Prospects for the Simultaneous Operation of the Tevatron Collider and $\bar{p}p$ Experiments in the Antiproton Source Accumulator

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Introduction

This document is a slightly expanded version of a portion of the Proton Driver design report. The Proton Driver group gets the credit for the original idea of running an Accumulator experiment in the BTeV era. The work presented here is a study of the feasibility of this idea.

Overview

The addition of the Recycler Ring to the Fermilab accelerator complex provides an opportunity to continue the program of $\bar{p}p$ physics in the Antiproton Source Accumulator that was started by Fermilab experiments E760 and E835. The operational scenario presented here utilizes the Recycler Ring as an antiproton bank from which the colliders makes "withdrawals" as needed to maintain the required luminosity in the Tevatron. The Accumulator is only needed to re-supply the bank in between withdrawals. When the $\bar{p}$ stacking rate is sufficiently high, and the luminosity requirements of the Collider experiments are sufficiently low, there will be time between Collider fills and subsequent refilling of the recycler to deliver beam to an experiment in the Accumulator. In the scenario envisioned here, the impact of the Accumulator experiment on the luminosity delivered to the Collider experiments is very small.

If the Run II antiproton stacking rate goals are met, the operational conditions required for running Accumulator based experiments will be met during the BTeV era. A simple model of the operation of the Fermilab accelerator complex for BTeV and an experiment in the Accumulator has been developed. The model makes predictions of the rate at which luminosity is delivered to BTeV and an Accumulator experiment. This model was used to examine the impact of the proton driver on this experimental program.

The Model

The model uses various Tevatron Collider parameters to calculate the antiproton demand during BTeV running. Recycler and Accumulator $\bar{p}$ stacking parameters are used to determine the rate at which the demand for $\bar{p}$'s can be met. The model also uses the parameters of the Accumulator and the E835 hydrogen gas jet target to determine the luminosity that can be delivered to an experiment in the Accumulator.

1. Tevatron Collider Parameters

The model derives the antiproton requirements of the Collider from the BTeV luminosity request[1] and from a model of luminosity evolution in the Tevatron Collider. The collider parameters used in the model are summarized in Table 1.

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[1] A. Kulyavtsev et. al., *Proposal for an Experiment to Measure Mixing, CP Violation and Rare Decays in Charm and Beauty Particle Decays at the Fermilab Collider – BTeV*, May 2000, page 51.

The greatest uncertainty in Table 1 lies in the luminosity and $\bar{p}$ lifetimes. At the time of this writing, 103-bunch operation of the Collider with a crossing angle has not yet been implemented. Thus, the luminosity and particle lifetimes in this mode have not been measured. The lifetime numbers chosen for the present model represent estimates from a model of the evolution of a collider store[2].

Table 1 Collider Parameters

Parameter	Value
Initial luminosity	2.0×10^{32} cm^{-2} s^{-1}
Tevatron Energy	1000 GeV
Protons/bunch	2.70×10^{11}
$\bar{p}$'s/bunch	5.95×10^{10}
Number of Bunches	103
Proton and $\bar{p}$ emittance	20π mm•mrad
Bunch length	37.1 cm
β^*	35 cm
Crossing Angle[3]	170 μrad
Revolution Frequency	47.713 kHz
Luminosity Lifetime	40 hr
$\bar{p}$ Lifetime	155hr
Store duration	18 hr

2. Antiproton Stacking Parameters

The parameters used to model antiproton stacking are given in Table 2.

Table 2 Antiproton Stacking Parameters

Parameter	Value
Accumulator Base Stacking Rate	52×10^{10} $\bar{p}$ hr^{-1}
Accumulator Stacking Rate for large stacks	21×10^{10} $\bar{p}$ hr^{-1}
Accumulator peak intensity during "fast" stacking	20×10^{10} $\bar{p}$
Recycler maximum stack size[4]	17.37×10^{12} $\bar{p}$

The Accumulator base stacking rate is the stacking rate goal for Run IIb[5]. This stacking rate is predicated on the availability of the Recycler Ring. The impact of the Proton Driver is incorporated into the model as a multiplicative factor that is applied to the Accumulator base stacking rate. Stacking with the Recycler Ring consists of repeated repetitions of stacking to peak intensity in the Accumulator and rapidly transferring the entire stack to the Recycler.

The Accumulator peak intensity is determined by the stacktail momentum cooling system. The increase in the stacking rate to its Run IIb value requires a steeper gain slope[6] in the stacktail

[2] Peter Bagley, Private communication.
[3] Peter Bagley, private communication. This is a change from the Run II parameter list. It is not yet certain what the crossing angle will be for BTeV running.
[4] The maximum Recycler stack size for this model is calculated from the beam current in the Accumulator at which the onset of instabilities prevent further increases in the stack size. This peak Accumulator beam current is approximately 250 mA. The maximum Recycler stack size is the number of antiprotons corresponding to a beam current of 250 mA in the Recycler.
[5] D. McGinnis, *TEVATRON Collider Luminosity Upgrades*, AAC Review presentation, May 22, 2000.
[6] Gain slope refers to the decrease in the gain of the stacktail cooling seen by the beam as it is pushed across the momentum aperture of the Accumulator into the core of the $\bar{p}$ stack.

momentum cooling. The steeper gain slope is accomplished by narrowing the gap between the plates of the stacktail cooling pickups. The increased gain slope aggravates an interaction between the stacktail cooling system and the core of the stacked beam that severely limits stacking for large stacks.

An experiment in the Accumulator will likely require larger stacks than what can be achieved with the Run IIb stacktail cooling system. The model assumes that larger stacks can be had at the cost of a slower stacking rate (the Stacking rate for large stacks in Table 2). In practice this could be realized by either modifying the design of the stacktail pickups to allow a variable gap, or by adding a second set of "wide-gap" pickups elsewhere in the Accumulator lattice. The smaller gain slope resulting from the wider pickups limits the flux of $\bar{p}$'s the stacktail cooling can push into the core. Thus, proton driver, will not be effective at increasing the stacking rate when the stacktail cooling is operated with wide-gap pickups.

3. Accumulator Experiment Luminosity Parameters

The model's determination of the luminosity delivered to the Accumulator experiment is based on measurements made during the 2000 run of Fermilab experiment E835. E835 utilized a variable density gas jet target that directed a stream of hydrogen gas directly into the Accumulator vacuum chamber[7]. The instantaneous luminosity, $\mathcal{L}$, is calculated according to:

$$\mathcal{L} = \alpha\rho N_{\bar{p}} \tag{1}$$

where α is a constant, $N_{\bar{p}}$ is the $\bar{p}$ intensity, and ρ is the target density. The model assumes that the target maintains a constant luminosity by automatically adjusting the density. The target density as a function of $\bar{p}$ intensity is:

$$\rho = \begin{cases} \rho_{max} \dfrac{N_c}{N_{\bar{p}}} & N_{\bar{p}} \geq N_c \\ \rho_{max} & N_{\bar{p}} < N_c \end{cases} \tag{2}$$

where ρ_{max} is the maximum allowed target density and N_c is the $\bar{p}$ intensity corresponding to the target for the requested luminosity.

During the course of target operations by the Accumulator experiment, beam is lost through luminosity producing interactions and non-luminosity producing interactions. This is modeled as:

$$\begin{aligned} \dot{N}_{\bar{p}} &= -\sigma\mathcal{L} - R_{loss} \\ &= -R_{loss} - \alpha\sigma\rho_{max} \bullet \begin{cases} N_c & N_{\bar{p}} \geq N_c \\ N_{\bar{p}} & N_{\bar{p}} < N_c \end{cases} \end{aligned} \tag{3}$$

where σ is the $\bar{p}p$ total cross-section and R_{loss} is the estimated non-luminosity producing beam loss rate. The model does not include the variation of σ with beam energy.

Table 3 gives the values of the model parameters that affect the luminosity delivered to the Accumulator experiment.

[7] D. Allspach, et. al., *The Variable Density Gas Jet Internal Target for Experiment 835 at Fermilab*, Nucl. Instrum. Meth. A410:195-205, 1998, FERMILAB-PUB-97-274-E.

Table 3 Accumulator Target and Luminosity Parameters

Parameter	Value
Accumulator Experiment luminosity ($\mathcal{L}$)	30×10^{30} cm^{-2} s^{-1}
Accumulator initial $\bar{p}$ intensity	60×10^{10} $\bar{p}$
Luminosity coefficient (α)	0.40×10^{6} cm s^{-1}/atom
Gas Jet max density (ρ_{max})	4.0×10^{14} atoms/cm^{3}
$\bar{p}p$ cross-section (σ)	70 mb
Non-luminosity producing beam loss rate (R_{loss})	0.3×10^{10} $\bar{p}$/hr
Critical $\bar{p}$ intensity (N_c)[8]	18.75×10^{10} $\bar{p}$

4. Operational Parameters

Operational parameters are used to model how well and the accelerator complex performs specific tasks and how long specific beam manipulations take. Another category of operational parameter is the occurrence rates of various failures and the time it takes to recover from them. The operational parameters used by the model are given in Table 4.

Table 4 Operational Parameters

Parameter	Value
$\bar{p}$ transfer efficiency from Recycler to Collisions in the Tevatron	85%
Fraction of $\bar{p}$'s recycled after a BTeV store	70%
Shot setup time	0.5 hr
Time to transfer $\bar{p}$'s from the Accumulator to the Recycler	1 min
Time to decelerate Accumulator stack	3 hr
Deceleration efficiency	85%
Minimum length of an Accumulator store	18 hr
Minimum $\bar{p}$ intensity in Accumulator for data taking	10×10^{10} $\bar{p}$
Time to recover from an Accumulator store (return to stacking)	20 min
Number of collider stores worth of $\bar{p}$'s required before stacking for the Accumulator experiment	2
Mean time between lost Accumulator stacks	14 days
Accumulator stack loss recovery time	2 hr
Mean time between lost Collider stores	14 days
Lost Collider store recovery time	2 hr
Mean time between lost Recycler stacks	21 days
Recycler stack loss recovery time	2 hr

[8] This value is calculated from $\mathcal{L}$, α, and ρ_{max} according to: $N_c = \dfrac{\mathcal{L}}{\alpha\rho_{max}}$.

Model Predictions

The model generates Collider stores and Accumulator stores according to the following priorities:

1st priority Put a store in the Tevatron for BTeV

2nd priority Stack $\bar{p}$'s into the Recycler until there are sufficient $\bar{p}$'s for two collider stores

3rd priority Stack and decelerate $\bar{p}$'s for the Accumulator experiment

The model accumulates the integrated luminosity delivered to BTeV and to the Accumulator experiment. For the results reported here, the model simulated Collider and Accumulator running over a period of 200 days.

Two separate model runs were done – one with and one without proton driver enhanced stacking. The model assumes that the proton driver will increase the Accumulator base stacking rate by a factor of 3[9]. The results of these runs are summarized in Table 5.

Table 5 Model Results

	No Proton Driver		Proton Driver Enhanced Stacking	
Total Time	200.00 days		200.11 days	
BTeV Up Time	191.71 days	95.85%	192.75 days	96.32%
Acc. Expt. Up Time	64.41 days	32.21%	126.55 days	63.24%
Collider Stacking	112.58 days	56.29%	41.56 days	20.77%
Accumulator Stacking	7.63 days	3.82%	11.35 days	5.67%
BTeV $\int \mathcal{L} dt$	92.80 pb^{-1}/week		93.44 pb^{-1}/week	
Acc. Expt. $\int \mathcal{L} dt$	5.84 pb^{-1}/week		11.47 pb^{-1}/week	

There are two significant findings from this analysis. The first is that, to the extent that the performance of the Fermilab accelerator complex is characterized by the above model parameters, it is possible to run an experiment in the Accumulator without significantly impacting the collider program. The second finding is that the proton driver will have a negligible impact on luminosity delivered to the collider[10] while significantly increasing the luminosity received by an Accumulator experiment.

To illustrate what the operational sequence of events looks like during this mode of running, the output of the model for 60 days of running is attached to the end of this document.

[9] The effect of the proton driver is to increase the proton intensity on the $\bar{p}$ production target by a factor of 3 or 4. Without additional upgrades to the Antiproton Source (i.e. to the stacktail momentum cooling), the increase in protons on target will not be translated into the same increase in $\bar{p}$ production rate.

[10] This statement is not true if there are other competitors for protons from the Main Injector (e.g. NUMI, KAMI, etc).

Timeline 1

Push this button to re-run the model

BTeV Up Time:	28.72	days	95.72%
Acc Expt Up Time:	10.04	days	33.47%
Collider Stacking:	16.18	days	53.91%
Accumulator Stacking:	1.14	days	3.82%
Total Time:	30.00	days	
BTeV Int Lum:	93.91	pb^{-1}/week	
Acc. Int Lum:	6.07	pb^{-1}/week	

Key Parameters:

F_{PD}	1	
F_{Astore}	2	
T_{store}	18	hr

Time	Time in Collider Store	Time in Accumulator Store	Pbars in Recycler	Pbars in Accumulator	Flags				Event
days	hr	hr	E10	E10	BStore	AStore	Stacking	A Stacking	
0.000			1737	0.00					Start
0.000			1737	0.00					Shot setup begins
0.021	0.00		1016	0.00	X				Collider Store Begins
0.021	0.00		1016	0.00	X		X		Collider Stacking Starts
0.513	11.80		1589	0.00	X		X		Stop Collider Stacking
0.513	11.80		1589	0.00	X			X	Stacking for Accumulator Experiment
0.608	14.09		1589	60.00	X			X	Stacking Complete
0.733	17.09	0.00	1589	51.00	X	X			Accumulator Store Begins
0.775	18.09	1.00	1737	49.99	X	X			End Collider Store
0.775		1.00	1737	49.99		X			Shot setup begins
0.795	0.00	1.50	1016	49.49	X	X			Collider Store Begins
1.545	18.00	19.50	1398	31.38	X	X			End Collider Store
1.545		19.50	1398	31.38		X			Shot setup begins
1.566	0.00	20.00	677	30.88	X	X			Collider Store Begins
1.575	0.20	20.20	677	30.68	X	X			End Accumulator Store
1.588	0.53		677	0.00	X		X		Collider Stacking Starts
2.322	18.13		1532	0.00	X		X		Stop Collider Stacking
2.322	18.13		1737	0.00	X				End Collider Store
2.322			1737	0.00					Shot setup begins
2.342	0.00		1016	0.00	X				Collider Store Begins
2.351	0.20		1016	0.00	X		X		Collider Stacking Starts
2.842	12.00		1589	0.00	X		X		Stop Collider Stacking
2.842	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
2.938	14.29		1589	60.00	X			X	Stacking Complete
3.063	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
3.096	18.09	0.80	1737	50.20	X	X			End Collider Store
3.096		0.80	1737	50.20		X			Shot setup begins
3.117	0.00	1.30	1016	49.69	X	X			Collider Store Begins
3.867	18.00	19.30	1398	31.58	X	X			End Collider Store
3.867		19.30	1398	31.58		X			Shot setup begins
3.888	0.00	19.80	677	31.08	X	X			Collider Store Begins
3.896	0.20	20.00	677	30.88	X	X			End Accumulator Store
3.910	0.53		677	0.00	X		X		Collider Stacking Starts
4.643	18.13		1532	0.00	X		X		Stop Collider Stacking
4.643	18.13		1737	0.00	X				End Collider Store
4.643			1737	0.00					Shot setup begins
4.664	0.00		1016	0.00	X				Collider Store Begins
4.672	0.20		1016	0.00	X		X		Collider Stacking Starts
5.164	12.00		1589	0.00	X		X		Stop Collider Stacking
5.164	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
5.260	14.29		1589	60.00	X			X	Stacking Complete
5.385	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
5.418	18.09	0.80	1737	50.20	X	X			End Collider Store
5.418		0.80	1737	50.20		X			Shot setup begins
5.439	0.00	1.30	1016	49.69	X	X			Collider Store Begins
6.197	18.20	19.50	1398	31.38	X	X			End Collider Store
6.197		19.50	1398	31.38		X			Shot setup begins
6.218	0.00	20.00	677	30.88	X	X			Collider Store Begins
6.226	0.20	20.20	677	30.68	X	X			End Accumulator Store
6.240	0.53		677	0.00	X		X		Collider Stacking Starts
6.973	18.13		1531	0.00	X		X		Stop Collider Stacking
6.973	18.13		1737	0.00	X				End Collider Store
6.973			1737	0.00					Shot setup begins
6.994	0.00		1016	0.00	X				Collider Store Begins
7.002	0.20		1016	0.00	X		X		Collider Stacking Starts
7.494	12.00		1589	0.00	X		X		Stop Collider Stacking
7.494	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
7.589	14.29		1589	60.00	X			X	Stacking Complete

Time	Time in Collider Store	Time in Accumulator Store	Pbars in Recycler	Pbars in Accumulator	Flags				Event
days	hr	hr	E10	E10	BStore	AStore	Stacking	A Stacking	
7.714	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
7.748	18.09	0.80	1737	50.20	X	X			End Collider Store
7.748		0.80	1737	50.20		X			Shot setup begins
7.769	0.00	1.30	1016	49.69	X	X			Collider Store Begins
8.527	18.20	19.50	1398	31.38	X	X			End Collider Store
8.527		19.50	1398	31.38		X			Shot setup begins
8.548	0.00	20.00	677	30.88	X	X			Collider Store Begins
8.556	0.20	20.20	677	30.68	X	X			End Accumulator Store
8.570	0.53		677	0.00	X		X		Collider Stacking Starts
9.303	18.13		1531	0.00	X		X		Stop Collider Stacking
9.303	18.13		1737	0.00	X				End Collider Store
9.303			1737	0.00					Shot setup begins
9.324	0.00		1016	0.00	X				Collider Store Begins
9.332	0.20		1016	0.00	X		X		Collider Stacking Starts
9.824	12.00		1589	0.00	X		X		Stop Collider Stacking
9.824	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
9.919	14.29		1589	60.00	X			X	Stacking Complete
10.044	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
10.078	18.09	0.80	1737	50.20	X	X			End Collider Store
10.078		0.80	1737	50.20		X			Shot setup begins
10.099	0.00	1.30	1016	49.69	X	X			Collider Store Begins
10.857	18.20	19.50	1398	31.38	X	X			End Collider Store
10.857		19.50	1398	31.38		X			Shot setup begins
10.878	0.00	20.00	677	30.88	X	X			Collider Store Begins
10.886	0.20	20.20	677	30.68	X	X			End Accumulator Store
10.900	0.53		677	0.00	X		X		Collider Stacking Starts
11.633	18.13		1531	0.00	X		X		Stop Collider Stacking
11.633	18.13		1737	0.00	X				End Collider Store
11.633			1737	0.00					Shot setup begins
11.654	0.00		1016	0.00	X				Collider Store Begins
11.662	0.20		1016	0.00	X		X		Collider Stacking Starts
12.154	12.00		1589	0.00	X		X		Stop Collider Stacking
12.154	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
12.249	14.29		1589	60.00	X			X	Stacking Complete
12.374	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
12.408	18.09	0.80	1737	50.20	X	X			End Collider Store
12.408		0.80	1737	50.20		X			Shot setup begins
12.429	0.00	1.30	1016	49.69	X	X			Collider Store Begins
13.187	18.20	19.50	1398	31.38	X	X			End Collider Store
13.187		19.50	1398	31.38		X			Shot setup begins
13.208	0.00	20.00	677	30.88	X	X			Collider Store Begins
13.216	0.20	20.20	677	30.68	X	X			End Accumulator Store
13.230	0.53		677	0.00	X		X		Collider Stacking Starts
13.963	18.13		1531	0.00	X		X		Stop Collider Stacking
13.963	18.13		1737	0.00	X				End Collider Store
13.963			1737	0.00					Shot setup begins
13.984	0.00		1016	0.00	X				Collider Store Begins
13.992	0.20		1016	0.00	X		X		Collider Stacking Starts
14.484	12.00		1589	0.00	X		X		Stop Collider Stacking
14.484	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
14.579	14.29		1589	60.00	X			X	Stacking Complete
14.704	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
14.738	18.09	0.80	1737	50.20	X	X			End Collider Store
14.738		0.80	1737	50.20		X			Shot setup begins
14.759	0.00	1.30	1016	49.69	X	X			Collider Store Begins
15.517	18.20	19.50	1398	31.38	X	X			End Collider Store
15.517		19.50	1398	31.38		X			Shot setup begins
15.538	0.00	20.00	677	30.88	X	X			Collider Store Begins
15.546	0.20	20.20	677	30.68	X	X			End Accumulator Store
15.560	0.53		677	0.00	X		X		Collider Stacking Starts
16.293	18.13		1531	0.00	X		X		Stop Collider Stacking
16.293	18.13		1737	0.00	X				End Collider Store
16.293			1737	0.00					Shot setup begins
16.314	0.00		1016	0.00	X				Collider Store Begins
16.322	0.20		1016	0.00	X		X		Collider Stacking Starts
16.814	12.00		1589	0.00	X		X		Stop Collider Stacking
16.814	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
16.909	14.29		1589	60.00	X			X	Stacking Complete
17.034	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins

page 2 S. Werkema 6/7/01 10:13 AM

Time	Time in Collider Store	Time in Accumulator Store	Pbars in Recycler	Pbars in Accumulator	Flags				Event
days	hr	hr	E10	E10	BStore	AStore	Stacking	A Stacking	
17.068	18.09	0.80	1737	50.20	X	X			End Collider Store
17.068		0.80	1737	50.20		X			Shot setup begins
17.089	0.00	1.30	1016	49.69	X	X			Collider Store Begins
17.847	18.20	19.50	1398	31.38	X	X			End Collider Store
17.847		19.50	1398	31.38		X			Shot setup begins
17.868	0.00	20.00	677	30.88	X	X			Collider Store Begins
17.876	0.20	20.20	677	30.68	X	X			End Accumulator Store
17.890	0.53		677	0.00	X		X		Collider Stacking Starts
18.623	18.13		1531	0.00	X		X		Stop Collider Stacking
18.623	18.13		1737	0.00	X				End Collider Store
18.623			1737	0.00					Shot setup begins
18.644	0.00		1016	0.00	X				Collider Store Begins
18.652	0.20		1016	0.00	X		X		Collider Stacking Starts
19.144	12.00		1589	0.00	X		X		Stop Collider Stacking
19.144	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
19.239	14.29		1589	60.00	X			X	Stacking Complete
19.364	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
19.398	18.09	0.80	1737	50.20	X	X			End Collider Store
19.398		0.80	1737	50.20		X			Shot setup begins
19.419	0.00	1.30	1016	49.69	X	X			Collider Store Begins
20.177	18.20	19.50	1398	31.38	X	X			End Collider Store
20.177		19.50	1398	31.38		X			Shot setup begins
20.198	0.00	20.00	677	30.88	X	X			Collider Store Begins
20.206	0.20	20.20	677	30.68	X	X			End Accumulator Store
20.220	0.53		677	0.00	X		X		Collider Stacking Starts
20.936	**17.73**		**1512**	**0.00**	**X**		**X**		**Lost Recycler Stack**
20.936	**17.73**		**1512**	**0.00**	**X**		**X**		**Stop Collider Stacking**
21.028	19.93		0	0.00	X		X		Collider Stacking Starts
21.711	36.33		796	0.00	X		X		Stop Collider Stacking
21.711	36.33		1136	0.00	X				End Collider Store
21.711			1136	0.00					Shot setup begins
21.732	0.00		415	0.00	X				Collider Store Begins
21.741	0.20		415	0.00	X		X		Collider Stacking Starts
22.482	18.00		1279	0.00	X		X		Stop Collider Stacking
22.482	18.00		1661	0.00	X				End Collider Store
22.482			1661	0.00					Shot setup begins
22.503	0.00		940	0.00	X				Collider Store Begins
22.511	0.20		940	0.00	X		X		Collider Stacking Starts
23.070	13.60		1591	0.00	X		X		Stop Collider Stacking
23.070	13.60		1591	0.00	X			X	Stacking for Accumulator Experiment
23.165	15.89		1591	60.00	X			X	Stacking Complete
23.290	18.89	0.00	1591	51.00	X	X			Accumulator Store Begins
23.298	19.09	0.20	1737	50.80	X	X			End Collider Store
23.298		0.20	1737	50.80		X			Shot setup begins
23.319	0.00	0.70	1016	50.30	X	X			Collider Store Begins
24.069	18.00	18.70	1398	32.19	X	X			End Collider Store
24.069		18.70	1398	32.19		X			Shot setup begins
24.090	0.00	19.20	677	31.68	X	X			Collider Store Begins
24.098	0.20	19.40	677	31.48	X	X			End Accumulator Store
24.112	0.53		677	0.00	X		X		Collider Stacking Starts
24.846	18.13		1532	0.00	X		X		Stop Collider Stacking
24.846	18.13		1737	0.00	X				End Collider Store
24.846			1737	0.00					Shot setup begins
24.866	0.00		1016	0.00	X				Collider Store Begins
24.875	0.20		1016	0.00	X		X		Collider Stacking Starts
25.366	12.00		1589	0.00	X		X		Stop Collider Stacking
25.366	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
25.462	14.29		1589	60.00	X			X	Stacking Complete
25.587	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
25.620	18.09	0.80	1737	50.20	X	X			End Collider Store
25.620		0.80	1737	50.20		X			Shot setup begins
25.641	0.00	1.30	1016	49.69	X	X			Collider Store Begins
26.391	18.00	19.30	1398	31.58	X	X			End Collider Store
26.391		19.30	1398	31.58		X			Shot setup begins
26.412	0.00	19.80	677	31.08	X	X			Collider Store Begins
26.420	0.20	20.00	677	30.88	X	X			End Accumulator Store
26.434	0.53		677	0.00	X		X		Collider Stacking Starts
27.167	18.13		1532	0.00	X		X		Stop Collider Stacking
27.167	18.13		1737	0.00	X				End Collider Store

Time	Time in Collider Store	Time in Accumulator Store	Pbars in Recycler	Pbars in Accumulator	Flags				Event
days	hr	hr	E10	E10	BStore	AStore	Stacking	A Stacking	
27.167			1737	0.00					Shot setup begins
27.188	0.00		1016	0.00	X				Collider Store Begins
27.196	0.20		1016	0.00	X		X		Collider Stacking Starts
27.688	12.00		1589	0.00	X		X		Stop Collider Stacking
27.688	12.00		1589	0.00	X			X	Stacking for Accumulator Experiment
27.783	14.29		1589	60.00	X			X	Stacking Complete
27.908	17.29	0.00	1589	51.00	X	X			Accumulator Store Begins
27.942	18.09	0.80	1737	50.20	X	X			End Collider Store
27.942		0.80	1737	50.20		X			Shot setup begins
27.963	0.00	1.30	1016	49.69	X	X			Collider Store Begins
28.713	18.00	19.30	1398	31.58	X	X			End Collider Store
28.713		19.30	1398	31.58		X			Shot setup begins
28.733	0.00	19.80	677	31.08	X	X			Collider Store Begins
28.742	0.20	20.00	677	30.88	X	X			End Accumulator Store
28.756	0.53		677	0.00	X		X		Collider Stacking Starts
29.489	18.13		1532	0.00	X		X		Stop Collider Stacking
29.489	18.13		1737	0.00	X				End Collider Store
29.489			1737	0.00					Shot setup begins
29.510	0.00		1016	0.00	X				Collider Store Begins
29.518	0.20		1016	0.00	X		X		Collider Stacking Starts
30.001	11.80		1580	0.00	X		X		End