A Measurement of Beauty Photoproduction through Decays to Muons and Jets

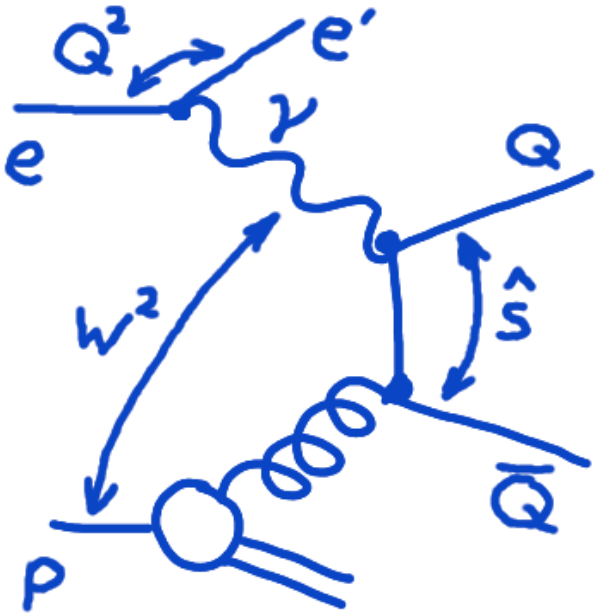
Benno List
University of Hamburg
for the H1 Collaboration

DIS 2009, 27.4.2009

SPONSORED BY THE
Federal Ministry of Education and Research

Introduction

- Beauty quarks at HERA
  are mainly produced in Photon-Gluon-Fusion
  → sensitive to the **gluon** in the proton
- Photoproduction:
  Virtuality Q^2 of the photon is small ($Q^2 < 1\text{GeV}^2$)
- Hard scales for perturbative QCD:
  $m_b \sim 5$ GeV, p_T of quarks/jets
  → usually combined to $\mu_0 = \sqrt{(m_b^2 + p_T^2)}$
- Interpretation of Heavy Flavour Measurements:



Trust the pQCD calculations
→ Constrain the gluon density of the proton

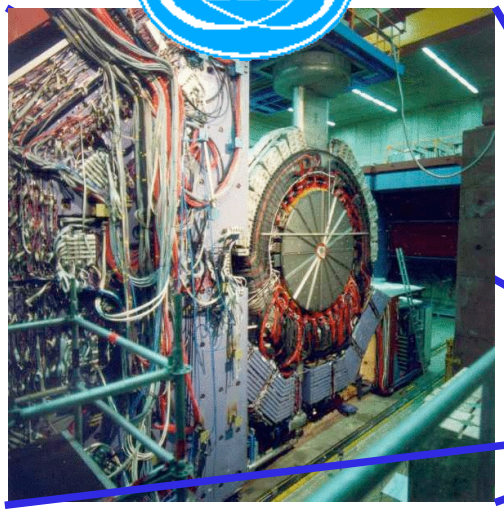
⟺

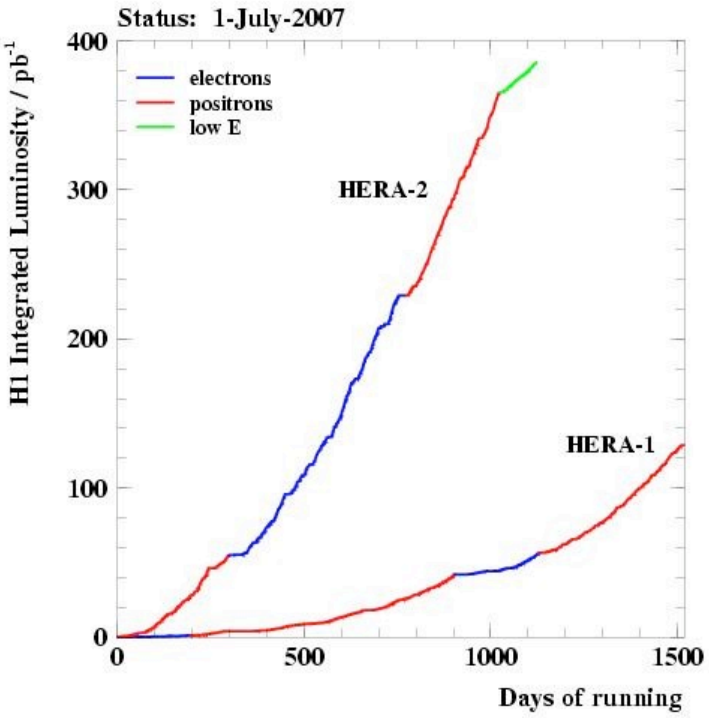
Take the gluon from elsewhere
→ Investigate accuracy of pQCD calculations

QCD Models for Beauty Photoproduction

- Leading Order Monte Carlo Generators:
  - Pythia 6.1: Based on collinear factorization / DGLAP evolution
  - Cascade: k_T factorization / CCFM evolution
  - Use parton showers to approximate higher order effects
  - Full hadronisation based on Lund string model
  - Pythia used for data correction, Cascade for model error
- Next to Leading Order Calculation:
  - FMNR: Calculation in a massive scheme
  - No parton showers, only independent fragmentation
  - Hadronisation corrections done based on Pythia

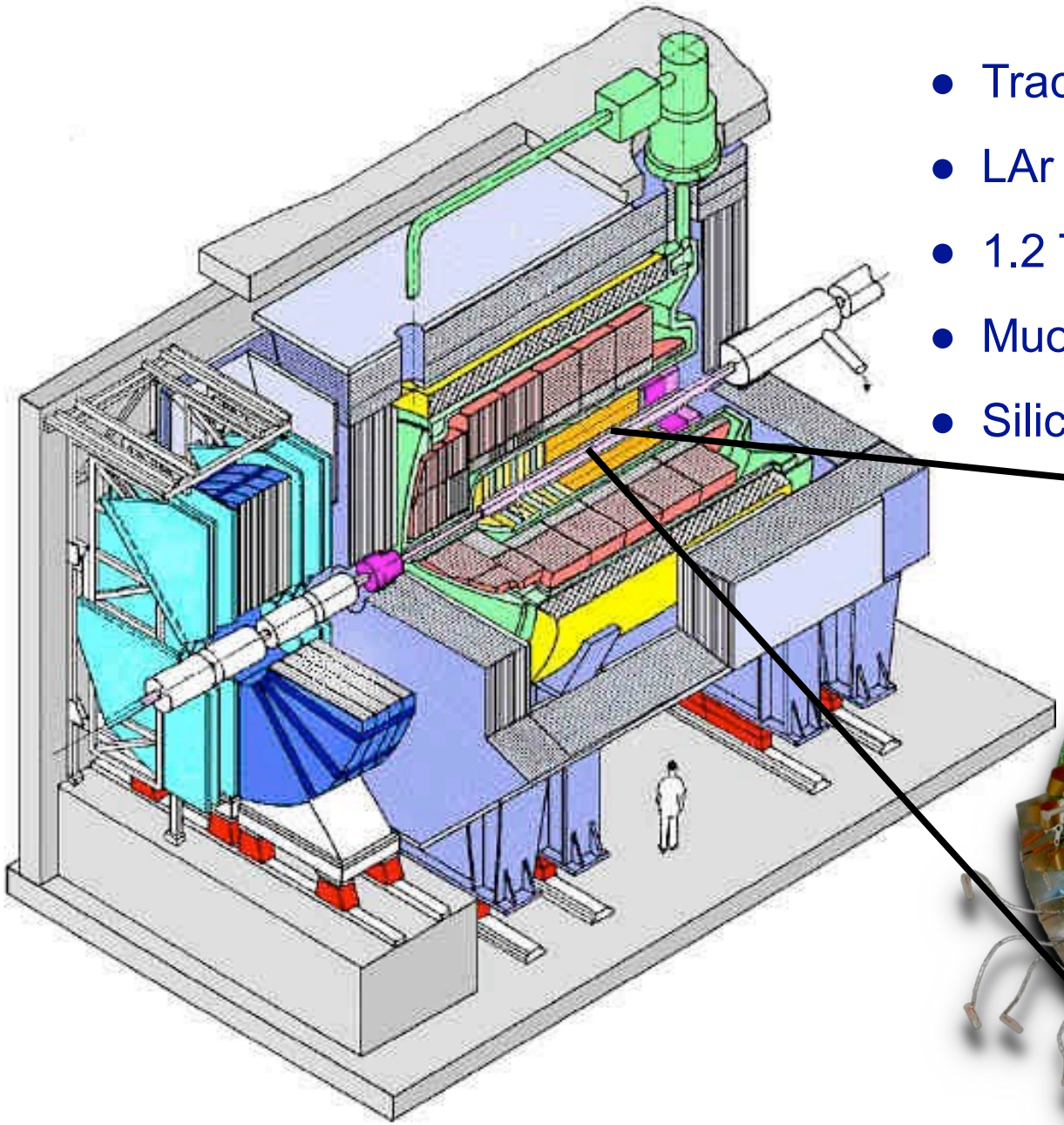
HERA: 1992 - 2007



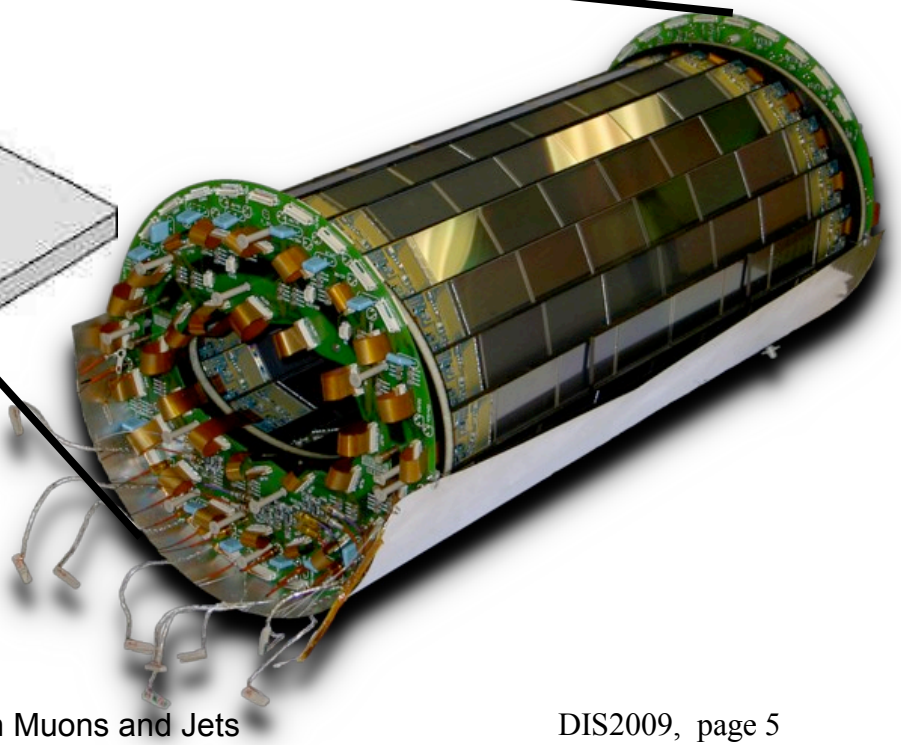


- 920GeV protons – 27.5GeV electrons/positrons → $\sqrt{s}$=320GeV
- ~ 0.5fb^{-1} luminosity per experiment

The H1 Detector

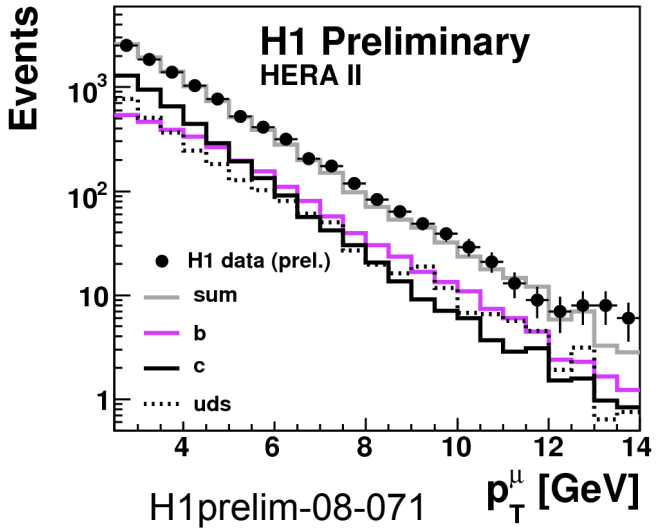


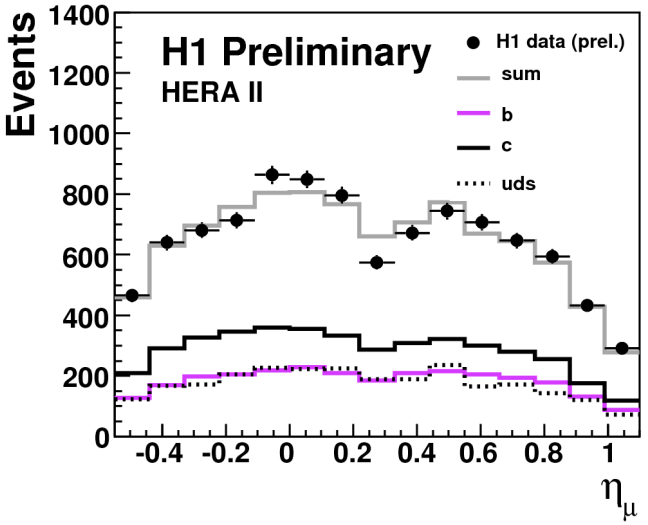
- Tracker with Central Jet Chamber
- LAr and Spaghetti Calorimeter
- 1.2 Tesla field
- Muon system
- Silicon vertex detector



Data Selection

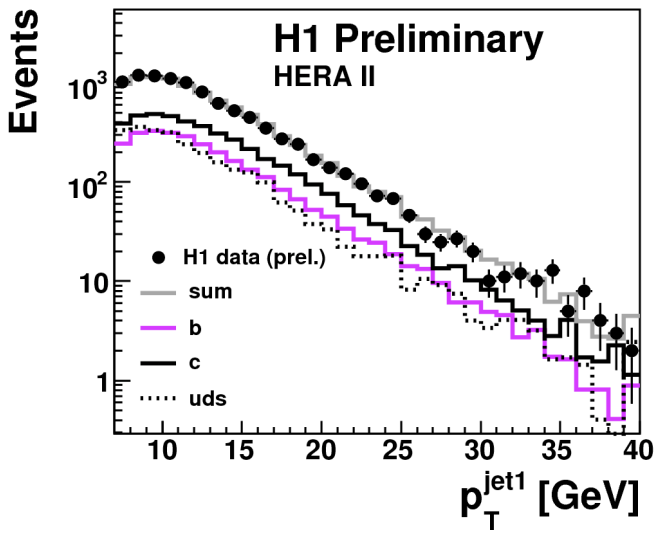
- Reference: H1prelim-08-071, www-h1.desy.de/publications/H1preliminary.short_list.html
- HERA-II data from 2006/07, integrated luminosity 170pb^{-1}
- Cuts defining visible range:
  - Photoproduction: $Q^2<1\text{GeV}^2$, $0.2 < y < 0.8$
  - Dijet events: $p_T^{jet} > 7$ (6) GeV for leading (subleading) jet, $|\eta^{jet}| < 2.5$
  - Muon with $p_T^{\mu} > 2.5\text{GeV}$, $-0.55 < \eta^{\mu} < 1.1$
- Muon must have hit in silicon vertex detector

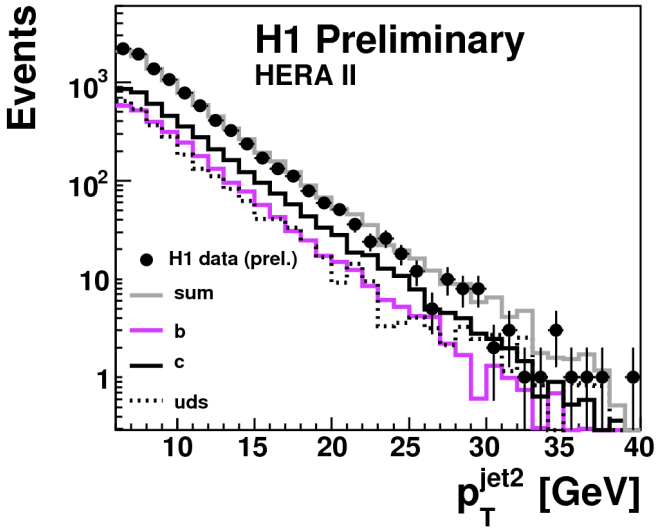


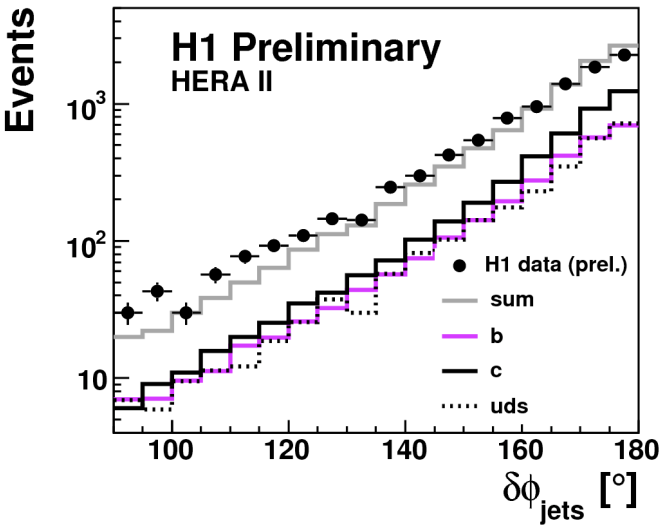


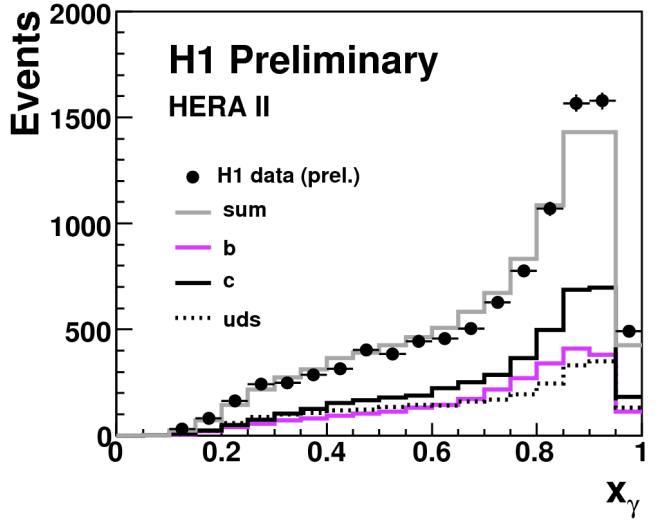
Jet Control Plots

- p_T spectra well described
- Beauty a bit harder than uds background
- Δφ:
  MC predicts not enough at small opening angles (QCD radiation!)
- x_γ well described
  → note significant b contribution to resolved ($x_\gamma < 0.75$) region!



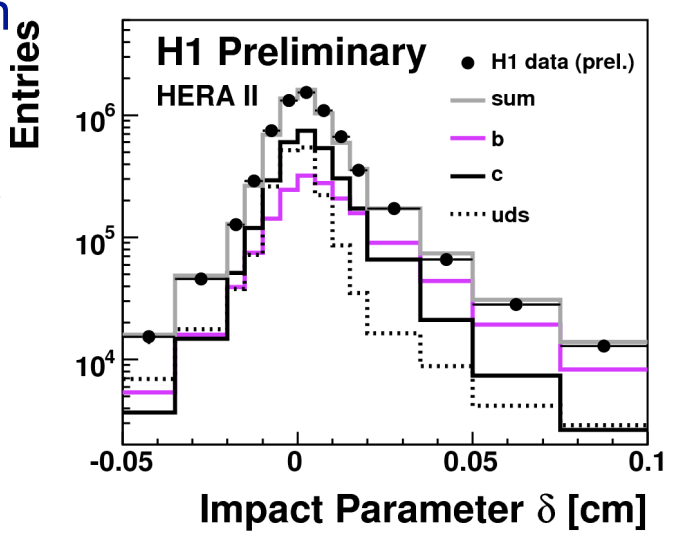


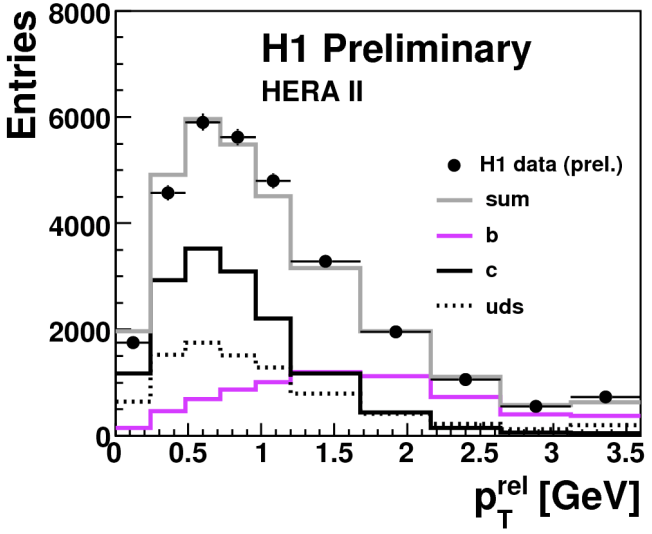


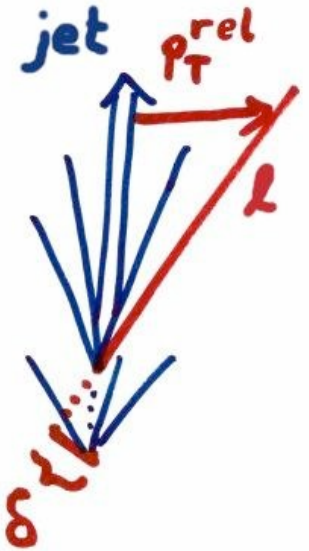


Extraction of the Beauty Contribution

- Beauty is only ~ 0.03% of total γp cross section
- Enrichment is possible with:
  - ▸ 1 high-p_T muon plus 2 jets → 15-20% beauty
  - ▸ Restricts phase space severely
- Use impact parameter δ (lifetime) and relative p_T^{rel} of muon to jet (b mass) as discriminating variables
- p_T^{rel} is superior variable for b fraction, but cannot separate uds and c
- δ allows separation of uds and c → reduced systematics
- Determine b fraction from a 2-dimensional fit of p_T^{rel} and δ with 3 components: uds, c, b







Systematic Uncertainties

- Normalization:
  - Trigger efficiency
  - Muon identification
  - Muon track reconstruction
  - Luminosity
- Bin-by-bin uncertainties:
  - Impact parameter resolution
  - Jet axis resolution
  - Hadronic energy scale
  - Model uncertainty (PYTHIA vs. CASCADE)
  - Fragmentation function (Peterson vs. Lund)
  - Fragmentation fractions (c, b $\rightarrow$ mesons)
  - Inflight decays of pions and kaons
- Overall: 12% systematics

Result: Integrated Cross Section

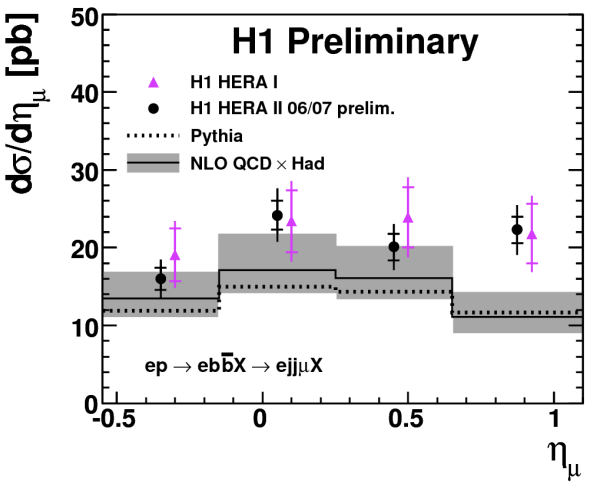
- σ_{vis} (ep → e'b$\bar{b}$X → e'jjμX) = 31.4 ± 1.3(stat) ± 3.8(syst) pb
- HERA-I (H1, EPJ **C41**(2005)453):
  σ_{vis} (ep → e'b$\bar{b}$X → e'jjμX) = 38.4 ± 3.4(stat) ± 5.4(syst) pb
- Improved precision in statistics and systematics
- New result is lower than, but compatible with HERA-I result

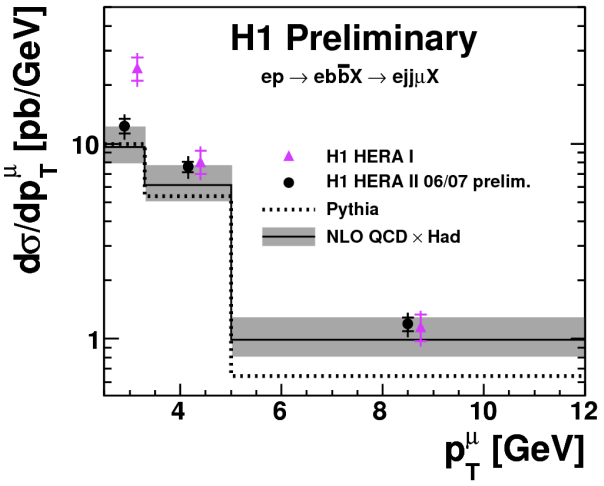
Theory predictions:

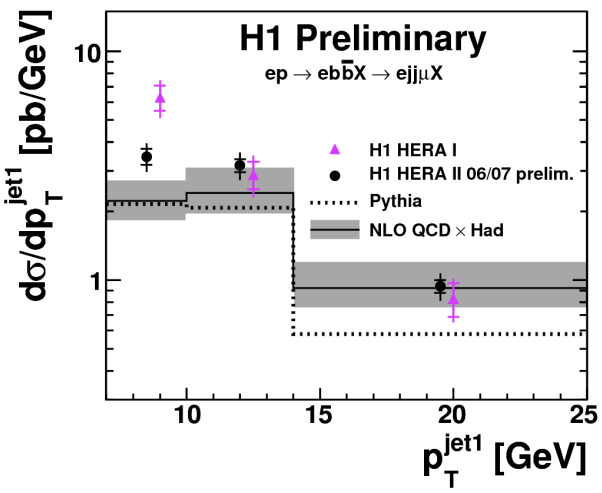
- FMNR NLO (CTEQ5F4 + GRV-G HO) x hadronisation, $\mu_{r,f}^2 = m_b^2 + p_T^2$
  $25.4\ ^{+6.4}_{-4.7}$ pb
- PYTHIA 6.2 (CTEQ6L + SAS-1D, massless mode):
  21.7 pb
- NLO QCD is on the low side → a low scale is preferred;
  PYTHIA is too low → expected for LO Monte Carlo

Differential Cross Sections

- Slight deficiency of FMNR and PYTHIA predictions in forward direction → similar in charm production → needs better models!
- New result is lower at low p_T (muon and jet) than HERA-I result → NLO QCD describes p_T spectra reasonably well
- Still a deficiency of NLO QCD at low jet p_T
- PYTHIA prediction too low overall, but shapes well described

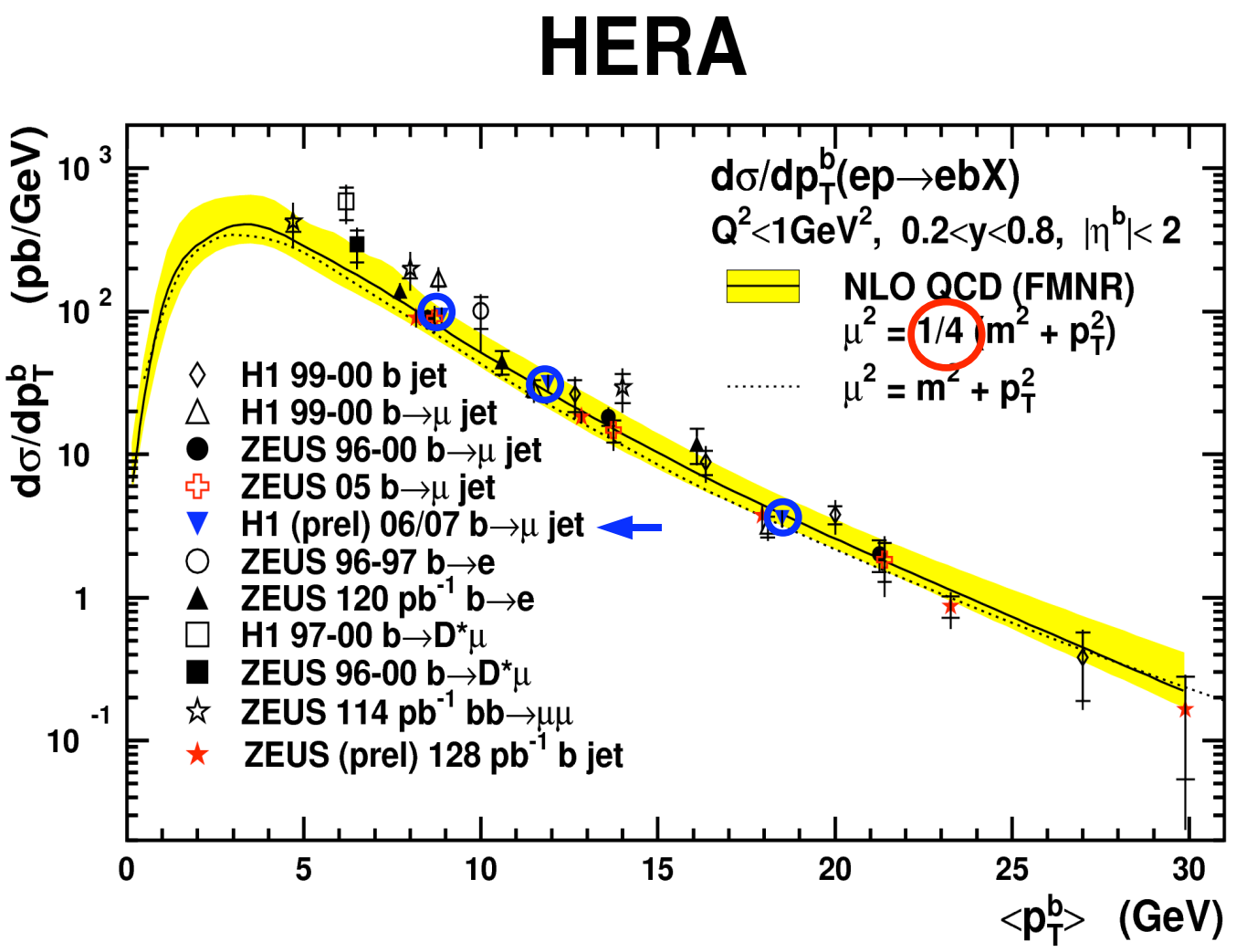






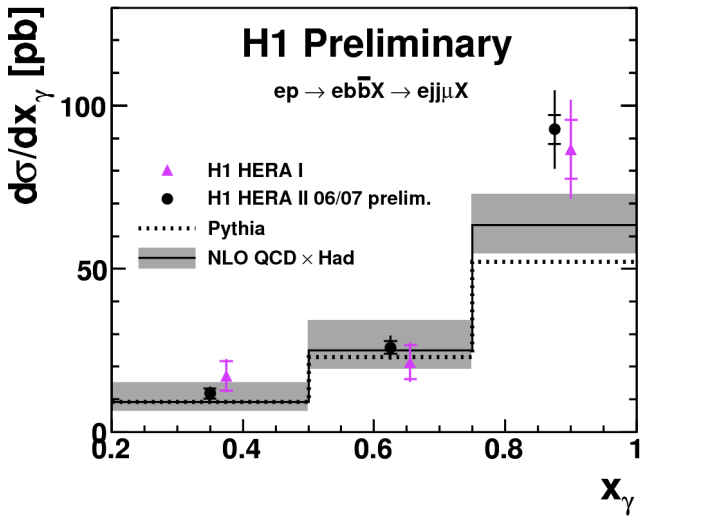
The Global View

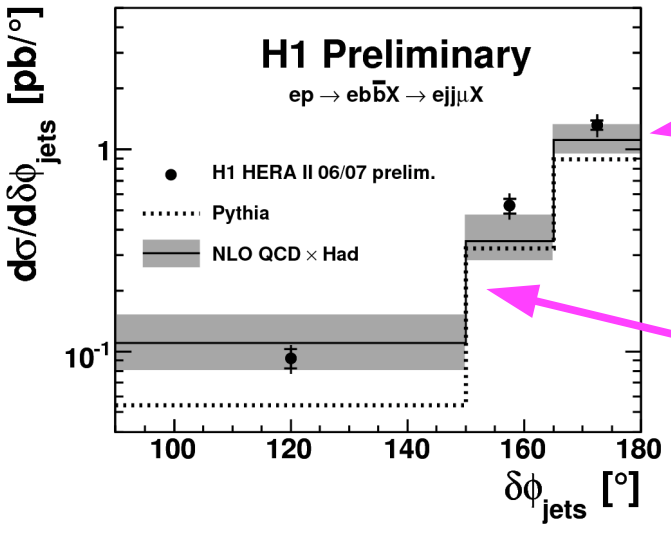
- New Data fit well into global picture
- Nicely described by NLO QCD (note: central scale set to ½ the naïve value)

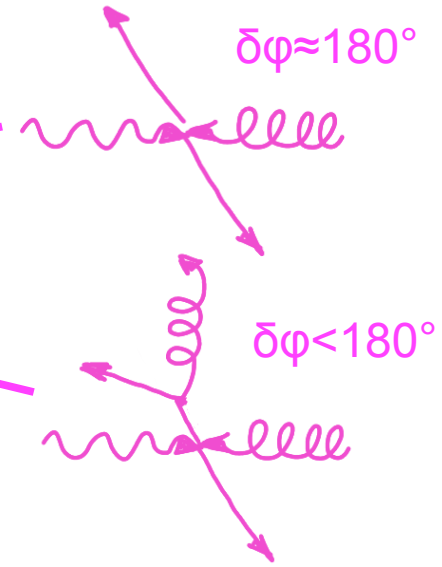


Differential Cross Sections 2

- x_γ: Photon momentum fraction entering hard interaction
  $x_\gamma > 0.75$: dominated by direct / $x_\gamma < 0.75$: mainly resolved
- NLO QCD and PYTHIA predict resolved contribution accurately, but are low in direct region
- $\delta\varphi_{jets}$: Expect 180° for Leading Order (no hard gluons)
  → low $\delta\varphi_{jets}$ probes higher order effects
  (NLO matrix element or parton showers)
- FMNR does well for $\delta\varphi_{jets}$, PYTHIA falls to steeply towards low $\delta\varphi_{jets}$







Summary and Conclusions

- New measurement of $ep \rightarrow b\bar{b}X$ going to 2 jets with a muon
- Increased statistics compared to HERA-I: $50pb^{-1} \rightarrow 170pb^{-1}$
  $\rightarrow$ improved precision (statistics and systematics)
- Total cross section is lower, but compatible with HERA-I
- New result is significantly lower at low p_T (muon and jet)
- NLO QCD (FMNR) gives good description of the data
- Test of NLO effects ($\delta\varphi_{jets}$):
  FMNR (hard gluon in ME) does better than PYTHIA (parton showers)