SDC-91-106

SDC Front-End Electronics Review Report

September 9–11, 1991

Andy Lankford and Holly Durden, Editors

Revised October 11, 1991

TABLE OF CONTENTS

1.0 Review of Front-End Electronics 1
1.1 Subject of Review 1
1.2 Purpose of Review 1
1.3 Format of Review 1
1.4 Readout Subsystems Considered 2
1.5 Readout Subsystems NOT Considered 2
1.6 Review Materials Provided by Subsystems 2
1.7 Representatives of Subsystems Present 3
2.0 Recommendations 6
2.1 Calorimeter Readout 6
2.1.1 Calorimeter Electronics General Recommendations 6
2.1.2 Calorimeter Readout via Switched Capacitor Arrays. 7
2.1.3 Calorimeter Readout via Floating Point Flash Digitizer 9
2.2 Scintillating Fiber Readout 9
2.2.1 General Comments 9
2.2.2 Documentation 10
2.2.3 Design Issues 11
2.2.4 Performance Issues 11
2.2.5 Implementation Plan 11
2.3 Wire Chamber Readout 11
2.3.1 Straw Electronics General Recommendations 11
2.3.2 Straw Readout via TVC/AMU 11
2.3.3 Straw Readout via TMC (Time Memory Cell) 12
2.3.4 Muon System Readout 13
Appendix A: Preliminary Electronics Conceptual Design Document 15
Appendix B: SDC Preliminary Conceptual Design and R&D Review 18
Appendix C: Guidelines for SDC Front-End Electronics Review 20
Appendix D: Invitation to Outside Reviewers of SDC Front-End Electronics 24
Appendix E: Agenda of SDC Front-End Electronics Review 25

1.0 REVIEW OF FRONT-END ELECTRONICS SYSTEMS FOR SDC

1.1 Subject of Review

The status of SDC front end electronics subsystem conceptual designs and R&D was reviewed on September 9–11, 1991 at the SSC Laboratory.

1.2 Purpose of Review

The purpose of the review was to:

- Review the status of conceptual designs.
- Critically assess the technical soundness of proposed designs.
- Provide direction for further conceptual design work.
- Review the appropriateness of proposed designs to the overall electronics architecture of the experiment.
- Initiate system engineering of the SDC electronics systems as a whole.
- Advise on choice of designs to be included in the Technical Proposal.
- Review the status of critical R&D, particularly in context of conceptual designs.
- Narrow options and define priorities for directed R&D.

1.3 Format of Review

Written "preliminary conceptual design documents" were requested from representatives of development efforts on front-end systems. This documentation was to serve as the basis of the review. The first request called for documentation to be ready for the August SDC Collaboration Meeting. Subsequently, documentation was requested for receipt at least two weeks in advance of the review meeting. All documentation received more than one week in advance was distributed from SSCL to all participants and reviewers. Some additional documentation was distributed at the review meeting. A description of the requested documentation and the final call for documentation are included as Appendices A and B. Lists of the subsystems covered by the review and of the documentation received are included in section 1.4.

Guidelines for the review were distributed to reviewers and participants shortly prior to the review meeting. The guidelines are included as Appendix C. Appendix D is a typical invitation to a reviewer.

The review meeting included short presentations in open session by representatives of conceptual design developments and extensive question/answer and discussion periods for each development, also in open session. A list of representatives of developments, organized by subsystem, is included in section 1.7.

Discussion of each development was continued in executive session by the review committee (excluding committee members involved in that development). A brief summary and set of recommendations based upon committee discussions was drafted by the subcommittee for each development. A joint summary and recommendation was also drafted for front-end subsystems

where alternative approaches existed. The draft summaries and recommendations were then discussed and edited by the review committee. The review committee is listed in section 1.8. The agenda of the meeting is included as Appendix E.

It is anticipated that the committee's summaries and recommendations included in this report will be circulated to the representatives of the conceptual design efforts, review committee members, Electronics, Data Acquisition, and Triggering Technical Steering Committee, and the SDC Technical Board.

1.4 Readout Subsystems Considered

The review included consideration of the following readout subsystems:

- Fiber Tracking (digital portion of system only)
- Straw Tracking
- Muon System
- Calorimetry
- Shower Max (cursory consideration only)

1.5 Readout Subsystems NOT Considered

The review did not include consideration of the following readout subsystems:

- Silicon Tracking
- Fiber Tracking - photodetectors and analog electronics

1.6 Review Materials Provided by Subsystems

The following documents were provided for the review. The authors and their institutions are included in parentheses.

- Fiber Tracking

  "PCDR for Fiber Tracker" (Baumbaugh; FNAL)

  "VLPC Device and Packaging Development: Status and Planning" (transparencies of Eric Anderson, Rockwell, 8/8/91)

- Straw Tracking

  "SDC Straw Tracking Electronics Preliminary Design Report"; Draft Version 1.1, August 16, 1991 (Newcomer, Van Berg, Williams; Pennsylvania)

  "Conceptual Design of Straw Tube Readout with TMC"; Version 1.0, Aug. 21, 1991 (Arai, Ikeda, Watase; KEK)

- Muon System

  "Preliminary Conceptual Design Report: Muon Front End Electronics"; 8/1/91 (Oliver; Harvard)

  "SDC Muon Trigger Preliminary Conceptual Design"; DRAFT, August 27, 1991 (provided at meeting) (Chapman, Thun; Michigan)

- Calorimeter

  "Scintillating Tile Barrel and Endcap Calorimeter and Shower Maximum Electronic Cost Estimate"; 4 September 1991 (Bebek, Ely, Franck, Jared, Kipnis, Kirsten, Kleinfelder, Levi, LeDu, Merrick, Milgrome, Minor, Pope, Salz, Theil, Zelver; LBL)

  "Front End Electronics for SSC Calorimetry Progress Report"; August 16, 1991 (Bebek, Ely, Jared, Kipnis, Kirsten, Kleinfelder, Levi, Merrick, Milgrome; LBL)

  "Toward a 62.5 MHz Analog Virtual Pipeline Integrated Data Acquisition System" (Kleinfelder, Levi, Milgrome; LBL)

  "Baseline Implementation of the Digital Phototube Readout System for the SDC Calorimeter"; September 3, 1991 (provided at meeting) (Baumbaugh, Foster, Hansen, Hoff, Larwill, Newman-Holmes, Rivetta, Yarema, Zimmerman; FNAL)

- Shower Maximum

  "Scintillating Tile Barrel and Endcap Calorimeter and Shower Maximum Electronic Cost Estimate"; 4 September 1991 (Bebek, Ely, Franck, Jared, Kipnis, Kirsten, Kleinfelder, Levi, LeDu, Merrick, Milgrome, Minor, Pope, Salz, Theil, Zelver; LBL)

  "The Shower Max Electronics: Summary of the Saclay group investigations"; V2.0, July 1991 (Bonamy, Bauville, Brisson, Ernwein, Hubbard, Lugiez, LeDu; Saclay)

- Trigger (provided as background for consideration of front end subsystems)

  "Conceptual Design of the SDC Trigger from the SDC Trigger Group"; DRAFT, August 27, 1991 (Contreras, Frisch, Grosso-Pilcher, Eno, Miller, Rosenberg, Sanders, Shochet, Sullivan, Baumbaugh, Foster, Yarema, Amidei, Campbell, Chapman, Thun, LeDu, Fordham, Foudas, Gorski, Jaworski, Lackey, Panescu, Robl, Smith; Chicago, FNAL, Harvard, Michigan, Saclay, Wisconsin)

1.7 Representatives of Subsystems Present

The following representatives of subsystems were present at the review:

- Fiber Tracking
  - Al Baumbaugh
  - Bill Foster
- Straw Tracking
  - Yasuo Arai
  - Rick Van Berg
  - Brig Williams
- Muon System
  - Jay Chapman
  - John Oliver

- Calorimetry
  - Al Baumbaugh
  - Bill Foster
  - Ray Yarema
  - Chris Bebek
  - Richard Jared
  - Fred Kirsten
  - Stuart Kleinfelder
  - Michael Levi
- Shower Max
  - Same as calorimetry

Review Committee

The review committee was composed of some of the members of the SDC Electronics, Data Acquisition, and Triggering Technical Steering Committee, other members of SDC, and invited critics from outside SDC. The reviewers were:

- Members of SDC Electronics, Data Acquisition, and Trigger Technical Steering Committee
  - Myron Campbell (Michigan)
  - Bill Foster (FNAL)
  - Henry Frisch (Chicago)
  - Irwin Gaines (FNAL)
  - Andy Lankford (Irvine)
  - Michael Levi (LBL)
  - Richard Partridge (Brown)
  - Wesley Smith (Wisconsin)
  - Brig Williams (Pennsylvania)
- Other members of SDC
  - John Dawson (ANL)
  - Richard Jared (LBL)
  - Fred Kirsten (LBL)
  - Gene Oberst (LLNL)
  - John Oliver (Harvard)
  - Jim Patrick (FNAL)
  - Harold Sanders (Chicago)
  - Helmuth Spieler (LBL)

- Invited critics from outside SDC
  - Jheroen Dorenbosch (SSCL)
  - Gunther Haller (SLAC)
  - Dan Marlow (Princeton)
  - Leo Paffrath (BNL)
  - Sergio Rescia (BNL)

2.0 RECOMMENDATIONS

The review committee formulated the following summaries and recommendations:

2.1 Calorimeter Readout

2.1.1 Calorimeter Electronics General Recommendations

The committee reviewed preliminary conceptual designs and R&D progress for readout of calorimetry based on two different approaches. The first approach is based on readout through a preamplifier, analog storage in a switched capacitor array (SCA), and digitization subsequent to a level 2 trigger. This approach is an evolution from previous systems and is well advanced towards proof-of-principle of the required performance, particularly dynamic range; nevertheless, it must cope with demanding problems at the system level. It is the opinion of the committee that certain studies made over approximately the next three months could demonstrate that this approach is suitable for adoption by SDC. These studies include tests of existing circuitry with realistic signals, on-chip and on-board digital-to-analog crosstalk, signal dispersion and crosstalk in cables, and studies of bipolar preamplifier designs. The second approach is based upon a floating point flash encoder which splits the current of PMT signals into an array of gated integrators which are then digitized at the beam crossing rate by a commercial flash ADC. The committee finds this approach to be forward looking and potentially very promising as IC technology develops. It concentrates the technical challenges in one block—the current splitter and gated integrator. It is also conceptually simpler and potentially more robust. However, this approach is not presently as advanced in its development as the other. In particular, current division of the signal over the required dynamic range must be demonstrated, and this dynamic range must be maintained in face of parameter variations, as well as through the gated integrators and the rest of the system. The committee feels that significantly more may be known with regard to the feasibility of this approach in approximately three months following measurements on splitter and integrator test circuits which are currently being fabricated. The committee believes that the detailed technical challenges are different for the two approaches.

In light of the above considerations, the committee feels that it is presently premature to choose either approach over the other, but the progress of these two approaches can be revisited on the December to January timescale in order to consider whether one of the two approaches can be adopted at that time. The committee perceives that, in order to meet the overall SDC schedule, the latest possible date to choose a calorimeter readout technique and design, provided that the chosen technique has already demonstrated the requisite performance in a prototype system, is the end of Calendar Year 1992, although it may be possible to adopt one of these designs prior to that date.

The committee briefly considered the applicability of these two approaches to readout of shower max detectors. An implementation of readout with amplifiers and SCA's was presented, showing that a high density and reasonably low cost system can be achieved. No fundamental reason why the splitter/integrator approach wouldn't work is seen; however, no detailed consideration was given with regard to packaging density and cost.

Recommendations with regard to the focus of development efforts specific to each particular approach are included in the following sections. In the SCA approach, the committee was able to make more extensive comments because the documentation was received prior to the review meeting as requested. More detailed comments were also possible because of the relatively

advanced state of development of this system. For that approach, the committee recommends that highest priority be given to studies which mimic key aspects of the final configuration in order to demonstrate that the dynamic range of the SCA will be maintained in a full readout system from preamp to ADC. For the splitter/integrator approach, the committee recommends that highest priority be given first to demonstrating the performance of the splitter. The committee did not review cost estimates for the two approaches.

2.1.2 Calorimeter Readout via Switched Capacitor Arrays.

The SCA group provided a good description of the proposed electronics. It is appreciated that the documents were available before the meeting, so a detailed review could take place.

Overall the basic structure of the system seems sound and practical. The principal performance of the SCA and ADC looks very good and is encouraging. There are some concerns especially about the performance of the preamplifier.

The suggestions of the review committee on how to proceed are listed in three categories of importance (the items in each category are just listed, not ordered).

1) These items are felt to be most important and should be investigated in the near future:
   - The SCA looks very good with respect to DC linearity, dynamic range, and cell-to-cell pedestal variations. More detailed measurements with AC (including pulse) input signals in view of linearity and crosstalk are suggested. In addition, a better characterization/demonstration of the noise due to the simultaneous asynchronous write/read is needed. Temperature stability should also be measured.
   - A demonstration that one can achieve 12-bit resolution in the 16 ns time-frame with a specific input cable (from preamp to SCA card) should be made. This measurement can be made with a good pulser and does not require a preamplifier at this time. A discussion of anticipated crosstalk in the interconnect system should be added.
   - For the "cable, SCA, ADC" subsystem, a test with high random input signal rates should be performed to investigate whether the high resolution and linearity is sustained. Effects of clock jitter should be evaluated.
   - The performance of the present MOS preamplifier is not satisfactory. It is not clear how the goals in linearity, dynamic range, etc., can be met with sufficient margin. The SCA group is encouraged to pursue a bipolar solution for the preamplifier. Although prototyping of bipolar circuits is not without cost, we feel that overall bipolar is more cost effective (considering manpower) and more likely to achieve the desired performance. Since bipolar circuits can be simulated more accurately, a bipolar circuit should be designed and extensively simulated.

     The criteria for performance parameters should be clearly defined. Simulation results on linearity, dynamic range, impedances, power supply sensitivity (e.g., to 60 MHz), gain, temperature sensitivity, etc., should be examined. If time permits, some simulations on how the amplifier output reacts to individual transistor parameter variations (beta, V_{be}) are desirable.
   - The calorimeter specifications should be reviewed for consistency with the calorimeter conceptual design report.

2) The items in category 2 should be addressed with less priority (compared to 1):
   - The effort on investigating alternative approaches to the delay-line clipping method should be continued (e.g., gated integrator, RC shaping, others ?) and the results should be discussed.
   - Although a bipolar implementation of the preamplifier is recommended, measurements and evaluations to understand the deficiencies of the present MOS amplifier are encouraged. Modifications in the design, in order to achieve the required performance, can be proposed.
   - A circuit for the ×32 and ×1 amplifier and how it will be implemented should be proposed.
   - It should be evaluated if propagation delay compensation for individual channels is needed and how it would be implemented if required.
   - The minimum/maximum charge at the preamplifier input should be specified and it should be demonstrated that the gain in each stage of the system is appropriate (e.g., effect of variations on dynamic range)
   - Some failure analysis of the electronics system identifying the weak spots should be undertaken. (Applies to all SDC systems.)
   - The goals and anticipated accuracy of the calibration system should be stated.
   - The design choice of packaging the front end on 8-channel cards should be compared to a single-channel package in the multiplier base.

3) These items should also be addressed:
   - Studies of the radiation hardness requirement and the behavior of integrated circuits fabricated by the selected manufacturer are proposed.
   - It is recognized that the ADC meets the speed specifications. A discussion of what the trade-offs would be of a faster ADC and their significance is desirable (e.g., 5 times faster).
   - What would the strategy be if information for level 2 trigger were required ? This discussion could be postponed until further trigger studies have been completed.
   - A discussion on how a longer SCA pipeline (e.g., >256) would affect allowable level 1 pipeline length and level 2 latency would be interesting.

These are the issues that were raised during the review. Overall the proposed read-out of the calorimeter utilizing switched capacitor arrays is promising and two of the major components, the SCA array and the Ramp-ADC show good performance. The on-going effort on VME test boards for the electronics looks promising and important. The results should also give indications on the noise floor from the VME system and the effects on the analog performance.

The SCA system was reviewed thoroughly. The documentation provided was good and two of the major analog custom integrated circuits are already well-developed. The cost estimates look complete and with the inclusion of the items in category 1 and 2, the concept should be ready for the Technical Proposal if this system is chosen.

The group is strongly encouraged to continue with their effort.

2.1.3 Calorimeter Readout via Floating Point Flash Digitizer

Although the project is still in its infancy, and the documentation could be markedly improved, the concept has inherent strengths. The calorimeter signals exist in analog form as briefly as possible, and after conversion to digital signals, are processed in straight-forward logic.

The project requires the development of three ASICs. Two of these ASICs are digital. The other, the Splitter/Gated Integrator which is involved in the digitization, deals with the analog signals. The goal for the Splitter/Gated Integrator calls for operation over a 20-bit dynamic range. In the committee's opinion, development of the Splitter/Gated Integrator ASIC is a major challenge. Successful realization of this ASIC is essential to a proof-of-principle for this system.

A custom monolithic device which implements a subset of the Splitter/Gated Integrator circuit has been submitted to the Orbit foundry and is expected in October 1991. This device will accommodate an overall dynamic range of 17 bits. This is a critical step toward the development of the front end, and it would be advantageous to set forth a detailed strategy for testing this device. It is important to develop a plan with milestones for the further development of the ASICs. The overall Splitter/Gated Integrator is of first importance, and a comprehensive testing program including thermal effects should be defined. Some testing must await completion of the full system, and a testing plan for the full system should be set forth. Precise calibration points are needed to assure confidence in the overall transfer function of the system, and a plan for obtaining calibration constants should be generated.

The committee would encourage more Monte Carlo simulation to investigate the effects of parameter variations. Thermal effects in the Splitter need detailed examination.

Phototube measurements, looking at linearity and dynamic range, should be made. Some questions remain relating to FADC testing for this application, testing of the gated integrator, and confidence in the four-capacitor system.

The committee felt the plan for the C-W base was well conceived and that some development of this sort will be essential for the SDC calorimeter. There was some concern about the adequacy of cooling for the bases. Additionally, there was a feeling that the relay as planned may be troublesome.

As previously stated, the essential development in this proposal is the current splitter integrated circuit. A successful proof-of-principle of this device requires performance at a dynamic range of at least 17 bits. We anticipate this will require several fabrication and testing cycles; two to three at the minimum. The committee feels that it is unrealistic to expect a working device by December 1991 and that support should be continued to produce a working prototype Splitter with the required dynamic range.

2.2 Scintillating Fiber Readout

2.2.1 General Comments

The review of this detector subsystem was hampered by the level of documentation that was available to the committee before the meeting and by the lack of information on the analog portions of the subsystem. Based on that documentation and the comments of spokesman Al Baumbaugh, the committee concluded:

1) The documentation of the subsystem must be updated and greatly expanded if this project is to be included in the Technical Proposal (April 1992).
2) To permit a realistic evaluation of this subsystem, the documentation should include the salient features of the fibers and the photodetector, as well as a complete discussion of the analog and digital instrumentation.
3) The digital instrumentation of the detector seems to be technically feasible. No fundamental reasons why the instrumentation could not be built as presently described were identified.
4) Because of the amount of revision required, a preliminary version of the new documentation should be distributed to the Steering Committee by November 1, 1991.
5) There is concern about the level of risk associated with the sole-source nature of the VLPC.
6) There needs to be broad SDC involvement in the development of the VLPC electronics.

2.2.2 Documentation

Documentation. The documentation presented to the committee appears to have been assembled from one or more previous presentations. The level of documentation must be raised substantially to be appropriate for the Technical Proposal. Besides a complete description of the requirements, functionality, and conceptual system design, the documentation should include:

1) Statements of scope, subsystem performance goals, and the relationship of these goals to the overall physics goals, particularly with regard to triggering.
2) Sketches showing the physical arrangements of fibers in layers and superlayers.
3) Adequate descriptions of both ASIC I and ASIC II.

   There should be:

   - Descriptions of operation of both chips.
   - Block diagrams with sufficient detail to understand the functionality of each chip.
   - Evaluation of the capability of the proposed technology for successfully implementing each chip. Estimates of die sizes should be included.
4) A realistic schedule. The schedule should include the development of the instrumentation components, a program of simulation of the components and the system, and the construction of the complete system. The schedule presently included is not sufficiently detailed, and the dates are unrealistic.
5) A cost estimate must be completed that conforms to the format and standard effort rates used by the other subsystem proposals.

   From the level of documentation presently available, it is not possible to determine if all system components are included in the cost estimate. Some items that are included have not been properly costed. Incorrect manpower rates have been used.
6) A description of the system and trigger requirements; justification of the momentum cuts for the trigger; methods of modifying momentum cuts on line.

2.2.3 Design Issues

1) Momentum cuts and Neighbor signals. The number of "Neighbor" signals required depends on the range and the granularity of P_t covered in the trigger signals developed by this subsystem. Justification for the choice of these parameters should be given. The relation between these parameters and the number of Neighbor signals should be discussed.

2) Number of signals into and out of the VME cards: The present design results in a very high density of input and output signals for the cards (i.e., 640 discriminator signals (double-ended?) and 562 Neighbor signals). Is this physically feasible on a 9U VME card? Could a different partitioning (e.g., ASICS I and II on different cards) reduce the number? Are 562 Neighbor signals necessary (see 1, above)?

3) Crate: Is it necessary to design a special crate for this application? Is the "SDC standard crate" usable?

4) Diagnostics: What features are being provided for diagnostics?

5) Trigger Signals: Indicate the methods of fanning out the clock and trigger signals received from the Trigger Processor and for locally adjusting the timing of the level 1 Trigger and Clock signals.

2.2.4 Performance Issues

1) Optical parameters: Number of photons delivered to photodetector as a function of trajectory location on fiber; quantum efficiency of photodetector; effect of optical reflections from far end of fiber.

2) Propagation delay: Effect on beam bucket correlation of propagation delay along fiber (for both trigger and data).

2.2.5 Implementation Plan

1) It was not clear to the committee that the exercise of implementing some of the functions of ASIC I on a printed circuit board with discrete components is a prudent use of effort at this time.

2.3 Wire Chamber Readout

2.3.1 Straw Electronics General Recommendations

We have benefited from parallel efforts on straw electronics (TVC and TMC projects) up to now. However, limited resources (especially manpower) and the severity of still unsolved problems (especially packaging issues) suggest that the current parallel efforts be integrated into a cooperative effort to produce a single system design. A possible starting point could be to use the Penn preamp together with the Time Memory Cell (TMC) chip. A system test should be scheduled as soon as possible.

2.3.2 Straw Readout via TVC/AMU

The overall systems concept for straw tube readout is sound and well documented. A great deal of effort has gone into understanding the problems of systems integration and readout issues.

Work on the Preamp/shaper/discriminator is very impressive and appears to be going well. It is in good shape for the Technical Proposal, and the costs and schedule are well understood. This design should be vigorously pursued. This electronics will also likely be an important component of the muon system readout. A critical test that remains to be done in the next year is to combine all of these functions on a single integrated circuit.

Regarding the preamp-shaper-discriminator, there are two minor points. First, there needs to be a better understanding, or at least a better explanation, of the signal/noise ratio for the chambers. Second, while it is useful and appropriate to continue to pursue two separate chip designs in the two separate processes (Tektronix Quicktile and AT&T full custom), it is important that this multiplicity of efforts not detract from the critical system tests that must be done in the next year. We would like to see a schedule for these system tests to ensure that there is adequate manpower.

The TVC/AMU is a sound concept and looks like it could do the job. However, it is clearly a complicated design with lots of work still needed. In light of the fact that there is a working alternative (the Time Memory Chip), it would not make sense to devote a large portion of our limited resources to this effort. Therefore, we recommend that further R&D on the TVC/AMU concept be given lower priority. Note that this conclusion would change if SDC had any detectors requiring sub-nanosecond time resolution, as the TVC/AMU idea is the only one currently being pursued that could meet that need.

The Penn group's efforts should be integrated into the combined straw electronics group. Particular effort needs to be devoted to study of packaging issues, design of the level 2 buffers and DAQ/trigger interfaces, and overall system integration. Our feeling is that these issues are far from well understood; in particular, packaging and cooling are very severe problems for which neither group has satisfactory solutions. The TVC/AMU group has put considerable thought into readout and control issues. We need a clearer design for the trigger/DAQ interface to the straw system.

2.3.3 Straw Readout via TMC (Time Memory Cell)

The key element of the TMC-based readout, the TMC is a good concept, well designed, and a prototype has been successfully built and tested. We strongly encourage the prompt development of a device suitable for SDC in a rad hard process. We recommend that work with this device continue towards developing a readout system for straws.

The other components of straw readout, in particular the preamp-shaper-discriminator, level 2 buffer, and data collection chip are not as far along at this point. There is not a clear set of specifications for these components presented in the documentation.

One minor problem with the TMC design is that the encoding of double pulses where the time between pulses is less than 32 nsec is not consistent. It depends on whether or not a transition from 0 to 1 occurs at a word boundary.

There remains a lot of work to do for packaging the circuits on the straw tubes. In particular, there are several packaging constraints not addressed having to do with triggering. The proposed hybrid has eight channels; this number may or may not be commensurate with the number of channels needed to identify a track segment. Also there is no provision made for sending signals from one module to the next to trigger on tracks which cross module boundaries.

There is concern regarding the radiation hardness of the current TMC. We do not expect that there will be problems in fabricating the devices in a rad hard process; however, there are potential problems with changing the design (number of transistors per cell) and buffer length with regard to how these changes affect performance and power requirements.

We recommend that the problems of designing a preamp, level 2 buffer, and data collection chip, be closely coordinated with the Penn Group. The problems of packaging and cooling also need to be coordinated with Penn and Oak Ridge.

The TMC may also find application in the muon system readout where the problems of radiation hardness, power dissipation, and packaging are much less severe.

2.3.4 Muon System Readout

The review committee received a brief report from J. Oliver on the wire chamber preamplifier cards and a draft review of the muon trigger requirements from J. Chapman and R. Thun. These documents only provided a "thumbnail" sketch of the electronics and could not be used as a basis for a technical review. It was apparent from the presentations, especially on the front-end crates, that the state of the documentation accurately reflects that of the design. The committee expressed concern that the muon system electronics design would not be ready for the Technical Proposal deadline.

The committee reviewed the documentation for the amplifier-shaper-discriminator cards. The write-up on this area was thought to be incomplete. The proponents need to provide additionally:

- A requirement statement.
- An expanded description of the conceptual design.
- Definition of the interface to the front-end crate, calibration, etc.
- Specifications for the critical components.
- A description of packaging solutions.
- Resource requirements: space, power, cooling, cabling.
- A cost estimate that conforms to the format used by other subsystem proposals.
- A schedule with defined milestones.

The committee felt that the disarray in the design of the front-end crates was largely driven by the uncertainty in the trigger requirements for this system. The trigger requirements of the combined scintillator and wire technologies strongly affects the desired architecture and layout for this front-end. The muon group needs to settle on a consistent set of requirements with high priority. These requirements and the electrical implementation of these should address in particular:

- The input of the soft P_t threshold.
- The physics mapping of BW1/2/3 into trigger towers and the possible use of BW1 in the trigger.
- The trigger scheme and the mix of scintillators with wire chambers.

- The impact and special pathologies of the uncertain time tagging of the wire chamber signals and the transfer in and out of Level 2.
- The application of mean timing in the wire chambers.

A design document for the front-end crates needs to be provided. This document should include:

- A requirements statement.
- A conceptual design.
- A block diagram showing functionality.
- A block diagram showing physical layout.
- Definition of interfaces with other subsystems.
- Identification of critical components, with specifications.
- A description of packaging solutions.
- Resource requirements: space, power, cooling, and cabling.
- A cost estimate conforming with the format found on other subsystem proposals.
- A schedule with milestones.
- The identification of critical R&D, and statements of R&D status.

In general, it is apparent that the muon electronics effort suffered from a lack of coordination and from a lack of manpower. The muon system will be able to reuse a number of key components developed for the straw system such as the ASD, TMC, DCC, etc., but these are embedded in a different application with its own special requirements. The muon group is therefore urged to develop a concept for the front-end crates.

APPENDIX A: PRELIMINARY ELECTRONICS CONCEPTUAL DESIGN DOCUMENT

The week-long August 1991 SDC Collaboration Meeting in Berkeley (August 5–10) will be used to assemble a comprehensive, but preliminary, conceptual design report for the overall SDC electronics system and all its subsystems. This document will be the basis for further conceptual design work and for the final conceptual design report which will become part of the SDC Technical Proposal due in April 1992. This preliminary conceptual design document will also serve as the departure point for serious system engineering and integration of the electronics systems as a whole. Completion of the preliminary version by the August collaboration meeting was stated as a milestone at the beginning of the year and is required to enable system engineering and the final conceptual design report to converge in time for the Technical Proposal.

The preliminary conceptual design document will include all the elements of the final conceptual design report for the overall system and all subsystems. For the overall system architecture, it will include:

(a) A description of a complete, credible conceptual design, including data flow and trigger rates

(b) A definition of the physics requirements of the trigger

(c) Definition of interfaces between subsystems

(d) A discussion of common electronics.

For each subsystem, it will include:

a) A requirements statement.

b) A complete, credible conceptual design.

c) A block diagram showing functionality.

d) A block diagram showing physical layout.

e) Definition of interfaces with other subsystems.

f) The identification of critical components, with specifications where appropriate, and with statements of R&D status.

g) A description of packaging solutions.

h) Resource requirements; space, power, cooling, cabling.

i) A reliable cost estimate, including manpower requirements.

j) A schedule, with defined milestones.

k) The identification of crucial R&D.

The August meeting will not be used to produce these items. They are documentation which should be generated from the conceptual design work on subsystems which has been proceeding since the LOI and from ongoing R&D efforts. The meeting will be used to assemble the material from individual subsystems into a single document and to discuss its contents.

Consequently, it is important that the above material for each subsystem be brought to the outset of the August meeting. The documentation should be complete in the sense of covering all of the above topics; however, it will be viewed as preliminary in the sense of reflecting the current, unfinished state of conceptual design.

In addition to serving as a preliminary version of the final conceptual design report in the Technical Proposal and as the departure point for system engineering, the preliminary conceptual design document will serve two additional important purposes. The first of these purposes is to provide a firm basis for a coherent critique of the technical soundness and status of the design of the overall architecture and of the individual subsystems. A multiday critique will take place in late August or early September (tentatively the week of September 9–10). A goal of this critique will be to narrow options for directed R&D and to define the process for technology selections. It is likely that this critique will serve to define what designs will be included in the Technical Proposal. The critique will be conducted in the form of a review by the Electronics, Data Acquisition, and Trigger Technical Steering Committee, augmented by a small number of other SDC members and other outside reviewers. The written material of the preliminary conceptual design document will serve as the basis of the review.

The second additional important purpose of the preliminary conceptual design document is to provide background to the prioritization of proposed SDC electronics R&D. It is likely that actual R&D funds made available to SDC will be significantly less than (perhaps only one-half of) those proposed in the current SDC FY92 R&D Plan. Our request for electronics R&D funds will have to be prioritized (and justified) after more is known about available funds. Priorities will be set at the preliminary design critique, based on the material in the preliminary conceptual design document.

Recipients of this note are expected to contribute to the preliminary conceptual design document by assembling the required materials for an electronics subsystem as outlined below. If you are listed but don't agree that you are responsible for providing the required material, please contact Andy Lankford as soon as possible. If you are listed with someone else, please organize yourselves to provide the required material. In cases where technical options are listed below, efforts to provide a single combined set of materials prior to the August meeting would be helpful.

Responsibilities for Preliminary Conceptual Design Document
Front-End Systems

System	Contacts
Pixels	Nygren (LBL), Pellet (UCD)
Silicon Strips	Spieler (LBL), Nickerson (Oxford)
Fibers	Baumbaugh, Elias (FNAL)
Straws (TVC)	Van Berg, Williams (Penn)
Straws (TMC)	Arai (KEK)
Intermediate Tracker	

Muon	Oliver, Feldman (Harvard), Chapman, Thun (Mich)
Calorimeter (SCA)	Jared, Levi (LBL)
Calorimeter (FADC)	Yarema, Foster (FNAL)
Shower Max	LeDu (Saclay)

Data Acquisition, Online, and Controls

System	Contacts
Data Acquisition	Barsotti, Gaines (FNAL)
Online	Fry (SSCL)
Controls	Moore (LLNL)

Trigger Systems—Coordinator: W. Smith

System	Contacts
Global	W. Smith (Wisconsin)
Muon	Oliver (Harvard), Chapman (Michigan)
Calorimeter	W. Smith (Wisconsin), Frisch (Chicago)
Shower Max	LeDu (Saclay)
Fibers	Baumbaugh, Foster (FNAL)
Straws	Chapman (Michigan)
Silicon	Foster, Heath (Bristol)

APPENDIX B: SDC PRELIMINARY CONCEPTUAL DESIGN AND R&D REVIEW

Preliminary conceptual designs for the front-end electronics systems of the SDC detector will be reviewed Monday and Tuesday September 9–10 at SSCL. R&D status and plans for these systems will also be reviewed. Front-end systems for straw and fiber trackers, shower-max detector, calorimeters, and muon system will be covered. Some discussion of readout electronics for silicon trackers, at least with respect to interfaces to data acquisition and trigger systems, is expected.

The purpose of this review of front-end systems is to:

- Review the status of conceptual designs.
- Critically assess the technical soundness of proposed designs.
- Review how each front-end system fits into the overall electronics architecture of the experiment.
- Tentatively choose designs to be included in the SDC Technical Proposal.
- Provide direction for further conceptual design work.
- Initiate system engineering of the SDC electronics systems as a whole.
- Narrow options and directions for directed R&D.
- Prepare an R&D plan for FY92.

The review will be conducted by the SDC Electronics, Data Acquisition, and Trigger Technical Steering Committee (ETSC), augmented by several other members of the collaboration and outside experts.

The basis of the review will be preliminary conceptual design documents for each detector component, as called for at the August SDC Collaboration meeting at LBL. The format of the review meeting will be almost entirely question and discussion periods, with only very short presentations which highlight the most significant issues. Each subsystem will be assigned a small number of key reviewers who will lead the review of that subsystem and may address questions prior to the review meeting. The review meeting will consist of executive sessions as well as open discussions. Written recommendations to the authors of the preliminary conceptual designs and to the SDC Technical Board will be made.

Because the review will be based upon the preliminary conceptual design documents, these written documents will be extremely important to the success of the review. Documents already exist for most front-end systems. The deadline for documents, either new or revised, to be considered by the review is receipt by Friday, August 23. Please send material to:

Andrew J. Lankford
Department of Physics
University of California
Irvine, CA 92717.

All material will be distributed to members of the review committee on Monday, August 26.

Because of the important R&D aspects of this review, preliminary conceptual design documents should contain ample information on the status of critical R&D work and on plans for future R&D, particularly work proposed for FY92 under SDC auspices.

More information about the agenda of the review will be sent later.

Thank you for your help in making this review a successful step towards the realization of the SDC detector.

APPENDIX C: GUIDELINES FOR SDC FRONT-END ELECTRONICS REVIEW

The purpose of the SDC Electronics Review on September 9-11 is to review progress and status of conceptual designs and associated R&D for front-end electronics of SDC detector subsystems. Conceptual designs for these long- lead time systems are expected to be complete by December of this year, for adoption and inclusion in the SDC Technical Proposal (due April 1992) and in order that detailed design work can commence in 1992. They are being reviewed at this time in order to guide their completion, to initiate system engineering across systems, and to influence the FY92 R&D Plan. Status of R&D efforts, as they are important to proving the feasibility of conceptual designs, crucial to the long-term schedule of SDC, and influence the FY92 R&D Plan, are also being reviewed.

This review is intended to evaluate conceptual designs and R&D on technical grounds and on their appropriateness to the SDC, rather than in a comparative fashion in cases where alternatives exist. Nonetheless, limited resources (funding and manpower) require that parallel efforts be maintained only where necessary, a plan for selecting between alternatives be formulated, and R&D for FY92 be prioritized. The review is also intended to provide recommendations on these matters.

Given the tight funding for the detector as a whole, costs of electronics systems must ultimately be taken into account. While it is clearly beyond the charge of the reviewers to perform a cost analysis, they are encouraged to point out cases where they believe existing cost estimates are significantly in error, where significant cost savings may be available through use of a technique different than proposed, and where significant cost differences may exist between two alternative approaches.

Status of conceptual designs and R&D should be reviewed with the above issues in mind. The following lists of questions were compiled to assist in the review process. These questions should, of course, be supplemented as necessary. The material requested for each subsystem is outlined at the bottom of this message. Please do your best to work with the material which has been provided; however feel free to ask numerous questions before and during the review meeting about any of following and related subjects.

General Questions, applicable to all subsystems:

1) Are design requirements adequately and correctly defined?

2) Is the conceptual design technically sound? (i.e., will it work?; is it credible?)

   What are the major uncertain technical issues?

   What are the crucial developments which are still needed?

   What crucial measurements, tests, and demonstrations are needed?

   When must the crucial developments and tests be accomplished?

3) How suitable will the design be with respect to:

   Meeting requirements

   Performance, such as dynamic range, stability, calibration, speed, etc.

   Radiation hardness

   Technical feasibility

   Suitability for triggering

   Reliability and maintainability

   Cost

   Applicability to other subsystems

   Ability to adapt to evolving technology

   Degree of risk with respect to:

      Technical issues

      Cost

      Schedule

   Other issues

4) Is the status of R&D appropriate for this time?

   For what aspects is R&D lagging?

   Is the R&D program adequately defined?

   What are the priority research and developments for FY92?

5) Is the conceptual design mature and complete enough for the Technical Proposal?

   What are the major elements missing from the conceptual design?

   Is the presentation of the design sufficiently clear?

6) Does the conceptual design fit the overall SDC electronics architecture?

   Are subsystem interfaces completely and correctly defined?

   Is the conceptual design complete enough to allow system engineering across subsystems?

7) Is the integration information (e.g., physical layout, resource requirements, cost estimates, and schedules) adequate?

   Are cost estimates reasonably accurate?

   Is the long-term schedule reasonable for all SDC electronics to be operational in 1999?

8) Is the conceptual design suitable for the Technical Proposal?

Should the conceptual design be included in the Technical Proposal?

Should alternative designs be included?

What options in the designs should be included?

Additional questions which apply to subsystems with readout alternatives:

1) What distinguishes each readout approach?

In what aspects are the approaches similar?

2) Has either approach presently demonstrated its feasibility?

Can either approach presently be set aside as infeasible or impractical?

3) What are the strong points and weaknesses of each approach?

Does either approach offer advantages to the electronics system as a whole, for instance, by providing an output which is more suitable for trigger purposes or by providing readout solutions for more than one subsystem?

Is it feasible to combine the strong points of each approach into a more optimal system?

Are there significant cost differences between approaches?

4) Is it appropriate at this time to make a selection between alternatives?

Upon what criteria should the alternatives be compared?

What criteria are likely to be decisive?

When will it be appropriate to make a selection?

Subsystem-specific Considerations:

Calorimeter—Compare/contrast approaches, recommend selection criteria

Shower Max—Are requirements sufficiently different from calorimeter to demand a separate solution? Can readout be combined with the calorimeter?

Fibers—Restrict review to electronics which follows discriminator except for general comments.

Straws—Compare/contrast approaches; Recommend selection criteria.

Muons—Are requirements sufficiently different from straws to demand a separate solution?

It is foreseen that the Technical Proposal will contain the following elements for each electronics subsystem, and it was requested that the preliminary conceptual design documents for the review contain the same elements:

1) Requirements statement.

2) Complete, credible conceptual design.

3) Block diagram showing functionality.

4) Block diagram showing physical layout.
5) Definition of interfaces with other subsystems.
6) Identification of critical components, with specifications where appropriate, and with statements of R&D status.
7) Description of packaging solutions.
8) Resource requirements; space, power, cooling, cabling.
9) Reliable cost estimate, including manpower requirements.
10) Schedule, with defined milestones.
11) Identification of crucial R&D.

APPENDIX D: INVITATION TO OUTSIDE REVIEWERS OF SDC FRONT-END ELECTRONICS

Dear XXX:

We are planning to review the status of development of front-end electronics systems for the SDC detector for the SSC. We would like to request your assistance in this review as one of a small number of critics from outside the SDC collaboration. The review will be held on Monday and Tuesday September 9 and 10 at the SSC Laboratory. Wednesday, September 11 will be used to complete documentation of the conclusions of the review.

The purpose of the review is to critically assess the technical soundness of conceptual designs of front-end systems which we expect to include in the SDC Technical Proposal next April and to evaluate the status of R&D which is critical to those designs. The conclusions of the review will be used to guide completion of conceptual designs, selection of designs to be included in the Technical Proposal, and prioritization of R&D efforts for in FY92.

We will review two options for front-end electronics for calorimetry, one based on a "floating-point" flash digitization every beam crossing followed by digital data buffering, and a second based upon analog data storage in a switched capacitor array followed by digitization after level 2 triggers. For calorimeters, we will also review designs for readout of shower maximum detectors. For tracking detectors, we will review readout of fiber trackers and two options for readout of wire chambers, one based on digital storage of drift times and one based on a time-to-voltage converter followed by analog storage of drift times in a switched capacitor array. We will also review readout of muon systems. The reviews will cover the status of development of critical circuits as well as development of overall system designs. Reviews will be based on written material which will be circulated prior to the review meeting.

We sincerely hope that you will assist us in this important but informal review. We also expect that the review will be interesting and informative for you. Please let me know as soon as possible whether you will participate. I can be contacted at 714-725-2632 or LANKFORD@SLACVM. When I hear from you I will tell you more about the format and content of the meeting, as well as travel arrangements, and will send you the review materials.

Sincerely yours,

Andy Lankford,

for the SDC Electronics, Data Acquisition, and Trigger Technical Steering Committee

APPENDIX E: AGENDA OF SDC FRONT-END ELECTRONICS REVIEW

Monday, September 9

- Executive Session
  - Introductory remarks on purpose of review
- Open Session
  - Discussion of Readout for Calorimetry
    - Readout via Switched Capacitor Array
    - Readout via Splitter/Gated Integrator
    - Readout for Shower Max
  - Discussion of Readout of Scintillating Fibers
- Executive Session
  - calorimetry summary and recommendations

Tuesday, September 10

- Executive Session
  - Fibers summary and recommendations
- Open Session
  - Discussion of Wire Chamber Readout
    - Straw Readout via TVC/AMU
    - Straw Readout via TMC
  - Discussion of Muon System Readout
- Executive Session
  - Review draft calorimetry summary and recommendations
  - Straw summary and recommendations
  - Muon summary and recommendations
  - Review draft fiber summary and recommendations

Wednesday, September 11

- Executive Session
  - Review all draft summaries and recommendations