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Double Parton Scattering with CMS detector at LHC

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Summary. — Multi-parton interactions (MPI) are experiencing a growing popularity and are widely invoked to account for observations that cannot be explained otherwise. With the large integrated luminosity available, the Double Parton Scattering (DPS) measurements (2 hard events in the same proton-proton collision) can be performed in different final states and at different energy scales. The proposed contribution is intended to present the CMS results of DPS analysis on W+2jets events. That is actually the first direct measure of DPS with CMS detector. The analyzed data correspond to an integrated luminosity of $5\,\mathrm{fb}^{-1}$ collected in pp collisions. It will be shown how the simulations of W+2jets events with MADGRAPH5+PYTHIA8 (or PYTHIA6) and NLO predictions of POWHEG2+PYTHIA6 (or HERWIG6) provide a good description of the observables but fail to describe the data if multiple parton interactions are not included. Then the fraction of DPS in W+2-jet events is extracted from a DPS+SPS sample and the value measured is $f_{DPS} = 0.055 \pm 0.002(stat) \pm 0.014(syst)$ with a corresponding effective cross section of $\sigma_{eff} = 20.7 \pm 0.8(stat) \pm 6.5(syst)\,\mathrm{mb}$.

PACS 29.20 – Accelerators.
PACS 14.20.Dh – Protons and neutrons.
PACS 4.70.Fm – W bosons.

1. – Double Parton Scattering

The study of DPS processes is important because it provides valuable information on the transverse distribution of partons in the proton and on the multi-parton correlations in the hadronic wave function. DPS also constitutes a background to new physics searches at the LHC. Various measurements in pp and $\mathrm{p\bar{p}}$ collisions at $\sqrt{s} = 63\,\mathrm{GeV}$, $630\,\mathrm{GeV}$, and $1.8\,\mathrm{TeV}$ are consistent with DPS contributions to multijet final states, as well as to $\gamma + 3$-jet events at $\sqrt{s} = 1.8\,\mathrm{TeV}$ and $1.96\,\mathrm{TeV}$. Additional searches for DPS have been proposed via double Drell-Yan, four jet, and same-sign WW production, as well as in W production associated with jets. This poster presents a study of DPS based on $\mathrm{W} + 2$-jet events in pp collisions at $7\,\mathrm{TeV}$. DPS with a $\mathrm{W} + 2$-jet final state occurs when one hard interaction produces a W boson and another produces a dijet in the same pp collision,

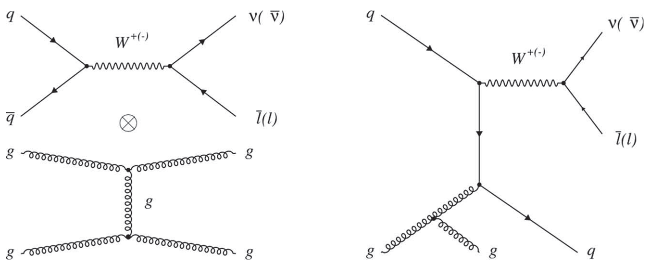

Fig. 1. – left: DPS and right: SPS processes.

as sketched in fig. 1. The W + 2-jet process is attractive because the muonic decay of the W provides a clean tag and the large dijet production cross section increases the probability of observing DPS. Events containing a W + 2-jet final state originating from single parton scattering (SPS) constitute an irreducible background (fig. 1).

2. – DPS measurement

The effective cross section, σ_{eff}, is a measure of the transverse distribution of partons inside the colliding hadrons and their overlap in a collision. The effective cross section involves the cross section for two processes to occur simultaneously and the cross sections for the individual processes. If A and B are two independent processes, whose production cross sections are σ_A and σ_B, respectively, σ_{eff} can be written as

$$\sigma_{DPS}(A+B) = m \cdot \sigma_A \cdot \sigma_B / \sigma_{eff},$$

where m is a symmetry factor for indistinguishable ($m = 1$) and distinguishable ($m = 2$) final-states and $\sigma_{DPS}(A+B)$ is the cross section of the two processes to occur simultaneously. According to various phenomenological studies, the above cross sections should be inclusive. This requirement makes the determination of σ_{eff} independent of the specific mechanisms of the first and second interactions, as well as of the parton distribution functions (PDF). However, in the present analysis an exclusive selection is performed by considering the events with one W boson and exactly two jets with $p_T > 20\,\text{GeV/c}$ and pseudorapidity, η, within 2. The pseudorapidity is defined as $\eta = \ln[\tan(\theta)/2]$, where θ is the polar angle measured with respect to the anticlockwise beam direction. In the kinematic region of the present study, due to the requirement of having exactly 2 jets, the missing contribution of a larger number of parton scatterings is expected to be small and is estimated, with a sample of simulated events, to be less than 1% of the DPS contribution.

For the extraction of the DPS fraction, f_{DPS}, observables that can discriminate between SPS and DPS are needed. For DPS events, the W and the dijet system are independent of each other, while for SPS events they are highly correlated. The present analysis uses the following observables:

– the relative p_T-balance between the two jets, $\Delta^{rel}\, p_T$, defined as

$$\Delta^{rel}\, p_T = \frac{|\overrightarrow{p_T}(j_1) + \overrightarrow{p_T}(j_2)|}{|\overrightarrow{p_T}(j_1)| + |\overrightarrow{p_T}(j_2)|}.$$

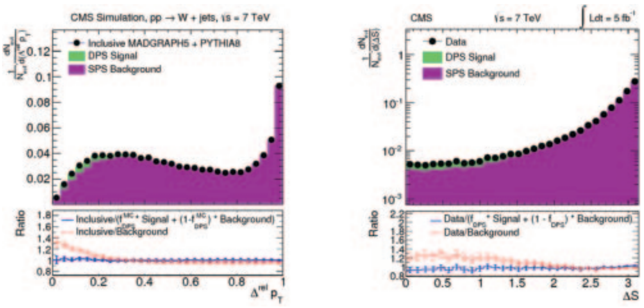

Fig. 2. – left: $\Delta^{rel}\, p_T$ and right: ΔS corrected distributions.

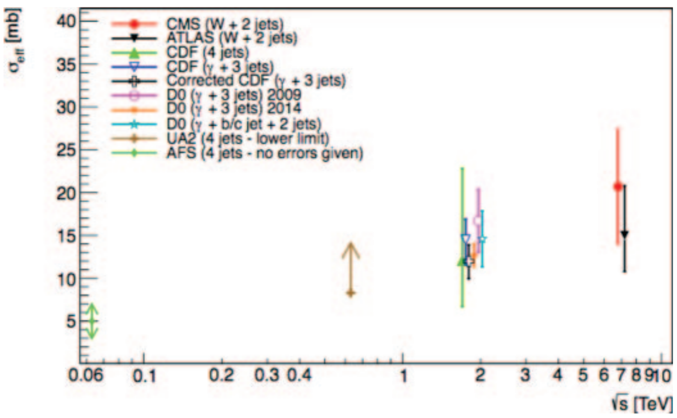

Fig. 3. – σ_{eff} obtained using different processes at various centre-of-mass energies in different experiments.

– The azimuthal angle between the W-boson and the dijet system, ΔS, defined as

$$\Delta S = \arccos\left(\frac{\overrightarrow{p_T}(\mu, MET)\cdot\overrightarrow{p_T}(j_1, j_2)}{|\overrightarrow{p_T}(\mu, MET)|\cdot|\overrightarrow{p_T}(j_1, j_2)|}\right).$$

The sample of W + 2-jet events is selected as described in [1]. The contributions of all backgrounds are subtracted from the data distributions before unfolding. The distributions of the DPS-sensitive observables for the selected events are corrected for selection efficiencies and detector effects. The shape of the distribution of $\Delta^{rel}\, p_T$ and ΔS is more important than the absolute normalization in the extraction of the DPS fraction. Therefore, the unfolding is carried out for the shapes of the $\Delta^{rel}\, p_T$ and ΔS distributions. The measured distributions are unfolded to the level of stable particles and various simulations at particle level are compared with the fully corrected DPS-sensitive observables.

The fraction of W + 2-jet events produced by DPS is extracted by performing a template fit using the signal and background templates to the fully corrected distributions of $\Delta^{rel}\, p_T$ and ΔS (fig. 2). The signal template is obtained by randomly mixing independently produced W and dijet events, whereas the background template is produced from the W + 2-jet sample simulated with MADGRAPH5 + PYTHIA8, in which events with MPI-tagged partons within the acceptance ($|\eta| < 2$) are removed. The fitted value of σ_{eff} is

$$\sigma_{eff} = 20.7 \pm 0.8(stat) \pm 6.6(syst)\,\text{mb}.$$

Figure 3 shows a comparison of the effective cross sections obtained using different processes at various centre-of-mass energies.

From the experimental results, a firm conclusion on the energy dependence of σ_{eff} cannot be drawn because of the large systematic uncertainties. The CMS measurement is consistent with previous measurements performed at the Tevatron and by the ATLAS Collaboration at the LHC. The CMS measurement is also consistent with predictions from PYTHIA of 20–30 mb, depending on the tune.

REFERENCES

[1] The CMS Collaboration, *JHEP*, **03** (2014) 032.