# Very low $Q^2$ Physics and the ePIC Inclusive Group

GD/I Working Group Meeting
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with
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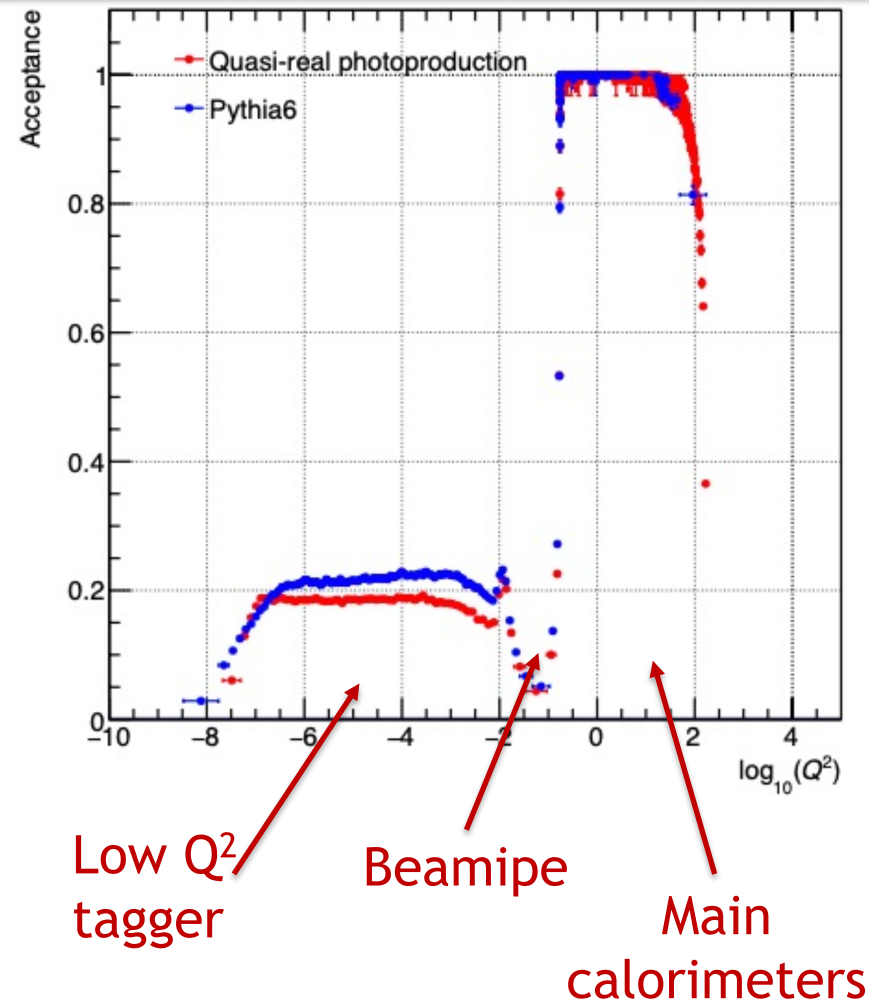
# Not a new question
## (e.g. from 'Complementarity' studies for Yellow Report)

**Complementarity by Mitigating Acceptance Gaps**

**All detectors have gaps and cracks**
… e.g. place gap in scattered electron acceptance between main detector & dipole/tagger in different places?

Can be mitigated by having 2 detectors with different high |η| layouts?




- Inclusive group studies have so far focused on $Q^2 > 1\ GeV^2$

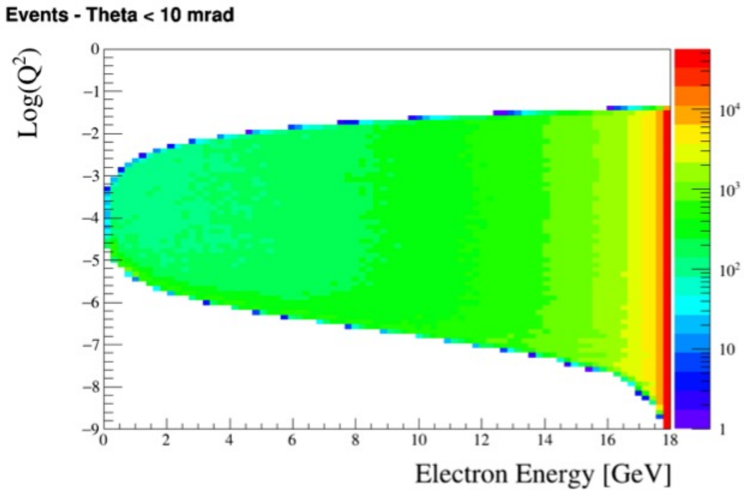
- Lower $Q^2$ yet to be tackled quantitatively, though it is on our wish list!

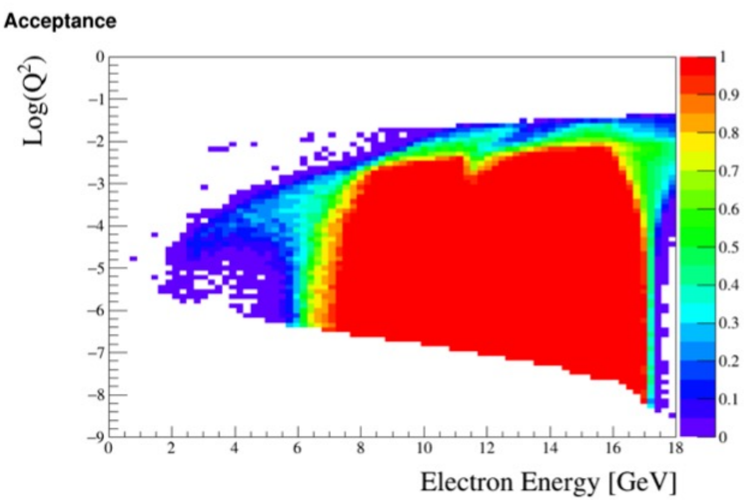
# ePIC very low $Q^2$ tagger

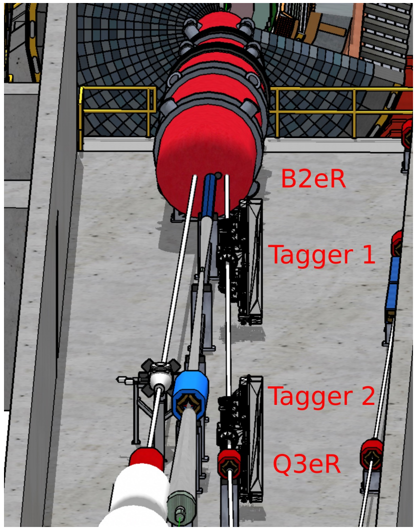
[Igor Korover / Simon Gardner / Far Backward group, January ePIC Collab meet]

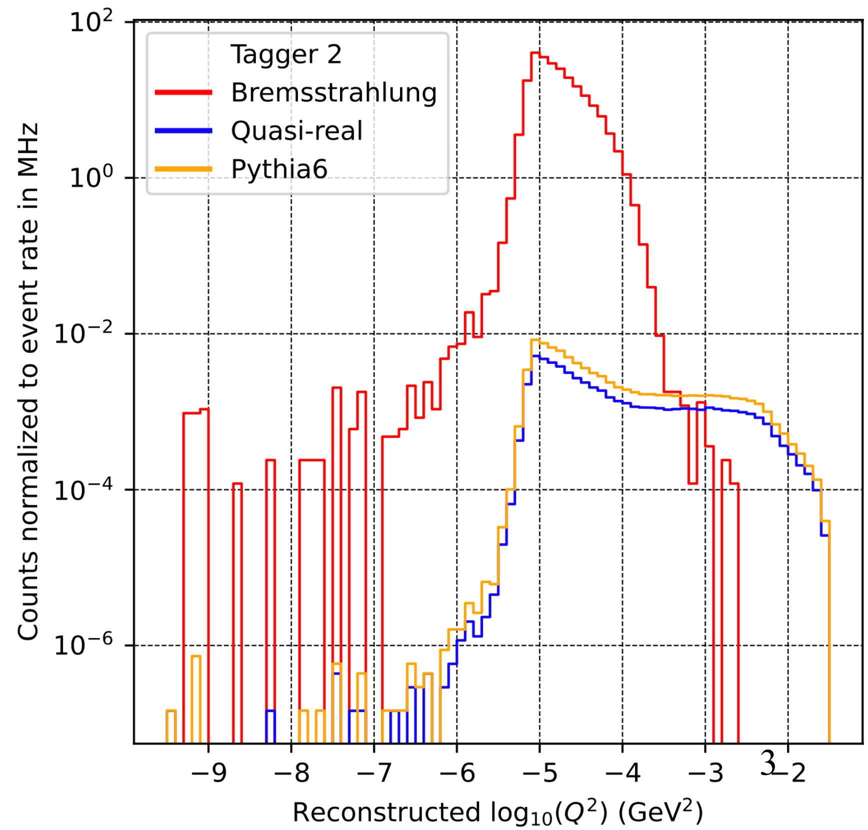
**Target region for 'photoproduction' is $10^{-3} < Q^2 < 10^{-1}$**

Detector acceptance



# Why should we care?

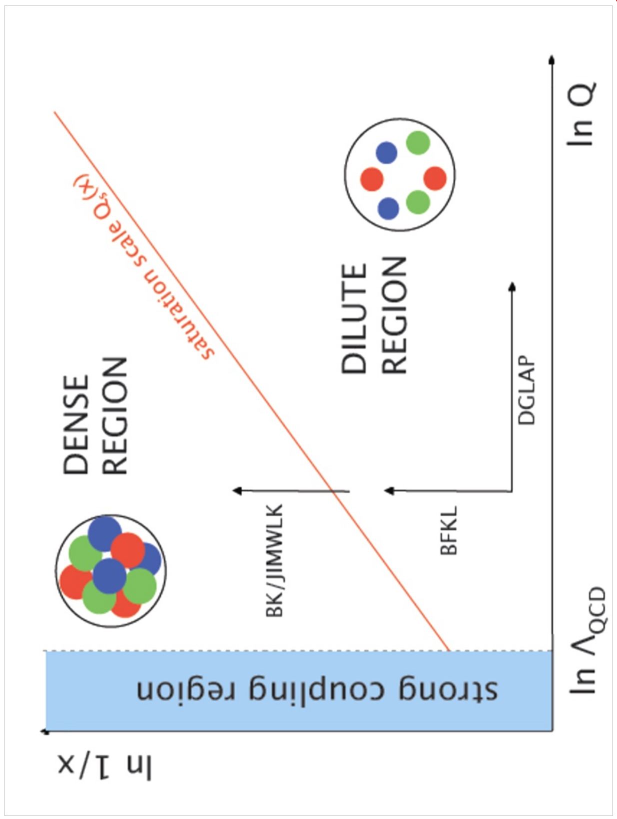
$Q^2 \ll 1\text{GeV}^2$ corresponds to non-perturbative regime …

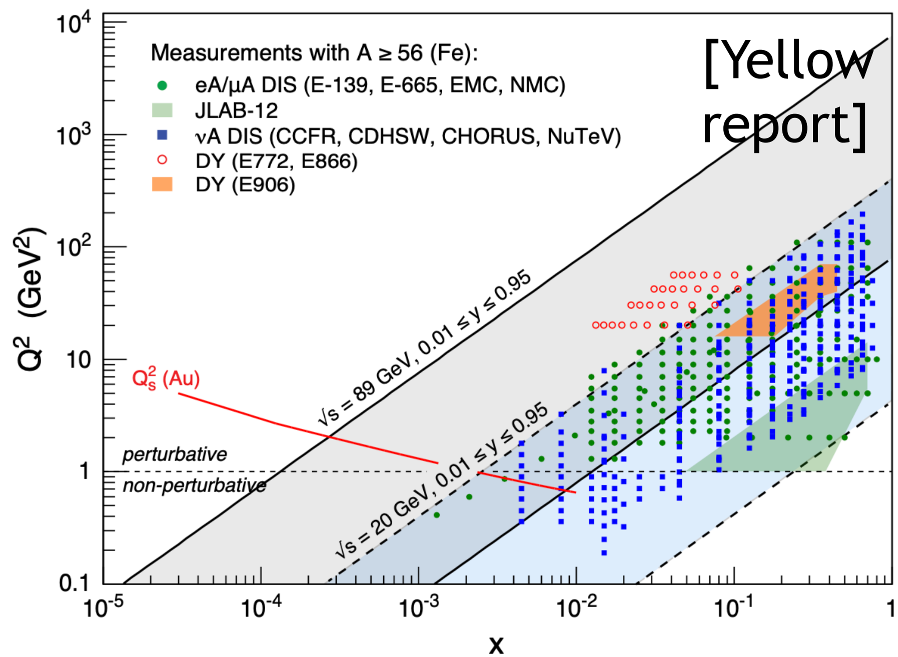
→ Proton structure not (well) resolved

→ x no longer identifiable as a parton momentum fraction

**BUT**

- Crucial for access to novel (low x) density-based effects (saturation)




[Yellow report]

- Crucial for understanding the (confinement!) transition from partons to hadrons as appropriate degrees of freedom

# Notes on Kinematics

$$Q_e^2 = 2E_eE'_e(1+\cos\theta) \qquad y_e = 1 - \frac{E'_e}{E_e}\sin^2\frac{\theta}{2}$$

- In 'kinematic peak' region where $E'_e \approx E_e$ …

$$Q^2 \to 2E_e^2(1+\cos\theta)$$

… **Strong correlation between $Q^2$ and θ**

- As $Q^2 \to 0$ and $\vartheta \to 180^o$…

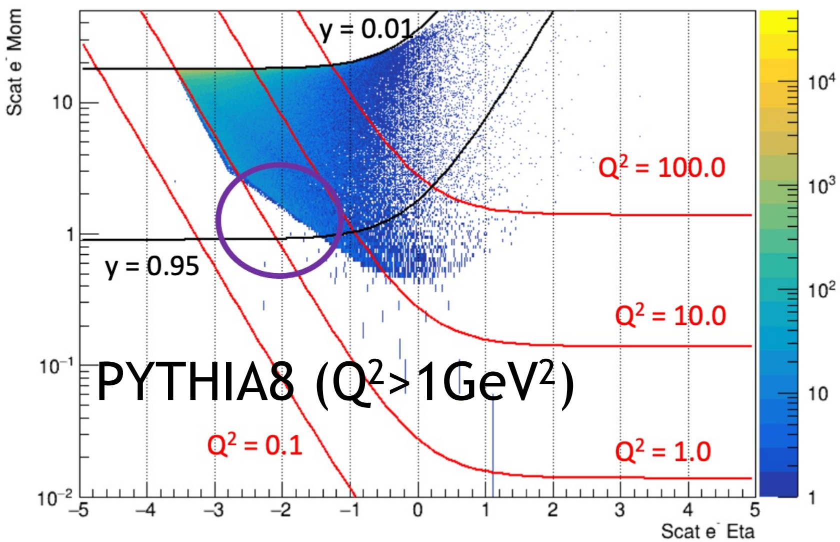
$$y \to 1 - \frac{E'_e}{E_e} \equiv \frac{E_\gamma}{E_e} \qquad \text{(and } W^2 \to ys\text{)}$$

- Note that these expressions only depend on the electron beam energy (proton energy is irrelevant)

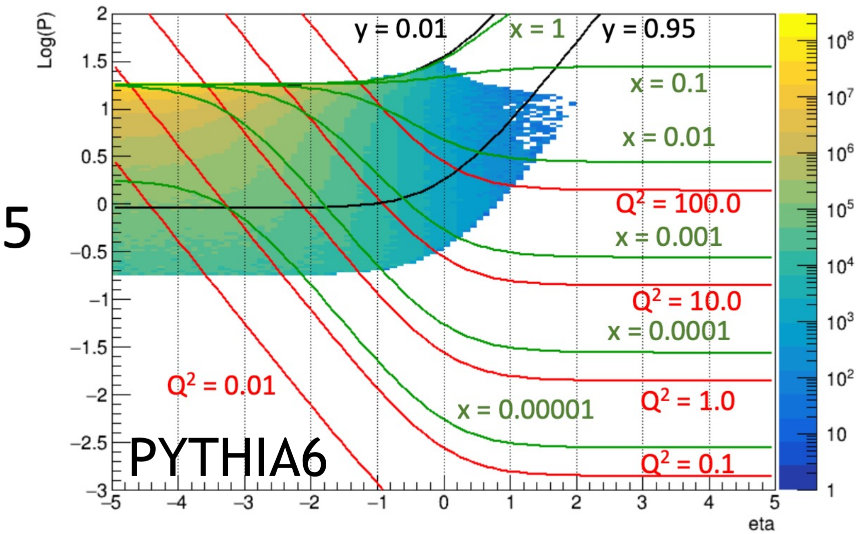
# MC Generators

[Brian Page, Barak Schmookler]

Need MC samples extending to(wards) $Q^2 \rightarrow 0$ kinematic limit … BEWARE!



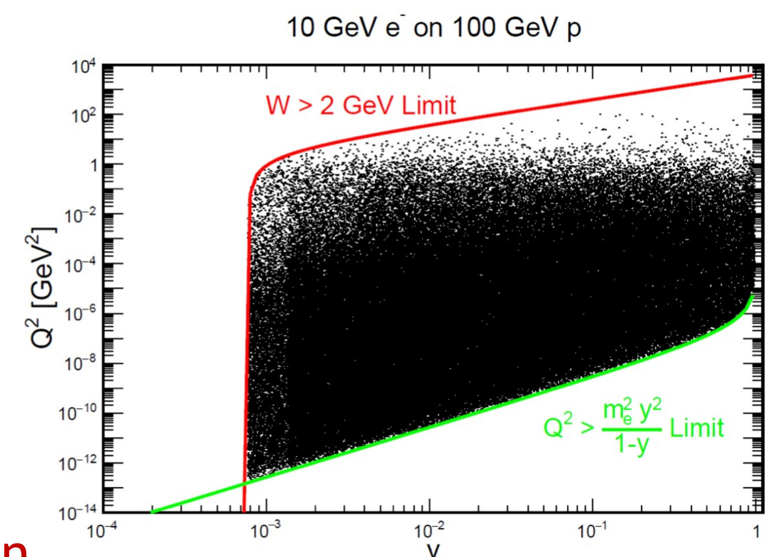

18x275




- No MC can be relied on (?) for inclusive cross section predictions in $Q^2 \rightarrow 0$ limit

- Issues with PYTHIA8 already at $Q^2$~1GeV$^2$

- PYTHIA6 (and DJANGO?) at least produce events … enough for now …




- Zeroth order approach is a simple particle gun …

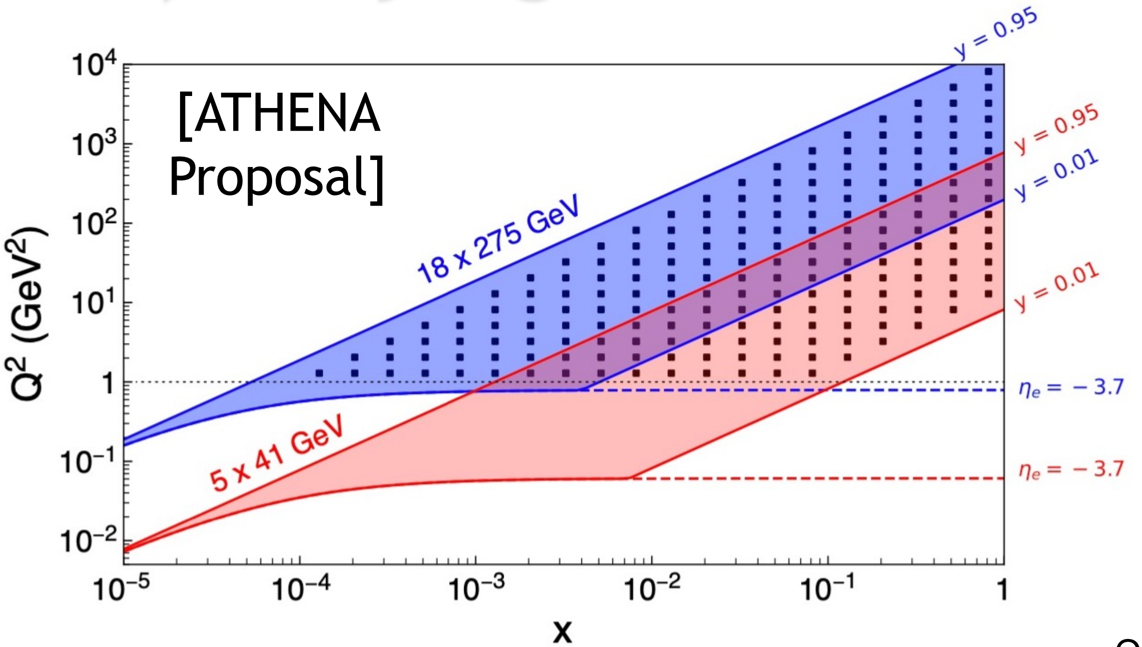
# Some possible approaches

1) Vary the electron beam energy?

2) Shift the vertex?

3) Add instrumentation between main detector and very backward Low $Q^2$ tagger?

# 1) Varying the Electron Beam Energy




At kinematic peak:

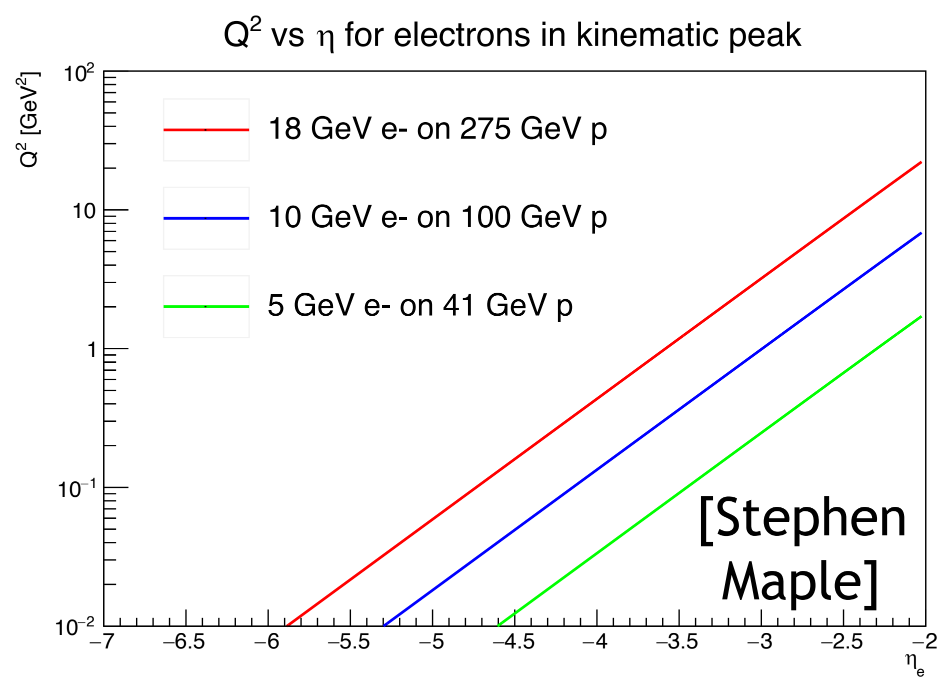
$$Q^2 \to 2E_e^2(1+\cos\theta)$$

… min $Q^2$ scales approximately with $E_e{}^2$ for fixed detector acceptance

- $Q^2 \sim 0.05$ GeV$^2$ achievable with $E_e$ = 5 GeV

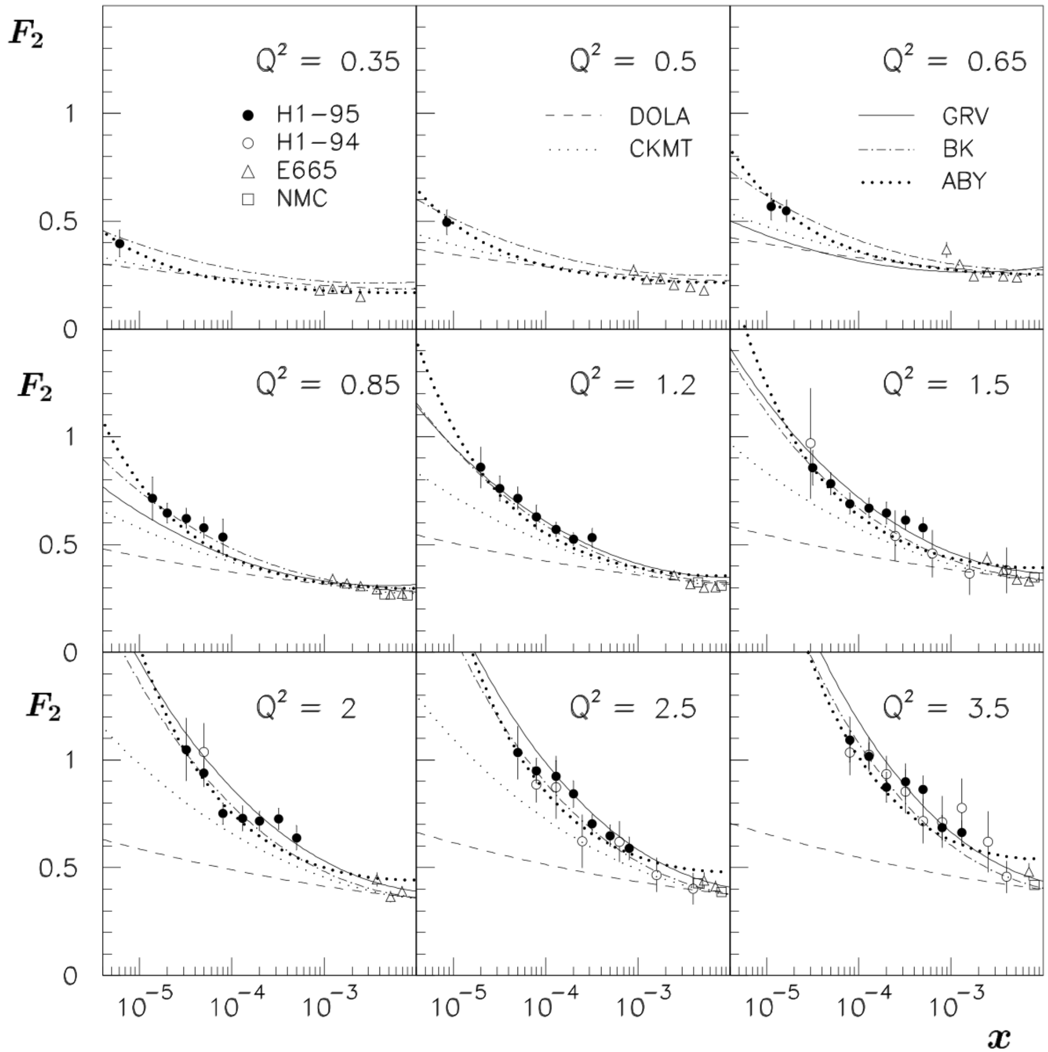
- Powerful technique, but limits low x coverage, so reduced sensitivity to saturation phenomena

- $E_p$ is irrelevant here



# 2) Shifting the vertex

Shifting the mean z of the interaction point in the outgoing hadron direction extends acceptance to larger $|\eta|$




Example from H1:

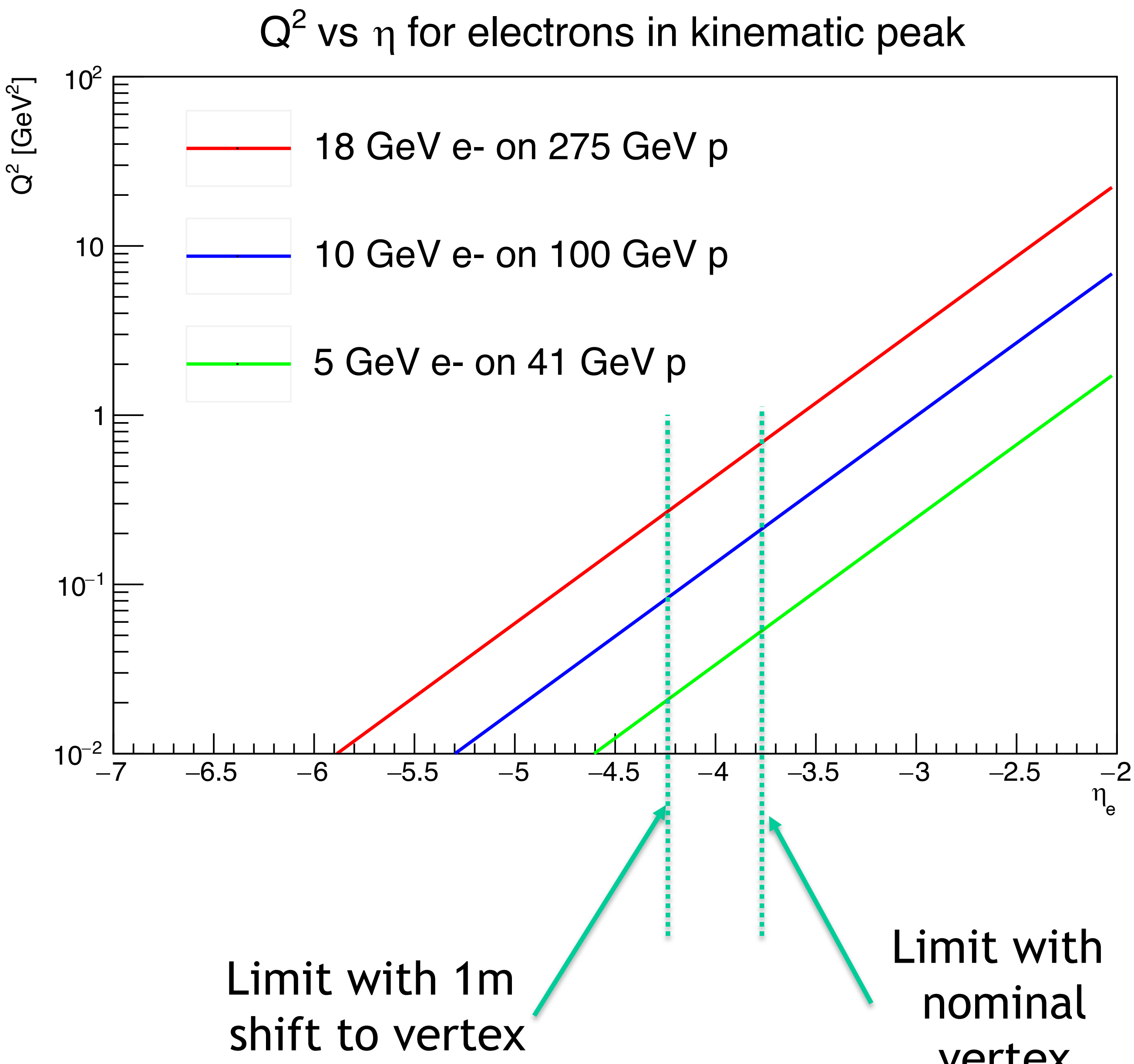
`H1-94' are nominal vertex ($Q^2$ >~ 1.5 $GeV^2$)

`H1-94 are with vertex shifted by 70cm ($Q^2$ >~ 0.35 $GeV^2$)

… 70cm shift achieved factor ~4 in min $Q^2$

[similar techniques applied at RHIC?]

# Shifting the vertex at ePIC




e.g. effect of 1 metre shift on acceptance for $E_e' = E_e$

# Shifting the vertex at ePIC

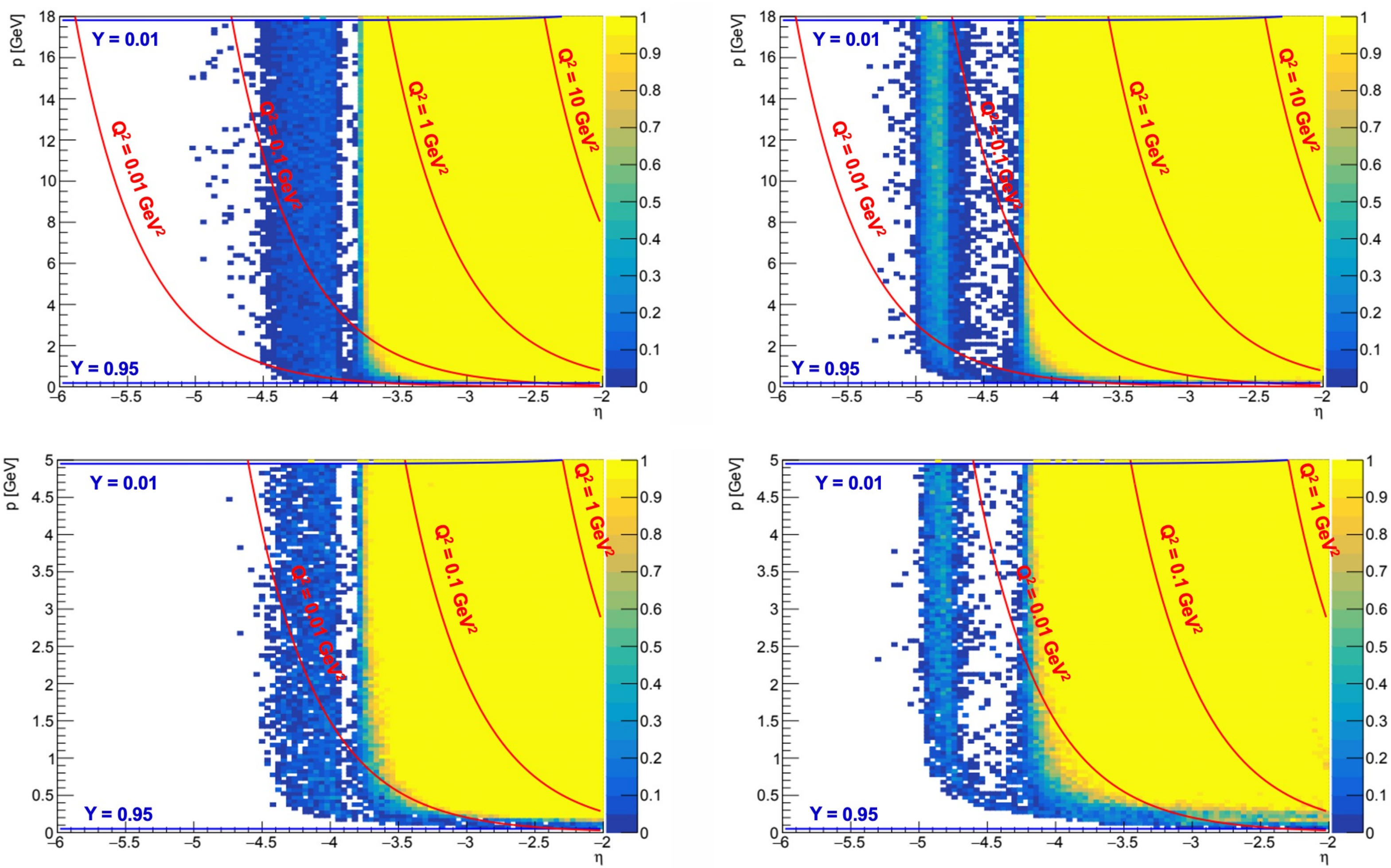
[Stephen Maple]

## Particle gun ePIC simulations (ARCHES)
## … probabilities of registering cluster in calorimeters

Nominal vertex | 1m shift to vertex

18 GeV electron beam

5 GeV electron beam

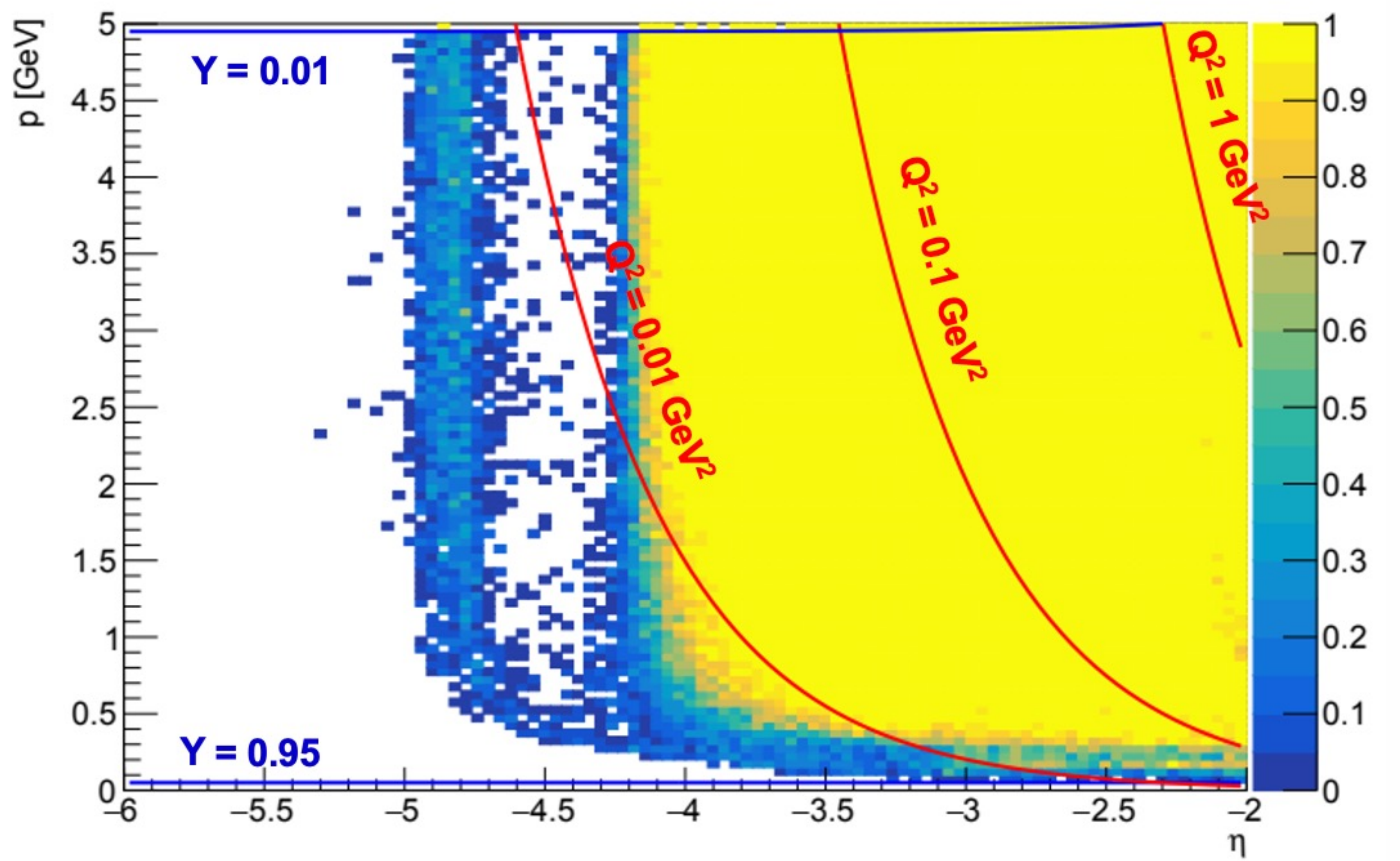


# Shifting the vertex at ePIC

[Stephen Maple]

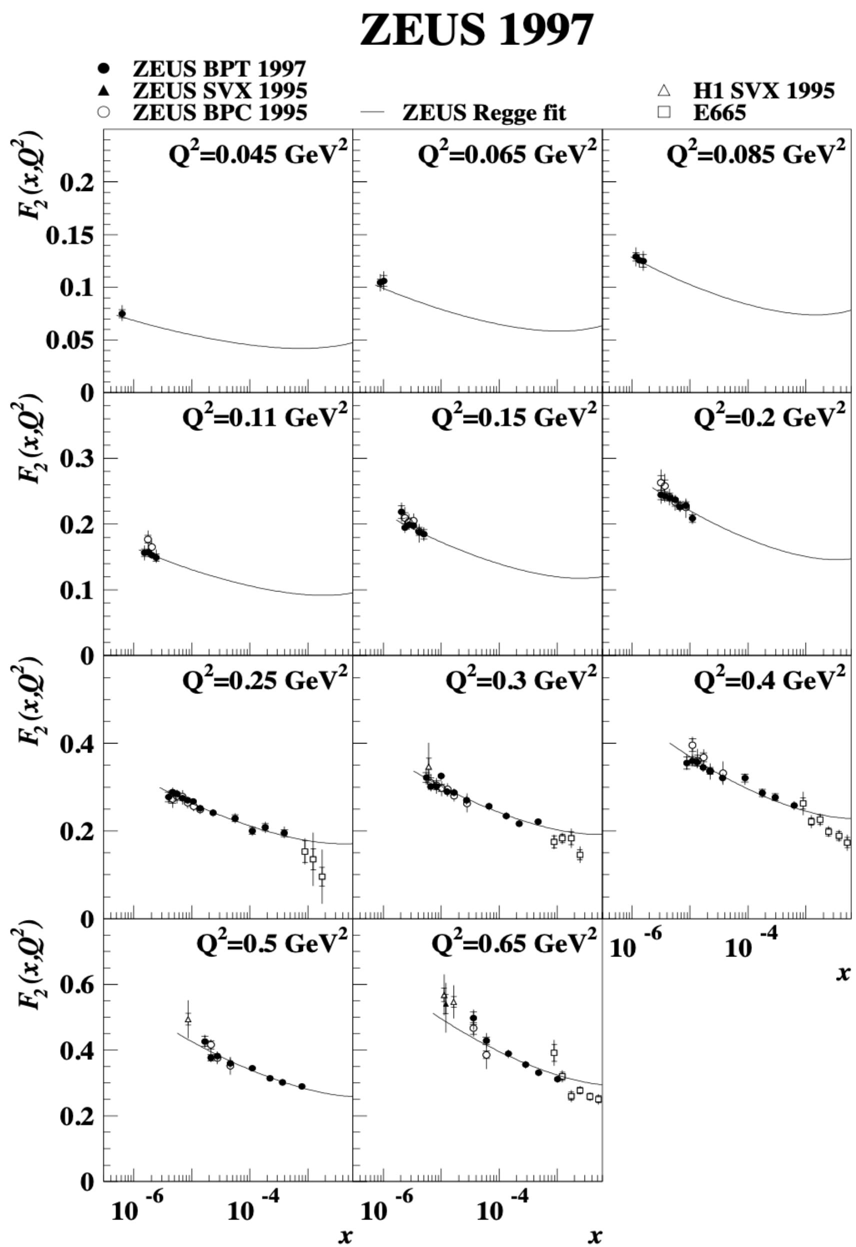
5 GeV electron beam

1m shift to vertex




Gets us towards $Q^2 = 10^{-2}$ $GeV^2$ but best for low $E_e$
(cf loss of sensitivity to saturation region)

# 3) Adding instrumentation




'Retrofits' at HERA …

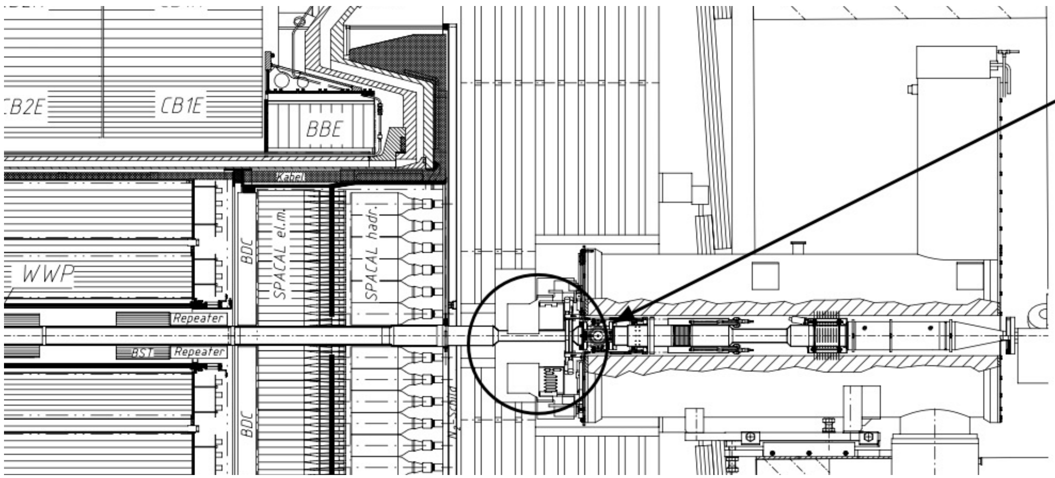
e.g. ZEUS beampipe calo / tracker (Bernd's talk)

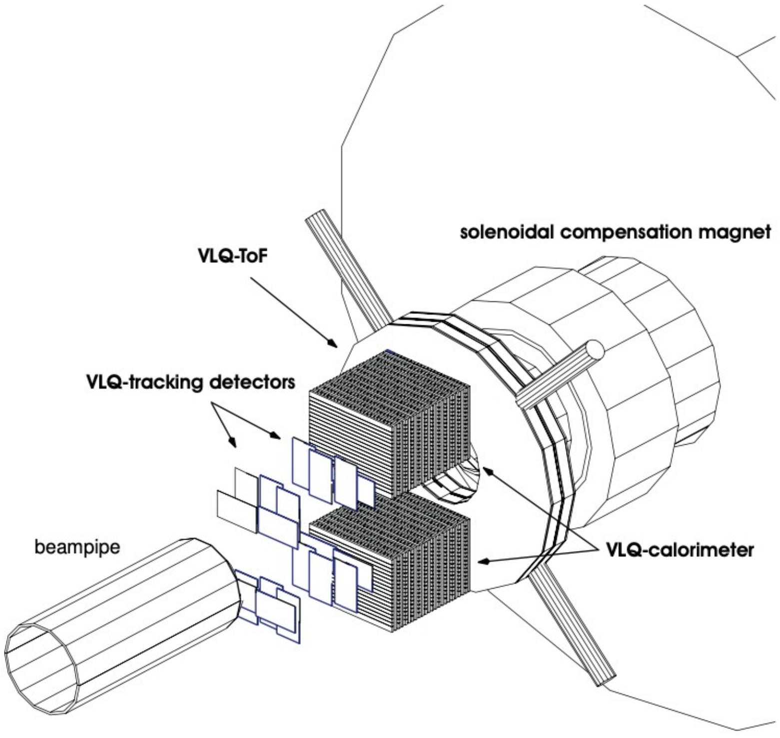
- Electrons exited beampipe through exit window to reach the detectors

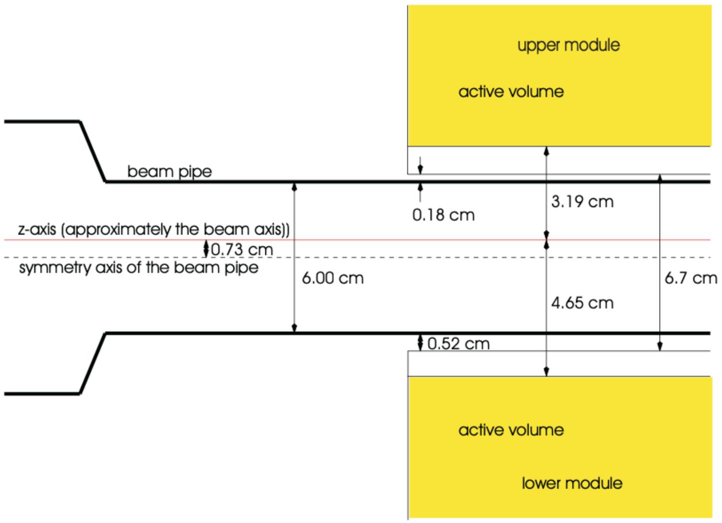
… approaching Q2 = 10-2 GeV2

[H1 equivalent (VLQ) was less successful]

# H1 VLQ Spectrometer



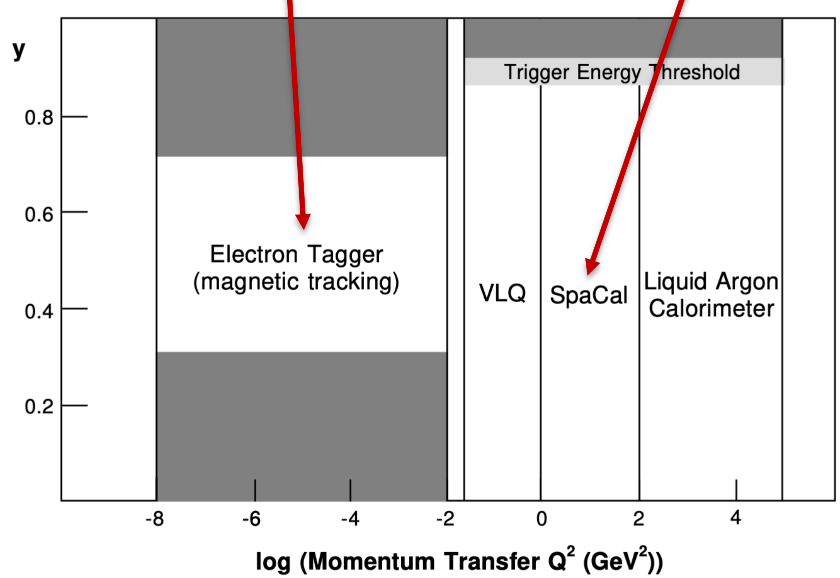



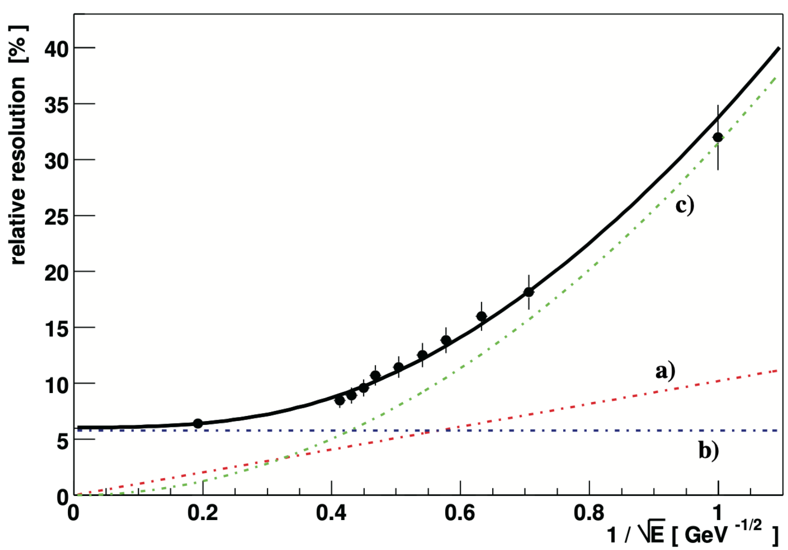

- Silicon tracker + Tungsten/Scintillator sandwich calorimeter + ToF
- Approximately 3m from the interaction point
- Modified (Al) beam-pipe shape kept material traversed to < 1 $X_0$
- Operational 1999-2000

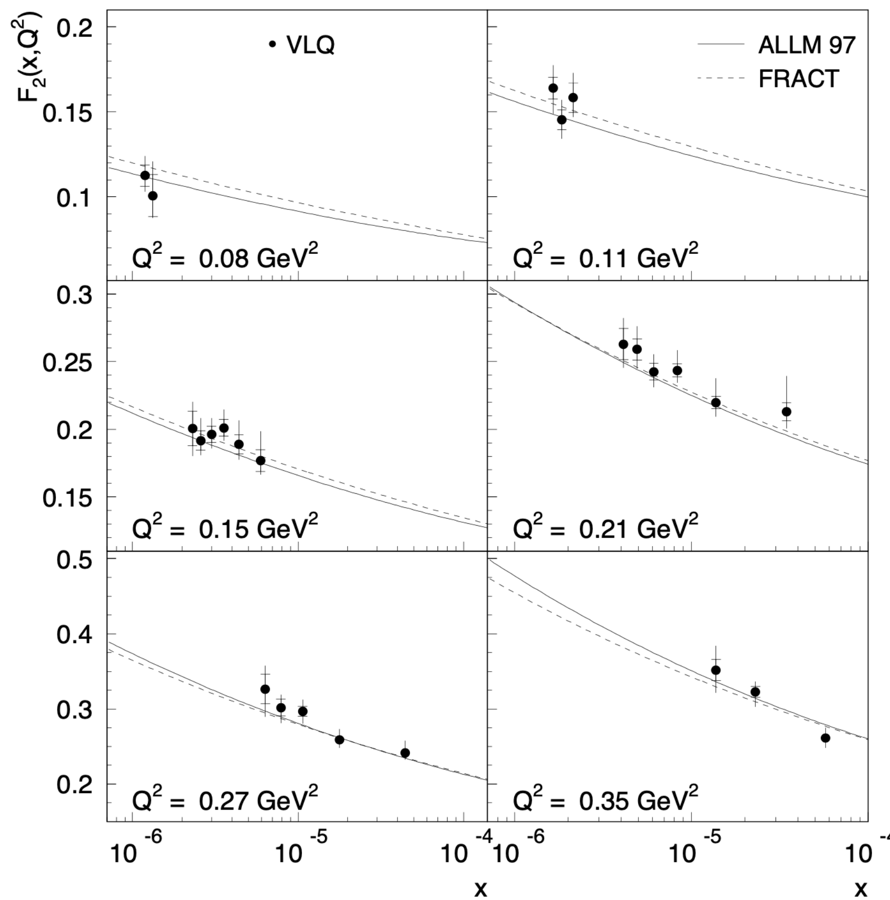
# H1 VLQ Spectrometer

34m downstream

3m downstream



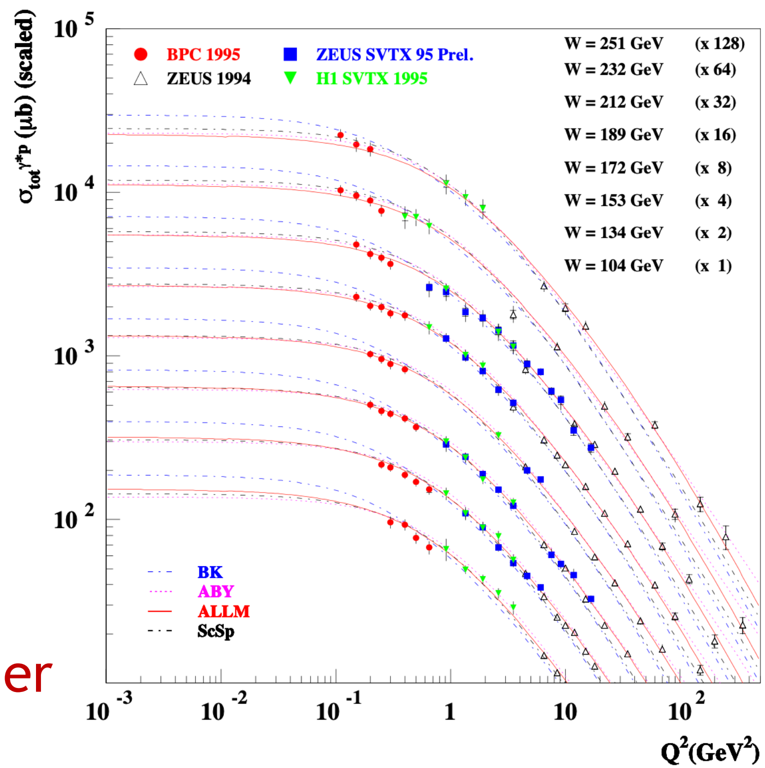




- Achieved ~5% resolution at kinematic peak
- Sensitivity to $Q^2 < 0.1\mathrm{GeV}^2$
- Results from Carlo Duprel PhD thesis (unplublished)

# Summary / Comments

- There are ways of reaching $Q^2 = 10^{-1}$ GeV$^2$ and approaching $10^{-2}$ GeV$^2$ …
  - → Maybe enough for many purposes (e.g. $\sigma_{tot}^{\gamma^* p}(W, Q^2)$ already flattens
  - → Reducing the beam energy is most powerful … but sacrifices high density physics
  - → Shifting the vertex can help
- Adding more near-beam instrumentation closer to interaction point could take us further




- So far, we just scratched the surface using particle gun simulations.
  - → Need detailed MC studies to study performance in presence of backgrounds and hadronic final state particles
  - → Influence of crossing angle?

From inclusive group Twiki

**Inclusive Physics in the Photoproduction Limit**

- **Description:** Investigate EPIC capabilities in the Q2->0 limit
  - Understand beam-line detector capabilities and background sources (liaison with far backward group)
  - Investigate, benchmark and optimise Monte simulations
  - Simulate inclusive photoproduction and evaluate achievable precision
- **Work Start:** Anytime
- **Expected Duration:** 6-12 months
- **Required Expertise:** Medium
- **Contact:** Paul Newman (paul.newman@cern.ch) & Claire Gwenlan (claire.gwenlan@physics.ox.ac.uk)