PEP Run 4 Overview & Run 5 Planning

U. Wienands
PEP-II Run Coordinator
Deputy AD Head for PEP Beams

In preparing this talk I have used slides and material from:

S. DeBarger, S. Ecklund, J. Seeman, M. Stanek, M. Sullivan, G. Yocky, T. Smith, A. Novokhatski and the Mercury News.

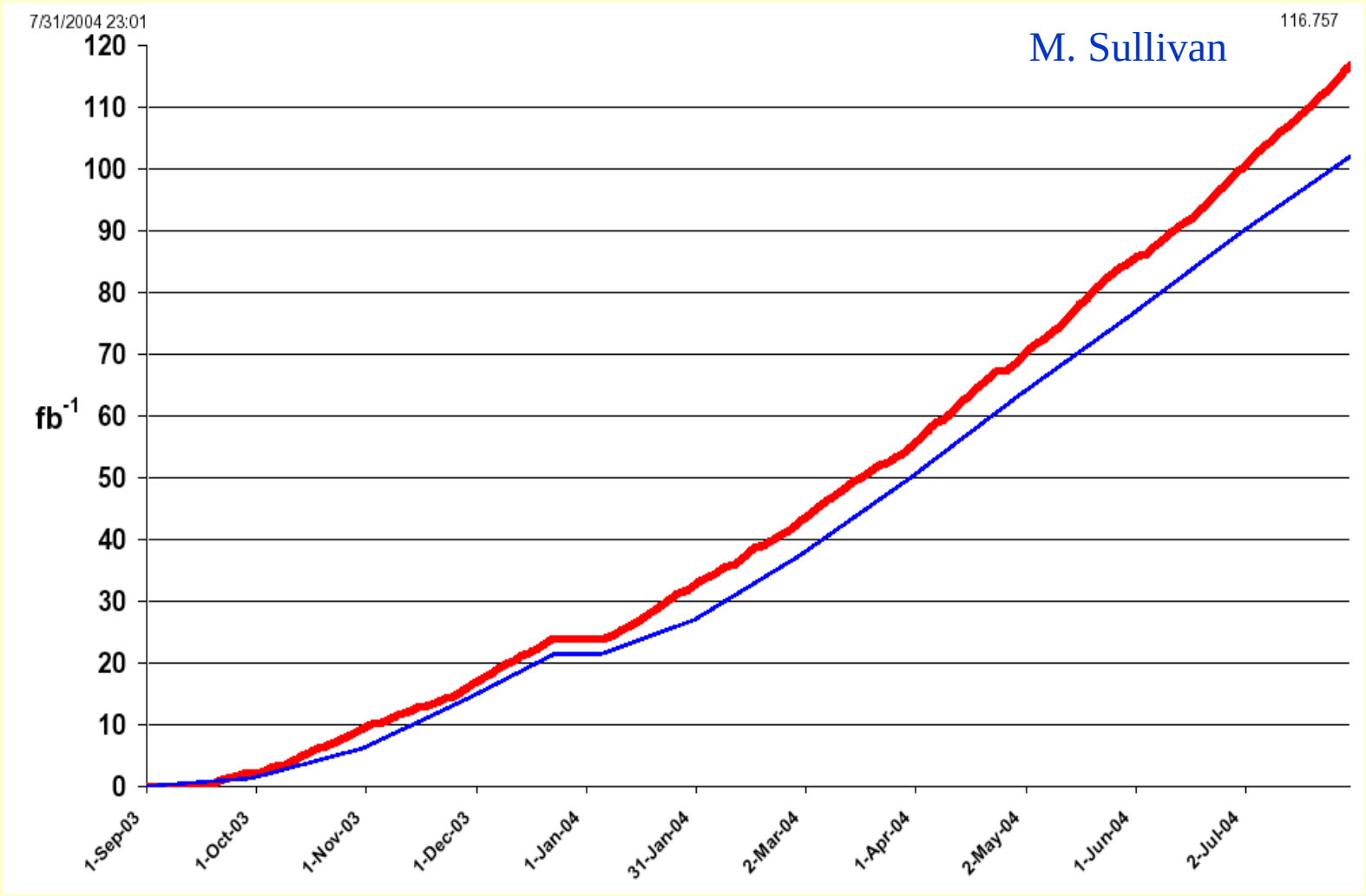
Outline

- Run 4 Synopsis & Statistics
- Beam Parameters
- Improvements during Summer Downtime
- Run 5 Preparation and Planning

Run 4 Synopsis

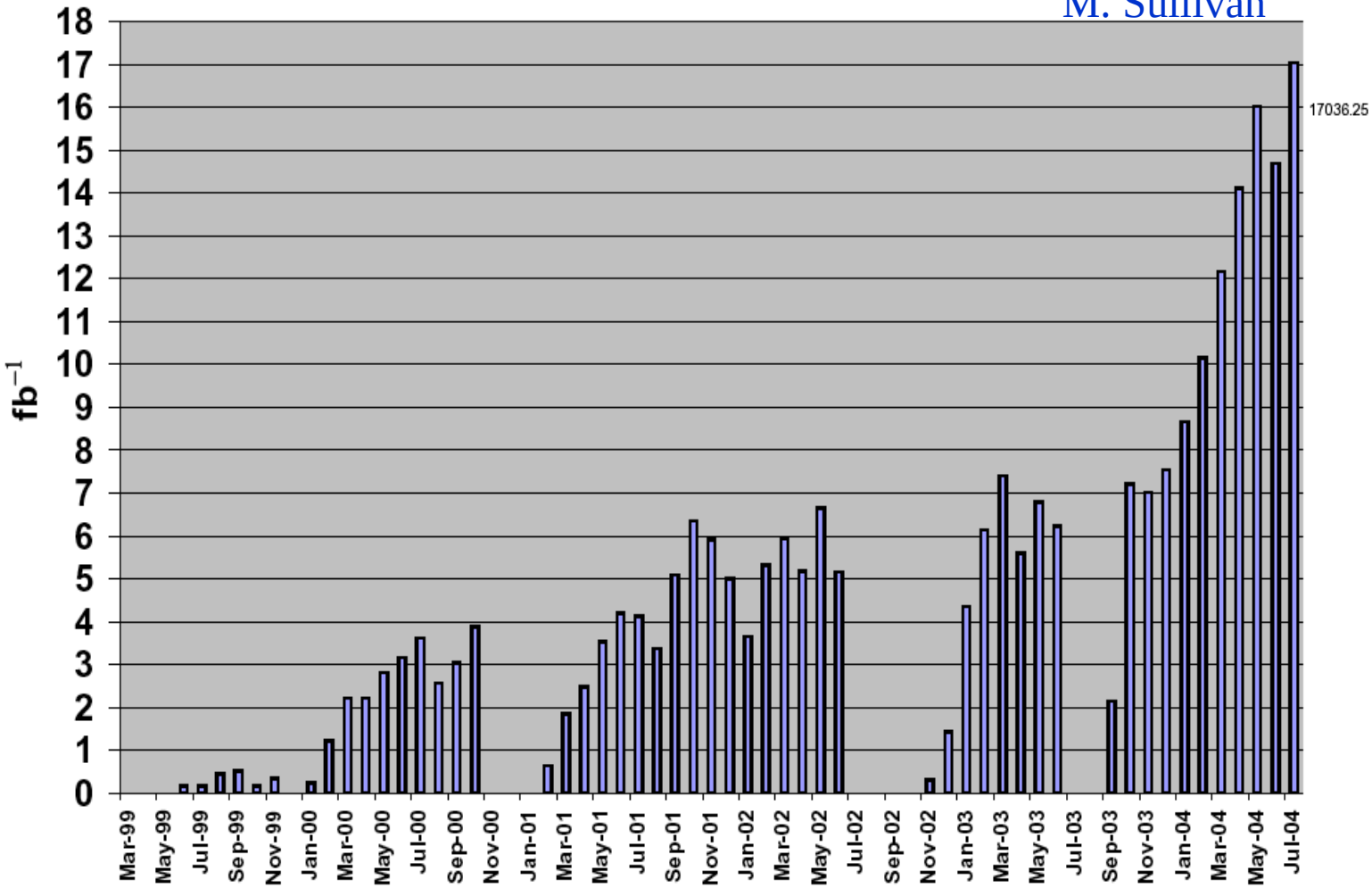
- PEP has delivered 116.7/fb in Run 4 over 256/fb total
- ≤2.5 the rate of Run 3, peak >5 times CDR rate
- Key improvements:
  - Trickle-charge (continuous injection) both rings
  - Raise peak Lumi to 9.21E33 (currents, ß*, orbit)
  - Aggressively tracked down & reduced rf trips.
  - MD program focused on near-term improvements + strategic studies needed for upgrades.

PEP Run 4 Delivered Luminosity

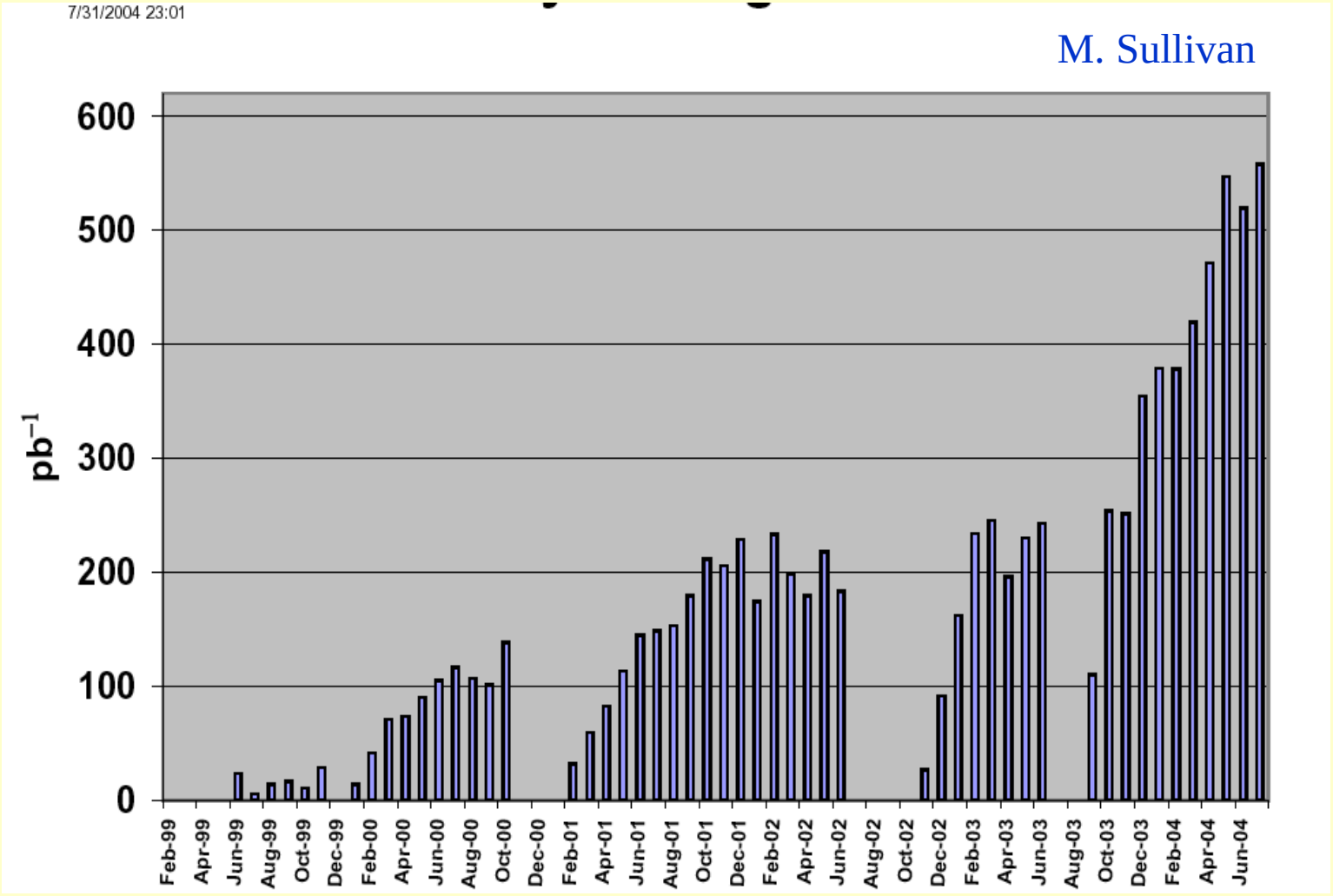


PEP-II Monthly Delivery

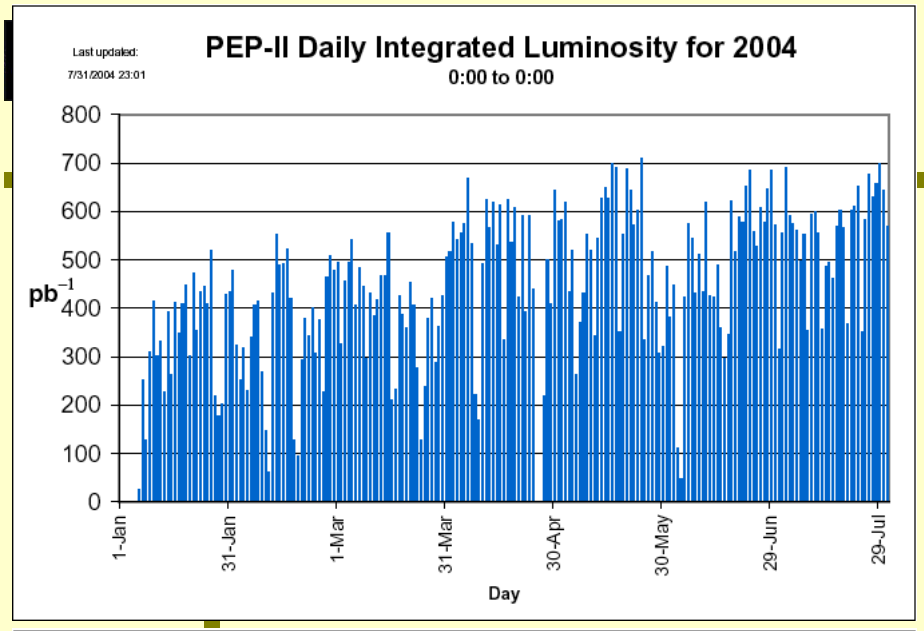
M. Sullivan

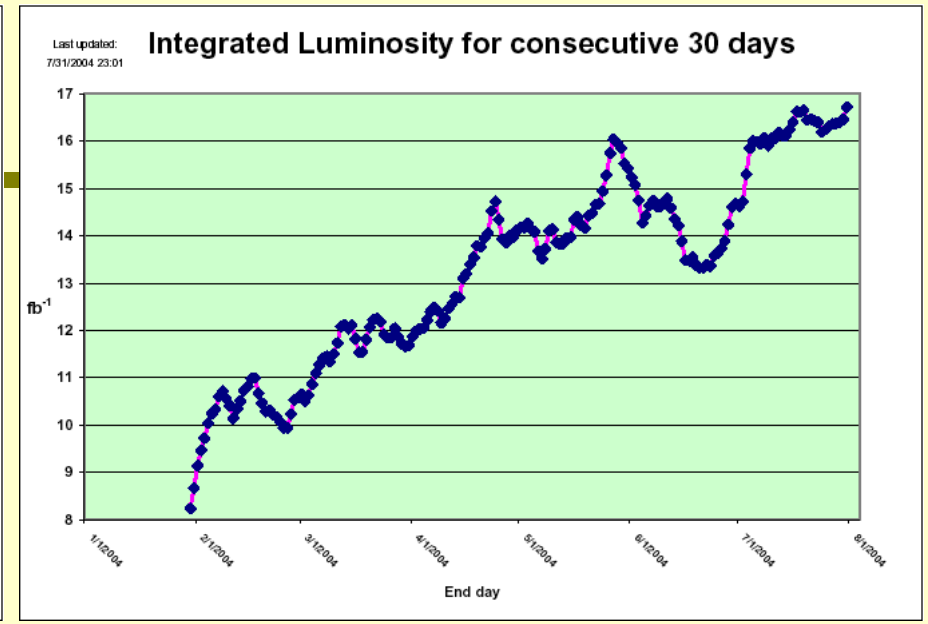


PEP-II Run 4 Daily Average/Month



M. Sullivan


Last updated:
7/31/2004 23:01
PEP-II Daily Integrated Luminosity for 2004
0:00 to 0:00
pb⁻¹
Day
1-Jan
31-Jan
1-Mar
31-Mar
30-Apr
30-May
29-Jun
29-Jul


Last updated:
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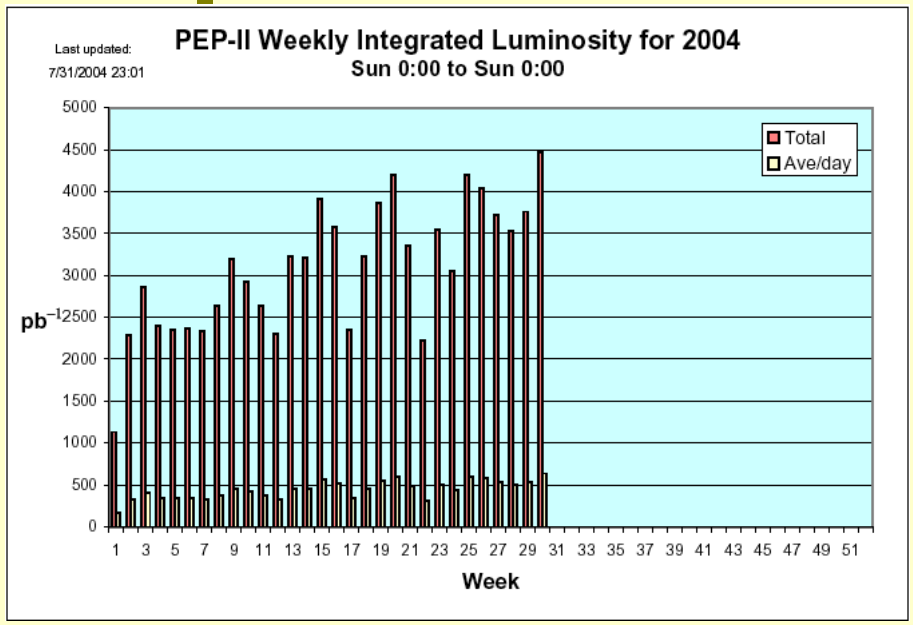
Integrated Luminosity for consecutive 30 days
fb⁻¹
End day


Last updated:
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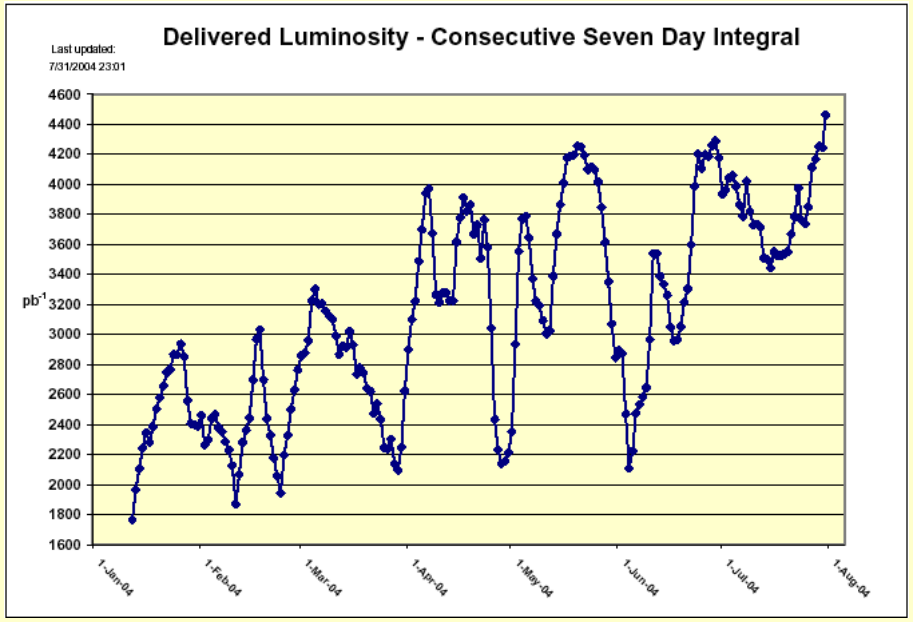
PEP-II Weekly Integrated Luminosity for 2004
Sun 0:00 to Sun 0:00
Total
Ave/day
pb⁻¹
Week


Last updated:
7/31/2004 23:01
Delivered Luminosity - Consecutive Seven Day Integral
pb⁻¹

PEP-II Records

M. Sullivan

Peak Luminosity

July 31, 2004

9.213×10^{33} cm^{-2}sec^{-1}		May 21, 2004
1588 bunches	2450 mA LER	1550 mA HER

Integration records of delivered luminosity

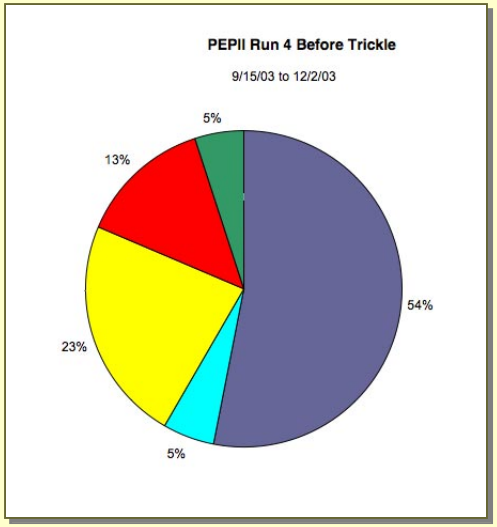
Best shift (8 hrs, 0:00, 08:00, 16:00)	246.3 pb^{-1}	May 21, 2004
Best 3 shifts in a row	710.5 pb^{-1}	May 24, 2004
Best day	710.5 pb^{-1}	May 24, 2004
Best 7 days (0:00 to 0:00)	4.464 fb^{-1}	Jul 25-Jul 31, 2004
Best week (Sun 0:00 to Sat 24:00)	4.464 fb^{-1}	Jul 25-Jul 31, 2004
Peak Ave Lum	8.705×10^{33}	May 14, 2004
Best 30 days	16.720 fb^{-1}	Jul 2 – Jul 31, 2004
Best month	17.036 fb^{-1}	July 2004
Total delivered	256 fb^{-1}	

PEP-II Run Time Dist. Run 4

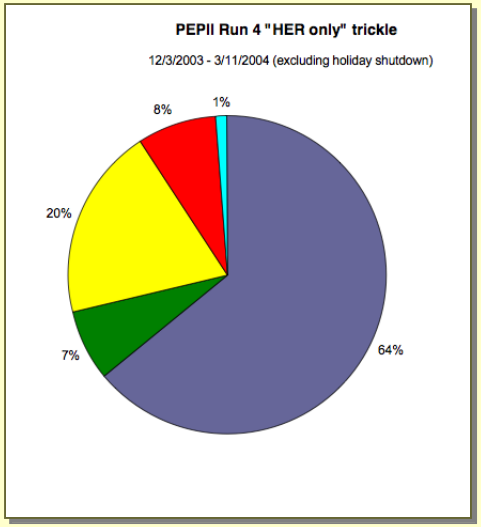
M. Stanek

- Average delivery: 65%
- Average tuning+injection: 17%

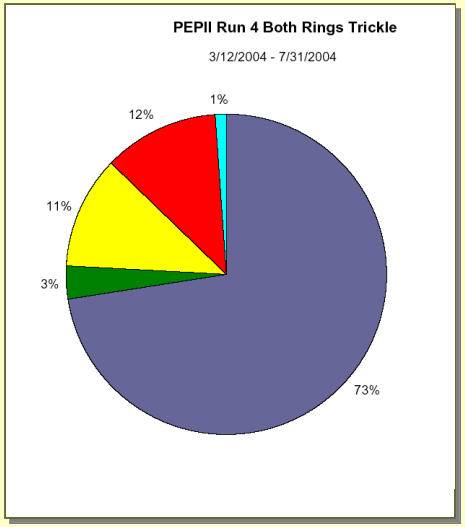
Pre-trickle

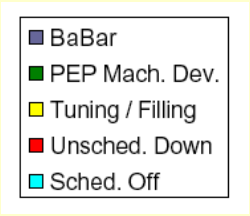


LER-trickle

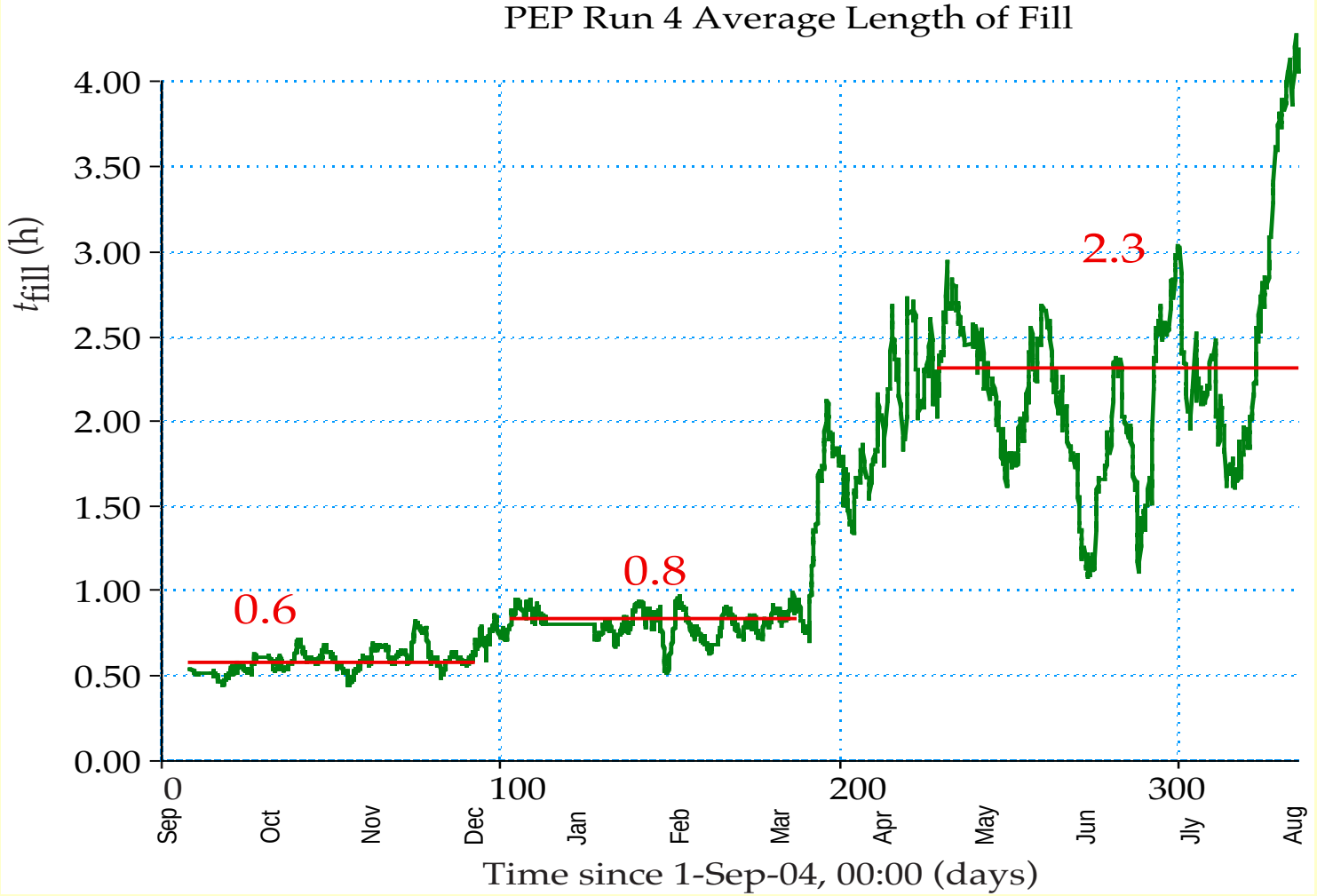


Double-trickle

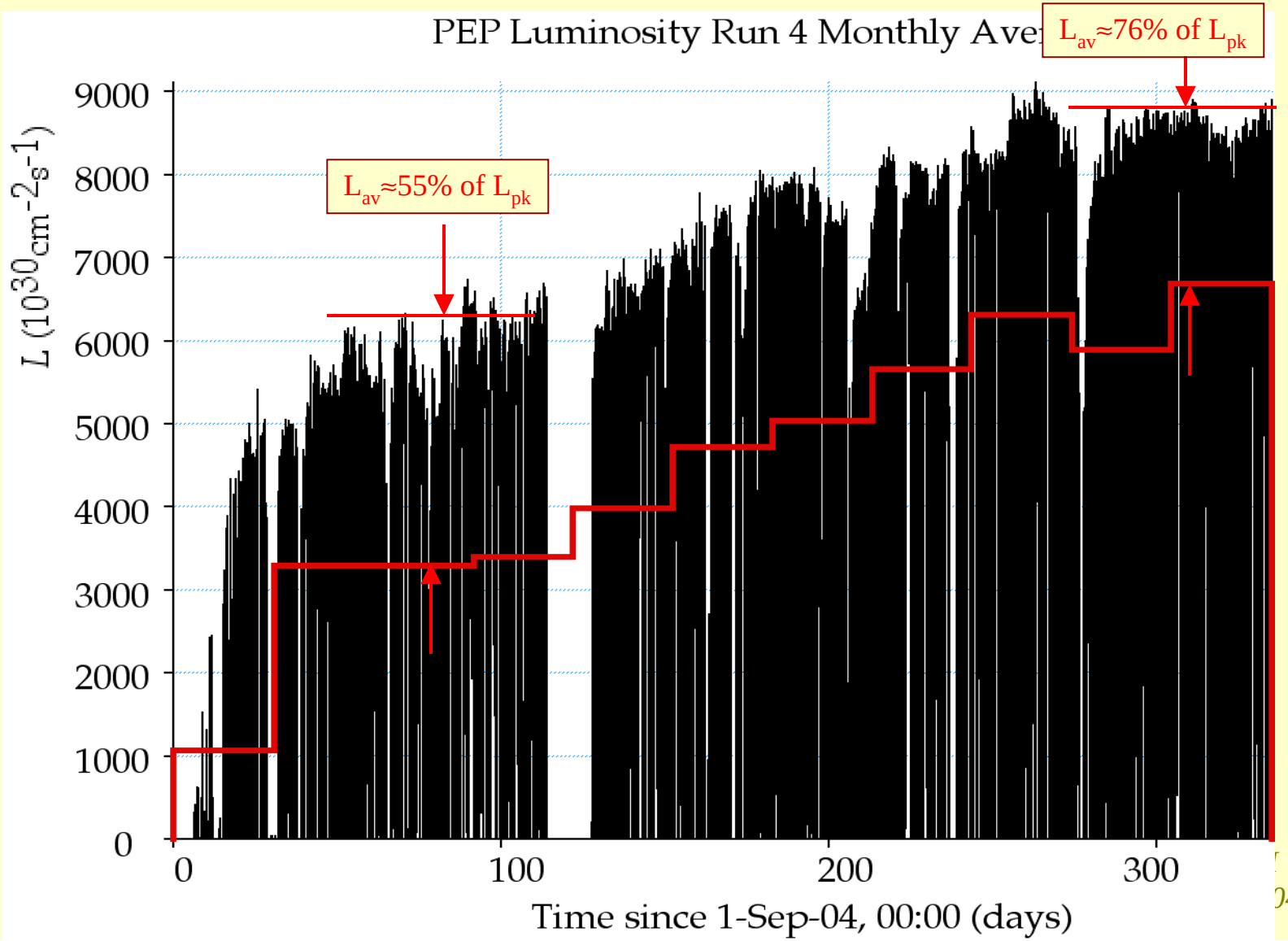




Trickle Charge: Length of Fill



Trickle Charge: Ave/Peak Lumi



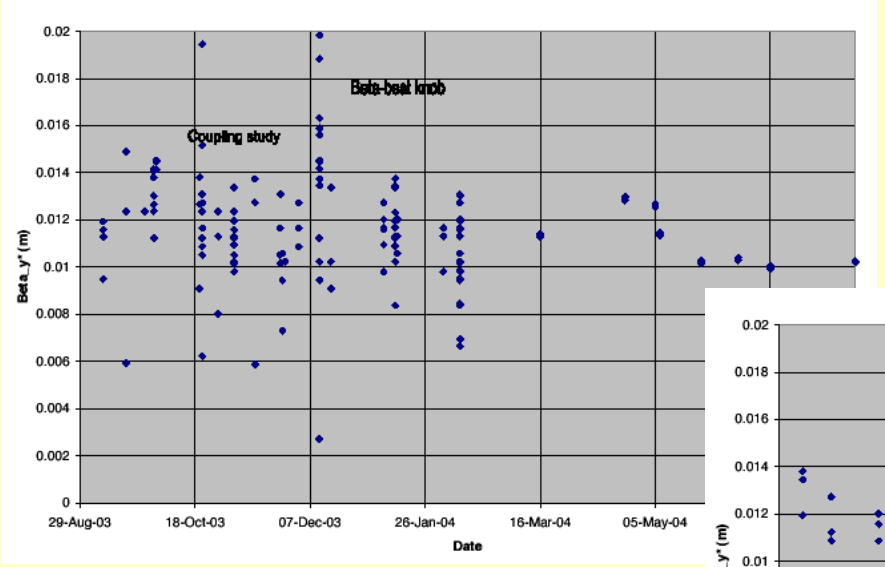
Run 4 Major Issues

- IR 2 vacuum-related problems
  - VAT vacuum gate valve failed, replaced by spool
  - outgassing at high (LER) current, likely from NEG
- HER longitudinal instabilities
  - fixed with LGD Woofer
- Rf trips

Evolution of beam parameters

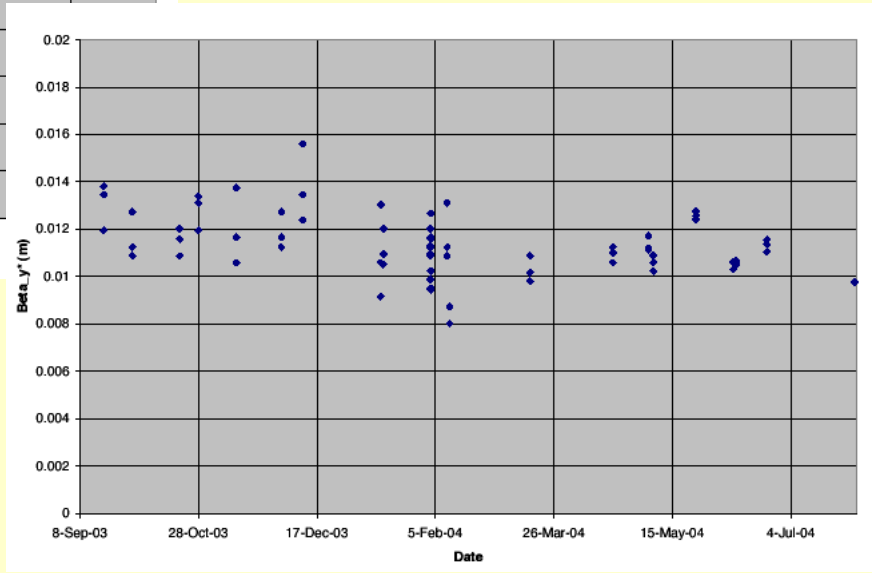
- β_y^*: 12 –> 10.5 mm

G. Yocky



HER

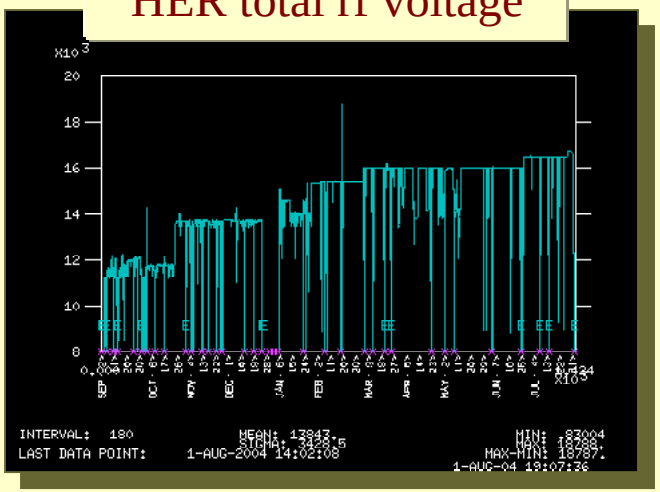
LER



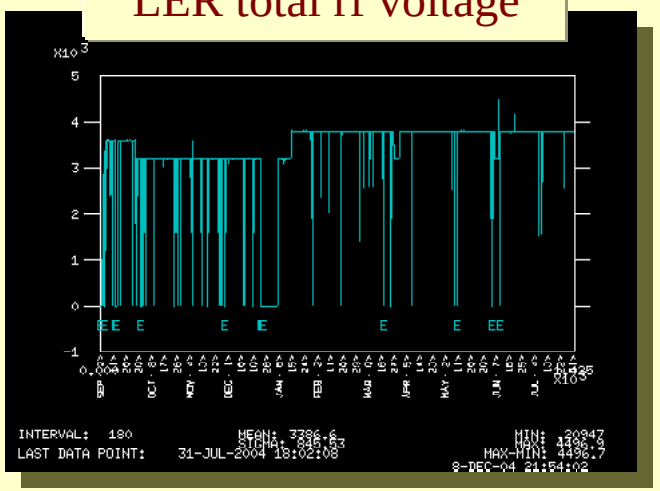
Bunch Length Estimates

- σ_l:
  - 13.4 –> 11.4 mm (HER), 13.5 –> 12.4 mm (LER)
  - based on BPM measurements & $\sqrt{V_{rf}}$ scaling
  - consistent with BaBar estimates
  - Streak-camera measurements yield high values.

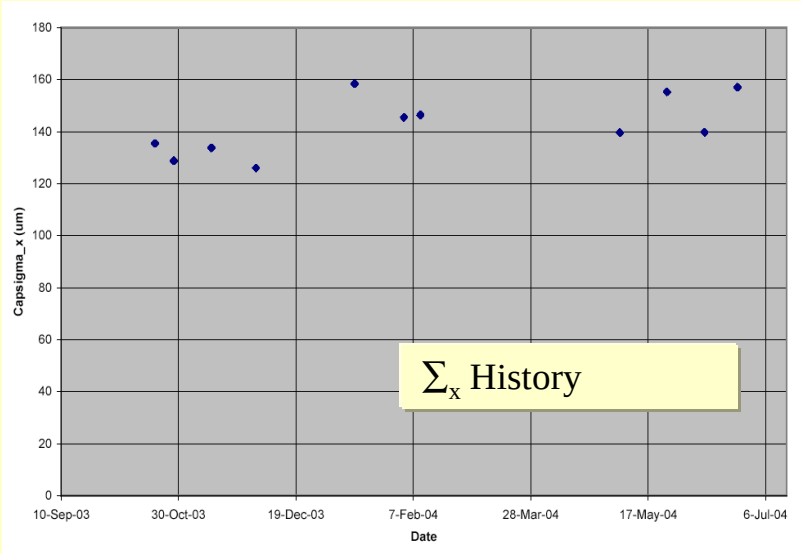
HER total rf voltage



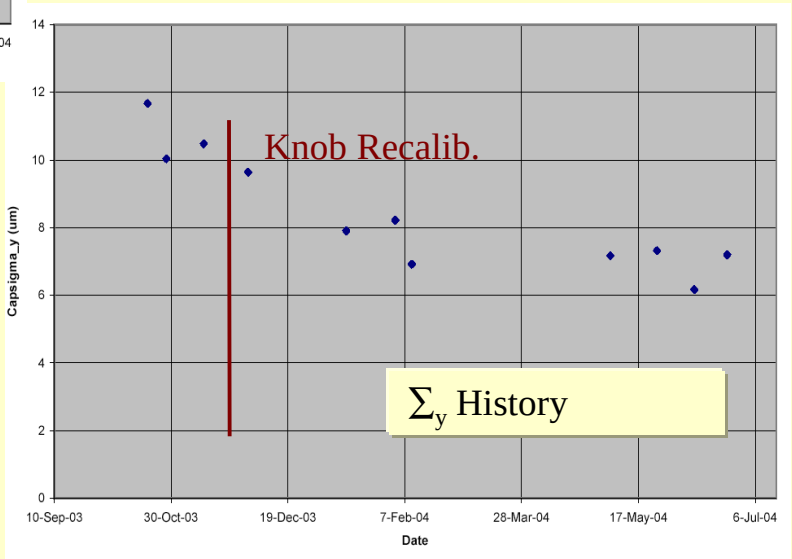
LER total rf voltage



History of $\Sigma_{x,y}$ Measurements



G. Yocky



Optics Understanding

- Online phase advance routinely used
  - tracking of coupling (C_{12}) and β^*
  - quick analysis of effect of lattice knobs
- ORM analysis –> "Fudge Factors"
  - ability to run MAD (Wolski) for configuration optics
    - estimate actual beam emittances
    - check and fit parameter knobs to work better on actual lattice
    - attempt to understand acceptance of actual optics
  - create magnet config. for design optics
  - Procedure being automated for fast turn-around

More Optics…

- BBA analysis
  - IR 2 offsets in LER now understood
  - feeds back into ORM analysis (sextupole feed down)
- –> Talks by Woodley, Tenenbaum
- 90° lattice design for the HER complete
  - hardare being designed (see talk tomorrow)

Understanding Luminosity

- Parameter Set (May 21 record $L = 9.21 \times 10^{33}$)
  - $I_{HER} = 1.55A$, $I_{LER} = 2.45A$, #bunches = 1588
  - Beam parameters from conf. lattice, BaBar & SN:
    - HER
      - ε_x: 51 nmr; ε_y: 1.7 nmr, σ_z: 11.4 mm (conf. lat., Sasha)
      - $ß_x$: 30 cm, $ß_y$: 11 mm (ph. adv. measurement)
      - ν_x: 0.5253, ν_y: 0.6368 (ph. adv. measurement, 1 bunch)
    - LER
      - ε_x: 27 nmr; ε_y: 1.4 nmr, σ_z: 12.3 mm (conf. lat., Sasha)
      - $ß_x$: 50 cm, $ß_y$: 10.3 mm (ph. adv. measurement)
      - ν_x: 0.5151, ν_y: 0.6075 (ph. adv. measurement, 1 bunch)
  - A model incl. dynamic ß, hourglass, parasitics can match these parameters
    - Exception: LER ε_y adjusted to fit L_{act} (2.3 from config. lattice)

Comparison to Measurements

- $\Sigma_{x,y}$ at low beam current:
  - Σ_x=150 μm, Σ_y=7.2 μm model, very similar to meas.
- Luminous-region width (high current):
  - σ_x=67 μm model, 66 μm BaBar
- Luminous region length (high current):
  - σ_z=8.2 mm model vs 8.26 from BaBar
    - assuming ß$_y$*≈10.5 mm; some unresolved issues w/ shape
- HER SLM σ_y: 0.26 mm model = measurement
- LER SLM σ_x: 2.4 mm model ≠ 1.7 mm meas't
- Other parameters not measured reliably

Beam-beam parameters…?

- Without dynamic ß, parasitic tune spread & hourglass
  - ξ_x(HER): 0.038, ξ_x(LER): 0.112;
    ξ_y(HER): 0.043, ξ_y(LER): 0.064

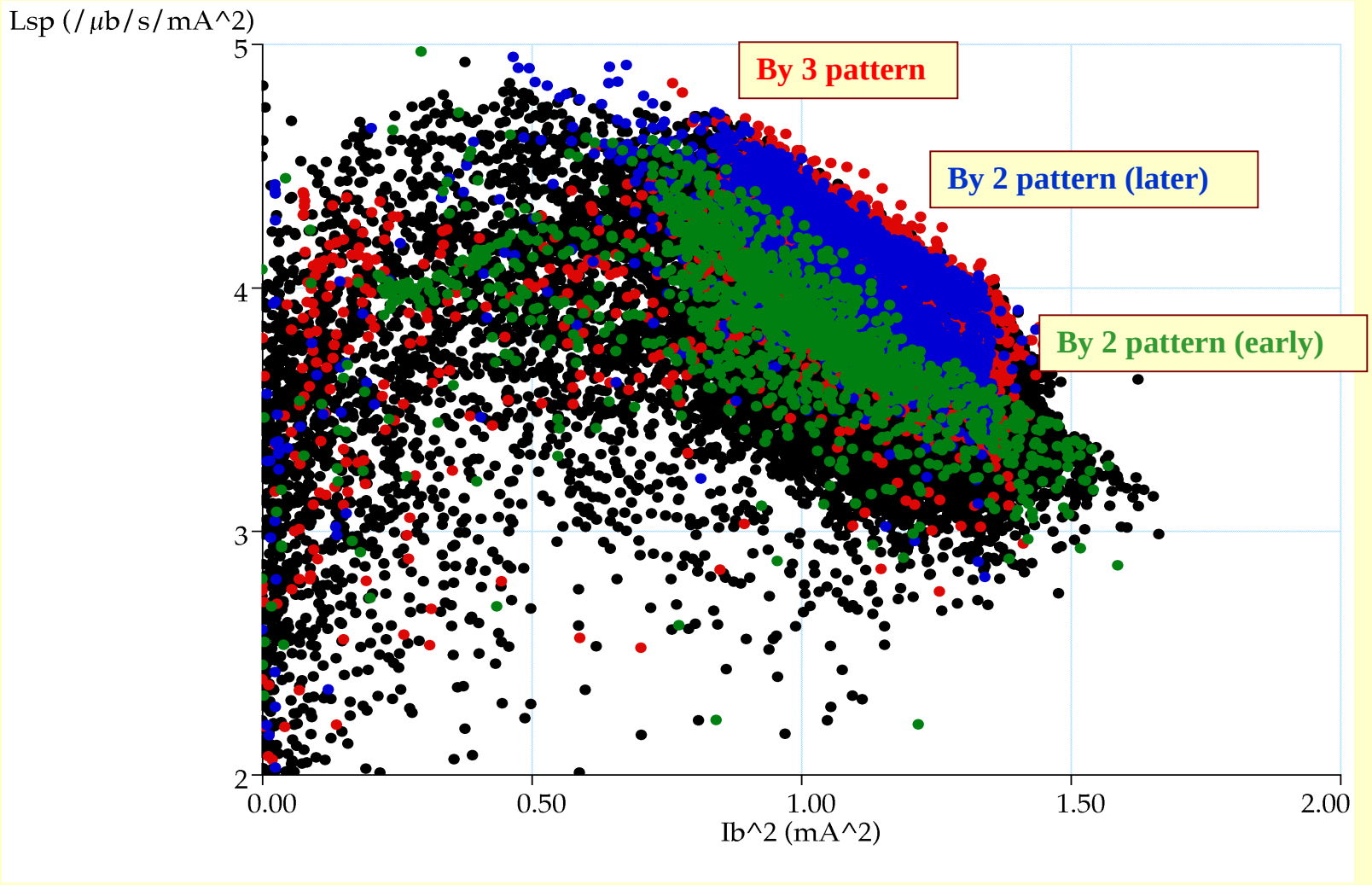
- With all effects included:
  - ξ_x(HER): 0.039, ξ_x(LER): 0.038;
    ξ_y(HER): 0.037, ξ_y(LER): 0.054
  - calculated using final beam sizes and dynamic ß*

Issues

- Consistency with beam parameters, beam sizes; effect of crossing angle, parasitics
  - simulations & measurements (see YC & WK talks)

- Effect of parasitic collisions
  - experiment: ≈6%, simulation: ≈7%, model: ≈4%
  - indication change in xing angle reduces effect (–> WK)
  - operationally: very small, maybe 2%

Spec. Luminosity vs I_b^2



Summer 2004 Downtime Improvements

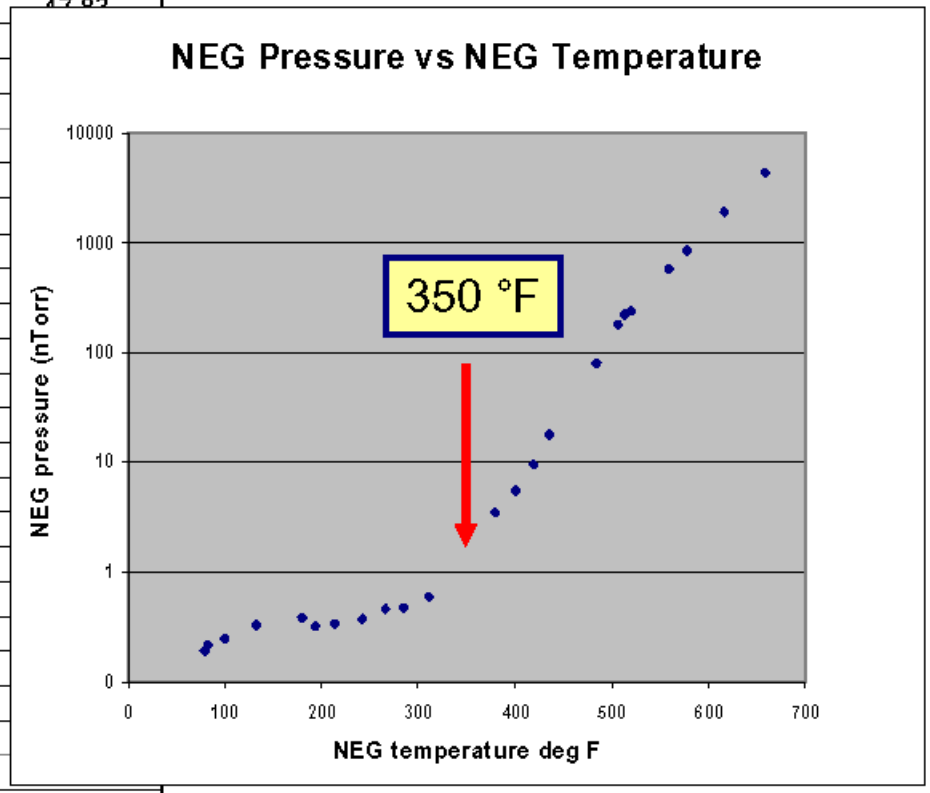
- IR 2 vacuum fixes
- LER Rf 4-2
- HER Rf 12-1 split in two
  - 12-1 and 12-2, 2 cav's ea.
- LER LFB kickers
- LER TFB kicker electrodes & data acquisition
- New LGD Woofers, both rings
- HER bellows fans deployed
- 2 Injection pulsers/ring
- LER X-ray monitor
- LER BBA system
- BIC IOC
  - address stalls & crashes

IR-2 Vacuum Improvements

- Outgassing most significant limit for Run 4
- 9 NEGs with “C” screens removed LER incoming
  - includes all the “high-temperature” NEGs
  - LER QD4R NEG replaced by TSP/ISP combo
- LER collimators at -10 & -25 m generate HOMs
  - Removed to reduce levels of HOM in beam pipe
- Total reduction of NEG about 20%
  - somewhat made up by QD4R TSP & ion sputter pump.
- Expect better vacuum at high LER current.

LER NEG Pump Temperatures

NEG #	Chamber	Screen type	Temperature	Location (m)	Location (feet)
3022A/B	Q2	A	82	3.4	11.25
3023	QD4	B	465	5.5	18.00
3025	QF5	B	300	7.8	25.75
3042	BV1B	C	750	9.8	32.25
3043	Coll 3043	B	425	12.4	40.67
3052	QDCX21	C	600	14.6	
3053	QDCX21	B	130	16.0	
3061	BCX21A	B	110	16.3	
3062	BCX21B	C	500	18.6	
3063	BCX22	B	120	20.8	
3066	QDCX2A	B	100	22.3	
3072	QDCX2B	C	775	22.5	
3074	QDCX2B	B	150	24.3	
3076	Coll 3076	B	725	25.5	
3082	QFCX1	C	425	26.6	
3101	SCX2	C	600	26.7	
3102	BCC1	B	140	30.4	
3112	QDCY21	C	425	32.2	
3114	Drift 32 (right)	D	90	32.3	
3115	Drift 32 (left)	D	90	37.0	
3116	Drift 38 (right)	D	90	37.3	
3118	Drift 38 (left)	D	90	42.0	
3132	QDCY22	D	90	44.8	
3141	BCC4	D	95	45.7	
3142	BV2	C	825	47.7	
3149	QFBM1	C	850	51.3	
3165	QFBM2	D	90	54.4	
3174	QFBM4A	D	90	56.2	
4011	BBM1B	D	90	63.1	207.17
4012	B	D	95	65.5	214.83



Lab test data of NEG outgassing as a function of temperature

M. Sullivan
Sep. 16, 2004

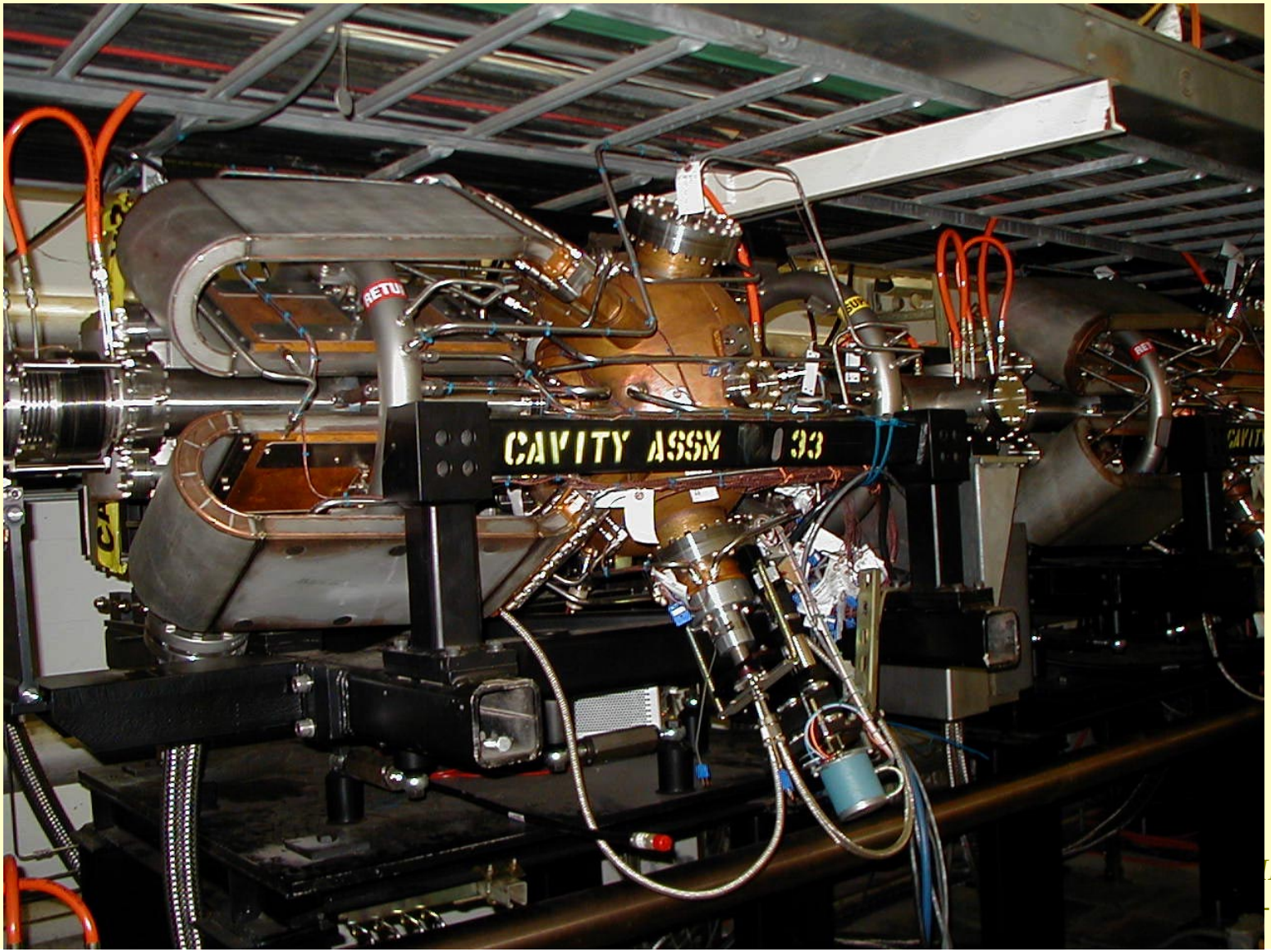
Upstream side

4

PEP Rf Changes

- 2 additional klystrons: 1 MW addl. power/ring
  - LER current limit -> 3.5 A
  - HER current limit -> 1.8 A
- HER max V_{rf} unchanged (≈ 20 MV)
  - Aim to raise oper. voltage to ≥18 MV for $\sigma_l \approx 10.5$ mm
- LER max V_{rf} up by ≈1.5 MV
  - Aim for 5.5 MV total for $\sigma_l \approx 10$ mm (now ≈ 12.5 mm)
- Higher voltage shortens bunches, helps stability
- 2 more LER cavities hurt stability
  - LFB upgrades should more than compensate.

LER Rf 4-2 Cavity B



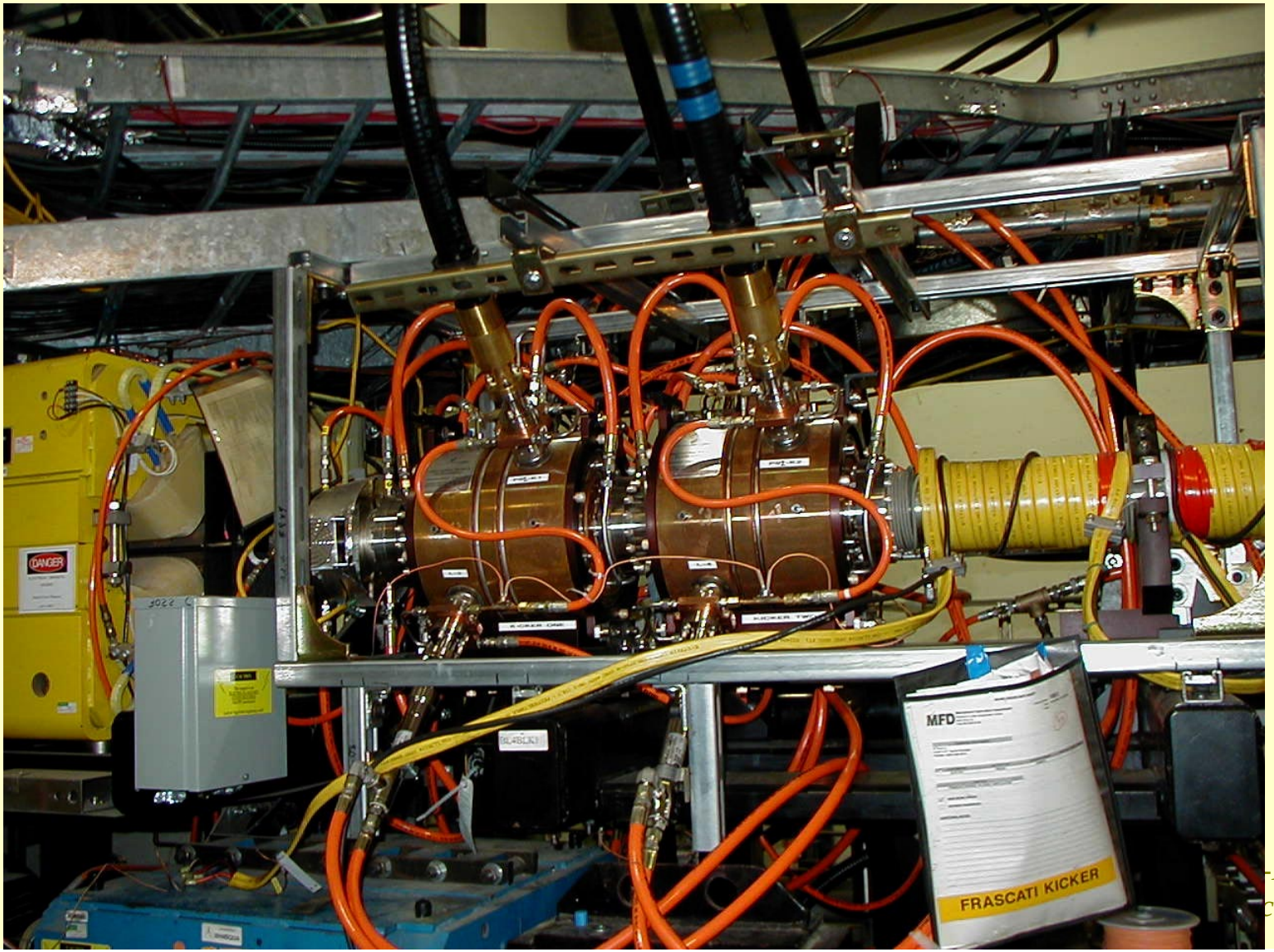
LER LFB Feedback Upgrades

"Frascati-style" overdamped (Q≈5) cavity kicker

- Better cooling, higher shunt impedance
  => stronger kick, higher max. beam current
- Not directive => reflected-power characteristics will change.
- Larger feedthrough & cable size for kicker, less heat problems.

- **Back to short delay in front-end filter**
  - Better optimization of LFB front-end setup
  - => no more by-3 bunch pattern possible!
- **Production-unit LGD "Woofers" for both rings**
  - Better control of low-lying longitudinal modes
  - Pre-prod. unit in HER worked very well with clear benefit.
    - I_{max} from 1400–>1600 mA (roughly), less instability aborts.
  - Important for LER with 8 rf cavities.

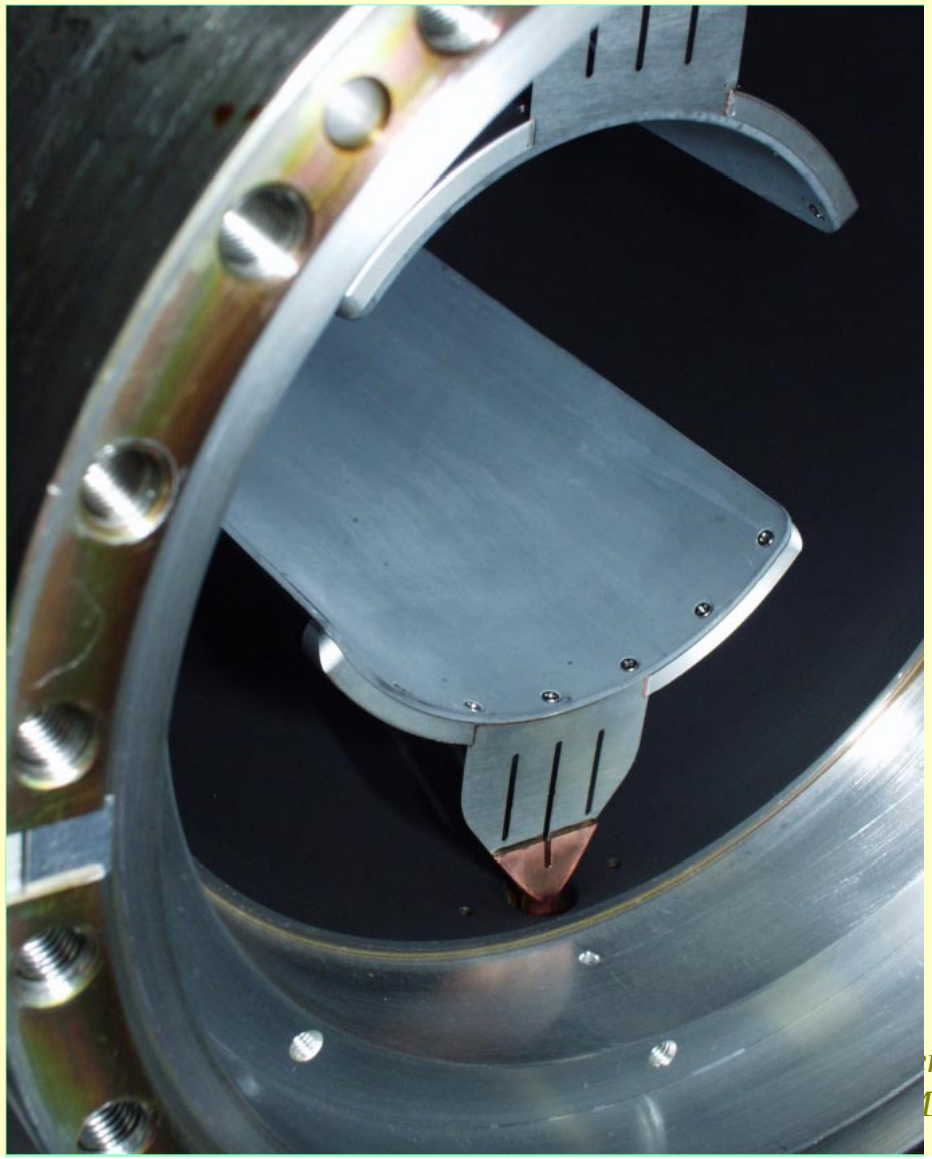
The New LER LFB Kicker



TFB Feedback Upgrades

- Replaced Al electrodes with Mo electrodes (LER)
  - Much higher temperatures allowable => higher beam *I*
- HER Receiver upgraded to allow better timing
  - Previously done successfully for LER
- New bunch-by-bunch diagnostics & event buffer.
  - Improved abort diagnostics, system diagnostics
  - Fast digitizer boards can store 40 ms of TFB data
    - bunch-by-bunch, turn-by-turn,
    - 4 channels: HER, LER; *X*, *Y*
  - Triggered on a beam abort or deliberately
    - abort diagnostics, grow-damp measurements.

TFB Kicker Mo Electrode



New Injection Pulsers

- Originally, two kickers powered from one modulator
  - Closed bump if exactly equal
  - Timing done by different cable length to each kicker
  - In practise, strength not exactly equal
- Now each kicker is powered individually,
  - Can control each kicker's strength & timing
  - If phase advance is correct, can always close bump.
  - Phase advance can be fixed optically.
- Expect to be able to further reduce trickle backgrounds

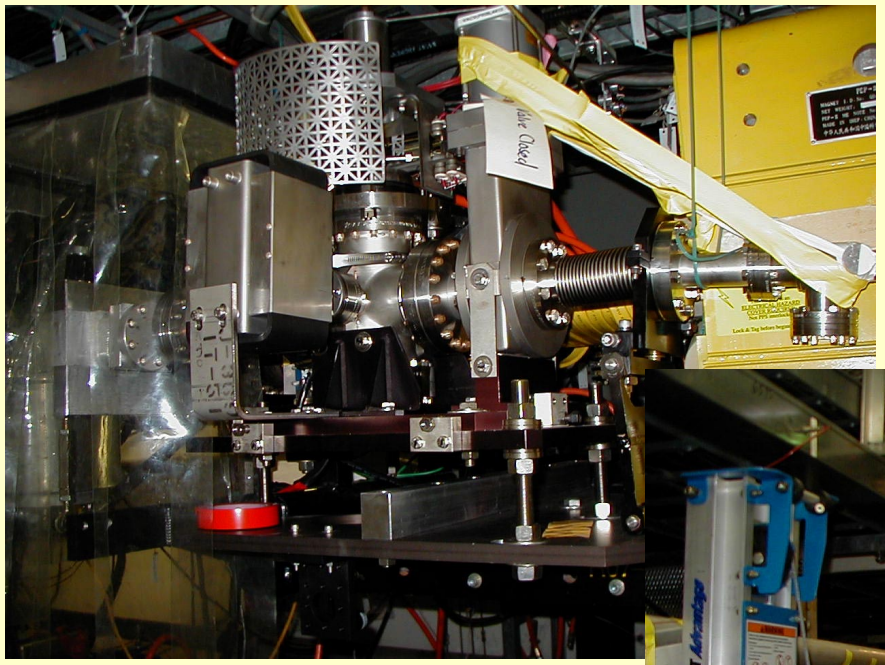
New LER BBA System

- Expected to significantly enhance our optics-correction capability.
- To find the magnetic center of quadrupoles at optically sensitive locations in the ring. Shunts are used to vary the field in one magnet which otherwise lacks individual control.
- In IR2, there are four strings powering a total of 14 quads: QFCY1 (4), QDCY2 (4), QFCX3 (2), QDCX2 (4)
- Throughout the ring there are 37 individual QD and QF quads which have been identified as prime candidates for BBA.
  - These are in the arcs, immediately adjacent to sextupoles
  - There are 2-5 quads per half-arc

New LER Synchrotron-light monitor

- X-Ray pinhole camera
  - Very good resolution
    => expect vertical beam size info.
  - At a non-coupled location
    => vertical beam size meaningful
  - $ß_x$=5.6 m, $ß_y$=27.9 m, η_x=0.2 m
    (config. model)
- Important to better understand beam-beam behaviour at high beam current
- Significant input & help from CalTech

New LER SRM Arc 7a



Valve @ PR06-4012

Light pipe through gate

Run 5 Planning

- PEP was within 5 days of final lockup when work at SLAC was halted.
- Subsequently, AD established a procedure to certify its members back to work
  - Daily safety meetings
  - Training requirements (Elec. Safety, PPE, LOTO, Fall Prot.)
  - Review of applicable safety-related documents, JHAM, AHA
- We established a list of tasks needed to finish the downtime work
  - Make sure nothing “falls through the cracks”
  - Assess safety implications in light of new ES&H Bulletins

Near-term Plan for Startup

- At present, working towards being ready for PEP startup early January
  - Technical schedule drivers:
    - IR 12 rf cavity HOM load repair
    - IR 2 work (lots of relatively short tasks) and PPS
- The Linac was running before the accident so we do not expect undue delays in Linac startup
  - The destroyed panel has been removed; power expected to be restored by end of this week.
  - But vacuum issues in front-end and potentially in e^+ source
- Actual startup contingent on Corrective-Action Plan resulting from Type-A accident investigation.

Strategy for Run 5

- Most luminosity will come from higher currents
  - 3.3 A on 1.8 A by summer 2005, LER wiggler?
- Lowering β_y^* should be helpful even at present bunch length
  - the lower, the better; aim for 9 mm
  - better optics modelling should help achieving this
- Shortening the bunches is expected to help as well
  - model indicates significant gains possible
  - higher synchrotron tune may reduce gains
  - some questions about accuracy of hourglass models

Run 5 Startup Tasks

- Commissioning of new injection system
- New converted BPMs need checkout, timing
- New Rf setup (12-1 and 12-2, 4-2 setup)
  - May initially park new stations
- New LFB setup (LGDW, LER from scratch)
- New HER TFB setup (mod'd receiver)
  - Both need back-end timing check
  - Gage boards to be done parasitically
- New SRM commissioning (mostly parasitic)
- "The usual": steering, collide, …
  - Scrub vacuum while delivering
- Somewhat more hardware commissioning than Run 4

Particulars of Run 5

- No more by-3 pattern!
  - By-2 with initially rather short mini trains
- We will maintain our good HER orbit
- We will steer the LER down, hopefully
- We expect less IR-2 vacuum problems in the LER
- We will improve the optics of the rings
  - New BBA system will facilitate better orbits
  - Better models from ORM analysis will allow for more sophisticated correction
  - New SRM will give better LER beam-size information
  - BaBar-provided beam-size diags will be used routinely
    - already being used to improve our luminosity models

MD Plans

- Likely will be doing 1 MD/week, on average
  - Occasionally take a month of straight running
- MD activities will center around
  - Hardware commissioning (LGDW, SXM, RF, FB,…)
  - Optics improvements (LER steer, ß beat reduction,…)
  - New operational modes (LER wiggler)
  - AP understanding (e-cloud, luminosity,…)
- Detailed planning of MD activities is underway
  - List of planned activities with responsible persons
  - Presently reviewing detailed plans.

MD Plan Part I

PEP Accelerator Physics (MD) Projects for Run 5, UW *et al.*, Rev. 2.3

Steer the LER (JLT)

LER Wiggler turn-on (MS, JLT, GY)

BBA in the LER (GY)

ORM in HER and LER (JLT)

Try to implement "design lattices" (UW)

LGD Woofer (DT, DvW)

New rf station tuning

LER grow-damp measurements longit. and transverse(DT)

Transverse BTF measurements at different modes (RA, UW)

Raise LER Rf voltage, characterize Lumi vs voltage (UW)

Measure effect of parasitic crossings on β_y^* (UW)

Measure Luminosity vs bunch current at low-ish total beam current (SN)

Measure tune shift with amplitude (YC)

MD Plan Part II

Measure frequency maps

Push x tunes closer to 1/2 integer (JLT,GY)

e-Cloud experiment

New SRM commissioning (AF)

Heating issues vs V_{rf} (SE, SN)

Test of Klystron Linearizer (DT, DvW)

Test emittance control in LER using eta beat (FJD)

Minimize LER eta_y

Study beam-size growth with beam-beam (FJD)

Test possibility of 2-bunch injection (FJD)

Measure luminous-region length (BaBar) and bunch length (BPM) for different bunch currents

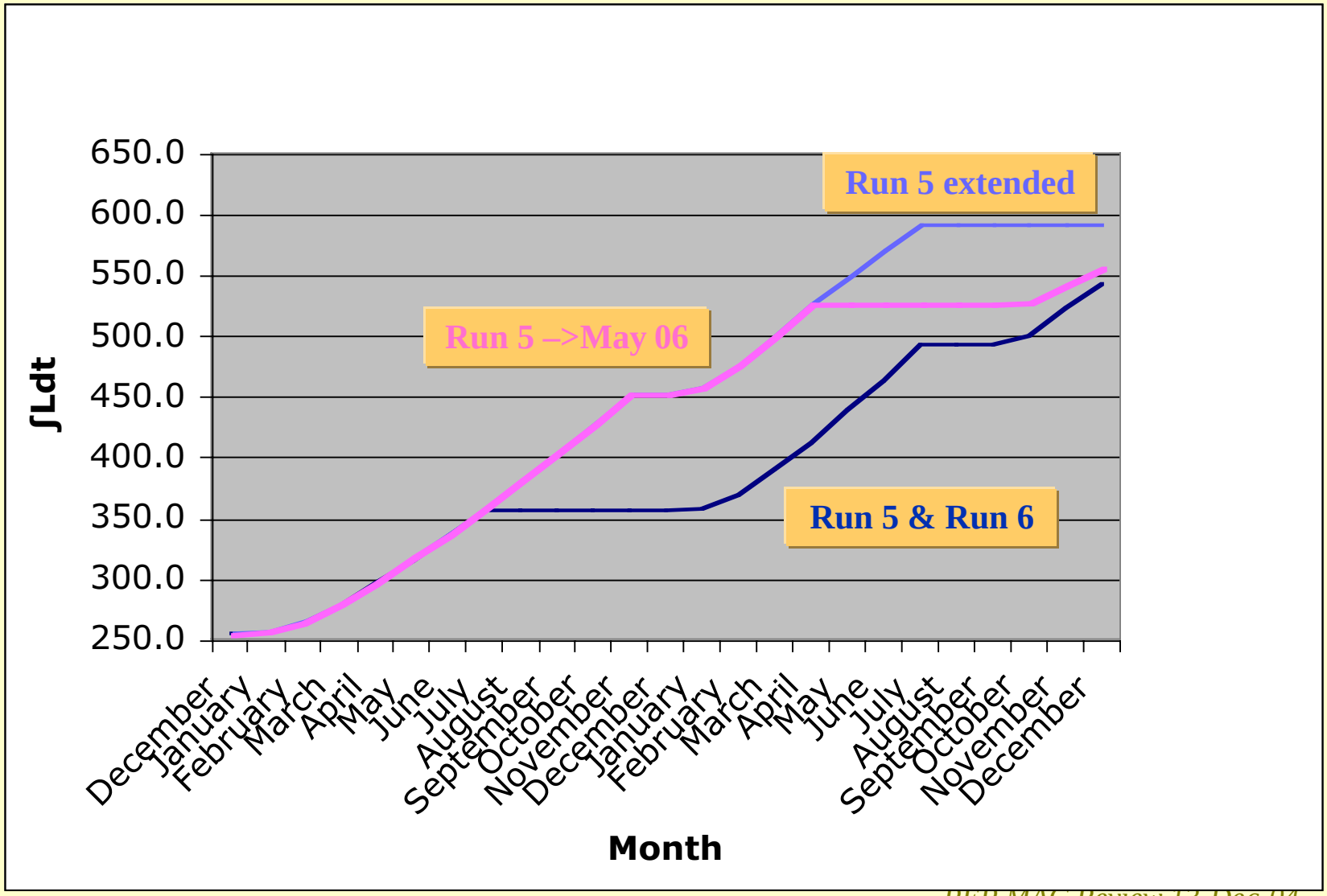
Rf phase scan over a wide range. (MS)

HER and LER SLM calibration, LER SXM calibration (AF)

Run Plan

- The Plan for Run 5 is affected by the present uncertainty.
- Baseline:
  - Run 5: Jan. 2005 –> July 2005, 5 mo shutdown
  - Run 6: Jan. 2006 –> July 2006, 2 mo shutdown
  - Run 7: Oct. 2006 –> …
- Alternatives:
  - Run 5: Jan. 2005 –> July or Aug. 2006, 5 mo shutdown
  - Run 5: Jan. 2005 –> April 2006, 5 mo shutdown
  - need ≈2 wks for PPS –>1 mo off in winter 05/06.

2005/2006 Running Scenarios



Total Luminosity Integral

- **Extending Run 5 will increase short-term delivery**
  - Aim for >500/fb total by spring 2006, >600/fb by Aug. 2006
  - With 5-month down in 2005 project ≤500/fb by Aug. 2006
- **Long term, expect to lose 50…80/fb of ≈1800/fb projected**
  - Peak luminosity limited during Run 5 extension at 1.3E33
  - Running through summer 2005 will incur some inefficiency
    - likely a small effect, offset by minimizing down time
- **Running until April 2006 somewhat favoured by BaBar**
  - still make 500/fb but avoid running Summer 2006
  - get LST and PEP IR 2 upgrade work going a little earlier
- **At present, Run 5 likely to continue until Dec. 2005**
  - decision about exact date for long shutdown likely in spring 2005