BTeV Trigger Requirements

BTeV Document 0001

02 February 2001

Updated: 29 June 2001

Editors

Joel Butler, Erik Gottschalk, Vince Pavlicek, Michael Haney

1 INTRODUCTION 2

2 HIGH LEVEL REQUIREMENTS 2

2.1 RATE REQUIREMENT 3
2.2 ALGORITHM REQUIREMENT 3
2.3 OUTPUT DATA RATE REQUIREMENT 3
2.4 REJECTION AND EFFICIENCY REQUIREMENTS 3
2.5 LIVETIME & UPTIME REQUIREMENTS 5
2.6 EXCESS CAPACITY & SCALABILITY 5
2.7 FLEXIBILITY REQUIREMENT 5
2.8 FAULT TOLERANCE & SECURITY 6
2.9 DETECTOR PERFORMANCE ENVELOPE 6
2.10 CONTROL & MONITORING 6
2.11 SUPPORT FOR COMMISSIONING AND DEBUGGING 7

3 ELECTRICAL REQUIREMENTS 7

3.1 BTEV STANDARDS 7

4 SOFTWARE REQUIREMENTS 7

4.1 SOFTWARE DEVELOPMENT 8

5 SAFETY REQUIREMENTS 8

DEPENDENCY APPENDICES 9

A. DAQ DEPENDENCIES 9

A.1 Trigger Interface to DAQ Data Links to Front-End Electronics 9
A.2 Trigger Interface to Level 1 Buffers 9
A.3 Global Level 1 Interface to the DAQ 9

B. PIXEL DETECTOR DEPENDENCIES 9

B.1 Trigger Interface to the Pixel Detector 9

C. MUON DETECTOR DEPENDENCIES 10

C.1 Trigger Interface to the Muon Detector 10

D. FORWARD TRACKER DEPENDENCIES 10

D.1 Trigger Interface to the Forward Tracker 10

E. BTEV DETECTOR DEPENDENCIES 11

E.1 Detector Dependency 11

1 Introduction

This document describes the high level requirements for the BTeV Trigger System. The purpose of the BTeV Trigger System is to accept or reject beam crossings that occur in the C0 interaction region. Beam crossings that are accepted are recorded on archival storage. The goal is to record only those beam crossings that contain events that would plausibly survive all the requirements of the BTeV data analysis programs and contribute to physics signals (as well as special calibration and monitoring data), while rejecting all other beam crossings. This goal would be easily achievable if the full BTeV offline analysis could be run for each beam crossing at the beam-crossing rate of 7.6 MHz. At present, this is not feasible with a reasonable expenditure on the trigger, so compromises must be made to come as close to the ideal as possible. The requirements that are listed in this document are based on detailed investigations of algorithms and technology, which have led to a baseline set of trigger requirements that are believed to enable the experiment to achieve its physics goals while being both affordable and technically achievable. The detailed design is discussed elsewhere. The Baseline Requirements for the BTeV Trigger System determined by these investigations are presented here. The considerations that have gone into determining these requirements include:

- The physics goals of the experiment
- The physical characteristics that distinguish events of interest from those that are not interesting
- The characteristics and performance of the Tevatron and the C0 interaction region
- The characteristics of the detector systems and their “performance envelopes”
- The funding available to the trigger task
- The performance and cost of various electronics and computing technologies involved in the trigger system – including projections of these when they must be procured
- The cost of data storage and data access at the time the experiment runs
- The complexity and technical risk of various approaches

It is important to recognize that the performance of the trigger depends on the quality of the inputs to it from the detector, the performance of the Tevatron, and even some unverified physics assumptions about the largely unexplored forward rapidity region. The trigger must be able to cope, up to some reasonable extent, with deviations from these assumptions.

The current design of the BTeV Trigger System implements the trigger in three levels called Level 1, Level 2, and Level 3. Level 1 consists of several subsystems. The *Pixel Trigger*, which is the primary physics trigger for BTeV, receives data from the pixel detector to perform its task of reconstructing tracks and vertices to produce a trigger decision. The *Muon Trigger* receives data from the muon detector to search for muon tracks that come from the interaction region. This trigger operates independently from the Pixel Trigger, and can be used to perform a cross check of the efficiency of the Pixel Trigger. Other triggers that are part of Level 1 include triggers that combine information from more than one detector (for example, a trigger that uses information from the pixel detector and muon detector), prescaled minimum bias triggers, alignment and calibration triggers. The hardware that receives the trigger results from all of the Level 1 subsystems and decides whether to accept or reject a particular beam crossing is called Global Level 1. In the event that Global Level 1 issues a Level 1 accept for a beam crossing, data for the beam crossing are sent to Level 2 by the DAQ. For a Level 1 reject the data for the beam crossing are flushed from Level 1 buffers so that the memory can be used for data from subsequent beam crossings. At Level 2 more refined calculations and selection criteria are used to determine which beam crossings will be rejected, and which ones will be passed on to the Level 3 Trigger. Level 3 performs additional calculations and selects the beam crossings that are recorded on archival storage.

2 High Level Requirements

This section describes the high-level trigger requirements that are necessary for BTeV to achieve its physics goals. The primary goal of the BTeV Trigger system is to reject beam crossings with minimum bias interactions, while maintaining high efficiency for beam crossings with *B*-decay modes of interest to the experiment and modest efficiency for charm decay modes. The trigger decision for a beam crossing, accept or reject, is produced by Global Level 1 after it receives trigger results from Level 1 subsystems, such as the Pixel Trigger and Muon Trigger.

2.1 Rate Requirement

BTeV is designed to operate at a luminosity of 2×10^{32} cm^{-2} s^{-1} with a 132 ns beam-crossing interval. This corresponds to an average of 2 interactions per beam crossing. The BTeV trigger must be able to handle this collision rate with good efficiency and rejection.

- **Requirement 2.1-1 (Level 1 trigger rate):** The Level 1 trigger must make trigger decisions at the beam-crossing rate, every 132 ns on average.
- **Requirement 2.1-2 (Number of interactions per beam crossing):** The BTeV trigger must be able to handle an average of two interactions per beam crossing, and maintain good efficiency for *B* events (see section 2.4) accompanied by an average of two minimum bias events.

2.2 Algorithm Requirement

BTeV requires the ability to study a broad range of decays of particles containing b-quarks, including B_d, B_u, B_s, B_c, and all types of b-baryons. BTeV intends to study the decay of these particles into a wide variety of final states including those that contain only charged hadrons, those containing charged and neutral hadrons, photons and π^os, electrons, and muons. Moreover, BTeV requires a broad range of flavor tagging techniques, including muon and electron tags, kaon tags, same-side tags, jet-charge tags, etc.

- **Requirement 2.2-1 (Trigger algorithm):** The BTeV trigger must base its decision on the characteristic properties of *B* decays so as not to limit the physics potential of the experiment. These properties must be determined well enough so that any needed corrections do not unduly limit the physics reach of the experiment.

2.3 Output Data Rate Requirement

Analyses of the costs of data storage and retrieval have led to the conclusion that the output data rate should be no more than 200 Mbytes per second. This corresponds to 2 PetaBytes per Snowmass year (10^7 seconds of effective running) of raw data.

- **Requirement 2.3-1 (Output data rate):** The output of the trigger must average to no more than 200 MByte/sec at design luminosity.

2.4 Rejection and Efficiency Requirements

An analysis of simulated data indicates that an average event size (after sparsification by the readout or front-end electronics) of 200 Kbytes per beam crossing is achievable. A further reduction by a factor of 4 can be obtained by eliminating some away-side information, which is not useful to the final analysis, some information clearly associated with the non-*B* events on the signal-side, summarizing and condensing the remaining information, and possibly applying a compression algorithm somewhere between the trigger and data storage. The result is that the average amount of data per beam crossing written to archival storage is 50 Kbytes, which implies a factor of 4 reduction. This also implies that the output rate must be less than 4000 beam crossings per second.

- **Requirement 2.4-1 (Output crossing rate):** The BTeV trigger must accept no more than 4000 beam crossings per second.

The efficiency of the trigger depends on the particular parent *B* particle and its final state decay topology. The efficiency is defined for a particular analysis that is tuned to have acceptable signal to background to achieve the physics goals of the analysis. The events that survive the analysis cuts represent the sample of events used to determine the trigger efficiency. The efficiency is defined as the fraction of these events that survive the trigger. Extensive simulations have shown that an efficiency of greater than 50% can be achieved for most decay topologies with at least two charged hadrons associated with the *B* vertex, or the *B* vertex and an associated charm vertex. In cases with only one charged particle emerging from the *B* vertex and a non-charm decay such as a K_s, or a charm decay that has only one prong, the efficiency will be somewhat lower but should be at least greater than 10%. This determination of the trigger efficiency assumes 100% pixel efficiency and does not take into account the trigger livetime and uptime, which have their own requirements and are described in section 2.5. Inefficiencies in the pixel detector influence the trigger performance, and we specify a dependency on the pixel detector in Appendix B. Although we encourage the pixel group to strive towards 100% pixel efficiency, we require that the trigger efficiency does not drop below 45% as long as the pixel detector is operating within its performance envelope.

- **Requirement 2.4-2 (Efficiency):** The efficiency of the trigger must be greater than 50% (not including livetime or uptime, and assuming 100% pixel efficiency) for nearly all *B* decays having two or more charged particles emerging from the *B* or daughter charm vertex. The trigger efficiency must be greater than 45% when the pixel detector is operating within its performance envelope.
- **Requirement 2.4-3 (Single prong efficiency):** The efficiency for less well defined states such as those with a single prong and a K_s must be greater than 10%.

Extensive studies have been carried out to determine realistic goals and corresponding baseline algorithms for the trigger. The baseline design subdivides the trigger processing into Levels 1, 2, and 3. Each level is associated with a set of selection criteria that determine which beam crossings are accepted, and which are rejected. For Level 1 the selection criteria are implemented in Global Level 1, which receives trigger results from different Level 1 subsystems such as the Pixel Trigger and the Muon Trigger. Global Level 1 combines these results to produce a trigger decision for each beam crossing at Level 1. For Levels 2 and 3 selection criteria are imposed on a beam crossing by the processor that has been assigned to handle the data for that beam crossing. The selection criteria for all levels are tuned to improve the trigger efficiency (as defined above) for interesting events with *B* decays, while rejecting beam crossings with uninteresting events. “Rejection” is defined as the fraction of beam crossings that are rejected by a particular trigger level relative to the number of crossings that are processed by that trigger level.

The first level of the trigger must inspect every beam crossing and must make a decision on average every 132 ns (a decision rate of 7.6 MHz). This limits the amount of time available to Level 1, which is further limited by the amount of data it can deal with (the total data rate after sparsification is 1500 Gbytes per second). Level 2 has to deal with beam crossings that survive Level 1, so if the Level 1 rejection is R_1, then Level 2 receives beam crossings at a rate of $(1- R_1) \times 7.6$ MHz and must make a decision every $132 / (1- R_1)$ ns. Similarly, if the Level 2 rejection is R_2, then Level 3 will receive beam crossings at a rate of $(1- R_1) \times (1- R_2) \times 7.6$ MHz and must make a decision every $132 / (1- R_1) (1- R_2)$ ns. Finally, if the Level 3 rejection is R_3, then the total rejection must be such that $(1- R_1) \times (1- R_2) \times (1- R_3) \times 7.6$ MHz is less than 4000.

Level 1 Rejection and Efficiency:

- **Requirement 2.4-4 (Level 1 rejection):** The Level 1 rejection must be at least 99% of all beam crossings.
- **Requirement 2.4-5 (Level 1 efficiency):** The Level 1 efficiency, as defined above, must be greater than 55% for *B* decays having two or more charged decay particles. The efficiency must be greater than 50% as long as the pixel detector is operating within its performance envelope.

Level 2 Rejection and Efficiency:

- **Requirement 2.4-6 (Level 2 rejection):** The Level 2 rejection must be greater than 80% of beam crossings sent to Level 2.
- **Requirement 2.4-7 (Level 2 efficiency):** The Level 2 efficiency must be greater than 90%.

Level 3 Rejection and Efficiency:

- **Requirement 2.4-8 (Level 3 rejection):** The Level 3 rejection must be greater than 75% of beam crossings sent to Level 3.
- **Requirement 2.4-9 (Level 3 efficiency):** The Level 3 efficiency must be greater than 95%.

2.5 Livetime & Uptime Requirements

The trigger performance can be affected adversely by factors both within the trigger and outside of it. Factors outside of the trigger system include an unusually "dirty" beam that produces extra background in the detector, badly imbalanced bunch populations, poorly performing or noisy detectors, etc. These "external factors" have the effect of reducing the pipeline "length" as measured in beam crossings and can therefore cause the front end systems to run out of buffer space during the trigger decision time, or can cause the trigger decision time to be longer than average due to noisier than average events. "Internal factors" include high failure rates for processors or bottlenecks in the data-transport network, which would prevent processors from being used efficiently. Any of these problems can cause the processing to fail to keep up with the beam-crossing rate and must inevitably result in data being discarded and therefore lost.

- **Requirement 2.5-1 (Livetime):** With a suitably pipelined architecture, the trigger should have almost no deadtime. We set the livetime requirement based on factors "internal" to the trigger to be greater than 95%.

The trigger design must be such that it is robust against individual component failures and is fault tolerant, which means that the trigger can continue to run (perhaps at reduced efficiency) in the presence of some failures. Moreover, an uptime requirement for the trigger imposes limits to reduce the amount of downtime, which can come from time spent on system initialization or system resets.

- **Requirement 2.5-2 (Uptime):** The trigger uptime must be greater than 95%.

2.6 Excess Capacity & Scalability

While extensive simulations have been and continue to be carried out to verify the trigger performance, it is impossible to predict exactly what reality will be like. It is therefore important that the trigger has extra capacity built in, and that the architecture be such that additional expansion is possible with incremental funding.

- **Requirement 2.6-1 (Capacity):** The trigger must have at least 50% extra capacity.
- **Requirement 2.6-2 (Scaleability):** The trigger architecture must permit an increase in capacity of at least a factor of 2 in processing and data throughput at every level, and a factor of 2 in the size of buffer memories.

2.7 Flexibility Requirement

The trigger architecture must be capable of including possible expansion to satisfy new physics goals that might arise in the future.

- **Requirement 2.7-1 (Flexibility):** It must be possible to add additional types of triggers.

2.8 Fault Tolerance & Security

Fault tolerance and redundancy must be designed into the architecture of the trigger system. Moreover, the trigger system must have adequate computer security for computing systems that are part of the trigger and are accessible from systems external to the trigger.

- **Requirement 2.8-1 (Component failure):** The trigger must continue operating, perhaps at reduced capacity and efficiency, in spite of the failure of processors, network connections, etc.
- **Requirement 2.8-2 (Trigger arbitration):** If the trigger system is having difficulty keeping up with the data rate, it must be able to drop less important triggers and calculations so that it can maintain high efficiency for the most important physics.
- **Requirement 2.8-3 (Trottling):** The trigger system must be able to throttle the input data rate when the rate is too high. A mechanism that logs data loss due to throttling must be implemented.
- **Requirement 2.8-4 (Timeouts):** Timeouts must be used to impose limits on excessive calculations that tie up resources. The system must monitor and record the frequency of timeouts as a warning and diagnostic tool.

2.9 Detector Performance Envelope

Detectors never perform perfectly. BTeV detectors will have specific performance envelopes that must be achieved and maintained. The trigger must be able to achieve its efficiency and rejection goals when all of the detectors are within their performance envelopes. There should also be enough overhead for the trigger to degrade gradually if one or two detectors move slightly outside of their worst acceptable performance. Since the performance of the trigger depends on detector performance, we have included appendices at the end of this document to describe the dependencies. These dependencies are still under development as we improve our understanding of the trigger and detector performance.

- **Requirement 2.9-1 (Performance envelope):** The trigger must achieve efficiency and rejection requirements when all detectors that affect the trigger performance are within their performance envelopes.

2.10 Control & Monitoring

The trigger system will have at least two control and monitoring systems that are interfaced to the control and monitoring system for the BTeV experiment. The first of the two control and monitoring systems for the trigger will be used for Level 1. The second will be used for Levels 2 and 3. The Level 1 system requires a dedicated computer system that manages control and monitoring functions using distributed high-speed links to subsystems, such as the Pixel Trigger, Muon Trigger, Global Level 1, and any other system that is part of Level 1. Examples of functions performed by the Level 1 control and monitoring system include Field Programmable Gate Array (FPGA) programming, Digital Signal Processor (DSP) programming and initialization, in-situ diagnostics and testing, performance monitoring, as well as status and error message reporting. In addition to performing these functions, the Level 1 control and monitoring system must be able to receive commands from and report back to the BTeV control and monitoring system. It must record any unusual conditions or problems in the trigger system and report them. A similar control and monitoring system will be used for Levels 2 and 3.

- **Requirement 2.10-1 (Control and monitoring):** The control and monitoring systems must receive commands from and report back to the BTeV control and monitoring system.
- **Requirement 2.10-2 (Read-back for programmable devices):** The control and monitoring systems must be able to read data that are stored in programmable devices in Levels 1, 2, and 3.

This includes the programs, parameters, device configurations, status and error messages, any temperature and voltage measurements, as well as processed data at useful probe points in the data stream.

2.11 Support for Commissioning and Debugging

The trigger system must be able to support not only steady-state operation but also commissioning and runtime troubleshooting. It will be necessary to test new trigger algorithms and new trigger hardware (for example, burning in a new set of processors). During commissioning, several detectors may be running almost autonomously for debugging or calibration purposes. The trigger system must be able to support partitioning. This means that it must simultaneously provide several different and independent triggers for different subsystems, send data to different groups of processors, and be able to write data to different output streams.

- **Requirement 2.11-1 (Partitioning):** The trigger system must be able to support partitioning.
- **Requirement 2.11-2 (Testing):** All programmable devices that are part of the trigger must be testable in-situ.

The trigger system encompasses a large number and different types of programmable devices, a large number of data links into and out of trigger subsystems, as well as numerous interconnections between devices within each subsystem. The commissioning and debugging of such a large system requires a resource identification and configuration database to keep track of all hardware and software used in the system. The database is used to track the location of individual devices (such as crate and slot number and whether the device is in use), device configuration information that includes firmware revision numbers, device status indicating whether the device is operational or not, and a maintenance history. A separate software database (see Section 4.1) that keeps track of software developed for the trigger will need to be used in conjunction with the resource identification and configuration database.

- **Requirement 2.11-3 (Database):** A resource identification and configuration database must be used to keep track of hardware used in the trigger system.

3 Electrical Requirements

3.1 BTeV Standards

The hardware that is designed and built, or purchased to implement the trigger will consist of digital electronics. This hardware must comply with the *BTeV Digital Electronics Standards* document. This document contains requirements, standards, and recommendations that apply to all digital electronics in BTeV. The subjects that are addressed in the document include interfaces, grounding, EMI, shielding, infrastructure, safety, reliability, and maintainability.

- **Requirement 3-1 (Electronics standards):** The trigger system must comply with the *BTeV Digital Electronics Standards* document.

4 Software Requirements

The "software" for the trigger system refers to algorithms, specialized operating system code, as well as diagnostic and testing code developed for programmable devices in the three trigger levels, Global Level 1, and the control and monitoring system. The software includes FPGA (Field Programmable Gata Array) firmware, software developed for specialized processors such as DSPs (Digital Signal Processors), and software developed for general purpose processors.

4.1 Software Development

Software must be developed using standard software tools that allow version tracking, assist code reviews, encourage documentation, and help with maintainability. The software must be robust and stable. Software bugs that could stop operation or induce errors in the trigger must be eliminated.

- **Requirement 4.1-1 (Error detection):** Processes that regularly verify code purity and run standard datasets for testing purposes must be part of the development process, and must be used for testing the trigger after the development of the trigger has been completed.
- **Requirement 4.1-2 (Database):** Trigger parameters and constants (such as geometry and alignment constants) must reside in a database so that the particular values used to process data can always be identified.
- **Requirement 4.1-3 (Software repository):** All software must reside in a software repository that must be used to keep track of different versions of the software during development.
- **Requirement 4.1-4 (Version control):** The version numbers of software used to process data must be managed in such a way that the particular version that was used to process data can always be identified and reproduced.

5 Safety Requirements

The trigger system does not pose safety concerns beyond the usual and customary issues associated with low-voltage digital electronics:

- **Requirement 5-1 (Low voltage, high current safety):** If the trigger electronics uses high-current (greater than 10 amps operating or 50 amps rated current) low-voltage (less than 50 volts) power supplies, the safety requirements for low-voltage, high-current power distribution systems must be followed. These requirements are detailed in the Fermilab ES&H Manual, Occupational Safety And Health section on Electrical Safety.
- **Requirement 5-2 (General safety):** The trigger system must comply with all Fermilab ES&H safety standards.

Dependency Appendices

A. DAQ Dependencies

A.1 Trigger Interface to DAQ Data Links to Front-End Electronics

The trigger system receives a large amount of data at fairly high rate. The data must be relatively error free so that the best possible trigger decisions can be made. This places constraints on front-end electronics and those portions of the DAQ (such as data links) that deliver data from the front-end electronics to the trigger. We have not yet performed the necessary simulations to determine an acceptable error rate for data links that deliver data to the trigger, and it is possible that the acceptable error rate will be less than the error rate that is established for the DAQ system.

- **Dependency A.1-1 (Link error rate):** The limits on error rates that can be tolerated for DAQ data links that deliver data to the trigger must be better than some number (to be determined) to avoid degradation of the trigger performance.

A.2 Trigger Interface to Level 1 Buffers

The trigger system accesses L1 buffers for various purposes, such as saving raw data and intermediate trigger results for subsequent trigger calculations.

- **Dependency A.2-1 (L1 Buffering):** The DAQ must be able to receive raw data and intermediate trigger results from the Level 1 Trigger at the beam-crossing rate of 7.6 MHz, and save these data until requested by subsequent stages of the trigger.

A.3 Global Level 1 Interface to the DAQ

The Global Level 1 Trigger accepts trigger results from the Pixel Trigger, Muon Trigger, and any other Level 1 Triggers. Global Level 1 uses these results to generate a Level 1 accept or reject for each beam crossing, and transmits this signal to the DAQ.

- **Dependency A.3-1 (Level 1 trigger rate):** The DAQ must be able to receive trigger decisions at the beam-crossing rate of 7.6 MHz.

B. Pixel Detector Dependencies

B.1 Trigger Interface to the Pixel Detector

- **Dependency B.1-1 (Input data requirement 1):** The input pixel hit data must include the beam crossing number, chip identification number, and the pixel hits for that beam crossing.
- **Dependency B.1-2 (Input data requirement 2):** The pixel data must have row and column numbers, and pulse height information for each hit.
- **Dependency B.1-3 (Input data requirement 3):** The pixel data must be time ordered as well as ordered by row and column numbers.
- **Dependency B.1-4 (Pixel efficiency):** The pixel efficiency must be greater than some number (to be determined).
- **Dependency B.1-5 (Noise and hot channels):** The number of extra hits due to noise or hot pixel channels must be less than some number (to be determined).

- **Dependency B.1-6 (Alignment):** The alignment of the pixel system must (to be determined).
- **Dependency B.1-7 (Pixel resolution):** The pixel resolution must be better than some number (to be determined).

C. Muon Detector Dependencies

C.1 Trigger Interface to the Muon Detector

- **Dependency C.1-1 (Beam-crossing requirement):** The muon hit data for one beam crossing must be delivered to the Muon Trigger before data from any other beam crossing is delivered.
- **Dependency C.1-2 (Octant-arm requirement):** All views (R, U, V, R) of all stations (μ1, μ2, μ3) for one arm of one octant must be delivered to the same "place". The data may arrive on multiple fibers per octant. However, the 16-fold symmetry of the trigger, with complete octant-arm independence, demands that no channel connected to the trigger contain data from more than one octant.
- **Dependency C.1-3 (Radially-ordered data):** The data delivered to the Muon Trigger must be radially ordered from outermost to innermost muon hit.
- **Dependency C.1-4 (Muon detector efficiency):** The muon detector efficiency must be greater than some number (to be determined).
- **Dependency C.1-5 (Noise and hot channels):** The number of extra hits due to noise or hot muon detector channels must be less than some number (to be determined).
- **Dependency C.1-6 (Alignment):** The alignment of the muon detector system must (to be determined).
- **Dependency C.1-6 (Muon detector resolution):** The muon detector resolution must be better than some number (to be determined).

D. Forward Tracker Dependencies

D.1 Trigger Interface to the Forward Tracker

- **Dependency D.1-1 (Straw and strip efficiency):** The straw and strip efficiencies must be greater than some number (to be determined).
- **Dependency D.1-2 (Noise and hot channels):** The number of extra hits due to noise or hot channels must be less than some number (to be determined).
- **Dependency D.1-3 (Alignment):** The alignment of the straw and strip systems must be (to be determined).
- **Dependency D.1-4 (Straw and strip resolution):** The straw and strip resolution must be better than some number (to be determined).

E. BTeV Detector Dependencies

E.1 Detector Dependency

- **Dependency E.1-1 (Event size):** The average event size (after sparsification by the readout or front-end electronics) must not exceed 200 Kbytes per beam crossing.