LT Separation Experiments in Hall C

Presented by Nathan Heinrich

Representing the Pion-LT and Kaon-LT Collaborations

2023 Winter Meeting

NSERC CRSNG

Jefferson Lab
Thomas Jefferson National Accelerator Facility

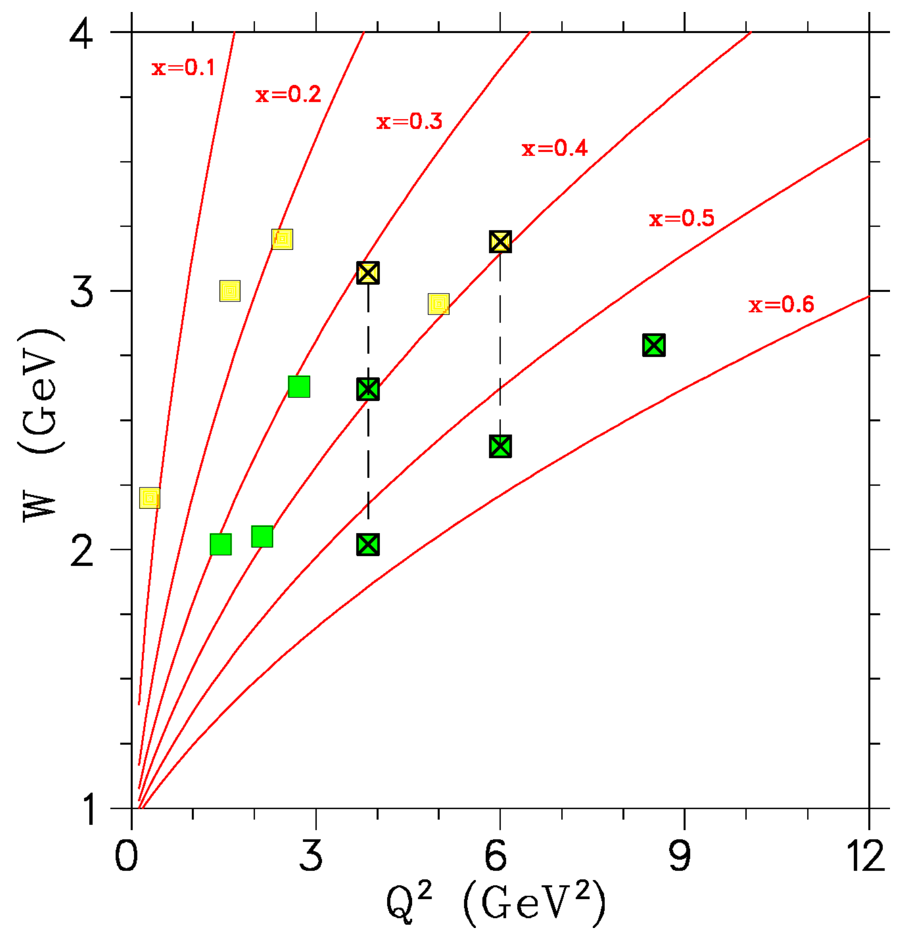
University of Regina

Outline

- Talk covers both PionLT and KaonLT experiments
- Will give updates on progress
- PionLT Finished taking data
- KaonLT is beginning to do the first LT separations

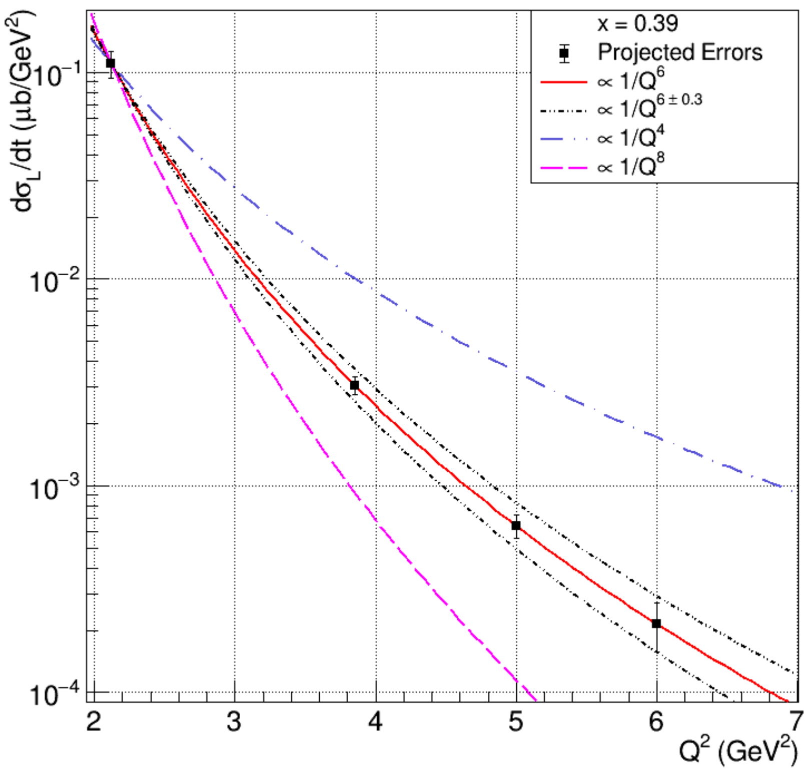
Pion-LT

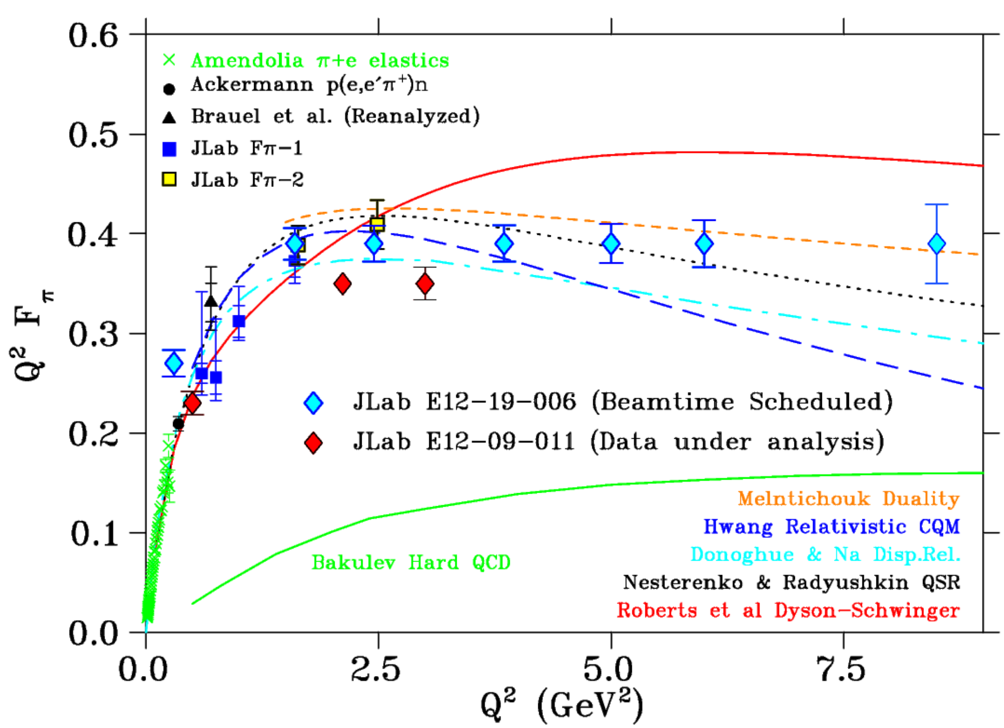
- Finished taking data in the fall
- Just beginning Process of data analysis
- Got all of our requested data
  - Thanks to all of the Hall C and Accelerator staff as well as the shift workers and run coordinators that made it possible!



Projected Data

- With the data in hand updated error estimates can be done.
- Encouragingly the relative error of most points has increased by <1%
- With exception of the Q^2 = 8.5 GeV^2 and Q^2 = 6 GeV^2 π^- point.
  - These increase by 4% and 7% when compared to the PAC Proposal





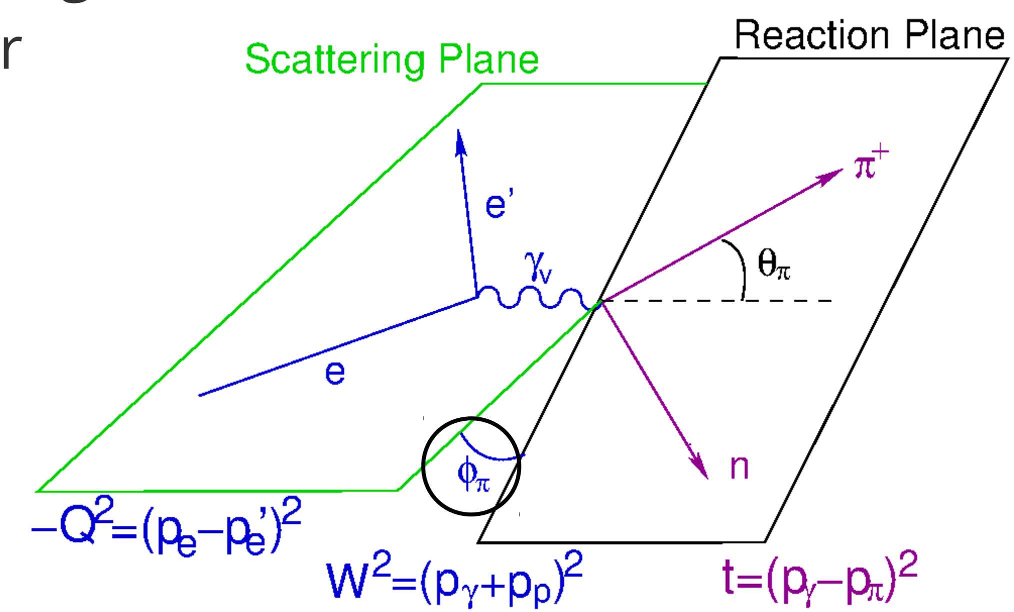
Rosenbluth Separation

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

- LT experiments seek to separate the total cross sections into the components of the photon polarization.
- To do this need to have full φ coverage at 2 values of ε while keeping other kinematics (Q^2, W, t) fixed.

Virtual-photon polarization:

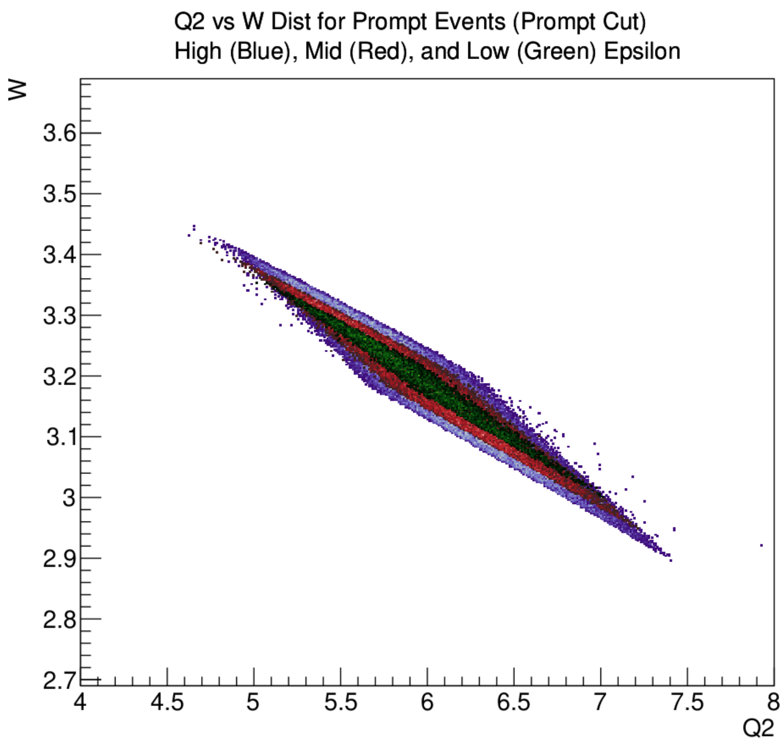
$$\varepsilon = \left(1 + 2 \frac{(E_e - E_{e'})^2 + Q^2}{Q^2} \tan^2 \frac{\theta_{e'}}{2} \right)^{-1}$$



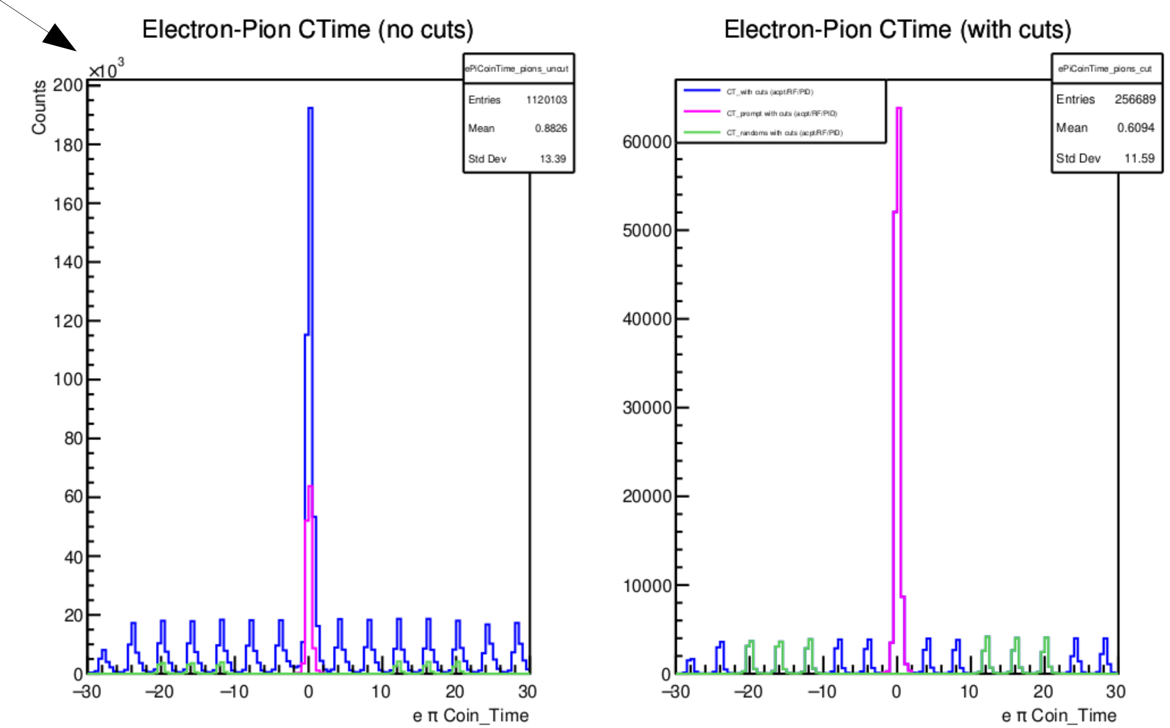
Data Quality Checks

- During the experiment plots were made to monitor data quality
- Will be used to gauge the quality of any improvements to the analysis
- Diamond Plot to show Q^2 and W overlap for all ε values of a setting.

Coin Time plots allow prompt selection and random subtraction



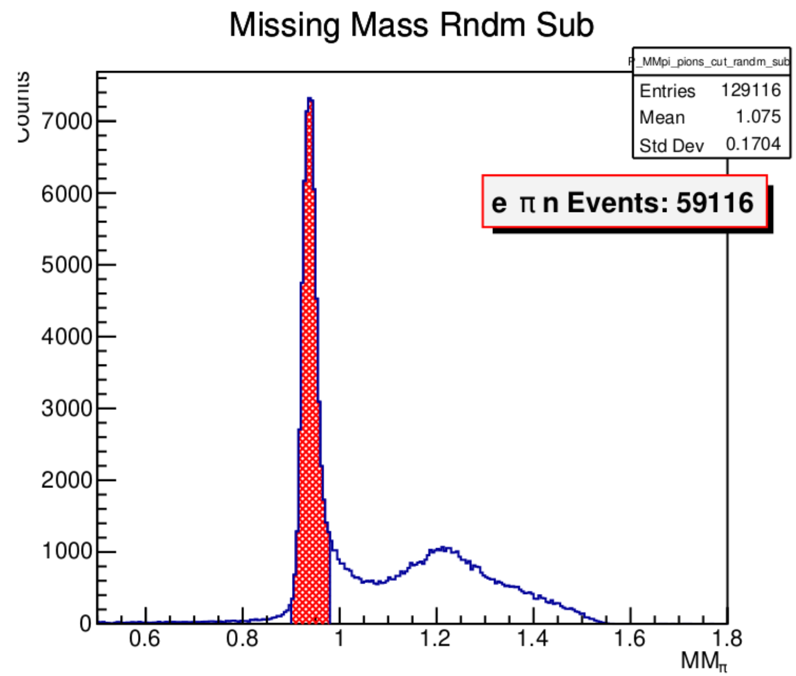
Q^2 = 6.0 GeV^2 W = 3.19 GeV



Q^2 = 2.45 W = 3.2 center high ε

Online Plots Continued

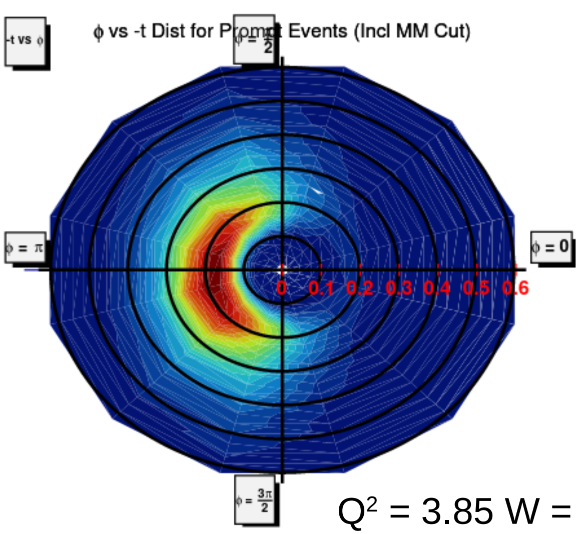
Missing mass plots verify that the reaction is $p(e^-,\pi^+ e^{-\prime})n$



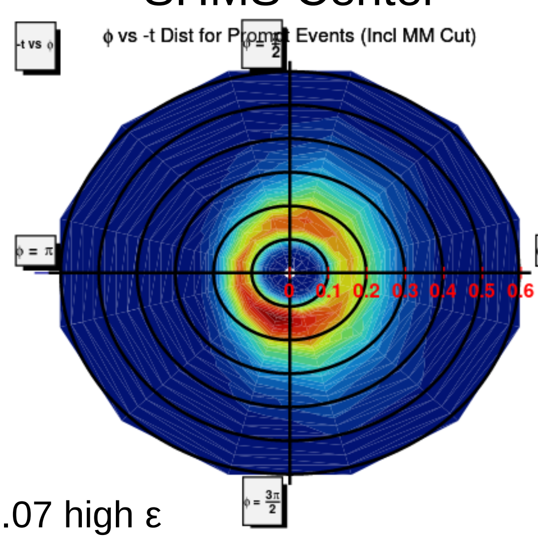
Q^2 = 2.45 W = 3.2 center high ε

-t – φ plots allow for verification of full φ coverage at fixed value of t.

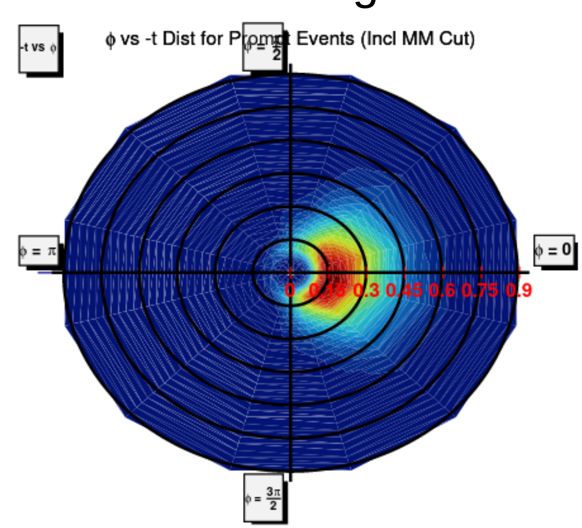
SHMS Left



SHMS Center



SHMS Right



Q^2 = 3.85 W = 3.07 high ε

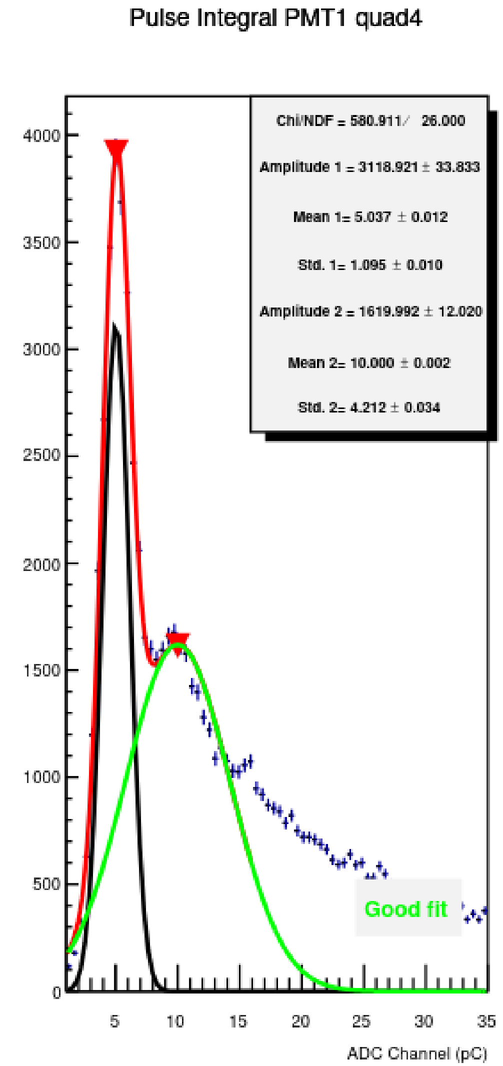
First Steps of PionLT Analysis

- Detector calibration is underway
- Analysis of Magnetic Optics from our data has begun:
  - See Jacob Murphy's talk Tomorrow at 10 am
- This experiment took a wide range of Luminosity and Heep data.
  - If others are interested please contact the spokespersons!

Garth Huber: huberg@uregina.ca,

Tanja Horn: hornt@cua.edu,

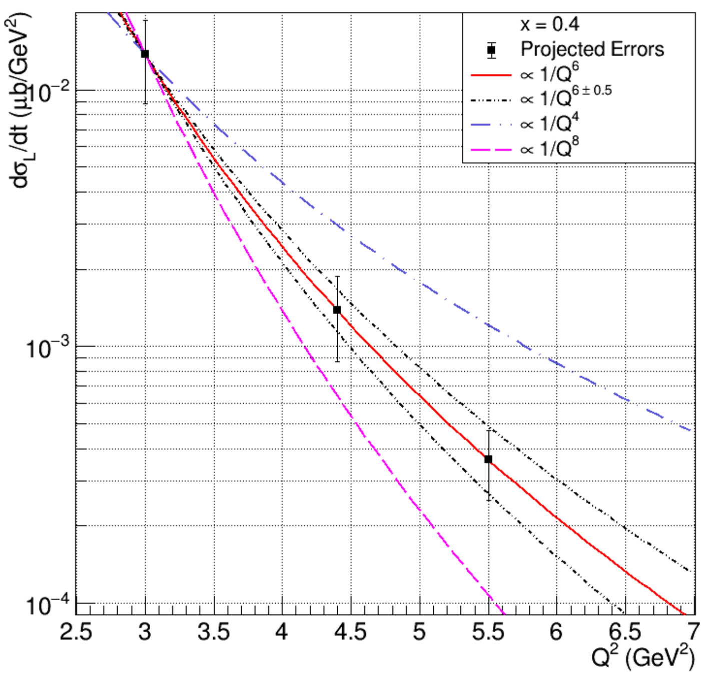
Dave Gaskell: gaskelld@jlab.org

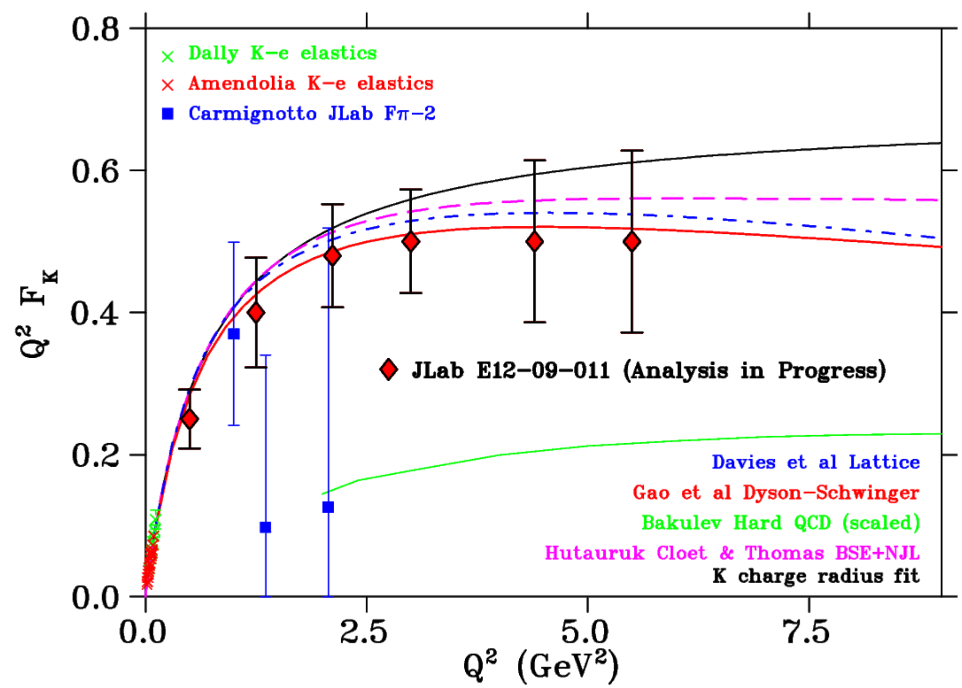


Example HGC Calibration Plot

Kaon-LT

- This experiment finished running in spring 2019
- Been hard at work analyzing the data ever since.
- Finalizing all the efficiencies
- Commissioning experiment, learned a lot about the SHMS
- Beginning cross-section extraction





Challenges of KaonLT Commissioning Experiment

Tracking

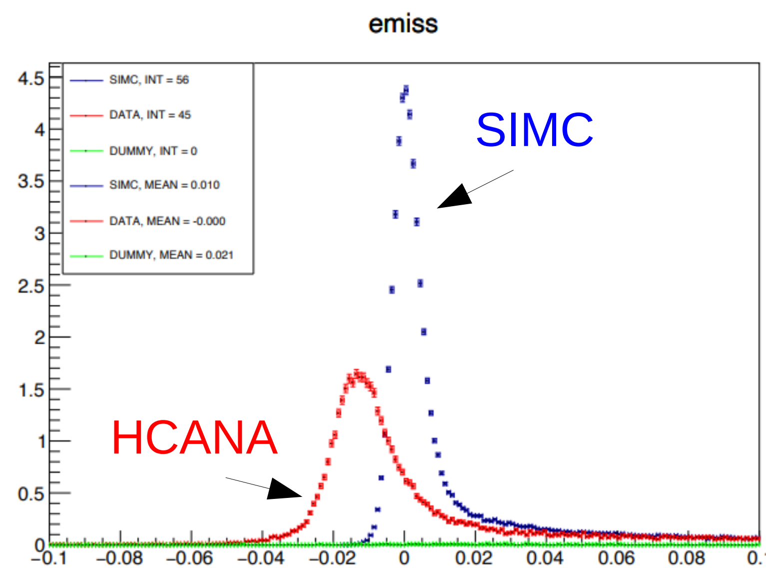
- Tracking algorithm was initially insufficient for the high precision hadron tracking required
- Detailed Track Parameter Optimization and Rate Dependence Study done by Ali Usman with help from Peter Bosted and Mark Jones an improved algorithm was implemented (Commissioning meeting 2021/04/01, 2021/05/18)

EDTM Live Time Correction:

$$TLT^{\#} = \frac{EDTM^{\#}_{acc}}{C^{\#} * EDTM_{sent}}$$

EDTM and Prescaling

- EDTM calculation is made complex when prescaling is involved
- Further EDTM data taken during PionLT helped develop a rigorous formula for the EDTM calculation
- See Jacob Murphy and Richard Trotta's talks at the Hall C Quarterly Analysis Meeting



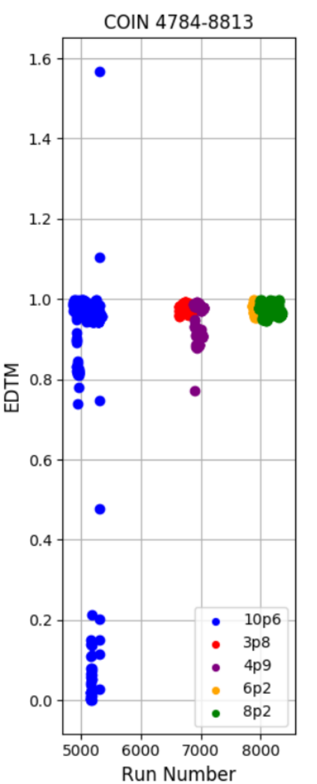
HCANA vs SIMC calculations

- Discrepancies in the calculations used in HCANA vs those used SIMC resulted in differing distribution for high level physics variables
- Changes to SIMC calculations are being implemented so this shouldn't be an issue for future groups
- Should be topic of future Analysis Meeting.

Finalizing Yields

To Finalize Yields must finalize all Efficencies:
This is nearly finished for Kaon-LT

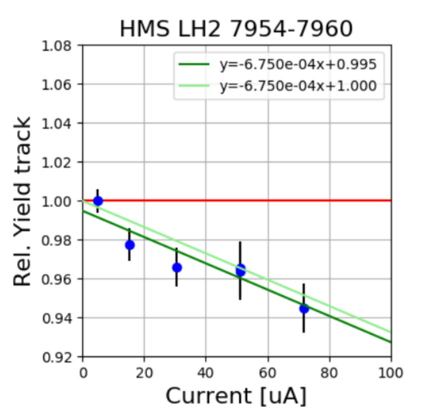
Live Time

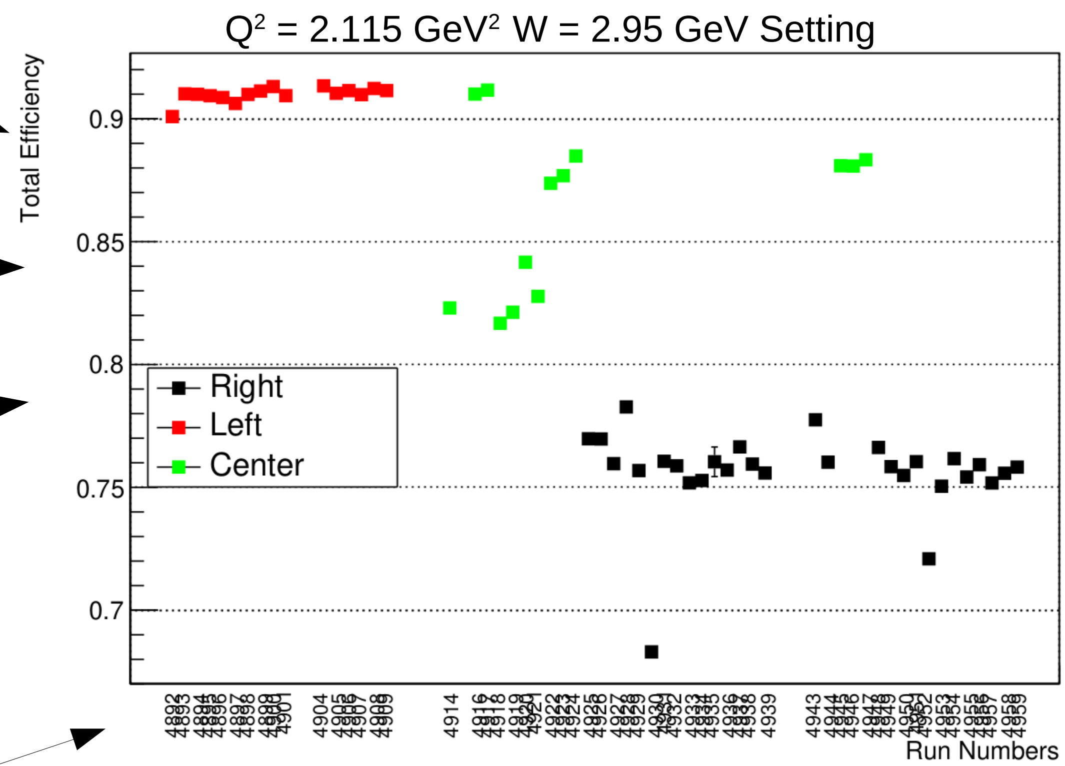


Tracking Efficiency

Detector Efficiencies

Target Boiling



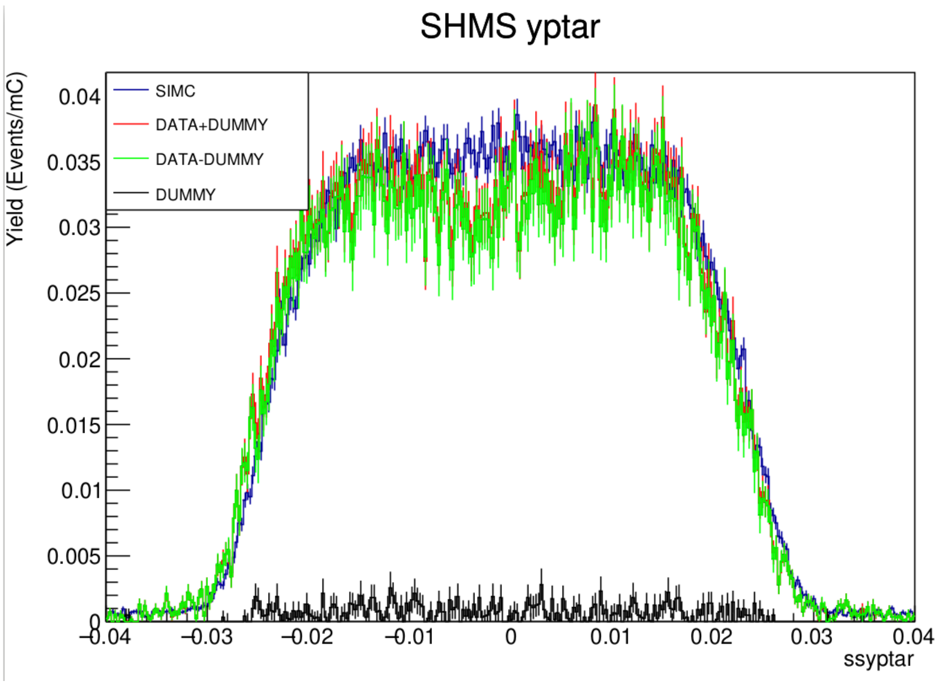


LT Separations – Progress Report

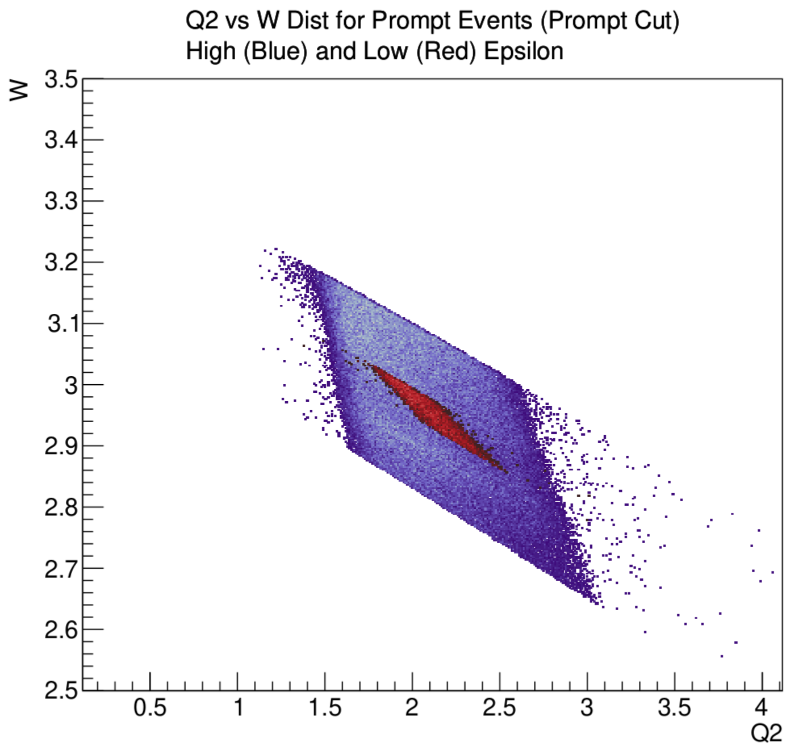
- **Step 0.1** – finalize all efficiencies\yields for all settings.

Any changes to the yield after beginning the process will require restarting all over again.

- **Step 0.2** – pick t bins
- **Step 1 –** pick functional form of cross section parameterization and compare simc fit to data



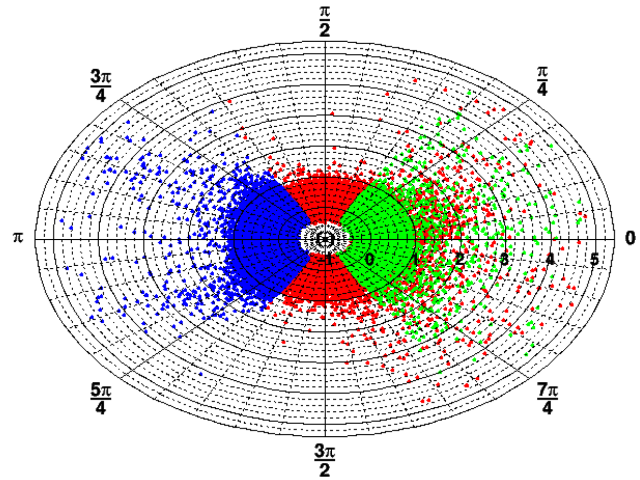
Q^2 = 0.5 GeV^2, W = 2.40 GeV, low ε, center



Q^2 = 2.115 GeV^2 W = 2.95 GeV Setting

Step 2 - Combine SHMS Settings

- Add together Left, Center, Right SHMS settings at high and low ε, for each ($W,Q^2,t,\varphi,\varepsilon$) bin for both both Data and Monte Carlo (MC)
- Obtain Yields for both Data and MC, for each ($W,Q^2,t,\varphi,\varepsilon$) bin

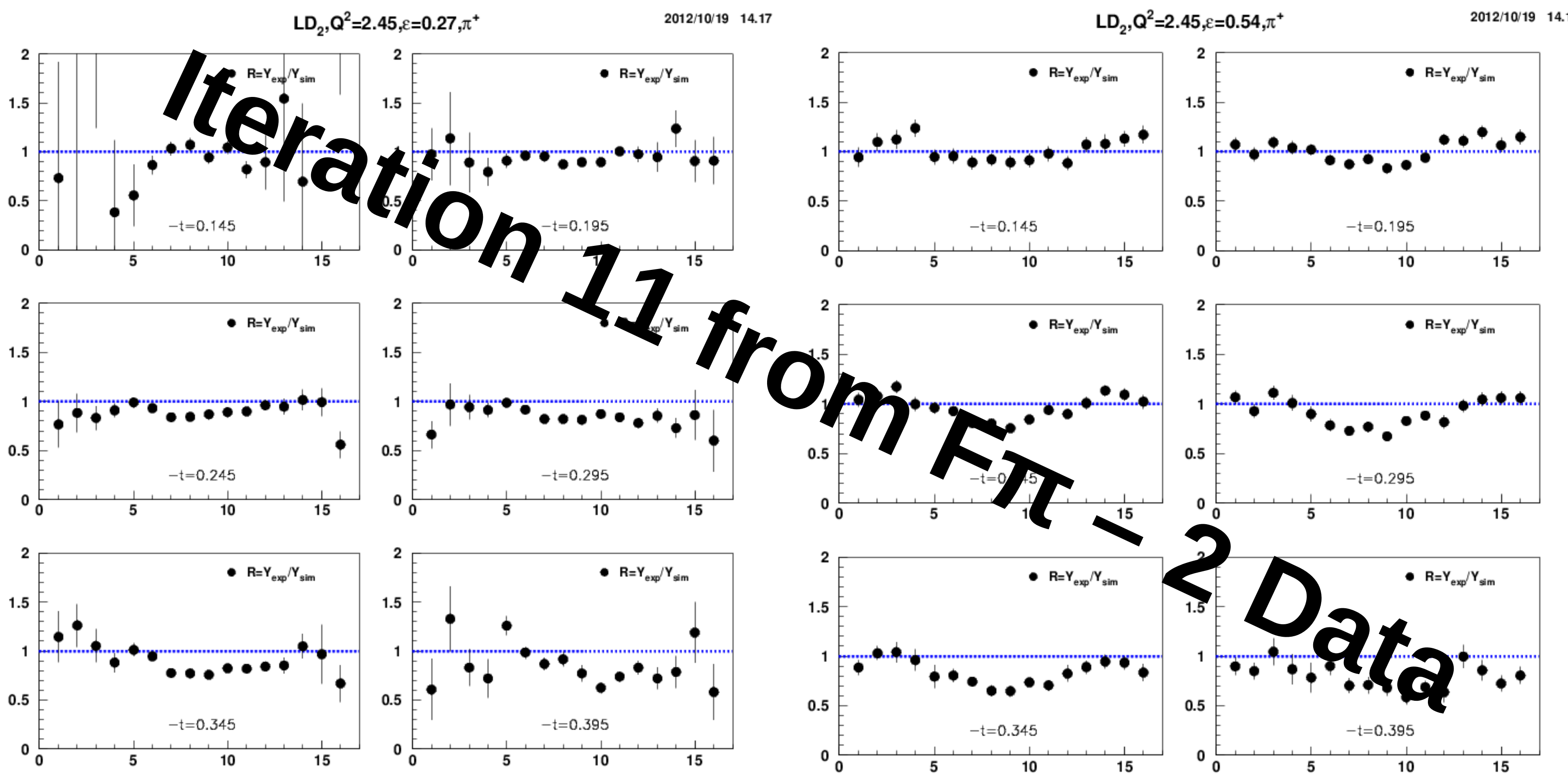


Step 3 – Calculate average kinematics

- Find the mean values of W, Q^2, θ, and ε for each t bin.
- Average of high and low ε is used, as they will differ slightly

Step 4 – Carefully inspect the Data/SIMC Ratios

- Ratio of Data to MC Yield ($R=Y_{exp}/Y_{MC}$) should be R~1 over a broad range of kinematics.



Step 5 – Calculate unseparated Cross-sections

- Using the parameterization, evaluate cross-section at average value of kinematic.
- This procedure comes from Blok et al, PRC 78 (2008) 045202

were fitted. For all five t bins at every (central) Q^2 setting, ϕ-dependent cross sections were determined at both high and low ϵ for chosen values of $\overline{W}$, $\overline{Q}^2$ (and corresponding values of θ_π and ϵ) according to

$$\sigma_{\mathrm{exp}}(\overline{W}, \overline{Q}^2, t, \phi; \overline{\theta}, \overline{\epsilon}) = \frac{\langle Y_{\mathrm{exp}} \rangle}{\langle Y_{\mathrm{sim}} \rangle} \sigma_{\mathrm{MC}}(\overline{W}, \overline{Q}^2, t, \phi; \overline{\theta}, \overline{\epsilon}). \quad (14)$$

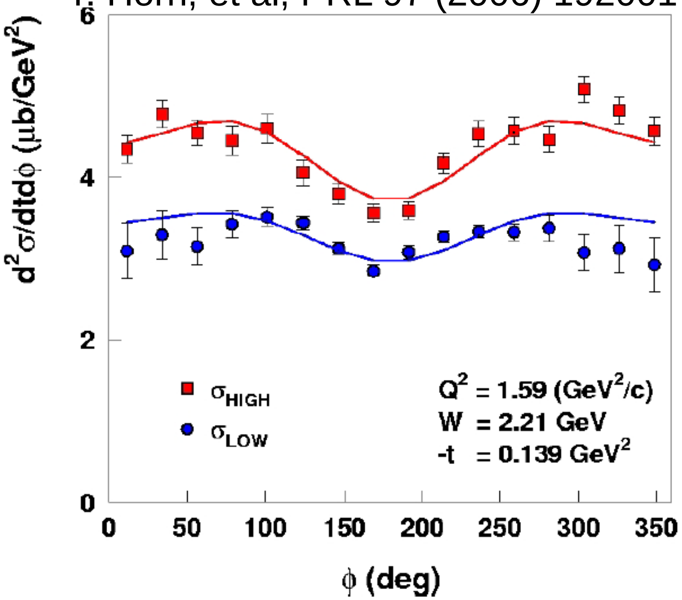
The fitting procedure was iterated until σ_{exp} changed by less than a prescribed amount (typically 1%). A representative

Step 6 – fit Rosenbluth Equation

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

- **Each t-bin is fit separately**
- Fit result gives L, T, LT, TT cross sections for each t bin

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



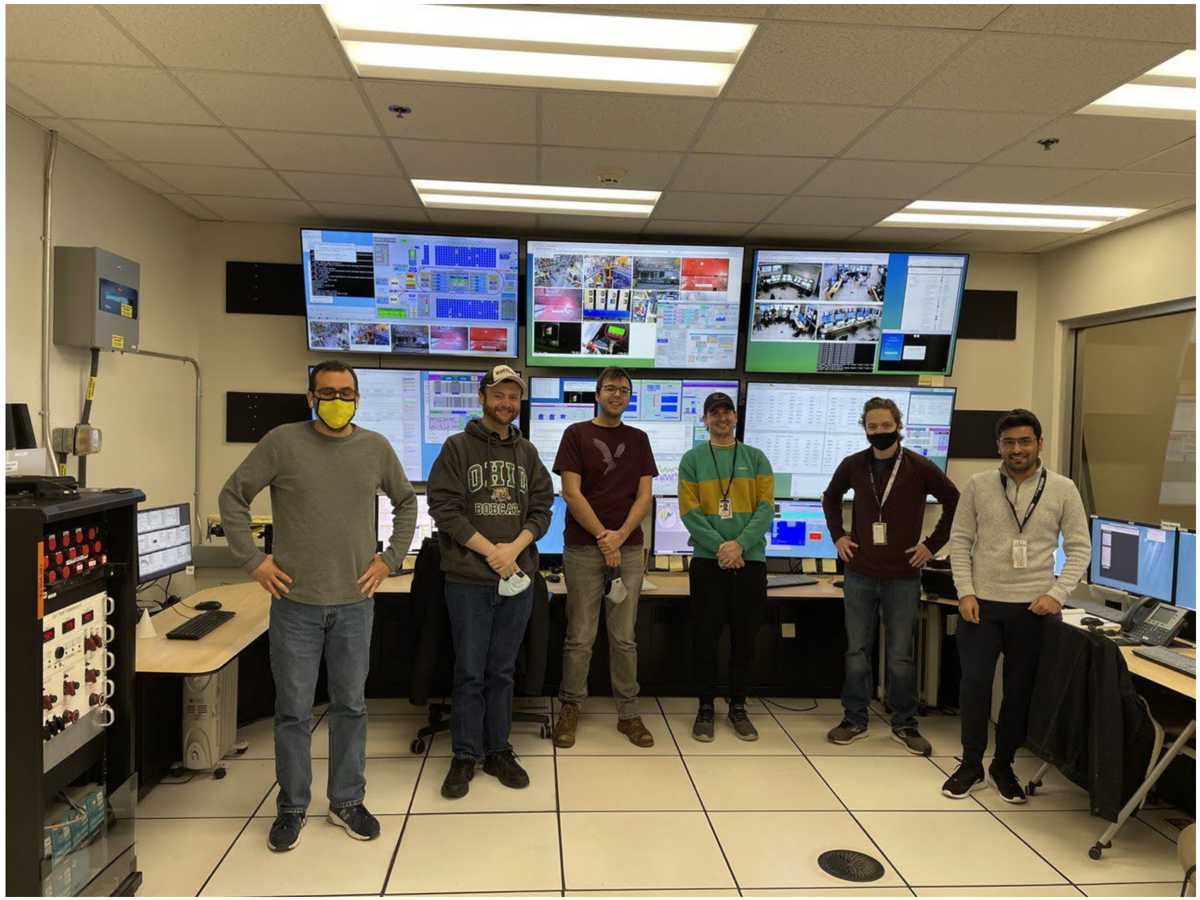
Step 7 – Iterate Cross section Model

- Update the model and return to step 1
- Repeat until model is self consistent

Outlook

- Pion-LT just finished taking data
  - Progress is being made on Analysis
- Kaon-LT Is beginning Cross-section extraction
  - Expect publishable results before the end of this year!

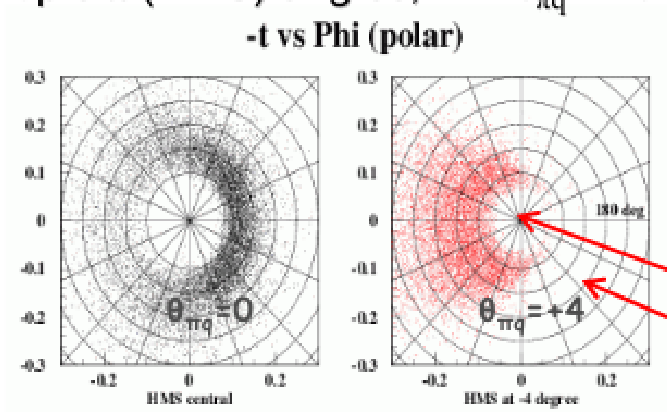
Thank You



Thanks To All Our Collaborators

Iteration procedure summary

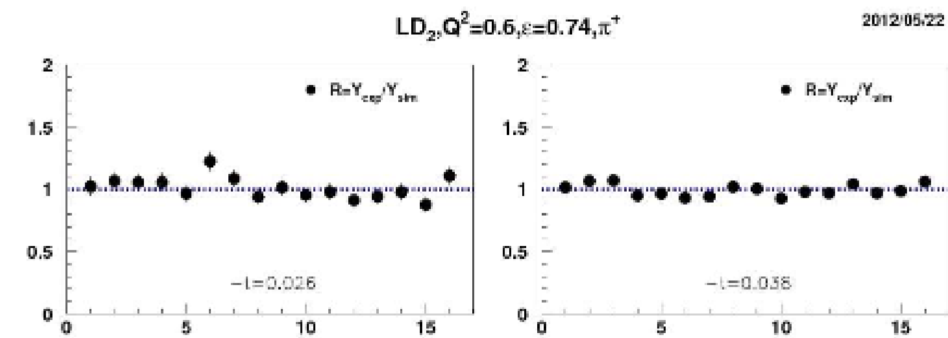
Improve φ coverage by taking data at multiple π (HMS) angles, $-4^o < \theta_{\pi q} < 4^o$.



For each π HMS setting, form ratio:

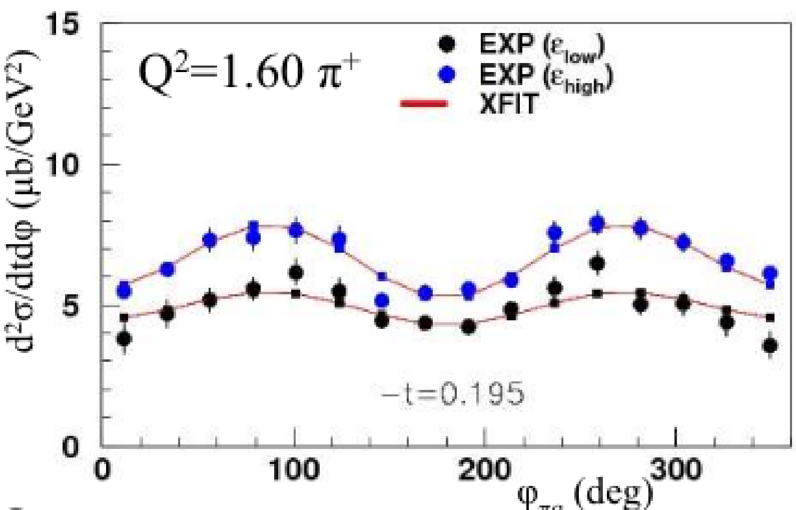
$$R = \frac{Y_{EXP}}{Y_{SIMC}}$$

Combine ratios for π settings together, propagating errors accordingly.



$$\frac{d^2\sigma}{dtd\phi}_{EXP} = \left(\frac{Y_{EXP}}{Y_{SIMC}}\right)\frac{d^2\sigma}{dtd\phi}_{SIMC}$$

Extract via simultaneous fit of L,T,LT,TT



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