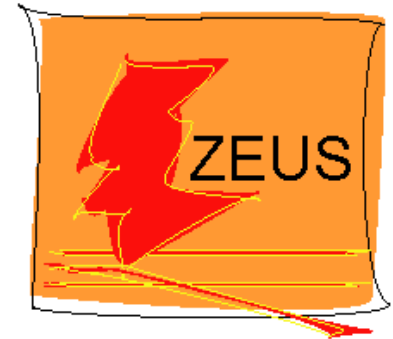# MULTIJET PRODUCTION IN DIS AT HERA

Makarenko Inna

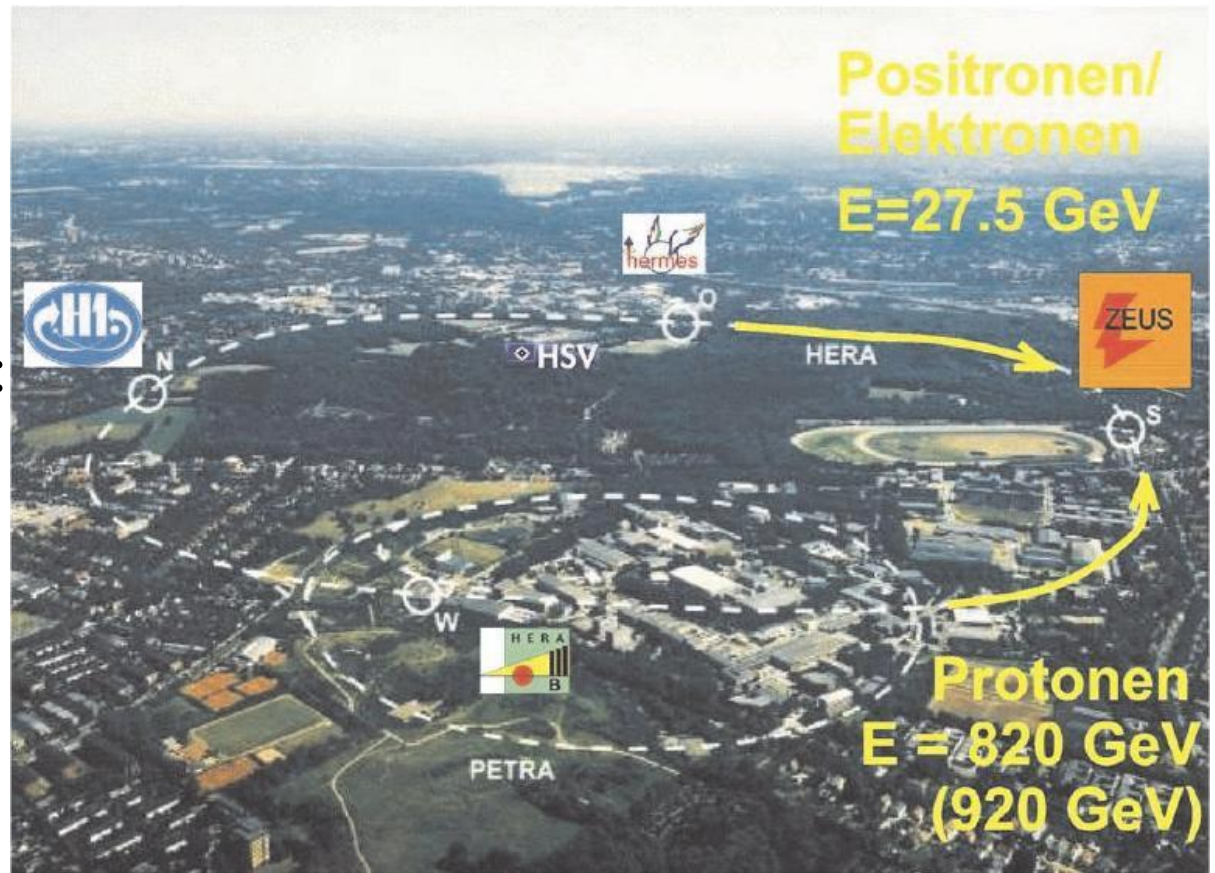**DESY/Hamburg Uni.**

WE-Heraeus-Summerschool

Heidelberg

September 2013

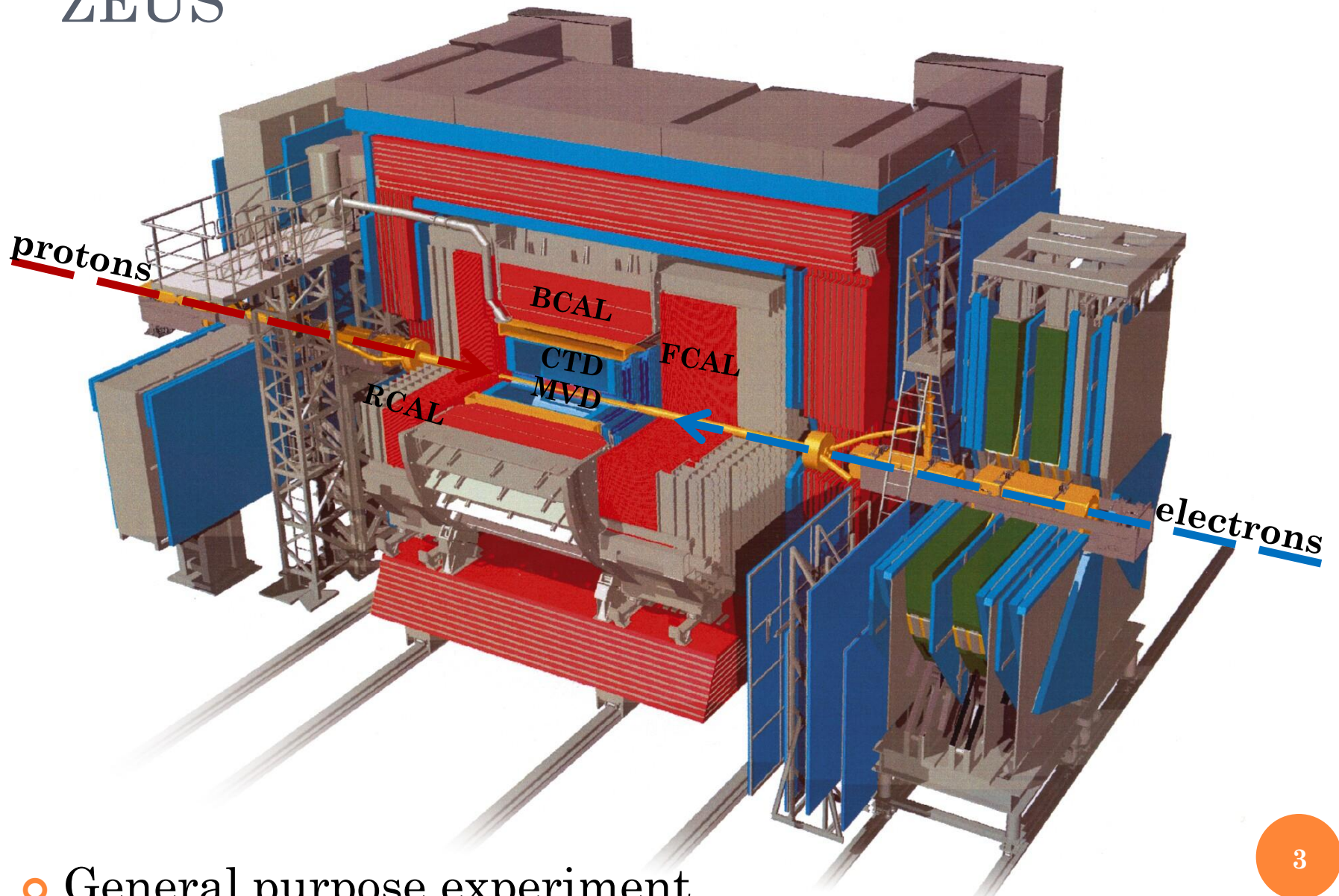# HERA

- ep collider
- E_{CMS} = 318 GeV
- Operating period: 1992-2007

- Four experimental halls
- Two collider experiments: H1 and ZEUS
- Two data taking periods: HERA I and HERA II
  - Integrated $\mathcal{L} \approx 0.5$ fb^{-1}

2

ZEUS

- General purpose experiment
- 4π geometry

Kinematic at HERA

- Centre-of-mass energy

$$\sqrt{S} = \sqrt{(l+p)^2}$$

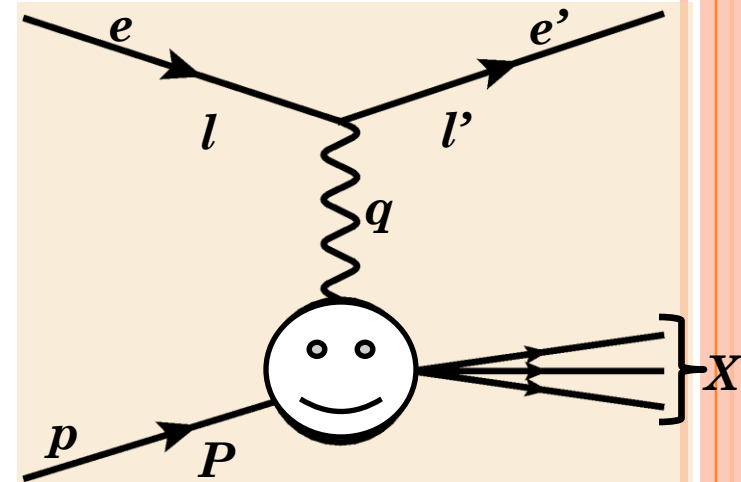- Virtuality of the exchanged boson

$$Q^2 = -q^2 = -(l-l')^2$$

- Inelasticity of the scattering process

$$y = \frac{Pq}{Pl}$$

- Bjorken scaling variable

$$x_{Bj} = \frac{Q^2}{2Pq}$$
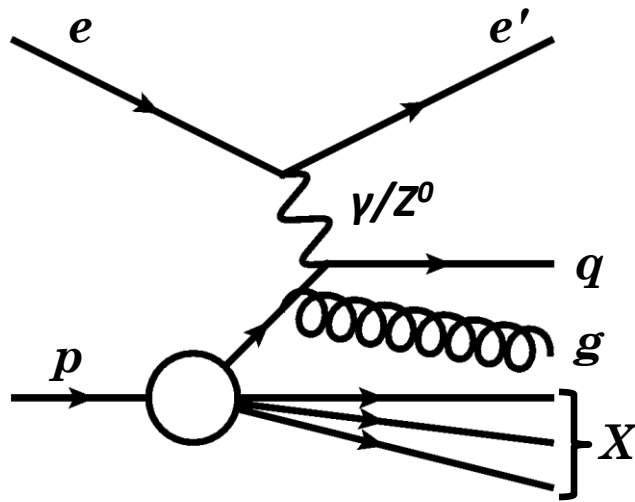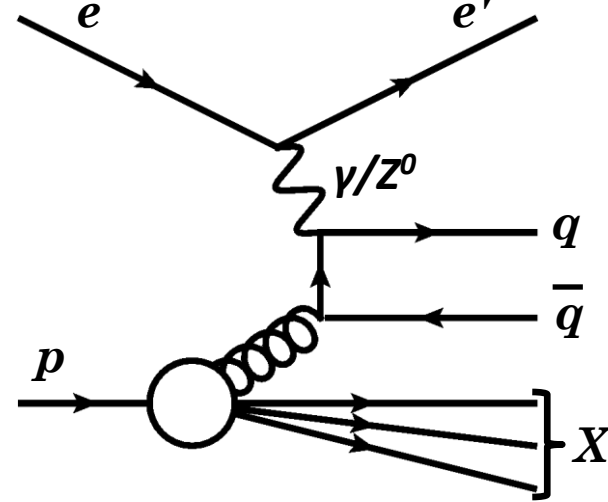
- Photoproduction:
  - $Q^2 < 1\,\text{GeV}^2$
- DIS:
  - $Q^2 > 1\,\text{GeV}^2$

4

Introduction

Two processes contribute in lowest order QCD:

QCD-Compton   Boson-gluon fusion

- Goal:
  - Stringent tests of pQCD
  - Measurement of the cross sections ratio, $R_{3/2}$, of the inclusive trijet and dijet production at high Q^2 NC DIS
- Motivation:
  - $R_{3/2}$ allows an extraction of value of α_s with partially reduced systematic uncertainties

INTRODUCTION

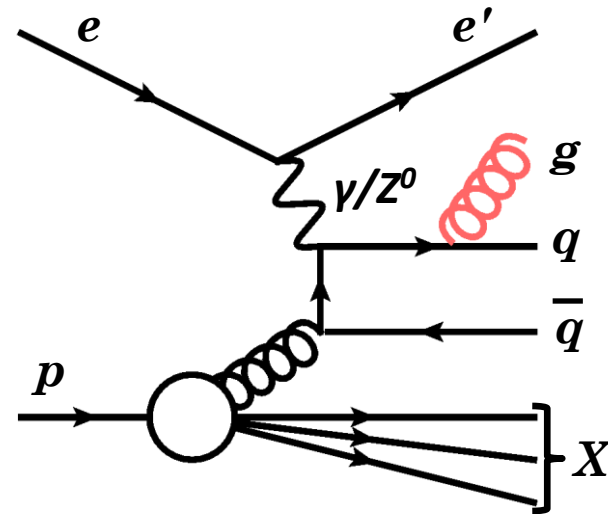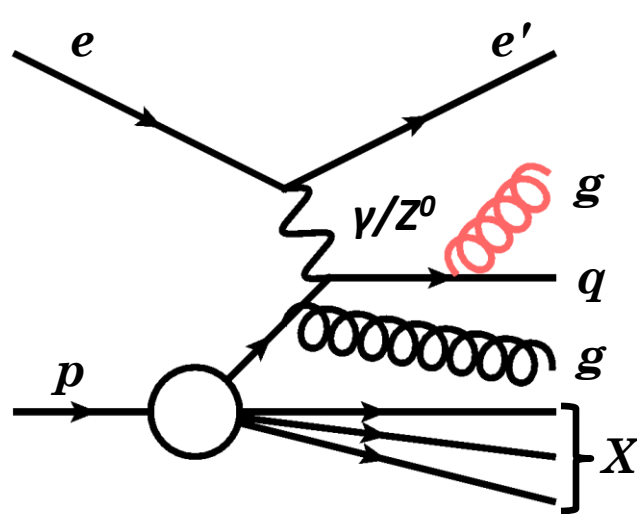**Examples** of **trijet** production diagrams:

- Goal:
  - Stringent tests of pQCD
  - Measurement of the cross sections ratio, $R_{3/2}$, of the inclusive trijet and dijet production at high Q^2 NC DIS
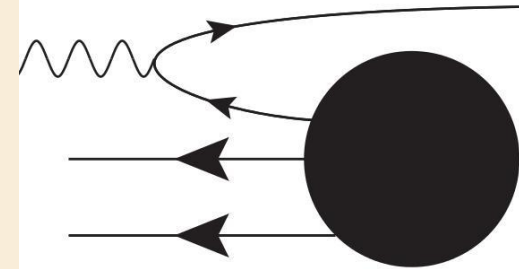
- Motivation:
  - $R_{3/2}$ allows an extraction of value of α_s with partially reduced systematic uncertainties

DATA & MC

- HERA II data sample: e⁻ p($\mathcal{L} \approx$ 186 pb⁻¹) & e⁺p($\mathcal{L} \approx$ 106 pb⁻¹)

- MC: LEPTO(default) & ARIADNE

- Jet searched using the longitudinal invariant $k_\perp$ cluster algorithm in the Breit frame

Breit frame

- Phase space
  - $125 < Q^2 < 20000$ GeV²
  - $0.2 < y < 0.6$
  - $E_{T,Breit}^{jet} > 8 GeV$ and $-1 < \eta_{lab}^{jet} < 2.5$
  - $M_{jj} > 20 GeV$

- Investigated experimental uncertainty:
  - Hadronic energy scale: scaling jet energy in MC by
    - +/-1% for $E_{T,lab}^{jet} > 10$ GeV and
    - +/-3% for $E_{T,lab}^{jet} < 10$ GeV
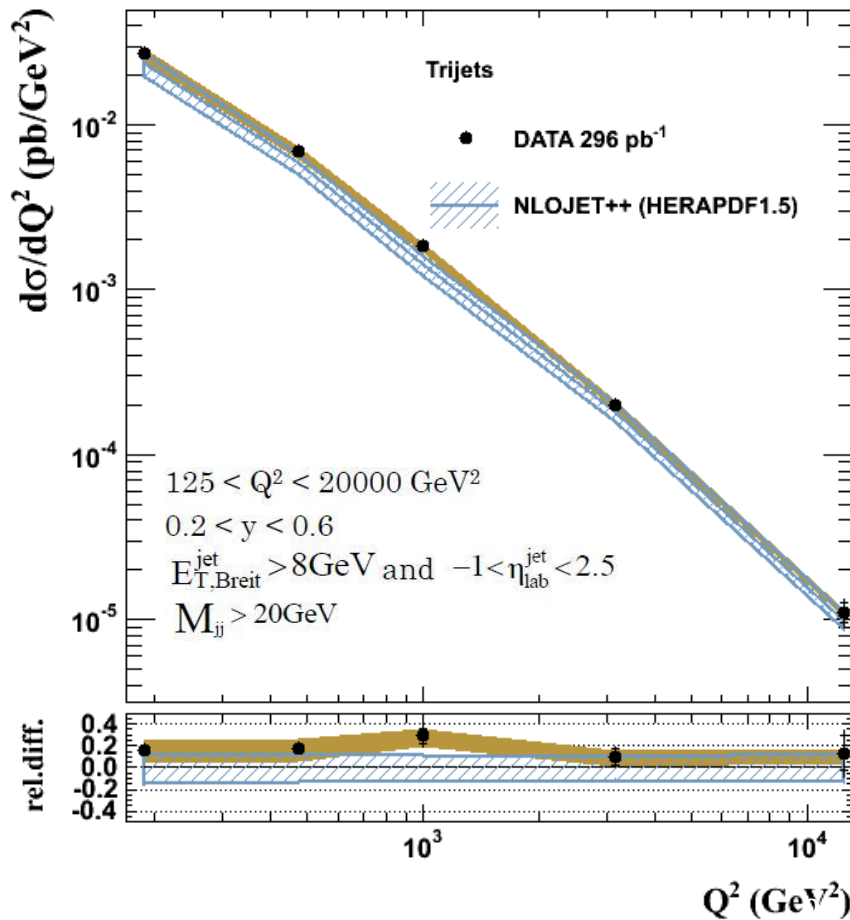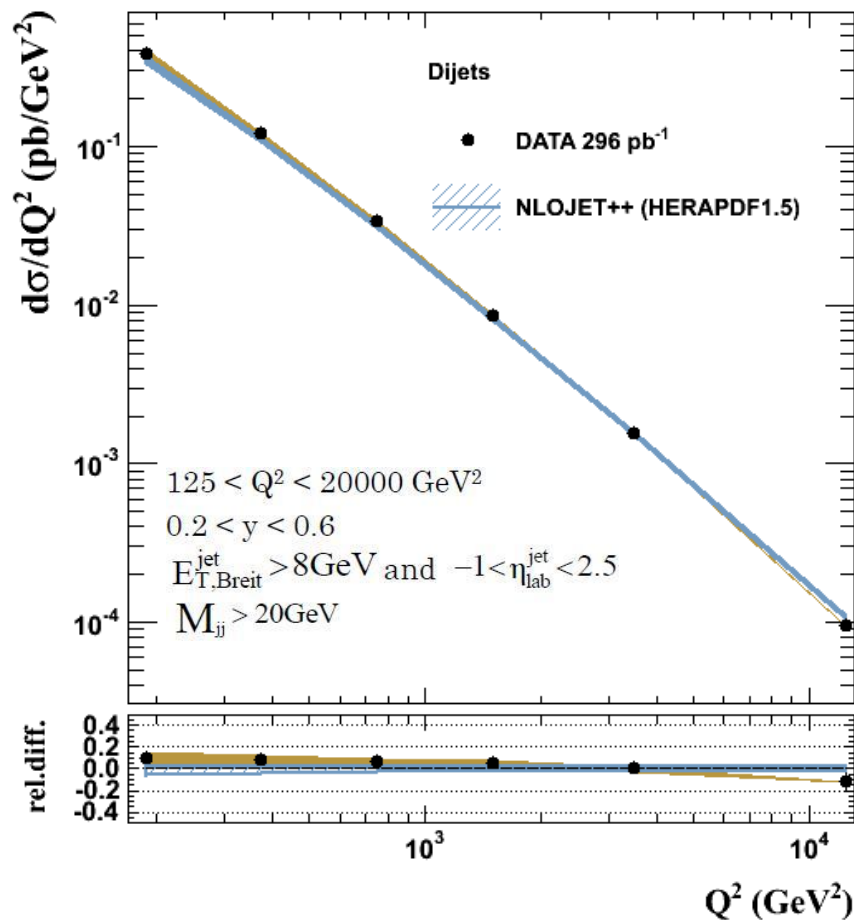
6

QCD PREDICTIONS

- NLO calculations:
  - NLOJET++
  - pPDF: <u>HERAPDF</u>1.5
  - $\mu_r = \sqrt{Q^2 + \overline{E}_{T,Breit}^{jet\,2}}$
  - $\mu_F = Q$
  - $\alpha_s(M_Z) = 0.1176$
- Investigated theoretical uncertainties:
  - Hadronisation: using alternatively ARIADNE MC
  - Value of $\alpha_s(M_Z)$: using two additional sets from the HERAPDF analysis
  - Terms beyond NLO: varying μ_r by a factor of 2 up and down
  - Factorisation scale: varying μ_F in the range $\dfrac{Q}{2} < \mu_F < 2Q$
- Corrected for hadronisation and Z^0 effects
- Data were corrected for QED effects

$$\frac{d\sigma}{dQ^2}$$ **Dijets and trijets**

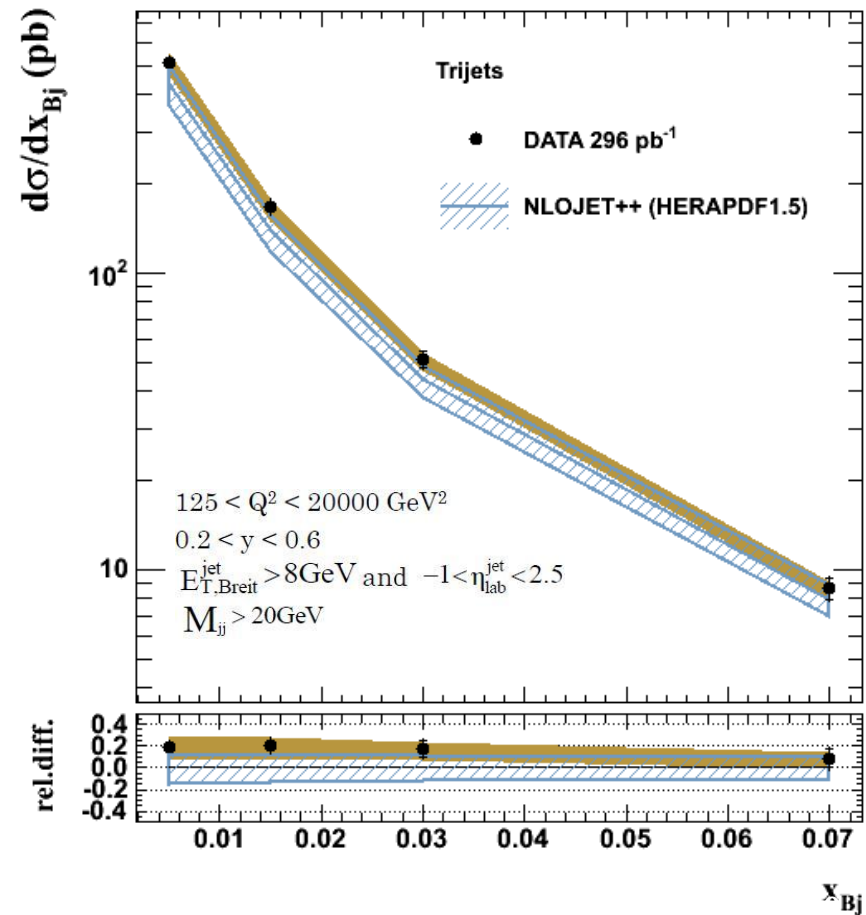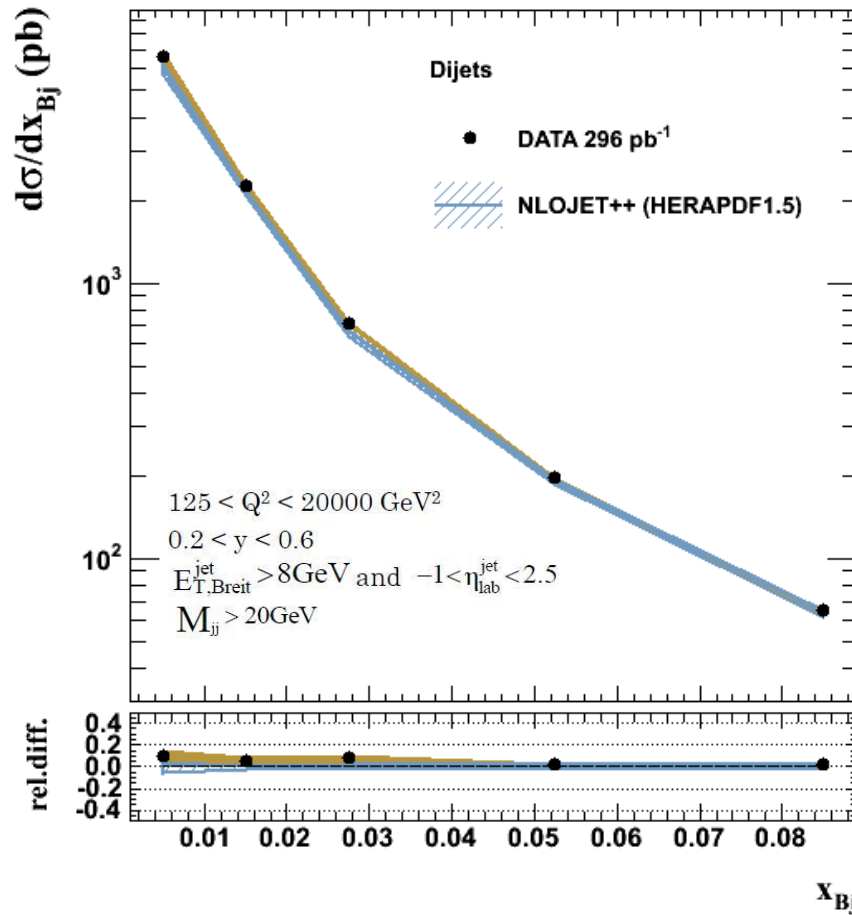Dijets

DATA 296 pb⁻¹

NLOJET++ (HERAPDF1.5)

$125 < Q^2 < 20000 \ \mathrm{GeV}^2$

$0.2 < y < 0.6$

$E_{T,Breit}^{jet} > 8 \mathrm{GeV}$ and $-1 < \eta_{lab}^{jet} < 2.5$

$M_{jj} > 20 \mathrm{GeV}$

Trijets

DATA 296 pb⁻¹

NLOJET++ (HERAPDF1.5)

$125 < Q^2 < 20000 \ \mathrm{GeV}^2$

$0.2 < y < 0.6$

$E_{T,Breit}^{jet} > 8 \mathrm{GeV}$ and $-1 < \eta_{lab}^{jet} < 2.5$

$M_{jj} > 20 \mathrm{GeV}$

○ Good description of data in shape and normalisation by NLO QCD

$\dfrac{d\sigma}{dx_{Bj}}$ **Dijets and trijets**

Dijets

- DATA 296 pb^{-1}
- NLOJET++ (HERAPDF1.5)

$125 < Q^2 < 20000 \text{ GeV}^2$
$0.2 < y < 0.6$
$E_{T,Breit}^{jet} > 8\text{GeV}$ and $-1 < \eta_{lab}^{jet} < 2.5$
$M_{jj} > 20\text{GeV}$

Trijets

- DATA 296 pb^{-1}
- NLOJET++ (HERAPDF1.5)

$125 < Q^2 < 20000 \text{ GeV}^2$
$0.2 < y < 0.6$
$E_{T,Breit}^{jet} > 8\text{GeV}$ and $-1 < \eta_{lab}^{jet} < 2.5$
$M_{jj} > 20\text{GeV}$

- Measured cross sections are very well described by the NLO predictions in the whole measured range
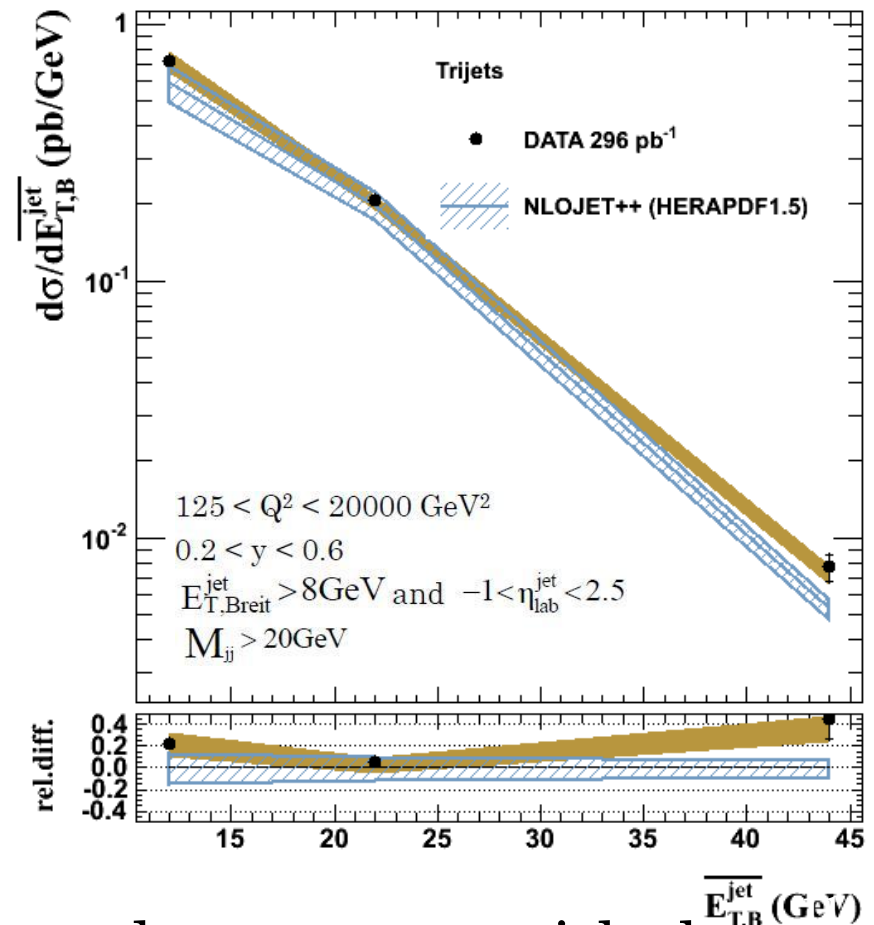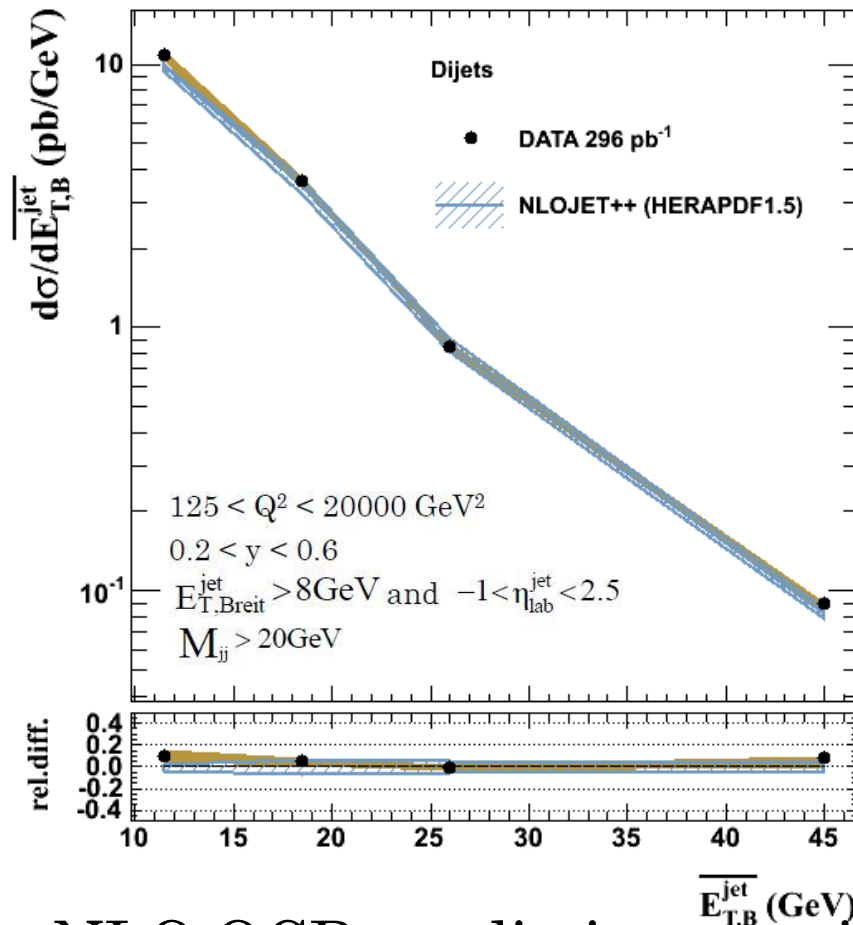
- NLO QCD predictions are in good agreement with the measurements

$$\frac{d\sigma}{d\overline{E}^{jet}_{T,Breit}} \quad in \quad Q^2 \; bins$$

Dijets

in progress
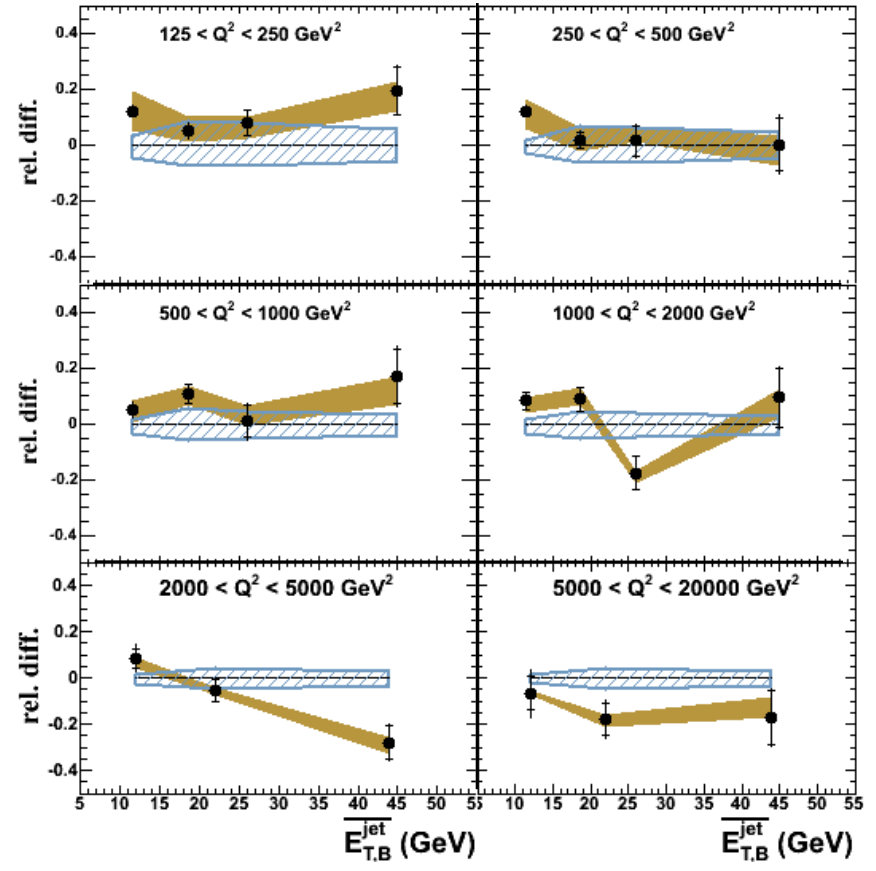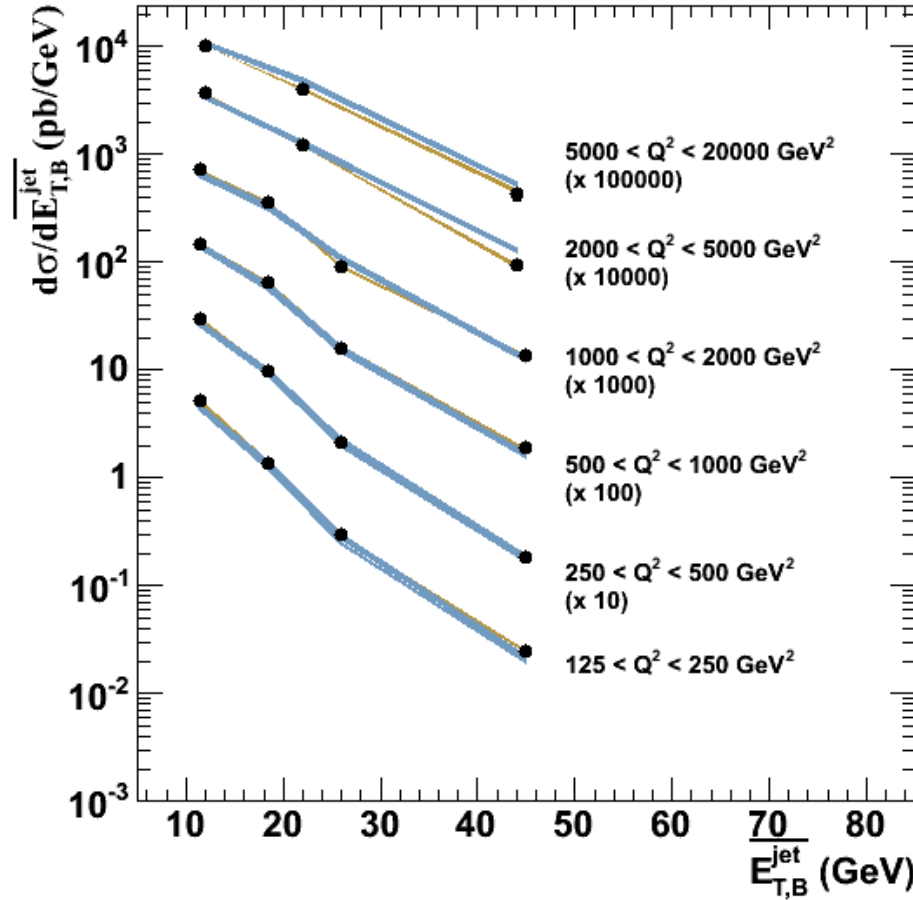
- Measured cross sections are reasonably described by the NLO predictions

$$\frac{d\sigma}{d\overline{E}_{T,Breit}^{jet}} \quad \text{in} \quad Q^2 \text{ bins}$$

Trijets
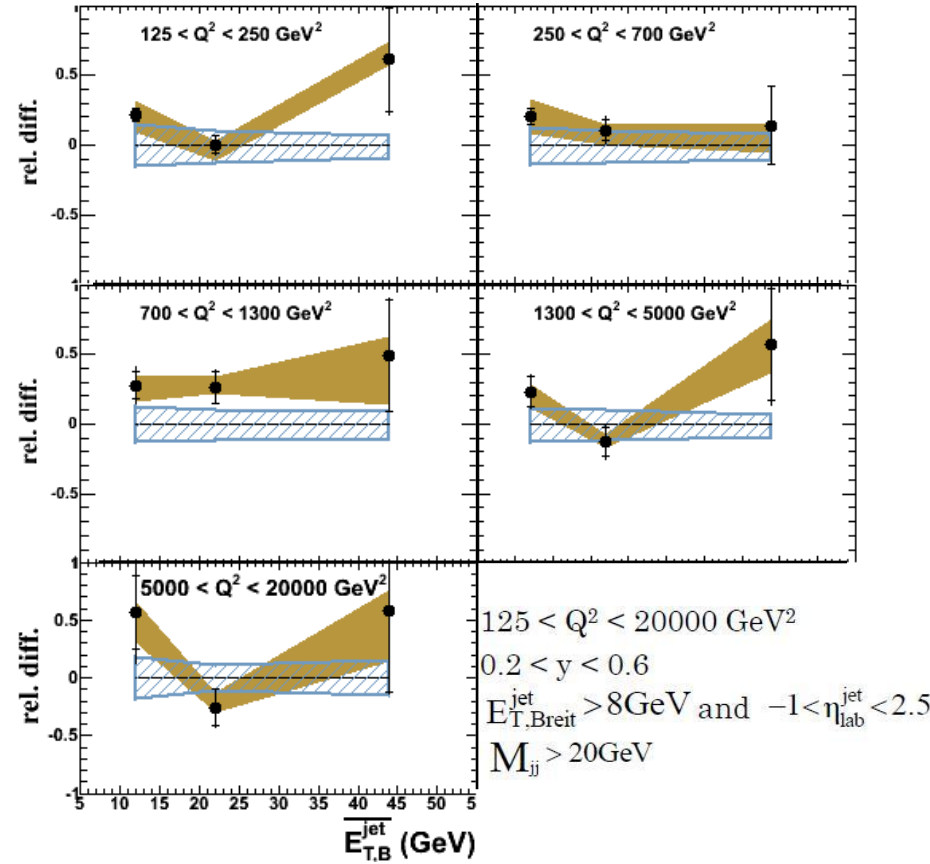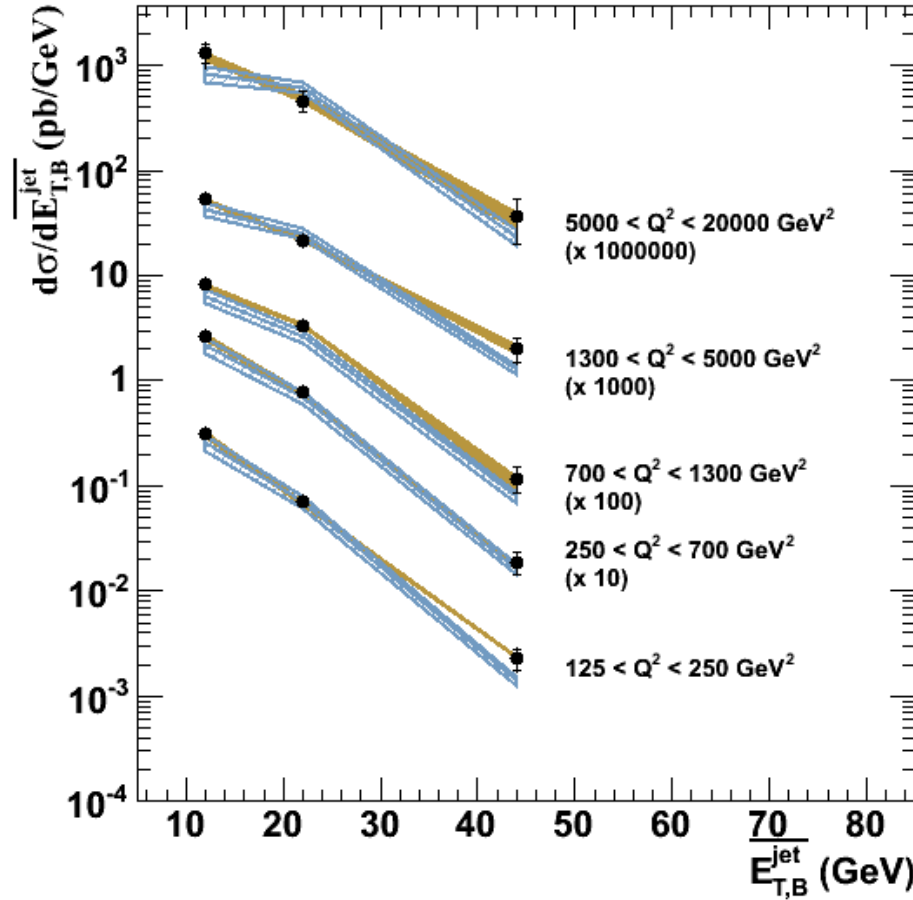
NLO QCD predictions are in reasonable agreement with the measurements
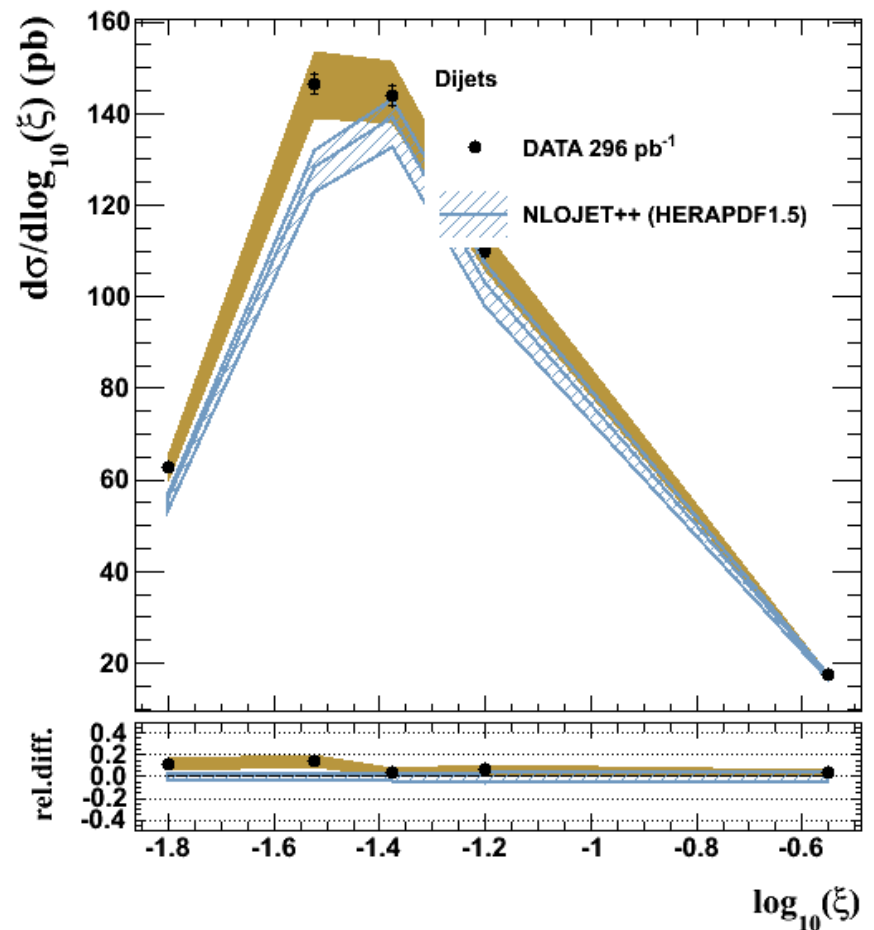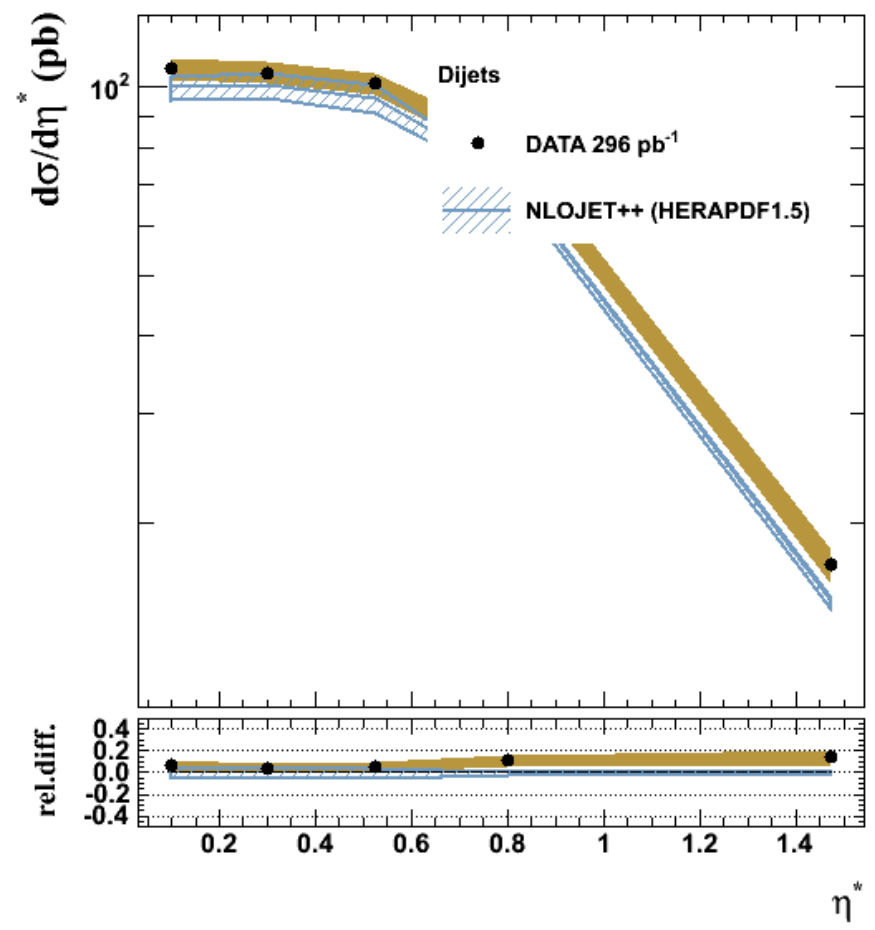
Summary and plans

- Summary:
  - Multijet production cross sections in NC DIS at HERA have been presented
  - Dijet and trijet cross sections are well described by the preliminary version of NLO predictions

- Plans:
  - Investigate theoretical and experimental uncertainties in detail
  - Measure cross sections ratio, $R_{3/2}$, of the inclusive trijet and dijet production
  - Extract value of α_s

13

$$\frac{d\sigma}{d\eta^*} \qquad \frac{d\sigma}{d\log_{10}(\xi)}$$

➢ η^* is closely related to the angular dependent parts of the QCD matrix element
➢ $\log_{10}(\xi)$ represents the momentum fraction of the parton entering the hard process

o NLO QCD predictions are in good agreement with the measurements