CDF/PHYS/TRIGGER/CDFR/6358

Measurement of the Level 1 Trigger Efficiency for the Muon Plus Track Trigger

S. Baroiant [1], M. Chertok [1], T. Kamon [2], V. Khotilovich [2], R. Lander [1], T. Ogawa [3], C. Pagliarone [4], G. M. Piacentino [4], F. Ratnikov [5], A. Safonov [1], A. Savoy-Navarro [6], S. Tourneur [6], E. Vataga [4]

(for the Lepton plus Track Trigger Group)

(1) University of California, Davis, California 95616

(2) Texas A & M University, College Station, Texas 79409

(3) Waseda University, 169-8555 Tokyo, Japan

(4) INFN-Pisa, via F. Buonarroti, 2 – 56100 Pisa, Italy

(5) Rutgers University, Piscataway, New Jersey 08854

(6) LPNHE, University of Paris 6-7 and CNRS-IN2P3, France

Abstract

In this note we report on the measurement of the Level 1 muon trigger (`L1_CMUP6_PT4`) efficiency for the Lepton plus track trigger. The measurement has been performed using a $J/\Psi \rightarrow \mu^+\mu^-$ sample collected with the inclusive `CMUP` triggers between February 7, 2002 and February 13, 2003. The measured efficiency has a value of $\varepsilon_{plateau} = 95.7 \pm 0.6$ %.

1. Introduction

In this note we present the measurement of the Level 1 L1_CMUP6_PT4 trigger efficiency for the high-P_T muon plus track Trigger: TAU_CMUP8_TRACK5_ISO. A detailed description of the trigger itself can be found in Ref. [1]. This note is organized as follows: first we describe the overall technique used to perform the present measurement; then we review, schematically, the logic of the high-P_T CMUP trigger; we then describe the procedure used to match offline muons to the Level 1 muon trigger primitives; the dataset selection criteria is then explained and, finally, we collect and discuss the results obtained.

The Lepton (muon) Plus Track Trigger is designed to select μμ, μe and μτ events. At Level 1 it requires the presence of hits in the CMP chambers associated with a CMU stub with $P_T^{Stub}(CMU) > 6.0\ GeV/c$ that matches an XFT track. The muon stub is obtained by asking for matched hits in the CMU chambers, with arrival times within 124 ns of each other, on one of two projective wire pairs within a single stack, and a matching pattern of projective hits in at least 3 CMP layers. CSP, as well as hadron TDC, is not a part of the trigger decision procedure. The XFT track, matched to a stub, must have $P_T^{XFT} > 4.09\ GeV/c$. Since, at present, no Level 2 trigger is available for the muons, events are automatically passed from Level 1 to Level 3 of the trigger decision path. Table 1 schematically reviews the main features of Level 1, Level 2 and Level 3 Muon Plus Track Trigger logic.

The present muon trigger architecture, as well as the way in which the trigger information is stored in the banks, does not allow for a trigger efficiency measurement based on a standard unbiased leg technique. This means that it is not possible, in our case and for our purpose, to select a reasonably large $J/\Psi \to \mu^+\mu^-$ data sample by simply triggering on one leg, using the other one, the unbiased muon, to measure our trigger efficiency. Most of the available muon datasets, as a matter of fact, are collected by requiring the presence of two muons or a muon and a track at different levels in the trigger path logic. A straightforward way to measure the high-P_T CMUP muon efficiency would then be to use CMX muons, but this dataset has very limited statistics. So we are forced to proceed following a different approach. We choose datasets that at Level 1 use the trigger under study (L1_CMUP6_PT4), avoiding, at Level 2 and Level 3, any additional requirement on the presence of an extra muon or an isolated track. Our $J/\Psi \to \mu^+\mu^-$ sample is thus selected by using the CdfMuon Collection.

In principle, there is no way to distinguish which of the two muons fired the trigger. Regardless,

TAU_CMUP8_TRACK5_ISO	
LEVEL 1 **L1_CMUP6_PT4**	$P_T^{Stub} > 6.0\ GeV/c$
	No CMU Hadron TDC
	No CSP hits
	Required CMP hits
	$P_T^{XFT} > 4.09\ GeV/c$
LEVEL 2 **L2_TRK8_L1_CMUP6_PT4**	**Number = 0**
	Track Isolation Type = 0
	$\Delta\Phi_0^{\min} = 0$
	$P_T^{XFT} > 8.0\ GeV/c$
	$\Delta\Phi_0^{\max} = \pi$
LEVEL 3 **L3_CMUP8_TRACK5_ISO**	**muonCMUP8** **L3MuonFilterModule**
	$dx_{CMP} = 20\ cm$
	$dx_{CMU} = 15\ cm$
	$P_T^{\mu} > 8.0\ GeV/c$
	$N(\mu) \geq 1$
	CMUP = true
	isoTrack5 **L3TrackFilterModule**
	$\lvert\Delta\eta\rvert < 1.5$
	0.175 < Isolation Cone < 0.524
	$\Delta Z_{ISO} = 15.0\ cm$
	isolated = 3
	$P_T^{trk} > 5.0\ GeV/c$
	muonCMUP8Track5 **L3TwoTrackFilterModule**
	$\Delta Z_{Max} = 15.0\ cm$
	$\Delta R_{Min} = 0.175$
	RcpObjName = isoTrack5
	RcpObjName = muonCMUP8
	RcpPckgName = L3MuonFilterModule
	RcpPckgName = L3TrackFilterModule
	TwoViewMode = true
	useView1RcpId = true
	useView2RcpId = true

Table 1: *Muon plus Track Trigger Logic for Level 1, Level 2 and Level 3 path.*

both muons can be used for the efficiency measurement, and an event will always end up belonging to one of the following two classes:

1) "11" events: which means that both muons have fired the trigger[1];
2) "10" events: which means only one of the two muons has fired the trigger.

This makes it possible to measure the trigger efficiency by examining the two muons independently, and by applying the right normalization. Naturally, this procedure requires an unambiguous match between the offline muon and online trigger primitives and a detailed simulation of the `Level 1` trigger decision logic.

To better explain the way in which the efficiency will be measured, by knowing the number of type "11" events (N^{11}) and type "10" events (N^{10}), let's consider a simple example. If ε is the probability for a muon to fire the trigger and N is the total number of muon couples produced in the collision, then we have that:

$$\begin{aligned} N^{11} &= \varepsilon^2 \cdot N \\ N^{10} &= 2 \cdot \varepsilon(1-\varepsilon) \cdot N \\ N^{00} &= (1-\varepsilon)^2 \cdot N \end{aligned} \qquad (1)$$

Because of the unitarity: $\varepsilon^2 + 2\varepsilon(1-\varepsilon) + (1-\varepsilon)^2 = 1$ this set of 3 equations in 2 variables is reducible to a system of 2 linearly independent equations in the 2 variables ε and N. The solution for the problem is then:

$$\varepsilon = \frac{2N^{11}}{2N^{11} + N^{10}} \qquad (2)$$

By generalizing the previous system of equations (1) it's also possible to determine the efficiencies for both positive and negative muons:

$$\begin{aligned} N^{11} &= \varepsilon^+ \cdot \varepsilon^- \cdot N \\ N^{10} &= \varepsilon^+ \cdot (1-\varepsilon^-) \cdot N + \varepsilon^- \cdot (1-\varepsilon^+) \cdot N \\ N^{00} &= (1-\varepsilon^+) \cdot (1-\varepsilon^-) \cdot N \end{aligned} \qquad (3)$$

The efficiency for positive and negative muons is then expressed as follow:

[1] With the expression "fired the trigger" we mean that the offline muon has a matching trigger primitive that passed `L1_CMUP6_PT4` trigger simulation (see paragraph 4).

$$\varepsilon_+ = \frac{N^{11}}{N^{11} + N_+^{10}}$$
$$\varepsilon_- = \frac{N^{11}}{N^{11} + N_-^{10}} \qquad (4)$$

where N_+^{10} (N_-^{10}) is the number of type "10" events in which the trigger leg was a positive (negative) muon. Both these quantities are related together by the expression: $N^{10} = N_+^{10} + N_-^{10}$.

2. L1_CMUP6_PT4 Trigger Logic

`L1_CMUP6_PT4` is a hardware trigger used to find muon candidates using a subset of detector elements. Muon candidates are detected in the muon chambers from the stubs they leave. The `L1_CMUP6_PT4` trigger logic uses both the CMU and CMP muon subsystems. The CMU is a set of proportional wire chambers stacked on the top of each other forming four radially aligned layers [2]. The time difference between hits on different layers is a direct measurement of the track transverse momentum. However, the time difference is not a precise measure, especially for tracks far from the wires. The maximum time difference, corresponding to a transverse momentum under 1.5 GeV/c for example is 396 ns. In principle, it is possible to have three different P_T thresholds for `Level 1` muon triggers, however, at present, CDF is using only 2 of them. In general, these P_T thresholds are programmable and they are allowed to be different in the various muon detector sub regions. The `L1_CMUP6_PT4` trigger selects events with high- P_T muon stubs. In further discussions we refer to the two available thresholds as low-P_T and high-P_T muon stubs. The CMU detector covers the full azimuthal angle ϕ with a pseudorapidity coverage of $|\eta| \leq \sim 0.6$. The total volume consists of 288 stack locations on each side East and West of the CDF detector. Each stack contains 4 muon chambers: 0, 1, 2, 3, arranged vertically to cover an angle of $\Delta\Phi_{Stack} = 1.25^\circ$. Two stacks together make a tower ($\Delta\Phi_{Tower} = 2.5^\circ$) and 6 towers, for a total of 12 stacks, make a wedge. A wedge covers an angular range of $\Delta\Phi_{Wedge} = 15^\circ$. The physically instrumented area covers, in reality, a smaller angular range of about $\sim 12.6^\circ$. The full azimuth angle is then filled with 24 wedges for each side. While in Run I the muon trigger was made of 3 towers per wedge, in Run II, the muon trigger granularity counts 6 towers per wedge at `Level 1` and 12 towers at `Level 2`. CMU as well as CMX trigger primitives are a pair of hits of projective wires. The CMU layers

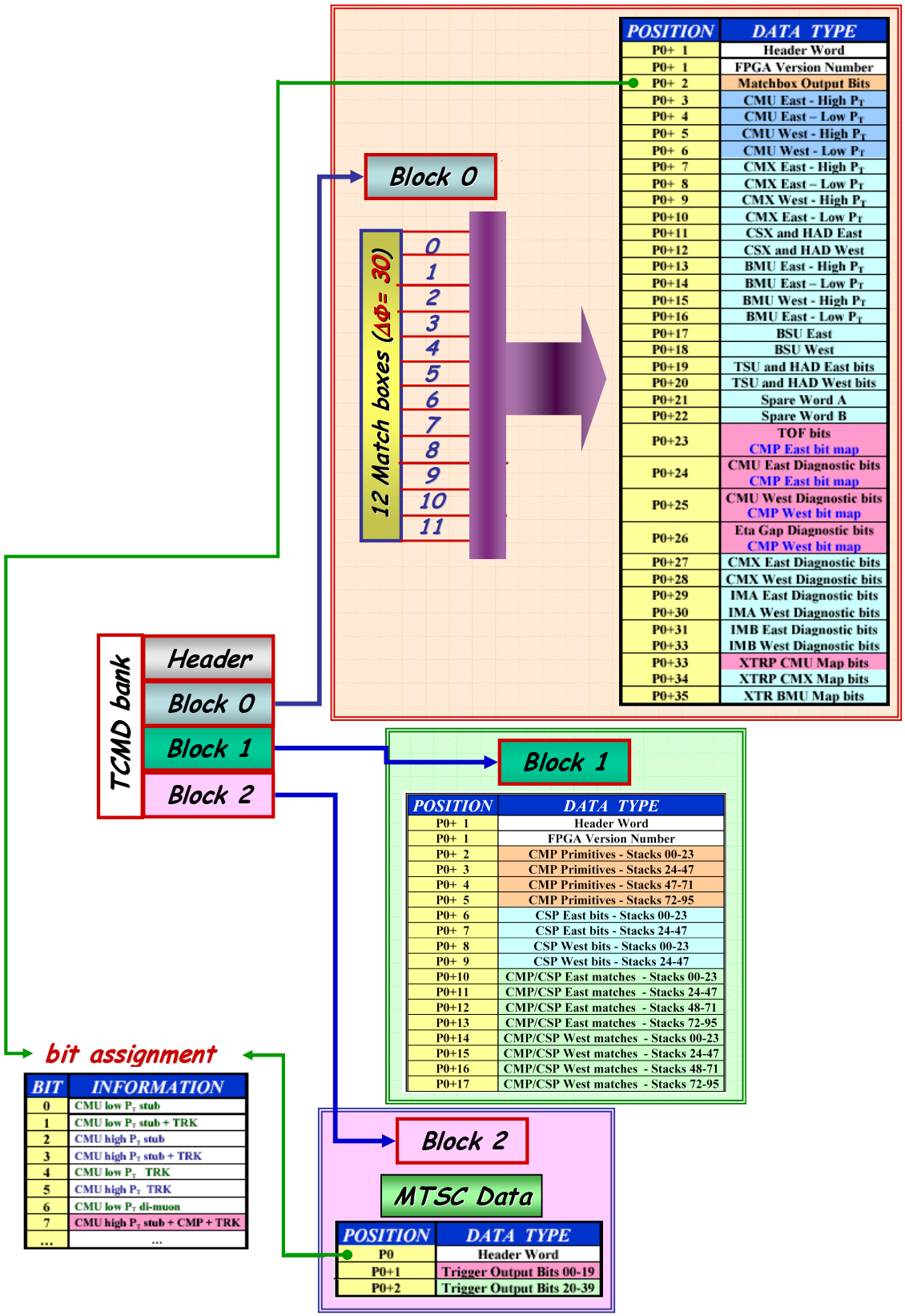

Figure 1: *TCMD bank format and bit assignment for trigger decision words (we include only CMUP related information).*

DATASETs		level 1	level 2	level 3	Online Luminosity
blpc08	**LEPTON_CALIB-08**	**L1_CMUP6_PT4**	**L2_AUTO**	**L3_MUON_CMUP_8**	**64.8 pb^{-1}**
bmcl08	**MUON_CALIB-08**	**L1_CMUP6_PT4**	**L2_AUTO**	**L3_MUON_CMUP_8**	**48.1 pb^{-1}**
jbmu08	**B_MUON-08**	**L1_CMUP6_PT4**	**L2_AUTO**	**L3_MUON_CMUP_4**	**97.7 pb^{-1}**

Table 2: *Datasets used for measuring the trigger efficiency.*

number 0 and number 2 are OR-ed together as well as layers number 1 and number 3. In other words, the CMU trigger muon must have at least 2 hits in one tower: on layer 0 and layer 2 or layer 1 and layer 3. The CMP system does not use time difference, instead the CMP trigger primitive is generated if a pattern of hits in a stack is found that is consistent with the passage of a track through it. As the CMP wire cells cover the full central pseudorapidity range (η), from East to West, there is no way to know, by using only the CMP information, on which side of the muon system a particular hit falls. As there are separate CSP counters for the East and West sides of the CDF detector. By combining both CMP and CSP information, it is possible to determine whether a particular muon crossed at $\eta > 0$ or at $\eta < 0$. However, at the moment, the CSP hits are not part of the `Level 1` trigger decision logic. Since the CMP chambers have a rectangular section in the R-ϕ plane, in order to perform a match with the stubs in the CMU, the hit positions, in the muon chambers, have to be converted in a $\Delta\phi$ intervals of 2.5^0. This task is assigned to the prematch cards.

The matching between the CMU-CMP stubs and the XFT tracks is done, at `Level 1`, with a granularity of 2.5^0. This operation is performed in 12 specially designed electronic units generally called cards or muon matchboxes. Each matchbox serves 2 consecutive wedges ($\Delta\Phi_{Matchbox} = 30^\circ$) either side of the detector. These cards, numbered $j_{card} = 0,1,....,11$, collect the muon information (trigger primitives from all subsystems) and make the trigger logic decision for each group of 2 towers. Trigger primitive information is then saved in TCMD banks. These banks consist of a header and three blocks. Block 0 contains data coming from the 12 matchboxes; block 1 is reserved for prematch cards both for CMP and CSP matches; block 3 stores the data from the Muon Trigger Summary Card (MTSC) that collects outputs from each of the 12 matchboxes and generates the final trigger decisions that are passed to FRED. Each matchbox collects signals from primitive cards. Thus `Level 1` and `Level 2` trigger decisions are produced. Each has four 24-bit words for both CMU and for CMX stubs. In particular, words 3, 4, 5 and 6 are used for CMU East or West, low-P_T or high-P_T stub information. Words from 7 to 10 are used in order to collect the information for the CMX detector. Each bit in the word corresponds to a single stack, so the trigger

	Applied Selections
DATASETS	***blpc08, bmcl08, jbmu08***
Muon P_T	$P_T^{\mu(1)} > 4.5$ **GeV/c,** $P_T^{\mu(2)} > 4.5$ **GeV/c**
Central Muons	$\left\|\eta^{\mu(1)}\right\| < 1.2$, $\left\|\eta^{\mu(2)}\right\| < 1.2$
Dimuon opposite charge	$chrg^{\mu(1)} \cdot chrg^{\mu(2)} < 0$
Dimuon invariant mass window	$2\ \text{GeV/c}^2 < M_{\mu^+\mu^-} < 4\ \text{GeV/c}^2$

Table 3: *Filtering requirements.*

stub azimuth angle can be obtained by using the following conversion formula:

$$\Phi_{TriggerStub}^{TCMD} = j_{card} \cdot \Delta\Phi_{Matchbox} + (k_{bit} - 0.5) \cdot \Delta\Phi_{Stack} \qquad (5)$$

where $j_{card} = 0,1,....,11$ is the card number, $\Delta\phi_{Matchbox} = 30^0$, $\Delta\phi_{Stack} = 30^0/24 = 1.25^0$ and $k_{bit} = 0, 1,...., 23$ is the bit number inside the 24-bit word. In Figure 1 we give a short description of TCMD bank and the function words used for measuring the `Level 1` μ + Track Trigger efficiency. Detailed information on TCMD storable bank can be found in reference [3][2].

XFT tracks are mainly defined by P_T, charge and ϕ_{SL6}. These three quantities, together with the detector geometry and the map of the magnetic field, give enough information to know where this track would enter the muon chambers. Matchboxes also collect the information coming from the extremely fast tracker. The XFT data enter the muon trigger as projected hits into the various portions of the muon system. The XFT architecture classifies the full COT azimuth angle in 288 segments each covering a range in $\Delta\phi$ of 1.25^0, allowing only one track per each angular sector. Each XFT track has six P_T bits, a sign bit, three mini-phi bits, an isolation bit, a superlayer 6/8 bit, and one spare bit. `Level 1` XFT tracks are extrapolated to the radii of the CMU or CMX chambers, by means of look-up tables [4], by the extrapolation unit (XTRP) that distributes the information derived from the tracks to the Level 1 and Level 2 trigger subsystems. Every 132 ns data from the 288 segments are sent from XFT to XTRP even if no track is found. One or more bits, each corresponding to a $\Delta\phi$ range of 2.5^0, are set according to XFT information: P_T, ϕ, size of multiple coulomb scattering. The extrapolation is performed in the following steps: XTRP takes

[2] Information in CDF Note 4152 is not quite complete (work in progress): it describes what can be found in the lower 24 bits of each word in the bank. The upper eight bits can contain more information, for example the CMP bit map is saved in upper bits of words 23-26.

	Applied Cuts
Muon P_T	$P_T^{\mu(1)} > 5$ **GeV/c,** $P_T^{\mu(2)} > 5$ **GeV/c**
Central Muons	$\lvert\eta^{\mu(1)}\rvert < 0.6$, $\lvert\eta^{\mu(2)}\rvert < 0.6$
Dimuon opposite charge	$chrg^{\mu(1)} \cdot chrg^{\mu(2)} < 0$
Vertex fiducial region	$\lvert z_0^{\mu(1)}\rvert < 60$ **cm,** $\lvert z_0^{\mu(2)}\rvert < 60$ **cm**
Distance between the two muon vertexes	$\lvert z_0^{\mu(1)} - z_0^{\mu(2)}\rvert < 5$ **cm**
Good quality tracks (COT Axial hits)	$N_{COT}^{Axial}(\mu(1)) > 24$, $N_{COT}^{Axial}(\mu(2)) > 24$
Good quality tracks (COT Stereo hits)	$N_{COT}^{Stereo}(\mu(1)) > 24$, $N_{COT}^{Stereo}(\mu(2)) > 24$
XFT inefficiency due to COT geometry (I)	$Z_{SuperLayer}^{2,4,6}(\mu(1),\mu(2)) > 2.0$ **cm**
XFT inefficiency due to COT geometry (II)	$Z_{SuperLayer}^{8}(\mu(1),\mu(2)) > 8.0$ **cm**
Good stub-track match	$\lvert dx(\mu_1)\rvert < 5$ **cm,** $\lvert dx(\mu_2)\rvert < 5$ **cm**
MIP in the EM Calorimeters	$E_{EM}^{\mu(1)} < 2$ **GeV,** $E_{EM}^{\mu(2)} < 2$ **GeV**
MIP in the Hadronic Calorimeters	$E_{HAD}^{\mu(1)} < 6$ **GeV,** $E_{HAD}^{\mu(2)} < 6$ **GeV**
Muon opening Angle	$\Delta\Phi(\mu_1,\mu_2) \equiv \lvert\phi^{\mu(1)} - \phi^{\mu(2)}\rvert \leq 130°$
Dimuon invariant mass cut	**2.7 GeV/c^2** $< M_{\mu^+\mu^-} <$ **3.6 GeV/c^2**

Table 4: *Muon identification cuts and J/Ψ selection.*

XFT tracks with $P_T > 1.5\ GeV/c$ and projects a $\Delta\phi$ range where the tracks could enter the muon chambers, making use of the following formula:

$$\Delta\phi_{CMU} \equiv \phi_{CMU} - \phi_{XFT} \cong \pm\frac{K_{CMU}}{P_T} \pm \sigma_{CMU} \tag{6}$$

where $\sigma \cong K_{CMU}^{*}/P_T$ and $K_{CMU} = 27.61^{\circ}\ GeV$ and $K_{CMU}^{*} = 2.53^{\circ}\ GeV$.

TCMD banks reserve two words for XTRP information in every matchbox, with twelve bits for each low-P_T and high-P_T track. Word number 33 contains the XTRP-CMU map bits and word number 34 the XTRP-CMX map bits. In particular, the first 12 bits of the 24-bit word are used for low-P_T tracks, the next 12 bits for high-P_T tracks. Naturally each high-P_T track also has the corresponding low-P_T bits on. In each matchbox, CMU, CMP and XTRP trigger primitives are correlated. Matchbox output bits are produced and saved in word number 2 (see Figure 1 for a description of the bit assignment). In particular, bit number 7 in word number 2 corresponds to possible `L1_CMUP6_PT4` candidates. This bit assumes a value equal to one if there is a high-P_T CMU stub, matched to a high-P_T CMP stub and to a high-P_T XFT track. The Muon Trigger Summary Card

(MTSC) collects the outputs of the 12 matchboxes and propagates a Level 1 Muon Trigger decisions further on (word number 1 in the MTSC has the same bit assignment as word number 2 inside the matchboxes).

3. Data Sample Selection

The data sample used in the present study is obtained by selecting $J/\Psi \to \mu^+\mu^-$ events selected at `Level 1` by the `L1_CMUP6_PT4` trigger, with no additional requirements at `Level 2` or `Level 3`, such as the presence of an extra muon or isolated track. Three datasets meet our requests: `blpc08`, `bmcl08` and `jbmu08`. Table 2 gives the list of such datasets together with the full trigger path and the overall luminosity[3]. Our data sample includes Runs spanning from 138610 to 158732, taken between February 2002 and February 2003, and data collected with both 2-miss and 1-miss XFT design [5]. Using the offline muon collection (reconstructed with `Release 4.8.4a`) we select a sample of opposite charge dimuon events with invariant mass in the mass window: $2.0\ GeV/c^2 < M_{\mu^+\mu^-} < 4.0\ GeV/c^2$. The fraction of events that has an overlap in the different datasets used is around 8.4 %, and such an event have been taken out of the final data sample. The list of cuts applied in the stripping procedure is given in Table 3.

4. Matching offline muons to Level 1 muon primitives

In order to measure the muon efficiency we need to determine whether the muon under consideration fired the trigger or not. To do so we construct a match between the offline muon and the trigger object. Offline muons are selected by requiring the following conditions:

- Events pass the offline selection cuts listed in Table 4;
- neither muon in the event must come from West CMU wedge number 17 as this wedge has hardware problems [6].

For each of the two muons in the event, and for all CMU hits associated to the muons, we determine

[3] Starting with the trigger table PHYSICS_1_03_v1 MUON_CALIB path (L3_ MUON_CMUP8) was moved from *blpc* to *bmcl*.

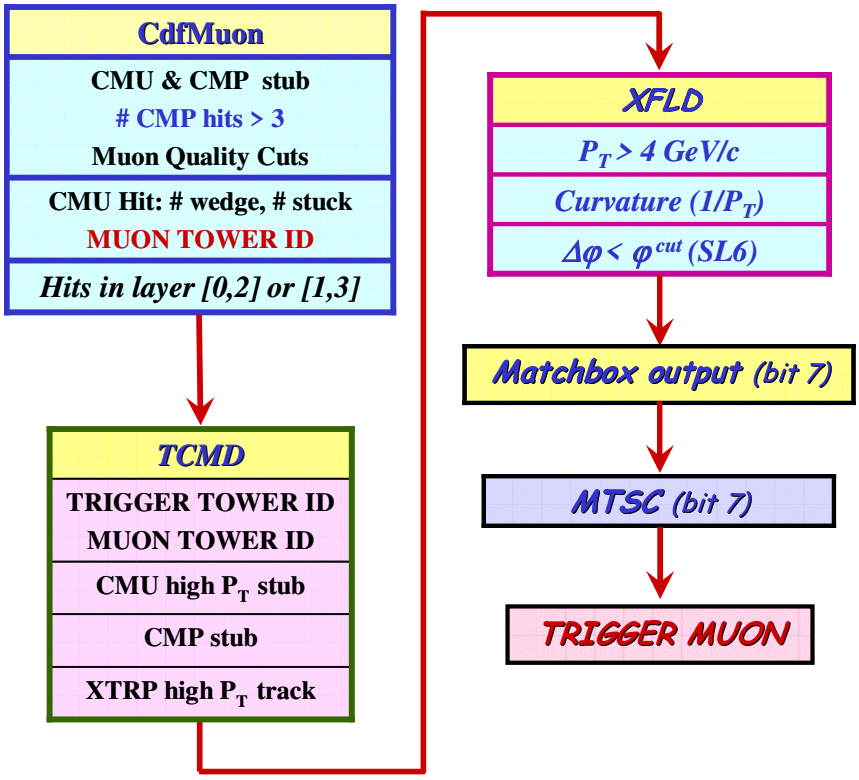

Figure 2: *Diagram of matching between offline CdfMuon and L1 trigger primitives.*

wedge, stack and layer number. At Level 1 there are only 12 bits per matchbox available in order to define the ϕ angular position of a CMU stub. Then, the muon wedge and stack number, as well as words number 3, 4, 5, 6, from matchboxes in TCMD banks, have to be translated in tower granularity of 2.5^0. Muons are required to have at least two hits in one tower (Layer 0 and 2 or Layer 1 and 3), have the same tower ID and to have a CMU stub in TCMD banks that is from the same side (East or West) of the CDF detector. In the TCMD banks, there are two words per side. The first of these words is used for low-P_T muon stubs, the other for the high-P_T ones. As each high-P_T stub should also have a low-P_T bit set to 1, we check both these words when we look for an associated trigger primitive. As soon as an unambiguous match between a muon and a CMU high-P_T stub have been found we verify other trigger components:

- CMP stub: the 12-bit word for CMP stub is extracted from matchbox words number 25 and 26 and logically AND-ed with the CMU high-P_T stub word;
- We check that the corresponding bits in the XTRP high-P_T track 12-bit word are on.

The next step is to make sure that the match between the offline muon and the XFT track does exist. In order to perform this task we use the information stored in XFLD banks. Matching is achieved

α	β	γ
-1.35 ± 0.69	4.48 ± 3.78	0.957 ± 0.006

Table 5: *Results of the fit of the L1 Trigger efficiency by using the formula (8).*

using two variables: curvature (~ $1/P_T$) and the azimuthal angle ϕ measured at the 6th Stereo Layer of COT. To ensure that the trigger decision was propagated correctly to FRED we check in matchbox the bit number 7 in word number 2 and the bit number 7 in word number 1 in the Muon Trigger Summary Card. No muon is found to fail this check. If all these conditions are satisfied then the muon is considered to be a "trigger muon". This matching procedure is summarized in Figure 2.

5. Level 1 Trigger Efficiency Measurement

The invariant mass distribution for dimuon pairs, passing our cuts and used in the present trigger efficiency measurement, is shown in Figure 3. If $M_{J/\Psi}$ is the fitted mass, σ the Gaussian width, obtained by fitting the invariant mass of our sample, then the signal region is defined as the $\pm 3\sigma$ window around the J/Ψ mass peak ($M_{J/\Psi}$). The two sideband windows are: $[M_{J/\Psi} - 7\sigma, M_{J/\Psi} - 4\sigma]$ and $[M_{J/\Psi} + 4\sigma, M_{J/\Psi} + 7\sigma]$. Fake muons are removed, by applying a standard sideband subtraction procedure [6] using the dimuon invariant mass information.
The P_T distributions for both the first and the second muon after the sideband subtraction is given in Figure 4.

The `Level 1` trigger efficiency is then calculated using the following expression:

$$\varepsilon(\Delta P_T^J) = \frac{2\left[N(\Delta P_T^J)_{11}^{Peak} - N(\Delta P_T^J)_{11}^{Sideband}\right]}{\left(2 \cdot N(\Delta P_T^J)_{11}^{Peak} + N(\Delta P_T^J)_{10}^{Peak}\right) - \left(2 \cdot N(\Delta P_T^J)_{11}^{Sideband} + N(\Delta P_T^J)_{10}^{Sideband}\right)} \qquad (7)$$

where ΔP_T^J is the J^{th} bin in which we want to measure the trigger efficiency. So if we define:

$$\begin{aligned} N(\Delta P_T^J)_{11} &= N(\Delta P_T^J)_{11}^{Peak} - N(\Delta P_T^J)_{11}^{Sideband} \\ N(\Delta P_T^J)_{10} &= N(\Delta P_T^J)_{10}^{Peak} - N(\Delta P_T^J)_{10}^{Sideband} \end{aligned} \qquad (8)$$

and with $\delta^2\left[N(\Delta P_T^J)_{10}\right]$ the statistical error on the number of type "10" events and with $\delta^2\left[N(\Delta P_T^J)_{11}\right]$ the analogous error for the events that do pass the trigger, then the uncertainty on the trigger efficiency measurement can be expressed as follow:

$$\delta\left[\varepsilon(\Delta P_T^J)\right] = \frac{\sqrt{\delta^2\left[N(\Delta P_T^J)_{10}\right]\varepsilon^2(\Delta P_T^J) + 4\cdot\left(\varepsilon(\Delta P_T^J) - 1\right)^2\delta^2\left[N(\Delta P_T^J)_{11}\right]}}{N(\Delta P_T^J)_{10} + 2\cdot N(\Delta P_T^J)_{11}} \qquad (9)$$

The measured bin by bin efficiencies ($\left[\varepsilon(\Delta P_T^J)\right] \pm \delta\left[\varepsilon(\Delta P_T^J)\right]$) is fit using the function:

$$\varepsilon(P_T) = \frac{\gamma}{1 + e^{(\alpha P_T + \beta)}} \qquad (10)$$

We use this expression instead of the one utilized for the electron plus track trigger efficiency [8] because in the muon case there are two main contributions to the trigger inefficiency, the XFT inefficiency has an error function behaviour and the stub matching inefficiency has a slower turn-on. The convolution of both these effects can then be parameterized as in equation (10). We study the Level 1 Trigger efficiency dependence on the muon P_T, finding a plateau efficiency of $\varepsilon_{plateau}$= 95.7 ± 0.6 %. The parameters obtained in the fit are given in Table 5. The trigger efficiency as function of the offline muon P_T is shown in Figure 5 where the blue line is the fit obtained by using the function (10). We check if the efficiency shows dependencies on time, offline muon azimuth angle ϕ, the muon pseudorapidity and position of the muon primary vertex and muon charge. The results are given in Figure 6, Figure 7, Figure 8 and Figure 9. The measured efficiency looks to be quite stable with respect to these variables. The dependence of the trigger efficiency on the run number is given in Table 6. Finally, Figure 10 contains the contributions coming from the different parts: stub finding efficiency, track matched stub efficiency and so on.

At the end, we want to outline that, as the efficiency is expressed by the ratio given in (2), any possible Level 3 trigger dependence, due to the fact that events have been selected by using `L3_MUON_CMUP_8`, is automatically washed out. Anyhow, this have been also tested on the data, by looking at the behaviour of the efficiency for P_T below and above the 8 GeV/c trigger threshold. No discrepancy from the expected behaviour have been observed.

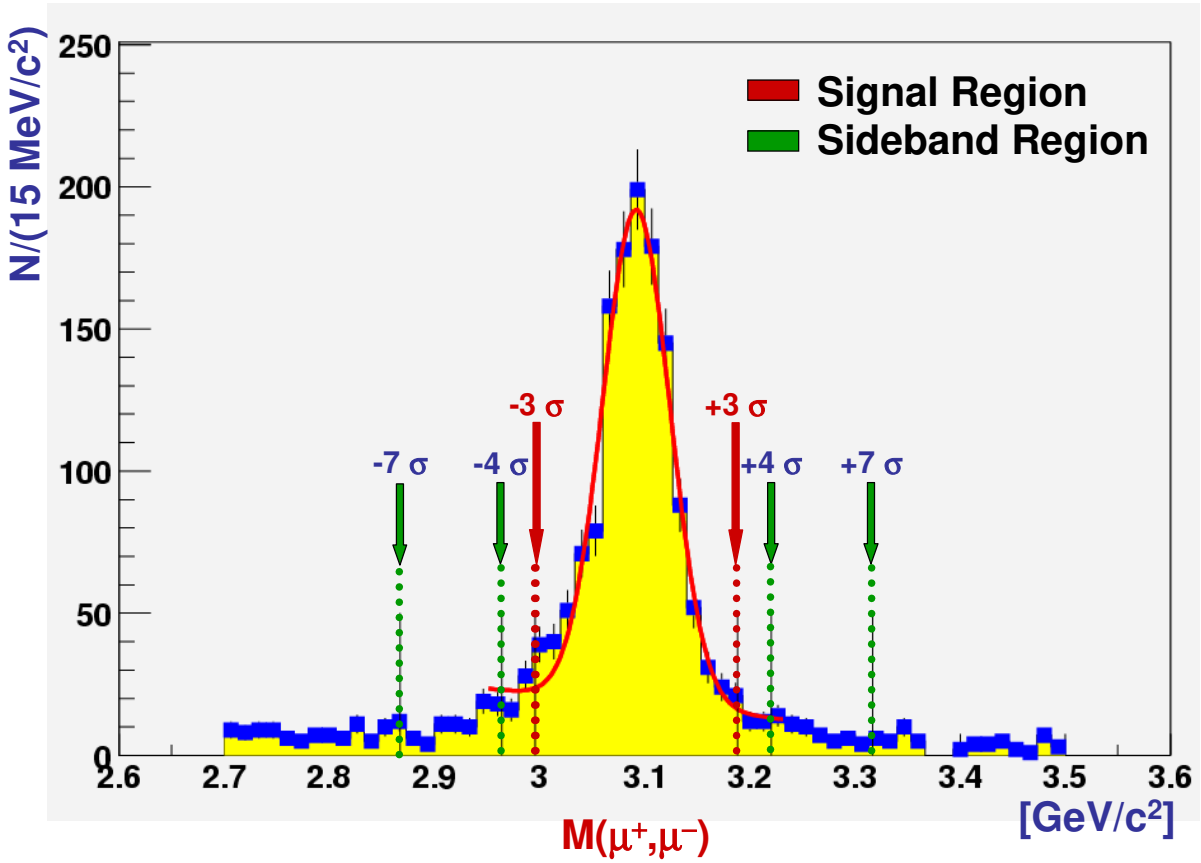

Figure 3: *Dimuon invariant mass distribution for events that passed our selection cuts.*

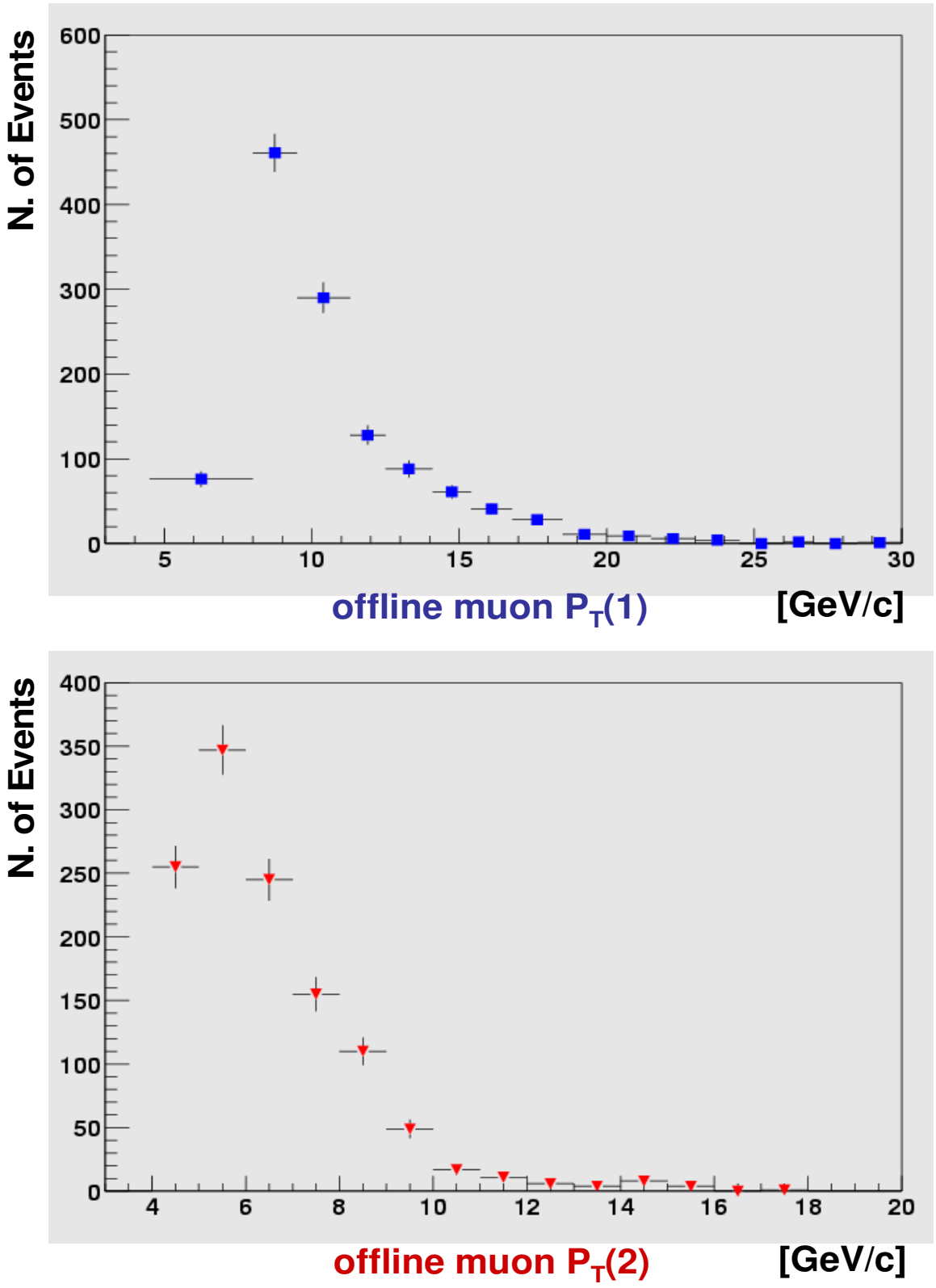

Figure 4: *P_T distributions for first and second muons (sorted as function of muon P_T) in events that passed our selection cuts.*

From Run	To Run	Time Interval	Luminosity	Efficiency
138610	*149945*	*7 Feb 02 - 15 Aug 02*	32461 nb^{-1}	*96.3 ± 0.8*
150001	*153947*	*15 Aug 02 - 7 Nov 02*	37274 nb^{-1}	*96.4 ± 0.8*
153985	*158732*	*7 Nov 02 – 13 Feb 03*	42974 nb^{-1}	*94.9 ± 1.1*
TOTAL				***95.7 ± 0.6***

Table 6: *Measurement of L1_CMUP6_PT4 trigger efficiency as function of the time (Run number).*

6. Summary

In this note we present the measurement of the Level 1 trigger efficiency for the Muon Plus Track Trigger. Data have been fitted with the function:

$$\varepsilon(P_T) = \frac{\gamma}{1 + e^{(\alpha P_T + \beta)}}$$

The resulting efficiency in the plateau region is $\varepsilon_{plateau} = 95.7 \pm 0.6$ % ($\varepsilon_{plateau} \equiv \gamma$). This number is consistent with other similar measurements [9]. The measured efficiency proves to have little dependence on z, ϕ and η.

7. Acknowledgments

We would like to thank Eric James and Yuri Gotra for useful discussions on the trigger architecture.

8. References

[1] M. Chertok et al., "*Letpon + Track Trigger for Run II: A New Approach for Triggering on Dileptons (Muon Case)*", CDF Note 5157.

[2] D. Amidei et al., "*Muon Trigger Data Flow"*, http://www-cdf.fnal.gov/internal/upgrades/muon/run2-trig/muondisc.ps.

[3] F. Chlebana et al., *"The CDF Run II Event Structure",* CDF Note 4152.

[4] L. Holloway and J. Strologas, "*Determination of the XTRP maps from XFT to CMU and CMX"*, CDF Note 4146.

[5] CDF II Collaboration, *"Technical design report"*, FERMILAB-Pub-96/390-E. October 1996.

[6] Y. Gotra et al., "*Run-II Muon Trigger Efficiency Measurement"*, CDF Note 6162.

[7] B. Ward, "*Level 1 CMU-CMX Trigger studies"*, CDF Note 5944.

[8] A. Savoy-Navarro et al., *"Measurement of Level 3 Trigger Efficiency for 8 GeV Inclusive Electron Trigger Using Conversions"*, CDF Note 6324.

[9] K.Bloom, E.James, J. Kang and M. Schmitt, "*Muon Efficiencies"*, CDF Note 6293.

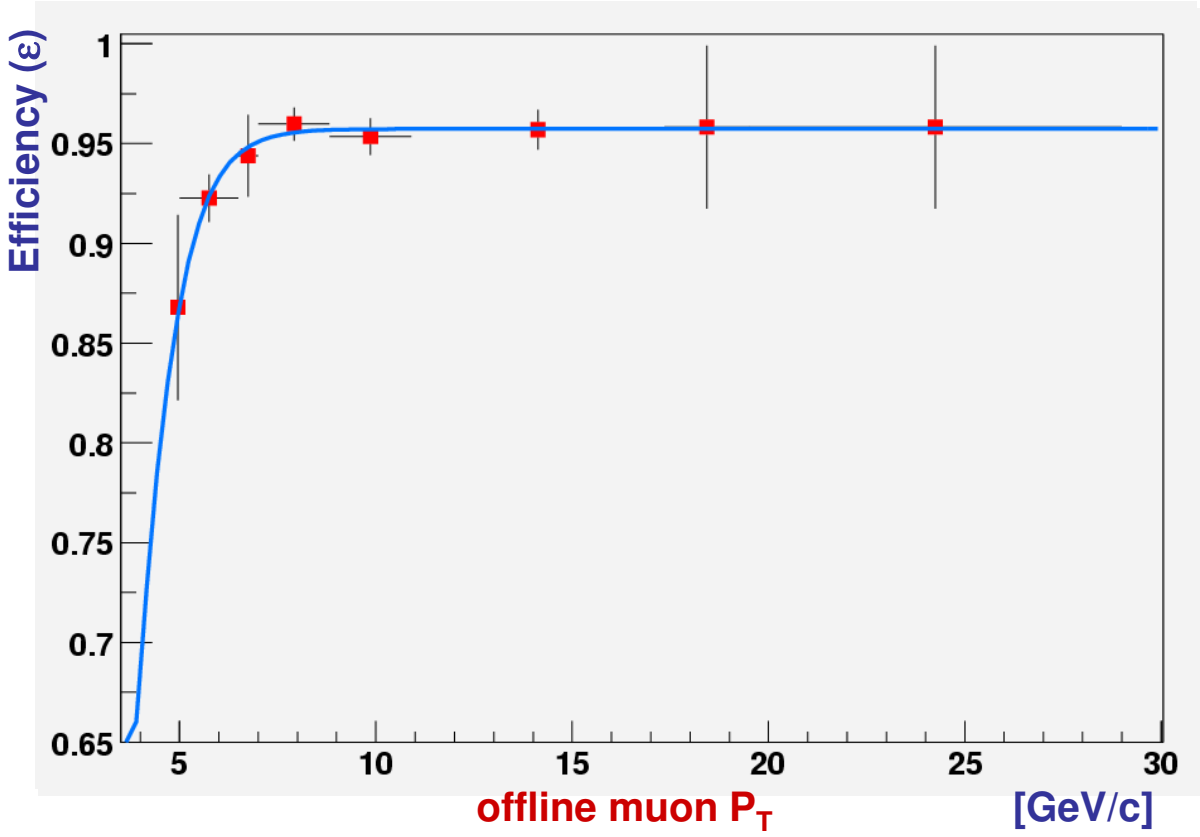

Figure 5: *L1_CMUP6_PT4 trigger efficiency as function of muon P_T. The points are fit to the function:* $\varepsilon(P_T) = \frac{\gamma}{1 + e^{(\alpha P_T + \beta)}}$.

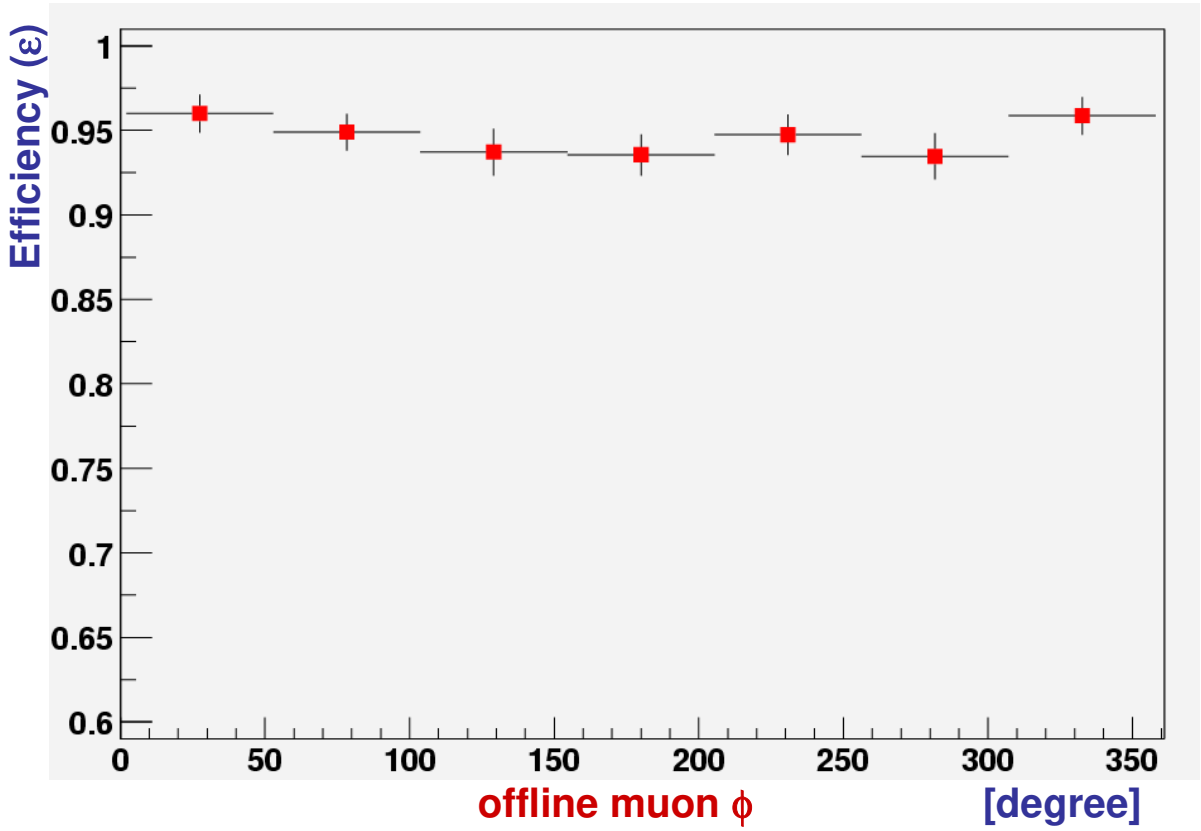

Figure 6: *Overall trigger efficiency of L1_CMUP6_PT4 as a function of the stub Φ angle.*

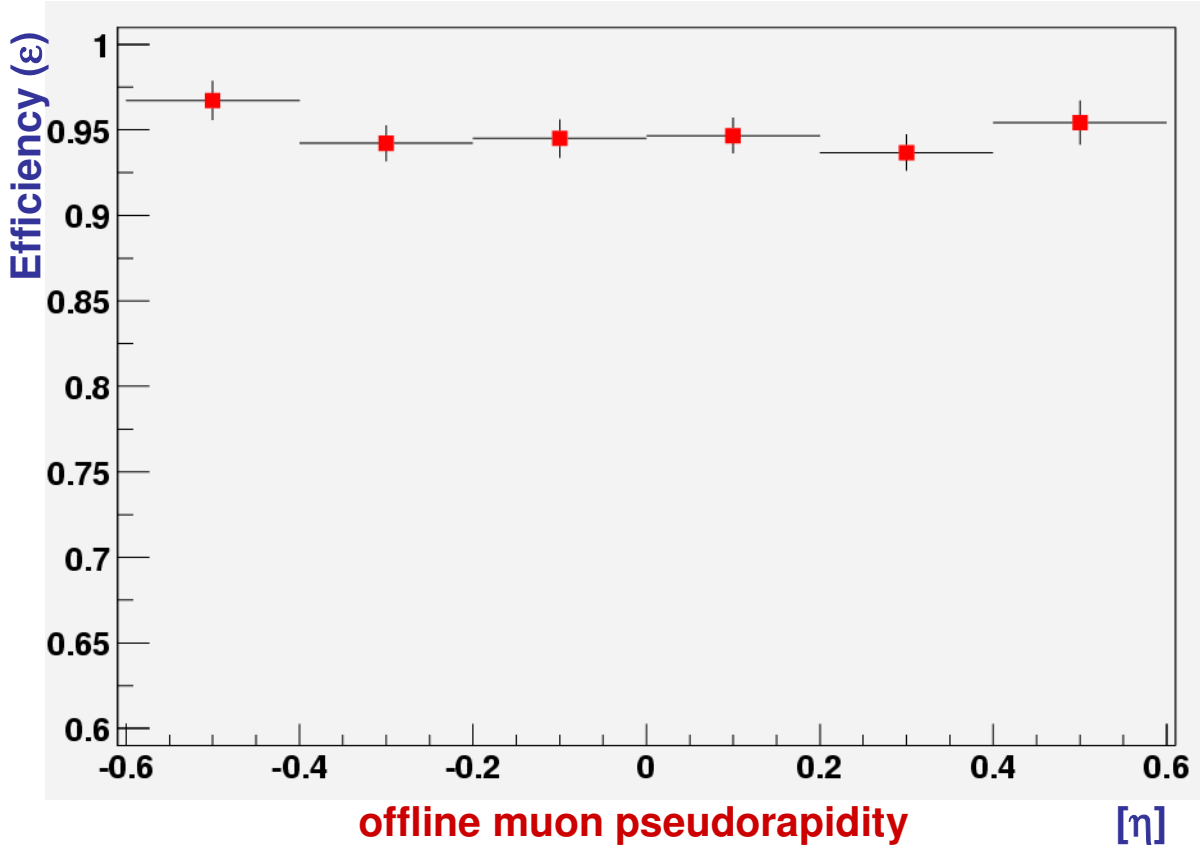

Figure 7: *Overall trigger efficiency of L1_CMUP6_PT4 as a function of the track pseudorapidity.*

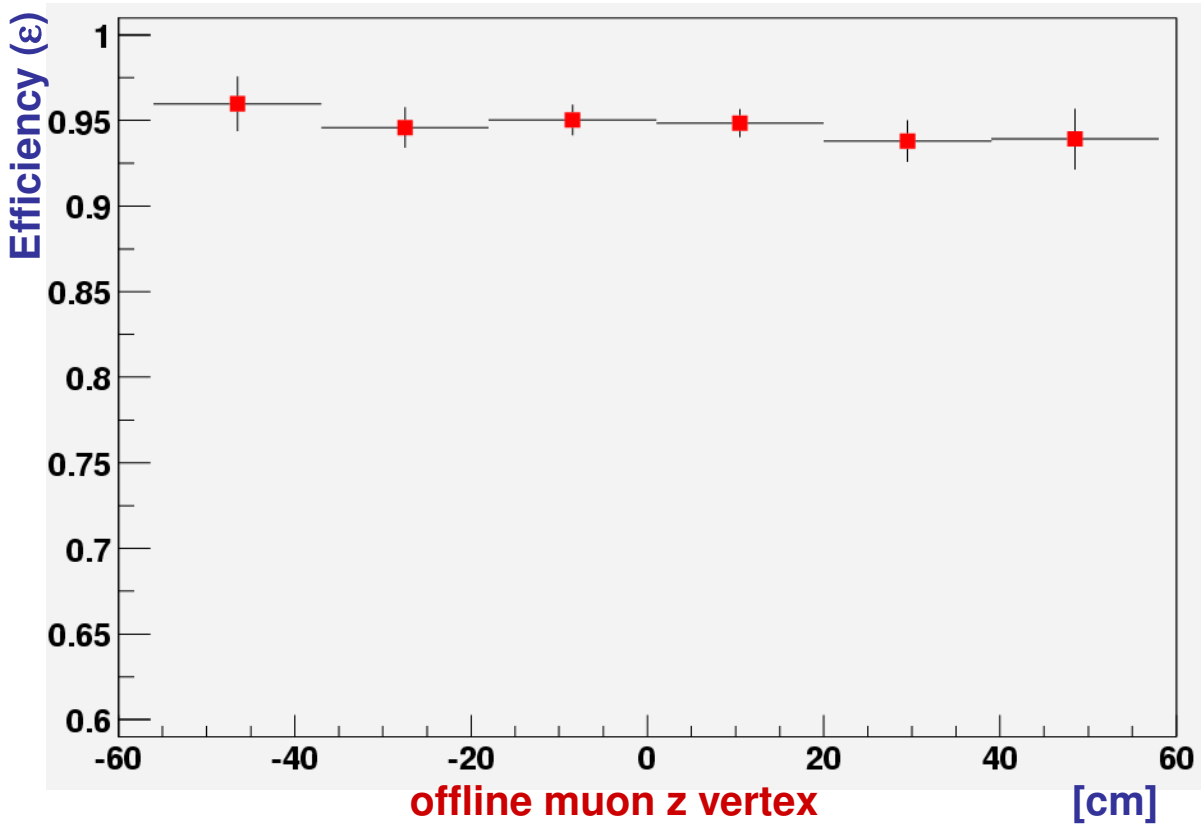

Figure 8: *Efficiency of L1_CMUP6_PT4 trigger as function of z of the offline muon.*

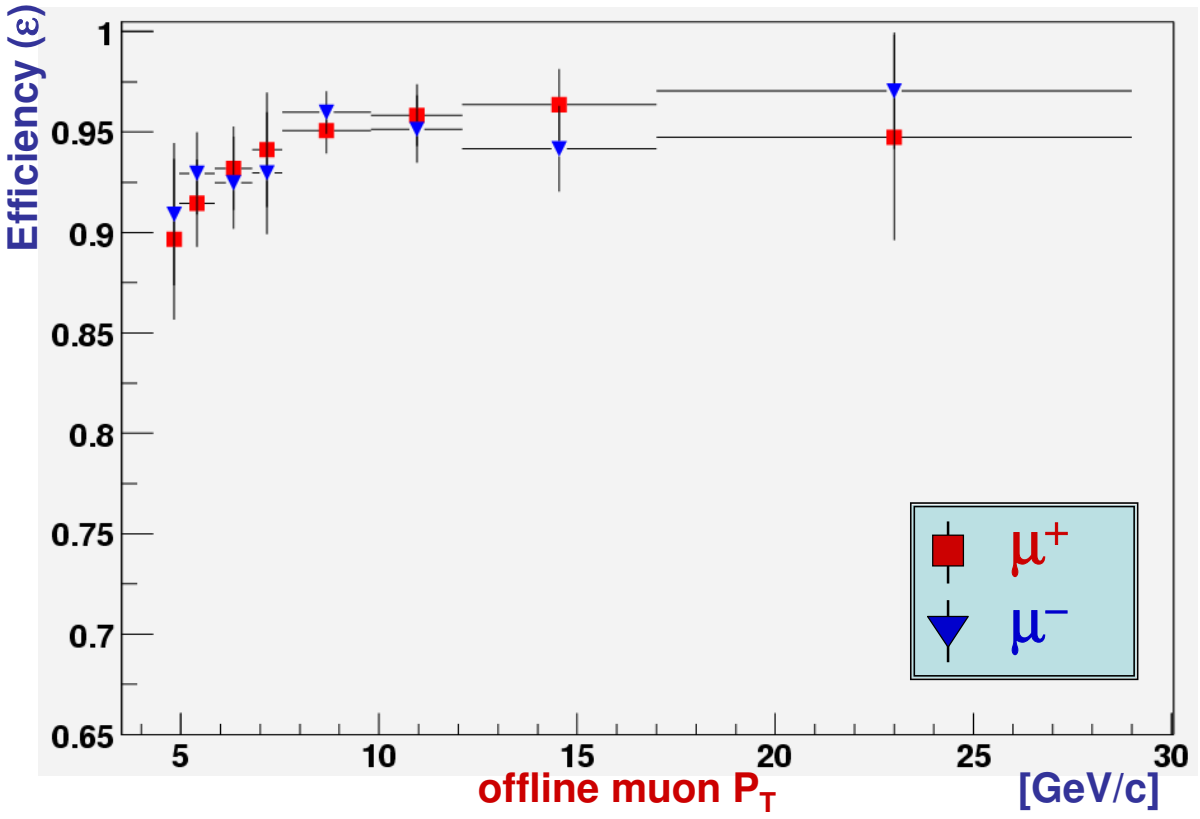

Figure 9: *L1_CMUP6_PT4 trigger efficiency as function of muon P_T for positive and negative muons* ($\varepsilon(\mu^+) = 96.1 \pm 0.16$, $\varepsilon(\mu^-) = 95.7 \pm 0.13$).

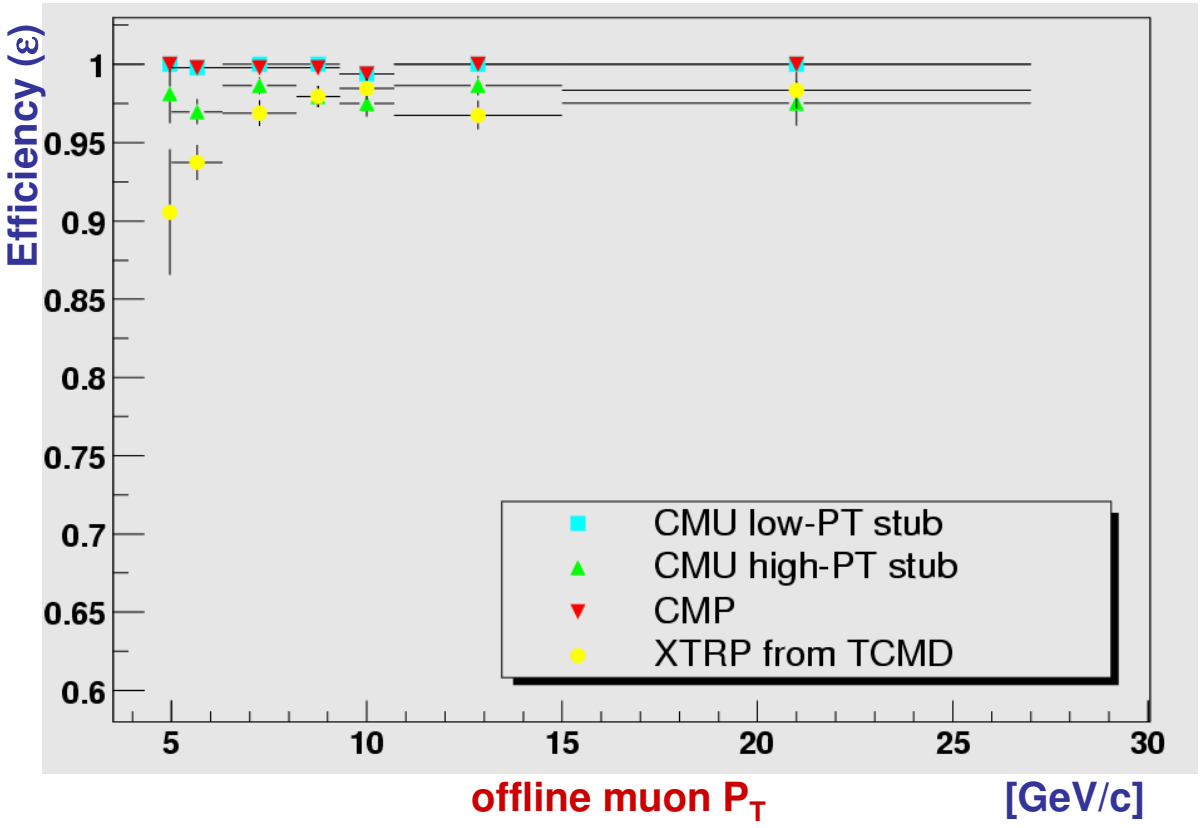

Figure 10: *Trigger efficiency as function of muon P_T containing the different contribution: high-P_T and Low-P_T CMU efficiency, CMP efficiency, XTRP matching efficiency.*