Exclusive production at the Tevatron/LHC

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- Inclusive vs. exclusive diffraction models
- Dijet mass fraction as measured by CDF
- Soft color interaction
- Dijet mass fraction at the LHC
- Conclusion

In collaboration with M. Boonekamp, R. Peschanski, C. Royon, L. Schoeffel
Hard diffraction at the Tevatron/LHC

Exclusive channel interesting:
- Tagging outgoing protons: good mass resolution (as good as $2 \sim 3$ GeV for a $M_H = 140$ GeV)
- Absolute determination of quantum numbers of any resonance

double pomeron exchange

- Gaps between produced jets and outgoing protons, no color interaction
- **Pomeron model:**
  - exchange of colorless objects - pomerons
  - central production is described as a hard scattering of pomeron constituents $\Rightarrow$ pomeron parton densities
Diffractive structure functions from HERA

- Global fits of HERA $F_2^D$ (see previous presentation of L. Schoeffel)
- Pomeron is gluon dominated, gluon poorly constrained at high $\beta$ ($\beta$ - momentum fraction of the pomeron carried by gluon)

- Gluon density function smaller than in older H1 fits
Production of heavy objects diffractively

**Inclusive:**
\[
\begin{align*}
p & \rightarrow p \\
\hat{p} & \rightarrow \hat{p} \\
x_1, v_1 & \\
\end{align*}
\]

**Exclusive:**
\[
\begin{align*}
H, \overline{QQ}, gg & \\
\end{align*}
\]

- **Inclusive diff:** pomeron from HERA used for prediction at the Tevatron
- **Exclusive diff:** heavy object produced alone, no pomeron remnants
- **Dijet mass fraction** - suitable observable to see exclusive signal
  \[
  R_{JJ} = \frac{M_{JJ}}{M_X}
  \]
- **Increase of signal** in \( R_{JJ} \rightarrow 1 \) for exclusive production
- **Another observable suggested** (hep-ph/0605113)
  \[
  R_J = \frac{2E_T(cosh \eta^*)}{M_X} \quad \eta^* = \eta - Y_M
  \]
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
DPEMC monte carlo

- All DPE models implemented in DPEMC
  (Double pomeron exchange monte carlo)

  It is a flexible interface to study also:
- Single diffraction, exclusive $\chi_c, \chi_b$ production
- QED processes: $\gamma\gamma$ interaction between protons (or heavy nuclei)
- Production of dijets, dileptons, diphotons, WW, H, Z, SUSY particles...
- Embedded in HERWIG
- Various parton densities in the pomeron included
- Interfaced with ATLAS full simulation ATHENA
- [http://boonekam.home.cern.ch/boonekam/dpemc.htm](http://boonekam.home.cern.ch/boonekam/dpemc.htm)
Gluon uncertainty at high $\beta$

- Caution: high $\beta$ 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: \( p_{T}^{jet1,2} > 10 \text{ GeV} \) \hspace{1cm} \( p_{T}^{jet1,2} > 25 \text{ GeV} \)

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

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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
Other observables

- Other variables to identify the exclusive contribution
- Relative norm. between inc. and exc. fixed by fit to DMF $p_T^{min} = 25$ GeV
- Optimal signal for jets $p_T^{min} = 30$ GeV

Number of jet events

Mean value of DMF dist.

![Number of jet events for 200pb$^1$](image1)

![Mean value of dijet mass fraction](image2)
$p_T$ dependance of exclusive cross section

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

- After development of partonic shower, additional soft color interaction can occur between partons with probability $P$.
- From $F_2^D$, $P \sim 0.5$

Enberg, Ingelman, Timneanu
Phys. Rev. D64(2001)114015

- Based on Lund string model

![Diagram of particle interactions]

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Dijet mass fraction with SCI

SCI+KMR: \( p_{T}^{jet1,2} > 10 \text{ GeV} \)

\[ \frac{x}{M_{jj}} = M_{jj} R \]

Events

\[ R_{jj} = M_{jj}/M_{x} \]

- Less exclusive contribution needed for \( p_{T}^{jet1,2} > 10 \text{ GeV} \), no for 25 GeV
- But the model has a cavity:
  Probability to get two protons in final state is very small!
Rapidity distribution in SCI

Particle flow ($\eta_{\bar{p}} \sim 8$)

Jet1 rapidity distribution

- Strictly speaking only SD signal: tagging $\bar{p} +$ rapidity gap as CDF
- $\bar{p}$ accompanied by other particles (mainly pions)
- Jet $\eta$ distribution not symmetric, unlike pomeron models and CDF data
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

- Neither of models (Factorized and BPR model) can explain the CDF dijet mass fraction preliminary data even if taking the gluon uncertainty in the pomeron into account ⇒ suggests that other contribution needed
- If soft color interaction model is to be considered, probability of producing two protons must be fixed (increased)
- Exclusive signal and gluon uncertainty are entangled at the LHC
  Full QCD analysis will have to be performed fitting parton densities and exclusive production