30^{th} April 2002 - 4^{th} May 2002

Study of Virtual Photon Structure in Charm Production

DIS 2002 - Cracow, Poland.

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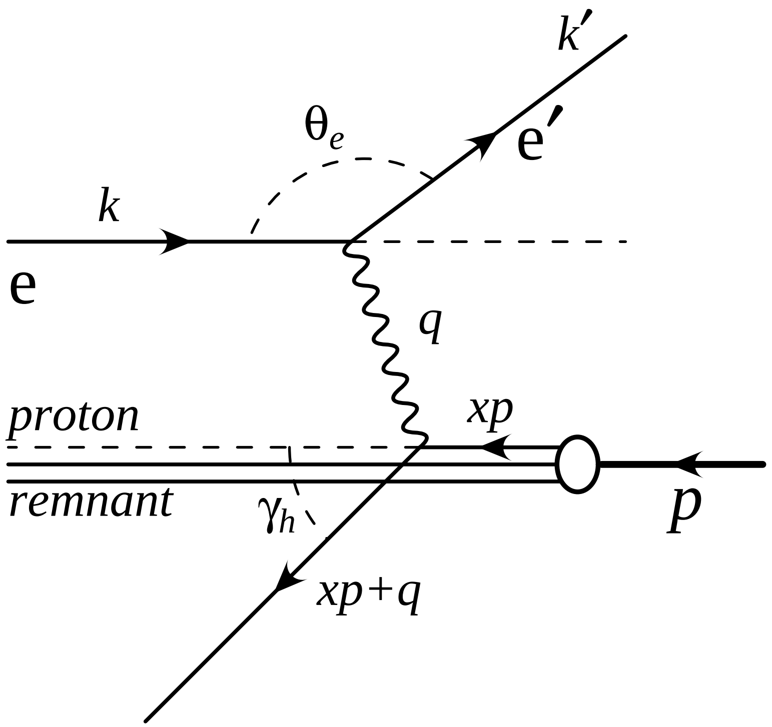
Introduction

- Photon Structure.
- Charm in the Photon.
- Results and comparisons with LO pQCD.
- Summary

Introduction

▷ **HERA collides 27.5 GeV $e^{\pm}$ with 920 (820) GeV protons**

$$\rightarrow \sqrt{s} = 320\ (300)\ \mathrm{GeV}$$



$$ep \rightarrow e^{'}X$$

Q^2 photon virtuality

$$Q^2 \equiv -q^2 = -(k - k^{'})^2$$

x fraction of proton's momentum carried by struck parton

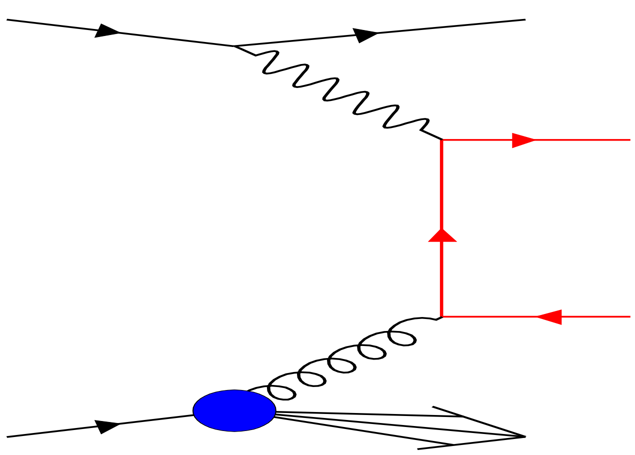
$$x \equiv \frac{Q^2}{2p.q}$$

y inelasticity

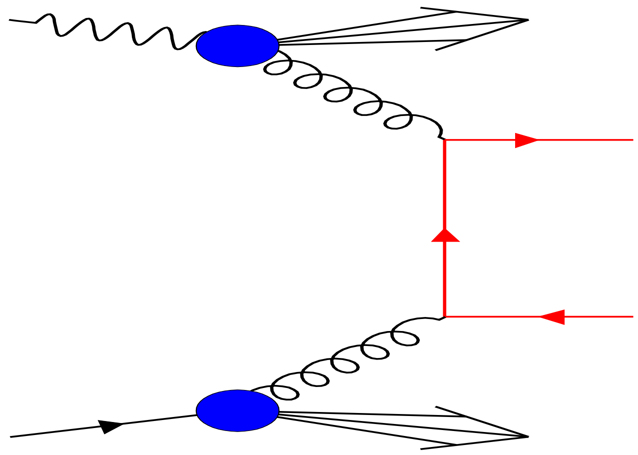
$$y \equiv \frac{q.p}{k.p}$$

Photon Structure

- The need for a photon structure has been well established at leading order.
- Photon interactions can be classified as Direct or Resolved.



BGF Direct



Gluon Resolved

- Experimentally we define x_γ^{obs} to differentiate between the two regimes at all orders.

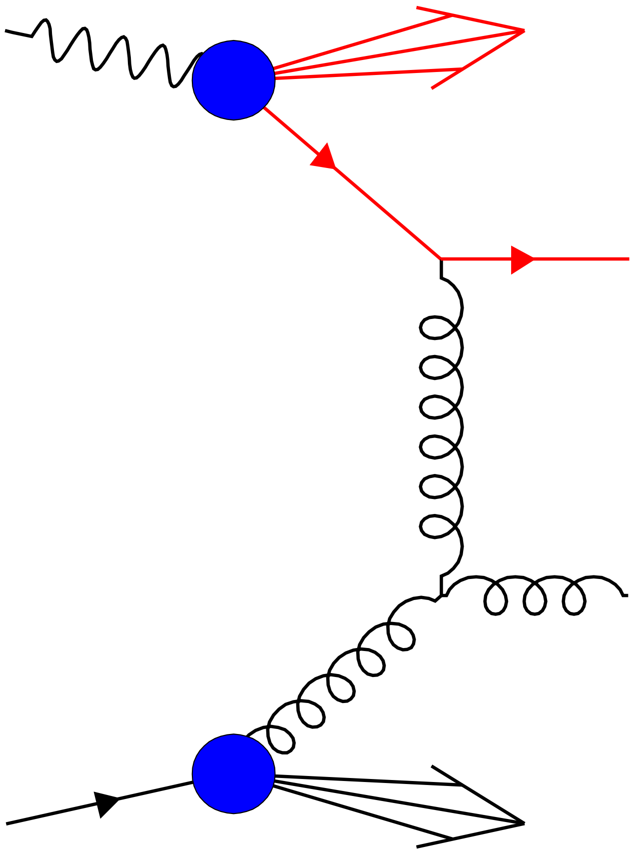
$$x_\gamma^{\mathrm{OBS}} = \frac{\Sigma_{jets} E_T^{jet} e^{-\eta^{jet}}}{2yE_e}$$

x_γ^{obs} < 0.75 ▷ "Resolved-Like"

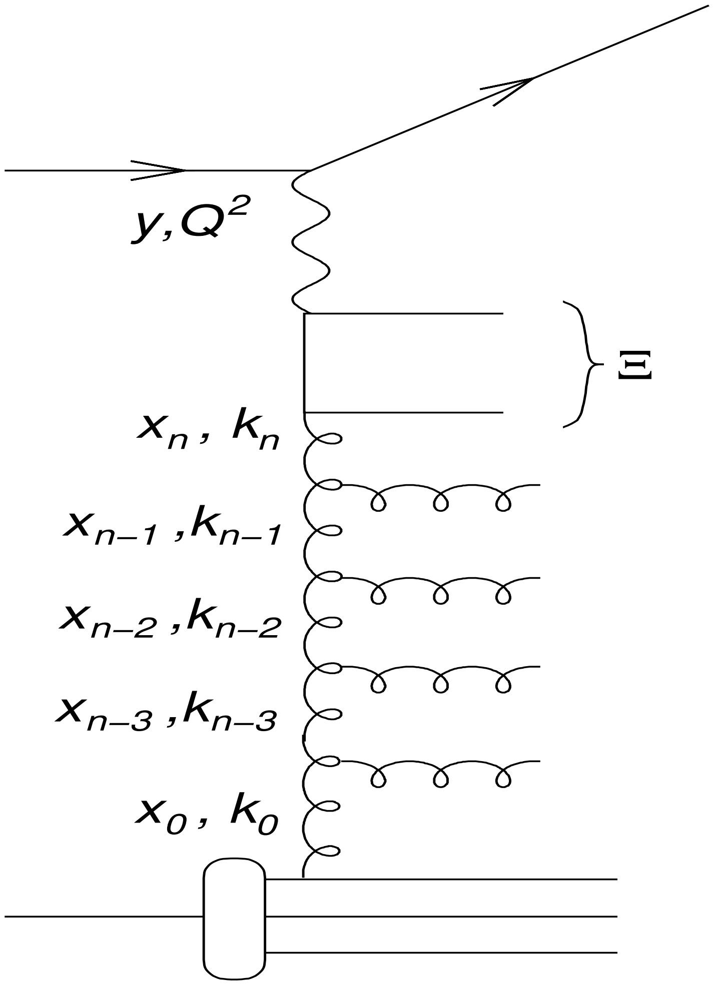
x_γ^{obs} > 0.75 ▷ "Direct-Like"

Virtual Photon PDF's

- Virtual photon structure:
  - ▷ Assign PDF to virtual photon. (c.f. proton pdf)
- The evolution equations of virtual photon pdf's (in Q^2) can be perturbatively calculated in a restricted range.
- SaS1D photon structure function used for this analysis.
  - ▷ Attempts to describe larger Q^2 range.
  - ▷ Valid for real and virtual photons.



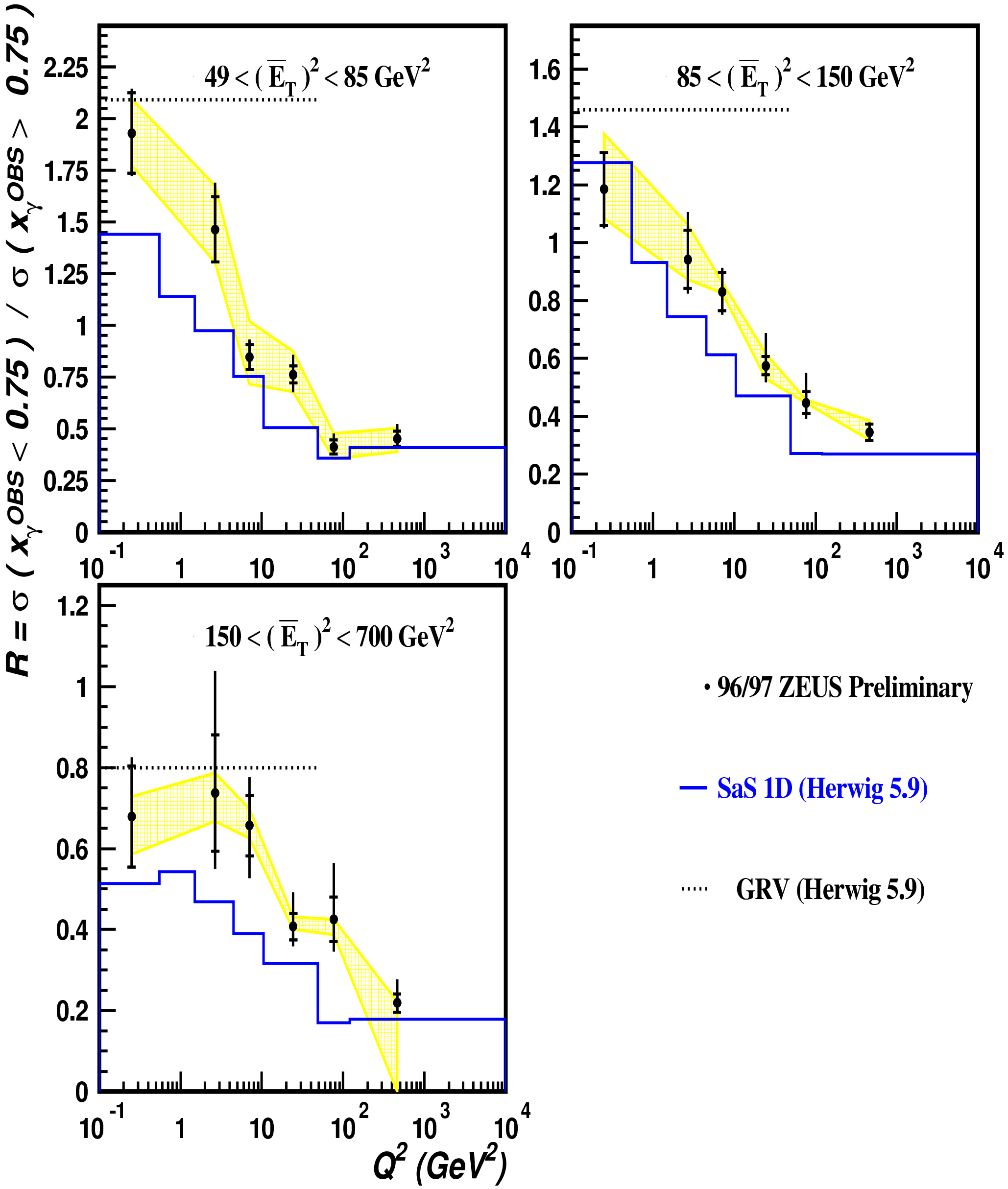
QCD Evolution Schemes



	DGLAP	BFKL	CCFM
Ordering	k_T^2	x	η

- DGLAP evolution describes $Q^2 \geq 1$ range measured in DIS at HERA, but is expected to break down at low x (high ln 1/x).
- BFKL describes low x, but not Q^2 evolution.
- CCFM Attempts to unify the approaches.

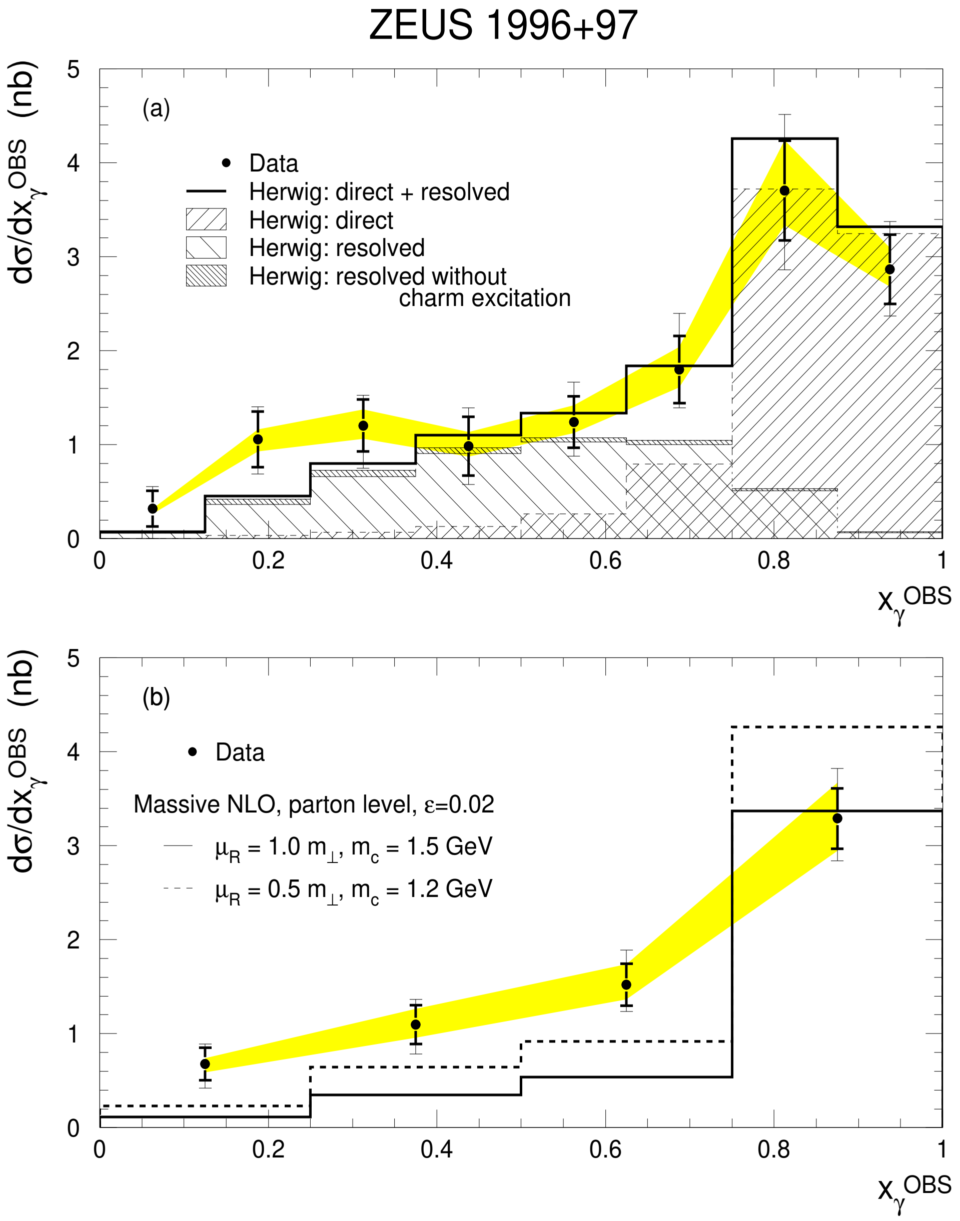
Suppression of Virtual Photon Structure with Q^2



$$R = \frac{\sigma(x_\gamma^{obs}<0.75)}{\sigma(x_\gamma^{obs}>0.75)}$$

- Inclusive dijet measurement shows strong suppression of low x_γ^{obs} events with Q^2.
- HERWIG with SaS1D (γ structure function) describes shape of suppression well.
- Ratio of low to high x_γ^{OBS} shown to be sensitive to photon structure function.

Charm and the Photon in Photoproduction



- **Resolved component clearly suppressed by the presence of charm in the real photon.**
  - ▷ **45% resolved-like with charm.**
  - ▷ **$\sim$90% for inclusive.**
- **How does this suppression evolve with Q^2?**

Q^2 and charm suppressions independent?

Data Selection Criteria

- **1996-2000 data, (103.7pb^{-1})**
- **Charm Tagging:**

  $D^{\star +} \rightarrow K^{-}\pi^{+}\pi_{s}^{+}$ **(+c.c.)**
- **Kinematic Region:**

  $p_T(D^\star) > 3\mathrm{GeV}$

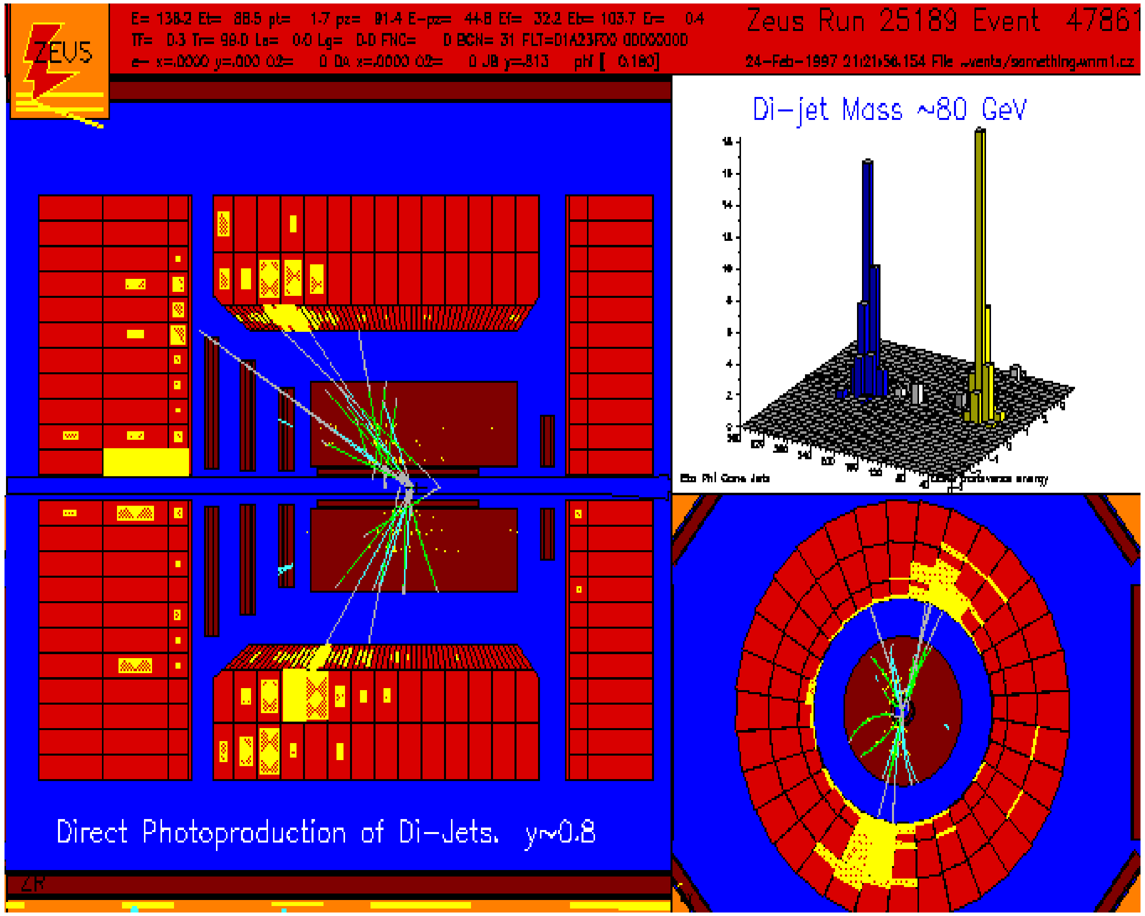
  $|\eta(D^\star)| < 1.5$

  0.20 < y_{jb} **< 0.65**
- **Dijet Selection: KTCLUS**

  E_t^{jet1} **> 7.5 GeV**

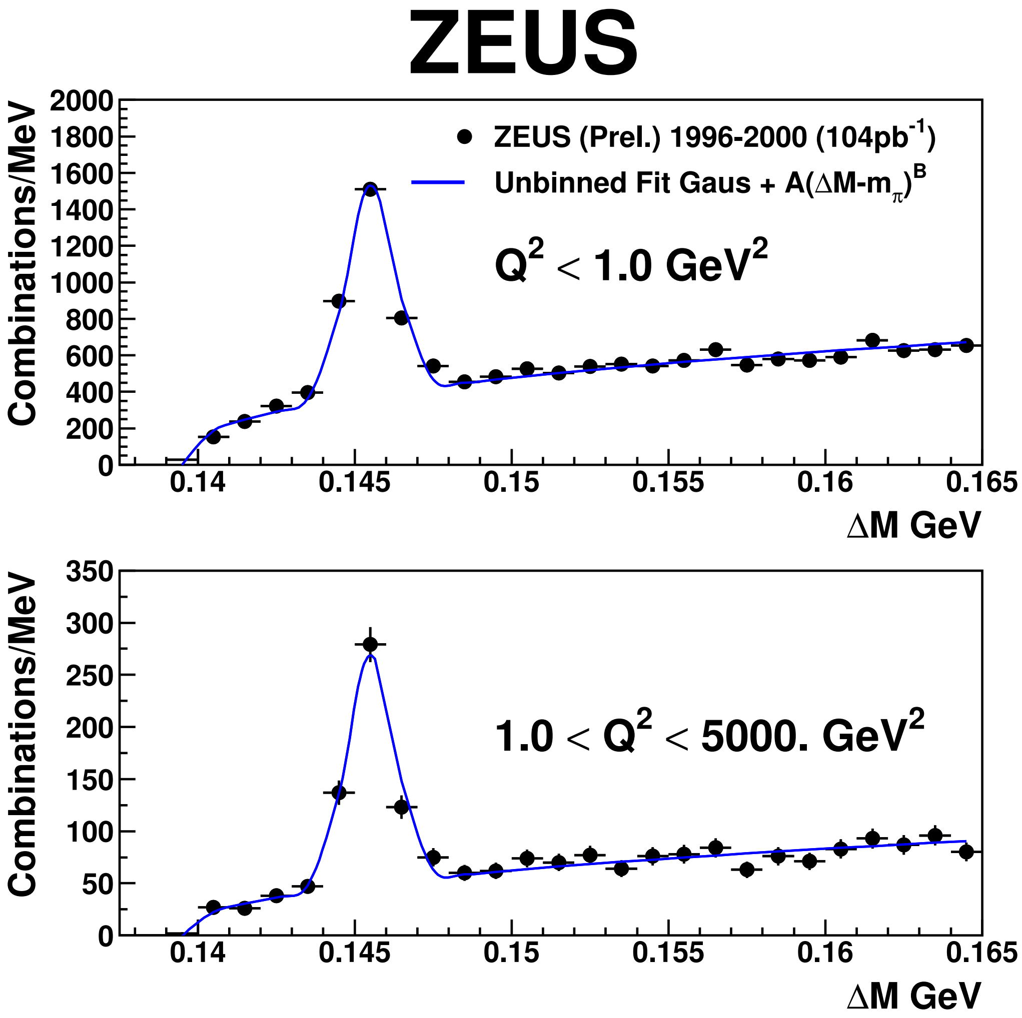
  E_t^{jet2} **> 6.5 GeV**

  $|\eta^{jet}|$ **< 2.4**



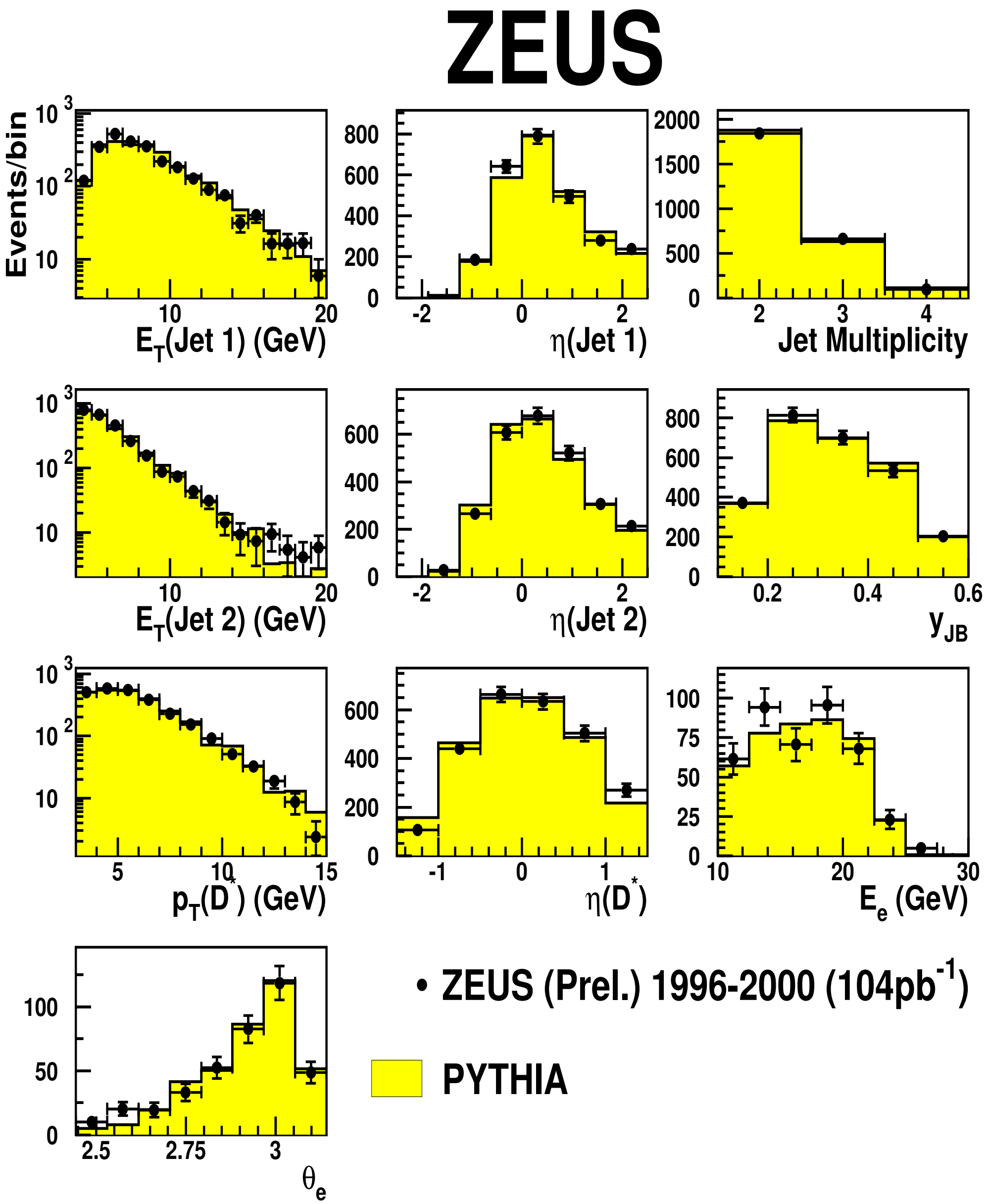
$D^\star$ *Signal Plots*

- ΔM method used for extracting events.
- Clear signals in both PHP and DIS:
  - ▷ 2088 $\pm$61 in php
  - ▷ 395 $\pm$25 in DIS
- DIS sample split into four sub-samples.
- Number of $D^\star$'s extracted from a three parameter unbinned fit.



$$\Delta M = m(K\pi\pi_s) - m(K\pi)$$

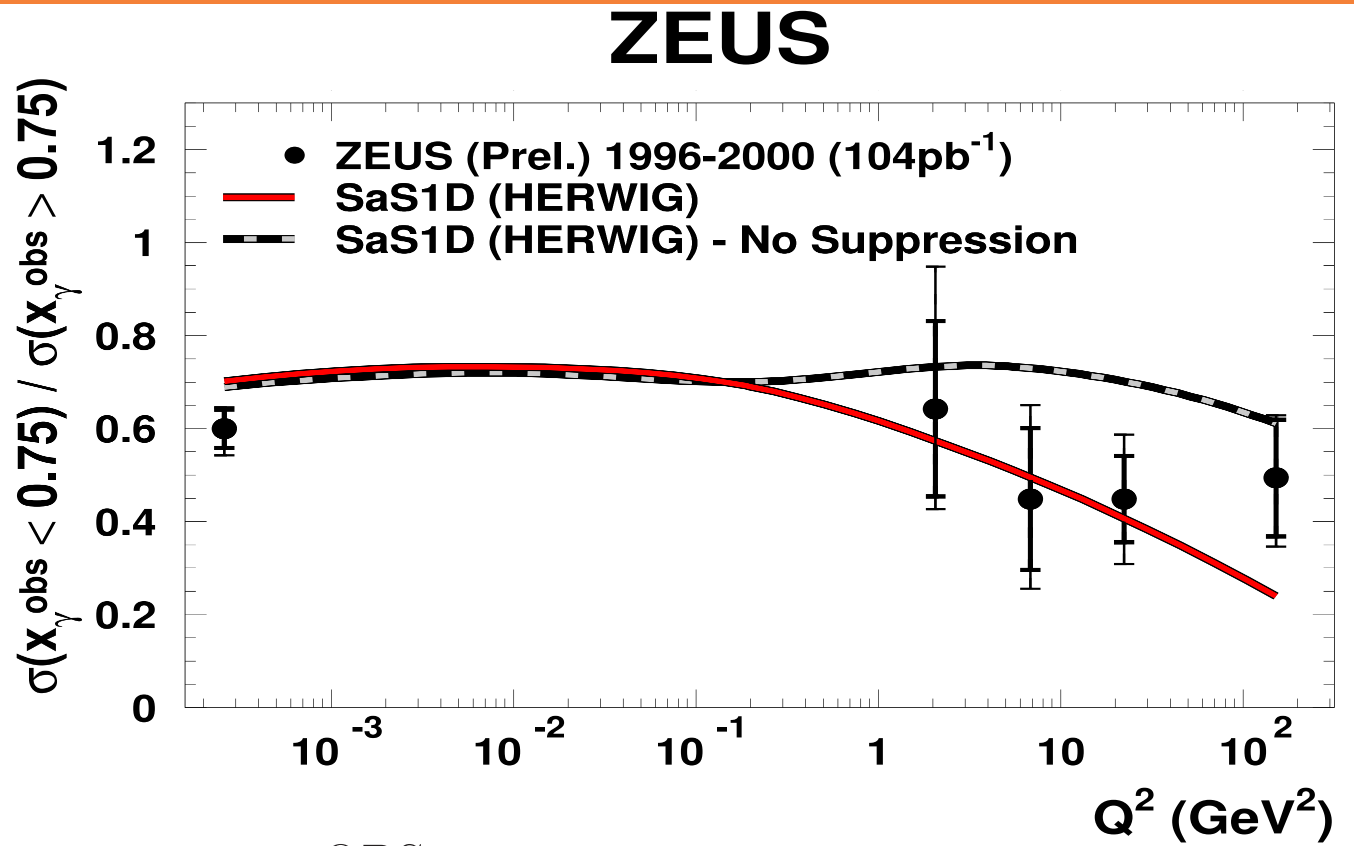
Monte Carlo Description



- Data compared to Monte Carlo.
- PYTHIA used to correct for detector and trigger inefficiencies:-

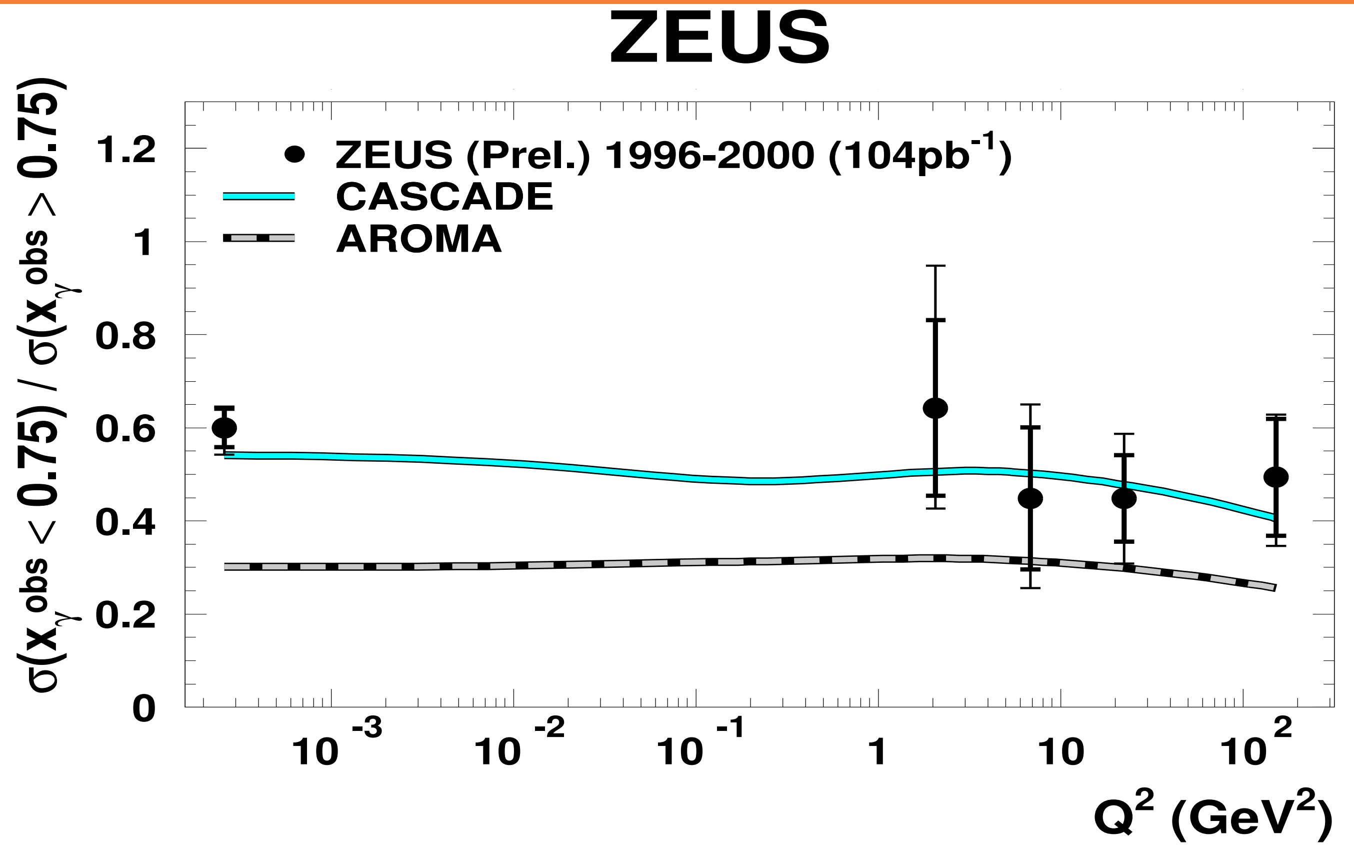
  Direct and Resolved samples generated seperately.
- Excellent description of all quantities.
- Systematic uncertainty due to choice of Monte Carlo estimated using HERWIG sample.

Result



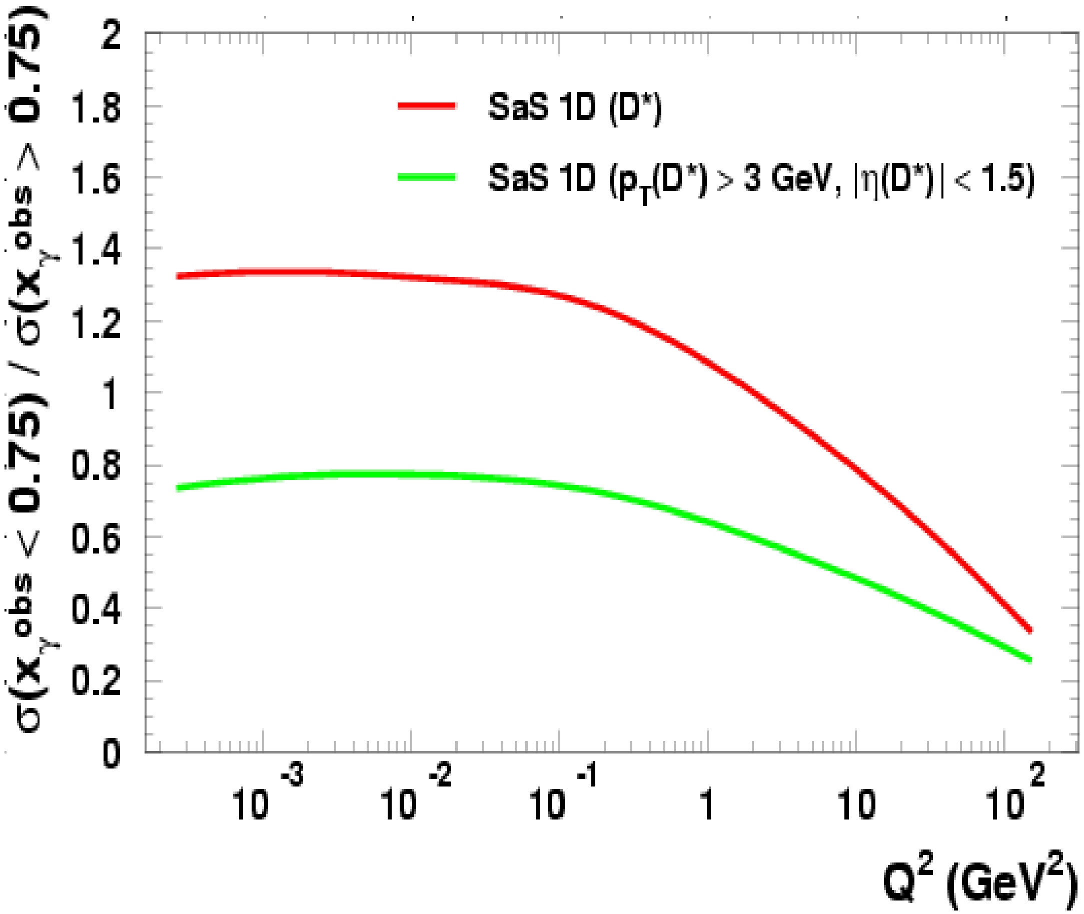
- **Ratio of low to high x_γ^{OBS} vs Q^2 measured for charm production.**
- **Ratio shows little suppression of photon structure with Q^2.**
- **Prediction of SaS1D virtual photon structure function shown.**
  - ▷ **Good agreement.**

LO predictions with no γ PDF



- **No photon structure explicitly assumed.**
- **Low x_γ^{OBS} contribution comes from parton shower evolution.**
- **AROMA with DGLAP evolution, lies below the data.**
- $CASCADE$ **with CCFM evolution is closer to the data.**

Comparison to inclusive ratio

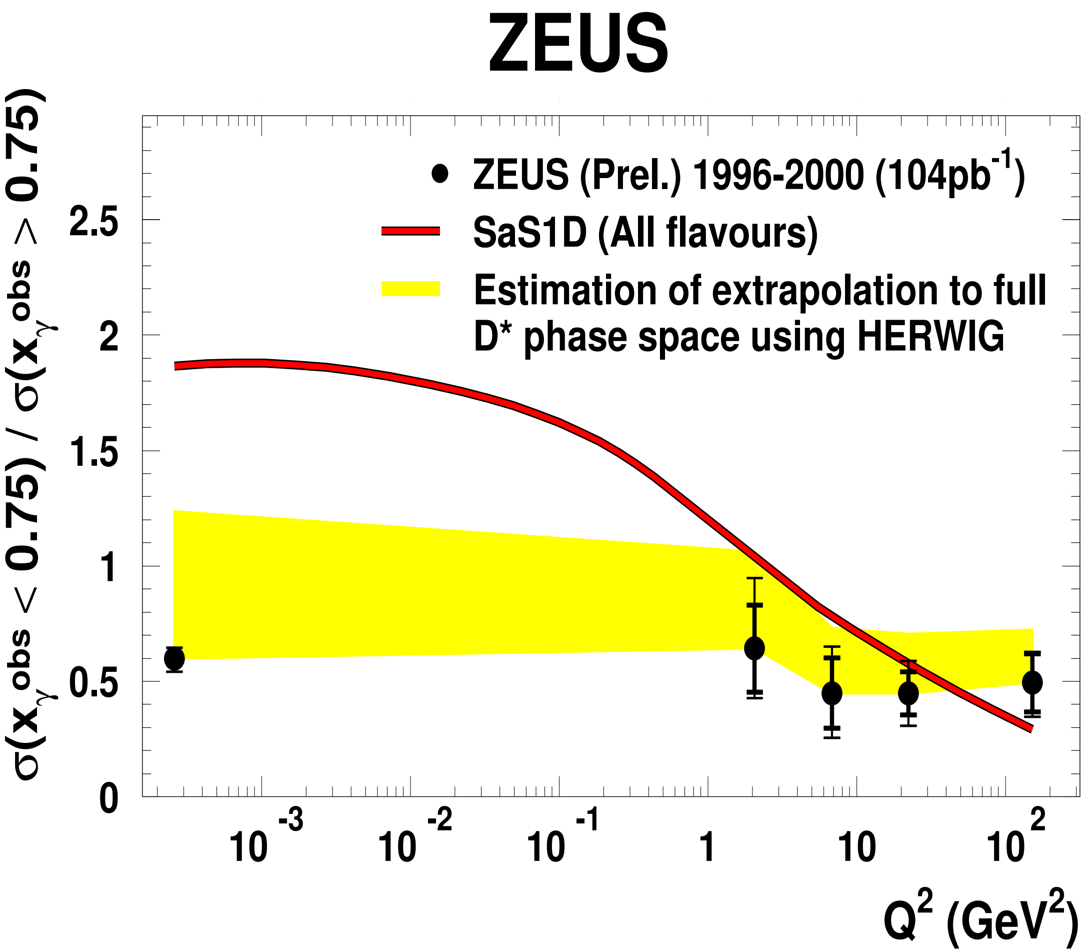


- Ratio's shape in marked contrast to strong suppression with Q^2, observed in inclusive case.
  - ▷ How much of this is due to $D^\star$ kinematics ?
- Estimate the effect on the ratio using Herwig/SaS1D sample.
  - ▷ Some suppression is observed due to kinematics.

- How much of the suppression can be attributed to the presence of charm?
- Suppression from charm and Q^2 not independent?

Comparison to inclusive ratio

- **Previous measurement in different kinematic region.**
  - ▷ **Yellow band shows maximum suppression due to $D^\star$ kinematics.**
- **SaS1D shown to describe shape of data.**
  - ▷ **Use to estimate untagged ratio in the correct kinematic region.**



- **Resolved component falls off less rapidly in the presence of charm.**

Q^2 and charm suppressions are not independent.

Summary

- **Ratio of low to high x_γ^{OBS} measured for dijet events containing a $D^\star$.**
- **Comparisons to LO pQCD.**
  - ▷ SaS1D (virtual photon PDF) describes the ratio.
  - ▷ CASCADE (LO CCFM) also describes the ratio.
  - ▷ AROMA (LO DGLAP) underestimates the ratio.
- **To describe data requires either:**
  - ▷ A virtual photon PDF when using DGLAP evolution.
  - ▷ CCFM evolution.
- **Result compared to SaS1D untagged prediction.**
  - ▷ Low x_γ^{OBS} cross section falls off less rapidly in the presence of charm.
  - ▷ Charm and Q^2 suppressions not independent.

Outlook

- **NLO predictions:**
  - ▷ **A clearer message?**
- **Perhaps jet selection in the $\gamma^{\star}p$ frame.**
  - ▷ **Do we have high enough statistics?**
- **Basically all of HERA I data.**
- **Looking forward to HERA II data !**
  - ▷ **More data, clearer message?**