ZEUS UK Collaboration Status Report
— Part I —

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Outline

- HERA collider ***central*** to understanding of the hadronic structure of the ***proton*** and ***photon*** at ***high scales*** and bridges the gap between e^+e^- annihilation and $p\bar{p}$ collisions.
- HERA completes coverage of the standard model QCD sector, post-upgrade will also extend the spacelike electroweak sector.
- UK involvement ***central*** to the ZEUS physics effort...

- *Central Tracking Detector Status...*
  - *Performance.*
  - *Trigger.*
- *ZEUS UK Physics (Part I)...*
  - *Heavy flavour.*
  - *The hadronic final state in DIS.*
  - *Hard photoproduction.*

- *ZEUS Microvertex Detector...*
  - *Overview.*
  - *Online Alignment.*
  - *Clock and Control.*
  - *Patchbox and Installation.*
  - *Trigger.*
- *Summary and Outlook.*

Central Tracking Detector Performance

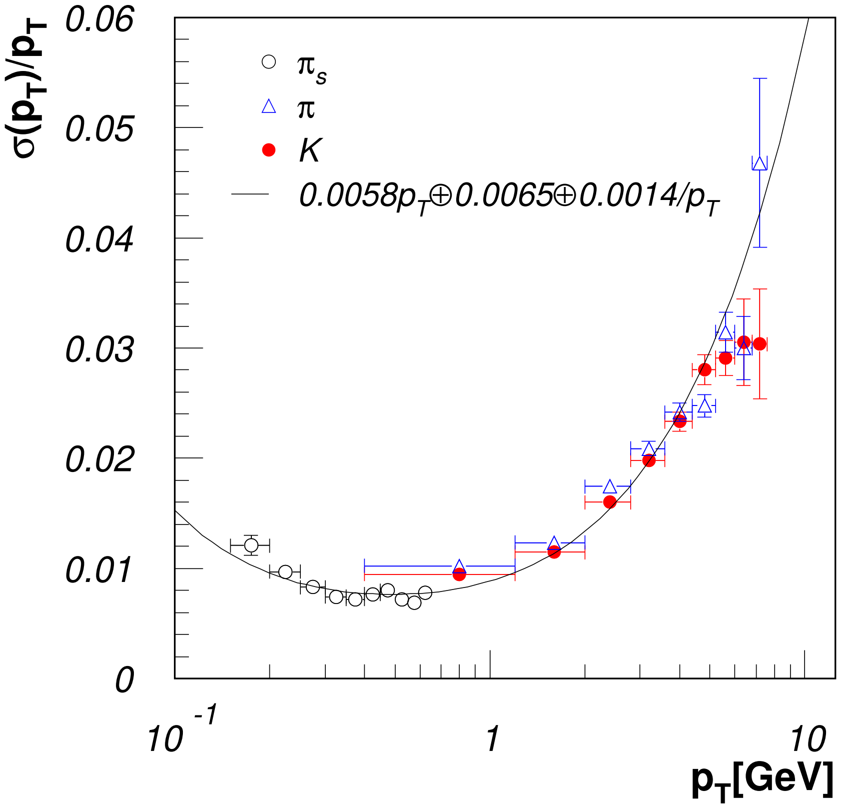
- The CTD is a large cylindrical drift chamber...
  - ▷ 5 layers of **axial** wires for $r - \phi$ reconstruction.
  - ▷ 4 layers of **stereo** wires for z reconstruction.

- **Essential** for physics analyses at ZEUS...
  - ▷ Provides charged particle detection,

$$\sigma(p_T)/p_T = 0.0058 p_T \oplus 0.0065 \oplus 0.0014/p_T$$

  - ▷ Provides event vertex – offline, and for Second and Third Level Trigger,

$$\sigma(z_{\rm vtx}) = 2\text{mm};\ \sigma(x_{\rm vtx}, y_{\rm vtx}) = 1\text{mm}$$



ZEUS **does not take data** without the CTD!

ZEUS CTD Performance

CTD has functioned reliably over the last 8 years.

- *Increased understanding of chamber performance*
  - *Hit resolutions are stable* – $\sigma(r-\phi) \sim 230\mu\mathrm{m}; \quad \sigma(z) \sim 500\mu\mathrm{m}$
  - *Better simulation of detector response.*

- *Better understanding of dE/dx for physics...*
  - *Improved background rejection in heavy flavour analysis.*
  - *Semi-leptonic heavy flavour analysis.*

- *Continuing effort essential to monitor CTD Data Quality...*
  - *DQM now WWW based, now monitored* ***from the UK*** *and DESY.*
  - *Increased* ***automation****, more efficient, faster identification of possible problems.*

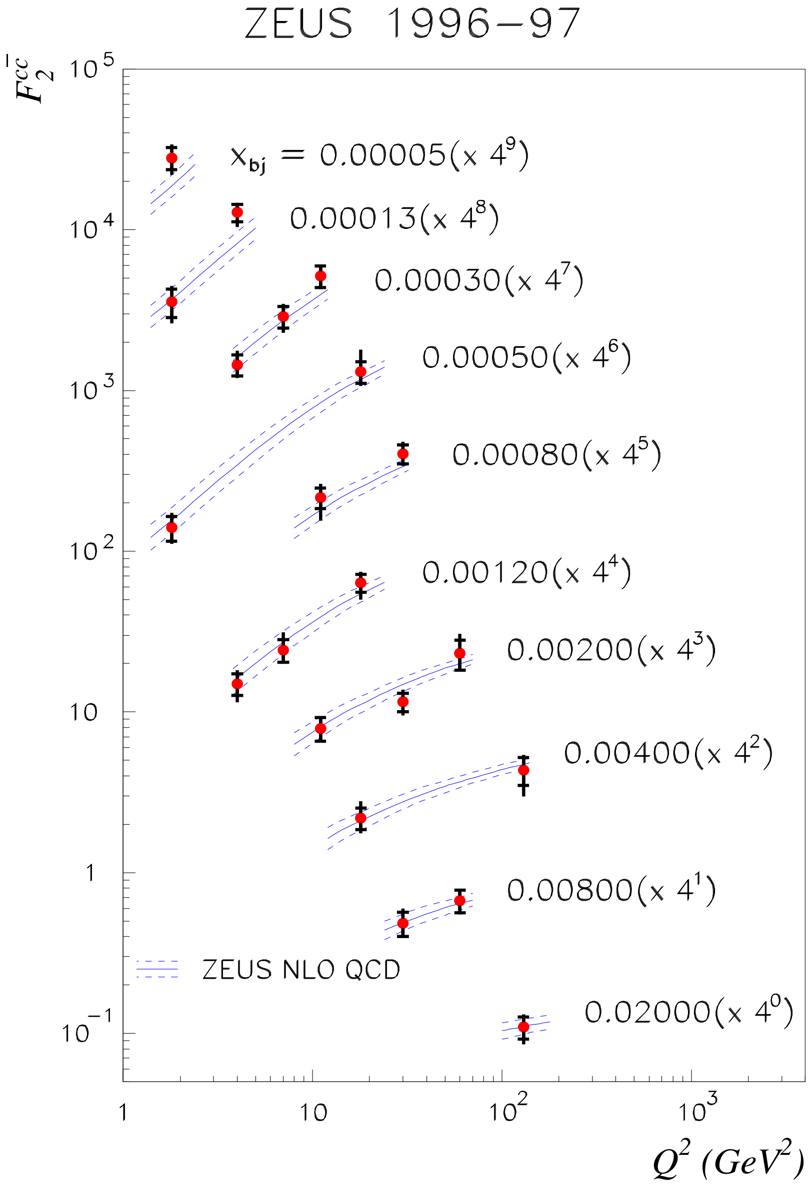
- *Continuously reviewing software and running procedure...*

ZEUS CTD Trigger

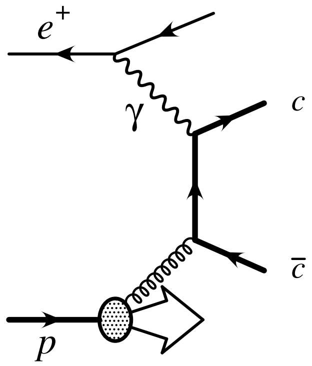
ZEUS – Three level trigger for selection of interesting events from ep interactions, essentially dead-time free (96ns bunch crossing).

- Powerful background rejection ∼10KHz FLT input rate to ∼5Hz physics rate at TLT.
- CTD Stand-alone component Triggers for First and Second Level.
  - ▷ CTD FLT – track information required in most Global First level Triggers.
  - ▷ Transputer based CTD SLT provides event vertex within ∼12ms of GFLT decision.
- Complete ZEUS information available at the Third Level Trigger
  - ▷ complete tracking information – **online** reconstruction of D^* and J/ψ mesons etc.
- Existing ZEUS trigger OK for after HERA upgrade, but...
- Ongoing plan to develop Global Tracking Trigger...
  - ▷ combine CTD information with that from **new**, post-upgrade detector components (MVD, STT).

Heavy Flavour Production - $F_2^{c\bar{c}}$

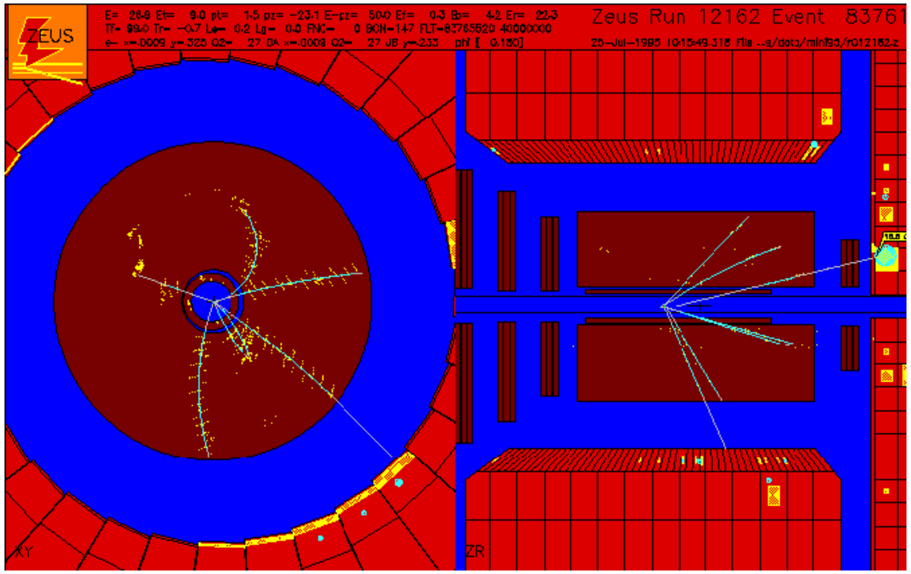


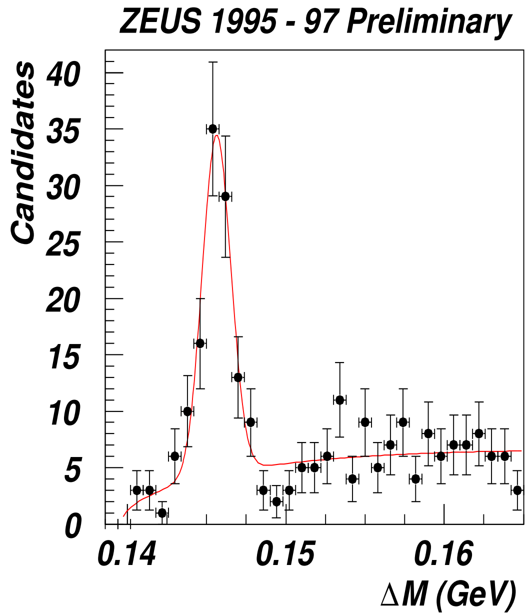
- *Contribution to F_2 from **charm** production.*
- *Dominant process BGF diagram.*
  - ▷ *sensitive to gluon structure of proton.*
  - ▷ *Large ($\sim$20%) contribution to F_2 at this Q^2.*



- *Significant improvement over previous HERA measurement.*
  - ▷ *Agrees with fixed order QCD.*
- *Further significant improvement expected following HERA upgrade.*

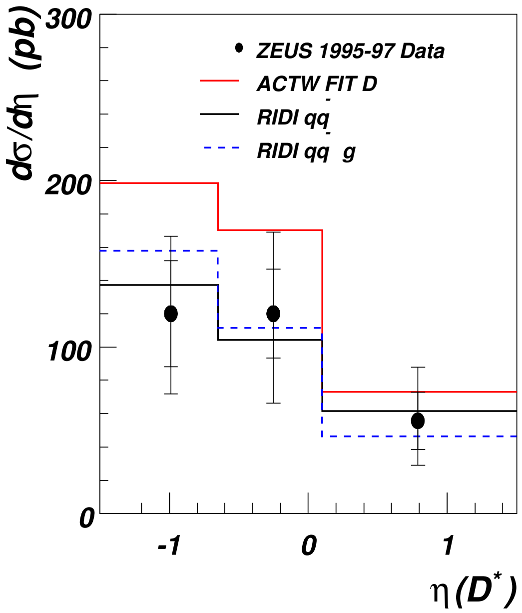
Heavy Flavour Production - Diffractive D^* Production

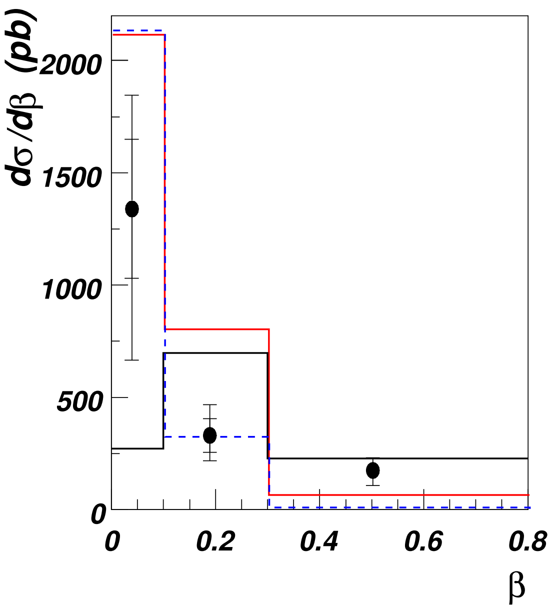




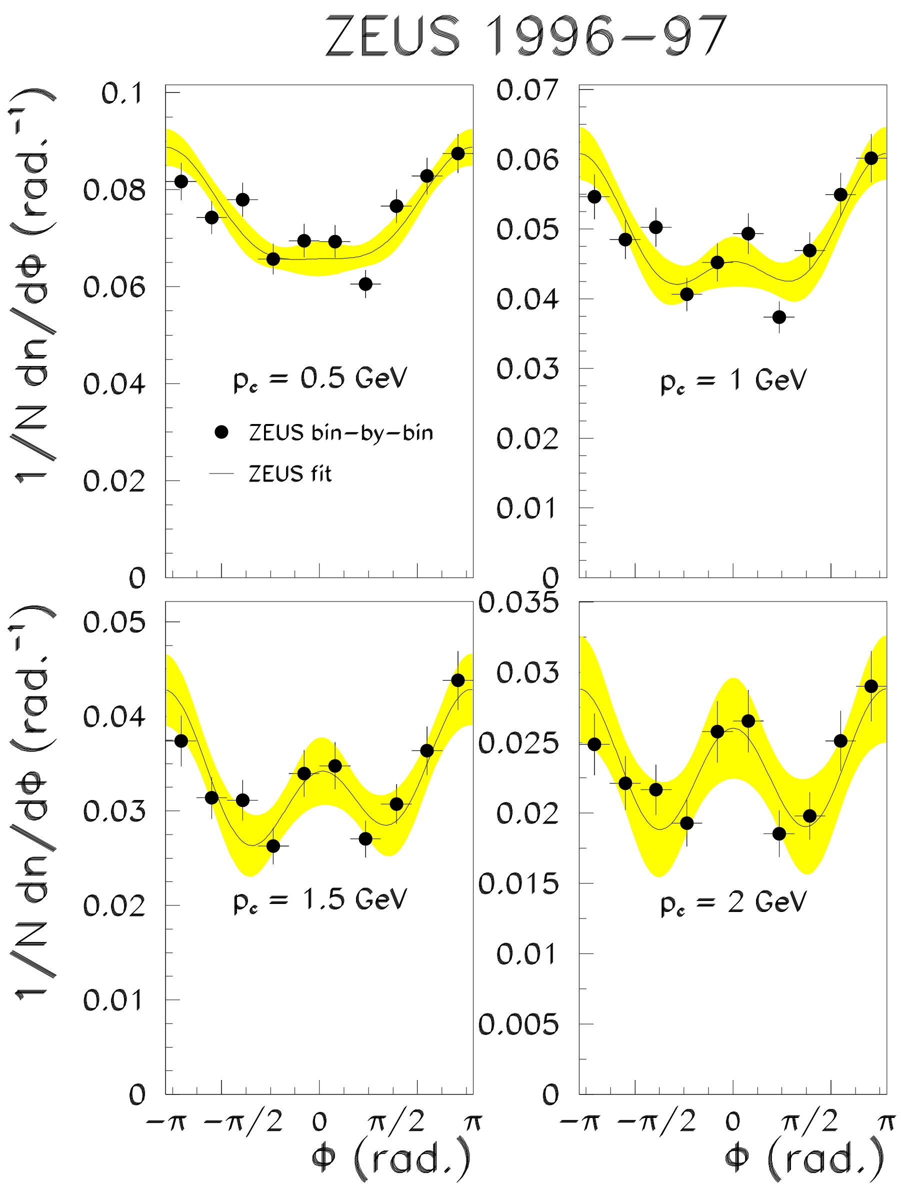
- *Charm production sensitive to the gluon...*
  ⇒ *provides information on underlying diffractive mechanism.*

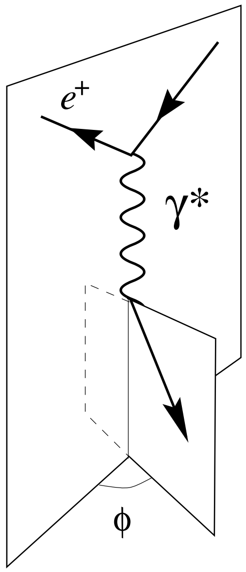
- *Clear diffractive signal in diffractive events with large forward rapidity gap.*





Charged Particle Asymmetries in DIS





- Particle angle, ϕ in the hadronic centre-of-mass as a function of lower momentum threshold, p_c.

- Distribution of the form

$$\frac{1}{N}\frac{dn}{d\phi} = A + B\cos\phi + C\cos 2\phi$$

predicted by QCD.

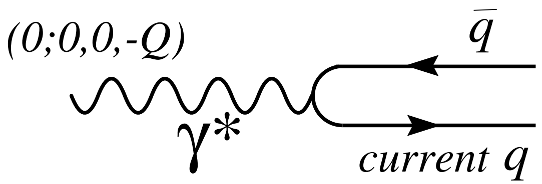
- Non-perturbative effects small for $\cos 2\phi$ term.

- At higher p_c see first observation of clear $\cos 2\phi$ contribution.

➡ Clear evidence for asymmetry arising from from perturbative QCD.

Event Shapes in DIS

- *Breit frame: entirely space-like photon,*



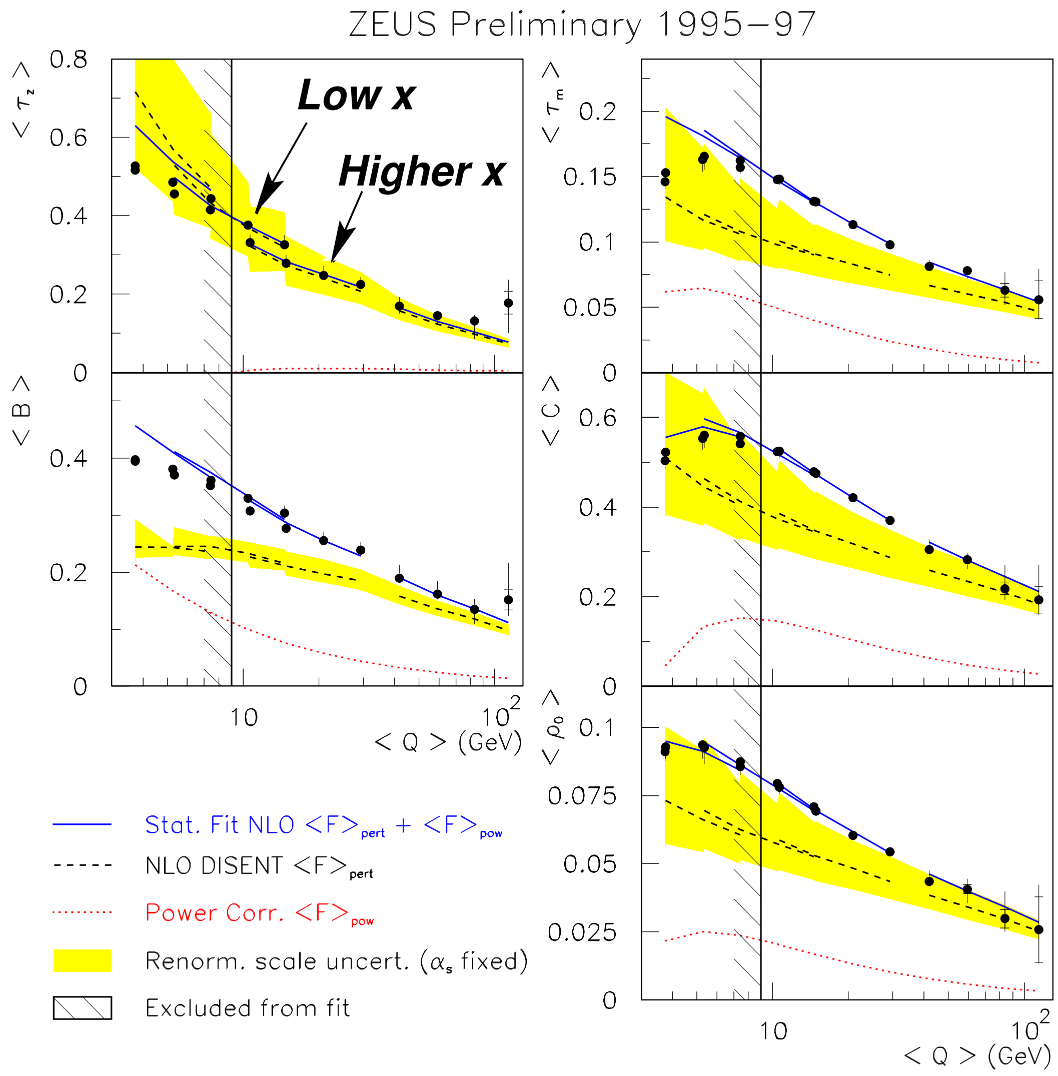
  - ▷ *current fragmentation region resembles 1 hemisphere of e^+e^- annihilation.*

- *Test universality of Power correction models*

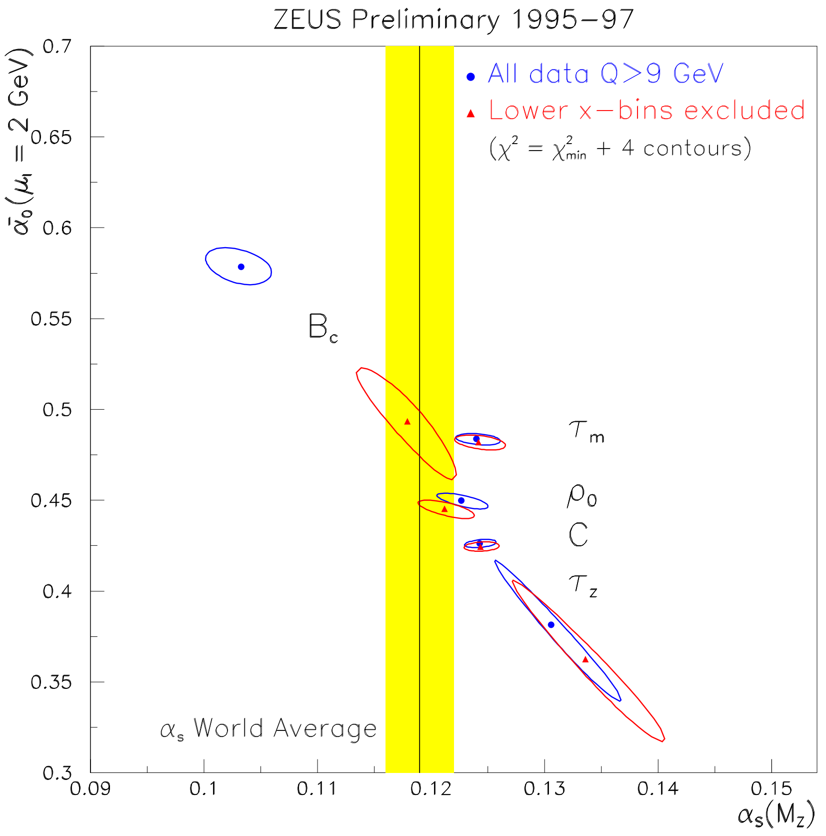
$$< F > = < F >^{\mathrm{pert}} + < F >^{\mathrm{pow}}$$

of the form $1/Q^p$.

- *Variation over 4 orders of magnitude of Q^2 allows the study of the scale variation in a single experiment.*



Event Shapes in DIS



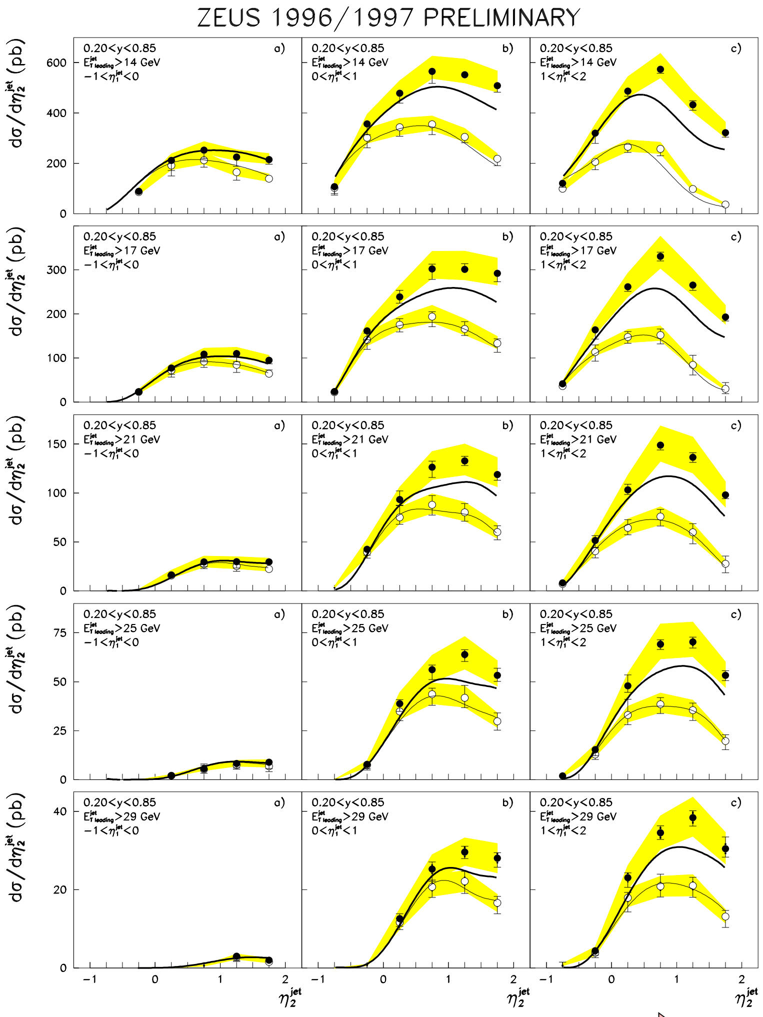
- *Power correction characterised by parameter* $\bar{\alpha}_{p-1}(\mu^2)$.
- *Fit power correction with* $p = 1$, *of the form*

$$< F >^{\mathrm{pow}} = a_F \frac{32\mathcal{M}}{3\pi^2 p} \left\{\frac{\mu_I}{Q}\right\}^p \times \left[\bar{\alpha}_{p-1}(\mu^2) - \alpha_s(Q^2) - \frac{\beta_0}{2\pi}\alpha_s^2(Q^2)...\right]$$

simultaneously for $\bar{\alpha}_0(\mu^2)$ *and* $\bar{\alpha}_s(\mu^2)$.

- *Values of* $\bar{\alpha}_0(\mu^2)$ *reasonably consistent with LEP expectation.*
  ⇒ *possible differences due to observed* x *dependence.*

High E_T Dijet Photoproduction

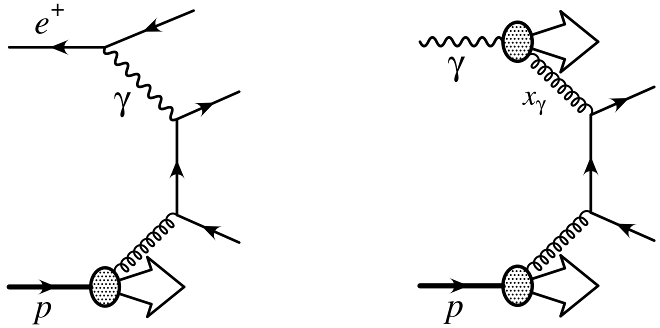


low E_T^{jet1}

high E_T^{jet1}

forward η_{jet1}

- *In Resolved photoproduction, photon acts as a source or partons carrying momentum fraction* x_γ*...*

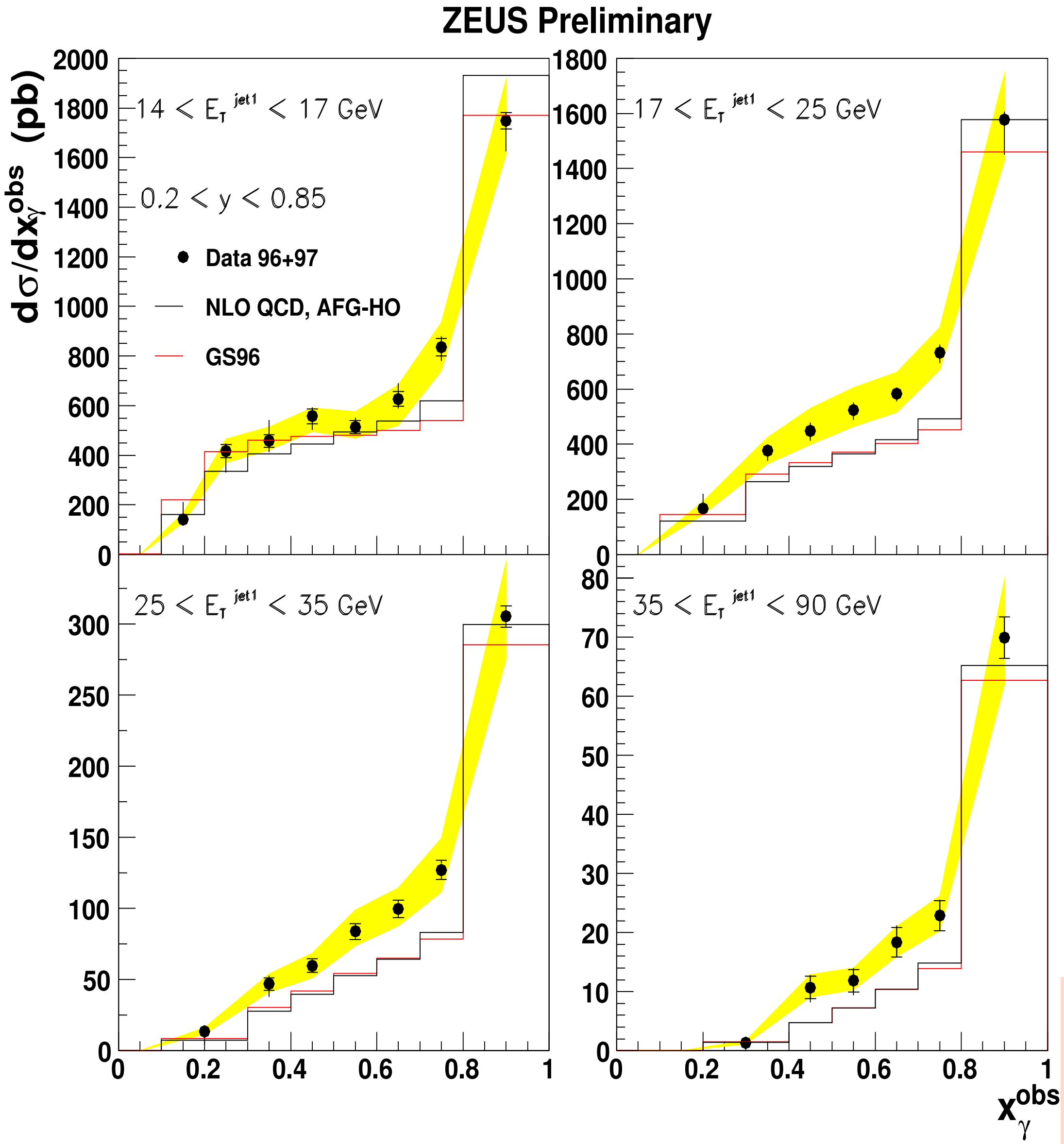


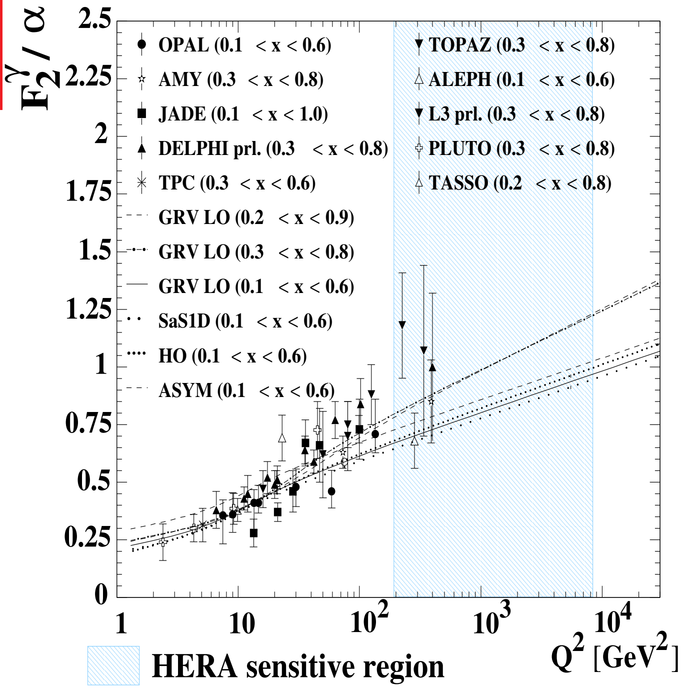
Direct　　　　Resolved

⇒ *sensitive to hadronic structure of photon.*

- *Comparison with NLO calculation at parton level.*
- *Lower curve, "direct" –* $(x_\gamma^{\rm OBS} > 0.75)$*, Upper curve, total cross-section.*
- *Predicted "resolved" cross-section too low for intermediate and forward* $\eta^{\rm jet}$.

NLO Comparison – the x_γ^{OBS} Distribution

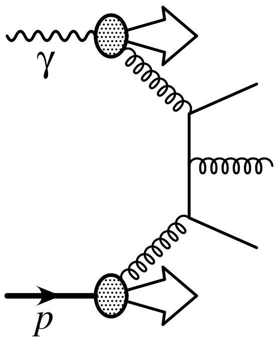




- *Probe photon structure at scales **higher** than accessible elsewhere.*
  - *gluon in photon effectively unconstrained by LEP data.*
  - *HERA directly sensitive to gluon.*
  - *Predicted low $x_\gamma^{\rm OBS}$ cross-section below the data.*

- *None of the available γ-pdf's describe **"resolved" cross-section** at high E_T ⇒ require new γ-parton density global fit.*

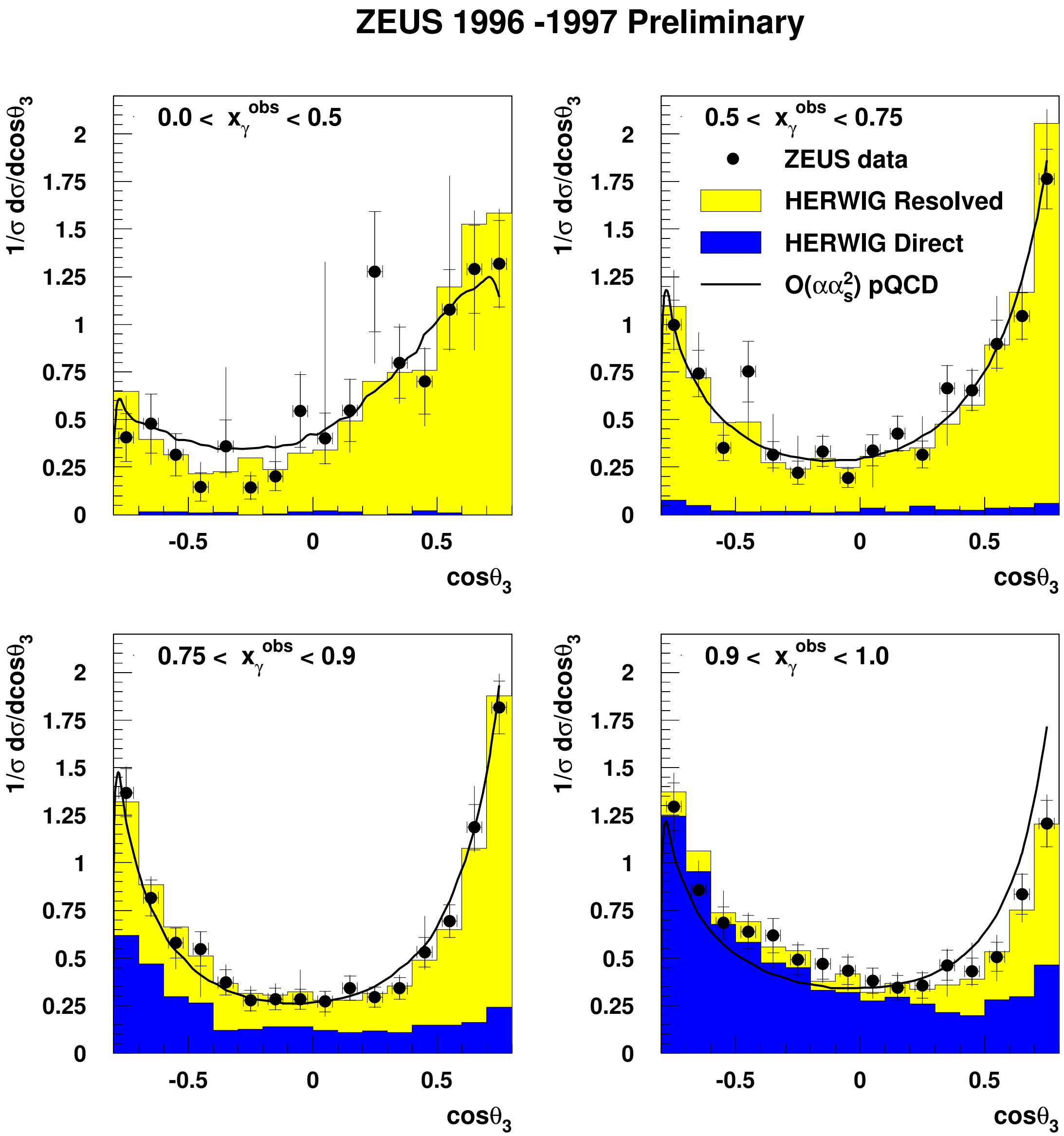
Multi-Jet Photoproduction



- Multi-jet production $\mathcal{O}(\alpha\alpha_s^2)$ to Leading Order...
- Sensitive to dynamics of QCD hard sub-process.
- $\cos\theta_3$ – angle of leading jet in three-jet CMS.
  - ▷ more forward for low $x_\gamma^{\rm OBS}$.
- $\mathcal{O}(\alpha\alpha_s^2)$ ***shape*** in reasonable agreement with data.

  ▷ suggests dynamics of hard-subprocess well understood.

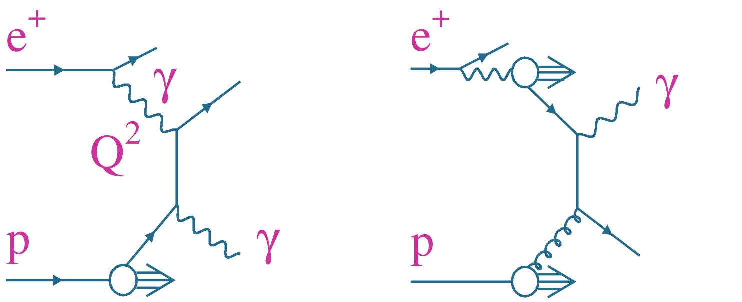
  ⇛ Supports γ-structure conclusion from dijet data.



Prompt Photon Production

*High E_T prompt photon observed in final state, couples **directly** to (QCD) hard subprocess.*

➡ ***Less** sensitive to hadronization and the gluon in the photon, **more** sensitive to intrinsic k_T effects.*

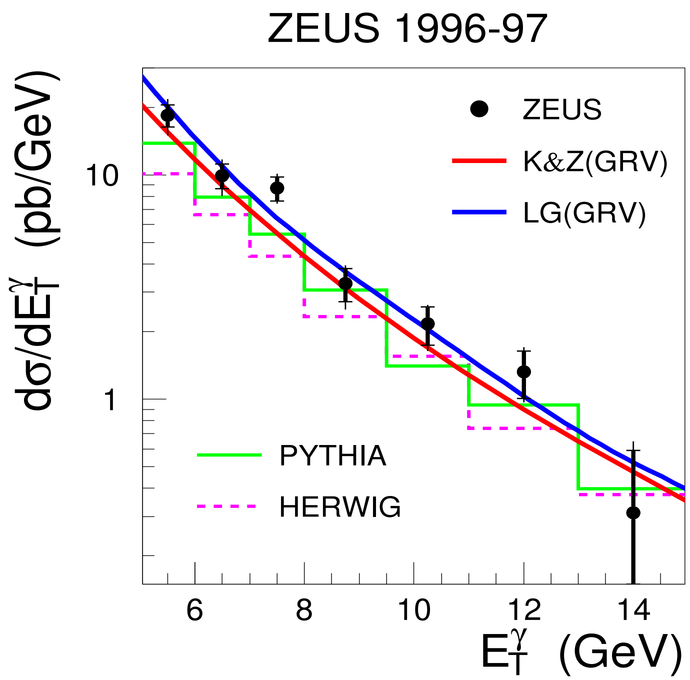


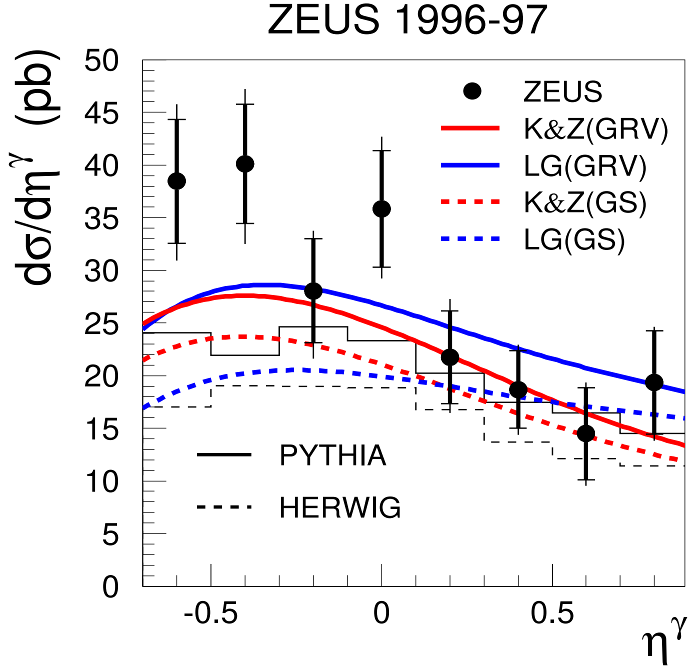
Direct process   Resolved process

- *NLO parton level calculations...*
  - ▷ *Gordon,*
  - ▷ *Krawczyk and Zembrzuski.*

- *NLO theory lies below the data for backward going η_γ.*

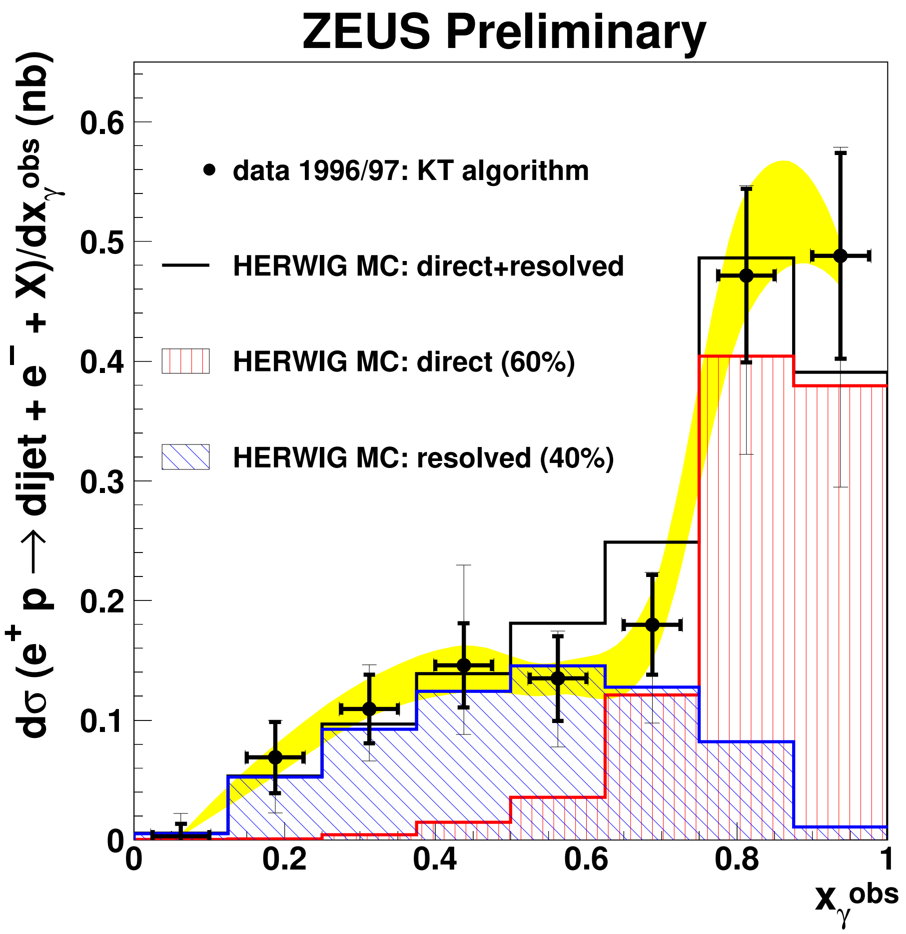
  ➡ *Discrepancy due to initial state soft gluon emission or intrinsic k_T effects?*

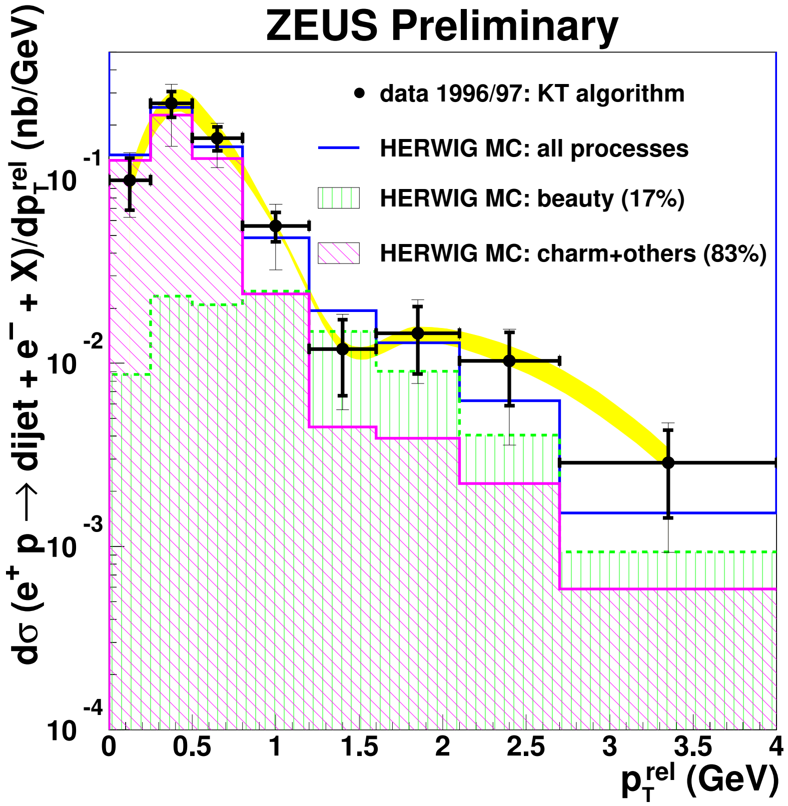




Heavy Flavour Dijet Photoproduction

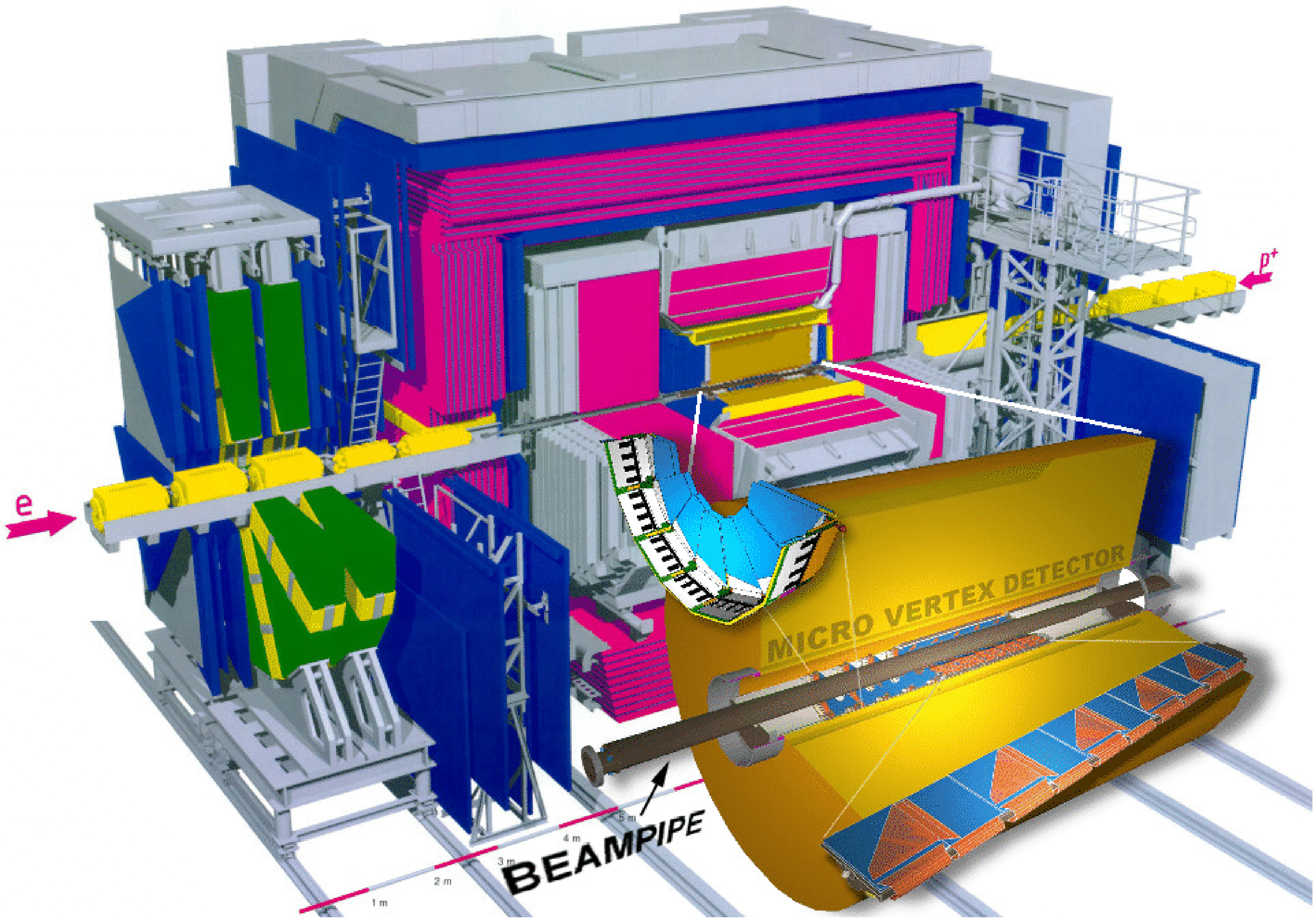
- *Role of $b\bar{b}$ production in $p\bar{p}$ collisions not well understood.*
- *Heavy quark contribution to structure of the **photon** not well constrained.*





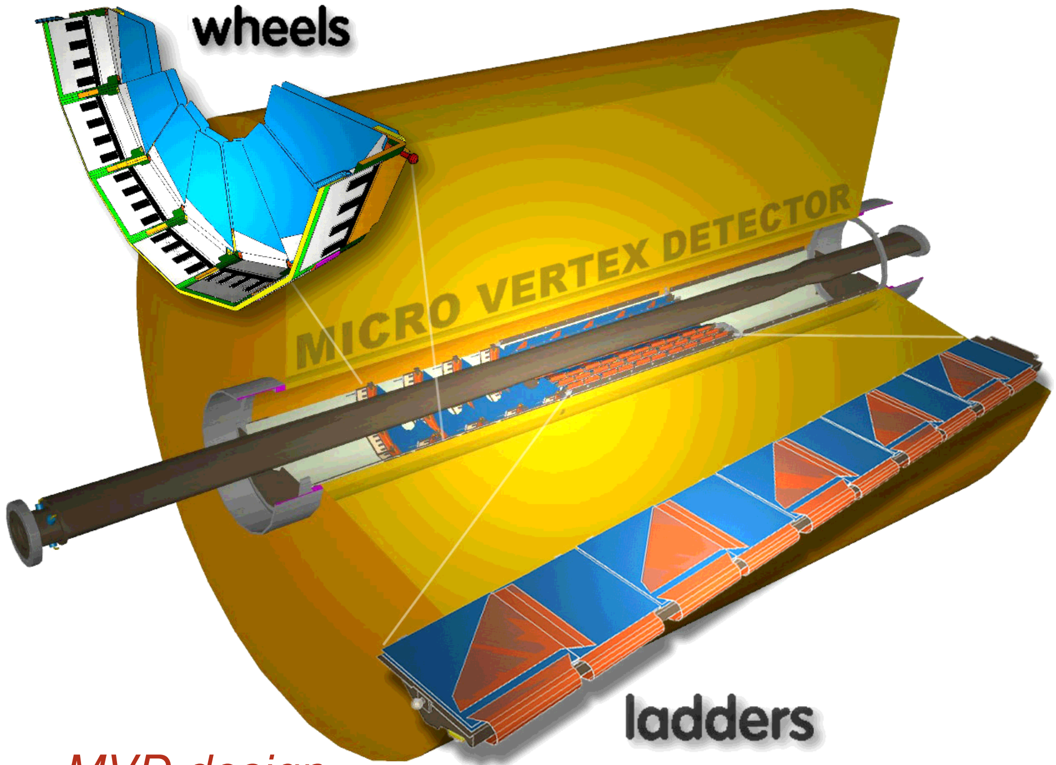
- *Electrons from semi-lepton heavy meson decays tagged using dE/dx.*

- *Sensitive to b-quark production.*
  - ▷ *large (17%) b-quark contribution.*
- *Large resolved photoproduction component.*



The ZEUS Detector

ZEUS Microvertex Detector



- *MVD design...*
  - ▷ up to 3 layers of Si-wafers in Barrel.
  - ▷ up to 4 layers in Forward Wheels.
  - ▷ acceptance 7°-170°, IP resolution $\sim$100μm.

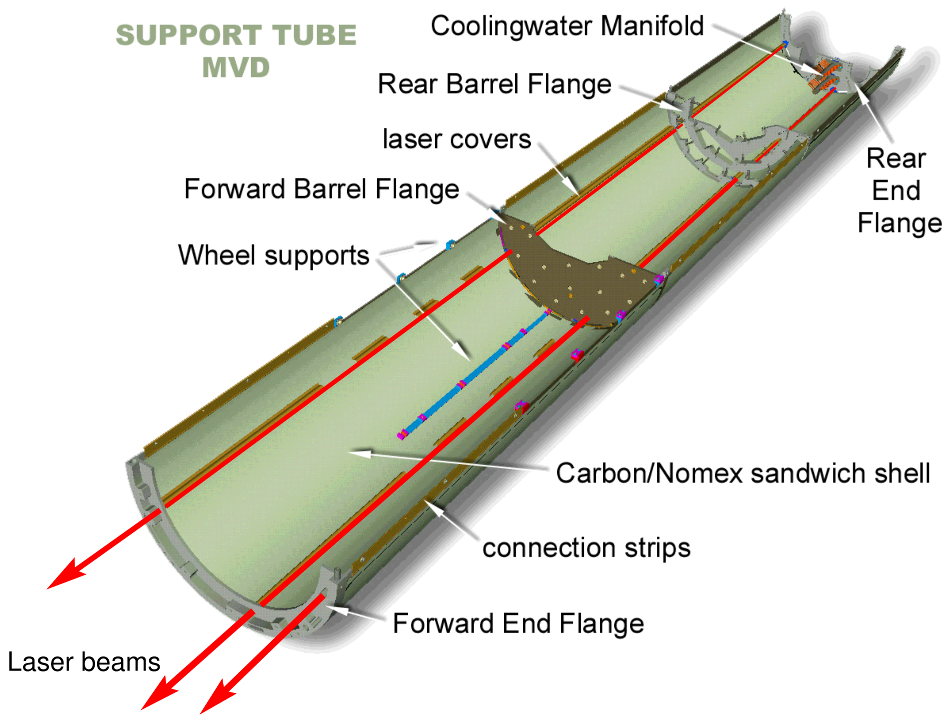
Physics motivation...

- *Detect presence of long-lived particles in the final state...*
  - ▷ high precision determination of gluon and heavy quark densities in **proton** and **photon**.

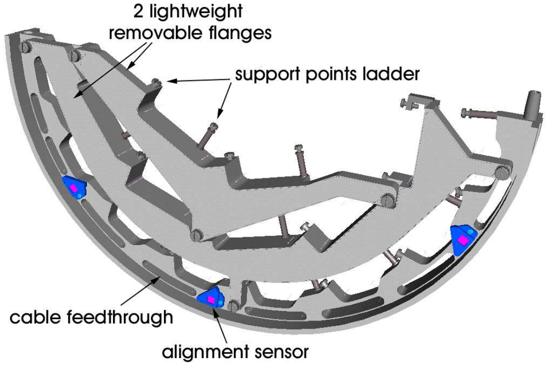
    ➡ pin down treatment of a heavy parton in target hadron.
  - ▷ gluon jets in final state of **hadronic** interactions.
- *Significantly improve tracking acceptance and resolution...*
  - ▷ outgoing lepton in high Q^2 NC DIS.
  - ▷ isolated high p_T particles.

- *Detector construction well underway – on schedule for installation early 2001.*

Microvertex Detector – Laser Alignment System



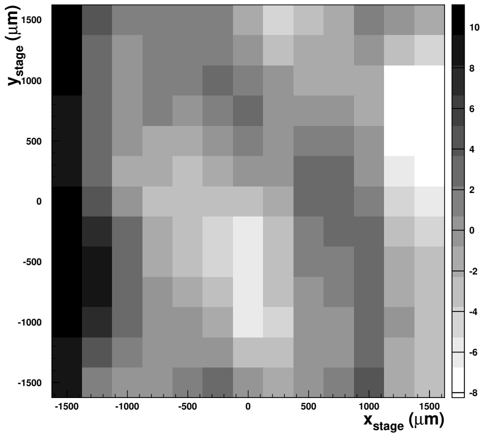
- *Measure MVD support structure position relative to the CTD to 20μm or better.*
- *Define periods of stability for offline tracking alignment (intrinsic MVD Si hit resolution $\sim$8μm).*
- *Monitor MVD Support structure during construction and transportation.*

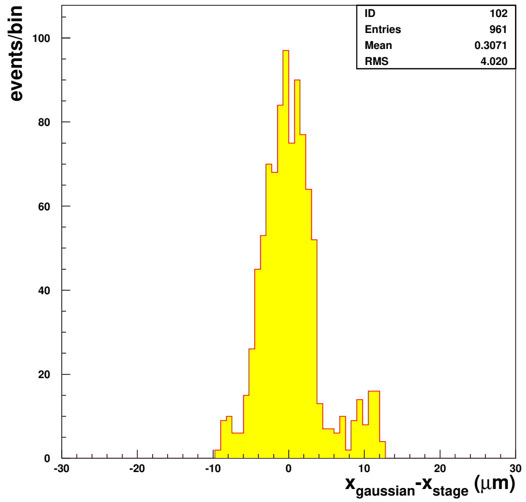


- *Five laser paths, each with up to 6 position sensors mounted on MVD support structure (2 reference sensors on CTD).*
  - ▷ *5mm$\times$5mm amorphous Si photo-diodes 16 readout strips in each of x and y.*

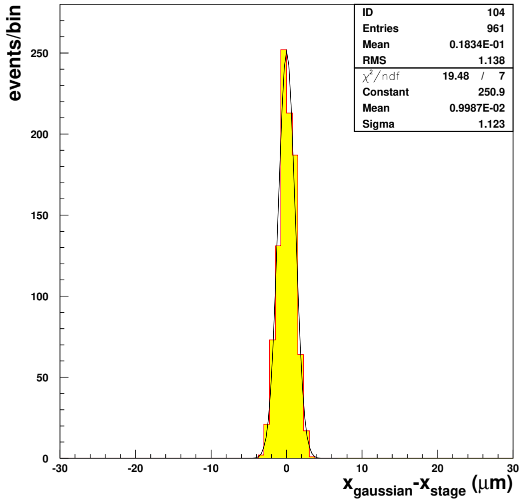
Microvertex Detector – Alignment System Resolution

- *Raw sensor resolution – 9μm*
  - ▷ *correct for sensor "orientation"* ➡ *4.0μm.*
- *map residuals using precision optical stage – 250$\times$250μm grid spacing...*
  - ▷ *Use residual "maps" to correct positions,* ➡ *resolutions 1.2μm in x and y.*

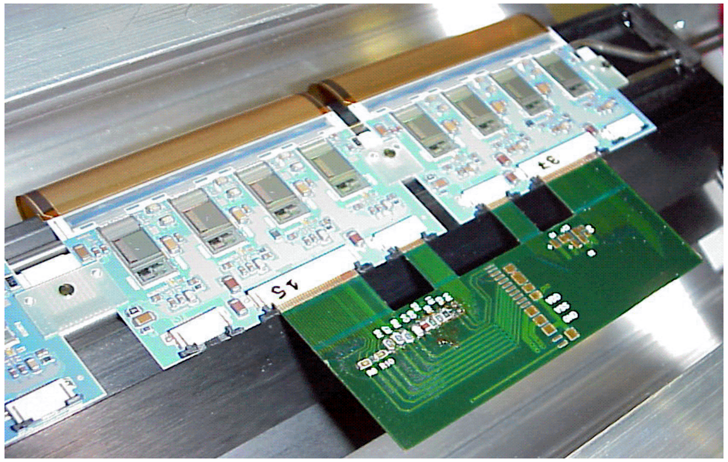




- *Final lasers and optics developed and delivered.*
- *Custom (20m kapton) cables complete. Sensors under construction, installation on support structure later in June.*
  - ▷ *Necessity to develop laser system and custom cables lead to cost overrun.*
- *Loading tests already performed with up to 6 sensors on support structure at NIKHEF.*



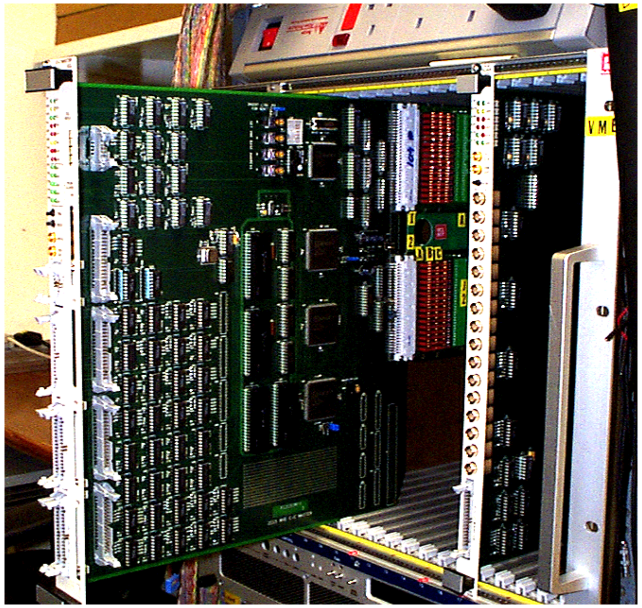
Microvertex Detector – Clock and Control



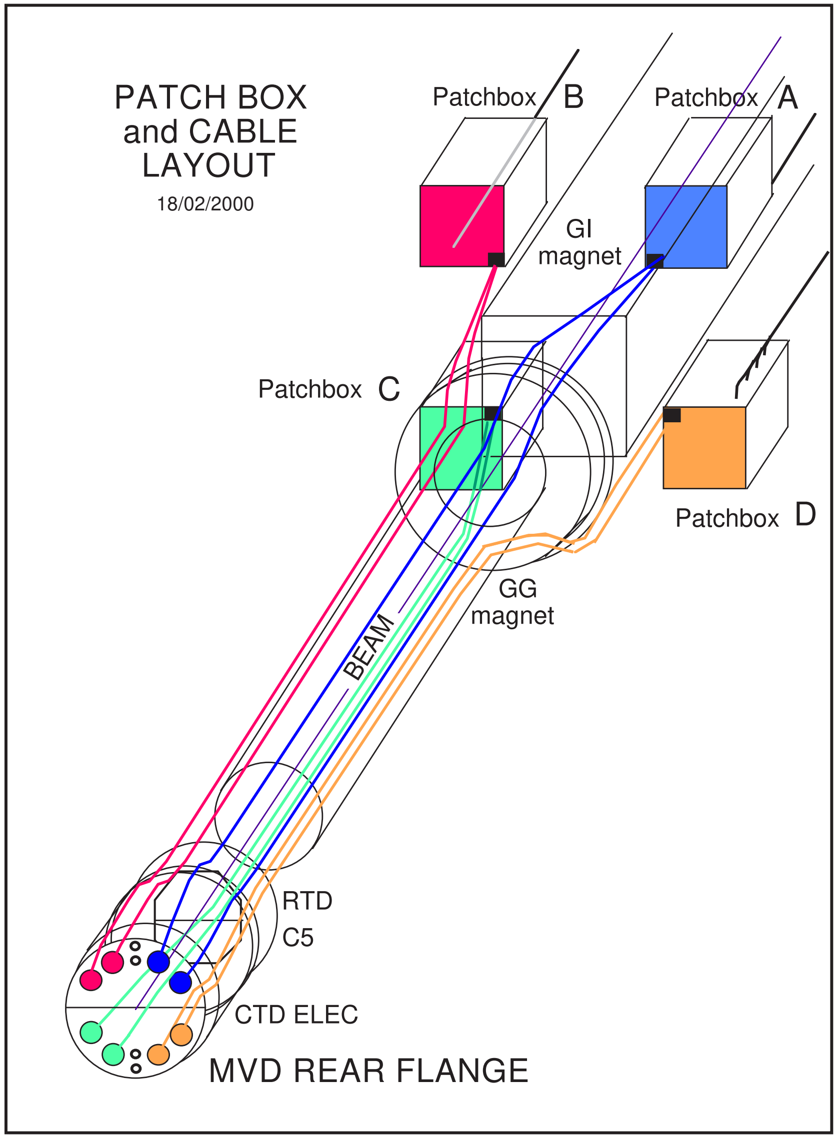
- HELIX3.0 analogue readout chips mounted directly on Si-detectors.
  - ▷ store MVD signals, readout only on a GFLT accept.
- HELIX Driver prototype board under test – design of final board almost complete.

- C+C distributes HERA clock and GFLT decision to HELIX readout and ADC system and interfaces ADC back to the GFLT.

- C+C Master and Slave boards completed and tested at UCL...
  - ▷ delivered to DESY ready for testing with ADC readout.



Microvertex Detector – Patch box and Installation

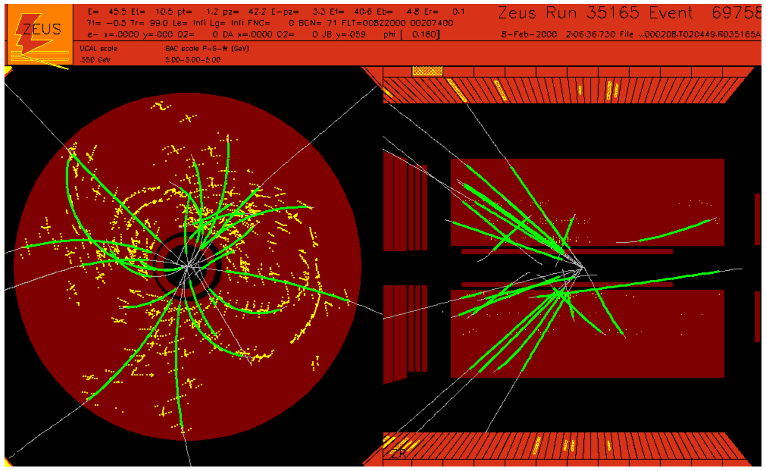


- *Off detector electronics (ADC system, HELIX driver etc) situated 24m from detector.*
  - *After installation access to rear of MVD not available.*
    ⇒ Patch boxes 4m from MVD, inside main ZEUS detector.
  - *Grown out of UK responsibility for Installation and Clock and Control.*
- *Complicated by very restricted space, and need for active components.*

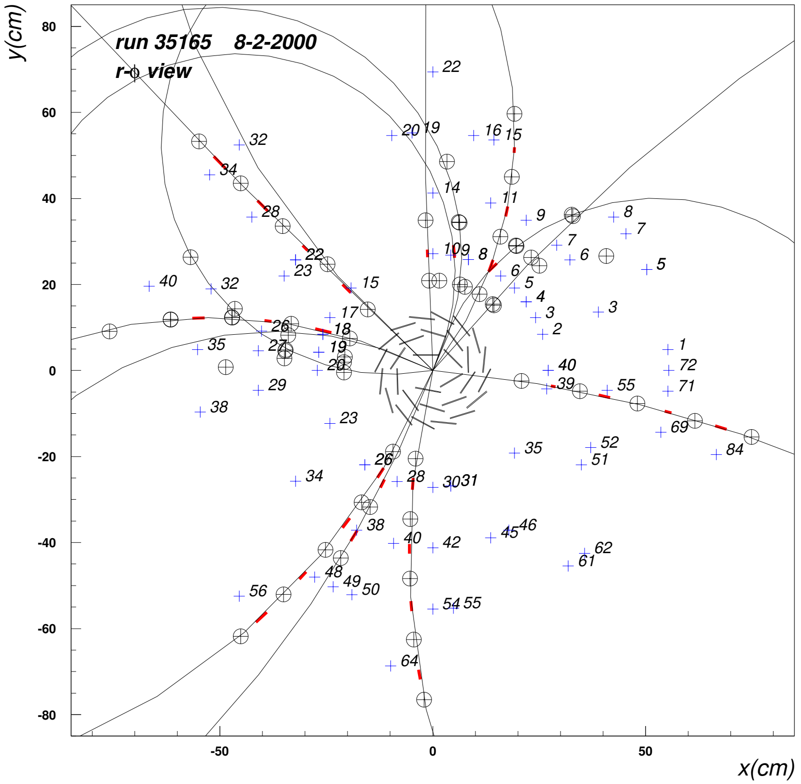
> *⇒ Not part of original request, but **essential** – estimated cost £ 35,000.*

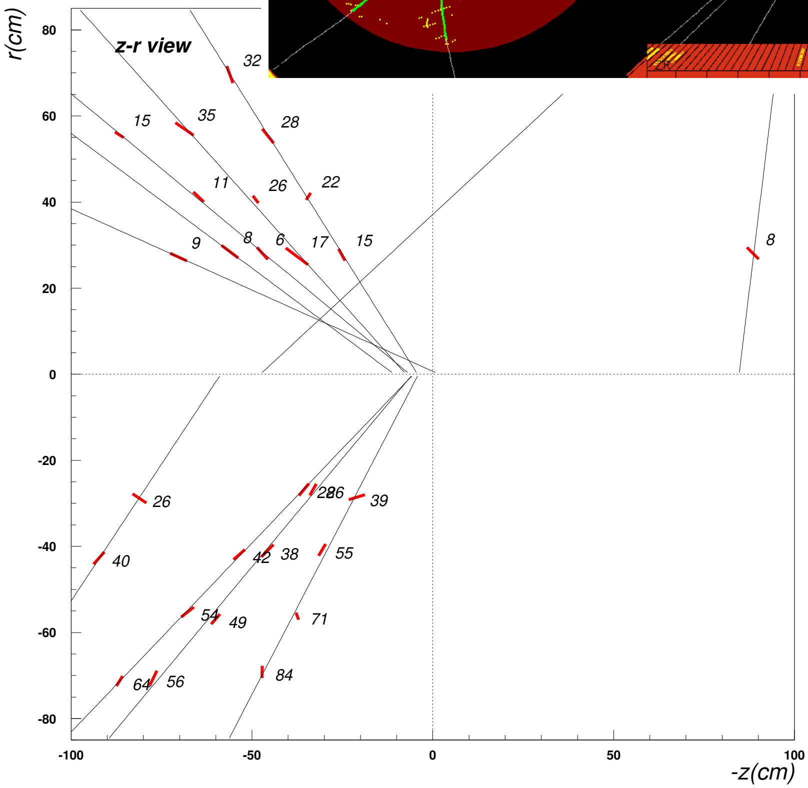
- *Installation procedure...*
  - *MVD and 4m cables rolled through CTD from the front using custom apparatus.*
  - *Apparatus – design complete and under construction.*

Microvertex Detector – Global Tracking Trigger



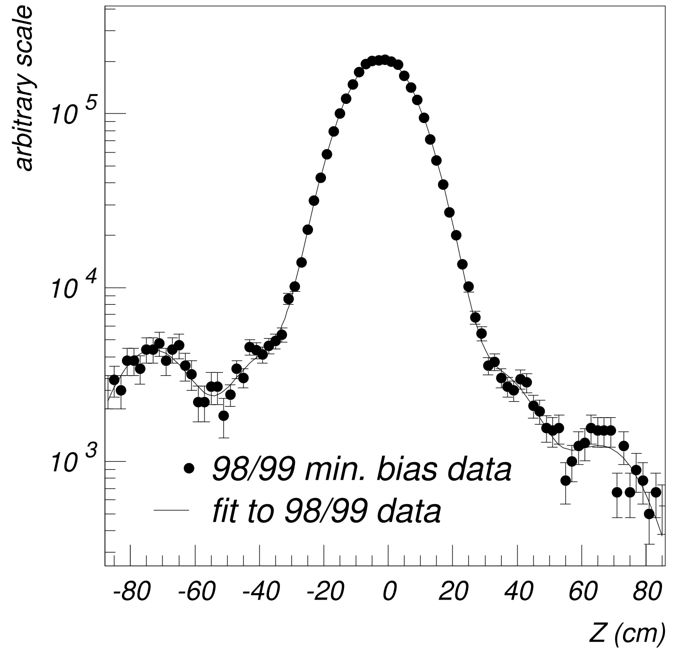
- *Combined Second Level Trigger using information from CTD, MVD and new forward tracker (STT).*
  - ▷ *Decision required within existing CTD latency.*
  - ▷ *Utilise CTD stereo data.*

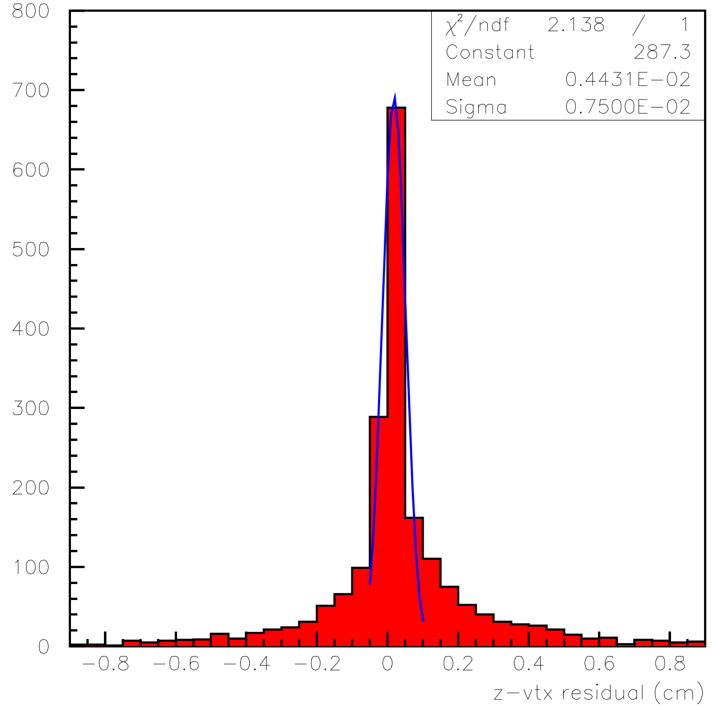




Microvertex Detector – Global Tracking Trigger

- *Broad interaction region, width σ_z ~11cm from proton bunch length.*
  - ▷ *Current CTD-SLT event z-vertex resolution ~9cm.*
- *GTT development algorithm vertex resolution...*
  - ▷ *CTD only mode ~1cm.*
  - ▷ *Include nominal MVD information ~100μm.*





- *Current development algorithm performance...*
  - ▷ *Mean processing latency better than 4ms on a 450MHz PIII (current CTD-SLT latency ~12ms).*

Summary and Outlook – (Part I)

- CTD Vital to physics analysis at ZEUS.
- Leading UK involvement in a rich physics programme...
  - ▷ Heavy flavour production.
  - ▷ The hadronic final state in DIS.
  - ▷ Photon structure.
- Vital UK involvement in ZEUS MVD project...
  - ▷ Alignment, Clock and Control, Trigger and Installation.
- HERA upgrade will provide five-fold increase in luminosity.
  - ▷ Maximise physics potential after the upgrade by building upon current UK expertise.
  - ▷ MVD project will allow precision measurements of heavy quark production in DIS and photoproduction.

    ⇒ pin down heavy flavour structure of proton and photon.
- Physics potential for proton structure and electroweak ⇒ next presentation...