MODELING OF BEAM LOSS IN TEVATRON AND BACKGROUNDS IN THE BTEV DETECTOR *

A.I. Drozhdin†, N.V. Mokhov, FNAL, Batavia, IL 60510, USA

Abstract

Detailed STRUCT simulations are performed on beam loss rates in the vicinity of the BTeV detector in the Tevatron C0 interaction region due to beam-gas nuclear elastic interactions and out-scattering from the collimation system. Corresponding showers induced in the machine components and background rates in BTeV are modeled with the MARS14 code. It is shown that the combination of a steel collimator and concrete shielding wall located in front of the detector can reduce the accelerator-related background rates in the detector by an order of magnitude.

MODELING WITH STRUCT AND MARS14

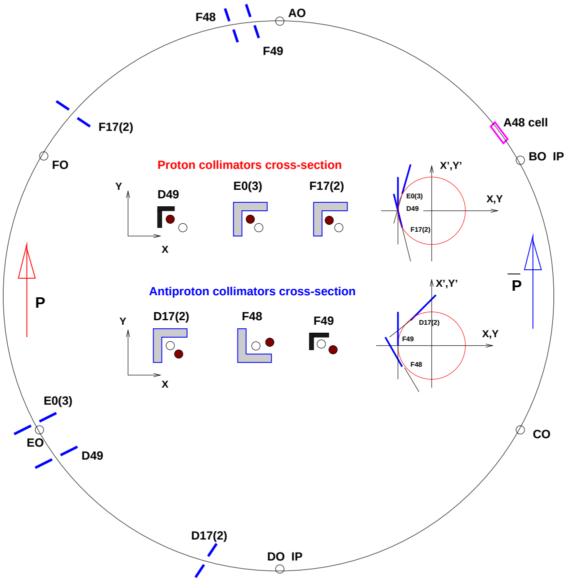


Figure 1: Tevatron Run II beam collimation system.

As a result of halo interactions with limiting apertures, hadronic and electromagnetic showers are induced in accelerator and detector components causing excessive backgrounds in the CDF and D0 collider detectors these days and in the future BTeV detector. A two-stage collimation system has been developed for the Tevatron Run II [1] to reduce uncontrolled beam losses in the machine to an allowable level. About 0.1% of halo particles hitting the collimators are scattered back into the beam pipe. These particles are lost mostly in the high-β regions upstream of the experimental halls producing the background rates in the detector on the level of a few percent of those due to $\bar{p}p$ collisions.

To evaluate these rates for the BTeV detector, a multi-turn proton beam tracking through the Tevatron lattice with elastic beam scattering on the residual gas [2] and halo interactions with the collimators was conducted with the STRUCT code [3]. All the accelerator components with their real strengths and aperture restrictions were taken into account. Using the beam loss distributions calculated this way in the vicinity of the C0, detailed hadronic and electromagnetic shower simulations with the MARS14 code [4] were performed in the machine, detector and tunnel components with a cutoff energy for hadrons, leptons and photons of 0.1 MeV. Two protective measures – a short steel collimator at the B48 location and a concrete shielding wall at the tunnel/hall interface on the proton side – were considered as a way to reduce the machine-related backgrounds in the BTeV detector.

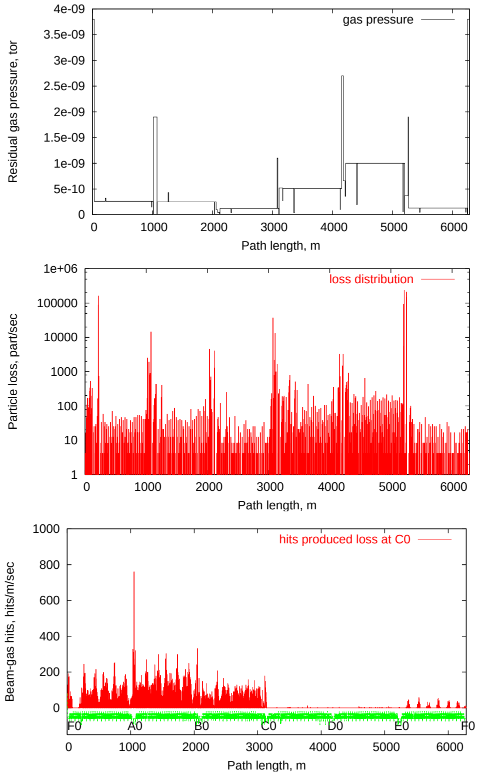


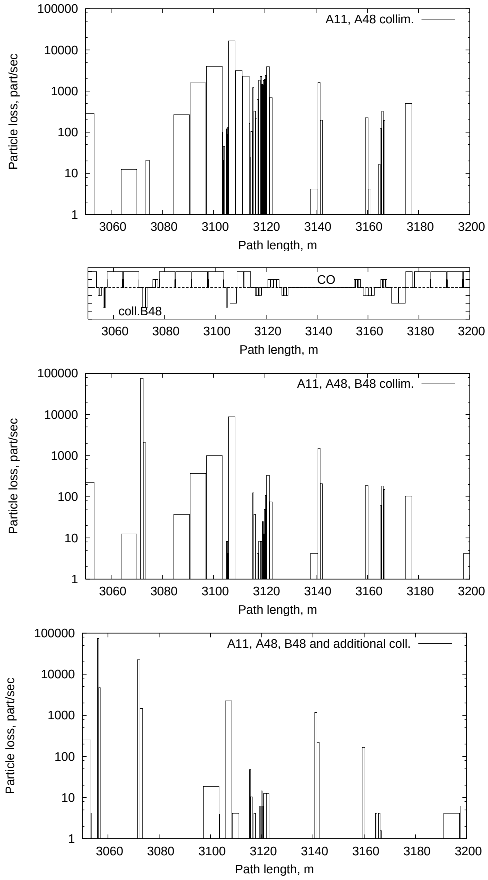
Figure 2: Residual gas pressure in the Tevatron Run-II (top), beam-gas induced loss distributions (middle) and beam-gas hit distribution for protons lost at C0 (bottom).

The Tevatron lattice, that corresponds to the BTeV operation, with $\beta^*_{x,y}$=0.35 m at C0 was used without collisions at B0 and D0 ($\beta^*_{x,y}$=1.7 m). The BTeV pixel detectors aperture radius is 2.75 mm ($31\sigma_{x,y}$), the C0 triplet quadrupoles aperture radius is 31.5 mm ($14\sigma_{x,y}$), and all other machine components with their strength and apertures were implemented in the model. The luminosity at C0 is assumed to be $\mathcal{L} = 2 \times 10^{32} cm^{-2} s^{-1}$. The collimation system (Fig. 1) and residual gas pressure distribution (Fig. 2) of the Run-II [1, 2] were assumed in the model-

---

[*] Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U. S. Department of Energy.

[†] drozhdin@fnal.gov



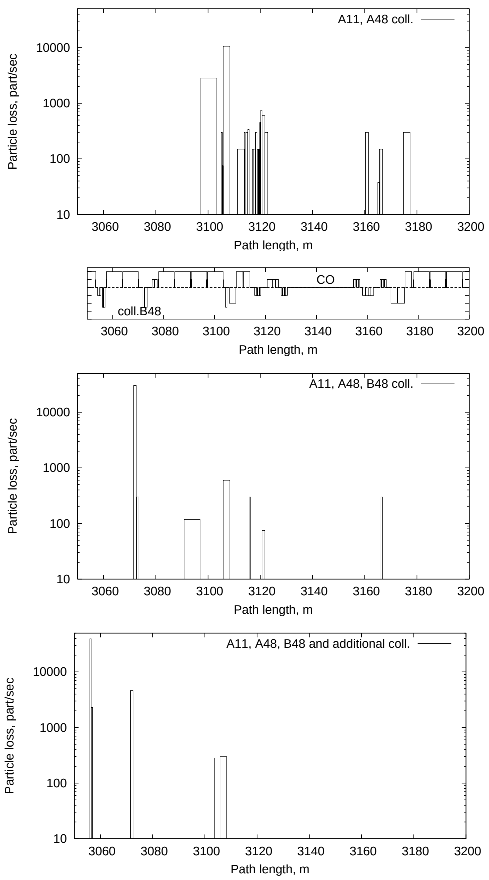


Figure 3: Beam-gas induced beam loss distributions in the CØ region: baseline (top), with B48 collimator (3-d line) and with additional collimator (bottom).

Figure 4: Collimation system induced beam loss distributions in the CØ region: baseline (top), with B48 collimator (3-d line) and with additional collimator (bottom).

ing. Detailed 3D geometry, magnetic field and materials description in a 70-m region upstream of the CØ IP were implemented in the MARS14 model for lattice and tunnel components along with a few meters of the dirt surrounding the tunnel.

RESULTS

For the current vacuum conditions, the nuclear elastic beam-gas interactions is a dominant source of beam loss on the electrostatic separators and low-β quadrupoles as shown in Table 1.

Calculated beam loss distributions in the CØ region due to elastic beam-gas interactions and collimation system inefficiency are shown in Figs. 3 and 4 for the baseline layout and the case with a 1.2-m long stainless steel collimator at the B48 warm region upstream the last four SC dipoles preceding the IP. The collimator jaws are at $12\sigma_{x,y}$ from the beam axis, with their rectangular full aperture of 15.6 mm (hor.) and 4.6 mm (ver.). A further substantial reduction is possible with an additional short collimator located at $12\sigma_{x,y}$ in $\sim 25\ m$ upstream of the B48 one. Unfortunately this collimator should be placed in a short region between superconducting magnets, that makes it difficult for realization.

The calculations show that the B48 collimator in a combination with a recently installed A48 collimator protects the BTeV pixel detectors and the low-β quads at an abort kicker prefire, reducing a number of particle lost by three orders of magnitude.

Particle flux isocontours (E_{th}=0.1 MeV) in the orbit plane in the 60-m long region preceding the BTeV experimental hall are presented in Fig. 5. Shown are neutrons in the baseline configuration and charged hadrons for the case with the B48 collimator and a 2-m concrete wall at 12.7 m upstream of the CØ IP. Fig. 6 shows hadron flux XY-isocontours at the entrance to the hall (12.2 m from IP) for the case with the B48 collimator and shielding wall.

Total background rates are summarized in Table 2. The dominant component is photons: about 10^8 soft photons per second (baseline) entering the hall around the beamline. There is no wall effect at R<0.25 m. The B48 collimator

Table 1: Beam loss rates (10^4 s^{-1}) in the 70-m regions upstream of DØ and BØ (now) and CØ (2009) with Run-II vacuum parameters.

Source	DØ	BØ	CØ
Nuclear elastic beam-gas	8.8	8.0	9.4
Large angle Coulomb beam-gas	0.12	0.06	0.1
Tails from collimators	2.4	3.5	0.99
Elastic $p\overline{p}$ at two IPs	0.144	0.105	-

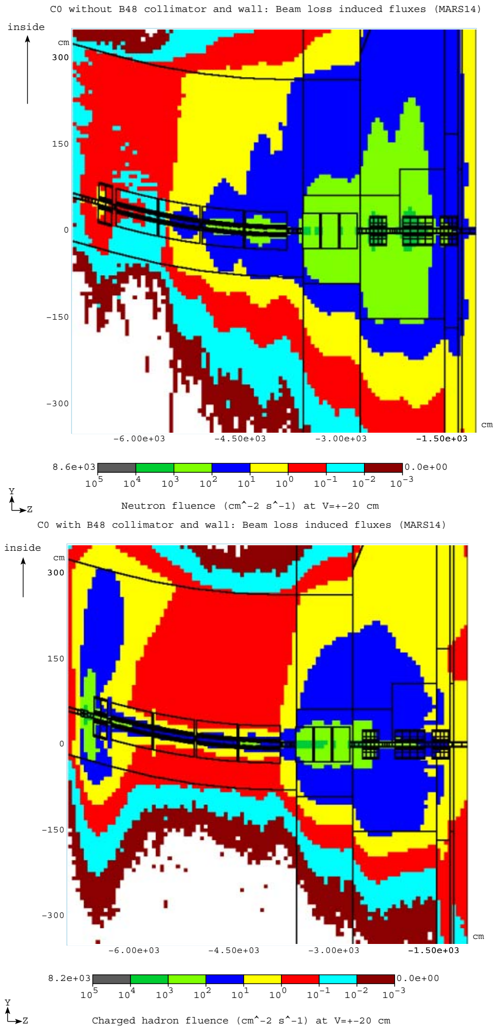


Figure 5: Particle isofluxes in the CØ region: neutrons, baseline (top) and charged hadrons with B48 collimator and 2-m concrete wall (bottom).

alone reduces the backgrounds by a factor of two compared to the baseline configuration. Installation of the shielding wall results in a combined reduction effect of a factor of ten. The numbers in the table are to be increased by 10% to account for tails from the Tevatron main collimators.

CONCLUSIONS

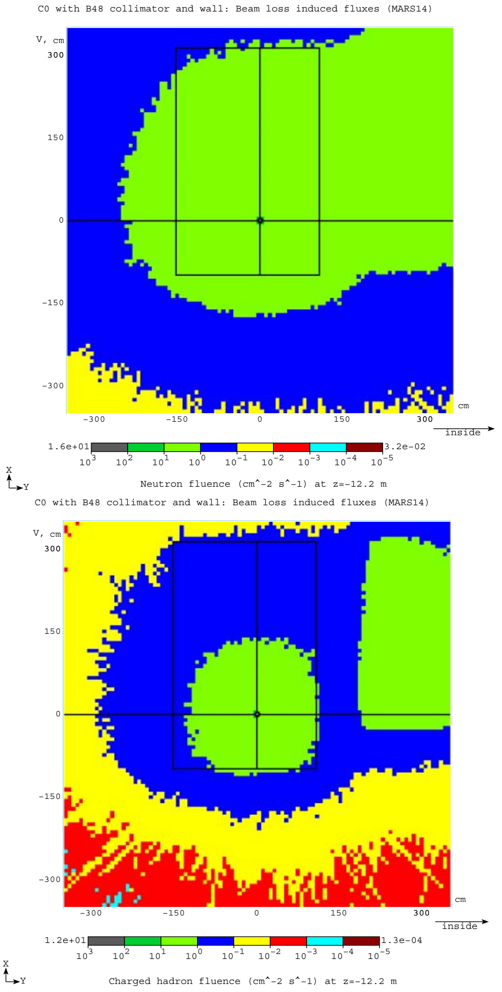


Figure 6: Neutron (top) and charged hadron (bottom) isofluxes at the entrance to the CØ hall, with B48 collimator and 2-m concrete wall.

A combined reduction of particle flow by a factor of 10 is obtained from the B48 collimator and a 2-m concrete shielding wall at 12.7 m from the IP. Machine-related backgrounds at the last muon plane of the BTeV detector are quite low: 3.5 charged hadrons and 160 photons per cm ^{2} per second. With a 5-GeV cut this makes the machine-related backgrounds in the BTeV pixel detectors at a percent level of those from $p\bar{p}$ collisions. Calculations show that a further substantial reduction is possible with an additional short collimator (unfortunately in the cold region) 25 m upstream of the B48 one. Simulations show that B48 collimator in a combination with a recently installed A48 collimator protects the BTeV pixel detectors and the low-β quads at an abort kicker prefire.

Table 2: Number of particles (10^5 s^{-1}) above 0.1 MeV entering the BTeV hall at z=-12.2 m and R<3.5 m.

Scenario	n	$h^\pm$	$e^\pm$	γ	$\mu^\pm$
No B48, no wall	24.2	14.5	58.9	1147	2.80
B48, no wall	11.0	9.29	42.4	730	1.81
B48, 2-m wall	6.29	2.48	7.55	132	1.00

REFERENCES

[1] M.Church, A.I.Drozhdin, A.Legan, N.V.Mokhov, R.Reilly, “Tevatron Run-II Beam Collimation System”, Proc. 1999 PAC New York,p. 56, Fermilab-Conf-99/059 (1999).

[2] A.I.Drozhdin, V.A.Lebedev, N.V.Mokhov, et al., “Beam Loss and Backgrounds in the CDF and DØ Detectors due to Nuclear Elastic Beam-Gas Scattering”, Proc. 2003 PAC Portland, OR, Fermilab-FN-734, Fermilab-Conf-03/088 (2003).

[3] I.S.Baishev, A.I.Drozhdin, N.V.Mokhov, “STRUCT Program User’s Reference Manual”, SSCL–MAN–0034, 1994; http://www-ap.fnal.gov/∼drozhdin/

[4] N.V.Mokhov, “The MARS Code System User’s Guide”, Fermilab-FN-628,1995; “Status of MARS Code”,Fermilab-Conf-03/053, 2003; http://www-ap.fnal.gov/MARS/.