Exclusive production at the Tevatron/LHC

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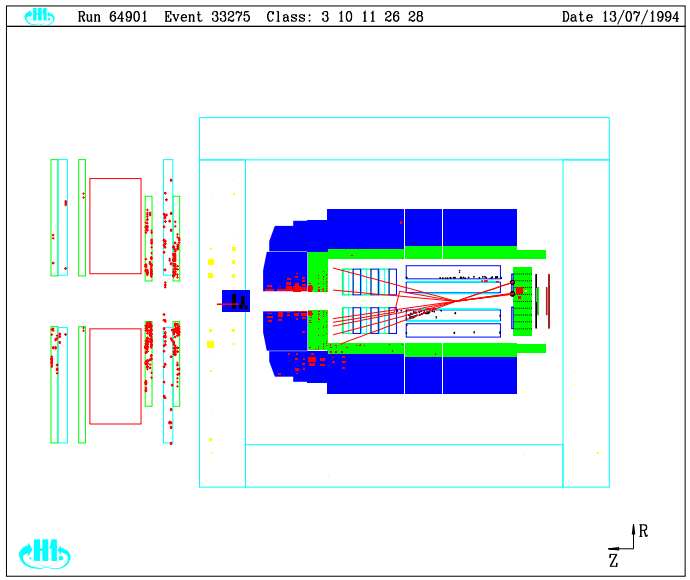
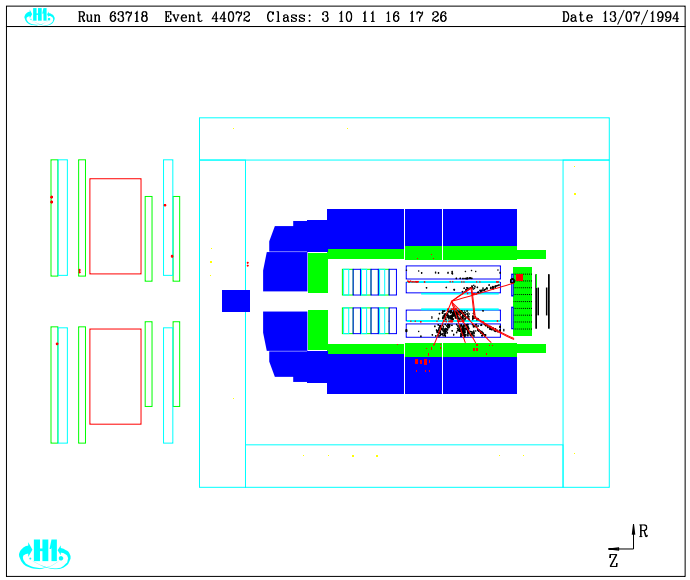
- Hard diffraction at HERA
- Double pomeron exchange processes
- Exclusive DPE production at TeV and LHC
- Conclusion

DIS vs. diffractive event at HERA

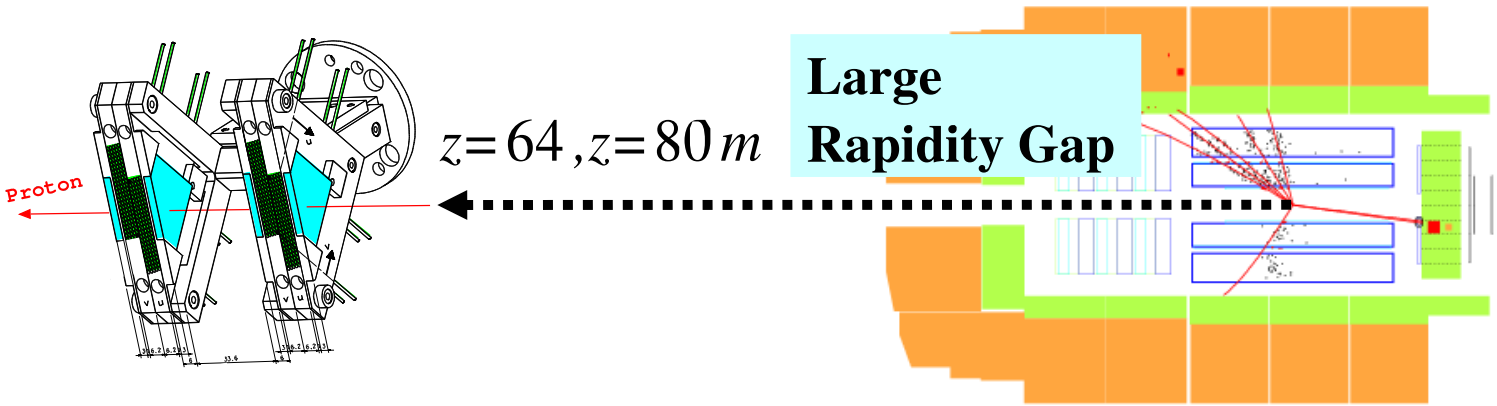
- Proton destroyed: debris fly in the direction of the proton and hadronize
- High activity in the front calorimeter, muon system

- Proton intact: caries away longitudinal momentum
- No activity in front region - no color exchange between outgoing jets and proton
- About 10% of all events are diffractive





Definition of diffractive events

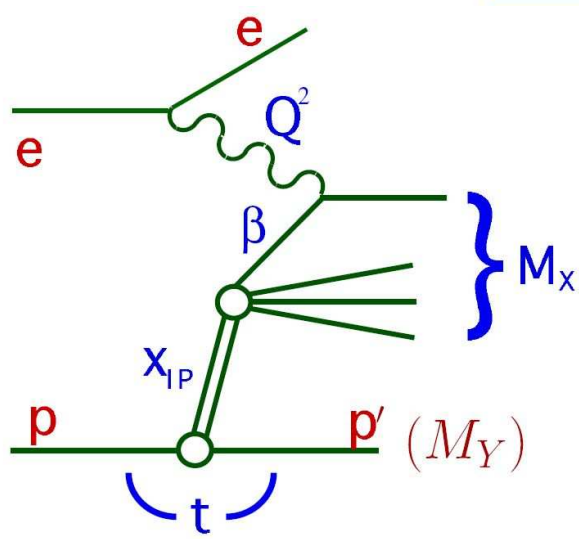


Two experimental definitions of diffractive events:

- Tagging outgoing proton escaping close to the beam
  - Requires special detectors which are placed close to the beam
- Request large rapidity gap in the forward calorimeter

Diffractive kinematic variables

$$x = x_{\mathbb{P}}\beta$$
$$\beta = \frac{Q^2}{Q^2+M_X^2}$$
$$\xi \equiv x_{\mathbb{P}} = \frac{Q^2+M_X^2}{Q^2+W^2}$$

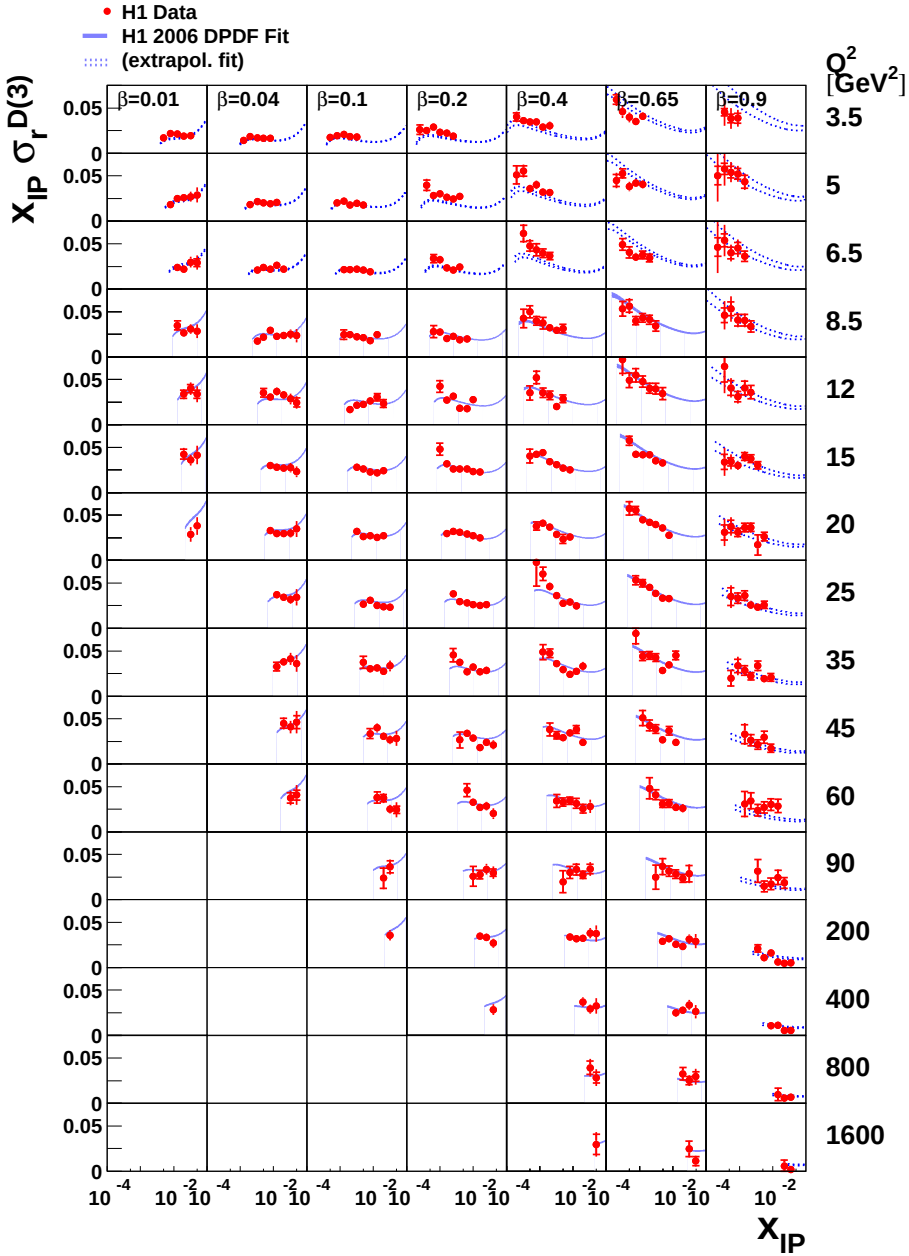


Invariant mass of the diffractive final state

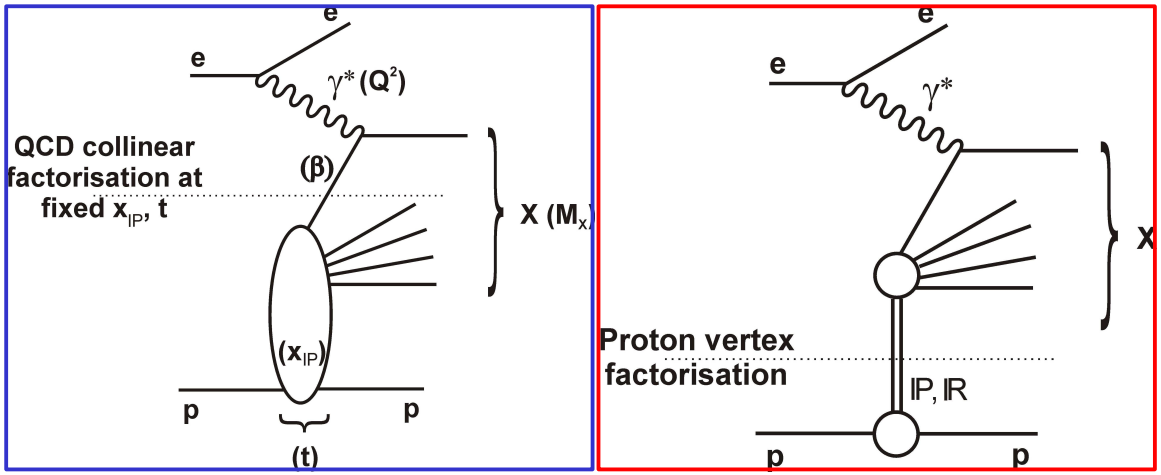
- $x_{\mathbb{P}}$ Momentum fraction of the proton carried by the colorless object: pomeron (vacuum quantum numbers: C=1, P=1, S=0)
- β Momentum fraction of the pomeron carried by the interacting parton
- t Transfered momentum to the pomeron $t = (p - p')^2$
- Cross section in terms of structure function:

$$\frac{\mathrm{d}^4\sigma^{ep\to eXp}}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}x_{\mathbb{P}}\mathrm{d}t} = \frac{4\pi\alpha^2}{xQ^4}\left(1 - y + \frac{y^2}{2}\right) F_2^{D(4)}(x_{\mathbb{P}}, x, Q^2, t)$$

Measurement of diffractive structure function



Two levels of factorization



QCD hard scattering collinear factorisation (Collins) at fixed $x_{\mathbb{P}}$ and t

$$F_2^{D(4)}(x_{\mathbb{P}}, x, Q^2, t) = \sum_{\text{parton } i} \sigma^{ei}(x, Q^2) \otimes f_i(x_{\mathbb{P}}, \beta = \frac{x}{x_{\mathbb{P}}}, Q^2, t)$$

"Proton vertex" factorization of $x_{\mathbb{P}}$ and t into pomeron flux and pomeron structure function

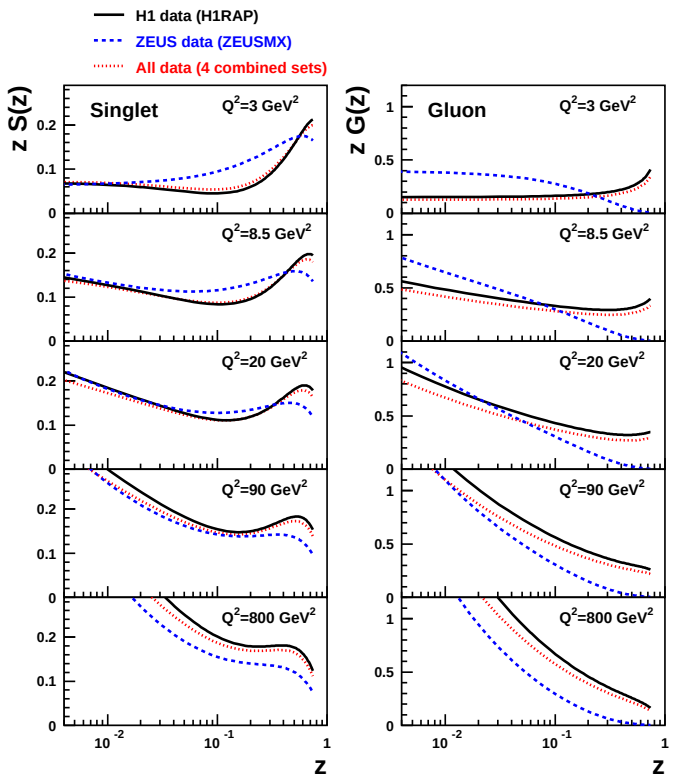
$$f_i(x_{\mathbb{P}}, \beta, Q^2, t) = f_{\mathbb{P}/p}(x_{\mathbb{P}}, t) f_i^{\mathbb{P}}(\beta, Q^2)$$

$$f_{\mathbb{P}/p} \sim 1/x_{\mathbb{P}}^{2\alpha_{\mathbb{P}}(t)-1} \qquad \alpha_{\mathbb{P}}(t) = \alpha_{\mathbb{P}} + \alpha'_{\mathbb{P}} t$$

- Flux: probability to find the pomeron in the proton

Extraction of parton densities in the pomeron

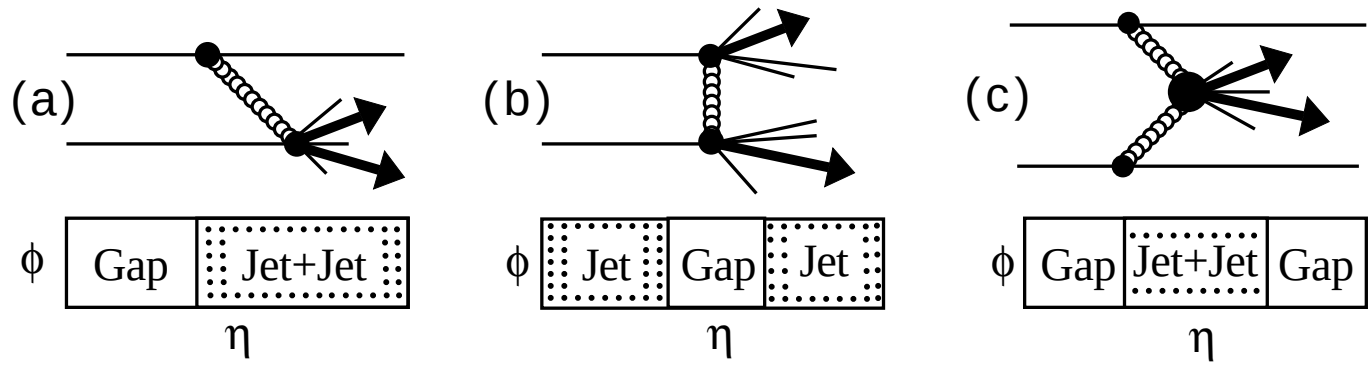
- What is the pomeron structure?
- Assumption: pomeron made of quarks and gluons
- Quark q and gluon g densities fitted using DGLAP



- Pomeron is gluon dominated, densities poorly constrained at high β
- Universal parton densities will be used for predictions at the Tevatron

Diffraction at the Tevatron

- Only CDF collaboration has diffractive program
- Roman Pot Spectrometer to tag $\bar{p}$, rapidity gap for p



single pomeron exchange double diffraction double pomeron exchange

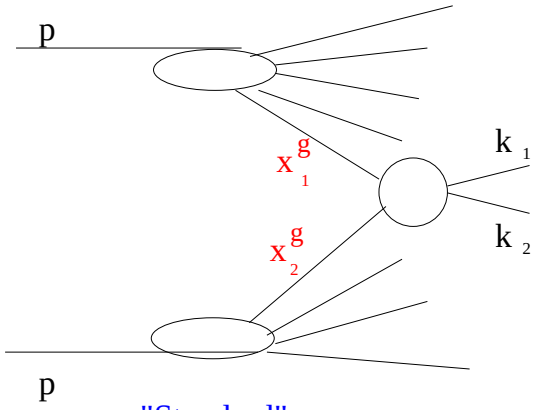
$\xi_{1,2}$ Momentum fraction of the (anti)-proton carried out by the pomeron

$\beta_{1,2}$ Momentum fraction of the pomeron carried out by the interacting parton (mostly gluon) $\beta_{1,2} = x_{Bj1,2}/\xi_{1,2}$

M^2 Diffractive mass produced $M^2 = s\xi_1\xi_2$

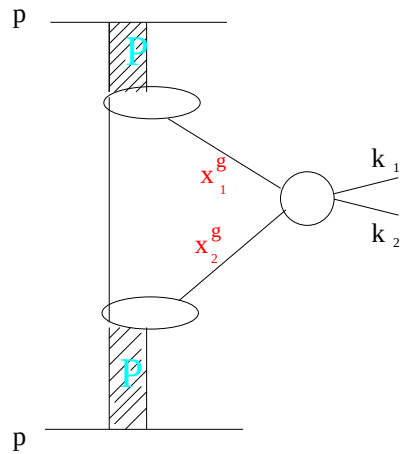
$\Delta\eta_{1,2}$ Rapidity gap $\Delta\eta_{1,2} \sim \ln 1/\xi_{1,2}$

Production of heavy objects diffractively



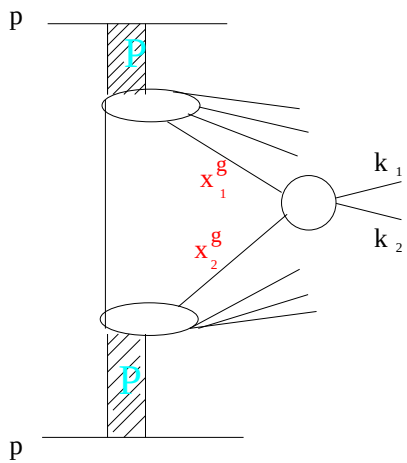
H , $Q\bar{Q}$, $\gamma\gamma$

"Standard"



H , $Q\bar{Q}$, $\gamma\gamma$

"Exclusive "

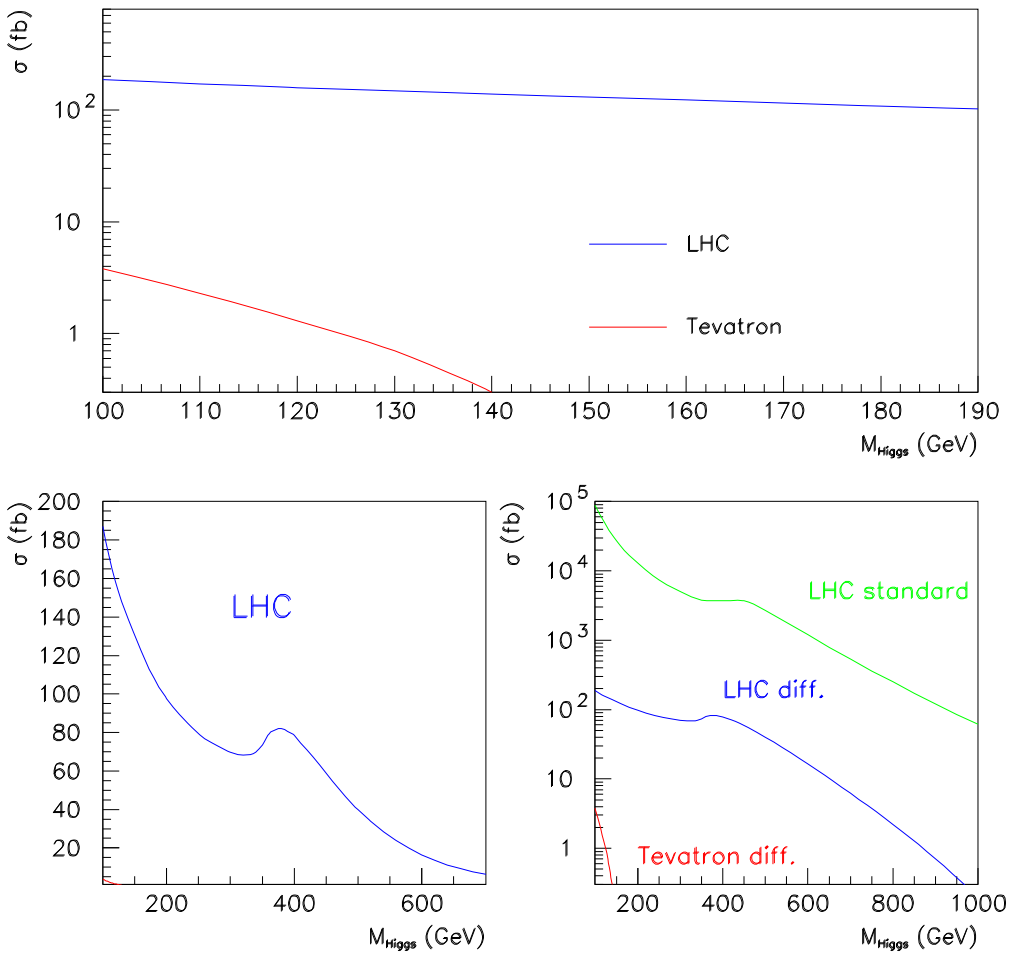


H , $Q\bar{Q}$, $\gamma\gamma$

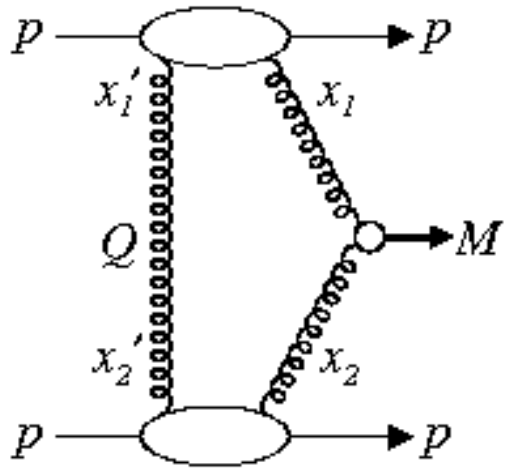
"Inclusive"

Inclusive Higgs mass production

Large cross section, but mass purely reconstructed due to partial energy loss in pomeron remnants



Exclusive production



- All diffractive energy used to produced central object M (Higgs, dijets, diphoton)
- Fully constrained system e.g. $pp \to pHp$
- Precise mass M reconstruction of the produced object

$$M = \sqrt{s\xi_1\xi_2}$$

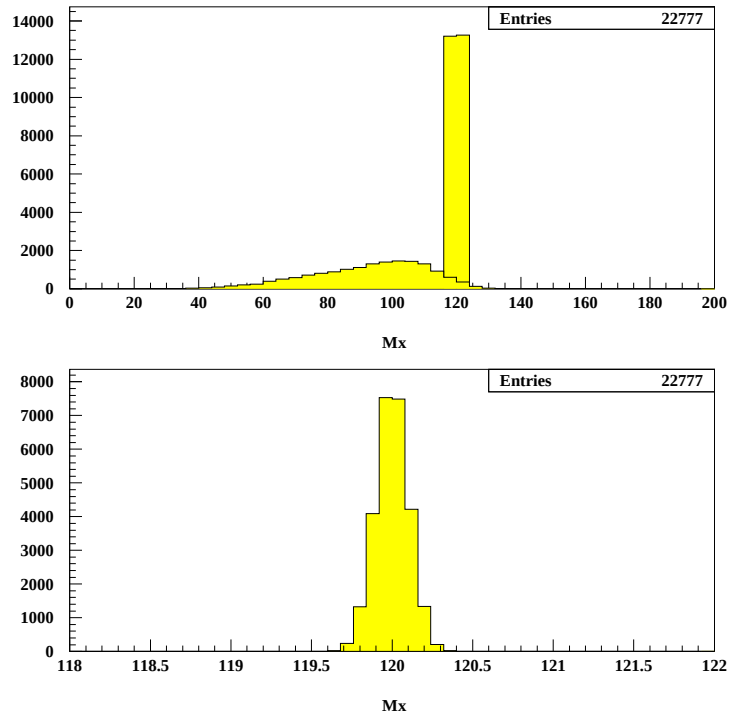
($\xi_{1,2}$ proton momentum loss, measured with roman pots)
- Selection rules: system produced in 0^{++}, precise determination of quantum numbers

Exclusive Higgs production

- Good Higgs mass reconstruction: using both tagged protons in the final state ($\sim 1-2$ GeV)

- Exclusive Higgs production (in fb)

M_{Higgs}	σ (fb)
120	1.4
125	1.3
130	1.1
140	1.0



DPE models

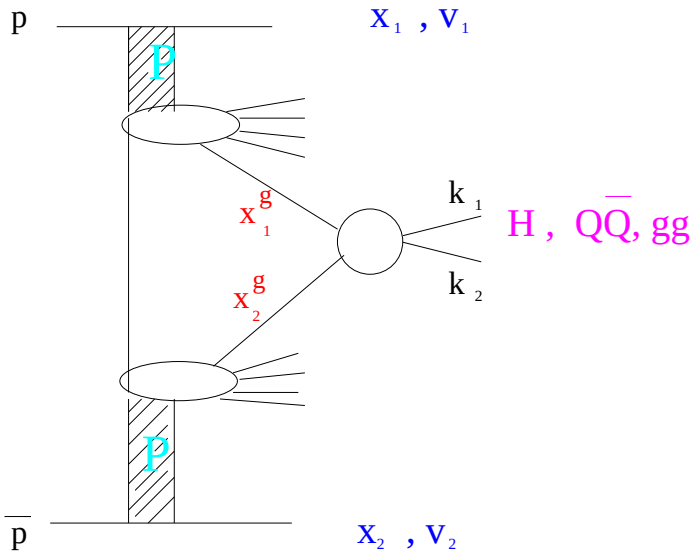
Inclusive models:

- Factorized model (FM)
  - exchange of perturbative pomerons (reggeons)
  - factorization break-up only up to the survival probability factor
- BPR model (BL inclusive)
  - non-perturbative, soft pomeron, utilizes shape of the pomeron PDFs, normalization must be adopted from data
  - (inclusive extension of the Bialas-Landshoff exclusive model)

Exclusive models:

- KMR model
  - perturbative calc., direct coupling of two gluons to the protons
- Bialas-Landshoff exclusive model
  - non-perturbative, soft pomeron

How to look for exclusive events?



- Dijet mass fraction - suitable observable to see exclusive signal

  $$R_{JJ} = M_{JJ}/M_X$$

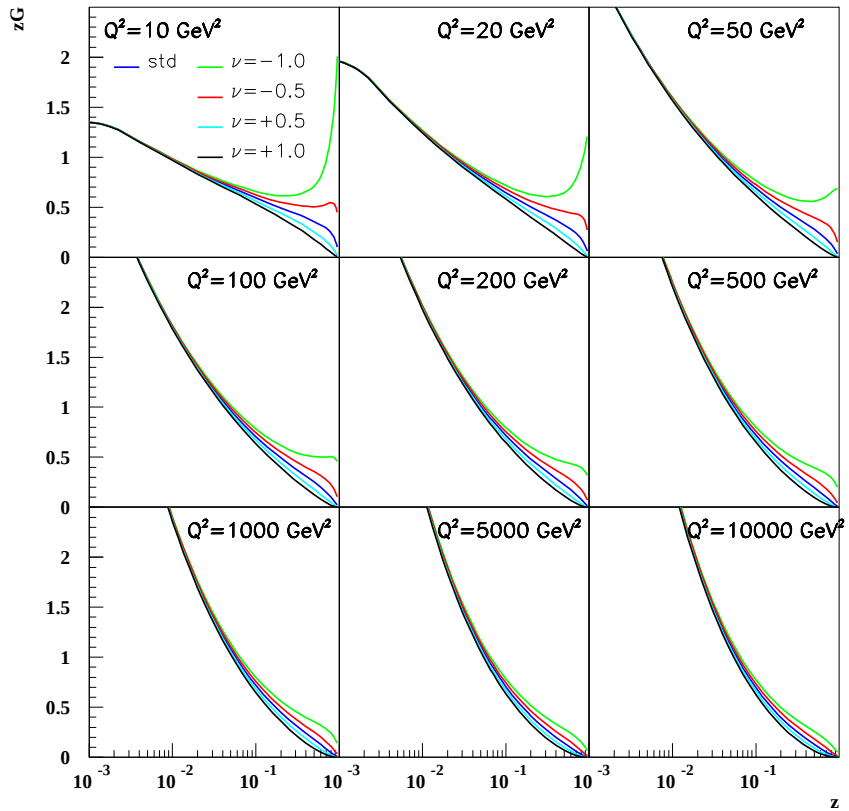
- Increase of signal in $R_{JJ} \to 1$ for exclusive production
- Another observable suggested (`hep-ph/0605113`)

  $$R_J = 2E_T(\cosh\eta^*)/M_X \quad \eta^* = \eta - Y_M$$

- Comparison of all models on the market with preliminary CDF data.

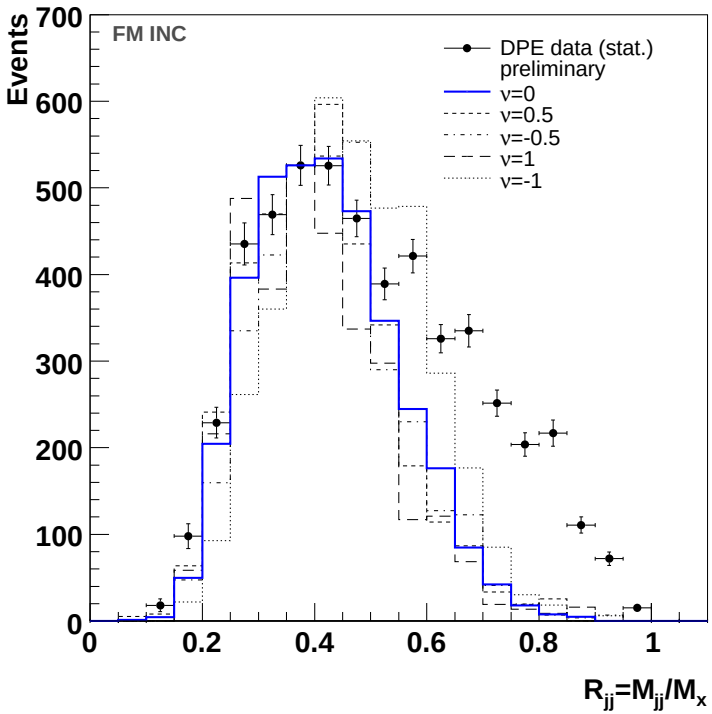
Gluon uncertainty at high β

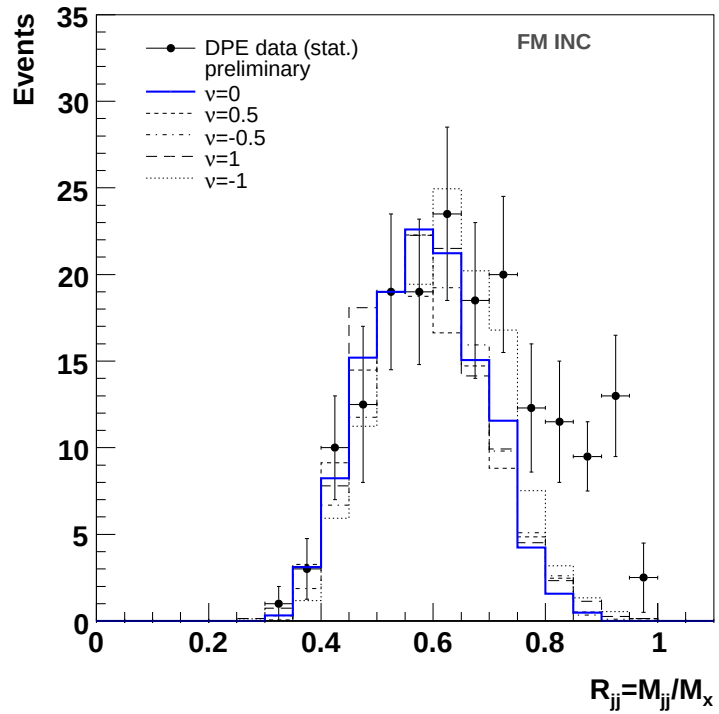
- Caution: high β gluon not well constrained
- Study of the gluon uncertainty: multiply the gluon by factor $(1-\beta)^{\nu}$
- Reminder: QCD fits yield $\nu = 0 \pm 0.6$



DMF at the Tevatron - inclusive models

Factorized model: $p_T^{jet1,2} > 10\,\text{GeV}$ $p_T^{jet1,2} > 25\,\text{GeV}$

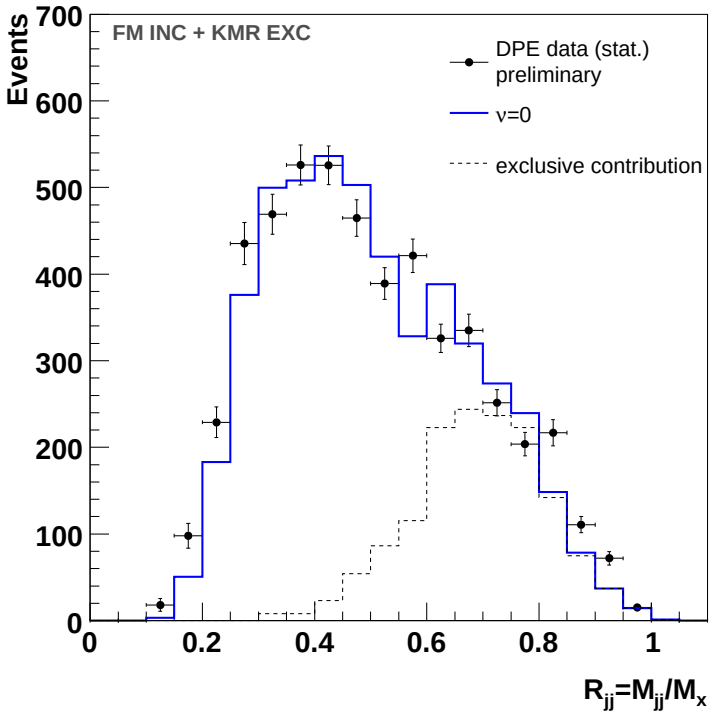




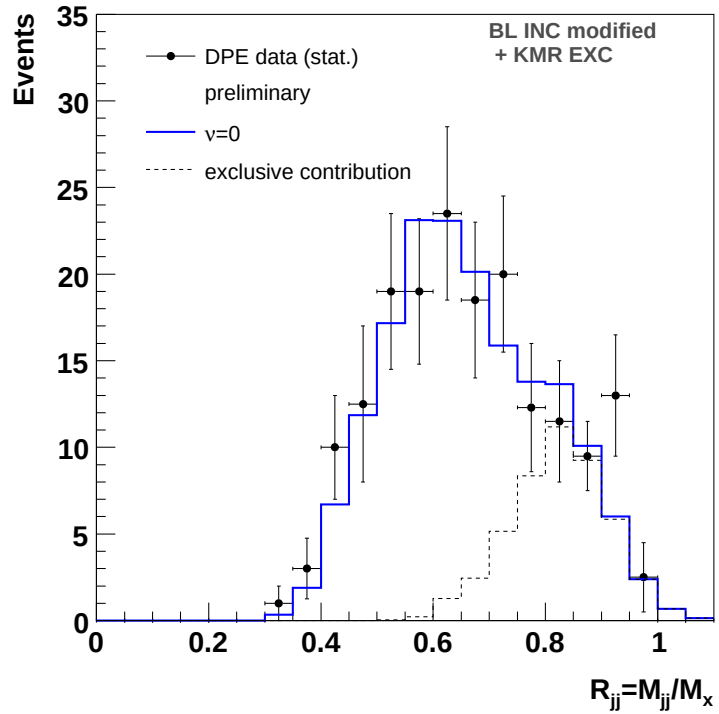
- Preliminary results, CDF note 8493, (2006)
- Can we explain the tail of DMF by enhancing gluon dens. at high β?
- No. Other contribution needed $\Rightarrow$ exclusive production
- Same conclusion for BPR model

DMF - inclusive + exclusive models

Factorized + KMR model:
$p_T^{jet1,2} > 10\,\text{GeV}$

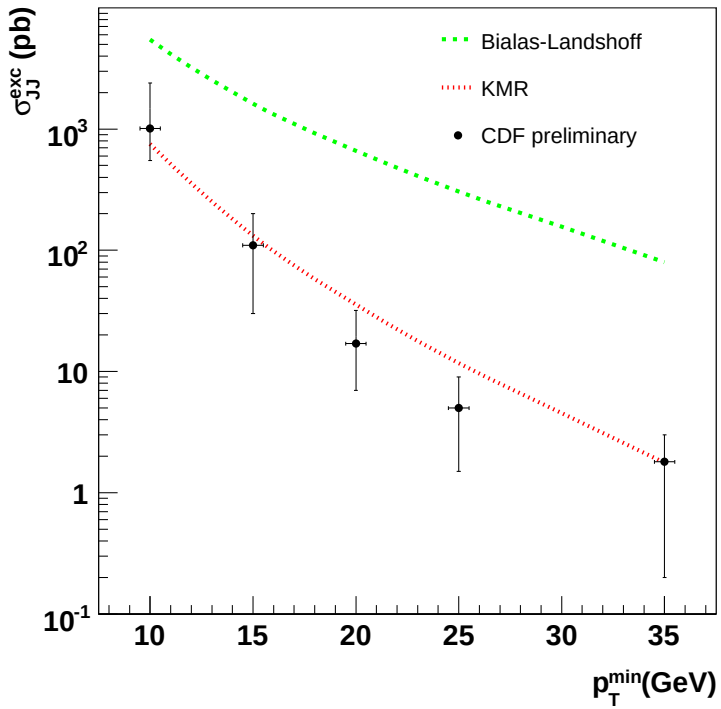


BPR + KMR model:
$p_T^{jet1,2} > 25\,\text{GeV}$



- Binned likelihood fit of inclusive and exclusive contribution
- Good description of the data

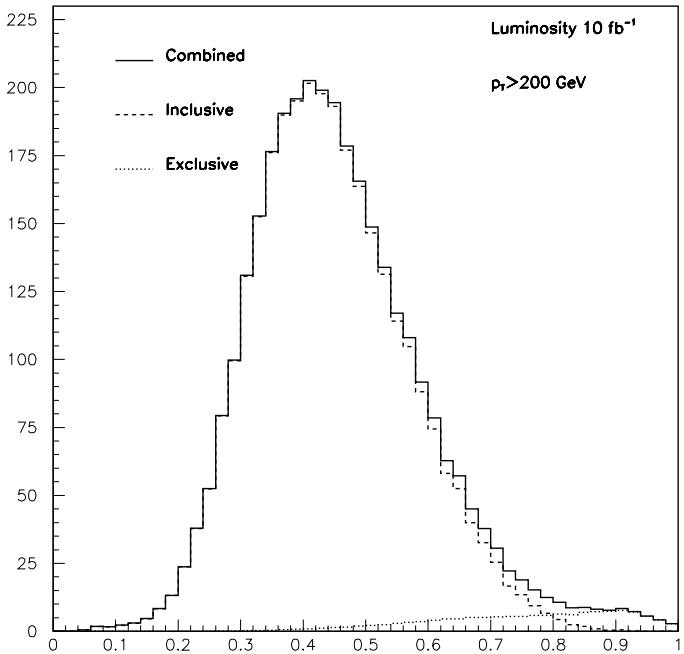
p_T dependance of exclusive cross section



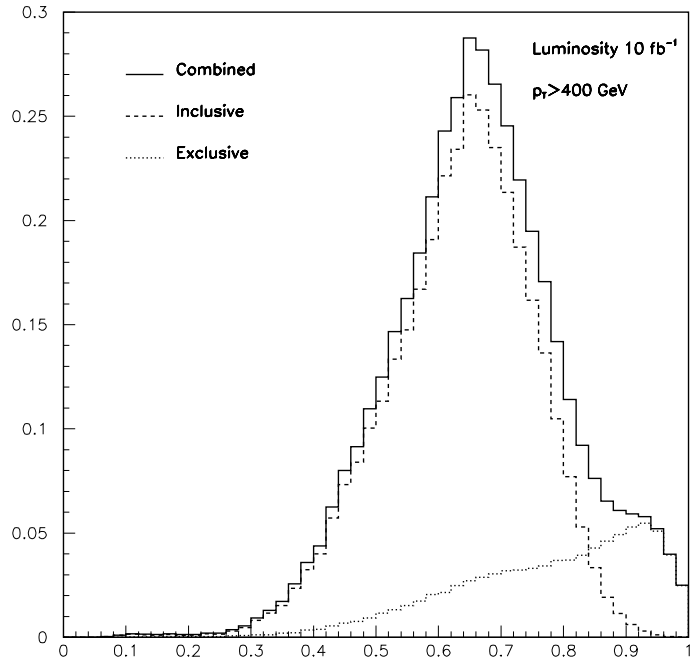
- KMR model in agreement with data
- CDF data clearly disfavour Bialas-Landshoff exclusive model

Dijet mass fraction at the LHC

FM+KMR: $p_T^{jet1,2} > 200$ GeV



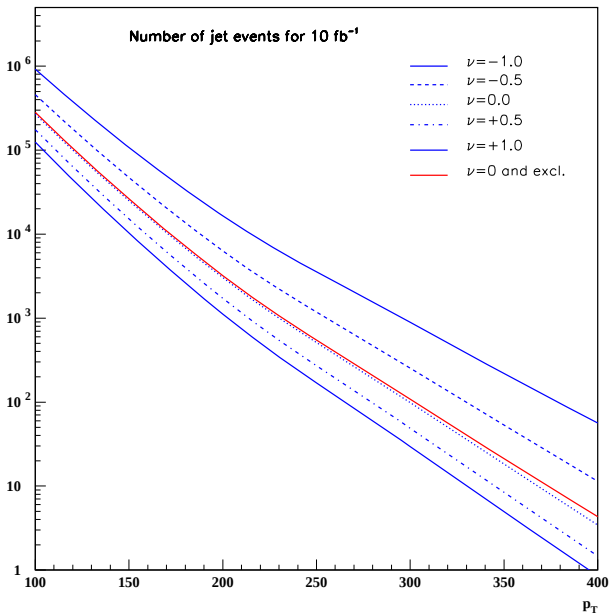
FM+KMR: $p_T^{jet1,2} > 400$ GeV



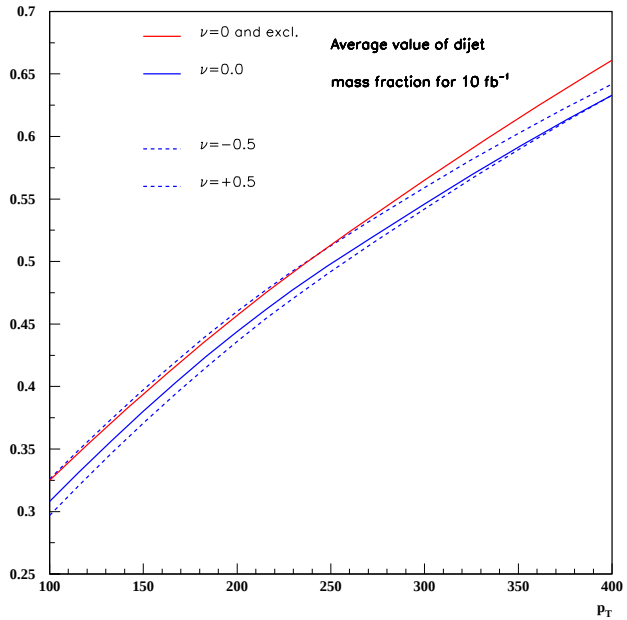
- Exclusive production dominates for e.g $R_{JJ} > 0.8$

Other observables at the LHC

FM+KMR: Number of jet events



FM+KMR: Mean of dijet mass fraction



- Exclusive contribution and uncertainty on the gluon density entangled
- Full QCD fit will have to be performed at the LHC: fitting the parton densities using DGLAP and the exclusive contribution at the same time

Conclusion

- Signal for existence of exclusive DPE at CDF that cannot be explained by taking into account the uncertainties of current predictions (due to the gluon density)
- Exclusive diffraction could be used for precise mass measurement (1-2 GeV) of produced heavy objects and it's propreties
- RP220 and FP420 projects for tagging protons in ATLAS

BACKUP SLIDES

Inclusive SPE contribution

- Parton densities taken from H1 (shape only)
- Cross section factorizes into hard matrix element and parton densities in the pomeron up to Survival probability factor: probability that the diffractive event will be destroyed by additional soft interaction of spectator partons after the hard scattering
- Models predict 0.1 for the Tevatron (in agreement with data) and 0.03 for the LHC