$F_2^{b\bar{b}}$ measurement at ZEUS

Philipp Roloff
(DESY & University of Hamburg)

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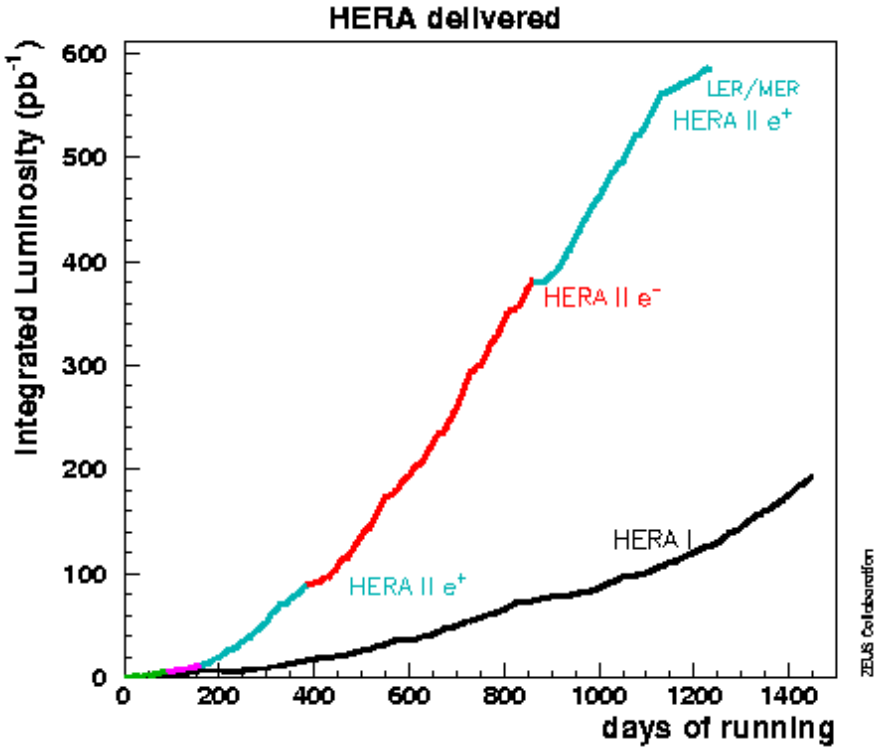
Outline

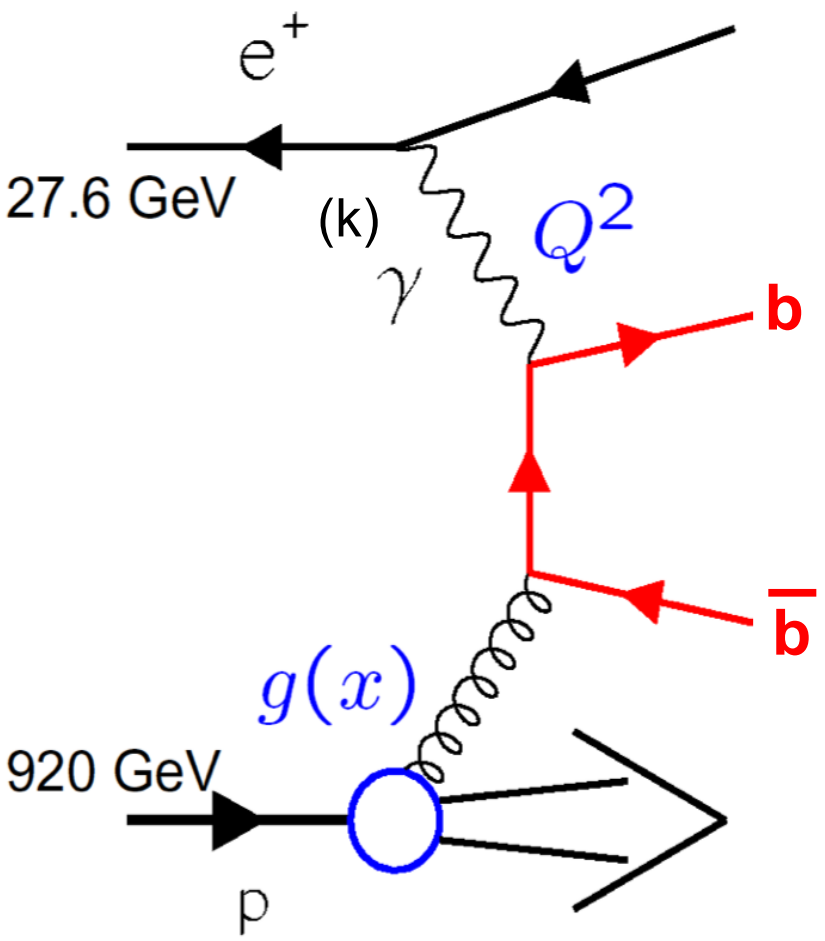
This talk:
Two measurements of beauty production in DIS at HERA:

- $F_2^{b\bar{b}}$ using events with a muon and a jet (DESY 10-047)
→ Full HERA I dataset

- (Double) differential cross sections using inclusive secondary vertices (ZEUS-prel-10-004)
→ Full HERA II dataset



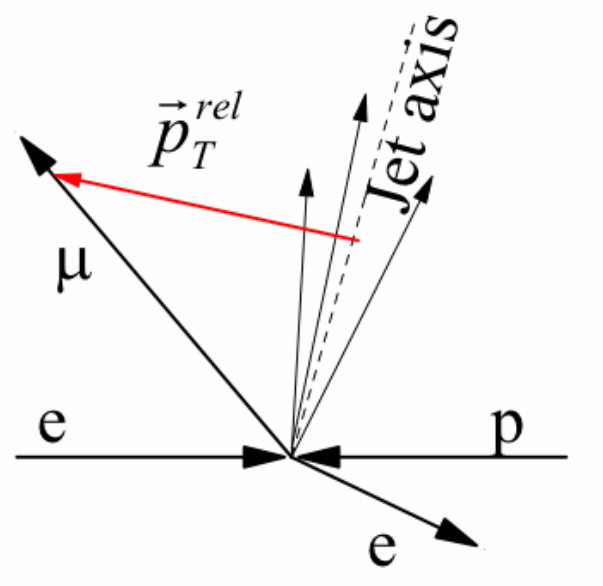
Beauty production at HERA

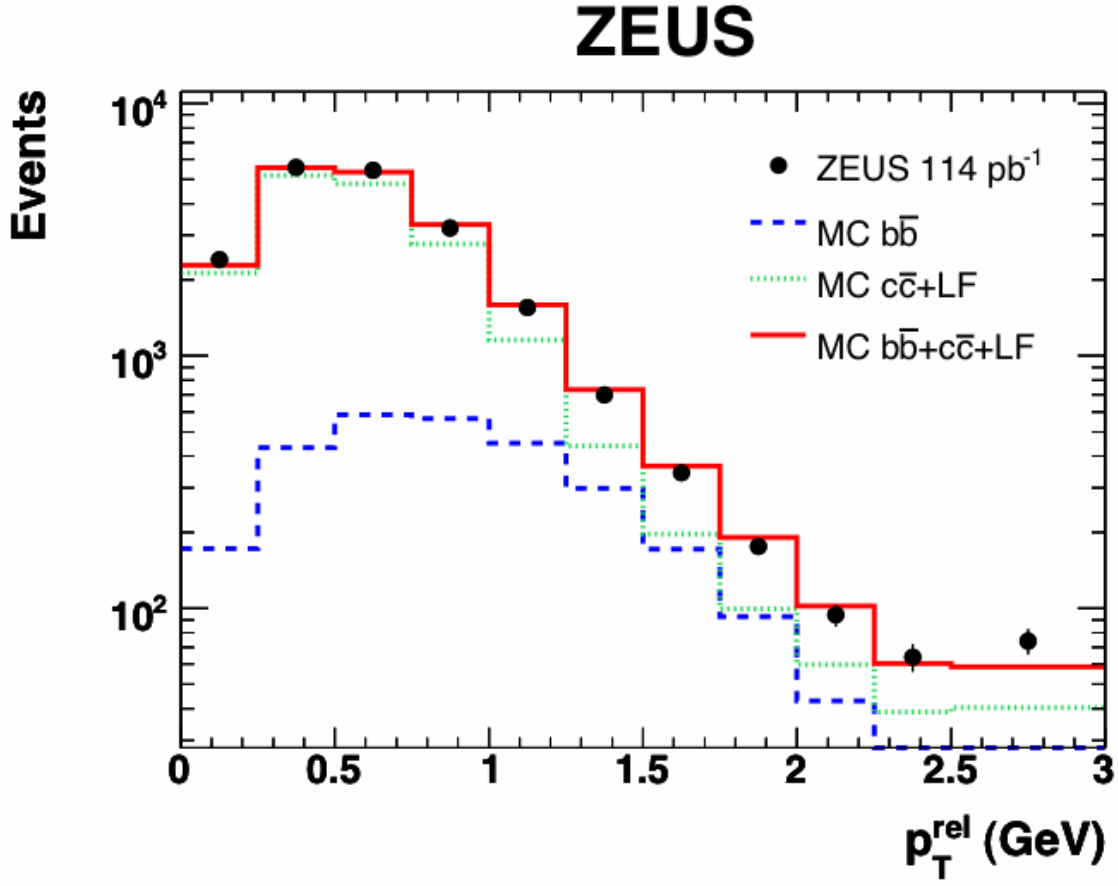


- Dominant process for beauty production in DIS (Q^2 > a few GeV^2): Boson-Gluon-Fusion (BGF)
- Multiple hard scales: $\mu^2 = m_b^2, p_b^2, Q^2$
- Mass effects are relevant in a large part of the phase space accessible at HERA
- The double differential cross section for the production of open beauty can be written as:

$$\frac{d^2\sigma^{b\bar{b}}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left(\left[1+(1-y)^2\right]F_2^{b\bar{b}}(x,Q^2) - y^2 F_L^{b\bar{b}}(x,Q^2)\right)$$

Beauty identification using the p_T^{rel} method (HERA I)





- **p_T^{rel}:** the muon momentum component transverse to the jet axis

- The p_T^{rel} spectrum is harder for beauty than for charm or light flavours → statistical separation using MC templates

Control distributions

- **Kinematic range:**

$Q^2 > 2\ GeV^2$

$0.05 < y < 0.7$

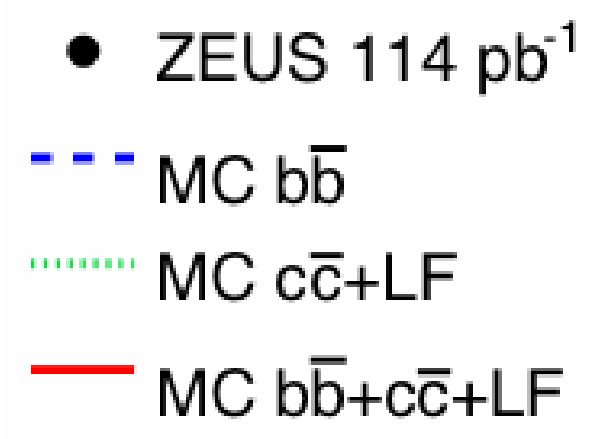
$p_T^{\mu} > 1.5\ GeV$

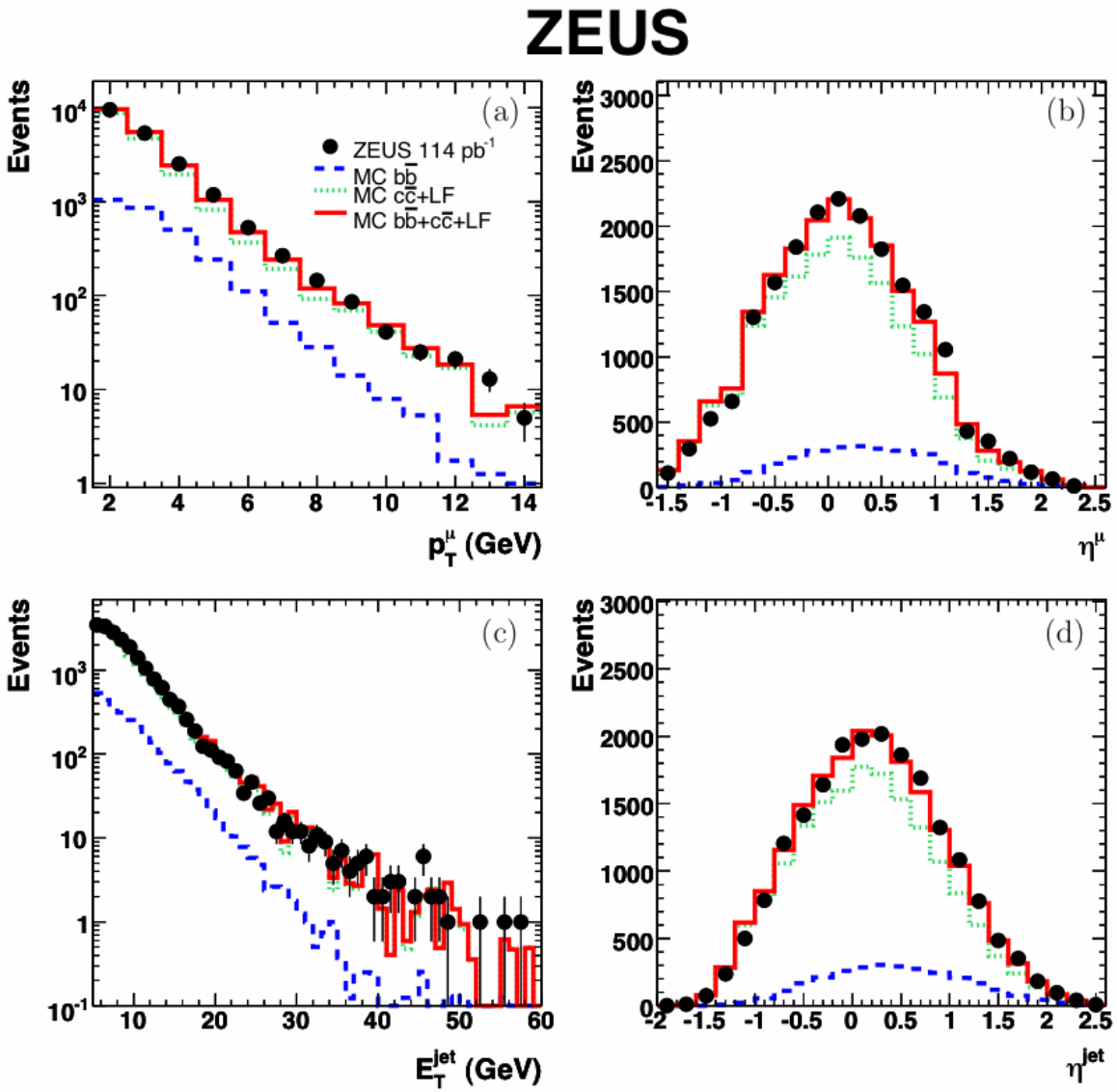
$\eta^{\mu} > -1.6$

$E_T^{jet,lab} > 5\ GeV$

$-2.0 < \eta^{jet} < 2.5$

- **Data sample:** 114 pb^{-1} HERA I (1996 - 2000)

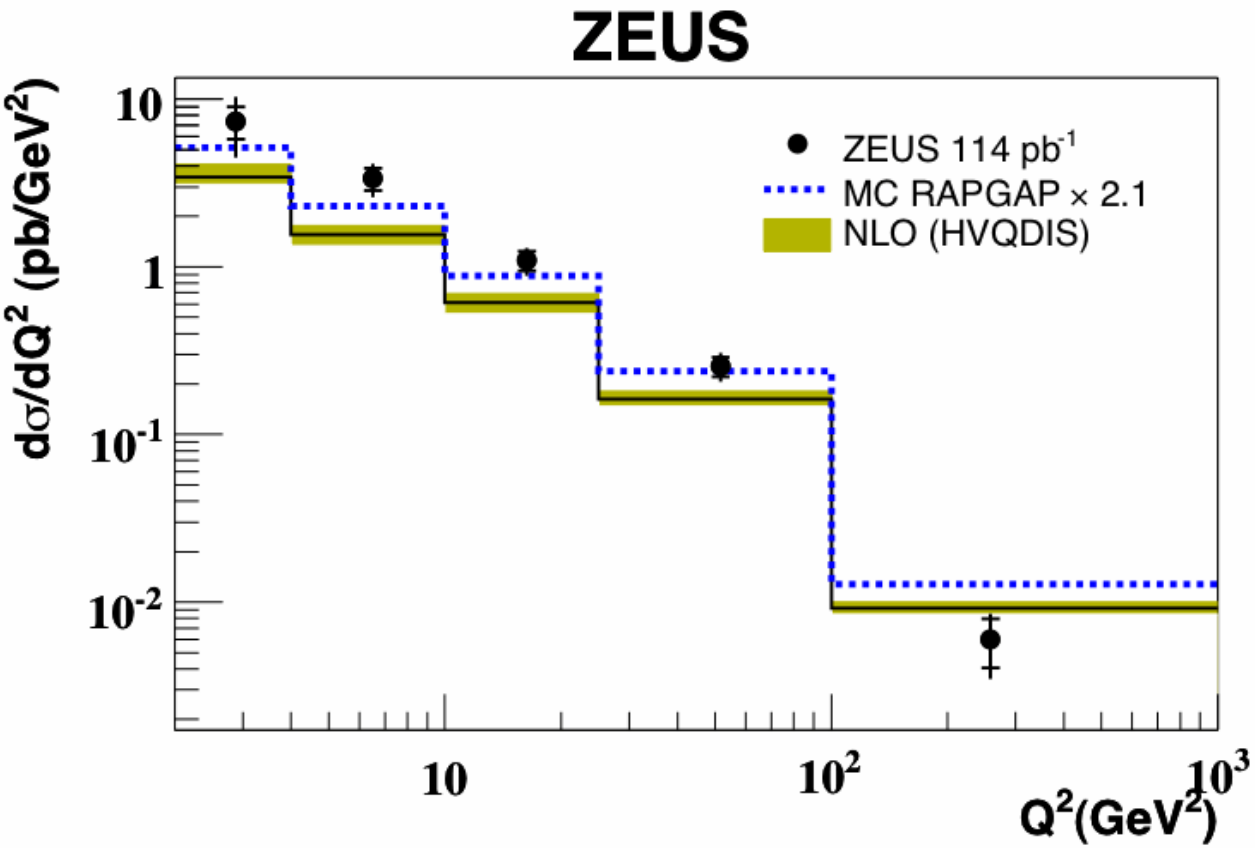




Cross sections: Q^2

- The low Q^2 region can only be measured at HERA I

- The HVQDIS NLO prediction (FFNS) and the RAPGAP LO+PS MC describe the shape of the data reasonably well

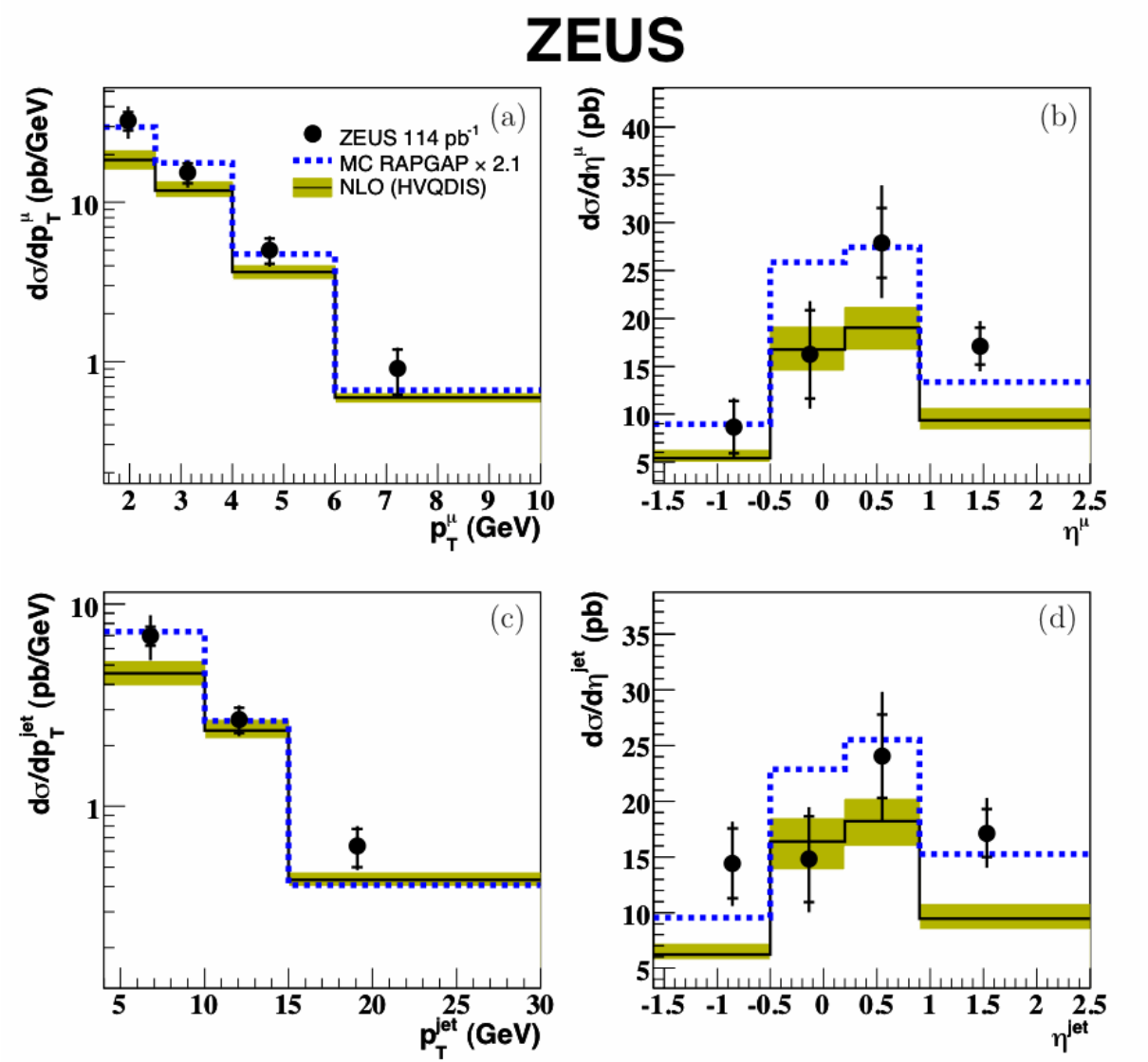


ZEUS 114 pb^{-1}
MC RAPGAP × 2.1
NLO (HVQDIS)

Cross sections: p_T and η

- The HVQDIS NLO prediction (FFNS) and the RAPGAP LO+PS MC describe the shape of the data reasonably well

- In the low Q^2, and therefore low p_T, region HVQDIS tends to underestimate the data



Extraction of $F_2^{b\bar{b}}$

Extrapolation needed:

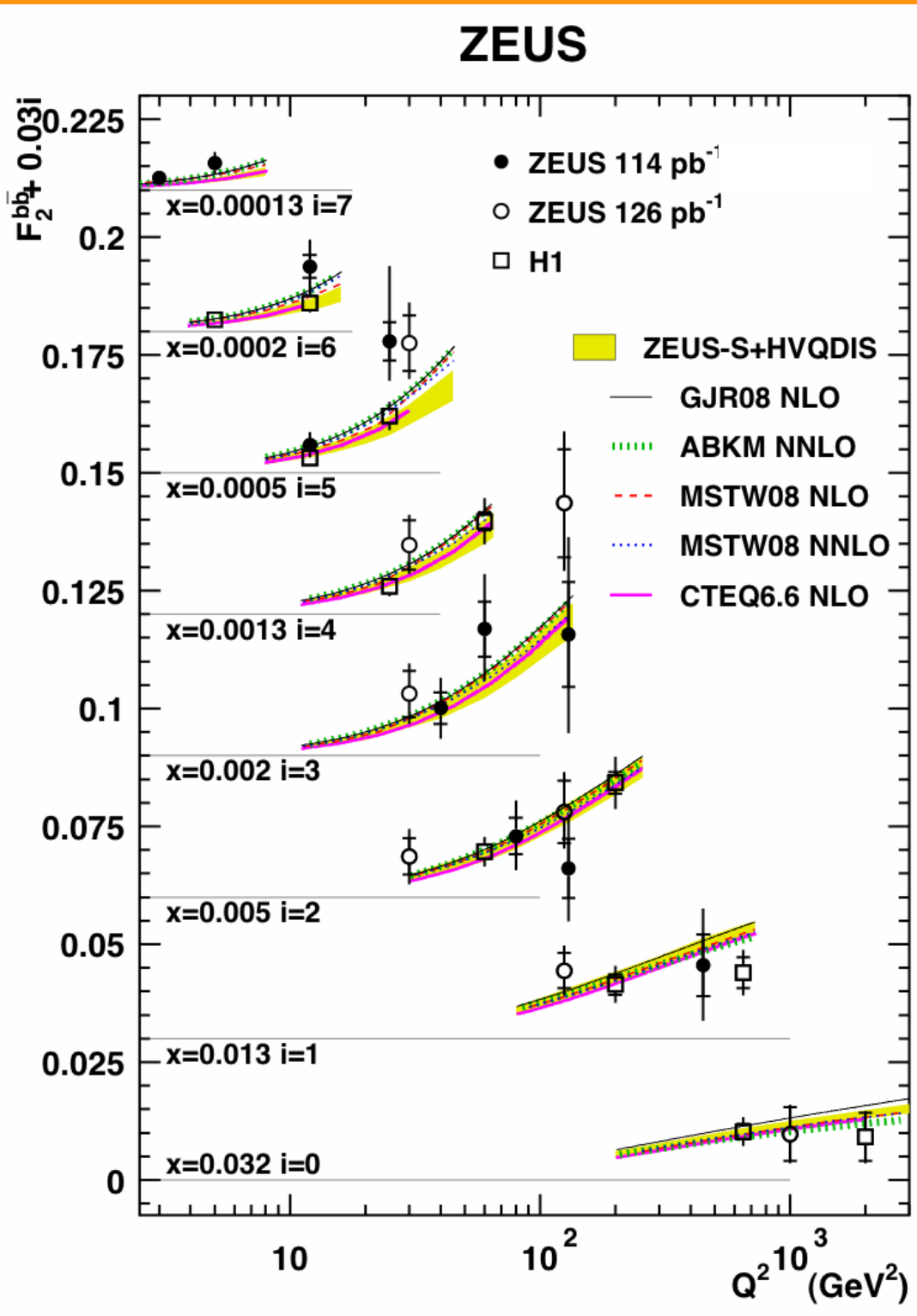
Measured cross section in bin i

$$F^{b}_{2,meas}(x_i, Q^2_i) = \frac{\sigma_{meas,i}}{\sigma_{theo,i}} \times F^{b}_{2,theo}(x_i, Q^2_i)$$

Calculated using HVQDIS (FFNS)

Calculated at NLO in FFNS

$F_L^{b\bar{b}}$ small in the measured Q^2 and x ranges → neglected



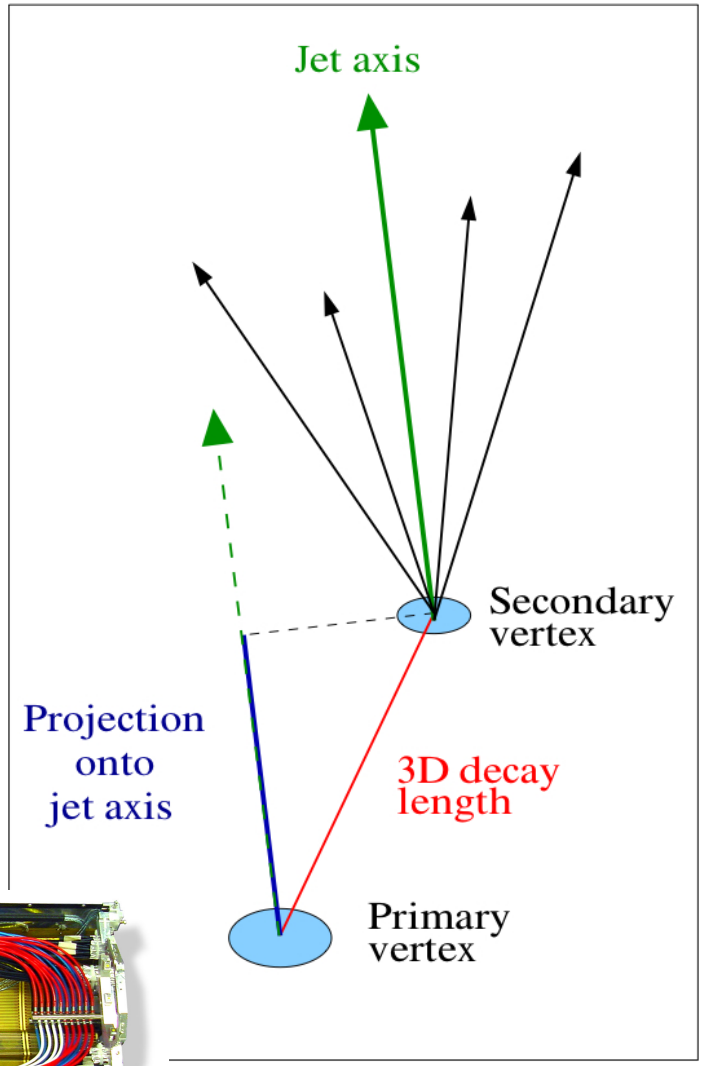
$F_2^{b\bar{b}}$ as a function of Q^2

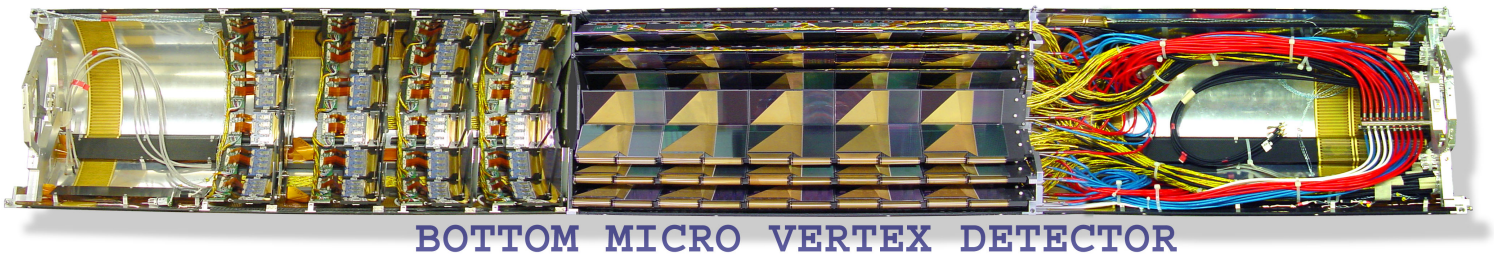
- The data are all compatible
- At low x the ZEUS data are slightly above H1
- QCD predictions in FFNS (ZEUS-S+HVQDIS, GJR08, ABKM NNLO) and the GM-VFNS (MSTW08 NLO, MSTW08 NNLO, CTEQ6.6) are shown
- At low Q^2 and x HVQDIS is somewhat lower than the ZEUS data, at higher Q^2 the data are described by all predictions

Beauty measurements using secondary vertices (HERA II)

- During the HERA II period ZEUS was equipped with a silicon Micro Vertex Detector (MVD)
→ Allows the reconstruction of charm and beauty decay vertices

- Procedure:
  - Associate tracks with $p_T > 500$ MeV to jets and fit secondary vertices in 3D
  - Calculate the 2D decay length L_{XY} and project onto the jet axis

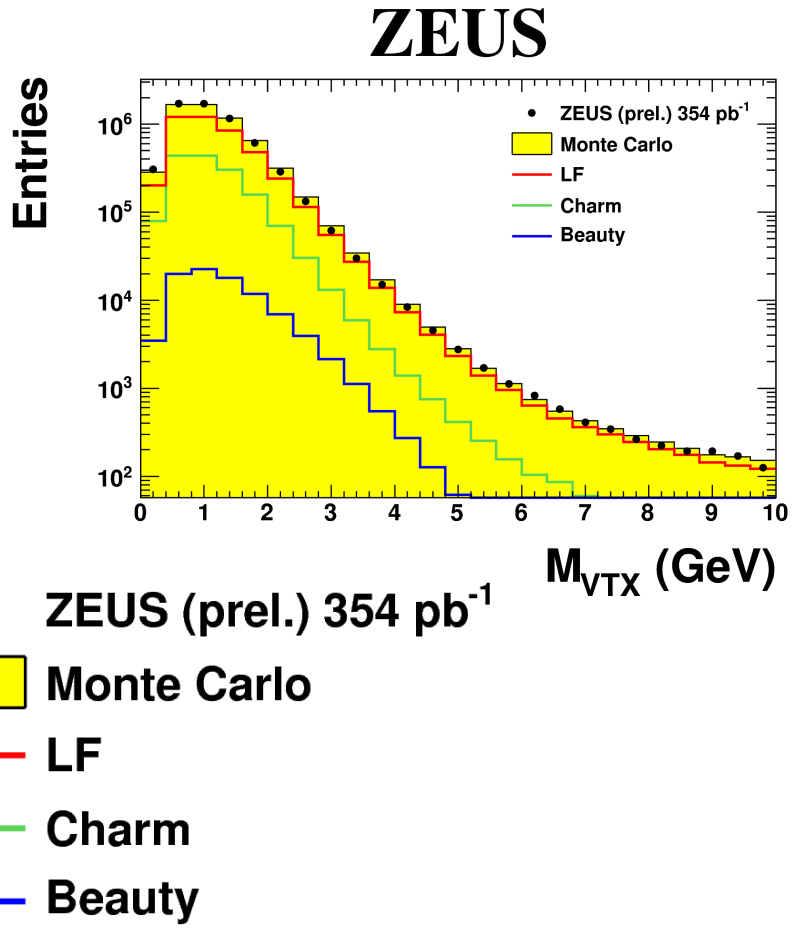



BOTTOM MICRO VERTEX DETECTOR

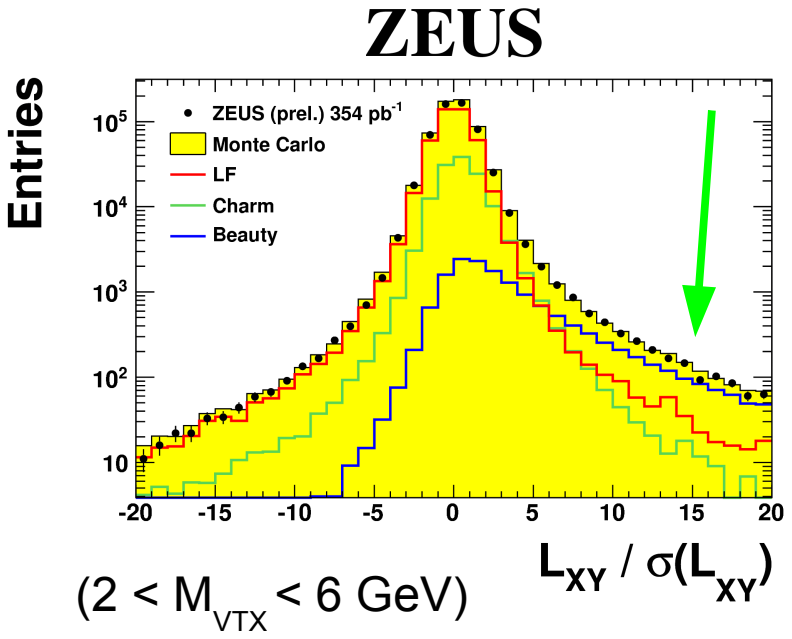
Discriminating variables

Discriminating variables:

- Vertex mass



- Significance $S = L_{XY}/\sigma(L_{XY})$



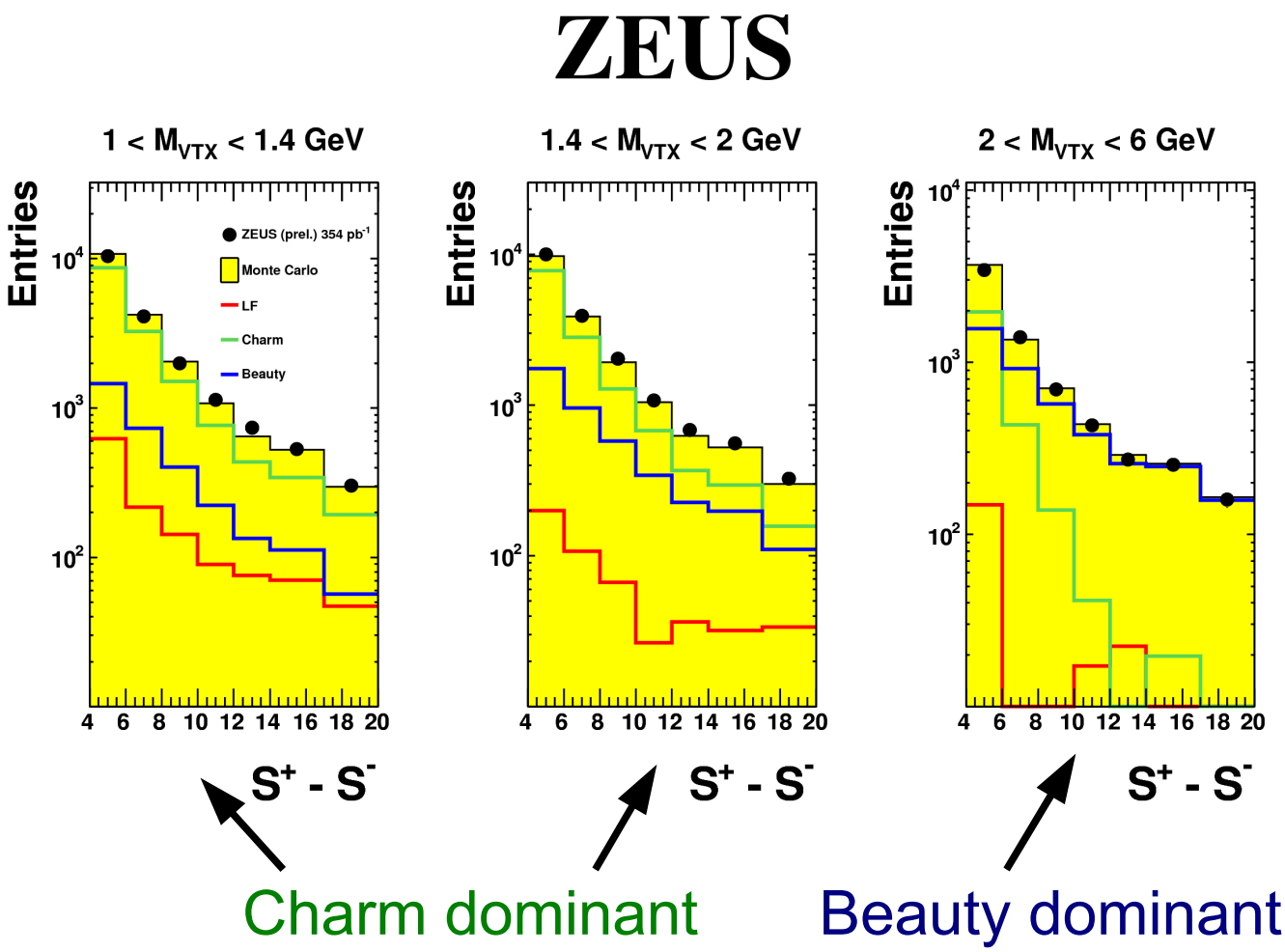
$(2 < M_{VTX} < 6$ GeV)

→ Beauty dominant at high mass and high significance

Beauty extraction

- The beauty fraction is extracted using a fit to the mirrored significance in bins of the vertex mass using MC templates

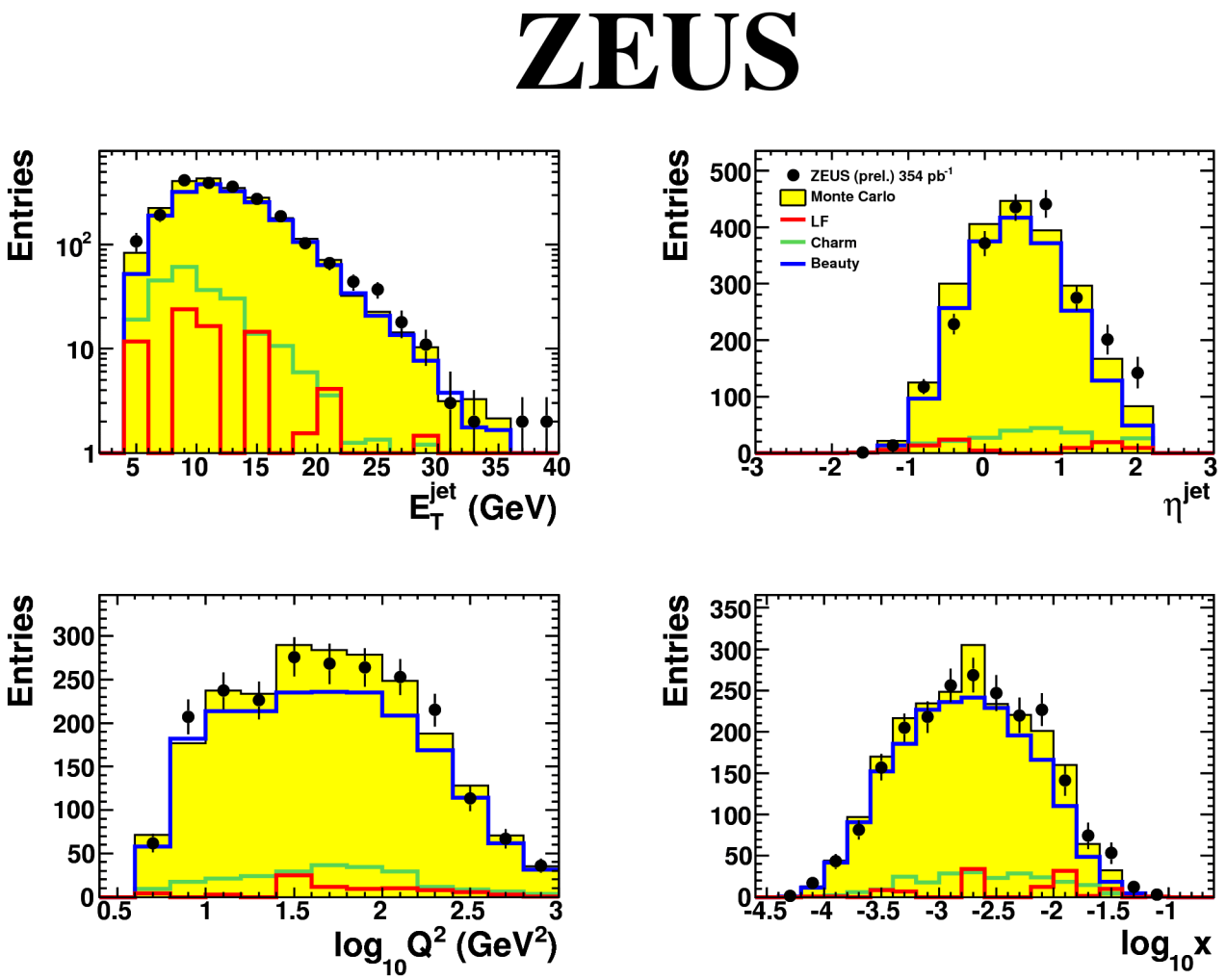
- The overall normalisation is fixed using the unmirrored distributions



Control plots in the beauty enriched region

It is possible to obtain an almost pure beauty sample:

- $M_{VTX} > 2$ GeV
- $S^{+} - S^{-} > 8$



Cross sections: E_T^{jet} and η^{jet}

- **Kinematic range:**

$5 < Q^2 < 1000\ \text{GeV}^2$

$0.02 < y < 0.7$

$E_T^{jet,lab} > 5\ \text{GeV}$

$-1.6 < \eta^{jet} < 2.2$

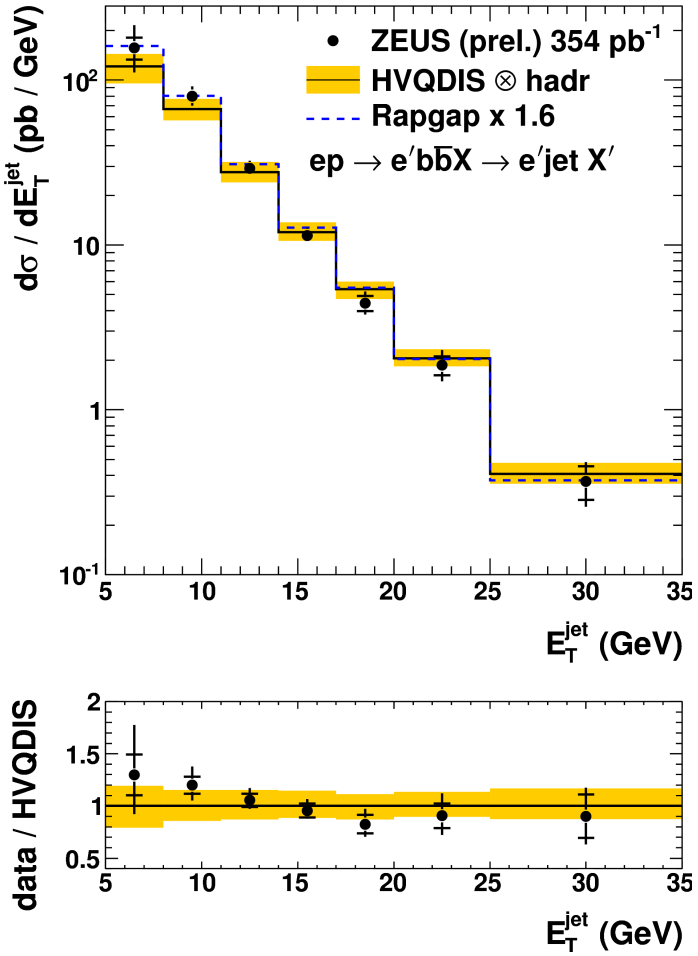
- **Data sample:**

354 pb^{-1}

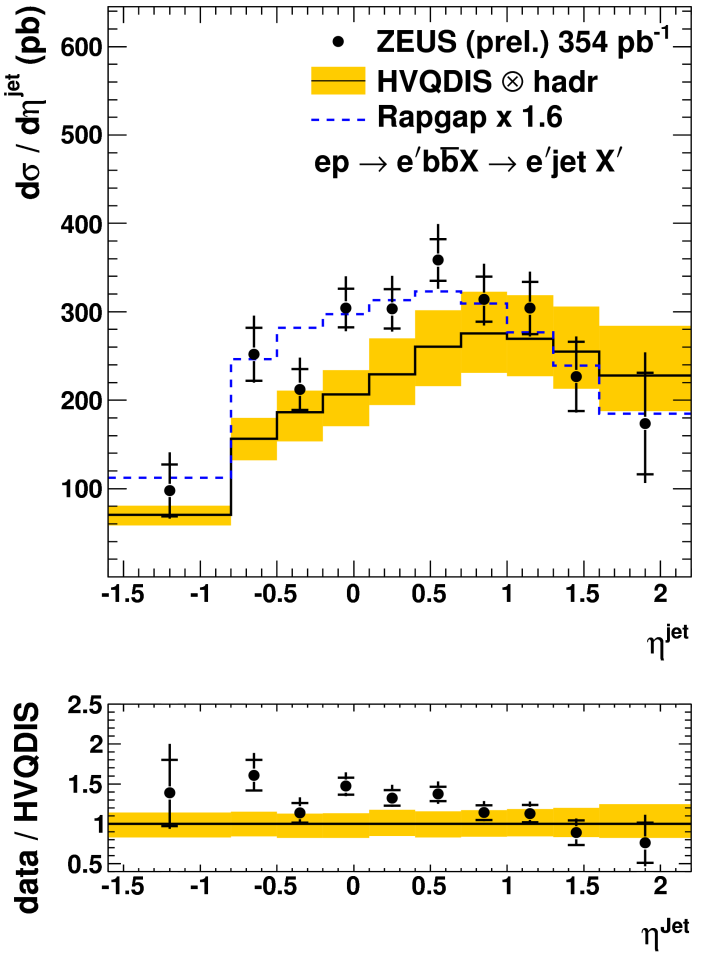
HERA II

(2004 – 2007)

ZEUS

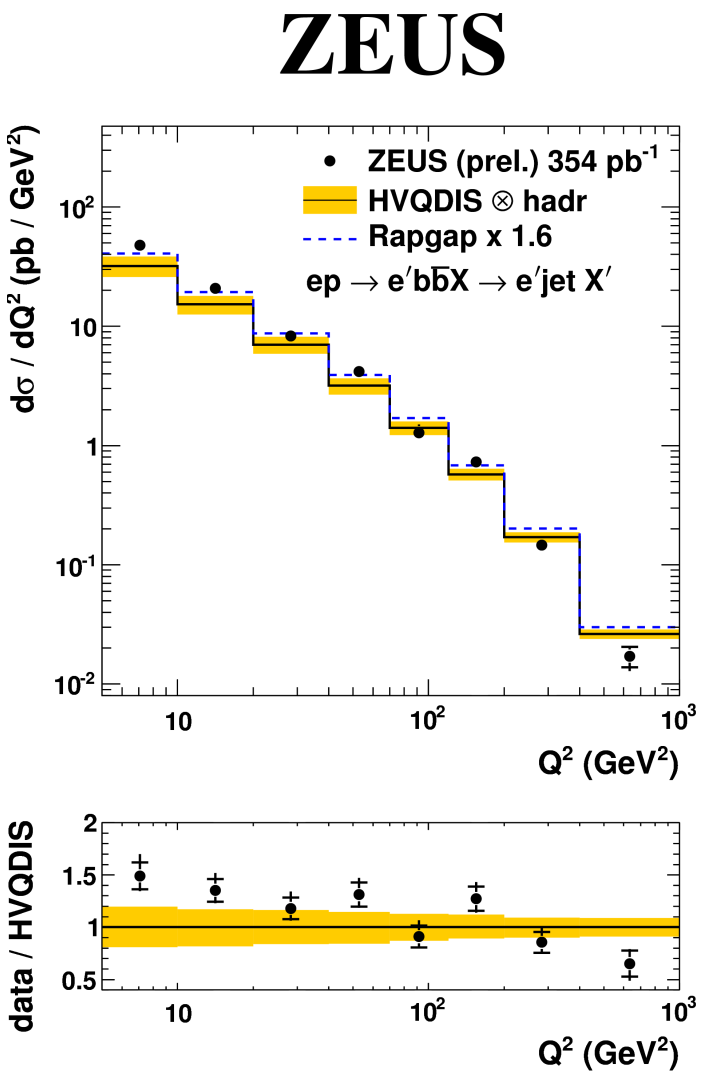


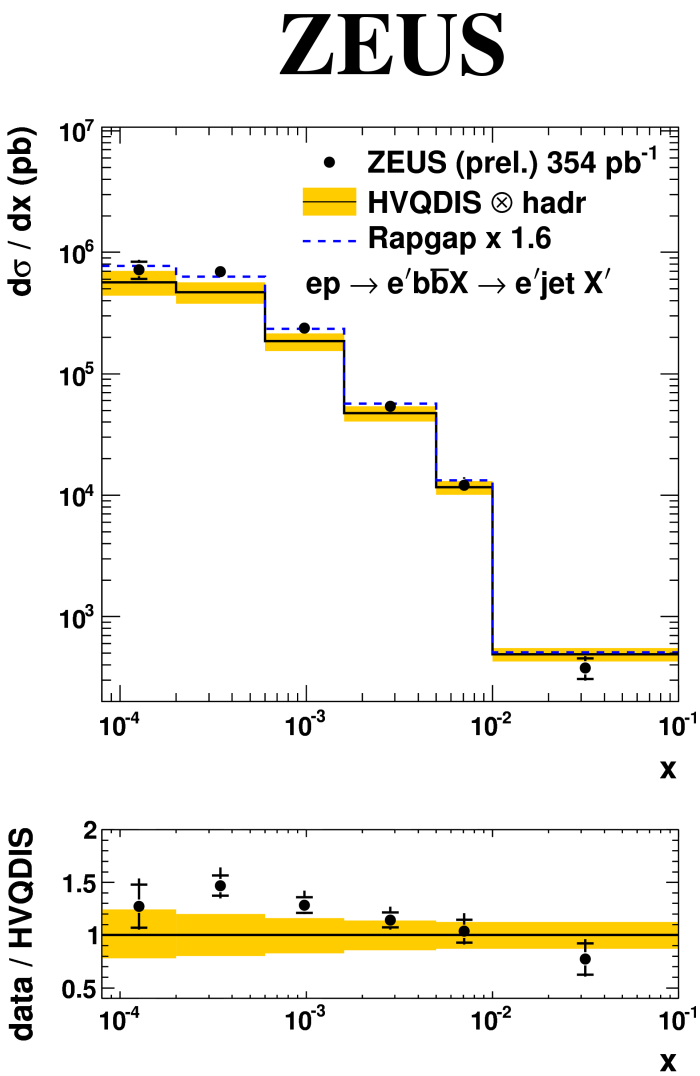
ZEUS



Cross sections: Q^2 and x

- The shapes of the data are described by HVQDIS and the Rapgap MC program
- The data are typically 20-30% above the HVQDIS NLO QCD prediction

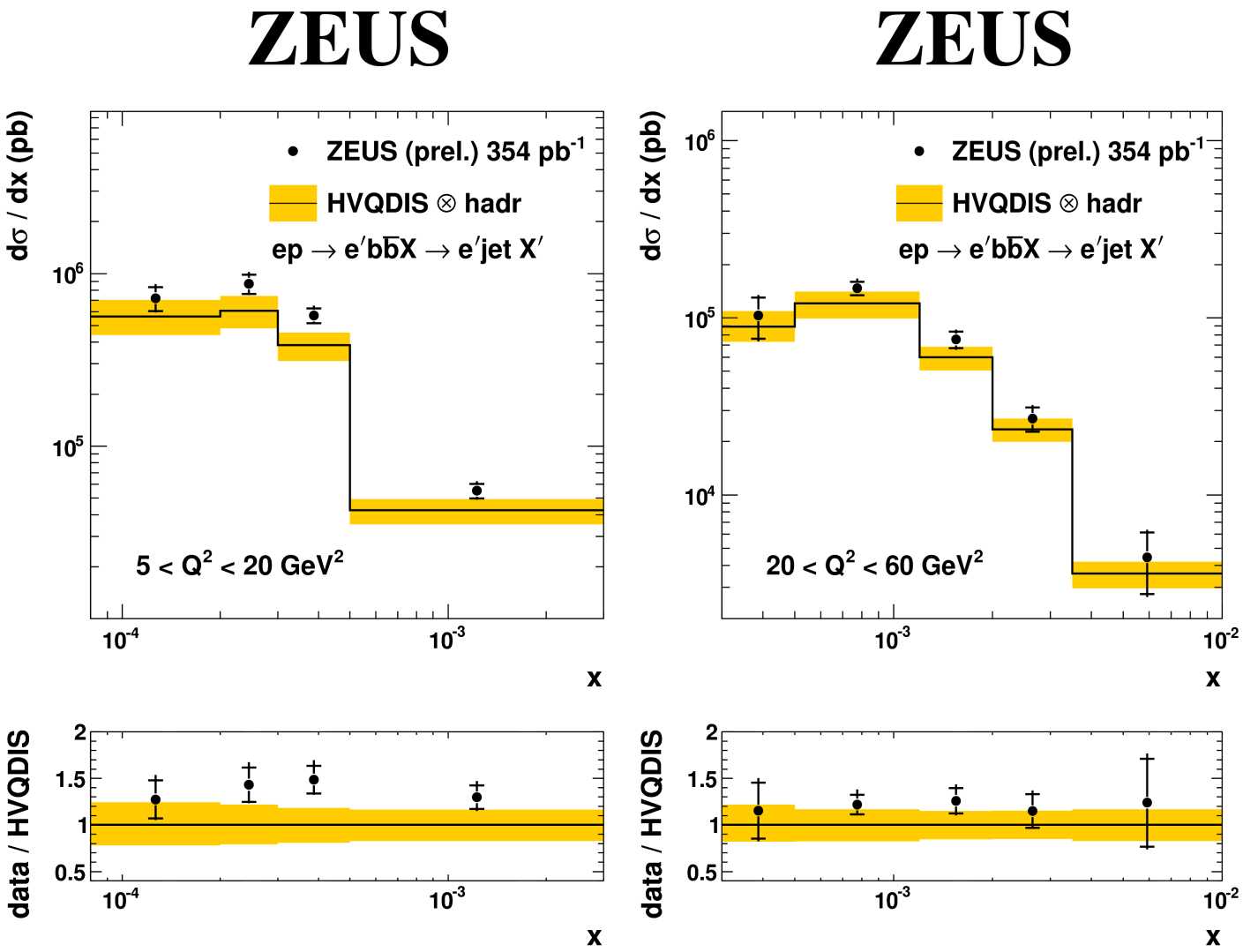




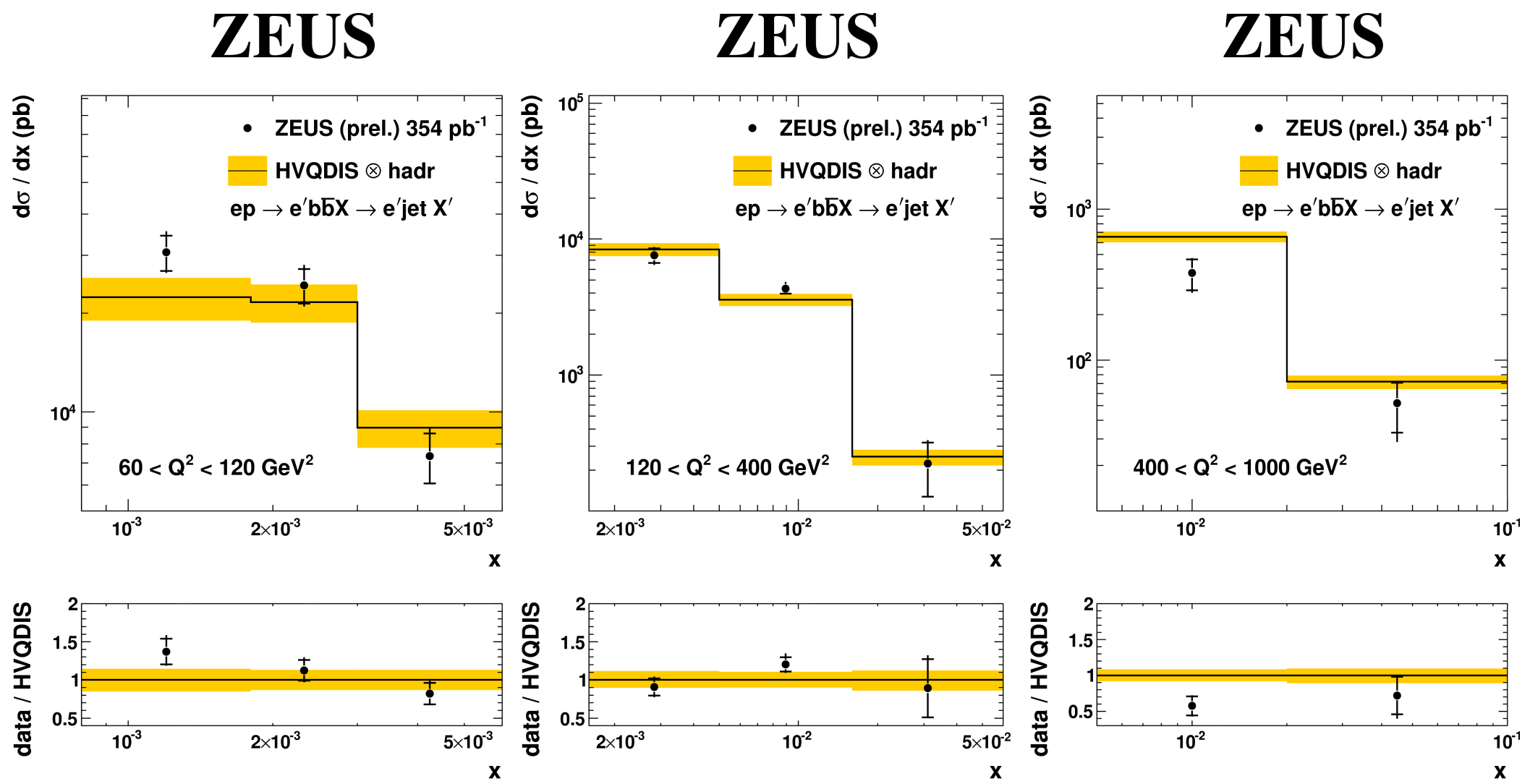
Towards $F_2^{b\bar{b}}$: dσ/dx in bins of Q^2

Extraction of $F_2^{b\bar{b}}$ imminent

→ Precision will improve dramatically compared to HERA I



dσ/dx in bins of Q^2



Summary and outlook

- Beauty production has been measured using events with a jet and a muon and using secondary vertices associated to jets

- Single and double differential cross sections are in reasonable agreement with predictions from HVQDIS

- $F_2^{b\bar{b}}$ was extracted for in the jet+muon analysis and is in agreement with previous measurements

- The precision on $F_2^{b\bar{b}}$ will improve using the secondary vertex measurement

pQCD Treatment of (charm and) beauty production in DIS

Massive, FFNS:

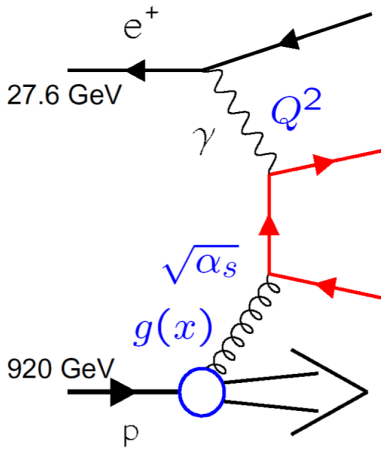
c and b produced dynamically
(not part of proton or photon)

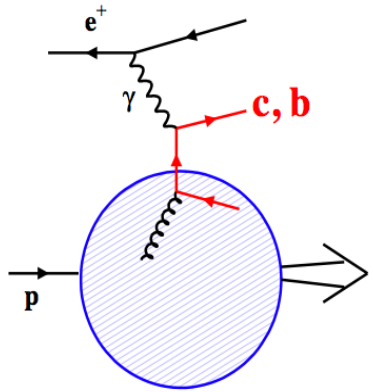
- c, b massive
- Neglects $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid at threshold

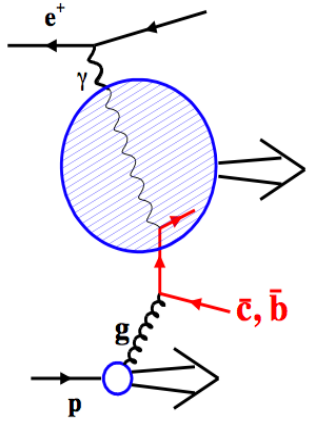
Massless, ZM-VFNS:

c and b massless partons in proton and photon

- c, b massless
- Resums $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid for $\mu^2 >> m^2$







Variable Flavour Number Scheme, (GM)-VFNS:

Interpolates / matches between both approaches

- Massive at low Q^2, massless at high Q^2

HVQDIS parameters

- FFNS version of ZEUS-S Fit (varied within errors)
- m_b = 4.75 GeV (4.5 – 5.0 GeV)
- $\mu_R = ½ (m_b^2 + p_T^2 + Q^2)^{½}$ (changed by 0.5 and 2)
- $\mu_F = ½ (m_b^2 + p_T^2 + Q^2)^{½}$ (changed by 0.5 and 2)
- Hadronisation corrections obtained using RAPGAP

Only HERA I analysis:

- Peterson fragmentation with $\varepsilon = 0.0035$
- Semileptonic decay spectrum for beauty hadrons taken from JETSET