Paul Stoler

Exclusive Reactions

and

Skewed Parton Distributions

High momentum transfer processes

I. High W

II. Form Factors

III. Other exclusive processes.

A. Radyushkin, P.S. coveners

M. Diehl, theory overview

The Program

Characterize the evolution of the structure of hadrons from the low Q - constituent quark regime, through the higher Q PQCD regime, using a variety of exclusive - coherent reactions.

soft - constituent quark model:

$Q < 1$ GeV $\quad r \lesssim 1$ fm

⇒ transition - soft + hard: (JLAB)

$Q \lesssim 10$ GeV $\quad r \sim .02$ fm

PQCD:

$Q >$??

Working Groups

I Deep structure of baryons

a) High Q^2 - hard electroproduction of $\gamma, \pi, \rho \cdots$

b) High t:

i) Form factors

ii) Large t Compton eff.

II Meson structure

a) Form factors

b) π^0, η, η' decay widths

Unified theoretical framework

relating high momentum transfer

exclusive reactions to

quark - gluon structure of baryons

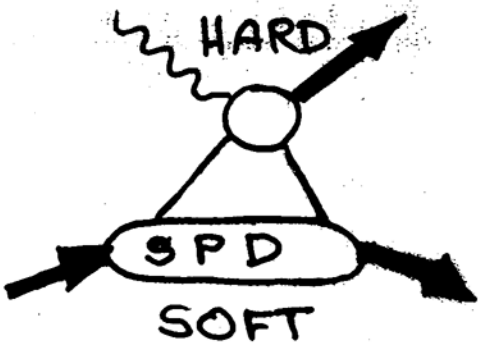
The language: SPD's

Factorize high momentum transfer reactions: hard - perturbative

soft - non-perturbative

W ≤ 10 GeV

quark distrib.

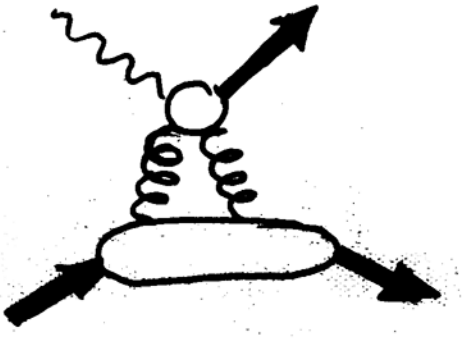


JLAB

@ 12 GeV

W > 10 GeV

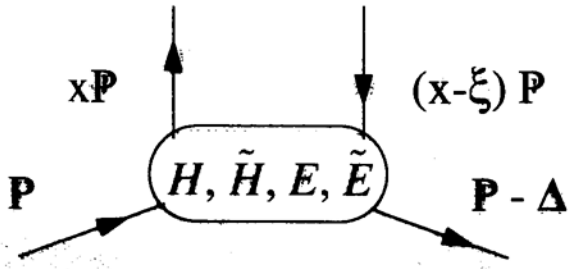
Gluon dist.



COMPASS, HERMES

Skewed Parton Distributions

Useful context for the study of exclusive meson production at high Q^2



$$\xi = \frac{\Delta \cdot z}{P \cdot z}$$

$$t = \Delta^2$$

Limits:

Ordinary Parton Distributions (Δ, t, ξ —> 0)

$$H_0(x,0) = q(x) \qquad \tilde{H}_0(x,0) = \Delta q(x)$$

unpolarized polarized

Nucleon Form Factors (Sum Rules)

$$\int H_\xi(x,t)dx = F_1(t) \qquad \int \tilde{H}_\xi(x,t)dx = g_A(t)$$

Dirac axial vector

$$\int E_\xi(x,t)dx = F_2(t) \qquad \int \tilde{E}_\xi(x,t)dx = h_A(t)$$

Pauli pseudoscalar

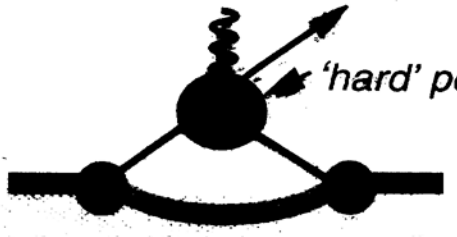
The experimental program

High Q^2, W hard processes.

Skewed Parton Dist. in Valence quark region

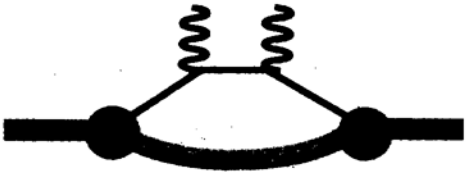
(Frankfort et al, X. Ji et al , A. Radyushkin et al.

Includes deep inelastic structure functions as special case.



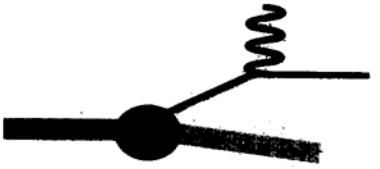
soft physics

off forward parton distributions- $H^q(x,\xi,t)$, $E^q(x,\xi,t)$



Compton scattering

$H^q(x,\xi,t)$ . . . .



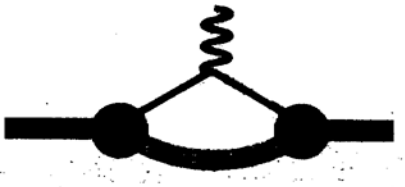
DIS

$H^q(x,0,0) \to g(x) \sim g_{\downarrow} + g_{\uparrow}$ . . .

$\tilde{H}^q(x,0,0) \to \Delta g(x) \sim g_{\downarrow} - g_{\uparrow}$.

meson production

$H^q(x,\xi,t), \tilde{H}^q(x,\xi,t)$, . . .



baryon and meson form-factors

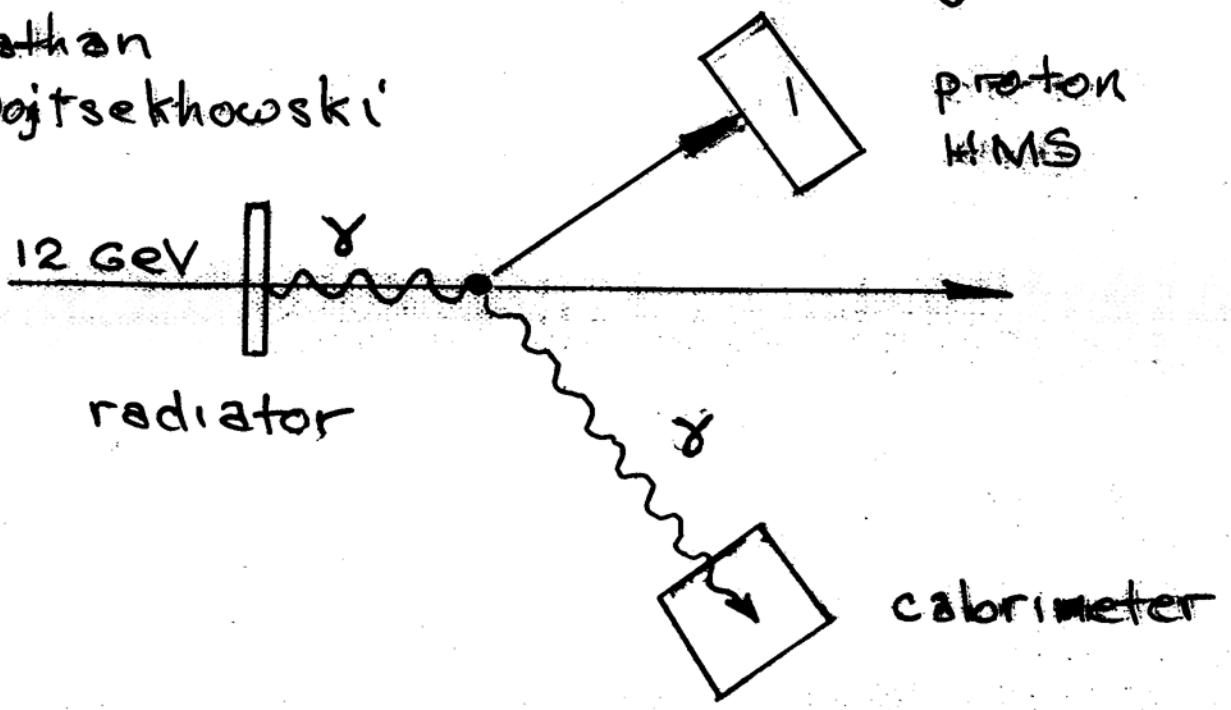
$\int H^q(x,\xi,t)$ . . . $\to G_E, G_M, A_{3/2}, A_{1/2}, C_{1/2}$

$\int \tilde{H}^q(x,\xi,t)$ . . . $\to G_A$ . . .

A key test case!

Real Compton Scattering

Nathan Wojtsekhowski



Test factorization

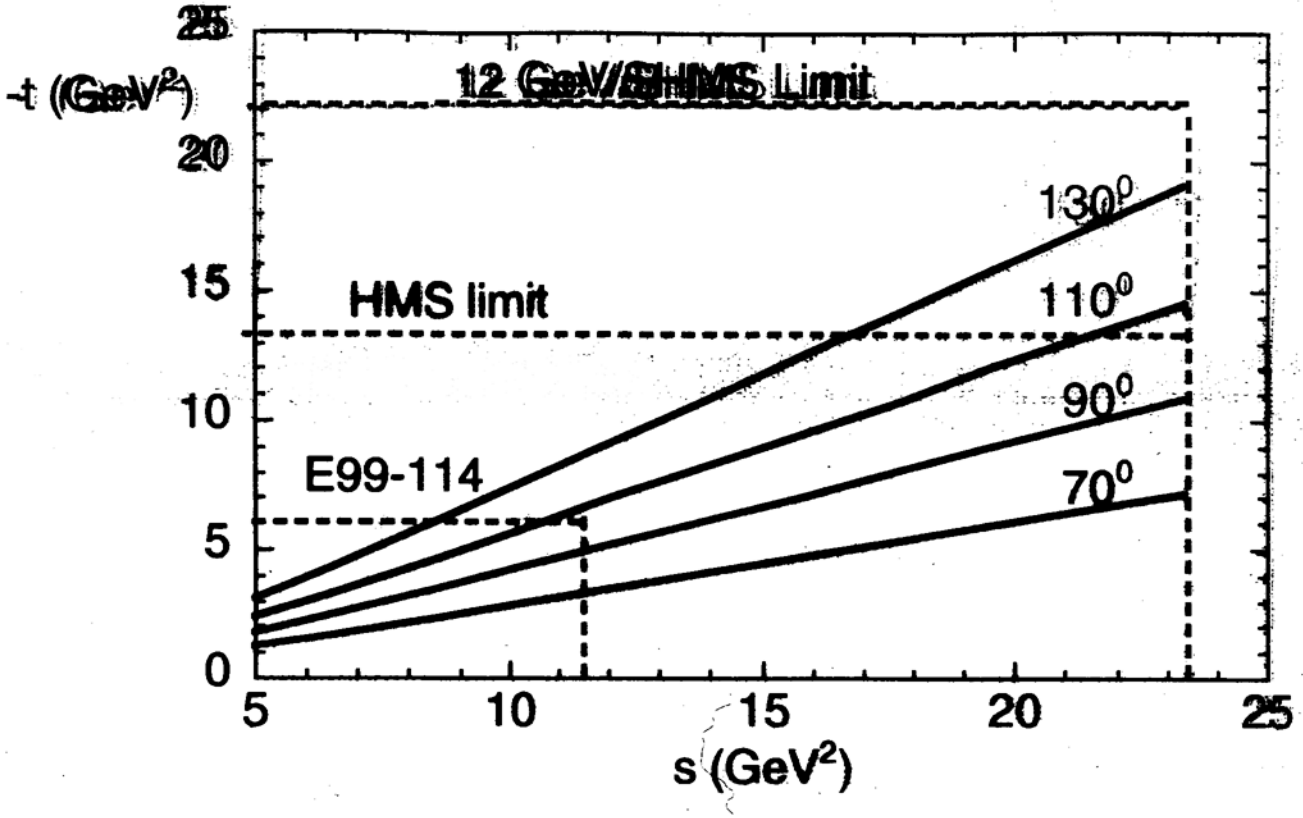
$$\frac{d\sigma}{dt} = \left(\frac{d\sigma(s,t)}{dt}\right)_{KN} f_v \, R_v^2(t)$$

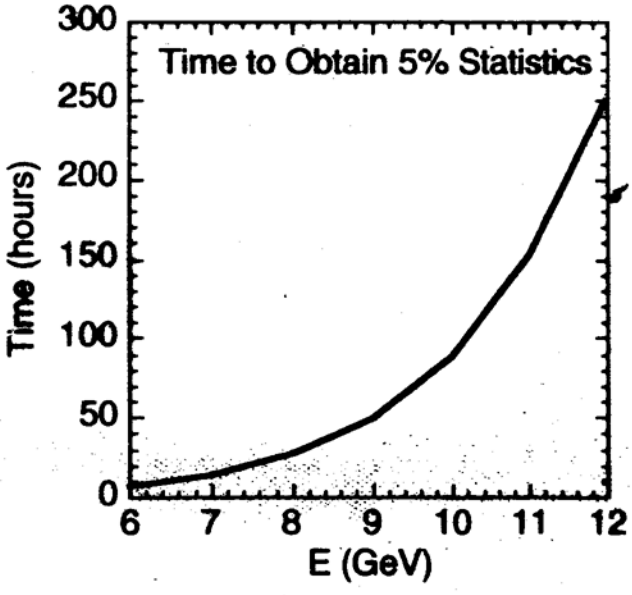
For fixed t $\quad \sigma(s) \rightarrow$ K-N

For $E = 12$ GeV

$s, t \sim 20$ GeV^2

Experimental Considerations for RCS





- $d\sigma/dt \sim s^{-6} \Rightarrow$ small cross sections!
- backgrounds a bit worse
- time for 5% statistics x60 relative to 6 GeV

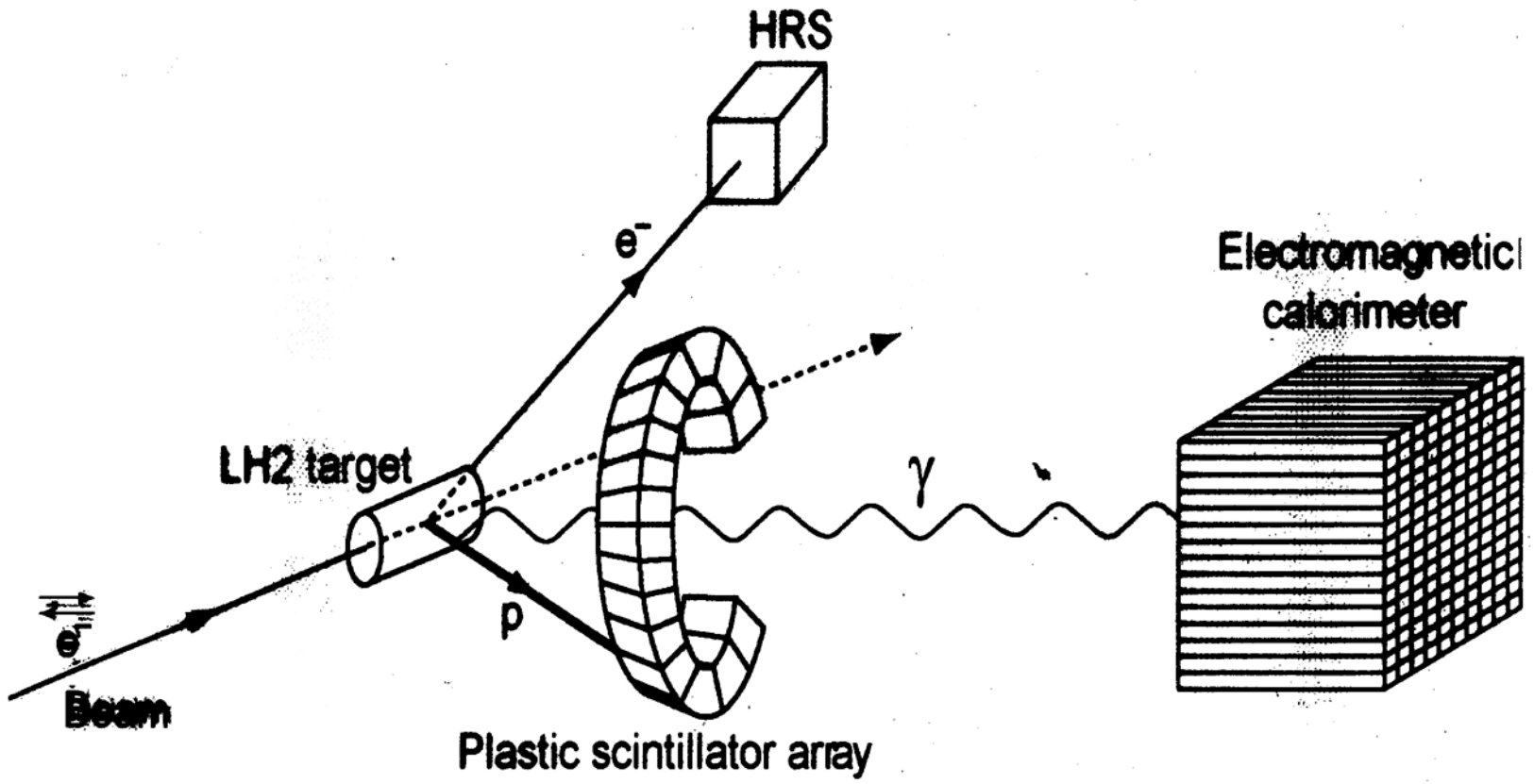
Deep Virtual Compton Scattering

Y.R. Roblin, December 1999 Hall A Collaboration meeting

Hyde-Wright
Roblin
Bertin

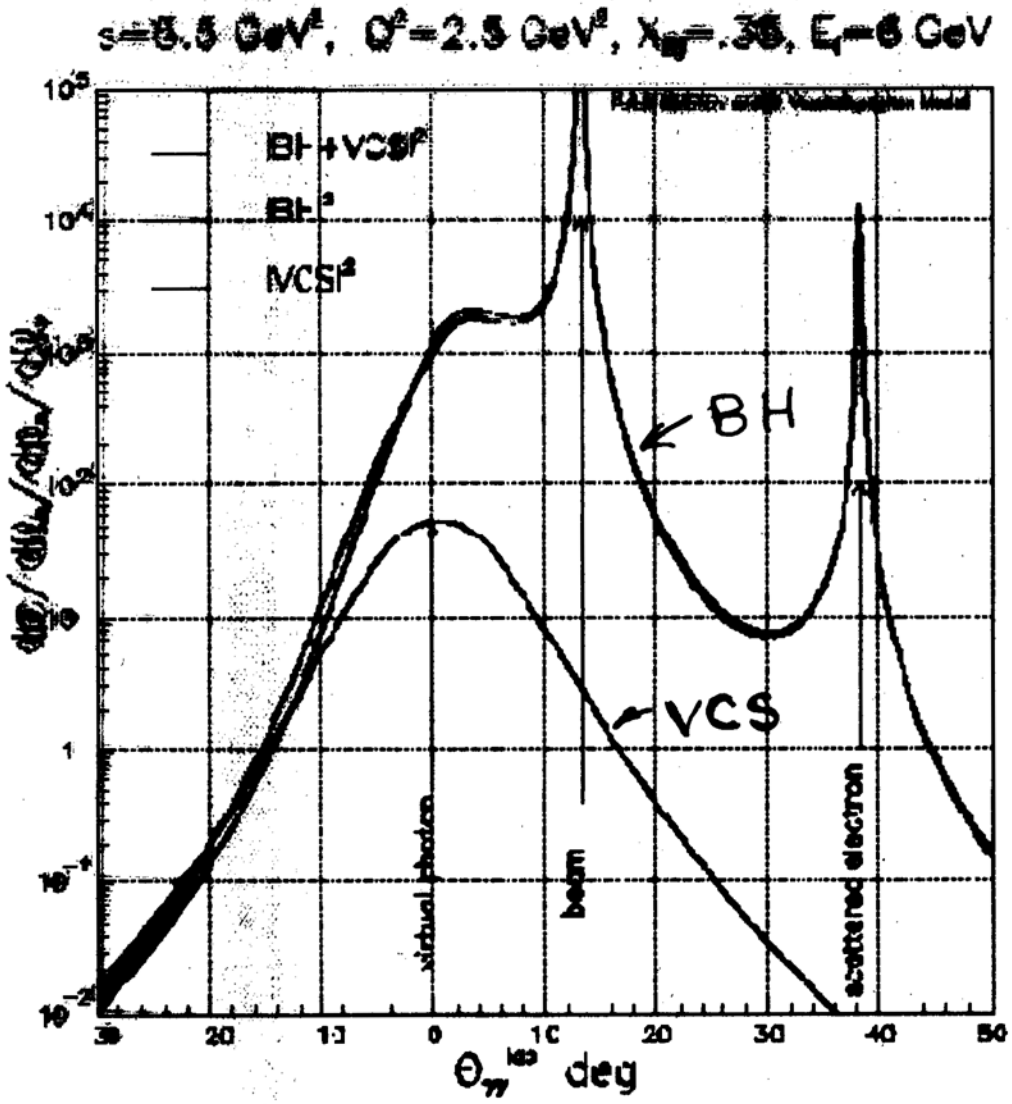
Experimental setup

DVCS $ep \rightarrow ep\gamma$



With large array $S \sim 10\ GeV^2$ $P_T \sim 1\ GeV$
$Q^2 > 1\ GeV^2$

Cross-sections



measure interference $A^*_{CS} A_{BH}$
relative phase information

Beam Helicity Asymmetry

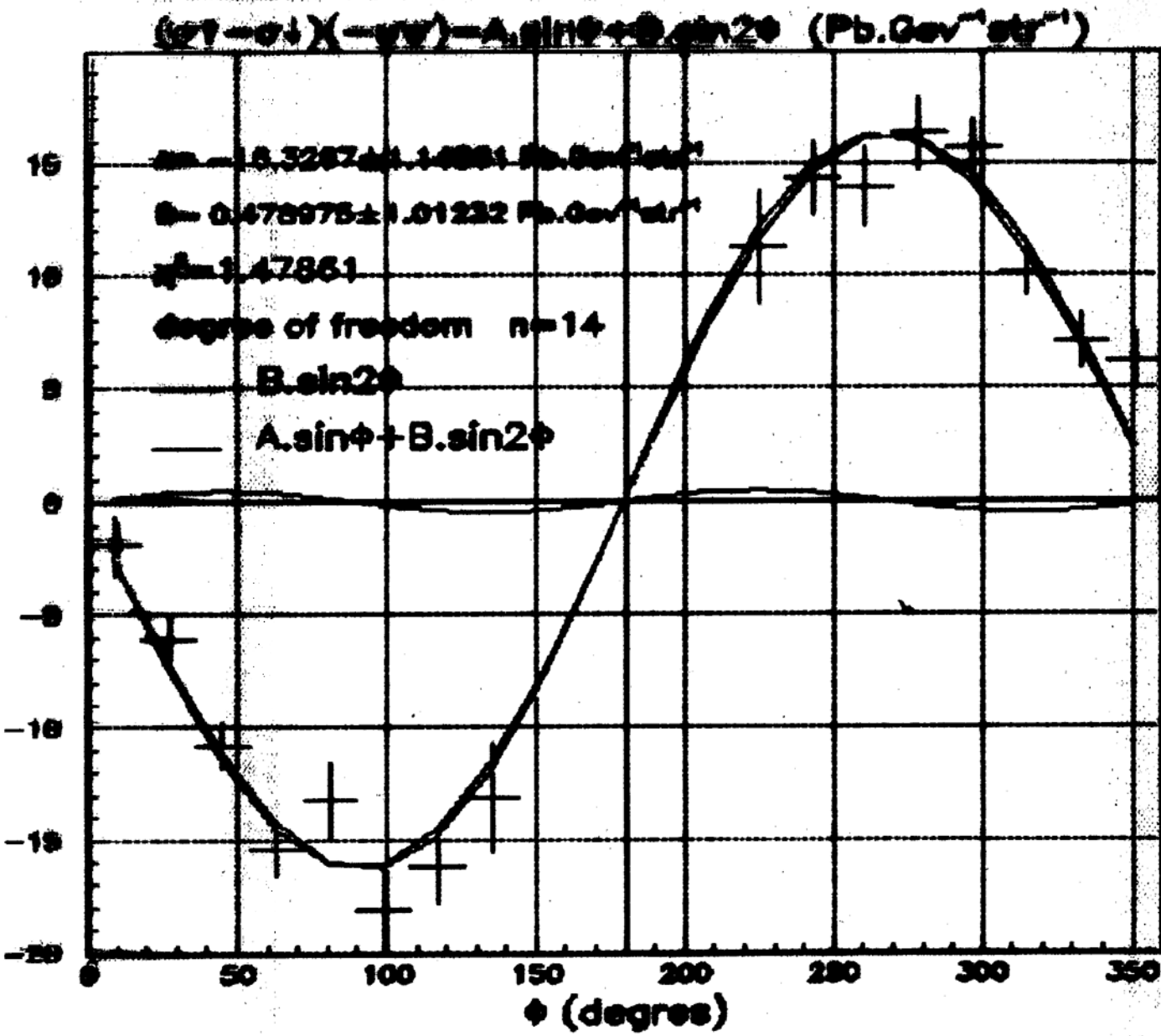
Asymmetry:

Leading term

$$(-s'u')\left|\sigma^{+}(\phi)-\sigma^{-}(\phi)\right|_{VCS.BH}=A\sin(\phi)+B\sin(2\phi)+C\sin(3\phi).$$

- **A scales** as 1/Q, leading term, contains SPD's.
- **B scales** as $1/Q^2$, higher twists terms.
- (-s'u') comes from BH propagators and is calculable.

Projected results, s=5.5 GeV^2, Q^2=2.5 GeV^2, E=6 GeV



Meson Production

pseudovector

$\rho, \omega, \phi \cdots$

$H, \; E \rightarrow q(x)$

spin aver.

---

pseudoscalar

$\pi, \eta, K \cdots$

$\tilde{H} \quad \tilde{E} \rightarrow \Delta q(x)$

spin diff.

$H, \tilde{H}$ proton non-spin flip

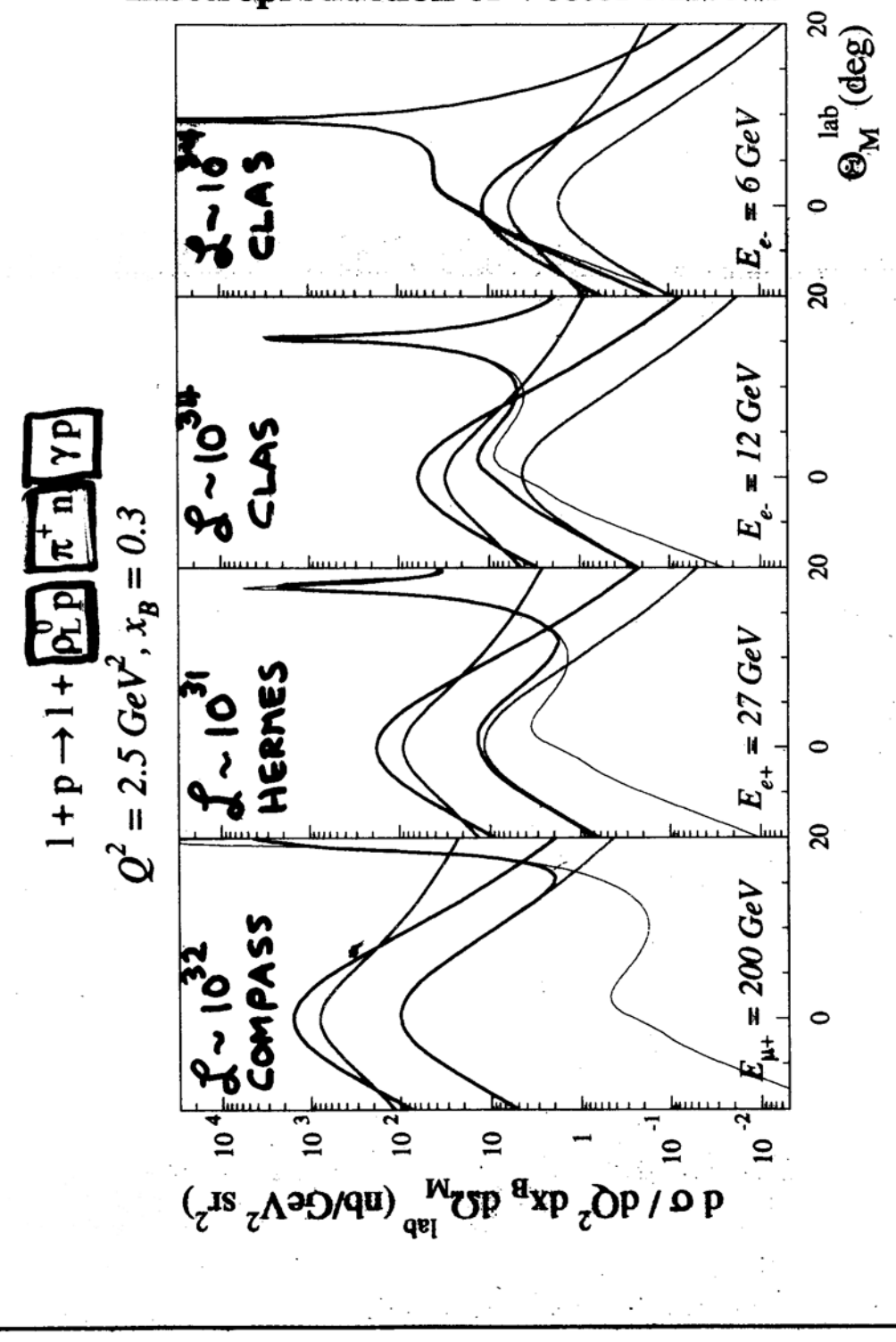
$E, \tilde{E}$ " yes " "

↑ orbital L of partons

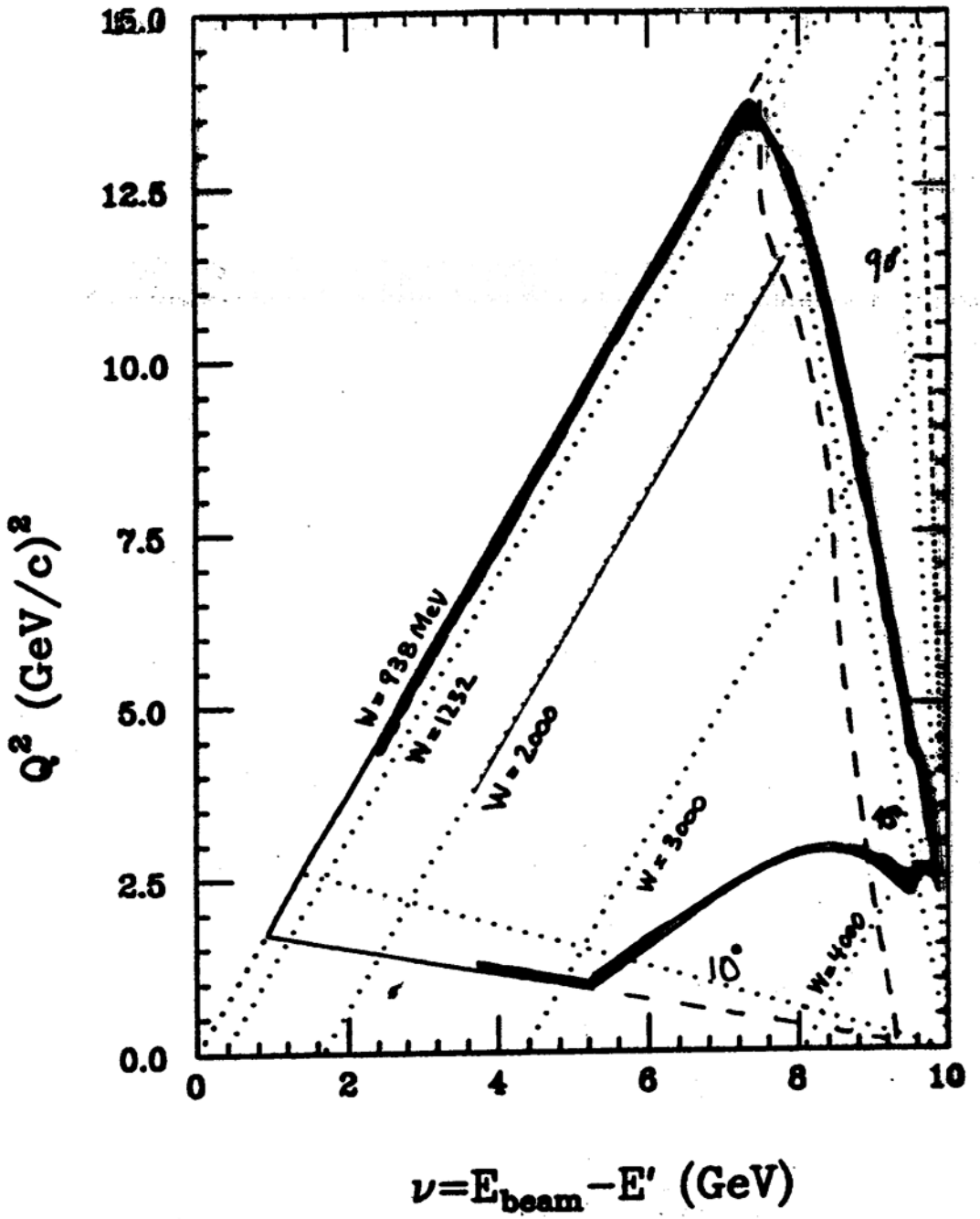
Factorization $\rightarrow \sigma_L$

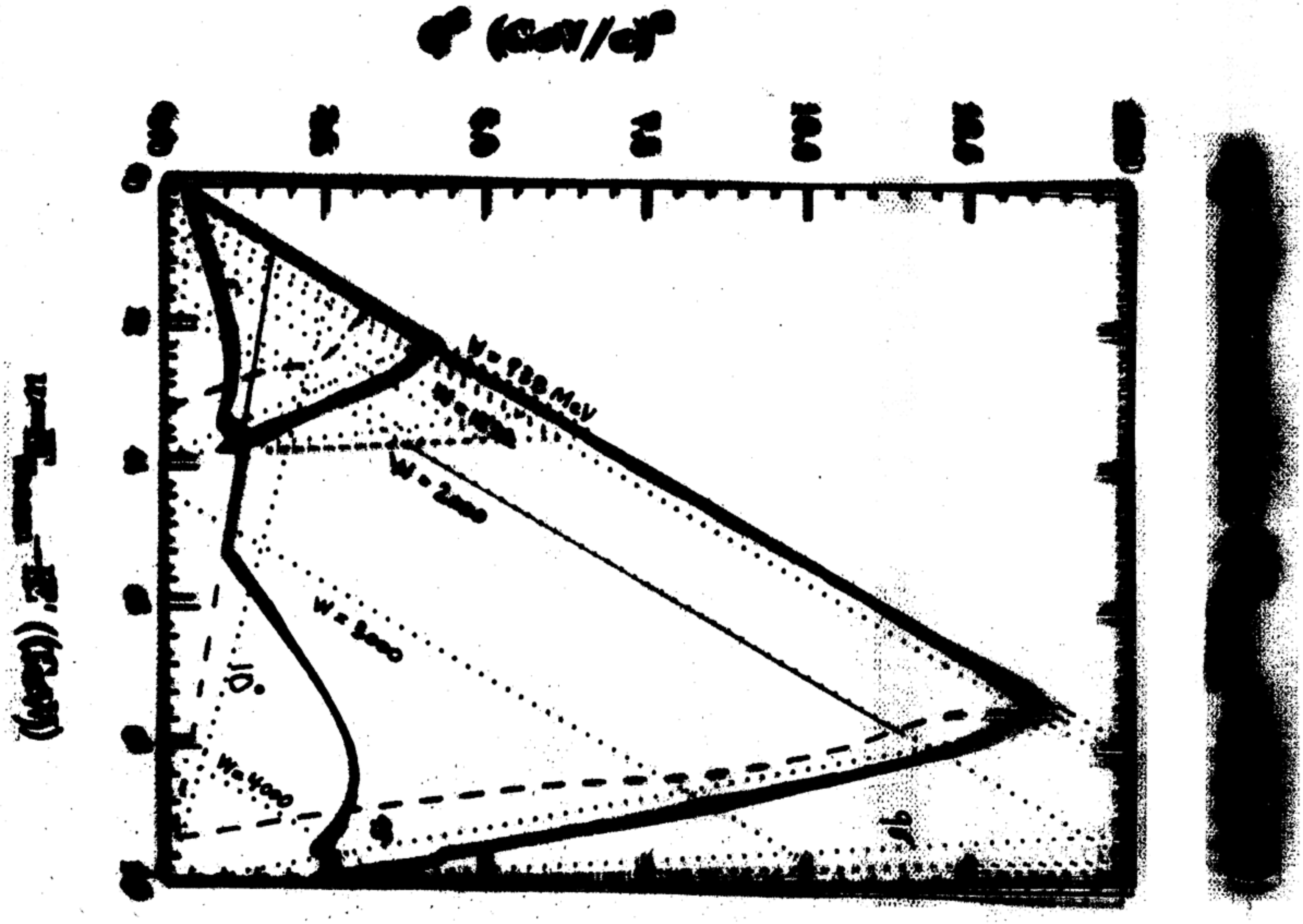
Higher twist $\rightarrow \sigma_T \cdots$

Electroproduction of Vector Mesons



ep Kinematics ($E_{beam} = 10$ GeV)




W = 2mc²
W = 4mc²

[redacted]

CLAS detecter upgrades needed to:

- extend particle id to higher momenta
  π/K/p momenta up to ~8 GeV/c

- improve tracking coverage to veto
  background particles

- improve coverage for γ detection
  to allow high energy π^0 detection at
  forward angles

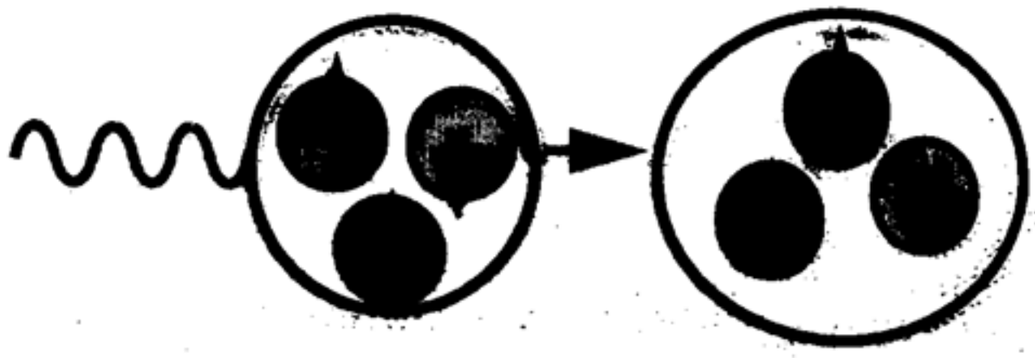
=> With these upgrades CLAS should be well suited to study exclusive ep -> eNπ reactions at high W, and high Q^2.

Baryon Form Factors

"Quark-Gluon" based models for exclusive reactions baryon elastic and transition form factors at increasing Q^2 .

Low Q^2:

Constituent quark models
strings, gluon-meson exchange,
quark FF, etc., lattice

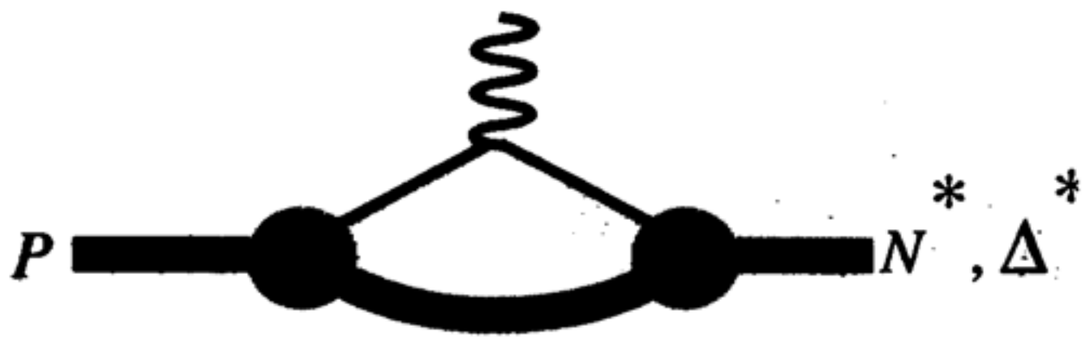


Intermediate Q^2:

Soft (Feynman) mechanism:
QCD sum rules for form factors,
skewed parton distributions.

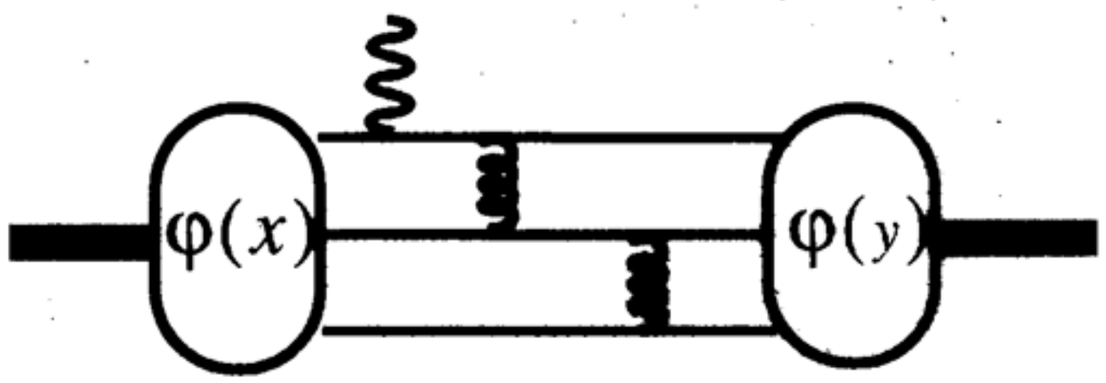
$$\int H^q(x,\xi,t)\ldots \rightarrow G_E, G_M, A_{3/2}, A_{1/2}, C_{1/2}$$

Hybrid:
Diquarks, etc.



Very high Q^2:

Perturbative QCD:
QCD-sum rules (SWZ)



constituent counting

$$F \propto \frac{\alpha_s^2}{Q^4}$$

helicity conservation

$$A_{1/2} \gg C_{1/2} \gg A_{3/2}$$

-Investigate the transition in Q^2 from the CQM, and the onset of soft and hard QCD processes.

Elastic Form Factors

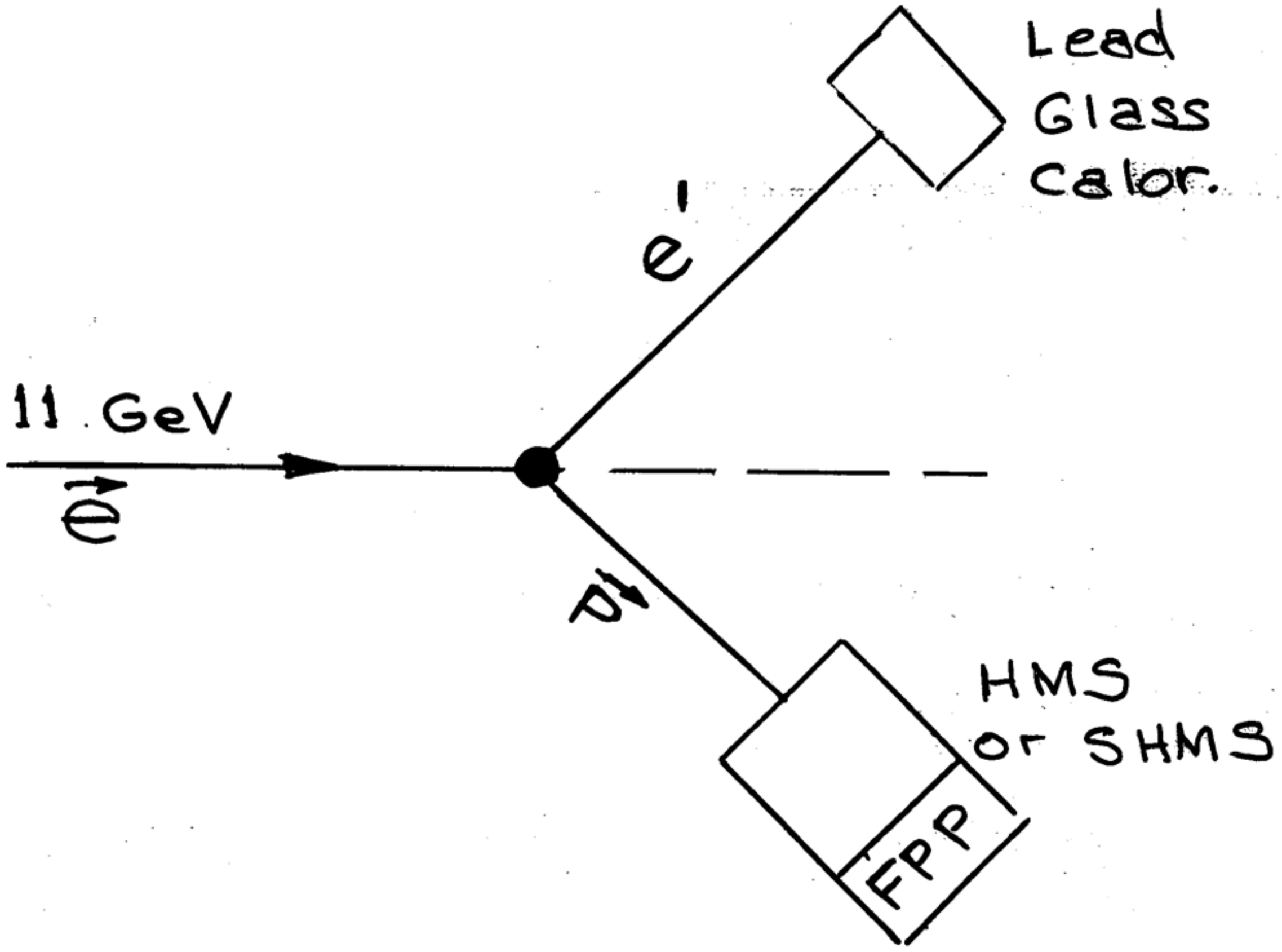
Knowledge of all 4 to as high Q^2 as possible necessary to constrain theory

const. quark • soft-handbag • pQCD

G_{MP}	Petratos	$Q^2 \sim 20$ GeV^2
G_{EP}	Perdrisat	$Q^2 \sim 15$ GeV^2
G_{MN}	Brooks	$Q^2 \sim 15$ GeV^2
G_{EN}	?	?

G_{EP} Perdrisat

Hall C



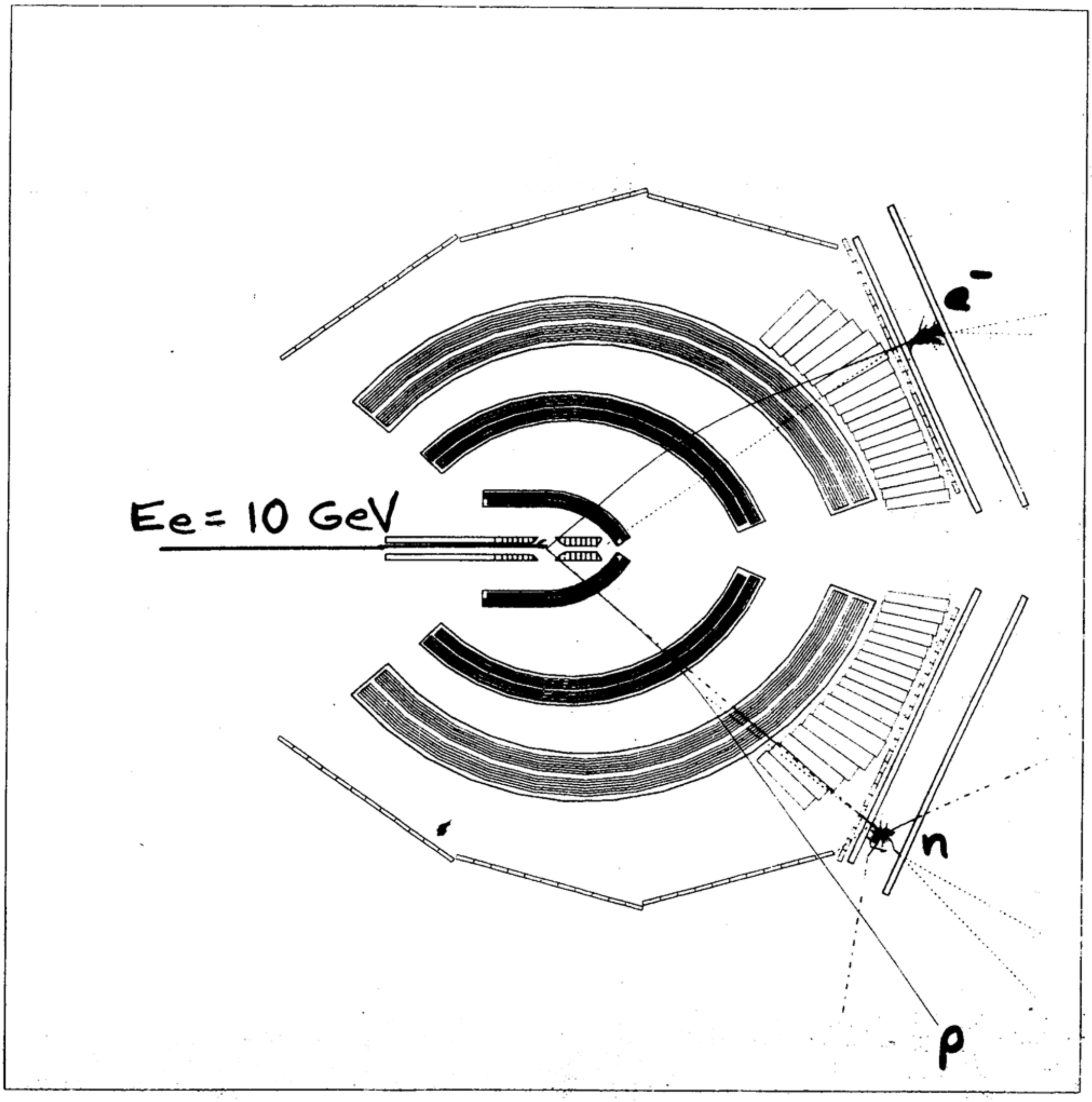
Q^2 max ~ 15-17 GeV2

Limited by FPP analyzing power

G_{Mn} Brooks

$$\frac{D(e,e'n)p}{D(e,e'p)n}$$

CLAS (horizonal slice)

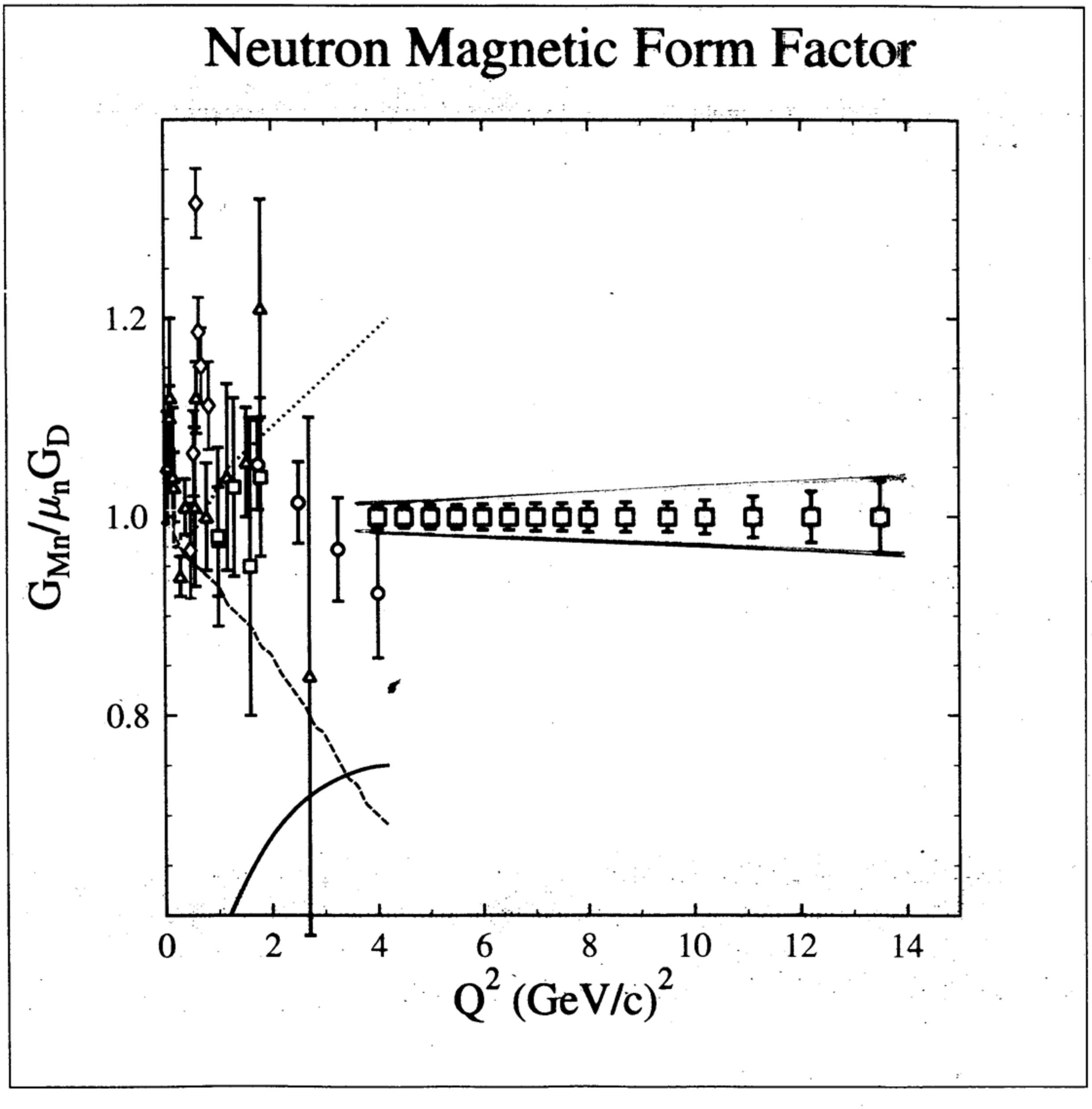


t = 30 - 60 days $L \sim 2 \times 10^{34}$

Q^2 max ~ 14 - 15 GeV^2

Measurement in CLAS with 30 days, $2 \times 10^{34} s^{-1} cm^{-2}$ using <u>10 GeV</u> beam

Black error bars show statistical error, green lines are a guess for systematic errors.



PS et al

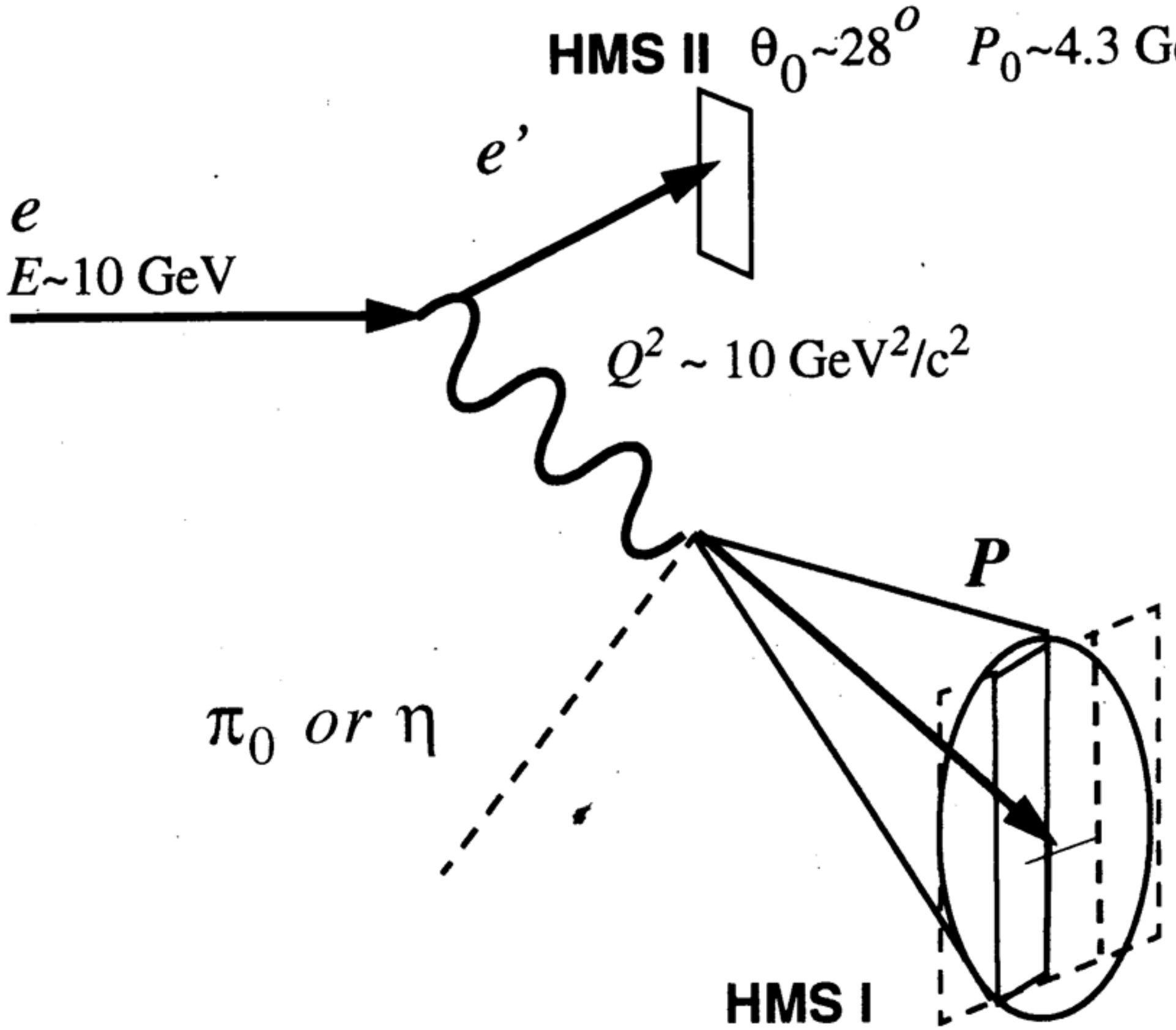
Baryon Transition Form Factors

Hall C

Kinematics of extension to JLAB at Higher Energy

$e + p \rightarrow \Delta(1232) \rightarrow \pi^0 + P \quad G_M, \frac{E2}{M1}$

$\rightarrow S_{11}(1535) \rightarrow \eta + P \quad A_{1/2}$



θ_0=16-21^o P_0=4- 6 GeV/c

Hall B

Extensive program planned

$\Delta(1232)$	π^+
$S_{11}(1535)$	π^0
$F_{15}(1680)$	π^-
$P_{11}(1440)$	η
⋮	2π

+ Polarization asymmetries

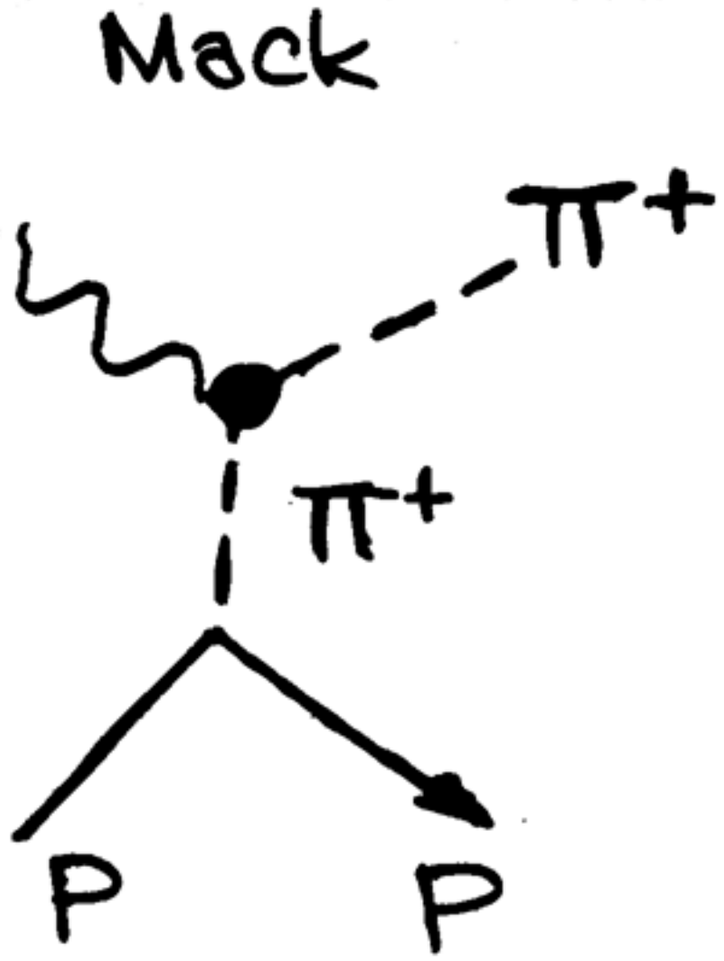
Measure all channels

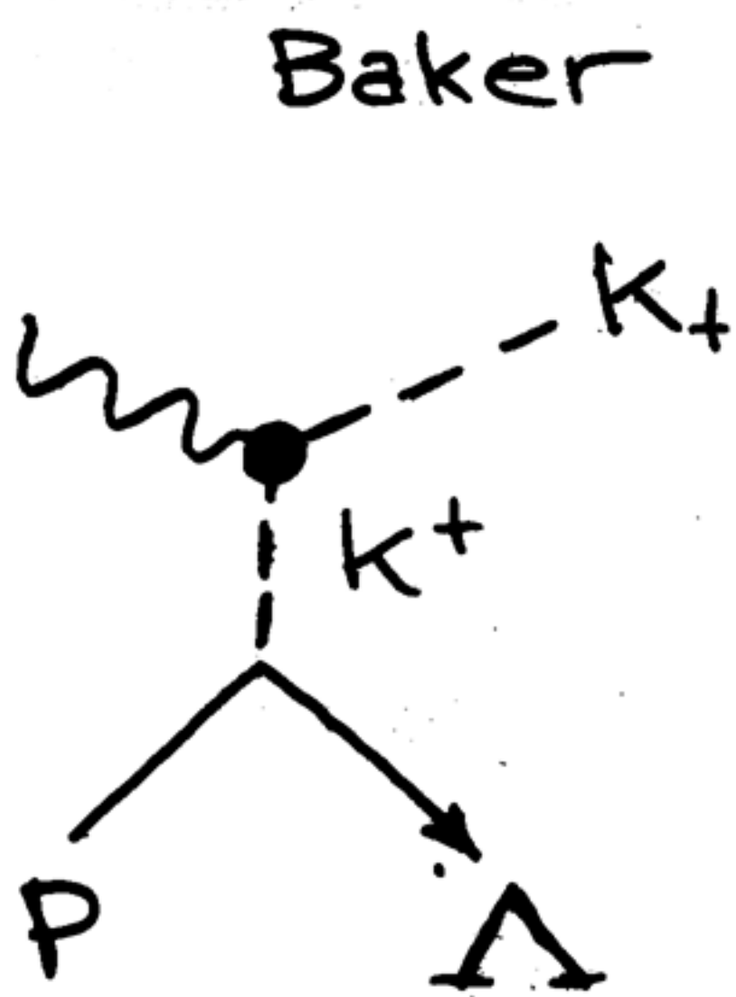
all Q^2 simultaneously

Q^2 max ~ 8-10 GeV^2 with increased Lum!

Structure of Mesons

Meson Form Factors





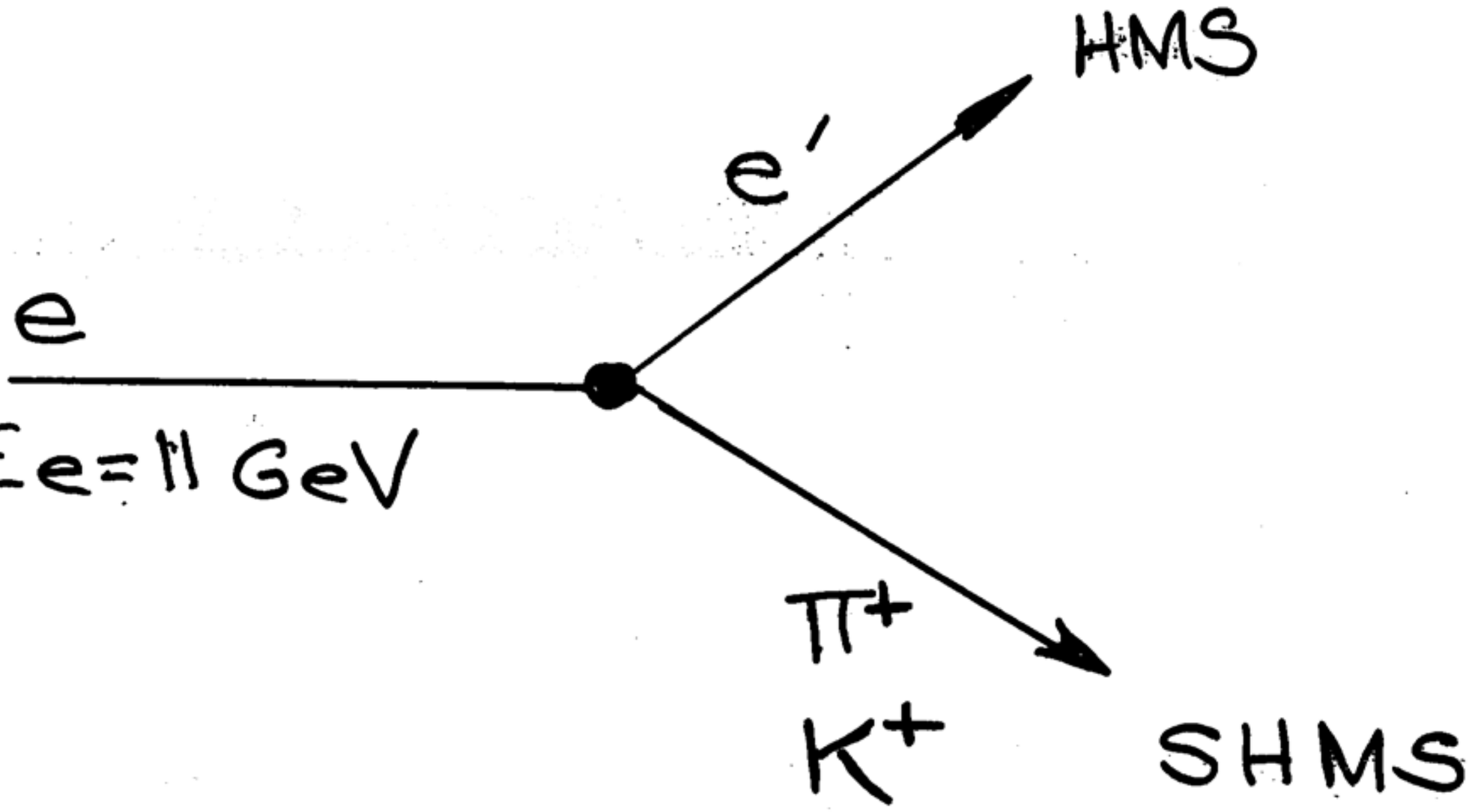
F_π

(not at pole)

F_K

(far from pole)

Hall C



Limitations

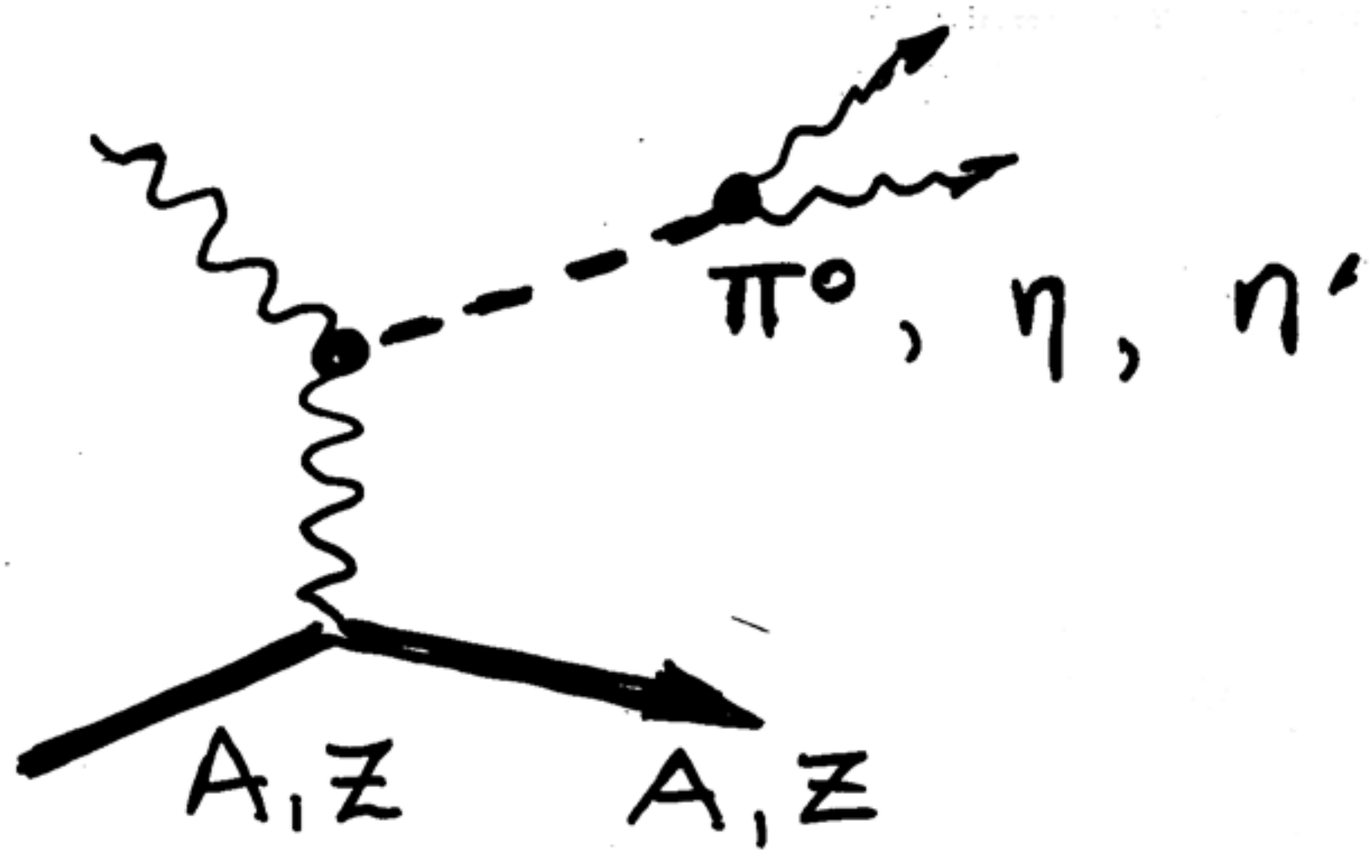
L/T separation

solid angle acceptance SHMS

$Q^2_{max} \sim 5\text{-}7 \ GeV^2$

structure of π^0, η, η' by Primikoff effect.

Miskimen, Goity, Gan



measure decay widths, form factors

$\Gamma(\eta \to \gamma\gamma)$
$\Gamma(\eta' \to \gamma\gamma)$
} $\eta_0 \longleftrightarrow \eta_8$ mixing Θ

currently $-16^\circ \to -23^\circ$!

Conclusions

Identified major physics programs to study hadronic structure and skewed parton distributions with exclusive reactions at $E_e = 12$ GeV

Set up working groups to prepare proposals for 3 - 4 experimental programs

Goal → PAC June 2000