Chapter 7

Summary

Inclusive jet production cross-section measured precisely as a function of jet transverse momentum is one of the important observables in understanding physics at hadron colliders. It provides the essential information about the structure of proton through parton distribution functions (PDFs) and the precise measurement of the strong coupling constant α_S. The value of the strong coupling constant at the scale of the Z boson mass $\alpha_s(M_Z)$ can be determined using cross-section ratio instead of individual cross-sections because many theoretical and experimental uncertainties (i.e. uncertainties due to luminosity, scale dependence, PDF dependence etc.) may cancel between numerator and denominator.

In this thesis, a measurement of the inclusive 2-jet and 3-jet event cross-sections as well as the cross-section ratio R_{32} has been presented. The data sample has been collected from proton-proton collisions recorded with the CMS detector at a centre-of-mass energy of 8 TeV corresponding to an integrated luminosity of 19.7 fb^{-1}. The jets are reconstructed with the anti-k$_t$ clustering algorithm for a jet size parameter R = 0.7. The inclusive 2-jet and 3-jet event cross-sections are measured differentially as a function of the average transverse momentum of the two leading jets, referred as $H_{T,2}/2$. The ratio R_{32} is obtained by dividing the differential cross-sections of inclusive 3-jet events to that of inclusive 2-jet one in each bin of $H_{T,2}/2$. An appropriate selection criteria has been designed for choosing the best events for analysis. The measurements are performed at a central rapidity of $|y| < 2.5$ in a range of $0.3 < H_{\mathrm{T},2}/2 < 2.0\,\mathrm{TeV}$ for inclusive 2-jet event cross-sections and $0.3 < H_{\mathrm{T},2}/2 < 1.68\,\mathrm{TeV}$ for inclusive 3-jet event cross-sections and ratio R_{32}.

The measured cross-sections after correcting for detector effects by using an iterative unfolding procedure are compared to the perturbative QCD predictions computed, using NLOJET++ program, at next-to-leading order (NLO) accuracy and complemented with non-perturbative (NP) corrections that are important at low $H_{\mathrm{T},2}/2$. The data are found to be well described by NLO calculations. The upwards trend observed in the inclusive 2-jet and 3-jet data at high $H_{\mathrm{T},2}/2$ in comparison to the prediction at NLO QCD, is explained by the onset of electroweak (EW) corrections in the 2-jet case. For the 3-jet event cross-sections these corrections have not yet been computed yet. In the 3-jet to 2-jet cross-section ratio R_{32}, the EW corrections are assumed to cancel. In fact, NLO QCD provides an adequate description of R_{32} in the accessible range of $H_{\mathrm{T},2}/2$. In contrast, leading order (LO) tree-level Monte Carlo (MC) predictions obtained using MADGRAPH5 event generator interfaced to PYTHIA6 exhibit significant deviations. The sources of experimental and theoretical uncertainties are studied in details. The experimental uncertainty ranges from 4 to 32% for inclusive 2-jet event cross-sections, from 4 to 28% for 3-jet event cross-sections and from 1 to 28% for cross-section ratio R_{32}. It is dominated by the uncertainty due to the jet energy corrections (JEC) at lower $H_{\mathrm{T},2}/2$ values and by statistical uncertainty at higher $H_{\mathrm{T},2}/2$ values. The theoretical uncertainty ranges from 3 to 30% and 5 to 34% for inclusive 2-jet and 3-jet event cross-sections respectively and from 3 to 11% for ratio R_{32}. The PDF uncertainty derived using the CT10-NLO PDF set is the dominant source of theoretical uncertainty.

The inclusive multijet cross-sections being proportional to the powers of the strong coupling constant α_S ($\sigma_{\text{n-jet}} \propto \alpha_S^{\text{n}}$) are used to determine the strong coupling constant at the scale of the Z boson mass $\alpha_s(M_Z)$. In cross-section ratio R_{32} which proportional to α_S, many uncertainties and PDF dependencies largely cancel and hence becomes the better tool to extract the value of $\alpha_s(M_Z)$. In this thesis, a fit of the ratio of the 3-jet over 2-jet event cross-section R_{32} in the range $0.3 < H_{\text{T},2}/2 < 1.68\,\text{TeV}$ using the MSTW2008 PDF set gives :

$$\begin{aligned}\alpha_s(M_Z) &= 0.1150 \pm 0.0010\,(\text{exp}) \pm 0.0013\,(\text{PDF}) \pm 0.0015\,(\text{NP})\,^{+0.0050}_{-0.0000}\,(\text{scale})\\ &= 0.1150 \pm 0.0023\,(\text{all except scale})\,^{+0.0050}_{-0.0000}\,(\text{scale})\end{aligned}$$

Very similar results are obtained using the MMHT2014 PDF set which gives :

$$\begin{aligned}\alpha_s(M_Z) &= 0.1142 \pm 0.0010\,(\text{exp}) \pm 0.0013\,(\text{PDF}) \pm 0.0014\,(\text{NP})\,^{+0.0049}_{-0.0006}\,(\text{scale})\\ &= 0.1142 \pm 0.0022\,(\text{all except scale})\,^{+0.0049}_{-0.0006}\,(\text{scale})\end{aligned}$$

The equally compatible values of $\alpha_s(M_Z)$ are determined with separate fits to the inclusive 2-jet and 3-jet event cross-sections provided the range in $H_{\text{T},2}/2$ is restricted to $0.3 < H_{\text{T},2}/2 < 1.0\,\text{TeV}$. The extracted $\alpha_s(M_Z)$ values in sub-ranges of $H_{\text{T},2}/2$ are evolved to corresponding $\alpha_S(Q)$ along with the error bars at different scales Q. The current measurement of $\alpha_s(M_Z)$ and the running of $\alpha_S(Q)$ as a function of Q is in agreement with the world average value of $\alpha_s(M_Z) = 0.1181 \pm 0.0011$ [58] and already existing determinations performed by the CMS and other experiments.

The inclusion of the EW corrections in inclusive 2-jet event cross-sections become relevant at $H_{\text{T},2}/2$ beyond 1 TeV. Their availability for 3-jet one and hence cross-section ratio R_{32} can improve the precision of the measurement of $\alpha_s(M_Z)$. Also as the theoretical calculations will be available for inclusive 4-jet event cross-sections, the various cross-section ratios such as $R_{43} \propto \alpha_S^1$ and $R_{42} \propto \alpha_S^2$ can be measured to extract the value of the strong coupling constant more precisely. Currently LHC is running at high center-of-mass energy of 13 TeV delivering a higher instantaneous luminosity and this makes possible to extend the accessible phase space and perform the measurements with more accuracy.