Report on JLab User Workshops on EIC Studies

Ron Gilman*, Rutgers University

Outline

- Background
- Some Physics
  - Partonic Transverse Momentum in Hadrons
  - Exclusive Reactions
  - Nuclear Chromo-Dynamics
  - Electroweak
- Summary

Organized by Users Group; Sponsored by JLab and JSA Initiatives Fund

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Background I

- JLab community has been very busy with
  - Running the 6-GeV program: form factors & DVCS (GPDs), nucleon spin structure, inclusive reactions (TMDs), nuclear physics (medium modifications, short-range correlations, hadronization, color transparency, few-body systems, ...), ...
  - Preparing for 12-GeV with new proposals & building equipment - First workshop 1994 (before CEBAF turned on), ..., a top priority in 2007 LRP, now under construction
- A small group has been spending limited time on a possible future EIC

Background II

- Nevertheless, there is a natural progression to and interest in EIC physics

4 GeV ⇨ 6 GeV ⇨ 12 GeV ⇨ EIC

Exclusive reactions
and GPDs:
form factors
DVCS
DVMP

QCD

QCD in nuclei:
color transparency
hadronization
medium modifications

Semi-inclusive
DIS and TMDs:
fragmentation functions
transverse momentum
spin structure

Inclusive reactions:
parton distributions
sum rules
polarizibilities
spin structure

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QCD
&
Electroweak physics

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Background III

- Some examples of the natural progression to and interest in EIC physics

	4 GeV ⇨	6 GeV ⇨	12 GeV ⇨	EIC
DVCS, SIDIS	-	tests / interpretation?	central program	central program
DIS parton spin distributions	-	valence, $x \approx 0.2$–0.6	valence, $x \approx 0.1$–0.8	sea, $x \to 10^{-3}$ (depending on EIC)
Partons accessed	-	u, d	+ s	+ c + g
parity/EW	s quarks	+ Q_{weak}, PVDIS	MOLLER, SOLID	+ $e \to \tau$
Form factors	$Q^2 \to 3.5$ GeV^2	$Q^2 \to 8.5$ GeV^2	$Q^2 \to 15$ GeV^2	$Q^2 \to 50$ GeV^2

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revolutionary

incremental
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DIS p sp distri				10^{-3} n EIC)
Par acce				g
parit				T

A cautionary tale: FF were incremental, evolutionary, and boring in 1998, but they became among the most highly cited JLab work. This time I think the judgment is right, but there will be other things that become much more interesting than expected.

revolutionary

Background IV

Meetings discussing various EIC options have been going on for over a decade

Natural interest, but limited involvement of JLab users, in collider eA+eN program

2007 Long Range Plan:

We recommend the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized electron-ion Collider. The EIC would explore the new QCD frontier of strong color fields in nuclei and precisely image the gluons in the proton.

Expected 2012 (?) LRP

JLab UGBoD decides to try to help "kick-start" greater user involvement by sponsoring series of workshops

12-GeV upgrade underway, "2013" start

The 5 Workshops

- Partonic Transverse Momentum in Hadrons, Duke, March 12-13, 2010, org. by M Anselmino, H Avagyan, M Burkardt, JP Chen, E Cisbani, H Gao, C Keppel, JC Peng, F Yuan
- Electron Nucleon Exclusive Reactions, Rutgers, March 14-15, 2010, org. by R Gilman, T Horn, P Nadel-Turonski, C Weiss
- Nuclear Chromodynamics, Argonne, April 7-9, 2010, org. by A Accardi, W Brooks, C Ciofi Degli Atti, D Gaskell, V Guzey, K Hafidi, P Hoyer
- Electroweak Physics, W&M, May 17-18, 2010, org. by A Deshpandhe, K Kumar, W Marciano, K Paschke, MJ Ramsey-Musolf, P Souder
- Detectors, JLab, June 4-5, 2010, org. by T Horn, C Hyde, P Nadel-Turonski

Each workshop had ~30-35 people

Disclaimer

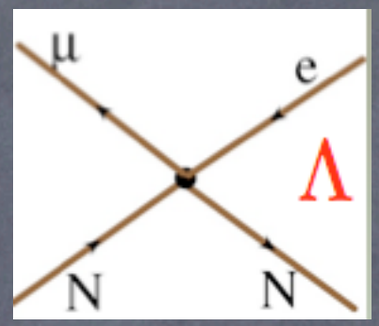
- 11 days of workshops are difficult to summarize in 20 minutes (~½ of which is gone)
- The physics is a work in progress (and likely will be until the accelerator is shut down)
- Following will be a few topics representative of work being done, not intended to be "golden experiment" review
- Errors or misinterpretations are undoubtedly my fault, not that of the original speakers
- Several topics will be presented in other talks this meeting

And now, examples of EIC physics ...

Electroweak: e→τ

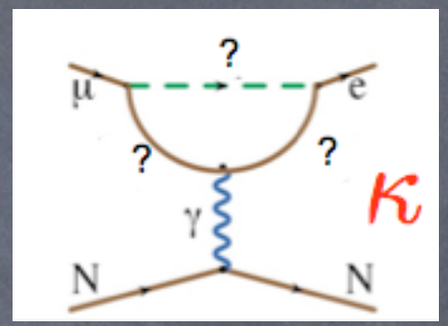
- Physics beyond standard model and EW couplings
- EW nucleon structure functions
- Charge symmetry violation
- Nuclear structure functions, PV $F_3^{\gamma Z}$ and medium modifications
- Lepton flavor violation - Ramsey-Musolf et al. for theory, Deshpandhe et al. for τ detection

Contact term with new massive particle, eg leptoquark



Contributes to EIC scattering but not to μ→eΥ decay

Loop term eg, SUSY+ heavy ν



Contributes to μ→eΥ decay and EIC scattering

Theory input: 10 - 100 fb^{-1} of DIS at EIC energies is competitive with rare decay experiments. Leptoquark limits can be improved by orders of magnitude, depending on LQ-quark couplings

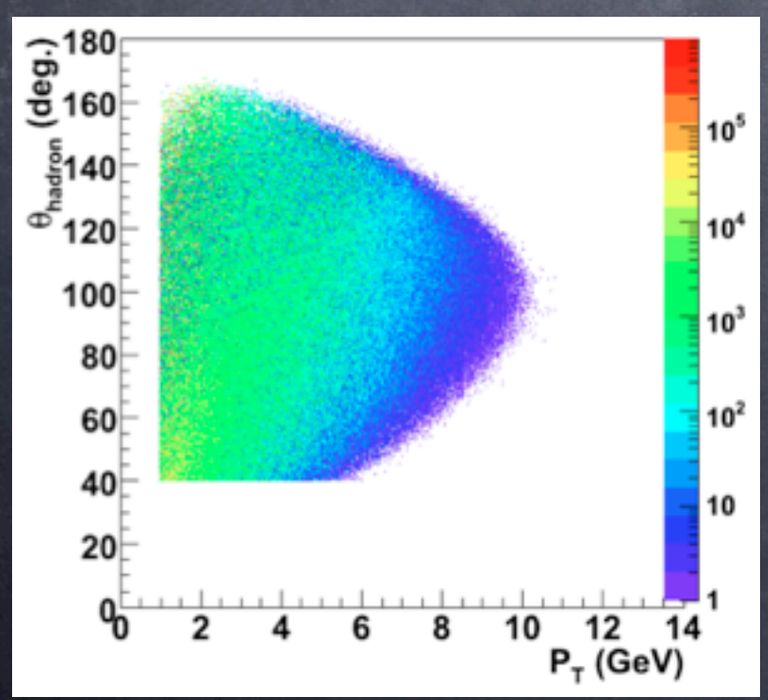
Experiment input: need MC study likely need vertex tracker for τ decay

Recall: at $L = 10^{34}/cm^2/s$, obtain ~1 fb^{-1}/day

Transverse Momentum in Hadrons

- Use SIDIS to obtain TMDs, access to Sivers, Collins, pretzelocity effects, transversity, Boer-Mulders, ... Gives information on orbital angular momentum, spin-orbit correlations, multi-parton correlations, sea and glue in nucleon
- Simulations and uncertainty estimates done for π, K, D mesons, comparisons with 12 GeV ... Talk by X Qian this afternoon
- Need high L to bin in Q^2, x, z, p_T simultaneously, ~100 fb^{-1}

$ep \rightarrow e'\pi^+X$ reaches p_T of few GeV

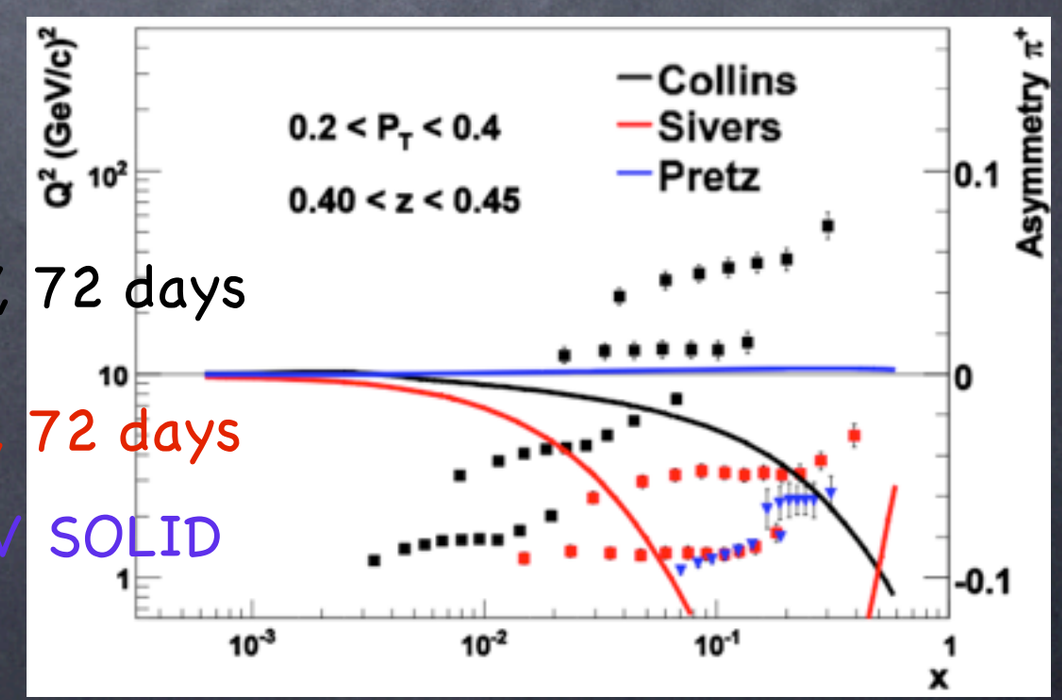


$ep \rightarrow e'\pi^+X$, 4D binning, ~100 fb^{-1} on each of p, d, ^3He

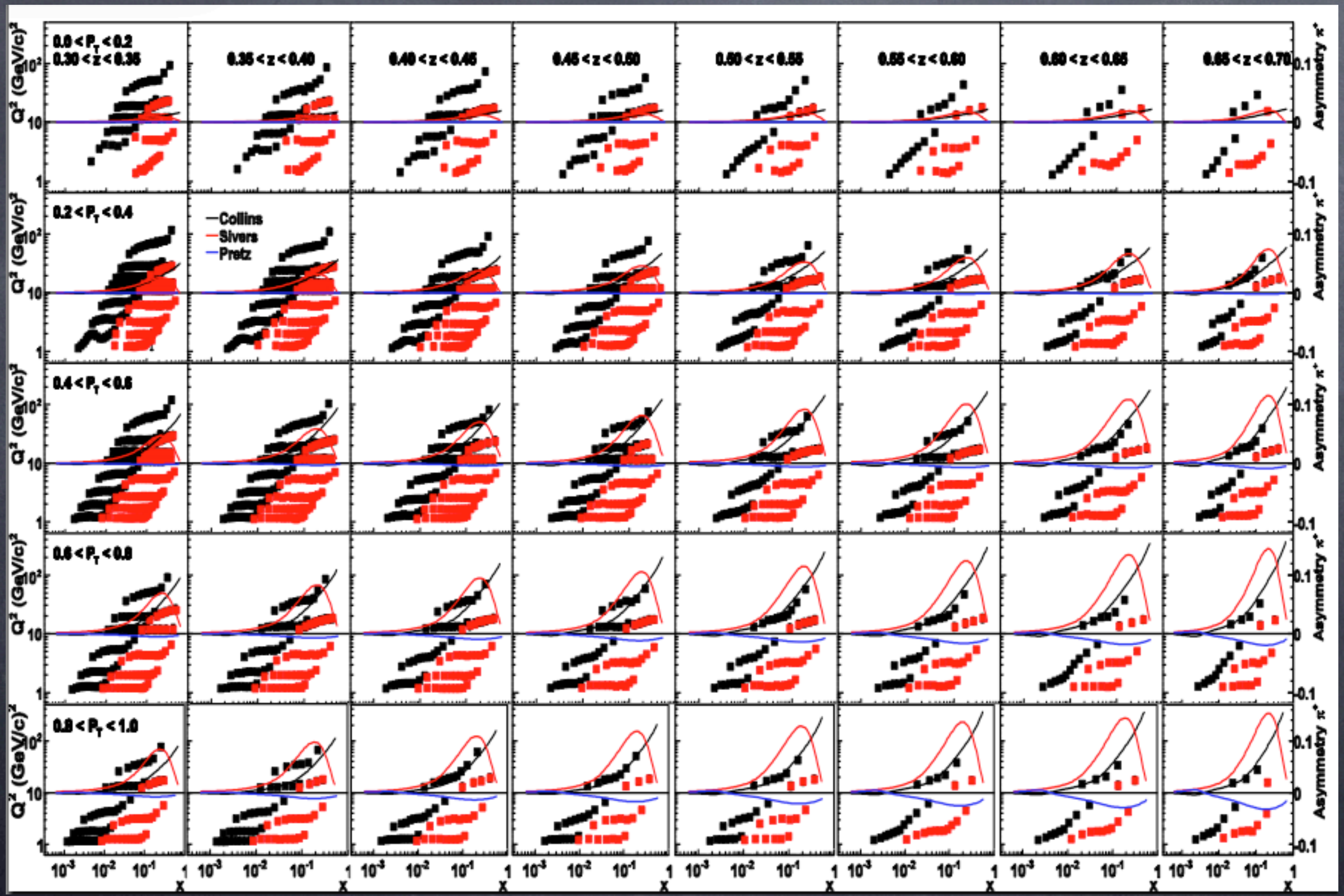
11+60 GeV, 72 days

3+20 GeV, 72 days

12 GeV SOLID



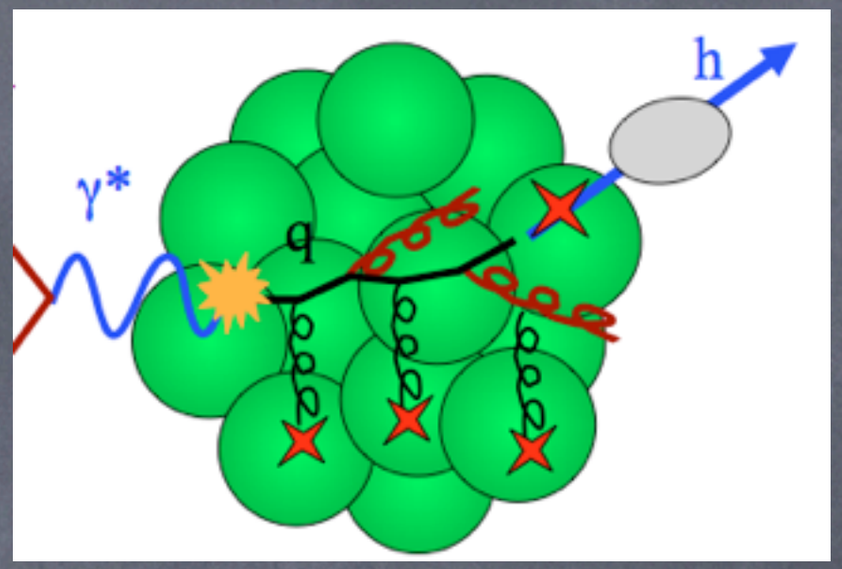
A TMD Postage Stamp Sheet



Nuclear Chromo-Dynamics

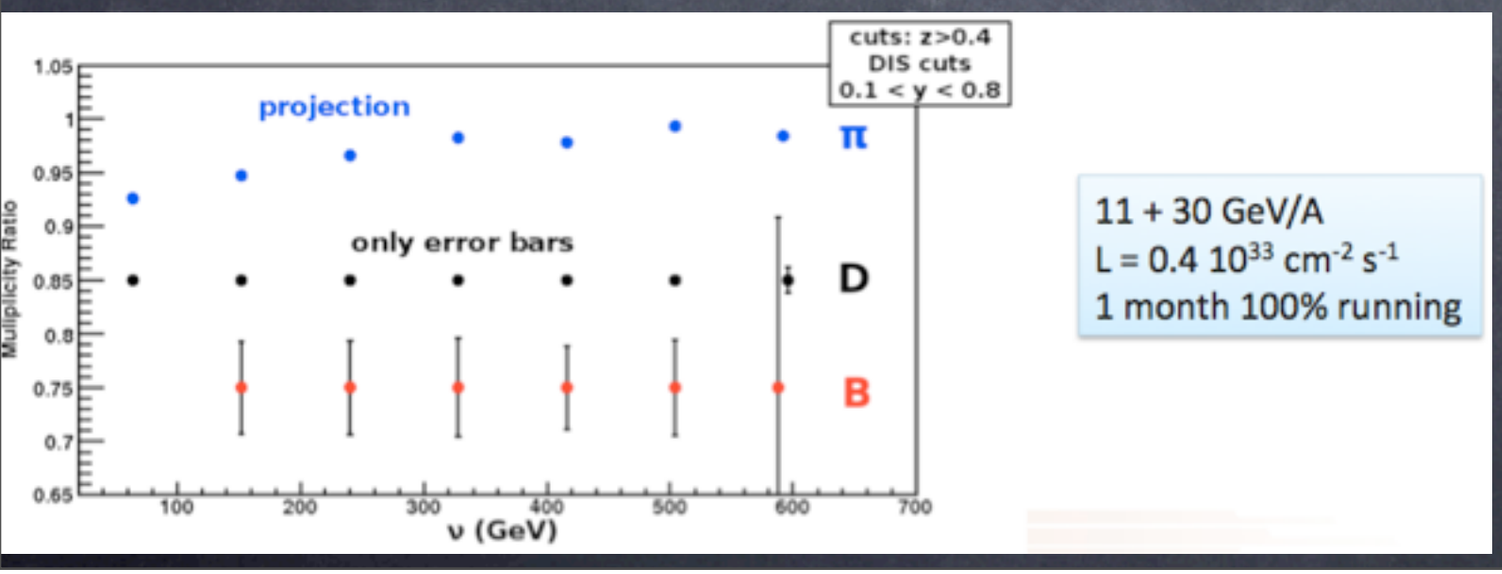
- Quark propagation and hadronization - Will Brooks talk just completed
- Color: transparency, hidden, glass condensate
- Short-range structure
- EMC effect, medium modifications, shadowing
- Exclusive reactions: form factors, DVCS

Cartoon of nuclear SIDIS, etc



Quark propagation & energy loss
Hadronization
Bound nucleon TMDs
Color transparency
Flavor-dependent EMC effect
Probing nuclear glue
Heavy quarks vs light quarks

Fragmentation of heavy q expected to be perturbative. Reduced relative energy loss of heavy q not seen at RHIC. Need L = few x 10^{34} for multi-dimensional binning.

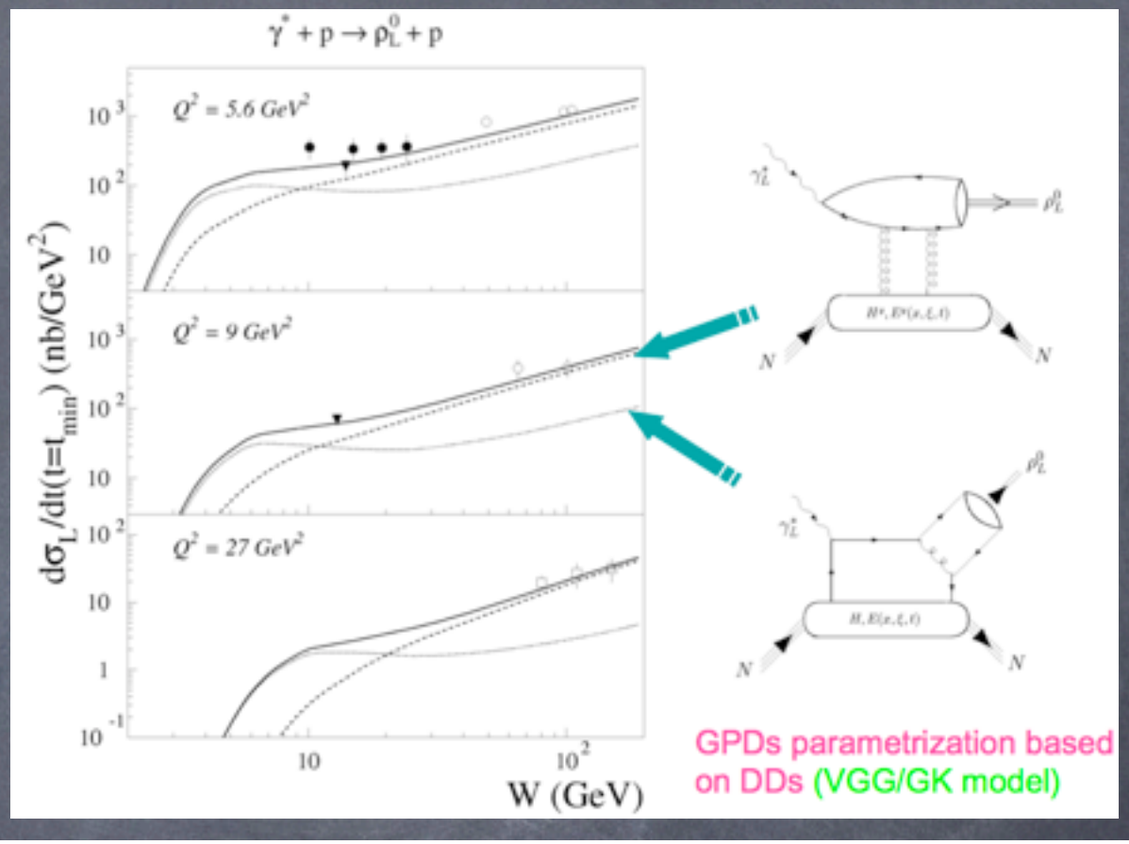


Exclusive Reactions and GPDs

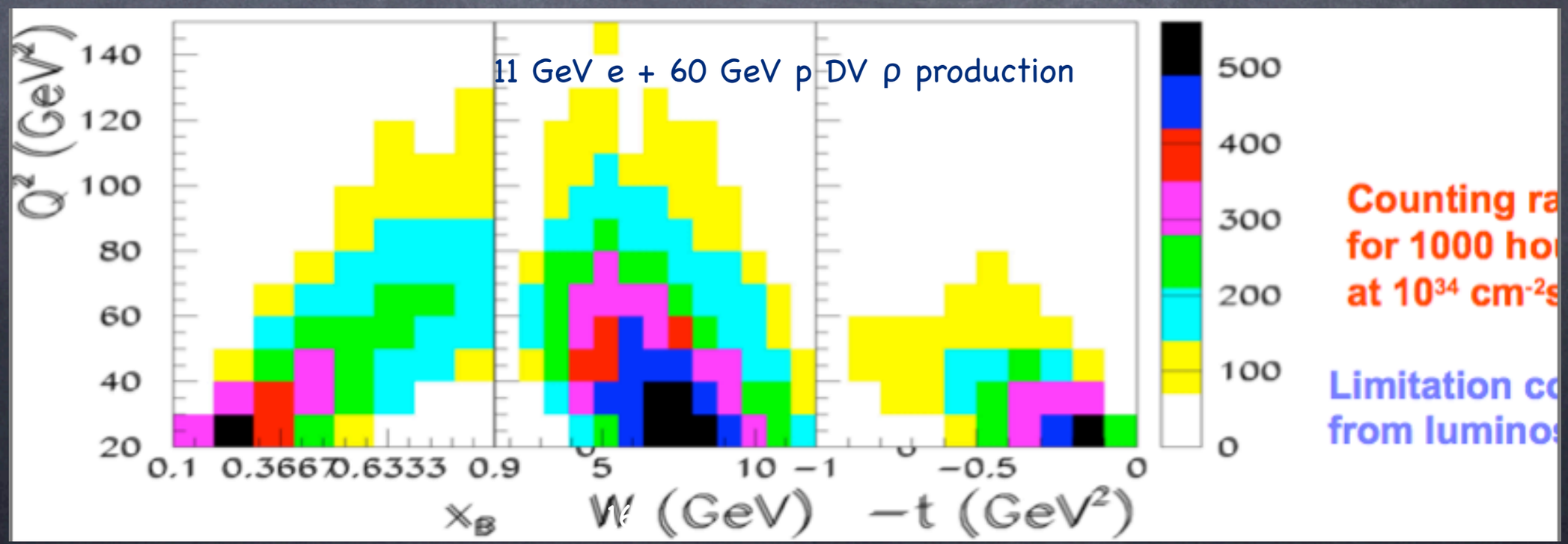
- Form factors
- Deep Virtual Compton Scattering
- Deep Virtual Meson Production
- Novel QCD Effects
- J/ψ and gluonic structure
- Nuclear Processes
- Meson/baryon spectroscopy

Exclusive Vector Meson Electroproduction, M. Guidal

- Lots of data from CLAS 6 GeV
  - GPD/handbag models work well for W>5 GeV for ϕ, $\rho^{0,+}$, ω, various issues at lower W, except for ϕ
- Extensive plans for 12 GeV
- Start of simulations for EIC



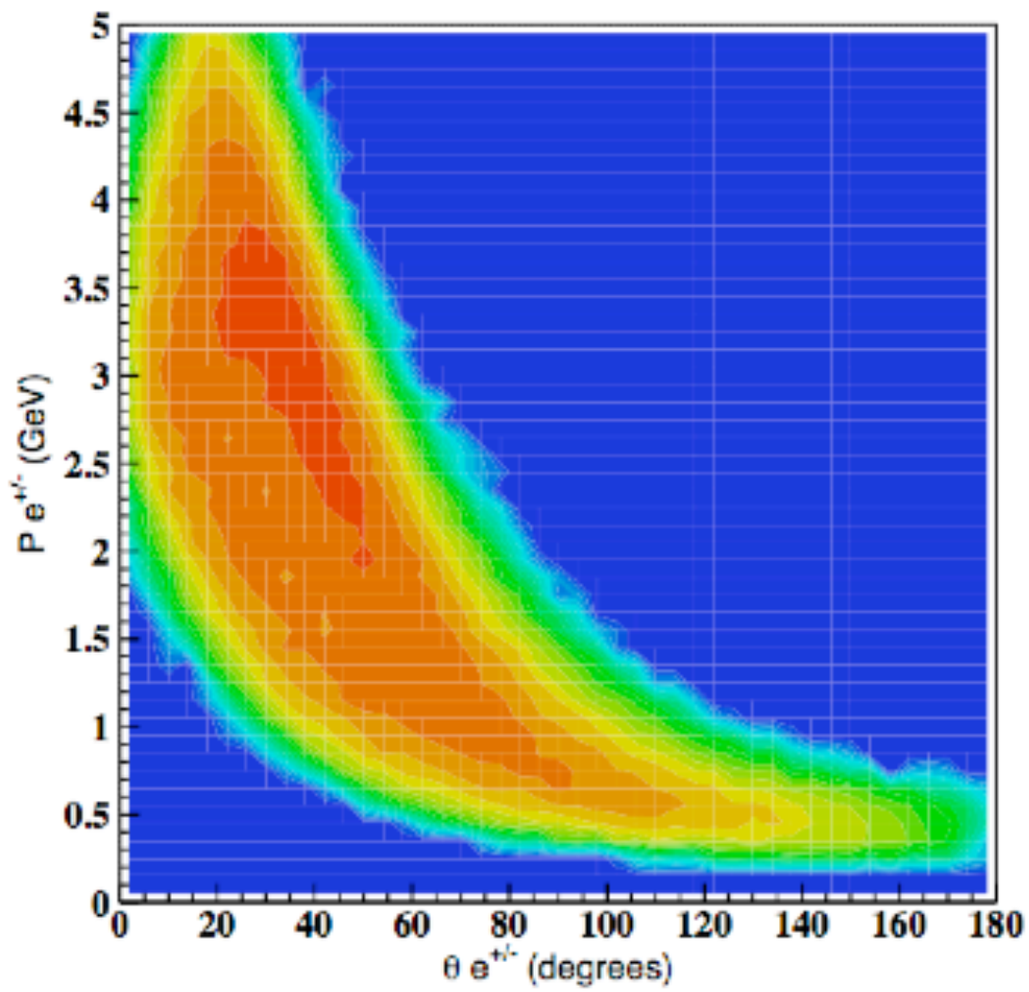
integrated over other variables

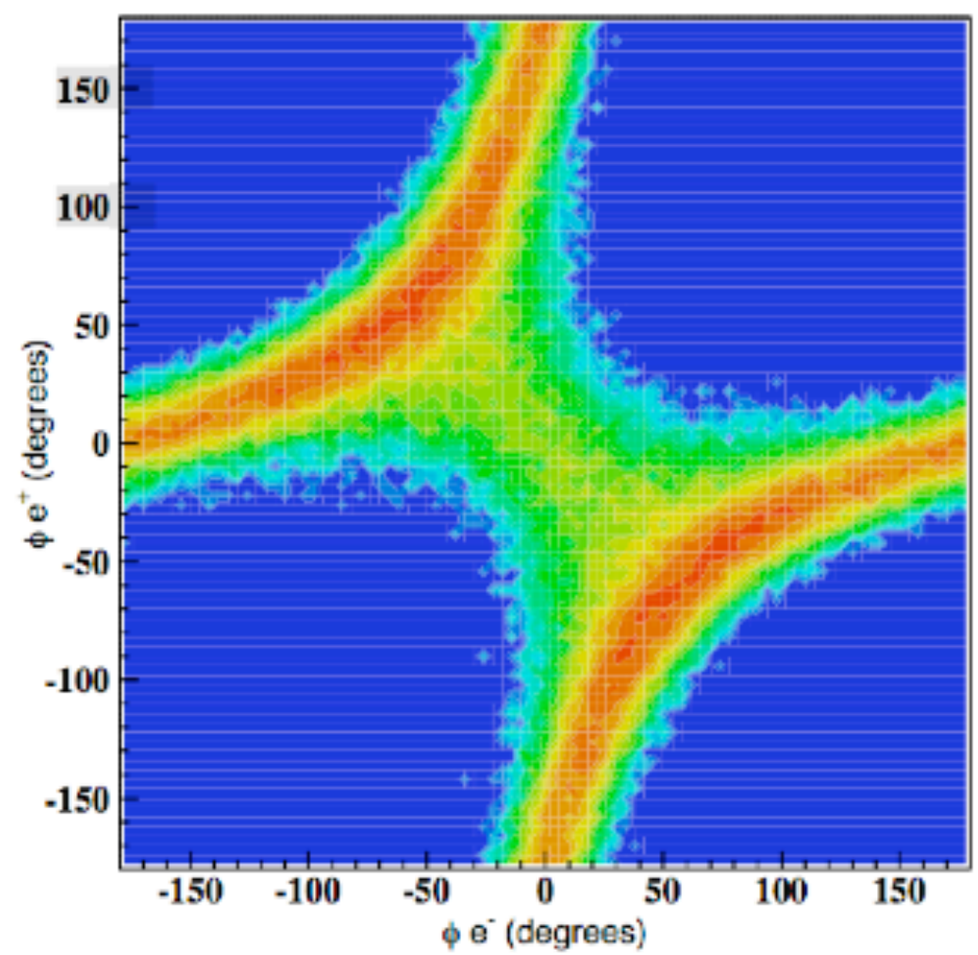


Time-Like Compton Scattering, S. Stepanyan

Simpler process to identify than DVCS
Cross section few - 10 pB (B. Pire et al.)
Access to sea quark and gluon GPDs in small-skewedness region

- 1 to 3 GeV scattered electron gets detected in very forward angles, ~0°
- Recoil proton escapes detection
- Two leptons can be detected in the main detector





Form Factor Measurements, G. Ron

Prospects for High Q^2 ep with EIC

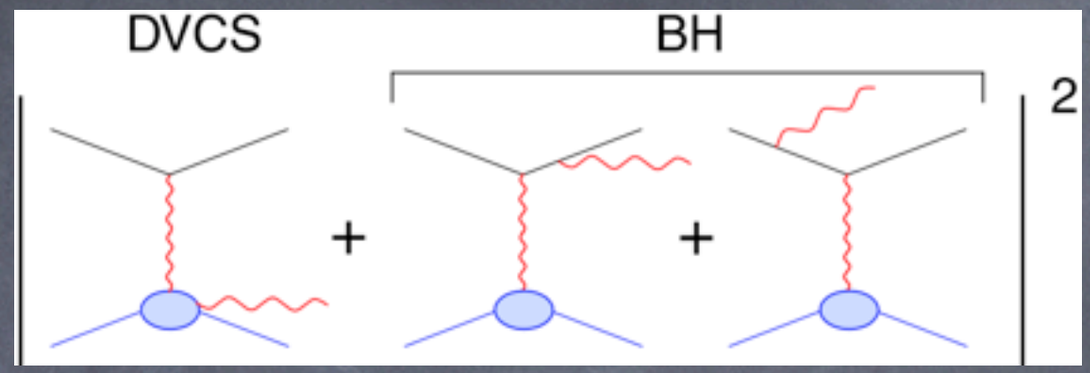
- 3GeV Electron + 30 GeV Proton.
- $\mathcal{L} = 10^{34}$ cm^{-1} sec^{-1}.
- Full angular (φ) detector coverage.
- $\Delta Q^2/Q^2 = 0.1$.

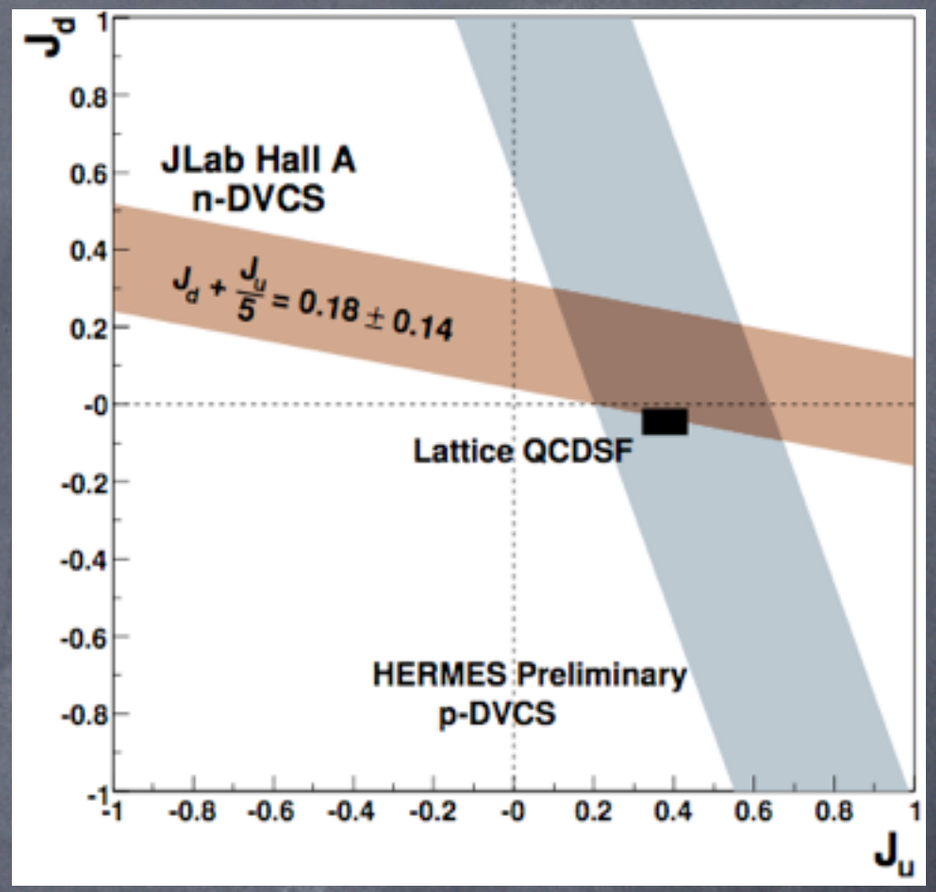
Systematics Limited ⟷ Statistics Limited

Q^2 (GeV^2)	10	20	30	40	50	60
θ_e	56.25	74.97	87.28	96.4	103.6	109.5
θ_p	6.12	8.77	10.9	12.76	14.5	16.1
E'_e	3.74	4.5	5.24	6	6.74	7.5
E'_p	28.3	27.56	26.81	26.06	25.31	24.56
Events / year	186000	7300	1000	250	80	30
$(\Delta\sigma/\sigma)_{stat}$	0.2%	1.2%	3.1%	6.3%	11.2%	18.2%
$(\Delta A/A)_{stat}$	0.3%	1.6%	4.4%	9%	15.8%	25.8%

DVCS, C. Munoz-Camacho

$ep \rightarrow ep\gamma$ =



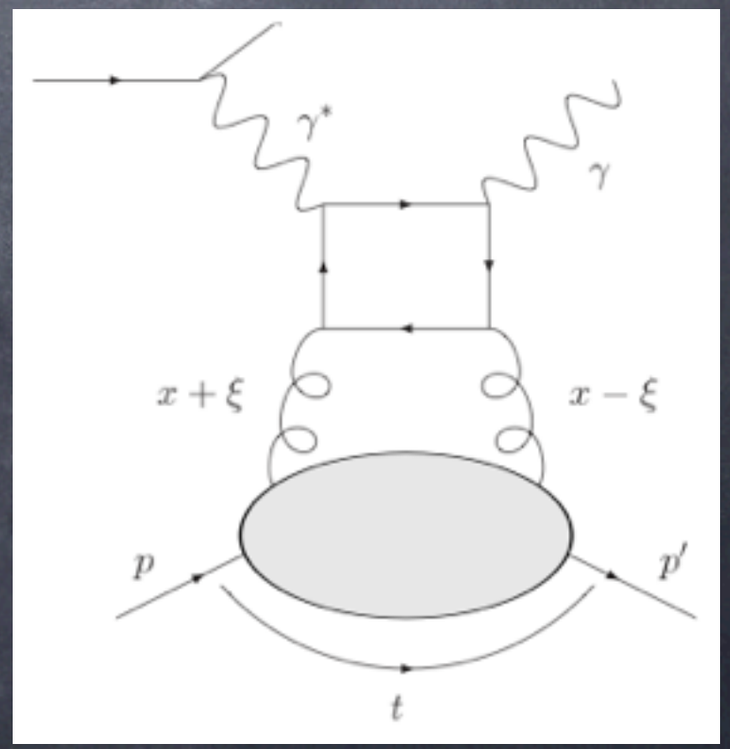


Existing data show twist-2 dominant at few GeV^2
☞ interpretation of handbag / GPDs

Allows model-dependent extraction of GPDs and contributions of u and d quarks to J_{proton}

EIC provides low x (access to gluon GPDs) at high-enough Q^2, and lever arm to study higher twist

Need many polarization observables (beam + target), absolute cross sections, variety of collision energies, exclusivity, proton detection ~5 mr from beam, high luminosity to measure small cross sections



Summary

- Although JLab has the largest NP users group, only a few have spent significant time on EIC
- Now is an appropriate time to ramp up efforts
- Users Group Workshops motivated some work from a few tens of people
- Level of effort now approaching 12-GeV in the early days
- Working groups are following up on the physics case, and expecting to write up work by early 2011