CONTROL OF THE BEAM SPILL AT THE PPA

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Summary

The PPA machine operates on a 20 cycle per second machine rate and is not flat topped. Due to these two factors spill lengths in the region of 5 - 10 milliseconds are not only "long" but contain up to 10% energy modulations. Conversely "short" spills are those occuring in less than a few hundred microseconds.

Another unusual feature of the PPA machine is the one to two nanosecond rf bunch width at spill time. This feature was inherent with the first spill techniques and has proven invaluable to experimenters doing time of flight measurements in neutral secondary beams and separating K's from Π's.

Consequently the preservation of the rf bunching during spill has become a prerequisite for any PPA spill system. Within this boundary condition only the following targeting techniques are feasible:

1. Moving Targets
2. RF Steering
3. Magnet Steering
4. Resonate Blow-Up

Each of these techniques is presently utilized by PPA with techniques two and four being our primary controls and techniques one and three used as secondary controls.

RF Steering

The first targeting system utilized at PPA was rf steering. The original system consisted of a pedestal generator controlling the rf frequency and thereby the spill. It was quickly observed that the discrete steps of the pedestal generator was creating spikes in the spill and exciting synchrotron oscillations. It was therefore modified by replacing the pedestal generator with a polynomial function generator and a reasonable improvement in spill quality was obtained.

This constituted the normal operating spill control at the end of 1965 giving a characteristic spill as seen in Fig. 1.

New Master Oscillator

At this time special emphasis was placed on spill quality improvement and three projects initiated. The first of these was the construction of a "narrow" band 29-30 mc spill master oscillator for use only during spill time. The rationalization behind this project was that the noise and jitter of the wide band 2.5-30 mc master oscillator was both making precise control of spill impossible and exciting synchrotron oscillation. At the present time no technique for changing oscillators during the machine cycle has been developed but by simply phase locking the old oscillator to the new one during spill time, spills as shown in Fig. 4 were achieved. It is of particular interest in this photo that not only is the general spill shape better but the peak synchrotron oscillations are smaller than in Fig. 1. This phase locking technique became part of the standard operating procedure during November of 1966.

Self Corrector

Another of the projects initiated in 1965 was the construction of a spill "self corrector". This device compares the actual spill occuring during each 100 μsec period within the spill to the desired or "ideal" spill for the same time period. The result is stored in a memory bank that integrates the error for each interval over several hundred machine cycles. This integrated memory of the error in each 100 μsec period is then read out of the memory and into the spill control program as a correction on succeeding machine cycles. This type of self correcting function generator is farther described in PPA Technical Note ED 54.

The resulting improvement in spill structure can be seen by comparing figures 4 and 5. Other advantages not seen in the photos are:

1. Manual adjustment of the spill controls is required, on the average, only every 4 hours instead of one minute without the self corrector.
2. The ability to set either constant average length or constant average intensity as the spill mode.

Fast Spill Magnet

The third improvement initiated in 1965 is that known as the fast spill magnet. This system is essentially a magnetic verner adjustment of the rf steering and is not capable of spill control by itself as its dynamic range, in terms of orbit displacement at the target, is approximately 5 millimeters. However, the system has a radial beam slew rate of approximately 10 millimeters per microsecond and consequently can modulate the instantaneous spill intensity at frequencies in the hundreds of kilocycles.

The primary purpose of this system which consists of a magnet, a photomultiplier, and an amplifier is to reduce the 10 kc synchrotron oscillations. It accomplishes this by servoing the beam to match an idealized spill command signal. The closed loop response of this system indicates a unity gain point of 500 kc. The amplifier involved has 120 db gain with a peak output of 400 KVA. Additional data on this system was presented at the 1965 conference. Figure 6 shows the typical reduction of synchrotron structure obtained by this system.

Resonant Blow Up

The second primary targeting system utilized by PPA is resonant blowup, employing the $V_r = 2/3$ resonance. Tests on this system were initiated in May of 1966 and it was placed in full operation for experimenters in February 1967.

The technique consists of exciting radial betatron oscillations of large amplitude in precisely the same manner as when the primary beam is extracted. See paper F-8 at this conference.

Resonant targeting differs in it's characteristic from rf steering in the following ways:

A. In this mode of targeting a lipless target is used and the target is illuminated in depth rather than only on the surface.

B. The time spread of the secondary particles is 2 nano seconds at fullwidth half maximum with resonant targeting versus 1.1 nano seconds for rf steering. The difference is due to the fact that particles are targeted indescriminant of their position in synchrotron phase space by the resonant system.

C. The resulting spill is characteristically free of synchrotron oscillation structure for the same reason.

D. The radial extent of the source is greater and is controlled by the amplitude of the resonance driving field. In the case of shadow targeting, only a fraction of the particles will strike the target and the rest will be extracted. In this case the shadow target will be nearly uniformly illuminated radially.

E. The ultra precise frequency control of the rf and the fast spill magnet are inappropriate for this targeting method.

F. The targeting efficiency is higher because one is not dependent on the non perfect action of the target lip. Measurements have indicated that the targeting efficiency is approximately 25% greater when resonant targeting is used.

Beam Sharing

The simultaneous existence of these four types of spill controls allows many modes of beam sharing. Two types of sharing have been used to date, and two more types will be used in the next few months. The first beam sharing system used consisted of rf steering into a rotating internal target to generate a spike spill for the bubble chamber, and then retracting the beam until the rotating target moved out of position. This was followed by normal internal rf targeting in a different straight section. This system was used for several months last year. Among the control loops placed on it were loops to: A) control the percentage of circulating beam spilled on the rotating target, B) to only spill on the rotating target when the bubble chamber cycle was such that the particles could be utilized, C) normal controls for the long spill on the second target.

The second system of beam sharing tried involved sharing the beam between internal and external targets. This has been accomplished by shadowing the septum of the extraction magnet with an energy loss target so that the particles striking it fall onto the internal target and the particles missing the shadow target are extracted. In this mode long spills can be simultaneously generated on both targets and the sharing ratio can be controlled by controlling the rate of the beam excitation.

The two additional systems planned for operation involve spilling by rf steering on an internal target for part of the spill time. Then retracting the beam to a central orbit and energizing the beam extraction equipment to give either a long or short external spill.

Future Plans

So far this paper has simply presented the accomplishments in targeting. The following are the major programs to improve spill currently active:

A. Design of switch such that master oscillators can be changed before spill time.

B. Design of a self corrector to servo the resonant targeting system.

C. Flat topping of the PPA Magnet, to achieve up to 50 millisecond spills.

D. Improvement of the Fast Spill Magnet.

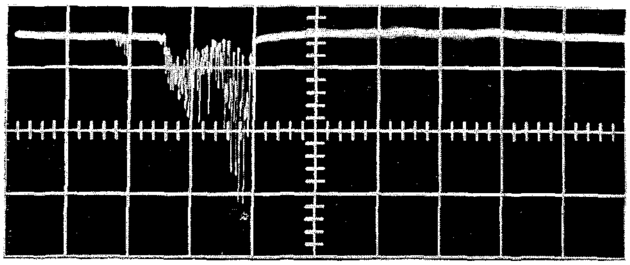

Figure #1

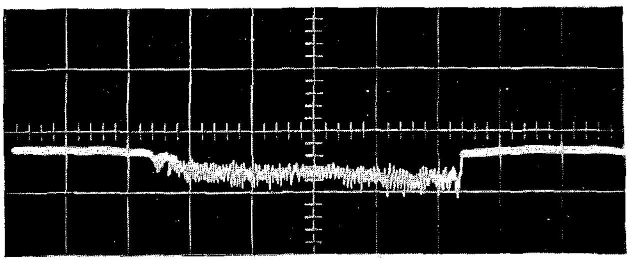

Figure #2

Figures #1 and #2 were both taken through a 200 KC filter with vertical axies at 5 mv per cm and horizontal axies at 2 milliseconds per cm. Figure #1 is the spill as of January 1966. Figure #2 as of January 1967. Of particular note is that the spill length in Figure #1 could not be increased. While that in Figure #2 could be if greater energy modulations could be tolerated.

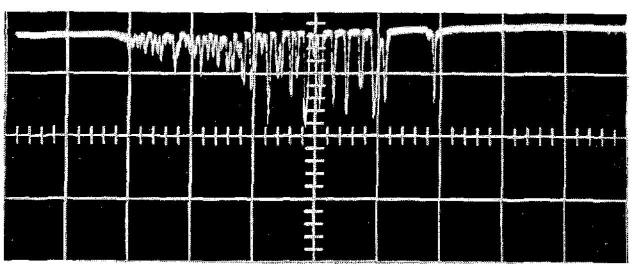

Figure #3

Spill with old master oscillator through 500 KC filter at 5 mv/cm and 1 millisecond per cm.

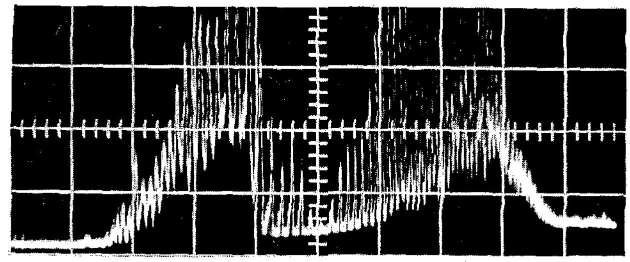

Figure #4

Spill with new master oscillator through 500 KC filter at 2 mv/cm and 1 millisecond per cm.

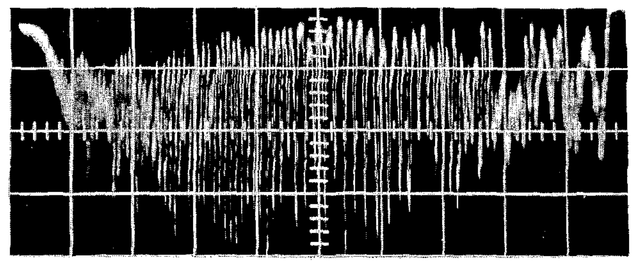

Figure #5

Same as Figure #4 but with the self corrector operating.

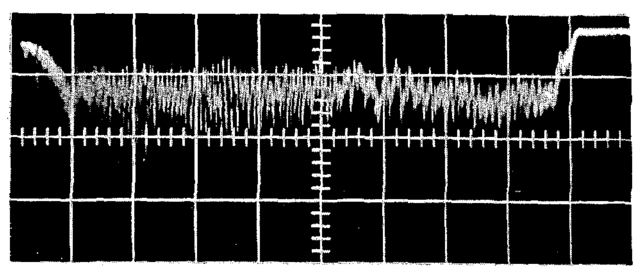

Figure #6

Same as Figure #5 but with the fast spill system operating.