DIS2011

Measurement of heavy-quark jet photoproduction at HERA

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Ian C. Brock
University of Bonn

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GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

universitätbonn

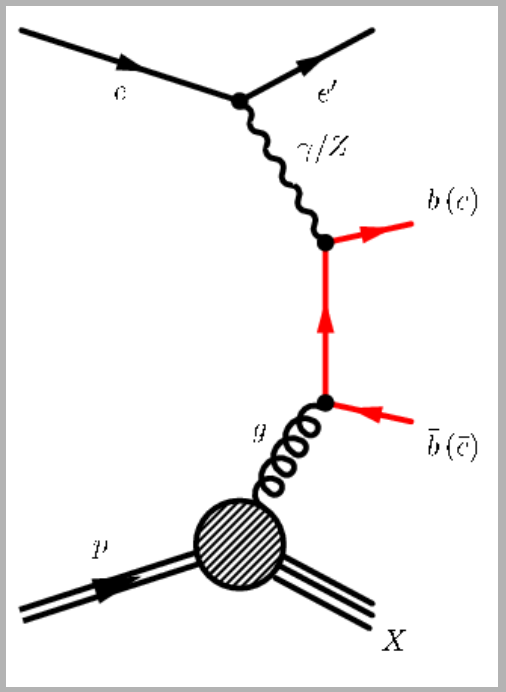
Outline

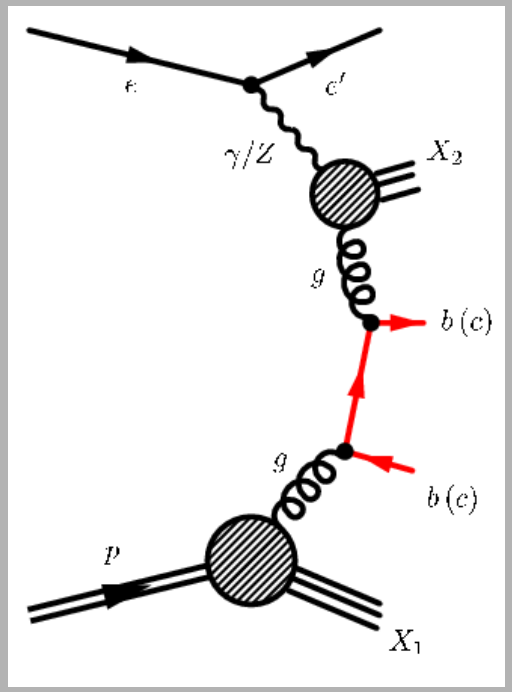
- Introduction
- Dataset and simulation
- Event selection
- Extraction of signal
- Cross-sections and comparison with NLO QCD
- Summary

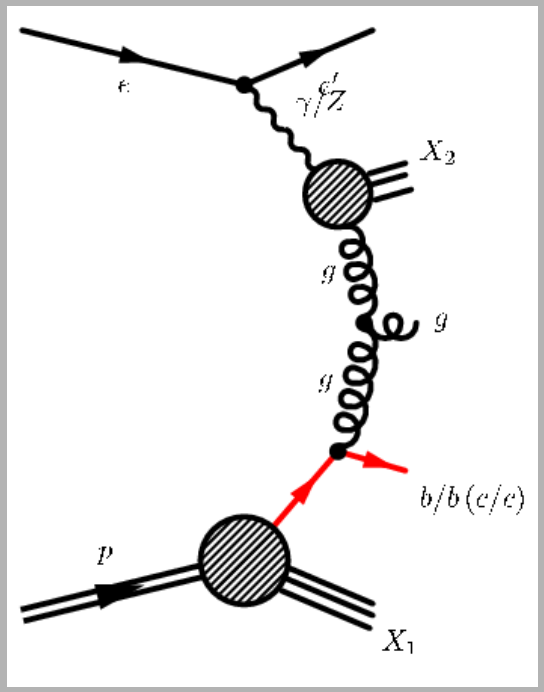
Jets in photoproduction

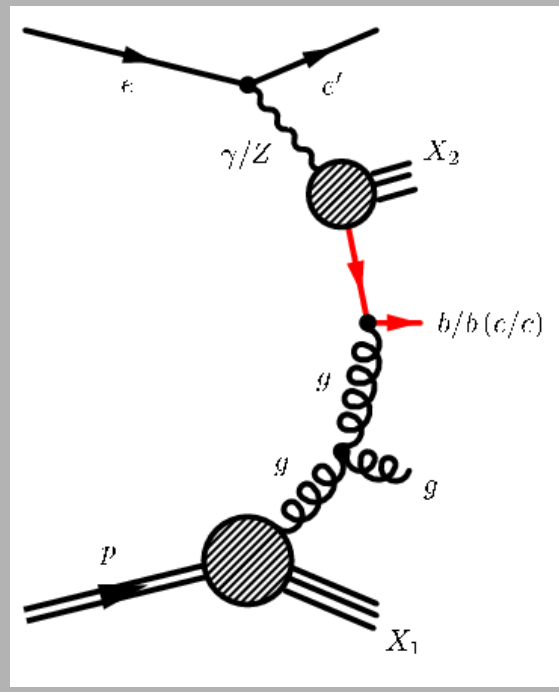
Boson-gluon fusion

Proton and photon excitation









Direct

Resolved

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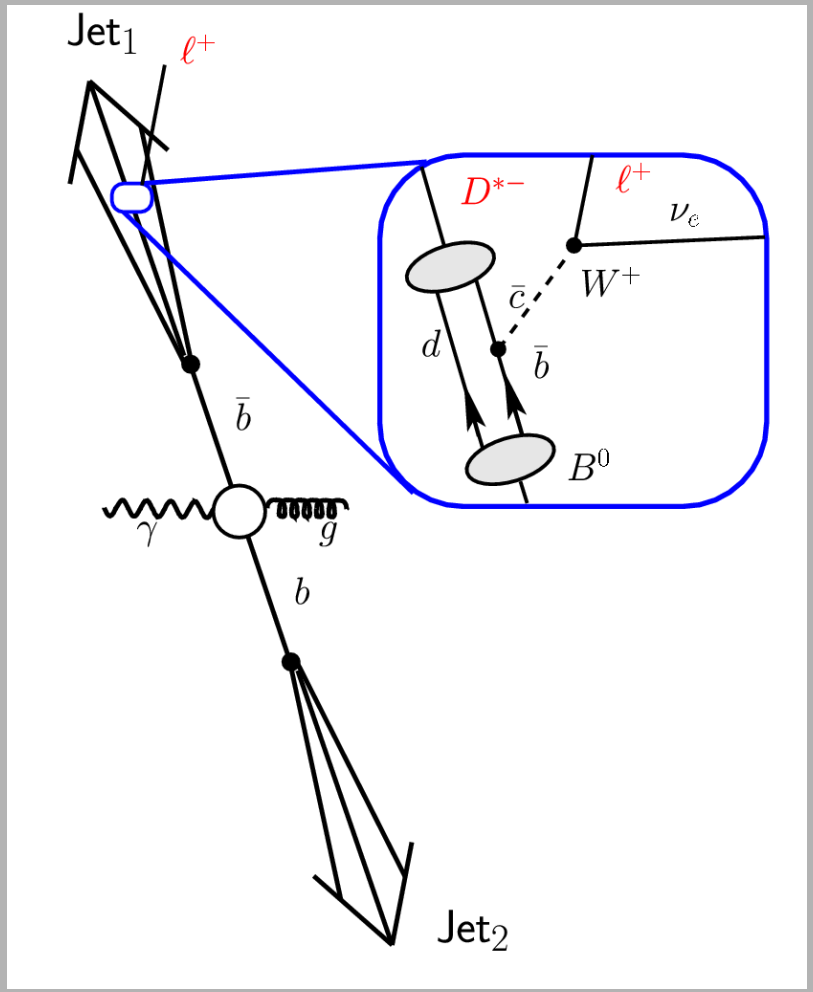
Idea of analysis

- Compare measurements of b,c dijet cross-sections with MC and NLO QCD predictions
- Use long lifetime (0.5-1.5ps) and large mass of b,c quarks to separate b,c jets from each other and from light-quark jets
- Keep analysis inclusive
  - High statistics
  - Less dependence on branching fractions



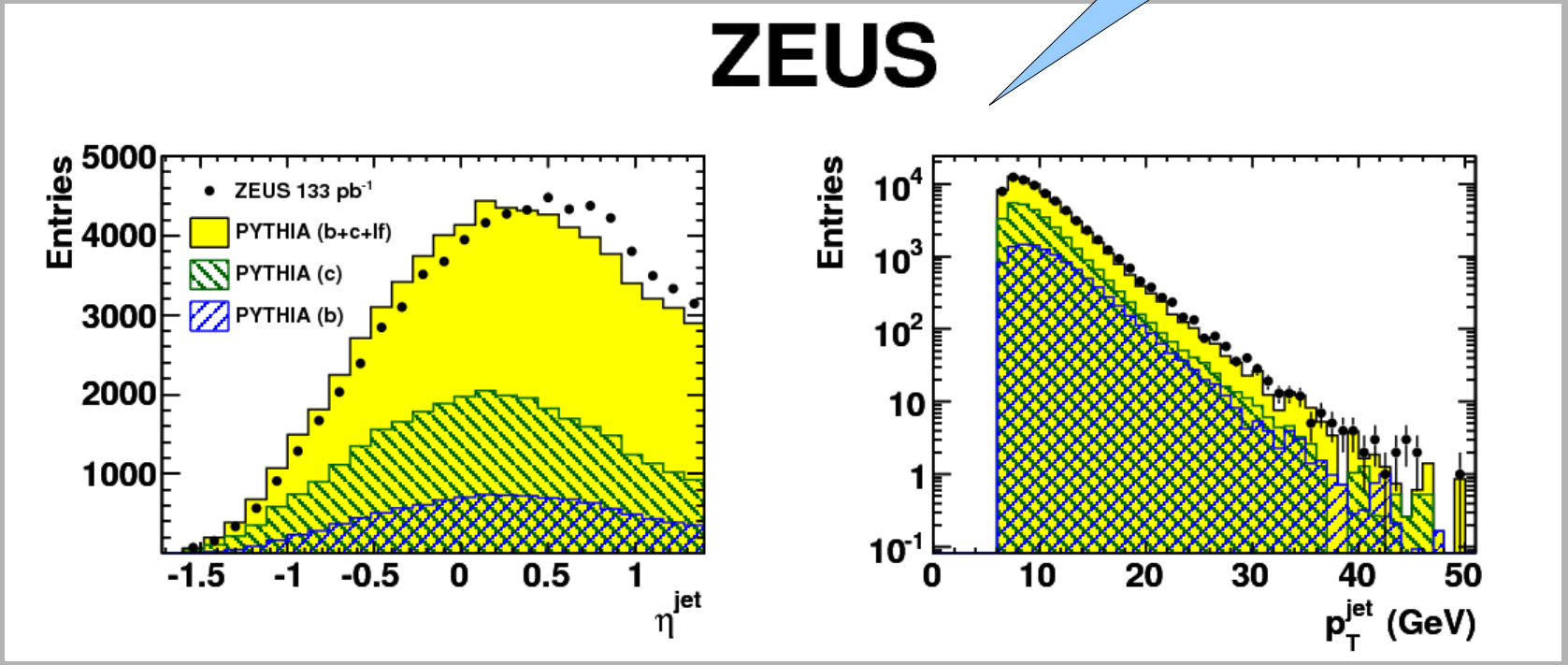
Data and MC samples

- 2005 $e^{-}p$ data – 133 pb^{-1}
- Monte Carlo (MC):
  - b, c samples (high statistics)
    - PYTHIA with CTEQ5L + GRV-G LO
    - m_b = 4.75 GeV, m_c = 1.5 GeV
    - Generate direct, resolved and excitation samples
  - Light flavour (lf) sample (1x data)
    - PYTHIA with CTEQ4L + GRV-G LO

Event selection

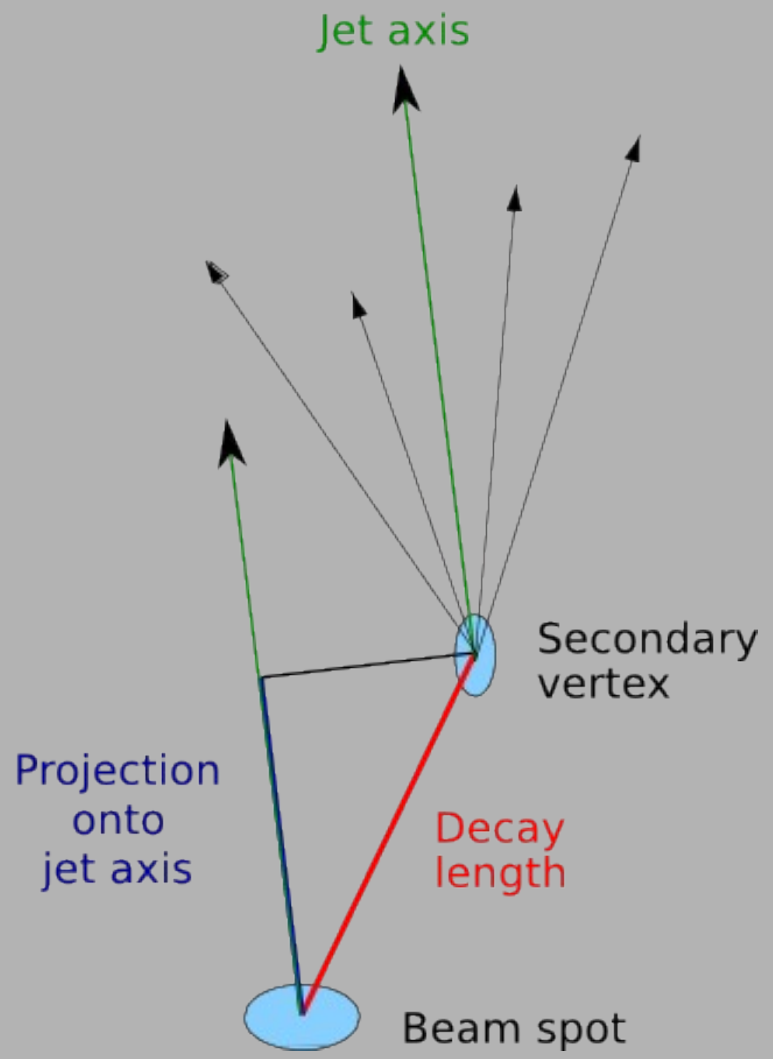
- No scattered electron
- $0.2 < y < 0.8$
- Two highest p_T jets
  - $|\eta| < 2.5$, $p_T > 7(6)$ GeV

Secondary vertex with |significance| > 3 required



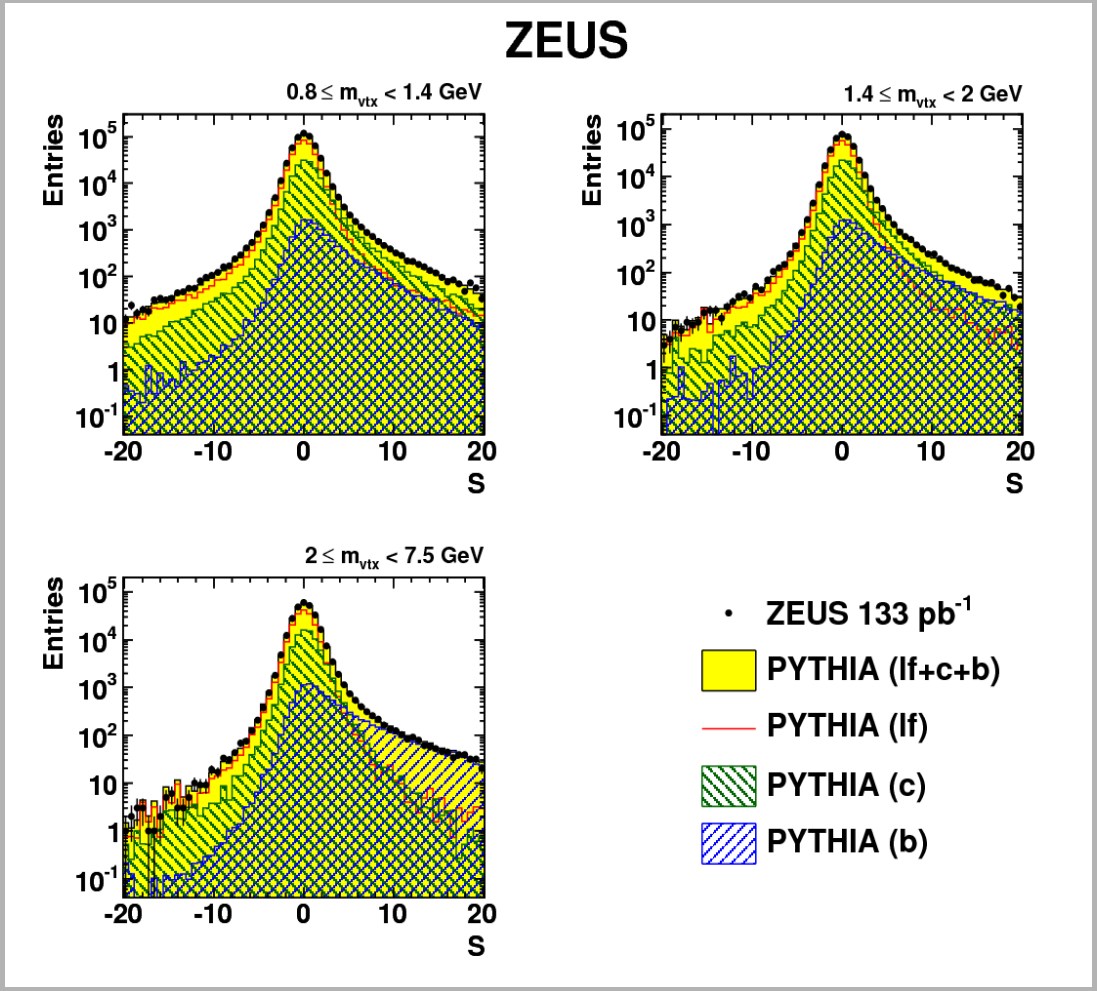
Secondary vertex procedure

- Secondary vertex:
  - Find 3-D vertex
  - Project onto XY plane
  - Project onto jet axis
- Also calculate invariant mass of tracks associated to vertex, m_{vtx}



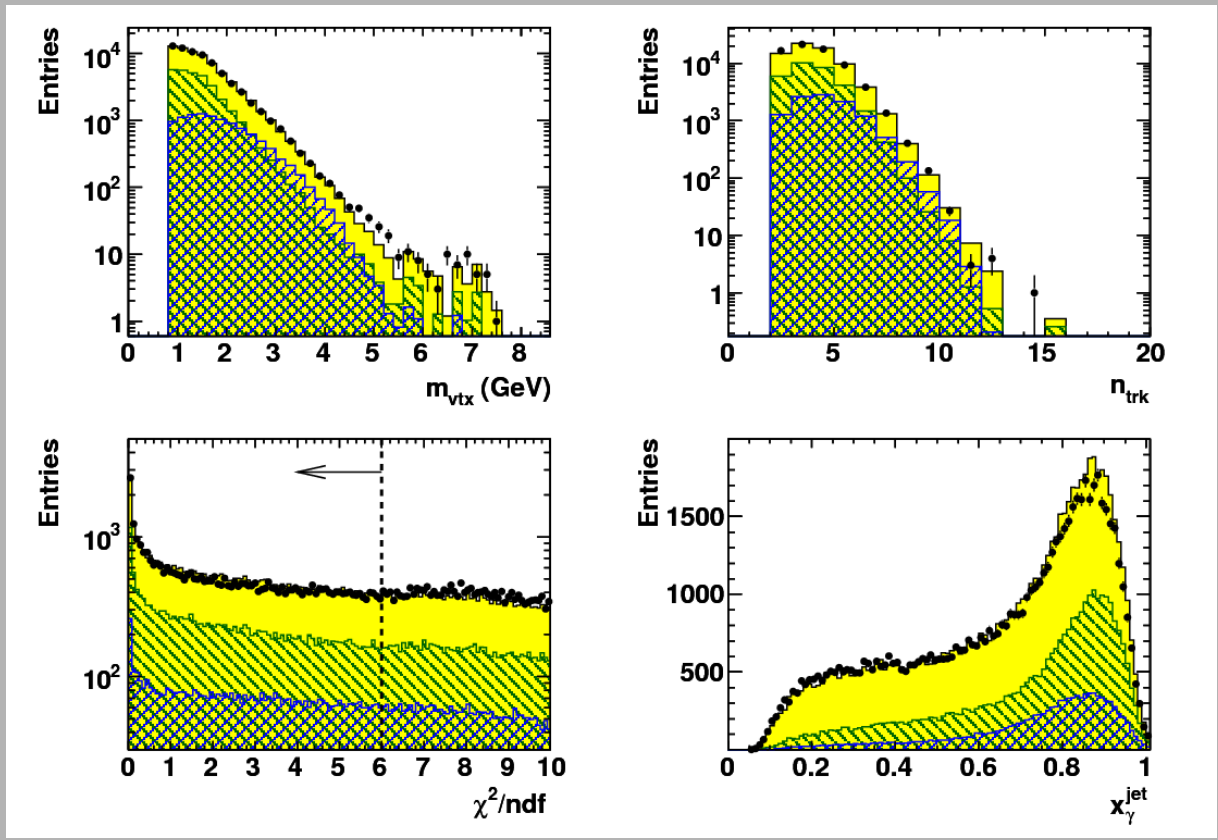
Significance distributions

- Use negative significance to check and tune MC resolution
- b, c, lf dominate in different mass bins and significance regions
- Subtract negative from positive significance to (almost) remove light flavour contribution



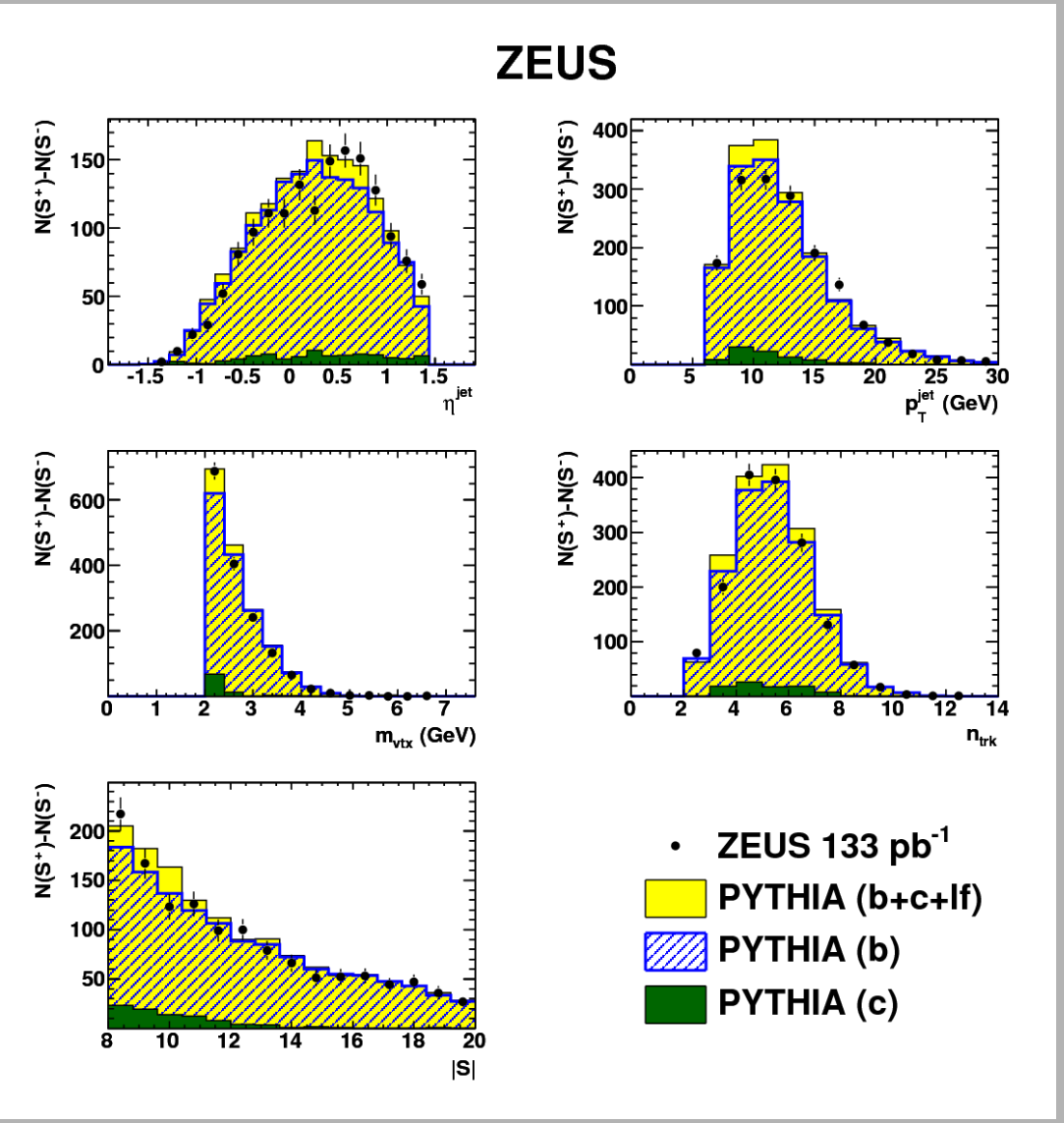
Control distributions

- Jets with associated secondary vertices used for cross-section
  - $-1.6 < \eta < 1.4$
  - $|S| > 3$
  - 70 433 jets remain



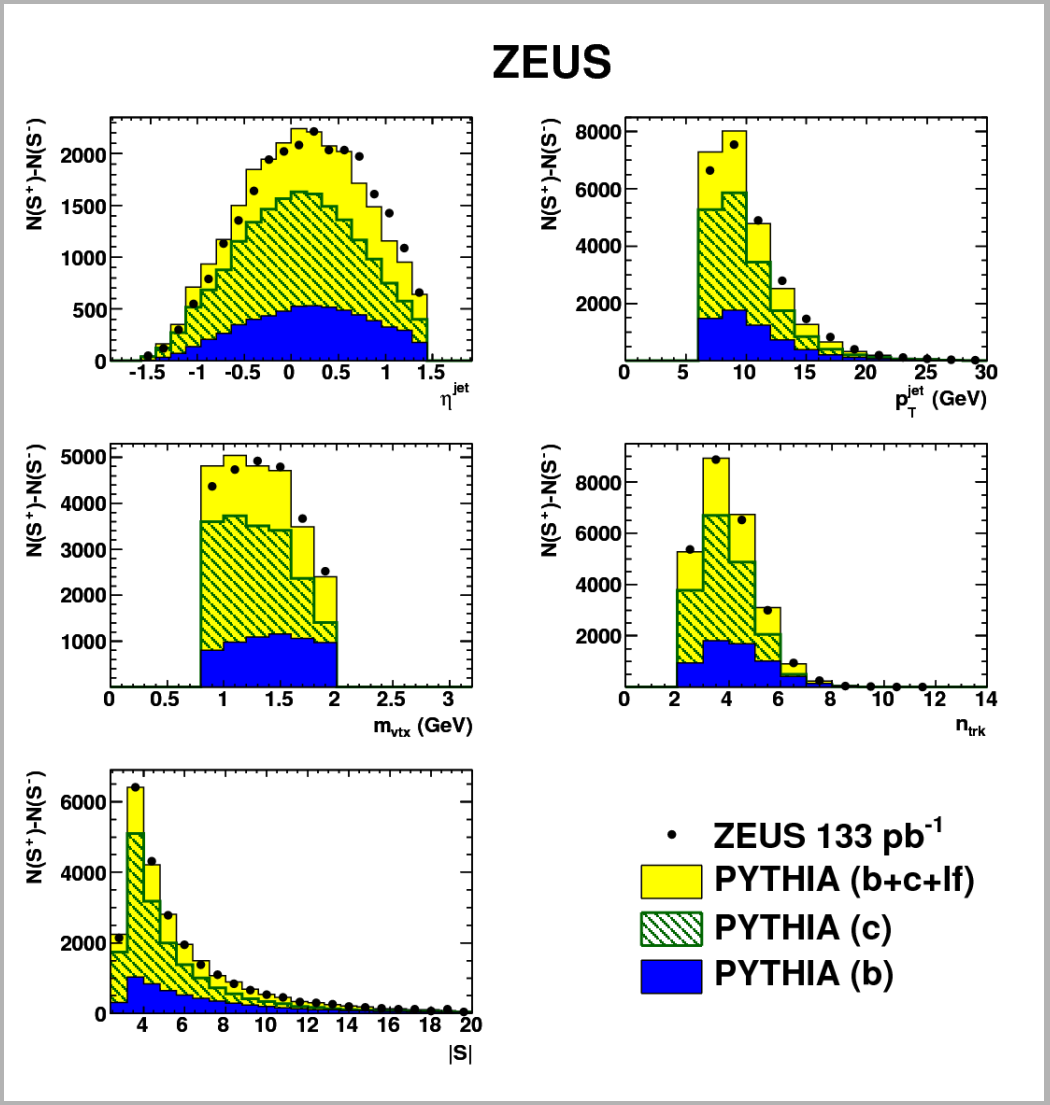
b-enriched sample

- As a cross-check, enrich b:
  - m_{vtx} > 2.0 GeV
  - |S| > 8
- Pure sample
  - >90%
- Good agreement with Monte Carlo

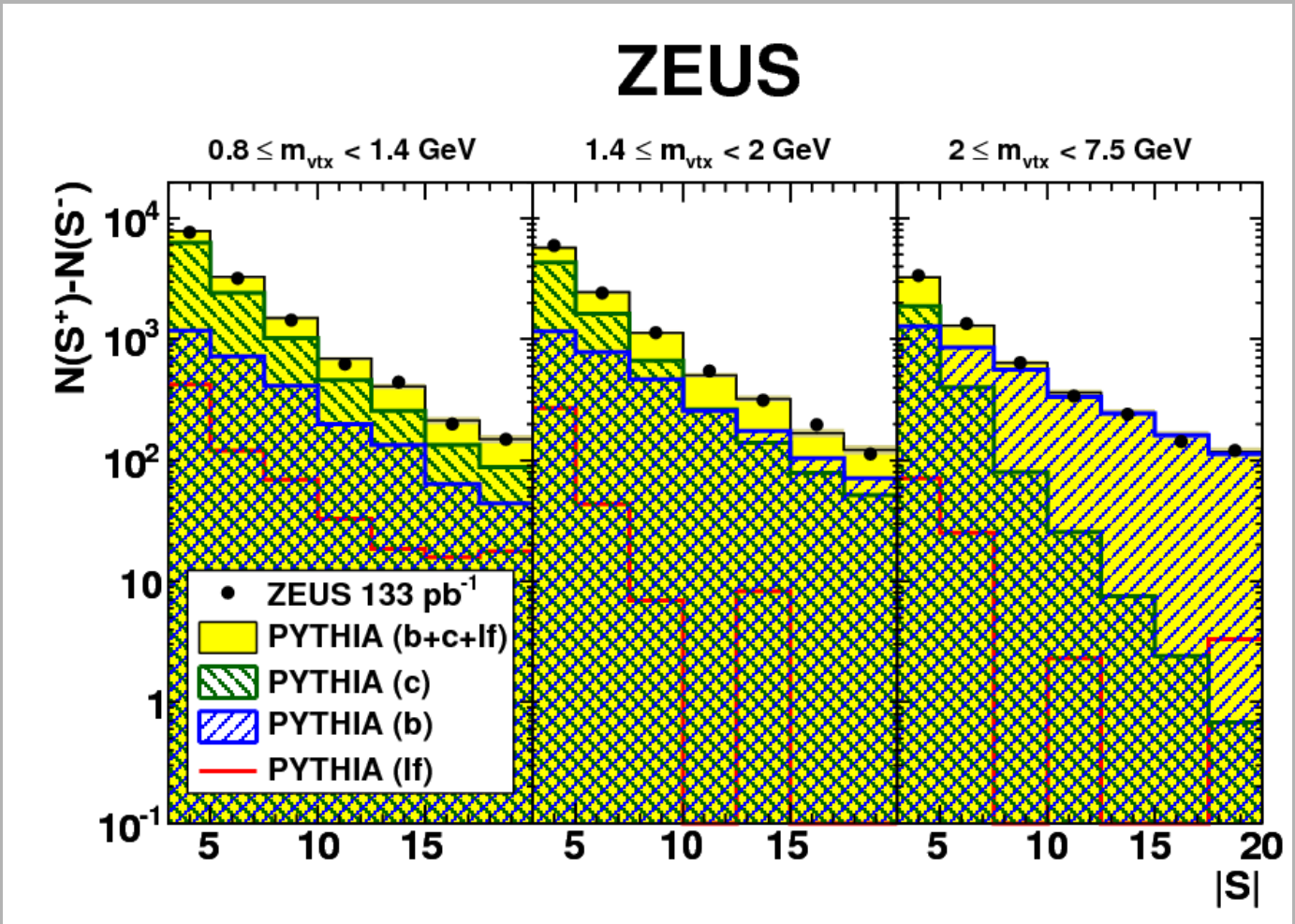


c-enriched sample

- As a cross-check, enrich c:
  - $0.8 < m_{vtx} < 2.0$ GeV
- Sample purity
  - ~70%
- Good agreement with Monte Carlo
  - Ongoing studies to improve m_{vtx}



Mirrored significance



Scale factors

$k_b = 1.11$

$k_c = 1.35$

- Fit distribution to 3 contributions
- Use unsubtracted distribution to constrain overall normalisation

Systematic uncertainties

- Uncertainties for total cross-section

Parameter	Uncertainty (%)	
	b	c
Trigger efficiency	+4.2/-3.9	+4.5/-3.2
Jet energy scale	±0.6	±4.3
Tracking/Decay length	+6.0/-1.0	+1.2/-0.7
Jet reweighting	-5.6	-1.5
Charm mesons	-1.8	+0.6/-2.2
Fragmentation	+1.8/-2.1	+1.2/-1.3
Luminosity	±1.8	±1.8
Total	+7.8/-7.7	+6.7/-7.0

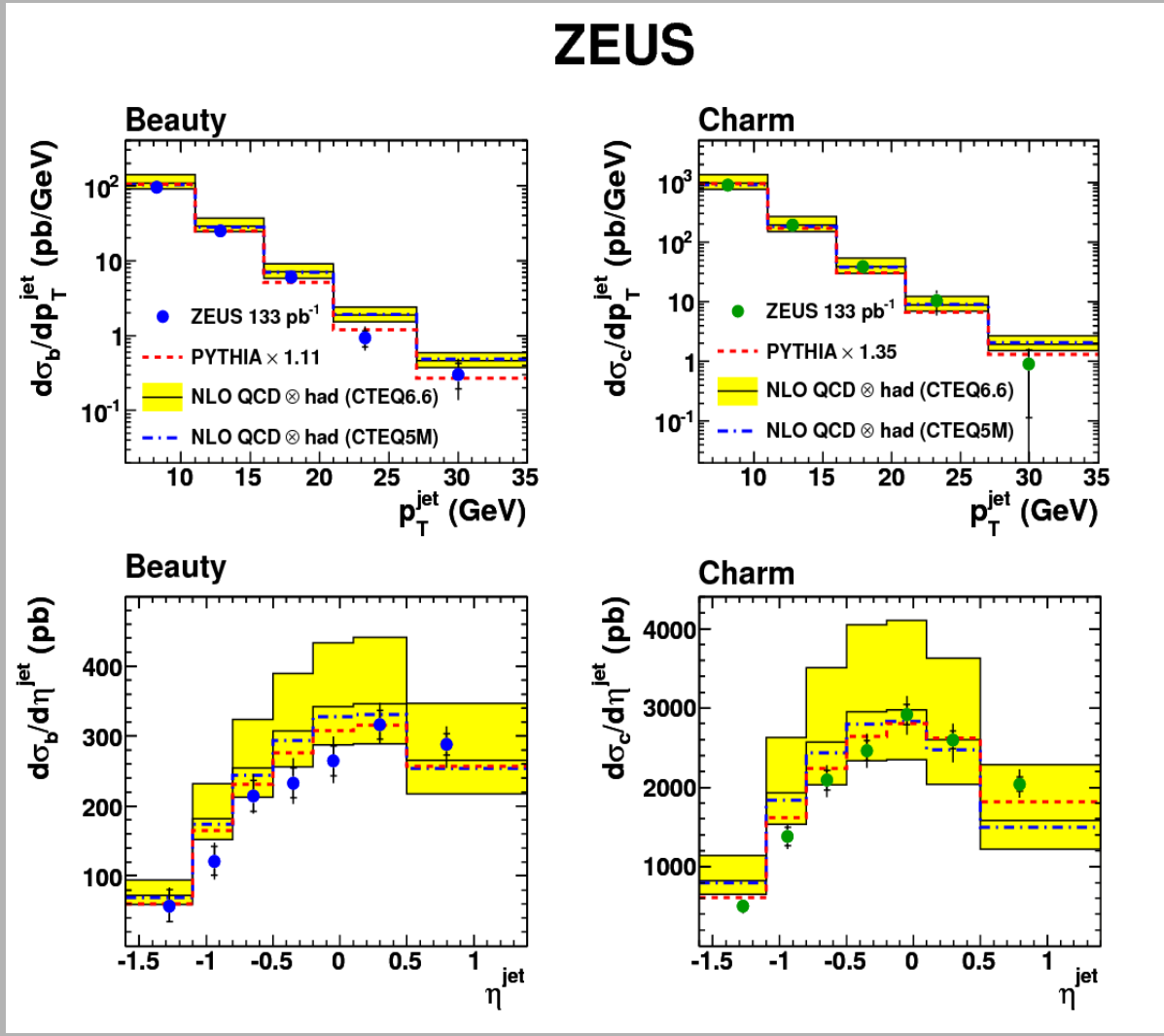
- No single dominant contribution

NLO QCD predictions

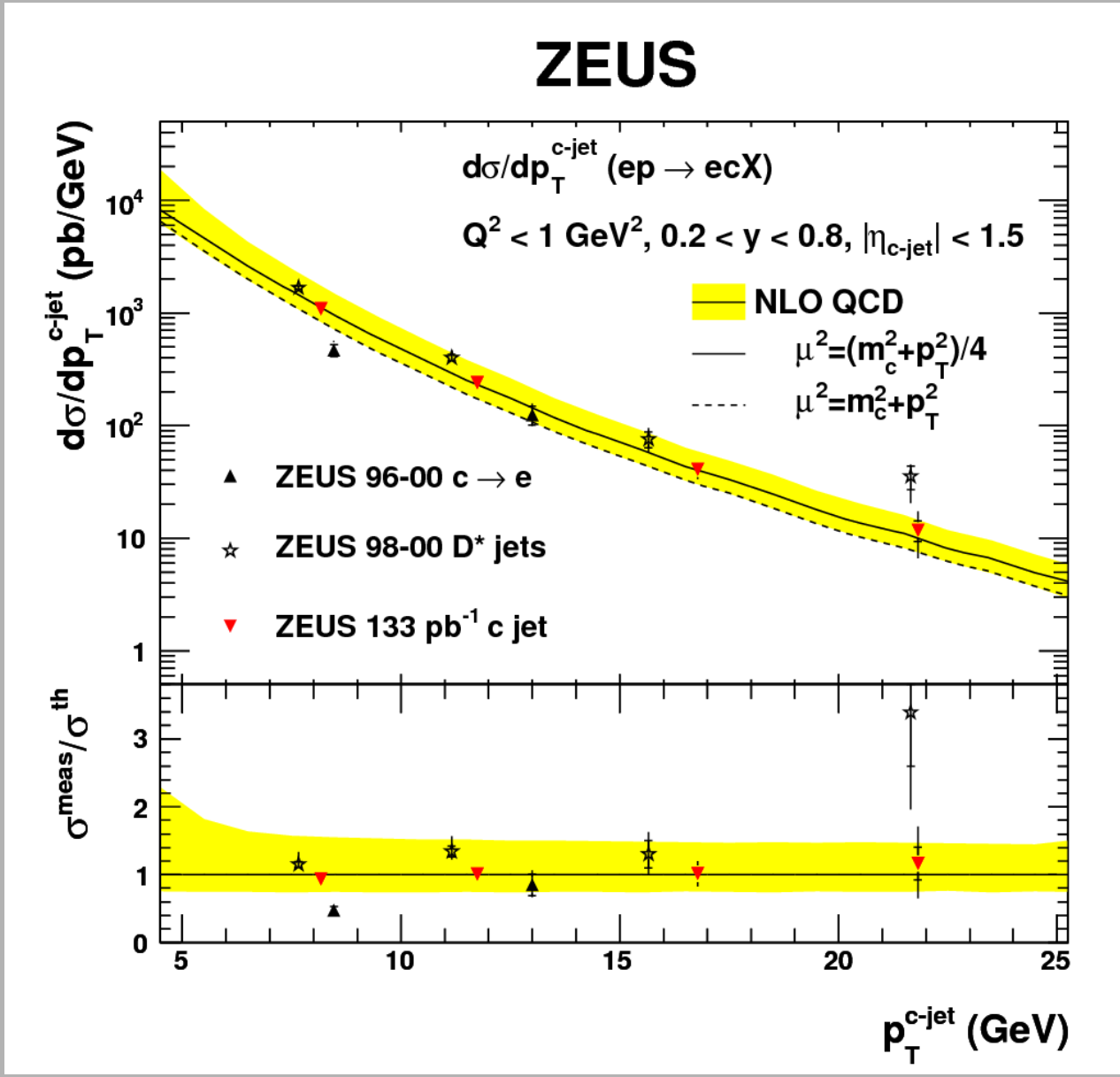
- Use FMNR program for predictions
  - $m_b = 4.75$ GeV, $m_c = 1.5$ GeV
  - $\mu_F = \mu_R = 0.5 \sqrt{(m_Q^2 + p_T^2)}$
- Vary masses and scales (by a factor of 2) to get theory uncertainty
- Dominant uncertainty comes from scale variation

Cross-sections

- Compare measured cross-sections with scaled MC and NLO QCD predictions
- Large theory uncertainty!
  - Small dependence on proton PDF

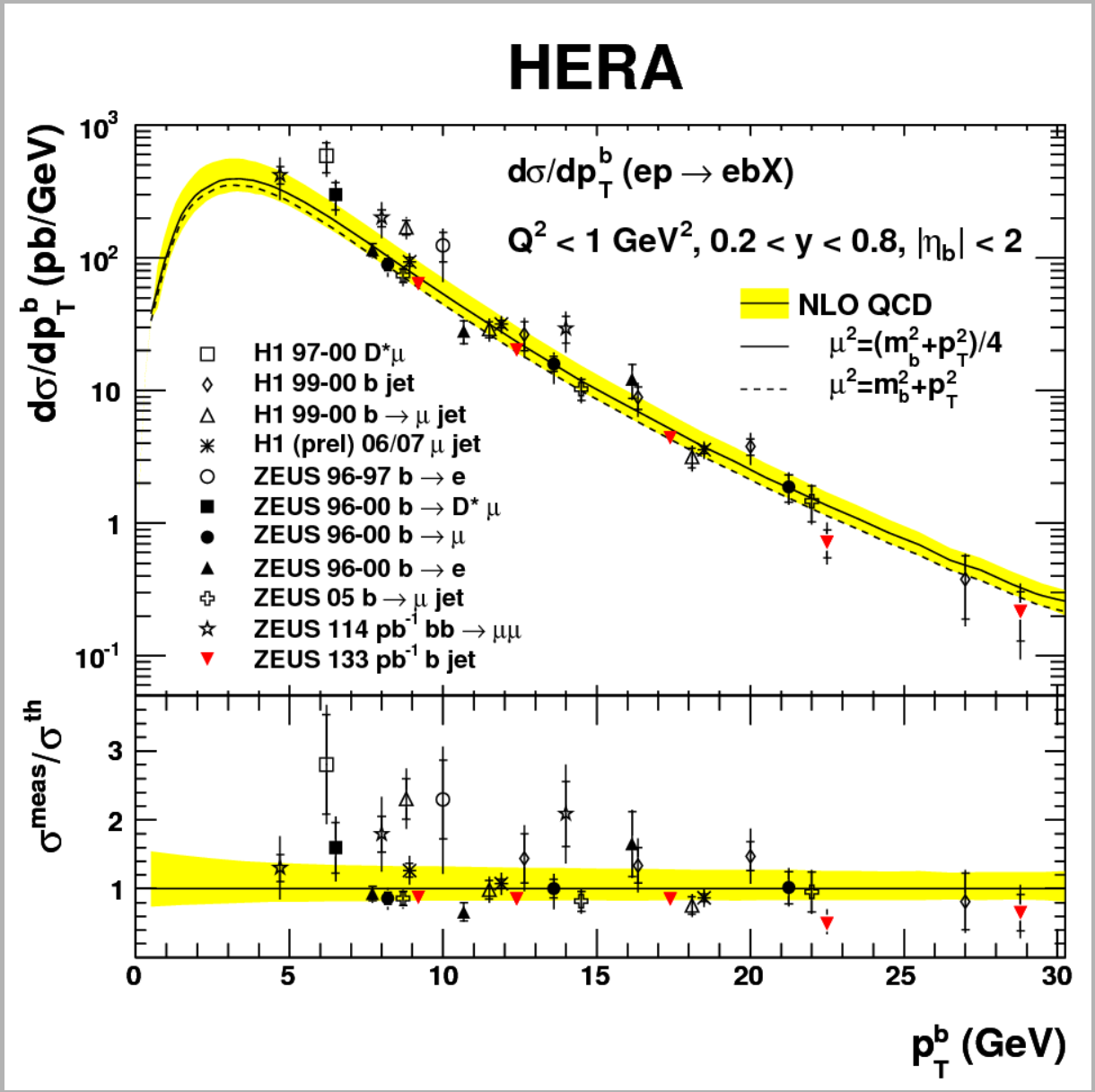


$p_T^{c\text{-}jet}$ comparison



- Reasonable agreement with previous ZEUS measurements
- Good agreement with NLO QCD predictions
- Addition of H1 measurements ongoing

p_T^b comparison



- Good agreement with previous ZEUS and H1 measurements
- Good agreement with NLO QCD predictions

Summary

- Precise inclusive measurement of b- and c-quark dijet cross-sections made in photoproduction regime at HERA
- Comparison of different measurements leads to a consistent picture of heavy quark production in ep collisions
- NLO QCD predictions agree with data
  - Theory errors are rather large
  - NNLO calculations?

Backup

Theory uncertainty

- Assess theory uncertainty by requiring physical observable to be independent of scale for a given order of calculation

$$\frac{d}{d\ln\mu^2}\sigma_{pp\to X} = O(\alpha_S^{l+1})$$

Equation motivates commonly adopted approach of varying renormalisation and factorisation scale by ½ and 2