Tevatron Performance Since March'02 and FY'03 Plans

Vladimir Shiltsev

Fermilab

Contents

- Luminosity progress
- Physics progress
- Diagnostics Progress
- Shutdowns
- FY'03: Luminosity goal
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- FY'03: Resources

Luminosity Formula

$$L = \frac{10^{-6} f\ B\ N_p N_{\bar{p}} (6\beta_r \gamma_r)}{2\pi\beta^* (\varepsilon_p + \varepsilon_{\bar{p}})} H(\sigma_l / \beta^*)$$

(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)

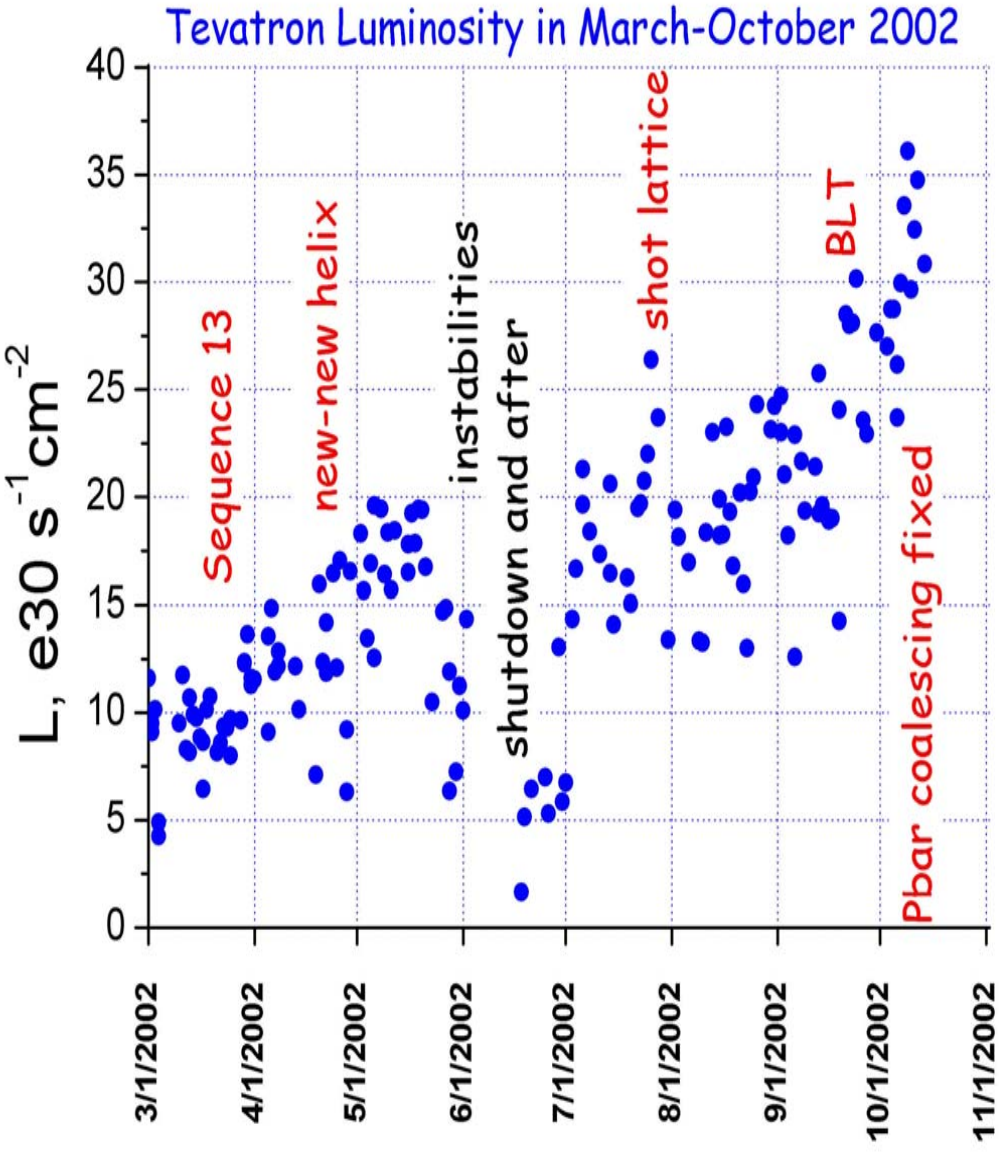
ε_p , ε_{pbar} = transverse emittances (π-mm-mrad)

σ_l = bunch length (cm)

Goals and Current Performance

Parameter	*Run IIa Goals*	*Current Performance*	
Protons/bunch	*270e9*	*170e9*	
Antiprotons/bunch	*30e9*	*22e9*	
Total Antiprotons	*1080e9*	*800e9*	
Peak Pbar Production Rate	*200e9*	*120e9*	*/hr*
Pbar: Inj. -> Low β efficiency	*0.90*	*0.75*	
Pbar: AA -> low β efficiency	*0.81*	*0.60*	
Proton emittance (95%, norm)	*20*	*20*	*πmm-mr*
Pbar emittance (95%, norm)	*15*	*18*	*πmm-mr*
Beta @ IP	*0.35*	*0.35**	*m*
Beam Energy	*1000*	*980*	
Bunch length (proton, rms)	*0.37*	*0.61*	*m*
Bunch length (pbar, rms)	*0.37*	*0.54*	*m*
Form Factor (Hourglass)	*0.74*	*0.62*	
Typical Luminosity	*8.1e+31*	*3.2e+31*	*$cm^{-2}sec^{-1}$*
Integrated Luminosity	*16.*	*6.7*	*pb^{-1}/week*

Tevatron since March 2002



- 157 HEP stores
- >70 pb-1 to each detector
- 3-fold increase in peak luminosity from 11.8e30 to 36.1e30
- 18 peak luminosity records since 03/01/02
- Run I record of 25.0e30 broken on 7/26/2002
- 6 Tevatron L records afterwards
- 2 weeks between records in average…
- … though records come in bunches after significant improvements, e.g., →

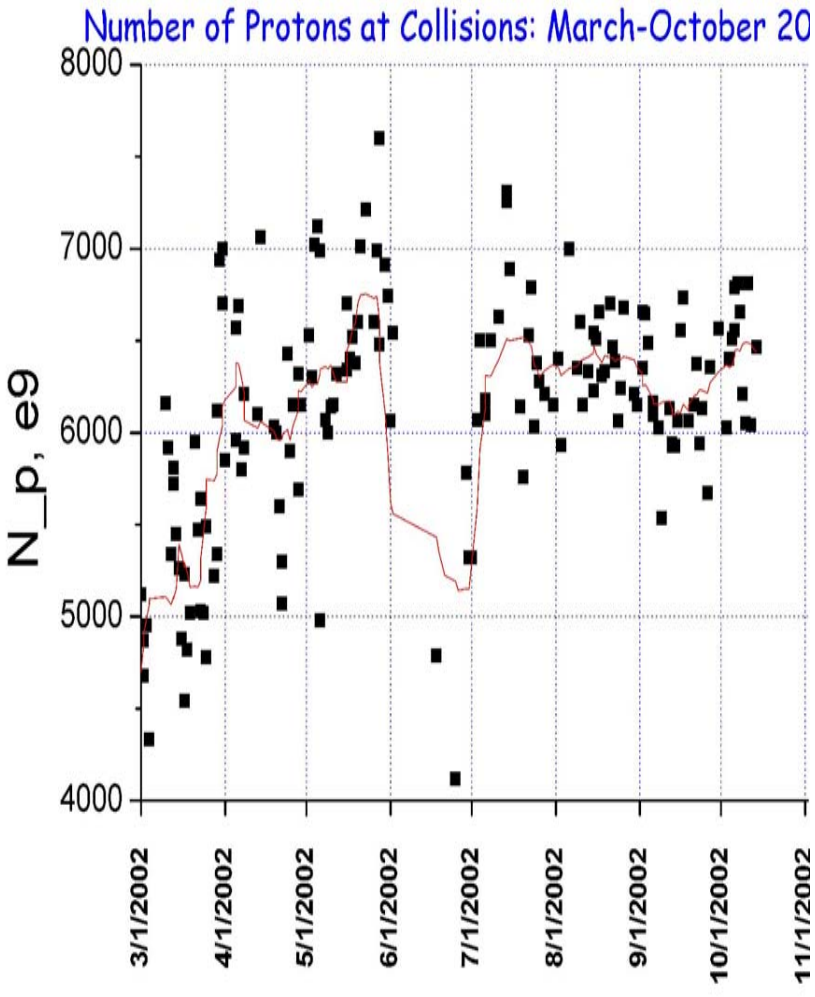
Major Reasons for $\mathcal{L}$-progress since Mar'02

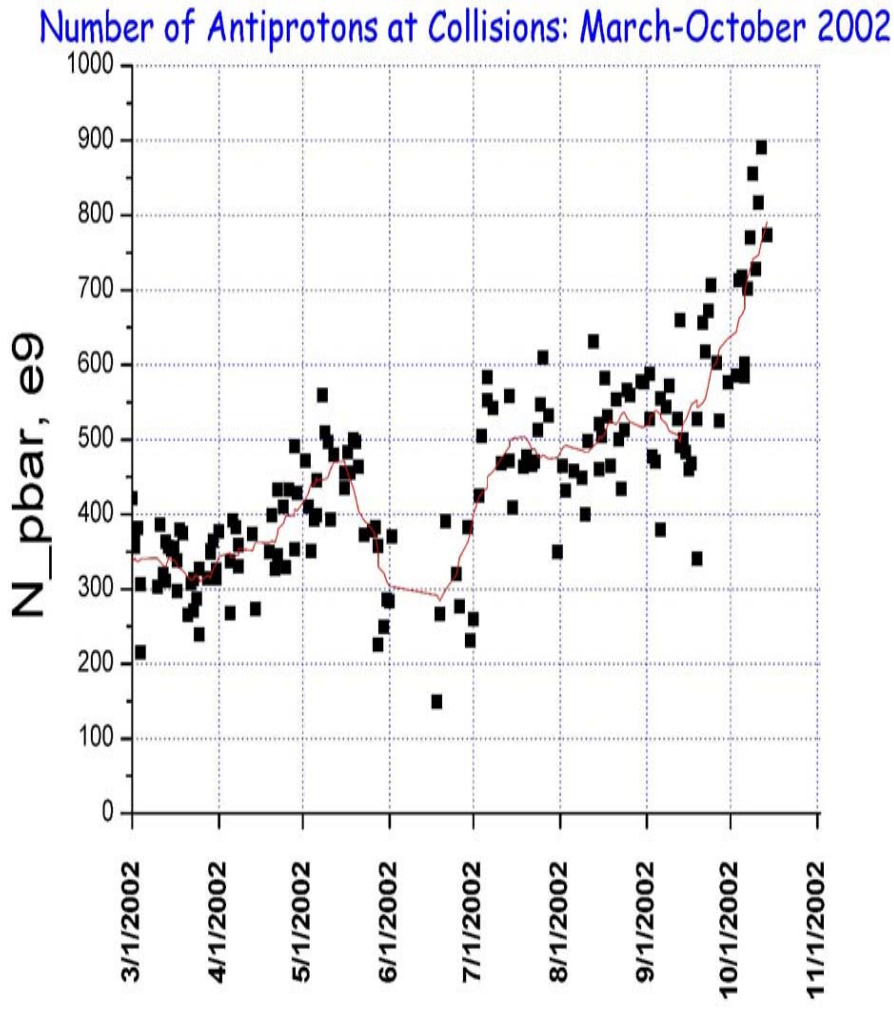
• "Sequence 13" fixed	Tev	x 1.40
• "New-new" injection helix	Tev	x 1.15
• "Shot lattice"	AA	x 1.40
• Pbar emittance at injection	Tev/Lines	x 1.20
• Pbar coalescing improvement	MI	x 1.15
	total	x 3.1

….plus additional improvements in the Tevatron:

- Longitudinal dampers to stop $\blacklozenge_s$ blowup
- Tunes/coupling/chromaticities at 150/ramp/LB
- Orbit smoothing
- Separators scan
- F11 vacuum

Beam Intensities in 2002

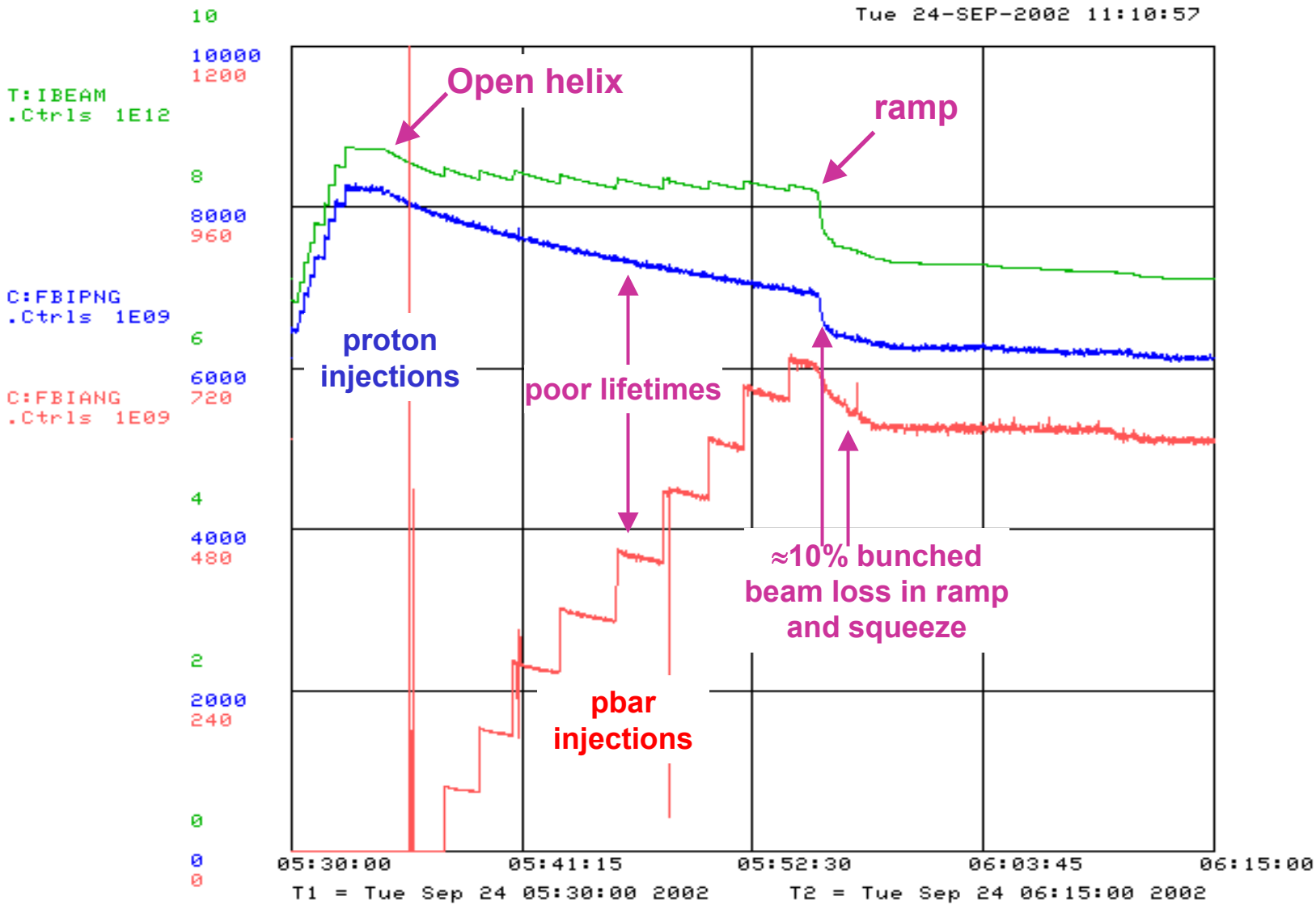




N_p : Oct/Mar=6500/4700=1.40

N_pbar : Oct/Mar=820/330=2.50

Tevatron Efficiencies



Antiproton Efficiencies Set by Beam-Beam

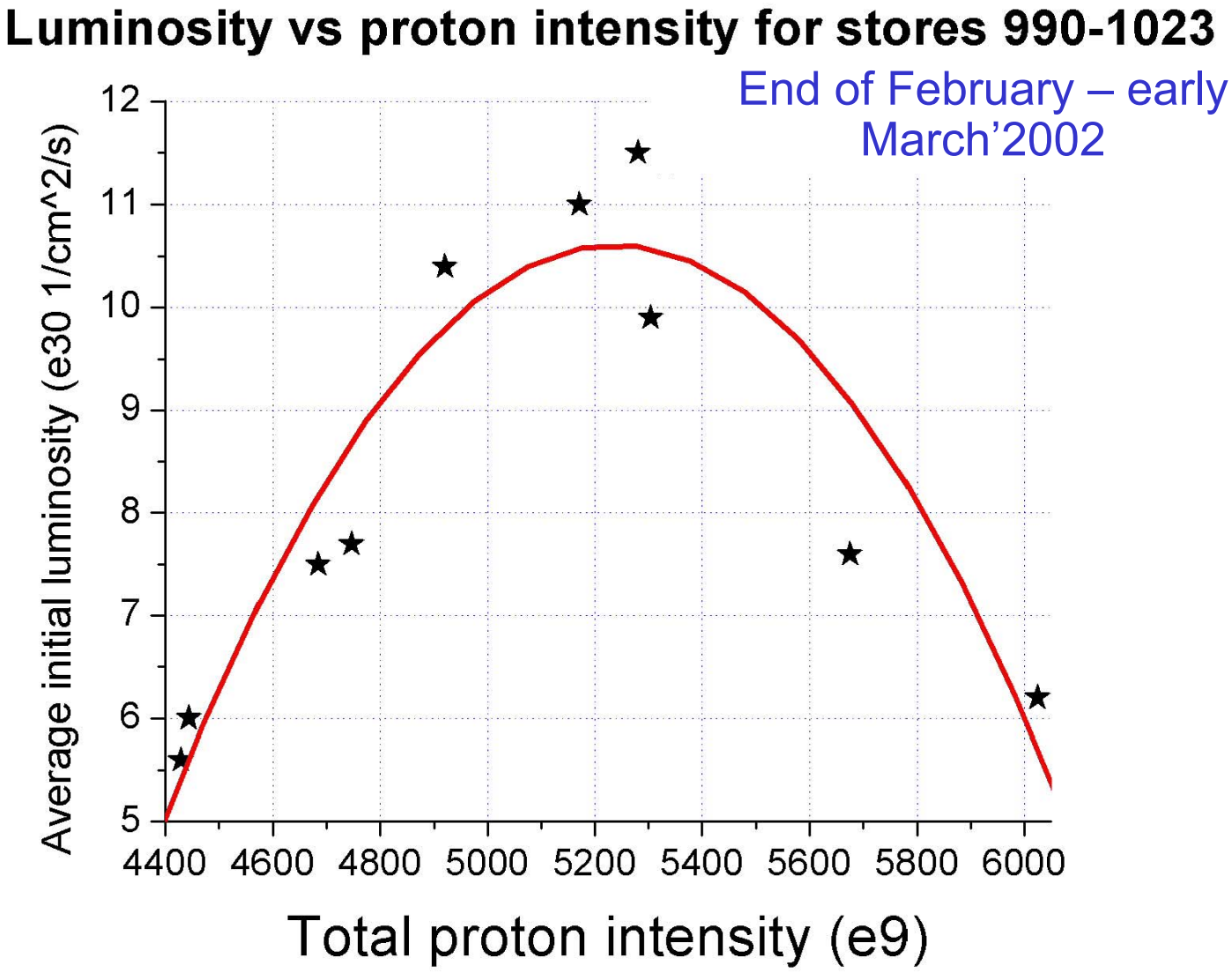
	Mar'02 *	Oct'02 **
Protons/bunch	140e9	170e9
Pbar loss at 150 GeV	20%	9%
Pbar loss on ramp	14%	8%
Pbar loss in squeeze	22%	5%
Tev efficiency Inj→low beta	54%	75%
Efficiency AA→low beta	32%	60%

* average in stores #1120-1128

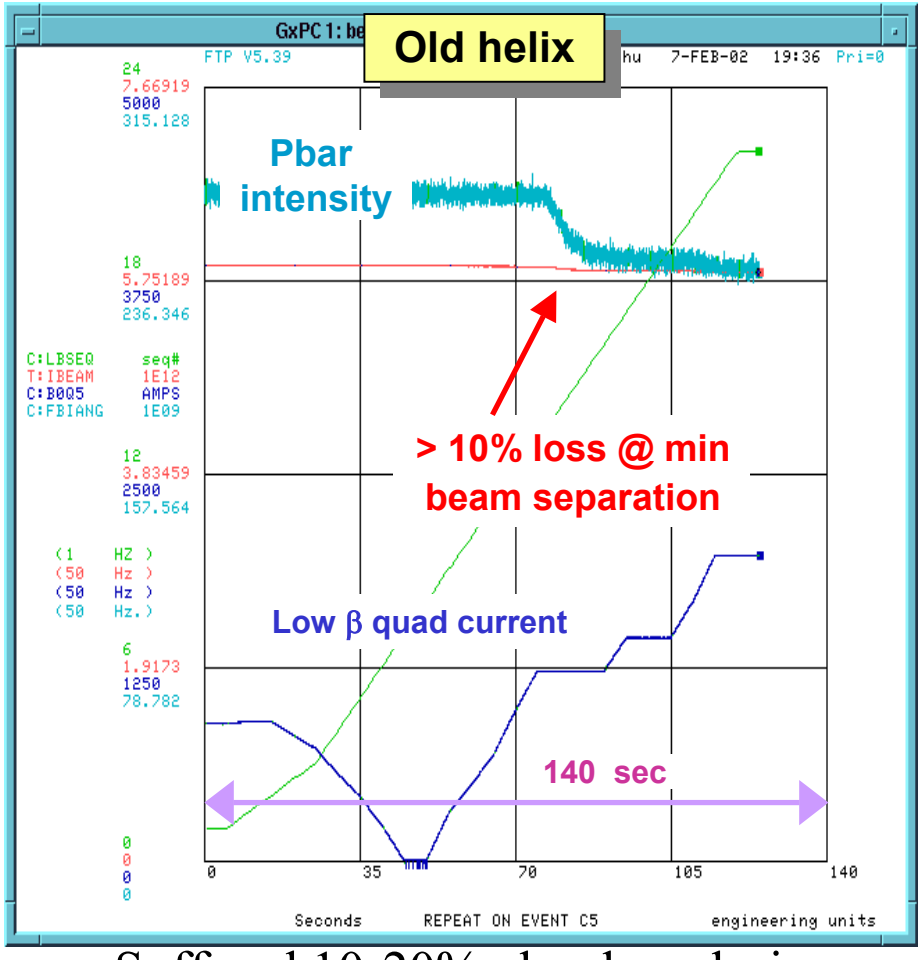
** average in stores #1832-1845

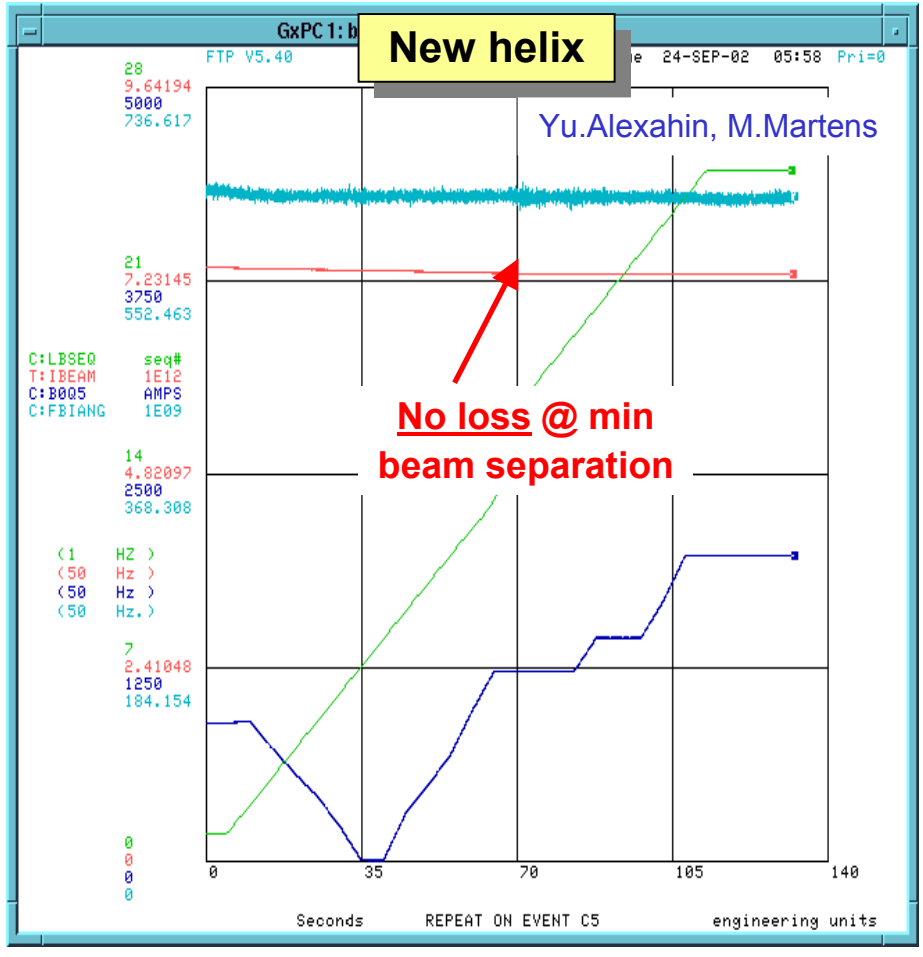
Pbar transfer efficiency depends on N_p, helix separation, orbits, tunes, coupling, chromaticities in the Tev and beam emittances at injection

“Sequence 13” Affects Luminosity



Pbar Loss During Squeeze ("Sequence 13")

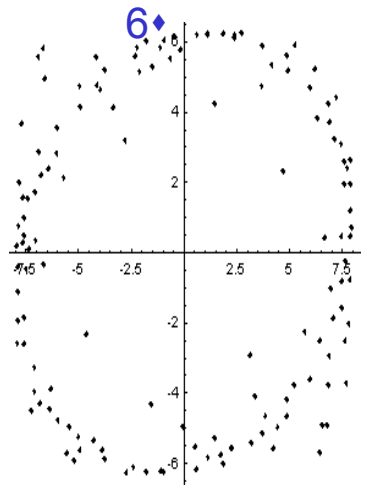




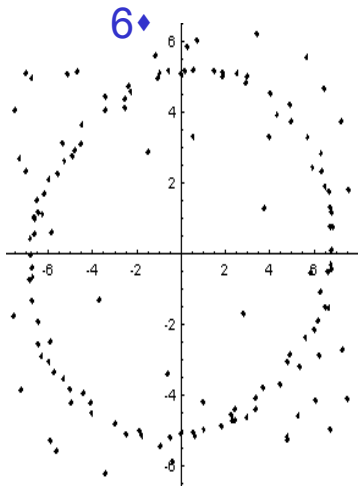
- Suffered 10-20% pbar loss during squeeze
  - –During transition from injection to collision helix
  - –Minimum beam separation was only ~1.8σ
  - –New helix increased min beam separation to ~3σ, loss essentially eliminated

Beam-Beam Effects in Squeeze

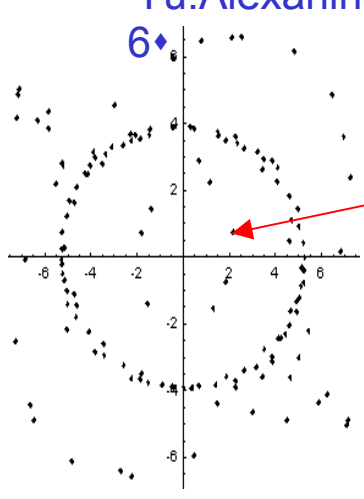
Yu.Alexahin



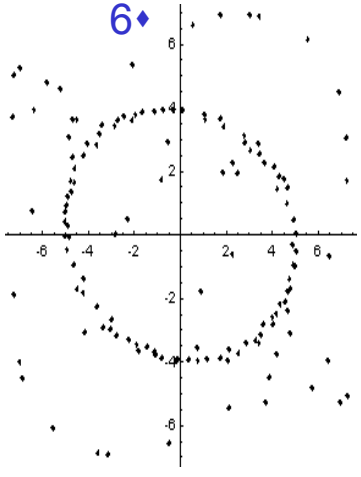
t = 0



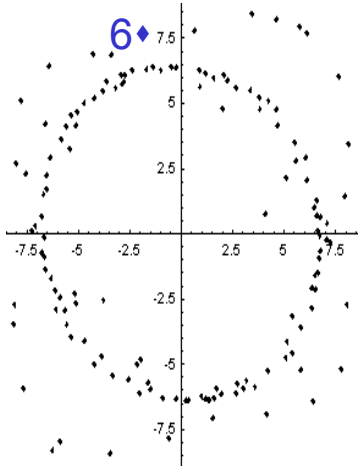
t = 0.1



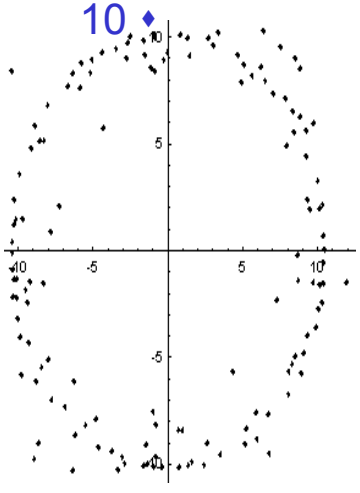
t = 0.3



t = 0.4



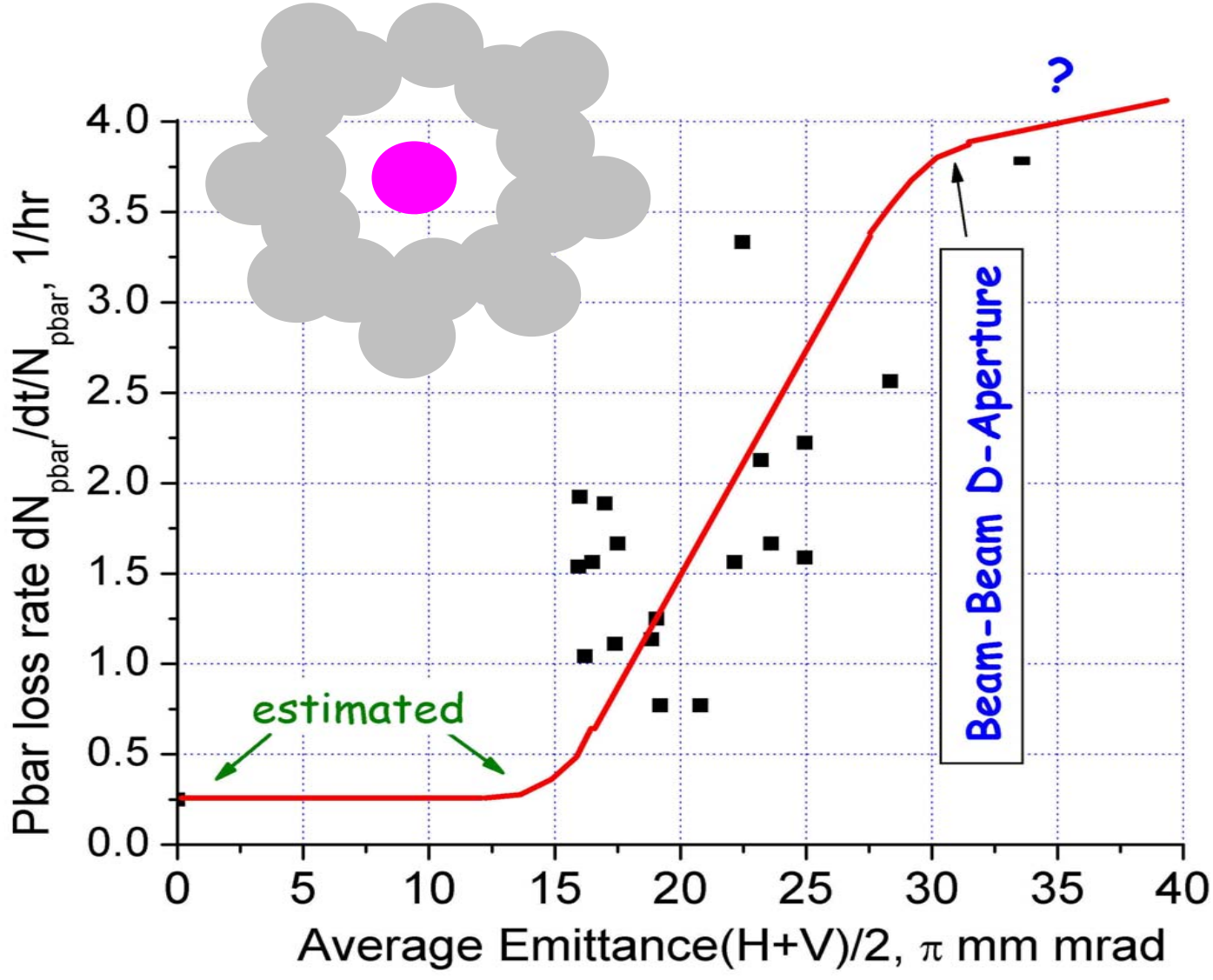
t = 0.7



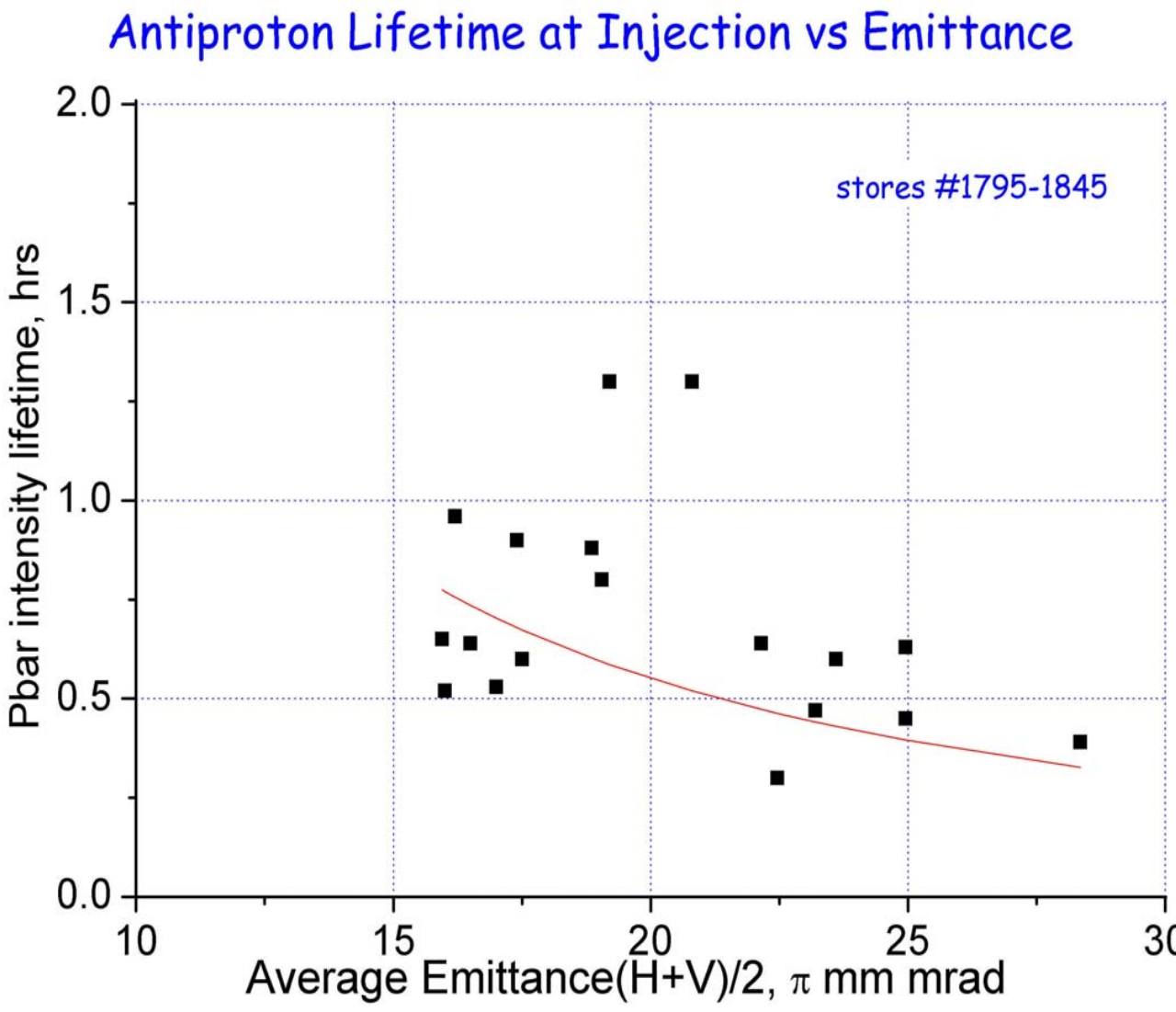
t = 1

- Minimum beam-beam separation turned out to be only **1.8σ**
- Normalized separations $\Delta x/\sigma_x$, $\Delta y/\sigma_y$ at all possible IPs with 36×36 collision cogging in sigma's for the reference emittance $\varepsilon_n = 15\pi$ mm·mrad. t = 0 – seq13, t = 1 – seq14 (see plots)
- The separation has been increased to 2.7σ by adding 2 more breakpoints, also speed of the squeeze doubled there and the loss gone
- Lesson – only minimum separation matters

Proton Beam as "Soft Donut Collimator"

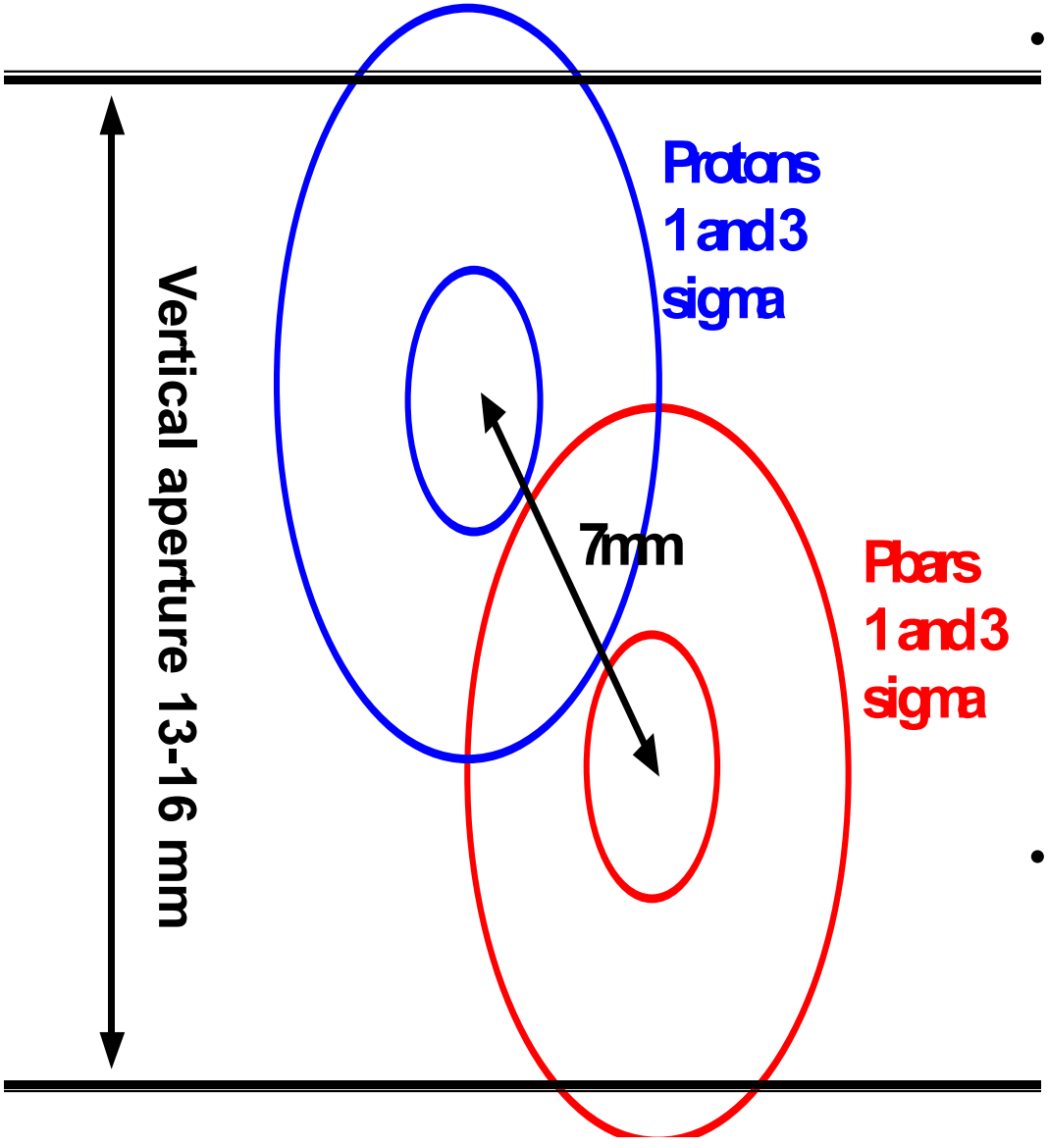


Pbar Losses vs Emittance



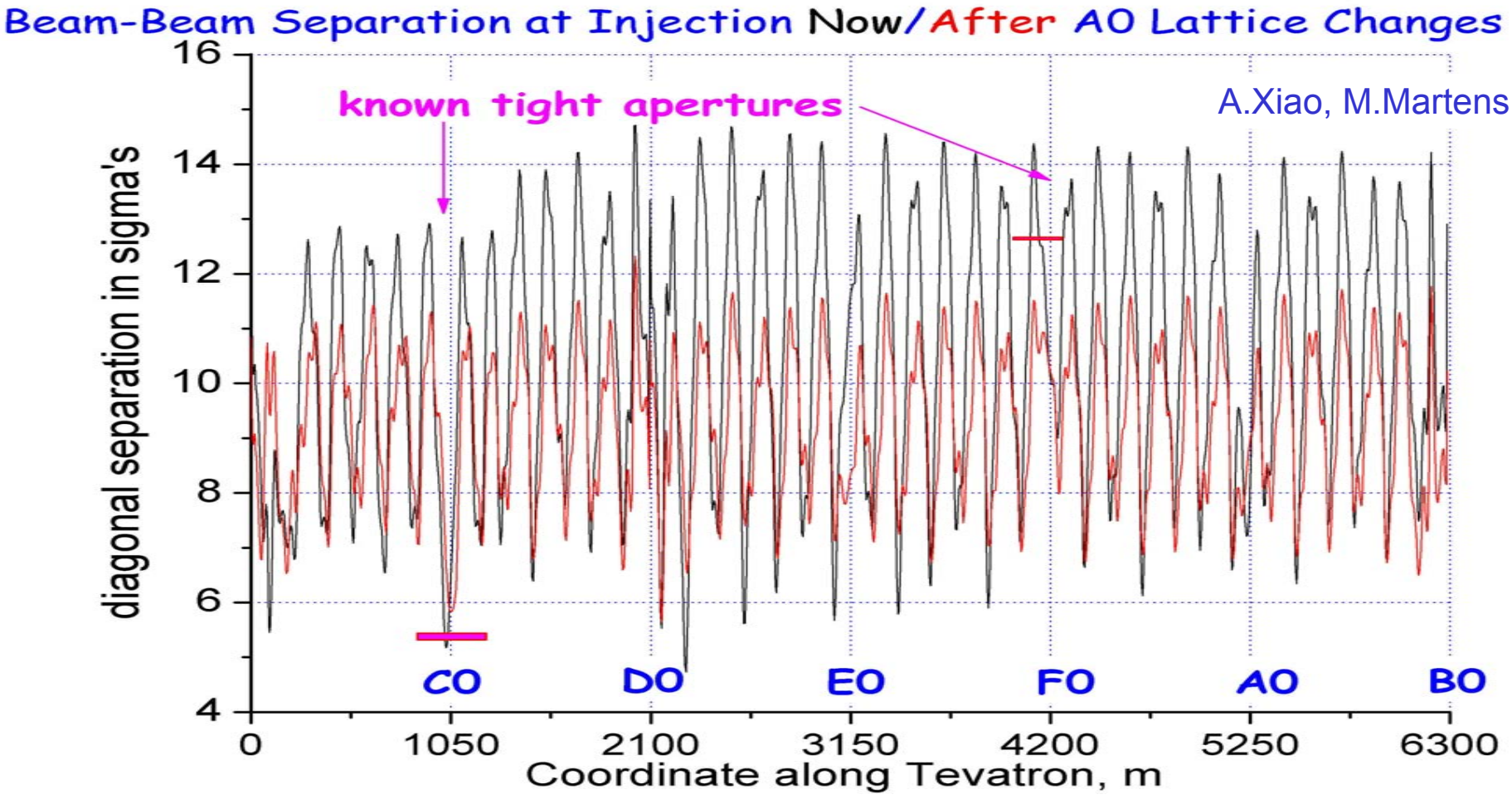
- pbar losses strongly depend on N_p and pbar emittances
- → reduce emittances – AA "shot lattice", fix injection errors, match injection lines
- increase beam-beam separation (helix) → C0 aperture, A0 lattice
- expected ♦✪A(2.2-3)

Lifetime Issues at 150 GeV



- LR beam-beam effects poor pbar lifetime 1-2 hr
  - Pbar lifetime depends on emittances, N_p and bunch number
  - Tried to modify and expand the helix, until limited by apertures ("new-new helix")
  - Replace lambertsons @ C0 – gain 25 mm vertically
  - Modify high β section at A0 formerly used for fixed-target extraction
- Poor proton lifetime on helix ~ 2 hr
  - depends on chromaticity
  - Instability prevents lower chromaticity (now 8)

Lattice Modification at Sector A0



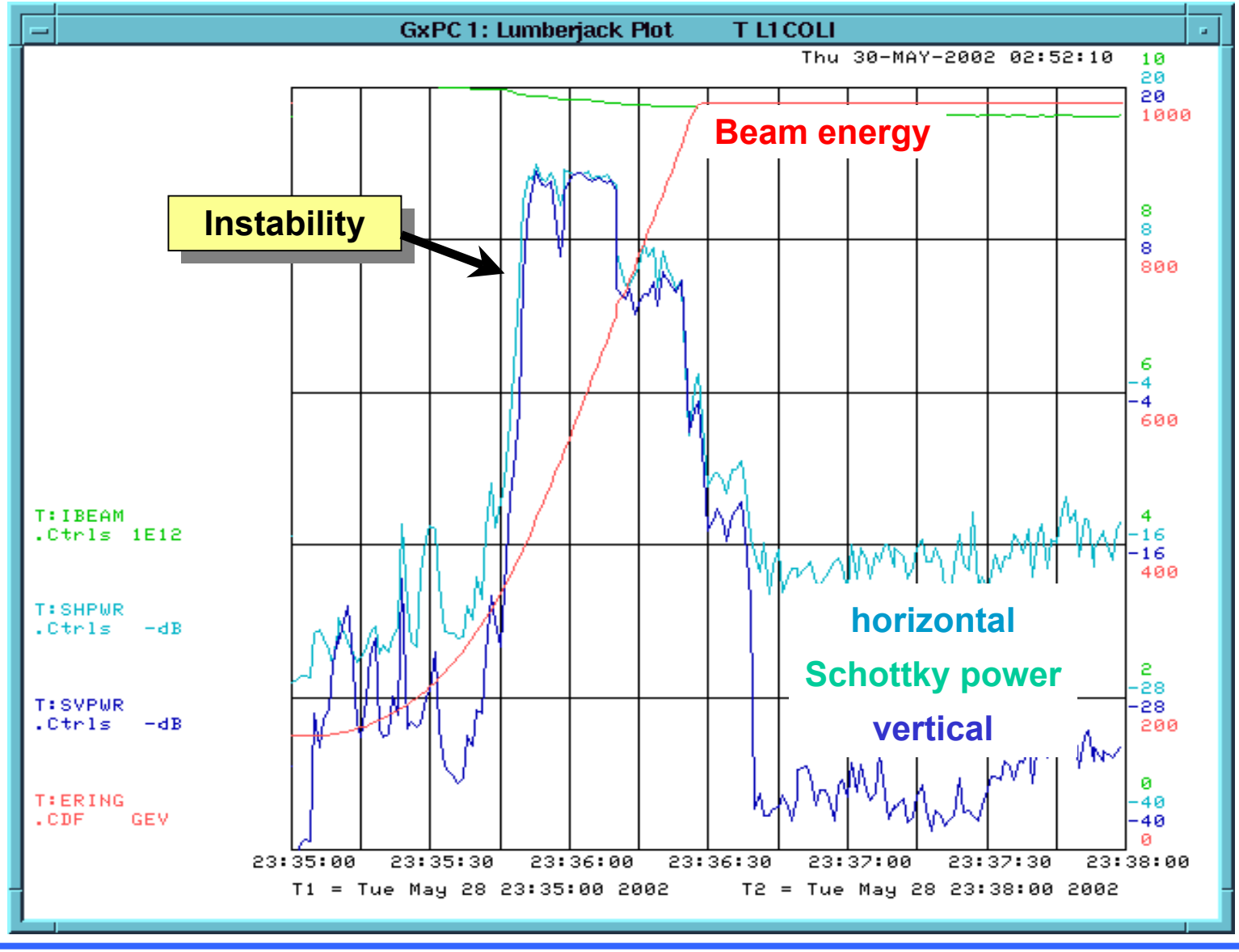
- Proposed modification promises 16% larger minimum separation at injection (5.6 vs 4.7 ♦) and similar at collisons
- very important at injection where aperture is tight – new lattice reduces maximum beam-beam separation by about the same 16%

Proton Transverse Instability

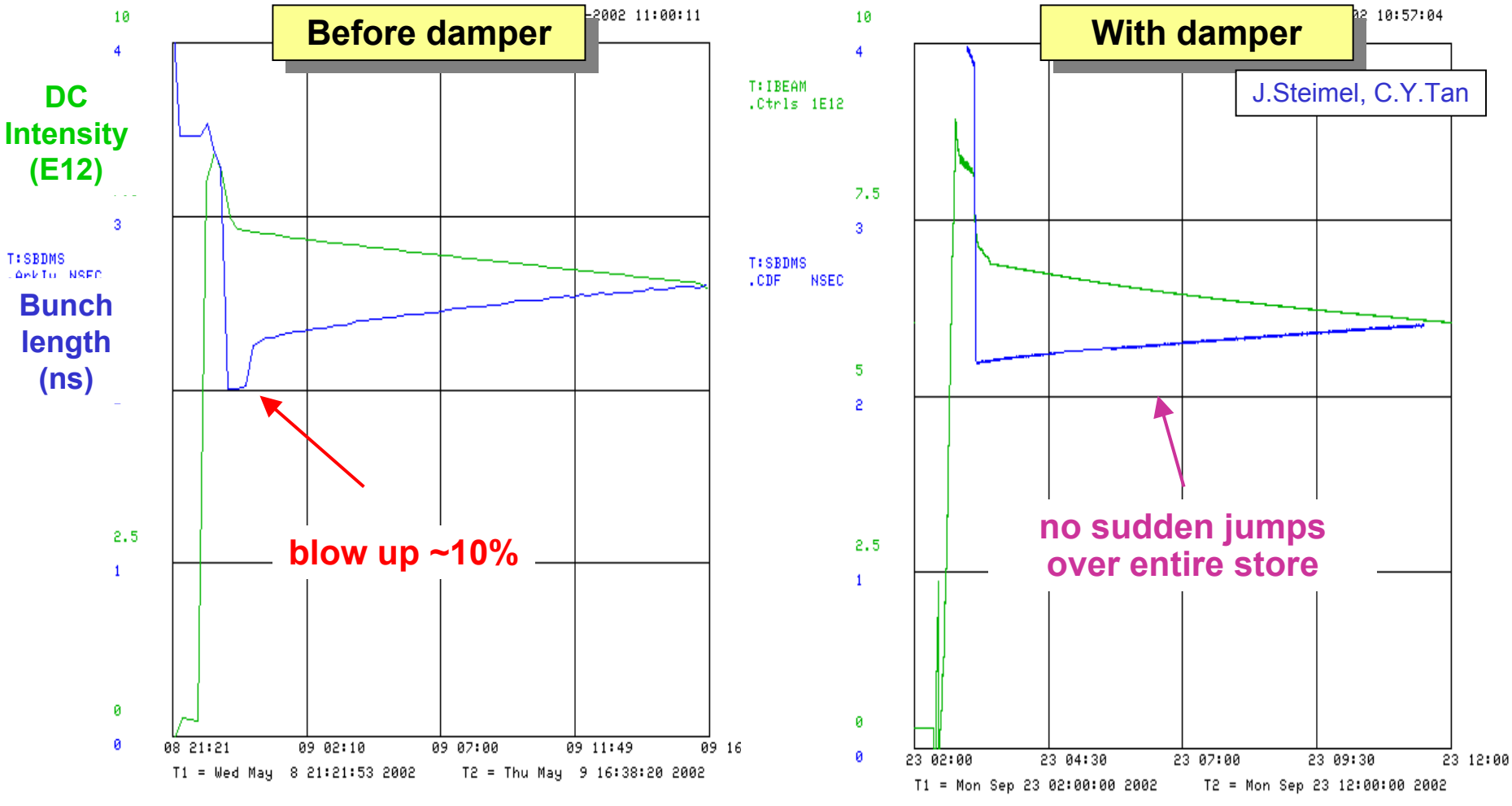
- Intensity-dependent: appears above ~170E9/bunch
  - Single bunch weak head-tail phenomenon (?)
- Can occur at 150 GeV, up the ramp, at 980 GeV
  - Schottky powers rise quickly
  - p/pbar emittances blow up for individual bunches
- Try to prevent/control instability via:
  - Raising chromaticities (8 @150, >20 at 980)
  - Adjusting coupling and tunes
  - Limiting p intensity to ~240E9/bunch at injection
  - More pbars help to stabilize protons
- Constructed bunch-by-bunch transverse dampers
  - hor chromaticity at injection lowered 8→ 3 at 150

… but the problem is not solved yet…

Transverse Instability On Ramp



Bunch Length Blowup During Stores

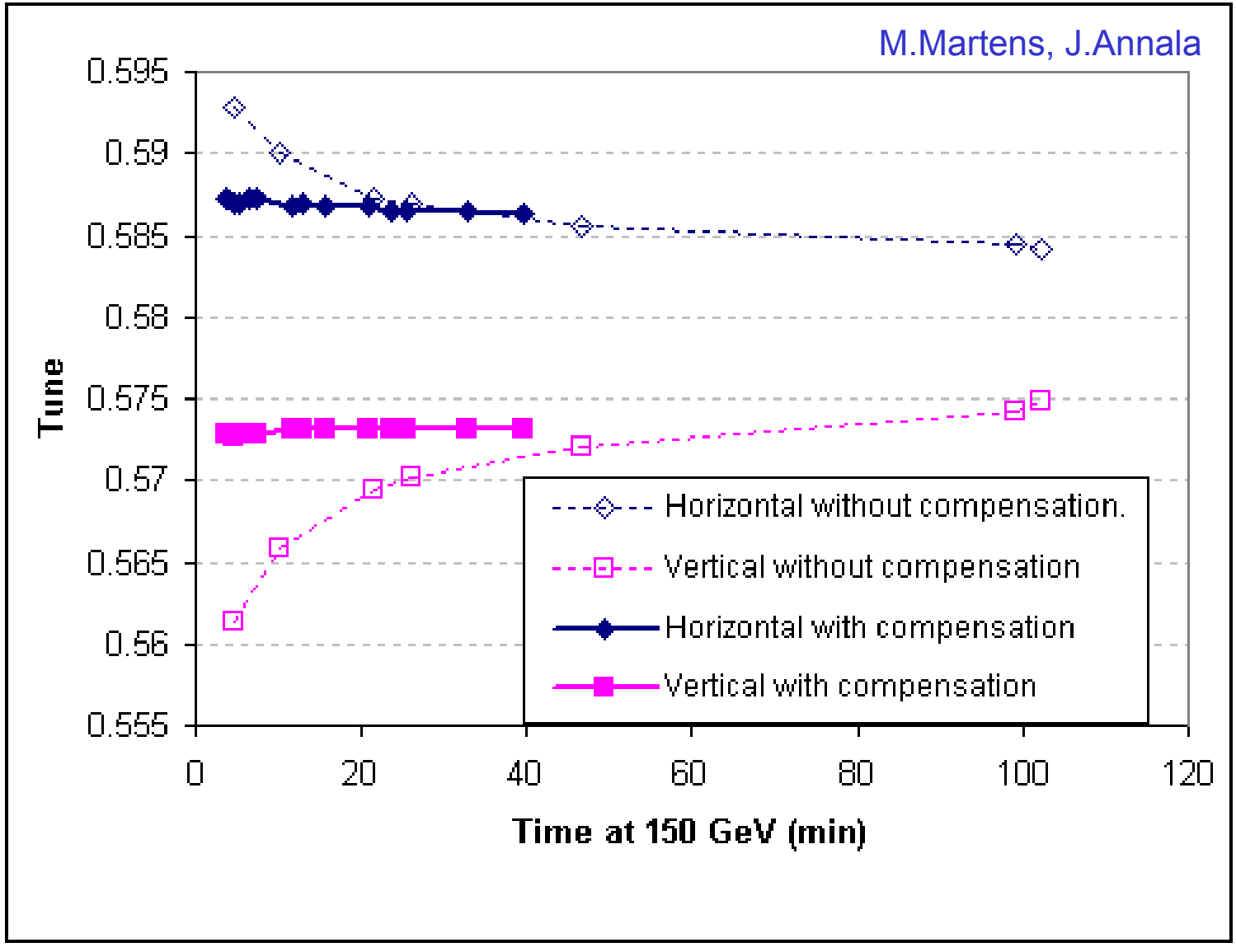


- Intensity-dependent, leads to significant CDF background rise
- Usually only one or a few bunches would suffer
- Problem solved by bunch-by-bunch longitudinal damper

Tune and Coupling Drifts at 150 GeV

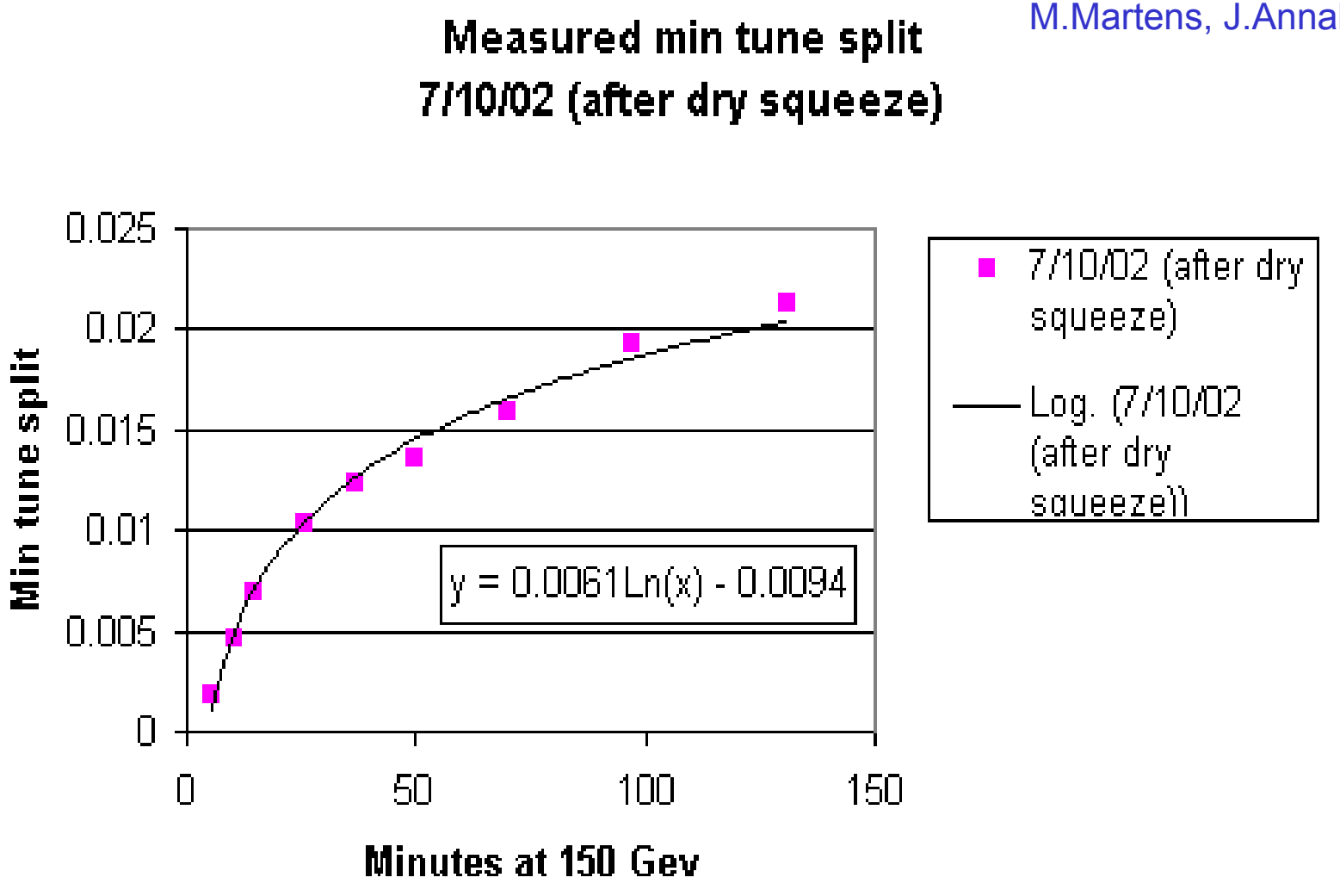
- Chromaticity drift from b_2 component in dipoles well-known from Run I
  - Compensated automatically by varying sextupole currents
- New for Run II, tune and coupling also vary logarithmically after returning to injection energy
  - Makes injection tune-up more difficult
- Likely caused by persistent currents in the superconducting dipoles and quadrupoles
- Recently implemented compensation with normal, skew quads similar to chromaticity scheme
  - Tune drift now < 0.001 after 3 hours
  - Coupling drift not measurable

Tune Drift @ 150 GeV

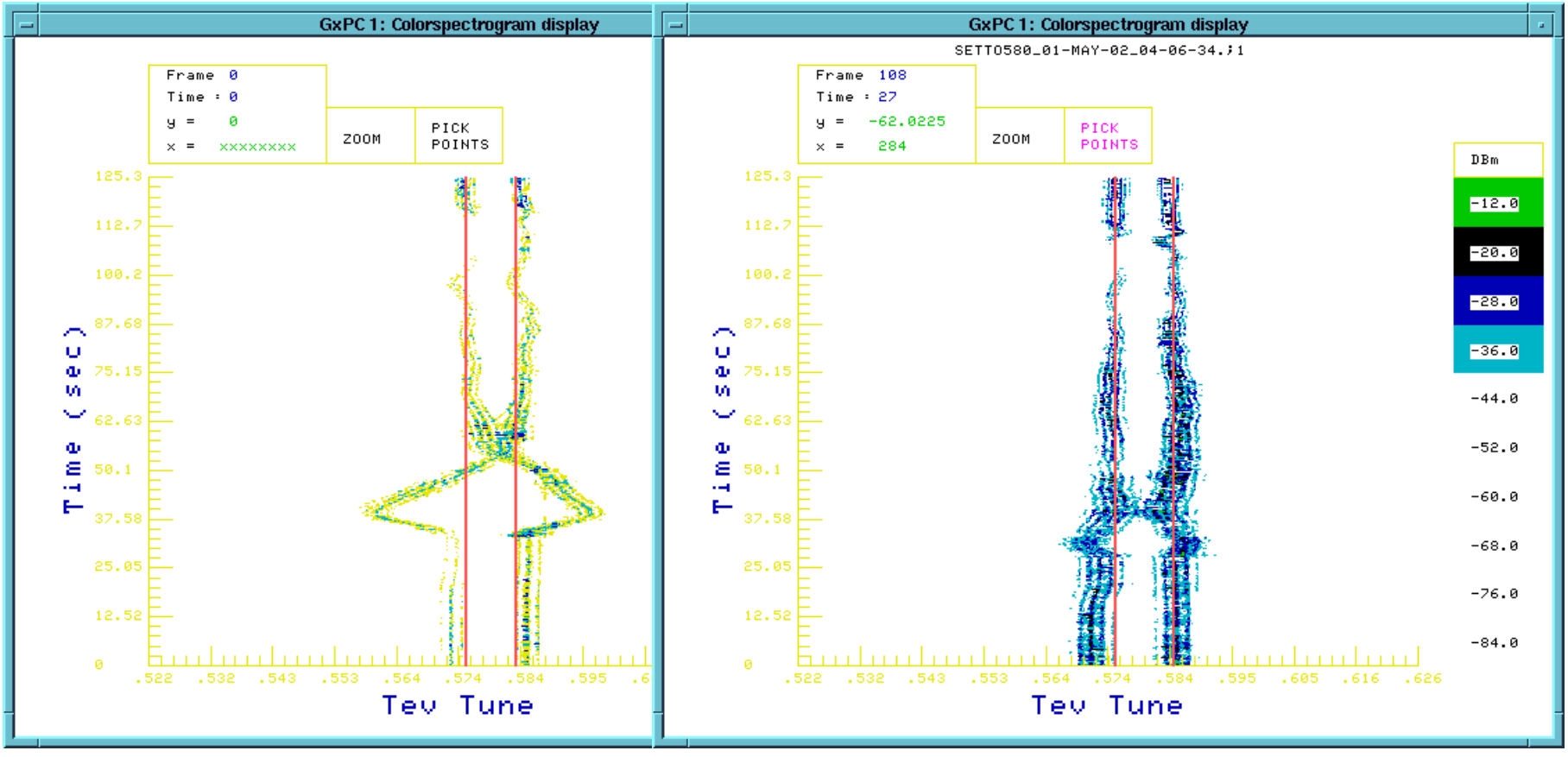


Coupling Drift @ 150 GeV

M.Martens, J.Annala

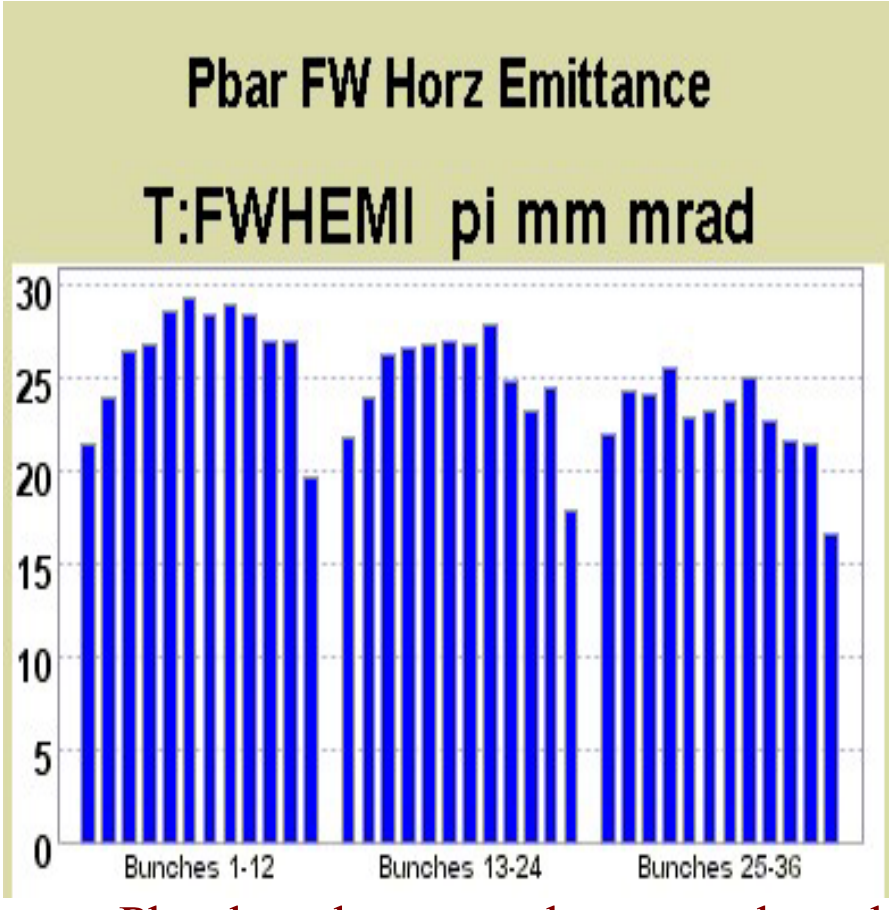


Tune Variations on Ramp/Squeeze

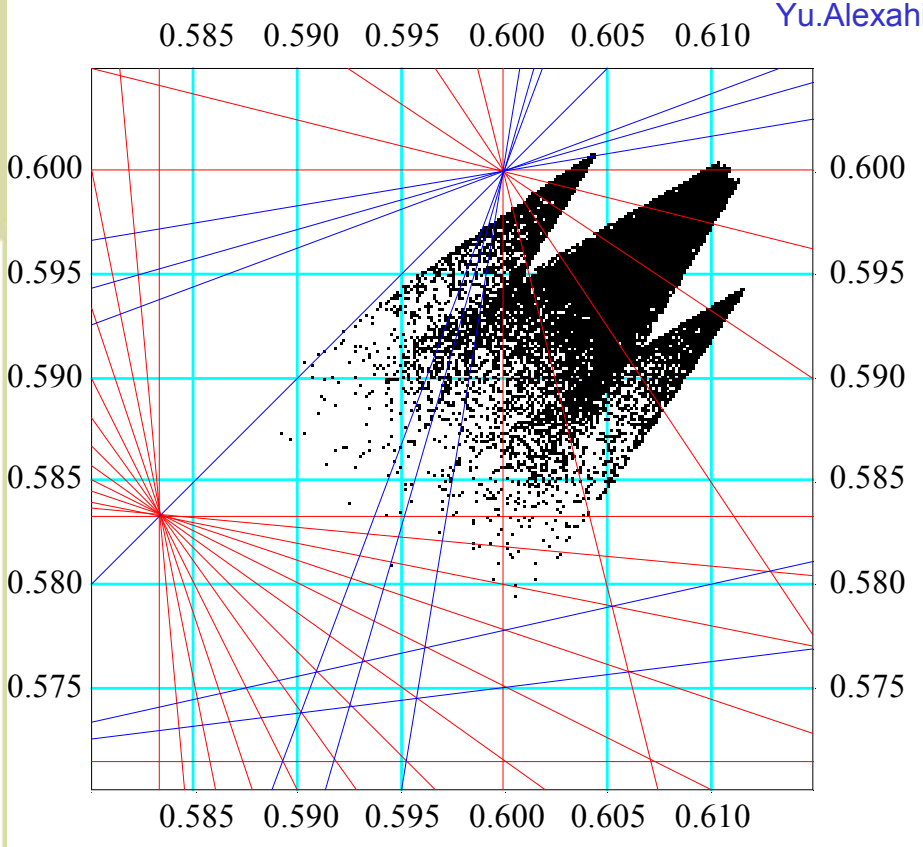


- Pbar loss at the ramp is due long-range beam-beam forces
- The loss depends on proton intensity, beam-beam separation (has been maximaized with given restrictions), tunes, coupling, chromaticities
- variations were corrected with additional break point at 153 GeV tunes)

Beam-Beam Effects at 980 GeV

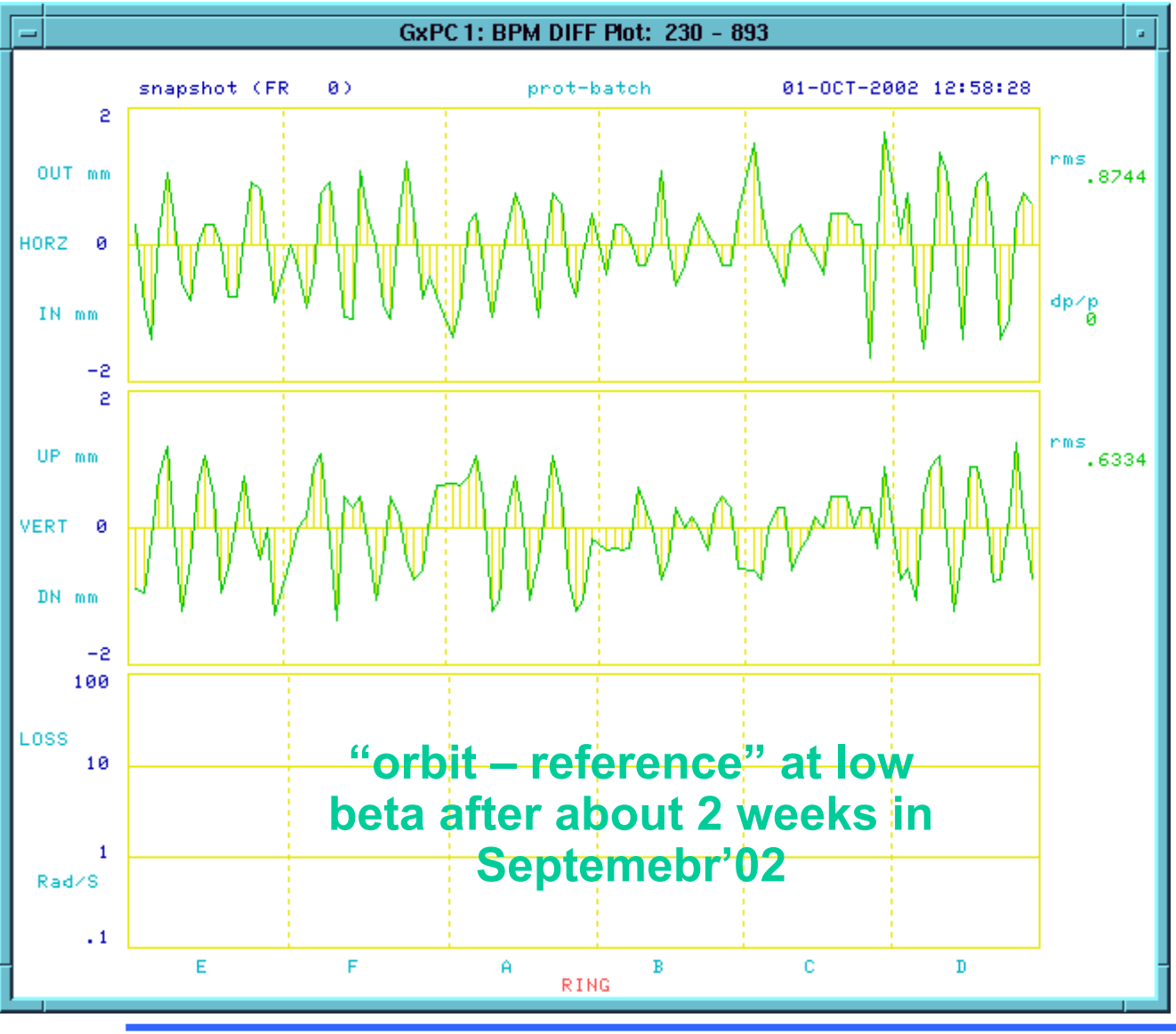


Yu.Alexahin



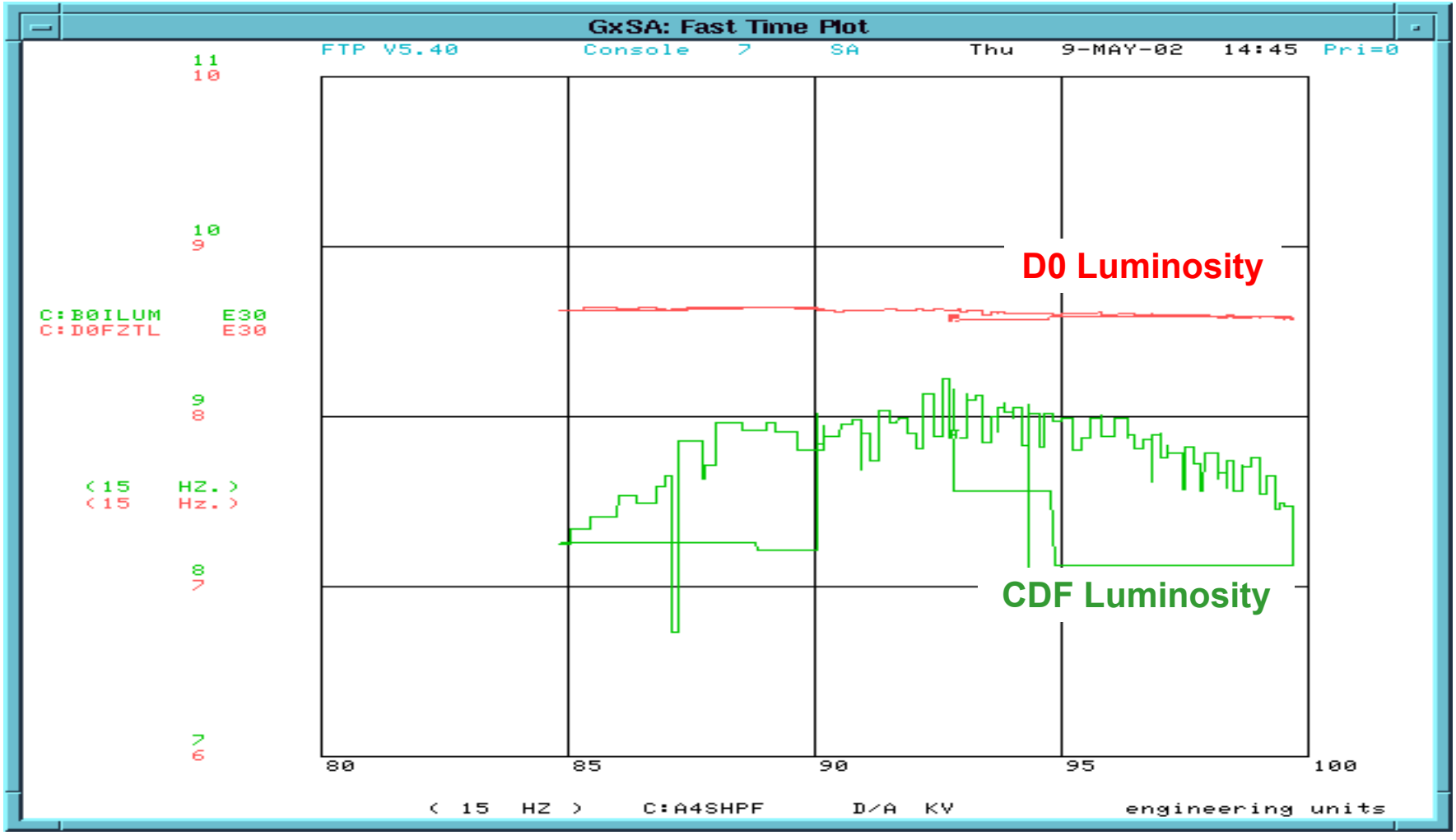
- Pbar bunches near abort gaps have better emittances and live longer
- emittances of other bunches are being blown up to 40% over the first 2 hours – see scallops over the bunch trains (small anti-scallops for protons)
- the effect (should be) tune dependent - see on the right

Orbit Smoothing



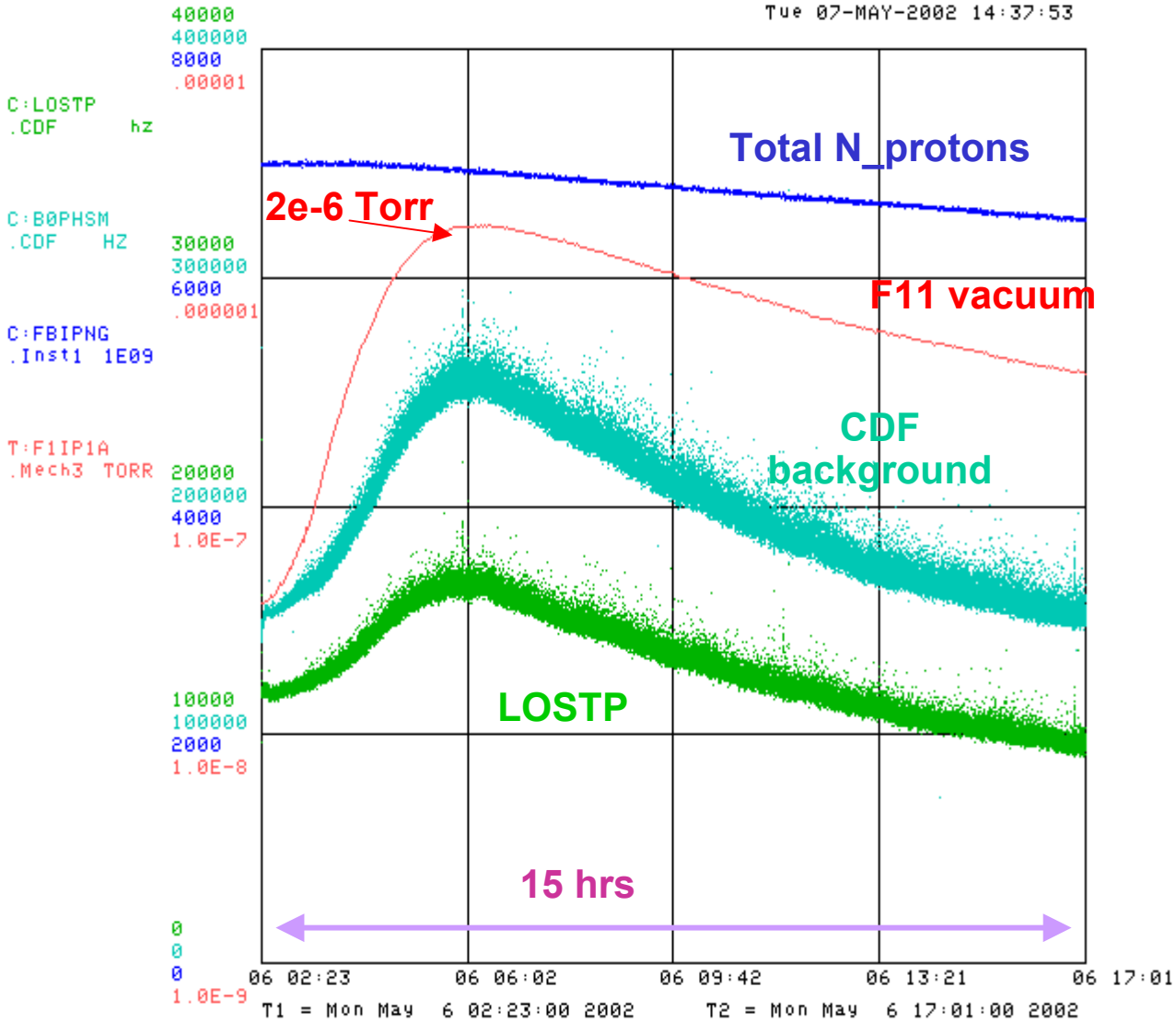
- proton and antiproton tunes, coupling, chromaticities significantly vary a lot with closed orbits distortions
- "rule of thumb" for stable operation to keep orbits under 0.5 mm rms from "sliver orbit"
- orbit drifts of that scale occur in 1-2 weeks
- that requires operational orbit smoothing at 150, ramp, flat-top, squeeze, low-beta.

IP Scan



• every once in a while we perform separators scan at IPs (like 5/10 resulted in +4% in the CDF luminosity

Vacuum and Background



- for several months the CDF losses had bump few hrs into stores
- reason was out-gassing of ferrite absorber in RWM due to beam heating
- fixed in June'02
- that allowed to estimate average equivalent Tev vacuum pressure to be 1e-9 Torr (room T, N_2)

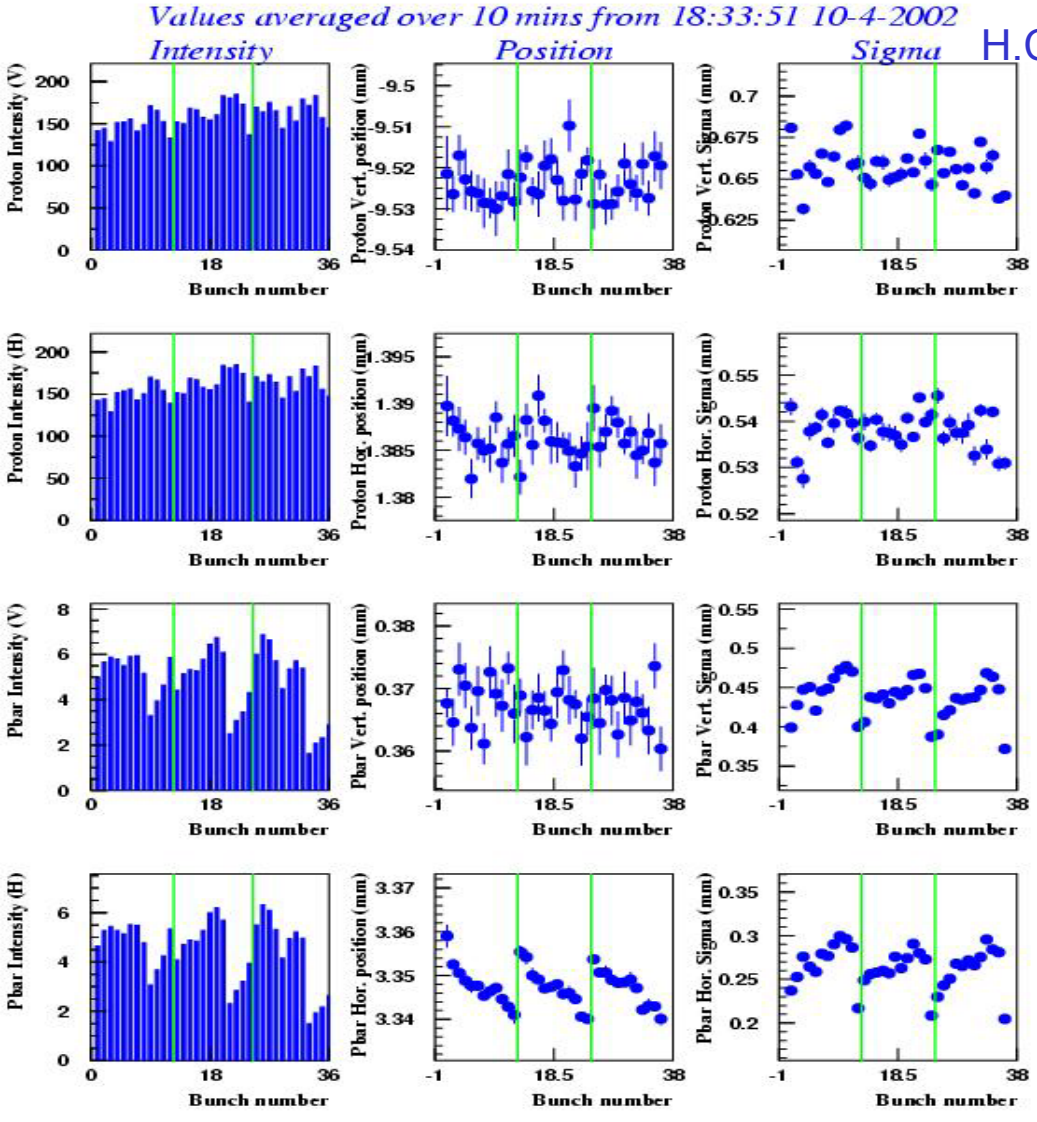
Physics Progress (see backup slides)

- Beam-beam issues
  - N_p effect (pbar only, efficiencies vs N_p)
  - Emittance+aperture effects (C0 + F0 + A0, ♦ vs Aperture)
  - Tune, κ, C_v,h, orbit effects (variations, smoothing, compensation)
  - Lifetime/other effects in collisions (breakdown, b-to-b orbits, tilts, sigmas)
  - Beam-beam effects for protons (at LB)
  - IPs (luminous regions, separator scans, coupling)
  - TEL (better lifetime, Gaussian gun)
- Instabilities/blowups
  - Coherent transverse (coherent, b-to-b, HOMs, C_v,h, dampers, octupoles)
  - Coherent longitudinal ($\blacklozenge_s$ blow-up, b-to-b, damper, dancing bunches)
  - Incoherent transverse (150 loss loss vs C_v,h, $d\blacklozenge_s/dt$, emittance growth)
  - Incoherent longitudinal ($d\blacklozenge_s/dt$ vs N_p)
  - Orbit drifts (tides+Temperature +drifts)
- Losses/background
  - Vacuum (F11, IPs)
  - DC beam (DC loss rate in store)
  - Collimators (new at A48)

Diagnostics Progress/Issues/Needs

[0 – not exists, 1 – poor, 2- fair, 3- good]	Mar'02	Oct'02
• BPMs	1	1
• Beam Line Tuner = BLT	1	3
• RF phase detector	0	3
• Flying Wires = FW	1	2.5
• SyncLite Monitor = SL	1	2.5
• Single Bunch Display = SBD	1.5	2
• Fast Bunch Integrator = FBI	1.5	2
• Schottky Detector (21 MHz, + 1.5 GHz)	1.5	2
• Tune-Meter	1	2
• Digital Mountain Range	0	2
• Fast Chromaticity Measurement	0	1.5
• Head-Tail Monitor	0	1
• Orbit Oscillations Monitor	0	1
• RF Noise	0	1
• Magnets motion	1.5	2

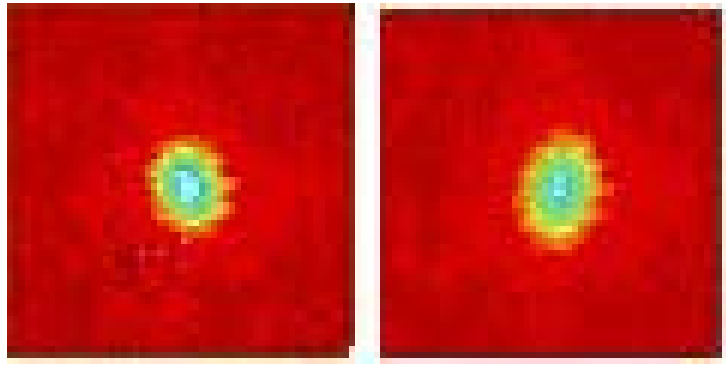
Diagnostics Progress: SyncLite Monitor



H.Cheung

- Works >800 GeV
- Significant progress since March'02
- Reports ♦, mean, N, tilt bunch-by-bunch for both protons and pbars
- Invaluable instrument

Bunch #1 Bunch #8



Shutdowns

- 2 week shutdown in June'02:
  - F11 RWM ferrites replaced
  - Aperture of F0 BPMs and striplines opened
  - A-sector collimator moved
  - TEL gun and HV modulator replaced

- 6 weeks shutdown in January'03
  - Increase C0 aperture (replace Lambertsons)
  - Install 1.5GHz Schottky detectors at E17
  - A0 lattice modification
  - TEL modification
  - Vacuum improvement (incl., warm two houses)
  - Install new collimator at A48
  - Alignment work

Performance: FY'03 Goals

Parameter	Oct'02	Oct'03 base/stretched	change in L	
Protons/bunch	170e9	190/220e9	+12/24%	*
Total Antiprotons	800e9	1100/1300e9	+36/60%	**
P-emittance (95%, norm), π	20	20		
Pbar-emittance (95%, norm), π	18	18		
Beta @ IP, effective, m	0.39(?)	0.39/0.36	+0/8%(?)	***
Bunch length (proton, rms), m	0.61	0.61/0.57		
Bunch length (pbar, rms), m	0.54	0.54/0.51		
Form Factor (Hourglass)	0.62	0.62/0.64	+0/3%	****
Typical Luminosity, $cm^{-2}sec^{-1}$	3.2e+31	5.0/7.0e+31		
Peak Luminosity, $cm^{-2}sec^{-1}$	3.6e+31	5.5/7.8e+31		
Integrated Luminosity, pb^{-1}/wk	6.7	10/15	+50/120%	*****

** Higher N_p leads to beam-beam, instabilities, backgrounds ...tough with less studies*

*** expect "no double benefit" due to smaller pbar emittances, N_pbar only*

**** may come from either better decoupling at IP or changing beta**

***** not that easy for higher intensities*

****** some 4% increase is possible due to better luminosity lifetime (Q_h,v, C_h,v, TEL)*

FY'02-'03 Resources

- Tevatron Department
  - staff of 16 + 2 Guests and 1 PhD student
- Out of 16 – only 6 Physicists
- All buried in operations and solving immediate (though physics) issues - "firefighters"
- Substantial help from outside:
  - V.Lebedev (formally in AA and Beam Lines, one of Tev Physics coordinators)
  - from Beam Physics Department: significant progress since Mar'02: Y.Alexahin then T.Sen, B.Erdelyi, V.Balbekov, M.Xiao, J.Johnstone, S.Drozhdin, N.Mokhov; A.Burov of BD/Ecool helps with instabilities
  - From PPD: A.Tollerstrup, H.Cheung; CD: P.Lebrun; TD: T.Khabibulin, G.Romanov, P.Bauer
  - Short term visitors (4-6 weeks): W.Fischer (BNL), F.Schmidt (CERN), coming - F.Zimmermann (CERN)

Tevatron Projects in FY'03

Priority	project	Leader	Date	N_P	N_A	emm
1	**Transverse dampers**	*Steimel*	Nov'02	■		
1	**Pbar emittance at injection: BLT,A1 line, inj.damper**	*Scarpine* *Lebedev* *Steimel*	Nov'02 Dec'02 Feb'03	■	■ ■	■ ■ ■
1	**C0 Lambertson replacement**	*Garbincius*	Feb'03	■	■	
1	**Tev Lattice (A0)**	*Martens*	Feb'03		■	
1	**Daily operations**	*TeV coord*	daily	■	■	■
1	**Operational orbit smoothing**	*Martens*	Dec'02	■	■	
1	**Beam-beam studies and calculations**	*Sen*	Sep'03	■	■	■

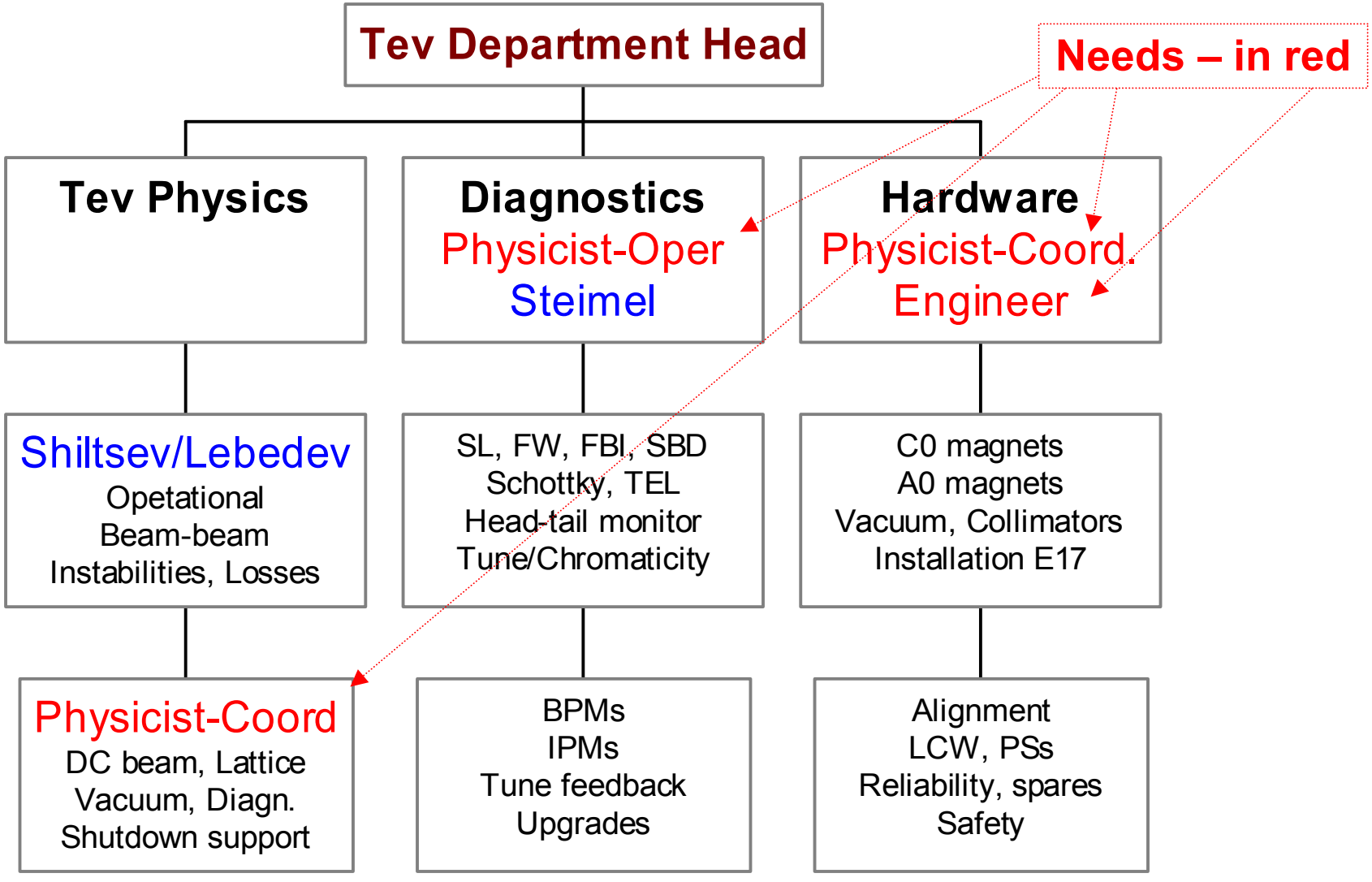
Tevatron Projects in FY'03 (cont'd)

Priority						
2	**Instability studies**	*Ivanov*	Dec'02	■	■	
2	**150 GeV tunecoupling drift compns; b2 unwind**	*Martens*	Oct'02		■	
2	**TEL**	*Shiltsev*	Feb'03	■	■	
2	**Schottky detector at E17**	*Pasquinelli*	Feb'03		■	
2	**Tune feedback**	*Tan*	Mar'03		■	
2	**Longitudinal dampers**	*Steimel*	Apr'03	■		
3	**Tevatron vacuum**	*Hanna*	Feb'03	■	■	
3	**Losses/collimators**	*Moore*	Feb'03	■		
3	**DC Beam/RF noise**	*Lebedev*	Apr'03	■		
3	**SBD/FBI/FW (BPMs)**	*Pordes*	Dec'02	■	■	■
3	**SynchLite**	*Cheung*	Dec'02	■	■	■
3	**Chromaticity measurement**	*Still*	Dec'02		■	
3	**Orbit motion spectrometer**	*Zhang*	Dec'02	■		■
3	**Pbar tunemeter**	*Tan*	Nov'02		■	

FY'02-'03 Resources (cont'd)

- That gives us 21 projects (27 including subprojects): 10 focused on protons, 16 on antiprotons, and 6 on their emittances
- 10 projects out of 21, including 4 out of 7 highest priority projects, experience need of the study time, especially after recent 2-fold reduction (5 shifts every other week). Weekly studies are needed to keep fast pace in luminosity.
- Concentration of physicists actively working on Run II would benefit the Collider progress ("Run II Center")
- 17 people are in charge of the projects (and several more for subprojects), all of them report to Tev Dept Head → restructuring needed →

FY'03 Resources (cont'd)



Summary

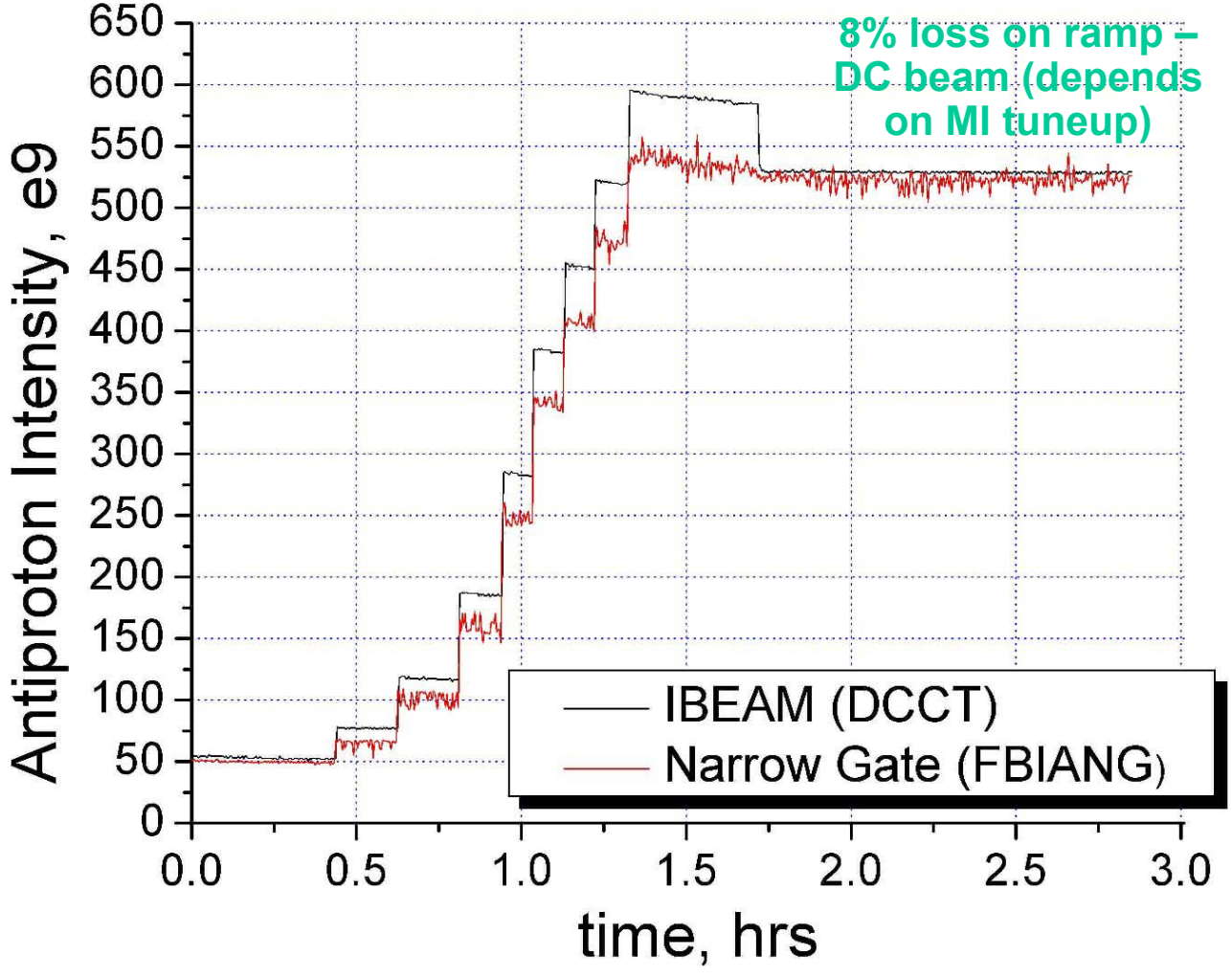
- Significant luminosity improvement
  - 5 times since October'01
  - 3 times since March'02
- Complex running well lately
  - Now consistently above Run I peak luminosities
- Delivered >80 pb^{-1} to each experiment in FY'03
- Beam-beam effects and transverse instability and hampering performance, but know how to remedy
- Looking forward to delivering 0.2-0.32 fb^{-1} in FY'03
  - increase peak luminosity to (5-7)e31
    - about +12% (stretched to 24%) more protons to collisions
    - about +35% (stretched to 60%) more antiprotons to collisions
    - about the same emittances

Back-up Slides

- Physics Issues
  - Beam-beam effects, TEL
  - Instabilities
  - Emittance growth
  - Beams at injection
  - Interaction points
  - Losses/background, DC beam
  - Orbit motion
- Diagnostics
  - BPMs
  - BLT
  - RF phase
  - FWs
  - SyncLite
  - SBD
  - Schottky detector
  - Tune meter
  - Chromaticity Measurements
  - Head-Tail Monitor
  - Scintillator paddles
  - Orbit Oscillation Detector
  - RF Noise
  - Tilt Meters/Geophones

Beam-Beam Effects: Pbar Only

Antiproton Only Store: 1% loss on ramp, τ_{150}=20 hrs, τ_{980}=160 hrs

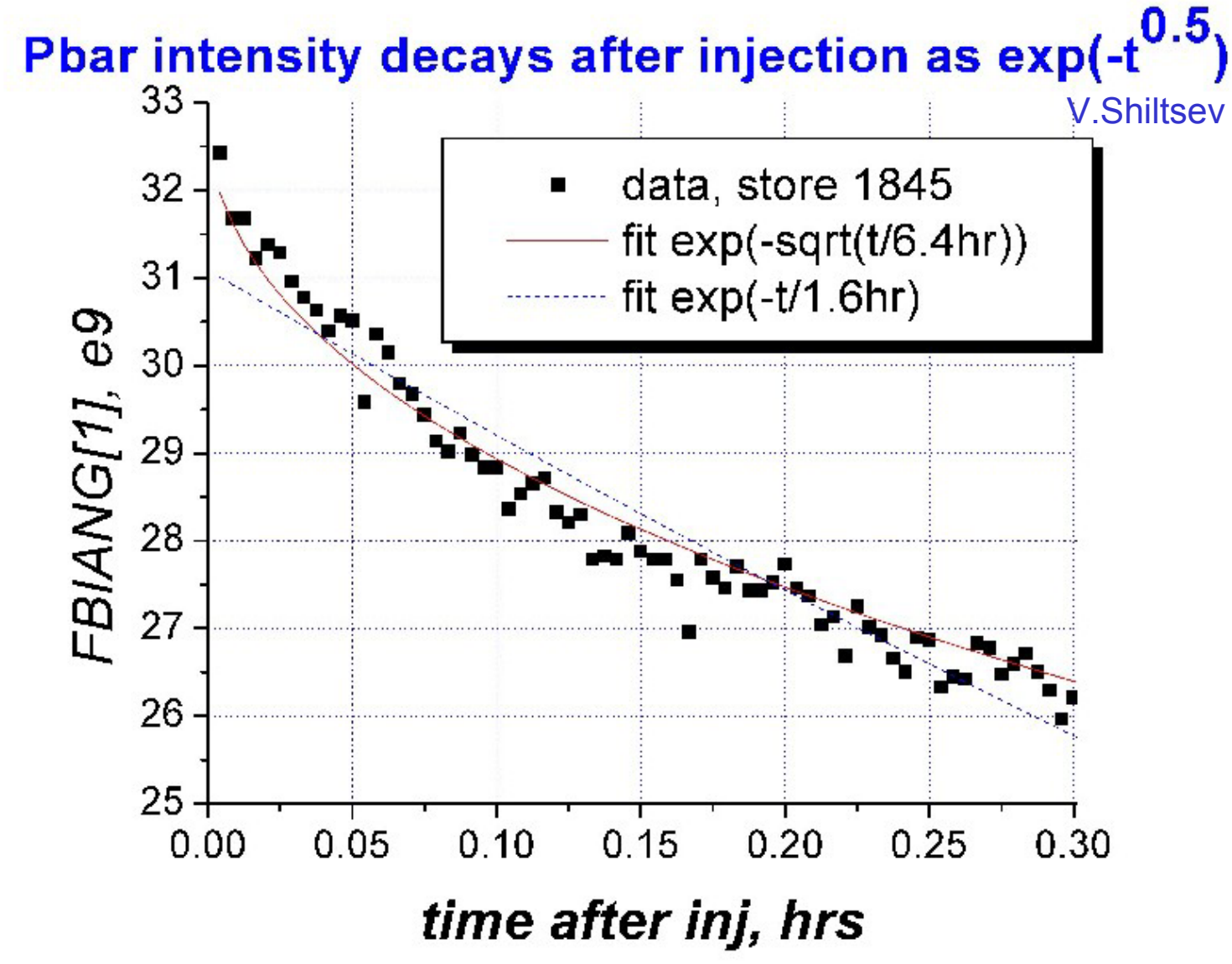


Beam-Beam Effects: Antiprotons Suffer

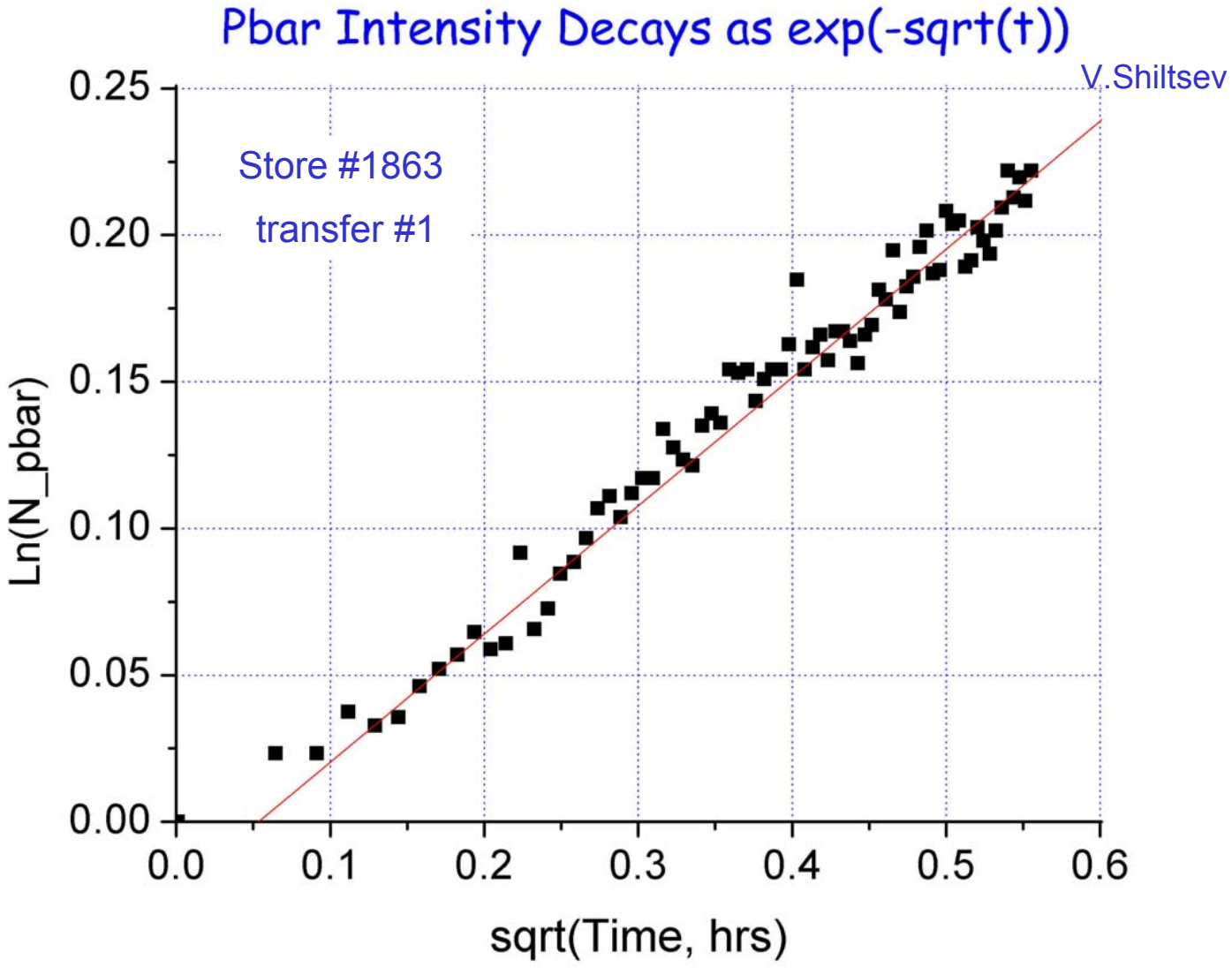
Store	*N_p, e9*	*Out of AA, mA*	*Loss at 150*	*Loss on ramp*	*Loss in squeeze*	*Pbars at low-beta*	*L, e30*
Mar'02	5100	90	20%	14%	22%	251	9.4
1303	6070	103	16.4%	11.6%	3%	476	19.5
1289	6990	105	18%	20%	11%	387	19.6
Oct'02	6430	132	9%	8.3%	5%	790	32.4

- Pbar intensity lifetime at low-beta is 15 to 50 hrs (50-70 due to luminosity)
- Pbar emittance lifetime at low-beta is 10 to 40 hrs
- Some effects are seen in protons (see below)

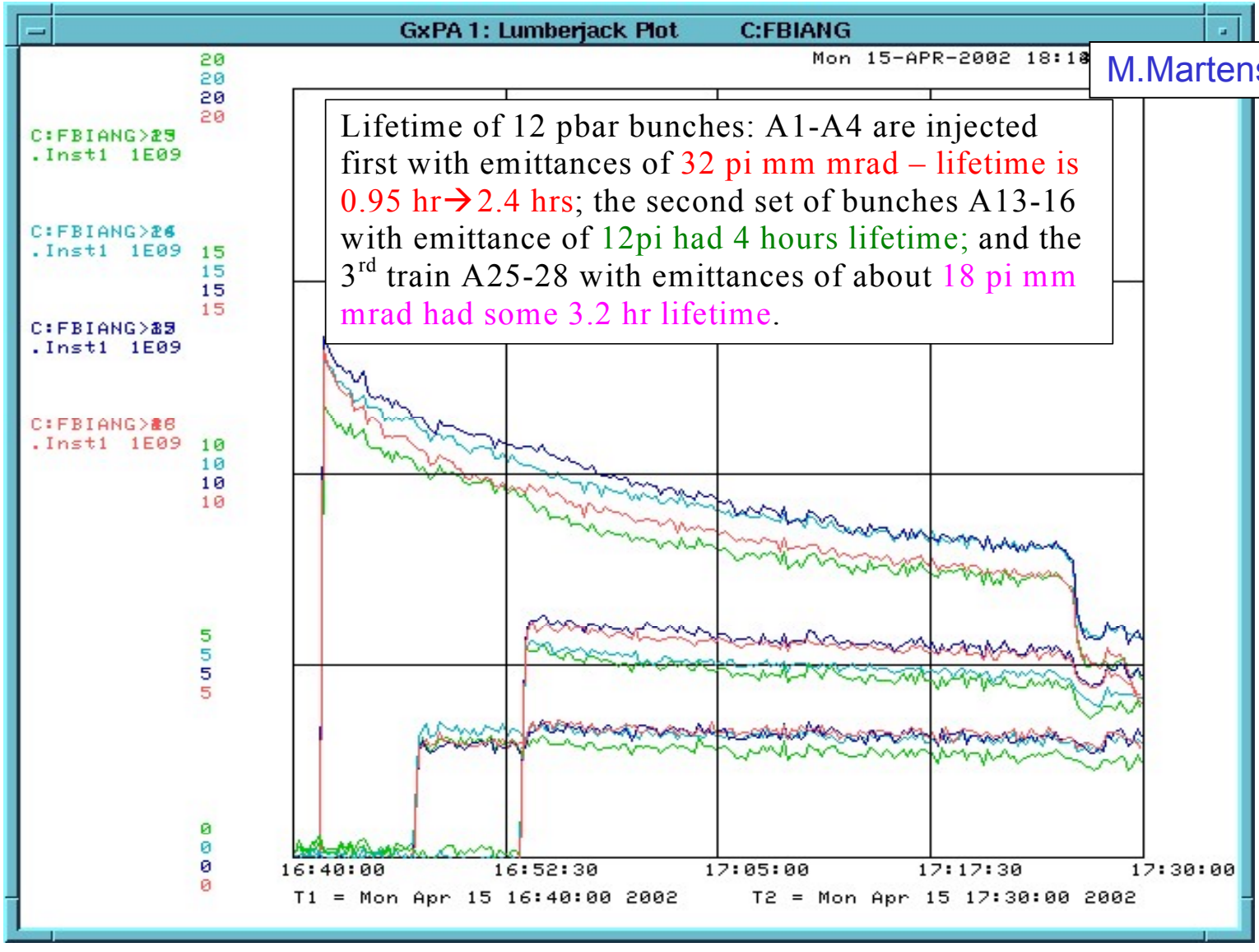
Beam-Beam @ Injection: Shaving



Injection Shaving in Detail



Beam-Beam @ Injection vs Emittance

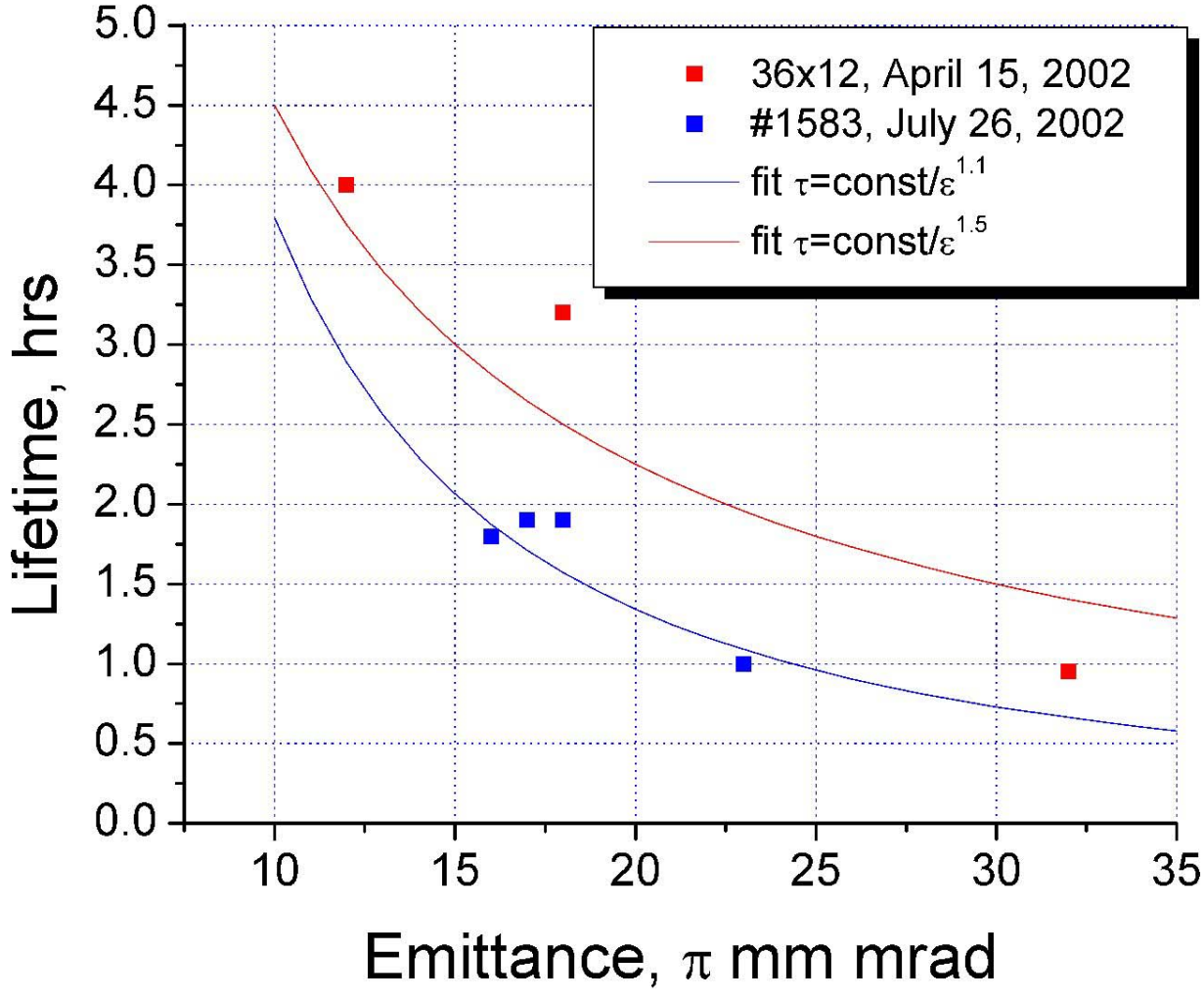


M.Martens

Lifetime of 12 pbar bunches: A1-A4 are injected first with emittances of 32 pi mm mrad – lifetime is 0.95 hr→2.4 hrs; the second set of bunches A13-16 with emittance of 12pi had 4 hours lifetime; and the 3rd train A25-28 with emittances of about 18 pi mm mrad had some 3.2 hr lifetime.

Beam-Beam @ Injection vs Emittance

Pbar lifetime vs emittance at injection scales as $1/\varepsilon^{(1.1-1.5)} = 1/A^{(2.2-3)}$



Beam-Beam @ Injection (cont'd)

Combining

$$(dN/dt)/N = -(\varepsilon_0/\varepsilon)^{\alpha}/\tau_1$$

where $\alpha = 1 \div 1.5$, *and*

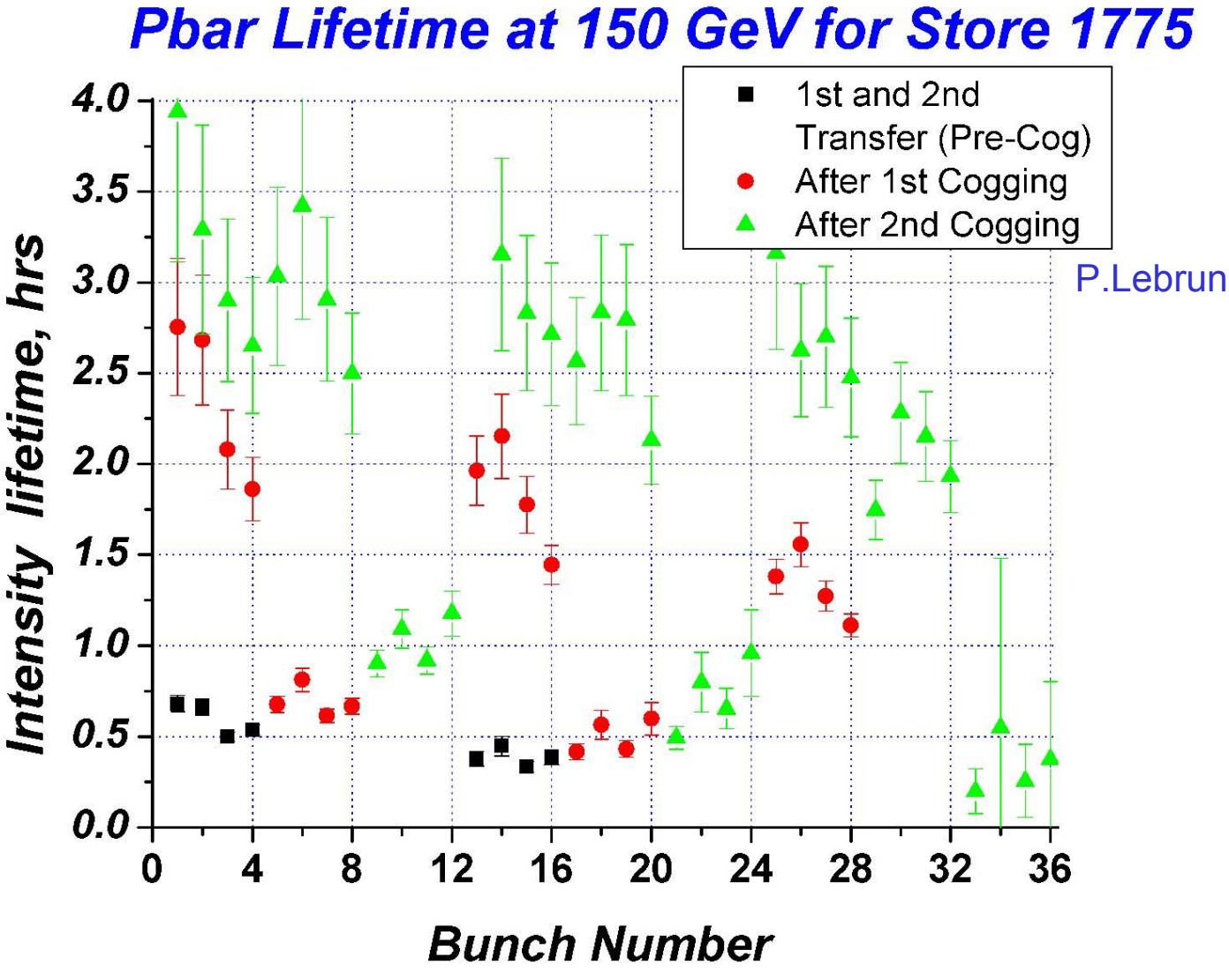
$$N \approx N_0 e^{-\sqrt{t/\tau_2}}$$

one gets

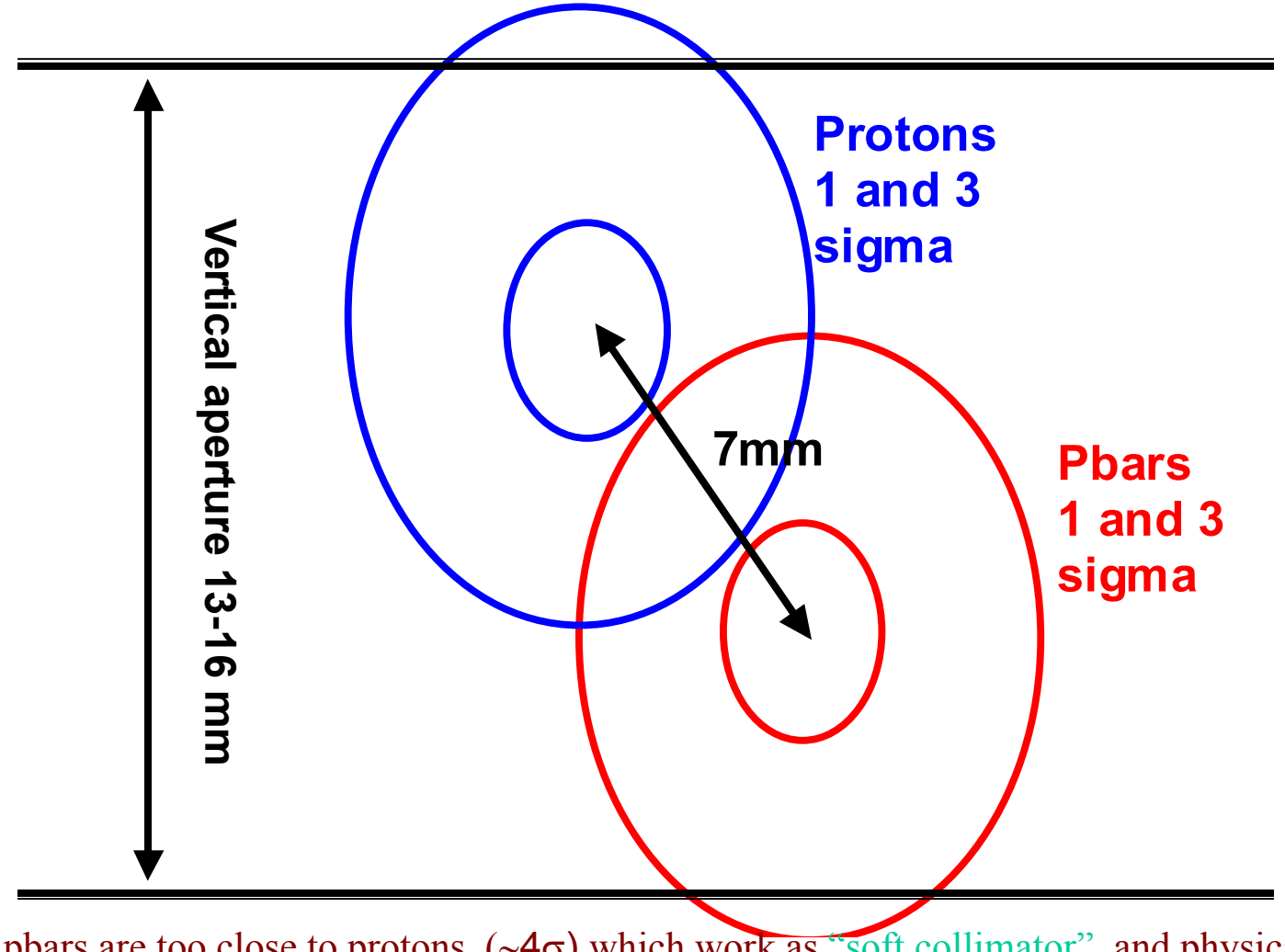
$$\varepsilon \propto (t/\tau_\varepsilon)^{-\beta}$$

where $\beta = 1/(2\alpha) \approx 1/2 \div 1/3$, *and* $\Delta_m = \Delta_1^2/(4\Delta_2)$,
i.e., we have shaving on aperture or "soft collimator"

Beam-Beam @ Injection: Bunch-by-Bunch



Beam-Beam @ Injection and Aperture



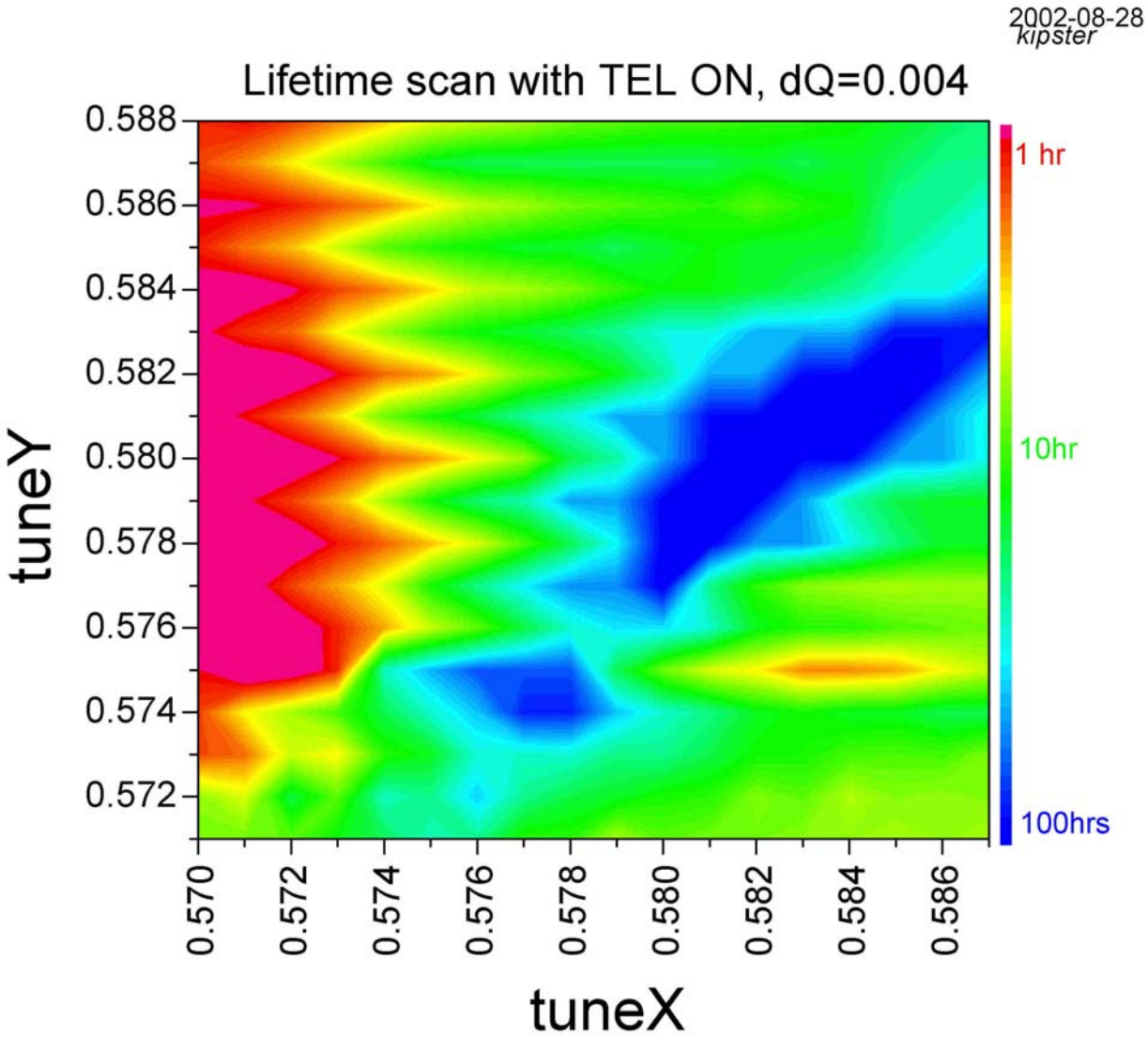
pbars are too close to protons (~4σ) which work as "soft collimator", and physical aperture at C0 Lambertson does not allow to open helix further. Options: increase separation (tilting helix) reduce sigma, increase aperture, inject faster.

Beam-Beam Effects at 980 GeV

- Suffered 10-20% pbar loss during squeeze
  - During transition from injection to collision helix
  - Minimum beam separation was only ~1.8σ
  - New helix increased min beam separation to ~3σ
  - Pbar loss during essentially eliminated

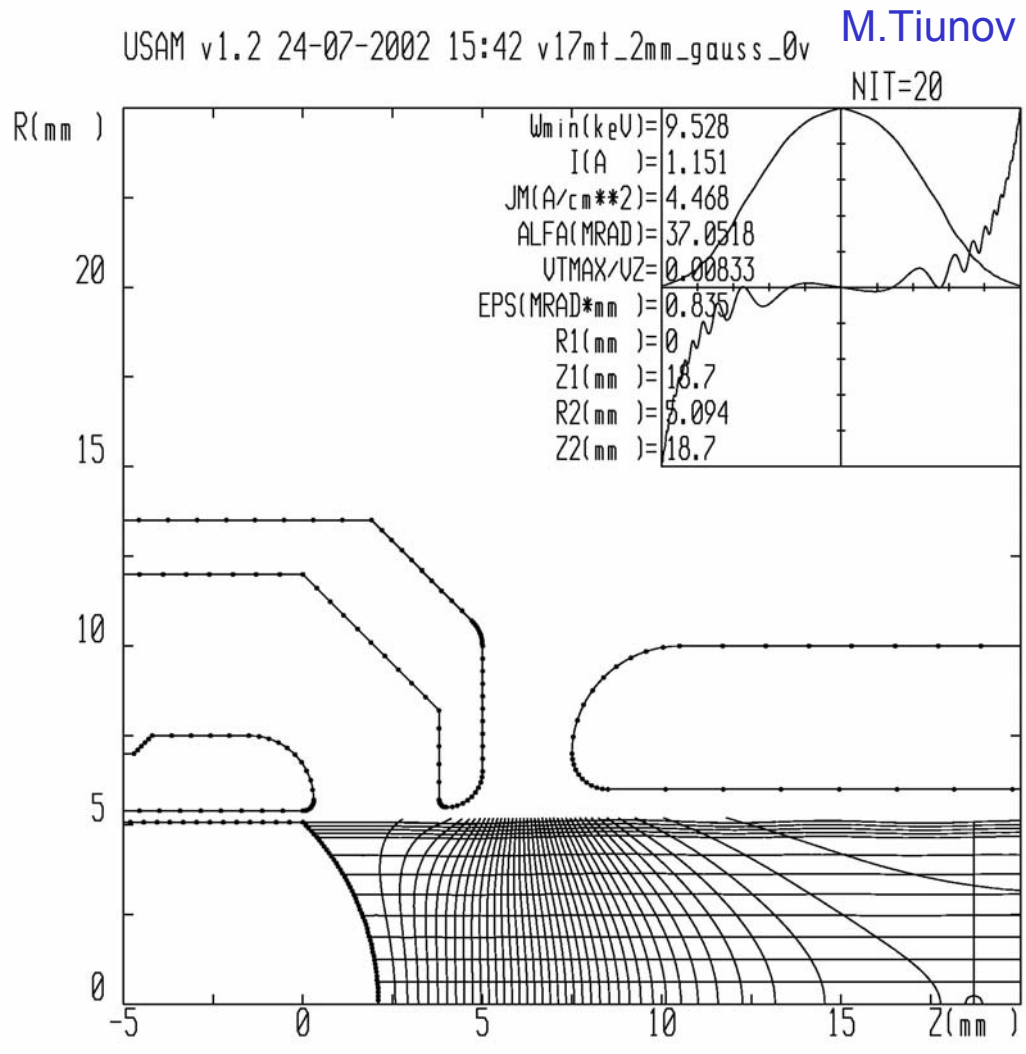
- ☹ lifetime ≈ 9-10 hrs in first two hours of store
  - Increase helix separation to reduce long-range beam-beam effects? (72 "parasitic" crossings)
  - Pbar tune shift depends position in train ⇒ optimize tunes for most bunches
  - Use electron lens to compensate pbar tune shifts

Beam-Beam Compensation with TEL



- TEL e-current noises are small
- p(pbar) lifetime reduction due to TEL comes from non-linear beam-beam effects - "donut collimator"
- Lifetime at good WPs is about 100 hrs
- e-beam positioning is important
- Smoother edge e-beam is needed → Gaussian gun
- Gun and magnets to be modified in Jan'03 shutdown

Gaussian Gun for TEL

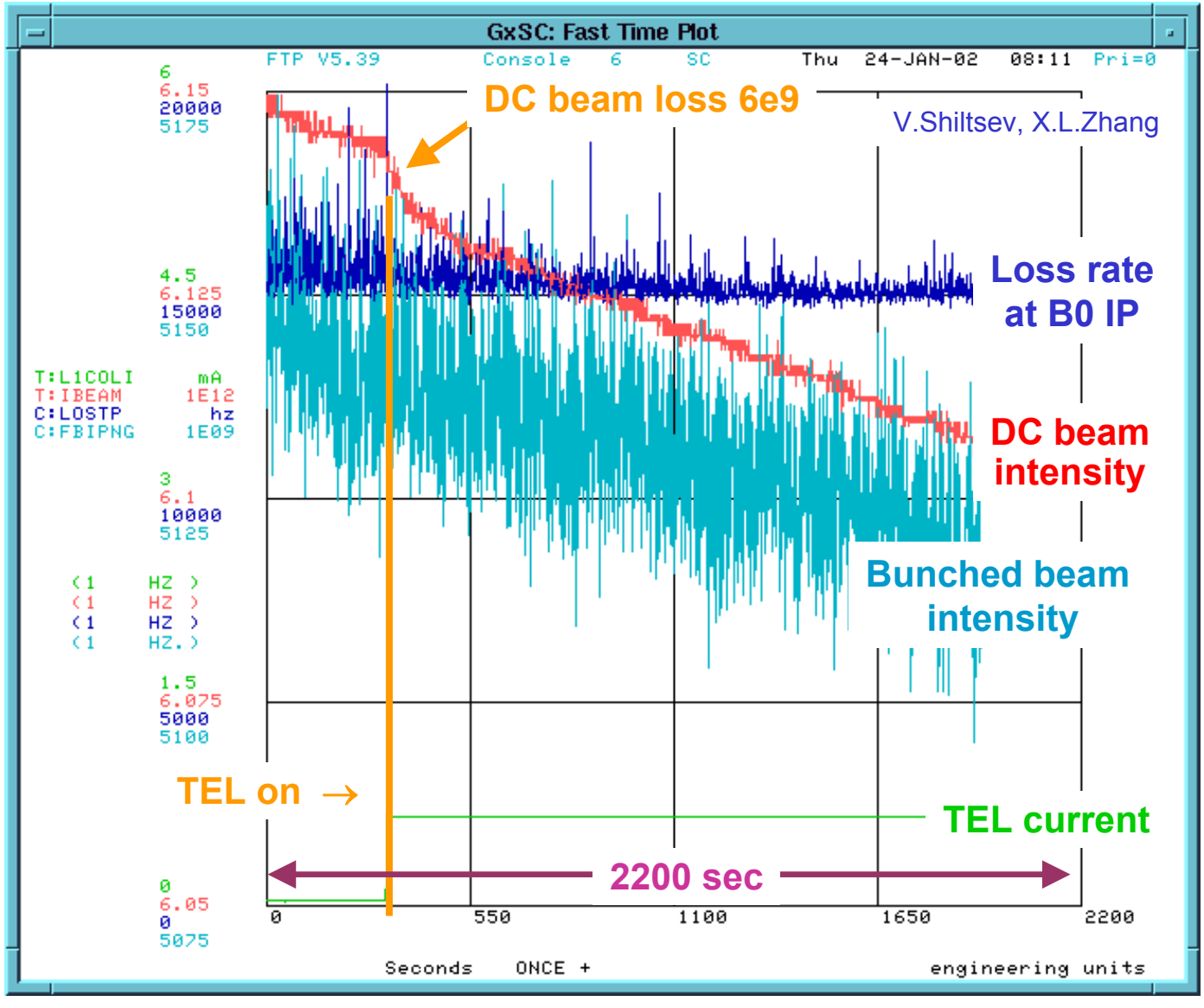


- Profile controlled by special electrode
- Somewhat reduced current density in the center → need of higher voltage
- Under fabrication
- To be installed in Jan'03 shutdown

TEL as the DC Beam Cleaner

- Phenomenon not yet understood causing beam to leak out of RF buckets
- At the end of store there is anough of the DC beam in the abort gap to cause quench on abort , $>6x10^9$ or ~0.1% of N_{total}
- e-beam placed to edge the p-orbit helix
- Fire TEL in 3 gaps every 7 turns to excite resonance
- TEL is equivalent to 100kW “tickler” (vs 50W in Q-mtr)
- TEL reduces DC beam intensity and eliminates spikes in the CDF losses
- currently TEL is operational: now it is turned ON early into each store, then OFF after store terminated (no TEL at injection as the DC beam is not a problem there)
- When needed, TEL is used for p/pbar bunch removal

Removing DC beam with TEL

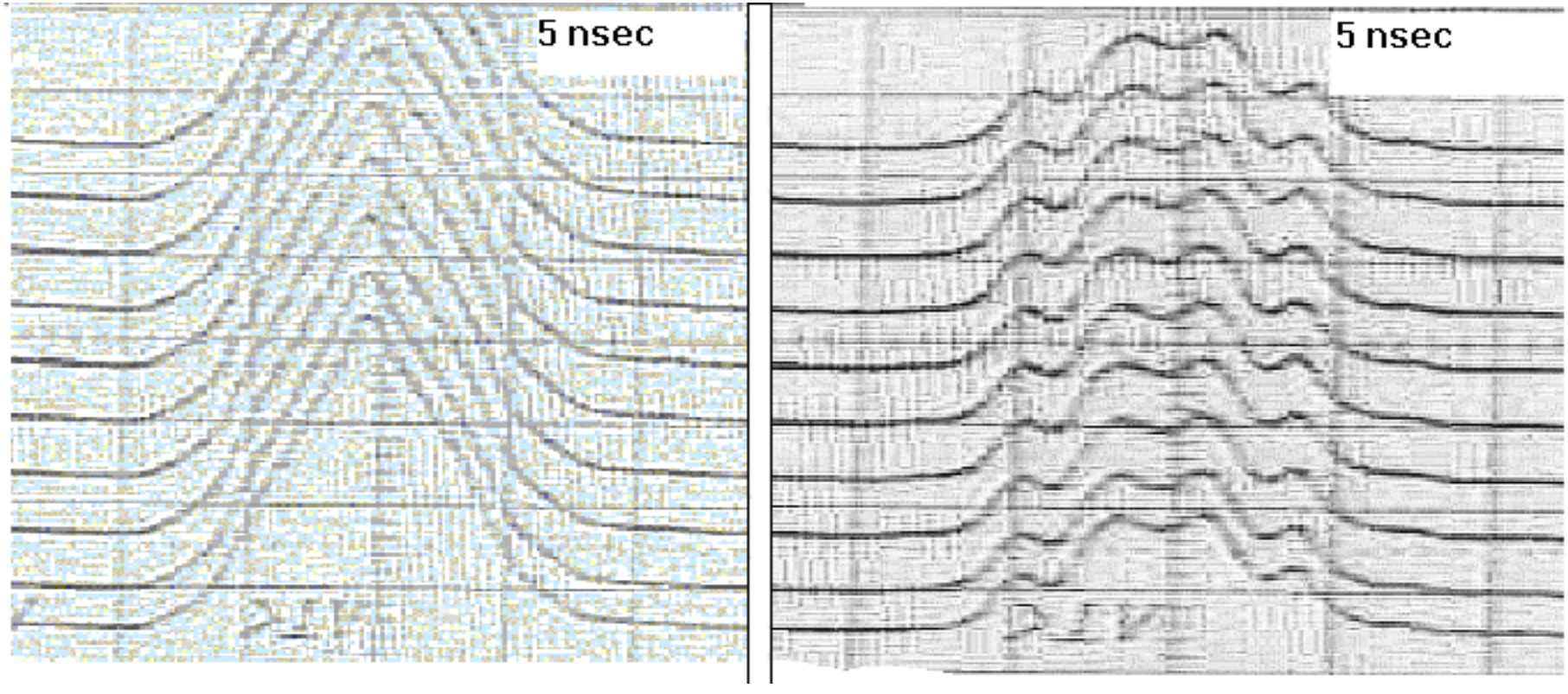


Transverse Instability

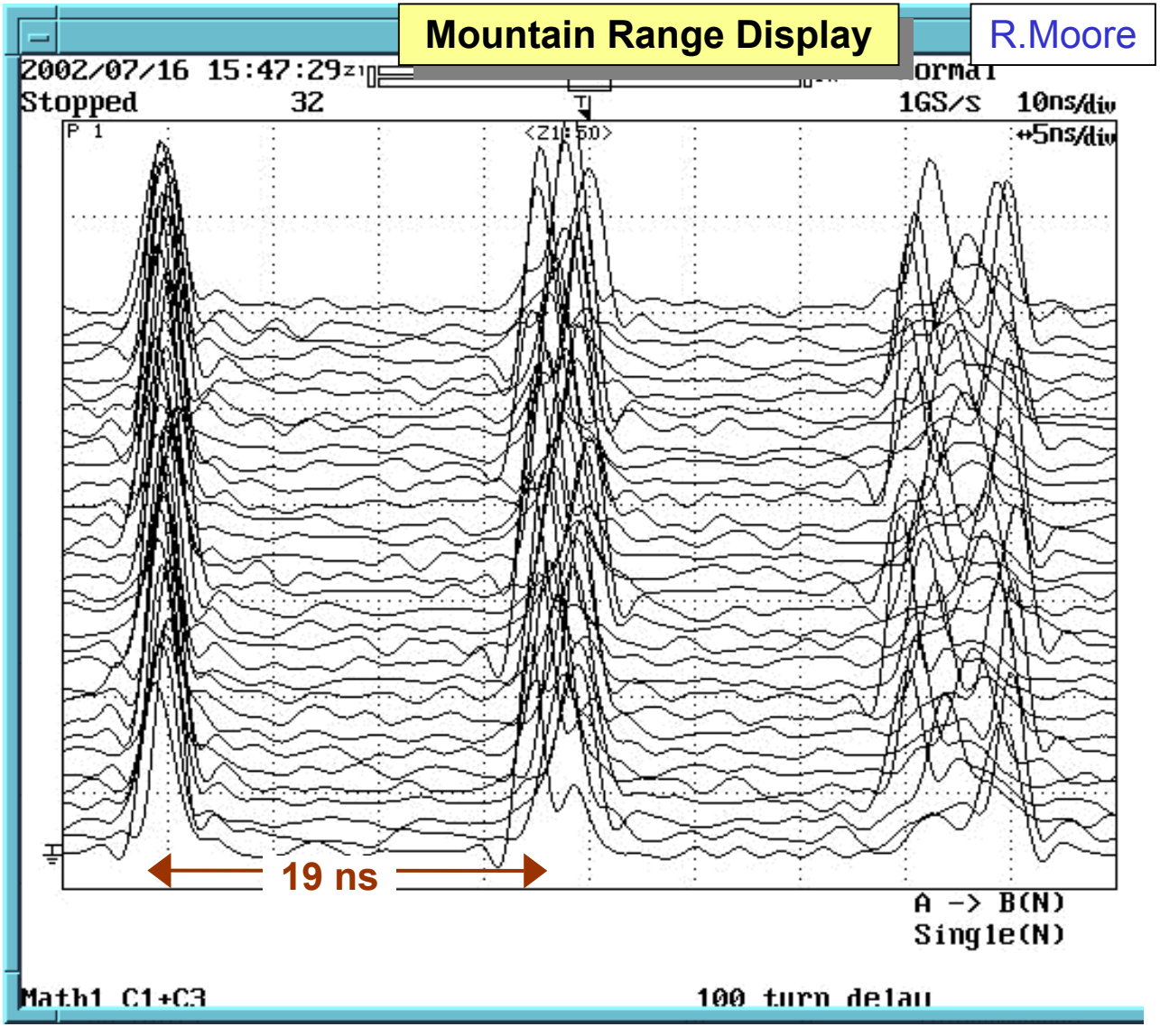
- Beam remains point to coherent betatron mode with ***l=2***

$$N_{ppb} = 2.6 \cdot 10^{11} (init.\ beam) \quad \Rightarrow \quad N_{ppb} = 1.03 \cdot 10^{11} (remain.\ beam)$$

P.Ivanov, A.Burov

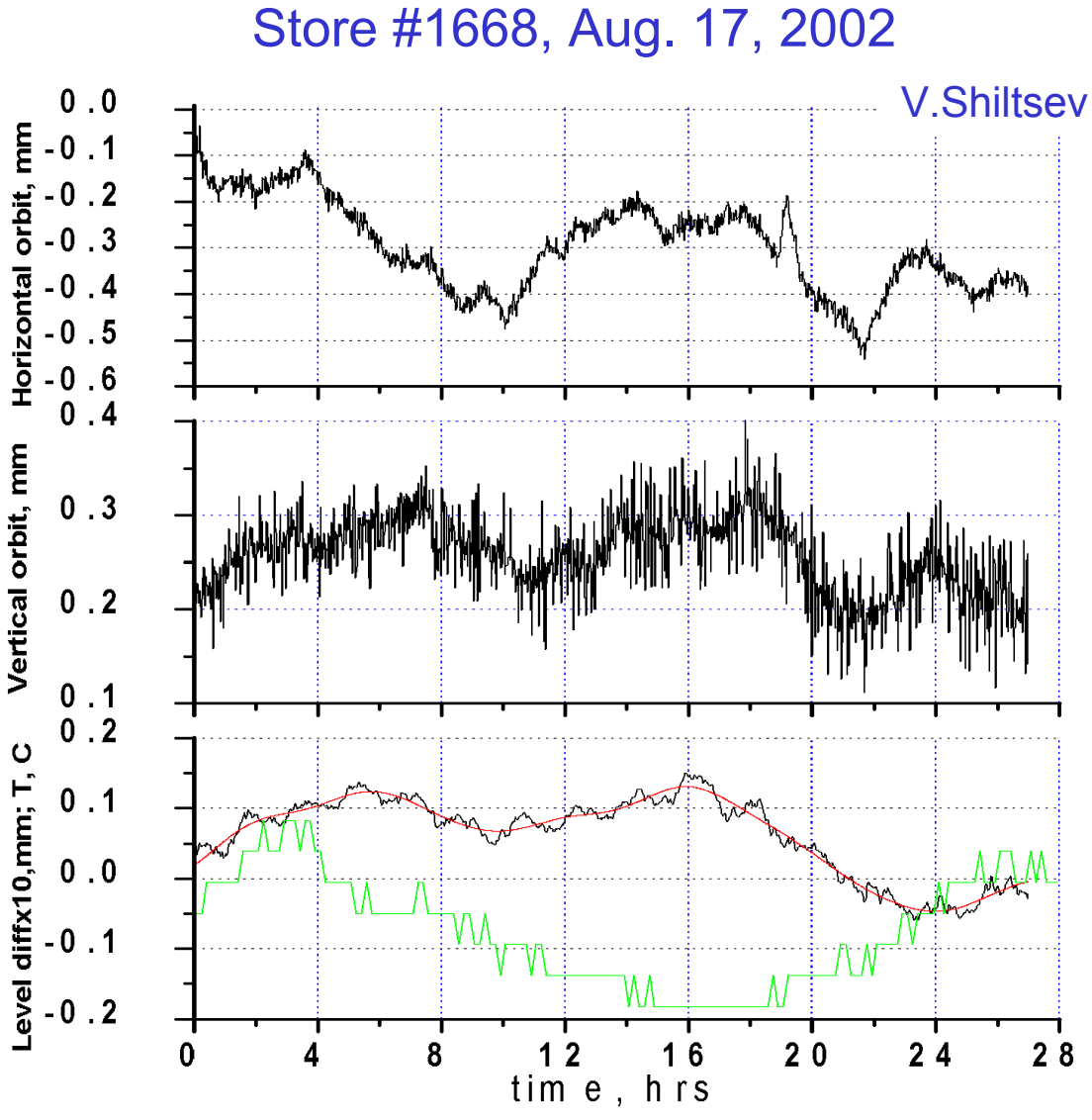


Longitudinal Impedance – "Dancing Bunches"



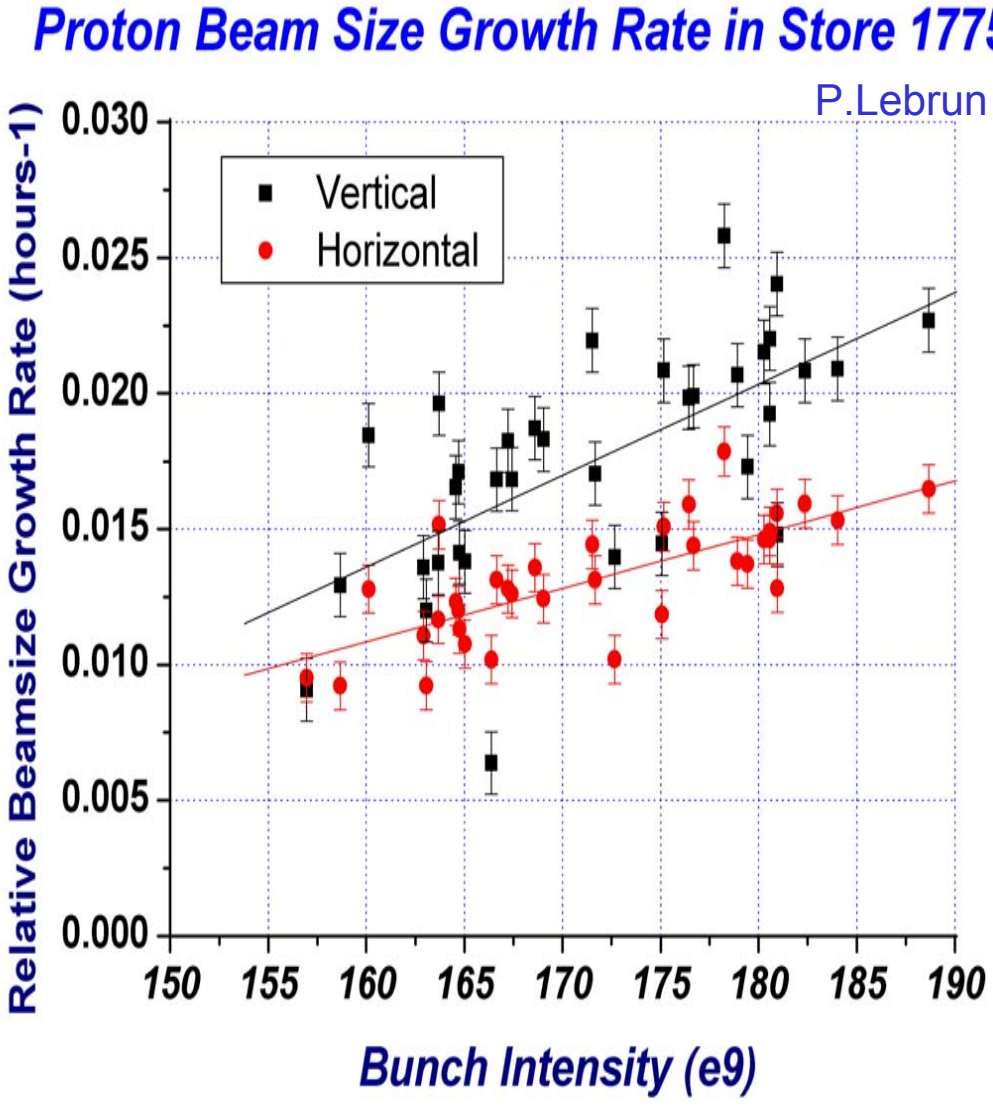
- Beam in 30 buckets
- 100 Tevatron turns (~2 ms) between traces
- Synch freq ~ 85 Hz
- Oscillation amplitude depends on bunch, changes slowly with time (minutes at 150 GeV, seconds at 980 GeV)
- Model needs inductive impedance Z/n ¤ 2 Ohm interplaying with cavity impedance
- Coalesced bunches have dancing bumps

Tevatron Orbit Movements



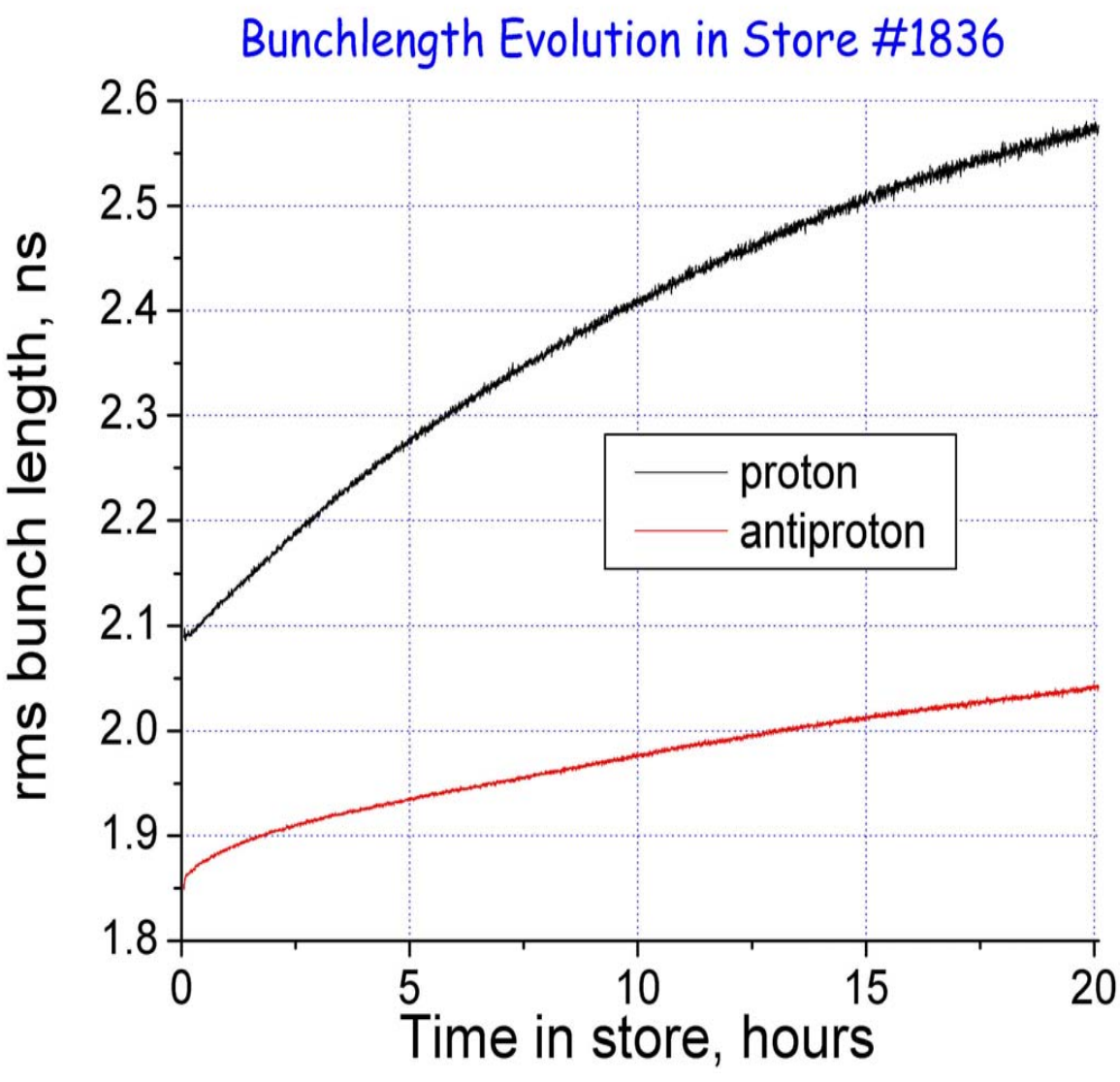
- Long-term orbit distortions are about 1 mm/week$^{1/2}$ and 2mm/ month$^{1/2}$
- Movements during stores are under 0.5 mm and contain 12-hr period due to Earthtides and 24-hr due to temperature variations
- Earthquakes are rare but seen
- High-frequency (1-400 Hz) oscillations are <30 microns in H and <10 microns

Transverse Emittance Growth



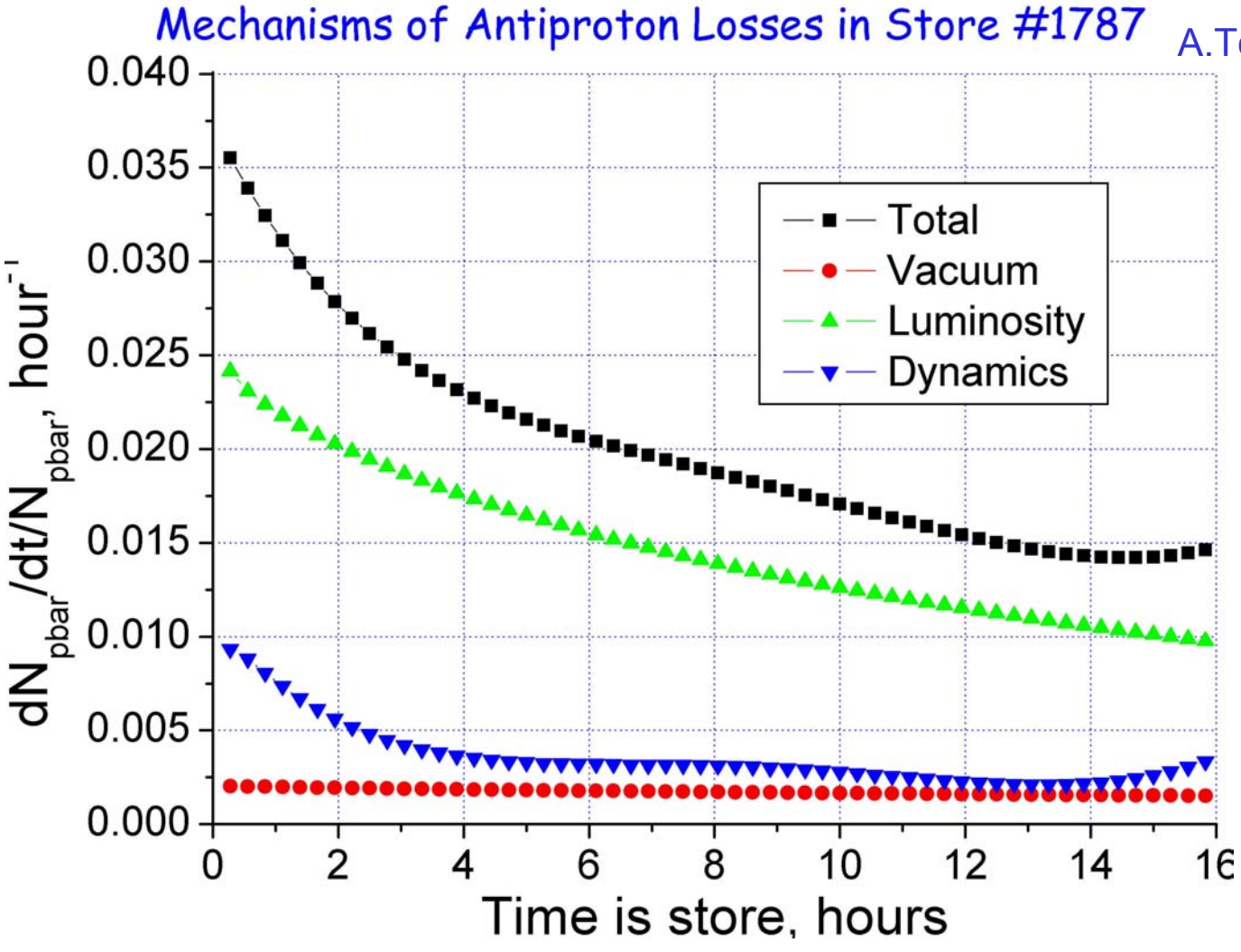
- Proton emittance lifetime is about 50 hours or 0.5 □ mm mrad/hr
- About 0.2 □ mm mrad/hr mm rate is intensity independent – consistent with known "equivalent" vacuum "1e-9 Torr (and noises?)
- The rest is intensity dependent, consistent with intrabeam scattering

Bunch Length Growth



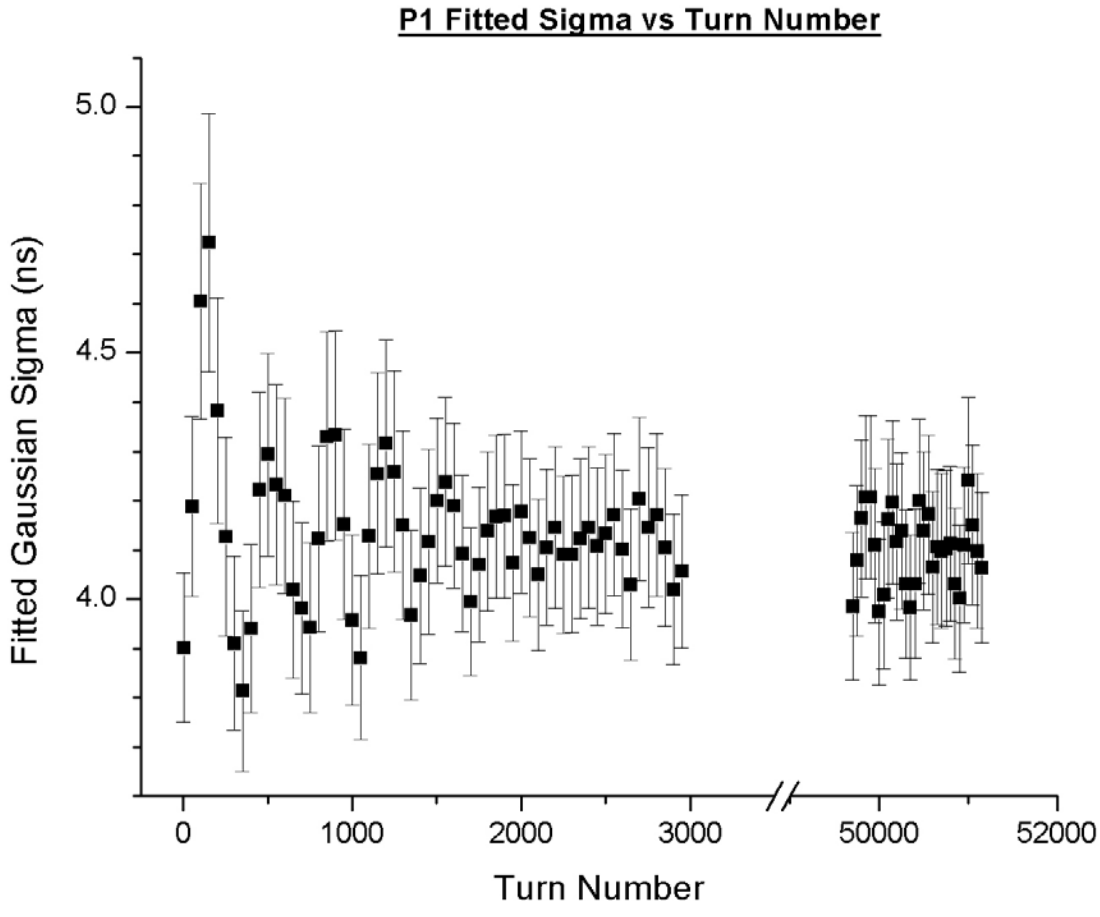
- Early in stores the rms bunch length growth time is about 50 hours for protons and 100 hours for antiprotons
- Pbar bunch length growth can be suppressed by beam-beam effects, e.g. sometimes it goes down a bit due to beam-beam "shaving"
- Proton bunch length growth correlation with intensity is not proven yet, so, it quite may be due to noises (some 50 microrad RF phase fluctuations are needed for that)

Beam Losses - Antiprotons



- Pbar lifetime of about 30 hours is dominated by luminosity losses

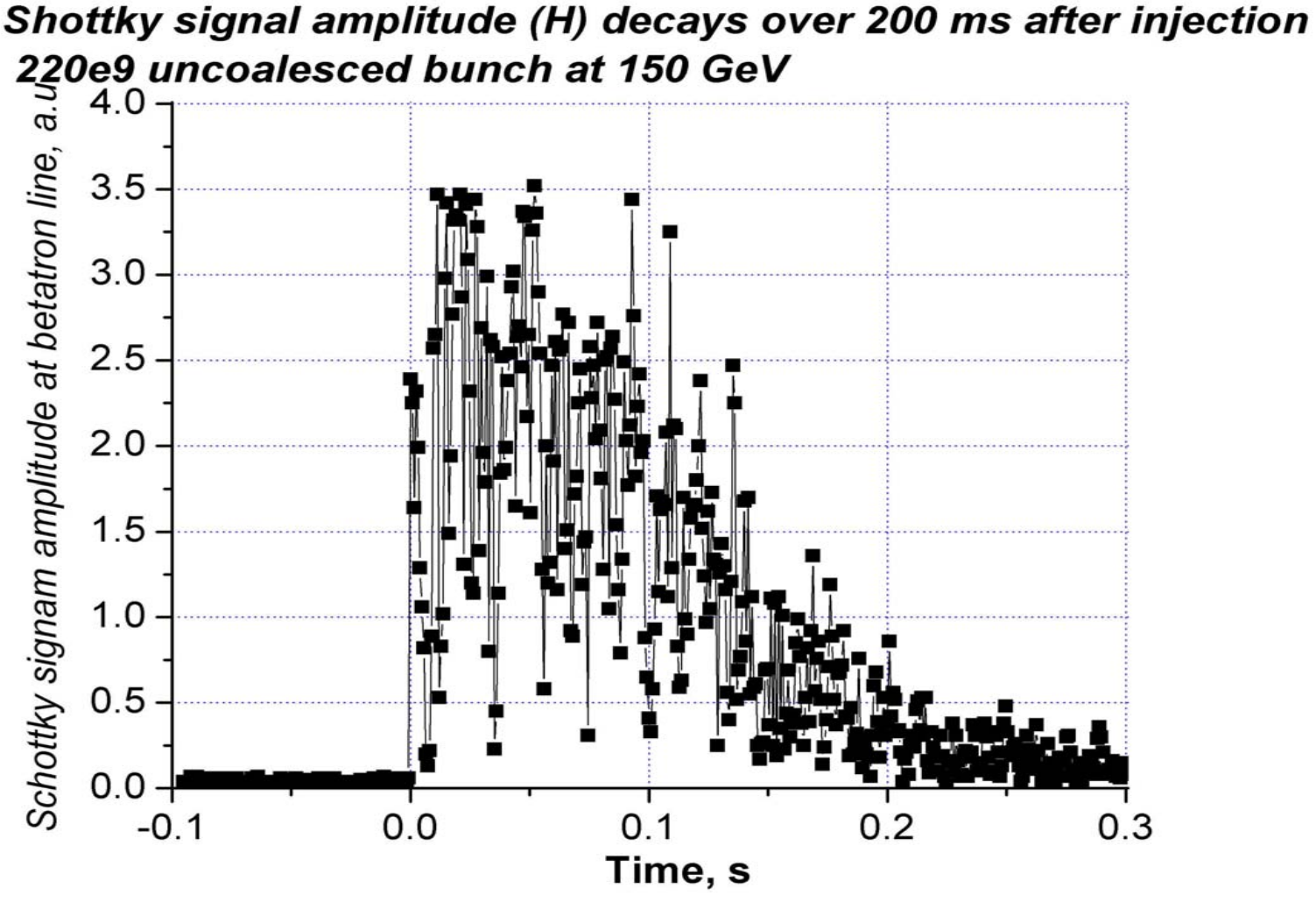
Beams at Injection – Longitudinal



R.Moore

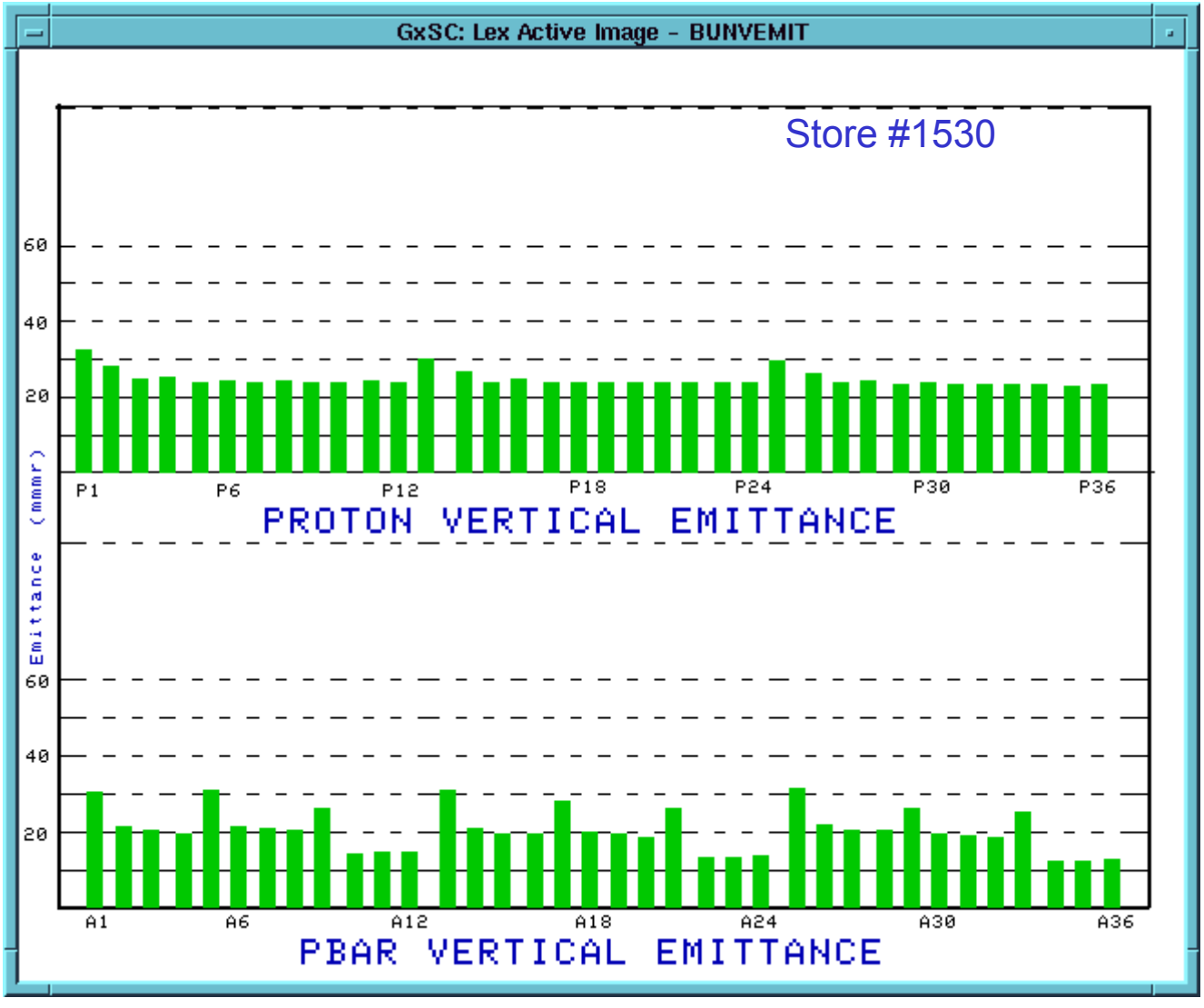
- No significant longitudinal emittance growth (<10%) – full bucket from MI
- Some <10 degree RF phase oscillations, 10% sigma oscillations, 1 s decay

Beams at Injection – Transverse Emittance



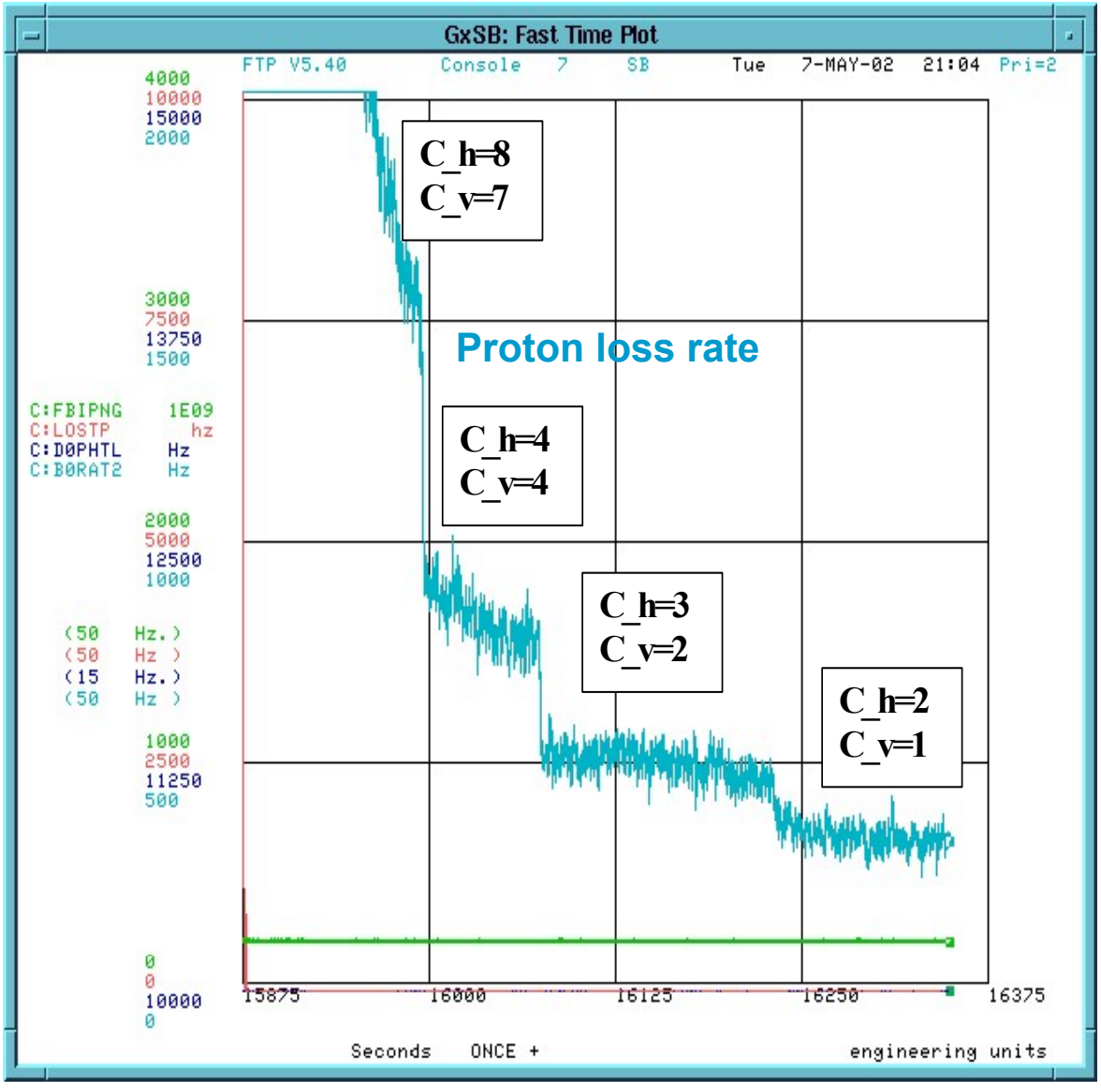
- coherent signal decay (n_x emittance dulution) time is about 10^4 turns

Transverse Emittance /Kicker Adjustment



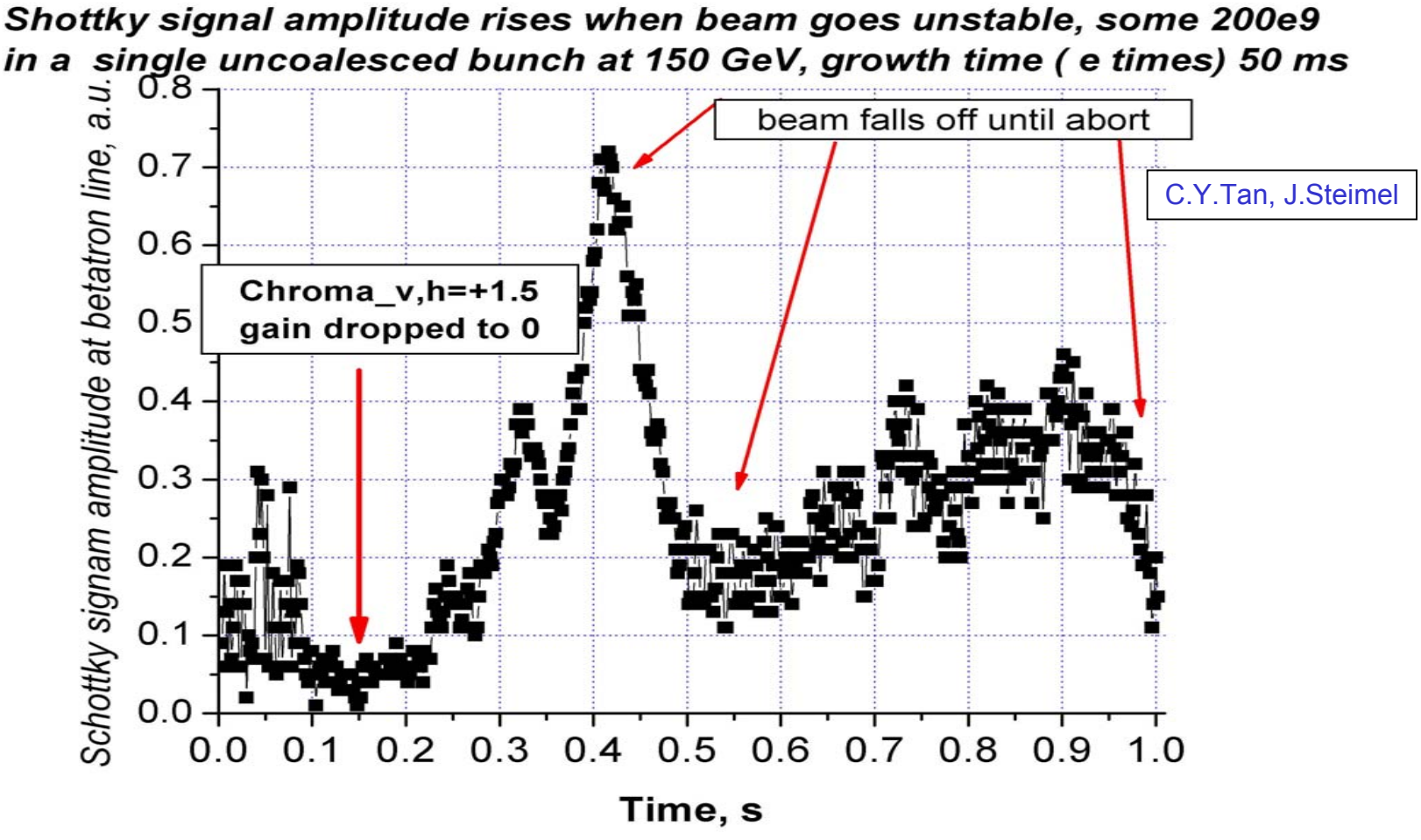
- emittances of the 1st pbar bunches in each transfer were 6□ larger than for other three due to AA→ MI injcetion kicker timing error and Tev injection kicker timing error – fixed
- emittances of P1, P13, P25 blown by pbar injection kickers – fixed by tuning "bumper" kickers (compensators)

Beams at Injection – p-Lifetime



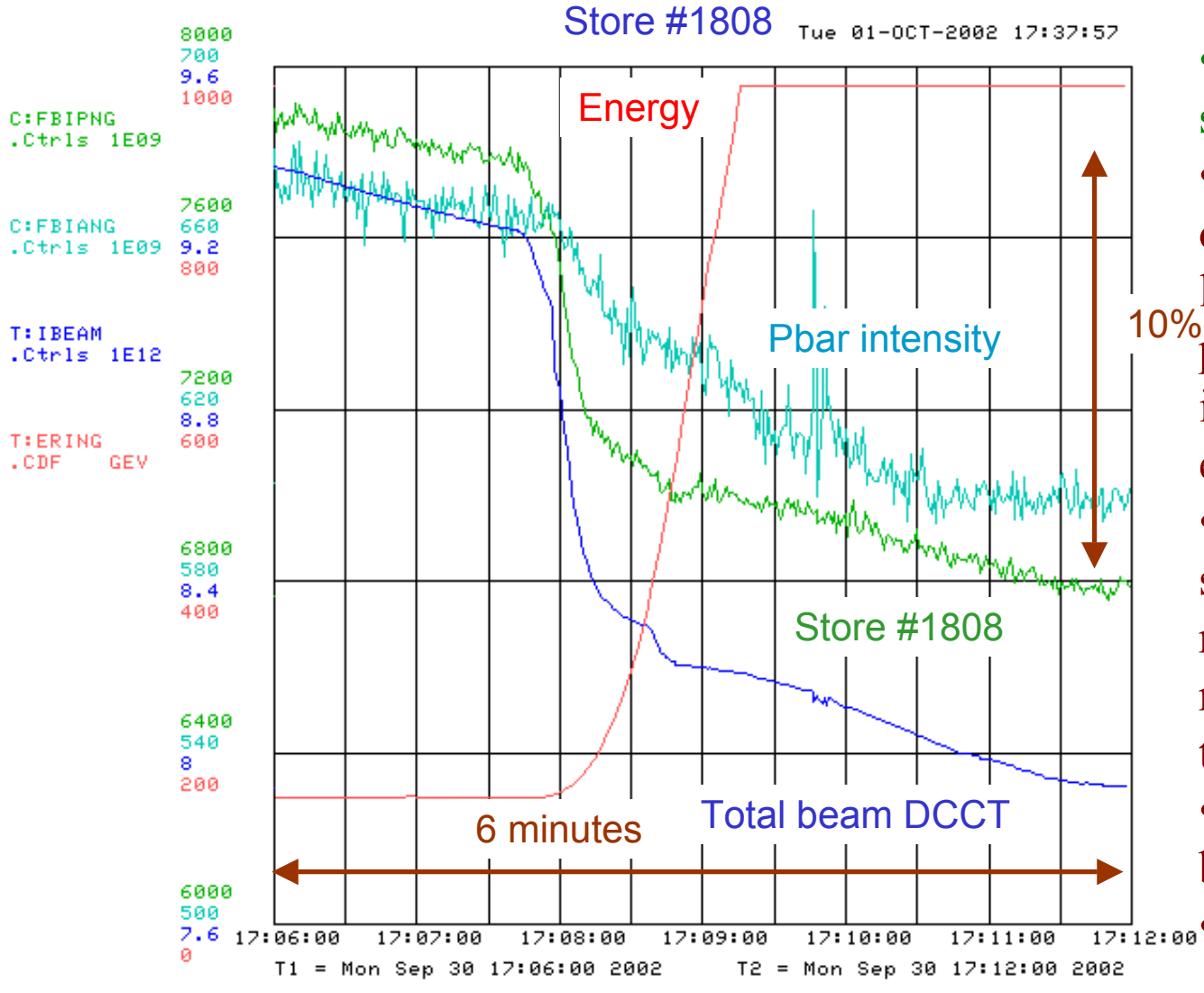
- Large dQ due to chromaticity in limited good working point space (tune aperture)
- p-loss rate (dN/dt) goes down for smaller chromaticities *C*_v,h
- with 36 p-bunches the only way to keep C_v,h=4 is to introduce tune spread by octupoles, or have effective dampers, otherwise beam is unstable (weak head-tail)

Beams at Injection – Transverse Dampers



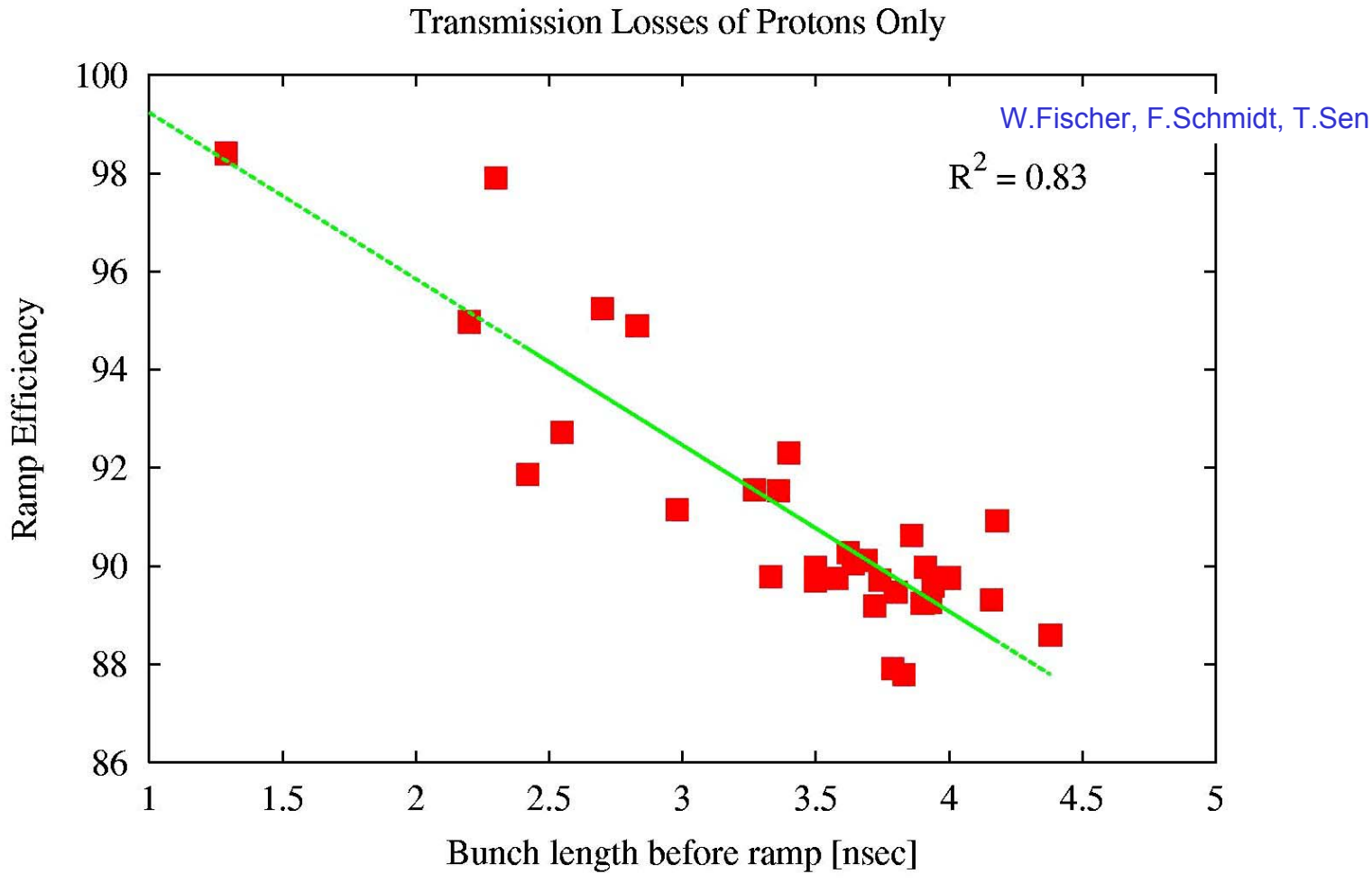
- dampers allow to reduce chromaticity significantly from usual $C_{v,h}$=8 and still have stable protons (*work in progress*)
- instability (*weak head-tail*) growth rate is about 2500 turns

Beam Loss on Ramp



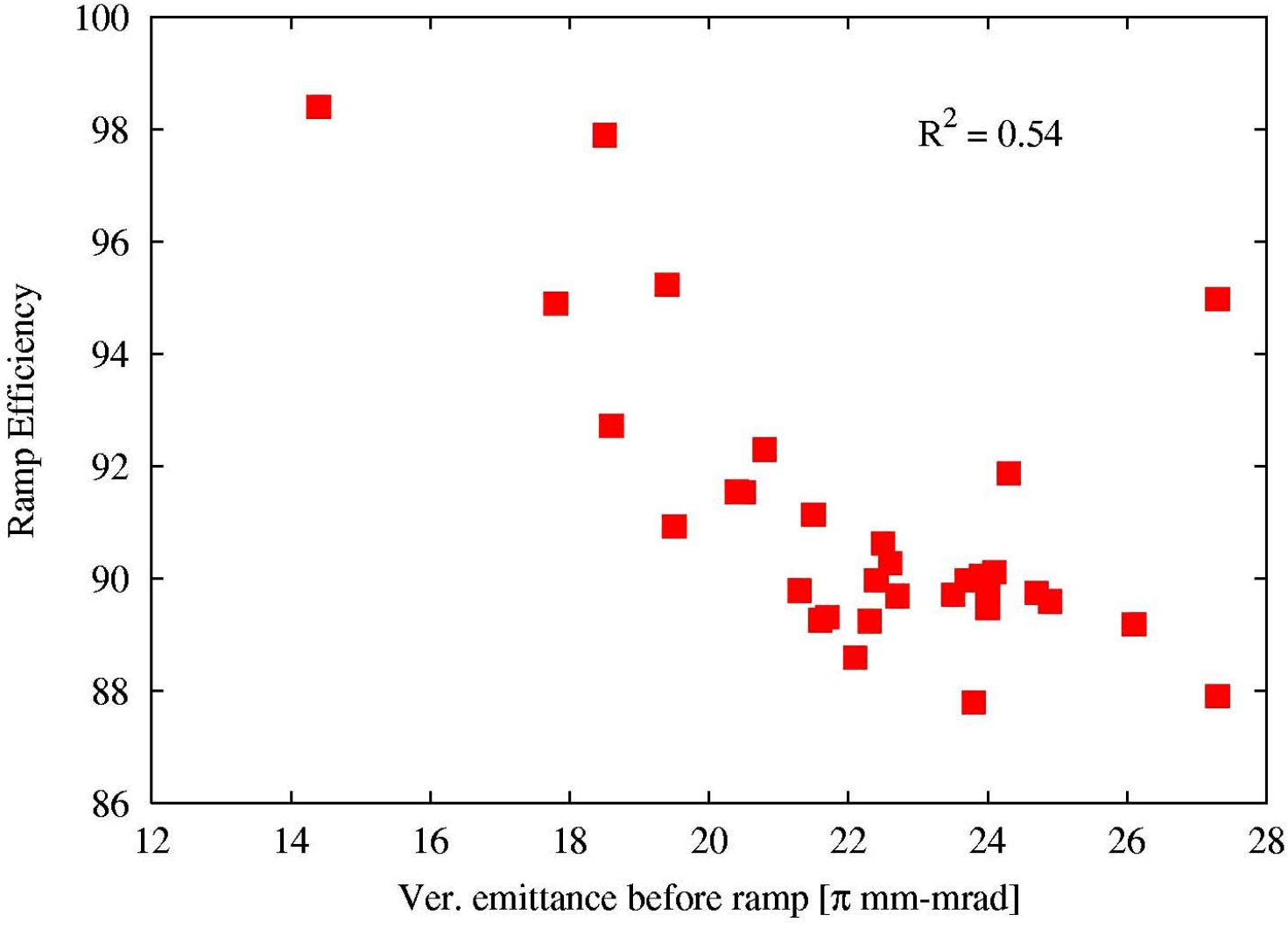
- (intensities are zero-suppressed)
- at the very beginning of the ramp DC beam is lost (some 2-3% in both p and pbars, depends on injected longitudinal emittance)
- then we have significant beam loss on ramp which – at smaller rate – continues at flat top and in squeeze
- For pbars, the reason is beam-beam interaction
- For protons - ? →

Proton Loss on Ramp



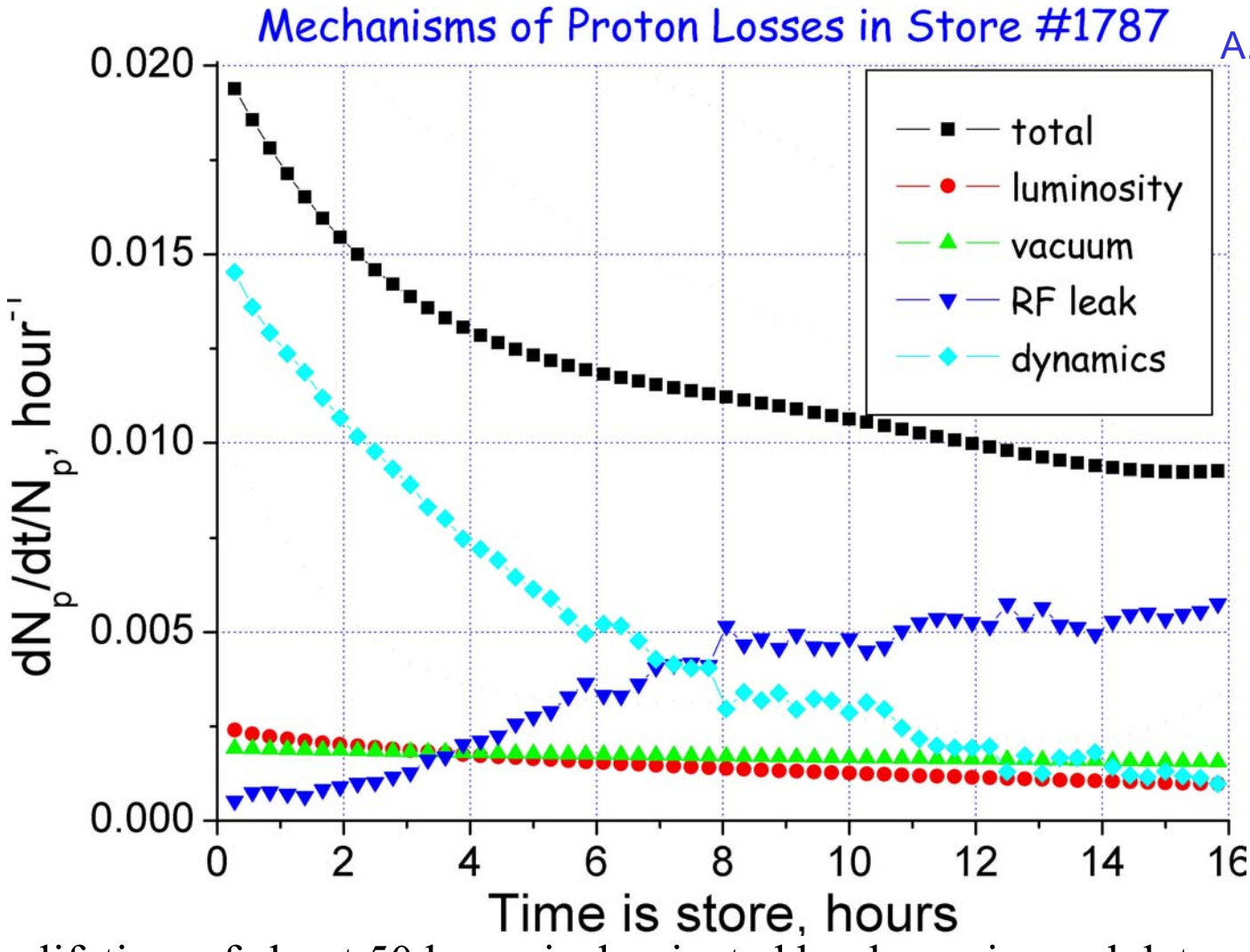
- ramp efficiency also anticorrelates with N_p, vertical emittance and ↓l-emittance

Proton Loss on Ramp vs Emittance



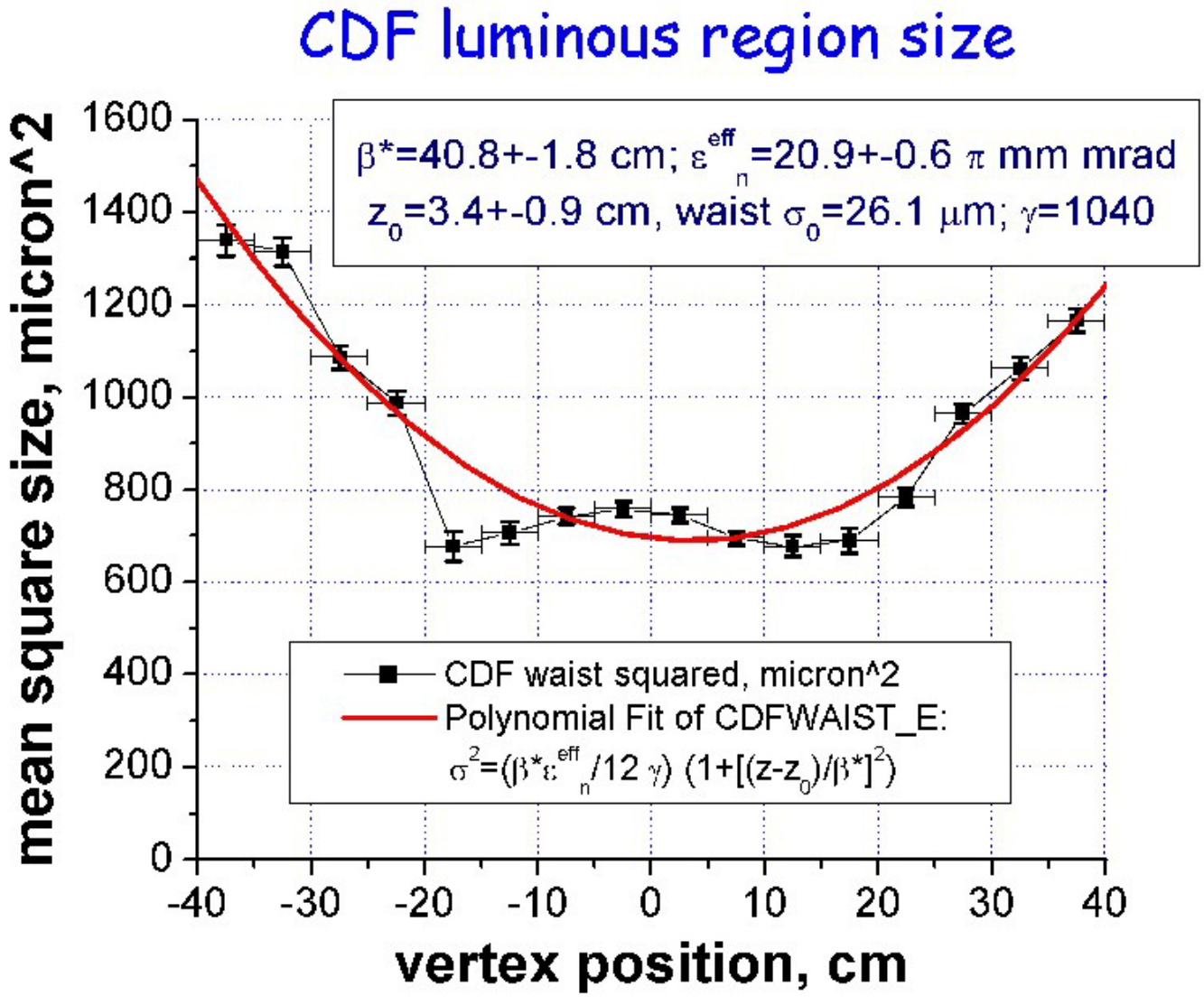
W.Fischer,
F.Schmidt,
T.Sen

Beam Losses - Protons

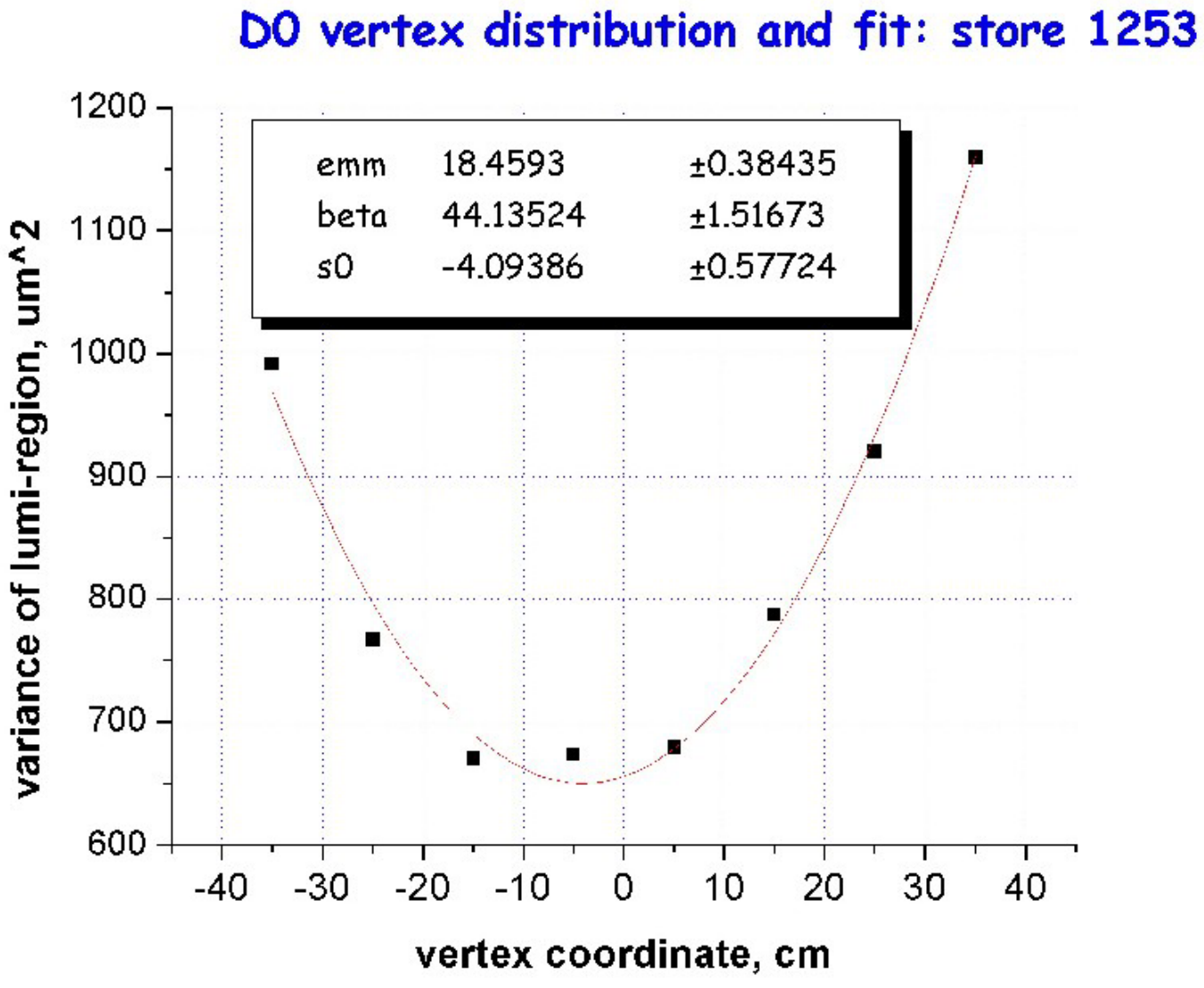


- Proton lifetime of about 50 hours is dominated by dynamics and, later, RF leaks

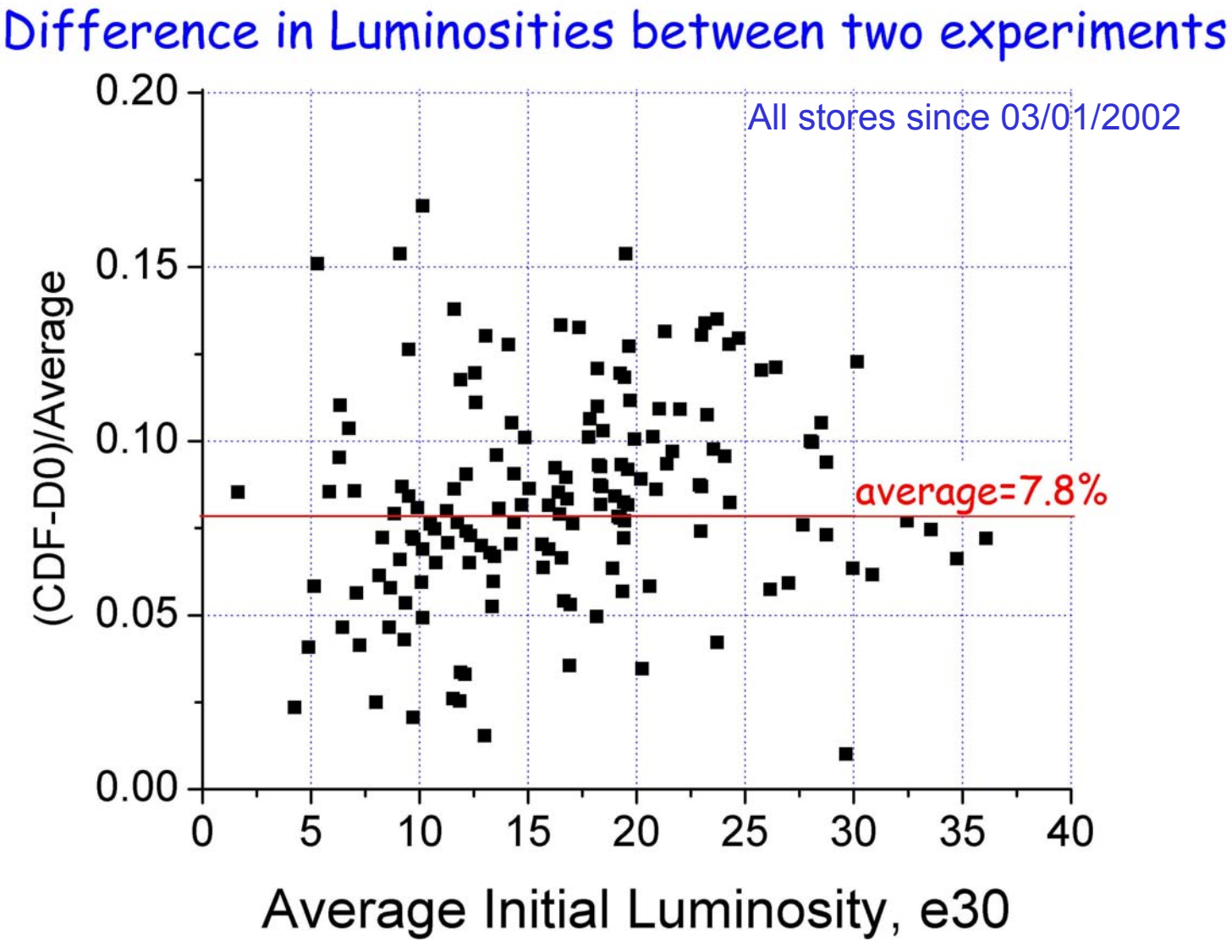
Interaction Points: CDF



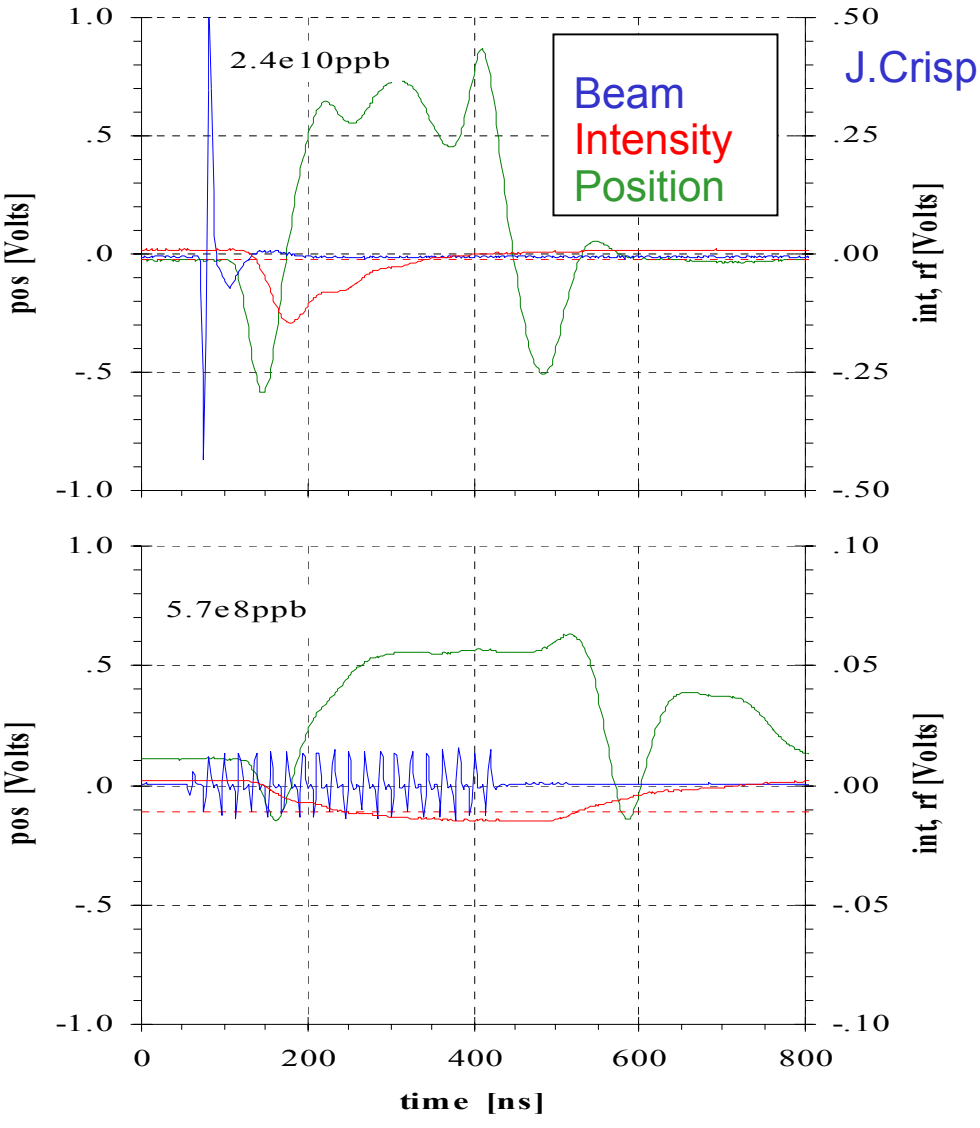
Interaction Points: D0



Luminosity: CDF vs D0

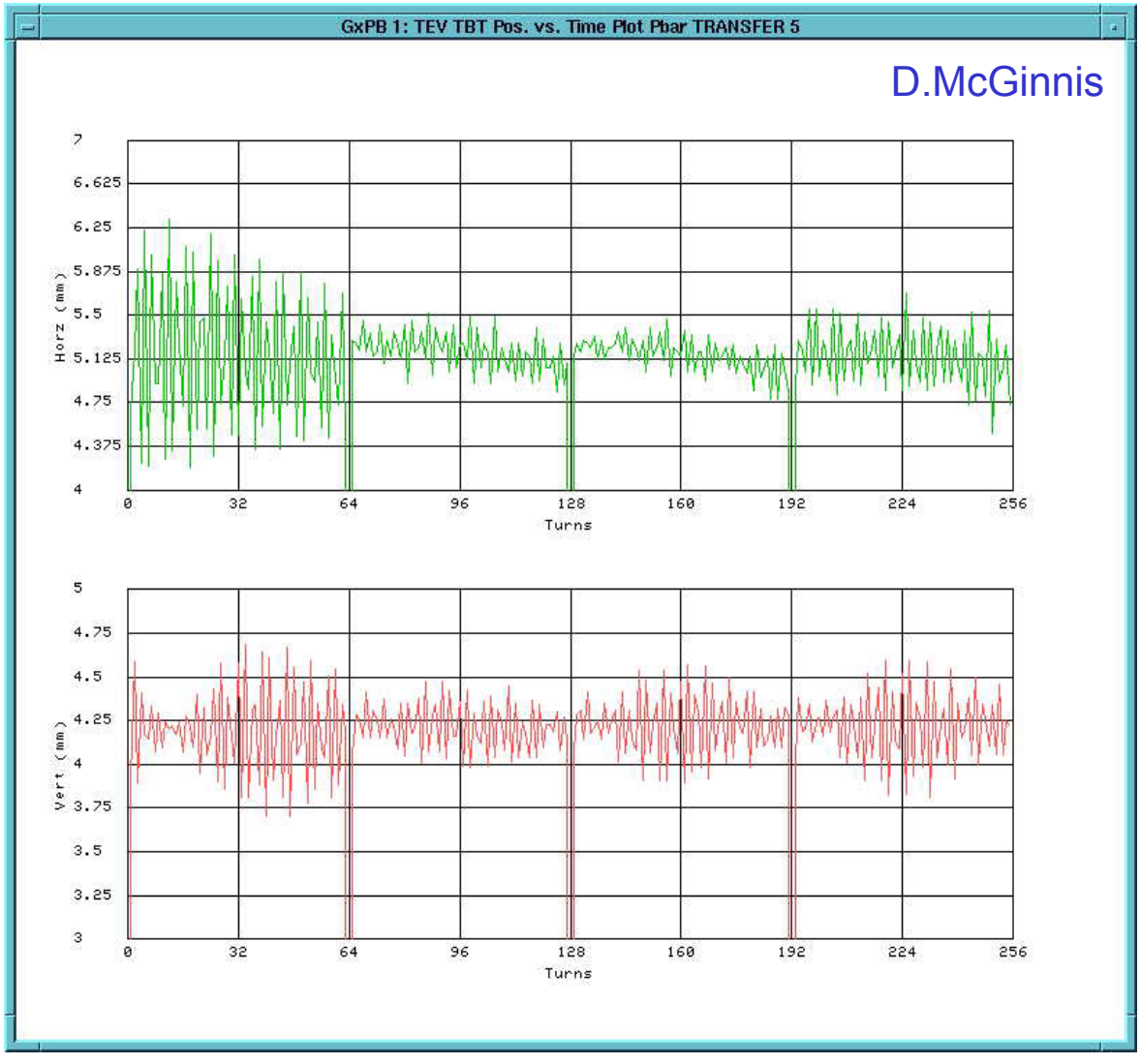


Diagnostics: BPMs



- BPMs originally designed for 53 MHz beam structure
- Work well now for uncoalesced beam
- After some tuning BPMs worked in Run I with 6x6
- Do not work with 36x36 because of bunch separation is smaller than filter ringing time

Diagnostics: Beam Line Tuner

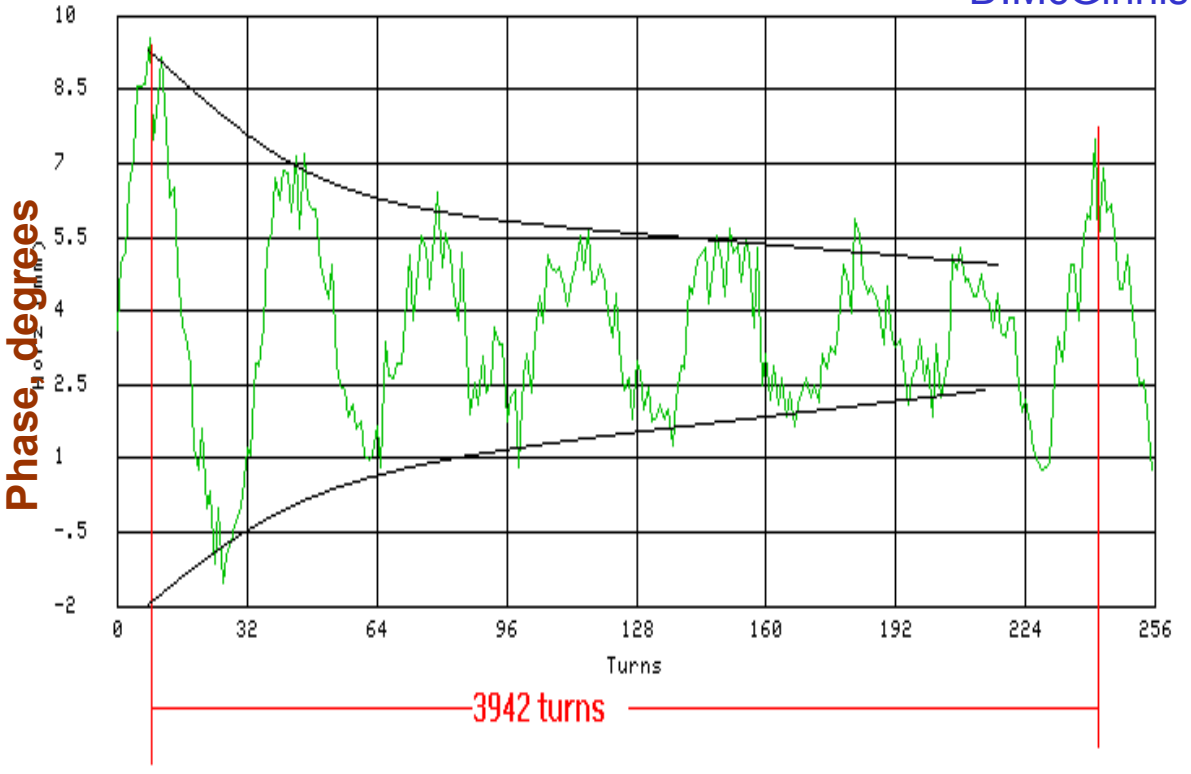


- Consists of strip-lines, DAQ, software and dipole correctors in A1/P1 lines
- Old version (RF integrator) was too sensitive to time jitter (now improved but not in use)
- New version based on segmented memory scope just commissioned and operational

Diagnostics: RF Phase Detector

Injection of coalesced bunch at the high positive chromaticities

D.McGinnis

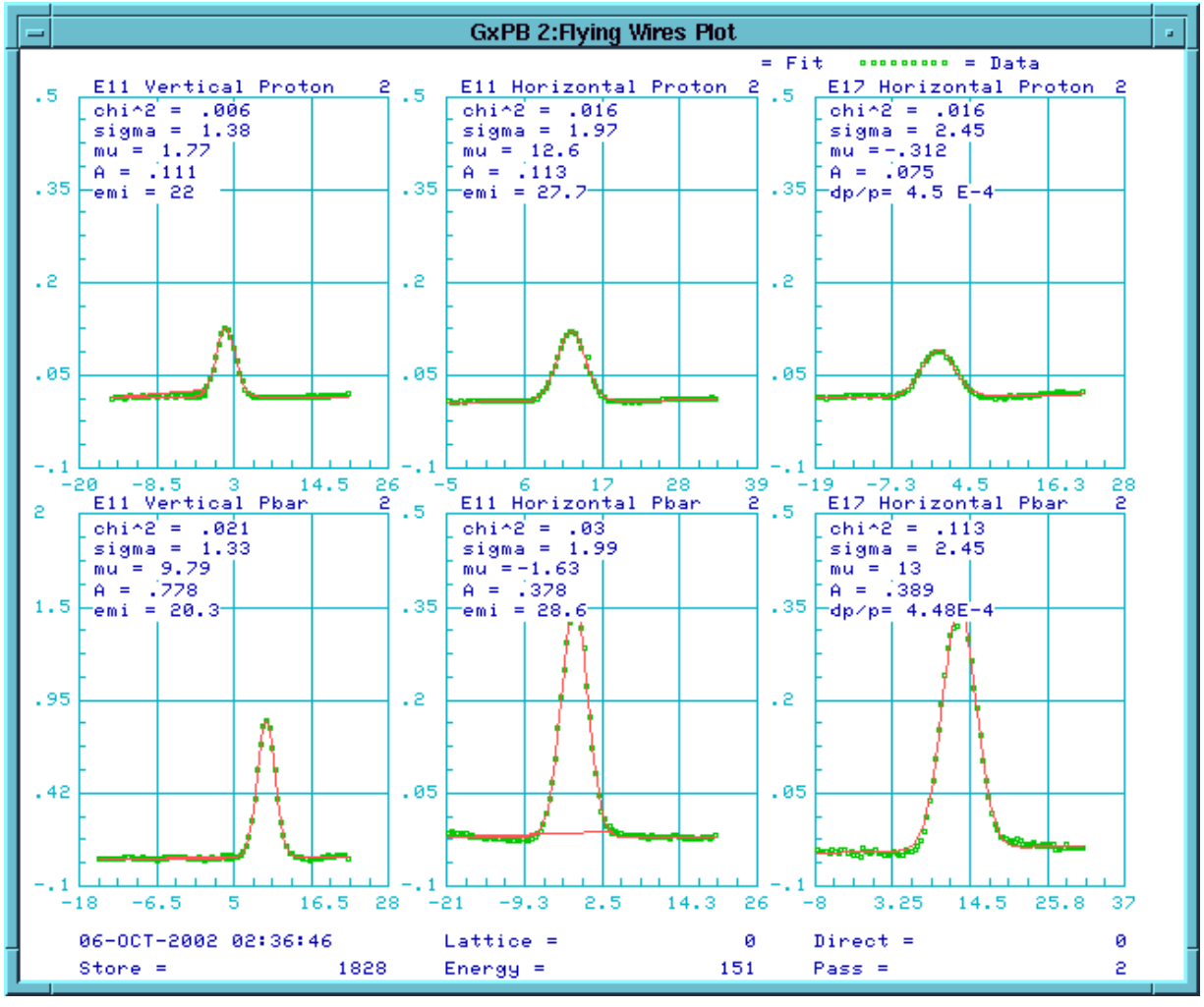


$$(\nu_s)_{coh} = \frac{7}{3942\ turns} \approx 1.78 \cdot 10^{-3},\ \xi_y \approx 8,\ \xi_x \approx 8,\ [\nu_y] = 0.5750,\ [\nu_x] = 0.5830$$

- Did not exist in March'02
- Horizontal BPMs were used to qualify phase/energy offsets at injection
- Later, longitudinal damper would be used for that purpose (needed modified DAQ)
- New detector on base of segmented memory scope is just commissioned

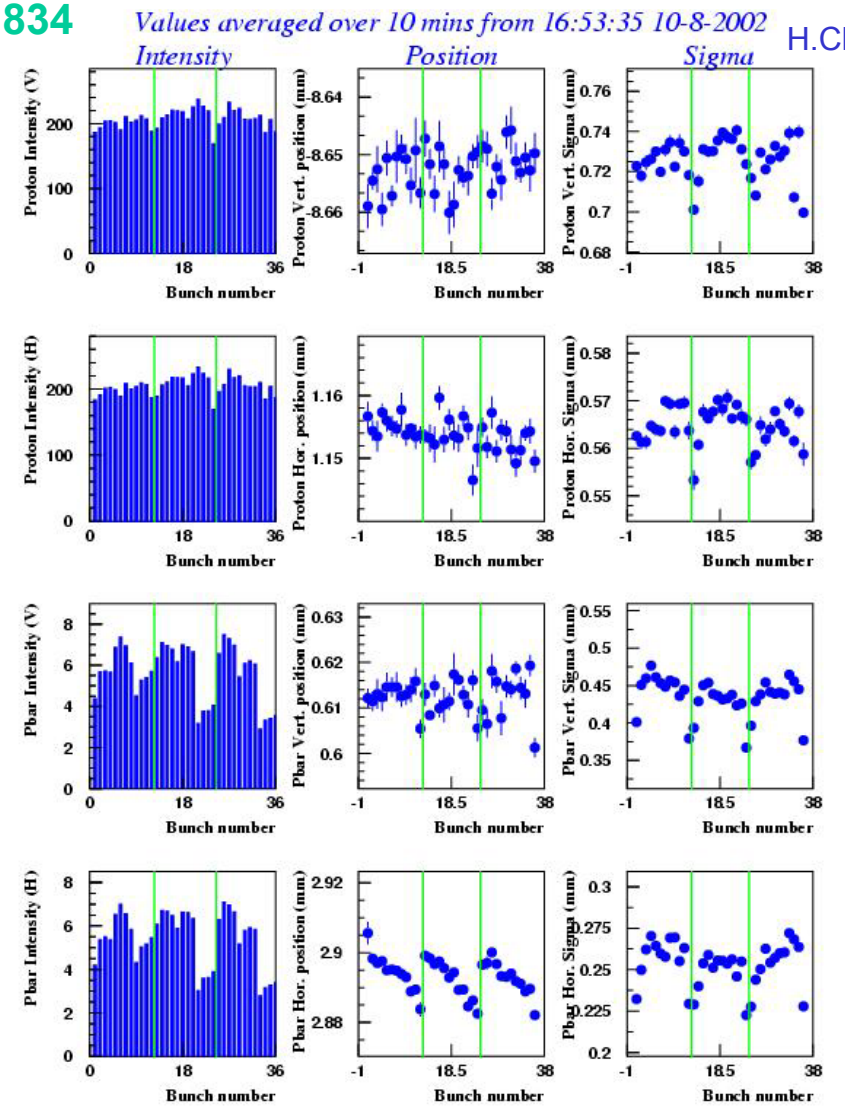
Diagnostics: Flying Wires

#1828, injection

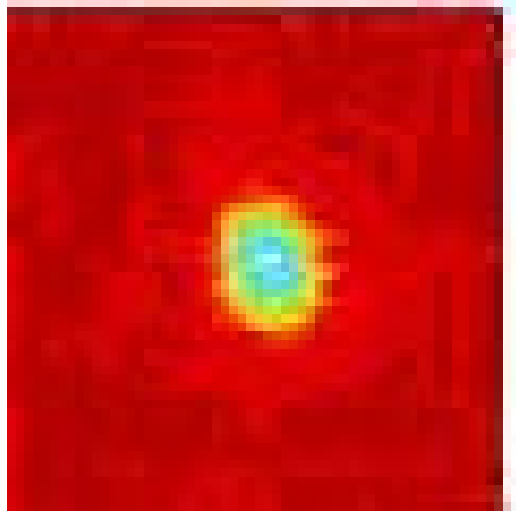


- Proton channels tuned up in March
- Still some (15% ?) calibration needed
- Pbar channels data are subject of correction
- “Jumping” emittances
- (improper dP/P?)
- Recalibration of both p and pbar channels is due
- Need raw data

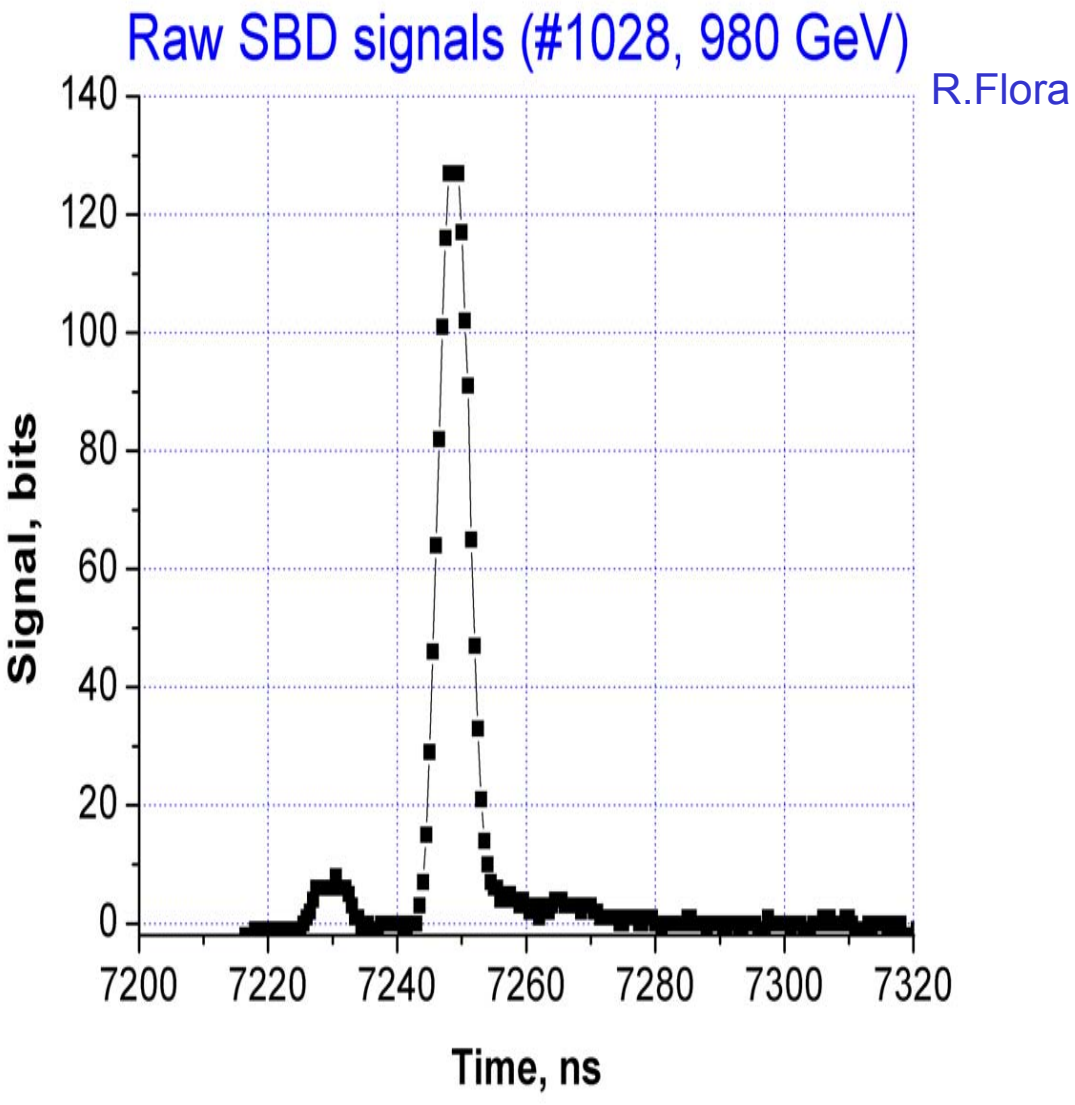
Diagnostics: SyncLite Monitor



- Works >800 GeV
- Significant progress since March'02
- Reports ♦, mean, N, tilt bunch-by-bunch for both protons and pbars
- Invaluable instrument
- Recalibration of both p and pbar channels is due
- Need raw data
- Tails? Head-tail?



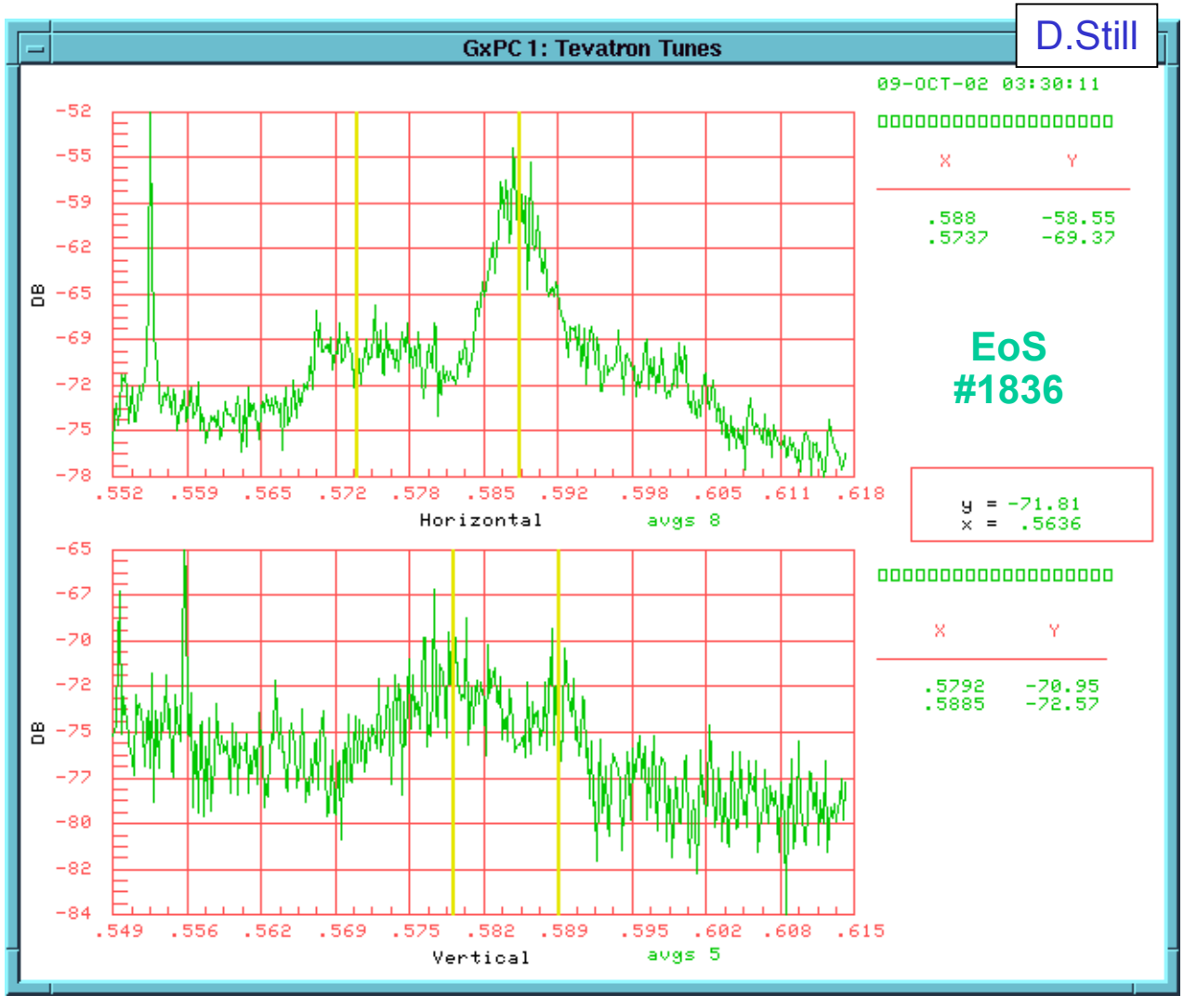
Diagnostics: SBD, FBI



- Dispersion in long cable adds to ♦, tails, satellites
- Raw data available On-Line
- Pbar channels affected by strong proton bunches
- Pbar bunch length not available in ACNET until final cogging (just fixed)
- FBI needs calibration (5%?) and proper offset subtraction especially in pbar channel
- FBI intensity depends on $♦_s$ - need to be fixed
- Intensity from SBD – coming soon

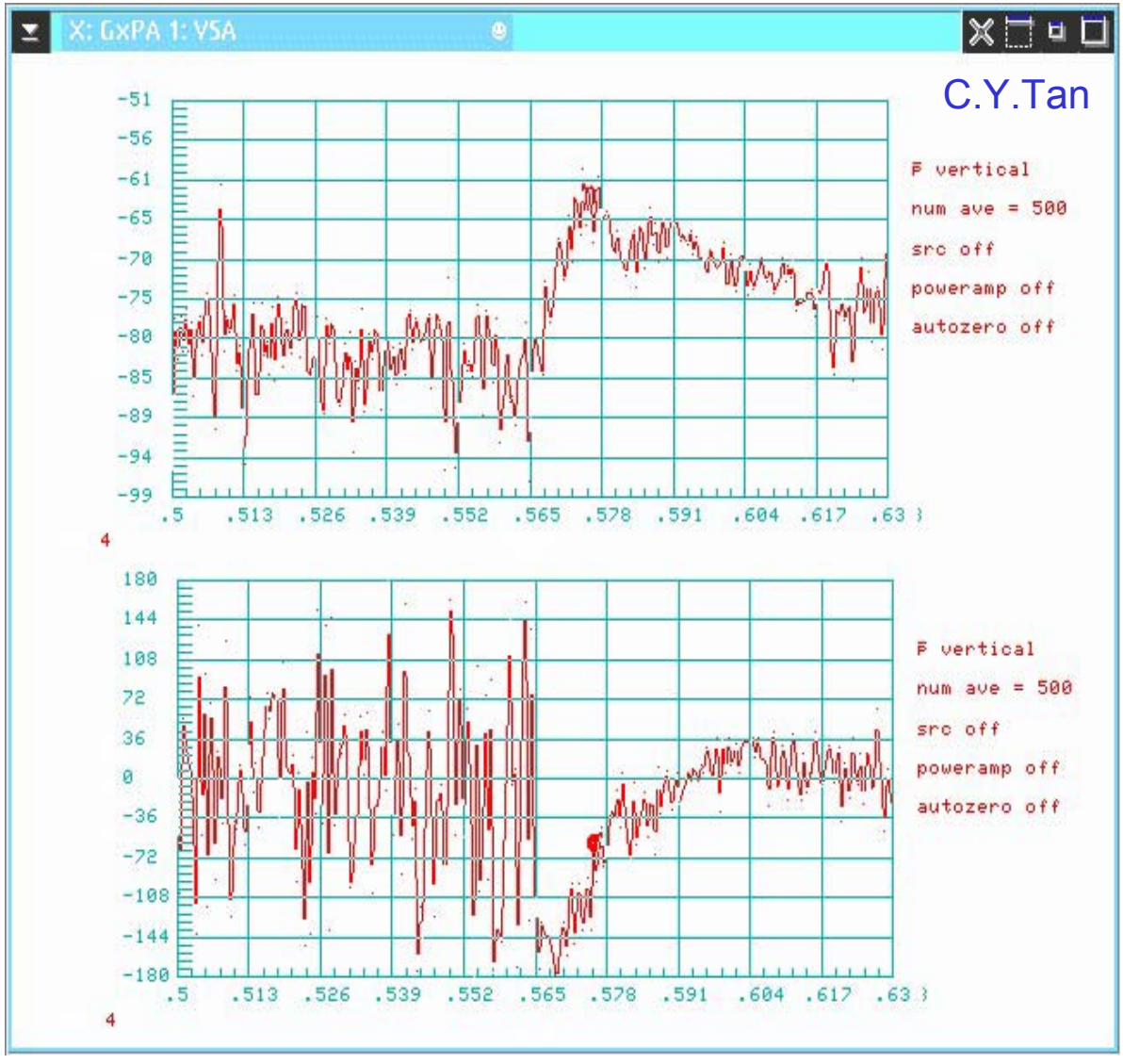
Diagnostics: Schottky Monitors

- 21 MHz resonant curcuit, 20 kHz band covered, V/H
- Used for tune measurements
- Reports V and H power over 20 kHz
- Does not see pbars or individual bunches
- “ghost” line - real
- Data in ASCII
- New Schottky detector at E17
  - 1.5 GHz
  - Pbars and protons
  - Bunch-by-bunch



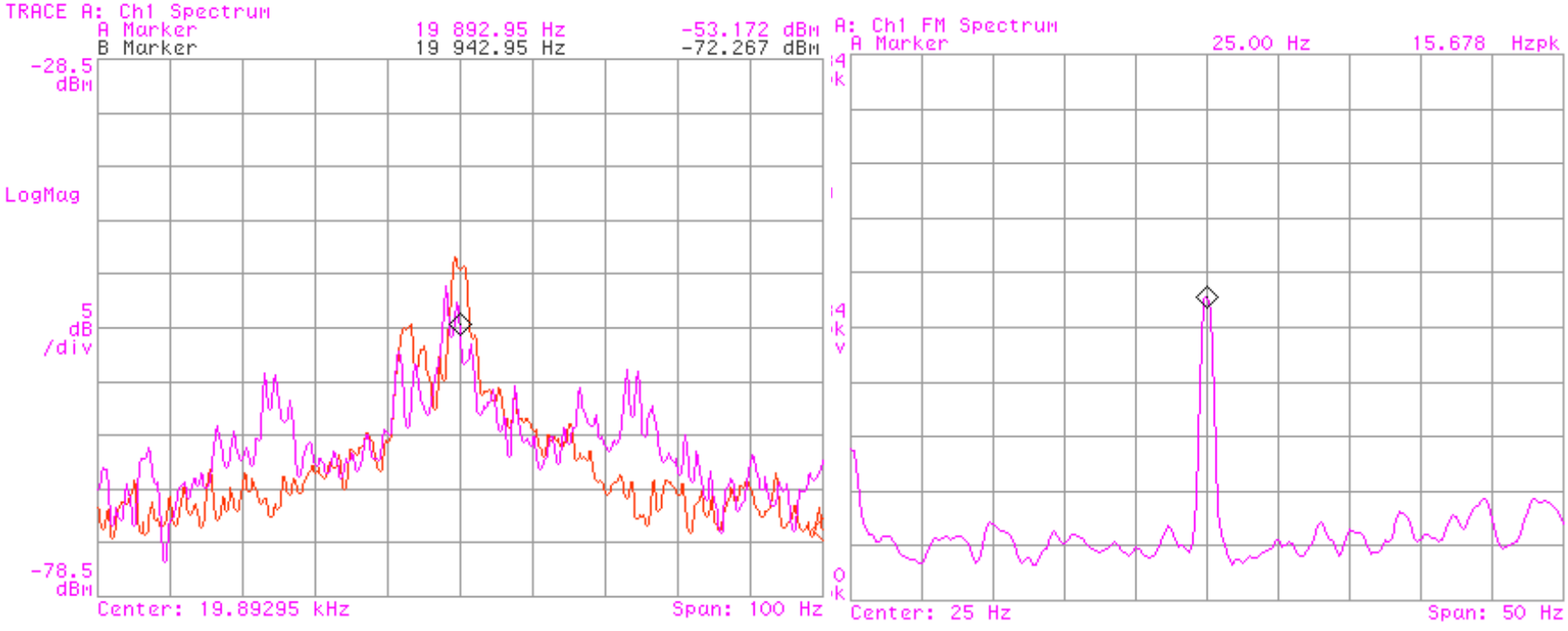
Diagnostics: Tune Meter

- Bunch-by-bunch
- Significant progress since March : cabling clean-up, reduced excitation
- Destructive (over 10's of minutes)
- Has been used for dedicated pbar tune measurements
- Recently disassembled – parts used in vertical damper
- To be re-assembled
- Need protons tunemeter
- Need raw data



Diagnostics: Chromaticity Measurements

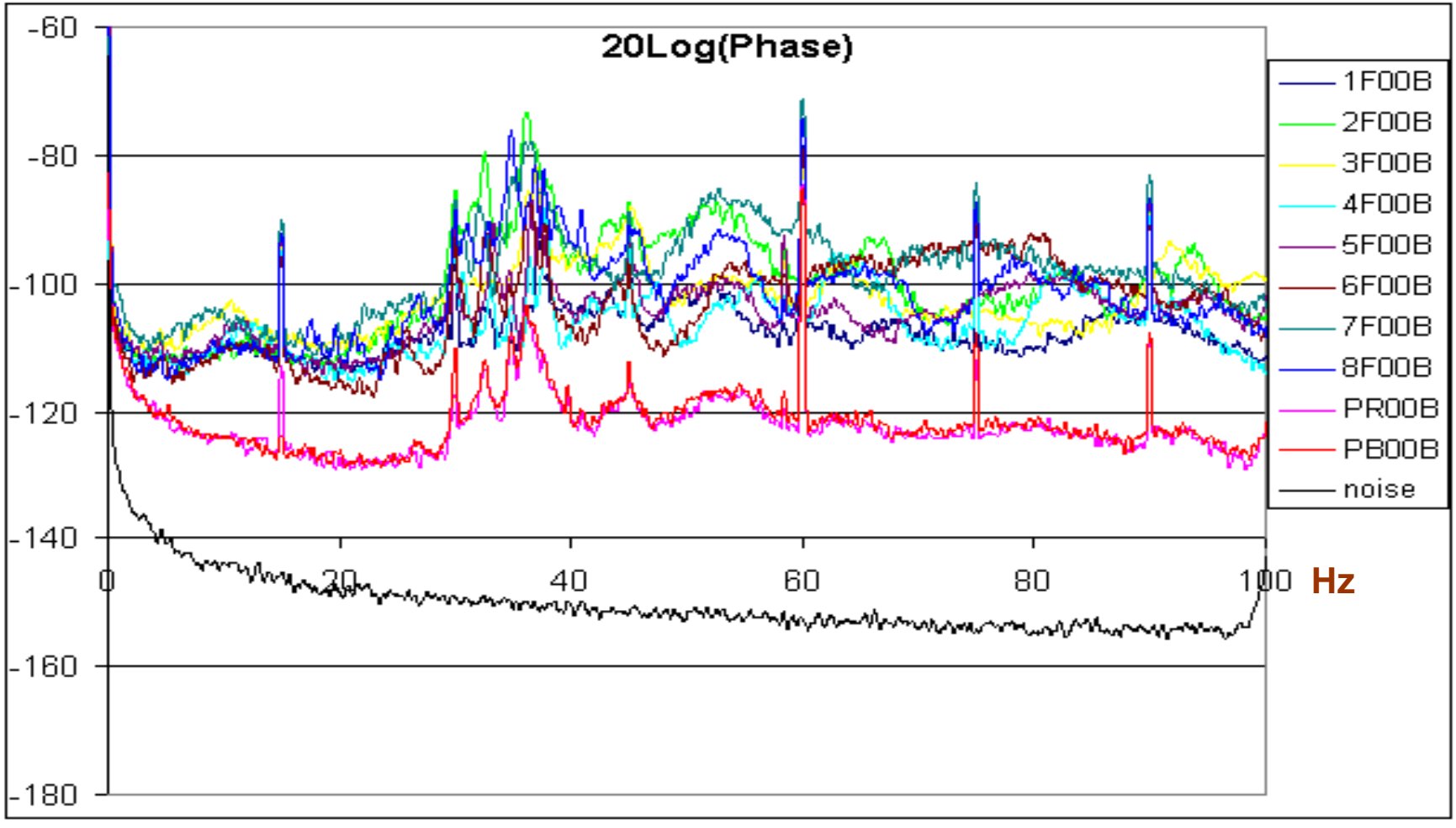
D.McGinnis



- δf_{RF} used for routine C_v,h measurements – slow
- RF phase modulation method C= $\delta Q \approx f_m / (f_{RF} \delta \tau)$ – faster, 10 times less destructive
- Not tested yet with coalesced beam, and anywhere except 150 GeV
- Plans to deduct C_v,h from natural Schottky spectra analysis

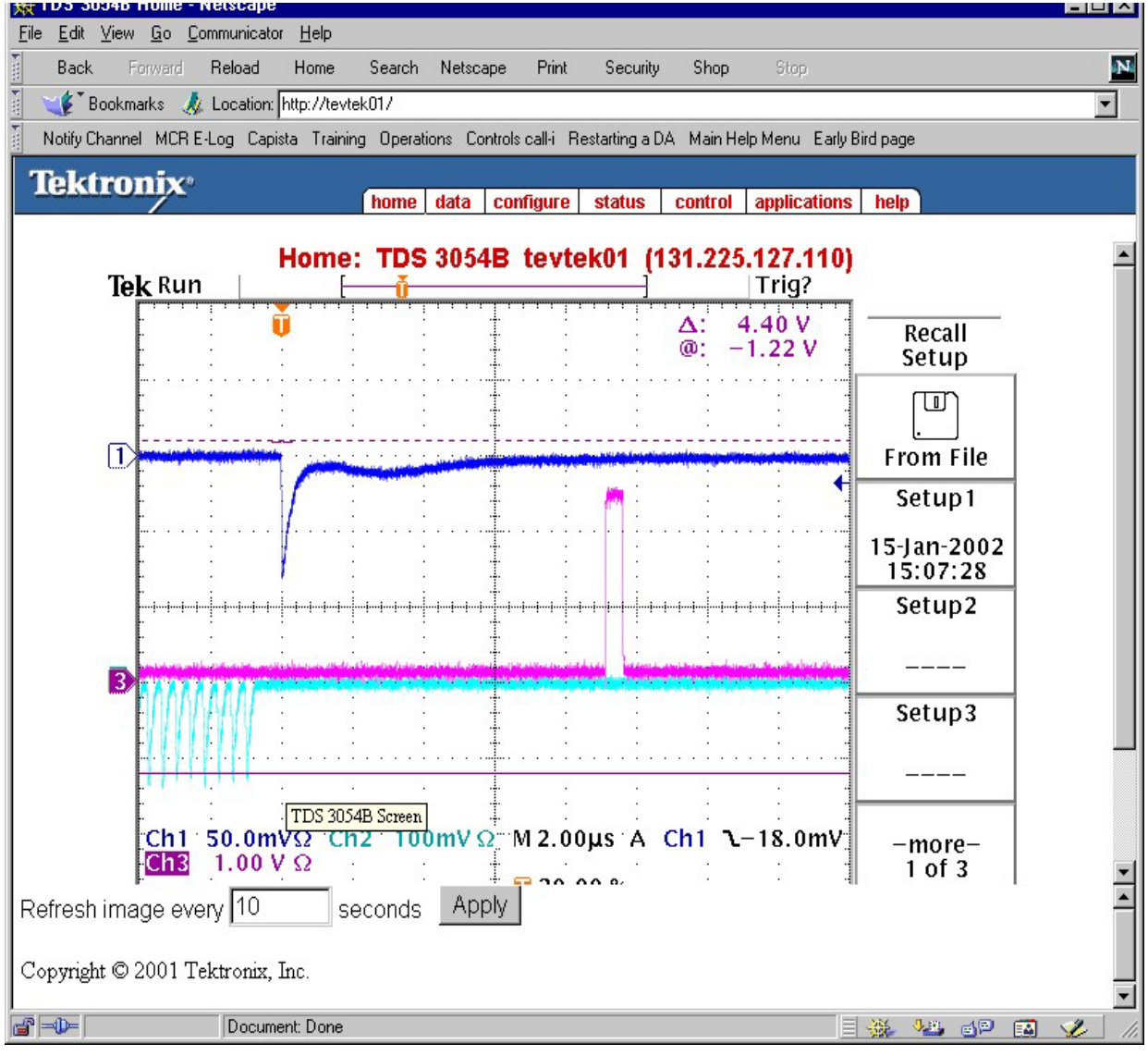
Diagnostics: Advanced RF Diagnostics

Spectra of RF Phase Noise in 8 Tevatron Cavities T.Khabibulin



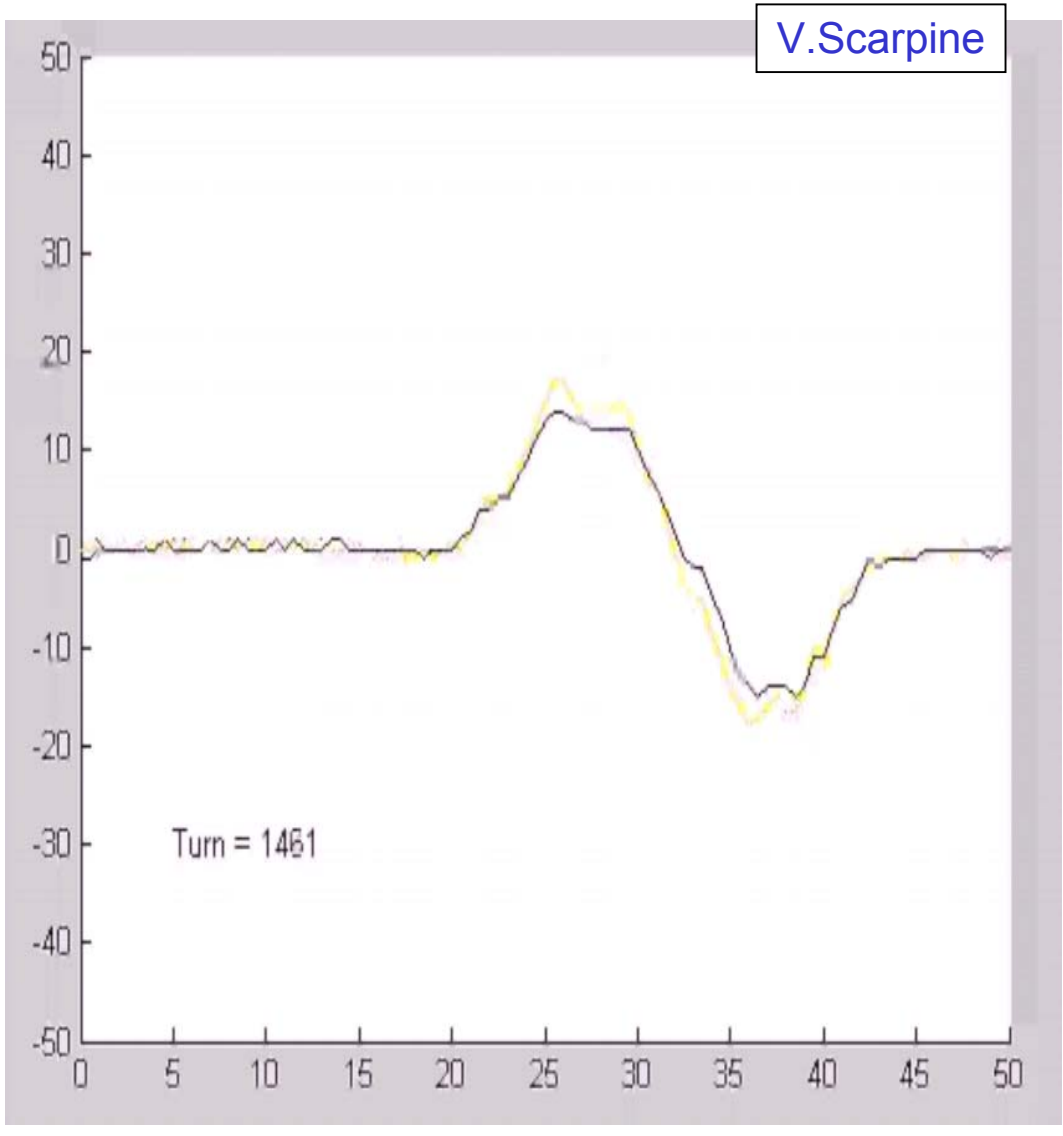
- RF voltage and cavity t are logged, other diagnostics possible at F0
- RF noise investigations just started

Diagnostics: Loss Monitors/Scintillators



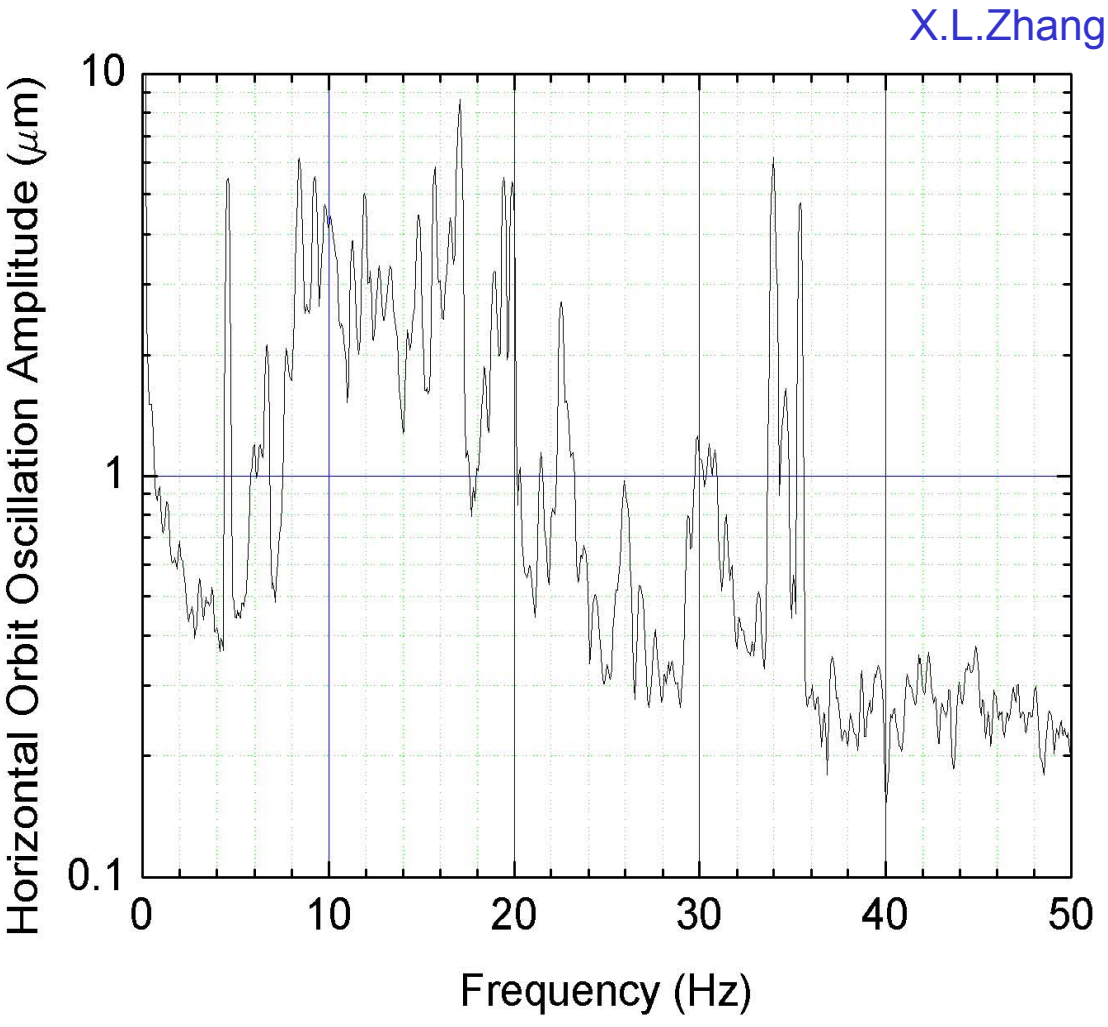
- Dozens of counters at CDF and D0
- Since March – new ones to monitor losses from bunches, between bunches and abort gaps
- Dedicated scintillator paddle on B0 LB quad
- More paddles on collimators

Diagnostics: Head-Tail Monitor



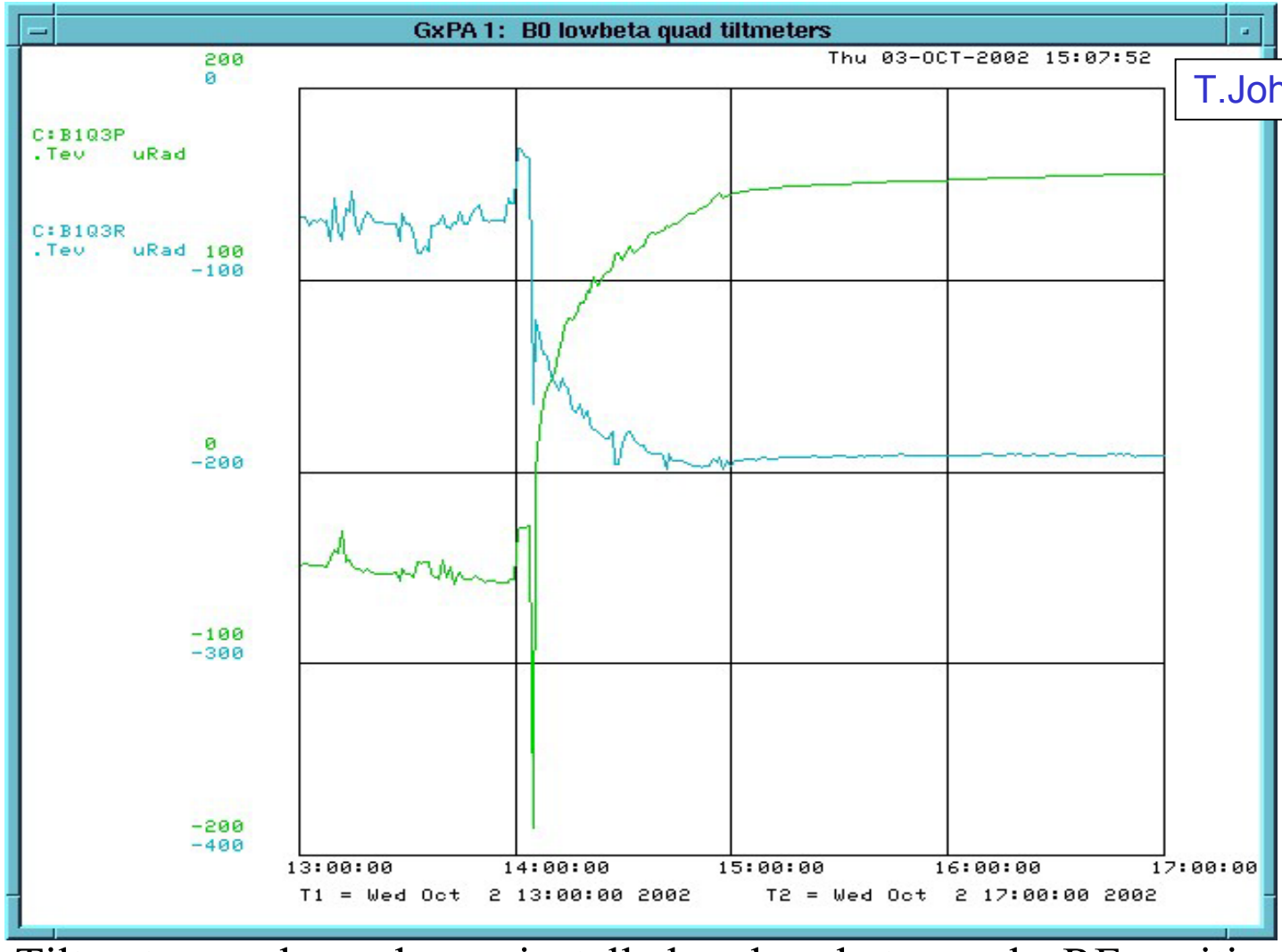
- BLT hard- and software allows to measure position within one bunch
- Goal of the HTM – monitor higher order head-tail modes
- Just started
- Can be used for chromaticity measurements (destructive)

Diagnostics: Orbit Oscillation Monitor



- Straightforward analysis of the BPM signal spectra
- Interesting first results 1-400 Hz
- Needs to be developed to become useful (e.g., ACNET)

Diagnostics: Tiltmeters/Geophones



T.Johnson

- Tiltmeters and geophones installed on low-beta quads, RF cavities