1 DØ Run 2b Trigger Upgrade Executive Summary

The DØ experiment has an extraordinary opportunity for discovering new physics, either through direct detection or precision measurement of SM parameters. An essential ingredient in exploiting this opportunity is a powerful and flexible trigger that will enable us to efficiently record the data samples required to perform this physics. Some of these samples, such as $p\bar{p} \rightarrow ZH \rightarrow b\bar{b}n\bar{n}$, are quite challenging to trigger on. Furthermore, the increased luminosity and higher occupancy expected in Run 2b require substantial increases in trigger rejection, since hardware constraints prevent us from increasing our L1 and L2 trigger rates. Upgrades to the present trigger are essential if we are to have confidence in our ability to meet the Run 2b physics goals.

To determine how best to meet our Run 2b trigger goals, a Run 2b Trigger Task Force was formed to study the performance of the current trigger and investigate options for upgrading the trigger. These studies are described in some detail in the Trigger Conceptual Design Report, along with the status and plans for changes in the fiber readout electronics, development of the Level 2β trigger system, DAQ, and online systems that are needed well before Run 2b. We summarize below the major conclusions of this report.

1. The Analog Front End (AFE) boards used to read out the fiber tracker and preshower detectors require modification to operate with 132 ns bunch spacing. The design of a new daughter board, which would replace the Multi-Chip Modules (MCMs) currently mounted on the AFE boards, is underway. Completion of the AFE modification is critical to our being able to operate with 132 ns bunch spacing.

2. The Level 1 Central Track Trigger (CTT) is very sensitive to occupancy in the fiber tracker, leading to a large increase in the rate for fake high-p_T tracks in the Run 2b environment. The most promising approach to increasing the selectivity of the CTT is to better exploit the existing axial fiber information available to the CTT. Preliminary studies show significant reductions in the rate of fake tracks are achievable by utilizing individual fiber "singlets" in the track trigger algorithm rather than the fiber doublets currently used. Another attractive feature of the fiber singlet upgrade is that the scope is limited to changing the current DFEA (Digital Front End Axial) daughter boards. While further study is needed to optimize and develop an FPGA implementation of the singlet tracking algorithm, the present studies indicate upgrading the DFEA daughter boards is both feasible and needed to maintain an effective track trigger.

3. The Level 1 calorimeter trigger is an essential ingredient for the majority of DØ triggers. Limitations in the current calorimeter trigger, which is essentially unchanged from the Run 1, pose a serious threat to the Run 2b physics program. The two most serious issues are the long pulse width of the trigger pickoff signals and the absence of clustering in the jet trigger. The trigger pickoff signals are significantly longer than 132 ns, jeopardizing our ability to trigger on the correct beam crossing. The lack of clustering in the jet trigger makes it very sensitive to jet fluctuations, leading to a large loss in rejection for a given trigger efficiency. Other limitations include exclusion of ICD energies, inability to impose isolation or HAD/EM requirements on EM triggers, and very limited capabilities for matching tracking and calorimeter information. The proposed upgrade of the L1 calorimeter trigger would allow these deficiencies to be addressed:

   - A digital filter would utilize several samplings of the trigger pickoff signals to properly assign energy deposits to the correct beam crossing.
   - Jet triggers would utilize a sliding window to cluster calorimeter energies and significantly sharpen jet energy thresholds.
   - ICD energy would be included in the calorimeter energy measurement to increase the uniformity of calorimeter response.
   - Electron/photon triggers would allow the imposition of isolation and HAD/EM requirements to improve jet rejection.
   - Tracking information could optionally be utilized to improve the identification of electron and tau candidates. Significant improvements in rates for both EM and track-based τ triggers have been demonstrated, but further study is needed to better understand how tracking information could be incorporated into the L1 calorimeter trigger and the cost and resources required.
   - Topological triggers (for example, an acoplanar jet trigger), would be straight-forward to implement.

4. No major changes are foreseen for the Level 1 Muon trigger. Modest upgrades that provide additional scintillator counters in the central region and shielding upgrades may be required for Run 2b. The improvement in background rejection achieved with the fiber singlet track trigger upgrade is probably also needed for the Run 2b muon trigger.

5. The Level 2 Alpha processor boards have suffered from low yield and poor reliability. The replacement of these processors with L2β processors is needed to fully deploy the L2 trigger for Run 2a. In addition, we expect to need to upgrade some of the L2 processors for Run 2b. The L2 Silicon Track Trigger (STT) requires additional cards to accept the increased number of inputs coming from the Run 2b silicon tracker.

6. The Level 3 trigger utilizes a high bandwidth Data Acquisition (DAQ) system to deliver complete event information to the Level 3 processor farm where the

Level 3 trigger decision is made. For Run 2b, the DAQ must be able to read out the detector at a rate of 1 kHz with a high degree of reliability. DØ is in the process of commissioning its Run 2a DAQ system based on custom hardware that provides the high-speed data paths. We are also exploring an alternative approach based on commercial processors and network switches. Maintaining Level 3 trigger rejection as the luminosity increases will require increasing the processing power of the L3 processor farm as part of the upgrade to the online system.

7. The online computing systems require upgrades in a number of different areas. These upgrades are largely needed to address the rapid aging and obsolescence of computing hardware. We anticipate upgrading our networking infrastructure, L3 farm processors, the online host system, control and monitoring systems, database and file servers, and the 1553 slow control system.

1.1 Cost Summary for Trigger Completion and Upgrades

In the two tables below, we present a summary of the preliminary cost of the trigger projects being proposed here. We segment the projects into two categories: those covering the completion of and upgrades to the detector for data taking prior to Run 2b, and those addressing the preparations for Run 2b and beyond. The estimates do not include manpower.

At Level 1, we propose the option for the SIFT upgrade that includes the Analog Front End (AFE) board replacement, as we believe there to be less technical risk associated with this option than with the version requiring removal of the MCMs (Multi-Chip Modules) from the existing AFE boards (see Section 3.4 of the CDR). We are also proposing an upgrade to the calorimeter trigger for Run 2b, which is included in Table 2 below. As mentioned above, we believe that further study is needed before a specific proposal that track information be incorporated into the Level 1 calorimeter trigger can be made. We therefore exclude it from financial consideration here, pending completion of our studies later this calendar year. The studies performed here suggest that an upgrade to the track trigger in which fiber singlet information is integrated at Level 1 will offer significant gains in rejection. In light of what these initial studies have demonstrated, we include the projected cost of this improvement in Table 2. Because it offers more processing power, and does not require the invasive and technically risky process of removing FPGAs from the existing daughter boards, we have chosen the option in which the daughter boards are replaced. Both of these upgrades are being targeted for FY03 and FY04.

The dominant portion of the funds required for the Level 2β system is earmarked for the Run 2a system, which will be completed within the next calendar year. These funds will therefore be needed in FY02. Taking into account the $192k in funding that has already been identified, completion of the Run 2a Level 2β project requires a total of $370k. In anticipation of a partial upgrade of the Level 2 trigger system for Run 2b – in particular, the handling and processing of information from the track trigger and possibly the Silicon Track

Trigger – we include in Table 2 a line item corresponding to a processor upgrade of 12 of the 24 Level 2β boards. In addition, we note that the funds for the upgrade of the STT for Run 2b are requested in FY02. This is to allow us to exploit significant gains in time and money by piggybacking on the Run 2a STT production run in early CY02. Obsolescence of some of the processors over the next three years is also a concern; these will be purchased for both the baseline and upgraded STT in FY02 as well.

As noted in Section 7.1.4 of the CDR, our baseline data acquisition system is financially covered in the original Run 2a cost estimate, with most (more than 80%) of the money having already been obligated. We therefore do not include a cost for that system below. We consider the risk associated with the delivery of this system to be substantial enough that we include the estimated cost for the commercial DAQ option in Table 1 below. Should this option be pursued, we anticipate that the bulk of the money will be needed in FY02, with some limited complementary portion required in early FY03.

An estimated total of $950k is needed to cover yearly project-related upgrades to the online system for the five year period spanning FY02 through FY06, inclusive. These upgrades include the LINUX filter farm for the Level 3 trigger, the slow controls system, etc. We assume here that this money will come out of the operating budget - pending final discussions with the Laboratory - and therefore do not include this sum in the tables below, which represent estimates for equipment expenditures. We note that this money for online upgrades is requested in addition to the yearly operating allocation for online support for DØ operations.

Table 1. Preliminary cost estimate to complete trigger sub-projects required prior to Run 2b. Total includes secondary (commercial) DAQ option. Manpower is not included. * Rows corresponding to Level 2β and TOTAL include the $192k in funds already identified for the Level 2β sub-project.

Sub-Project	M&S ($k)	Contingency (%)	Total ($k)	Fiscal Year Needed
SIFT Replacement (Option 1)	688	46	1001	FY02-03
Level 2β*	411	37	562	FY02
Commercial DAQ system	449	50	675	FY02-03
TOTAL*	$1,455k		$2,238k (incl. DAQ option)	

Table 2. Preliminary cost estimate for projects associated with detector upgrades for Run 2b. Manpower is not included.

Sub-Project	M&S ($k)	Contingency (%)	Total ($k)	Fiscal Year Needed
Level 1 Calorimeter Trigger	726	100	1,452	FY03-04
Level 1 Track Trigger	360	50	540	FY03-04
Level 2β	62	34	83	FY03-04
Level 2 Silicon Track Trigger	392	40	549	FY02
TOTAL	$1,540k		$2,624k	