PionLT: Extraction of the Charged Pion Form Factor to High Q^2

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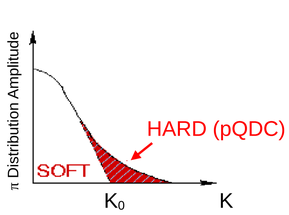
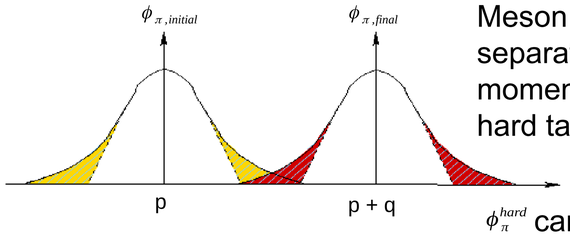
Motivation

The pion: a simple $q\bar{q}$ structure.
An ideal testing ground for bound quark systems.

In Quantum Field Theory the form factor is the overlap integral: $$F_\pi(Q^2) = \int \phi_\pi^*(p)\,\phi_\pi(p+q)\,dp$$

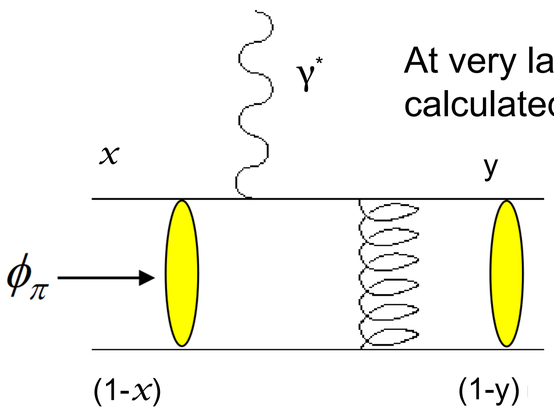




Meson wave functions can be separated into ϕ_π^{soft} with only low momentum contributions and a hard tail ϕ_π^{hard}.

ϕ_π^{hard} can be treated by pQCD, while ϕ_π^{soft} can not.

The study of form factor Q^2-dependence focuses on describing the hard and soft contributions of meson wave functions.



At very large Q^2, pion form factor (F_π) can be calculated using pQCD:

$$F_\pi(Q^2) = \frac{4}{3}\pi\alpha_s \int dxdy \frac{2}{3}\frac{1}{xyQ^2}\phi(x)\phi(y)$$

With asymptotically large Q^2:

$$\phi_\pi(x) \xrightarrow[Q^2\to\infty]{} \frac{3f_\pi}{\sqrt{n_c}}x(1-x)$$

Then F_π takes the simple form:

$$Q^2 F_\pi(Q^2) \xrightarrow[Q^2\to\infty]{} 16\pi\alpha_s(Q^2) f_\pi^2$$

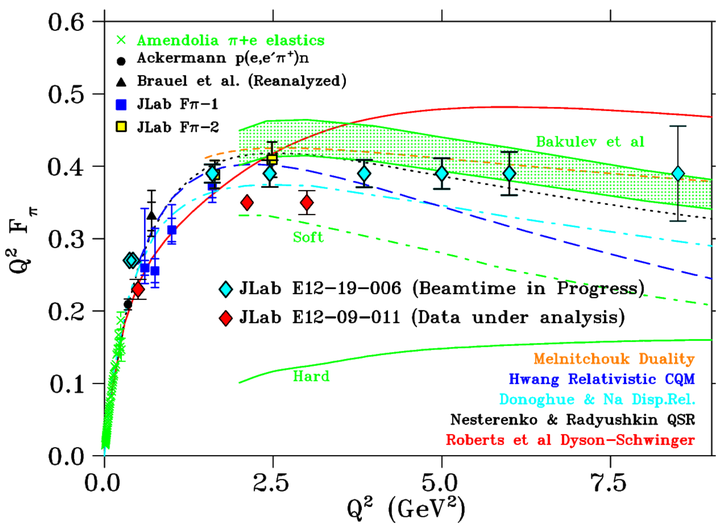
$f_\pi = 93\,MeV$ is the $\pi^+ \to \mu^+\nu$ decay constant.

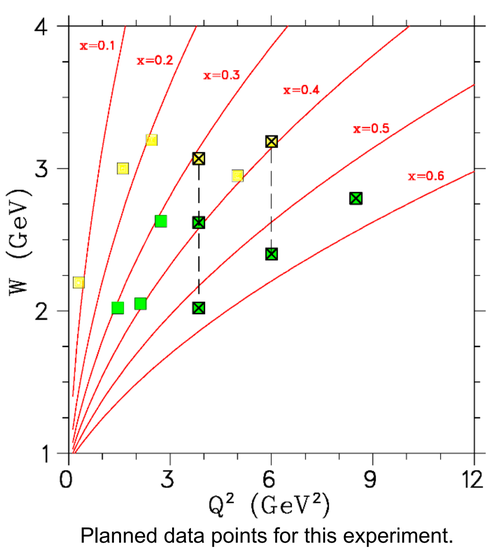
G.P. Lepage, S.J. Brodsky, Phys.Lett. 87B(1979)359.

This only relies on asymptotic freedom in QCD, i.e. $\left(\frac{\delta\alpha_s}{\delta\mu}\right) < 0\ as\ \mu\to\infty$.

At experimentally accessible Q^2, both hard and soft components (eg. transverse momentum effects) contribute, and the interplay of hard and soft components is poorly understood.

This experiment will probe the poorly understood transition region.

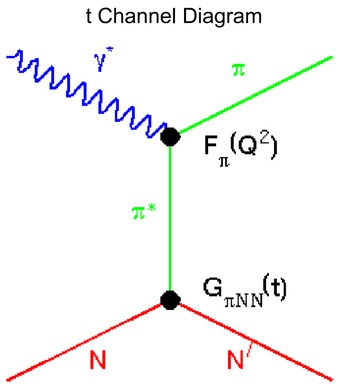




Planned data points for this experiment.

Method

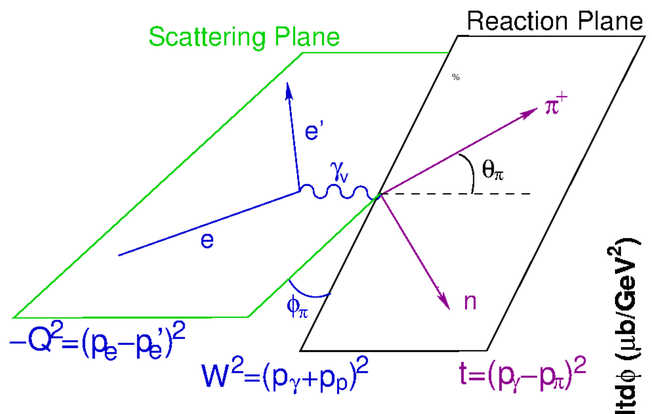
Take pion electro-production data using equipment provided by Jefferson Lab and Hall C: H(e⁻, e⁻ π⁺)n



Born Term Model gives: $$\sigma_L \propto \frac{-tQ^2}{(t-m_\pi^2)} g_{\pi NN}^2(t)\, F_\pi^2(Q^2,t)$$

To extract σ_L, fit the following equation data with varying E_e, θ_π, and ϕ_π but fixed Q^2, W, and t:

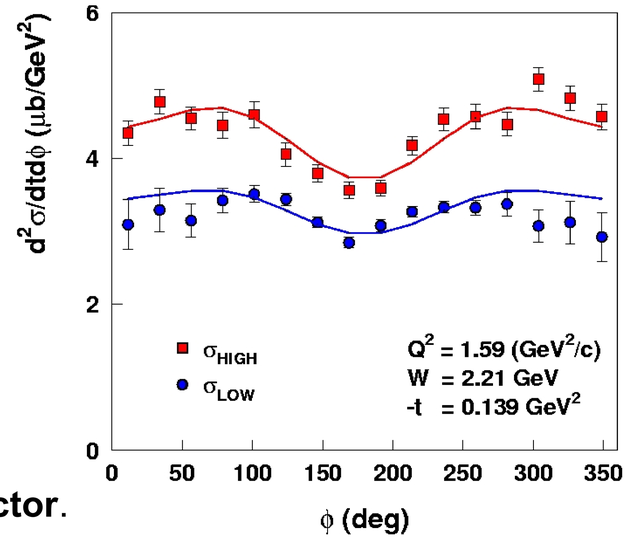
$$2\pi\frac{d^2\sigma}{dtd\phi} = \epsilon\frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\epsilon(\epsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi_\pi + \epsilon\frac{d\sigma_{TT}}{dt}\cos 2\phi_\pi$$



Virtual Photon Polarization:

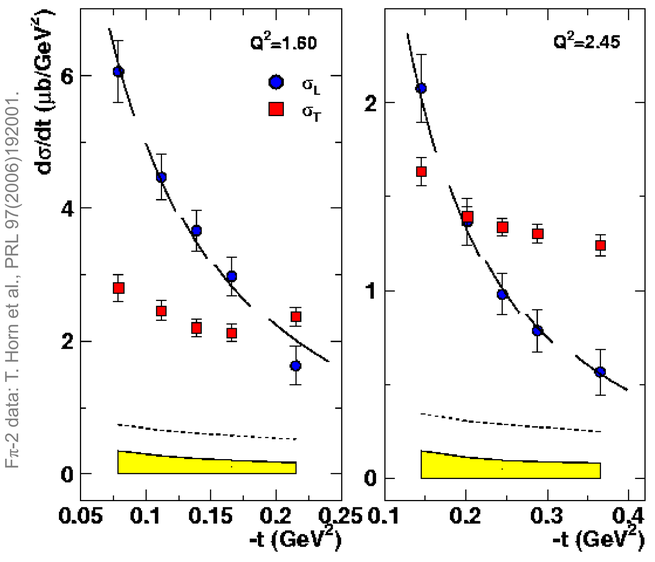
$$\epsilon = \left(1 + 2\frac{(E_e - E_{e'})^2 + Q^2}{Q^2}\tan^2\frac{\theta_{e'}}{2}\right)$$

To extract σ_T fit to data at 2 ε points, and multiple ϕ bins.



T. Horn, et al, PRL 97 (2006)192001

Because target pion was off shell, **need a model to extract Form Factor**.



Fπ-2 data: T. Horn et al., PRL 97(2006)192001.

VGL Regge Model is used, because it has 1 free parameter (Λ_π) that can be fit to data:

$$F_\pi = \left(1 + \frac{Q^2}{\Lambda_\pi^2}\right)^{-1}$$

Because of the use of model for fitting, several extra checks done to ensure accuracy.

See Jacob Murphy's poster for more Details.

[Vanderhaeghen, Guidal, Laget, PRC 57(1998)1454]

Thank you to my sponsors for making this research possible:

Jefferson Lab Hall C NSERC CRSNG University of Regina