Tevatron Run II Performance and Plans

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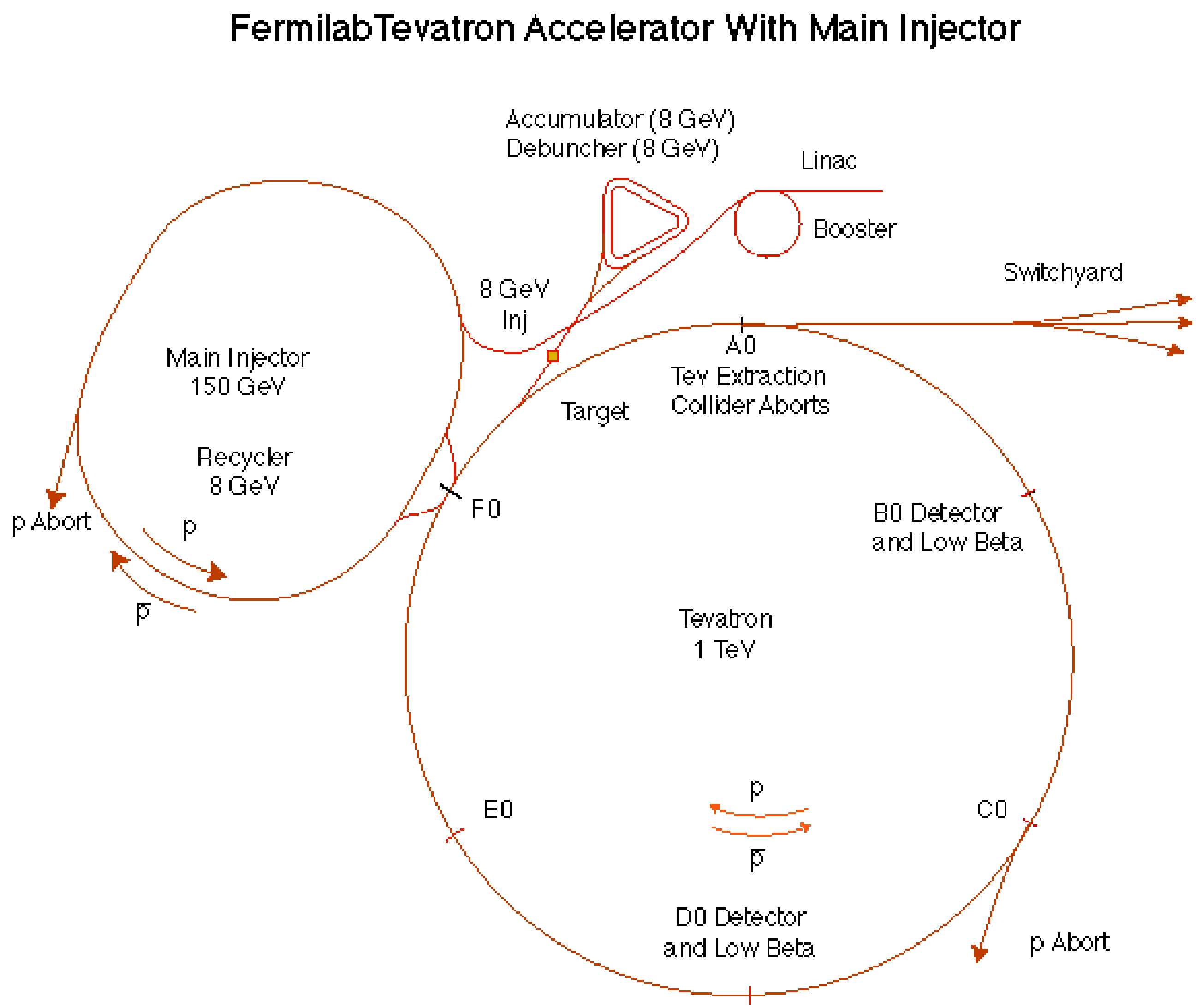
ANL, June 7, 2002

Outline

1) Brief description of operations
2) Run II luminosity: past, present, plan
3) Issues: battle for antiprotons
4) Proton issues
5) Next steps

FNAL Accelerator Complex



Luminosity Recipe

$$L = \frac{10^{-6} fBN_p N_{\bar{p}} (6\beta_r \gamma_r)}{2\pi\beta^* (\varepsilon_p + \varepsilon_{\bar{p}})} H(\sigma_l / \beta^*) \qquad (10^{31}\ cm^{-2}\ sec^{-1})$$

f = revolution frequency = 47.7 KHz

B = # bunches = 36

$\beta_r \gamma_r$ = relativistic beta x gamma = 1045

β^* = beta function at IR = 35 cm

H = hourglass factor = .60 - .75

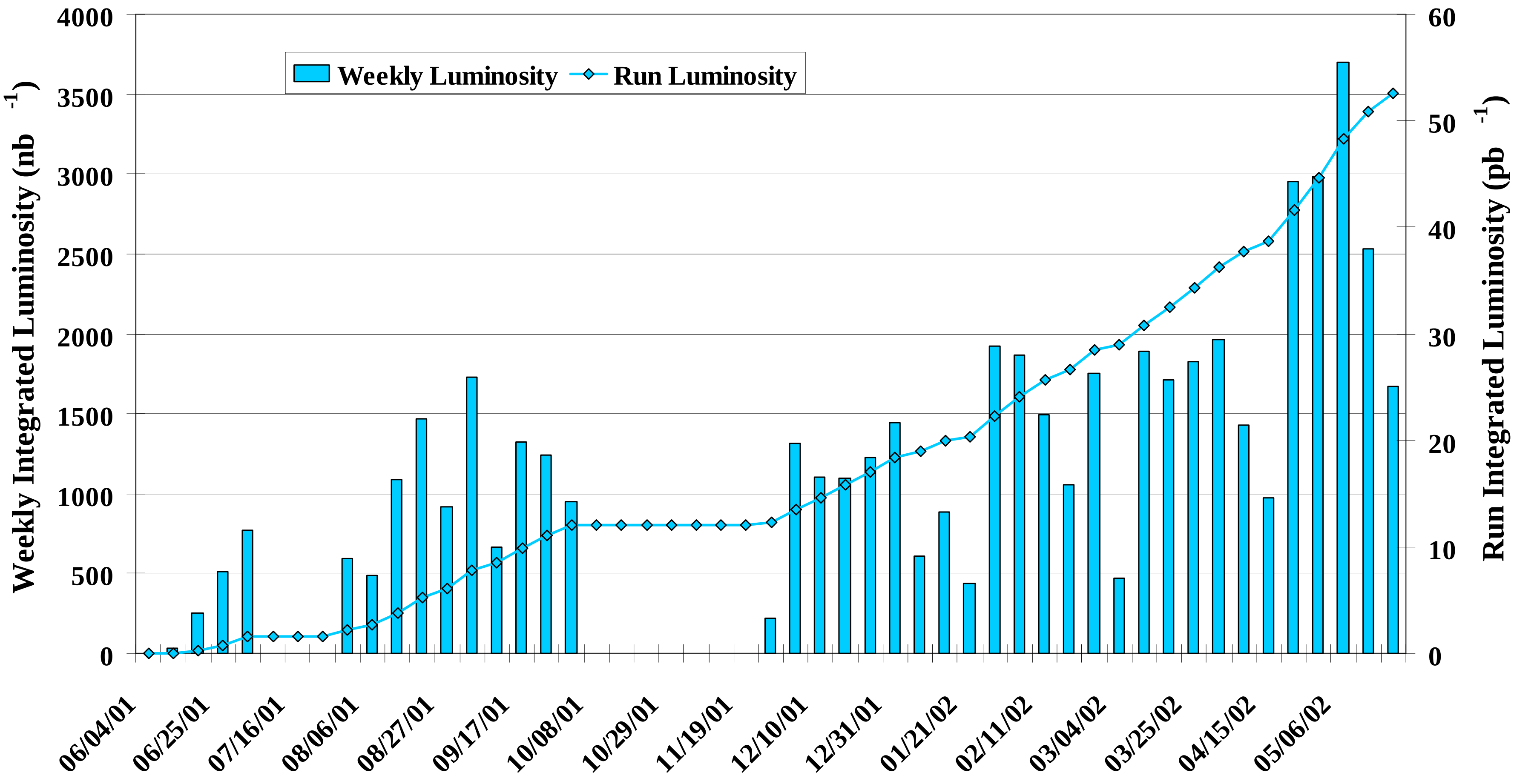
N_p , N_{pbar} = bunch intensities (E9)

ε_p , ε_{pbar} = transverse emittances (π-mm-mrad)

σ_l = bunch length (cm)

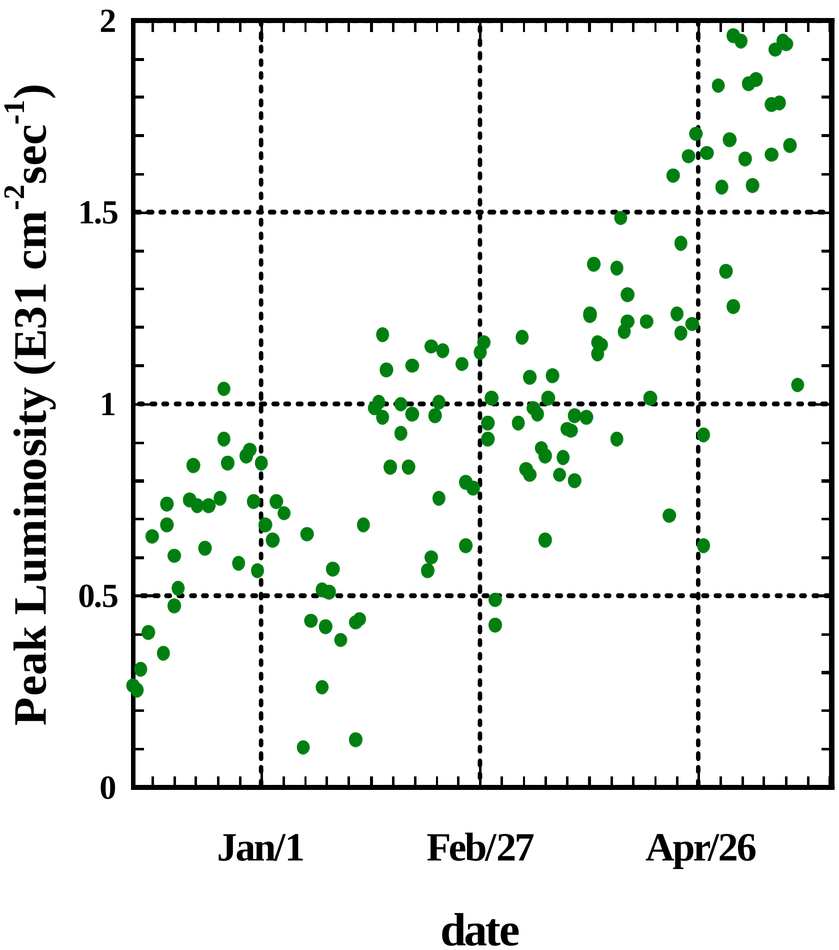
Integrated Luminosity History

Luminosity Per Week: 6/04/01-5/26/02

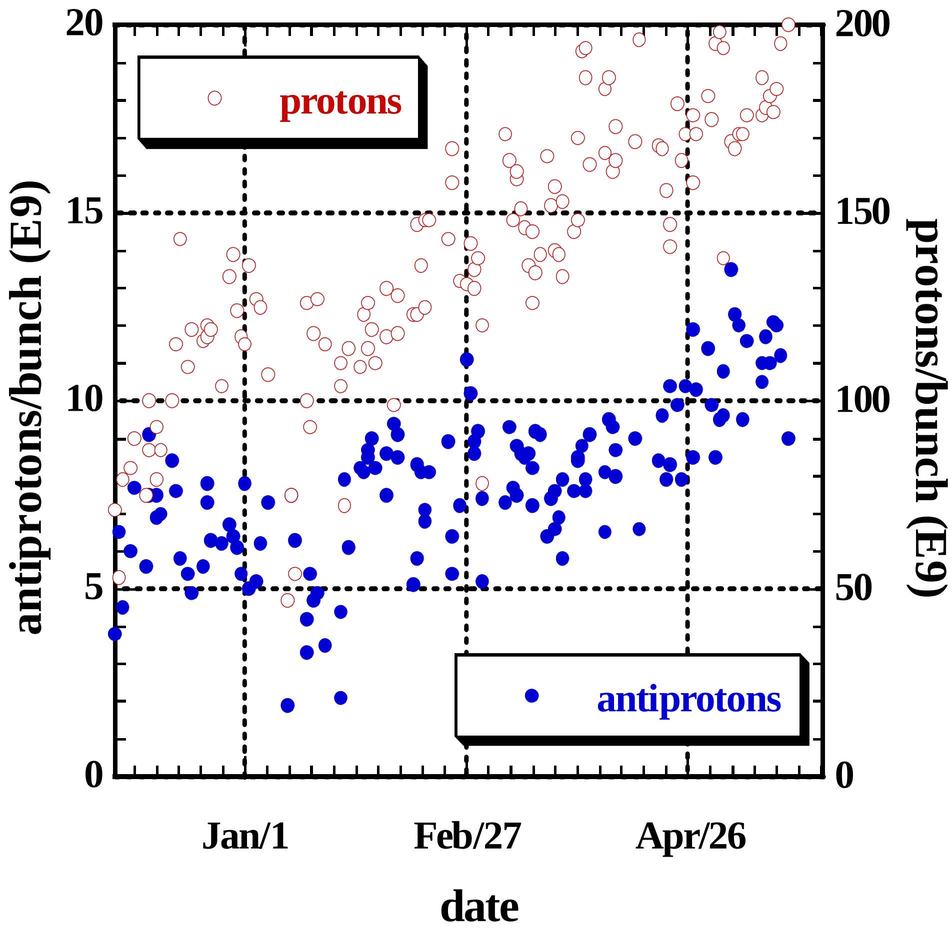


Peak Luminosity and Intensity

Peak Luminosity: 11/28/01 - 5/26/02



Intensity: 11/28/01 - 5/26/02



Status on Luminosity Parameters

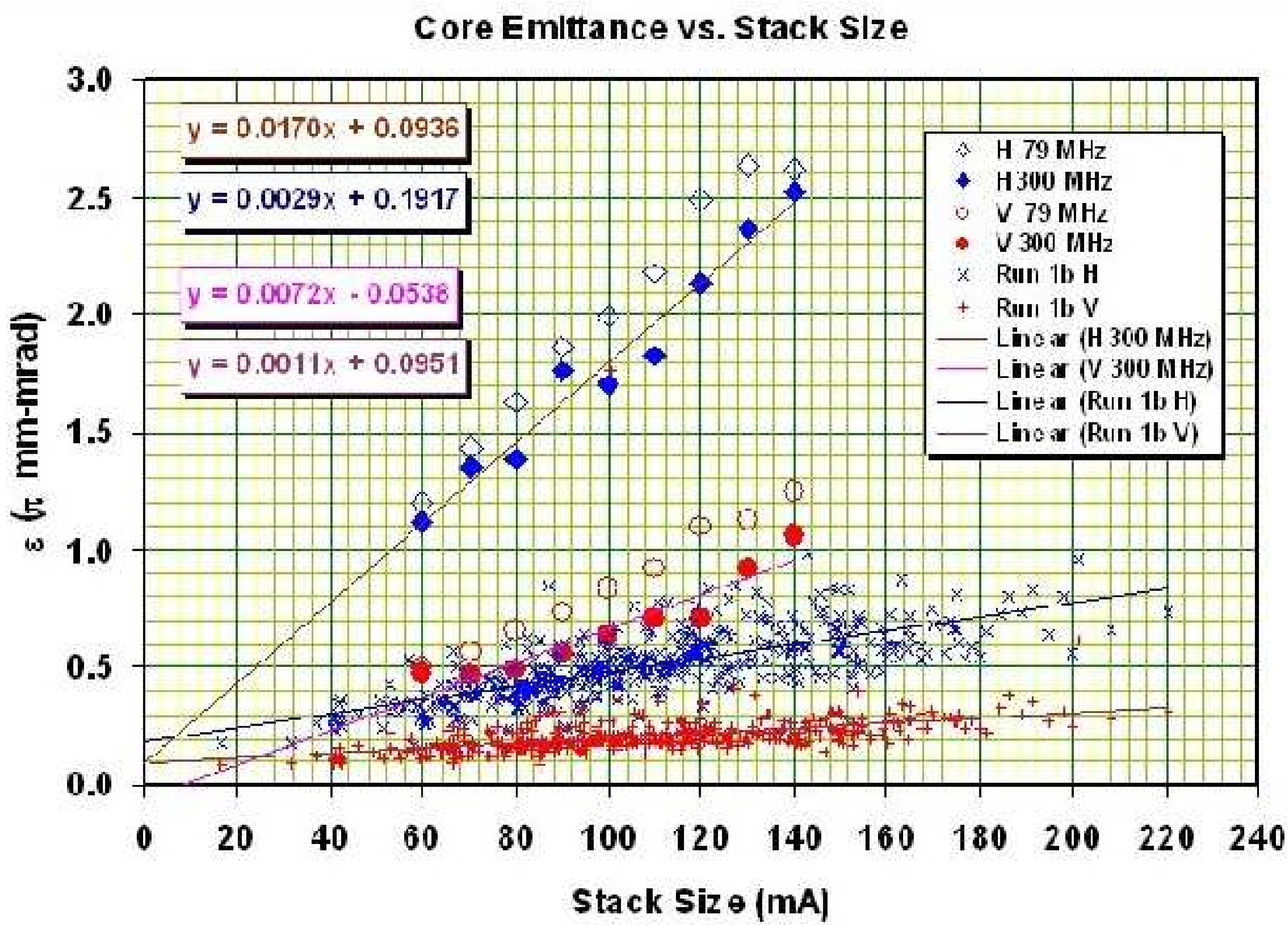
	highest luminosit y to 12/15/01	highest luminosity to date	Run IIa goals
max. antiproton stackrate (E10/hr)			18
max. antiproton stacksize (E10/hr)	115	120	165
pbar xfer eff.	.23	.37	.80
pbars/bunch at low beta (E9)	7.6	10.8	33.0
protons/bunch at low beta (E9)	115	194	270
emit. at low beta (π-mm-mrad)	16.0	16.3	17.5
peak luminosity (E31 $cm^{-2}sec^{-1}$)	0.84	1.96	8.6

The Major Problems (Run IIa)

- Transverse emittance in the Accumulator
  - lattice, cooling
- Long range beam-beam in the Tevatron
  - helix, aperture
- CDF and D0 backgrounds
  - vacuum (?), more shielding
- Everything else
  - mismatch, coalescing, beam stability, lifetime….

-- Luminosity not currently limited by pbar production rate

Accumulator Transverse Emittance

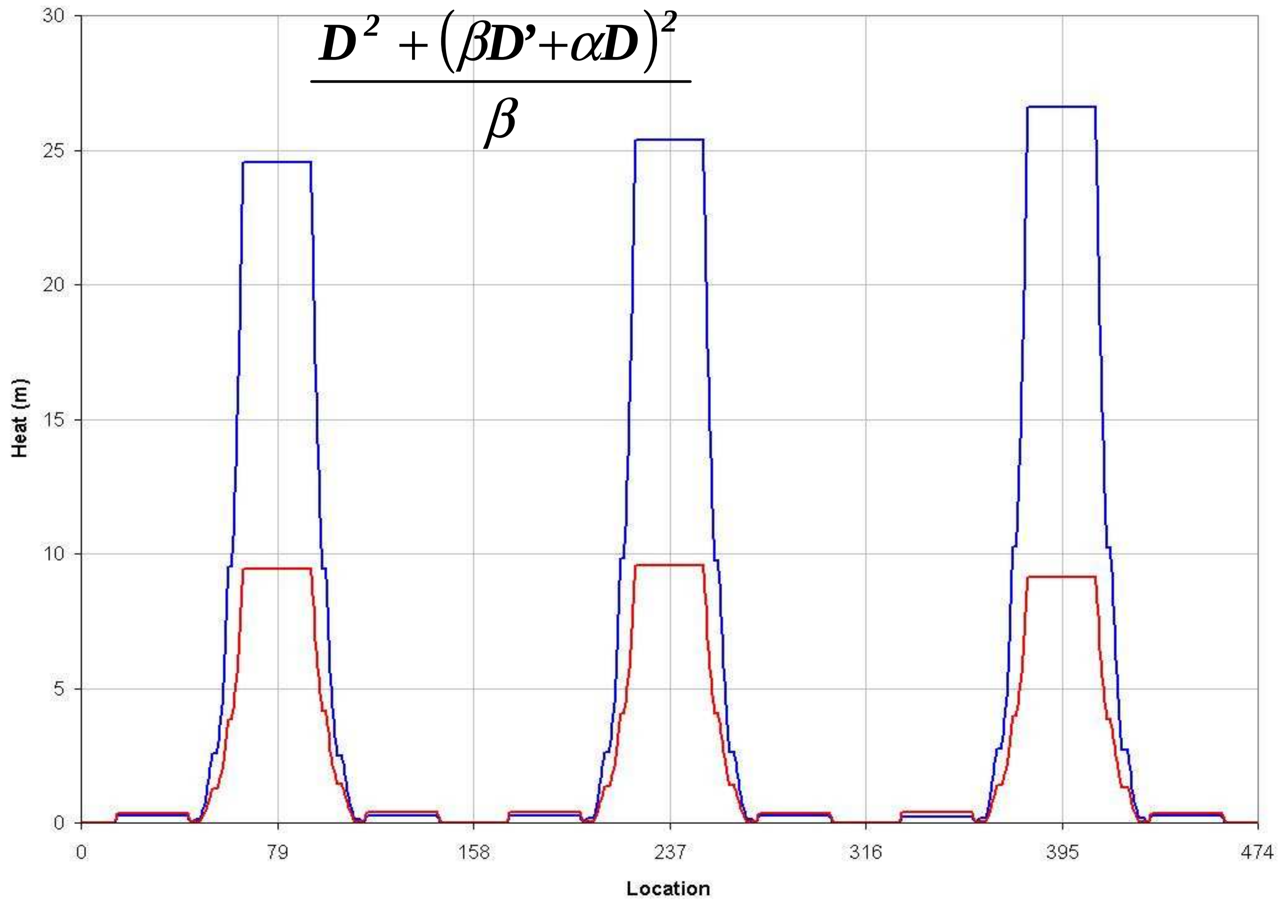


History:

Accumulator lattice was changed from Run I. <u>Motivation:</u> decrease η (slip factor) from .023 to .012 to accommodate higher bandwidth stacktail cooling system designed for higher pbar stacking rate.

Red is Run I lattice
Blue is Run II lattice

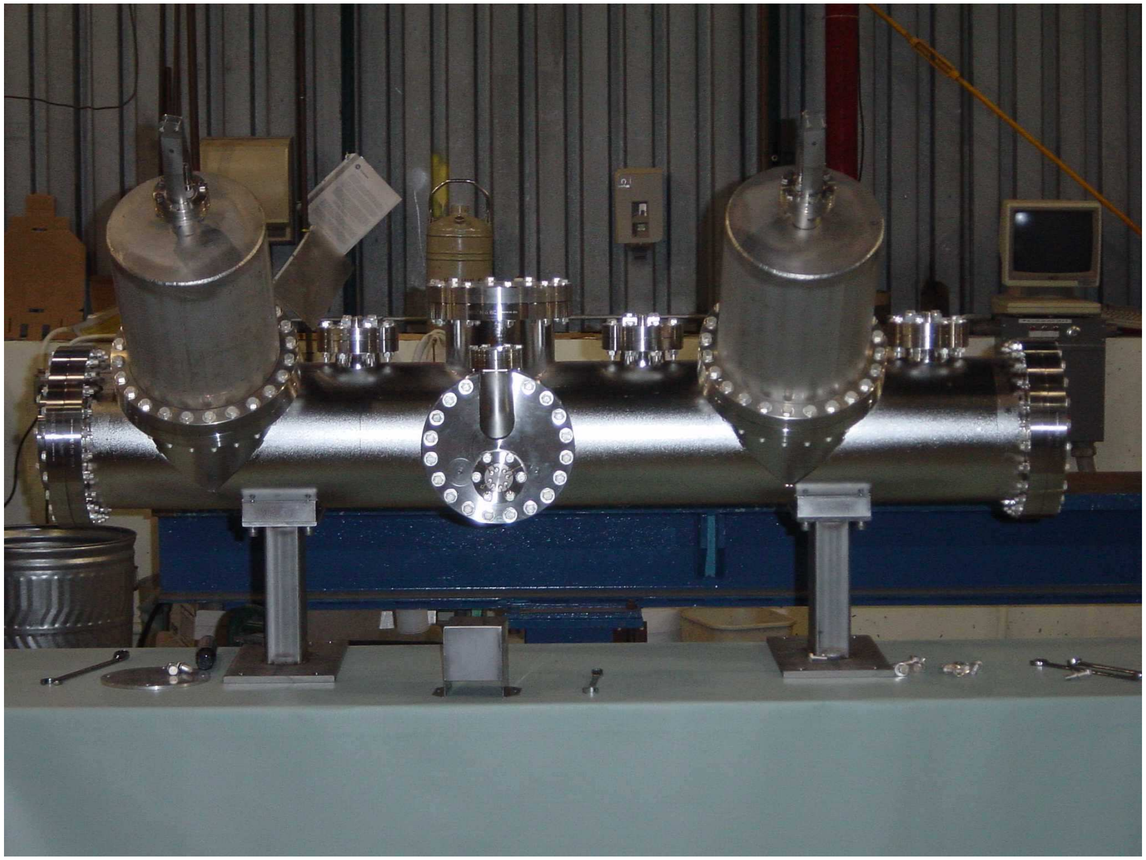
Accumulator Transverse Heating (IBS)



New "shot" lattice currently being commissioned.

Accumulator will have 2 lattices: 1 optimized for shots and 1 optimized for stacking.

Accumulator Core Cooling Upgrade



old arrays:

planar loops

2-4, 4-6 GHz

new arrays:

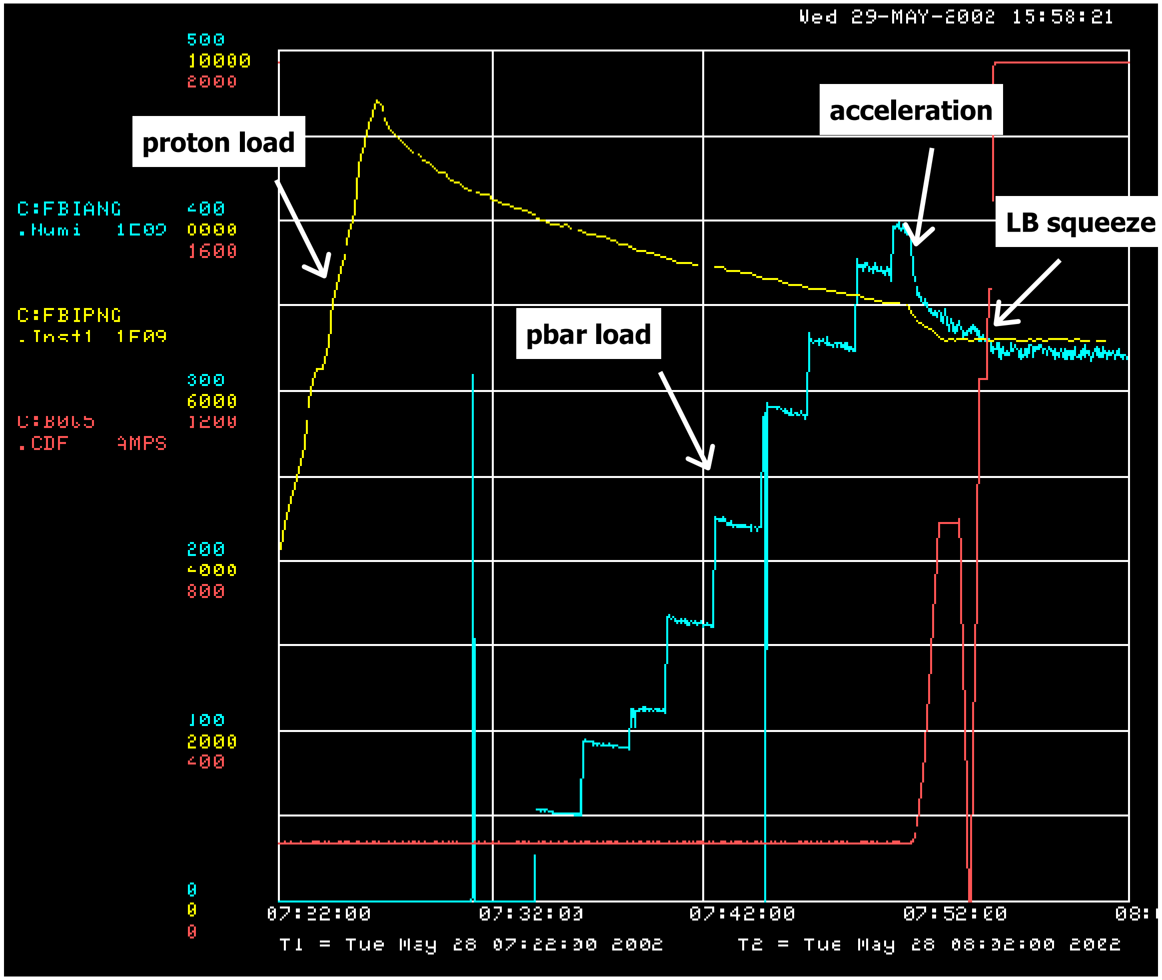
slotline array

4.4-7.6 GHz

(much better S/N)

Scheduled for installation June 3-17

Tevatron Efficiency

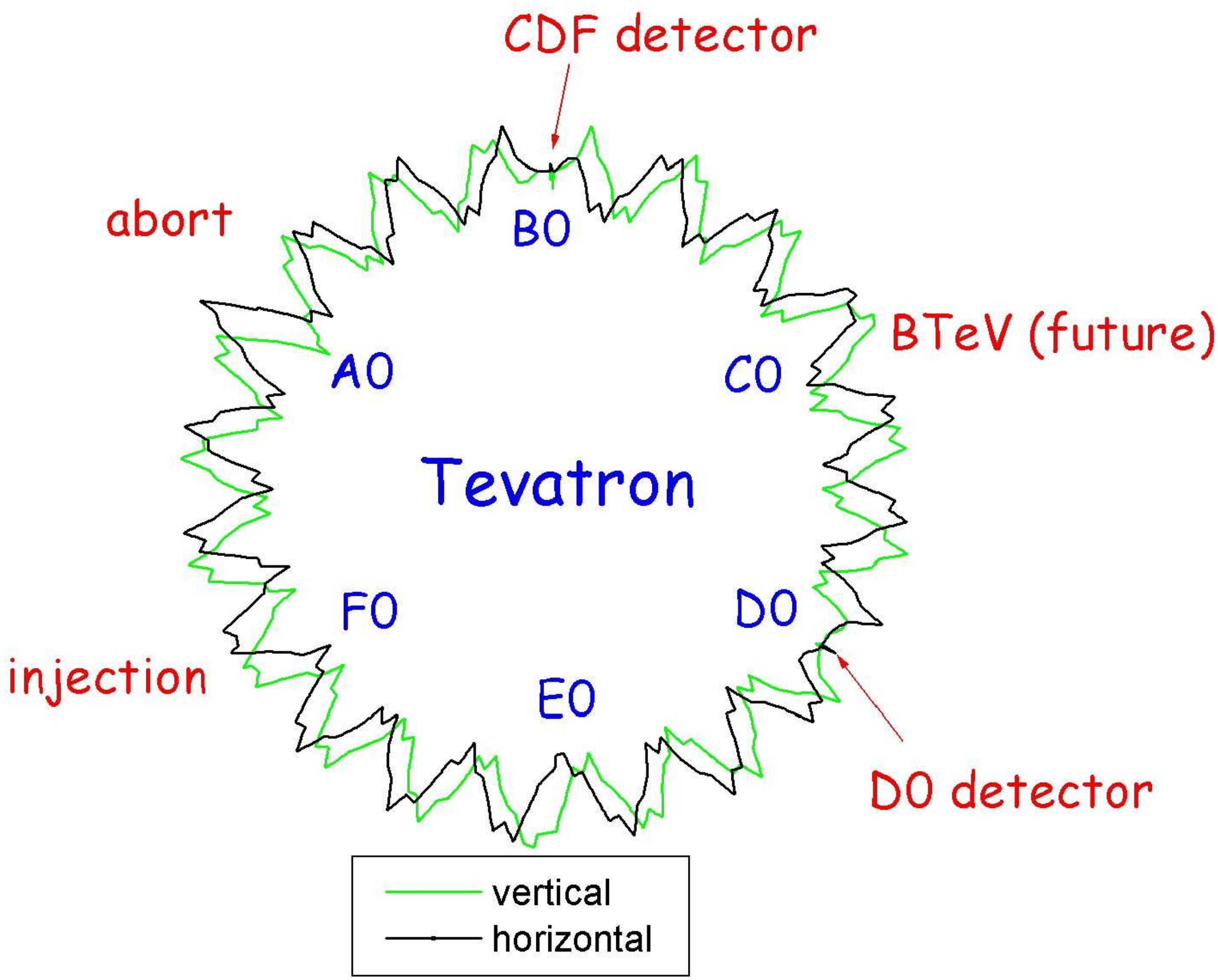


Overall pbar efficiency in the Tevatron is ~55% (xfer, 150 Gev lifetime, acceleration, LB squeeze)

Long range beam-beam: Issues and Plans

- **Head on beam-beam tuneshift @ 980 GeV is currently ~.01 with no serious problems (antiproton lifetime is good)**
- **Long range beam-beam tuneshift is ~.005 at 150 GeV; antiprotons are seriously degraded by high intensity protons**
- **Minimum beam separation on the injection helix is ~4 beam sigmas (72 crossings), ~3 sigma during transition from injection to collision helix and ~5 sigma at ciollision helix**
- **Significant improvements have been made by modifying the original helix (LB squeeze efficiency went from 75% to 97% while increasing proton intensity by 80%); helix size currently limited by physical aperture**
- **Plans:**
  - **- remove aperture limitation in Fall 2002 shutdown, opening up helix ~30%**
  - **- modify operations to decrease time spent at 150 GeV (24 min → 9 min)**
  - **- modify A0 long straight section to improve helix (Fall 2002?)**
  - **- commission octupoles to provide Landau damping for protons (some success with this already)**
  - **- commission octupole circuits as sextupole feeddowns to provide differential proton and antiproton chromaticity (under investigation)**

Beam-Bean Separation in Tevatron



Planned Antiproton Production Upgrades

- **The Run IIa goal for antiproton production is 18E10/hr. In order to support peak luminosities >1.5E32 $cm^{-2}sec^{-1}$ a higher antiproton production rate is required.**
- **The following upgrades are actively being worked on**

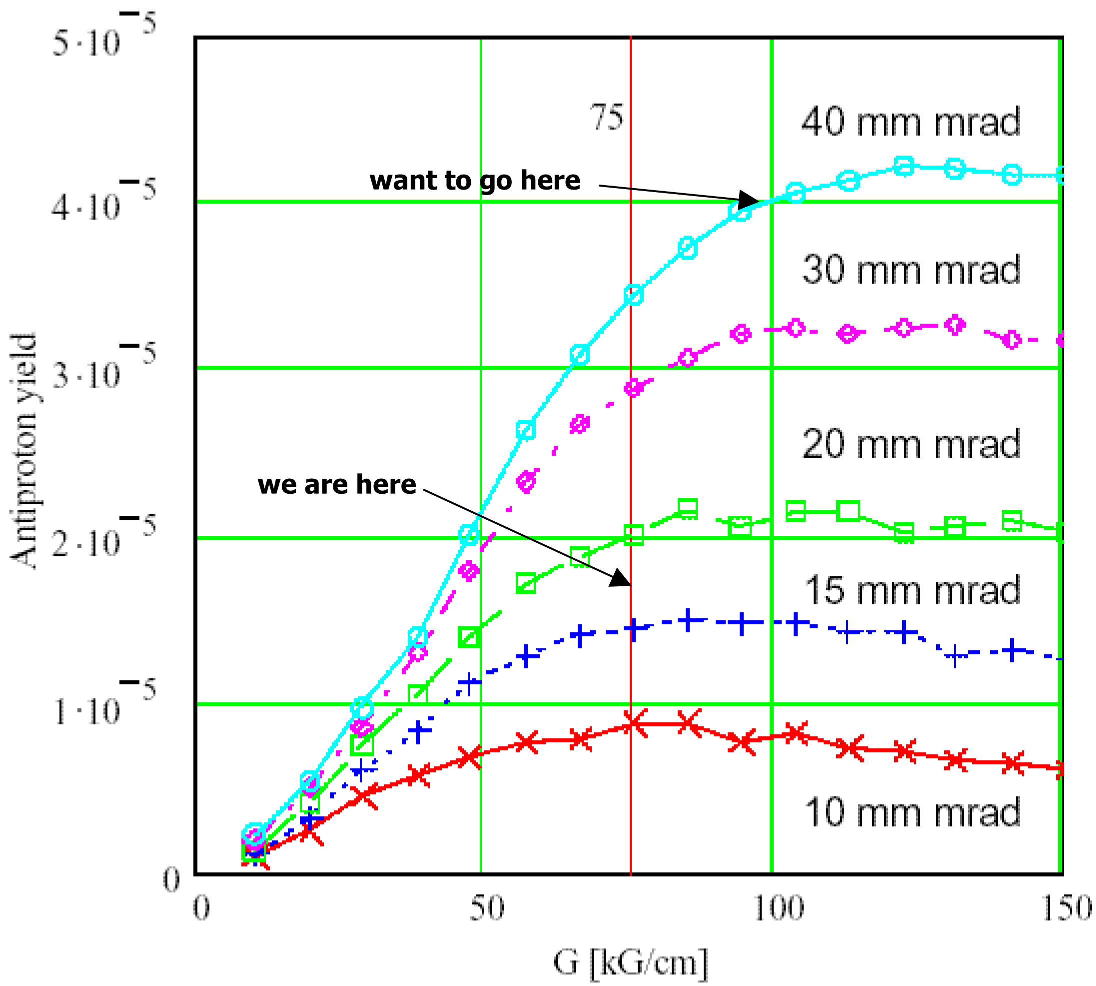
  -- "slip stacking" in the Main Injector

  -- lithium lens gradient increase

  -- 8 GeV antiproton collection aperture increase
- **These upgrades will necessitate the installation of a higher bandwidth (4-8 GHz) stacktail cooling system in the Accumulator, rapid transfers of antiprotons to the Recycler (every ~20 minutes), and the use of electron cooling in the Recycler**

Proton beam instability on the ramp

Lithium Lens and Beamline Aperture Increase



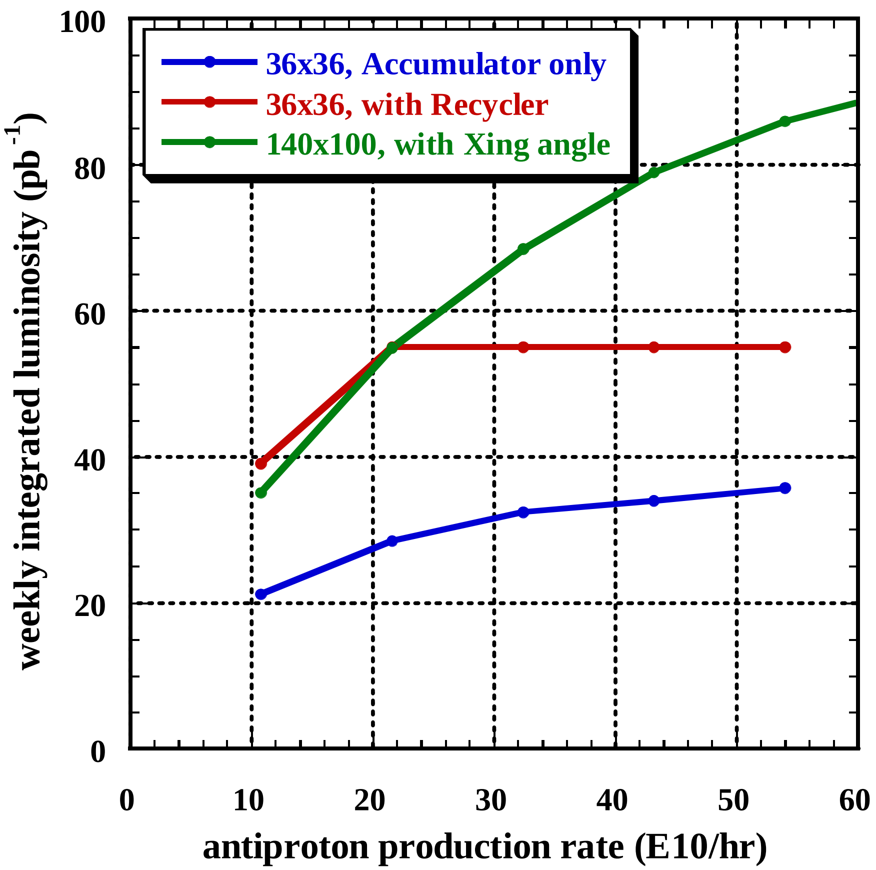
Lithium lens focuses pbars exiting from production target. Increasing gradient and downstream aperture will improve pbar collection efficiency.

Current lens gradient is 750 T/m; downstream aperture is ~15-20 π-mm-mrad.

Run II goal is 1000 T/m and 40 π-mm-mrad.

Courtesy V. Lebedev

Future Scenarios



Fine print:

- Acc. stack size limited to 250mA; stack rate is stack size dependent
- RR stack rate is not stack size dependent
- 8% loss in Acc. → RR transfers
- Intensity dependent RR → Tevatron transfer eff.
- Run II design emittances used
- Proton intensity = 270E9/bunch
- IBS only for growth rates
- Luminosity counted with ±35 cm from IR's
- 70 mb cross section for luminosity
- 3 ev-sec, 20 π-mm-mrad pbars are recycled
- IR Xing angle is ±136 μrad
- Luminosity levelled to <5 interations/Xing (48 mb inelastic cross section)
- 20% weekly downtime; 1 hour shot-setup time

Plans/Schedule

- **Now**
  - **-- commission new Accumulator lattice**
  - **-- ongoing tuning of all machines**
- **June 2002 shutdown**
  - **-- install new Accumulator core stochastic cooling tanks**
  - **-- improve Tevatron vacuum**
- **Fall 2002 shutdown**
  - **-- improve Tevatron physical aperture**
  - **-- improve Tevatron vacuum**
  - **-- improve Recycler vacuum**
  - **-- add more magnetic shielding to Recycler**
  - **2003 – integrate Recycler into Collider operations**
- **2004 – install/commission electron cooling in the Recycler**
- **???? -- 132 nsec bunch spacing**

Summary

- **Progress on Run IIa is being made but is slower than hoped for. We are factor of 2 behind schedule, and factor of 4 below design Run II luminosity**
- **Major (unexpected) problems are: long range beam-beam interaction (pbars), instabilities and detector backround (protons) – in Tevatron; instabilities and longitudinal and transverse emittance blow-up, multibunch coalescing – in Main Injector; pbar emittances – in Antiproton Accumulator.**
- **Run II is proving to be difficult, but we understand (most of) the problems, know how to fix them and are doing that.**
- **Progress is being made on commissioning the Recycler, which is required to attain luminosities above ~1E32cm^{-2}sec^{-1}**