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Dose estimate for zero-degree calorimeters

A. J. Stevens

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Collider Accelerator Department

Brookhaven National Laboratory

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Alan J. Stevens

Brookhaven National Laboratory
Upton, NY 11973

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I. Geometry/Description of Calculations

One issue associated with the proposed Zero-Degree calorimeters (ZCAL) is possible radiation damage to the scintillator fibers. This note describes calculations of energy deposition density (dose) using the CASIM[1] Monte Carlo code.

A crude sketch of the geometry in an IR is shown in Fig. 1 below. The ZCAL modules are approximated by rectangular blocks of tungsten 10 cm. by 10 cm. by 75 cm. The front face of a module is 18m from the crossing point. Each ZCAL module is considered to have three sources of dose: (1) neutrons from electromagnetic dissociation (ED - the signal of interest for ZCAL), (2) beam-gas interactions, and (3) beam-beam interactions. The ED dose was calculated using the standard CASIM whereas the other components were calculated using VENUS events[2] and a modified version of CASIM previously described.[3]

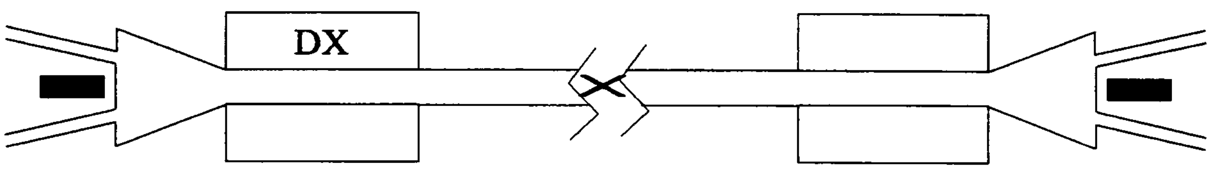

Fig. 1. Sketch Indicating two ZCAL modules (dark objects) at an IR.

In the case of the ED interaction, the geometry was not that shown in Fig. 1, but simply a tungsten block illuminated by a source of 100 GeV neutrons 18m away. The parameter critical to the maximum energy deposition is the source divergence. Here the assumption is made that the neutrons have projected angular distributions which are Gaussian with σ of 1 mrd.[4]

For both beam-gas and beam-beam interactions, the geometry illustrated by Fig. 1 is applicable. Although in principle the result depends on the material distribution in the IR (i.e., the actual detector) any such dependence is assumed to be a second order effect; the only material between the DX magnets in the simulation is a standard (0.16 cm. thick steel) beampipe.

The location of beam-gas interactions are assumed to be confined to the "warm" sections near each IR. Two such sections exist, one of length ~ 35m between the Q4 and Q3 magnets on either side of an IR, and the IR itself, of length ~ 18m, ± 9m from the crossing point between the DX magnets. Both ZCAL modules are included in the simulation where the source is in the Q4-Q3 region. Beam-gas interactions are in fact simulated by Au-proton interactions. A given VENUS event is processed many times with the point of interaction being randomly chosen.

Beam-beam interactions are simulated by minimum bias Au-Au interactions. In order to not waste computer time with soft, high p_t particles, the VENUS file was pre-processed and all particles with longitudinal momentum less than 1 GeV/c were discarded.

In the non-ED simulations, ZCAL was divided into 9 segments in the transverse directions and 5 segments in Z; thus energy deposition was binned in sub-volumes with dimension 3 1/3 by 3 1/3 by 15 cm. Additional information on approximations in the simulation are given in Ref. [3].

II. Dose Per Interaction

The maximum energy deposition density per interaction found in the CASIM simulations is shown in Table 1.

Table 1 Results of CASIM Calculations

Source	Max. Energy Dep. in GeV/g-Int
Electromagnetic Dissociation	3.68×10^{-3}
Beam-Gas Q4-Q3 (Upstream)	1.84×10^{-3}
Beam-Gas Q4-Q3 (Dnstream)	1.32×10^{-4}
Beam-Gas IR	3.16×10^{-2}
Beam-Beam	1.79×10^{-2}

In this table, the ED "interaction" assumes a single 100 GeV neutron per such interaction. The ZCAL module closest to the source in the Q4-Q3 region is called the "Upstream" ZCAL, although physically each ZCAL sees both sources, one "behind" it and one (in the other beam) on the other side of the IR.

III. Normalization/Dose per Year

In order to obtain the annual dose some normalization assumptions are required. It is important to note that the ED and Beam-Beam interactions scale by luminosity and that the beam-gas background scales by intensity. I have chosen to set the beam-gas interaction rate at a value given by Bill Christie of 0.6 interactions per cm per sec.[5] This corresponds to design beam intensity and 10^{-9} Torr pressure. Additional parameters consistent with this interaction rate are the design luminosity of 2×10^{26} cm^{-2} sec^{-1} and a total Au-Au inelastic cross section of 6.1 barns. Finally I choose a 10^7 sec year and take 100 barns for the ED cross section.[4]

Using these assumptions, and applying the conversion of 1 rad = 6.25×10^4 GeV/g to obtain a more familiar unit of dose give the results shown in Table 2. In this table the Upstream and Dnstream components of the dose per interaction given in Table 1 have been combined.

The error on the ~ **20 krad/year estimate** is not entirely clear. Only about 75 different events on the VENUS files were processed (each many times as mentioned above) which gives a statistical error of ~ 12%. The systematic error inherent in the physics approximations made likely swamps this so that the 20 krads/year estimate should not be regarded as more accurate than a factor of two.

Table 2 Dose/yr. with Assumptions in Text

Source	krads/year
Electromagnetic Dissociation	11.8
Beam-Gas (Q4-Q3)	0.7
Beam-Gas (IR)	5.5
Beam-Beam	3.5
Total:	**21.5**

<u>References/Footnotes</u>

1. A. Van Ginneken, "CASIM; Program to Simulate Hadron Cascades in Bulk Matter," Fermilab FN-272 (1975).

2. VENUS 4.12. Some of the “spectators” produced by VENUS form ions. Ron Longacre employed the FAI fragmentation model with some “tuning” to NA49 data. The set of possible ion fragments was restricted to those known to the GEANT code.

3. A.J. Stevens, "Estimate of Beam-Gas Background Rates from Upstream Source Locations in a Simple Detector," RHIC/DET Note 22 (1996).

4. S. White, private communication.

5. W. Christie, Viewgraphs in "2nd Workshop Machine Backgrounds at RHIC," S. White Ed. (1996).