Super-B-Factory Collider Work at SLAC

U. Wienands, for John T. Seeman
SLAC

Hawaii Super-B-Factory Meeting
April 20, 2005

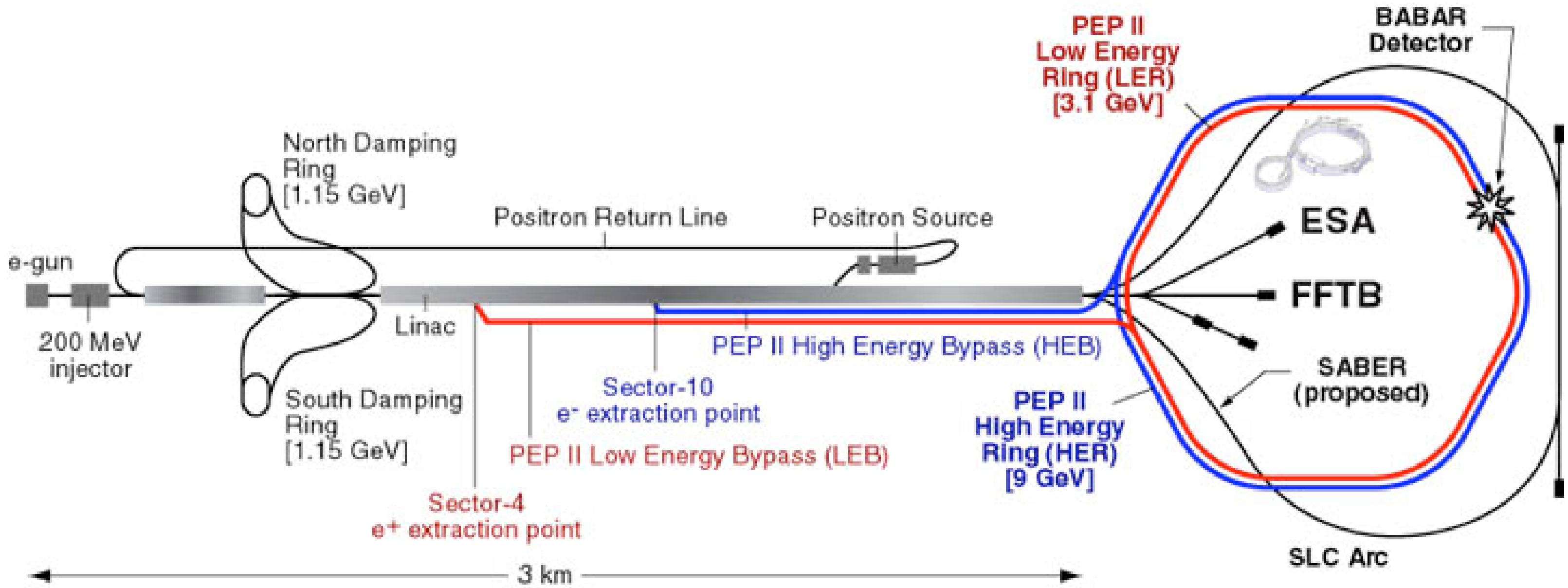
The PEP-II Team

August 2004

Topics

- Brief PEP-II status and plans
- Super-B-Factory Collider parameter studies
- Conclusions

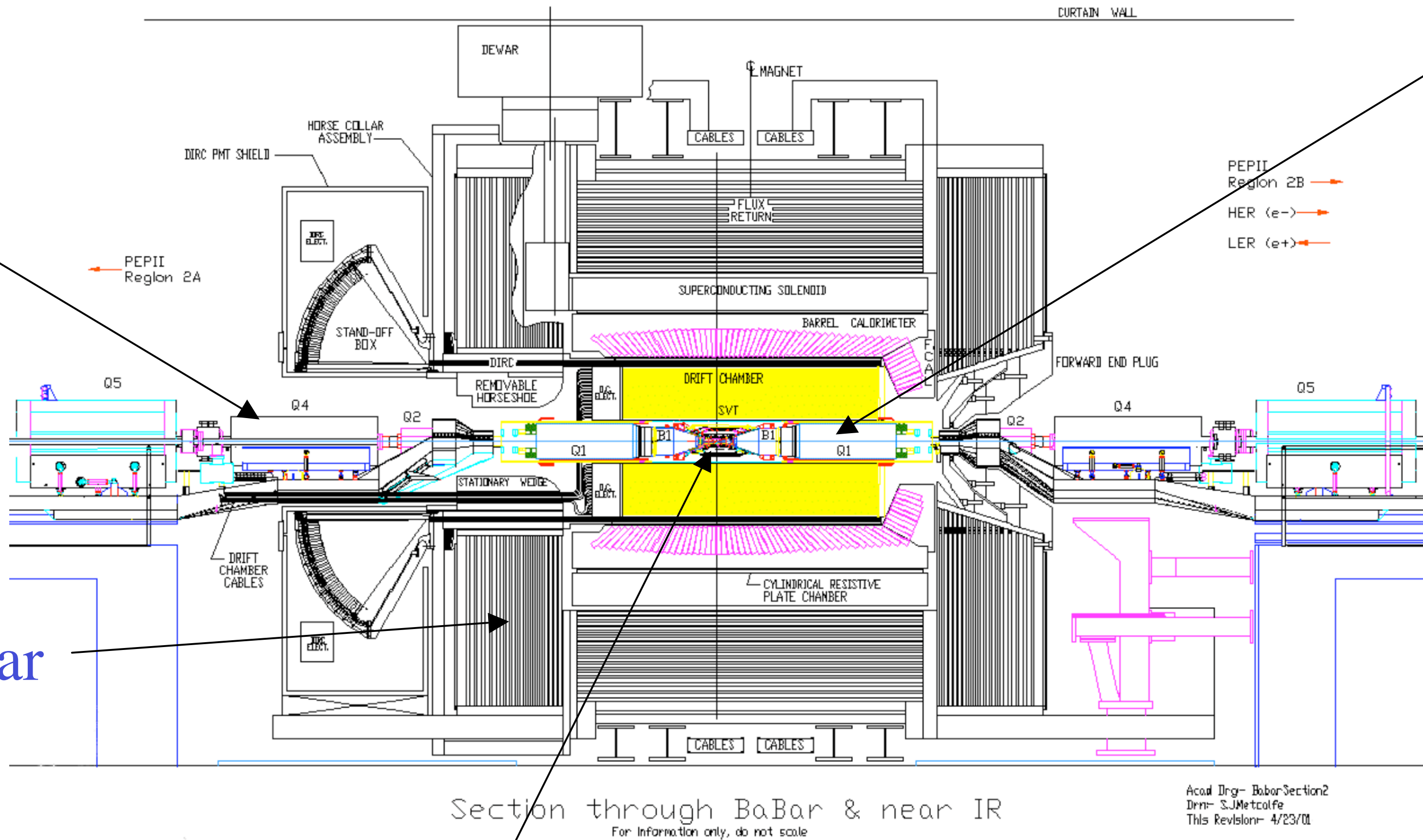
SLAC Beam Lines



PEP-II Interaction Region Components near BaBar

LER

HER

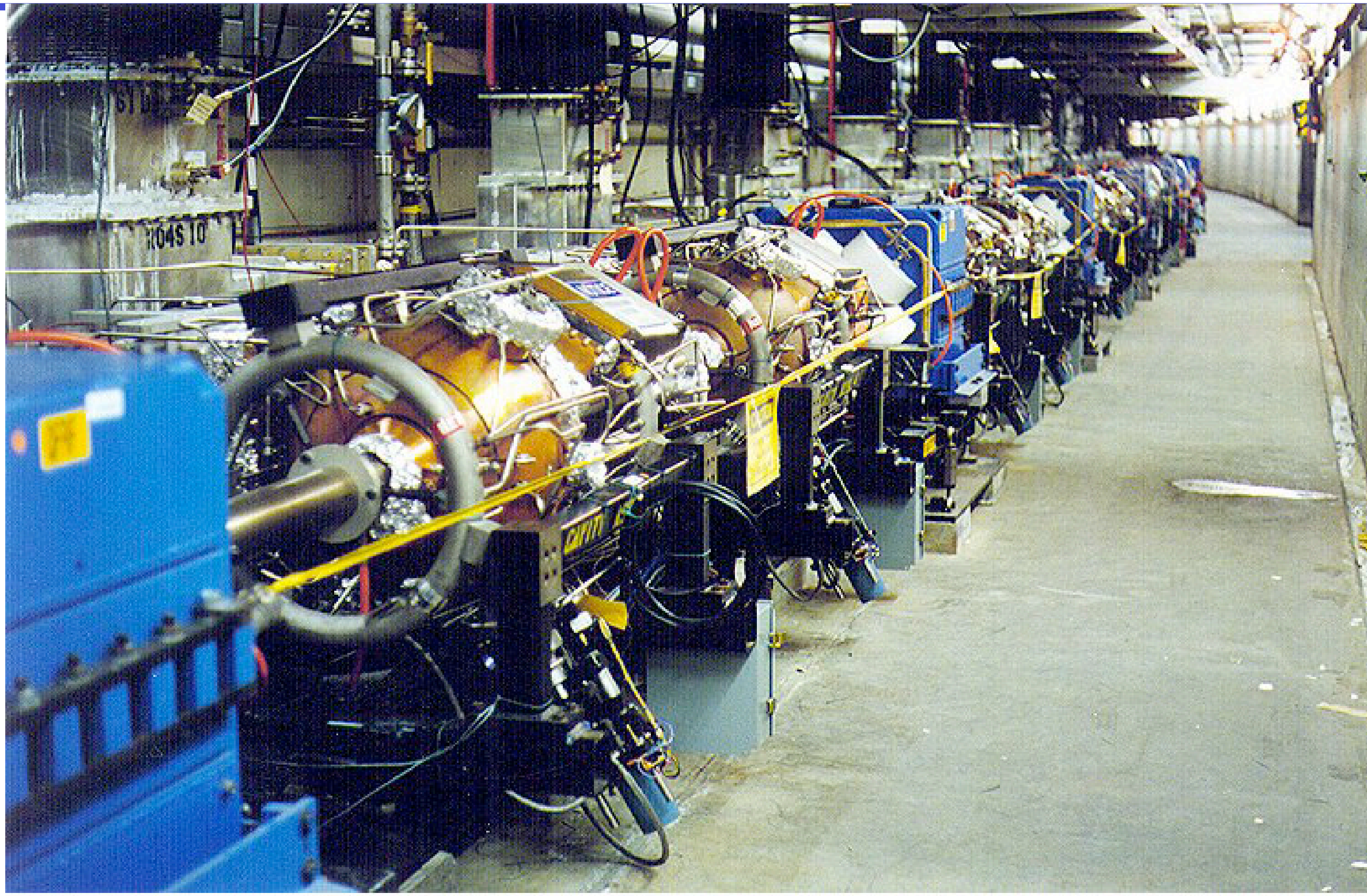


BaBar

Collision point

PEP-II arc section

PEP-II HER RF cavities



BR_049 HER Cavities Region 12 8-19-97

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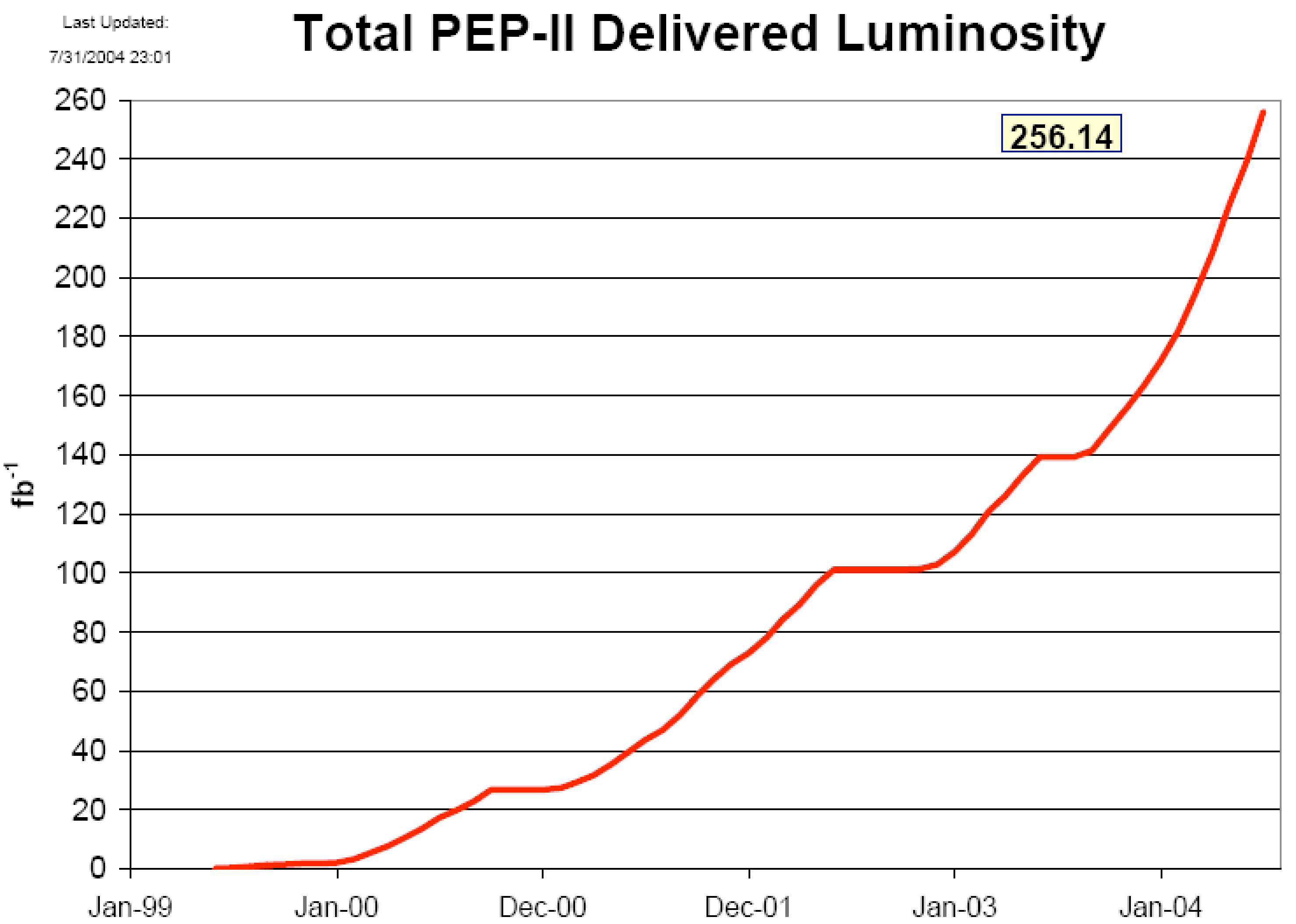
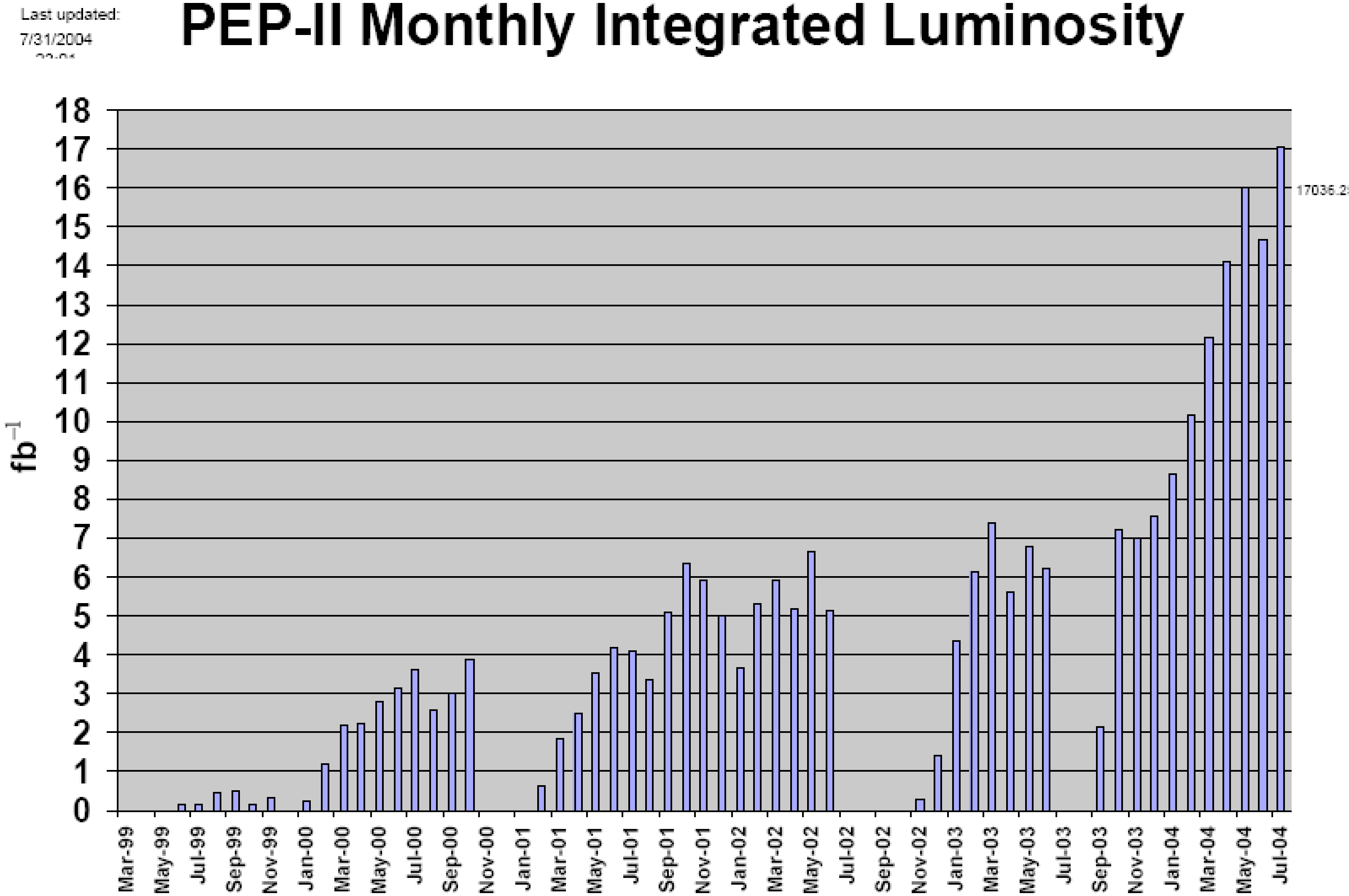
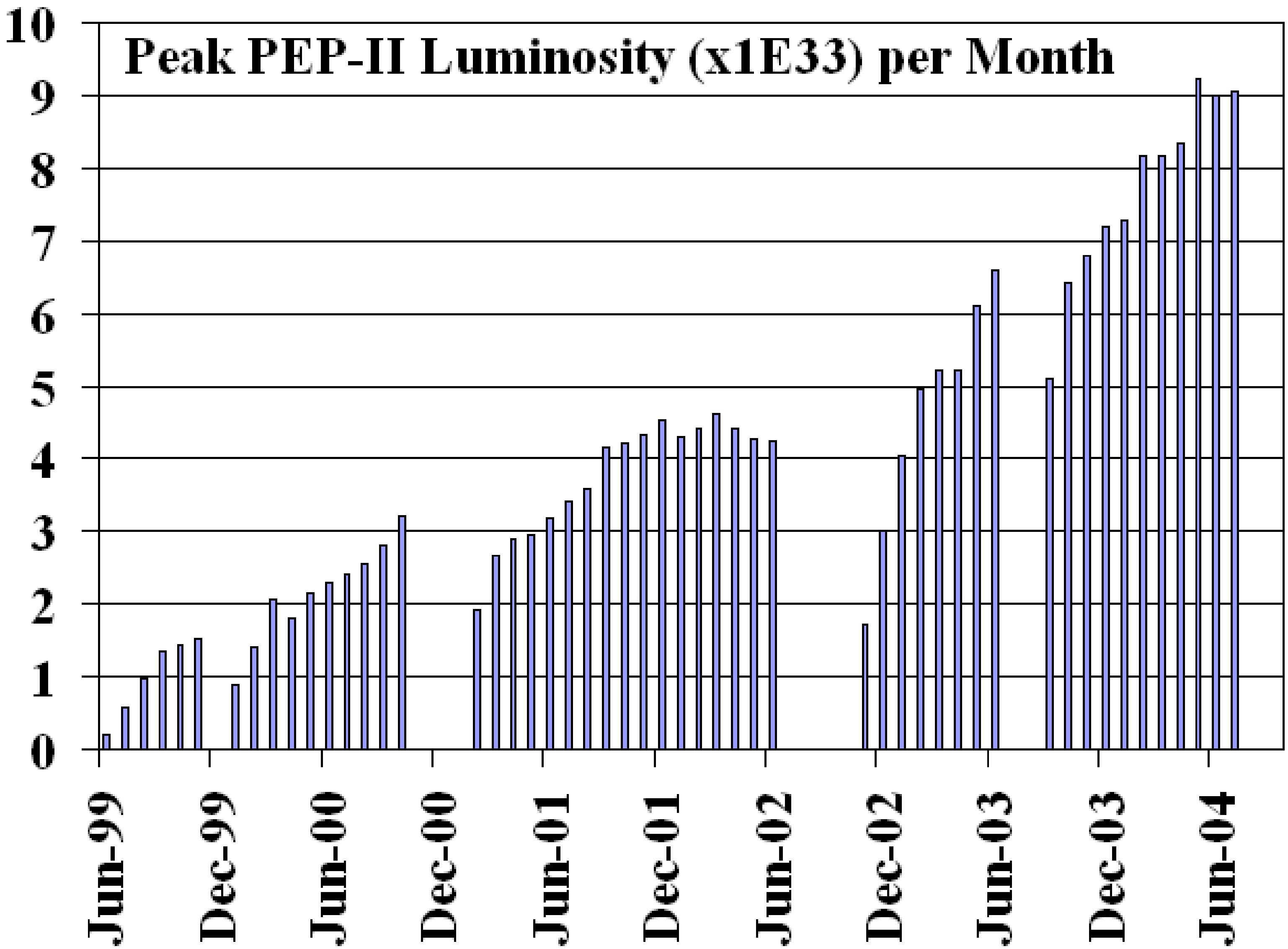

Last Updated:
7/31/2004 23:01
Total PEP-II Delivered Luminosity
256.14
fb-1
0
20
40
60
80
100
120
140
160
180
200
220
240
260
Jan-99
Jan-00
Dec-00
Dec-01
Jan-03
Jan-04

PEP-II Monthly Integrated Luminosity

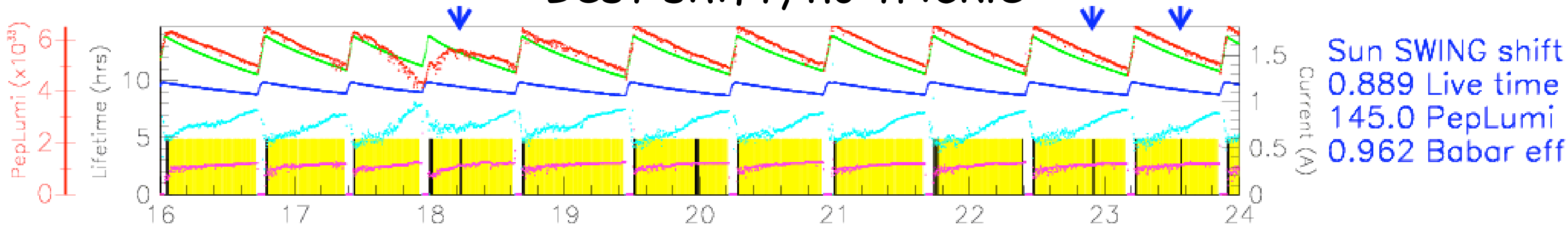


PEP-II Performance Measure: Peak Luminosity



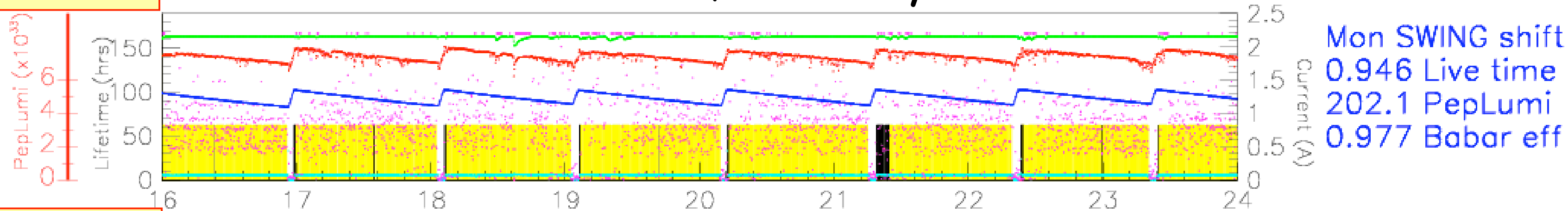
Trickle injection at the B Factories

Best shift, no trickle



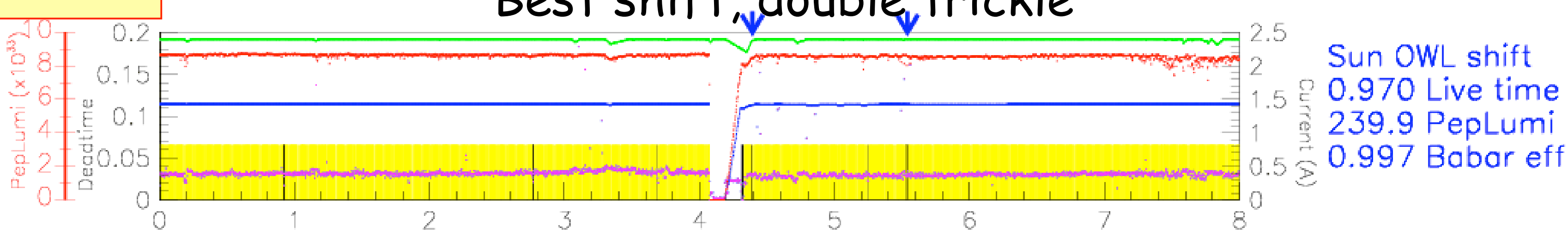
Nov 2003

Best shift, LER only trickle



Mar 2004

Best shift, double trickle



PEP-II: ~5 Hz continuous
KEKB: at ~5-10 min intervals

- PEP-II Lumi (red)
- HER current (blue)
- LER current (green)

Overall Parameters and Goals

Twice design

Parameter	Units	Design	Best in collision	Future 2007 goal
I+	mA	2140	2450	4500
I-	mA	750	1550	2200
Number bunches		1658	1588	1715
β_y*	mm	15-20	11	8.5
ξ_y		0.03	0.045, 0.07	0.055-0.08
Luminosity	$x10^{33}$	3.0	9.2	23
Integrated lumi / day	pb^{-1}	130	710	1800

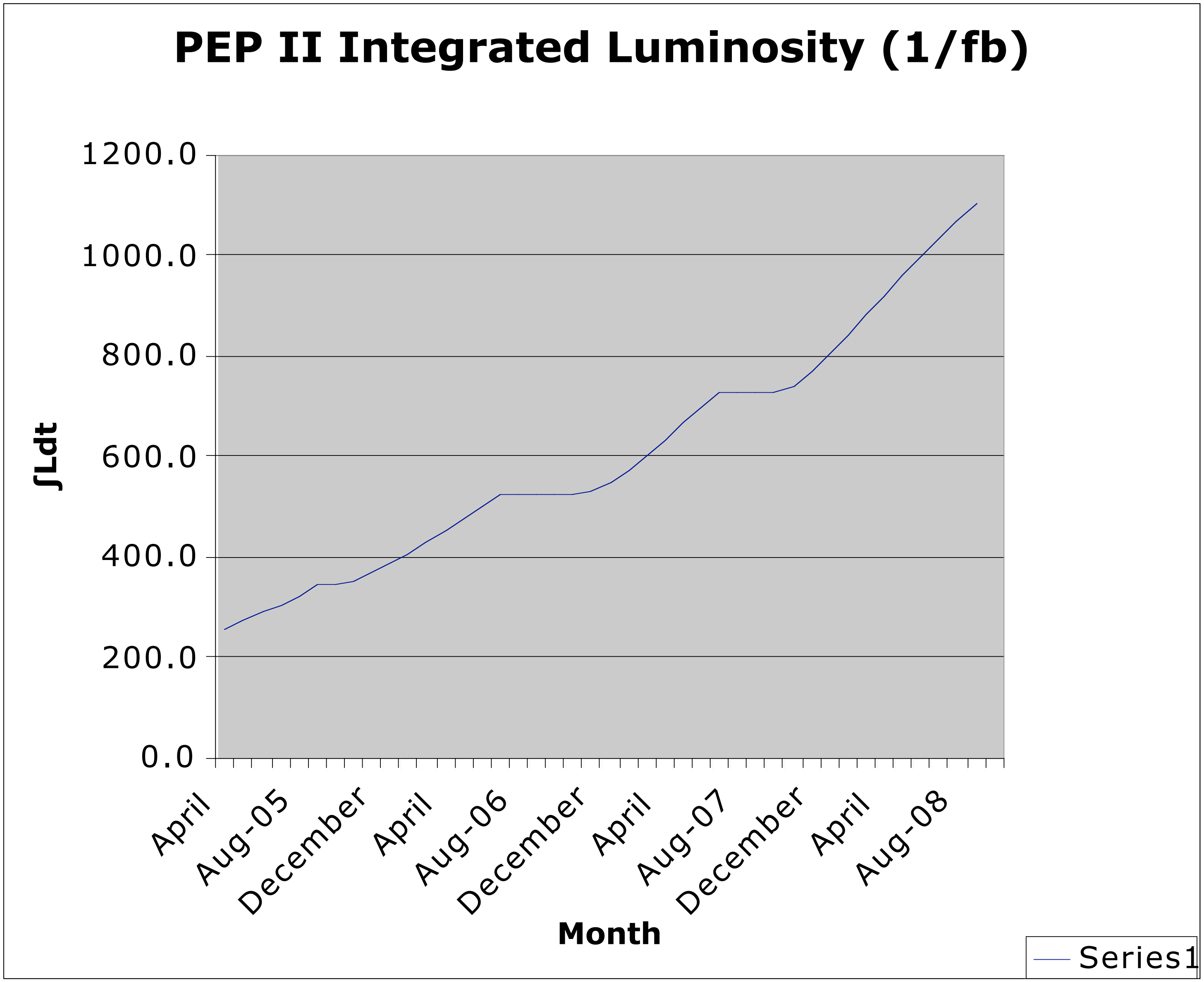
Over three times design

Over five times design!

PEP-II Run Schedule

- SLAC was shut down until early April due to electrical accident & ensuing safety reviews
- PEP-II Run 5 started April 15, 2005.
- Will collide steadily from April 2005 through July 2006 with a one month break in October 2005.
- Down in 2006 August through November for BaBar and PEP-II upgrade work.
- Three month down in Summer-Fall 2007 for LCLS work.
- Collide through September 2008.

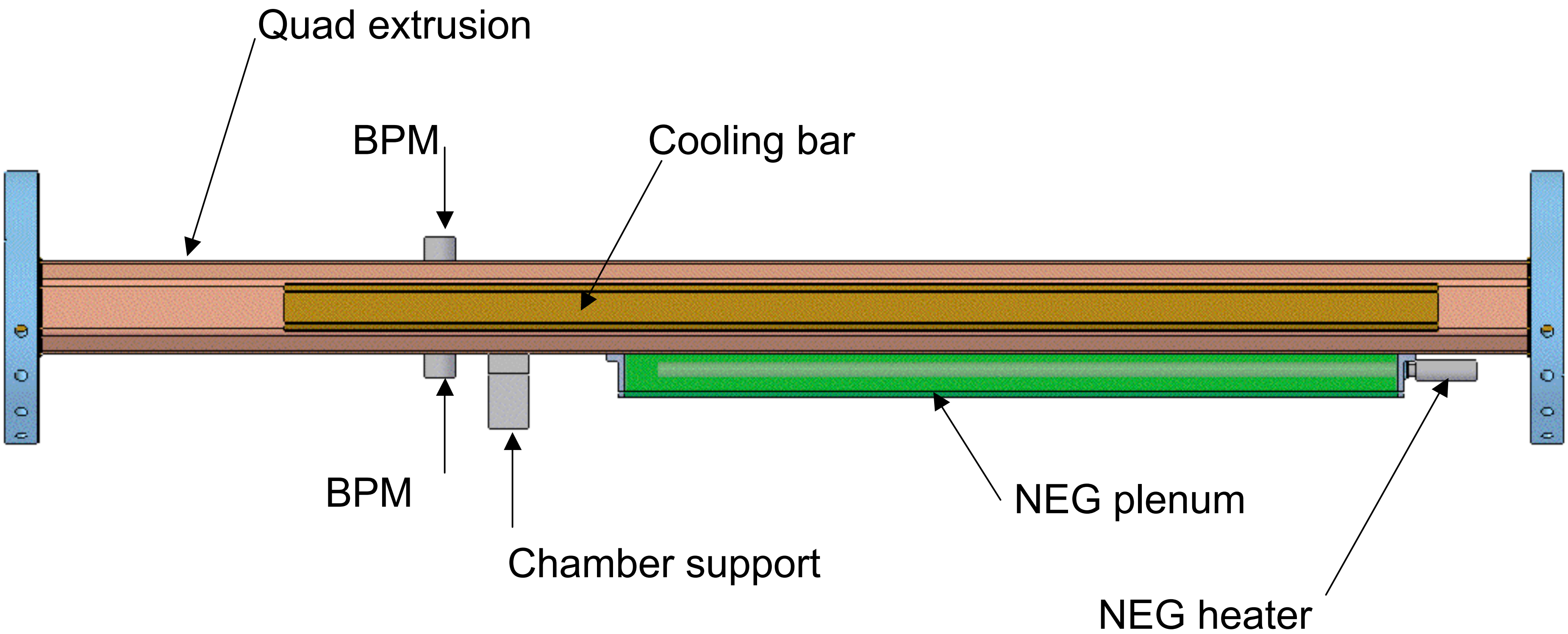
Integrated Luminosity Goal

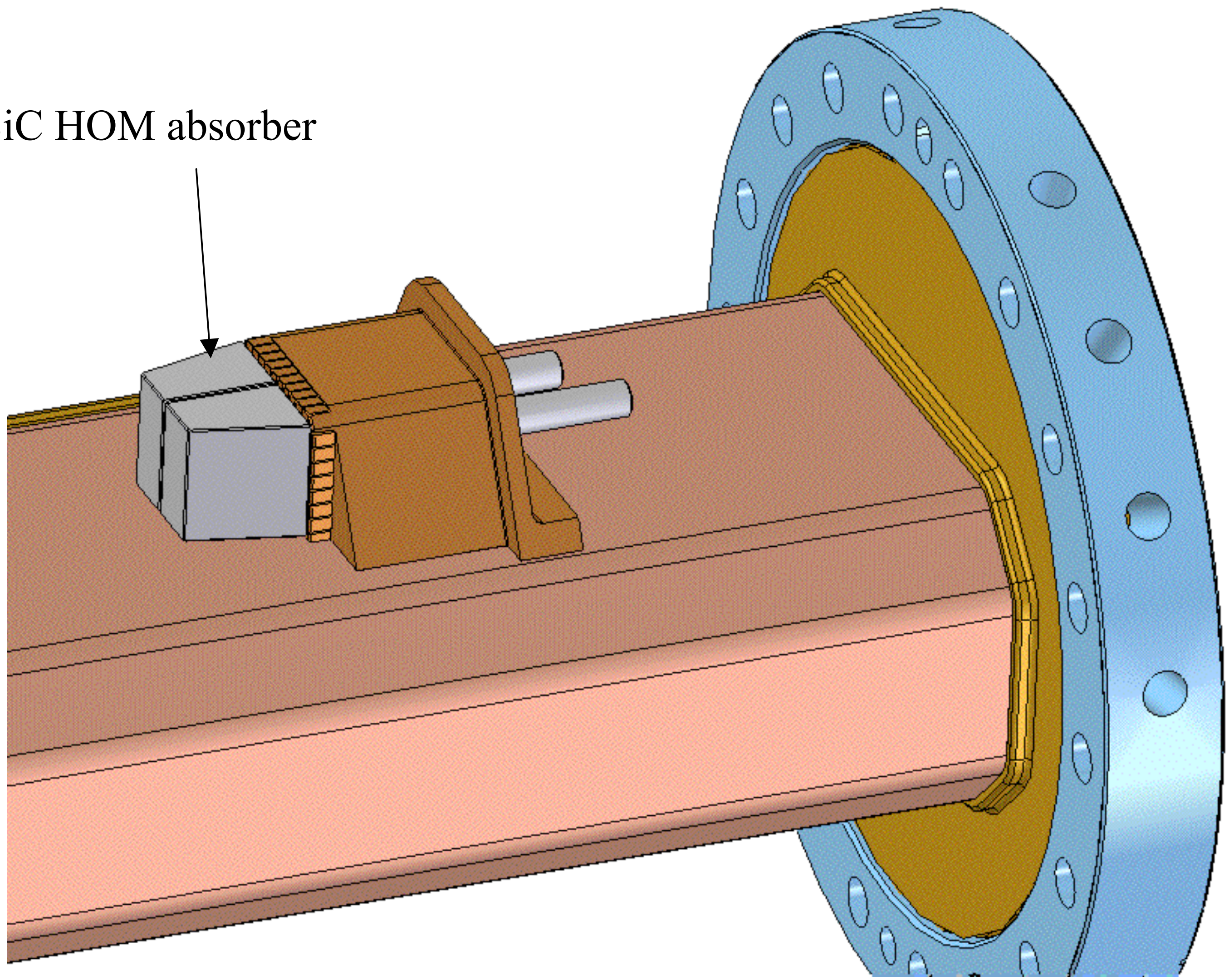


Upgrades for Run 5

- One additional rf station for each HER and LER
  - HER beam current >1.8 A, LER, 3.6 A
- Removed NEGs in the LER upstream of BaBar
  - rf power leaking through screen caused severe heating.
  - more to be replaced in October

Existing 3082 chamber





Chamber shown inverted and plenum not shown for clarity

PEP-II/BaBar Roadmap: Super B-Factory Study May 2004

- The Roadmap Committee is studying the long range future of PEP-II and BaBar with a possible large upgrade at the end of the decade.
- A Super-PEP-II could produce 10 ab^{-1} per year with a peak luminosity of 7 x $10^{35}/cm^2/s$.
- Accelerator parameter goals have been set and work towards a solid design has started.

Parameter	LER	HER
Energy (GeV)	3.5	8
RF frequency (MHz)	952	952
Vertical tune	72.64	56.57
Horizontal tune	74.51	58.51
Current (A)	15.5	6.8
Number of bunches	6900	6900
Ion gap (%)	1.2	1.2
HER RF klystron/cav	32/64	25/50
HER RF volts (MV)	43	33
β_y* (mm)	1.5	1.5
β_x* (cm)	15	15
Emittance (x/y) (nm)	28/0.3	28/0.3
σ_z (mm)	1.75	1.75
Hourglass-X-angle factor	0.80	0.80
Crossing angle(mrad)	15	15
IP Horiz. size (µm)	65	65
IP Vert. size (µm)	0.6	0.6
Horizontal ξ_x	0.105	0.105
Vertical ξ_y	0.107	0.107
Lumin. (x10^{34}/cm^2/s)	70	70

Recommended scenario: 7 x 10^{35}

- Replace present RF with SC 952 MHz frequency over period of time.
- Use 8 x 3.5 GeV with up to 15.5 A x 6.8 A.
- New LER and HER vacuum chambers with antechambers for higher power (x 4).
- Replace LER magnets to soften radiation and resistive wall losses; rework HER magnets as well.
- Push β_y^* to 1.7 mm: need new IR (SC quadrupoles) with 15 mrad crossing angle and crab cavities with bunch lengths of 1.8 mm.
- New bunch-by-bunch feedback for 6900 bunches (every bucket) at 1 nsec spacing. (Presently designing feedback system being 0.6-0.8 nsec spacing.)

SBF Overall Parameters and Goals

Parameter	Units	Best of PEP-II	7E35 SBF	1E36 SBF
I+	A	4.5	6.8	10.0
I-	A	2.2	15.5	23.0
Number bunches		1715	6900	6900
β_y*	mm	8.5	1.8	1.7
ξ_y		0.065	0.11	0.11
Luminosity	$x10^{34}$	2.3	70	100
Integrated lumi / day	fb^{-1}/day	1.8	50	75

Achieving Super B Luminosities

$$L \propto n\xi_y \frac{EI_b}{\beta_y^*}$$

I_b

Higher Currents:

- More rf power, cooling, injector
- More HOM heating (more bunches)
- Beam instabilities
- Electron clouds, fast ions

β_y*

Smaller β_y*:

- Smaller physical/dynamic aperture
- Shorter lifetime, more background

Shorter σ_z:

- More HOM heating
- Coherent synchrotron radiation
- Shorter lifetime, more background

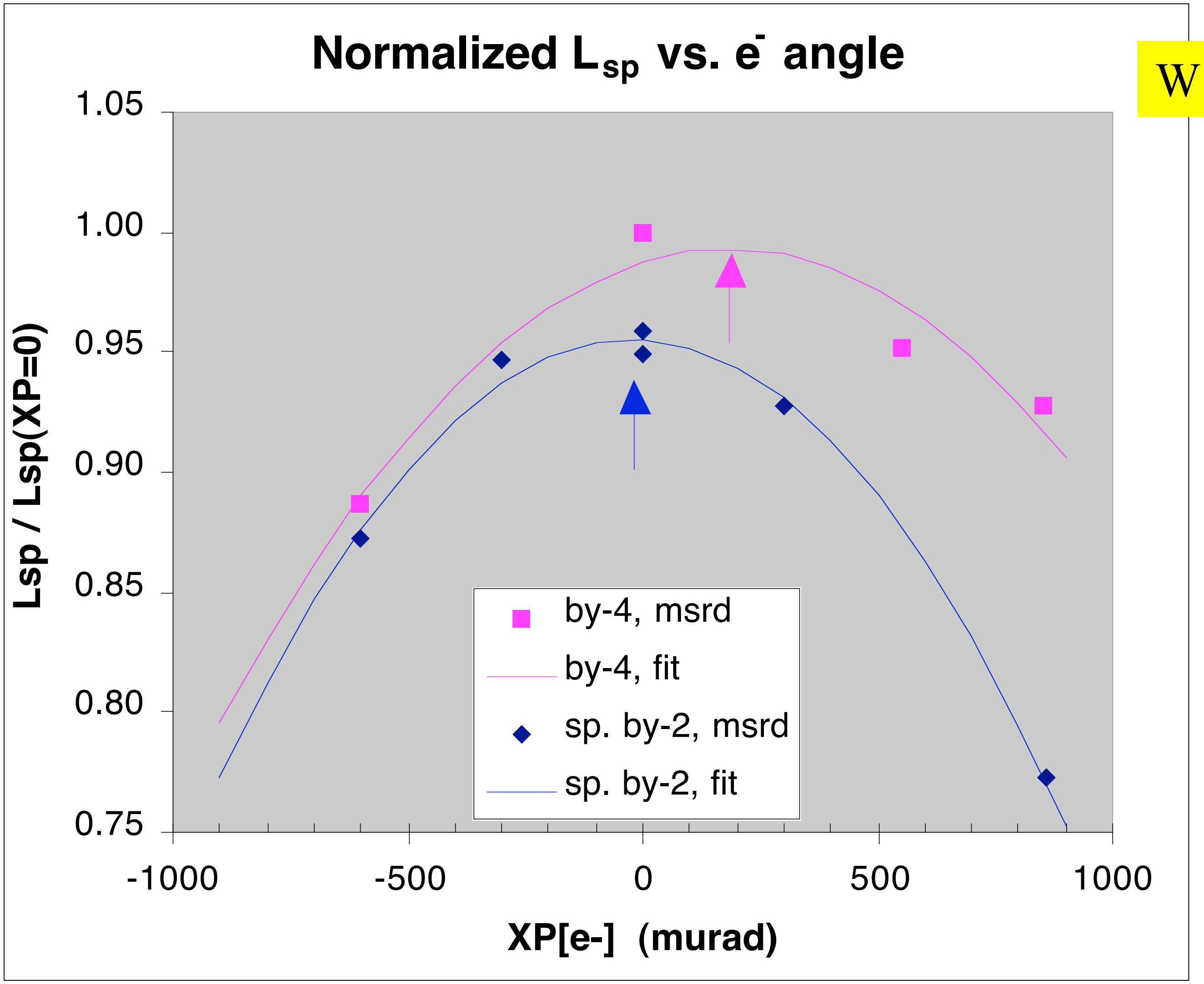
ξ_y

Higher tune shifts:

- Head-on collisions replaced by angled crossing
- Degrades maximum tune shift unless crabbing cavities used

Crossing-Angle Experiment

W. Kozanecki

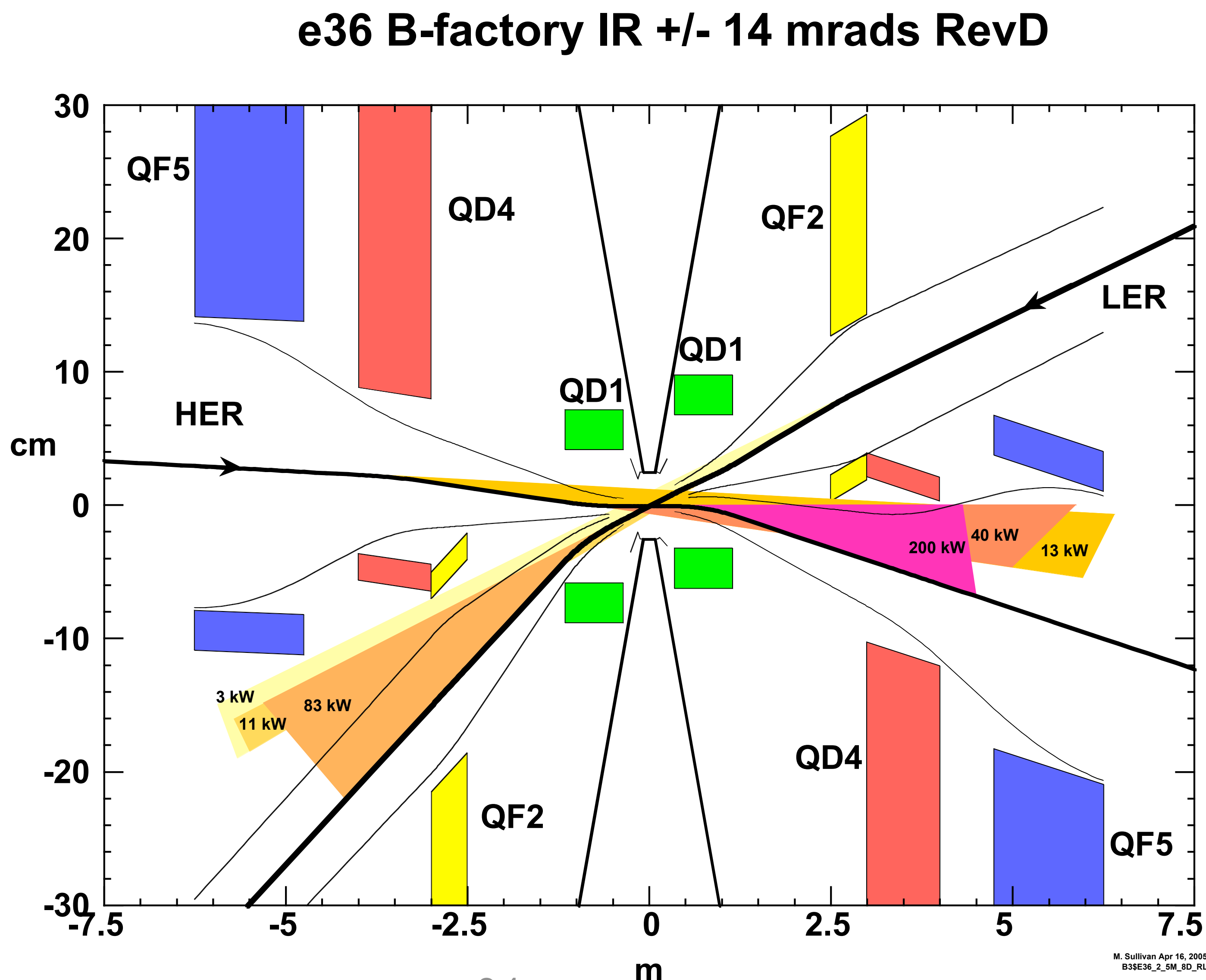


Initial IR Design for a Super B-Factory

±14 mr crossing angle

- First look at SR backgrounds

Try to limit luminosity component by minimizing bends



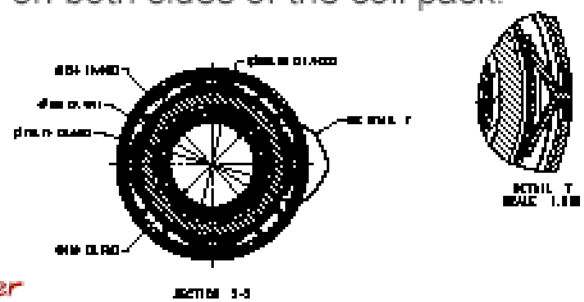
New IR magnet design (Parker)

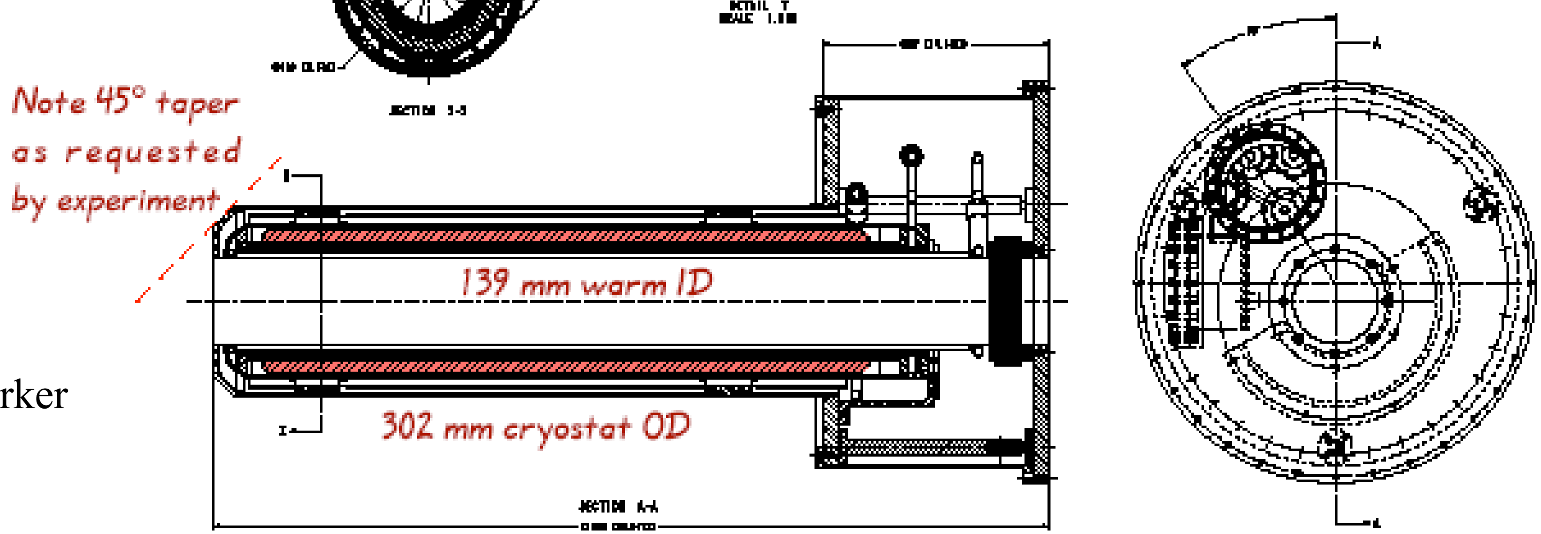
BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

First Pass at Super-B IR Magnet Cryostat Radial Buildup: Assume Same As BEPC-II.

Unlike HERA-II, the BEPC-II magnets have inner/outer gas cooled heat shields plus LHe cooling on both sides of the coil pack.

For BEPC-II we have just over 25 mm radial space between the inner coil and warm bore and just over 30 mm radial space between the outer coil radius and the outside of the cryostat.*



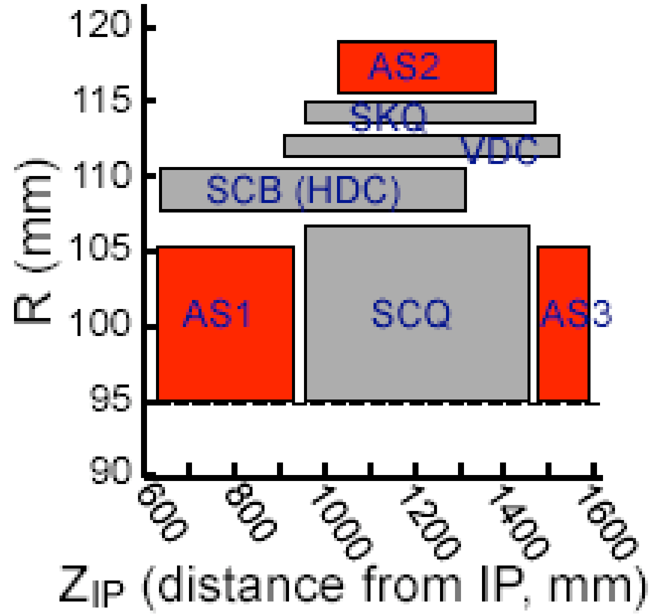


B. Parker

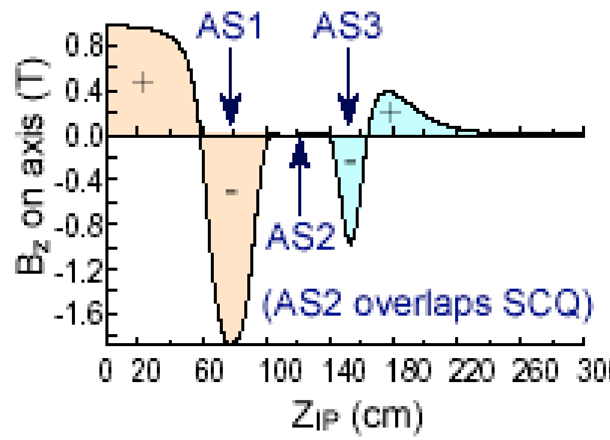
New IR magnet design

B. Parker

Quadrupole, anti-solenoid, skew quadrupole, dipole and trims located in one magnet.



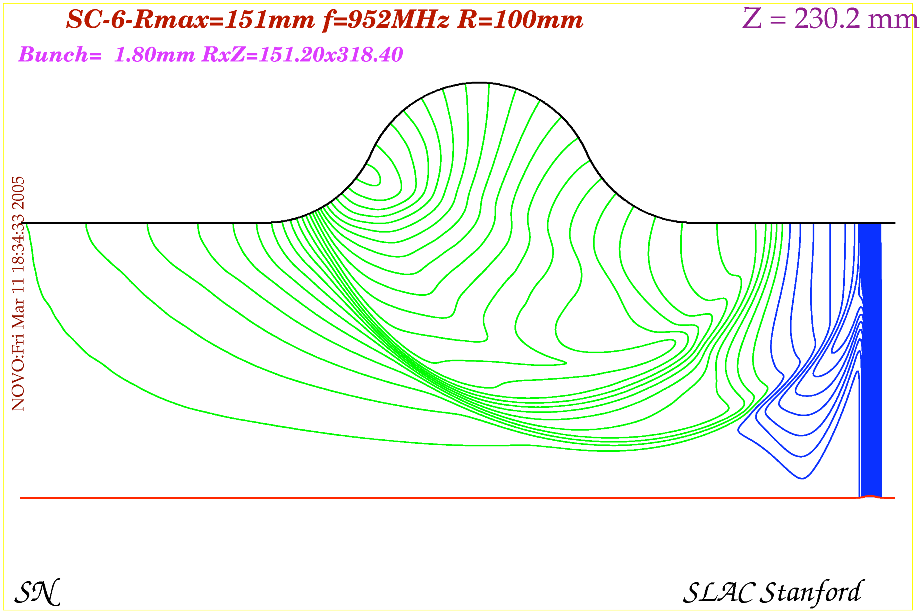
All coils numerically wound on a bobbin.



New Rf system, s/c Technology

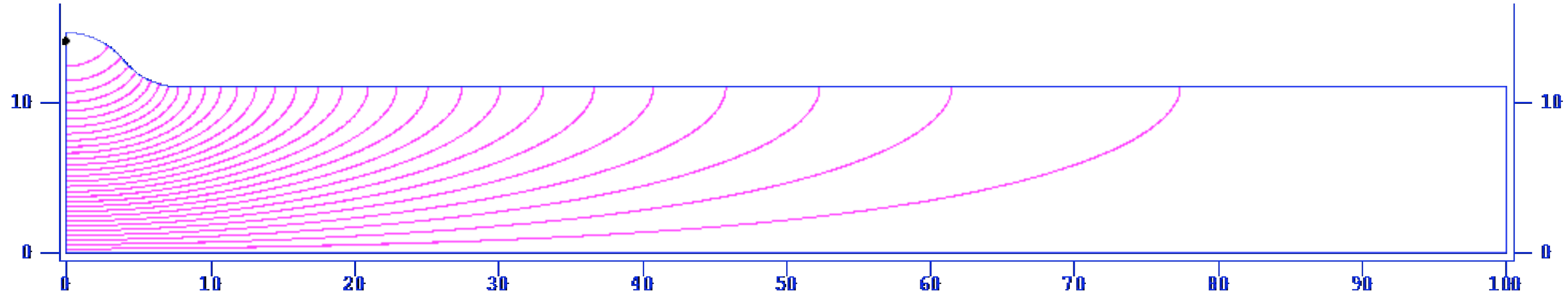
- 1…2 MV/cavity, 500 kW/coupler
- R/Q of 12Ω aimed at for beam stability
- 952 MHz => Potential for 6900 bunches
- up to 40 MW power to the beam (LER, 23 A)
- Support bunches as short as 1.8 mm

New cavity design for a SBF (SC, R/Q≈5Ω)



A. Novokhatski

Accelerating field



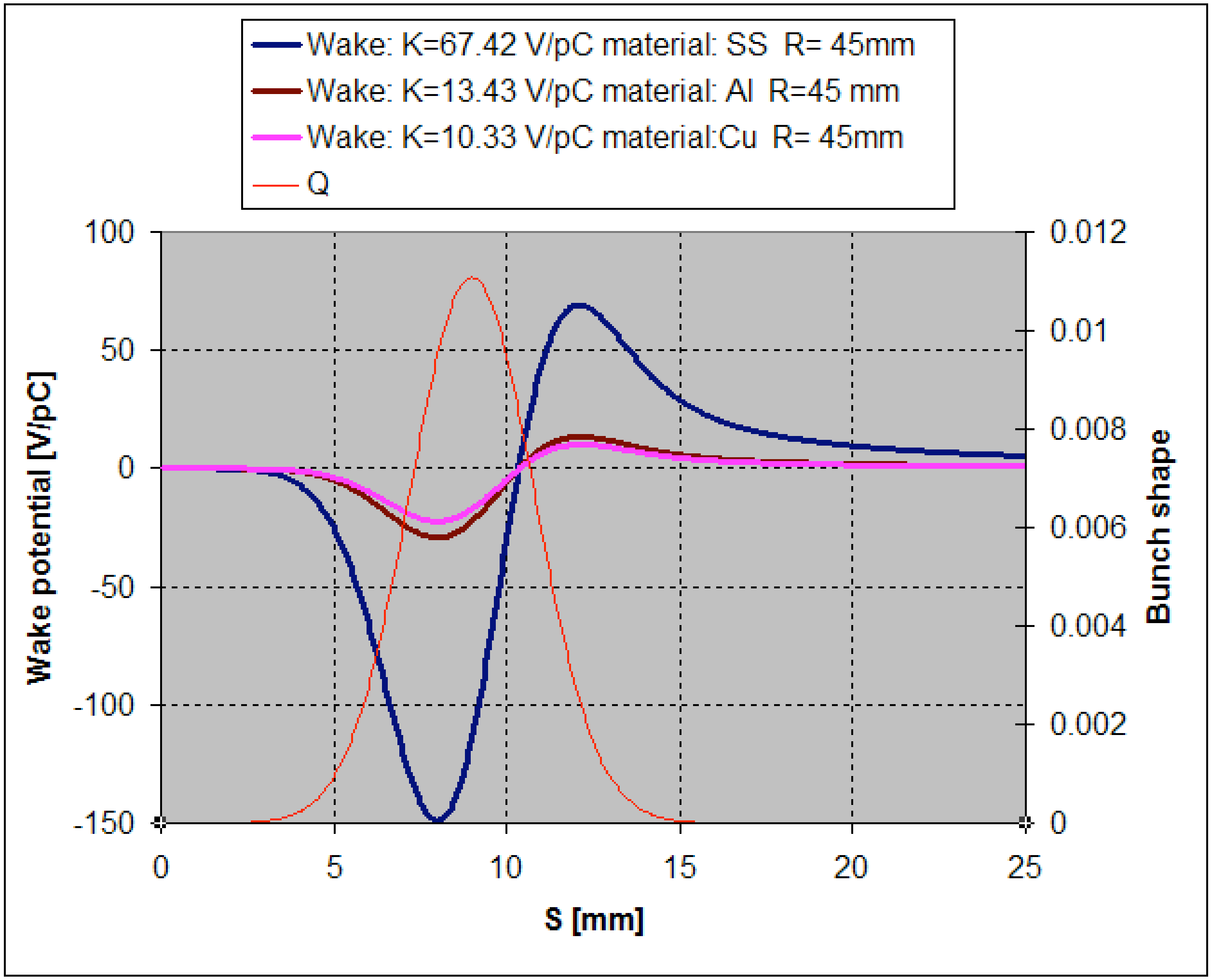
Distance (cm)

New Magnet Systems/Lattices

– Low momentum compaction
  - short bunches without excessive rf voltage
  - increase stability against longitudinal multibunch instability
  - maintain reasonable synchrotron tune
    – (simulations predict high ν_s to be detrimental to luminosity)

– Larger-aperture magnets than present PEP-II
  - allows increase of beam-pipe radius, lower res. wall loss
  - becoming an issue at SBF beam current & bunch length

Resistive-Wall Wake (bunch lengthening)



Power
SS: 45 MW
Al: 9 MW
Cu: 7 MW

SR: 18 MW

A. Novokhatski

New bellows design with HOM absorber

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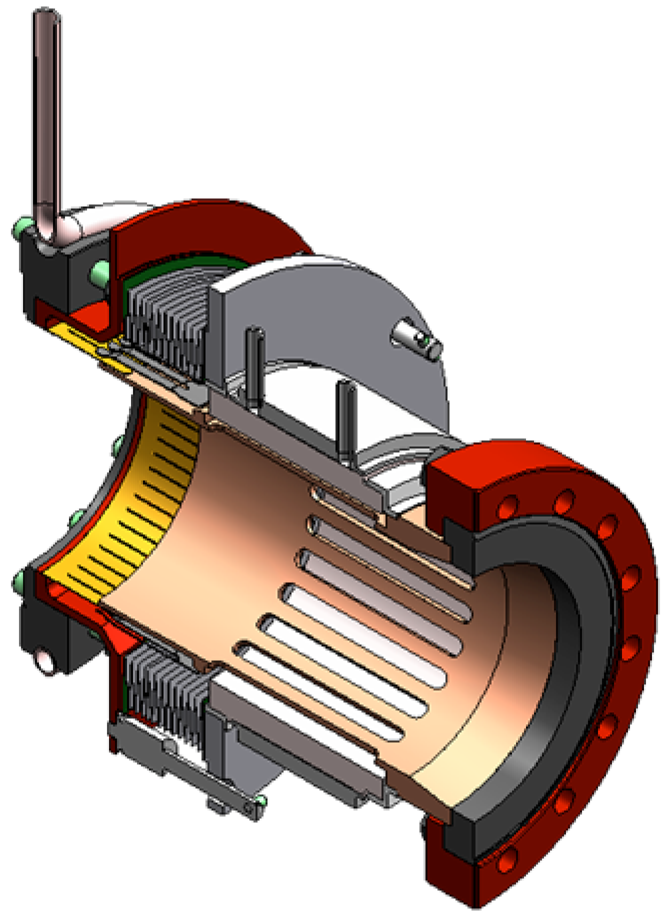
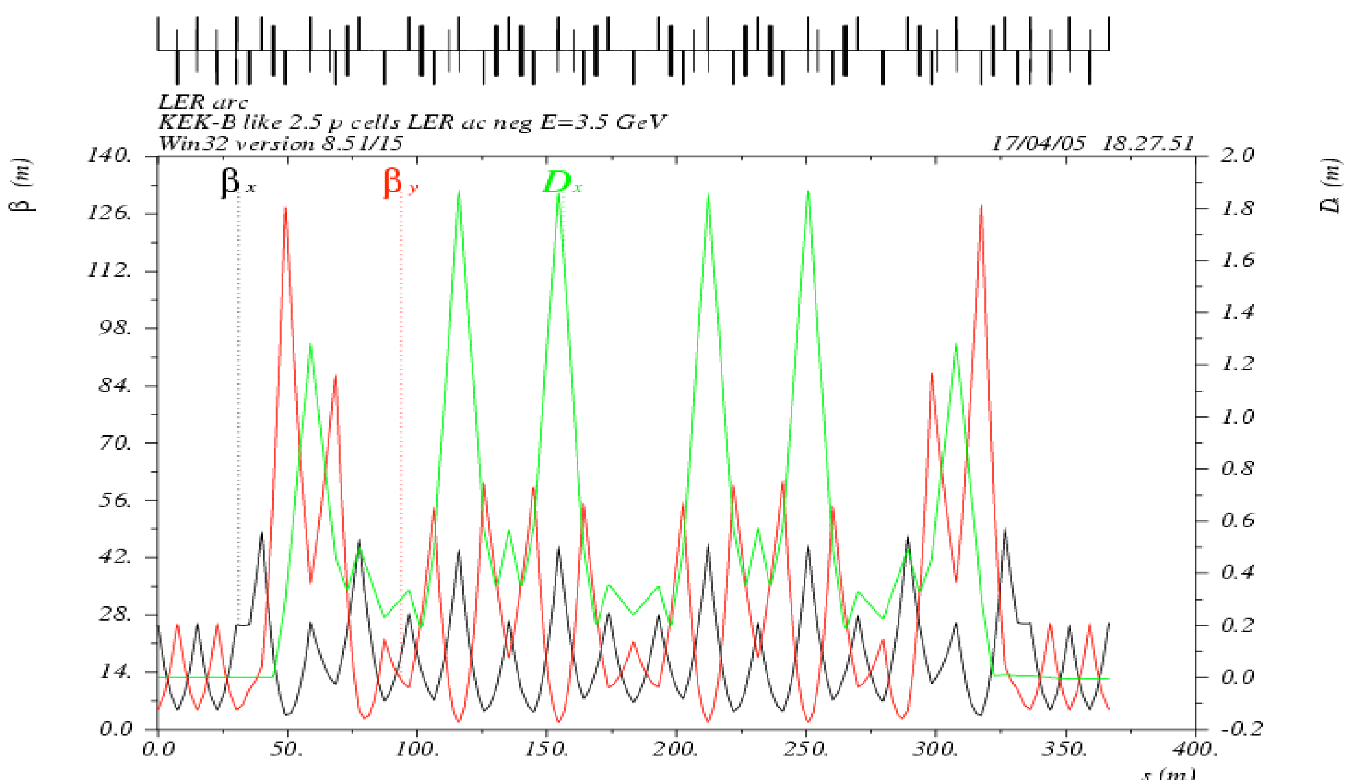


Kurita
Novokhatski
Weathersby

LER ring (no IR yet)

M. Biagini

One sextant



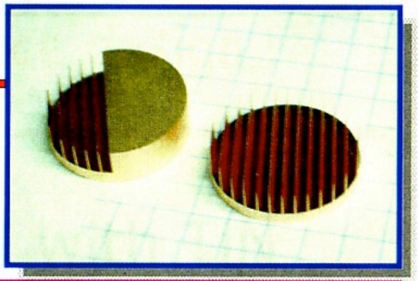
Small positive momentum compaction, using present LER dipoles & quads (16 families), 3 sextupole families

Electron Cloud Instability

- PEP-II uses solenoidal fields and gaps in the fill to mitigate ECI
  - Experiment at end of Run 4: fill all gaps
    - Luminosity scaled with bunch#
    - =>probably don't need the gap at present beam current (2.6 A).
- At Super-B beam currents, these may not be sufficient
  - Investigate means to further reduce secondary emission in the vacuum system

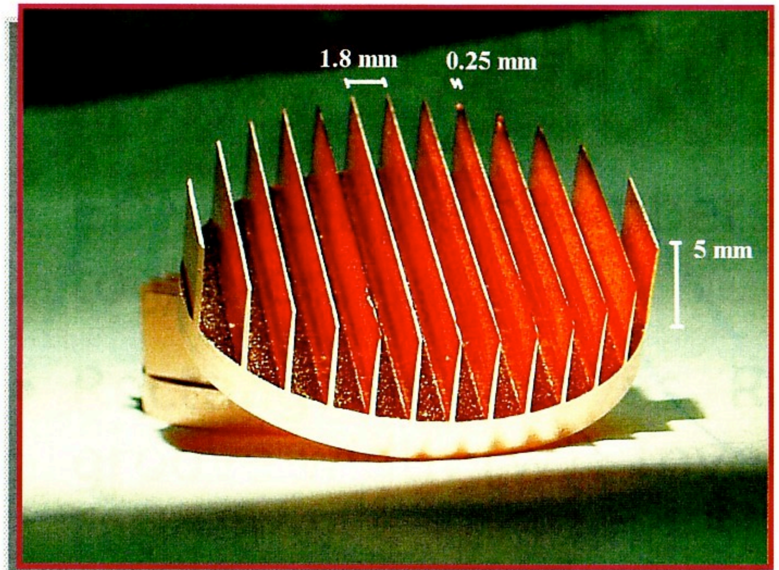
Windings added for ECI reduction

Rectangular (!) groove surface profile design

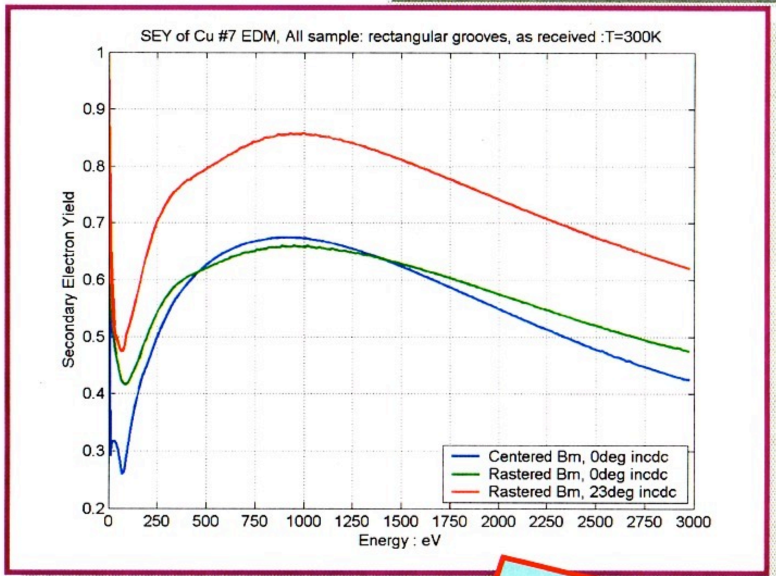


M.P. and G. Stupakov

Scaling a factor ~5 from previous sample for PEP-II application



Special surface profile design, Cu OFHC. EDM wire cutting. Groove: 5mm depth, 2mm step, 0.25mm thickness.

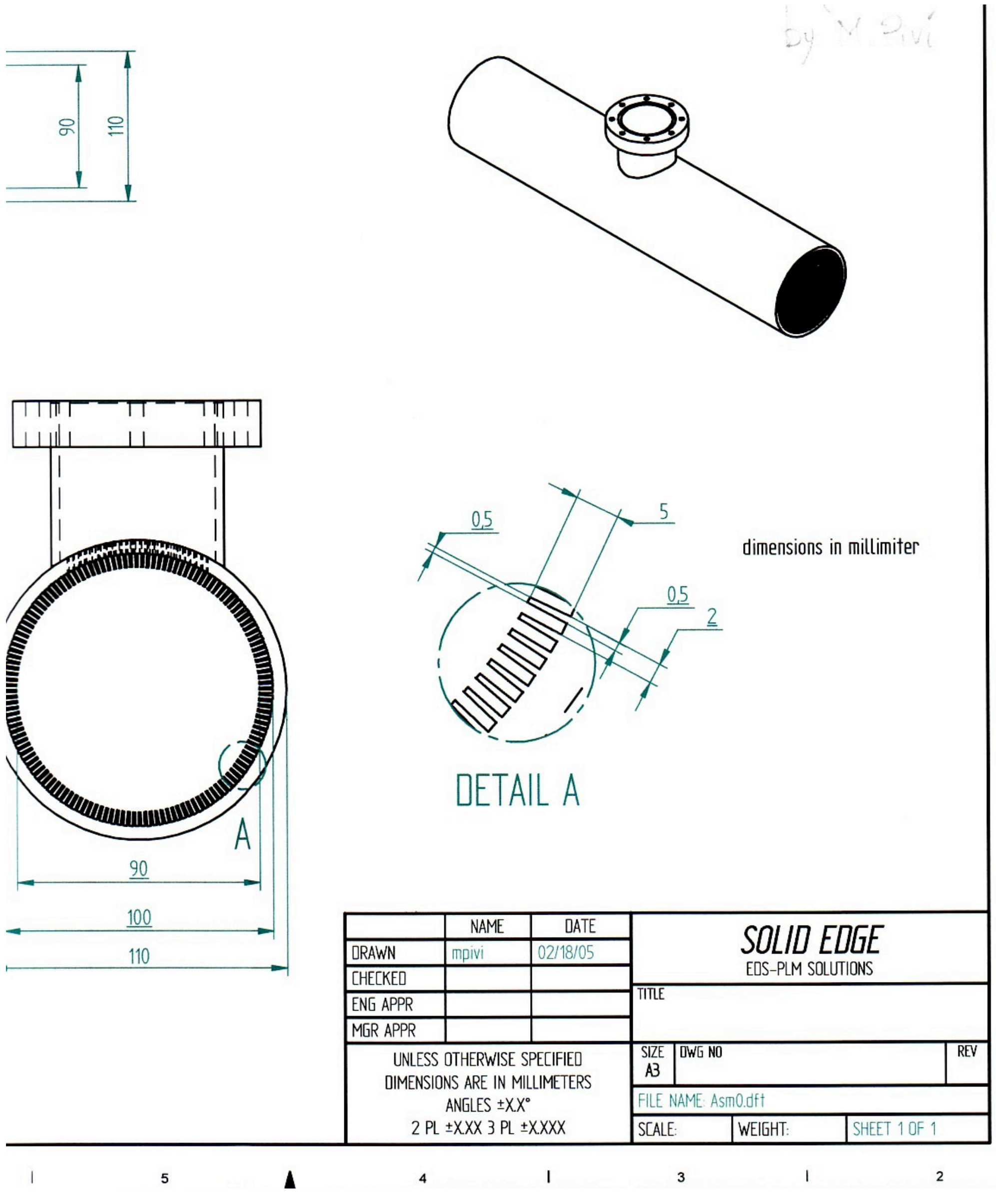


Secondary Yield reduction <0.7
More reduction with geometry

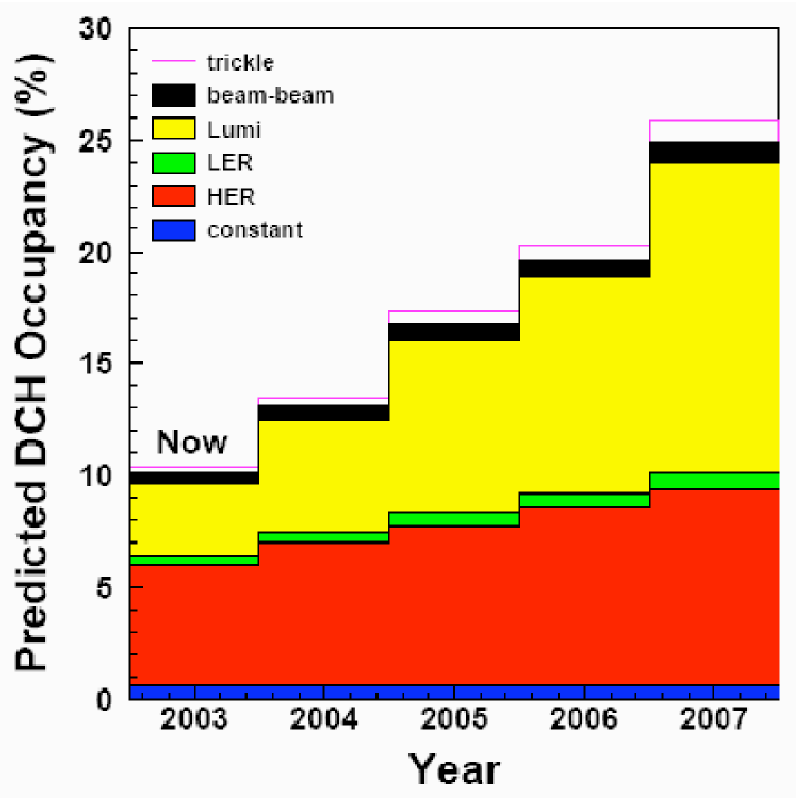
Preparing to install a test chamber rect. grooves in PEP-II, to be used for upgrade

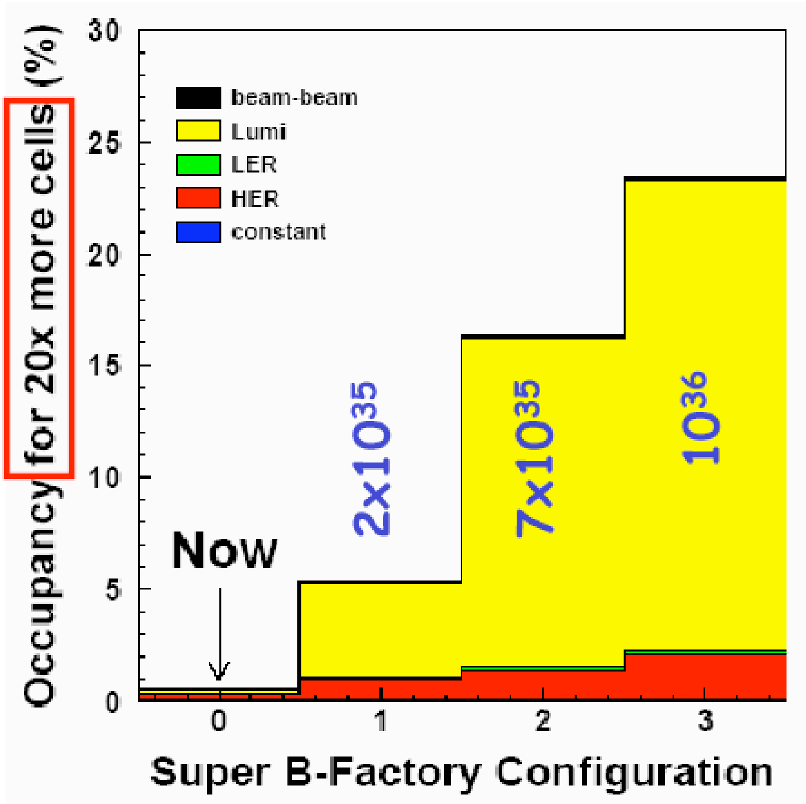
Low-Secondary Yield Test Pipe

M. Pivi



Detector Background Projections: DCH



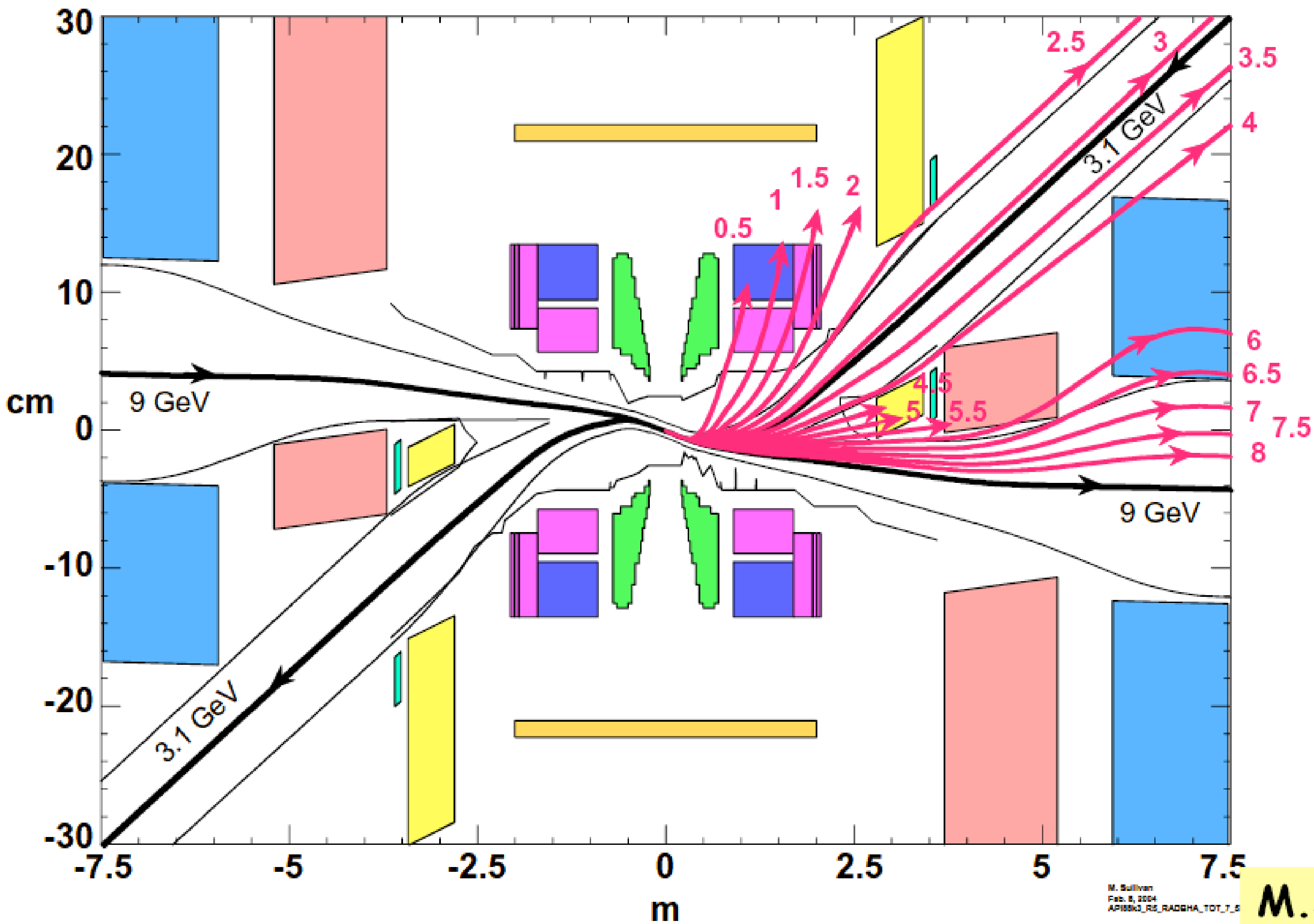


Rule of thumb: tracking inefficiency increases by 1% per 3% increase in occupancy

M.Cristinziani

Luminosity Dependent Backgrounds

HER Radiative Bhabhas



M.Sullivan

Wall-Plug Power

	Luminosity = 7.0 E+35				Luminosity = 1.0 E+36		
	LER	HER	Sum		LER	HER	Sum
Currents (A)	15.50	6.80			23.00	10.00	
Energy (GeV)	3.50	8.00			3.50	8.00	
HOM Losses							
Cavity loss (MW)	1.73	0.25	1.97		6.65	0.78	7.43
Cavity R/Q (Ω)	5.00	5.00			5.00	5.00	
Loss factor (V/pC)	0.29	0.29			0.29	0.29	
Number of cavities	24.00	18.00			42.00	26.00	
Resistive Wall (MW)	2.75	0.53	3.28		6.07	1.15	7.21
Cu coated Al Chamber R=45mm (V/pC)	10.92	10.92			10.92	10.92	
IP region (MW)	1.82	0.35	2.17		4.01	0.76	4.77
Loss factor (V/pC)	7.22	7.22			7.22	7.22	
Other HOMs (MW)	0.50	0.10	0.60		1.11	0.21	1.32
Loss factor (V/pC)	2.00	2.00			2.00	2.00	
Total HOM Losses (MW)	6.81	1.23	8.03		17.84	2.89	20.73
SR Losses							
loss per turn (MeV)	0.97	2.20			0.97	2.20	
SR power (MW)	15.04	14.96	30.00		22.31	22.00	44.31
Total RF Power (MW)	21.84	16.19	38.03		40.15	24.89	65.04
RF Efficiency (%)	50.00	50.00			50.00	50.00	
RF AC Power (MW)	43.68	32.37	76.06		80.29	49.79	130.08
Magnet AC Power (MW)	5.00	5.00	10.00		5.00	5.00	10.00
Cryogenics							
Loss per Cavity (W)	78.00	78.00			78.00	78.00	
Total Cavity Losses (kW)	1.87	1.40	3.28		3.28	2.03	5.30
Cryogenic Efficiency (%)	0.13	0.13			0.13	0.13	
Cryogenic AC Power (MW)	1.41	1.06	2.46		2.46	1.52	3.99
Injector, LCLS, SPEAR3 etc (MW)			40.00				40.00
TOTAL AC POWER (MW)	50.09	38.43	128.52		87.75	56.31	184.06

Conclusions

- PEP-II is again producing data.
- Present B-Factories will provide solid data for four or more years. PEP-II is heading towards 2.3 x 10^{34} in three years.
- Super-B-Factory designs are stabilizing.
- Designs of a Super-B-Factory should allow for upgrade paths to allow the accelerator to remain competitive over its lifetime.

Important Factors in Upgrade Direction

- Accelerator project should have headroom:
  - Design for 7 x 10^{35}
  - Headroom for machine up to 1 x 10^{36}; requires additional RF, which can be staged into machine over time.
- Accelerator built in the timely manner with a rapid turn on.