BEAM HALO MONITORING at CDF:

WHY and HOW We Provide Additional Beam Quantities to Beams Division from within the CDF Collision Hall?

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ABSTRACT

Losses from the Tevatron beams have been shown to produce a halo which contributes to backgrounds in CDF Detector. We have installed arrays of scintillation counters in the B0 (CDF) collision hall to provide a measure of the beam halo. We describe the physical configuration of these counters, their performance and give their designation in the Fermilab Accelerator Network (**ACNET**). We show correlations between these new devices and other accelerator parameters as described in CDF Note 5936 [1]. Finally, we remark on some further results.

1 Introduction

- Tevatron, even in nominal conditions, has a beam halo and losses accompanying the protons (p) and antiprotons ($\bar{p}$). Beam halo produces accelerator related backgrounds in the CDF and DO detectors.
- This background may effect physics analyses by faking γs, μs, ...
- When the level of backgrounds are high, the radiation safety of the detector parts also becomes an issue.
- Monitoring the beam quality in realtime is an important part of data taking routine.
- CDF has beam loss monitors (BSCs), close to the beam pipe, which aim to monitor the small angle beam losses affecting the subdetectors in the tracking volume [2].
- Since the beginning of Run II, CDF has observed unexpectedly high backgrounds related with losses in Tevatron beams.
- We installed two counter arrays in the CDF Collision hall as Beam Halo Monitors (BHM).
- The BHMs detect the halo particles in full azimuthal coverage and at maximum available radial and longitudinal distance from the CDF Interaction Point (IP).
- Large radii positioning of the BHMs allow beam halo monitoring for the outer regions of the detector making them complementary to the BSCs.

The BHM data is available for online monitoring and are being successfully used to measure the beam halo.

1.2 Tevatron Ring & Losses

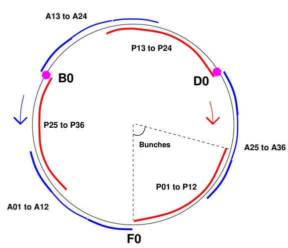


Figure 1. Beam spacing

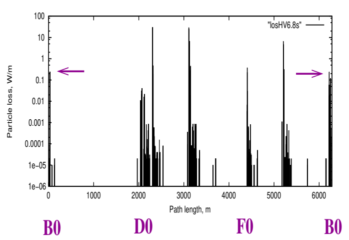


Figure 2. Proton beam losses

36 p and $\bar{p}$ bunches are in Tevatron ring for the 396 ns configuration (bunches repeating every 396 ns in the active period) Bunches are injected at F0. The period where there are no beam bunches is called Abort Gap (**AG**) [3].

For a certain combination of collimator settings along the beam line, one can estimate the losses around the ring [4]. The arrows point to the maximum values of losses expected at CDF for this specific study.

1.3 A Background Event in CDF Detector

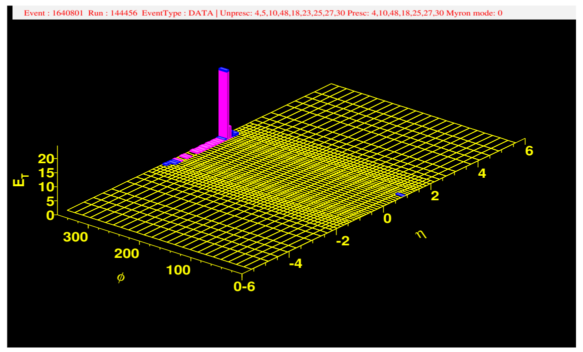


Figure 3. Lego plot showing the $\eta - \phi$ distribution of transverse energy (E_T) deposition in CDF Central Calorimeters for an event from run 144456.

The event in lego plot has:

$$E_T = 36 \text{ GeV (80\% EM)} \quad \text{and} \quad \not{E}_T = 36 \text{ GeV} .$$

as measured by the central calorimeters (Fig. 5) with **no visible tracks** in tracking volume. It therefore is a $\gamma + \not{E}_T$ signal candidate, a signature for exotic physics. This event topology with $\not{E}_T$ at $\phi = \pi$ is found to be excessive for the same run.

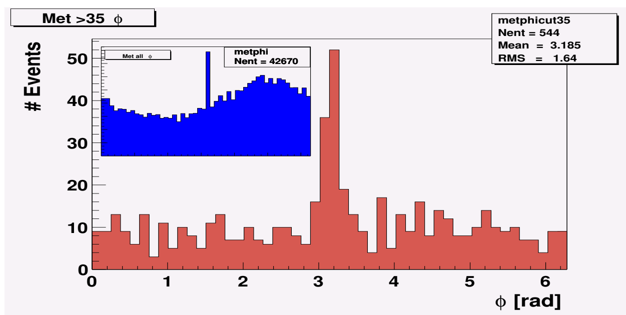


Figure 4. ϕ distribution for $\not{E}_T$ in run 144456. Data is obtained from ObjectMon, a CDF online monitor. Red histogram contains events satisfying $\not{E}_T > 35$ GeV cut; blue has all events.

1.4 Background Event Explained !

These events have been shown to come from high energy muons doing a hard bremsstrahlung and originating from near the CDF Roman Pots (detectors consisting of scintillating fibers) along the beam line at 57 meters downstream of $\bar{p}$ [5]. When the Roman Pots are moved out of the beamline, the peak at $\phi = \pi$ in Figure 4 disappears.

2 Installation & Setup of the BHMs

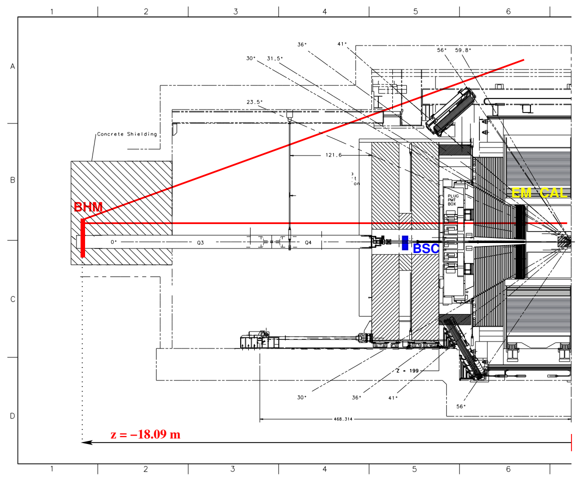
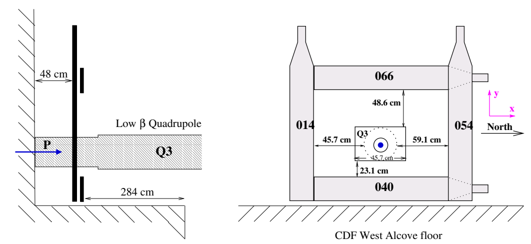


Figure 5. Elevation view of the B0 collision hall [6] shows the position of the proton BHM in the west alcove at $z = -18.09$ m. The antiproton monitor is at $z = +16.64$ m. Note that the calorimeters and the μ chambers are within the line of sight of BHMs (drawn for the top counter).



(a) (b)

Figure 6. Configuration of proton counters around the low β quadrupole (a) in the $y - z$ view (b) in the $x - y$ view in the west alcove. The p direction ($+z$ outwards) is shown at the beam center.

2.1 Counter Specifics

- Scintillator counters are from a spare pool originally manufactured for KTeV [7].
- The active area of the counters is 15 cm X150 cm.
- The PMT bias voltages are set 100 V above the knee of production-time plateau curves obtained with a discriminator threshold of 30 mV.
- After installation, the ungated singles rates (dark current) for each counter were measured using the same threshold of 30 mV at these bias voltages.

Counter ID	PMT bias Voltage (V)	Dark Count Rate (**Hz**)
E083	1875	50
E059	1637	91
E042	1888	32
E003	1785	184
W054	1668	114
W066	1495	84
W014	1843	22
W040	1786	60

Table 1. Operating parameters for counters.

2.2 Readout Logic

Beam halo is measured by forming a coincidence between the counter signals and beam bunch signal as the bunch passes through the plane of the counter array on their way to the CDF IP. In CDF, collision times are defined by the Bunch Crossing (**CDF_BC**) signal (38 ns wide gates). For the coincidence, CDF_BC signal is time-aligned with counter signals using a delay line. This alignment takes into account the 5 ns time-of-flight (TOF) difference between p and $\bar{p}$ side.

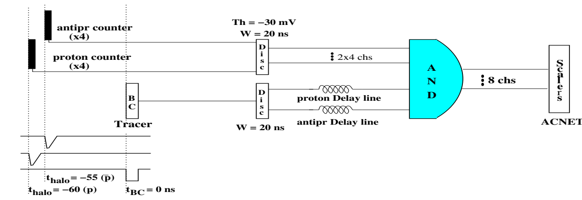


Figure 7. Logic setup for BHMs including the TOF of p & $\bar{p}$ to the CDF IP.

2.3 Coincidence Curve

Time-alignment for monitors is determined using a coincidence curve technique. Given a fixed counter signal propagation time, coincidence rates are measured as a function of the delays applied to CDF_BC. The mid-points of the coincidence plateaus is chosen to be the delay value. The *RMS* of the peaks is $\sim$ 35-40 ns as expected. The difference of $\sim$ 10 ns in the risetime of collision peak for p and $\bar{p}$ is a result of the relative differences in the z positions of the counter arrays.

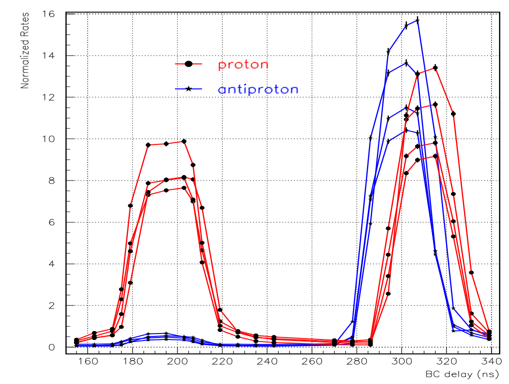


Figure 8. Coincidence curve for the CDF_BC signal showing the halo and collision coincidence peaks. Statistical errors are also shown for the data points.

2.4 Rate Calculation for the ACNET Scalers

The rates for the individual counters are calculated [a] using:

$$\text{Rate} = \frac{N_{2i} - N_{1i}}{N_{20} - N_{10}} \times (\text{Rate of Channel 0}), \quad (1)$$

where N_{1i} and N_{2i} are the two consecutive readings of scaler channel i. The total rate of each counter array, **P**roton **H**alo **S**u**M** (C:B0PHSM) and **A**ntiproton **H**alo **S**u**M** (C:B0AHSM), are calculated as:

$$\text{Rate} = \frac{\sum (N_{2i} - N_{1i})}{N_{20} - N_{10}} \times (\text{Rate of Channel 0}) \quad (2)$$

where the sum is over channels, i. Channel 0 of both CAMAC Scalers counts the 20.7 μs clock signal (one Tevatron revolution).

[a] implemented within the ACNET software framework.