Measurement of the b-jet cross section at Vs=1.96 TeV
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Chapter 3

DØ Trigger System

The frequency of beam crossings at the DØ detector is 2.5 MHz. At the design luminosity of $2.1 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$, this results in approximately 6 overlapping events per beam crossing\(^1\). This event rate, combined with the average event size of 250 kilobytes, makes it impossible to write all the events to tape without filtering. A dedicated system of filters, called triggers, is thus needed to keep interesting physics events and reject background events. Three levels of triggers have been designed to reach this goal:

- **Level 1**: A pipelined hardware stage using CFT fibers, preshowers, calorimetry and the muon system to reduce the 2.5 MHz input rate to 10 kHz;

- **Level 2**: A second hardware stage refining and combining the Level 1 output with multiple preprocessors and a global processor to reduce the 10 kHz rate to an output rate of 1 kHz;

- **Level 3**: Partial event reconstruction using high level software algorithms running on multiple PC’s, delivering a final event rate of 50 Hz to tape.

These trigger levels are explained in more detail below. Special emphasis is placed on the Level 1 muon and jet triggers, since those triggers have been used to select the data for this analysis. The Level 2 and Level 3 trigger systems are discussed in a more general fashion.

\(^1\)The typical luminosity at the time of data taking was approximately $10^{31} \text{ cm}^{-2}\text{s}^{-1}$, resulting in an event rate of 334 kHz.
3.1 Level 1

The Level 1 trigger is a hardware based system filtering the 2.5 MHz trigger rate to an output rate of 10 kHz as input to Level 2, with minimal dead time. The time available for the Level 1 trigger decision is 4.2\,$\mu$s. The system consists of a number of hardware components:

- Trigger Subsystems;
- Trigger Managers;
- Trigger Framework.

These components are made out of Field Programmable Gate Arrays (FPGAs), embedded on electronics boards, in which the trigger logic is implemented. Each of the Trigger Subsystems processes the data for each detector subsystem. The preshower and CFT are combined in the Central Track Trigger (CTT), as shown in figure 3.1. The Trigger Subsystem reports the physics results to a subsystem-specific Trigger Manager. This Trigger Manager evaluates these results, and produces And-Or Input Terms which are sent to the Trigger Framework. These input terms are flags which represent information about the event. This can be physics information, e.g. a found muon, but it can also be beam indicator signals, cosmic background vetoes or any information about the event that is required for a Level 1 Trigger decision. The entire trigger system contains a maximum of 256 of these And-Or Input Terms, which are combined in And-Or combinations in the Trigger Framework (e.g. a found muon in the muon Trigger Subsystem with a matching track in the CTT Trigger Subsystem). For every beam crossing, the Trigger Framework can evaluate 128 of these And-Or combinations. When at least one of these 128 combinations is positive, and the DAQ system is ready for acquisition of data, the Level 1 Trigger Framework issues an accept, and the event data is digitized and moved into a series of 16 event buffers to await a Level 2 trigger decision. Each of the Trigger Subsystems is discussed in more detail in the following sections.
3.1 Level 1

![Level 1 and Level 2 trigger system overview](image)

Figure 3.1: Level 1 and Level 2 trigger system overview. The acronyms are explained in chapter 2 and appendix C.
3.1.1 Central Track Trigger

The Level 1 Central Track Trigger (CTT) uses the following detector elements [40]:

- Axial fibers of the Central Fiber Tracker;
- Axial strips of the Central Preshower;
- Forward Preshower strips;
- Forward Proton Detectors.

At Level 1, no information is available from the CFT stereo fibers and the CPS stereo strips. The trigger is split up in a central part, using the Central Fiber Tracker and the Central Preshower, and a forward part, consisting of the Forward Preshower strips and the Forward Proton Detectors.

The central trigger is divided in 80 sectors in $\phi$. For each of these sectors, the central trigger determines the number of tracks per $p_T$ interval, as well as the number of fibers hit. There are 4 $p_T$ intervals available:

- 1.5 - 3 GeV/c;
- 3 - 5 GeV/c;
- 5 - 11 GeV/c;
- 11 - 1000 GeV/c.

In addition, the trigger also reports the number of tracks that have been successfully matched with a cluster in the central preshower. The tracks found are reported to the Trigger Manager, the Level 1 Muon Trigger and Level 2 preprocessors. A typical Level 1 trigger that uses a CTT term will fire on the presence of a track that matches with a muon object, on a single high $p_T$ track or multiple low $p_T$ tracks. At the time the data set under consideration for this analysis was taken, the CTT was inactive.

The forward trigger combines clusters in the backward $u$- and $v$-layers of the FPS with hits in the forward layer of the FPS to tag the clusters as electron- or photon-like. The number of electron and photon candidates per quadrant is reported to the Level 1 FPS Trigger Manager. In each of the FPD detectors, track segments are reconstructed and matched to form tracks [41]. The number of tracks found is reported to the Level 1 FPD Trigger Manager. Typically, a Level 1 FPD trigger will require one or two diagonally opposed tracks found in the FPD detectors in combination with one or two trigger towers found by the calorimeter trigger.
3.1 Level 1

3.1.2 Calorimeter Trigger

From the viewpoint of the Level 1 calorimeter trigger, the calorimeter is divided into 1280 projective towers, with 32 divisions in $\phi$ and 40 in $\eta$, resulting in a segmentation of $0.2 \times 0.2$ in $(\eta, \phi)$ for each tower. In depth, these towers are divided into three sections: an inner electromagnetic section, followed by a hadronic section and a coarse hadronic section. The electromagnetic section is divided into 7 segments in depth, while the hadronic section is divided in 3 segments with some variation depending on the position of the tower. Only the electromagnetic and hadronic sections are used for the Level 1 trigger decision since the coarse hadronic section typically generates too much noise at Level 1. The inputs for the trigger are the transverse energies deposited in each of the 1280 electromagnetic and 1280 hadronic sections. These transverse energies are combined in the trigger manager into quantities, which are then compared to various trigger criteria to pass or reject the event. Typically the trigger criteria require one or more towers with an energy higher than a certain threshold energy (generally 3, 5, or 7 GeV per tower).

3.1.3 Muon Trigger

The Level 1 muon trigger uses both the wires and the scintillators, with additional information from the Level 1 CTT (if available), to base a trigger decision on. The detector information is used in two different trigger algorithms to detect muon tracks. The first combines tracks that are found by the CTT with hits in the scintillators of the muon system. The segmentation of the scintillators matches the segmentation of the CTT in $\phi$, and tracks that are found in a $\phi$ slice of the CFT are matched with hits in the scintillators in the same $\phi$ slice. A timing gate of 25 ns is used in the scintillators to reject background hits, while a 50 ns timing gate defines cosmic ray veto hits. In the central system, high $p_T$ CFT tracks are matched with an A-layer scintillator hit, as well as with a B- or C-layer scintillator hit, since these tracks penetrate the iron core of the magnet between the A- and the B- and C-layers. In the forward system, all three planes of scintillating counters are used to match the CTT track with scintillator hits.

The other algorithm uses a binary readout (i.e. no drift time information, but solely hit/no-hit information) of the wires to find combinations of hits in different planes, compatible with a straight line track (centroids), and verifies these with matching hits in the scintillating counters. In the central system, the timing information of the scintillating counter hit is needed because the maximum drift time in the PDT's (500 ns) is greater than the bunch crossing time (396 ns). This is not needed in the forward system, where the maximum drift time is 60 ns. A low $p_T$ trigger is defined using only centroids found in the A-layer, while a high $p_T$ trigger is defined using correlations between centroids found in the A-layer and the B- or C-layer. For both algorithms,
four \( p_T \) thresholds (2, 4, 7 and 11 GeV/c) are defined.

The information for each octant in each region is combined in the muon Trigger Manager, which produces global muon trigger information. The muon trigger manager makes a trigger decision based on the \( p_T \) threshold (2, 4, 7 and 11 GeV/c), pseudorapidity region (\(|\eta| < 1.0\), \(|\eta| < 1.5\) and \(|\eta| < 2\)), quality and multiplicity information. This trigger decision is sent to the Level 1 Trigger Framework where it is included in the global physics trigger decision. Depending on the trigger list, the trigger will fire on a single high \( p_T \) muon, multiple low \( p_T \) muons, or muons in association with other physics objects (jets, electrons etc.). In case of an accept, the Level 1 Muon Trigger reports the results to the Level 2 Muon Trigger, and on a Level 2 Accept, to the Level 3 Muon Trigger.

### 3.2 Level 2

The Level 2 trigger reduces the 10 kHz Level 1 accept rate by an order of magnitude to 1 kHz as an input to Level 3, in an average time budget of 100 \( \mu s \) \cite{42}. This is done using multi-subdetector correlations of objects found in the event. The Level 2 trigger is running on alpha-processors, and consists of two stages: a preprocessor stage, which processes data from each Level 1 trigger for use in the second stage, which is a global processor that combines this data to make a trigger decision. There is a 1-to-1 mapping between Level 1 trigger bits and Level 2 trigger bits (see figure 3.1). In the preprocessor phase, each detector system builds a list of trigger information. There are preprocessors for the following subsystems:

- Central tracker;
- Preshower detectors;
- Calorimeter;
- Muon tracker.

Each of these preprocessors will be briefly discussed below. For each subsystem, the Level 1 information is collected and transformed into physical objects like hits, clusters and tracks. The maximum time budget for this preprocessing is 50 \( \mu s \). After the physical objects are formed, they are transmitted to the global processor. The global processor correlates the information from the different detector systems to make physics objects like jets, electrons and muons, and makes a trigger decision within maximally 75 \( \mu s \). The total deadtime for this Level 2 system is 5%.
3.2 Level 2

3.2.1 Central Track Preprocessor
The Central Tracker preprocessor collects the tracks found by the Level 1 CTT trigger and creates Level 2 tracks [43]. It performs the following tasks for each track:

- It converts the Level 1 binned $p_T$ information into a real $p_T$ value;
- Using the $\phi$ position at the innermost CFT layer and the measured $p_T$, the $\phi$ direction at the vertex is calculated;
- Using the above, the $\phi$ direction at the third layer of the electromagnetic calorimeter is calculated;
- The isolation of the track is measured.

The tracks are then ordered in $p_T$ and sent to the Level 2 global processor. The tracks are maintained in memory for Level 3 readout in case of a positive Level 2 trigger decision.

3.2.2 Preshower Preprocessor
At Level 1, the central tracks found by the central track trigger are matched to preshower clusters in $\phi$ only. The larger time budget at Level 2 allows the preshower preprocessor to improve this match [44]. To this avail, it uses the stereo information from the $u$- and $v$-layers of the preshower to calculate the global $\eta$- and $\phi$-positions of the clusters. These clusters can then be matched with the tracks found by the Level 2 Central Track preprocessor and with calorimeter objects found by the calorimeter preprocessor, to identify different physics objects.

3.2.3 Calorimeter Preprocessor
The calorimeter preprocessor runs three algorithms in parallel:

- Jet reconstruction;
- Photon and electron reconstruction;
- Calculation of missing transverse energy.

From the viewpoint of the Level 2 jet reconstruction algorithm, the calorimeter is divided in towers, which are groups of calorimeter cells with the same $\eta$- and $\phi$-position, at increasing radial distance from the beam pipe. Around the towers that fired the Level 1 calorimeter trigger, $5 \times 5$ groups of neighboring towers are clustered. The total $E_T$ of all the towers in such a group must pass a minimum $E_T$ cut to be considered
a jet candidate. The $E_T$ of the clusters is calculated assuming that the interaction point is at $z = 0$. Jets that pass a minimum $E_T$ cut, as defined in the trigger list, are passed to the Level 2 global processor. The photon and electron reconstruction algorithm processes the electromagnetic towers given by the Level 1 calorimeter trigger and turns them into seed towers. For each seed tower, it determines which of its nearest four neighbors contains the largest $E_T$, and the total electromagnetic and hadronic energy in the seed tower and the nearest neighbor is calculated. Based on the total electromagnetic energy, and the ratio of electromagnetic energy compared to hadronic energy, the electromagnetic tower is considered an electromagnetic candidate and passed to the Level 2 global processor. The missing transverse energy algorithm calculates the vector sum of the $E_T$ in individual trigger towers, passed to it from the Level 1 calorimeter trigger, and reports it to the Level 2 global processor if it exceeds a certain value.

3.2.4 Muon Preprocessor

The Level 2 Muon Trigger uses all the wire hits and scintillator hits of the muon system to detect muon tracks. It starts with a pattern recognition step in which straight track segments are reconstructed in each layer of the muon detector. The pattern recognition is done by shifting a 3-tube wide window over all the cells in an octant, looking for wire triplets with a matching scintillator hit (if a scintillator layer is present), as illustrated in figure 3.2. Combinations of hits are compared with a hit-map to determine which 3-tube combinations are compatible with a straight track segment. This hit-map is created offline using Monte Carlo samples. After this pattern recognition step, found track segments in the A-layer are then combined with track segments found in the B- and C-layers to form Level 2 objects which contain $\eta$, $\phi$, and $p_T$ information.

The pattern recognition step is implemented in a Level 2 sub-level, which runs before the actual Level 2 Muon Trigger. This sub-level incorporates 80 Digital Signal Processors (DSPs) running in a parallel scheme, in which each DSP finds track segments in a small region of the muon detector. The combination of the track segments into tracks is performed in the Level 2 Muon Preprocessor, which reports the found tracks to the Level 2 global processor. Upon a Level 2 Accept, the Level 2 objects are sent to Level 3 to serve as seeds for a more precise muon track reconstruction.

3.3 Level 3

The Level 3 trigger is a software based system characterized by parallel data-paths which transfer data from the detector front-ends to a group of Personal Computers, known as nodes. It reduces the input rate of 1 kHz to an output rate of 50 Hz in an
3.4 Triggers used in data selection

The measurement of the $b$-jet cross section with a muon tag requires the presence of both a reconstructed muon and a jet in the event. A trigger that requires both a muon and a jet will therefore give the highest purity at the highest rate. Single muon or jet
triggers give a lower purity, and due to the fact that they were prescaled\(^2\), they also give a lower rate.

At the time of data taking, only a part of the Level 1 Trigger System was working reliably enough to select muons and jets. Level 2 and Level 3 filters were either inactive, or were running in Mark & Pass mode, which means that the filters were run on the events that passed the Level 1 trigger, marked it if the event would pass the filter, but irrespective of the Level 2 and Level 3 trigger decision the event was accepted. The Level 1 Trigger System included the calorimeter trigger covering the \(|\eta| < 0.8\) region, as well as the muon scintillator trigger, albeit without the matching of tracks from the CTT. Therefore, the trigger used to select the data requires:

- An A+C scintillator coincidence in the muon detector with \(|\eta| < 2.0\), with no requirement on the presence of a central track in the CTT;
- A 5 GeV energy deposit in the calorimeter with \(|\eta| < 0.8\).

This trigger is combined under the name \textit{mulptxatxx.CJT5}, where the first part, \textit{mulptxatxx}, corresponds to the muon part while the second part, \textit{CJT5}, refers to the calorimeter part of the trigger.

### 3.5 Efficiency for the \(\mu+\)jet Trigger

To calculate the efficiency of this trigger, we split it in two parts: the Level 1 muon trigger efficiency, \(\epsilon_{L1}^\mu\), and the Level 1 calorimeter trigger efficiency, \(\epsilon_{L1}^{cal}\), and we calculate both efficiencies separately. If we ignore the correlation between those two triggers for now, we can state for the combined Level 1 efficiency:

\[
\epsilon_{L1} = \epsilon_{L1}^\mu \cdot \epsilon_{L1}^{cal}
\]

In section 3.5.3 we will discuss the possible correlation, which turns out to be small.

The strategy to measure \(\epsilon_{L1}^\mu\) and \(\epsilon_{L1}^{cal}\) is based on the use of independent reference triggers. Events that are triggered by these reference triggers are fully reconstructed. In the case that a jet or muon is present, it is checked if the corresponding trigger bit is set. This allows the calculation of the trigger efficiency, as explained in the following sections.

#### 3.5.1 Calorimeter Trigger Efficiency

The calorimeter trigger efficiency for the \textit{CJT5} trigger is calculated by selecting events that are triggered by a muon trigger, akin to the \textit{mulptxatxx} trigger explained above.

\(^2\)A prescaled trigger accepts only 1 in every \(N\) events that would fire that particular trigger, where \(N\) is the prescale factor
with the additional requirement of a hit coincidence in the luminosity counters, which signals the presence of a hard scattering. In addition, the presence of a reconstructed jet passing quality and kinematic cuts (see section 5.2) is required. The CJT5 trigger efficiency is calculated by selecting those events in which the $mulptxatxx.CJT5$ trigger fired, divided by the number of events in the selected sample, according to:

$$
\epsilon_{L1}^{\text{col}} = \frac{\text{Reconstructed jet and } mulptxatxx.CJT5}{\text{Reconstructed jet and } mulptxatxx}
$$

Figure 3.3a shows the efficiency of the CJT5 trigger as a function of reconstructed, uncorrected jet $E_T$. Correcting the jet energy with the Jet Energy Scale (see section 4.1) results in figure 3.3b. The statistical errors on the trigger efficiency are shown as the vertical lines on the data points.

The dominant systematic error originates from the uncertainty on the Jet Energy Scale correction, which is of the order of 7% (see section 4.1). To evaluate the systematic error we first add the error on the Jet Energy Scale correction to the correction for each separate jet, and the Level 1 efficiency is calculated. Then, the same is done but subtracting the error on the Jet Energy Scale correction. The maximum difference of these two efficiencies with respect to the efficiency calculated with no error on the Jet Energy Scale correction is taken as the systematic error, which is illustrated by the grey band on the bottom of figure 3.3b.

The Level 1 trigger efficiency shows a turn-on curve for jet energies below 40 GeV, reaching 100% efficiency above that energy.

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Figure 3.3: Level 1 Jet Trigger efficiency, uncorrected (left) and corrected (right) for the Jet Energy Scale. Data points show statistical errors only with the grey band showing the relative systematic error.
3.5.2 Level 1 Muon Trigger efficiency

The Level 1 muon trigger requires a coincidence of a scintillator hit in the A-layer and a scintillator hit in the B- or C-layer. Two reference triggers, which both contain the CJT5 And-Or Input Term, are used to calculate the efficiency of this trigger, namely:

- 2JTLO, requiring two Level 1 calorimeter towers, one with $E_T > 3$ GeV and one with $E_T > 5$ GeV. In addition, at Level 3, two jets reconstructed with a simple cone algorithm and with $E_T > 10$ GeV are required;

- CEM5.2CJT5, requiring two Level 1 calorimeter towers with $E_T > 5$ GeV, of which one has to be in the electromagnetic calorimeter.

For each of these triggers, a sub-sample is extracted from the initial sample for which the reference trigger fired, and an offline reconstructed tight muon that passed modified quality and kinematic cuts, as defined later in section 5.1, was present in the event. These modified quality cuts are the same ones as described in section 5.1, but with the scintillator hit requirement on the muon tracks removed. This is done to avoid the bias introduced by the fact that the standard quality cuts require both an A- and a B- or C-layer scintillator hit, which is the same requirement that fires the trigger if the timing of the hits is within the trigger gates.

Normally, requiring the presence of a reconstructed jet close to the muon practically removes all cosmic muons. However, the sample that is extracted here does not have that requirement and therefore still contains cosmic muons. The percentage of muons in the sample that are actually cosmic muons is estimated using two methods: using scintillator times associated with the muon track, and back-to-back muons. The first method selects all muon tracks in the sample that have one or more scintillator hits associated with them. The percentage of these tracks that have a measured time on one of the scintillator hits that is outside the trigger gate is taken as the cosmic muon contamination in the sample. This method results in a cosmic contamination of $(6.3 \pm 0.6(stat) \pm 1.4(sys))\%$, where the systematic error is estimated from the number of tracks that have both scintillator hits outside the trigger gate. The second method counts the number of back-to-back muons in the sample, which gives the cosmic muon contamination when divided by the total number of tight muons in the sample. In this scenario a back-to-back muon is defined by a tight muon in the muon system, with another muon at $\delta \phi > 2.5$ radians, at least 2 wire hits in the A-layer and at least 3 hits in the BC-layer of the muon system. This results in a cosmic muon contamination of $(2.8 \pm 0.4(stat) \pm 0.7(sys))\%$, where the systematic error is derived from decreasing the $\delta \phi$ cut to 2.0 radians. We estimate the total cosmic muon contamination by taking the average of these values and assign a systematic uncertainty to cover both methods: $(4.5 \pm 1.8)\%$. 


3.5 Efficiency for the $\mu$+jet Trigger

<table>
<thead>
<tr>
<th>Reference trigger</th>
<th>Efficiency</th>
<th>Statistical Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2JT. LO</td>
<td>57.8%</td>
<td>1.5%</td>
</tr>
<tr>
<td>CEM5.2CJT5</td>
<td>60.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Combined</td>
<td>59.0%</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Table 3.1: Level 1 muon trigger efficiencies measured with different reference triggers.

The efficiency of the $\text{mulptxatxx}$ trigger is now calculated by selecting the events in which the $\text{mulptxatxx.CJT5}$ trigger fired, divided by the number of events which contain a reconstructed muon in the selected sample:

$$
\epsilon_{\mu}^{L1} = \frac{\text{Reconstructed muon and mulptxatxx.CJT5}}{\text{Reconstructed muon and CJT5} - \text{cosmic contamination}}
$$

Figure 3.4 shows the Level 1 muon trigger efficiency as a function of $p_T, \eta$ and $\phi$ of the reconstructed muon for the 2JT. LO trigger on the left hand side of the plot, and for the CEM5.2CJT5 trigger on the right hand side. The trigger shows a drop in efficiency for high $p_T$ muons. This is not due to a physics or hardware effect, but is shown with later runs using more statistics to be a statistical effect. However, for the calculation of the $\mu$+jet cross section this effect is taken into account, since we do measure this efficiency over the run range used for the analysis. The drop in efficiency seen in the plot for the Level 1 $\eta$ efficiency for the 2JT. LO reference trigger between $0.1 < \eta < 0.5$ can also be attributed to statistics, since this effect is not seen for the CEM5.2CJT5 reference trigger. Both the $\phi$ plots show the effect of the hole in the bottom of the detector in the $\phi$ region 4.2-5.0, where few muons are reconstructed.

Combining the two data samples, taking into account those events for which both reference triggers fired, results in the final Level 1 muon efficiency as shown in figure 3.5 and summarized in table 3.1. The average efficiency of the Level 1 muon trigger, integrated over $\eta, \phi$ and $p_T$ is $59.0^{+2.7}_{-2.4}\%$, where the errors consist of the statistical error of 1.0%, the difference between the combined Level 1 trigger efficiency and the efficiency of the reference trigger (-1.2%, +1.7%), and an error of 1.8% for the cosmic muon contamination. For the calculation of the cross section we will use the value of the trigger efficiency in each bin separately, with the corresponding error in that bin.
Figure 3.4: Level 1 muon trigger efficiency as a function of $p_T$, $\eta$ and $\phi$, for the 2JT_LO reference trigger in the left plots and for the CEM5.2CJT5 reference trigger in the right plots. Missing data points (for example at $\phi_\mu \approx 4.8$) are due to zero events in the numerator.
Figure 3.5: Level 1 muon trigger efficiency as a function of $p_T$, $\eta$ and $\phi$, using both reference triggers. The black curves are fits to guide the eye.
3.5.3 Trigger correlations

Equation 3.1 is only valid if the correlation between the two separate triggers is zero. A priori this is not immediately clear: particles in a jet that fire the jet trigger can punch through the calorimeter, firing the muon trigger as well. Also, a muon, firing the muon trigger, could possibly deposit enough energy in the calorimeter to fire the jet trigger.

The correlation of the muon trigger with the jet trigger due to punch-through particles is zero by construction. The denominator in the efficiency calculation for the muon trigger is a muon with at least two wire hits in the A-layer, and at least three wire hits in the BC-layer. Any punch-through particle that creates such a track is indistinguishable from a real muon, and is treated as a real muon in the trigger efficiency measurements. Only at a later stage is the cross section corrected for the effects of punch-through (see section 5.1.2).

A muon passing through the calorimeter will fire the jet trigger if the muon deposits more than 5 GeV in one trigger tower \((0.2 \times 0.2\) in \((\eta,\phi))\). The extent of this effect on the jet trigger efficiency is investigated in two ways:

- By determining the energy a muon deposits in the calorimeter;
- By calculating the jet trigger efficiency, in the case that a muon is present in the event.

The energy deposited by a muon in the calorimeter is measured by looking at the energy in the calorimeter in a tower of 3 by 3 cells around an isolated muon track. This 3 by 3 tower is 2.25 times as big as the trigger tower, which causes an overestimation of the energy deposited in a trigger tower. The energy deposited by the muon in a 3 by 3 tower is only higher than 5 GeV in \(0.23 \pm 0.03\%\) of the cases, which means that the energy deposit of the muon will only fire the trigger in 0.23\% of the cases. However, even if the energy deposited is less than 5 GeV, it can still bias the jet trigger if the energy deposit is close to a jet, and adds to the energy of the jet. To exclude any possible effect, we also study the jet trigger efficiency in a sample of jets in which a reconstructed muon is present. We again select a sample of events in which the mu1p9atxx Level 1 trigger fired, a reconstructed jet that passes the quality and kinematic cuts is present, and a reconstructed muon that passes the quality and kinematic cuts is present. Then, we calculate the efficiency as a function of jet \(E_T\) according to equation 3.2, with the added requirement of the reconstructed muon in both the numerator and denominator. If we compare the result with figure 3.3, no significant deviation is observed, and we conclude that there is no significant correlation between the Level 1 muon trigger and the Level 1 jet trigger. Since the statistical error on the muon trigger is large compared to this effect, we choose not to add an additional systematic error for this correlation.