СООБЩЕНИЯ
ОБЪЕДИНЕННОГО
ИНСТИТУТА
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E1-97-303

S.R.Amendolia*, J.Budagov, V.Glagolev, N.Turini*

THE CDF INTERMEDIATE MUON UPGRADE TRIGGER GAIN SIMULATION

---

*INFN, Pisa, Italy

1997

Амендолия С.Р. и др. E1-97-303

Моделирование увеличения эффективности триггера при использовании промежуточной мюонной системы (IMU) CDF

Оценивается увеличение геометрической эффективности триггера для CDF, RUN II при регистрации мюонов в центральной + IMU области ($|\eta| < 1,5$) по сравнению с центральной областью ($|\eta| < 1,0$). Промоделированы три физических канала: $B^0 \to J/\Psi(\mu^+\mu^-) + K_s$, $W \to \mu\nu$ и одиночное рождение t-кварков.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1997

Amendolia S.R. et al. E1-97-303

The CDF Intermediate Muon Upgrade Trigger Gain Simulation

We report on the evaluation of the gain in the geometrical trigger acceptance for Run II using the central + intermediate muon upgrade (IMU) muons ($|\eta| < 1.5$) compared to using the central muons only ($|\eta| < 1.0$). Monte-Carlo data are used. Three physics channels are considered, namely $B^0 \to J/\psi K_s^0$, W-boson charge asymmetry and single top-quark production.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1997

1 Introduction

The Fermilab Tevatron Collider luminosity enhancement in conjunction with the upgrade of the collider detectors moves the experimental program into a regime of precision hadron collider physics. CDF II will investigate the open questions of high energy physics, including:

- characterization of the properties of the top quark
- a global precision electroweak program
- constraint of the CKM matrix with high statistics B decays
- direct search for new phenomena

Triggering and reconstructing of muons is at the core of several broad physics programs. Top quarks are identified in via muons from decays of their W and b daughters. W bosons are identified in part and their mass measured via their muon decay mode.The asymmetry in W decays constrains parton distribution functions, and many signatures of new physics involve one or more leptons.

The existing central muon system (rapidity coverage $|\eta| < 1.0$) has performed well in the present run. CDF is planning a program of incremental improvements rather than major replacements of the detectors. The goal is to preserve and improve the existing detector performance under the new operating conditions in the Main Injector era.

The Intermediate Muon Upgrade (IMU) detectors will be used in RUN II to extend the muon rapidity coverage up to $1.0 < |\eta| < 2.0$ [1].

For the $|\eta| > 1$ region in Run II, CDF has elected to cover rapidity interval ($\eta = 1.0 - 1.5$) with sufficient granularity to survive high luminosity, by a) building a cylindrical "barrel" of chambers similar to the existing central chambers around the outside radii of the toroids and b) installing scintillation counters for triggering and identifying which beam crossing generated the muon of interest. The design closely parallels that of the central detectors. The 1.0 - 1.5 rapidity region was chosen because:

- It covers more solid angle than the region covered by the original Forward Muon system. For high mass objects such as $t\bar{t}$ pairs and energetic lepton pairs used to constrain quark substructure, solid angle is the figure of merit, not rapidity.
- The W asymmetry is largest in this region.
- The region is contigious with the existing central detectors.

Between $\eta = 1.5$ and $\eta = 2.0$ there is also muon identification, with granularity (and therefore occupancy) insufficient for triggering, but adequate for identifying high p_T tracks in this region as muons.

The central muon system was used in the Run I. So the possibilities of the central muon trigger are well known for CDF collaboration [2, 3]. We decide to estimate the trigger acceptance increasing due to the IMU.

As a preliminary study for the implementation of Level 1 and Level 2 triggers using the IMU, we estimated the possible gain of such triggers for basic processes of the RUN II physics program. This gain gives the increment of the statistic which could be obtained using also the IMU ($|\eta| < 1.5$) over using only the central μ trigger ($|\eta| < 1.0$). The expected yield of events for the Run II one could find in the CDF TDR[1]. The number of the single top quarks ($t \to bW(\mu\nu)$) that could be taken by central muon trigger is about couple of hundreds. The number of ($W \to \mu\nu$) decays is about 600.000 for the central muon region. The gain was defined as:

$$\mathbf{gain} = \frac{N_{central+IMU} - N_{central}}{N_{central}} \tag{1}$$

where :

$N_{central+IMU}$ - number of events passed (central + IMU) trigger conditions;

$N_{central}$ - number of events passed central trigger conditions.

The gain is computed as a function of the IMU μ threshold.

Note that no secondary interaction nor any detector simulation is included in the calculation, which is purely geometrical. Thus these results are to be considered an upper limit to the actual gain attainable.

A parallel effort is being carried on [4] to evaluate the overall background rate vs. μ trigger threshold @ Level 1, using the full CDF II detector simulation. These results will be used to determine the minimal μ threshold applicable in the IMU region, which does not saturate the Level 1 rate budget.

2 CP Asymmetry in $B^0 \to J/\psi K_s$

One of the most important goals of the CDF II B physics program is the observation of CP violation in the B system. CP violation would manifest itself as an asymmetry in the partial decay rates of B^0 and $\bar{B}^0$ to the same final state, $J/\psi K_s$.

The production of the B mesons at the Tevatron energies and their decays $B \to$

$J/\psi(\mu^+\mu^-) + K_s(\pi^+\pi^-)$ were simulated using B-generator and CLEO Monte Carlo code [5].

According to the TDR we assume that the p_t threshold of a track or a muon will be set to 1.5 GeV/c for the central dimuon and (muon+track) triggers. For the single μ trigger, a 6 GeV/c threshold for the central region is planned. The trigger conditions which have been used in the simulation for central and combined (central + IMU) regions are, for this physics channel:

dimuon trigger

central region:

$((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 1.5))\ \&\ ((|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 1.5))$

central + IMU region :

$((|\eta_{\mu^+}| > 1.)\&(|\eta_{\mu^+}| < 1.5)\&(Pt_{\mu^+} > cut).or.(|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 1.5))\ \&$
$((|\eta_{\mu^-}| > 1.)\&(|\eta_{\mu^-}| < 1.5)\&(Pt_{\mu^-} > cut).or.(|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 1.5))$

1 muon + 1 track trigger

central region:

$((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 1.5)\ .or.\ (|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 1.5))\ \&$
$((|\eta_{\pi^+}| < 1)\&(Pt_{\pi^+} > 1.5)\ .or.\ (|\eta_{\pi^-}| < 1)\&(Pt_{\pi^-} > 1.5))$

central + IMU region :

$((((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 1.5)\ .or.\ (|\eta_{\mu^+}| > 1.)\&(|\eta_{\mu^+}| < 1.5)\&(Pt_{\mu^+} > cut))\ .or.$
$((|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 1.5)\ .or.\ (|\eta_{\mu^-}| > 1.)\&(|\eta_{\mu^-}| < 1.5)\&(Pt_{\mu^-} > cut)))\ \&$
$((|\eta_{\pi^+}| < 1)\&(Pt_{\pi^+} > 1.5)\ .or.\ (|\eta_{\pi^-}| < 1)\&(Pt_{\pi^-} > 1.5))$

single muon trigger

central region:

$((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 6.0))\ .or.\ ((|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 6.0))$

central + IMU region :

$(|\eta_{\mu^+}| > 1.)\&(|\eta_{\mu^+}| < 1.5)\&(Pt_{\mu^+} > cut).or.$
$(|\eta_{\mu^-}| > 1.)\&(|\eta_{\mu^-}| < 1.5)\&(Pt_{\mu^-} > cut).or.$
$((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 6.0)or(|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 6.0))$

A sample of 10.000 $B \rightarrow J/\psi(\mu^+\mu^-) + K_s(\pi^+\pi^-)$ events was generated. The IMU trigger gain against P_t threshold for IMU μ is shown in Fig. 1. We require the minimum P_t trigger cut for μ in the forward region not to be less than the fixed threshold used in the central region.

3 W-boson Charge Asymmetry

At Tevatron energies, $W^+(W^-)$ bosons are produced in $p\bar{p}$ collisions primarily by the annihilation of $u(d)$ quarks from the proton and $\bar{d}(\bar{u})$ quarks from the antiproton. Because u quarks carry on average more momentum than d quarks, the W^+'s tend to follow the direction of the incoming proton and the W^-'s that of the antiproton.

At Level 1, W boson decays to leptons are identified by the presence of a large amount of missing transverse energy accompanied by a track in one of the primary tracking detectors. Muon candidates are required to have a track in the muon tracking system. The transverse energy of the lepton and the missing transverse energy are required to be greater than 25 GeV.

The production of 10.000 W bosons in the $p\bar{p}$ collisions was simulated by the PYTHIA code at the Tevatron energies. The decay mode $W \rightarrow \mu\nu$ was chosen. The following formulae were used to simulate the trigger conditions.

single muon trigger + missing transverse energy

central region:

$((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 25.)\ .or.\ (|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 25.))\ \&$
$(Et_\nu > 25.)$

central + IMU region :

$(((|\eta_{\mu^+}| < 1)\&(Pt_{\mu^+} > 25.)\ .or.\ (|\eta_{\mu^+}| > 1.)\&(|\eta_{\mu^+}| < 1.5)\&(Pt_{\mu^+} > cut))\ .or.$
$((|\eta_{\mu^-}| < 1)\&(Pt_{\mu^-} > 25.)\ .or.\ (|\eta_{\mu^-}| > 1.)\&(|\eta_{\mu^-}| < 1.5)\&(Pt_{\mu^-} > cut)))\ \&$
$(Et_\nu > 25.)$

The IMU trigger gain, defined according to equation 1, is plotted against P_t threshold for IMU μ in Fig. 2.

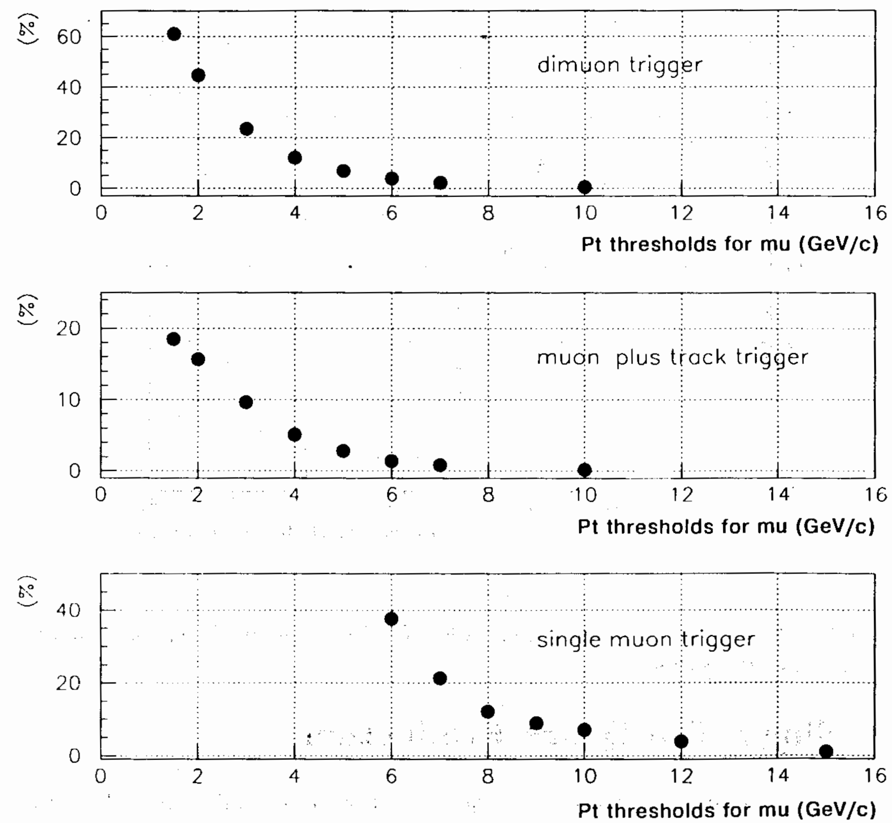

Figure 1: *The trigger acceptance gain with IMU for $B \rightarrow J/\psi(\mu\mu)K_s$ decays as a function of IMU muon threshold*

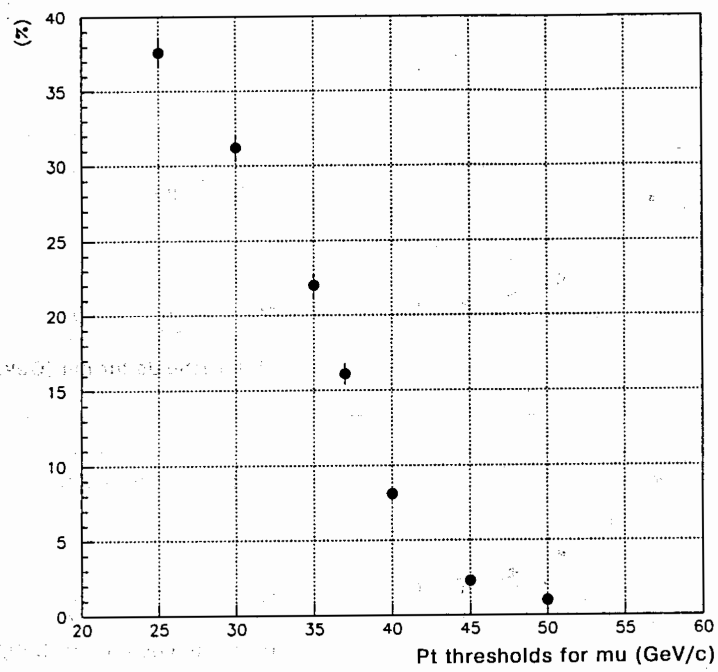

Figure 2: *The trigger acceptance gain with IMU for $W \to \mu\nu$ decays as a function of IMU muon threshold*

4 Single Top Quark Production

In addition to $t\bar{t}$ pair production, top quarks can also be produced singly via the electroweak interaction. This process depends on the t-W-b vertex, and the production rate is a measure of the top decay width to W+b and of the CKM matrix element $\mid V_{tb} \mid^2$.

The two largest single top processes at the Tevatron are the s - channel mechanism $qq \to t\bar{b}$, referred to as W^* production, and the t - channel interaction referred to as quark-gluon fusion. The uncertainties on this calculation are large - on the order of 30 % [1].

Single top quark production has more forward-backward muons compared to

$t\bar{t}$ pair production, therefore the IMU trigger gain is expected to be high. The production of 10.000 single top (quark-gluon fusion channel) in the $p\bar{p}$ collisions was simulated by PYTHIA code at the Tevatron energies. The decays of the $t \to bW(\mu\nu)$ were tested with the trigger formulae :

single muon trigger + missing transverse energy

central region:

$((\mid \eta_{\mu^+} \mid < 1)\&(Pt_{\mu^+} > 20.)\ .or.\ (\mid \eta_{\mu^-} \mid < 1)\&(Pt_{\mu^-} > 20.))\ \&$
$(Et_\nu > 20.)$

central + IMU region :

$(((\mid \eta_{\mu^+} \mid < 1)\&(Pt_{\mu^+} > 20.)\ .or.\ (\mid \eta_{\mu^+} \mid > 1.)\&(\mid \eta_{\mu^+} \mid < 1.5)\&(Pt_{\mu^+} > cut))\ .or.$
$((\mid \eta_{\mu^-} \mid < 1)\&(Pt_{\mu^-} > 20.)\ .or.\ (\mid \eta_{\mu^-} \mid > 1.)\&(\mid \eta_{\mu^-} \mid < 1.5)\&(Pt_{\mu^-} > cut)))\ \&$
$(Et_\nu > 20.)$

The IMU trigger gain (equation 1)against P_t cut for IMU μ is shown in Fig. 3.

5 Conclusion

Simulation shows that the IMU μ trigger could be useful for the processes that have been tested in this work. The maximum IMU gain could reach up to 60 % for the dimuon trigger in the CP violation measurement via $B \to J/\psi(\mu^+\mu^-) + K_s$ decay mode; up to 37 % for W asymmetry measurement via $W \to \mu\nu$ channel; and up to 24 % for single top triggering via $t \to bW(\mu\nu)$ decays. Note that these gains are purely geometrical, and that the maximum values refer to the minimum P_t muon threshold in the IMU region. Work is in progress to obtain the background rates vs. P_t, and to derive a more realistic trigger gain by using the full detector simulation, when available.

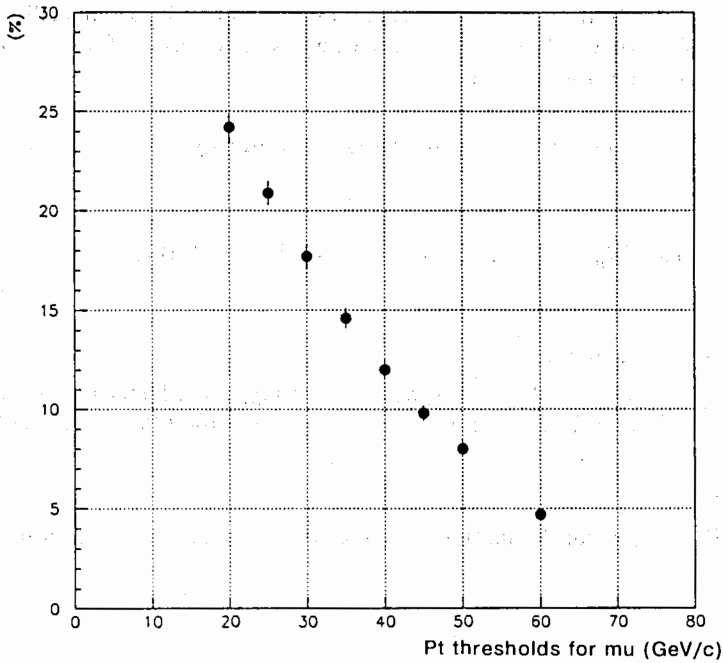

Figure 3: *The trigger acceptance gain with IMU for single $t \rightarrow bW(\mu\nu)$ decays as a function of IMU muon threshold*

References

[1] *CDF TDR (RUN II)*

[2] *CDF/ANAL/TRIGGER/CDFR/4017*

[3] *CDF/ANAL/TRIGGER/CDFR/4076*

[4] *J.Bellinger, work in progress*

[5] J.Lewis, P.Avery *Phys. CDF/DOC/MONTECARLO/PUBLIC/2724 July 25,1994*

Received by Publishing Department
on October 9, 1997.