Recent CMS and CMS–TOTEM results on diffraction

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outline

Single diffractive (SD) di-jet production
- Test of the Pomeron structure
- Access multiple parton interactions (MPI) via gap survival probability

Colour Singlet Exchange in jet-gap-jet events
- Hard “BFKL Pomeron” probing the BFKL dynamics
- Affected by MPI and soft colour interaction (SCI)
• **Rapidity gap based analysis (CMS-only):**
  - Possible for low $\zeta$ thanks to the large CMS detector acceptance
  - Blind to proton dissociation (SD vs ND/DD)
  - Gives quite rough estimate of $\zeta$

• **Intact proton based analysis (CMS+TOTEM):**
  - Requires direct detection of the intact proton
  - Allows rejection of events with proton dissociation
  - Gives direct measurements of $\zeta$ and $t$ for SD/CD cases

• In both cases, the studies are limited to the low pile-up collisions. Low cross-section central exclusive production processes are available with CT-PPS detector (not covered here)
the CMS detector

**Muons**
(CSC+DT+RPC)  
$|\eta| < 2.4$

**Tracker**
(Pixel+SiStrip)  
$|\eta| < 2.4; \ p_t > 100$ MeV

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**ECAL**

PbWO4: $|\eta| < 3$

**HCAL**

central: scint.+brass: $|\eta| < 3$  
$\Delta \eta \times \Delta \phi = 0.087 \times 0.087$

**HF**

steel+quartz: $2.9 < |\eta| < 5.2$  
$\Delta \eta \times \Delta \phi \sim 0.175 \times 175$

*Calorimetry + tracking → Particle Flow Objects*
CMS-TOTEM low lumi runs

CMS-TOTEM low luminosity runs with high $\beta^*$ optics

- Two tracking stations (near+far)@220m from IP
- Acceptance is defined by the beam optics

$90 \text{ m: } 0<\xi<0.1, \quad 0.03<|t|<0.01 \text{ GeV}^2$
CMS-only analysis (2010)

\[ \tilde{\xi} = C \frac{\sum (E \pm p_z)}{\sqrt{s}} \]

C-detector effect corrections \( \sim 1.45 \)

Acceptance: \( \xi < 10^{-2} \)

The ratio data/(bare diffractive MC) gives estimates for the gap survival probability (after MC-based corrections):

- \(0.21 \pm 0.07\) from POMPYT and POMWIG
- \(0.14 \pm 0.05\) from POWHEG

\[ \langle |S^2| \rangle = 0.12 \pm 0.05 \]
\[ \langle |S^2| \rangle = 0.08 \pm 0.04 \]

Confirmation of the factorization breaking in pp collisions:

CMS+TOTEM (8 TeV, special \(b^*\)=90m run in 2012)

Proton tagging with RP =>

much more precise studies + large acceptance
Trigger + offline selection:

CMS: di-jet events \( P_T > 40 \) GeV in \(|\eta| < 4.4\) + primary vertex

AND

TOTEM: RP single arm track (acceptance: \(0 < \xi < 0.1, 0.03 < |t| < 0.01 \) GeV²)

Observables: \( d\sigma/dt, d\sigma/d\xi\), where \( t \) and \( \xi \) are reconstructed from the proton track measured with Roman Pots

ratio of diffractive to inclusive yields \( R(x) \), where

\[
x_\pm = \frac{\sum_{\text{jet}} (E_{\text{jet}} \pm p^\text{jet}_z)}{\sqrt{s}}
\]

Background:

inclusive dijet with a fake or pile-uped single arm RP track
Rejected comparing \( \xi \) and \( \xi_{\text{CMS}} \):
For the acceptance region:

- $<S^2> = 9 \pm 2$ wrt POMWYG after dPDF normalization correction
- $\sigma_{jj}^{pX} = 21.7 \pm 0.9 \text{ (stat)}^{+3.0}_{-3.3} \text{ (syst)} \pm 0.9 \text{ (lumi)} \text{ nb}$
- $d\sigma/dt \propto \exp^{-b|t|} : b = 6.6 \pm 0.6 \text{ (stat)}^{+1.0}_{-0.8} \text{ (syst)} \text{ GeV}^{-2}$ for $0.03 < |t| < 0.45 \text{ GeV}^2$
- POMWYG corrected for the gap survival probability describes the data
- Pythia8 with Dynamic Gap model (DG) accounts for the MPI and describes the data reasonably well without any further corrections
- SD to inclusive cross-section ratio decreases with cme as observed at TEVATRON
**CSE in jet-gap-jet**

Colour singlet exchange – BFKL dynamics

Data: $8 \text{pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

Selection: 0 or 1 vtx,

2 jets with $p_t > 40 \text{ GeV}$ and $|\eta_{1,2}| > 1.5$

Observable: charged particles multiplicity in the gap

**Graph:**

- **Data**
- **Pythia6** (normalized for $N_{\text{tracks}} > 3$)
- **Herwig6** (normalized at $N_{\text{tracks}} = 0$)

$p_T^{\text{jet2}} = 100-200 \text{ GeV}$

8 pb$^{-1}$ (7 TeV)

**Models:**

- Pythia6 – LO DGLAP
- Herwig6 – LL BFKL (Mueller-Tang)

Gap events – Pythia+Herwig
N(CSE) = N(0) - N_{BG}(0)

Background estimation:

\[ N_{BG}(0): \text{Negative Binomial Distribution fit extrapolated to } N=0 \]

**HERWIG (LL BFKL) vs BG corrected data**

BG subtracted central track multiplicities are in good agreement with HERWIG6 prediction
\[ N(\text{CSE}) = N(0) - N_{\text{BG}}(0) \]

CSE fraction = \( \frac{N(\text{CSE})}{N} \)

- Comparison to CDF/D0 @1.8 TeV:
  - Suppression ~ factor 2
- CDF/D0 observation for 0.63 and 1.8 TeV:
  - Decrease of CSE fraction with cme
CSE in jet-gap-jet

CMS-FSQ-12-001,

CSE fraction:

- CSE fraction vs second jet $p_T$:

- CSE fraction vs gap size:

**Graphs:**

- $p_T^{jet_2} = 40-60$ GeV
- $p_T^{jet_2} = 60-100$ GeV
- $p_T^{jet_2} = 100-200$ GeV

**Legend:**

- Data
- EEI ($|S^2| = 0.7\%$)
- EEI (MPI, $|S^2| = 1.5\%$)
- EEI (MPI, $|S^2|$ from SCI)
- MT

**Equations:**

- $\eta^{jet_1} \cdot \eta^{jet_2} < 0$
- Gap region $-1 < \eta < 1$
**summary**

**Single diffractive (SD) di-jet production**

- Pythia8 Dynamic Gap Model describes the data in the best way.
- POMWIG with the corresponding $<S^2>$ correction describes the data as well.
- Obvious profit from intact-proton based analysis for the acceptance and precision.

**Colour Singlet Exchange in jet-gap-jet events**

- Fraction of CSE events is in a good agreement with earlier measurements and can in general be described with (N)LL-BFKL MC.
- The gap size dependence is described in the best way with NLL-BFKL (EEI) accounting for MPI+SCI, but still deviates from the data for high $P_T$ jets.
- Results for 13 TeV are coming soon.