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# Radioactivation Considerations for the HEB Test Beams and Beam Absorbers*

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## Introduction

The primary locations of radioactivation in the High Energy Booster (HEB) will be the beam absorbers and in the target-beam dump assembly used for producing the test beams. The purpose of this note will be to make preliminary estimates of the radioactivation of the components of these systems. These will be based, primarily, upon experience gained in the design of Tevatron components.

## Operating Conditions

At this point in time in the design, the expected operating conditions during "stand alone" usage of the HEB are as follows:

A maximum of $10^{13}$ protons per spill will be accelerated
A 5 minute cycle time (including a 2 minute spill) is assumed (this parameter, by itself, is irrelevant for the present discussion)
72000 cycles per year would be accelerated for test beam usage (compared with ≈ 28000 cycles/yr for injection)
Approximately 10 % of the spills will be delivered to beam absorbers.
Thus, about 6.5 X $10^{17}$ protons/yr will be sent to test beams and 7.2 X $10^{16}$ protons/yr will be sent to the beam absorbers.

## Test Beam Targetry

The test beam target stations might be expected to be very similar to those used in the fixed target program at the Tevatron. For purposes of long-term radioactivation, the relevant parameter is the *average* targeting rate of 2.1 X $10^{10}$ $s^{-1}$. The radiation safety considerations used at the Tevatron have been documented in detail in the Tevatron II Safety Analysis Report and its appendices. Typically, these facilities were designed to handle annual integrated intensities of $10^{18}$ protons at 1 TeV and so are in a quite analogeous radioactivation regime. The attached figure is a graphical representation of one such target pile, that used in the Proton area "PB" beam. In such a generic pile, a target is used to produce secondary particles. The sweeping magnets serve to deflect the primary beam into a suitable dump. The dump usually has a hole to accept the desired secondary particle. The target is usually 1 to 1.5 interaction lengths long. The exact details of target angle, sweeping magnet field integral, and dump hole angle and size are, of course, highly sensitive to the intended usage. In the particular case shown, the primary purpose is to produce an electron by conversion of $\pi^0$ decay photons at zero degrees immediately downstream of the components shown. For all conceivable applications, the vast majority of the radioactivation will be at this location, since the desired secondary test beam intensity will be a factor of at least $10^6$ lower than that of the incident proton beam.

First I consider the bulk exterior shielding. For this I will use the adaption of Barbier's danger parameter (*Induced Radioactivity*, 1969) discussed by Gollon [IEEE Trans. Nucl. Sci. **NS23 #4** (1976)1396] . The dose rate, D (mrad/h), is given by the following formula:

$$D = \frac{\Omega}{4\pi}\omega S$$

where the fraction is that of solid angle subtrended by a thick object and for contact residual dose rates is taken to be ≈ 0.5, $\omega$ is a parameter due Gollon which makes the conversion between star density rate (stars $cm^{-3}s^{-1}$) to residual absorbed dose rate (mrad/h) taking into account the pecularariaties of iron. S, then, is the star density rate. Gollon gives two values for the $\omega$ parameter, 9 X $10^{-3}$ for infinite irradiations with no decay time and 2.5 X $10^{-3}$ for 30 day irradiations with 1 day decay time. Values for other conditions can be obtained by simply scaling against the danger parameter curves of Barbier. For example, after 6 months, values about a factor of 10 lower would be expected. Thus one can calculate the star density at the surface using CASIM or some other similar code and estimate the residual dose rate using the stated operating conditions. Such calculations were made during the course of the Tevatron II design work for the NM and PB target piles with, conservatively, the following results:

| Location | Maximum Star Density (stars $cm^{-3}$ per proton) | Residual Dose Rates at Contact (mrad/hr) (at turnoff) | (6 months after turnoff) |
|---|---|---|---|
| front | $2.0 \times 10^{-5}$ | 1900 | 850 |
| side/top (near target) | $1.0 \times 10^{-7}$ | 9.5 | 1.0 |
| side/top (near dump) | $6.0 \times 10^{-7}$ | 54.0 | 5.0 |
| back | $1.0 \times 10^{-6}$ | 95.0 | 10.0 |

In a separate Fermilab TM (TM-1497), comparisons of predictions with measurement are reported for one of these Tevatron II target piles and show reasonable preliminary agreement.

Other quantities of radiological concern have been studied for the Tevatron II installations. For example, the above considerations of residual dose rate and groundwater activation where the chief ones determining the size of the steel lateral shielding. In a separate Fermilab TM (TM-1168) such matters as the activation of cooling water in the sweeping magnets, the activation of the sweeping magnets and of the beryllium target are described. These will be simply be referred to here since the expected integrated intensities are so similar.

## HEB Beam Absorber

C. T. Murphy, F. Turkot, and A. Van Ginneken have done a detailed safety analysis of the Tevatron beam absorber which will be documented in Fermilab TM-1196. According to this document, groundwater activation considerations "rate" this beam absorber dump for a maximum of 7.7 X $10^{17}$ protons per year. Many other aspects such as residual dose rates, cooling water activation, structural integrity, etc were studied. Given the much more severe operational demands on this beam absorber at the Tevatron (a factor of 10 in annual intensity), the design of an appropriate beam absorber for these test beams is straightforward. Of course, one needs to also include the number of protons expected to be absorbered during periods of injection into the collider. Total activities expected for this beam absorber used in the test beam mode can roughly be scaled from the more detailed calculations presently available for the 20 TeV beam absorbers by the factor $[(7.2 \times 10^{16})/(2 \times 10^{17})] \times [1/20]^{0.8} = 0.03$.

VERTICAL CROSS SECTION OF PB TARGET PILE
HORIZONTAL SECTION IS SIMILAR
(Concrete walls are 1 m distant on one side,
about 2.5 m distant on other side,
and concrete ceiling is about 5 m above.)