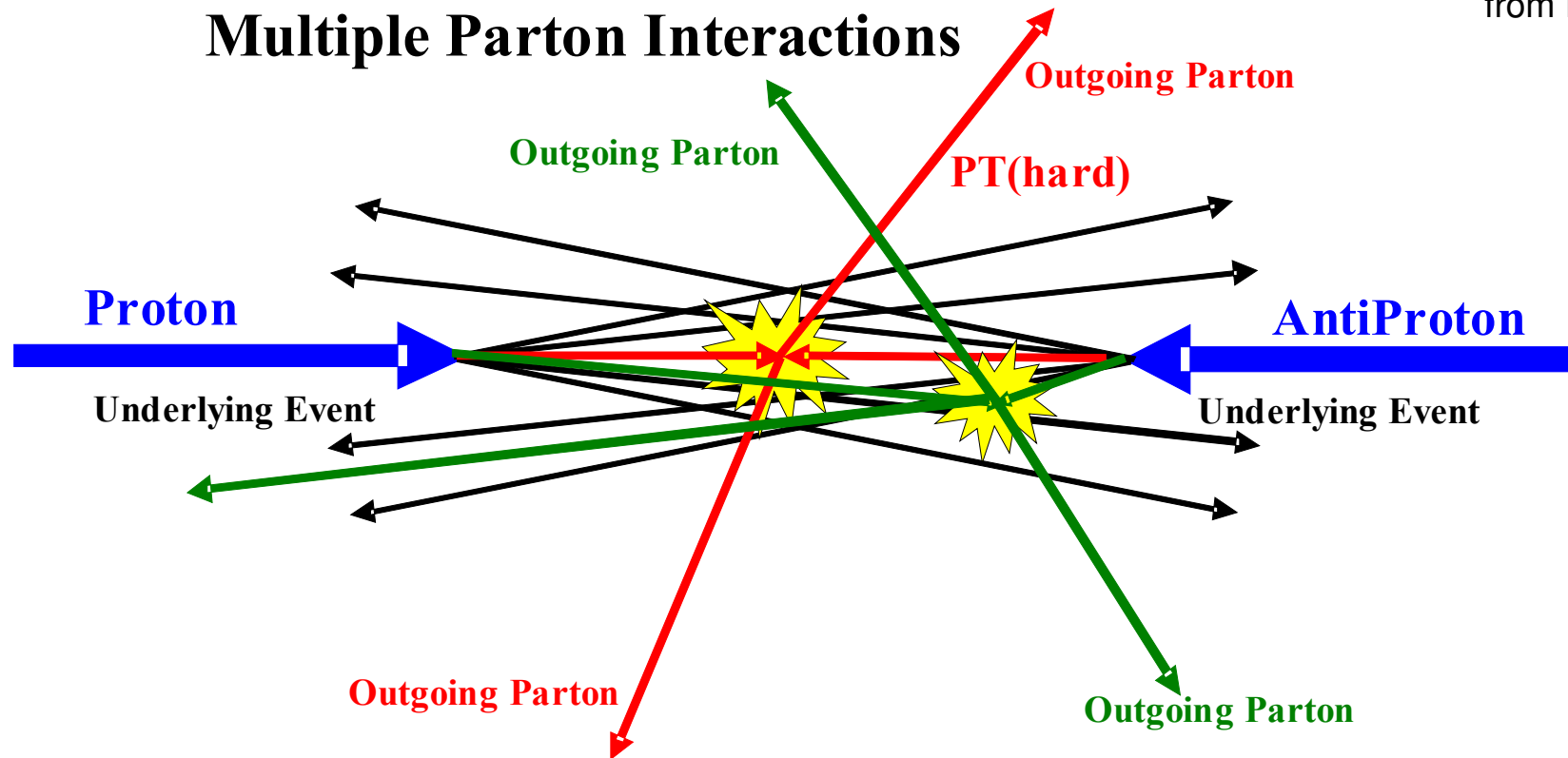


Multiple Interactions – why bother ?

- Why bother about Multiple Interactions ?
 - Experimental evidence:
 - HERA, Tevatron
- How-to better estimate contribution for LHC
 - Top mass determination, etc
- **How-to model MI ?**
 - What do available models reach ?
 - How-to improve ?
 - Which measurements at HERA are important to pin down contributions of MI ?
 -
- **Next steps – how to proceed**
- **Which contribution to HERA-LHC WS on 6-9 June ?**
- **Next mini-workshop**

Diffraction Saturation Multiple Interactions

from R. Field



What is the underlying event (UE), multiple parton interactions (MI)?

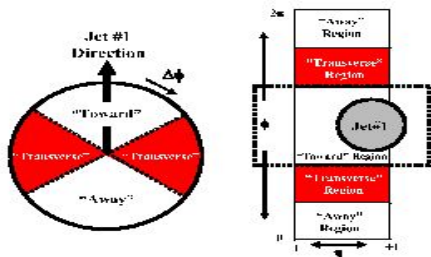
→ Everything, except the *LO* process we're currently interested in

- parton showers
- additional remnant – remnant interactions

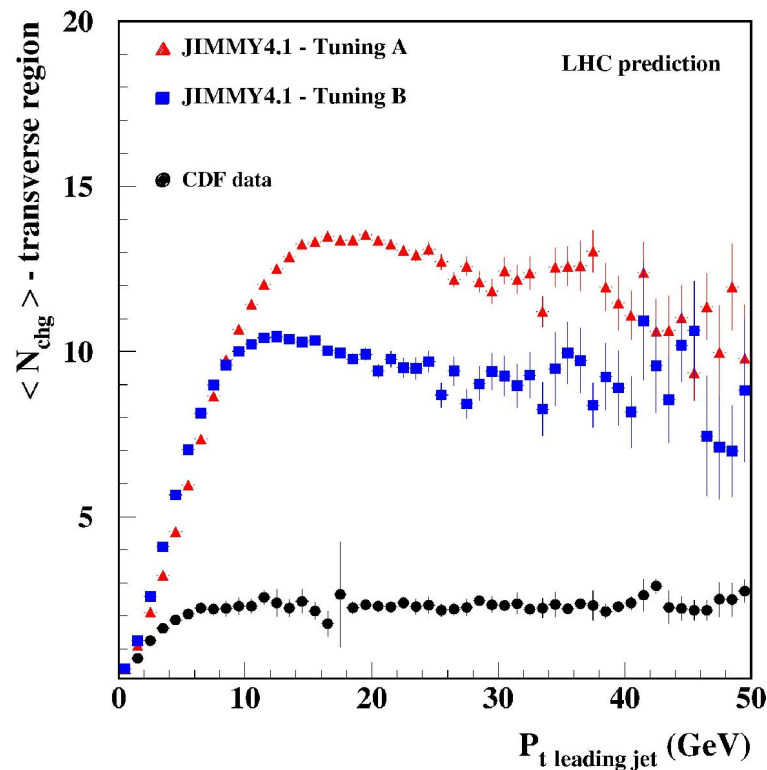
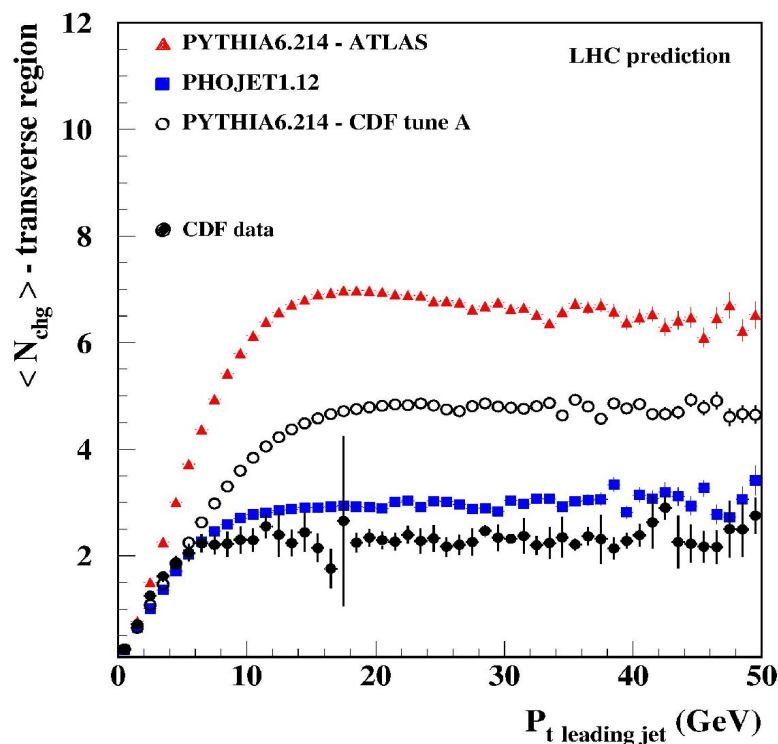
X NOT pile-up events (luminosity dependent)

Multiple Interactions at LHC

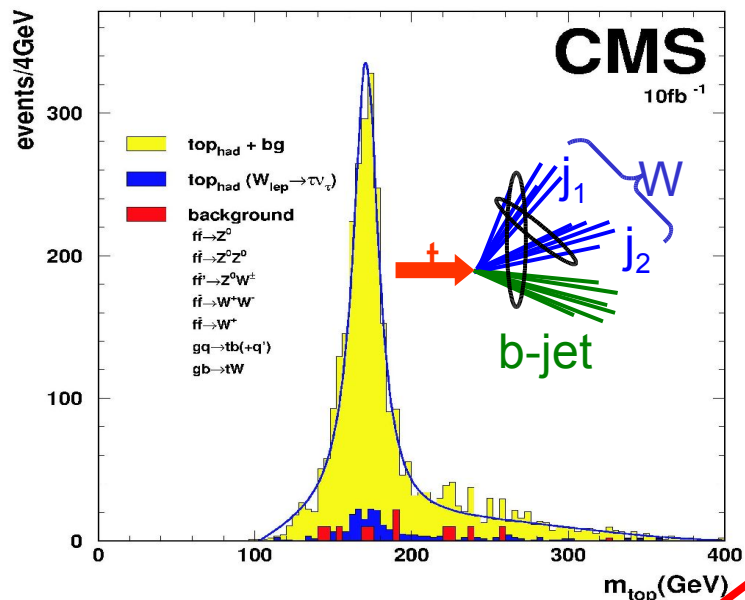
Charged multiplicities in transverse region C. Buttar et al



- Models tuned to TeVatron data
- ➔ give **HUGE** differences at LHC ...
- ➔ **better understand multiple interactions ...**



Multiple Interactions and top mass



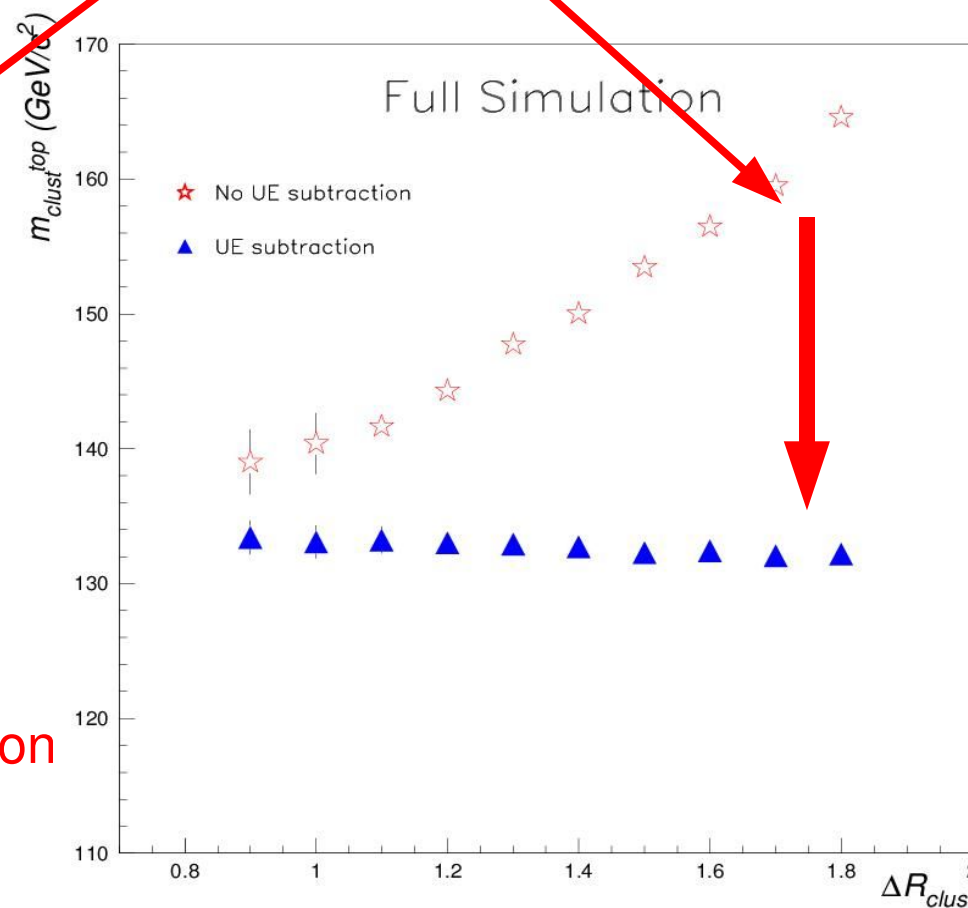
Source of error in GeV	Lepton+jets inclusive sample	Lepton+jets large clusters sample	Dilepton	All jets high pT sample
Energy scale				
Light jet energy scale	0.2	-	-	0.8
b-jet energy scale	0.7	-	0.6	0.7
Mass scale calibration	-	0.9	-	-
UE estimate	-	1.3	-	-
Physics				
Background	0.1	-	0.2	0.4
b-quark fragmentation	0.1	0.3	0.7	0.3
Initial state radiation	0.1	0.1	0.1	0.4
Final state radiation	0.5	0.1	0.6	2.8
PDF	-	-	1.2	-

hep-ex/0403021

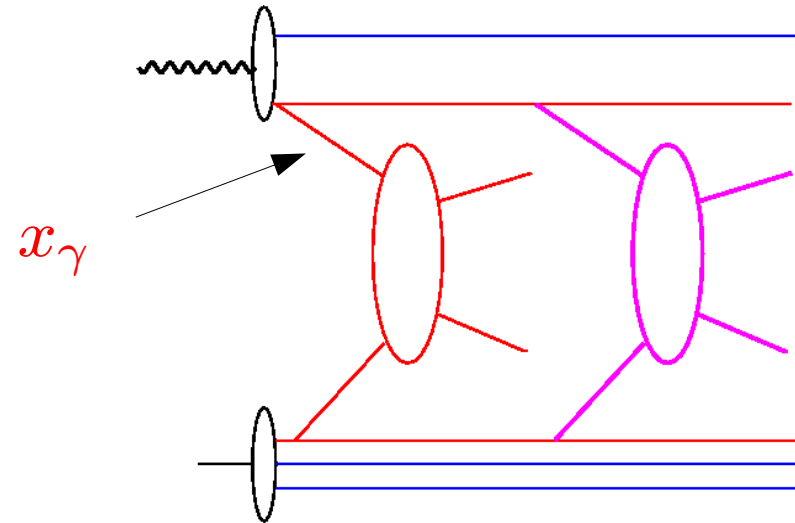
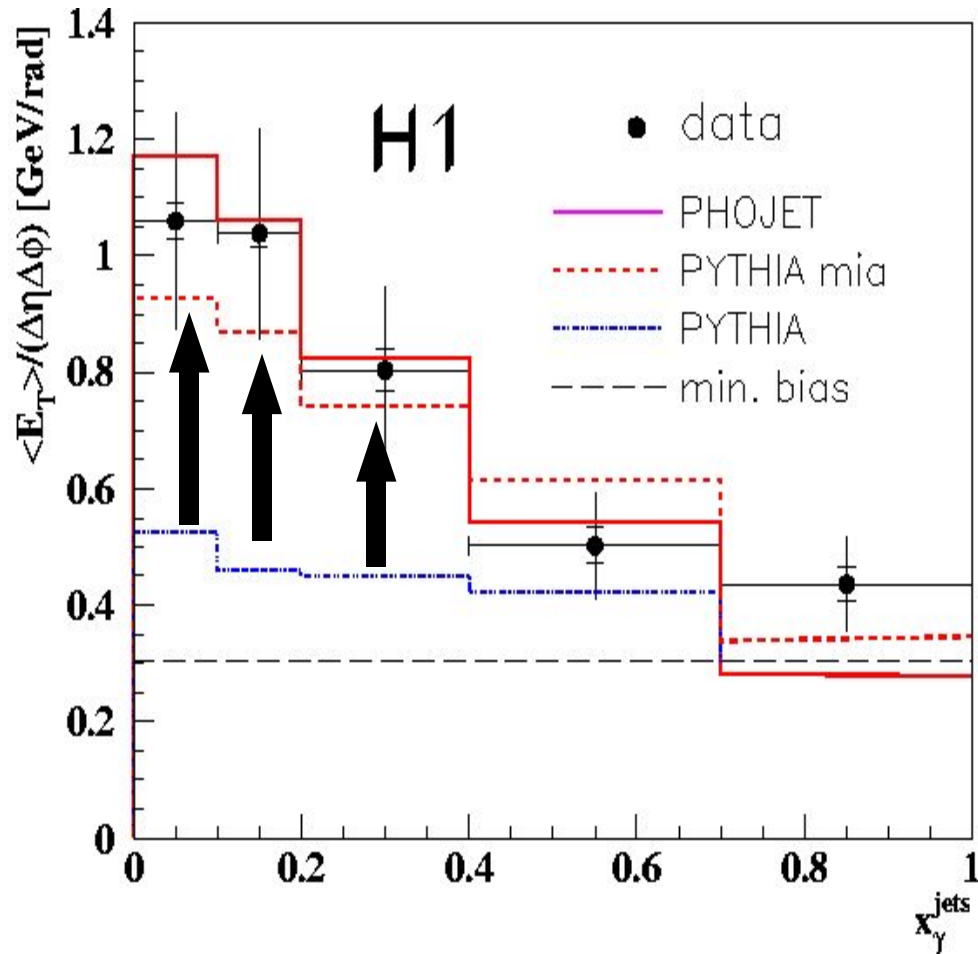
Are we sure ?

- Multiple Interactions
- Jet fragmentation properties, jet profiles
- Final state QCD radiation
- B-fragmentation

Significant effects on top mass determination
Better understand them !!!

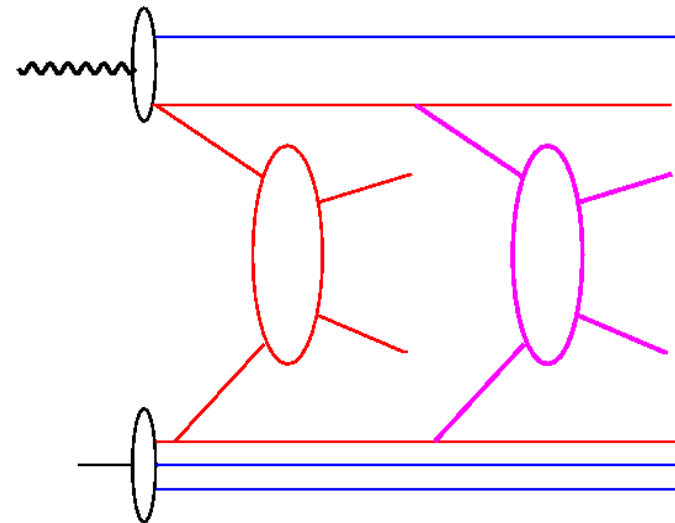
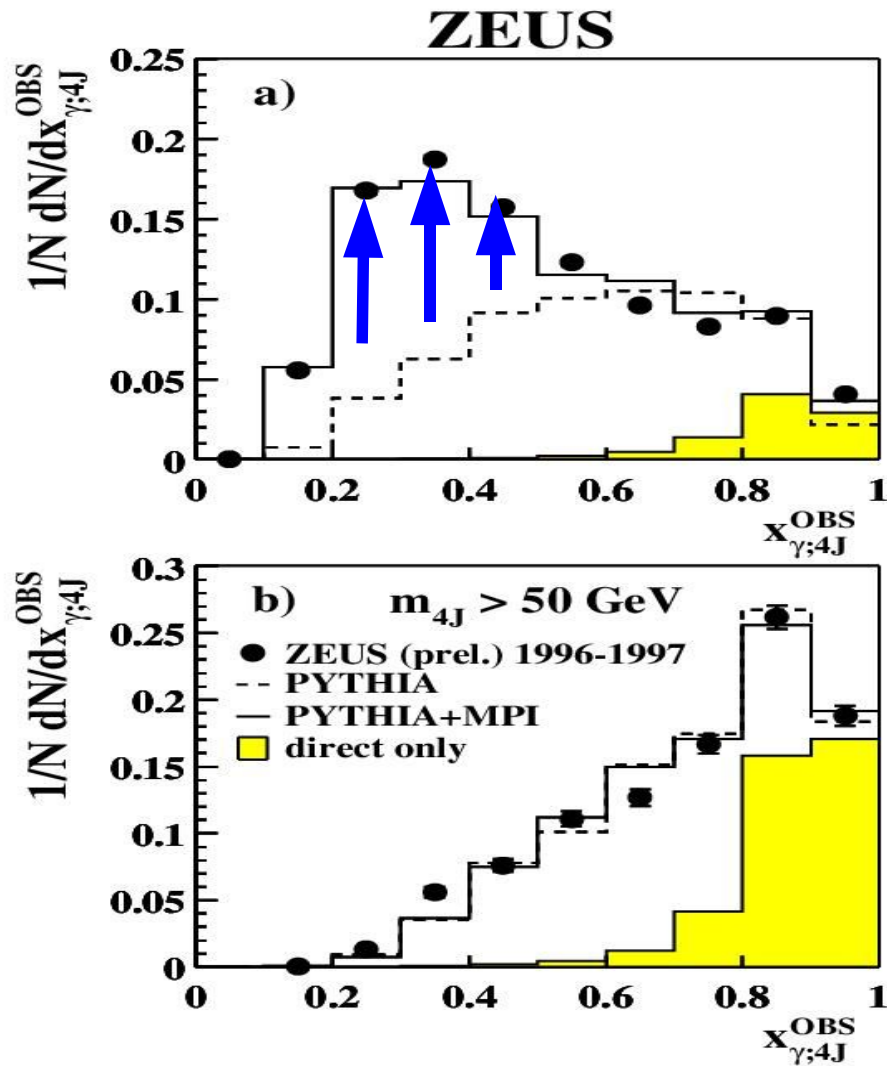


Multiple Interactions at HERA



photoproduction is effectively hadron-hadron production...
 Test and understand multiple interactions at HERA !!!

Multiple Interactions at HERA

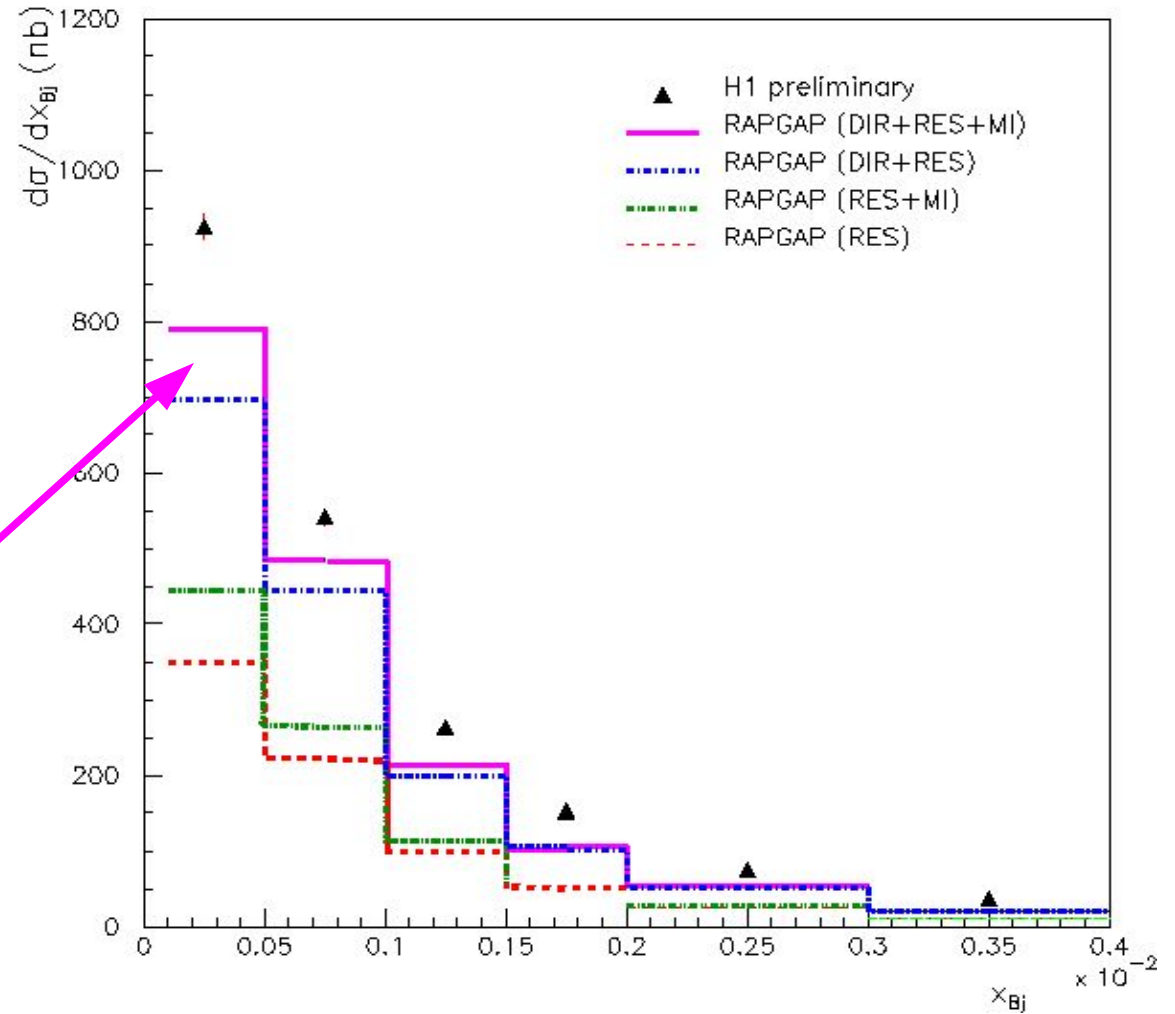
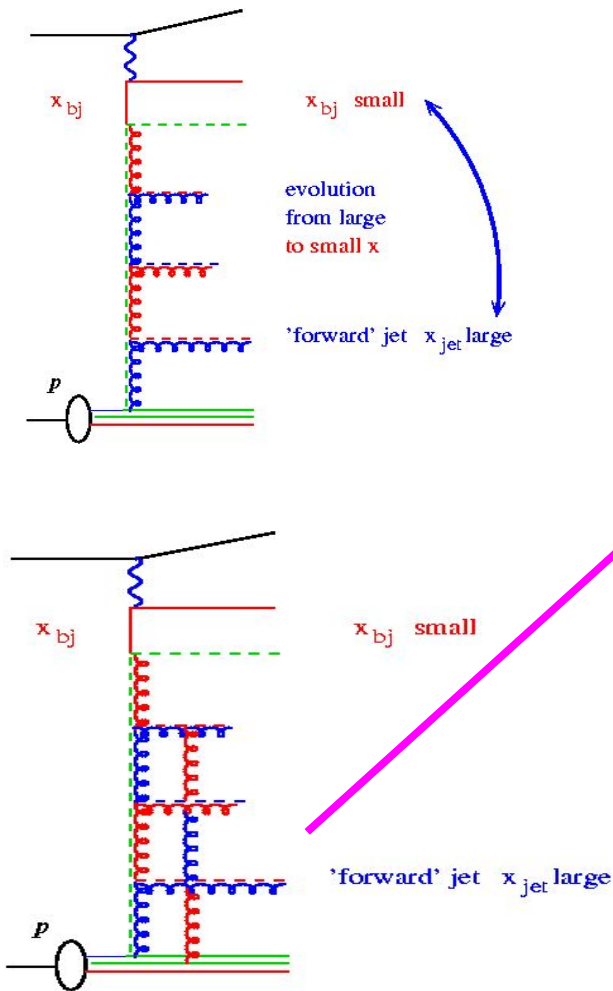


photoproduction is effectively hadron-hadron production...
 Test and understand multiple interactions at HERA !!!

Multiple Interactions at HERA

J. Turnau, L Lönnblad

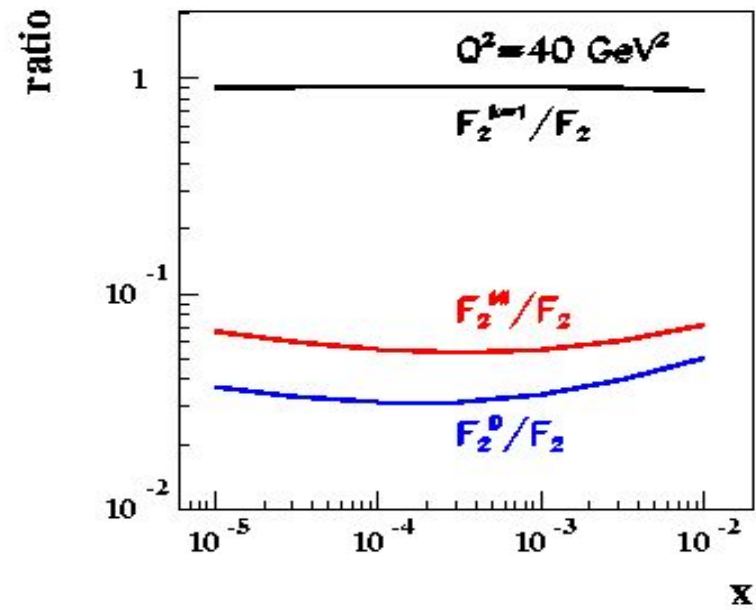
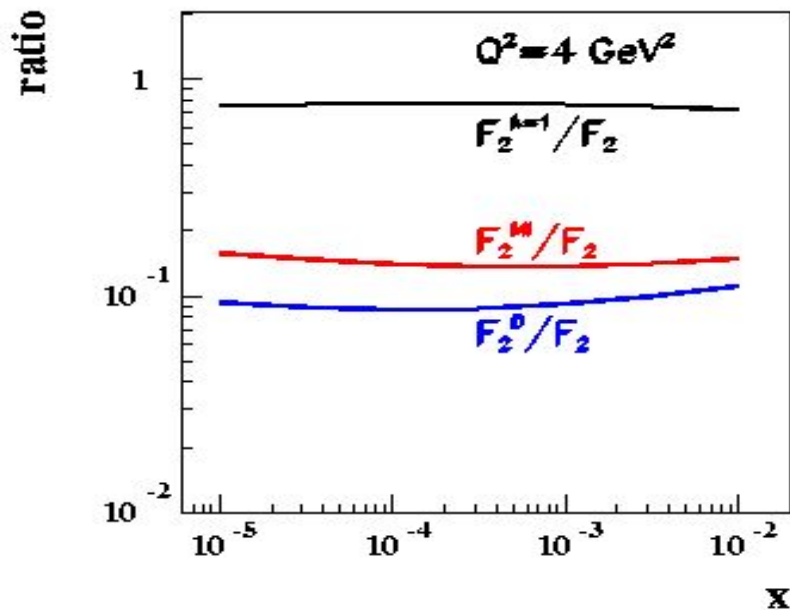
- forward jet production



- multiple interactions also in DIS forward jets at large Q^2 ?

Multiple Interactions in F_2

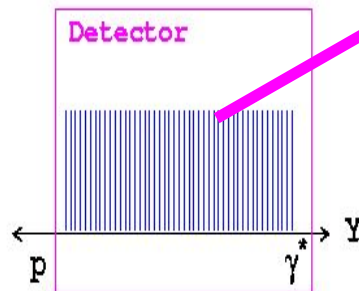
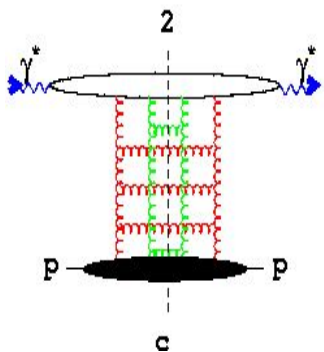
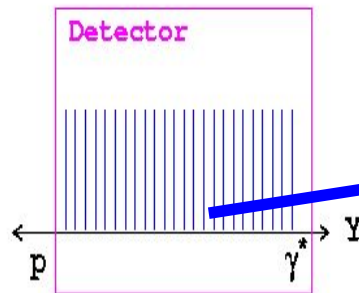
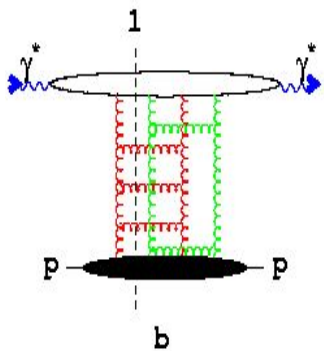
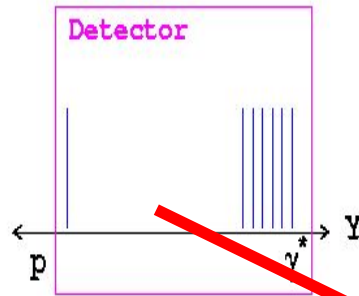
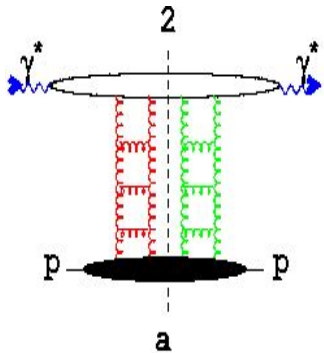
from H. Kowalski



- Color dipole model predict a large contribution of MI to F_2
- of similar size as **diffraction**
- Need to understand that ... AGK cutting rules in QCD and all that

Towards understanding of MI

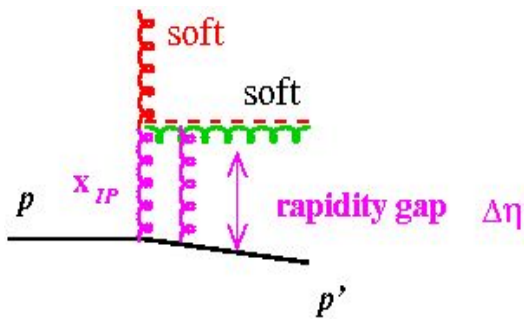
Bartels, Kowalski, Sabio-Vera



- Cutting rules (AGK) extended to QCD
- Relate **diffraction**, saturation and **multiple scatterings**
- All from the same amplitude, but different factors:
 - **+1 Diffraction**
 - **- 4 Saturation**
 - **+2 Multiple Interactions**
- Extended now also to pp !!!!
- further work needed ...
- ➔ **HERA is the place to understand MI !!!!**
(TeVatron to tune MC !!!)
- ➔ **Towards the description of "everything" !!!!!**

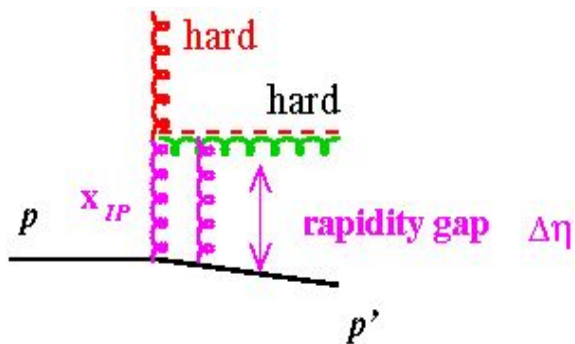
Diffraction and MI

- soft IP \longleftrightarrow soft, underlying events

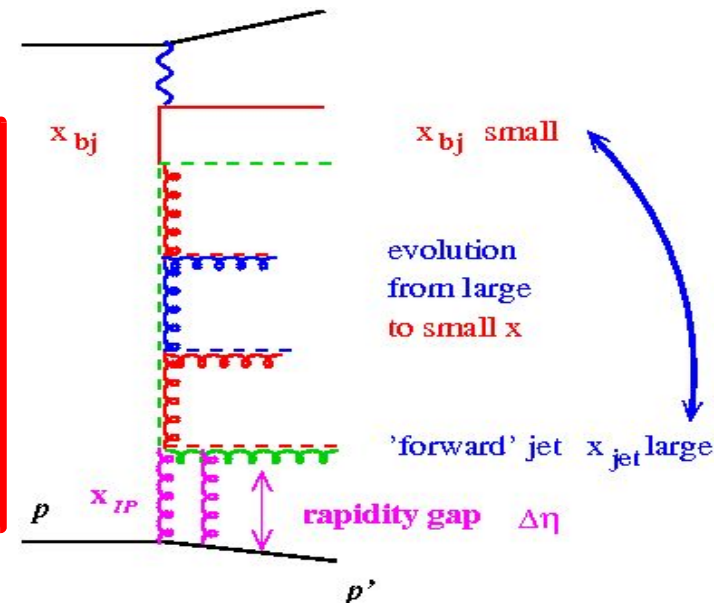


- diffraction is in initial condition
- start Q^2 evolution from Q_0
- DGLAP of F2D3 etc...

- hard IP \longleftrightarrow hard multiple interaction



- hard perturbative 2gluon exchange
- hard jet close to rapidity gap
- NOT included in DGLAP
- lead to high p_t multi-jets



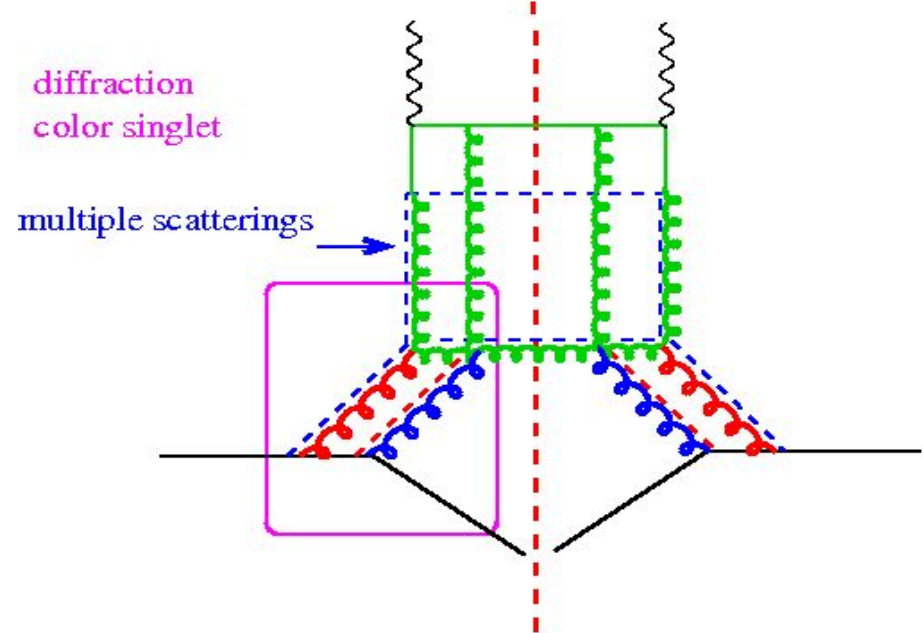
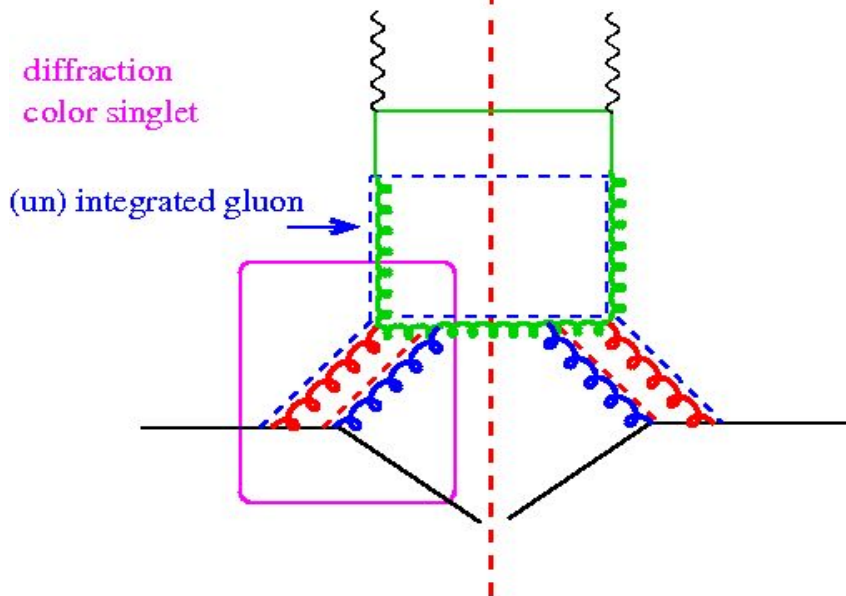
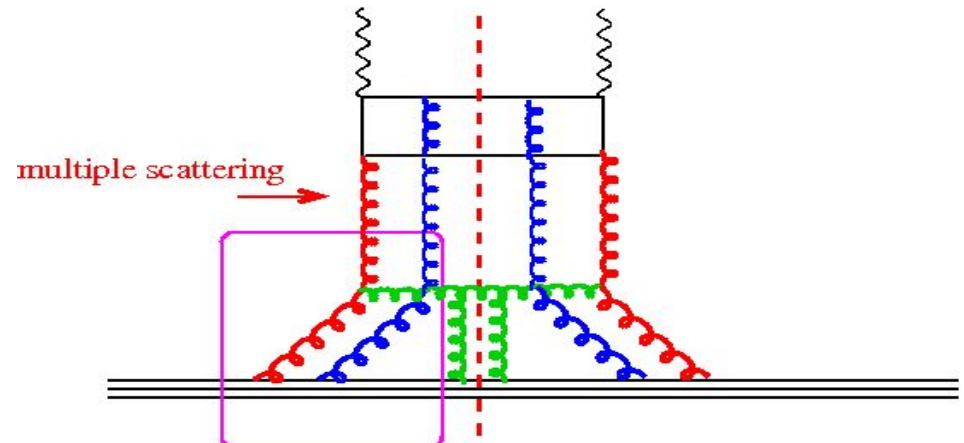
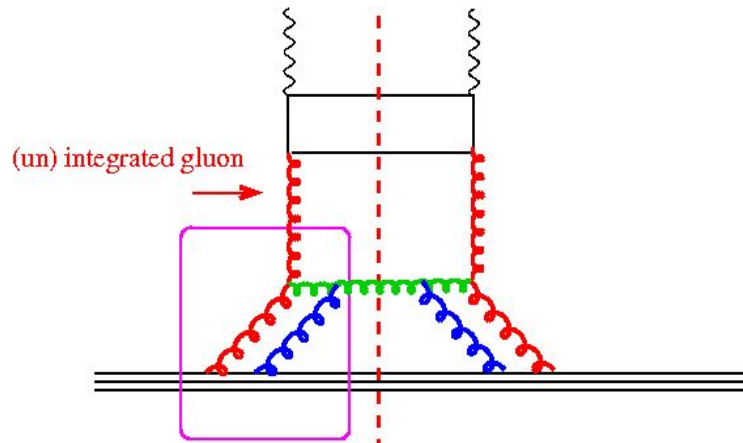
Measurements

- multijet events:
 - dijets in gamma-p and DIS
 - soft underlying events
 - remnant remnant rescatterings
 - factorisation breaking in diffraction
 - 3-4 jets in gamma-p and DIS
($\sigma_{4 \text{ jets}} \sim \mathcal{O}(100 - 600 \text{ pb})$)
 - hard multiple scatterings
 - angular and energy correlations between jets
 - jet – shapes, energy flows
- diffraction:
 - forward jets
 $\sigma_{\text{fwdjet}}^{\text{diff}} > 3 \text{ pb}$
 - contributions from pert. 2-gluon exchange
 - jet – shapes, energy flows

Next steps

- What can be achieved until end of the year and next year for LHC start ?
- Which measurements are needed at HERA ?
- Which measurements are need at LHC including detector upgrade ?
 - Instrument forward region $5 > \eta > 11$?
- **Who can do what, until when ?**
- Next mini-workshop ?

Understanding diffraction



Underlying event – Multiple Interaction

- Basic partonic perturbative cross section

$$\sigma_{\text{hard}}(p_{\perp\text{min}}^2) = \int_{p_{\perp\text{min}}^2} \frac{d\sigma_{\text{hard}}(p_{\perp}^2)}{dp_{\perp}^2} dp_{\perp}^2$$

- diverges faster than $1/p_{\perp\text{min}}^4$ as $p_{\perp\text{min}} \rightarrow 0$ and exceeds eventually total inelastic (non-diffractive) cross section, resulting in more than 1 interaction per event (multiple interactions, MI).
- Average number of interactions per event is given by:

$$\langle n \rangle = \frac{\sigma_{\text{hard}}(p_{\perp\text{min}})}{\sigma_{nd}}$$

- It depends how soft interactions are treated, **BUT** also on the parton densities and factorization scheme !!!!!!!!