



Super-B: RF parameters and longitudinal issues. Frascati site.

Sasha Novokhatski

SLAC National Accelerator Laboratory

Super-B General Meeting VIII

June 16-20, 2009

Perugia, Hotel Gio'

INFN Frascati new site.



Super-B parameters May 15, 2009



Sasha Novokhatski "RF/Impedance"

SuperB Parameters May 15 2009 (in bold: computed values)

Parameter		Units	Super-B Design	Super-B LNF	Parameter	Units	Super-B Design	Super-B LNF
			March 200	May 2009			March 200	May 2009
E HER	GeV		4	6.7	positrons			
E LER	GeV		7	4.18	electrons			
r0	cm		2.83E-13	2.83E-13	Sig x HEF microns		9.899	5.657
X-Angle (f mrad)			60	60	Sig y HEF microns		0.038	0.028
Beta x HE cm			3.5	2	Sig x LEF microns		5.657	5.657
Beta y HE cm			0.021	0.02	Sig y LEF microns		0.038	0.028
Coupling (high curr)			0.0025	0.0025	Piwinski .rad		15.15	26.52
Emit x HE nm			2.8	1.6	Piwinski .rad		26.52	26.52
Emit y HE nm			0.007	0.004	X-angle factor HER		0.066	0.038
Bunch len cm			0.5	0.5	X-angle factor LER		0.038	0.038
Beta x LE cm			2	2	Cap Sig x microns		11.402	8.000
Beta y LE cm			0.037	0.02	Cap Sig y microns		0.054	0.040
Coupling (%)			0.0025	0.0025	Uy (~betay/sigz)		0.05	0.04
Emit x LE nm			1.6	1.6	R (hourglass factor)		0.900	0.900
Emit y LE nm			0.004	0.004	Lumi calc /cm ² /s		1.05E+36	1.00E+36
Bunch len cm			0.5	0.5	Tune shift x HER		0.0035	0.0019
I HER	mA		2820	1500	Tune shift y HER		0.0810	0.1019
I LER	mA		2820	2335	Tune shift x LER		0.0011	0.0020
					Tune shift y LER		0.0820	0.1049
Circumfer	m		1800	1207	Damping_msec		15	
N. Buckets distance			1	2	Damping_msec		30.0	
Gap			0.95	0.97	Uo HER MeV		2.1	Bending radius
Fr _f	Hz		4.76E+08	4.76E+08	Uo LER MeV		0.6	Super-B
Fturn	Hz		1.67E+05	2.49E+05	alfa_c HER		4.40E-04	PEP-II
Fcoll	Hz		4.52E+08	2.31E+08	alfa_c LER		4.40E-04	HER 126 m
Num Bunch			2713	928	sigma-EHER		6.50E-04	LER 10.5 m
N HER			3.90E+10	4.06E+10	sigma-E LER		5.40E-04	
N LER			3.90E+10	6.33E+10	SR power MW		3.15	
					SR power MW		1.40	



RF power is needed to compensate losses

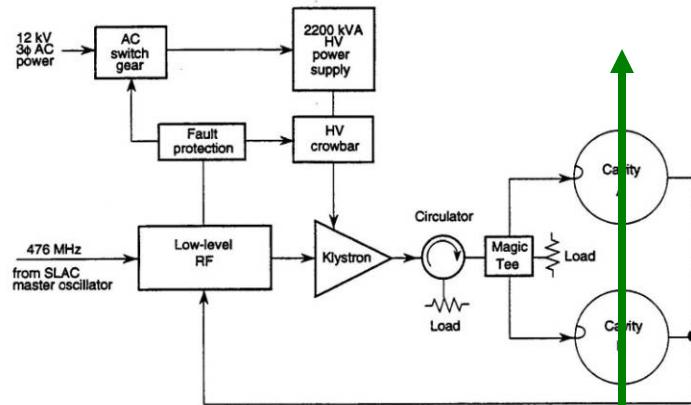
Sasha Novokhatski "RF/Impedance"

- 1) Synchrotron radiation
- 2) Joule energy loss in room-temperature cavities
- 3) Reflected power from cavities
- 4) HOM losses

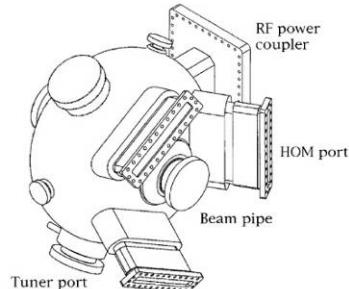
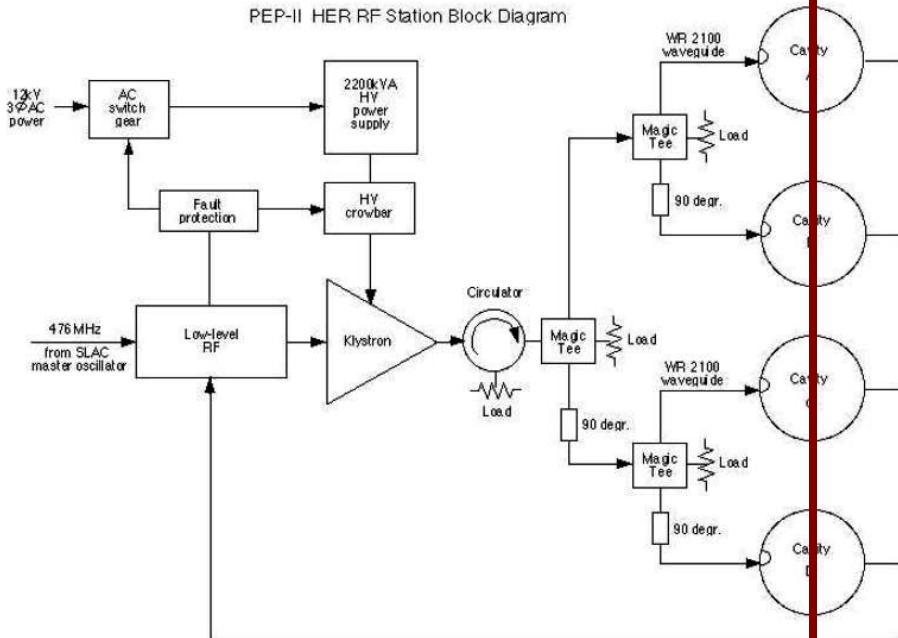


RF power distribution in PEP-II: 2 or 4 cavities per klystron

Sasha Novokhatski "RF/Impedance"



Block diagram of a single PEP-II RF station.



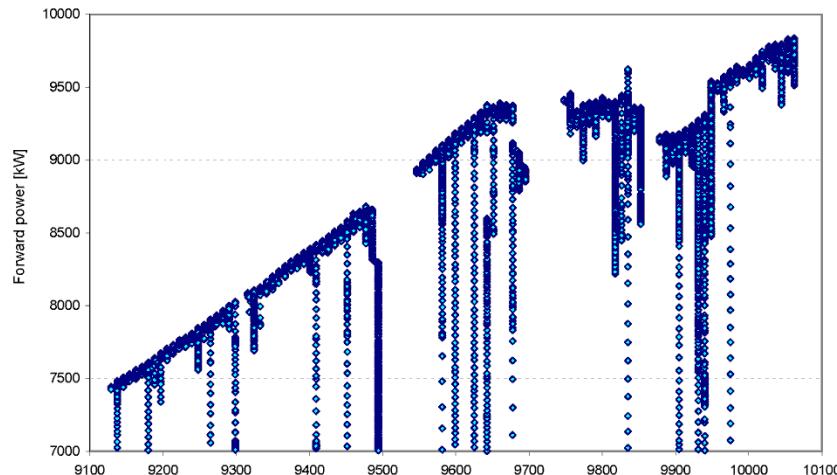
- Cavity voltage and forward power
 - Voltage in a cavity is limited by sparks and breakdowns
 - SLAC RF people consider voltage less than 0.6-0.7 MV per cavity
 - Forward power into a cavity and reflected power are limited by sparks in RF windows
 - SLAC people consider power less than 500 KW per cavity and less than 10% reflected



Maximum RF power achieved in PEP-II HER

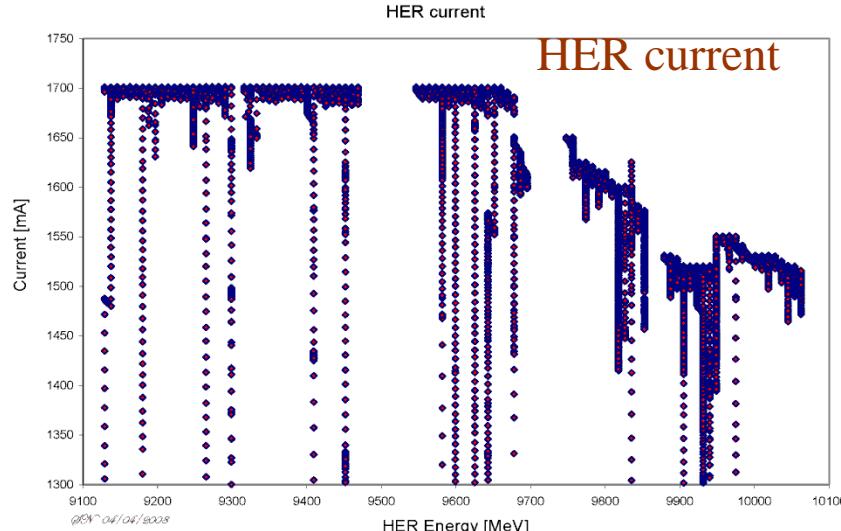


HER. Forward power to all cavities (11 klystrons, 28 cavities)



Forward power: 10 MW
11 klystrons 28 cavities

In average
350 KW per cavity



Comparison with

LEP-CERN

$E = 104.5 \text{ GeV}$

$\rho = 3.1 \text{ km}$

$\Pi = 26.7 \text{ km}$

$U_{\text{turn.}} = 3.4 \text{ GeV}$

$I = 1 \text{ mA}$

$P_{S.R.} = 3.4 \text{ MW}$

LEP LUMINOSITY REVISITED: DESIGN AND REALITY
Ralph W. Assmann, APAC, 2001



Super-B RF: Supply power 2009 in Frascati

Sasha Novokhatski "RF/Impedance"

HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER+
S.R. energy						Total	Zero I	Max			Number	Total	Total	Total	Total	Power for	LER	Power for	LER	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Total	cavity	forward	cavity	forward
energy	current	per turn	turn	com-	tum	voltag	length	pacinger	cavit	cavities	power	power	loss	power	power	MW	MW	MW	MW	MW	MW
GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
1E+36	6.7	1.5	2.1	4.4E-04	6.5E-04	8	6.0	4.2	0.7	12	3.15	0.1719	0.702	0.2171	4.24	0.35	6.58				
1E+36	6.7	1.5	2.1	4.4E-04	6.5E-04	9.5	5.5	4.2	0.7	14	3.15	0.2041	0.848	0.1045	4.31	0.31	6.61				
1E+36	6.7	1.5	2.1	4.4E-04	6.5E-04	11.5	5.0	4.2	0.7	16	3.15	0.2437	1.088	0.0188	4.50	0.28	6.91				
										8											
LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER+
S.R. energy						Total	Zero I	Max			Number	Total	Total	Total	Total	Power for	Supply	Power	Power	Power	eff.~50%
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Total	cavity	forward	cavity	forward
energy	current	per turn	turn	com-	tum	voltag	length	pacinger	cavit	cavities	power	power	loss	power	power	MW	MW	MW	MW	MW	MW
GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
1E+36	4.18	2.335	0.6	4.4E-04	5.4E-04	3.4	6.0	4.2	0.65	6	1.401	0.3545	0.254	0.3254	2.33	0.39	13.15				
1E+36	4.18	2.335	0.6	4.4E-04	5.4E-04	4	5.5	4.2	0.65	6	1.401	0.4013	0.351	0.1539	2.31	0.38	13.23				
1E+36	4.18	2.335	0.6	4.4E-04	5.4E-04	4.8	5.0	4.2	0.65	8	1.401	0.4849	0.379	0.1457	2.41	0.30	13.82				
										4											



Sasha Novokhatski "RF/Impedance"

- Only 18-24 cavities
- 9-12 RF stations are needed
- SLAC PEP-II has 36 cavities and 15 RF stations
- No coupler redesign is needed!
- Total consumption power for RF only 13.1 -13.8 MW



- Characterize wake fields by two parameters:
 - Loss factor
 - Energy spread
(or inductance)

$$k = \int W(s) \rho(s) ds$$

$$L = \sigma_0 \frac{\partial W}{\partial s}$$

$$L_{ind} = \sqrt{2\pi} \left(\frac{\sigma_0}{c} \right)^2 L$$



Bunch lengthening or shortening

Sasha Novokhatski "RF/Impedance"

$$\tilde{\sigma} = \sigma_0 * \left(1 + \frac{1}{2} \Lambda_w * L \right) \quad L = \sigma_0 \frac{\partial W}{\partial s} = \frac{L_{ind}}{\sqrt{2\pi} \left(\frac{\sigma_0}{c} \right)^2} \sim \Pi$$

Machine parameter for bunch lengthening

$$\Lambda_w = \frac{\sigma_0}{\Pi} \frac{Q_{bunch}}{\alpha E \left(\frac{\Delta E}{E} \right)^2} = \frac{Q_{bunch}}{\frac{\Delta E}{E}} \sqrt{\frac{1}{2\pi\alpha hEV_{RF} \cos\varphi}}$$



Parameters	EP-II (12 mm)	EP-II (6 mm)	Super-B LER	Super-B LER
Energy [GeV]	3.12	3.12	4.00	4.18E+00
Relative energy spread	7.70E-04	7.70E-04	8.00E-04	5.40E-04
Momentum compaction	1.23E-03	1.23E-03	3.20E-04	4.40E-04
Circumference [m]	2.20E+03	2.20E+03	1.80E+03	1.21E+03
Natural bunch length [mm]	12.00	6.00	6.00	6.00E+00
Bunch charge [nC]	8.83	8.83	8.83	10.11
Λ	0.021	0.011	0.036	0.094

Smaller momentum compaction in Super-B gives higher machine parameter for bunch lengthening , that means that impedance in Super-B must be smaller.

Sasha Novokhatski "RF/Impedance"

- PEP-II wake function for Super-B wake calculation
- Bunch length changes from 12 mm to 6 mm.
- Check every element to decrease total impedance



A sum. Repeat with new geometry.

Sasha Novokhatski "RF/Impedance"

LER bunch [mm]	PEP-II			PEP-II-Super-B			Super-B			Frascati	
	loss factor		L	loss factor		L	loss factor		L		
	12.0	12.0		6.0	6.00		6.0	6.0			
Element	Qnt			Qnt			Qnt				
RF cavity minus main mode	8	2.4	-0.6	10.0	4.7	-1.22	10	4.7	-1.22		
Resistive-wall	1	2.2	3.9	1.0	6.1	11.05	1	3.0	5.1	17" Cu pipe	
Interaction region	1	0.3	0.7	1.0	1.1	1.34	1	0.6			
Longitudinal Kicker	2	0.3	0.0	2.0	0.7	-0.73	2	0.7			
Transverse Kicker	4	0.2	-0.3	4.0	1.0	-0.98	4	1.0			
Injection kicker	2	0.026		2.0	0.1		2	0.1			
Abort kicker	2	0.026		2.0	0.1		2	0.1			
Collimators	6	0.9		6.0	3.5		6	1.8			
Transition round to octagonal	12	0.1		12.0	0.6		12	0.3			
Other Inductive elements	60	0.4		60.0	3.1		60	3.1			
Round BPM	150	0.08		150.0	0.11						
Octagonal BPM	200	0.66		200.0	1.06		350	0.54			
CSR											
Total loss and lengthening		7.4	41.1		22.1	164.41			15.8		



Summary

- SLAC PEP-II RF stations (modulators, klystrons and cavities) showed high performance in achieving very high power level, which is needed for successful operation of Super-B project.
- Small momentum compaction of the Super-B requires smaller impedance of the rings in order to avoid large bunch lengthening and single bunch instabilities and all other current dependant effects.
- Wake field studies showed that impedance can be reduced by changing materials of the chamber walls, avoiding open ceramic absorbing tiles in IR and other regions, smoothing chamber geometry, using symmetrical collimators, developing new BPMs. At this low level of impedance we have to consider other effects, which were ignored at "higher" impedance machines. For example, CSR wake fields and chamber coating (important for transverse fields)
- Final wake field analysis should be included in engineering design of every beam chamber element.

