

# List of Figures

2.1	The Standard Model summarizing the properties of elementary particles and their forces of interaction. . . . .	8
2.2	The fundamental Feynman rules for different processes of quantum chromodynamics. . . . .	13
2.3	Evolution of three fundamental coupling constants : the strong coupling constant $\alpha_S$ , the weak coupling constant $\alpha_w$ and the electromagnetic coupling constant $\alpha_e$ . . . . .	14
2.4	Feynman diagrams of leading-order (LO), next-to-leading order (NLO) and next-to-next-to-leading order (NNLO) processes in quantum chromodynamics. . . . .	16
2.5	Running of the strong coupling constant evolved at the energy scale $Q$ as a function of $Q$ . . . . .	19
2.6	Schematic illustration of the factorization theorem in a collision of two protons. . . . .	21
2.7	Illustration of the hadronization process in Lund string model. . . . .	23
2.8	A proton-proton collision involving the main hard scattering process along with the low momentum transfer underlying event (UE) contributions. . . . .	24
2.9	Formation of a jet in a proton-proton collision. . . . .	25
2.10	Illustration of infrared and collinear unsafe behaviour of jet algorithms. . . . .	27

2.11	The clustering of particles into jets using different jet algorithms. . .	30
3.1	An overview of the different experiments of the Large Hadron Collider (LHC), a complex particle accelerator and collider located at CERN.	33
3.2	The integrated luminosity delivered by stable beams to CMS during proton-proton collisions. . . . .	36
3.3	In a proton-proton collision, the particles produced from the hard interaction are clustered into a jet. The hard interaction corresponds to the main vertex. The particles produced in the interactions other than the hard one, form a pileup jet. . . . .	37
3.4	The three dimensional view of the CMS detector along with its sub-detector components. . . . .	39
3.5	Front view of the CMS detector along with its various components. .	40
3.6	The right-handed coordinate system used by the CMS detector. . . .	41
3.7	A longitudinal view of the CMS detector is shown in the $y$ - $z$ plane. .	42
3.8	A longitudinal view of the inner tracking system is shown in $r$ - $z$ plane.	43
3.9	A geometric view of one quarter of the electromagnetic calorimeter (ECAL) in $y$ - $z$ plane. . . . .	45
3.10	Longitudinal section of one quarter of the hadronic calorimeter (HCAL) in $r$ - $\eta$ plane. . . . .	47
3.11	A longitudinal view of the CMS muon system showing the location of the three gaseous particle detectors. . . . .	51
3.12	Work flow of the L1 trigger system consisting of local, regional and global components. . . . .	52
3.13	Architecture of the CMS Data Acquisition (DAQ) system. . . . .	55
3.14	The schematic overview of the CMS computing grid. . . . .	56

4.1	The comparison between Monte Carlo (MC) simulations generated by event generators and the real data produced by the particle collisions and observed in the detectors. . . . .	60
4.2	The Particle Flow (PF) algorithm is used by the CMS to identify and reconstruct the particles. The PF converts the sub-detector measurements back to physical particle objects. . . . .	67
4.3	Formation of jets in a proton-proton collision at different levels. . . .	69
4.4	A schematic diagram of the factorized jet energy corrections (JEC). . .	70
5.1	Trigger efficiencies turn-on curves for the single jet HLT trigger paths.	79
5.2	Missing transverse energy fraction of the total transverse energy per event in the data and simulated Monte Carlo events. . . . .	81
5.3	The fractions of jet constituents for different types of PF candidates for inclusive 2-jet events. . . . .	83
5.4	The fractions of jet constituents for different types of PF candidates for inclusive 3-jet events. . . . .	84
5.5	The jet ID efficiency is studied as a function of $H_{T,2}/2$ with tag-and-probe technique using dijet event topologies and it always exceeds 99%. . . . .	85
5.6	Number of reconstructed vertices before and after the pileup reweighting. . . . .	87
5.7	Comparison of differential cross-sections for the data with simulated events and CT10-NLO theory predictions. . . . .	88
5.8	Comparison of the cross-section ratio for the data with simulated events and CT10-NLO theory predictions. . . . .	88
5.9	Fitting of the jet energy resolution distribution as a function of $H_{T,2}/2$ .	92

5.10 Comparison of jet energy resolution calculated using Crystal Ball fit function and Gaussian fit function . . . . .	93
5.11 Jet energy resolution (JER) is shown as a function of Gen $H_{T,2}/2$ . . .	93
5.12 Additional unfolding uncertainty. . . . .	94
5.13 Fitted CT10-NLO spectrum of differential cross-section as a function of $H_{T,2}/2$ . . . . .	99
5.14 The response matrices are derived using the Toy Monte Carlo and forward smearing method. . . . .	100
5.15 Left : The ratio of cross-sections for inclusive 3-jet to that of 2-jet events as a function of $H_{T,2}/2$ . Right : The response matrix is derived using the Toy Monte Carlo and forward smearing method, for the cross-section ratio $R_{32}$ . . . . .	101
5.16 Closure test of the unfolding technique . . . . .	102
5.17 Reco differential cross-section distributions unfolded with the re- sponse matrices. . . . .	103
5.18 The measured differential cross-sections as well as the cross-section ratio $R_{32}$ are unfolded as a function of $H_{T,2}/2$ using the response matrices derived using the Toy Monte Carlo and forward smearing method. . . . .	104
5.19 The fractional statistical uncertainties of the unfolded data are com- pared with those of the measured one. . . . .	106
5.20 The unfolding procedure introduces the correlations of the statistical uncertainty through bin migrations. . . . .	107
5.21 Experimental uncertainties from different sources affecting the mea- surement of cross-sections and the cross-section ratio. . . . .	111
6.1 The k-factors using five different PDF sets. . . . .	116

6.2	The nonperturbative (NP) corrections are presented as a function of $H_{T,2}/2$ . . . . .	118
6.3	The electroweak (EW) corrections as a function of $H_{T,2}/2$ . . . . .	119
6.4	Ratio of the data over theory obtained using the CT10-NLO PDF set. . . . .	120
6.5	The systematic theoretical uncertainties affecting the cross-section measurement and the cross-section ratio. . . . .	123
6.6	Comparison of the measured differential inclusive 2-jet and 3-jet event cross-sections as a function of $H_{T,2}/2$ to theoretical predictions. . . . .	125
6.7	Cross-section ratio as a function of $H_{T,2}/2$ calculated from data in comparison to that from NLO pQCD predictions obtained using the CT10-NLO PDF set. . . . .	125
6.8	Ratio of the data over theory using the CT10-NLO PDF set. . . . .	127
6.9	Ratio of the data over the predictions from Monte Carlo simulations. . . . .	128
7.1	Ratio of the measured inclusive 2-jet differential cross-section to theory predictions using different PDF sets. . . . .	132
7.2	Ratio of the measured inclusive 3-jet differential cross-section to theory predictions using different PDF sets. . . . .	133
7.3	Ratio of the measured cross-section ratio to theory predictions using different PDF sets. . . . .	134
7.4	The running $\alpha_S(Q)$ as a function of the energy scale $Q$ . . . . .	143
9.1	The arrangement of Silicon Photo-Multipliers (SiPMs) on the Mounting Board (MB). . . . .	151
9.2	The breakdown voltage (BV) is estimated using LED method and its variation is shown over time for 18 channels of one readout module (RM). . . . .	153

9.3	The relative variation of the SiPM gain is presented over time for a single RM with 18 channels. The gain is stable over a time from the middle of February to the beginning of March in 2014 and the relative variation of the gain lies within 2% . . . . .	154
9.4	The distribution of the relative variations in gain for all the installed SiPMs is fitted with a Gaussian function. It has a width of only 0.5 % and all gain variations are within 3%. . . . .	155
9.5	$\mu$ TCA crate showing the different slots. . . . .	156
9.6	A test-stand designed to monitor the working of Power Mezzanines/Auxiliary Power Mezzanines (PMs/APMs) through stability tests. . . . .	157
9.7	A test-stand installed at Department of Physics, Panjab University, Chandigarh to perform the stability tests for monitoring the working of Power Mezzanines/Auxiliary Power Mezzanines (PMs/APMs). . .	158
A.1	The fractional jet energy correction (JEC) uncertainties from individual sources (Part I). . . . .	164
A.2	The fractional jet energy correction (JEC) uncertainties from individual sources (Part II). . . . .	165
A.3	The fractional jet energy correction (JEC) uncertainties from individual sources (Part III). . . . .	166