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Run 2b TDC Review Committee Report

Run 2b TDC Review Committee

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I. Introduction

A review of the Run 2b TDC project was held on May 21, 2004. The Charge to the Committee is included as Appendix A. The Committee was asked to review the status of the Run 2b TDC project and to comment on its readiness to proceed to the preproduction and production stages. The agenda for the review is included as Appendix B.

In an effort to get immediate feedback to the members of the TDC group, the Committee issued an Executive Summary that served as a preliminary report on the primary issues relevant for the review. As a consequence, this document is assembled in a somewhat non-standard format. We begin with the Executive Summary in the following section. After the Executive Summary, we expand upon a few of the most relevant points that were not thoroughly covered in the Executive Summary.

On behalf of the entire CDF Collaboration, we thank everyone who is (and has) contributed to these extensive efforts on both the Run 2a and Run 2b TDC systems. Both groups have made tremendous progress over the last year, and we recognize the tremendous effort by many people. The Committee also appreciates the well-prepared talks that were presented in the review. Finally, the Committee would like to thank Bill Badgett and Ray Culbertson for their input on data acquisitions issues.

II. Executive Summary

The Run 2b Review Committee is issuing this preliminary report so that the proponents may get immediate feedback on the review that took place on May 21, 2004. A detailed report will follow in the very near future.

First and foremost, the Committee wishes to thank and congratulate a number of people on their hard work and significant progress on several fronts:

- **Members of the Run 2a TDC, DAQ and offline groups.** They have done a tremendous job in improving the performance of the Run 2a TDCs.
- **Members of the Run 2b TDC group.** They have made excellent progress on design, prototyping and testing the new TDC.

On behalf of the entire CDF Collaboration, we thank everyone who has contributed to these efforts. The Committee also appreciates the well-prepared talks that were presented in the review.

Progress on the Run 2a TDC system has been impressive. It is crucial to get realistic estimates of the Run 2a TDC performance at higher rates and higher luminosity. Work has started on this front, and the Committee believes it is a high priority to further identify the limitations of the Run 2a system. The Committee recommends pursuing further improvements to the Run 2a system, which include a modified data format (see below) and techniques to reduce the latency between TDC_DONE and DONE.

The prototype stage of the Run 2b TDC project has been successful, and the Committee endorses proceeding with the preproduction plan. Although significant progress on prototype testing was shown, there are several items that need to be completed:

1. The ASDQ→TDC tests should be completed with a full 96-channel array. The understanding of the cross-talk issues shown in the review should be verified. Linearity and channel-to-channel variation measurements should be completed with both prototype boards to systematically characterize the two available boards.
2. The TDC→XFT tests should be continued. It is important to understand the timing of the trigger data in the new system and both 2-bin and 6-bin algorithms need to be fully exercised. The Committee believes it is crucial that the timing of the 2-bin trigger signals fully replicate the timing of the existing system.
3. The above tests should be performed at rates sufficiently high enough to exercise the pipelined capability of the CDF trigger/DAQ system. We specifically suggest testing the system with conditions such as four consecutive L1 accepts.

The Committee recommends that these tests proceed in parallel with preparation to submit the preproduction board. We request that the Run 2b TDC proponents provide an informal update before the release of the artwork for the preproduction board. We expect this to occur on timescale of one month.

The Committee advocates proceeding with preproduction on the Run 2b TDC and believes that the full crate tests planned for Fall 2004 are of the very highest priority. We are concerned with the lack of manpower performing testing and DAQ related work. In preparation for the full-crate tests, the Committee recommends:

1. Pursing the Run 2b data format in the Run 2a TDC. This will reduce data volume in the Run 2a device (improving performance) and additionally permits DAQ preparation for the Run 2b device.
2. Proceeding with development of the "virtual VRB". The Committee feels it is crucial to demonstrate this portion of the DAQ during the fall test.
3. Work with the relevant TDC and DAQ experts in understanding techniques to modify the Run 2a crates to allow CBLT in conjunction with TRACER interrupt mode.

The Committee supports the plan of finding a single vendor for the remainder of the project, but we recommend that further information be gained before purchasing production quantities of components. This should be revisited if procurement becomes a schedule risk. The Committee recommends purchasing production quantities of any components that may become unavailable in the near future.

In summary, we find the schedule aggressive but achievable. Our primary concern is manpower to prepare for and carry out the full-crate tests scheduled for this fall.

The TDC Review Committee
Morris Binkley
Eric James
Bruce Knuteson
Jim Patrick
Kevin Pitts - Chair
Terri Shaw

III. Detailed Comments

In this section, we elaborate on some of the points raised in the summary, in addition to raising some additional, more technical, points that were not included in the summary.

Specification and Documentation

The documentation for both the Run 2a TDC and the Run 2b TDC is inadequate. In several cases, the Committee found it difficult to evaluate portions of the projects due to a lack of detailed documentation. This applies to specifications as well as descriptions of the devices in areas such as: trigger interface, readout and data format. The Committee appreciates the priorities and lack of time available to produce documentation, however we feel that thorough documentation is a necessity to verify system compatibilities and to insure that all relevant tasks are accounted for.

Run 2a TDCs

Recent performance measures for the Run 2a system are encouraging, but incomplete. At this time, there is not sufficient information to know whether or not the Run 2a system can ultimately reach the Run 2b readout specifications. It is important that the ultimate performance of the Run 2a TDCs be quantified in a timely manner. We recommend the following for the Run 2a system:

- Implement the Run 2b data format in the Run 2a TDCs. This has the benefit of reducing data volume by a significant amount, which is the current limitation in COT readout rate. The goal of this implementation should be to make the Run 2b data format default for the Run 2a system as soon as possible. The Committee hopes that the bank versioning infrastructure will make this change less difficult than was the move to COTD compression.
- In implementing the Run 2b data format, important implementation decisions should be made in consultation between the TDC, DAQ and offline groups. For example, will the basic Run 2a COTD bank format be retained? If yes, where will the reformatting be done? If no, a new bank format must be thoroughly defined. The Committee recognizes that, because of the differing architecture, some aspects of the Run 2b data format may be awkward to implement in the Run 2a device. This

further underscores the need for close interaction between the Run 2a and Run 2b groups.

- Further test and measure of processing and readout latencies of the Run 2a system should be aggressively pursued. These tests should be decoupled as much as possible from other limitations of the Run 2a system, such as the event builder.
- The high luminosity data samples (derived by overlapping zero-bias data) developed by the Run 2b XFT group should be used along with the model of Run 2a processing and readout times to estimate the ultimate limitations of the Run 2a device.
- The high luminosity data samples can also be used to evaluate the utility of implementing the fast clear on the Rev. D boards. These boards populate the outer four COT superlayers where occupancies are significantly lower.
- The DAQ group should continue to investigate the time between TDC done and TRACER done to look for potential improvements. The possibility of having four separate data word counts (one per buffer) on each TDC should be considered if the time between dones is found to have a substantial effect on overall readout performance.
- It appears the TRACER/Spy mode readout will continue to be optimal for the Run 2a system, since the TDC readout rate is consistent with the rate limitation (12Mbytes/s) of this mode. This means that it is probably not feasible to pay the additional overhead of writing the data from the processor to a gigabit Ethernet interface. Retaining Spy mode readout limits how the data can be distributed further downstream and must be understood in the context of the event builder upgrade.

Run 2b TDCs

Progress on the Run 2b TDC project has been impressive, and the Committee encourages continued testing while proceeding with the preproduction stage of the project. We recommend the following for the Run 2b system:

Readout

- The Committee is concerned that the apparent gain in readout rate with the Run 2b TDC is not as significant as expected. The readout speed of the Run 2b TDC depends upon the VME readout speed over the crate backplane. Based upon measurements presented in the review, the rate is 17 Mbytes/s using chained block transfer (CBLT) which, after the 3 Mbytes/s overhead required for gigabit Ethernet, becomes 14 Mbytes/s. This is only 15% better than the 12 Mbytes/s achieved in the Run 2a system. It is important to determine whether or not 17 Mbytes/s can be improved. This requires investigation on improving the 17 Mbytes/s (although 20 Mbytes/s is the ceiling) and reducing the 3 Mbytes/s overhead.
- To further improve data transfer rate, we recommend investigating the possibility of implementing 64-bit VME transfer mode.
- As recommended for the Run 2a TDC, the Run 2b TDC group should utilize the high luminosity samples produced by the XFT group to understand anticipated data rates. This may also provide information on “last crate done” versus “average crate done”.

- Further clarification of the data format is necessary, including the bit-by-bit format of each word that is sent out per board, packaged in 64 bit longwords; both for the Header CBLT and the Hit-Data CBLT. As stated above, this should be done in consultation with the Run 2a TDC group.
- The Committee is concerned about the lack of clear responsibility for the Virtual VRB code. It is an important task that is currently unassigned.
- Is the Global-TDC-Done backplane (wire-OR) signal still valid?
- The Tundra/Universe VME chip has handles to speed up the VME cycle time when it is the VME master: "Delay of DS* after read" and "DS* high time during BLTs" and perhaps relaxing the DTACK filtering. Can a fully populated TDC crate handle these changes?
- The possibility of effectively disabling the Level 2 Accept VME interrupt generated by the Tracer would be very bad for the readout code, and would require interrupts to be replaced by polling, which precludes and internal pipelining of the outgoing data and the publishing of status messages. A solution to this issue must be found.

COT/XFT Interfaces

- Fully testing and debugging the XFT interface should be one of the very top priorities, as this is one place where possible layout modifications may be necessary. We urge the TDC and XFT groups to collaborate on this important task.
- Since it is likely that Run 2a Axial XFT system will be retained, an extreme effort should be made to match the current XFT signal timing. If this is not done, it will be necessary to time-in the entire XFT system, a lengthy process that involves numerous hardware switch settings. For instance, the "data strobe" shown in the review seems to have different timing than the rest of the data. Also, it is unclear how the system behaves during abort gaps. The current system continues to send data strobe and marker bits. This functionality must be retained.
- The XFT group is discussing the possibility of inverting the data bits in every other frame so that “rare one” and “rare zero” problems can be avoided. The need for this functionality should be clarified with the XFT group.
- Steve Chappa showed a scope trace that suggests that the input termination resistor is too large. The Committee recommends the signal quality and properties be compared between the Run 2a and Run 2b TDCs. The COT group should be consulted regarding TDC input termination. Improving the termination would give the Run 2b TDC better noise immunity.

Schedule

- Two necessary components of the full crate tests to be done in the collision hall during the upcoming shutdown are the full event builder path (MVME5500 + gigabit Ethernet + Virtual VRB PC) and L3 reformatting for the new TDC bank format. As discussed above, the latter can be accomplished by working now to convert the readout of the current TDCs to the new format.

- The Committee suggests that the Run 2b TDCs become the default post-shutdown option for the EM timing crate. This would be an extremely important test of the new TDCs to demonstrate reliable operation during normal run conditions. With this in mind, we suggest the pre-production order be increased from 25 to 35 boards so that we would have enough boards for both full-crate tests and full-time running in the EM timing crate. The installation of new boards into the EM timing crate could be done in two steps. We could start by using the new boards in this crate with the standard TRACER readout and later switch to using the new event builder path. The DAQ and offline groups should be consulted on issues such as EMTD bank format.
- It is important to plan early for the backplane modifications and fiber installation required for the upgrade. The backplane modifications definitely need to be done in a backward compatible manner, and our concerns about eliminating the TRACER interrupt capability need to be carefully considered.
- The overall schedule is aggressive, but achievable, if the appropriate manpower can be found. The Committee fully supports a significant involvement of PREP, beginning with the initial testing and debugging of production boards, followed by long-term maintenance responsibilities.

Manpower

- The Committee is concerned about physicist manpower on this project. We believe that the engineering manpower is sufficient. Without significant influx of physicist support very soon, it seems unlikely that the testing schedule can be maintained. It seems unlikely that sufficient influx of manpower with sufficient hardware and data acquisition experience will come in the next few months, which is when they are needed.
- Long-term committment to maintaining this system is also a concern for either the Run 2a or Run 2b TDCS. The Committee recommends one or more institutions take on the MOU responsibility for long term system maintenance.

IV. Final Recommendations

The Committee fully supports proceeding with the Run 2b preproduction order as soon as possible, followed by aggressive system level testing during the Fall 2004. We are concerned about the manpower for this project and hope that this can be strengthened through further collaboration support.

The Committee recognizes that additional testing of both the Run 2a and Run 2b systems is ongoing. We request a written progress reports on both the Run 2a and Run 2b efforts by July 9, 2004.

Appendix A: Charge to the Committee

Charge to Run 2B TDC Production Review Committee
Review Date May 21, 2004
May 6, 2004

A major component of the CDF Run 2B DAQ and Trigger upgrades is a project to design and build replacement TDCs to readout the COT. This project was initiated due to concerns that the existing (Run 2a) TDC design would not be able to meet the Run 2B readout specification of 1 kHz particularly in light of increasing hit occupancies at high luminosities. The new TDC is designed to be plug compatible with the Michigan TDCs they would replace but with higher readout bandwidth capabilities. In contrast to the existing TDC design the new TDC will generate the trigger outputs for the XFT directly on board without need for mezzanine boards. The requirements for the design are specified in CDF6997 "Time to Digital Converter Module for Run IIB". To fit within schedule requirements for Run 2B and access requirements for installation on the detector, the production and checkout of all 350 TDCs needs to be completed by August 2005.

In addition to new TDC modules, this upgrade includes changes to the readout architecture of the COT crate in coordination with the Run 2B Event Builder Upgrades.
This readout upgrade involves replacing the existing Motorola MVME2400 crate processors with a new model (e.g. MVME550) which provides both 100Mb/s Ethernet for control communication and a Giga-bit Ethernet interface which will be used for event readout. The giga-bit Ethernet path will replace the existing readout path through the TRACER module and its TAXI optical link to a VRB. The giga-bit Ethernet will be connected to a PC (Virtual VRB) which is further connected to the new Ethernet switch of the EVB upgrade.

As of May 2004, a first prototype version of the new TDC has been design and four fully populated boards have been assembled for testing. A series of tests are underway at University of Chicago and Fermilab. These tests include tests of all internal TDC functionality, compatibility with COT ASDQ/Repeater card system and with the L1 XFT trigger hardware. Tests of the timing performance are included in the testing with the ASD system. A few necessary improvements have been identified and it is expected that by the date of the review all required design changes will have been incorporated into schematics and artwork. In addition, the new crate processor that is proposed for use in the upgraded system is being evaluated by the CDF DAQ group.

The charge for this review is to evaluate whether the TDC project is ready to proceed from the prototype stage to Production. This evaluation should be based on results of tests using prototype boards. It should also be based on planning from PreProduction tests through board production and checkout to installation and commissioning. If this review is successful, we expect to order the production quantity of 360 TDC boards in three stages. The first two stages, making up PreProduction will consist of approximately five boards and twenty boards respectively. Assuming successful testing of pre-production boards the

remainder of the production contract would be released for assembly. In PreProduction, it is expected that the following will done:

1. Assemble 1 full crate of new TDCs (approximately 25 boards),
2. Test functionality of boards as a system, preferably including a test with the COT during the 2004 Fall shutdown,
3. Assemble a full slice of the readout system including a TDC crate with new crate processor and Virtual VRB PC to measure bandwidth capabilities.
4. Production readiness review prior to release of remainder of board production and procurement of remaining crate processors and PCs.

The committee's evaluation should include the following points:

1. Does the TDC module meet the timing performance specifications in cdf6997?
    a. Edge resolution
    b. Minimum pulse width and double pulse separation
    c. Pedestal and slope stability and channel to channel variation
    d. Cross-talk
2. Does the TDC module meet the readout requirements?
    a. 1 kHz operation given the anticipated hit occupancies at $3x10^{32}$ at 396 ns bunch spacing, e.g. performance of Chained BLock Transfer (CBLT) VME operation
    b. Meets CDF and TDC requirements such as event header with bunch counter and TDC_DONE signal implementation
3. Is the planned readout system capable of handling 1 kHz operation?
    a. Demonstration of MVME5500 operation with FISION and FER packages
    b. Bandwidth measurement of Gigabit ethernet
4. Is the TDC compatible with the existing XFT trigger system and provide the necessary flexibility for use with the planned XFT upgrade?
    a. Generate prompt-delayed hits as 2A design
    b. Generate 6 time bin hits per 2B specification
    c. Pass capture test with Run 2A XFT Finder Board
5. Is there a complete list of all modifications needed to the prototype board design to proceed to a pre-production version?
6. Is there sufficient documentation of the board, operation and test results?
7. Is there a credible plan and schedule for testing, production, production checkout, installation and commissioning?
    a. Is the new TDC compatible with simultaneous operation with the existing Michigan TDC?
8. Is there a credible plan and schedule for software needed, including test stand code, online readout, virtual event builder, and monitoring?
    a. Includes any software required to handle differences in data format (e.g. 1.2ns/bin instead of 1ns/bin and hit data structure)
9. Are the human resources identified to carry out the necessary hardware and software tasks?

10. What are the risks to ongoing CDF operations from testing, installation and commissioning efforts for the new TDCs? How do these compare to the risks of continuing to operate with the Michigan TDCs?

Appendix B: Review Agenda

- Introduction and Charge - Pat Lukens
- Michigan TDC Capabilities (eg DSP code) - Ron Moore
- Readout Performance of COT TDCs and Limits of other Crates - Frank Chlebana
- Overview of TDC Upgrade - Ting Miao
- Chicago TDC Design and Implementation - Mircea Bogdan
- Chain Block Transfer and Internal TDC Tests - Sasha Paramonov
- External Pulsing Tests - Rod Klein/Steve Chappa
- XFT Capture Tests - Greg Veramendi/Cheng-Ju Lin
- TDC Project Plan - Ting Miao
- TDC Installation - Tom Phillips
- Questions and Discussion
- Executive Session

Copies of all talks are available through the archived WebTalks page:
http://fcdfwww.fnal.gov/internal/WebTalks/Archive/0405/040521_run_2b_tdc_review/