PEP-II above 10^{34} cm^{-2}s^{-1} Luminosity

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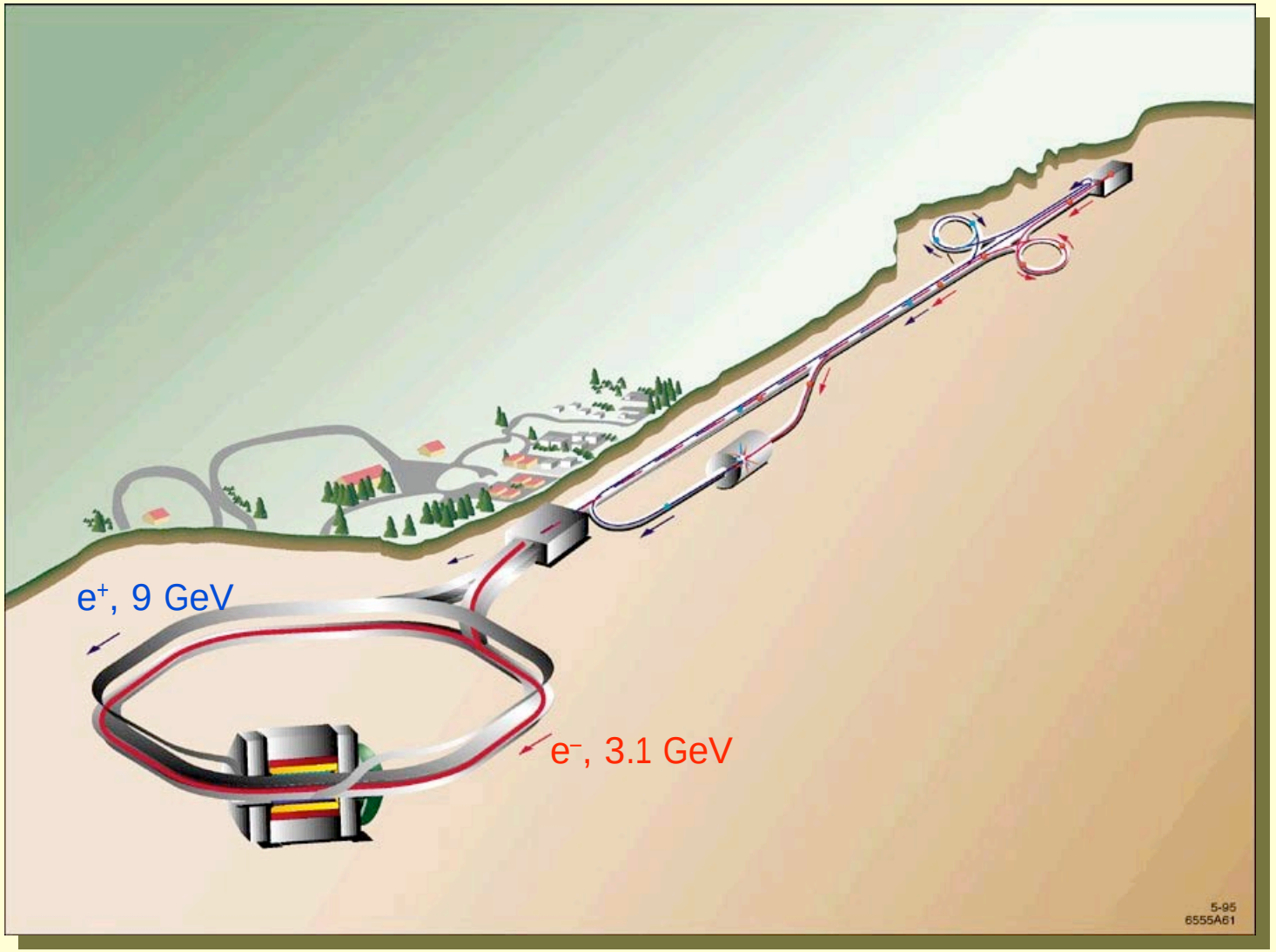
...for the PEP Team.

We are indebted to our colleagues for making PEP a success, in particular:

A. Fisher, M. Donald, A. Kulikov, S. Novokhatski, J. Turner, F.-J. Decker, S. DeBarger, Y. Nosochkov, W. Wittmer, G. Yocky, Y. Yan, & members of the BaBar collaboration.

SLAC AND PEP-II

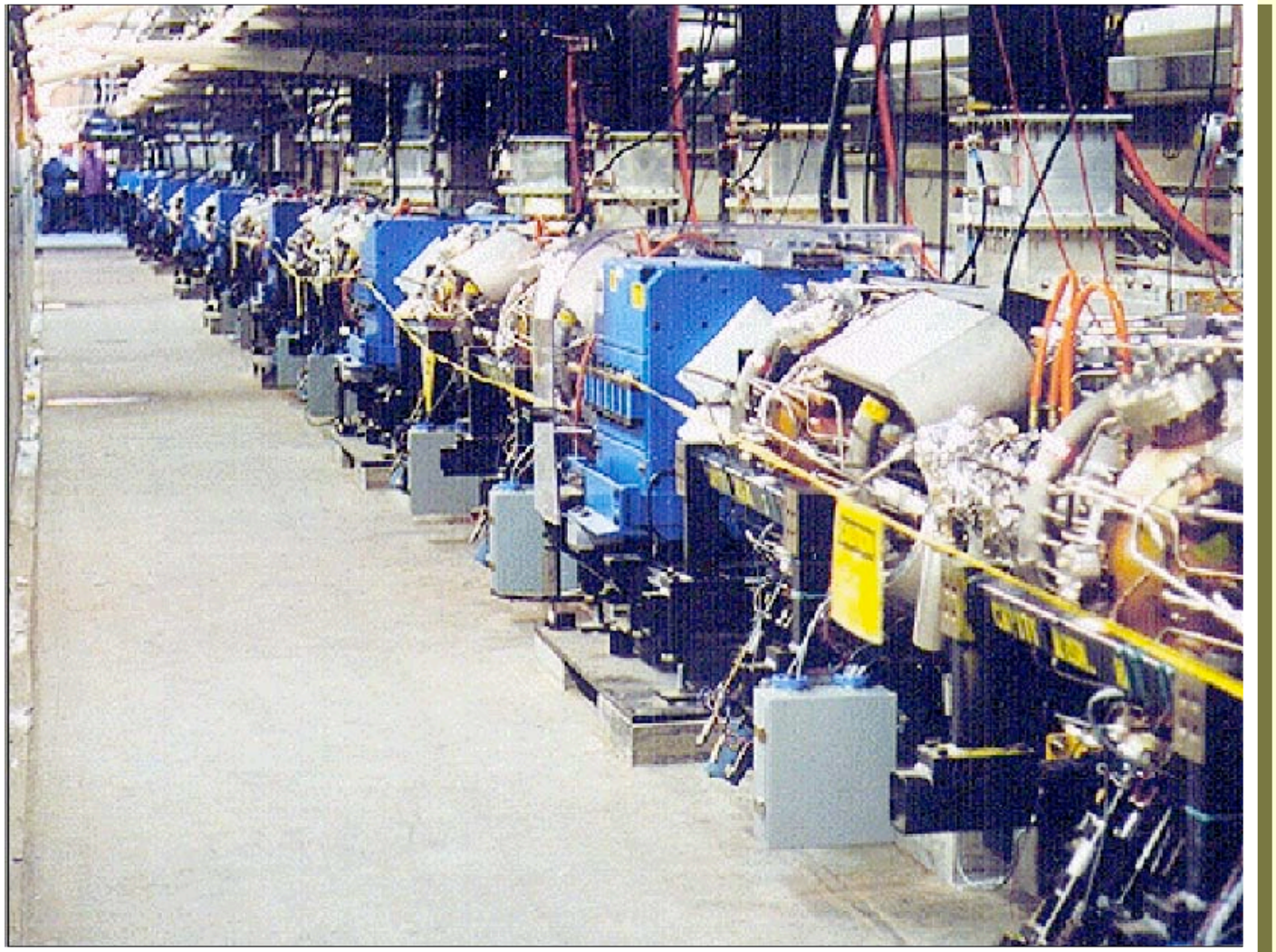


PEP Tunnel

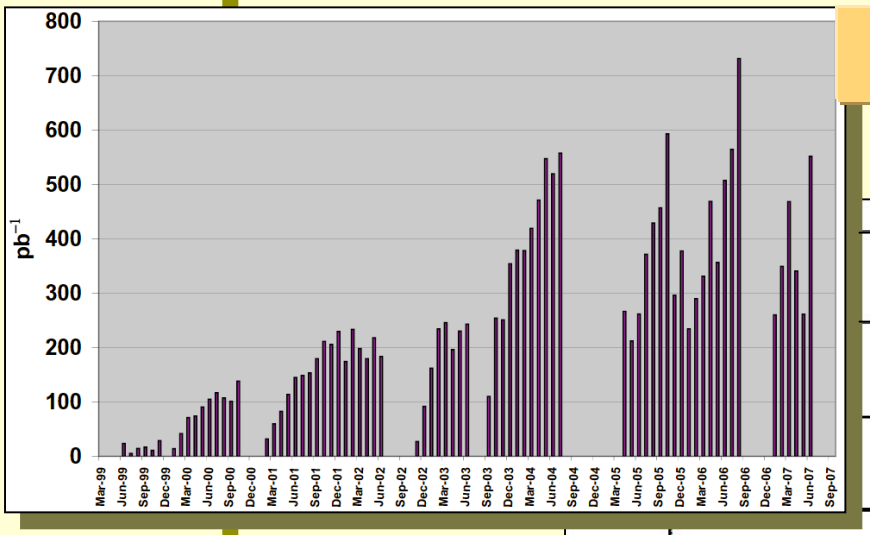
Machine Parameters

	HER	LER	HER	LER
	Design		**Achieved (delivery)**	
Energies e– / e+ (GeV)	8.973	3.119	8.973	3.119
Currents e– / e+ (A)	0.75	2.14	**1.875**	**2.99**
Single beam currents (A)			1.9	2.99
Number of bunches	1658		**1722**	
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
Bunch length (0 current) (mm)	10		11.0	11.5
Rf Voltage (MV)	18	3	**16.5**	**4.5(5.4)**
Rf Stations * # cavities	5*4	2*2	3*4+8*2	**4*2**
Luminosity ($\times 10^{33}$/cm^2/sec)	3.0		**12.0**	
Tune shift horiz. e– / e+	0.03	0.03	0.059	0.09
Tune shift vert. e– / e+	0.03	0.03	0.074	0.055
Beam crossing angle	0 (head-on)		0 (head-on)	

HER RF SECTION

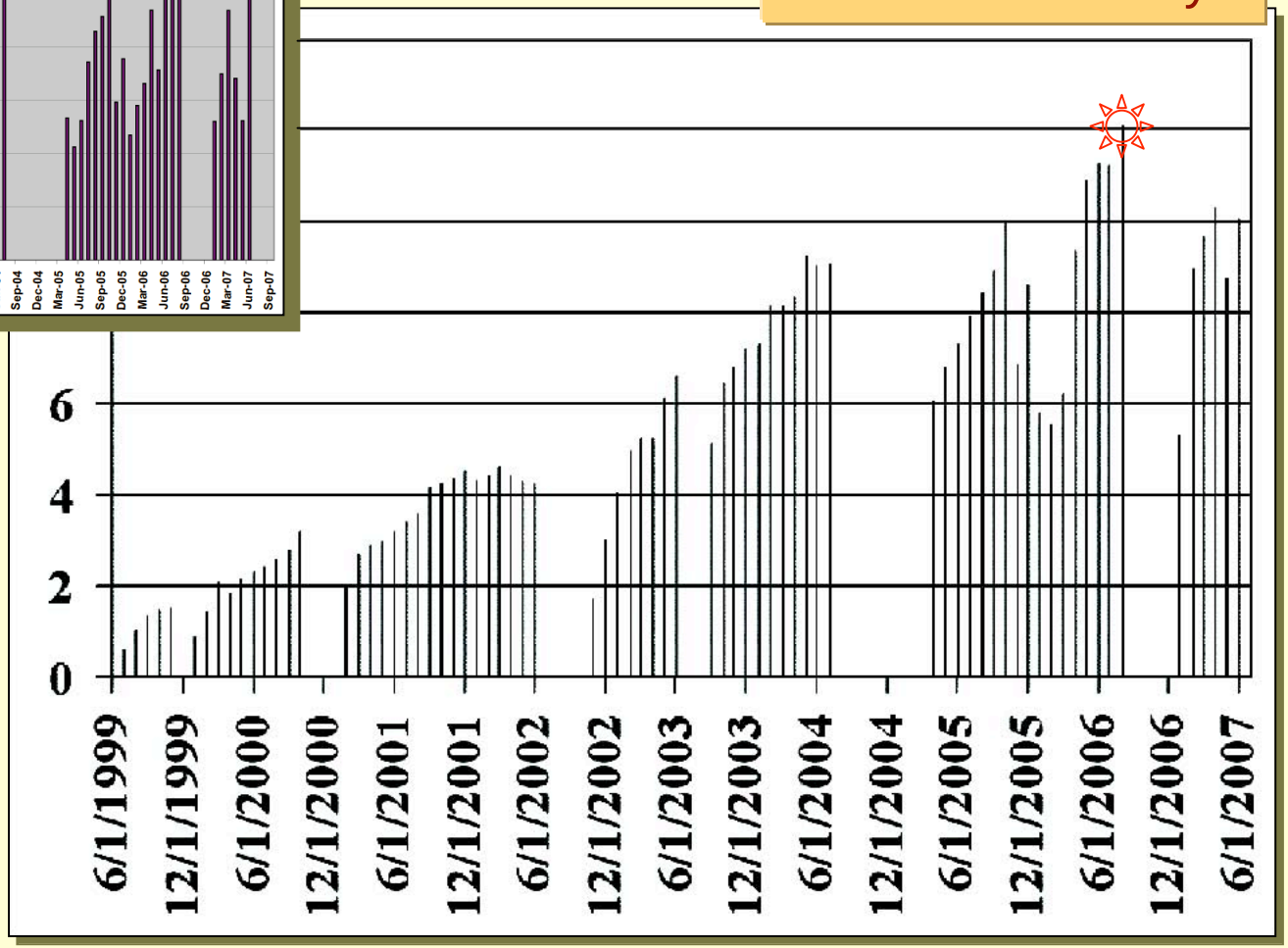


Luminosity, by Month



∫Ldt/day

Peak Luminosity



Grand Total delivered: 460/fb

PEP-II Records

Peak Luminosity

June 22, 2007

12.069×10^{33} $cm^{-2}sec^{-1}$ — August 16, 2006

1722 bunches 2900 mA LER 1875 mA HER

Integration records of delivered luminosity

Best shift (8 hrs, 0:00, 08:00, 16:00)	339.0 pb^{-1}
Best 3 shifts in a row	910.7 pb^{-1}
Best day	849.6 pb^{-1}
Best 7 days (0:00 to 24:00)	5.385 fb^{-1}
Best week (Sun 0:00 to Sat 24:00)	5.111 fb^{-1}
Peak HER current	1900 mA
Peak LER current	2995 mA
Best 30 days	19.315 fb^{-1}
Best month	17.036 fb^{-1}
Total delivered	460 fb^{-1}

Issues for 10^{34} & above

- Relatively high beam current (>3 on 1.9 A)
  - rf, vacuum system reliability
- Relatively high sp. luminosity(>4/μb/s/mA^2)
  - lattice functions, β^*
  - emittance: coupling, (vertical) dispersion.
- Exp. backgrounds need to be tolerable
  - machine tuning
  - vacuum pressure

High Current Issues

- In the absence of resonances, power loss scales like $\hat{I} * I/R$ or $I^2/n_{\text{bunches}} * \sqrt{V_{rf}}$
  - skin effect or selective higher frequency loss make dependence on bunch length steeper.
  - Bellows change dimension with temperature
  - > their resonances get scanned, “bad” currents
- Some IR chambers could not take full heat load
- Some NEG pump screens transmit rf power
  - > the pump heats up, outgasses.
- Sparse bunch patterns potentially dangerous!
  - richer spectrum i.e. more likely to hit a resonance

Vacuum Components

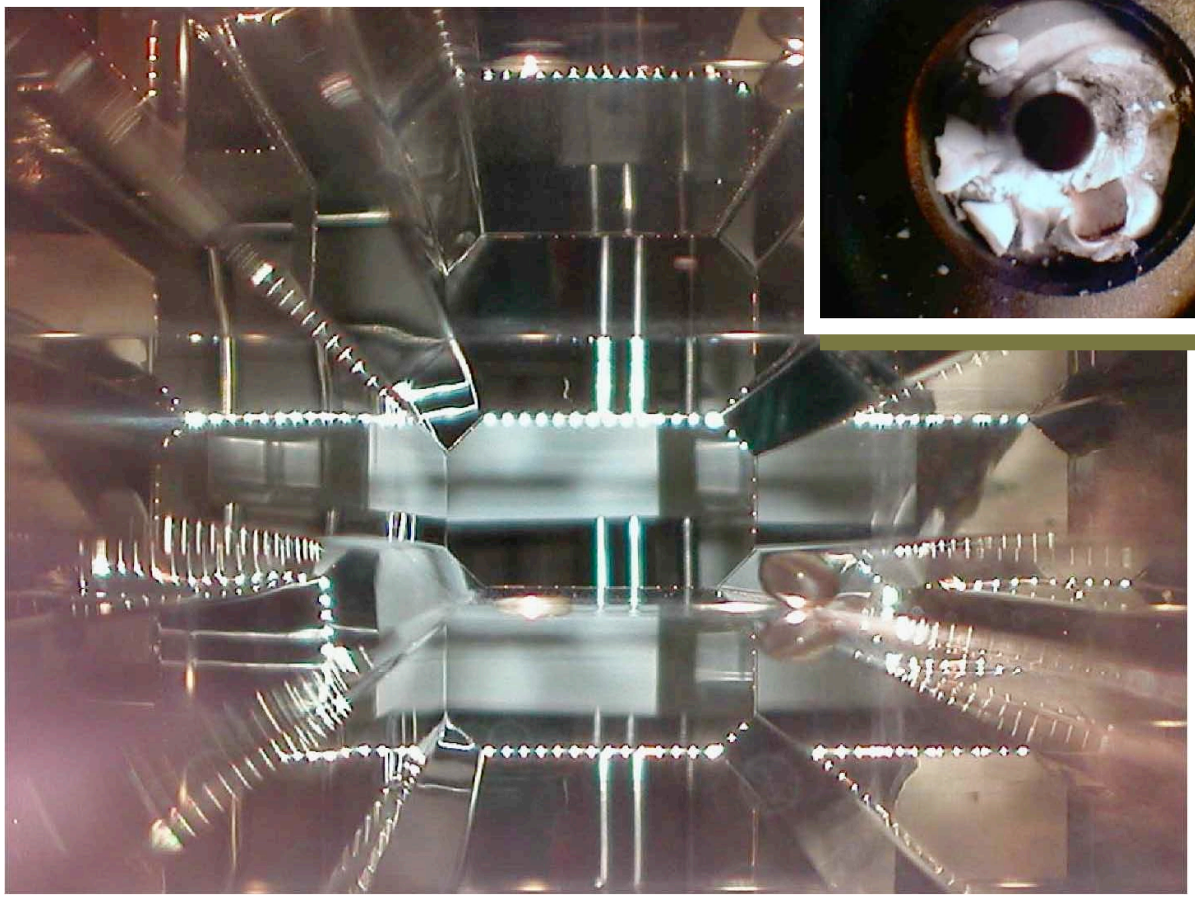
TUPAS068

Bellows r f shield

r f seal at Flex Flange

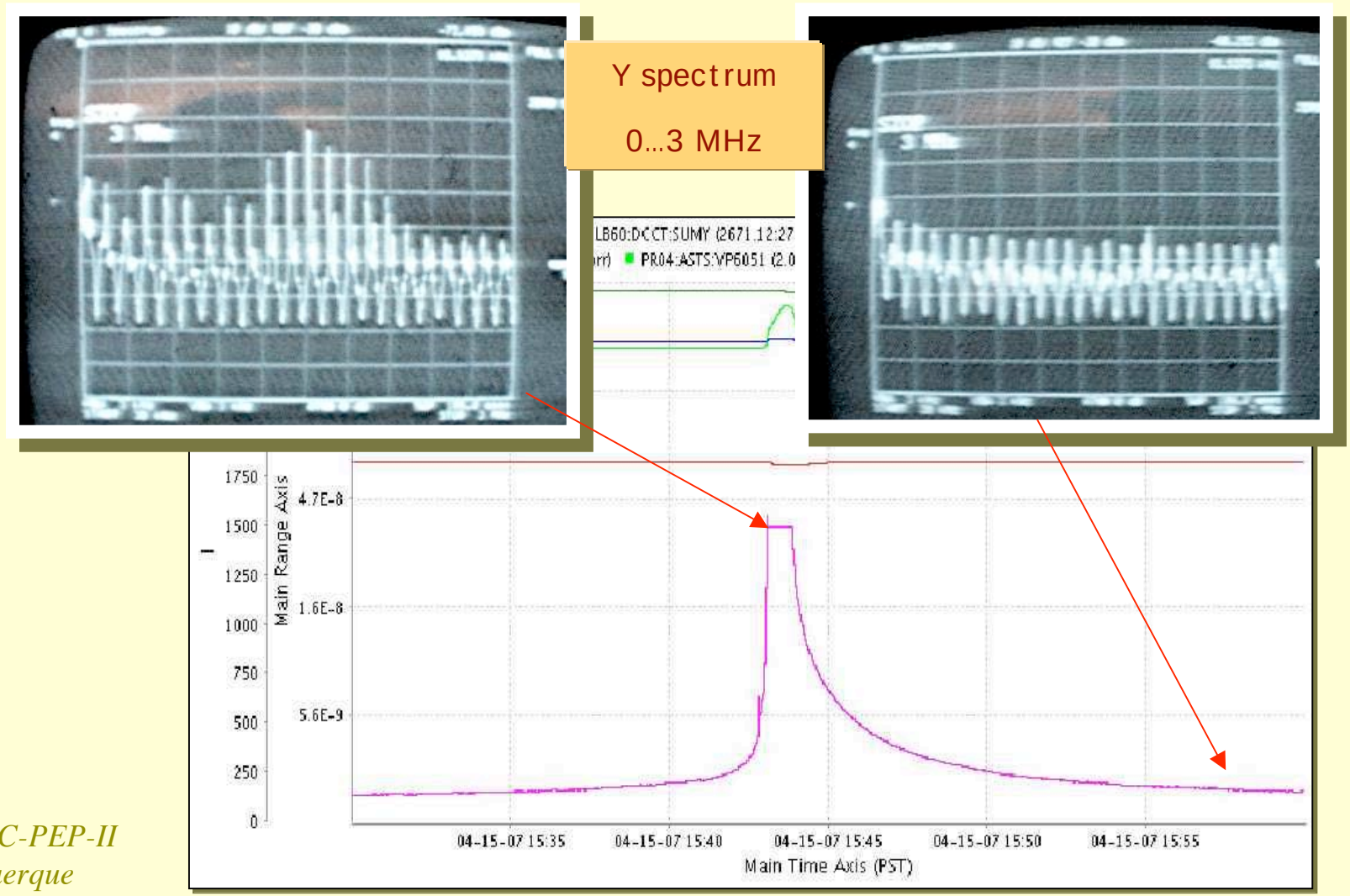
Effect of High Current

BPMs extract power at a 7 GHz resonance
Damage occurred at 5.4 MV rf



DIP Storms

PR04 VDIP 6082 (a number of other DIPS do this as well)



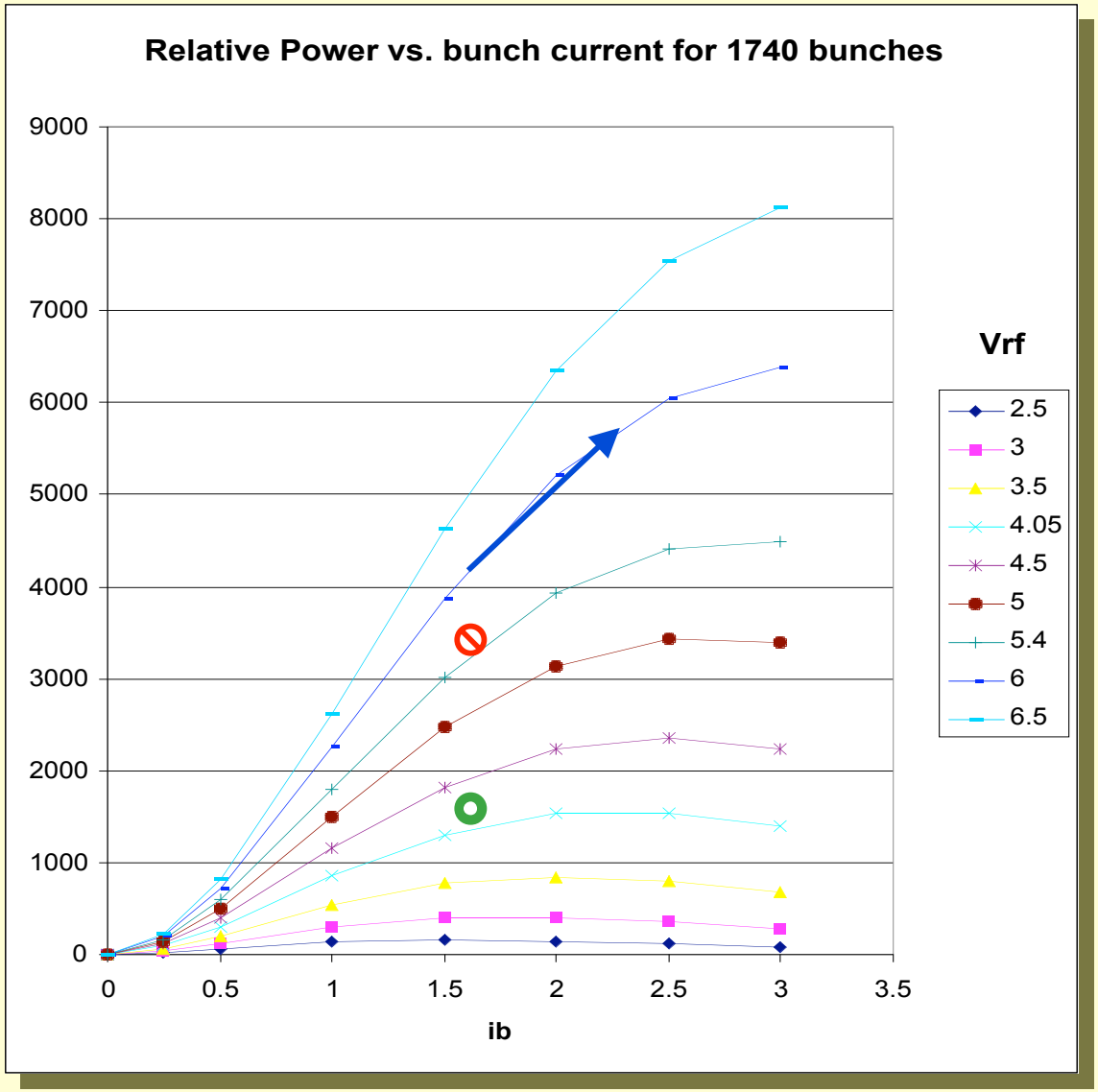
Addressing the Issues

- The likely root cause for bellows damage is too large expansion.
  - building extra-long bellows for large gaps
- The rf seals at the flex flange are being replaced by Inconel seals.
- LER Arc BPMs have been replaced with smaller ones, IR 2 BPMs had their buttons pulled
- "Storming" DIPs are being disconnected
  - could replace a limited number of chambers

LER BPM Fix

S. Ecklund

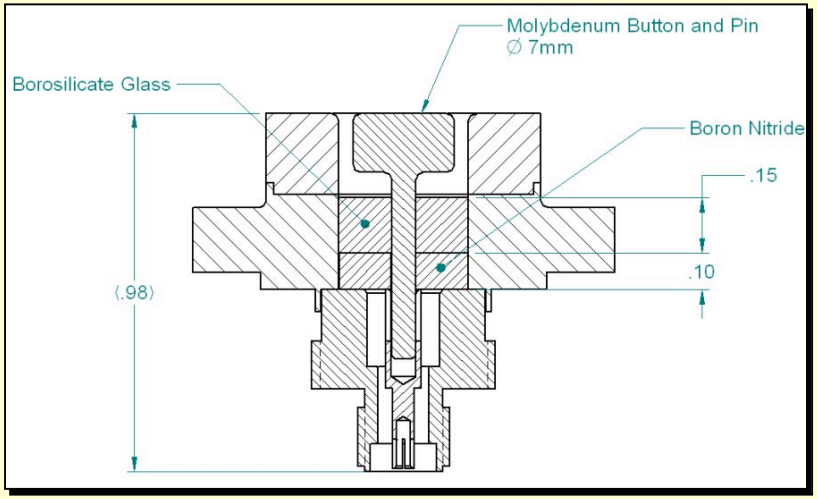
- Reduce BPM size by 1/2,
- pull buttons from IR 2 BPMs



LER BPM Upgrade

M. Kosovsky,
N. Reek,
N. Kurita

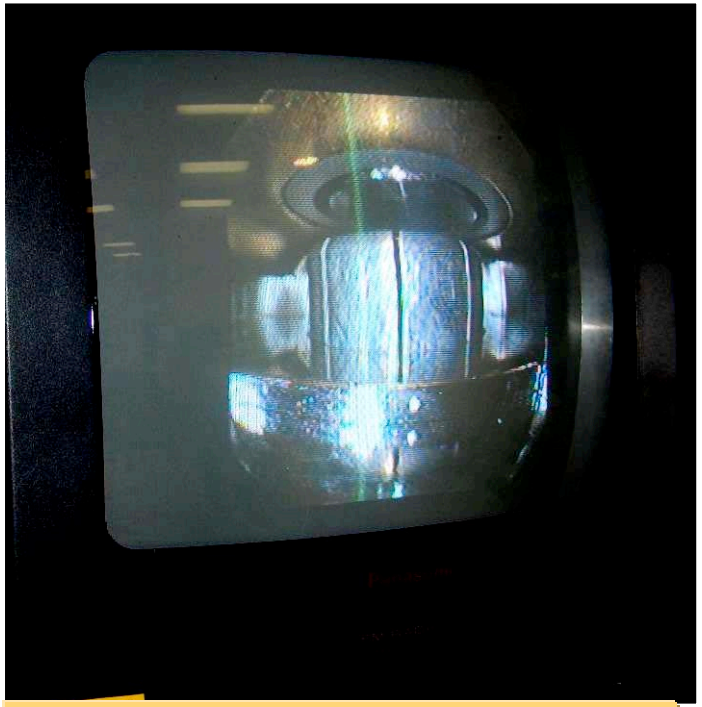
- Arc BPM feedthroughs/ buttons will be replaced with smaller buttons integral to the f/t



- IR-2 buttons have been pulled off the feed-through leaving pin

LER IR Botton Removal

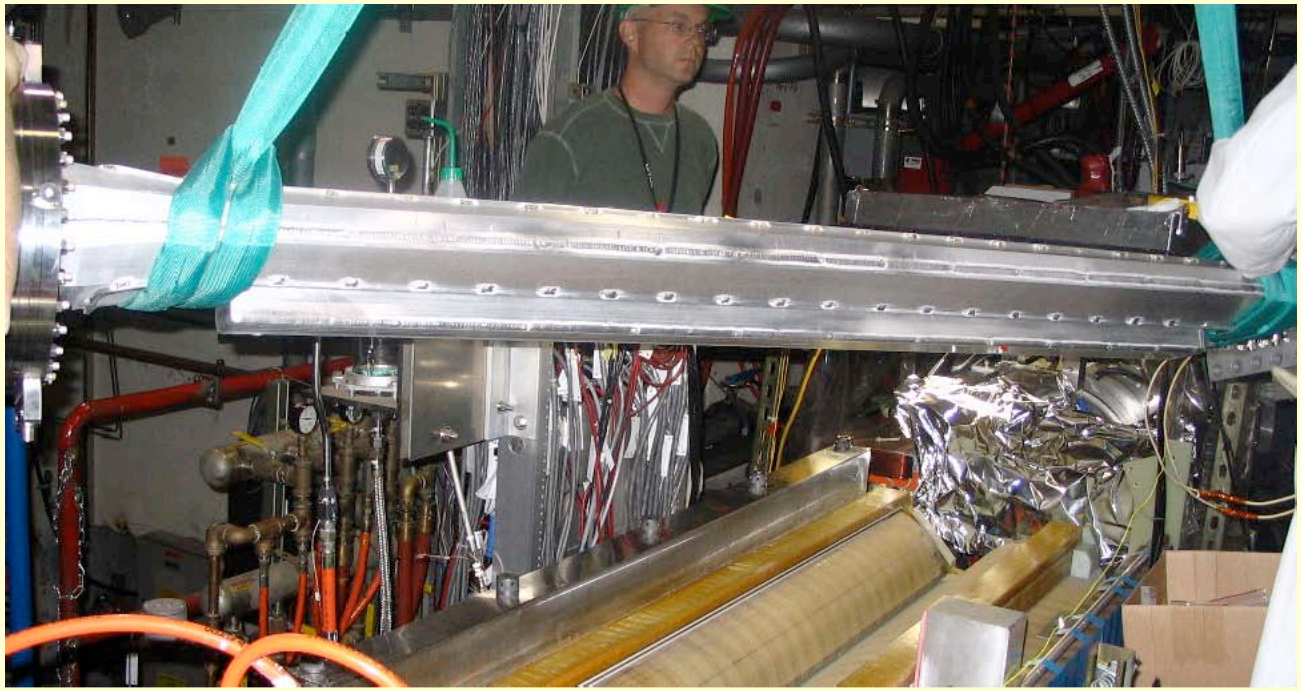
- Button removal tool (lab test) (N. Reek, M. Kosovsky)



Borescope view of tool in action

IR Chamber Upgrades

- Most of the IR chambers have been replaced
  - S.r. power rating, NEG screen improvements



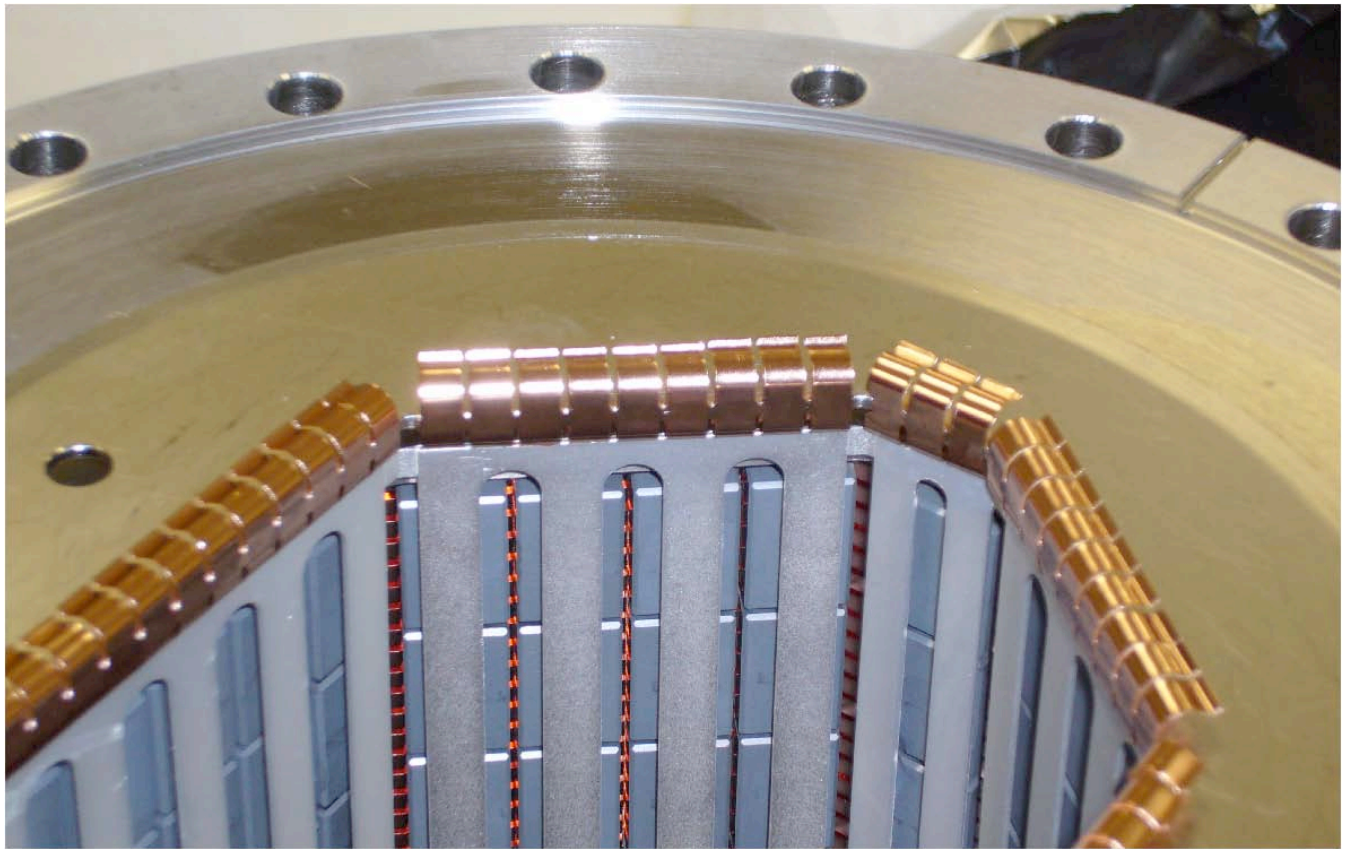
HOM Absorbers

FRPMS076

MOOAKI02

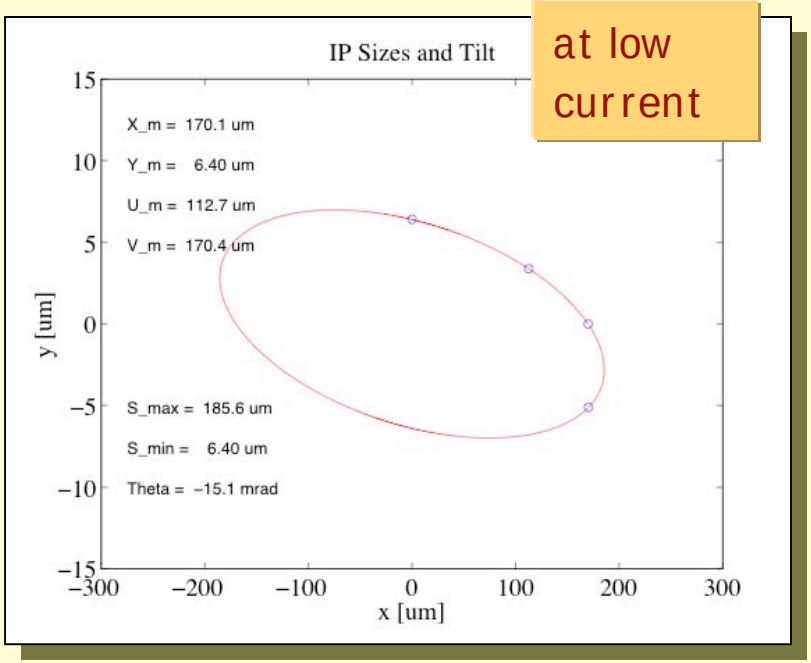
Novokhatski

- Absorb rf energy at special absorbers
  - SiC tiles behind a screen against direct absorption from beam



Parameters for 1.2E34

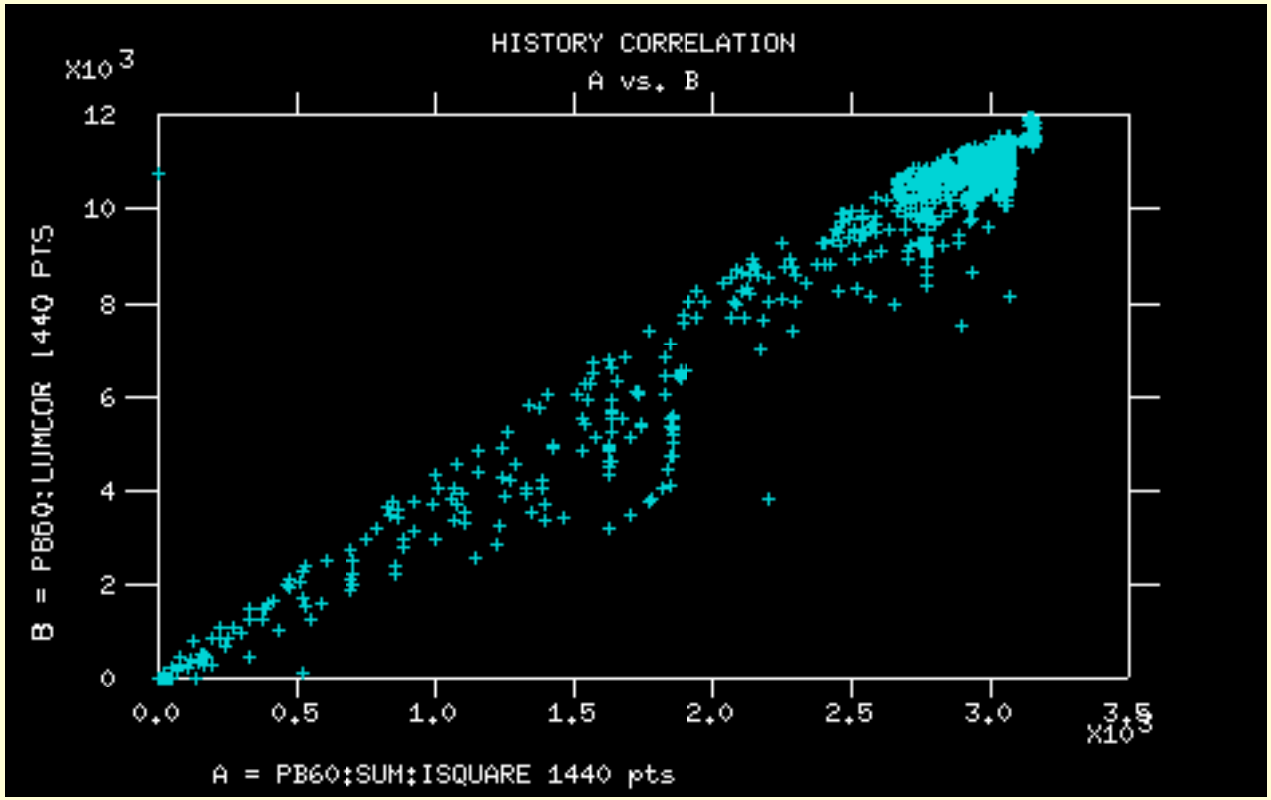
- HER: $\beta^*_x \approx 74$ cm, $\beta^*_y \approx 11$ mm, $\sigma_l \approx 12.5$ mm
- LER: $\beta^*_x \approx 21$ cm, $\beta^*_y \approx 10$ mm, $\sigma_l \approx 13.5$ mm
- HER: $\varepsilon_x \approx 73$ nmr, LER: $\varepsilon_x \approx 36$ nmr (model)
- IP Beam sizes: (estimate $\varepsilon_y \approx 1$ nmr)
  - measured $\Sigma_{x,y}$: 185, 6.4 μm (beam-beam scan).
  - est'd @ 220 on 160 mA (with dyn. β):
    $\Sigma_{x,y}$: 175, 6 μm
- $\xi_{y,H}$: 0.074, $\xi_{y,L}$: 0.058



at low current

Luminosity vs Current

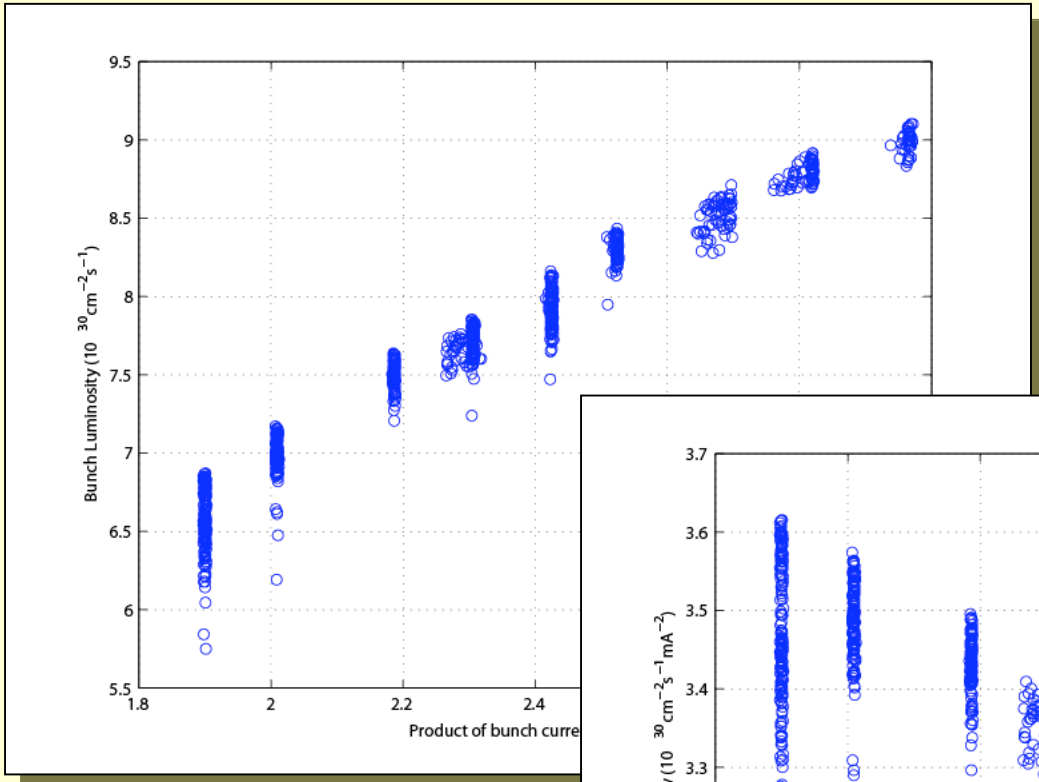
- $L_{sp} \approx 3.9/\mu b/s/mA^2$ at high luminosity
- ≈4.5 at optimum low beam current.



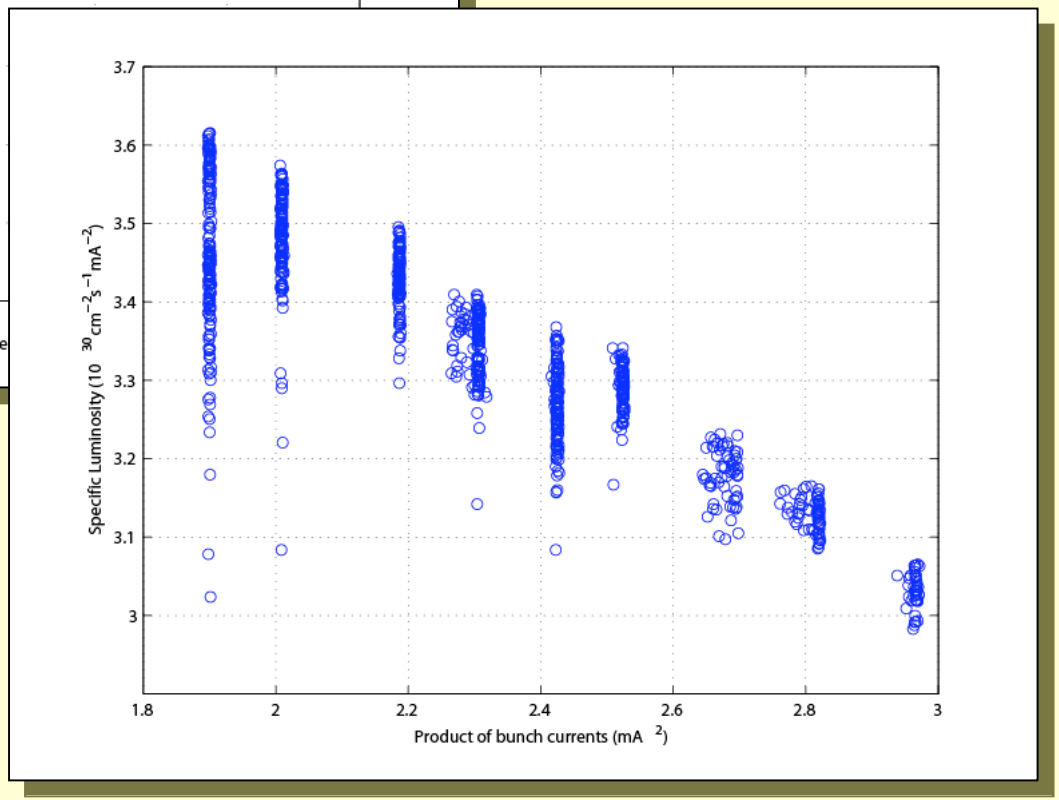
Can PEP run high I_B?

- Goal for Run 7: 4 A on 2.2 A
  - vacuum (LER) and rf (HER) limits
  - > bunch currents 2.3 mA on 1.3 mA
- To test possibility of running these bunch currents, we did an experiment
  - high bunch current
  - less bunches to stay within total current limit
  - Since HER rf did not like the short trains, we used a by-4 pattern (no parasitics)…

Lum vs $I_{HER} \cdot I_{LER}$

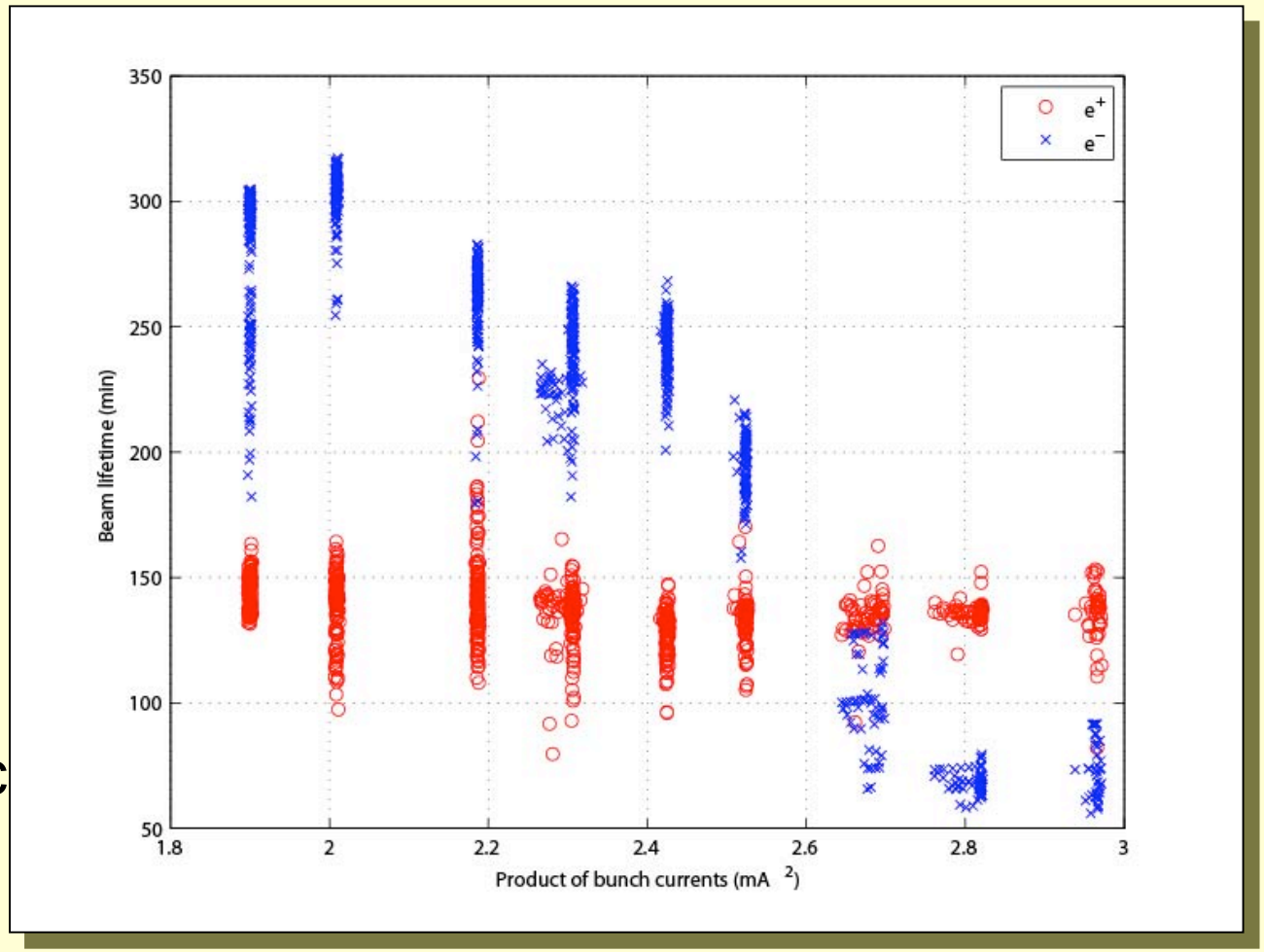


$\xi_{y,HER}$: 0.097
$\xi_{y,LER}$: 0.055



caveat:
no parasitic crossings

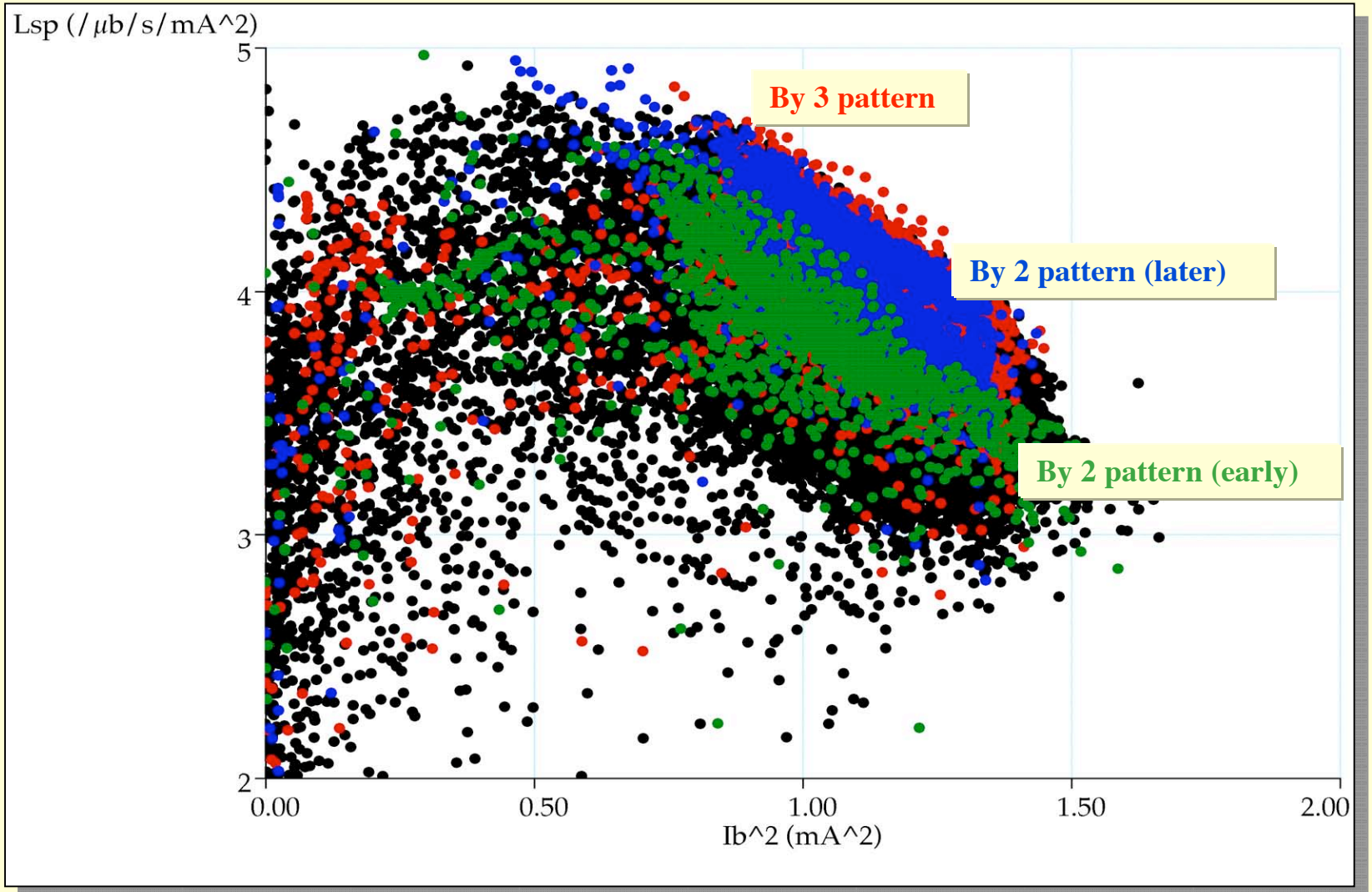
Beam Lifetimes



caveat:

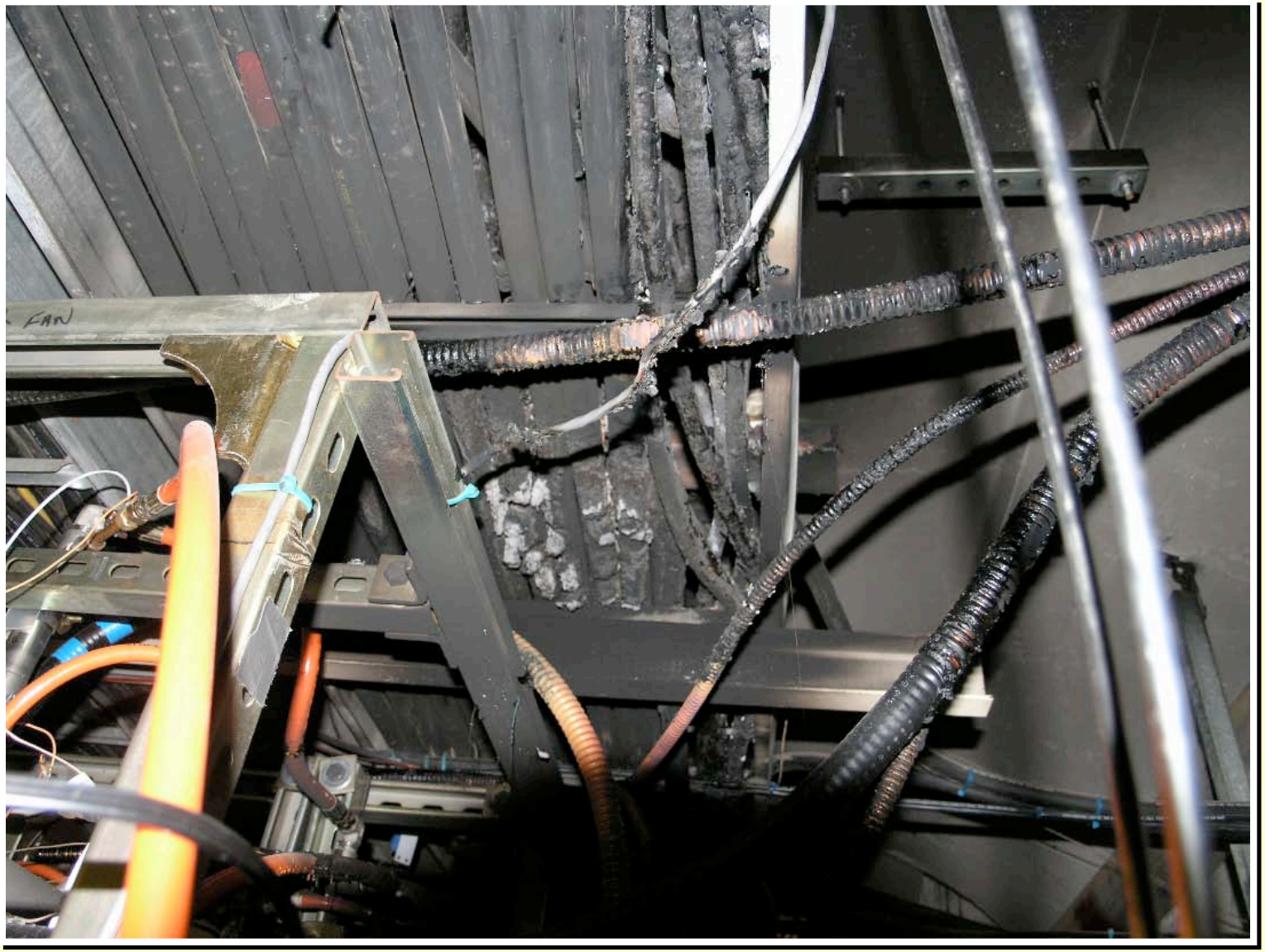
no parasitic crossings

PC EFFECT ON SP. LUM



- The experiment reached $1.6\times10^{34}/2$, clearly showing where the machine can go
- Combine with 20% reduction in β_y^* and σ_l
  - $\beta_y^* \approx 8$ mm, $\sigma_l \approx 10$ mm (at operating current)
  - $> 2\times10^{34}/cm^2/s$ appears realistic goal
- Bunch length reduction to be achieved with
  - 6 MV rf (LER, installed)
  - 18 MV rf + 90° lattice (HER, lattice to be commissioned)
    - reduce mom. compaction 0.00241–>0.00169
- But wait, there is more...

"Fiery End" of BY-4 Exp.

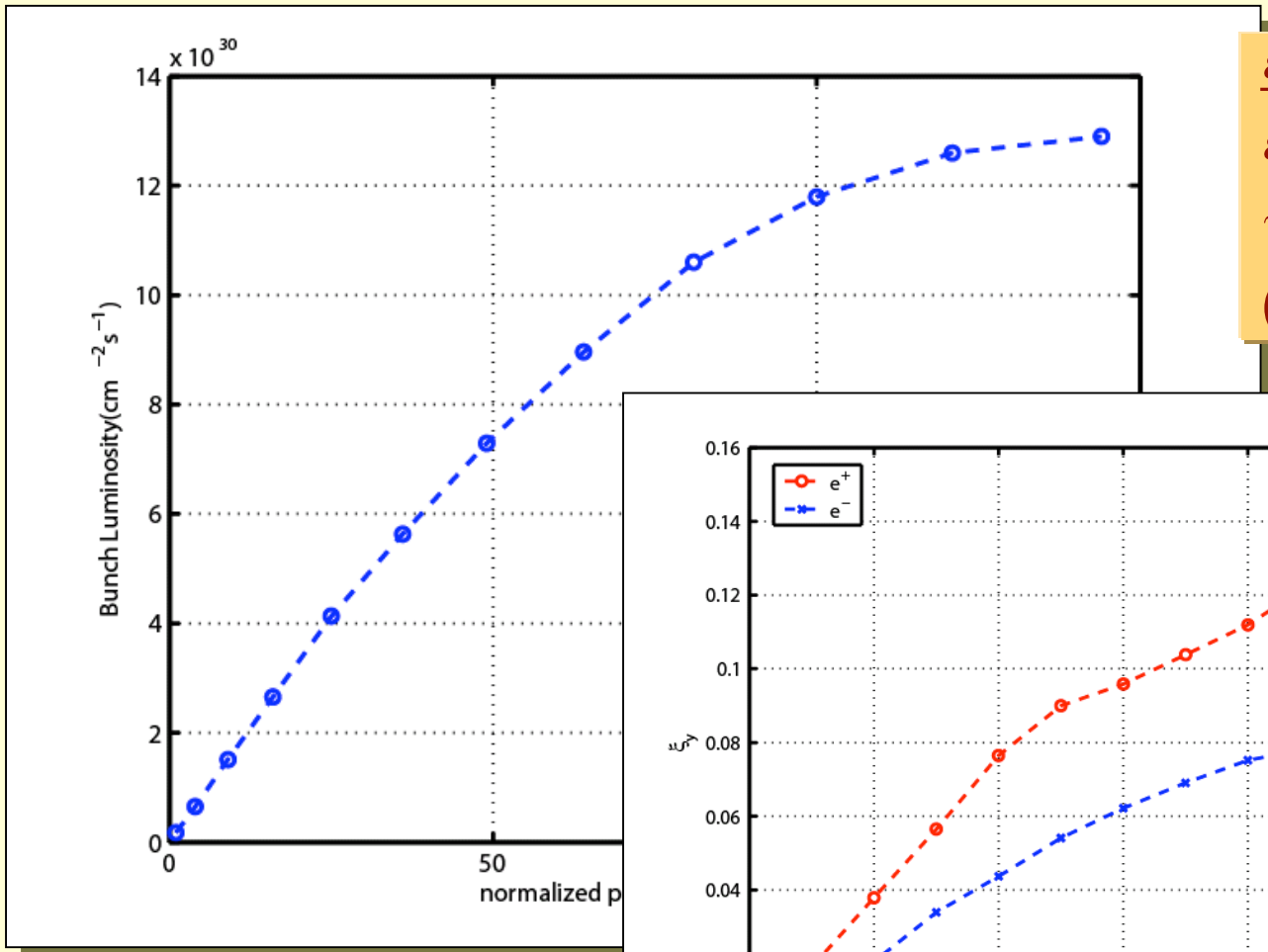


Low ε Option

TUPAS065
Cai et al.

- Simulation by Y. Cai indicates significantly higher beam-beam parameter may be achievable
  - > significantly reduce vertical beam sizes
  - still of advantage to reduce $ß_y$* & bunch length
  - would not need much more beam current than now to reach 2E34.

Luminosity



$\varepsilon_y \approx 0.3$ nmr

$\varepsilon_x \approx 30$ nmr

$\nu_y \approx 0.54$

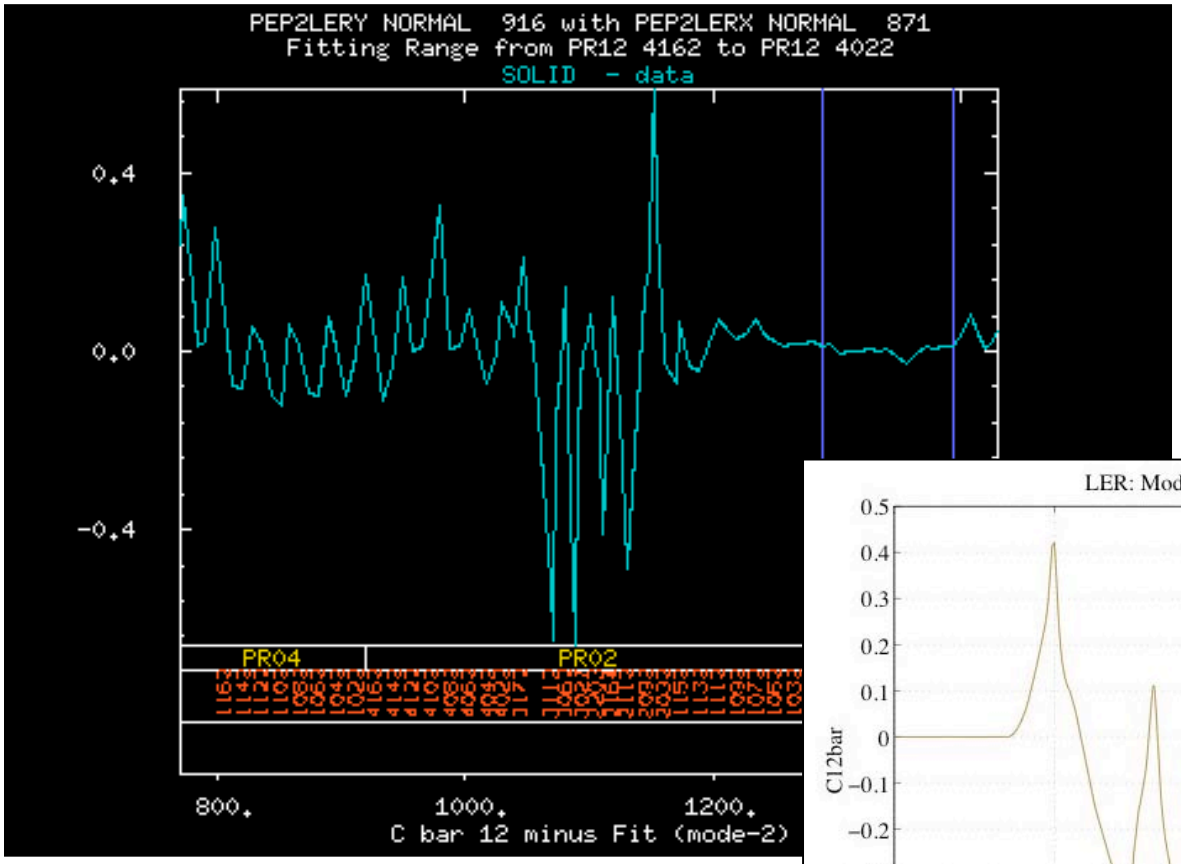
(Y. Cai)

LER Low ε Lattice

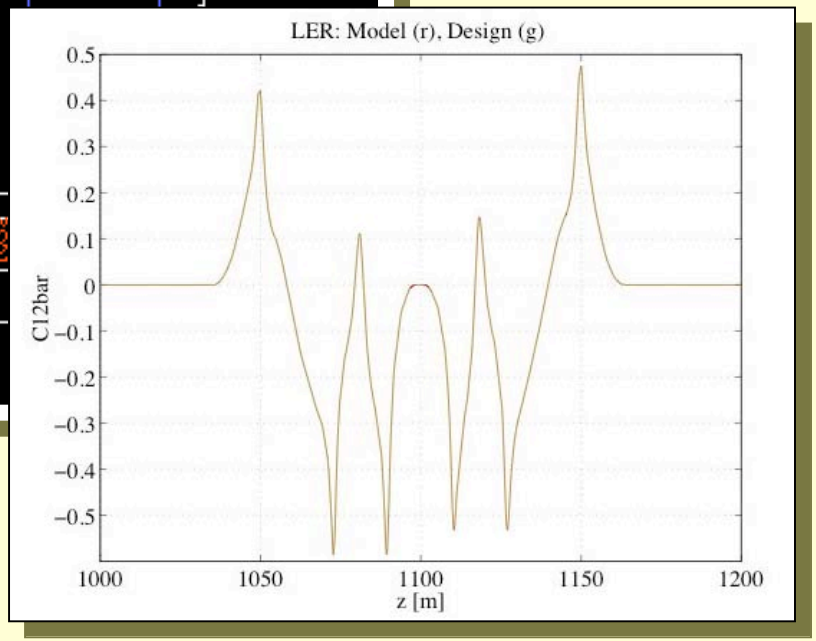
THPAS058
Decker et al.

- Low emittance LER lattice designed by Nosochkov, implemented by Decker using permanent skew quads
  - installed & operating
- Optics appears to work
  - more tuning needed to achieve low ε
- Can we reach a beam-beam parameter >0.1?

LER $\bar{C}_{12}$ MEAS. & DESIGN

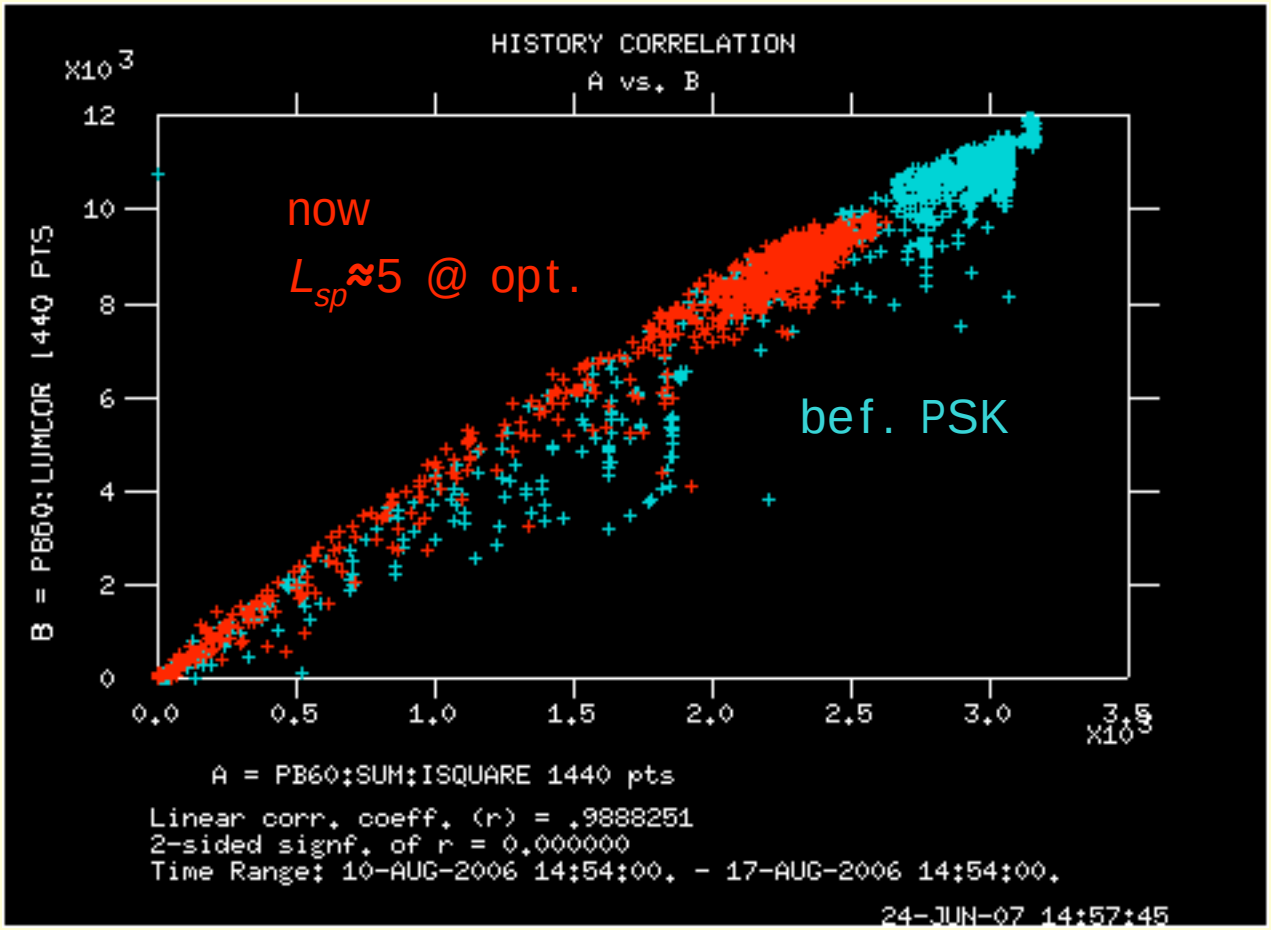


Fitting free oscillation removes global coupling & reveals solenoid compensation



Lum vs $\sum I_B^2$

- Promising, more work to do
  - coupling, dispersion, IP coupling…



Summary

- PEP-II has exceeded its design luminosity by a factor of 4
- Best delivery has been 7 × CDR estimate.
- Each run has has its unique challenge
  - Presently, it is stress on vacuum components due to high beam current
  - *Amperes of beam current at 1 cm bunch length is hard!*
- 2-pronged approach to increasing luminosity further
  - lower emittance, higher beam current
  - lower *ß**, shorter bunches
- We plan to maximize the delivered luminosity until end of operations at the end of Sept. 2008