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Estimate of beam-gas background rates from upstream source locations in a simple detector

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I. Description of Calculation

This note describes a calculation utilizing the CASIM Monte Carlo program[1] to estimate rates in a simple detector caused by beam-gas interactions in the long straight section (the region between the Q4 and Q3 magnets) upstream of an intersection region. CASIM was modified to read as "primaries" products of beam-gas interactions produced by an external event generator. The sample studied was a file created by Ron Longacre of Au (100 GeV/u), proton interactions created by the VENUS program.[2]

CASIM makes use of a variety of variance reduction techniques and is *only* capable of obtaining *average values*. In the version described here (a separate *muon* version exists), the world of CASIM consists only of protons, neutrons, pions, and (to some extent) ions. Produced hadrons are tracked to some threshold momentum which is normally chosen to be 0.3 GeV/c (T ~ 48 MeV for neutrons), but in the calculations described here was set to 0.1 GeV/c (T ~ 5 MeV), although cross-sections between these two energies is incorrect. When a hadron drops below the threshold momentum, the transport is terminated and *some approximation* is made for dispersal of the remaining energy. The same thing is true at each inelastic interaction in material; some approximation is made for the effects of low energy evaporation products and fragments, but no accurate transport is attempted. The photon threshold is 0.1 Mev and the electron threshold 0.5 MeV.

The quantity of interest that CASIM calculates is energy deposited in finite volumes specified by the user. If the volume is that of a tracking detector, the particle fluence is often desirable which is, to a reasonably high degree of accuracy, given by

$$F = \frac{\Delta E / \Delta V}{(dE/dx)_{min}}$$

II. Lattice Geometry - Approximations

A crude representation of the geometry is shown in Fig. 1 below

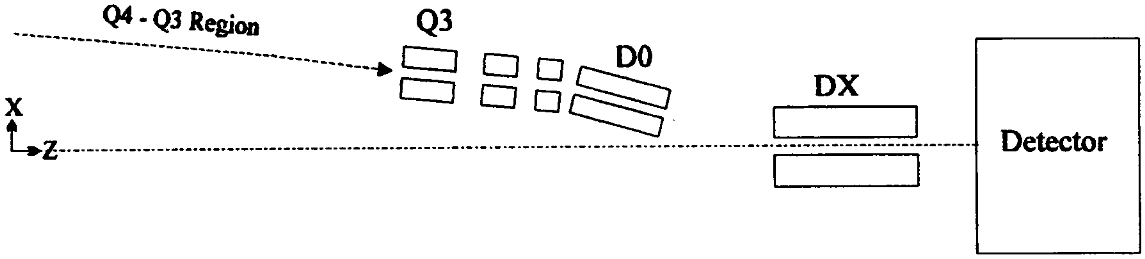

Fig. 1 Schematic of the Geometry (not to scale)

(5) No attempt was made to simulate the walls or floor of the tunnel.

(6) It should be noted that the fact that hadron transport is terminated at about 5 MeV may be a particularly bad approximation for detectors that are sensitive to low energy neutrons.

IV. Results

Each track was processed multiple times with an origin that was uniformly sampled along the 3500 cm. distance between Q4 and Q3. The best way to estimate the statistical sampling error in CASIM is to make multiple runs with different values of the random number seed. Early in the computer runs a very large fluctuation was observed which was traced to a particular alpha particle from a beam-gas interaction very near the beginning of the geometry interacting in the beam pipe near the detector. It was soon realized that this was a common occurrence. Light ions (alphas especially) are common fragments and have a direction and rigidity close to that of the beam. It is relatively *easy* for such particles to interact in or near the detector region. Separate runs were made for the ions and non-ions since the transport behavior in the lattice is so different in the two cases.

Each chamber was divided into 20 radial bins. Figs. 2 and 3 show the radial dependence for ions and non-ions.[3] The error bars on the "ions" data series represent the estimate of σ based on three subsets of the data sample.[4] The error bars on the "non-ions" are not shown, but are comparable.[5] The total fluence is, of course, the sum of ions and non-ions, and is shown in Fig. 4. **Note that the fluence close to the beam pipe is dominated by the ions and is about an order of magnitude higher than the fluence from non-ions.** The azimuth was divided into 4 bins (left, right, up, down), but no azimuthal dependence was observed within the statistical error.

V. Normalization; Comparison to Beam Halo Interactions

The results are normalized to rates presented by Bill Christie in the second "Dirt Workship".[6] Assuming 10^{-9} Torr, there are about 0.6 interactions per cm. per second in each ring at design intensity. This gives 2100 interactions in the 3500 cm. length considered. The highest fluence observed at small radii, about .06 per cm^2 per interaction, gives 126 particles per cm^2 per second.

For comparison to the beam-gas results, energy deposition was calculated in the same detector caused by beam scraping on the Q3 magnet. Here, the Au ions were simply treated as either 100 Gev/c protons or neutrons which are forced to interact with equal probability on either side of the beampipe at the position of the (horizontally focusing) magnet. The results are shown in Fig. 5 below. It is very difficult to normalize halo since the loss rate is not known. An upper

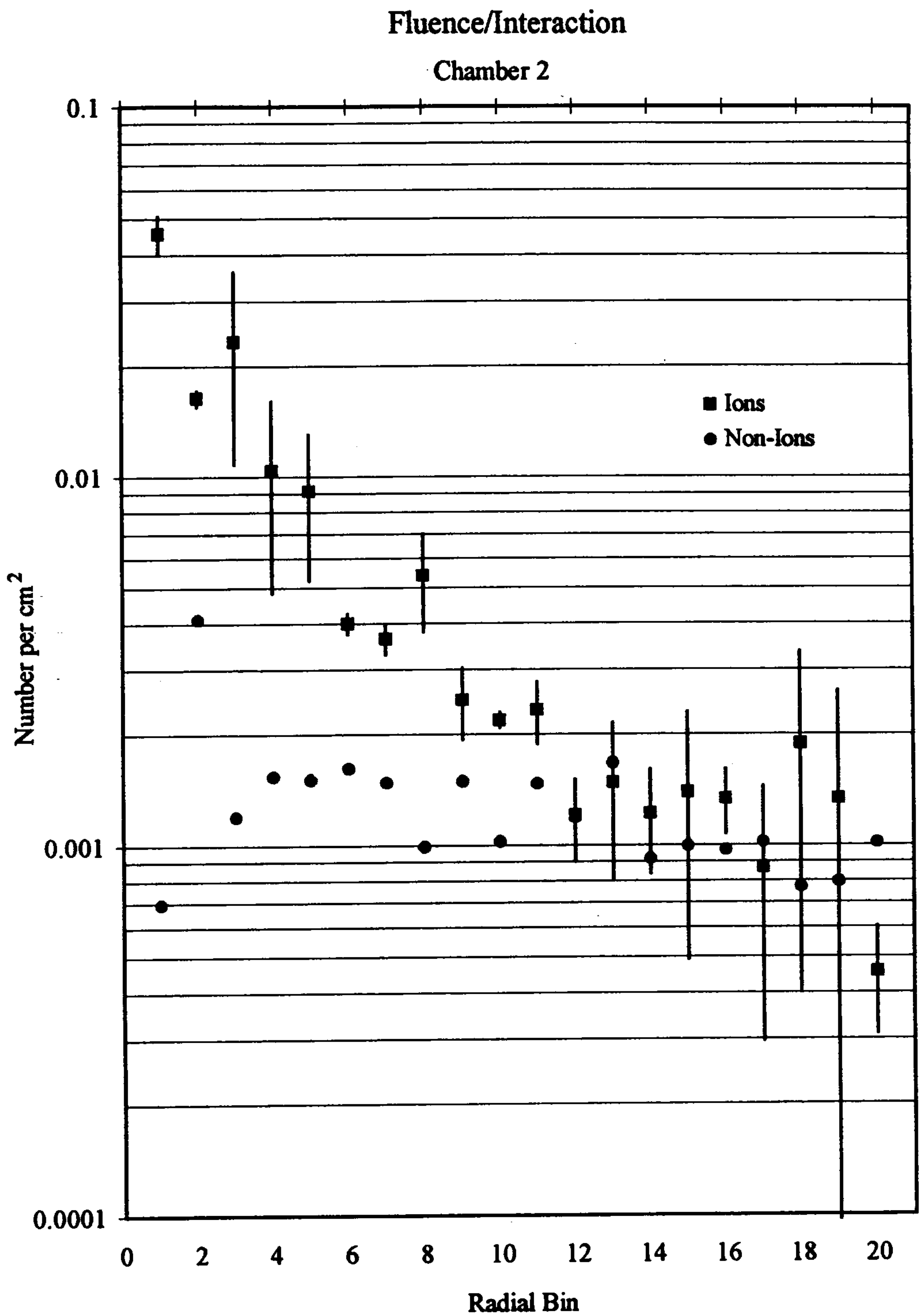

Fig. 3. As Fig. 2 but for Chamber 2

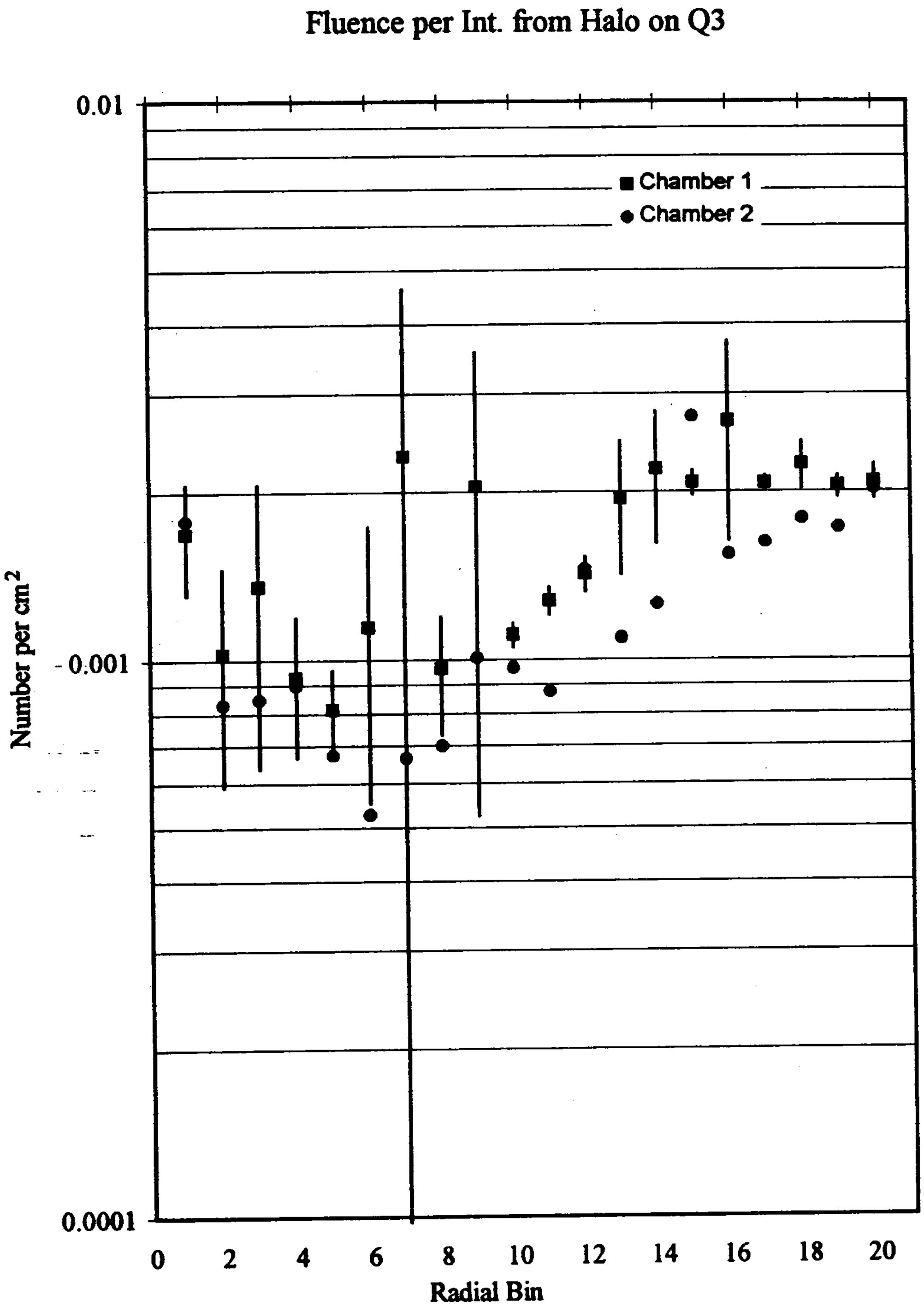

Fig. 5. Fluence from Beam Halo as Described in Text. Errors shown for Chamber 1 Only

3. The actual quantity calculated by CASIM is dE/dV in GeV per cc. The results were divided by 2.69×10^{-6} GeV/cm to obtain the fluence. The Argon gas was assumed to have density 1.78×10^{-3} g/cc.

4. The data sample is 1500 events which was divided into 3 subsets of 500 events each. The results for each subset was the average of three computer runs with different random number seeds. Each track was followed 100 times (with random vertex position) if the track was an ion and 40 times if it was not.

5. The length of computer runs was basically chosen so that the estimate of σ was less than the data value in the vast majority of bins. An exception is the second radial bin in chamber 2 for the non-ion data. Here the error was slightly greater than the value. The fact that this bin looks "high" in Fig. 3 is therefore not meaningful.

6. S. White, Ed.,"2nd Workshop Machine Backgrounds at RHIC." The relevant transparencies are the last set in this compilation. There are 54×10^{9} ions per ring.

7. Dejan Trbojevic in Ref. [6].

8. In the simulation code of this study, the "neck-down" from 7 to 4 cm occurs immediately downstream of the DX magnetic length. This is not realistic. The actual beam pipe in the experimental halls must be simulated more accurately than was done for this exercise.