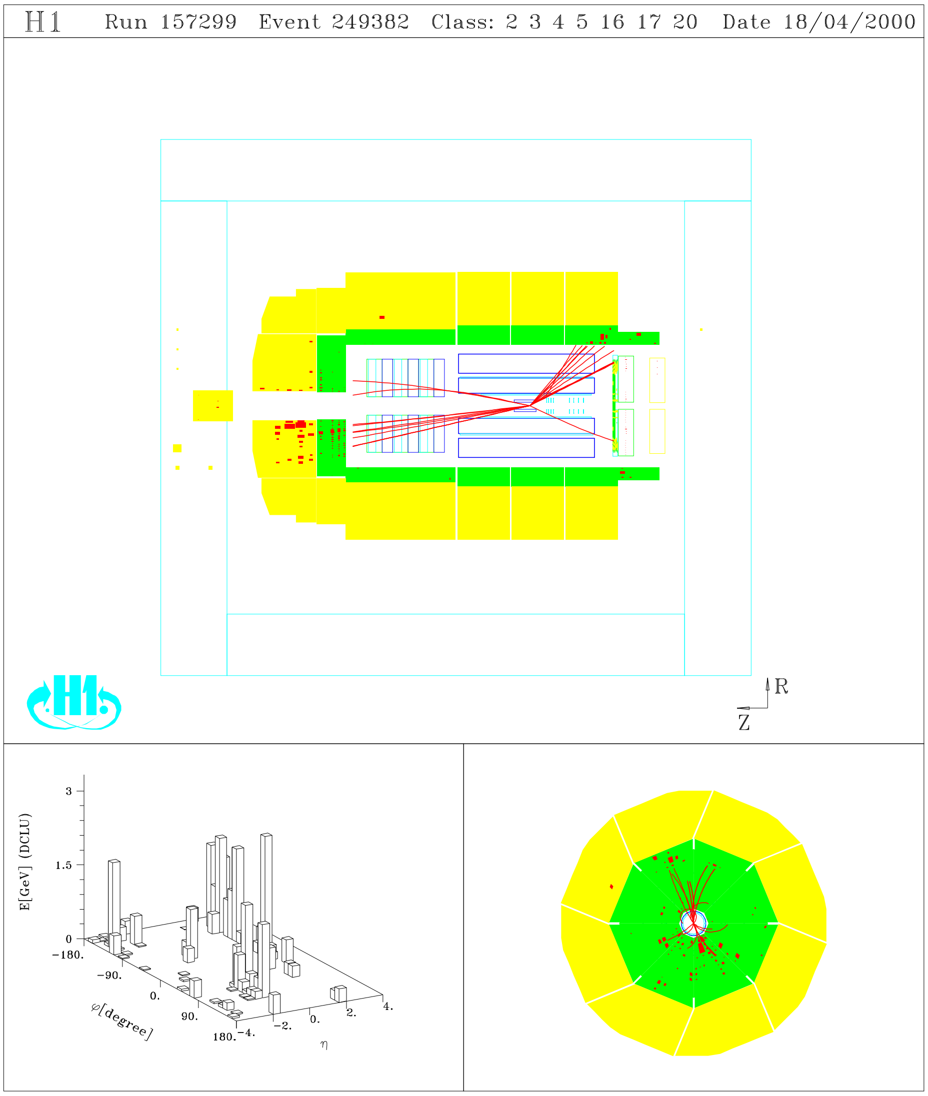
Energy Flow Between Jets in γ p Collisions at HERA

Angela Wyatt

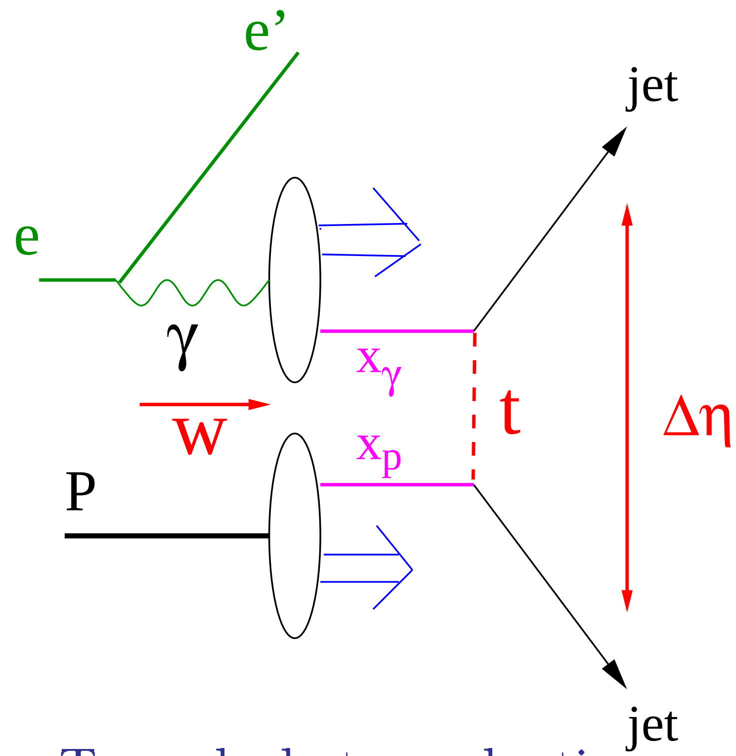
THE UNIVERSITY of MANCHESTER

THE H1 EXPERIMENT AT HERA

H1 Collaboration at DESY, Notkestr.85, D-22607 Hamburg, Germany



Gaps Between Jets in γ p Collisions



- Tagged photoproduction

  $Q^2 < 0.01$ GeV^2

  $165 < W < 233$ GeV

- Jet Finding - inclusive KT algorithm

  $P_t^{jet1} > 6.0$ GeV, $P_t^{jet2} > 5.0$ GeV , $\eta^{jet1,2} < 2.8$

- Other variables :

$$x_p^{jets} = \frac{\sum_{jets1,2}(E^{jet} + p_z^{jet})}{2E_p}$$

$$x_\gamma^{jets} = \frac{\sum_{jets1,2}(E^{jet} - p_z^{jet})}{\sum_{objects}(E^{obj} - p_z^{obj})}$$

Why are these events unexpected ?

- The 'soft' pomeron ?

  Pomeron trajectory : $\alpha(t) = \alpha(0) + \alpha' t$

  $\rightarrow \frac{\mathrm{d}\sigma}{\mathrm{d}t} \simeq s^{2(\alpha(0)+\alpha' t)}$

  Any reasonably large α' (~ 0.25) leads to vanishing cross section at high $|t|$

- QCD ?

  No fundamental colour singlet object $\rightarrow$

  BUT Large t $\rightarrow$ can construct one using pQCD

- LLA BFKL :

  $\frac{d\sigma(qq\rightarrow qq)}{dt} \approx (C_F\alpha_s)^4 \frac{2\pi^3}{t^2} \frac{\exp(2\omega_0 y)}{(7\alpha_s C_A \zeta(3) y)^3}$

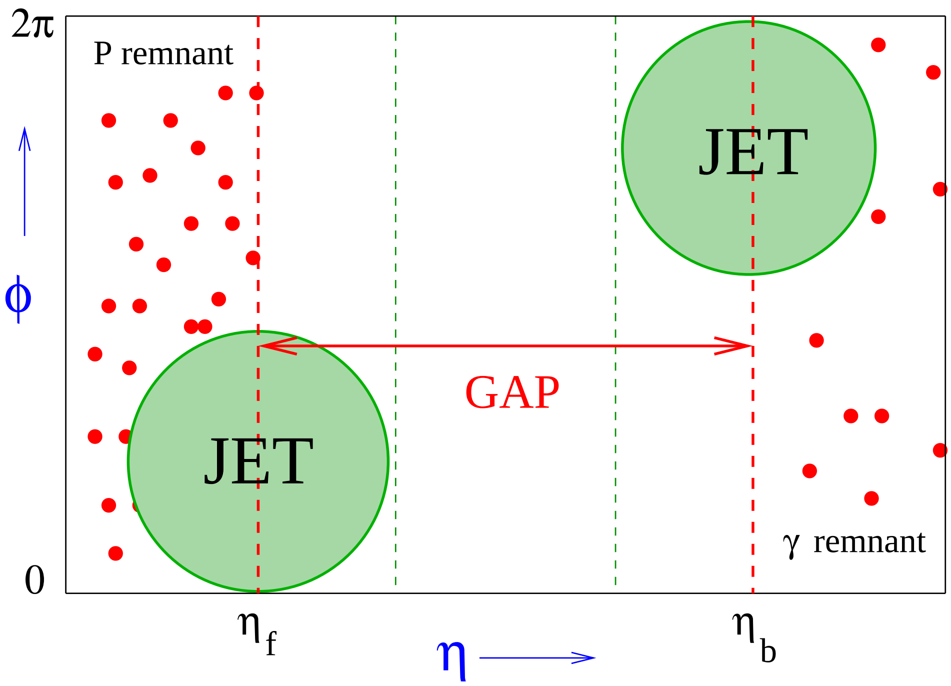
  $\omega_0 = C_A(4\ln 2/\pi)\alpha_s$, $y = \Delta\eta = \ln\left(\frac{\hat{s}}{-t}\right)$

- Free parameters :

  $\omega_0 = 0.45$, $(\equiv \alpha(0) = 1.45)$, $\alpha_s = 0.17$

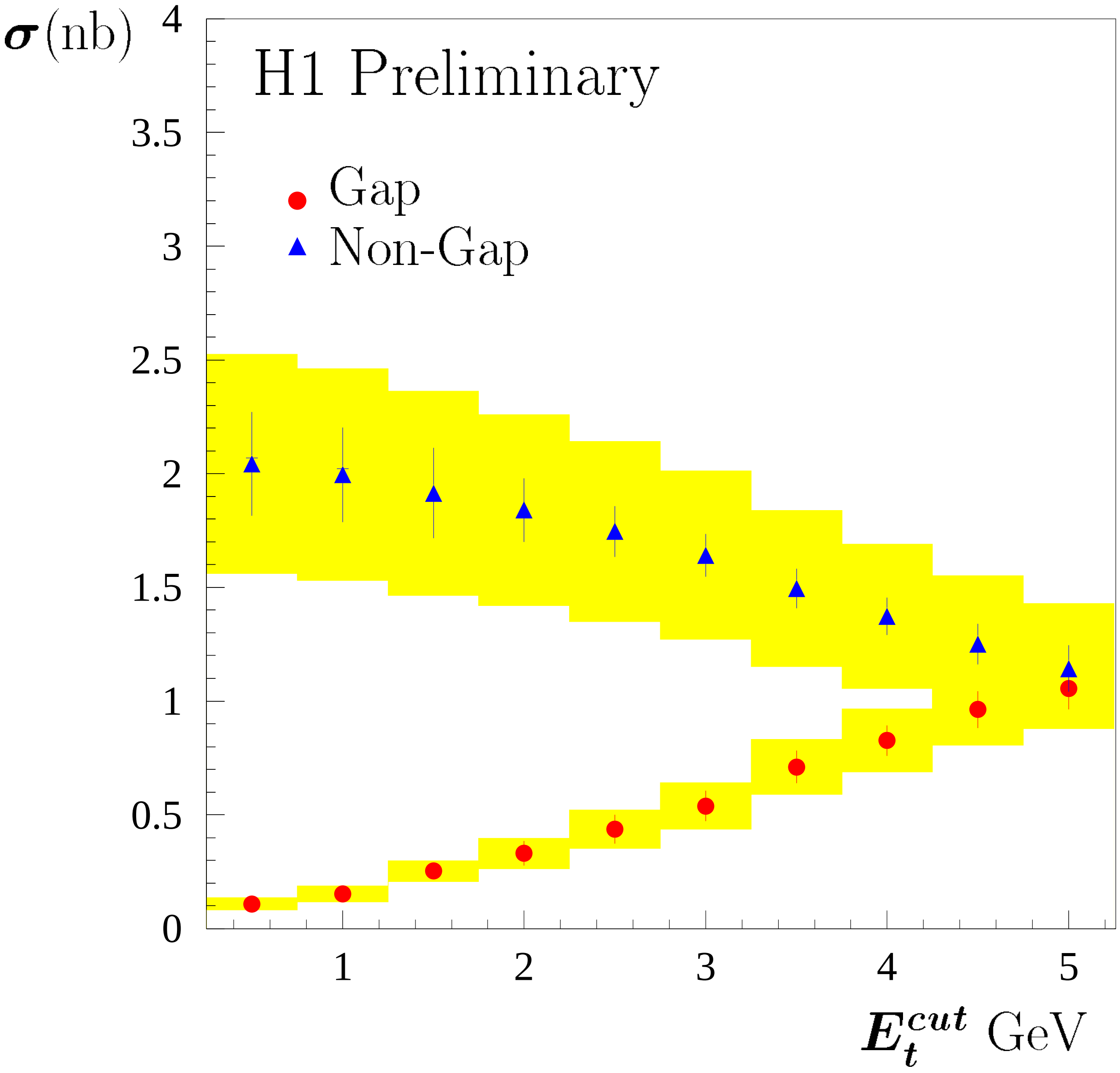
  c.f Tevatron data, Cox, Forshaw + Lönnblad, JHEP 10 (1999) 023

Definition of Rapidity Gap Events



- Inclusive KT algorithm → every object associated with a jet *(minijets)*
  $\not{E}_t^{jets} = \sum E_t^{minijets}, \eta_f^{jet} > \eta_{minijet} > \eta_b^{jet}$
- $\boxed{\text{Gap event : } \not{E}_t^{jets} < E_t^{cut}}$
- Large η region used to define $\not{E}_t^{jets}$
- Activity at edge of gap 'removed' from gap
- Completely infra-red safe definition of gap
- Perturbative calculation possible for $\not{E}_t^{jets} \gg \Lambda_{QCD}$

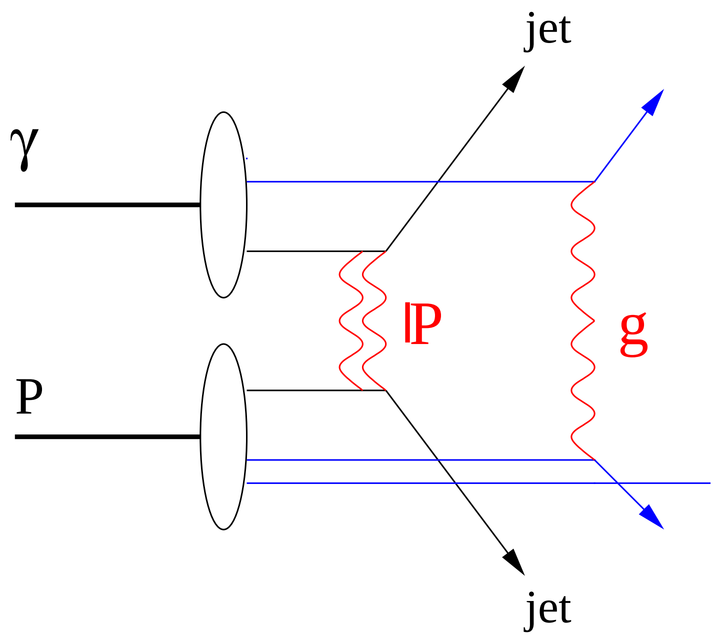
Dijet Cross Sections



$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$,
$\eta^{jet1}, \eta^{jet2} < 2.8$

- Yellow band $\rightarrow$ correlated systematic error

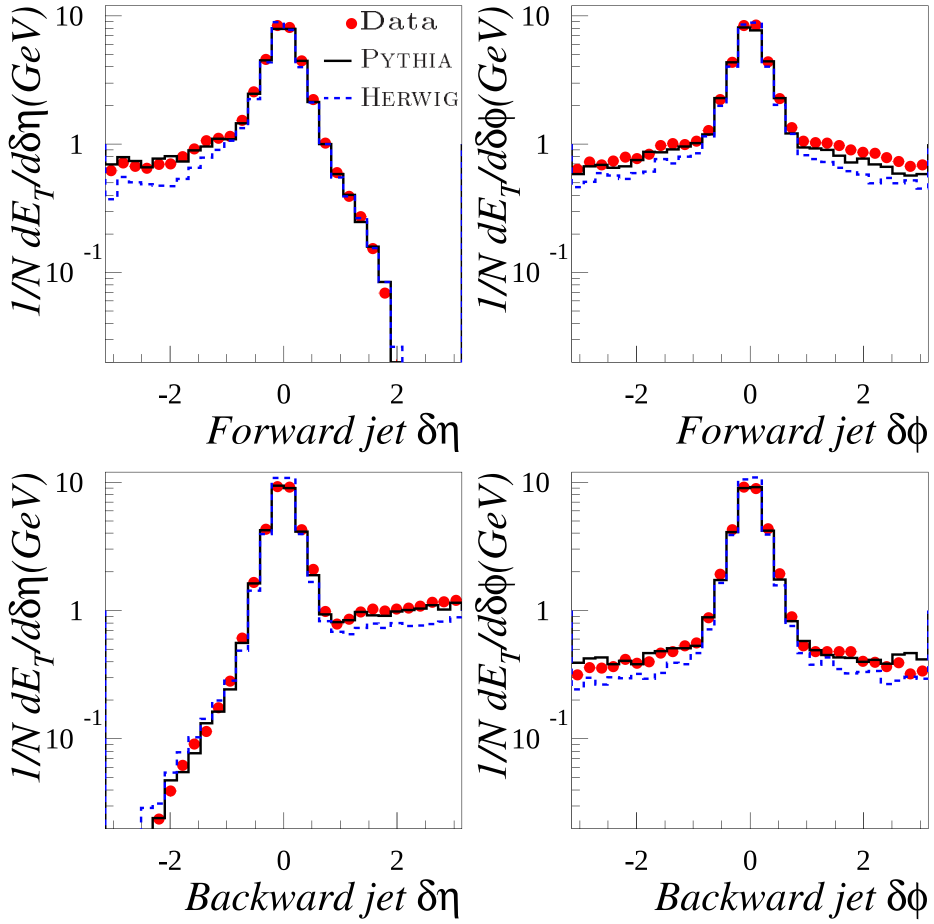
Complications



- Rapidity gap survival probability
  $\rightarrow$ potentially large non-perturbative corrections
- Unique place to study interplay between long and short distance physics
- All non-perturbative $\rightarrow$ soft color models
- Perturbative exchange (e.g BFKL) + gap survival probability
- Purely perturbative (up to pdfs) if E_t^{cut} large
  (Oderda + Sterman Phys Rev Lett 81,3591 (1998))

Underlying Event and Gap Survival Probability

- Rate of multiple scatters (p_t^{mi})
  $\rightarrow$ gap survival probability
- Rate of multiple scatters
  (+ energy flow / scatter) $\rightarrow$ jet pedestals
- PYTHIA 5.7 tuned to data



- Herwig 5.9 (no mi's) undershoots data $\rightarrow$ systematic errors

Monte Carlo Models

- Pythia 5.7

  Proton PDF : GRV-LO, γ PDF : GRV-LO

  $P_t^{min} = 2.2$ GeV, $P_t^{mi} = 1.5$ GeV

- Herwig 5.9 + JIMMY

  Proton PDF : GRV-LO, γ PDF : WHIT2

  $P_t^{min} = 1.8$ GeV, $P_t^{mi} = 1.8$ GeV

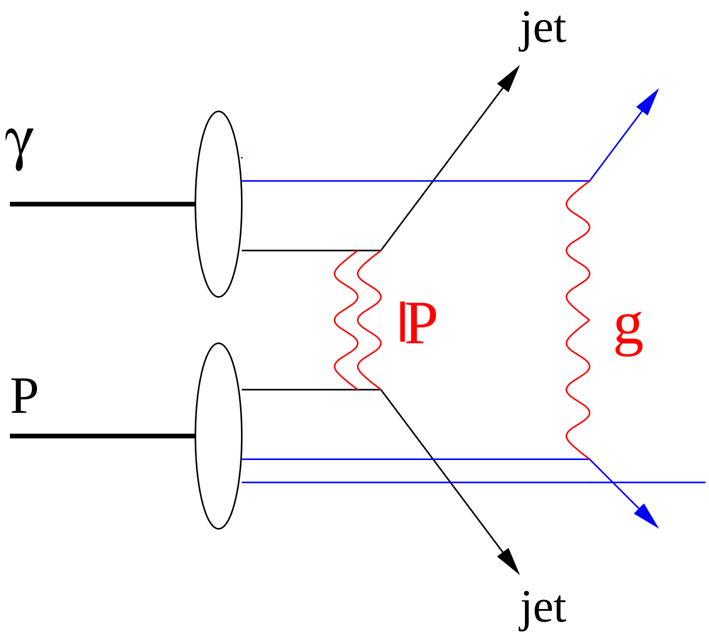
- HERWIG + JIMMY tuned to this and other HERA measurements

  http://www.hep.ucl.ac.uk/JetWeb/

The Gap Fraction

- Gap Fraction $f = \frac{N_{gap}}{N_{inc}}$

  (N_{gap} = # events with $\not{E}_t^{jets} < E_t^{cut}$)

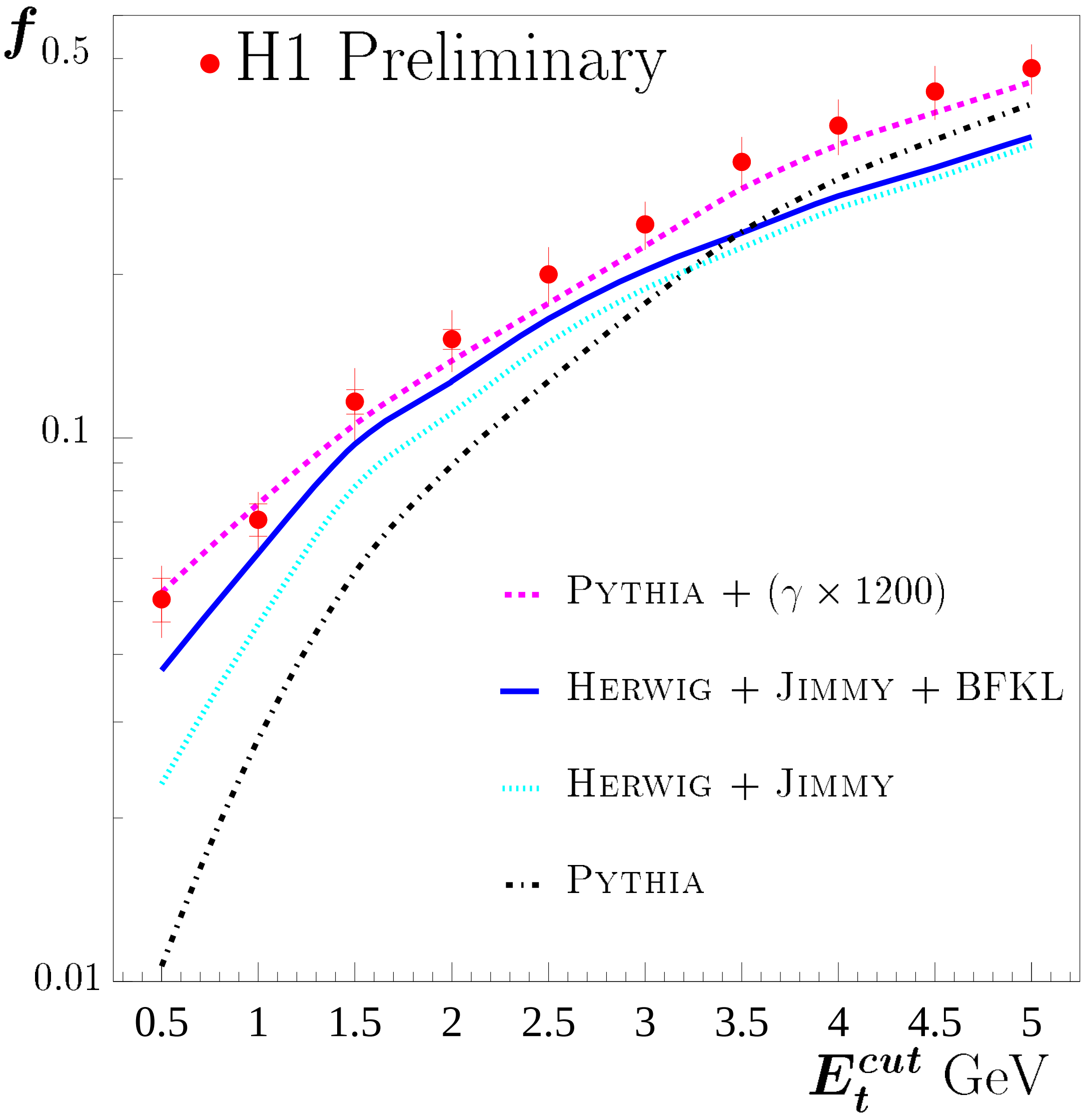


- 2 contributions :

  Cross section for colour singlet exchange

  Gap Survival Probability

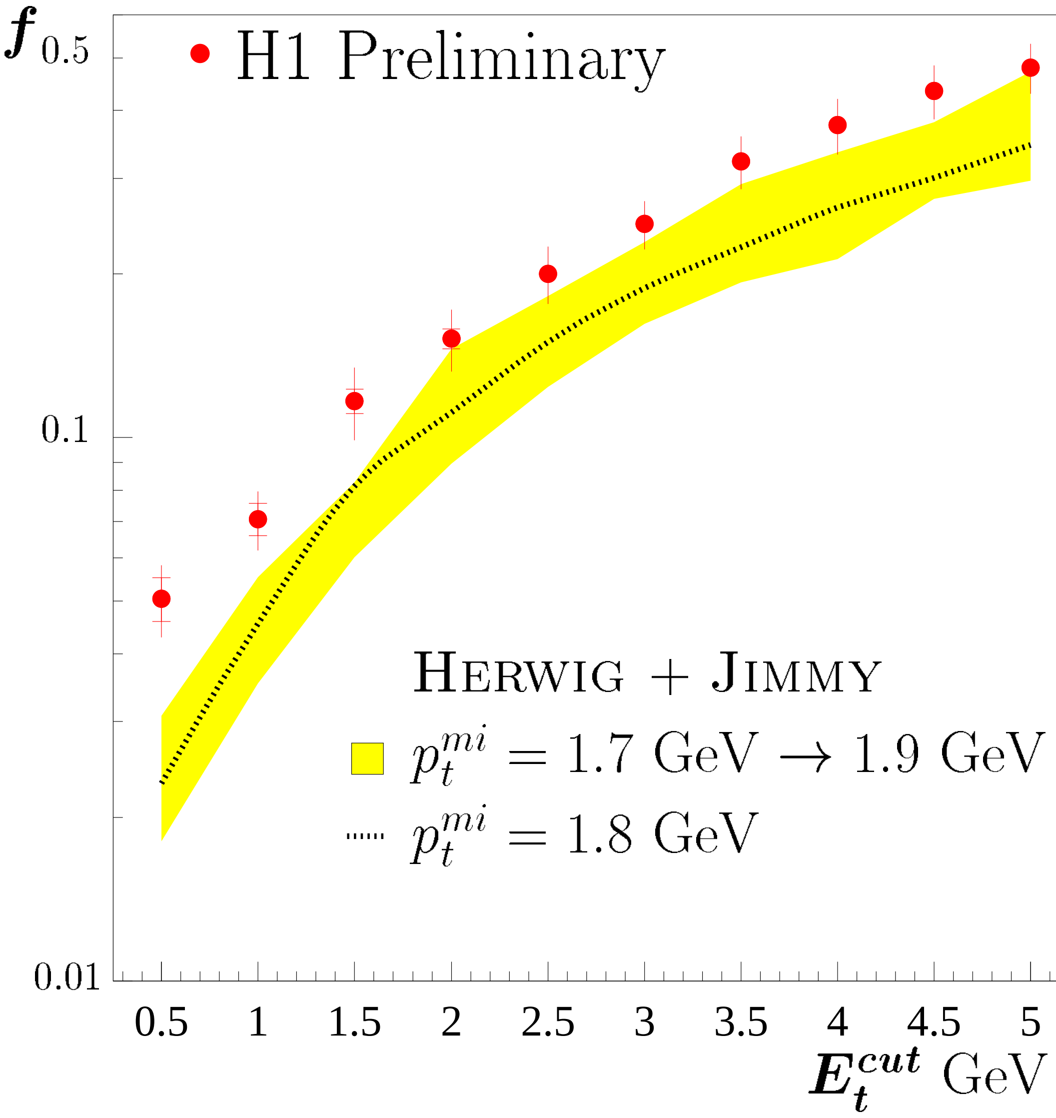
Inclusive Gap Fractions



$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$

- Large excess over Pythia and Herwig
- Very sensitive to underlying event models - can say little about colour singlet models

Sensitivity to Underlying Event Models



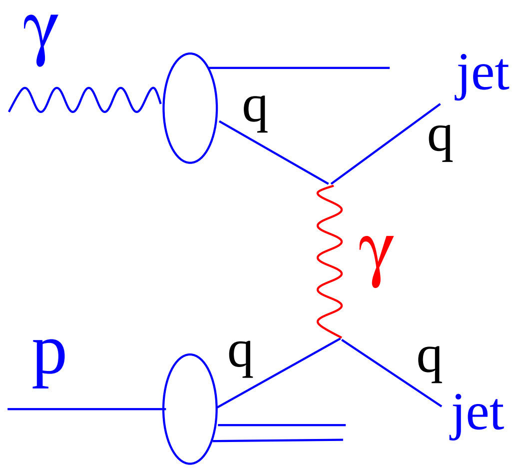
$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$

- p_t^{mi} varied between 1.7 GeV and 1.9 GeV in HERWIG + JIMMY model
- γp background prediction sensitive to p_t^{mi}

Colour Singlet Models

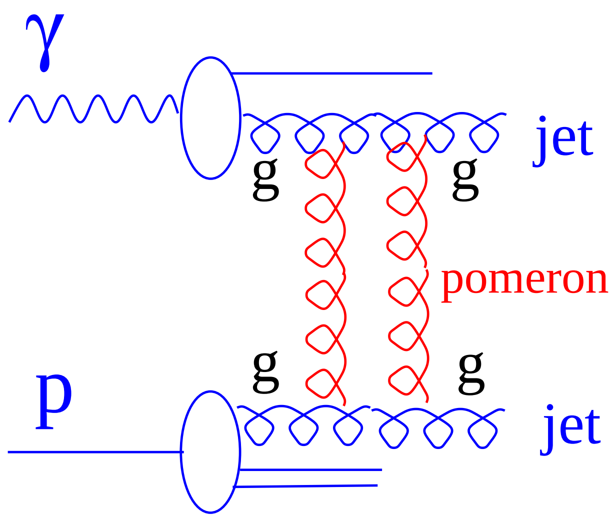
- Pythia 5.7

  high-t γ exchange ($\times 1200$)

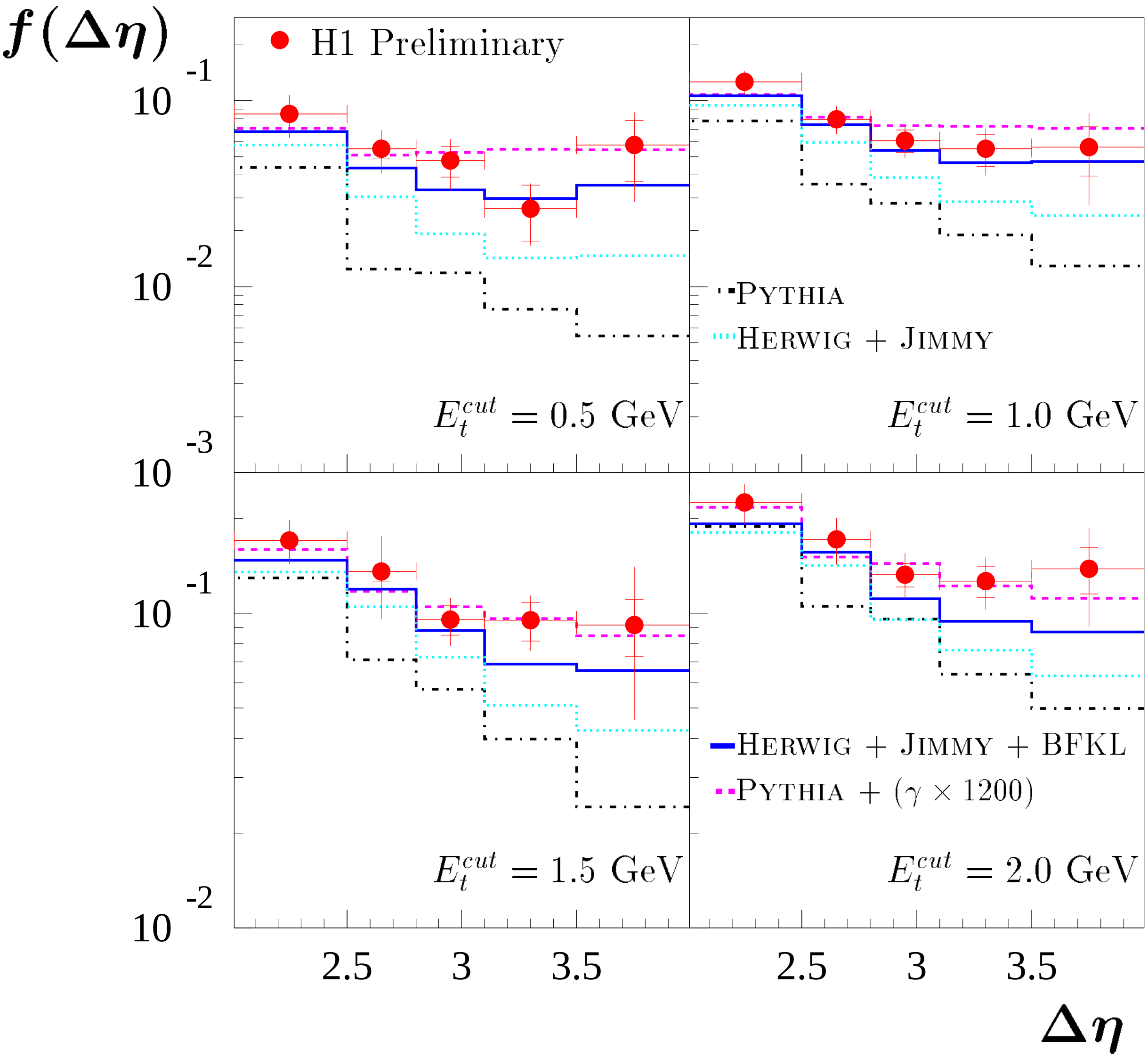


- Herwig 5.9 + JIMMY

  BFKL $\mathbb{P}$ $\alpha_s = 0.17$



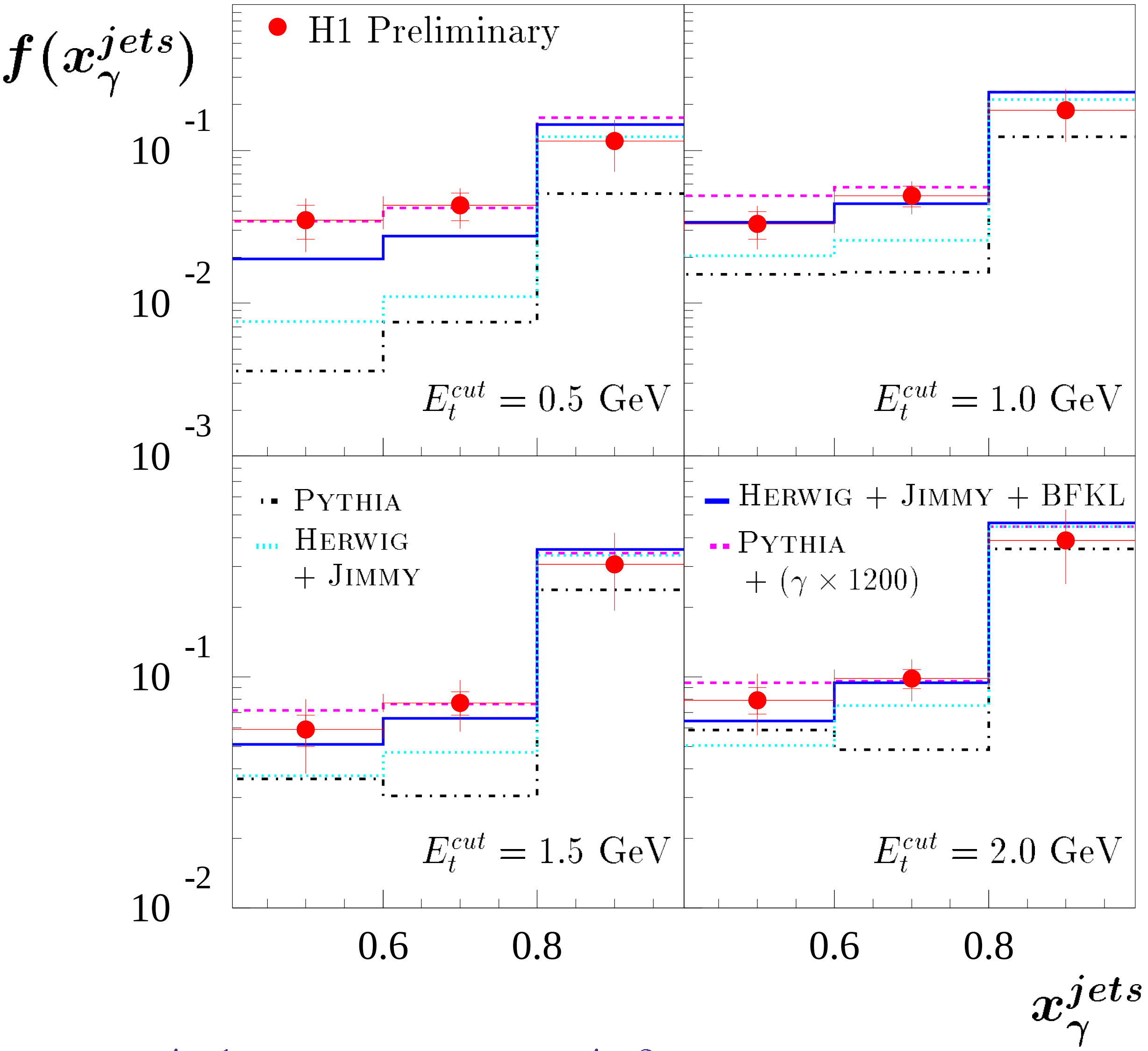
Gap Fraction Differential in $\Delta\eta$



$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$

- No sensitivity to underlying dynamics of colour singlet exchange process
- LO BFKL $\alpha_s = 0.17$ + HERWIG + JIMMY describes the data in normalisation and shape

Gap Fraction Differential in x_γ

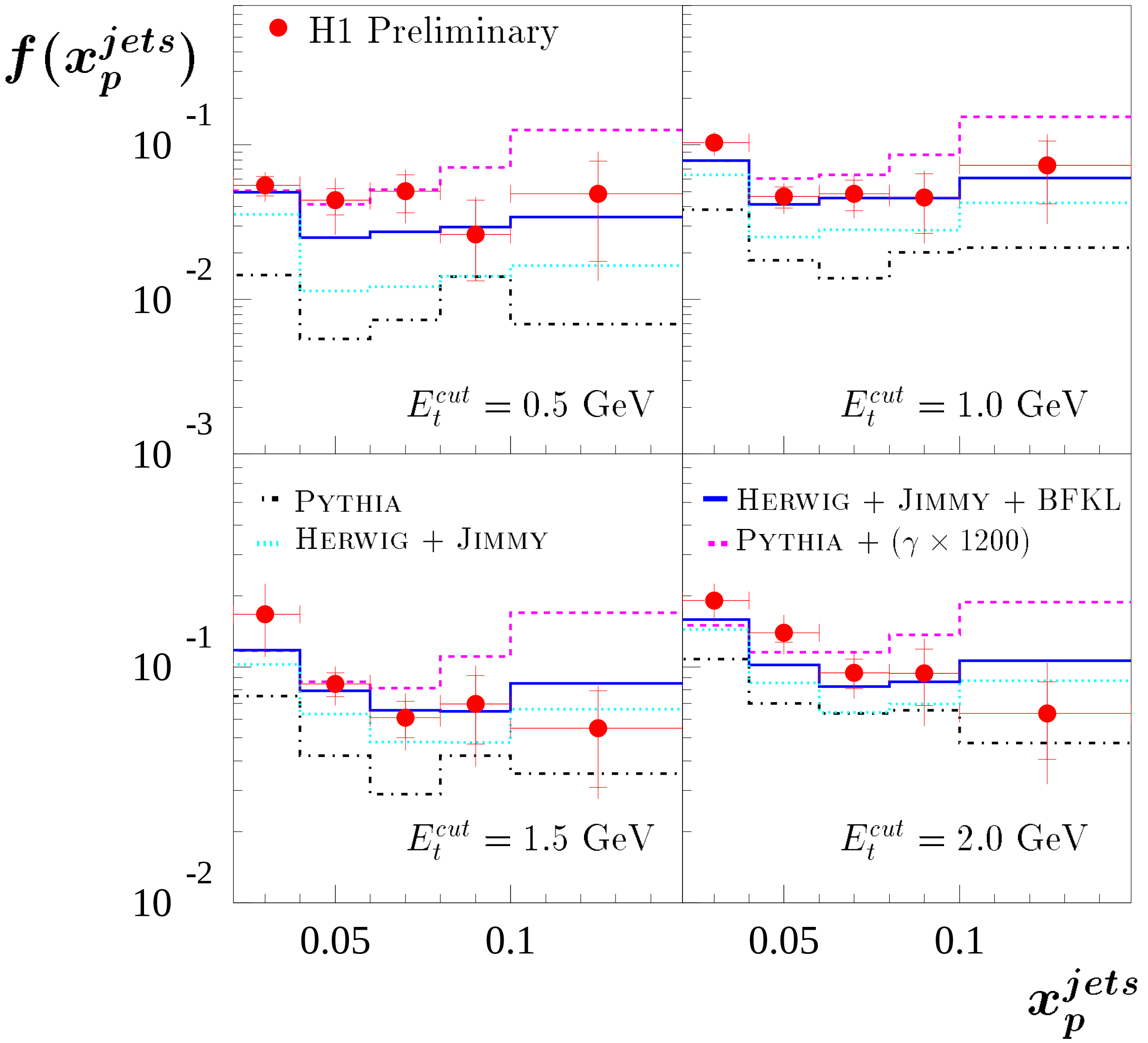


$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$

- 'Background' largely at high x_γ

  Direct events more likely to produce gaps

Gap Fraction Differential in x_p



$E_t^{jet1} > 6.0$ GeV , $E_t^{jet2} > 5.0$ GeV , $\Delta\eta > 2.5$

- Sensitive to underlying dynamics
  Difference between Pythia high-t γ and BFKL visible

Overall Conclusions

- Conclusive evidence of large excess of dijet events with low energy flow between the jets over that predicted by standard γp models at HERA

- x_p distribution is sensitive to models which couple primarily to gluons / quarks :
  Models which couple primarily to gluons favoured

- LO BFKL gives good description in both normalisation and shape for choice of
  $\alpha_s = 0.17$.
  !! although underlying event model also plays a significant role !!