PEP-II Operation and Machine Development

U. Wienands

PEP-II Run Coordinator

… for the PEP-II Team …

Outline of Talk

- PEP Run 5 Progress, Parameters & Statistics
- Specific Run 5 Challenges
- Machine Development
- Conclusion
- Outlook

Run 5 Progress

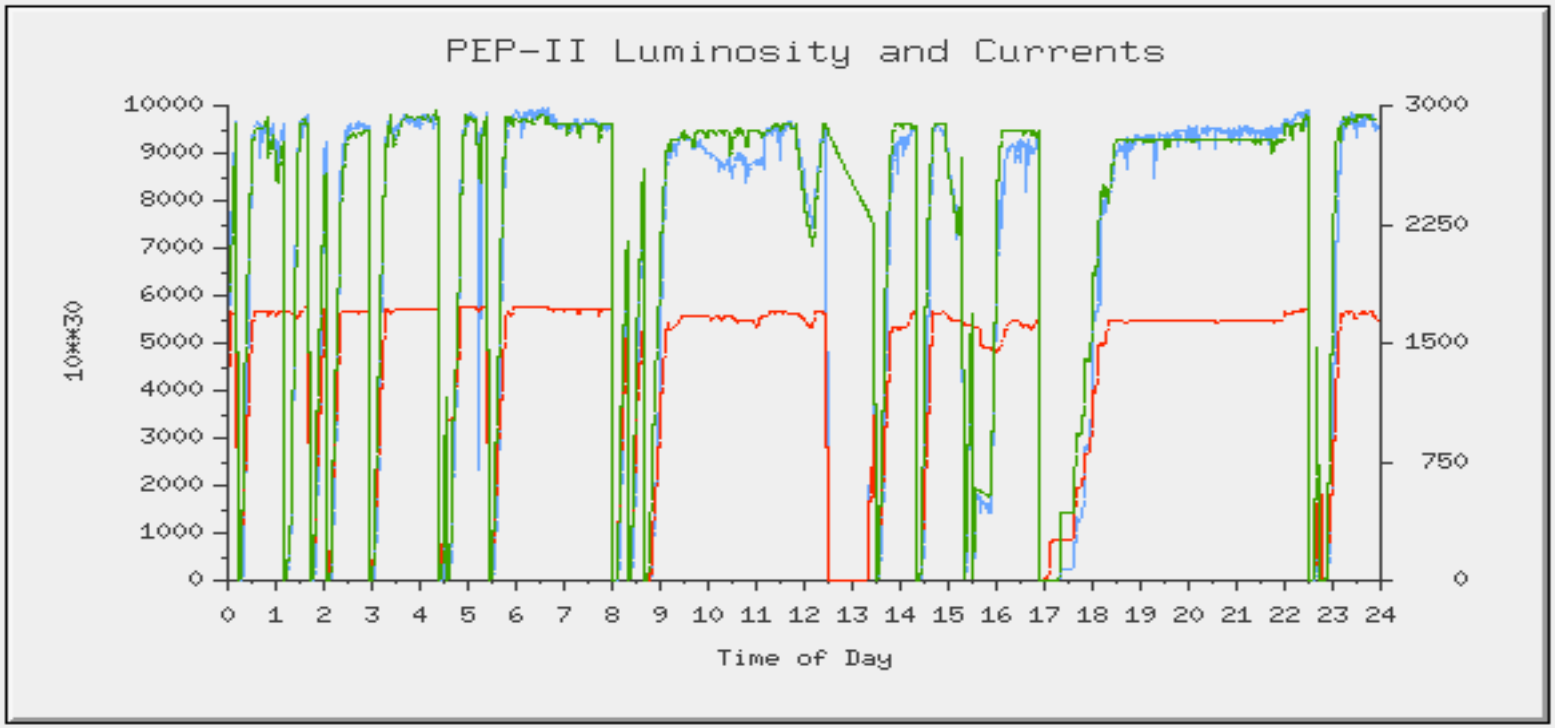
- Run 5 has been challenging
  - 5 month delay due to electrical accident & investigation
  - Severed 230kV line => total site blackout
- Significant technical issues got resolved
  - "Fast LER instability" (IR 4 rf seal issue)
  - IR-2 vacuum bursts
  - LER BPM heating causing buttons to drop
- Run 5 saw record heights in luminosity:
  - 1E34 peak luminosity
  - 727/pb/24hr delivery record

$\mathscr{L} = 10^{34}\ /cm^2/s$

I HER	I LER	Luminosity	Spec Lum	E HER	E LER	E CM
1616.74	2924.27	9360	3.41	8985	3120	10590
mA	mA	10**30/Sec	N*10**30 / mA**2/Sec	MeV	MeV	MeV

HER N Buckets / Pattern	LER N Buckets / Pattern
1732 by2_t36_her_30	1732 by2_t36_ler_30

Last Owl/Day/Swing/24hr	169.6	150.7	203.4	523.7	Shift:	1.12 /pb
Peak Luminosities	10008	9732	10025			9487



10/10/2005 00:01:04 The Quest for 1.0e34/cm^2s

PEP-II Parameters

	Design		Achieved (delivery)	
Energies e– / e+ (GeV)	8.973	3.119		
Currents e– / e+ (A)	0.75	2.14	**1.75**	3.0 **(3.0)**
Single beam currents (A)			1.8	2.10
Number of bunches	1658		**1732**	
Bunch currents e– / e+ (mA)	0.45	1.29	**1.24**	**2.09**
Bunch spacing (m)	1.26		**1.26**	
IP spot size σ_x^* / σ_y^* (μm)	155	4.7	147	5
Luminosity ($\times 10^{33}/cm^2/sec$)	3.0		**10.0**	
Tune shift horiz. e– / e+	0.03	0.03	0.059	0.09
Tune shift vert. e– / e+	0.03	0.03	0.031	0.07
Integrated lumi. / 3 shifts (pb^{-1})	135		**728**	
Integrated lumi. / week (pb^{-1})	785		**4464**	
Integrated lumi. / 7 days (pb^{-1})	785		**4464**	
Integrated lumi. / month (fb^{-1})	3.3		**17.0**	
Beam crossing angle	0 (head-on)		0 (head-on)	

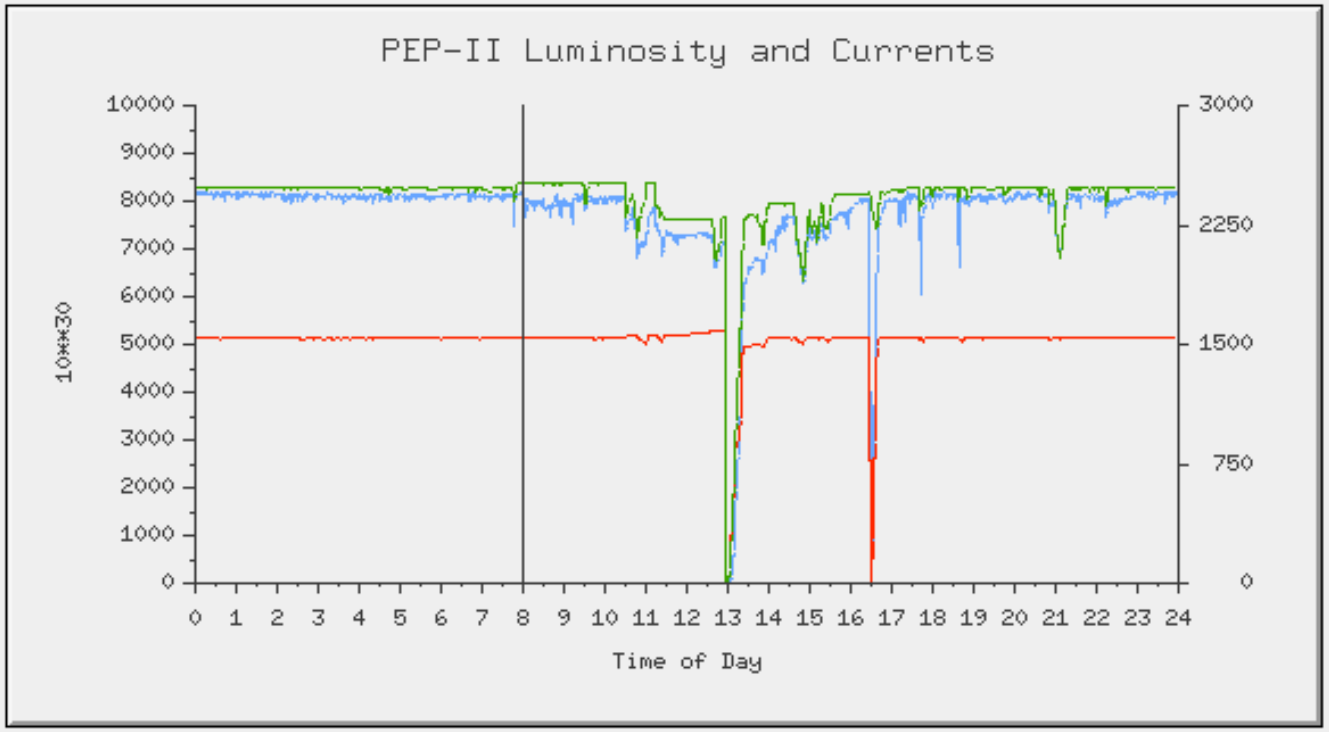
Most recent full Delivery Day

I HER	I LER	Luminosity	Spec Lum	E HER	E LER	E CM
1550.40	2516.68	8119	3.58	8985	3120	10589
mA	mA	10**30/Sec	N*10**30 / mA**2/Sec	MeV	MeV	MeV

HER N Buckets / Pattern
1722 0:3442:2

LER N Buckets / Pattern
1722 0:3442:2

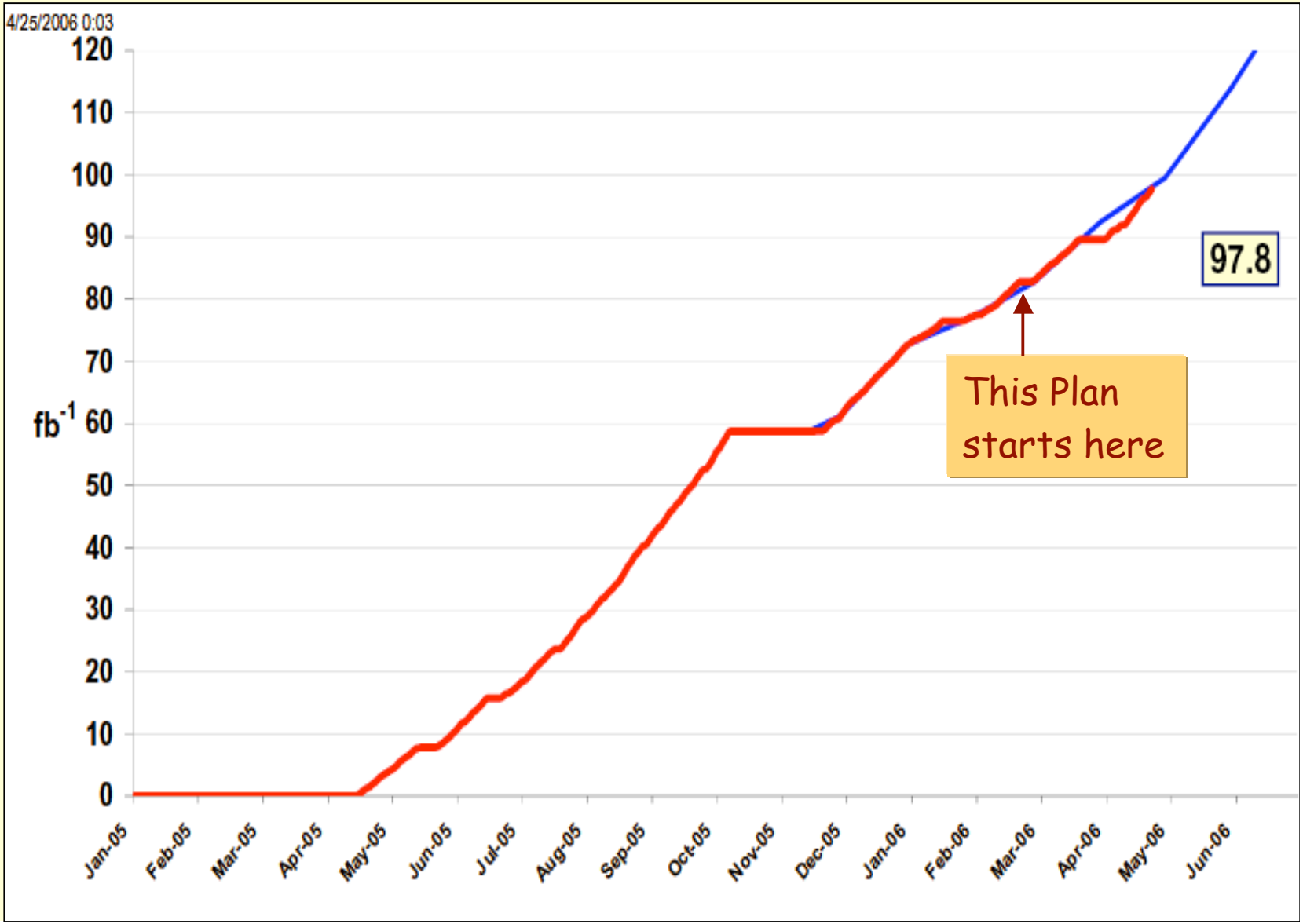
Last Owl/Day/Swing/24hr	233.8	204.0	225.7	663.5	Shift:	0.98 /pb
Peak Luminosities	8264	8196	8248			8237

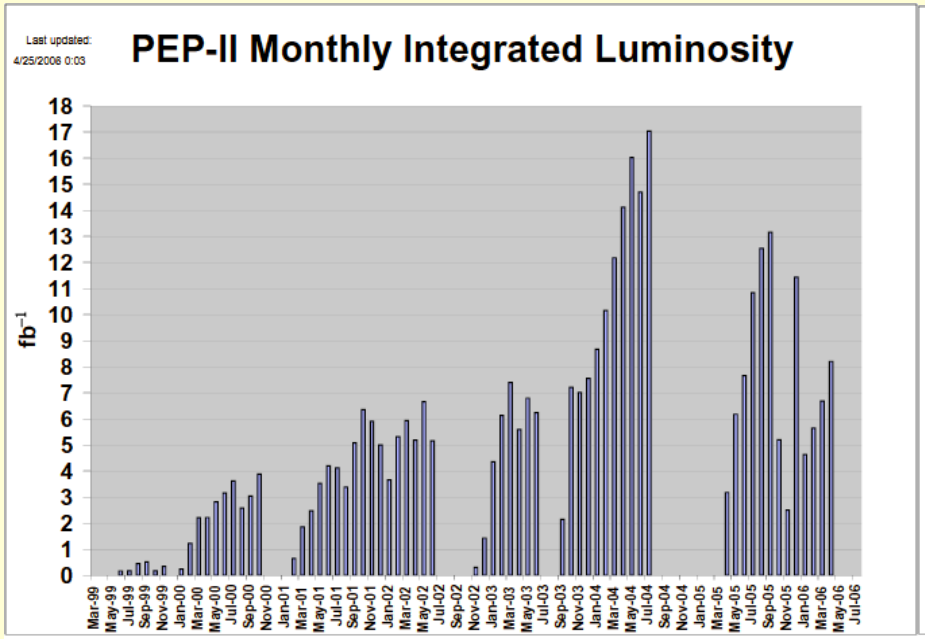


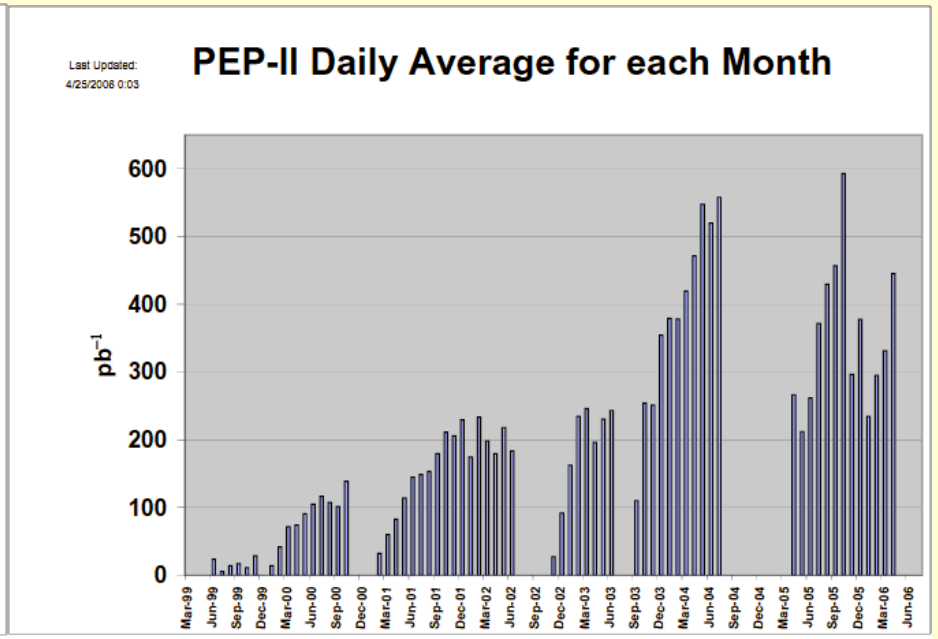
04/25/2006 08:01:17

Run 5 Plan

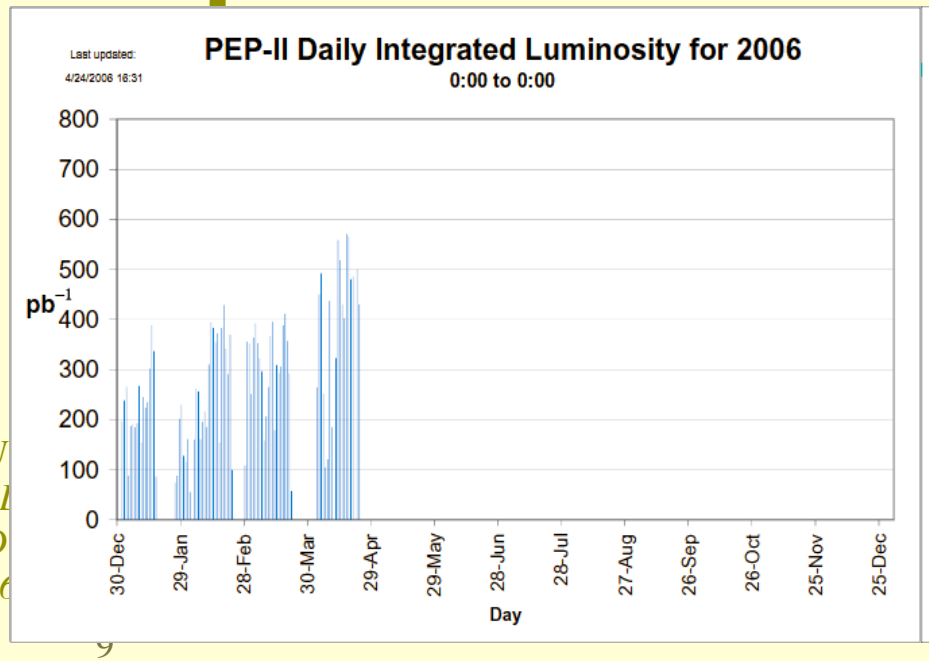
M. Sullivan

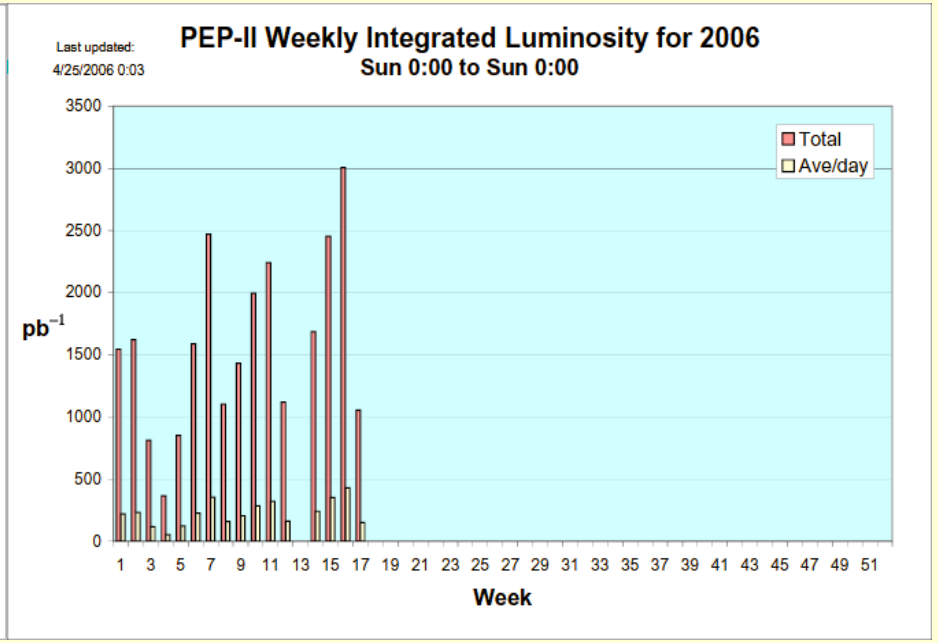






M. Sullivan





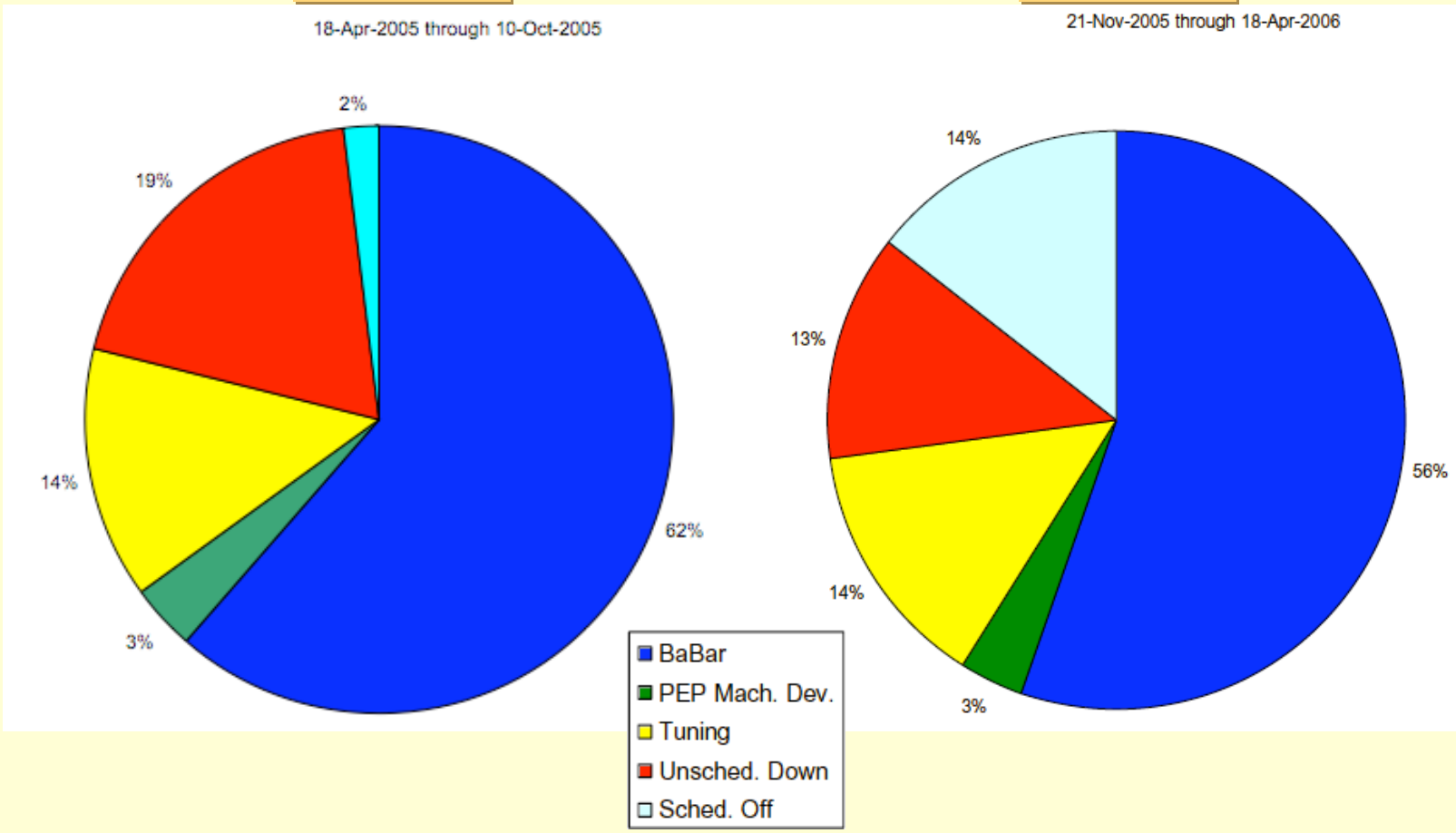
U
Sl
D
26

PEP-II Run 5 Time Accounting

M. Stanek

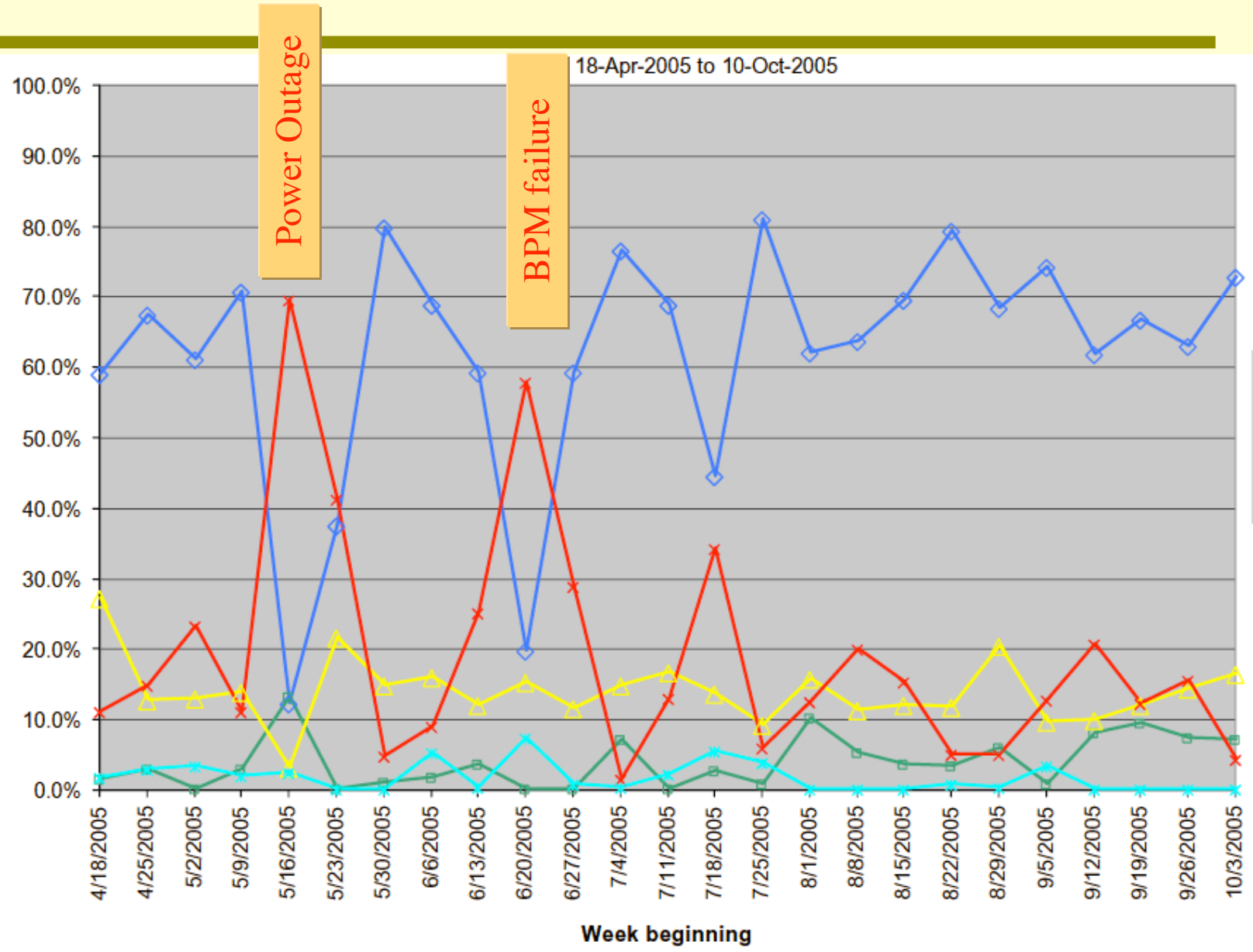
Run 5a

Run 5b



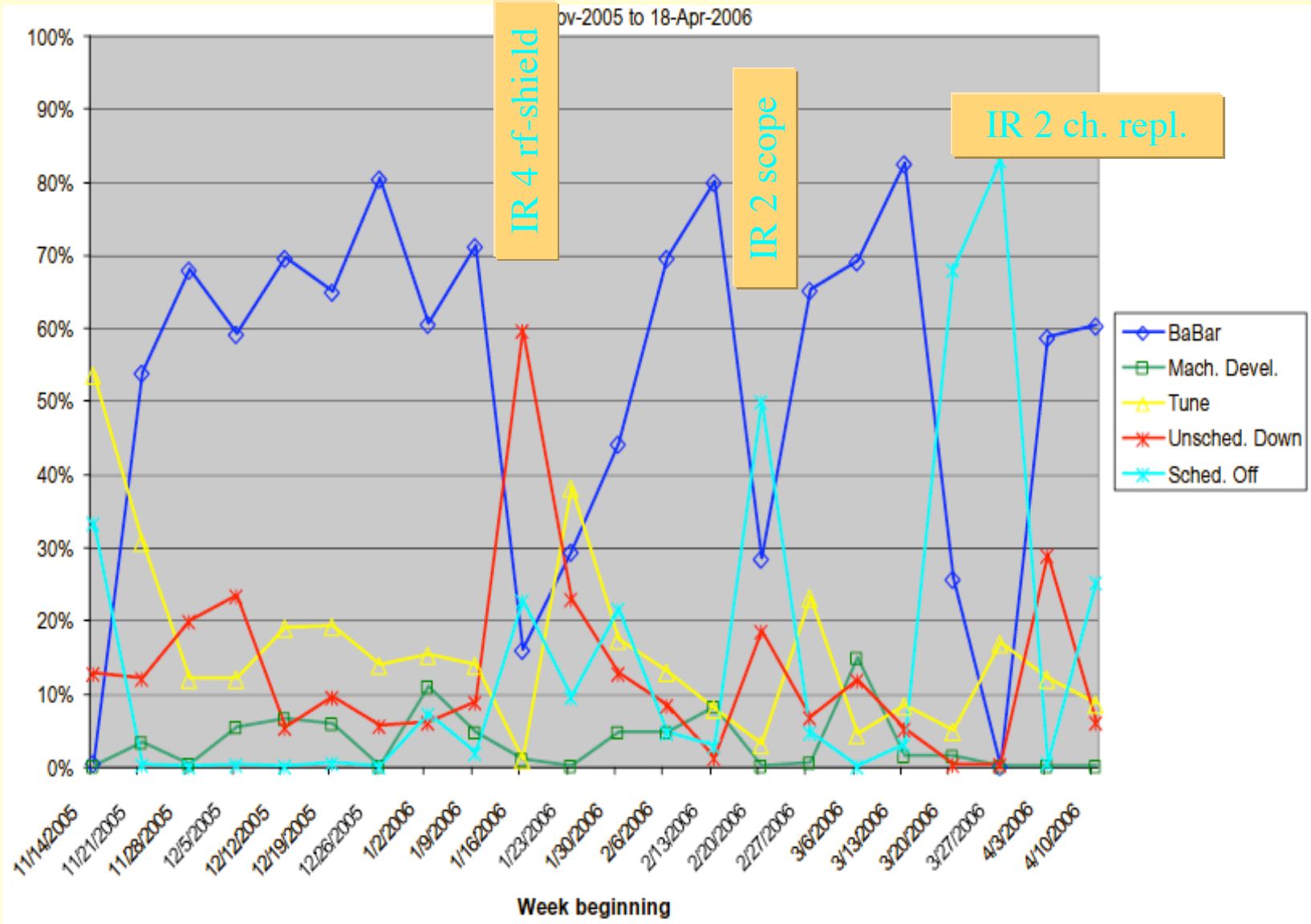
Run 5a Week by Week

M. Stanek



Run 5b Week-by-Week

M. Stanek



PEPII Revealed Failure table for the week of 04/18/05 - 10/09/05

MTTF	**14.05**	**Scheduled Operating Hrs**	**4131.30**
MTTR	**2.70**	**Total Events**	**294**
Availability	**80.81%**	**Total Hrs down**	**792.80**

W. Allen

Scheduled Operating Hrs = 4200 - Scheduled Outage
Scheduled Outage = 68.7

Subsystem Data

System	Events	Hrs Down	% SOH
Power Supplies	105	142.3	3.4%
Magnets	2	23.5	0.6%
RF	67	123.5	3.0%
Vacuum	10	124.7	3.0%
Utilities	44	254.9	6.2%
Cryogenics			
Controls	41	67.6	1.6%
Safety			
Other	25	56.3	1.4%
Totals	**294**	**792.80**	

Area Data

Area	Events	Hrs Down	% SOH
CID	6	5.4	0.1%
Sect. 0/1	19	43.3	1.0%
WTA	5	2.6	0.1%
NDR	22	52.6	1.3%
SDR	12	23.5	0.6%
DRIP			
Linac	24	39.7	1.0%
Positron	12	26.9	0.7%
PEPII-Inj	16	28.2	0.7%
BSY			
HER	66	109.9	2.7%
LER	69	222.0	5.4%
Near IR	8	13.8	0.3%
MCC	2	0.6	0.0%
ESA	1	1.5	0.0%
FFTB			
NLCTA			
NPI			
NARC			
SARC			
NFF			
SFF			
Other	32	222.8	5.4%
	294	**792.80**	

Grp Classification	PEP Only	Injection	BaBar	PG&E	Total
Hrs Down	350.7	228.4	57.2	156.5	**792.8**
Total Events	151	120	18	5	**294**

Printed 4/25/2006 3:16 PM

PEPII Revealed Failure table for the week of 11/14/05 - 04/16/06

MTTF	**19.93**	**Scheduled Operating Hrs**	**3128.50**
MTTR	**3.05**	**Total Events**	**157**
Availability	**84.67%**	**Total Hrs down**	**479.60**

W. Allen

Scheduled Operating Hrs = 3696 - Scheduled Outage
Scheduled Outage = 567.5

Subsystem Data

System	Events	Hrs Down	% SOH
Power Supplies	58	142.2	4.5%
Magnets	5	55.0	1.8%
RF	25	38.6	1.2%
Vacuum	9	119.1	3.8%
Utilities	22	55.8	1.8%
Cryogenics	1	23.8	0.8%
Controls	25	28.2	0.9%
Safety			
Other	12	16.9	0.5%
Totals	**157**	**479.60**	

Area Data

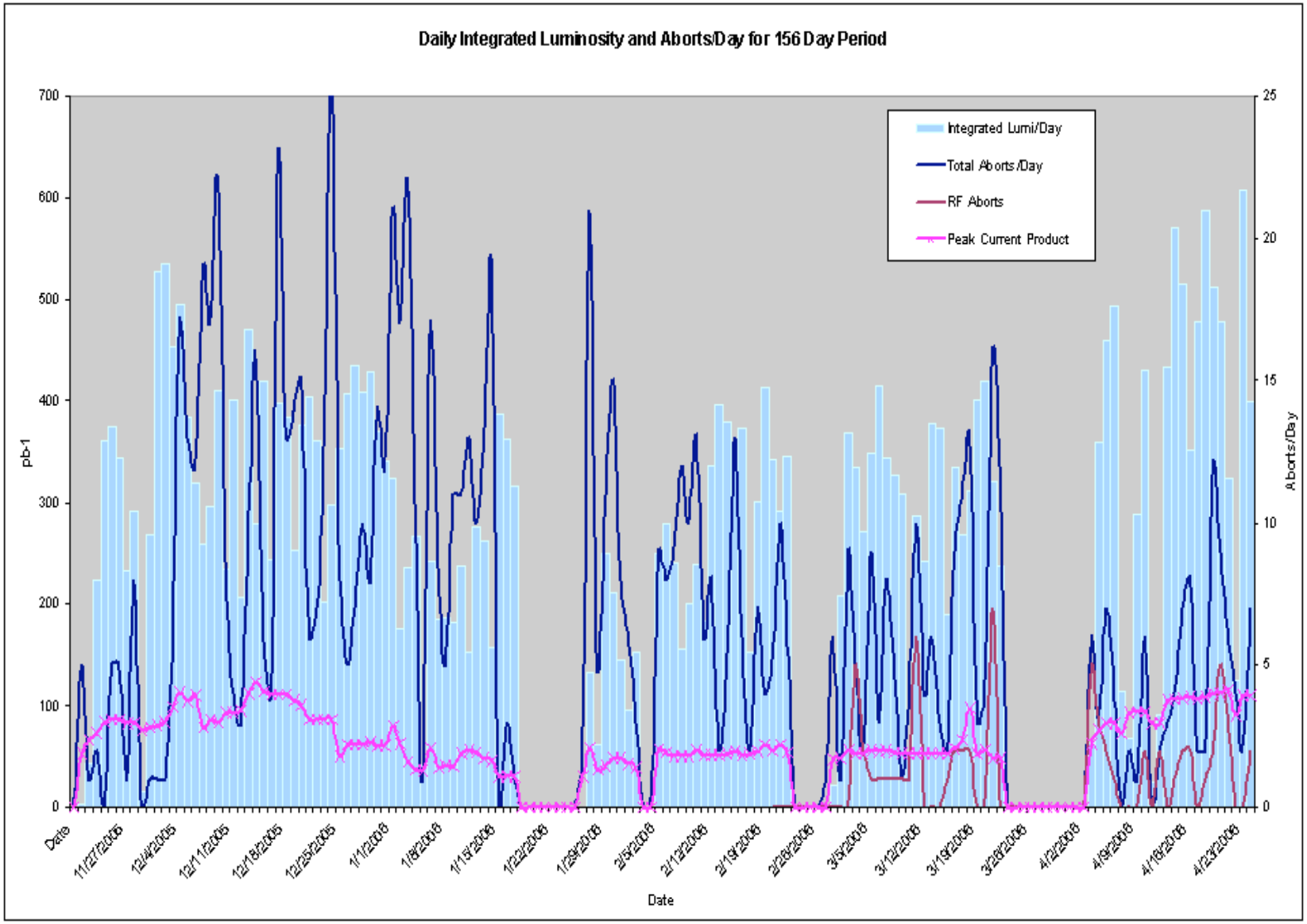
Area	Events	Hrs Down	% SOH
CID	1	0.1	0.0%
Sect. 0/1	10	14.7	0.5%
WTA	2	1.9	0.1%
NDR	19	29.4	0.9%
SDR	3	9.1	0.3%
DRIP	3	1.3	0.0%
Linac	20	30.6	1.0%
Positron	8	19.3	0.6%
PEPII-Inj	11	7.6	0.2%
BSY	1	2.5	0.1%
HER	22	74.8	2.4%
LER	30	182.7	5.8%
Near IR	4	39.3	1.3%
MCC	2	0.9	0.0%
ESA			
FFTB			
NLCTA			
NPI			
NARC			
SARC			
NFF			
SFF			
Other	21	65.4	2.1%
	157	**479.60**	

Grp Classification	PEP Only	Injection	BaBar	PG&E	Total
Hrs Down	340	122.2	15.4	2	**479.6**
Total Events	65	81	10	1	**157**

Printed 4/25/2006 4:51 PM

Beam Aborts (Rf-Group Analysis)

D. v.Winkle

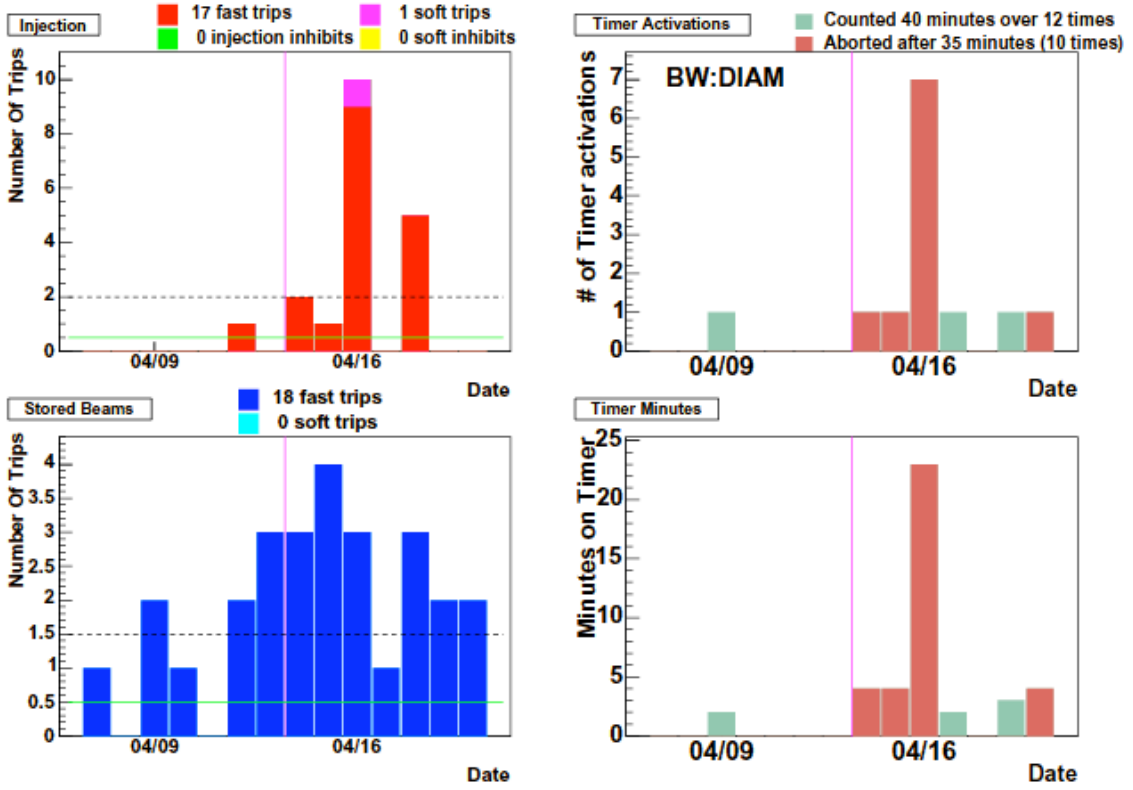


Beam Aborts (SVTRAD)

K. George
BaBar

This Week

18 stable beam aborts



Rf-Group Fault Classification Run 5b

D. v.Winkle

Last event	Count	Stations	Description
03/03/2006	425	ler(4),her(421)	IP Vacuum event with/without radiation
01/27/2006	157	ler(152),her(5)	didt with transverse
04/06/2006	30	LR44	Drive Glitch
04/21/2006	17	multiple	Unknown
02/08/2006	16	ler(14),her(2)	didt no motion
04/06/2006	13	multiple	Site Power Dip
04/20/2006	13	multiple	Power dip (Region 8 or 4)
11/30/2005	12	HR26	Klystron Output RE
04/15/2006	12	multiple	Cavity 1 arc (RE reported)
03/21/2006	9	multiple	Klystron vacuum
Top 10 events account for 704 faults (89%)			
Color code: being debugged not actively pursued non-RF			

Station	Faults
her	459
ler	191
LR44	42
HR26	27
HR22	16
HR21	13
HR83	10
HR41	9
LR43	8
HR81	7
HR85	6
HR25	2
HR23	2
LR42	2
LR45	1

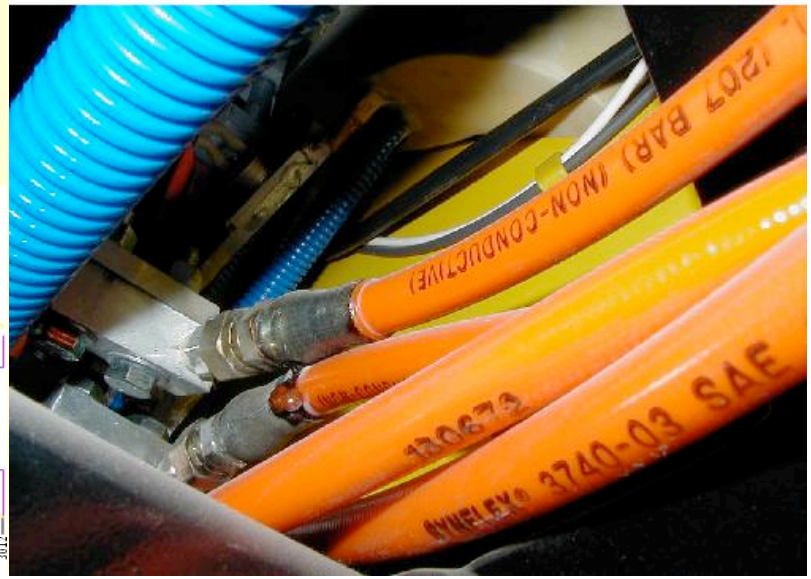
Run 5 Challenges

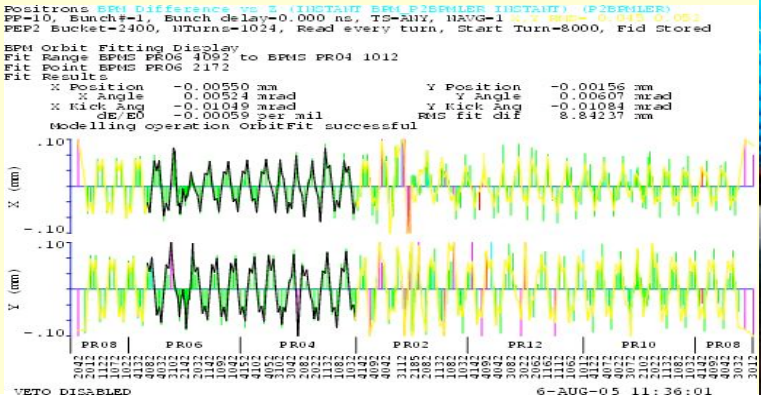
- Several magnets with partial shorts
  - luminosity loss, downtime
- Fallen tree knocks out site power
  - ≈1 week down
- LER BPM buttons overheat & a few fell off
  - Beam-current limit until lower Rf voltage, lengthening bunches
- LER fast instability causes frequent beam aborts
  - displaced rf gap rings
- IR-2 vacuum events limit beam current
  - Bad rf seal caused arcing & gas release
- NEG heating
  - background at high beam current

QFW1 short

M. Sullivan,
J. Turner

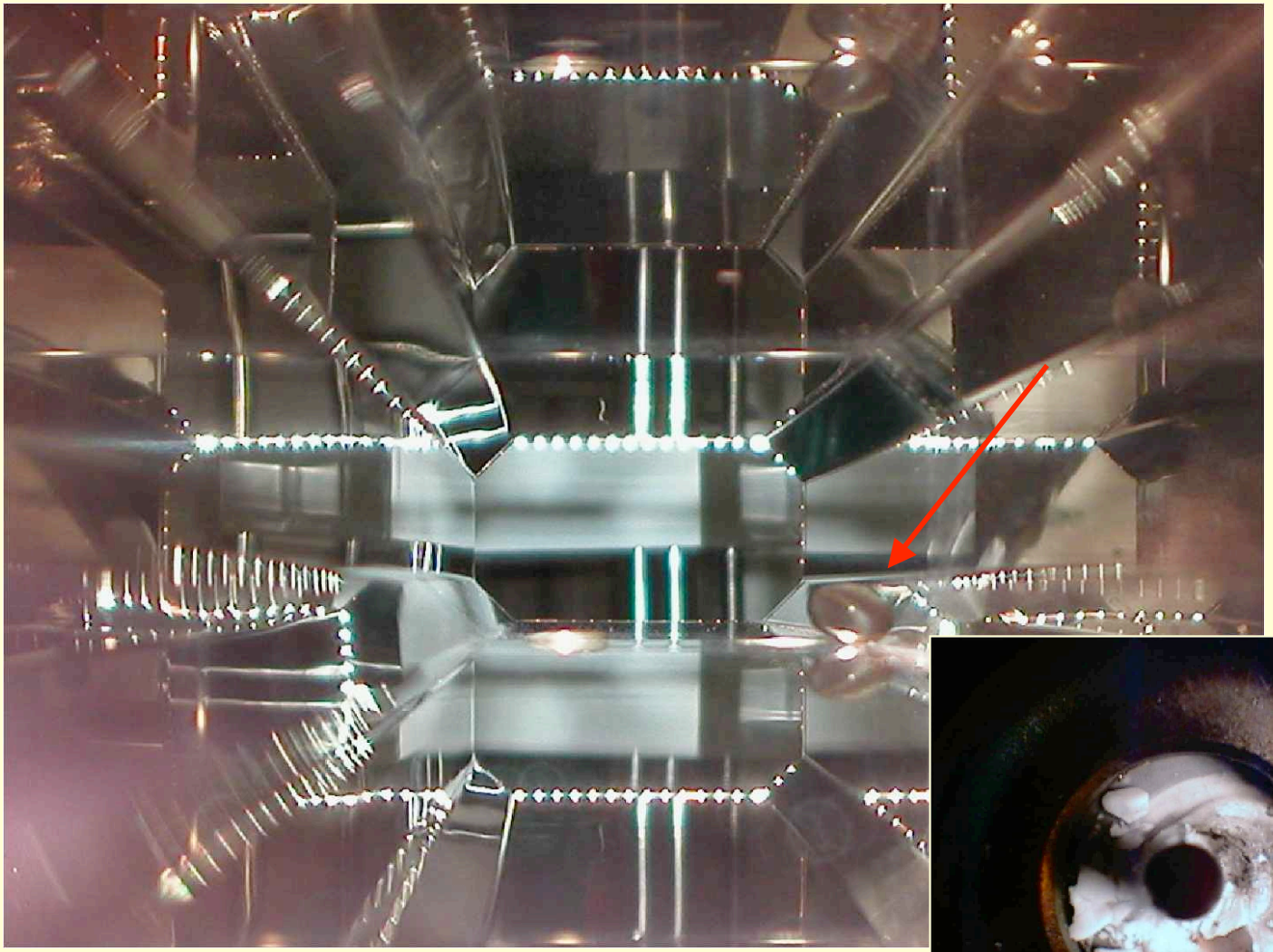
- During the shutdown, QFW1 developed a partial short
- The closeness to the wiggler, the shorting during a downtime and the subtle optical effect made detection difficult, even though we suspected a problem in this area.
- It revealed itself when the short became intermittent leading to orbit changes on Aug. 6.
- 100% inspection of LER quads during Fall '05 down time.





BPM-PR02-2062

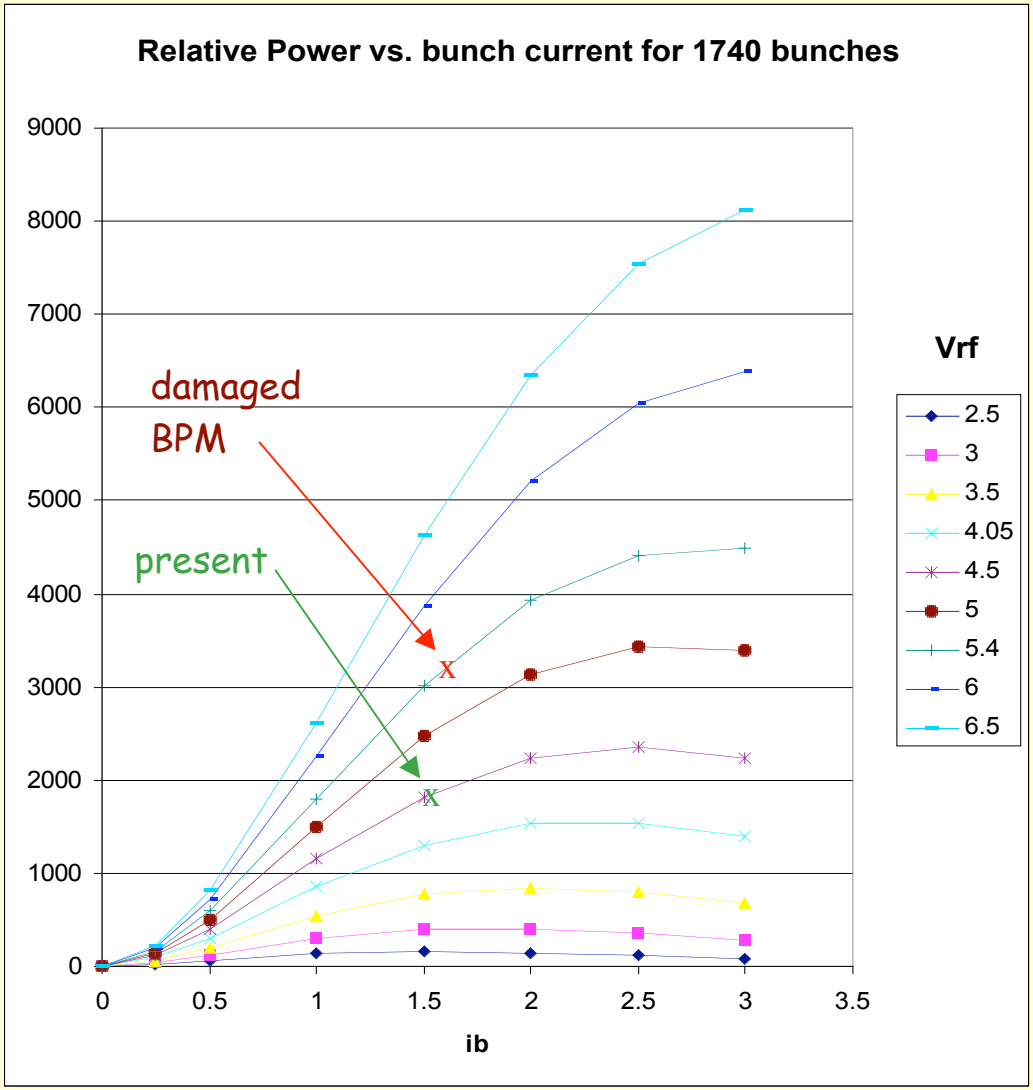
S. Smith



BPM Heating Estimate

S. Ecklund

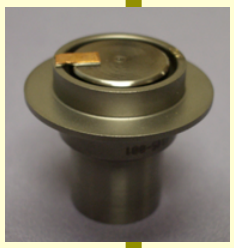
- Curves based on present knowledge & measurements (power absorbed into 7 GHz trapped mode)
- Operationally, we lowered the LER Rf voltage
  - reduce heating for same beam current



The Fix

S. Ecklund,
N. Kurita

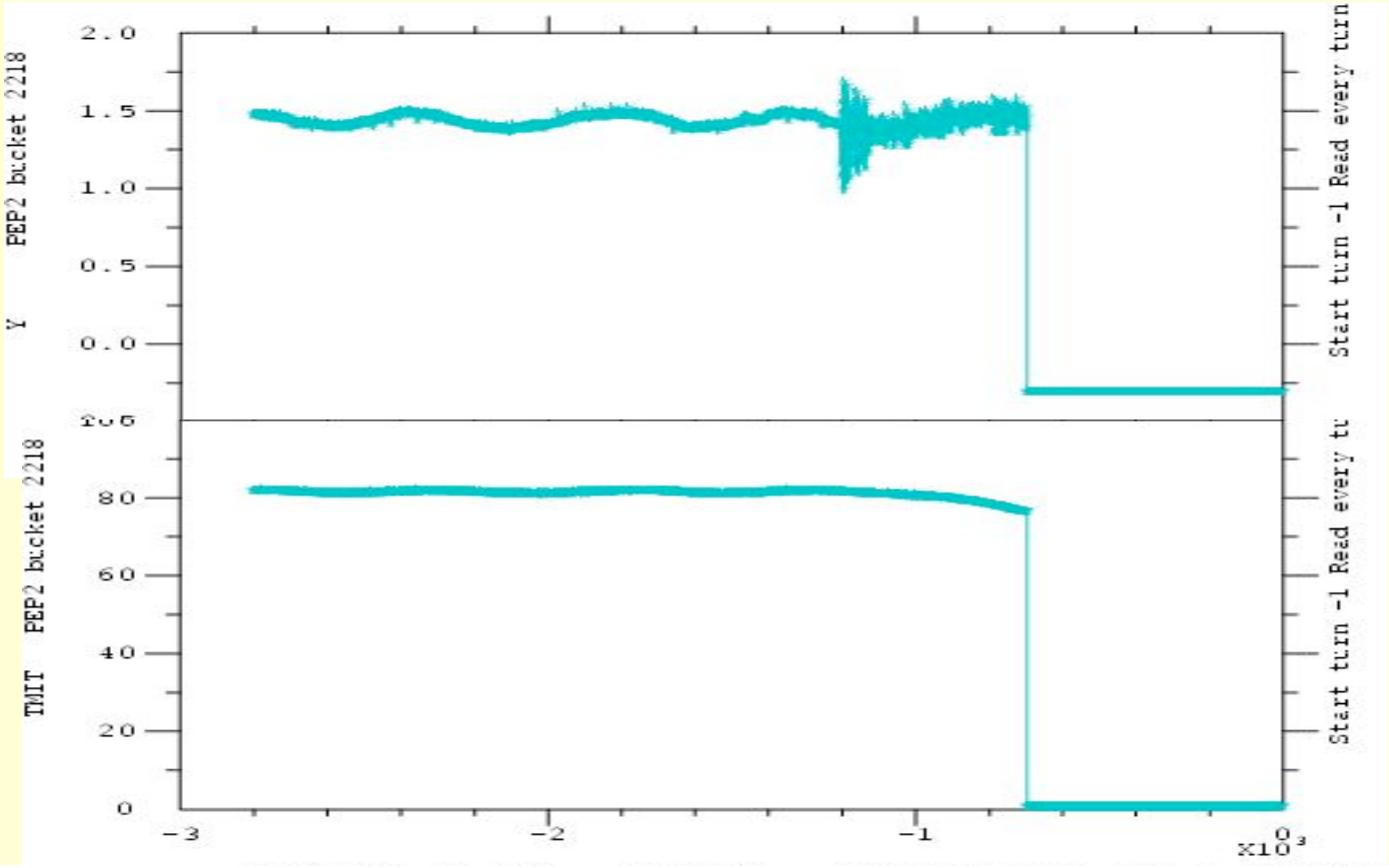
- We know how to fix this problem:



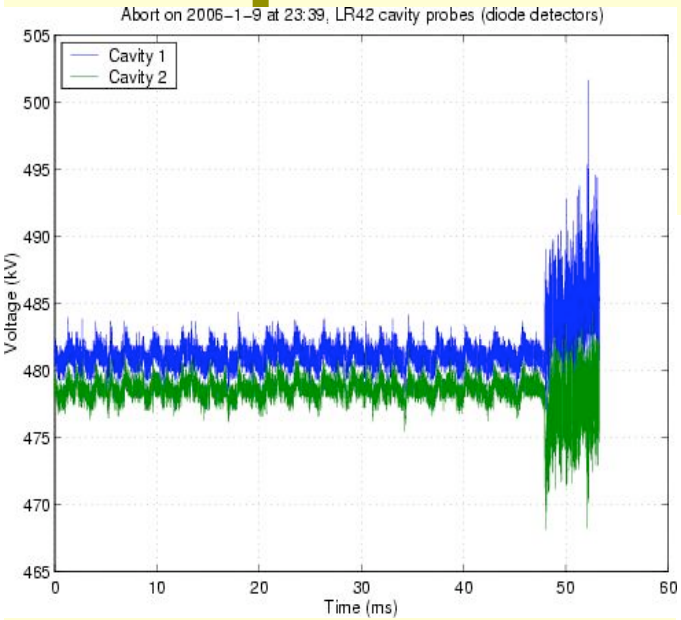
Unit	FIB dT (F)	FIB Power = dT/1.3	Button collar dT (F)
BPM 1022 15 mm shorted	76	58	8 to 10
BPM 1032 15 mm Normal	35	27	<= 11
BPM 1052 7 mm without insert	45	35	5
BPM 1092 7 mm with insert	17	13	3
BPM 2152 feed-thrus only	?	?	2 to 3

Fast LER Instability

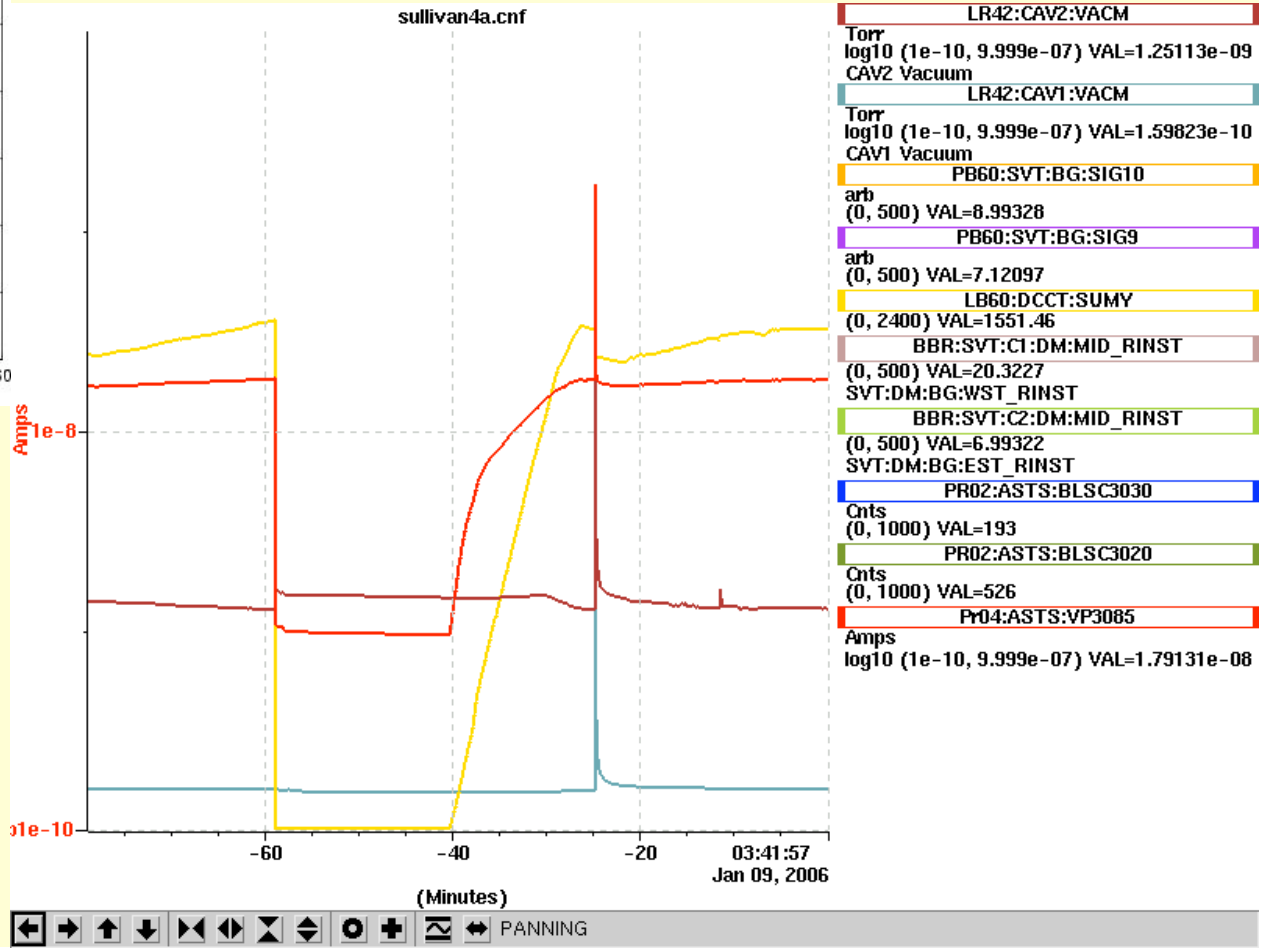
- Characterized by very fast initial growth but limited amplitude of the observable motion while the beam current drops



Activity near Rf 4-2



<— signal on Rf 4-2 cav. probes (D. Teytelman)

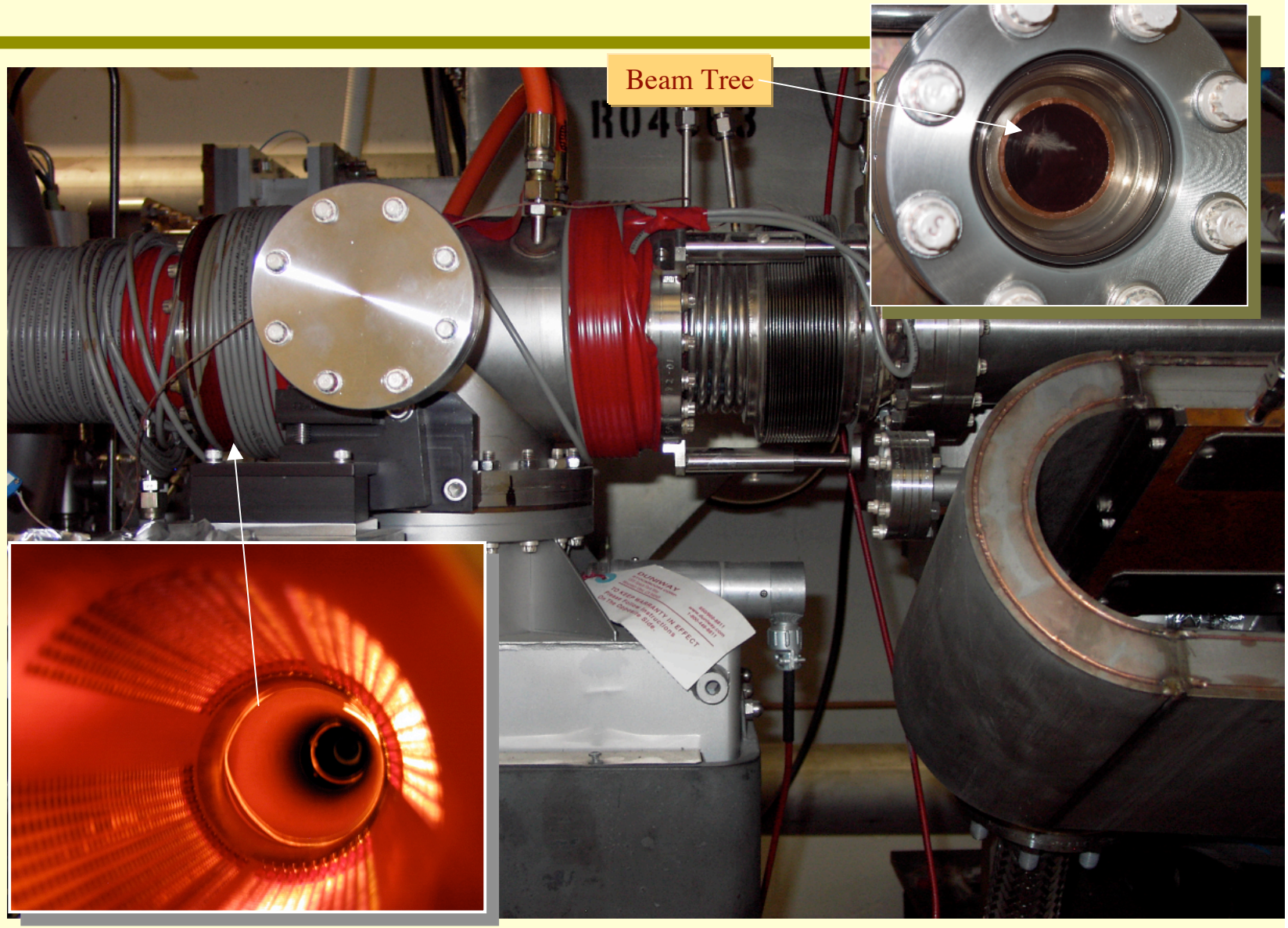


Vacuum spikes
in the same region
(S. Novokhatski,
M. Sullivan)

The Culprit…

M. Sullivan

D. Kharakh



U. Wienands, SLAC-PEP-II DOE Review 26-Apr-06

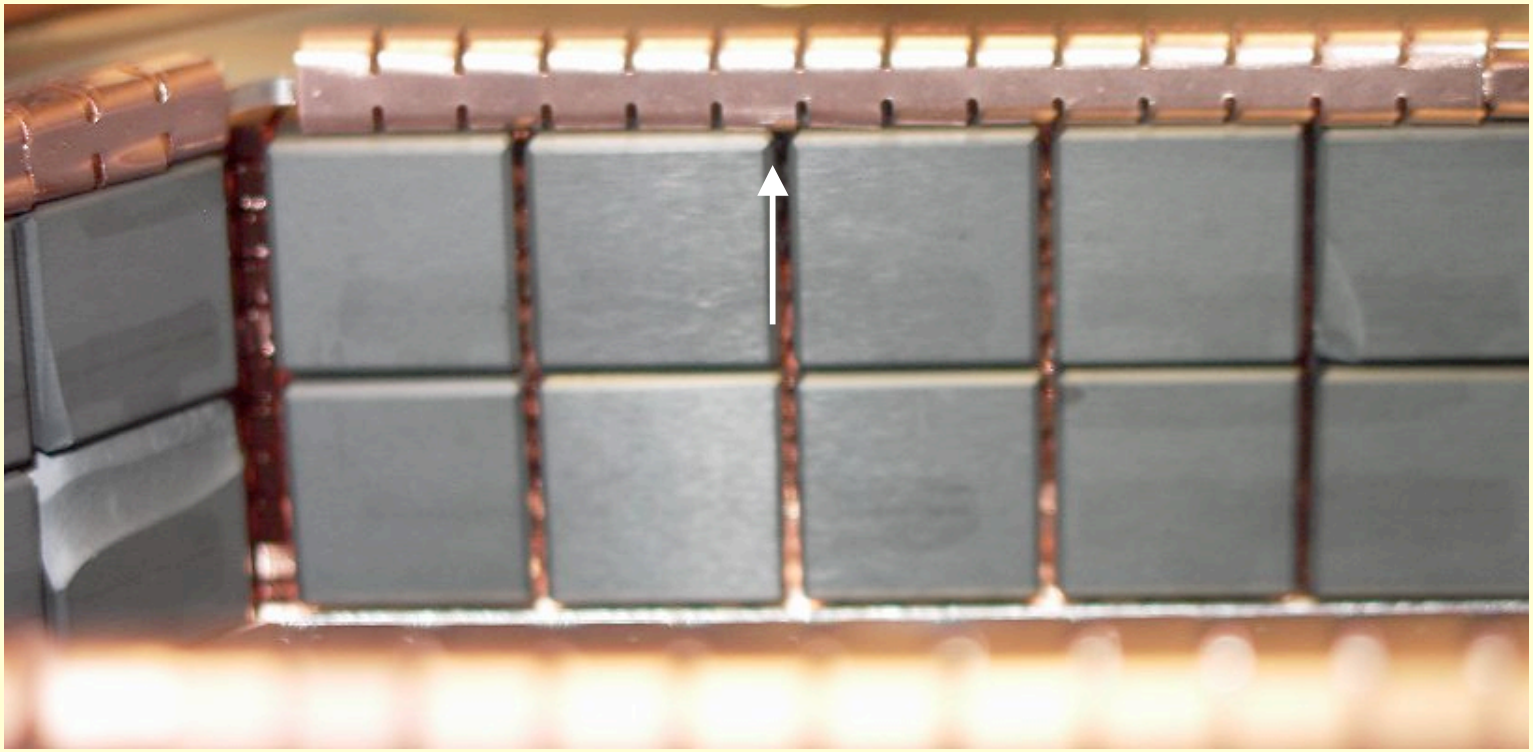
IR 2 Vacuum bursts

- Beam instability coupled with vacuum activity in IR 2
  - each ring could do it, but LER effect stronger
  - LER alone not unstable, HER unstable
  - more sensitive to bunch current than total
  - threshold varying with time, no obvious correlation with temperatures of machine components
  - signature of bursts pointing towards BaBar forward side
- Boroscoped twice, ntf
- Replaced suspect components …

Q2 Bellows & Rf Seal

M. Sullivan,
N. Kurita

- Where is the problem??



- The rf seal makes contact with tiles, not Cu
  - Redesigned seal has been deployed

The Challenges Addressed

- The magnet short led to a 100% inspection program for the LER quads & sextupoles, finding a few "close calls."
- The root causes of the IR-4 and the IR-2 instabilities have been found and have been fixed.
- The BPM heating will be addressed by a refurbishment program this summer/fall.
- The remaining hot NEGs will be removed this summer.
- The known beam-current limits at present are ≈1.8 A (HER, rf) and >3.5 A(LER, rf).

Run 5b Major MDs

- IR-4 and IR-2 event localization (parasitic and dedicated)
  - localized IR-4 events, aided in finding the IR-2 events
- Klystron Linearizer tests
  - linearizers work but beam-current capability not raised
- LER Comb-filter phasing (parasitic)
  - ≈ 30% reduction in fastest low-mode growth rate
    may get more using Comb-II asymmetric filter capability
- HER β_x beat fix
  - successful fix of QF5-induced β_x beating
- LER BBA
  - sucessfully established offsets for most of remaining BPMs
- LER steering
  - successfully established better centered LER orbit
- HER LBNL Delay lines installed
  - Also BTF measurement
  - Phase-II firmware deployment imminent

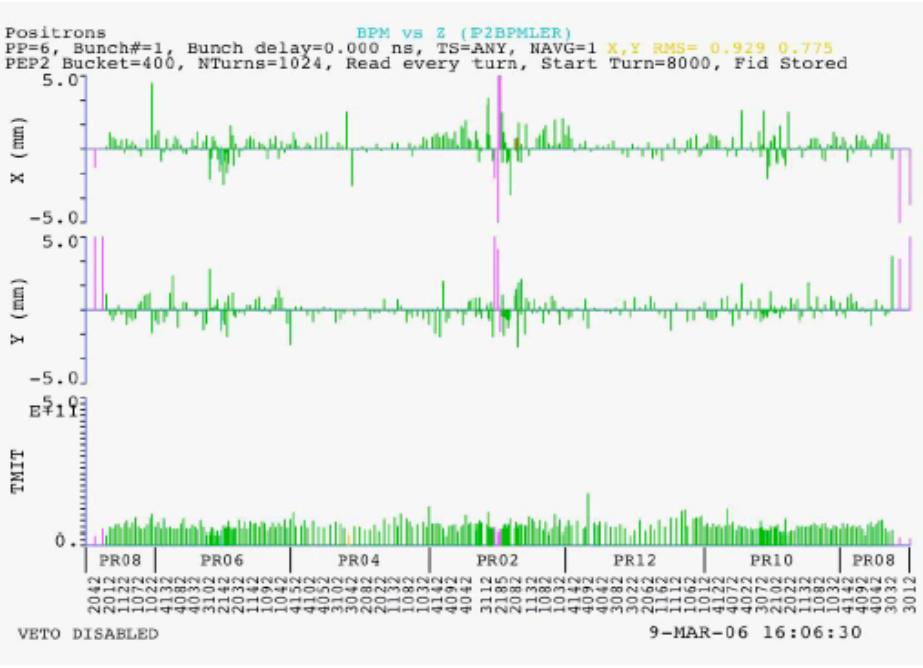
MD Program, Run 5b

Wkday	Date	HER MD topic	LER MD topic	Comment
Wednesday	25-Jan	More ßx beat test (fix orbit; MIA, ORM with knob in) (did not happen)	Characterize, Scrub, "Design config" test	dial knob in parasitically if ok
Thursday	26-Jan	Collision tuning, scrubbing, IR-2 vac.	Collision tuning, scrubbing, IR-2 vac.	may need TFB tuning
Monday	**30-Jan**	**Steer back to GOLD**		**parasitically done by JLT**
Wednesday	**1-Feb**	**Put back LBNL delay lines**	**BBA**	**success on both tasks**
Thursday	**2-Feb**	**(in access)**		**Remove VP3027**
Friday	10-Feb		Squirts	semi-parasitic
Thursday	**16-Feb**	**Charact.; ßx beat test**	Charact; Klys Linearizer	**ßx-beat fixed**
Thursday	**23-Feb**	**(in access)**		**Replace LER Q4R pipe**
Tuesday	28-Feb	Xverse BTF	LER BBA (not done, choppers broken)	GY BBA Plan (1/2 shift)
Thursday	2-Mar	**HER rf tuning**	**TFB Receiver 2 trouble shooting**	**Fixed LER Rcvr2, tuned HER rf**
Tuesday	7-Mar	HER Optics studies	**LER BBA**	**BBA offsets in DB**
Thursday	9-Mar		**Charact.;LER steering**	**Steered LER left in!**
Tuesday	14-Mar	(won't have injector)		Rf tuning?
Thursday	16-Mar		LER optics correction	fall-out from steering (semi parasitic
Tuesday	21-Mar	Various knob tests (ß*, X Waist)		
Thursday	23-Mar	Replace Q2R chamber & bellows		parasitic
Tuesday	28-Mar			
Thursday	30-Mar			
Tuesday	4-Apr			Recovery & tuning

LER Steering

J. Turner
et al.

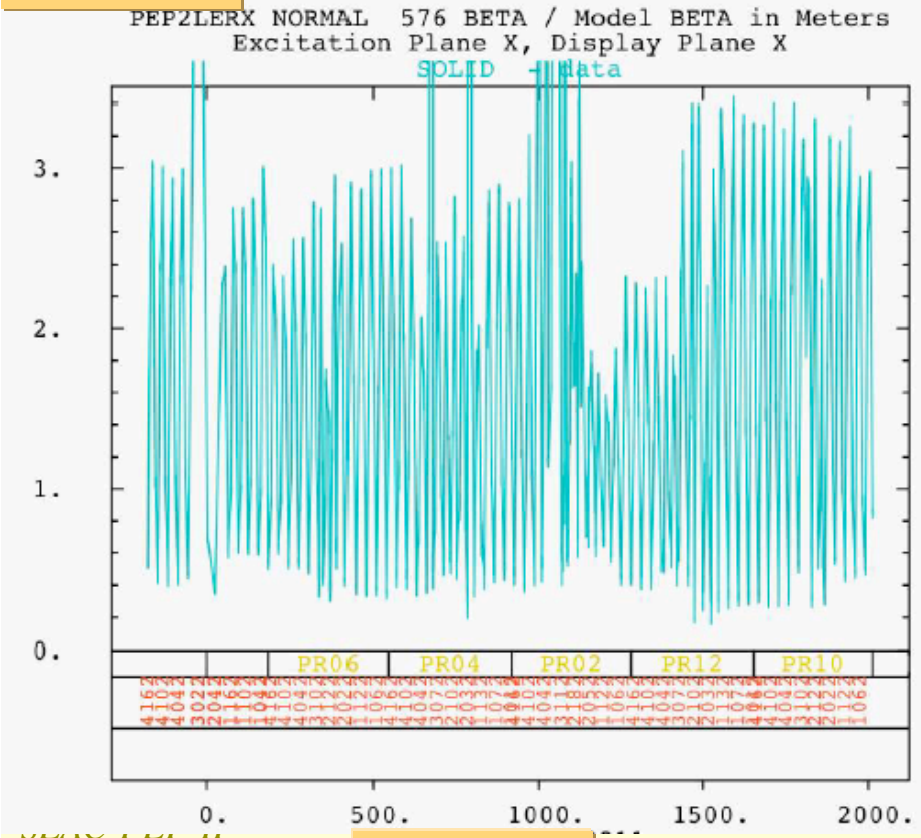
- Important for optics *and* BPM heating
- Strong sextupoles make this challenging



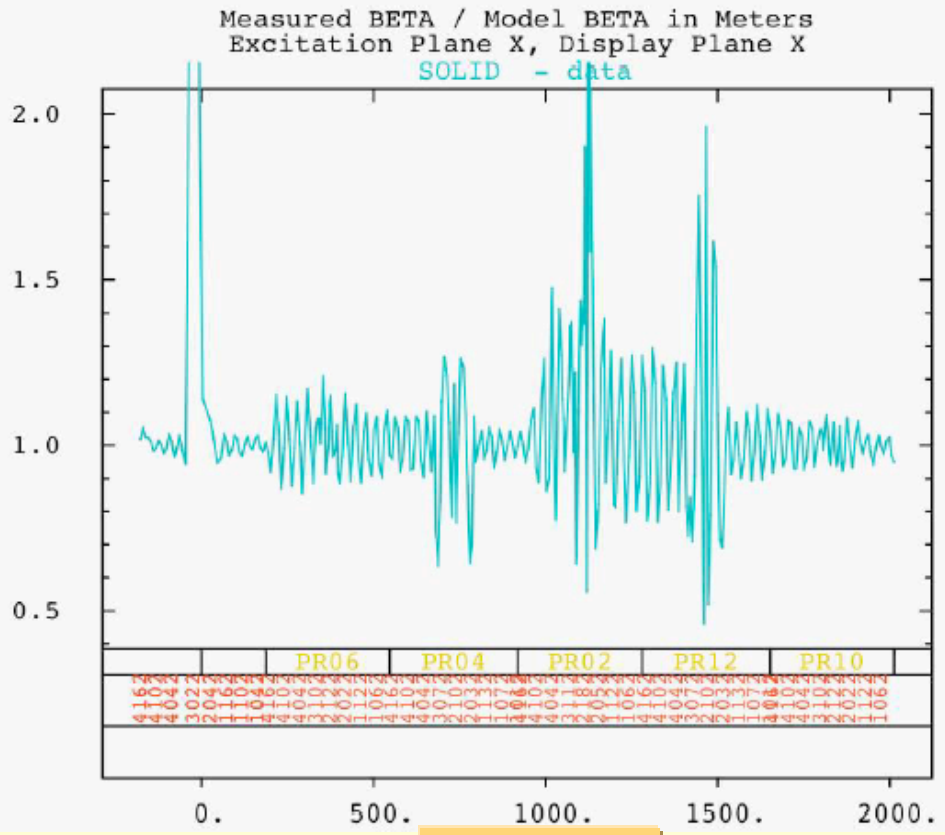
Optics fix to make Steering Work

J. Turner,
Y. Yan,
Y. Cai

- … a significant achievement for PEP-II!



before

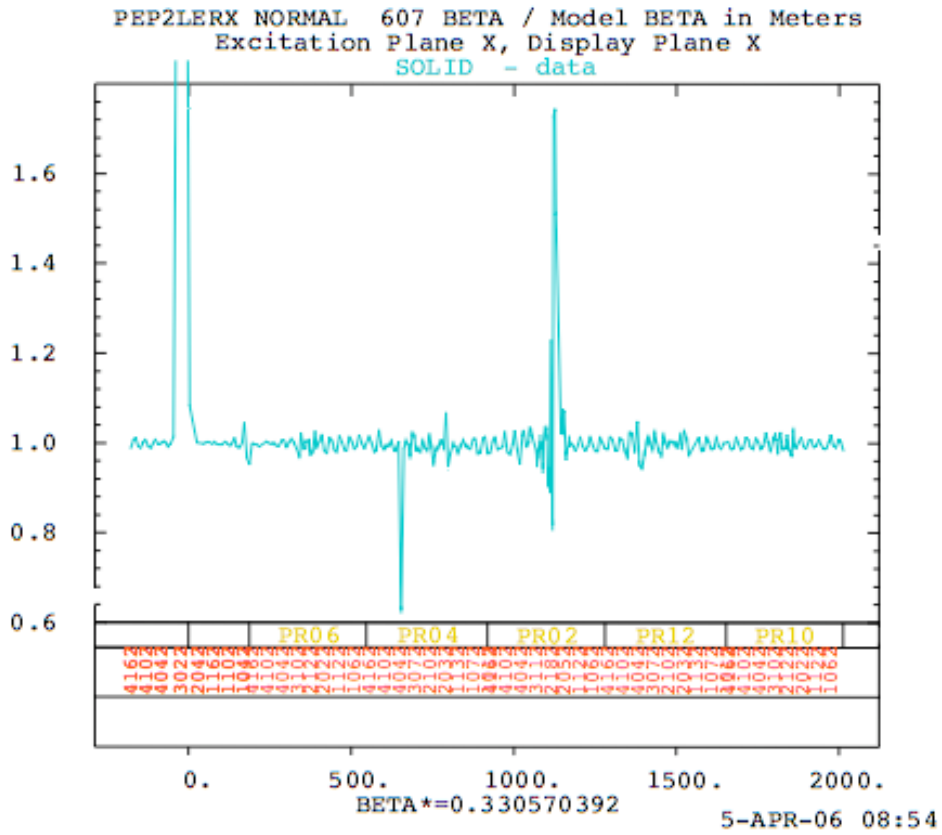


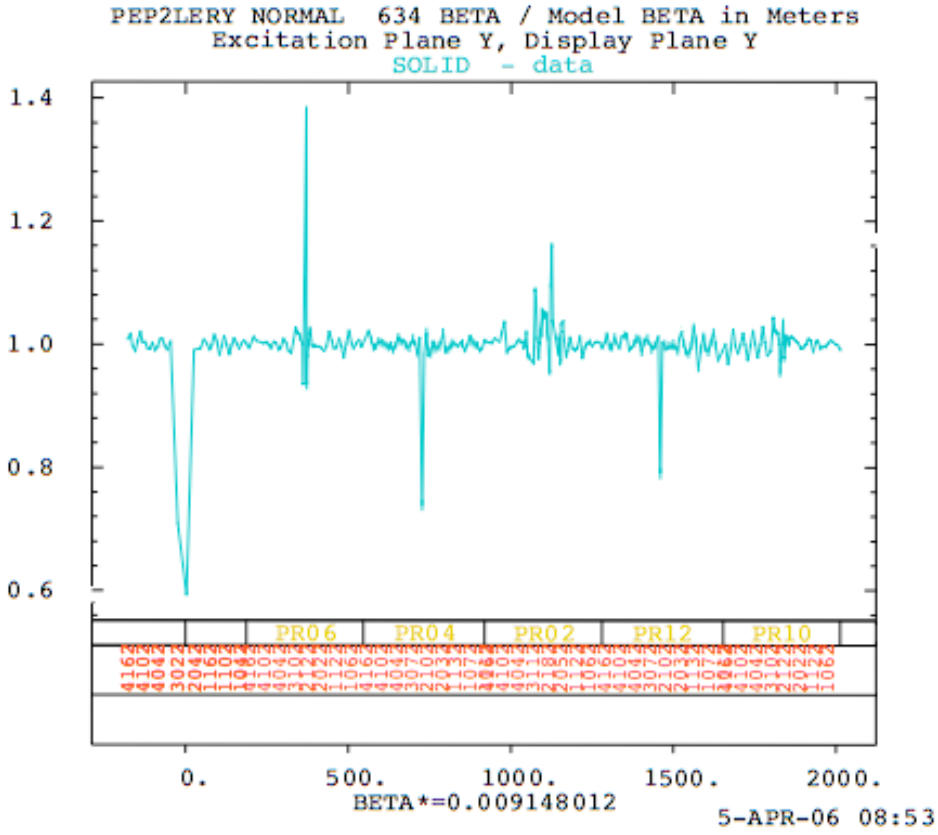
after

Comparison LER *vs.* Model

G. Yocky,
Y. Cai,
Y. Yan,
M. Woodley

- MIA models describe ring optics well for both rings





Setting MD Directions

- We follow a few well defined goals:
  - Meet or exceed the plan
  - Tracking down performance issues
  - Prepare for next Run's success, e.g.:
    - characterize thermal behaviour of critical comp.
    - Lower β_y*, shorten bunches
  - Test major lattice mods like wiggler operation
- Guidance for MD comes from simulations or off-line analysis
  - Beam-beam simulations (Sonnad, Cai)
  - Presently focusing on optics corrections (dispersion, ß beat, working point,…)
  - Increase stability margins for rf and feedback systems
  - Machine optics characterization (≈every 2 weeks)

Shift & MD Roster

Brachmann
Clendenin
Colocho
Decker
Fisher
Iverson
Kulikov
Novokhatski
Pivi (ILC)
Raimondi
Stanek
Schuh
Turner
Wittmer
Yocky

+2 from Run 4

Cai+Yan (ARD)
Ecklund
(Kozanecki [BaBar/DAPNIA])
Sullivan
Seeman
Wienands

15 Shift-takers (4..8 shifts/mo./ea.),
Program Deputies,
MD-shift takers

5 shifts=1 work-week!

5 add'l MD-shift takers
+ experts as needed (rf, ctrl, BaBar)

Regular shifts:

1 shifter day & eve + PD

MD shifts: as needed

up to 5 during day, 0...2 owl

Other Groups (SLAC/non-SLAC)

- We get significant help from ARDA…
  - Cai has been charged with leading the Optics effort, Nosochkov & Yan participate
  - Teytelman, van Winkle & Rivetta continue maintaining llrf tuning & improvements
- … and ILC
  - BBA team: Ross, Nelson, May, Woodley, Tenenbaum
  - Online model, ORM: Woodley, Tenenbaum
- MOU with LBNL for TFB upgrades and diagnostics
  - Byrd, Doolittle et al: new delay lines built & deployed, system diagnostics MD "in the queue"
- BaBar
  - Beam and machine parameter estimates at the IP (Weaver et al.)
  - MDI, background, general AP (Kozanecki)
  - IR-2 vac. event diagnostics (Petersen, Nicholls *et al.*)
- The various operational and engineering groups are fully engaged in maintaining & upgrading systems, e.g.:
  - Controls: COMB-2 project (Ross, Browne)
  - PEM: HER 90° lattice upgrade (Lipari)
  - MFD: Vacuum-system maintenance & upgrades
  - KLYS: BFK klystrons

The Next MD Steps

- Commissioning the Wiggler lattice
  - increase damping by 15%, increase emittance by 20%.
- Optimizing the betatron tunes
  - expect gain in luminosity from lowering both *x* & *y* tune
  - but beam lifetime ~~may~~ be *is* an issue (synchro-β coupling)
- Tune rf, feedbacks as we raise beam currents
  - *e.g.* SSB comb filters, tfb receivers *etc*.
- Commissioning the 90° HER lattice
  - shorten HER bunches
  - … an optics challenge.
- Lowering β_y*
  - 8…9 mm in both rings
- ***…Together with increased beam currents should double the luminosity over the next years***

Run 5 Performance Summary

- PEP's peak luminosity has reached 10^{34} /cm^2/s
  - 3.3 times the CDR peak luminosity
- PEP has delivered a peak of more than 5 1/2 times the CDR event rate (∫luminosity)/day.
- To-date delivery to BaBar has exceeded 354 /fb

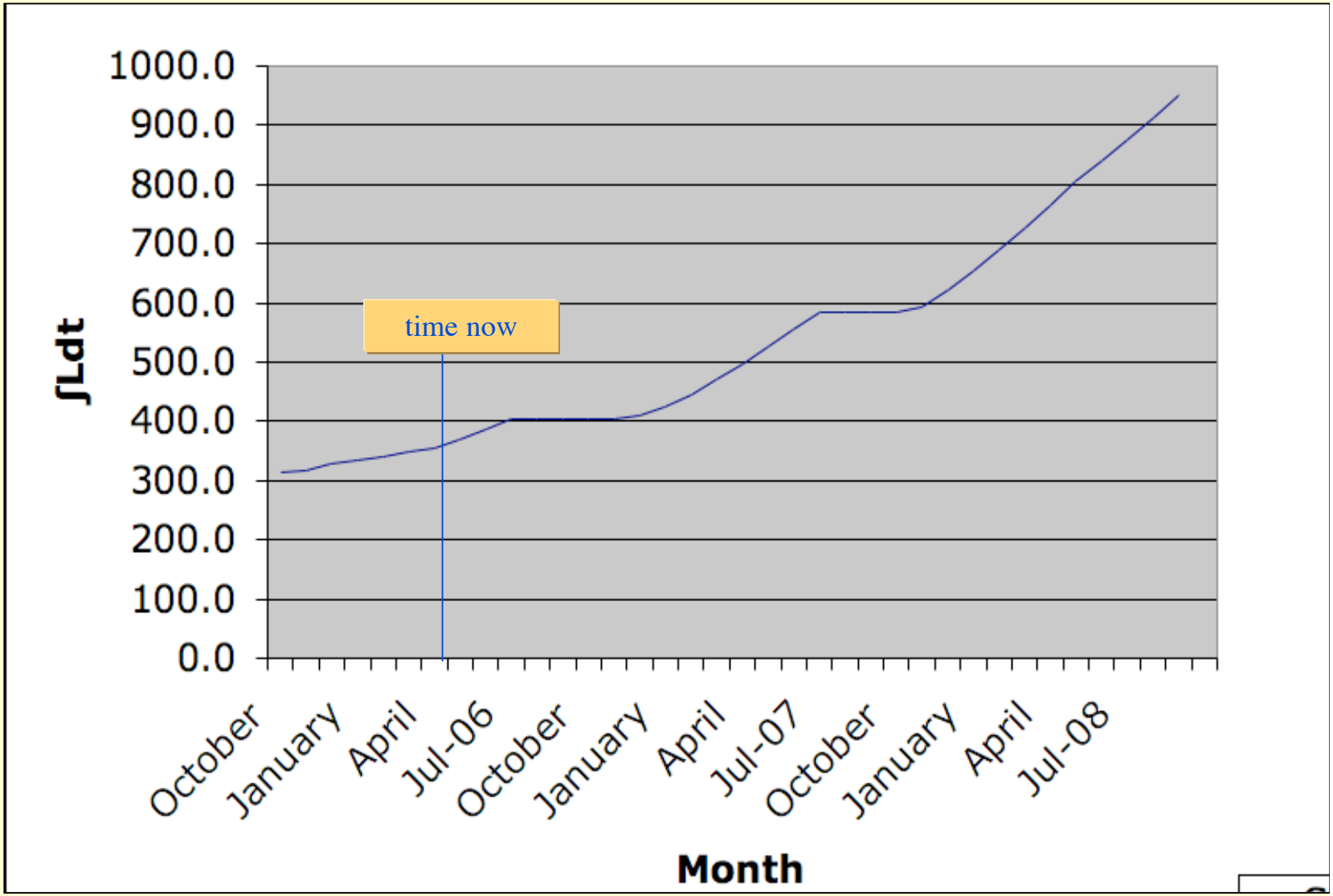
…By any measure, these numbers are impressive!

Outlook

- We will install the following improvements this Summer/Fall:
  - HER Rf (split one IR-12 station, new stn. in IR-4)
  - New HER, LER Q4 and Q5 chambers (IR)
  - 90° lattice upgrade for HER
  - Upgrade the LER arc & IR-2 BPMs
- We have 5 more SLAC BFK Klystrons "in the queue"
  - ≥ 1 MW additional rf power cf. Philips/Marconi
- With these upgrades we expect the following luminosity plan to be realistic:
  - Note: more than double the present data sample

PEP-II Luminosity Plan

J. Seeman



Year	Month	Days	Average to Peak Luminosity Ratio	Peak luminosity xE33 (at end)	Delivered Integrated luminosity per period fb-1	Cumulative delivered integrated luminosity fb-1	Positron current (mA)	Electron current (mA)	Beta y* (mm)	Beta x* (cm)	Number bunches	Comments	
2005	October	10	0.65	10.0	5.2	314.9						Down	Done
2005	November	15	0.40	6.9	2.5	317.4						Start Run 5b	Done
2005	December	31	0.55	8.6	11.4	328.8						Run	Done
2006	January	31	0.60	5.8	4.6	333.4						Run	Done
2006	February	28	0.65	5.6	5.5	338.9	1400	1000	12.00	40	1722	Run	Done
2006	March	31	0.65	5.6	9.7	348.6						Run	
2006	April	20	0.60	8.0	7.1	355.7						Run	
2006	May	31	0.60	10.0	14.5	370.2						Run	
2006	June	30	0.60	11.0	16.3	386.5						Run	
2006	Jul-06	31	0.60	12.0	18.5	405.0	3200	1800	10.00	30-40	1728	Run	
2006	Aug-06	31	0.00	0.0	0.0	405.0						Down	
2006	September	30	0.00	0.0	0.0	405.0						Down	
2006	October	31	0.00	0.0	0.0	405.0						Down	
2006	November	30	0.00	0.0	0.0	405.0						Down	
2006	December	31	0.50	7.0	4.7	409.7						Start Run 6	
2007	January	31	0.60	12.0	15.3	424.9						Run	
2007	February	28	0.70	13.0	21.2	446.1						Run	
2007	March	31	0.70	14.0	25.3	471.4						Run	
2007	April	30	0.70	15.0	26.3	497.7						Run	
2007	May	31	0.70	16.0	29.1	526.8						Run	
2007	June	30	0.65	17.0	27.8	554.6						Run	
2007	Jul-07	31	0.65	17.5	30.0	584.6	3600	2000	9.00	30-40	1728	Run	
2007	Aug-07	31	0.00	0.0	0.0	584.6						Down	
2007	September	30	0.00	0.0	0.0	584.6						Down	
2007	October	31	0.00	0.0	0.0	584.6						Down	
2007	November	30	0.50	13.0	8.4	593.0						Start Run 7	
2007	December	31	0.70	17.0	28.1	621.2						Run	
2008	January	31	0.70	19.0	33.7	654.9						Run	
2008	February	28	0.70	20.0	33.0	687.9						Run	
2008	March	31	0.70	21.0	38.4	726.4						Run	
2008	April	30	0.70	21.0	38.1	764.5						Run	
2008	May	31	0.70	21.0	39.4	803.8						Run	
2008	June	30	0.65	21.0	35.4	839.2						Run	
2008	Jul-08	31	0.65	21.0	36.6	875.8	4000	2200	8-8.5	30-40	1728	Run	
2008	Aug-08	31	0.65	21.0	36.6	912.3						Run	
2008	Sep-08	30	0.70	21.0	38.1	950.4						Run	

J. Seeman

The End