Future Physics at JLab

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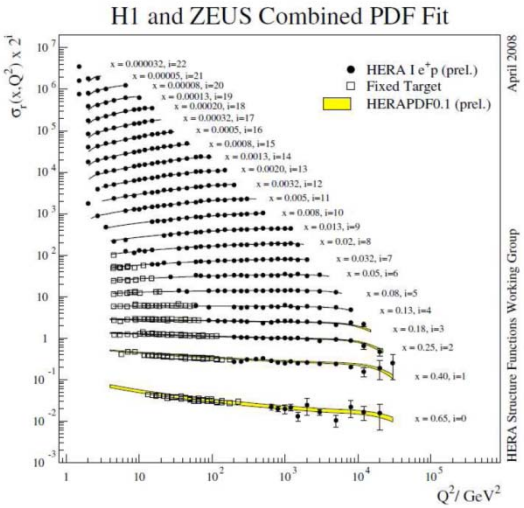
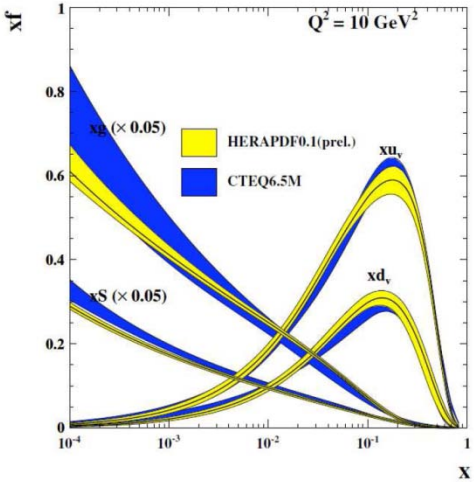
LANL medium energy physics internal review

12/14/2009

Semi-Inclusive Deep Inelastic Scattering (SIDIS)

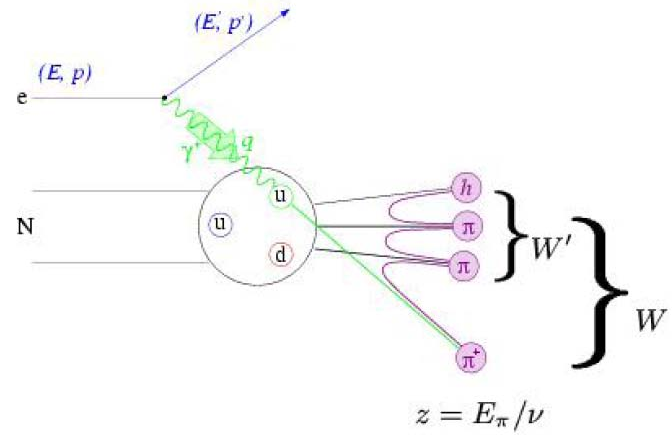
- Deep Inelastic Scattering N(e,e') (DIS)
  - Totally inclusive final state
  - Simplest reaction to study nucleon structure
  - Inherent limitations on what can be learned
- Semi-Inclusive DIS N(e,e'h)
  - Detect the leading hadron in the final state
  - "Flavor tagging" the struck quark
  - Promising way to enhance understanding of nucleon structure

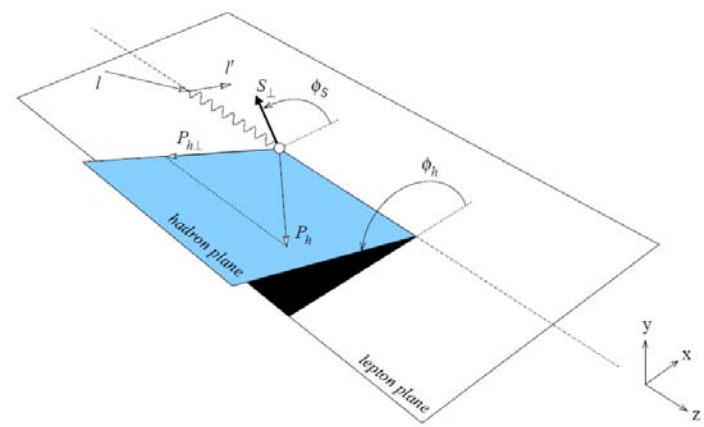




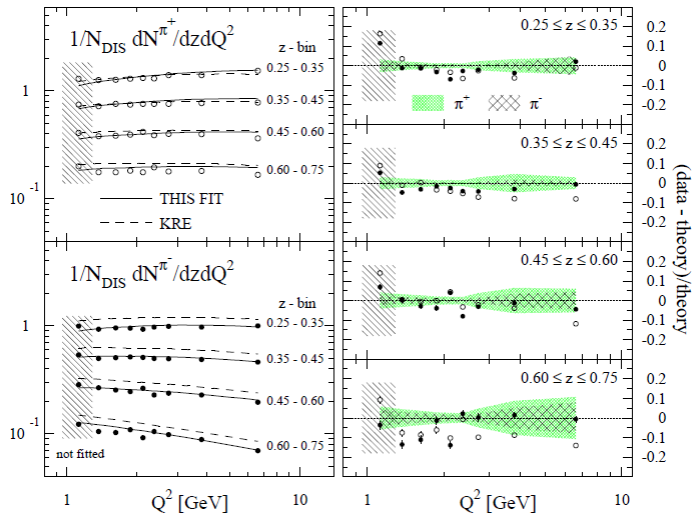
Reaction Mechanism in SIDIS (new proposal to JLab PAC35)

- SIDIS program for JLab 12 GeV:
  - Transverse spin structure of the nucleon
  - Transverse Momentum Dependent parton distributions (TMDs)
  - Single and double spin asymmetries in SIDIS
  - Flavor separated long.+trans. nucleon structure data—struck quark fragments into detected hadrons
- To what extent is information on the struck quark preserved in the fragmentation process in SIDIS reactions?



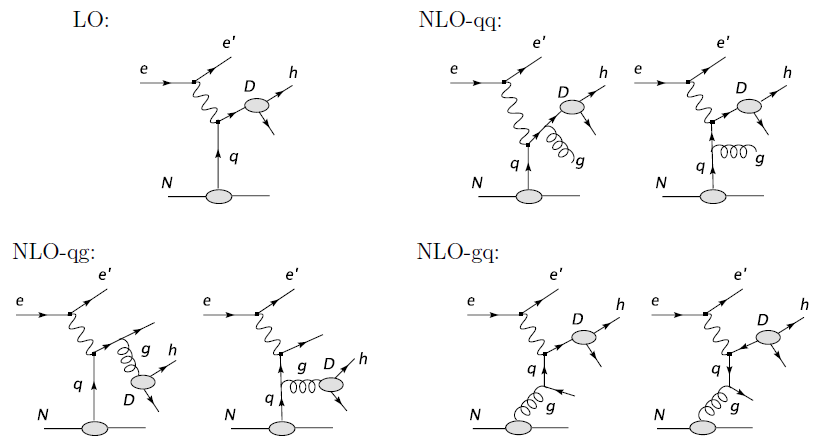


NLO QCD global fit to fragmentation functions

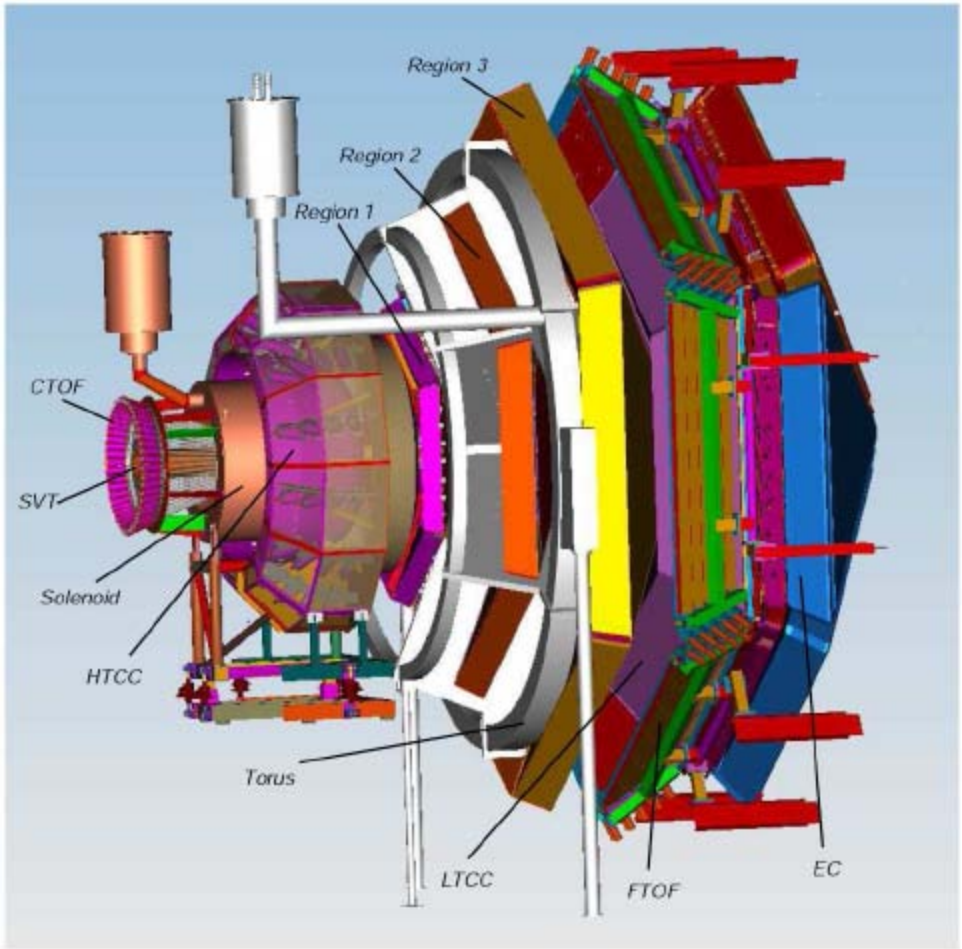


De Florian, Sassot, and Stratmann 2007—global analysis of F.F. including HERMES SIDIS, e+e- and pp data

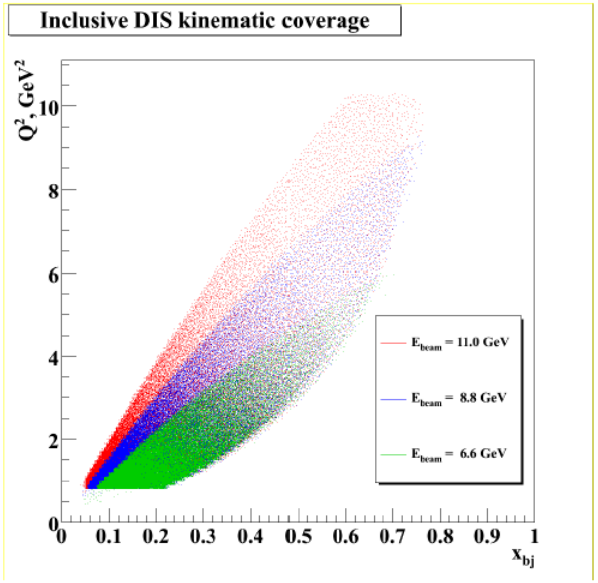
$$\frac{\sigma^h(x,z,Q^2)}{\sigma_{DIS}} = \frac{1}{\sigma_{DIS}} \int \frac{d\sigma^h}{d\Omega_h d^2 P_t^h}\, d\Omega_h\, d^2 P_t^h$$



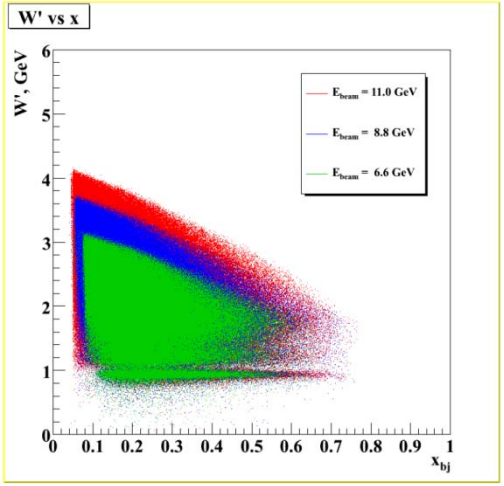
Precision hadron multiplicities with CLAS12



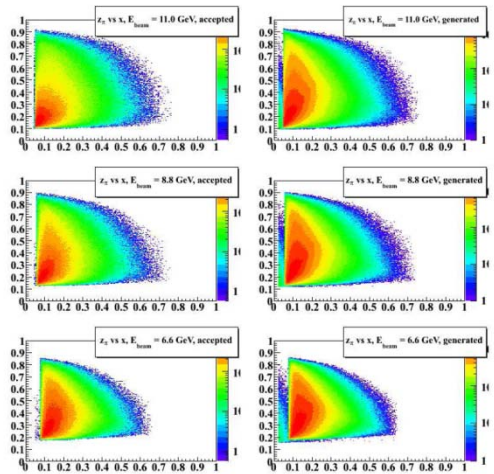
- Large acceptance spectrometer
- Full p_T/ϕ coverage for integration over transverse d.o.f
- Robust e/π detection
- Kaon ID limited to p_K<3 GeV/c—expand with RICH detector?
- Large DIS kinematic coverage



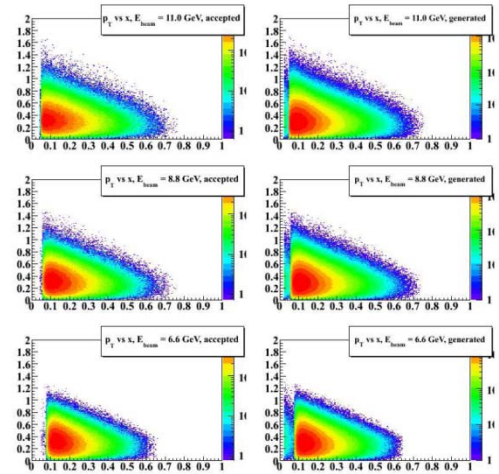
LEPTO DIS + LUND fragmentation + CLAS12 FASTMC



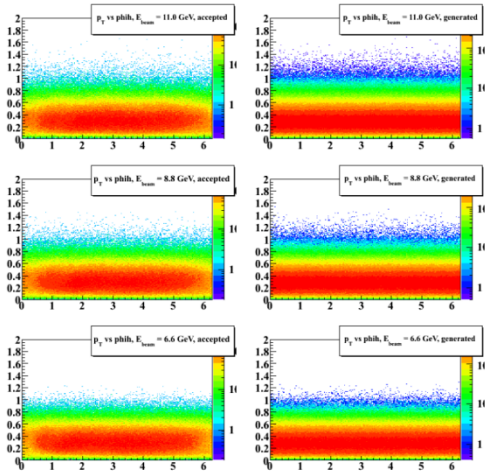
SIDIS "missing mass" vs x



z vs x coverage—accepted (left) and generated (right)



p_T vs x coverage—accepted (left) and generated (right)



p_T vs ϕ coverage—accepted (left) and generated (right)

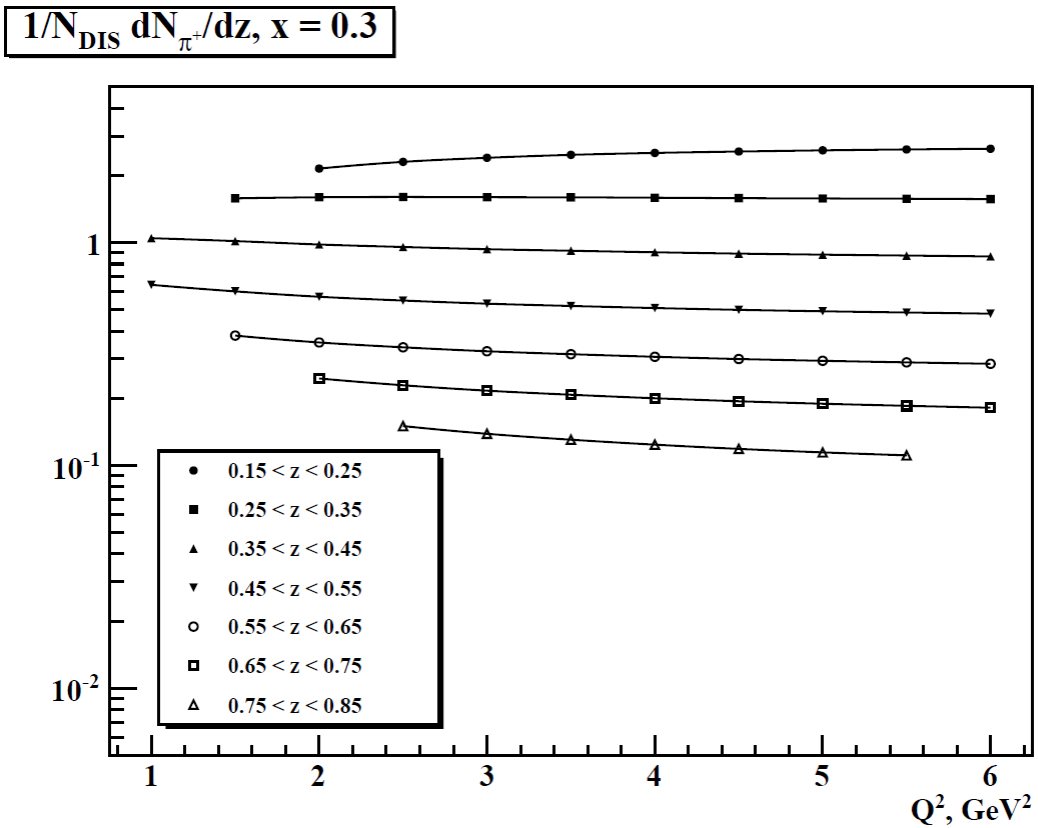
- Large acceptance, excellent transverse momentum and azimuthal angle coverage for all three beam energies—minimal uncertainties in integration over these variables
- Significant overlap in missing mass range for all three beam energies
- Detailed investigation of SIDIS reaction in the valence (high-x) region

Expected Results

- Q^2 dependence of multiplicities at fixed x, z—test NLO evolution
- z dependence at fixed x, Q^2—determine F.F.s
- x dependence at fixed z, Q^2—test independent fragmentation
- proton-deuteron ratios of combined charged pion multiplicities—z dependence cancels in ratios which depend only on PDFs (powerful test of independent fragmentation assumption)
- Dense 3D grid (Δx, ΔQ^2, Δz)=(0.05, 0.5 GeV^2, 0.1), Typically ~0.5% stat. uncertainty per bin.
  - $0.2 < z < 0.8$
  - $0.1 < x < 0.8$
  - $1.0\ GeV^2 < Q^2 < 10.0\ GeV^2$
- DIS cuts:
  - $W > 2$ GeV
  - $W' > 1.5$ GeV
  - $x_F > 0$ (restrict analysis to current fragmentation region)

Expected Results (continued)

- Precise charged and neutral pion multiplicity measurements over a dense 3D grid of x, Q^2, z
- Compare Q^2 evolution with the NLO calculation
- Example in figure—Q^2 dependence for different z bins of π^+ multiplicity for a single x bin: 0.275<x<0.325
- Curves are NLO prediction (Sassot et al, 2007)
- Measurements shown with projected stat. uncertainties (smaller than symbol size)



Experiment goals

- Establish the region of validity of NLO pQCD, collinear/leading-twist framework for the interpretation of SIDIS data for JLab 12 GeV kinematics
- Provide 2-3 orders of magnitude improvement in statistical precision of pion multiplicities compared to HERMES—input to next generation global F.F. fits—dense 3D grid of x, Q^2, z
- Measure "combined ratios of multiplicities" between proton and deuteron targets—z dependence mostly cancels, ratios determined by PDFs—strong evidence for the preservation of quark information in the SIDIS reaction
- Using three beam energies, E=11.0, 8.8 and 6.6 GeV, constrain epsilon dependence
  - Look for increasing deviations from NLO predictions
  - Rough constraint on long./trans. cross section ratio—relatively imprecise measurement, but with large kinematic coverage.
  - Pinpoint where assumptions underlying this framework for SIDIS reaction mechanism start to break down
- Quantify remaining effects beyond the NLO pQCD
  - Higher twist
  - Hadron/target mass corrections
  - Other

LANL role

- LANL core group for this proposal—Jiang, Puckett (cospokespersons), M. X. Liu, L. Guo, A. Klein
- Perform physics simulations, develop analysis tools
- Detector simulations + R&D
- Upon approval of this proposal, develop physics further—expand to kaon multiplicities by adding CLAS12 RICH detector (beyond baseline equipment)