# MANIPULATION OF THE ZGS BEAM FOR TARGETING

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## Abstract

The feeding of as many as four experimental areas from a single ZGS pulse calls for a flexible system for controlling the spill of the beam. The beam is displaced radially into as many as four targets plunged into position after radial damping of the beam has occurred. Beam spills have been adjusted in time duration from 5 micro-seconds to 500 milliseconds during a flat-top period of the main magnet cycle. Spills shorter than about 0.5 millisecond are accomplished by a pulsed magnetic bump which displaces the orbit center. Spills longer than about 0.2 milliseconds are accomplished by programmed adjustment of the accelerating rf so as to expand or contract the orbit radius. Radiation level monitors in the vicinity of the targets or in the experimental beam lines are used to feed back a signal into the rf program which results in the reduction of spill irregularities due to main magnet ripple and other noises. Such a spill has rf structure and is "on" from 25% to 50% of the time. The re-peatability for placing the beam into a given position for targeting is about 0.01 inch without employing feedback from radiation level monitors. A description of the equipment and instrumentation is given along with the performance.

## Manipulation Requirements

In two companion papers,[1] a description is given of the target and beam extraction routines. In what is identified as the L-3 straight section, the following targets are located:

1. Two swing targets are outside the beam orbit.
2. One swing target is inside the beam orbit.
3. One energy-absorption target with lip is plunged to a position inside the beam orbit.
4. One energy-absorption target is plunged to a position outside the beam orbit.
5. Two targets are flipped upward from the bottom of the beam chamber.

Work performed under the auspices of the U. S. Atomic Energy Commission.

The swing targets require about 200 milliseconds to move into place and to retract. All the other targets can be moved into position or removed in about 80 milliseconds. This helps define the delay between successive usages of targets in conflicting positions. The swing targets and flip targets are used primarily for meson and scattered beams. The energy-absorption targets are used for beam extraction.

By the time the magnet field has increased to the top value of 21.5 kG, the useful aperture has shrunk to about ±8 inches. By actual measurement, the radial width of the beam itself has shrunk to about ± 0.5 inch. The ripple in the magnetic field during a flat-top is about ±1 gauss, corresponding to a beam motion of about 0.1 inch. With 20 kV, peak voltage on the rf cavity, a minimum of about 10 milliseconds is required to move the beam during a flat-top from one extreme radial position to the other extreme radial position. Also the energy of the beam must be varied about ±600 keV to compensate for the magnetic ripple if long, smooth, spills are to be produced.

## Long Beam Spills

In a companion paper,[2] a general description is given of the equipment which accelerates and monitors the beam within the ZGS magnet. Figure 1 shows a logical block diagram attached to this equipment for the purpose of controlling the beam for long spills. Due to developments in experimental demands, this equipment changes from time to time, but this figure shows the approximate arrangement at one time.

The Master Oscillator actually includes a high stability oscillator to which it is locked for the purpose of noise reduction in beam position control above about half of maximum energy. This arrangement allows a repeatability of about 0.01 inch in beam position placement. Because of noises, it is also necessary to employ the phase lock with the beam as indicated.[3] The pass band of the phase lock loop is usually limited to about 200 cps to 100 kcps.

The instructions for beam manipulation are adjusted into the X Program Simulator. When the Slow Spill Feedback switch is "off", the size of the Spill Rate signal determines how fast the orbit radius is changed without any consideration of how fast the beam is being lost on any target. In this open loop fashion it is usually not possible to make the spill duration longer than 10 milliseconds and even this with some irregularity. This manipulation is accomplished by placing a simple ramp on the varicaps of the Master Oscillator. When a certain beam position is reached, as is chosen by the X Limit signal level and identified by the Amplitude Comparator, a command is given to the X Program Simulator to advance to the next item in the beam manipulation routines. This stepping process continues until the memory is exhausted or until it is interrupted by a command called Experiment Advance.

For many experiments, the type of spill just described is not satisfactory in terms of intensity, duration, and uniformity. In the ZGS arrangement, the necessary monitor of these parameters is provided in a number of ways. In a hole in the shield wall near the target area in the ZGS, a scintillation counter, which usually provides this monitor, is located. On certain occasions, a special solid state radiation detector, attached to the side of the L-3 vacuum box, is used. Occasionally a more appropriate monitoring signal is provided from devices in a beam pipe or in the experimental equipment using the beam.

When the Slow Spill Feedback switch is "on", a signal proportional to a spill monitor output is subtracted from the Spill Rate signal for the purpose of making the spill uniform at the level determined by the Spill Rate signal. This is done in the Sum Limit amplifier. The stiffness of this feedback is adjustable by gain controls in both the Sum Limit amplifier and the S Spill Gain control. It has been found necessary to limit the excursions of this feedback signal to prevent the beam from being knocked-out of the rf bunches. This adjustable limit is set in the Sum Limit amplifier. The frequency response of this system is determined primarily by the S Spill Integrator. Taken together, the Sum Limit amplifier and the S Spill Integrator have a gain which decreases at the rate of 20 dB per decade and has a value of unity at 230 cps. The possibility for a rather high frequency roll-off in the low pass filter of the S Spill Gain is a hang-over from the times when this feedback signal was fed directly into the Varicap Bias which has a pass band up to about 100 kcps.

For the reasons of flexibility and stability, it has been found desirable to provide a separate loop for a fast feedback of the spill monitor signal. This loop has greatly reduced the structure in the uniformity of the beam spill rate but has not eliminated it, especially during very long spill times. The targeting oscillator reduces the beam wobble due to magnet ripple and 60 cps noise from 0.1 inch to 0.01 inch. The slow feedback loop reduces the low frequency wobble considerably more. It appears, however, that the over-all wobble must be reduced to considerably less than 0.001 inch. In this endeavor, the monitor rectifier time constant has been reduced from 300 μsec to 10 μsec, and the low pass limit ahead of the Varicap Bias has been removed. Using gain adjustments that do not result in a beam loss from the rf bunches, it has not been possible to produce a peak-to-average spill ratio less than about 4 to 1 during very long spills.

It has been possible to increase the speed and stiffness of this feedback to the place where the peak-to-average spill ratio dropped to about 2 to 1. This, however, resulted in knocking about 25% of the beam out of the rf buckets. If this routine is pushed far enough, all bunching is lost upon targeting and the beam can coast during the flat-top. Even in this case, rf manipulation is possible by using the nearly empty phase buckets to push the beam onto certain targets. Of course in all of these cases the targeted beam has a 14 Mcps rf structure.

It has been possible to increase the duration of the spill time up to as long as 500 ms with the quality of spill described above. This is about 100 ms longer than the duration of the flat-top period of the magnet. The targeting started before and continued after the flat-top.

## Short Beam Spills

A rather rapid displacement of the beam onto targets is accomplished by a Beam Bumper magnet located in the L-3 straight section near the targets.[4] Its pole size is 12 inches in azimuthal and 16 inches in radial extent. It consists of an H-frame type of magnet fabricated from 0.004 inch iron laminations and with two current carrying turns of copper around the top and the bottom pole tips. It can be excited up to a field strength of 12 kG in periods of time adjustable from 25 μsec to more than 500 μsec. This is accomplished by a rather conventional arrangement of a capacitor bank discharged by ignitrons through the bumper coil. The back swing is clipped by a second set of ignitrons.

The ZGS parameters are such that the beam orbit center is displaced about 0.5 inch per kilogauss in the bumper magnet. It has been found that when the beam is bumped more than about 1.5 inches, the rf tune of the circulating beam changes so much that losses from the beam bunches occur. Arrangements have been made to feed a signal proportional to the bumper current into the summing amplifier for the varicaps in the master oscillator (see Figure 1). With this, it is possible to increase the bump displacement to about 4 inches before beam bunch losses start to occur. It is probable that extending the pass band of the summing amplifier above 5 kcps would allow increasing the bump size beyond 4 inches. This, however, does not seem to be necessary for any targeting.

## Sample Targeting Routines

The oscilloscope traces in Figure 2 can be used to illustrate the targeting routines. The bottom trace shows the magnetic guide field, its flat-top for 160 milliseconds and ripple with amplitude of about 1 gauss. The middle trace shows the spill monitor output from two different targeting operations. This signal was obtained from Mon at the Rectifier output shown in Figure 1. The display shows two different spill rates resulting from two different values of the Spill Rate signal. The fine structure is that seen when the rectifier had a high frequency roll-off at about 1 kcps.

The top trace shows the signal at the output of the S Spill Integrator when the Slow Spill Feedback switch is "on". The ramps are from the X Program Simulator as it advances through the targeting routines. These result in corresponding displacements of the beam into targets. In the case shown, both target positions used were outside the beam orbit. The interval between the two excursions is available for switching targets. The routines could have just as well included an inside target in which case the two Target Position switches, shown in Figure 1, would have been operated. The inside excursion could have involved the energy-absorption target with a lip for producing an external proton beam making its exit through L-2.

At any appropriate place in the above described routines, the Beam Bumper can be used for a rapid displacement of the beam onto any of the targets. In the case of proton beam extraction, the proper one is the energy absorption target outside the beam orbit.

The Experiment Advance into the X Program Simulator is an external access to the targeting routines in the simulator. By this route, an experimentalist or a ZGS operator can use appropriate additional logical equipment to reach a conclusion that one routine is finished and command that the simulator proceed to the next during a single ZGS pulse. One common use of this feature is that an experimentalist can conclude that he has had enough on a given pulse (such as 20 pi mesons into a bubble chamber) and command that the simulator move on to satisfy the next experimentalist later in the pulse.

At the present time, a device to execute priority decisions is being installed. It will assure the prime user of getting his beam allotment or percentage regardless of where he is during the spill time. It will allow the secondary users to dispose of their allotment in a time, intensity, quantity, or percentage distribution as is agreed upon.

## Acknowledgement

The authors wish to gratefully acknowledge the assistance of Theodore deParry in the initial design of the Beam Bumper and the members of the ZGS Operations Group for operating the synchrotron and for assistance in developing adjustment routines for the equipment described in this paper.

## References

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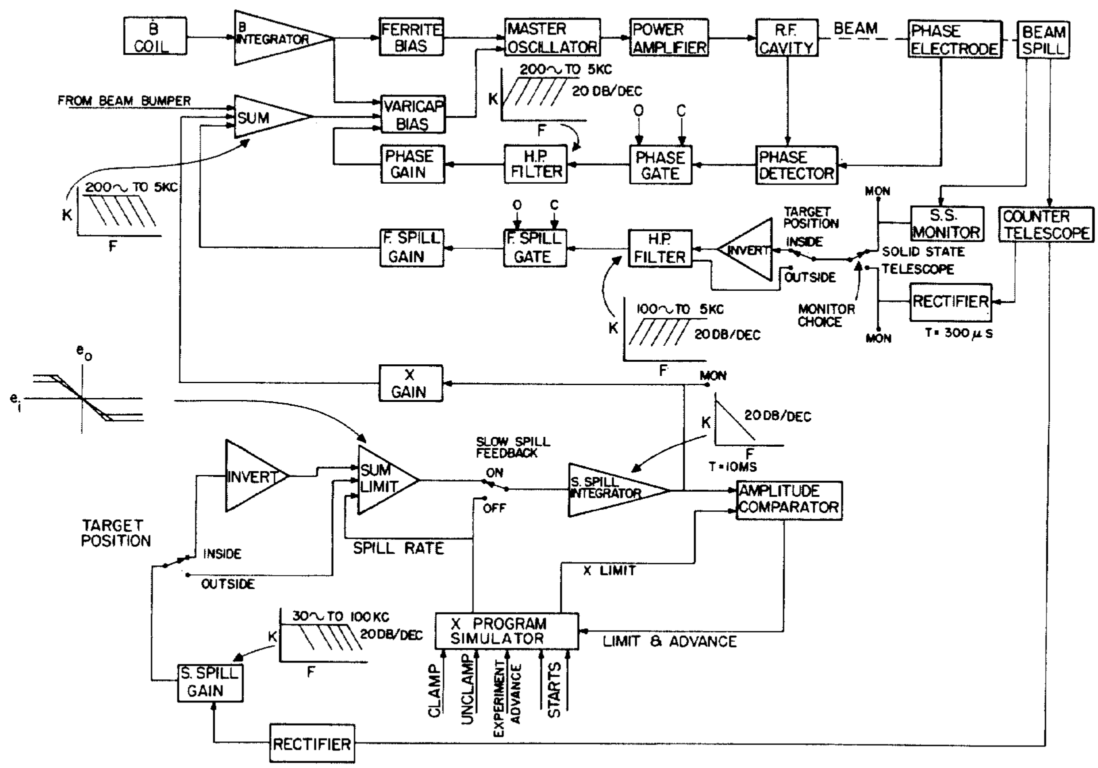


Fig. 1. ZGS Beam Control System for Targeting.

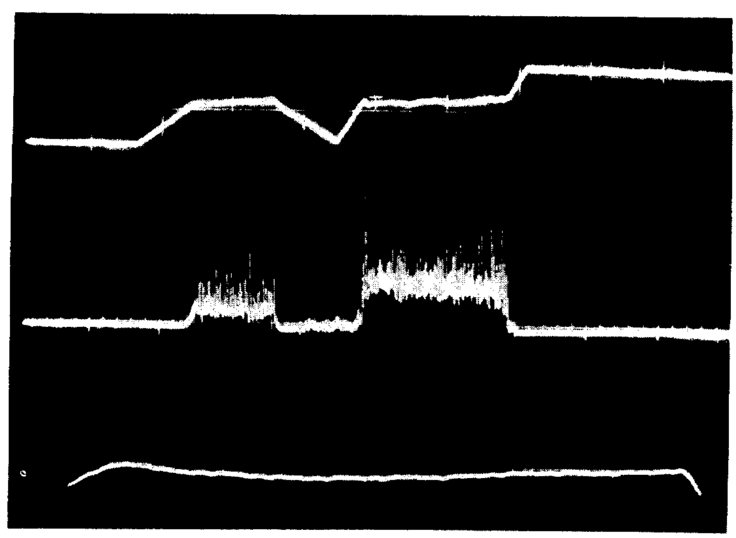

Fig. 2. Sample Displays of Beam Spill, Spill Command and Flat-Top of Magnet Guide Field.