Fermilab

$\bar{p}$ Note #386

Sequence of Events for the $p\bar{p}$ - SSC

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Sequence of Events

1. Two Booster Batches (~160 bunches) are accelerated in the Main Ring to 150 GeV. Each Proton Bunch is made of 3×10^{10} particl

Normalized Emittance (95%) 24π mm-mrad
Longitudinal Bunch Area (95%) 0.3 eV-sec

On a short flat-top the bunches are 90° rf-rotated in the Main Ring as in Tevatron I.

Final rms bunch length : 6-7 cm

100 proton bunches are extracted immediately after the rotation. The other 60 are disposed.

The Main Ring cycle time is taken to be the short as possible : 1.5 sec

2. The 100 Bunches are sent to hit a target at a new station (#2) -
By impinging the target $\bar{p}$'s are produced -

100 $\bar{p}$-bunches are generated out of the target with the same bunching of the primary beam -

$\bar{p}$'s	$\Delta p/p$ accepted	$\pm$ 3%
$\bar{p}$'s	β-emittance accepted	50 π mm·mrad
$\bar{p}$'s	Energy (Kinetic)	10 GeV

We assume the target efficiency is improved by a factor 1.5 over present TeV I value -

The total no. of $\bar{p}$'s produced <u>per cycle</u> is

$$5.5 \times 10^8$$

3. The antiproton pulse (about 2 μsec long) is injected into a new ring: the

Super Debuncher

This ring has an average radius of about 100 meters and operates at the kinetic energy of 10 GeV.

- The transfer is bunch-to-bucket. The RF system is at 53 MHz with 5-10 MV total.
- The bunches are rotated by 90° as in TeV I to exchange $\Delta p/p$ with length.
- The RF voltage is immediately dropped.
- The beam is then decelerated from 10 GeV down to 8 GeV (Kinet.) and adiabatically debunched.
- A gap (~ 500 nsec) is made in the beam with a special RF cavity as in Tevatron I.

- All the RF manipulation should not take more than 0.2 seconds.

- At 8 GeV the β-emittance has increased to 60 π mm-mrad and the energy width is ± 25 MeV

4. During the next 1.3 seconds the beam spends in the Super Debuncher Stochastic Cooling is applied.

<u>Betatron Cooling</u>:

to reduce the emittance from 60 π mm·mrad down to 20 π mm·mrad

<u>Momentum Cooling</u>:

to reduce the energy width from ±25 MeV down to ± 10 MeV

5. Using the gap in the beam, the beam is fast extracted from the Super Debuncher and transferred to the Debuncher Ring which is already part of the Tevatron I program.
The transfer is at 8 GeV.

A new pulse of $\bar{p}$'s is injected into the Super Debuncher Ring.

6. The beam in the Debunder Ring is kept debunched except for the gap as also required in Tevatron I.
The beam will spend 1.5 seconds in the ring. During this time fast β-cooling is applied to reduce the emittance even further

from 20 down to 5 π mm·mrad

The beam is then extracted with the help of the gap (which after the ring circumference adjustment is about 200 nsec long).
The beam is transferred to the Accumulator Ring. At the same time the subsequent pulse is transferred from the Super Debunder to the Debunder Ring and a new pulse of $\bar{p}$'s is generated at the target #2 and injected into the Super Debunder Ring.
This sequence will repeat every 1.5 sec.

7. The following steps are involved in the Accumulator Ring.

- The beam is adiabatically captured by a 53 MHz rf system in 84 bunches and RF stacked toward the middle of the aperture where momentum stochastic stacking takes over. This process is similar to the Tevatron I RF stacking.

- Momentum stochastic stacking is done as in Tevatron I but with these new parameters

Flux :	$8.25 \times 10^8\ s^{-1}$	
Cycle Time :	1.5 sec	
Init. Density	$60\ eV^{-1}$	
<u>Core</u> Density	$3.6 \times 10^4\ eV^{-1}$	uniform distribution
<u>Core</u> full Width	7.5 MeV	uniform distribution

- Slow betatron cooling on the <u>core</u> to reduce the β-emittance from 5 down to 2π mm·mrad

- 2.7×10^{11} $\bar{p}$'s are stored in the <u>core</u> every 225 cycles, that is 337.5 sec.

8. Every 337.5 sec (225 cycles) 2.7×10^{11} antiprotons are taken out of the Accumulator by RF un-stacking, as it is done in Tevatron I.

The same 53 MHz rf system is used. To make a gap 200 nsec long, four missing buckets are introduced with a special rf waveform. Each bunch has an area of 0.15 eV-sec and 3.2×10^9 particles.

The core is then replenished with the following 225 pulses (and so on ...).

9. The beam is extracted from the Accumulator Ring, past a shutter-magnet, and the transferred, bunch-to-bucket, into the Main Ring at 8 GeV.

The 80 $\bar{p}$-bunches are then accelerated to 150 GeV, extracted from the Main Ring and transferred to the Energy Saver that we call here the Super Conducting Ring (SCR).

10. The assumption is that the SSC will be operating in colliding beam mode for a period of at least 24 hours. During this time the SCR, as well the other rings in the Source, is available as a storage ring where to keep the antiprotons from the Accumulator Ring.

Each pulse in injected in the SCR on a "parking" orbit which corresponds to an off momentum value of $\Delta p/p = +0.125\%$.

Injection Kicker is at a location where the dispersion is larger and has a shutter to shield the stack of previously injected pulses.

There is a pulse every 337.5 sec. A total of eight (8) pulses are injected box-car fashion onto the "parking" orbit separated from each other by an empty gace 1.0 μsec long for injection kicker rise/fall time.

The transfer is bunch-to-bucket and the bunches

are captured by the (1.4 MV-) 53 MHz rf system. After 45 minutes the "parking" orbit is completely filled up with a total of 2.16×10^{12} antiprotons. All this beam is then moved by rf stacking to an inner orbit which correspond to an eff momentum value $\Delta p/p = -0.125\%$.

No missing buckets are introduced. There will be empty buckets (about 52 out of 136). Each bunch can be assumed to be distributed up to an area of 0.2 eV-sec. Including the empty buckets, the total area of each rf stacking cycle is 225 eV-sec. At the end of the cycle, after adiabatic debunching the contribution to the momentum spread from this cycle is 7.2×10^{-5} full (a total of 10.8 MeV).

In order to get a total of 3.4×10^{13} $\bar{p}$'s 16 rf stacking cycles are required, that is about 12 hours. Since there is plenty of time the stacking efficiency can be very high (80%). The total final beam area is 4500 eV-sec with a full momentum spread $\Delta p/p = 0.15\%$ (225 MeV).

11. The total stack is then adiabatically captured by the 53 MHz rf system in 1113 bunches. Each bunch has an area of 4 eV-sec and 3×10^{10} antiprotons.

The beam so bunched is then accelerated from 150 GeV to 1000 GeV in about a minute. A flat-top is then established at this energy.

The beam is completely debunched, adiabatically possibly. We assume that during these steps a dilution of a factor of 2 occured. So the total beam area is now

9000 eV-sec

The debunched beam momentum spread is only (full)

$$\Delta p/p = 0.045\% \qquad (450 \text{ MeV})$$

12. At the end of a colliding beam session, the SSC is empty and the antiprotons will have first to be transferred from the SCR to the SSC. The transfer has to happen so to create the required beam-bunch configuration. The process is done by rf unstacking. A total of 82 "batches" each with 54 bunches are to be output for a total of 4428 bunches each with 7.7×10^9 antiprotons. Each bunch is required to have an area of no more than 4.5 eV-sec, therefore a dilution of a factor of 2 is allowed during the process.

Each rf unstacking, 7 "batches" are created. The unstacking is done first with a $h=7$ rf system at 334 KHz. 7 bunches are taken out toward the extraction orbit. Each bunch has 4.14×10^{11} particles and initially an area of 110 eV-sec. Once this beam is on the extraction orbit ($\Delta p/p = +0.125\%$) the $h=7$ rf system is turned off and at the same time locally the 53.1 MHz system is turned on so that each of the previous bunches is now subdivided in the

desired 54 bunches. The batches are 1 μsec long and separated by about 2 μsec to match the rise/fall time of the extraction kickers.

This sequence of 7 "batches" so prepared are now past a shutter and extracted one by one and transferred into the SSC at the right location. In the SSC two consecutive "batches" are separated by 172 empty buckets. Of course the transfer is bunch-to-bucket, and the capturing rf system is also at 53.1 MHz.

The rf-unstacking is repeated 12 times until the whole beam has been transferred to the SSC. The transfer is at 1 TeV.

At this point the beam is displaced in orbit with the help of RF (I mean RF) separators.

13. It is time to transfer the proton beam to the SSC.

17 Booster batches, with bunches each with 3×10^{10} and an initial area of 0.3 eV-sec, are injected into the Main Ring at 8 GeV. The batches are equally spaced.

With the superdamper unwanted bunches are removed so that each batch is made of the only 54 bunches required.

The beam is accelerated to 150 GeV, extracted and transferred to the SCR where it is then accelerated to 1 TeV in about half a minute. One batch at the time is extracted as it was done with the antiprotons.

This step is repeated 12 time. Therefore it takes about 10 minutes to fill up the SSC with protons.

Special care must be taken to inject the proton bunches without perturbing the antiproton bunches.