F_L and the statistics/rates needed to make the measurement

R. Debbe

The neutral current inclusive e-nucleon cross section can be written as a combination of two terms:

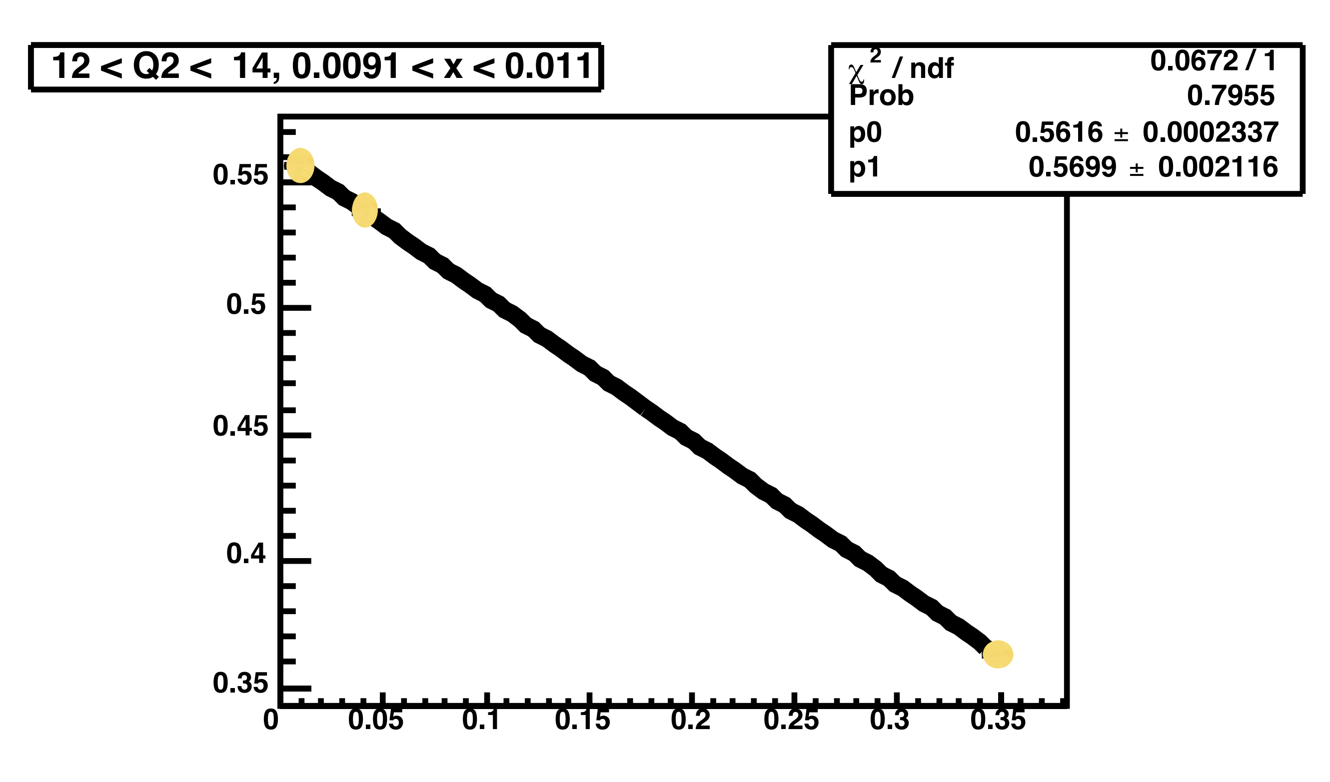
$$\sigma_r(x,Q^2,y) = \frac{d^2\sigma}{dxdQ^2} \cdot \frac{Q^4 x}{2\pi\alpha^2 Y_+} = F_2(x,Q^2) - \frac{y^2}{Y_+} \cdot F_L(x,Q^2) \; ,$$

"reduced cross section"

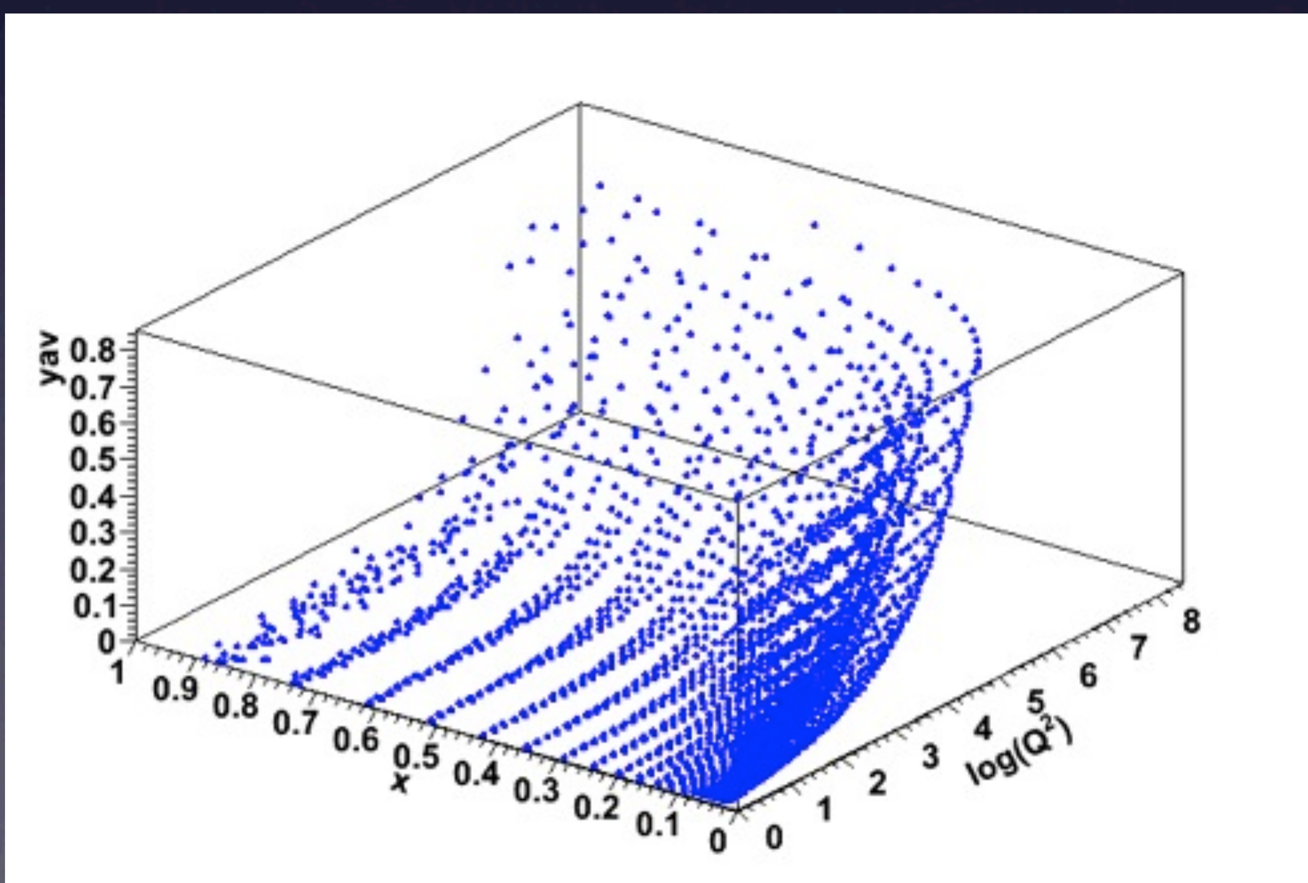
$F_2 \alpha (\sigma_T + \sigma_L)$ $F_L \sim \sigma_L$ where σ_T and σ_L are the γ^*P cross sections for transverse and longitudinally polarized virtual photons. The value of F_2 is determined by the sum of quark and anti-quark distributions, whereas F_L depends on quark + gluon distributions. Above some value of $Q^{2,}$ quark PDFs are much smaller than gluon PDFs hence F_L is mainly "driven" by gluon PDFs

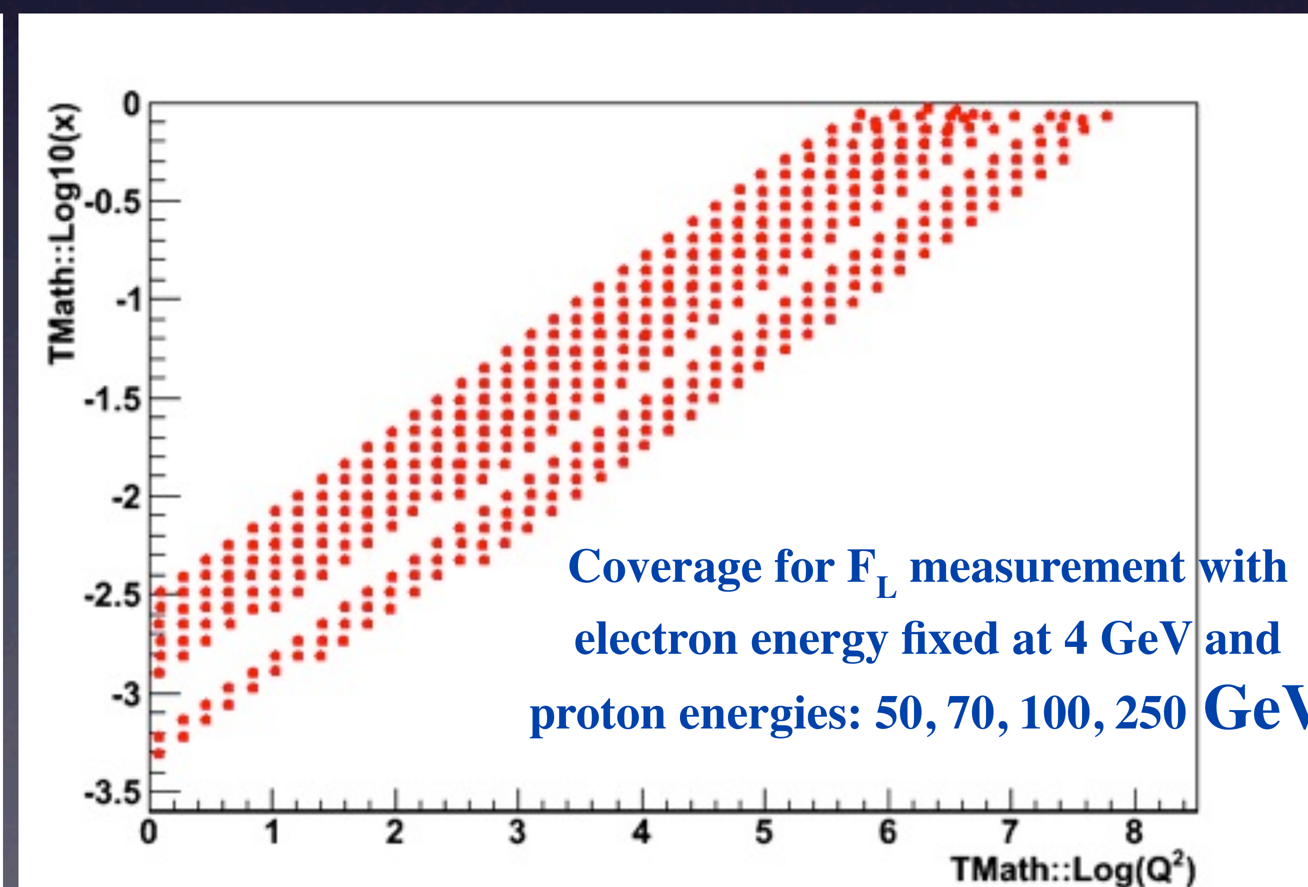
The measurement has experimental difficulties:
The highest sensitivity is obtained at high values of $y = Q^2/sx$, at low values of Q^2 high y corresponds to low energy of the scattered e that can be obscured by hadronic background.

F_L measurements are extracted from of inclusive measurements of e+p or e+A at a set of collision energies. A most convenient set would have a fixed electron energy and changing p or A energy.
At a fixed Q^2 and x, reduced cross sections are plotted as functions of y^2/Y^+ and fitted to straight lines; the intercept is then F^2 and the slope F_L



This extraction technique is very much dependent on the lever arm on the y^2/Y^+ variable (this set the first reduction in the reach in Q^2 and x space).
And very sensitive to statistical and systematic error. (Even with the best statistics it will be dominated by systematic errors)





F_L measurements with STAR TPC and electron beam fixed at 4 GeV

$\theta_{min}=40^{\circ}$

$\theta_{max}=140^{\circ}$

Description of Jamie's work on F_L

I use a package Jamie put together to investigate the extraction of F_L from inclusive measurements.
I calculates cross-section in bins of Q^2 and x for a set of e and p beam energies, using the MRST2002 parametrization.
Cross-sections are translated into counts for a set of given luminosities and each point is given error bars.
Additional errors (systematic) can then be added and the fits to straight lines in cross-section versus y^2/Y^+ is done.

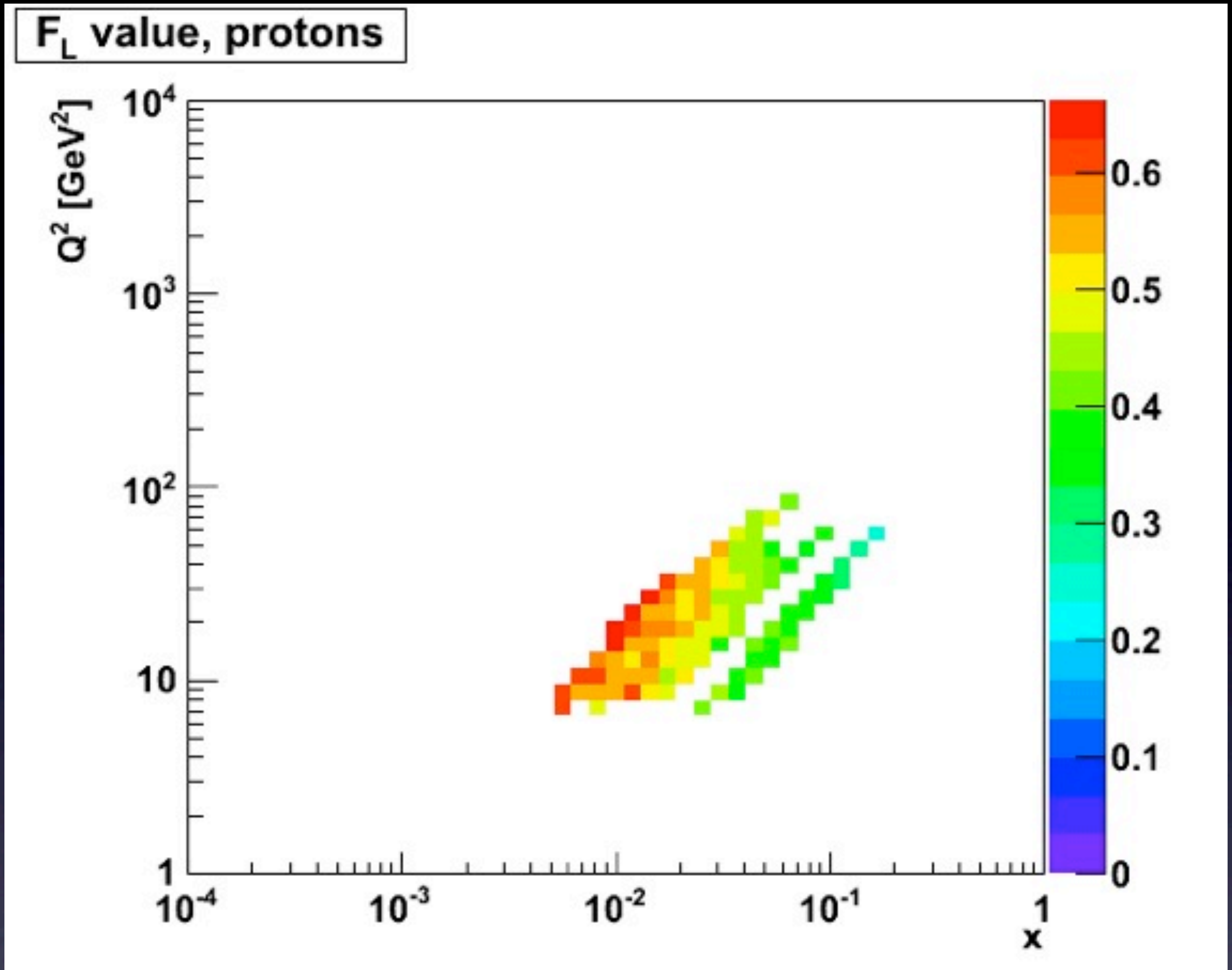
This first round of calculations have focused mainly in the reach in Q2 and x space. I have scaled the integrated luminosity used EIC work (...) by a factor of 10^{-2} to bring it down to roughly the average luminosity pp 500 GeV (I picked this number as a boundary of stability for the STAR TPC)

p↑- p↑ operation		(2009)	(2011/12)
Energy	GeV	100 / 250	100 / 250
No of bunches	…	109	109
Bunch intensity	10^{11}	1.3 / 1.1	1.3 / 1.5
Average L	**$10^{30} cm^{-2} s^{-1}$**	**28 / 55**	**30 / 150**
Polarization P	**%**	**56 / 34**	**70**

T. Roser RHIC retreat 2009

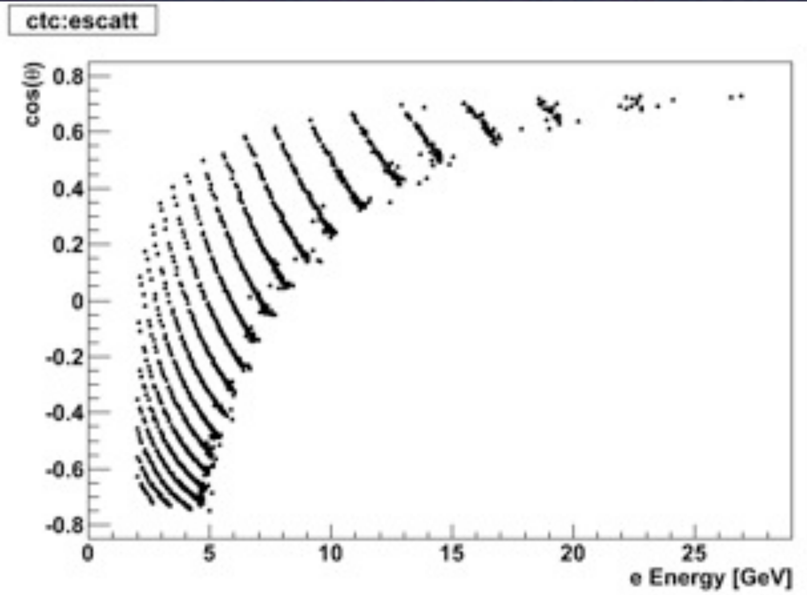
- eRHIC: 250 GeV p↑ × 10 – 20 GeV e↑ ; 3×10^{33} cm^{-2} s^{-1}

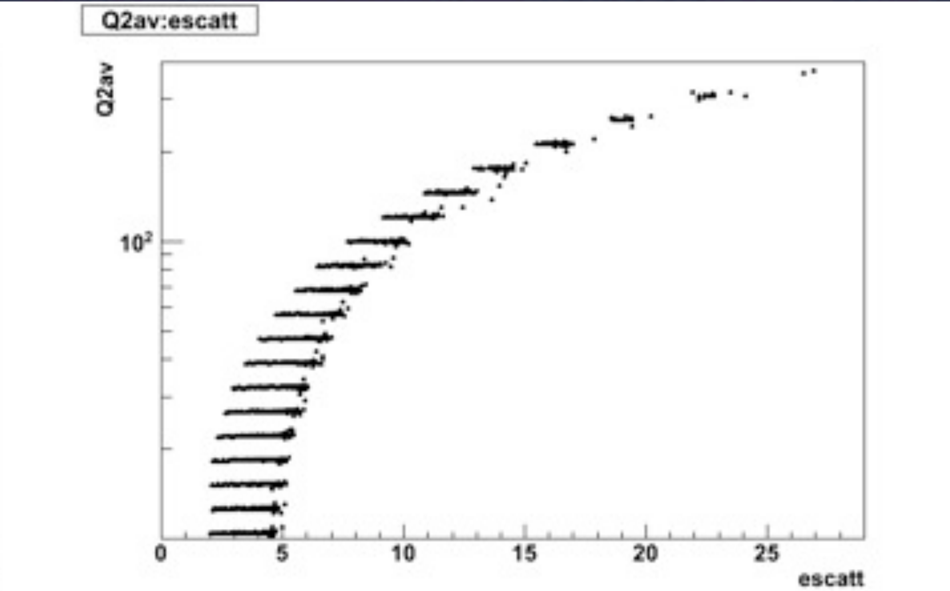
e: 4GeV p: 30 50 70 100 250 GeV



Events used in this plot have a lower limit on scattered electron energy at 2 GeV in order to be able to separate them from pions in the calorimeter.

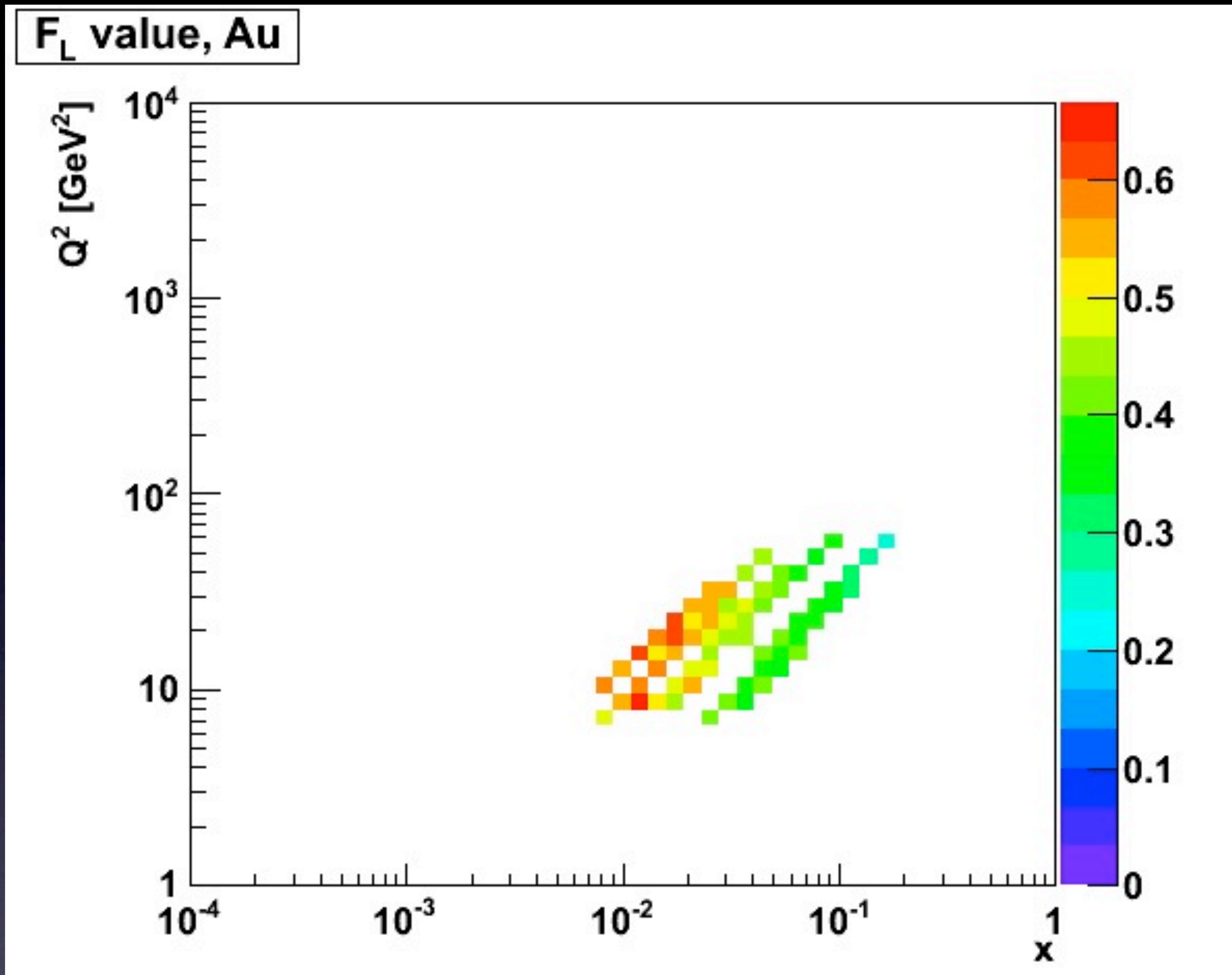
This plot only displays F_L values with an overall uncertainty smaller than 10%





Thursday, March 11, 2010

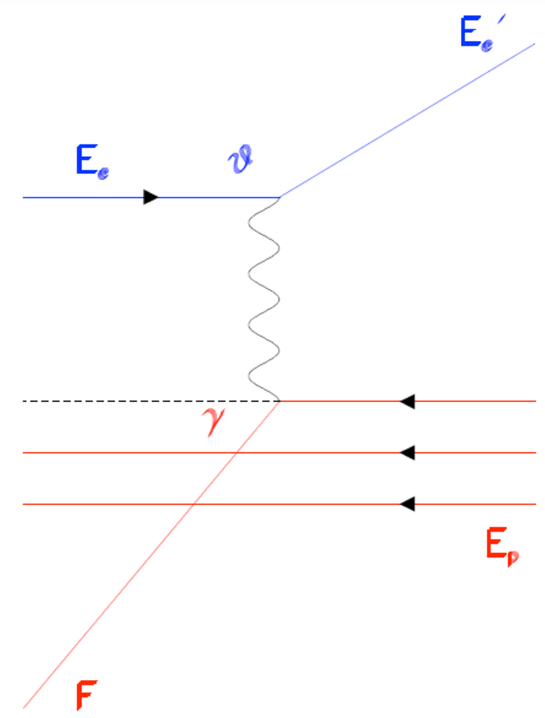
e: 4GeV p: 30 50 70 100



DIS Kinematics

Collider kinematics (1)

- Electron method: scattered electron



$$F = \frac{p_{T,h}^2 + (E-p_z)_h^2}{2\,(E-p_z)_h}$$

$$\cot\gamma = \frac{p_{T,h}^2 - (E-p_z)_h^2}{p_{T,h}^2 + (E-p_z)_h^2}$$

$$x_e = \frac{Q_e^2}{s y_e} = \frac{E_e' \cos^2\left(\frac{\theta_e'}{2}\right)}{E_p\left(1 - \frac{E_e'}{E_e}\sin^2\left(\frac{\theta_e'}{2}\right)\right)}$$

$$y_e = 1 - \frac{E_e'}{2E_e}\left(1 - \cos\theta_e'\right) = 1 - \frac{E_e'}{E_e}\sin^2\left(\frac{\theta_e'}{2}\right)$$

$$Q_e^2 = 2E_eE_e'\left(1 + \cos\theta_e'\right) = 4E_eE_e'\cos^2\left(\frac{\theta_e'}{2}\right) = \frac{p_{T,e}^2}{1-y_e}$$

- Jacquet-Blondel method: hadronic final state

$$x_{JB} = \frac{Q_{JB}^2}{s y_{JB}}$$

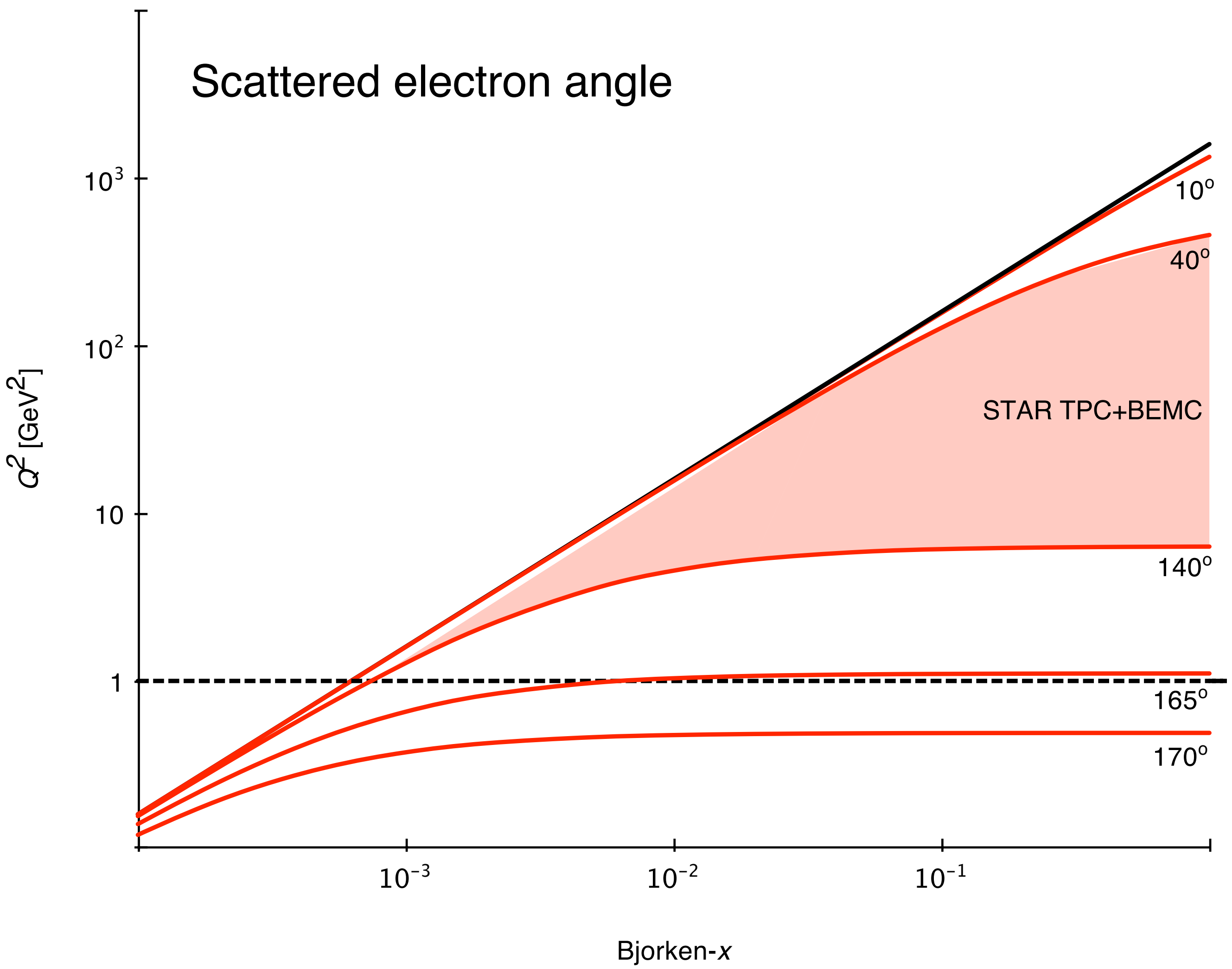
$$p_{T,h}^2 = \left(\sum_h p_{x,h}\right)^2 + \left(\sum_h p_{y,h}\right)^2$$

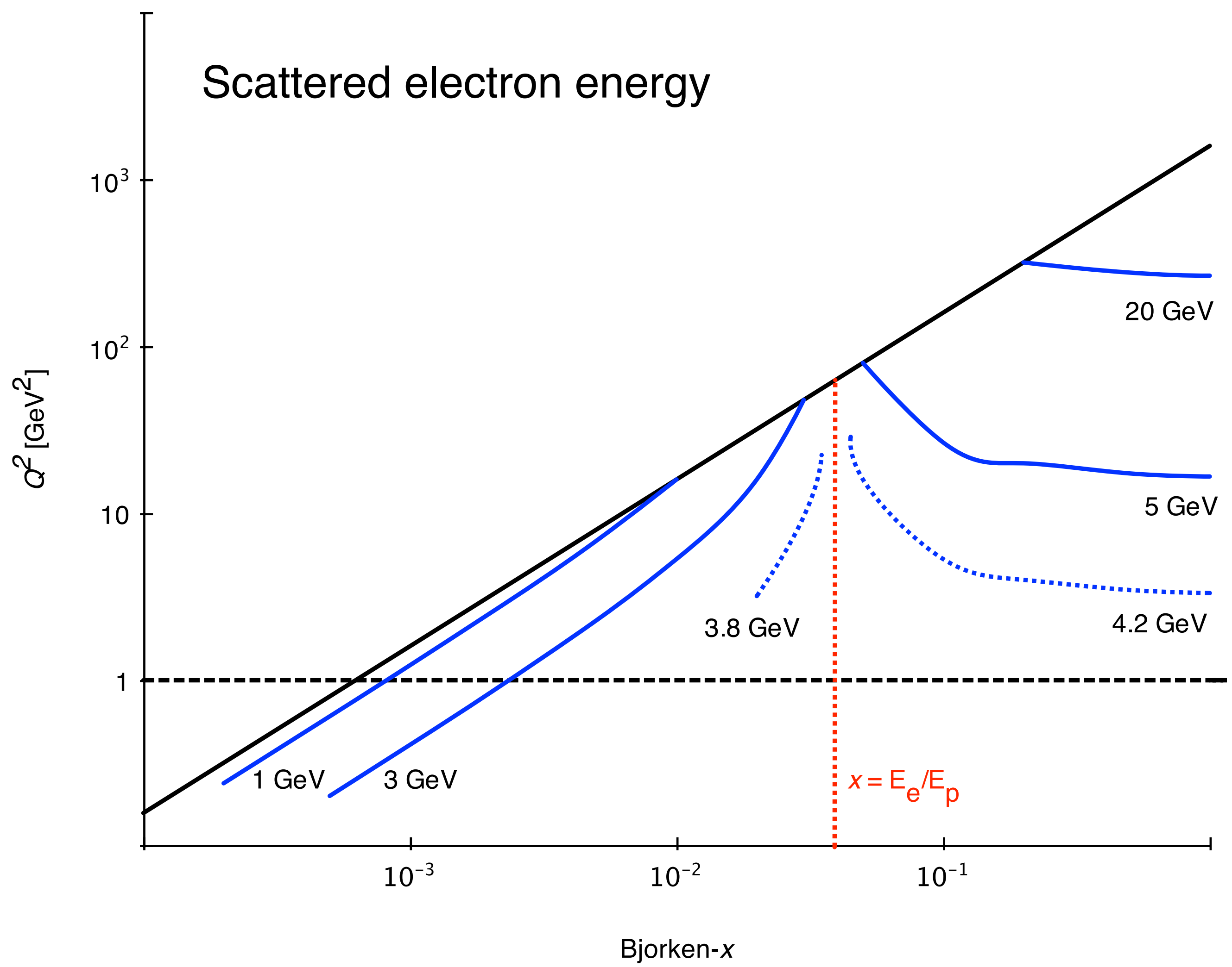
$$y_{JB} = \frac{(E-p_z)_h}{2E_e}$$

$$(E-p_z)_h = \sum_h \left(E_h - p_{z,h}\right)$$

$$Q_{JB}^2 = \frac{p_{T,h}^2}{1-y_{JB}}$$

Electron issues: low-x trigger,
electron energy resolution at intermediate to high x, and low-Q^2,
possibly high-x and high-Q^2 acceptance.





DIS Kinematics

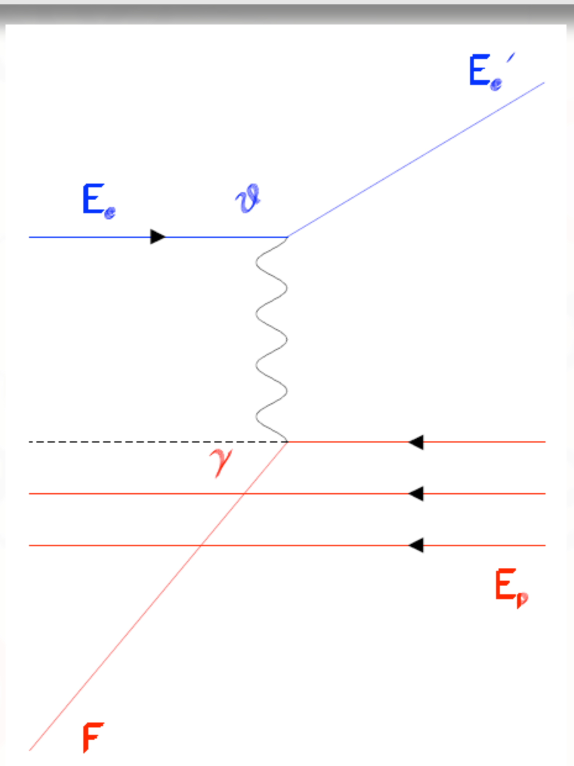
Collider kinematics (4)

- Electron method: scattered electron

$$\left(\frac{\delta x_e}{x_e}\right) = \left(\frac{1}{y_e}\right)\frac{\delta E'_e}{E'_e} \otimes \left[\frac{x_e}{E_e/E_p} - 1\right] \tan\left(\frac{\theta'_e}{2}\right)\delta\theta'_e$$

$$\left(\frac{\delta y_e}{y_e}\right) = \left(1 - \frac{1}{y_e}\right)\frac{\delta E'_e}{E'_e} \otimes \left[\frac{1}{y_e} - 1\right] \cot\left(\frac{\theta'_e}{2}\right)\delta\theta'_e$$

$$\left(\frac{\delta Q^2_e}{Q^2_e}\right) = \frac{\delta E'_e}{E'_e} \otimes \tan\left(\frac{\theta'_e}{2}\right)\delta\theta'_e$$



$$F = \frac{p^2_{T,h} + (E - p_z)^2_h}{2\,(E - p_z)_h}$$

$$\cot\gamma = \frac{p^2_{T,h} - (E - p_z)^2_h}{p^2_{T,h} + (E - p_z)^2_h}$$

- Jacquet-Blondel method: hadronic final state

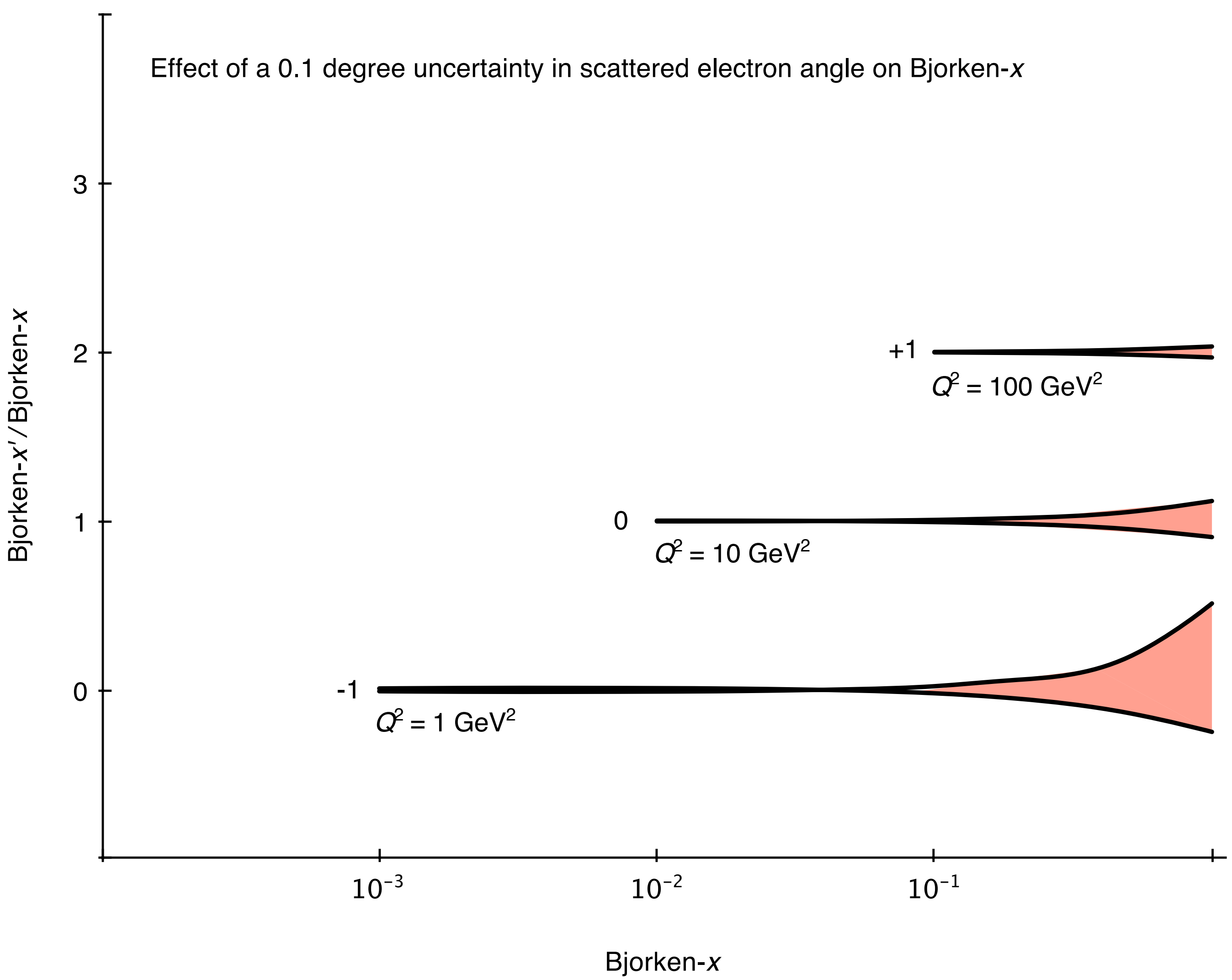
$$\left(\frac{\delta x_{JB}}{x_{JB}}\right) = \left(\frac{1}{1 - y_{JB}}\right)\frac{\delta F}{F} \otimes \left[2\cot\gamma + \left(\frac{2y_{JB} - 1}{1 - y_{JB}}\right)\cot\left(\frac{\gamma}{2}\right)\right]\delta\gamma$$

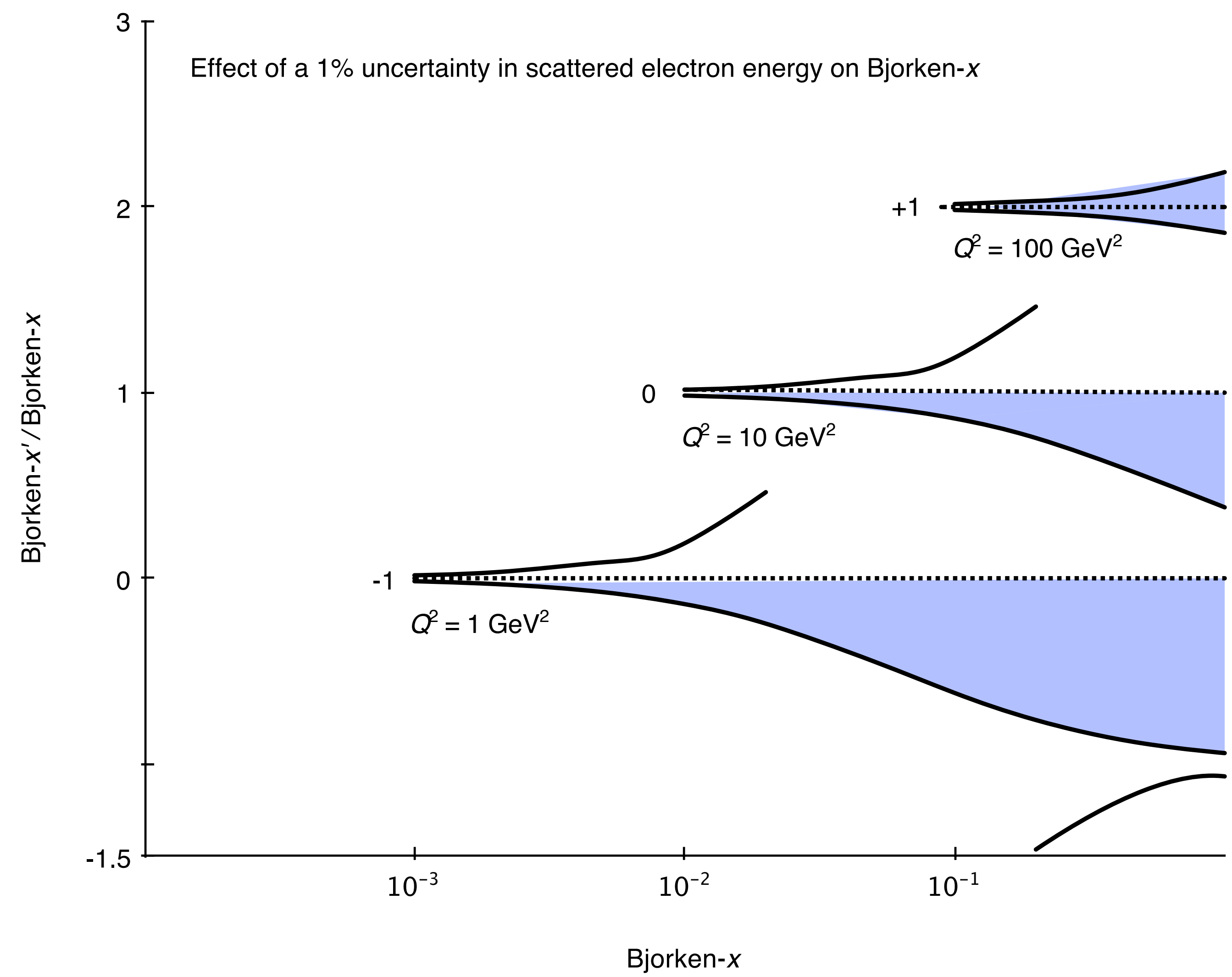
$$\left(\frac{\delta y_{JB}}{y_{JB}}\right) = \frac{\delta F}{F} \otimes \cot\left(\frac{\gamma}{2}\right)\delta\gamma$$

$$\left(\frac{\delta Q^2_{JB}}{Q^2_{JB}}\right) = \left(\frac{2 - y_{JB}}{1 - y_{JB}}\right)\frac{\delta F}{F} \otimes \left[2\cot\gamma + \left(\frac{y_{JB}}{1 - y_{JB}}\right)\cot\left(\frac{\gamma}{2}\right)\right]\delta\gamma$$

Electron issues: low-x trigger,
electron energy resolution at intermediate to high x, and low-Q^2,
possibly high-x and high-Q^2 acceptance.

Resolution:

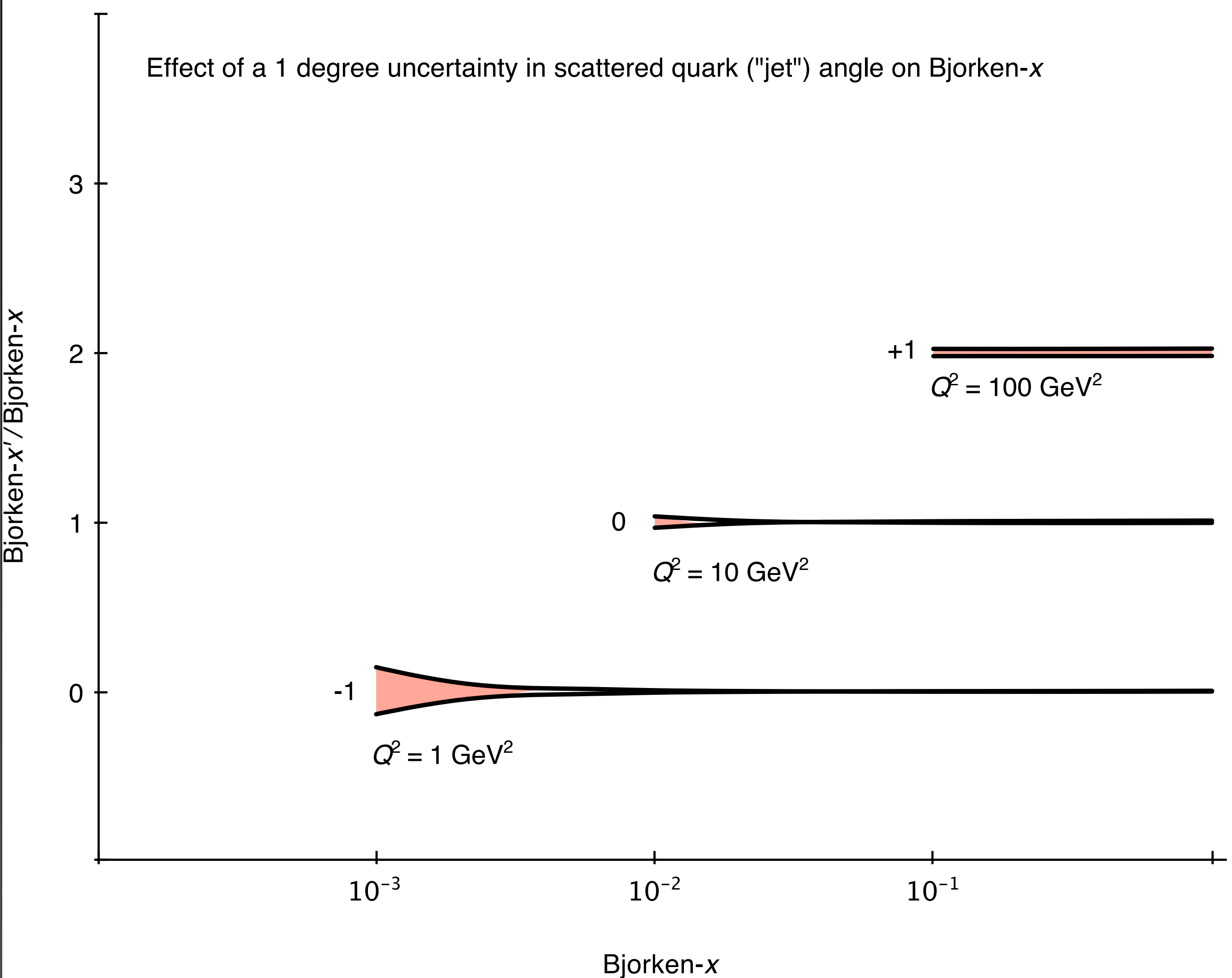


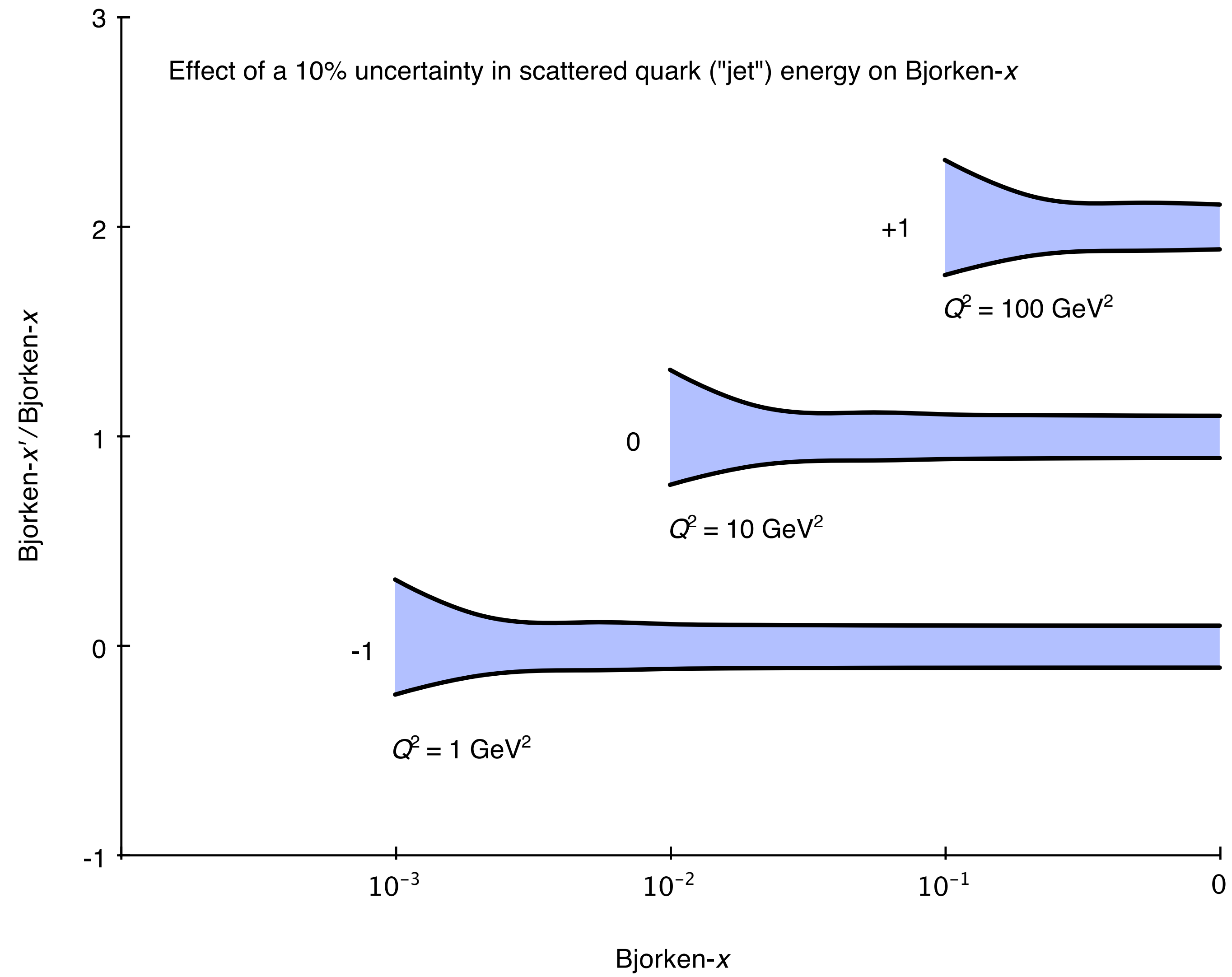


Ernst Sichtermann - LBNL

The role of jets is principally at high-*x*, and intermediate to high Q^2

The effects of resolution on Bjorken-*x*:

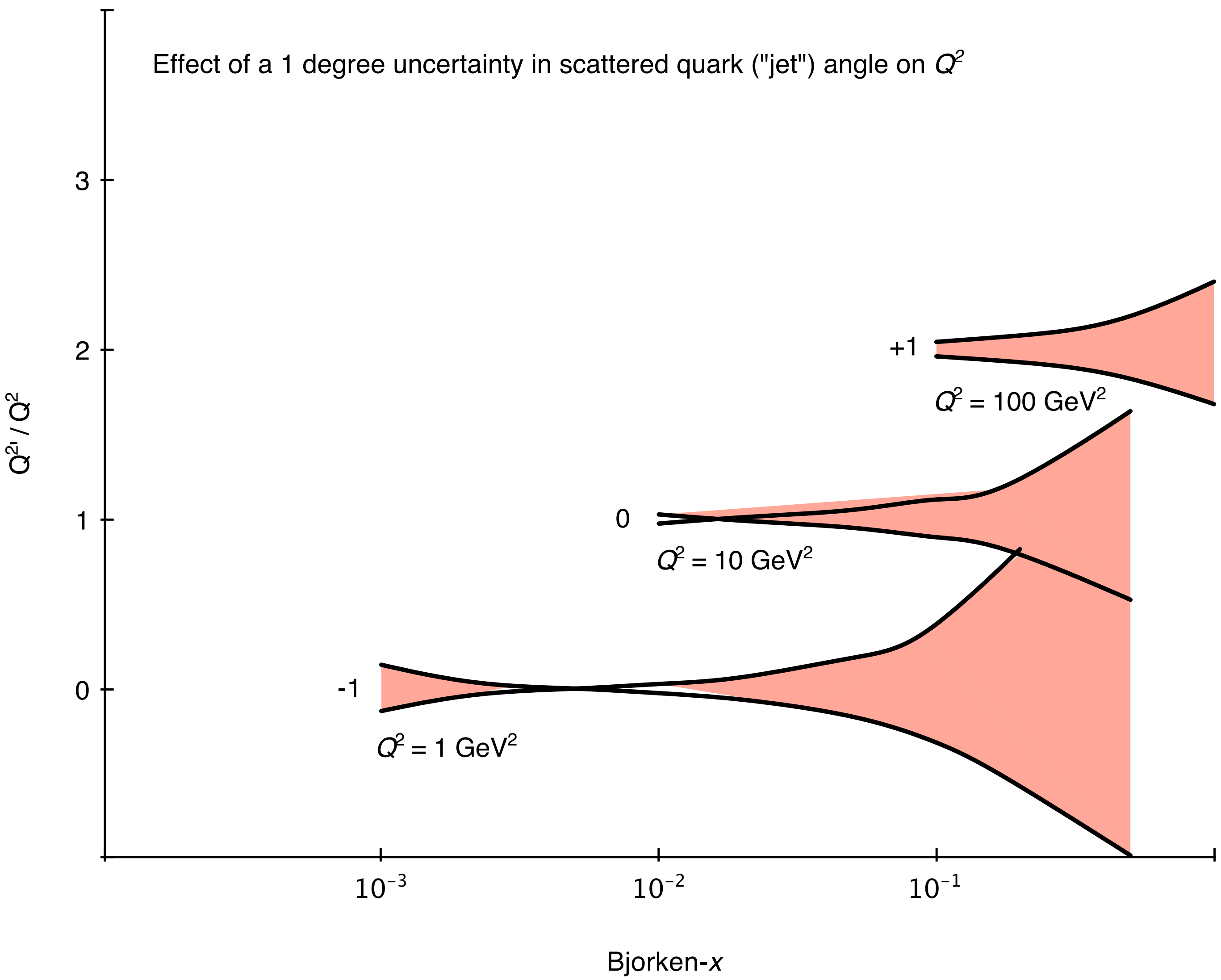


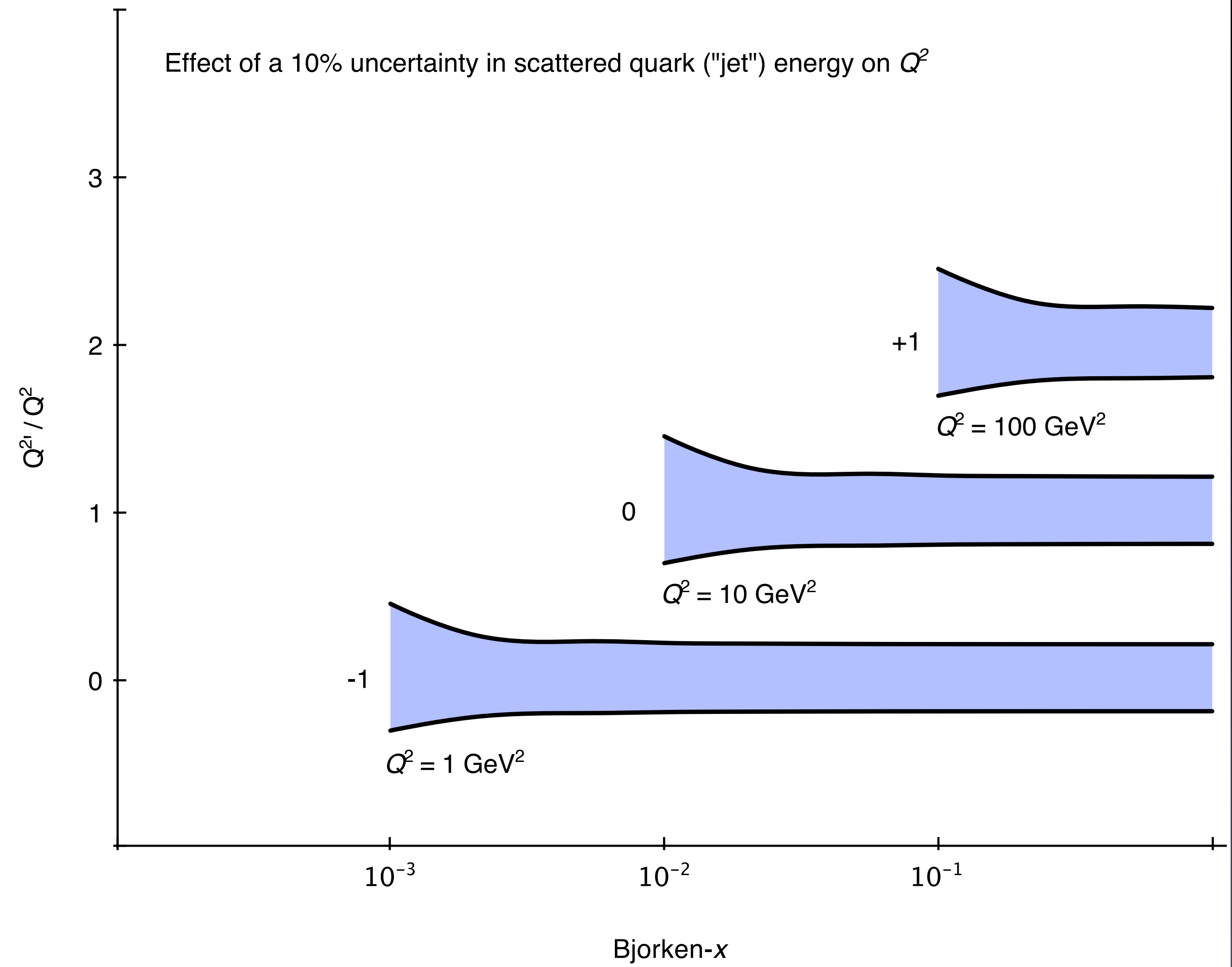


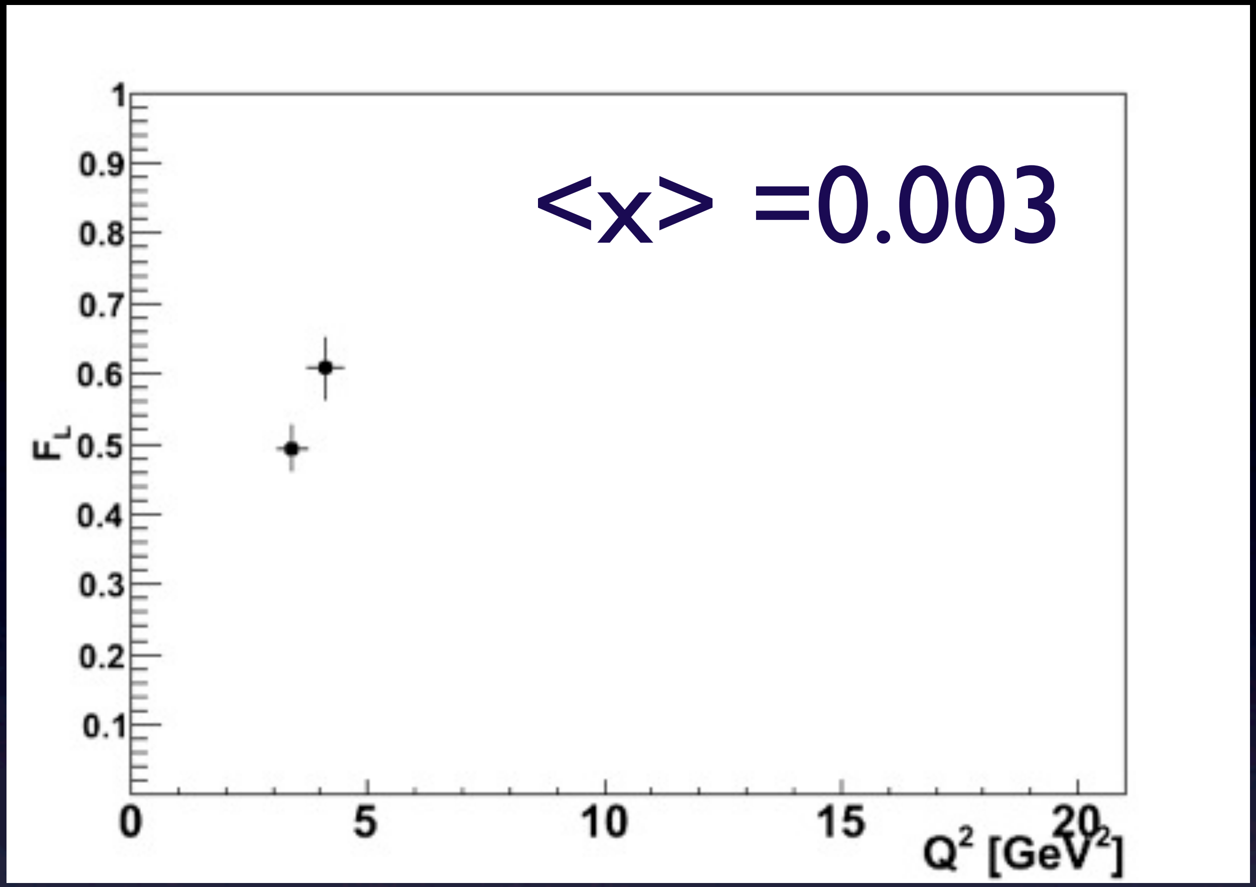
Ernst Sichtermann - LBNL

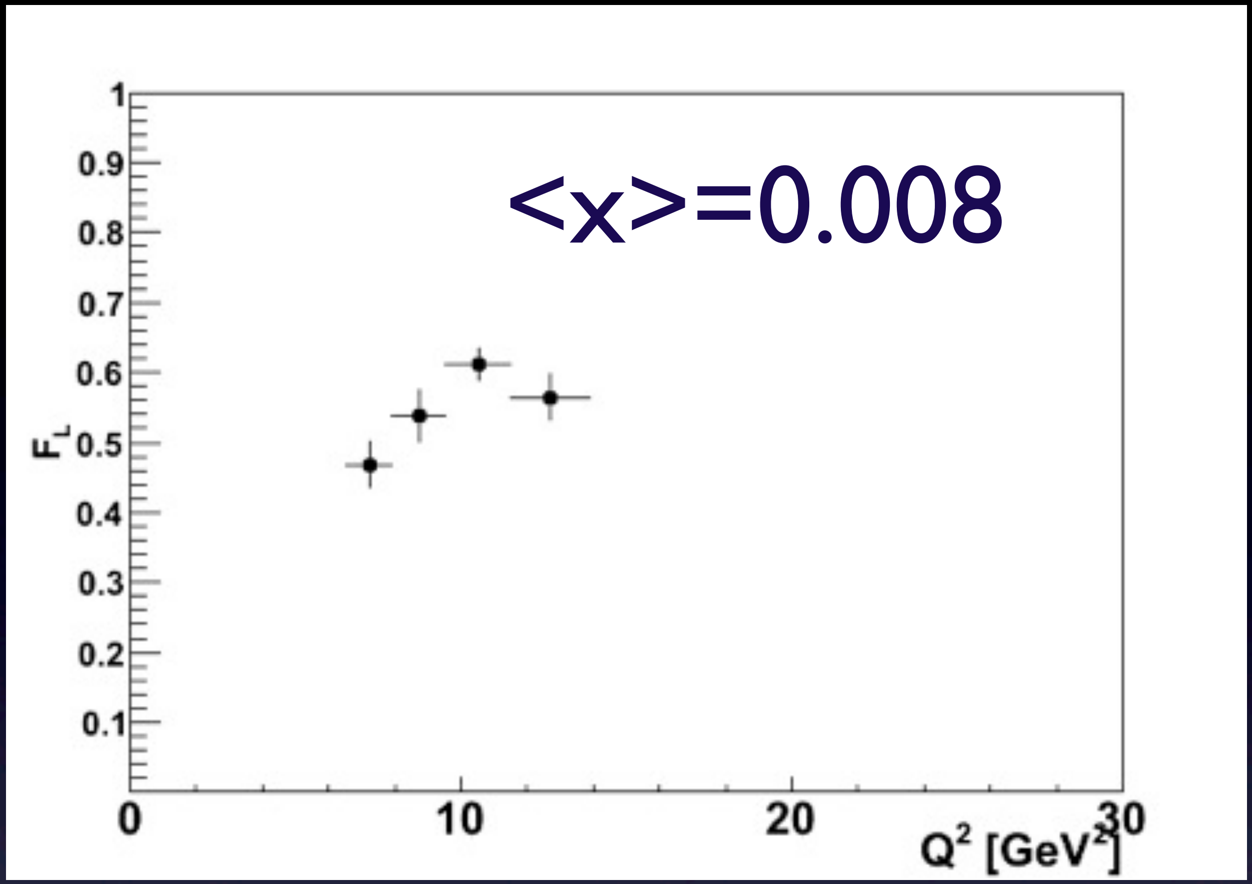
The role of jets is principally at high-x, and intermediate to high Q^2

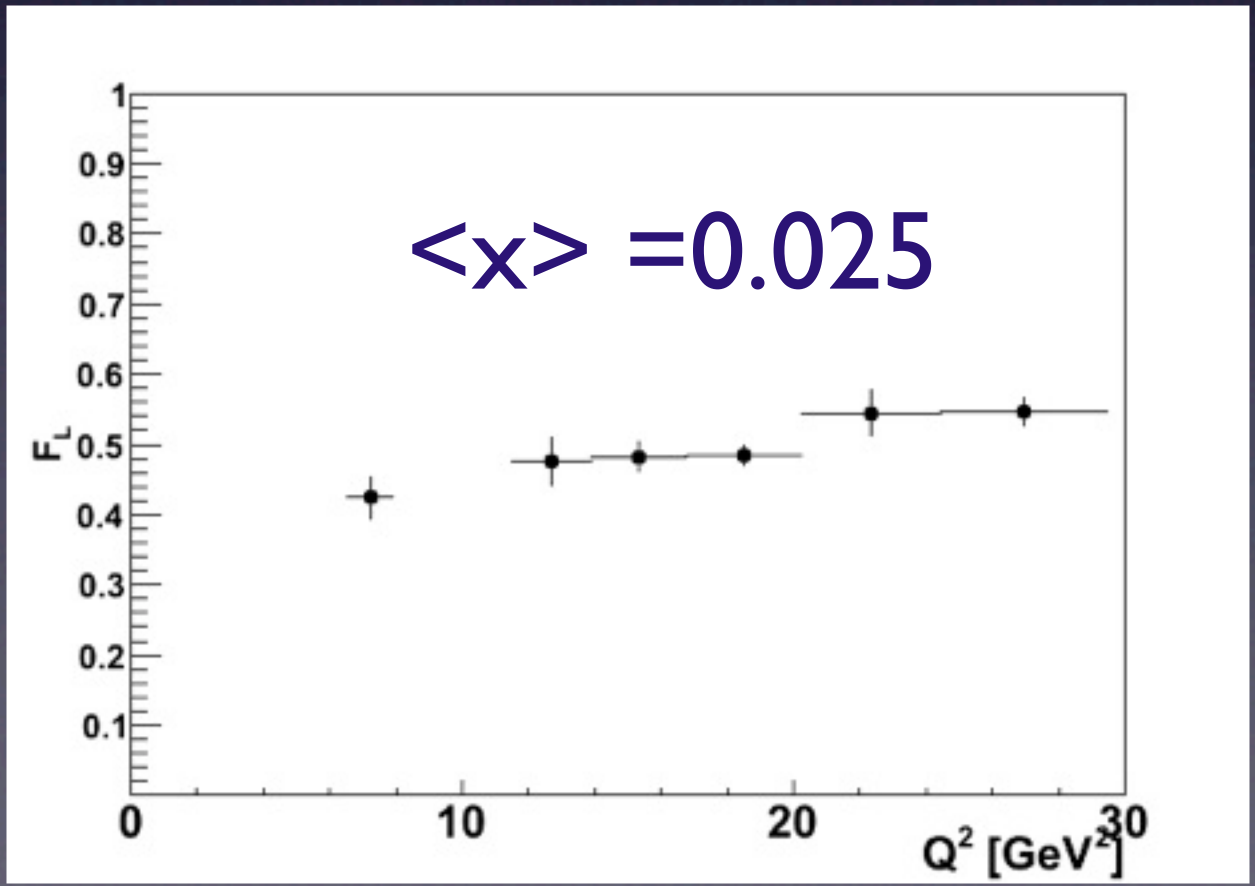
The effects of resolution on Q^2:

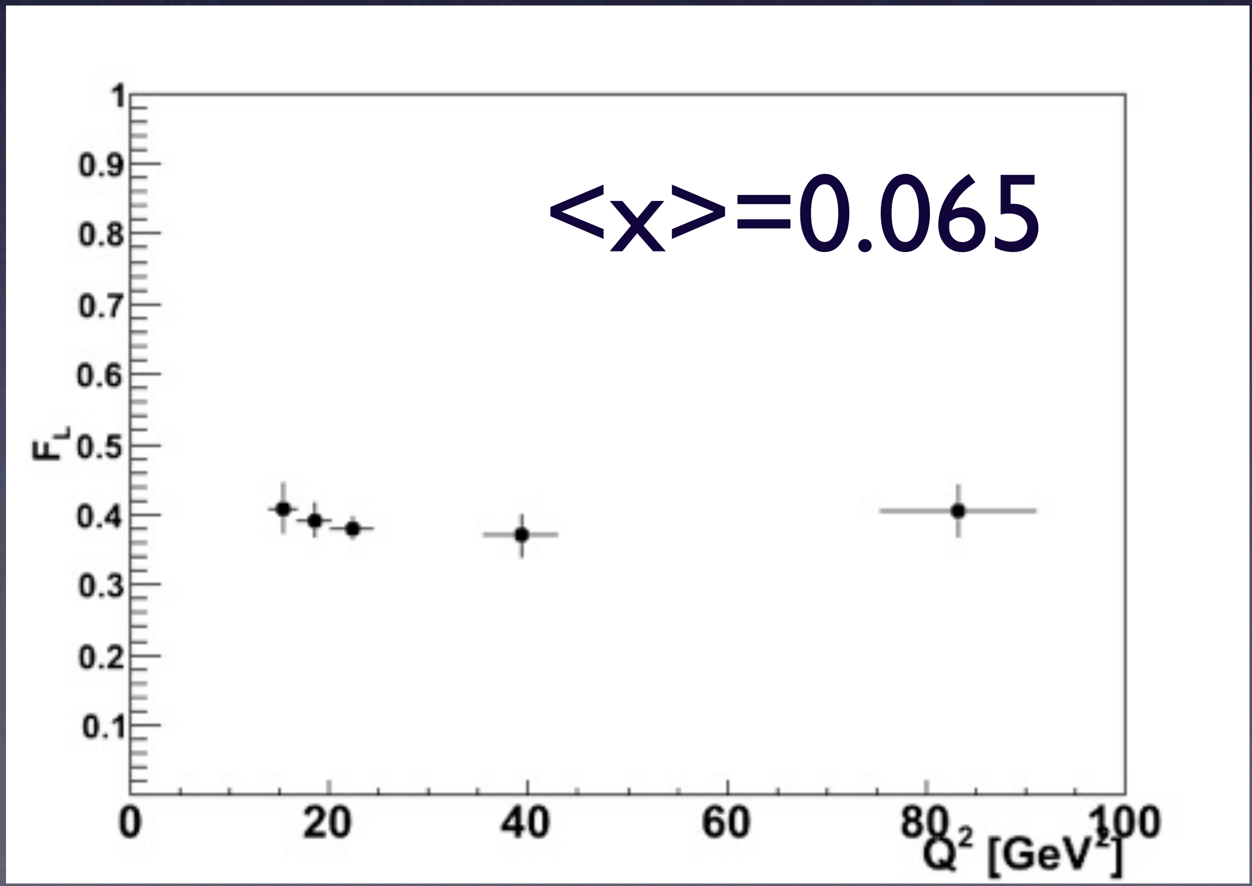




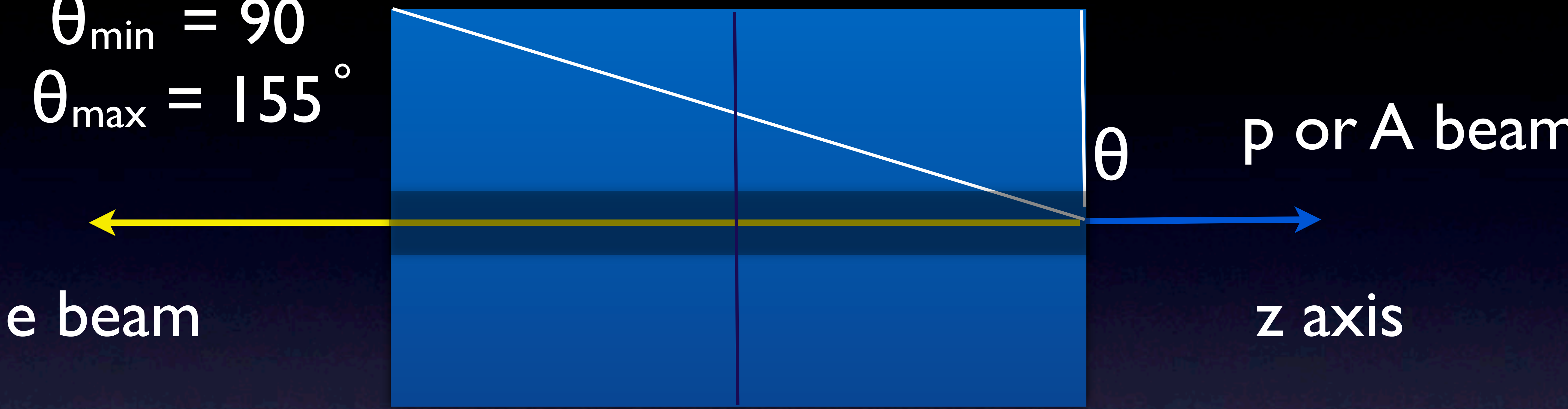

<x> =0.003
F_L
Q^2 [GeV^2]

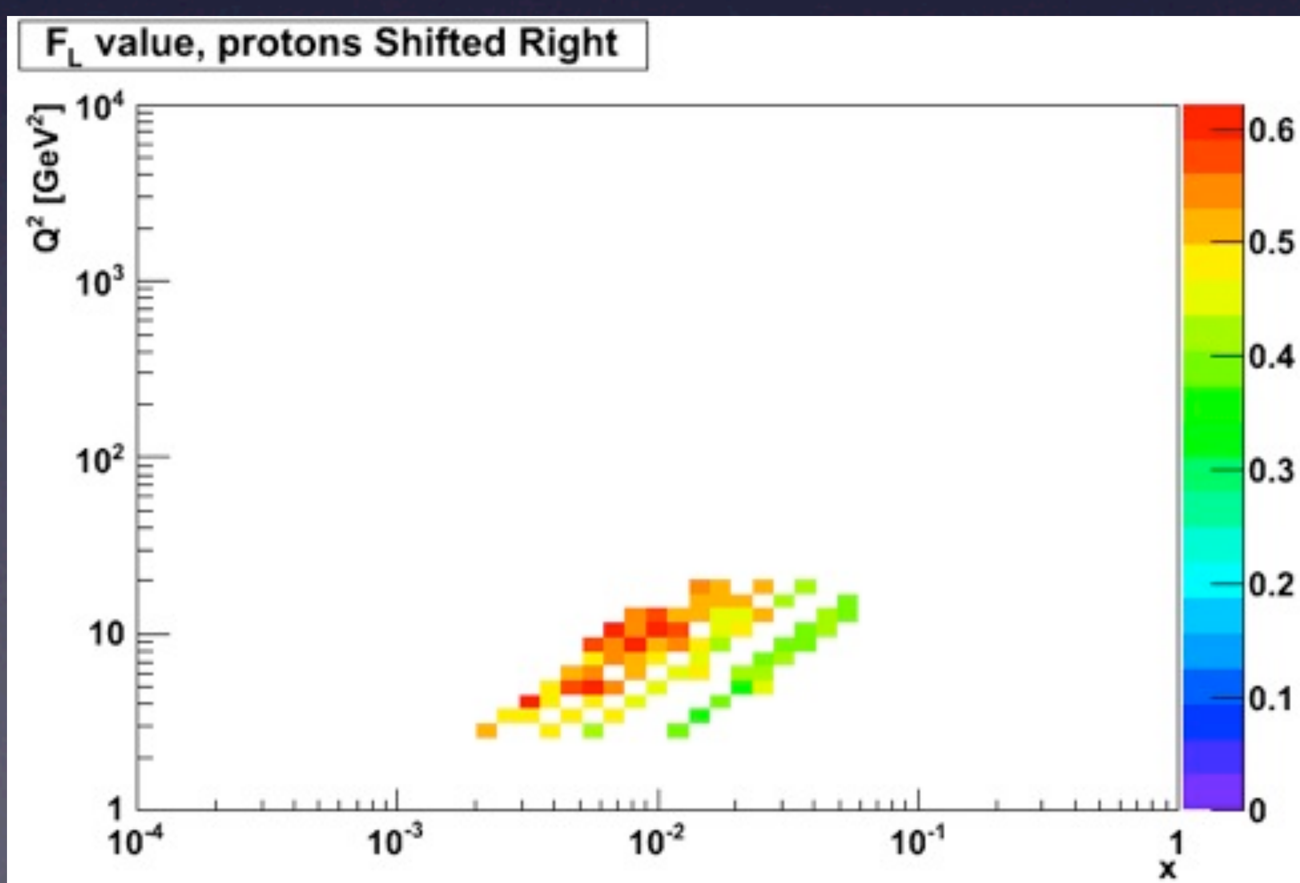

<x>=0.008
F_L
Q^2 [GeV^2]


<x> =0.025
F_L
Q^2 [GeV^2]

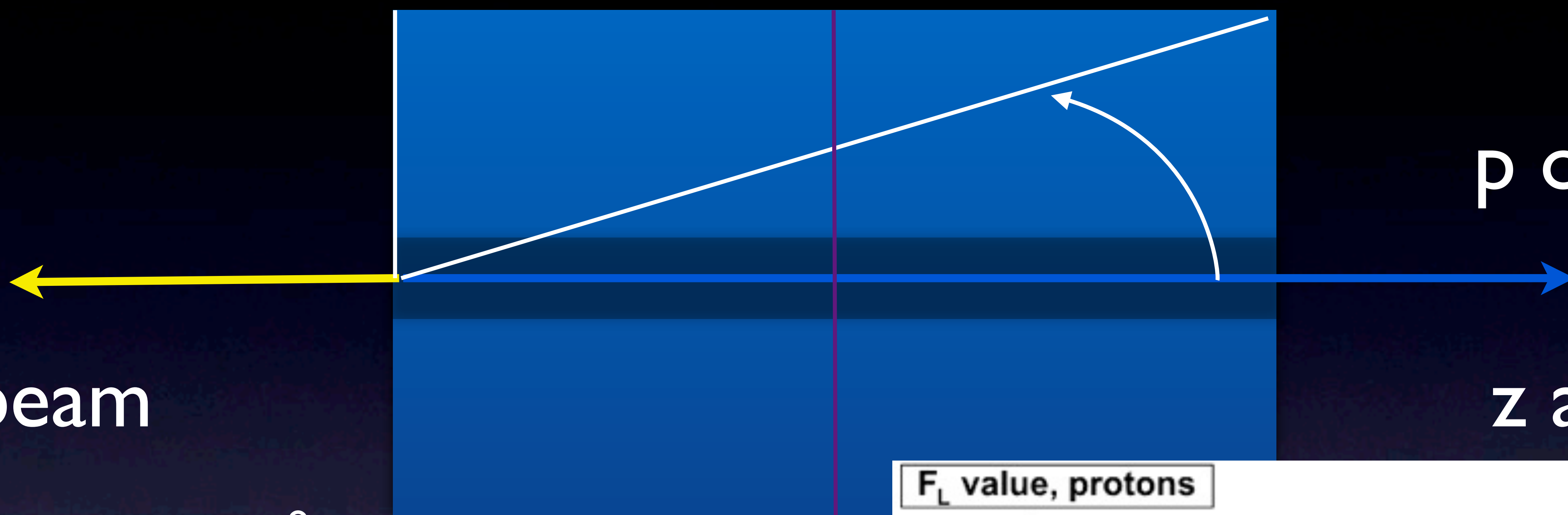

<x>=0.065
F_L
Q^2 [GeV^2]

$\theta_{min} = 90^{\circ}$
$\theta_{max} = 155^{\circ}$





Displaced interactions give us access to lower values of Q2.
Tracking reconstruction becomes convoluted, but in principle still possible.



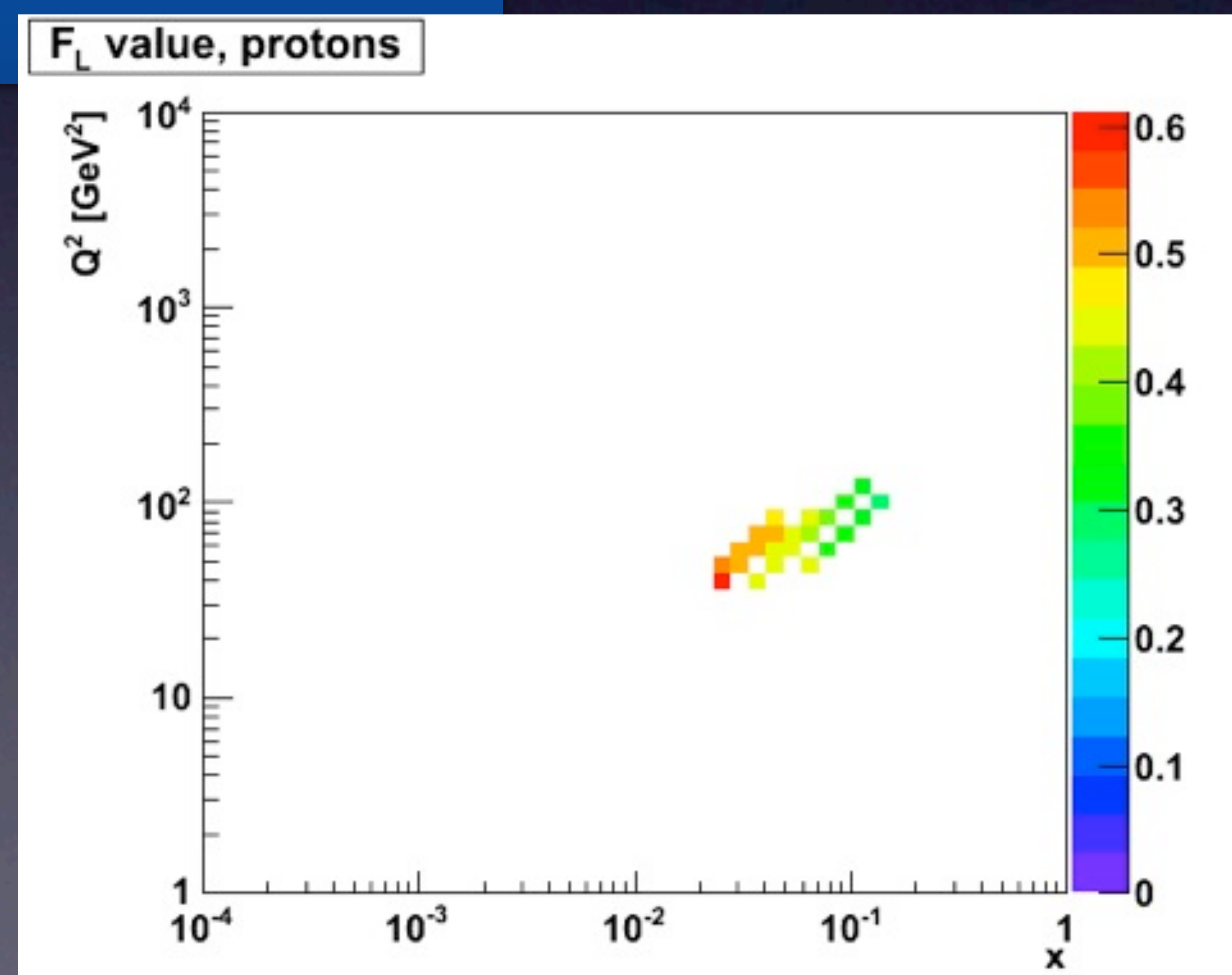
p or A beam

e beam

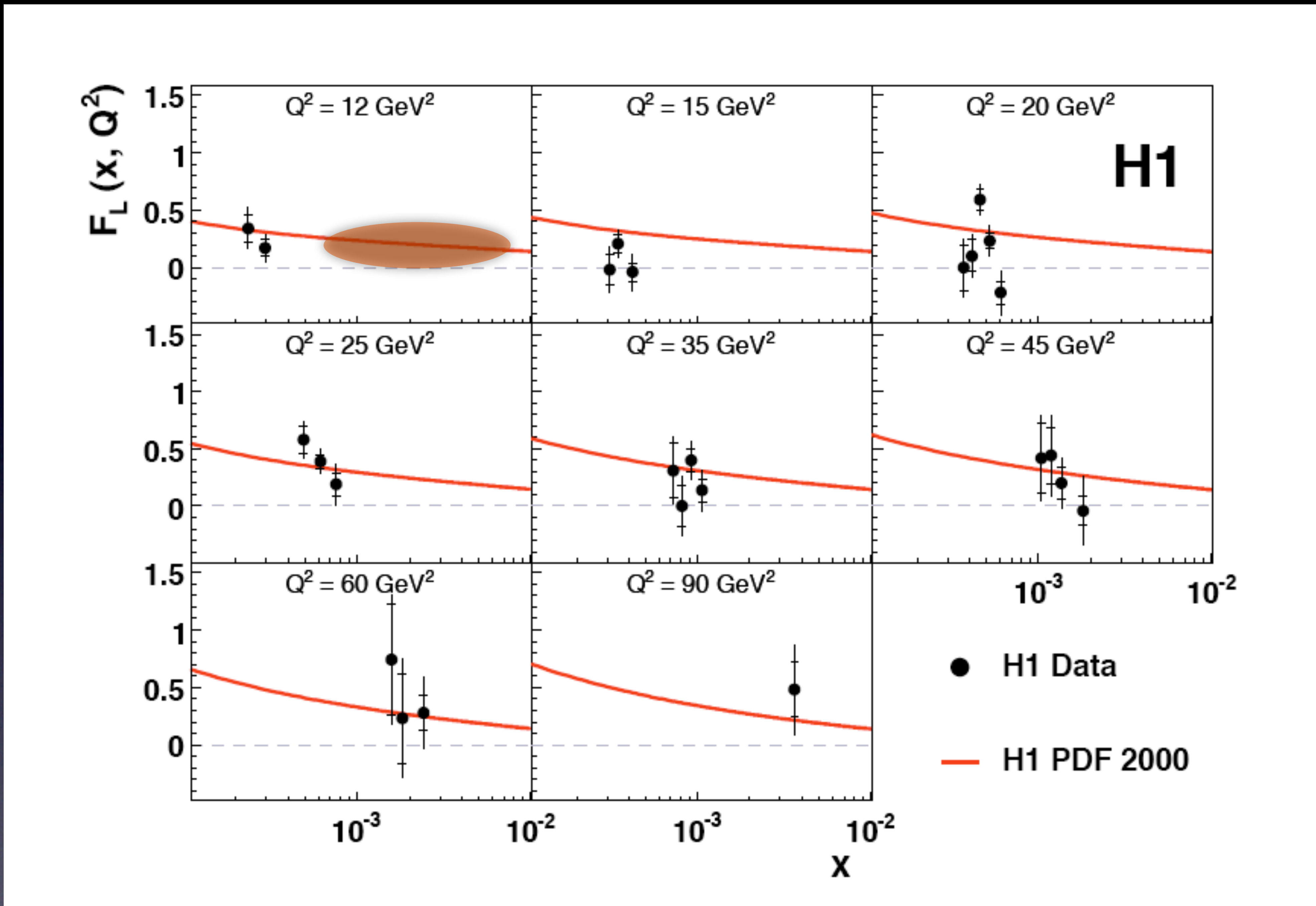
z axis

$\theta_{min} = 25^{\circ}$

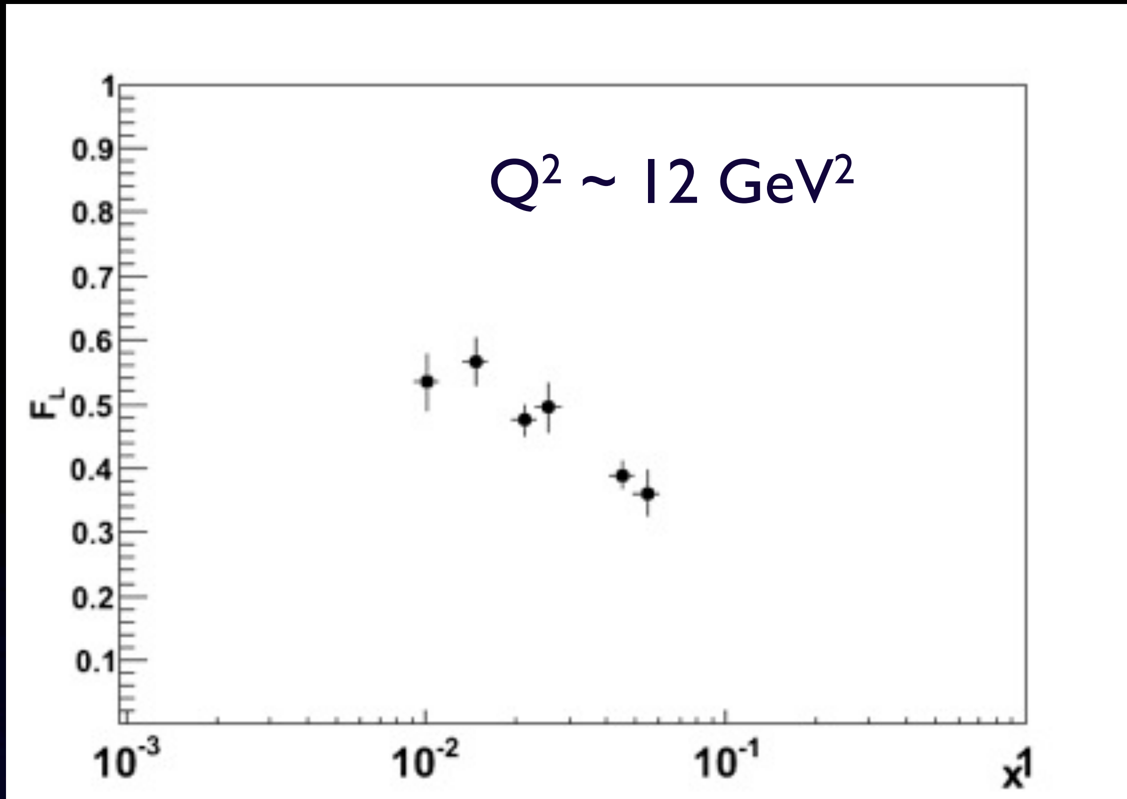
$\theta_{max} = 90^{\circ}$



FL measurement at HERA



STAR could reach values of Q^2 as low as 3 GeV^2 and provide coverage for: $10^{-3}<x<10^{-2}$ It can add coverage between 10^{-2} and 10^{-1} in x for Q^2 smaller than 60 GeV^2


Q^2 ~ 12 GeV^2
F_L
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10^{-3}
10^{-2}
10^{-1}
x
1