1.) Beauty production at HERA

- Introduction
- Recent results with muon and jets

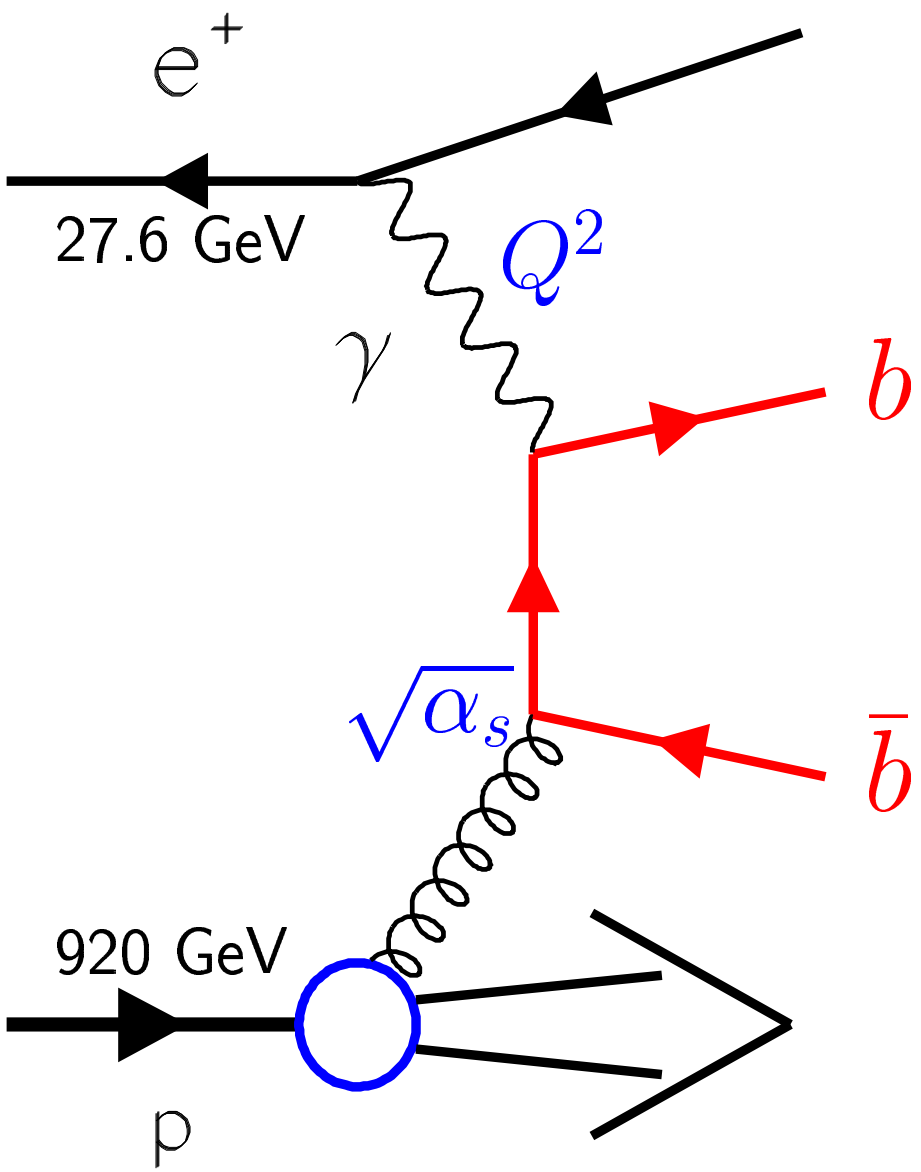
2.) $Q\bar{Q}$ correlations using events with a D^* and a muon

- Results from new H1 paper
  (to be released soon, based on H1prelim-02-071)

O. Behnke (Heidelberg)

March 21, 2005 HERA-LHC workshop

Beauty production at HERA



Key questions/points:

- Are available pQCD calculations in Next-to-leading order good enough?
- Multi-hard scale problem in pQCD: $[\alpha_s \ln(Q^2/m_b^2)]^n$ terms
  $\rightarrow$ pQCD approximations: Massive and Massless schemes (and variable s.)
- Probe hard scales over wide range:

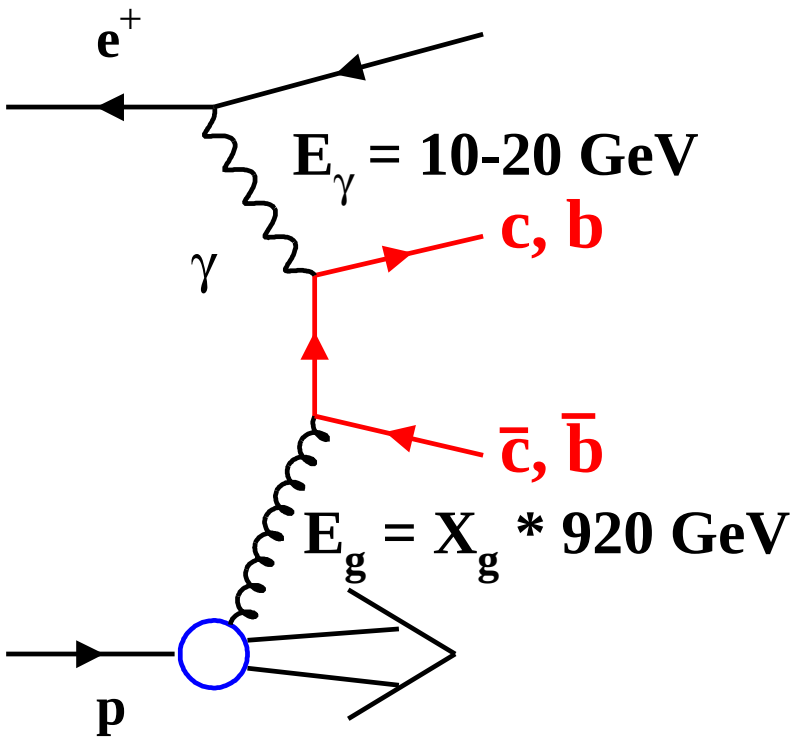
Kinematic region	Hard scales
γp: $Q^2 < 1$ GeV^2	m_b, p_T^b
DIS: $Q^2 > 1$ GeV^2	m_b, Q^2, p_T^b

Production rates at HERA

Total production rates at HERA:

$$\sigma_{\mathrm{uds}} \sigma_{\mathrm{charm}} \sigma_{\mathrm{beauty}} \sim 2000 : 200 : 1$$

Main reason for Beauty suppression: phasespace!

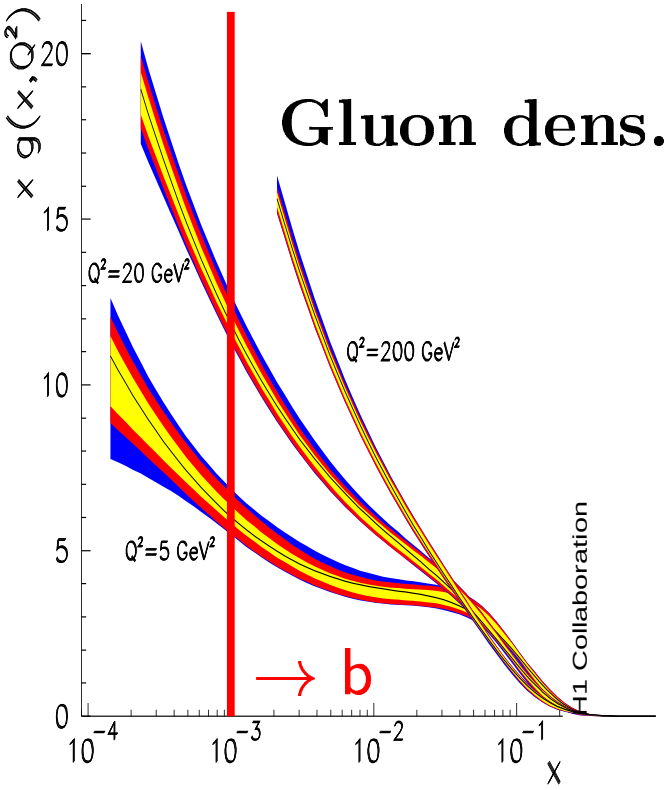


Kin. Threshold:

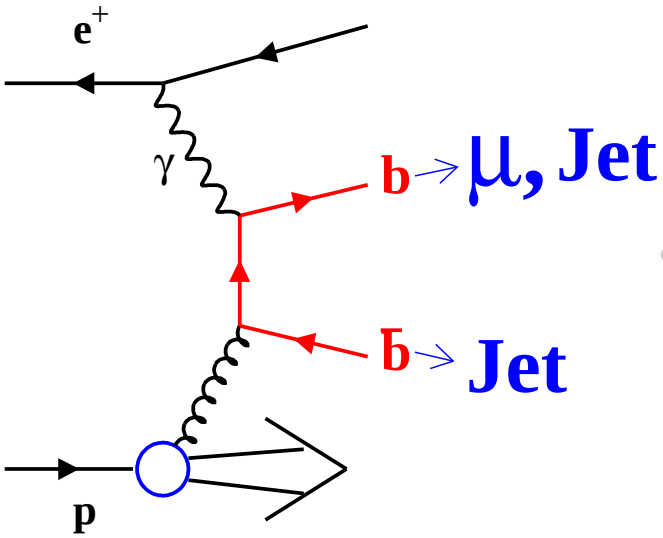
$$\mathbf{X}_g \geq \frac{m_Q^2}{E_\gamma \cdot 920\ \mathbf{GeV}}$$

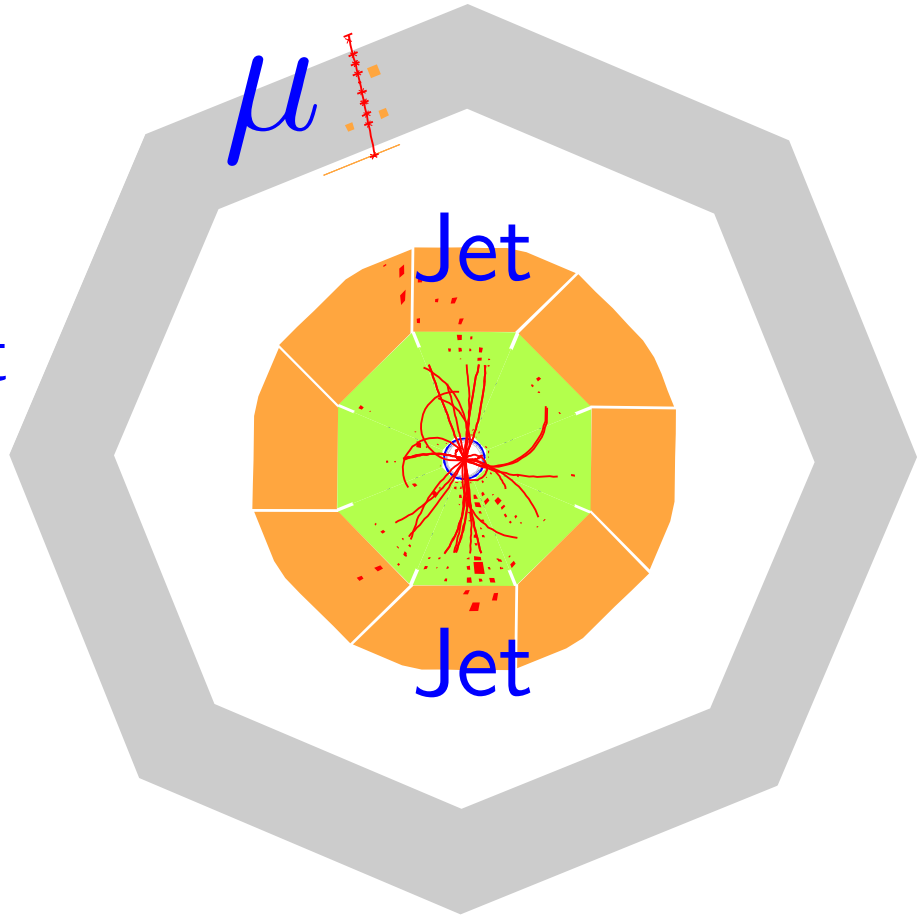
c: $\mathbf{X}_g \geq 10^{-4}$

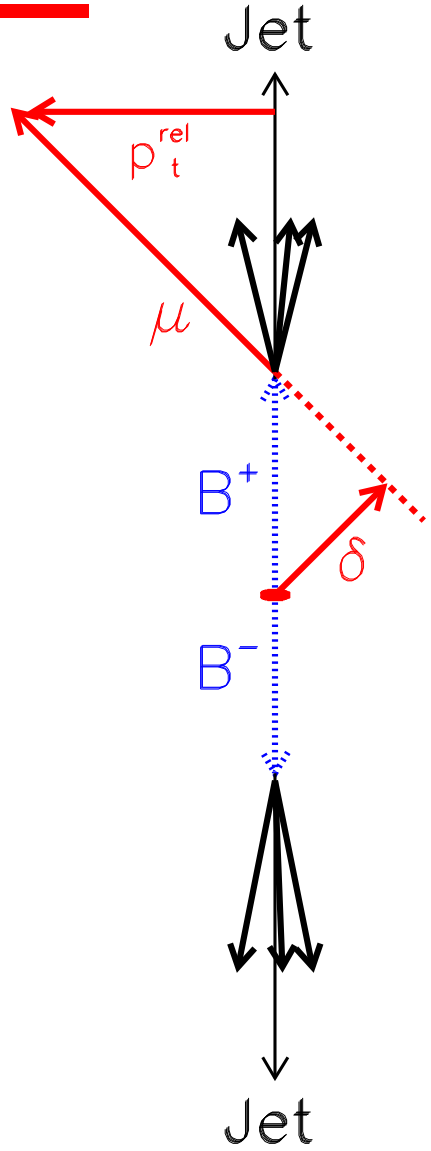
b: $\mathbf{X}_g \geq 10^{-3}$



Beauty *Tag* with muon and jets







Separate Beauty from c and uds:

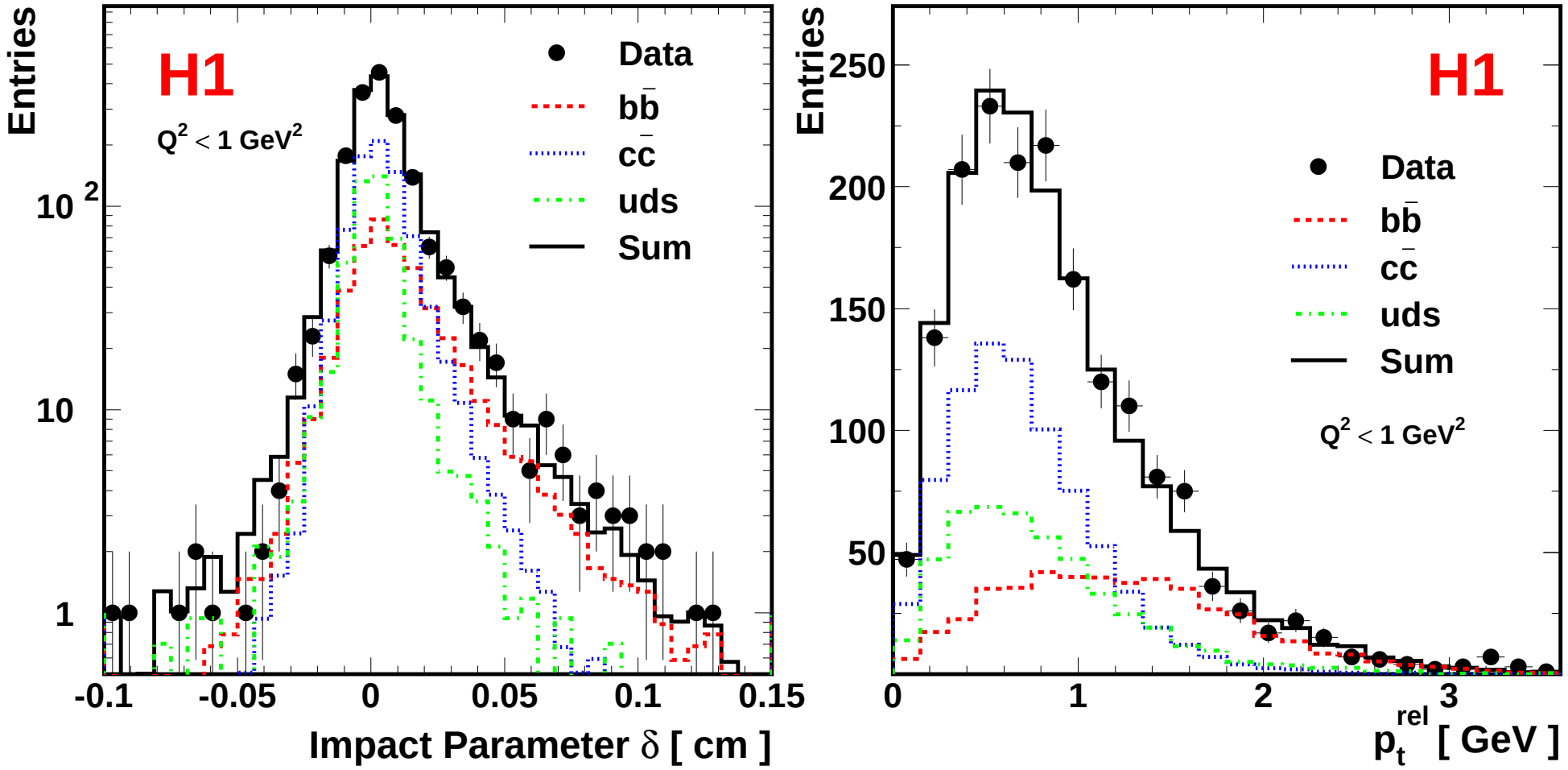
- Large b mass $\rightarrow$ Large Muon p_T^{rel}
- Long b lifetime $\rightarrow$ Large Muon Impactpar. δ

In the following focus on results

from the new H1 paper hep-ex/0502010

This measurement covers both γp and DIS

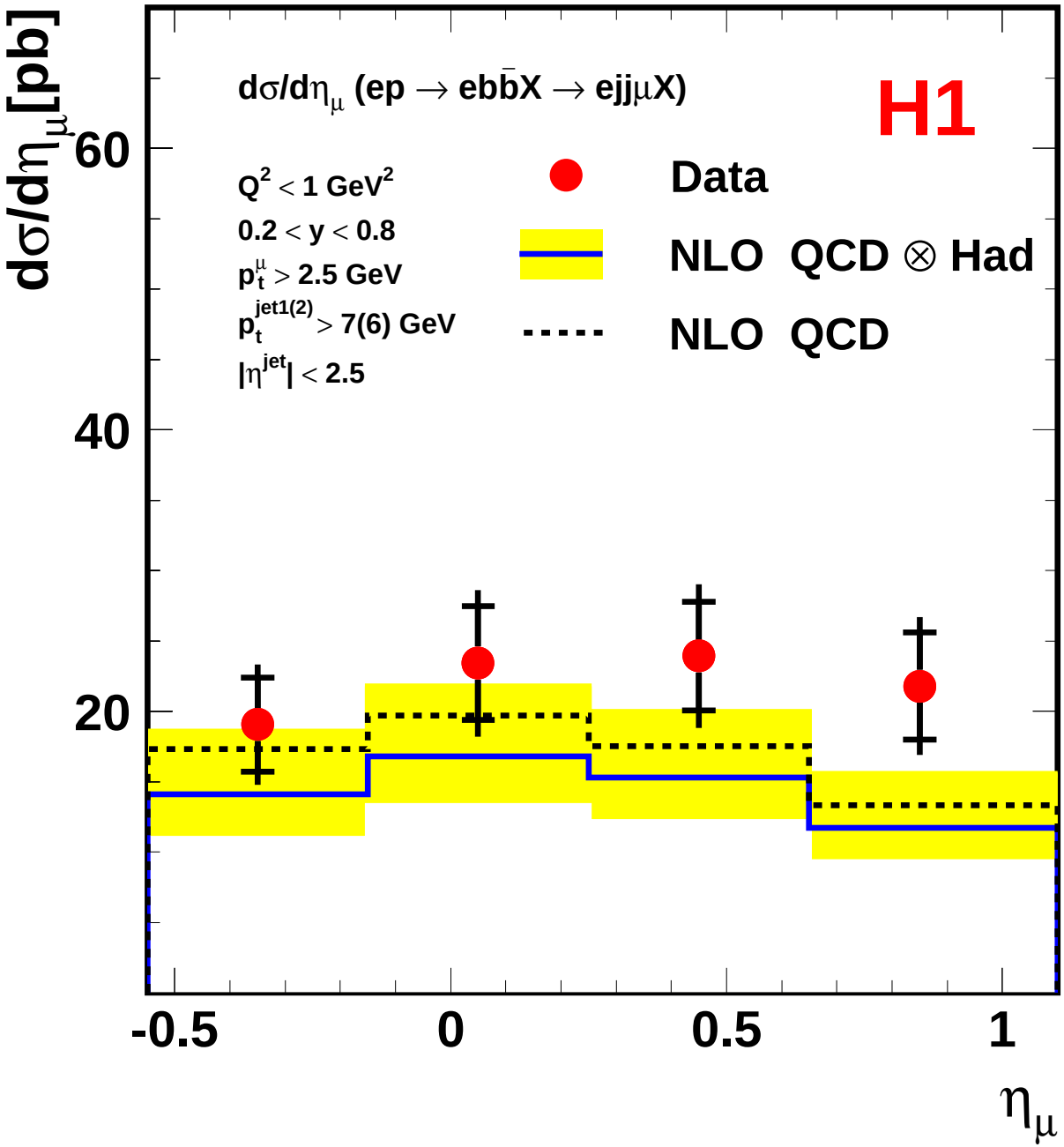
δ and p_t^{rel} in γp sample (≈ 1750 events)



Likelihood fit to 2-dimensional (δ, p_T^{rel}) distribution:

$\rightarrow f_b \sim 30\%$

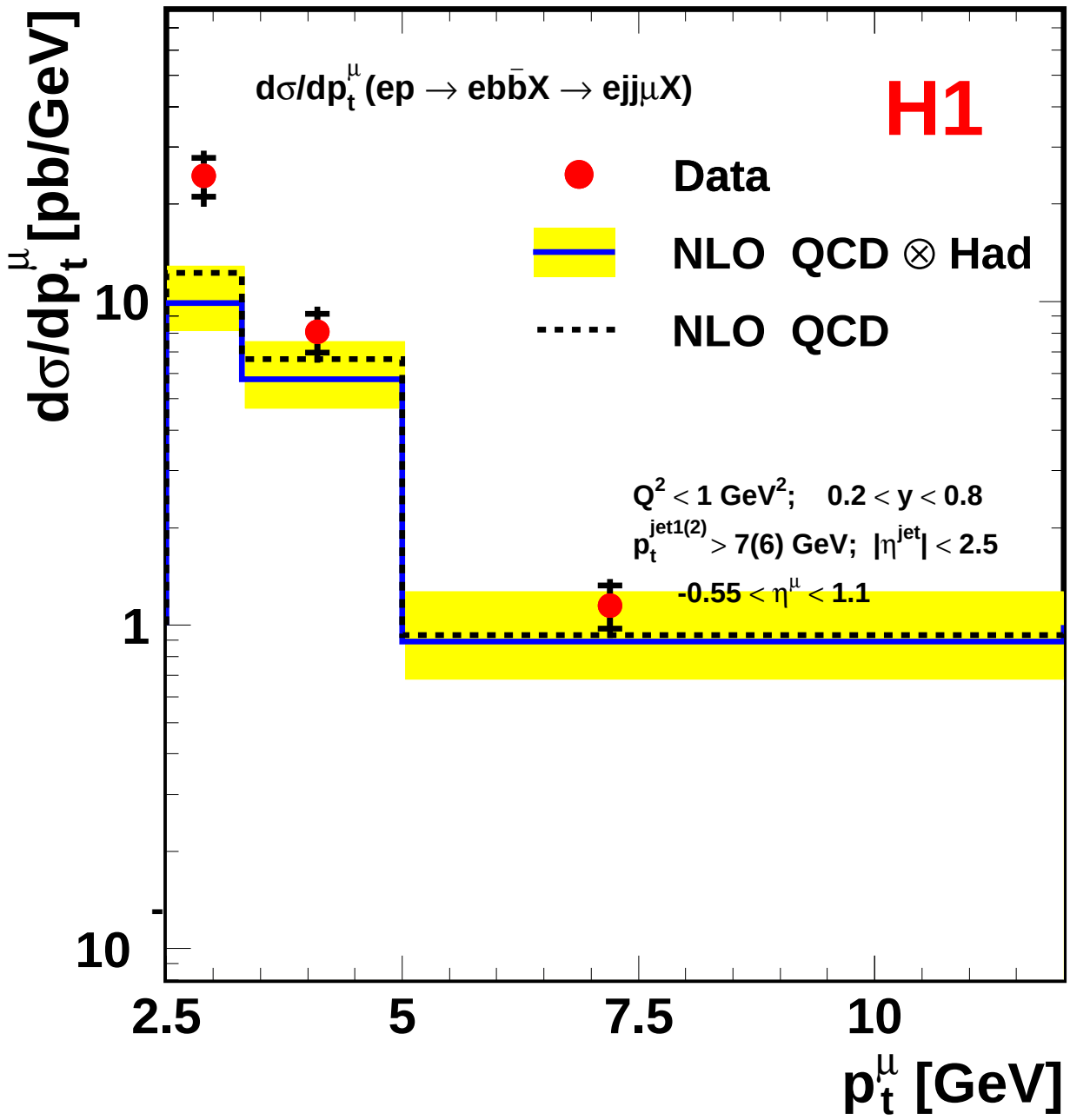
Beauty in γp: vs muon pseudorapidity



⇒ Flat distribution

⇒ Massive NLO (FMNR):
- somewhat too low
- describes shape

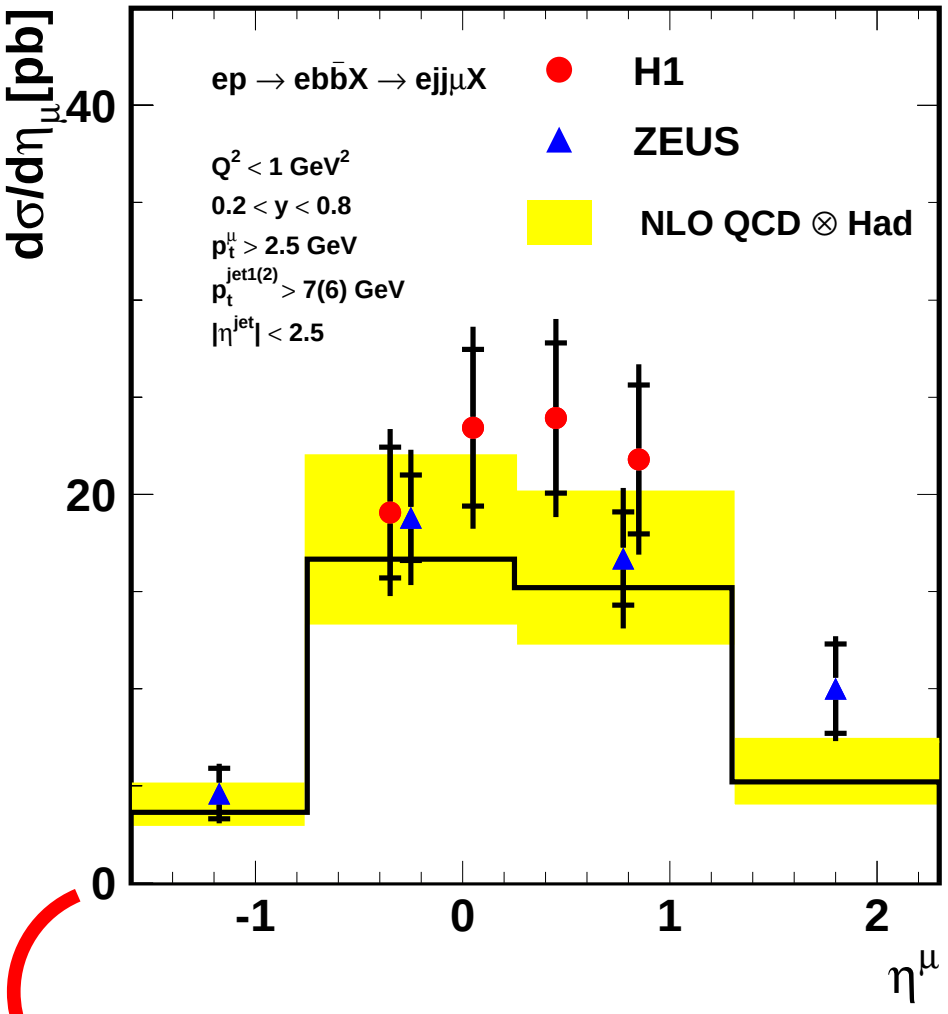
Beauty in γp: vs p_t^μ



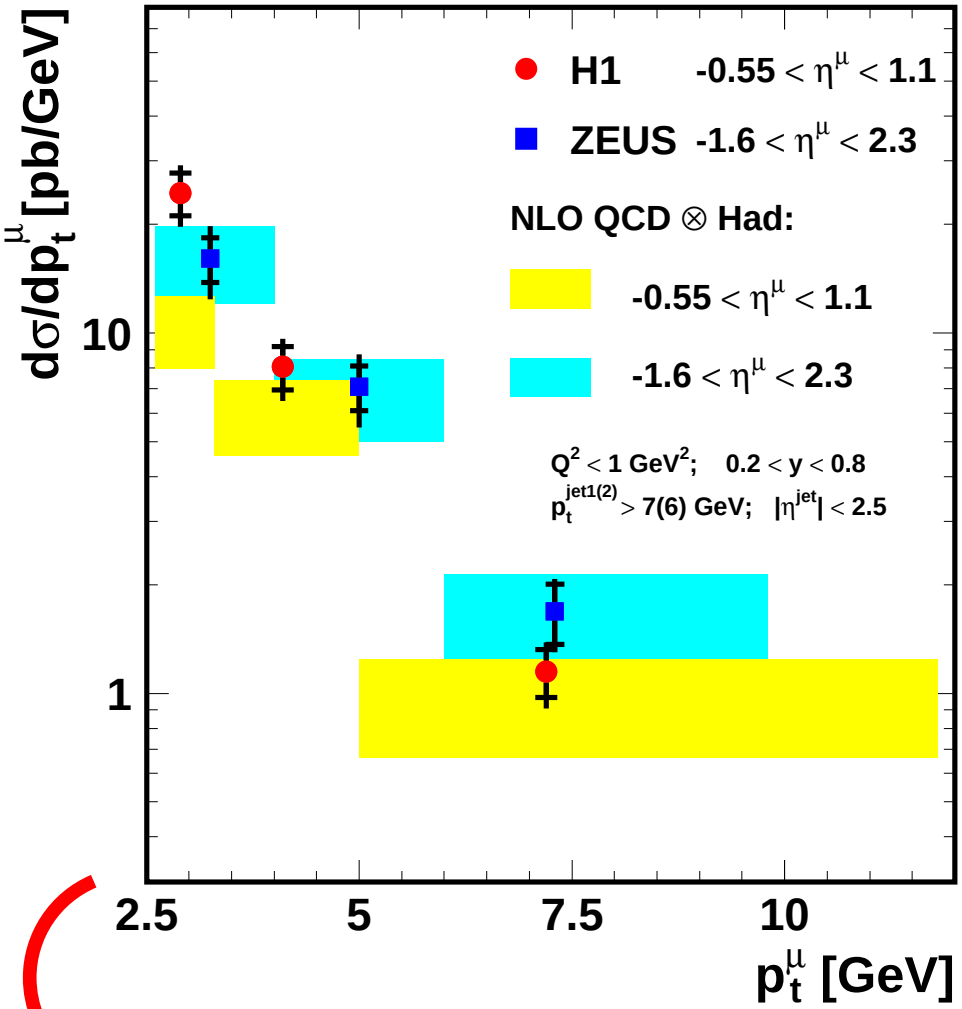
$\Rightarrow$ Steep drop-off

$\Rightarrow$ NLO too low at low p_t^μ

Comparison of H1 and ZEUS γp results

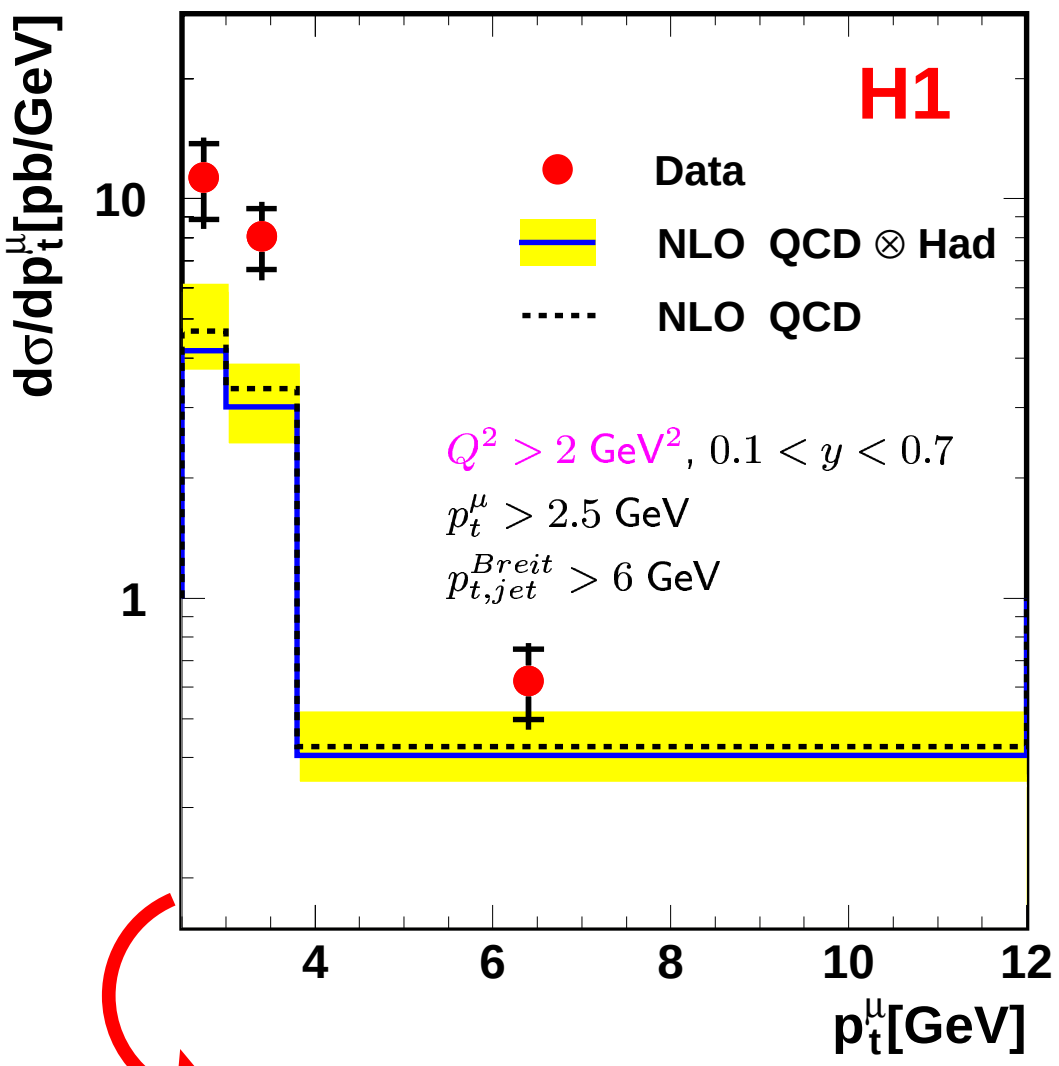


Good agreement H1 vs ZEUS

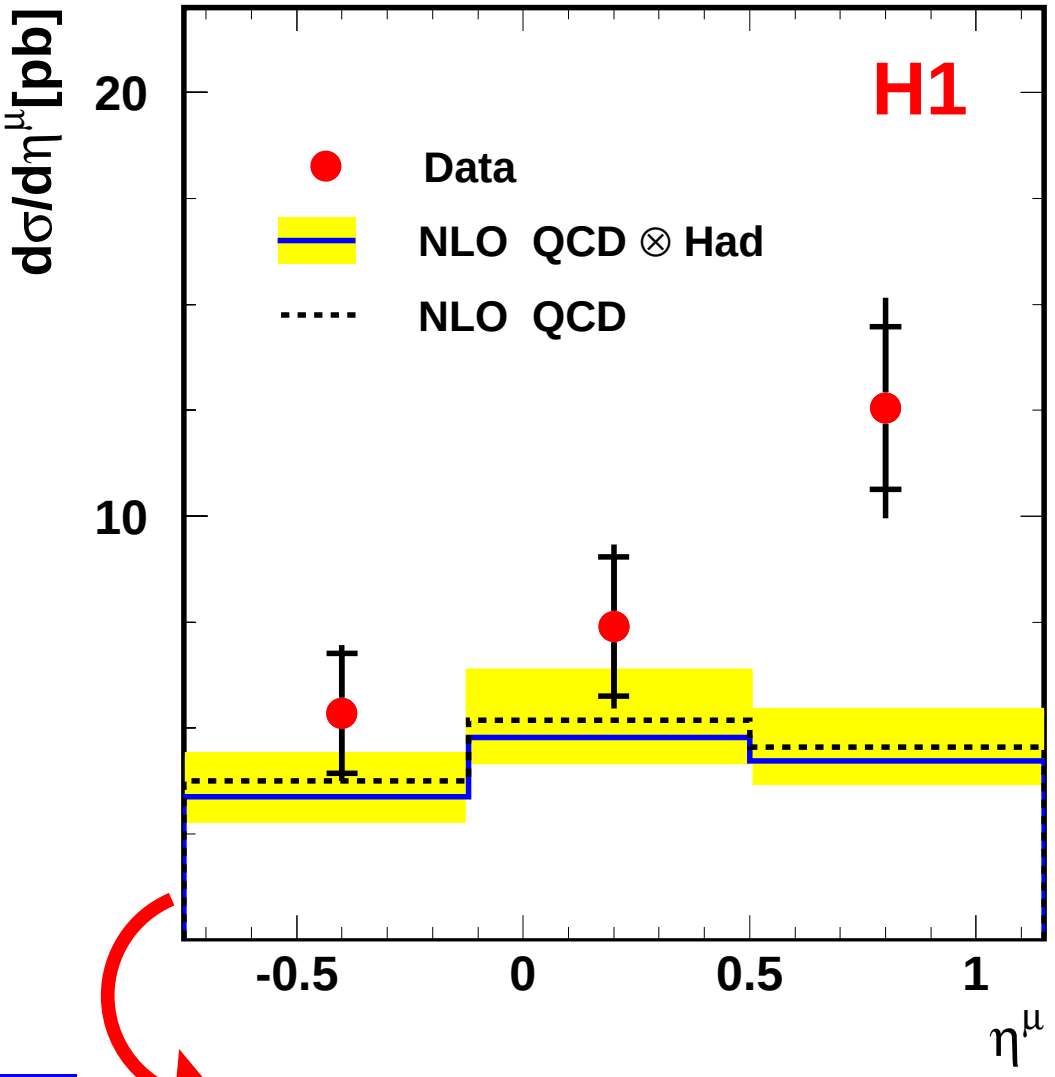


ZEUS: No excess at low p_t^μ

Beauty in DIS: vs. Muon p_T und η

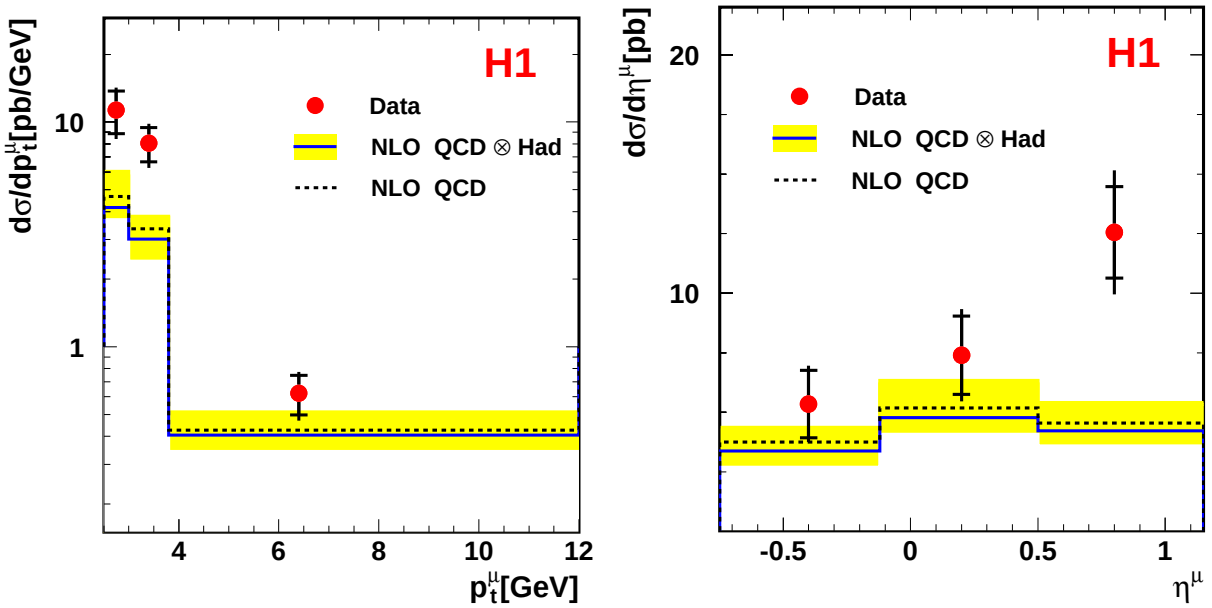


Massive NLO (HVQDIS): Too low at low p_T^μ

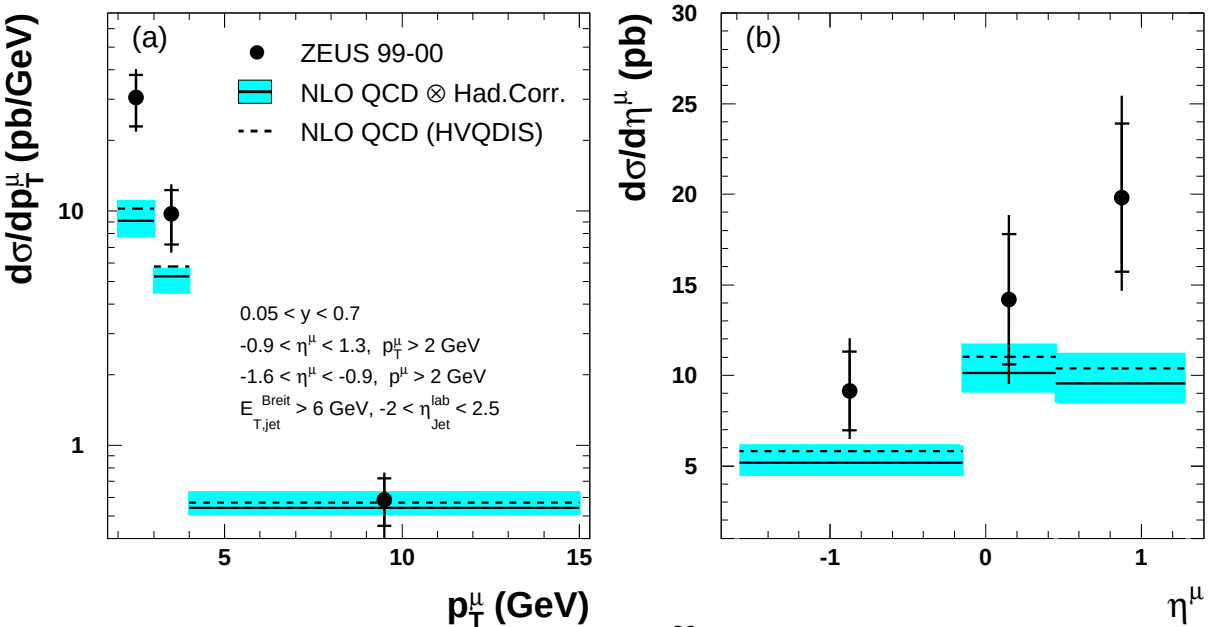


Massive NLO: Too low in forward direction

Beauty in DIS: Compare H1 and ZEUS results

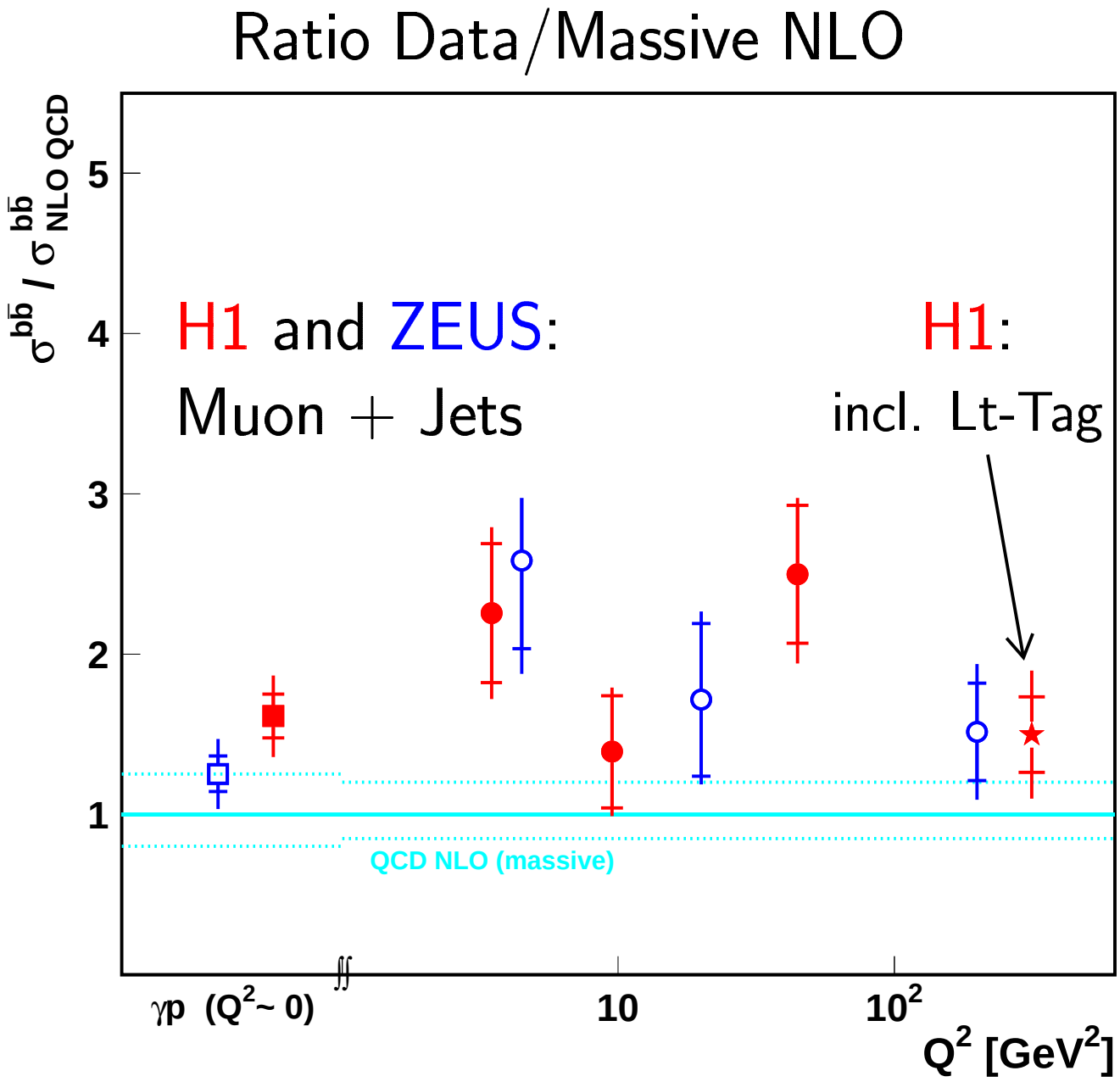


ZEUS



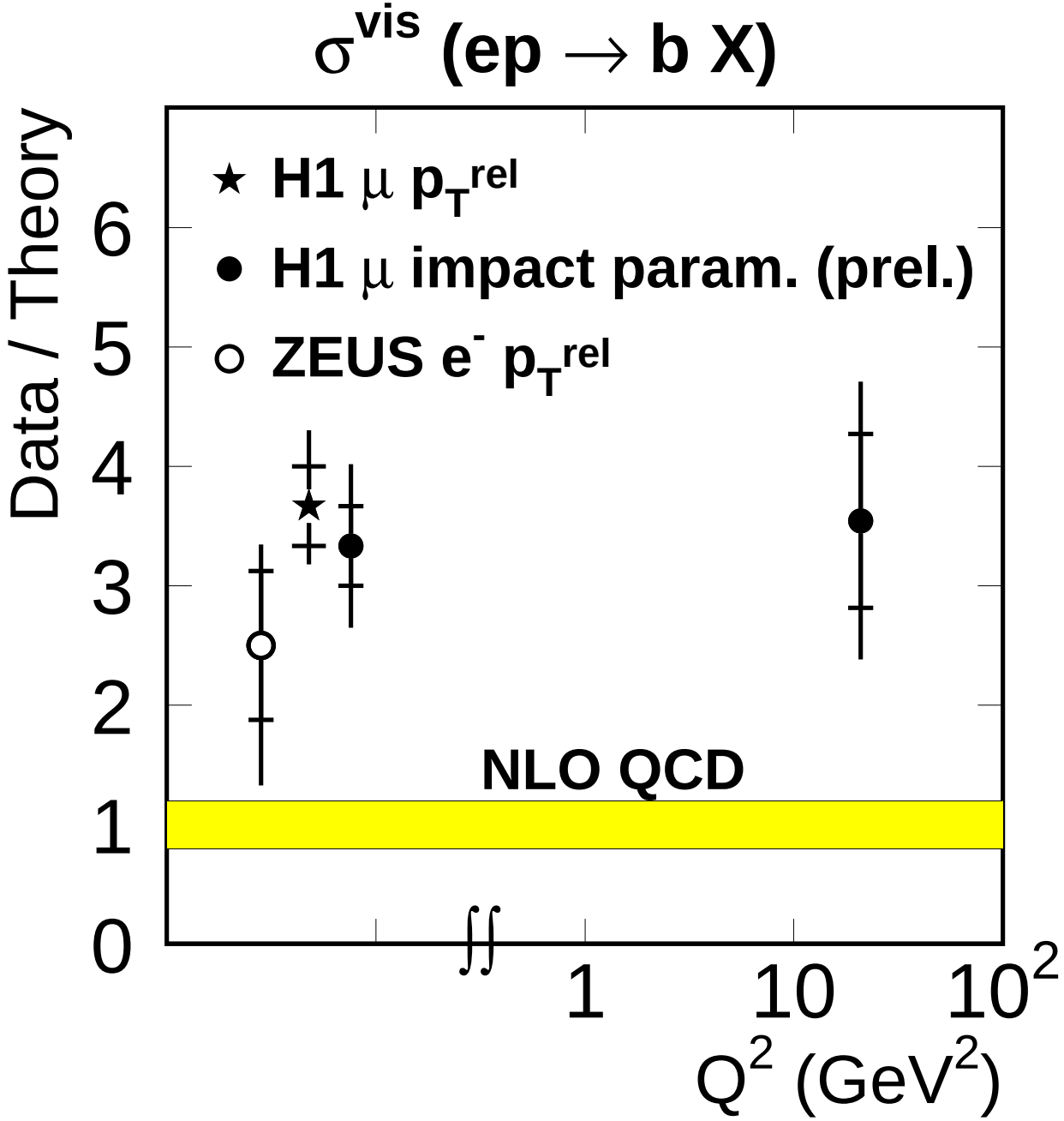
$\Rightarrow$ Good agreement

Recent HERA beauty results vs. Q^2



$\Rightarrow$ Data syst. above massive NLO

First HERA beauty results (Situation in 2001)



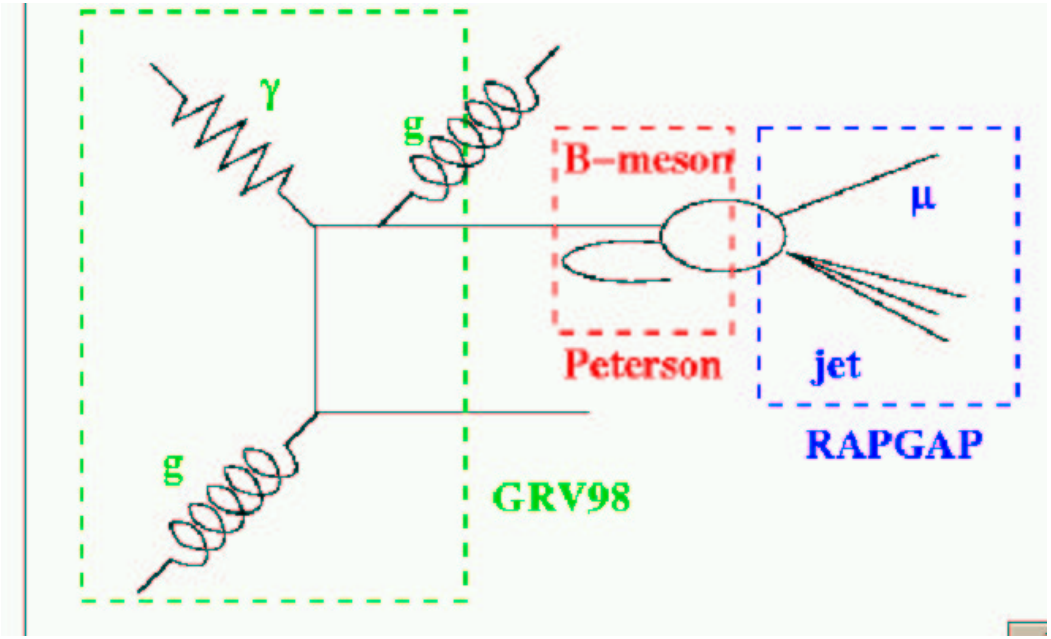
Why is the excess larger for the first H1 measurements???

For the first H1 measurements

- Data were extrapolated from the Muon+jets level to the Muon level using leading order AROMA MC and then compared to NLO. Reinvestigation $\rightarrow$ LO and NLO extrapolation consistent, no problem
- Softer p_T^{Jet} and p_T^{μ} cuts applied (e.g. $p_T^{\mu} > 2$ GeV instead of 2.5 GeV) $\rightarrow$ different kinematic phasespace!

NLO calculations: How it is done today

to compare with HERA data: Example: HVQDIS



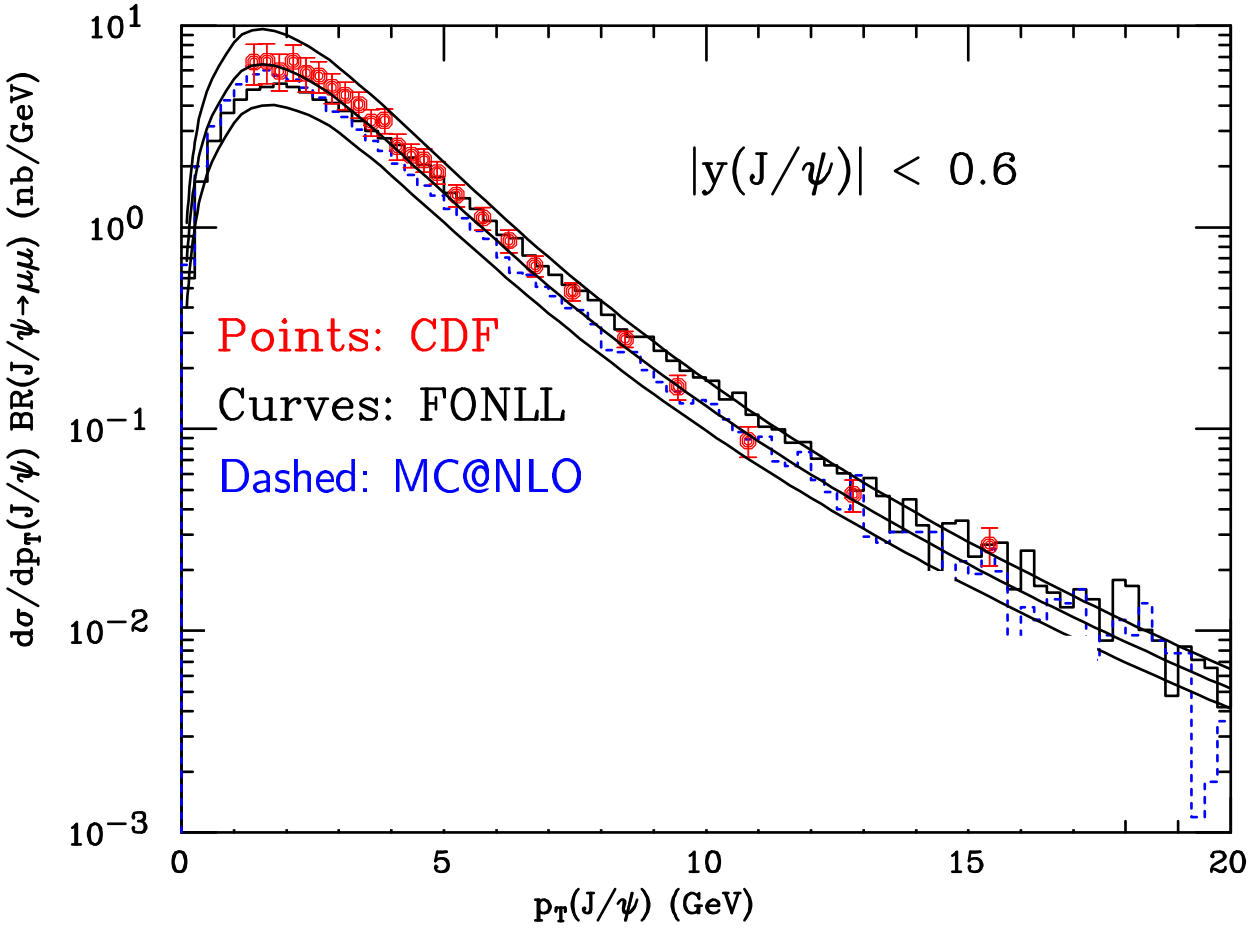
- Apply purely longitudinal Peterson fragmentation to b-quark
- Fragmented b-quark is 'decayed' using muon decay spectrum (e.g. from JETSET)
- Apply hadronisation corrections for parton jets using MC

⇒ Kniehl et al.: Fragmentation is arbitary → what is the uncertainty?

⇒ Fragm., Muon-decay and Hadronisation corr. for parton jets
→ All sources for considerable syst. uncertainties of calculation!

Beauty at Tevatron Run-II

Improved NLO calculations available with e.g. more consistent treatment of fragmentation



$\Rightarrow$ Much improved description!

We wanto have the improved models for HERA too!

Conclusions

- Recent results on B-production at HERA with Muons and Jets:
  - Generally good agreement between H1 and ZEUS data
  - Data are systematicaly above predictions from Massive NLO
  - Trend: Data above NLO at small hard scales p_t^b, Q^2 and in forward direction
  - Need for improved models: Theoreticians: Please provide them, e.g. MC@NLO!

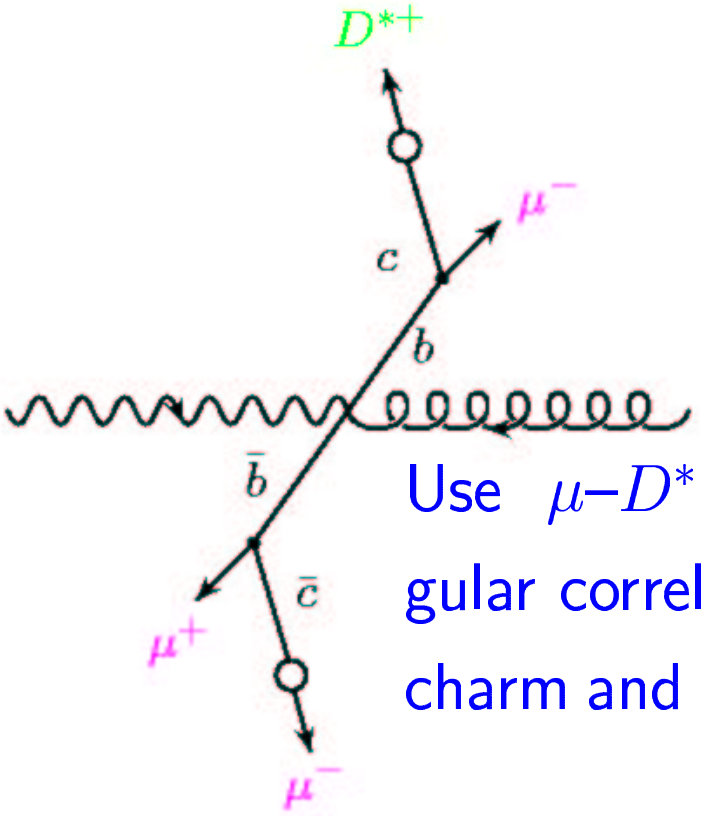
2.) $Q\bar{Q}$ correlations with D^* and muon

New results from upcoming H1 paper

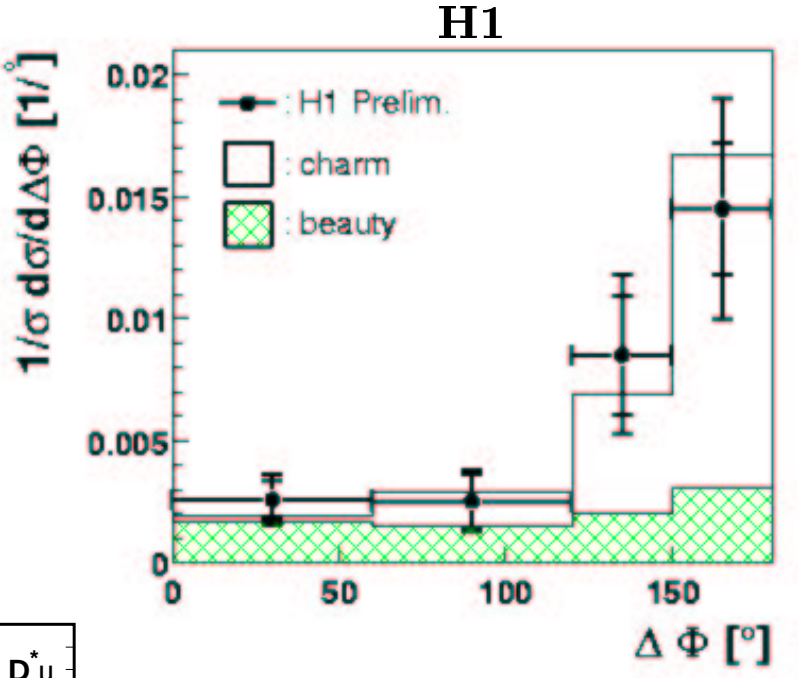
(based on H1prelim-02-071)

Note: Preliminary paper available at
$http://www-h1.desy.de/publications/H1preliminary.short\_list.html$

$Q\bar{Q}$ correlations with $D^*\mu$

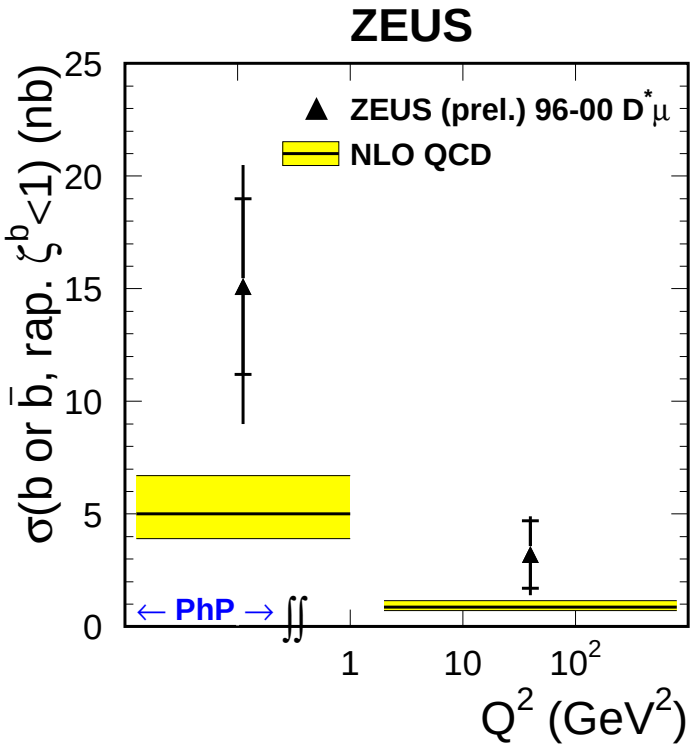


Use μ–D^* charge and angular correlations to separate charm and beauty events $\Longrightarrow$



ZEUS

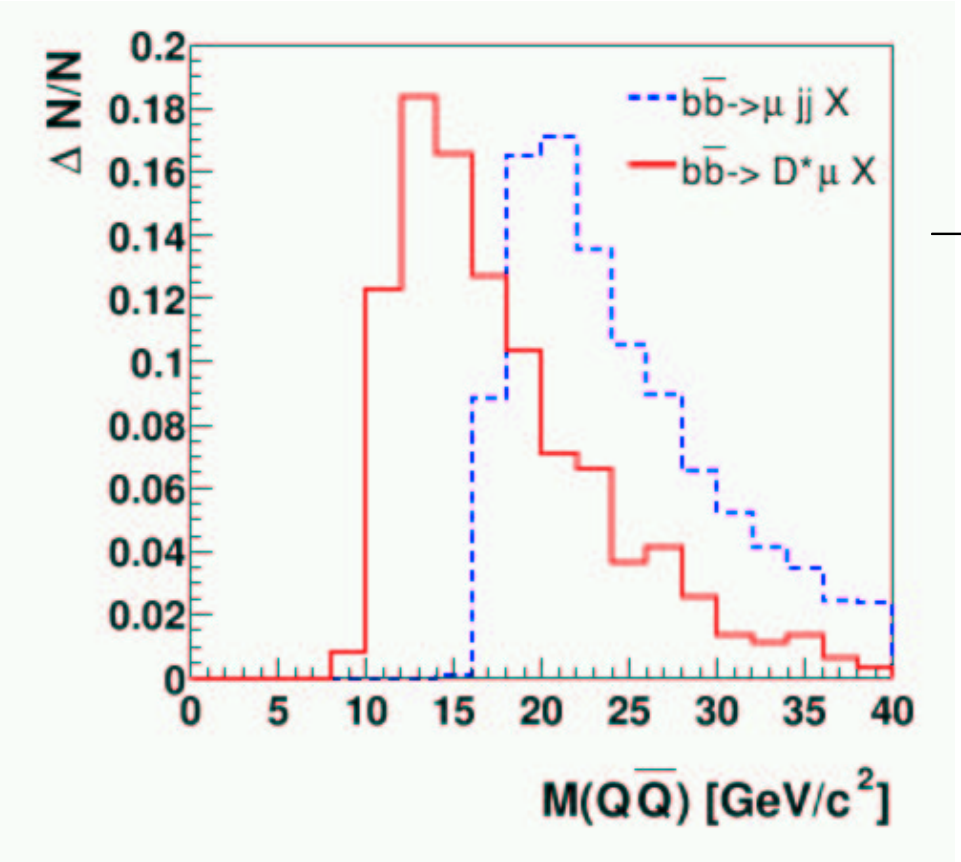
Beauty Data vs NLO QCD $\Rightarrow$



$\Rightarrow$ B Data $>$ NLO QCD

$\Rightarrow$ Large errors

$D^*\mu$: New H1 results for charm and beauty



→ $D^*\mu$ analysis extends to low b-quark energies!

Charm	Cross section [pb]	Data/Theory
Data	$250 \pm 57 \pm 40$	
PYTHIA (direct)	242 (142)	1.0
CASCADE	310	$0.9 \pm 0.2 \pm 0.1$
FMNR	286^{+159}_{-59}	0.9
Beauty		
Data	$206 \pm 53 \pm 35$	
PYTHIA (direct)	57 (44)	3.6
CASCADE	80	2.6
FMNR	52^{+14}_{-9}	$4.0 \pm 1.0 \pm 0.7$

Vis. kinematic range:

$p_T(D^*) > 1.5$ GeV, $|\eta(D^*| < 1.5$

$p(\mu) > 2$ GeV, $|\eta(\mu)| < 1.735$

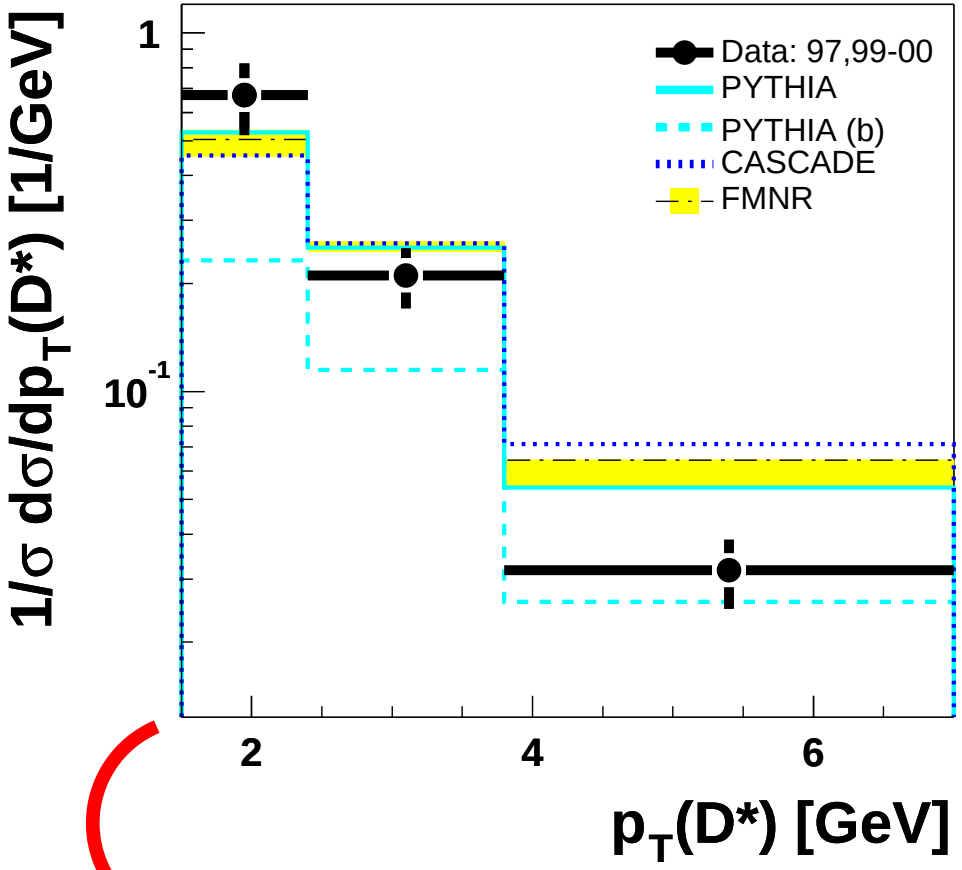
$0.05 < y < 0.75$, $Q^2 < 1$ GeV^2

99/00 Data, ≈ 89 pb^{-1}

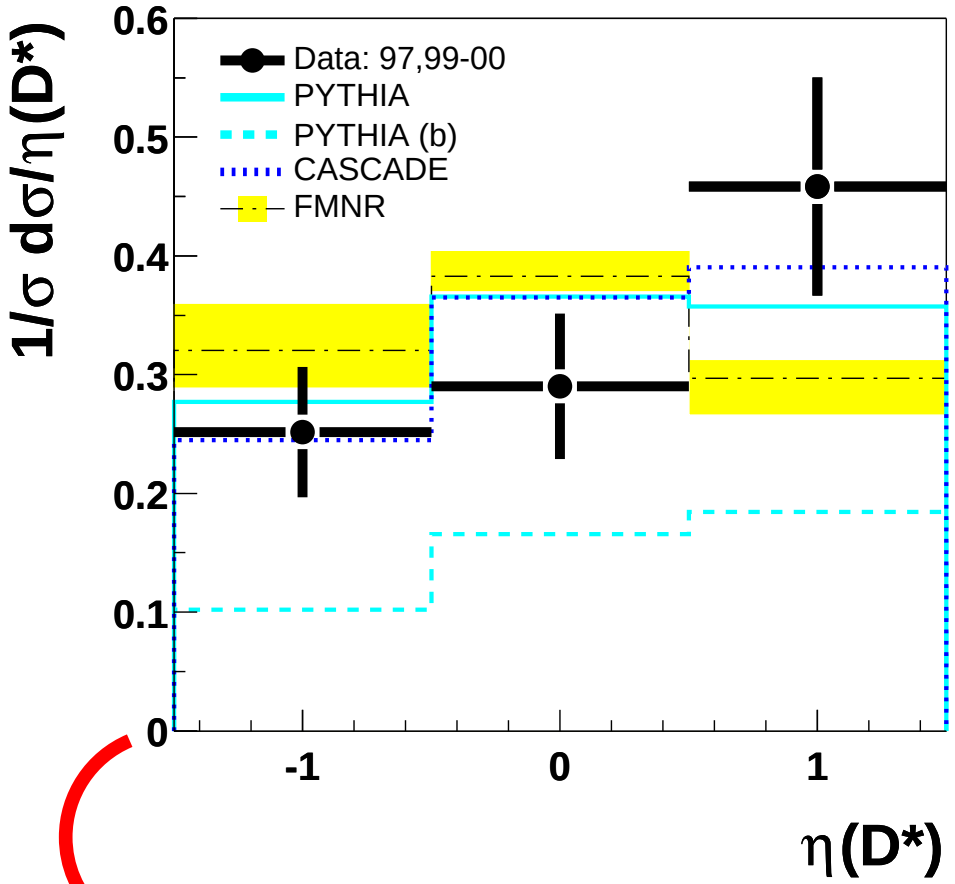
$\Rightarrow$ Beauty excess

H1 $D^*\mu$ results: vs. $p_T^{D^*}$ und η^{D^*}

Sum of beauty and charm contributions:



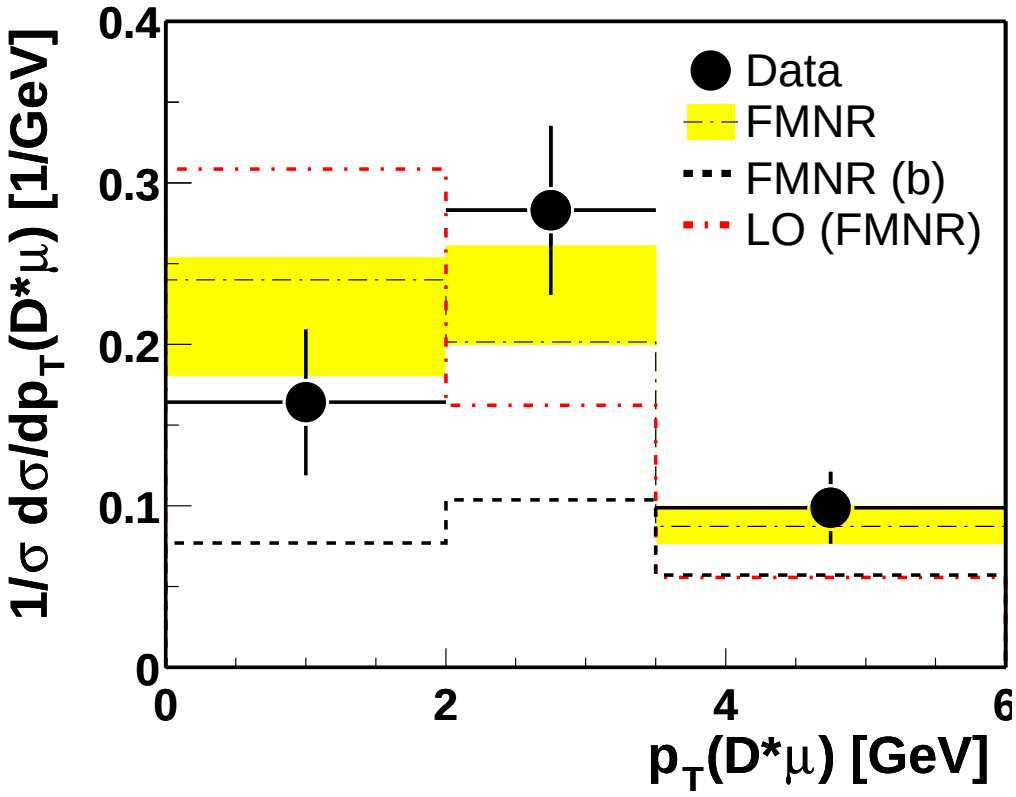
Massive NLO (FMNR): drops off less steeply

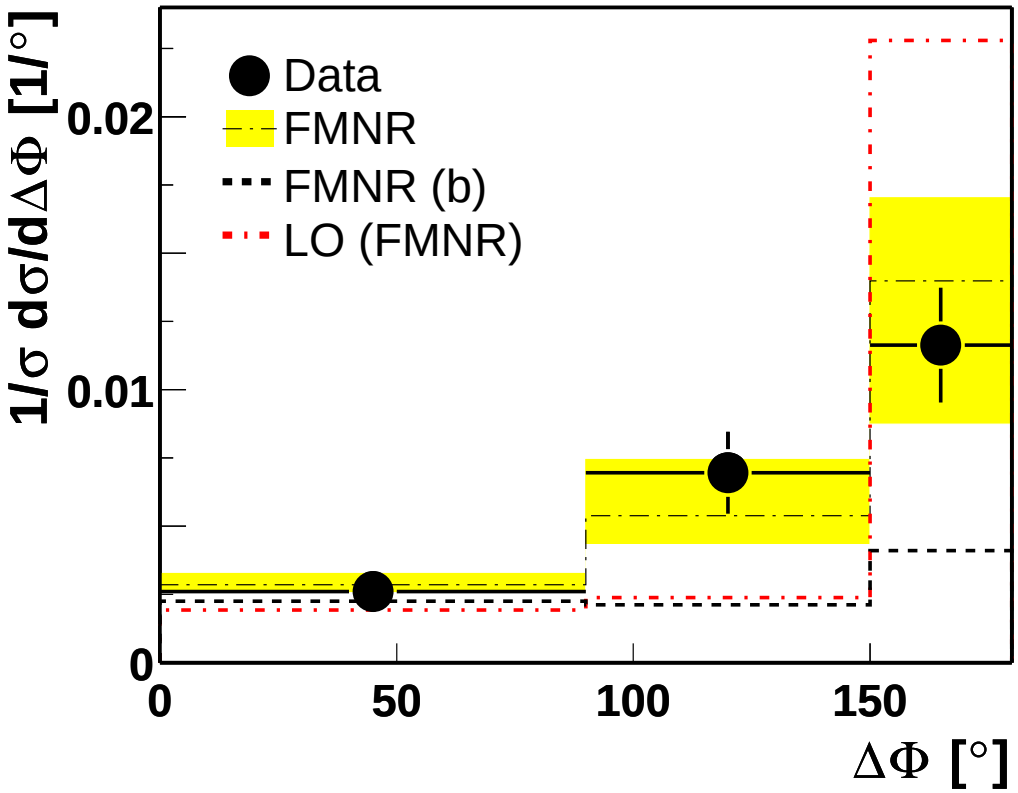


Massive NLO: somewhat low in forward direction (?)

H1 $D^*\mu$ results: vs. $p_T(D^*\mu)$ und $\Delta\Phi(D^*, \mu)$

Sum of beauty and charm contributions:



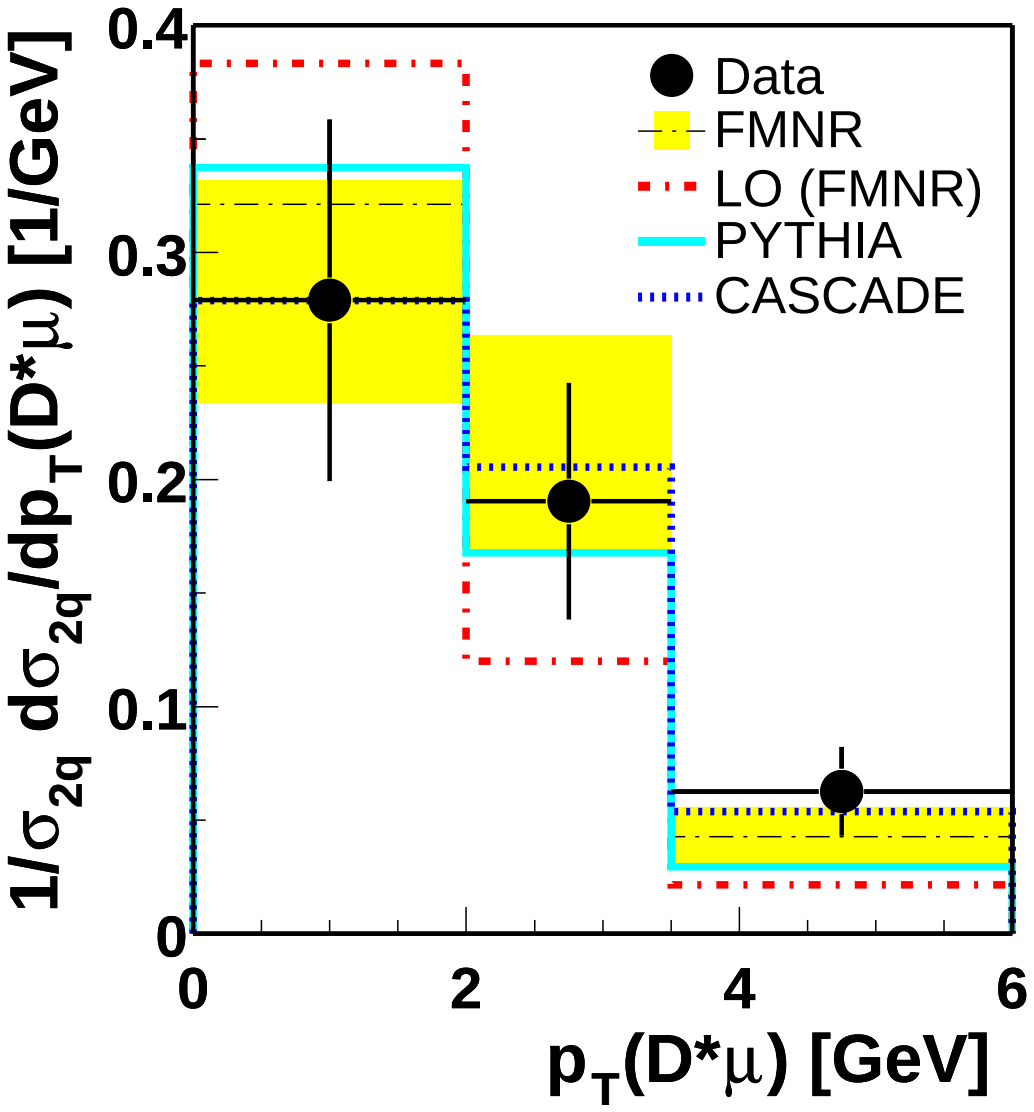


$\Rightarrow$ Clear indications for effects beyond Leading order pQCD

Good description by NLO

H1 $D^*\mu$ results: $\Delta\Phi > 90^\circ$ and $Q(D^*) \neq Q(\mu)$)

Charm dominated Quark-Antiquark Tag



- $p_T(D^*\mu)$ should be sensitive to intrinsic k_T of gluon from the proton
- CASCADE provides gluons with intrinsic k_T but differences to PYTHIA are small

Conclusions

- New $D^*\mu$ results on $Q\bar{Q}$ correlations:
  - Probes low $\hat{s}$ values
  - Excess data/NLO for beauty
  - Clear effects beyond Leading order pQCD in data
  - With current experimental precision: No separation of pQCD models with different parton evolution (PYTHIA vs CASCADE)

Backup slides

Beauty with muon and jets: Theory models

Leading order +P.S. MC's | *Massive NLO*

	PYTHIA	**RAPGAP**	**CASCADE**	**FMNR**	**HVQDIS**
Version	6.1	2.8	1.00/09; 1.2		1.4
Proton PDF	CTEQ5L	CTEQ5L	JS2001 J2003	CTEQ5M	CTEQ5F4
Photon PDF	GRV LO		GRV HO		
$\Lambda^{(4)}_{QCD}$ [GeV]	0.192	0.192	0.326	0.309	
Renorm. scale μ_r^2	$m_q^2 + p_{tq\bar{q}}^2$	$Q^2 + p_{tq\bar{q}}^2$	$\hat{s} + p_{tq\bar{q}}^2$	$m_b^2 + p_{tb\bar{b}}^2$	$m_b^2 + p_{tb\bar{b}}^2$
Factor. scale μ_f^2	$m_q^2 + p_{tq\bar{q}}^2$	$Q^2 + p_{tq\bar{q}}^2$	$\hat{s} + Q_t^2$	$m_b^2 + p_{tb\bar{b}}^2$	$m_b^2 + p_{tb\bar{b}}^2$
m_b [GeV]	4.75	4.75	4.75	4.75	4.75
m_c [GeV]	1.5	1.5	1.5		
Peterson ϵ_b	0.0069	0.0069	0.0069	0.0033	
son ϵ_c	0.058	0.058	0.058		