E12-06-101 and E12-07-105

S. Ali, D. Androic, K. Aniol, J. Arrington, A. Asaturyan, F. Benmokthar, V. Berdnikov, D. Biswas, W. Boeglin, P. Bosted, E.J. Brash, W. Boeglin, A. Camsonne, M. Carmignotto, J.-P. Chen, E.Christy, S. Covrig-Dusa, D. Day, D. Crabb, W. Deconinck, M. Diefenthaler, D. Dutta, M.Elaasar, R. Ent, **D. Gaskell**, H. Fenker, E. Fuchey, D. Hamilton, O. Hansen, F. Hauenstein, D.Higinbotham, **T. Horn**, **G.M. Huber**, C.E. Hyde, M. Jones, S. Joosten, S. Kay, D. Keller, C.Keppel, P. King, E. Kinney, M. Kohl, V. Kumar, W. Li, A. Liyanage, D. Mack, S. Malace, P.Markowitz, R. Michaels, A. Mkrtchyan, H. Mkrtchyan, M. Muhoza, C. Munoz-Camacho, A.Puckett, G. Niculescu, I. Niculescu, Z. Papandreou, J. Roche, B. Sawatzky, S. Sirca, G.R.Smith, H. Szumila, V. Tadevosyan, R. Trotta, A. Teymurzyan, A. Usman, B. Wojtsekhowski, S. Wood, C. Yero

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Overview E12-06-101/E12-07-105 (PionLT)

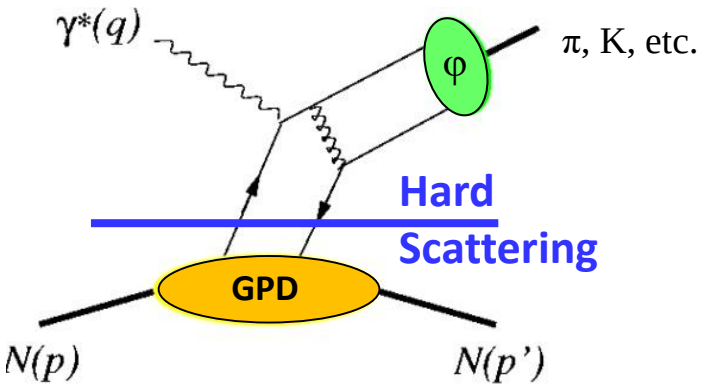
Goals

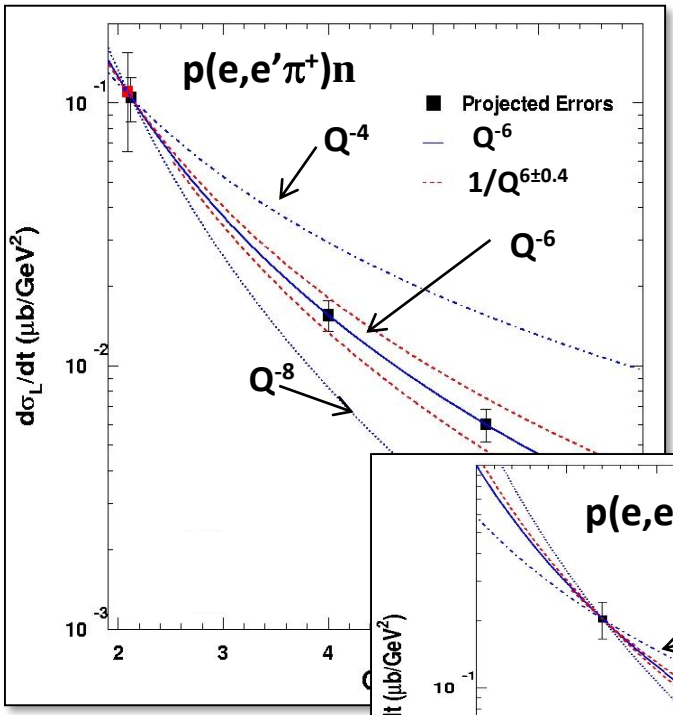
- Separated cross sections as a function of Q^2 at fixed x=0.3, 0.4, 0.55 to investigate the reaction mechanism towards 3D imaging studies
- Reliable pion form factor extractions up to the largest Q^2 accessible until the EIC
  - Combine two separately PAC-approved experiments to achieve more physics output from the same beam time (88 days)

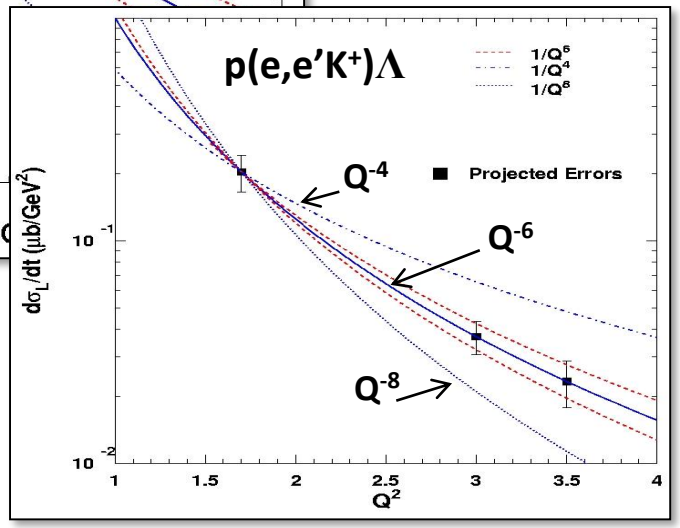
Motivation

- Pion structure is the clearest test case for studies of the transition from the nonperturbative to perturbative region
- Need to validate the hard-exclusive reaction mechanism – key are precision longitudinal-transverse (L/T) separated data over a range of Q^2 at fixed x/t
- L/T separated pion electroproduction is the clearest test case for studies of the transition from the nonperturbative to perturbative region beyond DVCS
- Pion electroproduction could allow access to transversity and regular GPDs

Review Scientific Motivation: Reaction Mechanism







π^+: to Q^2~9 GeV^2
K^+: to Q^2~6 GeV^2

Fit: $1/Q^n$

- One of the most stringent tests of the reaction mechanism is the Q^2 dependence of the π and K electroproduction cross section
  - σ_L scales to leading order as Q^{-6}
  - σ_T does not
- Experimental validation of reaction mechanism is essential for reliable interpretation of results from the JLab GPD program at 12 GeV for meson electroproduction
  - **If σ_T is confirmed to be large, it could allow for detailed investigations of transversity GPDs. If, on the other hand, σ_L is measured to be large, this would allow for probing the usual GPDs**

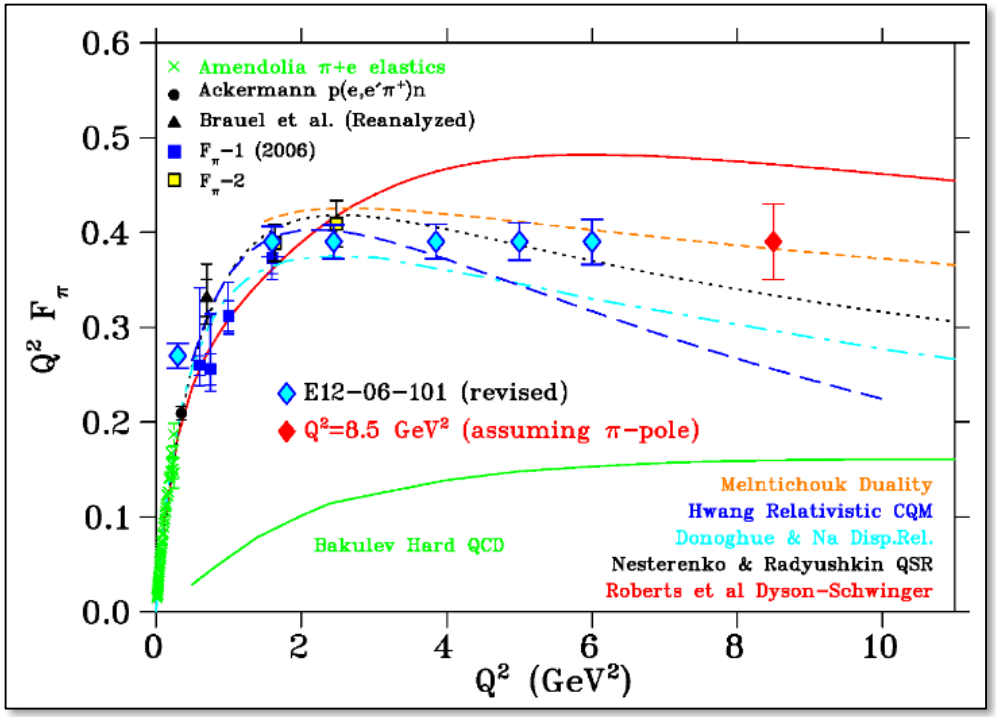
Review Scientific Motivation: Form Factors

- ***Pion and kaon form factors*** are of special interest in hadron structure studies
  - The *pion* is the lightest QCD quark system and also has a central role in our understanding of the dynamic generation of mass

Clearest test case for studies of the transition from non-perturbative to perturbative regions

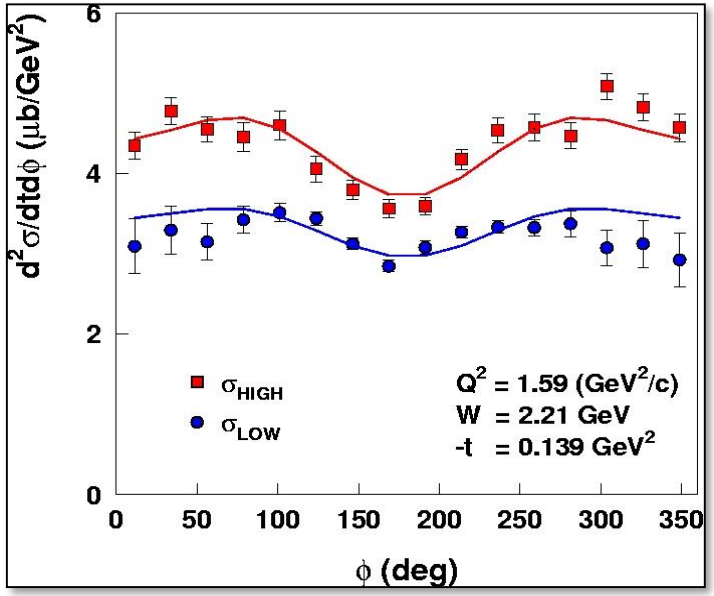
- Completed Hall C experiments have established JLab's capability for reliable F_π measurements and are among the top-cited works from JLab

- New higher Q^2 data would challenge QCD-based models in the most rigorous way and provide a real advance in our understanding of light quark systems



L/T Separation Example

- σ_L is isolated using the Rosenbluth separation technique
  - Measure the cross section at two beam energies and fixed W, Q^2, -t
  - Simultaneous fit using the measured azimuthal angle (ϕ_π) allows for extracting L, T, LT, and TT
- Careful evaluation of the systematic uncertainties is important due to the 1/ε amplification in the σ_L extraction
  - Spectrometer acceptance, kinematics, and efficiencies



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

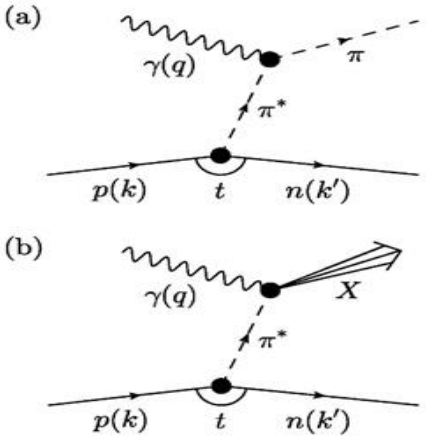
σ_L will give us F_π

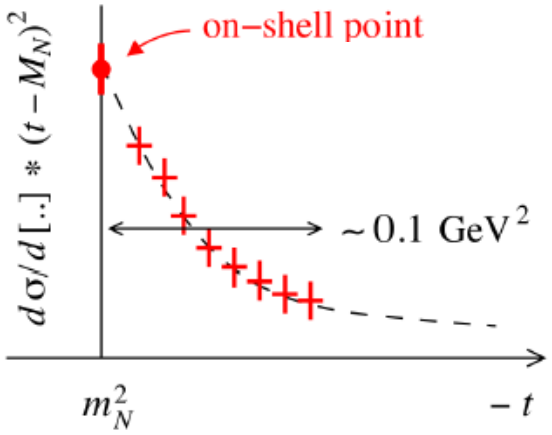
Magnetic spectrometers a must for such precision cross section measurements

- This is only possible in Hall C at JLab
- SHMS was built to meet these exp. req.

Accessing pion structure through the Sullivan Process

- The **Sullivan process can provide reliable access to a meson target** as *t* becomes space-like if the pole associated with the ground-state meson remains the dominant feature of the process and the structure of the related correlation evolves slowly and smoothly with virtuality.





- To **check these conditions** are satisfied empirically, one can **take data covering a range in *t*** and compare with phenomenological and theoretical expectations.

- Recent **theoretical calculations found that for -t ≤ 0.6 GeV², all changes in pion structure are modest** so that a well-constrained experimental analysis should be reliable The Sullivan processes can provide a valid pion target for -t ≤ 0.6 GeV²

[S.-X. Qin, C. Chen, C. Mezrag and C. D. Roberts, Phys. Rev. C 97 (2018) 015203.]

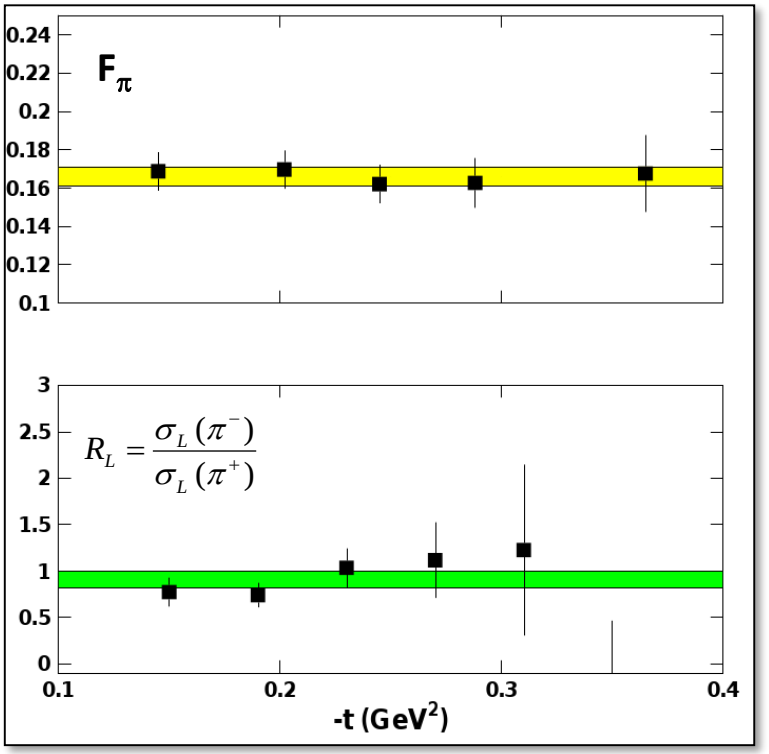
Experimental Validation (Pion Form Factor example)

Experimental studies over the last decade have given more *confidence* in the electroproduction method yielding the physical pion form factor

Experimental studies include:

- Check consistency of model with data
  - F_π values seem robust at larger -t (>0.2) – increased confidence in applicability of model to the kinematic regime of the data
- Verify that the pion pole diagram is the dominant contribution in the reaction mechanism
  - R_L (= $\sigma_L(\pi^-)/\sigma_L(\pi^+)$) approaches the pion charge ratio, consistent with pion pole dominance
- Extract F_π at several values of t_{min} for fixed Q^2 (not shown here)

Q^2=2.45 GeV^2, W=2.22 GeV



$$R_L = \frac{\sigma(n(e,e'\pi^-)p)}{\sigma(p(e,e'\pi^+)n))} = \frac{|A_v - A_s|^2}{|A_v + A_s|^2}$$

Using a model to extract of F_π from σ_L JLab data

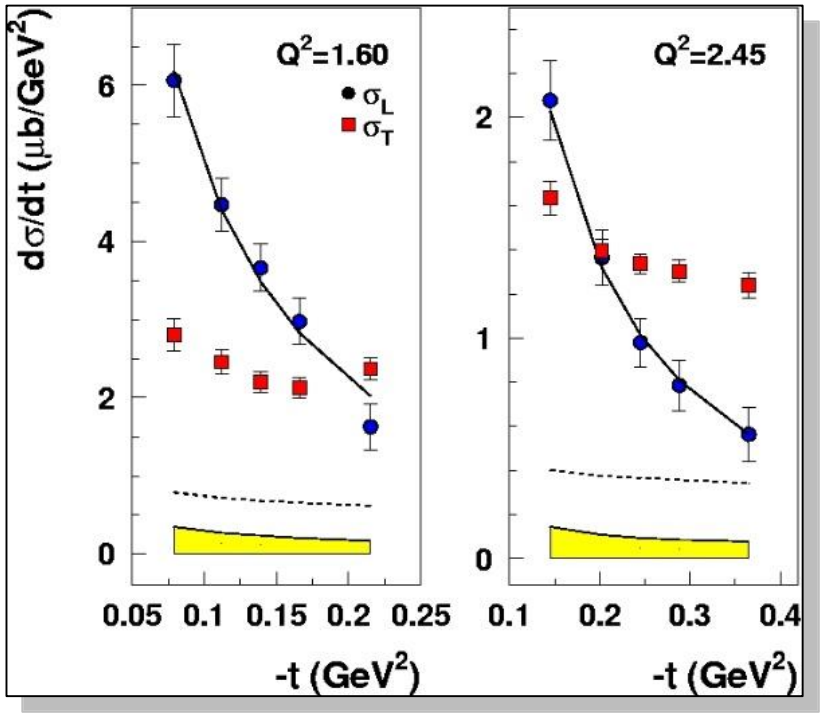
- JLab 6 GeV F_π experiments used the VGL/Regge model as it has proven to give a reliable description of σ_L across a wide kinematic domain

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

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

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

*[Horn et al., PRL **97**, (2006) 192001]*



- Separated L/T cross sections will be published, so F_π can be extracted using other models as they become available, e.g. *R. J. Perry et al., arXiv:1811.09356 (2018)*

$$\Lambda_\pi^2 = 0.513,\ 0.491\ GeV^2$$

$$\Lambda_\rho^2 = 1.7\ GeV^2$$

PionLT Publications – based on two 6 GeV pion experiments

~2000

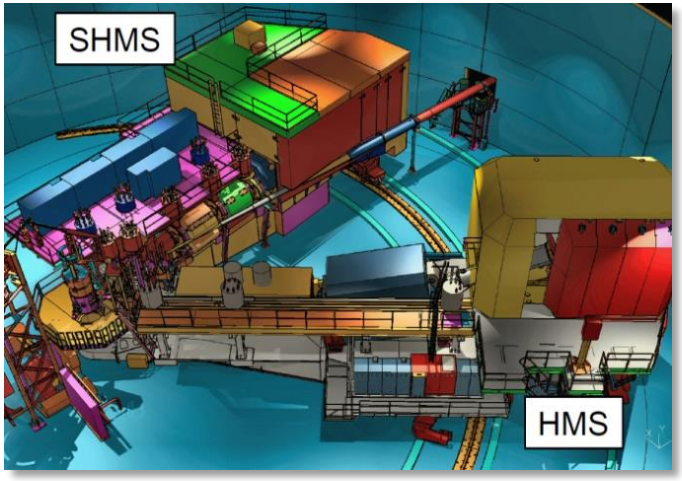
6 GeV Pion Experiments:
1997 (phase 1)
2003 (phase 2)

- J. Volmer, et al., Phys. Rev. Lett. **86** (2001) 1713 – **305 citations**
  - Precision F_π results between Q^2=0.60 and 1.60 GeV^2
- T. Horn, D. Gaskell, G. Huber, et al., Phys. Rev. Lett. **97** (2006) 192001 – **236 citations**
  - Precision F_π results at Q^2=1.60 and 2.45 GeV^2
- V. Tadevosyan, et al., Phys. Rev. C**75** (2007) 055205 – **200 citations**
- G. Huber, T. Horn, D. Gaskell, et al., Phys. Rev. C**78** (2008) 045203 – **175 citations**
  - Archival paper of precision F_π measurements at JLab 6 GeV
- H. P. Blok, T. Horn, G. Huber, et al., Phys. Rev. C**78** (2008) 045202 – **101 citations**
  - Archival paper of precision LT separated pion cross sections at JLab 6 GeV
- T. Horn, D. Gaskell, G. Huber, et al., Phys. Rev. C**78** (2008) 058201 – **62 citations**
  - L/T cross sections and F_π at Q^2=2.15 GeV^2 ,exploratory at Q^2~4.0 GeV^2
- Plus several spin-off papers on, e.g. L/T separations in π^- and ω production, high-t, transverse charge density (2012-present)

2019

Exclusive Pion Experiments in Hall C @ 12 GeV

- The pion experiments L/T separation requirements greatly influenced design specs of the new SHMS
  - Small forward-angle capabilities
  - Good angular reproducibilty
  - Missing mass resolution

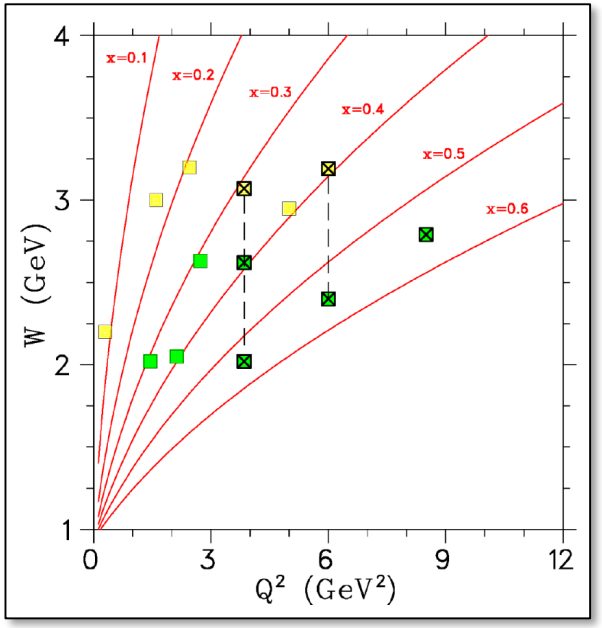


- The pion experiment proponents built (and are maintaining) key SHMS detectors for the experiments
  - Aerogel Cherenkov – funded by NSF MRI (CUA)
  - Heavy gas Cherenkov – partially funded by NSERC (U Regina)

Optimization of two experiments into one program

- Combined the kinematics of E12-06-101 and E12-07-105 to get more physics output from the same (approved) beam time:
  - L/T separated cross sections at fixed x=0.3, 0.4, 0.55 up to Q^2=8.5 GeV^2
  - Pion form factor at Q^2 values up to 6 GeV^2
  - Combining kinematics enables (within approved PAC days) pion form factor extraction at Q^2 =8.5 GeV^2, highest achievable at 12 GeV JLab

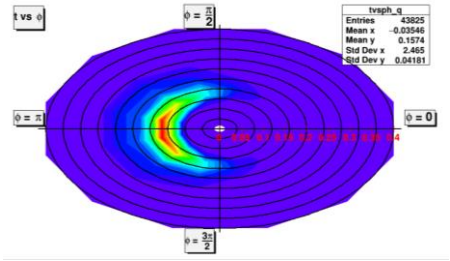
Consistent with PAC44 recommendation: "*The PAC confirms the high-impact status of the measurements of F_π to Q^2=6 GeV^2 and encourages the Lab to schedule the E12-06-101 component of this proposal accordingly. We recommend that the emphasis for the remaining beam time approved for E12-06-101 and E12-07-105 be further measurements of separated pion cross sections over a range of Q^2, x and, -t.*"

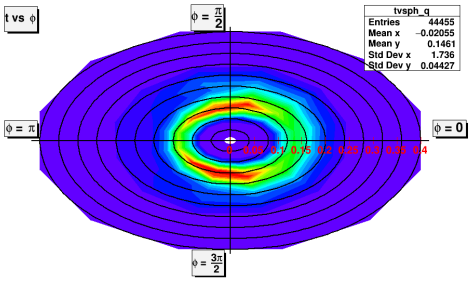


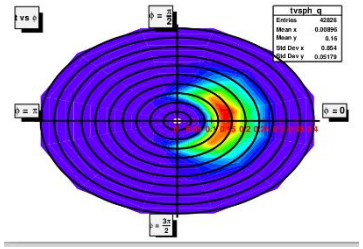
- Completed 3 PAC days out of 88 total in summer 2019 (at low energies) with this combined kinematics runplan

Low energy kinematic run summer 2019

With combined and optimized run plan completed 2 L/T separations at low Q^2 and took data for the low epsilon points for two more settings, which also required these beam energies







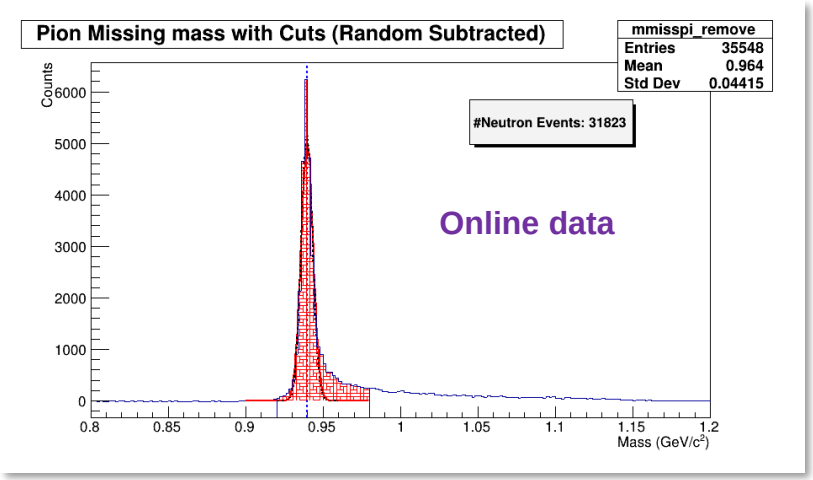
Three SHMS angles

Physics cross section

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

Two/three beam energies

Q^2 (GeV^2)	x_B	L/T complete	Purpose
0.375	0.09	Yes ✓	Form Factor
0.425	0.1	Yes ✓	Form Factor
1.45	0.3	No	Reaction mechanism
2.12	0.4	No	Reaction mechanism



Theory Report PAC47 (2019)

"Since the proposals were originally reviewed, the physics motivations for both studies have only increased"

- Calculations of the FF to highest values of Q^2 subject of ongoing activities in lattice community and calculations through, e.g. the DSE approach
  - Lattice: recent calculations have achieved ~6 GeV^2 (arxiv:1902.03808)
  - New methods to compute first principles calculation of the quark distribution amplitude (Braun et al.)
- Different approaches and calculational methods show significant differences as Q^2 increases, the emphasis in the combined run plan in attaining the highest possible Q^2 is particularly important

Selection of efforts benefitting from *new* L/T cross sections

2019

- P. Kroll, "Hard exclusive processes involving kaons", Eur. Phys. J. A**55** (2019) no. 5, 76
- *M. Carmignotto et al., "Separated Kaon Electroproduction cross section and the kaon form factor from 6 GeV Jlab data", Phys. Rev. C**97** (2018) no. 2, 025204*
- S.X. Qin, C. Chen, C. Mezrag, C.D. Roberts, "Off-shell persistence of [illegible]pions and kaons", Phys. Rev. C**97** (2018) no. 1, 0152203
- T. Horn, C.D. Roberts, "The pion: an enigma within the Stand[illegible]nys. G**43** (2016) no.7, 073001
- L. Favart, M. Guidal, T. Horn, P. Kroll, "Deeply Virtual M[illegible]n on the nucleon", Eur. Phys. J. A**52** (2016) no. 6, 158
- *M. Defurne et al., "Rosenbluth separation of th[illegible]duction cross section", Phys. Rev. Lett.**117** (2016) no. 26, 262001*
- G.R. Goldstein, J. Osvaldo Hernande[illegible]ie Parm. of GPDs: The Chiral Odd Sector", Phys. Rev. D**91** (2015) no.11, 114013
- T.K. Choi, K.J. Kong, B.G. Yu[illegible]. Soc. **67** (2015), L1089, arXiv:1508.00969
- T. Vrancx, J. Ryckebusch[illegible]*production above the resonance region*", Phys. Rev. C**89** (2014), 025203
- S.V. Goloskokov, P. Kroll, "[illegible]pole in hard exclusive VM leptoproduction", Eur. Phys. J. A**50** (2014) no. 9, 146
- S.V. Goloskokov, P. Kroll, "Transversity in exclusive vector-meson leptoproduction", Eur. Phys. J. C**74** (2014) 2725
- M. Carmignotto, T. Horn, G.Miller, "Pion transverse charge density and the edge of hadrons", Phys. Rev.. C**90** (2014)
- S. Liuti, G.R. Goldstein, J. Osvaldo Hernandez, K. Kathuria, "Chiral odd GPDs from exclusive p0 electroproduction", Nuovo Cim. C**036** (2013) no.05, 121
- P. Kroll, H. Moutarde, F. Sabatie, "From hard exclusive electroproduction to deeply virtual Compton Scattering", Eur. Phys. J. C**73** (2013) no. 1, 2278

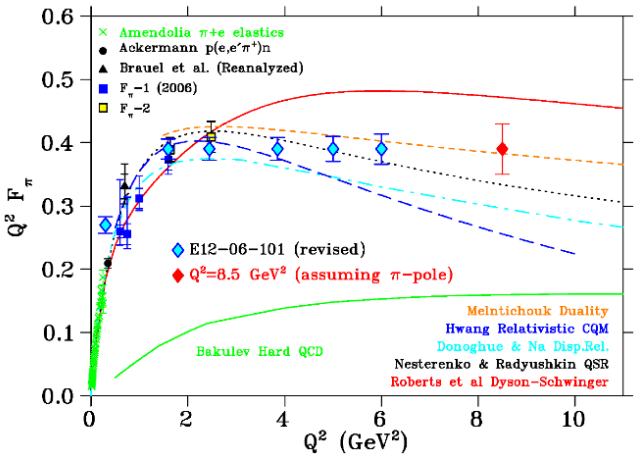
~2011 (PAC38)

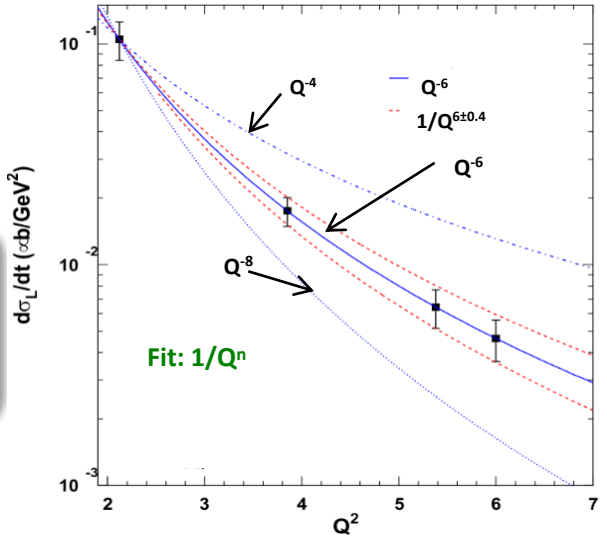
- S.V. Goloskokov, P. Kroll, "Transversity in hard exclusive electroproduction of pseudoscalar mesons", Eur. Phys. J. A**47** (2011) 112

Much progress in theory – need new data now to make further progress

Summary PionLT Program at 12 GeV

- Low-Q^2 data for E12-06-101/E12-07-105 (combined) completed this summer – equivalent to 3 PAC days
- Enables measurements of the separated π^+ cross sections as function of Q^2 at x=0.3, 0.4, 0.55
- Enables measurements of pion form factor at low t up to Q^2 = 6 GeV^2
- Combined allows for pion form factor extraction to the very largest Q^2 accessible at 12 GeV JLab, 8.5 GeV^2



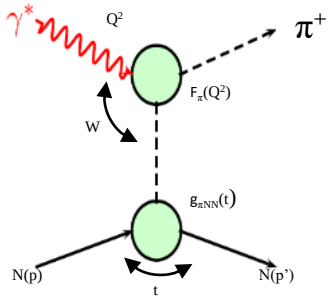


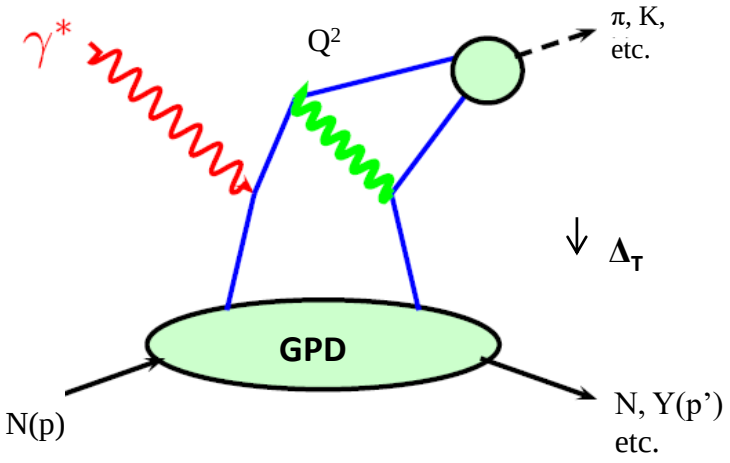
A comprehensive and coherent program of charged pion electroproduction, L/T-separated cross section measurements

F_π measurement up to Q^2=8.5 GeV^2 will contribute greatly to our understanding of QCD

Towards GPD flavor decomposition: DVMP

- Relative contribution of σ_L and σ_T to cross section are of great interest for nucleon structure studies





- described by 4 (helicity non-flip) GPDs: H E $\tilde{H}$ $\tilde{E}$
  - *H, E* (unpolarized), , (polarized)
- Quantum numbers in DVMP probe individual GPD components selectively
  - Vector : $\rho^o/\rho+/K^*$ select *H, E*
  - **Pseudoscalar: π,η,K select the polarized GPDs**
- Reaction mechanism can be verified experimentally - **L/T separated cross sections to test QCD Factorization**

- Recent calculations suggest that leading-twist behavior for light mesons may be reached at Q^2=5-10 GeV^2
- JLab 12 GeV can provide experimental confirmation in the few GeV regime

Previous PAC comments

PAC30

Issues: Since the measurement requires a large number of measurements at different energy and spectrometer settings, a careful optimization of the schedule is strongly recommended. The use of a longer target envisaged in the proposal requires a proper understanding of the corresponding variation in the acceptance. This does not look an issue since the simulated variation is smooth. On the other hand a longer target, but not beyond 10 cm, may allow a reduction in the beam current that could be a benefit for operation in other halls. Given the delicate nature of acceptance issues in Rosenbluth separations that require adequate understanding of the spectrometer performance, it is clear and acknowledged by the proponents that the experiment could only run after an adequate commissioning of the new SHMS.

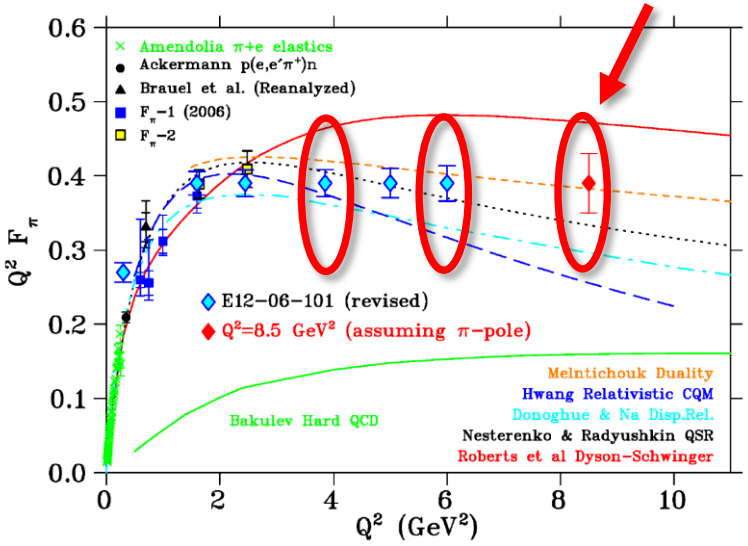
PAC32

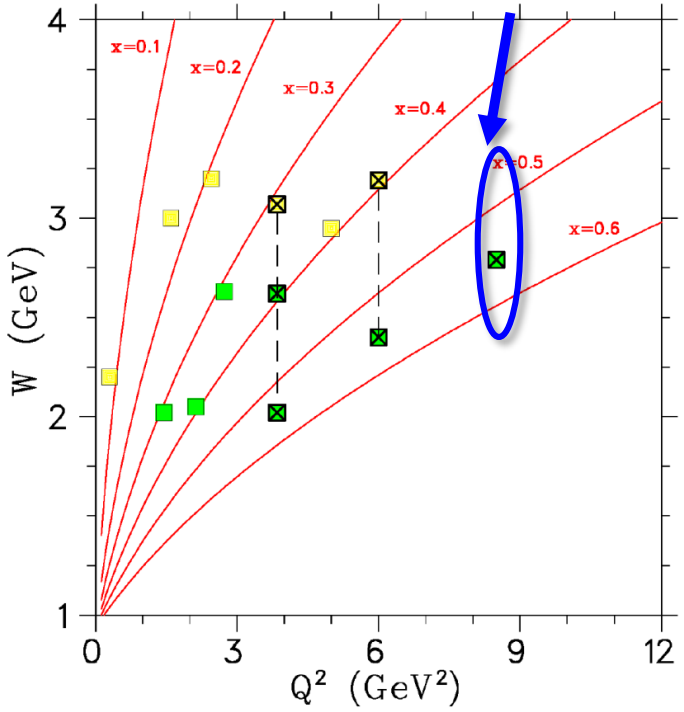
Issues: A detailed study to determine whether or not meson electroproduction can provide information on GPDs is important. The PAC believes that the kinematics might not be fully optimized. The experiment could better overlap the F_π-experiment. The collaboration should consider whether the highest x / Q^2 point fully justifies the large time required.

Justification of the beam time for the highest x/Q^2 point

Moved the previous E12-07-105 point at Q^2=9.1 GeV^2 to Q^2=8.5 GeV^2 to extend F_π extraction to the highest possible Q^2 at JLab 12 GeV

- Benefits from reduced uncertainties due to higher rate and more favorable $\Delta\varepsilon$ magnification
- Q^2 range for largest x = 0.55 now from 4.0 to 8.5 GeV^2, all kinematics also benefit F^π extractions



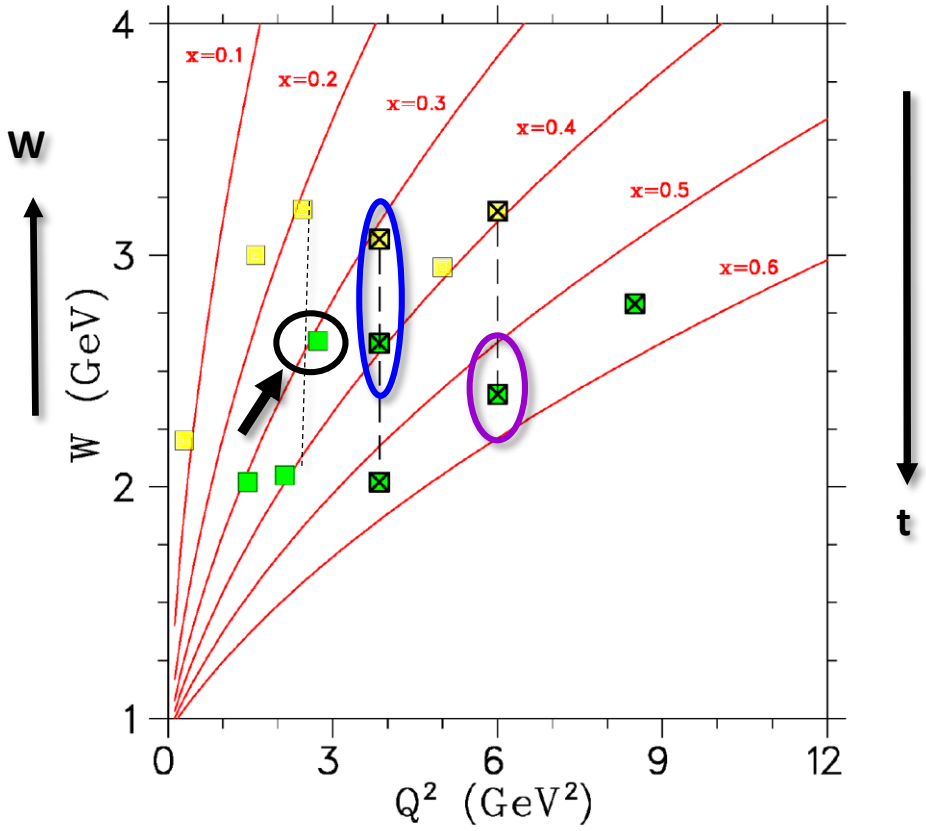


Potential physics outcome justifies the beam time requirement

Optimization between the two experiments (PAC32)

To achieve better overlap between the two experiments, move Q^2=6.6 point of E12-07-105 to 6.0 GeV^2 and re-arrange intermediate points to common Q^2=3.85 GeV^2

- t-scans at fixed Q^2
  - Q^2=3.85 GeV^2
    - t_{min}=0.12, 0.21, 0.49 GeV^2
  - Q^2=6.0 GeV^2
    - t_{min}=0.21, 0.53 GeV^2
  - Q^2=2.12 GeV^2
    - t_{min}=0.20 GeV^2



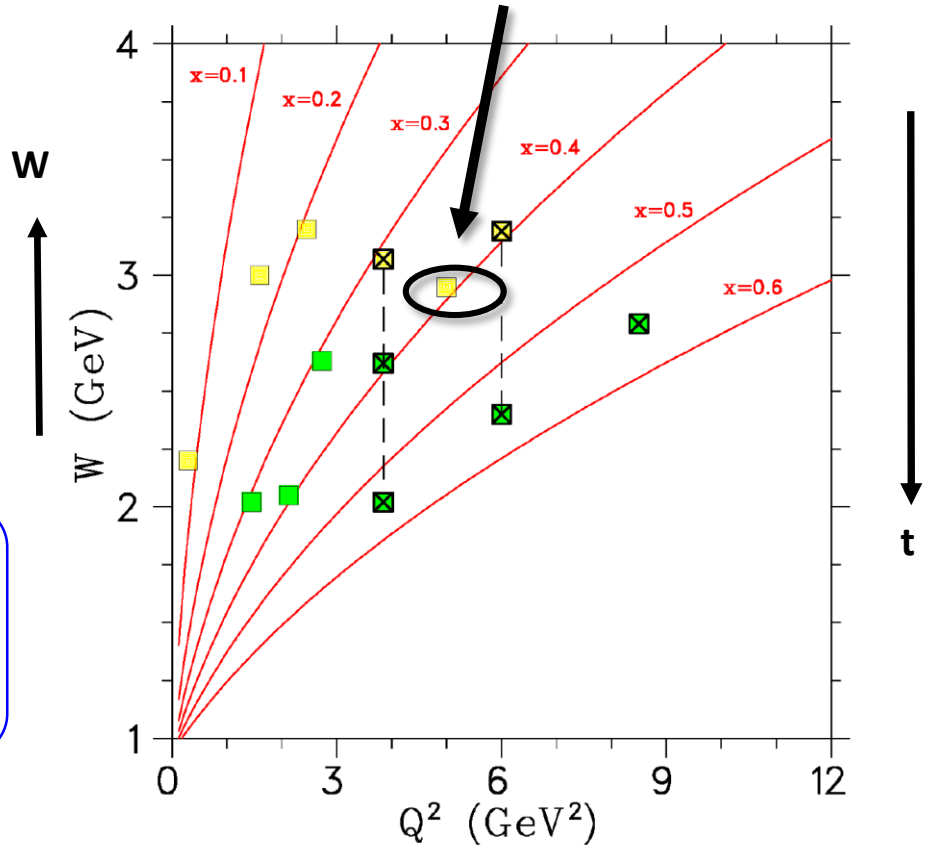
Note: W increases as t decreases

Optimization of the schedule (PAC30)

Eliminate points at Q^2=4.46 GeV^2 (E12-06-101) and Q^2=5.5 GeV^2 (E12-07-105) – move Q^2=5.25 GeV^2 point of E12-06-101 to Q^2=5.0 GeV^2 to also serve in x-scan

❑ Additional optimizations:

- ➢ Revised all settings to minimize the number of settings requiring special Linac gradients
- ➢ Reduced the most forward angle requirements
- ➢ Increased target cell length from 8 cm to 10 cm allowing for reduction in max beam current from 85 μA (with 8 cm target assumed for PAC35/38) to 70μA.



Note: W increases as t decreases

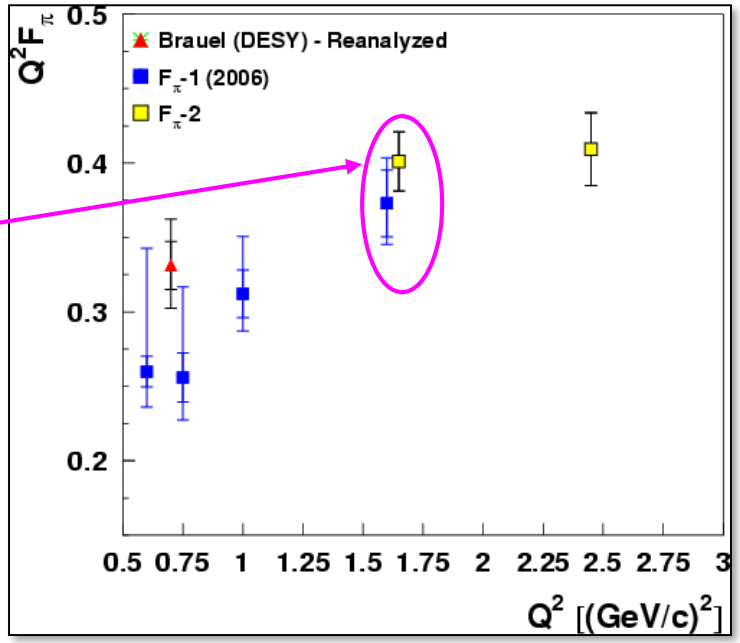
Extract FF at different values of t_{min}

- Test by extracting the pion form factor at different distances from the –t pole

  - Data from JLab 6 GeV show good agreement for different t_{min} values

    Fpi2: t_{min}=0.093 GeV^2

    Fpi1: t_{min}=0.150 GeV^2



- More detailed tests planned with future 12 GeV experiment taking data at even lower t_{min} (0.029 and 0.048 GeV^2 at Q^2=1.6 and 2.45 GeV^2)

Optimized settings for both experiments

Running summer 2019

Used for both FF and reaction mechanism validation, as well as validation FF extraction at high t

FF extraction at high Q^2

Q^2	W	x	$-t_{min}$	Type	E_e	ε	θ_q	$\theta_{\pi q}$	Hrs
0.38	2.20	0.087	0.008	LH+	2.8	0.286	5.70	0, +2, +4°	11.1
					3.7	0.629	8.87	-2, 0, +2, +4°	14.8
					4.6	0.781	10.33	-4, -2, 0, +2, +4°	18.5
1.60	3.00	0.165	0.029	LH+	6.7	0.408	6.36	0, +2°	9.9
					8.8	0.689	8.70	-2, 0, +2°	12.8
					11.0	0.817	9.91	-2, 0, +2°	12.8
1.60	3.00	0.165	0.029	LD+	6.7	0.408	6.36	0, +2°	9.9
					11.0	0.817	9.91	-2, 0, +2°	12.8
1.60	3.00	0.165	0.029	LD-	6.7	0.408	6.36	0, +2°	18.7
					11.0	0.817	9.91	-2, 0, +2°	12.8
2.45	3.20	0.208	0.048	LH+	8.0	0.383	6.26	0, +2°	9.9
					8.8	0.505	7.30	-1.8, 0, +2°	12.8
					11.0	0.709	9.03	-2, 0, +2°	12.8
3.85	*3.07*	*0.311*	*0.120*	*LH+*	*8.0*	*0.301*	*6.53*	*-1.03, 0, +2°*	*33.5*
					8.8	*0.436*	*7.97*	*-2, 0, +2°*	*18.2*
					9.9	*0.572*	*9.31*	*-2, 0, +2°*	*13.3*
					11.0	*0.666*	*10.27*	*-2, 0, +2°*	*12.8*
3.85	3.07	0.311	0.120	LD+	8.0	0.301	6.53	-1.03, 0, +2°	33.5
					11.0	0.666	10.27	-2, 0, +2°	12.8
3.85	3.07	0.311	0.120	LD-	8.0	0.301	6.53	0, +2°	118.8
					11.0	0.666	10.27	-2, 0, +2°	12.8
5.00	*2.95*	*0.390*	*0.209*	*LH+*	*8.0*	*0.238*	*6.35*	*0, +2°*	*74.5*
					9.9	*0.530*	*9.76*	*-2, 0, +2°*	*41.1*
					11.0	*0.633*	*10.88*	*-2, 0, +2°*	*27.0*
6.00	*3.19*	*0.392*	*0.214*	*LH+*	*9.2*	*0.184*	*5.13*	*0.37, +2°*	*189.2*
					9.9	*0.304*	*6.64*	*0, +2°*	*80.6*
					11.0	*0.452*	*8.22*	*-2, 0, +2°*	*71.9*
Calibrations									80.0
Beam Energy Changes									72.0
Total Hours (100% efficiency)									1054.6
PAC35 Approved Hours (100% efficiency)									1248.0
Time Saved: 1248-1054.6 hrs (100% efficiency)									-193.4

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Q^2	W	x	$-t_{min}$	Type	E_e	ε	θ_q	$\theta_{\pi q}$	Hrs
1.45	2.02	0.312	0.114	LH+	3.7	0.511	13.76	-2, 0, +2°	11.1
					6.7	0.880	20.17	-2, 0, +2°	10.0
2.73	2.63	0.311	0.118	LH+	6.7	0.513	10.30	-2, 0, +2°	13.8
					11.0	0.845	14.58	-2, 0, +2°	9.3
2.12	2.05	0.390	0.195	LH+	4.6	0.573	15.14	-2, 0, +2°	11.1
					8.8	0.907	21.44	-2, 0, +2°	12.8
3.85	2.62	0.392	0.208	LH+	6.7	0.360	8.94	-2, 0, +2°	22.5
					11.0	0.799	14.58	-2, 0, +2°	9.6
3.85	*2.62*	*0.392*	*0.208*	*LD+*	*6.7*	*0.360*	*8.94*	*-2, 0, +2°*	*22.5*
					11.0	*0.799*	*14.58*	*-2, 0, +2°*	*9.6*
3.85	*2.62*	*0.392*	*0.208*	*LD-*	*6.7*	*0.360*	*8.94*	*-2, 0, +2°*	*74.9*
					11.0	*0.799*	*14.58*	*-2, 0, +2°*	*9.6*
3.85	2.02	0.546	0.487	LH+	6.0	0.582	17.41	-2, 0, +2°	9.6
					11.0	0.898	21.92	-2, 0, +2°	9.6
6.00	2.40	0.551	0.530	LH+	8.0	0.449	11.26	-2, 0, +2°	48.5
					11.0	0.738	15.31	-2, 0, +2°	18.4
6.00	*2.40*	*0.551*	*0.530*	*LD+*	*8.0*	*0.449*	*11.26*	*-2, 0, +2°*	*48.5*
					11.0	*0.738*	*15.31*	*-2, 0, +2°*	*18.4*
6.00	*2.40*	*0.551*	*0.530*	*LD-*	*8.0*	*0.449*	*11.26*	*-2, 0, +2°*	*48.5*
					11.0	*0.738*	*15.21*	*-2, 0, +2°*	*18.4*
8.50	**2.79**	**0.552**	**0.550**	**LH+**	**9.2**	**0.156**	**5.52**	**0°**	**388.0**
					11.0	**0.430**	**9.36**	**0°**	**108.5**
Calibrations									48.0
Extra calibrations needed for large angle *ytar*									8.0
Beam energy changes									72.0
Total Hours (100% efficiency)									1057.3
PAC38 Approved Hours (100% efficiency)									864.0
Extra time: 1035.3-864.0 (Table I) hrs (100% efficiency)									+193.5

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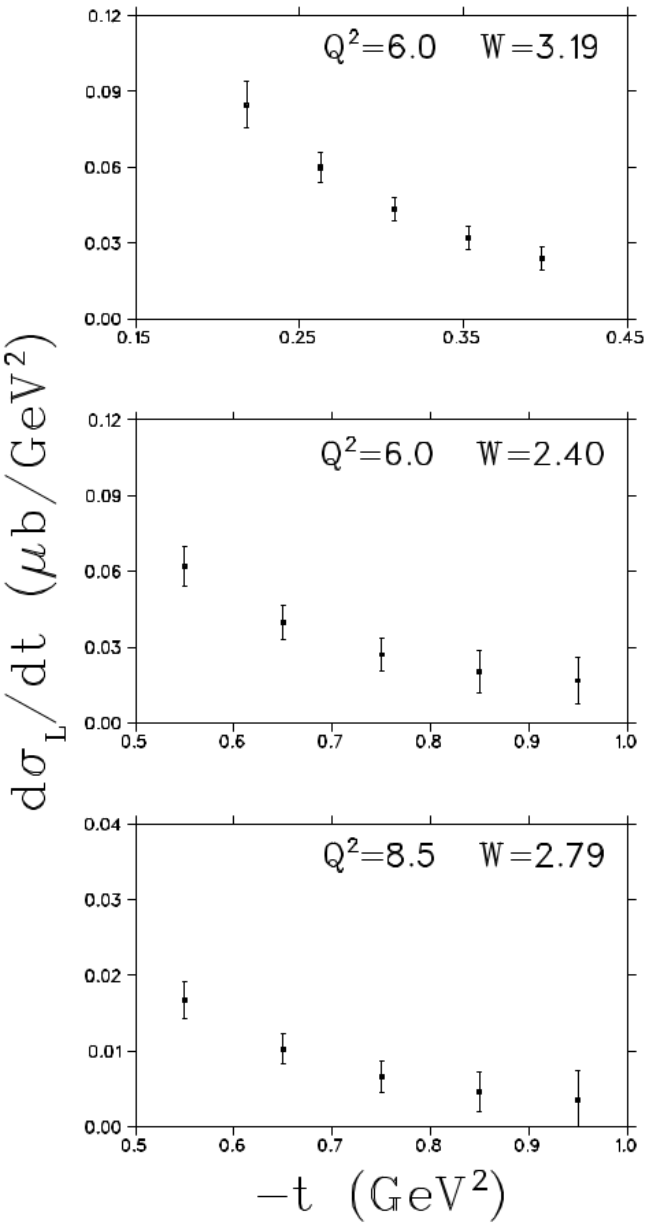
Longitudinal cross sections – projected uncertainties vs t



For the lowest t-bins, the $d\sigma_L/dt$ data at higher $-t_{min}$ are as close in quality as could be obtained to the lower $-t_{min}$ data

The $d\sigma_L/dt$ error bars are comparable to what we achieved in the Fpi-2 experiment. There, the (statistical and uncorrelated systematic) uncertainty in $d\sigma_L/dt$ was 8.7% for the lowest -t bin, and 9.2% for the second bin, rising to 21.8% for the highest t-bin. At Q2=6.0, W=3.19, we project the uncertainties for the two lowest -t bins to be 9.7% and 10.9%, rising to 18.7% for the highest -t bin. Here, r=T/L is favorable, as indicated in Table IV of the jeopardy document.

Although the statistical uncertainties in ds/dt are lower at W=2.40 than W=3.19, due to the higher virtual photon flux, the r=T/L ratio is projected to be 2.20, due to the larger -tmin. The projected uncertainty in dsL/dt is 13.0% for the lowest -t bin, and 16.5% for the second bin. As mentioned in the jeopardy document, these Q2=6.0 data are important for studying non-pole contributions at the same t-range as the Q2=8.5 data, as well as completing the Q2-scan at x=0.55.

The VR model projects the r=T/L ratio to be slightly more favorable here than at Q^2=6.0, W=2.40, due to the higher W=2.79 (see Table IV). But the rates are of course much lower. The projected uncertainty in dsigL/dt is 14.4% for the lowest -t bin, and 18.7% for the second t-bin