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Booster Vacuum Measurements for Gold Beam Injection

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AGS Studies Report No. 370

AGS Complex Machine Studies

(AGS Studies Report No. 370)

Title: Booster Vacuum Measurements for Gold Beam Injection

Study Period: Various

Participants: L A. Ahrens, C. Gardner, and S.Y. Zhang

Reported by: S.Y. Zhang

Machine: Tandem Transfer Line and Booster

Beam: Gold Au^{31+}

Tools: Vacuum Ion Guages, Electrometer, Steering magnets

Aim: To measure the vacuum condition due to Gold Ion Beam Loss.

I. Summary

1. Vacuum pressure created by the Booster Au^{31+} beam loss at injection shows a 35 ms decay time constant.

2. Real vacuum pressure created by the beam loss is about 100 times larger than the one observed in MCR.

3. Vacuum pressure higher than 10^{-7} $Torr$ was created by crashing beam at the C3 inflector.

4. Beam loss created vacuum bump in the ring is about 15 to 25 $meters$ long.

5. At Booster injection, a scraping Au^{31+} could produce as much as 10^5 molecules, according to the vacuum measurement.

II. Introduction

In [1], it is suggested that the Gold beam Booster injection efficiency decreases in proportional to the beam loss in the ring, rather than the circulating beam intensity. In [2], it is shown that the beam life time decreases after a beam scraping in the ring. These results suggest that the gold ion lost in the ring has negative impact on the beam survival.

A close look at the effects of lost gold ions shows that there might be large number of electrons, neutral particles, and ions (mostly positive) created when the gold beam scrapes wall.

Neutral particles can be detected by ion gauge. High energy electrons may stimulate gas desorption, which also produces neutral particles. To investigate the neutral particle production due to the beam loss, vacuum measurement was performed during 1998 HIP run.

The signal obtained from ion gauges is in pA level for a vacuum pressure of 10^{-11} $Torr$, whereas the noise can easily reach nA. Therefore, the vacuum measurements provided in 930 UEB and in MCR are mean values over several seconds.

An electrometer is used to look at ion gauges directly. Also, the beam was crashed into the location of the ion gauge, to make the vacuum pressure more visible.

Measurements at several locations in the ring show that the vacuum pressure created by the Booster Au^{31+} beam loss at injection has a 35 *ms* decay time constant.

This implies that for the Booster cycle of 3 seconds, the real vacuum pressure created by the beam loss could be 100 times larger than the one shown in 930 UEB and MCR.

By crashing beam at the C3 inflector, a high vacuum pressure of $> 2\times10^{-9}$ *Torr* was observed in MCR, which means that vacuum pressure higher than 10^{-7} *Torr* was created.

Meanwhile, the beam loss created vacuum bump in the ring is about 15 to 25 *meters* long.

A rough estimate shows that at Booster injection, a scraping Au^{31+} could produce as much as 10^5 molecules.

III. Time structure of vacuum pressure due to beam loss

Using an electrometer (Keithley 480 Picoammeter), ion gauges at different locations in the Booster ring were used to measure the vacuum pressure due to lost gold beam. The time structure of the vacuum pressure is figured out using simulations to match the response of the electrometer.

The vacuum pressures seen in the measurement are:

1. Observed either at 930 UEB, or in MCR, through the ion gauge controller. This is the average vacuum pressure over the whole Booster cycle, 3 seconds.

2. Response of the electrometer. The peak of this pressure is much higher than the average pressure. We are interested in its time structure, i.e. decay time and peak value.

The vacuum pressures used in the simulation are:

1. Simulated real pressure in ring. We are interested in both its peak value and time structure.

2. Simulated response of electrometer. This is obtained by putting the simulated real pressure in ring to the electronmeter model. The mean value of this pressure should be equal to the average pressure observed in 930 UEB. Its peak should be equal to the peak in the response of electrometer.

A. Experiment I

April 16, the beam was scraped at the location D1 to created 930 UEB pressure (For convenience, we use this for the vacuum pressure observed at 930 UEB) of 4×10^{-10} $Torr$, in user 2. The lost beam is estimated as 5×10^{8} ions. The response of the electrometer is shown in Fig.1*a*, where it has been transformed from voltage to vacuum pressure. The rising time (10% to 90%) at this response is about 100 ms, and the falling time is about 500 ms.

The time constant of Keithley 480 has a dependence on the source capacitance. For example, at the nA range we use, a source capacitance 230 pf implies a time constant of 250 ms, which is what we found in a calibration measurement. It is found that this time constant applies to most ion gauges we measured.

Simulation is used to find the real vacuum pressure time structure, i.e. its decay time constant. In Fig.1*b*, a simulation is shown, with a vacuum pressure decay time 35 ms (at the peak pressure 2.5×10^{-8} $Torr$).

In Fig.1*c*, the response of electrometer, filtered by a 60 Hz notch, and the simulated one are shown to be matched. The time structure of the simulated response of the electrometer depends on both the time constants of the input signal, i.e. the vacuum pressure shown in Fig.1*b*, and the time constant of electrometer. Therefore, it looks a beam loss created pressure has a decay time 35 ms.

B. Experiment II

April 12, at the location of C3B, 930 UEB pressure of 5×10^{-10} $Torr$ was observed, when both user 1 and user 2 were on. The response of the electrometer is shown in Fig.2*a*. The rising time and falling time are similar to that in experiment I.

In Fig.2*b* and 2*c*, the simulation (at the peak pressure 2.2×10^{-8} $Torr$) and its match with the filtered electrometer response are shown. Again, the vacuum pressure decay time is 35 *ms*.

C. Experiment III

April 22, the Booster input beam was steered at the end of Tandem transfer line to scrape at the C3 inflector cathode. At the location C3B, a very high pressure (930 UEB) of $> 2 \times 10^{-9}$ *Torr* was created.

In Fig.3, it is shown that to match the simulated and observed response of electrometer, the vacuum pressure decay time has to be 70 *ms*.

In such a very high pressure, the functioning of the ion pumps at C3 section is likely to be different from that with normal conditions, also the nonlinearity of the ion gauge has to be considered. Therefore, the vacuum decay time probably tends to be larger.

D. Other experiments

Another 6 experiments, marked by IV to IX, at different locations and conditions were performed. These are shown in Fig.4. In the cases V and VII, the vacuum decay time constant of 25 *ms*, together with a shorter time constant of electrometer are needed to get a good match. The difference in the time constant of electrometer could be because of the difference of the source capacitance, whereas the difference in the vacuum decay time constant is not large.

In the cases IV, VI, VIII, and IX, 35 *ms* vacuum pressure decay time constant provides good matches.

IV. Vacuum bump in the ring due to beam loss

A. Experiment III

The vacuum bump created by the scraped beam in the ring has been observed in MCR. This is shown in Fig.5.

Without beam, the vacuum pressure in the ring, in general, is below 6×10^{-11} *Torr*.

At a normal operation condition (3.6×10^9 Au^{31+} ions were injected, 1.8×10^9 ions accumulated at 2 *ms* after stacking), there are vacuum bumps built in ring, as shown in Fig.5*a*, where C3 is the injection section, and D6 is the beam dump. The location C3B is at the end of inflector, which shows the highest pressure as 2×10^{-10} *Torr*.

For the experiment III, discussed in the last section, the vacuum bump created by scraping beam at the inflector cathode is shown in Fig.5*b*, where at C3B, the pressure reaches 2×10^{-9} *Torr*.

If the vacuum pressure decay time is 35 *ms*, then the vacuum pressure shown above (which is average value over the Booster cycle, 3 seconds) accounts for only about 1% of the real pressure created by the beam loss. This implies that in experiment III, the real vacuum pressure is probably higher than 10^{-7} *Torr*.

In general, the distance between the ion gauges shown in Fig.5 is 4.2 *meters*. It is observed that the vacuum bump created by the beam scraping is between 15 to 25 *meters* long.

B. Experiments X and XI

April 13 and 16, at the location D1, the vacuum pressure observed at 930 UEB is summarized in Table 1. The vacuum pressure distribution is shown. For experiment X, the ion pumps at C7, D1, and D2 were also turned off. Within a minute, the vacuum pressure is about doubled.

V. Molecules created by the beam loss

In Table 2, the experiments I to IX are summarized.

The lost ion, responsible for the high vacuum pressure, is the estimated value. This is the best we can have, because there is no effective method to accurately calibrate it.

The sputtering can create neutral particles, in forms of particles, molecules, or clusters. For convenience, we simply consider it as molecules. Also, the high energy secondary electrons could stimulate gas desorption, which also generate neutral particle.

If we assume that all the beam loss created neutral particles are located in 5 *meter* long section in the ring. Then, the effective volume is $V_\ell = 500 \times 15 \times 10 = 75,000\ cm^3$. Thus, with the peak pressure P_p shown in Table 2, the molecules created by one lost gold ion can be calculated by,

$$N_{molec.} = 3.3 \times 10^{16} P_p V_\ell / N_{loss}$$

The resulted molecules per lost ion are shown in Table 2. It looks that about 10^5 molecules are produced per lost ion. For the case II, we have used twice of the peak pressure P_p to calculate the molecule per lost ion, because its structure is different from the others.

VI. Acknowledgment

We like to thank H.C. Hseuh, M. Mapes, T. Roser and P. Thieberger for valuable discussions, we also like to thank V. Usack and D. Warburton for technical assistant in the study.

References

[1]S.Y. Zhang and L.A. Ahrens, AGS Studies Report, No. 369, Feb. 1998.

[2]L.A. Ahrens, AGS Studies Report, No. 354, Feb. 1997.

	Ion Gauge	C6	C7	C8	D1	D2	D3A	Unit
	Normal Condition	0.3	0.2	0.1	0.0	0.2	0.2	10^{-10} *Torr*
	Distance	0	4.2	8.4	12.6	16.8	21	*meter*
X	4/13/98, 8:00 pm							
	Scraping $\sim 5 \times 10^8$ *ions* at D1	0.7	1.2	1.0	2.5	1.0	0.5	10^{-10} *Torr*
	Turn off C7, D1, D2 Ion Pumps	0.8	1.4	2.0	4.5	1.0	0.6	10^{-10} *Torr*
XI	4/16/98, 5:30 pm							
	Scraping $\sim 5 \times 10^8$ *ions* at D1	0.8	1.2	2.0	4.0	0.8	0.5	10^{-10} *Torr*

Table 1: Vacuum Bump Created by Beam Loss in Ring

Experiment	I	II	III	IV	V	VI	VII	VIII	IX	Unit
Time	4/16	4/12	4/22	4/2	4/11	4/13	4/13	4/14	4/15	
Ion Gauge	D1	C3B	C3B	C3B	D3A	C3B	C7	D1	C6	
User	2	1 & 2	1	1	2	2	2	2	2	
930UEB	4	5	15	6	2	5	6	3	2.5	10^{-10} *Torr*
Elec. Meter, Peak	40	35	100	60	25	50	50	25	30	10^{-10} *Torr*
Elec. Meter, τ_{meter}	250	250	250	250	150	250	100	250	250	*ms*
Simu. Pressure Decay, τ_p	35	35	70	35	25	35	25	35	35	*ms*
Simu. Pressure, Peak, P_p	350	220	600	500	250	400	600	250	250	10^{-10} *Torr*
Simu. Pressure, Mean	4.1	5.1	14	5.8	2	4.6	5	2.9	2.9	10^{-10} *Torr*
Volume, V	75	75	75	75	75	75	75	75	75	10^3 cm^3
Est. Lost Ion, N_{loss}	5	10	15	10	5	5	10	3	5	10^8 *ions*
Particle per lost ion	0.17	0.11	0.10	0.12	0.12	0.20	0.15	0.21	0.12	10^6

Table 2: Molecules Created by Beam Loss

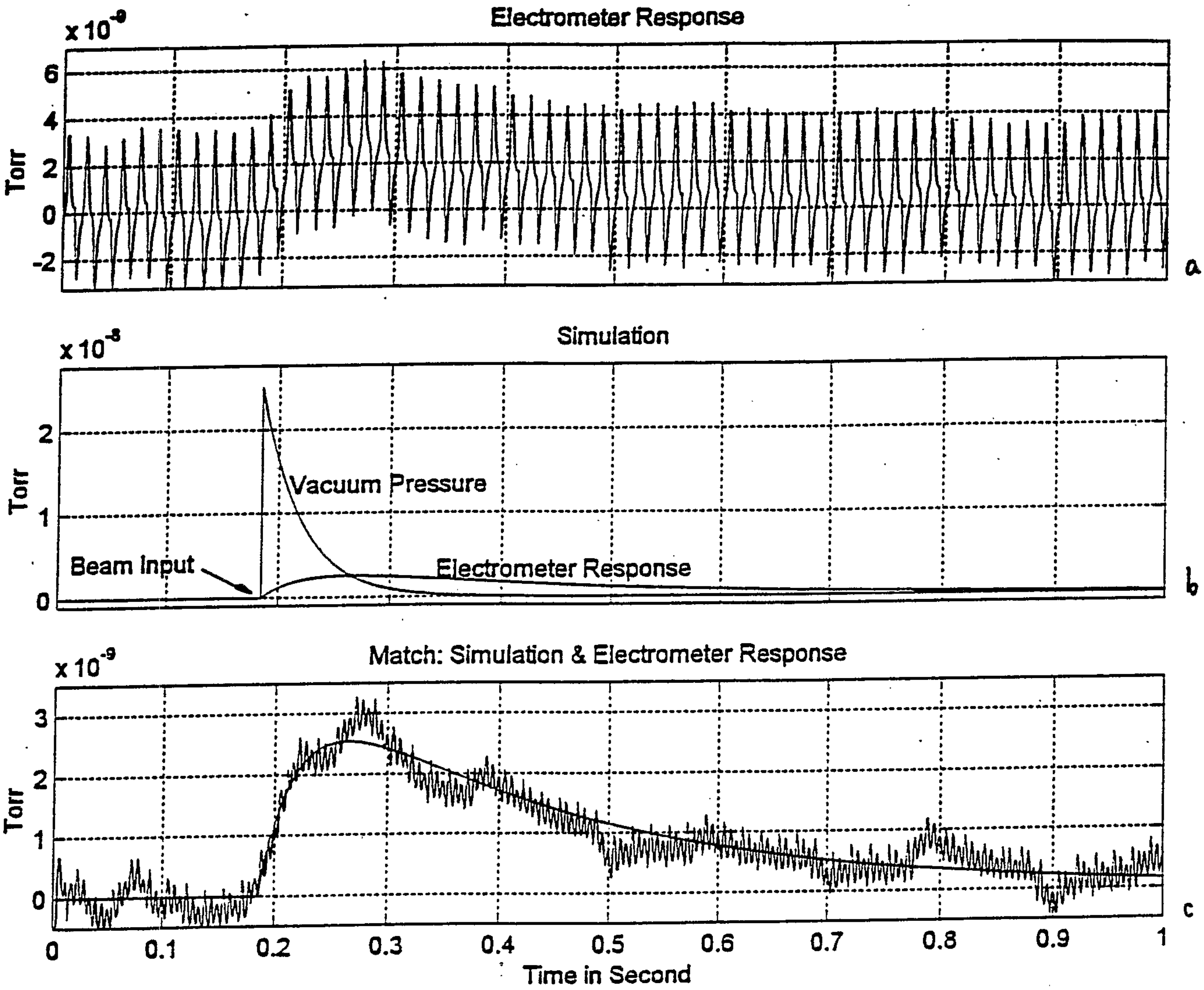


Fig.1: Experiment I. Simulated vacuum pressure decay time is 35 *ms*.

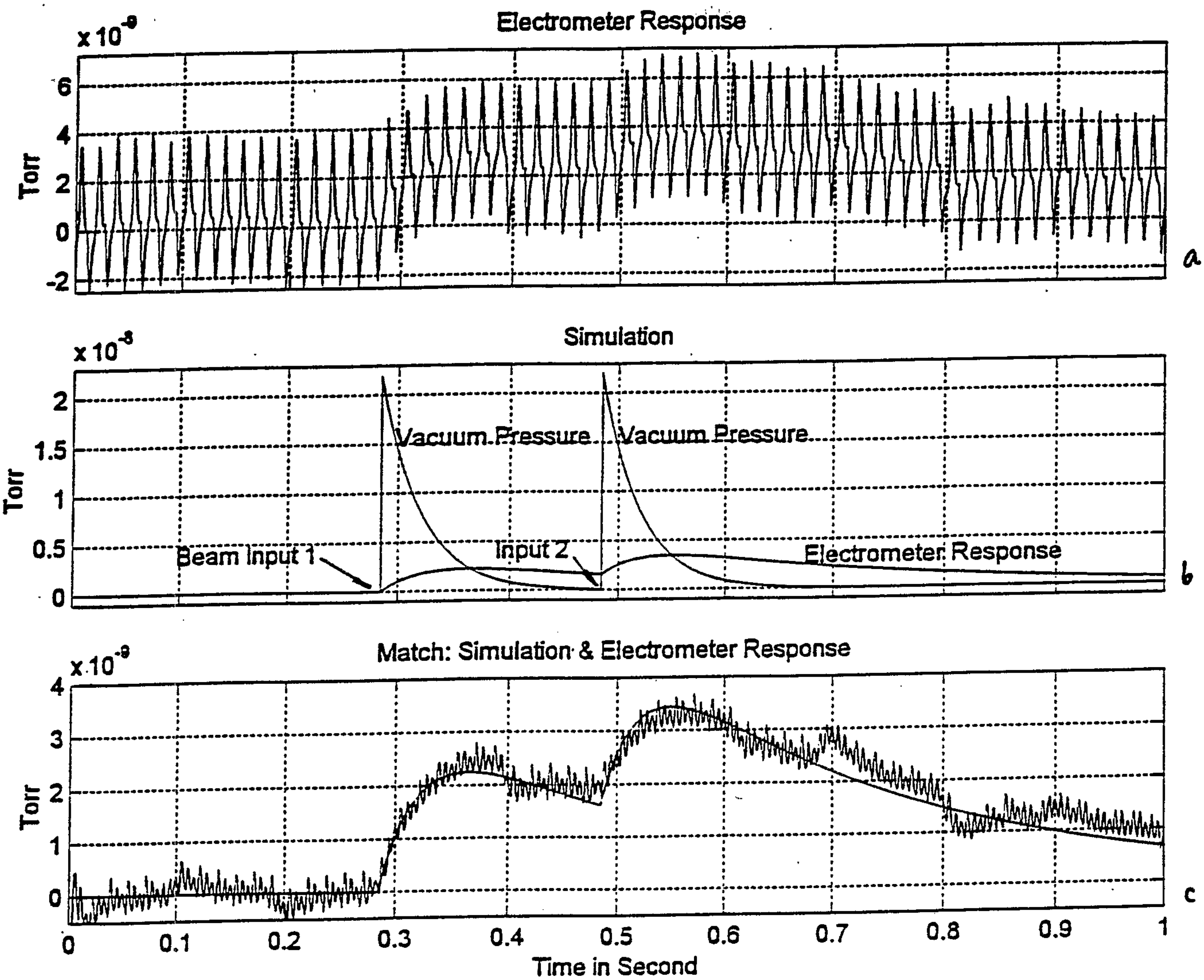


Fig.2: Experiment II. Simulated vacuum pressure decay time is 35 ms.

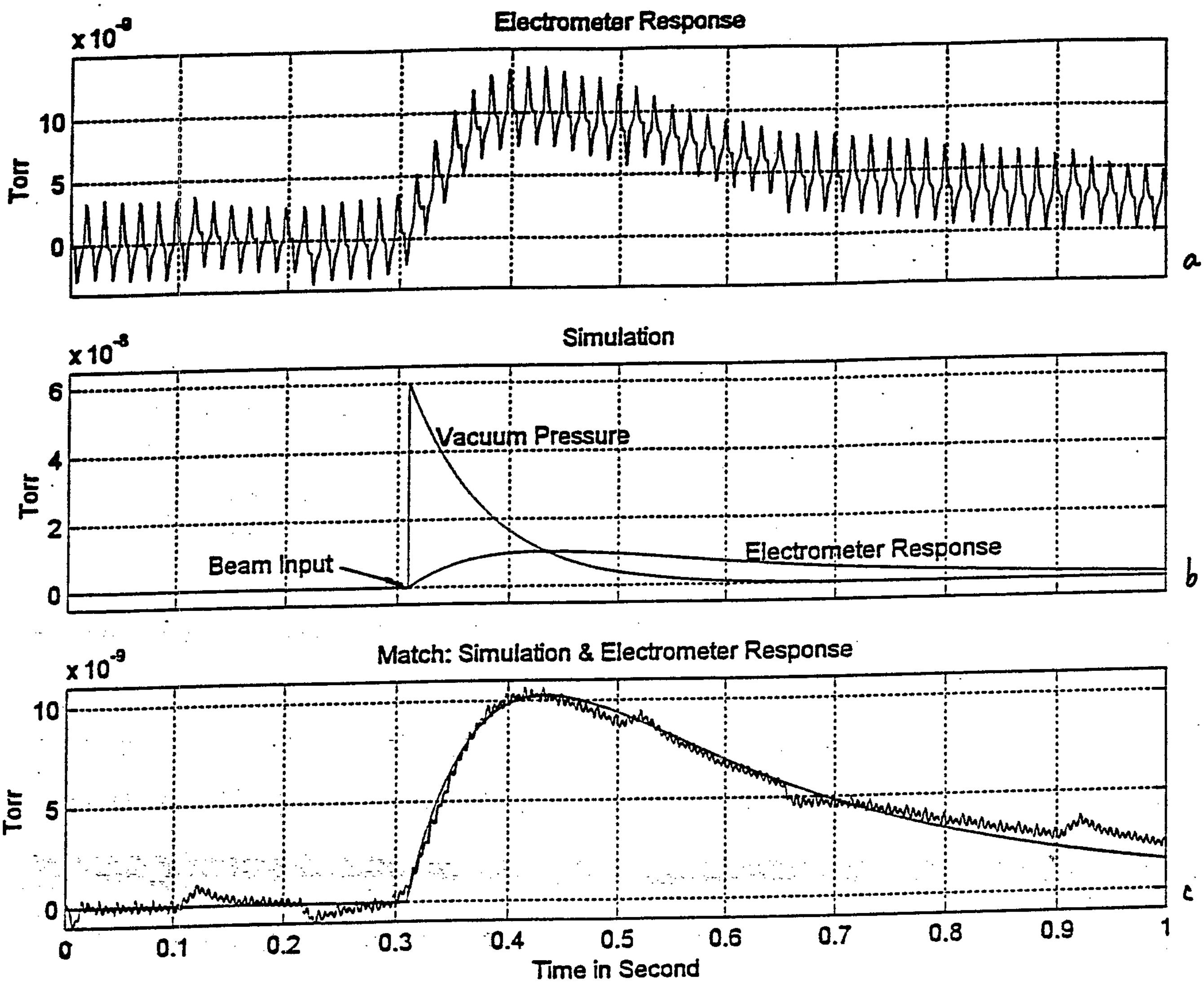
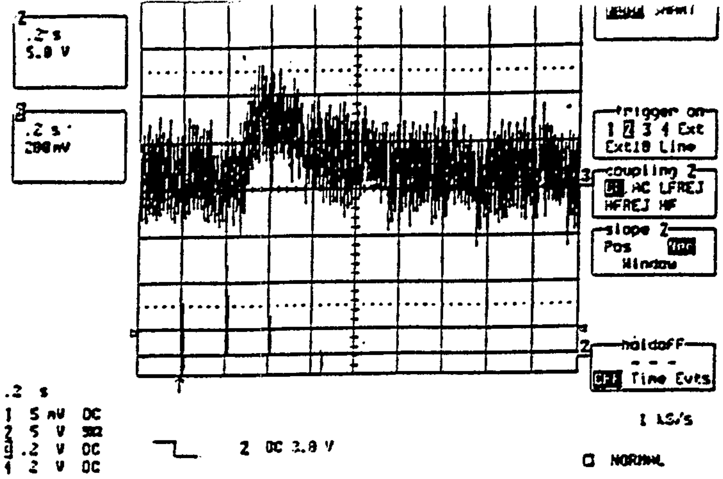
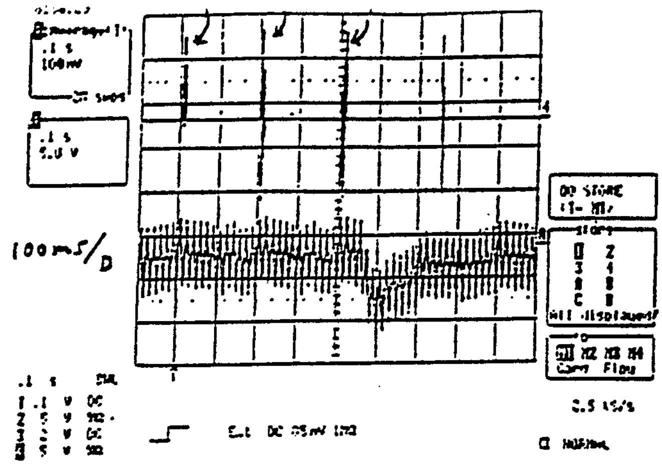


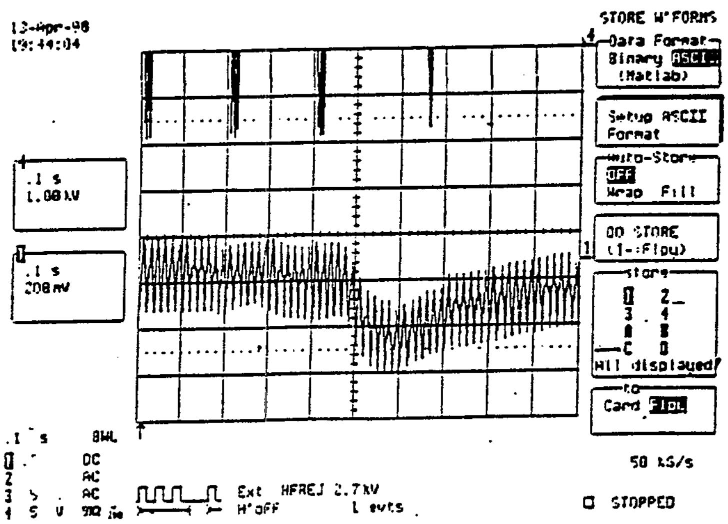
Fig.3: Experiment III. Simulated vacuum pressure decay time is 70 *ms*.



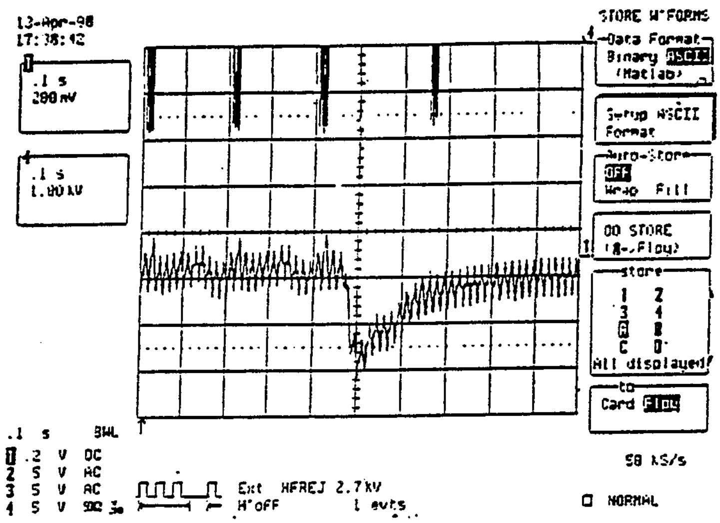
IV 4/2, C3B, User 1, 930 UEB:
6×10^{-10} Torr. Est. Beam Loss 10^9.



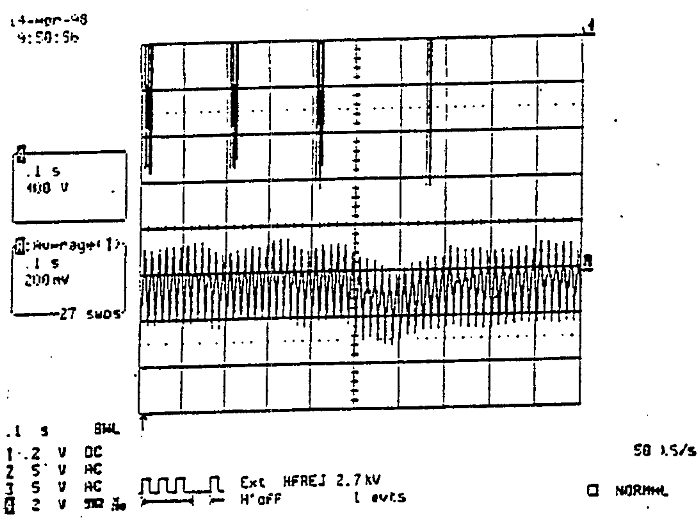
V. 4/11, D3A. User 2. 930 UEB:
2×10^{-10} Torr, Est. Beam Loss: 5×10^8.



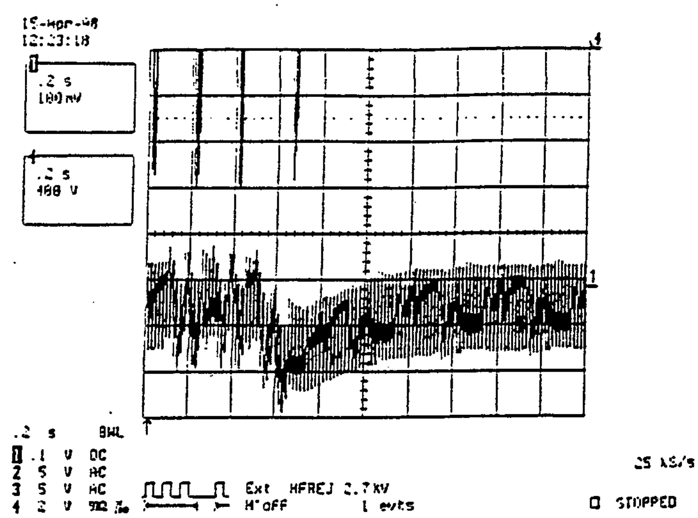
VI. 4/13. C3B, User 2. 930 UEB:
5×10^{-10} Torr. Est. Beam Loss: 5×10^8.



VII. 4/13. C7, User 2. 930 UEB:
6×10^{-10} Torr. Est. Beam Loss: 10^9.



VIII 4/14, D1, User 2. 930 UEB:
3×10^{-10} Torr. Est. Beam Loss: 3×10^8.



IX. 4/15, C6, User 2. 930 UEB:
2.5×10^{-10} Torr. Est. Beam Loss: 5×10^8.

Fig.4: Experiments IV to IX

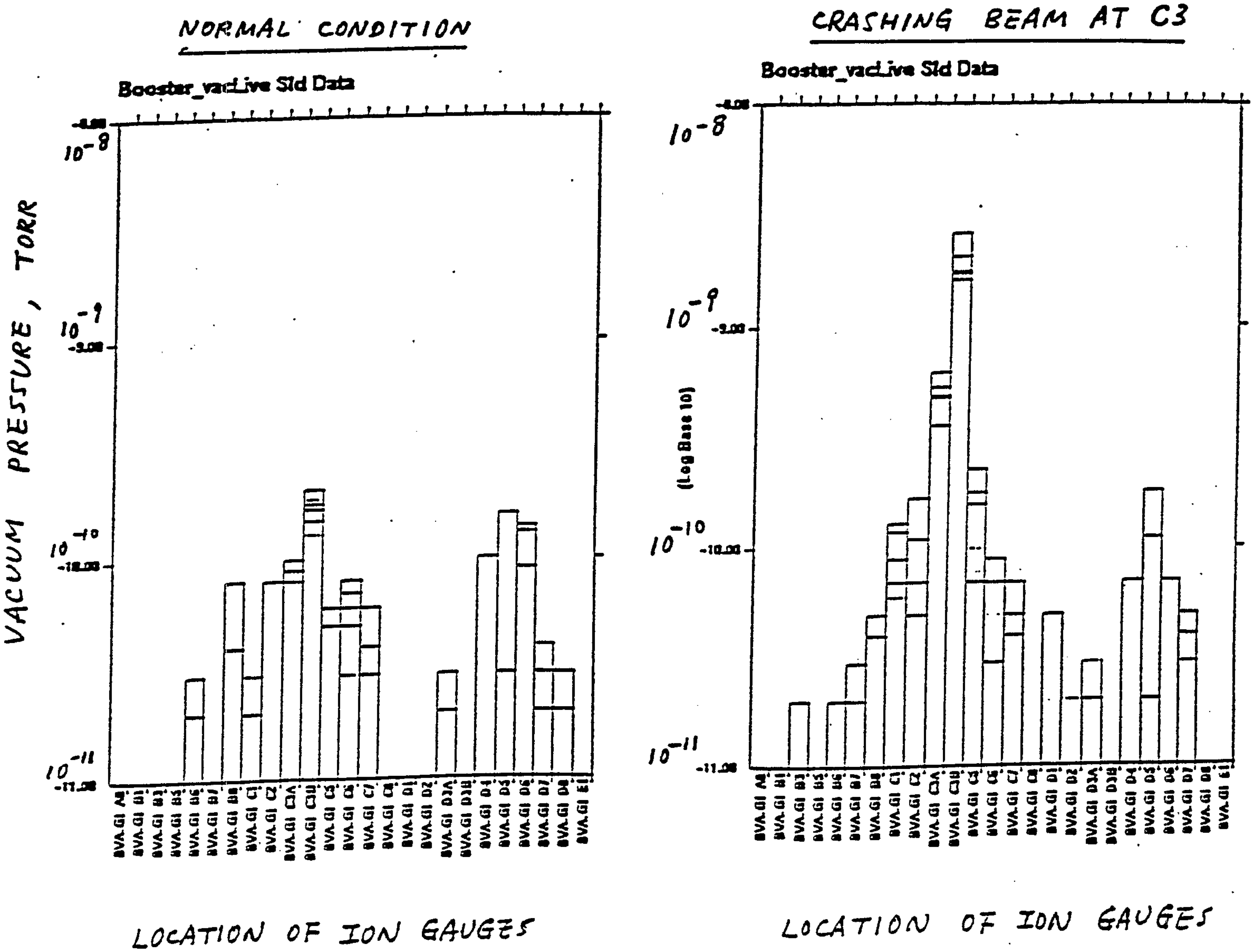


Fig.5: Vacuum Bumps

AGS STUDIES REPORTS INDEX

No.	Date(s) of Study	Title/Experimenter(s) /Author(s) /Date or Report
362	July 8-9, 1997	Calibration of the G-10 Loss Monitor L. Ahrens, W. Van Asselt September 9, 1997
363	Nov. 11- Dec. 23, 1996	Protons Incident on the Booster Dump in 1996 E. Bleser, P. Ingrassia October 6, 1997
364	Dec. 23, 1996 - Sept. 10, 1997	Protons Incident on the Booster Dump in 1997 E. Bleser, P. Ingrassia November 12, 1997
365	Oct. 21-24, 1997	A Study of the Effect of Linear Coupling on the Injection Ion into the Booster L. Ahrens, C. Gardner November 19, 1997
366	Oct. 15, 1997 Oct. 27, 1997	Fe (6+) and Fe (10+) Booster Losses M. Blaskiewicz, L. Ahrens November 25, 1997
367	Oct. 25, 1997	Scanning the New TtB Slits L. Ahrens, S.Y. Zhang, J. Benjamin December 10, 1997
368	Nov. 1-14, 1997	AGS Main Magnet Field Measurement using Polarized Protons E880 Group December 12, 1997
369	Jan. 13, 1997	Booster Gold Beam Injection Efficiency and Beam Loss S.Y. Zhang, L.A. Ahrens February 10, 1999
370	May 28, 1998	Booster Vacuum Measurement for Gold Beam Injection S. Y. Zhang May 28, 1998