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SDC
SOLENOIDAL DETECTOR NOTES

LEVEL 1 MUON TRIGGER SIMULATIONS

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Abstract

The level 1 trigger of the SDC muon system is studied using a simple computer model. Trigger efficiencies as functions of muon P_t and trigger rates are calculated for different trigger conditions. The trigger resolution is found to be completely dominated by the interaction region size and multiple scattering. However, the trigger performs well if a 1.5 m thick toroid is used. Digital trigger circuits operating at 60 MHz are found to have adequate time resolution. The nonlinear x-t correlation of simple drift tubes does not significantly degrade the trigger performance.

The level 1 trigger of the SDC muon detector is similar to that used by CDF. Wires in every other plane in the θ view are projective to the interaction point. The time difference Δt between pulse arrivals on paired wires is then inversely proportional to the transverse momentum of the trajectory of muons. Trigger thresholds are set on Δt by simple circuits. The level 1 trigger system arrives at a decision within 1 μs after the beam crossing.

1 Basic Trigger Arrangement

A minimum trigger system requires two layers of drift chambers. There are four major problems with a minimum system consisting only two chamber layers.

1. Geometric effects limit the efficiency. The drift tube walls create dead regions. Also, the acceptance of a trigger pair is not complete due to the toroid bend especially for lower P_t muons.

2. False triggers can be generated when low P_t muons cross the projective line between the two wires and appear to be high P_t muons.

3. False triggers can be generated due to the confusions caused by soft electrons accompanying muons with P_t lower than the threshold.

4. Triggers can be lost due to the confusions of soft electrons accompanying muons which have P_t higher than threshold.

In order to solve all four problems, we have to use more drift chamber layers. For example, we can use all 8 layers of θ-chamber in BW2 and BW3 as proposed by the Michigan group. A muon can fire four trigger pairs generating four time difference signals, T1, T2, T3 and T4. We require a good trigger to satisfy (T1$\times$T2)$\cdot$(T3$\times$T4). As a result, the false trigger problem (problem 2 and 3) and efficiency loss problem (problem 1 and 4) are minimized. Results of our simulation discussed below are based on this arrangement.

In our simulation, drift tubes are arranged in 8 cm $\times$ 8 cm matrices. Anode wires are projective. The barrel chamber length is 16 meters. The first section of calorimeter (0.7 meters) is assumed to be lead. This is one of the options of possible calorimeter configurations. The multiple scattering and toroid deflection are parameterized and calculated in 5 cm steps. The first station of trigger chambers (BW2) starts from r = 8.35m. We define the beam direction as z-coordinate in our study. For 1.5 meter toroid thickness, δz cuts of 3mm, 5mm and 10mm correspond to nominal P_t thresholds (50% efficiency) of 40, 25 and 15 GeV/c.

Effects such as the size of the interaction region, the iron toroid thickness, the trigger timing resolution, non-linear x-t relations and different trigger requirements are investigated.

2 Toroid Thickness

In fig. 1, trigger efficiency curves are given for three different toroid thicknesses, 1.5, 1.2 and 1.0 meters. The δz cut (Pt thresholds) have been adjusted to approximately 40 GeV/c for all three cases. The difference of trigger efficiencies between curves for 1.2m and 1.5m toroids is small. Even the 1 meter toroid does not look too bad. However, the capability of rejection against the low P_t muon is quite different for these three cases. All three curves in fig. 1 have 50% efficiency at about 40 GeV/c. AT 20 GeV/c, the efficiency of 1.5 meter thick toroid is 1.2%. On the other hand, the efficiency of 1.0 and 1.2 meter thick toroid is 3.7%. We can expect that the trigger rate will be much higher for thin toroid.

3 Interaction Region Size

Effects of the size of the interaction region is shown in fig. 2 and 3. One of the two curves in each plot is produced by assuming that $\sigma_z = 5$ cm and the other curve is for $\sigma_z = 15$cm. In fig. 2, the toroid thickness is 1.5 m and it is 1 m in fig. 3. Again, the δz cut is adjusted to 40 GeV/c. The consequence for 1m thick toroid if the interaction region is grown to $\sigma_z = 15$cm is disastrous.

4 θ Dependence

The P_t trigger threshold depends on θ for a fixed δz cut. We can consider two cases:

1. The distance between chamber layers is fixed and the drift direction in drift tubes is the beam direction. In this case

$$Pt_{threshold} \propto \delta z \times sin^2\theta$$

   Fig. 4 shows the comparison between a fixed cut of $\delta z = 3$mm and a variable δz cut of 3mm/sin$^2\theta$. The softening of the trigger threshold due to the 1/sin$^2\theta$ dependence is obvious.

2. In our drift chamber system design, the drift tube is arranged in such a way that the drift field is tilted and high momentum muon tracks are always perpendicular to the drift field lines. In this case, we have

$$Pt_{threshold} \propto \delta z \times sin\theta.$$

   We expect that the trigger can be improved by the 1/sinθ correction. However, hardware realization for this continuous correction is difficult. We may have to divide the detector into several regions and do this correction in steps rather

than continuously. Fig. 5 shows the comparison between a fixed cut of δz = 3mm and a variable δz cut of 3mm/sinθ. The improvement due to the 1/sinθ correction factor is quite large. Another curve is computed by dividing the central muon detector into three regions, 90°-60°, 60°-45°, 45°-35°. Three different cuts, 3 mm, 3.75 mm and 4.5 mm are used for these three region. These three cuts corresponds to 64 ns, 80 ns and 96 ns respectively. The fact that the two curves are nearly identical proves that a digital trigger circuit operating at 60 MHz is completely sufficient to correct the θ dependence of our trigger system.

5 Trigger Electronics Time Resolution

The designed resolution of muon drift chamber system is $\sigma_\theta = 250\ \mu m$ or 5 ns. This is the fundamental limitations of our trigger design. The resolution of the trigger electronics is another limit. However, these are not important factors because the resolution of our level 1 muon trigger is dominated by the multiple scattering and the finite size of the interaction region. Fig. 6 shows this is indeed the case. In fig. 6, one set of data is generated assuming that there is no time measurement error in our system. The other set assumes a randomly distributed error of $\pm 8ns$ in both start and stop time of our trigger electronics. These two curves are nearly identical indicating that the sharpness of the P_t cuts will not be degraded by using 60 MHz trigger electronics.

6 Non-linear x-t Correlation

Non-linear drift velocity is introduced in fig. 7. Cylindrical drift tube (without field shaping) and Ar-CO2-CH4 90-5-5 gas mixture are assumed. For comparison, fig. 8 shows the trigger efficiency curve assuming the x-t correlation is linear. As expected, the non-linear drift speed slows down the rise of efficiency curves but not in a significant fashion.

7 Trigger Rate

Single muon trigger rate is calculated for different muon P_t thresholds. The integrated trigger rates are summarized in the table below. The trigger rate is low because we use the trigger scheme described above which requires 8 layers of θ chambers in BW2 an BW33.

Table 1. Integrated Trigger Rate for Different P_t Threshold

z-cut (mm)	P_t Threshold (GeV/c)	Rate (Hz)
13	12	2701
10	15	1960
6.4	20	1062
3.2	40	259

The muon rate at the muon trigger chambers is take from Mr. Sakai's study which is shown in fig. 9. We use his dotdash curve which is for $|y| < 1.5$ at luminosity of $10^{33} cm^{-2} s^{-1}$. The trigger efficiency we used is computed for our proposed muon chamber system and trigger electronics described above. Toroid thickness of 1.5 m and interaction size of σ_z=5 cm is assumed. The error of the start and stop time of the trigger electronics is assumed to be $\pm 8ns$. Effects of δ-rays are not included in these calculations.

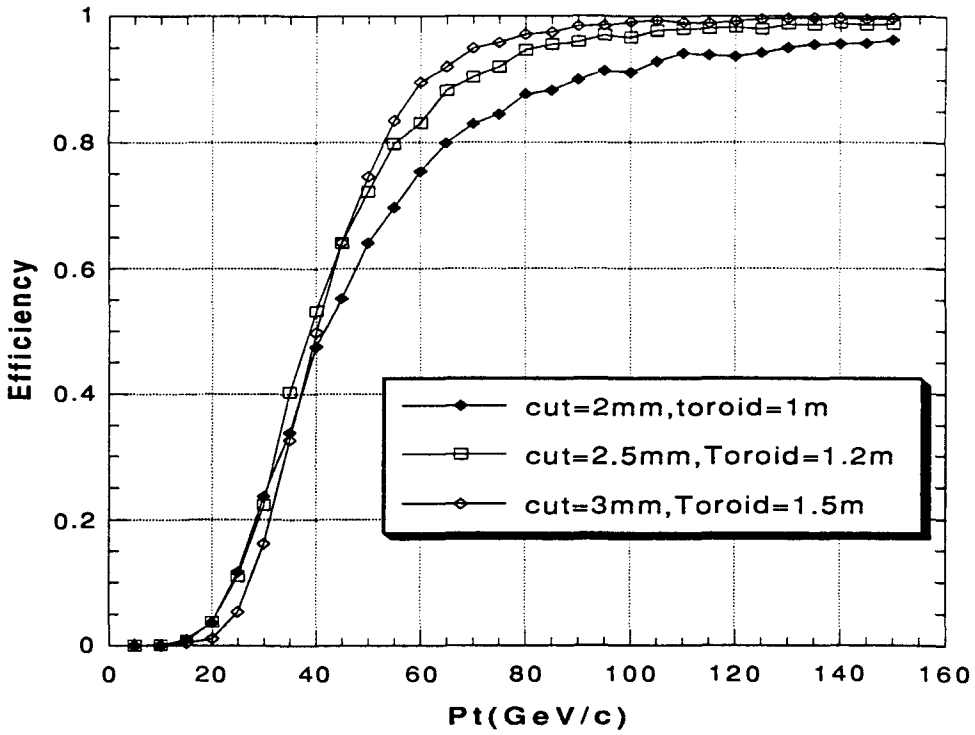

Fig. 1. Trigger Efficiency vs P_t for three toroid thickness

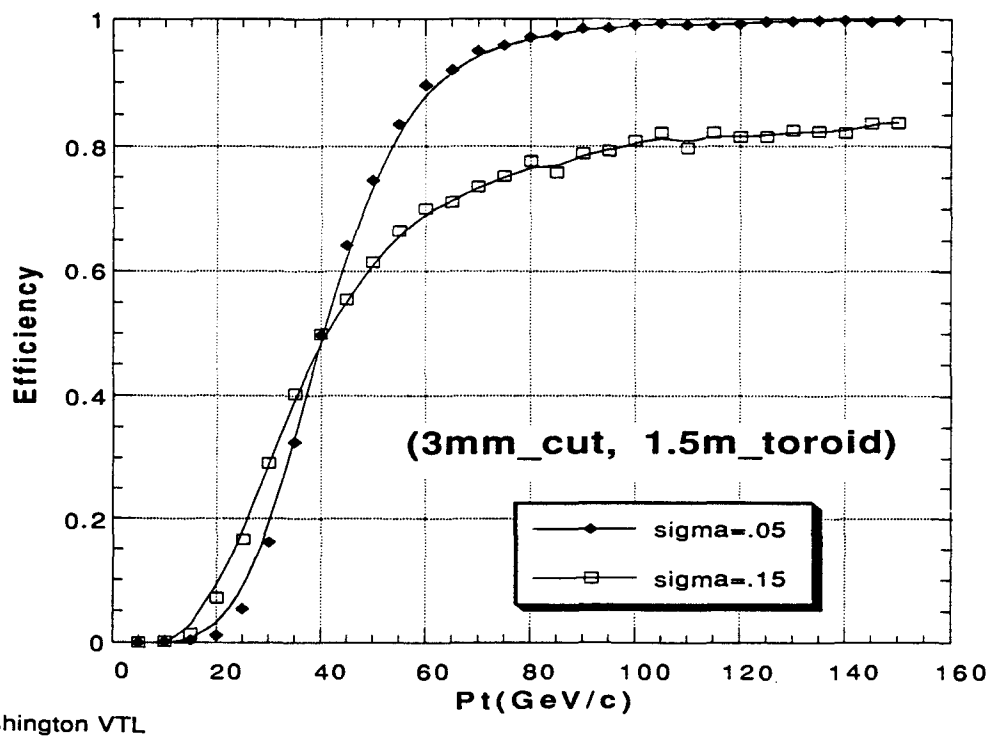

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Fig. 2. Different interaction region sizes and a 1.5 m thick toroid

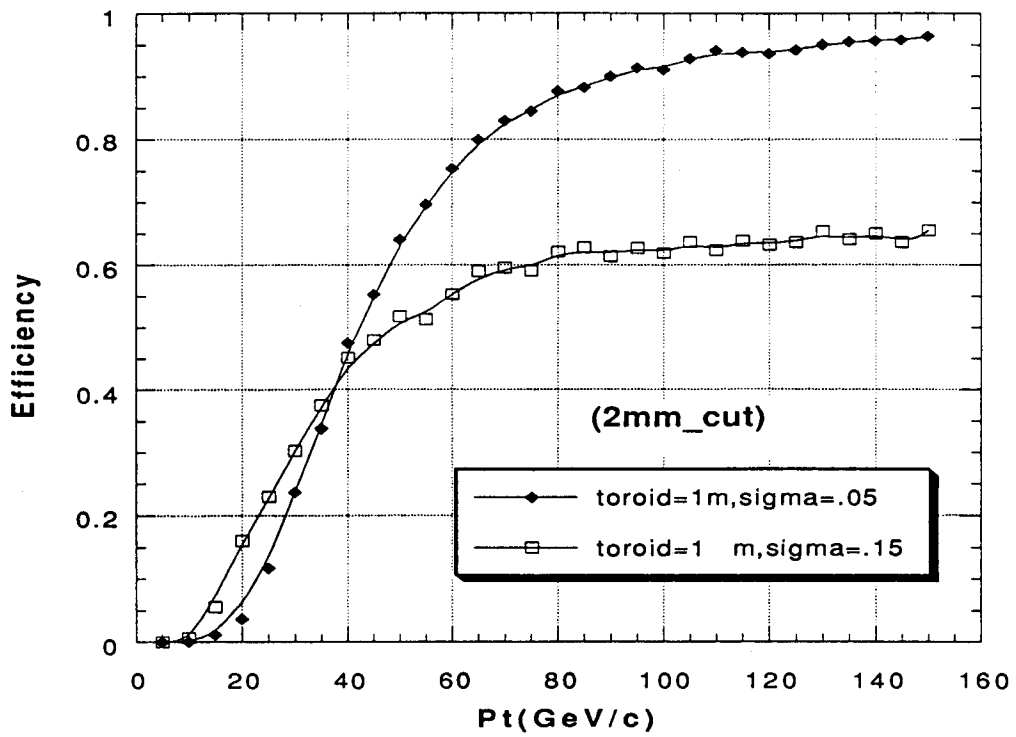

Fig. 3. Different interaction region sizes and a 1.0 m thick toroid

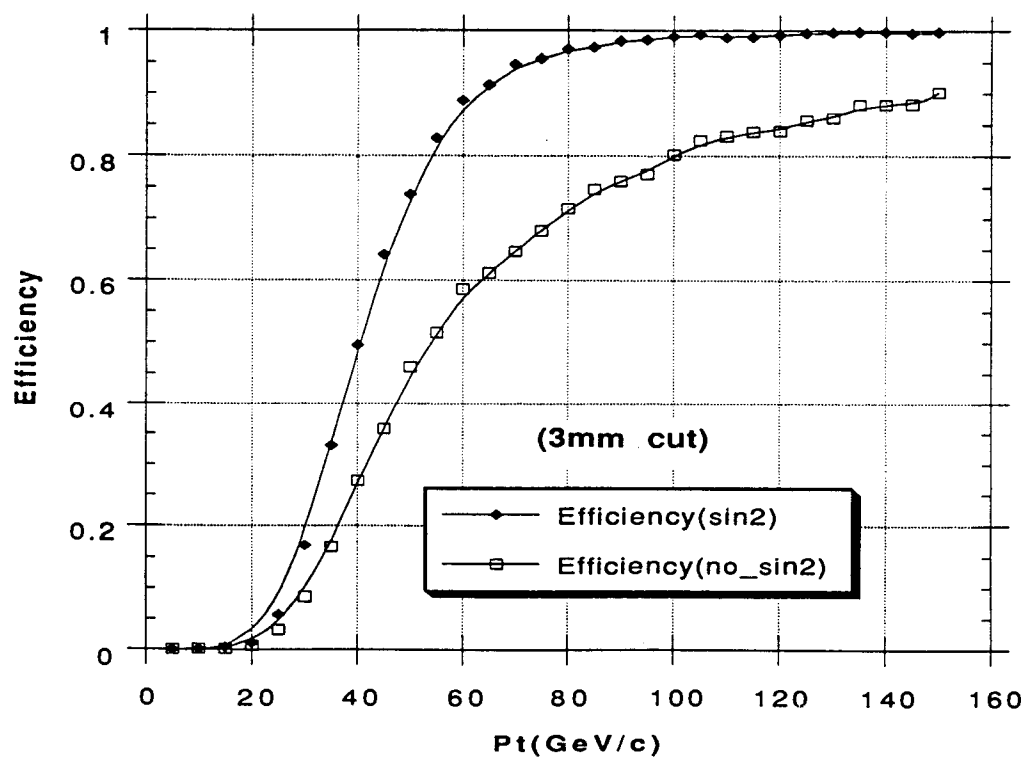

Fig. 4. Comparison between a constant 3 mm cut and a 3 mm/$\sin^2\theta$ cut

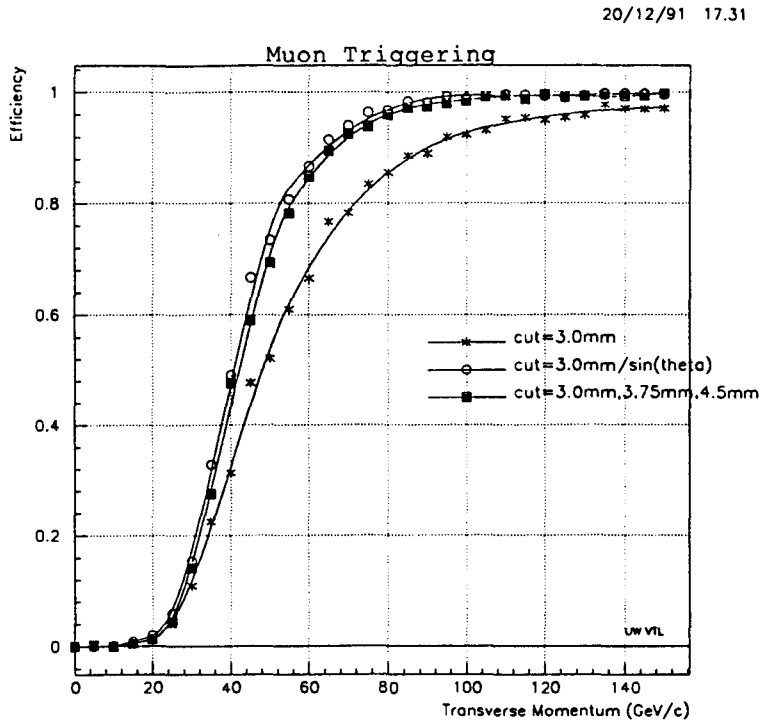

Fig. 5. Three different cuts for round tubes

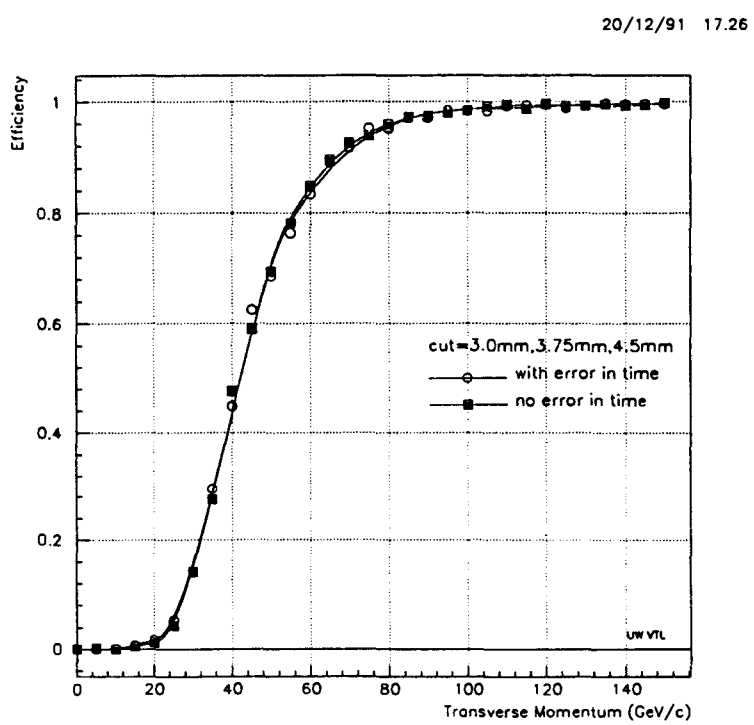

Fig. 6. $\pm 8ns$ error of trigger electronics start and stop time makes no difference

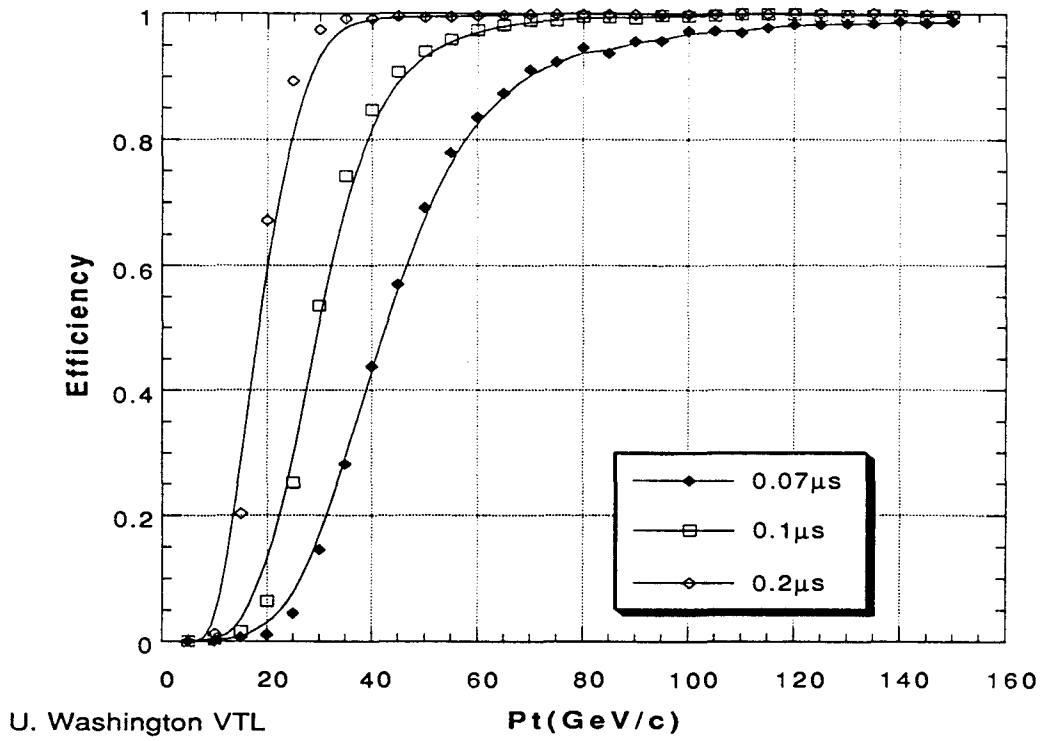

Fig. 7. Trigger efficiency vs P_t assuming a non-linear x-t correlation

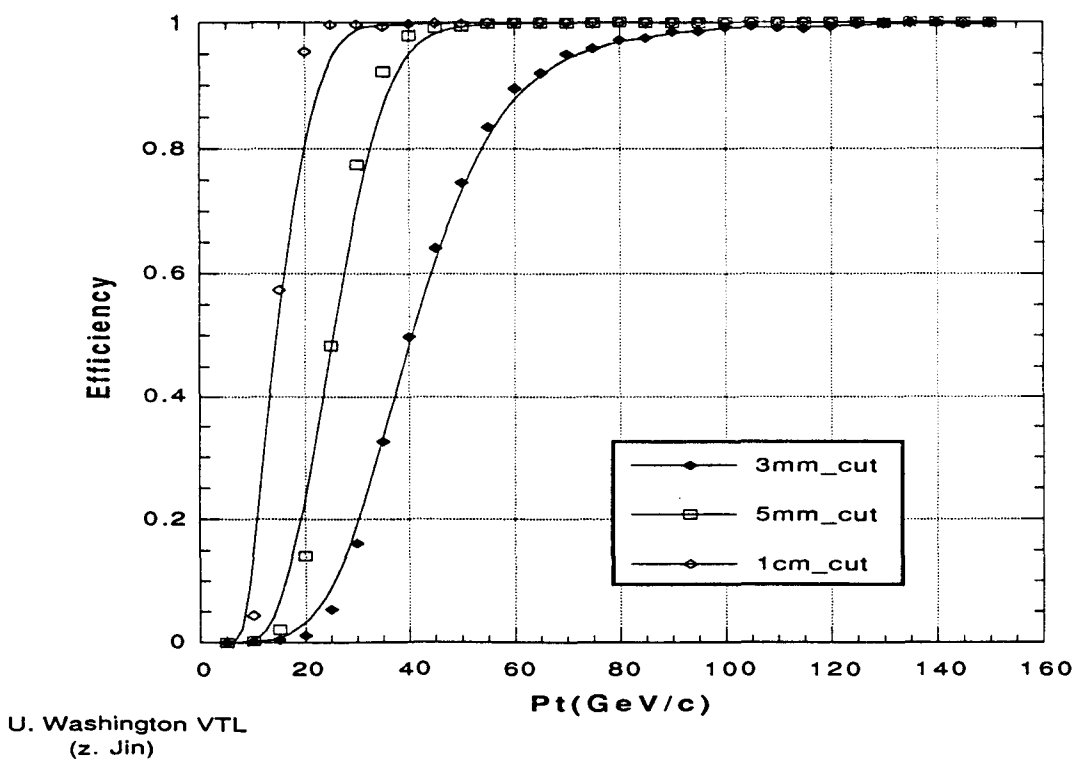

Fig. 8. Trigger efficiency vs P_t assuming a linear x-t correlation

Sakai's study

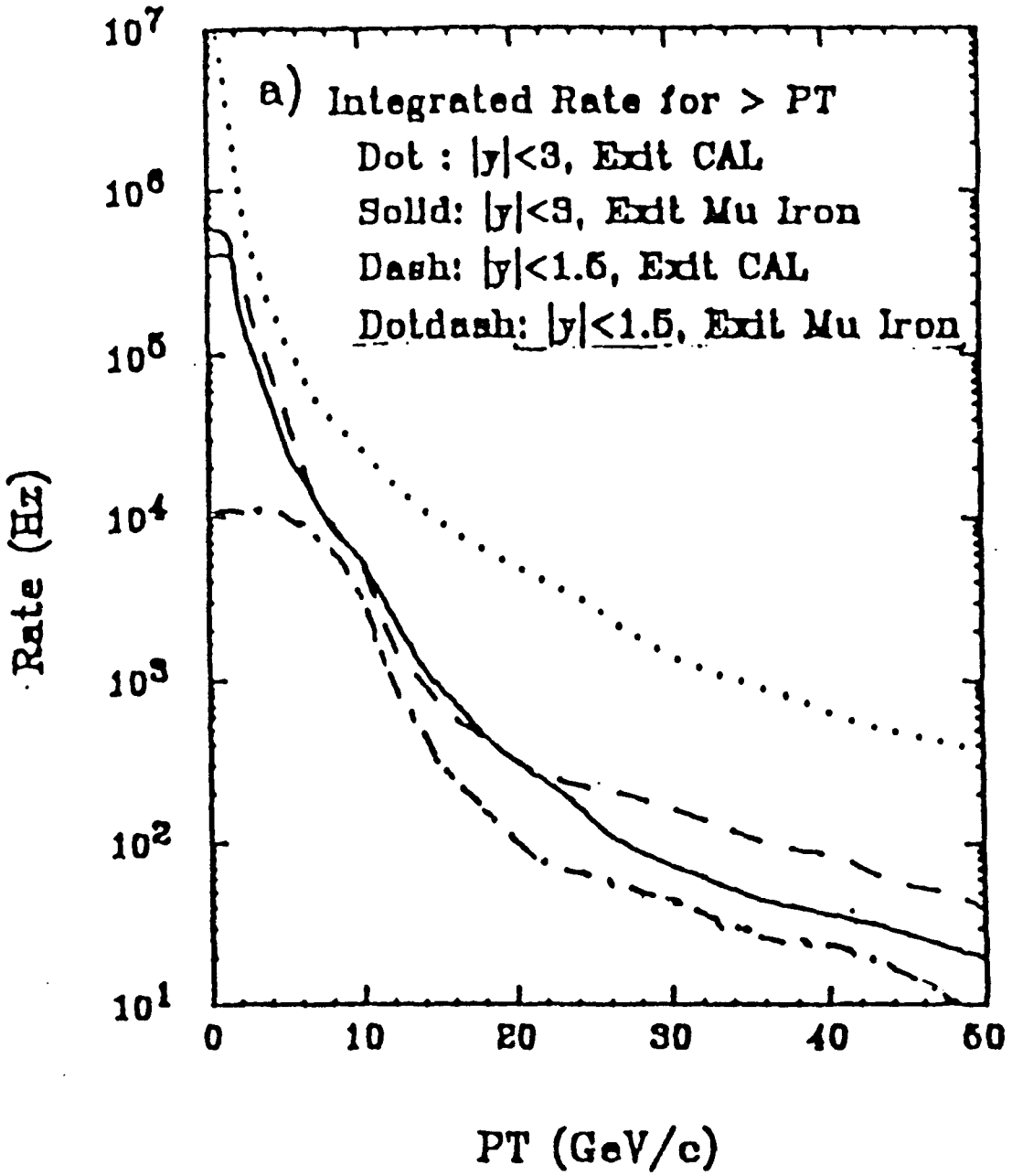

Fig. 9. Muon rate calculated by Sakai