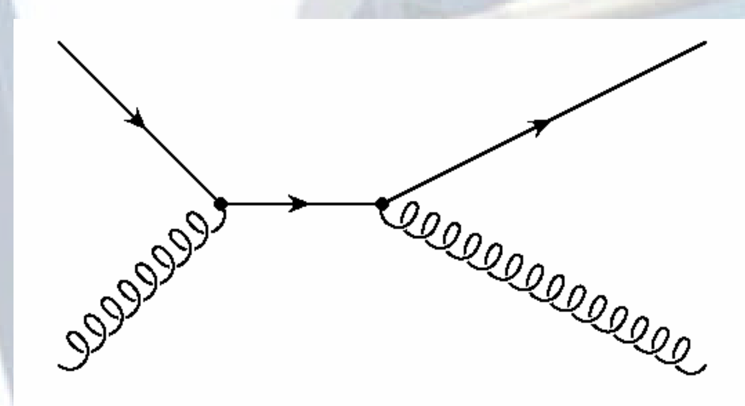
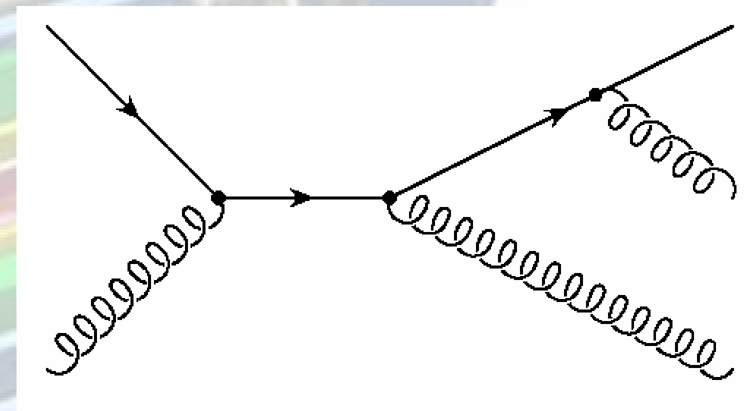
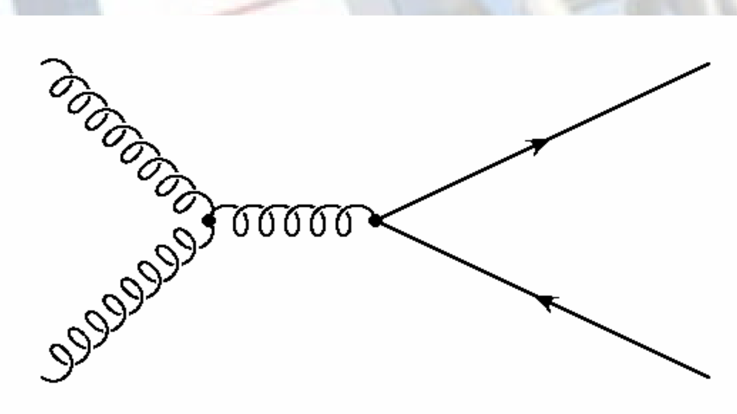
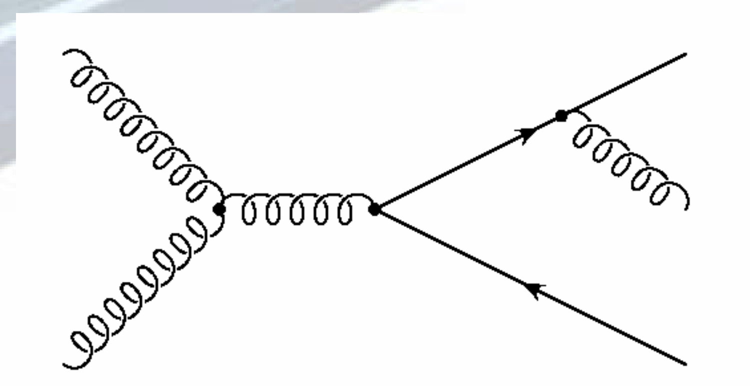
FIRST-YEAR TALK: NLO CROSS-SECTION PREDICTIONS FOR ATLAS/LHC USING ZEUS PDFS

Oliver Harris









CONTENTS

- Introduction: Physics at the LHC - motivation
- LO and NLO processes
- PDFs and their significance
- The HERA connection
- Results
- Conclusions
- Plans for future work

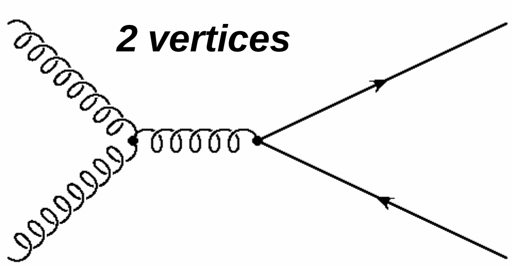
LHC PHYSICS

- LHC will collide proton bunches on proton bunches at $\sqrt{s}$ = 14 TeV
- Many different interaction processes can occur
- ATLAS will be a large, general-purpose detector to look for as many new signature as possible – complemented by CMS experiment
- New physics (beyond Standard Model) processes are expected to occur:
  - Higgs boson(s),
  - supersymmetric particles,
  - leptoquarks, excited Kaluza-Klein states, and ‘who-knows-what-else’
  - also precise measurements of CP-violation in the b-quark sector (LHCb experiment)

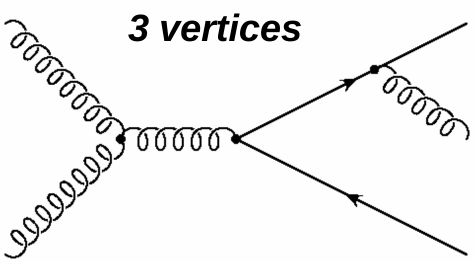
LO and NLO processes

- QCD processes occur with allowed vertices qqg and ggg
- Leading-order processes involve two vertices ∴ overall factor of a_s^2 i.e. one internal (virtual) propagator, and a general 2 → 2 event topology
- Next-to-leading order events are 2 → 3 or 3 → 2, i.e. an extra vertex, so an overall factor of a_s^3
- Frixione's and Ridolfi's code uses statistical integration method callesd VEGAS (cf. Monte Carlo – geddit?) to calculate cross-sections for both types of process, such as:

The LO processes gg ® qqbar



The NLO process gg ® gqqbar



PDFs

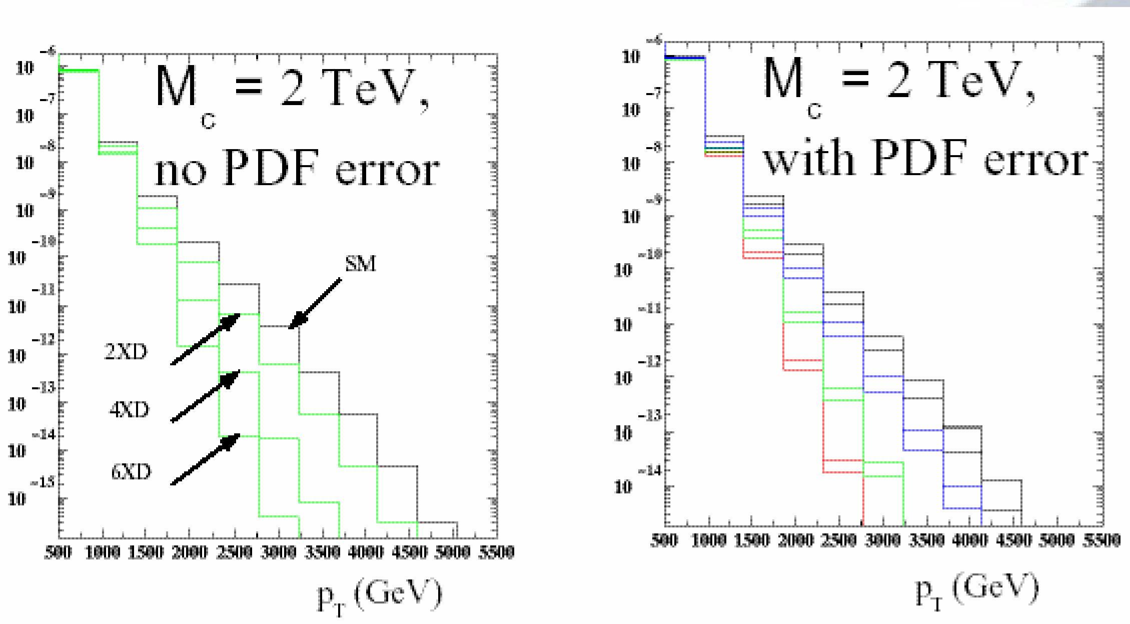
- Protons consist of partons, which come in three categories
  - valence (real) quarks: 2 u, 1 d
  - a sea of virtual quark-antiquark pairs: number of flavours present varies
  - gluons: quanta of QCD

- Structure functions F_1, F_2, F_3 are observables directly related to hadronic cross-sections; PDFs $f_i(x,Q^2)$ are elements of QCD model of hadron structure, and may be estimated from measurements of F.

- Partons of different sorts have momentum which adds up to total proton momentum; probability that a parton of flavour i has momentum fraction x is given by form factor $f_i(x,Q^2)$, such that

$$xf_i(x,Q^2) = \langle \text{ momentum of parton i } \rangle$$

in which Q^2 is the scale of the hard scatter.



Example given here, after Ferrag et al, showing -

left: predicted cross-sections for various new models (different numbers of extra dimensions, in this case) vs. SM prediction, and..

right: same plot with PDF errors – it can been seen that PDF errors make it impossible to distinguish between models below, say, p_t = 2000GeV – hence more precise PDFs essentially lower discovery threshold for new phenomena

HERA

- HERA is the world’s only hadron-lepton collider – leptons can be used to probe the internal structure of hadrons at high energies.
- We can use information taken in these experiments to create PDFs for protons and apply them to LHC physics.
- PDFs with errors are needed to constrain discovery potential for processes expected to occur at LHC: if process signature gives greater deviation from background then PDF error, process may be discovered
- PDF sets based on data taken with ZEUS are the first PDFs to feature combined systematic and statistical errors

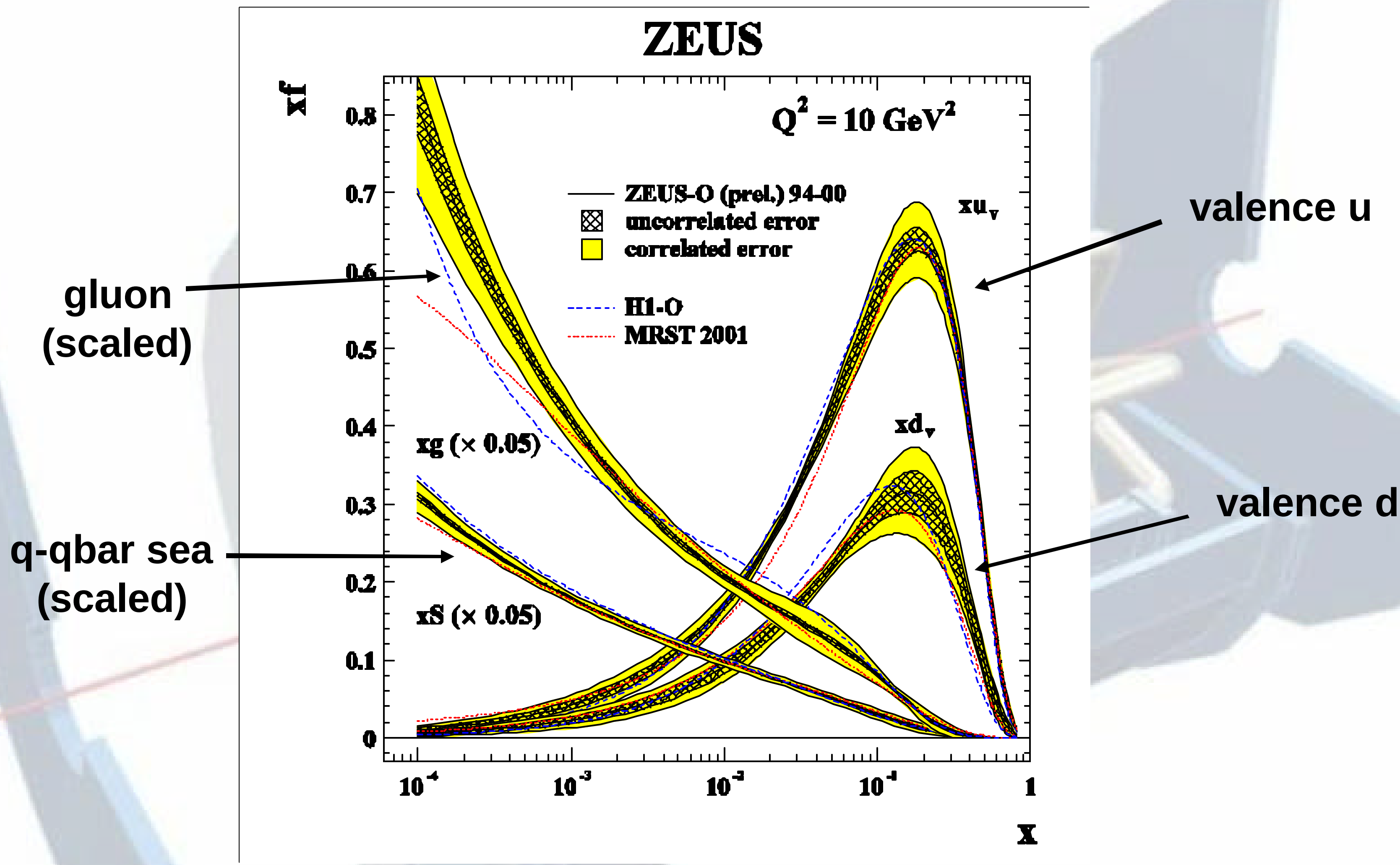
SIMULATED DATA

- Now we generate three plots of cross-section against p_t:
  - i) CTEQ5M PDF scheme (for reference),
  - ii) ZEUS PDF with all parton errors present,
  - iii) ZEUS PDF with gluon errors only.

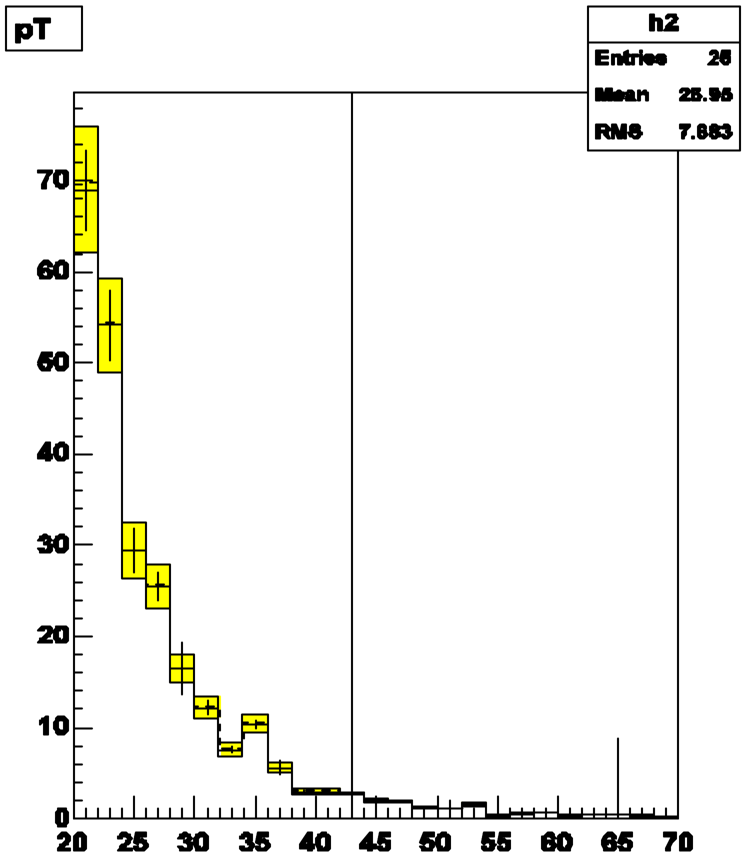
This is because gluons dominate the PDF at low-to-medium x, and errors on medium-x (and high-x) gluons are large, due to lack of data to constrain this region.

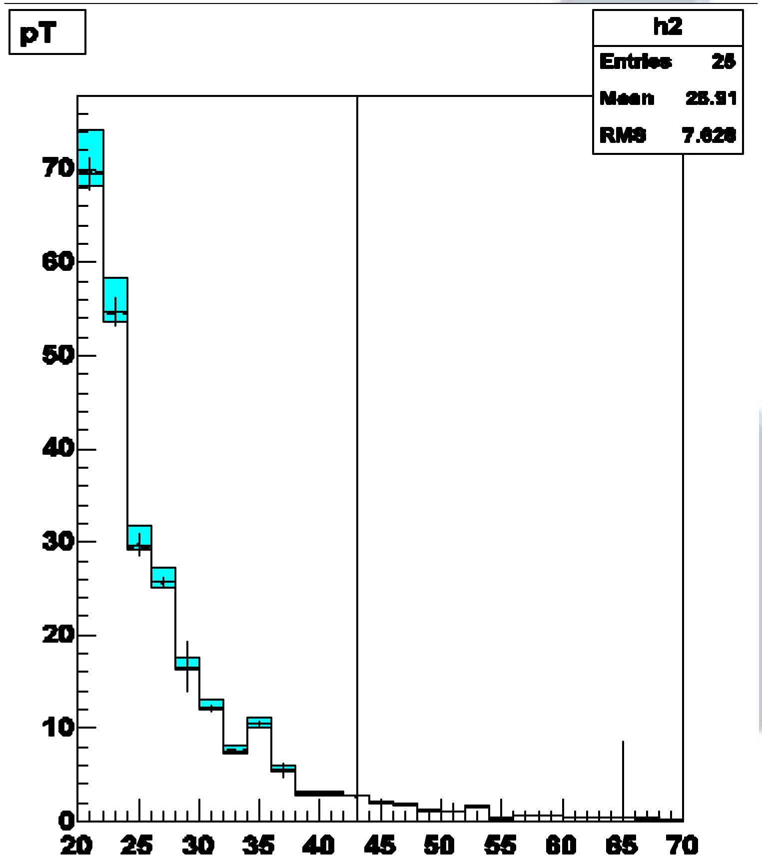
HOWEVER, recent work by ZEUS people, using jet data, has significantly reduced error on mid-x gluons – plots presented here are made with pre- and post-jet data ZEUS PDFs to illustrate improved precision. Before now, gluons were constrained only by the momentum-sum rule. (see next slide)

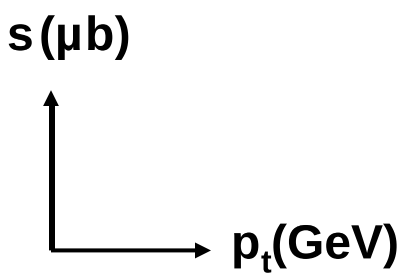
Then apply these PDFs to LHC physics (pp, 14 TeV) to get an idea of improvement in predictive power.



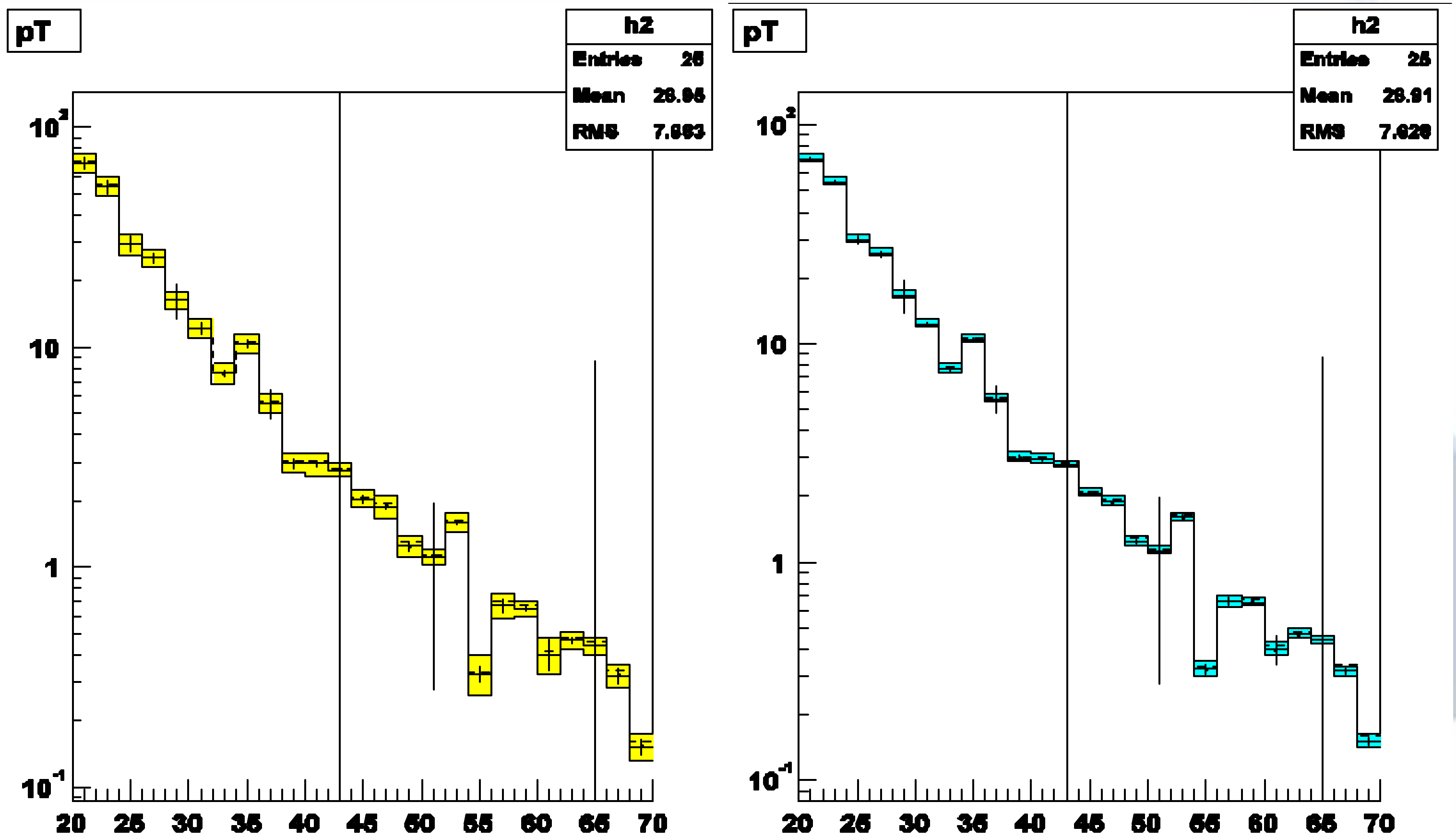
An example of a ZEUS PDF, showing errors (correlated and uncorrelated)





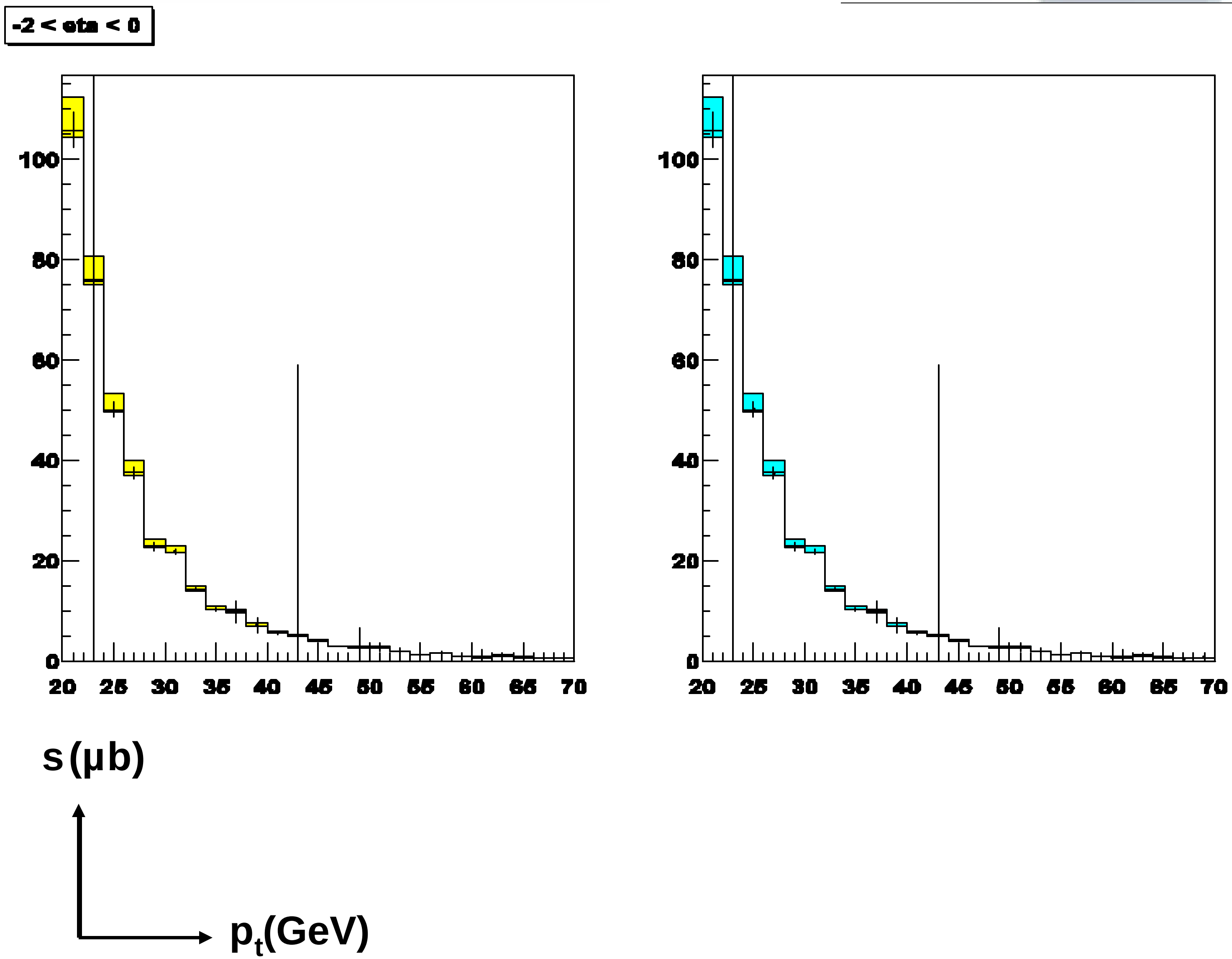


Cross-section vs. pt in the far backwards region: colour = gluon errors only, crosses = total parton errors. Apologies for obviously 'wrong errors' – need to sort them out!

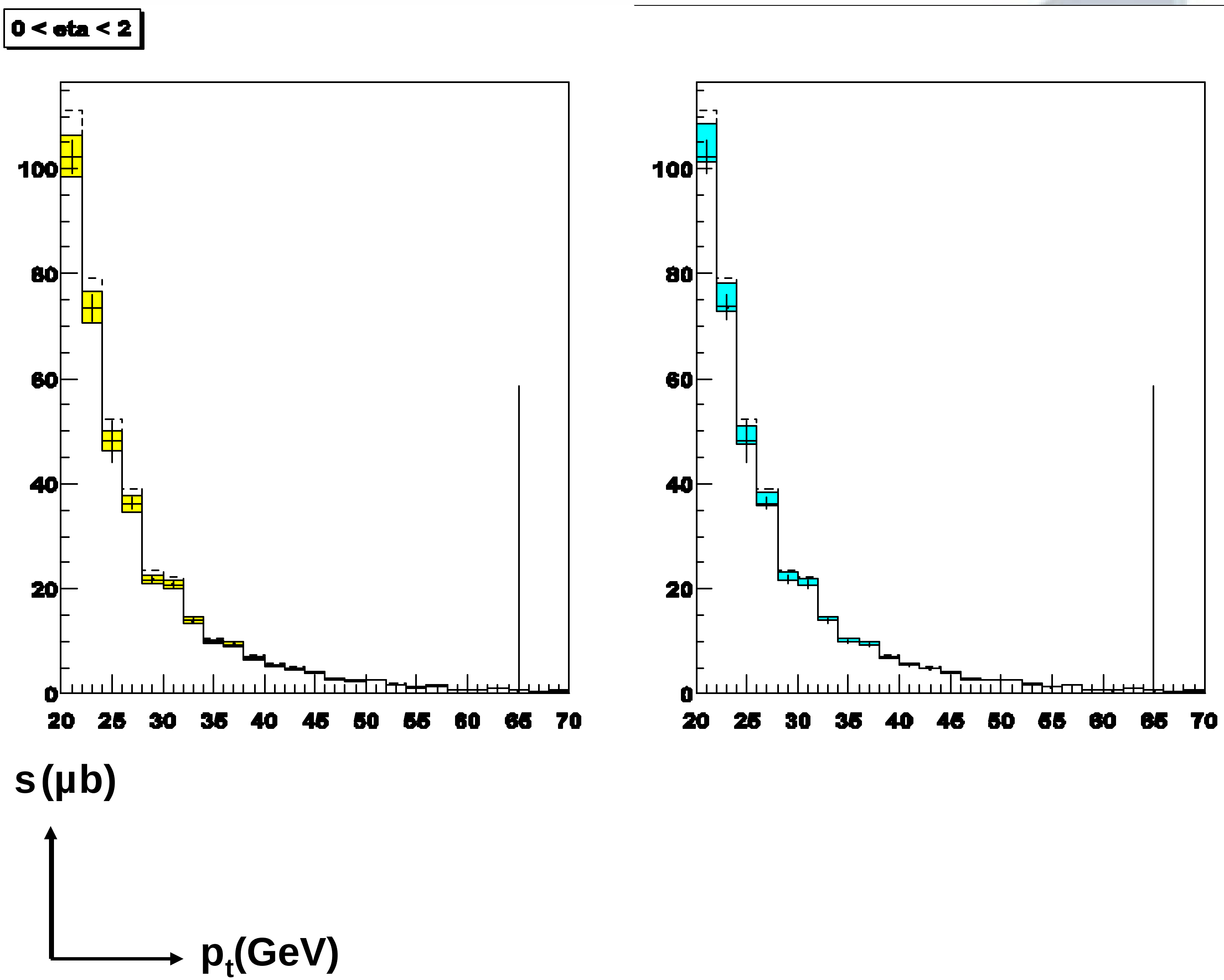


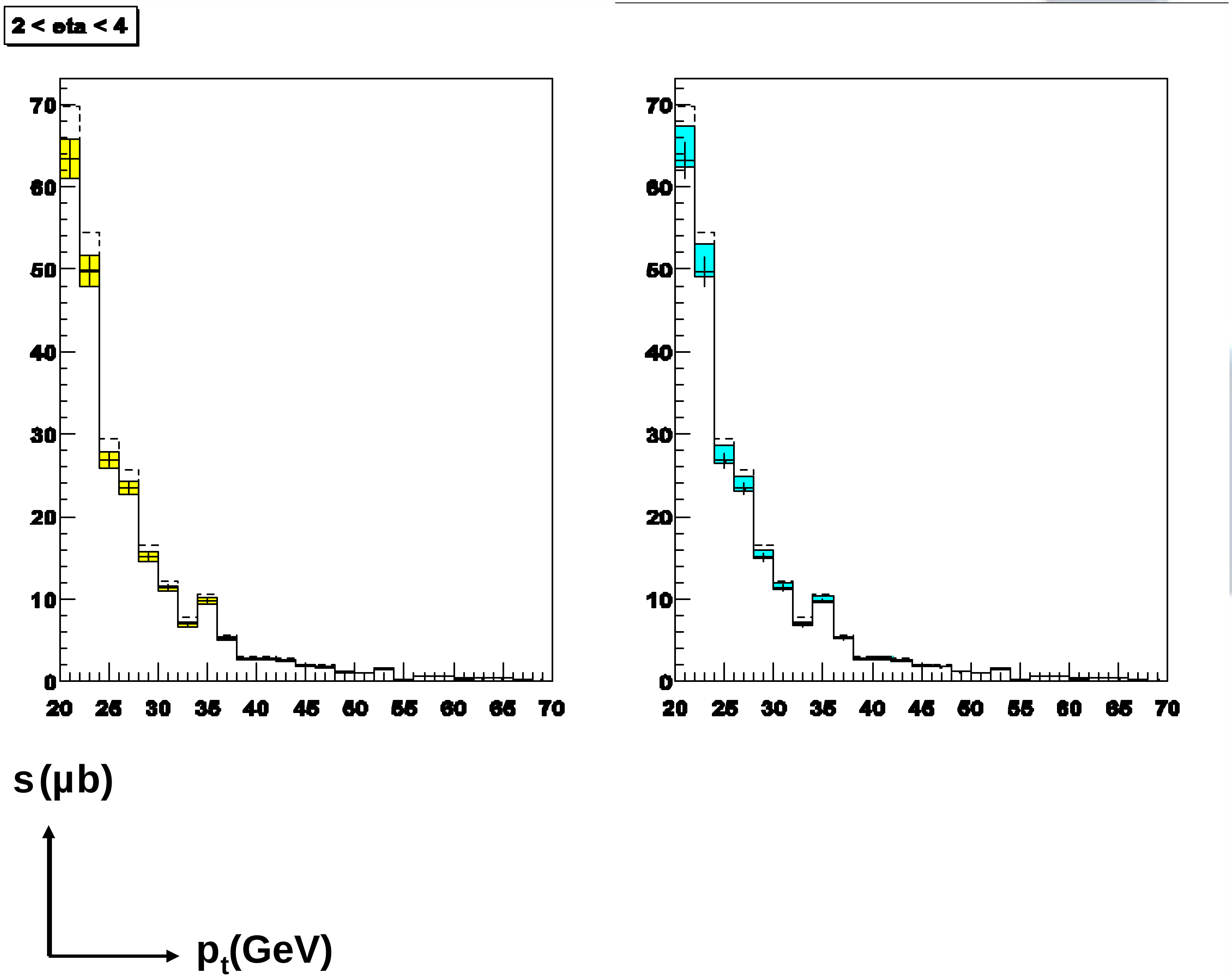
The same plot with log scale on the cross-section axis, to show significant reduction in gluonic errors (factor of 2 – 3 improvement at high p_t) bewteen old PDF and new (jet-based) PDF.

Such precision will be vital when LHC starts taking data.



-2 < eta < 0
0
20
40
60
80
100
20 25 30 35 40 45 50 55 60 65 70
s (µb)
p_t(GeV)


0 < eta < 2
100
80
60
40
20
0
20 25 30 35 40 45 50 55 60 65 70
s(μb)
p_t(GeV)


2 < eta < 4
70
60
50
40
30
20
10
0
20 25 30 35 40 45 50 55 60 65 70
s(μb)
p_t(GeV)

PLANS FOR THE FUTURE

- Generate cross-sections for jets with p_t up to high energies – say 3 GeV (i.e. x~0.4 for dijets at LHC energies)

- Investigate the impact of errors on jet measurements at high energies

- Use MC@NLO (Monte Carlo-NLO hybrid program) to generate parton showers and hadronisation

- Pass this data through ATLFAST – the ATLAS simulation

- Compare errors in cross-section calculations due to PDFs to statistical errors for a sizeable running period at LHC luminosity – say 100 fb^{-1} – at higher p_t where new physics is likely to occur.

SUMMARY

- Much work remains to be done, but it can be seen that
  - ZEUS jet data can significantly reduce errors on PDFs, leading to
  - greater sensitivity to new phenomena at the LHC

- After 10 fb^{-1} of integrated luminosity, we expect ~$2.4x10^5$ events at p_t = 70 GeV $\rightarrow$ statistical error of 0.2% so we need better precsision than this on PDFs in order for them to make a difference.