Measurement of VBS semi-leptonic cross-section

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2 Detector

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The raw output of the detector comes in the form of hits, energy deposition, times etc. These outputs are stored in Raw Data Object files (RDO). The ATLAS detector produces a huge amount of raw data. The sheer size of the data means it is impractical to distribute the raw data widely within the collaboration. Instead additional stages of dataset is made available to the physics analyzers. Unlike RDO these datasets contain objects that we are more familiar with, like vertices, tracks, electrons, muons, jets etc. The Event Summary Data (ESD) is produced from running pattern recognition algorithm on raw data and contains detailed output of detector reconstruction. The Analysis Object Data contains summary of the reconstructed event which is sufficient for most analyses. An additional level of compression is achieved when Derived Physics Data (DPD) datasets are created from AOD for different groups of physics analysis.

3.1 Vertices and pileup

In looking for interesting processes in proton-proton collision, it is important to reconstruct the interaction points, i.e. vertices. The hard interaction vertex is called the primary vertex. There may be secondary vertices in an event arising from decays and interactions of particles produced in the primary vertex. The reconstruction of vertices is dependent on reconstruction of charged particle tracks in the inner detector (ID). The high resolution pixel detector and silicon microstrip detector (SCT) are crucial for reconstructing these tracks. Additional information is provided by the transition radiation tracker (TRT). The vertex reconstruction proceeds in two stages, i) primary vertex finding (algorithm deals with associating the tracks to a primary vertex candidate) and ii) vertex fitting (algorithm reconstructs the vertex position and calculates the covariance matrix). First, the reconstructed tracks compatible with coming from the interaction region are pre-selected. From the distribution of z co-ordinates of tracks at the point of closest approach with respect to the nominal beam spot, a global maxima is found and used as a seed for the vertex. Taking this seed and its surrounding tracks as inputs, an adaptive χ^2-based vertex fitting algorithm is run to determine the vertex position. Each track is assigned a weight based on its compatibility with the fitted vertex position and outliers are down-weighted. Tracks that are incompatible with the vertex position by more than 7 σ are used for fitting another vertex. This procedure is continued until the list of tracks is exhausted. Secondary vertices are reconstructed using kinematic properties of the interaction likely to happen in that vertex. The displaced tracks are fitted with the secondary vertex candidate with the kinematic constraints set by, for example, the parent particle mass or the angular distribution of the daughter particles.

3.2 Electron

In ATLAS the inner detector and EM calorimeter is used for reconstructing electron objects. The inner detector tracks are matched to the energy deposits in the EM calorimeter for this purpose. The Transition Radiation Tracker (TRT) is used for electron identification.

The reconstruction of electrons and photons in the region $|\eta| < 2.47$ starts from energy deposits (clusters) in the EM calorimeter. The EM calorimeter is divided into a grid of $N_\eta \times N_\phi$ towers of size $\Delta\eta \times \Delta\phi = 0.025 \times$

0.025. Inside each of these elements, the energy of all cells in all longitudinal layers is summed to get the tower energy. A cluster is seeded by towers with total transverse energy above 2.5 GeV and then formed using a sliding-window algorithm, with a window size of 3 5 towers. Clusters matched to a well-reconstructed ID track originating from a vertex found in the beam interaction region are classified as electrons. If the matched track is consistent with originating from a photon conversion vertex, the corresponding candidates are considered as converted photons. Clusters without matching tracks are classified as unconverted photons. The electron cluster is rebuilt using 3×7 and 5×5 towers of longitudinal cells centered around the initial seed in the Electromagnetic Barrel (EMB) and Electromagnetic EndCap (EMEC) respectively. For converted photons, the same 3×7 cluster size is used in the barrel, while a 3×5 cluster is used for unconverted photons due to their smaller lateral size. Similar to electron, 5×5 cluster size is used in the end-cap for both converted and unconverted photons. The cluster energy is then corrected by a calibration scheme based on the full detector simulation.

The relative energy resolution for these EM objects can be parameterized as follows: $\sigma_E = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$, where a, b and c are η-dependent parameters; a is called the sampling term, b is the noise term, and c is the constant term. The sampling term contributes mostly at low energy; its design value is (9 –10)%/p_E[GeV] at low $|\eta|$, and is expected to worsen as the amount of material in front of the calorimeter increases at larger $|\eta|$. The noise term is about $350\times\cosh\eta$ MeV for a 3×7 cluster in $\eta\times\phi$ space in the barrel and for a mean number of interactions per bunch crossing $\mu = 20$; it is dominated by the pile-up noise at high η. At higher energies the relative energy resolution asymptotically approaches the constant term, c, which has a design value of 0.7%.

3.3 Muon

The ATLAS detector uses its Inner detector and Muon spectrometer to identify, reconstruct and precisely measure the properties of muons produced in pp collisions. Muon objects are identified using available information from the ID, the MS, and the calorimeter sub-detector systems. There are a few different types of muons in ATLAS depending on the reconstruction criteria. They are:

- Stand-alone muons: only the MS is used to reconstruct the trajectory of muons. The muon track parameters at the interaction point are determined by extrapolating the track back to the point of closest approach to the beam line, taking into account the estimated energy loss of the muon in the calorimeters. The muon has to travel through at least two layers of MS chambers to provide a track measurement. Standalone muons are mainly used to extend the acceptance to the range $2.5 < |\eta| < 2.7$ which is not covered by the ID. MuonBoy software package is used for this reconstruction.

- Combined muons: track reconstruction is preformed independently for ID and MS and a combination is done to reconstruct a combined track. This is the main reconstructed muon type. The software package used is called STACO.

- Segment-tagged (ST) muons: a track in the ID is classified as a muon if the extrapolated trajectory can be matched to at least one local track segment in the Monitored Drift Tube Chambers (MDT) or Cathode Strip Chambers (CSC). Segment-tagged muons can be used to increase the acceptance for muons which crossed only one layer of MS chambers. The package used for this is called MuTag.

- Calorimeter-tagged (CaloTag) muons: a track in the ID is identified as a muon if it could be matched to an energy deposit in the calorimeter compatible with a minimum ionizing particle. This type of muons has the lowest purity of all the muon types but it recovers acceptance in the regions not covered by the MS. The CaloTrkMuID algorithm is used for this type.

In ATLAS, the reconstruction of the Stand-alone, Combined and Segment-tagged muons has been performed using two independent reconstruction software packages, implementing different strategies (called "chains") both for the reconstruction of muon objects in the spectrometer and for the ID-MS combination. The first chain (called STACO) does a statistical combination of the track parameters of the Stand-alone muon and ID muon tracks. The second (called MUID) performs a global refit of the muon track using the hit information from the ID and MS. A new unified chain (called "MUONS") has been developed to incorporate the best features of the two original chains. In our analysis the Staco muons have been used uniformly. The ID tracks used for CB, ST or CaloTag muons need to satisfy the following quality requirements:

- at least 1 Pixel hit (nPix+nBadPix);
- at least 5 SCT hits (nSCT+nBadSCT);
- at most 2 active Pixel or SCT sensors traversed by the track but without hits;

in the region of full TRT acceptance, $0.1 < |\eta| < 1.9$, at least 6 TRT hits. (The number of hits required in the first two points is reduced by one if the track traverses a sensor known to be inefficient according to a time-dependent database).

3.4 Jets

Jets are collimated shower of hadrons produced in great quantity in a hadron collider. ATLAS calorimeters consist of cells which can record the signal from a particle when it traverses thorough them. The cells also record random noise from readout electronics and pileup interaction. We observe jets as a cluster of cells with energy deposition mostly in the hadronic calorimeter.

To construct the jets we need to consider cells that have large signal over the random noise ratio (S/N). As a first step cells with S/N greater than 4 is used as seed for a proto-cluster. All neighboring cells with S/N $>$ 2 are iteratively added to the proto-cluster. If a cell is in the boundary of more than one proto-cluster, the proto-clusters are merged. All neighboring cells of this proto-cluster is then added irrespective of its S/N ratio. At this stage, Proto-clusters are split around the local maximas with energy E$>$ 0.5 GeV greater than any of its neighboring cell. These local maxima cells are used to seed exactly one proto-cluster consisting only those cells that were part of the initial cluster. Cells that are shared by two proto-jets contribute to each according to the proto-cluster energies and distance of the cell from the proto-cluster centers. The resulting new proto-clusters and any original proto-clusters lacking local maxima are sorted in order of E_T and called topological clusters.

These topological clusters then are fed to the one of the sequential recombination jet-finding algorithms. Jet algorithms are defined by two distances,

distance between two clusters,

$$d_{ij} = min(k_{Ti}^{2p}, k_{Tj}^{2p}) \frac{(\Delta R)^2_{ij}}{R_c^2} \tag{1}$$

distance between a cluster and beam,

$$d_{ib} = k_{Ti}^{2p} \tag{2}$$

where

$$(\Delta R)_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

and k_{Ti}, y_i, ϕ_i are the transverse momentum, rapidity and azimuthal angle of the i-th cluster. The variable p takes different values for different algorithms, e.g. for k_T, $anti{-}k_T$ and Cambridge-Aachen algorithms the value of p is 1,-1 and zero respectively. The current ATLAS recommendation has been to use the $anti - k_T$ jet algorithm. R_c is called the characteristic radius parameter which decides the size of the eventual radius of the jet.

At first, the highest p_T cluster i is considered and the distances between it and other clusters (d_{ij}) and distance from the beam (d_{ib}) are calculated. If d_{ij} is smaller than d_{ib}, the j-th cluster is added to the i-th cluster. This goes on till there are no cluster with distance smaller than d_{ib}. The jet i is then considered to be complete and removed from further consideration. The same procedure is then continued for the remaining clusters until there is none remaining. The p=-1 value for anti-kT algorithm means the low pT clusters have larger weightage in d_{ij} and merge with the large p_T jets before harder jets at the same distance from the i-th cluster. This ensures that the algorithm produces roughly conical-shaped jets with a soft-resilient boundary which are infra-red safe. Also eqn. 1 and eqn. 2 ensure that any cluster j with $(\Delta R)_{ij} < R_c$ is merged with cluster i, which makes the algorithm collinear-safe.

The energy measurement of these topological clusters underestimate jet energy because jets have a lower detector response than electromagnetic shower objects, due mainly to the non-compensating nature of the ATLAS calorimeter. To correctly measure the jet response, cluster energies need to go through a Jet Energy Scale (JES) calibration. The local cell signal weighting (LCW) method of calibrating the topological cluster jet has been used in this analysis. The LCW method classifies the topo-clusters as either electromagnetic or hadronic, based on the measured energy density and the longitudinal shower depth. Corrections are applied for calorimeter non-compensation, signal losses due to noise threshold effects, and energy losses in the non-instrumented regions close to the clusters. The LC-jet calibration is carried out in a four-step procedure in the following way.

PileUp subtraction: Energy deposit due to pileup contribution is subtracted using MC simulation. The pileup contributions are derived as a function of reconstructed number of primary vertex, N_{PV} and the expected average number of interactions per branch-crossing, μ in bins of pT and $|\eta|$.

Origin subtraction: Keeping the jet energy unchanged the direction of jet momentum is corrected so that it points towards the primary vertex of the event instead of the center of the detector. This improves the η resolution of the jets tremendously.

Jet calibration based on MC simulation: Jet energy is calibrated by applying Jet Energy Scale (JES) derived from MC. These calibration factors are determined by spatially matching calorimeter jets to particle-level jets and then taking the ratio of the measured and true jet energies.

Residual in situ correction: Finally, a global sequential calibration scheme is employed. This leaves the mean jet energy unchanged but improves the jet energy resolution and reduce the sensitivity of the response to jet flavor.

After the full calibration, the scale of the calorimeter jets built from LCW-scale topo-clusters is referred to as LCW+JES.

3.5 MET

The conservation of momentum requires the total momentum in the transverse plane of the beam-pipe to be zero before and after the proton-proton collision. The unbalanced "Missing" Transverse Energy in the detector arises from particles that leave the detector without being detected. This is pertinent in our analysis because of the neutrino from the decay of W-boson which has very weak interaction with the detector material. The $E_T^{missing}$ is calculated by the MET_refFinal algorithm. It uses all the objects detected within the calorimeter system and also the muons detected using the inner detector and muon spectrometer. The missing transverse energy has x- and y-components, which can be written down in the form of

$$E_{x(y)}^{missing} = E_{x(y)}^{missing,calo} + E_{x(y)}^{missing,\mu} \tag{3}$$

The $E^{missing,calo}$ terms can be calculated as negative vector sum of calorimeter objects such as electron, photon, jet, tauon and soft energy contributions. The topo-cluster energies are replaced by the calibrated object energies. Muon energy deposited in the calorimeter is subtracted to avoid double counting.

The muon term is calculated as the negative sum of muon track momenta. Combined muon tracks are used for $|\eta| < 2.5$. For $2.5 < |\eta| < 2.7$ region, outside the inner detector acceptance, stand alone muons are used.

The total magnitude and azimuthal angle of the vector $E_T^{missing}$ are calculated as,

$$E_T^{missing} = \sqrt{(E_x^{missing})^2 + (E_y^{missing})^2} \tag{4}$$

$$\phi^{missing} = arctan(\frac{E_y^{missing}}{E_x^{missing}}) \tag{5}$$

4 Monte Carlo generation

4.1 Generators

4.2 Matrix element, Parton showering, underlying events

4.3 Data and MC samples

4.4 Whizard

4.5 MC correction:

4.6 Pileup reweighting,vertex reweighting, energy correction, calibration

5 Object and Event Selection

5.1 Object selection

5.2 vertex

The vertex with the highest sum of square of transverse momentum, Σp_T^2, of the associated tracks is chosen as the primary vertex.

5.3 Muon

Muons candidates are reconstructed using the STACO algorithm using both muon spectrometer (MS) and inner detector (ID) information. It has author =6. Muons are required to have pt $>$ 15 GeV and $|\eta| < 2.4$. To suppress non-prompt muons coming from hadron decay, impact parameter selections were placed, $|z0sin\theta| < 0.5$ mm. The inner detector tracks need to satisfy the following criteria: i) Number of pixel hits + number of dead pixel sensors hits > 0. ii) Number of SCT hits + number of dead SCT sensors hits > 4. iii) Number of pixel holes + number of SCT holes < 3. For 0.1$< |\eta| <$1.9, $n_{TRT}^{hits} + n_{TRT}^{outliers} > 5$ and $n_{TRT}^{outliers}/(n_{TRT}^{hits} + n_{TRT}^{outliers}) < 0.9$.

A tighter muon selection is considered called the good muon where muons need to have $|dosig| < 3$, calorimeter isolation $\Sigma(E_T cone30)/E_T > 0.07$ and track isolation $\Sigma(p_T cone30)/E_T > 0.07$. Standard ATLAS muon tool is used to apply corrections due to momentum scale and resolution, trigger, reconstruction, identification efficiency. The isolation scale factor is assumed to be 1.

5.4 Electron

Electron candidates are defined as clusters of energy deposited in the electromagnetic calorimeter associated to a track reconstructed in the Inner detector. They are required to meet the ATLAS medium++ identification criteria and to have transverse energy pt $>$ 15 GeV. They need to have author =1 or 3. They also must have $|\eta| < 2.47$, excluding the crack region between barrel and end cap of the EM calorimeter, $1.37 < |\eta| < 1.52$, to avoid energy mis-measurement. For electron there is an OTx cleaning cut that require OQ&1446==0. The OTxs refer to the Optical Transmitters on the Liquid Argon Calorimeter. This cleaning cut removes electrons that fall inside cells with dead OTxs. To make sure the electron candidate is coming from the primary vertex,$|z0sin\theta|$ needs to be $<$ 0.5 mm and $|\frac{d0}{\sigma_{d0}}|$ needs to be $<$ 5 . The electron cannot be within dR =0.1 of a good muon (described earlier in the muon section).

A tighter electron selection is also considered called the good electrons. Good electrons need to satisfy all the previous requirement. In addition it needs to pass the ATLAS tight++ identification criteria. There is also calorimeter and track isolation requirement. Calorimeter isolation $\Sigma(E_T cone30)/E_T$ <0.14 and track isolation $\Sigma(p_T cone30)/E_T$ <0.07. Monte Carlo samples fail to perfectly describe energy scale and resolution, isolation, identification, reconstruction, triggering of electrons seen in data. Correction due to these are applied to electron using the standard ATLAS egammaAnalysisUtils package.

5.5 Jets

Jets are reconstructed from the topological clusters using the anti-kT algorithm with radius parameter R= 0.4. The jets need to have pt> 30 GeV,

$|\eta| < 4.5$. To suppress pileup, for jets with pt$<$ 50 and $|\eta|$ <2.4, there is a jet vertex fraction (JVF) requirement. The JVF is defined as the ratio of pt associated with the tracks coming from the primary vertex to pt associated with all tracks. JVF needs to be > 5 for the jet to pass. Any jet that is too close to an electron or a muon within ΔR=0.3 is removed from consideration. For the analysis we used Cambridge-Aachen R = 1.2 jets with mass-drop filtering as our merged jets. The filtering parameters are $\mu_{frac} < 0.67$ and y_f needs to be > 0.09. The large-R jet needs to have pt $>$ 100GeV and $|\eta| <$ 1.2 and it is removed if it is within R=1.2 of an electron or a muon.

5.6 MET

Because of the neutrino in the final state, large unbalanced "missing" momentum, $E_T^{missing}$, is expected in the transverse plane. The "RefFinal" definition of MET is used in this analysis. This definition uses the sum of calorimeter energy deposits and of the pt of muons reconstructed in the inner detector or muon spectrometer. The estimate of the energy deposited in the calorimeter is refined by associating calorimeter energy deposits with reconstructed objects (electrons, photons, jets, etc.) and replacing the calorimeter energy estimate by the calibrated object pt. For the MET calculation the MissingETUtility package has been used. The smearing, energy correction, and calibration applied to the objects are propagated to the $E_T^{missing}$ calculation.

5.7 Event selection

6 Signal and background estimation

6.1 $t\bar{t}$ modeling

$t\bar{t}$ is one of the bigger backgrounds. It has been modeled by the Powheg generator which calculates the matrix element at next to leading order (NLO). The parton shower has been calculated with Pythia.

Previous ATLAS analyses have shown that Powheg-Pythia samples do not model experimental data perfectly, as evidenced by the unfolded differential top quark pair cross-section measurement. Following the conclusions of the study, two reweighting functions were derived so that the MC sample agrees with unfolded data for the p_T of the parton-level $t\bar{t}$ and the p_T of the top-quark (not anti-top). These weights are applied as additional event weights. The numerical value of the weights and more details can be found in [?]. This procedure has been followed by previous analyses [?].

6.2 QCD fit

There is a small background contribution from QCD multijet processes. These backgrounds come primarily from jets misreconstructed as electrons, or from leptons originating from heavy-flavor decays inside jets. For simplicity all of these sources will be referred to as “fake” leptons. Because of the very high cross-section and low fake rate of these processes, and because of the difficulty in modeling the fake-rate, this background is difficult to model with MC. Therefore, it has been estimated using a data-driven method.

A fake-lepton-enriched region can be constructed by modifying the identification criteria of the leptons, to create "bad" lepton candidates. Bad electrons are required to pass the medium++ requirement but fail the tight++ one. For bad muons, the cut on the significance of transverse component of impact parameter, $|d_0/\sigma_{d_0}|$, is inverted with respect to the good muon definition, i.e. bad muons must satisify $|d_0/\sigma_{d_0}| > 3$. In order to improve the statistics and purity of the fake-enriched region, the isolation requirements on the bad lepton are also modified with respect to the good lepton definition. We require bad leptons to have ΣE_TCone30/p_T ¿ 0.04 and Σp_TCone30/p_T ¡0.5.

7 Systematics

The estimation of systematic uncertainties in an experiment is of critical importance. Unlike the statistical uncertainty which arises due to statistical fluctuation in the dataset and which can be reduced by taking more data or generating bigger MC samples, the systematic uncertainties arise from experimental biases that introduce shifts in our measurement. It is important to understand the sources of possible biases and estimate their magnitude to report a meaningful scientific statement.

The systematic sources can be divided in two classes. One is experimental systematic uncertainties which are related to uncertainties in measurement of different object in the detector. The other class is theoretical uncertainties which are related to calculation of total and differential cross-sections by Monte Carlo generators.

7.1 JES

The biggest source of detector-related systematic uncertainties are from Jet Energy Scale and resolution uncertainties. These uncertainties affect both shape and normalization of the different templates. The uncertainty in measuring the jet energy scale is calculated by the JetUncertainty tool. We calculate the uncertainty as a function of pt and eta of jets. The latest ATLAS recommendation for jet uncertainty has been followed. The full set of nuisance parameters relating to JES uncertainties contain around 60 components. A reduced set of parameters has been used for this analysis which preserves the information on bin-by-bin correlations. The set of parameters includes

- Six nuisance parameters related to different in-situ measurements used for jet calibration.
- Two from η calibration due to modelling and statistics.
- One from the behavior of high-p_T jets.
- One from MC non-closure relative to MC12a.

- Four components come from Pileup related uncertainties.
- Flavor composition and flavor response uncertainty.
- Uncertainty due to close-by jets.
- b-jet JES response.

These sources for JES uncertainty is treated as uncorrelated and added in quadrature.

7.2 JER

The jet energy resolution was determined by two complementary techniques, the di-jet balance and bi-sector method. The experimental uncertainty due to jet energy resolution is assessed by applying a smearing factor to the nominal jet energy and momentum so that jet resolution is increased by 1σ. This is accomplished by randomly sampling a Gaussian with width equal to the JER fractional uncertainty. This is calculated by the JetResolution tool.

7.3 Lepton energy scale and resolution

Sources for lepton uncertainties include energy scale and resolution uncertainties. The official *egammaAnalysisUtils* and *MuonMomentumCorrections* tools are used for this. There were also uncertainties related to the scale factors used to correct mismodelling of trigger, identification and reconstruction efficiency and isolation in the MC.

7.4 $E_T^{missing}$ uncertainties

The soft terms uncertainty is calculated by the help of packages MetAnalysisCommon and MissingETUtility. There are two sets of soft term systematics. One is the global soft term systematics. These are ScaleSoftTermsUp (scales up the soft component of MET by one sigma), ScaleSoftTermsUp and ResoSoftTermsUp (smears the soft component by resolution uncertainty). The second set is called the "ptHard" uncertainties. There are six components and they are ScaleSoftTermsUp_ptHard, ScaleSoftTermsDown_ptHard, ResoSoftTermsUp_ptHard, ResoSoftTermsDown_ptHard, ResoSoftTermsUpDown_ptHard and ResoSoftTermsDownUp_ptHard.

7.5 W+jets uncertainty

W+jets is the biggest background in this analysis. The modelling of W+jets was done by Sherpa generator. The uncertainty due to modeling was investigated by varying different parameters of the generator.

- Factorization scale: Two variations have been considered, in one the two times the nominal scale has been used to generate W+jets samples, in the other half the nominal scale is used to generate sample.
- Renormalization scale: Like factorization scale, the renormalization scale is also varied to 2 $\times$ nominal and 0.5 $\times$ nominal scale.

- CKKW matching scale: Sherpa employs the CKKW scheme to match the matrix element particles with the parton shower particles. The nominal CKKW scale is 20GeV. For uncertainties we have used 15 GeV and 30 GeV.

7.6 $t\bar{t}$ uncertainty

$t\bar{t}$ modeling is done by the Powheg generator with parton showering handled by Pythia6. The modeling uncertainty is estimated by considering the followign sources.

- Generator: Take the difference between Powheg+Herwig and MC@NLO+Herwig.
- Parton shower: Take the difference between Powheg+Pythia and Powheg+Herwig.
- Initial and final state radiation (ISR and FSR): We have used AcerMC+Pyhtia for this estimation.

7.7 QCD uncertainty

7.8 Signal uncertainty

7.9 b-tagging uncertainty

For all MC events, depending on whether a jet passes the MV1 weight requirement for b-tagging, a b-tag efficiency or a b-tag inefficiency scale factor was calculated which corrects for discrepancy between data and MC. To estimate the uncertainty due to b-tagging, we used the sigma of the scale factors. The uncertainty is calculated in the following way:

- Vary the b-jet efficiency SF in all p_T,η bins up (down) by 1 sigma, at the same time vary the b-jet inefficiency SFs in all p_T,η bins down (up) by 1 sigma.
- Vary the c-jet efficiency SF in all p_T,η bins up (down) by 1 sigma, at the same time vary the c-jet inefficiency SFs in all p_T,η bins down (up) by 1 sigma.
- Vary the mis-tag rate efficiency SF in all p_T,η up (down) by 1 sigma, simultaneously vary the mistag rate inefficiency SF in all p_T,η bins down (up) by 1 sigma.

These three uncertainties are considered to be uncorrelated and added in quadrature to get the total uncertainty.

8 Fitting procedure

9 Results