Underlying Events and Minimum Bias Physics at HERA (and LHC)

Jon Butterworth - HERA/LHC Workshop

- What do “minimum bias” and “underlying event” mean
- How HERA is relevant
- What we know so far
- What we might we learn
- Over to Arthur (after Mike...)

Minimum Bias

- A “minimum bias” event is what one would see with a totally inclusive trigger.
- A single particle-particle interaction.
- Average event is has low transverse energy, low multiplicity. Many are elastic and/or diffractive.
- Many minimum bias events per bunch crossing at LHC. Will be seen if they accompany an “interesting” event which is triggered.
- Generally ~1 event per bunch crossing at HERA, though some overlaps are seen.

Underlying Event

- Several definitions possible
  - Everything except the LO process of interest.
  - Everything except the hard/interesting process.
  - All particles from a single particle collision except the process of interest.
- The third option is most commonly used. The first is wrong in principle.
- Implies a distinction between coherent radiation and other HO corrections (parton showers…) and incoherent “remnant-remnant” interactions.

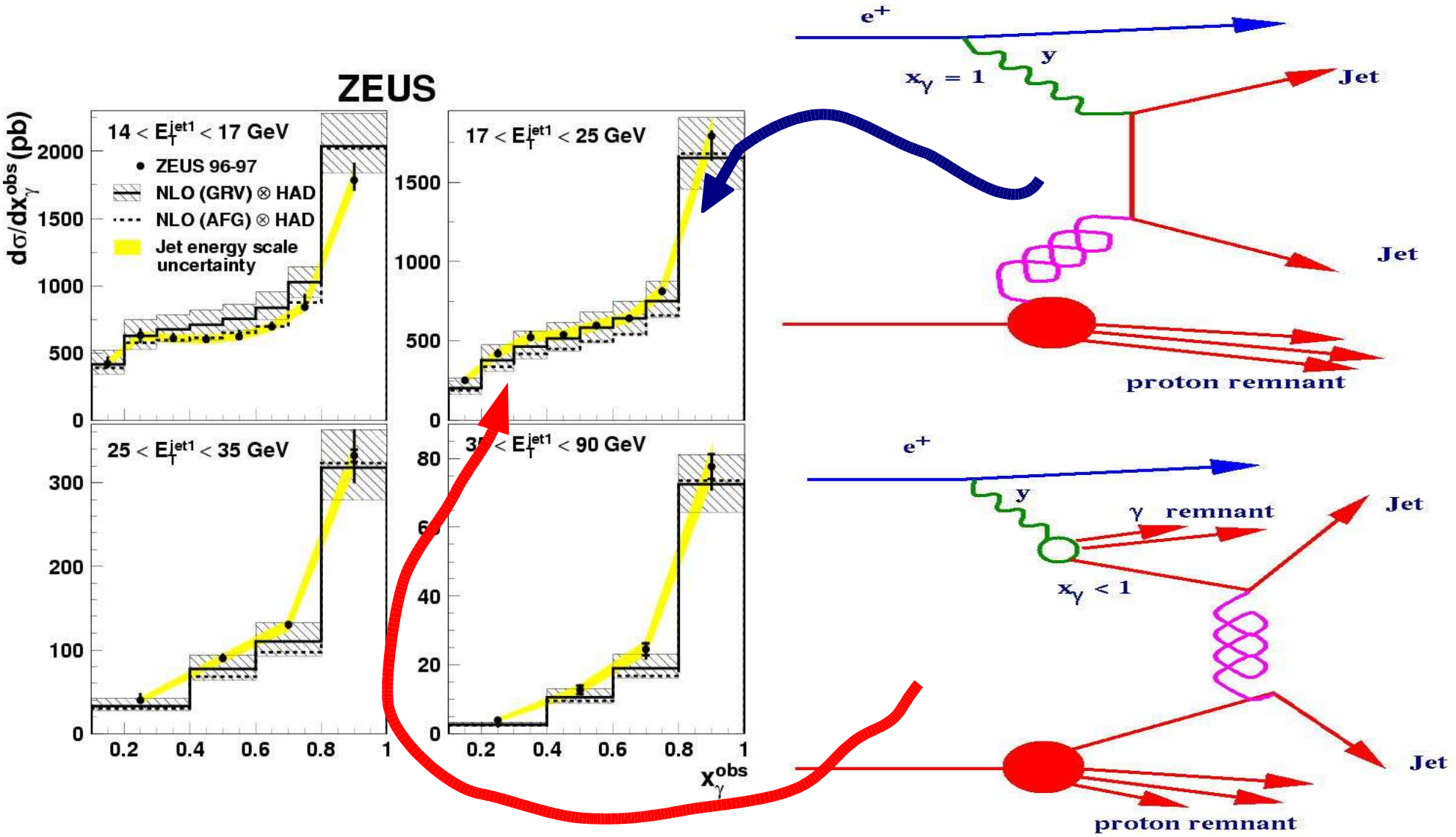
Underlying Event

- May be hard (i.e. contain high pT scatters) or soft.
- Will not simply be the equivalent of a minimum bias event added to the process of interest – correlations are very significant.
- Related to minimum bias events – use them to study correlations etc...
- Related to forward particle production – rescattering models; leading protons and neutrons.
- Related to survival probability for rapidity gaps – incoherent remnant interactions fill the gap.

How is HERA relevant: HERA as a 'hadron-hadron' collider

- Almost on-shell photons come along with the electron beam & collide with protons.
- These photons can fluctuate to acquire a hadron-like structure.
- HERA can look like a hadron-hadron machine (hadronic photon vs proton) but can also do "simpler" measurements with a pointlike photon. (in Deep Inelastic Scattering or direct photoproduction).
- Expect underlying event in the hadronic-photon vs proton collisions.

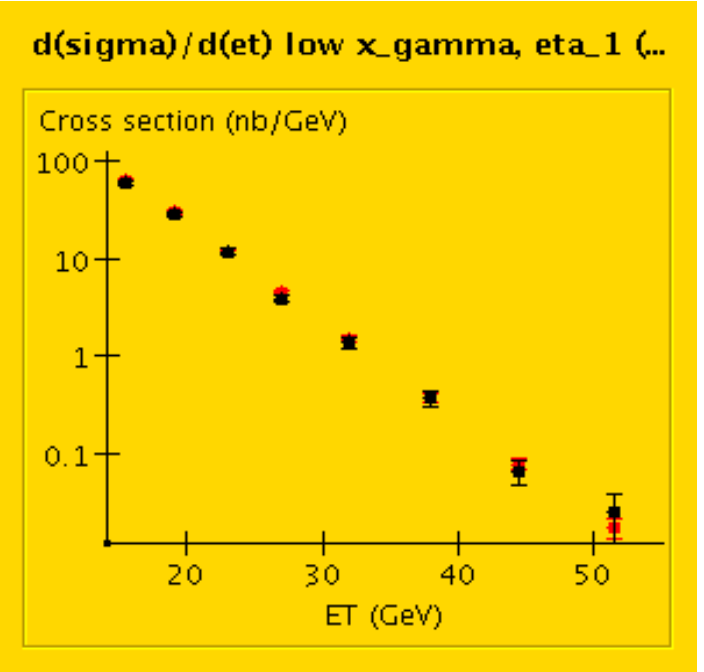
HERA as a 'hadron-hadron' collider



What do we know so far

- **Jet cross sections: Well described at High ET:**

Dijet photoproduction cross section for hadonic photon events as a function of the leading jet transverse energy.
Data vs Herwig x 1.6.



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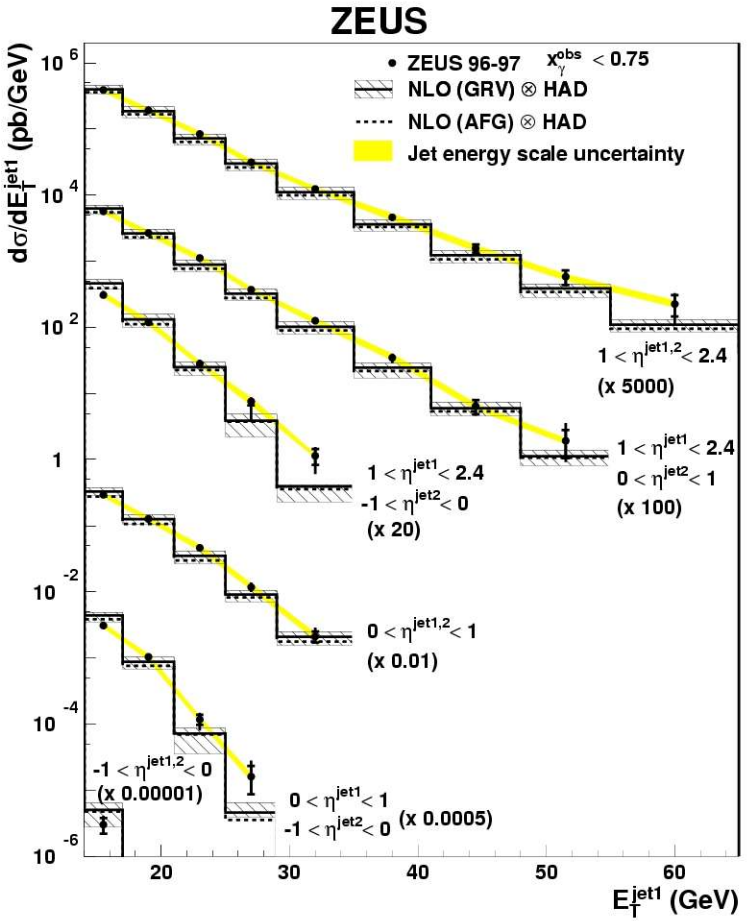

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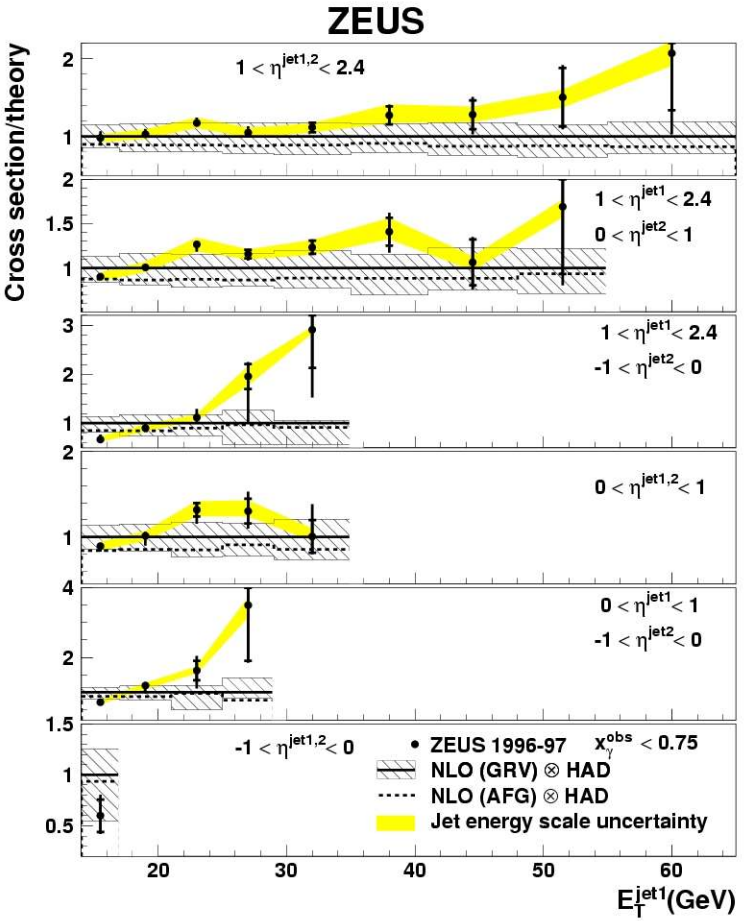
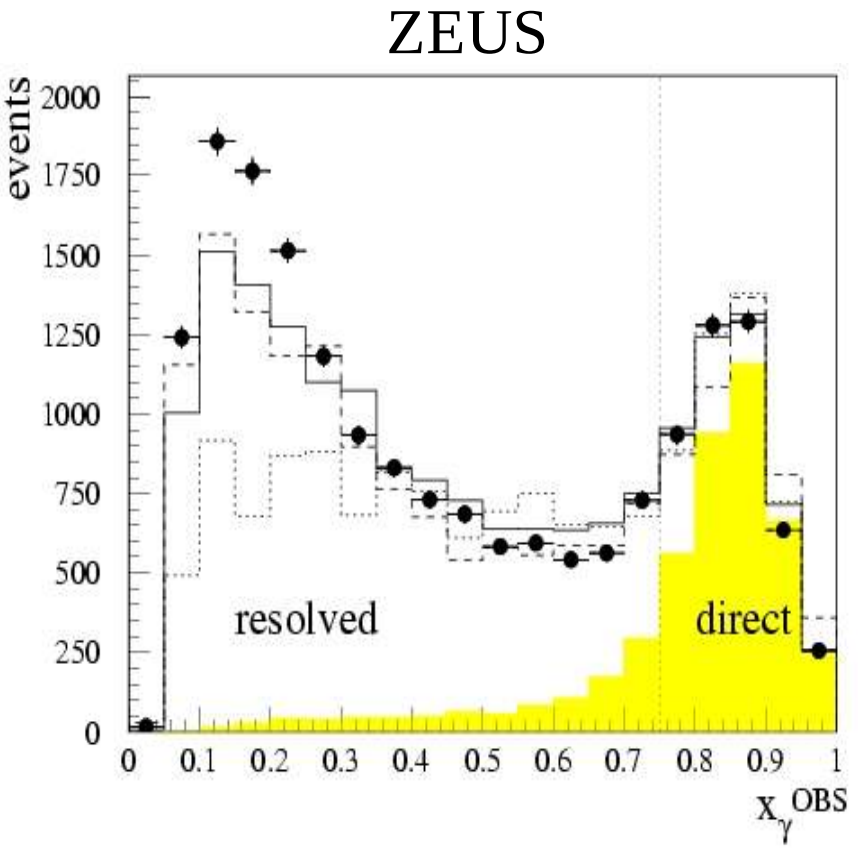


What do we know so far

- **Jet cross sections: Not so well described at lower ET:**

Low xgamma jet cross section only described by MI models... (and even then not very well!)

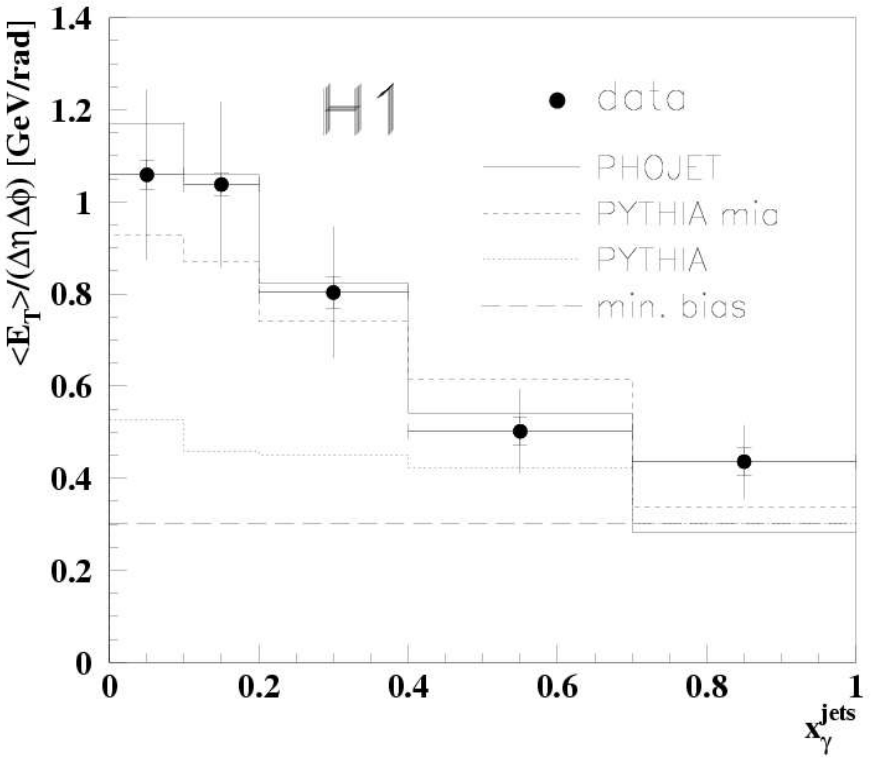
(6 GeV Dijets)



What do we know so far

- **Jet cross sections: Not so well described at lower ET:**

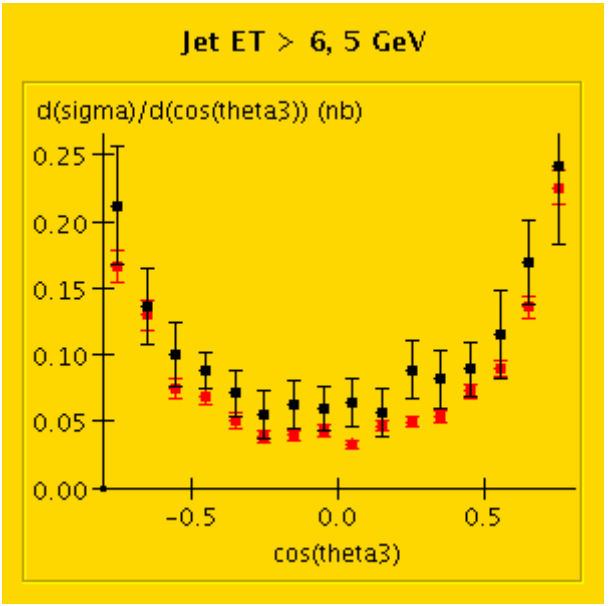
Energy flow outside jets only modelled by MI models...

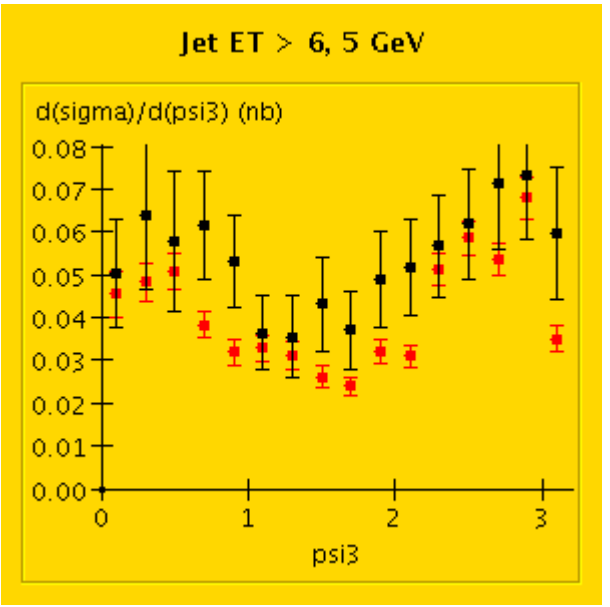


Three-Jet Cross Sections

Three-jet cross sections for Mjjj>50 GeV

Colour Coherence in initial & final state radiation.



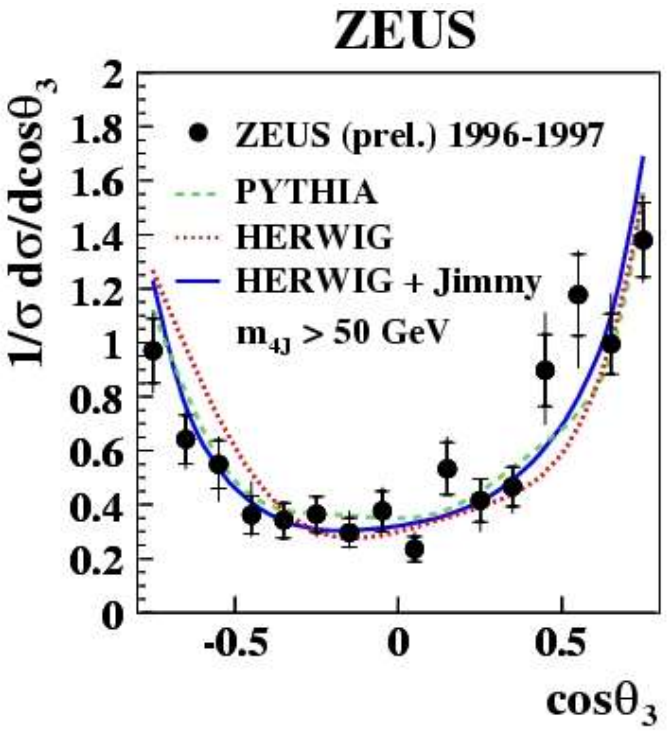


Data vs Herwig.

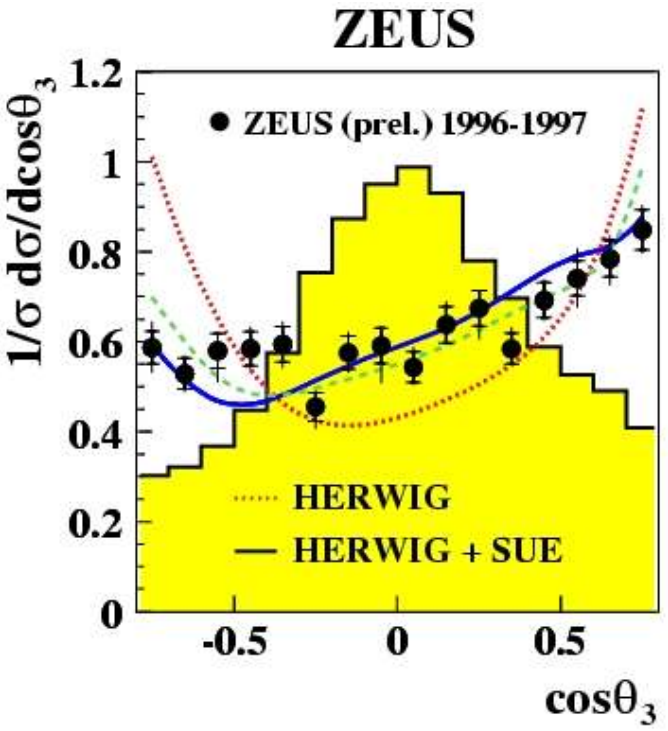
NB: HERWIG normalisation factor of 1.6x, determined by the high E_T dijet data. LO + Parton showers (alone) do very well.

Four-jet cross sections

Photoproduction, jet transverse energy > 6 (5) GeV. No mass cut.



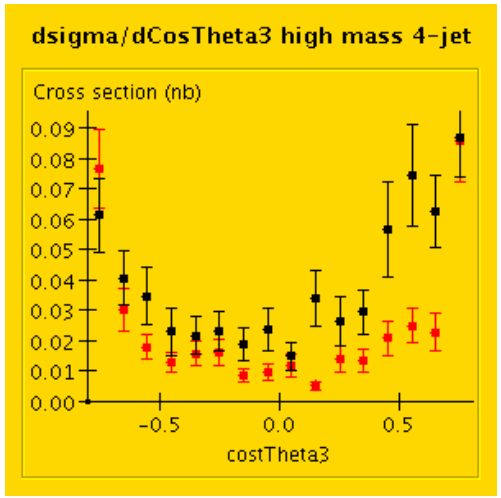
Four jet Mass > 50 GeV.
QCD (LO+PS) doing well.

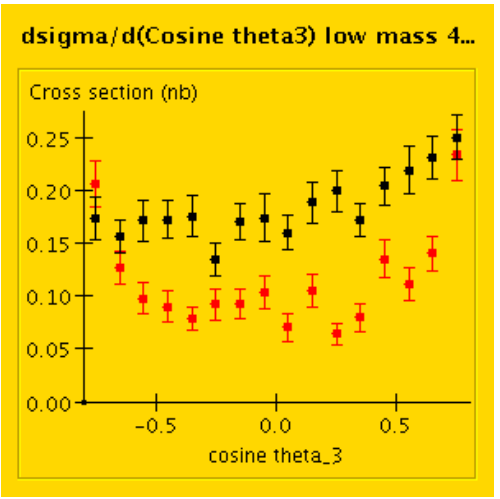


No mass cut. Need something else.
Multiparton interaction models are favoured.

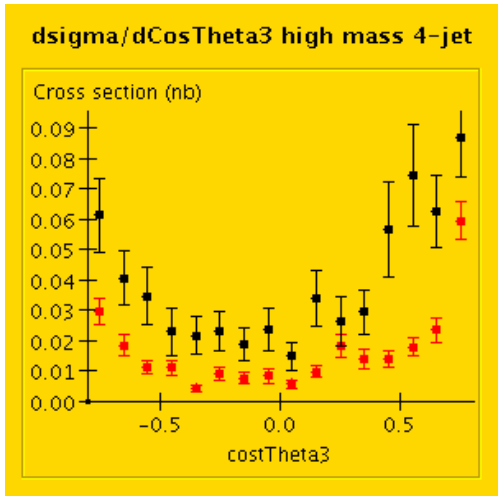
Four-jet cross sections

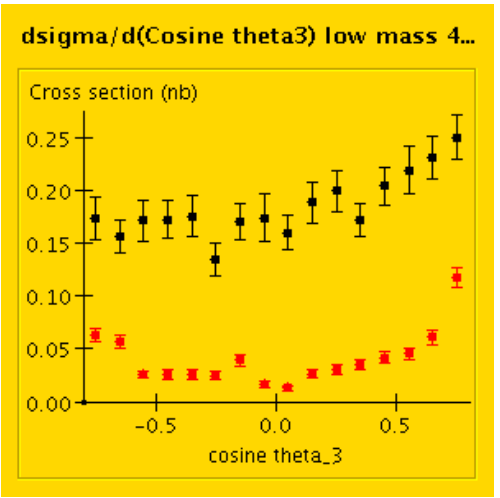
Same data: compare absolute cross sections.





HERWIG+JIMMY, as tuned to Tevatron data minimum bias data. *(I.Borozan,M.Seymour)*



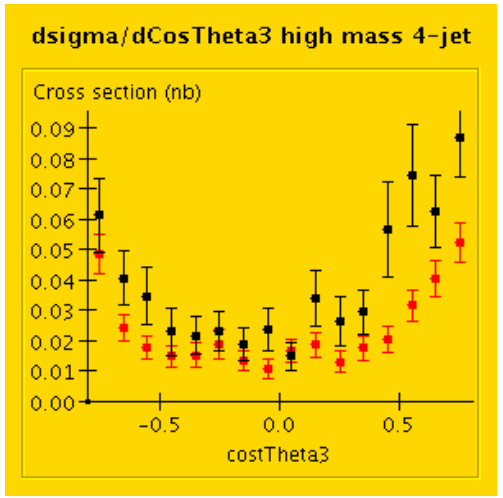


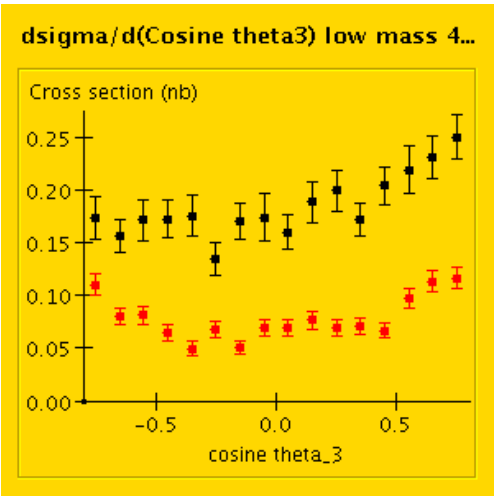
HERWIG default.

NB: Both these options give a decent fit to the high ET data.

Four-jet cross sections

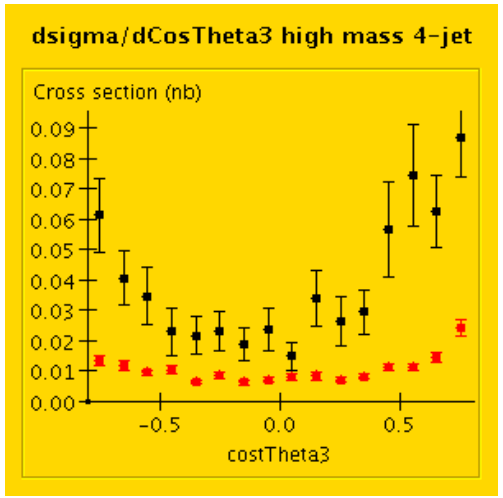
Same data: compare absolute cross sections.

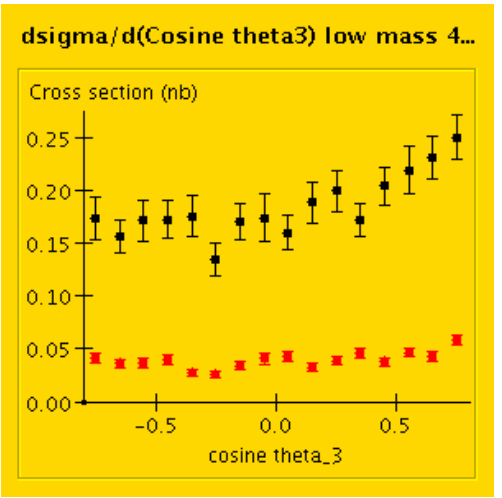




PYTHIA,
as tuned to Tevatron data
minimum bias data

(R. Field; C.Buttar,A.Moraes,I.Dawson).



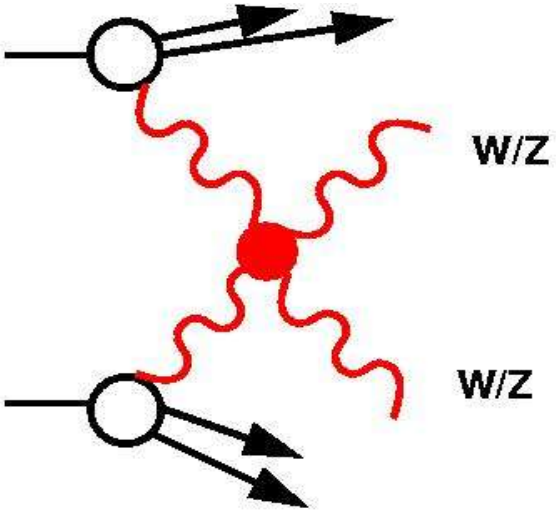


PYTHIA default.

NB: Both these options give a poorer fit to the high ET data than HERWIG

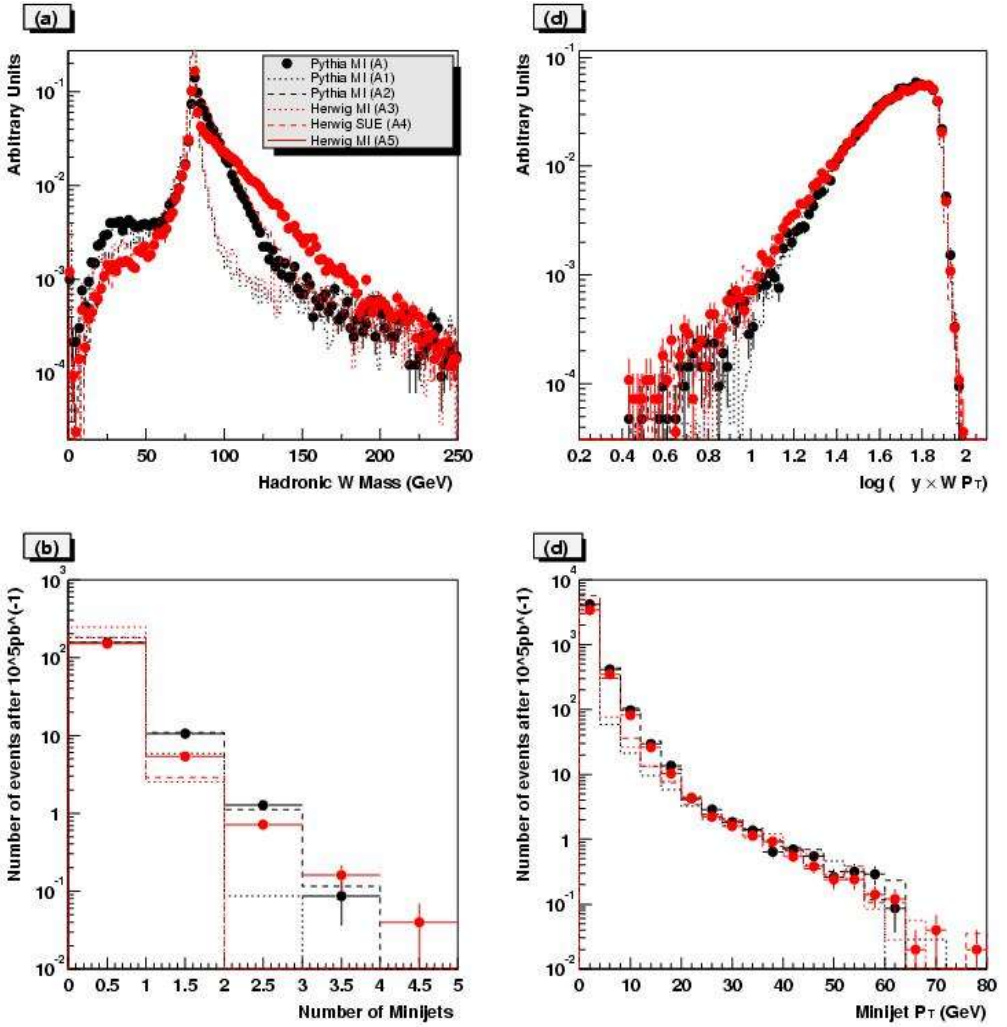
Minijets at LHC

Commonly used veto in WW events (see later session).



Great sensivity to choice of underlying event model.

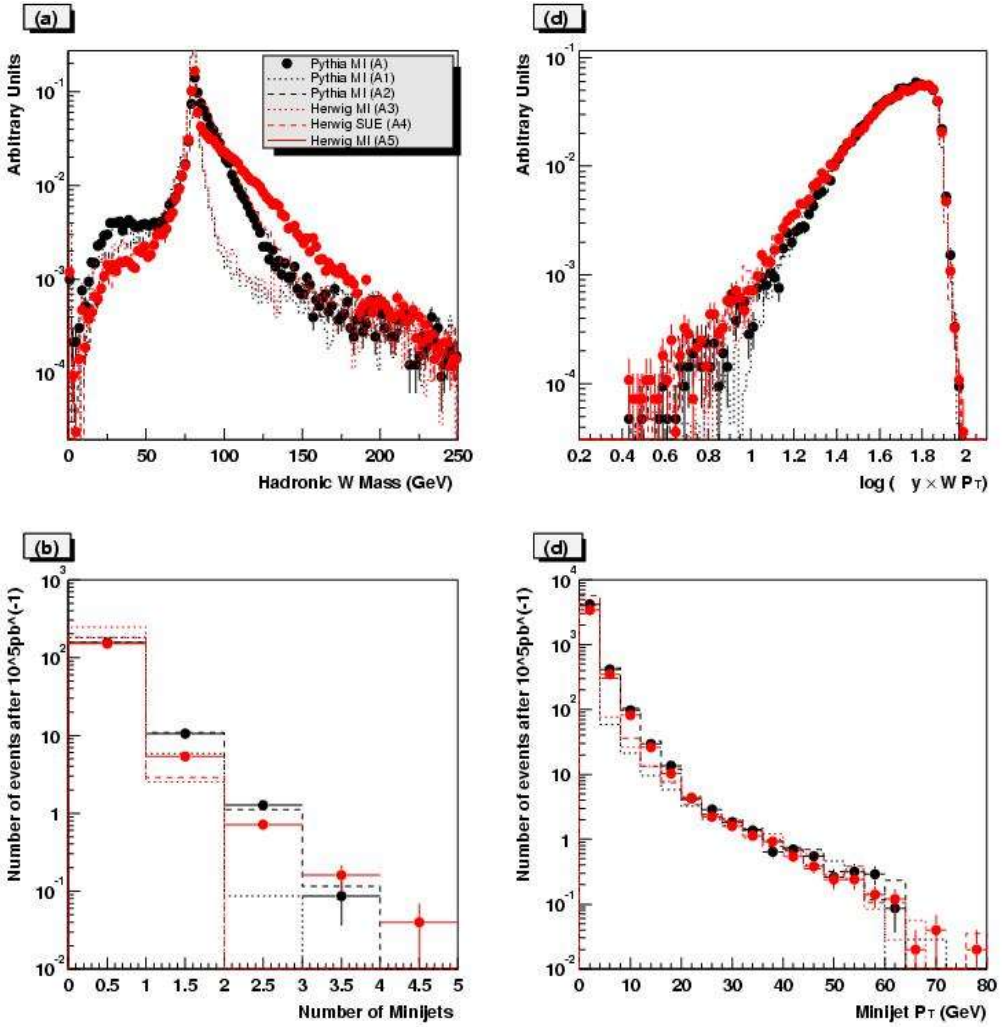
JMB,Cox,Forshaw, PRD65:096014(2002)



Minijets at LHC

Les Houche Higgs Working group: Minijet veto at 20-30GeV (hep-ph/0203056) just from (uncorrelated) multiparticle interactions.

Multiparton interactions will be worse.

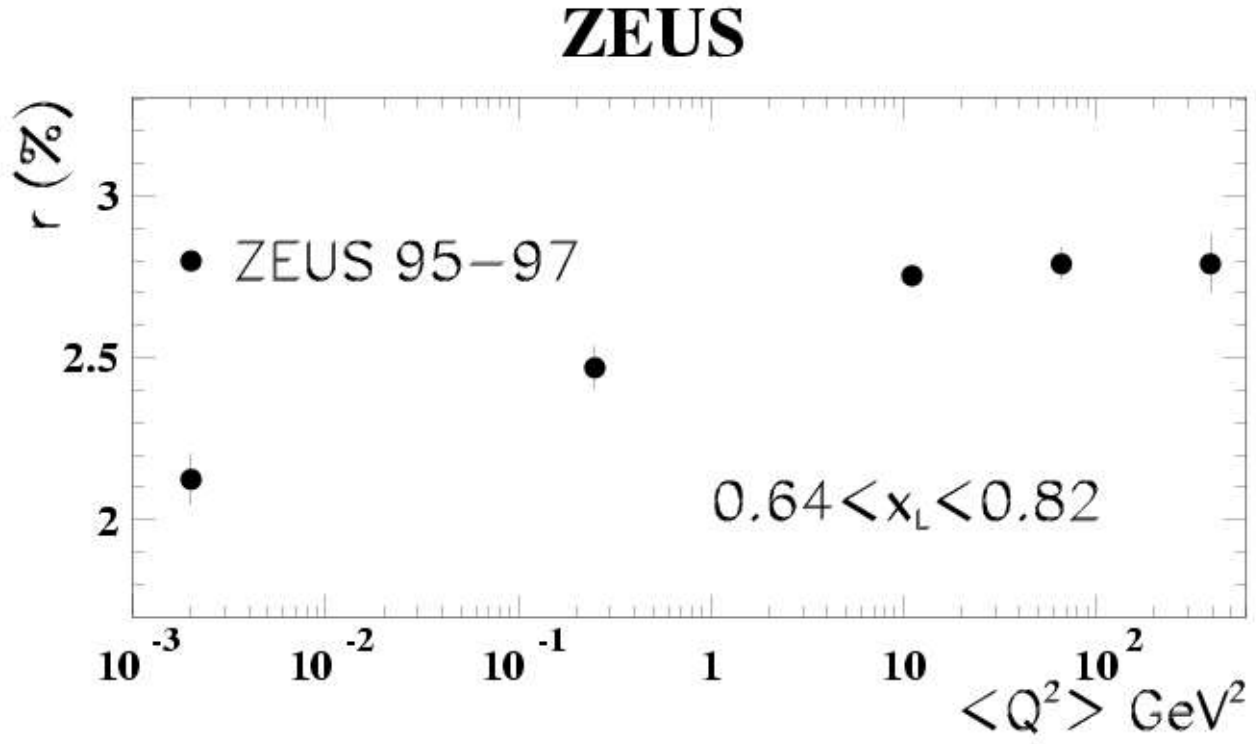


What might we learn from HERA

- Learn about energy dependence and target dependence of models by comparing γp, pp(bar) and $\gamma\gamma$.
- Learn about proton PDFs at low x -> input to multiparton interaction models.
- Look at behaviour of jet finding for the same kinematics but with & without an underlying event.
- Test models which predict both minimum bias & underlying event by studying tagged photoproduction.
- Look at forward neutron and proton rates in photoproduction vs DIS ->

Look at leading neutron rates

- Shown to be well described by pion exchange.
- Different rates of forward neutrons for different central events. Modelled by rescattering (absorption) of the neutron in the photon remnant.



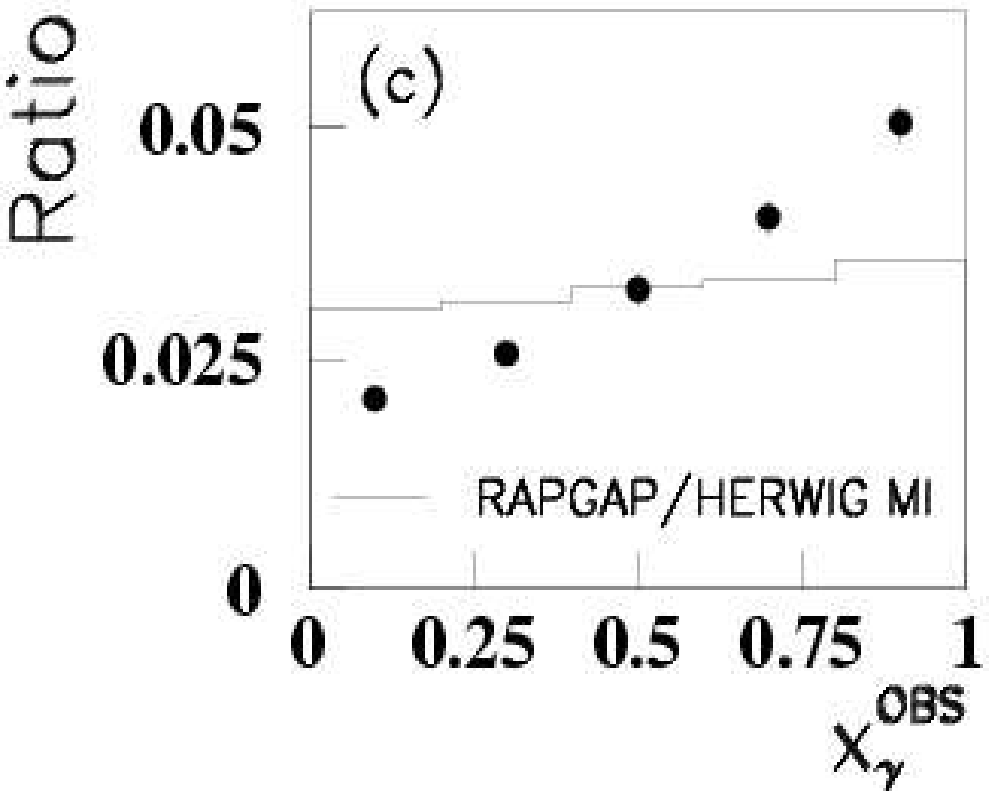
Uncorrected rate – real rate is ~8%

Look at leading neutron rates

- Inclusive photoproduction (Nucl. Physics B637 (2002) 3-56) :
  - No hard scale; Dominated by hadronic photon; Rescattering similar to hadron-hadron (?)
- DIS (same paper):
  - Hard scale; Pointlike photon; No rescattering
- Charm Photoproduction (DESY 03-221):
  - Hard scale; Some hadronic photon, but suppressed w.r.t. Inclusive case. No rescattering (rate ~9+/-1% agrees with DIS, not inclusive photoproduction).

Look at leading neutron rates

- Dijet Photoproduction :
  (Nucl. Phys. B596 (2001) 3)
  - Hard scale; can select between pointlike and hadronic photons.
  - Uncorrected jets
  - Suggestive trend vs xgamma.
- Compare with diffractive dijets- underlying event, survival probability.



Summary/Segue...

- A lot of potential.
- Obviously we need good models/theories to get the most out of the comparisons (Mike).
- Obviously we need to look at true hadron-hadron data as well (Arthur)
- Lots of work to be done...