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Measurement of Beam Loss of Au+78 at 267 MeV/æ in CO2 Pressure Bumps and the Calculated Charge Exchange Cross Sections

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Subject: Measurement of Beam Loss of Au^{+78} at 267 MeV/μ in CO_2 Pressure Bumps and the Calculated Charge Exchange Cross Sections

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Abstract:

Using B5 beam current transformer, the decay rates of gold beam(+78, 267 MeV/μ) at several vacuum levels were measured in AGS ring at injection flat porches. The injection flat porches were stretched from ~ 50 msec to 1 sec and to 1.8 sec. The average ring vacuum was varied between $2*10^{-8}$ Torr and $2*10^{-7}$ Torr by bleeding in CO_2 through variable leak valves located at C5 and E15 IPMs. The beam decay rates increased proportionally with increasing CO_2 pressures. Using the measured beam decay rates and average ring vacuum, the charge exchange cross section of Au^{+78} at 267 MeV/μ in CO_2 is estimated to be $(3.5 \pm 1.7)*10^{-21}$ cm^2.

Introduction:

Charge exchange processes (either electron capture or electron stripping) dominate the beam-vacuum loss mechanism for partially stripped, low β, very heavy ion. This is one of the reasons that we need Booster with its ultrahigh vacuum to pre-accelerate ions heavier than silicone to higher energy before injecting into AGS. Few experimental charge exchange cross section data exist for gold ions at Booster and AGS injection energies. The knowledge of them will allow us to estimate the vacuum induced beam loss in various acceleration modes in Booster and AGS, as well as for those of RHIC injection. With the commissionning of the gold heavy ion program, we are in a unique position to carry out these measurements.

for beam decay due to background residual gas in AGS vacuum. After the introduction of pressure bumps of CO_2 gas at the IPMs, the equivalent ring CO_2 pressure will induce additional beam decay as given by:

$$R' = I_t'/I_0' = e^{-1*10^{27}*(\sum \sigma_i * P_i + \sigma_{co_2} * P_{co_2}) * t} \quad (5)$$

with σ_{co_2} the cross section of Au in CO_2 and P_{co_2} the ring equivalent partial pressure of CO_2.. If we assume the rates of beam loss due to non-vacuum related mechanisms remains the same over the selected portion "t" of the flat porches and will cancel with each other, the ratios of beam decay rates will be proportional to CO_2 pressures according to:

$$R/R' = e^{-1*10^{27}*(\sigma_{co_2} * P_{co_2}) * t} \quad (6)$$

From eqn. (6), we can derive σ_{co_2} without knowing the composition of the background gas in AGS.

The σ_S and σ_C for Au at 267 MeV/μ in CO_2 are calculated to be $1.5*10^{-21}$ and $5*10^{-22}$ cm^2 using eqns. (1) and (2), respectively. Based on these theoretical cross sections, the product of P_{co_2} *t has to be greater than $2*10^{-7}$ Torr.sec, if one expects to observe tens percent in vacuum induced beam loss. The ring equivalent P_{co_2} of 10^{-7} Torr can be generated with pressure bumps of 10^{-5} Torr at IPMs. Flat porches of 1 sec or longer, therefore, is needed at injection.

Measurement of Equivalent CO_2 Pressure

The AGS ring vacuum is monitored through sputter ion pump currents. There are a total of 255 ion pumps located, approximately every three meters, on an elbow 1 m from beam channel. Detailed ring pressure profile converted from ion pump currents is available every AGS pulse from the "Log_Read" program. At the same pressure, the newly installed AGS ion pumps draw twice the current of the old ones, resulting in a pressure reading by the Apollo twice that of the true pressure at the pumps. However, due to conductance limitation of the elbows and the dipole chambers, the pressure inside the chambers is higher than that at the pumps. Using Eqn. (5) in ref. 4, the average pressure inside the chambers is calculated to be 2.5 times of the pressure at the nearby pumps. The ring average pressure, therefore, is approximately 25% higher than the readouts indicated.

The ring background pressure is $\approx 2*10^{-8}$ Torr(N_2 equivalent). Pressure bumps upto $1*10^{-5}$ Torr level were generated by bleeding-in CO_2 gas through the variable leak valves located at C5 and E15 IPMs. The pressure distributions around the IPMs are shown in Fig.1 with and without CO_2 leaks. For the short study period, the pressure bumps were confined within six ion pumps upstream and downstream of the leaks. The equivalent ring CO_2 pressure is derived by summing up the ΔP of twelve pumps around the leaks; then divided by the total number of ring ion pumps.

Measurement of Beam Decay at Flat Porches

The output voltages of B5 beam current transformer were used as a relative measure of beam intensity at flat porches. Typical outputs are shown in Figs. 2 and 3 for 1 sec flat porch and 1.8 sec flat porch, respectively. One volt signal equals to $3*10^9$ charges. To improve statistics, signals from consecutive pulses were accumulated and averaged. The decay in beam intensity could be caused by a number of mechanisms. The contribution from beam-residual gas charge exchange should give a monotonous decrease in beam intensity. We select the portion of flat porches which gave the monotonous beam decay and used them to derive the decay rates and the charge exchange cross sections.

For 1 sec flat porch, the region between 160 msec and 560 msec is selected as the time "t", based on above mentioned reasons. The decay rate over the whole second is also used for comparison. For 1.8 second flat porches, sharp drops in voltages were observed at 0-360 msec and 1.16 - 1.8 sec. The later was caused by a shift in the horizontal beam center as evident in Fig. 4 of the horizontal outputs of IPM. The time period between 0.56 - 1.16 sec, therefore, was used to derive the decay rates and the charge exchange cross sections.

Results and Conclusion

Several sets of measurements were carried out at flat porches of 1 sec and 1.8 sec. The pressure bumps were first generated at E15 IPM, then at both E15 and C5 IPMs; and the equivalent CO_2 pressure calculated accordingly. The output voltages from beam current transformer at the selected "t"s are listed in Table 1. The logarithmic ratios (Log(R/R')) of the beam decay rates are plotted in Fig. 5 against equivalent CO_2 pressures.

Table 1. Summary of Beam Current Transformer Output Voltages w/ and w/o CO_2

1 sec flat porch		BKG	CO_2	CO_2	CO_2	BKG
P_{CO_2} (*10^{-8} Torr)		0	5	8	20	0
# of AGS pulses		8	1	8	8	88
Xmer Output						
t(sec) =	0	0.86	0.78	0.85	0.75	0.7
	0.16	0.82	0.76	0.8	0.68	0.67
	0.56	0.8	0.67	0.7	0.53	0.64
	1.0	0.67	0.51	0.56	0.36	0.52

1.8 sec flat porch		BKG	CO_2	CO_2	BKG
P_{CO_2}(*10^{-8} Torr)		0	16	16	0
# of AGS pulses		7	8	46	10
Xmer Output					
t(sec) =	.36	0.74	0.6	0.52	0.46
	0.56	0.7	0.56	0.48	0.42
	1.16	0.67	0.36	0.25	0.41
	1.76	0.64	0.02	0.01	0.4

The ratios of the decay rates of 1.8 sec flat porches (the diamonds at $P_{CO_2} \approx 1.6*10^{-7}$ Torr) are much higher than those from 1 sec flat porches and might be caused by some other beam loss mechanisms such as the shift of the horizontal beam center indicated from IPM data in Fig. 4. If we ignore these two points, the remaining data fall almost on a straight line. The slope of this line represents the total charge exchange cross sections and gives a value of $(3.5 \pm 1.7) *10^{-21}$ cm^2, after correcting the 25% error in pressure readouts.

In summary, the measured total cross sections are consistent with theoretically calculated value of $\sigma_S + \sigma_C = 2*10^{-21}$ cm^2 using equations (1) and (2). Measurements with Au^{+79} and Au^{+77} beam in the future HIP runs will allow us measure the capture and stripping cross sections separately, since only capture is possible for Au^{+79}, and capture into L and M shells is much less likely than stripping in Au^{+77}.

Acknowledgment

The authors are indebted to R. Witkover for his original suggestion of using output signals from beam current transformer to measure the beam decay rates during injection.

References

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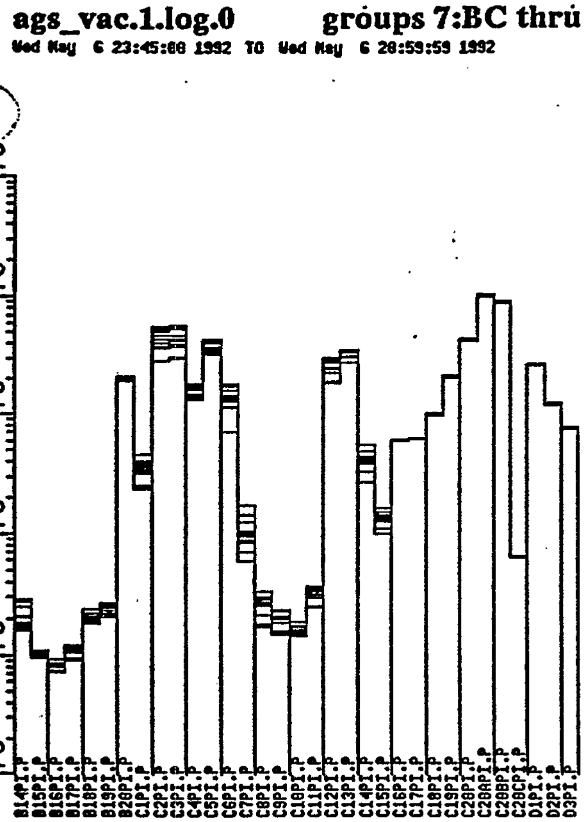
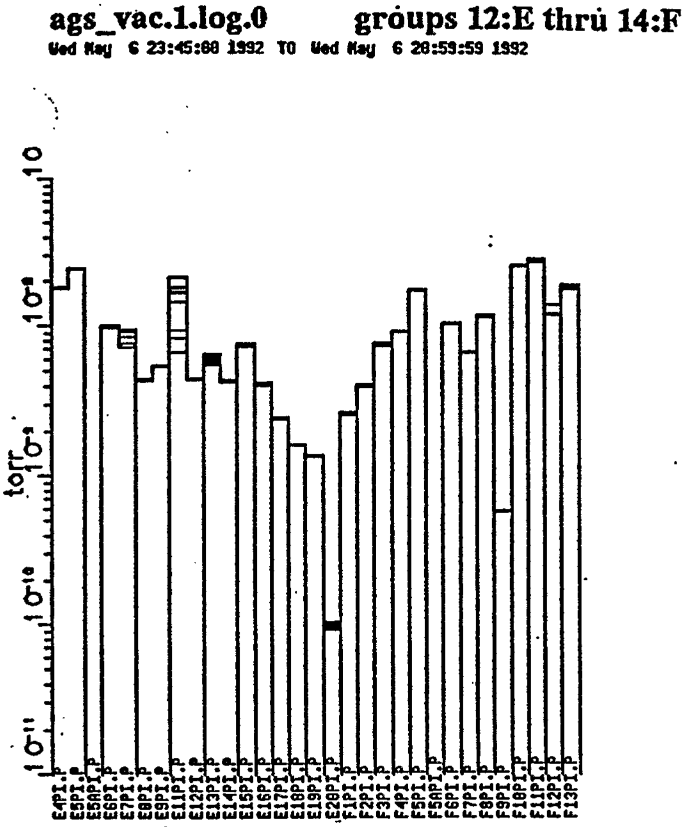
2. H.E. Bethe, Ann. Phys. 5, 225(1930).
3. G.R. Young, "Collider Vacuum Requirements", RHIC-PG-11, Dec., 1983.
4. H.C. Hseuh, "Pressure Distribution Along the AGS Vacuum Chambers", AGS/AD Tech. Note No.273, Jan., 1987.

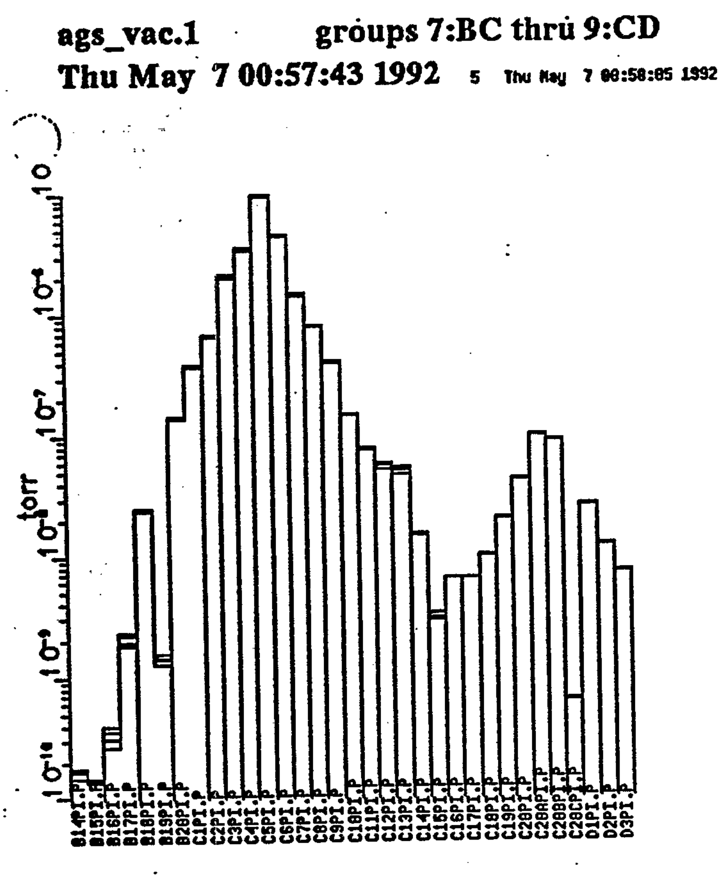
Fig. 1. Pressure profiles around IPMs.



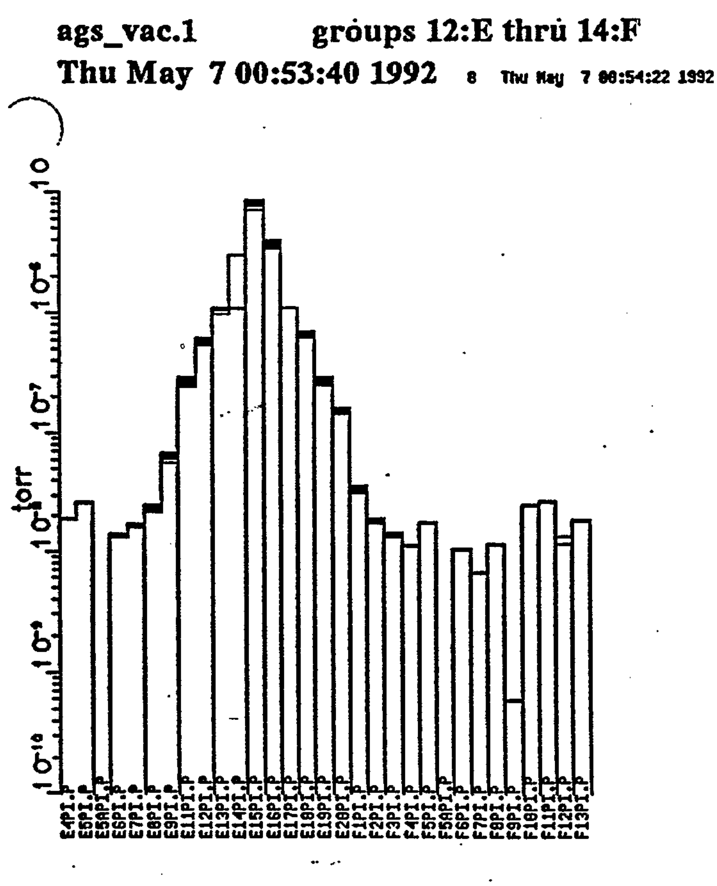
(a). Background around C5



(b). Background around E15

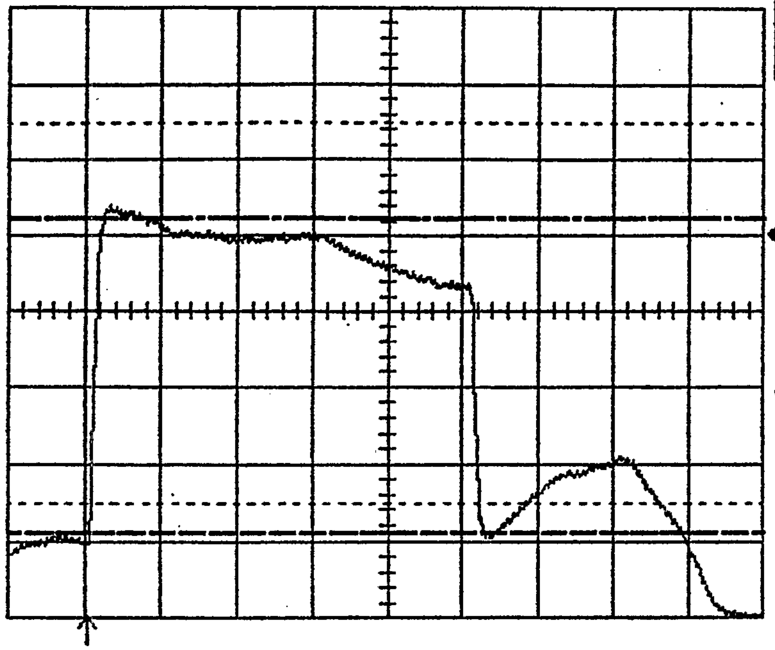


(c). With CO_2 leak at C5

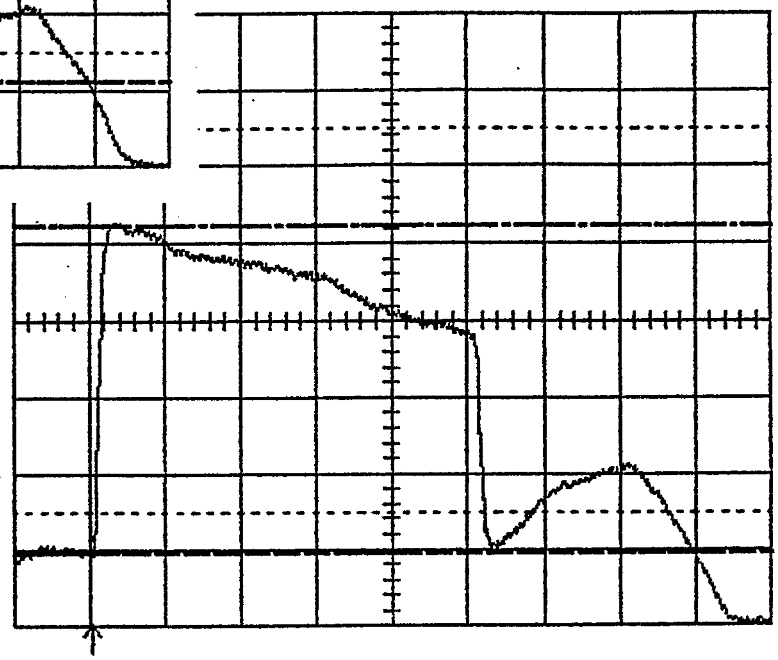


(d). With CO_2 leak at E15

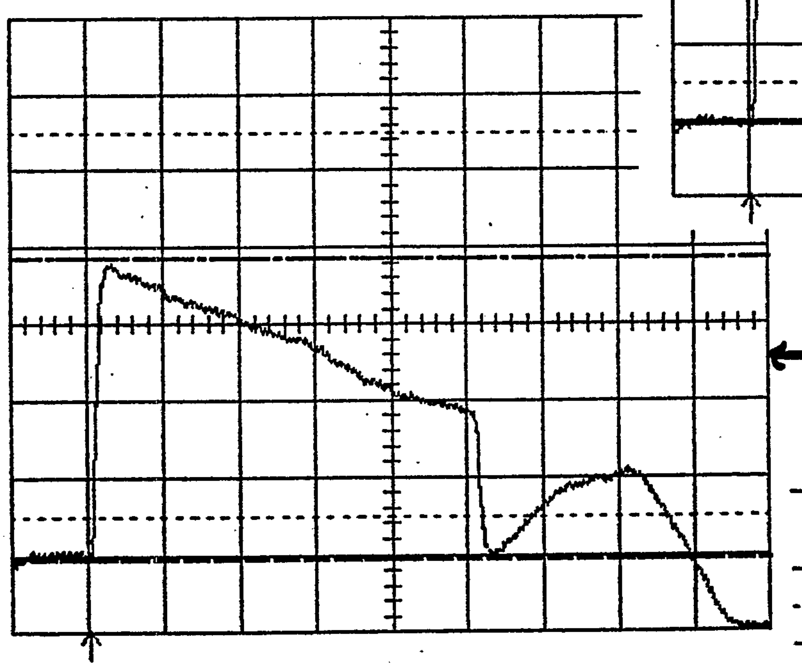
Fig. 2. Outputs of Beam Current Transformer at 1 sec flat porch. 0.2 s/div., 0.2 V/div.



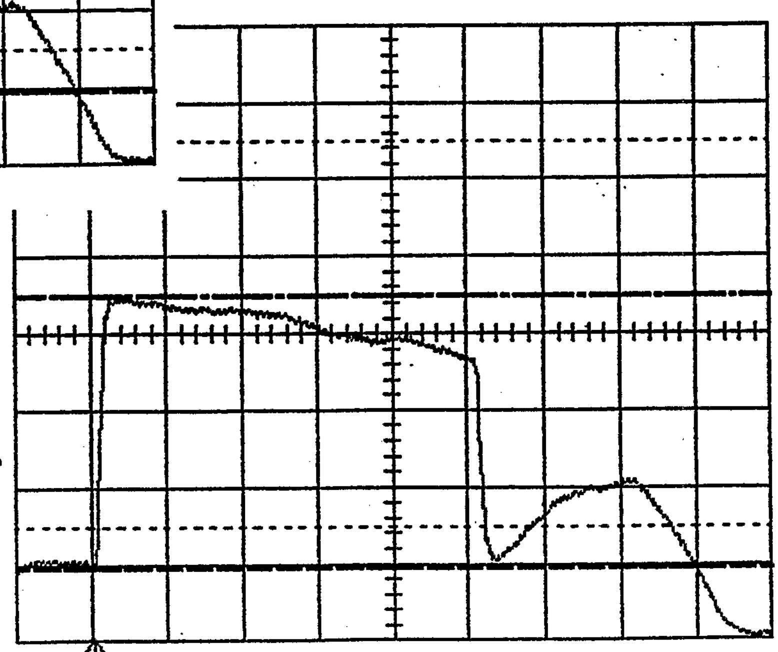
(a). Background w/ 8-pulse average



(b). $8*10^{-8}$ Torr CO_2 equivalent w/ 8-pulse average

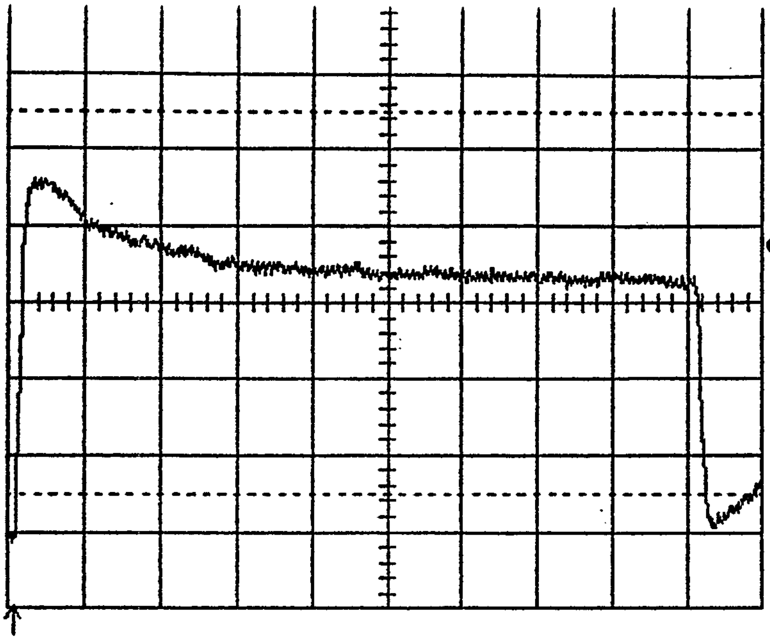


(c). $2*10^{-7}$ Torr CO_2 equivalent w/ 8-pulse average

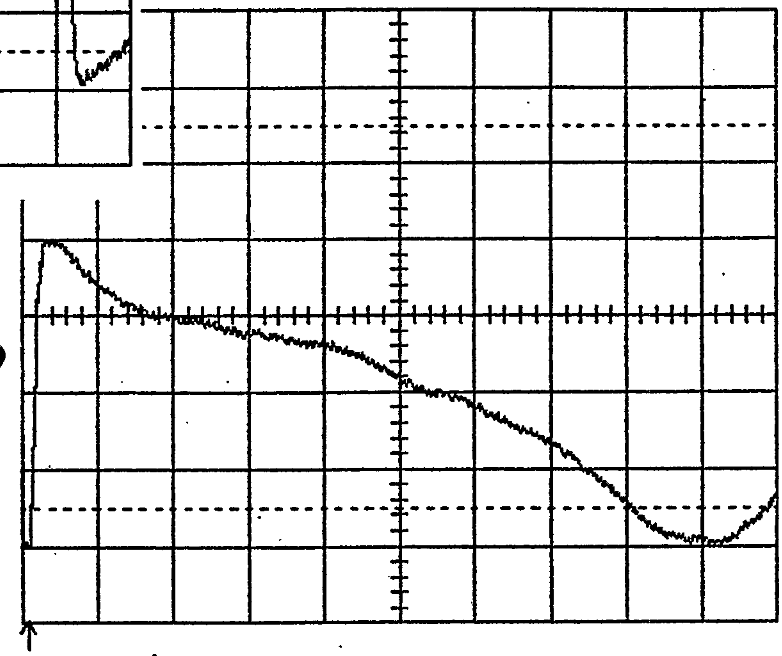


(d). Background w/ 88-pulse average

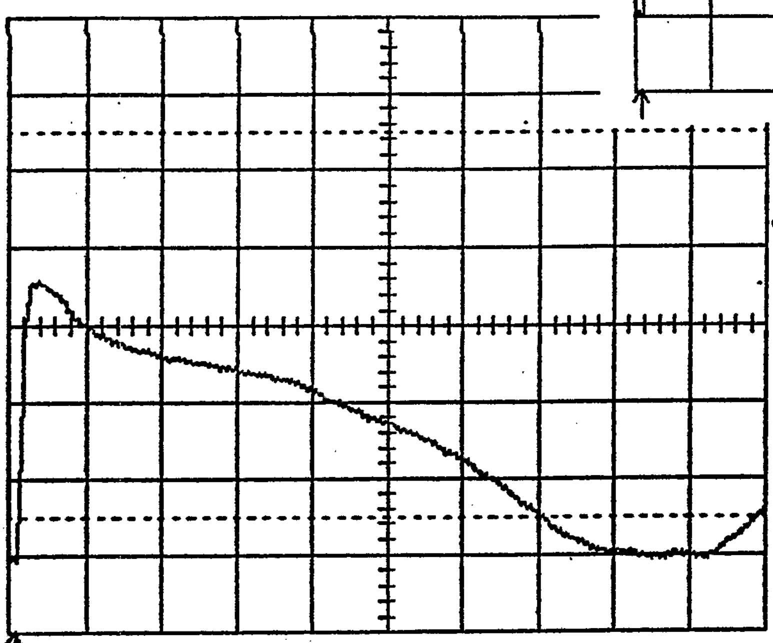
Fig. 3. Outputs of Beam Current Transformer at 1.8 sec flat porch, 0.2 s/div., 0.2V/div.



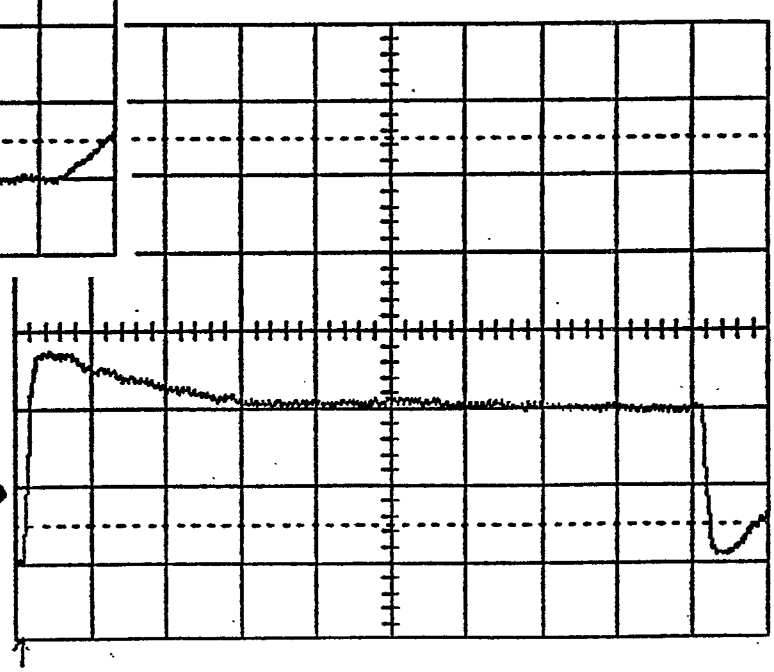
(a). Background, 7-pulse average



(b). 1.6*10^{-7} Torr CO_2 equivalent w/ 8-pulse average



(c). 1.6*10^{-7} Torr CO_2 equivalent w/ 46-pulse average



(d). Background w/ 10-pulse average

Fig. 4. Horizontal beam centroid and integrated intensity from C5 IPM

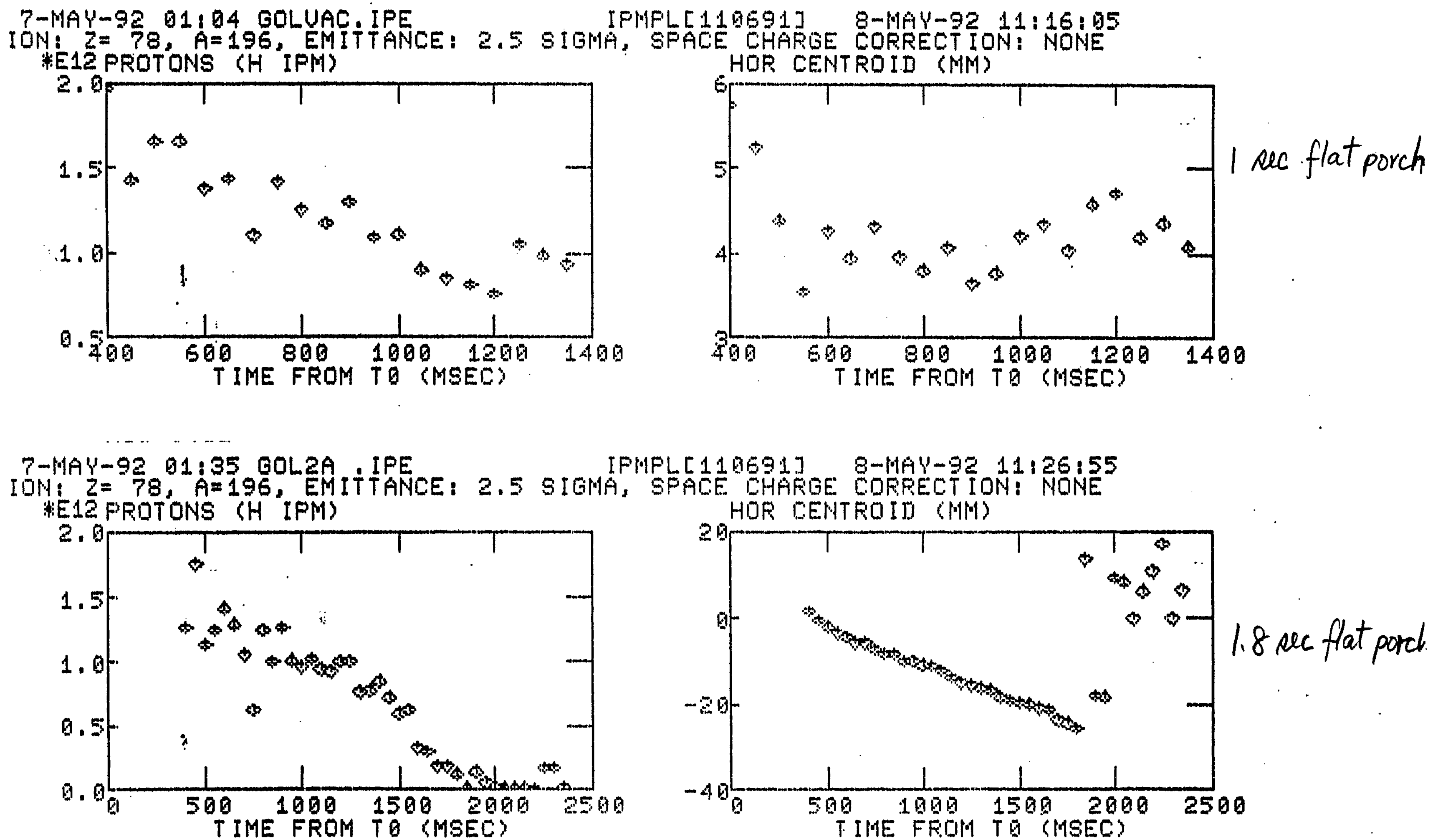


Fig. -

Decay Rate of Gold Beam vs P(CO2)

+78 and 267 MeV/u