Summary of 36x36 stores
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This note gives a summary of the two 36x36 stores attempted during the accelerator studies in the Fall of1995. The main focus of this note will be the two 36x36 stores in particular but relevant information from other 36x36 studies will also be included. Although the studies were generally successful this note concentrates on the difficulties encountered during 36x36 stores.

Overall the two 36x36 stores were successful although there were several problems which include:

- Tevatron quenches during multibunch proton injection.
- Proton bunch intensities lower than expected in Collider Run II and large satellite bunch intensities.
- Proton emittance blowup during Pbar injections.
- Poor pbar lifetime at 150 GeV and pbar beam loss during cogging at 150 GeV.
- Lack of Pbar flying wire data.
- Poor pbar lifetime at start of collisions.
- Tevatron quenches when aborting beam using A0 abort system.

For several reasons it is difficult to make any definitive conclusions about 36x36 operations during Collider Run II. First the proton bunch intensities for the 36x36 stores were about 70E9 whereas the expectations are for 300E9 in Collider Run II. Secondly with only two stores it is hard to tell if the particle losses and lifetime problems were the result of fundamental problems with 36x36 operations or if the Tevatron was simply not tuned up for optimal performance.
Finally, the lack of pbar emittance data made it more difficult to diagnose problems with the pbar lifetime.

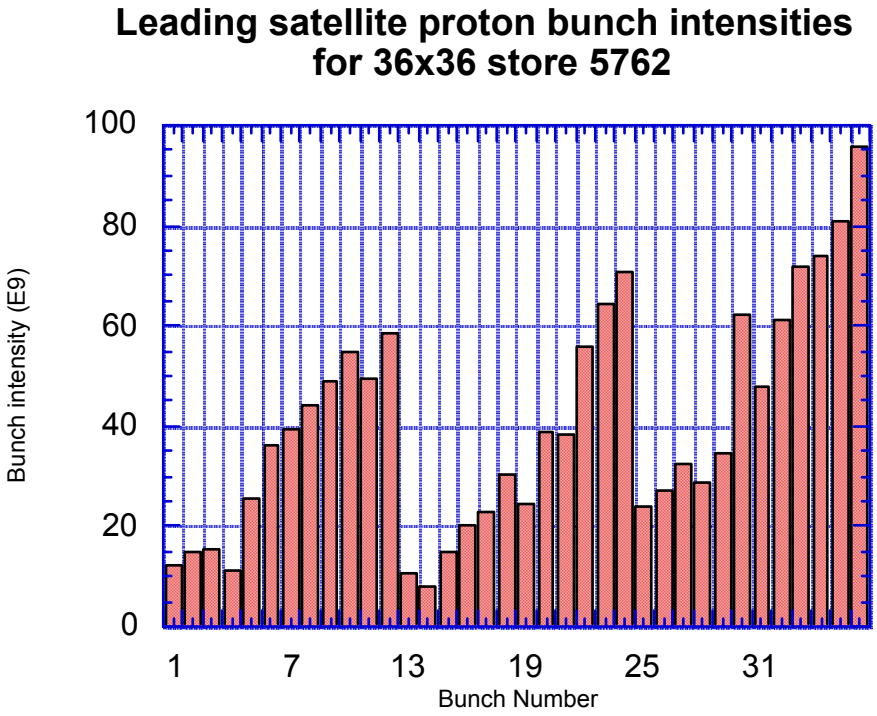
The next sections summarizes the results of the two 36x36 stores.
For the record the stores were store number 5756 on 11/18/95 (See logbook ED 46 page 49) and store number 5762 on 11/21/95 (See logbook ED 46 page 127 and three-ring binder titled "Tevatron 36x36 Startup Studies").

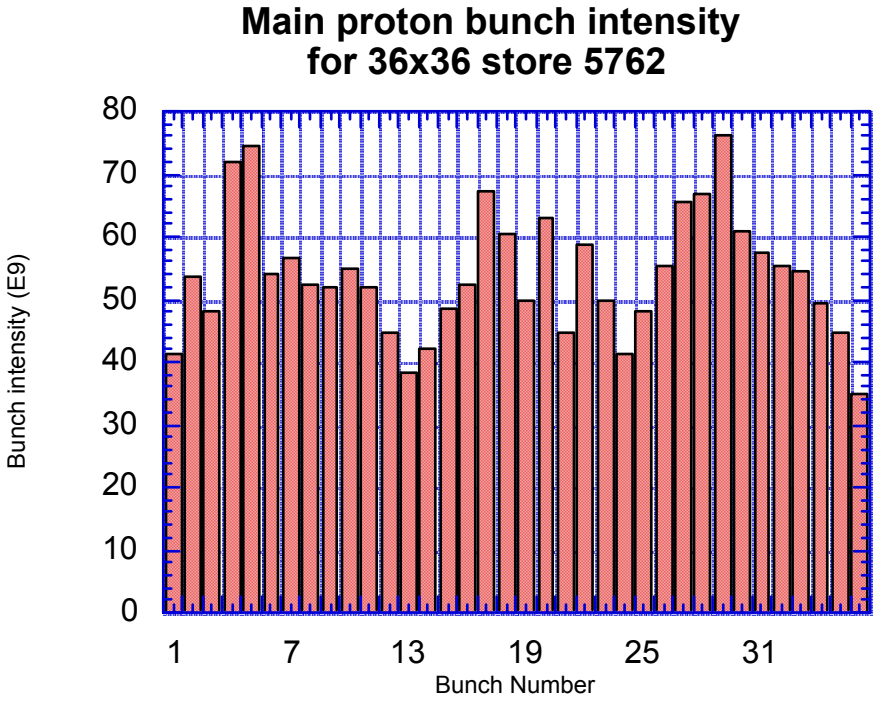
Multibunch Proton Injection

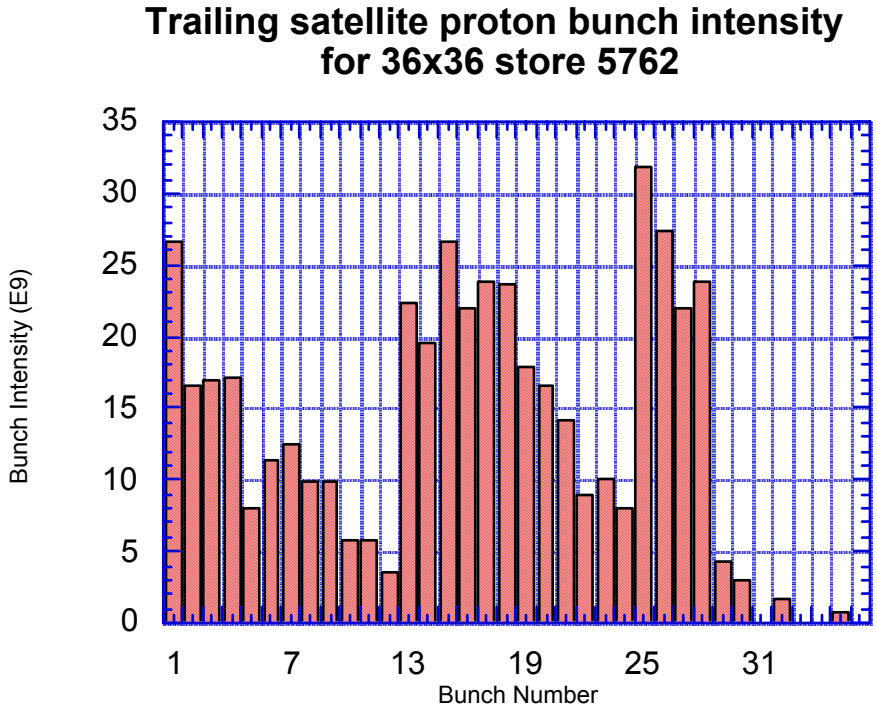
The amount of DC beam created in multibunch coalescing is larger than in previous operations. This was enough to surpass the Tevatron BLM limits and in some cases was enough to quench the Tevatron if the BLM limits were bypassed. The solution to this problem was to setup the MR abort kicker to fire on the last turn before injecting into the

Tevatron. The timing on the abort kicker was set so that the leading edge of the kicker pulse would begin just as the last bunch had passed the abort kicker. The leading edge of the injection kicker was also set up to reach its flattop just as the first proton bunch reached the injection kicker. With this configuration any DC beam not azimuthaly coincident with the 12 proton bunches would be sent to the MR abort. This solution allowed us to inject 36 proton bunches into the Tevatron although the BLM at E2 and F4 had to be masked out to accomplish this.

The intensities of the coalesced proton bunches during the 36x36 stores were lower than the intensities expected in Collider Run II.
There was also significant intensities in the leading and trailing satellite bunches. The three figures below show the intensities of main bunches and the leading and trailing satellites for store 5762.
The average proton intensity of the 36 coalesced main bunches injected into the Tev was 59E9.

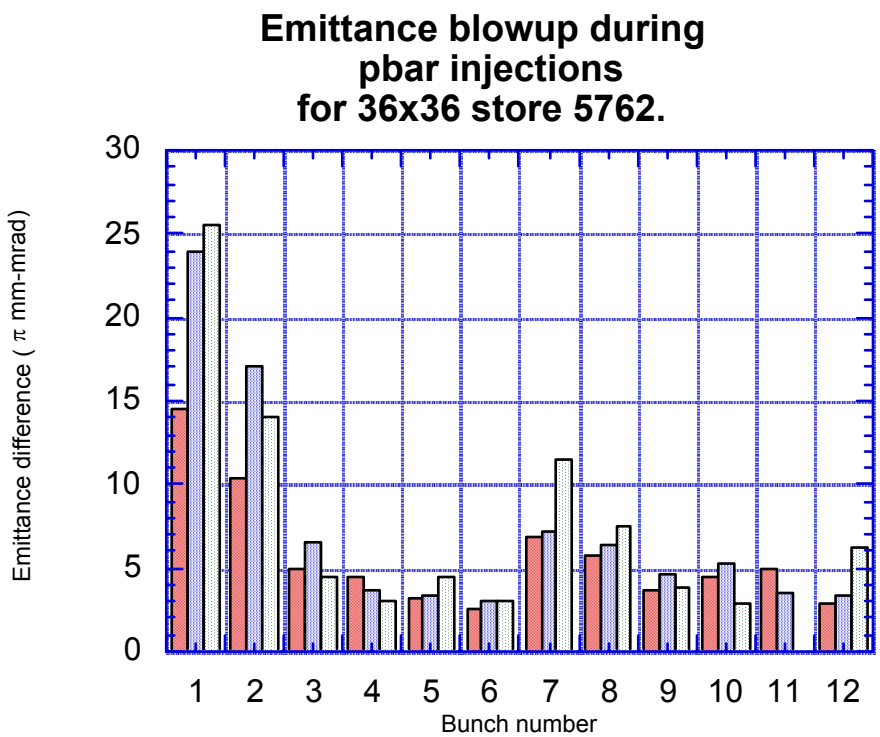



Main proton bunch intensity
for 36x36 store 5762
Bunch intensity (E9)
0
10
20
30
40
50
60
70
80
1
7
13
19
25
31
Bunch Number


Trailing satellite proton bunch intensity
for 36x36 store 5762
Bunch Intensity (E9)
0
5
10
15
20
25
30
35
1
7
13
19
25
31
Bunch Number

Pbar Injection

One problem discovered during the pbar injection process was the blowup of the proton bunches as a result of being kicked by the falling edge of the pbar injection kicker. There was also some evidence that the kicker may be ringing and kicking the sixth and seventh bunch in the proton batch. The figure below shows the difference in emittance before and after the pbar injection process. A closer look at the emittances during the pbar injection process confirms that it is the kicker that is causing the emittance blowup rather than some longitudinal position dependence on the emittance growth rate.



Pbar Lifetime at 150 GeV

After all of the pbars had been injected for store 5762 the pbar intensity lifetime at 150 GeV was about 2 hours which is poor. In addition there was a 15% pbar beam loss over a one minute measurement interval of the SBD. During this time the pbars had been cogged to their final collision point cogging value and the beam loss may have occurred while cogging.

Pbar lifetime at Collisions

There was problems with poor pbar lifetimes immediately after beams were brought into collisions for both 36x36 stores. Since the first 36x36 store lasted only 40 minutes no conclusions could be made about the lifetime except to say that the lifetime was initially poor with a lifetime of about 2 hours. Making some changes to the chromaticity and skew

quad circuits did lower the pbar losses and did seem to improve the pbar intensity lifetime. On the second 36x36 store the pbar losses at CDF were very high (>1000 kHz) and the initial pbar intensity lifetime was 30 minutes. About 10 minutes after reaching collisions the pbar intensity lifetime improved without making any changes to the Tevatron tune circuits. During a four hour period near the start to the store the proton intensity lifetime was 88 hours, the pbar intensity lifetime was 41 hours, and the D0 luminosity lifetime was 17 hours. These lifetimes are all considered good by the standards of normal 6x6 running so it is reasonable to assume that the Tevatron was tuned up correctly for this store and that the pbar loss was not caused by bad values of the tunes. Therefore it is likely that the process of initiating collisions exited the pbars in some way possibly blowing up the pbar emittances. The only flying wire data available for the pbars was two hours after we reached collisions. At that time the average pbar vertical emittance was 10.7 pi mm-mrad which is a typical value for pbars at collisions.

It should also be noted that there was trouble with the initiate collisions ramp on several of the 36x1 stores. In several of the 36x1 store there was a large loss of pbar intensity, about 50%, during the initiate collisions ramp. During the 36x36 studies there were several changes made in the way the approach to collisions was performed. The details of the approach to collisions will be discussed elsewhere but the main point to make here is that it was not demonstrated that the approach to collisions could be accomplished successfully in 36x36 operations.

Aborting Beam

During the 36x36 studies there was considerable trouble aborting beam from the Tevatron without quenching. Many times when 36 coalesced protons were aborted using the A0 abort system some of the low beta quads at B0 and/or D0 would quench. There were several attempts to solve this problem including adjusting the timing of the abort kickers, moving the orbit at A0, and lowering the A0 abort block. There were some measurements made which showed that there was as much as 10E8 particles per bunch in the buckets in the abort gap. There was also an attempt to solve this problem by firing the D48 kicker in the abort gap at 150 GeV to clear as much of the beam as possible but this did not solve the problem.

Instrumentation and Data Collection

The 36x36 studies would have benefited from improved instrumentation and data collection and display. In particular the update rates for the flying wires and SBD were slow enough that sigmas and bunch intensities were not updated by the time SDA was collecting data thereby making the SDA data unreliable. Much of the problem was due to using the present 6x6 instrumentation slightly modified for 36x36 studies. There are plans for upgrades to the flying wires and SBD for 36x36 operations so these problems are likely to disappear.

However, an effort is still needed to ensure the instrumentation collects data in a timely manner and that SDA is setup properly to collect the data. This effort should also include better display of real time data and SDA data. For instance a small program was written

to display the bunch intensities for all 36 proton and pbar bunches in bar chart format making it easier to monitor beam quality in the Tevatron.