Beam Loss Monitor Upgrade

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All Experimenters’ Meeting
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Motivation

• Don’t do this again.

Loss profile: Tokyo-pot 16-house quench
Response: Abort Upgrade

• **New Loss Monitor electronics**
  – Abort logic designed for collider operations
  – Improved diagnostic capabilities

• **Improvements to QPM**
  – Faster response
  – Running many months
  – Ask the Tevatron guys for details
Further Motivation

- **Scope broadened to improve high-intensity proton operations**

- **Tevatron**
  - Protect magnets from beam-induced quenches
  - Legacy system is not sufficiently flexible to use during complex operations cycle
    - Designed for fast-cycle fixed-target operations

- **Main Injector**
  - **Greater diagnostic capability needed for high-intensity operation**
    - Limit activation of accelerator components
    - Intensity 5x greater with NUMI operation
    - Maximize proton flux

- **Booster**
  - **Improved diagnostics**
    - Limit activation
    - Maximize flux
Existing System Characteristics and Limitations

• **Signal properties**
  – Good resolution and dynamic range
  – Fast leading edge response, slow discharge

• **Tevatron Aborts**
  – Fast: ~ 50-100 μs
  – Fires on single channel over threshold
  – Minimal compatibility with multiple machine configurations
    • Two abort levels, high and low field
    • Abort disabled when antiprotons are in the machine

• **Read out**
  – Updates slowly: ~ 3 ms period
  – Fast access to one channel per chassis
    • 24 signals multiplexed in MI

• **Difficult to enhance and maintain**
  – 23 years old
  – Read out via Multibus(!) with obsolete software
Requirements for New System

- Robustness: No false aborts
- Reliability: No missed aborts
- Respond to changing machine configurations
- Access to data from all channels
- Maintain resolution
  - System designed around low-noise integrator
- Large dynamic range
  - 0.02 Rad/s in 1 ms to 100 Rad in a single turn
- Good time resolution and depth
  - Multiple integration periods, each with >4k sample history
- Include experiments in Tevatron BLM system
  - Two Camac crates with special electronics hard to maintain
System Overview

- Integrate BLM current and digitize every ~20 μs
  - Tevatron turn frequency or MI frequency ÷2
- Form three running sums for additional integration periods
  - Programmable time constants
    - Example: 1ms, 50ms, 1s
  - Maintain history of >4000 cycles for each period
    - Also 8k injection turn-by-turn
  - Also record integrated loss through each MI cycle
- One abort threshold per integration period for each channel
- Abort requirements changed in response to machine states
  - Thresholds, masks, multiplicities
- Safe operation
  - Isolated from VME and Ethernet
    - Embedded microprocessor
    - Custom local bus on J2
Components

- **Digitizer Card**
  - 4 integrator channels
    - Deadtimeless operation
  - Form running sums
  - Compare to thresholds
  - Raw data buffers
  - Max 15 per crate

- **Timing Card**
  - Provides synchronous clock
  - Keeps time buffers
  - Decodes machine clock events

- **High Voltage Card**
  - Power up to 60 channels

- **Control Card**
  - Keeps diagnostic data
    - Running sum data
  - Updates abort requirements on state changes

- **Abort Card**
  - Reads abort data from Digitizers
  - Compares to mask and multiplicity requirement

- **Crate**
  - Wiener 6U VME chassis
  - Low-noise power supply
  - Custom J2 backplane
Status

• Digitizer
  – Extensive standalone testing of prototype
  – Updating design to extend functionality

• Timing Card
  – Testing prototype

• Crate
  – All received.

• Abort and HV Cards
  – Design nearly complete

• Controller
  – Firmware working in simulation
  – Card schematic done
Personnel

- **Alan Baumbaugh (PPD/EED)**
  - System design, Control card software
- **Kelly Knickerbocker (PPD/EED)**
  - Timing card, infrastructure
- **Craig Drennan (AD/BS)**
  - Digitizer
- **Marvin Olson (AD/ID)**
  - System support
- **Cecil Needles (PPD/EED)**
  - Digitizer Firmware
- **Mike Utes (PPD/EED)**
  - Abort Card
- **Jonathan Lewis (PPD/CDF)**
  - Management
- **Stephen Pordes (AD/ID)**
  - Wisdom and advice (solicited or otherwise)
- **Randy Keup (AD/ID)**
  - Applications programs
- **Brian Fellenz (AD)**
  - HV card
- **Jin-Yuan Wu (PPD/EED)**
  - Control Card
- **Charlie Briegel, Brian Hendricks (AD/Controls)**
Schedule

• Beam tests starting soon
  – Can do extensive testing with VME readout before Controller complete
    • Pre-production Digitizer, Controller and Abort card added in June
  – Duplicate BLMs to compare to legacy system
    • Tevatron: 6 at E1
    • Main Injector: 2 at MI60
  – Develop and test software
  – Get operational experience

• July 2005: Preproduction test

• Install crates when old BPM electronics removed
  – Get host CPUs running ASAP
Installation Schedule

• Modules available to install in November
  – Tevatron and MI

• Can install new system without removing old
  – Easy cabling changeover

• Can establish operations with small fraction of channels then move balance of cables
Experience

• Studies with 2-channel digitizer test card
• Understand signals and noise
  – Selected sites in Tevatron, MI and Booster
• Check calibration for Tevatron
  – Old system: 50nA ↔ 0.84 Rad/s (1 Rad ↔ 60nC)
  – New system: 50nA ↔ 56 counts (20μs bins)
• Explored noise suppression
  – Wide channel-to-channel variation
  – Filters
    • Chokes for common mode
    • Resistor to increase effective integration time
  – Running sums
MI: LM402G full cycle

~0.2pC/div (per 20μs)

Injection

Transition

25 ms/div
Proton Injection Loss During Shot Setup 8/22/04
LMF12: Old and New

Losses in F-sector from 120 GeV beamline during stacking

~0.2pC/div (per 20µs)

Small Choke

Small Choke, Smooth @ 100µs

LMF 12
0.025 R/s
per div

100 ms/div

1 ms/div
Conclusions

- In past year, we have completed most of the design work for a new BLM readout system
- Improved diagnostics will improve accelerator performance
- Greater flexibility will enable better protection of equipment
- Expected to be online February 2006
Backup Slides
Custom Digitizer Card

- **4 Loss Monitor Channels**
  - Dual Charge Integrator (Burr Brown ACF2101)
    - Alternately integrating or being readout and reset
    - Provides continuous measurement
    - 50 kHz maximum sample rate

- **FPGA**
  - Controls integrators
  - Reads ADCs
  - Stores readings (raw measurements)
  - Forms three running sums
  - Compares readings and sums to programmed thresholds
    - Results sent to Abort Card

- **Raw data buffers**
  - Running circular buffer
  - Triggered buffer for turn-by-turn studies

- **Maximum 15 cards per crate**
Other Modules

• **Timing Card**
  – Provides synchronous integration clock to digitizers
    • External input Clock reference or internal oscillator
    • Can also be divided (e.g. AA÷2 for MI)
  – Time stamp buffer in sync with the digitizers’ raw data buffers
  – Decoder to receive clock events

• **Abort Card**
  – Receives abort info from the digitizer cards, compares against abort masks and multiplicities and makes the abort signals
  – One abort input for each time-range from each channel
  – Separate decisions for each time-range
    • Independent masks and multiplicity thresholds
  – Aborts are formed in < 20 microseconds
  – Also transmits abort data on ring-wide serial link
Other Modules, 2

• **Controller Card**
  – Communicates with other cards on control bus
    • Bus master
  – **Isolates Abort functions from outside world**
    • FPGA VME slave and control-bus eZ80 access shared memory
      – Stores loss data buffers for running sums and provides to VME
      – Stores BLM thresholds and abort requirements for each machine state
    • Loads parameters into digitizer and abort concentrator cards based on machine state

• **Front-end CPU**
  – Motorola MVME 2xxx for communication with ACNET

• **High Voltage Card**

• **Wiener VME Chassis with low-noise power supply**
Proposed Machine States

- Tevatron Operation
  - Proton Studies (i.e. uncoalesced batch at 150)
  - Proton Injection
  - Activate Separators
  - Pbar Injection
  - Ramp
  - Squeeze
  - Scraping
  - HEP

- F Sector (change mask)
  - P2 Beam
  - P2 & P3 Beam
  - F-Sector Restore

- Experiments
  - CDF Silicon Biased
  - CDF Silicon Off
  - D0 Silicon Biased
  - D0 Silicon Off
Booster: LM23

~1pC/div (per 20μs)

1ms/div

720 Hz noise

Raw

Choke

Choke+25k

Signal
MI: LM402G

~0.4pC/div (per 20μs)

5 ms/div

- Large common-mode rejection from small choke
- Injection loss shows up cleanly
Worst Case Noise: LM322

~2pC/div (per 20μs)

1ms/div

Raw

80 ft Choke

Choke+25k
Smoothing: LM522F

~0.1pC/div (per 20μs)

Raw
Smooth @ 1ms
Small Choke +25k Smoothed

10 ms/div