Estimates of inclusive e+/e- cross sections and structure functions at Jlab

Eric Christy
Hampton University

JPos @ JLab **March 25, 2009**

Some things we can learn from unpolarized inelastic scattering with e+ beams

1γ exchange diagram doesn't depend on lepton charge

- 2γ effects in e-p unpolarized SFs

  Would want some lever arm in ε for e+ / e- ratios.

  Some information could already be in HERA data!

- 2γ effects in e-p transverse target asymmetries

For both (1) and (2) the 2-γ contributions flip sign for e+ vs e-

- Charge-asymmetry measurements give real part of DVCS amplitude – access to GPDs. (discussed by M. Burkardt, V. Burkert, and N. d'Hose)
- Definitive measurements of coulomb corrections for nuclear targets (to be discussed by P. Solvingnon)

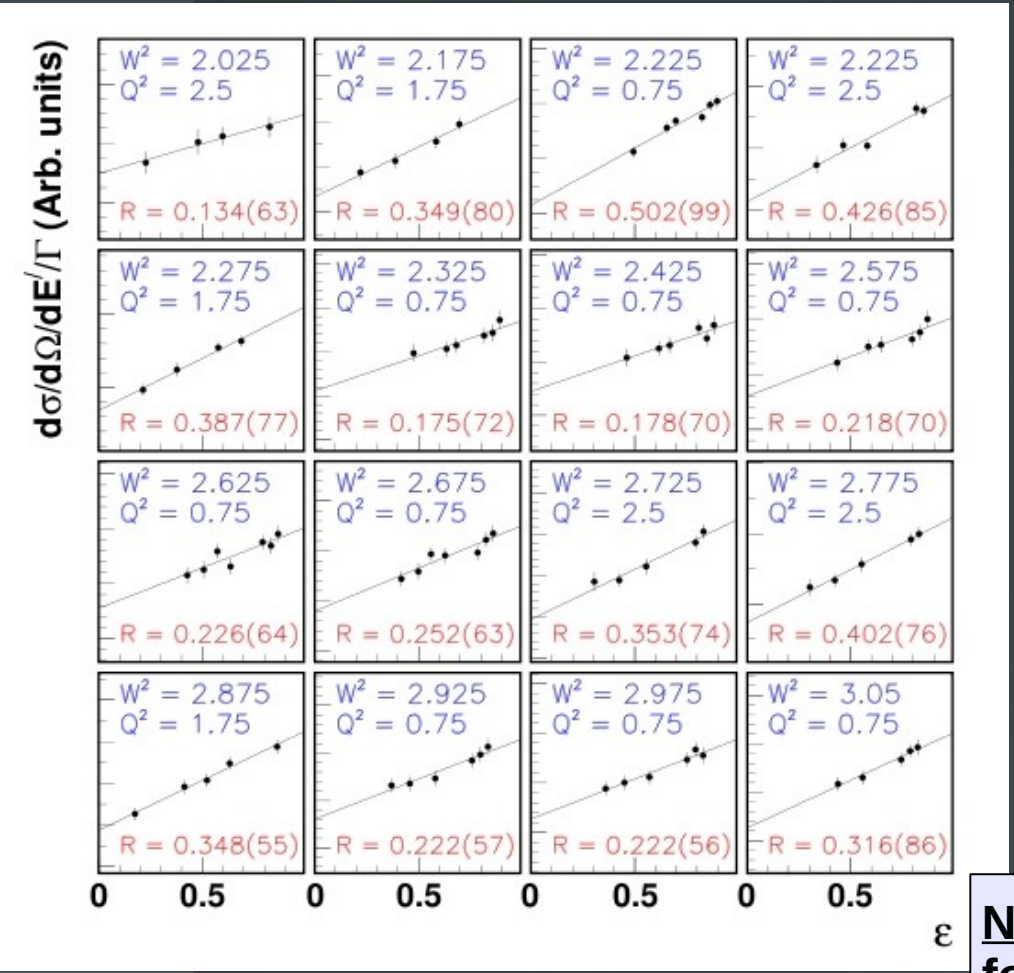
  - need to check 2γ effects with e-p first

2 photon exchange in inelastic unpolarized scattering.

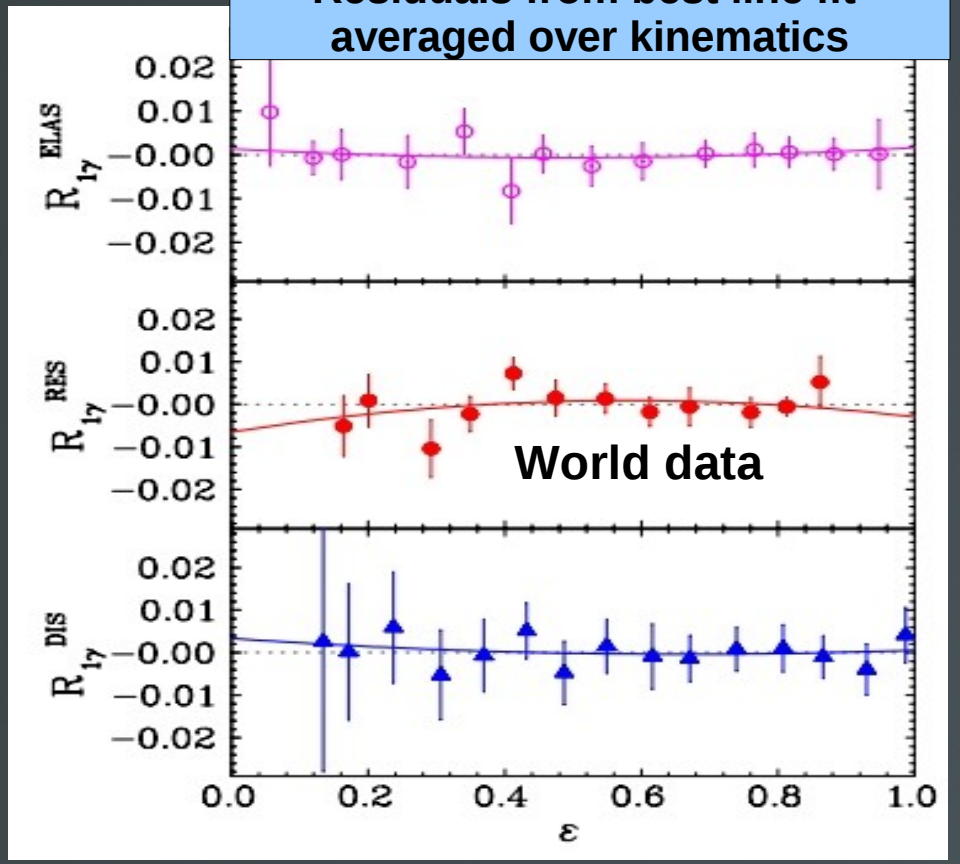
- The impact on the World structure function measurements for charged lepton scattering should be understood as well as possible. Likely to be small correction for F_2.
- If significant, this impacts R, F_L measurements from Rosenbluth separations.

  F_L DIS measurements can be used in Parton Distribution Fits to constrain the gluon distribution
- Must be understood to examine Coulomb distortion effects from e+/e- differences.

Non-linearities in inelastic ep scattering



Residuals from best line fit averaged over kinematics



Linearity studied for World L/T separations.

V. Tvaskis, *et. al,* Phys.Rev.C73:025206, 2006

No evidence for non-linearities in Rosenbluth's for inclusive e-p elastic, resonance, and DIS.

Even if 2-γ contributions are linear in ε they will have *opposite* signs for e+ and e-

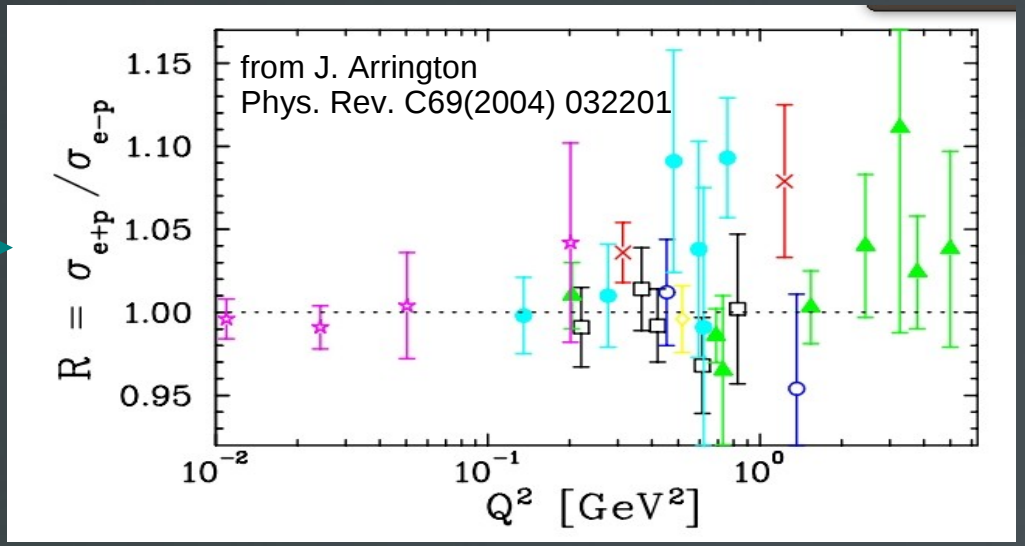
=> charge ratios will enhance this signal by **2x**

e^+p/e^-p differences: Previous Measurements

Elastic

Slac data for Q^2 range shown

epsilon dependence hinted at.

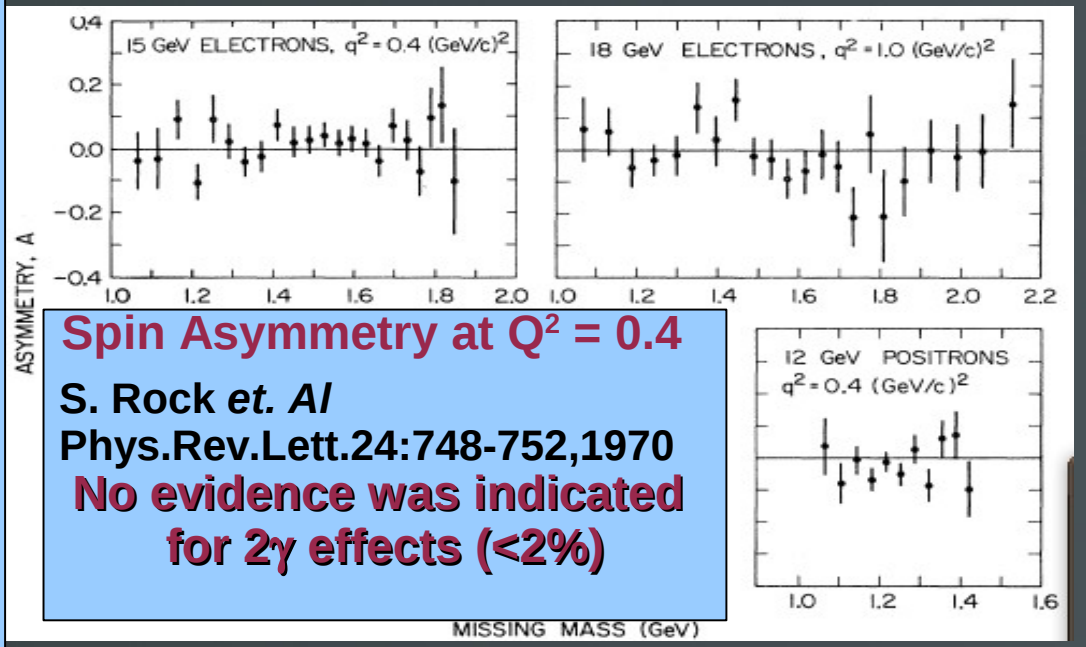


For both elastic and inelastic e-p the sign of 2γ e-p correction factor flips signs for e^+

Recent theoretical calculation for unpolarized scattering,

V. Pascalutsa, C. Carlson, M. Vanderhaegen, hep-ph/0509055

S. Kondratyuk, P. Blunden , Nucl.Phys.A778, 2006



Spin Asymmetry at Q^2 = 0.4

S. Rock *et. Al*
Phys.Rev.Lett.24:748-752,1970

No evidence was indicated for 2γ effects (<2%)

2-γ exchange in transverse target spin asymmetry measurements

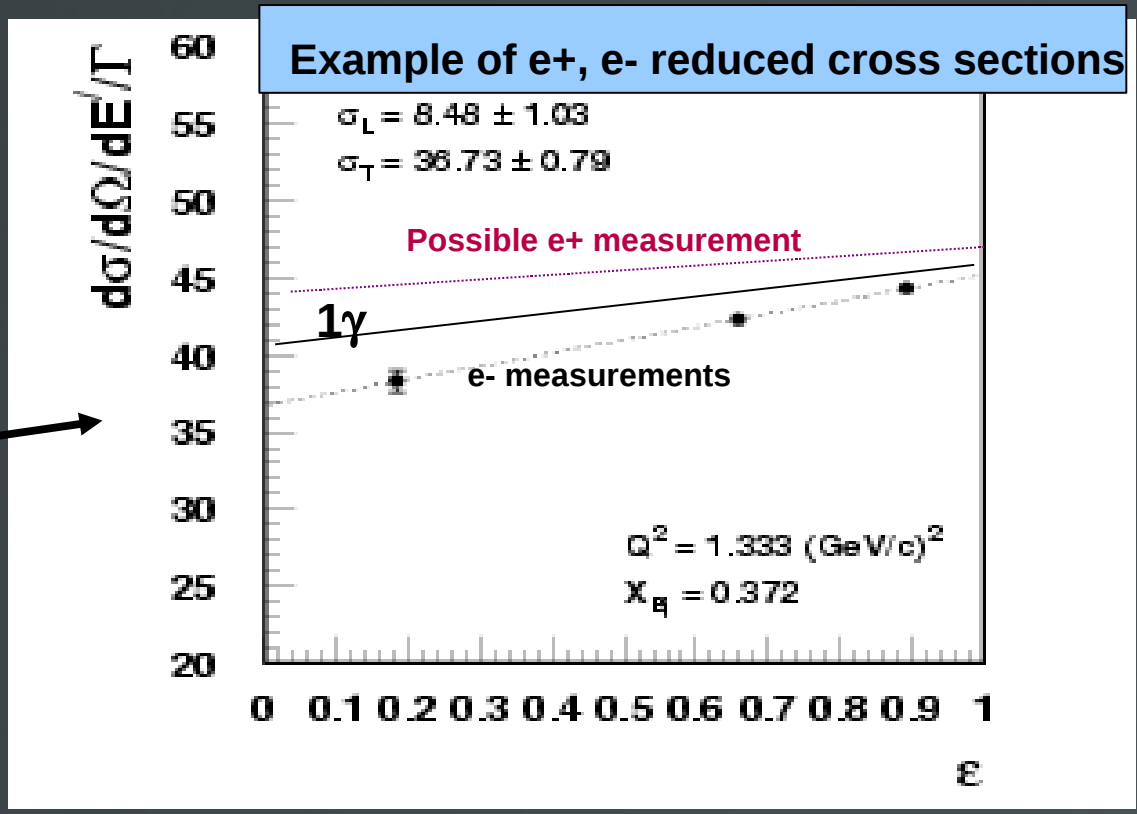
- 2-γ exchange give rise to asymmetry for transversely polarized target.
- Asymmetry arises from interference between 1-γ and 2-γ exchange.
- Changes sign for e+ versus e-.
- Recent calculation estimates ~10^{-4} (~10^{8} events with 100% polarization and no dilution.)

  A. Afanasev, M. Strikman, C. Weiss, Phys.Rev.D77:014028,2008

- This is an asymmetry so that most systematics drop out and statistics dominate.

Experimental requirements for testing 2-γ effects in unpolarized e+p scattering

- Would want to measure ratio of e+p / e-p inclusive scattering vs virtual photon polarization ε for range in *x* (W) and Q^2
- F_L is slope. F_L is sensitive to gluon distribution to be included in future global parton distribution fits.
- Requires the following



1) Varing beam energies to reach multiple ε at fixed Q^2 and x (W).
2) Good statistical precision (better than 1% on ratio).
3) Small systematic uncertainties

Complete systematic cancellation requires switching of beam polarity on relatively short time scales (minimum of several days?)

Kinematic dependence of rates

At fixed *x* and Q^2 the photon flux

~ E'/E*1/(1-ε)

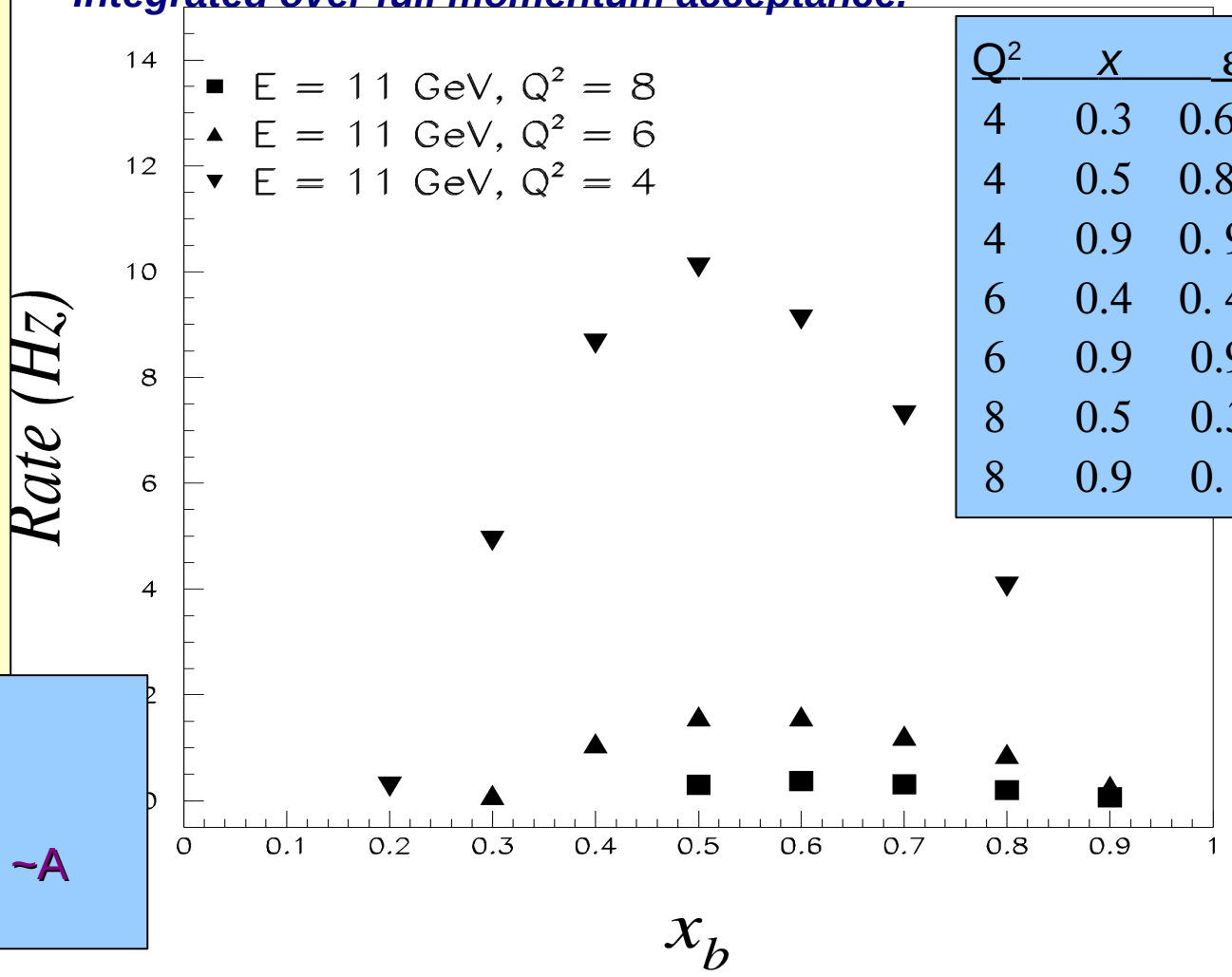
=> largest rate is when ε is largest.

Biggest ε is given by largest beam energy and smallest angle.

- Could possibly double target length for measuring ratios.
- Nuclear target rates scale by ~A

Assume 10cm LH_2 target, SHMS acceptance (4 mSr), and 100 nA.

Integrated over full momentum acceptance.



Q^2	x	ε
4	0.3	0.60
4	0.5	0.87
4	0.9	0. 95
6	0.4	0. 48
6	0.9	0.90
8	0.5	0.38
8	0.9	0. 81

➔ For $Q^2 > 4$ probably need *at least* 1uA of current.
➔ Rate limited ε lever arm at lower Q^2

More on rates in Hall C

	E	E'	θ	x	ε	Rate (Hz)	
$Q^2 = 4$							
	11	6.7	13	0.55	0.89	17	
	6.6	2.6	28	0.55	0.64	1.1	← Long runtime
	4.4	0.54 (Large y)	80	0.55	0.13	0.01	← Forget it
$Q^2 = 2$							
	11	8.6	8.3	0.45	0.96	200	
	4.4	2.0	27	0.45	0.67	5	
	3	0.6	61	0.45	0.27	0.25	← Long runtime

- Rates above Integrated over entire momentum acceptance
- Need *at least* 1 uA beam current for $\varepsilon < 0.5$

Can measure large kinematic range in CLAS at same time, but ε pt-pt systematics are typically too large for Rosenbluth separations. However, in e+/e- ratios versus ε most systematics drop out similar to Hall B elastic e-p E07-005 (L. Weinstein talk), except that e+/e- are not produced simultanously.

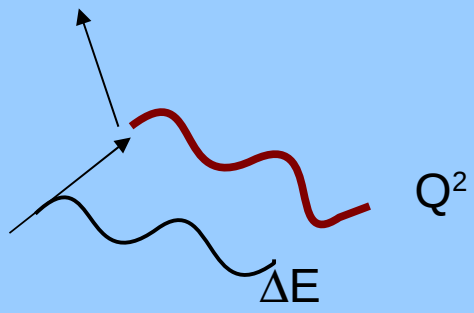
Uncertainties for e+/e- Structure Function Ratios

- In Hall C/A need at least 1 uA to measure SF ratios at $\varepsilon < 0.5$ for $Q^2 > 2$
- Could measure only positrons with a very short e- run to cross check absolute normalization with existing data.
- Time dependent systematics are typically small in Hall C and should mostly cancel out. (Luminosity monitor could further help)
- Systematics due to reproducebility of HMS spectrometer settings are typically 0.04% and 0.2 mrad for p and theta and well understood.
- Can measure in CLAS but would want to do both e+/e- during the same run period to adequately cancel time dependent systematics => reasonably good measurement of e+/e- versus ε possible, but not as good a handle on systematics compared to brems. produced e+/e-.

Radiative corrections at large *y*

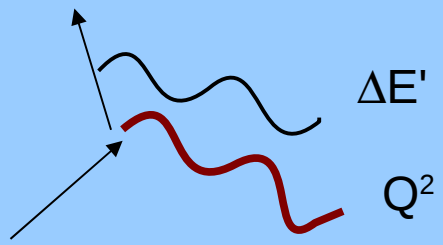
Radiative corrections at large *y*

Bremsstrahlung from beam electron



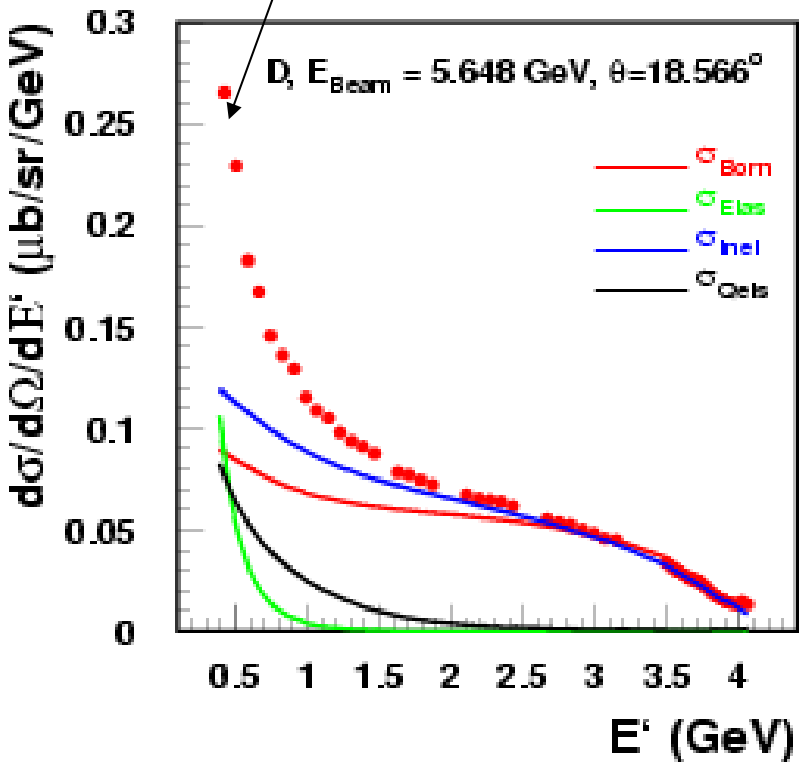
- E_{vertex} is *smaller* than E_{beam}
- Q^2_{vertex} is *smaller* than calculated
- W^2_{vertex} *typically smaller* than calculated.

Bremsstrahlung from scattered electron



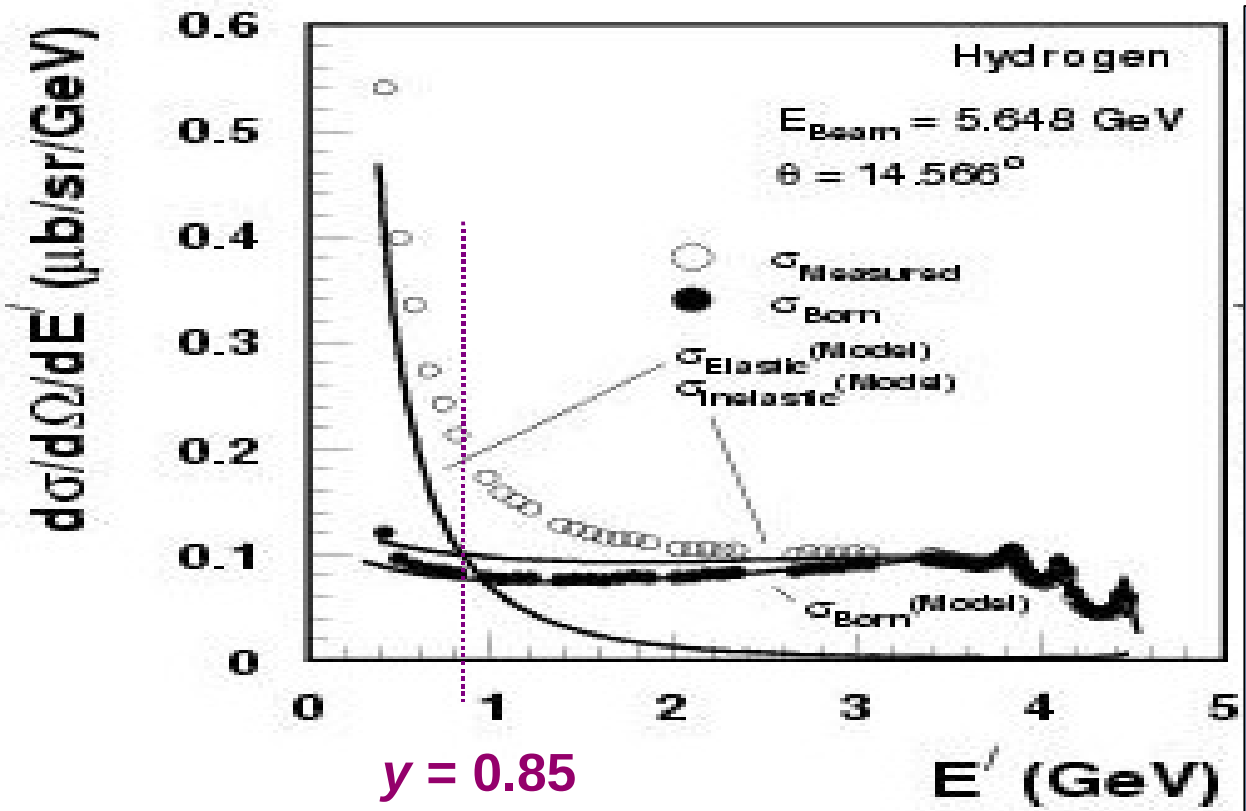
- E'_{vertex} is *larger* than E'_{HMS}
- Q^2_{vertex} is *larger* than calculated
- W^2_{vertex} is *smaller* than calculated.

Elastic events at lower Q^2 radiate to higher Q^2, W^2.



Radiative Corrections for inelastic processes

Examples from Jlab E99-118 – aka 'Measurement of elastic cross sections from DIS'
(from Dissertation of V. Tvaskis)



***y* = 0.85**

- Elastic tails become large as $y = \nu/E \rightarrow 1$
- Typically can't use data for ***y* > 0.85** due to large RCs
- Kinematically Limits range for L/T separations at small *x*.

This tail should be the **same for both** e+ and e- for single photon exhange at the elastic scattering vertex.

At large y this tail becomes a **measure** of the elastic cross section at very low Q^2!

=> Can measure ratio at much larger *y* than SF measurements

Summary of inclusive unpolarized rates

- Would want to measure e+/e- 2γ over significant range in Q^2, x to determine impact on unpolarized structure functions F_L (F_2).
- This will likely require at least 1μA positron currents for Hall C/A.
  - more is better, don't set sights too low
- Except at limited kinematics, only CLAS has large enough acceptance for required statistics at $Q^2 > 2$ for $\varepsilon < 0.5$....
  but ..

  1. can not use Rosenbluth separations to check time dependent systematics.
  2. can not cancel time dependent systematics as well as bremsstrahlung beam.

This would need to be looked at in detail by CLAs expert.