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Record luminosities at the Tevatron & Future potentiality

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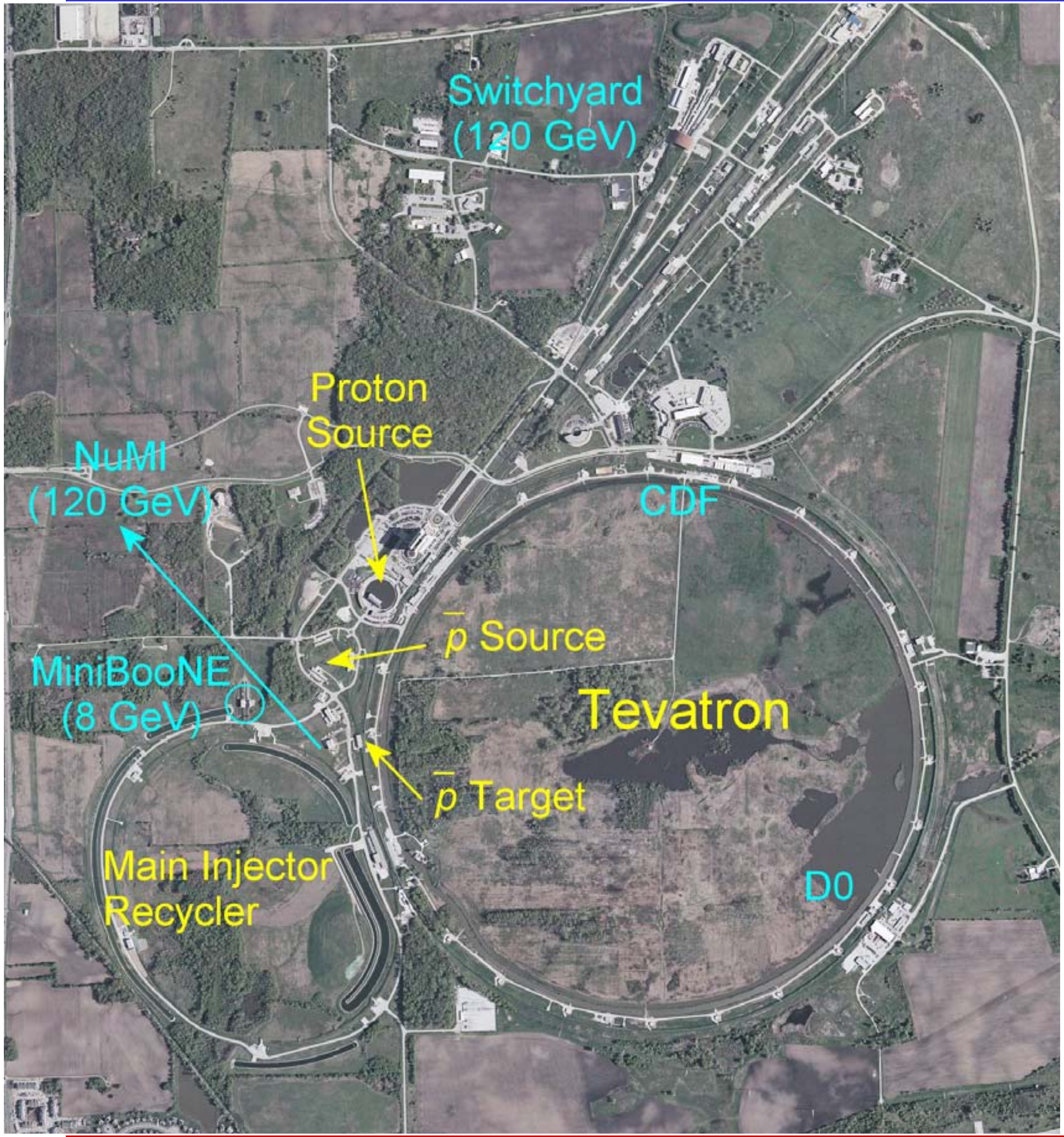
Outline

- Overview of Fermilab operations
- Major accomplishments
- Antiproton Production
- Recycler Only Operation
- Tevatron issues
- Conclusions

Fermilab Accelerator Complex



Two Collider Experiments
- CDF
- D0

Two neutrino Experiments
- NuMI
- MiniBooNE

120 GeV Fixed Target Experiments

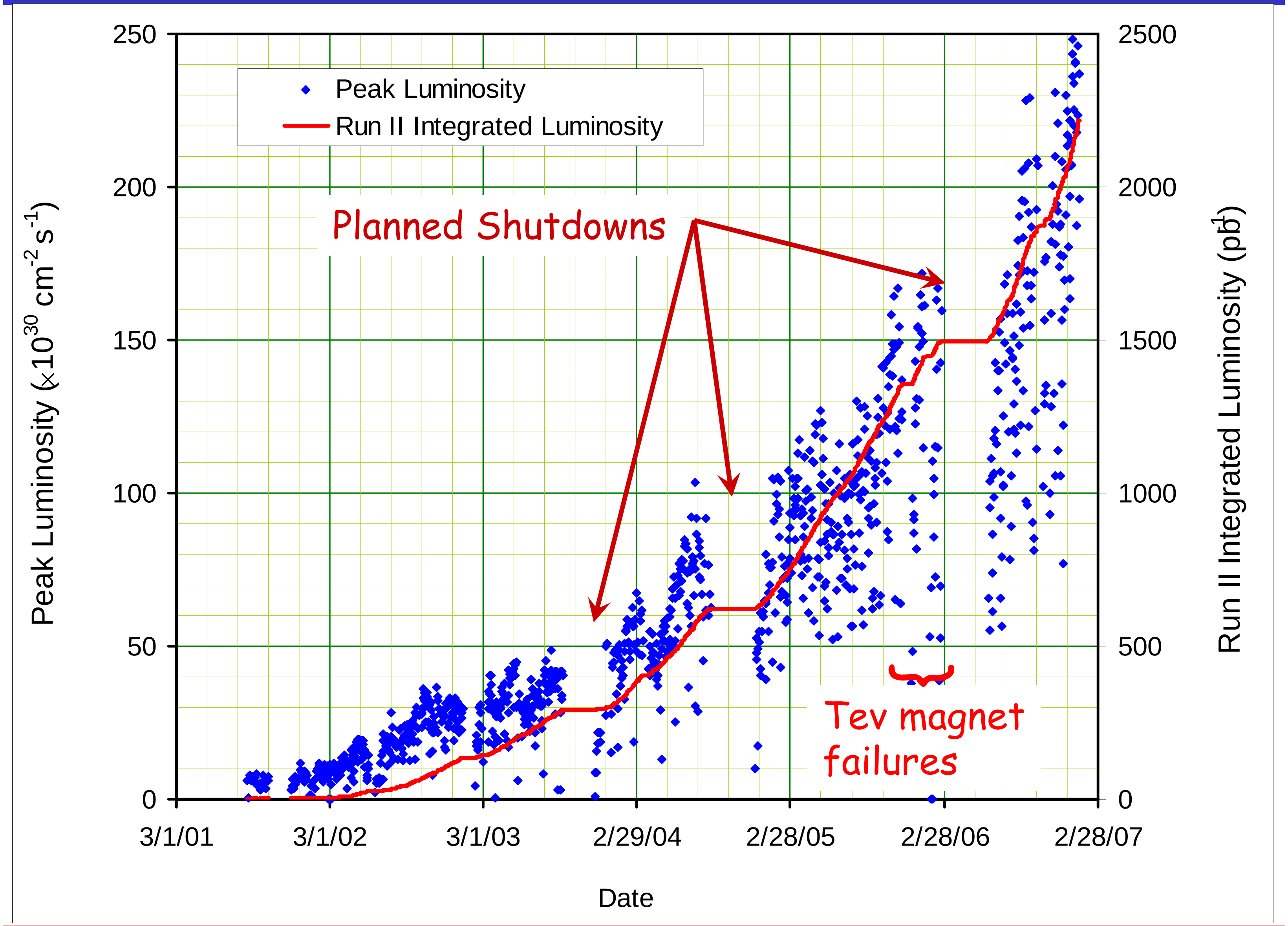
Ongoing program of
- Tevatron,
- $\bar{p}$ source,
- Main Injector, and
- Recycler upgrades

… One source of protons

Collider Parameters

Parameter	Present	Upgrade	Units
Peak Luminosity	185	300	10^{30} cm^{-2} s^{-1}
Luminosity Lifetime	8.5	-	hr
Store hours per week	97	105	hr/wk
Integrated Luminosity	5.1	-	pb^{-1}/store
Total Run II $\int Ldt$	2.2	7	fb^{-1}
Protons per bunch	250	270	10^9
$\bar{p}$ per bunch	58	127	10^9
Number of bunches	36×36	36×36	
β^* at IPs	28	28	m
$\bar{p}$ stacking rate to Accumulator	17.5	30	10^{10}/hr
$\bar{p}$ stacking rate to Recycler	12.0	-	10^{10}/hr

Luminosity Progress



Run II Milestones

Milestone	Date
Start of Run II Commissioning	March 2001
Collider Operational	July 2003
Recycler Electron Cooling Operational	July 2005
Slip Stacking Operational	August 2005
Lower β^* from 35 cm to 28 cm	September 2005
Recycler Only Operations	October 2005
Tevatron Separator Upgrade	Spring 2006

Antiproton Production

- Beam on target - Slip Stacking
- Consequences
- Lithium Lens & Aperture upgrades
- Stacktail Cooling Issues

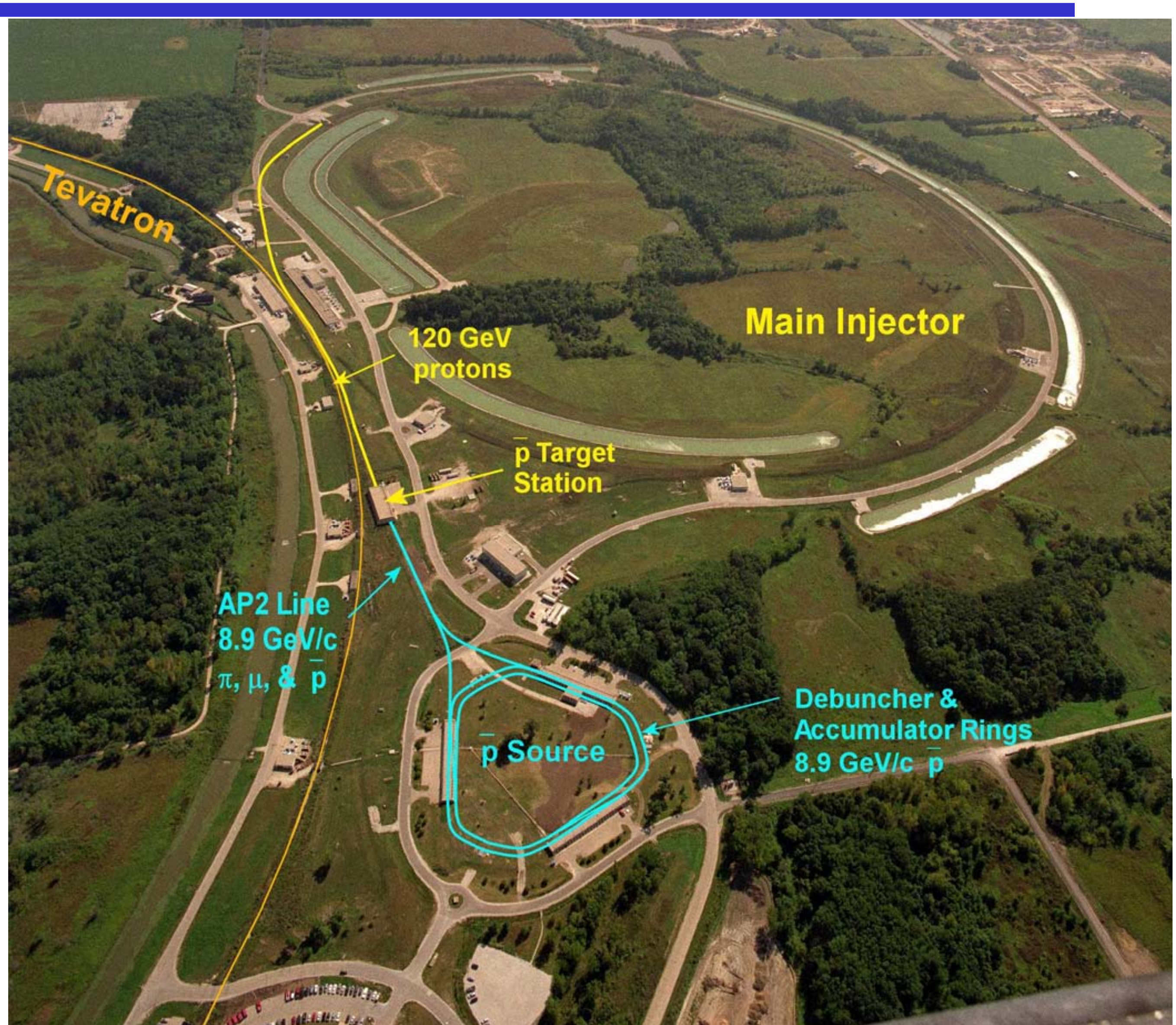
Collider Operation – $\bar{p}$ Stacking

120 GeV protons (8×10^{12}) on target

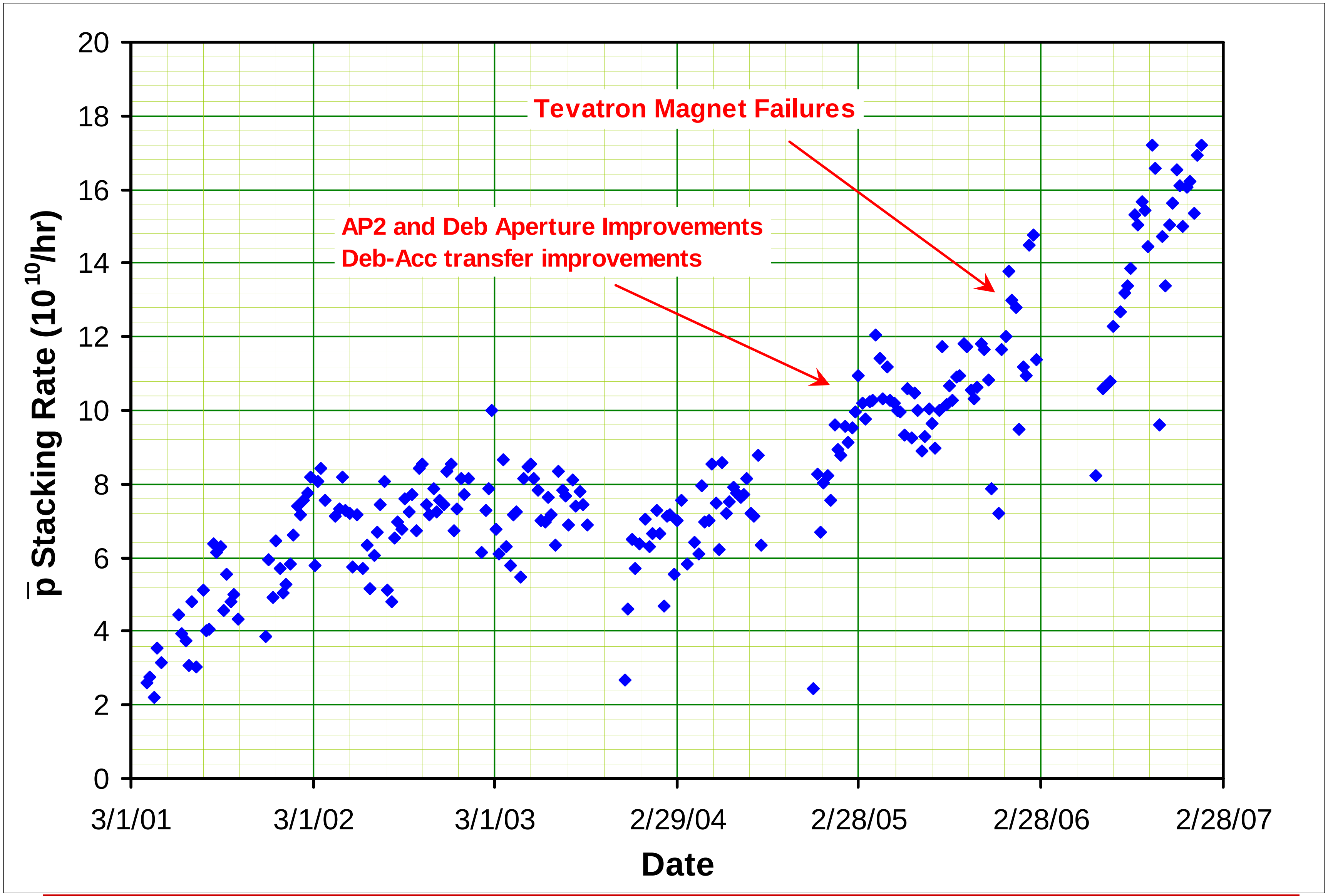
8 GeV π, μ, & $\bar{p}$ in AP2 line

Debunch and cool in Debuncher for 2.4 sec.

Stochastically stack in Accumulator



Stacking Rate History

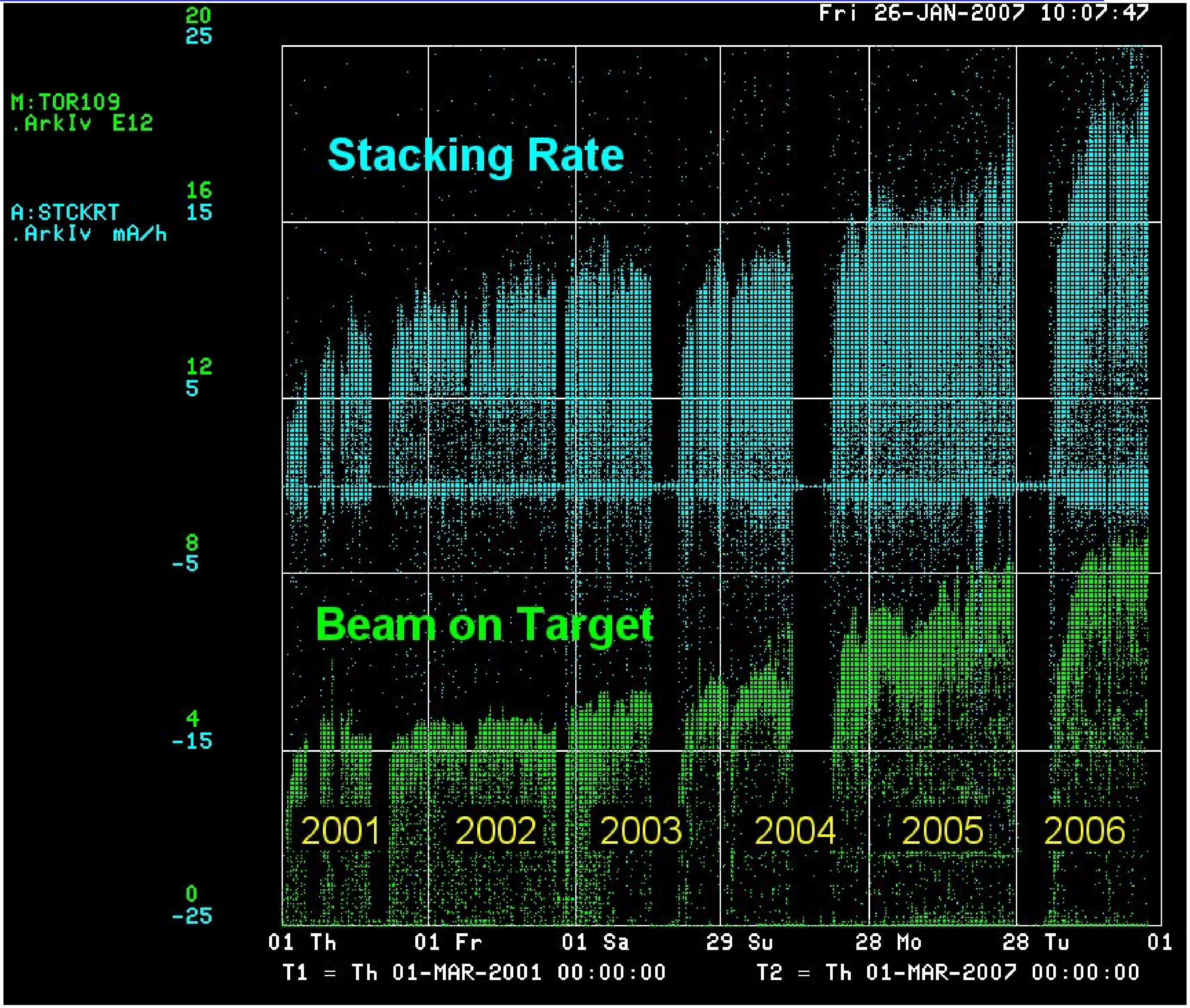


$\bar{p}$ Stacking - Beam on Target

Stacking rate increases have generally followed the increases in beam on target.

The steady increase after the 2004 shutdown is due to Slip Stacking.

Presently 8.2×10^{12} protons per cycle are routinely targeted.

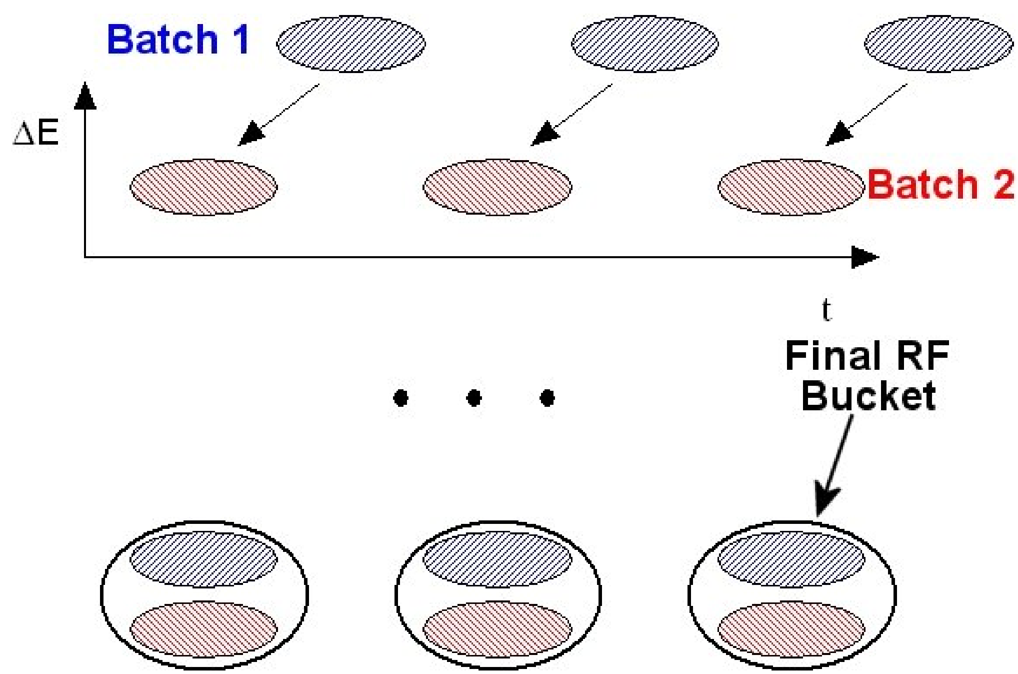


Slip Stacking

Two proton batches are injected into the Main Injector on different radial orbits. They will have different momenta and revolution frequencies.

Since the revolution frequency of these two batches are different they will slip longitudinally relative to one another.

When the two batches are azimuthally aligned they are captured in a common RF bucket and accelerated to 120 GeV.



Consequences - Target Damage

3 Nickel disks

Diameter: 11.43 cm

Height: 2.15 cm

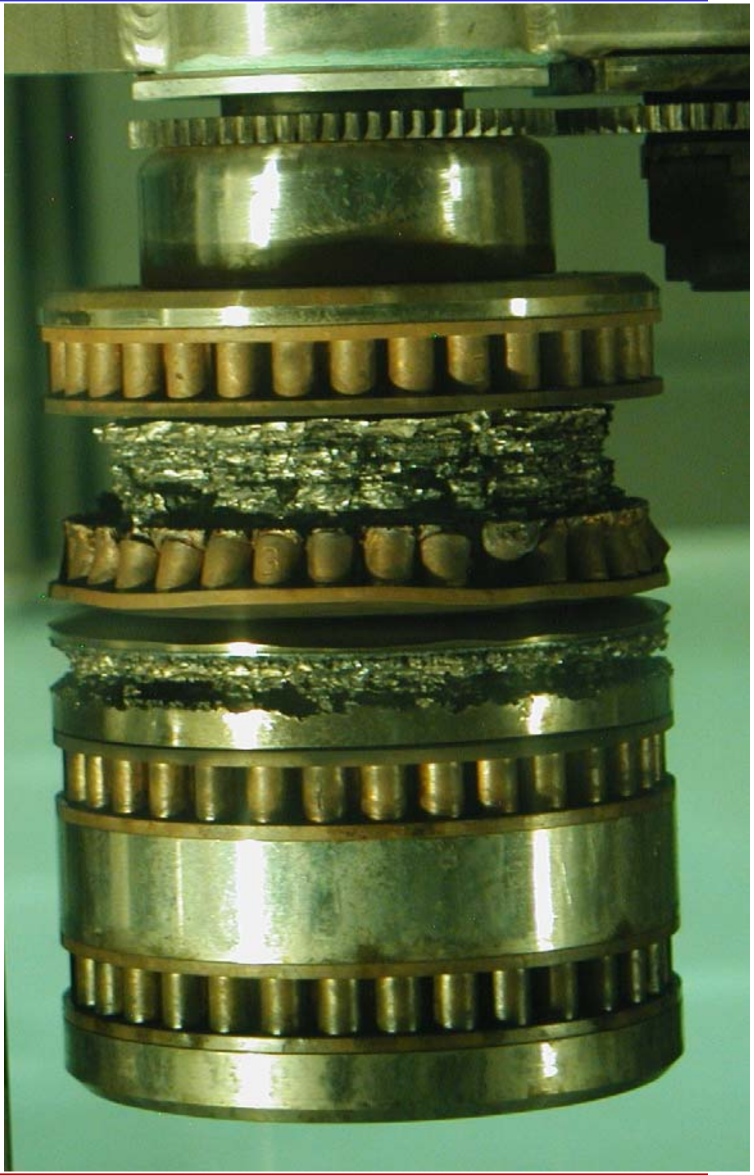
Air Cooled

Capacity: 6×10^{18} protons/disk

- Takes ~ 5 weeks to consume one disk

-Yield degraded by ~5% after this

-Target lifetime is ~3 months

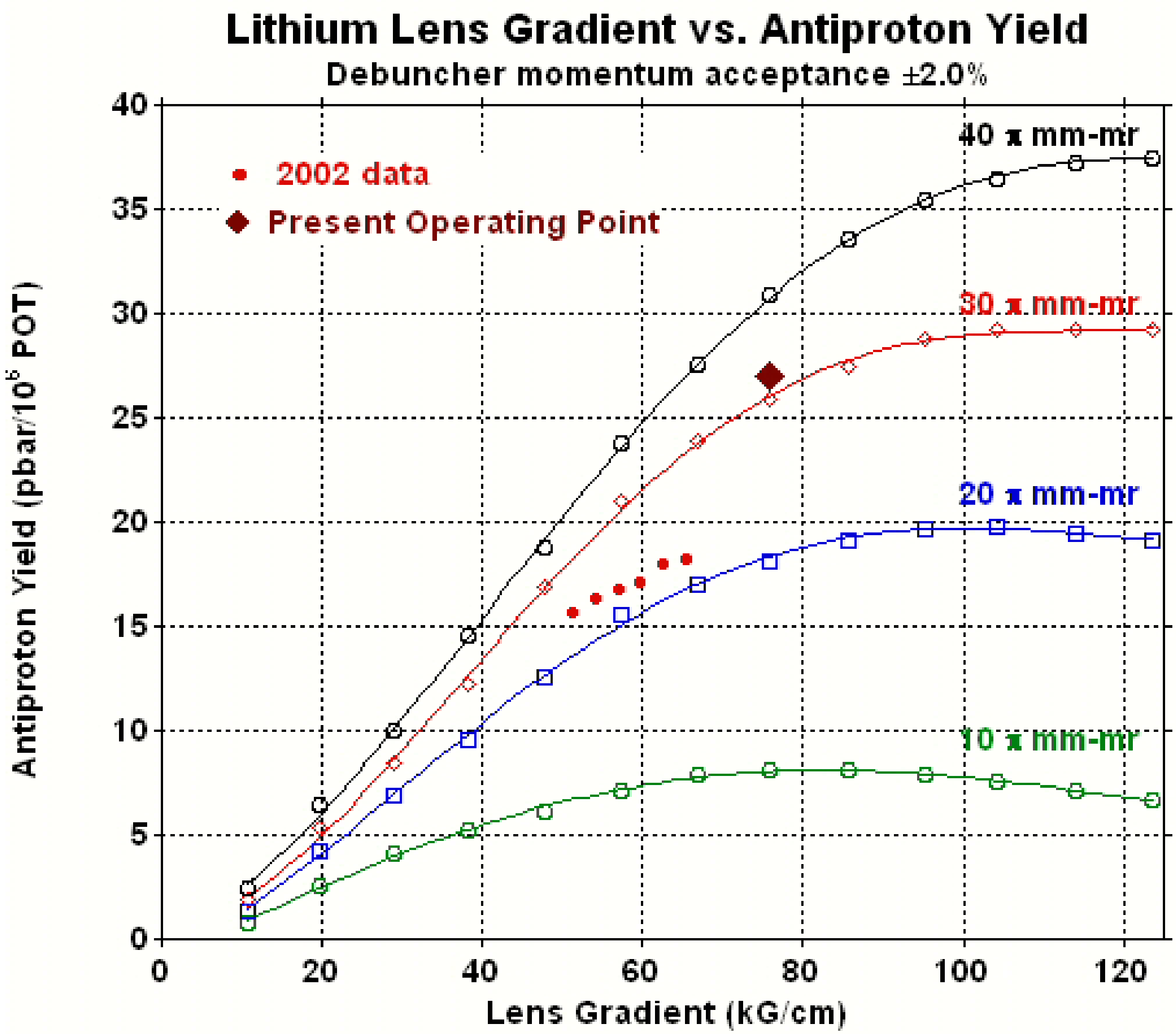


$\bar{p}$ Production – Collecting beam from the target

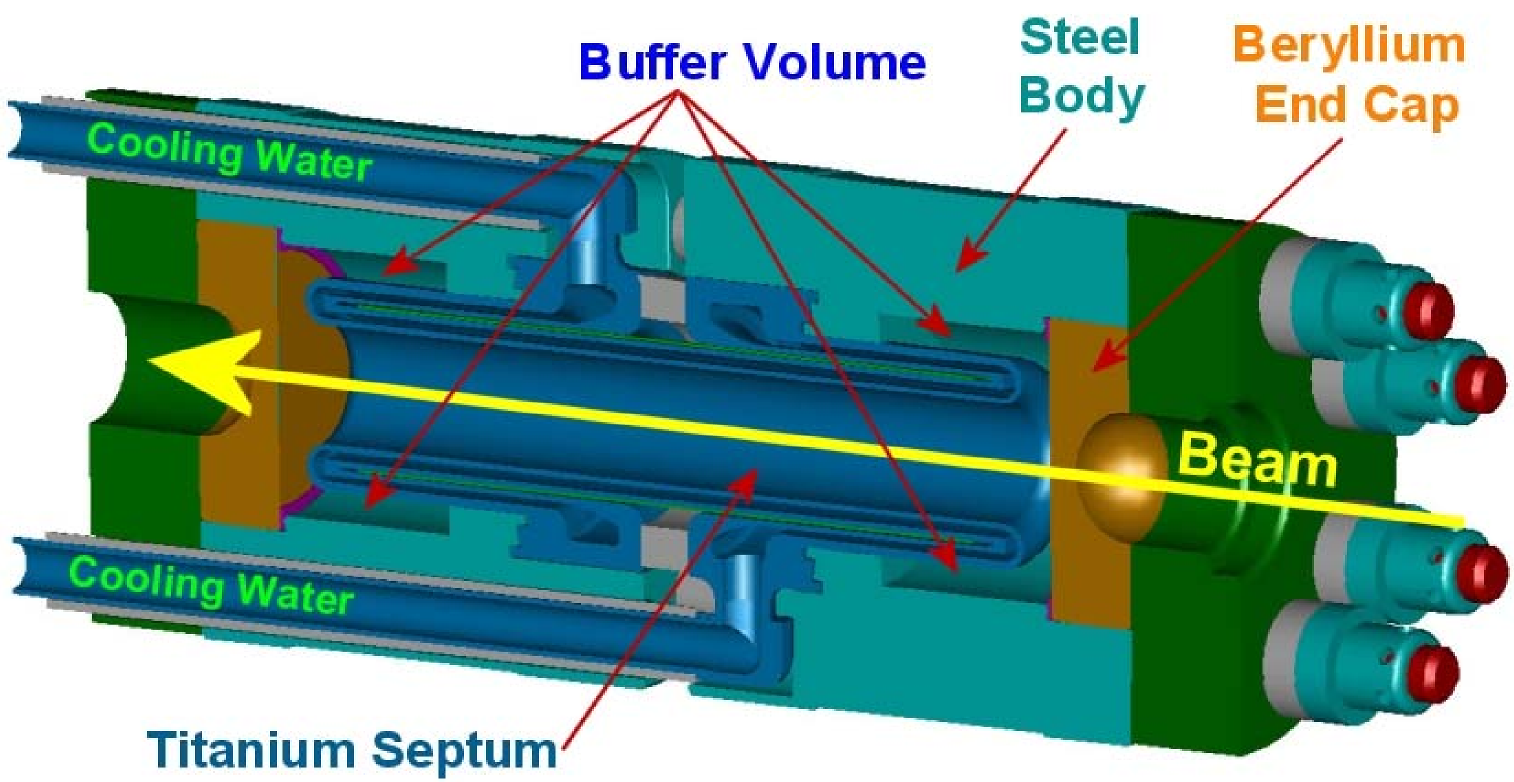
Two upgrade projects have increased the $\bar{p}$ yield by 60%:

Li Lens gradient upgrade

AP2 & Debuncher acceptance upgrade



Old Li Lens Design



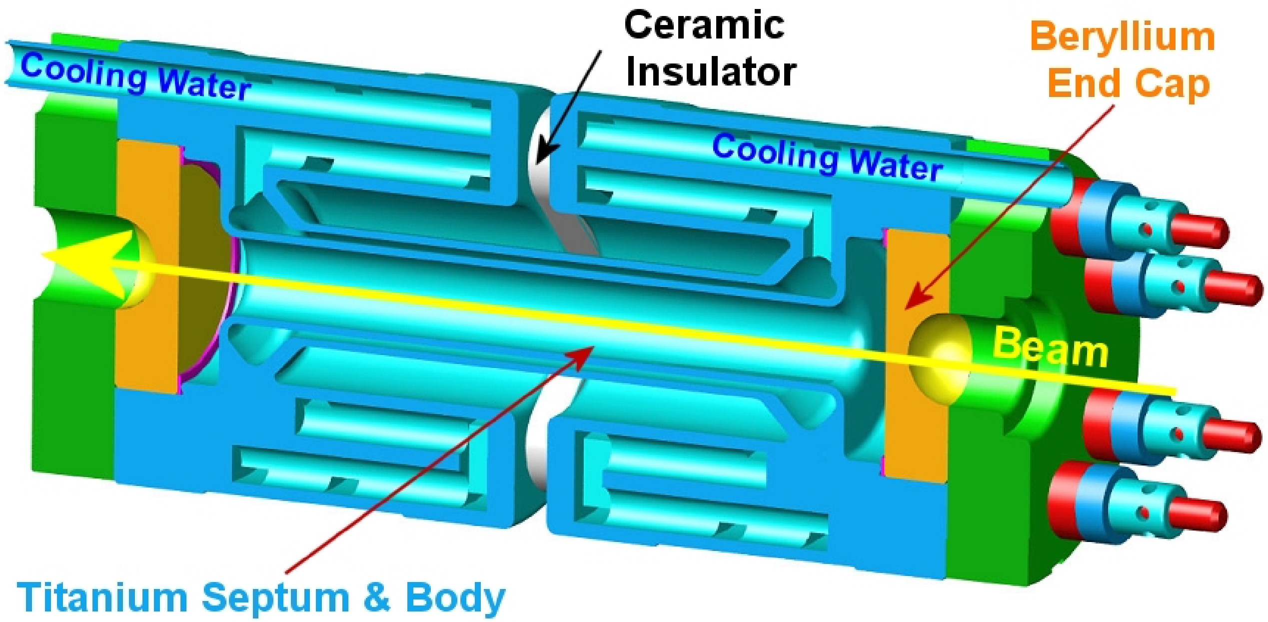
Note:

- No cooling of steel body
- Only septum is made of titanium

High Gradient Lithium Lens - New Design

<u>Features</u>:

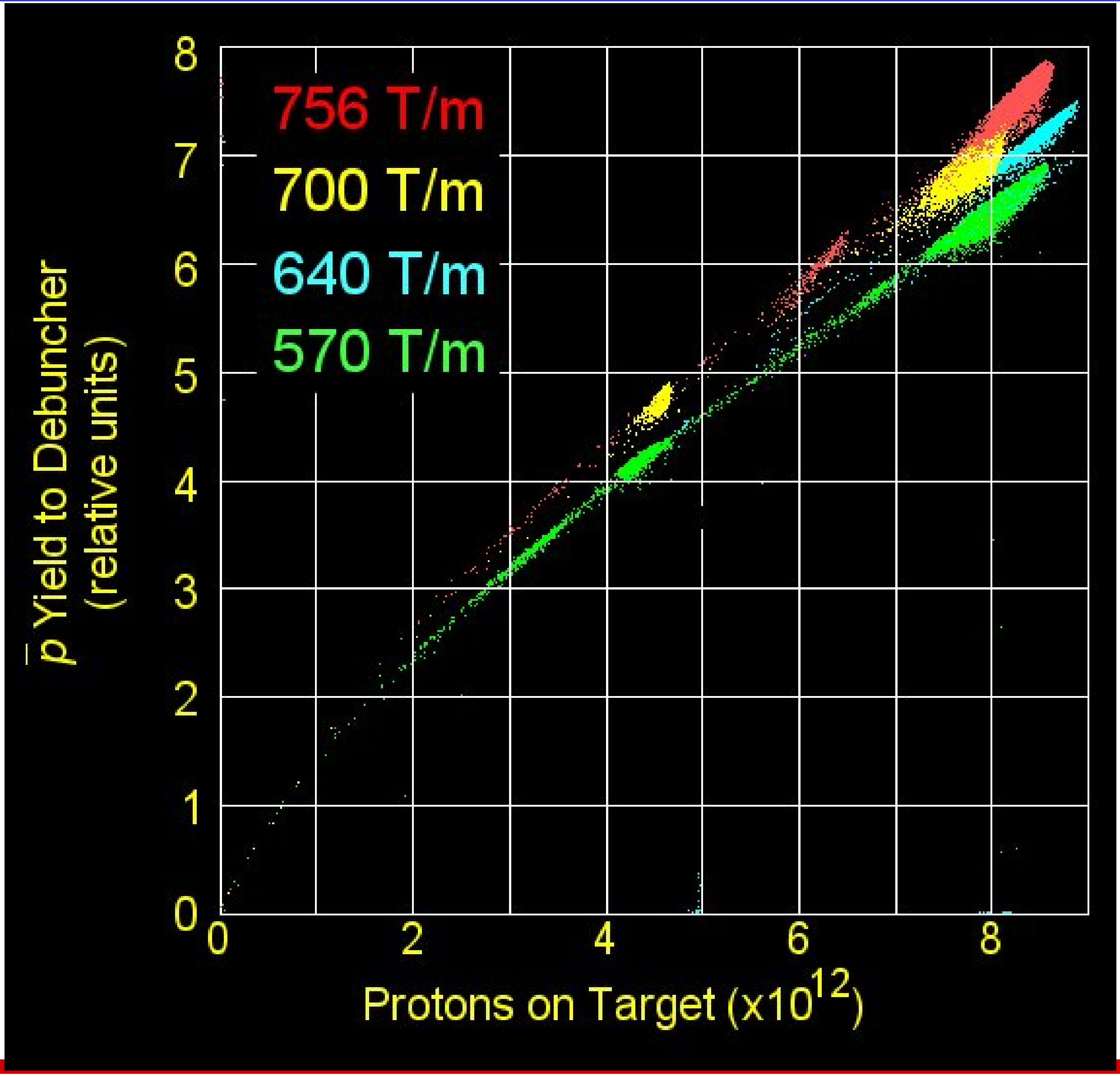
- Diffusion bonded titanium body
- Improvec cooling
- Li buffer volumes eliminated



<u>Diffusion Bonding</u>:

- Better, more uniform cooling of lens body
- Allows use of new Ti alloy (Ti 10V-2Fe-3Al)
- Simplified lens fabrication
- Elimination of weld joints on septum

Measured Yield Increase with Gradient

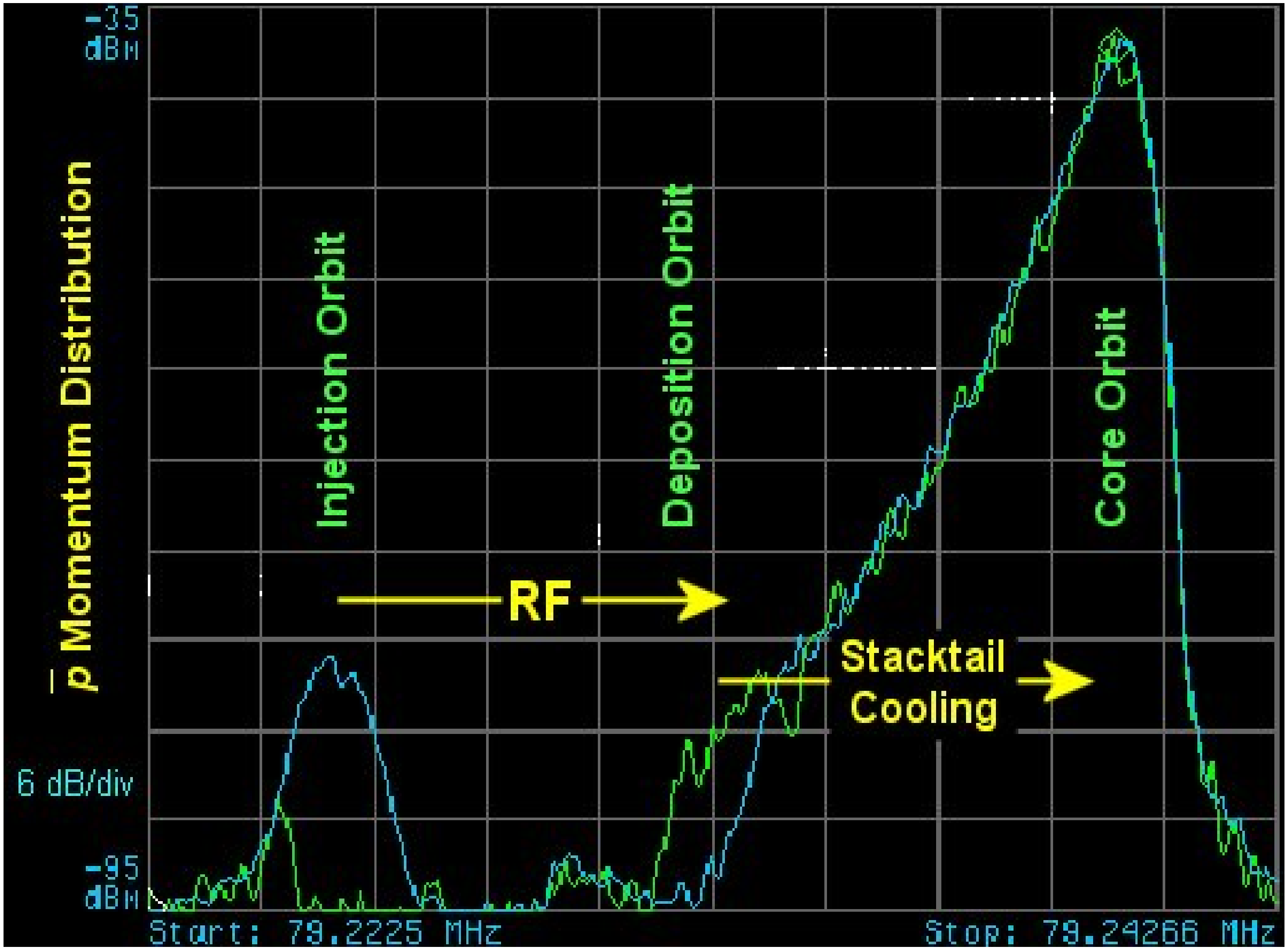


Accumulator Stacking

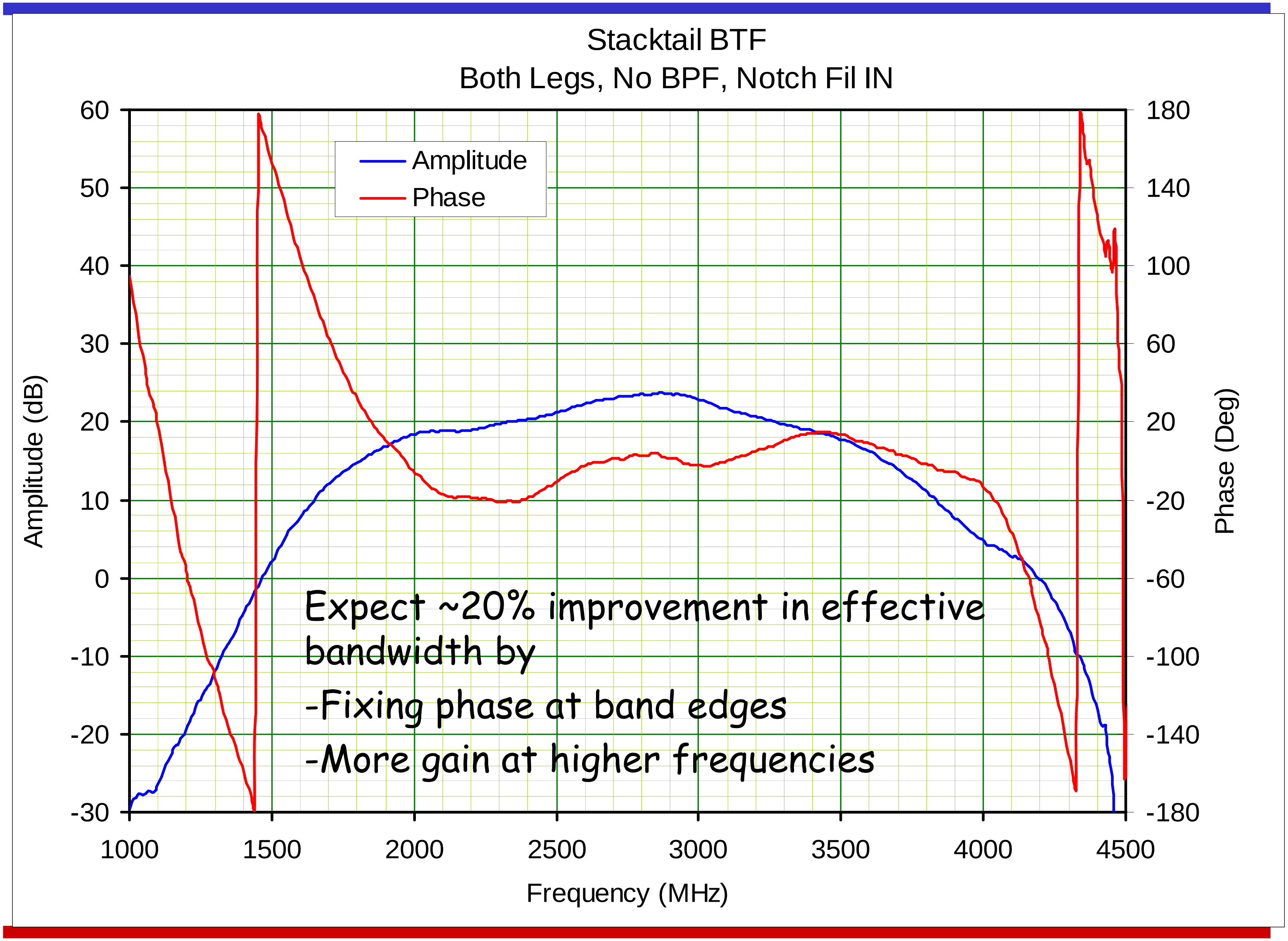
Injected beam is moved by RF to Deposition Orbit.

Deposited pulse is moved of the deposition orbit and stacked by the stacktail cooling system.

Deposition orbit must be cleared off prior to next pulse.



Stacktail Bandwidth Improvement



Expect ~20% improvement in effective bandwidth by

-Fixing phase at band edges

-More gain at higher frequencies

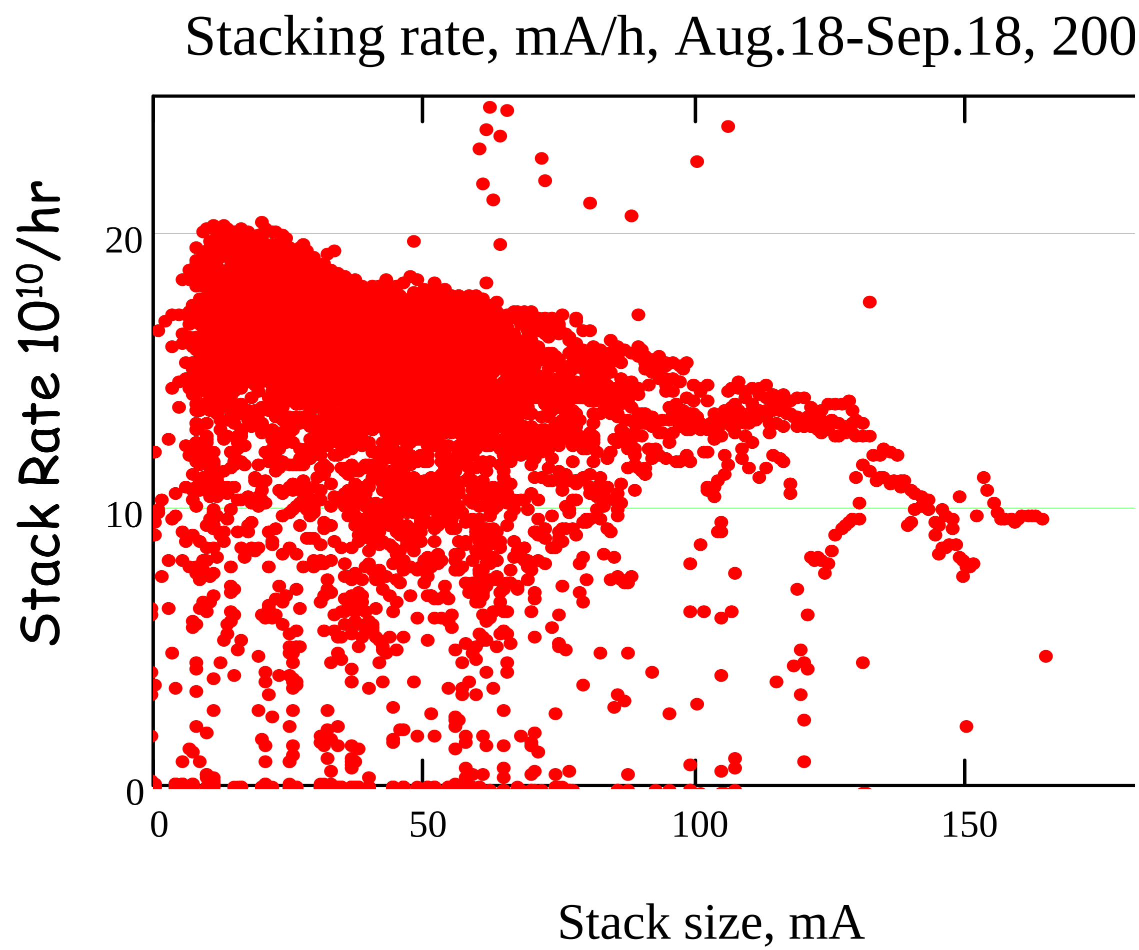
Recycler Only Operation (1)

Stacking Rate in the accumulator is stack-size dependant.

As the core grows its signal on the stacktail pickups grows also.

The result is core heating by the stacktail. Thus, as the core grows the stacktail gain must be lowered ⇒ stacking rate decreases.

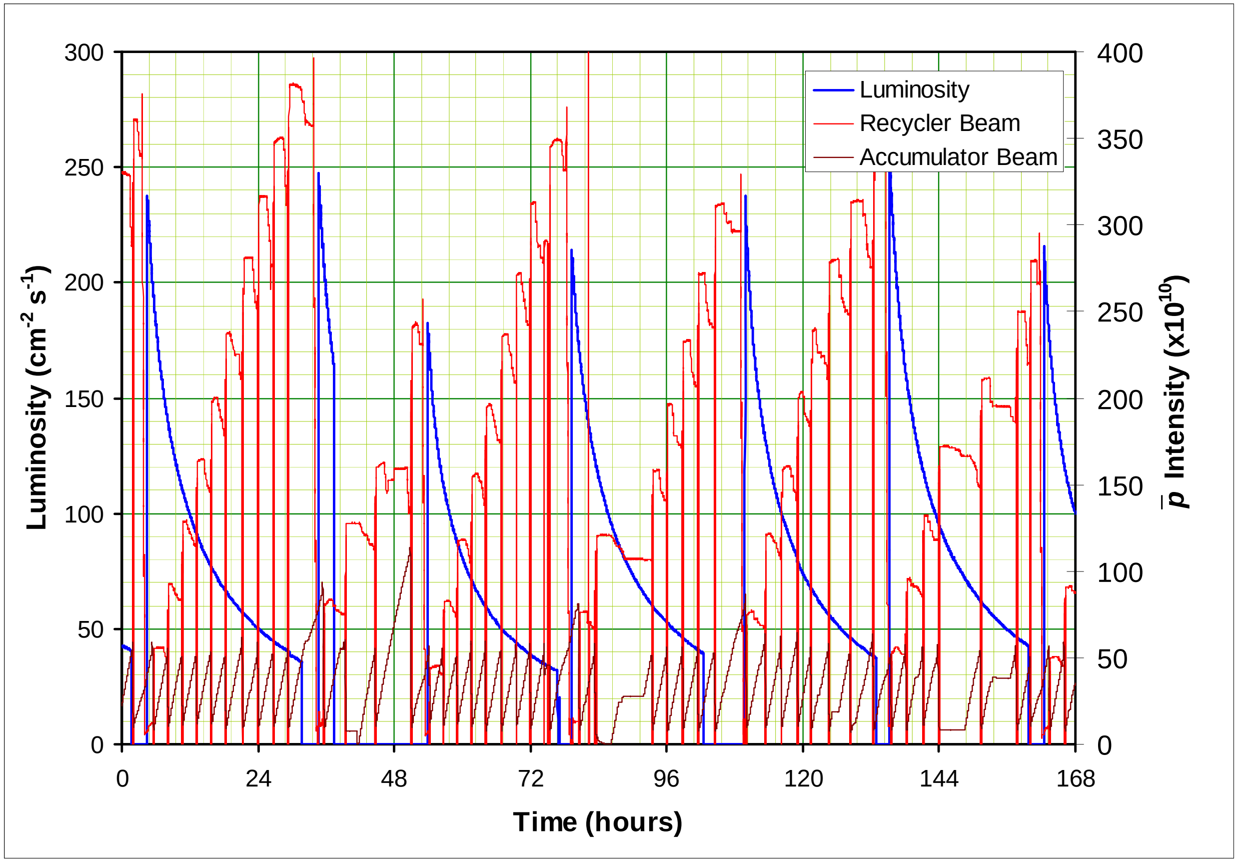
Solution: Transfer the beam to the Recycler before the core grows too large.



1 mA = 10^{10} $\bar{p}$

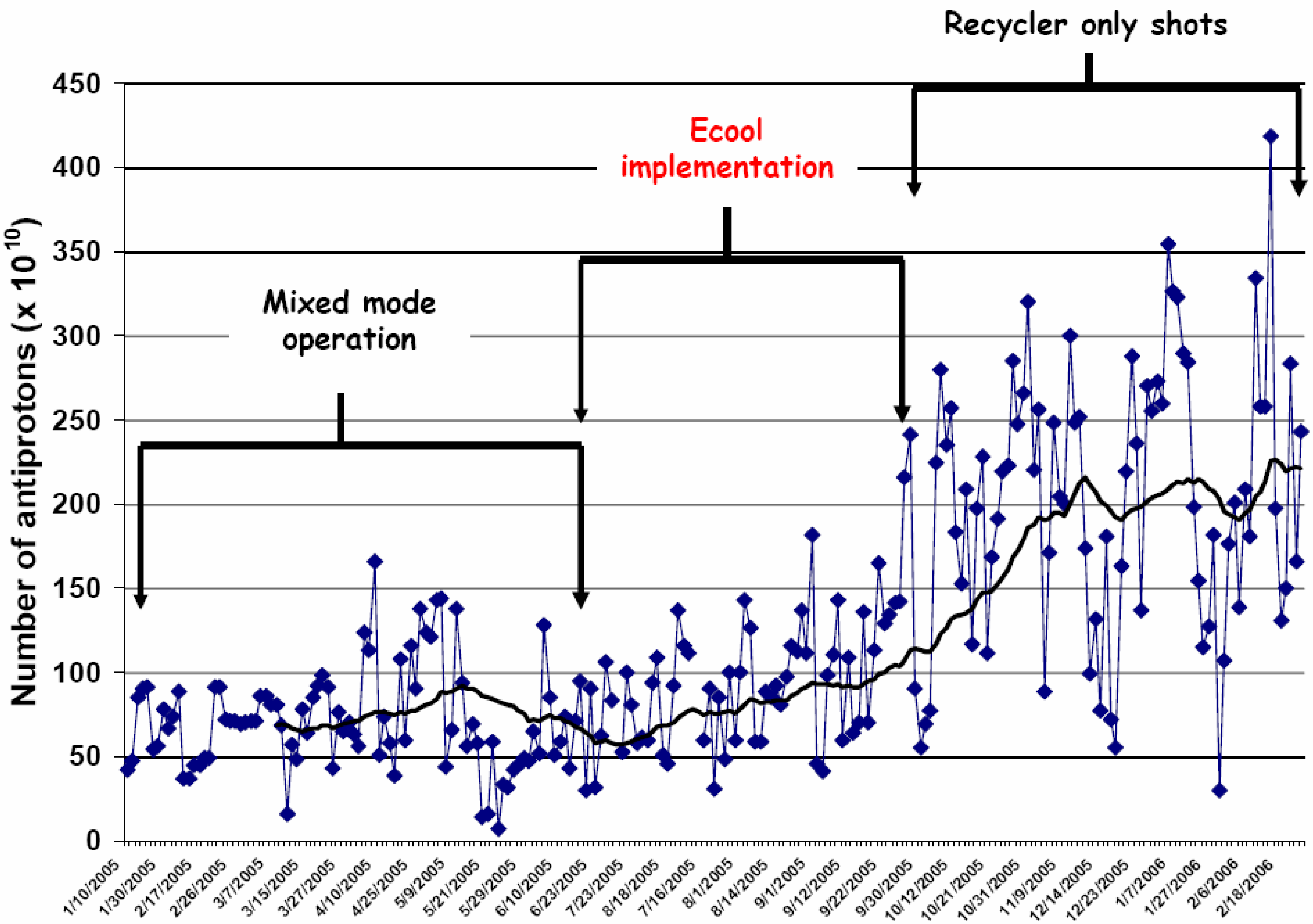
Recycler Only Operation (2)

- Stack into Accumulator to 50 – 60 x 10^{10} $\bar{p}$
- Transfer all $\bar{p}$ from Accumulator to Recycler
- When Collider store is terminated, transfer $\bar{p}$ from Recycler to the Tevatron.



For more information on rapid transfers to the Recycler see V. Nagaslaev poster

Shifting from Accumulator to Recycler Operation



Jan '05 Feb '06

Tevatron Improvements

Newly Operational

- BPM Upgrade
- Lower β^*
- Separator Upgrade

Problems

- Magnet Failures

Yet to Come

- Working point change

Tevatron Improvements

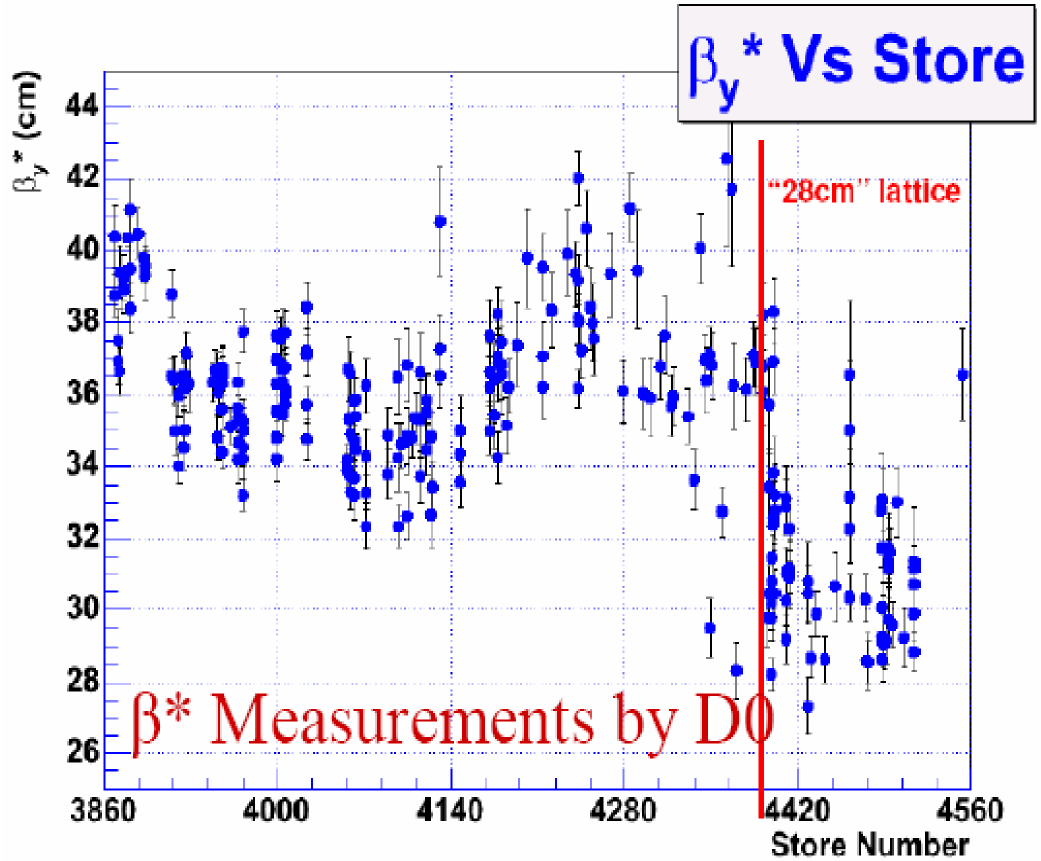
BPM upgrade

- 10 – 25 μm Resolution
- Accuracy of proton position measurement improved by order of magnitude.
- Ability to measure antiproton orbits for the first time

Tevatron Improvements

28 cm β^* Optics Change

- Lattice measurements exploited new BPM electronics.
- Tested after HEP prior to store termination.
- β^* change implemented in September 2005.



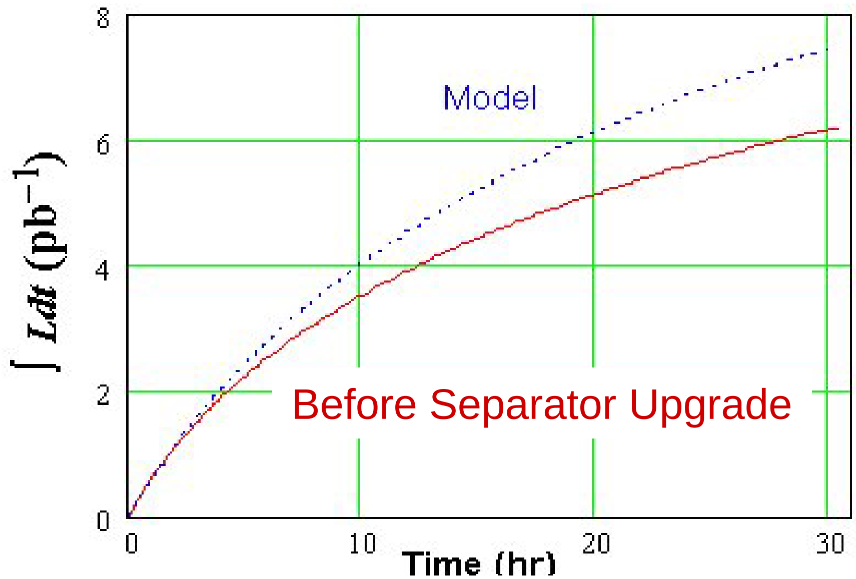
Tevatron Improvements

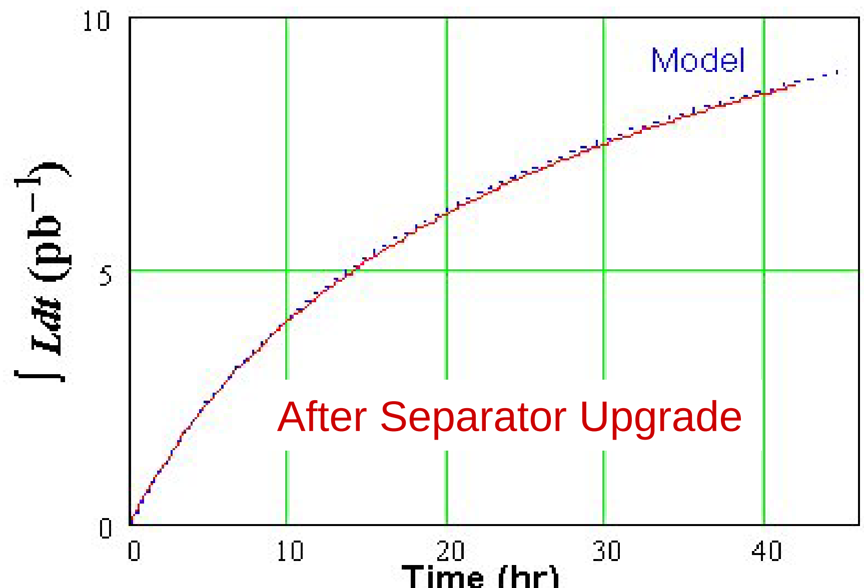
Separator Upgrade

- Additional HV modules installed
- Polarity reversing switches
- Increased HV capacity

Comparison of luminosity evolution with model that does not include beam-beam effects.

- Prior to separator upgrade a model without beam-beam does not well represent the data
- After separator upgrade – beam-beam mitigated – model matches data





Tevatron Failures

Three Tevatron magnet failures occurred in early FY 2006. Each were induced by components that failed to operate properly during "mild" quenches.

- Mild quench –10-15K magnet temperature, < 1 hour recovery
- Major quench –100k magnet temperature, multi-hour recovery

Two of the magnet failures were the result of failed "Kautzky" (pressure relief) valves.

- We view this as a systematic failure

Shutdown 2006:

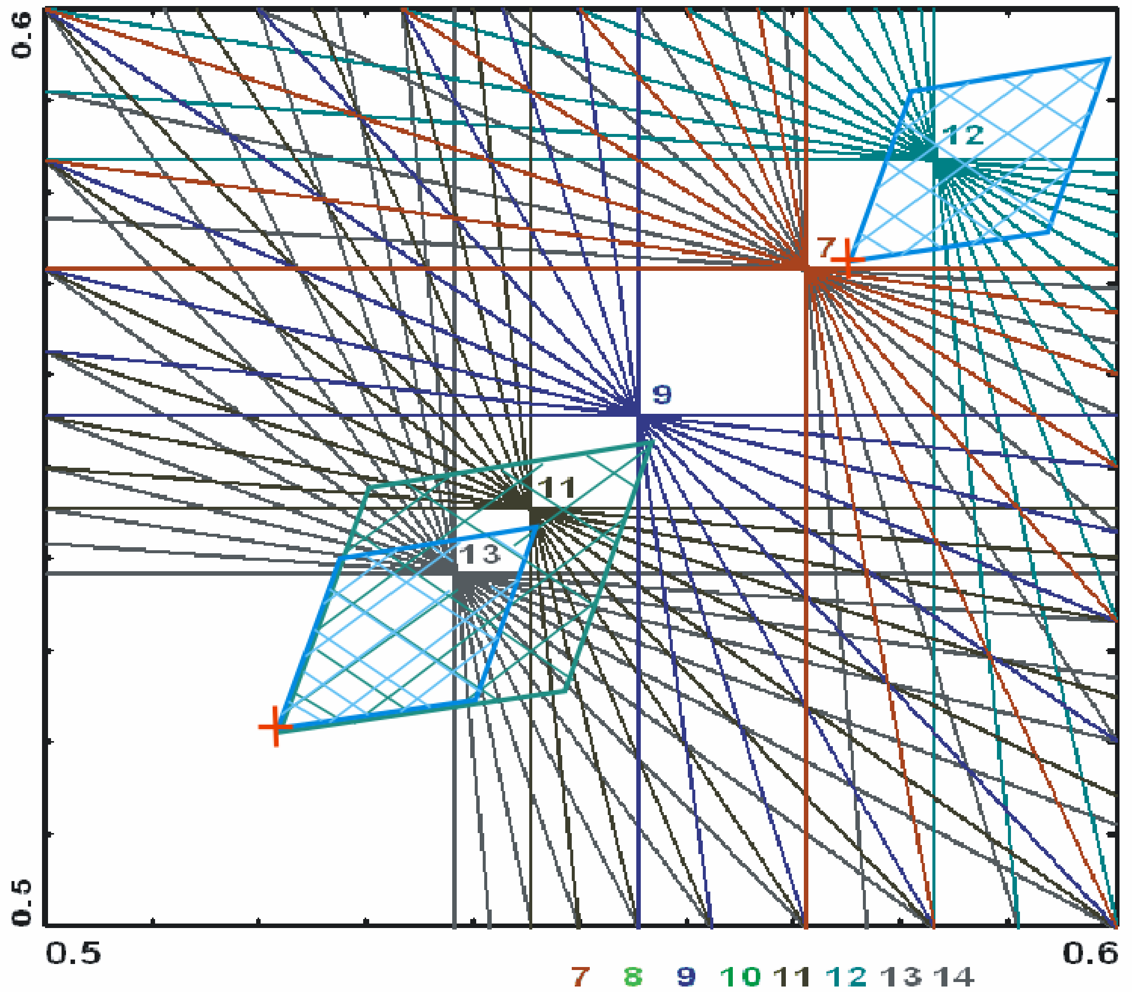
- Replaced the failed part in all of the Tevatron Kautzky valves (~1200) during this shutdown
- Repaired all known cold leaks (F4, E2, A3, B4)

Tevatron - Yet to Come

Normal operating point between 4/7 and 3/5.

Plan to move working point to vicinity of ½

- 40% more tune space
- Greater chromatic effects



Conclusions

- Enormous progress in the last two years
  - Peak luminosity increase by factor of 2.5
  - 30-40 pb^{-1}/week integrated luminosity
  - 2x increase in $\bar{p}$ stacking rate since early 2005

- More is expected
  - $\bar{p}$ stacking rate increase to ~30×10^{10}/hr
  - More protons, and antiprotons ⇒ higher initial and integrated luminosity
    - $L_0 \sim 270$ cm^{-2} s^{-1} (Last week had record $L_0 = 277$ $cm^{-2}s^{-1}$)
    - $\int Ldt \sim 6.4$ pb^{-1}/store ~ 320 pb^{-1}/week (my estimates – not official)
  - Run II total integrated luminosity of 7 fb^{-1} is within reach

Debuncher Operation

Debuncher Operation

Bunch rotation

19 ns bunch structure → DC

3-D Cooling for 2.4 sec