A Look at Tevatron Beam Signals through the New BPM System Filter Boards

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Measurements were made to check Tevatron BPM signal strength that is applied to the Echotek boards through the new BPM system filter boards. Signals from un-coalesced protons and from Collider proton and antiproton bunches are presented.

Shot Set-up Un-coalesced Beam Signals

On 2/2/05, measurements were made with 25E10 un-coalesced protons circulating in the Tevatron. Signals were viewed directly at the BPM filter board output into a wideband 50 ohm scope input with the scope sampling at 5GHz (0.2nsec/sample).

Figures 1, 2, and 3 respectively display scope screens for signals from VA37B, VA39A, and VA39B. The signal duration is about 600 nanoseconds as expected for ~30 bunches. The signal amplitude as would be presented to the EchoTek board inputs is observed to be 20-40 mV peak-to-peak. An EXCEL file, "25E10UNC_VA37B_protons.xls" contains the measurement data from the VA37B signal.

Collider Bunch Signals - Protons

On 2/4/05, measurements were made of signals from typical Collider bunches during Store #3962 in the Tevatron. Again, signals were viewed directly at the BPM filter board output into wideband 50 ohm scope input with scope sampling at 5GHz (0.2nsec/sample).

Figures 4 and 5 show the proton signals from the B and A plates of the VA37 BPM with about 225E9 protons per bunch. The A signal is seen to be about 50% larger than the B signal indicating that the protons are well off-center toward the A plate. This is not un-expected because of the helical orbits established by the Tevatron separators.

An EXCEL file, "VA37protons_BA_fast_store3962.xls" contains the measurement data from the signals shown in Figure 5.

Figure 6 shows that the proton intensity in the Tevatron at the time these measurements were taken was ~225E9/bunch. The 440 mV amplitude of the larger (A plate) signal for this bunch intensity is suitably matched to the 1100 mV p-p input range of the EchoTek boards considering that VA37 cables are medium length and that the requirements call for handling proton bunch intensity up to 350E9.

Collider Bunch Signals - Antiprotons

Figure 7 shows the expected timing of proton bunches (red) and antiproton bunches (blue) at the VA37 BPM location (only about 67% of the bunches in the ring are shown). The first (tall) proton bunch is Bunch #1 and the successive proton bunches are numbered sequentially. The tallest antiproton bunch, the 13th in the plot, is antiproton Bunch #1.

The signals from the antiproton and proton ends of the VA37 BPM A plate are shown in Figure 8. The relative proton to antiproton timing is as expected if the larger signals on the antiproton channel are in fact from the first antiproton bunches in a train of twelve,. From this picture alone however this is not obvious. The proton feedthrough results in signals of nearly the same magnitude as those from the smallest of the antiproton bunches and the timing from the last antiproton bunch of a train to the first bunch of the next proton train is almost identical to the time between bunches within a train. Figure 9 shows the VA37 B plate antiproton signal along with the same VA37 A plate signal as shown in Figure 8 (but on opposite scope channel). The B plate signal manifests much less proton signal contamination and confirms the expected relative bunch timing. Blue bars in Figure 9 span times of antiproton bunch trains and red bars span proton trains.

The antiproton bunch intensities as measured by the Tevatron Fast Bunch Integrator system at the time are displayed in Figure 10. This allows identification of the individual antiproton bunches in the figures. The first antiproton train in Figure 9 is comprised of bunches 13-24, the second bunches 35-36, and the third bunches 1-12.

The character of the two antiproton signals in Figure 9 is strikingly different; the A plate signal manifests much worse contamination from protons. Qualitatively, much of the explanation for this difference can be found in the separated proton and antiproton orbits. Figure 5 shows that the proton A signal is about 50% larger than the B signal; so assuming constant stripline directivity, 50% more proton signal should be expected in the A antiproton channel than in the B channel. The relative antiproton to proton signal ratio in the A channel is further reduced since the offset antiproton orbit produces a smaller antiproton signal in the A channel relative to the B channel (about 10% from Figure 9). Antiprotons farther from A than from B and protons nearer A than B both contrive to worsen the antiproton to proton signal ratio at plate A. This situation may be further compounded by sensitivity of the stripline directivity to beam position.

The A and B proton signal magnitudes for the 225E9 proton bunch intensity sum to about 720 mV. The antiproton A and B signals for bunch #13 at 40E9 add to about 420 mV. This gives an antiproton to proton channel gain ratio of 3.28 or 10.3 db in good agreement with the 10 db channel difference design.

Summary

The signals observed are consistent with the expectations and design parameters for the BPM system. Signals from un-coalesced protons are on the low end of the EchoTek range; bench tests should be done to verify position resolution for signals of this size. Antiproton signals suffer greatly different degrees of proton signal contamination.

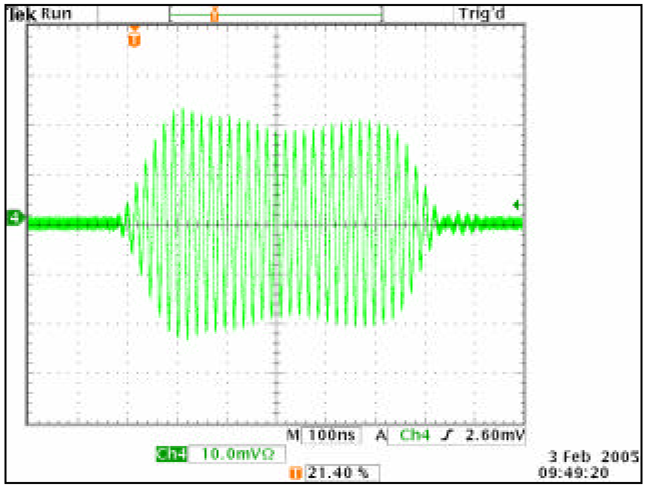

Figure 1. VA37B proton signal for 25E10 un-coalesced protons.

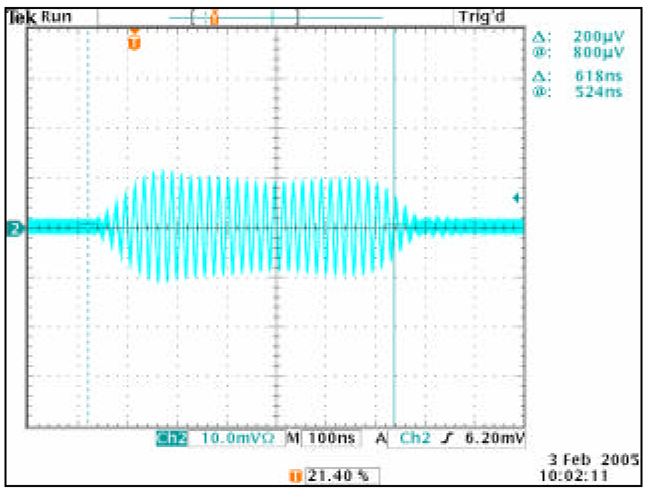

Figure 2. VA39A proton signal for 25E10 un-coalesced protons.

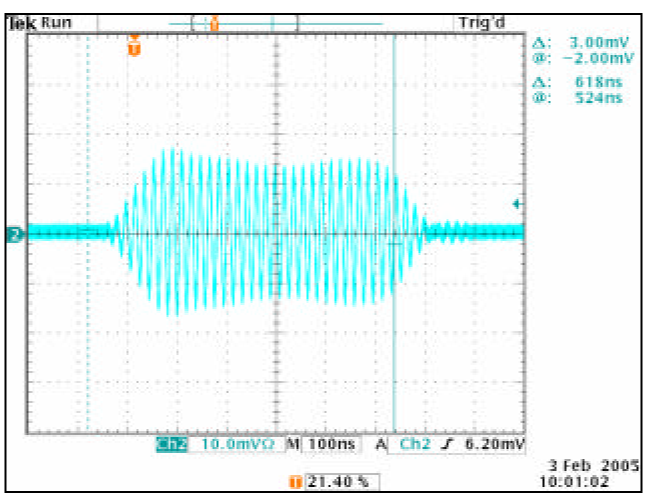

Figure 3. VA39B proton signal for 25E10 un-coalesced protons.

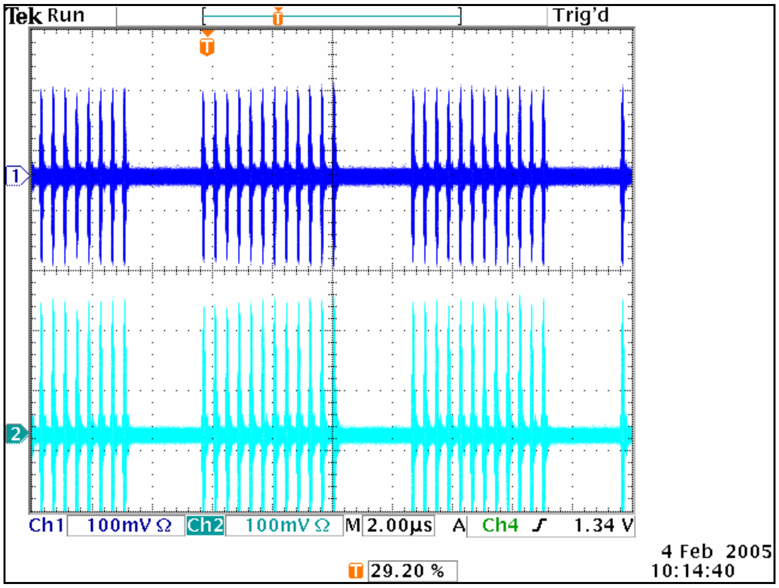

Figure 4. VA37 proton signals for ~225E9 coalesced protons per bunch; Channel 1 is VA37 B plate proton signal, Channel 2 is VA37 A plate proton signal.

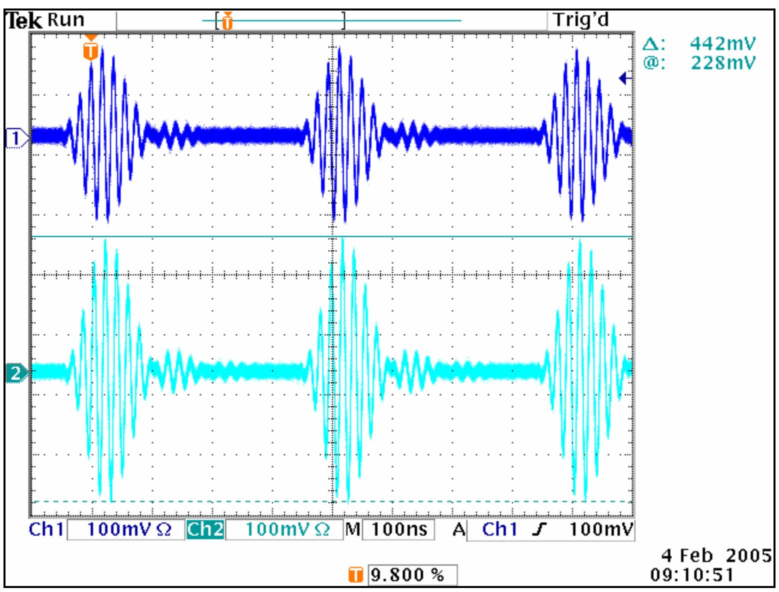

Figure 5. Same as Figure 4 with faster scope sweep speed; VA37 proton signals for ~225E9 coalesced protons per bunch


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COMMAND *TIMING STATISTICS *DBWORK used = /4096
-< 2>+ *DUMP DBWORK TO SS *LONG *E-FORMAT *CSET
sbd bpm flywir ibeams FBI blt blm ipm slight

-C:FBIPNG	TFBI	Prot	NaroGate	Inten	0	8191	E09
-C:FBIPNG[1]	TFBI	Prot	NaroGate	Inten	1	221.7	E09
-C:FBIPNG[2]	TFBI	Prot	NaroGate	Inten	22	219.2	E09
-C:FBIPNG[3]	TFBI	Prot	NaroGate	Inten	43	217.2	E09
-C:FBIPNG[4]	TFBI	Prot	NaroGate	Inten	64	226.5	E09
-C:FBIPNG[5]	TFBI	Prot	NaroGate	Inten	85	224.6	E09
-C:FBIPNG[6]	TFBI	Prot	NaroGate	Inten	106	231.7	E09
-C:FBIPNG[7]	TFBI	Prot	NaroGate	Inten	127	233.9	E09
-C:FBIPNG[8]	TFBI	Prot	NaroGate	Inten	148	227.7	E09
-C:FBIPNG[9]	TFBI	Prot	NaroGate	Inten	169	227.1	E09
-C:FBIPNG[10]	TFBI	Prot	NaroGate	Inten	190	232.2	E09
-C:FBIPNG[11]	TFBI	Prot	NaroGate	Inten	211	231.7	E09
-C:FBIPNG[12]	TFBI	Prot	NaroGate	Inten	232	236.8	E09
-C:FBIPNG[13]	TFBI	Prot	NaroGate	Inten	372	227.6	E09
-C:FBIPNG[14]	TFBI	Prot	NaroGate	Inten	393	225.5	E09
-C:FBIPNG[15]	TFBI	Prot	NaroGate	Inten	414	230.9	E09
-C:FBIPNG[16]	TFBI	Prot	NaroGate	Inten	435	221.3	E09
-C:FBIPNG[17]	TFBI	Prot	NaroGate	Inten	456	229.8	E09
-C:FBIPNG[18]	TFBI	Prot	NaroGate	Inten	477	229.1	E09
-C:FBIPNG[19]	TFBI	Prot	NaroGate	Inten	498	224.1	E09
-C:FBIPNG[20]	TFBI	Prot	NaroGate	Inten	519	233.3	E09
-C:FBIPNG[21]	TFBI	Prot	NaroGate	Inten	540	228.4	E09
-C:FBIPNG[22]	TFBI	Prot	NaroGate	Inten	561	236.2	E09
-C:FBIPNG[23]	TFBI	Prot	NaroGate	Inten	582	223.5	E09
-C:FBIPNG[24]	TFBI	Prot	NaroGate	Inten	603	230.8	E09
-C:FBIPNG[25]	TFBI	Prot	NaroGate	Inten	743	232.7	E09
-C:FBIPNG[26]	TFBI	Prot	NaroGate	Inten	764	219.1	E09
-C:FBIPNG[27]	TFBI	Prot	NaroGate	Inten	785	229	E09
-C:FBIPNG[28]	TFBI	Prot	NaroGate	Inten	806	222.4	E09
-C:FBIPNG[29]	TFBI	Prot	NaroGate	Inten	827	226.1	E09
-C:FBIPNG[30]	TFBI	Prot	NaroGate	Inten	848	232.1	E09
-C:FBIPNG[31]	TFBI	Prot	NaroGate	Inten	869	227.4	E09
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-C:FBIPNG[34]	TFBI	Prot	NaroGate	Inten	932	228	E09
-C:FBIPNG[35]	TFBI	Prot	NaroGate	Inten	953	230.3	E09
-C:FBIPNG[36]	TFBI	Prot	NaroGate	Inten	974	231.8	E09
-C:FBIPNG[37]	TFBI	Prot	NaroGate	Inten	1033	-6.038	E09

Figure 6. Proton bunch intensities during Store 3962.

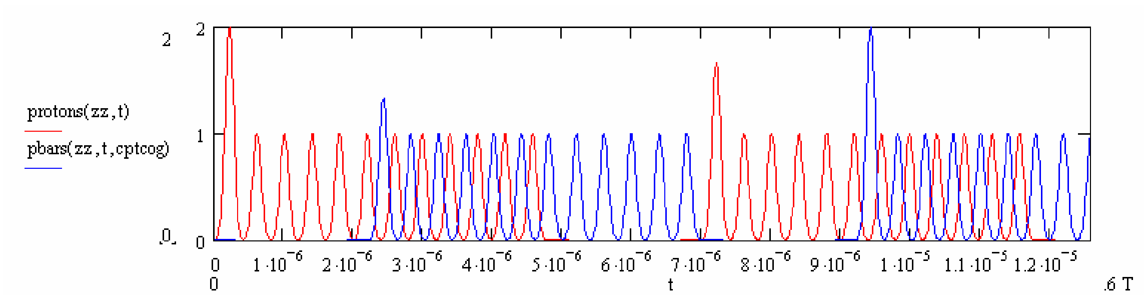


Figure 7. Proton (red) and antiproton (blue) bunch timing at VA37 BPM location.

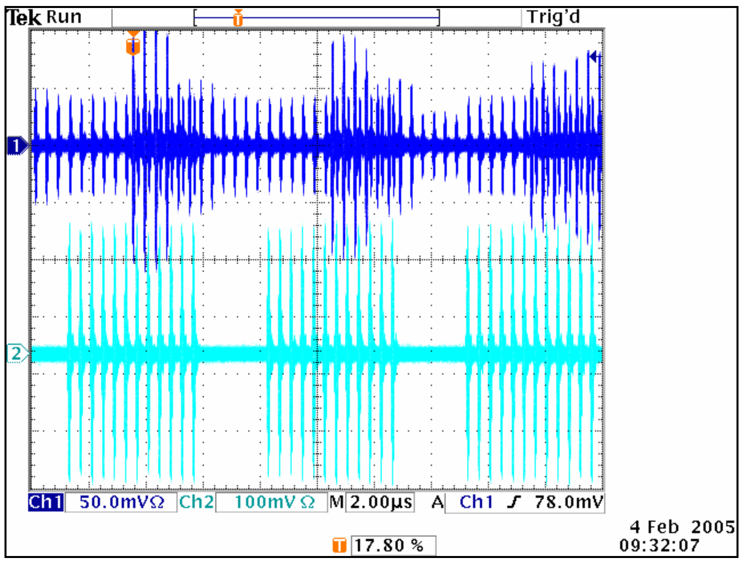


Figure 8. VA37 A plate antiproton signal (Channel #1) and proton signal (Channel #2)

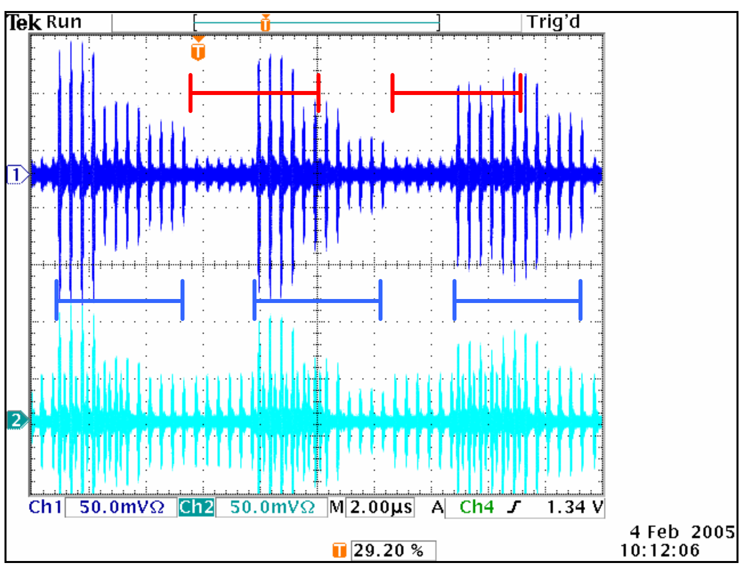
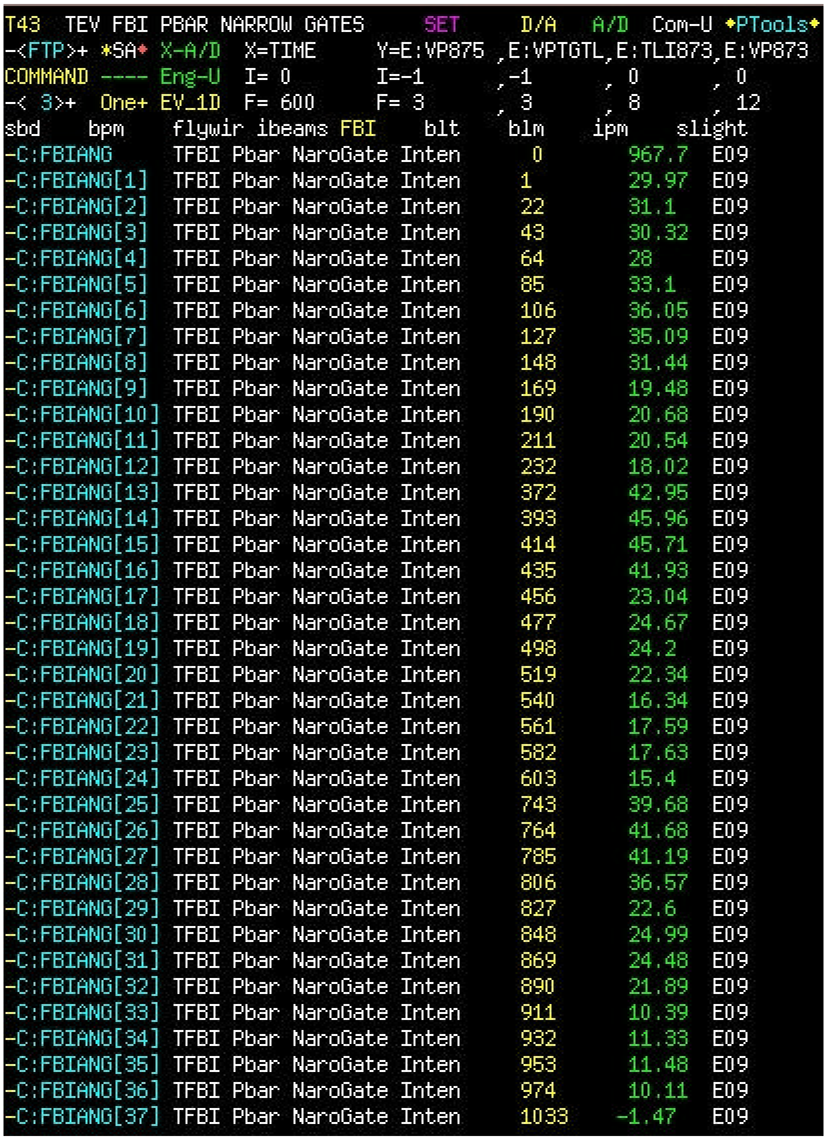


Figure 9. VA37 B (Channel #1) and A (Channel #2) plate antiproton signals in order from bunch 13-24, 25-36, and 1-12. Blue bars span time of antiproton bunch trains; red bars span time of proton bunch trains.



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COMMAND ---- Eng-U  I= 0       I=-1      ,-1      , 0      , 0
-< 3>+  One+ EV_1D  F= 600     F= 3      , 3      , 8      , 12
sbd    bpm    flywir ibeams FBI    blt    blm    ipm    slight
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-C:FBIANG	TFBI Pbar NaroGate Inten	0	967.7	E09
-C:FBIANG[1]	TFBI Pbar NaroGate Inten	1	29.97	E09
-C:FBIANG[2]	TFBI Pbar NaroGate Inten	22	31.1	E09
-C:FBIANG[3]	TFBI Pbar NaroGate Inten	43	30.32	E09
-C:FBIANG[4]	TFBI Pbar NaroGate Inten	64	28	E09
-C:FBIANG[5]	TFBI Pbar NaroGate Inten	85	33.1	E09
-C:FBIANG[6]	TFBI Pbar NaroGate Inten	106	36.05	E09
-C:FBIANG[7]	TFBI Pbar NaroGate Inten	127	35.09	E09
-C:FBIANG[8]	TFBI Pbar NaroGate Inten	148	31.44	E09
-C:FBIANG[9]	TFBI Pbar NaroGate Inten	169	19.48	E09
-C:FBIANG[10]	TFBI Pbar NaroGate Inten	190	20.68	E09
-C:FBIANG[11]	TFBI Pbar NaroGate Inten	211	20.54	E09
-C:FBIANG[12]	TFBI Pbar NaroGate Inten	232	18.02	E09
-C:FBIANG[13]	TFBI Pbar NaroGate Inten	372	42.95	E09
-C:FBIANG[14]	TFBI Pbar NaroGate Inten	393	45.96	E09
-C:FBIANG[15]	TFBI Pbar NaroGate Inten	414	45.71	E09
-C:FBIANG[16]	TFBI Pbar NaroGate Inten	435	41.93	E09
-C:FBIANG[17]	TFBI Pbar NaroGate Inten	456	23.04	E09
-C:FBIANG[18]	TFBI Pbar NaroGate Inten	477	24.67	E09
-C:FBIANG[19]	TFBI Pbar NaroGate Inten	498	24.2	E09
-C:FBIANG[20]	TFBI Pbar NaroGate Inten	519	22.34	E09
-C:FBIANG[21]	TFBI Pbar NaroGate Inten	540	16.34	E09
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-C:FBIANG[32]	TFBI Pbar NaroGate Inten	890	21.89	E09
-C:FBIANG[33]	TFBI Pbar NaroGate Inten	911	10.39	E09
-C:FBIANG[34]	TFBI Pbar NaroGate Inten	932	11.33	E09
-C:FBIANG[35]	TFBI Pbar NaroGate Inten	953	11.48	E09
-C:FBIANG[36]	TFBI Pbar NaroGate Inten	974	10.11	E09
-C:FBIANG[37]	TFBI Pbar NaroGate Inten	1033	-1.47	E09

Figure 10. Antiproton bunch intensities during Store 3962.