HER 90° Lattice Upgrade

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Outline

- Justification
- The Lattice
- The Magnet Configuration

Why do this…?

- Bunch length ≈ $\sqrt{\alpha}/\sqrt{V_{rf}}$.
- Cost:
  - raise V_{rf}: 2 M$/mm, low $\alpha \approx$ 0.4 M$/mm (@ present σ_l)
- However, there is a physics argument as well:
  - $\nu_s \approx 1/\sigma_l$ if rf voltage is used to shorten bunches
  - high ν_s is suspected to be detrimental to luminosity
  - $\nu_s \approx \sigma_l$ if α is reduced, this may be a benefit.
- Side effect (unwanted!)
  - our nice and robust HER lattice may get more finicky

Scenarios

- V_{rf} = 18.5 MV, α = 2.41E-3
  - σ_l = 10 mm, ν_s = 0.052
- V_{rf} = 18.5 MV, α = 1.67E-3
  - σ_l = 8.3 mm, ν_s = 0.043
- V_{rf} = 26 MV, α = 2.41E-3
  - σ_l = 8.3 mm, ν_s = 0.062

(all are zero-current estimates)

How to do it…

- There are a number of schemes to push a down
  - superperiodicity (Teng-Ohnuma & KAON Fact. lattices)
  - Dipole modulation (KF Booster designs, SSC LEB)
  - FMC lattices (S.Y. Lee, IUCF)
- In the PEP context:
  - can't modulate dipole pattern
    - not only cabling/ps but also vacuum system prevent this
  - Could modulate the quadrupole focusing, but this would cause large beam emittance
- => only $1/\sqrt{\alpha} \approx \nu_x$ left to use
- => 90° lattice for the HER

Lattice Design

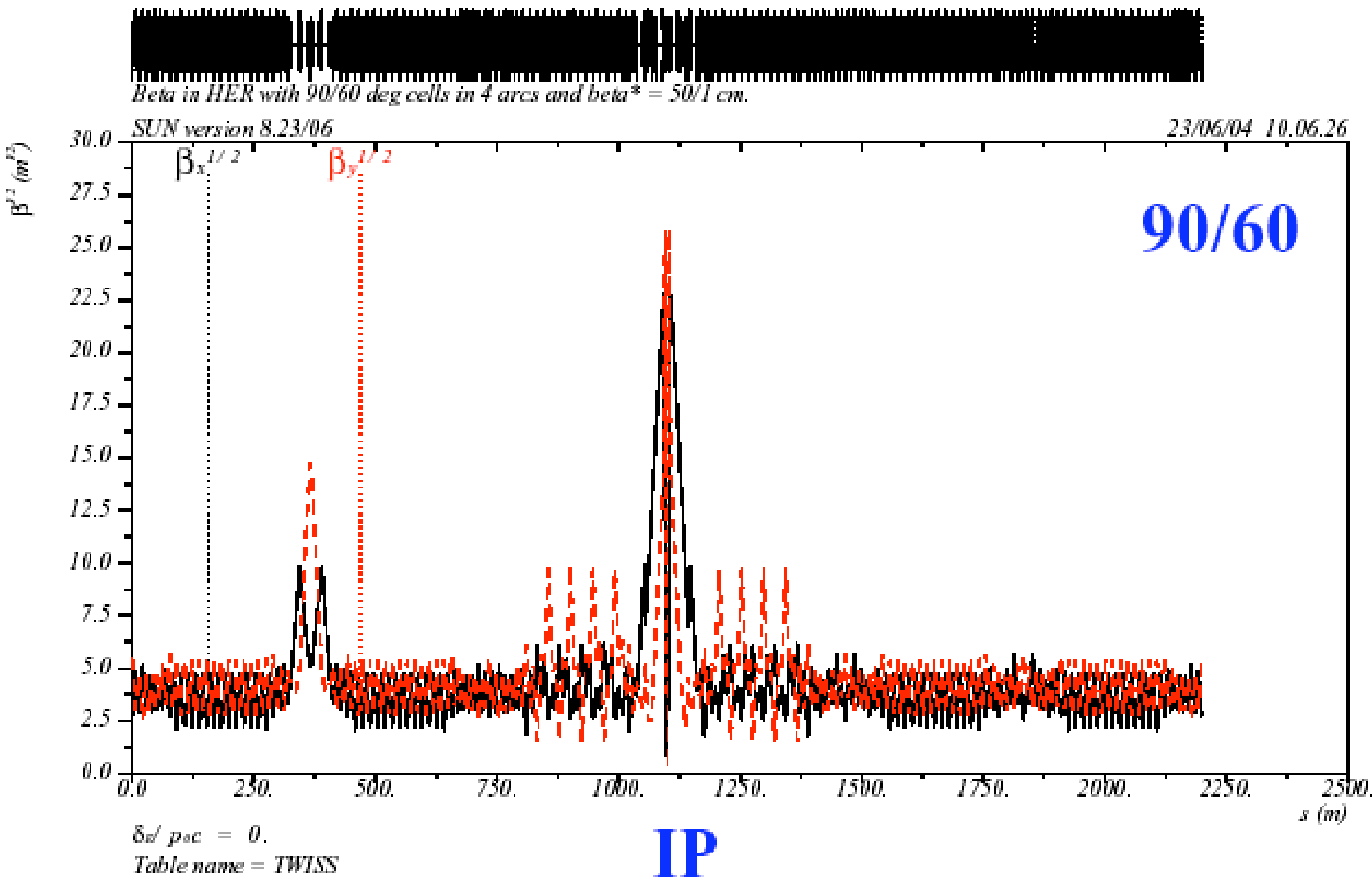
- At 90°/cell, beam emittance becomes small
  - 30 πnmr vs 48πnmr now
- The dispersion-beat technique again applied to maintain emittance at 48 πnmr
  - in practise this will remain tunable
- As it turns out, this also helps the optics
- Arcs 1 & 3 do the semi-local chromaticity correction
  - leave those alone (at 60°/cell)
  - the machine was "pre-wired" for this option

Options for *Y* phase advance

Table 1: Lattice parameters as a function of cell phase advance in four arcs 5,7,9,11.

Phase (x/y)	Tune (x/y)	Momentum compaction	β_x/β_y (SF)	β_x/β_y (SD)	Chromaticity (x/y)	BDES (SF/SD)
90/30	28.52 / 20.63	1.662e-3	20.2 / 18.5	5.6 / 48.0	-45.7 / -72.2	267.4 / -356.7
90/40	28.52 / 21.63	1.665e-3	20.6 / 13.6	5.5 / 37.4	-46.0 / -71.1	265.5 / -388.0
90/45	28.52 / 21.63	1.667e-3	20.9 / 11.9	5.4 / 34.0	-45.9 / -70.8	264.8 / -397.4
90/50	28.52 / 22.63	1.669e-3	21.2 / 10.5	5.4 / 31.4	-46.3 / -71.5	262.3 / -412.2
90/60	28.52 / 23.63	1.677e-3	21.8 / 8.5	5.3 / 27.7	-46.8 / -71.7	256.2 / -434.5
90/90	28.52 / 27.63	1.699e-3	24.0 / 4.9	4.9 / 24.0	-48.6 / -75.7	234.7 / -475.1

90/60 Lattice



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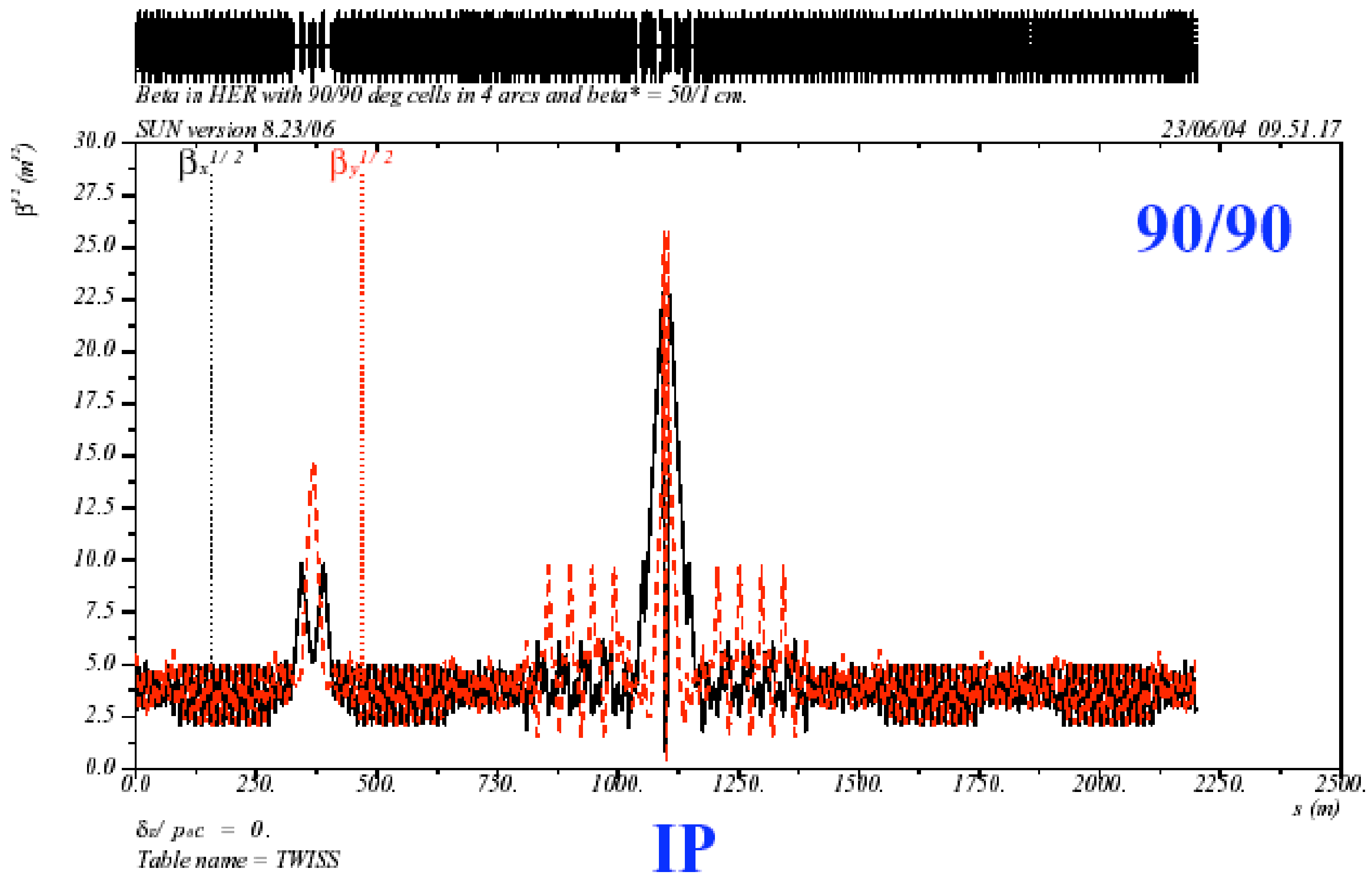
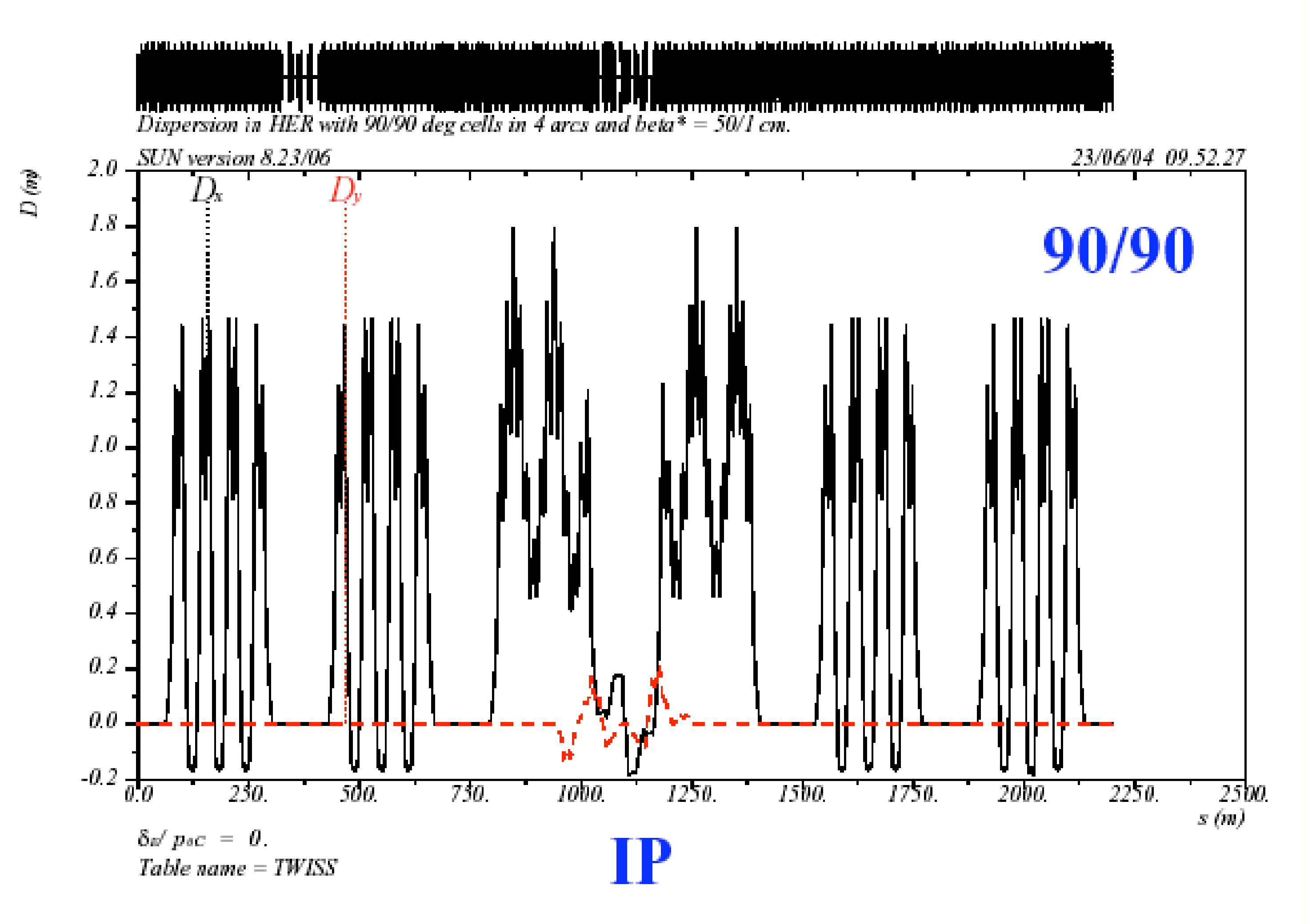
90/90 Lattice



Dispersion Function



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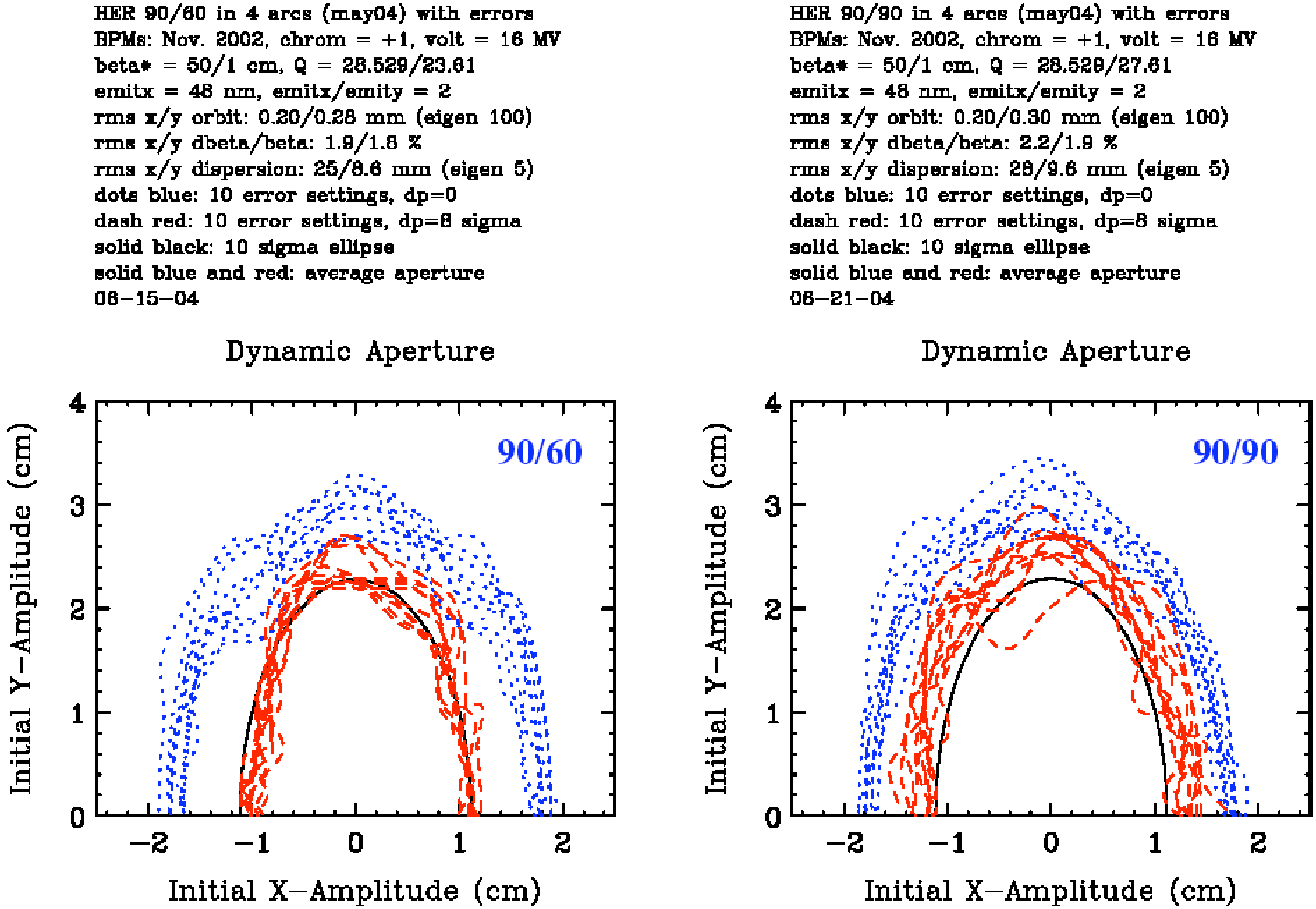
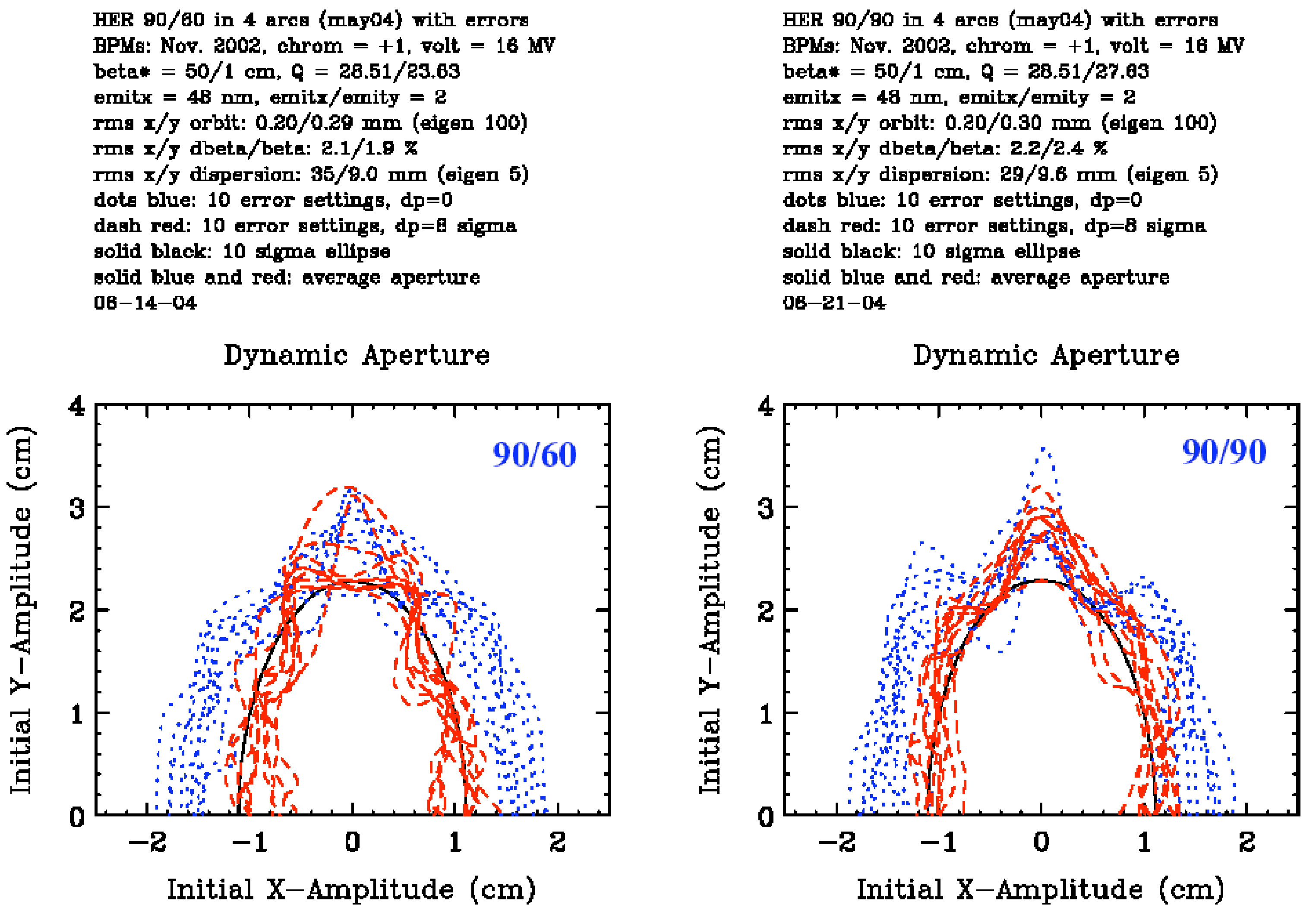
Acceptance

Dynamic aperture at Q = .529 / .61



Acceptance closer to $\nu_x \approx 0.5$

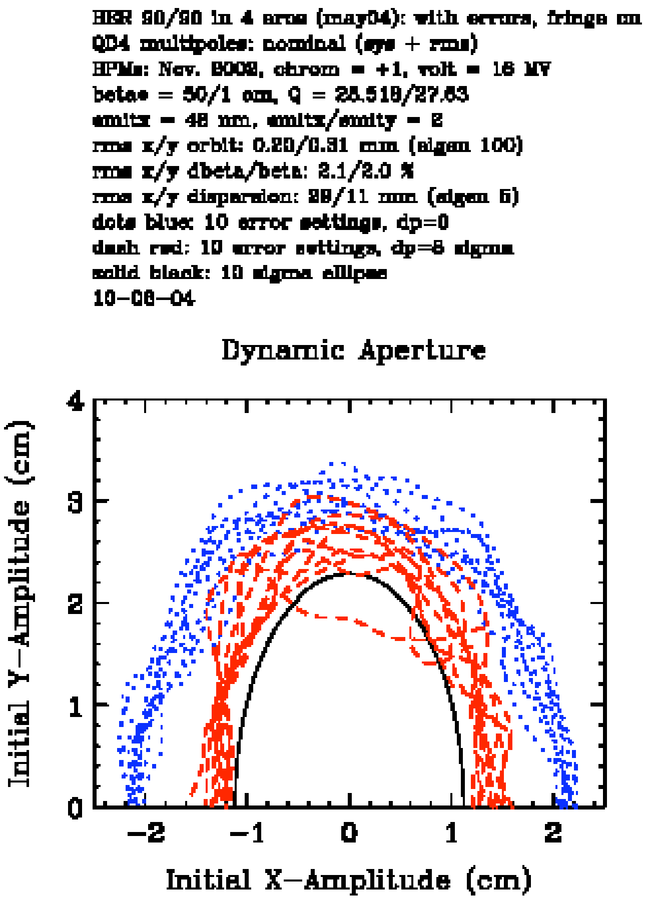
Dynamic aperture at Q = .51 / .63



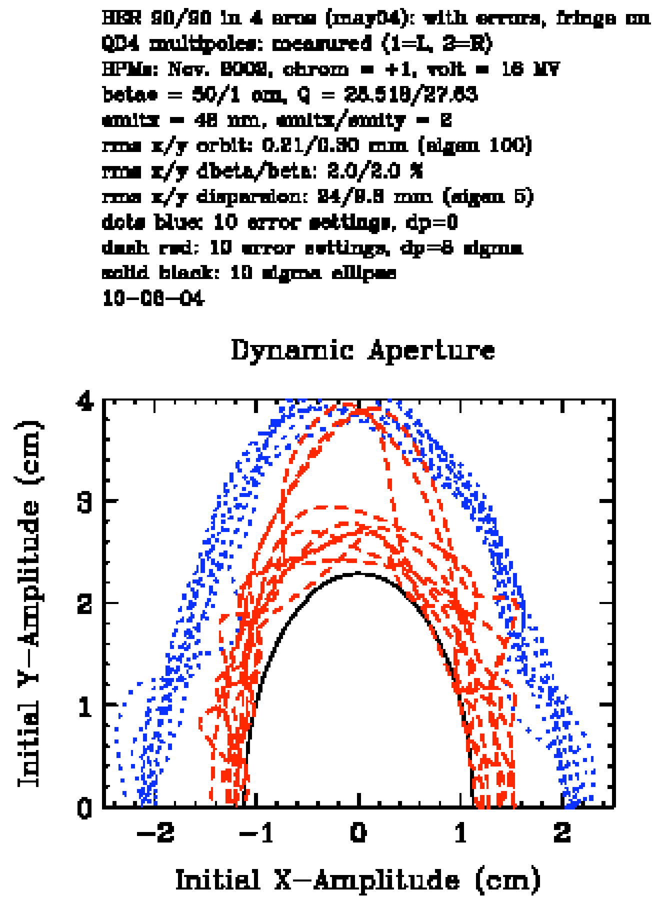
90/90 with Quad Fringe Fields

- tunes: (0.518,0.63)

With fringe, nominal QD4 multipoles



With fringe, measured QD4 multipoles



Manget Values

- This is an excerpt from the complete list
  - magnets that need upgrades

Quadrupoles

NAME	L (m)	60/60 deg	90/60 deg	90/90 deg	Limit	Upgrade
QD90	0.558356	-40.3018	-44.6953	-57.0526	-52.0	Strength (90)
QF90	0.558356	40.3607	54.6954	57.1110	49.0	strength
QDS0E	0.558356	-38.6072	-37.9544	-38.0891	-50.0	
QDS0XE	0.558356	-43.9643	-43.3110	-43.4465	-66.5	
QFS1E	0.558356	44.6427	42.4083	42.7714	67.0	
QDS1E	0.558356	-40.6393	-40.6966	-41.7849	-67.0	
QFS2E	0.558356	47.5400	51.1368	51.5964	66.8	
QDS2E	0.558356	-40.1402	-42.9757	-47.0365	-67.0	
QFS3E	0.558356	44.0621	56.0795	57.3357	66.7	
QDS3E	0.558356	-40.3018	-45.0163	-54.6982	-61.0	New PS
QFOI	0.558356	36.4784	36.4552	36.4555	50.0	
QDOI	0.558356	-29.3774	-29.3725	-29.3723	-38.0	
QFI	0.558356	21.5467	21.5332	21.5334	28.0	
QDI	0.558356	-12.1043	-12.1030	-12.1030	-20.3	

for chromaticity = +4

SD	0.250000	-235.3086	-484.6879	-524.5683	-300.0	Strength
SF	0.250000	140.9374	286.2000	260.4632	300.0	

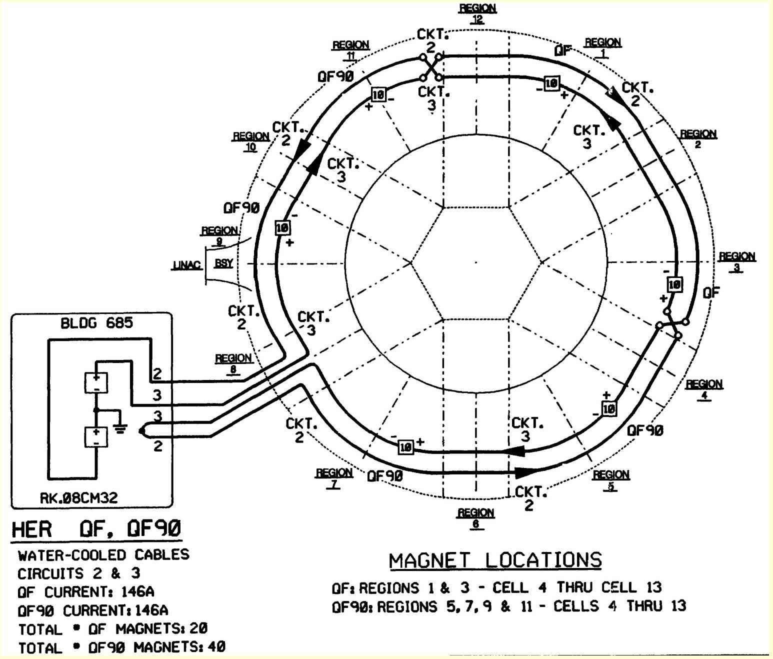
Implementation issues

- Biggest job is the split-off of QF90/QD90 from QF/QD
  - cabling mostly in place, but new choppers needed
  - also split off QDS3S
  - Upgrade QDS3E supply retains emittance control.

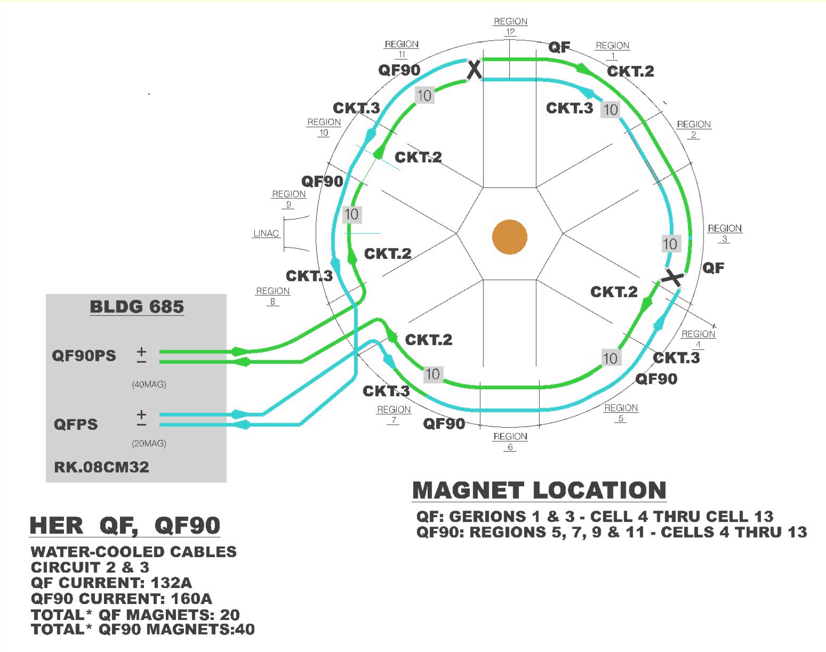
- Sextupoles will run significantly hotter
  - cooling needs reconfiguration for more circuits
  - add’l chopper needed to raise voltage for SD
  - add’l cable needed to raise ampacity for SD

QF90 Reconfiguration

Present configuration



Future configuration



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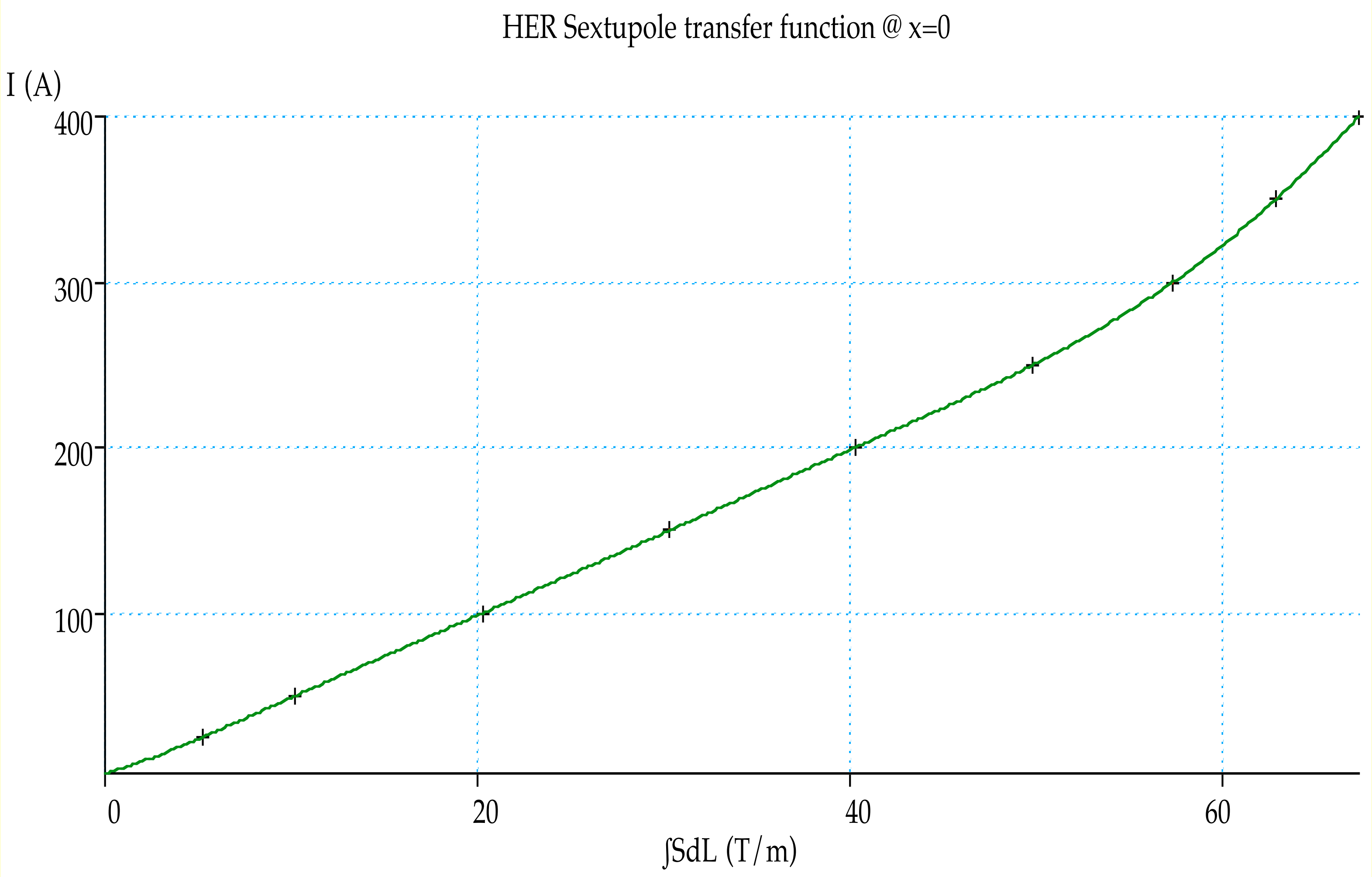
Power Supply Summary

Present			*New*			
System	***Cable***	***Power Supply V/A/kW***	***System***	***V/A/kW***	***Cable***	***Power Supply V/A/kW***
QD/QD90/ QDS3S	*WC 2 loop*	*1000V, 400A 2 choppers*	*QD*	*250/150/37.5*	*WC 1 loop*	*250/150/37.5 new*
			QD90	*704/206/145*	*WC 1 loop*	*1200/400/480 Use 2 QD existing choppers*
			QDS3S	*36/155/5.6*	*4/0 Cu 2 loop*	*36/155/5.6 new*
QDSOE	*4/0 Cu 2 loop*	*60V, 165A Intermediate*	*QDSOE*	*52/227/11.8*	*4/0 Cu 2 loop*	*52/227/11.8 new*
QF/QF90	*WC 2 loop*	*1000V, 400A 2 choppers*	*QF*	*256/146/37.4*	*WC 1 loop*	*256/146/37.4 new*
			QF90	*726/207/150*	*WC 1 loop*	*1200V, 400A - 2 choppers*
SD	*350Al 1 loop*	*500V, 400A 1 chopper*	*SD*	*1016/309/314*	*500 Cu 1 loop*	*1200V, 400A 2 choppers, 1 new*
SF	*350Al 1 loop*	*500V, 400A 1 chopper*	*SF*	*510/157/80*	*350Al 1 loop*	*600V, 400A - 1 chopper*

Sextupole Excitation Function

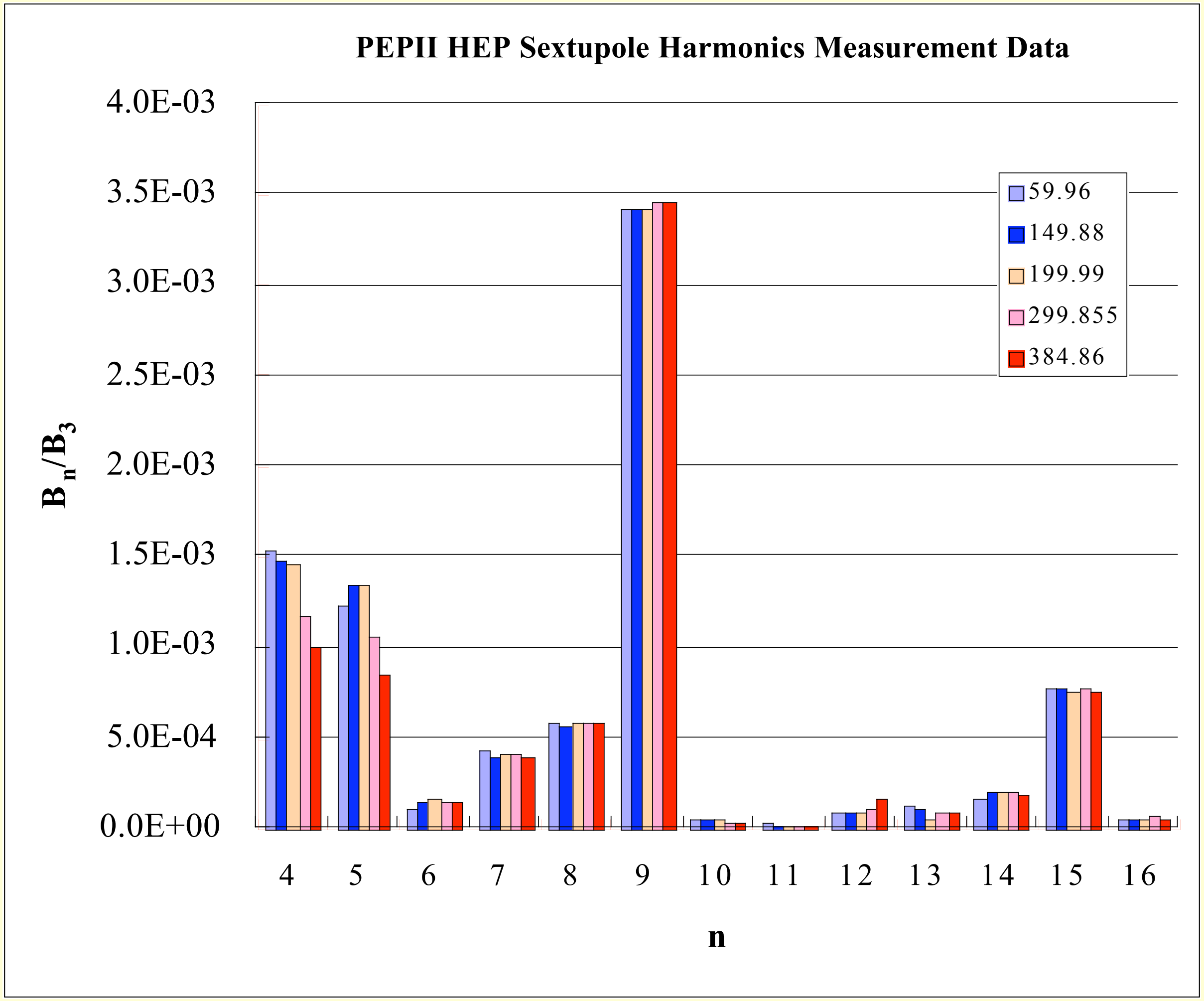


Sextupole Thermal Estimate

PEPII HER Sextupole Allowed Current Calculation

Turn/per coil	24			
Conductor: edge L/hole D/ corner R(in)	0.327		0.118	0.032
Conductor Area (in^2)	0.0951	*Hole D (ft):*	*0.0098*	°°
One coil length (ft)	51.23			
ΔP (psi)	75	*ΔP (lb/ft^2)*	*10,800*	°°
Allowed ΔT °C	30			
Sextrupole r_o (in)	2.362	*r_0 (m)*	*0.06*	°°
Water circuit(s)/magnet	1	2	3	6
Water Flow QTY (gpm)/circuit	0.0942	0.1417	0.1794	0.2618
Power Lost (watt)/circuit	744.05	1118.35	1416.55	2066.66
Al resistivity(Ω–inch)	1.20E-06			
Al Coil Resistance/circuit (Ω)	0.0465	0.0233	0.0155	0.0078
Allowable Current (Al)/magnet (Amp)	**126.45**	**219.23**	**302.19**	**516.19**
Air permeability (Wb/A*m)	1.2566E-06			
Current Density Al	2.06	3.57	4.92	8.41
Allowable B" (Al Coil) - T/m^2 @20°C	105.96	183.71	253.23	432.56
Bp (Al) @ r_o	0.19	0.33	0.46	0.78

Sextupole Harmonics



Conclusion

- The HER 90° lattice project has been funded as AIP
- Power supply additions have been enumerated and circuit modifications designed
- Deployment of hardware planned for next long shutdown