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SINGLE PASS COLLIDER MEMO CN-332**TITLE: BACKGROUND RADIATION IN THE SLC R FROM COLLIMATORS AND TUNE-UP DUMPS IN THE****ARCS****AUTHORS: T. M. Jenkins****SLAC-CN--332****DATE: 8 July 1986****DE86 013387**

INTRODUCTION. There are various beam intercepting devices between the interaction point and the beam dumps. Of these, the adjustable collimators, collimator PC18 and the tune-up dumps will intercept enough of the beam to warrant calculating the fluxes inside the interaction hall from them. The three types of devices which are of concern are:

1. **Tune-up dumps.** There are two of these in each line. One or the other will be placed in the beam line 3 hours every day, intercepting full beam current (5×10^{10} electrons per pulse), but at a reduced rep rate of 10 pps (i.e., 4 kW beam power). Beam will strike from either direction (i.e., before reaching the IP or after having passed the IP).
2. **Adjustable collimators.** These will intercept differing amounts of the beam after the beam has passed the IP.
3. **One collimator, PC-18** is expected to intercept 10% of the full beam power (7.2 kW) continuously after the beam has passed the IP.

Whether the beam has passed the IP or not is important in choosing a source term, primarily for photons. Neutron calculations here are done only for giant resonance neutrons (which are isotropic) since they are much more abundant than higher energy neutrons.

The fluences of neutrons and photons in the interaction hall from these sources is the subject of this note.

CALCULATIONS. CN-219¹ covered radiation backstreaming from the main SLC dumps to the interaction halls. Since that note, other devices have been identified which will be sources of radiation seen in the interaction region. For these calculations, we make the following assumptions:

1. Except for ST-4 and PC-3, all beam intercepting devices are shadowed from the CEH either by beam transport components, or by tunnel walls. Thus, we ignore the high energy, forward-directed radiation component and concentrate on the lower energies, i.e., giant resonance neutrons and bremsstrahlung.
2. Any tunnel curvature between the dump and the CEH is ignored since it is slight.
3. There is attenuation by the air in the tunnel, but any attenuation of the scattered radiation by material in the tunnel is ignored. This is done since beam transport components occupy only a small fraction of the tunnel, but

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the answers will be conservative. The apparent removal mean-free-path for neutrons in air is 52.5 m (172 ft), and for photons is 305 m (1000 ft).

For photons, we use the dose rate as a function of production angle from a thick target as given in the SLAC Big Book². For the adjustable collimators and PC-18, the number in the backward direction is used;

$$D = \frac{500}{r^2} \quad R - m^2 - hr^{-1} - kW^{-1},$$

with r in meters. This is justified since almost all beam losses are from a beam which has already passed through the IP³. For ST-4 and ST-14, the number at a forward production angle of about 20° is used;

$$D = \frac{5000}{r^2} \quad R - m^2 - hr^{-1} - kW^{-1}.$$

For giant resonance neutrons which are isotropic, we use

$$H = \frac{1.25 \times 10^{12}}{4\pi r^2} \\ = \frac{1 \times 10^{11}}{r^2} \quad n - cm^{-2} - sec^{-1} - kW^{-1}$$

with r in centimeters. This is increased by a factor of 3 to account for tunnel build-up, giving

$$H = \frac{3 \times 10^{11}}{r^2} \quad n - cm^{-2} - sec^{-1} - kW^{-1}.$$

Transmission down the tunnel may be handled in a number of different ways. For example, since there is the possibility of a direct line-of-sight to the CEH (no tunnel curvature), the fluences can be calculated directly, using appropriate build-ups. There is some problem with this in that the CEH is partially shadowed, to some extent, by the beam transport components close to the source. Alternately, one can calculate fluences close to the source (for example, in the tunnel aisle), and then transport these down the tunnel using ducting formulae. Finally, as a third method we made measurements inside the SLC arc using a CF neutron source (which also has a sizeable photon output) placed on top of the beam pipe between bending magnets, and to the extent that this approximates the source term with SLC, we could use this. However, I'm reluctant to use this last data since it is not complete enough i.e., it needs to be augmented with more measurements at different locations in the tunnel, and with more beam transport components in place.

Using the ducting formula gives neutron numbers that are a factor of 2 higher than the direct calculation for the close-in distances, but about the same numbers for the longer distances (i.e., beyond about 40 m). Using the Cf measurements gives neutron numbers that are about 38% lower than the direct calculation at close distances, but a factor of 3 lower for the longest distances calculated. This isn't too important since the close distances (i.e., devices near the IP) generate all the significant fluences. Thus, for this report, we use a direct calculation along with attenuation by the air for the neutron fluences.

For photons, we also will use a direct calculation (i.e., we let the fluences drop off as $1/r^2$ and include attenuation in air). This gives numbers that agree with the Cf measurements for distances greater than 13 m, and which agree with ducting formula for ST-4, but which are lower for the adjustable collimators than using the ducting method.

The type, location and beam loss of each device are listed next.

- * Tune-up dumps, ST-4 and ST-14. ST-4, located between Q-4 and Q-5, is 19.8 m (64.9 ft) from the IP. ST-14 is located 146 m (480 ft) from the IP. Full beam (5×10^{10} electrons per pulse) is lost but at a reduced rep rate.
- * Adjustable collimators. These are expected to intercept varying amounts of the beam all the time. The locations and beam losses at these adjustable collimators (in $e^\pm$ per pulse)³ are listed below:
 - . PC-3 - 13.3 m (43.5 ft) from the IP, (Low loss),
 - . PC-4 - 17.6 m (57.7 ft) from the IP, (Low loss),
 - . PC-5 - 24.8 m (81.2 ft) from the IP, (Low loss),
 - . PC-6 - 32.0 m (105 ft) from the IP, (Low loss),
 - . PC-6.5 - 42.4 m (139 ft) from the IP, (Low loss),
 - . PC-7.5 - 46.8 m (153 ft) from the IP, (4.0 + 8),
 - . PC-8 - 50.6 m (166 ft) from the IP, (2.8 + 8),
 - . PC-10 - 65.5 m (215 ft) from the IP, (9.9 + 8),
 - . PC-10.5 - 71.9 m (236 ft) from the IP, (1.3 + 9),
 - . PC-11.5 - 77.2 m (253 ft) from the IP, (9.4 + 7),
 - . PC-12 - 81.0 m (266 ft) from the IP, (4.9 + 7)
 (where the convention is to read 4.0 + 8 as 4.0×10^8).
- * PC-18, located in front of the septum near Q18, is 124 m (407 ft) from the IP. It intercepts 1.0×10^6 electrons per pulse in the South arc and 5.0×10^9 electrons per pulse in the North arc.

Table 1 lists the radiation levels at the IP from these sources. The values are given in number per cm^2 per pulse. For neutrons, the annual fluence, number $-\text{cm}^{-2} - \text{year}^{-1}$, is also given. For photons, we also give the annual dose in rad/yr , where the fluence-to-dose conversion factor for silicon is $4.4 \times 10^{-10} \text{ rad} - \gamma^{-1} - \text{cm}^{-2}$.

This conversion factor was arrived at in the following way:

1. Assume that the average energy of photons emerging from iron (i.e., magnets, etc) is 4 MeV, and that after at least one bounce going down the tunnel, the

average energy is about 1 MeV.

2. Assume electron equilibrium in the Si (there'll be electrons in the tunnel from air, and also from the electronic boxes around the Si devices which complicates the picture, but it's probably a good enough assumption).
3. In silicon, the energy absorption coefficient at 1 MeV is $0.0277 \text{ cm}^2/\text{g}$. Then, the conversion factor is derived from

$$\begin{aligned} \text{rad} &= \phi \left(\frac{\gamma}{\text{cm}^2} \right) \times \frac{1.6 \times 10^{-8} \text{ g-Rad}}{\text{MeV}} \times \text{MeV} \times \frac{2.77 \times 10^{-2} \text{ cm}^2}{\text{g}} \\ &= 4.4 \times 10^{-10} \frac{\text{rad}}{\gamma/\text{cm}^2} \end{aligned}$$

Table 1
Dose and fluences in the IR

Source Location	Beam Loss $e^\pm/\text{pulse}$	Photons		Neutrons	
		$\gamma/\text{cm}^2/\text{pulse}$	Rad/yr	$\text{n}/\text{cm}^2/\text{pulse}$	$\text{n}/\text{cm}^2/\text{yr}$
PC-3	-	-	-	-	-
PC-4	-	-	-	-	-
PC-5	-	-	-	-	-
PC-6	-	-	-	-	-
PC-6.5	-	-	-	-	-
PC-7.5	$4.0 + 8$	$1.0 + 2$	$1.1 + 2$	$1.8 + 1$	$4.6 + 10$
PC-8	$2.8 + 8$	$2.3 + 2$	$2.6 + 2$	$1.0 + 1$	$2.6 + 10$
PC-10	$9.9 + 8$	$4.7 + 2$	$5.4 + 2$	$1.6 + 1$	$4.2 + 10$
PC-10.5	$1.3 + 9$	$1.2 + 2$	$1.4 + 2$	$1.6 + 1$	$9.9 + 9$
PC-11.5	$9.4 + 7$	$3.1 + 1$	$3.5 + 1$	0.87	$2.3 + 9$
PC-12	$4.9 + 7$	$1.4 + 1$	$1.6 + 1$	0.38	$9.8 + 8$
PC-18*	$5.0 + 9$	$5.4 + 2$	$6.2 + 2$	7.3	$1.9 + 10$
ST-4	$5.0 + 10$	$3.2 + 6$	$2.5 + 4$	$2.1 + 4$	$3.8 + 11$
ST-14	$5.0 + 10$	$3.6 + 4$	$2.9 + 2$	$2.4 + 1$	$4.3 + 8$

* Numbers for PC-18 are for North arc. (Note: Read $4.0 + 2$ as 4.0×10^4 .)

A comparison of these numbers with those from the SLC dump is given in Table 2, where we note that the SLC dump numbers are different from those given

in CN-219 since the geometry has changed somewhat, and an error was made on the photon number.

Table 2
Comparison of fluences with Dump fluences

Source Location	Photons		Neutrons	
	$\gamma/\text{cm}^2/\text{pulse}$	Rad/yr	$n/\text{cm}^2/\text{pulse}$	$n/\text{cm}^2/\text{yr}$
Dump	2.0 +1	2.3 +1	7.3 -2	1.9 +8
All Adjust.				
Collimators	9.9 +2	1.1 +3	6.1 +1	1.3 +11
PC-18*	5.4 +2	6.2 +2	7.3	1.9 +10
ST-4	3.2 +6	2.5 +4	2.1 +4	3.8 +11
ST-14	3.6 +4	2.9 +2	2.4 +1	4.3 +8

* Numbers for PC-18 are for North arc. (Note: Read 2.0 +1 as 2.0×10^1 .)

SUMMARY. The numbers given in this note are from fluences of giant resonance neutrons and bremsstrahlung that reach the IP through perhaps at least one scattering though they were calculated assuming line-of sight. This assumption shouldn't affect the fluences (or doses) at the IP since the various methods of calculating fluences give answers that are reasonably similar, and especially since the fluences are dominated by the device closest to the CEH, i.e., ST-4, and this is close enough that the method used, i.e., direct line-of-sight, is the most probable.

The numbers given in the tables are the fluences and doses from a single arc. There will be a corresponding level at the IP from the devices in the other arc (except for PC-18 which has a markedly lower beam loss in the South arc). The beam losses in the collimators closest to the IP, i.e., PC's 3 through 6.5, are listed as being very small (i.e., zero). If this turns out not to be the case, then these devices may add significantly to the fluences at the IP, but still will be small compared to those from ST-4.

We should note that a very important radiation component, namely, the high energy component including muons, wasn't considered here, but will be the subject of a future note. For this high energy component, only ST-4 will be important.

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3. K. Kozanecki and K. Young, "Estimate of Beam Losses in the SLC Final Focus", to be issued as a CN (1986).

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SINGLE PASS COLLIDER MEMO CN-332 Addendum

TITLE: BACKGROUND RADIATION IN THE SLC IR FROM
COLLIMATORS AND TUNE-UP DUMPS IN THE
ARCS - Addendum
AUTHORS: T. M. Jenkins
DATE: 24 July 1986

ADDITIONS. Two devices were missed in CN332; C1X,Y and MSK1. These are included here.

C1X,Y: Distance from the IP = 371 ft (113 m).

This device intercepts $1.1 \times 10^9 e^\pm$ per pulse. Radiation at the IP from this beam loss will be:

1. Photons: $2.2 \times 10^2 \gamma - \text{cm}^{-2} - \text{pulse}^{-1}$, and $2.5 \times 10^2 \text{ rad/yr}$.
2. Neutrons: $2.1 \times 10^1 \text{ n} - \text{cm}^{-2} - \text{pulse}^{-1}$, and $5.3 \times 10^{10} \text{ n} - \text{cm}^{-2} - \text{yr}^{-1}$.

MSK1: Distance from the IP = 26.9 ft (8.2 m).

This device intercepts $1.4 \times 10^7 e^\pm$ per pulse incoming, and $5.9 \times 10^6 e^\pm$ per pulse outgoing. Radiation at the IP from this beam loss will be:

1. Photons: $5.5 \times 10^3 \gamma - \text{cm}^{-2} - \text{pulse}^{-1}$, and $6.3 \times 10^3 \text{ rad/yr}$.
2. Neutrons: $7.1 \times 10^1 \text{ n} - \text{cm}^{-2} - \text{pulse}^{-1}$, and $1.9 \times 10^{11} \text{ n} - \text{cm}^{-2} - \text{yr}^{-1}$.

The fluences from all adjustable collimators (Table 2 of CN332) becomes (after including these numbers):

1. Photons: $6.7 \times 10^3 \gamma - \text{cm}^{-2} - \text{pulse}^{-1}$, and $7.7 \times 10^3 \text{ rad/yr}$.
2. Neutrons: $1.5 \times 10^3 \text{ n} - \text{cm}^{-2} - \text{pulse}^{-1}$, and $3.7 \times 10^{11} \text{ n} - \text{cm}^{-2} - \text{yr}^{-1}$.