# Report of the TeV 33 Detector Working Group

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ABSTRACT

We have considered changes that would be required to run CDF and D Zero at a luminosity of $2\times10^{33}$ cm$^{-2}$s$^{-1}$. We find that both detectors will function well with upgrades providing that the average number of interactions per crossing does not greatly exceed 6 to 7. Implementation of luminosity leveling is an important consideration in making a plan for high luminosity.

## I. INTRODUCTION

The main effort of the group was to understand the impact on the two existing Fermilab detectors of an order of magnitude increase in luminosity beyond Run 2. The physics that can be done at these luminosities are well described in the TeV2000 report [1] and will not be repeated here. The 'window of opportunity' for such an experiment is after the completion of Run 2 at Fermilab and before the turn on of LHC at CERN. We assumed that the accumulation of integrated luminosity at the LHC would allow running between 2003 and 2007.

Most of the studies were done for a peak luminosity of $2\times10^{33}$ cm$^{-2}$s$^{-1}$ but we have included the results from some analysis that used L= to $1\times10^{33}$ cm$^{-2}$s$^{-1}$ .

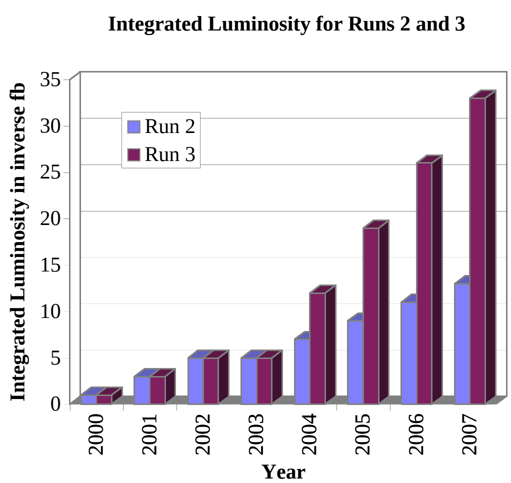



Figure 1: Integrated luminosity as a function of year. The 'Run 2' data is the extension of Run 2 with no increase in L beyond $2\times10^{32}$ cm$^{-2}$s$^{-1}$ while 'Run 3' is an increase to $1\times10^{33}$ cm$^{-2}$s$^{-1}$ starting in 2004.

Figure 1 shows the integrated luminosity for 2 possible running modes between the year 2000 and 2007. This plot was generated as follows. Run 1 produced 100 pb$^{-1}$ in roughly 1 year with a peak L ~$1\times10^{31}$ cm$^{-2}$s$^{-1}$. Run 2 should have 20 times this peak value and Run 3 100 times (peak L $=1\times10^{33}$ cm$^{-2}$s$^{-1}$ rather than $2\times10^{33}$ cm$^{-2}$s$^{-1}$ ). We assumed luminosity leveling for Run 3 with a penalty of 30%. The first year of both Run 2 and Run 3 are taken to have only half of the maximum luminosity which is similar to Run 1. The year 2003 is taken as a shutdown year to replace the silicon detectors. After that, one can continue with Run 2 intensities (lower curve) or move to TeV33 (upper curve). By 2007 TeV33 has accumulated 3 times as much data as would be accumulated if the accelerator continued with Run 2 luminosities. We used this run plan as a guide for our study.

Since the primary physics goals all involve high $P_t$ reactions, we restricted our studies to high $P_t$ experiments. This allows us to set high thresholds to control the overall trigger rate and to reduce the effect of the large number of minimum bias events that will occur at every crossing.

### A. Ground Rules

Assuming that Run 2 lasts for the 3 years from 2000 to 2002, one immediately sees that there is no time for a long shutdown to install new detector components. It is likely that any shutdown will be no more than a year. This puts significant restrictions on what can be done. We also felt that with the demands of the current upgrade, serious development of TeV33 upgrades would not occur until 2000. This allows 3 more years advancement in detector technology. For example, pixel detectors for LHC experiments should be well developed by then. Finally, we assumed that current Run 2 upgrade funding would continue for 3 additional years. Thus, we assumed \$20M per detector would be the approximate upgrade cost.

### B. Limitations of the Run 2 Detectors at TeV33

We found two main limitations of the Run 2 detectors: radiation damage and trigger accept rate (from both real and fake triggers). Radiation damage occurs for many subdetectors and accounts for the bulk of the cost for the upgrade. The inner layers of both the CDF and D0 silicon detectors must be replaced. Figure 2 shows silicon detector bias voltage as a function of 10 fb$^{-1}$ years. Assuming that we can run at 100 volt bias voltages, the inner silicon layers last a little over a year in Run 3. It is not clear that there are new strip silicon detectors on the horizon that will have the necessary radiation hardness. Since the readout chips may also have difficulty surviving, the detectors may need to move to larger radii or be replaced by silicon pixel devices. These options will be described more completely below.

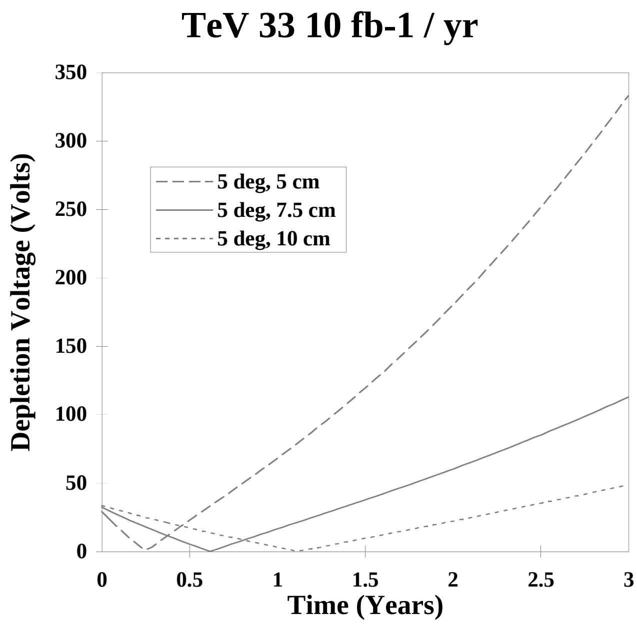



Figure 2: Bias voltage for silicon detectors versus years of operation at 10 $fb^{-1}$ per year.

Scintillator will also suffer radiation damage. Calculations show that the light yield from the inner layer of the D0 scintillating fiber detector will fall by roughly half after 10 $fb^{-1}$. The inner fiber layers will probably not be functional by the end of TeV33. Again, the options are to move them to larger radii or to put in a new detector. Both of these options are described below.

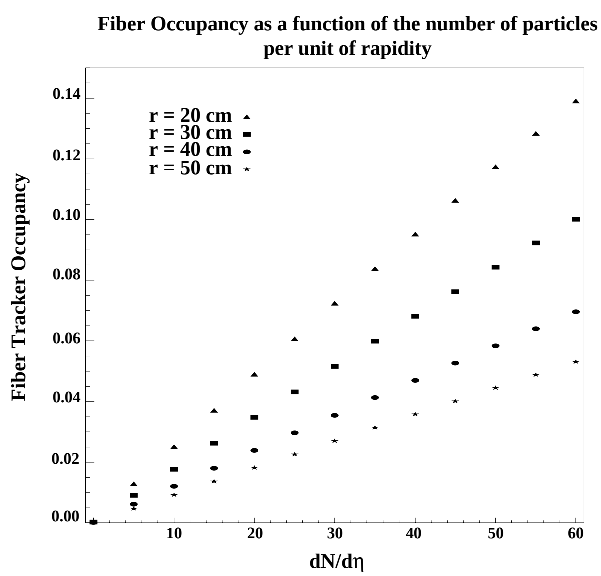



Figure 3: Fiber occupancy as a function of the number of particles per unit of rapidity for the D0 fiber tracker.

Some portions of the D0 forward preshower detectors at high $\eta$ will see 400 KRad in a 30 $fb^{-1}$ run. These detectors must either be changed to a different detector or they must be replaced during the run.

Finally, some of the D0 and CDF wire chambers will show significant aging. The central D0 muon chambers need to be replaced because of this. The CDF pre shower (CPR) and shower maximum (CES) wire chambers may also need to be replaced.

Fig. 3 shows the occupancy of the D0 fiber tracker (0.83 mm fiber diameter) as a function of the number of particles per unit of rapidity for different tracker radii. [2] A typical minimum bias event has an effective $dN/d\eta = 8$ in the fiber tracker. The inner layers of the tracker will have 15% occupancy from 7 minimum bias events per crossing. Monte Carlo studies indicate that once the occupancy rises above a few percent, fake trigger rates increase dramatically.

## C. TeV33 Physics Trigger Rates.

The assumption for TeV33 is that we will concentrate on high $P_t$ physics. We expect the high $P_t$ L1 trigger rate to be 3 to 4 kHz in Run 2 (D0's estimate at $L=2\times10^{32}$ $cm^{-2}s^{-1}$). Luminosity leveling is expected to cut the trigger rate by a factor of 2 so we expect roughly a factor of 5 increase in the trigger rate. Twenty kHz is about twice the Run 2 rate for D0 and well within CDF's Run 2 goal of 50 kHz.

There are two ways D0 can deal with the increased L1 rate. It can follow CDF and adopt the SVX 3 chip and rebuild some of the Run 2 electronics or it can move some of the rejection power in their L2 processors to L1 so that all the high $P_t$ physics can fit into the estimated 10 kHz bandwidth. Since the calorimeter trigger will likely be rebuilt for 146 bunch operation (132 ns between crossings), the latter solution appears to be the best option.

## D. Some Possible Beam Configurations for TeV33

The proper metric to compare various options is the number of interactions per crossing, n. The average number of interactions per crossing at $L=2\times10^{33}$ $cm^{-2}s^{-1}$ and 108 bunches is 18. Calorimeter based triggers are not very sensitive to the number of minimum bias events in a crossing but tracking triggers are quite sensitive because of fake tracks. In addition, the number of minimum bias events per crossing are Poisson distributed. One percent of the crossings will have 28 or more events. If one is not careful, tracking triggers will select crossings with large numbers of minimum bias events rather than events of interest.

There appear to be only two solutions to this problem. One is to increase the resolution of the detectors so that the occupancy per channel decreases and the other is to decrease the intensity per bunch. The latter can be accomplished by increasing the number of RF buckets filled with particles or applying some form of luminosity leveling or a combination of the two. Our preference was to keep as much of the existing detectors as possible so we concentrated on the latter option. However, it is likely that all of the options will be needed to get to $L=2\times10^{33}$ $cm^{-2}s^{-1}$.

There are two ways of filling more RF buckets with particles. One is to decrease the bunch spacing to less than

132 ns and the other is to fill empty buckets in 2 of the 3 beam abort gaps. Reducing the bunch spacing to less than 132 ns would require rebuilding most of the electronics for both detectors. Shorter bunch spacings are also not desired for accelerator physics reasons. Thus, we did not consider this alternative. However, filling 2 of the abort gaps presents only a few problems. At 132 ns spacing each of the gaps will hold 19 bunches. Thus, the 38 bunches in the abort gaps plus the 108 bunches already scheduled for beam (146 total) would reduce the number of interactions per crossing from 18 to 13.3. Since the two collision points are not directly across the ring from one another, there will be a difference in luminosity at the two points. Which detector gets the higher luminosity depends on the location of the abort kicker.

Luminosity leveling is also possible and is anticipated as part of the Accelerator Division's plan for higher luminosity. At the beginning of a store beta* is set to roughly twice its minimum value giving about one half of the maximum possible luminosity. As the luminosity decays away, beta* is decreased at the same rate so that constant luminosity is achieved until the minimum beta* is reached. After this point the luminosity would decay away just as it did in Run 1. This has not been done before and although the idea is straight forward, the inefficiency for such a process must be determined. An estimate of the inefficiency is between 20 and 30%. However, when luminosity leveling is combined with filling the abort gaps, the number of interactions per crossing is reduced to 6.7 which is only 3 to 4 times larger than Run 2 rather than 10 times larger. We felt that there would be more good data on tape at the lower interaction rate.

## II. DETECTOR SPECIFIC OPTIONS

The following sections describe some of the changes that are required for the two detectors. The list of possible changes should be considered preliminary at this stage. Experience with Run 2 will be important in verifying these changes.

### A. CDF Muon

The CDF muon system appears to be able to survive to L= $1\times10^{33}$ $cm^{-2}s^{-1}$. The system that had the most difficulty in Run 1 was the Forward Muon System, and CDF has elected to replace it with a fine-grained Intermediate Muon System (IMU) that covers the region $\eta$=1.0 to 1.5. The IMU will have occupancies below that of the existing muon systems, so it will survive to L=$1x10^{33}$ $cm^{-2}s^{-1}$. At L=$1\times10^{33}$ $cm^{-2}s^{-1}$, the system with the largest occupancy will be the CMX chambers (1%/ch), but this assumes that no shielding is added. In fact, the CDF Run 2 shielding plan is expected to drop the CMX rate by a factor of 5 or more, which will make the system with the largest expected occupancy at 0.5%/channel/event.

Radiation damage is not an issue. The chambers have already received more radiation from the Main Ring than they will in the entire TeV33 run, and show no signs of developing problems.

The ability to trigger depends critically on the performance of the tracking trigger and the total DAQ bandwidth at L=$1\times10^{33}$ $cm^{-2}s^{-1}$. The muon trigger will depend more on these elements than the actual muon detection capability which will be preserved in TeV33.

### B. CDF Calorimeter

For the most part, the CDF calorimeter should work at TeV33 luminosities. [3] For the Region of $|\eta|<2.3$, the calorimeters should still be able to provide a precision energy measurement. [4] Radiation damage is not a problem except for the high eta regions of the EM plug calorimeter. After 50 $fb^{-1}$, the energy response in the plug region of $2.3<|\eta|<2.6$ will be degraded by 40% and the energy resolution will worsen by 2% while measurements beyond $\eta$ =2.6 will show more degradation due to radiation. The shower maximum (CES) and preshower (CPR) detectors are wire chambers using Argon-C02. While there have been no signs of aging in either system to date in the data, bench mark tests indicate that radiation damage occurs after exposures of order one Coulomb/cm. [5] After 50 $fb^{-1}$ of luminosity, the preshower chambers approach this damage limit with exposures of .45 C/cm.

The effect of the pile-up of minimum bias events will cause pulse height shifts of about 300 MeV in both the Central and Plug EM calorimeters which both use a 3 X 3 clustering of towers. This pile-up effect will have to be corrected, but studies indicate there will be no significant energy resolution degradation due to it.

The calorimeters signals are read out using photomultiplier tubes which are very fast and easily fit within a 132 ns gate. The central wire chambers however are much slower, with 400-600 ns needed to collect all the charge. The single channel occupancies at L=$1\times10^{33}$ $cm^{-2}s^{-1}$ would be 18% for the central photomultiplier tubes, 3% for the CES and about 33% for the CPR. The PMT occupancy is just a pedestal shift, but for the case of the CPR which is looking for the absence of a signal, the occupancy is more problematic. The CPR occupancy and possible solutions using the existing detector need more study, but replacing the CPR with a new fast detector is a possible option.

### C. CDF Tracking

CDF is building an entirely new tracking detector for Run 2. It consists of two silicon detectors and a jet chamber (the Central Outer Tracker). All detectors have less than 132 ns response time and all are capable of pipelined readout. Fig 4 [6] shows the resolution of the COT plus silicon for various track fitting parameters as a function of the number of interactions per crossing. One sees that the resolution is independent of the number of minimum bias events up to 6 per crossing. With luminosity leveling and filling the abort gaps, n is only 6.7 so occupancy should not be a problem if n can be kept in this range.

In Run 3 the inner layers of the Run 2 silicon system will fail from radiation damage. Since CDF also has an intermediate silicon layer, one option is to simply abandon the inner layers. Alternatively CDF can pursue new detectors such as diamond strips or pixels.

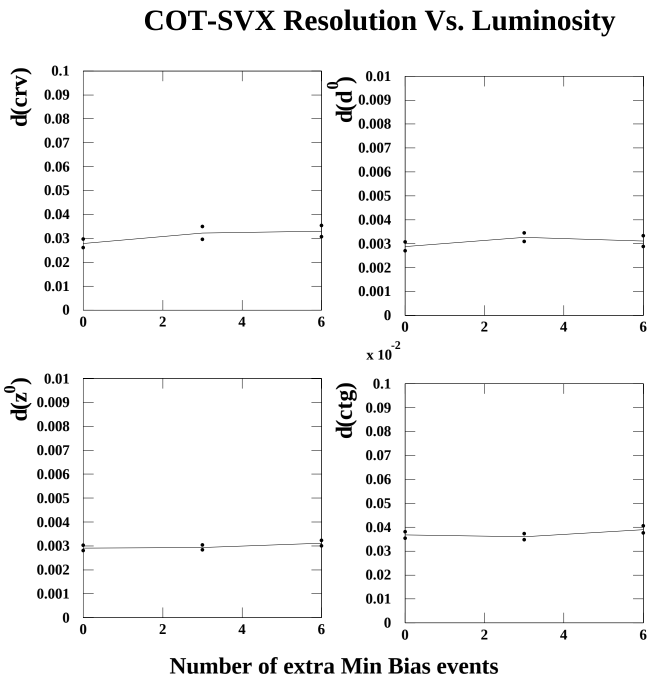


Figure 4: Resolution of the Central Outer Tracker plus the silicon detectors for curvature, z position, cotangent and impact parameter as a function of the number of minimum bias events.

## D. D0 muon

D0 muon coverage extends to $|\eta| = 2$. The inclusive single muon rate over this region is 1 kHz at $L=1\times10^{33}$ $cm^{-2}s^{-1}$. Most of these muons are from b quark decays. Thus, the rate from real muons is small compared to other background sources.

The most serious background is from remnants of high energy showers leaking through cracks in the detector. There is also a substantial contribution from the ‘gas’ of low energy neutrons that fill the collision hall. D0 has done detailed studies using both Monte Carlo analysis and data from Run 1.[7] These studies predict about a 15% occupancy in the central chambers (PDT), .3% in the forward mini drift tube (MDT) chambers and 0.5% for the scintillator trigger counters. The difference between the MDT and PDT occupancy is due to cell size and electron drift time. D0 has a well defined program to design and install shielding to reduce these backgrounds by a factor between 10 and 50 depending on location.

The only detectors that will suffer radiation damage during a 30 $fb^{-1}$ run are the PDT’s. These suffer radiation damage when the collected charge approaches 1 mC/cm. [8] Using Run 1 data, this point will be reached after about 1 $fb^{-1}$ of integrated luminosity. Thus, these chambers will need to be rebuilt for TeV33. They would probably be replaced by MDT’s which will also solve the occupancy problem.

All of the muon electronics are being rebuilt for Run 2 so changes for TeV33 are not expected.

D0’s muon trigger is also dependent on the tracking trigger. However, the muon system forms its own track segments first and then compares the track to the tracking system. If there are 6 or fewer trigger track candidates from each 4.5 degree tracking sector, the muon trigger rate will be acceptable.

## E. D0 Calorimeter

The present calorimeter has two potential problems for TeV33. The first is signal pileup during the 400 ns integration time and the second is voltage sag caused by large charge particle fluxes in the showers that produce high currents in the resistive coat on the calorimeter signal readout boards. The pileup effect has been studied using minimum bias data from Run 1. Scaling these results to n=9 gives an average energy contribution from background events of 200 MeV in the central EM towers and 75 MeV in the central hadron towers. This will have little impact on D0 physics analysis. The most sensitive area is the precision W mass. Studies show that a precision measurement is still achievable.

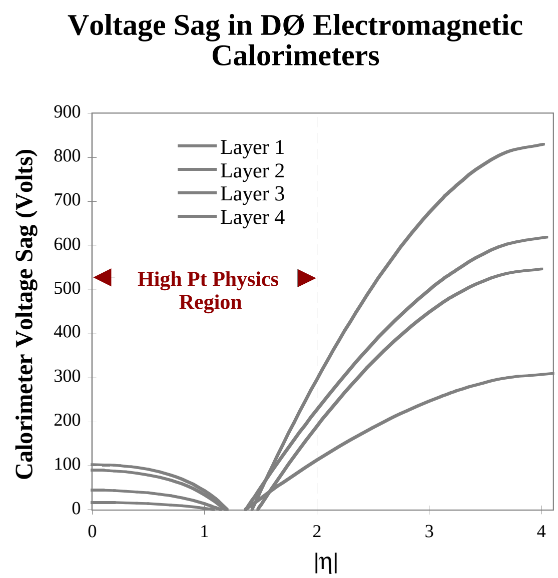


Figure 5: Voltage sag for the EC and EM sections of the D0 calorimeter for $L=1\times10^{33}$ $cm^{-2}s^{-1}$. There are four depth readout sections which are labeled EM1 to EM4.

High voltage is distributed in the D0 calorimeter via a resistive coat on the signal boards. As the absorbed energy increases, the current in this coat increases which causes a decrease in voltage in parts of the calorimeter. Figure 5 shows the voltage drop for the four EM layers as a function of $\eta$ for $L=1\times10^{33}$ $cm^{-2}s^{-1}$. For forward EM showers, $|\eta|>1.5$, where the voltage drop in the third layer of the calorimeter ($5X_0$ to $11X_0$) will cause some degradation of response, D0 will need to make a luminosity dependent correction to the measured ionization. Estimates of the errors on such a correction are still under study.

The present calorimeter Level 1 trigger forms towers that are 0.2 by 0.2 in eta-phi space. Each tower is summed in depth in two sections to give an EM and a Hadron signal. These signals are available to the trigger framework. In addition signals from 4×8 (eta × phi) trigger towers are summed to form 'large tile' signals which are used to search for jets. There are 4 EM threshold reference sets, 4 jet (EM+HAD) threshold reference sets, and 8 large tile reference sets. Each reference set consists of energy threshold values for each tower. Finally, several global quantities are summed over the entire calorimeter and compared to reference set values. These include the vector sum of momentum (used for missing $E_t$ triggers) and scalar EM $E_t$ and scalar jet $E_t$. The only changes anticipated for Run 2 are to provide direct readout to the DAQ system and to provide a history of the previous 25 crossings.

Increasing the calorimeter trigger rejection requires a new L1 calorimeter trigger system. This system would move the isolation cut for EM jets to level 1. It would improve the hadron part of level 1 by allowing a more flexible combination of towers than is provided by the large tiles. That is, one could have a moving window which would search for isolated jets rather than large fixed tiles. It would provide the phi of the trigger so that there could be a phi match between the tracker, pre shower and calorimeter. Putting the isolation cut at L1 should easily get an additional rejection factor of 2 to 3 for electrons. The flexible tile system will substantially sharpen the jet thresholds resulting in lower trigger rates.

It is estimated that the design, construction and installation of these trigger changes would take at least 2.5 years. This upgrade would allow D0 to implement some other useful features such as digital filtering of the input signals to get rid of some of the pile up effects from adjacent crossings.

## F. D0 Tracking system

Radiation damage will require the replacement of the inner layers of the silicon and fiber tracker. There are at least two possibilities for the silicon. One is to replace the inner layers with either pixels or diamond strips. The pixels could be quite useful for trigger purposes as is described below. The other option is to go to larger radius. That is, remove the inner silicon detector and add new layers on the outside replacing the inner layers of the fiber tracker which would be inefficient anyway. A third alternative is to replace the inner layers of the fiber tracker with a micro strip gas chamber. Then the inner radius channels of Visible Light Photon Counters could be used to read out additional fiber layers at larger radii. This is described in more detail below.

The L1 tracking trigger for Run 2 is formed by the logical AND of hits from the 8 axial layers of the scintillating fiber tracker. Monte Carlo studies show that the probability of finding a fake track is a strong (more than linear) function of the number of tracks in the detector. The only known solution for TeV33 is to increase the resolution of the trigger elements either by using more layers of (possibly smaller) fibers or by adding some sort of pixel device.

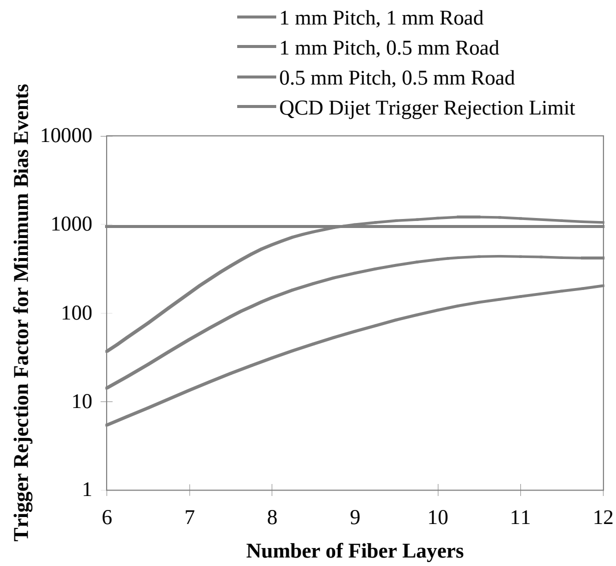


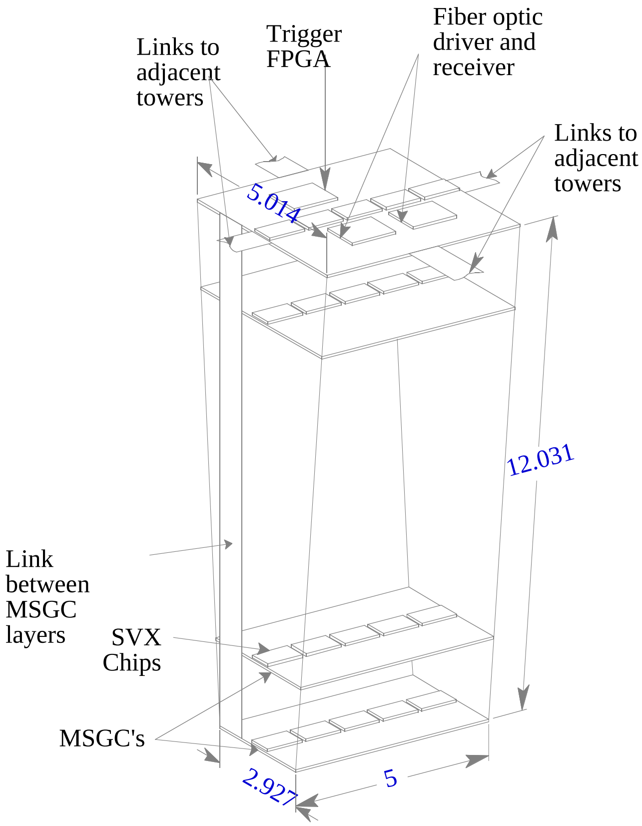

Figure 6: Trigger rejection as a function of the number of fiber barrels for the D0 fiber tracker for L= $1\times10^{33}$ $cm^{-2}s^{-1}$ and 146 bunches. The horizontal line at 1000 is the expected number of high $P_t$ events. That is, if all fake tracks were rejected, the rejection factor would be 1000.

D0 has looked at the possibility of rearranging the existing fiber tracker and not increase the number of detector channels. [9] They studied the effect of putting additional layers of 1 mm or 0.5 mm fibers in the region between 30 and 51.5 cm radius. Figure 6 shows the rejection factor as a function of number of layers for various road sizes for 146 bunch operation at L=$1\times10^{33}$ $cm^{-2}s^{-1}$. High $P_t$ events occur in one out of every 1000 crossings at this luminosity. Thus one needs a minimum bias rejection of 1000 which is shown in the figure. One sees from the figure that this rejection can be obtained by going to .5 mm diameter fibers and increasing the number of layers to 9 or 10 (from 8 in the Run 2 design). Note that since there is no stand alone tracking trigger, 100% fake rejection is not required. One only needs the final trigger fake rate to be small.

This design doubles the number of axial fibers which would require either adding more channels of VLPC's or converting all the Run 2 stereo layers to axial ones. Effective off line reconstruction requires good 3D space points throughout the tracking volume so it is important that any new design take these off line needs into account.

A second possibility is to replace the inner fiber layers with microstrip gas chambers (MSGC) or possibly silicon pixel detectors. [10] These devices would be built as rectangular pixels and assembled into towers. Fig. 7 shows a picture of such a device using MSGC's. It consists of 4 layers of gas microstrip chambers at radii of 20, 22, 30 and 32 cm arranged into 40 towers in phi by 40 towers in z. The detectors are wedge shaped in the phi direction which is also the pitch direction of the MSGC's. Thus, the pitch varies from 245 to

392 microns. The readout is by an SVX type of chip with a trigger pick off mounted directly on the detector. The device is constructed as a series of towers inserted into a egg crate like frame. We have assumed 128 channels in phi and 5 pixels in z for each module so at the top the tower is approximately 5 cm square. The trigger is formed by routing the signals from the inner layers to the outer layer via thin Kapton cables. The fourth (outer) layer is also connected by small Kapton cables to each of its four adjoining neighbors. Connection to the diagonal neighbors is possible but it is not thought to be necessary. The fourth layer has a large Field Programmable Gate Array chip in addition to the SVX chips so it can form the trigger right there. Timing and trigger information are sent to the module over fiber optic cables. Readout is also over fiber.




Schematic diagram of one cell of a MSGC pixel detector

Figure 7: Schematic representation of a trigger tower that could be used either with microstrip gas chambers or silicon pixels. Detector signals are digitized on the detectors and then sent to the outer layer via thin ribbon cables where a local trigger is formed.

There are 40 of these modules in phi and 40 in z for a total of 160 modules. The idea is to build each of these modules in a jig and then insert tested modules into the frame. This should allow reasonably easy repair provided that the assembly could be removed from the center of the fiber tracker.

There are about 5 million channels in this device which is a factor of 500 more channels than in the Run 2 fiber trigger that it replaces. One would expect that the occupancies would be reduced by roughly the same amount.

A Monte Carlo study of this detector has been done using the DTUJET [11] generator. For L=$1\times10^{33}$ cm$^{-2}$s$^{-1}$ we get an acceptance for fake 10 GeV/c tracks of .09% which is very close to the required rejection factor of 1000 mentioned above. Thus, this trigger can work without any other device. It would be fairly straightforward to connect this to the fiber tracker in the same way as is done for the muons. Both the MSGC and the fiber would find tracks independently and then their results matched to confirm the tracks.

An MSGC system would be very powerful for a silicon level 2 trigger. The z segmentation should allow one to easily determine which silicon barrels contain the event of interest. This gives an effective silicon segmentation of 6 in z which should help considerably in reducing the background.

This scheme could also be adapted to silicon pixels. One option would be to use pixels in place of MSGC's at an inner radius of around 20 cm. The second would be to replace the inner two layers of silicon strips will have to be replaced anyway because of radiation damage (see above). The technical difficulty with the second option is that the silicon system would be much smaller making all devices a factor of 5 to 10 smaller. This makes it difficult to fabricate cables etc. Industry may solve all of the interconnect problems. Note that the Monte Carlo results for the MSGC pixels are also valid for inner layer silicon pixels. The silicon pixels are about a factor of 6 or so smaller but they are also about a factor of 6 closer to the beam.

For either type of pixel, the important concept is the idea of local trigger generation. If one takes all of the signals off to some large box, the distribution of information to all the parties that need it becomes a nearly impossible task. In some sense, the data is first randomized on a series of cables and then reordered - a hard task indeed. In this scheme, trigger information is processed right where it is gathered and only modules that have a trigger would send out anything. Of course, once a valid L1 accept has occurred, all the towers would be read out for L2 and L3 processing.

## III. CONCLUSION

If the accelerator can provide luminosity leveling, then leveling in combination with filling more RF buckets can reduce a conventional peak luminosity of $2\times10^{33}$ cm$^{-2}$s$^{-1}$ to an equivalent of about $6\times10^{32}$ cm$^{-2}$s$^{-1}$ or only about 3 times the value planned for Run 2. Both detectors should be able to run at this luminosity without major modifications. The most serious problems are the failure of the inner silicon detectors from radiation and the high fake rate from tracking. Both detectors will need to replace some of their detector components (e.g. shower maximum and pre shower for CDF and inner layers of the fiber tracker for D0) with new technological choices or perhaps enhanced versions of existing technology.

## III. REFERENCES


[1] D. Amidei and R. Brock, editors, Future ElectroWeak Physics at the Fermilab Tevatron: Report of the TeV2000 Study group, Fermilab-Pub-96/082.

[2]David Adams, Adding pads to XUV_X and XU_XV Scintillating Fiber Superlayers", D0 Note 2918.

[3] Larry Nodulman, " On CEM and Company at TEV33", CDF note 3707.

[4] K. Hara, " Radiation Induced Performance Degradation of the Plug Tile-Fiber Calorimeter", CDF note 2958.

[5] S. Kuhlmann, "Preradiator Chamber Aging Tests", CDF note 1290.

[6] A. Yagil, Private Communication

[7] R. Jayanti *et al.*., "The D0 Muon System Upgrade", D0 Note 2780.

[8] J. Butler *et al*.., "D0 muon chamber pulse heights", D0 Note 2319.

[9] R. Partridge and G. Watts, "Upgrading the D0 Fiber Tracker for TeV33", these proceedings.

[10] G. Watts and M. Johnson, "Using Microgap Chambers as Self Contained Trigger for D0 in TeV33", these proceedings.

[11] P. Aurenche, *et al*.., Phys. Rev. D **45,** 92 (1992). See also, F.W. Bopp, *et al*.., Z. Phys. C **51,** 99 (1991).