Parton density functions and jet cross-sections

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Introduction

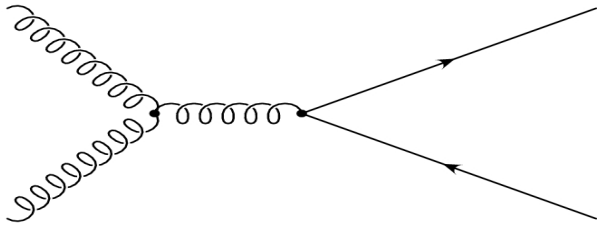
- Why study PDFs?
  - allows predictions to be made for hadron-collider processes
- Use data from finished/existing experiments as input
  - HERA experiments are ideal PDF probes
  - HERA-II data (700 pb^{-1} collected by 2007) expected to have a large impact on PDFs
- Knowledge of PDFs important for predicting both signal and background event rates:

$$\sigma(Q^2) = \sum_{i,j=1}^{n_f} \int_{x_1=0}^{1} \int_{x_2=0}^{1} \hat{\sigma}_{1,2\to X}(p_1, p_2, \alpha_s(\mu^2), Q^2/\mu^2) f_1^i(x_1, Q^2) f_2^j(x_2, Q^2) dx_1 dx_2$$

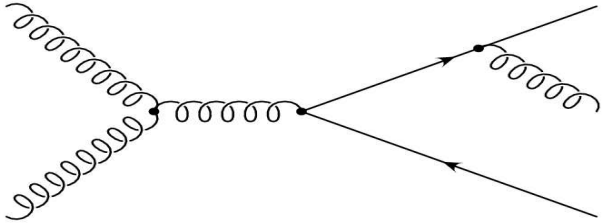
hadronic x-section **partonic x-section** **PDFs for incoming hadrons**

Background

- Use a next-to-leading-order program* to generate dijet and trijet events at LHC energies:



LO example process (2->2)



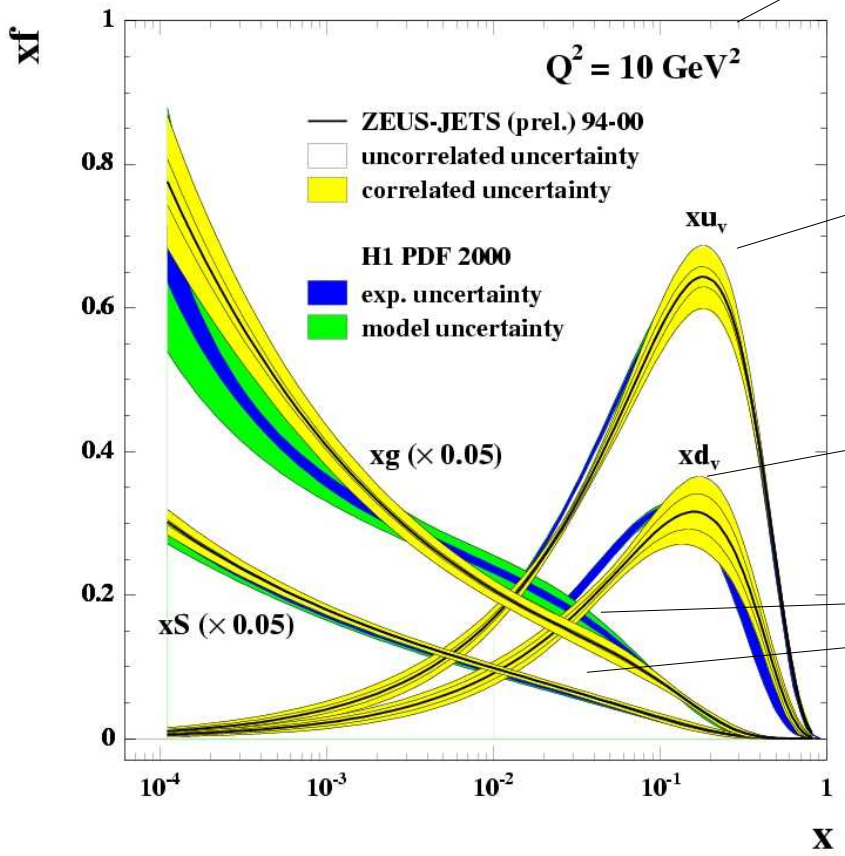
NLO example process (2->3)

- Use PDFs based on data taken at ZEUS experiment as input to program
  - 11-parameter fit: $xf(x) = p_{1f}x^{p2f}(1-x)^{p3f}(1+p_{5f}x)$
  - Certain constraints - e.g. number and momentum sum rules - reduce 16 parameters to 11
- Analyse contributions to x-section uncertainty from various sources

*S. Frixione and G. Ridolfi, Nucl. Phys. B507(97)315

Example of a proton PDF:

***xf(x)* = expectation value of parton's momentum fraction *x* (for parton of flavour *f*)**



behaviour of PDF depends strongly on energy scale, *Q*

contribution from *u* valence quarks

contribution from *d* valence quarks

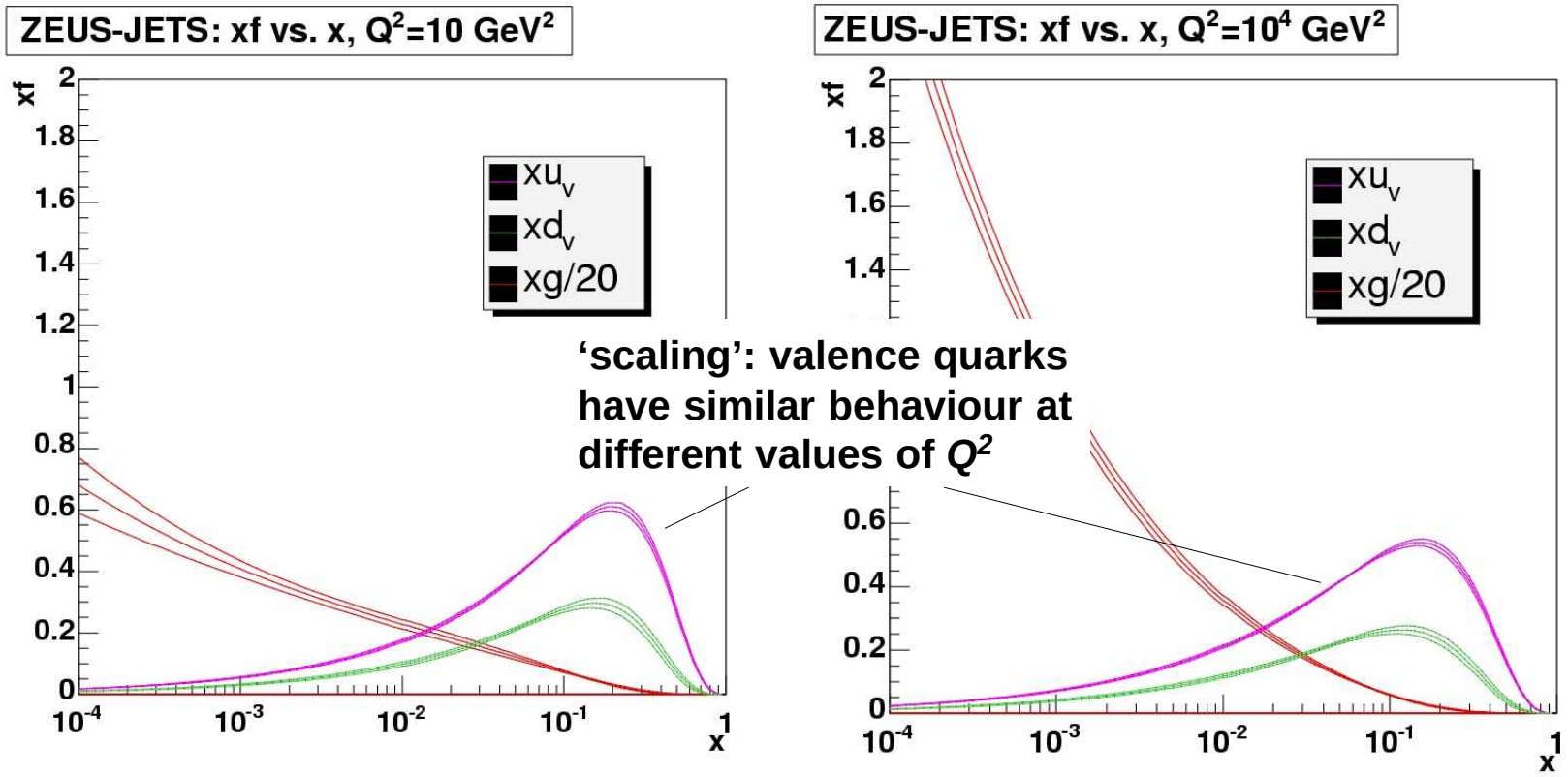
contributions from sea quarks and gluons (scaled down)

x = parton's momentum/proton's momentum

Example results

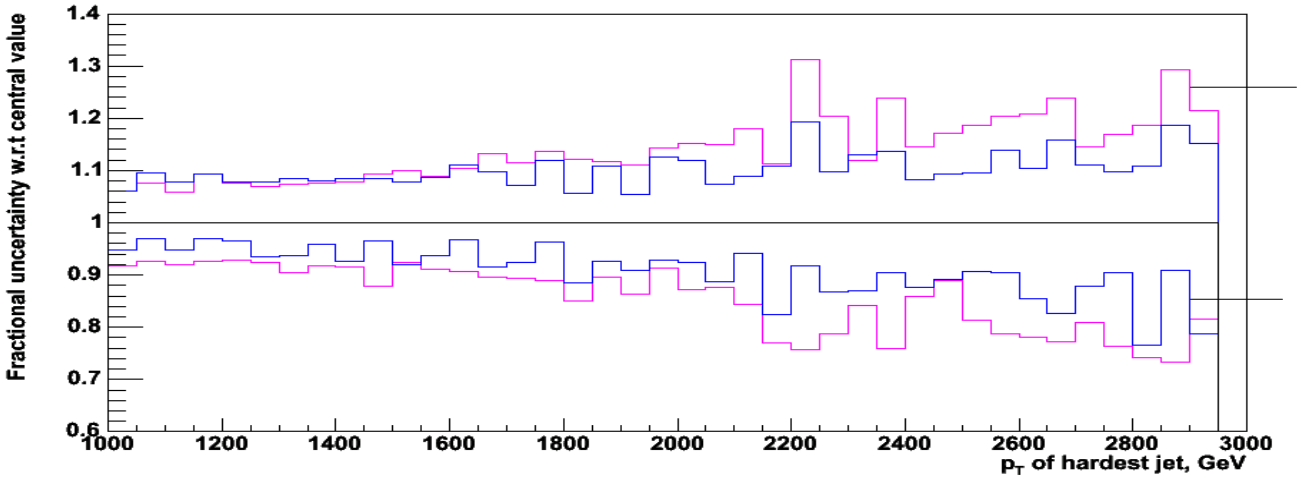
- Began by generating my own PDF sets based on ZEUS data, as published sets didn't go to high enough Q^2:

  (subsequently resolved)



Example results

- New PDF set released last year: ZEUS-JETS 2005, based solely on ZEUS data
  - **includes jet data which helps reduce uncertainty on gluon w.r.t older ZEUS fits**
  - **is available with Q^2 values of up to 2 x 10^8 GeV^2**
  - **comes in 23 member sets – a central value and up/down 'excursions' along 11 eigenvectors of an uncertainty matrix**

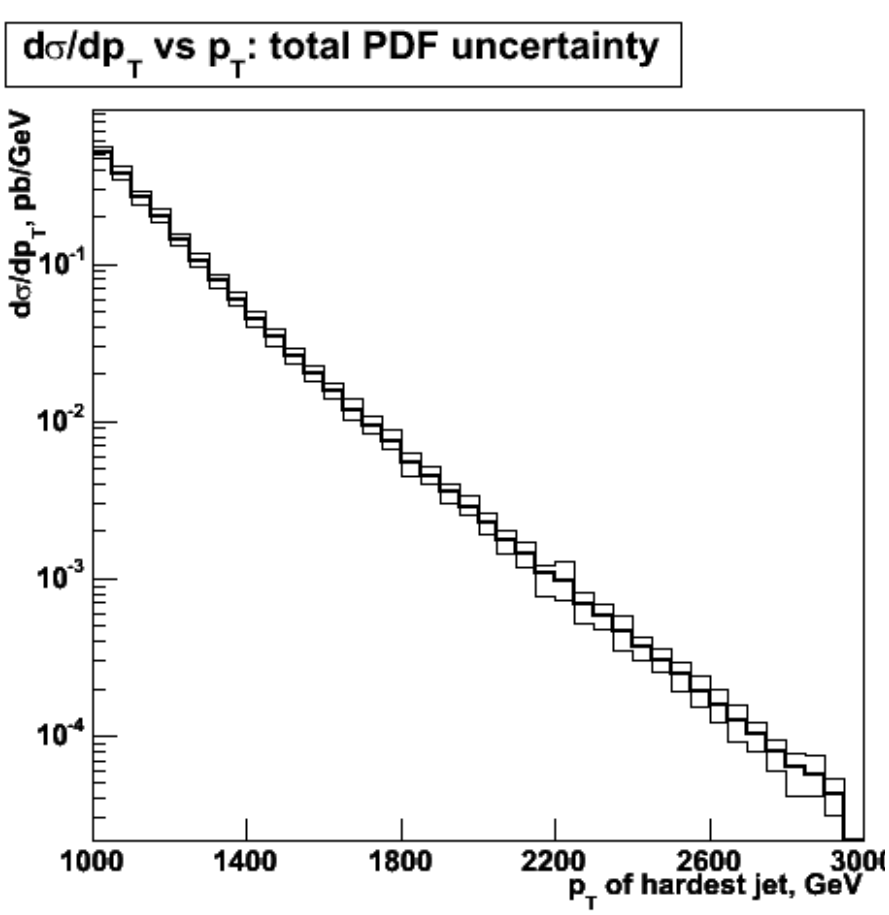


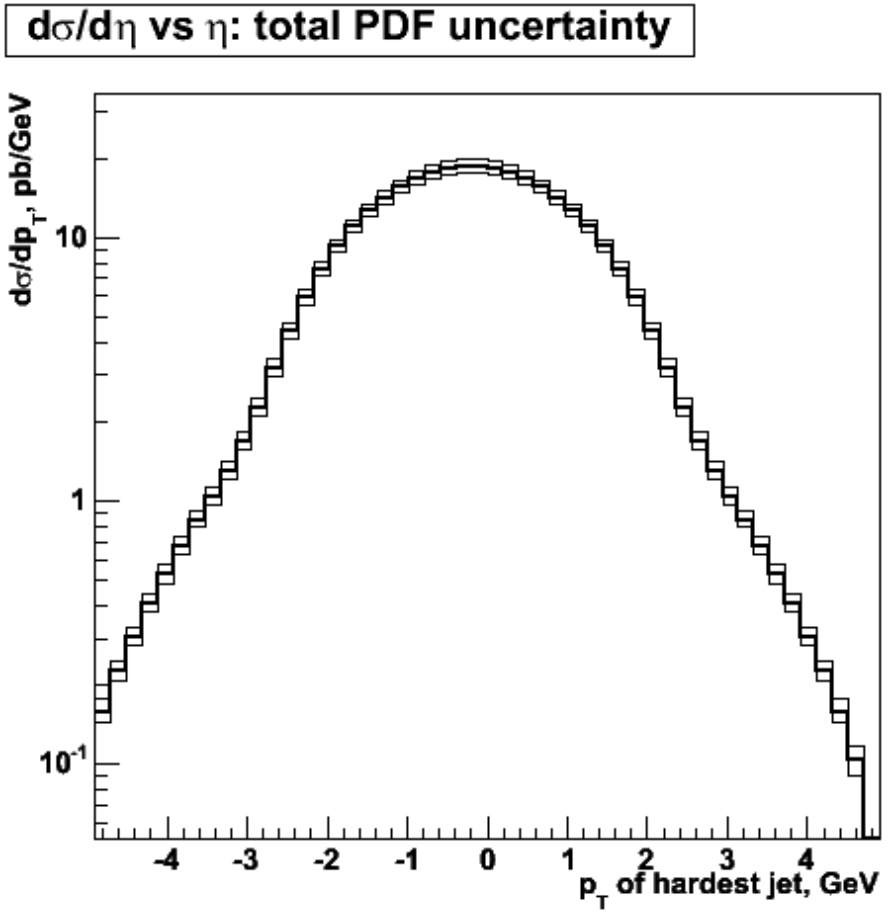
total fractional error on $d\sigma/dp_T$

error contribution due to uncertainty on gluon PDF

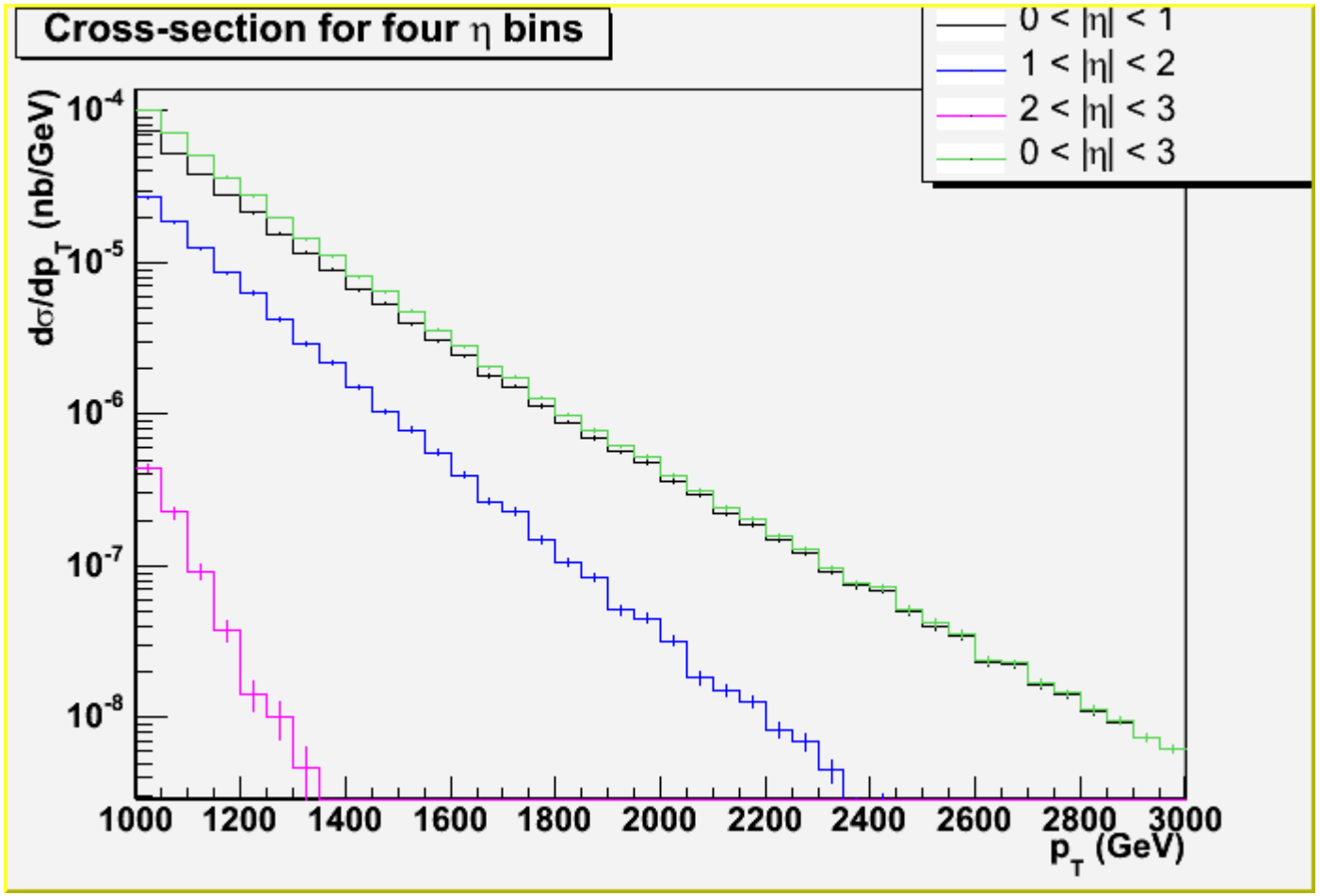
Total error due to PDF uncertainties: errors from each eigenvector (see below) added in quadrature

($d\sigma/dp_T$ integrated over $-2 < \eta < 2$; $d\sigma/d\eta$ integrated over $0 < p_T < 3{,}000$ GeV)

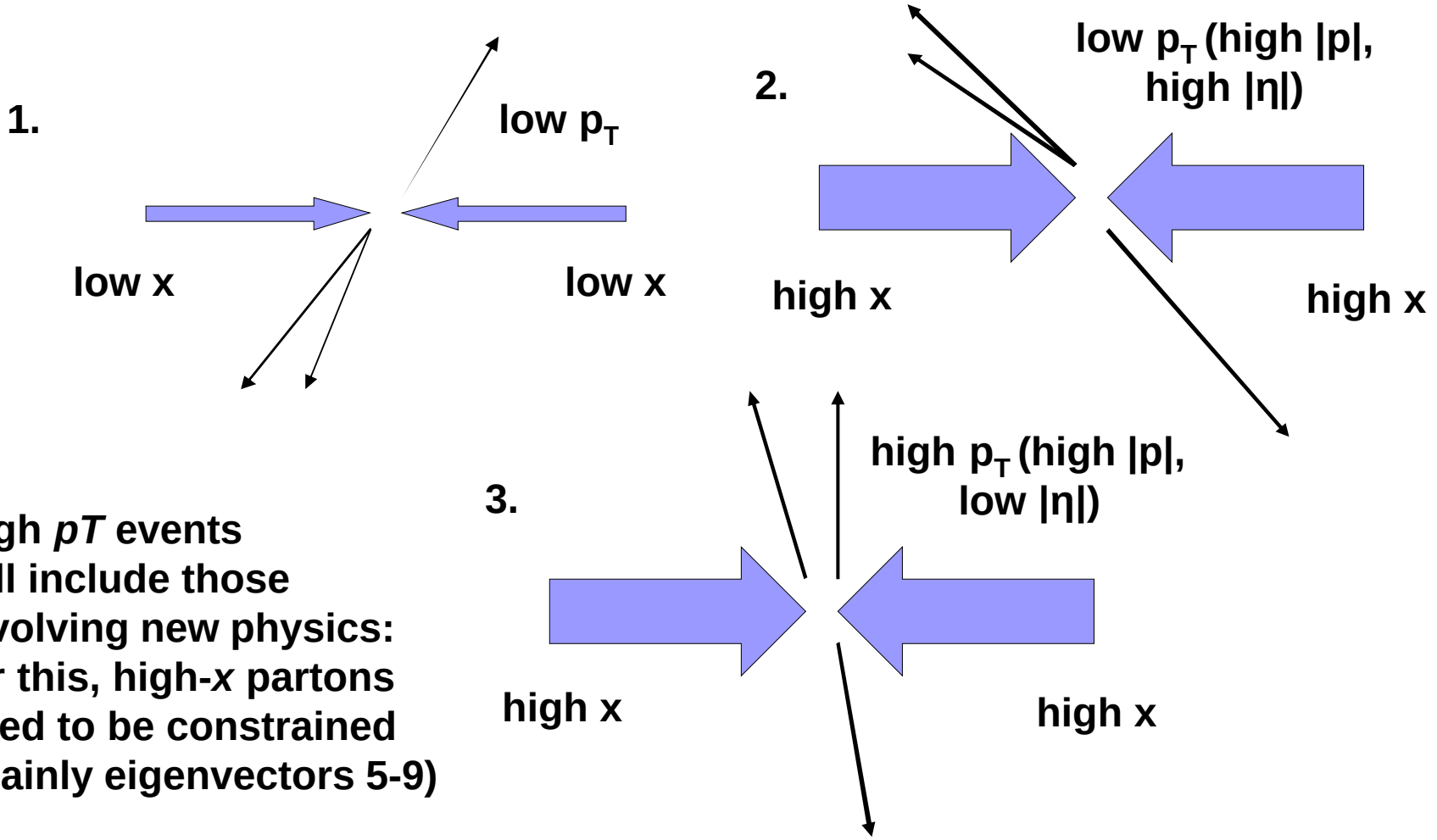




$d\sigma/dp_T$ spectra in different η regions; sensitive to different regimes of x and Q^2

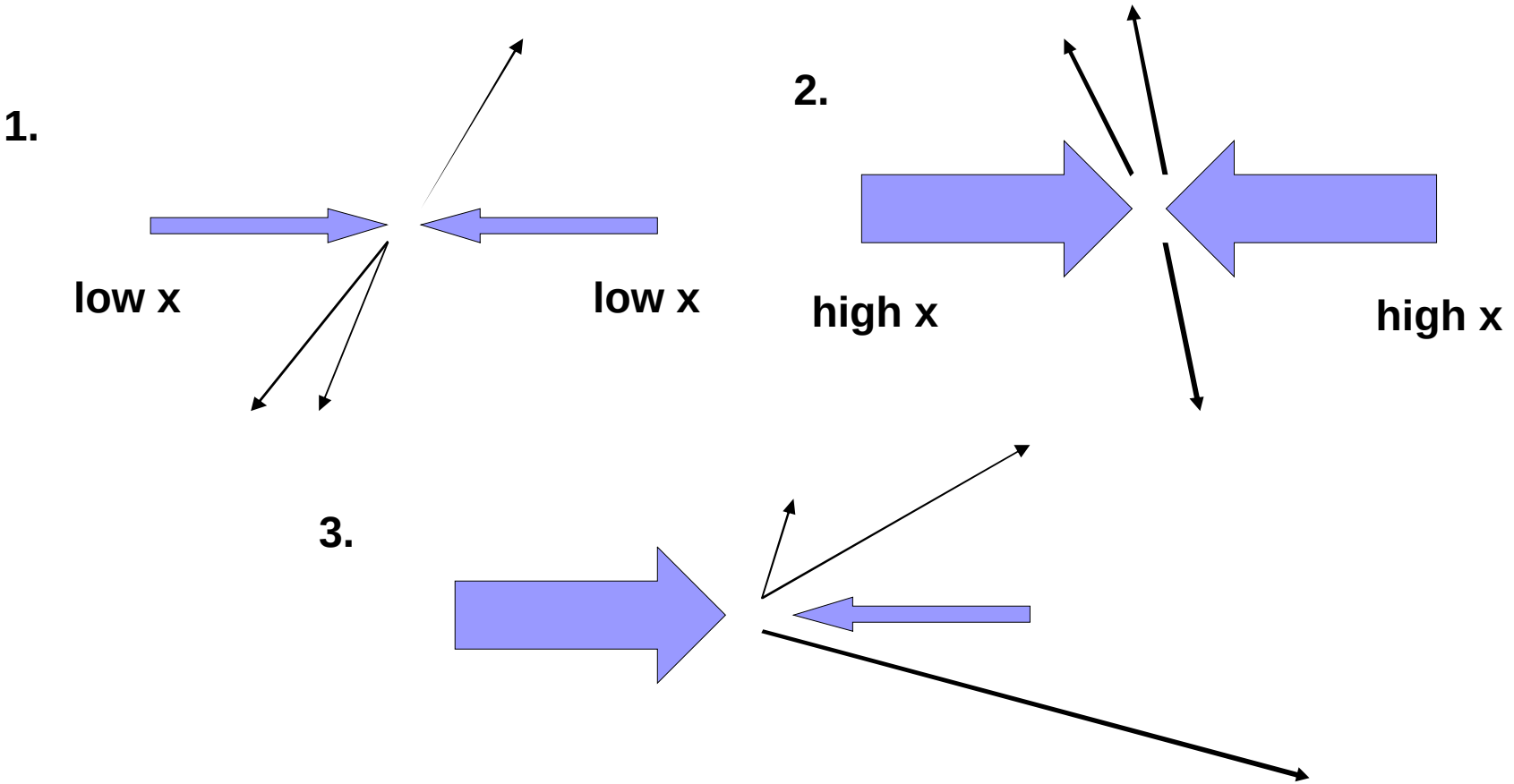


Need jets with high p_T to probe high-*x* partons:



High *pT* events will include those involving new physics: for this, high-*x* partons need to be constrained (mainly eigenvectors 5-9)

Jets are boosted in direction of parton with higher x:



Case 3 – jets with high |η| of same sign – can be used to probe low and high x

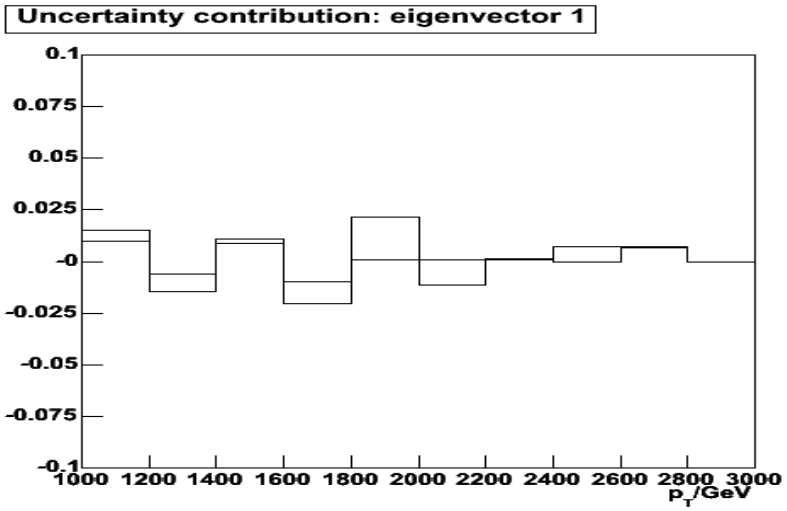
The Hessian uncertainty matrix: parameters -> eigenvectors. Table showing approximate correlation between PDF parameters (across) with eigenvectors (down): signs are ignored and values given to nearest quarter. Blank cells have entries < 1/4.

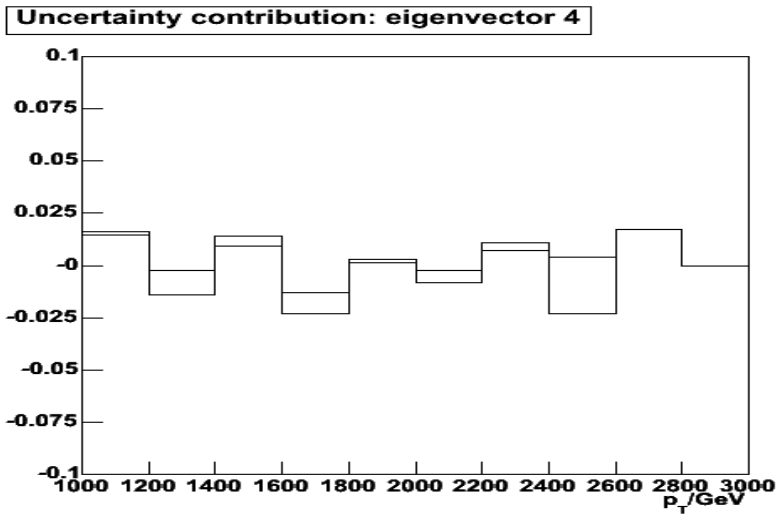
EV:	p2u	p3u	p5u	p3d	p5d	p1s	p2s	p3s	p2g	p3g	p5g	parton/x-regime:
1							1		1/4			low-x s
2	1											low-x u
3									1			low-x g
4						1						total S
5		1										high-x u
6				1	1/4							high-x d
7		1/4	3/4					1/2		1/2		mid-x u; high-x S, g
8										1		high-x g
9			1/2		1/2			3/4				mid-x u, d; high-x S
10				1/4	3/4							mid-x d
11											1	mid-x g

Major sources of $d\sigma/dp_T$ uncertainty

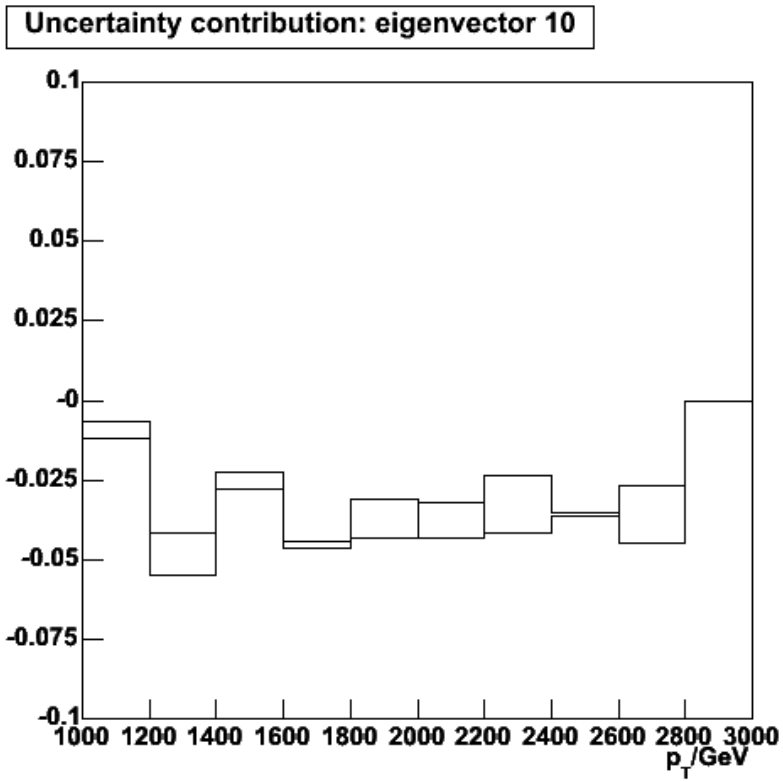
Major sources of $d\sigma/d\eta$ uncertainty

Tiny uncertainty contributions from EVs 1 and 4: sea quarks well constrained at low x



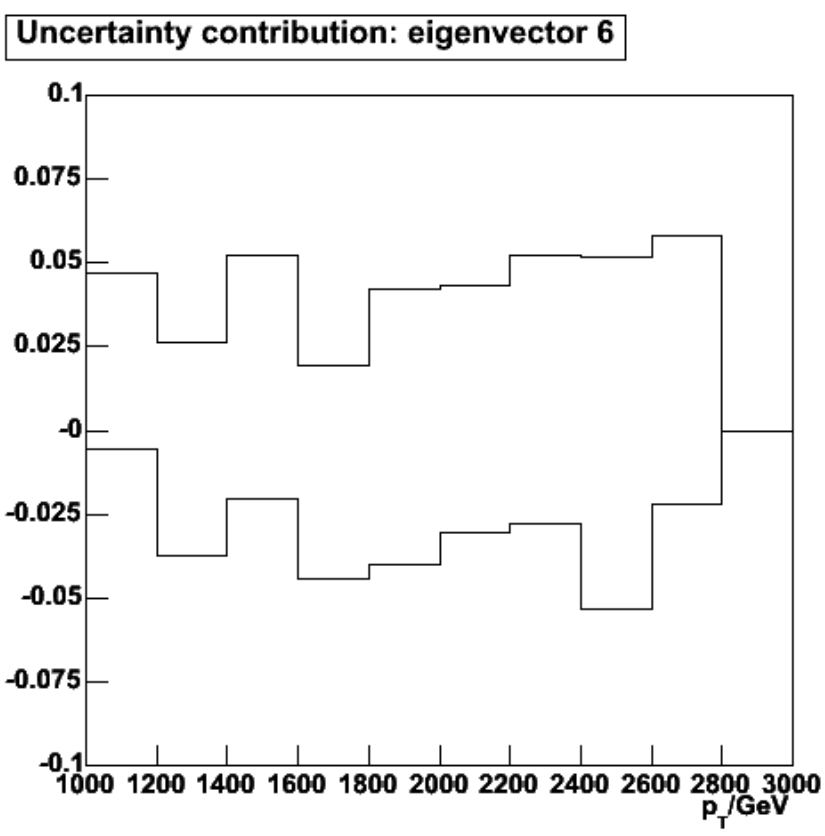


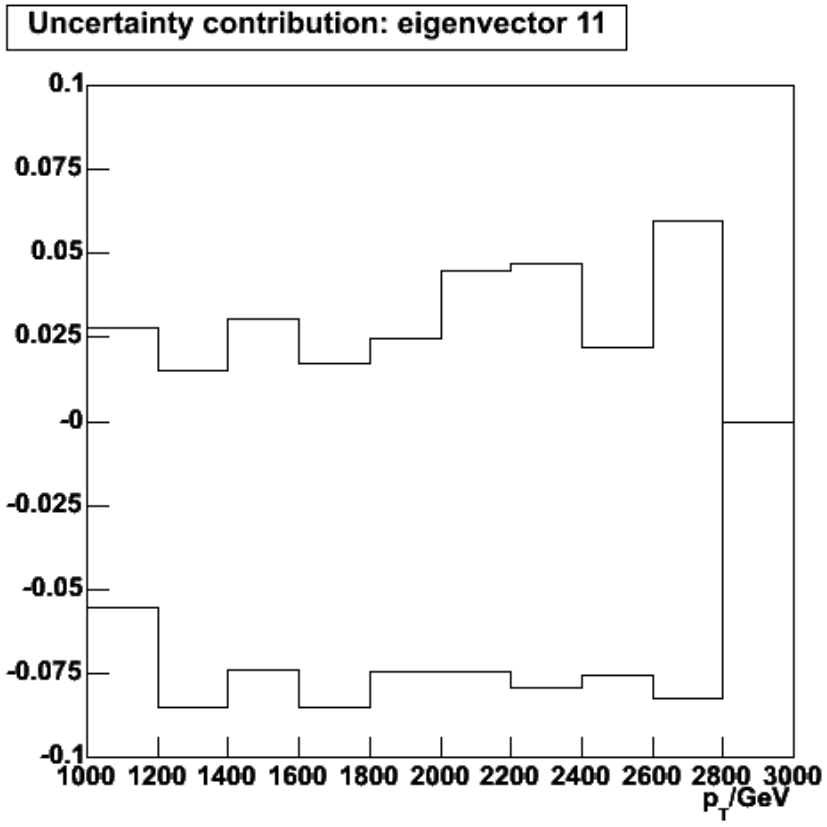
EV 10 is 'deficient': upper and lower error limits are both below central value (mid-x d_v) – same effect seen in other studies*



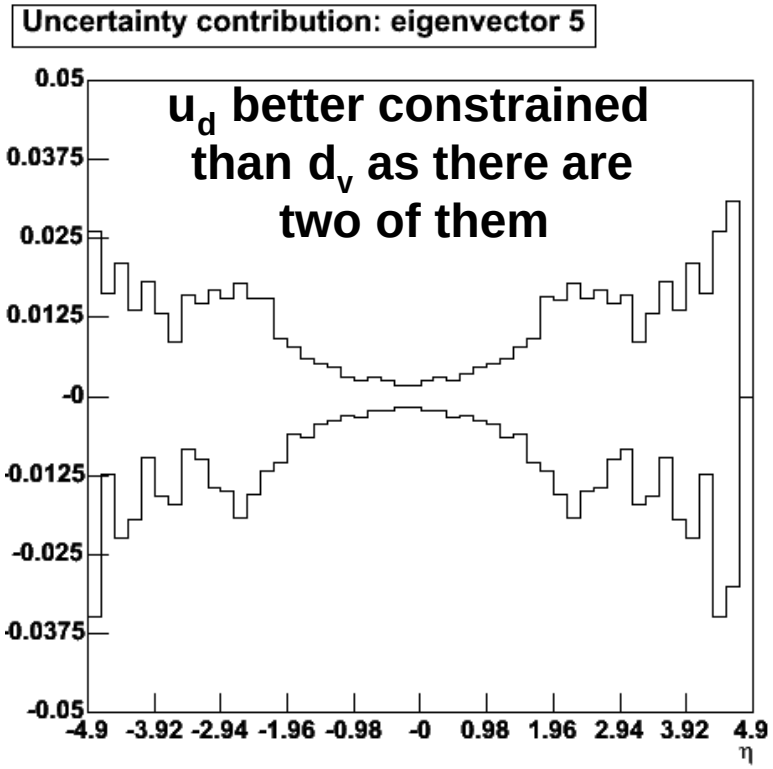
*C. Gwenlan, 'Impact of future HERA data on PDF uncertainties…', ATLAS-SM WG, July 14th 2006

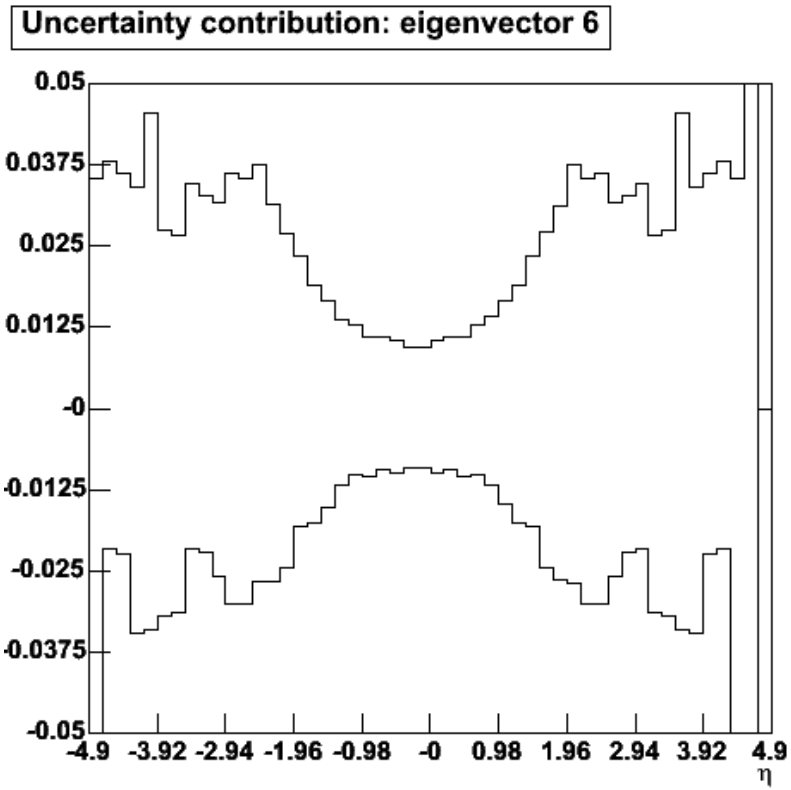
Largest contributions from EVs 6 (high-x d_v: less well constrained than high-x u_v) and 11 (high-x g: explodes as x->0)



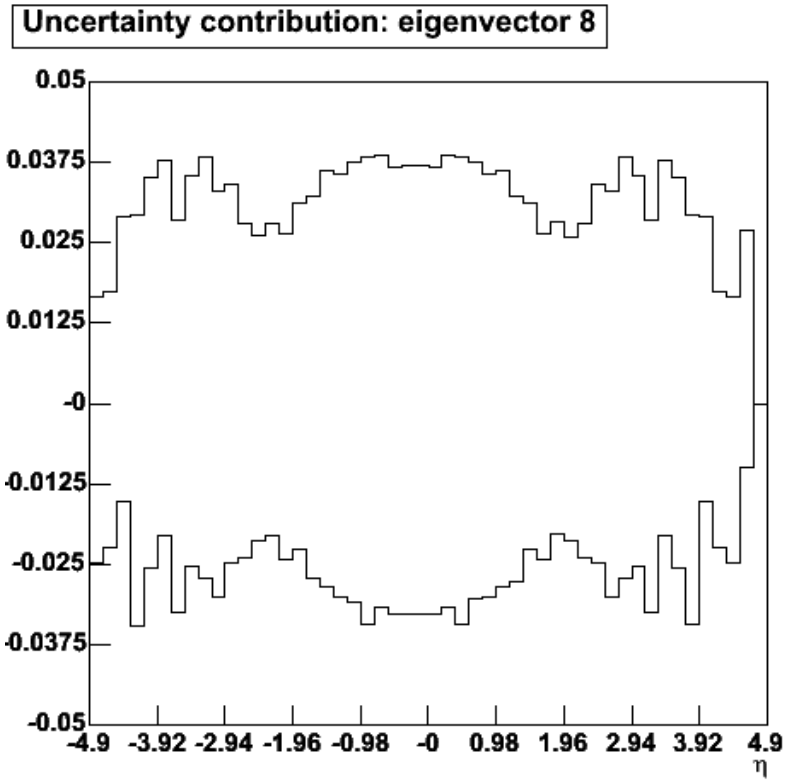


EVs 5 and 6 – high-x u_v and d_v – errors increase with |η| (valence quarks important in glancing collisions, where exchanged gluon has low q^2)

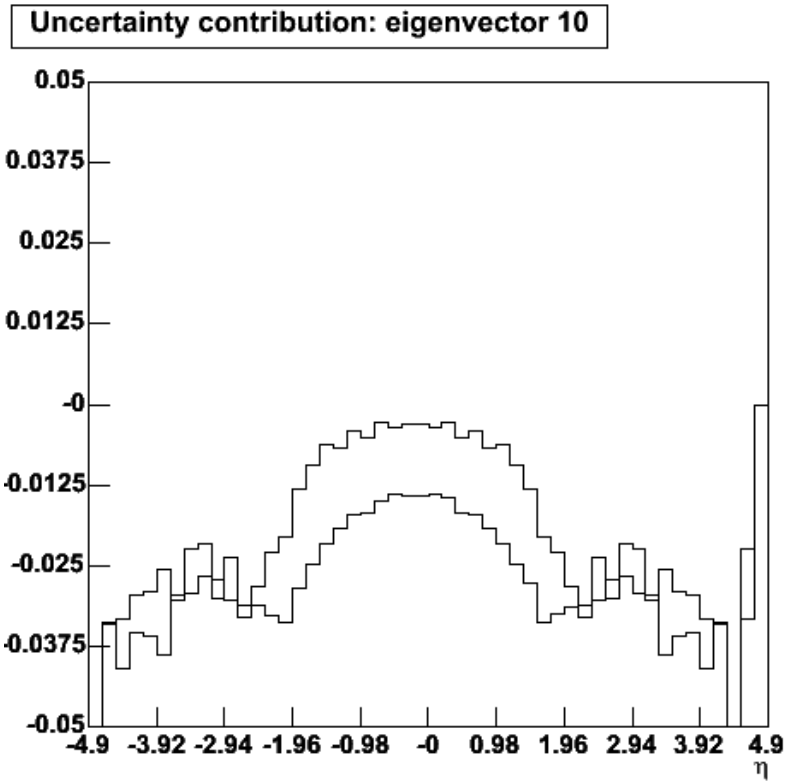




EV8: high-x gluon major contributor to uncertainty over wide range in η



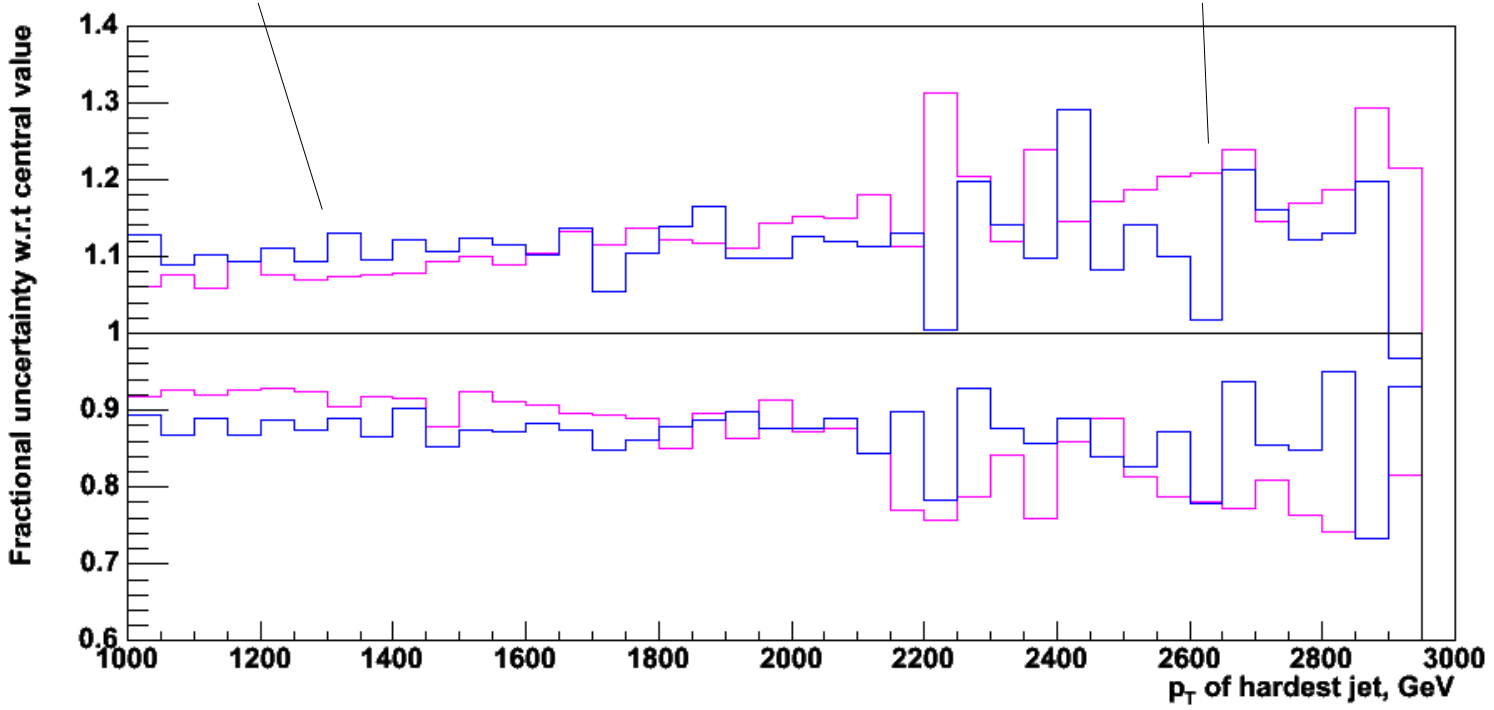
EV10: mid-x d_v is 'deficient' in ZEUS-JETS PDF (lower and upper bounds are below central value), as with $d\sigma/d\eta$ spectrum



Uncertainty in energy scales (renorm. and factor.) create other uncertainties in cross-section:

energy scale uncertainty dominates at low p_T (~ 1.8 TeV)

PDF uncertainty more important at very high p_T



Summary

- ZEUS is an ideal probe of proton structure
- Understanding of proton PDF important in predicting both backgrounds and discovery processes at LHC
- Different parton flavours/x-regimes have different characteristic uncertainties
  - correspond to different kinematic regimes
- Uncertainties in QCD energy scales has comparable impact to PDF uncertainties

Work in progress:

- Develop analysis algorithm within Athena (the ATLAS simulation/analysis framework) to continue PDF studies, for
  - QCD jets to make comparison with Frixione
  - New physics processes to assess impact of PDFs on discovery potential
- Begin looking at impact on ‘PDF-ology’ once ATLAS itself starts taking data