



Fermilab

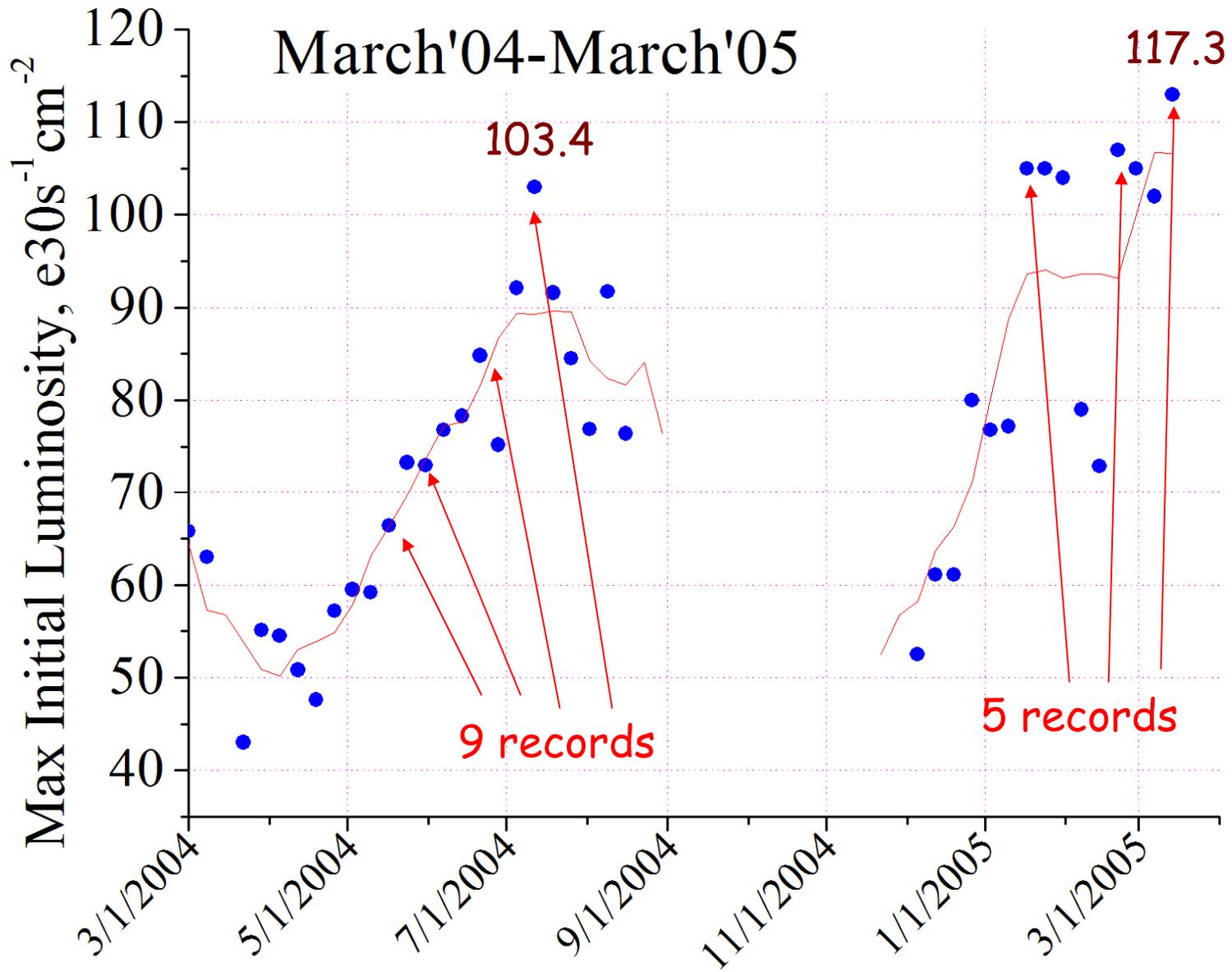
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# Tevatron Operations

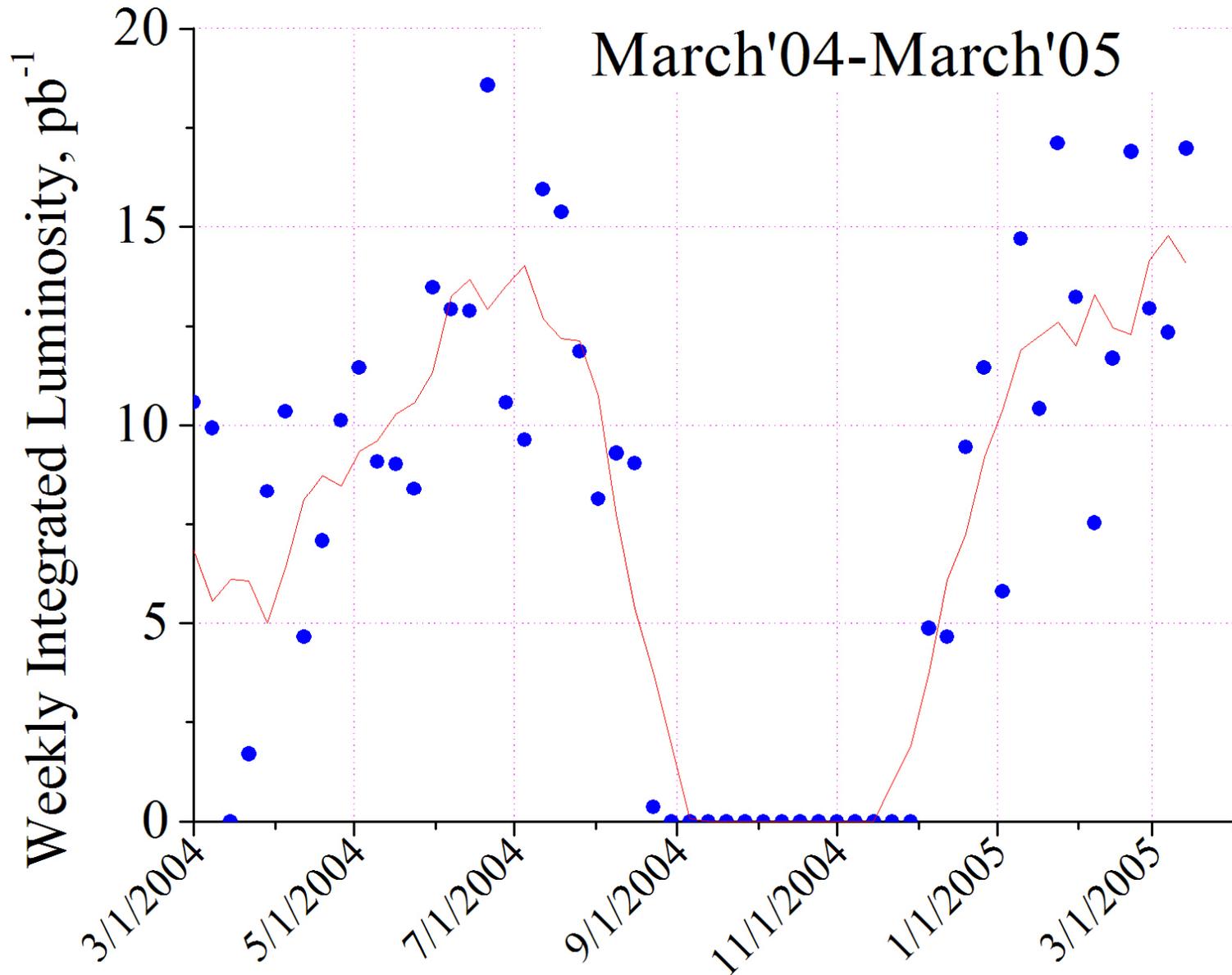
Vladimir Shiltsev  
Fermilab

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# Tevatron Peak Luminosity Progress



# Weekly Integrated Luminosity



# Tevatron progress: Mar'04 to Mar'05

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## ■ Luminosity:

➤ Record, e30  $L = 68.5 \rightarrow 117.3$  +71%

➤ Avg 2 mos  $L = 52.7 \rightarrow 83.4$  +58%

(Feb+Mar)

beta\* +28%

N\_a +13%

emittance +8%

$H(\sigma, \theta)$  +4%

N\_p -2.5%

➤  $L$ -lifetime, hrs 9.4  $\rightarrow$  8.9 -6% (only!)

➤ Integral pb-1/wk 8.7  $\rightarrow$  13.1 +51%

## ■ FY'05 goal integral 470 pb-1 (now ~180 pb-1)

# Major TeV Events in 2<sup>nd</sup> half of FY'04 & FY'05

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- Beta\* function at IP reduced
- Shutdown work - Reshimming, Alignment
- Shutdown work - D17 separators
- MI, AA progress and Recycler shots
- Octupoles @ 150 GeV
- Diagnostics progress

# Reduce $\beta^*$ at CDF&D0 IPs

Final results for optics correction see V.Lebedev, beams-doc-1311

Next changes were performed to correct optics and dispersion

BOQ2 and BOQ3 were decreased by 6 A

BOQ2: from 4722 to 4716

BOQ3: from 4666 to 4660

D0QT3 was decreased by 2.7 A from 24.06 to 21.3

QA42 was changed by -2.5 A from -44.24 to 46.86

AQ7\* was changed by -5 A from 607.4 to 602.6

CQ7\* was changed by -7 A from 607.4 to 600.9

DQ0 was changed by -3.5 A from 49.82 to 46.28

DQ7 was changed by -25.6 A from 680 to 654.4

\*AQ7 and CQ7 made minor dispersion correction in both IPs

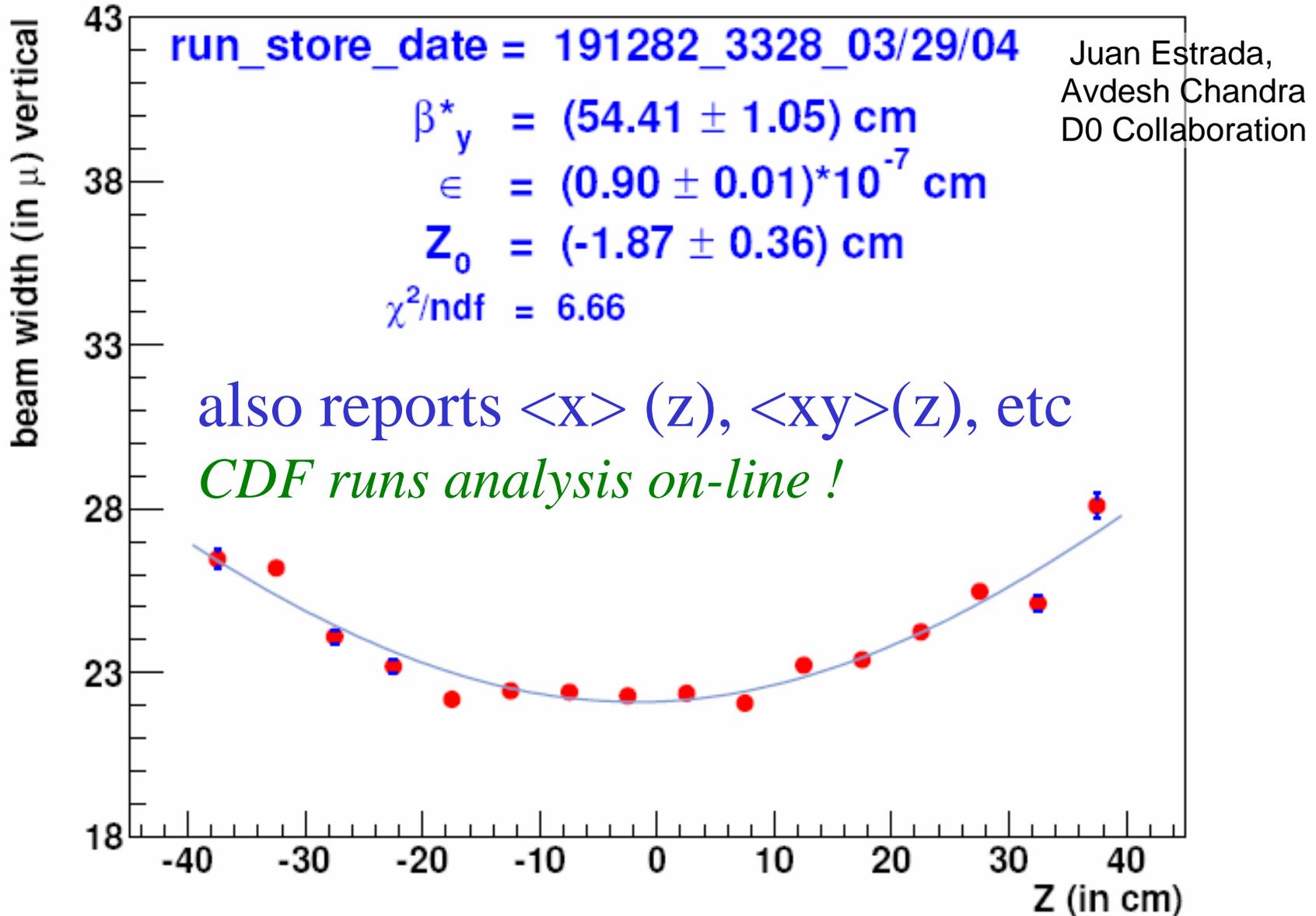
**from the model:**

BO  $\beta^*47/42 \rightarrow 30/33 \pm 5\text{cm}$

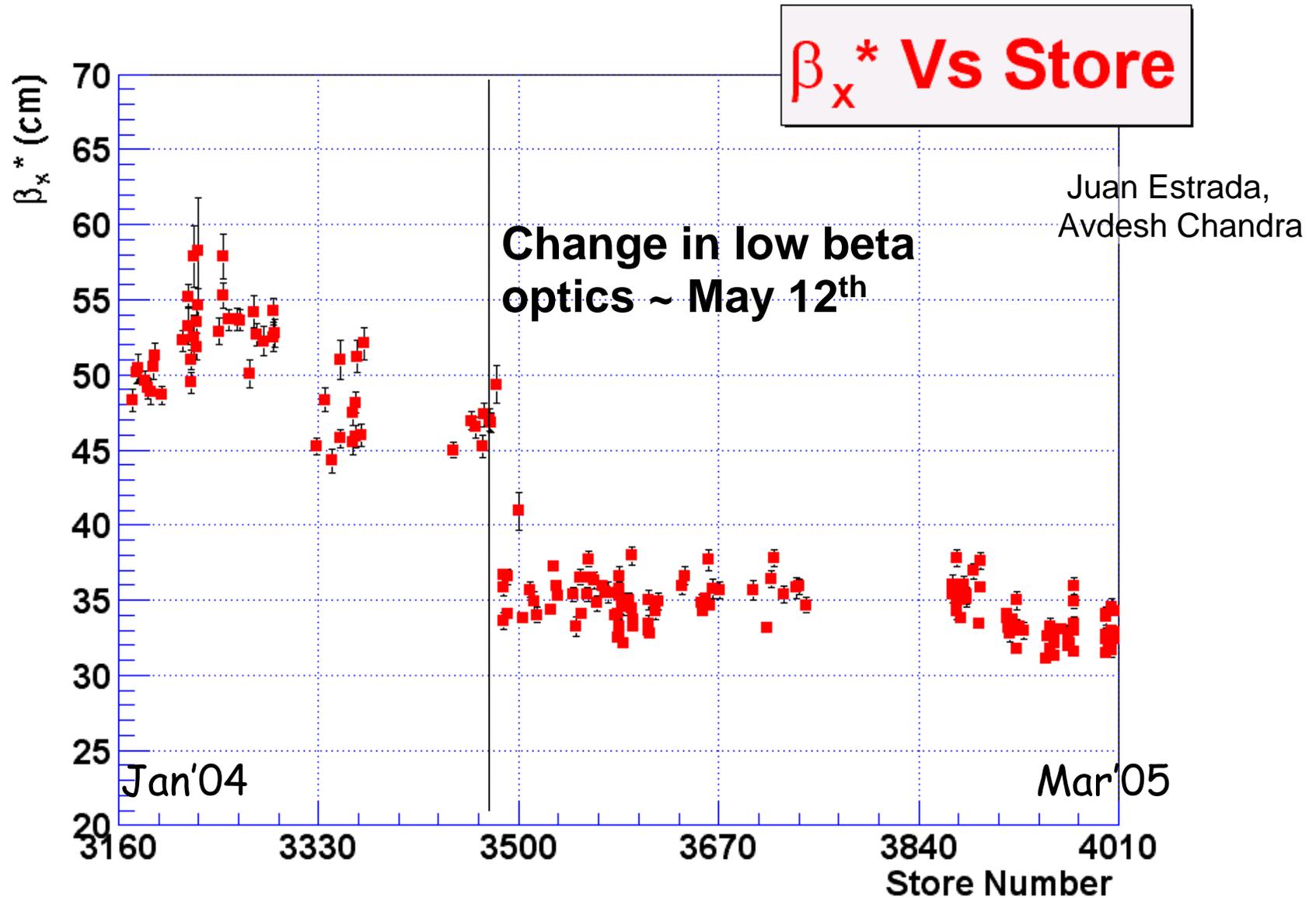
D0  $\beta^*38/39 \rightarrow 33/30 \pm 2\text{cm}$

- Then do "alpha-bumps" (center waist z-position)
- Then optimize separators for head-on collisions
- Then adjust correction circuits
- Then fix all the mess (tune for losses, etc)

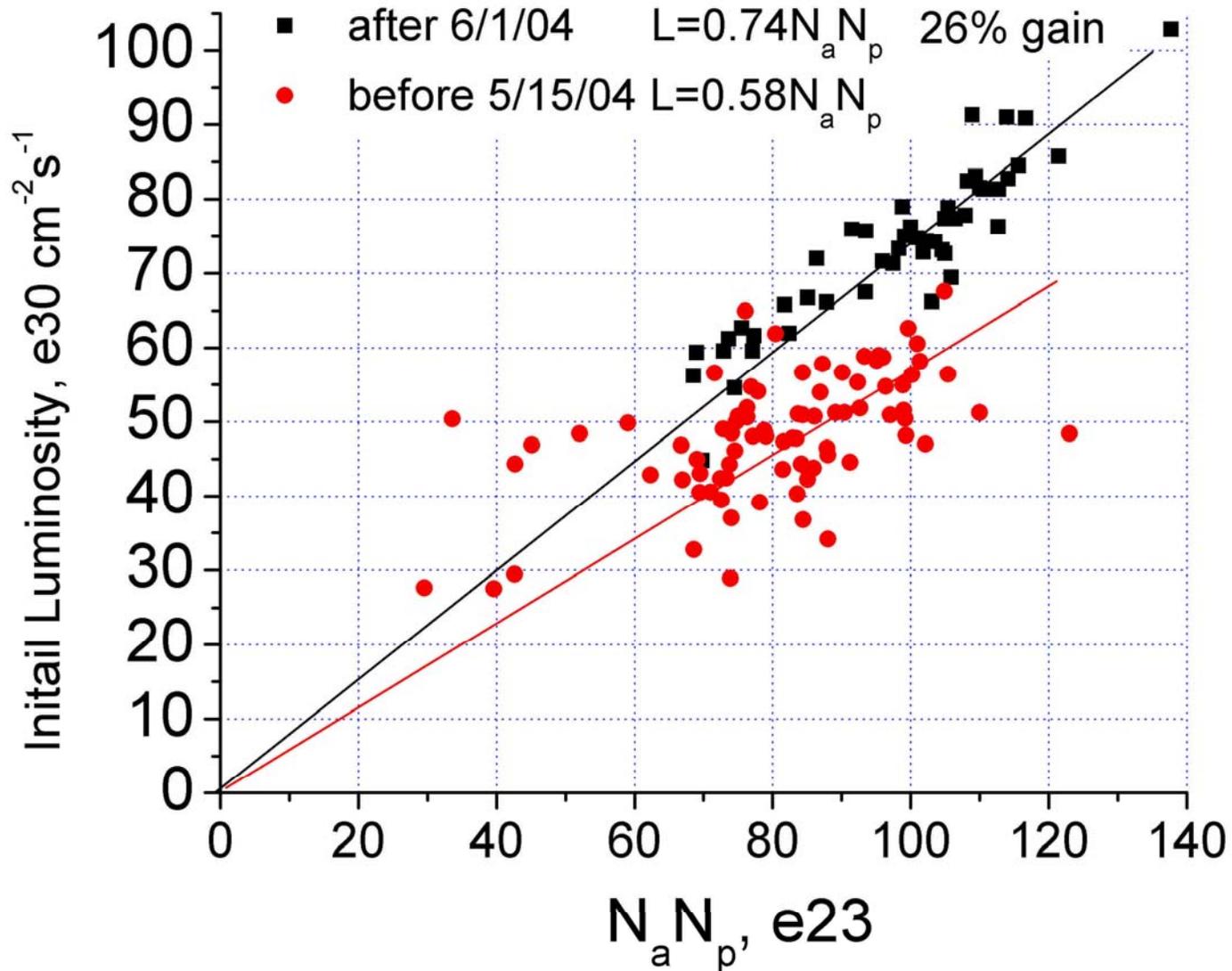
# $\beta^*$ from Luminous Region Analysis



# $\beta^*$ Reduction Confirmed by Detectors



# 26% in Peak Luminosity



# Shutdowns

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- FY'04 shutdown : 12 weeks, 28 jobs, including
  - SNEG pipes at D0
  - CDF LB girders support replaced
  - 2 separators @D17+polarity switches
  - 412 dipoles reshimmed
  - Thinner 7 um FWs at E11
  - Kaiser coil and roll measmnts
  - B0 and D0 HLS systems installed
  - 4 houses warmed up/cold leaks fixed

5x better vacuum  
no 12Hz beam jitter  
better helix, studies  
SQ current dropped  
-1/2pi, fly in stores  
no bad anchors  
monitor LBQs online  
a must
- Power Outage 01/05/05:
  - CDF quads moved IP +3.9mm Hor

CDF b-tagging effic.
- Short 3 days shutdown Feb'05: 15 jobs including
  - F17 kicker magnet replaced
  - Crystal collimator fixed
  - Vacuum leak A49 fixed

fluorinate leak  
was misaligned  
a must

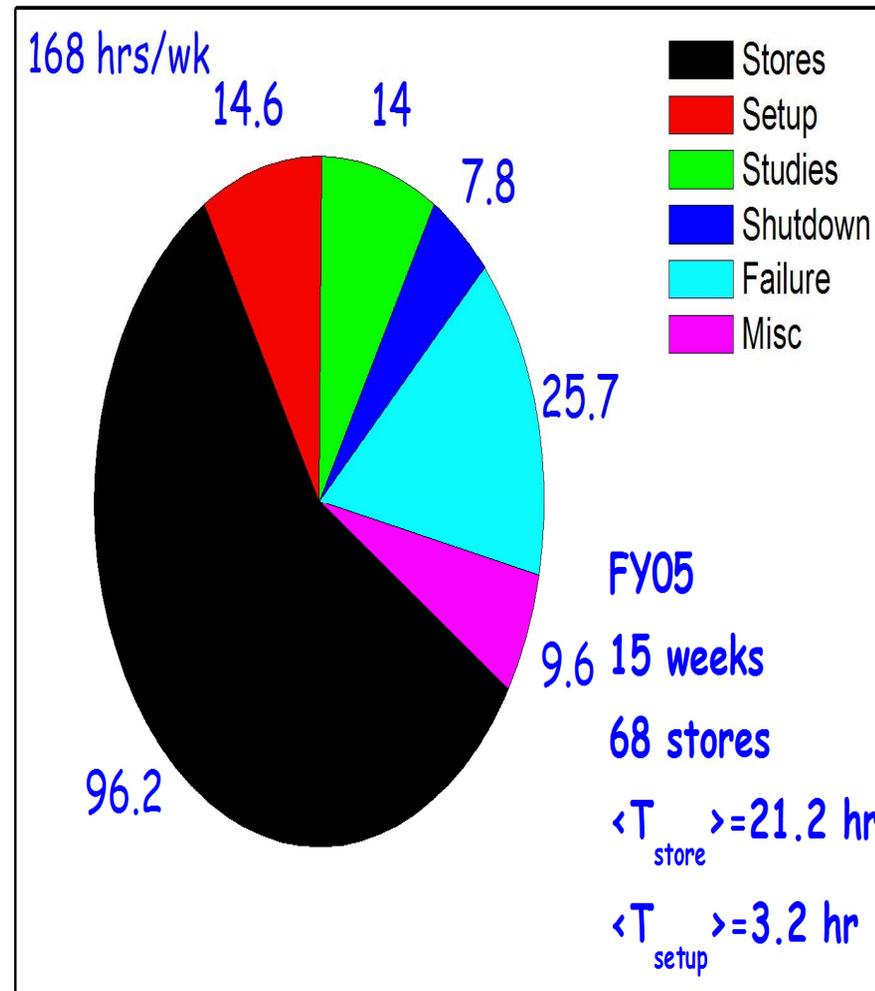
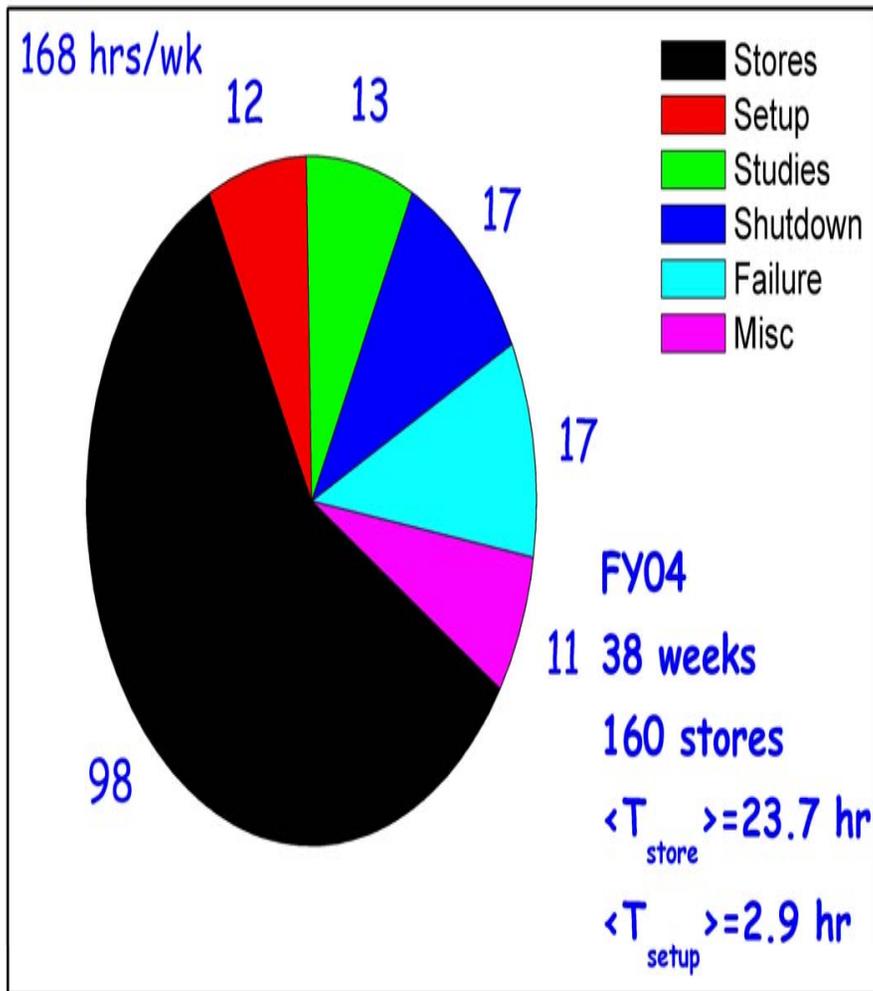
# Highlights on Operations/Reliability (1)

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- Beam startup took 24 shifts ( ~ as planned)
  - A bit slowed by troubles with vacuum valves controls
- Reached pre-shutdown  $L \sim 60e30$  after 9 stores
- 68 stores in FY'05, 24 or 35% ended unintentionally (26.5% in FY'04):
  - Various LB and Corrector PSs trips/problems (6)
  - Separators (6)
  - Abort kicker prefires/etc (4) ← addressed
  - Human errors (3)
  - Cryo (2)
  - Dampers long and transv (2)
  - Power outage (1)

# Time Breakdown: FY'04 & part of FY'05

Courtesy of J.Crawford

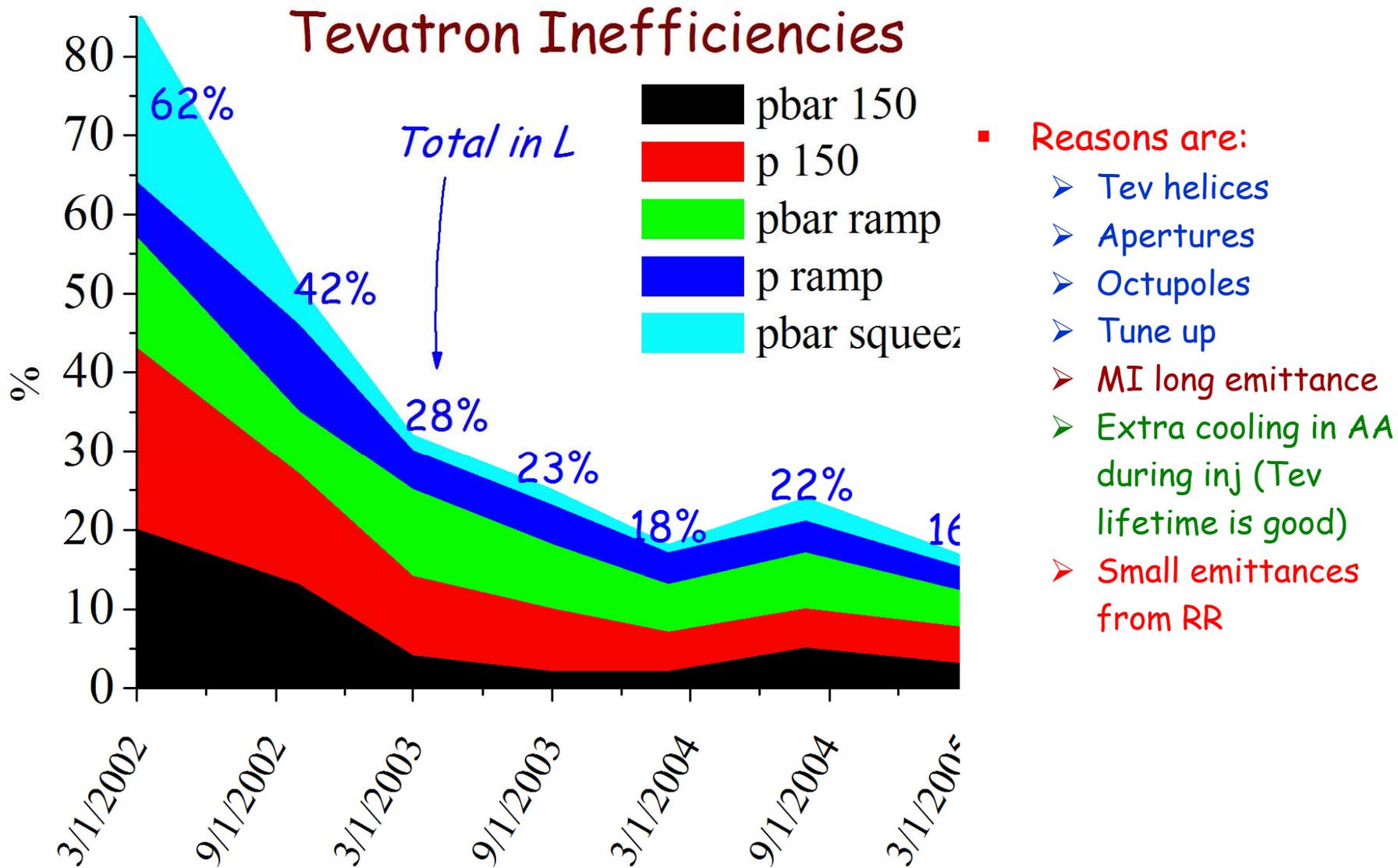


## Highlights on Operations/Reliability (2)

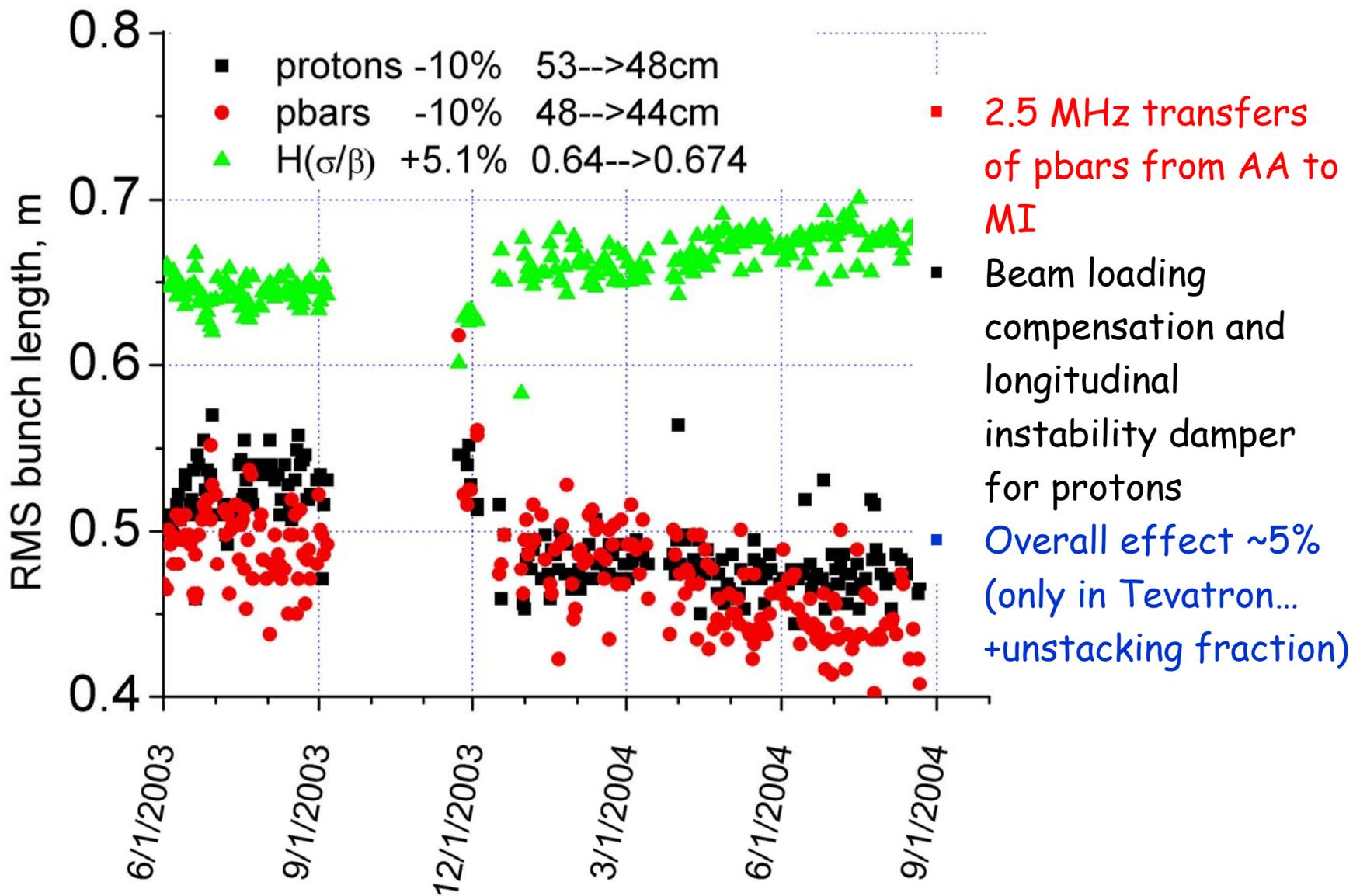
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- CDF and D0 IP positions and angles corrected (upto 3mm) - with correctors or by alignment of B0 LB quadrupoles
- Double scraping/better vacuum → lower halo rates CDF / D0
- A11,A48 collimator set closer to beam to minimize kicker prefire damage
- QPM code upgrade for faster quench detection (16→2 ms)
- Losses in squeeze ~1% p/pbars, dropped Q' 20→8, fixed Q excursion
- "Scallops" - were regular, disappeared after dQ -0.002 change
- D0 luminosity monitor scaled up +10% (mid-March)
  
- Transv-dampers problems → Octupoles → Lifetime at 150 improved
- Longitudinal Instability at 150 and 980 - even with damper
- P-lifetime at LB wandering 60hrs→160hrs→60hrs...

# Tevatron Efficiency Progress

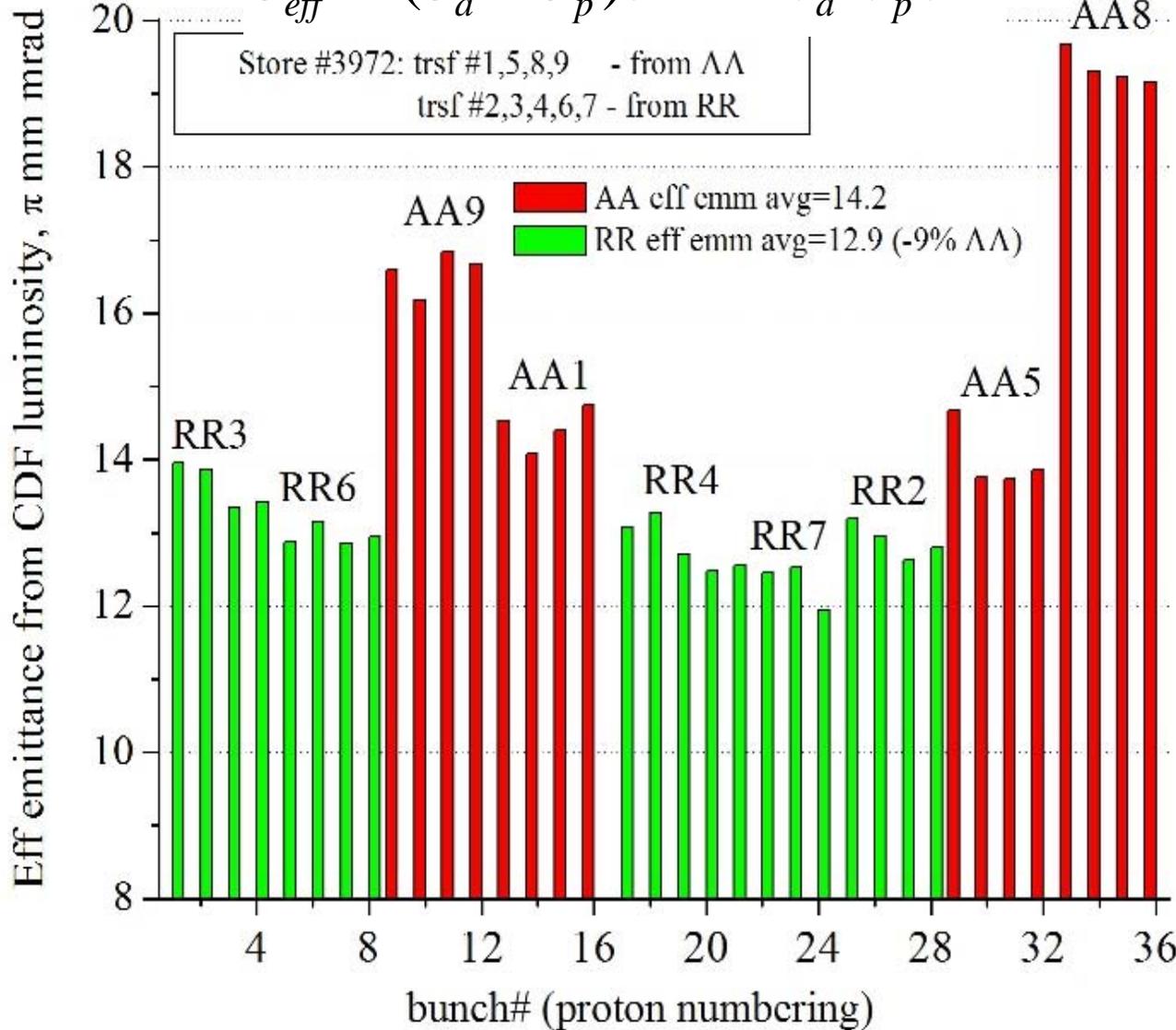


# Improvements Coming from Injectors: MI



# Improvements Coming from Injectors: RR

$$\varepsilon_{eff} \approx (\varepsilon_a + \varepsilon_p) / 2 \propto N_a N_p / L$$

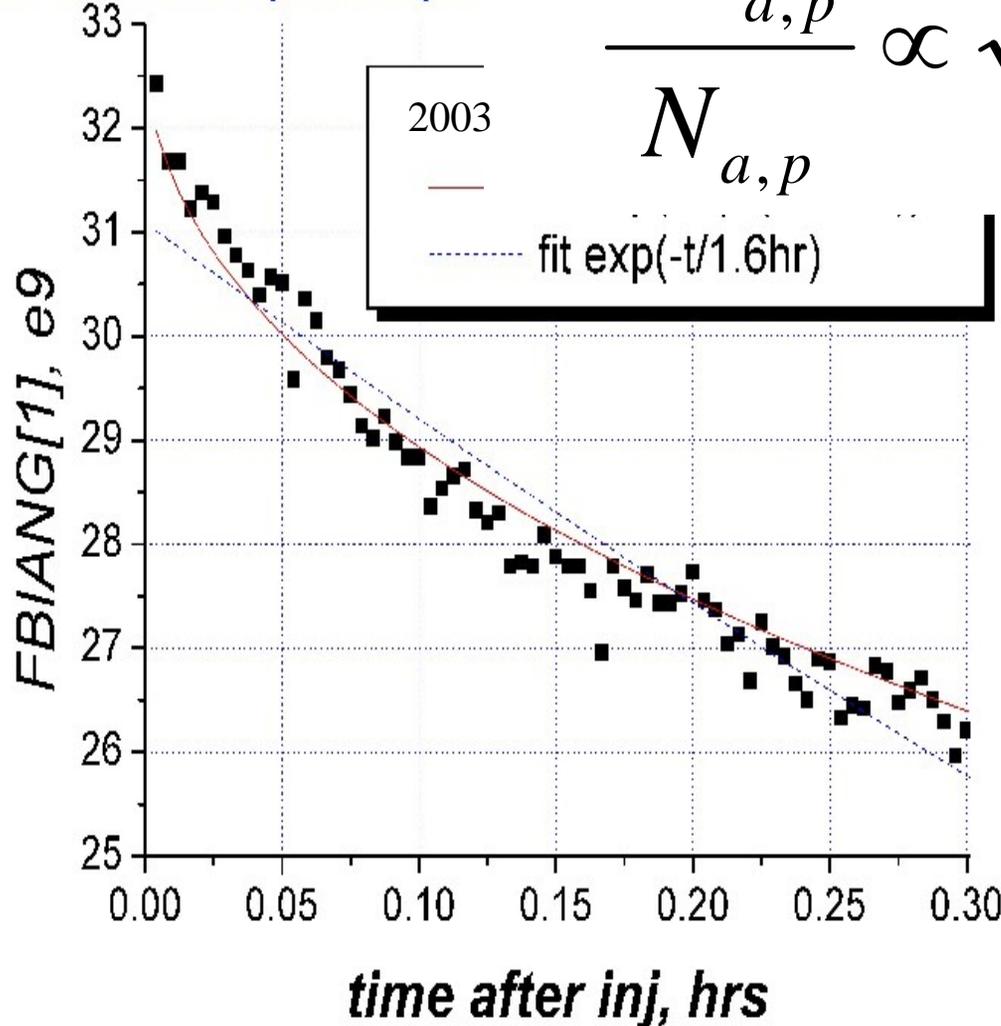


- Smaller pbar emittances from RR result in reduced losses at 150 GeV, ramp and squeeze
- Smaller effective emittance (i.e., higher luminosity for same intensity)
- About same luminosity lifetime
- Overall effect ~3-4%... Like to see more RR pbars

# Beam “Shaving” (Longitudinal) after Injection

Pbar intensity decays

$$\frac{dN_{a,p}}{N_{a,p}} \propto \sqrt{t} \cdot \varepsilon_{a,p}^2 N_{p,a} Q'_{a,p}$$



- $Q' = dQ/(dP/P)$  - chromaticity
- $dN(t) \sim \text{Sqrt}(\text{time})$
- Larger for larger emittances
- Mostly Beam-beam induced
- Larger for larger  $dp/p$  as bunchlength shrinking
- Protons affected as well
- Aperture matters
- Tunes matter (e.g. 4/7)
- Cogging matters

# 150 GeV Lifetime Improvements (2002-2004)

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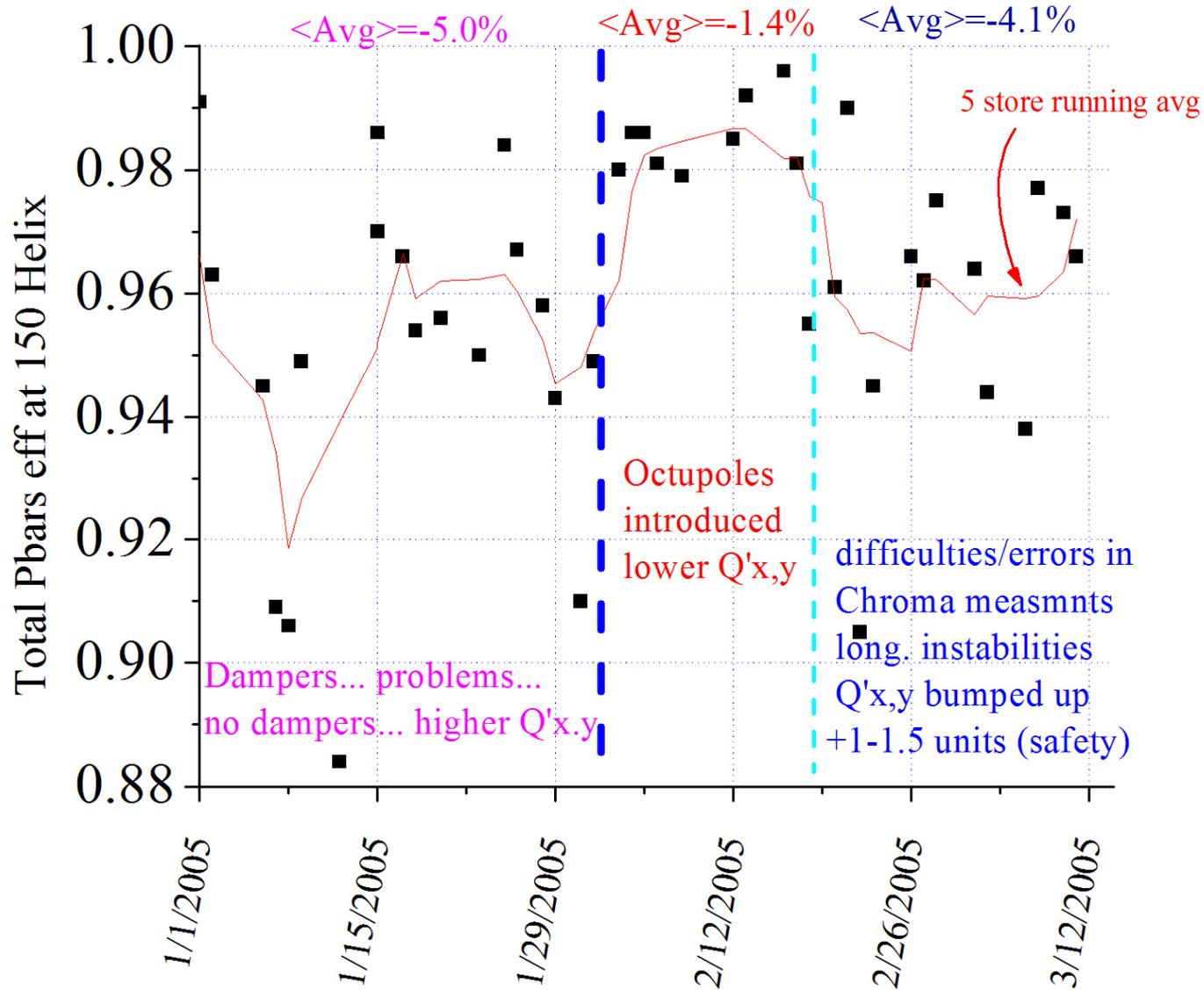
- Things which helped to improve lifetime at 150 GeV
  - Emittances greatly improved since 2002 ← thanks to AA, Booster and MI (recently - RR) in addition to Tev work: better pbar BLT closure; vert dispersion matched at inj after four P1 quads rolled and 100+440 Tev dipoles reshimmed
  - Apertures opened: lambertsons replaced @ C0 - gain 25 mm vertically, kickers, separators, LB quads aligned
  - Original injection helix has been modified, separation increased and optimized to fill the aperture ("new-new helix" "5\*" etc)
  - F0 liners and transverse dampers to drop  $Q'$  from (8-10)→(4-5)
- Issues
  - Dampers (intrinsically) stabilize mostly mode 0, so chromaticity can not be dropped below 2-3 units in each plane
  - There was no control of differential chromaticity (upto 8 units!)
  - Dampers sensitive to local coupling→ various problems in Jan'05

# Octupoles at 150 GeV Helix

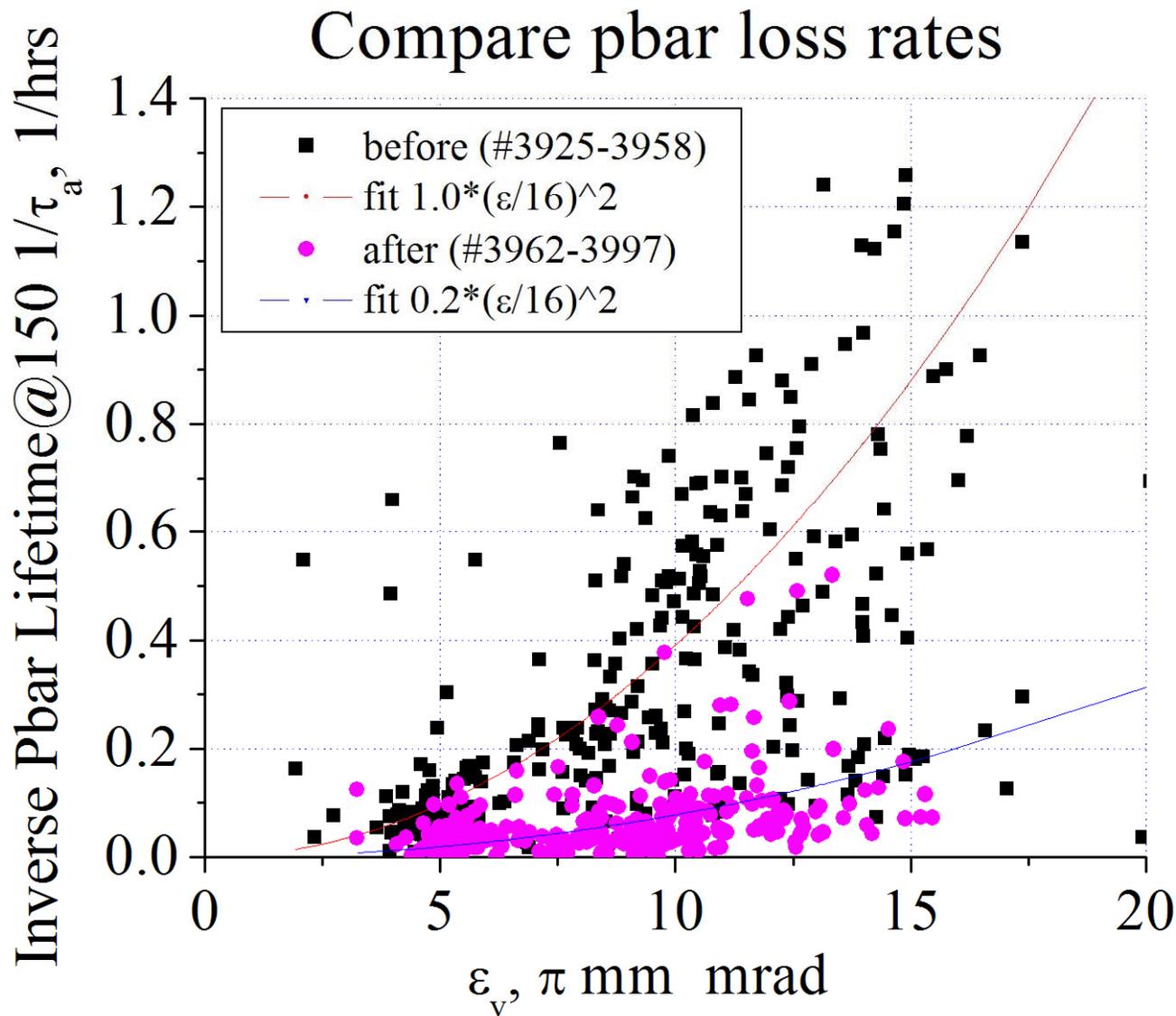
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- First Considered and Used for Operations in 2003 (OZD and OZF families, Yu.Alexahin)
- New Circuits Designed, Reconnected and Commissioned during Fall'03 Shutdown (P.Ivanov, J.Annala, Yu,Alexahin)
  - OD and OF to control tune spread for Landau damping
  - O1 and O2 to control differential p/a chromaticities
  - ~insensitive to orbit drifts ( $dQ < 0.001$   $dQ' < 1$  for 1 mm)
- In routine operation since Feb 4, 2005
  - Save ~2% of pbars and ~1% of protons  $\rightarrow$  ~+3% in L

# Pbar Loss at 150: With and W/O Octupoles

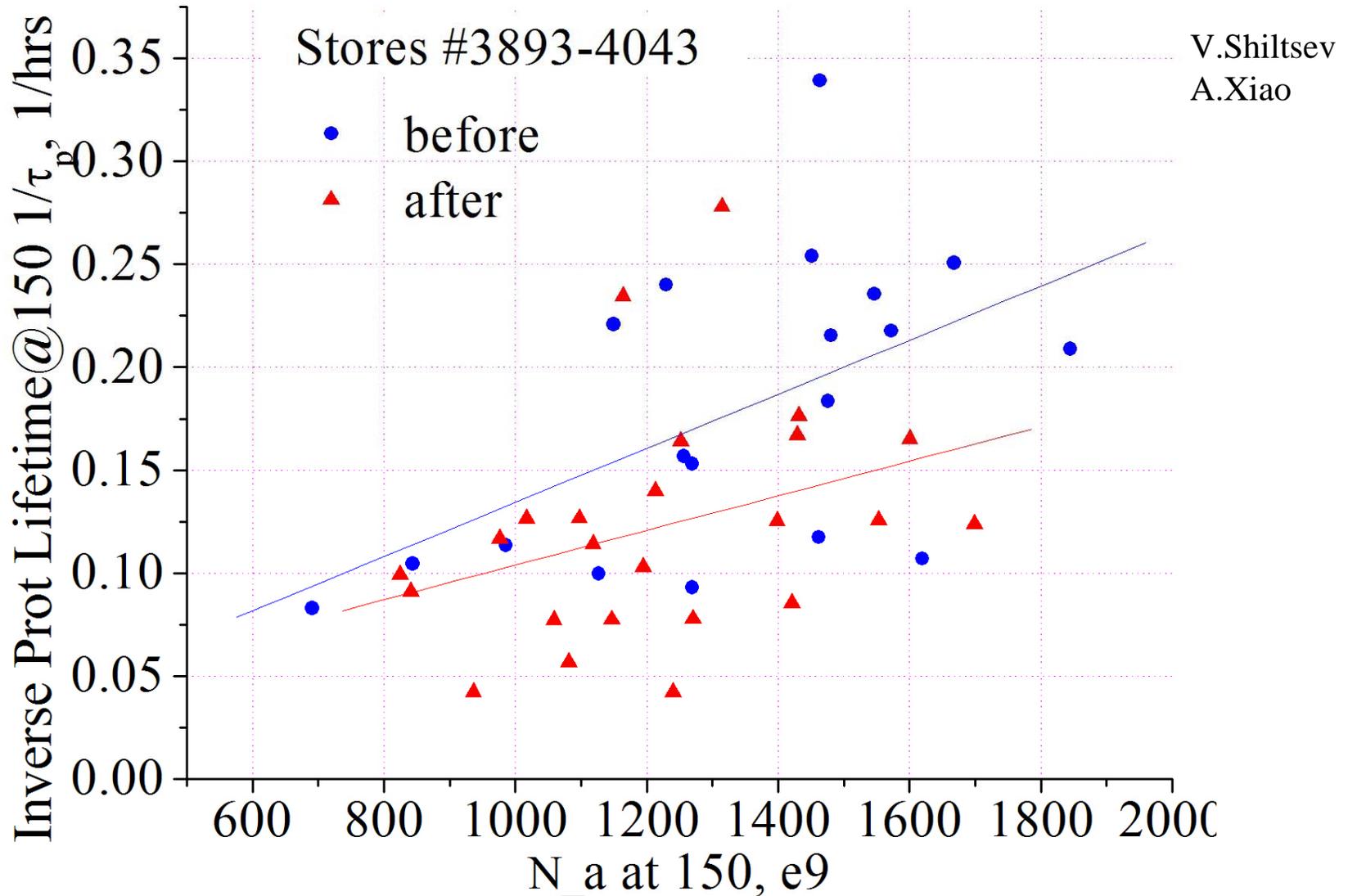


# Pbar Bunch Loss Rate $1/\tau$ vs $\epsilon_{\text{pbar}}$

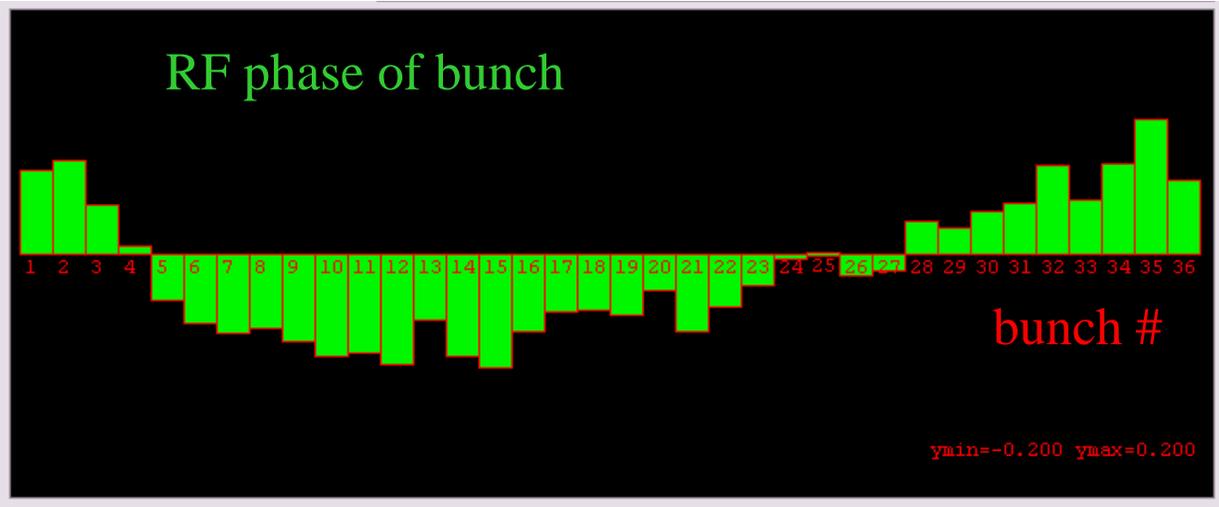
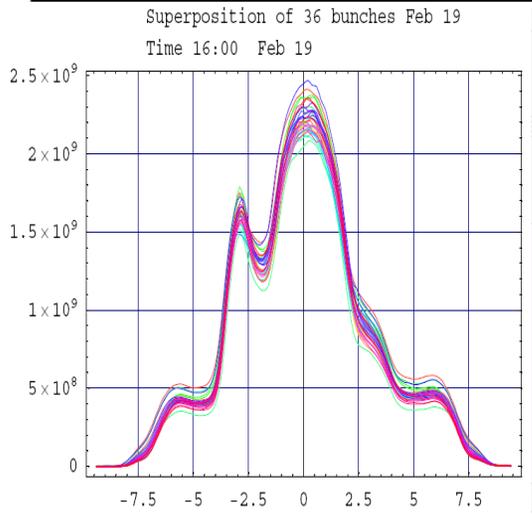
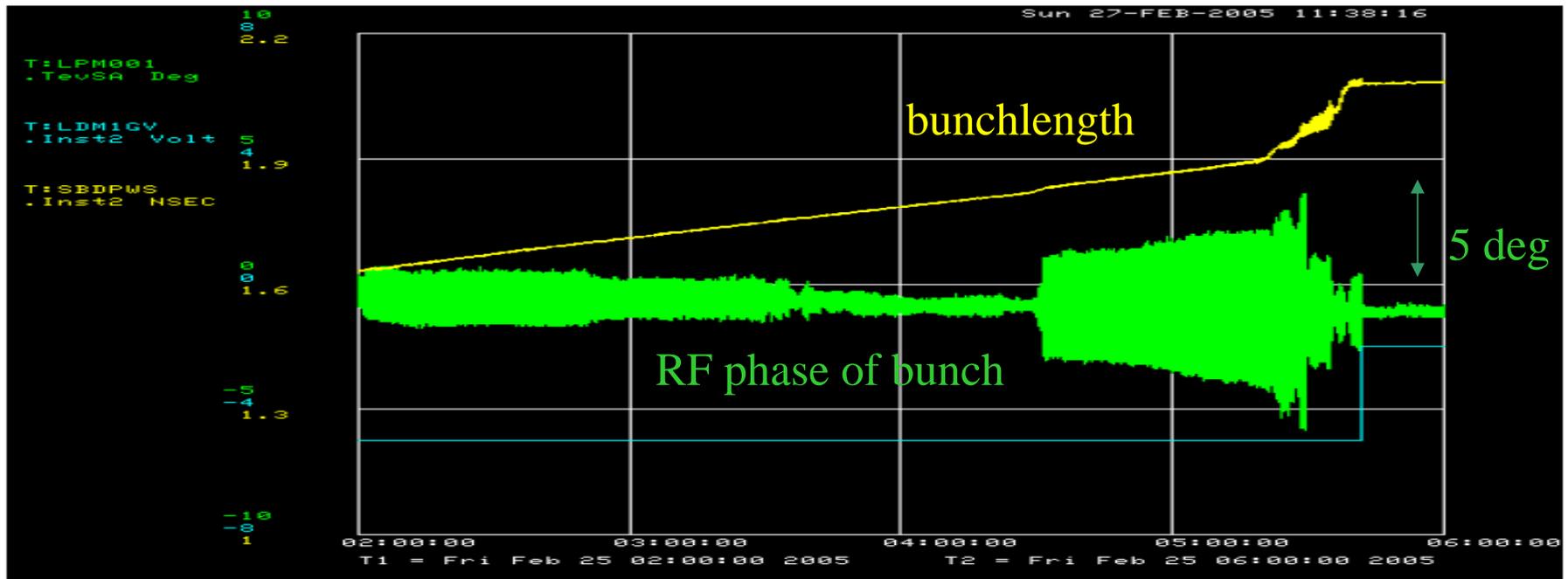


V.Shiltsev  
A.Xiao

# Proton Loss rate at 150 $1/\tau$ vs $N_a$



# Longitudinal Instability

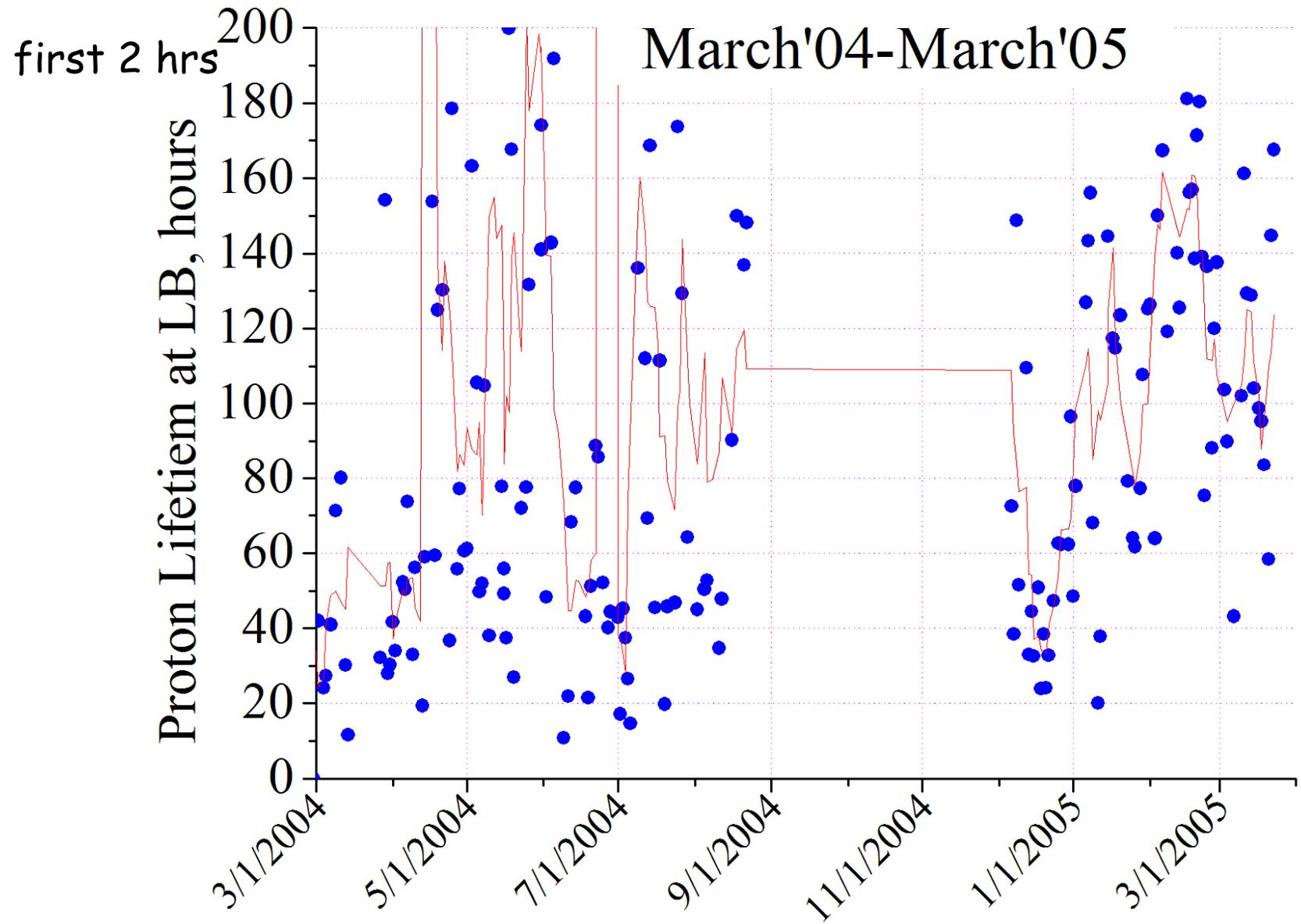


# Longitudinal Instability (cont'd)

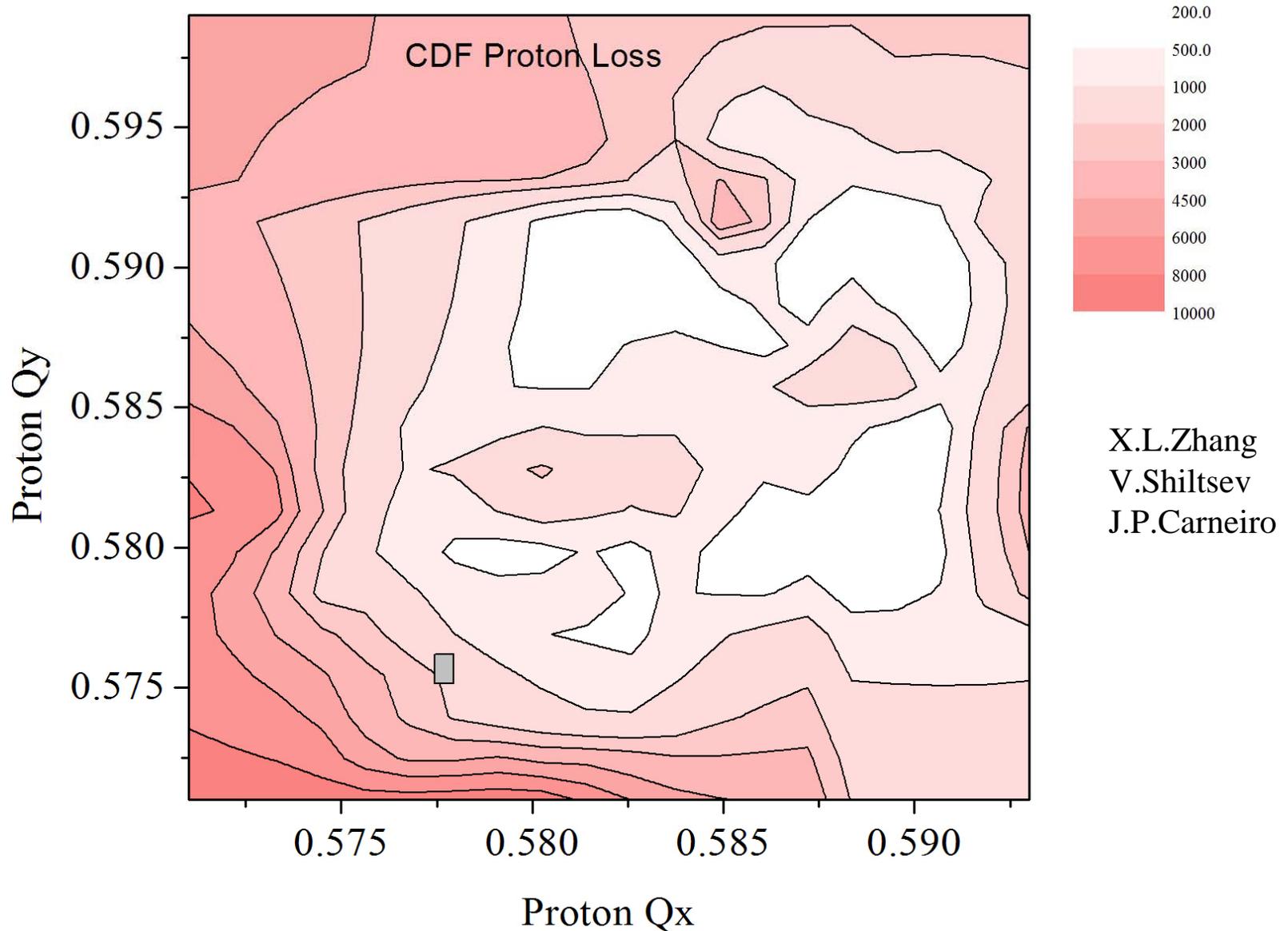
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- Temporary cure:
  - Carefully adjust gain of the longitudinal instability damper during HEP stores as  $N_p$  and bunch length are changing
- Plan:
  - Employ Robinson damping by shifting resonant frequency of the RF cavities down
  - Perform studies at 150 and 980 GeV with uncoalesced and coalesced bunches (36x0)
  - First on studies priority list

# Proton Intensity Lifetime in Collisions



# Tune Scan Offers $7/12 < Q < 3/5$



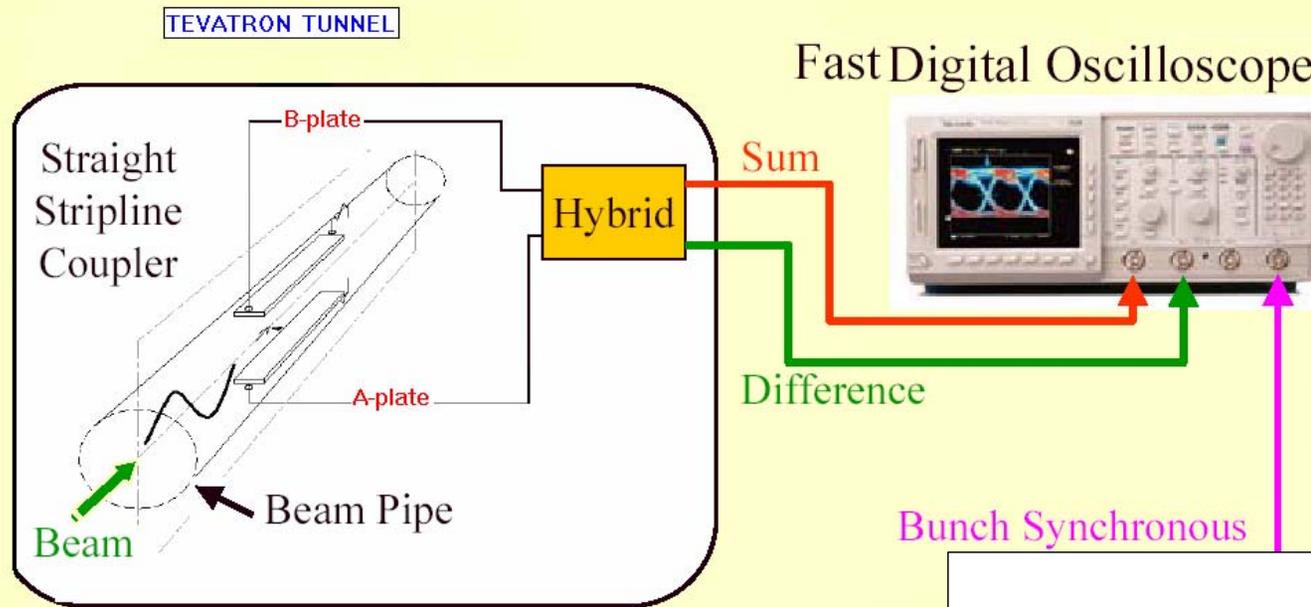
# Directions for Improvements/Studies

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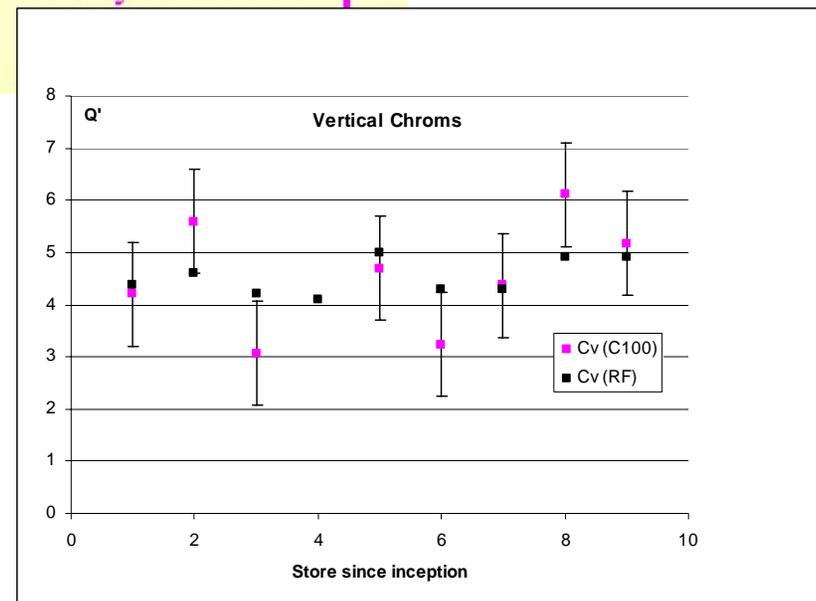
- Fix Longitudinal Instability
- Lifetime improvements at HEP → 5-10% in  $\int L$ 
  - Differential Q' at LB (lower for pbars)
  - Raise pbar tunes in stores
  - Explore new proton WPs  $7/12 < Q < 3/5$
- Reduce  $\beta^*$  35 → 28 cm → 8-12% in  $L$ 
  - As soon as new BPMs operational (>May'05)
- Increase  $N_p$  230 → 250 → 280e9/bunch → 10...20% in  $L$ 
  - With same emittances!
- Injection dampers to reduce  $d\varepsilon$  → 3-6% in  $L$
- Diagnostics development/improvements
  - New BPMs, BLMs, new Schottky, AGM → separate talks
  - Many other instruments → see below
- MD time: FY'04 5.3 → 7.3 hrs/wk - balanced with operation

# Diagnostics: $Q'$ from Head-Tail Monitor

V.Ranjbar



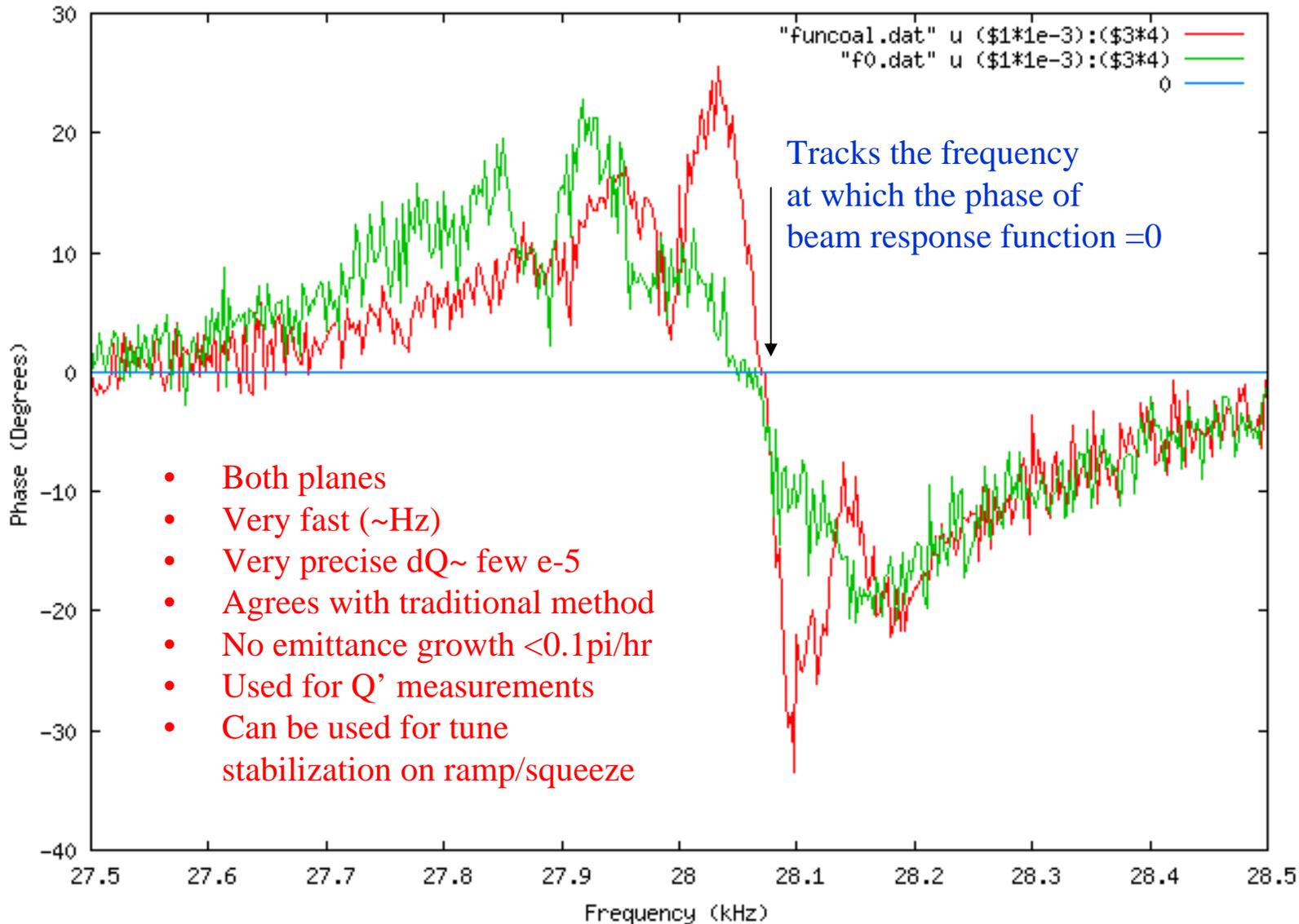
- Very fast method
  - Ops like it!
- Just few  $\pi$  d $\epsilon$  kick
- Currently used for monitoring
  - No difficulty to measure  $Q'$  with octupoles



# Tune Tracker (Phase Lock Loop)

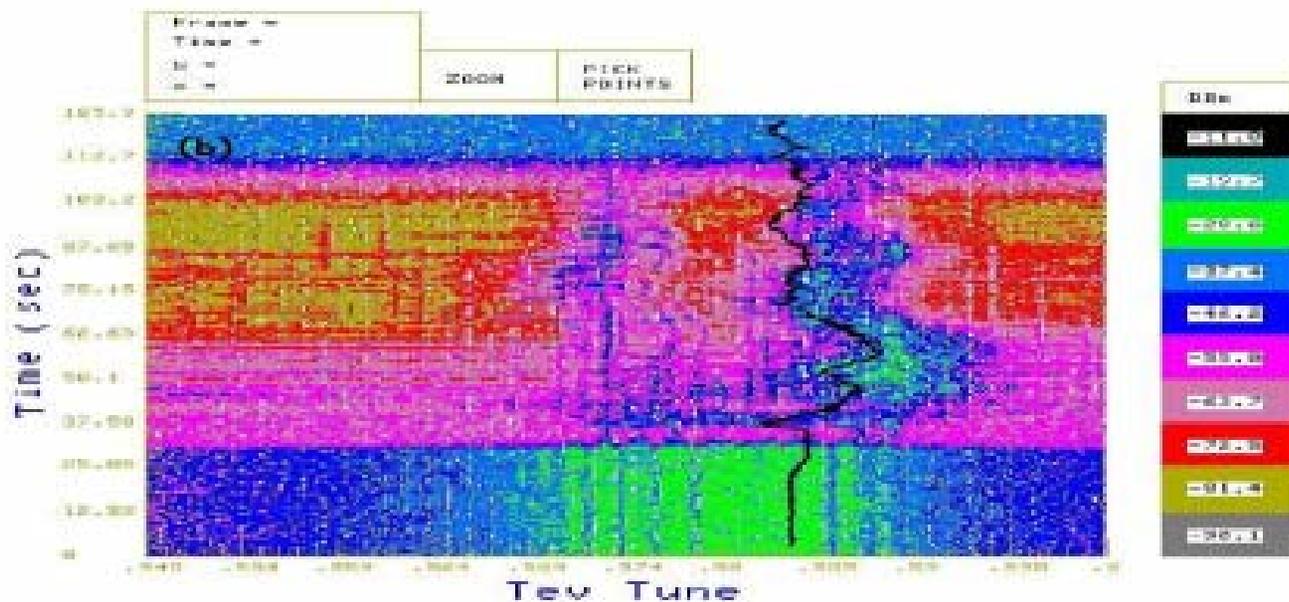
Comparison between uncoalesced and coalesced response

C.Y.Tan

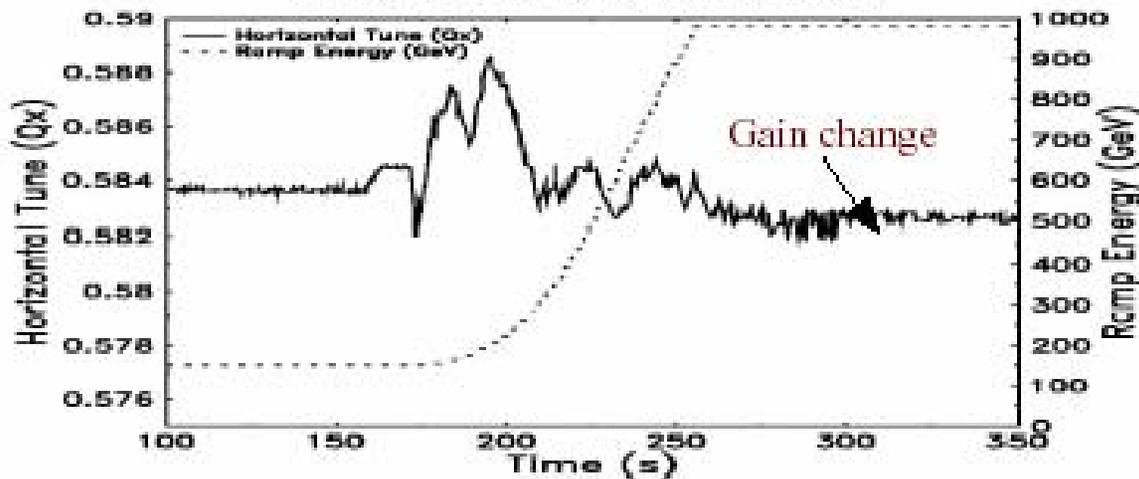


# TuneTracker

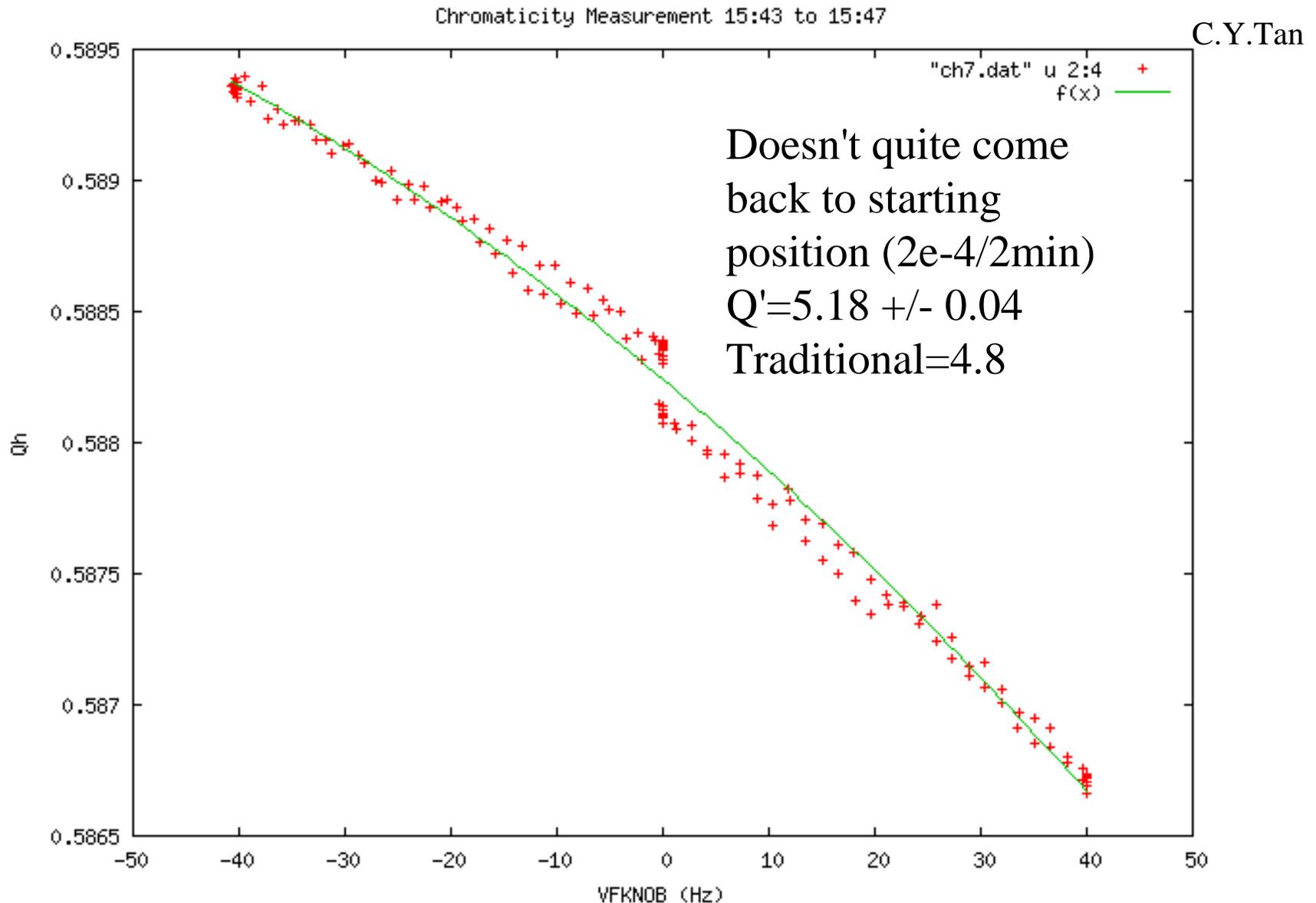
C.Y.Tan



Tracking Up the Ramp (Proton Helix)



# Q' Measurements with Tune Tracker



# Other Diagnostics:

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- 7 um FWs @E11 ~acceptable for CDF&D0
  - Lattice functions to be remeasured
- SBD reports "correct" dP/P and long-Emittance
  - RWM profiles saved every 10 min
  - Raw data available at any time
- Longitudinal phase monitor
  - All 72 bunches, fast (200Hz), <0.1 degree
  - Under development
  - Already helpful for long instability studies
- HLS systems at B0/D0 operational
- Progress with SyncLite Monitor
  - Pbar pickup mirror goes in at start of HEP
  - Better understanding of images/systematics
  - Reports believable data/waiting for lattice functions
- Q' from 21MHz Schottky under studies
- IPM electronics to be ready for installation ~May'05

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# Back-up slides

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# Getting More MD Time: 7.4hr/wk vs 5.3 in FY04

FY'05 Tev MD Study Time		as of 03/05	Requested
#	Project	MD Shifts	MD Shifts
1	New Helix/Separators	0.9	0(startup)
2	New BPMs	0.05	7.75
3	Lattice/28 cm beta*	0.85	4.5
4	Octupoles/Instabilities	7.5	5
5	TEL	0.4	2.75
6	Injection Dampers	0	5
7	Tune Tracker	1.6	3
8	Dampers on Ramp	0.75	1
9	IPM	0	0.875
10	Q' x,y /Coupling on Ramp	0.5	0.875
11	Orbit Stabilization	0	2
12	b2 Studies	0.4	4
13	Crystal Collimator	0	5
14	23 RFC bunch spacing and Other Beam-Beam	0	1.875
15	FWs/SL/OTR/Other diagnostics	0.3	2.125
16	BLM Upgrade/Other Controls	0	1
17	TBT/Coupling/Nonlinear/beta* CPM	0.25	1.25
<b>Total shifts</b>		<b>13.5</b>	<b>48</b>

MD hrs/week **7.4 (5.3 in FY04)** **9.6**

18 Maintenance studies hrs/week **5.3 (11 inFY04)** as needed

# Tevatron Diagnostics Score Card

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- DCCT t:beam done
- Fast Bunch Integrator c:fbipwg done
- Sampled Bunch Display t:sbdpcs done (uncoalesced?)
- Injection tune up BLT done
- New BPMs t:vpa33 1/3 done
- Abort Gap Monitor t:agigi2 done
- 1.7GHz Schottky t:tulaht done
- Flying Wires t:ahemit 2 of 3 done (7u wire)
- SyncLite t:slpsv understood, needs recalibr
- Longitudinal phase monitor t:lpm001 commissioning
- IP waist analysis D0 done, CDF ongoing
- HLS systems (Water levels) at B0/D0 commissioning
- New Beam Loss Monitors ongoing
- TuneTracker ongoing
- Q' from Head-Tail under evaluation
- Ionization Profile Monitor and OTR ready to install ~May'05
- Emittance blowup at injection t:bltvd not fully operational

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# Tevatron Alignment Status

J.Volk, V.Shiltsev, et al

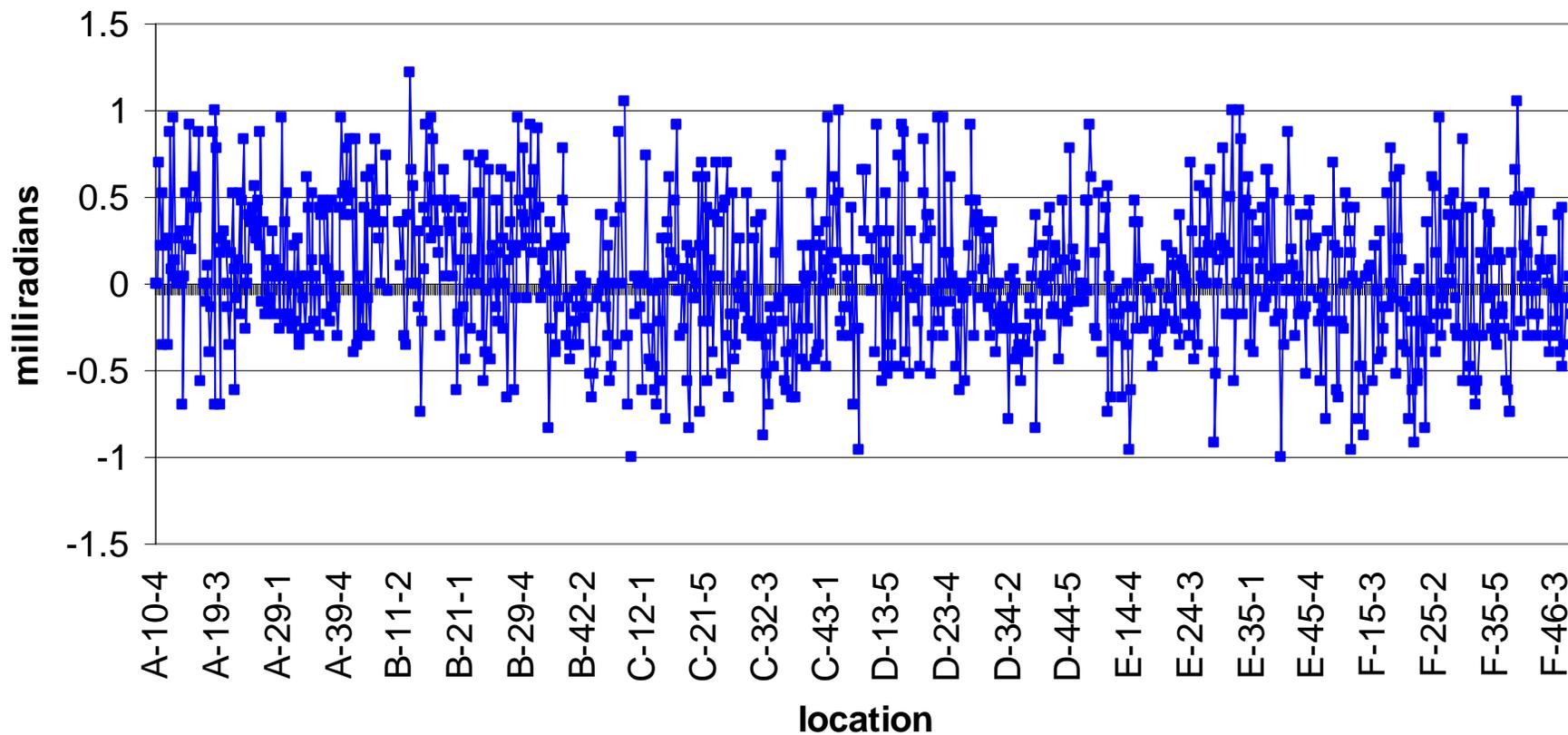
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# Tevatron Magnet Roll Fixture



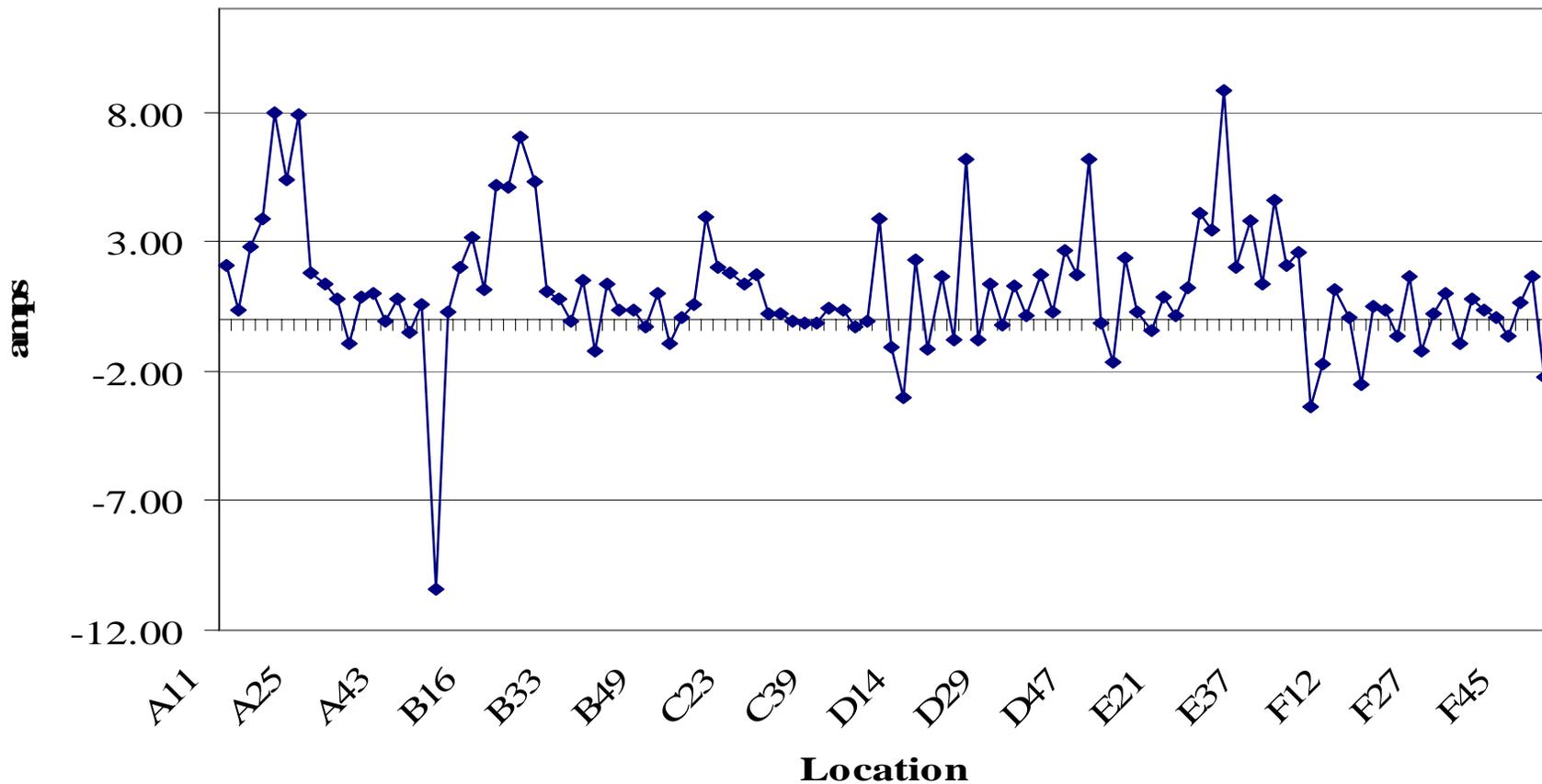
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## Roll Measurements November 2004 all magnets



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## Change in Corrector Currents 2003-2004



# What has been done

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- Magnet roll is now less than 1 mr around the ring. Was as high as 8 mr in 2003.
- Some 50 bad stands have been replaced.
- Low beta quads at B0 and D0 have been aligned such that IP is very close to what both experiments desire
- Separators at B0 and D0 have been realigned. Some were out as much as 70 mr.
- Water levels have been installed at B0 low betas B sector Both BINP and Fermi systems and at E sector Fermi system. We see quenches and also motion of quads with suspect bad stands
- low beta quads at B0 Q3 and 4 supported from floor. This has reduce vibration problems backgrounds.
- TevNet a new alignment network has been installed. All dipoles quads, and spools have been measured relative to this network Norm Gelfand is working on comparing these data with model of Tevatron to find where we have mis aligned magnets.

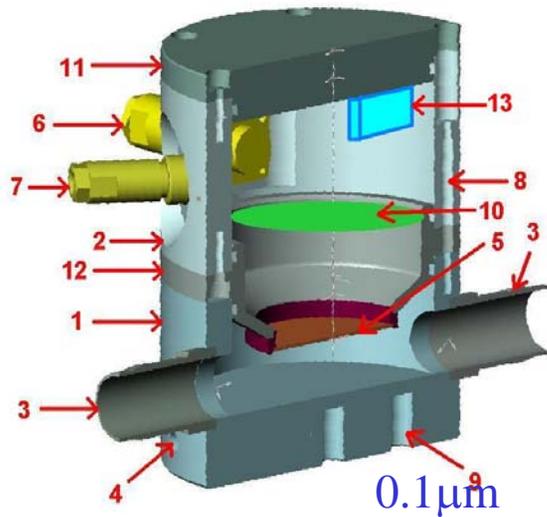
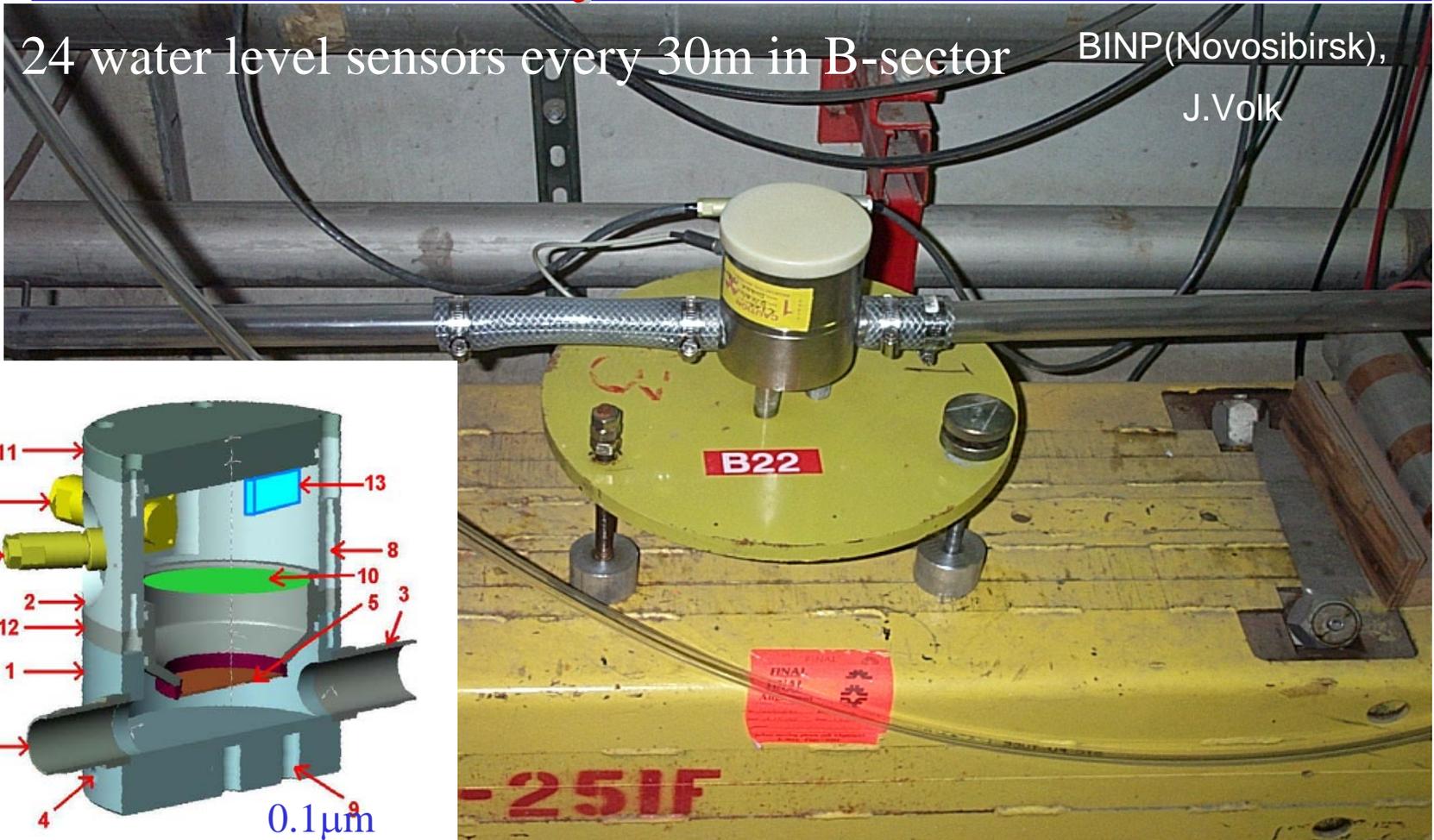


# On-Line Survey: B-sector + B0 + D0

24 water level sensors every 30m in B-sector

BINP(Novosibirsk),

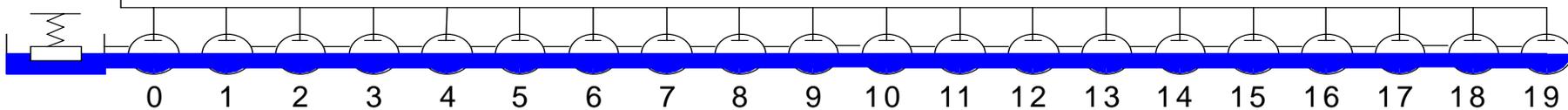
J.Volk



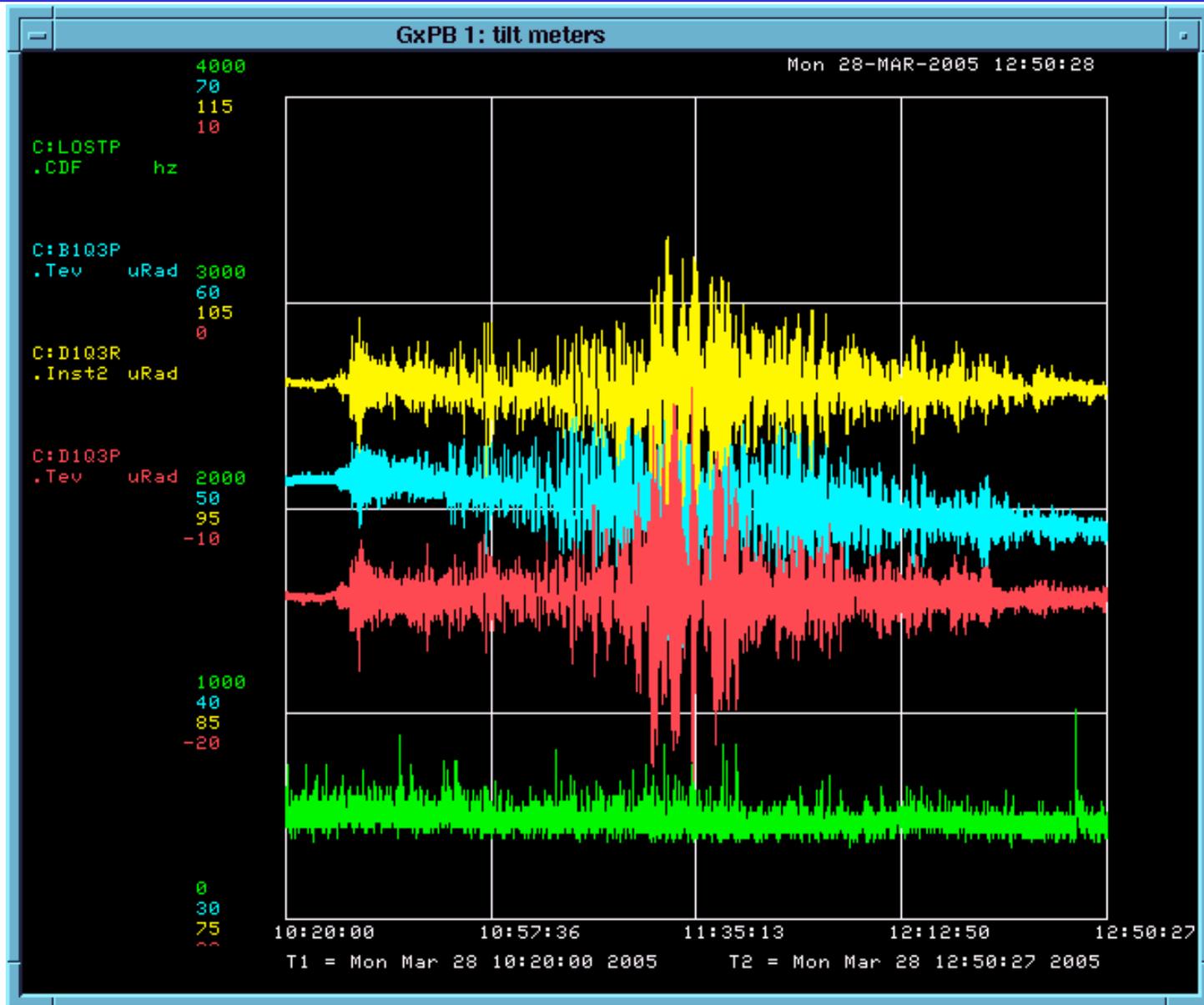
0.1µm  
resol'n)

PC

Data Flow



# M8.7 Sumatra Quake this Mon – in Tev



# What needs to be done

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- Install Fermi system water levels A,C,D F sectors monitor motions of ring
- Identify all mis aligned magnets for quads more than 0.25 mm from ideal for dipoles 1 m from ideal is sufficient then re align these. Will use TevNet data and Gelfands model to do this.
- Replace some 50 more bad stands around the ring.
- Raise CDF detector? The low beta at B0 Q2,3,4 are 1.25 mm below magnets at A48 and B11 This will reduce corrector currents and improve aperture.
- Start using Laser tracker to align regular cell magnets This eliminates optical tooling and hand written notes. Speeds data acquisition and transmission of information to Tev dept from AMG (from few months to 2 weeks).
- Speed up LB quad alignment from 24-30 hrs to <16 hrs; use EXCEL spread sheets to align low beta quads and other straight sections. This eliminates errors to to hand writing data.
- Re measure network to understand how machine is moving relative to a fixed point.
- Make installed HLSs at CDF and D0 work reliably