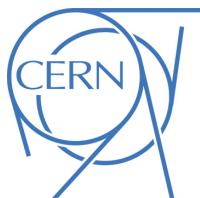




ATLAS NOTE

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2 Search for massive supersymmetric particles in multijet final states 3 produced in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS 4 detector at the LHC

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8 Abstract

9 Results of a search for supersymmetric gluino pair productions with subsequent R -parity-
10 violating decays to quarks are presented. This search uses 36.1 fb^{-1} of data collected by
11 the ATLAS detector in proton-proton collisions with a center-of-mass energy of $\sqrt{s} = 13$
12 TeV at the LHC. The analysis is performed using both a requirement on the number of jets
13 and the number of jets tagged as containing a b -hadron as well as a topological observable
14 formed from the scalar sum of large-radius jet masses in the event. No significant deviation is
15 observed from the expected Standard Model backgrounds. Limits are set on the production
16 of gluinos in the gluino direct and cascade decay models in the UDD scenarios of RPV
17 SUSY. In the gluino cascade decay model, gluinos with masses up to 1000 GeV - 1920 GeV
18 are excluded, depending on the neutralino mass; For the gluino direct decay model, the limit
19 on the cross section times branching ratio varies between 0.80 fb^{-1} at $m_{\tilde{g}} = 900 \text{ GeV}$ and
20 0.011 fb^{-1} at $m_{\tilde{g}} = 1800 \text{ GeV}$. Model independent limits on the cross section of signal in the
21 defined SRs are also reported.

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88 List of contributions

Brian Amadio	Analysis framework, data processing, signal study, signal production, statistics interpretation, large-R jet performance study.
Samuel Bright-Thonney	evaluating signal systematic uncertainties
Jennet Dickinson	Signal study, event display.
Ian Hinchliffe	Advising analysis team
89 Simone Pagan-Griso	advising analysis team
Marjorie Shapiro	Advising analysis team
Sicong Lu	running background estimation and statistical interpretation programs
90 Haichen Wang	Background estimation, signal study, statistics interpretation, analysis coordination, contact and editor.

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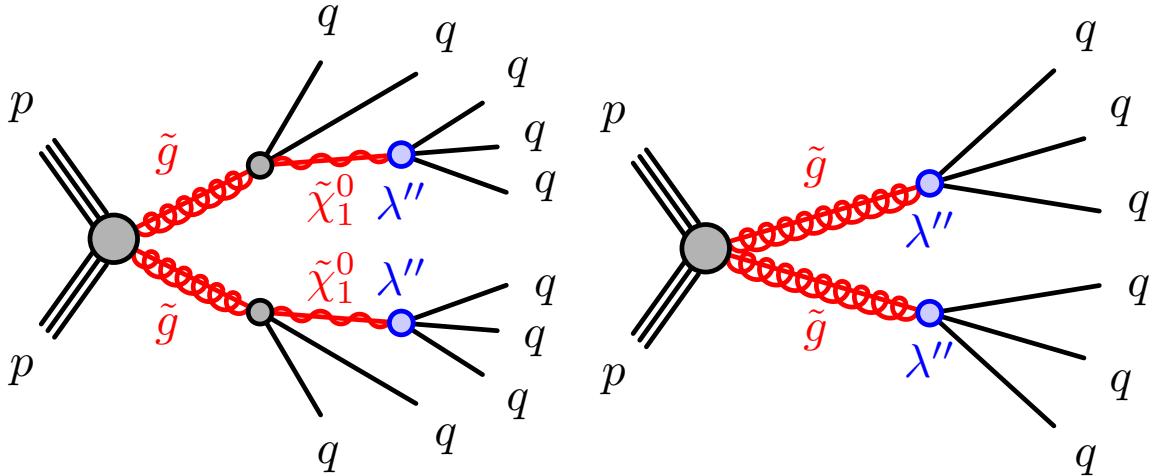


Figure 1: Diagrams for the benchmark processes considered for this analysis. The solid black lines represent Standard Model particles, the solid red lines represent SUSY partners, the gray shaded circles represent effective vertices that include off-shell propagators (e.g. heavy squarks coupling to a neutralino and a quark), and the blue shaded circles represent effective RPV vertices allowed by the baryon-number-violating λ_{00} couplings with off-shell propagators (e.g. heavy squarks coupling to two quarks).

91 1. Introduction

92 This note documents the search for R-Parity Violating (RPV) supersymmetry (SUSY) signal in the multijet
93 final state.

94 We present a search for the pair production of massive particles that subsequently cascade to a final state
95 characterized by a large number of quarks using the $\sqrt{s} = 13$ TeV data collected in 2015 and 2016. Such
96 high multiplicity final states are expected in some models of Supersymmetry (SUSY) when gluinos (\tilde{g}) are
97 pair produced and then decay via squarks to two quarks and a neutralino. In RPV scenarios, the neutralino
98 itself can then decay to three quarks via an RPV decay vertex with a Yukawa coupling strength denoted
99 by λ . Alternatively, the gluinos can directly decay to three quarks via the same RPV coupling. In both
100 scenarios, it is assumed that all other SUSY partners are “decoupled,” or so massive that their presence in
101 the decay chain of the gluino, or even direct production, is negligible. These processes are illustrated in
102 Figure 1.

103 The analysis strategy closely follows the one that was performed with the $\sqrt{s} = 8$ TeV data by ATLAS [1].
104 The high jet multiplicity in the signal event motivates the use of an event-level observable, the total jet
105 mass M_J^Σ , constructed from multiple individual large-radius jets. This provides significant discrimination
106 between signal and background by capitalizing on the topological differences between them. The
107 background estimation relies on a “jet mass template” method, which was first proposed in Ref. [2]. The
108 predicted background total jet mass distribution is constructed from individual jet mass templates that are
109 obtained from data in control samples. Extensive studies have been done to validate this method with
110 several Monte Carlo samples as well as data validation regions. The systematic uncertainties associated
111 with this method are also understood and quantified from these studies.

¹¹² The analysis uses data collected in 2015 and 2016, corresponding to an integrated luminosity of 36.1 fb^{-1} .
¹¹³ The datasets taken in 2015 and 2016 are analyzed as one uniform sample.

¹¹⁴ This note is organized as follows: Section 2 describes the data and Monte Carlo samples. Section 3
¹¹⁵ discusses the search strategy, presents the event selection and defines the control, validation and signal
¹¹⁶ regions. Section 4 explains the background estimation strategy, and in Section 4.6 the predicted M_j^Σ dis-
¹¹⁷ tribution and background yield in the signal regions are shown. Section 5 introduces the signal systematic
¹¹⁸ uncertainties. Section 6 presents the statistics analysis and interpretation.

¹¹⁹ 2. Data and Monte Carlo samples

¹²⁰ 2.1. Data

¹²¹ This analysis uses data collected in 2015 and in 2016 up to the summer conference. The ALL_GOOD
¹²² Good Run List (GRL) is used to select events with good data quality. The DS1 data sample is used for the
¹²³ current version of the note. A total of 3.2 fb^{-1} 2015 data and a total of 32.9 fb^{-1} 2016 data are analyzed.

¹²⁴ 2.2. Signal simulation

¹²⁵ Signal samples are generated at the leading order using MG5_aMC@NLO event generator [3] inter-
¹²⁶ faced to Pythia 8.186 [4]. The A14 [5] set of tuned parameters (tune) is used for underlying event together
¹²⁷ with the NNPDF2.3LO [6] parton distribution function (PDF) set. The EvtGen v1.2.0 program [7] is
¹²⁸ used to describe the properties of the b- and c- hadron decays in the signal samples and the background
¹²⁹ samples except those produced with Sherpa [8]. The signal cross-sections are calculated at next-to-leading
¹³⁰ order (NLO) in the strong coupling constant, adding the resummation of soft gluon emission at next-to-
¹³¹ leading-logarithmic accuracy (NLO+NLL) [9–13]. The nominal cross-section is taken from an envelope
¹³² of cross-section predictions using different PDF sets and factorization and renormalization scales, as
¹³³ described in [14], considering only light-flavour quarks (u, d, s, c). Cross-sections are evaluated assuming
¹³⁴ masses of 450 TeV for the light-flavour squarks in case of gluino-pair production.

¹³⁵ Signal samples are produced covering a wide range of both $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$. In the six-quark direct gluino
¹³⁶ decay model, the gluino mass is varied from 900 to 1800 GeV with a step of 100 GeV. In the case of the
¹³⁷ cascade decays, for each gluino mass (1000 GeV to 2.1 TeV), separate samples are generated with multiple
¹³⁸ neutralino masses ranging from 50 GeV to 1.9 TeV, which is shown in Figure 2.

¹³⁹ It has been shown that the ATLFast II agrees with the full simulation very well in the kinematic region
¹⁴⁰ relevant to the RPV signals [15]. Therefore, ATLFast II samples are requested for all signal points,
¹⁴¹ while full simulation samples are requested at a few representative points.

¹⁴² 2.3. Background simulation

¹⁴³ While a data-driven method is used to estimate the background, simulated events are used to establish, test
¹⁴⁴ and validate the methodology of the analysis. Therefore, simulation is not required to accurately describe
¹⁴⁵ the background, but it should be sufficiently similar that the strategy can be tested before applying it to
¹⁴⁶ data. Multijet events constitute the dominant background in the search region, with small contributions

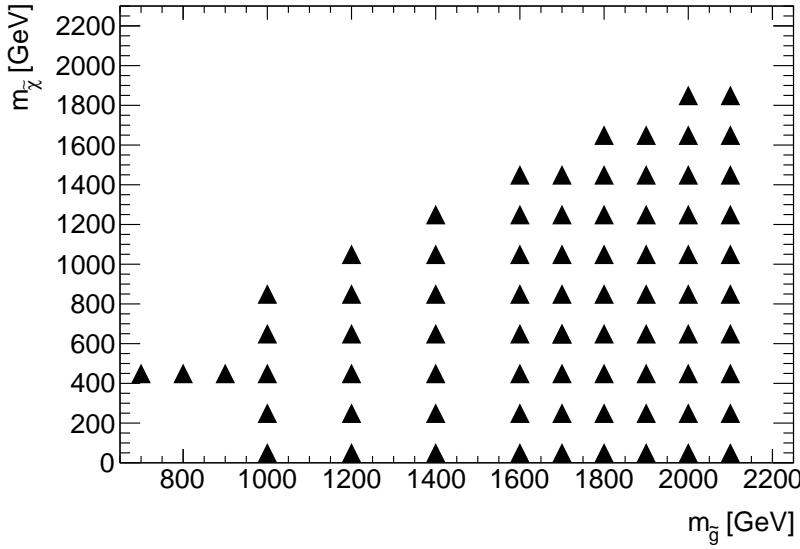


Figure 2: The grid of simulated signal samples for the 10-quark model.

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¹⁴⁷ from top-quark pair-production ($t\bar{t}$); $\gamma + \text{jets}$, $W + \text{jets}$, $Z + \text{jets}$, single-top quark, and diboson background
¹⁴⁸ contributions are negligible.

¹⁴⁹ The multi-jet background is generated with PYTHIA8 8.186 using the A14 underlying-event tune and
¹⁵⁰ the NNPDF2.3LO parton distribution functions. SHERPA multi-jet samples, with up to three partons
¹⁵¹ included in the matrix-element calculation, are also generated and tested for the background estimationx.
¹⁵² For the generation of $t\bar{t}$ processes the Powheg-Box v2 [16] generator is used with the CT10 PDF set [17].

¹⁵³ The multijet samples (often known as the JZW samples in ATLAS) are created in 13 slices defined
¹⁵⁴ by the leading jet p_T . The slice with the lowest jet p_T needed in the analysis is the JZ3 slice with a
¹⁵⁵ leading jet p_T between 160 GeV and 400 GeV. The Monte Carlo luminosity is 1.9 fb^{-1} and 3.6 fb^{-1} for
¹⁵⁶ the PYTHIA8 multijet sample and Herwigpp multijet sample, respectively. For the JZ4W slice, both
¹⁵⁷ PYTHIA8 and Herwigpp samples have an MC integrated luminosity at least three times that of data.
¹⁵⁸ Table 1 summarizes the information of the three multijet MC samples.

DSID	sample	events	MC luminosity
361021	mc15_13TeV.361021.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ1W.evgen.EVNT.e3569	15999000	0.0
361022	mc15_13TeV.361022.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ2W.evgen.EVNT.e3668	15989500	0.02
361023	mc15_13TeV.361023.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ3W.evgen.EVNT.e3668	15882500	1.88
361024	mc15_13TeV.361024.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ4W.evgen.EVNT.e3668	15983500	118.4
361025	mc15_13TeV.361025.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ5W.evgen.EVNT.e3668	15994500	3809.9
361026	mc15_13TeV.361026.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ6W.evgen.EVNT.e3569	17859000	73815.3
361027	mc15_13TeV.361027.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ7W.evgen.EVNT.e3668	15986000	2513966.94
361028	mc15_13TeV.361028.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ8W.evgen.EVNT.e3569	16000000	2517789.09
361029	mc15_13TeV.361029.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ9W.evgen.EVNT.e3569	15998500	67555778.44
361030	mc15_13TeV.361030.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ10W.evgen.EVNT.e3569	16000000	2268373246.28
361031	mc15_13TeV.361031.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ11W.evgen.EVNT.e3569	15998000	141400009484.0
361032	mc15_13TeV.361032.Pythia8EvtGen_A14NNPDF23LO_jetjet_JZ12W.evgen.EVNT.e3668	15996000	3.62941428448e+13
426043	mc15_13TeV.426043.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ3W.evgen.EVNT.e4410	15618500	3.67
426044	mc15_13TeV.426044.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ4W.evgen.EVNT.e4410	15647000	236.73
426045	mc15_13TeV.426045.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ5W.evgen.EVNT.e4410	15658000	7701.24
426046	mc15_13TeV.426046.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ6W.evgen.EVNT.e4410	3908000	32569.15
426047	mc15_13TeV.426047.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ7W.evgen.EVNT.e4410	3901500	1154204.14
426048	mc15_13TeV.426048.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ8W.evgen.EVNT.e4410	1963500	566055.81
426049	mc15_13TeV.426049.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ9W.evgen.EVNT.e4410	491000	3700042.34
426050	mc15_13TeV.426050.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ10W.evgen.EVNT.e4410	491000	127287866.54
426051	mc15_13TeV.426051.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ11W.evgen.EVNT.e4410	489500	8624206090.08
426052	mc15_13TeV.426052.HerwigppEvtGen_UEEE5_CTEQ6L1_jetjet_JZ12W.evgen.EVNT.e4410	488000	2.41659846758e+12
426133	mc15_13TeV.426133.Sherpa_CT10_jets_JZ3.evgen.EVNT.e4355	7975000	0.03
426134	mc15_13TeV.426134.Sherpa_CT10_jets_JZ4.evgen.EVNT.e4355	7987000	2.99
426135	mc15_13TeV.426135.Sherpa_CT10_jets_JZ5.evgen.EVNT.e4355	7999000	159.65
426136	mc15_13TeV.426136.Sherpa_CT10_jets_JZ6.evgen.EVNT.e4355	1999400	1102.81
426138	mc15_13TeV.426138.Sherpa_CT10_jets_JZ8.evgen.EVNT.e4635	1999000	412920.04
426139	mc15_13TeV.426139.Sherpa_CT10_jets_JZ9.evgen.EVNT.e4635	1986000	10979179.58
426141	mc15_13TeV.426141.Sherpa_CT10_jets_JZ11.evgen.EVNT.e4635	1979550	22272130962.5

Table 1: Information of the multijet Monte Carlo samples. The lowest relevant jet p_T slice is JZ3, which has a leading jet p_T filer of 160 GeV - 400 GeV. p_T slicing information of the multijet samples can be found [here](#).

¹⁵⁹ **3. Search strategy**

¹⁶⁰ **3.1. Choice of discriminating variables**

¹⁶¹ The search utilizes the large-R jet so that the jet mass template method can be implemented to estimate the
¹⁶² background. The large-R jet is a trimmed Anti-kt jet with a radius of 1.0 (anti-kt 1.0 jet). The reconstructed
¹⁶³ anti-kt1.0 jet is first re-clustered with kt 0.2 sub-jets (radius = 0.2). If the transverse momentum of the
¹⁶⁴ sub-jet is less than 5% of transverse momnetum of the original jet, then the sub-jet is removed. The
¹⁶⁵ discriminating variable of this analysis, M_J^Σ , the sum of jet mass variable, is defined with largeR jet:

$$M_J^\Sigma = \sum_{i=1}^4 m_{jet}^i \quad (1)$$

¹⁶⁶ where i is the index of the large-R jet ordered by p_T , and m_{jet}^i is the mass of the i -th large-R jet. In
¹⁶⁷ the case of 3-jet events, the M_J^Σ variable is calculated with all three large-R jets' masses in the event.
¹⁶⁸ Simulation studies show that M_J^Σ provides greater sensitivity than variables such as H_T , the scalar sum
¹⁶⁹ of jet p_T : the masses contain angular information about the events by definition, whereas a variable
¹⁷⁰ like H_T simply describes the energy (or transverse momentum) in the event. A large M_J^Σ implies not
¹⁷¹ only high energy, but also rich angular structure. Previous studies at the Monte Carlo event generator
¹⁷² level have demonstrated the power of the M_J^Σ variable in the high-multiplicity events that this analysis
¹⁷³ targets [18, 19]. Figure 3(a) presents examples of the discrimination that the M_J^Σ observable provides
¹⁷⁴ between the background (represented here by SHERPA and PYTHIA8 multi-jet MC simulation) and several
¹⁷⁵ signal samples, as well as the comparison of the data to the Monte Carlo multi-jet background.

¹⁷⁶ Another discriminating variable that is independent of M_J^Σ is necessary in order to define suitable control
¹⁷⁷ and validation regions for the analysis. The signal is characterized by a considerably higher rate of central
¹⁷⁸ jet events as compared to the primary multi-jet background. This is expected due to the difference in the
¹⁷⁹ production processes that is predominantly s -channel for the signal, while the background can also be
¹⁸⁰ produced through u - and t -channel processes. Figure 3(b) shows the distribution of the pseudorapidity
¹⁸¹ difference between the two leading large- R jets, $|\Delta\eta_{12}|$ for several signal and background Monte Carlo
¹⁸² samples, as well as data. A high $|\Delta\eta_{12}|$ requirement can be applied to establish a control region or a
¹⁸³ validation region where the potential signal contamination needs to be suppressed.

¹⁸⁴ The RPV signal events are expected to have a large number of jets, and therefore, the search will require a
¹⁸⁵ high large-R jet multiplicity. Figure 4(a) shows large- R jet multiplicity for signal and background multijet
¹⁸⁶ Monte Carlo samples, as well as data.

¹⁸⁷ The RPV model considered by this analysis assumes that the decay branching ratio is identical for all
¹⁸⁸ possible final states, which leads to a large number of b-jets in the final state. The choice of equal
¹⁸⁹ coupling to the allowed UDD final states indicates the final states are likely to contain at least one third
¹⁹⁰ generation quarks. In some theoretical model, such as the Minimal Flavor Violating SUSY [20–24], the
¹⁹¹ decays to final states containg third generation quarks are also favored. Figure 5 shows the number of
¹⁹² reconstructed b-jets in events with ≥ 4 large- R jets for two representative RPV signal samples as well
¹⁹³ as the PYTHIA8 multijet MC sample. The search takes advantage of this characteristics by defining the
¹⁹⁴ signal region with a b-tagging requirement. The event should have at least one Anti-kt4 EMtopo jet that
¹⁹⁵ is b-tagged, but the b-tagged jet is not required to be matched to a selected large R jet.

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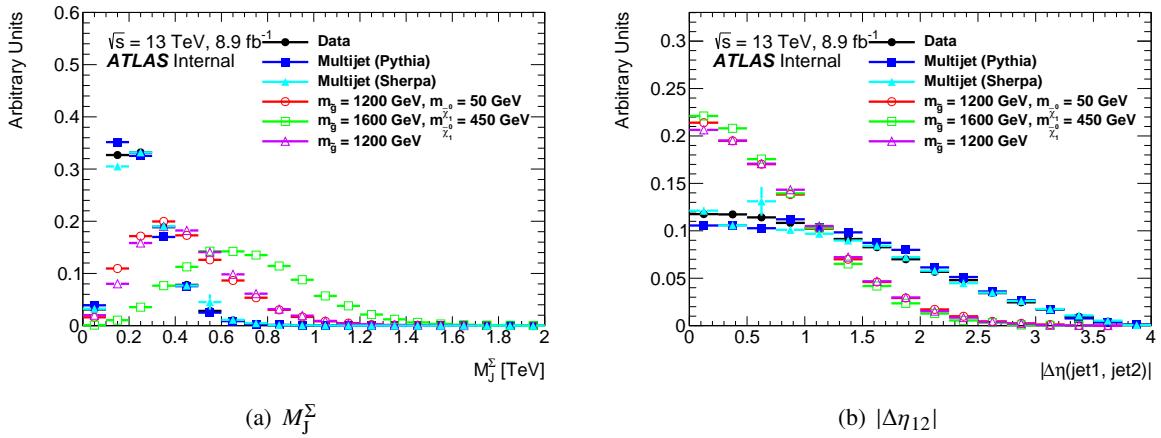


Figure 3: Comparison between signal sample and background dominant data control sample for (a) the scalar sum of the masses of the four leading large- R jets M_J^Σ and (b) the difference in pseudorapidity between the two leading large- R jets $|\Delta\eta_{12}|$. Several typical signal points are shown, as well as the distributions obtained from the data. All distributions are normalized to the same area. The selection requires four or more jets, and are inclusive in $|\Delta\eta_{12}|$ and have no b-tagging requirements.

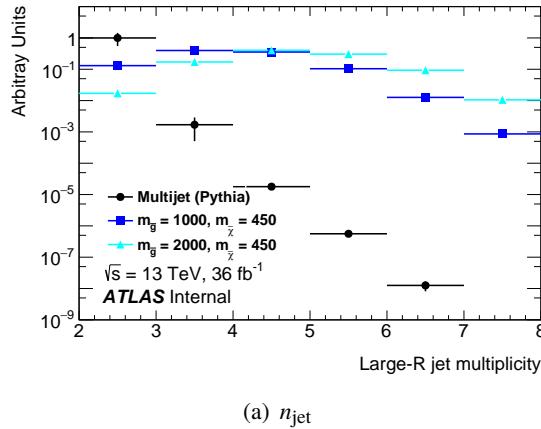


Figure 4: Comparison between signal sample and background dominant data control sample for the large- R jet multiplicity. Several typical signal points are shown, as well as the distributions obtained from the data. All distributions are normalized to the same area. The selection requires two or more jets, and are inclusive in $|\Delta\eta_{12}|$ and have no b-tagging requirements.

196 One additional variable that can be used to suppress signal contamination is the p_T of the leading large- R jet.
 197 Figure 6 shows distributions of leading jet p_T for signal and background MC samples. The p_T distribution
 198 strongly depends on the mass of gluino assumed in the signal model. For a signal of $m_{\tilde{g}} = 1000$ GeV and
 199 $m_{\tilde{\chi}} = 450$ GeV, its p_T distribution peaks at around 500 GeV with a steep turn-on between 200 GeV and 500
 200 GeV. For signals with a larger $m_{\tilde{g}}$ value, the peak and the turn-on region of the leading jet p_T distribution
 201 shift towards higher p_T ranges. This motivates to use a leading jet p_T veto in some cases to suppress signal
 202 contamination.

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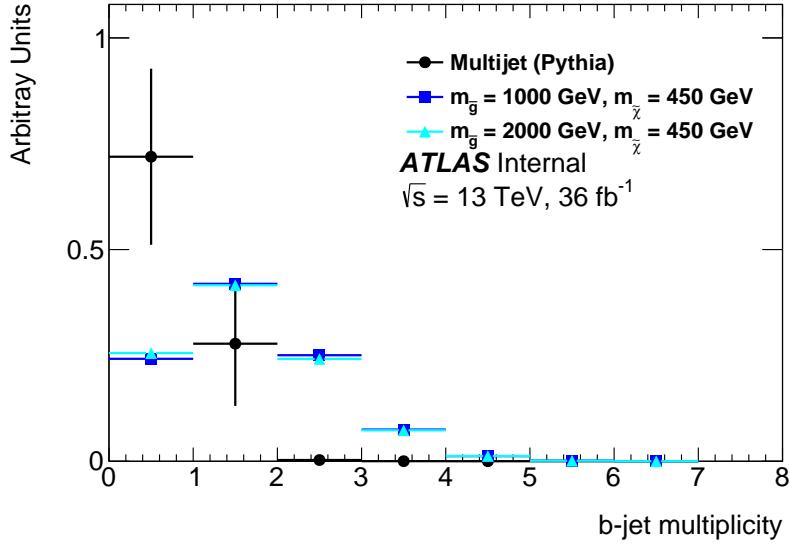


Figure 5: Reconstructed number of b-jets in the events with ≥ 4 large- R jets for two representative RPV signal samples as well as the PYTHIA8 multijet MC sample.

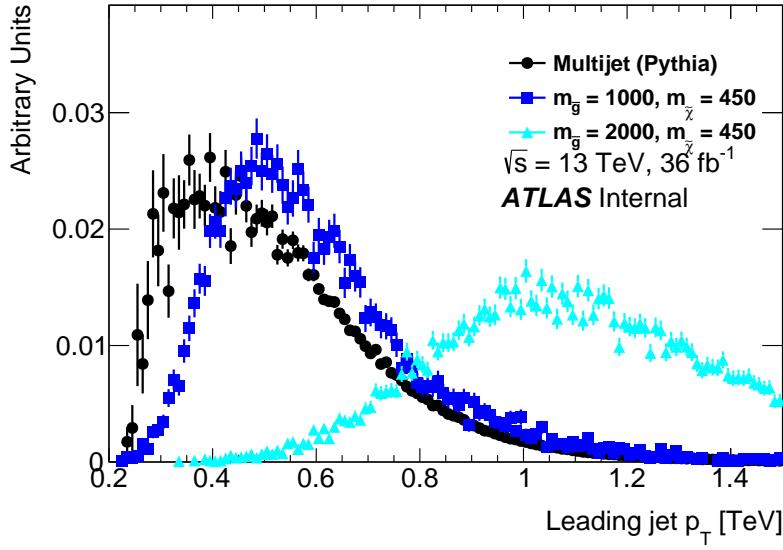


Figure 6: p_T of leading jet for events with four or more large- R jets. Distributions from the PYTHIA8 multijet MC sample and two signal samples are shown. The values of $m_{\tilde{g}} = 1000 \text{ GeV}$ and $m_{\tilde{g}} = 2000 \text{ GeV}$ represent the two extremes of the signal coverage of this analysis, with the former just beyond the limit set by the Run-1 analysis and the latter around the sensitivity reach of this analysis.

203 **3.2. Event selection**

204 The ALL_GOOD GRL is applied to select events in data. In addition, events must not have LAr/Tile/Core/SCT
 205 errors. Events used in the analysis are required to pass a H_T based trigger, seeded from a level-one jet
 206 with p_T greater than 100 GeV, the HLT_ht1000_L1J100 trigger. This is the lowest unprescaled H_T based
 207 trigger for the 2016 data taking ¹. AntiKt4EMTopoJets (anti-kt4-jets) are used to tag b-jet, and they
 208 are required to be within $|\eta| < 2.8$ and have a p_T greater than 50 GeV. An anti-kt4-jet is considered as a
 209 b-tagged jet if its $|\eta|$ is less than 2.5 and it passes the b-tagging requirement of fixed 70% working point of
 210 the MV2c10 tagger. AntiKt10LCTopoTrimmedPtFrac5SmallR20Jets (largeR jets) are used to define
 211 discriminating variables, such M_j^Σ and n_{jet} . These large-R jets must have a minimum p_T of 200 GeV and
 212 be within $|\eta| < 2.0$. To ensure the trigger is fully efficient for the offline analysis, a preselection requiring
 213 at least one large-R jet with a p_T greater than 440 GeV is applied. The following preselection is applied.

214 • **GRL ALL_GOOD**

215 • **Event quality** No LAr / Tile / Core / SCT

216 • **Trigger HLT_ht1000_J100**

217 • **Object definition**

218 – **Large-R jet** AntiKt10LCTopoTrimmedPtFrac5SmallR20Jets, $p_T > 200$ GeV, $|\eta| < 2.0$.

219 – **B-tagged jet** AntiKt4EMTopoJets, $p_T > 50$ GeV, $|\eta| < 2.5$. The selected AntiKt4EMTopoJet
 220 should pass the 70% fixed working point of MV2c10 tagger.

221 • **Categorization** Events are further classified into control, uncertainty determination, validation and
 222 signal regions.

223 Figure 7 shows the background trigger turn-on curves for events with five or more large- R jets and events
 224 with four or more large- R jets, which contain the signal regions that are defined later in the note. For
 225 events with five or more large- R jets, a jet p_T threshold at 200 GeV is fully efficient for offline analysis; for
 226 events with four or more large- R jets, the p_T threshold beyond which the offline analysis is fully efficient
 227 is slightly higher. The analysis addresses the inefficiency in events with four or more large- R jets by
 228 increasing leading jet p_T threshold to 400 GeV. Appendix P documents further checks to understand if
 229 trigger turn-on has any effect on various regions used in the analysis.

230 The large-R jet (AntiKt10LCTopoTrimmedPtFrac5SmallR20Jet) is trimmed from a regular anti-kt jet with
 231 a radius of $R = 1.0$. The clusters contained by the anti-kt 1.0 jet are regrouped to jets with $R = 0.2$ using
 232 the anti-kt algorithm (small-R jets). A small-R jet is removed if its p_T is less than 5% of the original anti-kt
 233 1.0 jet's p_T . The survived small-R jets are then rebuilt into an anti-kt jet with a radius of $R = 1.0$. This
 234 resulting jet is the large-R jet used in this analysis, and the standard large-R jet calibration is applied.

235 The fixed efficiency working point is chosen for b-tagging as its systematic uncertainties are already
 236 available. Results documented in earlier versions of the note used a flat efficiency working point. The 70%
 237 working point was chosen to achieve a balance between signal efficiency and background reduction. The
 238 choice of b-tagging working point can be further optimized, but this may be beyond the timescale of this
 239 analysis.

¹ For the 2015 data taking, the lowest unprescaled H_T based trigger is HLT_ht850_L1J100. For the sake of consistency between the two data taking periods, the HLT_ht1000_L1J100 trigger is chosen for both 2015 and 2016 data analyses.

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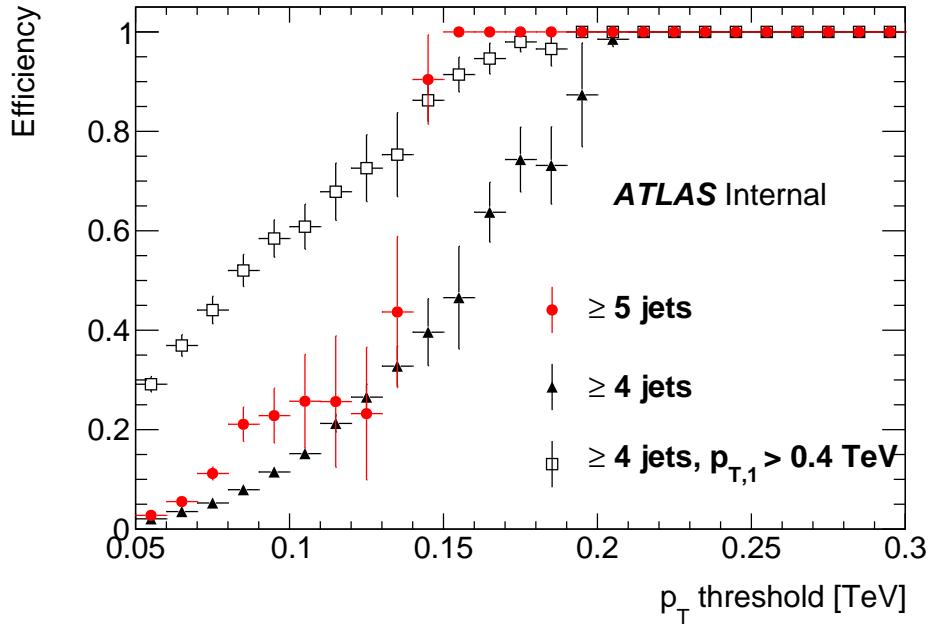


Figure 7: Trigger efficiency is shown as a function of large- R jet p_T threshold for events with our or more large- R jets. Events with five or more large- R jets.

240 4. Background estimation strategy

241 4.1. Overview

242 The use of M_j^Σ in this analysis provides an opportunity to employ the fully data-driven jet mass *template*
 243 *method* to estimate the background contribution in signal regions. The jet mass template method is
 244 discussed in great detail in [2], and its first experimental implementation is described in [1]. In this
 245 method, single jet mass templates are extracted from signal-depleted control regions, or *training samples*.
 246 These jet mass templates are created in bins of jet p_T and η , which effectively provides a *probability*
 247 *density function* (PDF) that describes the relative probability for a jet with a given p_T and η to have a
 248 certain mass. This method assumes that jet mass templates only depend on jet p_T and η and are the same
 249 between control regions and signal regions. A sample where the background M_j^Σ distribution needs to
 250 be estimated, such as a validation region or a signal region, is referred to as the *kinematic sample*. The
 251 only information used is the jet p_T and η , which are inputs to the templates. For each jet in the kinematic
 252 sample, the p_T - η dependent jet mass template is sampled to generate a random jet mass. A M_j^Σ distribution
 253 can be constructed from the randomized jet masses of the kinematic sample. This procedure is referred
 254 to as “dressing”, and the resulting sample is referred to as a *dressed sample*. If jet mass templates are
 255 created from a control sample of background events and the number of events in the kinematic sample is
 256 sufficiently large, then the M_j^Σ distribution constructed from randomized jet masses should reproduce the
 257 shape of background M_j^Σ distribution.

258 In practice, the jet mass templates are the templates of m/p_T , the jet mass normalized to its p_T . The
 259 randomized jet mass is then the product of the actual jet p_T and its randomized m/p_T . Using the

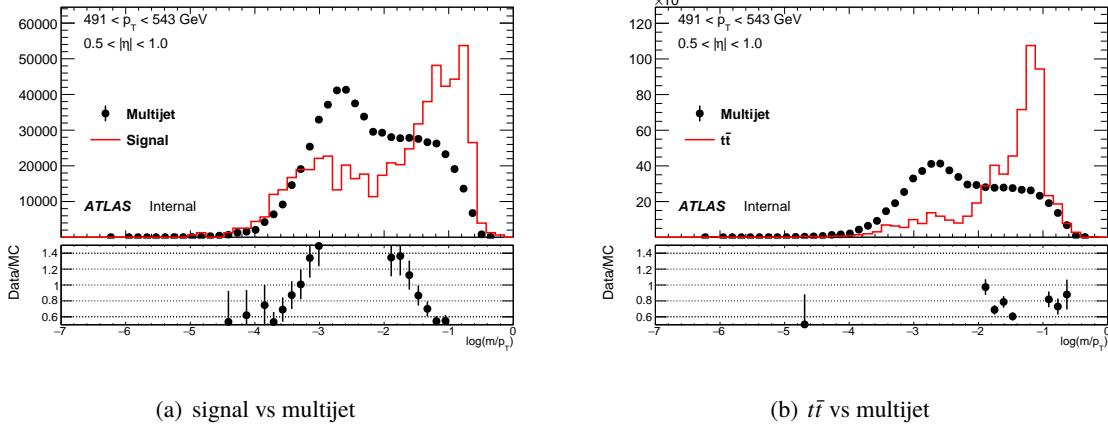


Figure 8: Example jet mass templates in the bin of $0.0 < |\eta| < 0.5$ and $491 \text{ GeV} < p_T < 543 \text{ GeV}$. Subfigure (a) compares the jet mass templates between RPV signal events and multijet events generated by PYTHIA8; subfigure (b) compares the jet mass templates between $t\bar{t}$ events generated by PowhegPYTHIA8 and multijet events generated by PYTHIA8.

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260 normalized jet mass, m/p_T , reduces the jet mass PDF's dependence on p_T . Figure 8(a) shows the jet mass
 261 templates in a particular bin of p_T and $|\eta|$ ($0.0 < |\eta| < 0.5$ and $491 \text{ GeV} < p_T < 543 \text{ GeV}$) for simulated
 262 signal and multijet background events generated by PYTHIA8. Figure 8(b) compares the jet mass PDFs
 263 between PYTHIA8 multijet events and $t\bar{t}$ events using the same p_T and $|\eta|$ bin, and it shows that the jet
 264 mass PDF in the $t\bar{t}$ events are different from that in the multijet events. $t\bar{t}$ events constitute less than 5% of
 265 background events in the analysis, and the $t\bar{t}$ MC sample is always included in the background estimation
 266 study in order to account for possible effect due to the presence of $t\bar{t}$ events. The kinks in the jet mass
 267 PDFs are due to the trimming applied to the large- R jets, and the position of the kink depends on the
 268 radius of the small-R jet (0.2) as well as the p_T fraction used in the trimming (5% in this case).

269 This analysis adopts basically the same procedure employed in the Run-1 analysis [1]. First, the statistical
 270 fluctuations in the jet mass templates is propagated to the prediction of background yield in the signal
 271 region, and therefore considered as a systematic uncertainty of the jet mass template method, whereas the
 272 Run-1 analysis smoothed the jet mass templates with a Gaussian kernel technique. Second, the predicted
 273 M_J^Σ distribution is normalized to the observation in $0.2 \text{ TeV} < M_J^\Sigma < 0.6 \text{ TeV}$, whereas the Run-1 analysis
 274 did not introduce any normalization region, effectively normalizing the prediction to the observation in
 275 the entire M_J^Σ range. In the region of $0.2 \text{ TeV} < M_J^\Sigma < 0.6 \text{ TeV}$, contamination from signal models not
 276 yet excluded by the ATLAS Run-1 search [1] is negligible compared to the statistical uncertainty of
 277 background.

278 Since the ICHEP CONF note [25] was released, a data driven method has been studied to estimate the
 279 systematic uncertainty of the jet mass template method. In this method, the predicted jet mass is compared
 280 to the observed jet mass in regions free of significant signal contamination (the uncertainty determination
 281 regions), and the difference between the prediction and the observation is used to estimate the systematic
 282 uncertainty. This uncertainty estimation method is tested in the Monte Carlo sample and found to cover
 283 the discrepancy between the prediction of the jet mass template method and the observation.

284 The impact of the $t\bar{t}$ contribution on the background estimation performance has been questioned in the
 285 past reviews of the analysis. In response, the standard MC results shown in this section include both

²⁸⁶ multijet and $t\bar{t}$ MC samples. Appendix C also shows that the background estimation performance is
²⁸⁷ essentially the same with or without including the $t\bar{t}$ contribution.

²⁸⁸ This section is organized as follows: Section 4.2 describes the implementation of the jet mass template
²⁸⁹ method. Section 4.3 defines the regions used in the analysis and briefly discusses the roles of these regions.
²⁹⁰ Section 4.4 describes the data driven determination of the systematic uncertainty. Section 4.5 presents the
²⁹¹ result of the background estimation. Section 4.7 discusses the contribution to the predicted background
²⁹² yield due to the presence of signal events.

²⁹³ 4.2. Implementation and systematic uncertainties

²⁹⁴ This section provides a concise description of the procedure used to generate the predicted M_J^Σ distribution
²⁹⁵ and then introduces the systematic uncertainties associated with the jet mass randomization. A more
²⁹⁶ detailed and technical description of how the jet mass template method is implemented can be found in
²⁹⁷ the Appendix N.

²⁹⁸ The jet mass templates are built from jets in a control region. Jets are binned in three dimensions, using
²⁹⁹ its p_T , $|\eta|$, and b-matching² information. In each bin, the distribution of jet mass over p_T is obtained, and
³⁰⁰ it is referred to jet mass PDF/template hereafter. For regions of interest, such as a signal region, the four
³⁰¹ leading jets in p_T in an event are selected. For each selected jet, its jet mass PDF is retrieved and used to
³⁰² generate a random number. The randomized jet mass is the product of this random number and the actual
³⁰³ p_T of the jet. Then, the randomized total jet mass variable, M_J^Σ , can be calculated from the randomized jet
³⁰⁴ masses, and repeating this procedure for all events in the region of interest yields a randomized jet mass
³⁰⁵ distribution.

³⁰⁶ Since the jet mass randomization is subject to statistical fluctuation, a large number of pseudo-experiments
³⁰⁷ (PEs) are generated, and each PE yields a randomized M_J^Σ distribution. For the purpose of presentation
³⁰⁸ and performing statistical test, the M_J^Σ distribution is binned. Each M_J^Σ bin has a distribution of event
³⁰⁹ yields from randomized M_J^Σ distributions in the PEs. The mean of this yield distribution and the RMS
³¹⁰ are considered as the central value of the predicted yield and its statistical uncertainty, respectively. This
³¹¹ procedure produces a predicted M_J^Σ distribution with bin-by-bin statistical uncertainties. The predicted
³¹² M_J^Σ distribution is further normalized to the observed M_J^Σ distribution in the region of $0.2 \text{ TeV} < M_J^\Sigma <$
³¹³ 0.4 TeV .

³¹⁴ The systematic uncertainty of this method has two components, one of statistical nature, the other of physics
³¹⁵ nature. First of all, the prediction of M_J^Σ distribution and the event yield in the signal region is subject
³¹⁶ to statistical uncertainty in the jet mass PDF and jet kinematics sample. The statistical uncertainty in
³¹⁷ the jet kinematics sample is quantified by pseudo-experiment procedure described above. The statistical
³¹⁸ uncertainty in the jet mass PDFs can be estimated by introducing Poisson fluctuations to the jet mass
³¹⁹ PDFs. In the implementation, these two sources of statistical uncertainty are estimated in one set of
³²⁰ PE generation. In every PE, a bin-by-bin fluctuation is introduced to the jet mass PDF according to
³²¹ its statistical uncertainty; then, these fluctuated jet mass PDFs are used to randomize jet masses in the
³²² kinematics sample. The statistical uncertainty determined in this ensemble of PEs reflects the total
³²³ uncertainty of both sources.

² b-matching is referred to whether or not a large- R jet is matched to a b-tagged jet by requiring $\Delta R < 1.0$.

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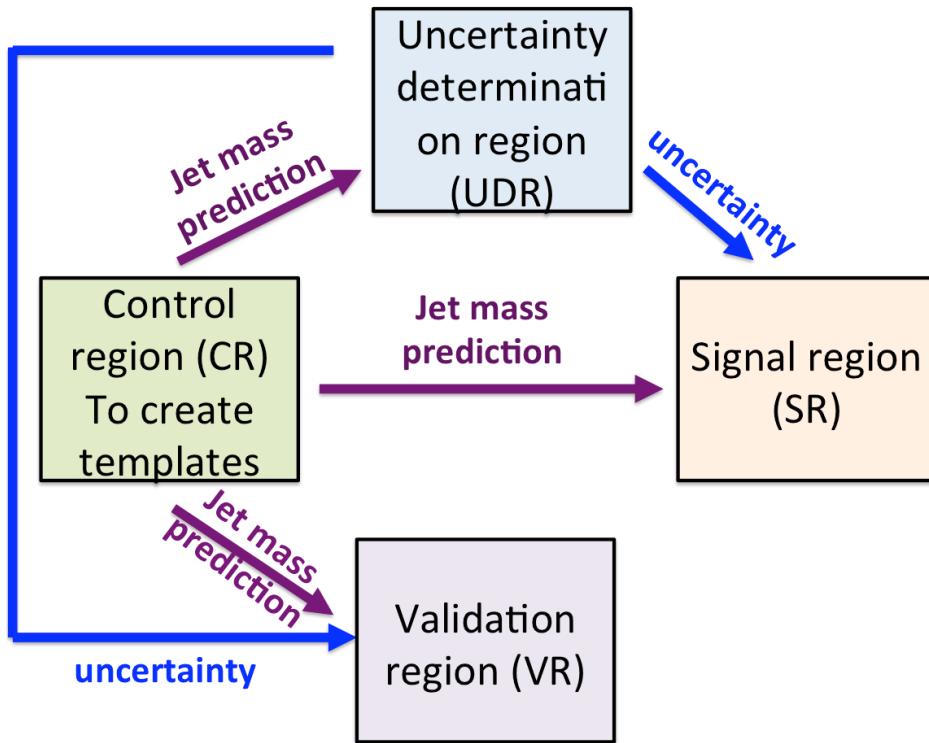


Figure 9: Workflow diagram that shows the role of various regions in the analysis.

324 The second component of the systematic uncertainty is related to the method's assumption on the jet mass
 325 PDF's dependence on a number of variables as well as the assumption that jets in the same events are
 326 uncorrelated. This is discussed in detail in Section 4.4.

327 **4.3. Definition of regions**

328 A number of regions serving different roles in the background estimation are defined. A Control Region
 329 (CR) is defined to create the jet mass templates. Then the jet mass templates are applied to predict
 330 masses of jets in Uncertainty Determination Regions (UDRs) where distributions of predicted jet mass
 331 and observed jet mass are compared, in order to understand the systematic uncertainty of the estimation;
 332 The jet mass templates are used to predict the M_j^{Σ} distributions in the signal and validation regions, where
 333 the systematic uncertainties are propagated from the jet mass estimation uncertainty determined in the
 334 UDRs. This workflow is illustrated by Figure 9.

335 The control region requires the event have exactly three large- R jets with $p_T > 200$ GeV, and in case that
 336 the event contains a b-jet, the $|\Delta\eta_{12}|$ of the event be greater than 1.4. The requirement on $|\Delta\eta_{12}|$ variable
 337 for b-tag events is introduced to suppress signal contamination. Jet mass templates are binned in p_T and η ,
 338 and created separately for b-matched jets and non-matched jets. In the Run-1 analysis, separate sets
 339 of jet mass templates are created for the first two leading jets and the third and fourth leading jets, and no
 340 speration in jet mass templates between b-matched jets and non-matched jets is made. Figure 10
 341 shows comparisons of jet mass templates between different types of jets in the PYTHIA8 multijet MC

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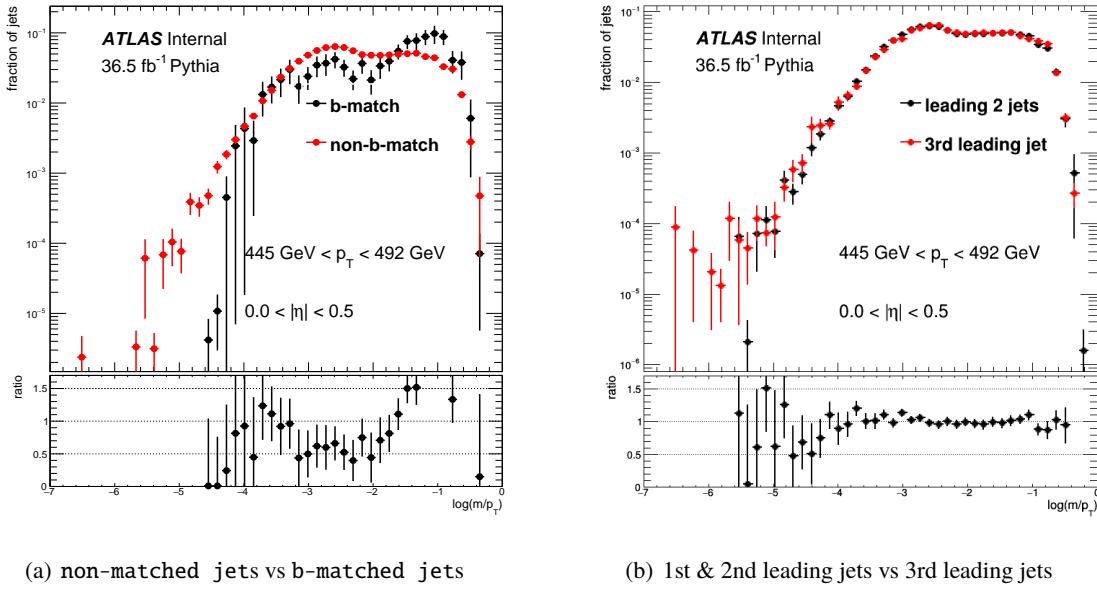


Figure 10: Jet mass template ($\log(m/p_T)$) comparison between the non-matched jets and b-matched jets ((a)), and between the two leading jets and the third leading jets ((b)), in PYTHIA8 multijet sample.

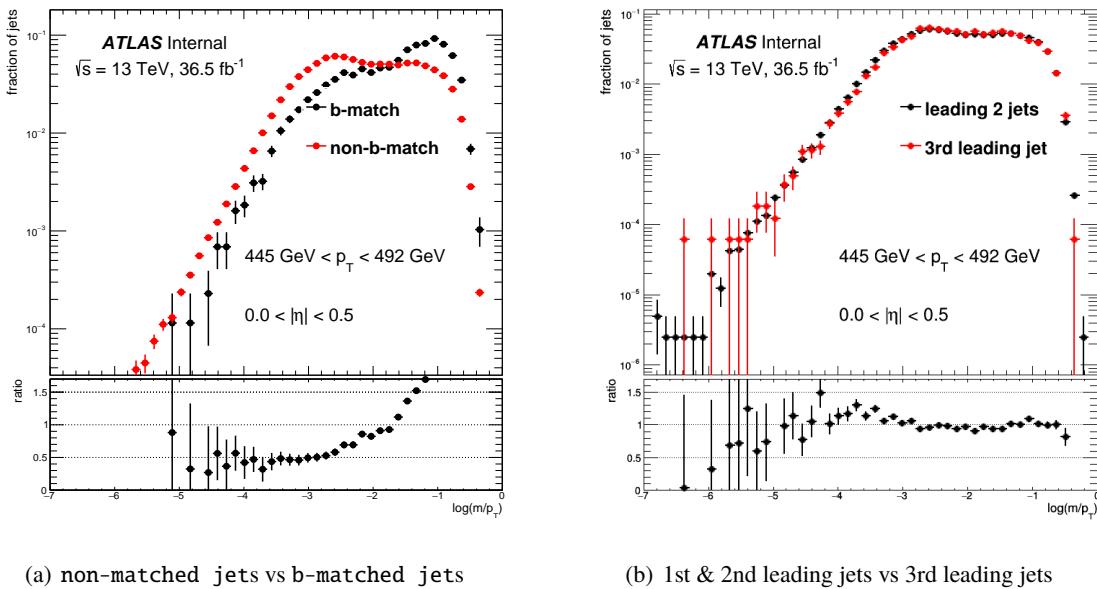


Figure 11: Jet mass template ($\log(m/p_T)$) comparison between the non-matched jets and b-matched jets ((a)), and between the two leading jets and the third leading jets ((b)), in data.

sample. The differences in the jet mass template shapes between b-matched jets and non-matched jets, as shown in Figure 10(a), are found to be larger than the differences between the two leading jets and the third leading jets, as shown in Figure 10(b). This observation is also confirmed in data, as shown by Figure 11. Appendices Q and T show all comparisons of jet mass templates between b-matched jets and non-matched jets, and between the two leading jets and the third and fourth leading jets, respectively. In this study, the differences in jet mass templates between b-matched jets and non-matched jets are found to be greater than the differences between the two leading jets and the third and fourth leading jets, which motivates the change in the binning of jets in the control region. The Run-1 binning is also implemented as a cross check and found not to improve the performance of the background estimation, as documented in Appendix I to be included.

To understand the systematic uncertainty of the jet mass template method, two Uncertainty Determination Region (UDR) are defined. The first UDR requires the events have exactly two large- R jets with $p_T > 200$ GeV; and the second UDR requires events have exactly four large- R jets with $p_T > 200$ GeV, and the leading jet p_T should be less than 400 GeV. The leading jet p_T cut is motivated by Figure 6, which indicates that a p_T veto significantly suppresses signal contribution in high jet multiplicity events. More detailed discussion of the UDRs can be found in Section 4.4.

The search is performed in multiple overlapping signal regions defined with jet multiplicity and b-matching requirements. The signal region with the best expected sensitivity to the RPV signals is selected for the model-dependent interpretation, while other signal regions are used for model independent statistical test. The first set of signal regions are defined with ≥ 4 large- R jets, $|\Delta\eta_{12}| < 1.4$, and a M_J^Σ cut³. One of the signal region requires the presence of a b-jet (4jSRb), while the other does not have any b-jet requirement (4jSR). The second set of signal regions are defined with ≥ 5 large- R jets, $|\Delta\eta_{12}| < 1.4$, and a M_J^Σ cut; the one requiring the presence of at least one b-jet is referred to as 5jSRb, and the one without a b-jet requirement is referred to as 5jSR.

To validate the performance of the background estimation, two Validation Regions (VRs) are defined corresponding to the two SRs. They are defined with the same requirements as the SRs except that the $|\Delta\eta_{12}|$ cut is reversed to be greater than 1.4. The two VRs, 5jVR and 5jVRb, are corresponding to the 5jSR and 5jSRb, respectively.

The event level and jet level requirements used to define various regions are summarized in Table 2.

The expected signal and background (as predicted by PYTHIA8 multijet samples) yields are calculated for all the regions defined in this section and shown in Tables 22 and 23 in the Appendix M. Figure 12 shows the expected background (PYTHIA8) and signal ($m_{\tilde{g}} = 1.0$ TeV, $m_{\tilde{\chi}} = 0.45$ TeV) yields and the signal-to-background ratios in various regions, at 36.1 fb^{-1} . The signal point ($m_{\tilde{g}} = 1.0$ TeV, $m_{\tilde{\chi}} = 0.45$ TeV) is at the limit set by the Run-1 analysis. For this signal point with very large cross section, there is no significant contamination in various control, validation and uncertainty determination regions. Figure 13 shows the same plot for a signal point with $m_{\tilde{g}} = 1.6$ TeV, $m_{\tilde{\chi}} = 0.45$ TeV, and the contamination becomes much smaller in all regions.

4.4. Data-driven systematic uncertainty determination

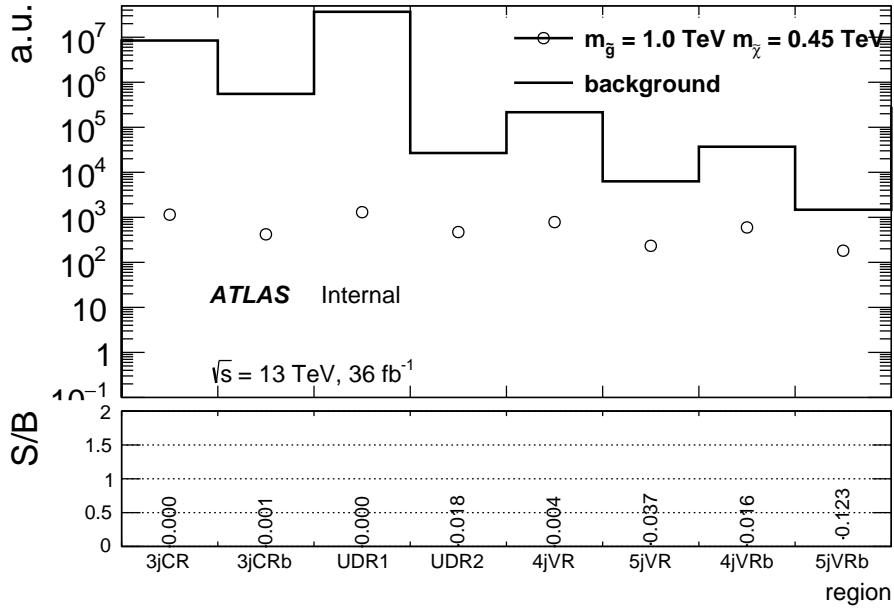
One of the background systematic uncertainty arises from the fundamental assumption that the jet mass template of background jets in the signal region follows the same template derived from the control region.

³ to be presented later

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		n_{jet}	b-tag	b-match	$p_{T,1}$	$ \Delta\eta_{12} $	M_J^Σ
CR	3jCRb	= 3	-	Yes	-	> 1.4	-
	3jCR	= 3	-	No	-	-	-
UDR	UDR1	= 2	-	-	> 400 GeV	-	-
	UDR2	= 4	-	-	< 400 GeV	-	-
VR	4jVRb	≥ 4	Yes	-	> 400 GeV	> 1.4	-
	5jVRb	≥ 5	Yes	-	-	> 1.4	-
	4jVR	≥ 4	-	-	> 400 GeV	> 1.4	-
	5jVR	≥ 5	-	-	-	> 1.4	-
SR	4jSRb	≥ 4	Yes	-	> 400 GeV	< 1.4	> 1.0 TeV
	5jSRb	≥ 5	Yes	-	-	< 1.4	> 0.8 TeV
	5jSR	≥ 5	Yes	-	-	< 1.4	> 0.6 TeV
	4jSR	≥ 4	-	-	> 400 GeV	< 1.4	> 1.0 TeV
	5jSR	≥ 5	-	-	-	< 1.4	> 0.8 TeV

Table 2: Summary of the event level and jet level requirements used to define various regions.

Figure 12: Expected background (PYTHIA8) and signal ($m_{\tilde{g}} = 1.0 \text{ TeV}, m_{\tilde{\chi}} = 0.45 \text{ TeV}$) yields and the signal-to-background ratios in various regions. The total yields of signal and background are normalized to 36.1 fb^{-1} .

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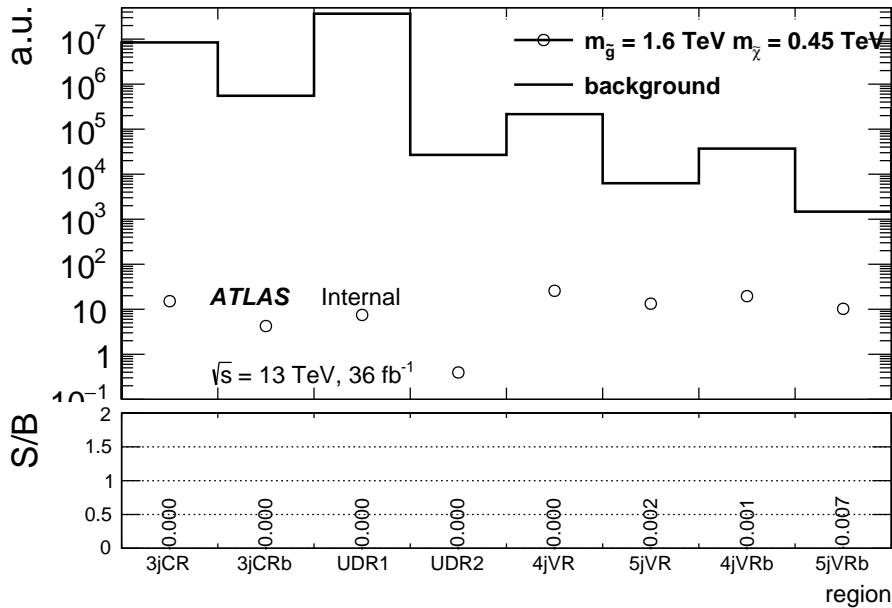


Figure 13: Expected background (PYTHIA8) and signal ($m_{\tilde{g}} = 1.6$ TeV, $m_{\tilde{\chi}} = 0.45$ TeV) yields and the signal-to-background ratios in various regions. The total yields of signal and background are normalized to 36.1 fb^{-1} .

To understand the systematic uncertainty associated with the assumption that the jet mass DPF is the same between the signal regions and the control region, a data-driven method is developed. This method studies the performance of the jet mass prediction using signal-depleted jet samples in data. The predicted and observed individual jet mass distributions are compared in p_T and $|\eta|$ in the UDRs. Specifically, the jet mass response, defined as the mean value of the jet mass distribution in a given p_T and $|\eta|$ bin, is used to quantify the performance of the jet mass template method. In the ideal scenario, Ideally, the jet mass response should be in agreement between the observed jet masses and predicted jet masses, and any discrepancy in the jet mass response between the observation and prediction indicates a non-closure of the jet mass template at the individual jet mass level, which is a metric to quantify the systematic uncertainty of the jet mass prediction. The uncertainties on individual jet mass can be propagated to the prediction of the M_J^Σ distribution and therefore the predicted background yield in the signal region.

As an example, Figure 14 shows the jet mass response for all jets in 3jCR region of the PYTHIA8 multijet and $t\bar{t}$ MC samples. In such a plot, the top pane shows the jet mass response for predicted jet masses (histogram with vertical lines connecting adjacent bins) and observed jet masses (histogram with horizontal error bars only), and the bottom pane shows the ratio of the observed jet mass response over the predicted jet mass response. A ratio over 1 in the bottom pane suggests an under-prediction of jet mass, while a ratio below 1 suggests an over-prediction.

4.4.1. Jet mass response

Plots like Figure 14 are the primary tool to understand the performance of the jet mass template method. For example, Figure 15 shows the predicted and observed jet mass responses of 3-jet events separately for

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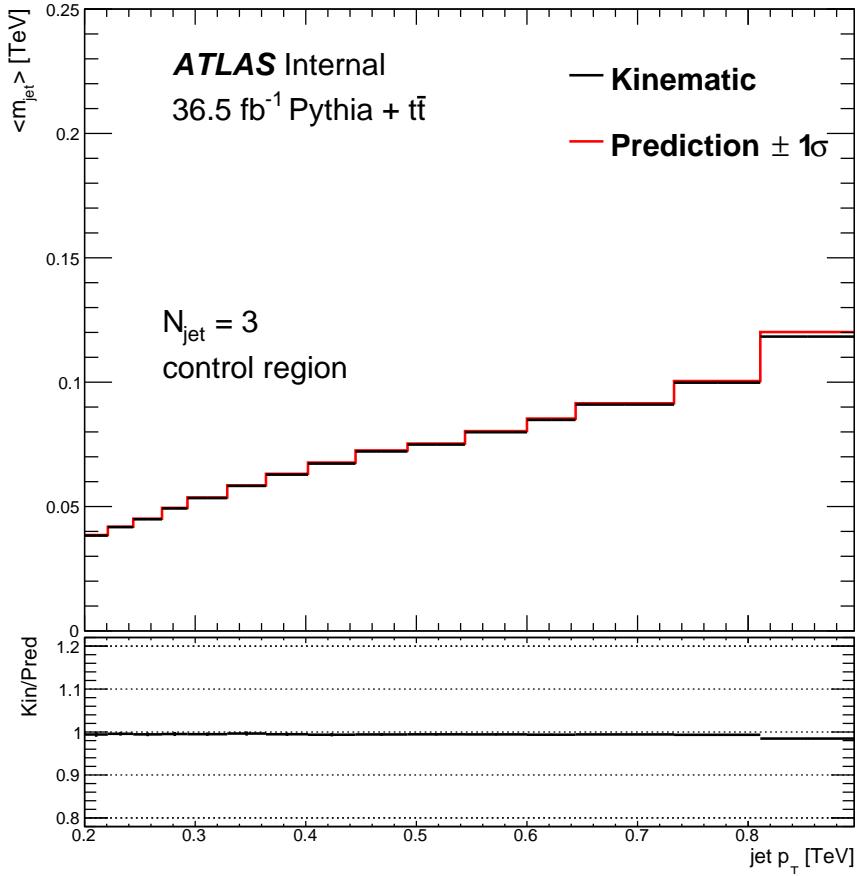


Figure 14: Jet mass response for jets in the 3jCR (control region) of the PYTHIA8 multijet plus $t\bar{t}$ MC samples. The jet mass response is defined as the mean of jet mass distribution in a given bin defined by p_T , $|\eta|$, and b-matching requirements. The black points with vertical and horizontal error bars are the observed jet mass response values, while the red histogram corresponds to the predicted jet mass response.

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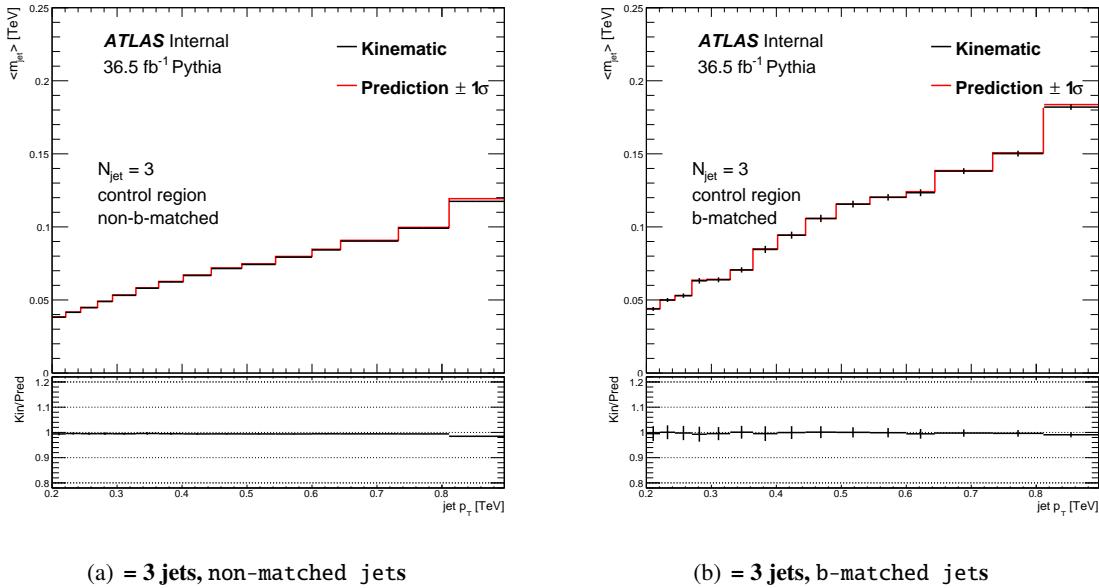


Figure 15: Jet mass response of 3-jet events for non-matched jets (15(a)) and b-matched jets (15(b)) in PYTHIA8 multijet MC sample.

402 non-matched jets (15(a)) and b-matched jets (15(b)) in PYTHIA8 multijet MC sample. The observed
 403 and predicted jet mass responses overlap in these plots, indicating a closure of the jet mass template
 404 method in the control region, as expected.

405 Figure 16 shows the observed and predicted jet mass response in ≥ 4 jets 16(a) and ≥ 5 jets 16(b) events
 406 in PYTHIA8 multijet plus $t\bar{t}$ MC samples. The result is statistics-limited, nevertheless, it appears that both
 407 ≥ 4 jets and ≥ 5 jets regions suffer a moderate over-prediction for jet with $p_T < 400$ GeV and a
 408 small under-prediction for jets with $p_T > 400$ GeV. A very similar trend is seen in the ≥ 4 jets region
 409 of Herwigpp multijet plus $t\bar{t}$ MC samples, as shown in Figure 17(a), while the response ratio in the \geq
 410 5 jets region (Figure 17(b)) is completely dominated by statistical fluctuation and therefore renders no
 411 information.

412 4.4.2. Estimate the systematic uncertainty with uncertainty determination regions

413 The jet mass template method involves two major assumptions: first, jet mass PDFs only depend on
 414 observables including jet p_T , η , and b-matching information; second, jets in the same event are uncorrelated
 415 and their masses can be modeled independently. Both assumptions are known to be invalid to some extent.
 416 For example, jet mass PDFs depend on the quark or gluon origin of jet, which cannot be determined
 417 experimentally on a jet-by-jet basis. In addition, jets in the same events are also not completely independent
 418 from each other at both particle level and reconstruction level.

419 This analysis develops an effective approach to probe the systematic uncertainty of the background
 420 estimation using data UDRs. The UDRs are defined by jet multiplicity and p_T in a way so that they
 421 contain jets that are different in origin. The jet mass prediction is tested in the UDRs, and the discrepancy
 422 between the observation and the prediction indicates the level of systematic uncertainty of the background

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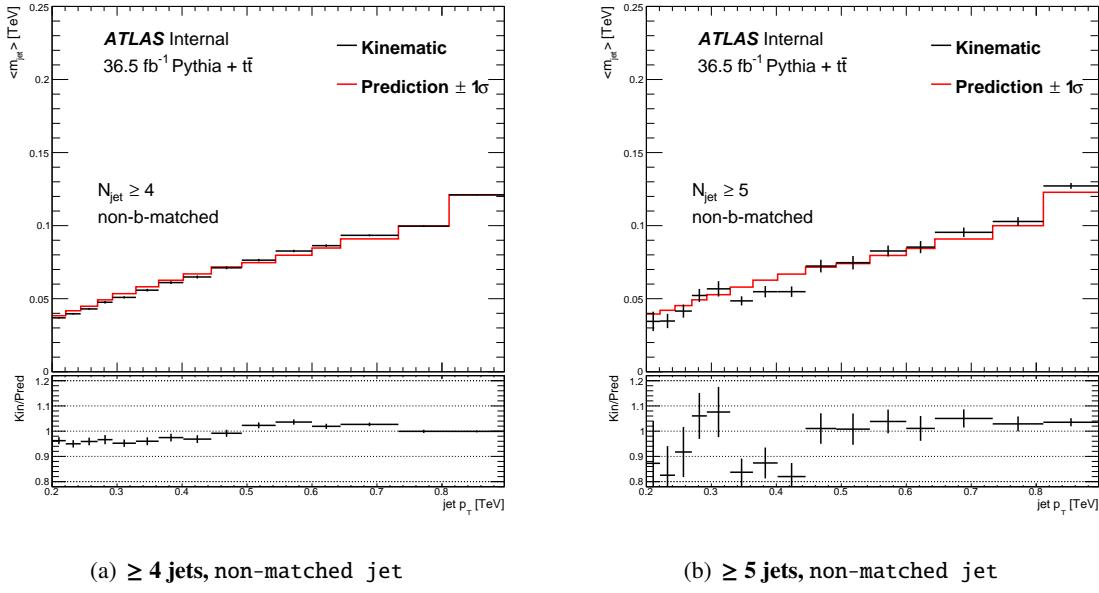


Figure 16: Observed and predicted jet mass response in ≥ 4 jets 16(a) and ≥ 5 jets 16(b) events in PYTHIA8 multijet plus $t\bar{t}$ MC samples.

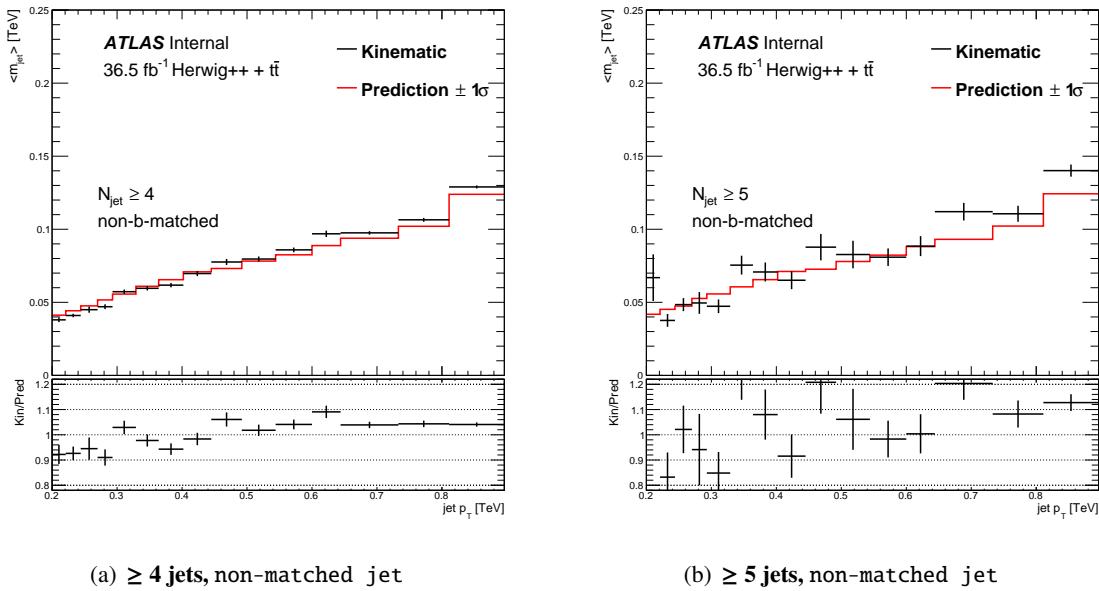
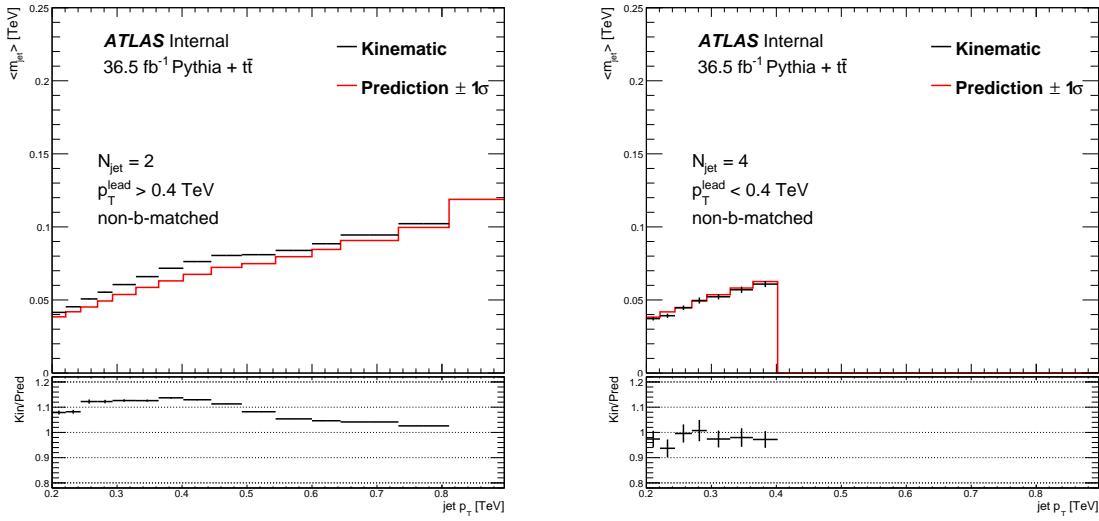


Figure 17: Observed and predicted jet mass response in ≥ 4 jets 17(a) and ≥ 5 jets 17(b) events in Herwigpp multijet plus $t\bar{t}$ MC samples.

(a) = 2 jets, leading jet $p_T > 400$ GeV non-matched jet (b) = 4 jets, leading jet $p_T > 400$ GeV non-matched jetFigure 18: Predicted and observed jet mass responses in the UDR1 (a) and UDR2 (b) with PYTHIA8 multijet plus $t\bar{t}$ MC samples.

estimation. These UDRs need to be orthogonal to signal and validation regions, and certain cuts may be introduced to suppress signal contamination.

The 2 UDRs considered in the analysis are defined as follows:

- UDR1 2 large- R jets, the leading large- R jet $p_T > 400$ GeV.
- UDR2 4 large- R jets, the leading large- R jet $p_T < 400$ GeV.

In the UDR1, events are selected by requiring exactly two large- R jets. High p_T jets in the UDR1 are likely resulted from hadronization of an outgoing parton at the leading order (LO) of the parton scattering. Since all events are required to pass an `HLT_ht1000_L1J100` trigger, the outgoing partons at the leading order are unlikely to have a $p_T < 500$ GeV; at the reconstruction level, the large- R jets with $p_T < 400$ GeV are more likely to be resulted from partons radiated from the hard scattering at the LO. Similarly, jets in the UDR2, which is defined as events with four large- R jets with $200 \text{ GeV} < p_T < 400 \text{ GeV}$, are also likely to be associated with partons radiated from the LO hard scattering. The low p_T jets in the UDR1 and UDR2 may be similar in their origin, however, they are produced from every different types of events. The UDR1 events with a low p_T jet tend to be “imbalanced”, as there is a leading jet with $p_T > 400$ GeV and the H_T of the event needs to be greater than 1000 GeV. The events in the UDR2 should be more “balanced”, as they are selected by vetoing high p_T jets and requiring high multiplicity. The jet mass response distributions of the low p_T jets indeed exhibit different behaviors in the UDR1 and UDR2, as shown by Figures 18 and 19. This observation is confirmed by both PYTHIA8 and Herwigpp multijet samples, as well as data.

Figure 18 shows the jet mass responses in the two UDRs in the PYTHIA8 multijet plus $t\bar{t}$ MC samples. In the “low p_T ” range ($p_T < 400$ GeV), the UDR1 shows a sizable (10 - 15% level) under-prediction, while the UDR2 shows a small (~ 5% level) but systematic over-prediction. In the “high p_T ” range ($p_T > 400$ GeV

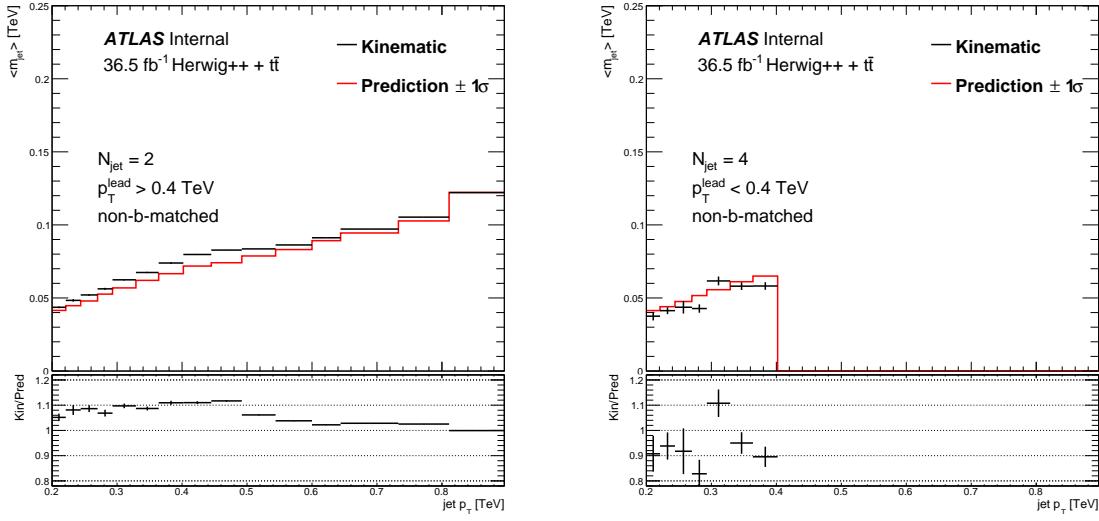


Figure 19: Predicted and observed jet mass responses in the UDR1 ((a)) and UDR2 ((b)) with Herwigpp multijet plus $t\bar{t}$ MC samples.

of the UDR1, there is a consistent under-prediction at 15% level starting from p_T just beyond 400 GeV and gradually dropping to just a few percents for $p_T > 600$ GeV. Very similar behaviors are also found in Herwigpp multijet sample, as shown in Figure 19. The discrepancy at the high p_T range appears to be qualitatively consistent with those in the high p_T part of ≥ 4 jets and ≥ 5 jets regions, as shown in Figure 16. The discrepancy at the low p_T range of UDR2 is also qualitatively consistent with those in the low p_T part of the ≥ 4 jets and ≥ 5 jets regions. The difference in the sign and size of the discrepancy for low p_T jets between the UDR1 and the UDR2 suggests that the jet mass PDF depends on factors beyond the origin of jets.

Jets collected by the UDRs correspond to some extreme scenarios, and the jets in the signal and validation regions are a mix of these different extremes. The discrepancies quantified by the UDRs can be considered as an upper limit of the discrepancy that may appear in the signal and validation regions. Using Monte Carlo samples, this assertion can be examined. Figure 16 suggests that for high p_T jets a 4-5% level of under-prediction exists for events with ≥ 4 (or 5) jets in the PYTHIA8 multijet MC sample. Figure 17, made with Herwigpp multijet sample, indicates similar behavior, especially in events with ≥ 4 jets. These discrepancies are indeed qualitatively consistent with the discrepancy seen in the high p_T region of UDR1, as shown in Figures 18(a) and 19(a). For low p_T jets in events with ≥ 4 jets, there is a systematic over-prediction shown in both PYTHIA8 (Figure 16) and Herwigpp (Figure 17) multijet samples. This is more consistent with the discrepancy seen in the UDR2. In events with ≥ 5 jets, these jet mass response plots are statistically inconclusive.

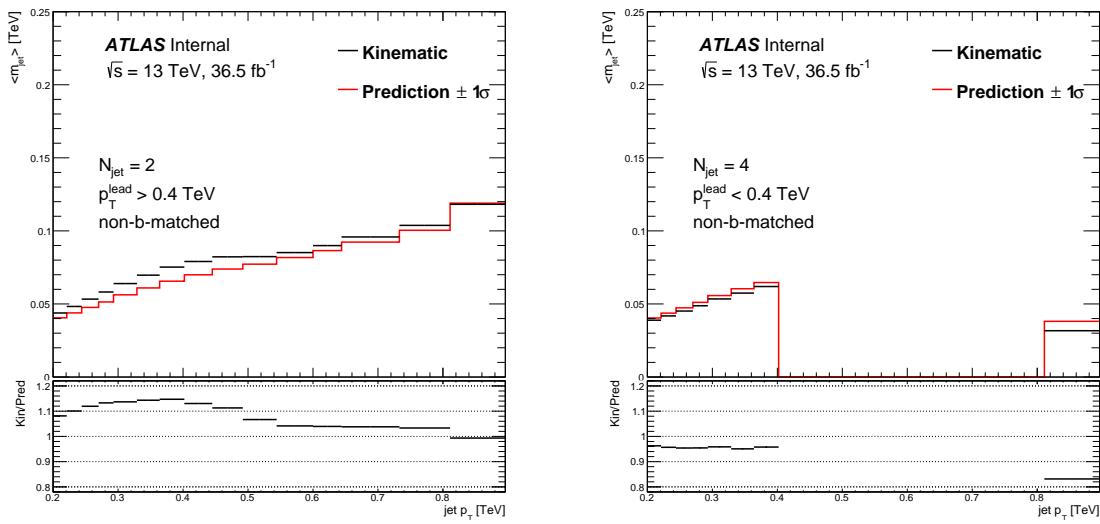
The jet mass response is further checked in data, as shown in Figure 20. The jet mass response in data is consistent with the jet mass response in the PYTHIA8 and Herwigpp multijet samples.

Table 3 summarizes the compatibility between the observed jet mass response and the prediction in various regions and different samples. In this table, the results from SHERPA multijet sample are also

	low p_T $< 400 \text{ GeV}$				intermediate p_T $400 \text{ GeV} - 600 \text{ GeV}$			high p_T $> 600 \text{ GeV}$		
	UDR1	UDR2	4j	5j	UDR1	4j	5j	UDR1	4j	5j
Data	↓	↑	-	-	↓	-	-	↓	-	-
PYTHIA8	↓	↑	↑	↑	↓	↓	×	↓	↓	↓
Herwigpp	↓	↑	↑	↑	↓	↓	×	↓	↓	↓
SHERPA	↓	✗	✗	✗	✗	↓	✗	↑	↓	↓

Table 3: A summary of compatibility between jet mass prediction and observation in various regions and different samples. In this table, the symbol \uparrow stands for over-prediction, \downarrow for under-prediction, \times for inconclusive due to low statistics, and “-” for not available.

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(a) = 2 jets, leading jet $p_T > 400 \text{ GeV}$ non-matched jet (b) = 4 jets, leading jet $p_T > 400 \text{ GeV}$ non-matched jet

Figure 20: Predicted and observed jet mass responses in the UDR1 ((a)) and UDR2 ((b)) with 36.1 fb^{-1} data.

467 listed, although they are statistically inconclusive in a few cases.

468 4.4.3. Systematic uncertainty determination

469 The jet mass response distributions in the UDR1 and UDR2 are used to estimate the uncertainty of jet mass
 470 prediction as a function of p_T and η of individual jets. In the prediction, the randomized jet mass value
 471 can be scaled up or down by the size of the discrepancy seen in the jet mass responses in the UDRs, and the
 472 M_J^Σ distributions resulted from the shifted randomized jet masses are used to determine the uncertainty
 473 on the predicted background yield in a signal region with a specific M_J^Σ cut. This implementation requires
 474 that the shift in jet mass response captures the main discrepancy in the jet mass PDF between different
 475 regions. Figure 21 compares the jet mass distributions between the CR and two UDRs in two example
 476 p_T - $|\eta|$ bins. While a simple scaling of jet mass may not completely correct the discrepancy at the tail part

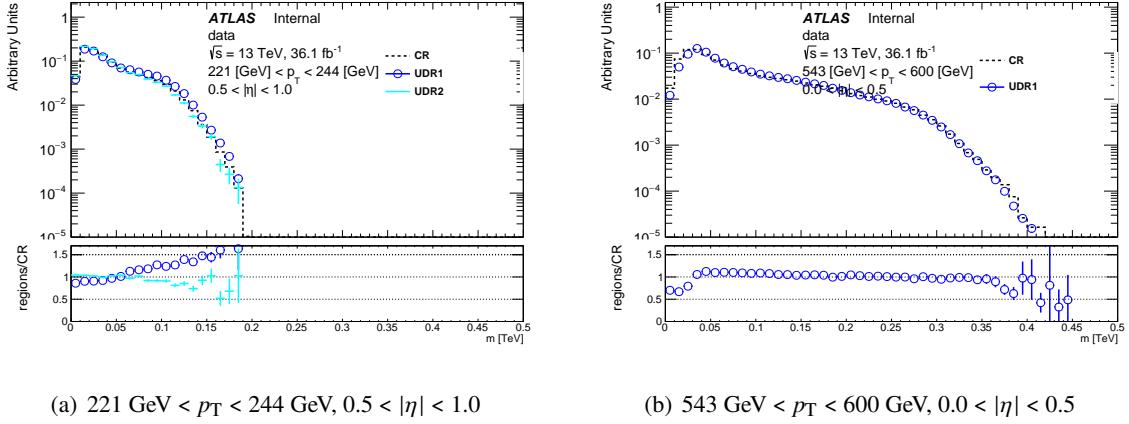


Figure 21: Jet mass distributions for the control region (dashed), UDR1 (open circle), and UDR2 (cyan cross) in two example p_T - $|\eta|$ bins, $221 \text{ GeV} < p_T < 244 \text{ GeV}, 0.5 < |\eta| < 1.0$ ((a)), and $543 \text{ GeV} < p_T < 600 \text{ GeV}, 0.0 < |\eta| < 0.5$ ((b)).

of the jet mass distribution, the discrepancy in the peak part of the jet mass distribution between these regions indeed can be captured by a shift in the jet mass. Appendix R presents the comparison plots for all p_T - $|\eta|$ bins.

The jet mass response distributions in four η regions for both UDRs are studied using PYTHIA8, Herwigpp, and SHERPA as well as data. Appendix F shows the jet mass response distributions in four η regions for both UDRs. The trends of the discrepancy between different η regions are very consistent. In each η region, the systematic uncertainty is determined in three different p_T ranges. For jets with $p_T < 400 \text{ GeV}$, the discrepancy is different in size and sign between the UDR1 and the UDR2, and the largest discrepancy observed in these two UDRs is considered as the systematic uncertainty. For jets with an intermediate p_T ($400 \text{ GeV} < p_T < 600 \text{ GeV}$), the discrepancy is dropping gradually over the p_T range, and the discrepancy observed at the bin right beyond $p_T = 400 \text{ GeV}$ is considered as the systematic uncertainty. For jets with $p_T > 600 \text{ GeV}$, the discrepancy is relatively flat in p_T and the average value is considered as the systematic uncertainty.

Tables 5 and 6 presents the systematic uncertainties determined with this procedure, for the PYTHIA8 multijet plus $t\bar{t}$ MC sample and the Herwigpp multijet plus $t\bar{t}$ MC sample, respectively. The uncertainty is relative to the jet mass and shown in four η regions and three p_T ranges.

The uncertainty on jet mass prediction is propagated to the prediction on background event yield in the signal region through pseudo-experiments. As described in Section 4.2, the nominal prediction of M_j^Σ is constructed from randomized jet masses in an ensemble of PEs; In the same ensemble of PEs, the randomized jet masses can be scaled up or down by the size of the jet mass prediction uncertainty determined here, and the resulting M_j^Σ distributions correspond to the $\pm 1 \sigma$ variation of the jet mass prediction uncertainty and can be used to derive the uncertainty on the predicted yield. This procedure is implemented separately for the “low p_T ” jet mass prediction uncertainty, which affects jets with a $p_T < 400 \text{ GeV}$, and the “high p_T ” jet mass prediction uncertainty, which affects jets with a $p_T > 400 \text{ GeV}$ and has different values for p_T ranges of $400 \text{ GeV} - 600 \text{ GeV}$ and $> 600 \text{ GeV}$.

In this uncertainty determination procedure, no separation between b-matched jets and non-matched

$ \eta $	low p_T	intermediate p_T	high p_T
$0 < \eta < .5$	10.96	10.63	2.31
$.5 < \eta < 1.0$	11.17	11.14	2.66
$1.0 < \eta < 1.5$	10.07	11.07	4.10
$1.5 < \eta < 2.0$	11.82	13.36	4.45

Table 4: Uncertainties (in percent) on predicted jet mass as determined from 36.1 fb^{-1} data.

$ \eta $	low p_T	intermediate p_T	high p_T
$0 < \eta < .5$	10.79	9.70	3.31
$.5 < \eta < 1.0$	9.99	13.14	3.95
$1.0 < \eta < 1.5$	9.56	11.32	3.65
$1.5 < \eta < 2.0$	10.60	11.70	4.19

Table 5: Uncertainties (in percent) on predicted jet mass as determined from PYTHIA8 and $t\bar{t}$ MC samples normalized to 36.1 fb^{-1} .

$ \eta $	low p_T	intermediate p_T	high p_T
$0 < \eta < .5$	6.41	8.74	1.82
$.5 < \eta < 1.0$	8.75	10.67	1.70
$1.0 < \eta < 1.5$	10.30	9.69	3.34
$1.5 < \eta < 2.0$	9.22	13.15	5.78

Table 6: Uncertainties (in percent) on predicted jet mass as determined from Herwigpp and $t\bar{t}$ MC samples normalized to 36.1 fb^{-1} .

503 jets is made. The jet mass response is checked separately for b-matched jets and non-matched jets
 504 in data and Monte Carlo samples and shown in Appendix H. In the UDR1, the discrepancies seen in
 505 the b-matched jets and non-matched jets are essentially the same, as shown by Figure 72. In the
 506 UDR2(73), PYTHIA8 multijet plus $t\bar{t}$ MC sample does not suggest significant discrepancy, and the jet mass
 507 response of b-matched jets is statistically limited; data suggest that there is an over-prediction at the
 508 level of 5 - 10% in both non-matched jets and b-matched jets, with the discrepancy in b-matched
 509 jets slightly larger. Since the larger discrepancy in the range of $p_T < 400 \text{ GeV}$ between the UDR1 and
 510 UDR2 is taken as the uncertainty and the discrepancy in the UDR1 is always larger than that in the UDR2, the
 511 merge of b-matched jets and non-matched jets does not yield any practical impact in the analysis.

512 Since UDR1 only requires two large- R jets, the `HLT_ht1000_L1J100` trigger may not be fully efficient
 513 in this region. The inefficiency of UDR1 events in principle should not affect the estimation of the jet
 514 mass prediction uncertainty, as this uncertainty is at the individual jet level. The UDR2 also suffer from
 515 a small inefficiency, as suggested by Figure 7. To check if the trigger inefficiency can introduce any
 516 significant change in the UDRs, an offline $H_T > 1.0 \text{ TeV}$ requirement is included and the discrepancies in
 517 the UDRs are found to be consistent with or without this offline H_T cut. Appendix E includes figures of
 518 this comparison.

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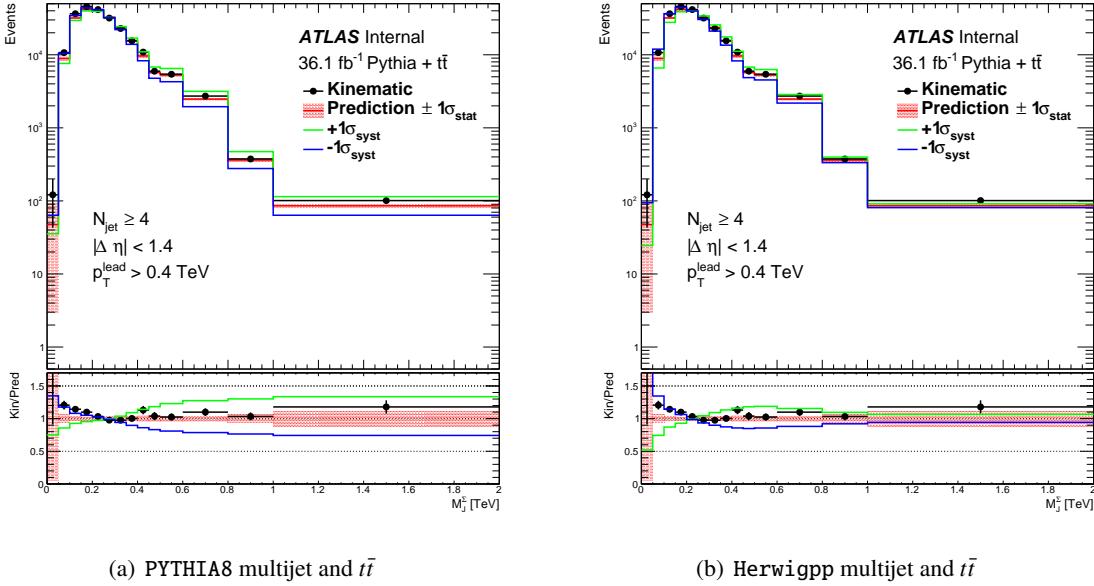


Figure 22: Example predicted and observed M_J^Σ distributions in Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. Results from PYTHIA8 multijet combined with $t\bar{t}$ sample are shown. (a) shows the systematic variation for the “high p_T ” component, and (b) shows systematic variation for the “low p_T ” component. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Additional systematic uncertainties are not included in these plots. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. Both multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} and 3.6 fb^{-1} for PYTHIA8 multijet sample and Herwigpp multijet sample, respectively.

519 4.5. Prediction from the MC and data

520 4.5.1. Background estimation performance in Monte Carlo sample

521 The full background estimation procedure is exercised on three multijet MC samples, including PYTHIA8,
 522 Herwigpp, and SHERPA. In certain regions, the samples are statistically limited. The equivalent MC
 523 integrated luminosity is as low as 1.9 fb^{-1} and 3.6 fb^{-1} for PYTHIA8 and Herwigpp samples. In the
 524 comparison of jet mass response in the CR and UDRs between SHERPA and data, it is found that the
 525 SHERPA multijet sample does not model data well, and therefore the SHERPA multijet sample is disfavored
 526 in this study.

527 Figures 23 - 26 show the predicted and observed M_J^Σ distributions in various signal regions using
 528 PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples, while Figures 27 - 30 show the predicted
 529 and observed M_J^Σ distributions in various validation regions using the same samples. The equivalent of
 530 these figures produced from Herwigpp multijet plus $t\bar{t}$ samples can be found in Appendix O.

531 In the regions defined with five or more large- R jets, the Monte Carlo statistics is severely limited. The

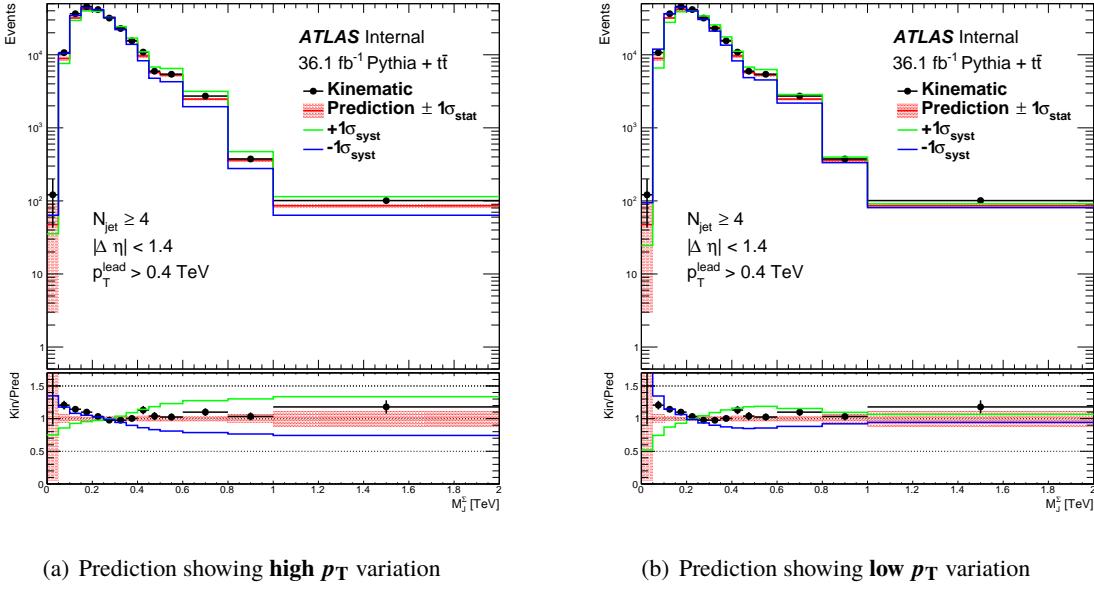


Figure 23: Predicted and observed M_J^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

532 prediction and observation agree wihtin statistical uncertainty, which is much larger than the systematic
 533 uncertainties determined in the UDRs. In the regions defined with four or more large- R jets, the overall
 534 agreement is reasonable. In the low M_J^Σ region, there is a systematic excess regardless of the b-tagging
 535 requirement. while in the high M_J^Σ region, there is a modest excess that is at the level of statistical
 536 uncertainty. Overall, the predicted M_J^Σ distribution is “narrower” than the observed M_J^Σ distribution. The
 537 excess in the low M_J^Σ part suggests an over-prediction of jet mass, while the excess in the high M_J^Σ part
 538 suggests an under-prediction of jet mass. It is clear that a single one-sided shift of jet mass cannot account
 539 for such kind of discrepancy. This observation is indeed consistent with the observation in the UDRs. The
 540 UDR2 sees an over-prediction of jet mass for jet with $p_T < 400$ GeV, while the UDR1 sees an under-prediction
 541 of jet mass for the entire p_T range. Two uncorrelated systematic components are needed to account for the
 542 discrepancy seen in the M_J^Σ distributions.

543 The predicted and observed background yields in a region with $M_J^\Sigma > 0.8$ TeV are shown in Table 7 and
 544 Table 8 for PYTHIA8 multijet plus $t\bar{t}$ sample and Herwigpp multijet plus $t\bar{t}$ sample, respectively. In
 545 general, there is a good agreement between the prediction and the observation.

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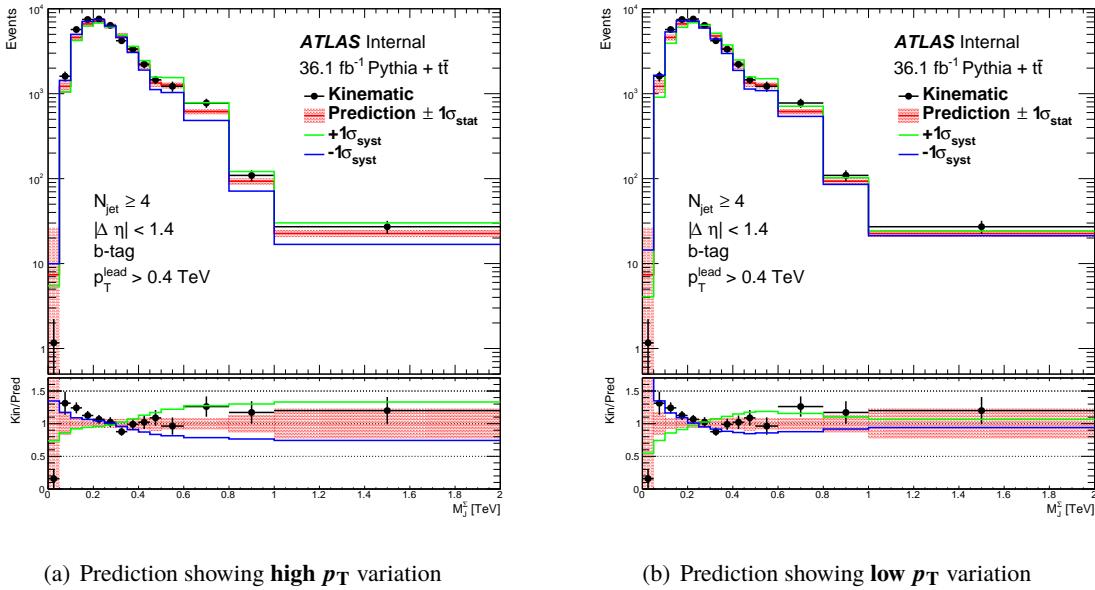


Figure 24: Predicted and observed M_J^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

Region	$\geq M_J^\Sigma$ [TeV]	Observed	Expected ($\pm (\text{Stat.}) \pm (\text{High } p_T) \pm (\text{Low } p_T)$)
4jSRb	0.8	129.1 ± 15.8	$117.1 \pm 7.6 \pm 36.5 \pm 10.9$
5jSRb	0.8	6.0 ± 2.0	$6.3 \pm 1.6 \pm 2.0 \pm .5$
4jSR	0.8	454.5 ± 22.7	$452.8 \pm 13.7 \pm 140.9 \pm 41.3$
5jSR	0.8	29.8 ± 4.9	$24.6 \pm 3.4 \pm 7.7 \pm 1.9$

Table 7: Predicted and observed yields in various search regions in PYTHIA8 multijet and $t\bar{t}$ MC.

Region	$\geq M_J^\Sigma$ [TeV]	Observed	Expected ($\pm (\text{Stat.}) \pm (\text{High } p_T) \pm (\text{Low } p_T)$)
4jSRb	0.8	81.6 ± 20.1	$76.8 \pm 9.8 \pm 16.3 \pm 6.0$
5jSRb	0.8	4.8 ± 2.1	$3.7 \pm 1.4 \pm .8 \pm .2$
4jSR	0.8	419.9 ± 110.7	$304.0 \pm 18.5 \pm 64.8 \pm 21.9$
5jSR	0.8	16.7 ± 3.7	$18.3 \pm 4.1 \pm 4.1 \pm .9$

Table 8: Predicted and observed yields in various search regions in Herwigpp multijet and $t\bar{t}$ MC.

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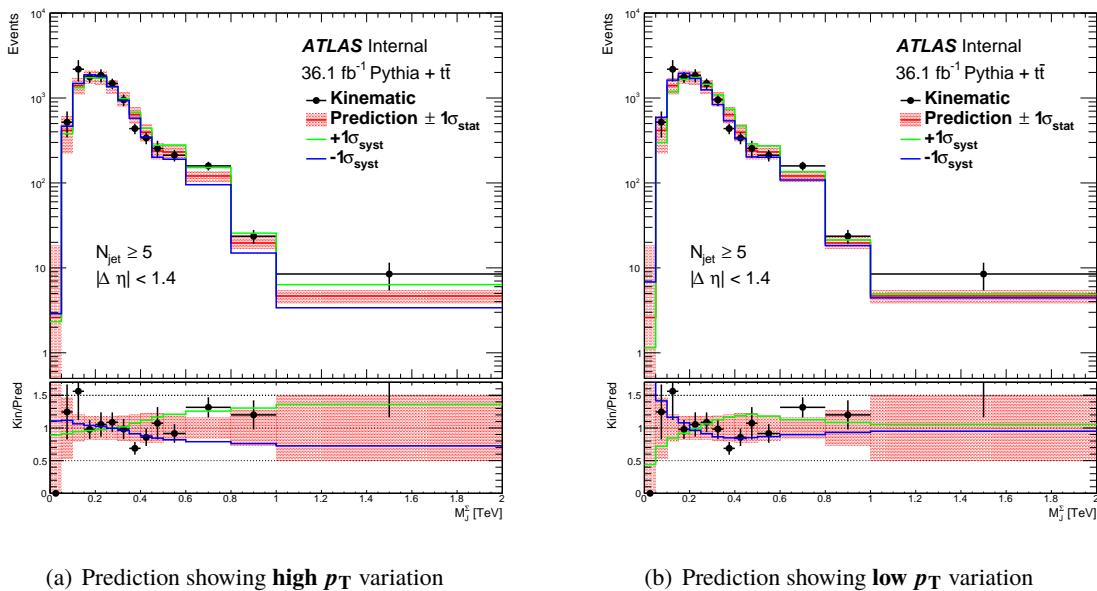


Figure 25: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

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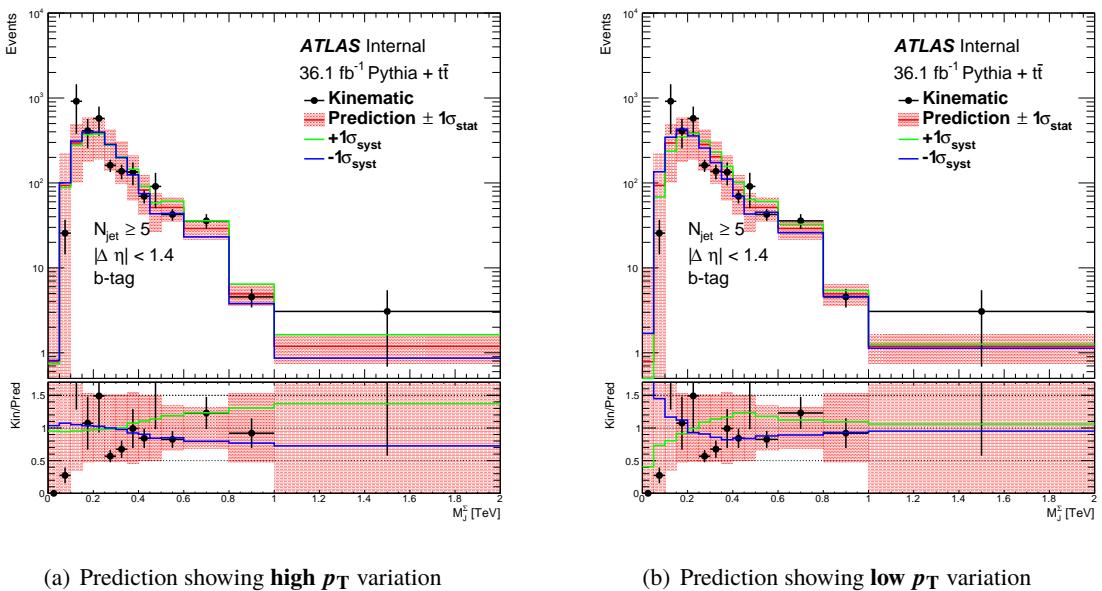


Figure 26: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

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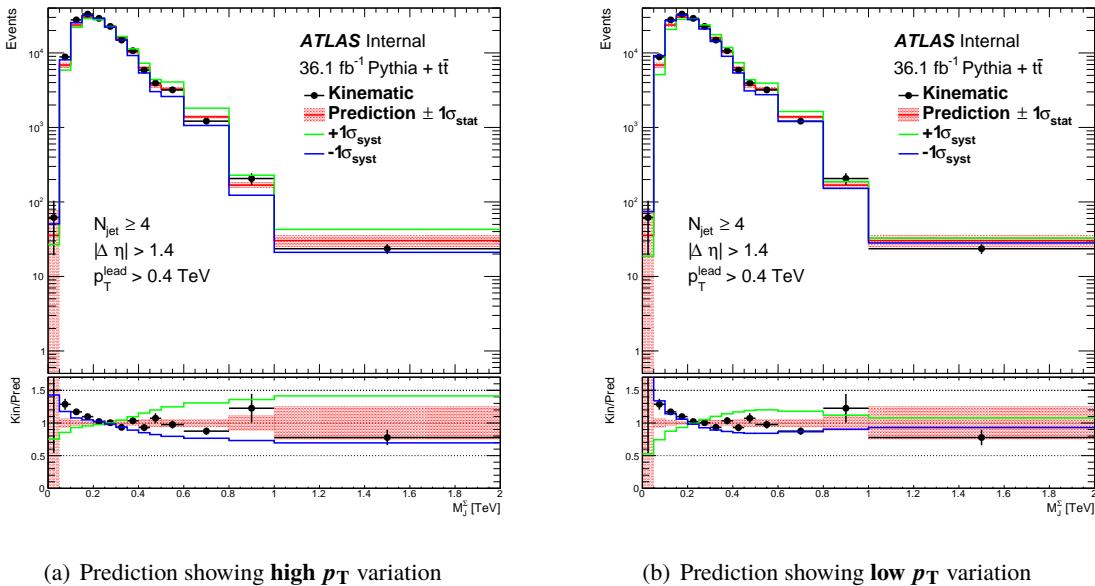


Figure 27: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

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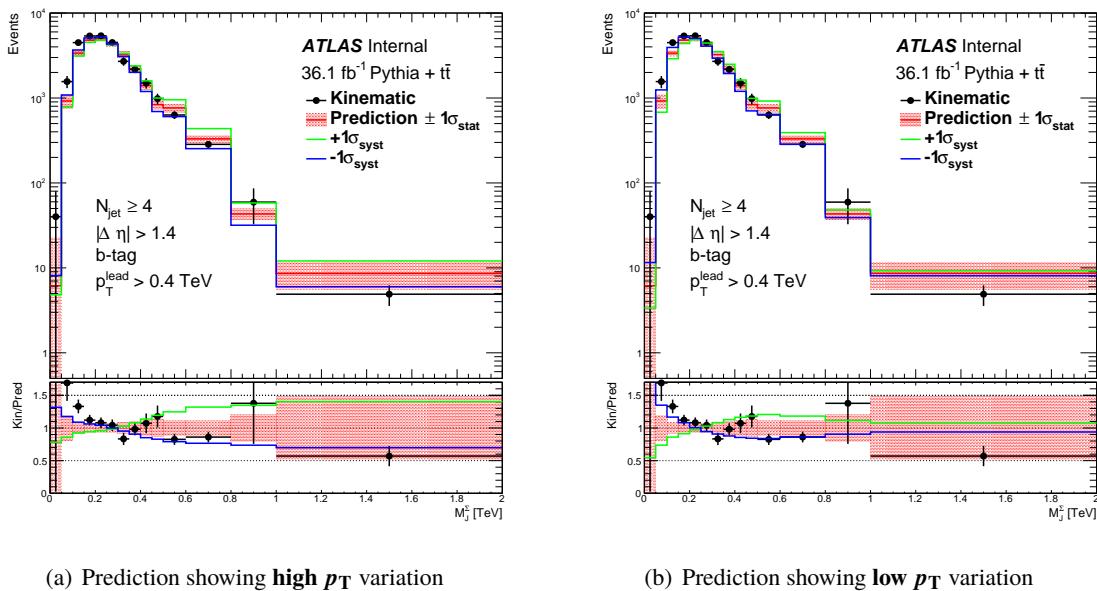


Figure 28: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

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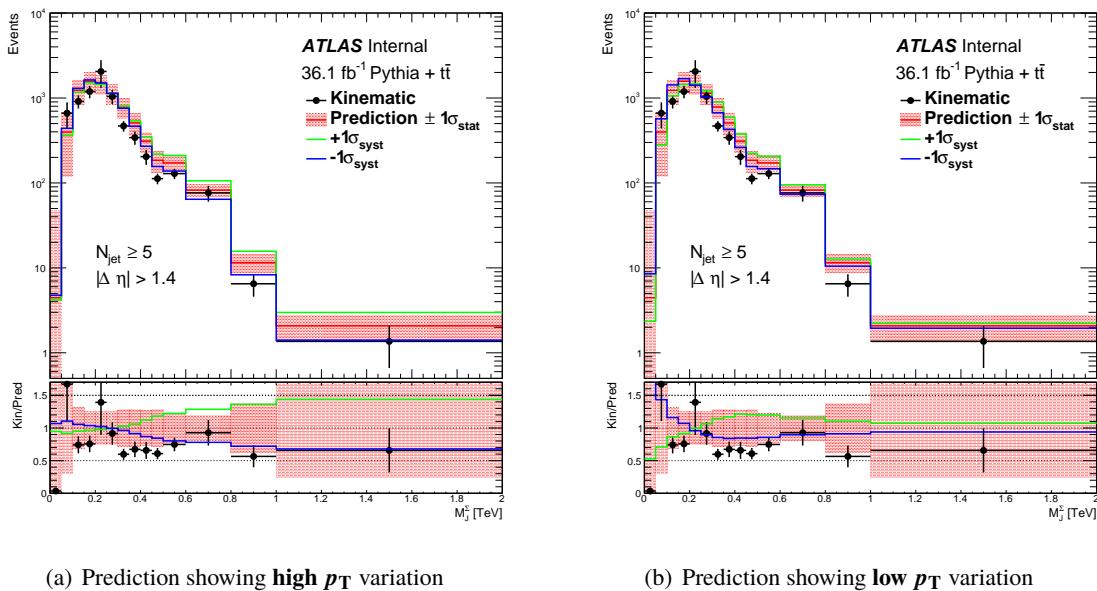


Figure 29: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

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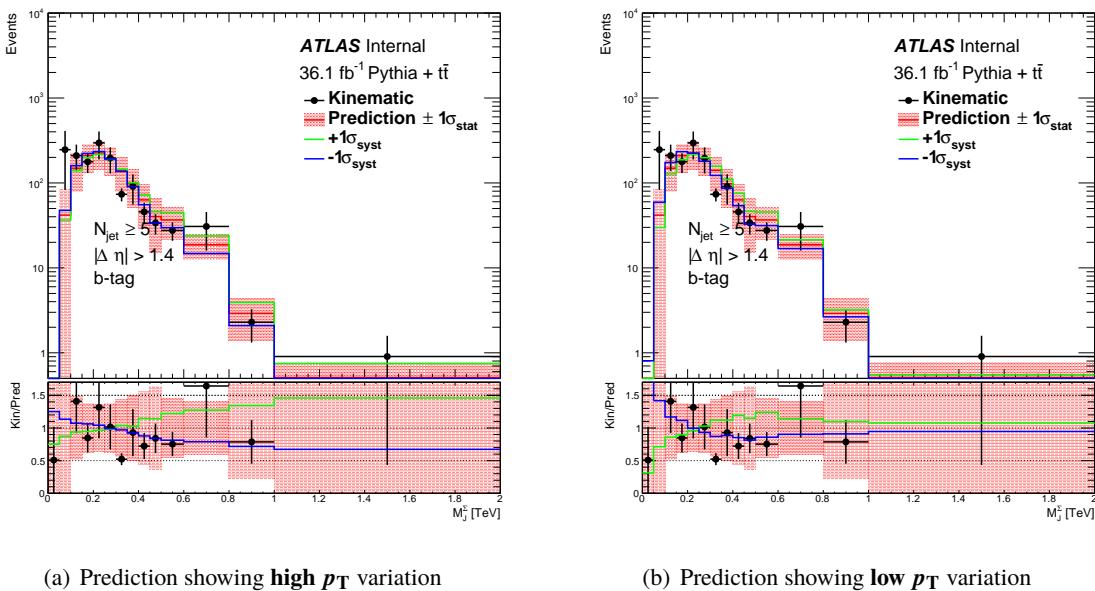


Figure 30: Predicted and observed M_j^Σ distributions in PYTHIA8 multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The PYTHIA8 multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 1.8 fb^{-1} .

Region	$\geq M_J^\Sigma$ [TeV]	Observed	Expected (\pm (Stat.) \pm (High p_T) \pm (Low p_T))
5jSRb	0.6	61	$44.0 \pm 7.5 \pm 11.2 \pm 7.2$
5jSRb	0.8	10	$7.0 \pm 2.4 \pm 1.9 \pm .7$
5jSR	0.8	31	$18.0 \pm 3.7 \pm 4.6 \pm 1.5$
4jSRb	1.0	15	$23.6 \pm 4.6 \pm 6.1 \pm 1.7$
4jSR	1.0	82	$68.2 \pm 7.6 \pm 15.8 \pm 4.4$

Table 9: Predicted and observed yields in various search regions in data for a number of different M_J^Σ cuts

Region	$\geq M_J^\Sigma$ [TeV]	Observed	Expected (\pm (Stat.) \pm (High p_T) \pm (Low p_T))
4jSRb	0.8	- ± -	$121.9 \pm 10.0 \pm 32.5 \pm 13.4$
5jSRb	0.8	- ± -	$7.0 \pm 2.4 \pm 1.9 \pm .7$
4jSR	0.8	- ± -	$325.1 \pm 16.7 \pm 85.0 \pm 33.5$
5jSR	0.8	- ± -	$18.0 \pm 3.7 \pm 4.6 \pm 1.5$
4jSRb	0.9	- ± -	$53.6 \pm 6.9 \pm 13.4 \pm 4.6$
5jSRb	0.9	- ± -	$3.0 \pm 1.7 \pm .7 \pm .3$
4jSR	0.9	- ± -	$142.4 \pm 12.9 \pm 35.0 \pm 11.3$
5jSR	0.9	- ± -	$8.9 \pm 2.5 \pm 1.8 \pm .5$
4jSRb	1.0	- ± -	$23.6 \pm 4.6 \pm 6.1 \pm 1.7$
5jSRb	1.0	- ± -	$1.3 \pm 1.0 \pm .3 \pm .1$
4jSR	1.0	- ± -	$68.2 \pm 7.6 \pm 15.8 \pm 4.4$
5jSR	1.0	- ± -	$4.8 \pm 1.9 \pm .9 \pm .2$
4jSRb	1.1	- ± -	$11.4 \pm 3.1 \pm 3.1 \pm .8$
4jSR	1.1	- ± -	$35.8 \pm 4.9 \pm 7.6 \pm 1.8$
4jSRb	1.2	- ± -	$5.5 \pm 2.6 \pm 1.3 \pm .3$
4jSR	1.2	- ± -	$21.0 \pm 3.8 \pm 3.5 \pm .8$

Table 10: Predicted and observed yields in various search regions in data for a number of different M_J^Σ cuts

546 4.6. Prediction in data

547 The determination of systematic uncertainty on the jet mass prediction is presented in Table 4 in Sec-
 548 tion 4.4.3.

549 The predicted M_J^Σ distributions for validation and signal regions with ≥ 4 or 5 jets are shown in Fig-
 550 ures 31, 32 33 and 34. For all signal regions, the observed distribution beyond $M_J^\Sigma > 0.6$ TeV is blinded.

551 Table 10 shows the predicted background yields in four different signal regions with a number of M_J^Σ cuts,
 552 which are used to determine the optimal signal region selection.

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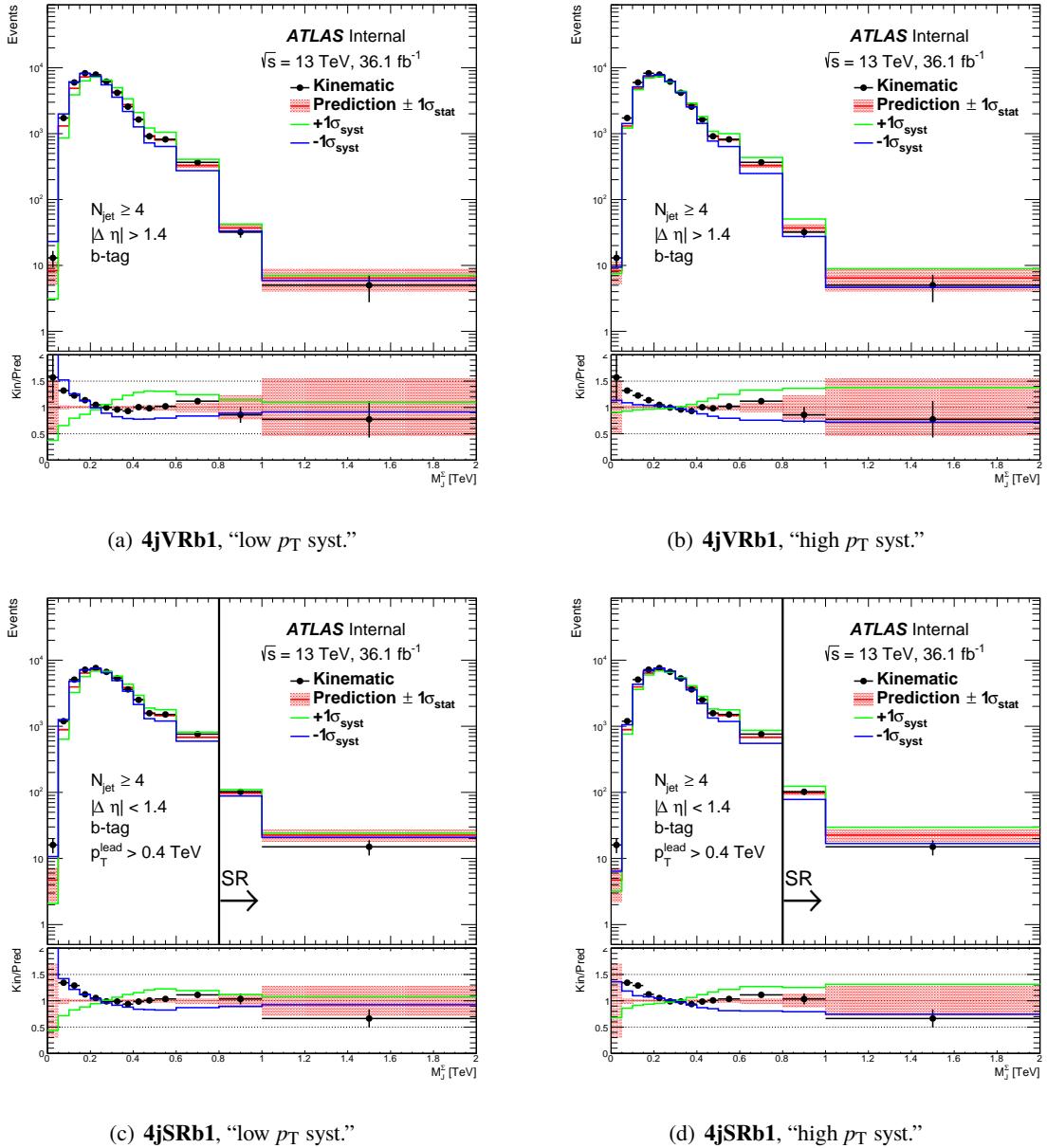


Figure 31: $M_j^\Sigma \geq 0.6 \text{ TeV}$ blinded for SRs Predicted and observed M_j^Σ distributions in the 4-jet b-tag events in data. The two subfigures on the top row are from the **VR**, while the two subfigures on the bottom row are from the **SR**. Subfigures on the left column show the systematic variations of the “**low p_T** ” systematic uncertainty in the jet mass estimation, while subfigures on the right column show systematic variations of the “**high p_T** ” systematic uncertainty. For the same region (SR or VR), the observed data, nomination background prediction and its statistical uncertainty, are the same between subfigures showing different systematic variations.

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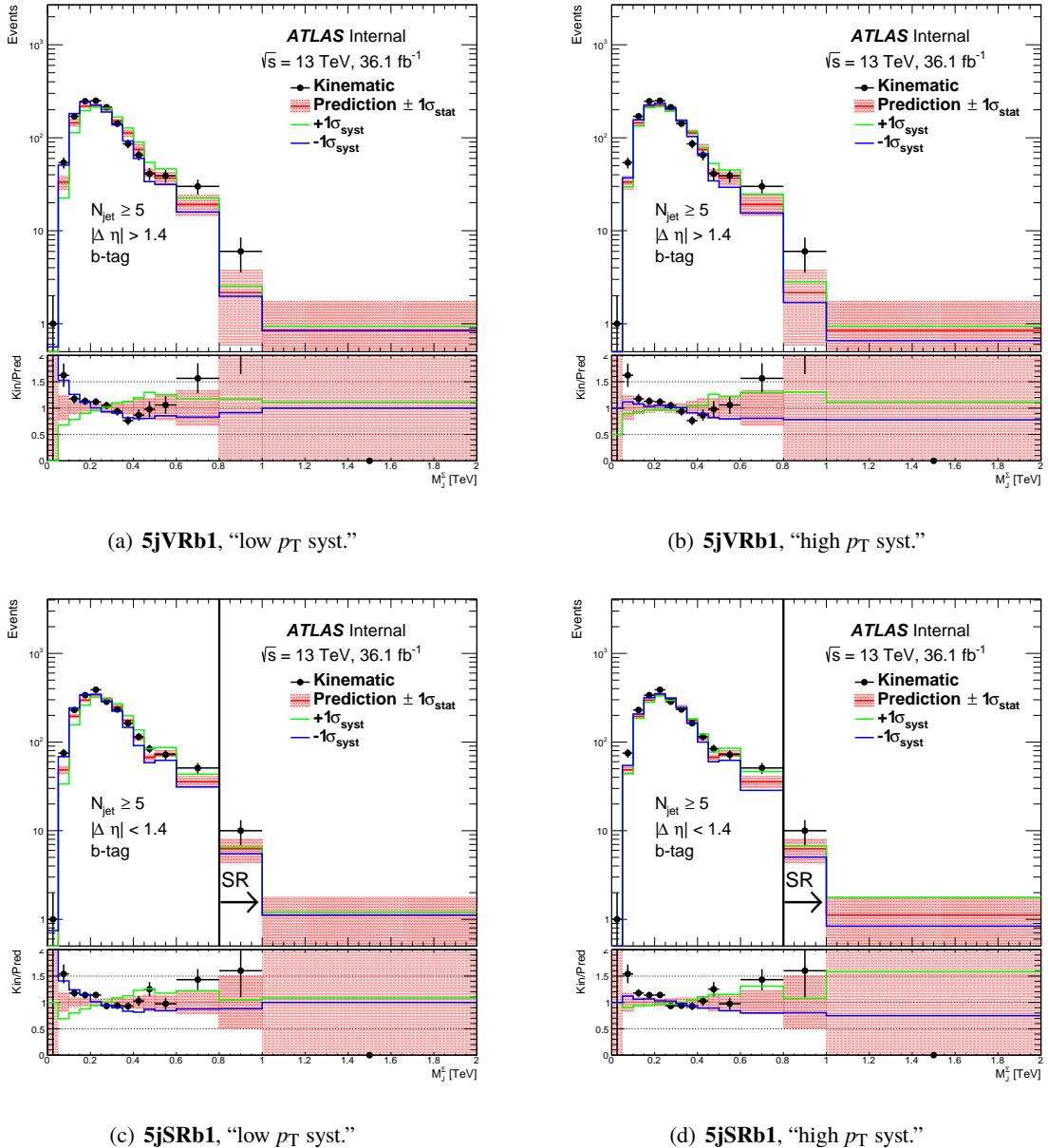


Figure 32: $M_j^\Sigma \geq 0.6$ TeV blinded for SRs Predicted and observed M_j^Σ distributions in the 5-jet b-tag events in data. The two subfigures on the top row are from the **VR**, while the two subfigures on the bottom row are from the **SR**. Subfigures on the left column show the systematic variations of the “**low p_T** ” systematic uncertainty in the jet mass estimation, while subfigures on the right column show systematic variations of the “**high p_T** ” systematic uncertainty. For the same region (SR or VR), the observed data, nomination background prediction and its statistical uncertainty, are the same between subfigures showing different systematic variations.

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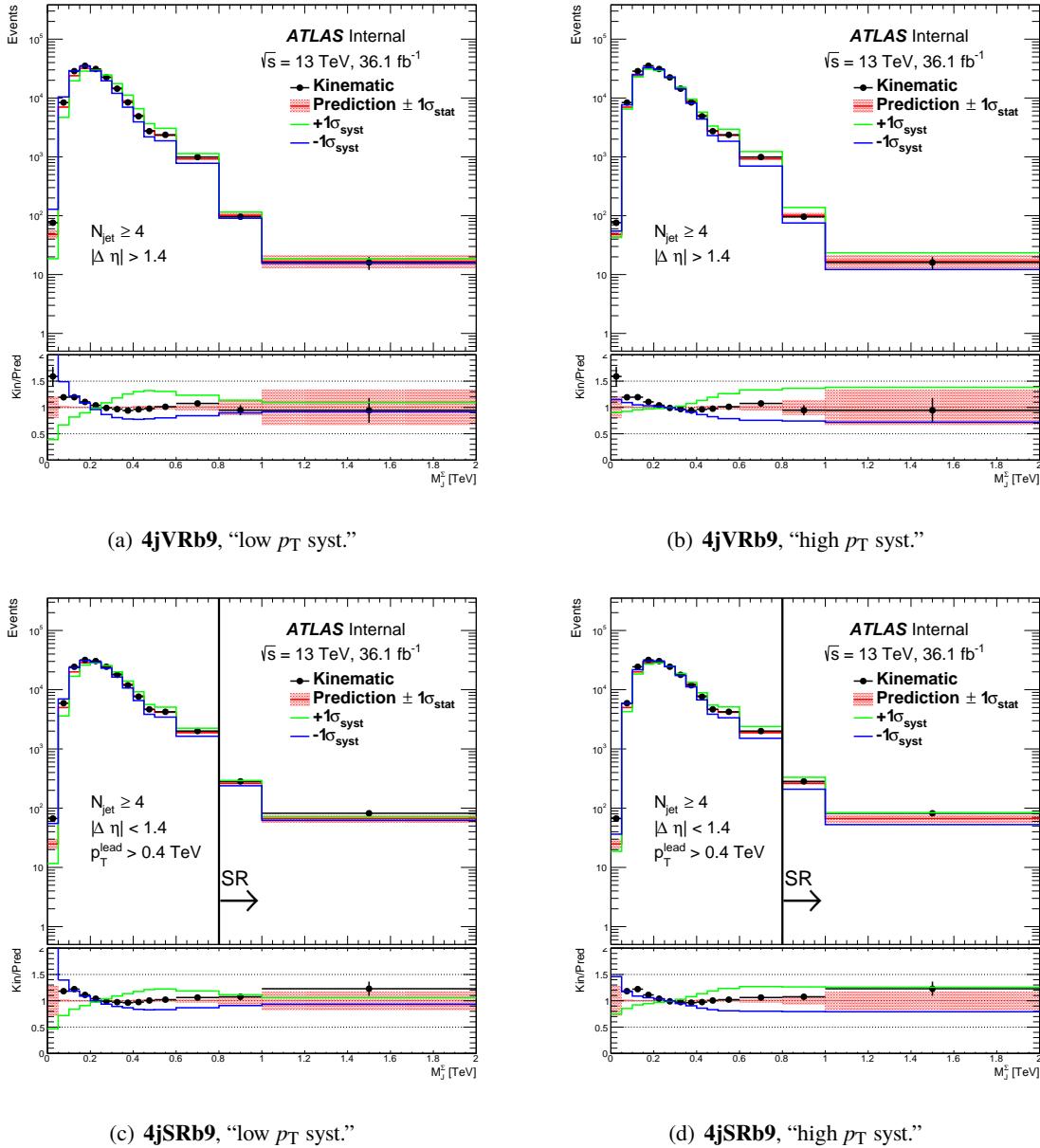


Figure 33: $M_j^\Sigma \geq 0.6$ TeV blinded for SRs Predicted and observed M_j^Σ distributions in the 4-jet b-tag events in data. The two subfigures on the top row are from the **VR**, while the two subfigures on the bottom row are from the **SR**. Subfigures on the left column show the systematic variations of the “**low p_T** ” systematic uncertainty in the jet mass estimation, while subfigures on the right column show systematic variations of the “**high p_T** ” systematic uncertainty. For the same region (SR or VR), the observed data, nomination background prediction and its statistical uncertainty, are the same between subfigures showing different systematic variations.

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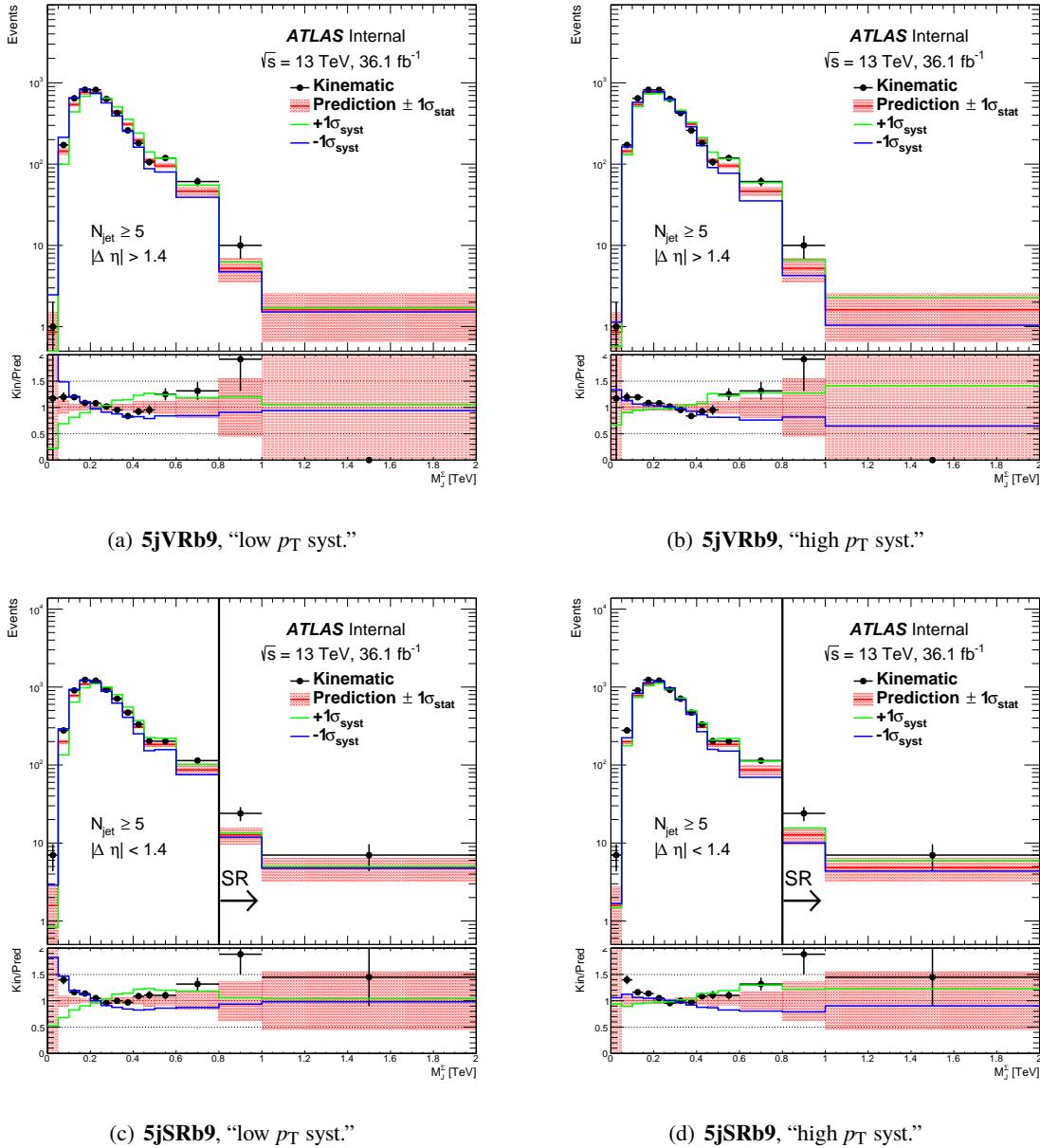


Figure 34: $M_j^\Sigma \geq 0.6$ TeV blinded for SRs Predicted and observed M_j^Σ distributions in the 5-jet b-tag events in data. The two subfigures on the top row are from the **VR**, while the two subfigures on the bottom row are from the **SR**. Subfigures on the left column show the systematic variations of the “**low p_T** ” systematic uncertainty in the jet mass estimation, while subfigures on the right column show systematic variations of the “**high p_T** ” systematic uncertainty. For the same region (SR or VR), the observed data, nomination background prediction and its statistical uncertainty, are the same between subfigures showing different systematic variations.

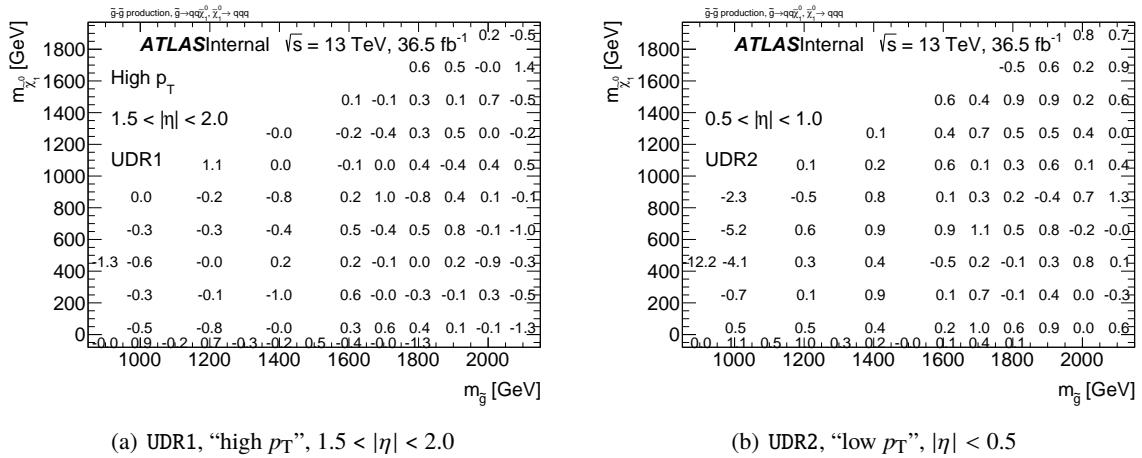


Figure 35: Variation in the jet mass prediction uncertainty due to the injection of signal events. (a) shows the “high p_T ” region of UDR1, with jets in $1.5 < |\eta| < 2.0$, and (b) shows the “low p_T ” region of UDR2, with jets in $|\eta| < 0.5$. The entry shown in the plot represents the change in the jet mass prediction uncertainty normalized to the nominal uncertainty, and this change is shown in percentage, i.e., the absolute change in the systematic uncertainty is the product of the entry shown in here and the uncertainty shown in Table 4.

553 4.7. Signal contamination

554 The presence of signal events in the data sample may impact both the central value and the uncertainty of
 555 the predicted background yields.

556 To understand the impact on the jet mass prediction uncertainty, a series of signal injection tests are
 557 performed. In each injection test, a signal MC sample corresponding to a particular 10-quark model or
 558 6-quark model is injected to data and the background estimation procedure is carried out. The jet mass
 559 prediction uncertainty is determined in the data sample injected with signal events, and the uncertainty is
 560 compared to the uncertainty determined without signal contamination. Figure 35 shows the variation in
 561 two regions as example, and the full set of plots can be found in the Appendix G. It is evident that the jet
 562 mass prediction uncertainty is not affected by the presence of signal events.

563 The signal contamination of the kinematic sample may bias the predicted background yield due to the
 564 differences in the observables (p_T , $|\eta|$, and b-tag, etc.) used to bin jets in the control region between the
 565 signal events and background events. The level of signal contamination can be studied with signal Monte
 566 Carlo samples. The jet mass PDFs as well as the uncertainties determined from data are applied to the
 567 kinematic sample of signal events. The predicted yield in the signal region represents the bias due to the
 568 presence of signal events, which can vary from signal point to signal point because of the differences in
 569 signal cross section as well as kinematics.

570 Tables 11 and 12 show the predicted event yield in the signal region of 5jSRb with an M_J^Σ cut of 0.8
 571 TeV due to the presence of signal event. This number is compared to the predicted background yield of
 572 7.0 events presented in Section 4.5. In the statistics interpretation, this contribution can be accounted in
 573 the likelihood function when a specific signal hypothesis is tested. Specifically, the event yield expectation

DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	Δb	f_{sig}	f_{bkg}
403550	700	450	2.58	0.05	0.36
403551	800	450	3.14	0.06	0.44
403552	900	450	3.31	0.05	0.47
403553	1000	50	4.18	0.30	0.59
403554	1000	250	2.54	0.08	0.36
403555	1000	450	3.10	0.05	0.44
403556	1000	650	3.34	0.06	0.47
403557	1000	850	3.26	0.08	0.46
403558	1200	50	3.39	0.32	0.48
403559	1200	250	3.16	0.12	0.45
403560	1200	450	2.99	0.06	0.42
403561	1200	650	3.85	0.06	0.55
403562	1200	850	2.97	0.05	0.42
403563	1200	1050	2.69	0.10	0.38
403564	1400	50	2.41	0.45	0.34
403565	1400	250	2.16	0.16	0.30
403566	1400	450	2.60	0.08	0.37
403567	1400	650	2.98	0.06	0.42
403568	1400	850	2.88	0.06	0.41
403569	1400	1050	2.53	0.07	0.36
403570	1400	1250	2.18	0.12	0.31
403571	1600	50	1.55	0.45	0.22
403572	1600	250	1.57	0.18	0.22
403573	1600	450	1.89	0.10	0.27
403574	1600	650	2.10	0.08	0.30
403575	1600	850	2.18	0.07	0.31
403576	1600	1050	2.06	0.07	0.29
403577	1600	1250	1.75	0.08	0.25
403578	1600	1450	1.50	0.15	0.21

Table 11: Table of Δb , the predicted event yield in the signal region of 5jSRb with an M_j^Σ cut of 0.8 TeV due to the presence of signal event (**Part one**). Also shown here are f_{bkg} , the predicted yield normalized to the total predicted yield in data, and f_{sig} , the predicted yield normalized to the total signal yield.

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	Δb	f_{sig}	f_{bkg}
403579	1700	50	1.28	0.49	0.18
403580	1700	250	1.26	0.21	0.18
403581	1700	450	1.39	0.11	0.19
403582	1700	650	1.65	0.09	0.23
403583	1700	850	1.76	0.08	0.25
403584	1700	1050	1.68	0.07	0.24
403585	1700	1250	1.59	0.08	0.22
403586	1700	1450	1.29	0.11	0.18
403587	1800	50	.98	0.48	0.14
403588	1800	250	1.01	0.21	0.14
403589	1800	450	1.18	0.13	0.16
403590	1800	650	1.36	0.10	0.19
403591	1800	850	1.42	0.09	0.20
403592	1800	1050	1.39	0.08	0.19
403593	1800	1250	1.36	0.09	0.19
403594	1800	1450	1.19	0.11	0.17
403595	1800	1650	.90	0.18	0.12
403597	1900	250	.74	0.23	0.10
403598	1900	450	.91	0.15	0.13
403599	1900	650	1.05	0.11	0.15
403601	1900	1050	1.14	0.09	0.16
403602	1900	1250	1.06	0.09	0.15
403603	1900	1450	.96	0.10	0.13
403615	2000	50	.53	0.56	0.07
403616	2000	250	.59	0.26	0.08
403617	2000	450	.66	0.16	0.09
403618	2000	650	.78	0.13	0.11
403619	2000	850	.85	0.11	0.12
403620	2000	1050	.86	0.10	0.12
403621	2000	1250	.85	0.10	0.12
403622	2000	1450	.79	0.11	0.11
403624	2000	1850	.52	0.20	0.07
403626	2100	250	.41	0.27	0.05
403627	2100	450	.49	0.17	0.07
403628	2100	650	.57	0.15	0.08
403629	2100	850	.64	0.13	0.09
403982	2100	1250	.66	0.11	0.09
403983	2100	1450	.61	0.11	0.08
403984	2100	1650	.55	0.13	0.07

Table 12: Table of Δb , the predicted event yield in the signal region of 5jSRb with an M_J^Σ cut of 0.8 TeV due to the presence of signal event (**Part two**). Also shown here are f_{bkg} , the predicted yield normalized to the total predicted yield in data, and f_{sig} , the predicted yield normalized to the total signal yield.

⁵⁷⁴ is written as

$$\lambda = \mu \times s + b \quad (2)$$

⁵⁷⁵ where s and b are expected signal yield and expected background yield, respectively; μ is the signal
⁵⁷⁶ strength. When the contribution to the expected background yield from the presence of signal events, Δb
⁵⁷⁷ is considered, Equation 2 becomes

$$\lambda = \mu \times s + b - \mu \times \Delta b \quad (3)$$

$$\lambda = \mu \times (s - \Delta b) + b. \quad (4)$$

⁵⁷⁸ Equation 4 indicates that the effect of the signal contamination is equivalent to a reduction of the expected
⁵⁷⁹ signal yield. The ratio of Δb over the expected signal yield, f_{sig} , is also shown in Tables 11 and 12 for
⁵⁸⁰ various signal points, in the region of 5jSRb with an M_J^Σ cut of > 0.8 TeV. For signal points with relatively
⁵⁸¹ large $m_{\tilde{\chi}}$, the contamination corresponds to $\approx 10\%$ level of reduction in the expected signal yield. For
⁵⁸² signal points with $m_{\tilde{\chi}} < 450$ GeV, the reduction can be significant, ranging from $\approx 16\%$ at $m_{\tilde{\chi}} = 450$ GeV
⁵⁸³ to $\approx 45\%$ at $m_{\tilde{\chi}} = 50$ GeV. This effect needs to be taken into account when the M_J^Σ cut is optimized.

⁵⁸⁴ The numbers corresponding to other signal regions or a different M_J^Σ cut are also available [in the svn](#).

⁵⁸⁵ 5. Signal systematic uncertainties

⁵⁸⁶ A number of systematic uncertainties affect the prediction of signal yield. Samples with systematic
⁵⁸⁷ variations are generated following various performance group recommendations (see Appendix U for
⁵⁸⁸ details). The uncertainty on the predicted signal yield is evaluated by comparing the nominal signal
⁵⁸⁹ sample with signal samples with systematic variations. While Tables 18 and 19 provide a breakdown of
⁵⁹⁰ the systematic uncertainty values evaluated for the signal region (5jSRb) with an M_J^Σ cut of 0.8 TeV for
⁵⁹¹ various signal samples, main findings of the systematic uncertainty study are summarized here.

- ⁵⁹² • **b-tagging uncertainty** is found to have an impact on the expected signal yield at the level of 15%
⁵⁹³ - 20% for signal regions with a b-jet requirement.
- ⁵⁹⁴ • **largeR jet uncertainty** has four components. The uncertainty of the **baseline** component ranges
⁵⁹⁵ from $\approx 10\%$ at $m_{\tilde{g}} = 1.0$ TeV to $\approx 4\%$ at $m_{\tilde{g}} = 2.0$ TeV. The **modeling** component ranges from $\approx 6\%$
⁵⁹⁶ at $m_{\tilde{g}} = 1.0$ TeV to $\approx 3\%$ at $m_{\tilde{g}} = 2.0$ TeV. The **statistical** component ranges from $\approx 8\%$ at $m_{\tilde{g}} =$
⁵⁹⁷ 1.0 TeV to $\approx 5\%$ at $m_{\tilde{g}} = 2.0$ TeV. The **tracking** component ranges from $\approx 17\%$ at $m_{\tilde{g}} = 1.0$ TeV to
⁵⁹⁸ $\approx 9\%$ at $m_{\tilde{g}} = 2.0$ TeV.
- ⁵⁹⁹ • **luminosity uncertainty** is found to be 3.2 % for the 2015 and 2016 data sets.
- ⁶⁰⁰ • **Jet energy scale and resolution uncertainties.** The jet energy scale uncertainty is found to have
⁶⁰¹ negligible impact on the predicted signal yield, so is the jet energy resolution uncertainty. Therefore,
⁶⁰² these two uncertainties are not included in the final statistical interpretation.

- 603 • **Pile-up effect on jets** are found to have negligible impact on the analysis, and therefore not included
 604 in the final statistical interpretation.

- 605 • **PDF, α_s , QCD scale uncertainties** are evaluated by checking the variation of truth level signal
 606 acceptance when varying these configurations are changed. Specifically, the PDF uncertainty is
 607 calculated using the event internal weights of the PDFset NNPDF 3.0; the QCD scale and α_s
 608 uncertainties are calculated by varying these parameters in the event generation. Appendix J also
 609 shows the nominal and systematically varied distributions of the observables used to define the
 610 signal regions.

611 The breakdown of each systematic uncertainty for all the RPV signal points are documented in the
 612 Appendix L. Table ?? summarizes the expected signal yield and its total systematic uncertainty at 36.1
 613 fb^{-1} .

DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}_1^0}$	4jSRb, MJ > 1.0 TeV	4jSR, MJ > 1.0 TeV	5jSRb, MJ > 0.8 TeV	5jSR, MJ > 0.8 TeV
403553	1000	50	22.1 ± 8.4	36.2 ± 13.0	13.8 ± 5.1	24.7 ± 8.4
403554	1000	250	37.7 ± 16.5	54.7 ± 22.0	28.4 ± 9.6	42.7 ± 15.4
403555	1000	450	73.2 ± 22.5	89.6 ± 27.4	52.5 ± 18.6	59.9 ± 21.1
403556	1000	650	90.2 ± 32.1	114.1 ± 39.3	54.6 ± 20.5	64.3 ± 23.4
403557	1000	850	48.8 ± 19.6	59.6 ± 23.9	40.1 ± 15.1	47.9 ± 18.0
403558	1200	50	15.4 ± 5.2	26.6 ± 9.8	10.6 ± 3.8	16.8 ± 5.3
403559	1200	250	36.4 ± 12.1	49.3 ± 16.5	25.7 ± 8.6	33.6 ± 10.5
403560	1200	450	61.1 ± 18.9	78.9 ± 22.6	45.1 ± 13.8	59.7 ± 16.7
403561	1200	650	74.8 ± 23.5	96.7 ± 30.7	63.5 ± 20.3	77.0 ± 23.3
403562	1200	850	67.4 ± 20.8	84.8 ± 24.9	53.7 ± 16.3	68.0 ± 20.2
403563	1200	1050	40.5 ± 12.8	52.6 ± 15.9	26.7 ± 8.2	32.7 ± 9.6
403564	1400	50	9.9 ± 3.1	17.0 ± 4.8	5.3 ± 1.5	9.0 ± 2.7
403565	1400	250	21.9 ± 6.1	31.5 ± 8.5	12.9 ± 4.0	19.3 ± 5.8
403566	1400	450	36.9 ± 9.1	49.5 ± 11.8	30.1 ± 8.0	40.2 ± 10.6
403567	1400	650	49.4 ± 11.3	61.3 ± 14.2	42.8 ± 10.8	51.4 ± 13.3
403568	1400	850	51.3 ± 11.7	64.7 ± 14.8	46.4 ± 11.4	58.3 ± 14.1
403569	1400	1050	43.2 ± 9.7	55.1 ± 12.7	35.8 ± 9.6	43.6 ± 11.8
403570	1400	1250	24.6 ± 7.1	30.7 ± 9.1	17.6 ± 5.1	22.0 ± 6.3
403571	1600	50	6.3 ± 1.7	10.9 ± 3.0	3.4 ± 1.1	5.9 ± 1.8
403572	1600	250	13.3 ± 3.2	18.7 ± 4.5	8.7 ± 2.6	11.7 ± 3.3
403573	1600	450	22.5 ± 4.4	29.4 ± 5.8	17.3 ± 4.1	22.2 ± 5.4
403574	1600	650	26.2 ± 4.9	34.1 ± 6.4	24.1 ± 4.7	31.7 ± 6.1
403575	1600	850	30.6 ± 5.7	39.8 ± 7.3	29.9 ± 5.2	37.4 ± 6.4
403576	1600	1050	30.1 ± 6.0	38.1 ± 7.4	27.7 ± 5.4	35.0 ± 6.9
403577	1600	1250	25.1 ± 4.8	32.1 ± 5.8	21.0 ± 4.4	26.6 ± 5.4
403578	1600	1450	14.0 ± 3.3	18.3 ± 4.1	9.6 ± 2.6	12.5 ± 3.4
403579	1700	50	4.9 ± 1.3	8.1 ± 2.1	2.6 ± 0.7	4.3 ± 1.2
403580	1700	250	9.7 ± 2.0	13.5 ± 2.7	5.9 ± 1.4	8.4 ± 2.0
403581	1700	450	15.9 ± 2.8	21.0 ± 3.7	11.7 ± 2.5	15.5 ± 3.4
403582	1700	650	20.0 ± 3.4	25.3 ± 4.4	17.8 ± 3.1	22.6 ± 3.8
403583	1700	850	22.0 ± 3.6	27.9 ± 4.6	21.7 ± 3.8	26.9 ± 4.8
403584	1700	1050	22.6 ± 3.5	28.5 ± 4.4	22.1 ± 3.6	27.5 ± 4.7
403585	1700	1250	21.0 ± 3.3	26.3 ± 4.2	18.9 ± 3.8	23.4 ± 4.6

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403586	1700	1450	14.8 ± 2.8	19.2 ± 3.5	10.9 ± 2.4	13.8 ± 2.9
403587	1800	50	3.4 ± 0.8	5.9 ± 1.4	2.0 ± 0.6	3.4 ± 1.0
403588	1800	250	7.4 ± 1.4	10.1 ± 1.9	4.7 ± 1.1	6.5 ± 1.4
403589	1800	450	12.0 ± 2.1	15.8 ± 2.7	8.9 ± 1.6	11.5 ± 2.1
403590	1800	650	14.8 ± 2.2	19.1 ± 2.8	13.0 ± 2.0	16.5 ± 2.6
403591	1800	850	16.3 ± 2.2	20.6 ± 2.8	15.6 ± 2.2	19.6 ± 2.8
403592	1800	1050	16.6 ± 2.4	21.3 ± 3.0	16.0 ± 2.3	20.3 ± 2.9
403593	1800	1250	16.5 ± 2.3	20.8 ± 2.9	15.0 ± 2.2	19.0 ± 2.8
403594	1800	1450	12.9 ± 2.1	16.7 ± 2.7	10.7 ± 2.0	13.7 ± 2.5
403595	1800	1650	7.6 ± 1.4	10.1 ± 2.0	4.9 ± 1.1	6.6 ± 1.4
403596	1900	50	2.6 ± 0.6	4.6 ± 1.0	1.3 ± 0.3	2.3 ± 0.6
403597	1900	250	5.4 ± 0.9	7.4 ± 1.2	3.1 ± 0.7	4.4 ± 1.0
403598	1900	450	8.5 ± 1.2	11.2 ± 1.6	6.0 ± 1.0	7.9 ± 1.3
403599	1900	650	10.3 ± 1.4	13.3 ± 1.8	9.0 ± 1.3	11.4 ± 1.6
403600	1900	850	11.7 ± 1.4	14.9 ± 1.8	11.0 ± 1.5	13.7 ± 1.8
403601	1900	1050	12.0 ± 1.5	15.3 ± 1.9	11.8 ± 1.5	15.1 ± 1.8
403602	1900	1250	11.8 ± 1.5	15.1 ± 1.9	11.2 ± 1.4	14.2 ± 1.7
403603	1900	1450	10.4 ± 1.4	13.4 ± 1.8	8.8 ± 1.3	11.3 ± 1.6
403604	1900	1650	7.5 ± 1.1	9.7 ± 1.5	5.5 ± 0.9	7.1 ± 1.2
403615	2000	50	1.9 ± 0.4	3.3 ± 0.6	0.9 ± 0.2	1.6 ± 0.4
403616	2000	250	3.8 ± 0.6	5.2 ± 0.9	2.2 ± 0.4	3.1 ± 0.6
403617	2000	450	5.8 ± 0.8	7.7 ± 1.0	4.0 ± 0.6	5.2 ± 0.8
403618	2000	650	7.2 ± 0.9	9.3 ± 1.1	5.9 ± 0.8	7.5 ± 1.0
403619	2000	850	7.8 ± 0.9	10.0 ± 1.1	7.5 ± 0.9	9.5 ± 1.1
403620	2000	1050	8.3 ± 1.0	10.8 ± 1.2	8.2 ± 0.9	10.3 ± 1.1
403621	2000	1250	8.3 ± 0.9	10.7 ± 1.1	8.0 ± 1.0	10.2 ± 1.2
403622	2000	1450	7.9 ± 0.9	10.1 ± 1.2	7.0 ± 0.9	8.9 ± 1.1
403623	2000	1650	6.3 ± 0.8	8.3 ± 1.0	5.0 ± 0.7	6.5 ± 0.9
403624	2000	1850	3.7 ± 0.6	5.0 ± 0.9	2.5 ± 0.5	3.4 ± 0.7
403625	2100	50	1.3 ± 0.3	2.3 ± 0.5	0.7 ± 0.2	1.2 ± 0.3
403626	2100	250	2.6 ± 0.4	3.7 ± 0.5	1.5 ± 0.3	2.1 ± 0.4
403627	2100	450	4.0 ± 0.5	5.4 ± 0.6	2.8 ± 0.4	3.6 ± 0.5
403628	2100	650	4.7 ± 0.5	6.1 ± 0.7	3.8 ± 0.4	4.9 ± 0.6
403629	2100	850	5.3 ± 0.6	6.9 ± 0.7	4.9 ± 0.5	6.3 ± 0.6
403981	2100	1050	5.8 ± 0.5	7.4 ± 0.7	5.5 ± 0.5	7.0 ± 0.7
403982	2100	1250	5.8 ± 0.6	7.4 ± 0.7	5.7 ± 0.6	7.2 ± 0.7
403983	2100	1450	5.6 ± 0.5	7.3 ± 0.7	5.1 ± 0.5	6.6 ± 0.6
403984	2100	1650	4.8 ± 0.5	6.4 ± 0.7	4.1 ± 0.5	5.3 ± 0.6
403985	2100	1850	3.5 ± 0.5	4.7 ± 0.6	2.6 ± 0.4	3.4 ± 0.5
403605	900	-	29.6 ± 14.4	41.9 ± 19.4	16.4 ± 8.0	21.8 ± 10.2
403606	1000	-	20.6 ± 7.9	26.9 ± 11.1	17.7 ± 7.5	20.5 ± 8.6
403607	1100	-	27.6 ± 9.1	33.3 ± 11.4	15.3 ± 5.9	18.8 ± 7.5
403608	1200	-	20.8 ± 7.3	27.1 ± 9.5	13.6 ± 5.6	19.1 ± 7.5
403609	1300	-	15.6 ± 4.8	21.5 ± 6.3	10.9 ± 3.7	14.1 ± 4.8
403610	1400	-	13.6 ± 4.2	18.1 ± 5.4	8.8 ± 2.4	11.2 ± 3.1
403611	1500	-	10.4 ± 2.9	14.2 ± 3.9	6.5 ± 1.9	9.1 ± 2.5
403612	1600	-	8.2 ± 1.9	11.0 ± 2.6	6.1 ± 1.7	7.6 ± 2.1

403613	1700	-	6.2 ± 1.7	8.2 ± 2.2	3.7 ± 1.0	4.9 ± 1.3
403614	1800	-	4.8 ± 1.0	6.7 ± 1.4	2.8 ± 0.7	3.9 ± 1.0

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Region	$\geq M_J^\Sigma$ [TeV]	Observed	Expected (\pm (Stat.) \pm (High p_T) \pm (Low p_T))
5jSRb	0.8	10	$7.0 \pm 2.4 \pm 1.9 \pm .7$
5jSR	0.8	31	$18.0 \pm 3.7 \pm 4.6 \pm 1.5$
4jSRb	1.0	15	$23.6 \pm 4.6 \pm 6.1 \pm 1.7$
4jSR	1.0	82	$68.2 \pm 7.6 \pm 15.8 \pm 4.4$

Table 14: Predicted and observed yields in various search regions in data for a number of different M_J^Σ cuts

6. Results

This section presents the following results. First, p-values of observed data in the four signal regions are reported. Second, the model-dependent limits on the 10-quark and 6-quark models are presented. The model-dependence in the likelihood model is primarily resulted from the correction term due to the signal contamination, although signal systematic uncertainties also contribute to a lesser extent. For the 10-quark model, the limit is presented as exclusion contours on the $m_{\tilde{g}}\text{-}m_{\tilde{\chi}}$ grid; for the 6-quark model, the limit is set on the cross section times branching ratio as a function of $m_{\tilde{g}}$. Third, model-independent limits are reported for the four signal regions, assuming no contribution to the background expectation from signal contaminations. This is a reasonable assumption given that no signal events are observed in data. The limits are set on the cross section times efficiency times acceptance.

As explained in Section 4.3, four overlapping signal regions are investigated. For each signal region, a M_J^Σ cut is determined so that the sensitivity to RPV signals is maximized, and the region with the best sensitivity is chosen for the model-dependent interpretation. Table 10 presents the predicted background yields in these signal regions for a number of candidate M_J^Σ cuts.

In general, signal regions with a b-tag requirement perform better for the RPV signal models, and they are used for model-dependent interpretation. The 5jSRb with an M_J^Σ cut of > 0.8 TeV is found to be the most sensitive signal region for most 10-quark models and all 6-quark models, while 5jSR with an M_J^Σ cut of > 0.8 TeV is found to be the most sensitive signal region for RPV signals with $m_{\tilde{\chi}} = 50$ GeV.

Model-independent limit and p-value are reported for all four signal regions. For 4j signal regions, $M_J^\Sigma > 1.0$ TeV is found to be most sensitive to RPV signal models and therefore is chosen as the cut used for the model-independent interpretation.

6.1. Summary of unblinded M_J^Σ distributions and event yields in the SRs

Figure 37 shows the predicted and observed M_J^Σ distributions in signal regions, and Figure 36 shows the predicted and observed M_J^Σ distributions in validation regions.

Table 14 summarizes the predicted and observed event yields in the signal regions.

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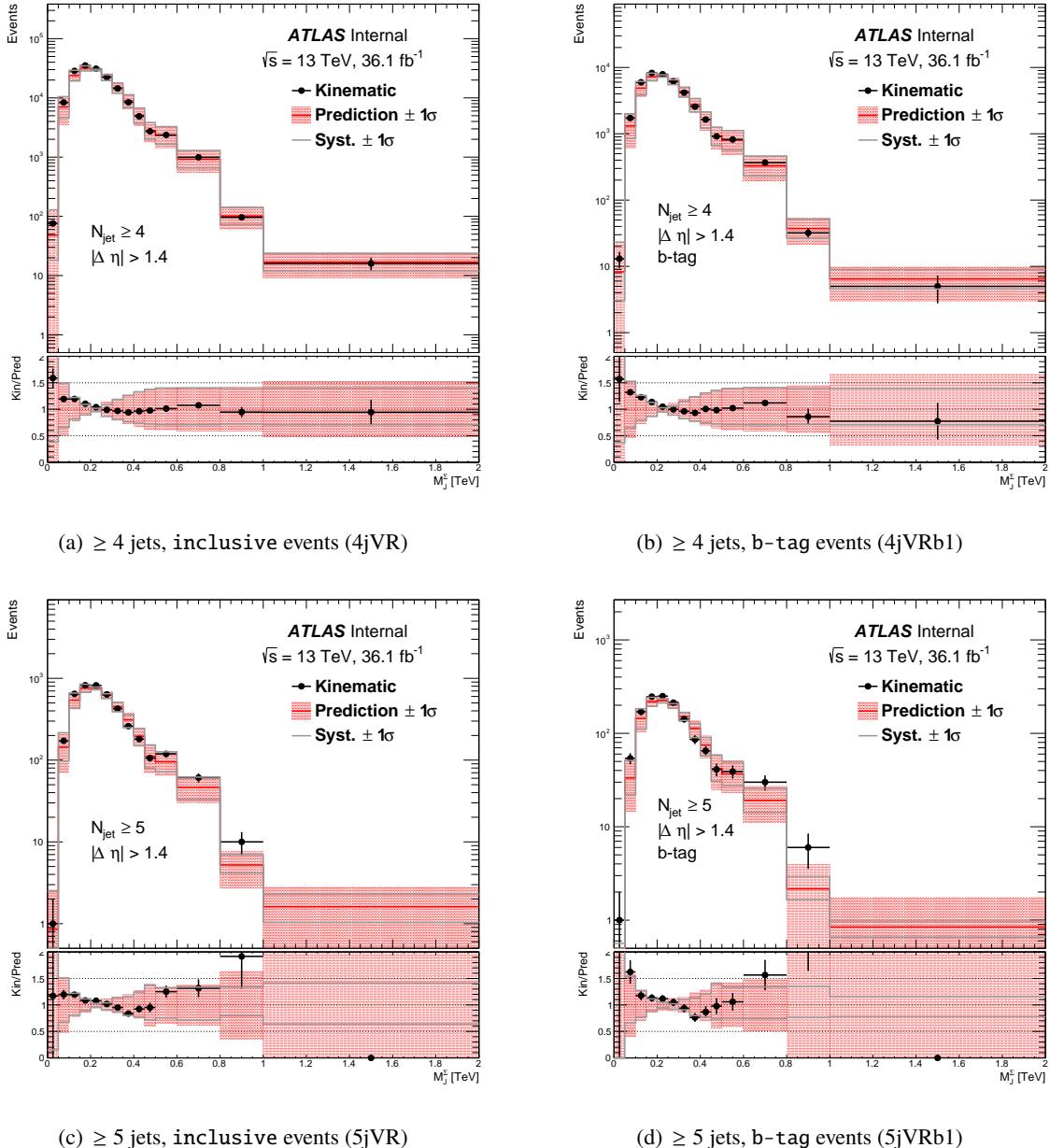


Figure 36: Predicted (solid line) and observed (dots) M_j^Σ distributions for validation regions 4jVR (a), 4jVRb1 (b), 5jVR (c), and 5jVRb1 (d). The shaded area surrounding the predicted M_j^Σ distribution represents the systematic uncertainty of the background estimation, predicted M_j^Σ distribution, and the residual p_T -dependent uncertainty. The predicted M_j^Σ distribution is normalized to data in $0.2 \text{ TeV} < M_j^\Sigma < 0.6 \text{ TeV}$, where expected contamination from signals of gluino direct or cascade decay models not excluded by the Run-1 analysis [1] is negligible compared to the background statistical uncertainty. The expected contribution from two RPV signal samples are also shown.

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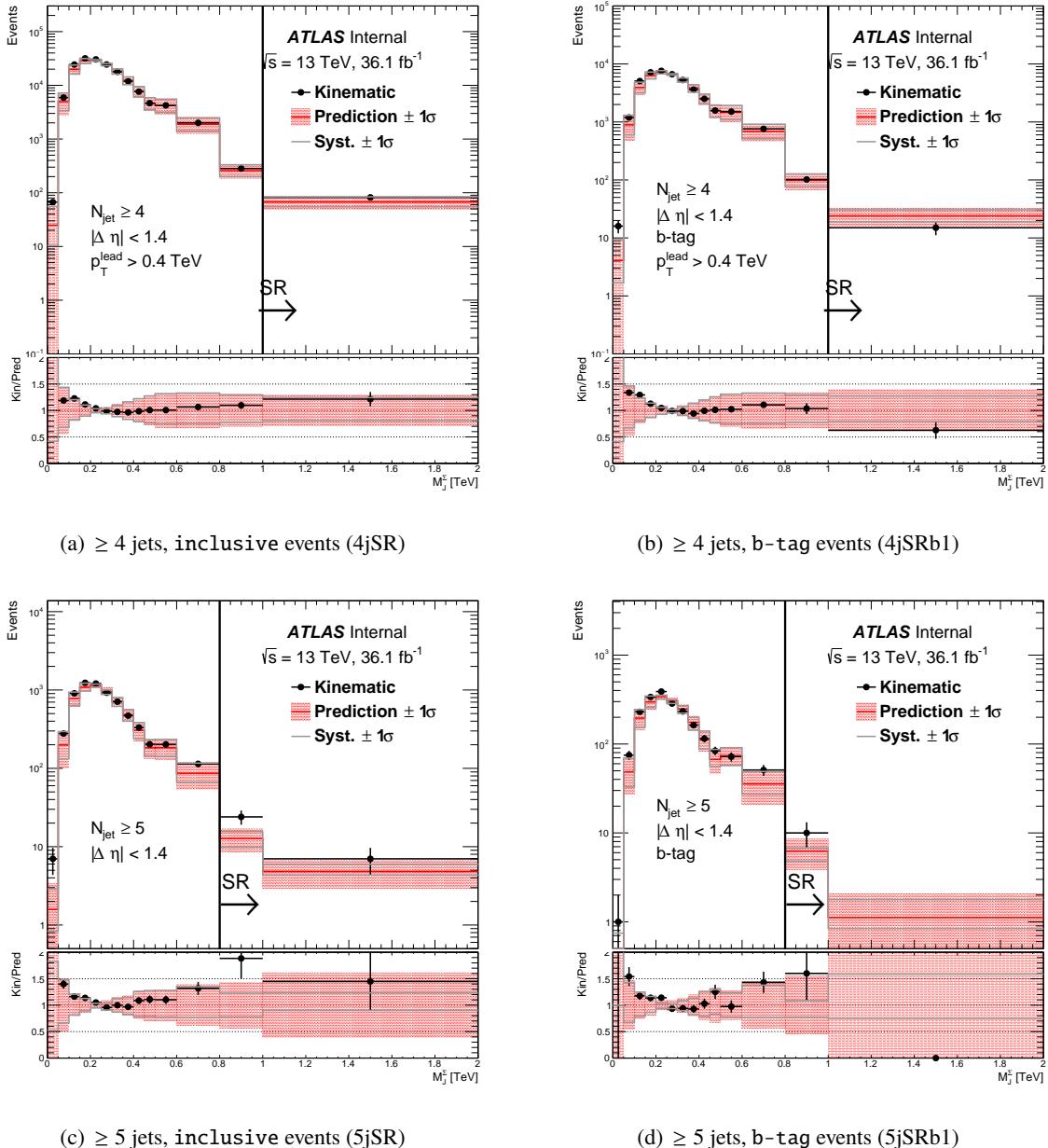


Figure 37: Predicted (solid line) and observed (dots) M_J^Σ distributions for signal regions 4jSR (a), 4jSRb1 (b), 5jSR (c), and 5jSRb1 (d). The shaded area surrounding the predicted M_J^Σ distribution represents the systematic uncertainty of background estimation. The predicted M_J^Σ distribution is normalized to data in $0.2 \text{ TeV} < M_J^\Sigma < 0.6 \text{ TeV}$, where expected contamination from signals of gluino direct or cascade decay models not excluded by the Run-1 analysis [1] is negligible compared to the background statistical uncertainty. The expected contribution from two RPV signal samples are also shown.

639 6.2. Likelihood function and statistical interpretation procedure

640 A frequentist approach is used to interpret data. A likelihood is built from the event yield expectation and
 641 observation in the signal region, and the associated systematic uncertainties. In a given inclusive n_{jet} bin,
 642 the expected event yield in the signal region can be written as:

$$\lambda = \mu \prod_i (1 + \theta_i \sigma_i) S_0 + B_0 \prod_j (1 + \theta_{b,j} \sigma_{b,j}) \quad (5)$$

643 where S_0 is the nominal signal yield, μ is the signal strength parameter, i is the index that labels signal
 644 systematic uncertainty, θ_i is the nuisance parameter associated with the systematic uncertainty i , σ_i is the
 645 size of the systematic uncertainty i , B_0 is the expected background yield predicted by the fit extrapolation,
 646 $\theta_{b,j}$ is the nuisance parameter associated with the background extrapolation uncertainty component j , and
 647 $\sigma_{b,j}$ is the size of the background extrapolation uncertainty component j .

648 Given an observed number of events k and the expected event yield λ , the likelihood function can be
 649 written as:

$$L(\mu) = P(k|\lambda) \prod_l G(0|\theta_l, 1) \quad (6)$$

650 where $P(k|\lambda)$ is the Poisson term of the event count and $G(0|\theta_l, 1)$ is the constraint term associated with
 651 a systematic uncertainty l . The standard procedure recommended in ATLAS uses LogNormal as the
 652 constraint term, which protects against large negative deviation of nuisance parameter in the case where
 653 the size of the uncertainty is large.

654 As discussed in Section 4.7, the background expectation receives a contribution from the presence of
 655 signal events and needs to be corrected. The event yield expectation (Eq. 5) then becomes

$$\lambda = \mu \left(\prod_i (1 + \theta_i \sigma_i) S_0 - \Delta b (1 + \theta_{b,stat} \sigma_{b,stat}) \right) + B_0 \prod_j (1 + \theta_{b,j} \sigma_{b,j}). \quad (7)$$

656 The correction is a negative term in the event yield expectation and scales with the signal strength μ , and
 657 therefore the effect of the signal contamination is equivalent to a reduction of the expected signal yield.
 658 The only uncertainty associated with the correction term is its statistical uncertainty, as the low p_T and
 659 high p_T jet mass prediction uncertainties, which are introduced to cover discrepancy between the true
 660 background yield and the expected background yield, do not apply.

$$q_\mu = -2 \ln \frac{L(\mu, \hat{\theta})}{L(\hat{\mu}, \hat{\theta})} \quad (8)$$

661 The Profile Likelihood Ratio (PLR) is shown in Eq. 8, and it is constructed by two maximum likelihood
 662 fits. The numerator of the PLR corresponds to a fit of the likelihood model to data, where the parameter of
 663 interest μ is fixed the value being tested; the denominator of the PLR corresponds to a fit where μ is free.
 664 In the limit setting procedure, a μ times signal plus background hypothesis is tested, and μ in the numerator
 665 of PLR is fixed to 1. Since the correction term is signal point dependent, the statistical test cannot yield
 666 a model independent limit on the number of signal events. However, in the p-value calculation, the
 667 hypothesis being tested is the background only hypothesis, i.e., $\mu = 0$, therefore the likelihood function
 668 does not have a model dependent contribution from the correction term. The model dependent correction
 669 term that appears in the denominator of the PLR does not affect the p-value calculation, as it only alters
 670 the total expected signal yield, which has no role in the p-value calculation.

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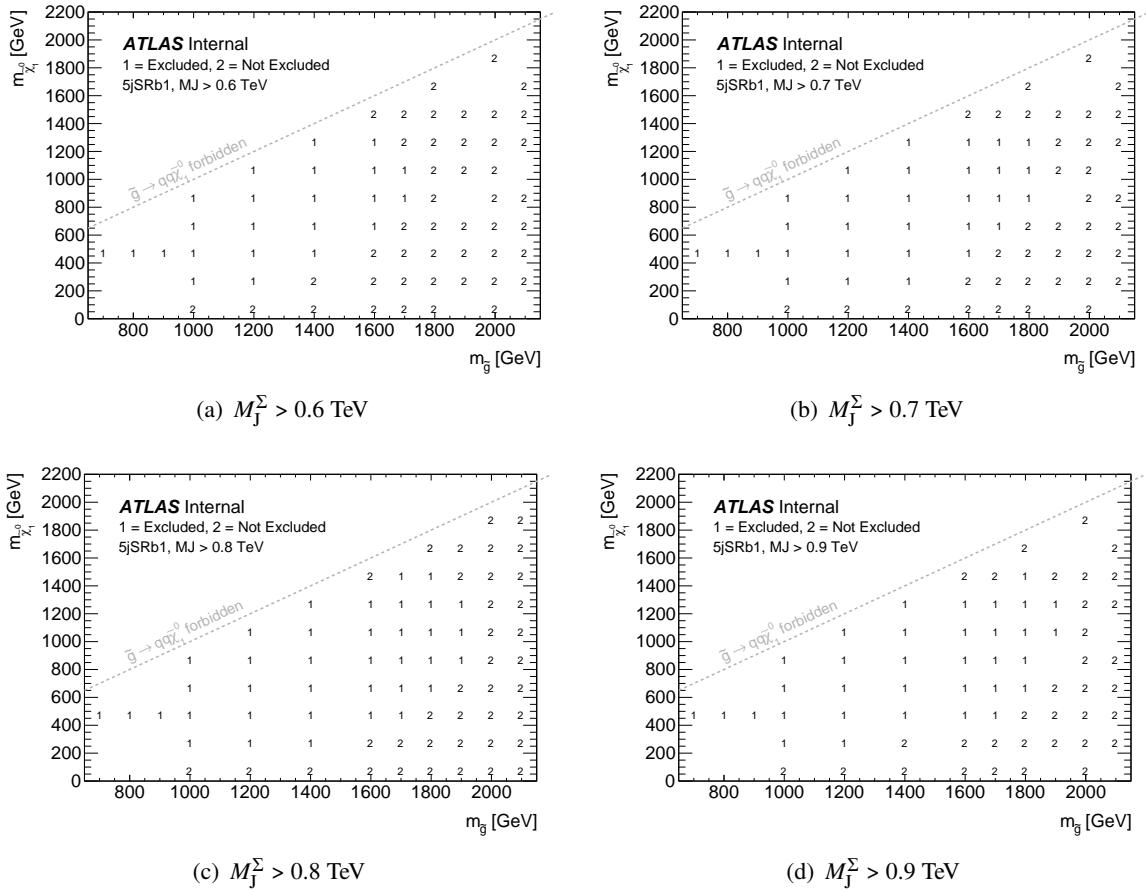


Figure 38: Expected exclusion for RPV 10-quark signal models. (a), (b), (c), and (d) show the result for $M_J^\Sigma > 0.6$ TeV, 0.7 TeV, 0.8 TeV, and 0.9 TeV, respectively. Results are available only for signal points where simulation samples exist.

This likelihood function, saved as `RooWorkspace` object is then passed to the `RooStats` package, to construct the profile likelihood ratio, which is used to calculate the p_0 -value and limit. Pseudo experiments are generated for calculating p_0 -value and limit. This procedure is implemented in a package that is previously used for $H \rightarrow \gamma\gamma$ and black hole multijet analyses. The package can be found in [research].

6.3. Expected sensitivity

Table 10 shows the predicted and observed event yields in various search regions. These results are used in the model dependent and model independent interpretations.

Figure 6.3 shows the expected exclusion for RPV 10-quark models with a number of candidate M_J^Σ cuts. The exclusion is only shown for signal points where simulated samples exist. The entries in the figure indicates whether or not the signal point is excluded at 95% CL. The best performance is achieved with $M_J^\Sigma > 0.8$ TeV cut, and the $M_J^\Sigma > 0.9$ TeV cut achieves slightly looser exclusion for $m_{\tilde{\chi}} = 250$ GeV signal points. For the 5jSRb, $M_J^\Sigma > 0.8$ TeV is adopted for the model dependent interpretation.

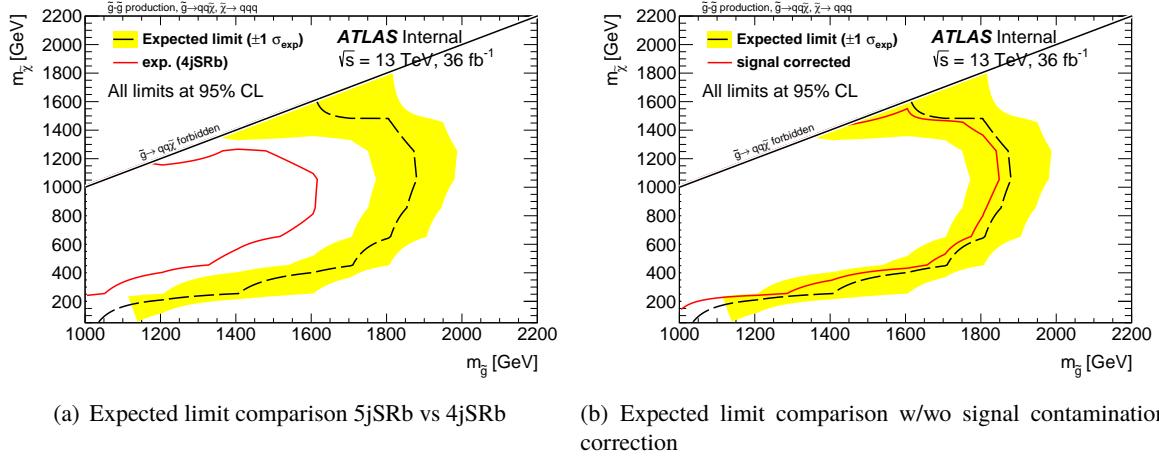


Figure 39: Expected 95% CL limit for the RPV 10-quark model. The signal region of 5jSRb combined with an $M_J^\Sigma > 0.8$ TeV cut is used for the interpretation. The long-dashed line indicates the expected limit, while the yellow area indicates its $\pm 1 \sigma$ variations. Figure (a) compares the results from 5jSRb with the expected limit from signal region of 4jSRb combined with an $M_J^\Sigma > 1.2$ TeV cut. Figure (b) compares the results from 5jSRb with the expected limit from the same signal region but accounting for a correction due to the signal contamination.

683 Figure 39(a) compares the results from 5jSRb with the expected limit from signal region of 4jSRb
 684 combined with an $M_J^\Sigma > 1.2$ TeV cut, which is found to be the most optimal for 4jSRb. This demonstrates
 685 that the 5jSRb is the most sensitive signal region for the 10-quark model, as found in the previous analysis
 686 ⁴. Figure 39(b) compares the results from 5jSRb with the expected limit from the same signal region but
 687 accounting for a correction due to the signal contamination. Since the correction of the signal contamination
 688 is essentially a reduction of the signal yield, the expected limit accounting for the signal contamination is
 689 slightly weaker than the one without accounting for the contamination.

690 6.4. Interpolation of result

691 Since simulated signal samples only exist for a limited number of points, an interpolation is needed to
 692 produce limit contours. In the ICHEP CONF note, a limit is set on the number of signal yield, the expected
 693 signal yield is interpolated in $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$, and then the limit contour is drawn using the limit on the signal
 694 yield and the interpolated signal yield in $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$.

695 This procedure is no longer applicable since the event expectation now includes a correction term that
 696 depends on the signal point and therefore the limit setting procedure needs to be performed at every signal
 697 point. Two interpolation procedures are studied. The results shown in the current note are based on an
 698 interpolation of the CL_s value in the $m_{\tilde{g}} - m_{\tilde{\chi}}$ plane (Figures 39(a) and 39(b)). Since the CL_s value variation
 699 as a function of $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$ has a much larger slope compared to the yield variation, the interpolated
 700 contours are not smooth and show some artifact.

701 A new interpolation procedure is being developed. This procedure interpolates both the expected signal
 702 yield and the expected correction term in $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$, and therefore create inputs for the statistical

⁴ Results shown in Figures 39(a) and 39(b) do not account for the correction of the signal contamination. They are presented to show the relative sensitivity between different setups

703 interpretation at a much finer $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$ grid. Then the CL_s values are calculated on this fine $m_{\tilde{g}}$ and
 704 $m_{\tilde{\chi}}$ grid.

705 6.5. Unblinded statistical interpretation

706 The p-value is calculated for each of the four overlapping signal regions, in order to quantify the significance
 707 of an excess or deficit. The observed p-value does not depend on the signal model, and a test finds that
 708 the observed p-value calculated from likelihood models built using different signal hypotheses return the
 709 same p-value within numerical precision of Roofit. Table 15 shows the observed p-value in the four signal
 710 regions. The most significant excess is seen in 5jSR with a p-value of 0.062, corresponding to a statistical
 711 significance of 1.54σ . The 5jSRb and 4jSR saw small excess, and the 4jSRb saw a deficit at 1σ level.

712 Since no significant excess is seen in any of the four signal regions, limits are set on the production of
 713 RPV signals in the context of gluino direct and cascade decay models. The limit contours for the 10-quark
 714 model are derived from 5jSRb, with $M_J^\Sigma > 0.8$ TeV, while the limits for the 6-quark model are a combination
 715 of limits derived from 5jSRb with two different M_J^Σ cuts. For $m_{\tilde{g}} \leq 1050$ GeV, the limit is calculated from
 716 5jSRb with $M_J^\Sigma > 0.6$ TeV, and for $m_{\tilde{g}} \geq 1050$ GeV, the limit is calculated from 5jSRb with $M_J^\Sigma > 0.8$
 717 TeV.

718 For the 10-quark model, the exclusion on $m_{\tilde{g}}$ strongly depends on the $m_{\tilde{\chi}}$. Gluinos with a mass of less
 719 than 1920 GeV is excluded for a neutralino mass of 1050 GeV, and this constraint is weakened for heavier
 720 neutralino, an exclusion of $m_{\tilde{g}} < 1150$ GeV is achieved when the $m_{\tilde{\chi}}$ is very close to $m_{\tilde{g}}$. For light
 721 neutralinos down to 170 GeV, the exclusion only reaches $m_{\tilde{g}} = 1000$ GeV; and for neutralino with lighter
 722 masses no exclusion is achieved. The observed exclusion is weaker than the expected exclusion.

723 Figure 40 also shows the limit placed on the 6-quark model. The expected exclusion on $m_{\tilde{g}}$ is around
 724 1150 GeV; however, due to the observed excess in the 5jSRb, the observed limit does not exclude any
 725 6-quark signal considered in the analysis. The observed limit on the cross section of 6-quark model varies
 726 between 0.95 fb^{-1} at $m_{\tilde{g}} = 900$ GeV and 0.022 fb^{-1} at $m_{\tilde{g}} = 1800$ GeV. A comparison of the current limit
 727 on the 6-quark model and the limit reported in Ref. [25] is documented in the Appendix V.

728 Model independent limit is also reported. The signal correction term is removed from the likelihood model
 729 in the calculation of the model independent limit, so are signal theoretical uncertainties such as PDF and
 730 QCD scale uncertainties. A limit on the number of signal events in the signal region can be calculated and
 731 converted to a limit on the cross section times acceptance times efficiency. The experimental uncertainties
 732 also vary as a function of $m_{\tilde{g}}$ and $m_{\tilde{\chi}}$, and the largest signal uncertainties are chosen in the calculation.
 733 The expected and observed model independent limits are shown in Table 15.

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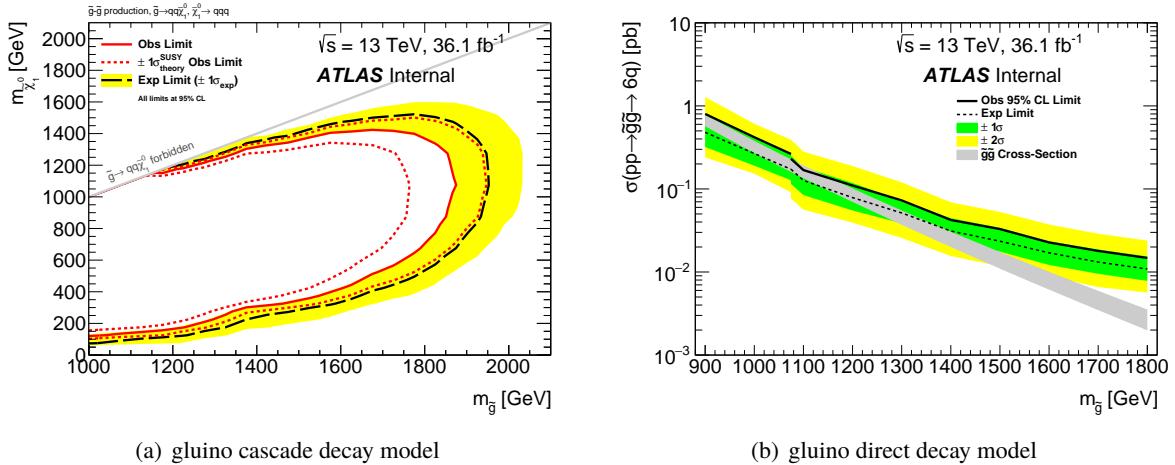


Figure 40: (a) Expected and observed exclusion limits in the $(m_{\tilde{g}}, m_{\tilde{\chi}})$ plane for the gluino cascade decay model. Limits are obtained by using the signal region with the best expected sensitivity for every signal point (5jSRb1 with $M_J^\Sigma > 0.6$ TeV). The dashed black lines show the expected limits at 95% CL, with the light (yellow) bands indicating the 1σ excursions due to experimental uncertainties. Observed limits are indicated by medium dark (maroon) curves, where the solid contour represents the nominal limit, and the dotted lines are obtained by varying the signal cross-section by the renormalization and factorization scale and PDF uncertainties. The observed limit from the Run-1 analysis [1] is also shown as a solid line. (b) Expected and observed cross-section limits for the gluino direct decay model gluino models.

Signal Region	M_J^Σ cut	Expected limit (fb)	Observed Limit (fb)	p_0 -value
4jSRb	> 1.0 TeV	$0.53^{+0.20}_{-0.12}$	0.37	0.86
4jSR		$1.12^{+0.50}_{-0.32}$	1.50	0.24
5jSRb	> 0.6 TeV	$0.86^{+0.40}_{-0.20}$	1.32	0.20
5jSRb	> 0.8 TeV	$0.24^{+0.10}_{-0.06}$	0.34	0.26
5jSR		$0.43^{+0.08}_{-0.06}$	0.84	0.062

Table 15: Expected and observed limits on the signal production cross-section for the four signal regions, and p_0 -values of excesses in the 5-jet signal regions.

7. Conclusion

A search for R -Parity Violating SUSY signals in events with multiple jets is conducted. Distributions of events as a function of total jet mass are examined. No significant excess is seen in any signal regions. Limits are set on the production of gluinos in the gluino direct and cascade decay models in the UDD scenarios of RPV SUSY. In the gluino cascade decay model, gluinos with masses up to 1000 GeV - 1920 GeV are excluded, depending on the neutralino mass; For the gluino direct decay model, the limit on the cross section times branching ratio varies between 0.80 fb^{-1} at $m_{\tilde{g}} = 900 \text{ GeV}$ and 0.011 fb^{-1} at $m_{\tilde{g}} = 1800 \text{ GeV}$. Model independent limits on the cross section of signal in the defined SRs are also reported.

Acknowledgements

7G

*Appendix

A. M_J^Σ , p_T , and η distributions vs $m_{\tilde{\chi}}$

This section presents plots that show how observables, e.g., M_J^Σ , p_T , and η vary between signal points with different $m_{\tilde{\chi}}$ but the same $m_{\tilde{g}}$.

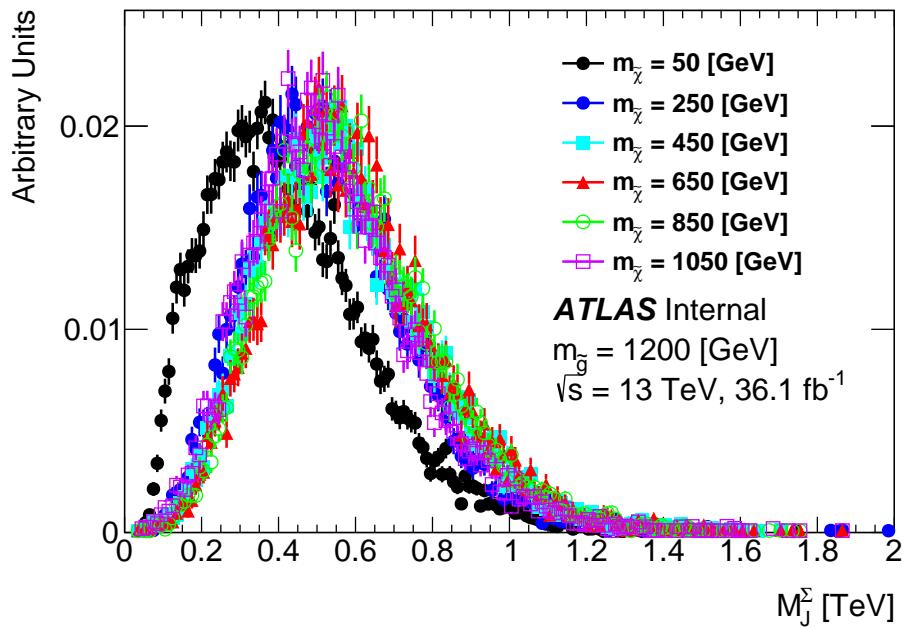


Figure 41: M_J^Σ distributions for RPV signals with $m_{\tilde{g}} = 1200 \text{ GeV}$ and different $m_{\tilde{\chi}}$.

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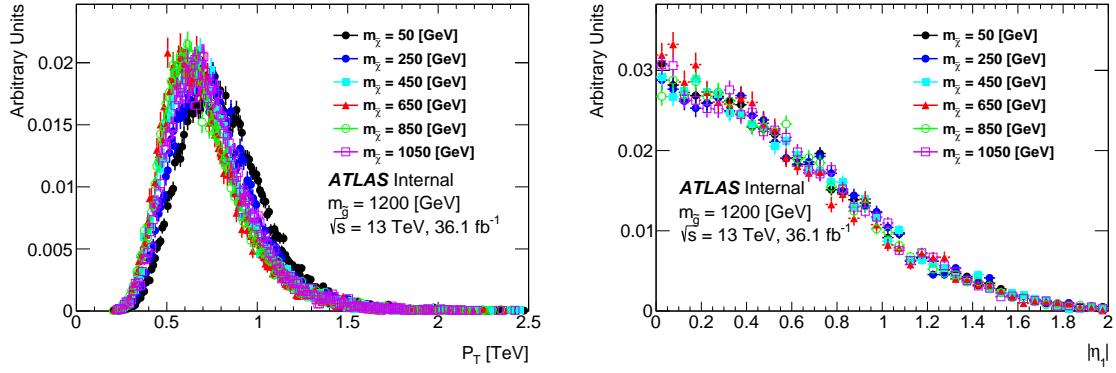


Figure 42: Leading jet p_T (left) and η (right) distributions for RPV signals with $m_{\tilde{g}} = 1200$ GeV and different $m_{\tilde{\chi}}$.

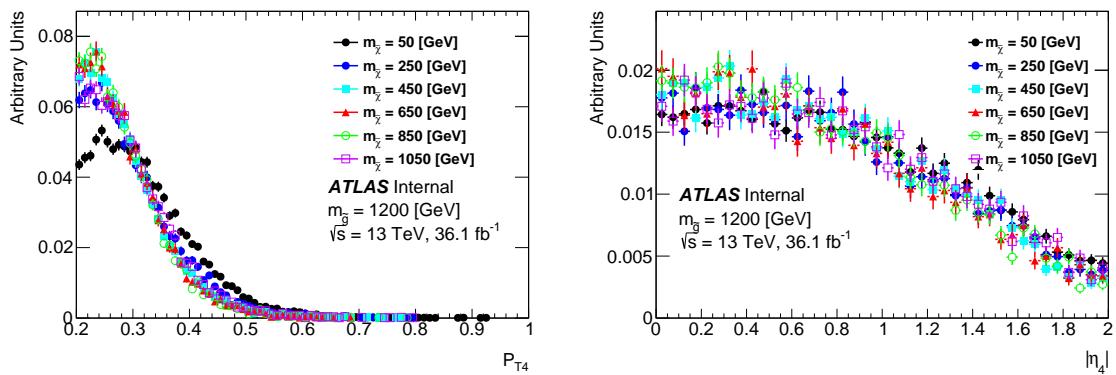


Figure 43: Fourth leading jet p_T (left) and η (right) distributions for RPV signals with $m_{\tilde{g}} = 1200$ GeV and different $m_{\tilde{\chi}}$.

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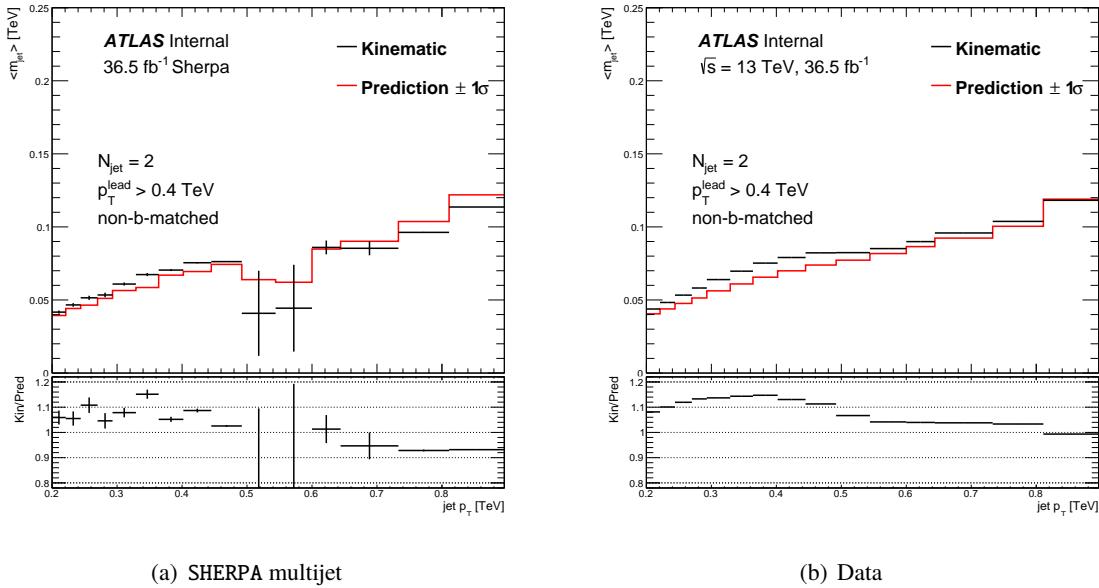


Figure 44: Jet mass response comparison in UDR1 with non-matched jets between SHERPA multijet sample(left) and data(right).

748 B. Background estimation result in Sherpa multijet sample

749 SHERPA multijet sample is studied in this analysis, but it is disfavored due to low MC statistics and
 750 mis-modeling data.

751 Figures 44 - 47 compare the jet mass response between the SHERPA multijet sample and data in
 752 UDR1 and UDR2, for non-matched jets and b-matched jets. In the sample with highest statist-
 753 ics, the non-matched jetsample in the UDR1, SHERPA shows qualitatively similar behavior in the ratio
 754 of observation over prediction as data for the p_T range of < 500 GeV; for $p_T > 600$ GeV the discrepancy in
 755 SHERPA is opposite the one seen in data. For b-matched jets in the UDR1, the result in SHERPA sample
 756 is statistically inconclusive. For jets in the UDR2, SHERPA appears to show an under-prediction while the
 757 discrepancy in data is the opposite.

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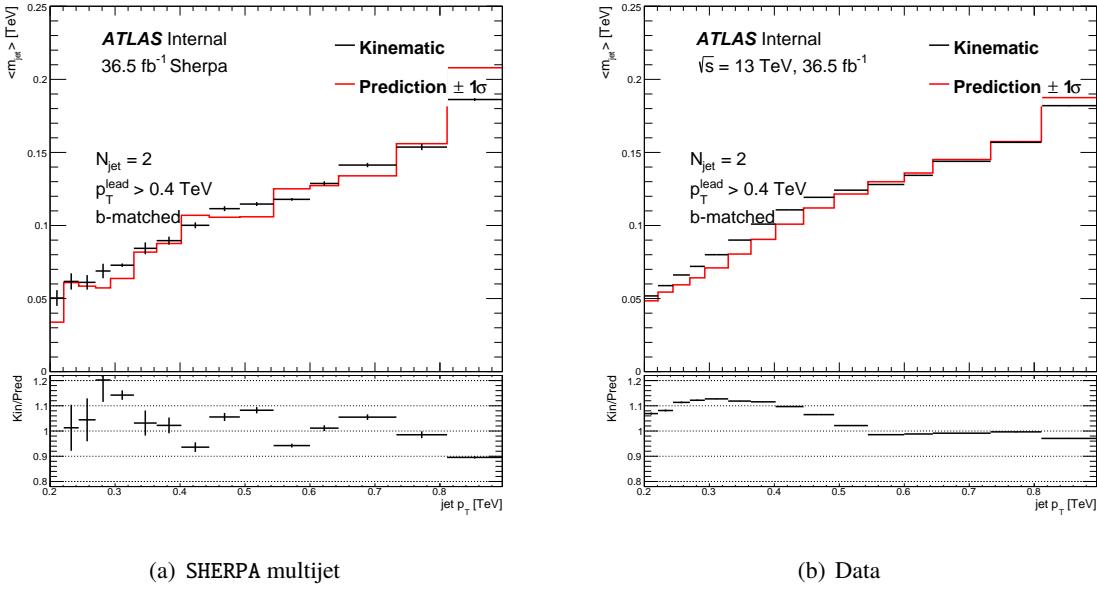


Figure 45: Jet mass response comparison in UDR1 with b-matched jets between SHERPA multijet sample(left) and data(right).

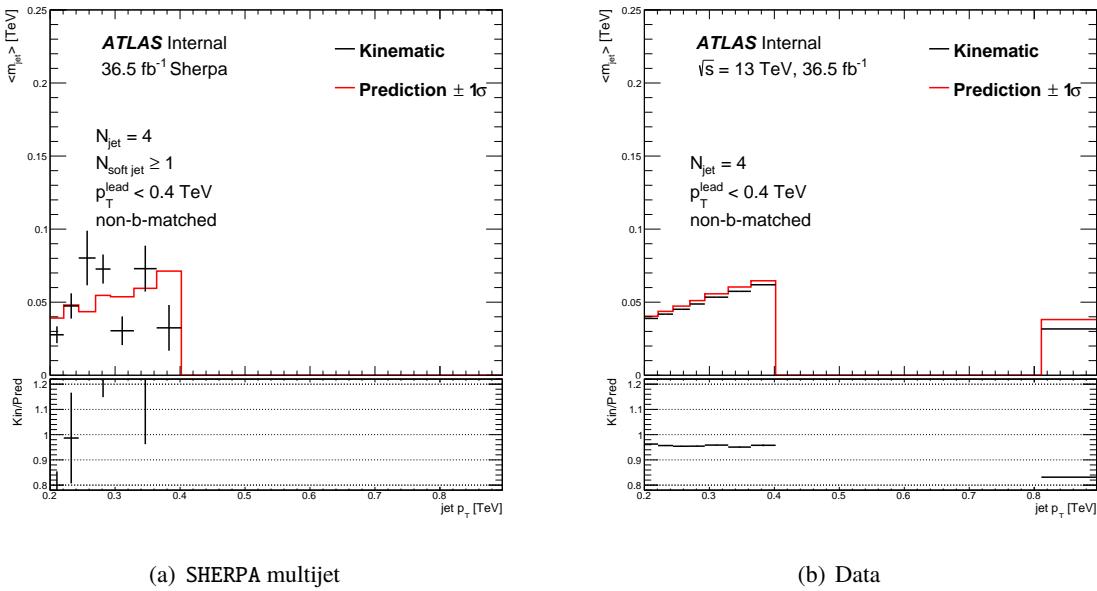


Figure 46: Jet mass response comparison in UDR2 with non-matched jets between SHERPA multijet sample(left) and data(right).

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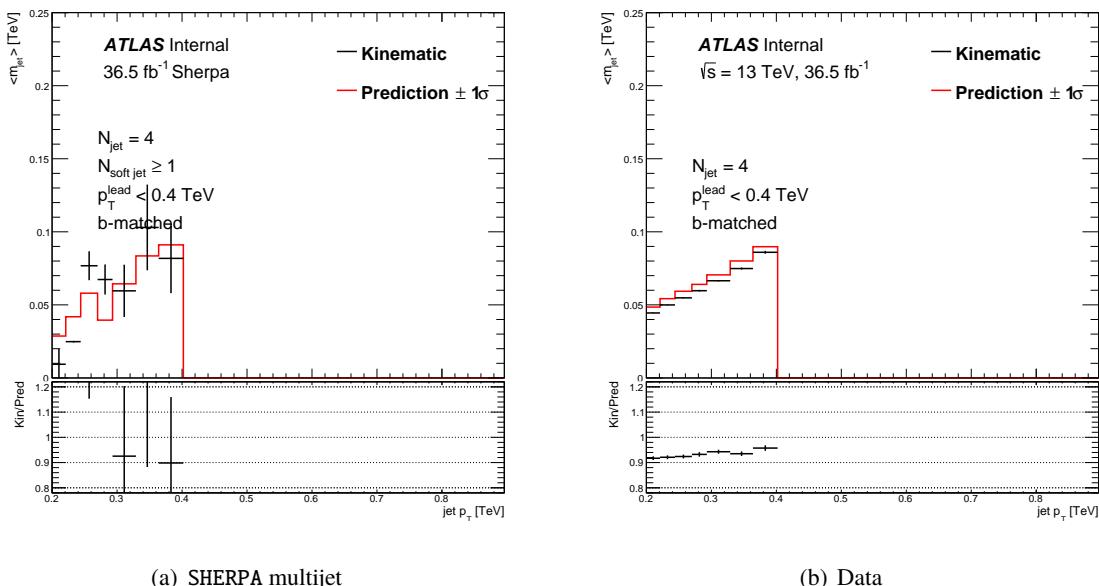


Figure 47: Jet mass response comparison in UDR2 with b-matched jets between SHERPA multijet sample(left) and data(right).

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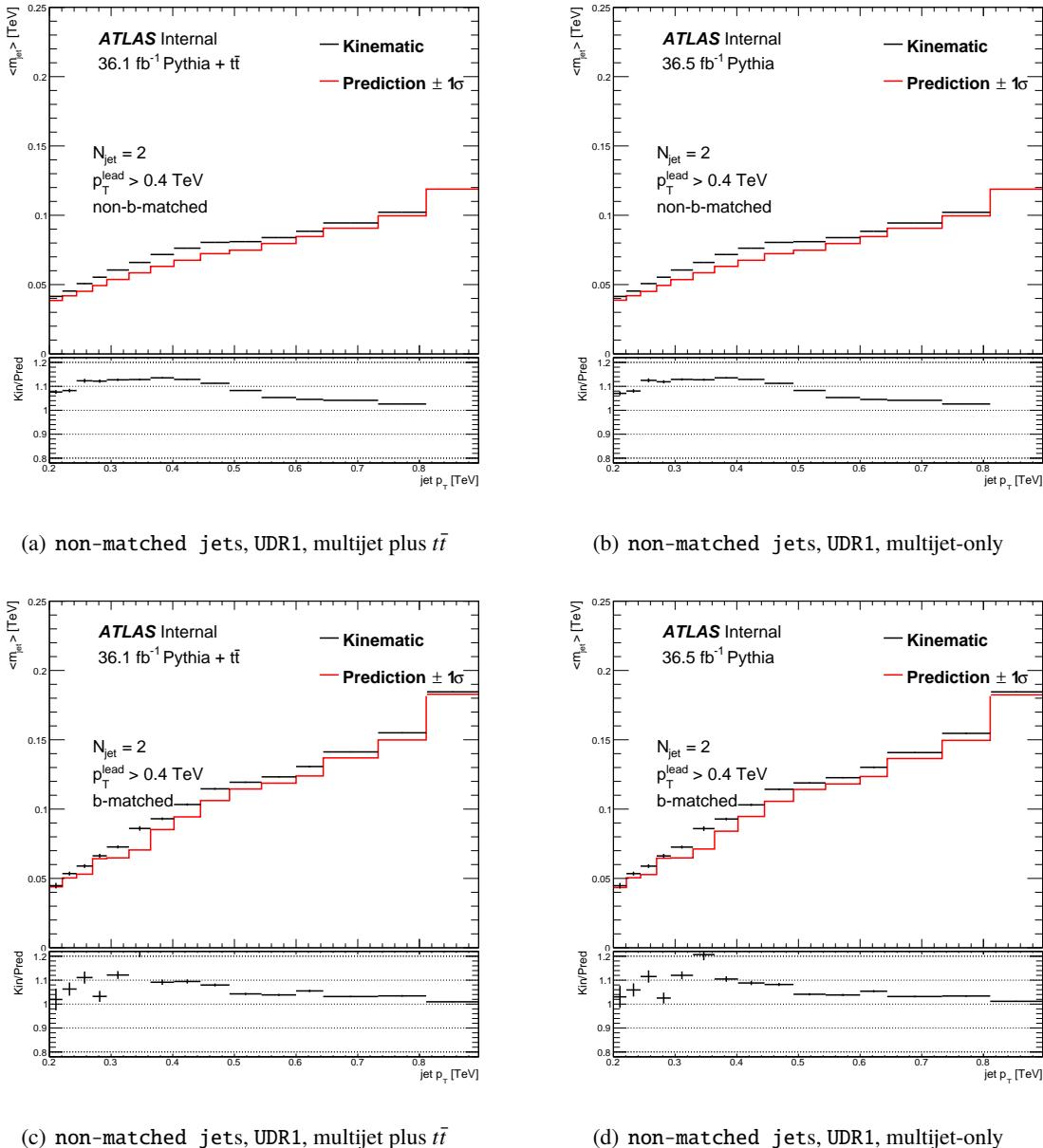


Figure 48: Jet mass response in the UDR1. Left column shows results from PYTHIA8 multijet plus $t\bar{t}$ sample; right column shows results from PYTHIA8 multijet sample only.

758 C. Impact of $t\bar{t}$ events on the background estimation performance

759 Jet mass response plots are compared between PYTHIA8 multijet only sample and PYTHIA8 multijet plus
 760 $t\bar{t}$ sample, for the UDR1 (Figure 48) and the UDR2 (Figure 49). It is shown that the presence of $t\bar{t}$ events
 761 does not change the jet mass prediction uncertainty in any significant way.

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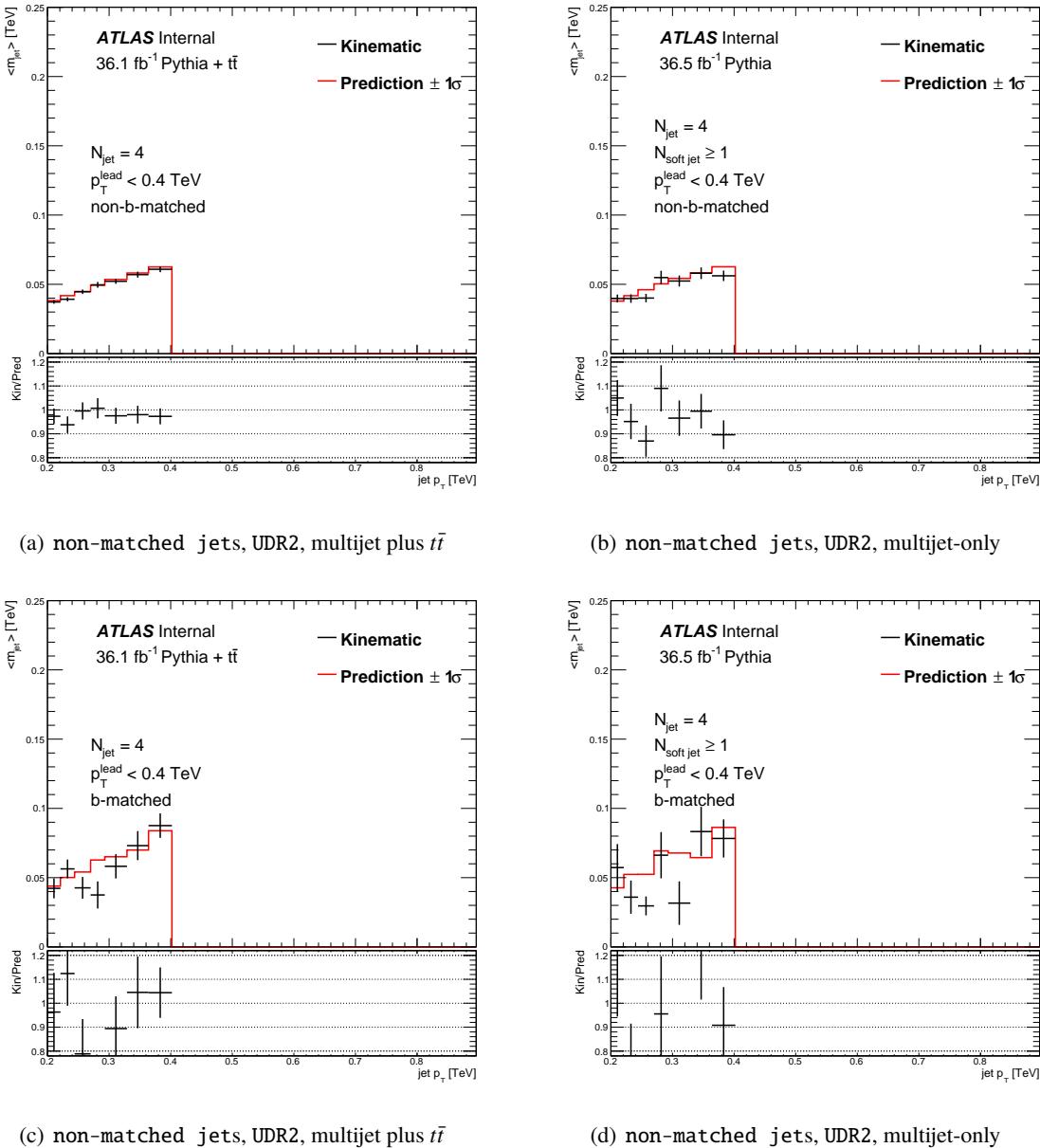


Figure 49: Jet mass response in the UDR2. Left column shows results from PYTHIA8 multijet plus $t\bar{t}$ sample; right column shows results from PYTHIA8 multijet sample only.

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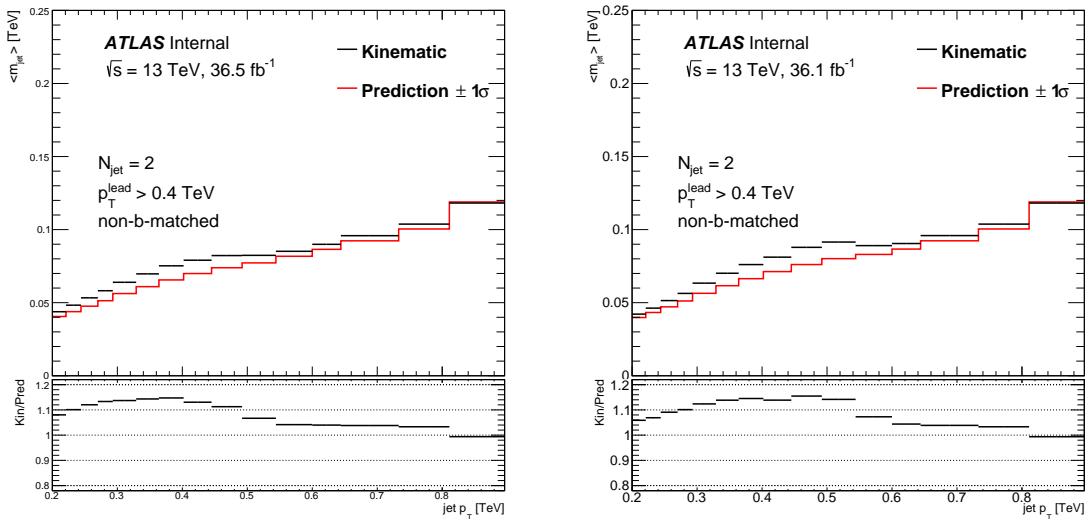


Figure 50: Jet mass response in the UDR1in data. Left column shows results from standard analysis of data; right column shows results from the analysis with additional offline cut of $H_T > 1.1 \text{ TeV}$.

762 D. Trigger impact on CR and UDR

763 To understand how the trigger inefficiency in the UDR and CR would affect the analysis, the jet mass
 764 response plots in the UDRs and CR are produced with alternative selections, compared to those produced
 765 with the standard selection. Figures 50 - 52 show the jet mass response plots in data. In each figure, the
 766 jet mass response produced with the standard selection is shown on the left, and the jet mass response
 767 produced with the standard selection and an offline $H_T > 1.1 \text{ TeV}$ requirement is shown on the right. The
 768 offline H_T is computed with small-R jets with $|\eta| < 2.8$ and $p_T > 50 \text{ GeV}$. The $H_T > 1.1 \text{ TeV}$ requirement
 769 ensures that the offline analysis is fully efficient with respect to the HLT_ht1000 trigger. The jet mass
 770 response in the UDRs is not sensitive to the H_T requirement, and any effect due to the addition of H_T
 771 requirement is further mitigated by the way that the jet mass prediction uncertainty is determined.⁵
 772 The average predicted jet mass in the CR is also shown not to be affected by the introduction of the H_T
 773 requirement.

774 The same set of jet mass response plots are also produced for the Pythia8 multijet sample and are shown
 775 in Figures 53- 55. A trend similar to that observed in data can be seen, although in some cases it is
 776 statistically inconclusive.

⁵ The final jet mass prediction uncertainty is determined in three p_T regions, and in each region, a flat uncertainty is assigned. In the region of $p_T < 400 \text{ GeV}$, the RMS of the discrepancies is calculated separately for the UDR1 and the UDR2, and the larger one is taken as the uncertainty. In the region of $400 \text{ GeV} < p_T < 600 \text{ GeV}$, the largest discrepancy is considered as the uncertainty. In the region of $p_T > 600 \text{ GeV}$, the RMS of the discrepancies is considered as the uncertainty.

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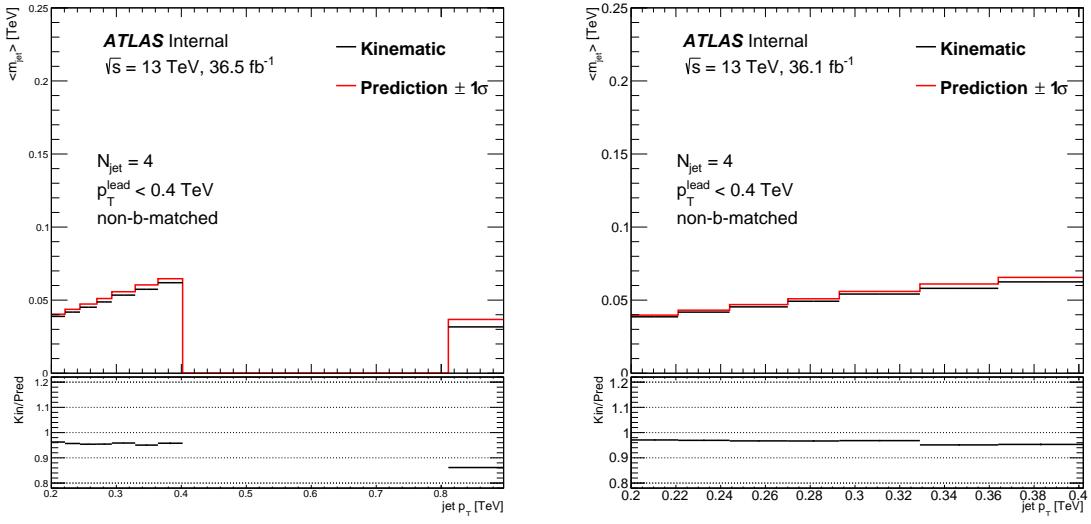


Figure 51: Jet mass response in the UDR2in data. Left column shows results from standard analysis of data; right column shows results from the analysis with additional offline cut of $H_T > 1.1 \text{ TeV}$.

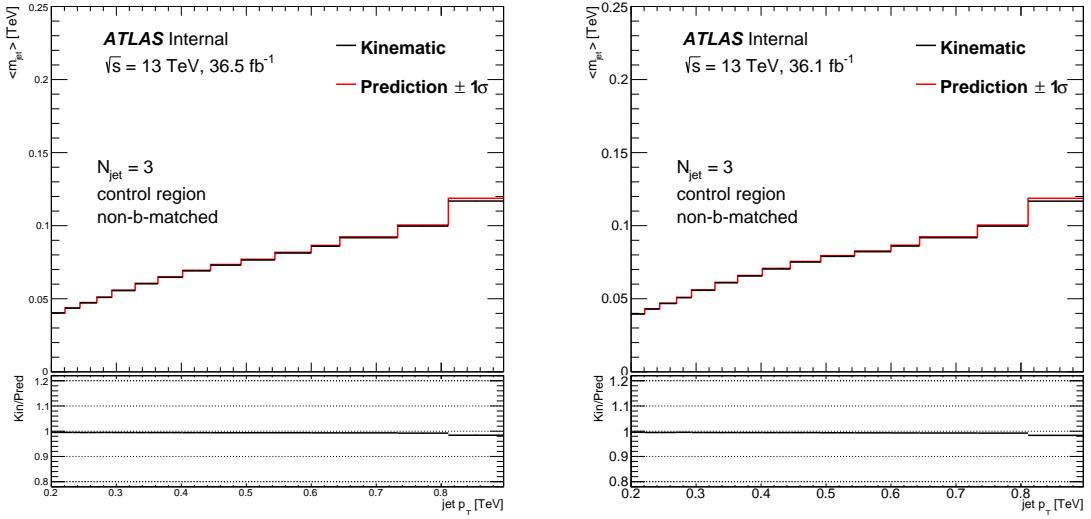


Figure 52: Jet mass response in the 3jCR in data. Left column shows results from standard analysis of data; right column shows results from the analysis with additional offline cut of $H_T > 1.1 \text{ TeV}$.

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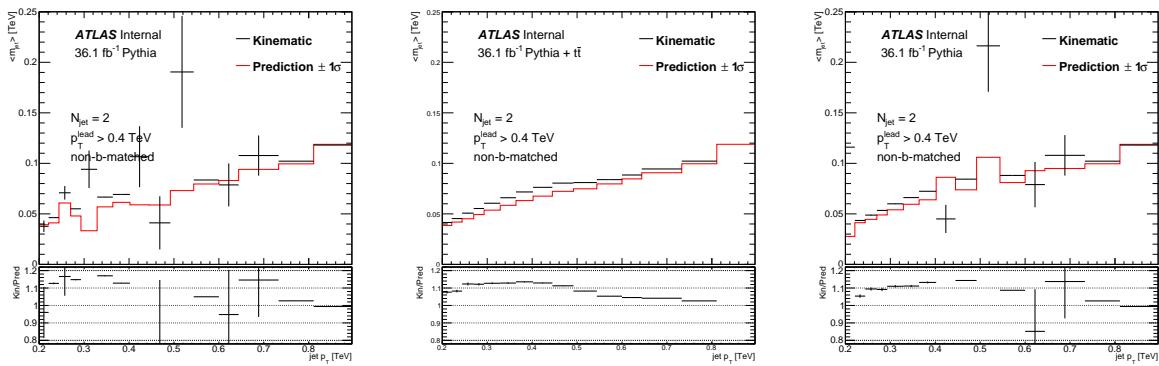


Figure 53: Jet mass response in the UDR1in Pythia8 multijet sample. The three plots from left to right correspond to the standard selection without trigger requirement, the standard selection, and the standard selection with an offline H_T cut of > 1.1 TeV.

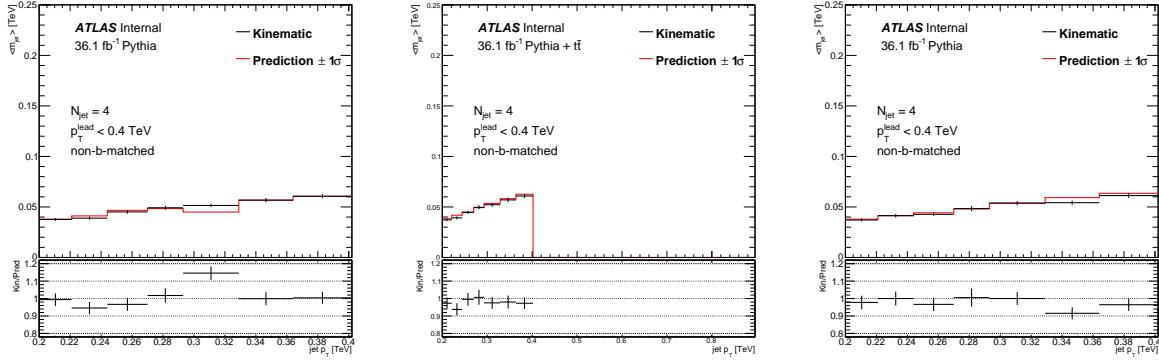


Figure 54: Jet mass response in the UDR2in Pythia8 multijet sample. The three plots from left to right correspond to the standard selection without trigger requirement, the standard selection, and the standard selection with an offline H_T cut of > 1.1 TeV.

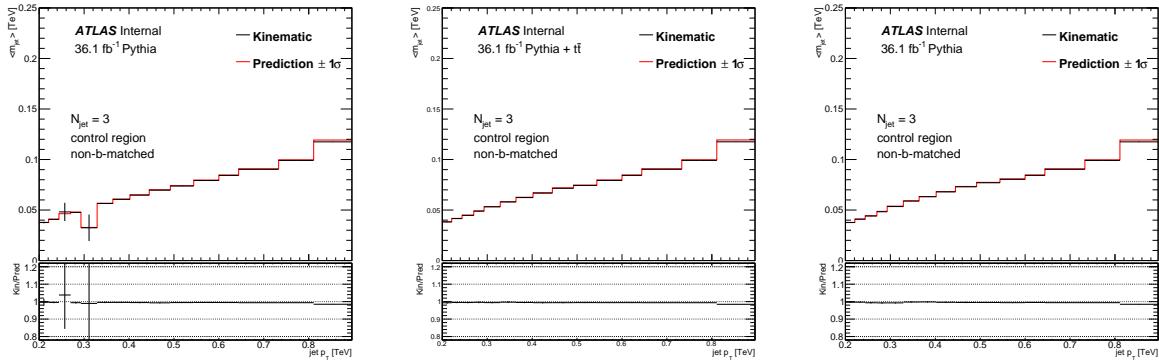


Figure 55: Jet mass response in the 3jCR in Pythia8 multijet sample. The three plots from left to right correspond to the standard selection without trigger requirement, the standard selection, and the standard selection with an offline H_T cut of > 1.1 TeV.

Not reviewed, for internal circulation only

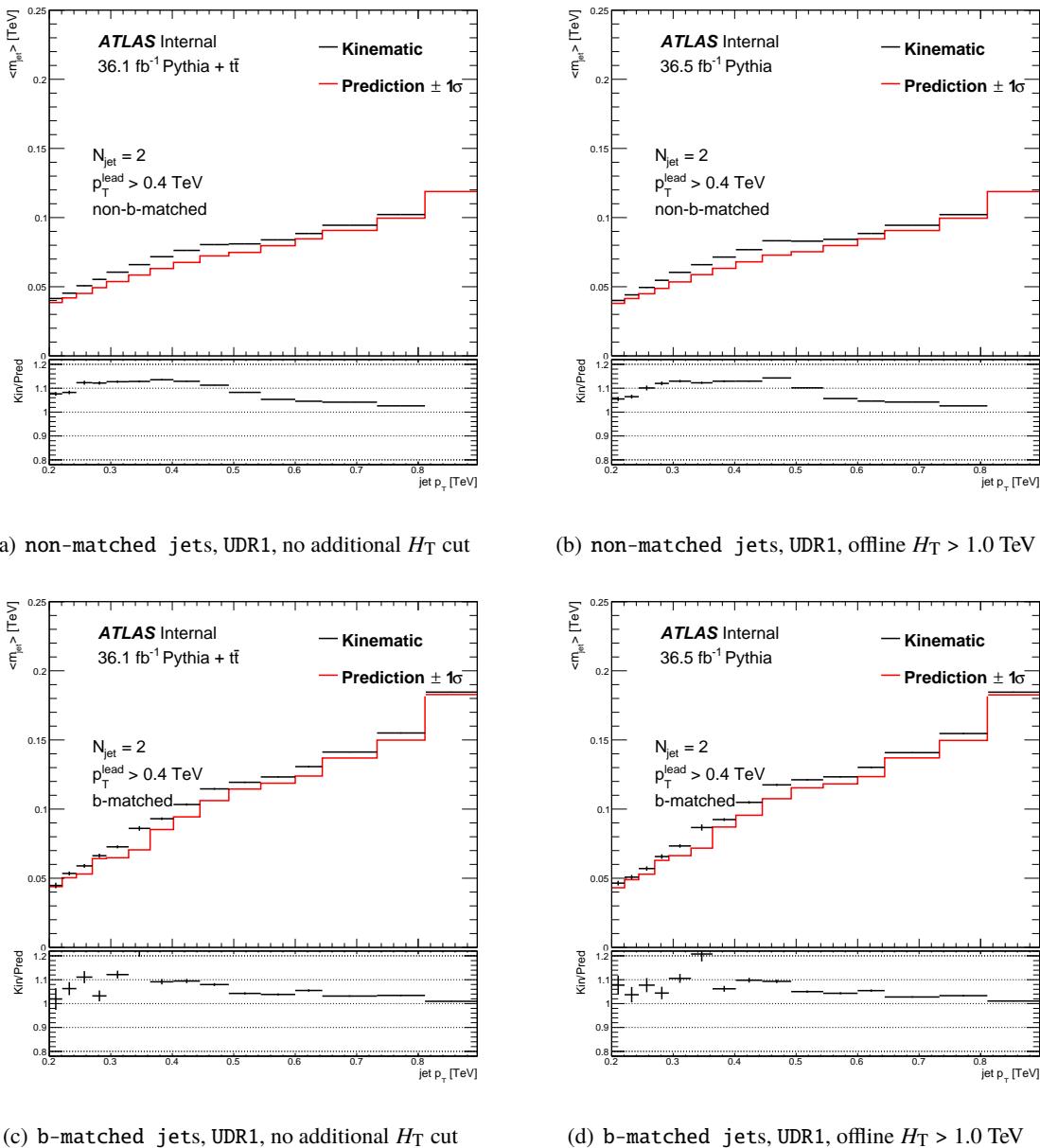


Figure 56: Jet mass response in the UDR1. Left column shows results from standard analysis of PYTHIA8 multijet plus $t\bar{t}$ MC sample; right column shows results from the analysis with additional offline cut of $H_T > 1.0$ TeV.

777 E. Trigger impact on the UDR

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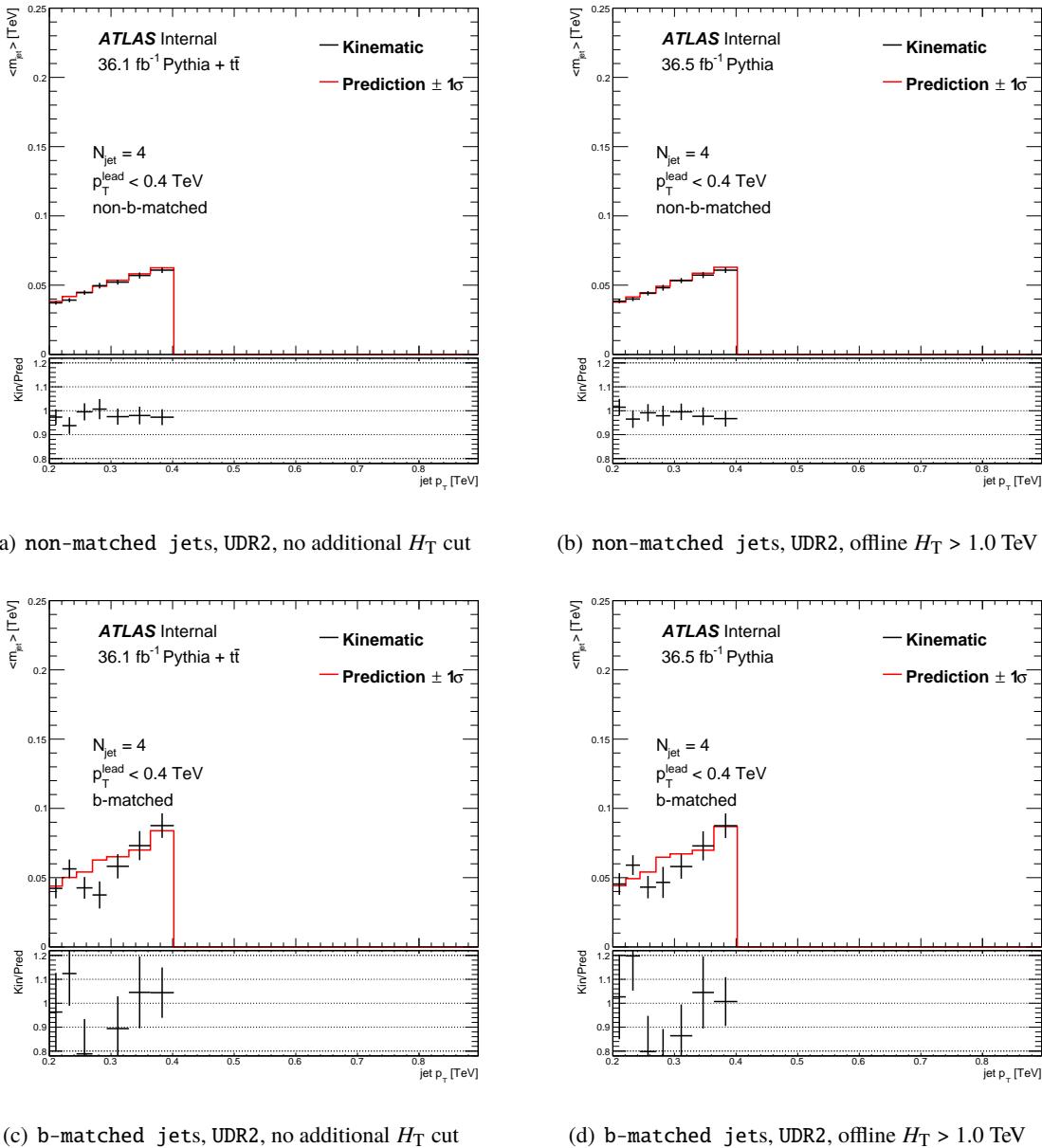


Figure 57: Jet mass response in the UDR2. Left column shows results from standard analysis of PYTHIA8 multijet plus $t\bar{t}$ MC sample; right column shows results from the analysis with additional offline cut of $H_T > 1.0$ TeV.

Not reviewed, for internal circulation only

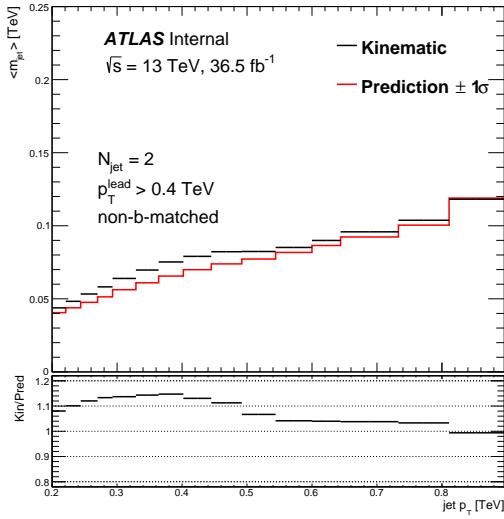
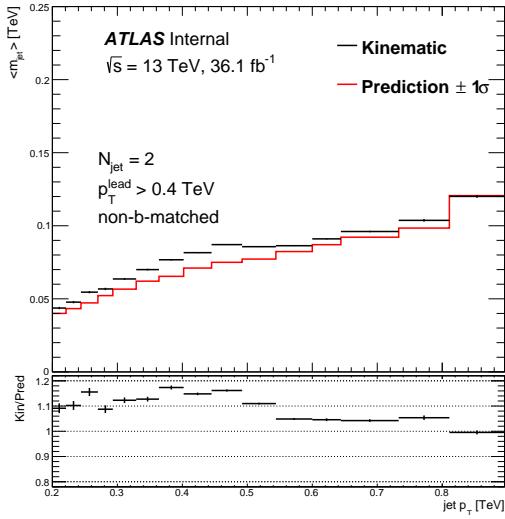
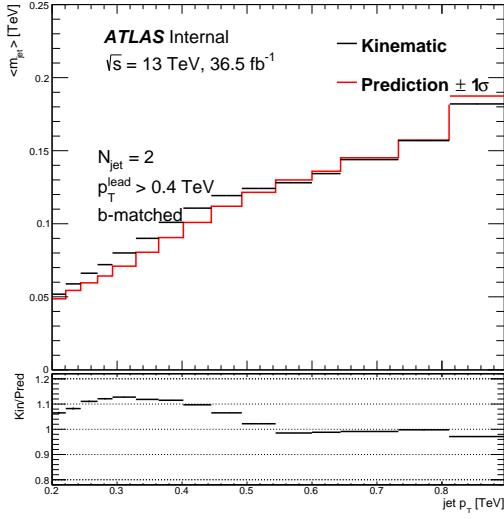
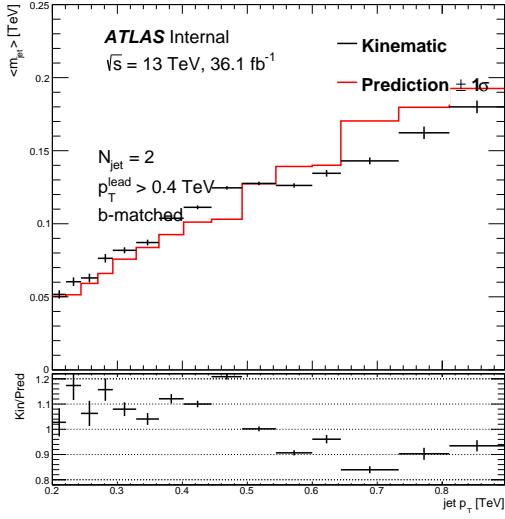
(a) non-matched jets, UDR1, no additional H_{T} cut(b) non-matched jets, UDR1, offline $H_{\text{T}} > 1.0 \text{ TeV}$ (c) b-matched jets, UDR1, no additional H_{T} cut(d) b-matched jets, UDR1, offline $H_{\text{T}} > 1.0 \text{ TeV}$

Figure 58: Jet mass response in the UDR1. Left column shows results from standard analysis of data; right column shows results from the analysis with additional offline cut of $H_{\text{T}} > 1.0 \text{ TeV}$.

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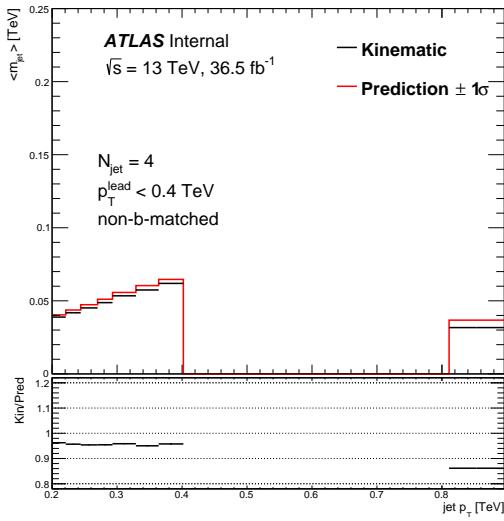
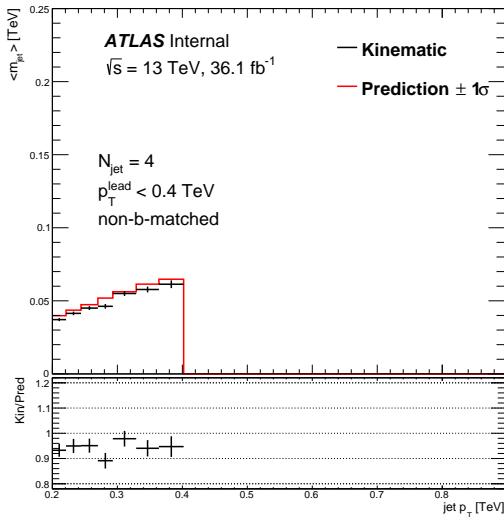
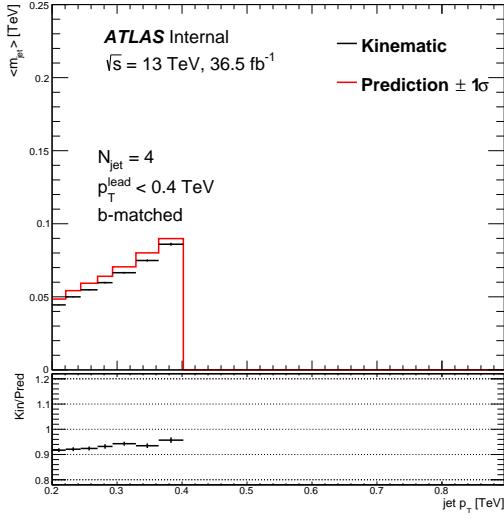
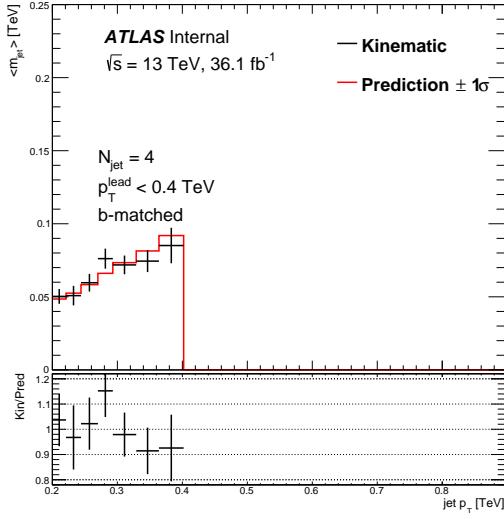
(a) non-matched jets, UDR2, no additional H_{T} cut(b) non-matched jets, UDR2, offline $H_{\text{T}} > 1.0 \text{ TeV}$ (c) b-matched jets, UDR2, no additional H_{T} cut(d) b-matched jets, UDR2, offline $H_{\text{T}} > 1.0 \text{ TeV}$

Figure 59: Jet mass response in the UDR2. Left column shows results from standard analysis of data; right column shows results from the analysis with additional offline cut of $H_{\text{T}} > 1.0 \text{ TeV}$.

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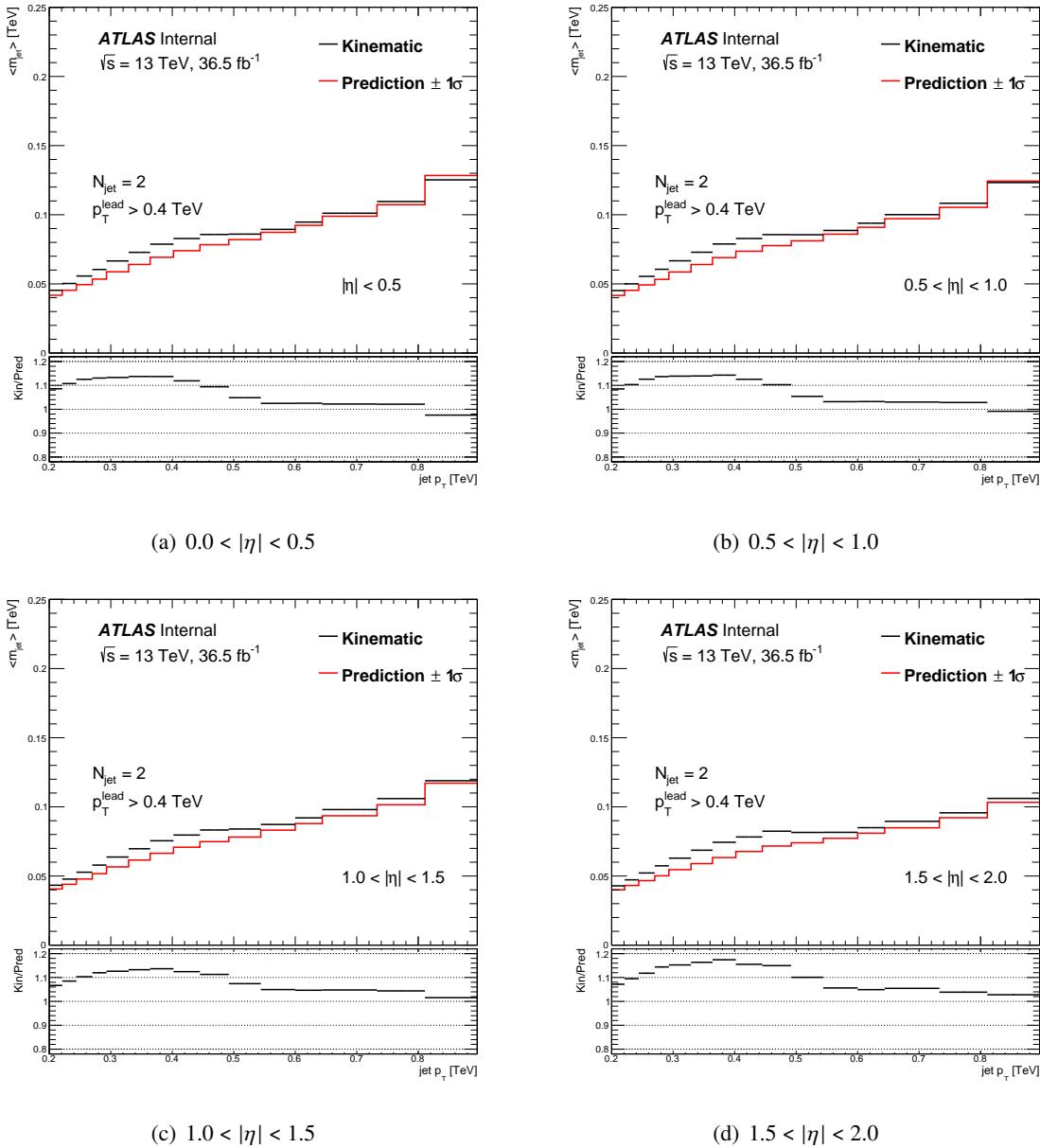


Figure 60: Jet mass response in four different $|\eta|$ regions in the UDR1 using data.

Not reviewed, for internal circulation only

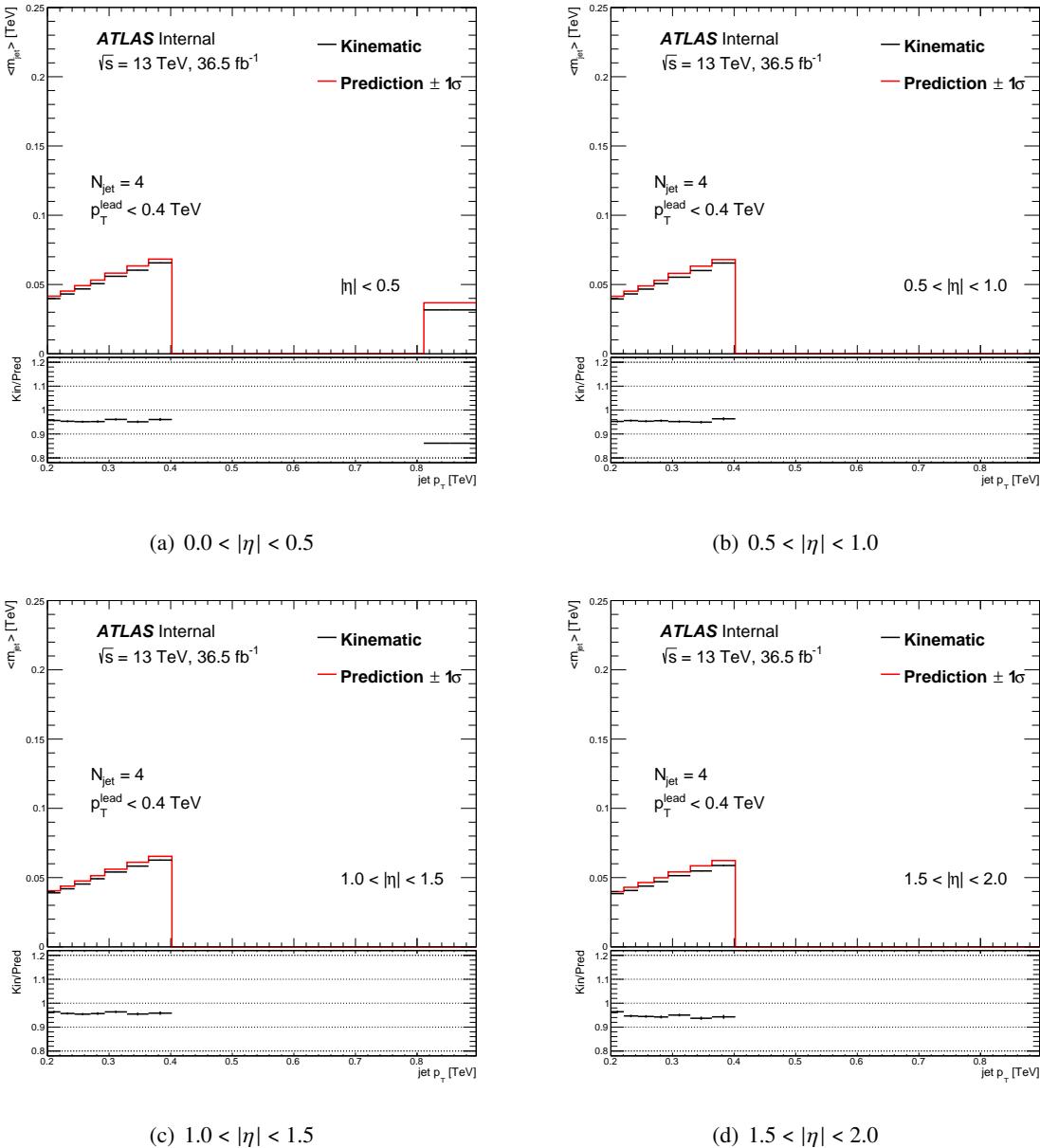


Figure 61: Jet mass response in four different $|\eta|$ regions in the UDR2 using data.

Not reviewed, for internal circulation only

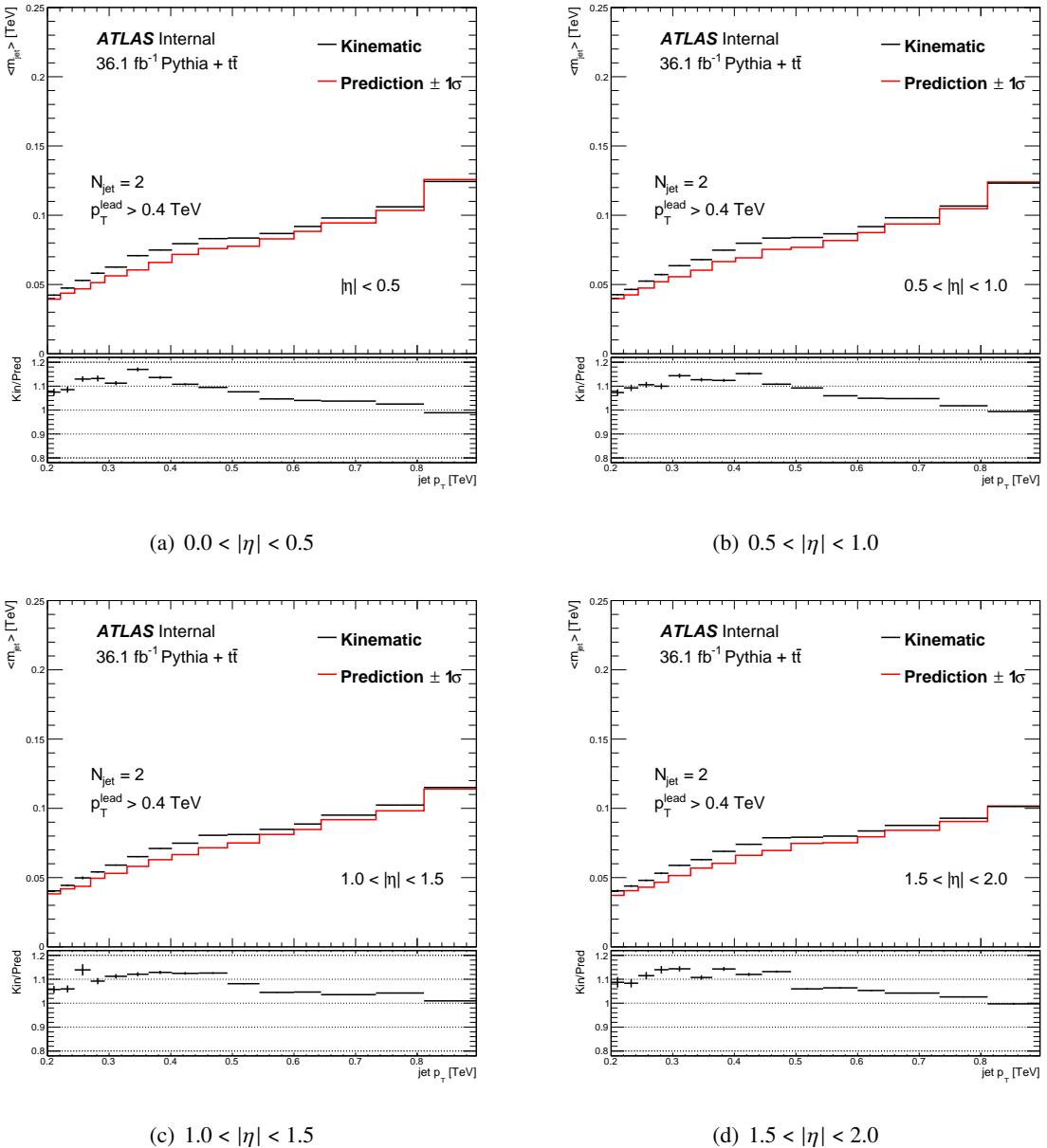


Figure 62: Jet mass response in four different $|\eta|$ regions in the UDR1 using PYTHIA8 multijet plus $t\bar{t}$ sample.

Not reviewed, for internal circulation only

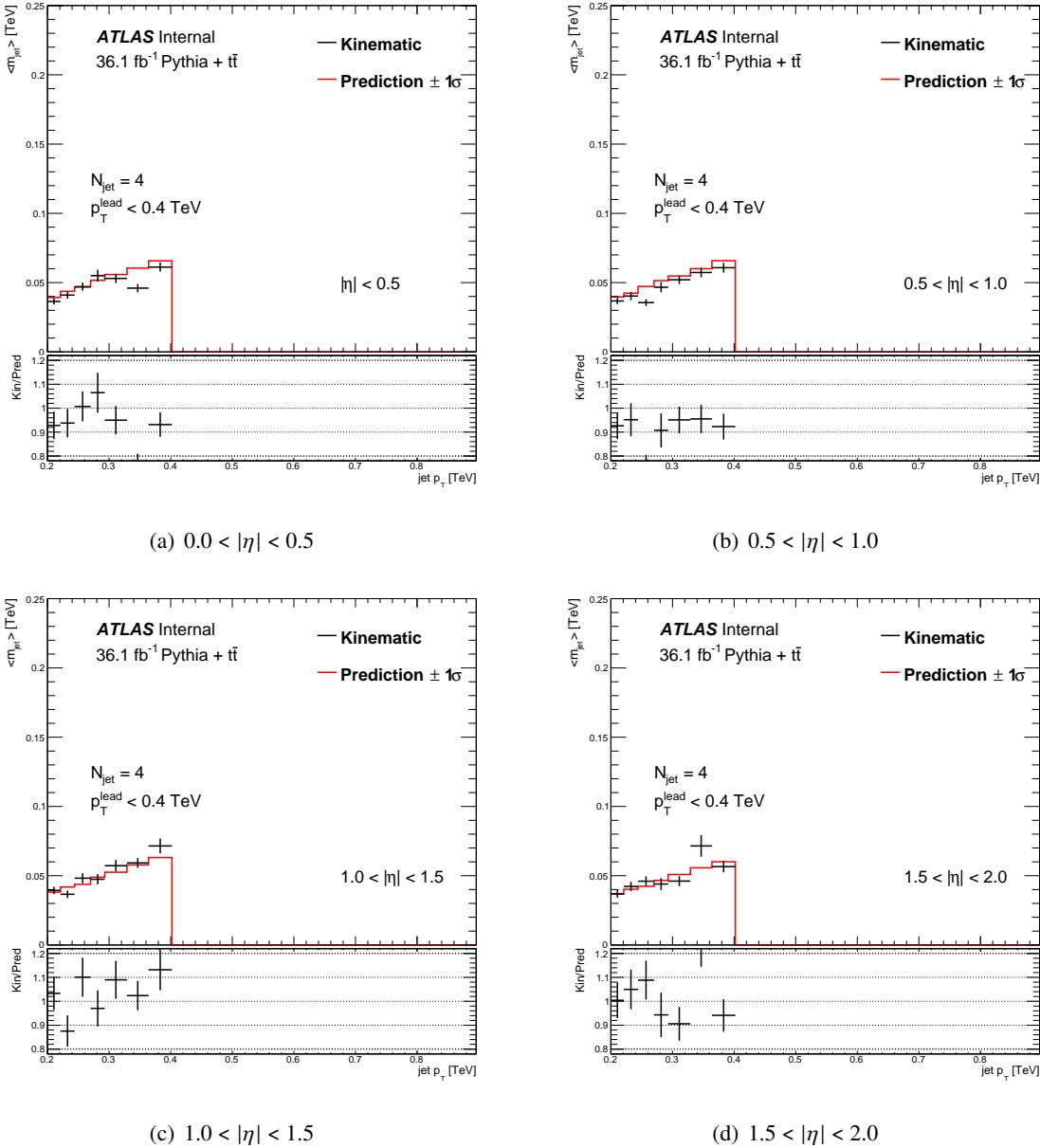


Figure 63: Jet mass response in four different $|\eta|$ regions in the UDR2 using PYTHIA8 multijet plus $t\bar{t}$ sample.

Not reviewed, for internal circulation only

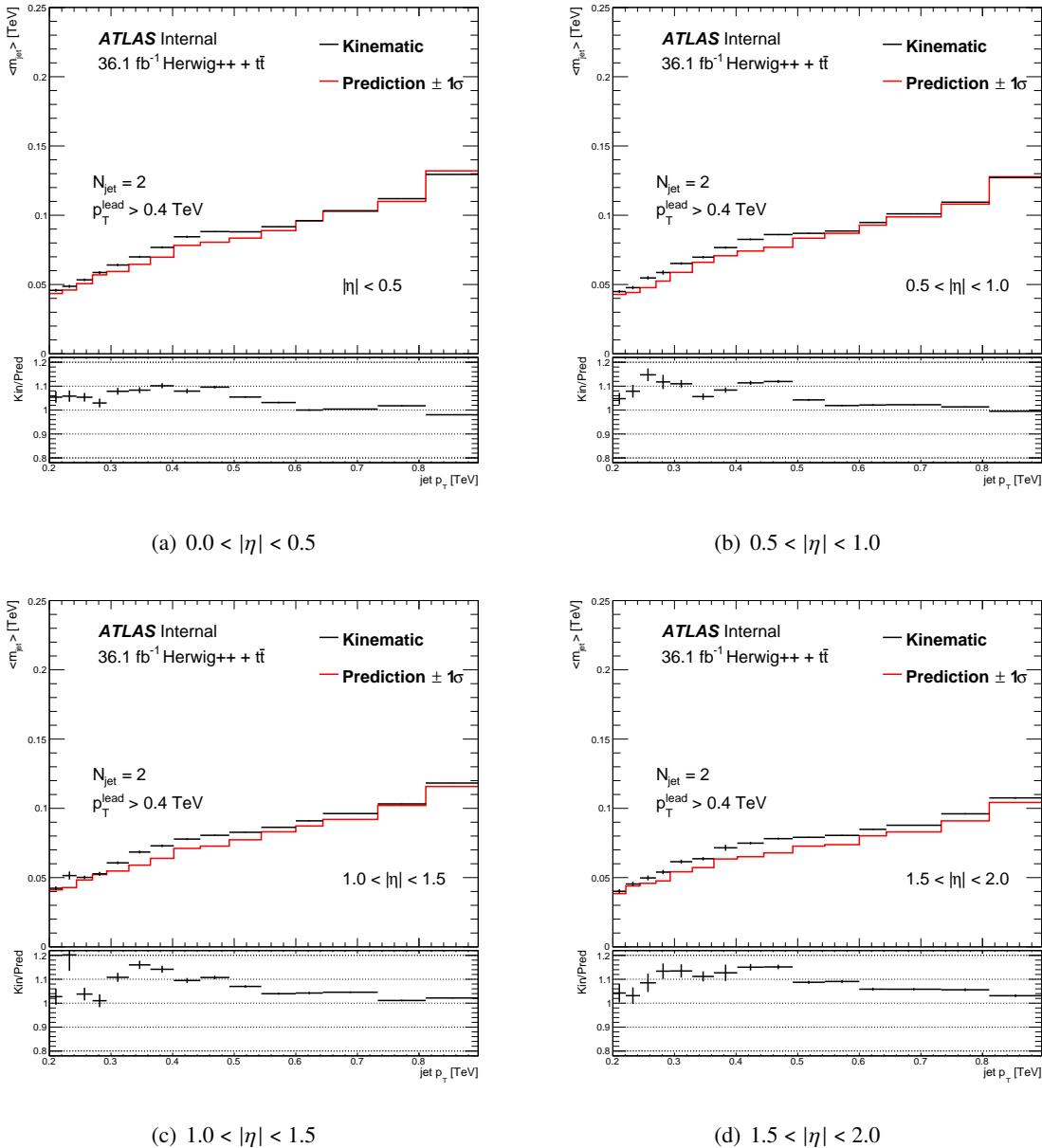


Figure 64: Jet mass response in four different $|\eta|$ regions in the UDR1 using Herwigpp multijet plus $t\bar{t}$ sample.

Not reviewed, for internal circulation only

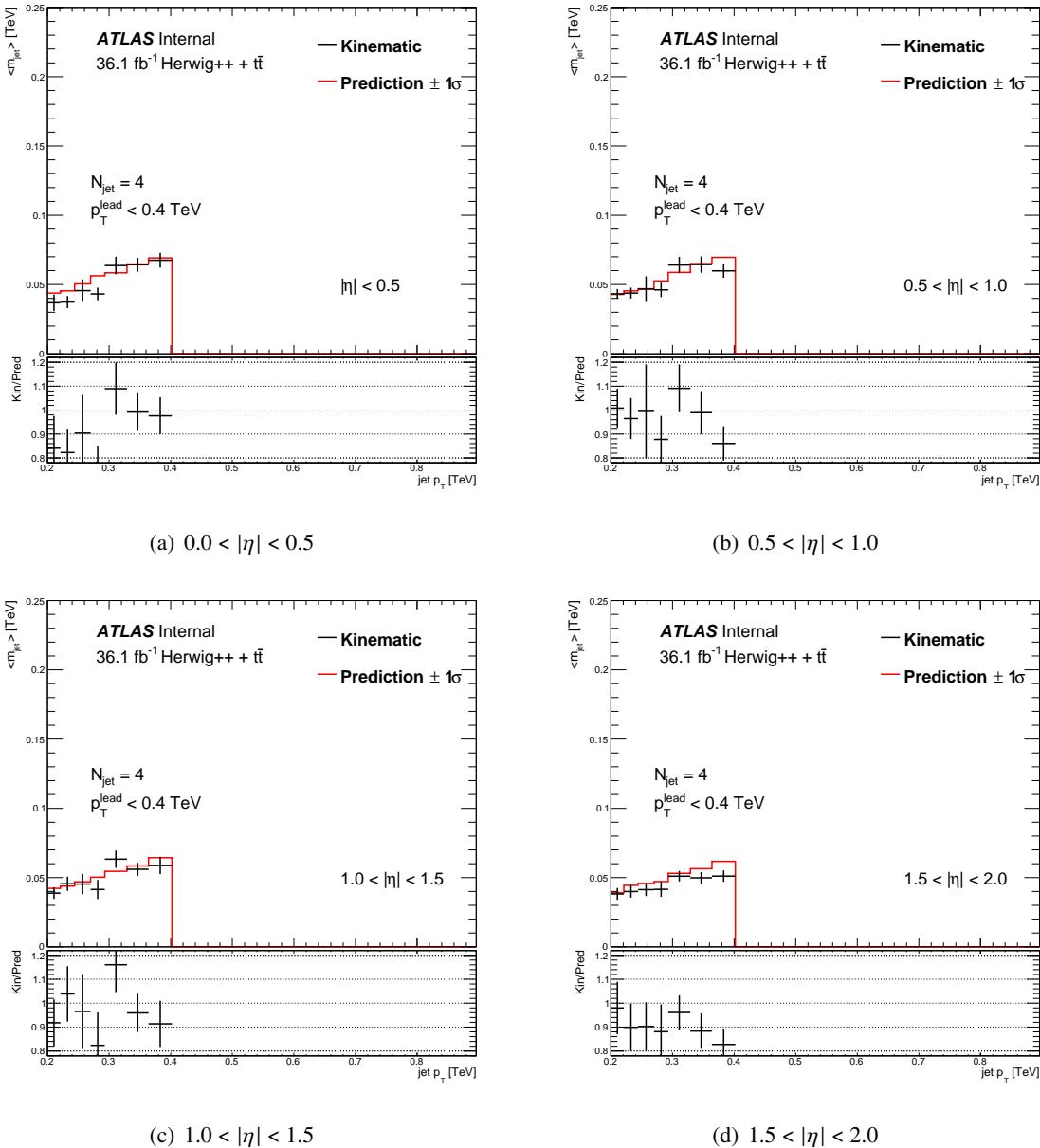


Figure 65: Jet mass response in four different $|\eta|$ regions in the UDR2 using Herwigpp multijet plus $t\bar{t}$ sample.

778 **F. Jet mass response in the UDR**

779 **F.1. Data**

780 **F.2. PYTHIA8 multijet plus $t\bar{t}$ sample**

781 **F.3. Herwigpp multijet plus $t\bar{t}$ sample**

782 **F.4. SHERPA multijet sample**

Not reviewed, for internal circulation only

Not reviewed, for internal circulation only

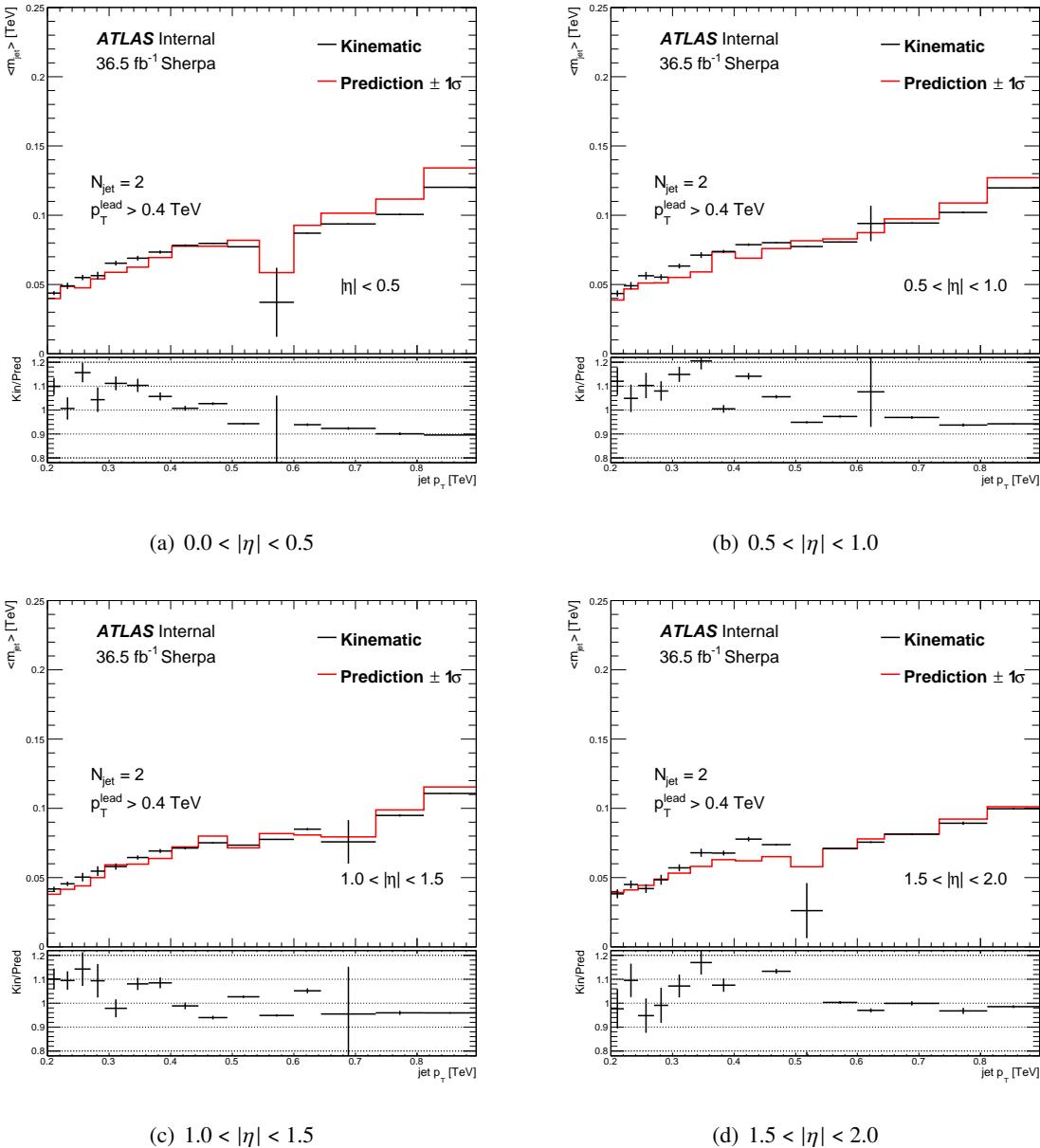


Figure 66: Jet mass response in four different $|\eta|$ regions in the UDR1 using SHERPA multijet sample.

Not reviewed, for internal circulation only

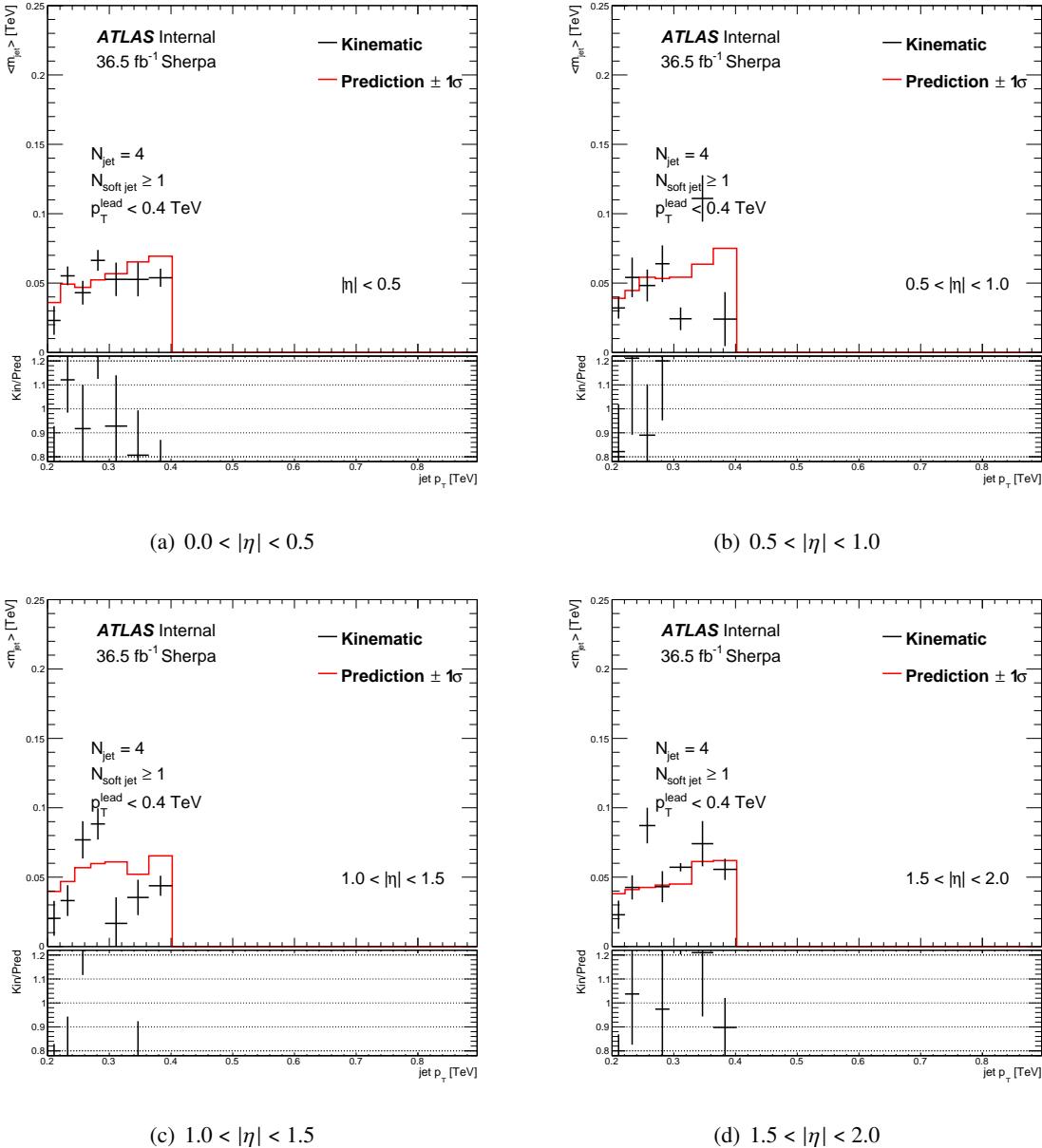


Figure 67: Jet mass response in four different $|\eta|$ regions in the UDR2 using SHERPA multijet sample.

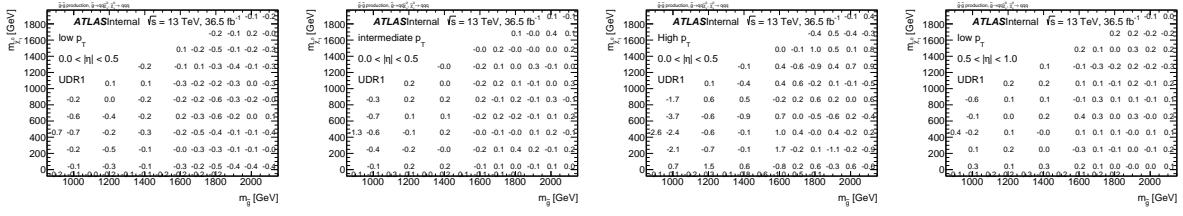


Figure 68: Variation in the jet mass prediction uncertainty due to the injection of signal events for low p_T jets in the UDR1. The four plots correspond to four different η regions where the jet mass prediction uncertainty is determined separately. The entry shown in the plot represents the change in the jet mass prediction uncertainty normalized to the nominal uncertainty, and this change is shown in percentage, i.e., the absolute change in the systematic uncertainty is the product of the entry shown in here and the uncertainty shown in Table 4.

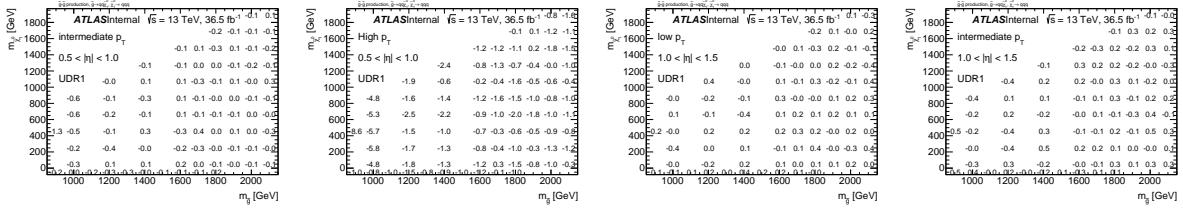


Figure 69: Variation in the jet mass prediction uncertainty due to the injection of signal events for intermediate p_T jets in the UDR1. The four plots correspond to four different η regions where the jet mass prediction uncertainty is determined separately. The entry shown in the plot represents the change in the jet mass prediction uncertainty normalized to the nominal uncertainty, and this change is shown in percentage, i.e., the absolute change in the systematic uncertainty is the product of the entry shown in here and the uncertainty shown in Table 4.

783 G. Systematic uncertainty vs signal injection

The presence of signal events in the UDRs may affect the estimation of jet mass prediction uncertainty. To check this potential effect, a series of signal injection tests are done using the 10-quark and 6-quark signal samples. In each injection test, a signal sample is injected to data, and the background estimation procedure is carried out. The jet mass prediction uncertainty is determined in the data sample injected with signal events, and the uncertainty is compared to the uncertainty determined without signal contamination. Figures 68 - 71 show the change in the jet mass prediction uncertainty normalized to its nominal value, and it is evident that the jet mass prediction uncertainty is not affected by the presence of signal events.

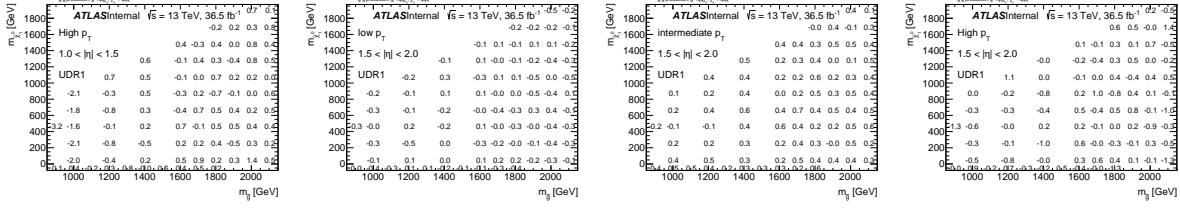


Figure 70: Variation in the jet mass prediction uncertainty due to the injection of signal events for high p_T jets in the UDR1. The four plots correspond to four different η regions where the jet mass prediction uncertainty is determined separately. The entry shown in the plot represents the change in the jet mass prediction uncertainty normalized to the nominal uncertainty, and this change is shown in percentage, i.e., the absolute change in the systematic uncertainty is the product of the entry shown in here and the uncertainty shown in Table 4.

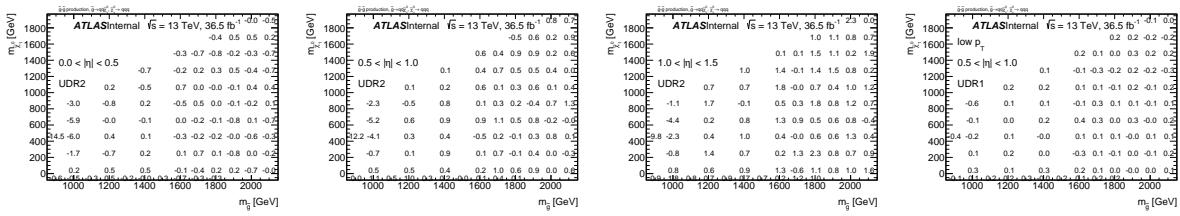


Figure 71: Variation in the jet mass prediction uncertainty due to the injection of signal events for low p_T jets in the UDR2. The four plots correspond to four different η regions where the jet mass prediction uncertainty is determined separately. The entry shown in the plot represents the change in the jet mass prediction uncertainty normalized to the nominal uncertainty, and this change is shown in percentage, i.e., the absolute change in the systematic uncertainty is the product of the entry shown in here and the uncertainty shown in Table 4.

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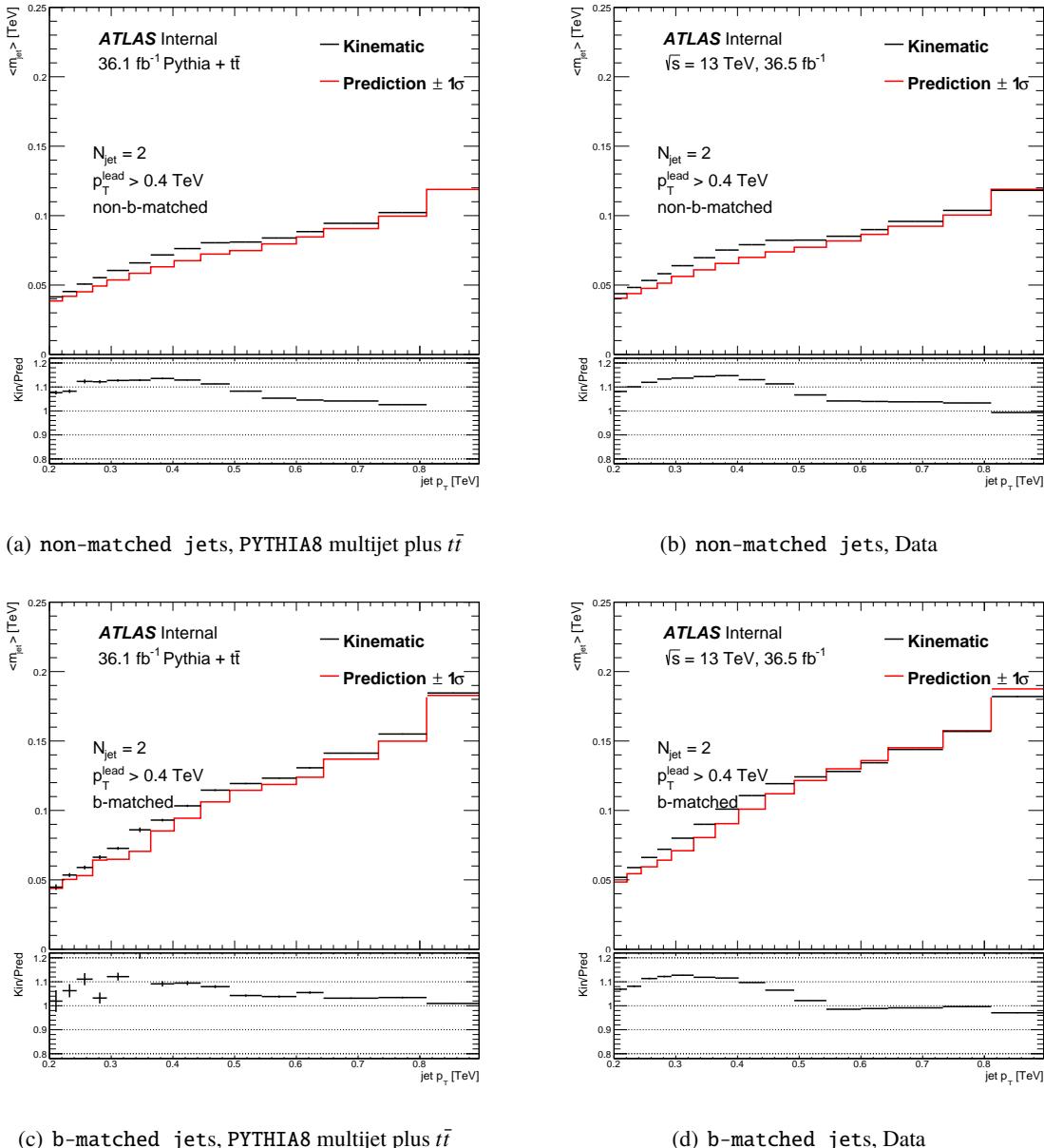


Figure 72: Jet mass response comparison in UDR1 with non-matched jets between PYTHIA8 multijet plus $t\bar{t}$ sample(left) and data(right).

791 H. Jet mass response between non-matched jets and b-matched jets

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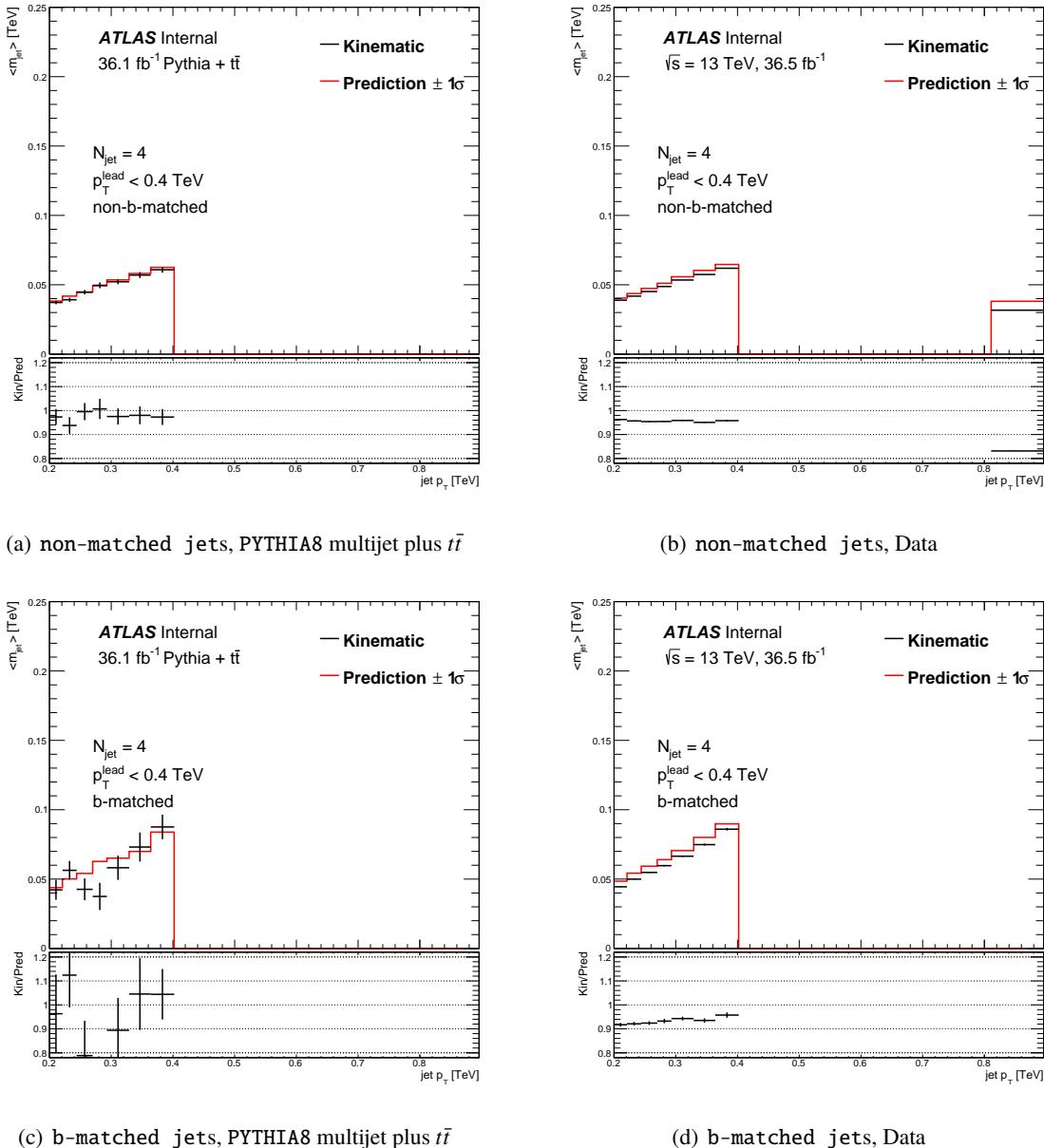


Figure 73: Jet mass response comparison in UDR2 with non-matched jets between PYTHIA8 multijet plus $t\bar{t}$ sample(left) and data(right).

Not reviewed, for internal circulation only

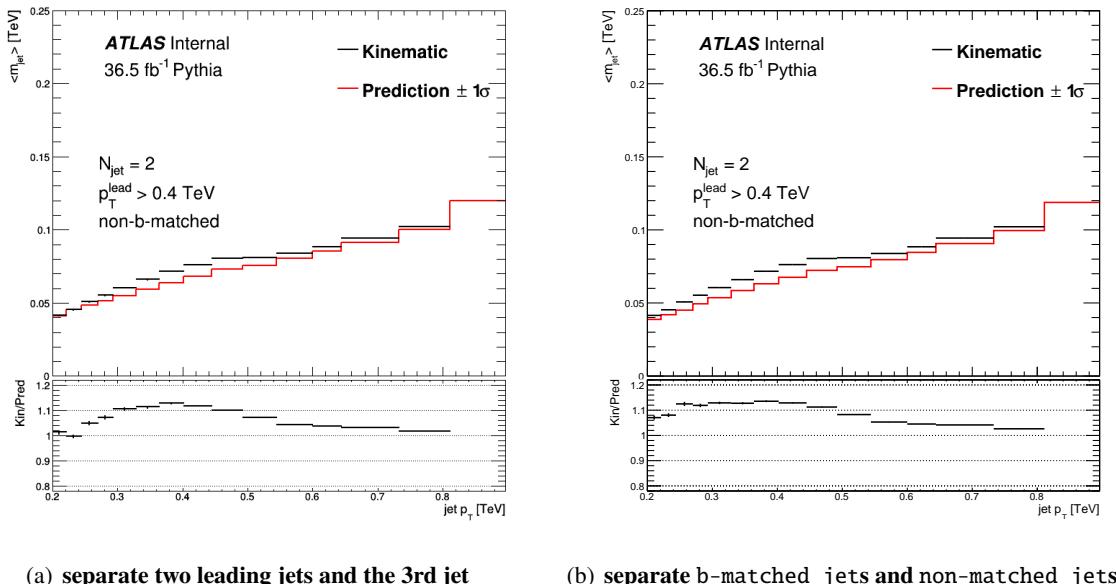


Figure 74: Jet mass response of non-matched jets in the UDR1 using PYTHIA8 multijet sample. (a) shows the result when the jet mass templates are separately made for two leading jets and the third leading jet. (b) shows the result when jet mass templates are separately made for b-matched jets and non-matched jets.

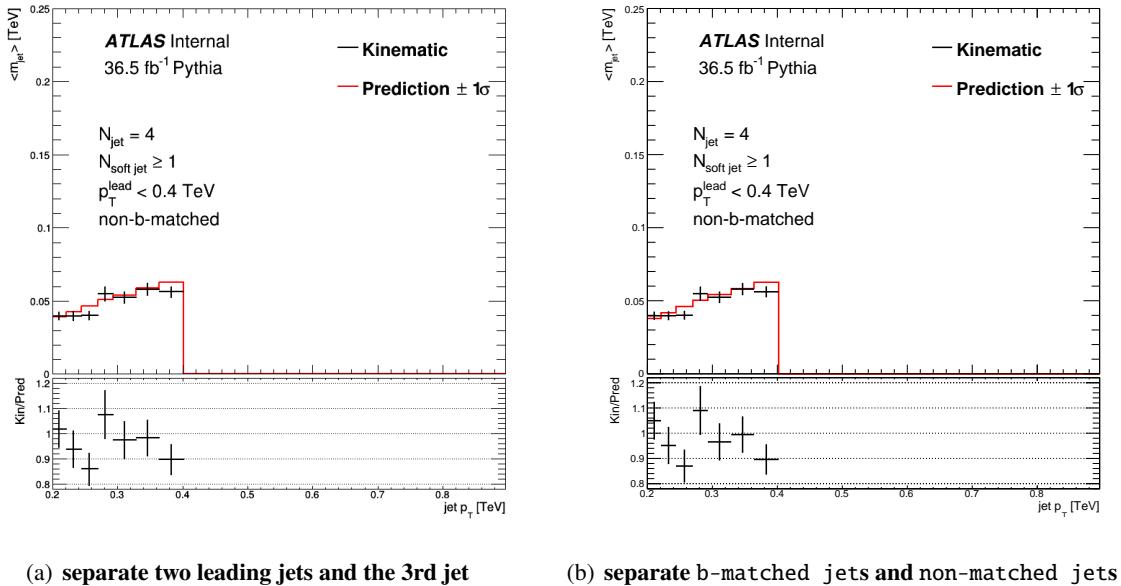
792 I. Background estimation performance with alternative binning for 793 control region

794 The jet mass template paper suggested the ordering of jets in p_T can serve as one observable that the
 795 jet mass PDF can have a dependency [2]. It is believed that the leading jet in p_T in the event may have
 796 different quark or gluon origin than jets trailing in p_T . The Run-1 analysis found that the jet mass PDFs
 797 are similar between the leading jet and the subleading jet while the jet mass PDFs are more different
 798 between the two leading jet and the third and the fourth leading jets. In response to this observation, the
 799 Run-1 analysis binned control region jets not only in p_T and η but also between the two leading jets and
 800 the third and fourth leading jets. In the Run-2 study, the separation between two leading jets and the third
 801 and fourth leading jets is found not to improve the prediction of jet mass response and the M_J^Σ distribution,
 802 and as a result, this separation is not included in the binning of control region jets.

803 Figure 77 (75) show the jet mass response for non-matched jets in the UDR1 (UDR2) using PYTHIA8 multijet
 804 sample under two different binnings for the jet mass templates. Figure 76 shows the predicted and
 805 observed M_J^Σ distributions in the 4jSR region using PYTHIA8 multijet sample under two different binnings
 806 for the jet mass templates. The jet mass response and M_J^Σ prediction are checked in all regions defined in
 807 the analysis, no significant improvement in the result is seen due to the separation in the jet mass templates
 808 between the two leading jets and the third leading jet.

809 However, there is some indication that the binning used in the Run-2 analysis does not result in a full
 810 closure in the prediction of control region jet masses, if the prediction and observation are compared
 811 separately for leading jets and trailing jets. This non-closure can be due to either that control region

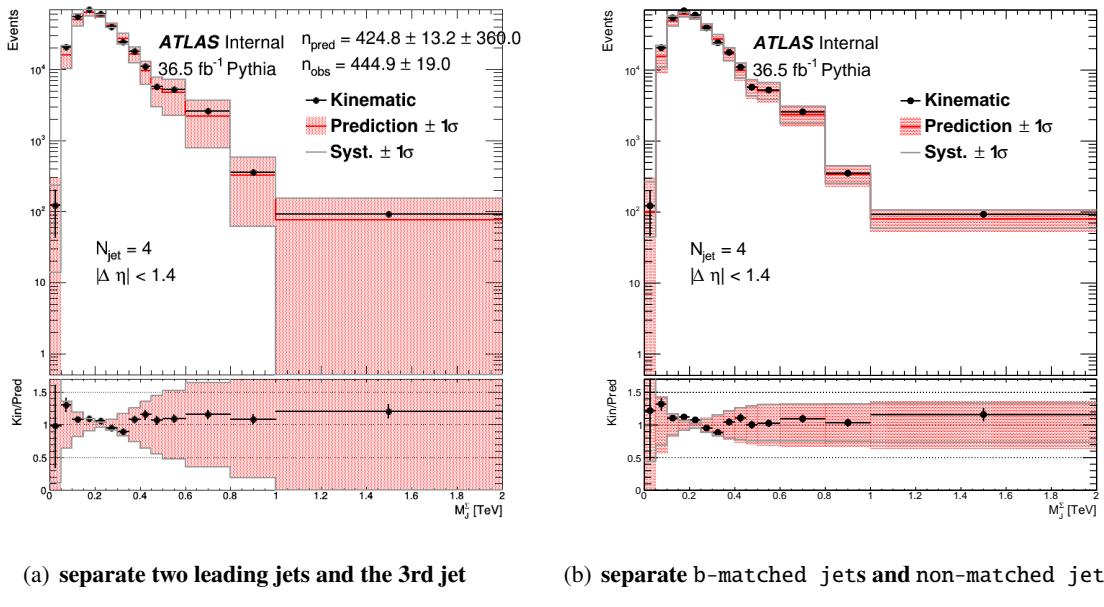
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(a) separate two leading jets and the 3rd jet

(b) separate b-matched jets and non-matched jets

Figure 75: Jet mass response of non-matched jets in the UDR2 using PYTHIA8 multijet sample. (a) shows the result when the jet mass templates are separately made for two leading jets and the third leading jet. (b) shows the result when jet mass templates are separately made for b-matched jets and non-matched jets.

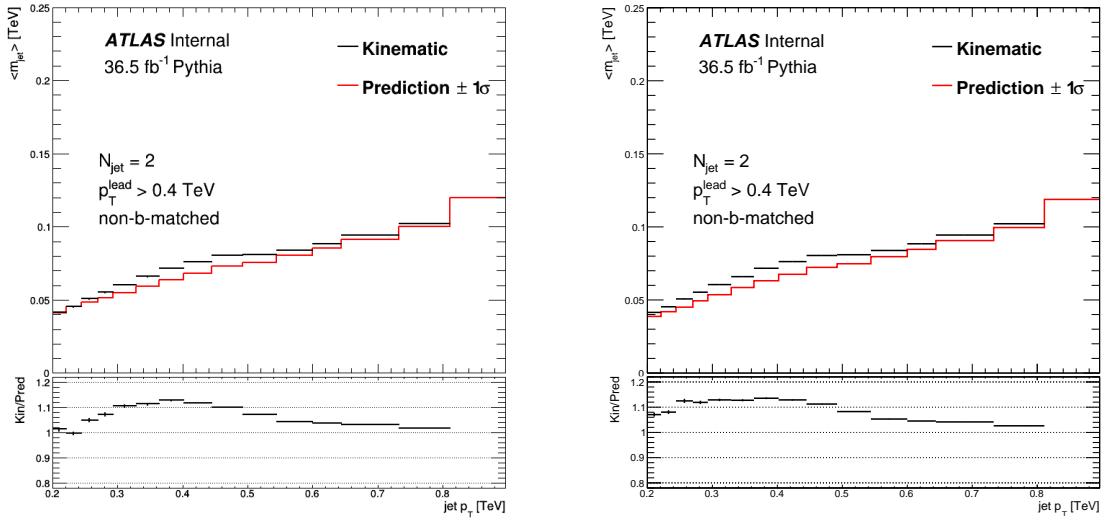


(a) separate two leading jets and the 3rd jet

(b) separate b-matched jets and non-matched jets

Figure 76: Predicted and observed M_J^Σ distributions in 4jSR using PYTHIA8 multijet sample. (a) shows the result when the jet mass templates are separately made for two leading jets and the third leading jet. (b) shows the result when jet mass templates are separately made for b-matched jets and non-matched jets.

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(a) separate two leading jets and the 3rd jet

(b) separate b-matched jets and non-matched jets

Figure 77: Jet mass response of non-matched jets in the UDR1 using PYTHIA8 multijet sample. (a) shows the result when the jet mass templates are separately made for two leading jets and the third leading jet. (b) shows the result when jet mass templates are separately made for b-matched jets and non-matched jets.

812 jets are not binned with the right list of observables or that correlations between jets are not taken into
 813 account.

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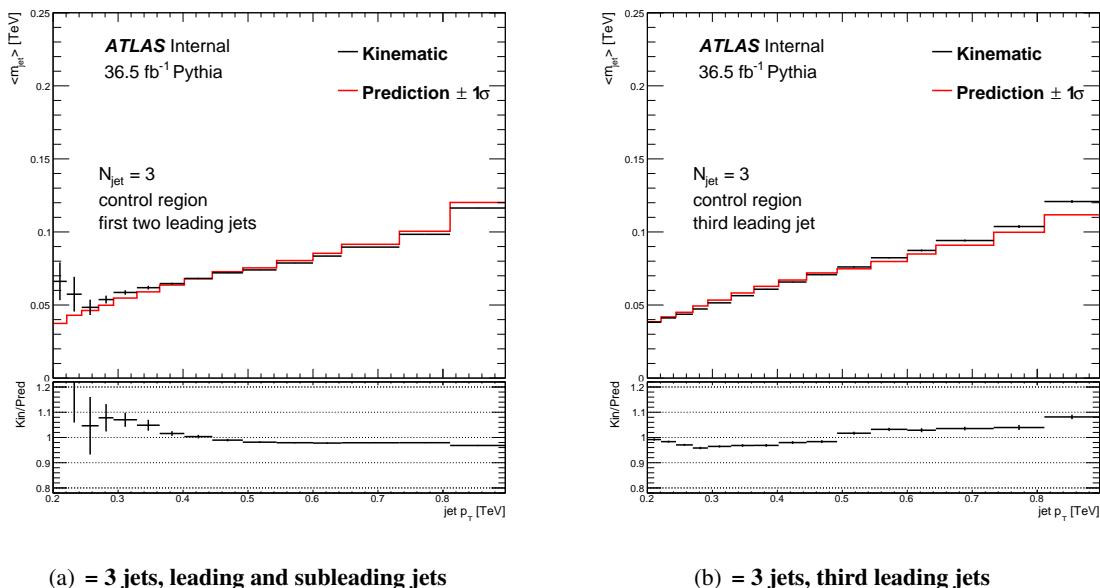


Figure 78: Jet mass response of 3-jet events for the two leading jets (15(a)) and the third leading jets (15(b)) in PYTHIA8 multijet MC sample.

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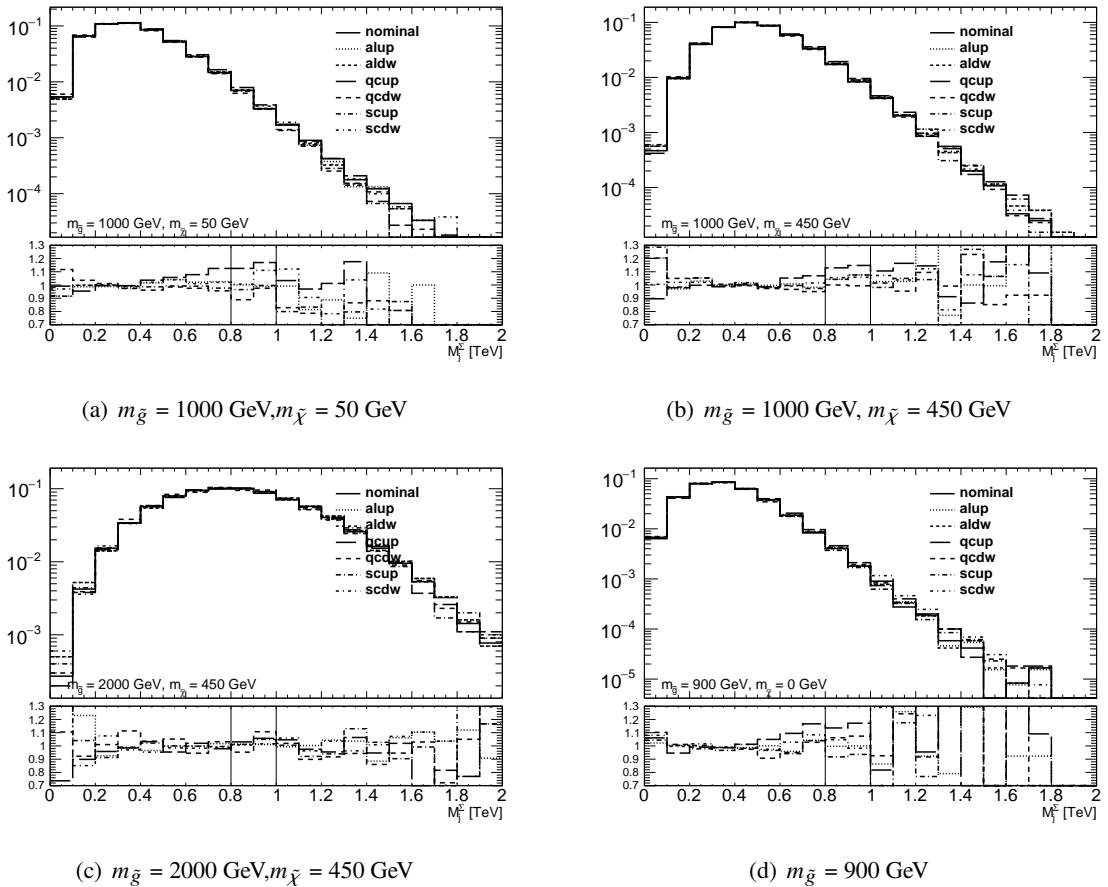


Figure 79: Nominal M_J^Σ distribution and its systematic variations for four different signal points. The cuts used to define the signal regions are indicated by vertical lines in these plots.

814 J. Scale variation uncertainty

815 To understand the size of the scale uncertainties shown in Table 20, the nominal and systematically varied
 816 distributions of the observables used to define SRs are shown in Figures 79 - 82. Four representative
 817 signal points are checked. No anomaly is observed in these distributions. The level of variation seen in
 818 these distributions is consistent with the systematic uncertainties quoted in Table 20.

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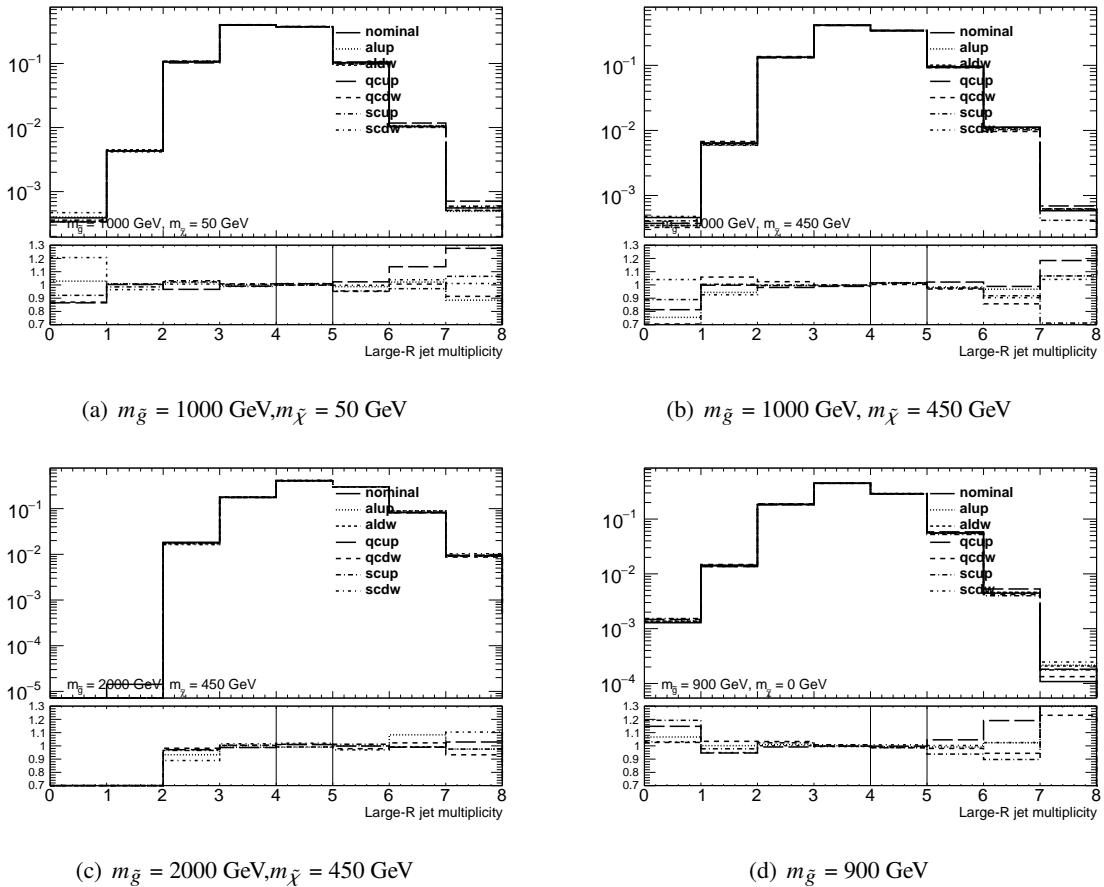


Figure 80: Nominal n_{jet} distribution and its systematic variations for four different signal points. The cuts used to define the signal regions are indicated by vertical lines in these plots.

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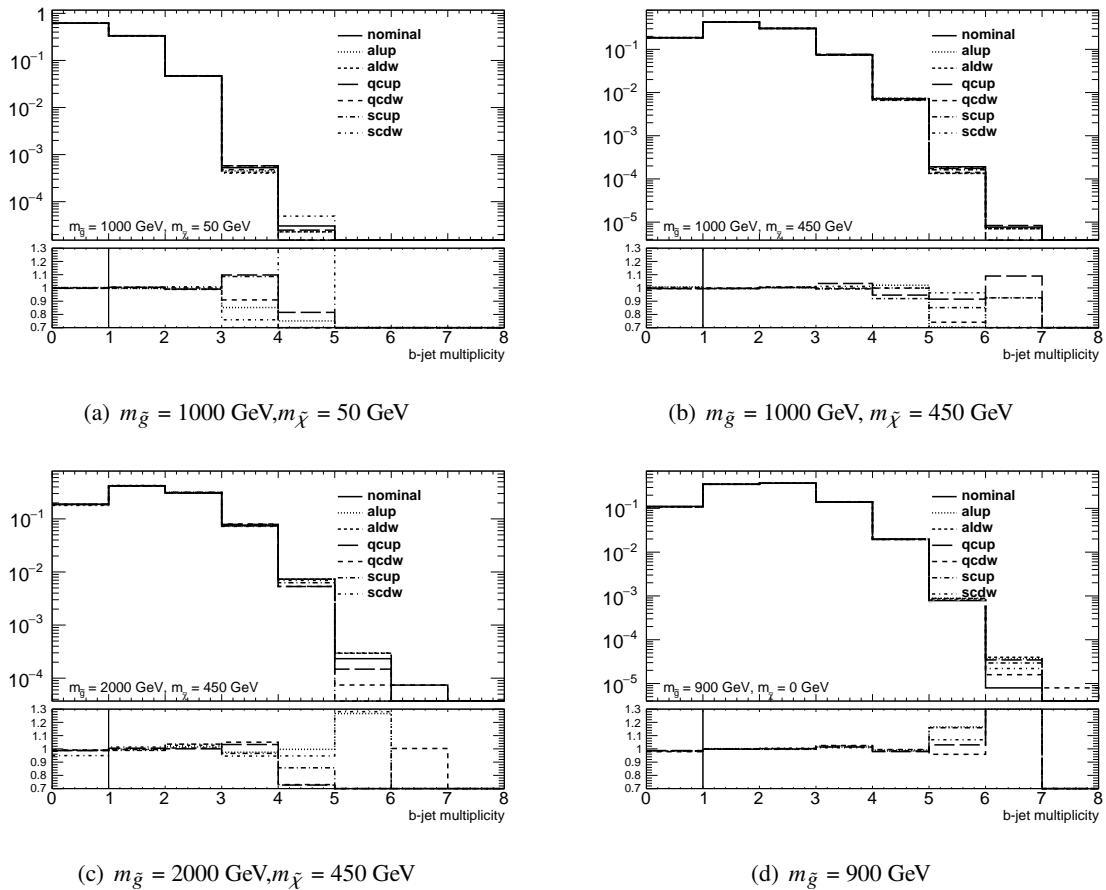


Figure 81: Nominal $n_{b\text{-jet}}$ distribution and its systematic variations for four different signal points. The cuts used to define the signal regions are indicated by vertical lines in these plots.

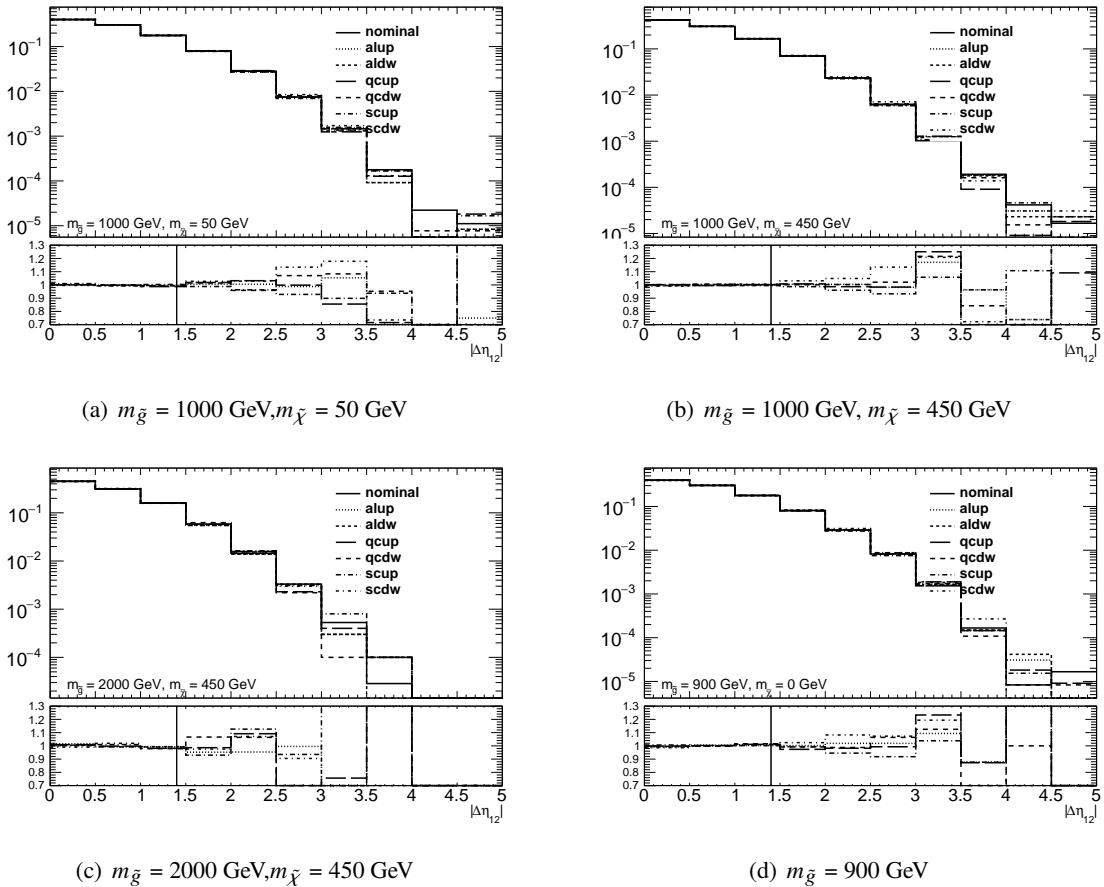


Figure 82: Nominal $|\Delta\eta_{12}|$ distribution and its systematic variations for four different signal points. The cuts used to define the signal regions are indicated by vertical lines in these plots.

K. Selection stability as a function of data-taking periods

819 Table 16 shows the selected number of events in various regions normalized to the integrated luminosity
820 for each run in data.

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Run	lumi (pb^{-1})	all	all/lumi	trigger	trigger*/lumi	4jSR	4jSR/lumi	4jSRb	4jSRb/lumi	5jSR	5jSR/lumi
276262	6.1669	49498	8026.4	7026	1139.31	70	11.3509	12	1.94587	0	0
276329	11.7065	91021	7775.25	12426	1061.46	132	11.2758	43	3.67317	3	0.256268
276336	0.673924	5061	7509.75	663	983.79	4	5.93539	1	1.48385	0	0
276416	4.21279	31792	7546.54	4337	1029.48	54	12.8181	13	3.08584	0	0
276511	8.766604	63876	7286.76	8720	994.748	81	9.2402	22	2.50969	3	0.34223
276689	10.6565	80145	7520.77	10783	1011.87	111	10.4162	26	2.43983	1	0.0938395
276778	0.657529	5425	8250.59	670	1018.97	7	10.6459	2	3.04169	0	0
276790	1.59535	11565	7249.19	1554	974.081	20	12.5364	4	2.50729	1	0.626822
276952	6.47731	45885	7083.96	6294	971.7	65	10.0351	18	2.77893	0	0
276954	0.73329	5254	7164.97	753	1026.88	6	8.1823	2	2.72743	1	1.36372
278880	21.4192	155686	7268.52	20527	958.345	234	10.9248	53	2.47441	6	0.280122
278912	19.6332	138096	7033.79	18658	950.328	186	9.47374	49	2.49577	5	0.25467
278968	9.883	71447	7229.28	9488	960.032	100	10.1184	27	2.73196	5	0.505919
279169	55.0055	382554	6954.83	51743	940.688	603	10.9625	172	3.12696	11	0.19998
279259	7.31293	52213	7139.82	7022	960.217	81	11.0763	20	2.73488	0	0
279279	16.8971	130590	7728.55	15606	923.59	135	7.98954	38	2.24891	3	0.177545
279284	31.8164	219032	6884.25	29736	934.612	338	10.6235	90	2.82873	5	0.157152
279345	52.6837	362412	6879.02	48304	916.869	576	10.9332	168	3.18884	21	0.398606
279515	0.347662	2453	7055.7	323	929.063	5	14.3818	1	2.87636	0	0
279598	67.859	464685	6847.8	61713	909.43	722	10.6397	199	2.93255	22	0.324202
279685	74.471	530118	7118.45	66892	898.229	773	10.3799	212	2.84675	26	0.349129
279813	47.6167	335367	7043.05	43646	916.611	487	10.2275	127	2.66713	13	0.273013
279867	29.5636	227481	7694.63	26804	906.655	302	10.2153	74	2.50308	5	0.169127
279928	1.09603	8117	7405.82	1081	986.287	12	10.9486	4	3.64954	0	0
279932	44.6415	301398	6751.52	40507	907.384	473	10.5955	133	2.97929	14	0.313609
279984	65.2751	529187	8107.03	59601	913.075	668	10.2336	165	2.52776	15	0.229797
280231	88.2841	649052	7351.86	7944	905.532	877	9.93384	211	2.39001	23	0.260523
280273	1.62778	11704	7190.16	1473	904.913	15	9.215	6	3.686	0	0
280319	93.6371	661895	7068.73	85209	909.992	954	10.1883	246	2.62716	24	0.256309
280368	8.2273	60722	7380.55	7699	935.787	54	6.56351	10	1.21547	1	0.121547
280423	68.5733	483235	7046.98	62652	913.65	734	10.7039	208	3.03325	29	0.422905
280464	58.3428	415726	7125.58	53593	918.588	622	10.6611	151	2.58815	14	0.239961

280500	7.27397	55659	7651.8	6845	941.027	83	11.4106 22	3.02448	2	0.274953
280520	12.1185	107469	8868.19	11420	942.362	123	10.1498 36	2.97067	3	0.247556
280614	24.2357	174034	7180.91	22199	915.964	245	10.1091 64	2.64074	3	0.123785
280673	149.063	1013871	6801.62	134322	901.108	1547	10.3782 392	2.62976	43	0.284668
280753	45.2146	315691	6982.06	41552	918.995	449	9.93042 109	2.41073	12	0.265401
280853	7.21388	50849	7048.77	6730	932.924	73	10.1194 22	3.04968	5	0.693108
280862	131.154	892579	6805.58	117061	892.547	1351	10.3009 325	2.478	30	0.228739
280950	125.75	851851	6774.19	112897	897.792	1303	10.3619 359	2.85488	32	0.254474
280977	34.9327	255793	7322.46	32741	937.26	363	10.3914 92	2.63364	11	0.314891
281070	12.7946	93408	7300.59	12010	938.679	135	10.5513 33	2.57922	5	0.39079
281074	46.6601	328043	7030.48	43215	926.166	504	10.8015 124	2.65752	8	0.171453
281075	1.07213	10386	9687.26	1126	1050.25	7	6.529062	1.86545	0	0
281317	24.3629	174537	7164.05	22665	930.309	268	11.0003 69	2.83218	7	0.287322
281385	93.2571	740478	7940.18	78228	838.842	882	9.45772 242	2.59498	21	0.225184
281411	146.742	1034527	7049.99	134037	913.422	1505	10.2561 402	2.73951	51	0.34755
282625	10.6752	80477	7538.69	10416	975.719	95	8.89913 37	3.46598	2	0.18735
282631	26.7692	190499	7116.36	24815	926.999	268	10.0115 71	2.6523	10	0.373564
282712	93.9324	713703	7598.05	89558	953.43	1040	11.0718 287	3.05539	27	0.287441
282784	2.88326	97693	33882.8	3163	1097.02	34	11.7922 5	1.73415	1	0.34683
282992	106.771	782989	7333.32	98968	926.915	1089	10.1994 271	2.53813	31	0.29034
283074	55.8008	425440	7624.26	52497	940.792	586	10.5016 161	2.88526	19	0.340497
283155	28.7327	221281	7701.36	27493	956.854	337	11.7288 83	2.88869	7	0.243625
283270	13.2713	101894	7677.77	12627	951.452	152	11.4533 47	3.54148	1	0.0753506
283429	234.568	1682245	7171.67	213270	909.204	2510	10.7005 612	2.60905	55	0.234474
283608	23.809	155270	6521.49	20912	878.325	244	10.2482 70	2.94007	4	0.168004
283780	145.09	990980	6830.11	128780	887.588	1444	9.95246 361	2.48811	38	0.261907
284006	38.9189	292064	7504.42	36343	933.813	408	10.4833 109	2.80069	16	0.411111
284154	9.99866	78350	7836.05	9661	966.229	93	9.30125 22	2.20029	2	0.200027
284213	199.991	1417552	7088.09	181351	906.797	2019	10.0955 555	2.77513	55	0.275013
284285	247.886	1786875	7208.46	227551	917.966	2512	10.1337 602	2.42854	65	0.262217
284420	57.5	453409	7885.37	54098	940.834	615	10.6956 150	2.60869	17	0.295652
284427	35.2553	273723	7764.02	33181	941.163	350	9.92759 81	2.29753	6	0.170187
284484	103.397	758433	7335.16	95027	919.051	1099	10.6289 274	2.64998	32	0.309487

297730	3.33307	84226	25269.8	3749	1124.79	48	14.4012	12	3.60029	0	0	0	0
298595	0.288888	18706	64753.5	262	906.95	0	0	0	0	0	0	0	1.03696
298609	1.92872	35038	18166.5	2027	1050.96	27	13.9989	8	4.14784	2	2	1.03696	0.513379
298633	5.84364	76116	13025.5	5814	994.928	78	13.3479	19	3.2514	3	3	0.513379	0.291597
298687	20.5763	222066	10792.3	21550	1047.32	217	10.5461	46	2.23558	6	6	0.291597	0.706864
298690	1.4147	17716	12522.8	1628	1150.77	25	17.6716	5	3.53432	1	1	0.706864	0.251138
298771	7.96374	96219	12082.1	8604	1080.4	109	13.687	30	3.76707	2	2	0.251138	0.387024
298773	7.75146	95988	12383.2	8548	1102.76	87	11.2237	20	2.58016	3	3	0.387024	0.0850155
298862	23.5251	271135	11525.3	25154	1069.24	271	11.5196	75	3.18808	2	2	0.0850155	0.374249
298967	53.4403	555898	10402.2	55781	1043.8	649	12.1444	168	3.14369	20	20	0.374249	0.427638
299055	44.4301	498492	11219.7	45704	1028.67	501	11.2761	126	2.83591	19	19	0.427638	0.269156
299144	29.7225	278089	9356.18	29306	985.987	311	10.4635	82	2.75885	8	8	0.269156	0.21574
299147	23.176	276440	11927.8	23555	1016.35	259	11.1753	66	2.84777	5	5	0.21574	0.428631
299184	90.9875	877904	9648.63	91628	1007.04	1038	11.4082	278	3.05537	39	39	0.428631	0.17071
299243	5.85789	105874	18073.7	5525	943.172	62	10.584	14	2.38994	1	1	0.17071	0.293859
299584	221.194	2101217	9499.41	202515	915.552	2335	10.5563	604	2.73063	65	65	0.293859	0.191313
300279	5.22704	57848	11067.1	5437	1040.17	59	11.2875	15	2.86969	1	1	0.191313	0.20914
300345	4.78149	52245	10926.5	4671	976.893	62	12.9667	18	3.76452	1	1	0.20914	0.293335
300415	88.636	830312	9367.66	85323	962.623	1001	11.2934	240	2.7077	26	26	0.293335	0
300418	5.53841	40630	7336.05	5742	1036.76	60	10.8334	13	2.34725	0	0	0	0.292468
300487	119.671	1059538	8853.76	114547	957.182	1342	11.2141	325	2.71578	35	35	0.292468	0.256397
300540	175.509	1347228	7676.12	169004	962.936	1917	10.9225	472	2.68932	45	45	0.256397	0.367978
300571	141.313	1086347	7687.53	140037	990.972	1618	11.4498	445	3.14904	52	52	0.367978	0.416081
300600	48.0675	381110	7928.64	49500	1029.8	625	13.0025	154	3.20383	20	20	0.416081	0.350315
300655	228.366	1444283	6324.43	225414	987.075	2583	11.3108	667	2.92075	80	80	0.350315	0.330003
300687	324.24	2205769	6802.89	310362	957.199	3567	11.0011	945	2.91451	107	107	0.330003	0.710646
300784	7.03585	47926	6811.69	7198	1023.05	87	12.3652	20	2.84258	5	5	0.710646	0.314653
300800	273.317	1808884	6618.27	269374	985.574	3001	10.9799	735	2.68919	86	86	0.314653	0.258004
300863	325.576	2226437	6838.45	313260	962.171	3606	11.0757	983	3.01926	84	84	0.258004	0.298632
300908	210.962	1364332	6467.18	204186	967.879	2330	11.0446	587	2.78249	63	63	0.298632	0.487055
301912	6.15947	75916	12325.1	7451	1209.68	87	14.1246	25	4.05879	3	3	0.487055	0.261282
301918	19.1364	249581	13042.2	21022	1098.53	236	12.3325	58	3.03087	5	5	0.261282	0.262935
301932	353.699	2857379	8078.55	344188	973.109	3968	11.2186	1054	2.97993	93	93	0.262935	

301973	462.801	3449719	7454	441094	953.096	5096	11.0112 1402	3.02938	132	0.28522
302053	377.646	2649116	7014.82	374271	991.064	4332	11.4711 1122	2.97104	116	0.307166
302137	194.974	1365945	7005.79	198706	1019.14	2305	11.8221 577	2.95937	61	0.312863
302265	100.983	711527	7046.02	103162	1021.58	1229	12.1704 311	3.07973	28	0.277275
302269	55.7169	404703	7263.57	58583	1051.44	665	11.9353 162	2.90756	12	0.215375
302300	380.62	2856525	7504.93	359593	944.756	4164	10.94 1090	2.86375	109	0.286375
302347	193.572	1331531	6878.73	195125	1008.02	2319	11.98 617	3.18744	56	0.289298
302380	103.515	721058	6965.73	107200	1035.6	1284	12.404 340	3.28455	33	0.318794
302391	124.635	956443	7673.97	129052	1035.44	1458	11.6982 374	3.00077	39	0.312915
302737	78.8367	582011	7382.49	83825	1063.27	928	11.7712 260	3.29796	21	0.266374
302831	15.5568	183100	11769.8	14031	901.92	155	9.96348 34	2.18554	3	0.192841
302919	61.2587	471368	7694.71	63933	1043.66	721	11.7698 196	3.19955	18	0.293836
302925	126.145	867826	6879.61	132685	1051.85	1446	11.463 388	3.07584	40	0.317096
302956	330.688	2190626	6624.46	324343	980.814	3777	11.4217 984	2.97562	104	0.314496
303007	15.4962	97804	6311.49	16903	1090.78	203	13.1 55	3.54926	7	0.451724
303079	99.6504	632803	6350.23	103908	1042.72	1207	12.1123 326	3.27144	27	0.270947
303201	90.618	599853	6619.58	95689	1055.96	1103	12.172 293	3.23335	28	0.308989
303264	29.9594	228570	7629.31	32260	1076.79	357	11.9161 101	3.37122	10	0.333785
303266	266.481	1778150	6672.71	266304	999.337	3010	11.2954 820	3.07715	85	0.318972
303291	167.275	1119747	6694.04	169961	1016.06	1929	11.5319 497	2.97115	56	0.334778
303499	413.796	2791437	6745.93	387253	935.855	4548	10.9909 1231	2.9749	126	0.304498
303560	321.545	2074913	6452.94	311884	969.954	3681	11.4478 952	2.9607	103	0.320328
303832	92.5147	469797	5078.08	80657	871.829	916	9.90113 281	3.03736	24	0.259418
303846	483.396	2823914	5841.82	451097	933.183	5297	10.9579 1342	2.77619	130	0.268931
303892	453.483	2627085	5793.13	425496	938.284	5032	11.0963 1312	2.89316	147	0.324158
303943	462.478	2208738	4775.88	436115	942.996	5393	11.6611 1433	3.09852	142	0.307042
304006	146.025	804391	5508.6	150372	1029.77	1811	12.402 471	3.22548	59	0.404042
304008	465.976	2268596	4868.48	437764	939.455	5175	11.1057 1384	2.97011	140	0.300444
304128	545.181	2647320	4855.85	516861	948.054	5957	10.9266 1608	2.94948	145	0.265967
304178	422.372	2056749	4869.51	400492	948.196	4644	10.995 1102	2.60907	126	0.298315
304198	157.807	817589	5180.94	156329	990.634	1910	12.1034 481	3.04803	62	0.392885
304211	125.247	648077	5174.38	125380	1001.06	1430	11.4174 361	2.8823	35	0.279447
304243	352.399	1650508	4683.64	323812	918.88	3820	10.84 1006	2.85472	100	0.28377

304308	28.0061	153607	5484.77	28746	1026.42	328	11.711781	2.89223	7	0.249946
304337	405.894	2001055	4930	387163	953.853	4669	11.5031150	2.83325	117	0.288253
304409	95.2906	544757	5716.8	99606	1045.29	1196	12.5511312	3.2742	31	0.325321
304431	142.291	775486	5450.01	145501	1022.56	1732	12.1723435	3.05712	50	0.351393
304494	56.0731	318541	5680.82	58918	1050.74	665	11.8595180	3.2101	16	0.285342
305380	314.812	1686991	5358.72	324781	1031.67	3779	12.004964	3.06214	101	0.320826
305543	183.07	1351941	7384.84	167987	917.611	2000	10.9248498	2.72027	42	0.229421
305571	18.0813	159915	8844.21	19432	1074.7	232	12.830962	3.42895	14	0.774279
305618	302.936	1486524	4907.06	294711	972.85	3497	11.5437882	2.91151	75	0.247577
305671	25.5572	143582	5618.06	27496	1075.86	339	13.264493	3.6389	14	0.547791
305674	18.3192	102183	5577.92	19282	1052.56	257	14.02958	3.16608	4	0.21835
305723	273.643	1390454	5081.28	272975	997.56	3159	11.5442797	2.91256	105	0.383712
305727	66.938	295328	4411.96	60367	901.834	705	10.5321185	2.76375	21	0.313723
305735	123.592	644413	5214.03	125457	1015.09	1491	12.0639375	3.03417	46	0.372192
305777	314.87	1574698	5001.1	308225	978.895	3709	11.7795892	2.83291	105	0.333471
305811	268.176	1334284	4975.4	263769	983.566	3193	11.9063833	3.10617	98	0.365431
305920	254.499	1282342	5038.69	251141	986.804	3020	11.8664755	2.96661	77	0.302555
306269	155.935	827514	5306.79	160690	1030.49	1958	12.5565524	3.36037	50	0.320646
306278	386.02	1882015	4875.43	374212	969.41	4490	11.63151203	3.11642	134	0.347132
306310	384.258	1863983	4850.86	365973	952.414	4403	11.45841128	2.93553	120	0.31229
306384	194.371	1019406	5244.64	193984	998.009	2308	11.8742601	3.09203	71	0.365281
306419	89.8166	500773	5575.51	94314	1050.07	1089	12.1247287	3.1954	23	0.256077
306442	30.532	183736	6017.81	32539	1065.73	428	14.0181105	3.43901	10	0.327525
306448	103.519	549022	5303.59	105855	1022.57	1243	12.0075322	3.11054	31	0.299462
306451	325.781	1637372	5026	318869	978.785	3947	12.11551017	3.12173	106	0.325372
307126	26.8389	192167	7160.02	33197	1236.9	338	12.593791	3.3906	14	0.521631
307195	215.163	1084078	5038.4	214402	996.463	2637	12.2558682	3.16969	63	0.292801
307259	305.696	1890062	6182.82	295788	967.589	3524	11.5278900	2.9441	85	0.278054
307306	187.745	967912	5155.46	189632	1010.05	2203	11.734560	2.98277	57	0.303603
307354	82.9182	448850	5413.17	85560	1031.86	985	11.8792244	2.94266	28	0.337682
307358	381.183	1872509	4912.36	369837	970.234	4406	11.55871070	2.80705	107	0.280705
307394	358.435	1731123	4829.68	343175	957.427	4121	11.49721073	2.99357	112	0.31247
307454	485.312	2330174	4801.39	461113	950.137	5492	11.31641431	2.94862	122	0.251385

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307514	198.841	1042926	5245.02	201386	1012.8	2367	11.904 582	2.92696	73	0.367128
307539	75.359	420311	5577.45	79089	1049.5	884	11.7305 231	3.06533	25	0.331745
307569	330.64	1651392	4994.53	319379	965.942	3898	11.7893 1051	3.17868	96	0.290346
307601	303.043	1567959	5174.04	300599	991.934	3533	11.6584 934	3.08207	91	0.300287
307619	68.1649	364693	5350.16	69694	1022.43	794	11.6482 172	2.52329	21	0.308076
307656	434.657	2109864	4854.09	414207	952.951	4797	11.0363 1203	2.7677	107	0.246171
307710	78.5731	471542	6001.32	84292	1072.78	983	12.5106 263	3.3472	22	0.279994
307716	218.402	1184682	5424.32	223634	1023.96	2671	12.2298 664	3.04027	76	0.347982
307732	533.065	2567858	4817.16	505784	948.823	6086	11.417 1600	3.00151	152	0.285144
307861	292.883	1473760	5031.91	288160	983.874	3421	11.6804 849	2.89877	89	0.303876
307935	404.919	2018785	4985.66	395348	976.364	4751	11.7332 1268	3.13149	131	0.323522
308047	473.422	2238186	4727.68	446052	942.187	5243	11.0747 1367	2.88749	136	0.28727
308084	348.362	1676260	4811.83	338226	970.903	4023	11.5483 1041	2.98827	110	0.315763
309375	44.2901	524334	11838.6	47161	1064.82	529	11.944 125	2.8223	12	0.270941
309390	286.596	2312403	8068.53	271685	947.974	3234	11.2842 821	2.86466	75	0.261693
309440	439.843	2055520	4673.3	401728	913.343	5040	11.4586 1281	2.9124	122	0.277371
309516	365.271	1747378	4783.78	343725	941.012	4308	11.794 1086	2.97313	123	0.336736
309640	381.193	1756429	4607.72	348679	914.705	4406	11.5584 1120	2.93814	128	0.335788
309674	337.652	1625041	4812.76	318757	944.039	3940	11.6688 1053	3.11859	98	0.290239
309759	354.179	1688493	4767.35	328196	926.64	4117	11.6241 1062	2.99849	102	0.28799
310015	2.13918	78340	36621.5	2207	1031.7	26	12.1542 6	2.80481	2	0.934938
310247	24.5241	190913	7784.72	26842	1094.52	326	13.2931 75	3.05822	3	0.122329
310249	407.346	2169041	5324.81	393852	966.873	4823	11.84 1173	2.87961	139	0.341233
310341	417.879	2082088	4982.51	405278	969.845	4950	11.8455 1262	3.02001	133	0.318274
310370	15.4696	208029	13447.6	16618	1074.24	231	14.9325 59	3.81393	4	0.258572
310405	184.017	950444	5164.99	184866	1004.62	2280	12.3902 585	3.17906	47	0.255412
310468	151.452	834760	5511.71	157253	1038.3	1936	12.7829 473	3.1231	58	0.38296
310473	221.731	1217828	5492.36	228363	1029.91	2847	12.8399 750	3.38247	77	0.347267
310634	531.489	2575070	4845.01	506488	952.96	6253	11.7651 1573	2.95961	147	0.276581
310691	323.242	1662712	5143.86	322301	997.089	3831	11.8518 993	3.072	101	0.312459
310738	391.103	1978137	5057.85	382733	978.6	4658	11.9099 1234	3.15518	119	0.304268
310809	376.438	2306368	6126.81	359922	956.124	4425	11.7549 1151	3.0576	113	0.300182
310863	115.387	661050	5728.98	122558	1062.15	1474	12.7744 371	3.21527	44	0.381325

310872	182.851	987910	5402.82	184558	1009.34	2338	12.7864595	3.25402	65	0.355481
310969	173.278	872507	5035.3	163744	944.979	1989	11.4787515	2.9721	52	0.300096
311071	227.685	1150703	5053.93	225506	990.431	2808	12.3328686	3.01294	78	0.342579
311170	370.33	1711282	4620.96	345932	934.118	4350	11.74631159	3.12964	118	0.318635
311244	250.779	1307649	5214.36	252345	1006.25	3101	12.3655784	3.12626	87	0.34692
311287	366.393	1797975	4907.24	354058	966.335	4382	11.95981201	3.2779	90	0.245638
311321	364.174	1758051	4827.5	347231	953.474	4255	11.6841070	2.93815	121	0.332258
311365	275.696	1523714	5526.79	275758	1000.22	3378	12.2526876	3.17741	93	0.337328
311402	330.467	1646640	4982.77	319872	967.94	3903	11.81061014	3.06839	94	0.284446
311473	102.189	474917	4647.44	95764	937.126	1169	11.4396310	3.03359	29	0.283788
311481	339.157	1675312	4939.63	327755	966.381	4011	11.8264995	2.93374	136	0.400994

822 L. Signal systematic uncertainties

823 This section presents the signal systematic uncertainties evaluated for every signal point in the 10-quark
 824 and 6-quark models.

Not reviewed, for internal circulation only

$m_{\tilde{g}}$	$m_{\tilde{\chi}_1^0}$	Yield	NP Combined + JER (%)	largeR Jet Mass Scale (%)	b-tag (%)	All Combined (%)
700	450	50.0	+0.0	+21.6	+4.9	+22.1
800	450	52.0	-0.0	-19.1	4.9	-19.8
900	450	55.5	+0.0	+52.5	+2.8	+52.5
1000	50	13.8	-0.0	-40.3	2.8	-40.4
1000	250	28.4	+0.0	+33.7	+2.9	+33.9
1000	450	52.5	+0.0	-21.2	2.9	-21.4
1000	650	54.6	+0.0	+22.3	+2.9	+22.4
1000	850	40.1	+0.0	-9.3	2.9	-9.7
1200	50	10.6	+0.0	+17.3	+4.7	+17.9
1200	250	25.7	+0.0	-25.5	4.7	-25.9
1200	450	45.1	+0.0	+24.8	+2.8	+25.1
1200	650	63.5	+0.0	-18.2	2.8	-18.4
1200	850	53.7	+0.0	+25.5	+2.7	+25.7
1200	1050	26.7	+0.0	-19.8	+1.4	+20.0
1400	50	5.3	+0.0	+23.1	1.4	+23.1
1400	250	12.9	+0.0	-25.7	+6.3	-25.8
1400	450	30.1	+0.0	+24.8	+6.3	+25.7
1400	650	42.8	+0.0	-20.4	6.3	-21.5
1400	850	46.4	+0.0	+14.0	+1.3	+14.1
1400	1050	35.8	+0.0	-24.4	1.3	-24.4
1400	1250	17.6	+0.0	+21.9	+1.3	+22.0
1600	50	3.4	+0.0	-18.6	1.3	-18.7
1600	250	8.7	+0.0	+24.6	+2.0	+24.7
1600	450	17.3	+0.0	-20.4	2.0	-20.5
1600	650	24.1	+0.0	+18.5	+1.2	+18.6
1600	850	29.9	+0.0	-22.3	1.2	-22.4
1600	1050	27.7	+0.0	+18.4	+1.5	+18.4
1600	1250	21.0	+0.0	-16.7	1.5	-16.7
1600	1450	9.6	+0.0	+16.1	+3.3	+16.5
1700	50	2.6	+0.0	-13.1	3.3	-13.8
1700	250	5.9	+0.0	+19.7	+2.8	+19.9
1700	450	11.7	+0.0	-14.8	+1.4	+15.9
1700	650	17.8	+0.0	+15.8	+1.4	+15.9
1700	850	21.7	+0.0	-15.9	+1.6	+16.0
1700	1050	22.1	+0.0	+14.1	+1.6	+16.0
1700	1250	18.9	+0.0	-13.3	+1.4	+14.2
1700	1450	10.9	+0.0	+13.0	+1.7	+13.4
1800	50	2.0	+0.0	-13.1	+1.7	+13.1
1800	250	4.7	+0.0	+12.6	+1.4	+12.7
1800	450	8.9	+0.0	-14.7	+1.4	+14.5
			-0.2	+14.4	+1.4	+14.5
			-0.1	-16.0	1.4	-16.1
			+0.5	+19.8	+1.7	+16.9
			-0.4	-14.6	1.7	-14.7
			+0.3	+15.7	+3.7	+16.1
			-0.3	-12.9	3.7	-12.8
			+0.3	+13.9	+1.5	+14.0
			-0.3	-16.3	1.5	-16.4
			+0.6	+13.2	+1.3	+13.3
			-0.6	-14.6	1.3	-14.7
			+0.1	+13.0	+1.4	+13.1
			-0.3	-12.8	1.4	-12.8
			+0.2	+14.1	+1.3	+14.2
			-0.2	-12.5	1.3	-12.6
			+0.2	+12.4	+1.2	+12.4
			-0.3	-12.4	1.2	-12.4
			+0.2	+15.6	+1.2	+15.6
			-0.2	-12.8	1.2	-12.9
			+0.3	+15.7	+1.0	+15.8
			-0.2	-14.7	1.0	-14.7
			+0.0	+14.4	+4.0	+14.9
			-0.0	-17.4	4.0	-17.8
			+0.3	+15.7	+1.7	+15.8
			-0.2	-15.8	+1.3	-15.9
			+0.5	+12.3	+1.3	+12.4
			-0.2	-11.9	1.3	-12.0

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1800	650	13.0	+0.4	+11.7	+1.3	+11.8
1800	850	15.6	-0.2	+11.6	+1.3	+11.3
1800	1050	16.0	-0.2	-10.6	+1.4	+10.6
1800	1250	15.0	+0.1	+10.7	1.4	+10.8
1800	1450	10.7	-0.3	-10.8	+1.2	+11.0
1800	1650	4.9	+0.1	+10.9	+1.1	+11.0
1900	50	1.3	-0.1	+13.1	+1.1	+12.7
1900	250	3.1	-0.0	-10.5	+1.3	+13.1
1900	450	6.0	-0.5	+15.8	2.6	+10.8
1900	650	9.0	+0.3	-13.4	+1.5	+15.8
1900	850	11.0	-0.2	+11.7	+1.5	+13.9
1900	1050	11.8	-0.1	-10.3	+1.8	+11.9
1900	1250	11.2	+0.2	+10.8	1.8	+10.4
1900	1450	8.8	+0.2	-10.2	+1.4	+10.9
1900	1650	5.5	+0.1	+9.3	1.4	+9.4
2000	50	0.9	-0.3	-10.6	+1.4	+10.7
2000	250	2.2	+0.0	+9.7	+1.2	+9.8
2000	450	4.0	-0.2	-9.3	1.2	-9.4
2000	650	5.9	+0.3	+9.4	+1.3	+9.5
2000	850	7.5	-0.2	-9.3	1.3	-9.4
2000	1050	8.2	+0.1	+12.0	+1.3	+12.0
2000	1250	8.0	-0.2	-11.1	1.3	-11.2
2000	1450	7.0	+0.1	+12.6	+0.9	+12.6
2000	1650	5.0	-0.3	-12.3	+5.0	+12.3
2000	1850	2.5	+0.0	+11.2	5.0	-13.4
2100	50	0.7	-0.4	-12.4	+1.4	+10.6
2100	250	1.5	-0.3	+10.5	-8.7	-8.8
2100	450	2.8	+0.2	-8.7	1.4	+10.2
2100	650	3.8	-0.4	+10.1	+1.5	+10.9
2100	850	4.9	+0.4	-10.3	+1.2	-9.7
2100	1050	5.5	-0.2	+10.8	-9.0	+9.1
2100	1250	5.7	+0.1	-11.1	+1.4	+8.3
2100	1450	5.1	-0.2	+9.3	+1.4	-8.9
2100	1650	4.1	+0.1	-12.8	+1.3	-7.6
2100	1850	2.6	-0.1	+12.4	-5.2	-12.9

$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	yield	NP1	NP2	NP3	Baseline	Modeling	Stat.	Tracking	b-tagging	JER
1000	50	9568	+0	+0	+0	+9.92126	+6.59674	+7.72605	+17.1342	+19.0886	+0
1000	250	7016	0	0	0	-1.0603	0	-4.61731	-7.94586	-18.7538	0
1000	450	0.0283	+1.34419	+0	+1.34419	-12.5288	-9.13083	-7.7059	-18.7155	-17.0376	0
1000	650	1553	+0	+0	0	+15.7229	+7.26627	+8.62344	+15.4911	+18.2239	+1.34419
1000	850	49.5058	+0.499982	+0.499982	+0	-10.5864	-4.4484	-5.52358	-15.152	-14.3225	+0
1200	50	6603	+0	0	0	-13.2442	-7.76541	-7.92841	-19.0671	-15.7007	0.499982
1200	250	9358	-1.14237	0	0	+11.9454	+8.89238	+11.212	+16.4068	+20.5419	+1.14237
1200	450	45.5436	+0.342709	+0	+0	+6.84794	+3.33118	+3.20893	+11.333	+16.8085	+0
1200	650	64.0737	+0	+0	0	-12.2674	-8.41613	-8.30266	-17.4709	-16.5355	0
1200	850	54.2682	-0.287612	0	+0	+11.0349	+5.63919	+4.42583	+17.5407	+16.2848	+0.342709
1200	1050	26.996	+0	+0	+0	-10.591	-5.60195	-6.65214	-12.5952	-16.0936	0.342709
1400	50	5.32206	+0	+0	+0	+13.6515	+7.37842	+8.86569	+16.8898	+16.2082	+0.0398369
1400	250	13.0419	+0.707038	+0.353523	+0.353523	+9.1827	+2.98881	+3.89766	+13.4692	+17.26	+0.8663
1400	450	30.3609	+0.680577	0	+0	-7.40794	-4.26569	-3.55835	-12.4133	-17.5577	0
1400	650	43.2508	-0.16873	0	-0.16873	+10.1877	+4.13589	-5.51762	-11.4765	-16.4381	+1.05224
1400	850	46.8191	+0.117441	+0	+0	-7.37048	+4.86148	+5.75051	+12.3135	+17.0725	+0.106599
1400	1050	36.1507	-0.224616	0	0	-9.29045	+3.89626	-5.17957	-11.8859	-17.1412	-0.106599
1400	1250	17.7803	+0.314833	+0.0984747	+0	+10.0729	+4.67039	+5.17772	+14.2632	+17.9466	+0.190623
1400	1450	-0.196949	0	0	0	-10.2292	-5.01723	-5.82069	-12.4677	-17.8982	-0.190623
1400	1600	-0.430188	+0	+0	+0	+11.8271	+6.34944	+7.28154	+16.0652	+16.4809	+0.127535
1400	1800	-0.127535	+0	+0	+0	-10.2984	-6.51655	-6.47378	-12.6511	-18.4098	0.127535
1400	2000	-0.403022	+0	+0	+0	+9.82518	+3.72301	+6.15608	+12.5966	+18.3653	+0
1600	50	3.43774	+0	+0	+0	-10.8054	-5.05572	-6.01951	-14.7181	-18.0728	0
1600	250	8.75381	+1.07022	+0.193995	+0.193995	+8.2618	+6.22217	+4.52736	+6.19098	+12.8495	+18.865
1600	450	17.4806	-0.699078	0	-0.337316	-8.14852	+7.7825	+4.62298	+4.70744	+12.1973	+17.3675
1600	650	24.3764	+0.188661	+0.104201	+0.104201	-7.63052	+4.85109	-5.52267	-11.891	-17.3183	-0.112428
1600	850	30.1695	-0.267949	0	0	+7.02068	+4.20445	+4.27551	+10.6304	+17.8815	+0.182849
1600	1050	27.993	+0.43426	+0.0708677	+0.13143	-6.88794	-4.42195	-4.28531	-9.58554	-17.6199	0.182849
1600	1250	21.2404	-0.121129	0	0	+6.76672	+3.41227	+3.99773	+9.81728	+17.8316	+0.158674
1600	1450	9.71014	+0.0978705	+0	+0	-6.86537	-3.46826	-3.91721	-9.82335	-17.6153	0.158674
1600	1600	-0.0472896	-0.0472896	-0.0472896	-0.0472896	-6.44743	+3.80735	+3.94616	+9.36692	+17.6285	+0.00171829
1600	1800	+0.263705	+0	+0	+0	-7.74471	-4.66849	-4.65473	-10.5567	-17.5539	-0.00171829
1600	2000	-0.158222	0	-0.0527382	+0.139018	+7.27931	+4.00618	+4.28647	+10.9937	+17.9287	+0.0723481
1600	2200	+0.139018	+0	+0.139018	+0.139018	+7.2931	+7.29001	+6.43851	+14.6492	+17.7443	+0.324733
1600	2400	-0.0695045	-0.0695045	-0.0695045	-0.0695045	-8.6574	-4.498	-4.81661	-11.7942	-17.8335	-0.0723481
1600	2600	+0.324733	+0	+0.152037	+0.152037	+6.19071	+7.29001	+6.43851	+14.6492	+17.7443	+0.324733
1600	2800	-0.18457	0	0	-7.24729	-4.29783	-5.03074	-10.7466	-18.2399	0.324733	

Table 18: Expected signal yield (normalized to 36.1 fb^{-1}) and systematic uncertainties (in percentage) for various signal points.

$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	yield	NP1	NP2	NP3	Baseline	Modeling	Stat.	Tracking	b-tagging	JER
1700	50	2.3076	+0 -0.34298 +0.144489	+0 0 +0.144489	+0 0 +0.144489	+6.00431 -5.32507 +6.92585	+3.90336 -3.31421 +4.35479	+8.74344 -6.05798 +5.08608	+10.8286 -8.17634 +10.0404	+17.6677 -17.4235 +18.5893	+0.34298 -0.34298 +0.000804674
1700	250	5.96515	-0.287386 +0.527124	0 +0.0723514	-0.143701 +0.0895803	-8.15383 +6.57429	-4.17971 +4.10297	-5.28911 +3.94158	-12.4553 +9.76422	-18.3837 +18.0842	0.000804674 +0.221292
1700	450	1.8463	+0.0954299 -0.244061	+0.0477177 -0.0953854	-0.0677339 -0.0476676	-6.99605 +6.49726	-3.95041 +4.10297	-4.08211 +3.94158	-11.4772 +9.76422	-17.2851 +18.0842	+0.0476676 +0.15947
1700	650	1.964	-0.244061 +0.0954299	-0.0953854 +0.0477177	-0.0476676 -6.39547	-3.879 +6.71587	-4.2695 +3.76349	-4.2695 +4.27939	-9.41534 +11.0089	-18.0123 +17.8748	-0.0476676 +0.15947
1700	850	2.8893	-0.0391561 +0.0384597	0 +0.0384597	0 +0	-6.40035 +6.23038	-3.25202 +3.60714	-3.9233 +3.82953	-9.4533 +9.32174	-17.6833 +17.7188	-0.15947 +0.192289
1700	1050	2.2883	-0.155876 +0.144243	-0.0384552 +0.0448087	-0.0769149 +0	-5.74032 +7.56817	-3.44758 +4.44509	-4.54326 +5.38779	-9.34053 +11.6582	-17.5793 +17.8156	-0.192289 +0.196114
1700	1250	1.302	-0.137892 +0.156294	0 +0.156294	0 +0.0781469	-5.98555 +8.02214	-3.3928 +4.26262	-4.00434 +5.35662	-10.0708 +11.676	-17.7816 +18.0507	-0.196114 +0.156294
1700	1450	1.9691	-0.0781377 +0	0 +0	0 +0	-7.59694 +6.48747	-4.78658 +4.00964	-5.42074 +5.97193	-10.2901 +10.6589	-17.8717 +20.3841	0.156294 +0
1800	50	2.96136	+0 0	+0 0	+0 0	-8.39383 +7.83083	-4.44779 +4.47659	-6.97588 +5.81027	-12.75 +11.4347	-19.9478 +18.8096	0 +0.222284
1800	250	4.6642	+0.111132 -0.111132	+0.111132 0	+0.111132 0	-8.15411 +5.73372	-4.97967 +3.77446	-6.24697 +4.96756	-10.9817 +8.94801	-18.6787 +18.4663	-0.222284 +0.00329588
1800	450	8.9809	+0.398401 -0.168112	+0.286319 -0.0560411	+0.225378 0	-5.79242 +5.64986	-3.02421 +3.1305	-4.38701 +3.47139	-8.95407 +9.14944	-18.2645 +18.1584	0.00329588 +0.0769454
1800	650	15.0807	+0.311512 -0.161383	+0.115422 -0.0459608	+0.192367 -0.0459608	+5.61618 +5.37046	-3.36782 +3.01303	-3.86226 +3.3792	-8.78644 +8.77497	-17.9602 +17.8526	0.0769454 +0.0159727
1800	850	15.7394	+0.191844 -0.159873	+0.0319772 0	+0.0319772 -0.063948	-5.1814 +5.1814	-2.98954 +3.14182	-3.76545 +3.38604	-7.8387 +7.94218	-17.8326 +17.7407	0.0159727 +0.0739014
1800	1050	16.1553	-0.0664797 +0.0333319	-0.032788 +0	-0.0664797 +0	-5.23343 +4.95029	-2.9956 +3.10778	-3.68929 +3.48306	-8.14463 +8.53644	-17.6747 +18.3532	-0.0739014 +0.266629
1800	1250	15.0996	-0.16664 +0.0464736	-0.0333253 +0.0464736	-0.0333253 +0	-5.43091 +6.452	-2.85379 +3.43248	-3.4751 +4.33726	-8.161 +9.92289	-18.2112 +18.6192	-0.266629 +0.000664832
1800	1450	10.8298	-0.188424 +0.434277	-0.0464736 +0.107323	0 +0	-6.11882 +7.25314	-3.88584 +3.37897	-4.10318 +4.55322	-9.43109 +11.0629	-18.6249 +18.4292	-0.000664832 +0.098388
1800	1650	4.93556	0 +0.285626	0 +0.0951872	0 +0	-6.07951 +7.03734	-3.44826 +3.85246	-4.55687 +5.49527	-9.67582 +12.4242	-18.4954 +18.6592	+0.098388 +0.0356473
1900	250	3.13067	-0.482197 +0.295881	-0.194271 +0.049319	0 +0.049319	-6.31452 +5.89957	-3.36736 +2.96379	-6.25795 +4.22265	-9.49068 +8.7282	-18.4333 +18.2011	-0.0356473 +0.10423
1900	450	6.04433	-0.14794 +0.171113	-0.0493024 +0.0329233	-0.0493024 +0.0329233	-5.38308 +5.363287	-2.71473 +3.18969	-3.31541 +3.49499	-7.62054 +8.09326	-18.8921 +18.3742	-0.10423 +0.136013
1900	650	9.05133	-0.164661 +0.174538	0 +0.0498728	0 +0.0498728	-4.93055 +4.77695	-2.74067 +2.67764	-3.20811 +3.35336	-7.58327 +7.31769	-18.2049 +18.652	+0.0242337 +0.136013
1900	1050	11.9544	-0.224402 +0.0790188	-0.024928 +0.0263337	-0.0498644 +0	-4.56125 +4.57323	-2.46205 +2.66984	-3.1565 +2.79082	-7.10717 +7.304	-18.4949 +18.6814	0.0242337 +0.133551
1900	1250	11.3163	-0.131695 +0.0670707	-0.0263425 +0.0335354	-0.0263425 +0.0335354	-4.63671 +6.16808	-2.4279 +3.27656	-2.72268 +4.01307	-7.15217 +8.85653	-18.5907 +18.5674	0.133551 +0.169477
1900	1450	8.88912	-0.100595 +0	-0.0670595 +0	0 +0	-5.4409 +4.75916	-2.78945 +1.94621	-4.00169 +4.9756	-8.41542 +8.66672	-18.3797 +21.2918	-0.169477 +0
2000	50	0.944348	-0.195691 +0.426838	0 +0.174698	0 +0.0790784	-4.40854 +5.09375	-2.94108 +2.38637	-6.01823 +3.74605	-9.50021 +8.03707	-20.9505 +19.9156	0 +0.409235
2000	250	2.26105	-0.237235 +0.308774	0 +0.132332	0 +0.0441106	-3.80081 +4.70269	-2.37235 +2.84151	-3.01228 +4.02709	-6.75974 +7.44505	-19.6077 +18.8949	0.409235 +0.132332
2000	450	4.05344	-0.178885 +0.282782	0 +0.0628367	0 +0.0628367	-5.19805 +5.38701	-2.48825 +2.95989	-3.00602 +3.71802	-6.60445 +8.09759	-18.7063 +18.6055	0.132332 +0.0566766
2000	650	5.99013	-0.131834 +0.21451	0 +0.047188	-0.0628367 +0.0729462	-4.76699 +4.27937	-2.72729 +2.793	-3.42644 +3.29302	-7.19158 +6.63332	-18.4241 +18.79	0.0566766 +0.0510676
2000	850	7.57819	-0.188752 +0.067116	-0.0943761 +0.0434323	-0.047188 -0.0434323	-4.13266 +3.9738	-2.43838 +2.21217	-3.25169 +2.64471	-6.82688 +6.2091	-18.7553 +18.7138	-0.0510676 +0.0651485
2000	1050	8.2335	-0.217162 +0.19841	-0.0434323 +0.0661365	-0.0434323 +0.0881821	-4.37353 +4.38058	-2.56377 +2.59042	-3.00602 +3.05901	-6.49254 +7.11383	-18.6765 +18.7417	-0.0651485 +0.0220455
2000	1250	8.11049	-0.176364 +0.0253256	-0.0220455 +0.0253256	-0.0220455 +0.0253256	-3.57767 +4.66199	-1.87553 +2.53326	-2.52093 +3.24636	-5.71823 +6.80568	-18.6097 +18.8145	-0.0220455 +0.133016
2000	1450	7.06006	-0.0812316 +0.212452	0 +0.0354086	0 +0.0354086	-4.5399 +5.1817	-2.66843 +2.64159	-3.29392 +3.38594	-6.92474 +8.46959	-18.7614 +19.389	-0.133016 +0.0354086
2000	1650	5.04962	-0.106226 +0.212452	-0.0354086 +0.0354086	-0.0354086 +0.0354086	-5.60837 +5.99186	-3.31306 +5.21343	-3.88255 +4.07278	-8.1424 +8.43427	-19.2099 +18.7489	-0.0354086 +0.00472563
2000	1850	2.51818	+0 -0.355018	+0 -0.0710036	+0 -0.0710036	-5.52279 -3.73337	-3.73337 -5.15467	-5.15467 -9.34741	-9.34741 -18.9577	-18.9577 -0.00472563	

Table 19: **continued from Table 18** Expected signal yield (normalized to 36.1 fb^{-1}) and systematic uncertainties (in percentage) for various signal points.

DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	4jSRb (%)	4jSR (%)	5jSRb (%)	5jSR (%)
403550	700	450	0.236624	0.236819	0.308249	0.277641
403551	800	450	0.27918	0.249127	0.294387	0.28902
403552	900	450	0.234498	0.225028	0.199591	0.185502
403553	1000	50	0.225741	0.25638	0.250047	0.264714
403554	1000	250	0.209673	0.215408	0.206608	0.189883
403555	1000	450	0.208957	0.207684	0.185579	0.177785
403556	1000	650	0.196782	0.192365	0.244046	0.263884
403557	1000	850	0.224021	0.228428	0.241838	0.241219
403558	1200	50	0.203403	0.215866	0.219683	0.237405
403559	1200	250	0.203227	0.210131	0.205529	0.211705
403560	1200	450	0.194538	0.195742	0.191454	0.202765
403561	1200	650	0.185178	0.176881	0.187564	0.186292
403562	1200	850	0.20197	0.206697	0.189673	0.190681
403563	1200	1050	0.19102	0.185923	0.216026	0.222248
403564	1400	50	0.192773	0.196036	0.231155	0.203585
403565	1400	250	0.172009	0.164512	0.179917	0.190101
403566	1400	450	0.152216	0.142841	0.175889	0.169058
403567	1400	650	0.143855	0.144749	0.149313	0.153336
403568	1400	850	0.140294	0.137299	0.149739	0.150202
403569	1400	1050	0.155632	0.156696	0.149016	0.145901
403570	1400	1250	0.185034	0.184522	0.196556	0.192621
403571	1600	50	0.177965	0.165404	0.227007	0.21367
403572	1600	250	0.148996	0.148041	0.193514	0.195676
403573	1600	450	0.121962	0.12176	0.15579	0.156931
403574	1600	650	0.120264	0.118353	0.130474	0.133179
403575	1600	850	0.110106	0.106116	0.110396	0.11106
403576	1600	1050	0.122558	0.121997	0.121356	0.121321
403577	1600	1250	0.11099	0.112479	0.131765	0.130103
403578	1600	1450	0.137892	0.138825	0.170557	0.172584
403579	1700	50	0.140821	0.149835	0.19214	0.186207
403580	1700	250	0.119502	0.116116	0.166172	0.160268
403581	1700	450	0.106901	0.100312	0.15247	0.145359
403582	1700	650	0.100844	0.0965058	0.1148	0.111538
403583	1700	850	0.0901765	0.0931163	0.100439	0.0999855
403584	1700	1050	0.0906817	0.0899911	0.100769	0.0971868
403585	1700	1250	0.0953923	0.0939165	0.12235	0.120566
403586	1700	1450	0.117725	0.119581	0.151816	0.154949
403587	1800	50	0.122812	0.117751	0.208666	0.212758
403588	1800	250	0.113594	0.114736	0.144148	0.145294
403589	1800	450	0.086218	0.0844961	0.129716	0.131807
403590	1800	650	0.0849159	0.0829334	0.103732	0.0994394
403591	1800	850	0.0805418	0.0817488	0.0833116	0.0848519
403592	1800	1050	0.0827547	0.0823001	0.0895339	0.0875088
403593	1800	1250	0.0770665	0.0784044	0.097701	0.0984775
403594	1800	1450	0.0989083	0.101447	0.122089	0.119335

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403595	1800	1650	0.117695	0.119435	0.155718	0.157358
403596	1900	50	0.12367	0.117766	0.202181	0.198077
403597	1900	250	0.0894459	0.0832758	0.156728	0.147307
403598	1900	450	0.0793711	0.0789673	0.116667	0.116381
403599	1900	650	0.0762129	0.0777106	0.089842	0.0896488
403600	1900	850	0.0661505	0.0659411	0.0784583	0.0796338
403601	1900	1050	0.062224	0.0623871	0.0727556	0.0727169
403602	1900	1250	0.0691312	0.0681364	0.0782443	0.0771157
403603	1900	1450	0.067924	0.0687919	0.085014	0.0828698
403604	1900	1650	0.0893179	0.087497	0.118957	0.115981
403605	900	-	0.279386	0.280273	0.224981	0.240588
403606	1000	-	0.229607	0.231146	0.157095	0.159549
403607	1100	-	0.226276	0.232722	0.258429	0.271138
403608	1200	-	0.239368	0.237869	0.250437	0.256864
403609	1300	-	0.209871	0.20765	0.22563	0.22664
403610	1400	-	0.196773	0.197528	0.221672	0.223218
403611	1500	-	0.160614	0.158983	0.223195	0.220001
403612	1600	-	0.144304	0.143509	0.201267	0.202456
403613	1700	-	0.141125	0.141093	0.19898	0.201755
403614	1800	-	0.129563	0.126698	0.176546	0.174071
403615	2000	50	0.105598	0.118347	0.200052	0.212375
403616	2000	250	0.0938572	0.0906801	0.143678	0.144153
403617	2000	450	0.0693571	0.0686977	0.103049	0.100368
403618	2000	650	0.0639893	0.064938	0.0763289	0.0767481
403619	2000	850	0.057722	0.0586827	0.0647408	0.0644235
403620	2000	1050	0.0558919	0.0549441	0.0628274	0.0623307
403621	2000	1250	0.0522671	0.0533018	0.062553	0.0613861
403622	2000	1450	0.0578024	0.0569448	0.0748852	0.0768788
403623	2000	1650	0.0638951	0.0640528	0.0850755	0.0868447
403624	2000	1850	0.0948428	0.0949894	0.144849	0.145075
403625	2100	50	0.0878434	0.0832108	0.178234	0.158416
403626	2100	250	0.0684991	0.0676035	0.116253	0.119274
403627	2100	450	0.0578327	0.0543384	0.086814	0.0835584
403628	2100	650	0.0514231	0.0505085	0.0712988	0.0700441
403629	2100	850	0.0436191	0.044406	0.0579108	0.0565892
403981	2100	1050	0.0424189	0.0404847	0.0527266	0.0498703
403982	2100	1250	0.0429578	0.0422897	0.0559083	0.0541256
403983	2100	1450	0.0478182	0.0470562	0.0552312	0.0527911
403984	2100	1650	0.0474111	0.0471178	0.0638693	0.0650037
403985	2100	1850	0.0692943	0.0707137	0.101532	0.103373

Table 20: QCD scale, α_s uncertainties.

DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	4jSRb (%)	4jSR (%)	5jSRb (%)	5jSR (%)
403550	700	450	0.360206	0.360206	0.412338	0.412338
403551	800	450	0.102777	0.102777	0.207427	0.207427

403552	900	450	0.126069	0.126069	0.155417	0.155417
403553	1000	50	0.160333	0.160333	0.130914	0.130914
403554	1000	250	0.144998	0.144998	0.108043	0.108043
403555	1000	450	0.0964474	0.0964474	0.175025	0.175025
403556	1000	650	0.0923077	0.0923077	0.0730694	0.0730694
403557	1000	850	0.0318233	0.0318233	0.12871	0.12871
403558	1200	50	0.0751647	0.0751647	0.0735415	0.0735415
403559	1200	250	0.10388	0.10388	0.0826058	0.0826058
403560	1200	450	0.0521002	0.0521002	0.0660822	0.0660822
403561	1200	650	0.113108	0.113108	0.0798755	0.0798755
403562	1200	850	0.0370598	0.0370598	0.071088	0.071088
403563	1200	1050	0.0801567	0.0801567	0.101411	0.101411
403564	1400	50	0.071718	0.071718	0.10235	0.10235
403565	1400	250	0.0616935	0.0616935	0.145871	0.145871
403566	1400	450	0.0260102	0.0260102	0.0579708	0.0579708
403567	1400	650	0.0534314	0.0534314	0.0994129	0.0994129
403568	1400	850	0.0778691	0.0778691	0.0417791	0.0417791
403569	1400	1050	0.0386117	0.0386117	0.0338794	0.0338794
403570	1400	1250	0.0646494	0.0646494	0.0735857	0.0735857
403571	1600	50	0.084153	0.084153	0.0945781	0.0945781
403572	1600	250	0.0341451	0.0341451	0.065537	0.065537
403573	1600	450	0.0608412	0.0608412	0.0825174	0.0825174
403574	1600	650	0.0226267	0.0226267	0.023287	0.023287
403575	1600	850	0.0314268	0.0314268	0.026356	0.026356
403576	1600	1050	0.0583082	0.0583082	0.045578	0.045578
403577	1600	1250	0.0143696	0.0143696	0.0339898	0.0339898
403578	1600	1450	0.0688314	0.0688314	0.0770537	0.0770537
403579	1700	50	0.144724	0.144724	0.148742	0.148742
403580	1700	250	0.0469454	0.0469454	0.0399466	0.0399466
403581	1700	450	0.0428287	0.0428287	0.0472713	0.0472713
403582	1700	650	0.0337162	0.0337162	0.0249037	0.0249037
403583	1700	850	0.0305686	0.0305686	0.0344235	0.0344235
403584	1700	1050	0.0207023	0.0207023	0.0400941	0.0400941
403585	1700	1250	0.0181012	0.0181012	0.022123	0.022123
403586	1700	1450	0.0306521	0.0306521	0.0111622	0.0111622
403587	1800	50	0.0320123	0.0320123	0.112356	0.112356
403588	1800	250	0.0367441	0.0367441	0.0667025	0.0667025
403589	1800	450	0.0560918	0.0560918	0.036927	0.036927
403590	1800	650	0.0304842	0.0304842	0.0258506	0.0258506
403591	1800	850	0.02256	0.02256	0.0179578	0.0179578
403592	1800	1050	0.0283868	0.0283868	0.0273356	0.0273356
403593	1800	1250	0.0200056	0.0200056	0.0216611	0.0216611
403594	1800	1450	0.0140548	0.0140548	0.047995	0.047995
403595	1800	1650	0.0602605	0.0602605	0.039856	0.039856
403596	1900	50	0.0672439	0.0672439	0.0509026	0.0509026
403597	1900	250	0.0509805	0.0509805	0.0713956	0.0713956
403598	1900	450	0.0142215	0.0142215	0.037855	0.037855

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403599	1900	650	0.0264694	0.0264694	0.0213384	0.0213384
403600	1900	850	0.00674613	0.00674613	0.0137325	0.0137325
403601	1900	1050	0.025343	0.025343	0.0119476	0.0119476
403602	1900	1250	0.0133266	0.0133266	0.00888444	0.00888444
403603	1900	1450	0.0180073	0.0180073	0.0195517	0.0195517
403604	1900	1650	0.0138375	0.0138375	0.0155516	0.0155516
403605	900	-	0.276289	0.276289	0.28537	0.28537
403606	1000	-	0.122065	0.122065	0.280728	0.280728
403607	1100	-	0.139437	0.139437	0.130411	0.130411
403608	1200	-	0.117504	0.117504	0.0680283	0.0680283
403609	1300	-	0.0623218	0.0623218	0.176242	0.176242
403610	1400	-	0.0784532	0.0784532	0.0540231	0.0540231
403611	1500	-	0.127603	0.127603	0.0737305	0.0737305
403612	1600	-	0.047918	0.047918	0.0519771	0.0519771
403613	1700	-	0.0959545	0.0959545	0.0987689	0.0987689
403614	1800	-	0.0815708	0.0815708	0.123194	0.123194
403615	2000	50	0.0551004	0.0551004	0.054329	0.054329
403616	2000	250	0.0360785	0.0360785	0.0614247	0.0614247
403617	2000	450	0.0462708	0.0462708	0.0423031	0.0423031
403618	2000	650	0.0215806	0.0215806	0.0379579	0.0379579
403619	2000	850	0.0194308	0.0194308	0.0256588	0.0256588
403620	2000	1050	0.0379085	0.0379085	0.0151485	0.0151485
403621	2000	1250	0.0350613	0.0350613	0.0444129	0.0444129
403622	2000	1450	0.0267852	0.0267852	0.0282129	0.0282129
403623	2000	1650	0.00985944	0.00985944	0.0461824	0.0461824
403624	2000	1850	0.0532942	0.0532942	0.0872003	0.0872003
403625	2100	50	0.0632303	0.0632303	0.0923489	0.0923489
403626	2100	250	0.0579379	0.0579379	0.0511582	0.0511582
403627	2100	450	0.0398985	0.0398985	0.0292309	0.0292309
403628	2100	650	0.0445307	0.0445307	0.0294402	0.0294402
403629	2100	850	0.0373669	0.0373669	0.0191655	0.0191655
403981	2100	1050	0.013561	0.013561	0.0276069	0.0276069
403982	2100	1250	0.0207286	0.0207286	0.0160121	0.0160121
403983	2100	1450	0.0184458	0.0184458	0.0132499	0.0132499
403984	2100	1650	0.0243378	0.0243378	0.0176747	0.0176747
403985	2100	1850	0.0232052	0.0232052	0.0376339	0.0376339

Table 21: PDF uncertainties.

⁸²⁵ **M. Expected signal yields in various regions at 36.1 fb⁻¹**

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	3jCR	UDR1	UDR2	5jSRb1	5jSRb1, $M_J^\Sigma > 0.8 \text{ TeV}$
403550	700	450	18007.19	26226.63	3563.41	1169.78	135.94
403551	800	450	8253.4	9748.88	2300.64	1262.93	220.71
403552	900	450	3641.39	3585.51	1099.23	1109.54	243.94
403553	1000	50	2546.68	1128.03	121.9	700.45	54.06
403554	1000	250	2021.49	1426.57	220.77	650.93	123.28
403555	1000	450	1581.89	1312.7	420.08	892.14	207.88
403556	1000	650	1474.7	1257.77	456.77	902.57	230.1
403557	1000	850	1599.84	1495.83	265.92	713.35	152.81
403558	1200	50	555.11	188.16	8.51	286.99	38.6
403559	1200	250	428.14	227.17	20.23	292.95	81.45
403560	1200	450	315.81	179.95	36.58	416.51	142.5
403561	1200	650	257.48	153.09	46.23	518.47	207.7
403562	1200	850	285.37	183.29	44.9	460.86	167.06
403563	1200	1050	354.18	232.89	25.72	327.94	92.95
403564	1400	50	138.21	37.3	0.55	114.33	20.02
403565	1400	250	105.07	43.95	1.98	117.48	40.26
403566	1400	450	71.65	34.02	3.03	178.68	81.21
403567	1400	650	55.12	26.19	4.16	223.07	108.39
403568	1400	850	52.25	25.28	3.82	237.66	119.47
403569	1400	1050	67.22	32.58	4.14	193.63	92.77
403570	1400	1250	84.69	45.63	2.25	139.2	49.37
403571	1600	50	37.28	9.77	0.1	42.95	9.98
403572	1600	250	28.18	10.73	0.04	48.54	23.17
403573	1600	450	19.54	7.54	0.33	68.67	36.47
403574	1600	650	13.83	4.89	0.32	90.01	51.77
403575	1600	850	10.95	3.82	0.38	99.26	61.03
403576	1600	1050	12.56	4.7	0.25	93.74	57.29
403577	1600	1250	17.92	6.49	0.41	74.82	43.55
403578	1600	1450	23.94	10.47	0.3	55.94	25.04

Table 22: Expected signal yield (normalized to 36.1 fb^{-1}) and systematic uncertainties (in percentage) for various signal points.

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	3jCR	UDR1	UDR2	5jSRb1	5jSRb1, $M_J^\Sigma > 0.8 \text{ TeV}$
403579	1700	50	20.6	4.72	0.03	27.12	6.96
403580	1700	250	15.55	5.36	0.06	30.36	14.7
403581	1700	450	10.8	4.15	0.09	40.59	24.02
403582	1700	650	7.31	2.17	0.15	55.12	34.57
403583	1700	850	6.06	1.67	0.1	62.45	40.99
403584	1700	1050	5.7	1.77	0.07	62.22	41.47
403585	1700	1250	7.71	2.46	0.13	55.07	35.58
403586	1700	1450	11.16	4.58	0.18	40.12	22.78
403587	1800	50	10.83	2.47	0.02	16.84	5.06
403588	1800	250	8.82	2.91	0.02	19.2	10.1
403589	1800	450	6.08	2.06	0.03	25.6	16.09
403590	1800	650	3.85	1.1	0.05	34.15	22.81
403591	1800	850	2.88	0.78	0.03	38.69	26.86
403592	1800	1050	2.87	0.76	0.01	39.95	28.37
403593	1800	1250	3.6	0.91	0.01	36.63	26.07
403594	1800	1450	5.14	1.5	0.05	29.38	19.53
403595	1800	1650	7.37	2.64	0.02	21.0	10.39
403597	1900	250	4.7	1.56	0.0	12.01	6.56
403598	1900	450	3.39	1.16	0.02	15.84	10.61
403599	1900	650	2.25	0.57	0.0	21.15	15.0
403601	1900	1050	1.37	0.29	0.01	25.11	18.95
403602	1900	1250	1.77	0.37	0.01	24.14	17.95
403603	1900	1450	2.25	0.59	0.0	20.33	14.7
403615	2000	50	3.74	0.75	0.0	6.32	2.18
403616	2000	250	2.91	0.87	0.0	7.6	4.41
403617	2000	450	2.04	0.6	0.0	9.68	6.72
403618	2000	650	1.34	0.32	0.0	12.99	9.43
403619	2000	850	0.9	0.19	0.0	14.95	11.43
403620	2000	1050	0.84	0.2	0.0	15.66	12.3
403621	2000	1250	0.84	0.19	0.0	15.56	12.18
403622	2000	1450	1.13	0.26	0.0	13.94	10.71
403623	2000	1650	1.64	0.48	0.0	11.34	8.28
403624	2000	1850	2.5	0.77	0.0	8.38	4.83
403626	2100	250	1.64	0.47	0.0	4.65	2.8
403627	2100	450	1.13	0.35	0.0	6.0	4.35
403628	2100	650	0.7	0.18	0.0	7.77	5.76
403629	2100	850	0.5	0.11	0.0	9.26	7.28
403982	2100	1250	0.46	0.11	0.0	10.01	8.17
403983	2100	1450	0.48	0.09	0.0	9.19	7.35
403984	2100	1650	0.72	0.15	0.0	7.81	6.12

Table 23: Expected signal yield (normalized to 36.1 fb^{-1}) and systematic uncertainties (in percentage) for various signal points.

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	4jVR	5jVR	4jVRb	5jVRb
403550	700	450	2164.7	411.5	1652.6	335.1
403551	800	450	1535.5	444.4	1174.8	330.7
403552	900	450	1048.3	307.1	776.2	229.7
403553	1000	50	866.4	263.0	466.5	147.8
403554	1000	250	705.4	215.3	489.6	157.1
403555	1000	450	676.6	233.0	515.7	181.4
403556	1000	650	618.7	222.5	480.1	172.0
403557	1000	850	681.1	206.5	528.5	165.3
403558	1200	50	273.4	98.4	151.6	56.4
403559	1200	250	238.9	79.3	168.0	55.4
403560	1200	450	233.0	104.2	175.3	77.8
403561	1200	650	230.7	116.5	181.3	90.5
403562	1200	850	222.4	103.2	176.7	81.3
403563	1200	1050	227.2	83.3	181.1	67.8
403564	1400	50	83.7	33.7	45.0	19.4
403565	1400	250	74.4	27.9	53.0	19.9
403566	1400	450	73.7	35.5	54.4	25.6
403567	1400	650	74.2	41.0	57.5	31.6
403568	1400	850	71.6	41.5	57.0	33.3
403569	1400	1050	73.8	37.7	58.0	30.7
403570	1400	1250	73.6	30.1	56.8	23.1
403571	1600	50	26.2	11.2	14.8	6.2
403572	1600	250	25.6	10.9	18.1	7.7
403573	1600	450	25.3	13.3	19.2	10.2
403574	1600	650	23.7	14.8	18.9	11.5
403575	1600	850	23.5	15.7	18.5	12.4
403576	1600	1050	23.2	14.7	18.2	11.6
403577	1600	1250	23.3	13.0	18.3	10.2
403578	1600	1450	24.4	10.2	18.7	7.8

Table 24: Expected signal yield (normalized to 36.1 fb^{-1}) for validation regions (**Part 1**).

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	4jVR	5jVR	4jVRb	5jVRb
403579	1700	50	15.2	7.0	8.3	4.0
403580	1700	250	14.6	6.2	10.5	4.7
403581	1700	450	15.2	8.3	11.3	6.2
403582	1700	650	14.1	9.0	11.2	7.2
403583	1700	850	13.1	8.6	10.2	6.7
403584	1700	1050	13.2	9.0	10.4	7.1
403585	1700	1250	13.4	8.5	10.3	6.8
403586	1700	1450	13.7	7.1	10.8	5.5
403587	1800	50	9.0	4.2	4.9	2.2
403588	1800	250	8.5	3.8	6.0	2.7
403589	1800	450	8.3	4.5	6.3	3.5
403590	1800	650	7.9	5.2	6.1	4.0
403591	1800	850	7.7	5.4	6.1	4.4
403592	1800	1050	7.1	5.2	5.7	4.2
403593	1800	1250	7.7	5.3	6.0	4.2
403594	1800	1450	8.0	4.8	6.1	3.7
403595	1800	1650	8.4	4.0	6.4	3.0
403596	1900	50	5.2	2.5	3.0	1.4
403597	1900	250	5.1	2.4	3.6	1.7
403598	1900	450	5.0	2.8	3.7	2.0
403599	1900	650	4.7	3.2	3.7	2.5
403600	1900	850	4.5	3.3	3.5	2.6
403601	1900	1050	4.2	3.1	3.3	2.5
403602	1900	1250	4.3	3.1	3.4	2.4
403603	1900	1450	4.8	3.2	3.7	2.4
403615	2000	50	3.1	1.5	1.7	0.8
403616	2000	250	2.8	1.3	2.0	0.9
403617	2000	450	2.9	1.6	2.2	1.2
403618	2000	650	2.8	1.8	2.1	1.4
403619	2000	850	2.6	1.9	2.0	1.4
403620	2000	1050	2.5	1.9	1.9	1.5
403621	2000	1250	2.4	1.8	1.8	1.4
403622	2000	1450	2.7	1.9	2.1	1.5
403623	2000	1650	2.9	1.8	2.2	1.3
403624	2000	1850	2.9	1.4	2.1	1.0
403625	2100	50	1.8	0.8	1.0	0.5
403626	2100	250	1.8	0.9	1.3	0.6
403627	2100	450	1.8	1.0	1.3	0.8
403628	2100	650	1.7	1.1	1.4	0.9
403629	2100	850	1.6	1.1	1.2	0.9
403981	2100	1050	1.4	1.1	1.1	0.8
403982	2100	1250	1.4	1.1	1.1	0.9
403983	2100	1450	1.5	1.1	1.1	0.8
403984	2100	1650	1.7	1.2	1.3	0.9
403985	2100	1850	1.7	0.9	1.2	0.7

Table 25: Expected signal yield (normalized to 36.1 fb^{-1}) for validation regions (**Part 2**).

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	UDR1	UDR2	3jCR	3jCRb
403550	700	450	2164.7	411.5	1652.6	335.1
403551	800	450	1535.5	444.4	1174.8	330.7
403552	900	450	1048.3	307.1	776.2	229.7
403553	1000	50	866.4	263.0	466.5	147.8
403554	1000	250	705.4	215.3	489.6	157.1
403555	1000	450	676.6	233.0	515.7	181.4
403556	1000	650	618.7	222.5	480.1	172.0
403557	1000	850	681.1	206.5	528.5	165.3
403558	1200	50	273.4	98.4	151.6	56.4
403559	1200	250	238.9	79.3	168.0	55.4
403560	1200	450	233.0	104.2	175.3	77.8
403561	1200	650	230.7	116.5	181.3	90.5
403562	1200	850	222.4	103.2	176.7	81.3
403563	1200	1050	227.2	83.3	181.1	67.8
403564	1400	50	83.7	33.7	45.0	19.4
403565	1400	250	74.4	27.9	53.0	19.9
403566	1400	450	73.7	35.5	54.4	25.6
403567	1400	650	74.2	41.0	57.5	31.6
403568	1400	850	71.6	41.5	57.0	33.3
403569	1400	1050	73.8	37.7	58.0	30.7
403570	1400	1250	73.6	30.1	56.8	23.1
403571	1600	50	26.2	11.2	14.8	6.2
403572	1600	250	25.6	10.9	18.1	7.7
403573	1600	450	25.3	13.3	19.2	10.2
403574	1600	650	23.7	14.8	18.9	11.5
403575	1600	850	23.5	15.7	18.5	12.4
403576	1600	1050	23.2	14.7	18.2	11.6
403577	1600	1250	23.3	13.0	18.3	10.2
403578	1600	1450	24.4	10.2	18.7	7.8

Table 26: Expected signal yield (normalized to 36.1 fb^{-1}) for UDRs and control regions (**Part 1**).

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DSID	$m_{\tilde{g}}$	$m_{\tilde{\chi}}$	UDR1	UDR2	3jCR	3jCRb
403579	1700	50	15.2	7.0	8.3	4.0
403580	1700	250	14.6	6.2	10.5	4.7
403581	1700	450	15.2	8.3	11.3	6.2
403582	1700	650	14.1	9.0	11.2	7.2
403583	1700	850	13.1	8.6	10.2	6.7
403584	1700	1050	13.2	9.0	10.4	7.1
403585	1700	1250	13.4	8.5	10.3	6.8
403586	1700	1450	13.7	7.1	10.8	5.5
403587	1800	50	9.0	4.2	4.9	2.2
403588	1800	250	8.5	3.8	6.0	2.7
403589	1800	450	8.3	4.5	6.3	3.5
403590	1800	650	7.9	5.2	6.1	4.0
403591	1800	850	7.7	5.4	6.1	4.4
403592	1800	1050	7.1	5.2	5.7	4.2
403593	1800	1250	7.7	5.3	6.0	4.2
403594	1800	1450	8.0	4.8	6.1	3.7
403595	1800	1650	8.4	4.0	6.4	3.0
403596	1900	50	5.2	2.5	3.0	1.4
403597	1900	250	5.1	2.4	3.6	1.7
403598	1900	450	5.0	2.8	3.7	2.0
403599	1900	650	4.7	3.2	3.7	2.5
403600	1900	850	4.5	3.3	3.5	2.6
403601	1900	1050	4.2	3.1	3.3	2.5
403602	1900	1250	4.3	3.1	3.4	2.4
403603	1900	1450	4.8	3.2	3.7	2.4
403615	2000	50	3.1	1.5	1.7	0.8
403616	2000	250	2.8	1.3	2.0	0.9
403617	2000	450	2.9	1.6	2.2	1.2
403618	2000	650	2.8	1.8	2.1	1.4
403619	2000	850	2.6	1.9	2.0	1.4
403620	2000	1050	2.5	1.9	1.9	1.5
403621	2000	1250	2.4	1.8	1.8	1.4
403622	2000	1450	2.7	1.9	2.1	1.5
403623	2000	1650	2.9	1.8	2.2	1.3
403624	2000	1850	2.9	1.4	2.1	1.0
403625	2100	50	1.8	0.8	1.0	0.5
403626	2100	250	1.8	0.9	1.3	0.6
403627	2100	450	1.8	1.0	1.3	0.8
403628	2100	650	1.7	1.1	1.4	0.9
403629	2100	850	1.6	1.1	1.2	0.9
403981	2100	1050	1.4	1.1	1.1	0.8
403982	2100	1250	1.4	1.1	1.1	0.9
403983	2100	1450	1.5	1.1	1.1	0.8
403984	2100	1650	1.7	1.2	1.3	0.9
403985	2100	1850	1.7	0.9	1.2	0.7

Table 27: Expected signal yield (normalized to 36.1 fb^{-1}) for UDRs and control regions (**Part 2**).

826 N. Implementation of the background estimation method

827 A data-driven method is used to predict the background yield in the signal regions, as well as the uncer-
 828 tainties on those predictions. First, jet mass templates are created from control region jets. Randomized
 829 jet masses, called dressed masses, are generated from these templates for each jet in the kinematic sample.
 830 Summing the dressed masses for each of the up to four leading jets in an event gives the dressed M_j^Σ for
 831 that event. The dressed M_j^Σ distribution for each signal region is used to estimate the expected background
 832 contribution to that region.

833 N.1. Jet mass templates

834 Separate templates are created for b-matched and non-b-matched jets. A b-matched jet is defined as a
 835 large-R jet within $\Delta R = 1.0$ of a b-tagged small-R jet. For the b-matched templates, only events with
 836 $|\Delta\eta_{1,2}| > 1.4$ are included in the templates.

837 Templates are binned in p_T and $|\eta|$. The p_T bins are approximately logarithmic, while the $|\eta|$ bin
 838 boundaries are at 0.0, 0.5, 1.0, and 1.5.

839 The template binning and number of jets contributing to each bin are shown in figure 83.

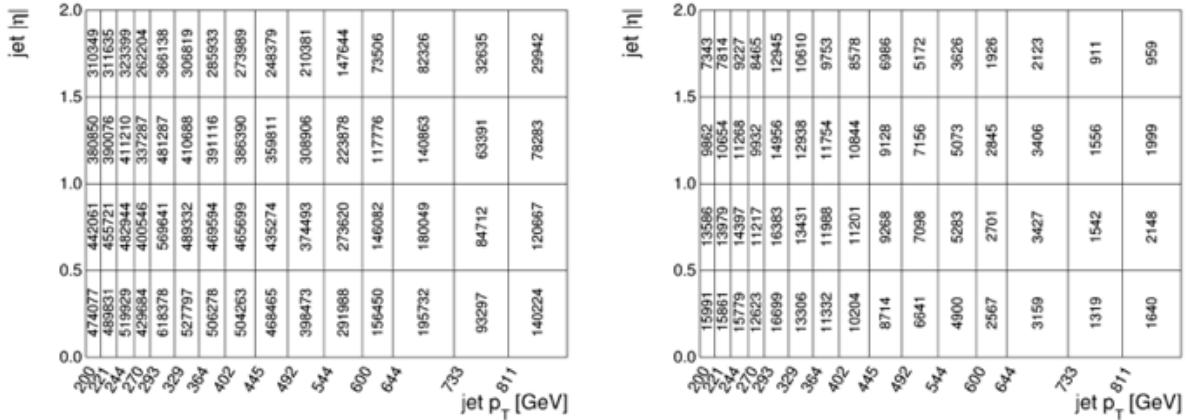


Figure 83: Number of jets contributing to each template bin for the non-b-matched (left) and b-matched (right) templates.

840 Each template is a one-dimensional histogram of $\log(m/p_T)$, with 50 bins. Jets with $\log(m/p_T) < -7$
 841 are excluded from the templates.

842 N.2. Jet mass randomization

843 For each jet in the kinematic region, a dressed mass is generated by sampling from the template corre-
 844 sponding to its p_T , $|\eta|$ and b-match bin. To generate a dressed mass, the empirical cumulative distribution
 845 function (ECDF) is calculated for the template. A uniform random number, y , in the range $[0, 1)$ is then
 846 generated. The inverse of the ECDF, $\Phi^{-1}(y)$, gives a randomized $\log(m/p_T)$ bin. A second uniform

random number, x , is sampled from the range $[x_1, x_2]$, where x_1, x_2 are the edges of the selected bin. The dressed mass is then computed as $m_{dressed} = p_T \exp(x)$.

To obtain a dressed M_J^Σ for an event, one dressed mass is generated for each jet, and the dressed masses are summed. For events with more than four jets, only the first four leading jets are included in the sum.

N.3. Dressed mass response

Dressed mass response plots are created by plotting the average dressed and kinematic jet mass in each p_T bin. The dressed mass response for the control region is shown in figure 84. A Good agreement between average dressed and kinematic masses is observed.

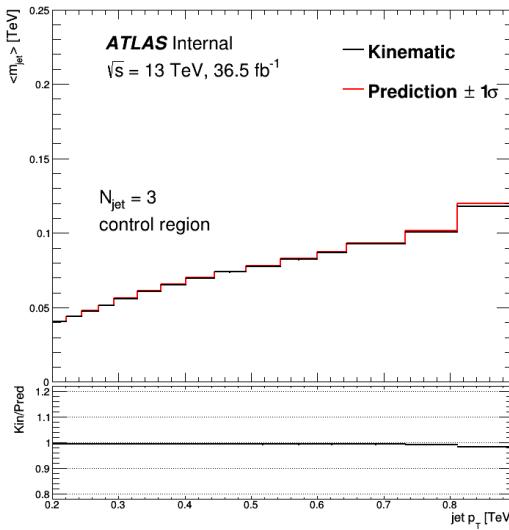


Figure 84: Average dressed and kinematic jet masses for each p_T bin in the control region

N.4. Dressed M_J^Σ distributions

To obtain the nominal dressed M_J^Σ distribution, n_{toys} histograms of M_J^Σ are created, where each histogram is generated by dressing all events in the sample once. For each M_J^Σ bin, the average bin content over all histograms is taken as the nominal value, and the standard deviation of bin contents is taken as the statistical uncertainty.

The M_J^Σ histograms are binned in the following manner. There are ten equal-width bins covering the range $0 \text{ TeV} \leq M_J^\Sigma < 0.5 \text{ TeV}$. The next three bins cover the ranges $0.5 \text{ TeV} \leq M_J^\Sigma < 0.6 \text{ TeV}$, $0.6 \text{ TeV} \leq M_J^\Sigma < 0.8 \text{ TeV}$, and $0.8 \text{ TeV} \leq M_J^\Sigma < 1.0 \text{ TeV}$. The final bin is $M_J^\Sigma \geq 1.0 \text{ TeV}$

863 N.5. Normalization

864 The dressed M_J^Σ distributions are scaled such that the dressed yield in the range $0.2 \text{ TeV} < M_J^\Sigma < 0.4 \text{ TeV}$
 865 is equal to the kinematic yield in the same range. Separate scale factors are derived for each of the validation
 866 and signal regions.

867 N.6. Systematic uncertainty

868 Systematic uncertainties are derived from the dressed mass response in the UDRs. Systematic uncertainties
 869 are binned in p_T and $|\eta|$. The lowest p_T bin is for jets with $p_T < 402 \text{ GeV}$. The second bin is for jets
 870 with $402 \text{ GeV} \leq p_T < 544 \text{ GeV}$, and the highest bin is for jets with $p_T \geq 544 \text{ GeV}$. For jets with
 871 $p_T \geq 402 \text{ GeV}$, uncertainties are derived only from UDR1.

872 For jets with $p_T < 402 \text{ GeV}$, uncertainties are derived from both UDR1 and UDR2, and the maximum
 873 uncertainty is used.

874 For each p_T bin in the UDR dressed mass response, a fractional error is calculated as $e_i = (\langle m_{kin} \rangle - \langle m_{dressed} \rangle) / \langle m_{dressed} \rangle$.

876 For the lowest and highest p_T systematic bins, the root-mean-square of fractional errors is taken as the
 877 systematic error. For the intermediate systematic bin, the maximum fractional error is taken

878 N.7. Propagation of uncertainty

879 Two separate systematic uncertainties are derived. The first uncertainty accounts for the discrepancy
 880 between dressed and kinematic masses for jets with $p_T \geq 402 \text{ GeV}$, and the second accounts for the
 881 discrepancy for jets with $p_T < 402 \text{ GeV}$.

882 To propagate the low- p_T systematic, two shifted M_J^Σ values are calculated for each dressed M_J^Σ . The first
 883 shifted value is obtained by increasing the dressed mass of every low- p_T jet by its corresponding fractional
 884 uncertainty. This yields n_{toys} histograms of shifted M_J^Σ . The average value of each bin content over all
 885 toys is taken to obtain the systematically-shifted M_J^Σ distribution.

886 The second shifted distribution is obtained by decreasing the dressed mass of every low- p_T jet by its
 887 corresponding fractional uncertainty, and averaging over all the toys to obtain a downwards-shifted
 888 distribution of M_J^Σ .

889 The same procedure is used to propagate the high- p_T systematic, but the high- p_T jets are shifted instead
 890 of the low- p_T jets.

891 N.8. Determining predicted M_J^Σ and uncertainties

892 To determine the nominal predicted background yield, one thousand toys are generated, where a toy
 893 consists of a dressed M_J^Σ value for each event in the kinematic sample. For each toy, the number of events
 894 with dressed M_J^Σ greater than the signal region M_J^Σ cut are counted, giving a distribution of one thousand
 895 dressed background yields. The central value of this distribution is multiplied by the scale factor to obtain

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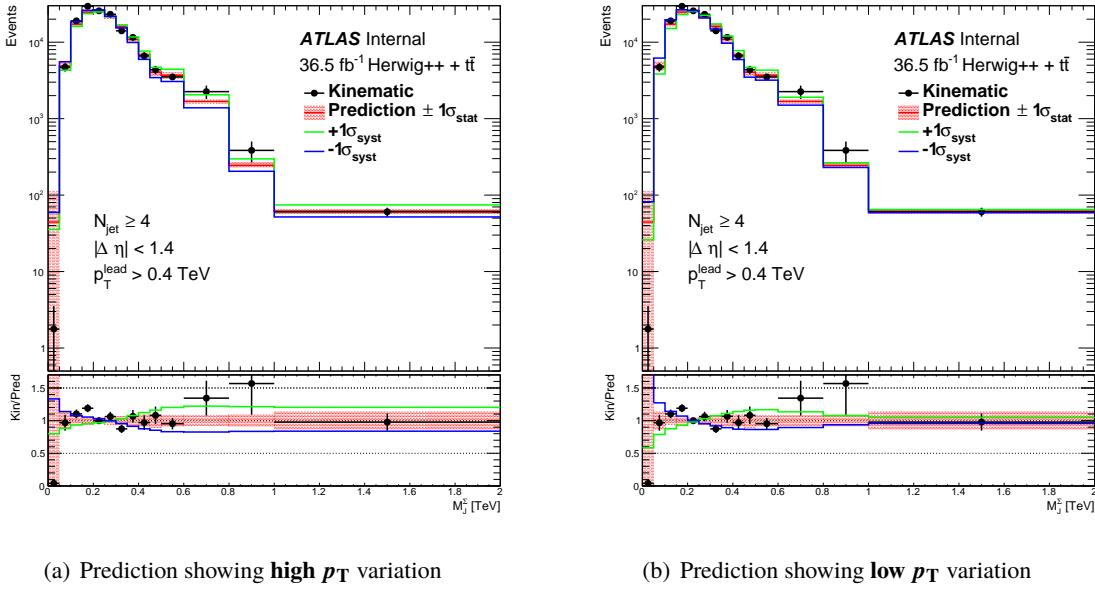


Figure 85: Predicted and observed M_J^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

- 896 the nominal background prediction. The standard deviation of this distribution is multiplied by the scale
897 factor to obtain the statistical uncertainty on the background prediction.
- 898 Systematically-shifted background yield predictions are determined by repeating the above procedure for
899 the systematically-shifted dressed M_J^Σ values. The systematic uncertainties are taken as the difference
900 between the nominal and systematically-shifted background yield predictions. Scale factors are only
901 derived from the nominal M_J^Σ distributions and applied to both the nominal and systematically-shifted
902 predictions.
- 903 The two systematic uncertainties are symmetrized by taking the maximum of the downward-shifted and
904 upward-shifted uncertainties.

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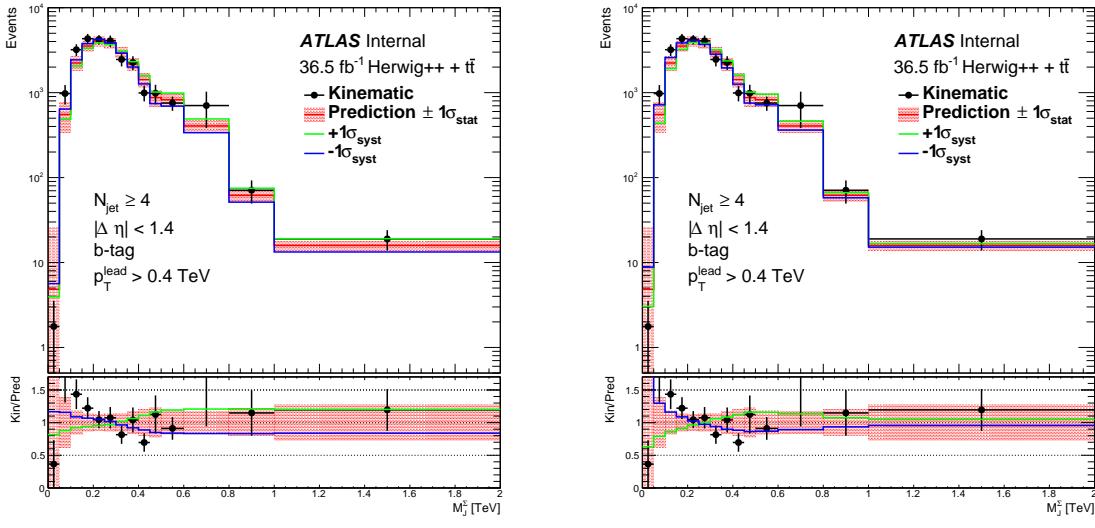


Figure 86: Predicted and observed M_J^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

905 **O. Predicted and observed M_J^Σ distributions in Herwigpp multijet plus**
 906 **$t\bar{t}$ MC samples**

907 **P. Trigger impact on CR and UDRs**

908 Figure 7 in Section 3.2 demonstrates the HLT_ht1000_L1J100 trigger is fully efficient for the signal and
 909 validation regions used in the analysis. Further checks are made to understand if the trigger turn-on has
 910 any effect on the jet mass response in the CR and UDRs. Figures 93, 94, and 95 compare the jet mass
 911 response between two versions of the same analysis, one with the current analysis selection, and one with
 912 an additional offline H_T requirement so that the HLT_ht1000_L1J100 trigger is fully efficient for the
 913 UDRs and CR. It is seen that the additional H_T requirement does not change the jet mass response in any
 914 significant way. Small variations are seen in the comparison, but these variations are within the level of
 915 jet mass systematic uncertainty.

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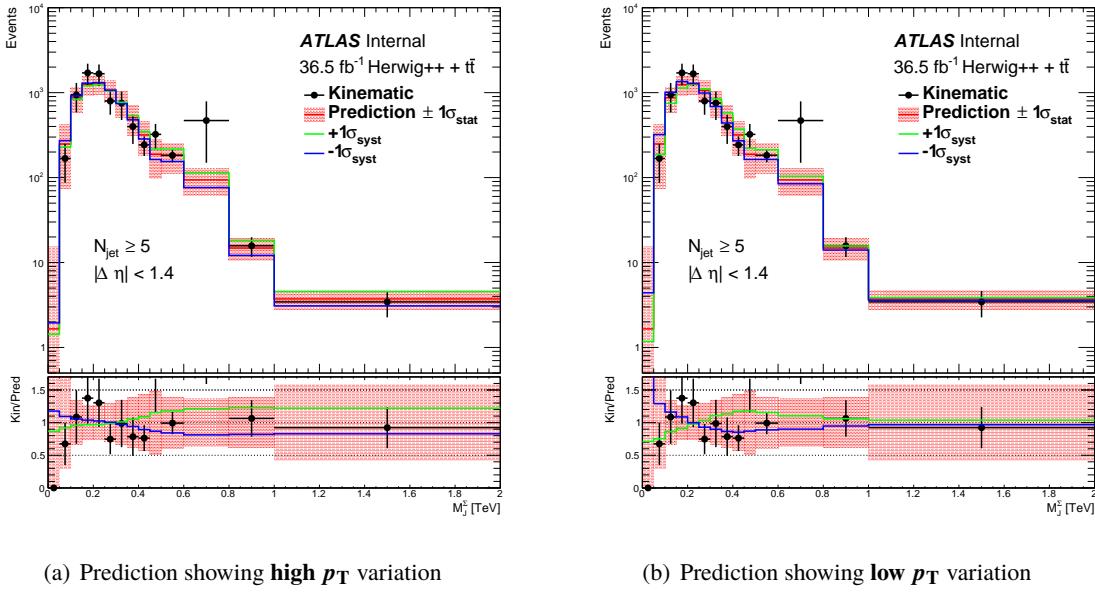


Figure 87: Predicted and observed M_J^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_J^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_J^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_J^Σ distribution over the expected M_J^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

916 **Q. Jet mass templates comparison between the b-matched jets and**
 917 **non-matched jets**

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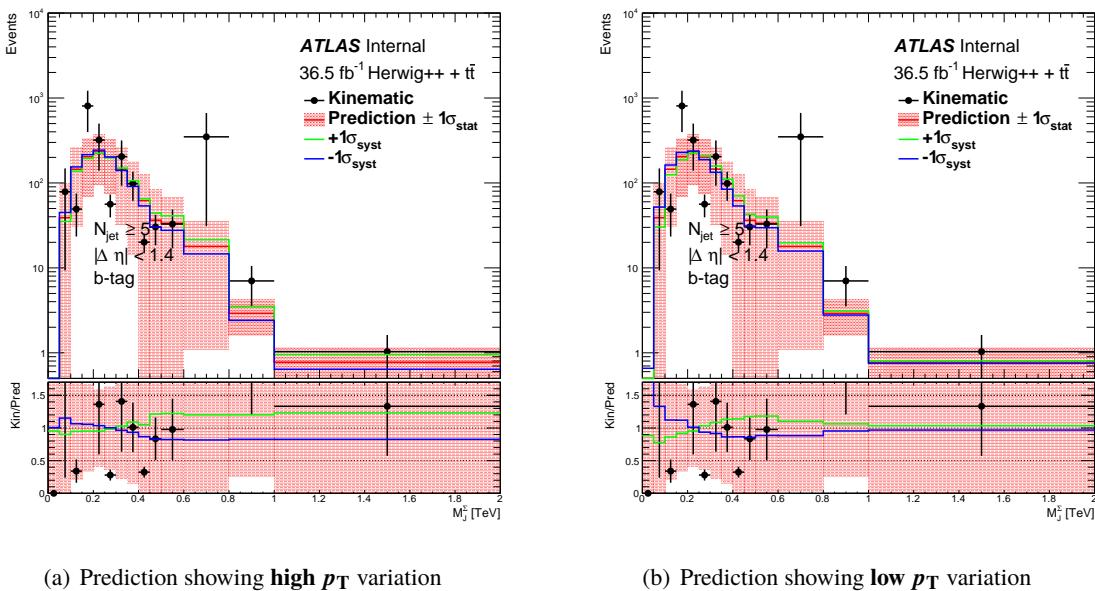


Figure 88: Predicted and observed M_j^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be less than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

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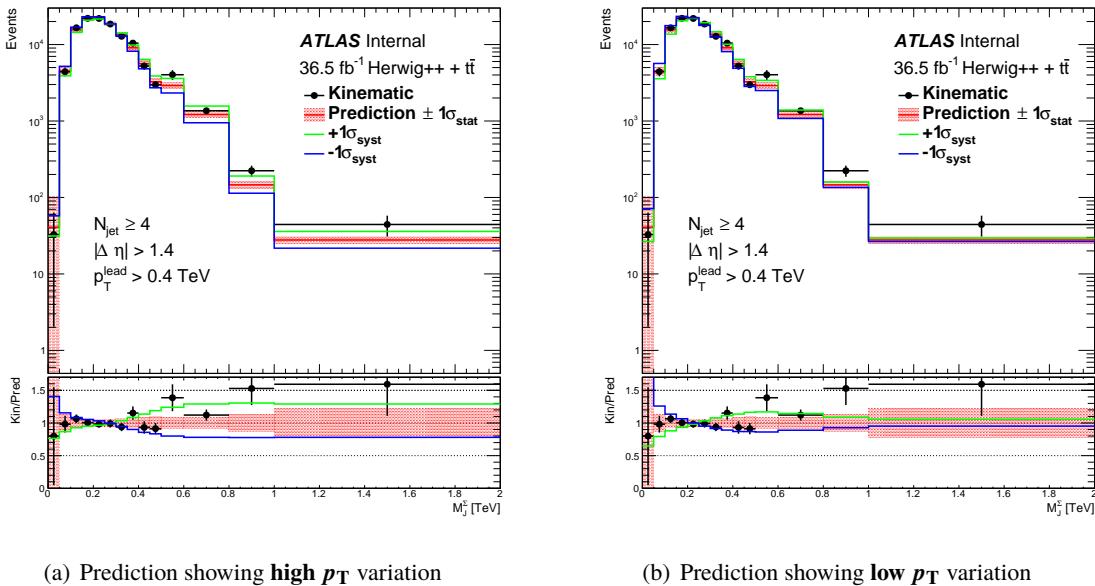


Figure 89: Predicted and observed M_j^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

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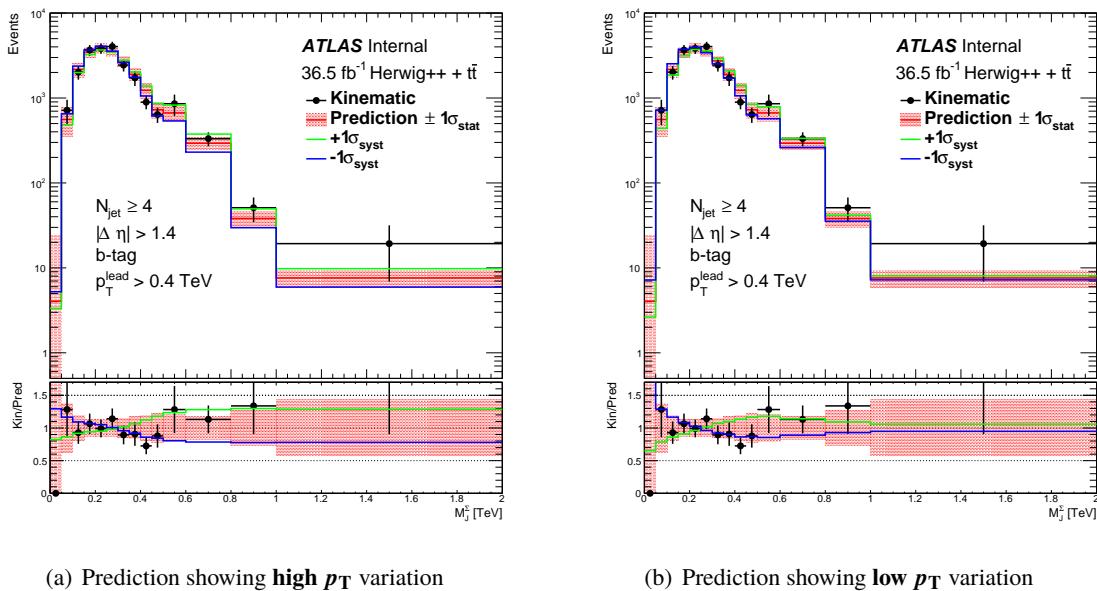


Figure 90: Predicted and observed M_j^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring four or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

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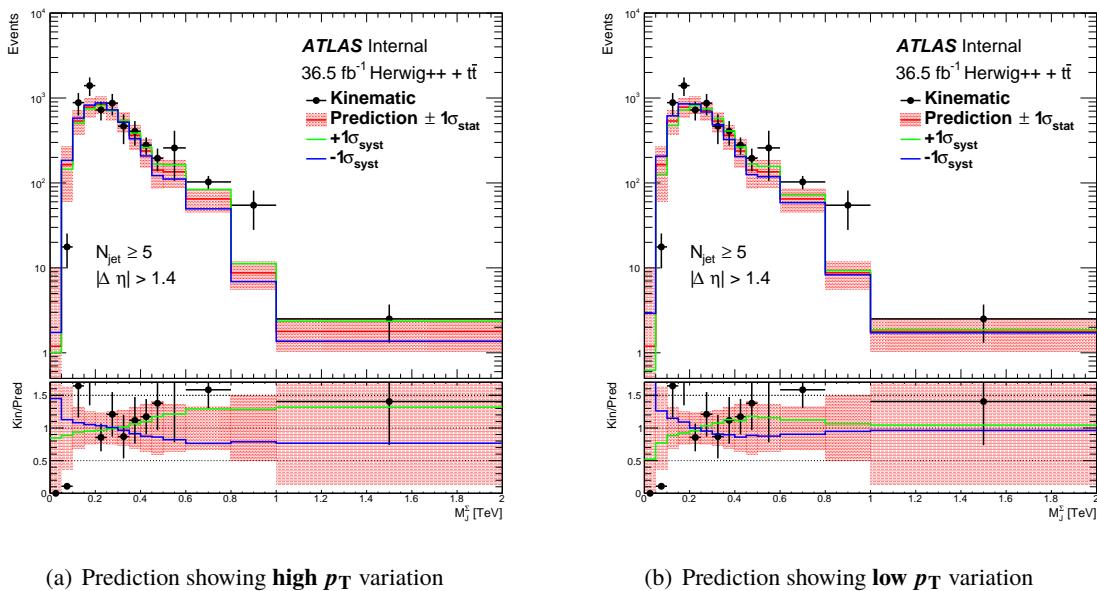


Figure 91: Predicted and observed M_j^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. There is no requirement on the presence of a b-tagged jet. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

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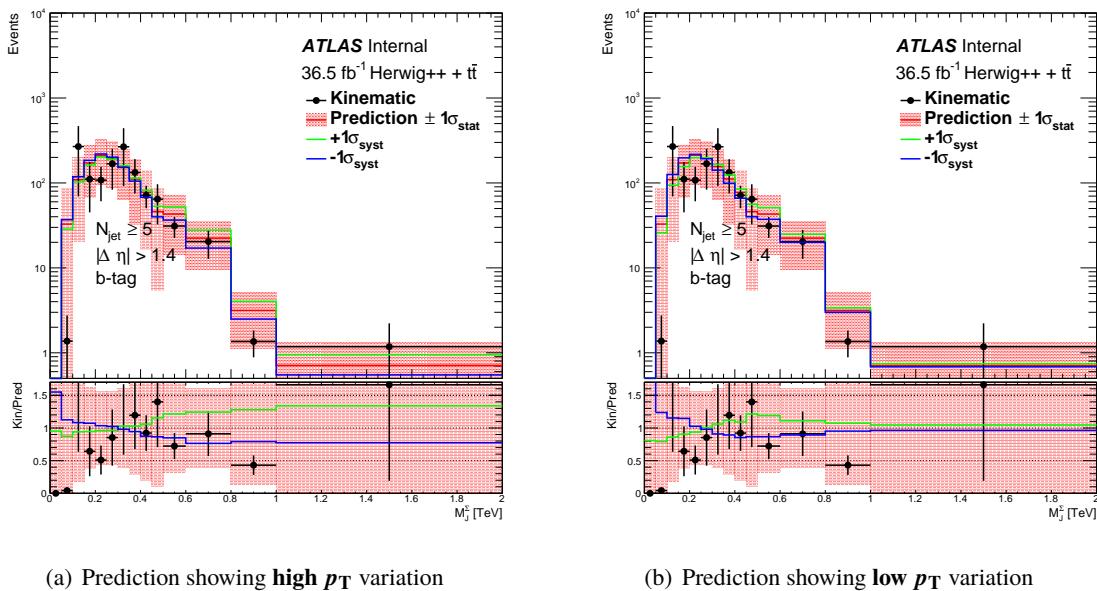


Figure 92: Predicted and observed M_j^Σ distributions in Herwigpp multijet and $t\bar{t}$ Monte Carlo background samples. The events are selected by requiring five or more large- R jets and a leading large- R jet with $p_T > 400$ GeV. The $|\Delta\eta_{12}|$ of the event is required to be greater than 1.4. At least one b-tagged jet is required to be present in the event. The black dots with error bars indicate the observed M_j^Σ distribution and its statistical uncertainty. The solid red histogram with shaded bands indicate the predicted M_j^Σ distribution and its statistical uncertainty. The green and blue histograms correspond to $\pm 1 \sigma$ variation of one of the systematic uncertainties identified in the analysis. Subfigure (a) shows variations of the “high p_T ” systematic uncertainty, while subfigure (b) shows variations of the “low p_T ” systematic uncertainty. The bottom pane show the ratio of the observed M_j^Σ distribution over the expected M_j^Σ distribution or its systematic variations. The Herwigpp multijet MC samples are a combination of samples with different leading jet p_T requirements (known as the JZW samples in ATLAS), and the lowest MC luminosity of these samples is 3.6 fb^{-1} .

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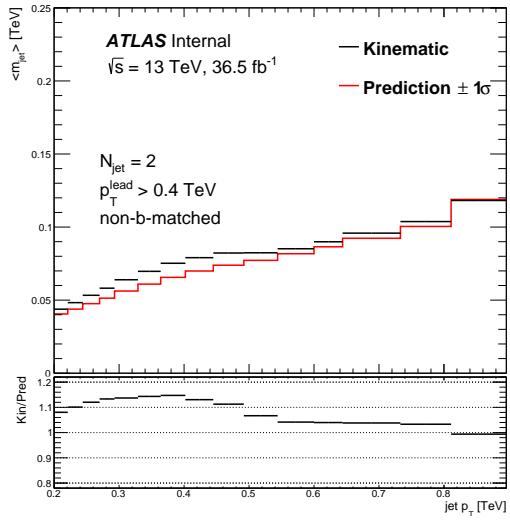
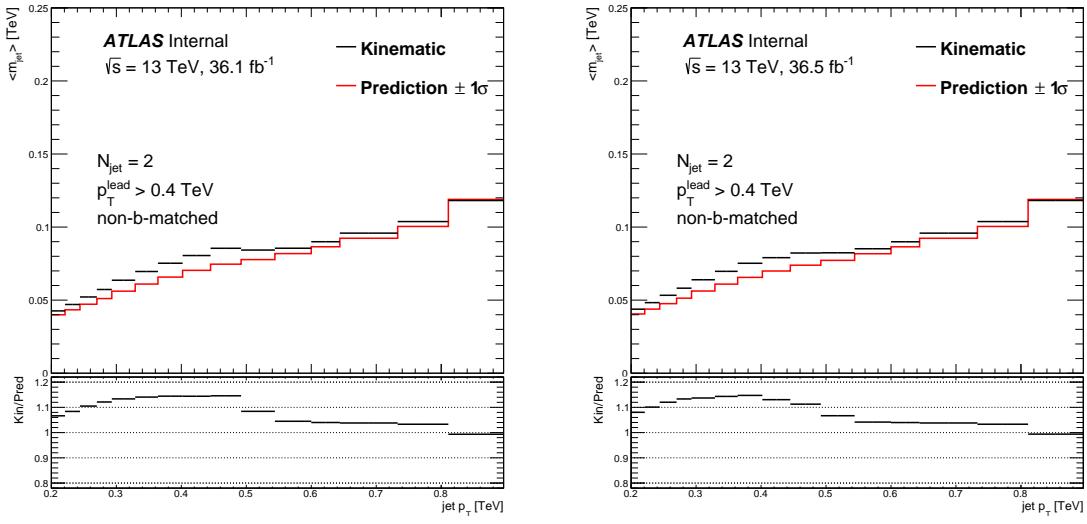


Figure 93: Trigger efficiency is shown as a function of large- R jet p_T threshold for events with our or more large- R jets events with five or more large- R jets.

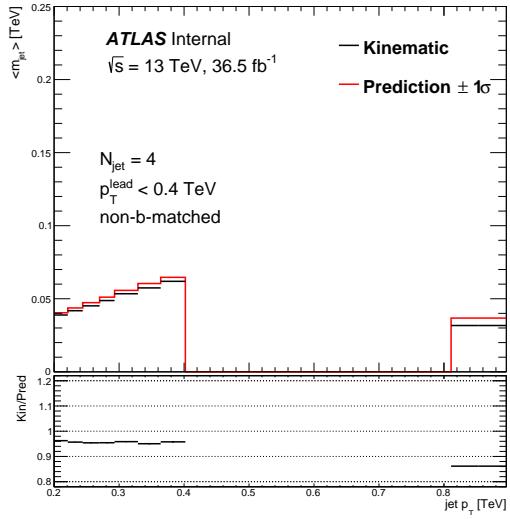
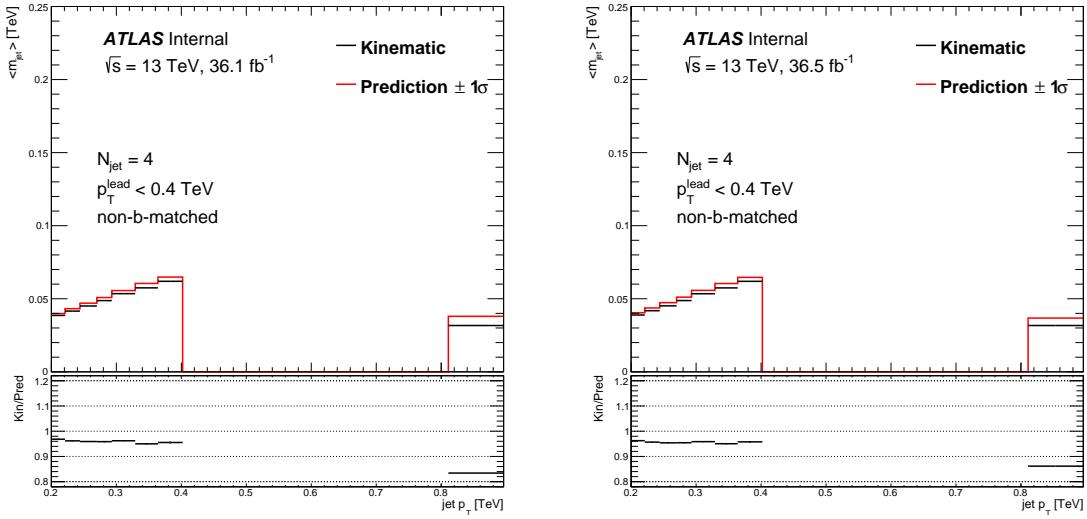


Figure 94: Trigger efficiency is shown as a function of large- R jet p_T threshold for events with our or more large- R jets events with five or more large- R jets.

Not reviewed, for internal circulation only

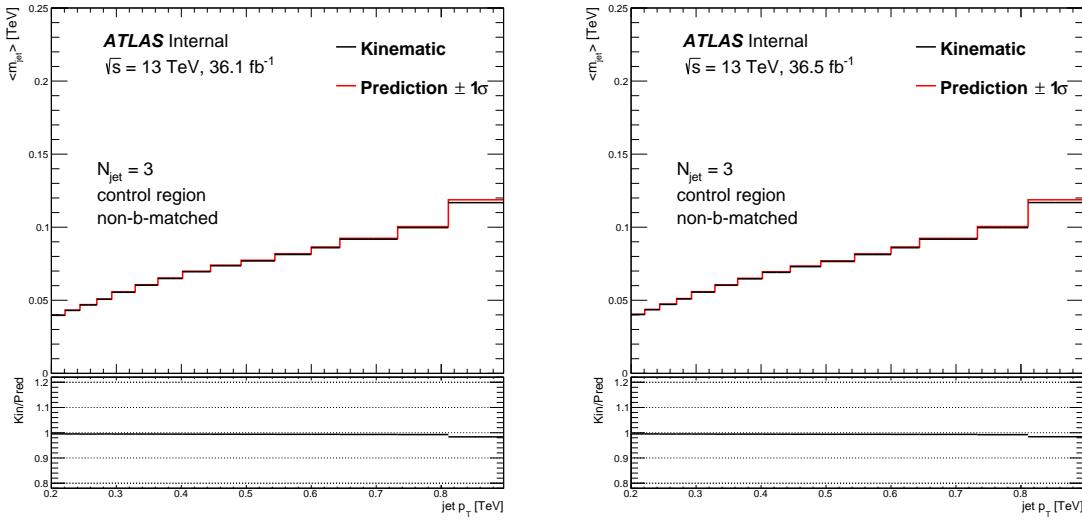


Figure 95: Trigger efficiency is shown as a function of large- R jet p_T threshold for events with our or more large- R jets events with five or more large- R jets.

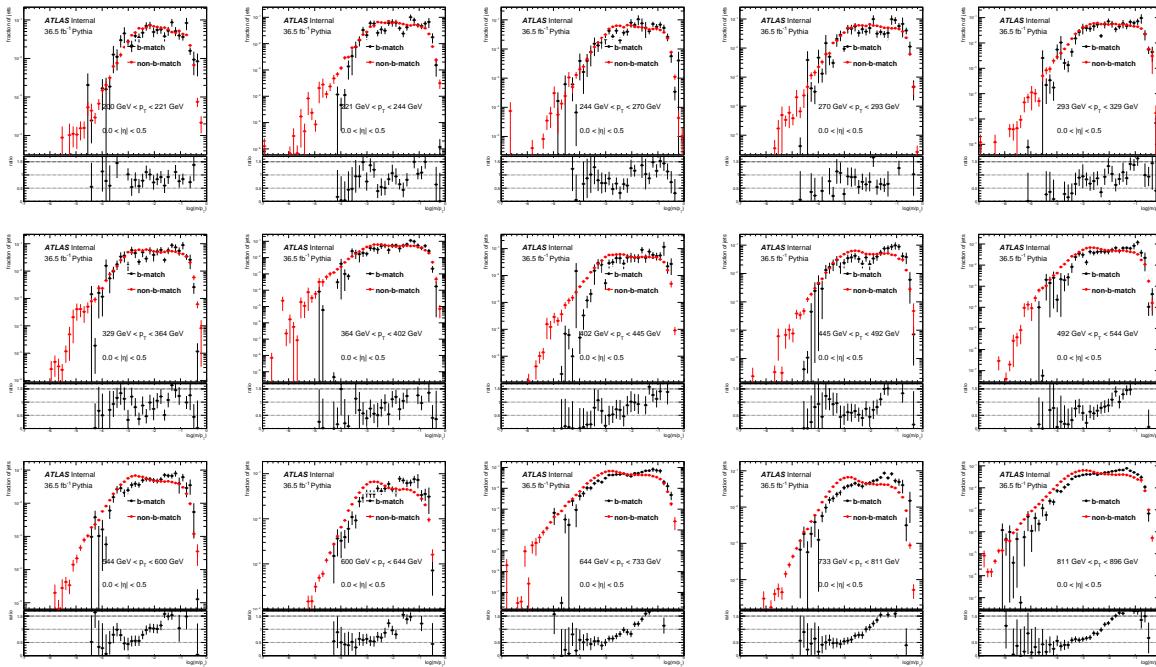


Figure 96: Jet mass templates comparison between b-matched jets and non-matched jets in the η region between 0 and 0.5. PYTHIA8 multijet sample is used for this comparison.

Not reviewed, for internal circulation only

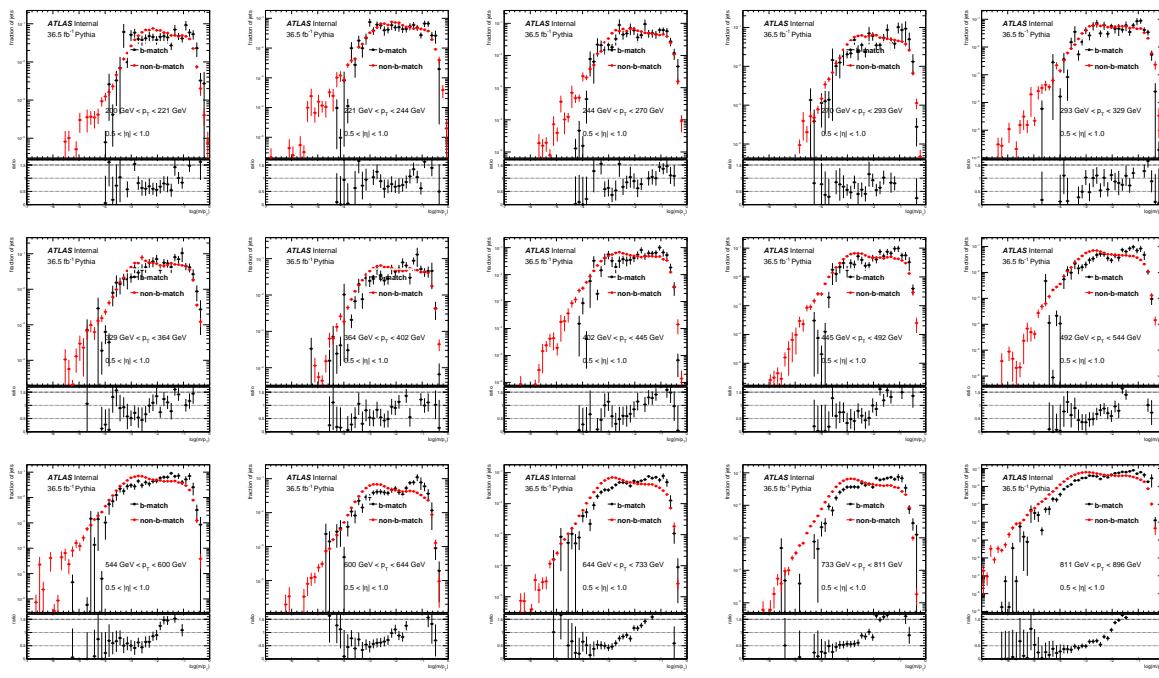


Figure 97: Jet mass templates comparison between b-matched jets and non-matched jets in the η region between 0.5 and 1.0. PYTHIA8 multijet sample is used for this comparison.

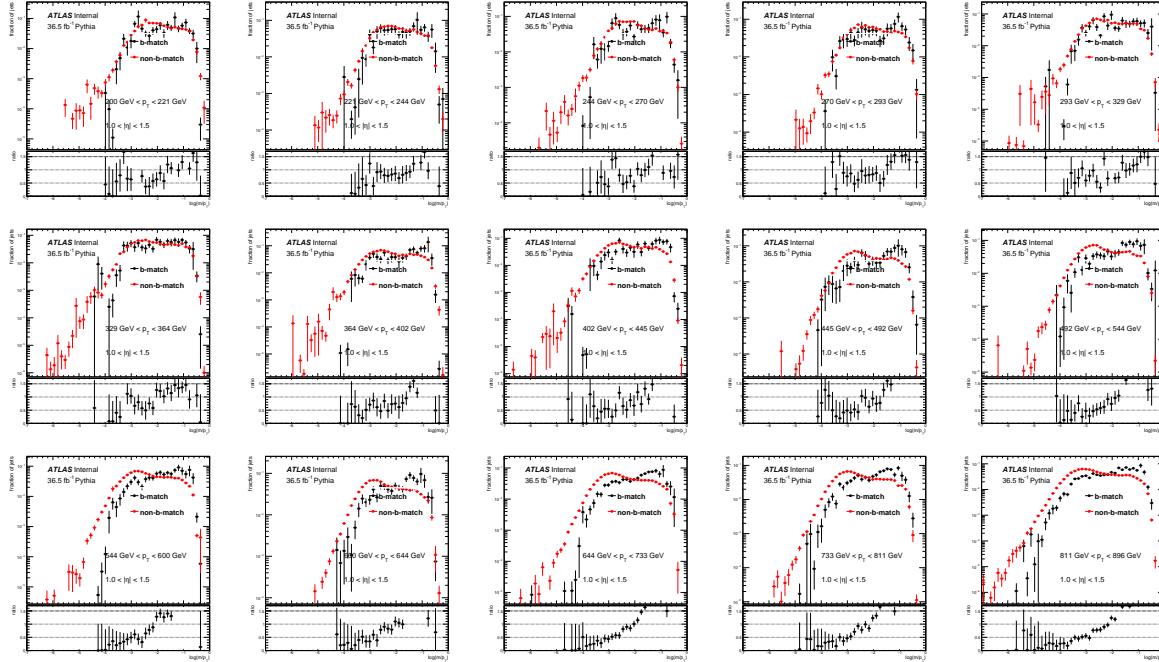


Figure 98: Jet mass templates comparison between b-matched jets and non-matched jets in the η region between 1.0 and 1.5. PYTHIA8 multijet sample is used for this comparison.

Not reviewed, for internal circulation only

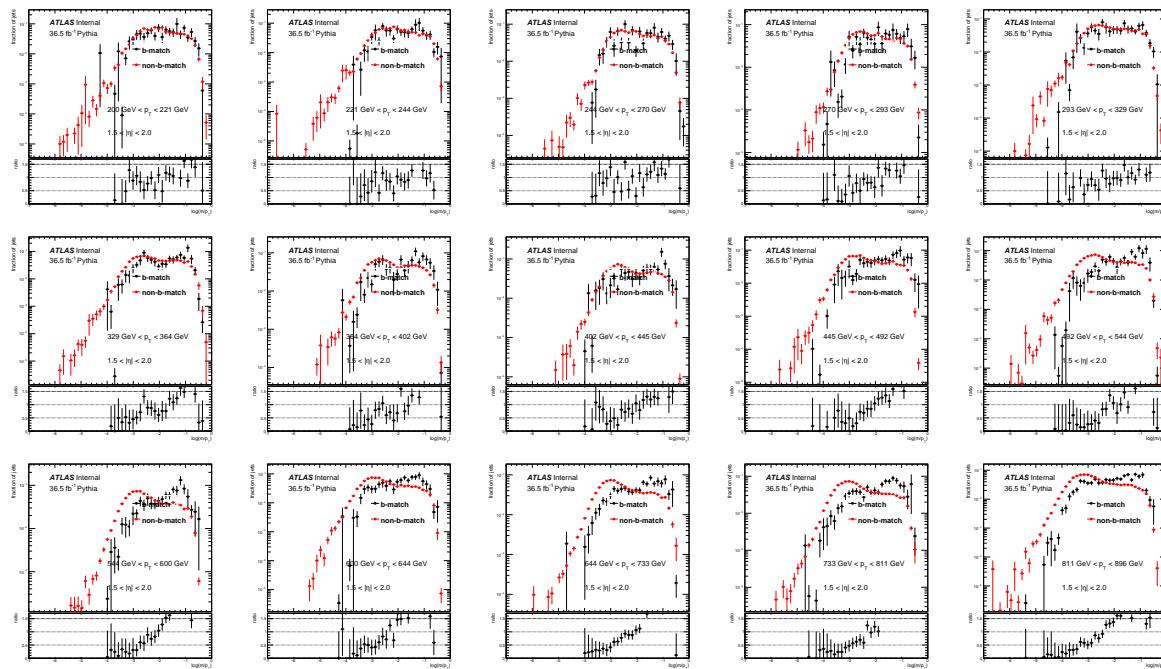


Figure 99: Jet mass templates comparison between b-matched jets and non-matched jets in the η region between 1.5 and 2.0. PYTHIA8 multijet sample is used for this comparison.

Not reviewed, for internal circulation only

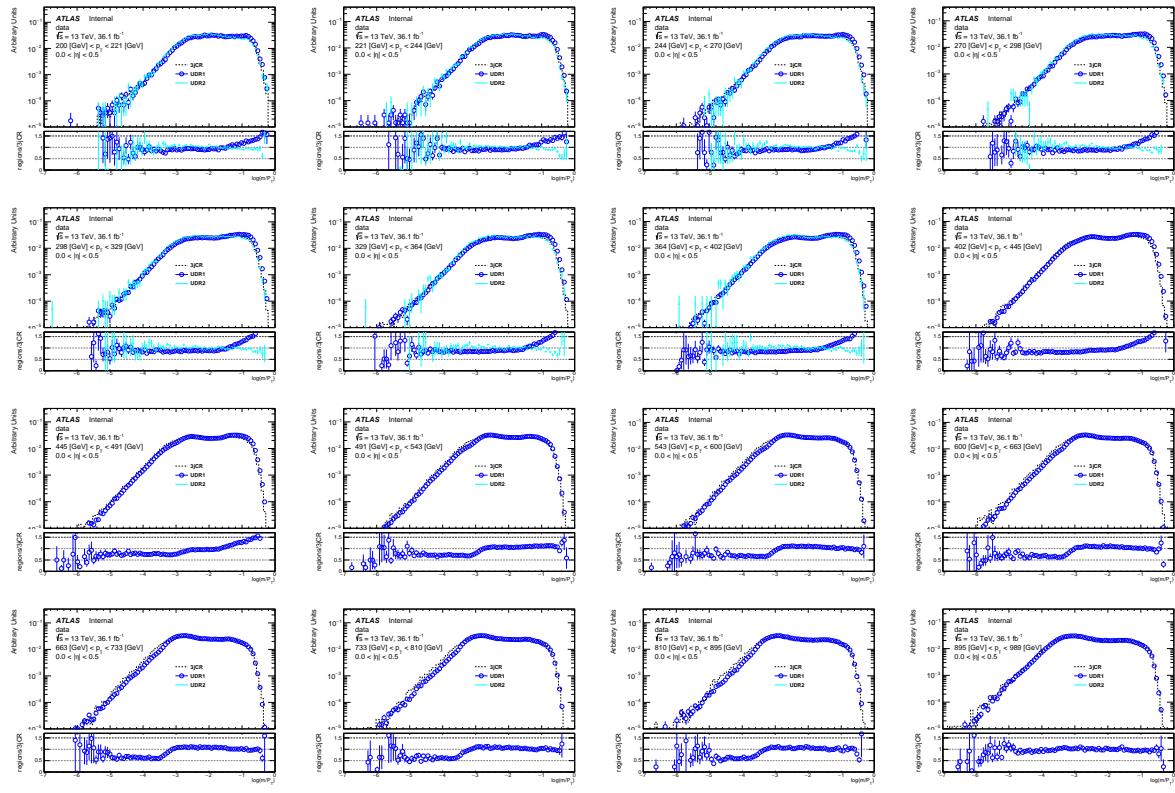


Figure 100: Jet mass PDFs comparison between CR and UDRs. Jets with $0.0 < |\eta| < 0.5$ from data are used.

918 R. Jet mass PDFs comparison between CR and UDRs

919 Figures 100 - 103 show the comparison of jet mass PDF between the control region and the two UDRs
 920 using data. Figures 104 - 107 show the same comparison plots for the jet mass distributions.

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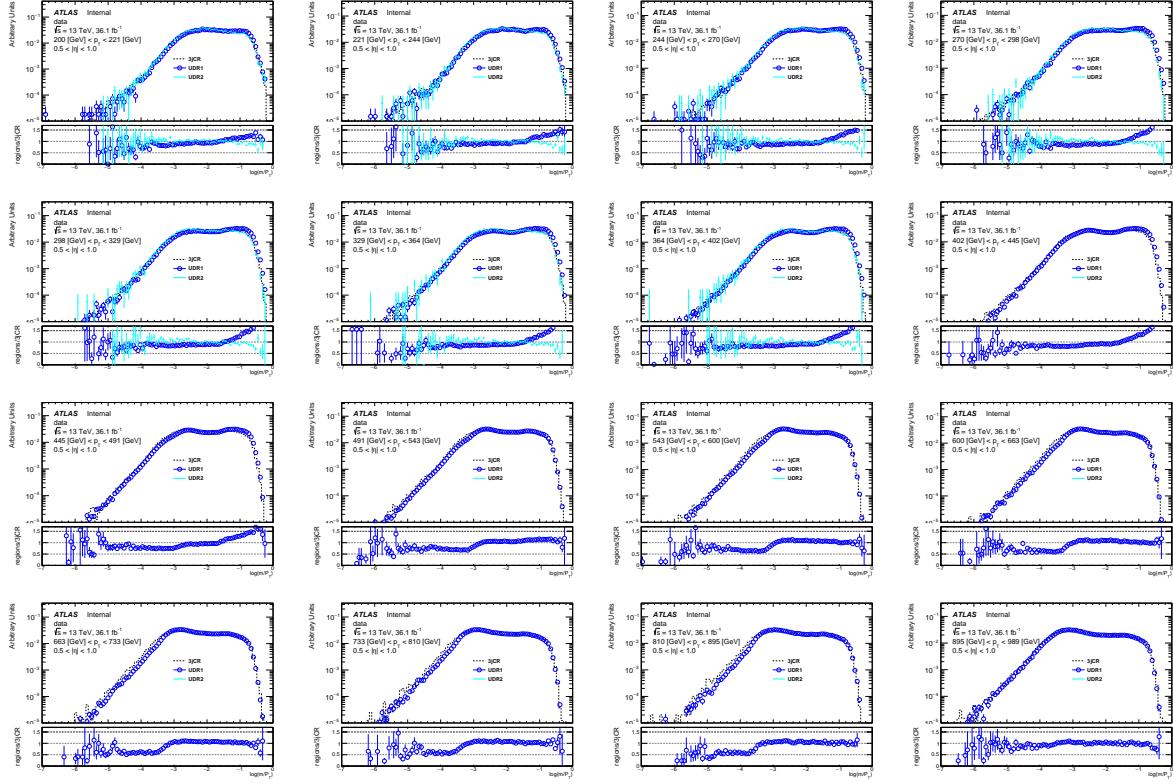


Figure 101: Jet mass PDFs comparison between CR and UDRs. Jets with $0.5 < |\eta| < 1.0$ from data are used.

Not reviewed, for internal circulation only

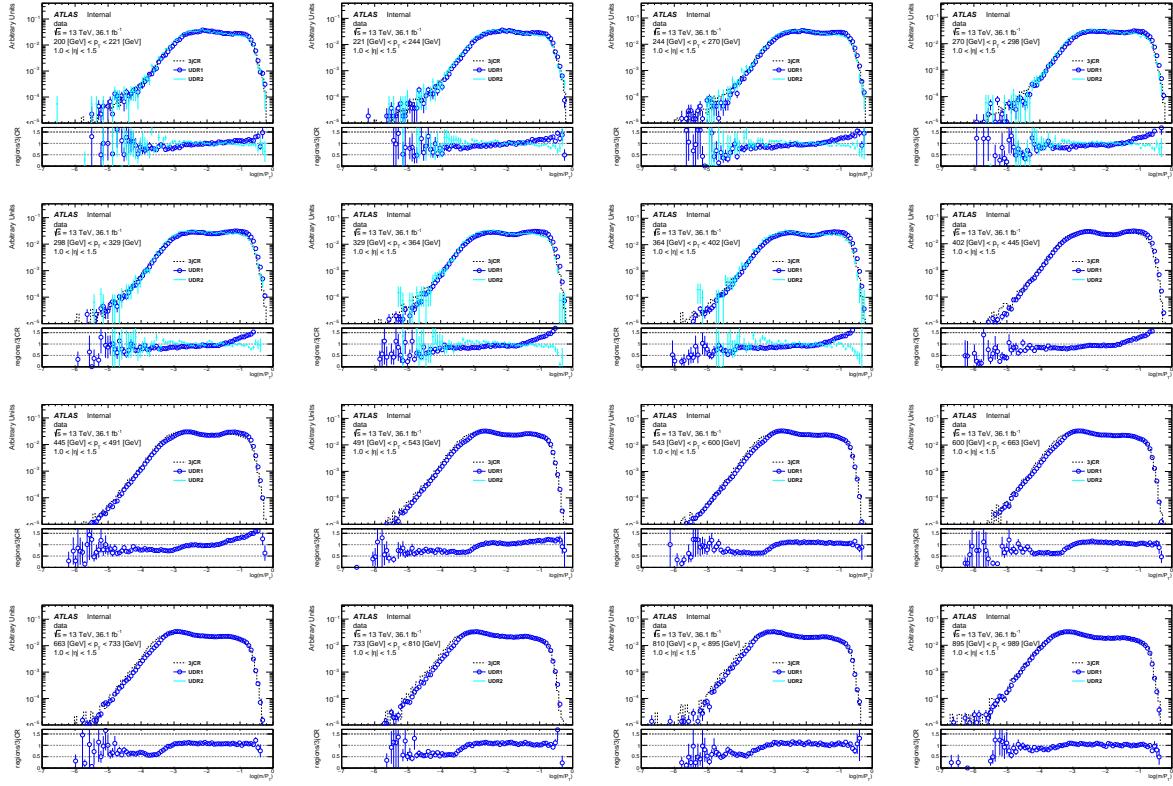


Figure 102: Jet mass PDFs comparison between CR and UDRs. Jets with $1.0 < |\eta| < 1.5$ from data are used.

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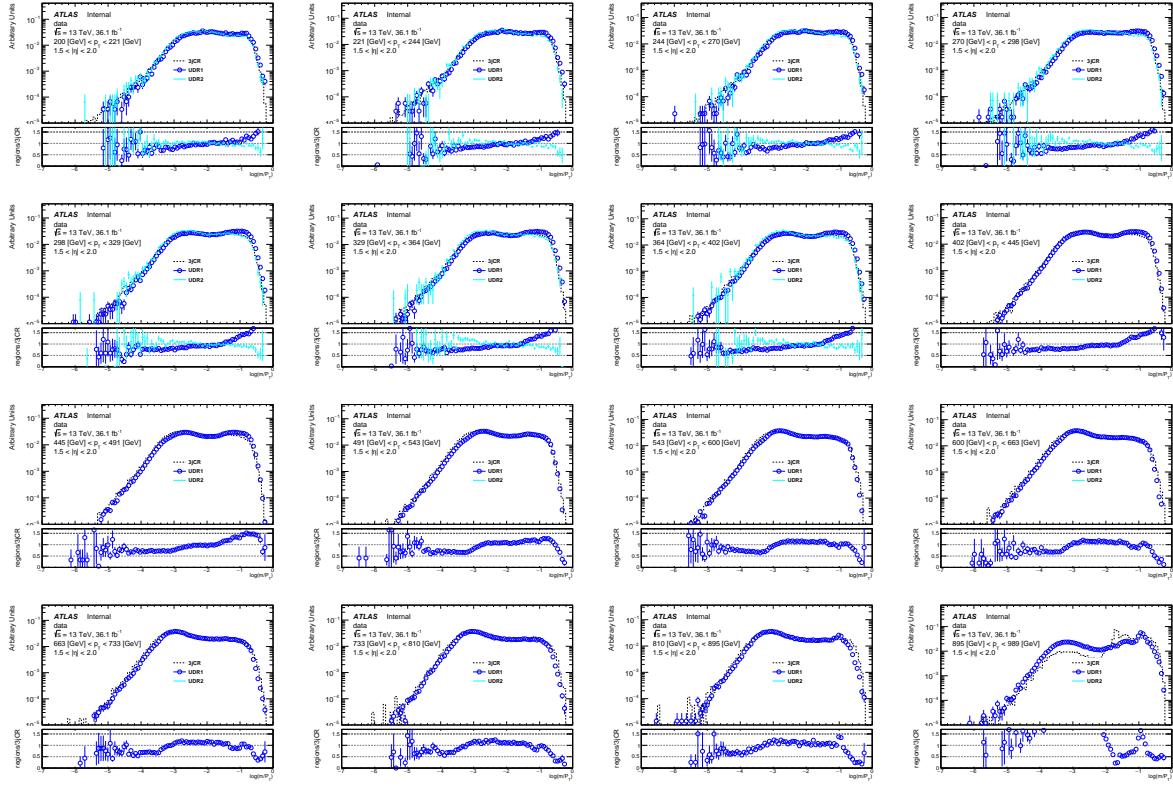


Figure 103: Jet mass PDFs comparison between CR and UDRs. Jets with $1.5 < |\eta| < 2.0$ from data are used.

Not reviewed, for internal circulation only

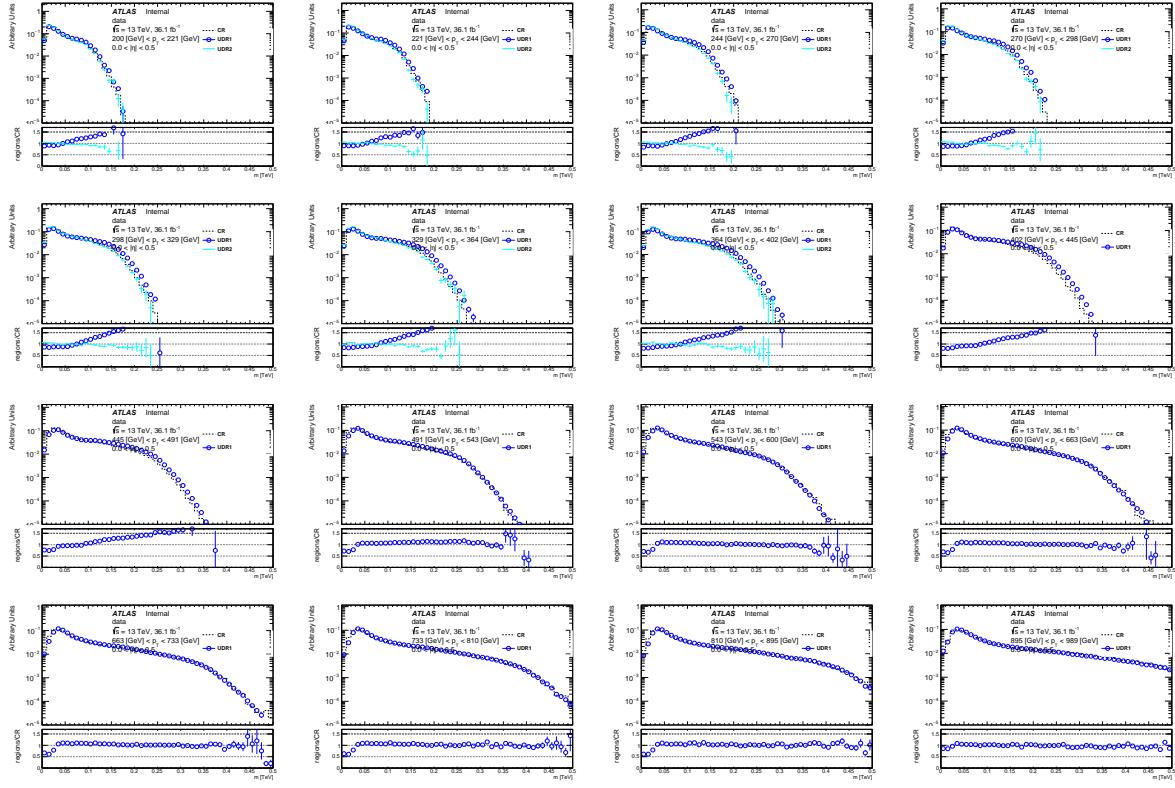


Figure 104: Jet mass distributions comparison between CR and UDRs. Jets with $0.0 < |\eta| < 0.5$ from data are used.

Not reviewed, for internal circulation only

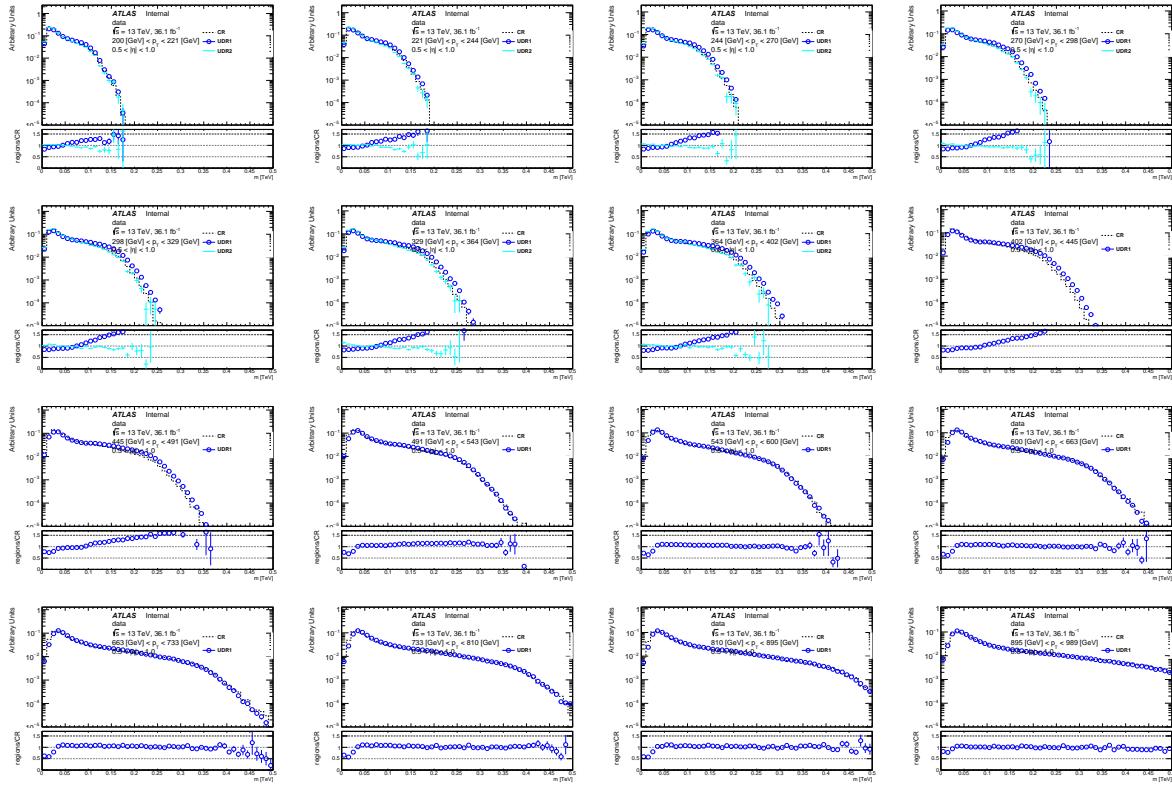


Figure 105: Jet mass distributions comparison between CR and UDRs. Jets with $0.5 < |\eta| < 1.0$ from data are used.

Not reviewed, for internal circulation only

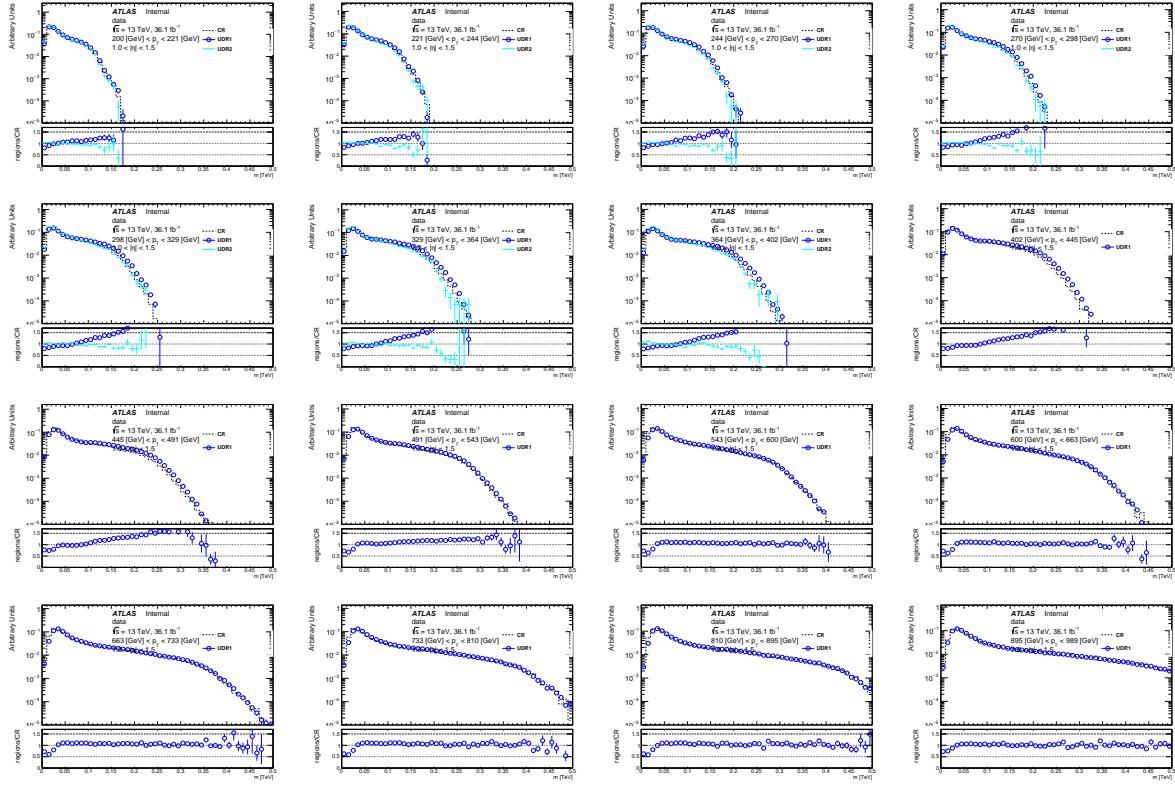


Figure 106: Jet mass distributions comparison between CR and UDRs. Jets with $1.0 < |\eta| < 1.5$ from data are used.

Not reviewed, for internal circulation only

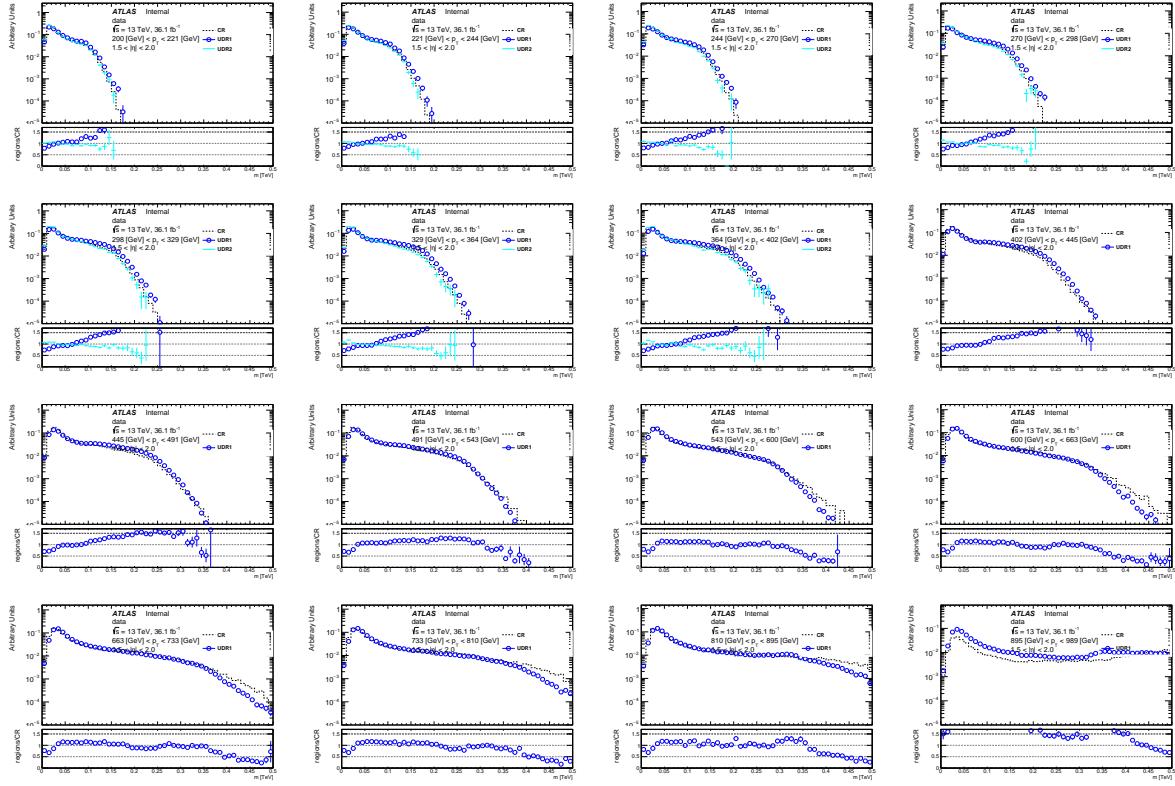


Figure 107: Jet mass distributions comparison between CR and UDRs. Jets with $1.5 < |\eta| < 2.0$ from data are used.

Not reviewed, for internal circulation only

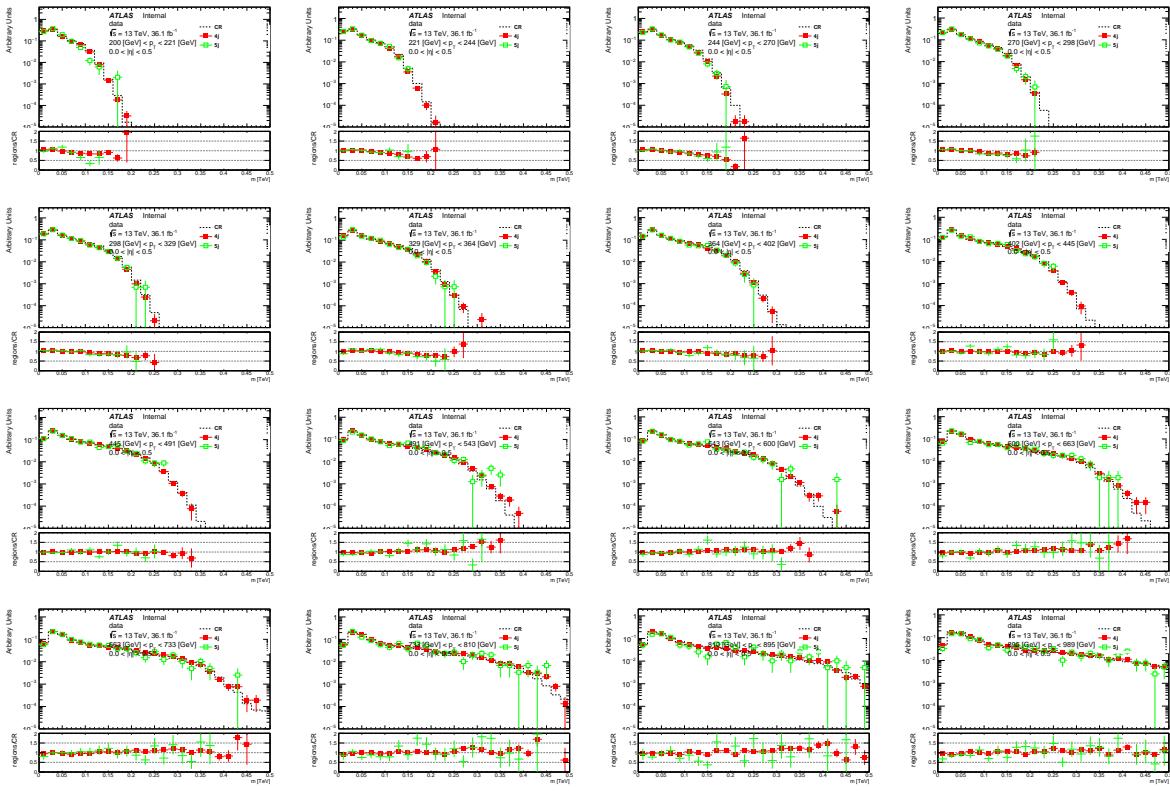


Figure 108: Jet mass PDFs comparison between CR and UDRs. Jets with $0.0 < |\eta| < 0.5$ from data are used.

921 S. Jet mass PDFs comparison between CR and 4j and 5j regions

922 Figures 108 to 111 show the comparison of jet mass distributions between the control region and regions
923 with ≥ 4 jets or ≥ 5 jets.

Not reviewed, for internal circulation only

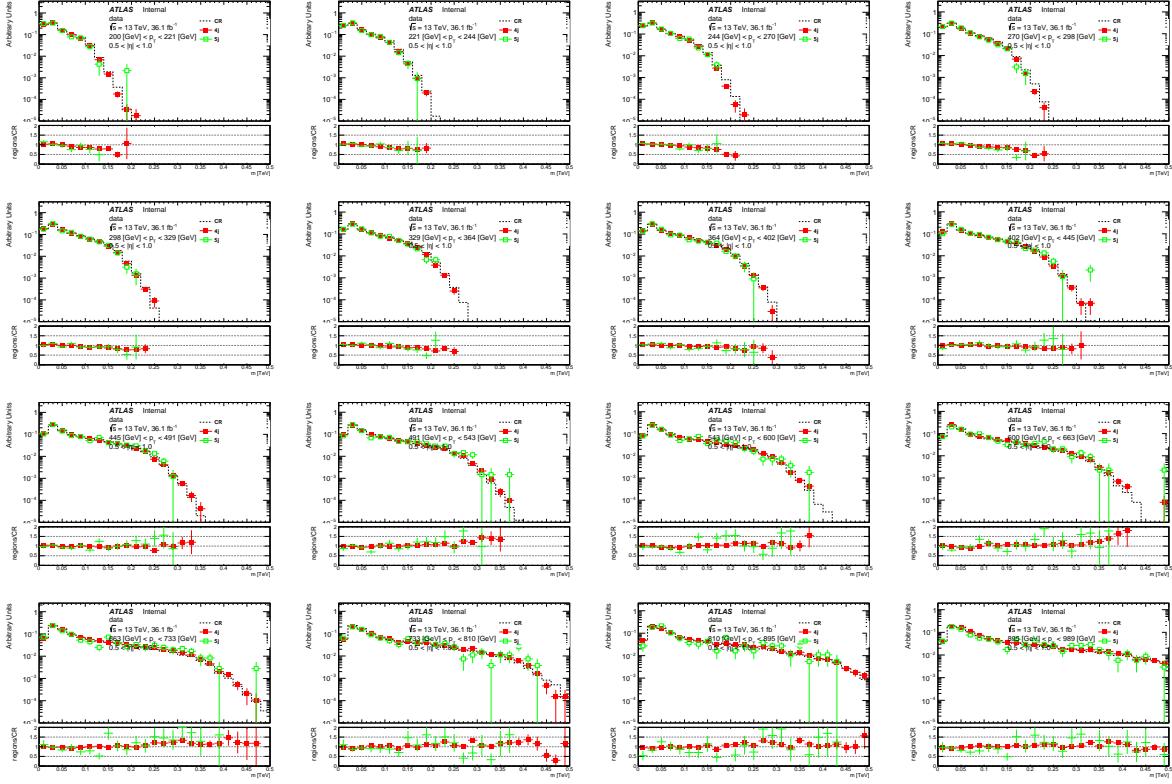


Figure 109: Jet mass PDFs comparison between CR and UDRs. Jets with $0.5 < |\eta| < 1.0$ from data are used.

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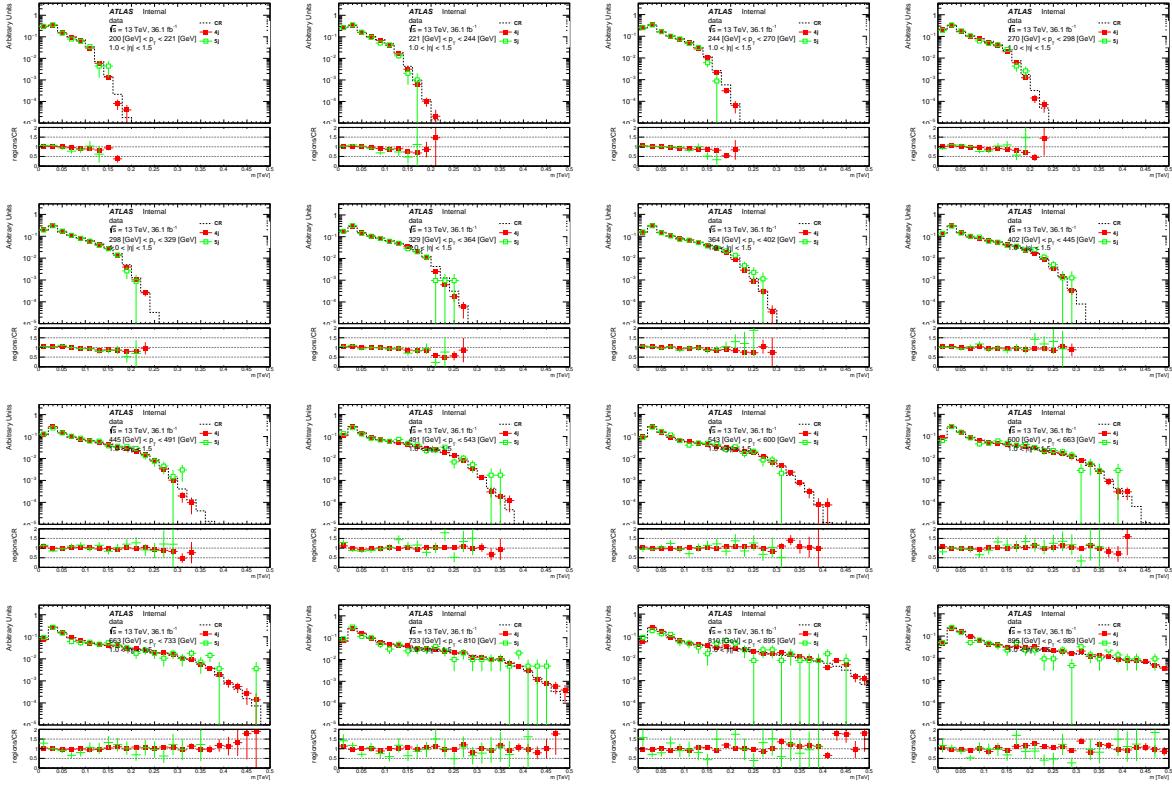


Figure 110: Jet mass PDFs comparison between CR and UDRs. Jets with $1.0 < |\eta| < 1.5$ from data are used.

Not reviewed, for internal circulation only

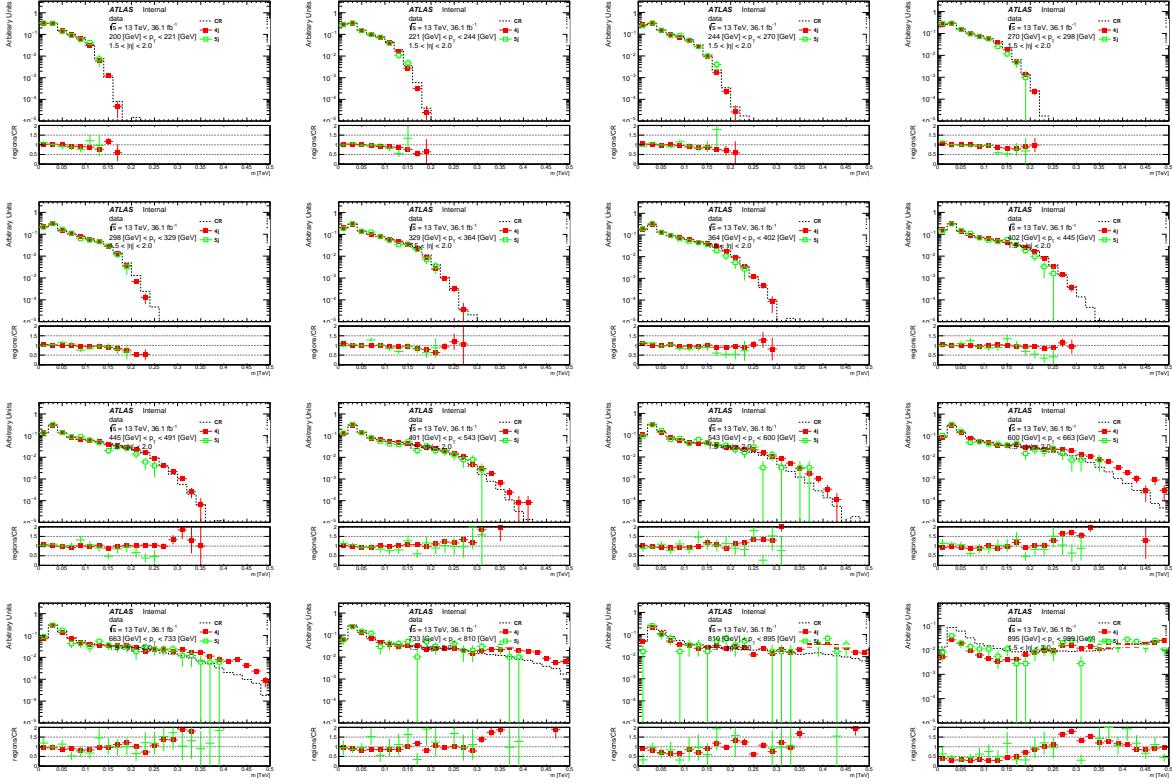


Figure 111: Jet mass PDFs comparison between CR and UDRs. Jets with $1.5 < |\eta| < 2.0$ from data are used.

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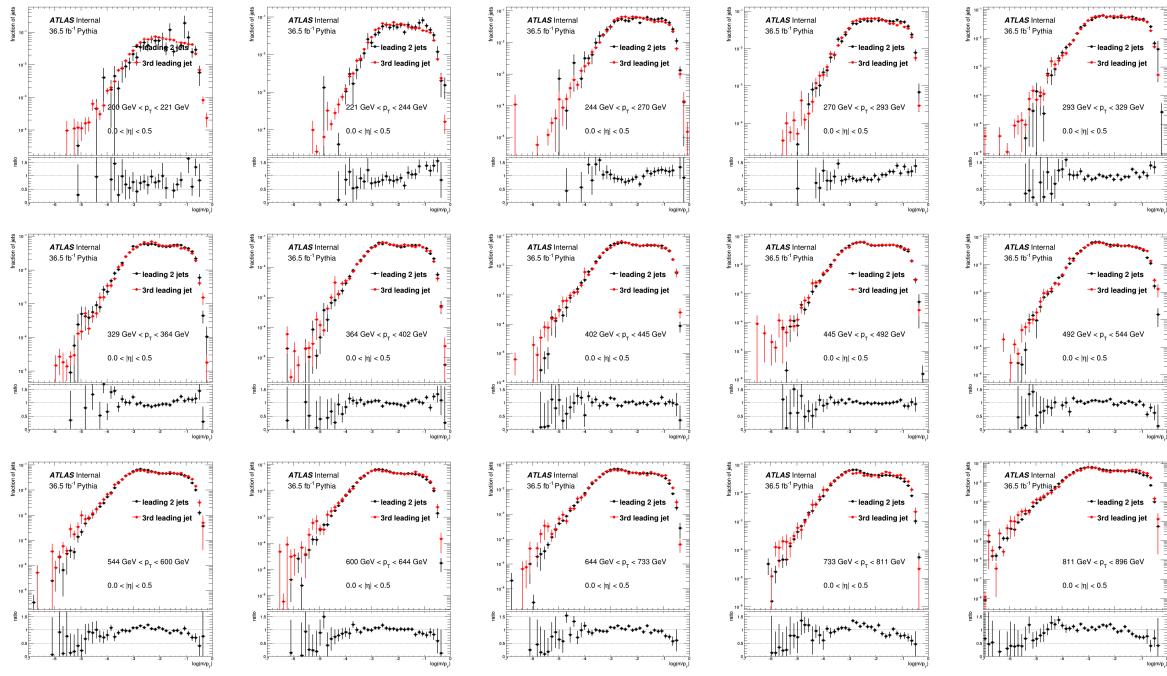


Figure 112: Jet mass templates comparison between the two leading jets and the third and fourth leading jets in the η region between 0 and 0.5. PYTHIA8 multijet sample is used for this comparison.

924 **T. Jet mass templates comparison between the two leading jets and the**
 925 **third and fourth leading jets**

Not reviewed, for internal circulation only

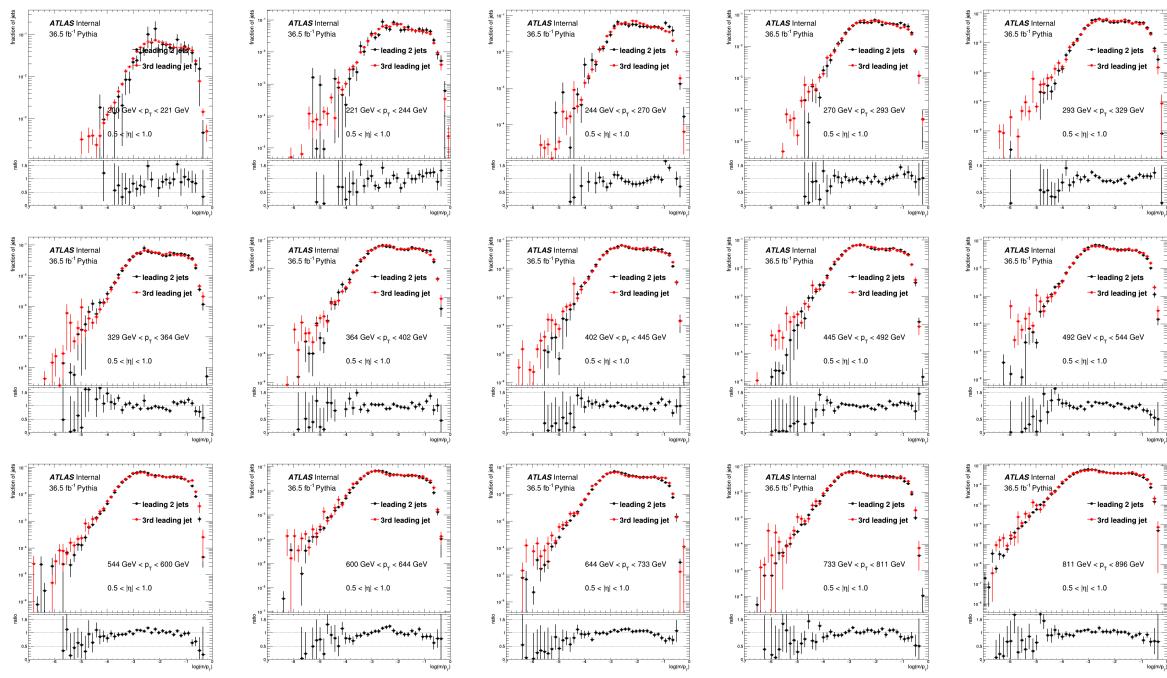


Figure 113: Jet mass templates comparison between the two leading jets and the third and fourth leading jets in the η region between 0.5 and 1.0. PYTHIA8 multijet sample is used for this comparison.

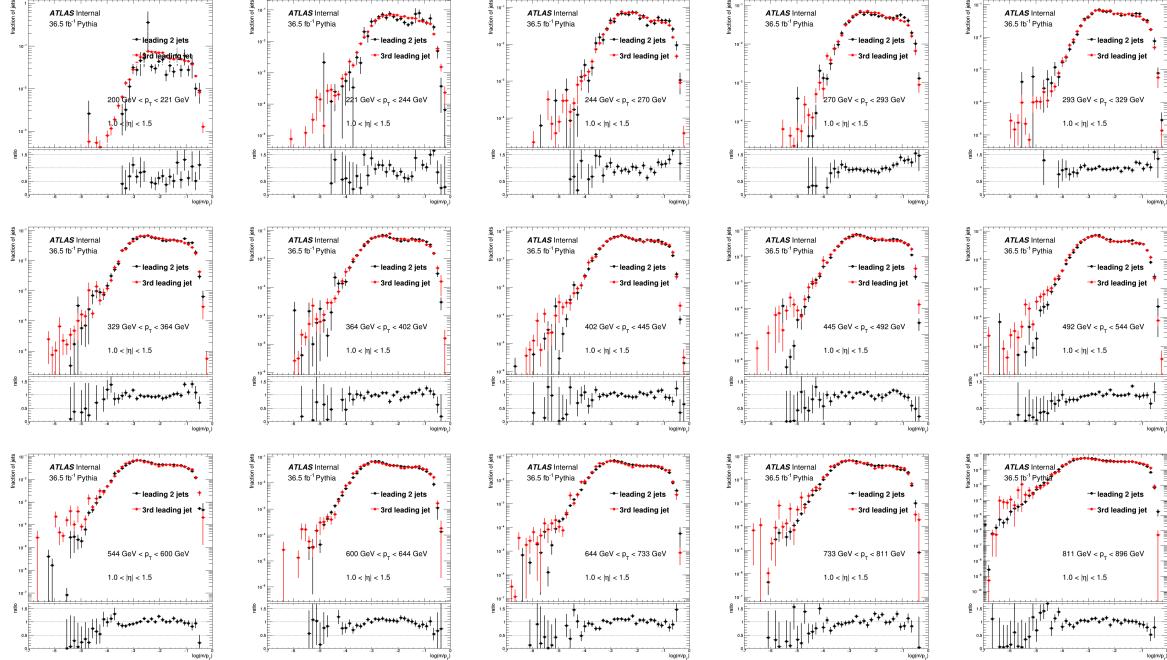


Figure 114: Jet mass templates comparison between the two leading jets and the third and fourth leading jets in the η region between 1.0 and 1.5. PYTHIA8 multijet sample is used for this comparison.

Not reviewed, for internal circulation only

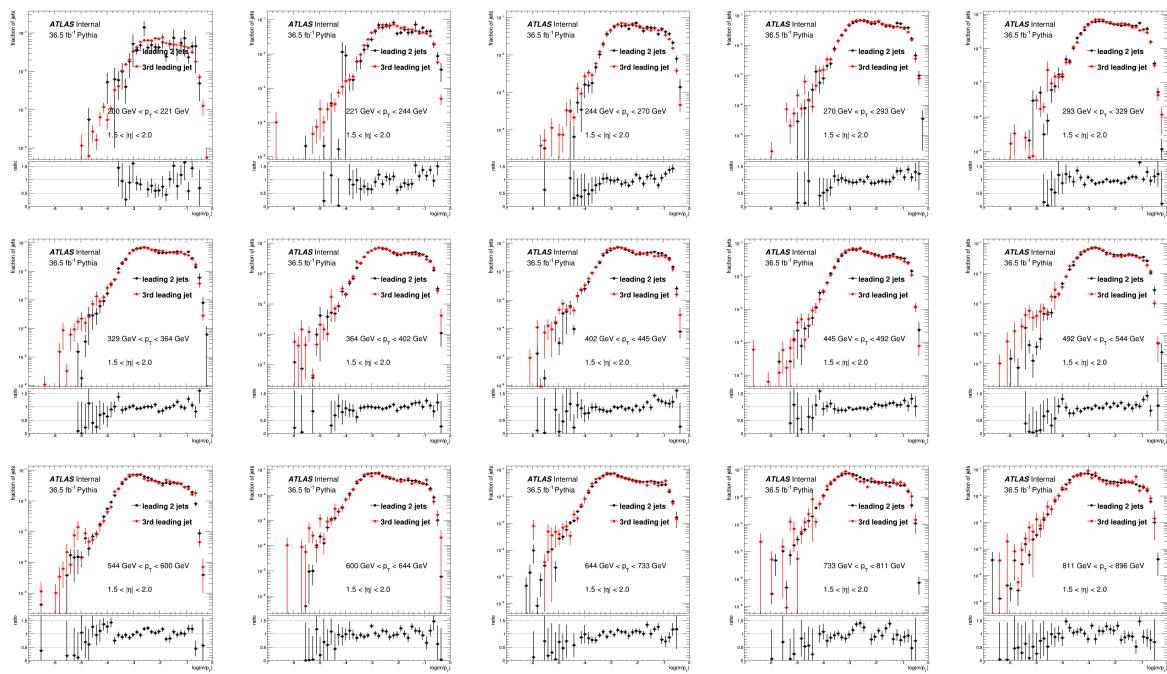


Figure 115: Jet mass templates comparison between the two leading jets and the third and fourth leading jets in the η region between 1.5 and 2.0. PYTHIA8 multijet sample is used for this comparison.

926 U. Packages and performance recommendations

927 Small-R JER

- 928 • Package tag: JetResolution-03-00-49
- 929 • configuration: JetResolution/Prerec2015_xCalib_2012JER_ReducedTo9NP_Plots_v2.root
- 930 • nuisance parameters: 1
- 931 • purpose: account for uncertainty on jet energy resolution by smearing jet energy

932 Large-R JMS

- 933 • Package tag: JetUncertainties-00-09-63
- 934 • configuration: UJ_2015/ICHEP2016/TopTagging_CombMass_strong.config
- 935 • Nuisance parameters: 4
- 936 • purpose: account for uncertainty on large-R jet mass and pT scales using Rtrk method

937 Small-R JES

- 938 • package tag: JetUncertainties-00-09-63
- 939 • configuration: JES_2015/ICHEP2016/JES2015_SR_Scenario1.config
- 940 • nuisance parameters: 4
- 941 • purpose: account for small-R jet JES uncertainty

942 b-tagging efficiency

- 943 • package tag: xAODBTaggingEfficiency-00-00-34
- 944 • configuration: 2016-20_7-13TeV-MC15-CDI-2016-11-25_v1.root
- 945 • nuisance paramters: 25
- 946 • purpose: account for uncertainty on b-tagging efficiency

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V. Sensitivity to the 6-quark model

Figure ?? compares the expected sensitivity to the 6-quark model between the result of Ref. [25] and results from the current data sample with a few different setups. The nominal results implement the correction of signal contamination in the likelihood function, which was not done for Ref. [25]. To understand the impact of the correction of signal contamination on the sensitivity to the 6-quark model, expected limits are also calculated using likelihood functions where the correction is removed. In Ref. [25], the signal region is defined as 5jSRb, $M_J^\Sigma > 0.6$ TeV, and the expected background yield in the SR is $18.2 \pm 4.2 \pm 2.5 \pm 3.0$. The current background prediction in this region is 44.0 ± 7.5 (stat.) ± 11.2 (low p_T) ± 7.2 (high p_T). The central value between these two results scales with luminosity, the current result has slightly larger systematic uncertainty and lower statistical uncertainty, and the total uncertainty is similar between these two results. Consequently, the expected limit is compatible between Ref. [25] and the current analysis using 5jSRb, $M_J^\Sigma > 0.6$ TeV and without correction of signal contamination. Once the correction is included, the expected limit is weaker.

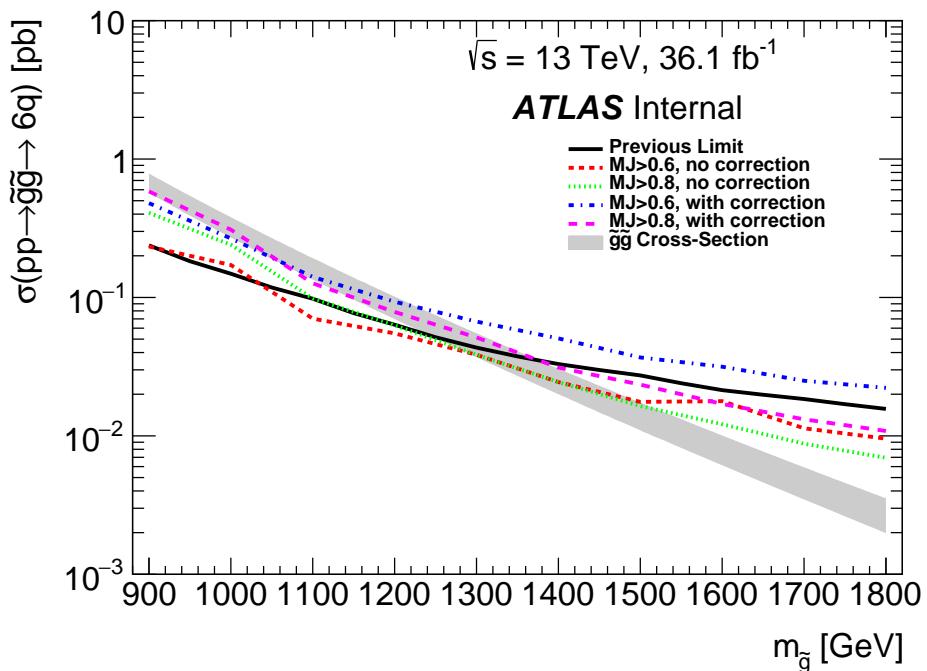


Figure 116: The expected limits on the RPV6 models in different setups are compared. The solid line shows the expected limit using 14.8 fb^{-1} data, reported in [25]. The expected limits calculated from two different signal regions (5jSRb, $M_J^\Sigma > 0.6$ TeV, and 5jSRb, $M_J^\Sigma > 0.8$ TeV) are also shown. For each of these two signal regions, an expected limit calculated without the signal contamination correction is also presented.

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