Brookhaven National Laboratory

BNL-104220-2014-TECH

AGS.SN348;BNL-104220-2014-IR

AGS Loss Monitor System Response Measurement on the Injection Porch

L. Ahrens

May 1996

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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Date: 7Aug96 **AGS Studies Report No. 348**

AGS Complex Machine Studies **(AGS Studies Report No. 348)** **Title: AGS Loss Monitor System Response Measurement on the Injection Porch**
Study Period: 15 May 96, 20 May 96
Participants: L. Ahrens, B. Tamminga
Reported by: L Ahrens
Machine: AGS
Beam: High Intensity Protons
Tools: AGS Loss Monitor system; systems used to kill the injected beam = F20 and G20 vertical dipoles; L20 injection bump and A5 kicker with different settings on different Booster transfers to kill spiraling beam in AGS; frequency steering function on AGS front porch to scrape beam on momentum apertures between transfers; low field back leg winding bumps; AGS beam current transformer.
Aim: Calibrate the sensitivity of the new AGS ring loss monitor system to proton losses on the AGS injection magnetic porch.

I. Introduction:

The sensitivity of the AGS ring loss monitor system has been substantially improved for the 1996 running with the rework of the electronics and controls. The system now resembles the Booster loss monitor system in that the currents from loss monitor cables (which act as ion chambers) are integrated at the front end over specified "windows" in time rather than being first processed as instantaneous loss rates and then integrated in a second step. The sensitivity of the system (on the low sensitivity range) is intentionally made much coarser than the original Booster system - by about a factor of 300. In fact the determination of this sensitivity just on the AGS injection porch is the point of the studies reported here. If an applicable sensitivity can be specified, then an independent measure of beam loss over the injection porch is possible. This is important because the other way to determine injection beam loss involves current transformers in different machines, and with time responses slow compared to the beam revolution period. Small fractional losses can represent significant numbers of protons.

One wants to measure the response of the loss monitors to known quantities of beam lost in many fashions. The response is expected to vary by of order a factor of two depending on the details of how the loss occurs. The loss "geometry" is important - e.g. whether it occurs in "open" magnets or "closed" magnets; or in regions intentionally built to contain the beam (the E20 "catcher"). The response will also depend on whether the loss is "fast" - single turn- or slow - occurring over milliseconds with instantaneous ionization rates lower by a factor of 1000. The studies summarized here attempt to explore these variables.

II. Procedure:

Two study sessions are reported here. The first (1800-2000,15 May 96) occurred during a dedicated study period. Single Booster transfers to AGS were available, at adjustable intensity. Additional Booster cycles with other "Users" in control were also available allowing AGS injection magnets -the A5 kicker and L20 bump - to be changed in value or fine timing and refired on the existing AGS beam. A (BU3 BU3 BU1 BU1 BU1) supercycle was used. The second session (20May96) was parasitic on the HEP program. For this the only knob turned was the momentum or radius of the AGS beam in a window between Booster transfers. The 133 ms is plenty long enough to allow the beam to be shifted over against an inside or outside aperture, scraped a bit, and then put back - to allow normal acceleration to proceed, albeit at a slightly reduced intensity.

Fast losses were produced by distorting the equilibrium orbit (or the first turn trajectory) in AGS sufficiently to kill the injected bunches on the first turn. The vertical "bump" magnet at F20, and another at G20 were each used (independently). A lower bound on the amount of beam being dumped was obtained by turning the bump off, allowing the injected beam to survive across the porch, and reading the beam current transformer. The (fast) wall gap monitor (at G5) gives a slightly less precise but more relevant measure since it explicitly sees the first turn beam (for the G20 bump). It also gives proof that no beam comes around twice. Another method to get a fast beam loss was tried using the A5 injection kicker to rekick the old (Booster User 3) beam at the next Booster (Booster User 1) transfer (with no new beam coming in), and then adjusting the (ppm) fine timing of this User 1 kicker to remove as much beam as possible. Similar fast losses could be generated using horizontal bends - AGS extraction bumps perhaps - in a similar fashion to that done vertically; this was not done here.

Slow losses were produced in the dedicated study by pulsing the L20 injection bump a second time, again using the ppm setup with a large enough amplitude to destroy the beam. The slow radial shifting employed in the parasitic study also produced a slow loss situation. The exact pattern for this loss could be varied at least slightly by modifying the equilibrium orbit of the AGS - e.g. adjusting the "injection" bump at the E20 catcher .

For each situation the losses produced by the machine change were measured by the AGS loss monitor system. This system, and in particular the application code controlling its use, were still evolving at the time of this study. Indeed the ability of the code to cope with ppm was pressed by and improved as a result of the study. Also cleanest data requires taking differences and doing background subtractions, features the details of which were also evolving. The situations for these studies were simple enough that these details are not critical. The loss monitor program does get an approximate copy of the standard AGS beam current transformer measured exactly at the window edges used for the loss monitors themselves, and necessarily on the same beam cycle. This can be very useful in determining the system sensitivity but comes with the requirement that the derived intensity be correct. Normalization and offset are concerns not necessarily perfected yet. The system gives background subtracted loss monitor counts for the time "window" specified for each loss monitor channel (2 AGS main magnets per loss monitor cable -e.g. at A2 "lmA2" stretches from the upstream end of the A1 main magnet to the downstream end of the A2 magnet). The sum of these channels around the ring normalized to the beam lost in that window is the primary measurement reported here - total loss monitor counts per teraproton. The window edges are AGS time line events - time intervals from AGS To. For the losses considered here, the time constraints on window edges were easy to satisfy - the losses to be measured were well separated from other events.

III. Results:

For all three fast loss setups described above the global sensitivity measured was (150+/-10) cnt/Tp. The two setups using the vertical dipoles involve identical geometries except that everything shifts by one superperiod. The measured loss patterns are essentially identical except for the superperiod shift. The loss peaks in the second superperiod monitor (the magnet 3-magnet 4) monitor and is nearly contained in the superperiod following the energized dipole. These data are shown in figure 1. That the response from any loss monitor given the same ionizing input is identical to that from any other loss monitor is assumed in most thinking about the system, and so this particular result is necessary (and very satisfactory) - though not sufficient of course. About 10 Tp of beam was killed in these setups. Another piece of information gleaned from this machine configuration is a measure of the contribution to the AGS ring loss monitors from losses actually occurring in the BtA line. No beam comes past the injection region a second time so all reported losses are from the single pass beam. A consistent pattern was seen in the loss monitors from magnets L11 through A2. This is reasonable since the BtA line enters the AGS just upstream of L11. Loss monitors L14 and L16 were highest, the sum over loss monitors L12-L18 with 10Tp surviving around to G5 was about 120 loss monitor counts for this setup; L20-A4 gave about 60 counts. BtA losses were not measured but the early L superperiod counts presumably are from BtA losses, not AGS losses so their existence opens up the possibilities under less clean conditions of confusing sensitivity measurements and loss causes.

The third fast loss situation, using the refire of the A5 kicker, produced a loss due to horizontal motion. The loss occurred mostly in the G and H superperiods and gave a very different pattern from the vertical kills. The dominant peak was lmG6 - the number 5 and 6 magnets in G. The measured sensitivity was the same - but fast horizontal dumps using other geometries, namely orbit distortions are possible and should be measured. This kicker result was a bit confused perhaps by the ppm switching business, the data may be flawed. Here about 6Tp - the beam which survived across the porch to the next transfer- was killed.

The slow loss creation resulted in sensitivities significantly greater than from the fast losses, and also with more variation depending on the details of the setup. The refire of the L20 bump during the dedicated study gave a sensitivity of 280cnts/Tp with 7Tp being wiped out. This loss was mostly localized at the peak and early lobe of the L20 bump - lmA2 (magnets A1 and A2) and lmL6 (magnets L5 and L6).

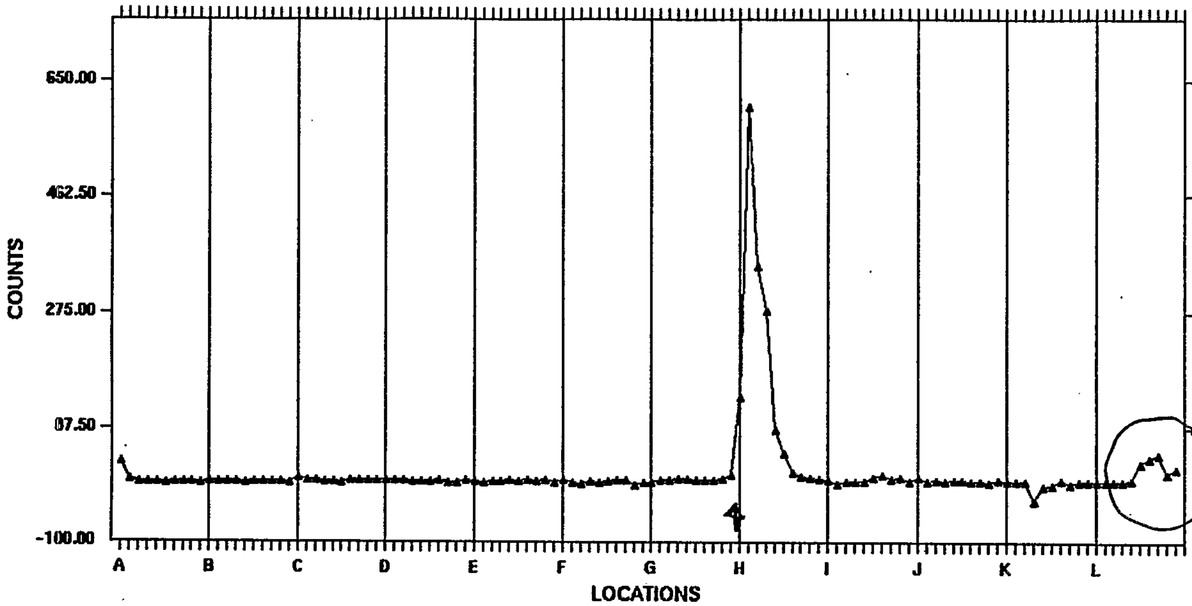
fast dump @ G20V bump

AgsLossMonitor

Setup Data Files EngineeringOptions — all gone 1 turn — He

DATA: CURRENT - REFERENCE FILE bkgnd ACQUISITION DATE: Wed May 15 19:07:46 1996 ~5.5TP @ CBM
GAIN SETTING: LOW AGS CYCLE: 16947

WINDOWS:	20 ms.*	40 ms.	153 ms.*	173 ms.*	286 ms.*	306 ms.*	420 ms.*	440 ms.*	550 ms.*
SUMS:	93 cts.	1748 cts.	64 cts.	0 cts.	38 cts.	33 cts.	-12 cts.	36 cts.	40 cts.
XFORMER:	-29 cts.	-28 cts.	-39 cts.	-40 cts.	-21 cts.	-30 cts.	-21 cts.	-21 cts.	-38 cts.



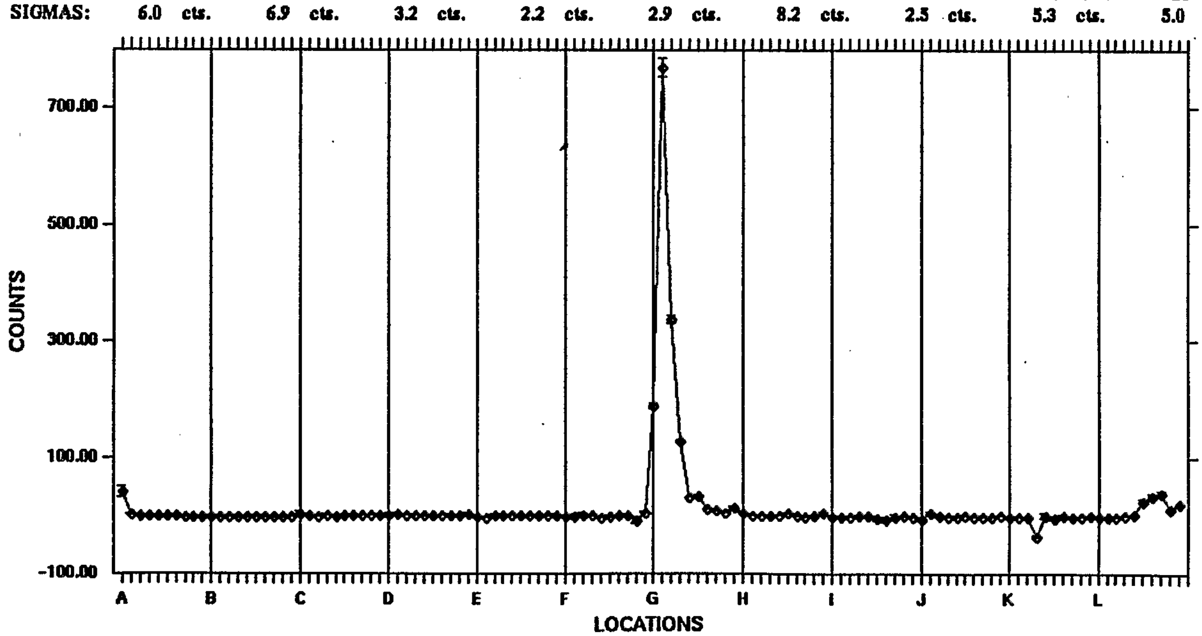
F20V Bump SP: 2500 RDBK: 730 Time on: 1

AgsLossMonitor

Setup Data Files EngineeringOptions He

DATA: CURRENT - REFERENCE FILE bkgnd ACQUISITION DATE: Wed May 15 19:21:29 1996
GAIN SETTING: LOW AGS CYCLE: 17175 17176 17177 17178 17179

WINDOWS:	20 ms.*	40 ms.	153 ms.*	173 ms.*	286 ms.*	306 ms.*	420 ms.*	440 ms.*	550 ms.*
SUMS:	13 cts.	1725 cts.	81 cts.	-7 cts.	-17 cts.	-52 cts.	-9 cts.	-44 cts.	4 cts.
SIGMAS:	26.2 cts.	23.1 cts.	31.6 cts.	36.5 cts.	20.2 cts.	39.4 cts.	19.2 cts.	42.2 cts.	29.8 cts.
XFORMER:	-26 cts.	-38 cts.	-31 cts.	-31 cts.	-30 cts.	-30 cts.	-29 cts.	-21 cts.	-26 cts.
SIGMAS:	6.0 cts.	6.9 cts.	3.2 cts.	2.2 cts.	2.9 cts.	8.2 cts.	2.5 cts.	5.3 cts.	5.0 cts.



* - not displayed

Figure 1 Fast Losses in G and H

The other injection porch losses were created by shifting the beam until some reduction was observed on the beam current transformer (here the AGS "F15" transformer). For this setup the shot-to-shot reproducibility was poorer than for the other work where all the beam was removed. Several cycles were averaged for each run, although this probably did not improve the quality of the results given the variation. For a series of runs the radial shift was placed after the second booster transfer. Figure 2 gives an oscilloscope picture from this setup. Included are the beam current in the AGS, the loss seen at one monitor, and the beam radius from the average of two pue's. The trigger (arrow at left) is at AGS To; the sweep 200 ms/box. The AGS beam current transformer can be seen to step up with each Booster batch (the first at 25 ms from To), and step back down by nearly a batch when the radial shift occurs - clearly a parasitic study. The radial average signal shows the beam moving - in this case toward the inside of the machine - and then back. The response of the F6 loss monitor is shown. The step up occurs when beam is lost; the step back down is the end of the integration window when the channel is reset. The previous reset for the loss monitors occurred at 200 ms from To- at the end of the second box in the figure.

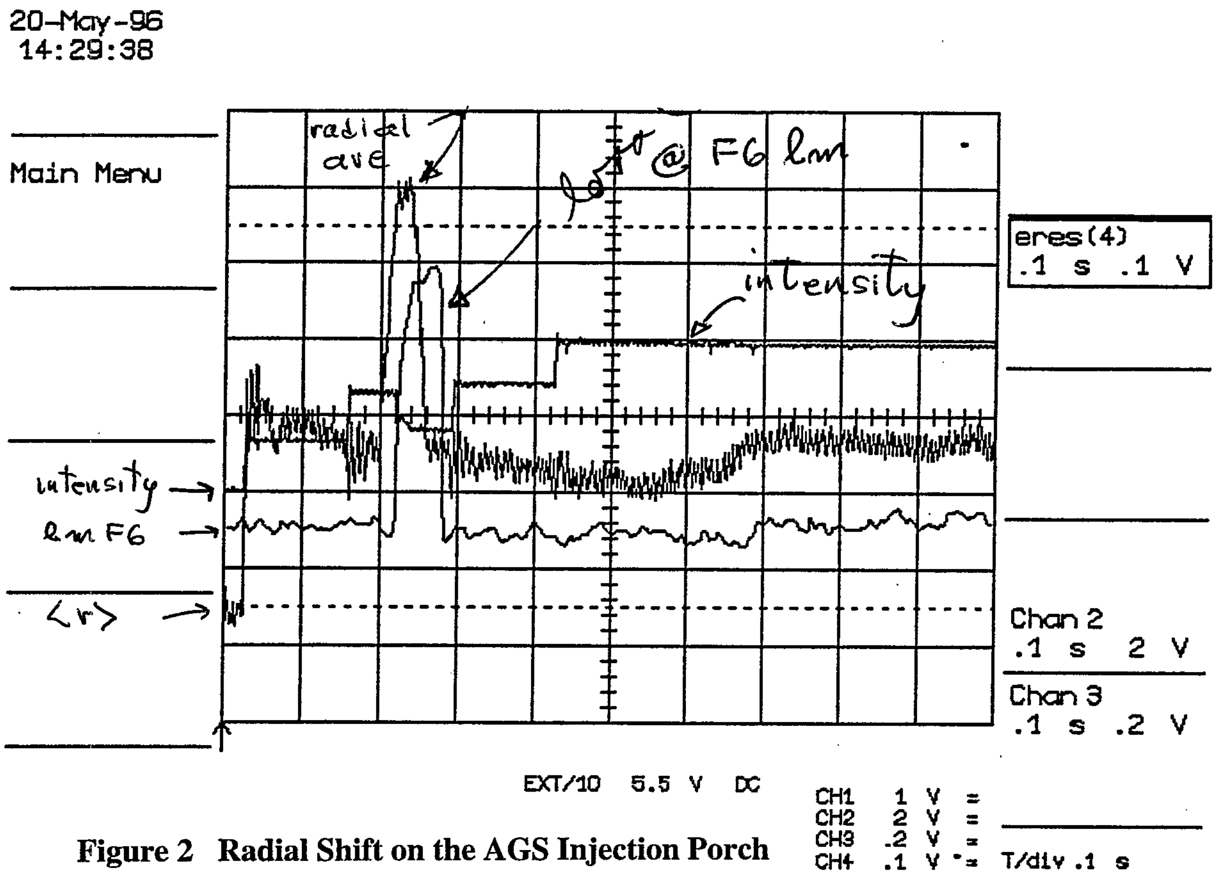


Figure 2 Radial Shift on the AGS Injection Porch

For shifts to the inside, the first aperture hit was the E20 catcher. The F2 loss monitor channel dominated. By changing the strength of the low field backleg bump at E20, the loss could be moved, but only to G18. For loss to the catcher (about half the reported counts from the sum of F2, E20 and F4), the sensitivity was stable at 285+/-15 counts/Tp. As more loss was moved to G18, the sensitivity increased to 500 counts/Tp with the G18 loss monitor accounting for about half of the ring total. Even subtle shifts to the outside proved impossible to do. Enough beam would be lost in the vicinity of the G10 kicker protection loss monitor to abort the beam.

This exercise was repeated slightly later on the injection porch after the third Booster transfer, with similar results. A summary table of all of these sensitivities is given in table 1.

setup	**measured sensitivity**	**beam lost**	**where lost**
fast kill	(loss monitor counts/Tp)	(Tp)=x10^{12} protons	AGS loss monitors, largest first
G20 Vert Dipole	157	10	H4
F20 Vert Dipole	155	10	G4
A5 kick	146	6	G6
slow kill			
L20 re-bump	283	7.4	A2,L6
2nd transfer, freq shift			
inside, as found	290	7.5	F2,F6,E20,G18
in, bump away from E20 catcher	500	3.7	G18
in, less bump	445	3.2	G18,G14,F6
3rd transfer, freq shift			
into catcher	271	19	F2,E20,I18
less hard (bump)	283	11	F2
bump away from catcher	416	18	G18,G14,F12

Table 1 Measured Sensitivities for Various Kill Geometries

This ends the presentation of the data collected during these studies. It does not close the sensitivity issue however. There is another source of calibration data on the AGS injection porch, namely the losses seen between transfers during normal running (frequently referred to as the "drool" loss). Here the loss reported by the beam current transformer should be accurate - the time scale is long relative to the current transformer response time. The ionization rate from the loss is slow. The window edges are set far from the transfers, typically extending from 15 ms after a transfer until 5 ms before the next. One set of data is given in table 2.

Loss window	Beam loss, measured using the loss monitor system's current transformer numbers (Tp)	Beam loss from loss monitor sum (counts)	derived sensitivity (l.m. counts/Tp)
after first transfer	.8 +/- .1	465 +/- 60	580+/-130
after second transfer	1.36 +/- .16	676 +/- 25	500+/-75
after third transfer	2.16 +/- .1	841 +/- 12	390+/-20

Table 2 Sensitivity Measurement using the Drool Loss

The data from the interval after the fourth (meaning the last) transfer is not shown because the window interval chosen included some acceleration, and capture losses - potentially a quite different situation. The largest contributing loss monitors are F12, F14, and F16. The sensitivities are as high or in fact higher than any measured in the other situations. The very high readings for the first transfer are typical for this transfer. The error shown is large because of the small amount of beam in the denominator but such high sensitivities are usual.

IV. Discussion:

The sensitivities reported from the somewhat contrived studies losses agree with experience gained with the old system and with the Booster system in many ways. The fast losses produce perhaps half as many counts as slow losses. The loss into the E20 catcher gives significantly fewer counts than if the beam misses the catcher. However as the loss situation moves closer to the injection reality - to the losses measured during the "drool" interval - the sensitivity keeps going up. What we wanted was a single number, or at least one "slow" and one "fast" number to apply to the loss monitor counts occurring during the injection intervals during high intensity running. Although we have a plausible range of values, it is also clear that the details of the loss pattern are important; for quantitative comparison against the current transformers a single number probably will not do. A next step would be to attempt to minimize the number of geometries which need different sensitivity numbers. Perhaps the same loss monitor position in different superperiods has the same sensitivity. Perhaps details like the catcher, or rf cavities will invalidate this. Perhaps open and closed magnets give significantly different results. The loss monitor program has the hooks to allow almost any variations if such can be shown to give more reliable results. More work to come, but a start.

The AGS loss monitor system upgrade, hardware and software, were big projects for small numbers of people this year - the Instrumentation Group E. Zitvogel and B. Clay building on E. Beadle's plans; the Controls Group including E. Keith-Monnia, and A. Abola getting the firmware going, and Agnes providing the resource to allow the application code to evolve as such codes must to be really useful. The improvement over the past, and not just the recent past, is very satisfactory. That a discussion of sensitivity at AGS injection can occur at all is a new "problem".