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MET-based Trigger Turnon Parametrizations for WH Search

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Abstract

This note is intended as documentation of the usage of MET-based triggers for the "isolated track" channel in the Neural Network analysis of the WH search. Since at CDF there is no dedicated "isolated track" trigger, we are using three MET-based triggers: MET+2Jets (MET2J), MET45/MET40 (MET45) and MET_DIJET (METDI). We parametrize the turnon curves for each of these triggers as a function of MET, we measure the prescales of each trigger and we evaluate the systematic uncertainties associated to using one trigger or a combination of triggers. For data up to period p23, if we divide the sample using all three MET-based triggers, the signal acceptance is expected to increase by almost a third compared to using MET2J alone.

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1 Introduction

We are searching for the production of a Higgs boson in association with a W boson (WH search) with the help of Artificial Neural Networks to better separate signal and backgrounds. We divide the analysis in various charged-lepton orthogonal categories: CEM, CMUP, CMX, PHX. The first three represent "central" charged leptons and all four represent tight charged leptons. In order to improve the sensitivity of the analysis, we increase the signal acceptance by also reconstructing an orthogonal category of charged leptons with looser requirements. We call it "isolated track" (ISOTRK).

ISOTRK candidates represent high-p_T tracks isolated from other activity in the tracking system that are not required to match a calorimeter cluster (as is typical for the electron candidates) or an energetic deposit in a muon detector (as is typical for muon candidates). Therefore, ISOTRK candidates include real charged-lepton candidates that pass through non-instrumented regions in the detector and therefore increase the signal acceptance.

The NN WH analysis used for the first time the ISOTRK channel for the round of conferences from the summer of 2008 (2.7 fb^{-1})[1]. Only one trigger was used: MET+2Jets. The channel offered increases in signal acceptance and sensitivity of 25% and 10%, respectively, when added to the central channels. Also, studies performed then revealed that ISOTRK candidates are muon candidates in 85% of the cases, electron candidates in 7% of the cases and tau lepton candidates in about 8% of the cases. The increase of signal acceptance by can be visualised in Figure 1 by comparing the ISOTRK candidates (red) with the CMUP candidates (black) and CMX candidates (blue).

We expanded that work by using all three MET-based triggers available in CDF - MET+2Jets (MET2J), MET45/MET40 (MET45) and MET_DIJET (METDI) - with the help of the ABCDF software package we developed. Having a modular structure, ABCDF will accomodate easily an unlimited number of triggers, if new triggers need to be added in the future.

Be begin this note by presenting the measurement of the turnon curves and effective

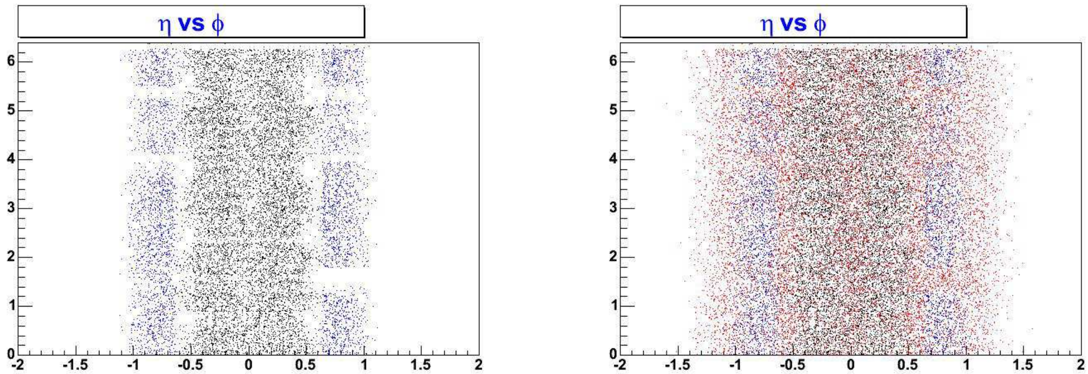

Figure 1: In the left plot, only CMUP muon candidates (black) and CMX muon candidates (blue) are shown. The η coordinate is on the x axis and the ϕ coordinate on the y axis. A lot of gaps can be seen. These gaps are filled by ISOTRK candidates (red), that are muon candidates in 85% of the cases.

prescales for each trigger. We conclude with the methodology for the usage of turnon curves in the WH NN analysis.

2 Measuring Turnon Curves

2.1 Definition of a Turnon Curve

A turnon curve of a trigger, also called a trigger turnon parametrisation, models the behaviour of that trigger. Given a value for the parametrized quantity and a turnon curve, one can deduce the probability of the event to fire that trigger as the value of the function at that particular point.

2.2 Choice of Parametrisation: MET

We are measuring the turnon curves for three MET-based triggers. We apply a different jet selection for each trigger used so that we are in the plateau region in terms of jet quantities. The only variable remaining is MET and this is the one used to parametrize the triggers. Ideally, we would use rawMET, as it is closest in value to the triggerMET. Unfortunately, Monte Carlo simulations at CDF do not model non-corrected quantities very well. This is why we corrected rawMET for the position of the z vertex of the event, as well as the tight and loose jets at L5. This quantity will be called MET from now on. Its physical meaning is the transverse energy of the W boson. We do not correct for the muon transverse momentum as this would change the physical meaning of MET into the transverse energy of the muon neutrino and it would not model the triggerMET anymore.

Trigger Level	Trigger Paths for MET2J
L1	L1_MET25_&_CLC_V
L1	L1_MET25_V
L1	L1_MET28_V
L2	L2_JET15_V
L2	L2_JET15_L1_MET25_V
L2	L2_TWO_JET10_L1_MET25_V
L2	L2_CJET10_JET10_L1_MET25_V
L2	L2_CJET10_JET10_L1_MET25_LUMI_190_V
L2	L2_CJET10_JET10_L1_MET25_DPS_V
L2	L2_MET30_CJET20_JET15_DPS_V
L3	MET35_&_TWO_JETS_V
L3	MET35_&_CJET_&_JET_V
L3	MET35_&_CJET_&_JET_LUMI_190_V
L3	MET35_&_CJET_&_JET_DPS_V

Table 1: The path for MET2J at each of the three trigger levels. This trigger is prescaled and is defined for all the periods.

Trigger Level	Trigger Paths for MET45
L1	L1_MET25_&_CLC_V
L1	L1_MET25_V
L1	L1_MET28_V
L2	L2_AUTO_L1_MET25_V
L2	L2_MET35_V
L3	MET45_V
L3	MET40_V

Table 2: The path for MET45 at each of the three trigger levels. This trigger is not prescaled and is defined for all the periods with MET45 up to p13 and MET40 starting with p14. Events with runs between 178637 and 192363 are excluded for this trigger only due to a bug in this trigger for those runs [2].

2.3 Trigger Paths Used: MET+2Jets, MET45 and MET_DIJET

CDF has a three level trigger system. The trigger paths used for each of the three triggers are detailed in the tables below: MET2J in Table 1, MET45 in Table 2 and METDI in Table 3.

2.4 Datasets and Trigger

In order to measure the turnon curve for MET-based triggers, we need to select data using another trigger that we consider orthogonal. This trigger is chosen as High-p_T

Trigger Level	Trigger Paths for METDI
L1	L1_JET10_MET15_V
L1	L1_JET10_MET28_V
L2	L2_MET28_TWO_JET3_V
L3	MET_DIJET_V

Table 3: The path for METDI at each of the three trigger levels. This trigger is prescaled and is defined from period 14 onwards.

Trigger	et1 (GeV)	et2 (GeV)	dR
MET2J	25	25	1
MET45	20	20	0
MET_DIJET	40	20	0

Table 4: Jet selection requirements for the three MET-based triggers considered.

Central Muon trigger[4] recorded on the data stream "*bhmu*"[5]. In this note we use data up to period 23.

2.5 Event Selection

First, we require that the event belongs to a run that is present in the good run list with silicon and for which the trigger is defined. Then, we require one and exactly one CMUP muon candidate with $p_T > 20$ GeV/c.

Then, we require that the event passes a kinematic jet selection that is specific to every MET-based trigger. If et1 (et2) is the corrected transverse energy of jet 1 (jet 2)[6] and $dR = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$, then we require the jet selection sumarized in Table 4 for each of the three MET-based triggers.

2.6 Methodology for Measuring Turnon Curves

In order to measure a turnon curve, we plot a histogram distribution of MET for a sample of events (denominator) and then for a subsample of these events that pass the desired trigger (numerator). By dividing the two histogram we obtain an efficiency histogram that we then fit.

[4]We choose High-p_T Central Muon and not High-p_T Central Electron since we are using the turnon curves for MET-based triggers in the ISOTRK channels and studies have shown that ISOTRK candidates are 85% of the cases muon candidates.

[5]More precisely, the data streams used are *bhmu0d*, *bhmu0h*, *bhmu0i*, *bhmumi*, *bhmumj*, *bhmumk* and *bhmumm* up to period p23.

[6]Jet 1 is defined as the jet with largest corrected energy at L5 from the tight jets with $|\eta| < 0.9$ and Jet 2 as the jet with the largest corrected energy at L5 from the remaining tight jets and $|\eta| < 2.0$.

Trigger and Level	Selection for denominators
MET2J_L1	Event Selection && true
MET2J_L2	Event Selection && MET2J_L1 taken
MET2J_L3	Event Selection && MET2J_L2 taken
MET45_L1	Event Selection && Not in Bad Run Range && true
MET45_L2	Event Selection && Not in Bad Run Range && MET45_L1 taken
MET45_L3	Event Selection && Not in Bad Run Range && MET45_L2 taken
METDI_L1	Event Selection && true
METDI_L2	Event Selection && METDI_L1 taken
METDI_L3	Event Selection && METDI_L2 taken

Table 5: The selection for the denominator sample for each of the three MET-based triggers at each of the three trigger levels.

For each of the three MET-based triggers, we measure a turnon curve for each trigger level and we do not take the trigger prescale into account[7].

Therefore, for L1 trigger level, we make no further requirement for the denominator sample other than the event selection. For L2 trigger level, we require that the event passes the event selection and that it was taken at L1. For L3 trigger level, we require the event passes the event selection and that it was taken at L2.

The denominator selection is the same for all three MET-based triggers. However, for MET45 we need to reject events in the run range 178637-192363, because a bug was present in these runs that reduced cut values for this trigger. This procedure is recommended in CDF Internal Note 9472 [2].

Table 5 summarizes the selection for the denominator samples for each MET-based trigger and each trigger level.

In order to obtain the numerator samples, for each of the denominators above we require the event to fire the desired MET-based trigger at the corresponding trigger level. Table 6 summarizes the selection for the numerator samples for each MET-based trigger and each trigger level.

[7]An event fires a trigger at a certain trigger level if the event satisfies the criteria of that trigger. However, the event is not automatically taken to the next trigger level, as there may be a quota of how many events can be taken by each trigger. This process is called prescaling. The ratio between the number of events taken at a given trigger level and the number of events fired for the same trigger level represents the prescale rate for that trigger level for that trigger. One can measure a prescale for each trigger level and the total prescale for that trigger equals the product of the prescales at each trigger level. Also, there is by definition no prescale at L3 trigger level, as any event that fires this trigger is also selected and saved to tape.

Trigger and Level	Selection for numerators
MET2J_L1	Denominator for MET2J_L1 && MET2J_L1 fired
MET2J_L2	Denominator for MET2J_L2 && MET2J_L2 fired
MET2J_L3	Denominator for MET2J_L3 && MET2J_L3 fired
MET45_L1	Denominator for MET45_L1 && MET45_L1 fired
MET45_L2	Denominator for MET45_L2 && MET45_L2 fired
MET45_L3	Denominator for MET45_L3 && MET45_L3 fired
METDI_L1	Denominator for METDI_L1 && METDI_L1 fired
METDI_L2	Denominator for METDI_L2 && METDI_L2 fired
METDI_L3	Denominator for METDI_L3 && METDI_L3 fired

Table 6: The selection for the numerator sample for each of the three MET-based triggers at each of the three trigger levels.

Trigger Path	Trigger Level	c_0	c_1	c_2	c_3
MET2J	L1	1	34.27	4.377	0
MET2J	L2	0.9945	36.5	2.813	0.6789
MET2J	L3	0.9997	42.57	3.338	0
MET45	L1	1	35.84	4.409	0
MET45	L2	1	46.32	5.619	0
MET45	L3	1	51.68	4.215	0
METDI	L1	0.9947	23.15	6.342	0
METDI	L2	0.994	31.38	2.974	0
METDI	L3	1	34.58	3.17	0

Table 7: The fit parameters for the turnon curves that we measured, for each trigger level and for each MET-based trigger.

2.7 Measured Turnon Curves

The measured turnon curves for each of the three MET-based triggers and for each of the three trigger levels are presented in Figure 2 for MET2J trigger, in Figure 3 for MET45 trigger and in Figure 4 for METDI trigger.

Each histogram is fit with a sigmoid function of the type $f(x) = c_3 + \frac{c_0 - c_3}{1+e^{(-x/c_1)}}$, where c_0 is the plateau value, c_1 the turnon point, c_2 the turnon width and c_3 the minimum starting point. You can read the fit parameters for these turnon curves in Table 7.

2.8 Turnon Curves for Systematic Uncertainty Measurement

In the procedure described above, we measure only one turnon curve per trigger and trigger level on the entire dataset after applying the event selection. The larger the dataset, the smaller the statistical uncertainty on the turnon curve fit. In this section we will describe the procedure to measure the systematic uncertainty for using the turnon curve for the MET-based trigger.

First, we make a list of possible kinematic and non-kinematic quantities that might change the shape and parameters of the turnon curve fit if measured in various bins of that variable. From Jet1 we pick et (et1), eta detector (η_1) and phi (ϕ_1). From Jet2 we pick et (et2), eta detector (η_2) and phi (ϕ_2). From Jet1 and Jet2 taken together we pick the absolute differences of et (dEt), eta detector ($d\eta$), phi ($d\phi$) and dR. We also pick the run number to gauge whether there is a difference between turnon curves from earlier data and those from later data.

Then, we divide the dataset after it passes event selection in a certain number of bins. For each of this bins, we repeat the whole procedure from above of measuring a turnon curve for each trigger and each trigger level. The binning is chosen by a script in such a way that in each bin there is a specified minimum number of events with MET in the expected turnon region, to ensure a good quality fit to data.

There are about 10-20 bins per variable. Since there are so many bins, we do not present these turnon curves in this CDF note, but the parameters of these curves are present in the ABCDF software package that we have developed that allows the user to easily obtain the weight for an event both for the main turnon curve, and for a systematic variation of the turnon curve.

3 Measuring Effective Prescales

The turnon curves measured above do not take the prescale into account. Instead, the prescale is taken into account in the luminosity at the analysis level.

3.1 Using Top Group Measurement

If only the MET2J trigger is used, as is the case for the summer 08 and 09 analyses, then one should use the effective integrated luminosity for MET2J measured by Veronica Sorin for the top group [3]. For data up to period 23, the effective integrated luminosity for MET2J is 4.0$\pm$0.3 fb^{-1} and for CMUP 4.3$\pm$0.3 fb^{-1}. Dividing the two numbers we find the effective prescale for MET2J trigger to be 0.9$\pm$0.1.

3.2 Measuring Effective Prescales

If we want to use more than one MET-based trigger at the same time, we need to measure the effective prescale for each trigger. However, the top group only measures the effective integrated luminosity for MET2J. We also know that MET45 is not prescaled.

Trigger	Period	Integrated Luminosity (fb^{-1})
MET2J	p00p23	3.960
MET45	p00p23	4.408
METDI	p14p23	2.136
MET45	p14p23	2.091

Table 8: The fit parameters for the turnon curves that we measured, for each trigger level and for each MET-based trigger.

Trigger	Effective Prescale
MET2J	0.90
MET45	1.00
METDI	0.98

Table 9: The effective prescales measured in data up to period 23 for all the three MET-based triggers

We need to measure ourselves the effective luminosity for METDI. For that purpose, we use the script dpslum.sh, as per the instructions from CDF Note 8980 [4].

We measure the effective integrated luminosity for MET2J, MET45 and METDI using the good run list from file goodrun_em_mu_si_cmxignored.list for data up to period 23. Since METDI is a trigger that only came online starting with p14, we also measure the effective luminosity for MET45 for the subset of good runs from p14 to p23. We obtain the results displayed in Table 8.

Since the MET45 trigger is not prescaled, we take it a sa rerefence. Therefore, the effective prescale of MET2J is 3.960/4.408=0.90 and of METDI is 2.091/2.136=0.98. The effective prescales for the three MET-based triggers are summarised in Table 9.

4 Methodology for Using Turnon Curves

At the analysis level, these MET-based-triggers turnon curves are used in the ISOTRK channel of the WH Neural Network (WH NN) analysis. They are used with different roles in data and in Monte Carlo simulations, as it is detailed below. Also, they are used differently depending if only one trigger is used, or if all three triggers are combined for a given sample.

4.1 If Only One Trigger is Used

For the summer 2009 WH NN analysis [5], the ISOTRK sample is divided in two orthogonal kinematic regions based on the jet quantities. For events with a tight jet selection (et1>25 GeV and et2>25 GeV and dR>1), only MET2J trigger is used. For events that fail this tight jet selection but pass a looser jet selection (et1>20 GeV and et2>20 GeV and dR> 0), only the MET45 trigger is used.

For data, we select the event only if it fires at L3 the desired trigger.

For Monte Carlo simulations, we cannot check if the event fired the desired trigger or not, as this information does not exist for the MC events. However, we weight every event by its turnon curve weight, which is obtained by multiplying together the weights at each of the three trigger levels. Each of these weights is obtained by reading the value on the turnon curve fit function for the MET value of the event. Finally, we multiply the event turnon curve weight for the prescale for that trigger. We use this final weight in the event counting over the entire sample.

4.2 If More Than One Trigger is Used

For the winter 2009 WH NN analysis, we plan to use the three triggers combined for one dataset, which improves the signal acceptance over dividing the sample in three kinematic orthogonal region and using only one trigger in each sample.

For data, for each event we evaluate the final weight for each trigger (as described above) and pick the trigger with the largest weight[8]. If the event fires the chosen trigger, the event is kept. If not, the event is rejected.

For Monte Carlo simulation, in the event counting we use the largest final weight between the three triggers.

For this analysis we will use the ABCDF software that we developed that is modular, easy to maintainn and is easy to use. We will discuss the ABCD package more thoroughly in a separate CDF note.

5 Conclusions

We have parametrised the turnon curves for three MET-based triggers (MET+2Jets, MET45/MET40 and MET_DIJET) as a function of MET, with jet selection specific for each trigger as to be in the plateau region for the jet quantities in data up to period 23. We have described how the turnon curves and the effective prescales were measured

[8]We need to choose only one between the three MET-based triggers and then (and only then!) check if the event fired that particular chosen trigger. If it has, then the event is kept. If it has not, than the event is rejected (even if it happens that the event fires one of the other not chosen triggers). In this way, there is a bijective relation between triggers and events and we are not using an "OR" operation between triggers. There are many ways that a trigger can be chosen (randomly or with a given algorithm). We are choosing the trigger that has the largest weight, as the weight means the a priori probability that the event actually fires the trigger when this is checked.

and how they can be used in the WH Neural Network analysis. Other analyses that use MET-based triggers can find this useful as well.

References

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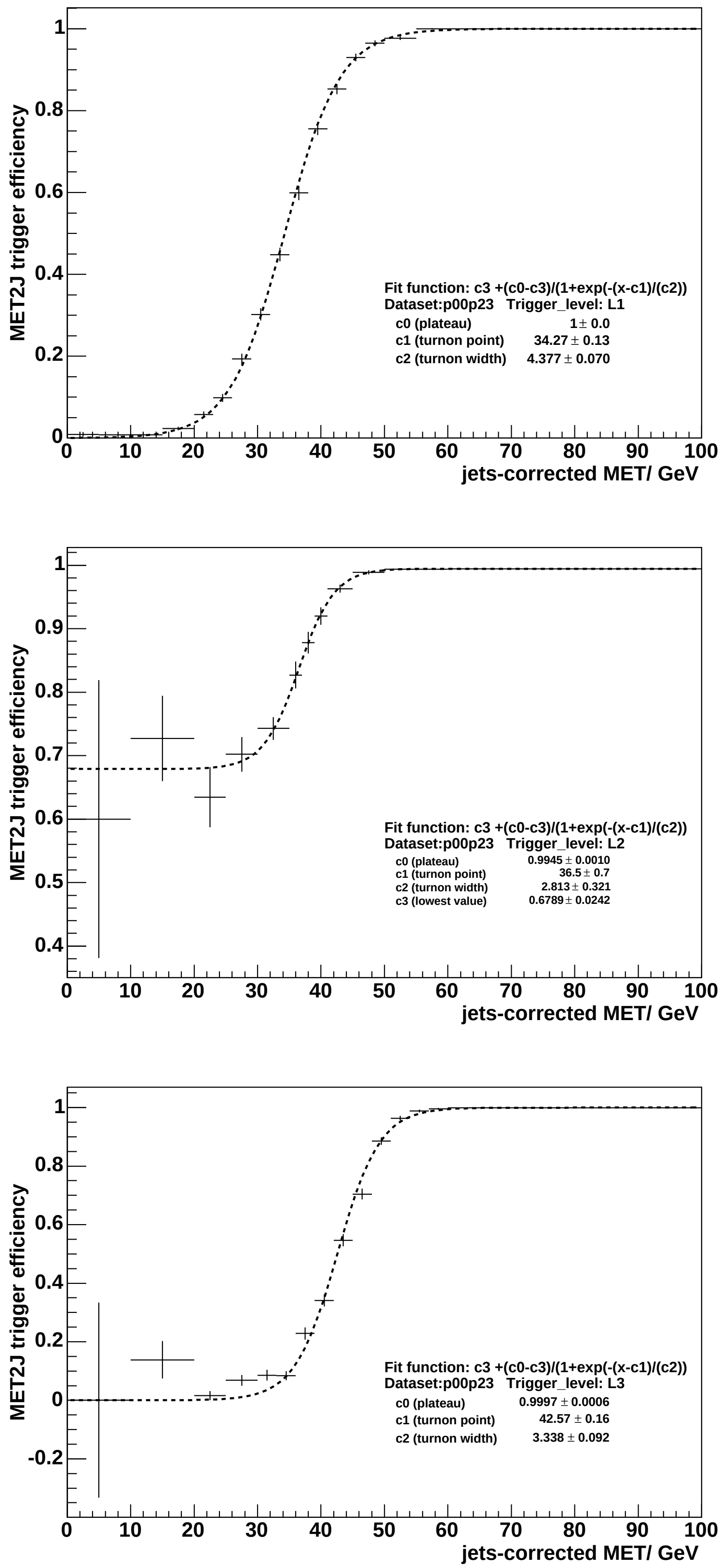

Figure 2: Turnon Curve for MET+2Jets (MET2J) at L1 (top), L2 (middle) and L3 (bottom) for p00p23.

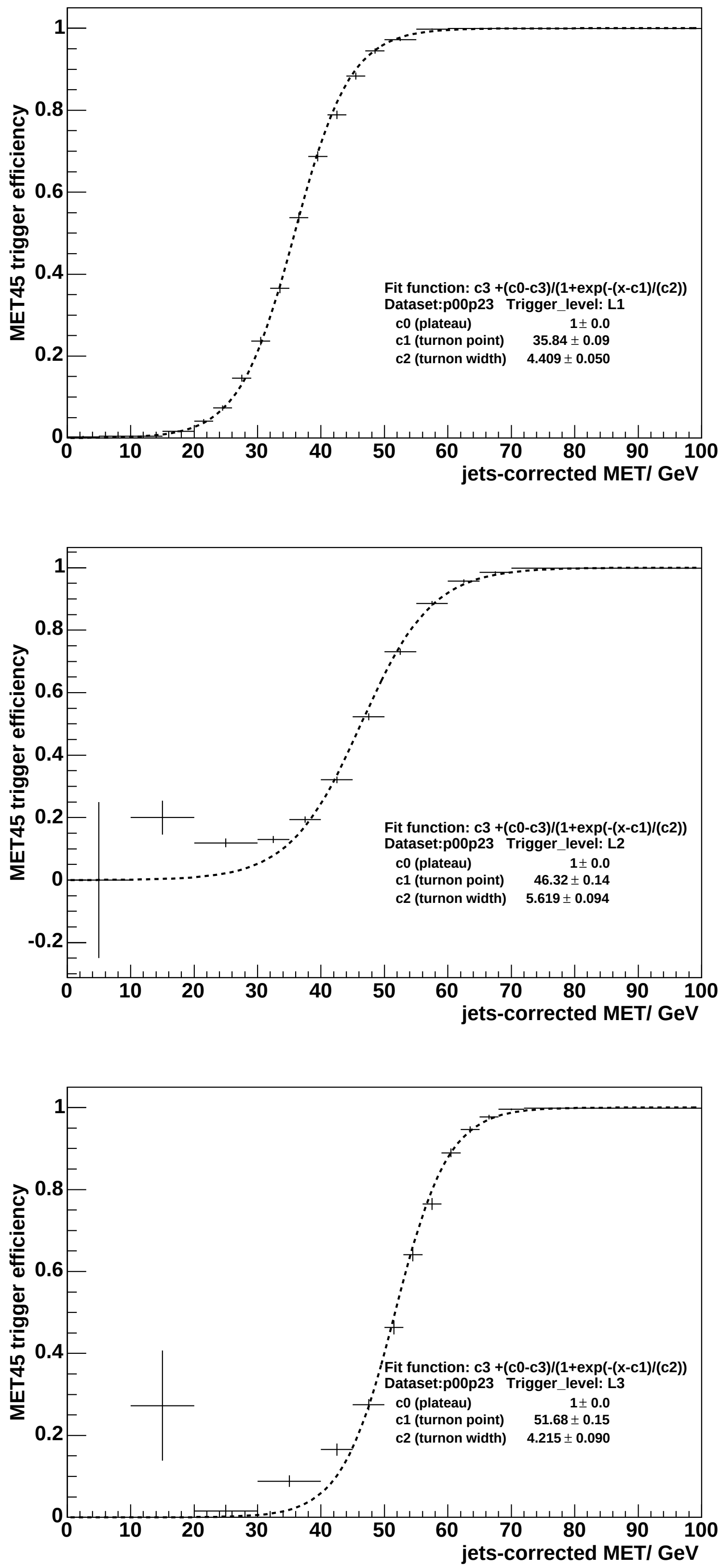

Figure 3: Turnon Curve for MET45/MET40 (MET45) at L1 (top), L2 (middle) and L3 (bottom) for p00p23.

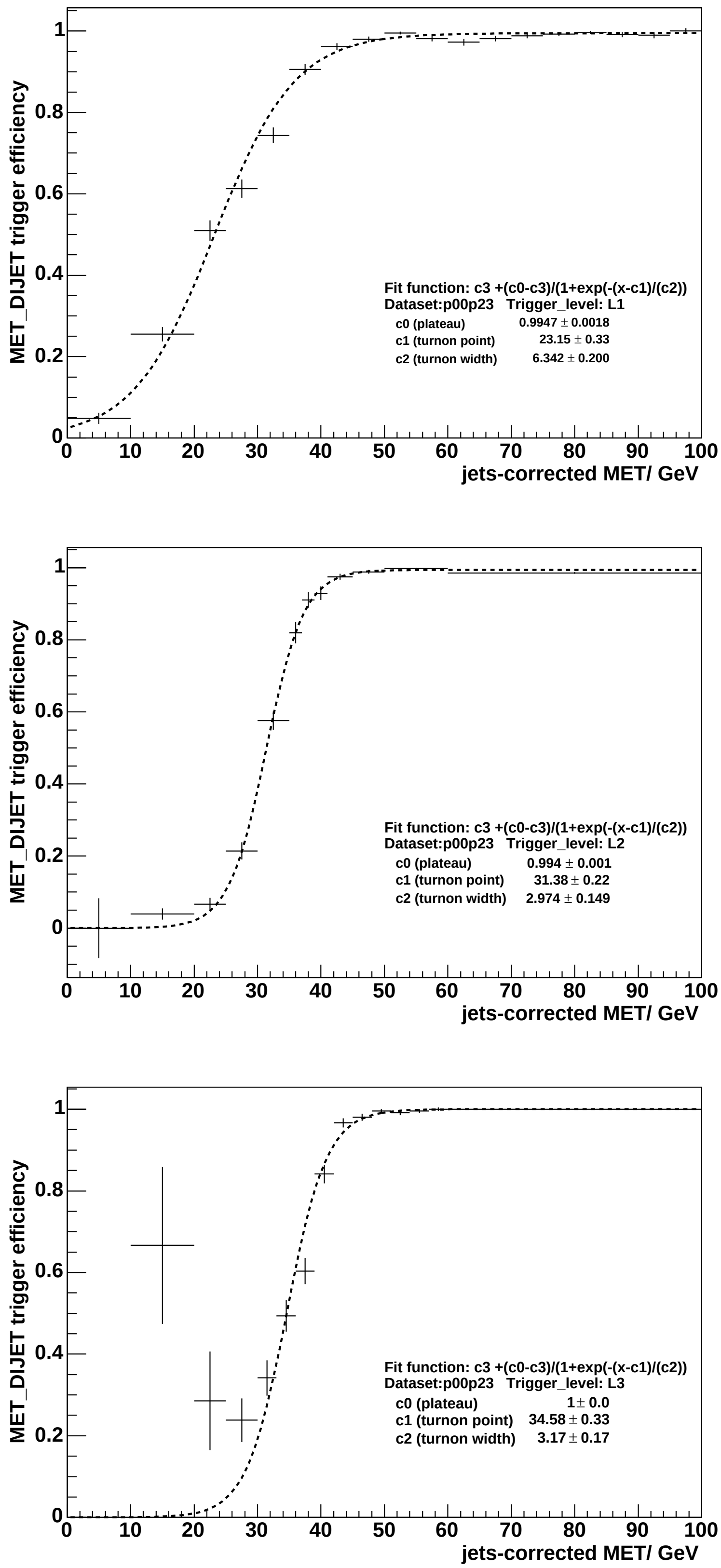

Figure 4: Turnon Curve for MET_DIJET (METDI) at L1 (top), L2 (middle) and L3 (bottom) for p00p23.