L–T Separations in Deep Exclusive Meson Production at JLab 20+ GeV

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Hall C Winter Workshop
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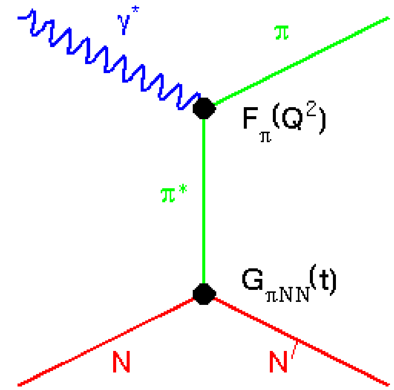
DEMP Opportunities in Hall C

1) Determine the Pion Form Factor to high Q^2:

- Indirectly measure F_π using the "pion cloud" of the proton via p(e,e'π^+)n

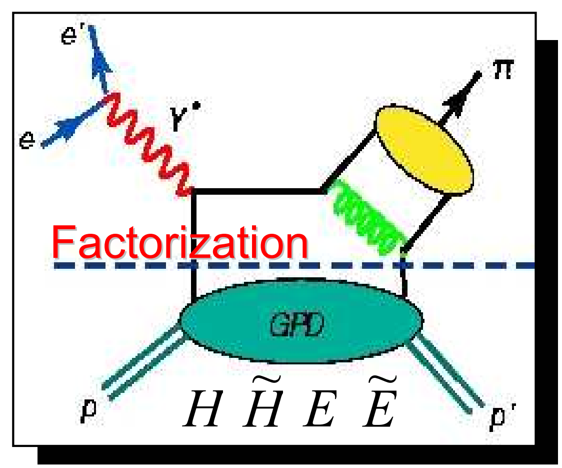
$$|p\rangle = |p\rangle_0 + |n\pi^+\rangle + \ldots$$



- **The pion form factor is a key QCD observable**
- Extension of studies to Kaon Form Factor expected to reveal insights on hadronic mass generation via DCSB

2) Study the Hard-Soft Factorization Regime:

- **Need to determine region of validity of hard-exclusive reaction meachanism, as GPDs can only be extracted where factorization applies**
- Separated p(e,e'π^+/K$^+$) cross sections vs. Q^2 at fixed x to investigate reaction mechanism towards 3D imaging studies
- Extension of studies to u–channel p(e,e'p)ω can reveal hard–soft factorization at backward angle



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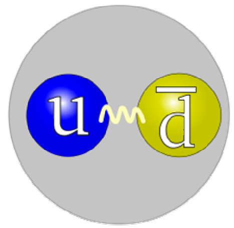
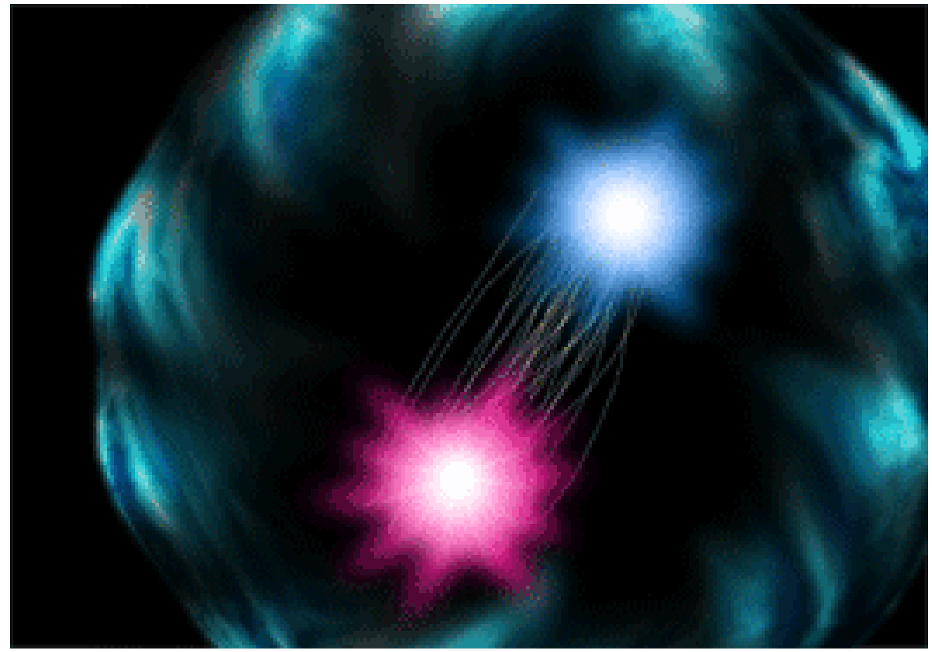
Charged Pion Form Factor

- **The pion is attractive as a QCD laboratory:**
  - Simple, 2 quark system



- **The pion is the "positronium atom" of QCD, its form factor is a test case for most model calculations**

- **The important question to answer is: What is the structure of the π^+ at all Q^2?**



Pion's structure is determined by two valence quarks, and the quark-gluon sea.

- **A program of study unique to Jefferson Lab Hall C** (until the completion of the EIC)

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Measurement of π^+ Form Factor – Larger Q^2

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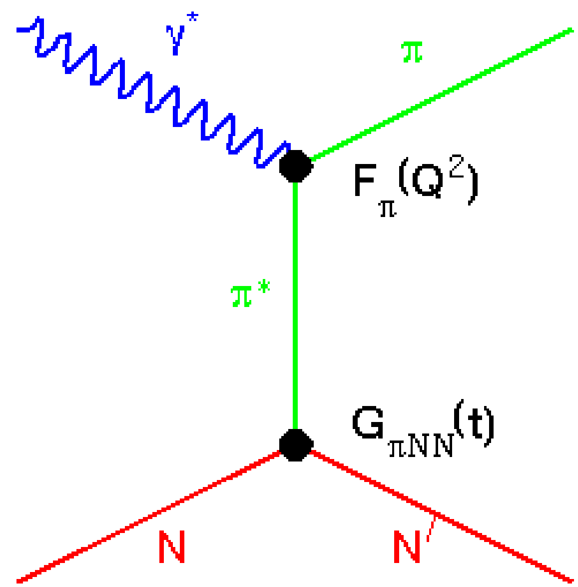
At larger Q^2, F_π must be measured indirectly using the "pion cloud" of the proton via pion electroproduction $p(e,e'\pi^+)n$

$$|p\rangle = |p\rangle_0 + |n\pi^+\rangle + \ldots$$

- At small $-t$, the pion pole process dominates the longitudinal cross section, σ_L
- In Born term model, F_π^2 appears as,

$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t-m_\pi^2)} g^2_{\pi NN}(t)\, F_\pi^2(Q^2,t)$$



Drawbacks of this technique

1. Isolating σ_L experimentally challenging
2. Theoretical uncertainty in form factor extraction.

$p(e,e'\pi^+)n$ Event Selection

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Coincidence measurement between charged pions in SHMS and electrons in HMS

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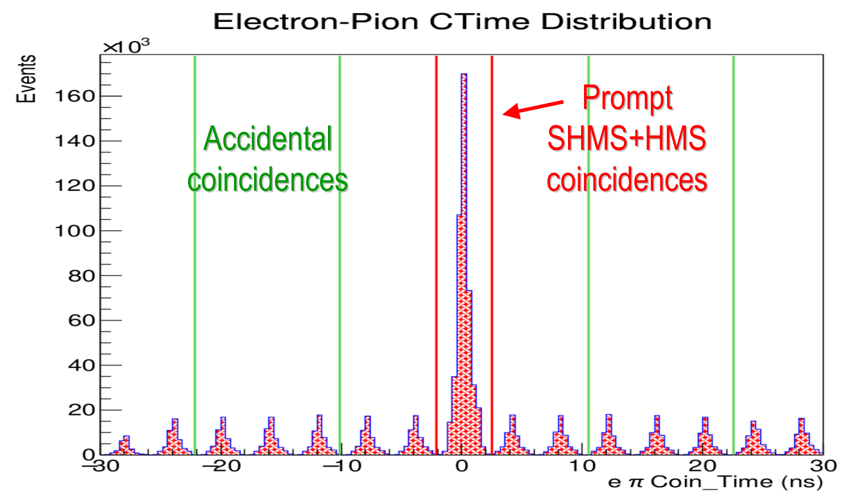
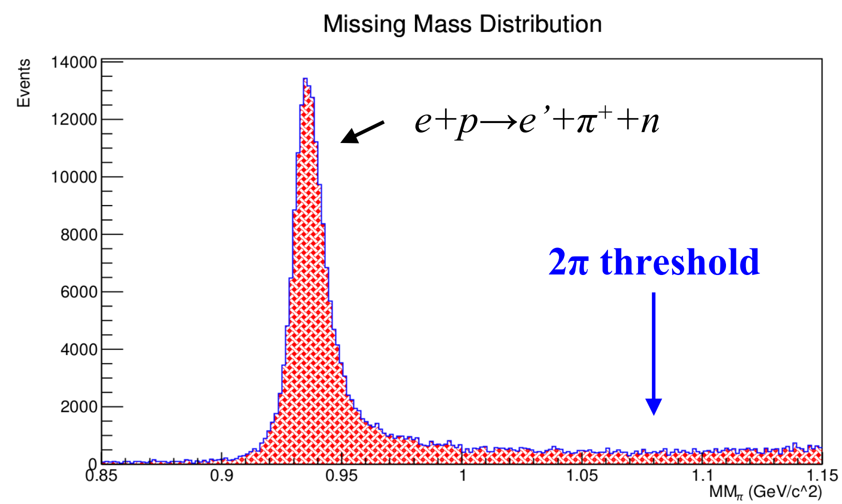
Easy to isolate exclusive channel

- Excellent particle identification
- CW beam minimizes "accidental" coincidences
- Missing mass resolution easily excludes 2–pion contributions





PionLT experiment E12–19–006 Data

Q^2=1.60, W=3.08, x= 0.157, ε=0.685

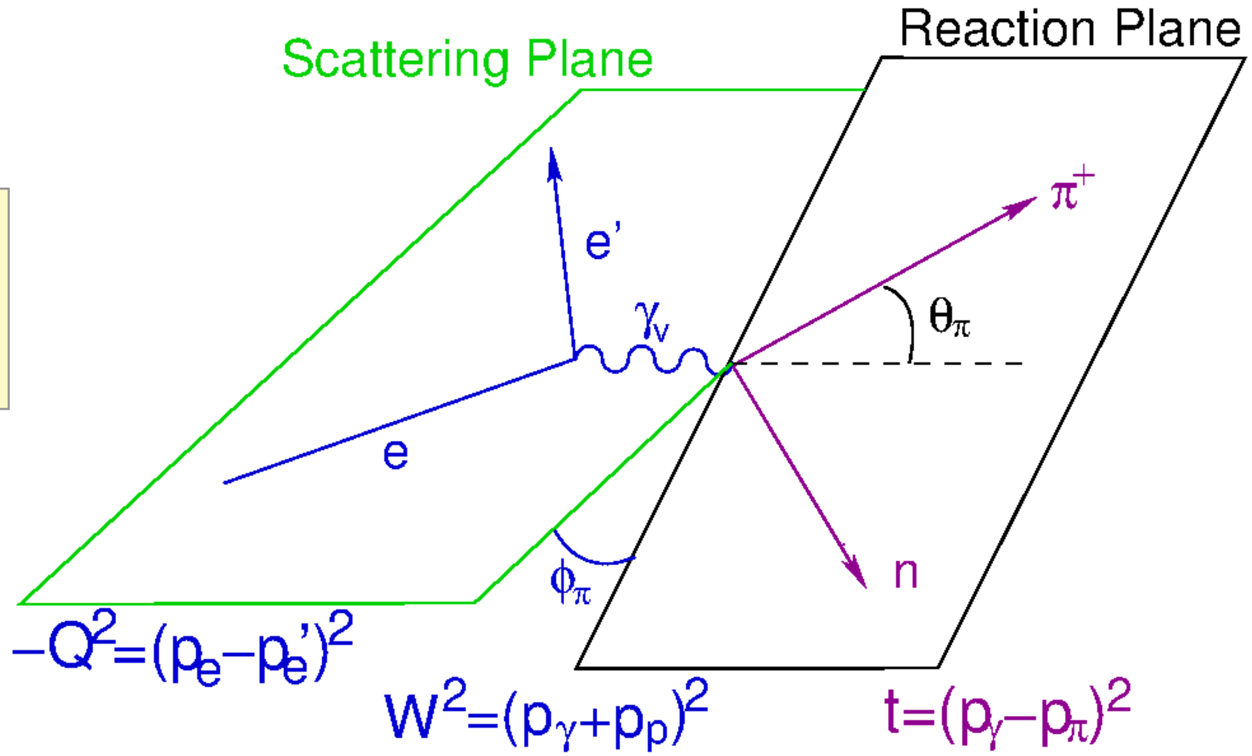
E_{beam}=9.177 GeV, P_{SHMS}=+5.422 GeV/c, θ_{SHMS}= 10.26° (left)

Plots by Muhammad Junaid

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

Virtual-photon polarization:

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



- **L-T separation required to separate σ_L from σ_T**
- **Need to take data at smallest available $-t$, so σ_L has maximum contribution from the π^+ pole**
- **Need to measure t–dependence of σ_L at fixed Q^2,W**

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L/T–separation error propagation

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Error in $d\sigma_L/dt$ is magnified by $1/\Delta\varepsilon$, where $\Delta\varepsilon=(\varepsilon_{Hi}-\varepsilon_{Low})$

→ To keep magnification factor <5x, need $\Delta\varepsilon$>0.2, preferably more!

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

$$\frac{\Delta\sigma_L}{\sigma_L}=\frac{1}{(\varepsilon_1-\varepsilon_2)}\left(\frac{\Delta\sigma}{\sigma}\right)\sqrt{(R+\varepsilon_1)^2+(R+\varepsilon_2)^2}\qquad \text{where } R=\frac{\sigma_T}{\sigma_L}$$

$$\frac{\Delta\sigma_T}{\sigma_T}=\frac{1}{(\varepsilon_1-\varepsilon_2)}\left(\frac{\Delta\sigma}{\sigma}\right)\sqrt{\varepsilon_1^2\left(1+\frac{\varepsilon_2}{R}\right)^2+\varepsilon_2^2\left(1+\frac{\varepsilon_1}{R}\right)^2}$$

The relevant quantities for F_π extraction are R and $\Delta\varepsilon$

$$\frac{d\sigma_L}{dt}\propto\frac{-tQ^2}{(t-m_\pi^2)}\,g^2_{\pi NN}(t)\,F_\pi^2(Q^2,t)$$

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Extract $F_\pi(Q^2)$ from JLab σ_L data

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Model incorporates π^+ production mechanism and spectator neutron effects:

VGL Regge Model:

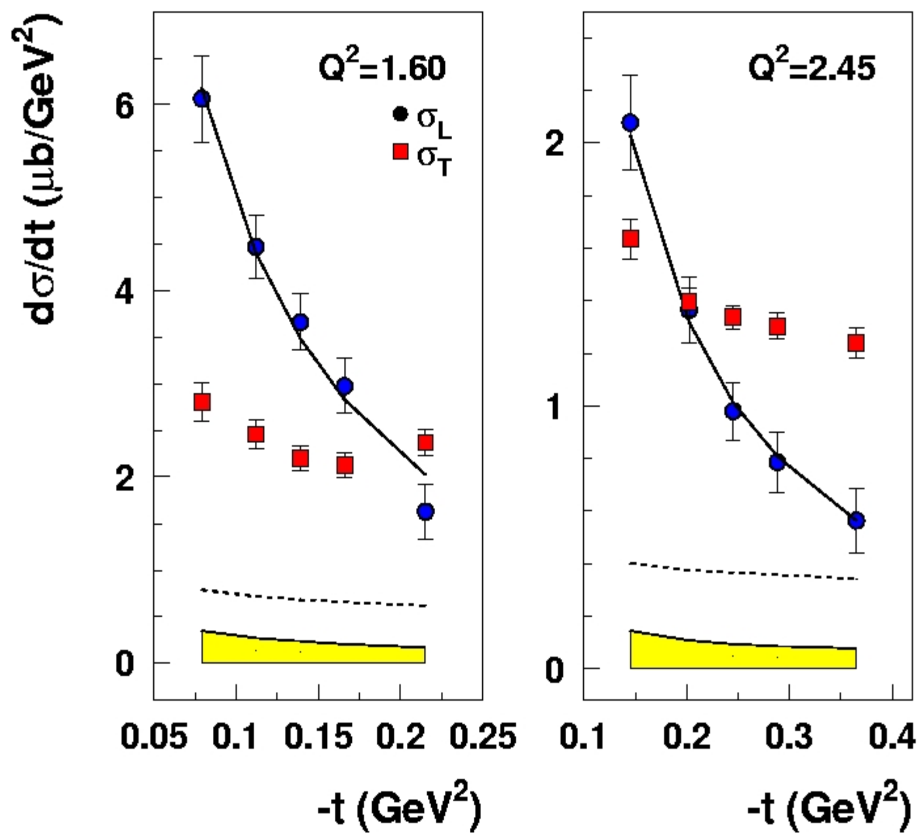
- Feynman propagator $\left(\frac{1}{t - m_\pi^2}\right)$

  replaced by π and ρ Regge propagators.
  - Represents the exchange of a series of particles, compared to a single particle.
- Free parameters: Λ_π, Λ_ρ (trajectory cutoff).

  [Vanderhaeghen, Guidal, Laget, PRC **57**(1998)1454]
- At small $-t$, σ_L only sensitive to F_π

$$F_\pi = \frac{1}{1 + Q^2/\Lambda_\pi^2}$$

Fit to σ_L to model gives F_π at each Q^2



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

Error bars indicate statistical and random (pt-pt) systematic uncertainties in quadrature.
Yellow band indicates the correlated (scale) and partly correlated (t-corr) systematic uncertainties.

Λ_π^2=0.513, 0.491 GeV^2, Λ_ρ^2=1.7 GeV^2.

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Current and Projected F_π Data

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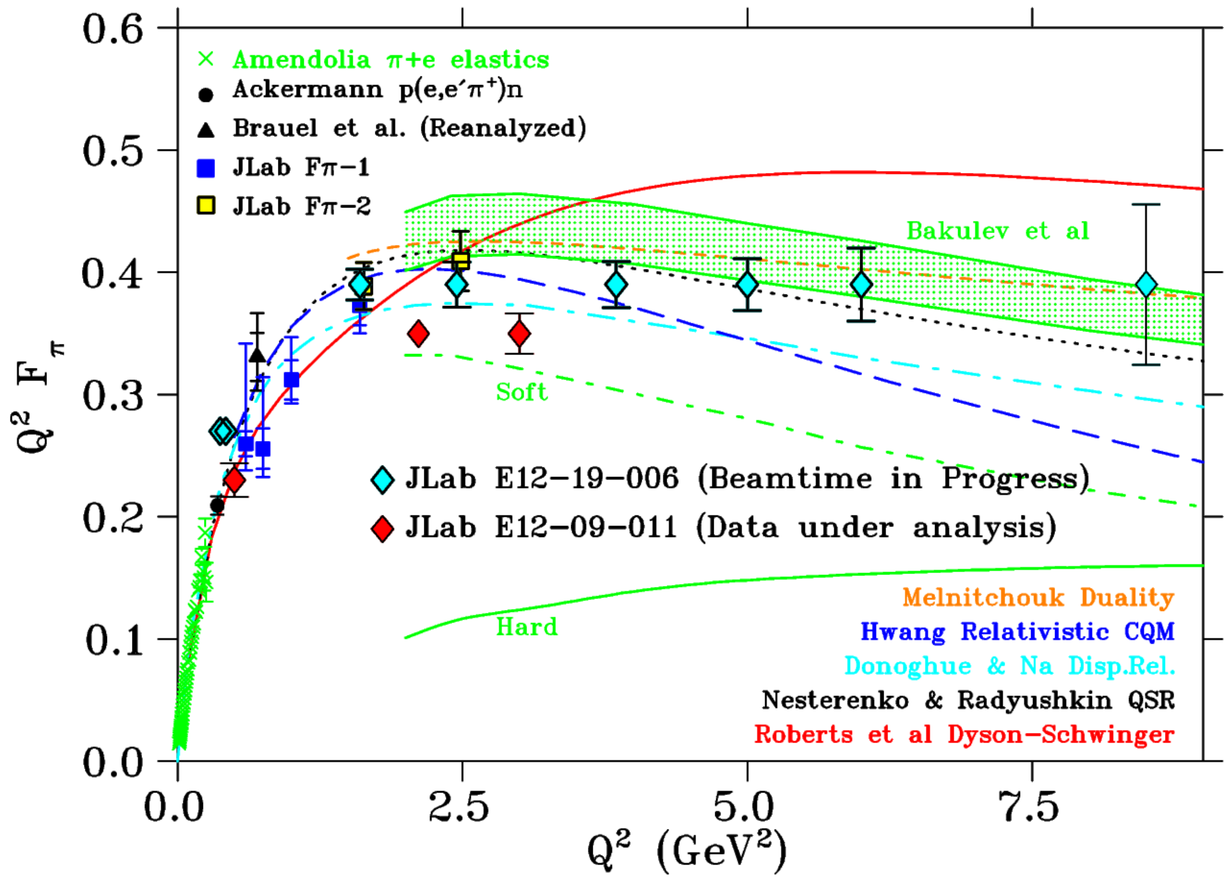
SHMS+HMS will allow measurement of F_π to much higher Q^2.

No other facility worldwide can perform this measurement.

The pion form factor is the clearest test case for studies of QCD's transition from non–perturbative to perturbative regions.



The ~17% measurement of F_π at Q^2=8.5 GeV^2 is at higher $-t_{min}$=0.45 GeV^2

E12–19–006: D. Gaskell, T. Horn and G. Huber, spokespersons

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The Charged Kaon – 2nd QCD test case

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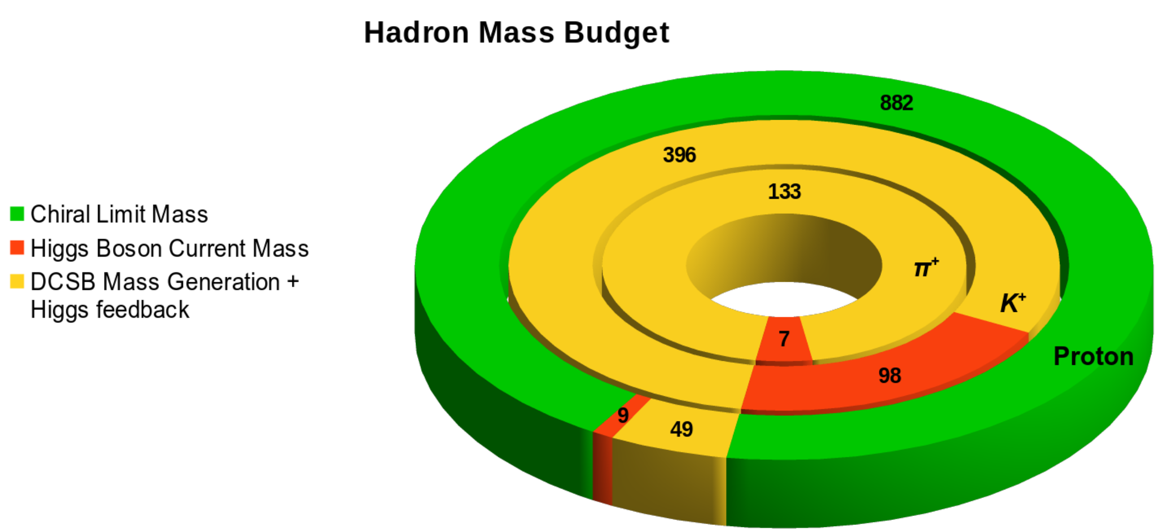
- In hard scattering limit, pQCD predicts π^+, K^+ form factors will behave similarly

$$\frac{F_K(Q^2)}{F_\pi(Q^2)} \xrightarrow[Q^2\to\infty]{} \frac{f_K^2}{f_\pi^2}$$

- Important to compare magnitudes and Q^2–dependences of both form factors



For more info:
J.Phys.G **48**(2021)075106

- Proton mass large in absence of quark couplings to Higgs boson (chiral limit). Conversely, K and π are massless in chiral limit (i.e. they are Goldstone bosons).
- The mass budgets of these crucially important particles demand interpretation.
- Equations of QCD stress that any explanation of the proton's mass is incomplete, unless it simultaneously explains the light masses of QCD's Goldstone bosons, the π and K.
- Understanding π^+ and K^+ form factors over broad Q^2 range is central to this puzzle.

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Projected Uncertainties for K^+ Form Factor

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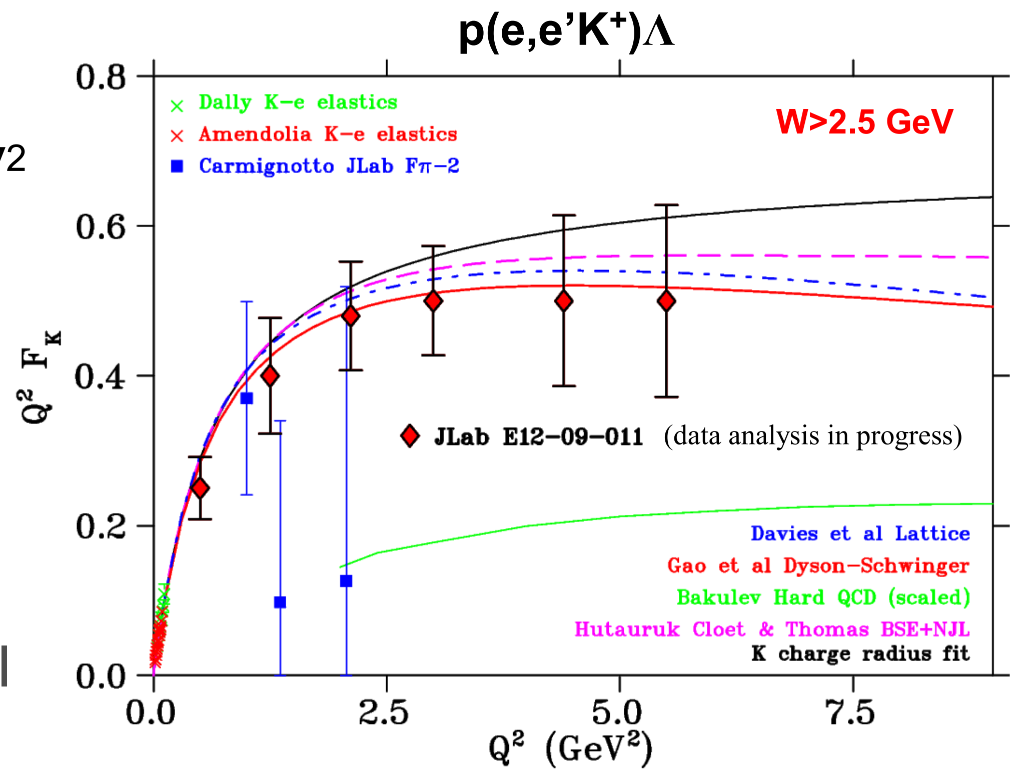
- First measurement of F_K well above the resonance region.
- Measure form factor to Q^2=3 GeV^2 with good overlap with elastic scattering data.
  - Limited by $-t$<0.2 GeV^2 requirement to minimize non–pole contributions.
- Data will provide an important second $q\bar{q}$ system for theoretical models, this time involving a strange quark.



E12–09–011: T. Horn, G. Huber and P. Markowitz, spokespersons

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Upgrade Scenarios Considered

Phase 1: higher energy beam, keep HMS+SHMS as is

Various Phase 2 Scenarios:

1. **Large upgrade to HMS momentum**
   - 7 GeV/c → 14 GeV/c
   - Keep θ_{min}=10.50° (HMS)
2. **Upgrade both HMS momentum and forward angle**
   - 7 GeV/c → 11 GeV/c
   - θ_{min}=10.50° → 7.5° (HMS)
   - θ_{open}=18.00° → 15.00°
3. **Keep HMS unchanged and upgrade SHMS momentum**
   - 11 GeV/c → 15 GeV/c (SHMS)
   - Keep θ_{min}=5.50° (SHMS), θ_{open}=18.00°

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Phase 1 Scenario: π^+ Form Factor

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- 7.2 GeV/c HMS & 11.0 GeV/c SHMS allow a lot of kinematic flexibility, **with no upgrades**
  - Experiment could be done as soon as beam energy is available!
  - Maximum beam energy and higher Q^2 reach constrained by sum of HMS+SHMS maximum momenta

	10.6 GeV	18.0 GeV	Improvement in $\delta F_\pi/F_\pi$
Q^2=8.5	Δε=0.22	Δε=0.40	16.8%→8.0%
Q^2=10.0	New high quality F_π data		
Q^2=11.5	Larger F_π extraction uncertainty due to higher $-t_{min}$		

p(e,e'π⁺)n Kinematics

E_{beam}	θ_{HMS} (e')	P_{HMS} (e')	$\theta_{q(SHMS)}$ (π^+)	P_{SHMS} (π^+)	Time FOM
Q^2=8.5 W=3.64 $-t_{min}$=0.24 Δε=0.40					
13.0	34.30	1.88	5.29	10.99	64.7
18.0	15.05	6.88	8.94	10.99	2.2
Q^2=10.0 W=3.44 $-t_{min}$=0.37 Δε=0.40					
13.0	37.78	1.83	5.56	10.97	122.7
18.0	16.39	6.83	9.57	10.97	4.5
Q^2=11.5 W=3.24 $-t_{min}$=0.54 Δε=0.29					
14.0	31.73	2.75	7.06	10.96	82.4
18.0	17.70	6.75	10.05	10.96	8.8

- **Since quality L–T separations are impossible at EIC (can't access ε<0.95) this extension of L–T separated data considerably increases F_π data set overlap between JLab and EIC**

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Phase 1 Scenario: K^+ Form Factor

- 7.2 GeV/c HMS & 11.0 GeV/c SHMS allow a lot of kinematic flexibility
- Maximum beam energy and higher Q^2 reach constrained by sum of HMS+SHMS maximum momenta
- Success depends on good K^+/π^+ separation in SHMS at high momenta, likely requires a modest aerogel detector upgrade
- Counting rates are roughly 10x lower than pion form factor measurement

	10.6 GeV	16.0 GeV	Improvement in $\delta F_K/F_K$
Q^2=5.5	$\Delta\varepsilon$=0.33	$\Delta\varepsilon$=0.40	17.9%→10.7%
Q^2=7.0	New high quality F_K data		
Q^2=9.0	Larger F_K extraction uncertainty due to higher $-t_{min}$		

p(e,e'K$^+$)Λ Kinematics

E_{beam}	θ_{HMS} (e')	P_{HMS} (e')	$\theta_{q(SHMS)}$ (π^+)	P_{SHMS} (π^+)	Time FOM
Q^2=5.5 W=3.56 $-t_{min}$=0.32 $\Delta\varepsilon$=0.40					
11.0	30.69	1.79	5.50	8.84	746
16.0	12.92	6.79	9.18	8.84	150
Q^2=7.0 W=3.90 $-t_{min}$=0.33 $\Delta\varepsilon$=0.29					
14.0	25.16	2.64	5.51	10.98	620
18.0	13.91	6.64	7.85	10.98	192
Q^2=9.0 W=3.66 $-t_{min}$=0.54 $\Delta\varepsilon$=0.30					
14.0	29.17	2.54	5.98	10.97	964
18.0	15.90	6.54	8.69	10.97	350

- **F_K feasibility studies at EIC are ongoing, but we already know that such measurements there are exceptionally complex.**
- **JLab measurements likely a complement to those at EicC.**

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Phase 1: Form Factor Projections

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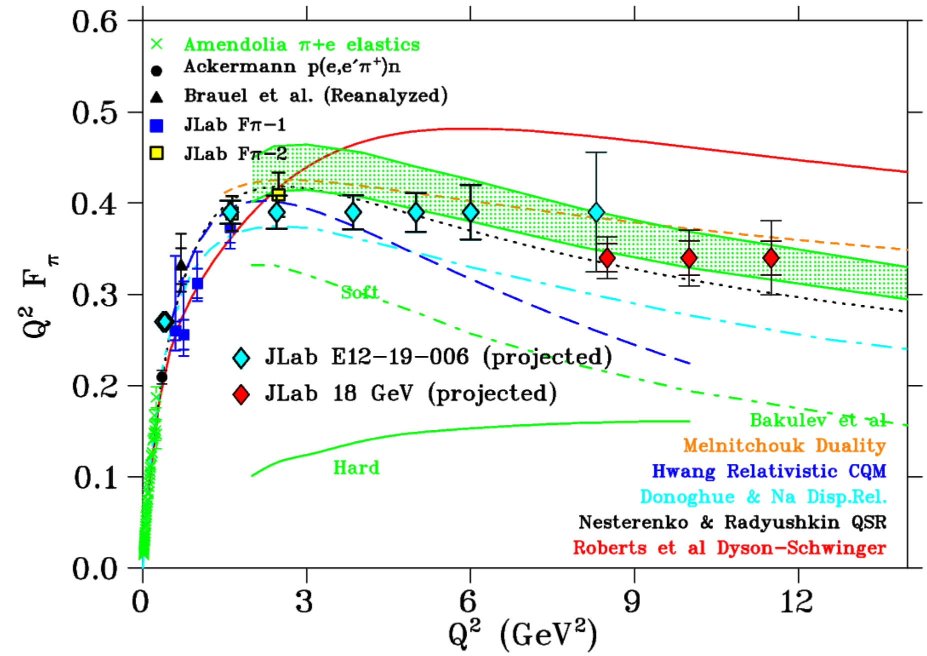
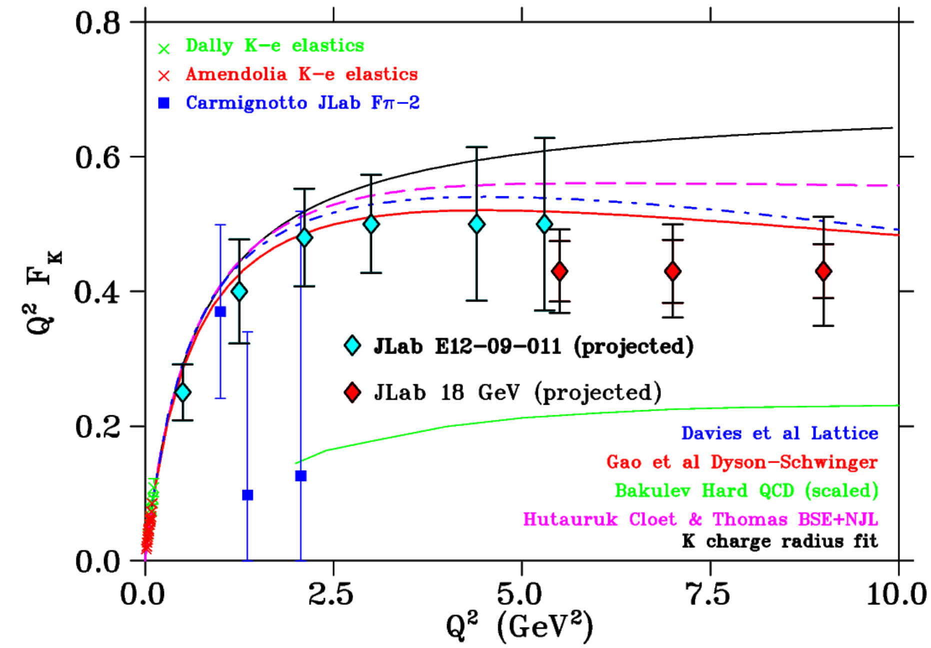
- Y-axis values of projected data are arbitrary
- The errors are projected, based on Δε from beam energies on earlier slides, and T/L ratio calculated with Vrancx Ryckebusch model
- Inner error bar is projected statistical and systematic error
- Outer error bar also includes a model uncertainty in the form factor extraction, added in quadrature
- F_π errors based on Fπ–2 and E12–19–006 experience
- F_K errors more uncertain, as E12–09–011 analysis not yet completed





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14 GeV/c HMS Scenario: π^+ Form Factor

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- **Replace HMS with a higher momentum spectrometer**
  - For high *z* reactions, such as DEMP, usable beam energy constrained by sum of HMS+SHMS maximum momenta
  - i.e. 22 GeV beam energy is a larger constraint than the maximum HMS momentum
- **New HMS would not extend the Q^2 reach beyond Scenario 1.** However, it would result in smaller errors due to larger Δε and faster high ε data rates

$p(e,e'\pi^+)n$ Kinematics					
E_{beam}	θ_{HMS} (e')	P_{HMS} (e')	$\theta_{q(SHMS}$ (π^+)	P_{SHMS} (π^+)	Time FOM
Q^2=8.5 W=3.64 $-t_{min}$=0.24 Δε=0.53					
13.0	34.30	1.88	5.29	10.99	64.7
22.0	10.81	10.88	10.23	10.99	0.6
Q^2=10.0 W=3.44 $-t_{min}$=0.37 Δε=0.54					
13.0	37.78	1.83	5.56	10.97	122.7
22.0	11.76	10.83	10.97	10.97	1.3
Q^2=11.5 W=3.24 $-t_{min}$=0.54 Δε=0.29					
14.0	31.73	2.75	7.06	10.96	82.4
22.0	12.66	10.75	11.56	10.96	2.5

- **This scenario is judged to not be worth it, at least for this reaction channel**

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Upgrade HMS Momentum and Angle: F_π

- **Upgrade both HMS momentum and forward angle capabilities**
  - 7 GeV/c → 11 GeV/c
  - θ_{min}=10.50° → 7.5°
  - θ_{open}=18.00° → 15.00°
- **This upgrade also does not extend the Q² reach beyond Scenario 1.**
- However, it would result in smaller errors due to larger Δε and faster high ε data rates

p(e,e'π⁺)n Kinematics					
E_{beam}	θ_{HMS} (e')	P_{HMS} (e')	$\theta_{q(SHMS)}$ (π^+)	P_{SHMS} (π^+)	Time FOM
Q^2=8.5 W=3.64 $-t_{min}$=0.24 Δε=0.53					
13.0	34.30	1.88	5.29	10.99	64.7
22.0	10.81	10.88	10.23	10.99	0.6
Q^2=10.0 W=3.44 $-t_{min}$=0.37 Δε=0.54					
13.0	37.78	1.83	5.56	10.97	122.7
22.0	11.76	10.83	10.97	10.97	1.3
Q^2=11.5 W=3.24 $-t_{min}$=0.54 Δε=0.29					
14.0	31.73	2.75	7.06	10.96	82.4
22.0	12.66	10.75	11.56	10.96	2.5

- **Basically the same as Scenario 2. Not worth it, at least for this channel**

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15 GeV/c SHMS Scenario: π^+ Form Factor

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- **Replace SHMS with higher momentum spectrometer, but keep HMS as is**
- Dramatic increase in upper Q^2 11.5 → 15.0 GeV^2
- Error bars for Q^2=8.5–11.5 GeV^2 would substantially decrease due to smaller $-t_{min}$ (better $R=\sigma_T/\sigma_L$) and shorter running times
- The Q^2=15.0 GeV^2 point would be "expensive" in terms of running time, but its high scientific priority would make it worthwhile
- **This seems a compelling scenario for a Phase 2 Upgrade**

p(e,e'π^+)n Kinematics

E_{beam}	θ_{HMS} (e')	P_{HMS} (e')	$\theta_{q(SHMS)}$ (π^+)	P_{SHMS} (π^+)	Time FOM
Q^2=8.5 W=4.06 $-t_{min}$=0.17 $\Delta\varepsilon$=0.26					
16.0	23.68	3.15	5.52	12.75	17.7
20.0	14.00	7.15	7.55	12.75	1.9
Q^2=10.0 W=3.96 $-t_{min}$=0.23 $\Delta\varepsilon$=0.28					
16.0	27.41	2.78	5.41	13.09	47.7
20.0	15.60	6.78	7.72	13.09	4.5
Q^2=11.5 W=3.96 $-t_{min}$=0.29 $\Delta\varepsilon$=0.27					
17.0	27.54	2.98	5.49	13.86	76.3
21.0	16.10	6.98	7.72	13.86	8.1
Q^2=13.0 W=3.96 $-t_{min}$=0.35 $\Delta\varepsilon$=0.25					
18.0	27.55	3.18	5.54	14.63	123.6
22.0	16.49	7.18	7.69	14.63	14.4
Q^2=15.0 W=3.78 $-t_{min}$=0.50 $\Delta\varepsilon$=0.27					
18.0	31.30	2.86	5.46	14.87	391
22.0	18.14	6.86	7.86	14.87	41.4

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20 GeV/c HMS Scenario: π^+ Form Factor

- **ADDENDUM: Dave Mack suggests 20 GeV/c HMS' for π^+, and SHMS for e'**
  - Assume θ_{min}=5.5°, θ_{open}=15.0°
  - HMS': $\Delta\Omega$, $\Delta P/P$ similar SHMS
- Q^2 reach remains 15.0 GeV^2, with similar errors, although running times are increased due to $\Delta\Omega_{HMS'}$ assumed smaller than $\Delta\Omega_{HMS}$
- $\theta_{HMS'}$<5.5° allows improved $\Delta\varepsilon$, but does not affect maximum Q^2 reach
- $P_{HMS'}$=15.0 GeV/c is sufficient, constrained by max beam energy
- θ_{SHMS}<12.0°, P_{SHMS}>9.0 not used
- **A more feasible scenario for Phase 2 Upgrade**

p(e,e'π^+)n Kinematics

E_{beam}	θ_{SHMS} (e')	P_{SHMS} (e')	$\theta_{q(HMS')}$ (π^+)	$P_{HMS'}$ (π^+)	Time FOM
Q^2=8.5 W=4.18 $-t_{min}$=0.15 $\Delta\varepsilon$=0.28					
17.0	21.39	3.63	5.55	13.29	20.5
22.0	12.15	8.63	7.62	13.29	1.8
Q^2=10.0 W=4.08 $-t_{min}$=0.21 $\Delta\varepsilon$=0.30					
17.0	24.49	3.27	5.52	13.62	53.3
22.0	13.46	8.27	7.85	13.62	4.3
Q^2=11.5 W=3.95 $-t_{min}$=0.29 $\Delta\varepsilon$=0.31					
17.0	27.34	3.03	5.55	13.82	124.8
22.0	14.66	8.03	8.12	13.82	9.3
Q^2=13.0 W=3.96 $-t_{min}$=0.35 $\Delta\varepsilon$=0.25					
18.0	27.55	3.18	5.54	14.63	209.5
22.0	16.49	7.18	7.69	14.63	24.4
Q^2=15.0 W=3.73 $-t_{min}$=0.52 $\Delta\varepsilon$=0.26					
18.0	30.24	3.06	5.73	14.66	560
22.0	17.88	7.06	8.07	14.66	65.7

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Importance of JLab F_π in EIC Era

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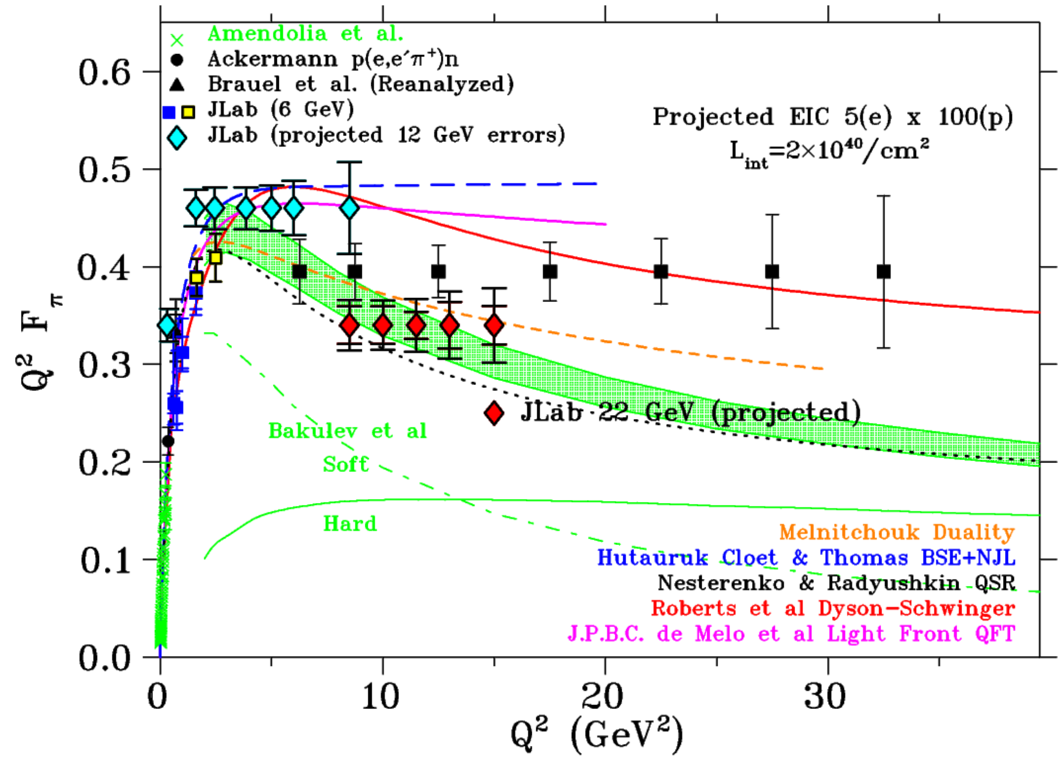
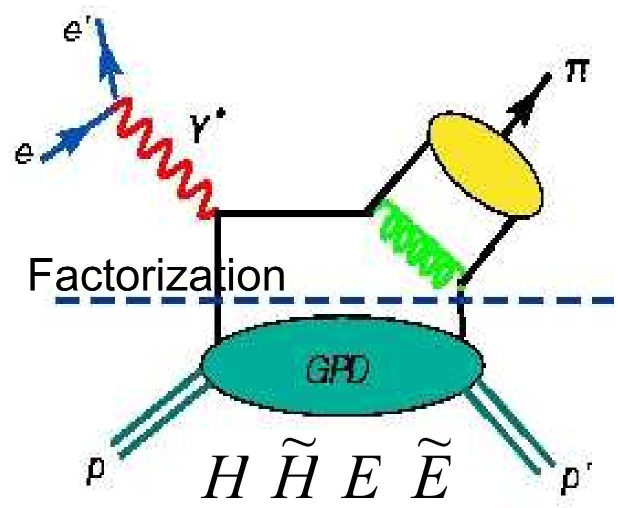


- Quality L/T-separations impossible at EIC (can't access ε<0.95)
- JLab will remain ONLY source of quality L–T separated data!
- **Phase 2: 22 GeV beam with upgraded HMS'**
  - Extends region of high quality F_π values to Q^2=13 GeV^2
  - Somewhat larger errors to Q^2=15 GeV^2
- Provides MUCH improved overlap of F_π data set between JLab and EIC!

Hard–Soft Factorization in DEMP

- **To access physics contained in GPDs, one is limited to the kinematic regime where hard-soft factorization applies**
  - No single criterion for the applicability, but tests of necessary conditions can provide evidence that the Q^2 scaling regime has been reached

- **One of the most stringent tests of factorization is the Q^2 dependence of the π/K electroproduction cross sections**
  - σ_L scales to leading order as Q^{-6}
  - σ_T does not, expectation of Q^{-8}
  - As Q^2 becomes large: $\sigma_L >> \sigma_T$



- **Experimental validation of onset of hard scattering regime is essential for reliable interpretation of JLab GPD program results**
  - Is onset of scaling different for kaons than pions?
  - K^+ and π^+ together provide quasi model-independent study

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DEMP Q^{-n} Hard–Soft Factorization Tests

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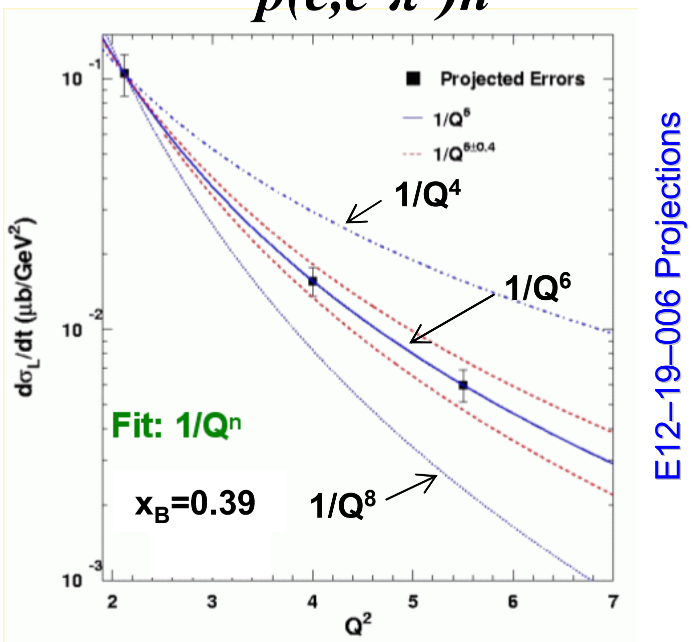
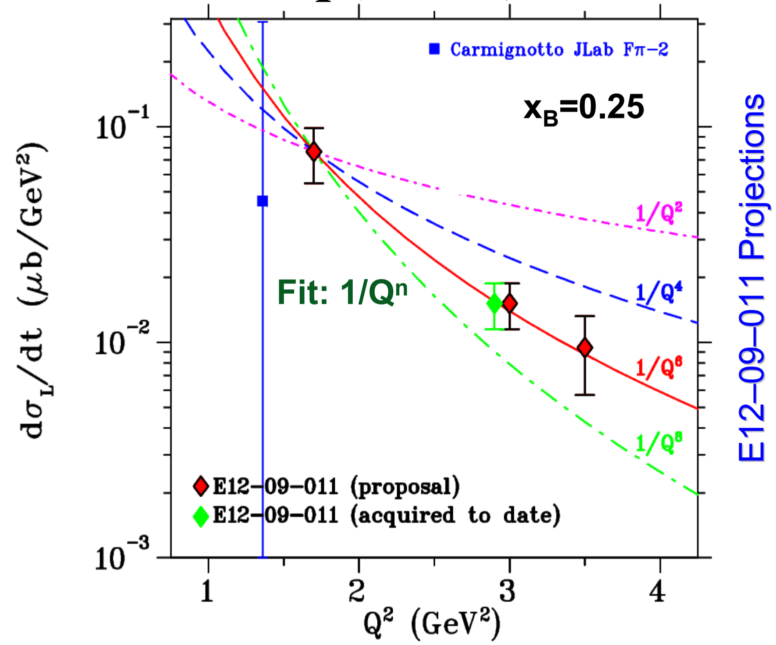
$p(e,e'\pi^+)n$



x	Q^2 (GeV^2)	W (GeV)	$-t_{min}$ (GeV^2)
0.31	1.45–3.65	2.02–3.07	0.12
	1.45–6.5	2.02–3.89	
0.39	2.12–6.0	2.05–3.19	0.21
	2.12–8.2	2.05–3.67	
0.55	3.85–8.5	2.02–2.79	0.55
	3.85–11.5	2.02–3.23	

$p(e,e'K^+)\Lambda$



x	Q^2 (GeV^2)	W (GeV)	$-t_{min}$ (GeV^2)
0.25	1.7–3.5	2.45-3.37	0.20
	1.7–5.5	2.45–4.05	
0.40	3.0–5.5	2.32–3.02	0.50
	3.0–8.7	2.32–3.70	

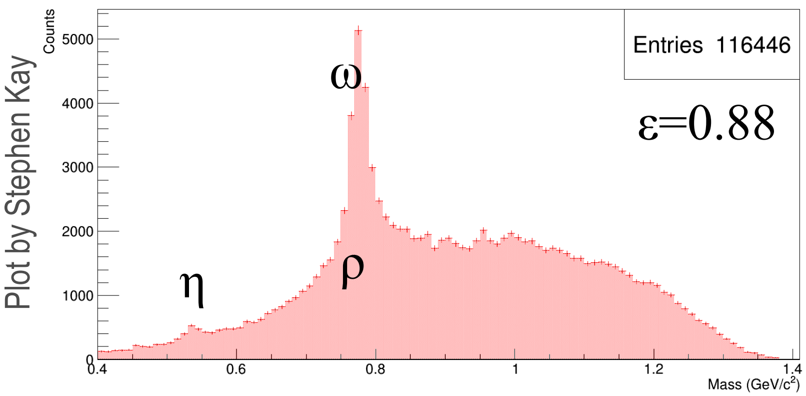
PHASE 1 SCENARIO

***Q^{-n}* scaling test range nearly doubles with 18 GeV beam and HMS+SHMS**

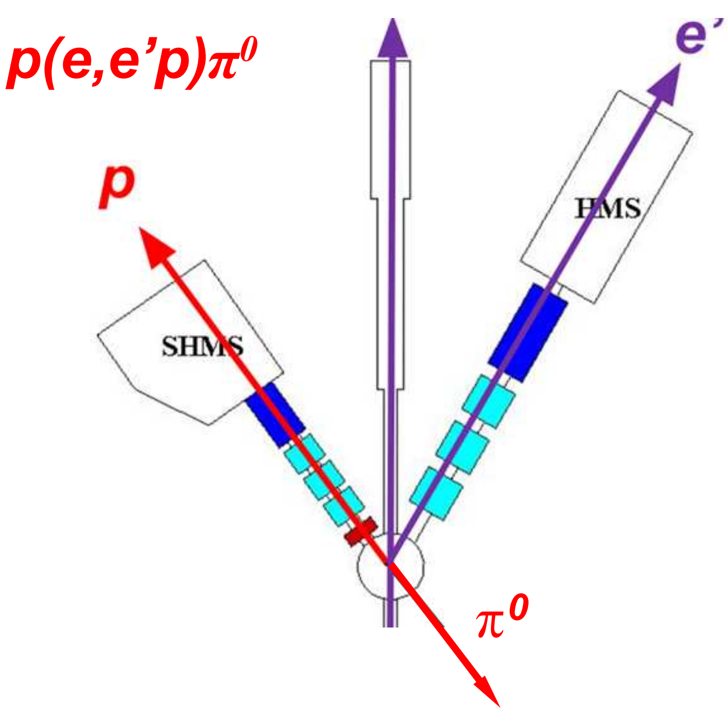
Hard–Soft Factorization in Backward Exclusive π^0

p(e ,e'p)X KaonLT Data Analysis

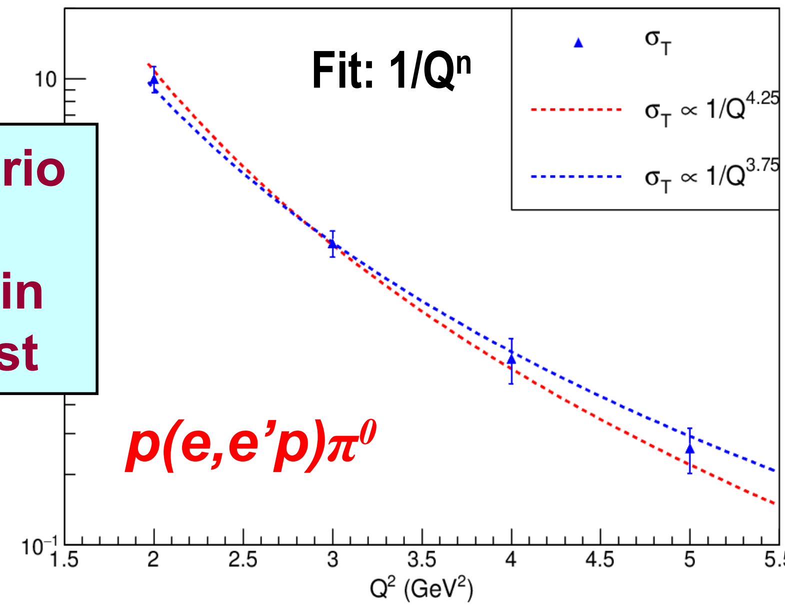
Q^2=3.00 W=2.32 θ_{pq}=+3.0° $-u$=0.15 ξ_u=0.15



- **Fortuitous discovery of substantial backward angle meson production during meson form factor experiments**
- Can be described by extension of collinear factorization to backward angle (u–channel)
- Backward angle factorization first suggested by Frankfurt, Polykaov, Strikman, Zhalov, Zhalov [arXiv:hep-ph/0211263]



Phase 1 Scenario will enable improvement in Q^{-n} scaling test



E12–20–007: First dedicated u–channel experiment

Spokespersons: W.B. Li, G.M. Huber, J. Stevens

Purpose: test applicability of TDA formalism for π^0 production

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Staged Upgrade Seems Logical

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- **Phase 1:** Upgrade Beam to 18 GeV, minor upgrades of SHMS, HMS PID, tracking and DAQ
  - Example Measurements:
  - Pion form factor to Q^2=10 GeV^2 with small errors, and to 11.5 with larger uncertainties
  - Kaon form factor to Q^2=7.0 GeV^2 with small errors, and to 9.0 with larger uncertainties
  - Hard–Soft Q^{-n} factorization tests with p(e,e'π^+)n and p(e,e'K^+)Λ
  - Studies of backward angle Q^{-n} factorization via u–channel p(e,e'p)π^0 and p(e,e'p)ω
- **Phase 2:** Upgrade Beam to 22 GeV, upgrade HMS' to 15 GeV/c
  - This would enable a significant increase in Q^2 reach of quality L–T separations for Deep Exclusive Meson Production
    - e.g. Pion Form factor up to Q^2=15 GeV^2

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The importance of L–T Separations

- Hall C is the world's only facility that can do L–T separations over a wide kinematic range
- The error magnification in L–T separations depends crucially on the achievable difference in the virtual photon polarization parameter, ε.
  - Errors magnify as $1/\Delta\varepsilon$, where $\Delta\varepsilon=\varepsilon_{High}-\varepsilon_{Low}$
  - To keep the magnification <500%, one desires $\Delta\varepsilon>0.2$
  - This is not feasible at the EIC, as the high ion ring energy constrains $\varepsilon>0.98$
  - Thus, Hall C will remain the world's main source of L–T separated data well into the EIC era
- As the interpretation of some EIC data (e.g. GPD extraction) will depend on extrapolation of Hall C L–T separated data, maximizing the overlap between the Hall C and EIC data sets should be a high priority

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New Collaborators Welcome!

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- **We are looking to identify interested groups of collaborators for Hall C Future Studies**
- **If you are interested, please contact any of the KaonLT / PionLT / u–Channel Leaders:**
  - Dave Gaskell, JLab
  - Tanja Horn, CUA
  - Stephen Kay, Regina
  - Wenliang (Bill) Li, Stony Brook
  - Pete Markowitz, FIU
  - GH, Regina

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PDF position available

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- **Contribute to this program and more!**
- Excellent opportunity for those who are looking forward to a permanent academic position in the future, to strengthen their research and teaching resumes and gain valuable experience in the classroom.
- High priority experiments in Deep Exclusive Meson Production at Jefferson Lab Hall C
- Feasibility studies to extend these measurements to higher energy at the EIC
- Cherenkov detector development for the Solenoidal Large Intensity Device (SoLID) in Jefferson Lab Hall A.
- Position is for a 3-year term. Upon mutual agreement, there is possibility of a further 2-year extension. Comprehensive benefits package is included.
- **Further information:** http://lichen.phys.uregina.ca
- **Application portal:** https://urcareers.uregina.ca/postings/11172
- **Contact me at** huberg@uregina.ca

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