Accessing Pion Structure with Electroproduction on Deuterium

Preliminary π+ Results

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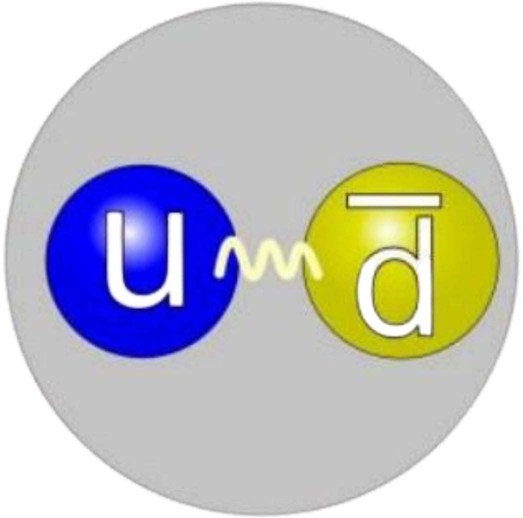
Probing the Internal Structure of the Pion

Why?

- The pion is the ***lightest*** meson and ***simplest*** quark-antiquark bound state.
- The pion exists because of a deep symmetry-breaking effect in the strong force, which is tied to where ***most mass*** comes from.
- Internal structure provides a clean test of ***non-perturbative QCD*** and hadron dynamics.
- ***Free pion targets*** do not exist ($\tau_\pi = 8.5\ \times 10^{-17}$s), so electroproduction offers a way to probe pion structure.



Probing the Internal Structure of the Pion

How?

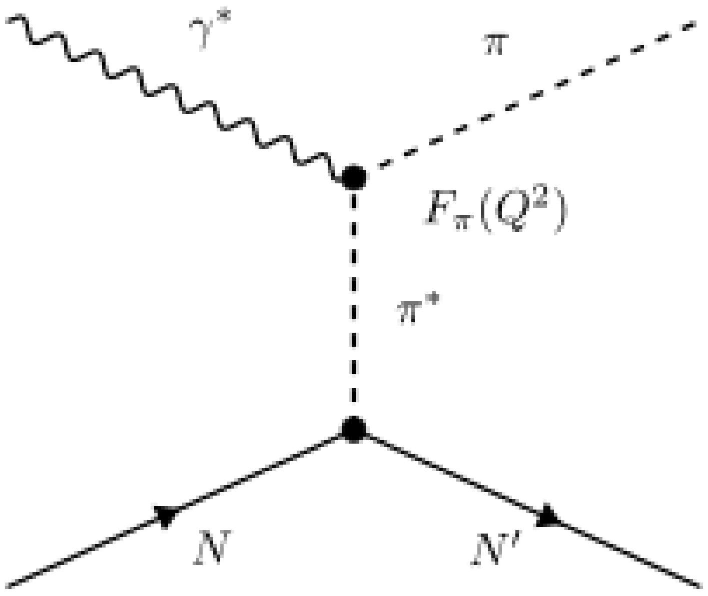
- The pion electromagnetic ***form factor*** ($F_\pi(Q^2)$) probes the spatial distribution of charge and partons within the pion
- $F_\pi(Q^2)$ is indirectly measured using the nucleon's virtual pion cloud as an effective target – the ***Sullivan Process***.

Experimental technique

Measure exclusive pion electroproduction

$$e + N \rightarrow e' + \pi^{\pm} + N'$$

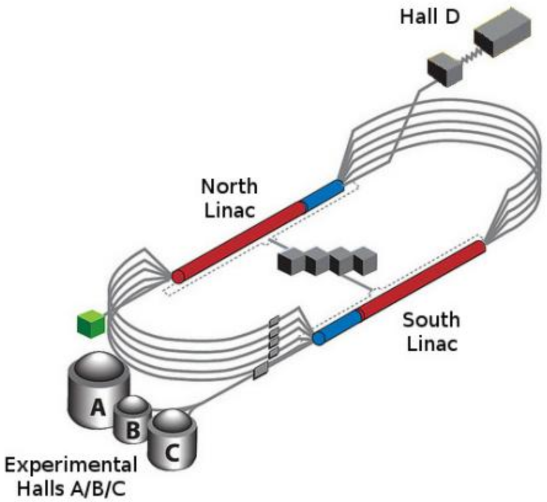
At ***low*** $-t$, pion exchange dominates, allowing extraction of $F_\pi(Q^2)$.



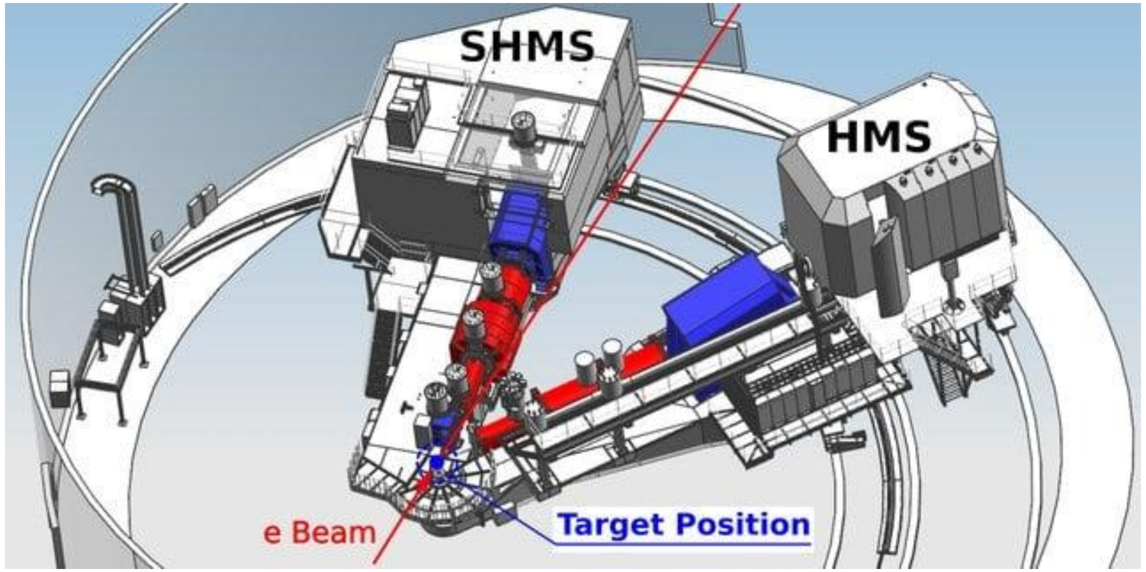
Jefferson Lab

Where?

- Jefferson Lab is a fixed target ***electron beam*** facility.
- ***12 GeV*** CEBAF, high luminosity to the ***four*** halls



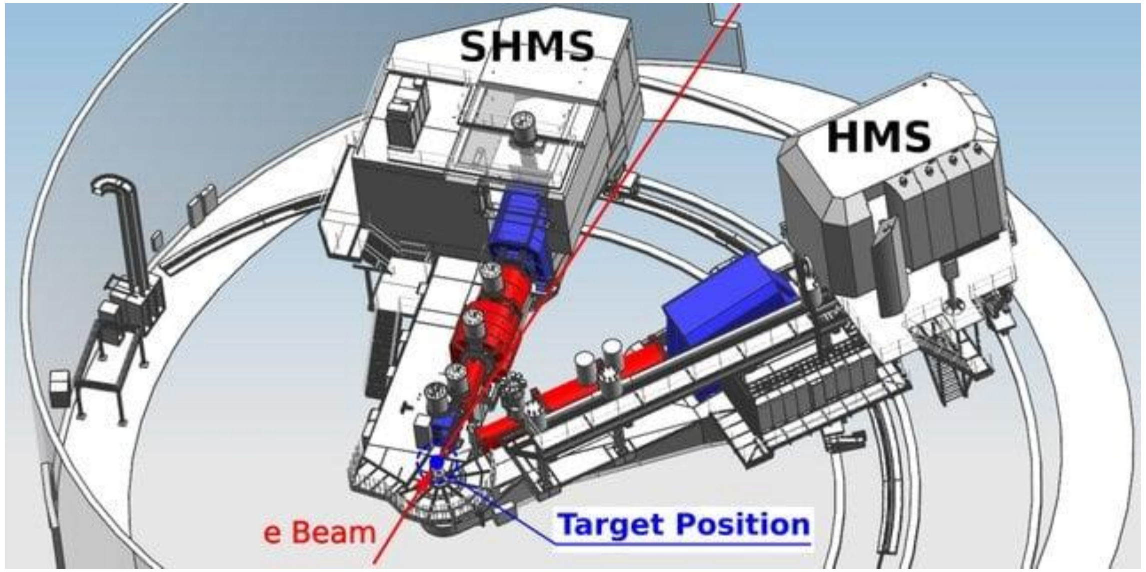
Jefferson Lab – Hall C

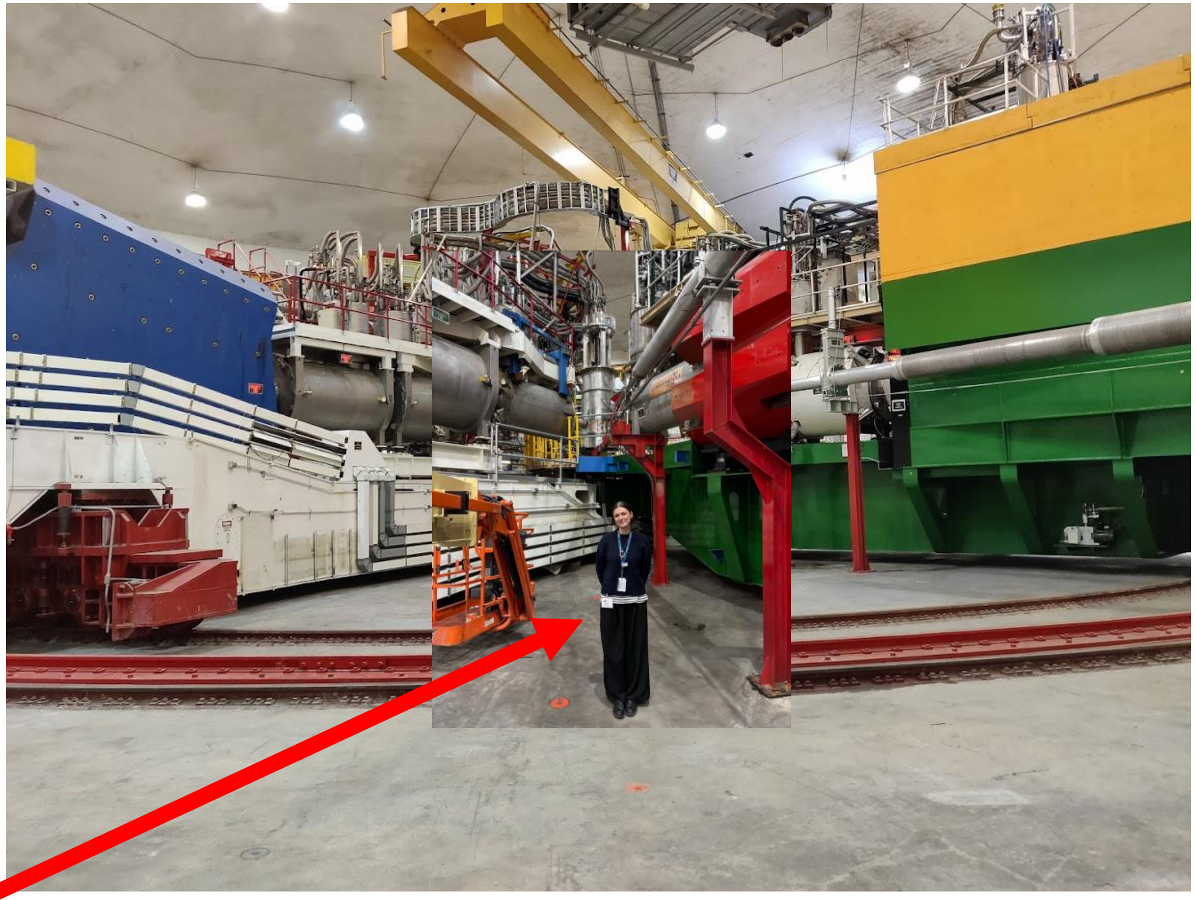


- Allows ***coincidence detection*** of the scattered electron $e'$and produced hadron $\pi^{\pm}$.

- Large momentum and angular acceptance enables broad coverage in $\boldsymbol{Q^2}$,$\boldsymbol{W}$,and $\boldsymbol{t}$.

Hall C – Jefferson Lab

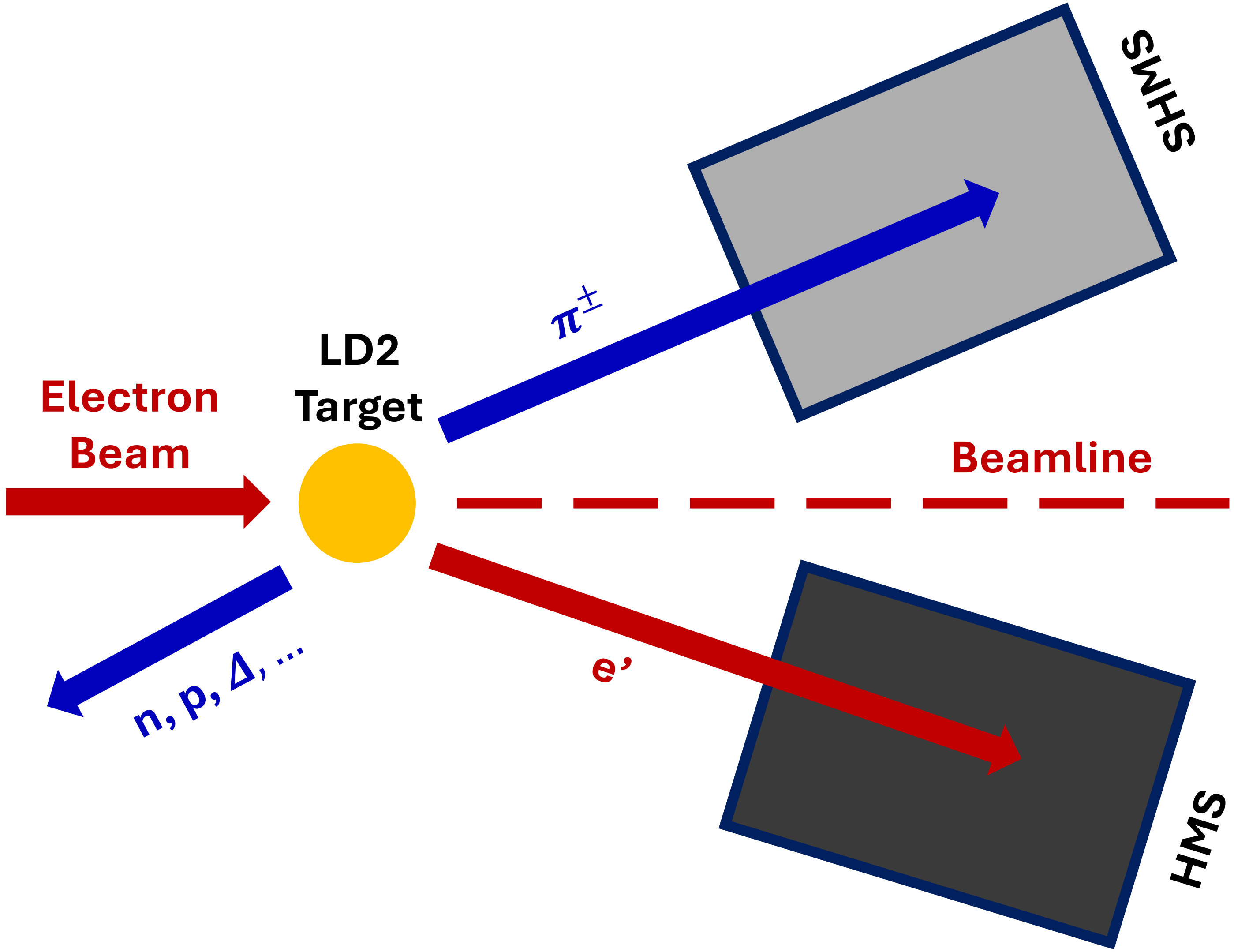


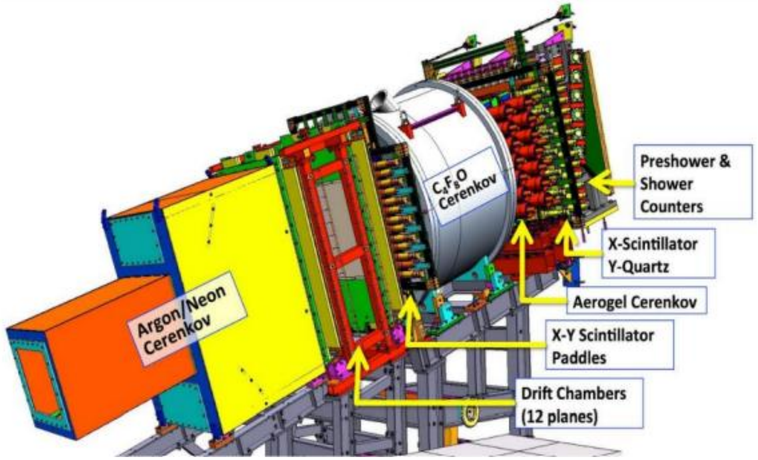


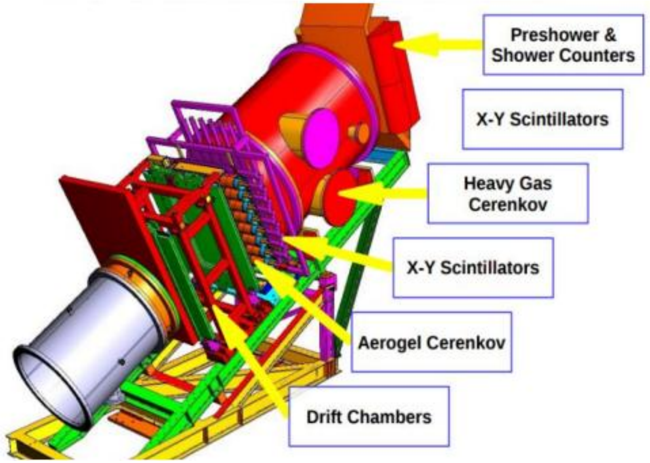
Me

- Allows ***coincidence detection*** of the scattered electron e' and produced hadron $\pi^{\pm}$.
- Large momentum and angular acceptance enables broad coverage in $\boldsymbol{Q^2}$,$\boldsymbol{W}$ and $\boldsymbol{t}$.

PionLT Experiment





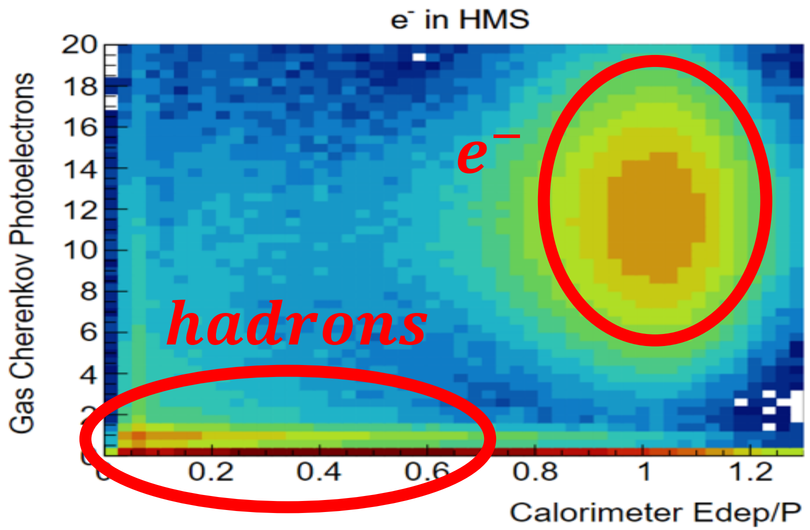


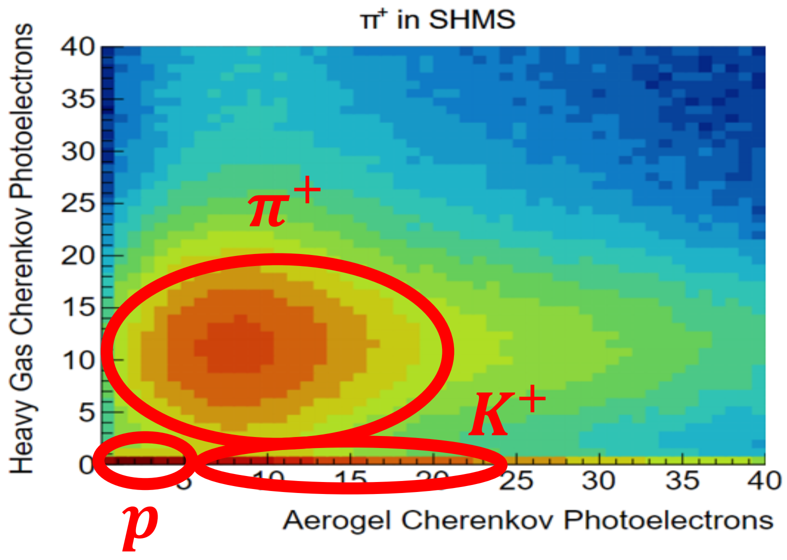
Preliminary Results

Example kinematic setting for $p(e, e'\boldsymbol{\pi}^{+})n$:

E_{beam}	Q^2	W	$-t_{min}$	x_B
6.40	1.60	3.08	0.03	0.17

- Low $-t$ brings the exchanged virtual pion closest to the physical **pion pole** (t $= m_{\pi}^{2} =$ 0.0195 GeV²).





Yield Extraction from Missing Mass

- Exclusive events are identified using the missing mass:

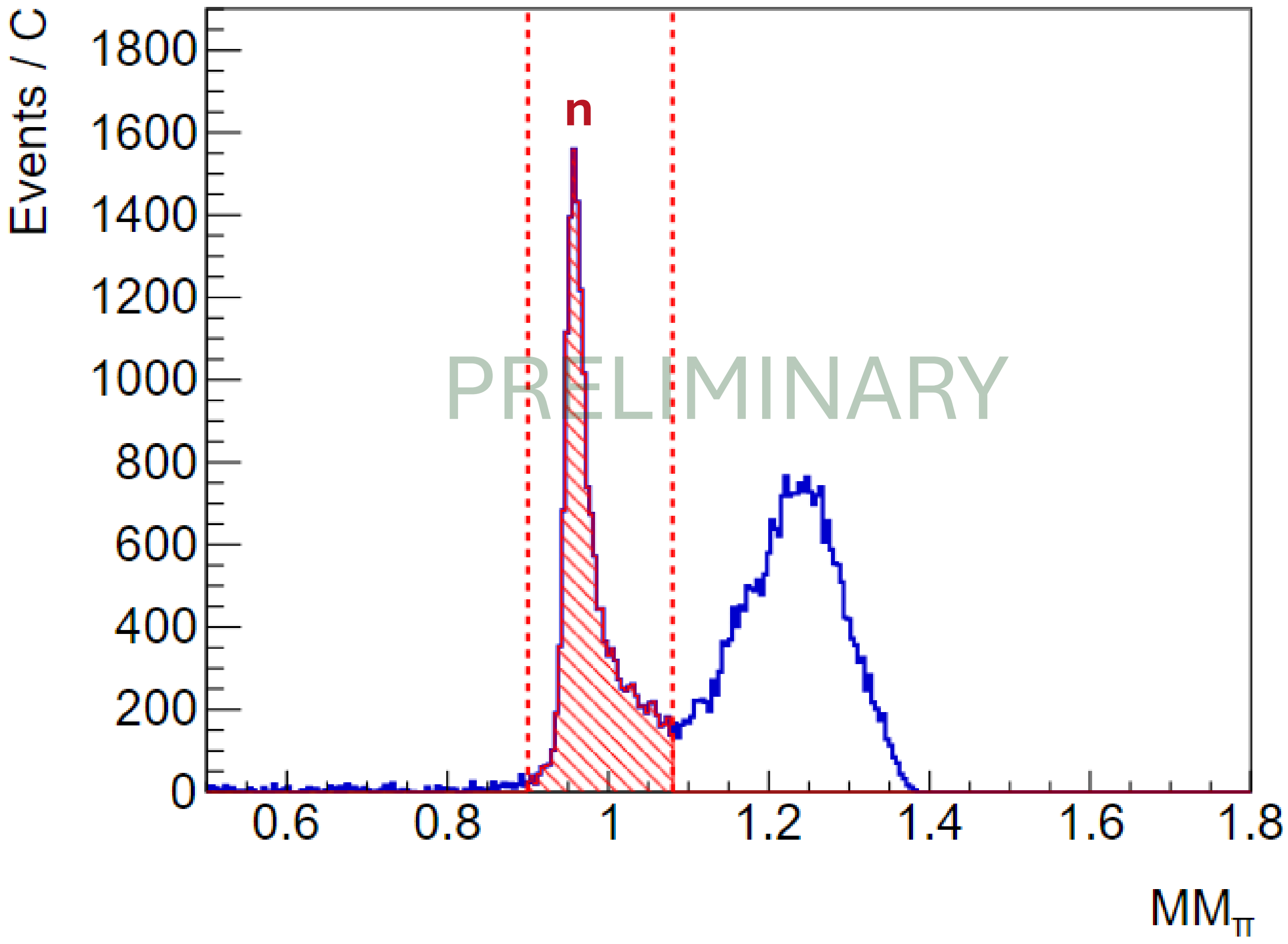
$$M_m^2 = (p_e + p_p - p_{e'} - p_\pi)^2$$

- Integrating under the peak gives a yield:

$$Y_{EXP} = 17010 \text{ events/C}$$

- Measured ***cross section*** is then obtained from:

$$\left(\frac{Y_{EXP}}{Y_{MC}}\right)\sigma_{MC}$$



LT Rosenbluth Separation

- The electroproduction cross section contains longitudinal (σ_L) and transverse (σ_T) virtual-photon contributions.

- By changing ***beam energy***, the virtual photon polarisation ϵ is varied while keeping Q^2, W, and t fixed.

- Measuring the cross section at two ϵsettings enables **Rosenbluth separation**:

$$2\pi \frac{d\sigma}{dt d\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)} \frac{d\sigma_{LT}}{dt} \cos\phi + \varepsilon \frac{d\sigma_{TT}}{dt} \cos 2\phi$$

$$\sigma_L = \frac{\sigma_1 - \sigma_2}{\epsilon_1 - \epsilon_2}$$

Towards Form Factor Extraction

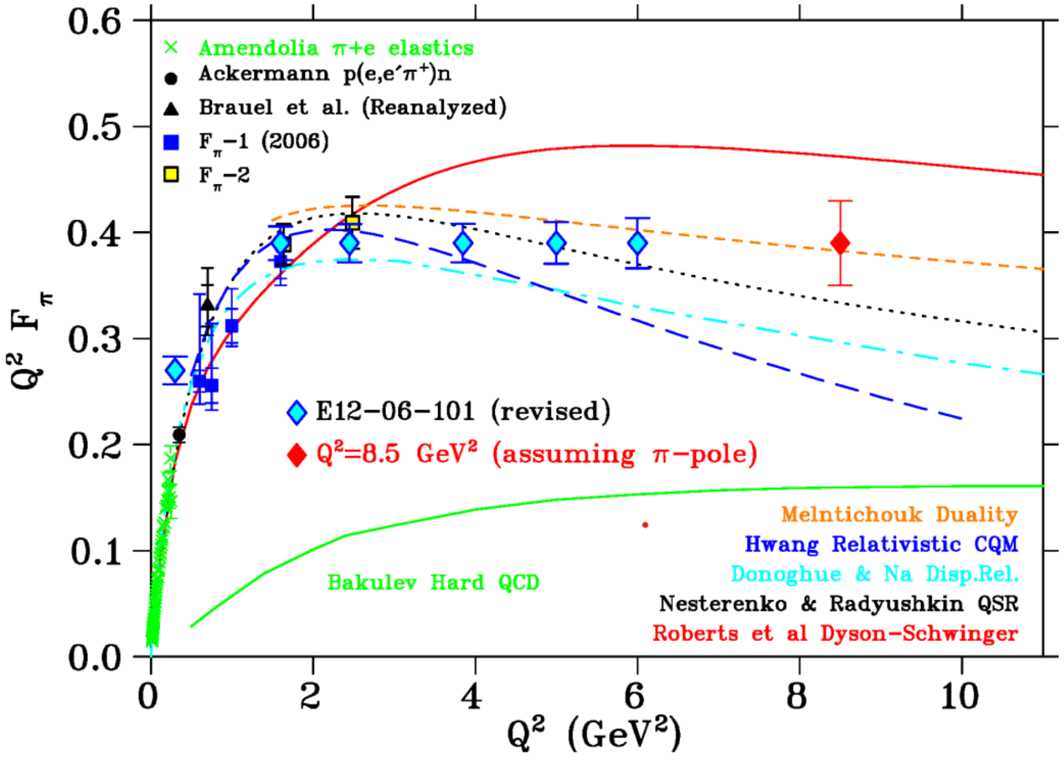
- Combined π^+ and π^- measurements test **pion-pole dominance** and validate the **Sullivan process**.

- Near the pole, the expected ratio is:

$$R_L = \sigma_L^{\pi^-} / \sigma_L^{\pi^+} = 1$$

- Once validated, the longitudinal cross section provides access to the pion form factor:

$$\boldsymbol{\sigma_L \propto F_\pi^2(Q^2)}$$



Summary and Outlook

- Preliminary π^+ event selection and yield extraction have been completed.
- Clean PID and missing mass reconstruction demonstrate ***strong sensitivity*** to exclusive pion electroproduction.
- Next steps are to apply efficiency and luminosity corrections, then compare with ***Monte Carlo*** simulations.
- ***Differential cross sections*** will then be extracted for both $\boldsymbol{\pi}^+$ and $\boldsymbol{\pi}^-$ channels.
- Final Rosenbluth L/T separation will test ***pion-pole dominance*** and determine $\boldsymbol{F_\pi(Q^2)}$.

Thank you for listening!