Beauty photoproduction at Hera

S. Miglioranzi
UCL / Argonne National Lab.

On behalf of the
H1 and ZEUS Collaborations

Outline:

- Introduction to beauty production at HERA
- B measurements using different tagging techniques
- Comparison of data to MC(LO) and NLO predictions

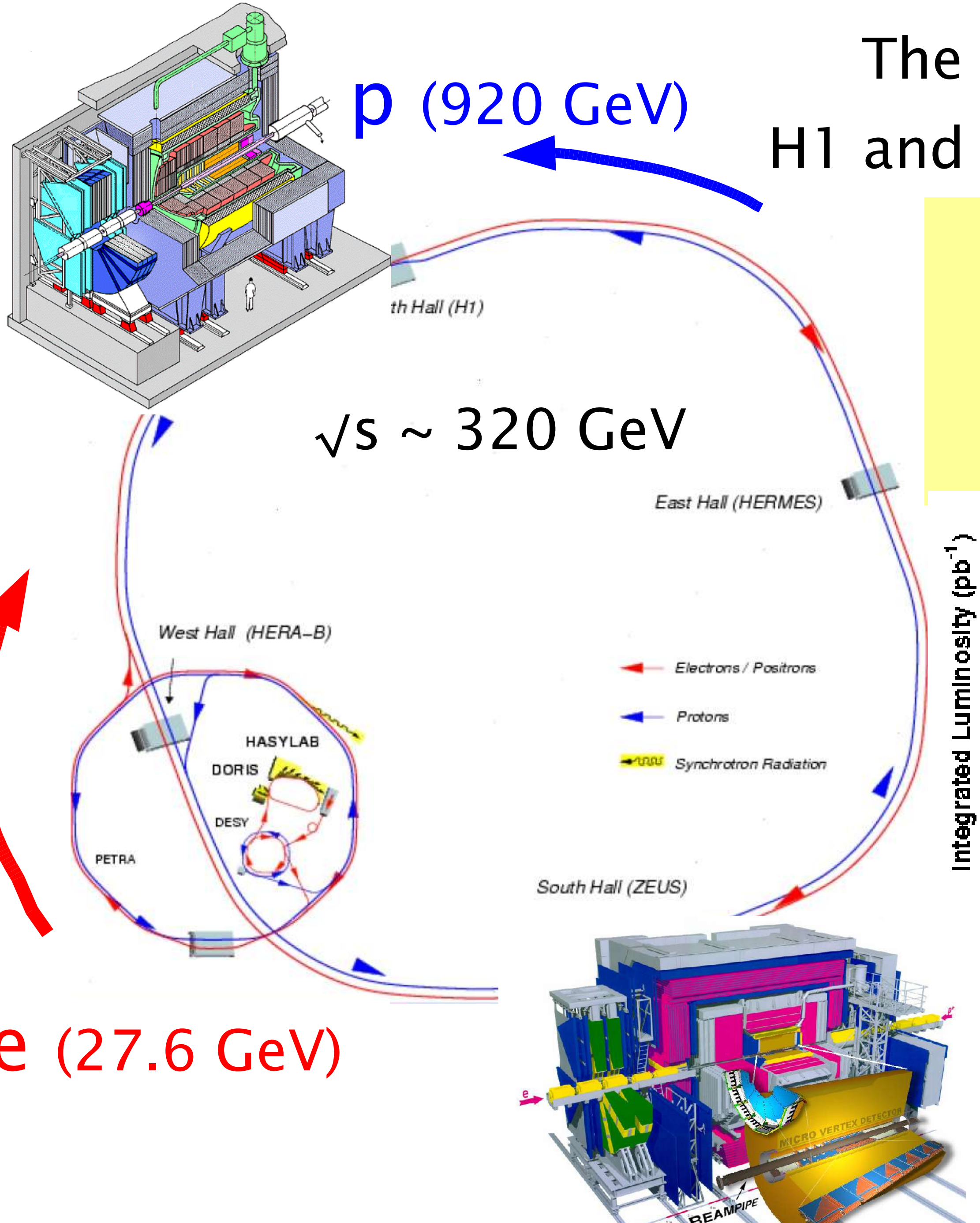
10^{th} International Conference on B-Physics at Hadron Machines
Assisi (Perugia), Italy. June 20-24, 2005

HERA collider

p (920 GeV)

e (27.6 GeV)

$\sqrt{s} \sim 320$ GeV



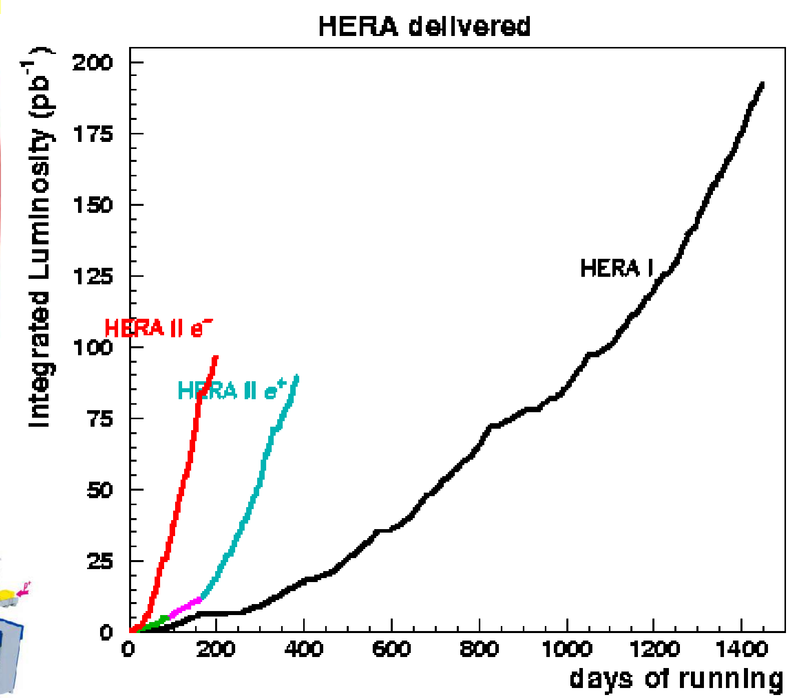
The world's only ep collider

H1 and ZEUS integrated luminosity:

96-00 /03-05

e^+ L ~ 100 /40 pb^{-1}

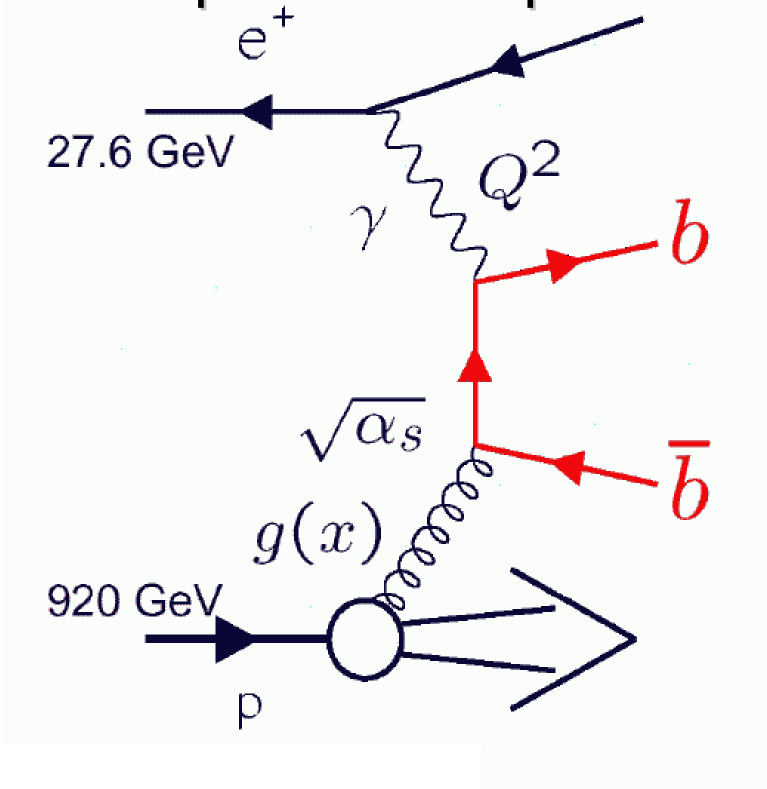
e^- L ~ 15 /100 pb^{-1}



2007 ~600pb^{-1} ?

b production in ep collision

Dominant production process in ep collision: Boson Gluon Fusion

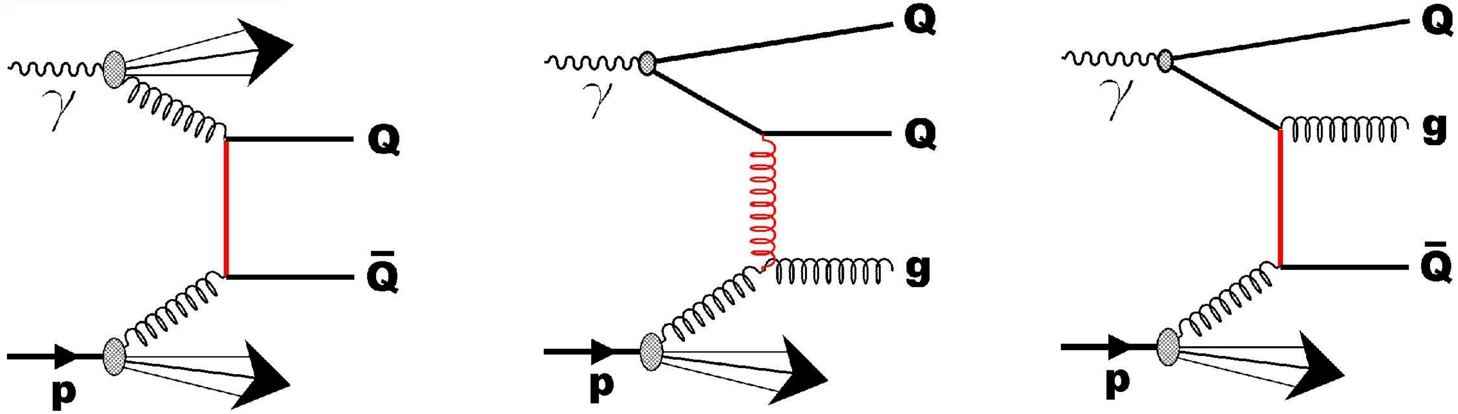


Multiple scales involved:

- M_b ~ 5 GeV
- $Q^2 \le 1$ GeV^2 (photoproduction – γp)
- $Q^2 \ge 1$ GeV^2 (deep inelastic scattering – DIS)
- P_t^b ~few GeV (event selection:p_t^{jet} >6,7 GeV)

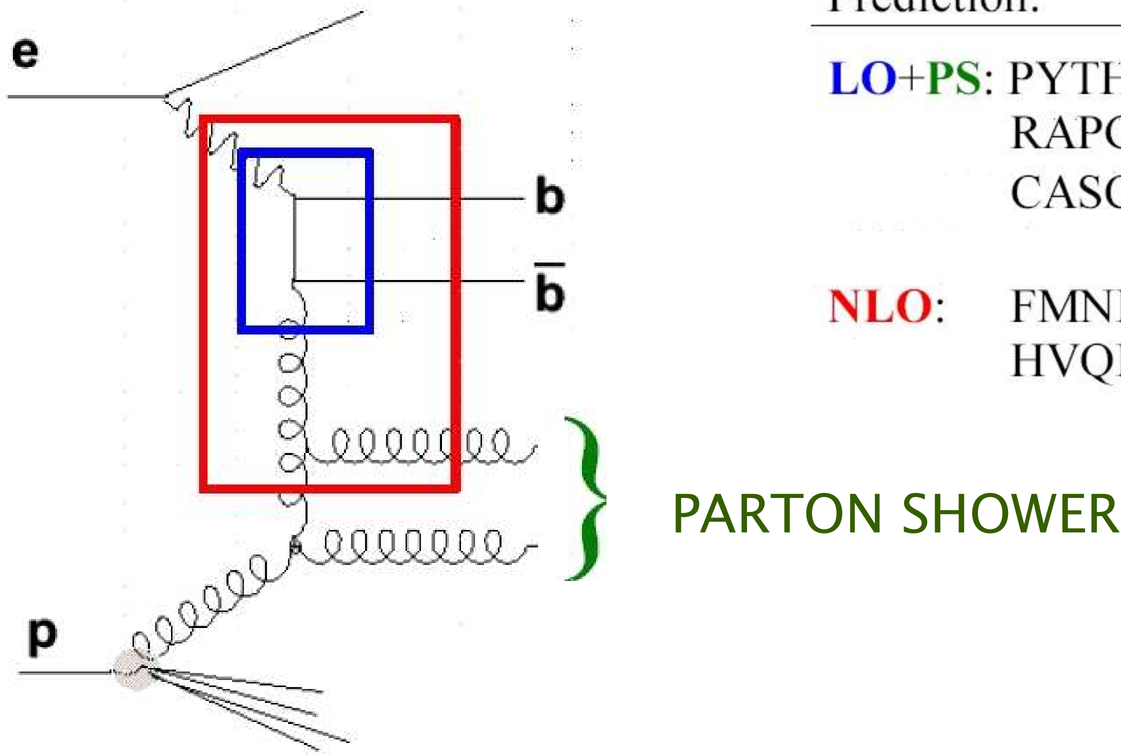
powerful tool for testing p structure and pQCD

resolved photon:



flavour excitation

b production in ep collision



Prediction:			Describes:
LO+PS:	PYTHIA, HERWIG	(DGLAP)	γp
	RAPGAP	(DGLAP)	DIS
	CASCADE	(CCFM)	γp&DIS
NLO:	FMNR		γp
	HVQDIS		DIS

MONTE CARLO:
leading order + parton shower models available, including flavour excitation, DGLAP evolution (PYTHIA , HERWIG)

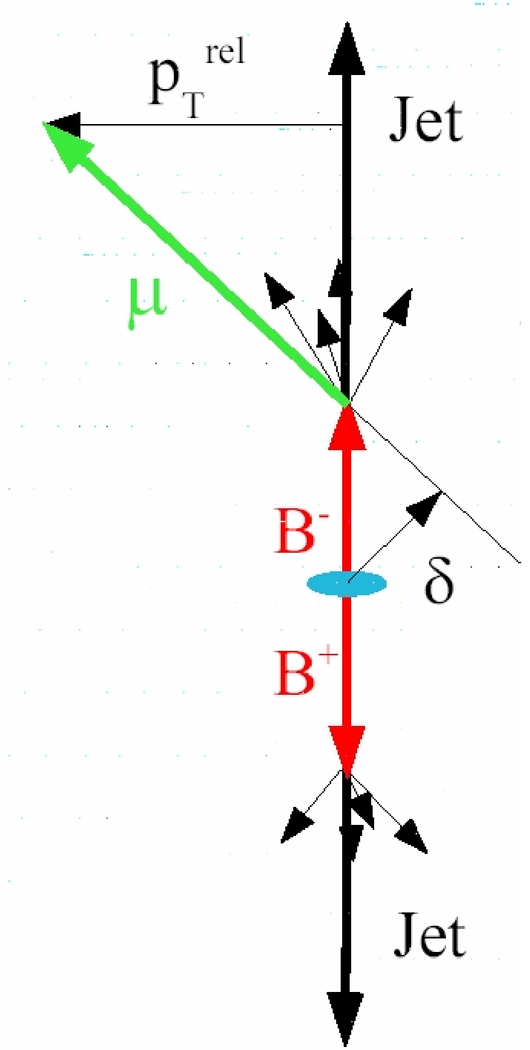
- CCFM evolution with k_t factorisation (CASCADE)

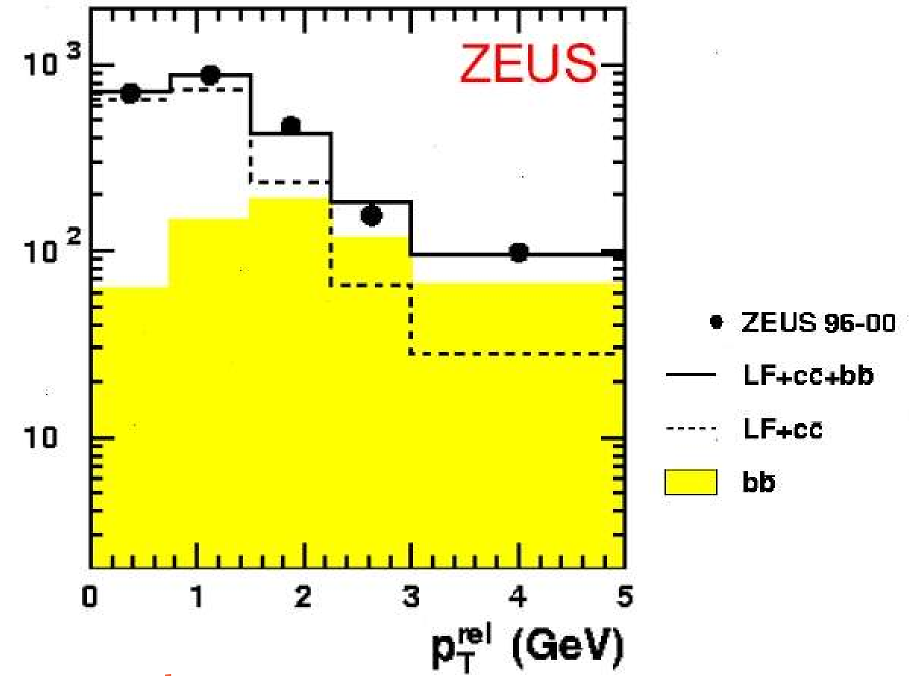
THEORETICAL CALCULATION: full NLO calculation (FMNR) available

MASSIVE scheme FFNS (heavy quarks dynamically generated in the hard process)

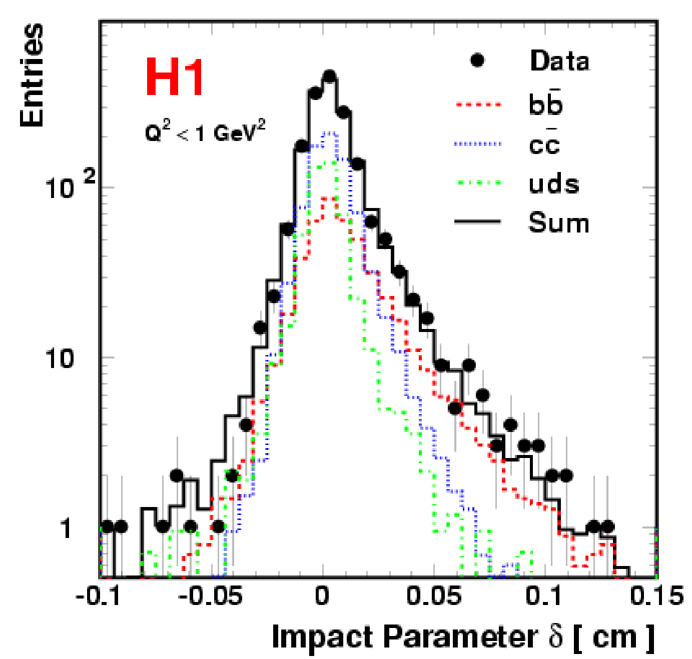
B tagging techniques

- Large B-mass
  p_t^{rel}: Pt of mu relative to jet axis
- Long B-lifetime
  δ: μ impact parameter



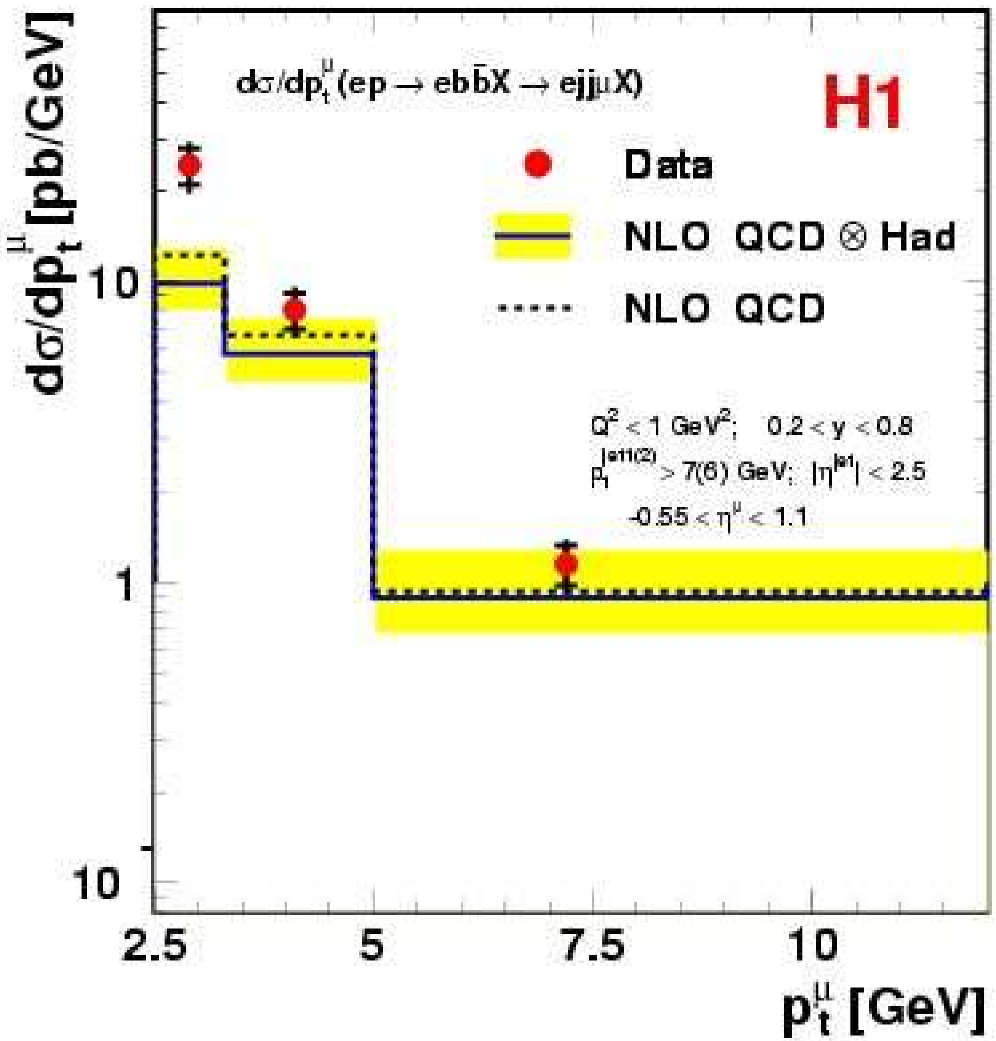


2jets + μ beauty events



μ + jets and δ (H1)

- simultaneous 2-dimensional Ptrel and δ fit
- enhanced statistics and reduced systematic uncertainties



$Q^2 < 1\,\mathrm{GeV}^2$

$0.2 < y < 0.8$

$p_t^{\mu} > 2.5\,\mathrm{GeV}$

$-0.55 < \eta_{\mu} < 1.1$

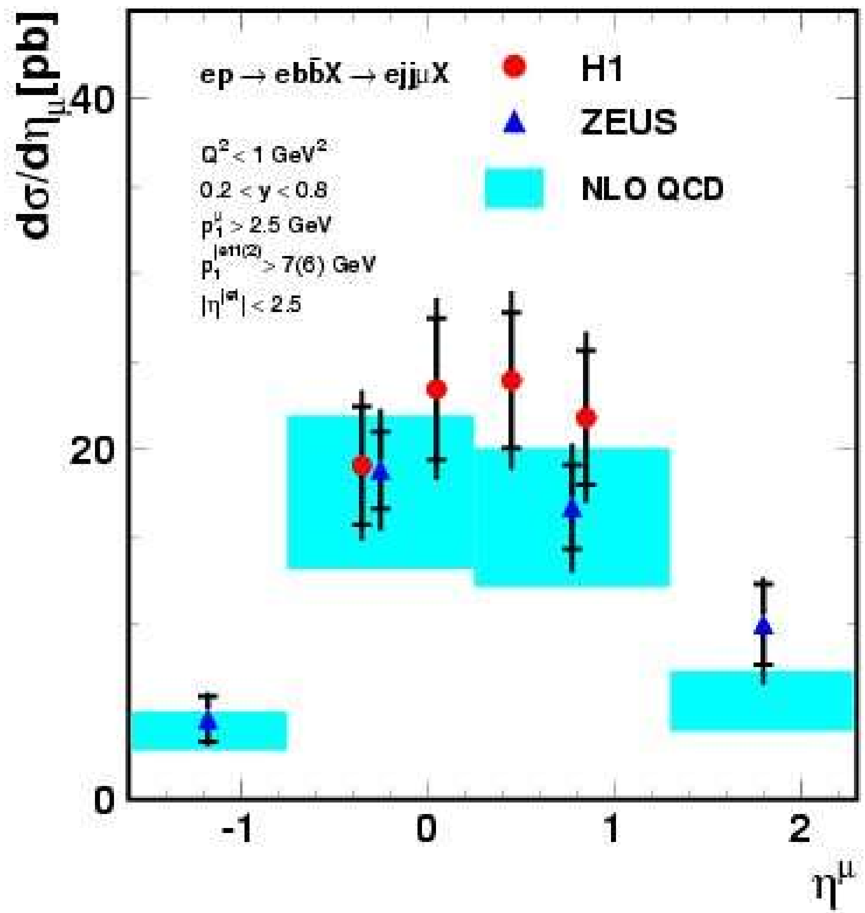
$p_t^{jet} > 7(6)\,\mathrm{GeV}$

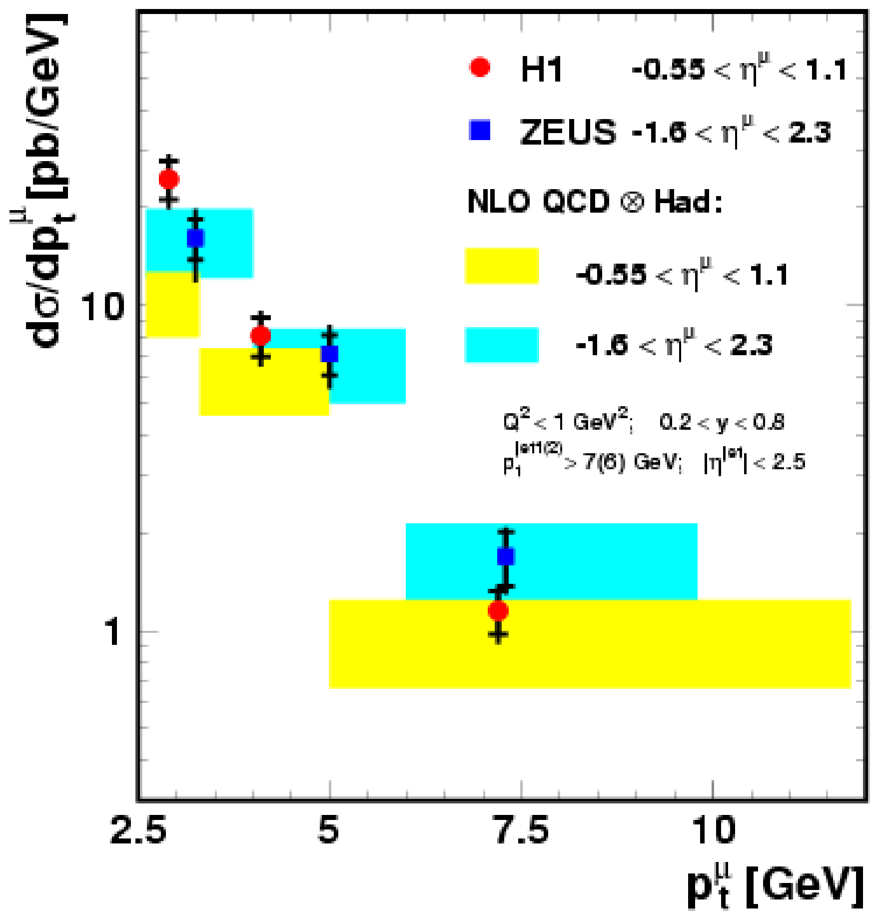
$|\eta_{lab}^{jet}| < 2.5$

data 99-00 (50 pb^{-1})

data tend to rise more steeply then NLO QCD at low p_t^{μ}

μ + jets and δ : comparison H1 - ZEUS



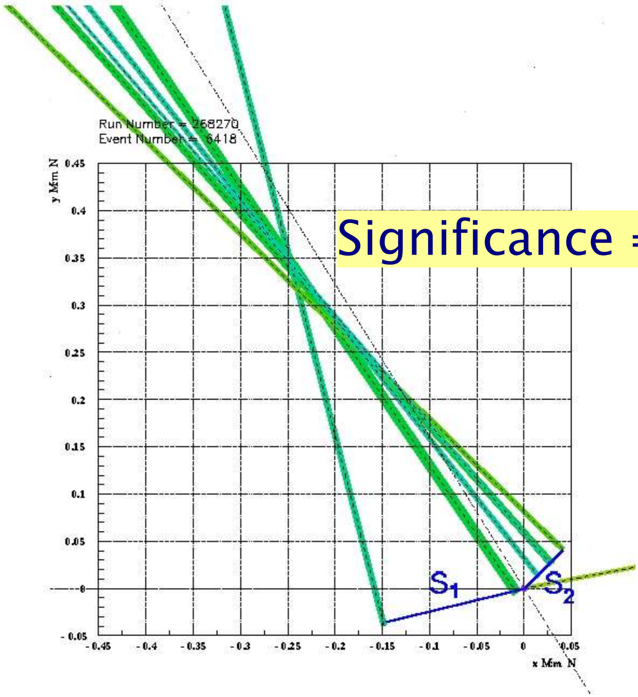


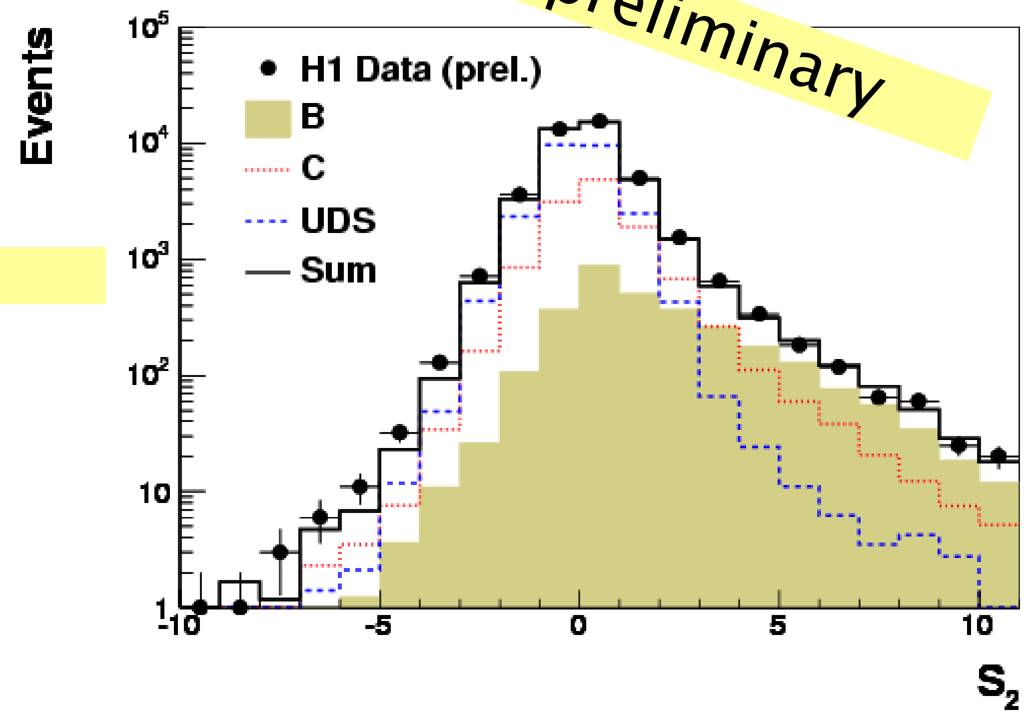
Agreement within errors of H1 and ZEUS
agreement within errors with massive NLO QCD (FMNR)

- H1: ptrel + delta , (hep-ex/0502010)
- ZEUS: Ptrel , (hep-ex/0312057)

lifetime tagging (H1)

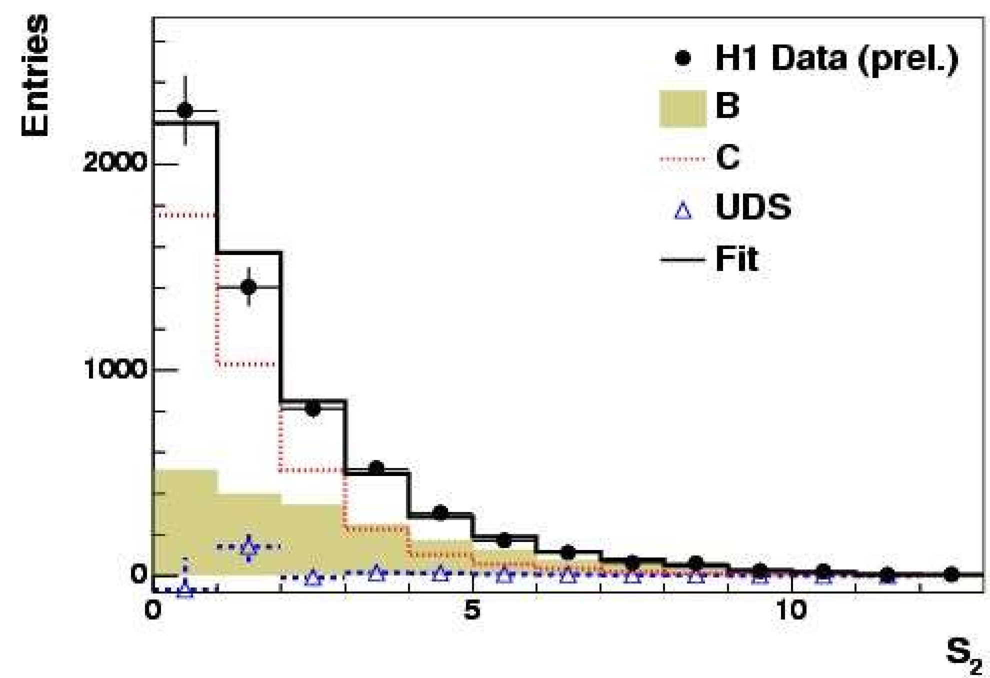
Inclusive sample (all tracks p_t>500MeV)





S1 (1 track associated to jet) significance of the track
S2 (≥2 tracks associated to the jet) second highest significance →enhanced sensitivity to b

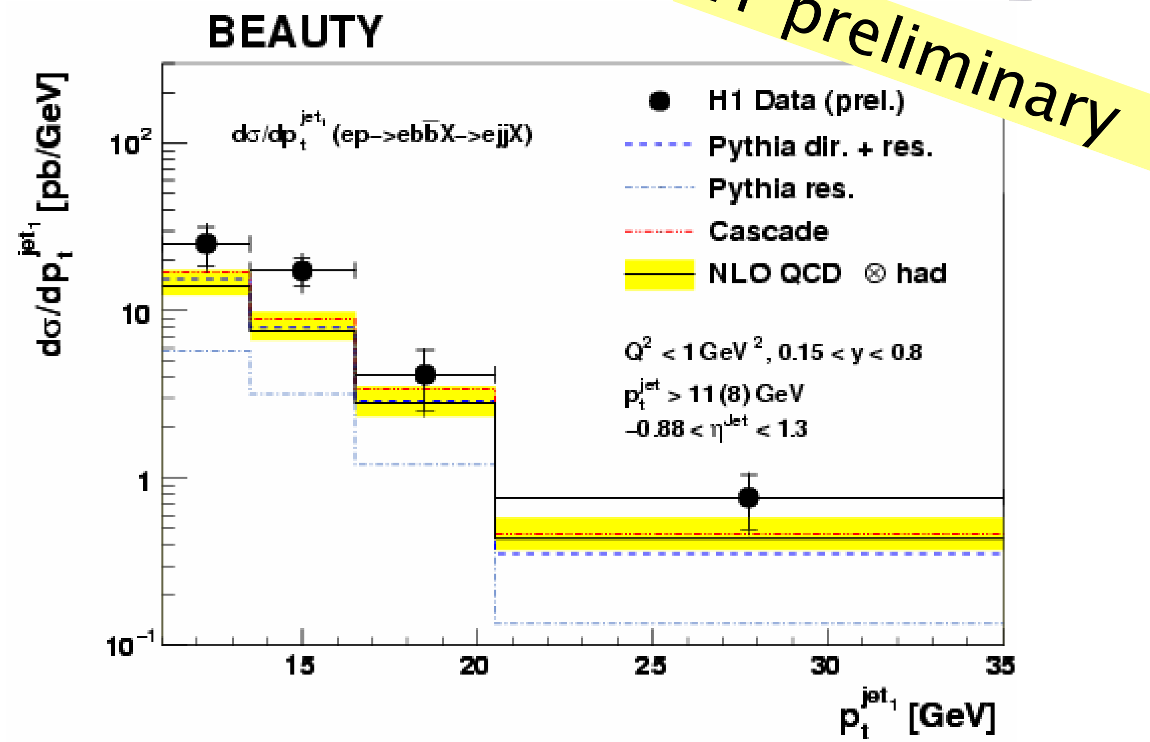
extract b and c fraction from fit to subtracted significance distributions



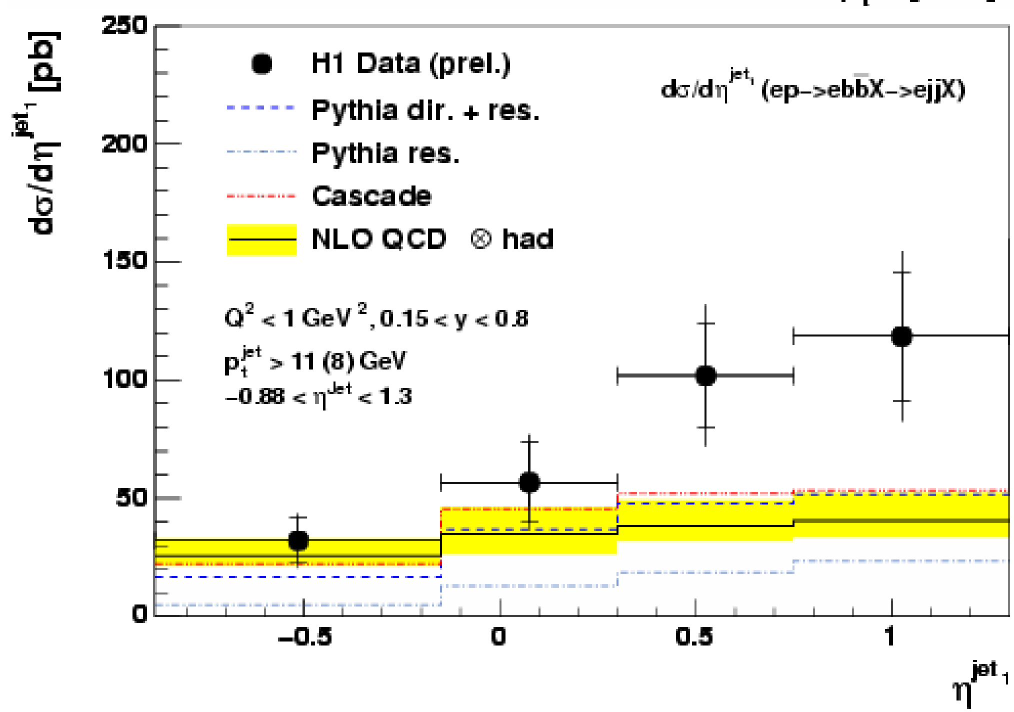
advantage: higher statistics w.r.t. D* or lepton analysis

lifetime tagging (H1)

PYTHIA and CASCADE (LO+PS): good shape description but generally data higher in normalisation (factors ~1.8,1.6)



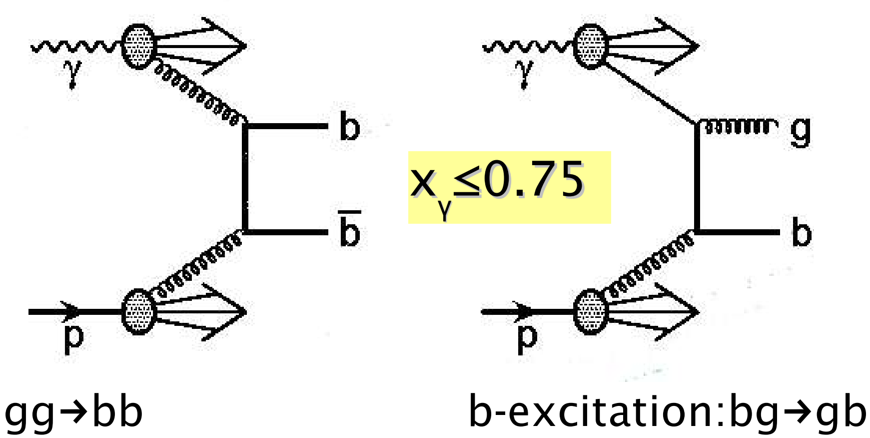
Main difference between beauty data and NLO QCD in region +ve rapidity → large contribution from resolved photon events to the xsections

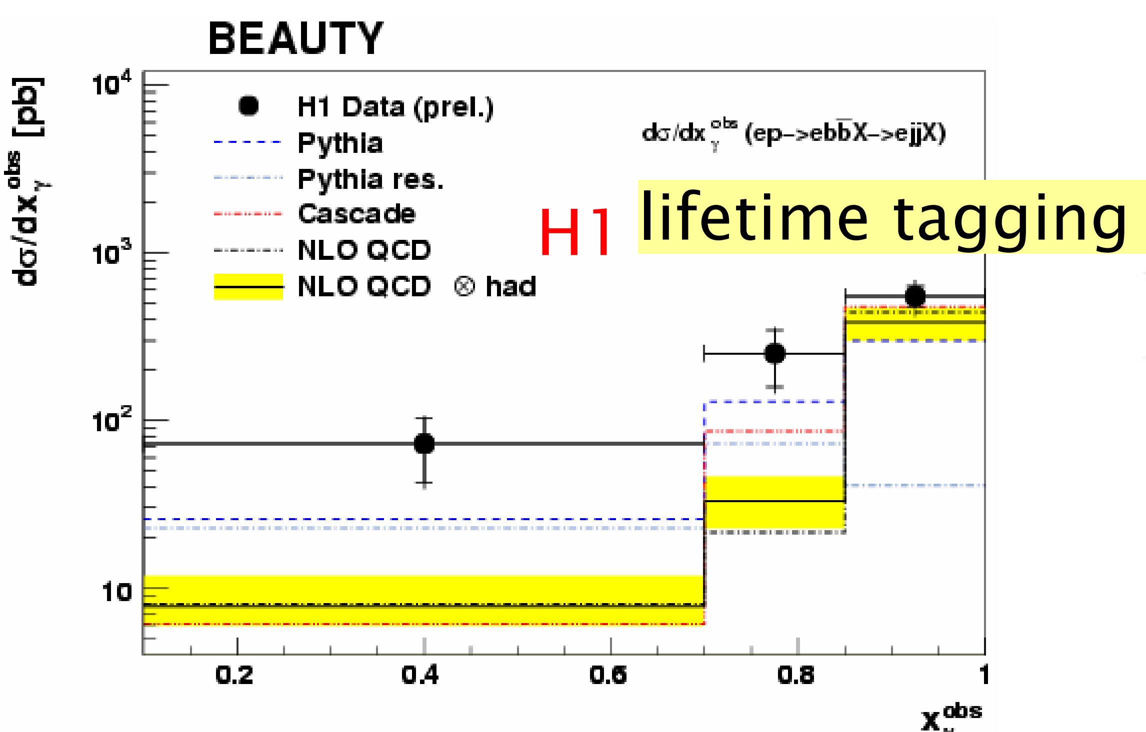


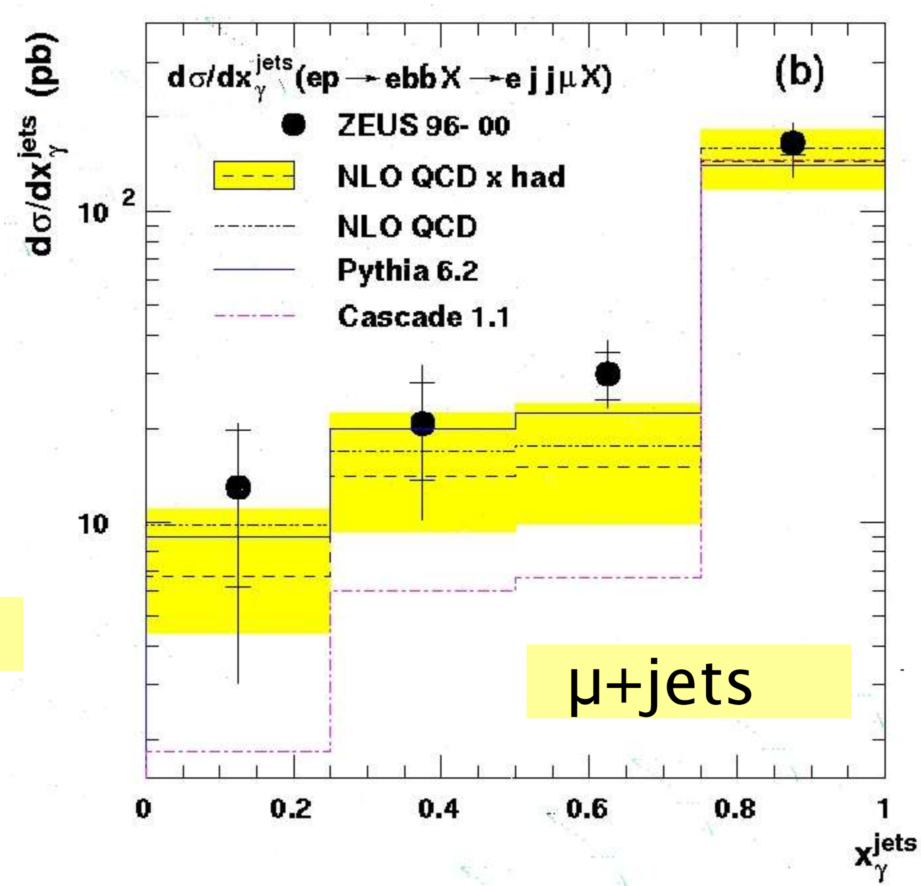
x_γ (H1 & ZEUS)

$$x_\gamma^{jet} = \Sigma_{j1,j2}(E-p_z) / \Sigma_h(E-p_z)$$

at LO QCD x_γ is the fraction of photon's energy entering the hard interaction

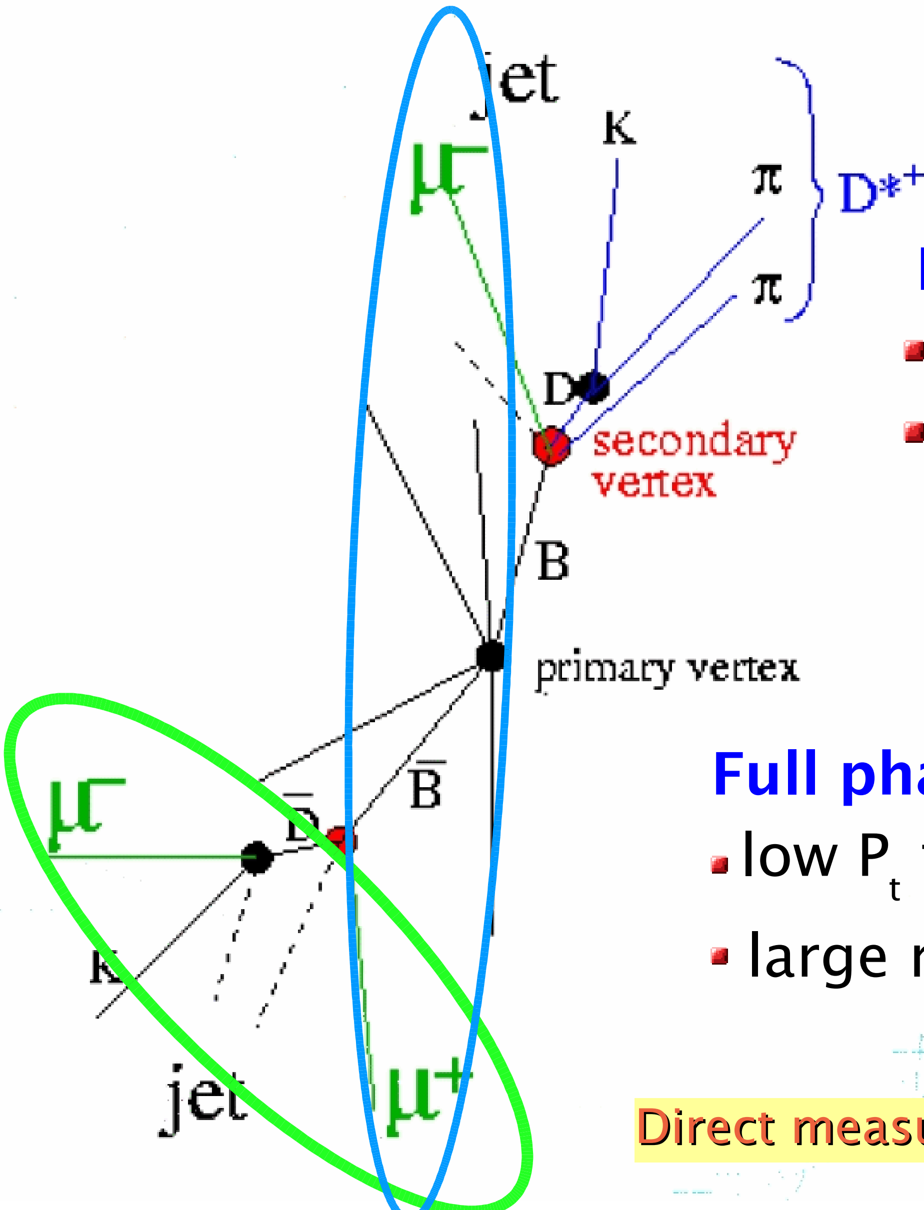






beauty from di-μ events

b double tag ep→b$\bar{b}$X→μμX'
→D*μX'



Low background

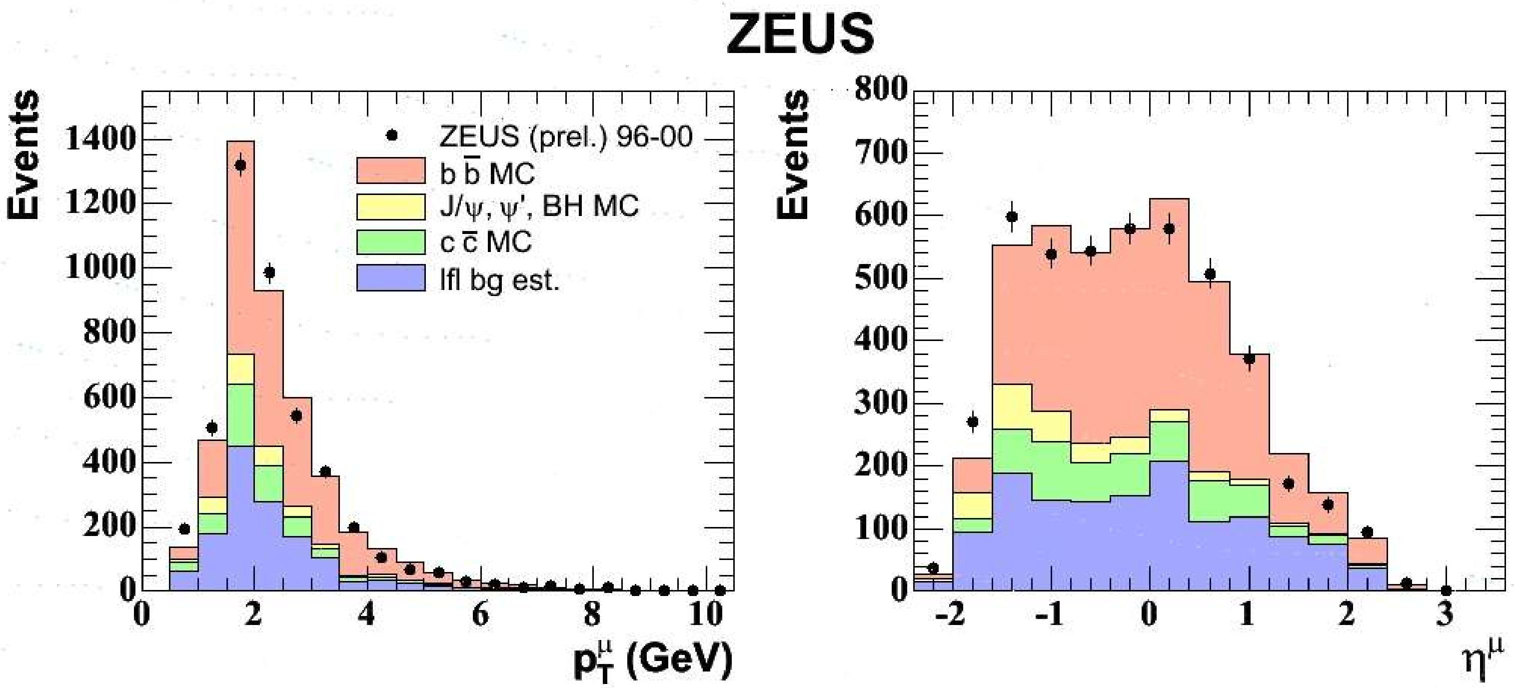
- di-mu selection
- separation of the sample in high-low mass, isolated and non-isolated,like and unlike-sign muon pair

Full phase space for beauty production

- low P_t threshold for muon identification
- large rapidity coverage of ZEUS muon system

Direct measure total b$\bar{b}$ cross section without any cuts

beauty from di-μ events (ZEUS)



low+high mass
unlike sign

- charm pair production contributes to the unlike-sign muon sample only and was estimated from D*+muon analysis

- fake muon bkg was removed by taking the difference between like sign and unlike sign samples (lfl contribution cancels)

what is left is only beauty contribution...

beauty from di-μ events (ZEUS)

ZEUS preliminary

Visible range:

1st μ :	$p_T > 1.5$ GeV		
2nd μ :	($p > 1.8$ GeV		for $\eta < 0.6$
	$p > 2.5$ *or* $p_T > 1.5$ GeV		for $\eta > 0.6$)
	and $p_T > 0.75$ GeV		
both μ:	$-2.2 < \eta < 2.5$		

Visible cross section (Prel. DIS05):

$$\sigma_{vis}\ ep \to b\bar{b}X \to \mu\mu X' = 63 \pm 7\ (\text{stat.})\ {}^{+20.2}_{-17.6}\ (\text{syst.})\ \text{pb}$$

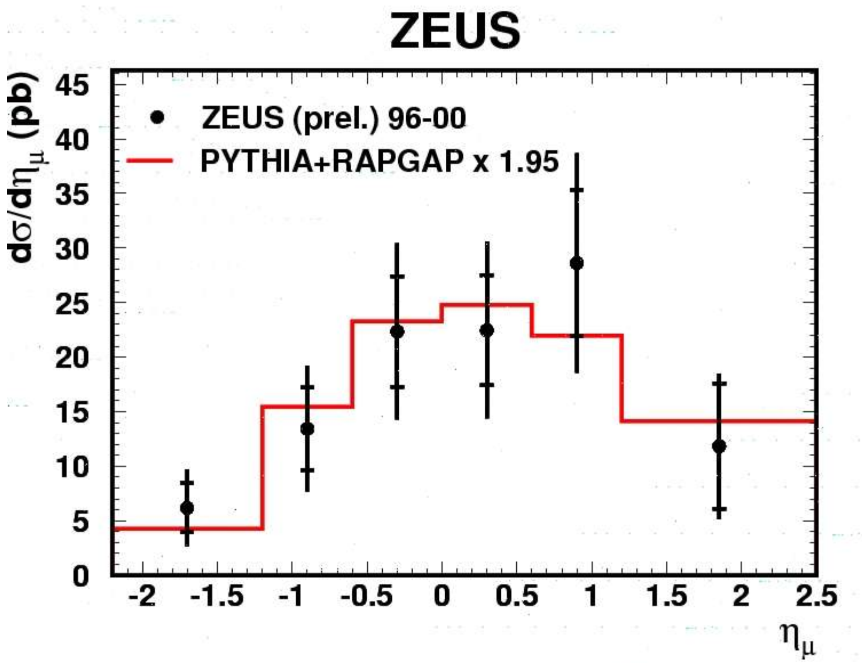
Measured total cross section (Prel. DIS05):

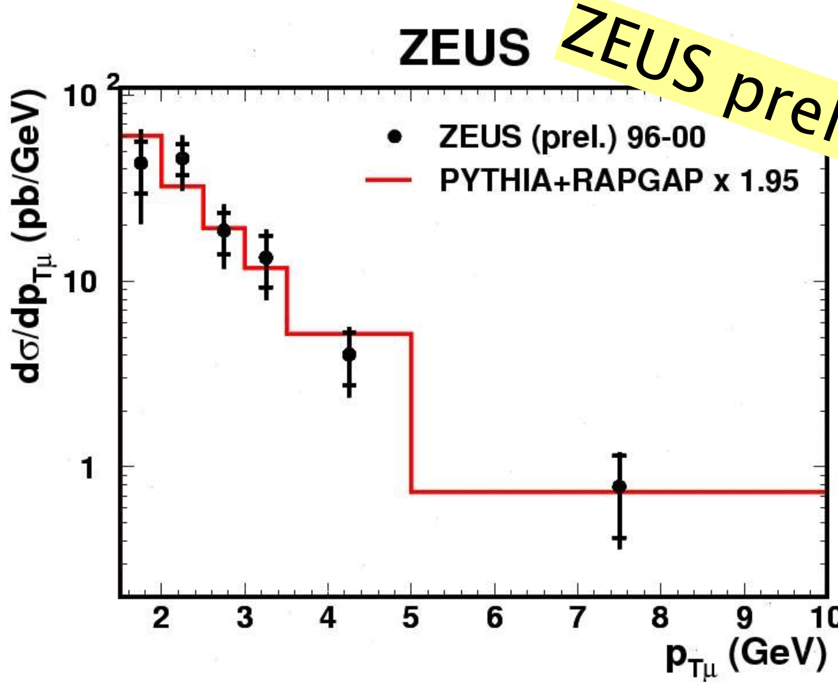
$$\sigma_{b\ tot}\ ep \to b\bar{b}X\ (318\ \text{GeV}) = 16.1 \pm 1.8\ (\text{stat.})\ {}^{+5.3}_{-4.8}\ (\text{syst.})\ \text{nb}$$

NLO QCD predictions:

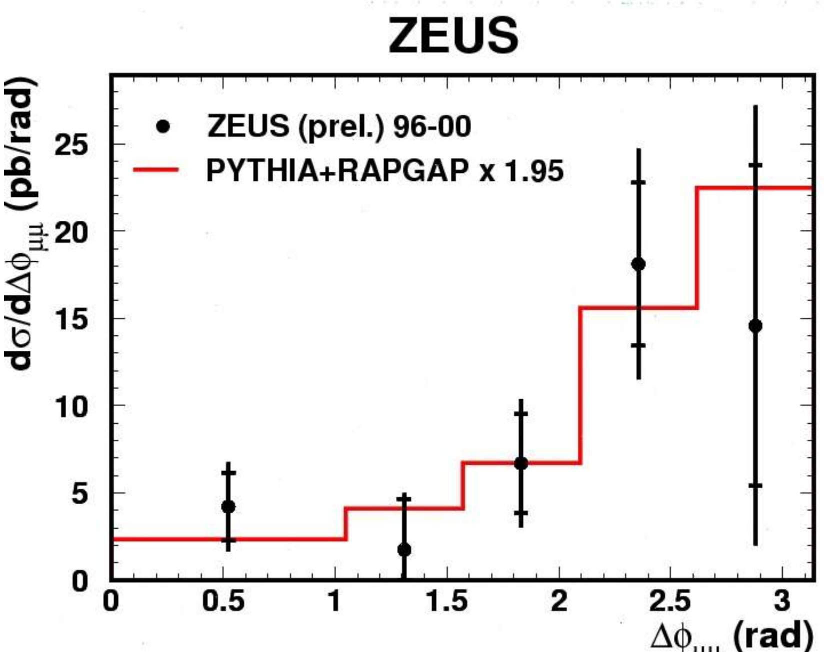
FMNR	**CTEQ5M**	**6.8** $^{+3.0}_{-1.7}$ **nb**	$4.5 < m_b < 5.0$
+ HVQDIS	**CTEQ5F4**		$0.5 < \mu/\mu_0 < 2$

beauty from di-μ events (ZEUS)





ZEUS preliminary



- $P_t^{\mu} > 1.5$ GeV
- $-2.2 < \eta < 2.5$

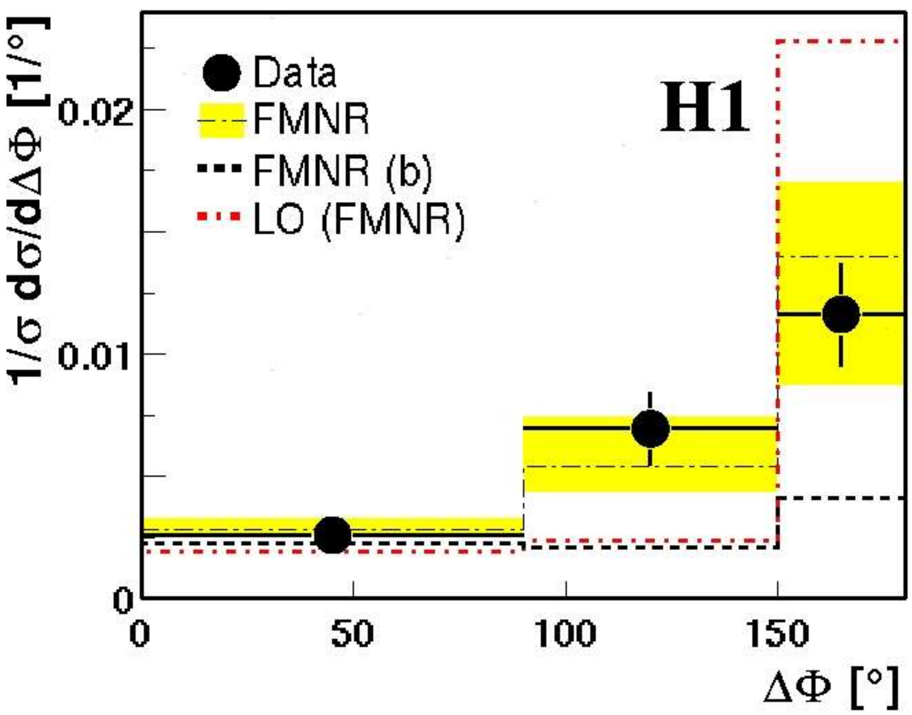
- for ΔΦ additional request:

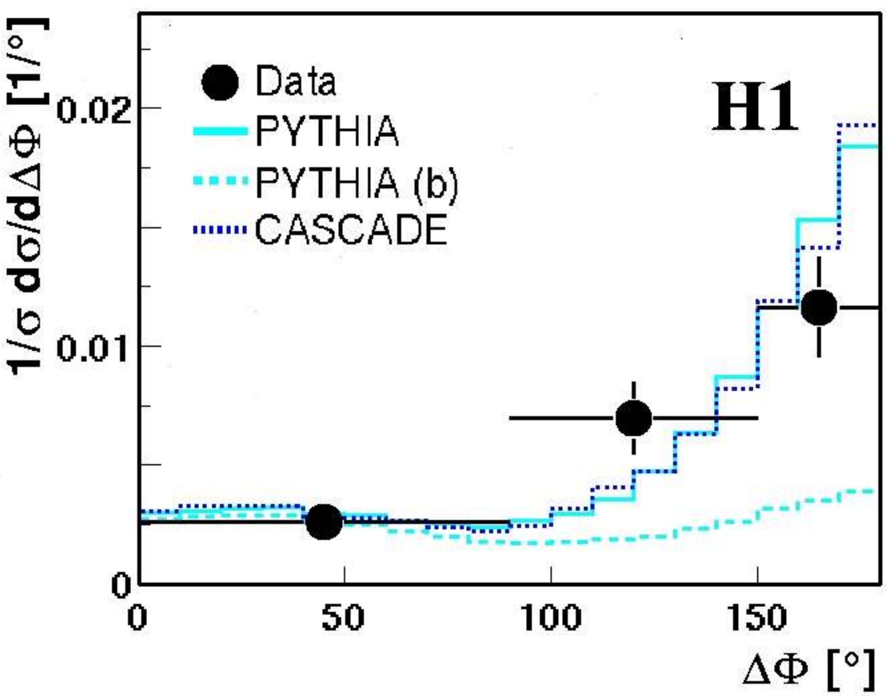
true level: μ coming from different bs
rec level: $m_{\mu\mu} > 3.25$GeV

agreement in shape with MC (LO+PS)

D* + μ events (H1)

- This measure extends to significantly lower centre-of-mass energies of bb system than previous HERA xsections.
- Simultaneously detection of D* and μ → test high order QCD effects
- D* μ sensitive to a possible transverse momentum k_t of the gluons entering the quark pair production process



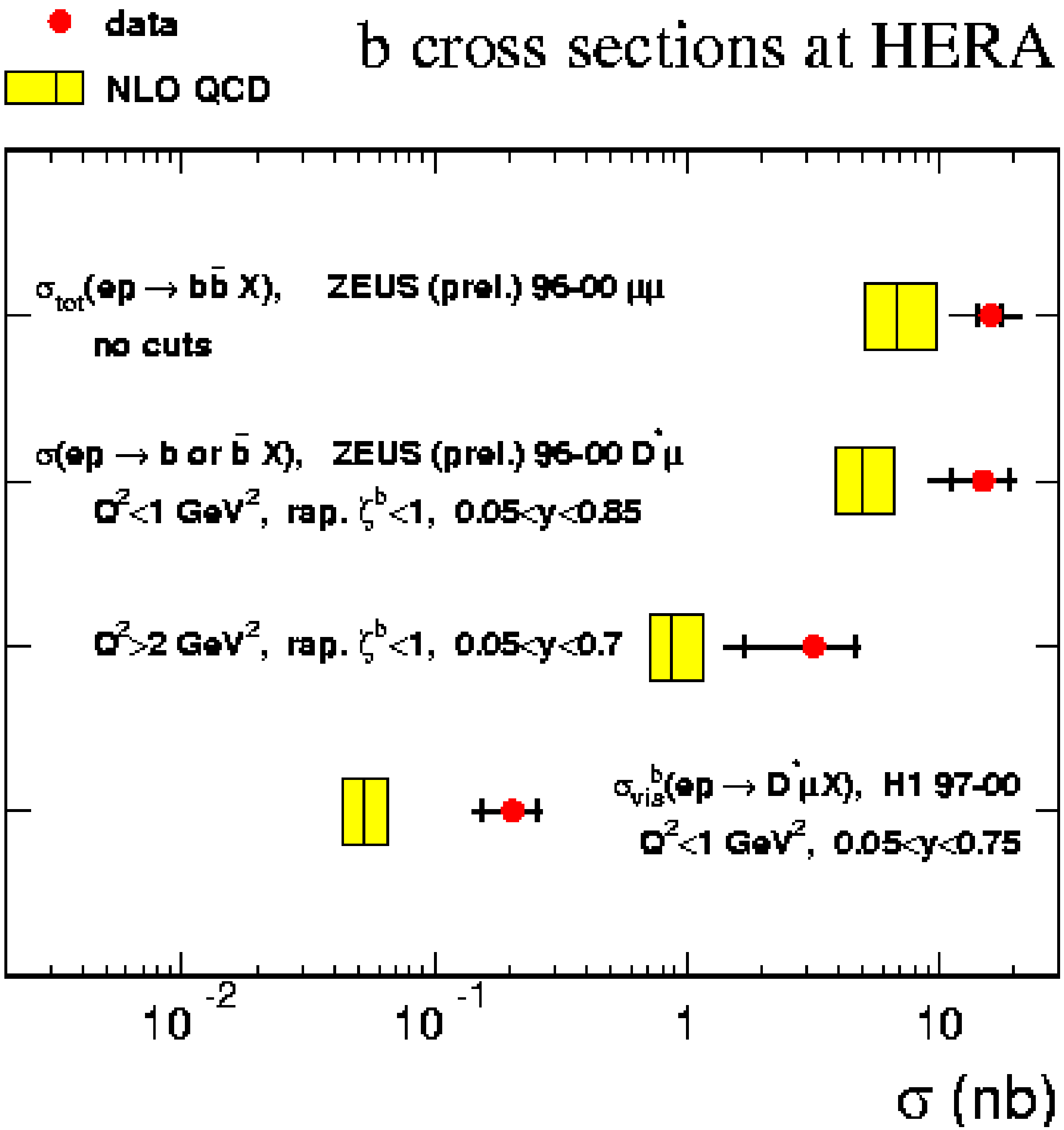


deviations from LO -> high order effects, good agreement with NLO

D* + μ events (H1 & ZEUS)

H1: $\sigma_b^{vis}(ep \to eD^*\mu X) = 206 \pm 57(stat.) \pm 40(syst.)pb$

ZEUS: $\sigma_b^{vis}(ep \to eD^*\mu X) = 159 \pm 41(stat.)^{+68}_{-62}(syst.)pb$



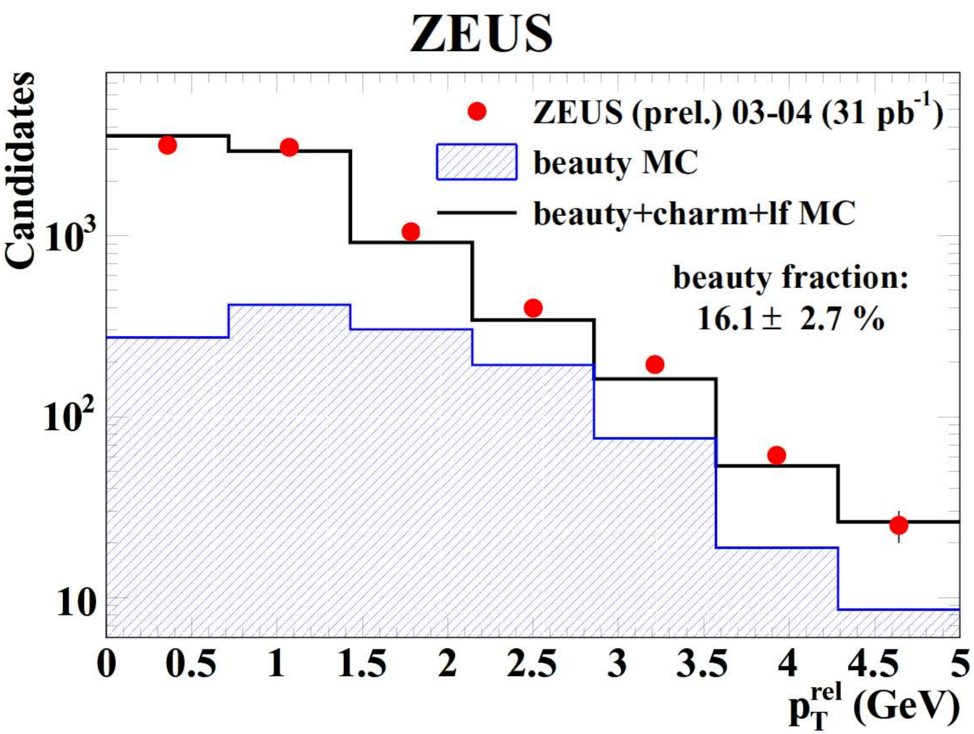
μμ PHP (ZEUS)

D*μ PHP (ZEUS)

D*μ DIS (ZEUS)

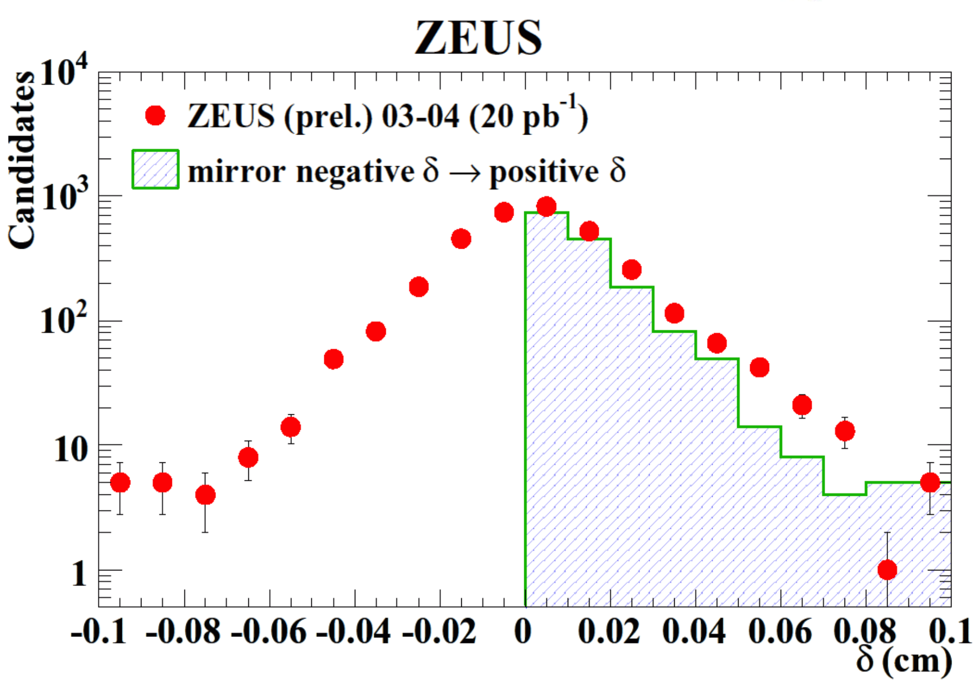
D*μ PHP (H1)

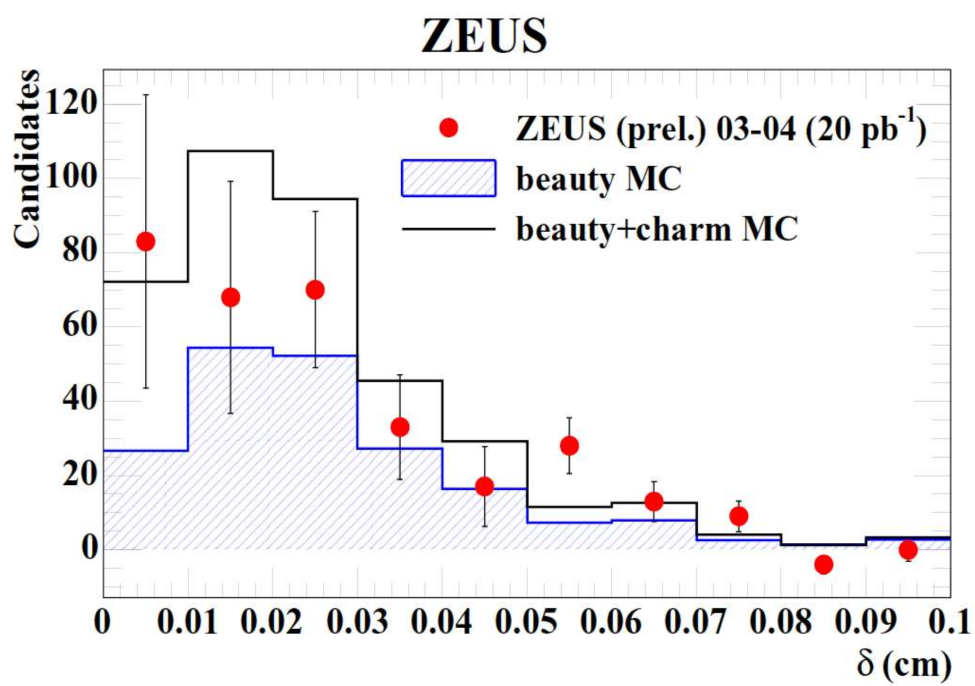
Hera II : μ + jets and δ (ZEUS)



ZEUS vertex detector since 2001 upgrade

First ZEUS result using impact parameter technique





summary

analysis with jets:

- p_t^{rel}, δ and significance measurements have been performed in php:
  - H1 and ZEUS measurements agree
  - general agreement at large P_t of beauty data with NLO QCD
  - H1 data slightly higher at low P_t^{μ},P_t^{jet1} (observed also in DIS)

double tag analysis:

- D*μ and di-μ measurements (sensitive at low P_t) have been presented
  - beauty data larger than NLO QCD

outlook

- HERA II is running smoothly in e^- mode
- Improved analysis and detector performances (e.g. ZEUS MVD)
- high precision results are coming...

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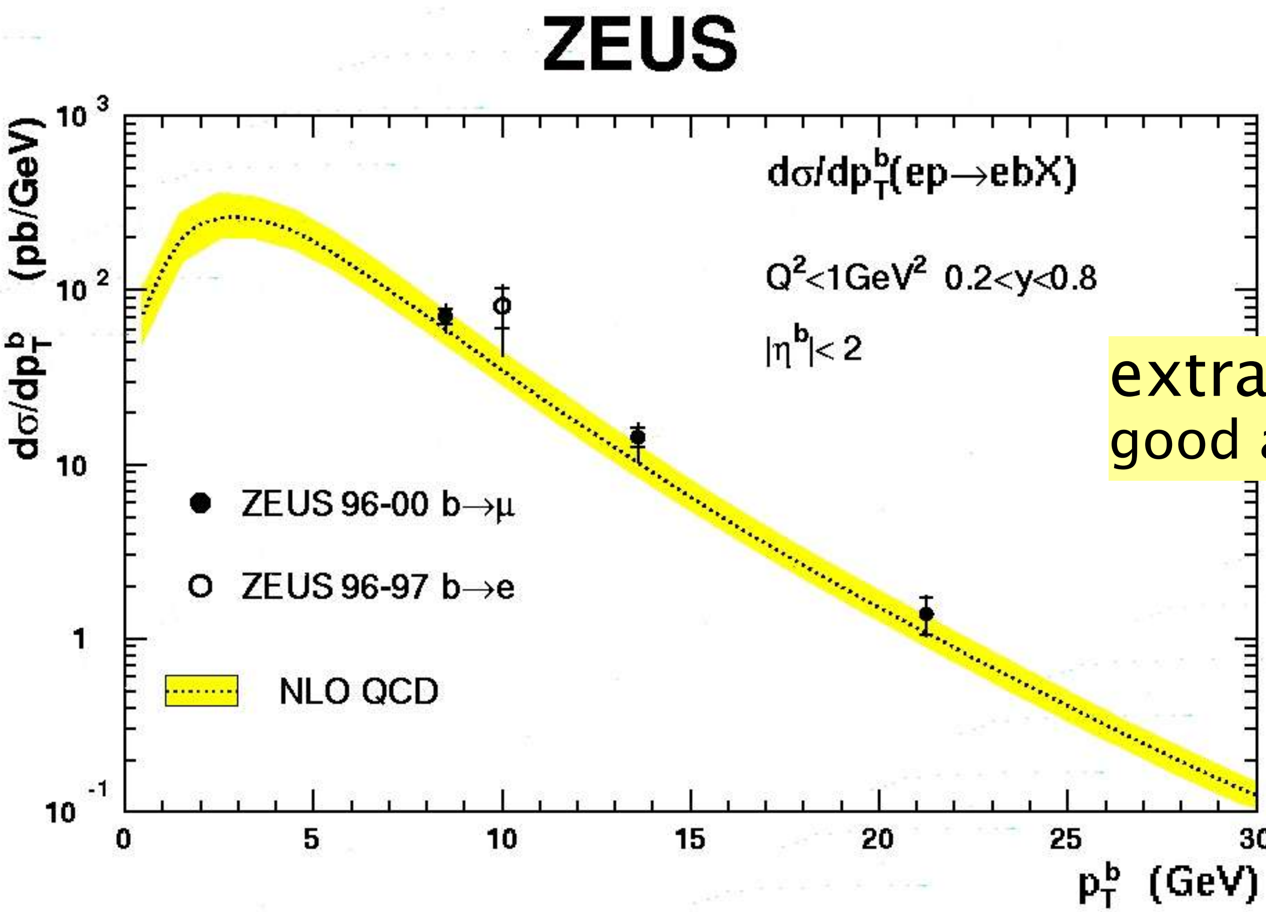
inclusive b-quark cross section



extrapolation to ep-> ebX
good agrement with NLO QCD

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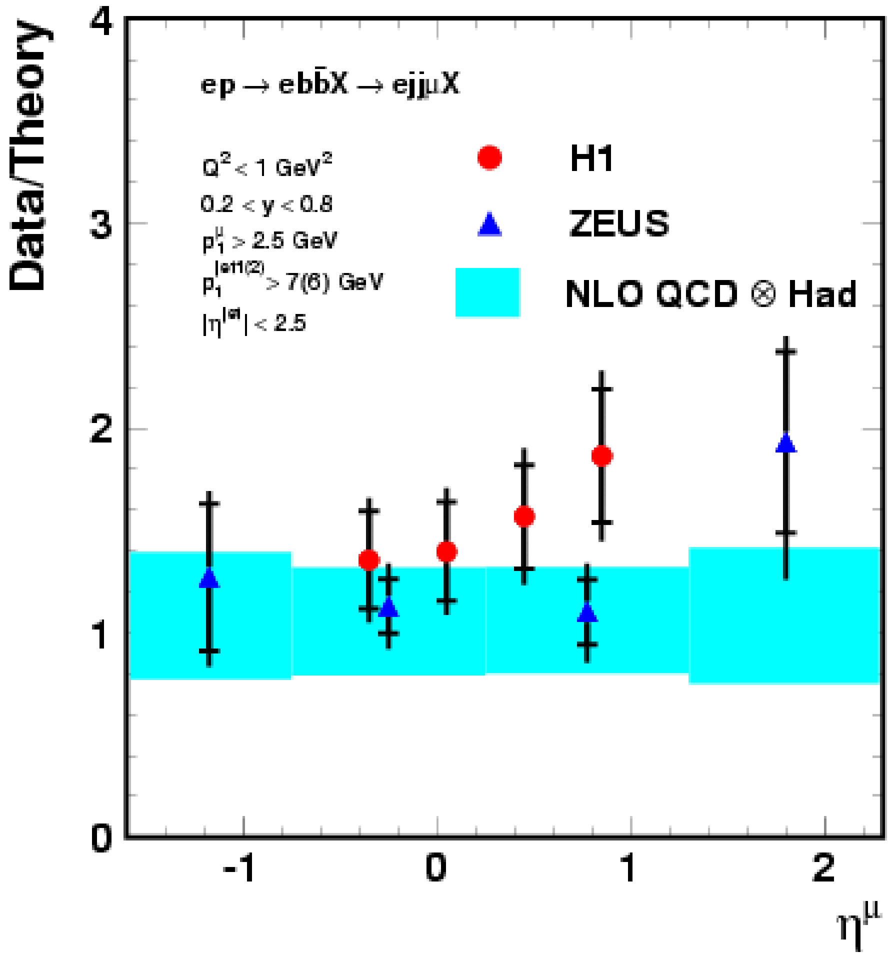
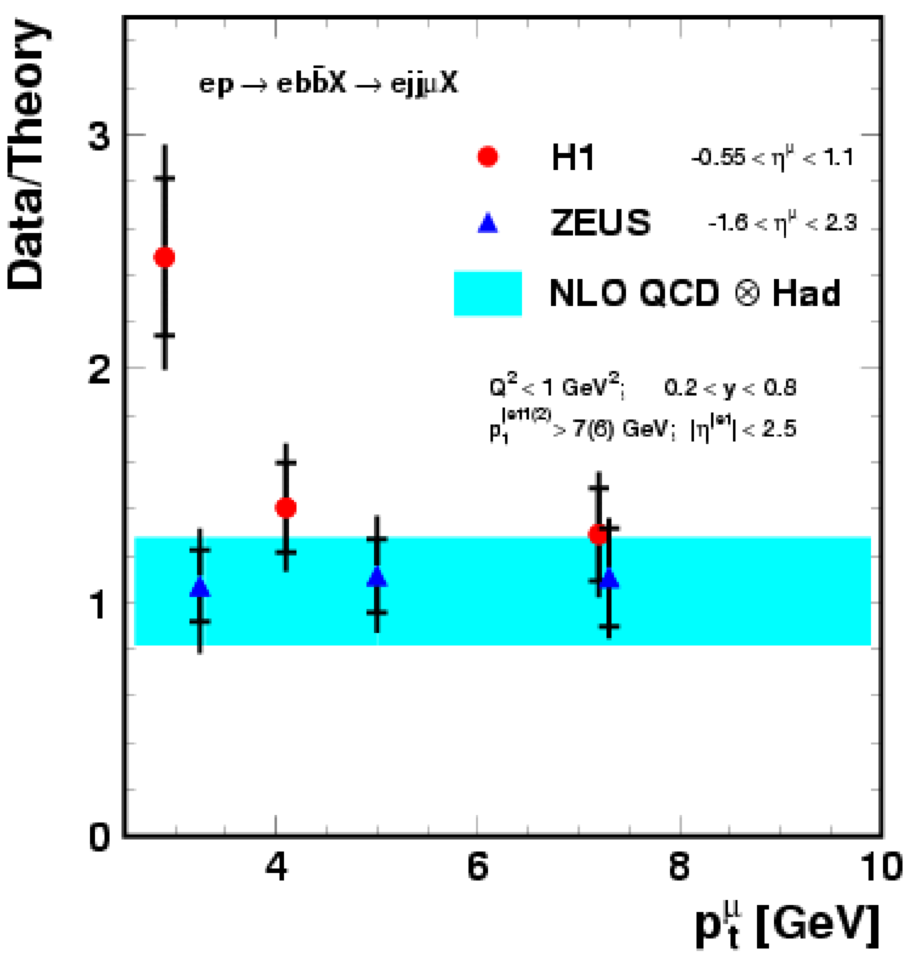
Data/theory





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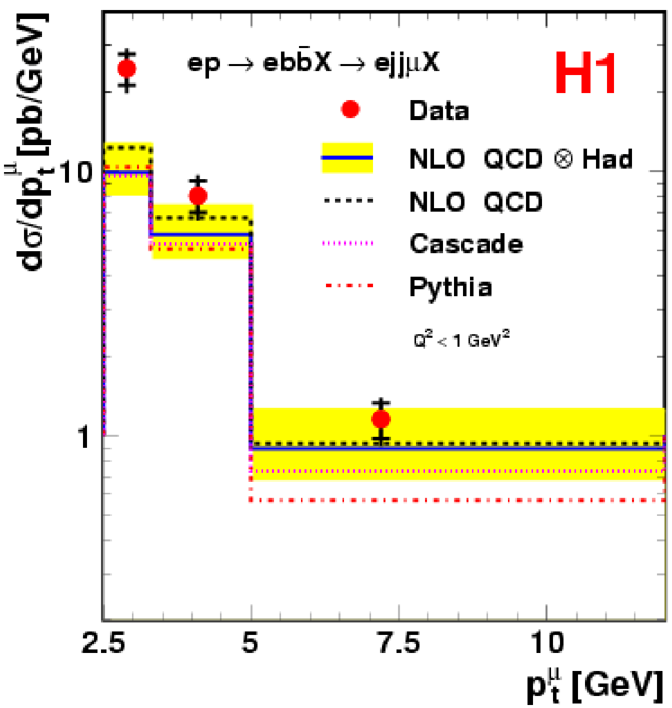
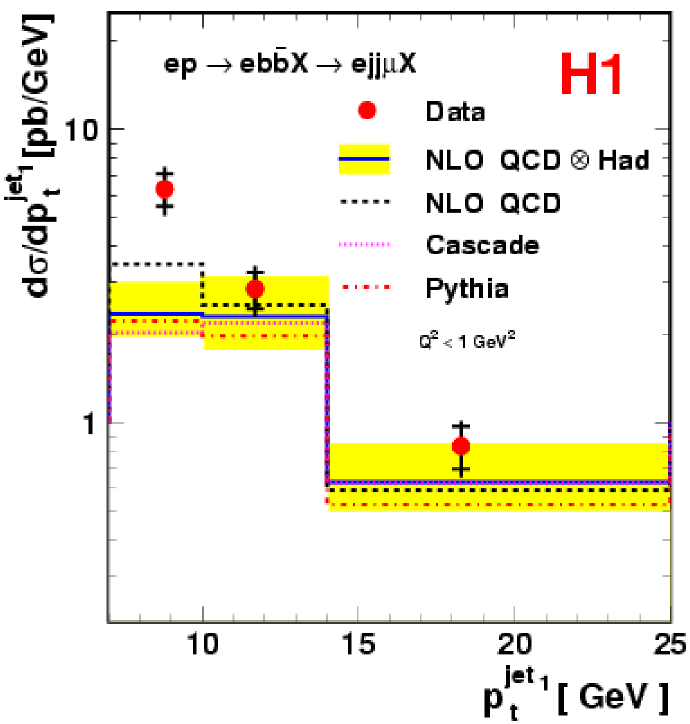
- simultaneous 2-dimensional Ptrel and δ fit
- enhanced statistics and reduced systematic uncertainties

data 99-00 (50 pb^{-1})





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$p_t^\mu > 2.5\,GeV$
$-0.55 < \eta_\mu < 1.1$
$p_t^{jet} > 7(6)\,GeV$
$|\eta_{lab}^{jet}| < 2.5$

data tend to rise more steeply then NLO QCD at low p_t^μ, p_t^{jet1}