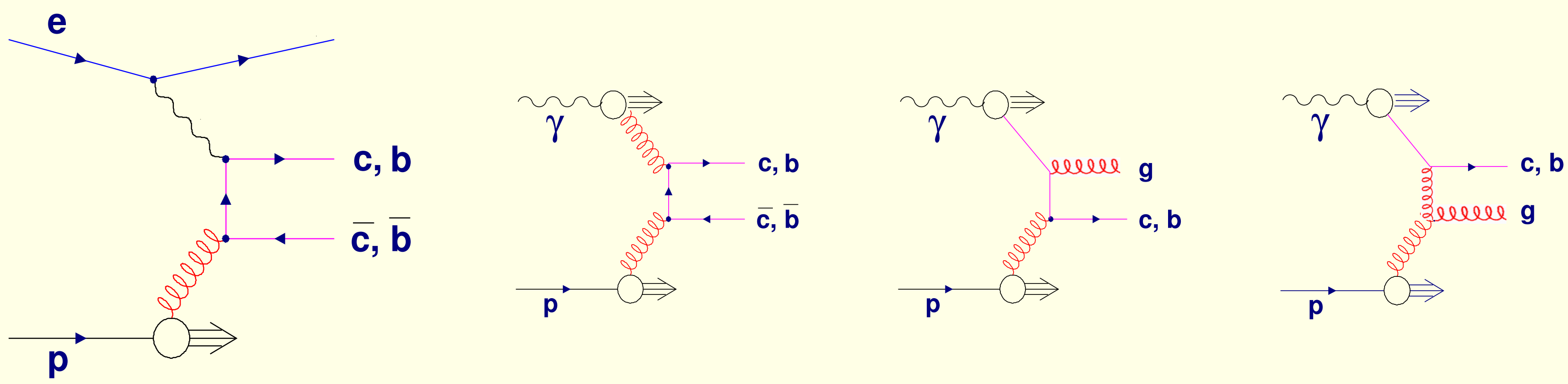
Measurement of Beauty & Charm Photoproduction at H1 using Inclusive Lifetime Tagging

Lars Finke

April, 29th 2005

Heavy Flavors Working Group

Photoproduction of Beauty & Charm at HERA



Relevant scales:

$m_{c,b}$: $\sim 1.5\ (4.75)$ GeV

$p_T^{c,b}$: Event selection:
$p_t^{jet_{1,2}} > 11, 8$ GeV

→ **Heavy quarks:**
Multiscale problem in pQCD.

Theory models:

▷ **LO $\mathcal{O}(\alpha_s)$ + Parton shower**

→ DGLAP evolution, incl. flavor excitation
PYTHIA

→ CCFM evolution
CASCADE

▷ **NLO $\mathcal{O}(\alpha_s^2)$ calculations**

→ FMNR (fixed order massive)

Motivation

▷ **Heavy quark production in ep collisions at HERA:**

- Sensitivity to proton and photon structure.
- Parton dynamics of the hard scattering.
- Hard scale provided by the heavy quark masses (m_c, m_b).
- Factorisation and perturbative QCD (massive/massless).

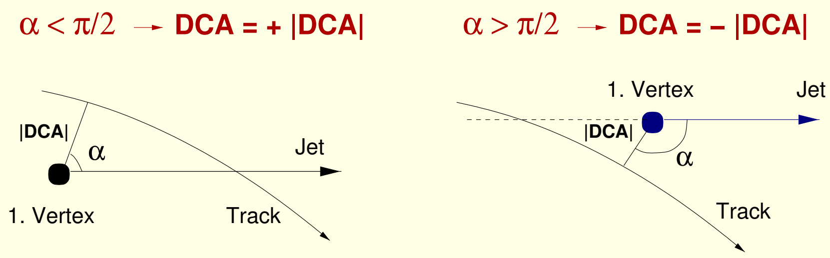
▷ **Aims of this analysis:**

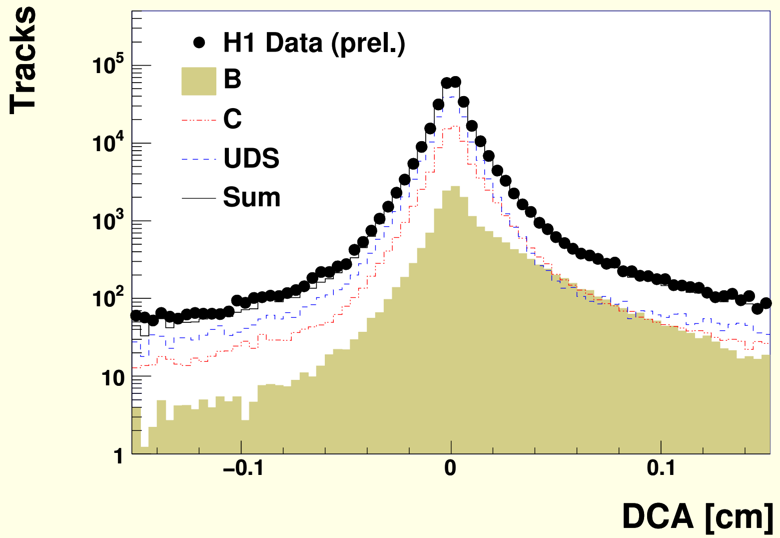
- First inclusive measurement of **beauty** $\&$ **charm** Dijets at high p_t in photoproduction.
- Inclusive lifetime tag
  $\longrightarrow$ Large statistics
  $\longrightarrow$ Large p_t ($p_t > 2 \cdot m_b$).

Heavy Flavor Signal Extraction

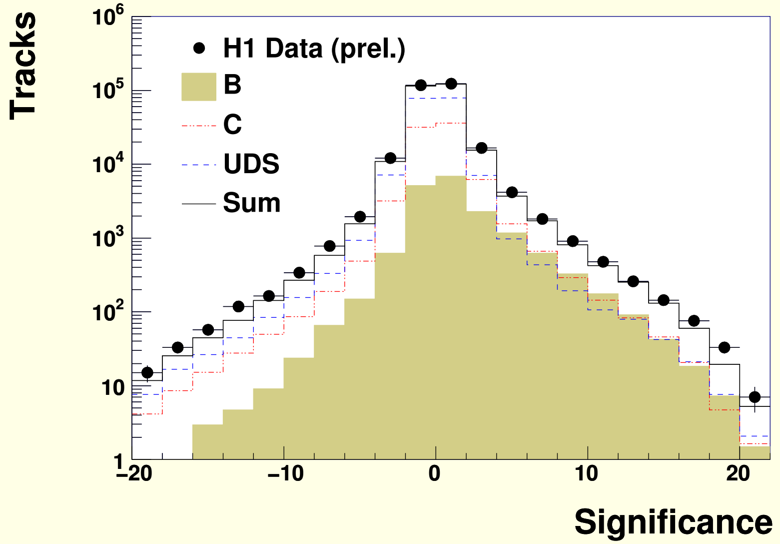
Use of precise tracking information available from H1 vertex detector

Signed Impact Parameter:





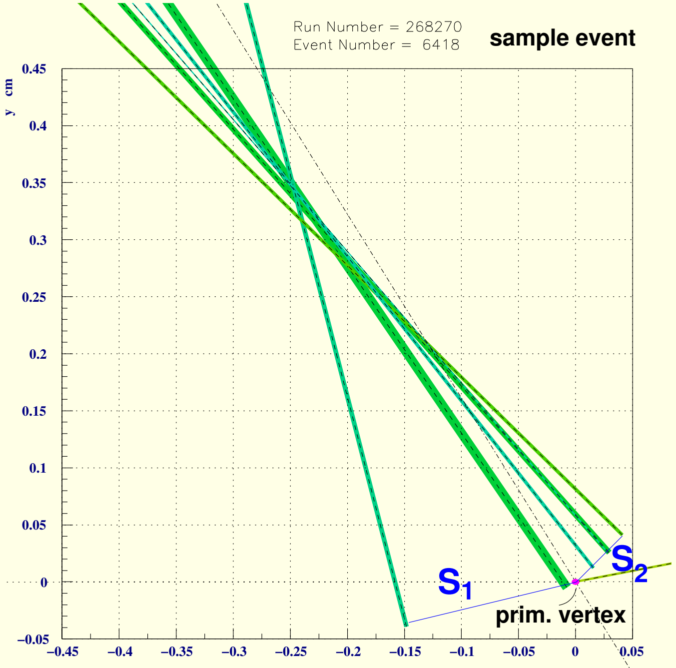
- ▷ MC used for simulation of b, c and uds
- ▷ Marked asymmetry for heavy quarks.
- ▷ Anti strangeness cut: $|DCA| < 1$ mm (remove e.g. K^0_S)

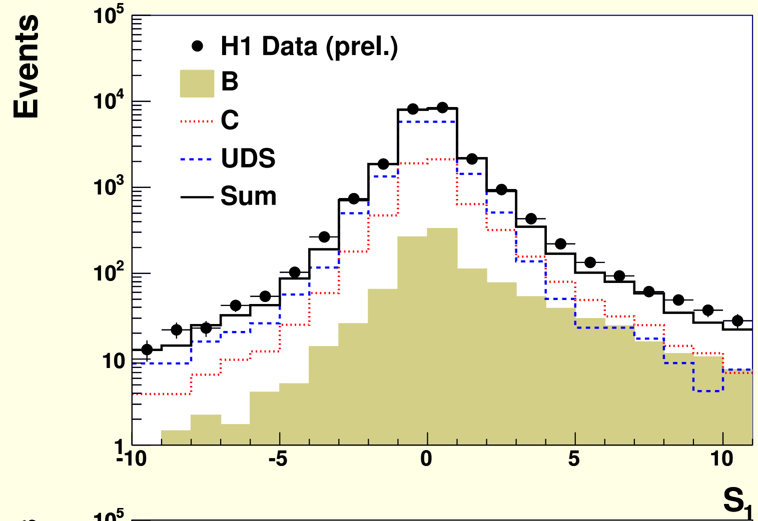


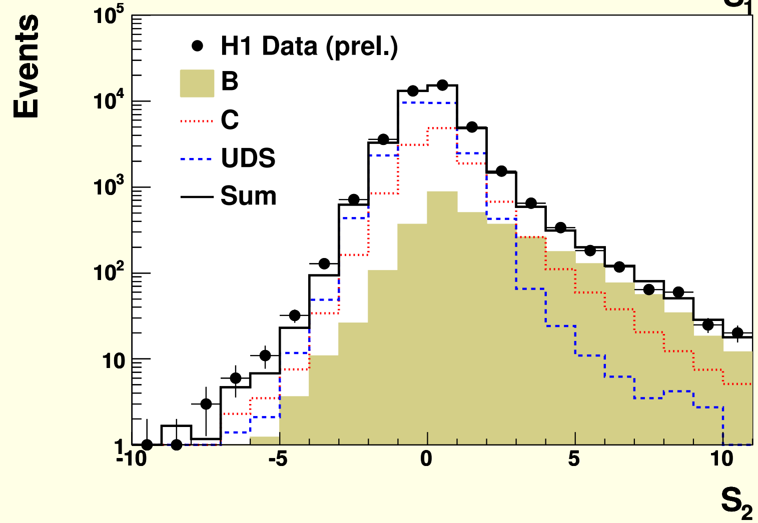
Significance$= \frac{DCA_i}{\sigma(DCA_i)}$

Lifetime Observables I

Using significances of the two highest significance tracks, S_1 and S_2





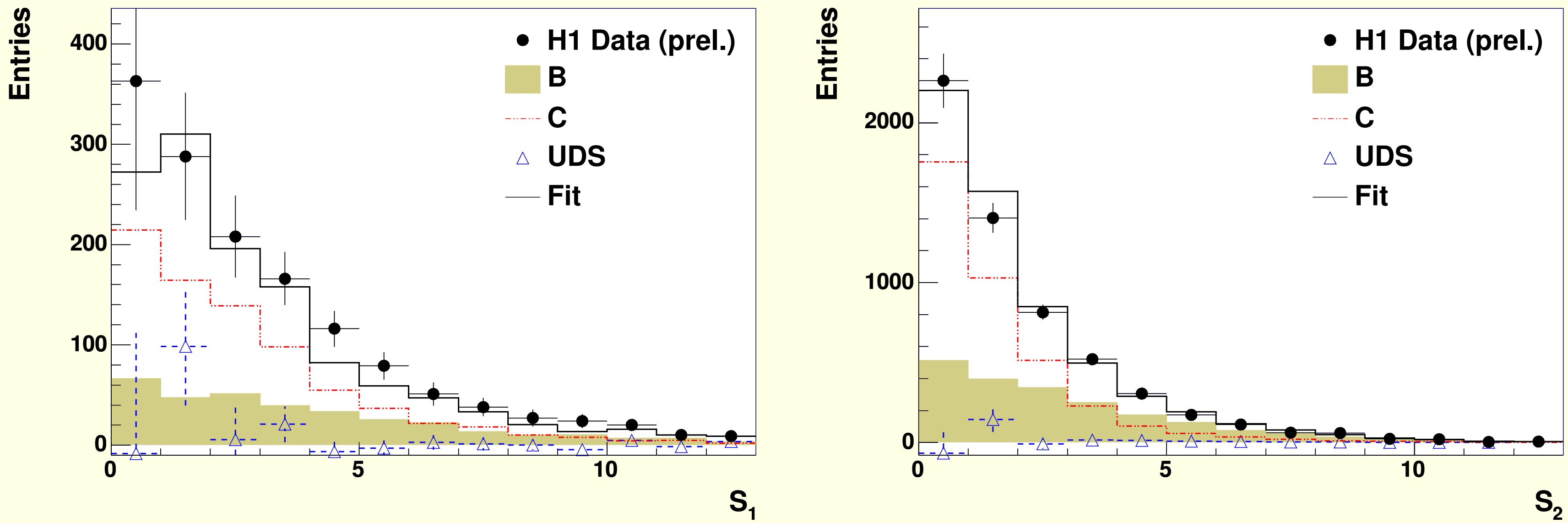


S_1 Highest significance track for 1 track events.

S_2 Significance of the 2^{nd} highest significance track for > 1 track events.

Negative Subtraction

Subtract negative bins in S_1 & S_2 from the positive



- ▷ Reduces sensitivity to resolution description of light quarks.
- ▷ Subtracted spectrum dominated by **charm**. Increasing **beauty** fraction at higher significances.
- ▷ Contribution from light quarks negligible.
- ▷ Fit scale factors for beauty, charm and uds from negative subtracted spectra ($+$ total number of events).

Integrated Cross Section

- **Kinematic range:**
  $Q^2 < 1$ GeV^2, $0.15 < y < 0.8$, $p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$

Beauty: $\sigma(ep \rightarrow eb\bar{b}X \rightarrow ejjX) = 149 \pm 18 \pm 31\,pb$

Charm: $\sigma(ep \rightarrow ec\bar{c}X \rightarrow ejjX) = 694 \pm 69 \pm 97\,pb$

- Dominating systematic error.

- Main contributions come from the track resolutions and model uncertainties.

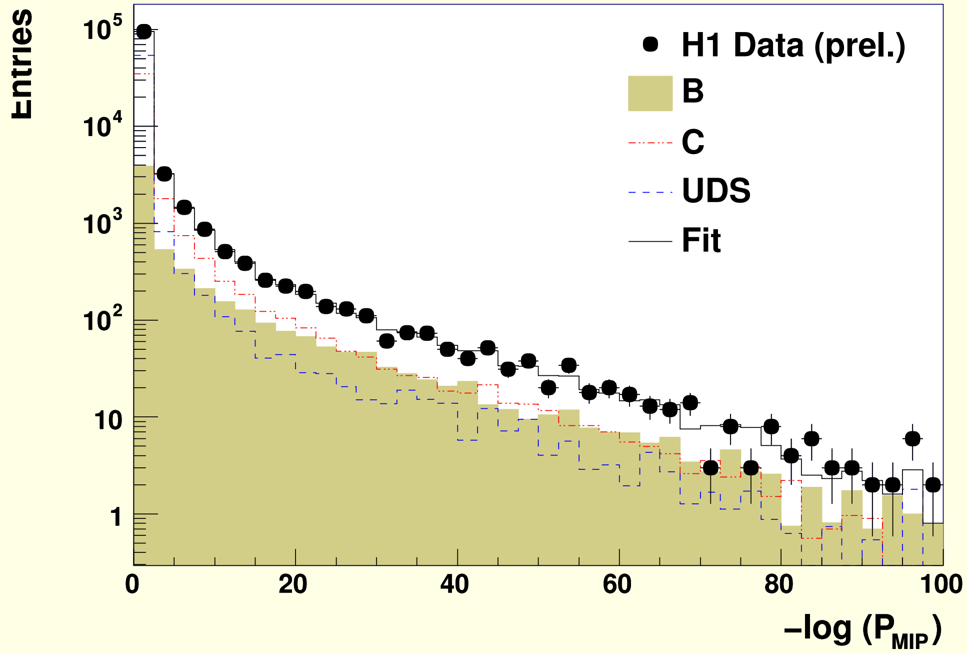
- **Fractions:**
  Beauty (Charm) fraction typically $\sim 7\%$ ($\sim 35\%$).

Lifetime Observables II

Alternative lifetime tag

Jet Probability*:

- ▷ Use **all selected tracks** within the two leading jets.
- ▷ Construct a probability P_{MIP} (from the significances) that the jets are compatible with the primary vertex.
- ▷ Low (i.e. large negative logarithm) probabilities indicate **secondary vertex**.
- ▷ Fit fractions of beauty, charm and light quarks.

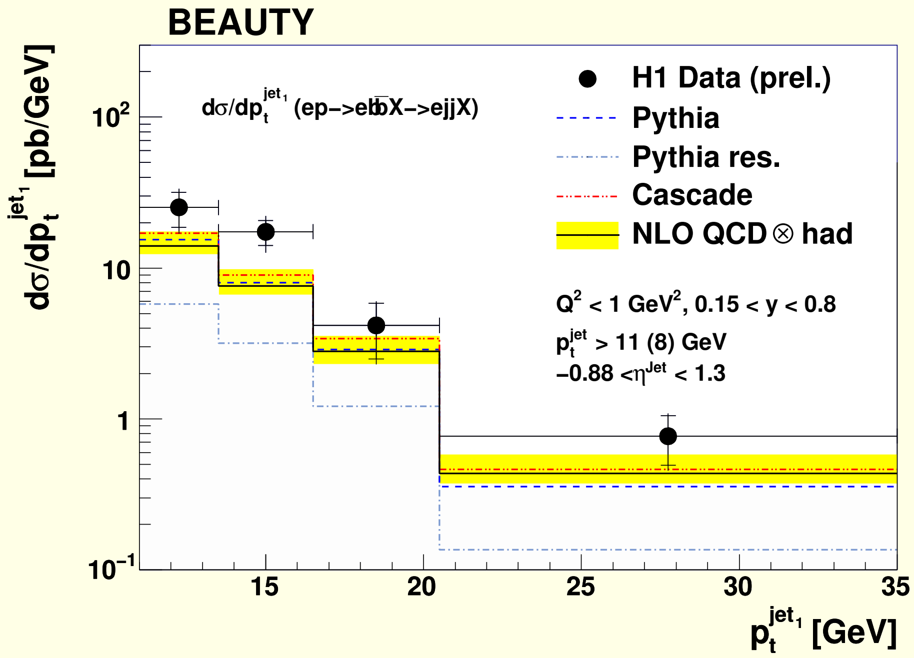


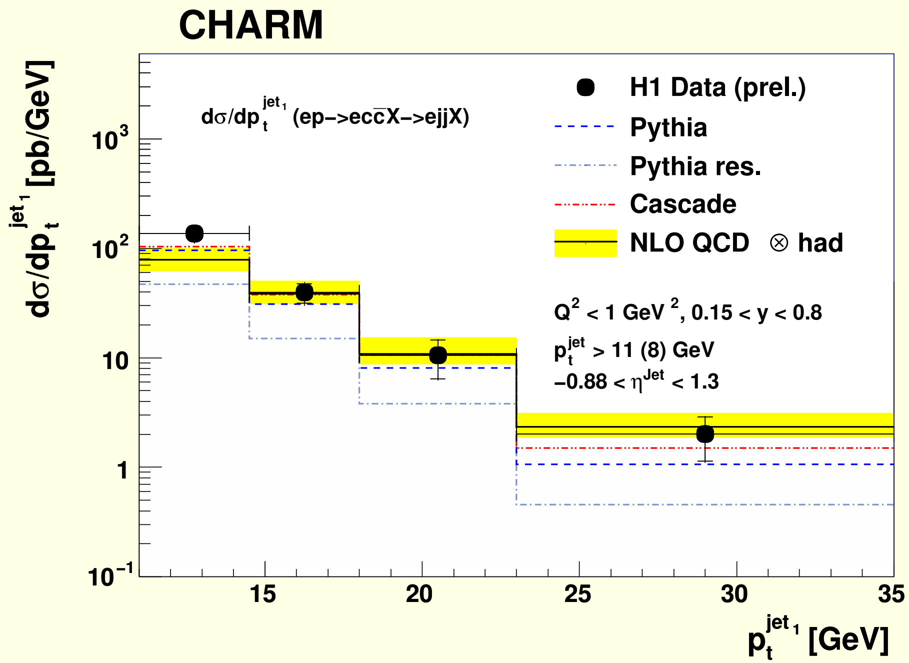
Resulting cross sections are found to agree with the results obtained with S_1 and S_2.

(*follows ALEPH paper Phys. Lett. B **313** (1993) 535)

Beauty & Charm in Photoproduction
$d\sigma/dp_t^{jet_1}(ep->ecc(bb)X->ejjX)$

H1 99/00 e^+ data: $Q^2 \sim 0,\ 0.15 < y < 0.8 \parallel p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$





Beauty:

- ▷ **LO + PS QCD Models:** Good description of shape.
- ▷ **NLO QCD (FMNR):** Slightly higher (at low p_t).

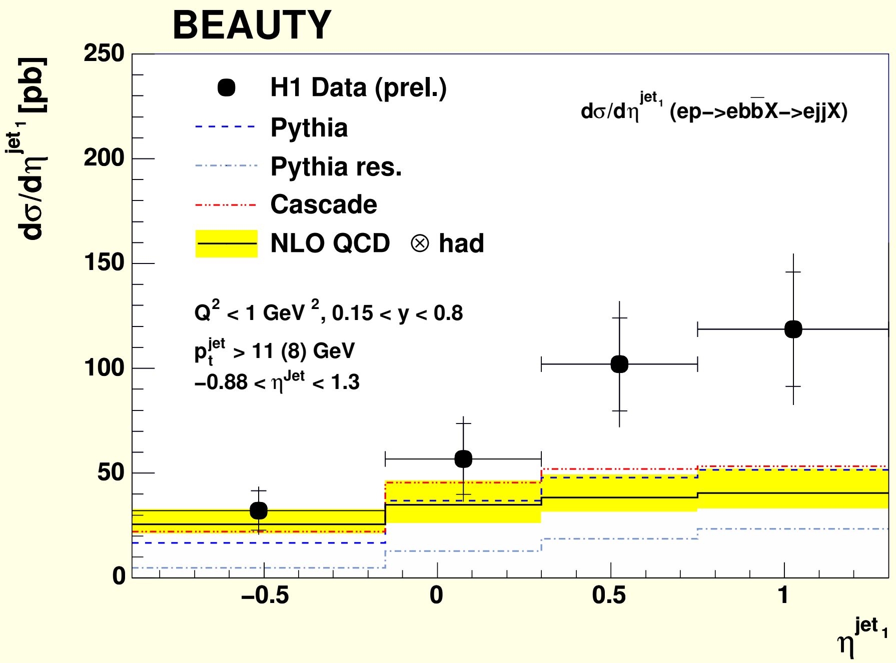
Charm:

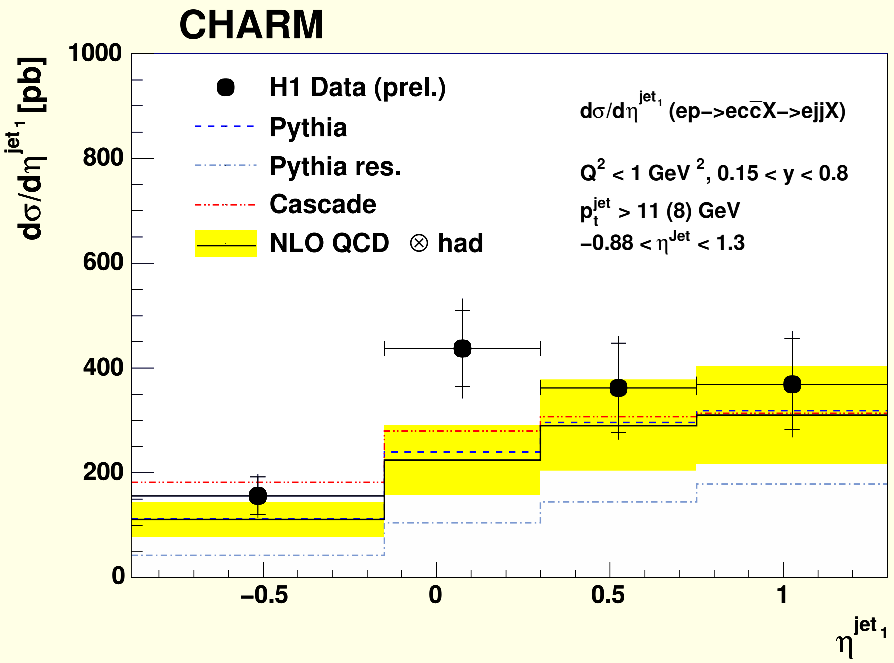
- ▷ **LO + PS QCD Models:** Good description of shape and norm.
- ▷ **NLO QCD (FMNR):** Fits within uncertainties.

Beauty & Charm in Photoproduction

$$d\sigma/d\eta^{jet_1}(ep->ecc(bb)X->ejjX)$$

H1 99/00 e^+ data: $Q^2 \sim 0,\ 0.15 < y < 0.8 \parallel p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$





- ▷ **LO + PS QCD Models &**
  NLO QCD (FMNR):
  Main differences in forward region.

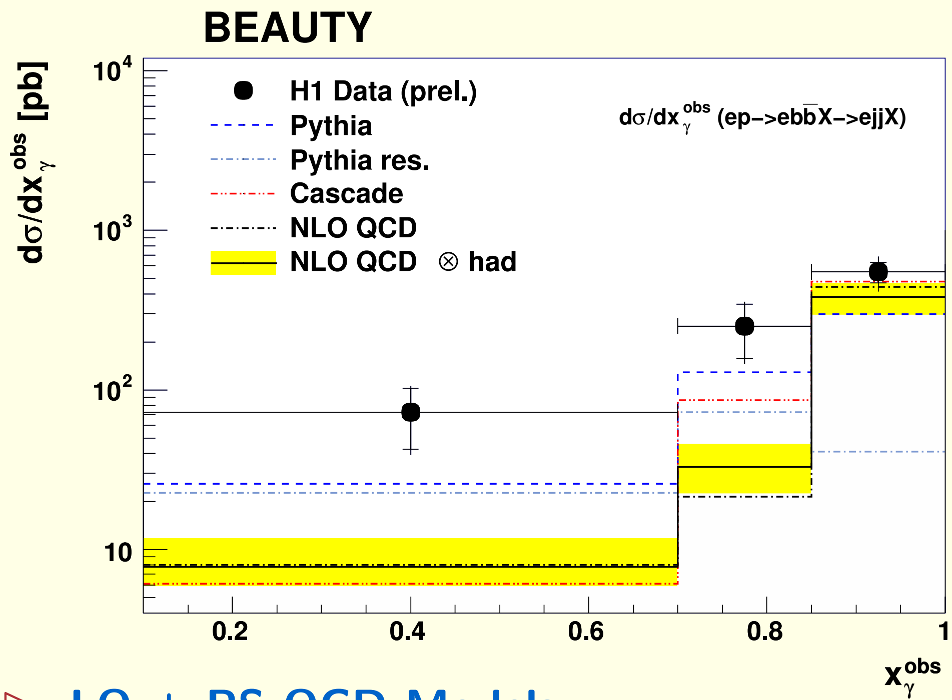
- ▷ **LO + PS QCD Models:**
  Good description of shape and norm.

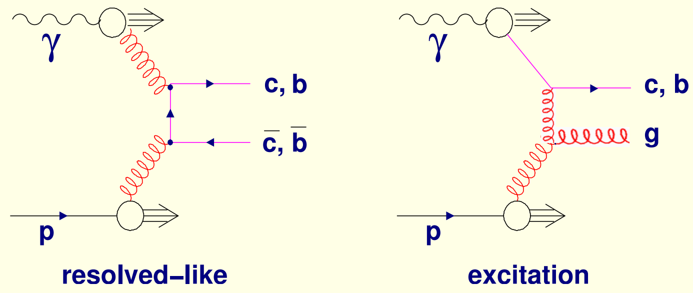
- ▷ **NLO QCD (FMNR):**
  Fits within uncertainties.

Beauty Contributions from Resolved Photons

$$d\sigma/dx_\gamma^{obs}(ep->ebbX->ejjX)$$

H1 99/00 e^+ data: $Q^2 \sim 0,\ 0.15 < y < 0.8$ || $p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$





$$x_\gamma^{obs} = \frac{\sum_{jet_1,jet_2}(E-P_z)}{\sum_{hadrons}(E-P_z)}$$

▷ Significant resolved like component ($x_\gamma^{obs} < 0.85$).

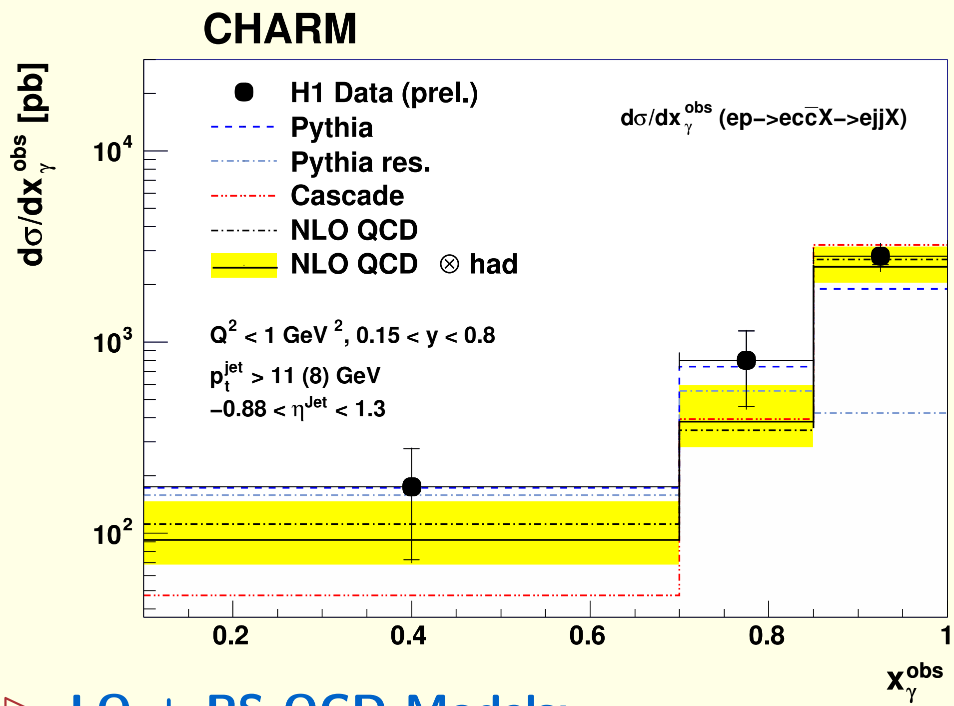
▷ **LO + PS QCD Models:**
PYTHIA shape okay but too low in normalisation.
CASCADE too hard.

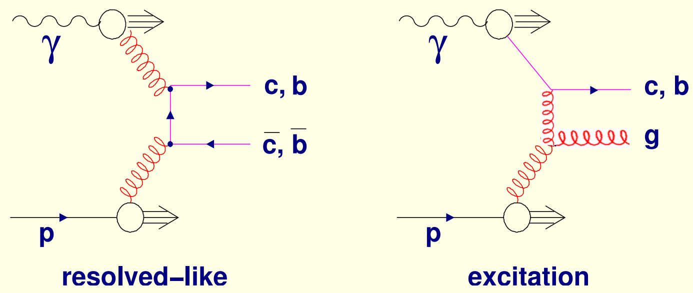
▷ **NLO QCD (FMNR):**
Lower than data at low x_γ^{obs}.

Charm Contributions from Resolved Photons

$d\sigma/dx_\gamma^{obs}(ep- > ecc X- > ejjX)$

H1 99/00 e^+ data: $Q^2 \sim 0,\ 0.15 < y < 0.8 \parallel p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$





$$x_\gamma^{obs} = \frac{\sum_{jet_1,jet_2}(E-P_z)}{\sum_{hadrons}(E-P_z)}$$

▷ Significant resolved like component ($x_\gamma^{obs} < 0.85$).

▷ **LO + PS QCD Models:**
PYTHIA with large excitation component okay, but too low for high x_γ^{obs}.
CASCADE too hard.

▷ **NLO QCD (FMNR):**
Good agreement between Data and NLO QCD within (large) uncertainties!

Conclusion

- Measurement of **beauty** & **charm** dijet cross sections in photoproduction has been presented.
  H1 Silicon Vertex Detector '99/00 data.
- **High p_t:**
  - Beauty (Charm) fraction $\sim 7\%$ ($\sim 35\%$) of total sample with $x_\gamma^{obs} > 0.85$.
    $\rightarrow$ In agreement with quark charge counting.
- **Charm:**
  - Data in general agreement with NLO QCD prediction (within uncertainties).
  - Resolved contributions somewhat underestimated by the NLO calculation.
- **Beauty:**
  - Data somewhat higher than NLO QCD, PYTHIA and CASCADE.
    Shape well described.
  - Main differences seen at low x_γ^{obs} and at lower p_t.

Backup – NLO Calculations

- FMNR: fixed order massive calculation: BGF and HO
- Calculations done in $\overline{MS}$ scheme using $CTEQ5M$, $GRV\text{-}HO$ and $m_C = 1.5\,\text{GeV}$ ($m_B = 4.75\,\text{GeV}$).
- $\mu_r = m_t = \sqrt{m_q^2 + p_{t,q\bar{q}}^2}$
  $\mu_f^{beauty} = m_t$; $\mu_f^{charm} = 2 \cdot m_t$
- p_t weighted k_t clustering jet algorithm used.
- Perturbative uncertainties estimated by variation of the scales μ_r and μ_f $(1/2 - 2)$.
- Parameter uncertainties estimated by variation of the quark masses and the pdf (added quadratically).
- Parton to hadron level corrections done using PYTHIA.
- Total uncertainties: $\sim 30\%$ for both, beauty and charm.