Diffractive Results at CDF II

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ISMD 2003, Krakow, Poland

- Diffraction at the Tevatron
- New Detectors for Run II
- Diffractive Dijets
- DPE Dijet Production
  - exclusive dijet production
  - exclusive low-mass states
Diffraction at the Tevatron

Large rapidity gaps are signatures for diffraction

Soft diffraction
- SD
- DD
- DPE
- multi-Gap

Hard diffraction
- SD (W, jet-jet, b-quark, J/ψ)
- SD (w/RP) dijets (630 GeV and 1.8 TeV)
- Forward jets (Jet-Gap-Jet)
- DPE dijets

SD dijets

DPE dijets
If you want to know more…

<table>
<thead>
<tr>
<th>Soft diffraction</th>
<th>SD</th>
<th>PRD 50 (1994) 5535</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD</td>
<td>PRL 87 (2001) 141802</td>
<td></td>
</tr>
<tr>
<td>DPE</td>
<td>to be submitted to PRL</td>
<td></td>
</tr>
<tr>
<td>multi-gap</td>
<td>to be published in PRL</td>
<td></td>
</tr>
<tr>
<td>Hard diffraction</td>
<td>W</td>
<td>PRL 78 (1997) 2698</td>
</tr>
<tr>
<td>b-quark</td>
<td>PRL 84 (2000) 232</td>
<td></td>
</tr>
<tr>
<td>J/ψ</td>
<td>PRL 87 (2001) 241802</td>
<td></td>
</tr>
<tr>
<td>jet-jet</td>
<td>PRL 79 (1997) 2636</td>
<td></td>
</tr>
<tr>
<td>DPE dijets</td>
<td>PRL 85 (2000) 4217</td>
<td></td>
</tr>
</tbody>
</table>

*for a review: K. Goulianos hep-ph/0306085*
First Goals for Run II

- Diffractive structure function
  - $Q^2$ and $\xi$ dependence

- Exclusive production
  - dijet, heavy flavor, low-mass
Tevatron Collider

- Tevatron and detector upgrades
  - C.M. energy 1.96 TeV
  - 396 nsec bunch spacing

- High (low ?) inst. luminosity
  \( L \sim 2-3 \times 10^{31} \text{ cm}^{-2}\text{sec}^{-1} \)

- Multiple interactions
New Detectors for Run II

- Tracking
  - Silicon
  - Central Outer Tracker
- Time of Flight
- Expanded Muon Coverage
- Endplug Calorimeter
- Forward Detectors
- Trigger
  - Tracks @ L1
  - Silicon Tracks @ L2
- DAQ (132 ns)
Forward Detectors

✓ Roman Pots Spectrometer
✓ Beam Shower Counters
✓ MiniPlug Calorimeter

⇒ Larger $\eta$ coverage for rapidity gaps and jets
New MiniPlug Calorimeter

- liquid scintillator + lead
- towerless geometry
- full coverage: $3.5 < |\eta| < 5.1$
- 32 r.l.
- installed in November 2001

Measure:

- very forward jet energies and position
- multiplicity
MiniPlug Design

East MP (viewed from IP)
Trigger

- RP is triggered on leading antiprotons
- Use RP + jet triggers

Acceptance: $0 < |t| < 2$, $0.03 < \xi < 0.1$
Event Samples

Dedicated triggers ⇒ total rate ~3Hz

<table>
<thead>
<tr>
<th>Event Sample</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND (J5)</td>
<td>at least one calorimeter tower with $E_T &gt; 5$ GeV</td>
</tr>
<tr>
<td>RP inclusive</td>
<td>three-fold coincidence in RP counters</td>
</tr>
<tr>
<td>RP+J5</td>
<td>RP inclusive together with J5</td>
</tr>
<tr>
<td>RP+J5+BSC_Gap_P</td>
<td>DPE dijet candidates</td>
</tr>
</tbody>
</table>
Diffractive Dijets

\[ \xi: \text{fraction of anti-proton momentum loss} \]

\[ \beta: \text{fraction of pomeron momentum carried by parton} \]

\[ \text{parton } x_{Bj} \equiv \beta \cdot \xi \]

\[ \frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F^D_{jj}(x)}{F^D_{jj}(x)} \]  
(LO QCD)

CDF Run I result suppressed by a factor of \(~10\) relative to HERA

\[ \Rightarrow \text{breakdown of QCD factorization} \]
(renormalization removes s-dependence)

K. Goulianos, PLB 358 (1995) 379

Michele Gallinaro, "Diffractive Results at CDF II" - XXXIII ISMD, Krakow, Sept. 5-11, 2003
\[ \xi : \text{Momentum Loss Fraction} \]

Measure fractional momentum loss of anti-proton

\[ \Delta y = \ln \left( \frac{1}{\xi} \right) \]

Diffractive events are boosted towards positive \( \eta \)

\[ \Rightarrow \text{small} \ \xi \]
Single Diffractive Dijets

- Compare diffractive events to ND
- Measure diffractive structure function from $R_{SD/ND}$ vs $x_{Bj}$

Measure $\xi$ (\ $p$ momentum loss fraction) from calorimeter information

Approx. flat at $\xi < 0.1$

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \frac{d\sigma}{d(\log \xi)} = \text{constant}$$
SD: Event Selection

Data presented from 8 pb\(^{-1}\):

<table>
<thead>
<tr>
<th>Event Category</th>
<th>Number of Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP+J5</td>
<td>352,359 events</td>
</tr>
<tr>
<td>(\geq 2) Jets ((E_T&gt;5\text{ GeV},</td>
<td>\eta</td>
</tr>
<tr>
<td>RP offline coincidence</td>
<td>168,153 events</td>
</tr>
<tr>
<td>SD ((0.02&lt;\xi&lt;0.1))</td>
<td>15,209 events</td>
</tr>
</tbody>
</table>

✓ RP acceptance \(~80\%\) (from Run I)
✓ negligible \(<1-2\%)\) RP background trigger
Kinematic Properties

Compare ND and SD
Ratio of SD/ND Events

\[ x_{Bj} = \frac{\sum_{\text{jet}} E_T e^{-\eta}}{\sqrt{s}} \]
(jet=1,2,3 if \( E_T > 5 \) GeV)

- slope and normalization agree with Run I result
- no appreciable \( \xi \) dependence (as in Run I)
- work in progress to evaluate ratio at smaller \( \xi \) values
$Q^2$ Dependence

$E_T^* = \frac{E_T^1 + E_T^2}{2}$

- mean dijet energy intervals
- overall norm. only

$\Rightarrow$ ratio is independent of $Q^2$

Pomeron evolves similarly to proton (?)
DPE Dijet Production

from SD data:
DPE Dijets in Run I

\[ R(\text{DPE}/\text{SD}) \approx k \times R(\text{SD}/\text{ND}) \]

**Question:** \( k = 1 \) ?

**Answer:**

\[ R(\text{DPE}/\text{SD}) \approx 5 \times R(\text{SD}/\text{ND}) \]

⇒ additional gap is un-suppressed
DPE Enhanced Sample

- use dedicated DPE trigger (RP+J5+BSC_Gap_P)

Data presented from 26 pb⁻¹:

<table>
<thead>
<tr>
<th>Triggers</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_{\text{vertex}} \leq 1, \</td>
<td>z_{\text{vertex}}</td>
</tr>
<tr>
<td>RP offline cut</td>
<td>309 k</td>
</tr>
<tr>
<td>( N_{\text{jets}} \geq 2 \ (E_T&gt;5 \text{ GeV}, \</td>
<td>\eta</td>
</tr>
<tr>
<td>( E_T(\text{jet2})&gt;10 \text{ GeV} )</td>
<td>116,473</td>
</tr>
<tr>
<td>SD (0.01&lt;ξ&lt;0.1)</td>
<td>54,552</td>
</tr>
<tr>
<td>DPE (MP-East ( N_{\text{hit}}=0 ))</td>
<td>17,101</td>
</tr>
</tbody>
</table>
DPE: kinematics

Compare ND and SD and DPE
Exclusive Dijet Production

Higgs?

Khoze, Martin, Ryskin

Exclusive dijets (using Run I kinematics): $\sigma \sim 1\text{ nb}$

Recent calculations: $\sigma \sim 60\text{ pb}$ (25<$E_T^{\text{jet}}$<35 GeV, $|\eta_1-\eta_2|<2$)
Exclusive Dijets in Run I

- antiproton tag: $0.035 < \xi < 0.095$
- 2 jets, $E_T > 7$ GeV
- proton-side gap ($2.4 < \eta < 5.9$)

$\Rightarrow$ observed 132 events

Mass fraction: $R_{jj} = \frac{M_{jj}}{M_x}$

$\Rightarrow$ $\sigma_{jj}$ (excl.) < 3.7 nb (95% CL)
Dijet Mass Fraction

CDF Run II Preliminary

Minimum $E_T$(Jet1) | Cross section ($R_{jj}>0.8$)
--- | ---
10 GeV | $970 \pm 65$(stat) $\pm 272$(syst) pb
25 GeV | $34 \pm 5$(stat) $\pm 10$(syst) pb

$\Rightarrow$ independent of rapidity gap size
Exclusive Dijet Events?

R_{jj}=0.81

R_{jj}=0.36
Exclusive low-mass states

\[ pp \rightarrow p\chi\bar{p} \rightarrow J/\psi \gamma \rightarrow \mu\mu\gamma \] (\( \gamma \) is soft)

(same quantum numbers as Higgs boson)

Event selection:
- start from J/\( \psi \) sample
- exclusive events
- invariant mass (\( \mu\mu \)+EM tower)

Background:
- cosmics
- calorimeter noise
Event Selection

Data sample of 93 pb$^{-1}$:

<table>
<thead>
<tr>
<th>Veto</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSC+MP veto</td>
<td>107</td>
</tr>
<tr>
<td>(calorimeter+CLC+trk+muon) veto</td>
<td>23</td>
</tr>
<tr>
<td>EM tower</td>
<td>10</td>
</tr>
</tbody>
</table>

- Mass resolution poor in both, worse in data
- Background from multiplicity fluctuations (under threshold)
- Difficult to estimate noise contribution

Cross section upper limit for exclusive production:

$$\sigma_{J/\psi+\gamma}^{(excl.)} = 49 \pm 18{\text{(stat)}} \pm 39{\text{(syst)}} \text{ pb}$$
Summary

- CDF forward detectors working well
- Dedicated diffractive triggers
- Re-established Run I measurements
- Preliminary results show no $Q^2$ dependence in SD/ND
- Increase in DPE events shows no exclusive dijet production

Run II analyses are well underway!
The ultimate Particle