Proposal for a Beam Position Monitor and Feedback System

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1 Introduction

This document describes the current status of a proposal for an online beam position monitor and feedback mechanism. For the Silicon Track Trigger (STT) [1], stability of the beam position and beam tilt angle during a physics run is of crucial importance. The STT determines impact parameters of tracks with respect to the nominal beam position. A shift of the beam position biases the impact parameter measurement . In order to keep the trigger rate due to these fake impact parameters at a low level, the STT requires the position of the beam to be stable within 30 μm. This corresponds to approximately the width of the beam. The tilt angle between the beam and the Silicon Microstrip Tracker must be smaller than 200 μrad. Knowledge and stability of the beam position and tilt may also be of importance for the Level 1 trigger based on tracks in the Central Fiber Tracker (CFT), or in the Level 3 trigger.

During the TeVatron Run IB period, tests on beam motion were undertaken by CDF in collaboration with the beams division [2]. Using a set of accelerator corrector magnets, the beam was moved in a controlled manner in the CDF interaction point, without changing the beam position at other places along the ring.

It is therefore proposed to measure the beam position in the DØ interaction point during data taking. This beam information can be fed back to the beams division for beam position corrections in order to keep the beam at its nominal position. It is expected that the measurement will be updated every few minutes, depending on beam stability. Beam corrections are limited to $\pm$1.1 mm in position and 1500 μrad in angle (these numbers are taken from [2] and need to be confirmed for the current accelerator lattice).

In the remainder of this document, the run scenario and the several components of the beam monitor are described. Also, some discussion points are listed.

2 Run Scenario

For the purpose of this monitor, the beam is parameterized by its centroid position (X_0, Y_0) and the tilt of the beam spot in the xz and yz planes (A_x, A_y). During physics runs, the beam monitor continuously receives information on the beam parameters. As long as these parameters are within a predefined range, no special action is undertaken. If the beam moves out of this range, an alarm is issued to the control room, and a request to move the beam is sent to the beams division. In this way, the beam is kept stable at the position it had at the beginning of the store.

At the start and end of each run, the beam monitor writes the beam parameters to a database. Significant movements are logged to the same database. Moreover, the beam parameters are made available to the STT (and possibly others). In the very first run of a new store, no information is available yet about the beam position in the store. Therefore, the STT uses the parameters from the previous store. During the first run, new beam parameters are determined. These are used by the STT in the second run of the store.

3 Beam Position and Tilt

3.1 Algorithms

The beam parameters (X_0, Y_0, A_x, A_y) can be obtained from track information in two different ways.

1. Using a vertex based algorithm. Explicitly reconstruct primary vertices on an event-by-event basis. Then use vertices from a certain number of events to infer the beam position and tilt.

2. Using a track based algorithm. Collect a sample of tracks (about 500) from a set of events. With the simple algorithm described in [3], the beam parameters can be calculated from these tracks without calculation of vertices.

Both algorithms should give the same result. The track based algorithm needs fewer events for a stable result and is therefore faster.

3.2 Vertex Examine

The `vertex_examine` package gets events from the Data Distributor and uses it to reconstruct primary and secondary vertices. A package `beam_tilt` has been written to calculate beam position and tilt. Both algorithms described before are implemented. In principle, `vertex_examine` and `beam_tilt` have been integrated and can provide the beam monitor with the necessary information.

At this point, it is not clear which of the two algorithms is going to be used for beam monitoring. This depends on the event rate at which the Vertex Examine can be run and on the required accuracy of the measurement. Also, it has to be studied whether any biases are present in beam position measurements due to certain triggers, or due to malfunctioning of parts of the detector (in particular the tracking system).

These issues cannot be addressed until the tracking system is fully operational and vertices and beam parameters are calculated by Vertex Examine. Clearly, the Vertex Examine must run to ensure a useful beam monitoring and beam stability.

4 Significant Event System

4.1 Input

Information on the DØ run state is provided by the Significant Event System (SES). This includes begin / end of store signals, begin / end of run signals, store / run numbers, run type and luminosity block number (lbn). The lbn is used as a time stamp. Store and run numbers are needed for proper logging of beam parameters, especially to tag runs where large shifts in beam parameters occurred. Moreover, they are used, together with begin / end of store / run signals to trigger the acceptance of information from Vertex Examine, and to trigger output to e.g. a database.

4.2 Output

The SES is used to inform the shift crew about the state of and alarms from the beam monitor. This implies that no separate display for the beam monitor is proposed. Information to be sent to the SES includes the running state of the beam monitor (e.g. 'no data from Vertex Examine', 'connections lost'). Warnings are issued to the SES in case of minor beam shifts. In case of a large shift, an alarm is activated. Clearly, if the feedback mechanism to the accelerator is running, no large beam shifts should occur.

5 Output to STT

The beam parameters are written to a Python `pickle` file. Information on which data these parameters are based is added (e.g. run-number, luminosity block number). During the STT initialization, this file will be read and used to download the beam parameters to the track-fit hardware modules. The contents of the `pickle` file are updated every time a new measurement becomes available. Thus, the STT always reads up-to-date information.

Other interested parties (e.g. Level 1 CFT trigger, Level 3 trigger) can access beam parameters from the same `pickle` file.

6 Database Output

Beam parameters are logged to a database at the begin and end of each run and whenever significant shifts occur. Also, an entry is added whenever information from the beam monitor cannot be trusted. For offline analyses, this information must be available to be able to reconstruct what happened during data taking. The STT is also going to record what is loaded into the track-fit hardware.

Currently, it is not decided yet which database is going to be used for this. A good candidate is the runs-database.

7 Interface to Beams Division

In the accelerator controls network (ACNET), devices have been set up to log beam parameters as measured by DØ and CDF. The DØ parameters are written to ACNET as often as they are measured (once every few minutes).

ACNET can be accessed in two different ways.

1. Via the existing luminosity interface.

2. Via an interface exclusively used by the beam monitor.

Luminosity information is being written to ACNET approximately once every five seconds. Beam information is updated at a much lower rate.

No automatic system to adjust beam positions based on measurements from the experiments is implemented yet by the beams division. The precise structure of the DØ interface to ACNET depends on how the automatic beam adjustment is going to be done. Therefore, this part of the beam monitor needs to be discussed with the beams division.

8 Technical Details

The transfer of data between the beam monitor on the on side, and the Vertex Examine and the SES on the other side, is done with the tools in the DØ Inter Task Communication (ITC) package. The type of connections to the database and the ACNET interface are not known yet. The beam monitor itself is written in Python.

9 Discussion Points

A few major issues are still open for discussion.

1. In which database is beam parameter information saved?
2. How is information passed on to the beams division (interface to ACNET)? This needs to be discussed between DØ and the beams division.

The following questions must be addressed at a later stage, when beam information measured by DØ becomes available, and a first version of the beam monitor is built. It largely depends on the beam stability.

1. Which algorithm is used to calculate beam parameters?
2. What is the required update frequency of beam information?
3. How accurate is the beam parameter measurement and what is the resolution?
4. What is the range of allowed beam fluctuations?
5. What is the range of possible beam corrections?
6. Do certain triggers bias the beam measurement?

The first two issues are related. The choice of algorithm depends on the required update frequency and the possible frequency, which may be limited by the Data Distributor. In principle, the track based algorithm can be run on any set of tracks, e.g. at Level 3.

References

[1] The DØ Collaboration, *A Silicon Track Trigger for the DØ Experiment in Run II – Proposal to Fermilab –*, DØ Note 3516, 1998.

[2] Paul Derwent, *Beam Motion and Feedback*, CDF Note 3859, 1999.

[3] Hans Wenzel, *Fitting the beam position with the SVX*, CDF Note 1924.