Forward Physics and Detectors

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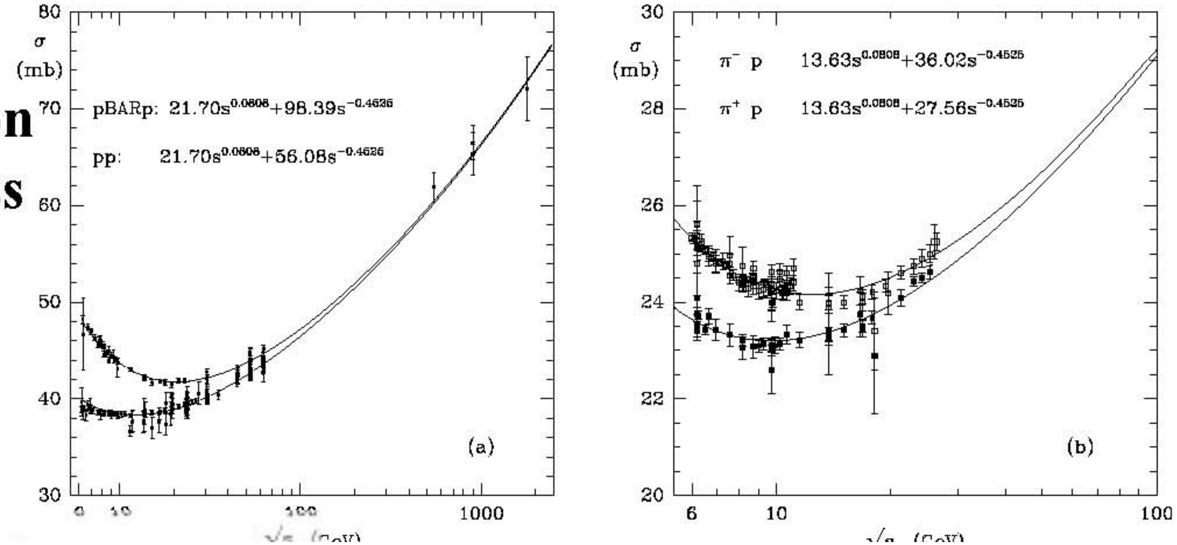
Physics motivation (examples):

1. The total photoproduction cross section
2. The transition from photoproduction to DIS
3. Longitudinal structure function F_L
4. High-x structure functions
5. Photoproduction of VM (J/psi)

Detector study, examples of performance

Hadron-Hadron Cross Section

Hadron-hadron scattering cross section versus CM energy

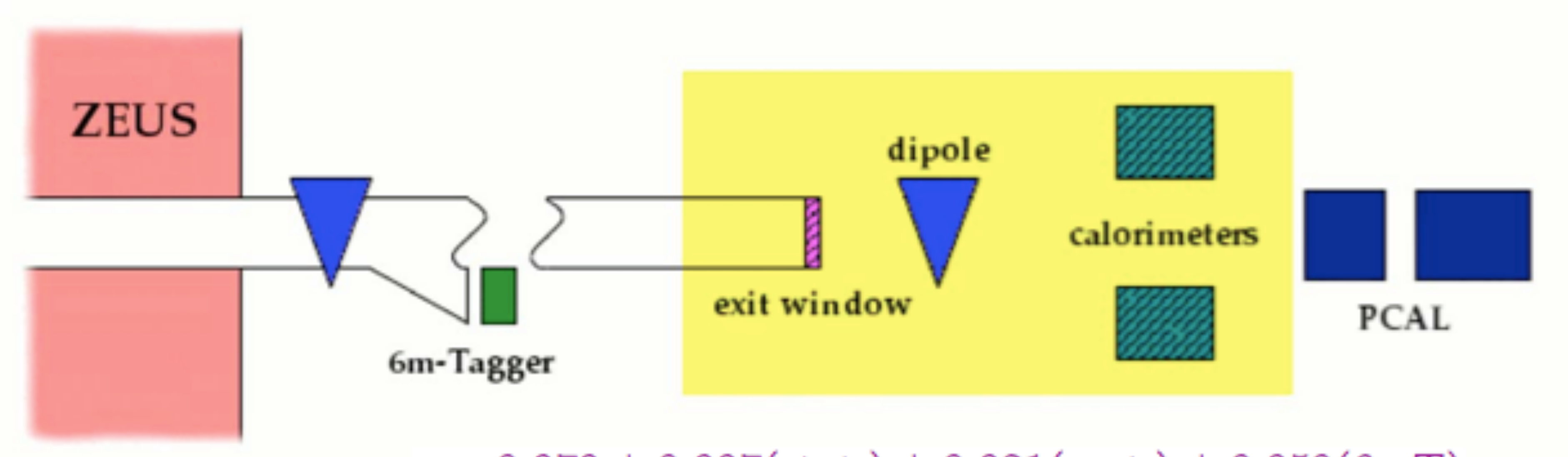


$\sigma \propto s^{0.08}$

- Total cross section not understood from QCD – phenomenological models based on Regge Theory
- EIC/ENC could provide high precision photoproduction measurements in new kinematic region
- Of great interest for interpretation of cosmic ray data
- eA behavior would be very interesting

HERA: total photoproduction cross section

$$s_{\gamma P} = W^2 \approx \frac{Q^2}{x} \qquad \sigma \propto (W^2)^{\varepsilon}$$



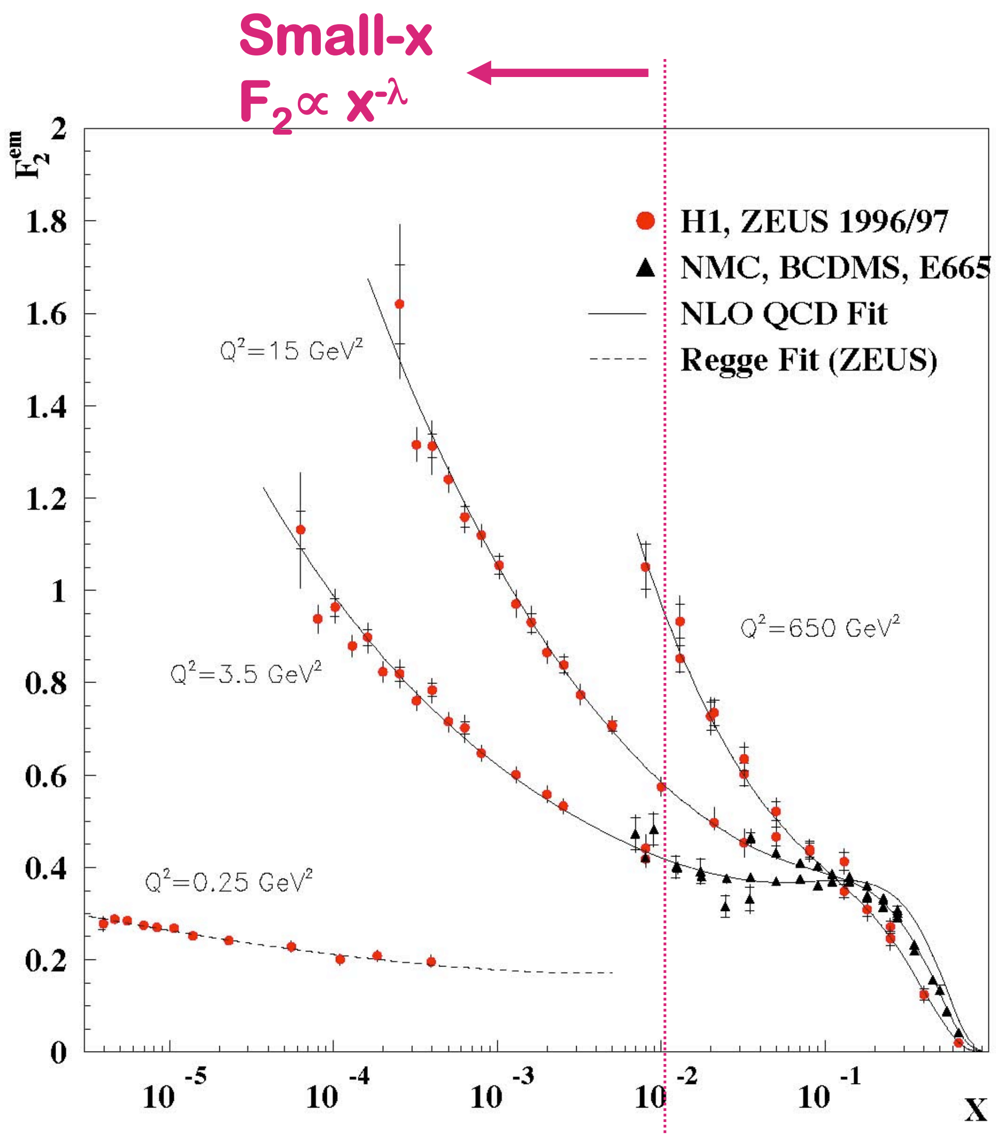
$$\varepsilon = 0.070 \pm 0.007(\mathrm{stat.}) \pm 0.021(\mathrm{syst.}) \pm 0.050(\mathrm{6mT})$$

ZEUS prel.

EIC-ENC: would need to measure the scattered electron. Minimum cuts on the hadronic state produced.

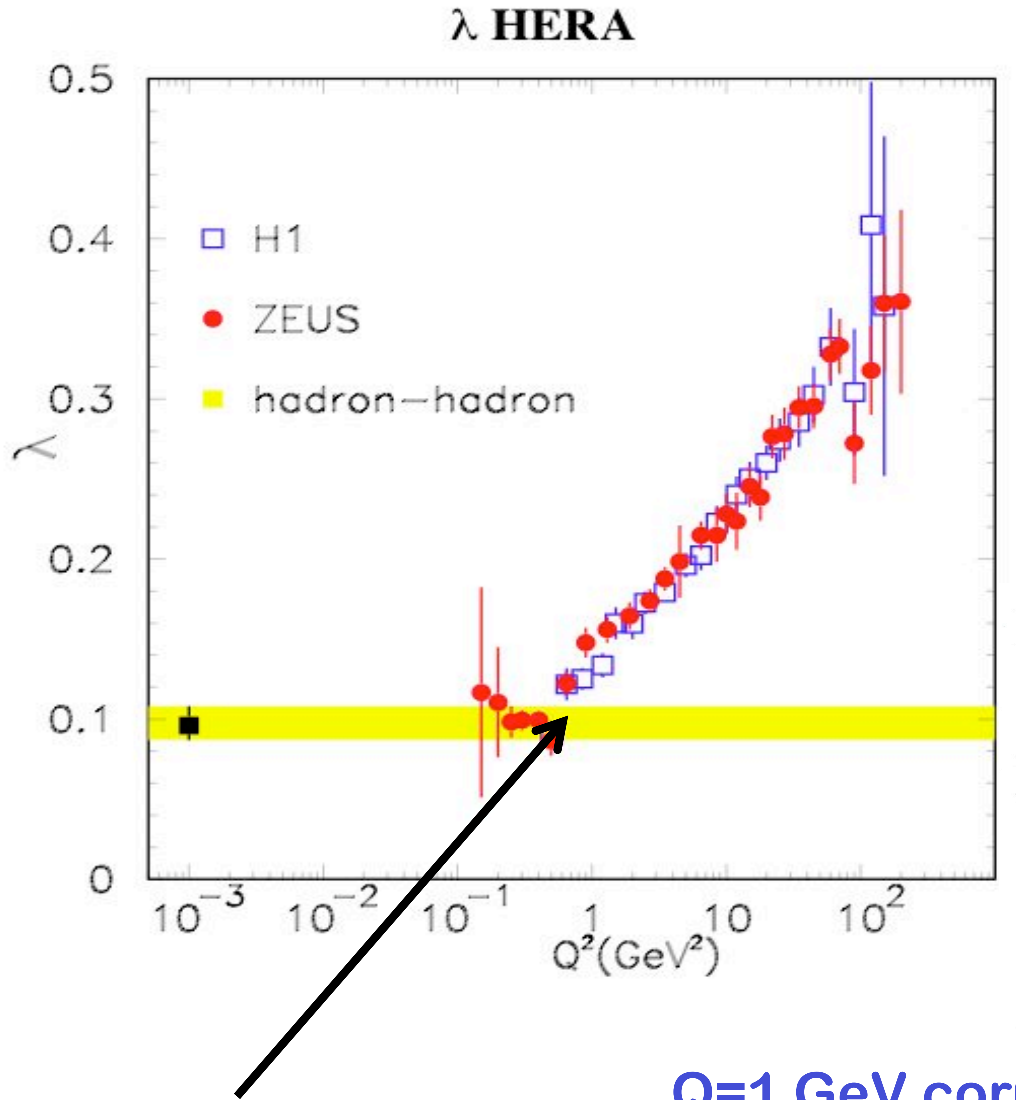
HERA Discovery!

The rise of the parton densities (and of F_2) with decreasing x is strongly dependent on Q^2. Implies very large density of partons in the proton when probe at high energies !



Small fraction of HERA data

The rise at small x

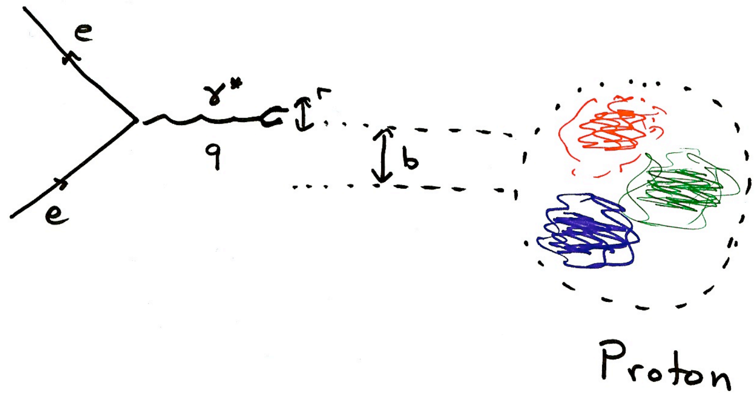


Parametrize:

$$F_2 = C(Q^2)x^{-\lambda} \qquad x < 0.01$$

Below $Q^2 \approx 0.5$ GeV^2, see same x (energy) dependence as observed in hadronic interactions

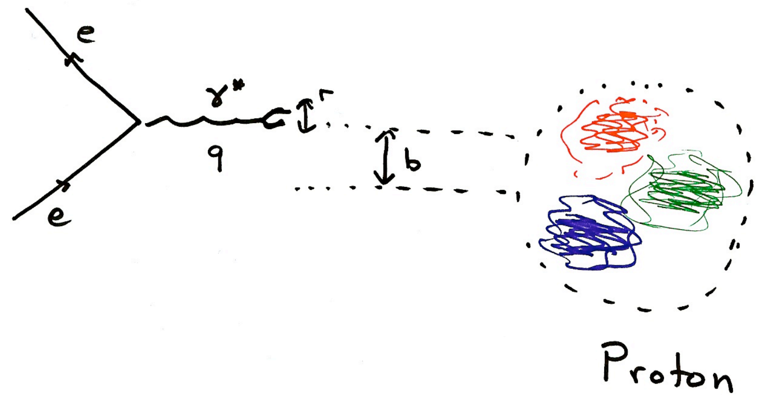
$$r \sim \frac{\hbar c}{Q}$$

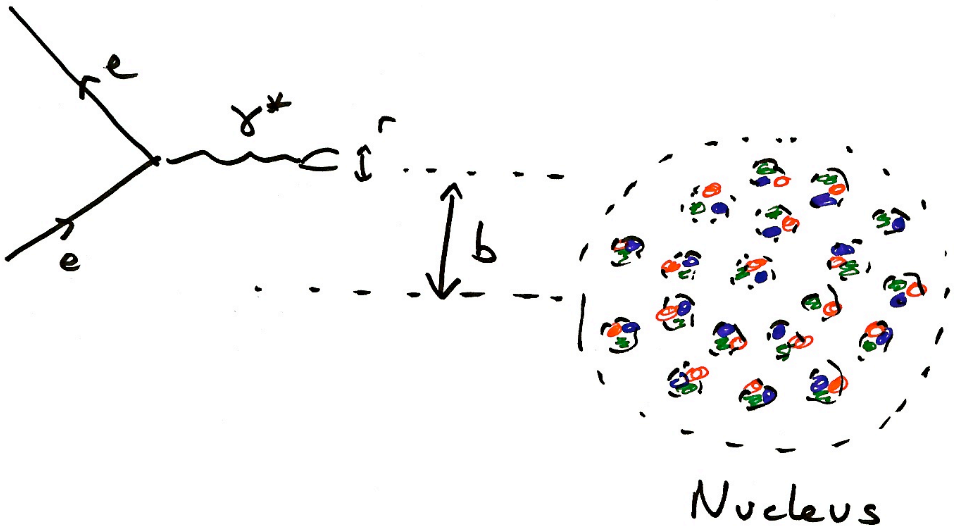


Transition region

Q=1 GeV corresponds to about 0.2 fm

Electron scattered at very small angle





Does the rise in F_2 set in at the same Q^2 in eA and in eP ?

Measuring F_L

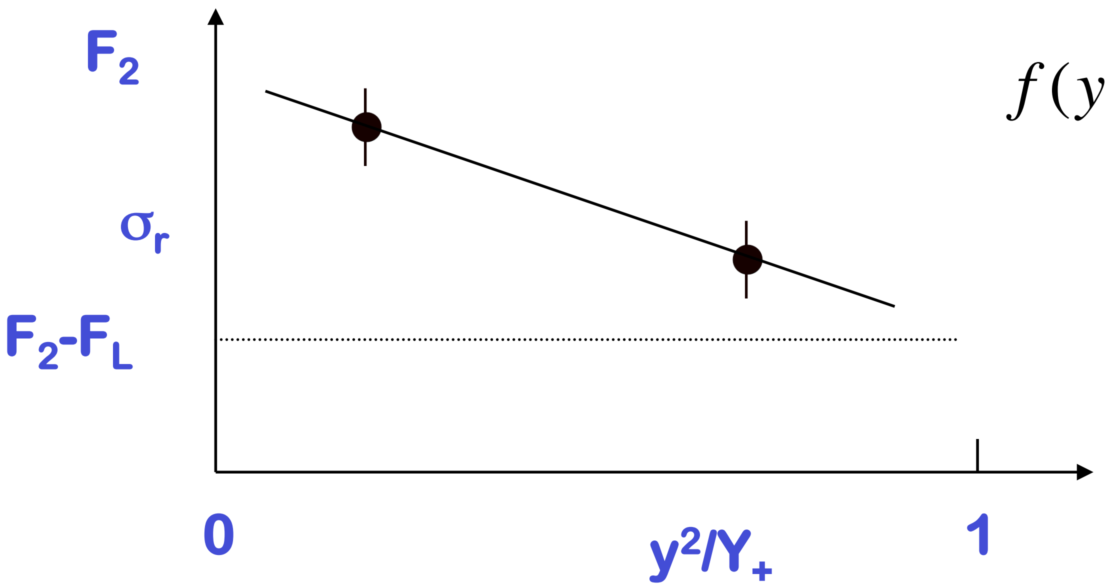
$$\sigma_r = \left(\frac{2\pi\alpha^2 Y_+}{xQ^4}\right)^{-1} \frac{d^2\sigma}{dxdQ^2} = \left[F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)\right]$$

Small Q^2, ignore F_3

F_L gives more direct access to gluons than F_2

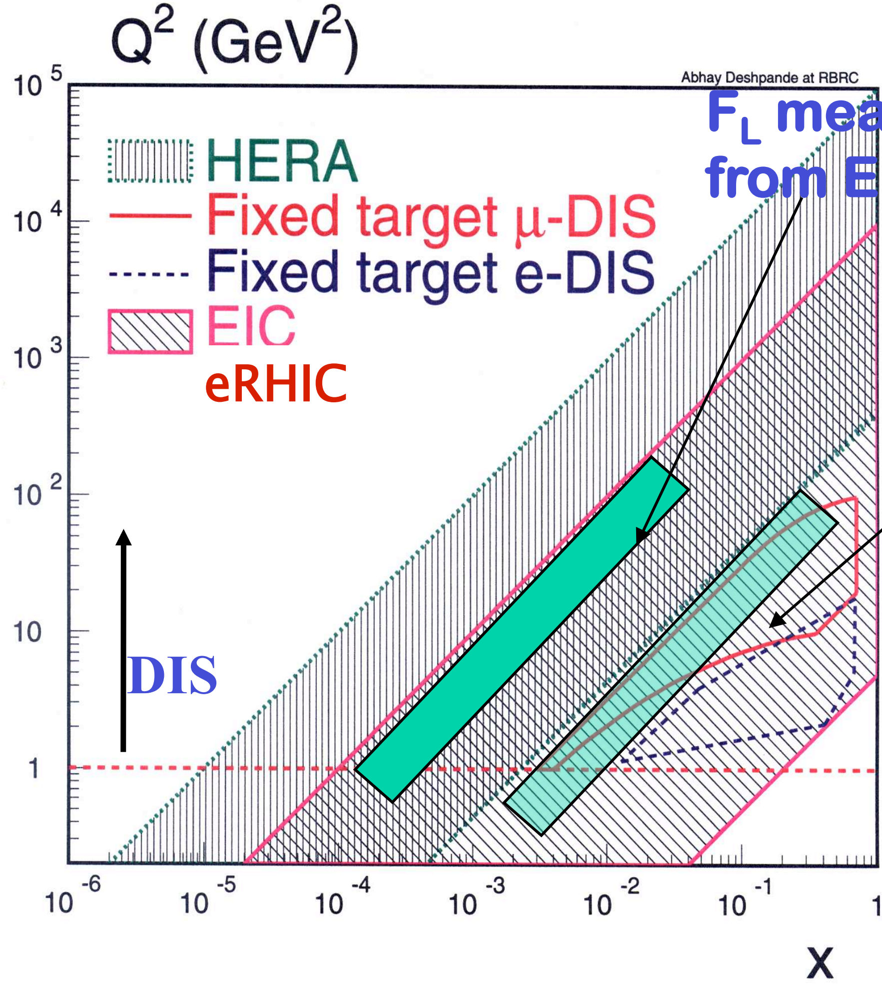
$$F_L(x,Q^2) = \frac{\sigma_r(x,Q^2,y_1) - \sigma_r(x,Q^2,y_2)}{f(y_2) - f(y_1)}$$

$$f(y) = {y^2}/{Y_+}$$



For best sensitivity, maximize lever arm (y-range). i.e., maximize difference in s

F_L EIC vs. Other DIS Facilities



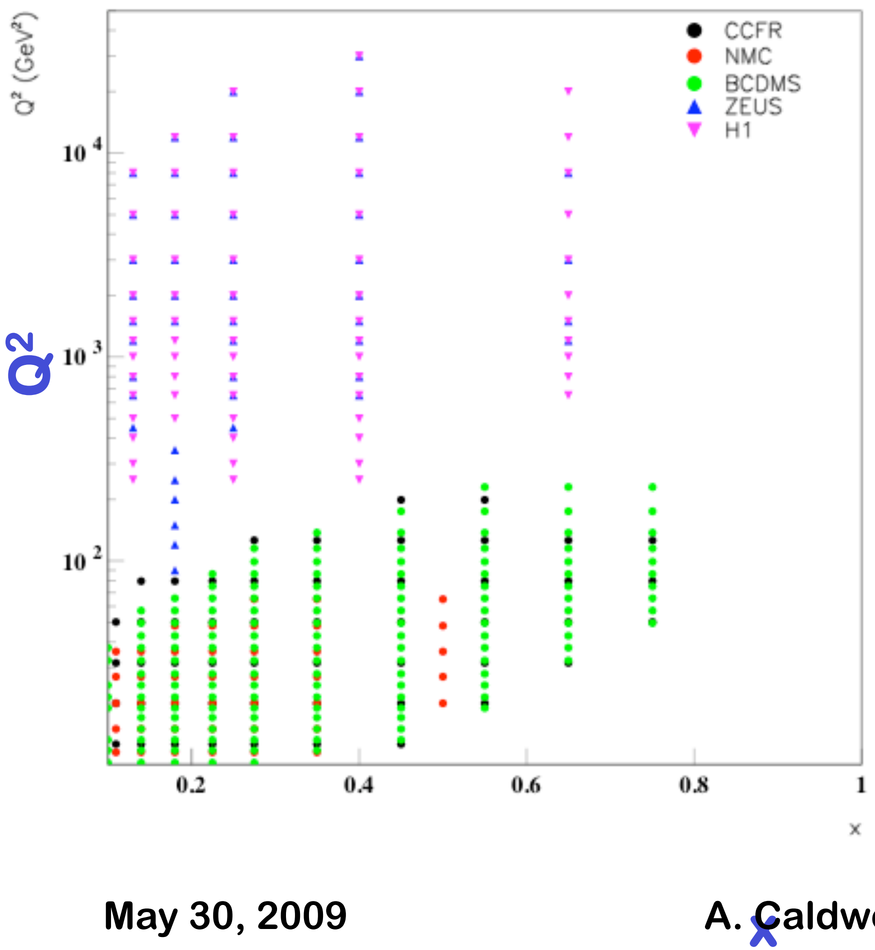
F_L measurement from EIC+fixed target

EIC is in an optimal energy range to extract F_L via cross section comparisons to previous experiments (maximum y difference).

High y means lowest possible scattered electron energies.

Small-x is not the only frontier …

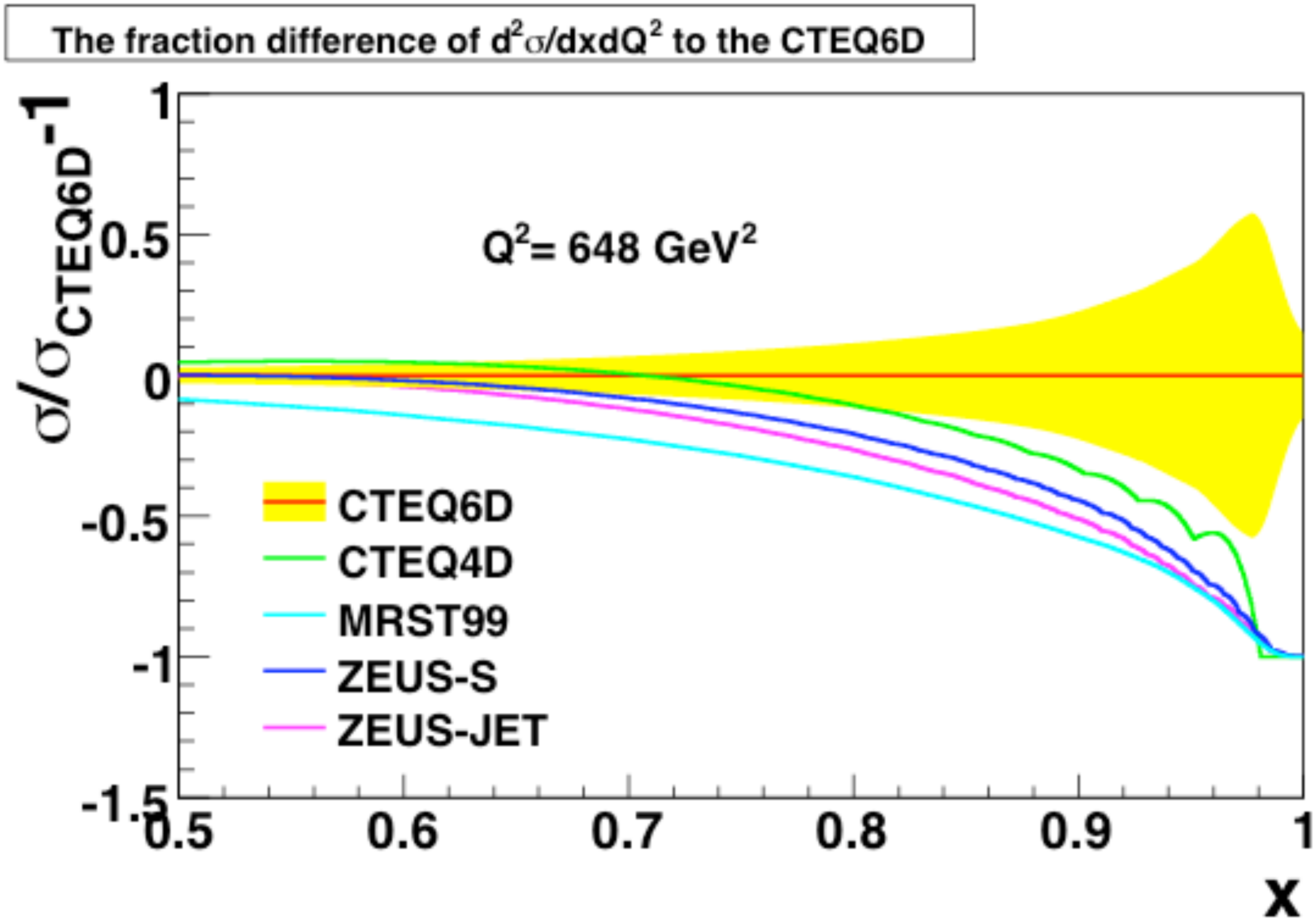
There is limited data on cross sections at high-x and high Q^2



BCDMS has measured F_2 up to x=0.75

H1, ZEUS have measured F_2 up to x=0.65

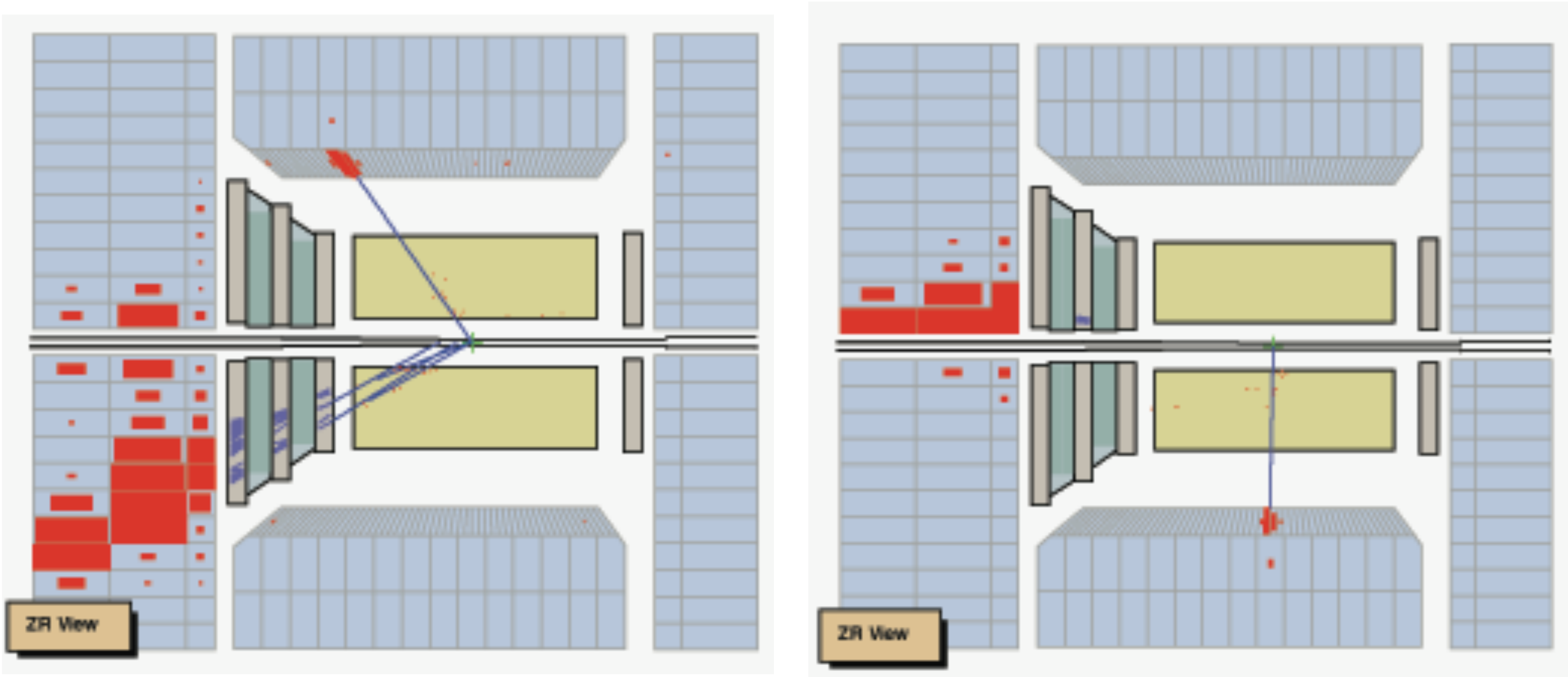
The PDF's are poorly determined at high-x. Sizeable differences despite the fact that all fitters use the same parametrization $xq \propto (1-x)^{\eta}$. Is it possible to check this ?



HERA Kinematics

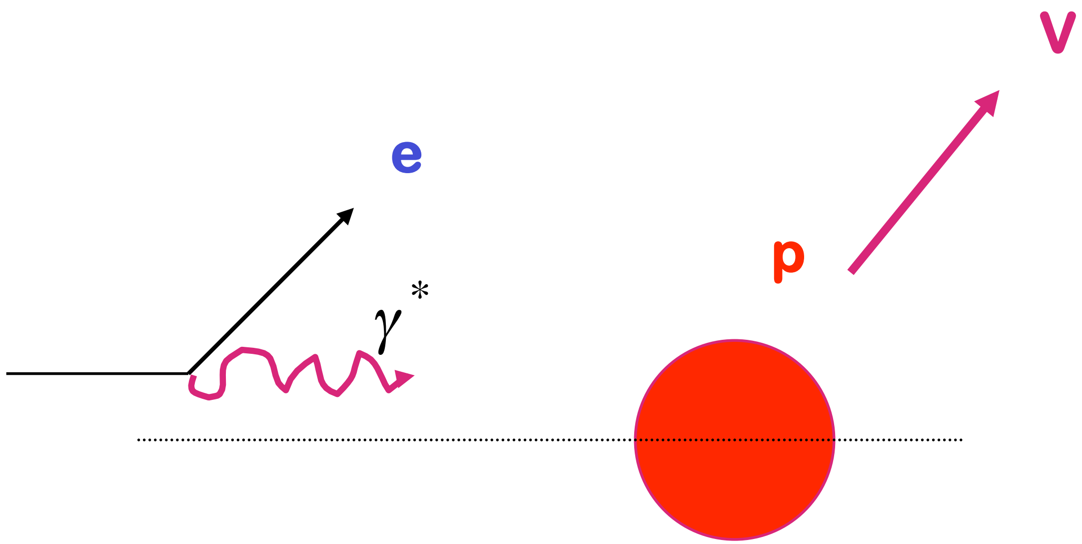
Jet found High x ~ 0.5

No jet found High x > 0.6

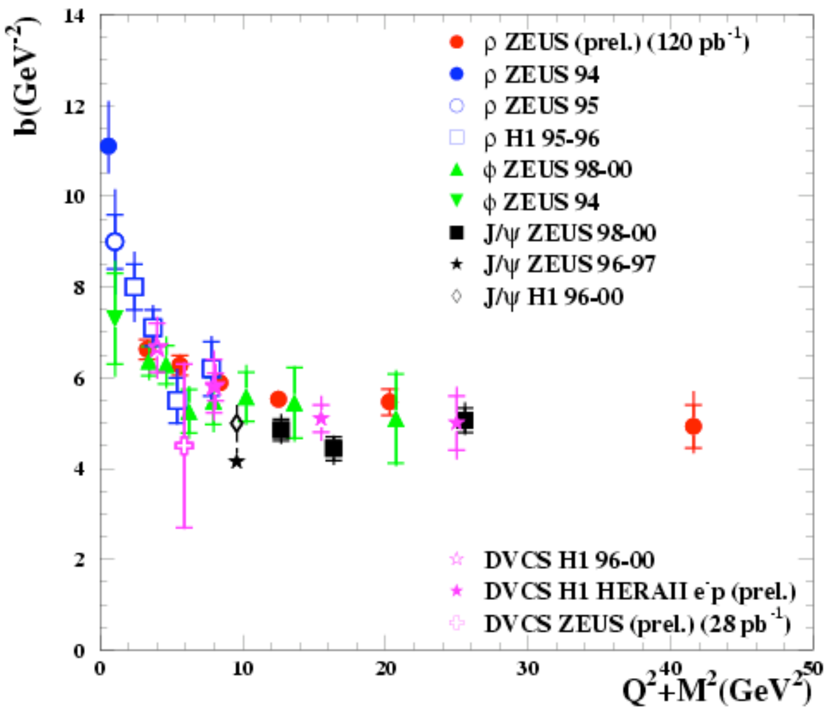


Need to measure hadronic jets to highest possible rapidity. Note, cannot reconstruct x accurately from electron information.

Exclusive Processes

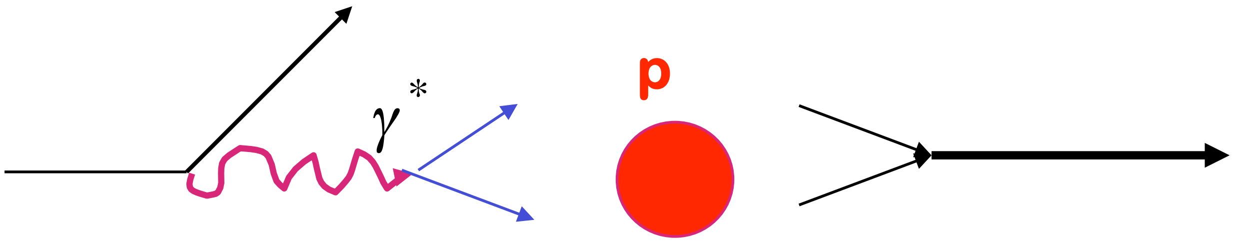


$$\frac{d\sigma}{dt} \propto e^{-bt}, \qquad b \rightarrow \mathrm{R_g}$$



b=4 GeV^{-2} found corresponds to an rms impact parameter of ~0.6 fm. smaller than the proton charge radius of 0.870 [PDG] …

Exclusive Processes



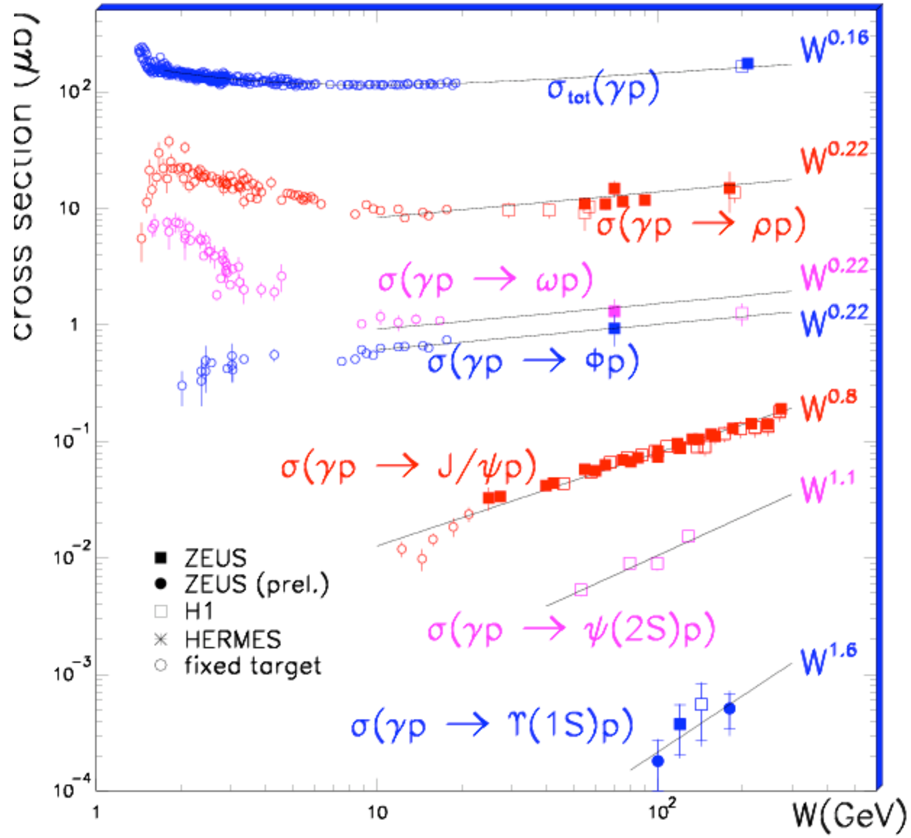
A long list of processes have been measured:

$$eP \to ePV \quad V = \rho, \omega, \varphi, J/\psi$$

$$eP \to eNV \quad V = \rho, \omega, \varphi, J/\psi$$

N is low mass system

and $\quad eP \to eP\gamma \quad$ QCD



Elastic Scattering

Ideal process to measure hadronic structure

Detector requirements:
- forward electron spectrometer
- forward p,A reconstruction (veto of dissociation)
- precision tracking in central detector

Accelerator requirements:
- substantial component free region around IP
- small P_T of beam particles (< few MeV)

EIC/ENC

1. Precise scan of the transition region between partonic & hadronic behavior. Something changes there - can we understand it ? Need acceptance in electron direction.

2. Make precision measurements at high-x to understand the valence quarks. Need acceptance in proton direction.

3. Make F_L a highlight of the program - much more direct access to gluon density than via F_2 scaling violations. Needs high precision measurements - good resolution, small systematics. Note: F_L can also be derived from comparison with HERA, fixed target.

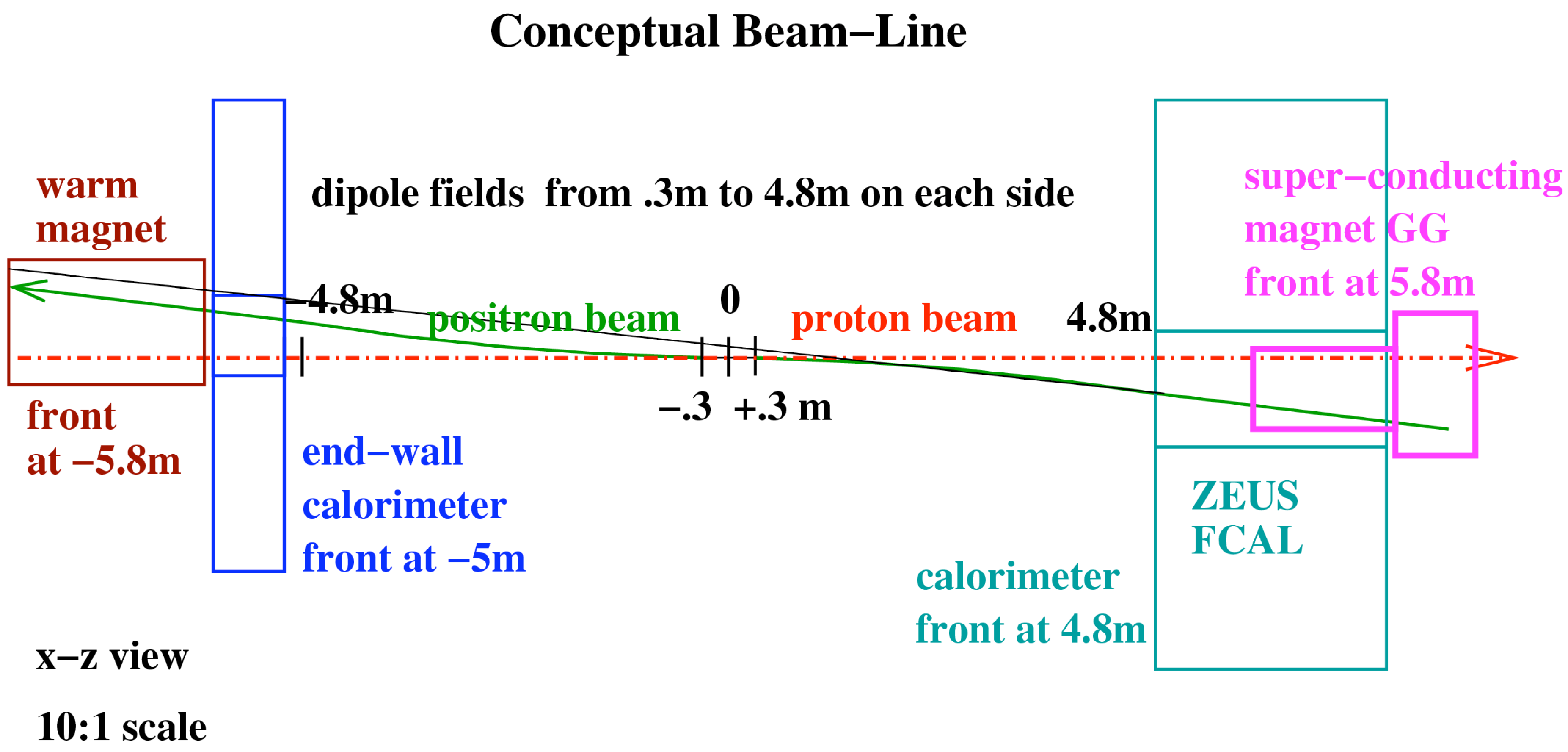
4. Focus on clean, high acceptance diffractive and elastic scattering measurements. Needs high efficiency rejection of proton/ion dissociation.

5. Photoproduction measurements benefit strongly from measurement of forward scattered electron.

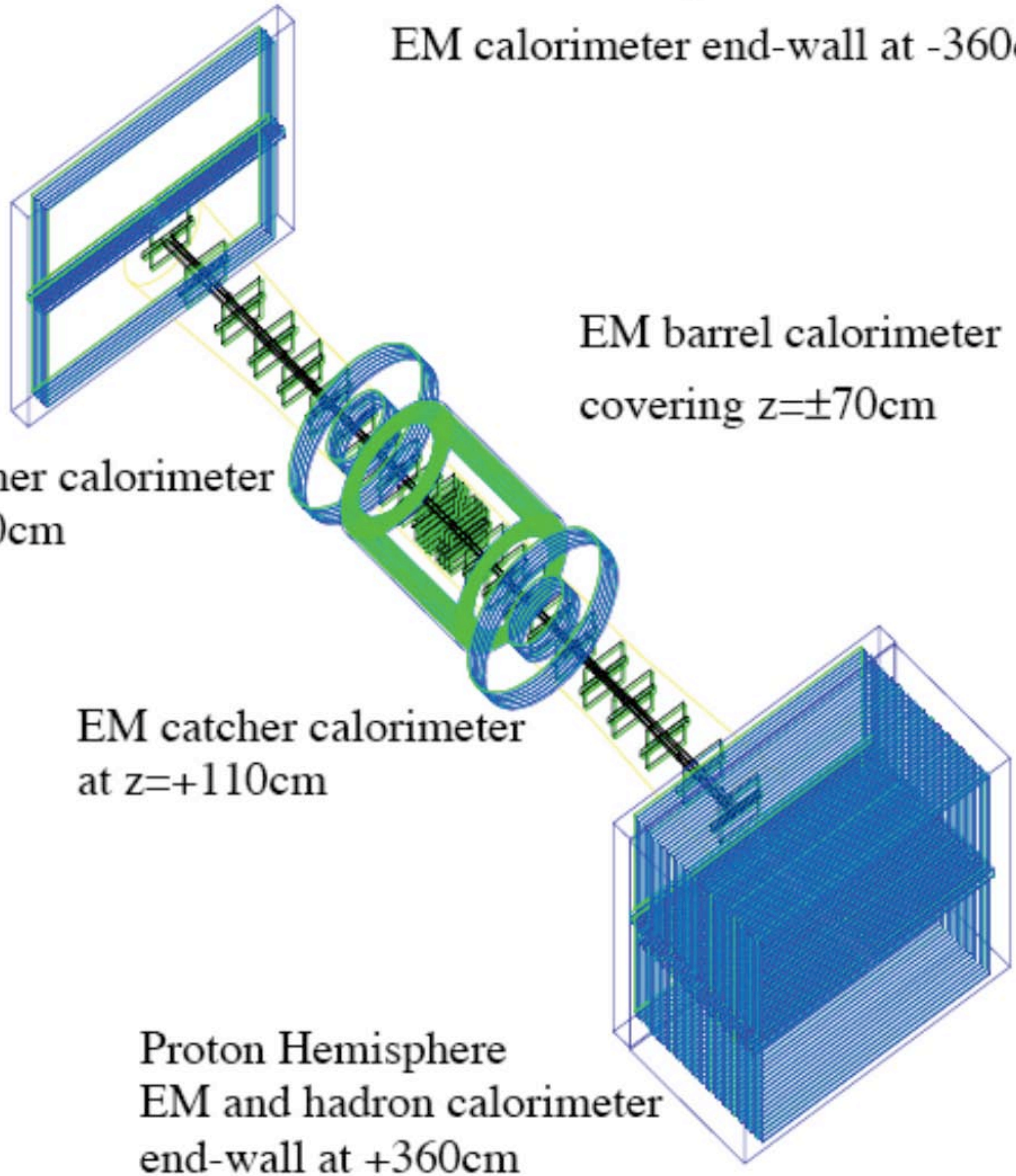
Full-acceptance detector studied for HERA-3, eRHIC

See:

HERA3 LoI and
I. Abt, A. Caldwell, X. Liu and J. Sutiak,
arXiv:hep-ex/0407053

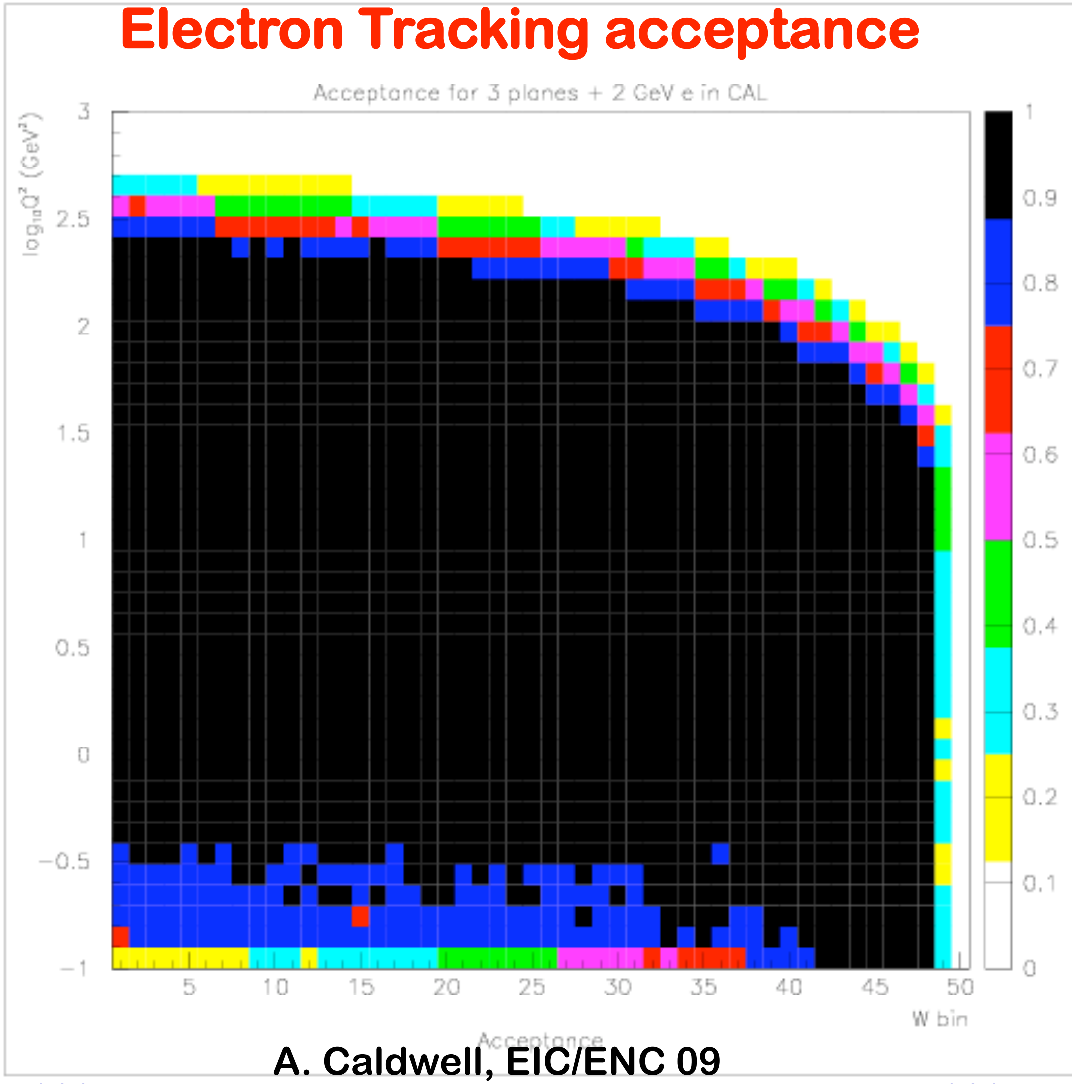


Optimized detector design will make a big difference in the physics which can be accessed. Towards Bjorken's FAD.



The focus of the detector was on providing complete acceptance in the low Q^2 region where we want to probe the transition between partons and more complicated objects.

HERA kinematics



Q^2=100

Q^2=10

Q^2=1

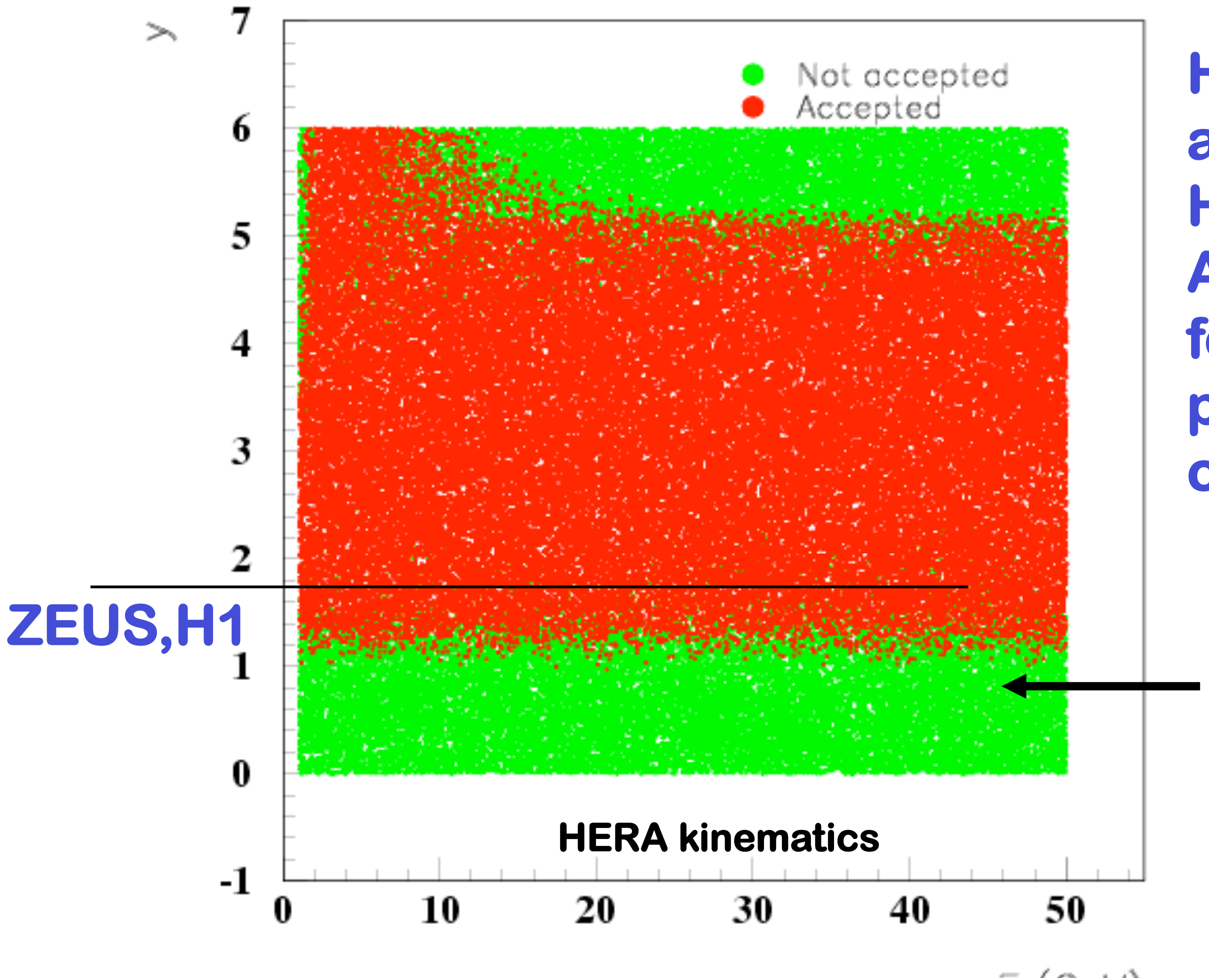
Q^2=0.1

W=0

W=315 GeV

Tracking acceptance in proton direction

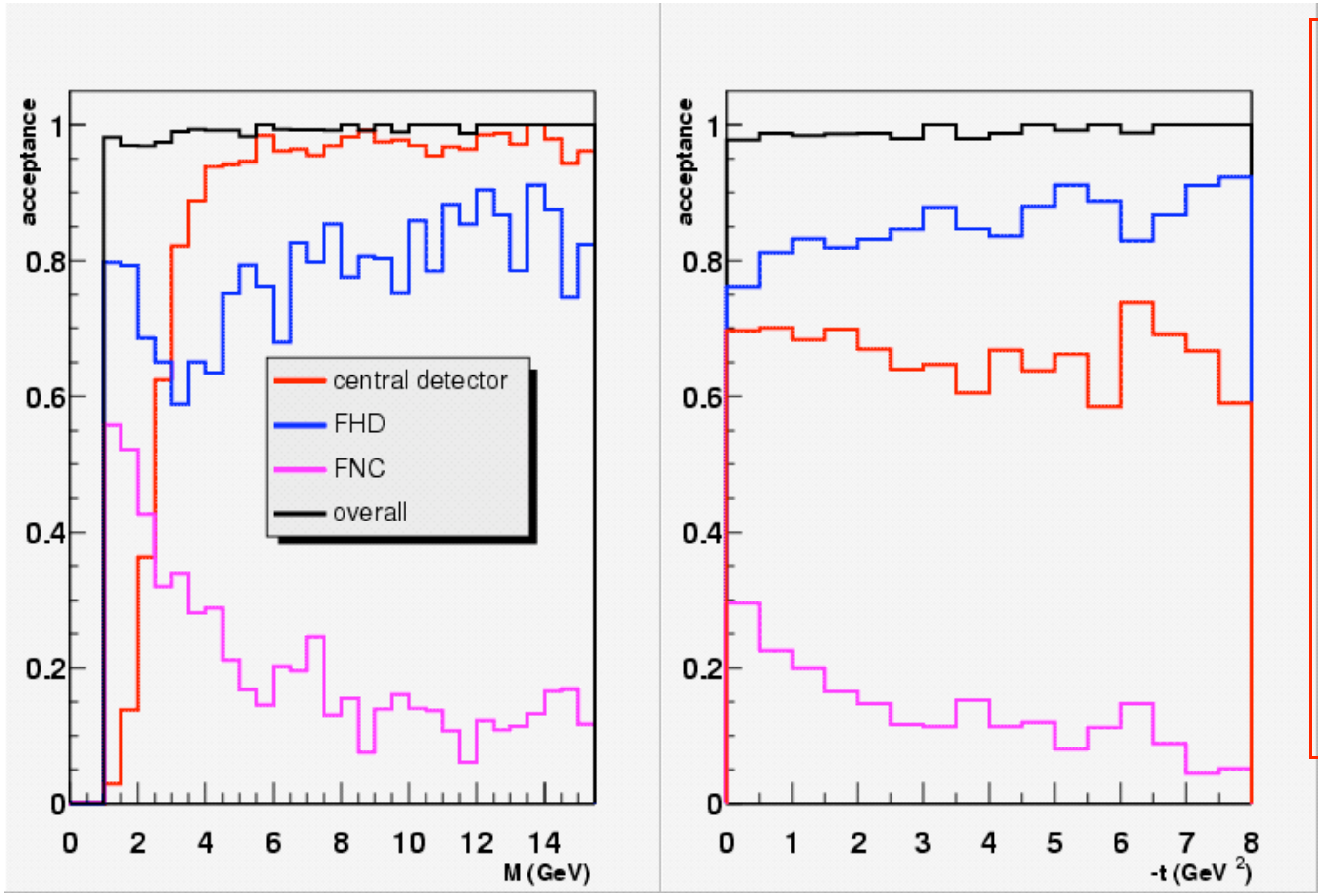
Accepted ≡ 4 Si stations crossed.



Huge increase in tracking acceptance compared to H1
And ZEUS. Very important for forward jet, particle production, particle correlation studies.

This region covered by calorimetry

Very large gain also for vector meson, DVCS studies. Can measure cross sections at small, large W, get much more precise determination of the energy dependence.

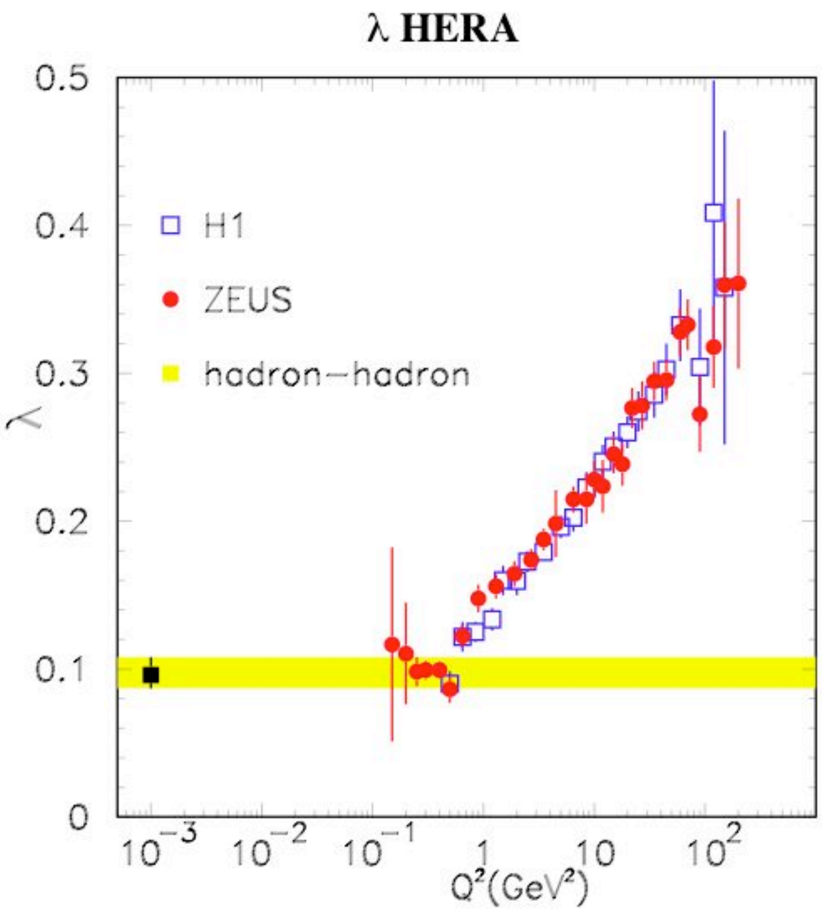


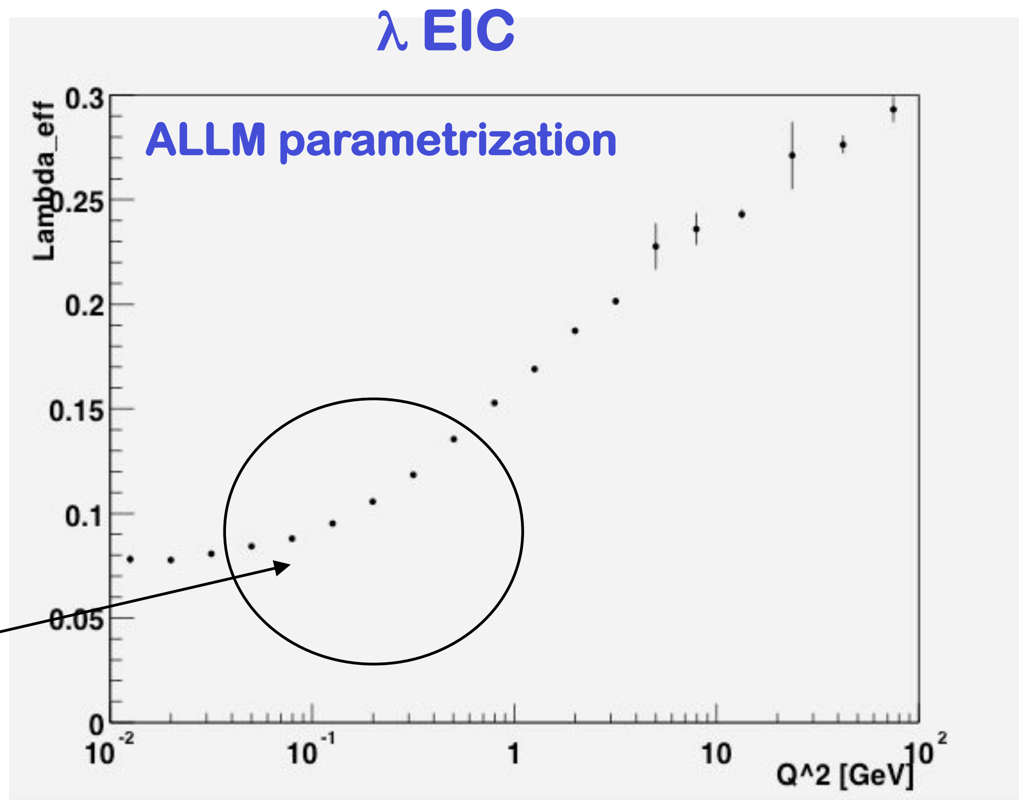
Can get rid of proton dissociation background by good choice of tagger:

FHD- hadron CAL around proton pipe at z=20m

FNC-neutron CAL at z=100m

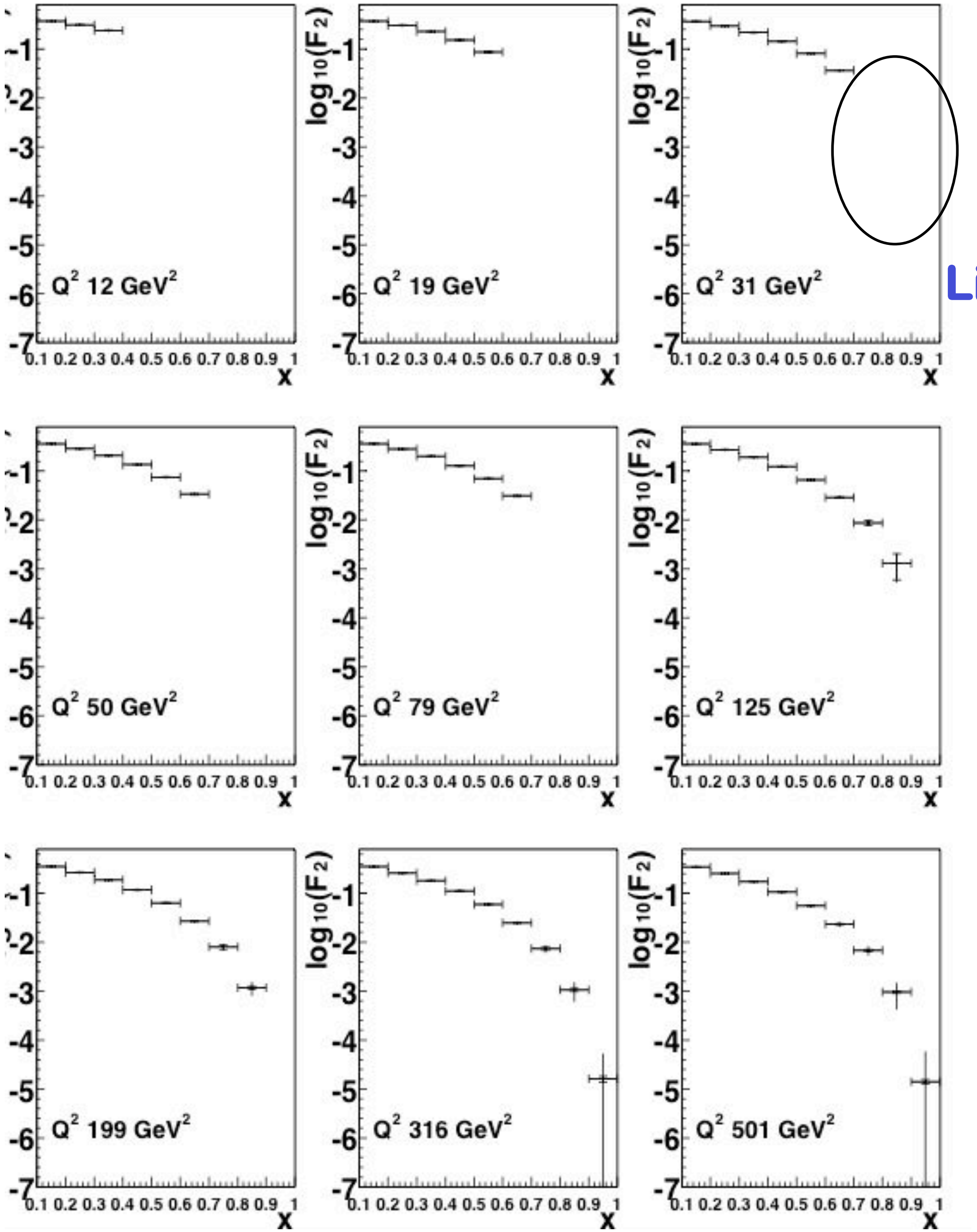
Probing the parton-hadron transition





Extremely precise measurements possible in this interesting region

eRHIC with 100 pb^{-1} and FAD

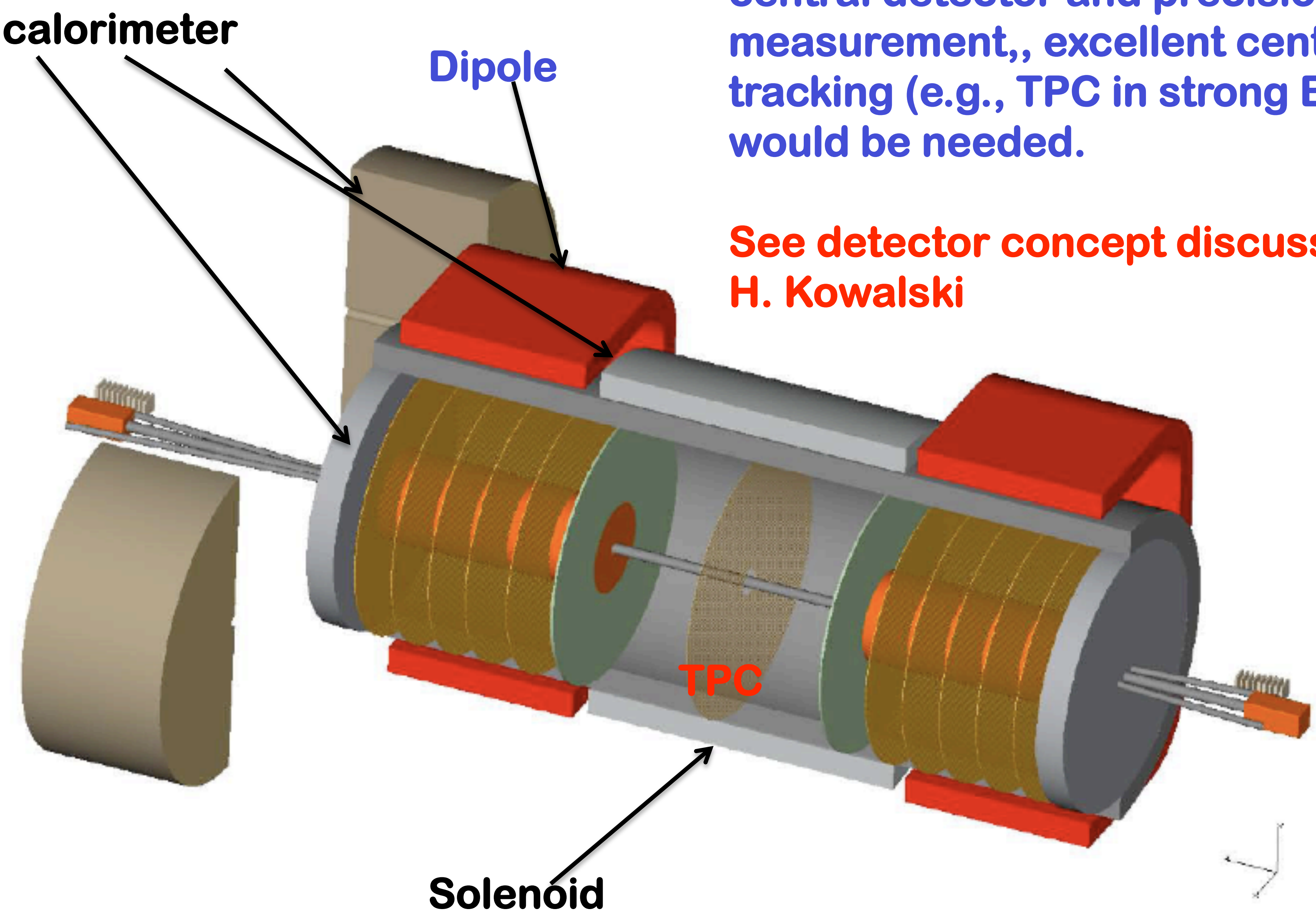


Limited by MC generator

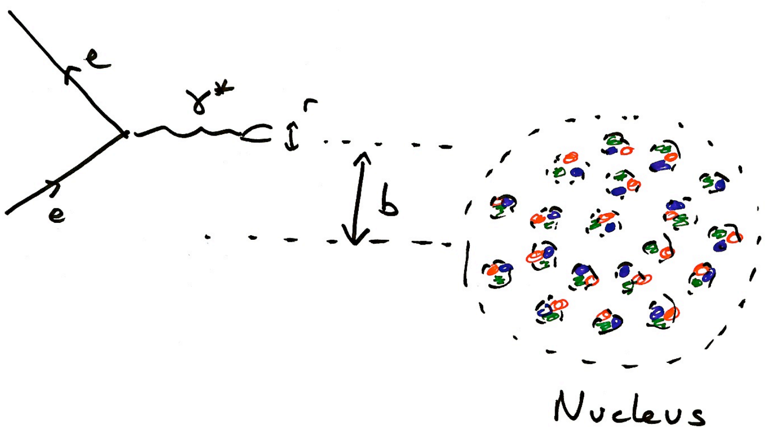
Measurements close to x=1 possible with good precision !

For reconstruction of the VM in the central detector and precision t measurement,, excellent central tracking (e.g., TPC in strong B field) would be needed.

See detector concept discussed by H. Kowalski



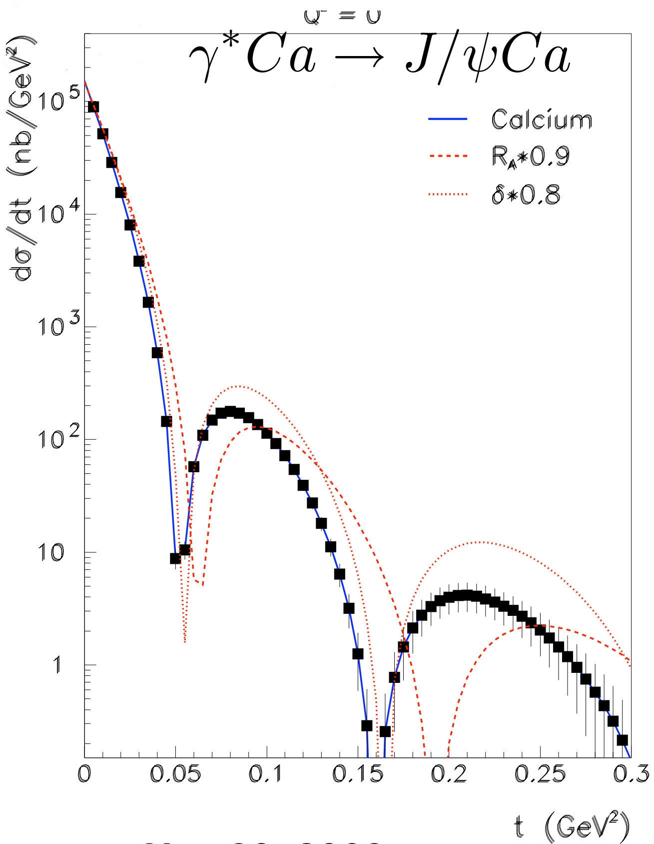
Work in progress, H. Kowalski, A. Caldwell



$$R_A = 1.2A^{1/3} \text{ fm}$$

Elastic scattering on full nucleus means long wavelength gluons (small t)

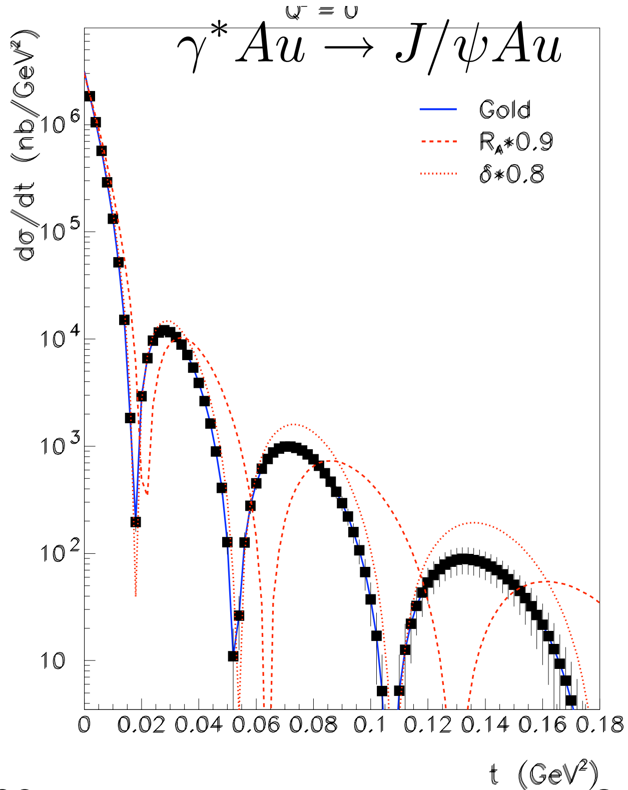
Woods-Saxon potential



Expectations for 1 Million

$$J/\psi \to \mu^+\mu^-$$

Momentum resolution of <10 MeV, great t resolution



Summary

There is tremendous physics potential for measurements in the forward electron and ion/proton direction.

Dipole magnetic field in extended region, considerable free space along beamline, precision tracking near the beamline will be important.

Some first detector concepts have been discussed – more work is needed.