Run II Performance and Plans

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Outline

- Run II Goals
- Current Performance
- Plan for achieving Run IIA goals
- Luminosity projection for 2002
- Beyond 2002 and Run IIB

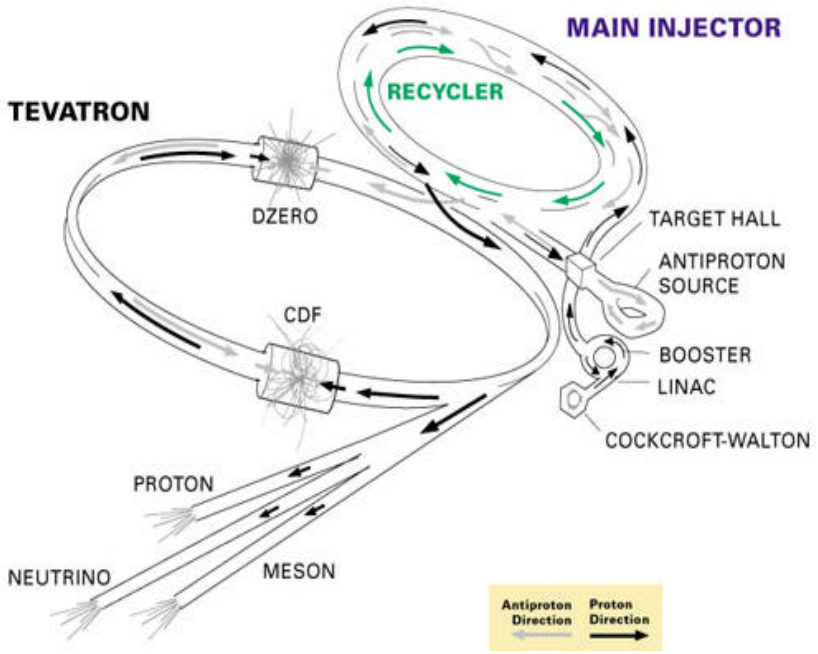
Run II Goals

Run II has been split into Run IIA and Run IIB. While the breakpoint is somewhat arbitrary, as a practical definition:

- **Run IIA** refers to operations supported by the collider configuration envisioned during the Main Injector construction.
  - Luminosity:
    - 5×10^{31} (Main Injector Project baseline)
    - 8×10^{31} (renormalized when we exceeded our Run I goal by 60%)
    - 2×10^{32} (Recycler Ring incorporated into the Main Injector Project)
  - Integrated luminosity: 2 fb^{-1} over a 2-3 year period
- **Run IIB** refers to this configuration augmented by a number of (substantial) hardware upgrades required to push the luminosity well above 2×10^{32} and to support a total accumulation of approximately **$15 fb^{-1}$ prior to LHC data taking.**

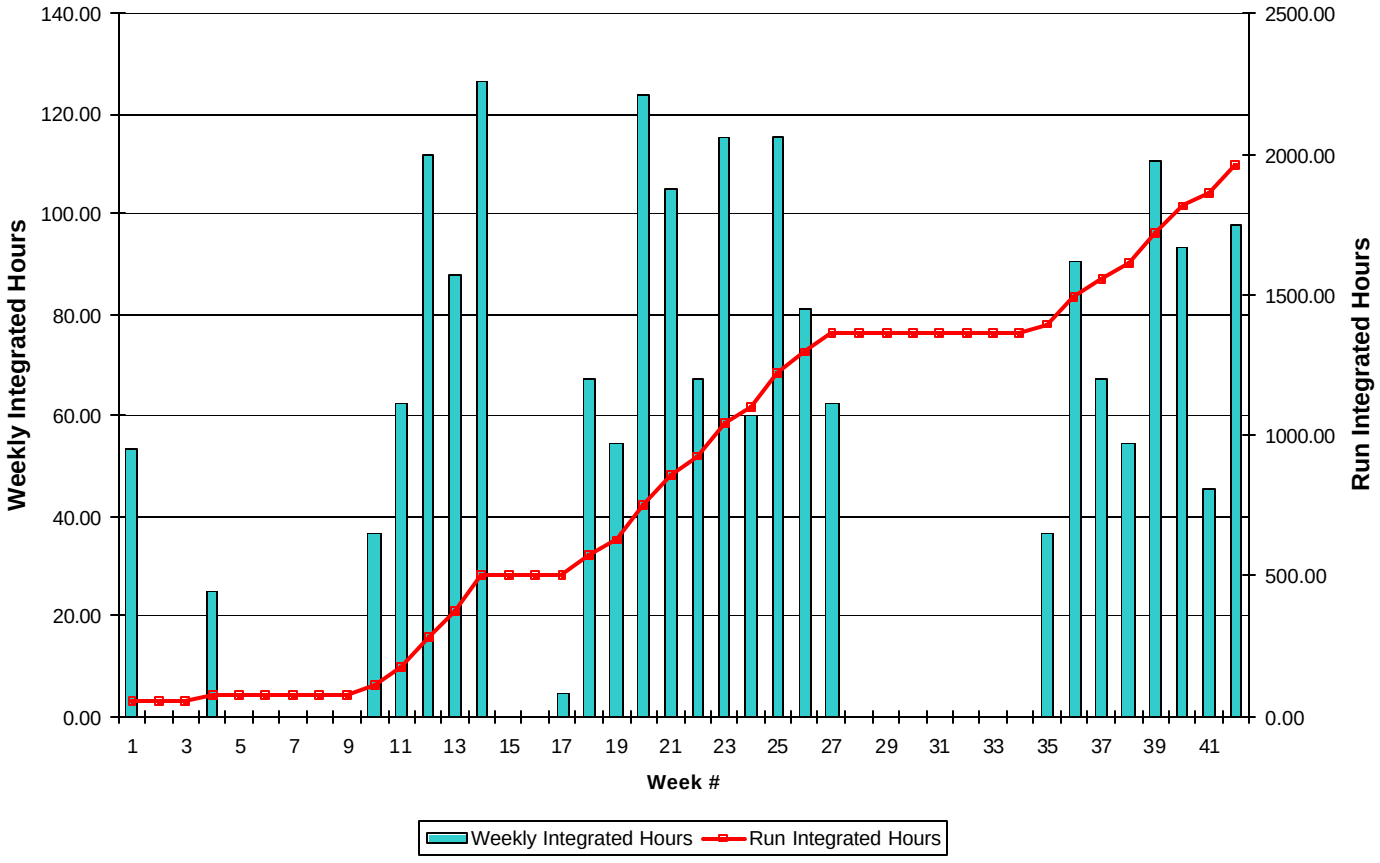
Current Performance
Accelerator Configuration

- All major hardware associated with Run IIA is in place:
  - Main Injector running at design goals for proton intensity
  - Recycler is in commissioning, not in use in collider operations at the moment.
  - Antiproton Source lattice and stochastic cooling upgrades are running at/close to design goals
- A number of minor hardware improvements, identified in early Run II operations, require implementation.



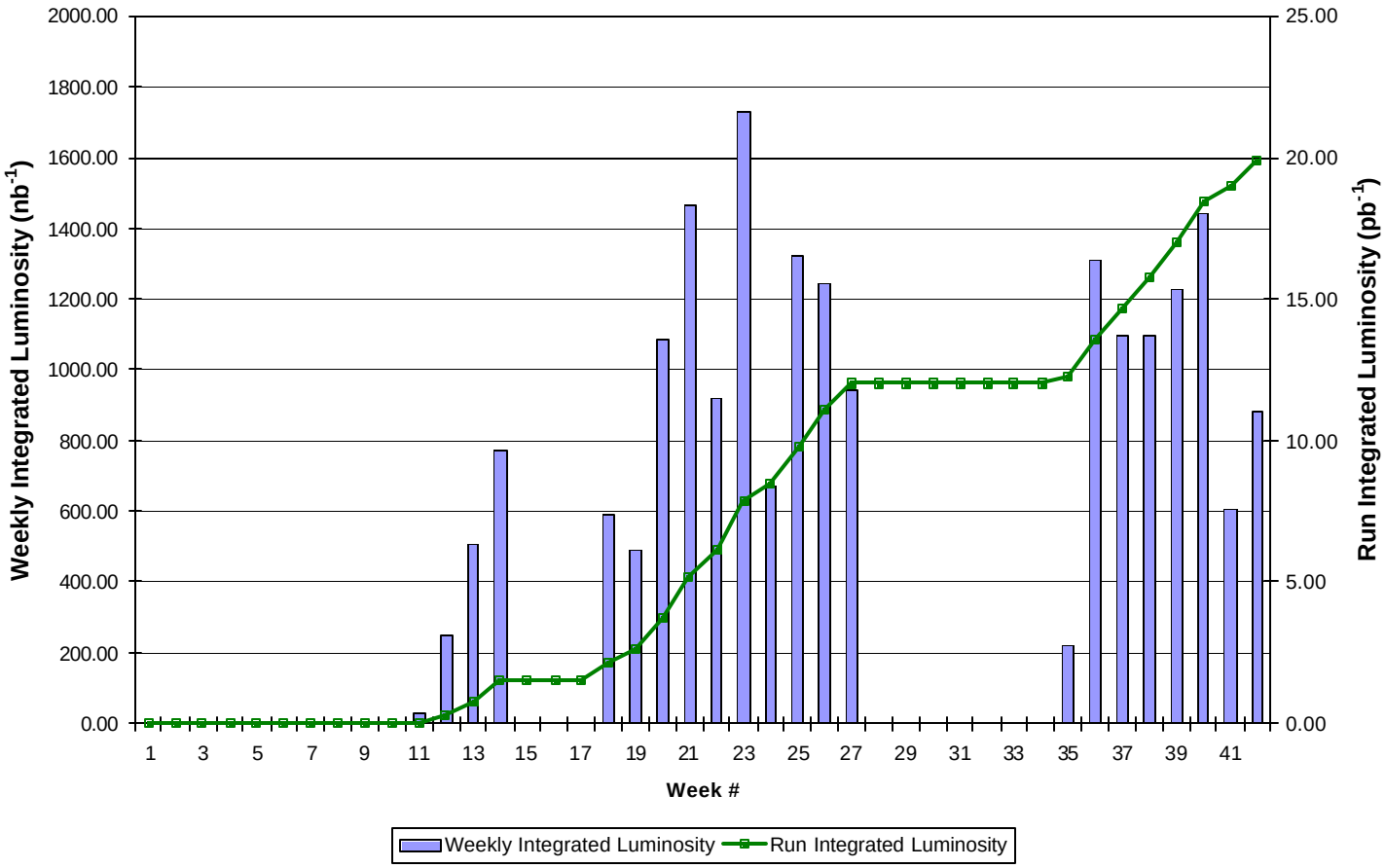
Current Performance

Store Hours

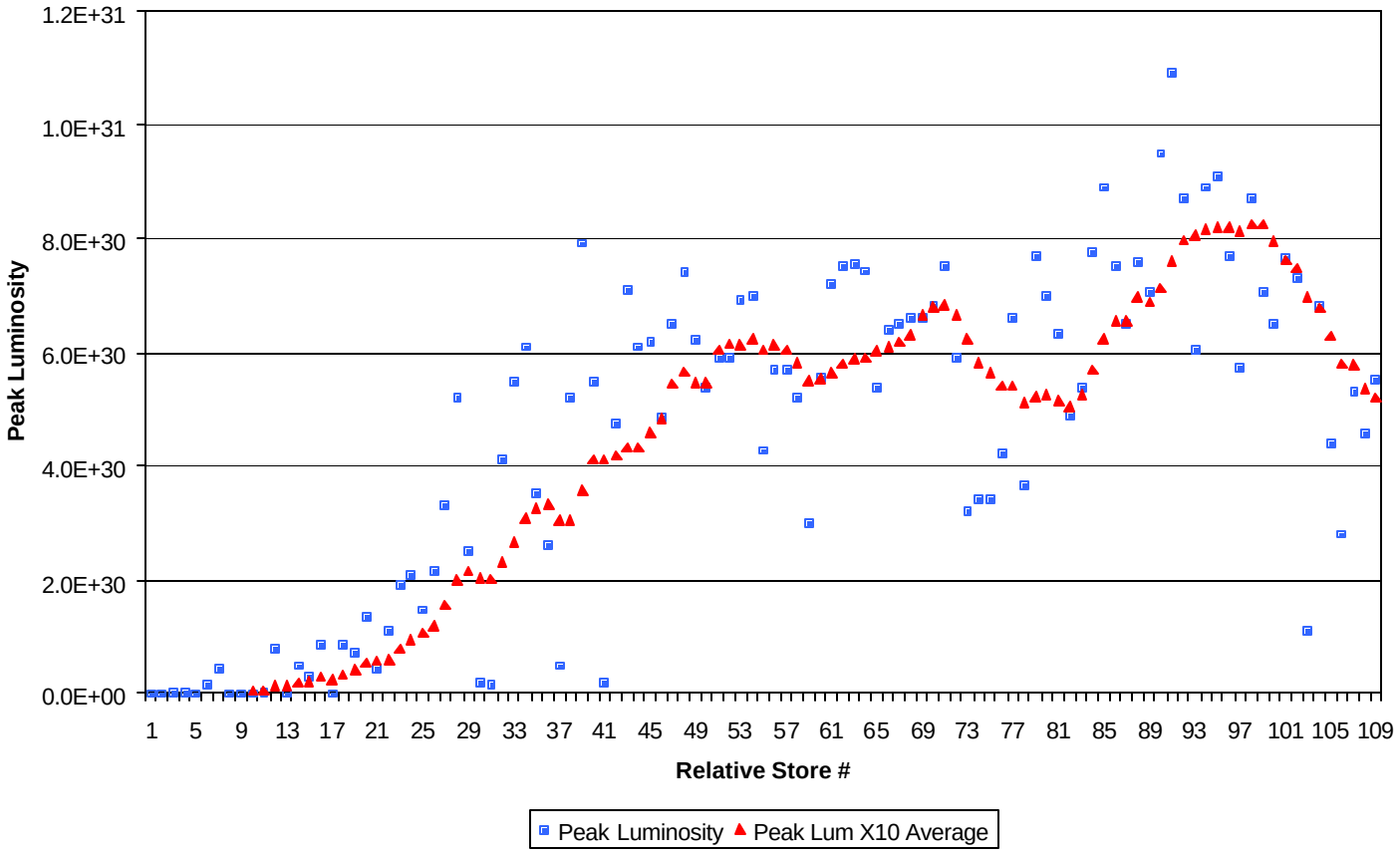


Current Performance

Integrated Luminosity



Current Performance
Luminosity



Current Performance
Comparison with Run IIA Goals

(http://www-bd.fnal.gov/lug/runII_handbook/RunII_index.html)

	Run IB	RunIIA Goal (wo/ recycling)	RunIIA (achieved)	
Protons/bunch	2.30E+11	2.70E+11	1.30E+11	
Antiprotons/bunch	5.50E+10	3.00E+10	7.28E+09	
Total Antiprotons	3.30E+11	1.08E+12	2.62E+11	
Antiproton Production Rate	6.0E+10	2.0E+11	1.0E+11	$hour^{-1}$
Accumulator->150 GeV efficiency	0.80	0.90	0.70	
150 GeV -> Low? efficiency	0.80	0.90	0.40	
Accumulator -> low? efficiency	0.64	0.81	0.28	
Proton emittance (95%, norm)	23	20	16	?mm-mr
Pbar emittance (95%, norm)	13	15	15	?mm-mr
Beta @ IP	0.35	0.35	0.35	m
Beam Energy	900	1000	980	GeV
Bunches	6	36	36	
Longitudinal Emittance (protons)	5	3	4	eV-sec
Longitudinal Emittance (pbars)	5	3	4	eV-sec
Form Factor (Hourglass)	0.59	0.70	0.65	
Typical Luminosity	1.6E+31	8.08E+31	1.00E+31	$cm^{-2}sec^{-1}$

Current Performance
Macroscopic Indicators

Typical shot showing:

Loading of 36 proton bunches

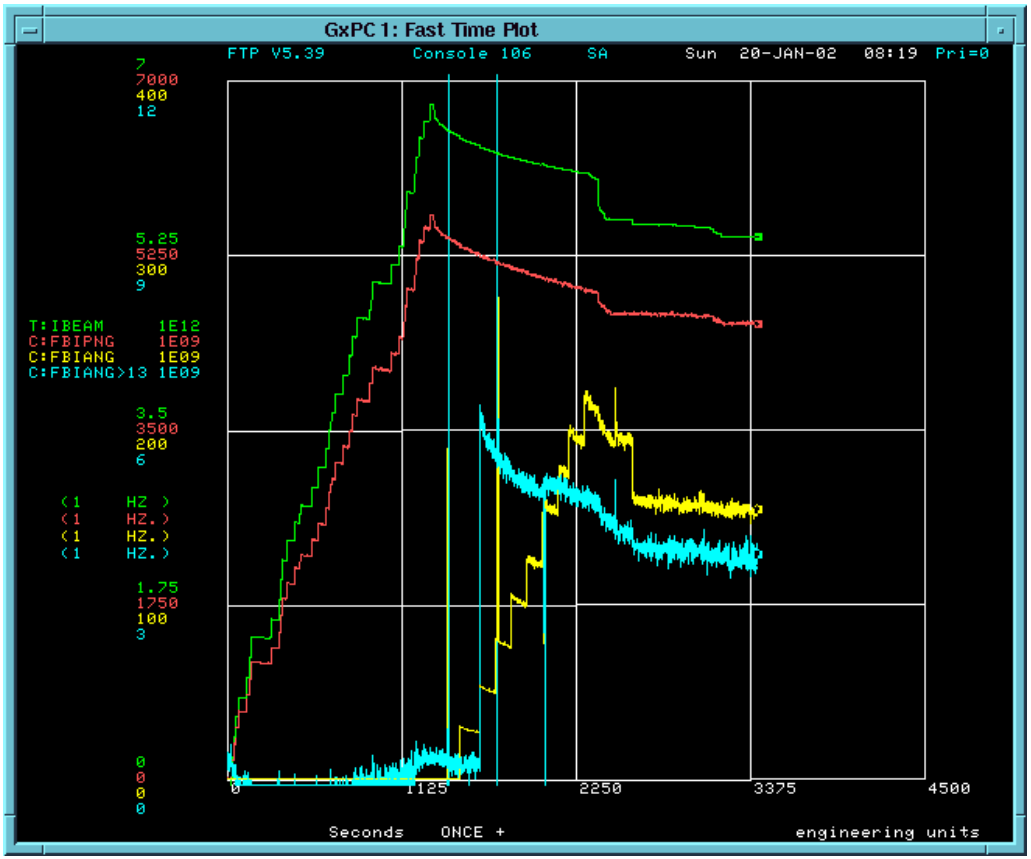
- Several hour beam lifetime on proton helix

Loading of 9x4 antiproton bunches

- < 1 hour beam lifetime on pbar helix

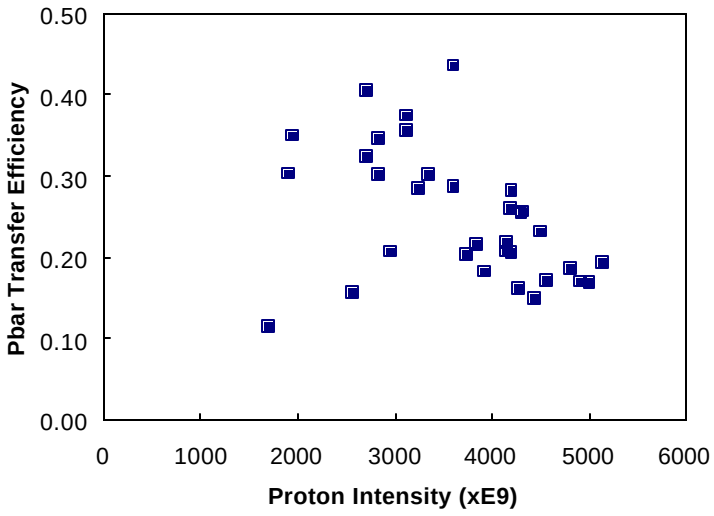
Modest beam loss at start of acceleration

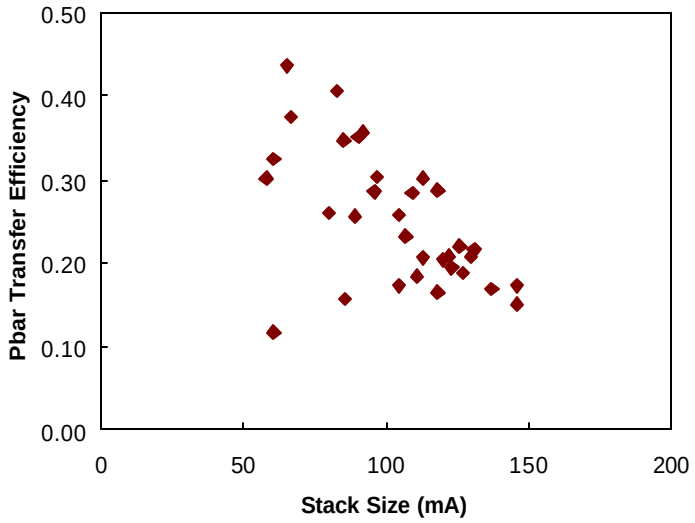
Significant antiproton beam loss at squeeze step 13



Current Performance
Macroscopic Indicators

- Current antiproton production rate is sufficient to support a luminosity in the 4-6x10^{31} $cm^{-2}sec^{-1}$ range.
- Protons are roughly one-half of what is required
- Antiprotons are roughly one-fourth of required
  - Transfer efficiency accumulator to low beta is terrible!





Current Performance
Underlying Issues/Protons

- Protons (Goal = 270E9/bunch, achieved = 130E9/bunch)
  - Have achieved 270E9/bunch in Main Injector
    - Coalescing efficiency is OK (~80%)
    - Longitudinal emittance is large (4 eV-sec, should be 3)
      - Booster performance
    - Transverse emittance at 200E9/bunch is OK (~14? mm-mr)
  - MI -> Tevatron transfer efficiency is poor (80%)
    - 100% efficiency if uncoalesced
  - Lifetime at 150 GeV is poor (10-20 hours)
    - Momentum aperture in Tevatron?
  - Antiproton lifetime at 150 GeV in Tevatron is very sensitive to proton intensity

Current Performance
Underlying Issues/Antiprotons

- Antiprotons (Goal = 30E9/bunch, achieved 7E9)
  - Accumulator transverse emittances roughly 50% larger than in Run I
    - Anomalous heating
  - Accumulator->MI transmission efficiency is marginal (85-90%)
    - Beamline optics
  - MI coalescing efficiency is marginal (85%)
    - Beamloading?
  - MI->Tev transfer efficiency is terrible (60%)
    - ~90-95% if uncoalesced
    - Tevatron momentum aperture?
  - Tev 150 GeV lifetime is poor (1-2 hours -> 80%)
  - Low beta squeeze efficiency is terrible (75%)

? Role of long-range beam-beam in the Tevatron?

Current Performance
Other Observations

- Overall reliability to date has been good, except:
  - We are currently quenching the B-0 low beta quadrupoles every time we abort the beam at the end of a store (since 12/22).
  - The Tevatron group is spending nearly all its time diagnosing/mitigating the problem--some progress at cleaning out abort gap(s).
  - Proton intensities are being intentionally suppressed at the moment
- We are running 5 shifts of dedicated studies per week (see discussion of the plan.
- There is no "silver bullet" (as there was in Run I)
  - Prior two pages indicate a number of issues throughout the complex
    - Accumulator emittance
    - Tevatron momentum aperture on the helix
    - Long-range beam-beam effects

Current Performance
Commentary

- What's changed since Run I?
  - Main Injector has replaced Main Ring
  - Debuncher stochastic cooling
  - Accumulator stack-tail cooling
  - Accumulator lattice
  - 36 bunch operations
  - Tevatron injection point
- What issues could be fundamental, as opposed to just making components perform up to specification?
  - The only thing I see in here that could be a fundamental accelerator limitation is the long-range beam-beam.
    - Appears relatively benign in collisions (as expected), but not at injection, nor during the injection to collision helix transition ("step 13").
    - Calculated tune shifts/spreads are not large (~.003 at full intensity)

Plan for Achieving Run IIA Goals
General Strategy

January 1 – July 1

- Improve antiproton efficiency from Accumulator to Tevatron low-?
- Improve proton intensity at Tevatron low-?
- Commission Recycler parasitically
- Minimize access time

July (or whenever cooling tanks are ready)

- Shutdown to install new Accumulator transverse core cooling
- Shutdown for continuing Recycler vacuum work (pumps courtesy of BNL)

August 1 – December 31

- Improve stacking rate
- Integrate Recycler into operations
- Minimize accesses

Plan for Achieving Run IIA Goals

Run IIA goals will be achieved through a combination of modest hardware improvements and complementary studies. This overview is a condensed version of a more detailed plan assembled and coordinated by Mike Church, Beams Division Deputy Head.

- Hardware upgrades
  - Accumulator core cooling 8/15
  - Possible Accumulator magnet repair or modification 4/15
  - Tev longitudinal damper 1/15
  - Tev transverse damper 6/1
  - MI 8 GeV transverse damper 3/15
  - MI beamloading compensation 3/15
  - Recycler vacuum 8/1
  - MI BPM 2.5 MHz upgrade 10/1

Plan for achieving Run IIA goals
Studies

- **Protons**

Proton intensity	
Recommission Booster dampers	2/15/02
Tune up Booster $2B cycles	3/1/02
Coalescing efficiency	
FBI calibration	Done
Longitudinal emittance calculation algorithm	3/1/02
Eliminate cogging loss	Done
Implement beamloading compensation	3/15/02
Tev 150 GeV lifetime	
Measure/improve momentum aperture on helix	2/15/02
Fix pbar injection bumps to eliminate proton loss	2/15/02
Commission longitudinal dampers	Done
Revised lattice for injection helix?	9/1/02
Tev acceleration/store	
Commission Tev transverse dampers	6/1/02

Plan for achieving Run IIA goals
Studies

- Antiprotons

Stacking rate	
Commission compensation leg in stacktail system	11/1/02
Accumulator emittance	
Commission and calibrate 300 MHz emittance monitors	2/15/02
Continue damper investigation and search for noise sources	3/1/02
Understand source of positive chromaticity at core	3/1/02
Modify or repair magnets if required	4/15/02
Complete IBS calculations and compare with Run I measurements	2/15/02
Try wider core momentum width for shots	In progress
Install and commission new transverse core cooling arrays	8/15/02
Accumulator->MI transfer	
Modify optics of AP3, AP1, P2, P1	2/15/02
Commission MI pbar injection damper	3/15/02

Plan for achieving Run IIA goals
Studies

- Antiprotons (continued)

Coalescing Efficiency	
FBI calibration	Done
Fix Accumulator rf unstacking mechanics	4/15/02
Tune up coalescing efficiency	4/15/02
MI->Tev transfer	
Fix antiproton injection bumps/kicker settings	3/1/02
Commission BLT for antiprotons	Done
Measure A1 beamline optics/retune transfer	3/1/02
Commission new DCCT for Tev bus and investigate stability of MI-Tev energy match	2/15/02
Tev 150 GeV lifetime	
Understand/improve momentum aperture on helix	3/1/02
Document antiproton transverse emittances in MI	Done
Tev low beta squeeze	
Accelerate squeeze and/or adjust tunes through step 13	3/1/02

Luminosity Projection for 2002
Performance Milestones

Milestone 1: 2/15

150E9/bunch protons; luminosity =1.77E31

Milestone 2: 3/15

150E9/bunch protons; 50% pbar xfer eff.; luminosity=2.46E31

Milestone 3: 4/15

150E9/bunch protons; 70% pbar xfer eff.; luminosity=3.44E31

Milestone 4: 6/01

200E9/bunch protons; 70% pbar xfer eff.; luminosity=3.93E31

Milestone 5: 8/15

200E9/bunch protons; 80% pbar xfer eff.; luminosity=4.65E31

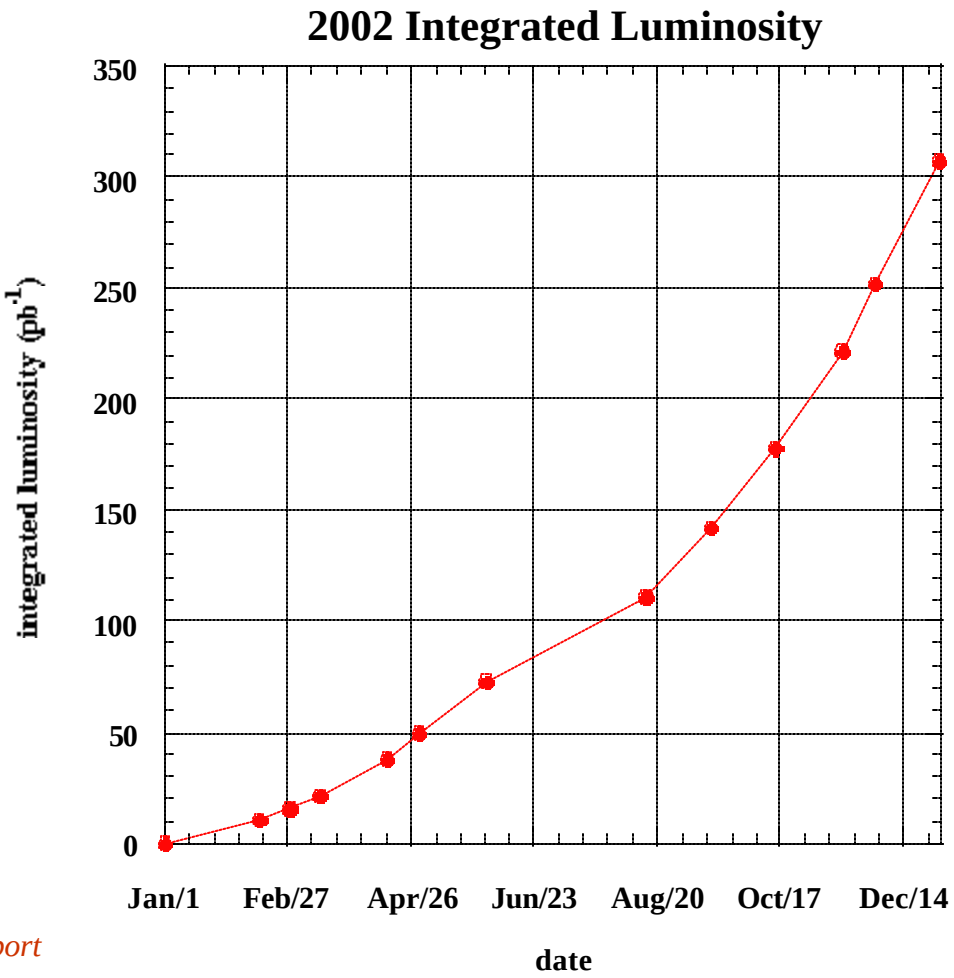
Milestone 6: 10/15

250E9/bunch protons; 80% pbar xfer eff.; luminosity=5.82E31

Milestone 8: 12/31

Run IIa goals; luminosity=8.6E31

Luminosity Projection for 2002
(50% Confidence Level)



Run IIA Beyond 2002

The plan described above leads to the maximum luminosity we believe we can obtain **without antiproton recycling**. The next steps:

- Integrate Recycler into operations (wo/recycling) Jan 2003
  - No specific luminosity advantage to this step unless the Accumulator has been choking at high stacks, in which case this will take heat off the Accumulator
  - Initiate commissioning of the recycling operation
- Integrate antiproton recycling Fall 2003
  - This will allow us to achieve 2×10^{32} luminosity with 36x36 bunches once we achieve an overall recycling efficiency of 50%
- Start 132 nsec operations Jan 2004
  - This will be accompanied by a crossing angle which will lower the luminosity by a factor of two. Overcoming this loss, and then some, is the goal of Run IIB

Run IIB Plan

http://cosmo.fnal.gov/run2b/Documents/TDR/tdr.pdf

- A plan has been assembled for Run IIB and reviewed by the Fermilab Accelerator Advisory Committee
- The overall strategy is to provide more antiprotons. Major sub-projects and resource requirements are identified below:

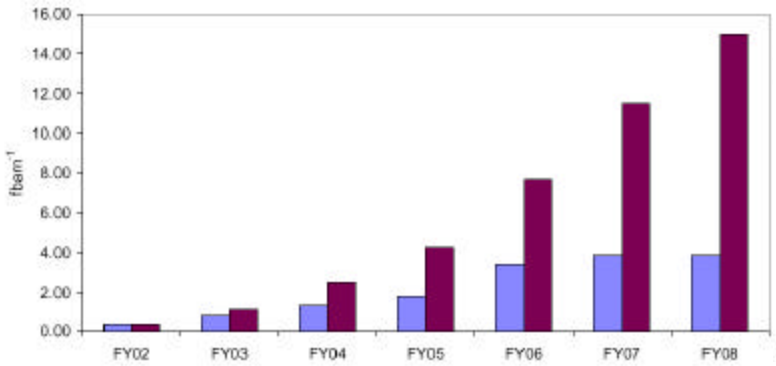


Figure 4.1.2 *Integrated Luminosity Schedule*

	Project Total	FYO2 Total	FYO3 Total	FYO4 Total	FYO5 Total
Slip Stacking	1160	770	390	0	0
Antiproton Target Station	2870	820	1140	710	200
Pbar Collection Aperture	7485	1410	2955	2180	940
Stacktail Upgrade	500	100	400	0	0
Electron Cooling	7995	4070	2605	1320	0
Pbar Transport	1080	380	700	0	0
Beam-Beam Compensation	7890	2070	2070	1875	1875
Total	28980	9620	10260	6085	3015

Table 4.2.1 *Total sub-project cost by fiscal year in k$*

This is an extremely technically challenging project. It appears to us that 4E32 is about the maximum luminosity achievable in the Tevatron under any conditions. Success will allow us to integrate 15 fb^{-1} by 2007-8.

Summary

Collider Run II is the most important activity we are engaged in at Fermilab.

- Collider performance in Run II is off to a disappointing start
- A plan has been formulated to address issues uncovered during startup
  - Leads to the achievement of the goal established with the Main Injector project by the end of this year.
- Some things that are going well, but not enough time …
  - Electron cooling has achieved 500 mA operation at 3.8 MeV
  - Recycler has demonstrated a 35? mm-mr aperture, cooling of antiprotons in all planes, and a beam lifetime of >50 hours in the presence of Main Injector ramping
- A plan for achieving 15 fb^{-1} by the time of LHC data taking has been develop and is being established as a project.
  - It is very technically challenging
  - Currently staffed at ~1/2 of planned level because of Run IIA needs