STUDIES OF INDUCED RADIOACTIVITY AT THE AGS*

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Abstract

With the goals of higher proton intensities, along with the many modes the AGS now runs and those being commissioned to run, we have begun detailed studies of the beam induced radioactivity in the AGS.

Introduction

The AGS beam intensity has been steadily increasing by continuous efforts in improving operational conditions and in updating machine components and instrumentations (e.g., during the 1986 spring Fast Extracted Beam (FEB) run, 1.6 to 1.8 × 10^{13} ppp has been continuously accelerated). In addition, the number of available operation modes has also increased, i.e., Slow Extracted Beam (SEB), FEB (with Single Bunch Extraction (SBE)), Polarized Protons, and Heavy Ions. Beam-loss induced radioactivity is also increasing, and exposure to it accounts for a major part of the doses received by the AGS personnel.

By using health physics and machine data for different running conditions, comparisons can be made with the expectation that the dose rates in certain areas can be predicted based on beam losses.

Relation Between Dose and Beam Loss

The radiation in the AGS is caused by beam losses at different energies and by the associated cascade particles. It has already been established that, for induced activity where many radionuclides have been produced, the rate of decay can be approximated by (see Ref. 1):

$$\ln (1 + T/t)$$

where T is the irradiation time and t is the cooldown time. Therefore, since the dose absorbed is proportional to the number of particles lost at different energies, if we call the dose measured D (in rads/hr) and the number of particles/sec lost ξ, and by introducing a proportionally constant k (rads/hr/particle/sec), then:

$$D = k \times \xi \times \ln (1 + T/t).$$

This assumes, of course, that D is the dose at some standard distance - which is twelve inches from the beam pipe for our measurements.

Comparisons made by estimating k have been found to be consistent and have allowed estimates of the dose rate based simply on beam losses.

Data From the AGS

It is known that large beam losses occur at very specific areas in the AGS. For example, injection losses are seen at the injection region (which is from A-19 through B-5; there are 12 superperiods in the AGS labeled from A to L), transition losses are now primarily seen on the E-20 Beam Catcher and the downstream areas (from F-1 to F-4), and extraction losses occur typically on and near the extraction equipment.

The following table gives some examples of the orders of magnitudes of beam losses per AGS pulse (a typical FEB repetition rate is 1.4 seconds and SEB repetition rate is 2.8 seconds) and the approximate amounts of beam which finally get to experimenters.

	FEB Run 1986	SEB Run 1986	SEB Run 1987	
TOT HRS OF RUN	= 596	400	394	
AV INJECT LOSS	= 15.0×10^{12}	5.9×10^{12}	14.0×10^{12}	ppp
AV TRANS LOSS	= 0.7×10^{12}	0.7×10^{12}	0.5×10^{12}	ppp
AV EXTRACT LOSS	= 0.4×10^{12}	0.2×10^{12}	0.2×10^{12}	ppp
AV EXT BEAM INT	= 14.0×10^{12}	7.0×10^{12}	8.2×10^{12}	ppp

Table 1.

By taking that the dose measured in the above areas represents the loss of the beam at the respective times in the cycle, values of k can be calculated. So far, we have collected radiation data from four different beam runs and calculated values of k for the different energies (i.e., injection, transition, and extraction). The results are shown in Figures 1 through 4.

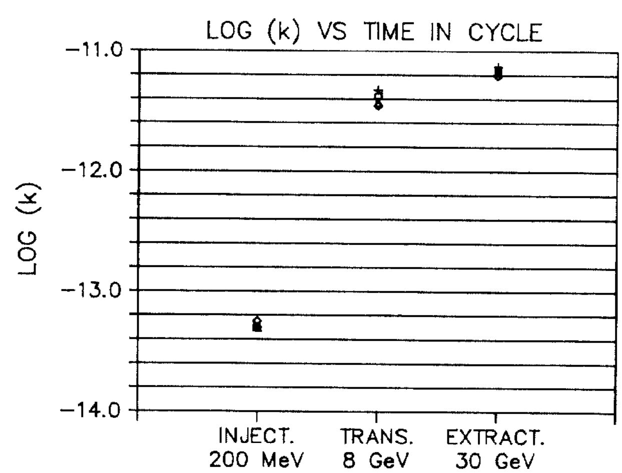

Figure 1.

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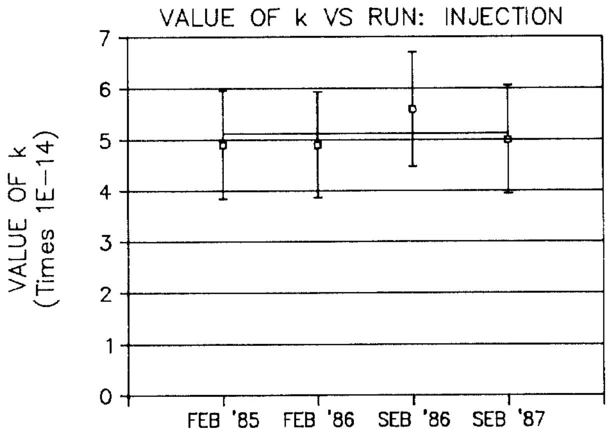

Figure 2.

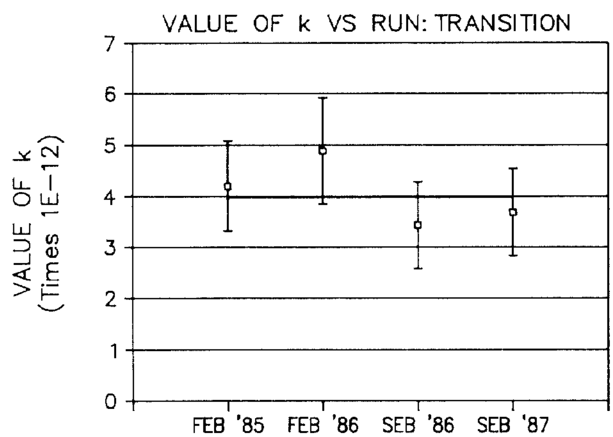

Figure 3.

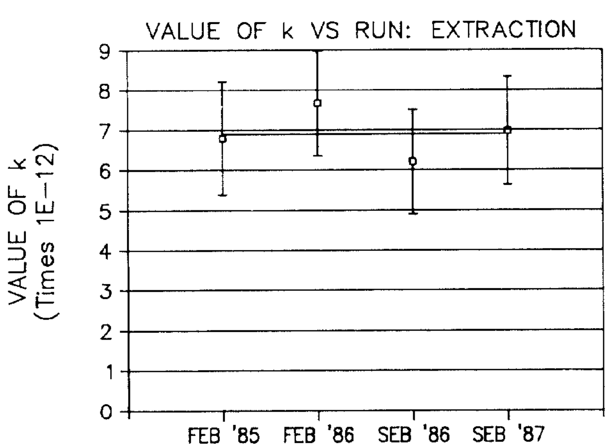

Figure 4.

Discussion

As you can see, the values of k are relatively consistent from one run to the next. Figure 1 shows the values of k at the different times in the cycle. Although the energy dependence of k is still not precisely known, it should be expected that k will be small for low energy beam and get larger with the energy. Figures 2 through 4 show the values of k as measured for the different runs. The error bars are calculated based on approximate uncertainties in the respective variables. There is less quantitative data on these uncertainties than would be desirable, but further studies will provide better knowledge of them.

This method of estimating the dose rate demands that we know certain information well. Specific considerations involve better measurements of beam losses, discrimination of where the losses occur in specific areas, and better resolution of the time (energy) at which the losses occur.

Conclusions

It is possible to predict the peak dose rates in specific areas of the AGS based on beam losses in the machine. By considering the same relationship in greater detail and in understanding the loss patterns in the AGS, it should also be possible to more accurately predict the dose rate around the whole machine. And so, a thorough understanding of the losses in the machine cycle and the amount of radiation induced by these losses will provide further insight into where to emphasize future work in getting to higher intensities while minimizing the increase of activity at the AGS.

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