Modeling of diffraction and min bias & UE

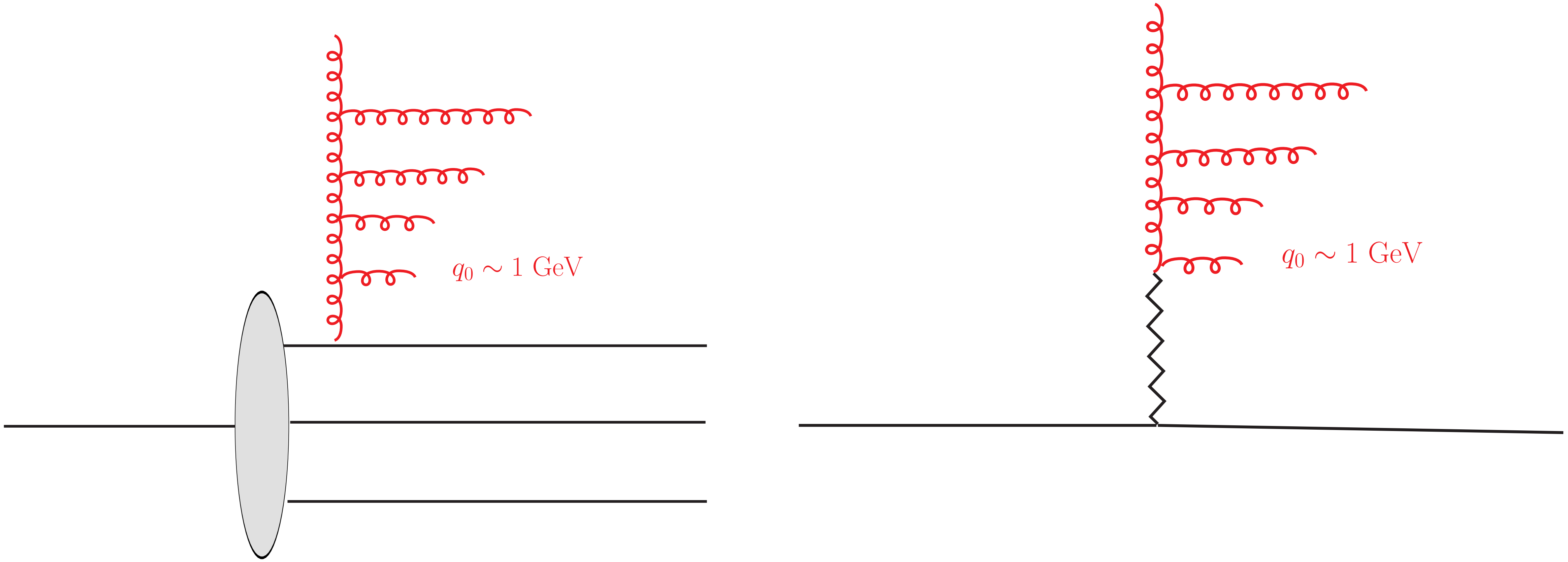
- hard diffraction and diffractive pdfs
  - diffraction at HERA
- how to relate diffraction at HERA with LHC
  - gap survival and multiple interaction
- importance to non diffractive processes

diffractive PDFs

- factorisation theorem of Collins et al (J. Collins Phys.Rev.D57:3051-3056,1998, Erratum-ibid.D61:019902,2000)

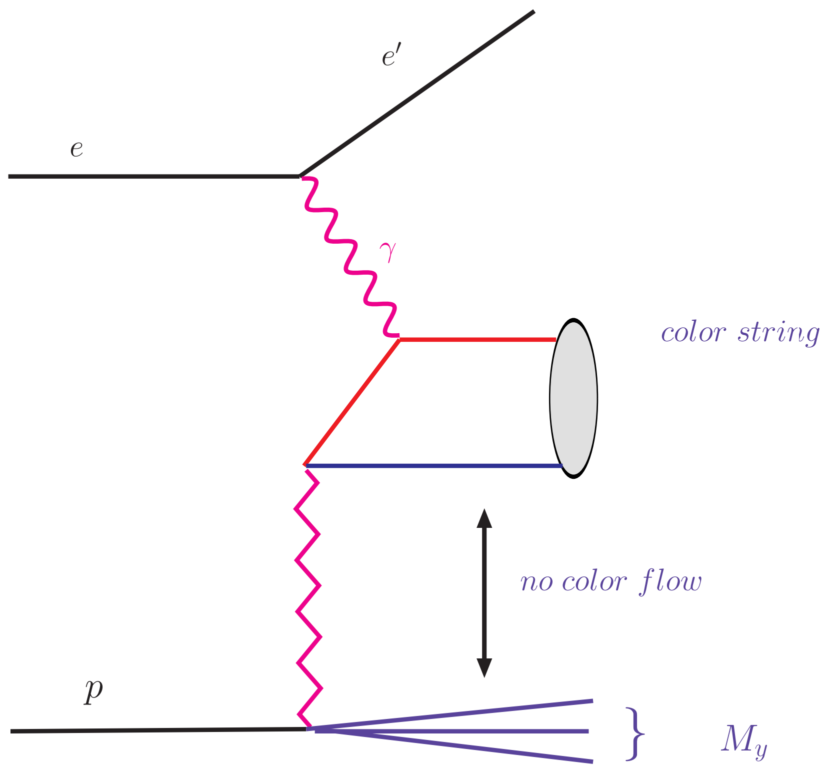
$$d\sigma = \sum_i \int d\xi f_i^{(D)}(\xi, x_{pom}, t; \mu) d\hat{\sigma}_i + \text{non} - \text{leading power of } Q$$

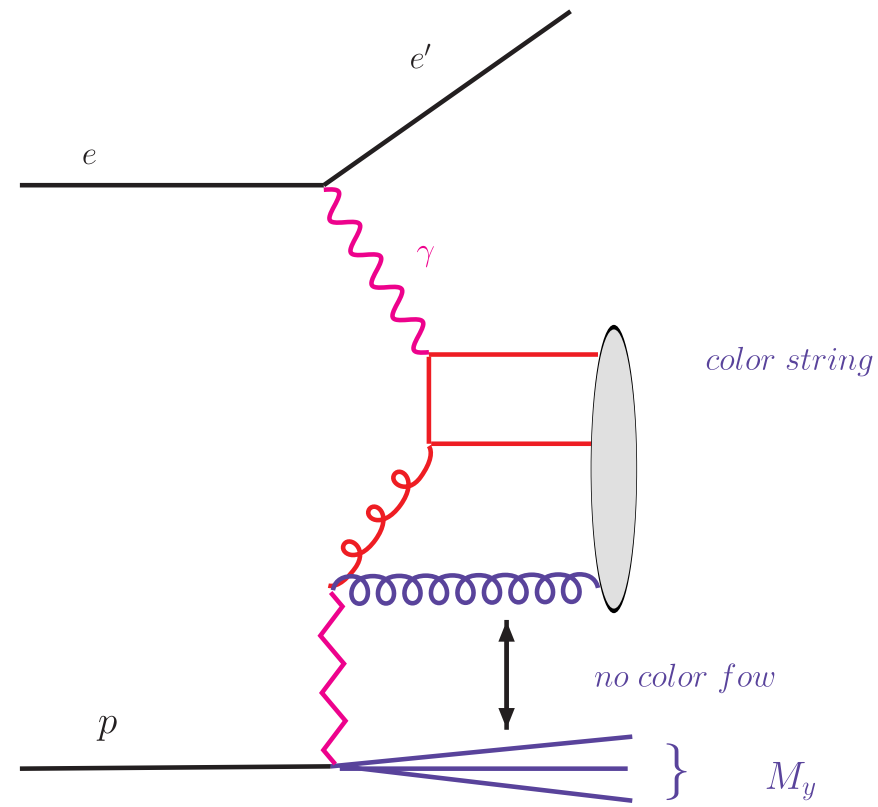
- dPDFs obey same Q2 evolution as usual PDFs
- diffraction is included in the initial condition of the PDF



Diffraction at HERA in DIS

- Simulation of hard scattering:





- hard scattering consists of: with a hard scale set by Q^2, p_t^2, etc

$$\begin{array}{lcl} \gamma^* q & \rightarrow & q \\ \gamma^* q & \rightarrow & qg \\ \gamma^* g & \rightarrow & q\bar{q} \end{array}$$

- parton densities: diffractive pdfs: $xq(x, \xi, \mu^2)$
- initial and final state parton shower ala DGLAP: PYTHIA like virtuality ordered
- dissociation of low mass diffractive system including all resonances

Hard diffraction and non-diffraction in ep

- Diffractive contribution is already implicitly included in parton densities.
- Inclusive di-jets include already diffractive di-jets
- How is it done in MC
  - in DIS we know how to do it (we have factorisation theorem for hard diffraction in DIS)
  - calculate diffractive x-section

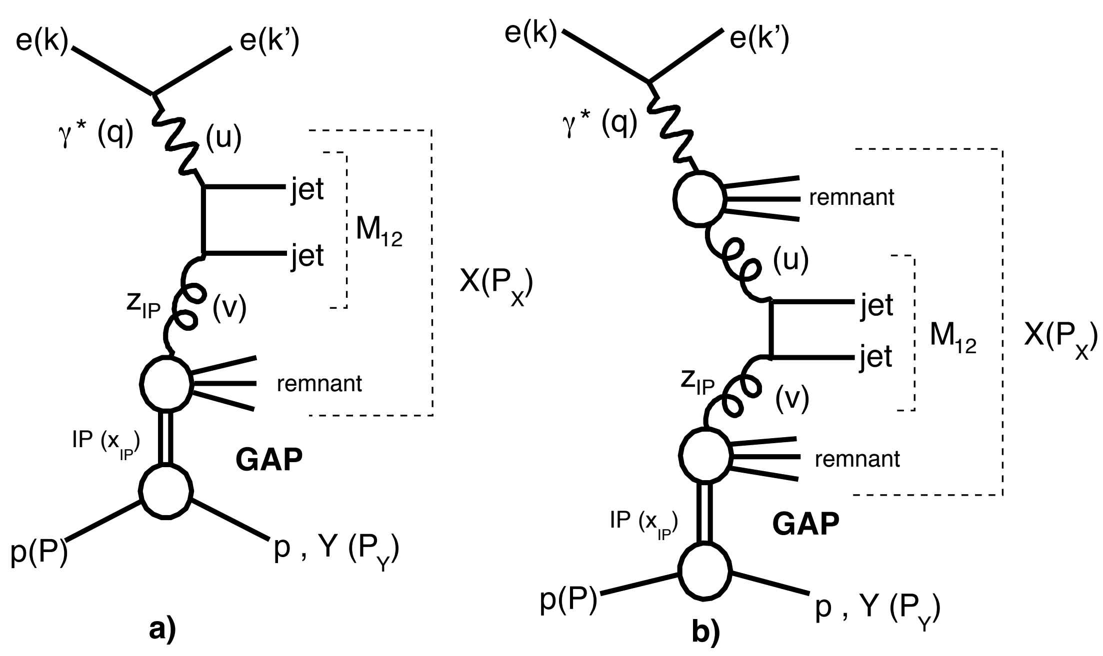
$$F_2(x,Q^2)^{non\ diff} = F_2(x,Q^2) - \int d\beta F_2^D(x_{pom},\beta,Q^2)\delta(x_{pom}\beta - x)$$

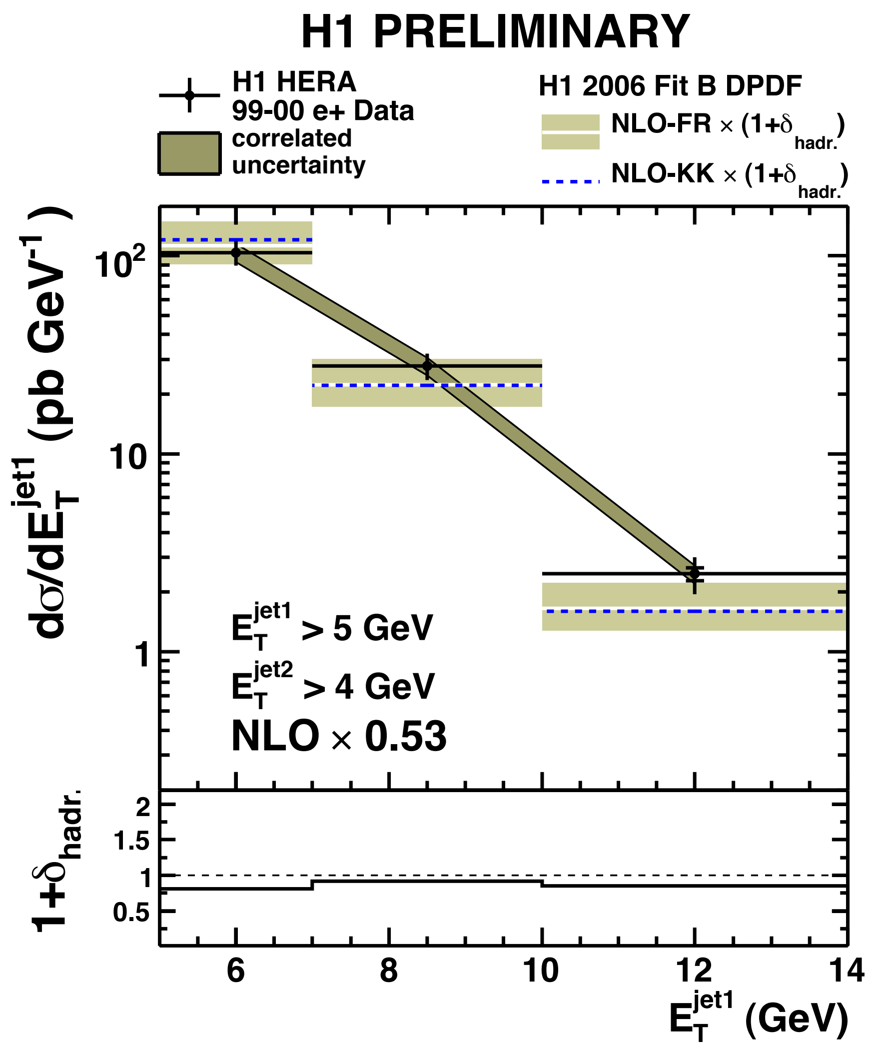
- calculate inclusive x-section
  - decide whether to generate diffractive or non-diffractive process
  - generate all lowest order and order alphas processes
  - perform parton shower and remnant fragmentation

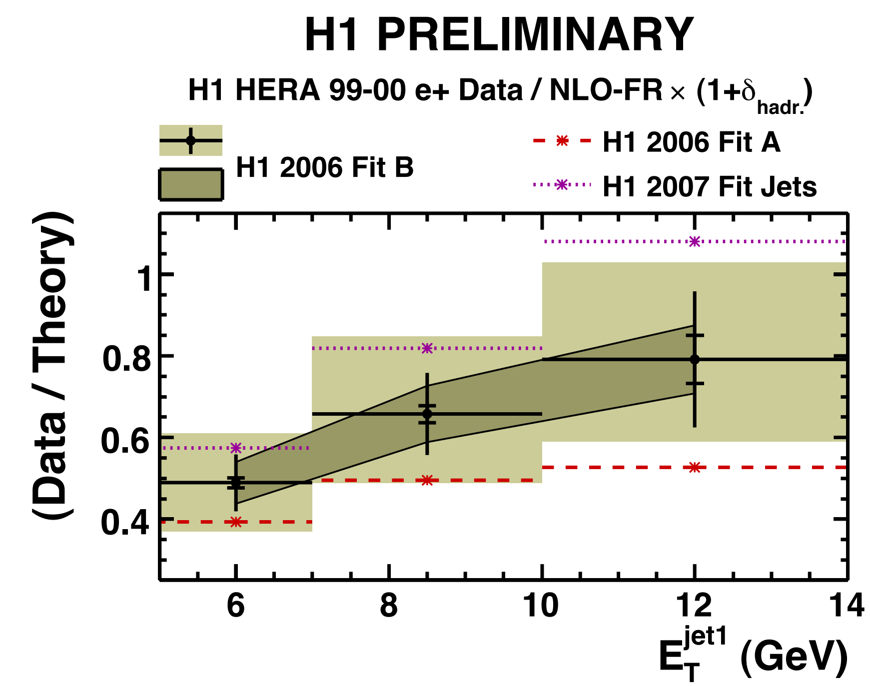
☑ no double counting
☑ correct mix of diffractive and non-diffractive events are obtained
☑ correct according to factorisation theorem

From DIS to pp

- photon has a hadronic component
- bridge form DIS to pp







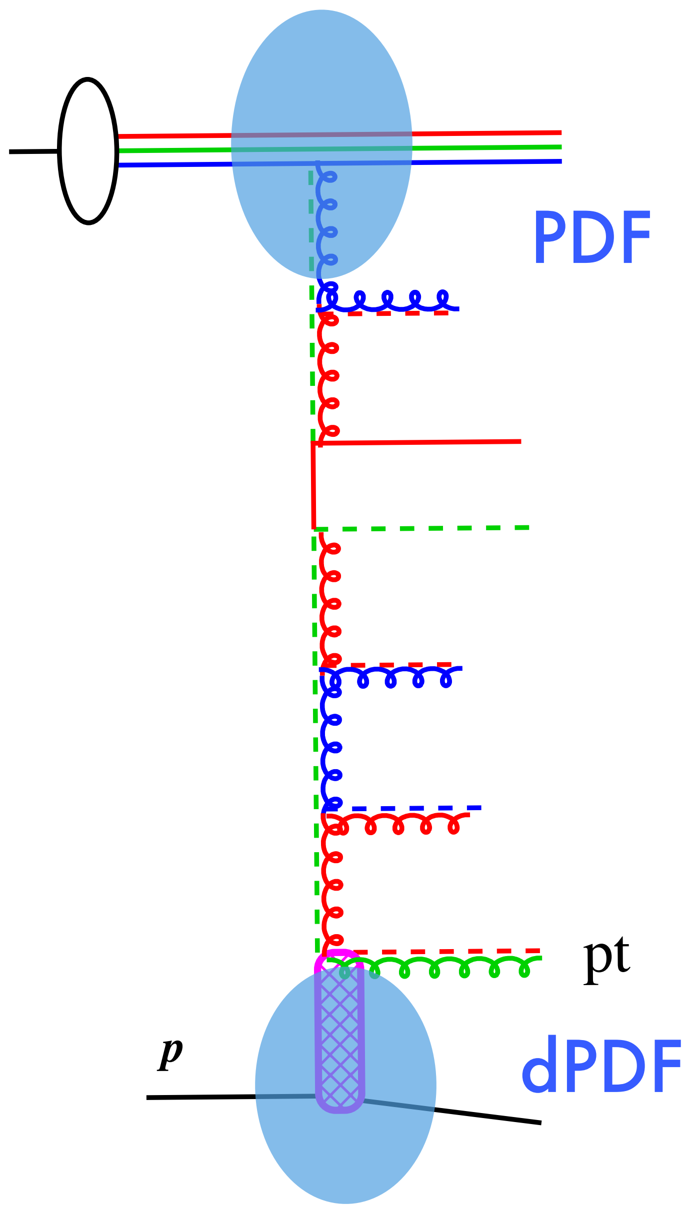
- observe factorisation breaking with NLO
- beware: there is an issue on NLO calc and the prediction of LO+PS MCs...
  - LO+PS MCs (RAPGAP) does describe both DIS and photoprod.
- there could be issues on initial and final state parton showering....

Diffraction in pp

- Assume same dPDFs as in DIS
- convolute with standard hard processes

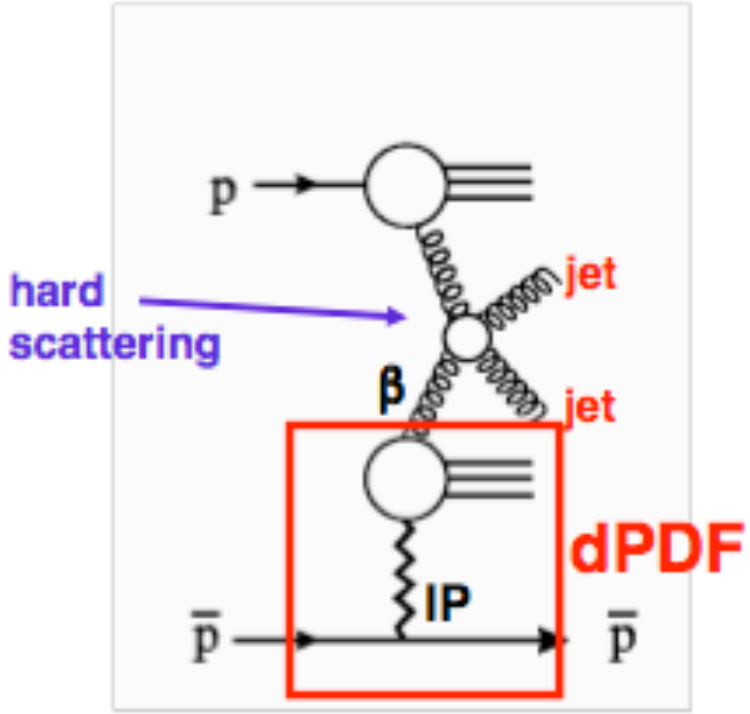
- Issues on hard diffraction in ep and pp
  - how well do we understand the diffractive remnant ?
    - details of remnant determine the rapidity gap
    - details of remnant determine colour flow
    - what is the pt of the remnant ?
      - non-pert. or hard ?

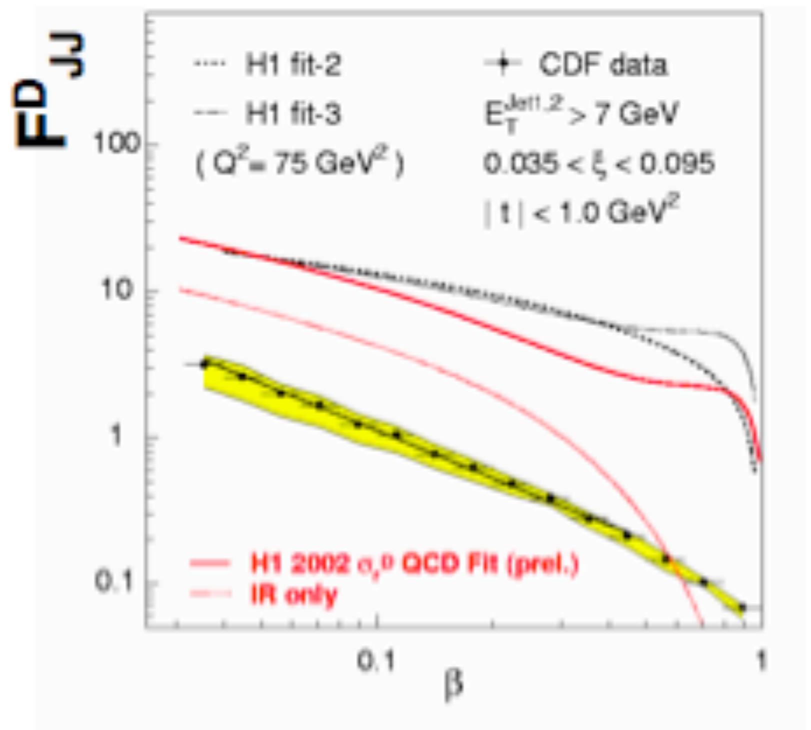
    - how well do we understand the parton shower ?



Diffraction in pp

- Proper mixing of hard diffraction and non - diffraction is also needed in pp
  - BUT ... we have factorisation breaking in pp



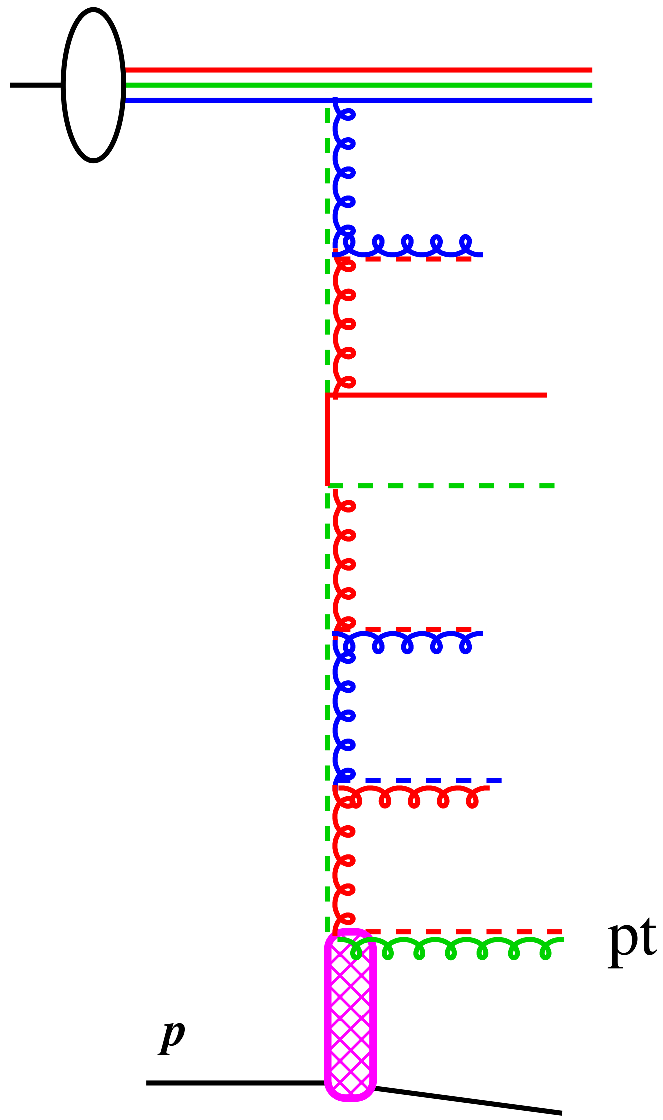


Normalisation discrepancy (x10)
(lots more evidence available !)

- How can we properly generate diffraction and non-diffraction without double counting and violation of factorisation ansatz ?

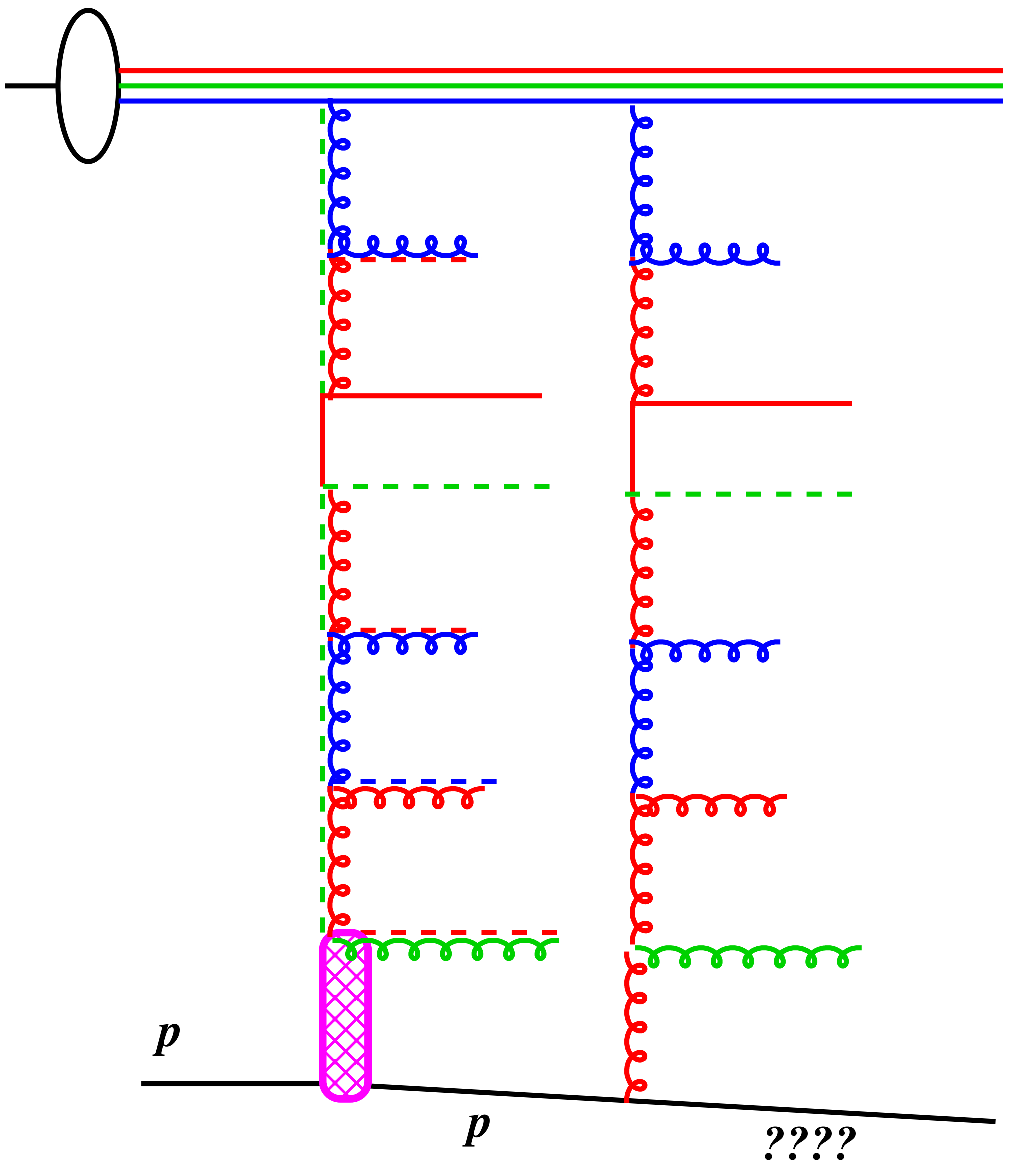
Multiparton interaction and diffraction

- Assume factorisation for every single chain
- use dPDF and inclusive PDFs on same footing



Multiparton interaction and diffraction

- Assume factorisation for every single chain
- use dPDF and inclusive PDFs on same footing
- Multiparton interaction including diffractive processes
- Where is rescattering happening ?
  - multi-parton scattering between remnant and leading proton
    - can be simulated, since secondary scattering happens on a proton ...
    - does it depend on the order of the scatterings:
      - 1st diffraction,
      - 2nd non-diffraction ?
- HOWEVER: this is not implemented it any Monte Carlo for multiparton interaction



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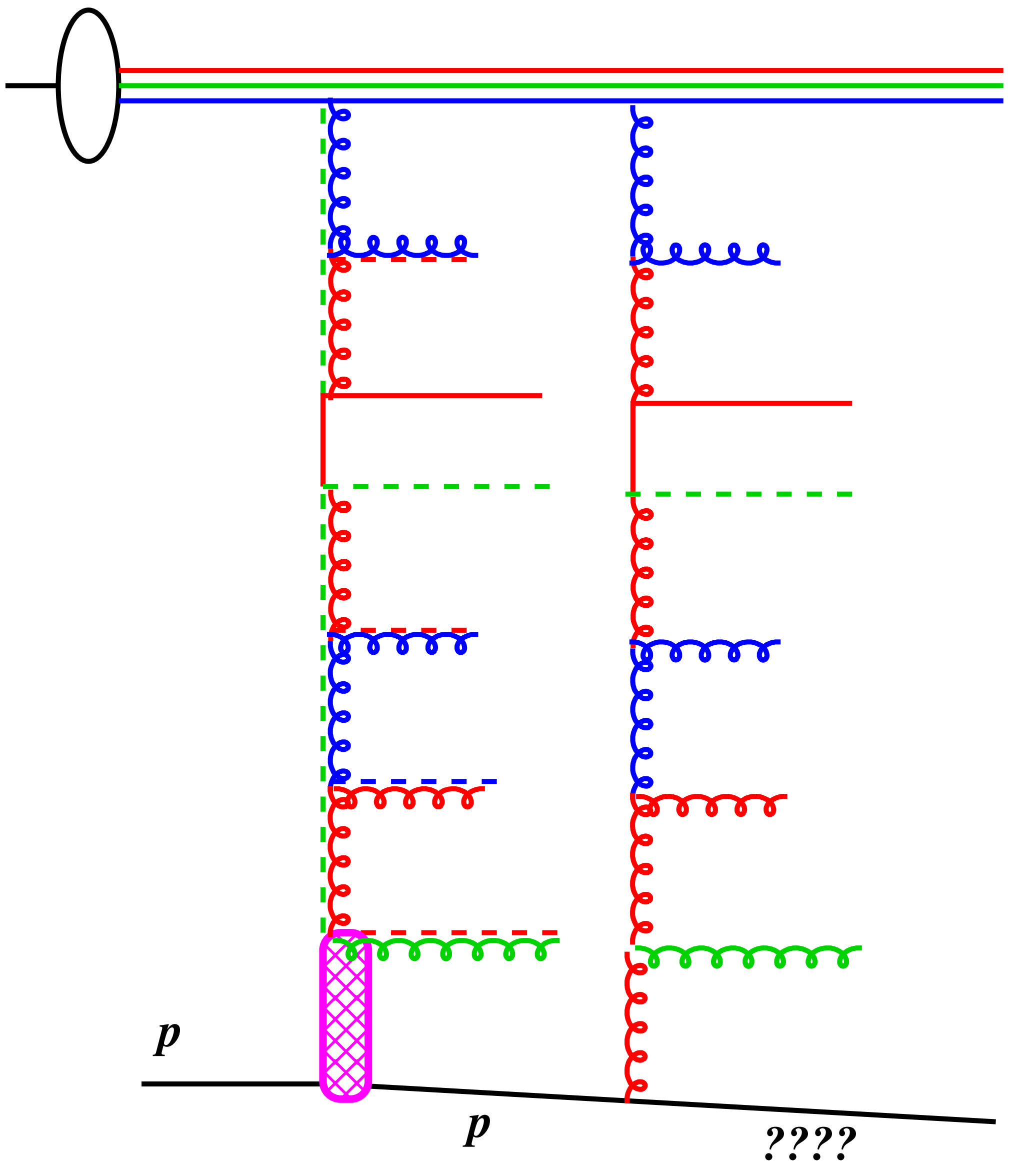

This is not only relevant for diffraction but also for energy flow and particle multiplicities in non-diffractive events

Multiparton interaction and diffraction

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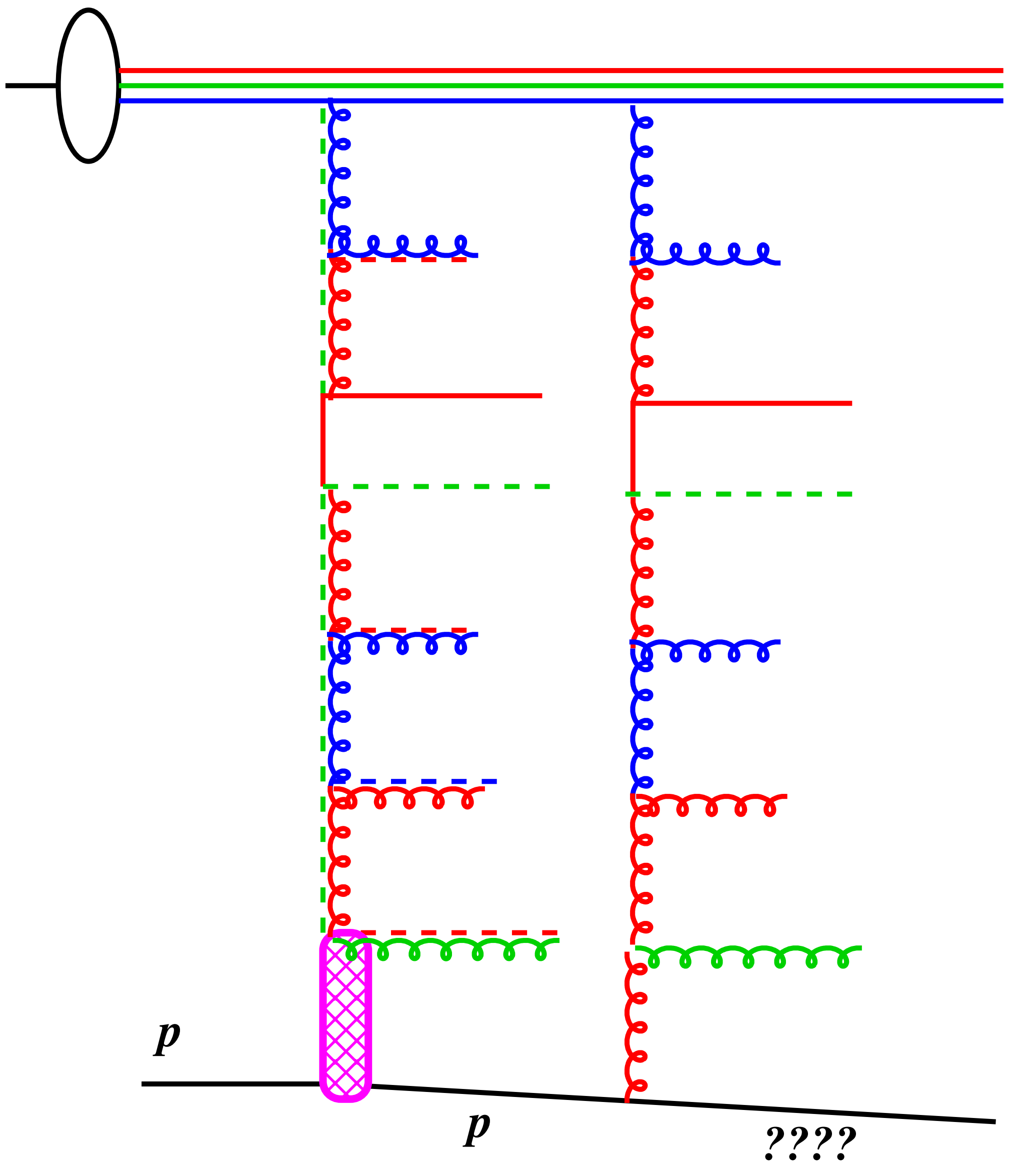
- **examples:**
  - *energy flow in forward region*
  - *particle multiplicity vrs average pt (in UE studies)*



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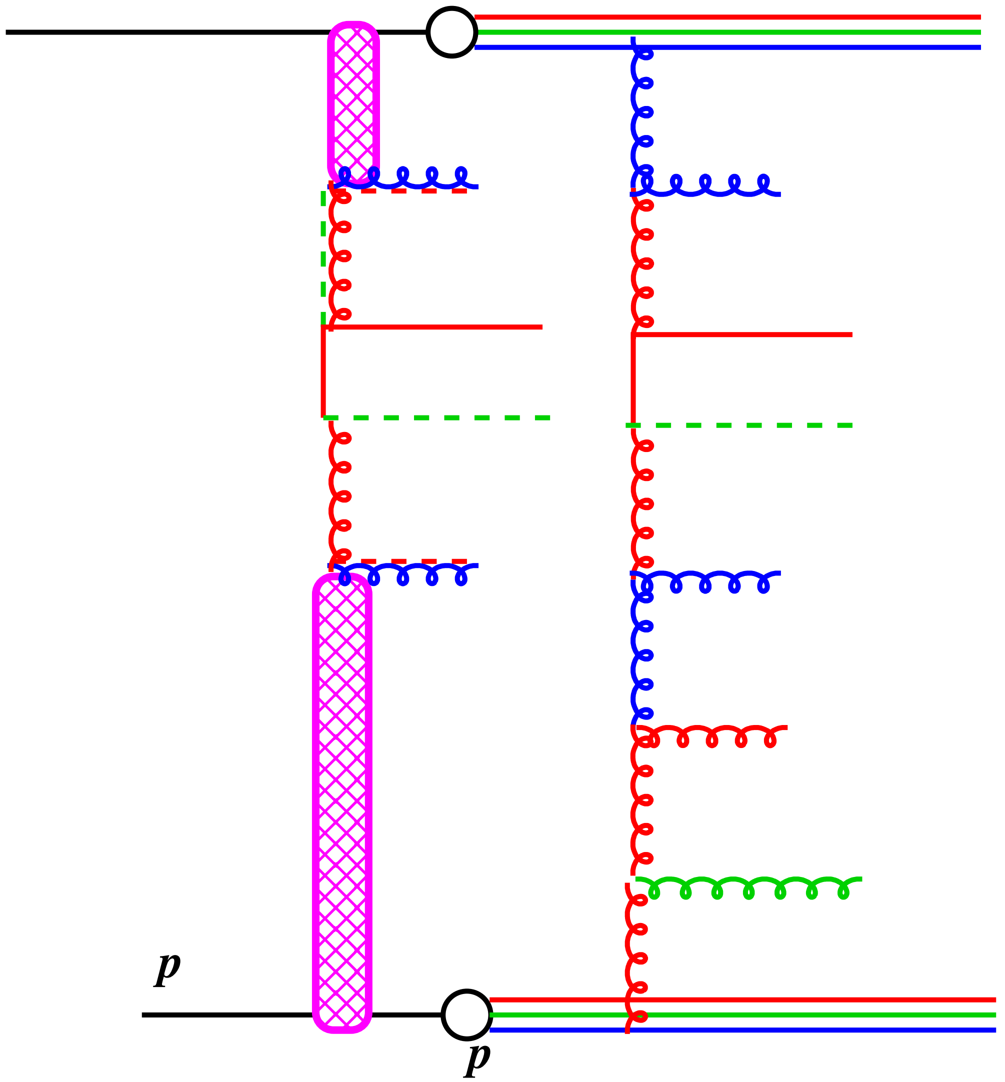
Multiparton interaction and diffraction

- **Assume** factorisation for every single chain
- use dPDF and inclusive PDFs on same footing
- Multiparton interaction including diffractive processes
- **examples:**
  - *energy flow in forward region*
    - *gap survival probability will change*
    - *transverse energy flow will change*
  - *particle multiplicity vrs average pt (in UE studies)*
    - *multiplicity in central region will change*



This is not only relevant for diffraction but also for energy flow and particle multiplicities in non-diffractive events

Conclusions

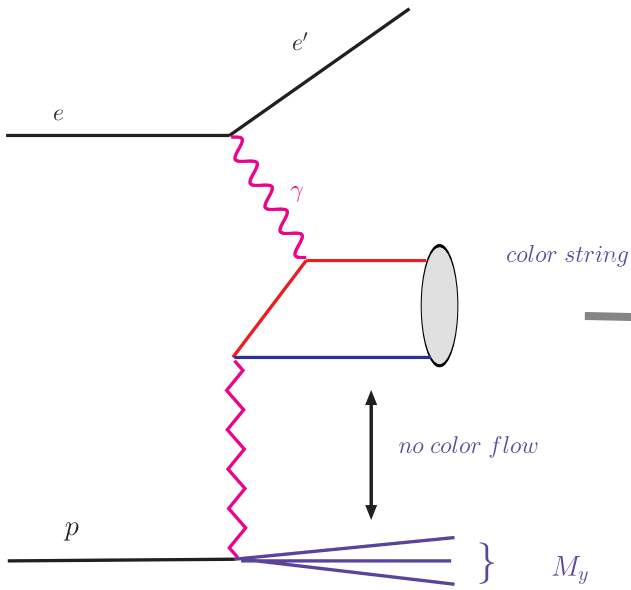
- detailed studies of hadronic final states in diffraction available form HERA
  - this knowledge MUST go into MCs for pp
- treat diffraction (soft & hard) as part of the x-sections determined by PDFs
  - MUST be included in simulation of final state
- include hard diffraction into simulation of MB and inclusive processes
  - mixing of diffraction with non-diffraction
  - estimate of gap survival probability
  - obtain prediction for hadronic final state in and central regions

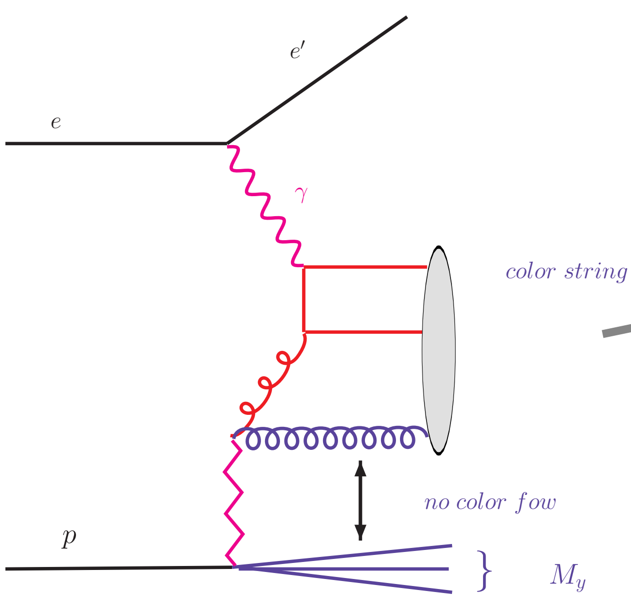
Diffraction (hard) is very important for better understanding of MPI and UE and to understand color connection and reconnections

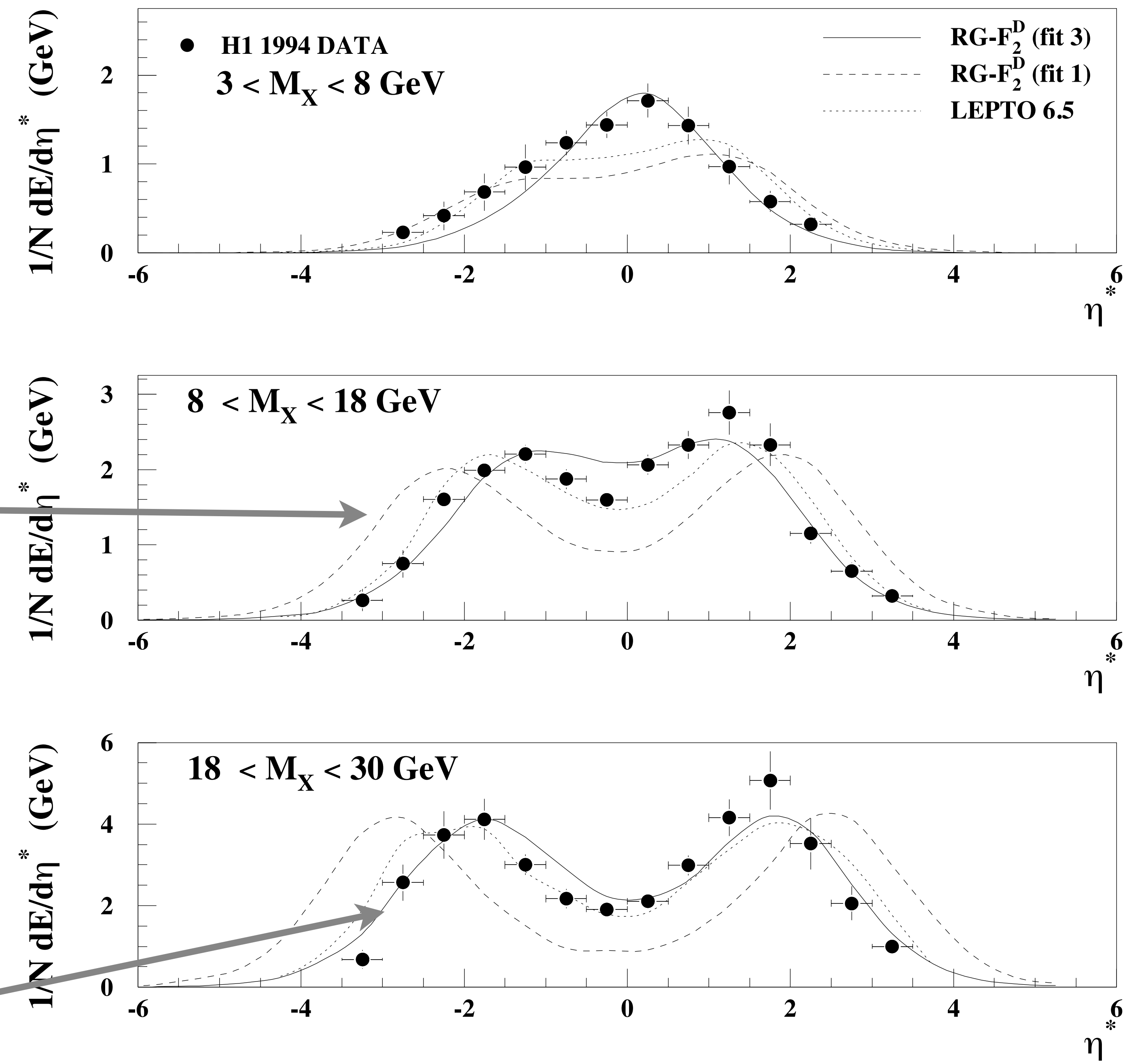
Backup

Examples: energy flow in diffraction

- energy flow in diffraction depends whether it is a $q\bar{q}$ or a $q\bar{q}g$ state

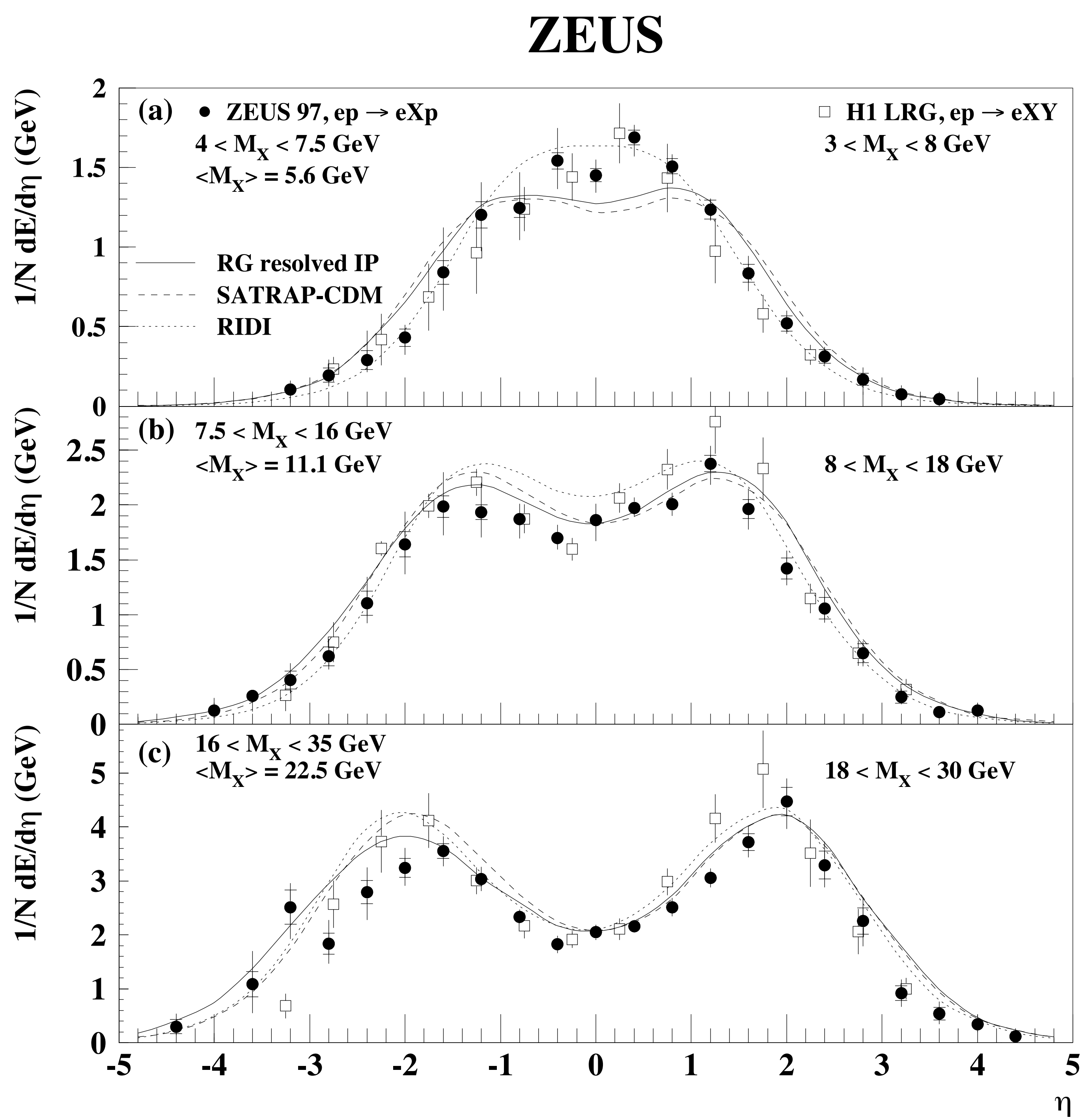






Examples: energy flow in diffraction

- energy flow in diffraction is reasonably well described with model of diffractive PDFs and pQCD hard scattering.
- details depend on the parametrisation of the dPDFs and the quark-gluon mix !



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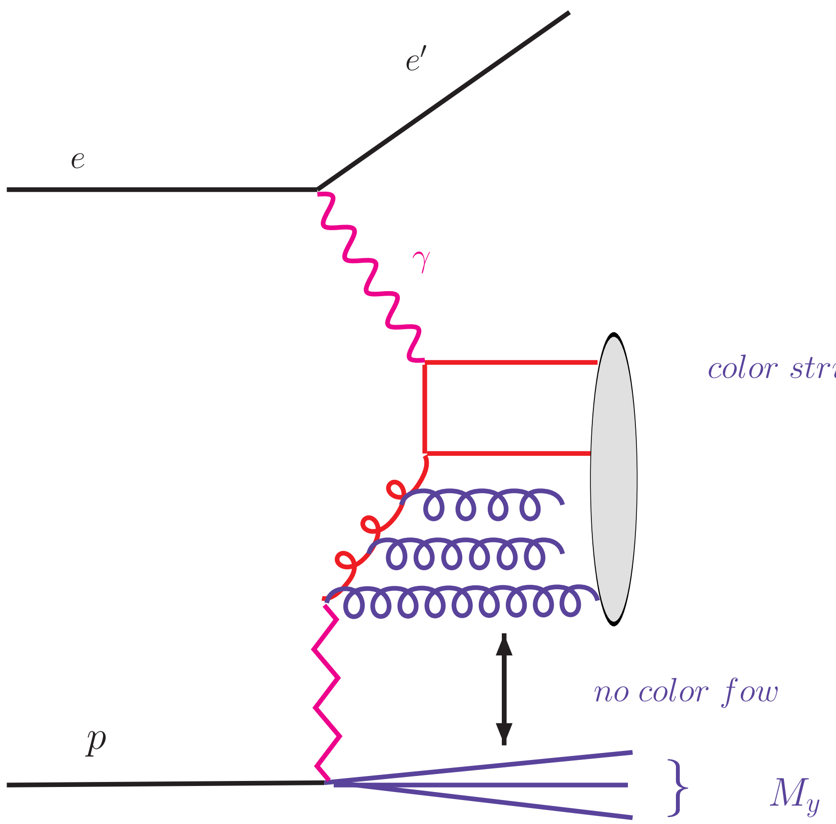
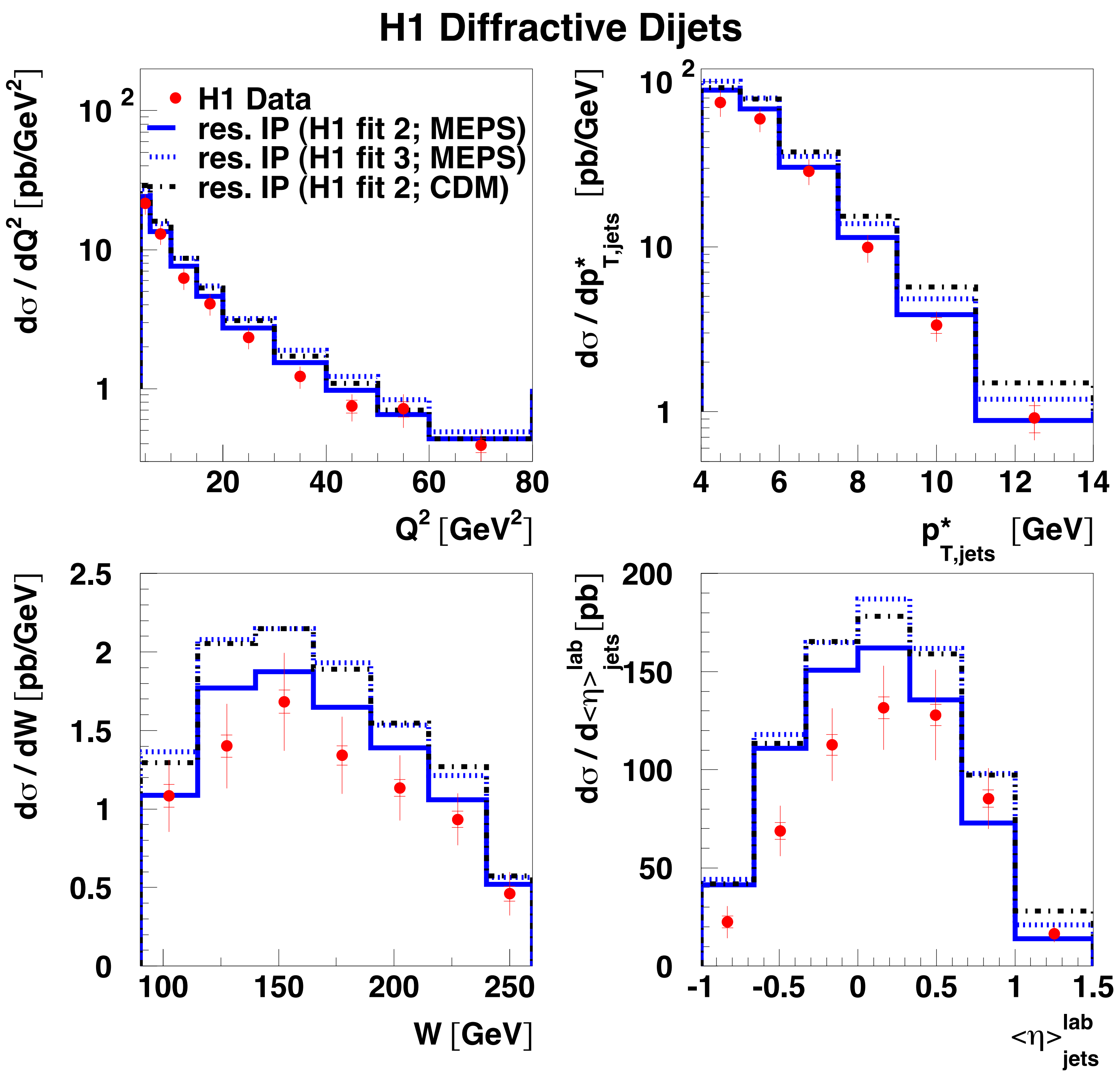
Example: diffractive dijet production

- Diffractive dijet production at large Q^2 are reasonably well described using MC with parton shower and diffractive PDFs





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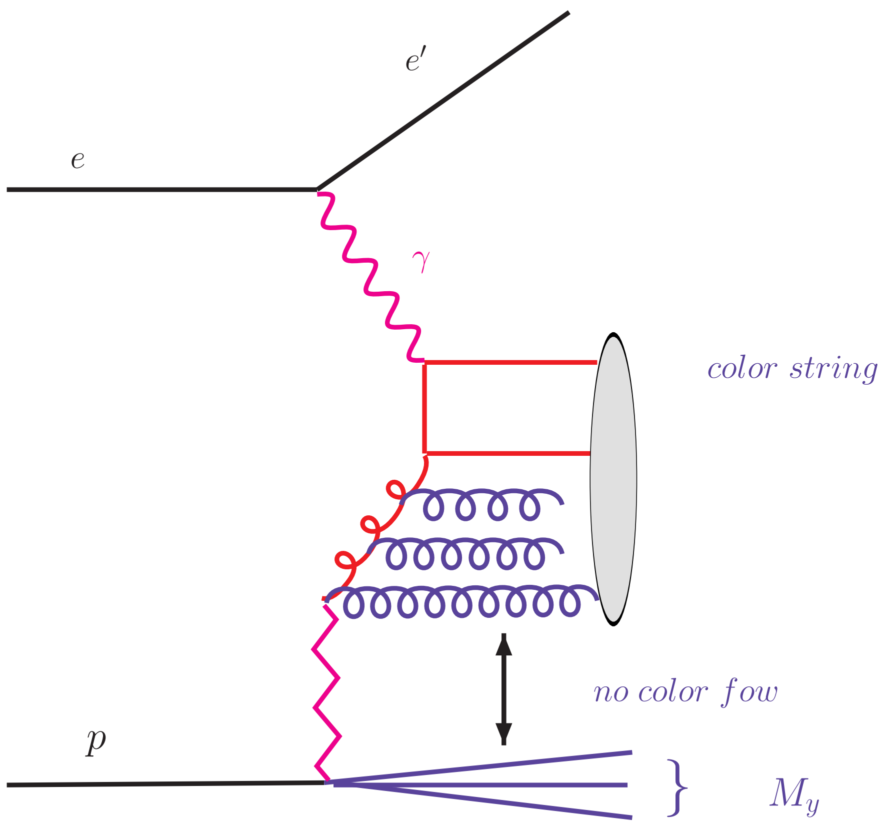

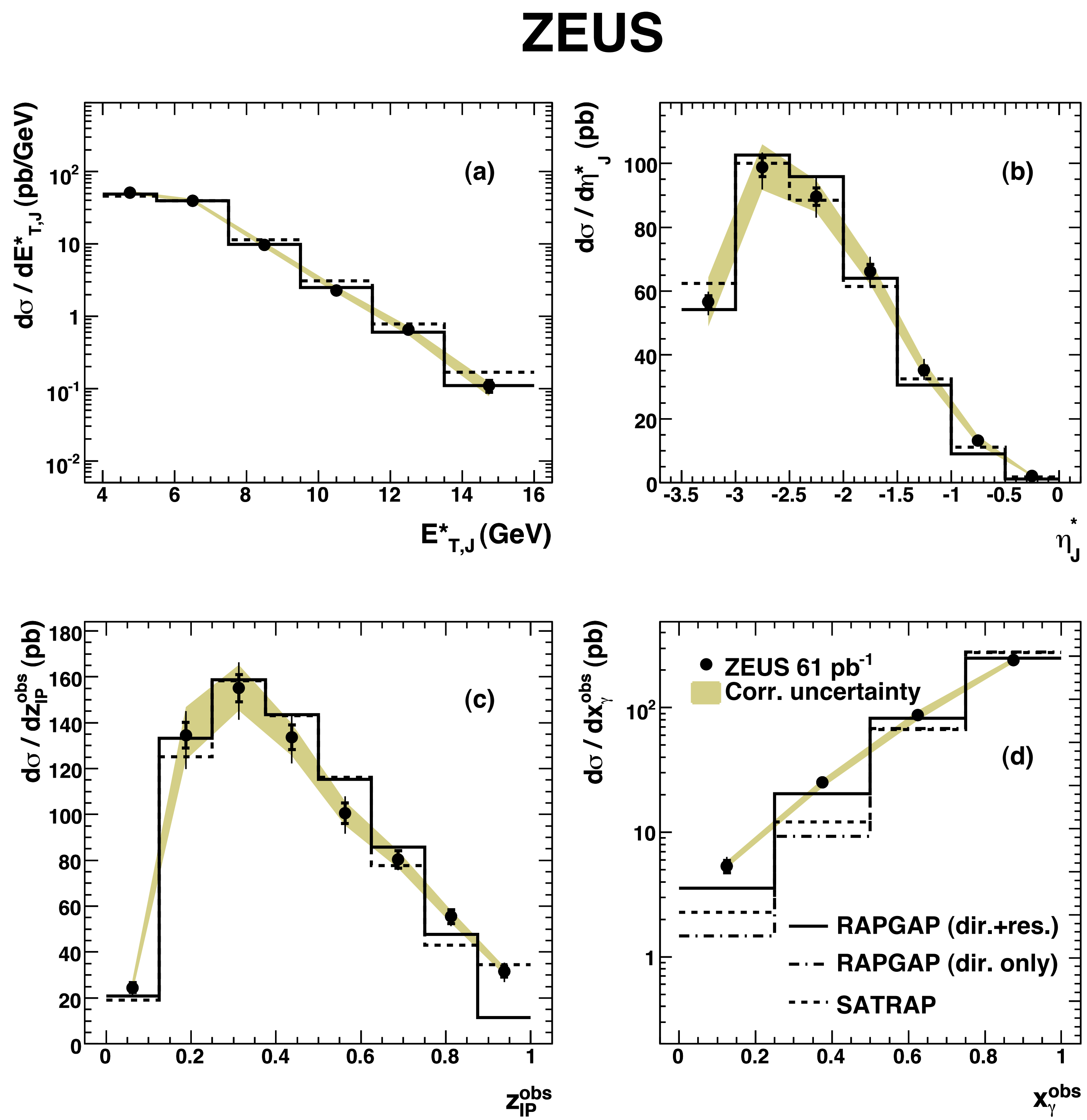

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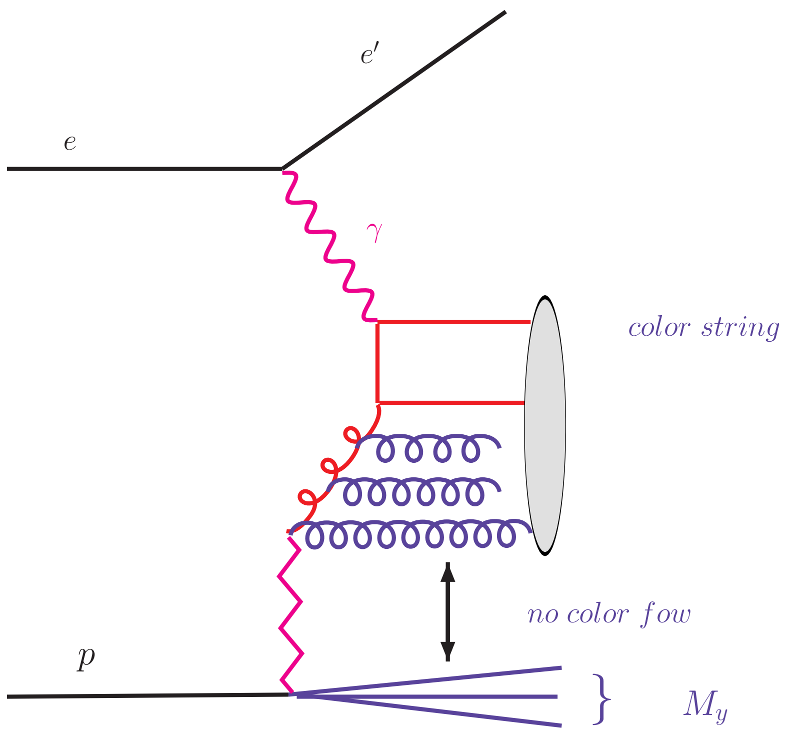
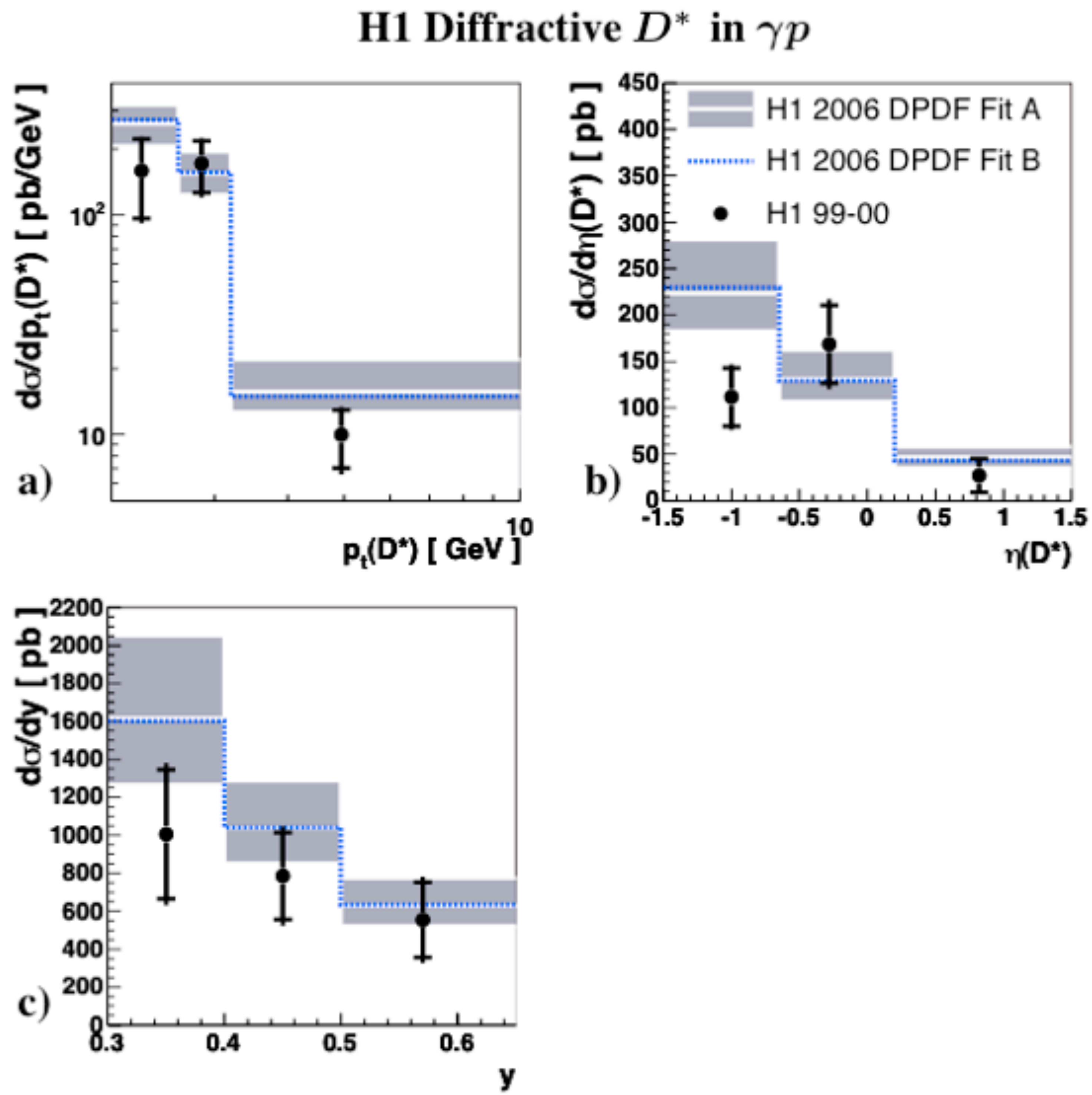
Diffractive charm production

- Diffractive charm production also reasonably well described with dPDFs and hard scattering processes in LO and NLO.





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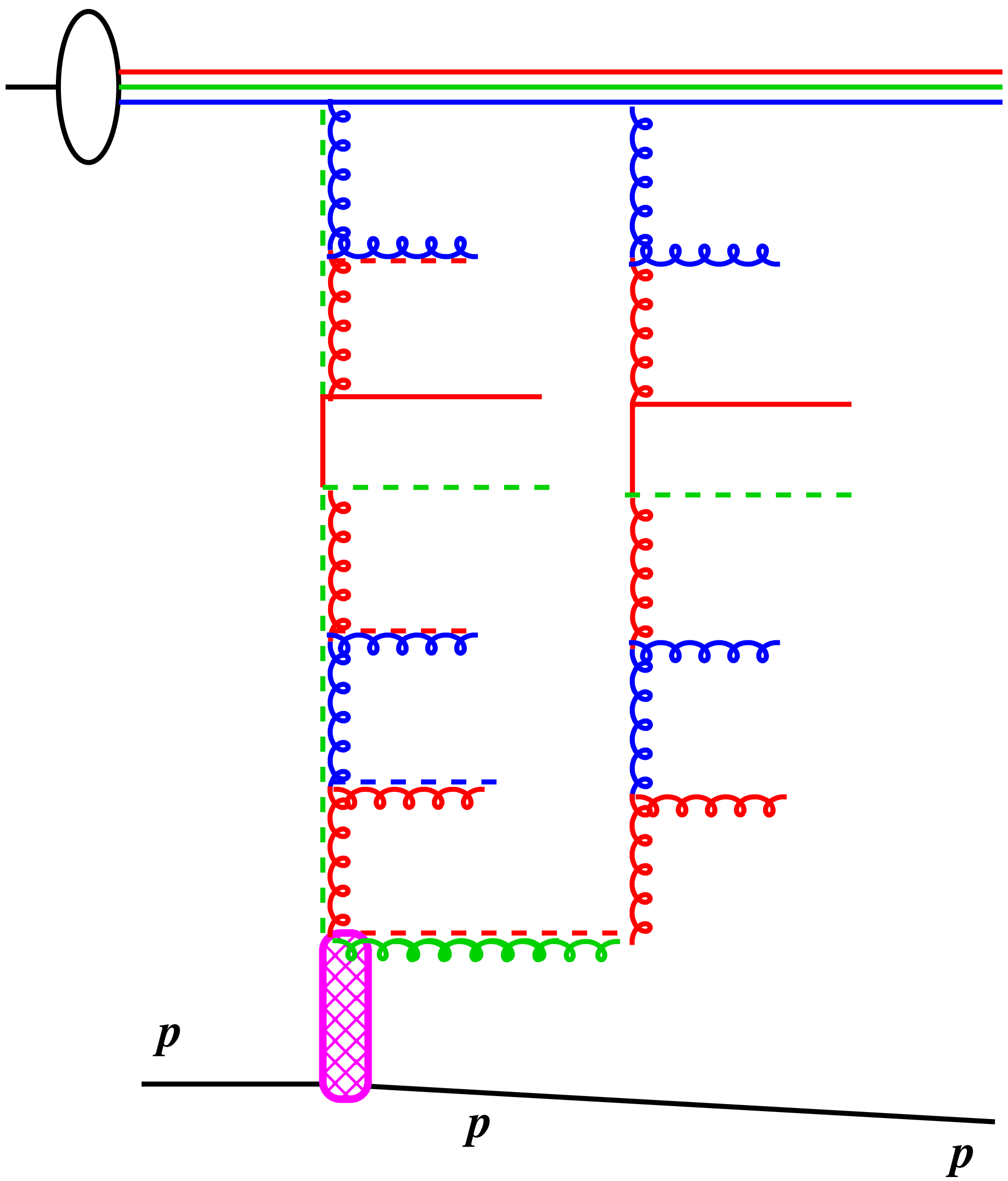
Origin of rescattering

- Where is rescattering happening ?
  - multi-parton scattering between remnant and leading proton
    - changing leading baryon nature
  - multiparton scattering between remnants (of proton and pomeron) ?



☑ how to separate scattering between diffractive remnant and proton from scattering between both protons ?

☑ is there any difference in showering from inclusive and diffractive scattering ?