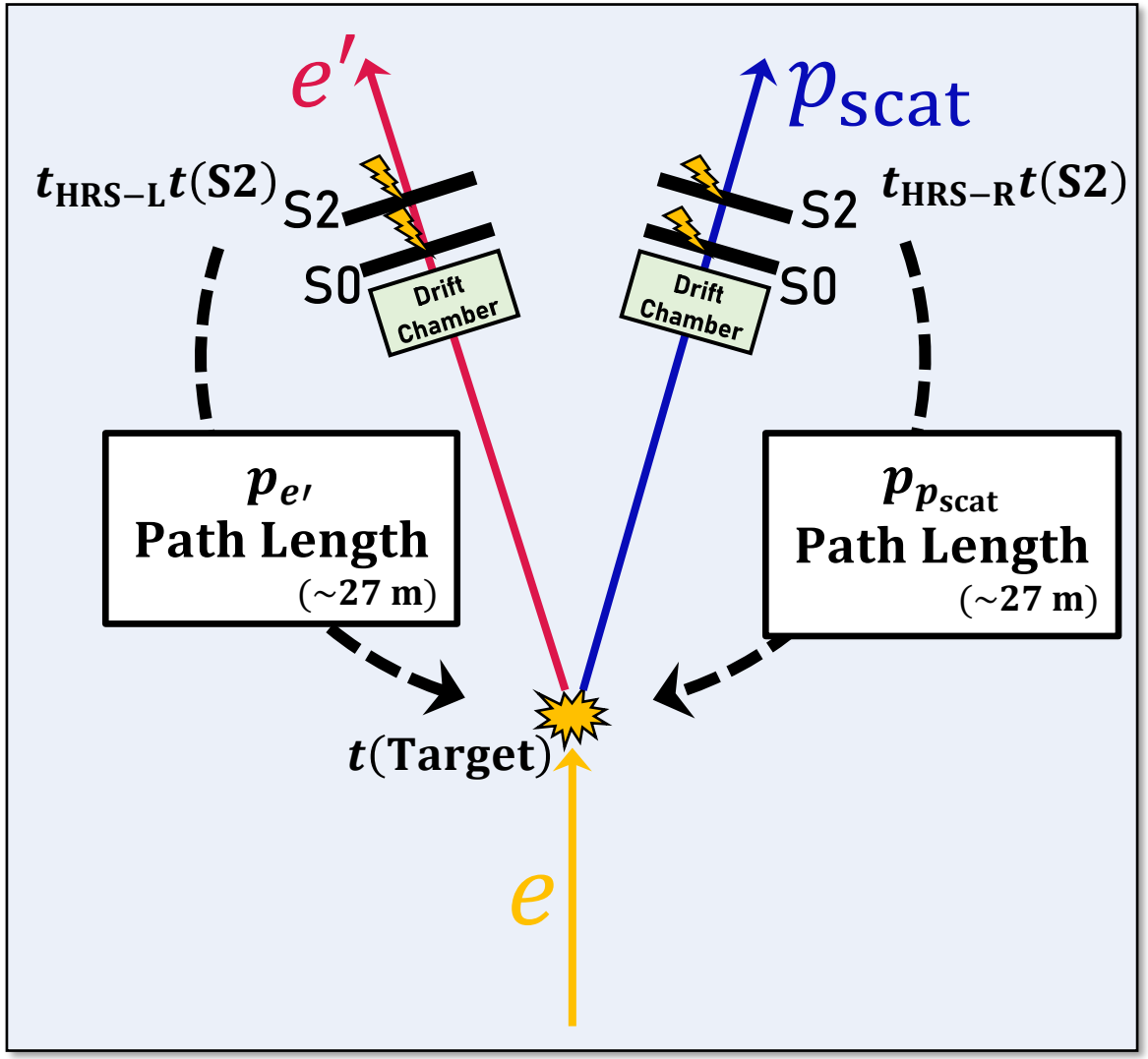
Now I am analyzing the ^{1}H data mainly

◆Event selection by Z_{vertex} cut



ANALYSIS STATUS

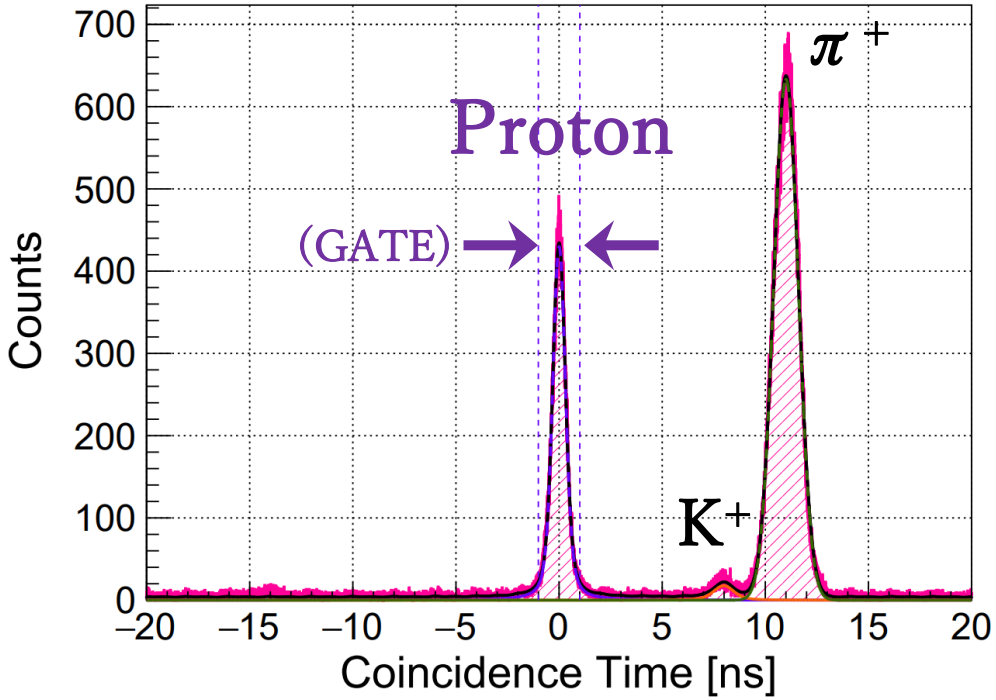
◆Particle ID by the Coincidence Time



$$\text{Coincidence Time} := t_{\text{HRS-L}}\,(\text{Target}) - t_{\text{HRS-R}}\,(\text{Target})\,,$$

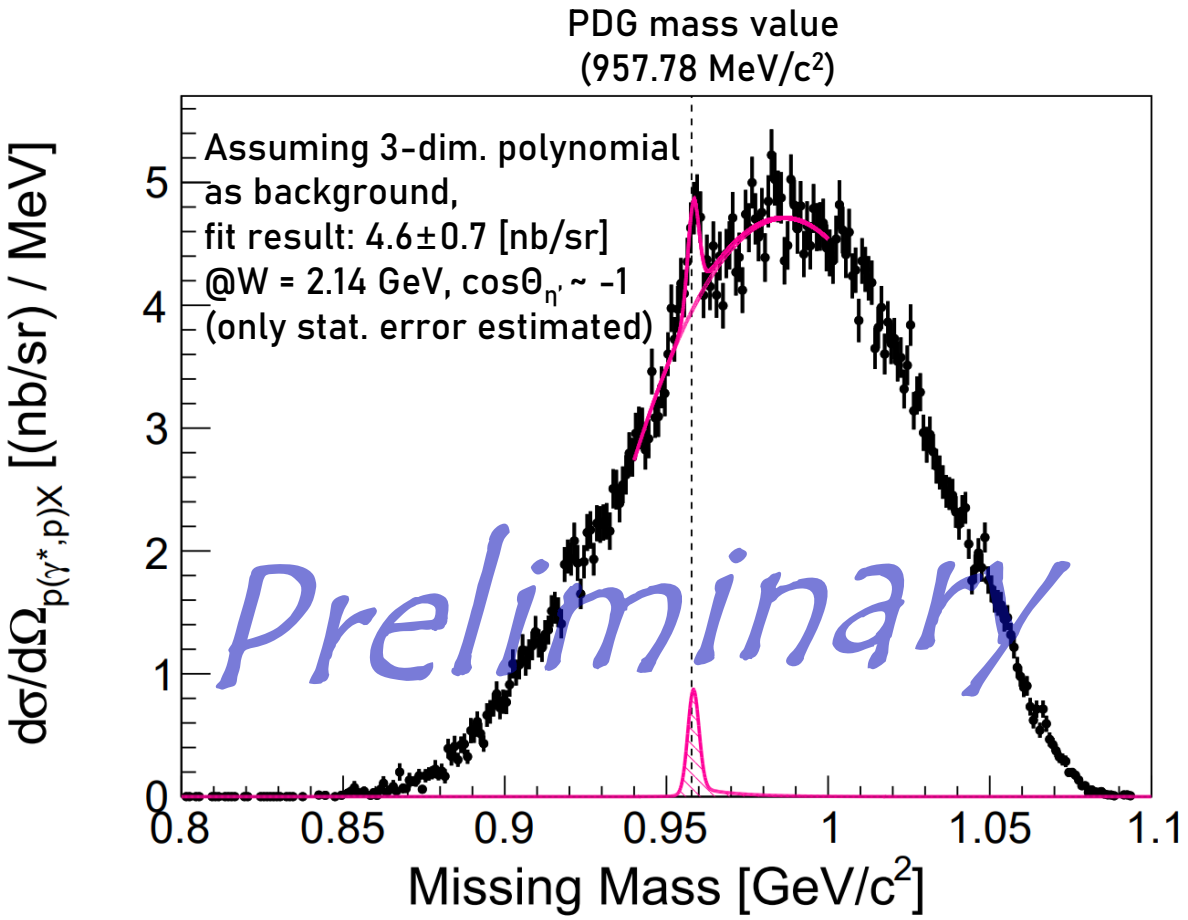
$$t\,(\text{Target}) = t\,(\text{S2}) - \frac{\text{Path Length}}{\beta c}$$

$$= t\,(\text{S2}) - \frac{\sqrt{p^2c^2 + m^2c^4} \times \text{Path Length}}{pc^2}$$



ANALYSIS STATUS

◆Missing mass spectrum of the p(e,e'p)X reaction



$$\overline{\left(\frac{\mathrm{d}\sigma_{\gamma^* p\to pX}}{\mathrm{d}\Omega_p}\right)} \simeq \frac{1}{N_{\mathrm{Target}}}\cdot\frac{1}{N_{\gamma^*}}\cdot\frac{1}{\bar{\varepsilon}}\cdot\sum_{i=1}^{N_{\mathrm{accept}}}\frac{1}{\varepsilon_i^{\mathrm{DAQ}}\cdot\Delta\Omega_{\mathrm{HRS-R}}\left(p_{p_{\mathrm{scat}}},z\right)}$$

$$\bar{\varepsilon} := \varepsilon^{\mathrm{Z_{vertex}}}\cdot\varepsilon^{\mathrm{AC}}\cdot\varepsilon^{\mathrm{CoinTime}}\cdot\varepsilon^{\mathrm{FP}}\cdot\varepsilon^{\mathrm{Single}}\cdot\varepsilon^{\mathrm{Track}}\cdot\varepsilon^{\chi^2}\cdot\varepsilon^{\mathrm{Detector}}$$

where the N_{γ^*} can be obtained by integrating the vertual photon flux Γ within the acceptance of HRS-L and the total beam charge,

$$\text{The vertual photon flux:}\quad \Gamma = \frac{\alpha}{2\pi^2 Q^2}\frac{E_\gamma}{1-\varepsilon}\frac{E_{e'}}{E_e}$$

$$\varepsilon = \left[1+2\frac{|\boldsymbol{q}|^2}{Q^2}\tan^2\left(\frac{\theta_{ee'}}{2}\right)\right]^{-1}$$

$$\varepsilon_L = \varepsilon\frac{Q^2}{\omega^2}$$

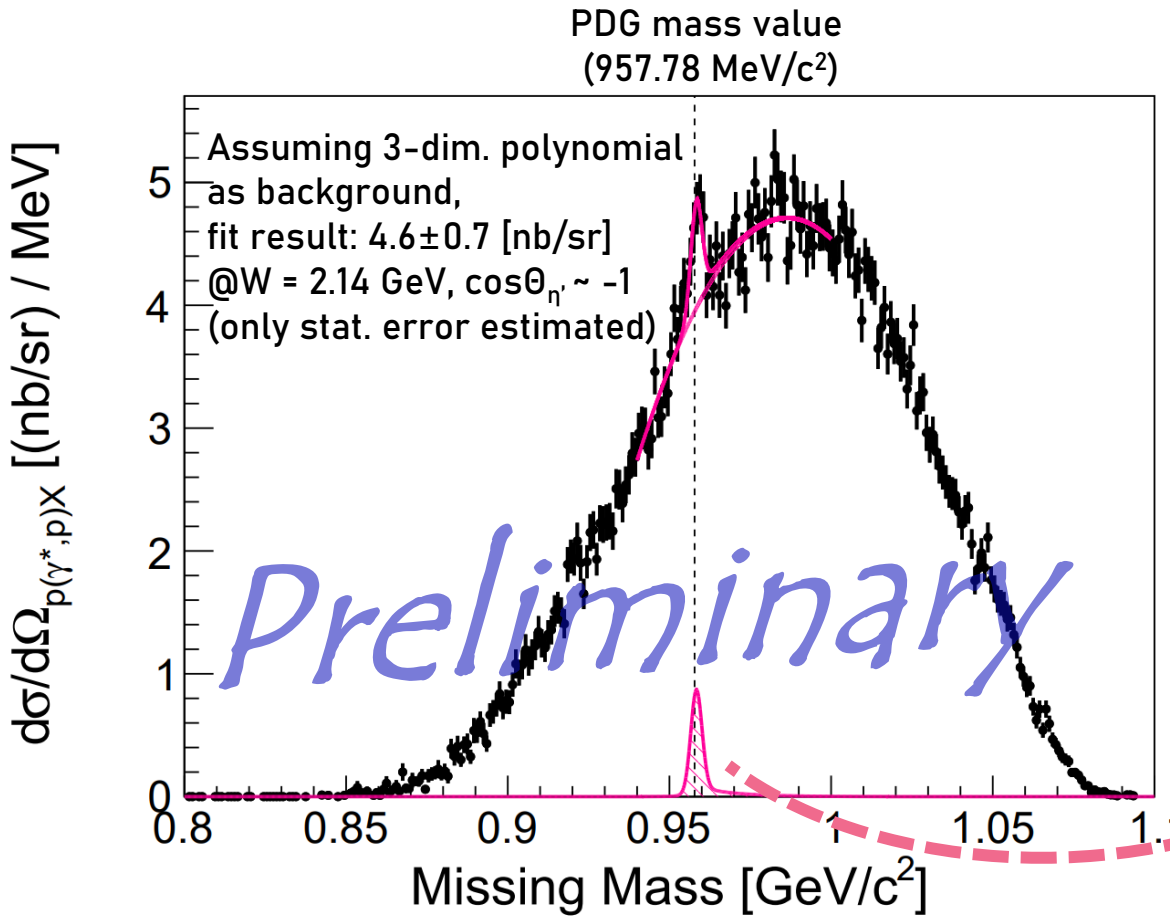
$$Q^2 = -q^2 = 2E_eE_{e'} - 2{m_e}^2 - 2\,|\boldsymbol{p}_e|\,|\boldsymbol{p}_{e'}|\cos\theta_{ee'}$$

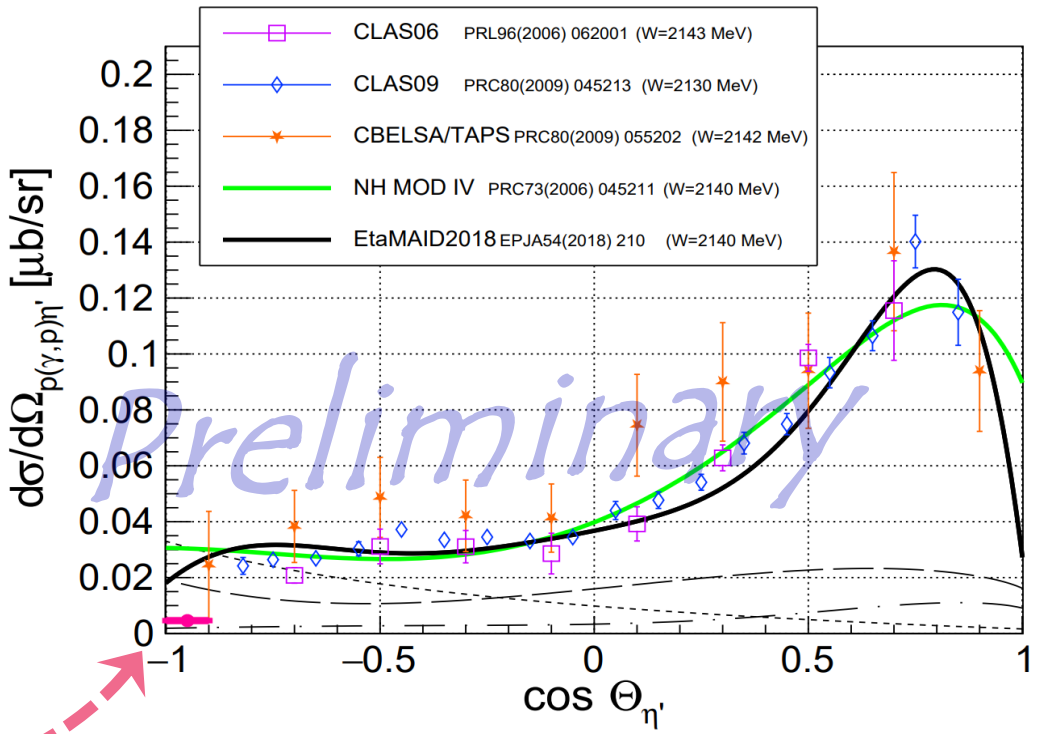
$$E_\gamma = \omega + \frac{q^2}{2m_p}$$

$$\text{Four-momenta of the vertual photon:}\quad q = (\omega,\boldsymbol{q}) = (E_e - E_{e'}, \boldsymbol{p}_e - \boldsymbol{p}_{e'})$$

ANALYSIS STATUS

◆Missing mass spectrum of the p(e,e'p)X reaction





- Theoretical calculation for $Q^2>0$ needs discussion
- Estimation of Sys.error etc. ongoing

Summary

- η' production has been studied from the interest of N* coupling and/or η'N interaction.
- Our data from JLab hypernuclear experiments include η' production events with the (e,e'p) reactions (in particular, at relatively low Q^2 and $\cos\Theta_{\eta'} \sim -1$).
- I am currently deriving the differential cross section off the proton target and comparing it with the theoretical calculation and other experiments for the photoproduction.

Future Prospect

- We should be able to find the upper limit of the η'-nuclei cross section by analyzing the data of the other targets (^{3}H, Al-cell, carbon multifoil) or in the experiments at Hall-C.
- Understanding of the elementary process off the proton target will be the basis of for the interpretation of the results.