Double parton scattering session: experimental introduction

Jonathan Gaunt, Paolo Gunnellini
Many interesting experimental talks:

- ATLAS results on double parton scattering
  → Ewelina Lobodzinska
- DPS measurements at the CMS experiment
  → Ramandeep Kumar
- Measurement of four-jet production at CMS
  → Paolo Gunnellini
- Study of DPS processes at LHCb
  → An Liupan

N.B. 17 + 3 min. for each talk!

Prospects for the future:

1. DPS energy dependence
2. New sensitive channels?
3. New sensitive observables?
4. New phase space?

N.B. Very personal and (CMS-) biased view!
Experimental overview

\[
\sigma_{AB}^{DPS} = \frac{m \sigma_A \sigma_B}{2 \sigma_{\text{eff}}}
\]

→ Which channels can be used to look for DPS signals?

**FEAURES OF THE FINAL STATE:**

- High multiplicity of physics objects

**Benchmark for the detection of the DPS**

- \(W(\mu\nu) + W(\mu\nu)\)
- \(W(\mu\nu) + bb\) \(Z(\mu\mu) + bb\)
- \(bb + jj\) \(\gamma + 3j\)
- \(4j\) \(W(\mu\nu) + jj\) \(Z(\mu\mu) + jj\)
- Double \(J/\psi\)
- Semi-hard (Minimum Bias) \(j + UE\)
- \(W + UE\) \(Z(\mu\mu) + UE\)

Credits: Paolo Bartalini

Paolo Gunnellini

MPI@LHC2016

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Is this not a clear evidence of DPS?

**ATLAS - CMS**: DPS fraction 5-8%
→ Diff. cross sections of DPS-sensitive observables

**LHCb**: DPS fraction 60 - 80%
→ Total production cross section for sensitive channels
Is this not a clear evidence of DPS?

More results (and new final states) continue to appear

3 pb\(^{-1}\) (7 TeV), pp→ 2 b + 2 j + X

Similar amount of DPS contribution as in W+dijet (∼ 7-9%)!

Collection of several measurements (jet, charm and vector-boson sector) allows studies on channel-dependence
Investigation of sensitive channels (same-sign WW, J/ψ+D,Λ)

Analysis cuts which increase DPS sensitivity

Currently, measurements scan different (and complementary) regions of phase space.
Experimental strategy for DPS measurements (II)

1st step
Corrected distributions
DPS-sensitive variables

2nd step
Data interpretation
and unambiguous
definition of signal and
background templates

3rd step
Extraction of the DPS
fraction and study of
the process dependence

- Compare the data to your own favourite predictions!

4th (future) step: possibility to measure sensitive corners of phase space
Role of the quantity $\sigma_{\text{eff}}$

- Is the value for $\sigma_{\text{eff}}$ a useful input?
- How can one reduce the exp. unc.?
- Should one try also a global extraction?

Combined extraction in different channels/energies?
Focus on associated charm production with some differential cross sections available

→ double $J/\psi$
→ $Z + $ charm mesons
→ $Y + $ charm mesons

From Vanya last year’s MPI@LHC:
"10% of "hard" events has additional charm!"

<table>
<thead>
<tr>
<th></th>
<th>measured</th>
<th>MCFM massless</th>
<th>MCFM massive</th>
<th>DPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z + D^0$</td>
<td>$2.50 \pm 1.12 \pm 0.22$</td>
<td>$0.85^{+0.12}<em>{-0.07}^{+0.11}</em>{-0.17} \pm 0.05$</td>
<td>$0.64^{+0.01}<em>{-0.01}^{+0.08}</em>{-0.13} \pm 0.04$</td>
<td>$3.28^{+0.68}_{-0.58}$</td>
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<tr>
<td>$Z + D^+$</td>
<td>$0.44 \pm 0.23 \pm 0.03$</td>
<td>$0.37^{+0.05}<em>{-0.03}^{+0.05}</em>{-0.07} \pm 0.03$</td>
<td>$0.28^{+0.01}<em>{-0.01}^{+0.04}</em>{-0.06} \pm 0.02$</td>
<td>$1.29^{+0.27}_{-0.23}$</td>
</tr>
</tbody>
</table>

→ Why does LHCb use the CDF result for $\sigma_{\text{eff}}$?

→ I had some rumours that some results at 13 TeV will be presented. :)
Status of DPS analysis in Run II

Not much more available at 13 TeV in terms of DPS understanding for the time being!

POSSIBLE (EXPERIMENTAL) REASONS:
- Poor low-PU runs ($\sim 2 \text{ pb}^{-1}$ - in Run I was $36 \text{ pb}^{-1}$)
- Jets (especially) at low $p_T$ not very well understood
- People are generally happy with evaluation of DPS cross sections for background estimation through the pocket formula $\rightarrow$ little contamination, large uncertainties for $\sigma_{\text{eff}}$
- Missing person power
HOW TO MAKE DPS ANALYSES (EVEN MORE) ATTRACTIVE?

- New ideas and new channels to be looked for
- Development of new theoretical approaches
- Possibility of using more sophisticated models to be tested in specific channels
- Going further: triple parton scattering
- .... more ideas to be collected during this week’s discussions!
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We hope to have a nice discussion during the DPS session!