Run II PMG

Dave McGinnis

April 15, 2004

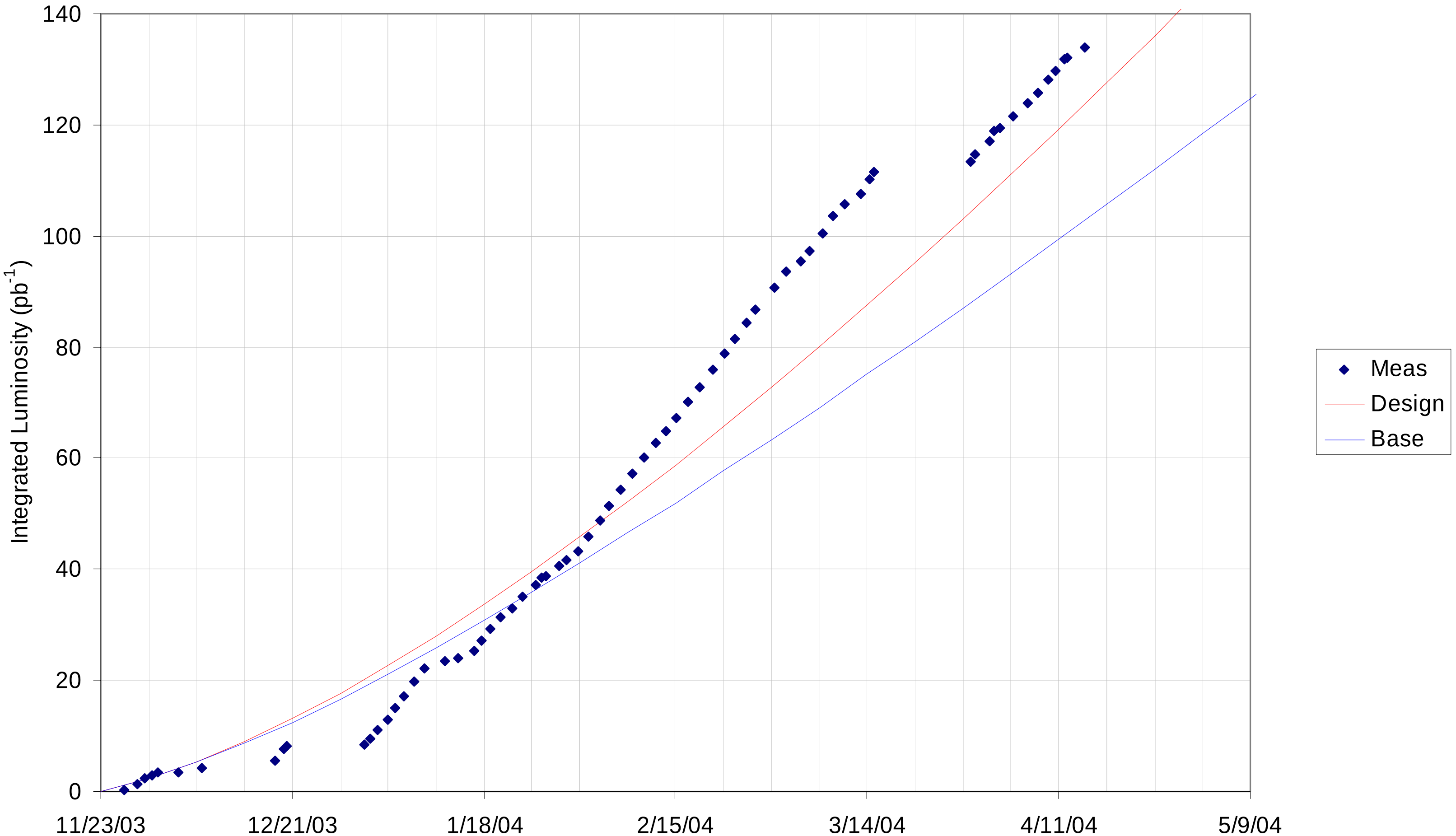
Summary of Shutdown Activities

- Booster
  - 9 vertical girder moves
  - Primary collimator foils changed
  - Alignment of 4 cavities
  - Switched to new vacuum controls
- Main Injector
  - P1 Quad roll
  - NUMI Installation
  - Partial cable pull for Slip-Stacking
  - Re-bussed MI52 Lambertson leads for Recycler shielding
- Pbar
  - Installed Debuncher optical notch filters
  - Installed different Accumulator core equalizers
  - Retrofitted old Debuncher Quad stands
  - Re-enabled Debuncher Quad shunts
  - Finished Survey of AP2
  - Began engineering prep work for next shutdown

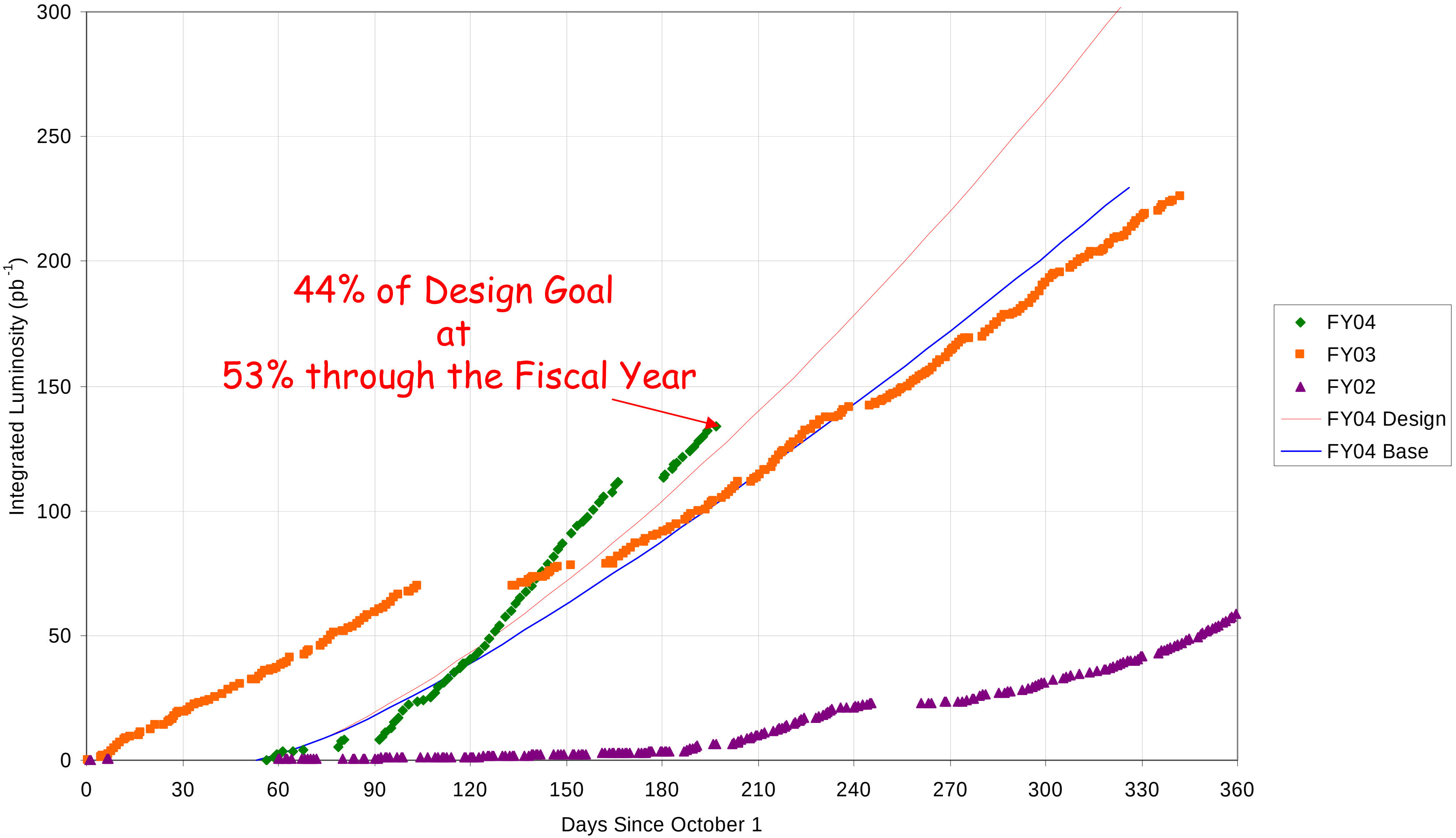
Summary of Shutdown Activities

- TEV
  - Vacuum fix of A44
    - Replaced dipole, quad, and interface
  - P1 Quad roll
  - Alignment of low-beta quads at CDF
  - Unroll of 41 dipoles
    - Thanks to CDF and D0 experimenters for their help!
  - Setup for Synch-light abort gap monitor
- Recycler
  - Cabled remote firing of TSP's for 618-620
  - Changed reference for ramp corrector cards
  - Repaired bad BPM's
  - Calibrated toriods
  - Installed sudden beam loss monitor
  - Survey work for preparing MI30 electron cooling installation

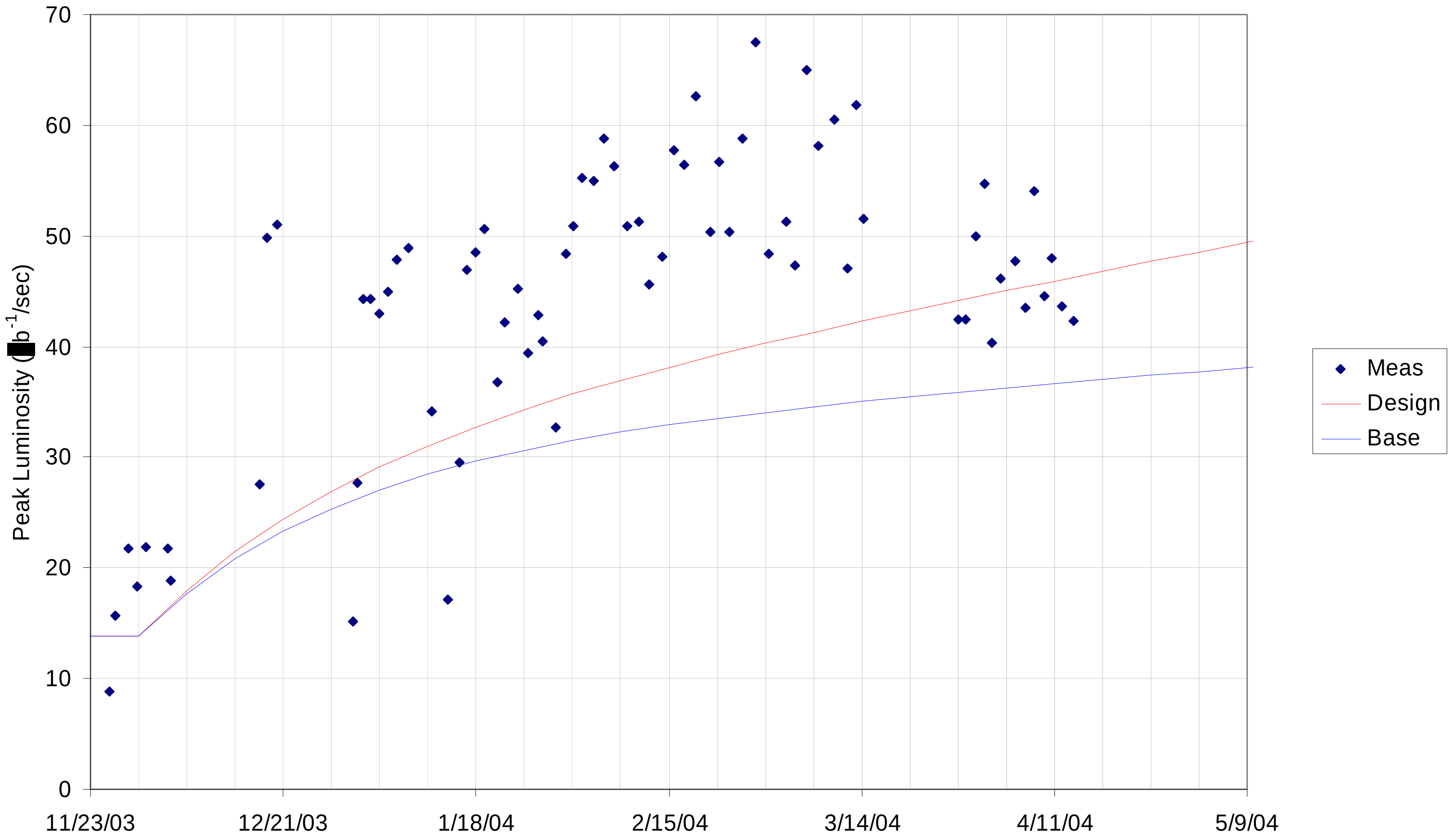
FY04 Integrated Luminosity



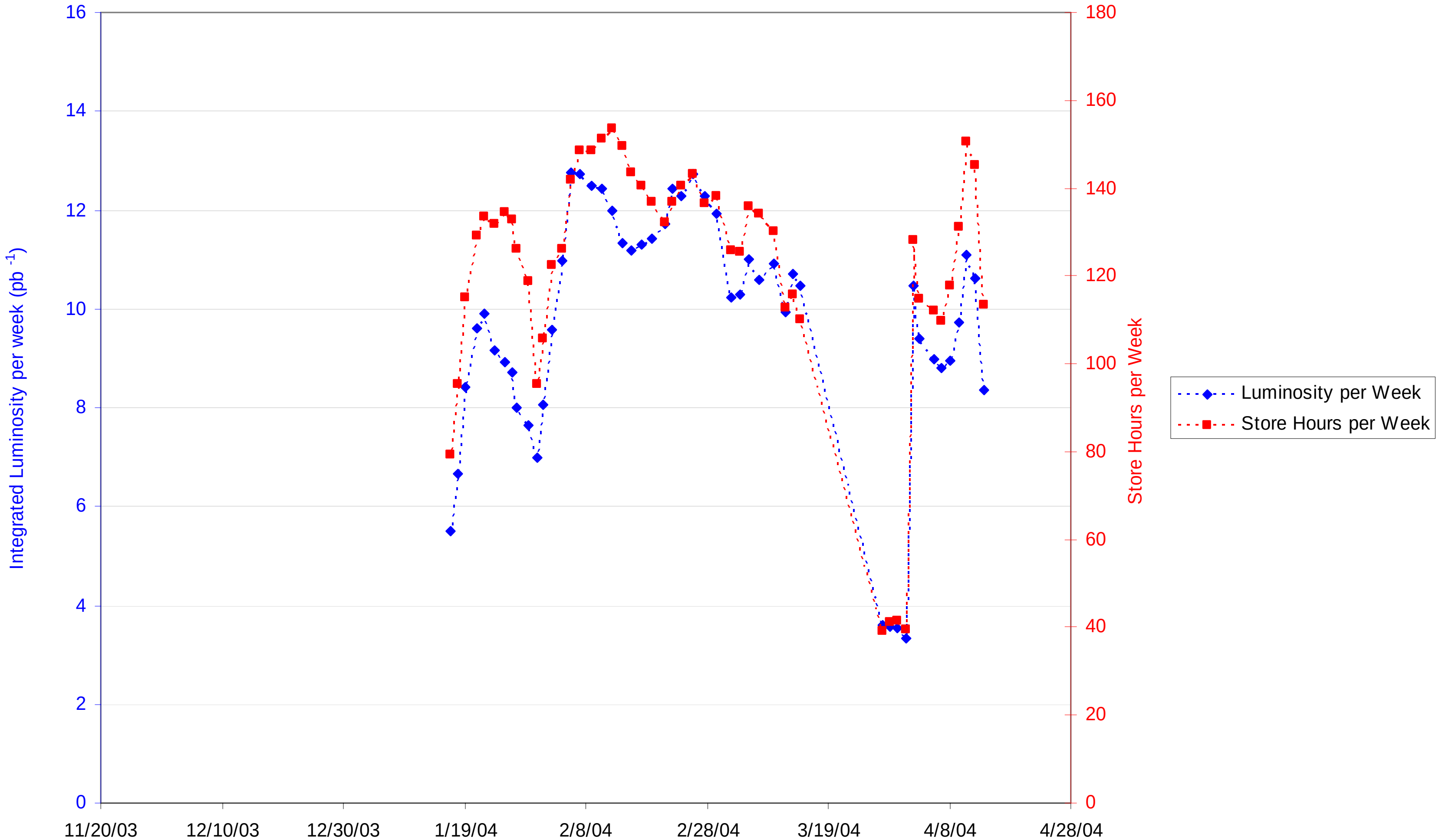
Integrated Luminosity



FY04 Peak Luminosity

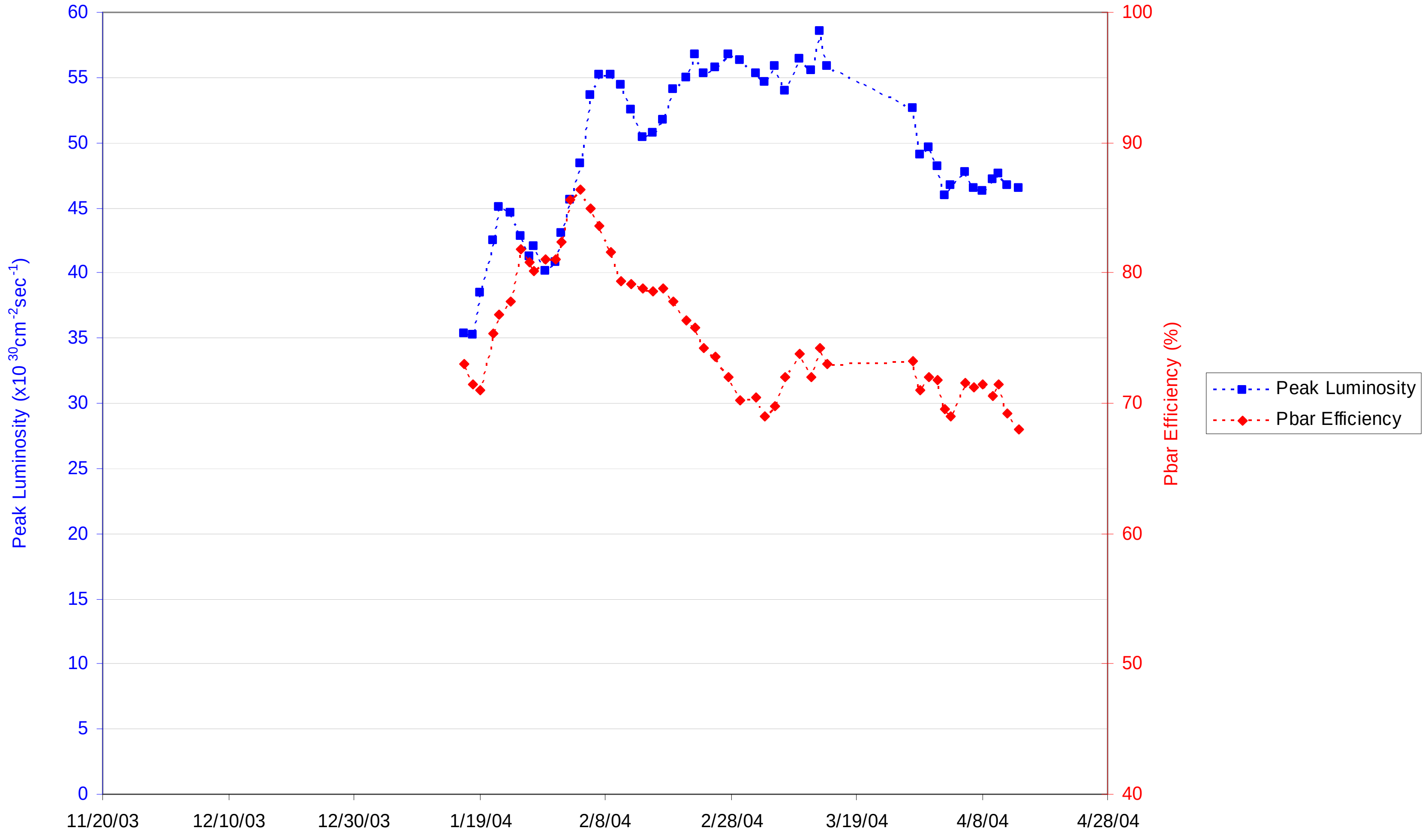


Integrated Luminosity and Store Hours per Week



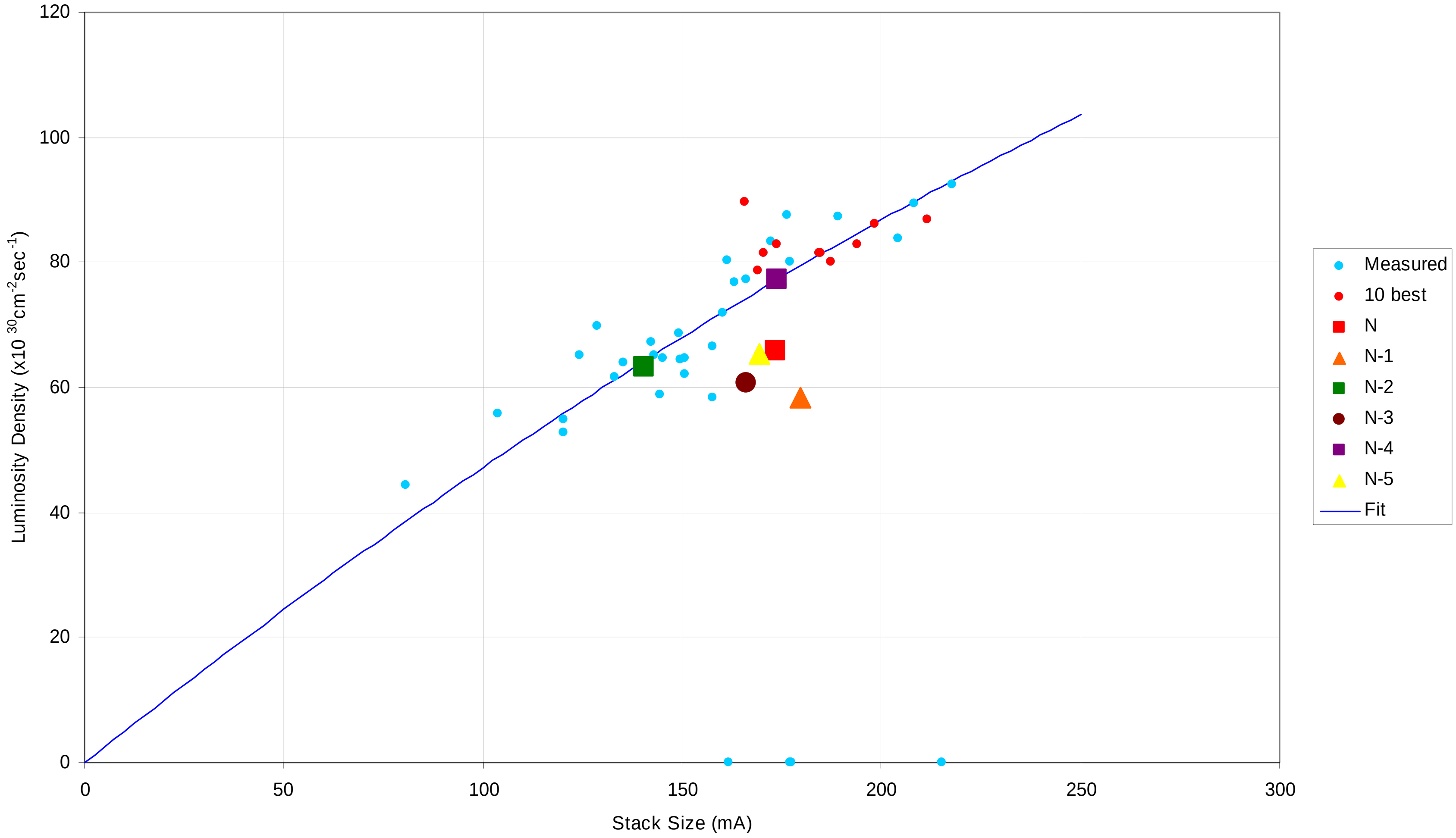
5 Store Running Average

Peak Luminosity and Pbar Efficiency

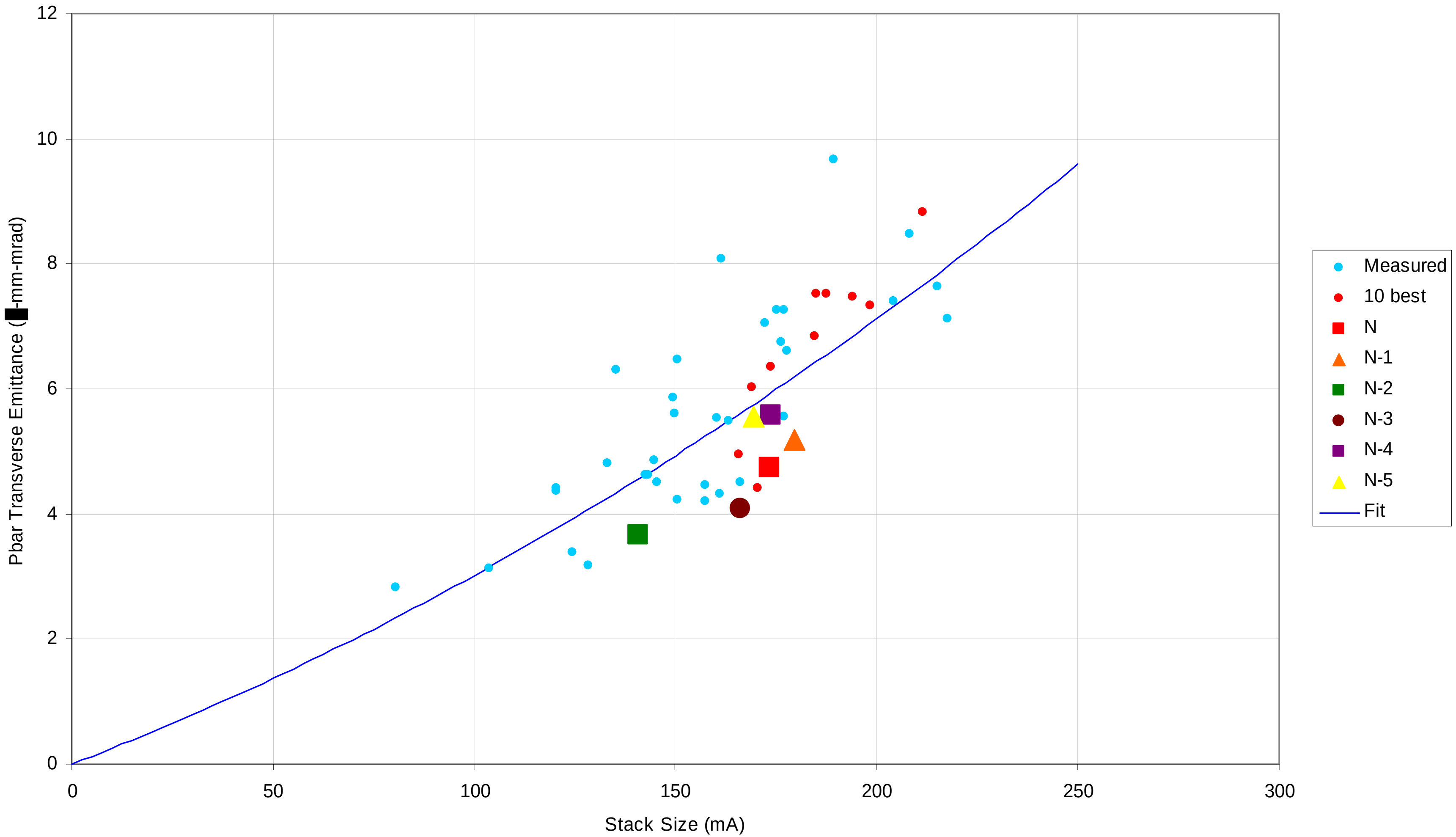


5 Store Running Average

Stack Size Potential



Accumulator Transverse Emittance



Data Summary Table

				Store Parameters					
Parameter	Last Store	Best Store	Last 10 stores Average	Best 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
Initial Luminosity (Average)	42.3	64.9	46.5	59.6	49.9	36.1	61.9	43.3	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per Store (Averaged)	1798	3136	1729	2737	2180	1089	2000	1300	nb^{-1}
Luminosity per week (Averaged)	-	-	8.7	-	8.5	6.4	11.3	7.4	pb^{-1}
Store Length	24.1	35.8	22.6	30.0	26.9	14.9	15.0	15.0	Hours
Store Hours per week	-	-	114	-	105	88	85	84	Hours
Shot Setup Time	3.2	2.1	2.4	2.2	2.5	2.3	2.2	2.2	Hours

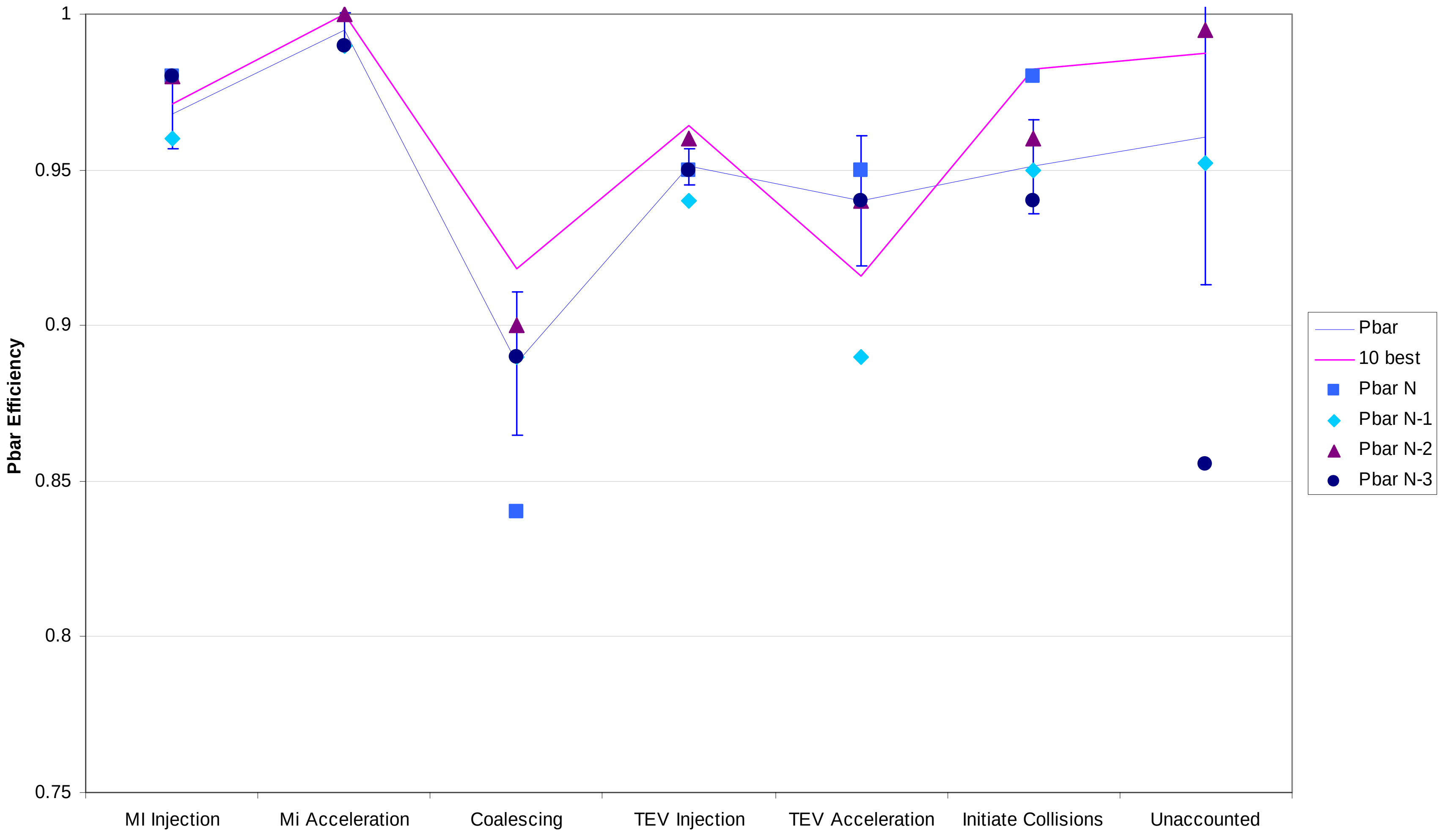
				TEVATRON Parameters					
Parameter	Last Store	Best Store	Last 10 stores Average	Best 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
Protons per bunch	220	234	232	240	232	237	260	260	$x10^{9}$
Antiprotons per bunch	26	33	27	33	29	22	31	25	$x10^{9}$
Proton Efficiency to Low Beta	60	75	70	80	78	58	-	-	%
Pbar Transfer efficiency to Low Beta	64	82	70	77	74	63	80	77	%
HourGlass Factor	0.71	0.70	0.71	0.71	0.71	0.71	0.65	0.65	
Initial Luminosity Lifetime	8.3	7.0	7.6	8.1	8.1	9.5	8.3	7.0	hours
Asymptotic Luminosity Lifetime	20.5	22.4	23.0	25.0	24.5	25.1	25.0	25.0	hours
Effective Emittance	20.9	18.3	20.6	20.3	20.2	21.9	21.0	23.0	π-mm-mrad

				Antiproton Parameters					
Parameter	Last Store	Best Store	Last 10 stores Average	Best 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
Zero Stack Stack Rate	11.6	10.7	10.9	11.8	11.2	11.5	18.0	13.7	$x10^{10}$/hour
Normalized Zero Stack Stack Rate	2.4	2.0	2.4	2.3	2.2	2.3	3.6	2.7	$x10^{-2}$/hour
Average Stacking Rate	4.3	6.0	5.5	5.7	5.7	7.1	9.3	7.6	$x10^{10}$/hour
Stacking Time Line Factor	92	82	87	81	84	88	75	75	%
Stack Size at Zero Stack Rate	228	324	262	288	280	300	300	300	$x10^{10}$
Protons on Target	4.9	5.3	4.7	5.2	5.0	5.0	5.0	5.0	$x10^{12}$
Start Stack	173	166	163	184	164	144	155	130	$x10^{10}$
End Stack	25	19	22	28	24	16	15	15	$x10^{10}$
Unstacked Pbars	148	146	141	156	140	128	140	115	$x10^{10}$

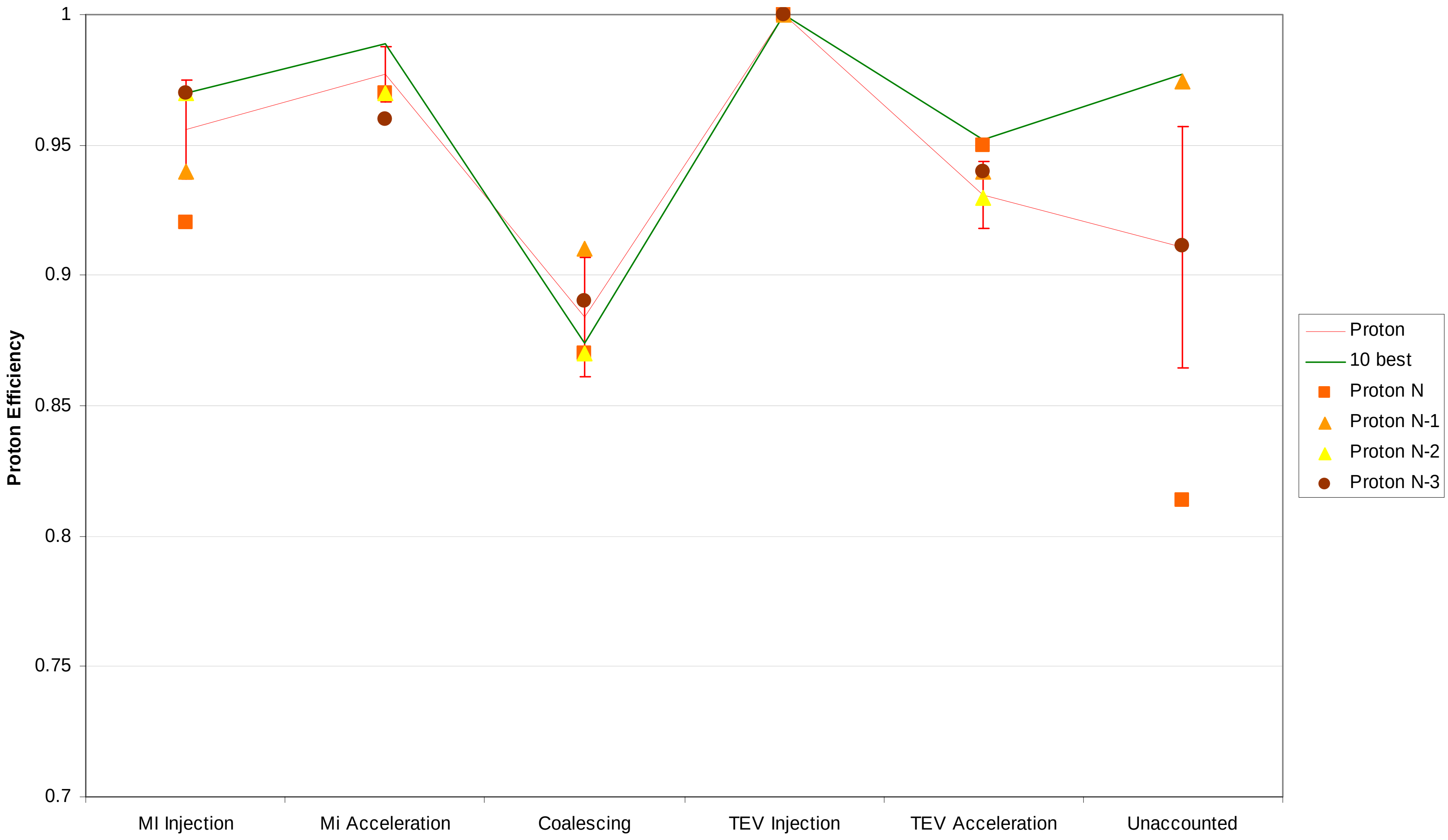
Luminosity Performance w.r.t. 10 Best Stores

- Store Length down by 25%
- Unstacked Pbars down by 10%
- Protons per bunch down by 3%
  - Proton transfer efficiency down by 12%
    - Main Injector Injection down by 2%
    - Acceleration down by 2%
    - Lifetime down by 6%
- Pbar Transfer efficiency down by 9%
  - Coalescing down by 3%
  - Low beta squeeze down by 3%
  - Lifetime down by 3%
- Peak Luminosity down by 22%

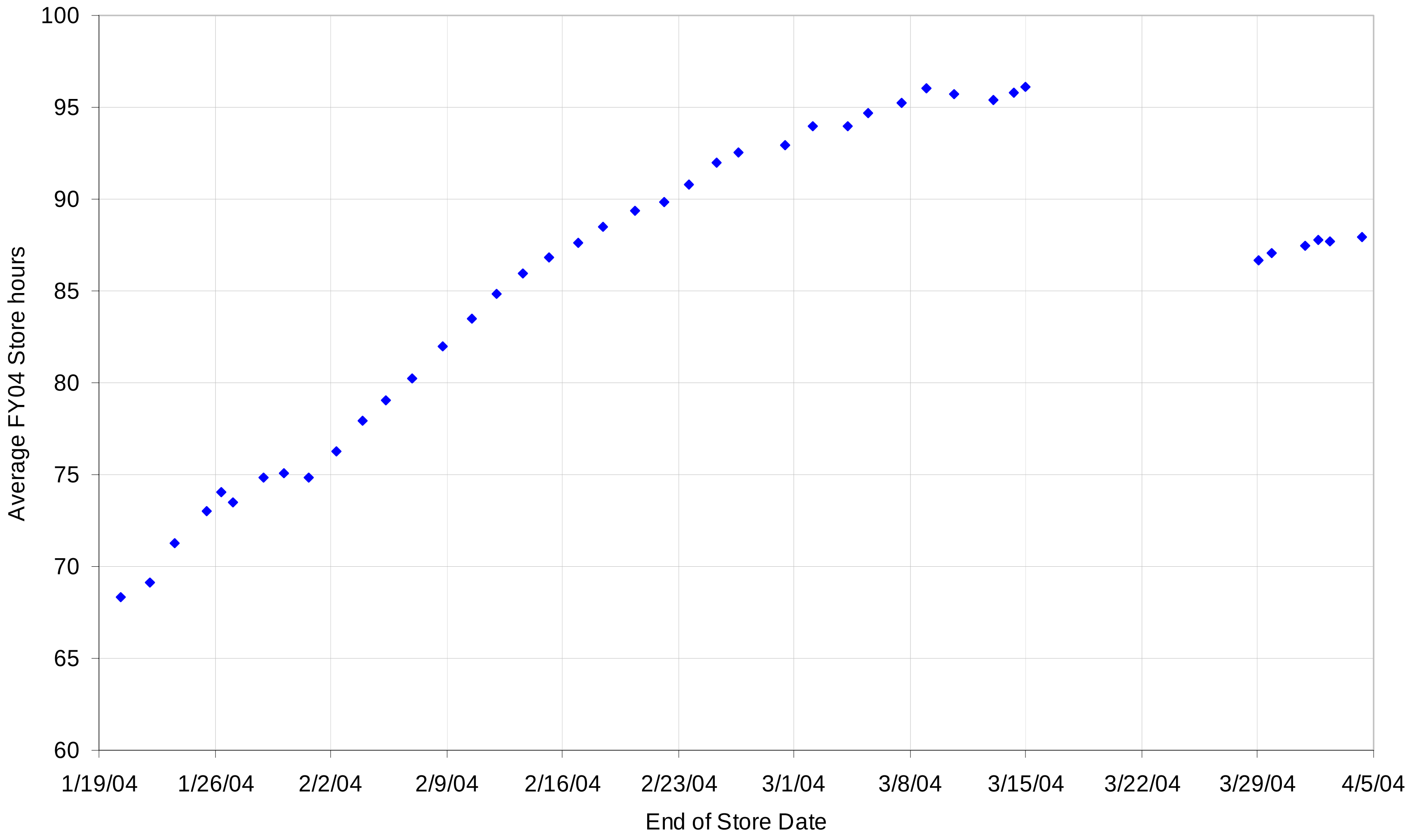
Pbar Efficiency



Proton Efficiency



FY04 Average Store Hours per Week



Main Injector Studies

Date	Duration (Hr)	Description
3/22/2004	8.0	MI -8 study
3/22/2004	8.0	NuMI and Stacking
3/22/2004	8.0	Slip stacking
3/22/2004	12.0	2.5 MHz acceleration
3/22/2004	8.0	P1 line optics and dispersion measurements
3/29/2004	4.0	Slip stacking
3/29/2004	8.0	2.5 MHz acceleration
3/29/2004	4.0	NuMI
3/29/2004	2.0	Barrier bucket study
	18.0	Sum for Week
	-	Sum for Year
	-	Average Per Week

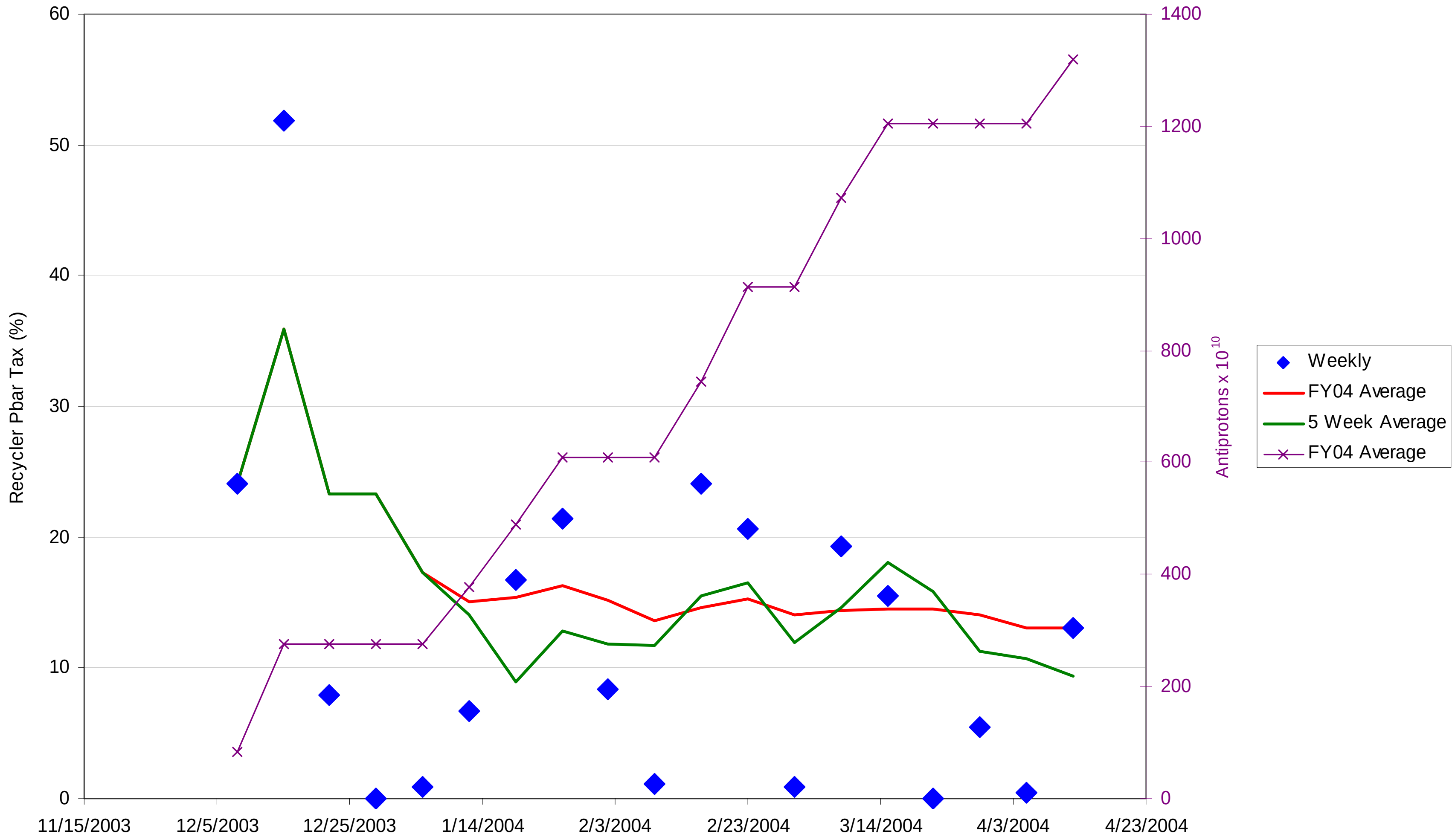
Pbar Studies

Date	Duration (Hr)	Description
3/14/2004	2.5	Accumulator and debuncher admittance measurements
3/21/2004	3.5	Beamline tune-up
3/21/2004	5.0	Debuncher momentum cooling phasing
3/22/2004	3.5	Beamline lattice measurements, improvement and tune-up
3/22/2004	4.0	Reverse protons, admittance of both rings
3/22/2004	3.0	Access to work on Debuncher momentum cooling
3/22/2004	7.0	Debuncher momentum cooling phasing
3/23/2004	9.0	Reverse protons, Debuncher orbits and bumps
3/23/2004	4.0	Reverse protons, AP-2 positions, Accumulator aperture and tunes across aperture
3/23/2004	2.0	Core cooling phasing
3/24/2004	4.5	Test shot setup and core cooling phasing on shot lattice
3/24/2004	3.0	AP-2 quad centering and momentum slicing
3/25/2004	3.0	AP-1 120 GeV optics, minimize spot size
3/25/2004	3.0	Shots to MI to test 2.5MHz transfers
3/26/2004	3.5	Debuncher momentum cooling tune-up
3/26/2004	4.0	AP-1 120 GeV optics, minimize spot size
3/29/2004	1.0	Debuncher momentum cooling characterization
3/30/2004	0.4	8 GeV lattice measurements during shot setup
3/31/2004	0.8	Debuncher momentum cooling characterization
4/8/2004	5.2	Reverse protons into Debuncher and AP-2, quad centering and AP-2 BPM's
4/12/2004	0.8	Debuncher momentum cooling characterization
	5.2	Sum for Week
	340.9	Sum for Year
	18.5	Average Per Week

TEV Studies

Date	Duration (Hr)	Description
3/25/2004	9.5	Establish circulating beam, smooth orbits through ramp and squeeze
3/25/2004	7.5	Adjust tunes through squeeze on central orbit
3/26/2004	2.0	P1 line dispersion measurements
3/26/2004	6.0	Parsing of squeeze
3/26/2004	3.0	Adjusting coupling and tunes up ramp
3/26/2004	8.0	Smooth tunes on proton helix, equalize tunes and coupling on both helixes
3/27/2004	11.5	Check proper function of longitudinal dampers and abort
3/27/2004	4.5	Adjust timing of TEL
3/27/2004	8.0	Final 36x0 to prepare for resuming collider operation
3/31/2004	2.5	Separator scans
3/31/2004	2.0	Collimator alignment
4/1/2004	2.0	Tune adjustments during low beta squeeze
4/2/2004	7.5	Orbit smoothing
4/4/2004	3.5	Tune adjustments during during the ramp to reduce proton losses
4/5/2004	2.6	Tune measurements through ramp and squeeze
4/6/2004	0.4	Lattice measurements and TBT program check-out during shot setup
4/7/2004	1.0	End of store collimator manipulation to help reduce CDF losses
4/7/2004	1.0	Between store study, optics and coupling measurements a low beta
4/9/2004	2.8	BPM upgrade measurement plus quench recovery
4/9/2004	0.3	Tune tracker test, during shot setup
4/12/2004	16.0	Maintenance, smooth orbits, correct tunes and coupling on ramp and squeeze
4/13/2004	11.0	Maintenance, adjust chromaticity on ramp, coupling on proton and pbar helices
	8.1	Sum for Week
	353.3	Sum for Year
	19.0	Average per Week

Recycler Pbar Tax



Short Term Focus

- Proton Source
  - Keep > 5.2e12 for stacking
  - 4e16/hour MiniBoone
  - Collimator Studies
  - Cogging Studiers
- Main Injector
  - Transmit 5e12/pulse to the Pbar Target
  - Demonstrate 2.5 MHz Acceleration with Pbars from the Recycler
    - If successful, use 2.5 MHz Acceleration for Shots
    - Better Coalescing Efficiency
    - Lower Longitudinal Emittance
  - COMMIT to 2.5 MHz Transfers from Accumulator for Shots
    - Better Coalescing Efficiency
    - Lower Longitudinal Emittance
    - Will be able to extract a bigger fraction of the stack
    - Calibrate MI 2.5 MHz BLT ?
  - Slip Stacking
- Pbar
  - Load in 8 GeV Optics into AP3-P1 line
  - Achieve production efficiency of 15e-6 with a 2 second rep. rate at stacks below 40 mA (ZSSR = 13.5mA/hr)
- TEV
  - Improve ramp efficiency
  - Correct low beta optics
- Recycler
  - Continue optimizing Rapid transfers with pbars
  - Support MI for 2.5 MHz acceleration with pbars

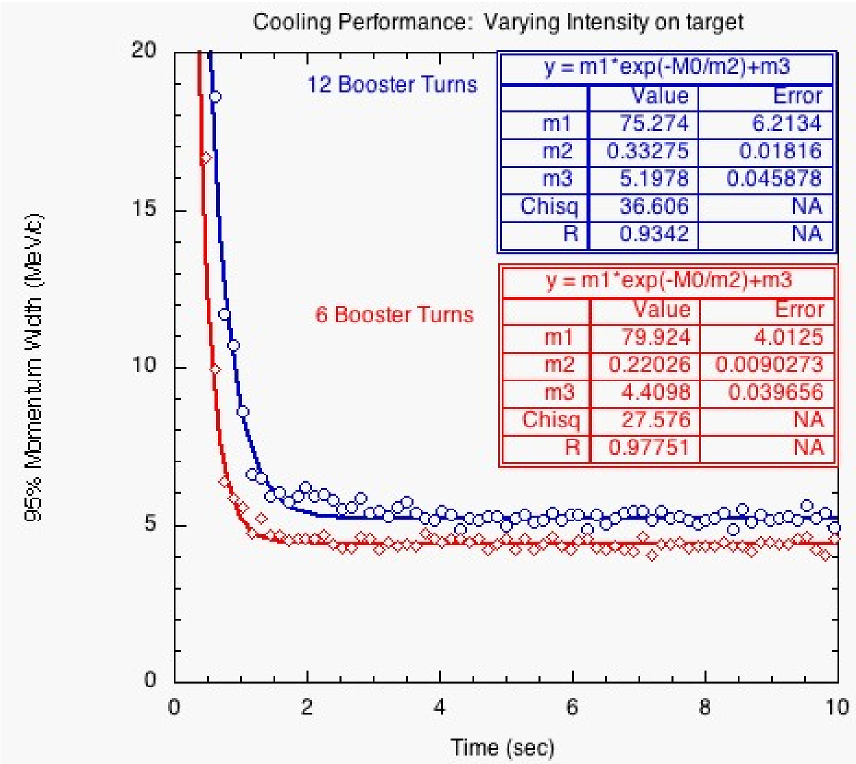
Antiproton Stacking

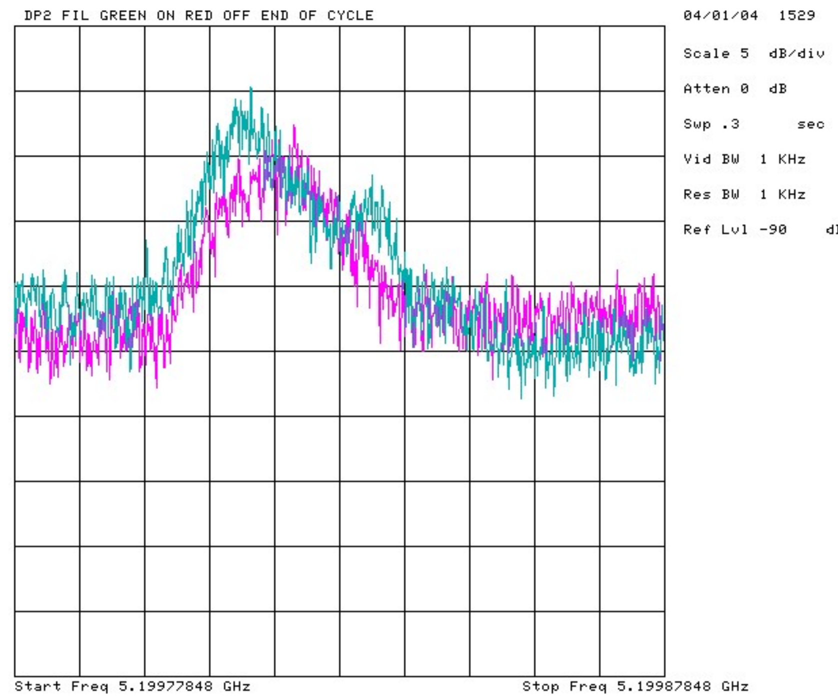
- The asymptotic momentum spread in the Debuncher was thought to be limited by dispersion in the Debuncher BAW momentum cooling filters
  - The BAW filters were replaced during the shutdown with a single optical filter which has 1/4 - 1/3 of the dispersion of the BAW filters
  - Asymptotic momentum spread was reduced by ~20%
- The limit on the momentum spread is now thought to be the result of operating at the momentum cooling system at optimum gain.
  - Should have seen this one coming

$$\frac{1}{\tau} = 2gW - g^2 WNM(\Delta p)$$

$$g_{opt} = \frac{1}{NM(\Delta p)}$$

Antiproton Stacking





$$\frac{1}{\tau} = 2gW - g^2 WNM(\Delta p)$$

$$g_{opt} = \frac{1}{NM(\Delta p)}$$

- Ways to decrease the momentum spread
  - Increase the bandwidth
    - With equalizers ~20-30%
  - Ramp the gain down during cooling
    - ~20%

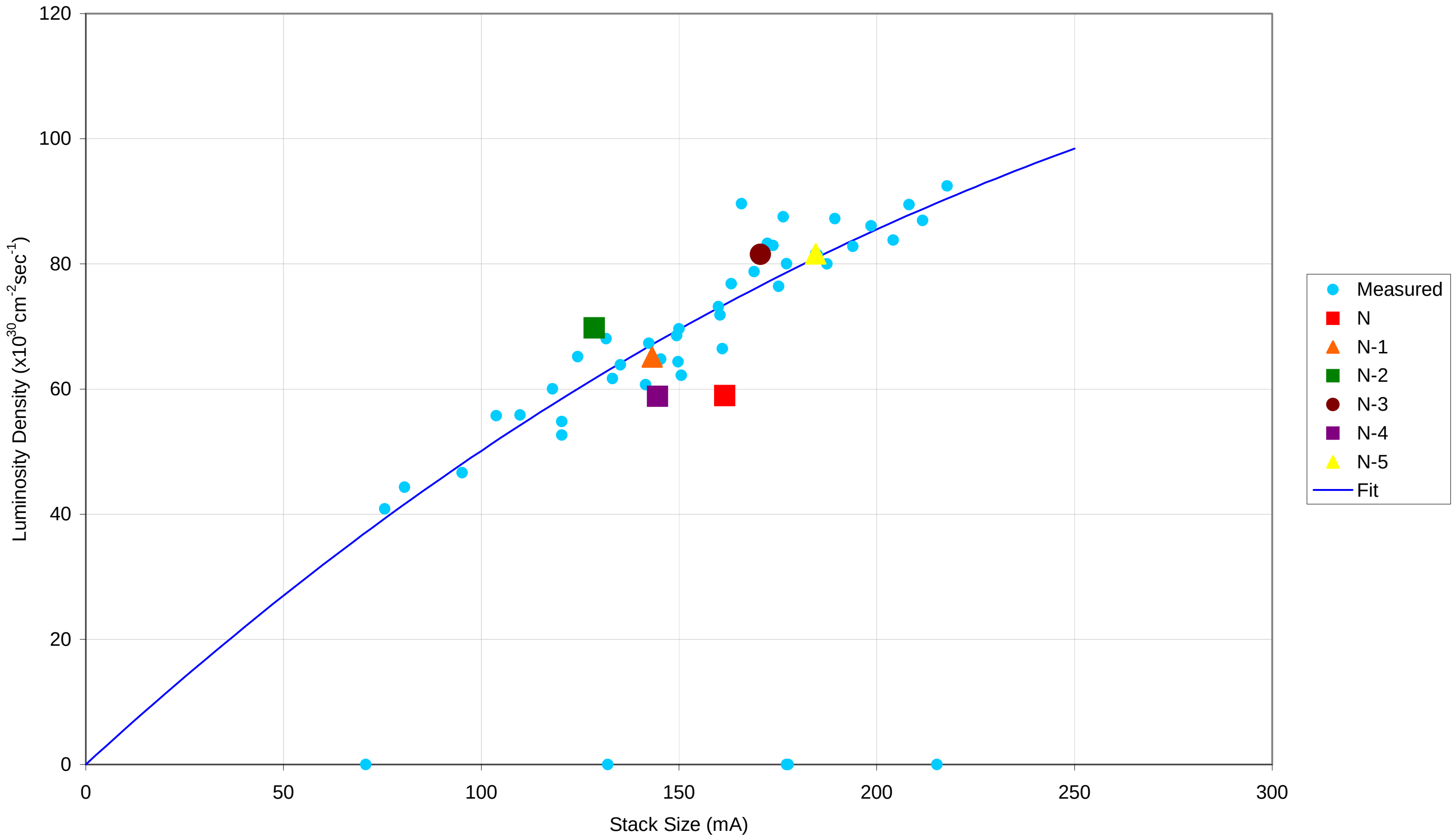
Pbar Cooling Plan Outside the Run II Upgrades

- Increase the bandwidth of the Debuncher Momentum cooling system (~20%) with equalizers (~3 months)
- Optimize gain and gain ramping in the Debuncher momentum cooling (~2 weeks)
- Investigate a static change in gamma-t in the Debuncher (~1 month)
  - Trade-off of bunch rotation bucket are vs good mixing for the accumulator
- Investigate the feasibility of ramping gamma-t in the Debuncher (~6 months)
- Implement momentum selective ARF1 curves (~1 month)
- Increase bandwidth of the Stacktail system by about 10-20% by extending bandwidth of the Stacktail notch filters (ready to go)
- Install controllable phase shifters in both legs of the Accumulator Stacktail (~1.5 months)
- Implement a phase crossover in the Stacktail system using phase shifters
- Implement 4-8 GHz momentum core cooling during stacking
  - For stacking fast at large stacks
  - Already used during shot setup

Mixed-Mode Pbar Extraction

- Extracting pbars from both the Accumulator and the Recycler for the same store i.e.
  - Twenty four bunches from the Accumulator
  - Twelve bunches from the Recycler
- Ratio $I_{Recycler}/I_{Accumulator}$ is governed by:
  - Recycler phase space density (cooling)
  - Recycler transfer time (Rapid transfers)
- Reasons
  - Push Recycler commissioning progress by plunging it into operations
  - Luminosity enhancement – larger amount of pbars for smaller emittances
    - Accumulator stack size limited to <200 mA
      - Stacking Rate
      - Transverse emittance vs Stack Size
  - Flexibility in the Run II Upgrade schedule
    - Natural merging of commissioning of electron cooling
- Obstacles
  - Injector Complex 8 GeV energy alignment
  - Accumulator non-zero intercept of longitudinal emmittance vs stack size
  - Recycler longitudinal emmitance vs stack size with stochastic cooling

Luminosity Potential



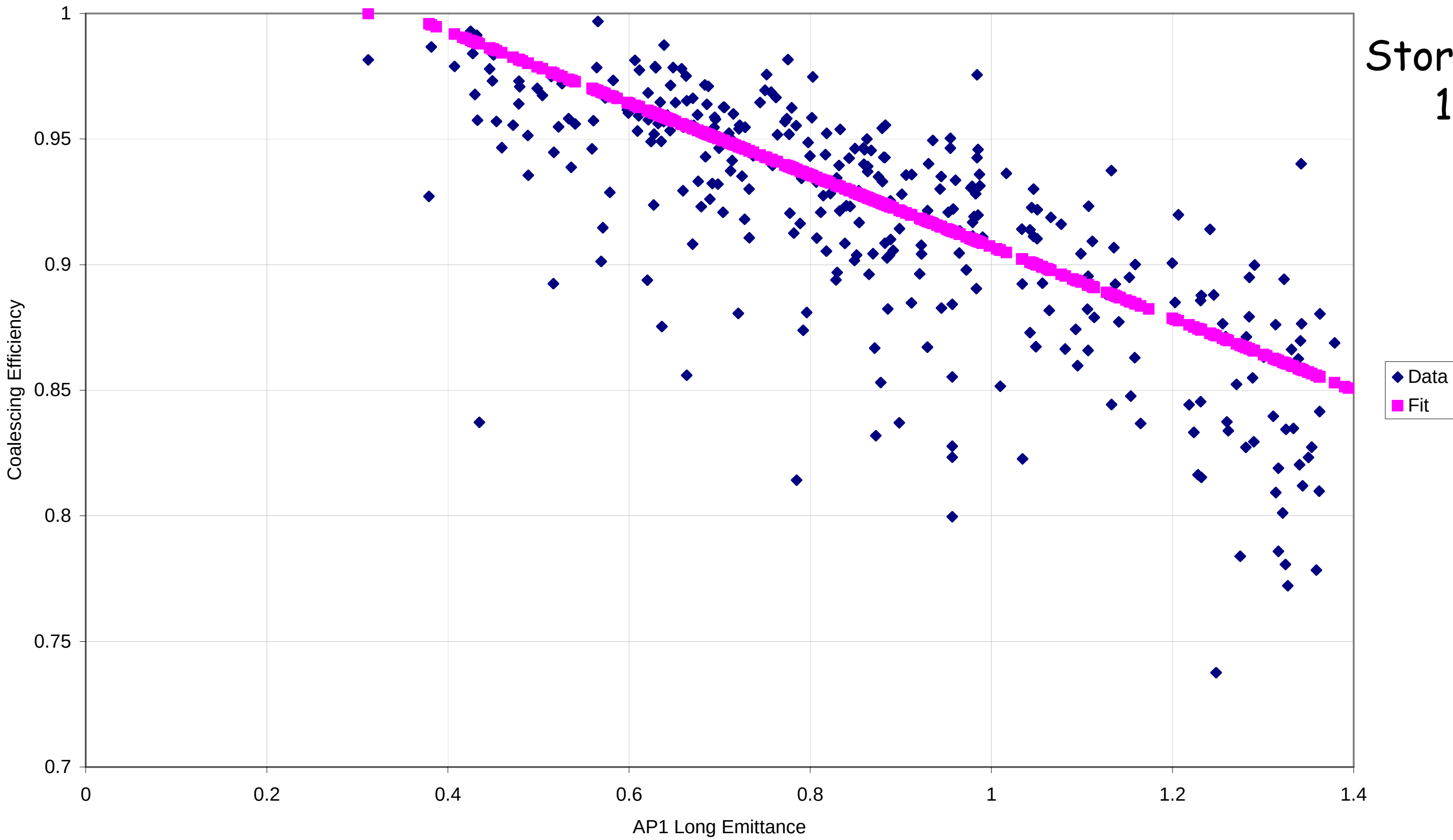
$$L := Lum_{scale} \cdot \frac{\frac{N_{proton}}{250} \cdot S \cdot Extract_{frac} \cdot eff_{coal}}{\left(PbarTranEmit + Emit_{offset}\right)}$$

$$L_{pot} := Lum_{scale} \cdot \frac{S}{\left(PbarTranEmit + Emit_{offset}\right)}$$

$$AccEmit_{offset} := 21.78$$

$$AccLum_{scale} := 12.67$$

Main Injector Antiproton Coalescing Efficiency

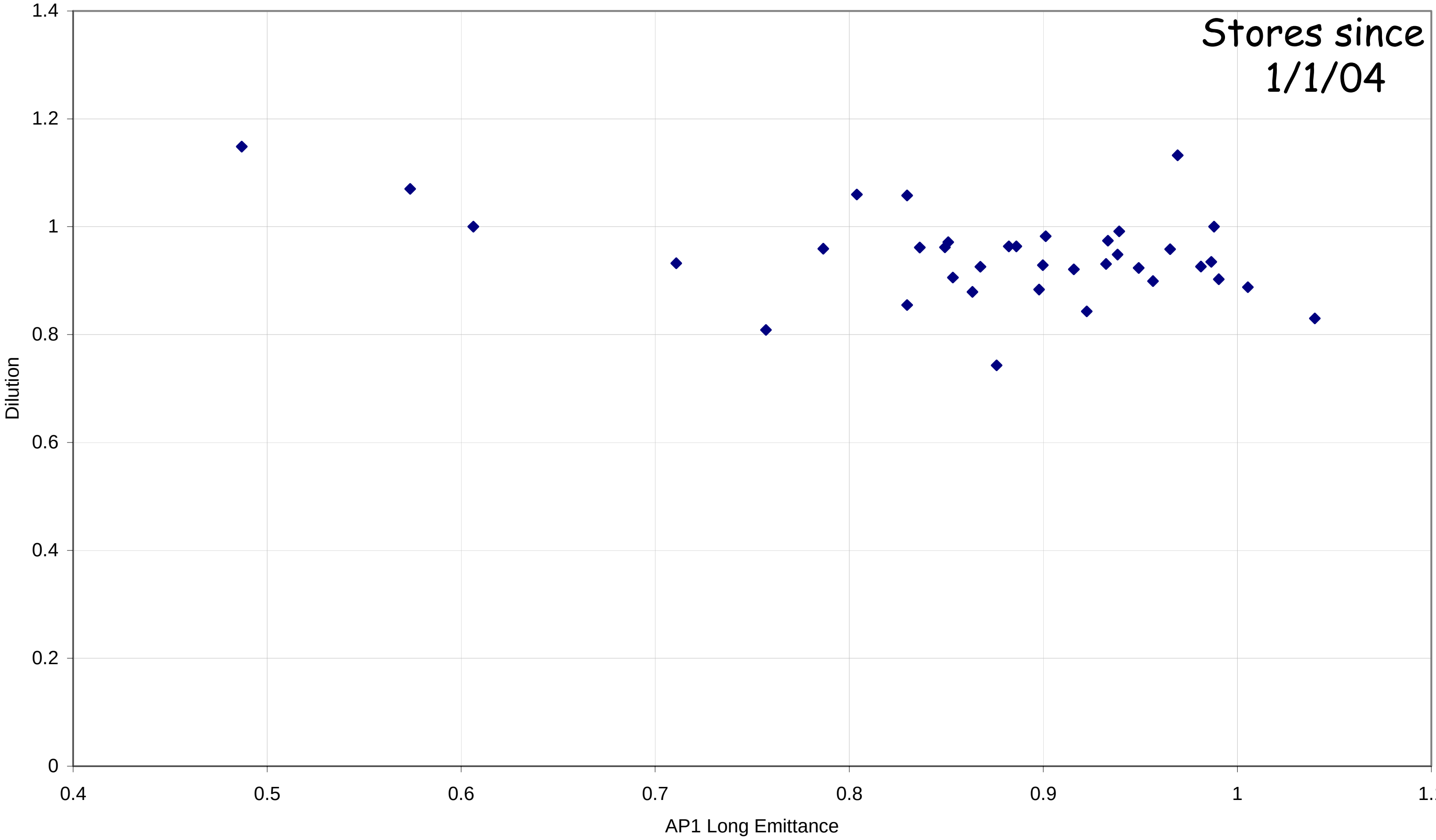


Stores since 1/1/04

$$\text{bucket\_eff}_{\text{coal}}\left(A, A_{\text{max}}, \text{Eff\_Intercept}\right) := \text{if}\left[A < A_{\text{max}}, 1, \text{Eff\_Intercept} - A \cdot \frac{(\text{Eff\_Intercept} - 1)}{A_{\text{max}}}\right]$$

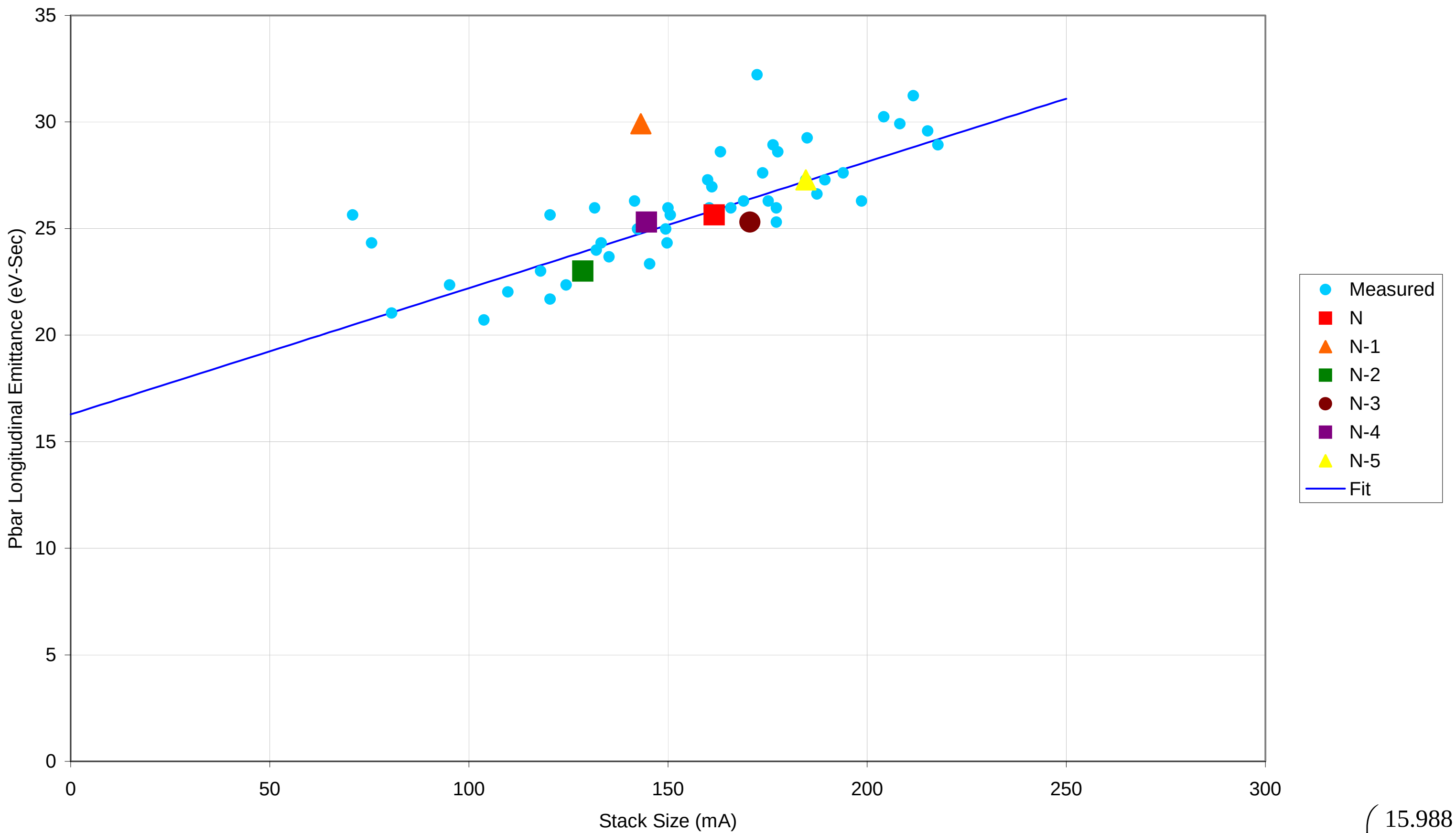
$$A_{\text{max}} := 0.35 \qquad \text{Eff\_Intercept} := 1.05$$

Accumulator Extraction Longitudinal Emittance Dilution



$$a_{i+1} \leftarrow a_i - \Delta a_i + D \cdot \Delta a_i$$

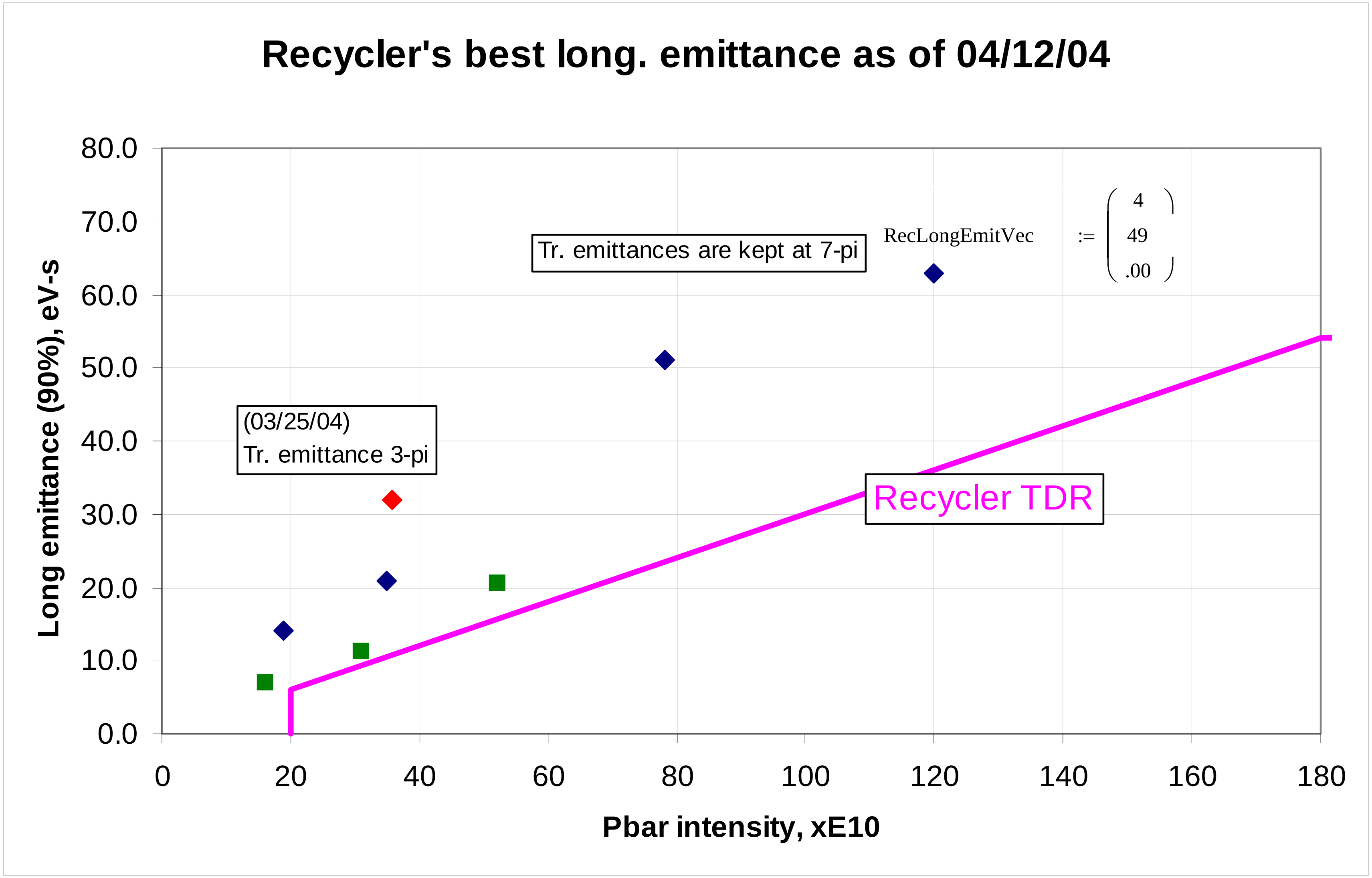
Accumulator Antiproton Longitudinal Emittance vs Stack Size



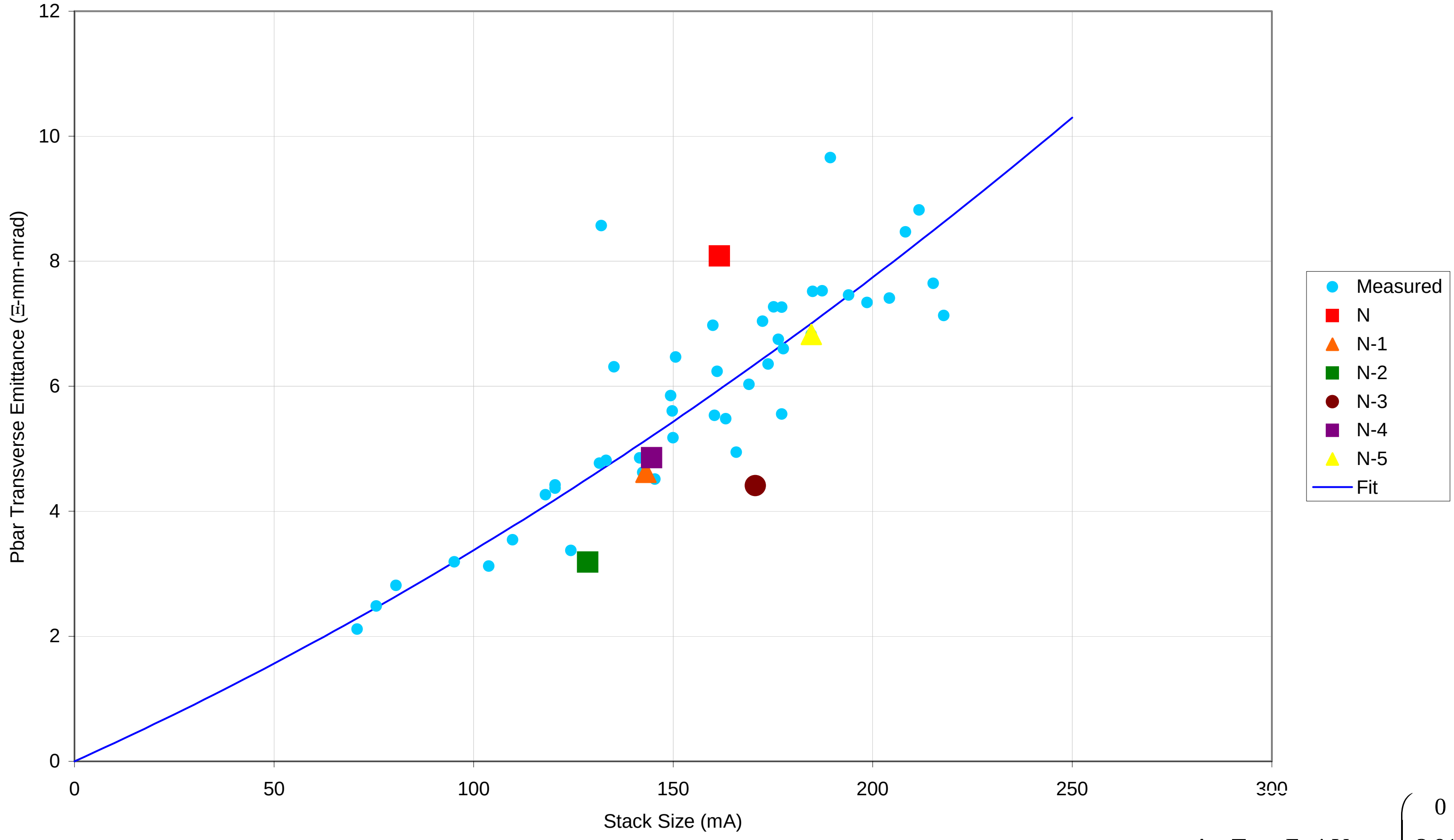
$$\text{PbarLongEmitFit}(\text{coefVec}, S) := \text{coefVec}_0 + \text{coefVec}_1 \cdot \frac{S}{100} + \text{coefVec}_2 \cdot \left(\frac{S}{100}\right)^2$$

$$\text{AccLongEmitVec} := \begin{pmatrix} 15.988 \\ 6.119 \\ .00 \end{pmatrix}$$

Recycler Longitudinal Emittance



Accumulator Antiproton Transverse Emittance vs Stack Size

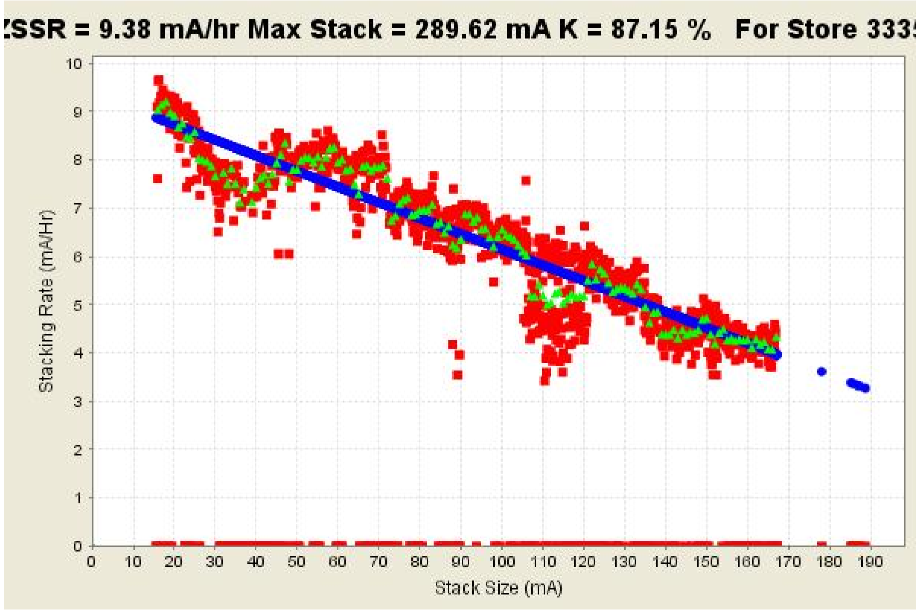


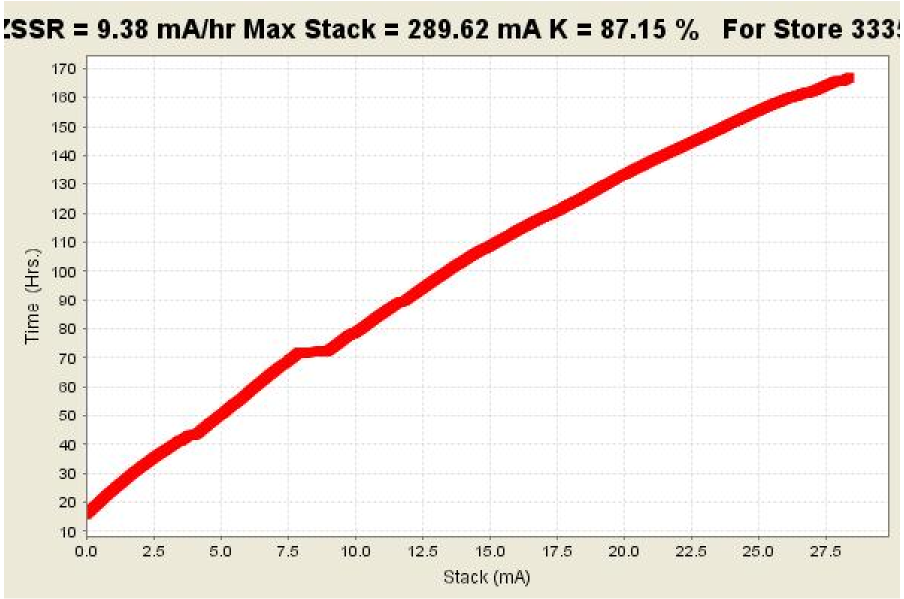
$$\mathrm{AccTransEmitVec} := \begin{pmatrix} 0 \\ 2.919 \\ .424 \end{pmatrix}$$

$$\mathrm{PbarTransEmitFit}\ (\mathrm{coefVec}\ , S) := \mathrm{coefVec}_0 + \mathrm{coefVec}_1 \cdot \frac{S}{100} + \mathrm{coefVec}_2 \cdot \left(\frac{S}{100}\right)^2$$

$$\mathrm{RecTransEmitVec} := \begin{pmatrix} 7 \\ 0 \\ 0 \end{pmatrix}$$

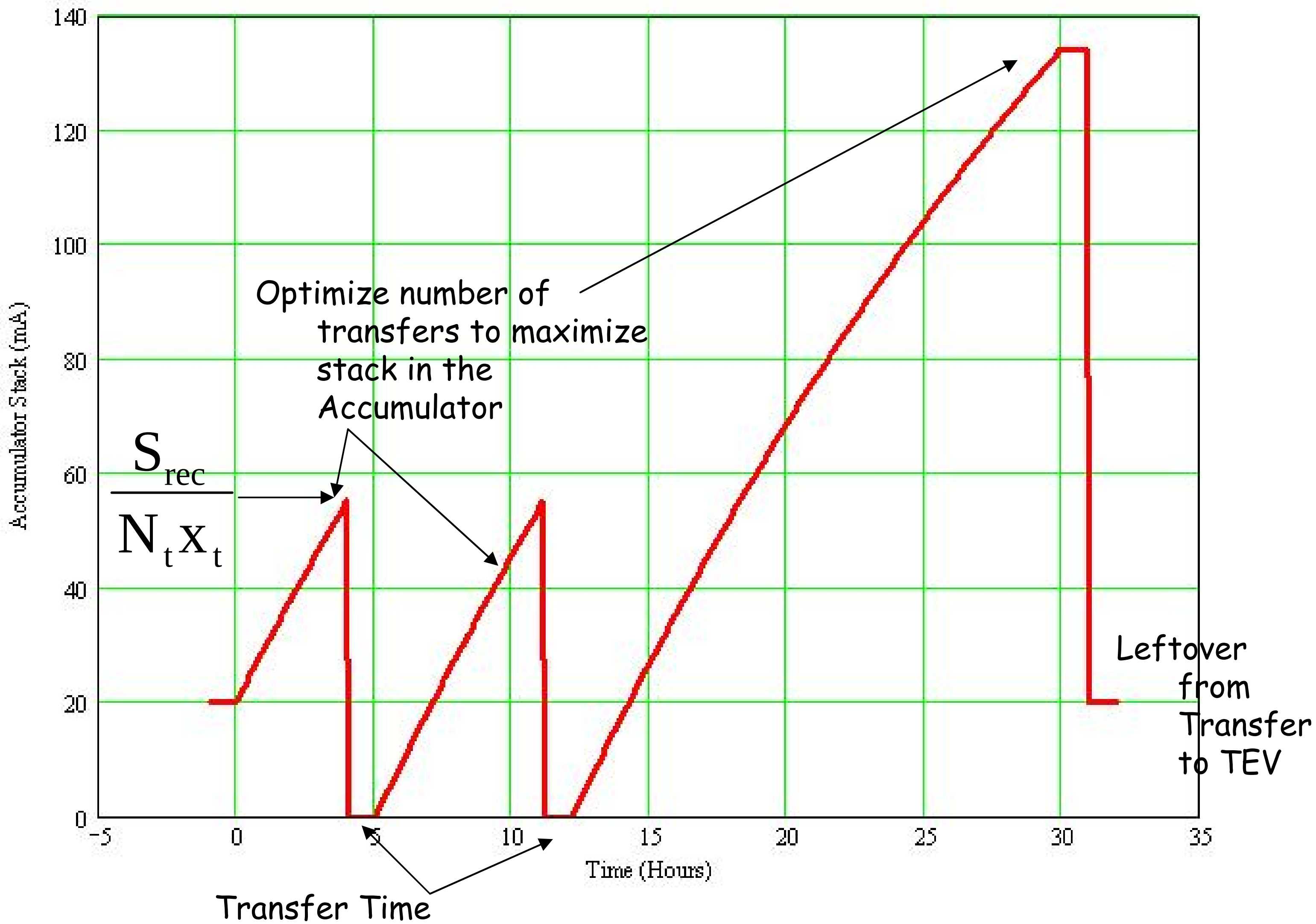
Stack Rate vs Time





$$S(t) = S_{\max} - \left(S_{\max} - S_o\right) e^{-\frac{R_o \kappa_e t}{S_{\max}}}$$

Stacking For the Recycler



Break Even Scenario

$AccLongEmitDilution := .9$ $AccLongEmitCutoff := 0.35$ $AccEffIntercept := 1.05$ $AccEmit_{offset} := 21.781$ $AccLum_{scale} := 12.672$

$AccTransEmitVec := \begin{pmatrix} 0 \\ 2.919 \\ .424 \end{pmatrix}$ $AccLongEmitVec := \begin{pmatrix} 15.988 \\ 6.119 \\ .00 \end{pmatrix}$

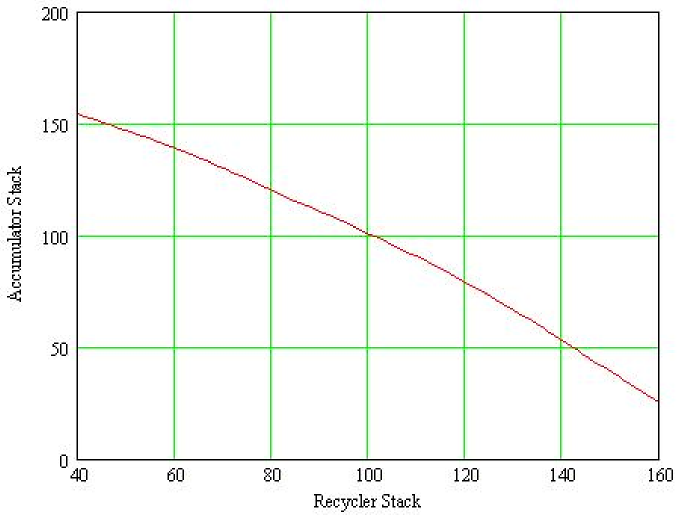
$RecLongEmitDilution := .9$ $RecLongEmitCutoff := 0.35$ $RecEffIntercept := 1.05$ $RecEmit_{offset} := 21.781$ $RecLum_{scale} := 12.672$

$RecTransEmitVec := \begin{pmatrix} 7 \\ 0 \\ 0 \end{pmatrix}$ $RecLongEmitVec := \begin{pmatrix} 4 \\ 49 \\ .00 \end{pmatrix}$ $RecLongEmitVecMeas := \begin{pmatrix} 4 \\ 49 \\ .00 \end{pmatrix}$

$Rate_o := 10$ $S_{max} := 300$ $AccRecTransEff := 0.90$ $AccRecTransTime := 1.0$ $StoreLength := 25$

$X_{e\_acc} := 0.85$ $X_{e\_rec} := 0.85$ $N_{Proton} := 250$

$Rstack_{min} := 40$ $Rstack_{max} := 160$



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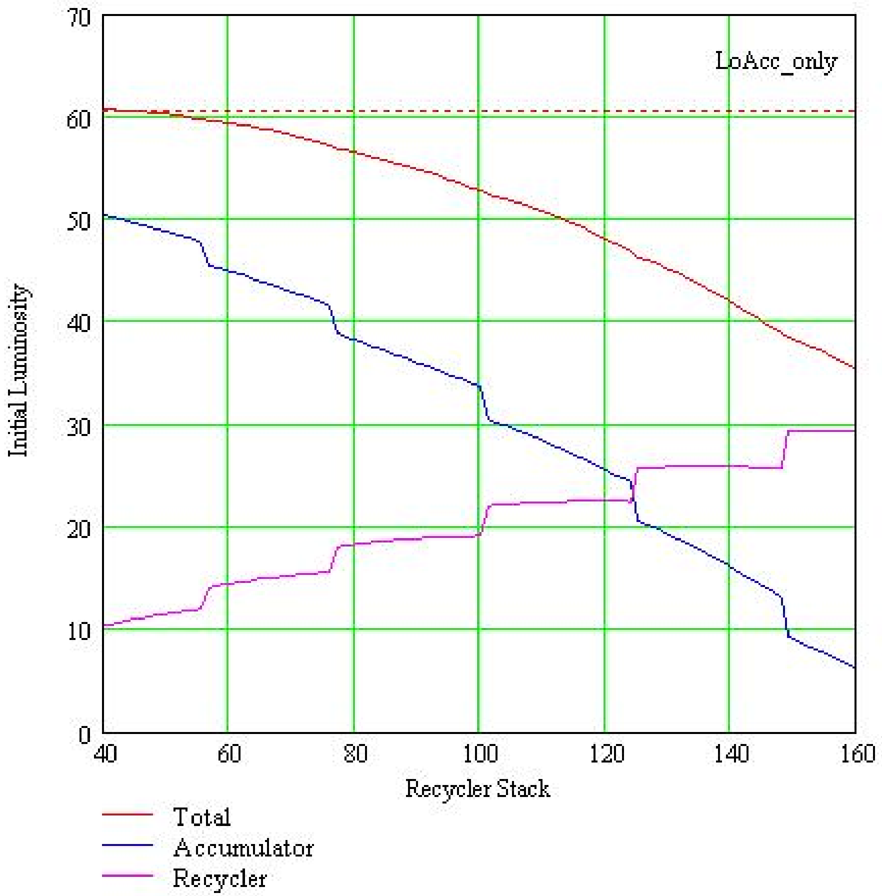
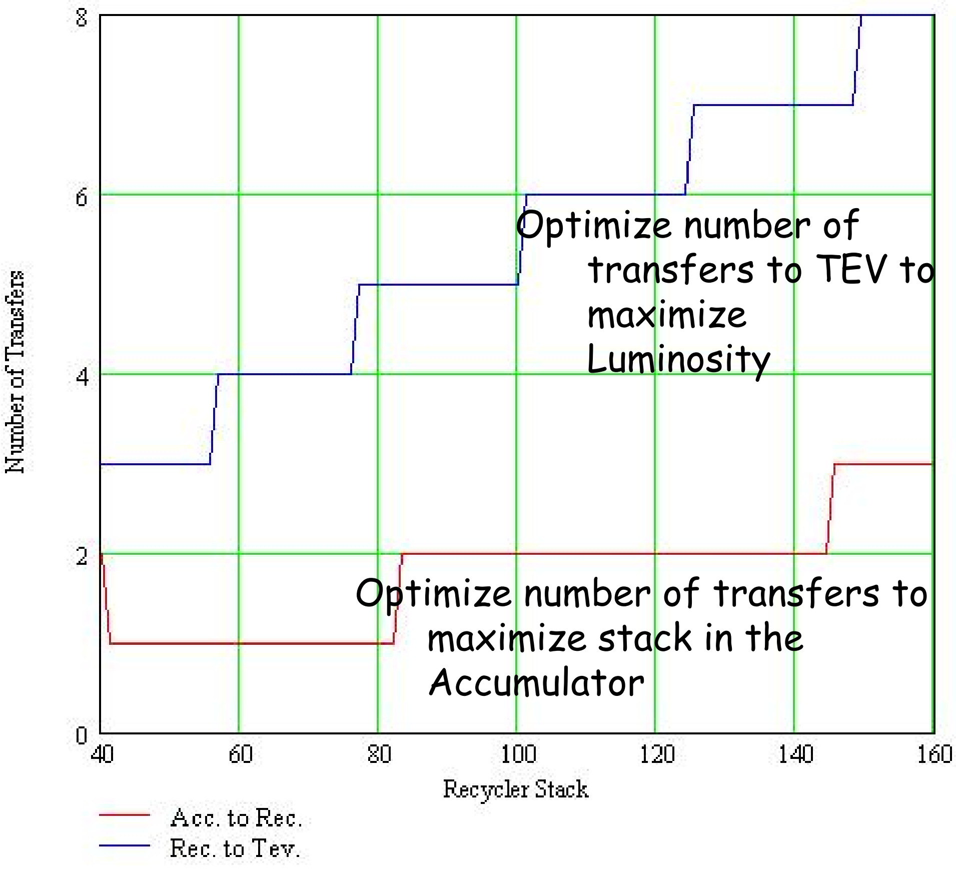




Optimistic Scenario

AccLongEmitDilution := .9 AccLongEmitCutoff := 0.35 AccEffIntercept := 1.05 $AccEmit_{offset}$:= 21.781 $AccLum_{scale}$:= 12.672

AccTransEmitVec := $\begin{pmatrix} 0 \\ 2.919 \\ .424 \end{pmatrix}$ AccLongEmitVec := $\begin{pmatrix} 15.988 \\ 6.119 \\ .00 \end{pmatrix}$

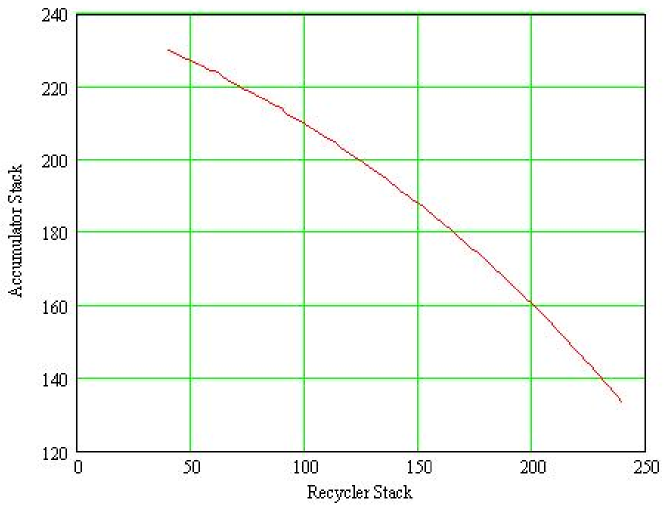
RecLongEmitDilution := .1 RecLongEmitCutoff := 0.35 RecEffIntercept := 1.05 $RecEmit_{offset}$:= 21.781 $RecLum_{scale}$:= 12.672

RecTransEmitVec := $\begin{pmatrix} 7 \\ 0 \\ 0 \end{pmatrix}$ RecLongEmitVec := $\begin{pmatrix} 4 \\ 25 \\ .00 \end{pmatrix}$ RecLongEmitVecMeas := $\begin{pmatrix} 4 \\ 49 \\ .00 \end{pmatrix}$

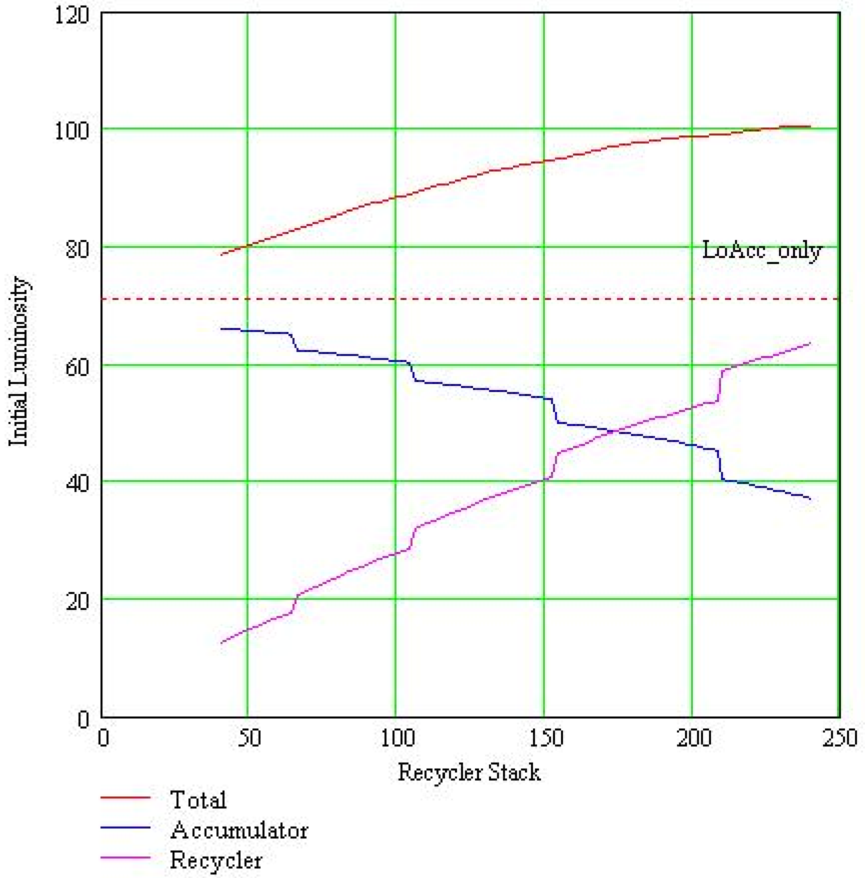
$Rate_o$:= 15 S_{max} := 300 AccRecTransEff := 0.95 AccRecTransTime := .25 StoreLength := 30

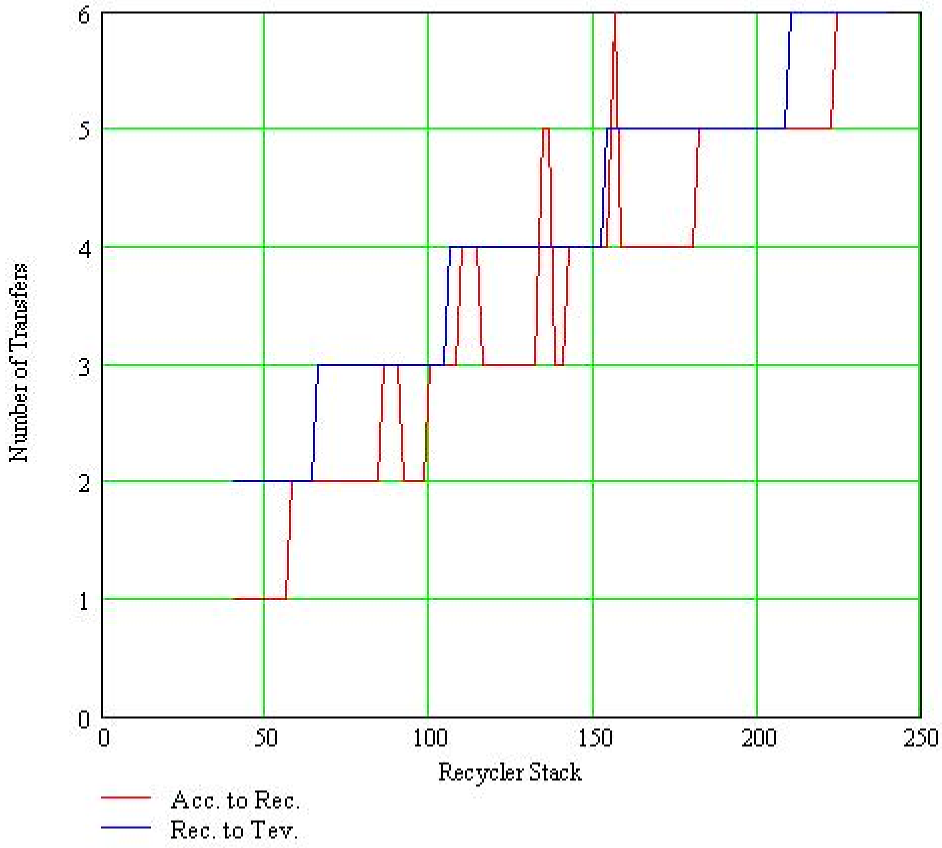
X_{e_acc} := 0.85 X_{e_rec} := 0.85 N_{Proton} := 250

$Rstack_{min}$:= 40 $Rstack_{max}$:= 240



Optimistic Scenario





TEV Abort System Review

- Develop a formal procedure for reviewing moveable devices to be installed in the TEV – June 1, 2004
- A UPS system for the TEV abort control electronics will be installed in the Fall shutdown
- Tev Abort Checkout and Tune-up procedure document - May 15, 2004
- Will investigate over-sampling in QPM's can be done – May 1, 2004
  - If it can be done, it can be implemented a couple of weeks (June 1, 2004)
- There was a study done to see if the entire BLM system would cause a false abort
  - Examined 17 stores.
  - 6 stores would have been ended but most of these were doing studies.
  - Proposal to have a group examine this question in more detail using not the entire BLM system but a select few around collimators. The group would consist of:
    - Tev operations person as the leader
    - Two people from controls – hardware reliability and software
      - Need to investigate the reliability of BLM inputs to the C200 Module
    - A number of people from CDF to help analyze data and scenarios

TEV Abort System Review

- The rewiring of the closing of TEV vacuum valves to the TEV abort system will be done by the end of the Fall shutdown
  - 1 crate down out of 23 during the past spring shutdown
  - Design done by May 15, 2004
  - Parts ordered by June 1, 2004
  - Parts in by July 15, 2004
- Corrector trips have lost 2 stores since Jan 03. There was one corrector trip that did not result in a lost store.
  - It is believed that unmasking dipole correctors would not cause many false aborts
  - Should investigate the clamping of corrector supplies instead of tripping them off at max current
- Will document the list of devices that are abort inputs by May 1 – TEV Dept.
  - Decide on which devices will stay in the abort loop and be unmasked during HEP by May 15 – TEV Dept.
- Proposal on moving the abort blocks from the center of the abort system to the end of the abort system was presented.
  - Could possibly reduce pre-fire rate by 40%