

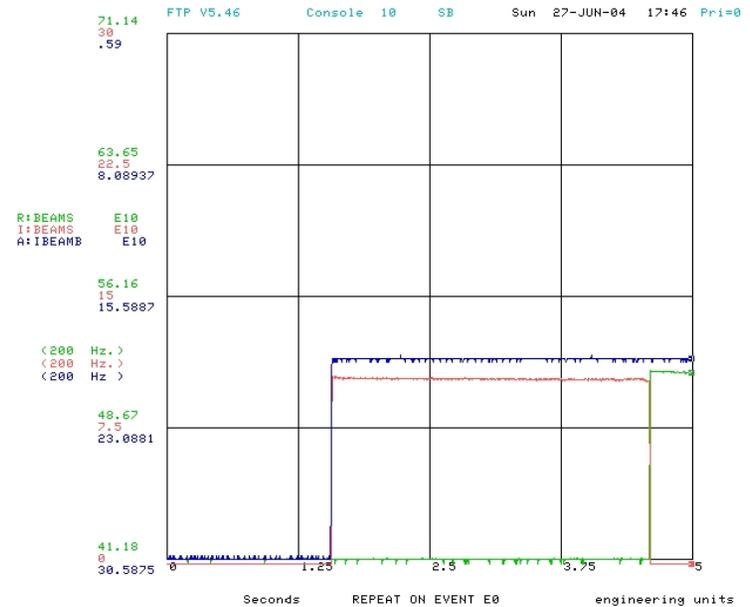
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# Recycler Startup

Cons Gattuso

# Recycler Pbar Injection Performance

- Since the December '03
  - Completed 71 Shot Setups
    - A total of 339 Pbar transfers
    - A total of 2953 E10 Pbars have been transfer into the Recycler
  - Average Transfer Efficiencies and initial beam parameter
    - Average transverse emittance after injection 8 pi mm mr
    - Average Long emit 8 eV-secs
    - Main Injector to Recycler ...>95%
    - Accumulator to Recycler .....>93%
  - Average Transfer Setup Time
    - 45 Minutes



# Recycler Pbar Extraction Performance History

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- We have completed 8 Mixed Pbar Source Shot Setups

- 4 transfer to the Tevatron supplying 3 of the the 9 transfers

- Average stash that we shot from .....85.5E10
- Average intensity per transfer.....23.0E10
- Percentage of beam captured for extraction.....83%

- 4 transfer to the Tevatron supplying 2 of the 9 transfers

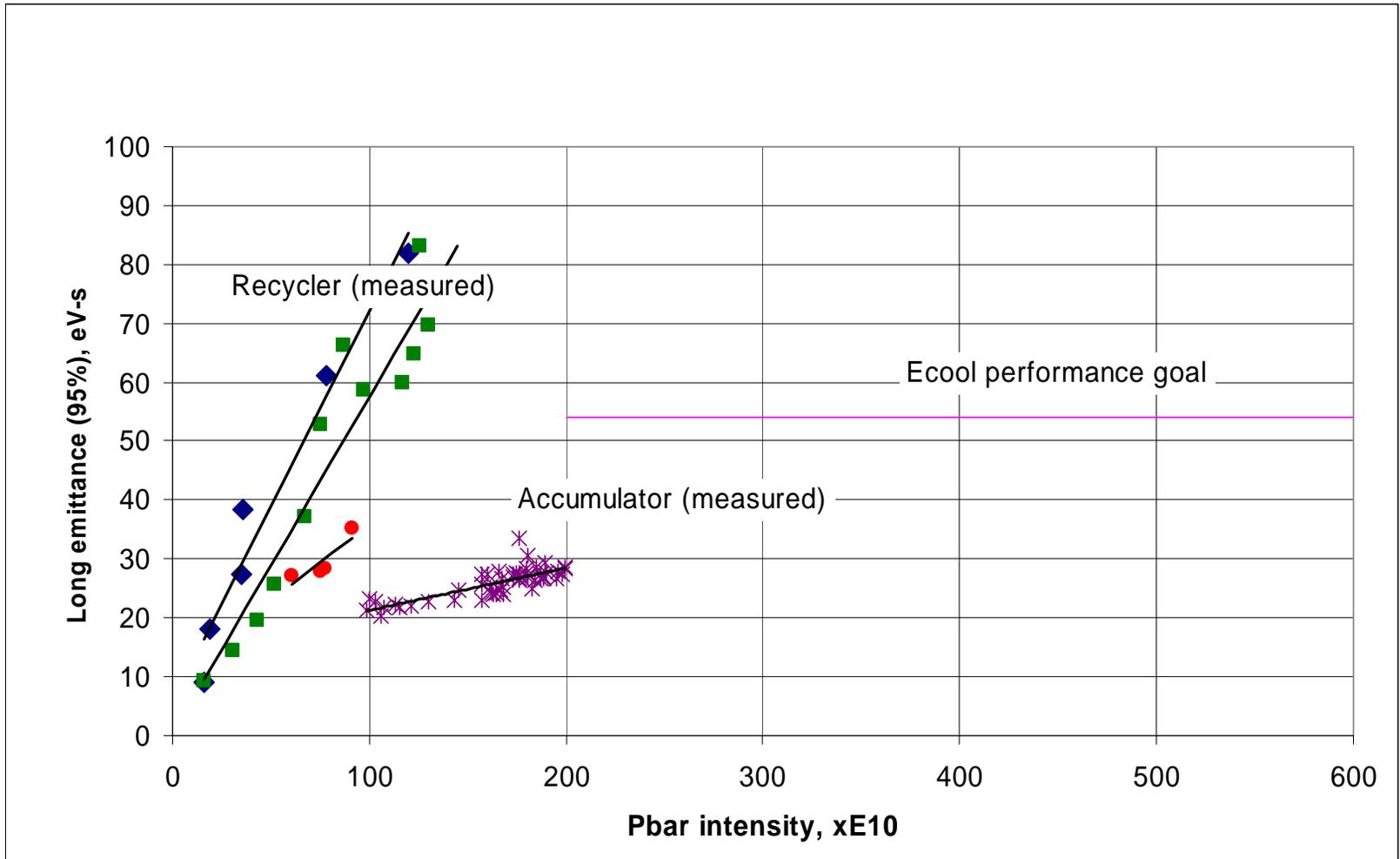
- Average stash that we shot from.....55.0E10
- Average intensity per transfer.....23.3E10
- Percentage of beam captured for extraction.....80%

- Current Luminosity Record of 103.0 E30

- Top 4 initial average luminosity records achieved in Mixed Pbar Source Mode

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- Largest Stack Size .....151.6 E10 (5/2/04)
  - Longest continuous duration of stored Pbar in Recycler 21 days 6 hours (4/16/04- 5/6/04)
  - Typical beam life time of > 500 hrs

# Recycler Machine Performance



# Machine Documentation

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- Recycler Tome
  - Electronic Save
    - All settable parameters (~30 K devices)
  - RF System
    - Hard/electronic copies of RF states and parameters
  - Instrumentation
    - Hard/electronic copies BPM positions, tunes, ect.
  - Sequencer Aggregates
    - Hard/electronic copies of Sequencer aggregates
  - Vacuum Profiles
    - Hard copies of the Recycler vacuum readbacks
  - Correction Element configuration
    - Hard/electronic copies of RF states and parameters

# Recycler Shut Down Work

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## ■ Recycler Work

- Stochastic Cooling Tanks Repaired
  - Three tanks:
    - Thermal couple feed through replaced
    - Internal water line braze joints reworked
- Damaged Corrector Replacement
  - RR30 and 60 straight sections, additional elements correct for cooling section bend magnets
- Additional Shielding Added
  - 620 and 213 MI Dipole Buss expansion regions
- Flying Wire installation
  - 620 Region
- Re-work of the 30 straight section for ECool
- Vacuum work in the 60 straight section

# NuMi Shutdown Work



- NuMi Shutdown Work
  - Completed installation of the NuMi Beam Line in the Main Injector/Recycler Enclosure
    - Dipole magnets shielding completed

# Main Injector Shutdown Work



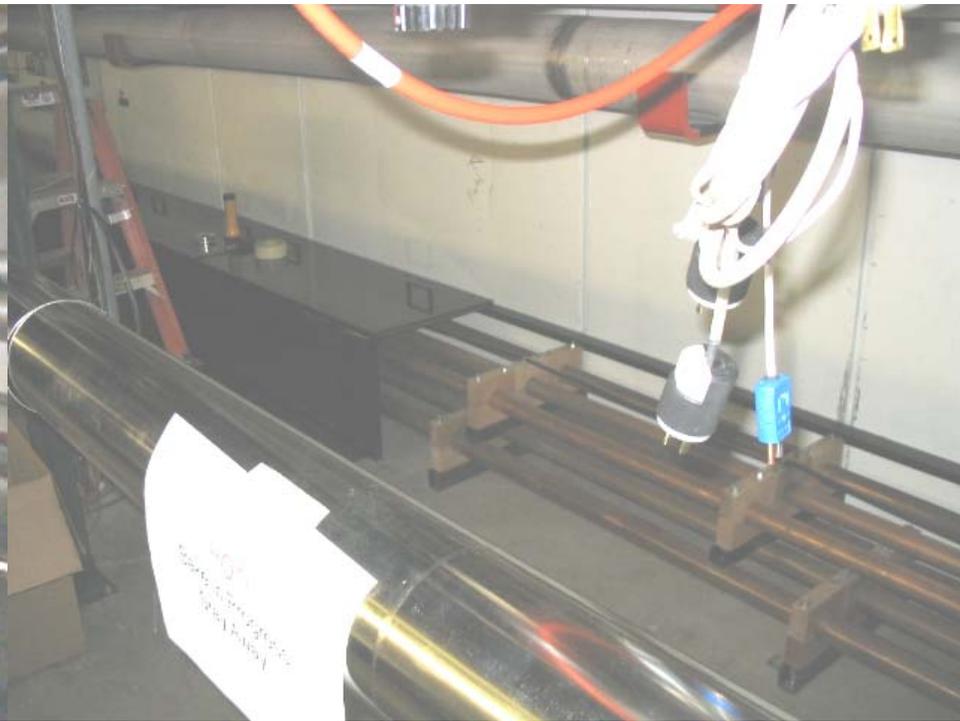
- Main Injector
  - Beam pipe alignment in the injection/extraction regions
    - Reduce losses in the MI, some hot spots  $>1$  rem/hr @ 1 ft

# Ecool Installation

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Before



After

- E-cool installations
  - Buss rework in the MI-30 straight sections

# Ecool Installation

- E-cool installations
  - Compensations for main 90/180 degree bends



# Startup/Checkout

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- System checkouts
  - Instrumentation
    - BPM/Clearing electrodes
      - Cable connects, ect
    - Flying Wire
      - Loss monitor/filter control/wire control
    - Toroids/DCCT
      - Calibration/Connections
    - Schottky pickups (21Mhz, 79Mhz and 1.75 Ghz)
    - Resistive Wall Monitor
    - Multi Wires
      - Interface modules/Control
  - Correction elements
    - Field/polarity test
  - Cooling system
    - Tank motion control
    - RF cabling
    - Water connections
    - Ect.
  - Shielding
  - RF
    - Dry runs of all the LLRF states

# Commissioning/Running Plan

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## ➤ Commissioning

- Start on Nov. 29 (Monday)
- Shifts
  - Manned by 2 studiers
  - Two shifts per day
    - » AM shift (0800-1400)
    - » PM shift (1400-2000)
- Weekly meetings to discuss commissioning results
- Milestones/Criteria

## ➤ Running Plan

- Mixed Mode Operations (operator run 12/28/04) uninterrupted until March 15<sup>th</sup>.
- Support E-cool Commissioning
  - By Personnel for Commissioning shifts (2/1/05)
  - Support beam studies as March 15<sup>th</sup>:
    - » 2 week cycle that will interrupt Recycler Pbar operations up to 20 % of the time.

# Commissioning Criteria

<b>Recycler FY2004 Performance Criteria (for antiprotons)</b>				
	Lifetime	$\underline{\varepsilon_L} \{ \Delta \underline{\varepsilon_L} \}$	$\varepsilon_{\perp} \{ \Delta \varepsilon_{\perp} \}$	Transfer/Stacking Performance
<b>MACHINE READINESS</b>	$\geq 150$ hr		$\{ \leq 3\pi$ mm-mrad/hr $\}$	
<b>PERFORMANCE @ <math>100 \times 10^{10}</math></b>	$\geq 150$ hr	$\{ \leq 15$ eV-s/batch $\}$	$\leq 10 \pi$ mm-mrad $\{ \leq 3 \pi$ mm-mrad /transfer $\}$	$\geq 85\%$
<b>EQUILIBRIUM PROPERTIES @ <math>100-200 \times 10^{10}</math> STOCHASTIC COOLING ONLY</b>		50eV-s	$\leq 10 \pi$ mm-mrad $\{ \leq 3\pi$ mm-mrad/hr $\}$	$\geq 200 \times 10^{10}$ in 10 hrs
<b>EXTRACTION PERFORMANCE</b>		Up to 36 bunches @ 1.5 eV-s in 30 min.	$\{ \leq 3 \pi$ mm-mrad /transfer $\}$	$\geq 70\%$

# Criteria Definitions

- **1. Machine Readiness**
  - **a) Vacuum**
    - Transverse emittance growth  $\leq 3 \pi$  mm-mrad /hr measured destructively for zero-zero beam without cooling.
  - **b) Vacuum and Machine Acceptance**
    - Beam Lifetime  $\geq 150$  hr measured with zero-zero beam without cooling.
- **2. Performance @  $100 \times 10^{10}$  with cooling and Batch Intensities  $\geq 10 \times 10^{10}$** 
  - **a) Cooling, Intensity Effects, Vacuum and Machine Admittance**
    - Beam lifetime  $\geq 100$  hr and transverse emittance  $\leq 10 \pi$  mm-mrad.
  - **b) MI  $\leftrightarrow$  Recycler Transfer Performance**
    - The round-trip transfer efficiency MI-RR-MI (or RR-MI-RR, if developed) shall be  $\geq 85\%$ . The round-trip transverse emittance increase of the beam shall be  $\leq 3 \pi$  mm-mrad.
  - **c) Recycler transfers with gated cooling**
    - The transfer efficiency between the MI and the Recycler for a single  $22e10$ ,  $10$  eV-s,  $10\text{-}\pi$  mm-mrad antiproton batch should be  $>85\%$ ;
    - Longitudinal phase-space manipulations should be accomplished in less than 5 minutes;
    - Merging the new batch with the stack and getting ready for the next injection should take less than 5 minutes.
  - **d) Extraction**
    - Up to 9 batch extraction, a complete Tevatron fill, shall not exceed 30 minutes. Only particles within 6 eV-s (as measured in the MI at 8.9 GeV/c) phase space shall be extracted per batch. For  $\geq 100 \times 10^{10}$  antiprotons in a 100 eV-s stack, not less than 30% shall be extracted. This criterion may change if the 2.5-MHz acceleration in the MI becomes efficient.
- **3. Equilibrium Beam Properties @  $200 \times 10^{10}$** 
  - The Recycler should be able to accumulate  $\geq 200 \times 10^{10}$  particles and maintain the stack within a  $10 \pi$  mm-mrad  $\times 100$  eV-s phase space volume. This is not a requirement but rather a test of ultimate properties of the Recycler stochastic cooling system.

# Milestones

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- Vacuum Performance 12/6/04
- Vacuum and Machine Admittance 12/9/04
- “Mi to RR Trans Eff, >85%, Round trip <3 pi growth” 12/14/04
- First Pbar transfer to Recycler 12/15/04
- Rapid Stacking Performance with 100E10 12/20/04
- Recycler Rapid Transfers Commissioned 12/28/04
- Extraction Commissioned 12/29/04
- Equilibrium properties at 100-200E10 1/11/05
- Recycler operational for Electron cooling 1/28/05

# First Week of Startup

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- Monday 29<sup>th</sup>
  - Injection tune up / Est. Circulating Beam
  - Defining a closed orbit
  - Closed orbit optimization
- Tuesday 30<sup>th</sup>
  - R22 Line Extraction
  - Acceptance Measurements
  - Cooling Insert Bump Check/LEP corrector setting
  - Aperture Scans of the Cooling insert region
  - Closed orbit optimization
- Wednesday 1<sup>st</sup>
  - Closed orbit optimization
- Thursday 2<sup>nd</sup>
  - Closed orbit optimization
  - R22 Line Extraction
  - Acceptance measurements
  - 120 and 150 Gev ramp compensation
  - QCL Ramp
- Friday 3<sup>rd</sup>
  - RF sequences for Stashing Beam
  - RF sequences for Mining Beam
  - Flying Wire Commissioning

# Proton Mode of Commissioning

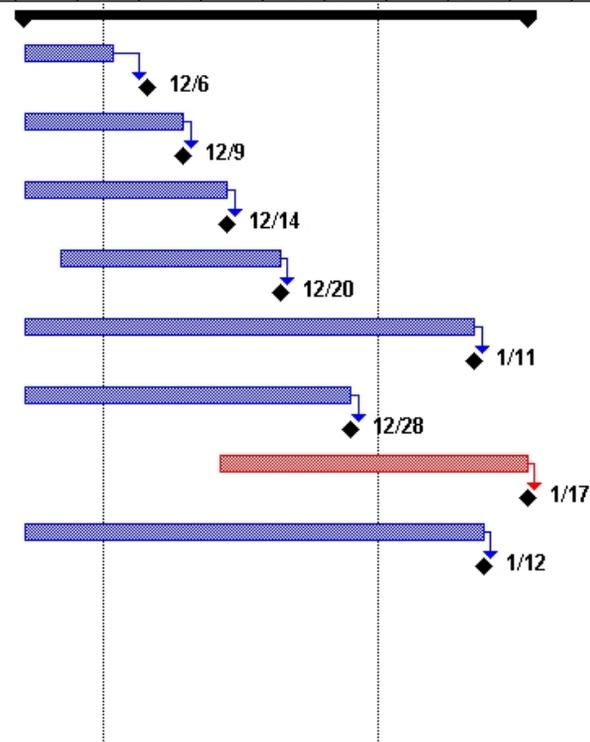
Task Name	Duration	Start	Finish	November				December				January	
				10/31	11/7	11/14	11/21	11/28	12/5	12/12	12/19	12/26	1/2
1													
2	41 days	Mon Nov 22	Mon Jan 17										
3	25.5 days	Mon Nov 22	Mon Dec 27										
4	2 days	Mon Nov 22	Tue Nov 23										
5	2 days	Mon Nov 22	Tue Nov 23										
13	23.5 days	Mon Nov 22	Thu Dec 23										
14	0.3 days	Tue Nov 23	Tue Nov 23										
18	0.7 days	Tue Nov 23	Tue Nov 23										
24	1 day	Wed Nov 24	Wed Nov 24										
27	0.5 days	Thu Nov 25	Thu Nov 25										
29	5.5 days	Thu Nov 25	Thu Dec 2										
38	3 days	Fri Dec 3	Tue Dec 7										
42	3 days	Wed Dec 1	Mon Dec 6										
46	13 days	Mon Dec 6	Thu Dec 23										
47	13 days	Mon Dec 6	Thu Dec 23										
64	15 days	Mon Nov 22	Fri Dec 10										
66	15 days	Wed Dec 1	Tue Dec 21										
70	20 days	Mon Nov 22	Fri Dec 17										
75	25.5 days	Mon Nov 22	Mon Dec 27										
76	25.5 days	Mon Nov 22	Mon Dec 27										
77	25.5 days	Mon Nov 22	Mon Dec 27										

# Pbar Mode of Commissioning

Task Name	Duration	Start	Finish	November				December				January				
				10/31	11/7	11/14	11/21	11/28	12/5	12/12	12/19	12/26	1/2	1.		
82	⊖ Anti Proton Commissioning	31.5 days	Mon Nov 22	Tue Jan 4												
83	⊖ Injection Commissioning	7 days	Mon Nov 22	Wed Dec 1												
84	⊕ R22 line tune up (injection)	7 days	Mon Nov 22	Wed Dec 1												
91	⊖ Circulating Beam Commissioning	31 days	Tue Nov 23	Tue Jan 4												
92	⊕ Injection Aperture scans	1.5 days	Tue Nov 23	Wed Nov 24												
96	⊕ Injection closure R22	3 days	Wed Nov 24	Mon Nov 29												
102	⊕ Energy Match machines	1 day	Mon Nov 29	Tue Nov 30												
104	⊕ Phase match	1 day	Tue Nov 30	Wed Dec 1												
106	⊕ Orbit Correction	3.5 days	Wed Dec 1	Mon Dec 6												
114	⊕ Long emit growth measurements	15 days	Wed Dec 15	Tue Jan 4												
116	⊕ Operating point	1.5 days	Wed Dec 15	Thu Dec 16												
120	⊕ instrumentation	20 days	Wed Nov 24	Tue Dec 21												
129	⊖ Extraction Commissioning	2 days	Fri Dec 3	Tue Dec 7												
130	⊖ extraction closure R32	1 day	Fri Dec 3	Mon Dec 6												
131	⊕ Commission Beam Line Tuner (BLT)	1 day	Fri Dec 3	Mon Dec 6												
134	BPM system	1 day	Mon Dec 6	Tue Dec 7												
135	⊖ Rapid Transfer Commissioning	21.5 days	Fri Dec 3	Mon Jan 3												
136	⊖ Sequencer modification	21.5 days	Fri Dec 3	Mon Jan 3												
137	⊕ Control system	2 days	Tue Dec 7	Thu Dec 9												
141	⊕ Instrumentation	3 days	Fri Dec 3	Wed Dec 8												
145	⊕ Cooling system	11.5 days	Fri Dec 3	Mon Dec 20												
151	⊕ Extraction	10 days	Tue Dec 21	Mon Jan 3												

# Milestones

Task Name	Duration	Start	Finish	November				December				January					
				10/31	11/7	11/14	11/21	11/28	12/5	12/12	12/19	12/26	1/2	1/9	1/16	1/23	
169	☐ Management, evaluation and planning	41 days	Mon Nov 22	Mon Jan 17													
170	Vacuum Evaluation	8 days	Mon Nov 22	Wed Dec 1													
171	<i>Vacuum Performance</i>	0 days	Mon Dec 6	Mon Dec 6													
172	Lifetime Evaluation	14 days	Mon Nov 22	Thu Dec 9													
173	<i>Vacuum and Machine Admittance</i>	0 days	Thu Dec 9	Thu Dec 9													
174	Transfers performance evaluation	17 days	Mon Nov 22	Tue Dec 14													
175	<i>Mi to RR Trans Eff, &gt;85%, Round trip &lt;3 pi grov</i>	0 days	Tue Dec 14	Tue Dec 14													
176	Rapid Stacking Evaluation	17 days	Fri Nov 26	Mon Dec 20													
177	<i>Rapid Stacking Performance with 100E10</i>	0 days	Mon Dec 20	Mon Dec 20													
178	Beam Properties Evaluation	37 days	Mon Nov 22	Tue Jan 11													
179	<i>Equilibrium properties at 100-200E10</i>	0 days	Tue Jan 11	Tue Jan 11													
180	Rapid Transfer Performance Evaluation	27 days	Mon Nov 22	Tue Dec 28													
181	<i>Recycler Rapid Transfers Commissioned</i>	0 days	Tue Dec 28	Tue Dec 28													
182	Extraction Evaluation	25 days	Tue Dec 14	Mon Jan 17													
183	<i>Extraction Commissioned</i>	0 days	Mon Jan 17	Mon Jan 17													
184	Overall evaluation	38 days	Mon Nov 22	Wed Jan 12													
185	<i>Recycler commissioned for Electron cooling</i>	0 days	Wed Jan 12	Wed Jan 12													



# Conclusion

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- We have completed all of the system checkouts that can be done without beam.
- A detailed set of performance milestones/criteria have been established to gauge our progress.
- We have established a reasonable schedule to accomplish our milestones/criteria