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

Sasha Novokhatski

SLAC National Accelerator Laboratory

SuperB Project Workshop and Proto-Collaboration Meeting X

October 6-9, 2009

SLAC National Accelerator Laboratory

INFN Frascati new site.

Super-B parameters July 22, 2009

Bending radius Super-B PEP-II
HER 126 m 165 m
LER 10.5 m 13.8 m

Parameter	Units	Super-B TorVergata 1-Mar-09 with SR	Super-B LNF 22-Jul-09 with SR LER
E HER (positrons)	GeV	6.9	6.7
E LER (electrons)	GeV	4.06	4.18
Energy ratio		1.70	1.60
Bunch length HER	cm	0.5	0.5
Bunch length LER	cm	0.5	0.5
I HER	mA	2200	2120
I LER	mA	2200	2120
Circumference	m	1800	1315
N. Buckets distance		2	2
Gap		0.97	0.97
Frf	Hz	4.76E+08	4.76E+08
Fturn	Hz	**1.67E+05**	**2.28E+05**
Fcoll	Hz	**2.31E+08**	**2.31E+08**
Num Bunch		**1385**	**1011**
N HER		**5.96E+10**	**5.74E+10**
N LER		**5.96E+10**	**5.74E+10**
Damping_long HER	msec	21	14.5
Damping_long LER	msec	20.0	22.0
Uo HER	MeV	2.3	2.03
Uo LER	MeV	1.40	0.83
alfa_c HER		3.50E-04	4.04E-04
alfa_c LER		3.20E-04	4.24E-04
sigma-EHER		5.80E-04	6.15E-04
sigma-E LER		8.20E-04	6.57E-04
CM sigma_E		**1.00E-03**	**9.00E-04**
SR power loss HER	**MW**	**5.06**	**4.30**
SR power loss LER	**MW**	**3.08**	**1.76**

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What change with circumference change?

Harmonic number $$h = \frac{P}{\lambda_{RF}}$$

1800m→1315m
H: 2856→2087

Synchrotron frequency and synchrotron tune

$$f_s = f_{RF}\sqrt{\frac{\alpha}{2\pi h}\times\frac{V_{RF}\cos\left(90^\circ-\phi_s\right)}{E}} \qquad \nu_s = h\frac{f_s}{f_{RF}}$$

Synchronous phase:

$$\sin\left(90^\circ-\phi_s\right)=\frac{U_{SR}}{V_{RF}}$$

Smaller ring => higher synchrotron frequency

Natural (zero current) bunch length

$$\sigma_0 = \frac{c}{f_{RF}}\times\delta_E\times\sqrt{\frac{\alpha h}{2\pi}\times\frac{E}{V_{RF}\cos\left(90^\circ-\phi_s\right)}}$$

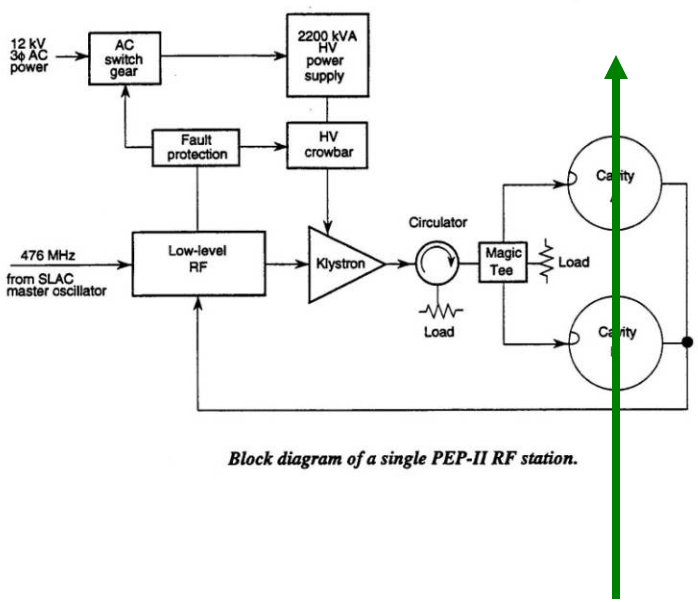
Smaller ring => shorter bunch length.

RF Voltage

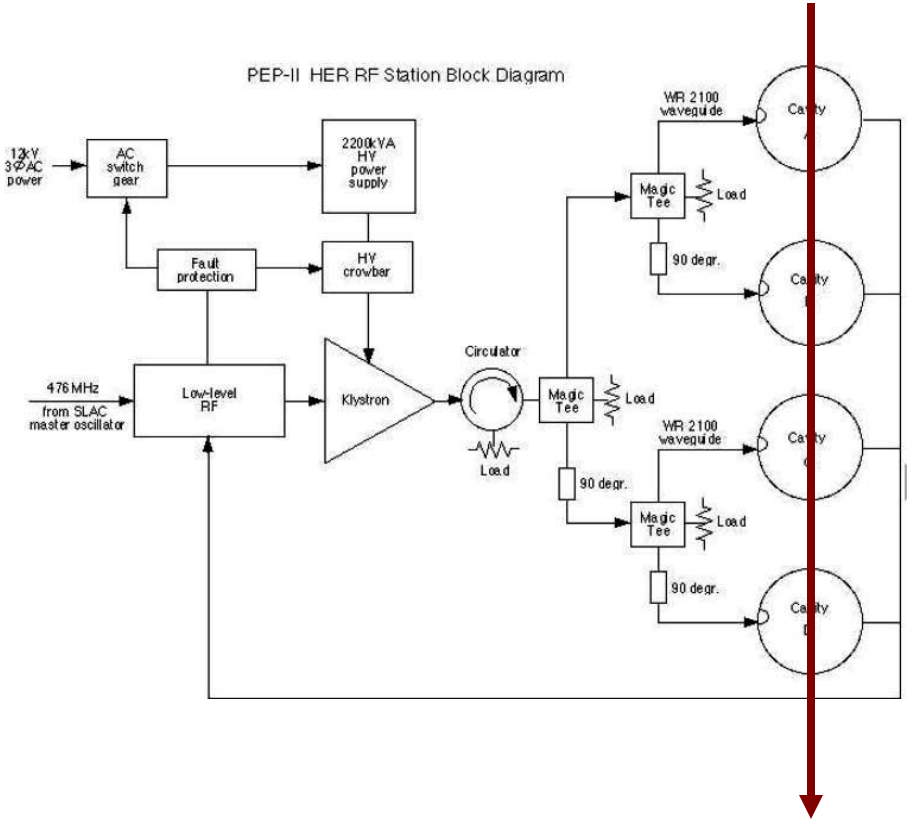
Parameter	Units	Super-B TorVergata 1-Mar-09	Super-B LNF 22-Jul-09	
Circumference	m	1800	1315	-0.2694444
E HER (positrons)	GeV	6.9	6.7	-0.0289855
alfa_c HER		3.80E-04	4.04E-04	0.0631579
sigma-EHER		5.80E-04	6.15E-04	0.0603448
HER RF Voltage		6.70	5.70	-0.1492537
E LER (electrons)	GeV	4.06	4.18	0.0295567
alfa_c LER		3.20E-04	4.24E-04	0.325
sigma-E LER		8.20E-04	6.57E-04	-0.1987805
LER RF Voltage		6.00	4.10	-0.3166667

Compensation by lowering the RF voltage leads to larger beam loading.

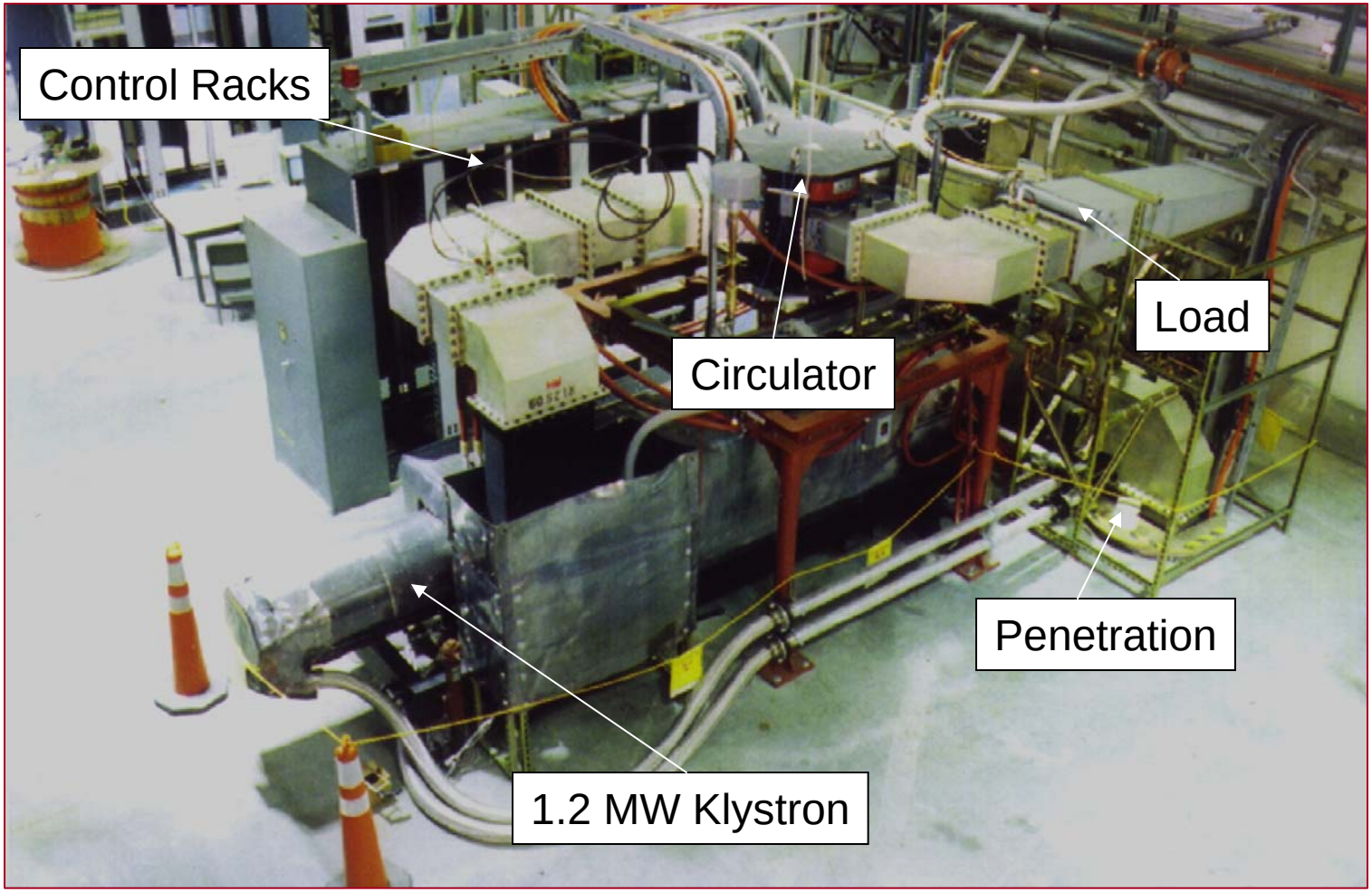
RF power distribution in PEP-II: 2 or 4 cavities per klystron



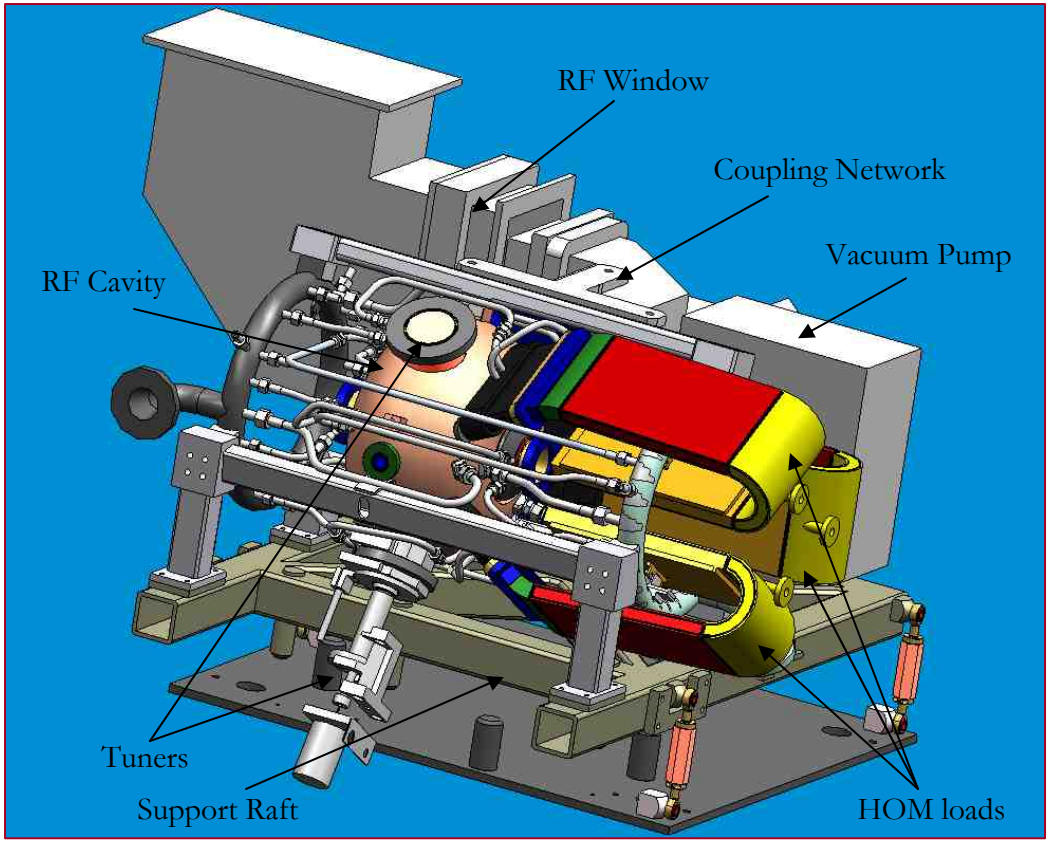
Block diagram of a single PEP-II RF station.



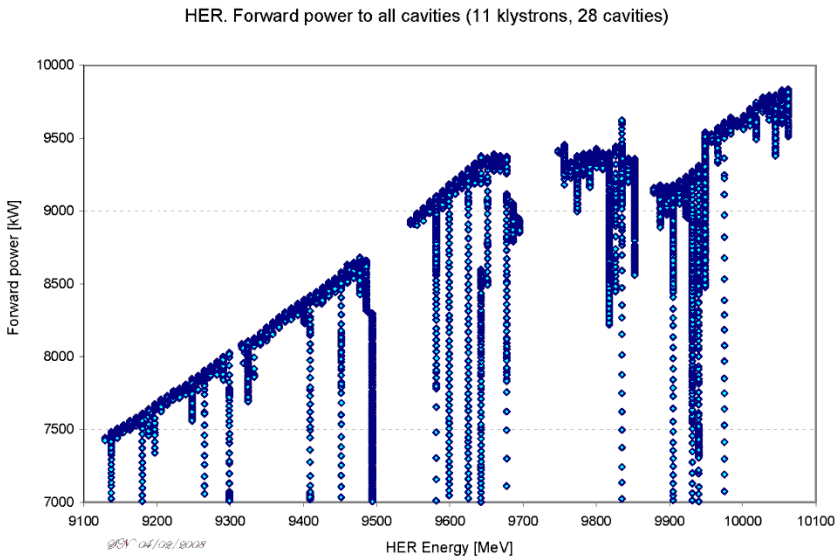
PEP-II RF System: klystron

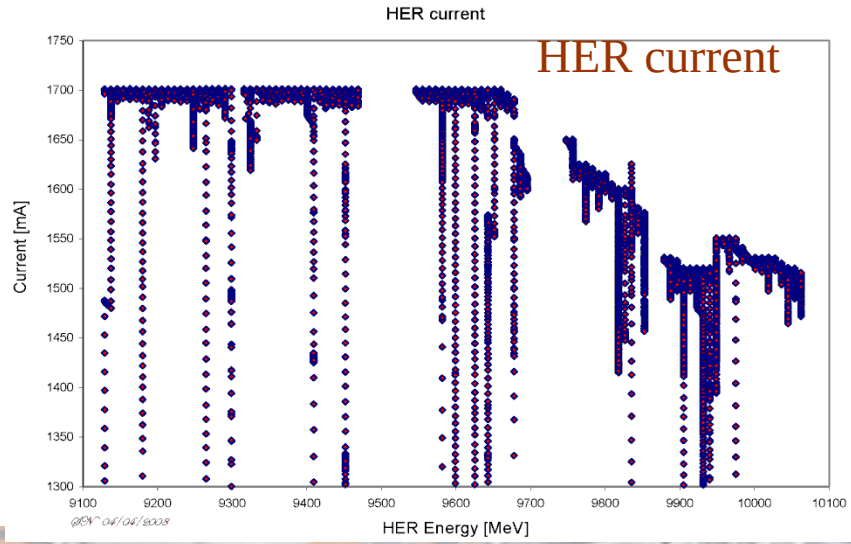


PEP-II RF System: cavity



Maximum RF power achieved in PEP-II HER





Forward power: 10 MW

11 klystrons 28 cavities

In average
350 KW per cavity

Comparison with

LEP-CERN

$E = 104.5$ GeV

$\rho = 3.1$ km

$\Pi = 26.7$ km

$U_{turn.} = 3.4$ GeV

$I = 1$ mA

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

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

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RF cavity limits

- Cavity voltage and forward power
  - Voltage in a cavity is limited by sparks and breakdowns
    - SLAC PEP-II experience: voltage should be less than 0.75 MV per cavity
  - Forward power into a cavity and reflected power are limited by sparks in RF windows
    - SLAC PEP-II experience: transmitted power should be less than 500 KW per cavity and reflected power less than 10%

Super-B RF: Supply power 2009 in Frascati in July

Using PEP-II cavities with coupling factor 3.6

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	Power for	LER
Lumi	Beam energy	Beam current	loss per turn	Momen-tum com-paction	Momen-tum spread	RF voltage	Bunch length	Bunch spacing	voltage per cavit	of cavities klystro	S.R. power	HOM power	cavity loss	reflected power	forward power	one cavity	Total forward
	GeV	A	MeV			MV	mm	nsec	MV		MW	MW	MW	MW	MW	MW	MW
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	5.7	5.0	4.2	0.3	20 10	4.3036	0.5187	0.214	5.8859	10.92	0.55	13.69
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	7	4.5	4.2	0.3	24 12	4.3036	0.6458	0.269	4.6467	9.86	0.41	12.73

LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+ LER Supply Power eff.~50%
		S.R. energy				Total	Zero I		Max	Number			Total	Total	Total	Power for	
Lumi	Beam energy	Beam current	loss per turn	Momen-tum com-paction	Momen-tum spread	RF voltag	Bunch length	Bunch spacing	voltage per cavit	of cavities klystro	S.R. power	HOM power	cavity loss	reflected power	forward power	one cavity	
	GeV	A	MeV			MV	mm	nsec	MV		MW	MW	MW	MW	MW	MW	MW
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	4.1	5.0	4.2	0.65	6 3	1.7596	0.3834	0.369	0.2604	2.77	0.46	27.39
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	5	4.5	4.2	0.65	8 4	1.7596	0.4693	0.411	0.2234	2.86	0.36	25.46

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Super-B RF: Supply power 2009 in Frascati in July

Changing coupling from 3.6 to 6.0

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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	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Total
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	forward
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	5.7	5.0	4.2	0.4	14	4.3036	0.4609	0.58	0.4461	5.79	0.41	8.66
										7							
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	7	4.5	4.2	0.5	14	4.3036	0.541	0.875	0.0884	5.81	0.41	8.86
										7							
LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+ LER
		S.R. energy				Total	Zero I		Max	Number			Total	Total	Total	Power for	Supply
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Power
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	eff.~50%
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	4.1	5.0	4.2	0.65	6	1.7596	0.3834	0.7	0.0245	2.87	0.48	17.32
										3							
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	5	4.5	4.2	0.65	8	1.7596	0.4693	0.781	0.0406	3.05	0.38	17.72
										4							

Super-B RF: Supply power 2009 in Frascati in July

Changing coupling from 3.6 to 7.0

Sasha Novokhatski "RF/Impedance"

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	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Total
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	forward
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	5.7	5.0	4.2	0.4	14	4.3036	0.4611	0.58	0.2858	5.63	0.40	8.53
										7							
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	7	4.5	4.2	0.5	14	4.3036	0.5411	0.875	0.0299	5.75	0.41	8.84
										7							

LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+
		S.R. energy				Total	Zero I		Max	Number			Total	Total	Total	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Supply
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	Power
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	eff.~50% MW
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	4.1	5.0	4.2	0.65	6	1.7596	0.3836	0.7	0.0533	2.90	0.48	17.05
										3							
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	5	4.5	4.2	0.65	8	1.7596	0.4694	0.781	0.0763	3.09	0.39	17.67
										4							

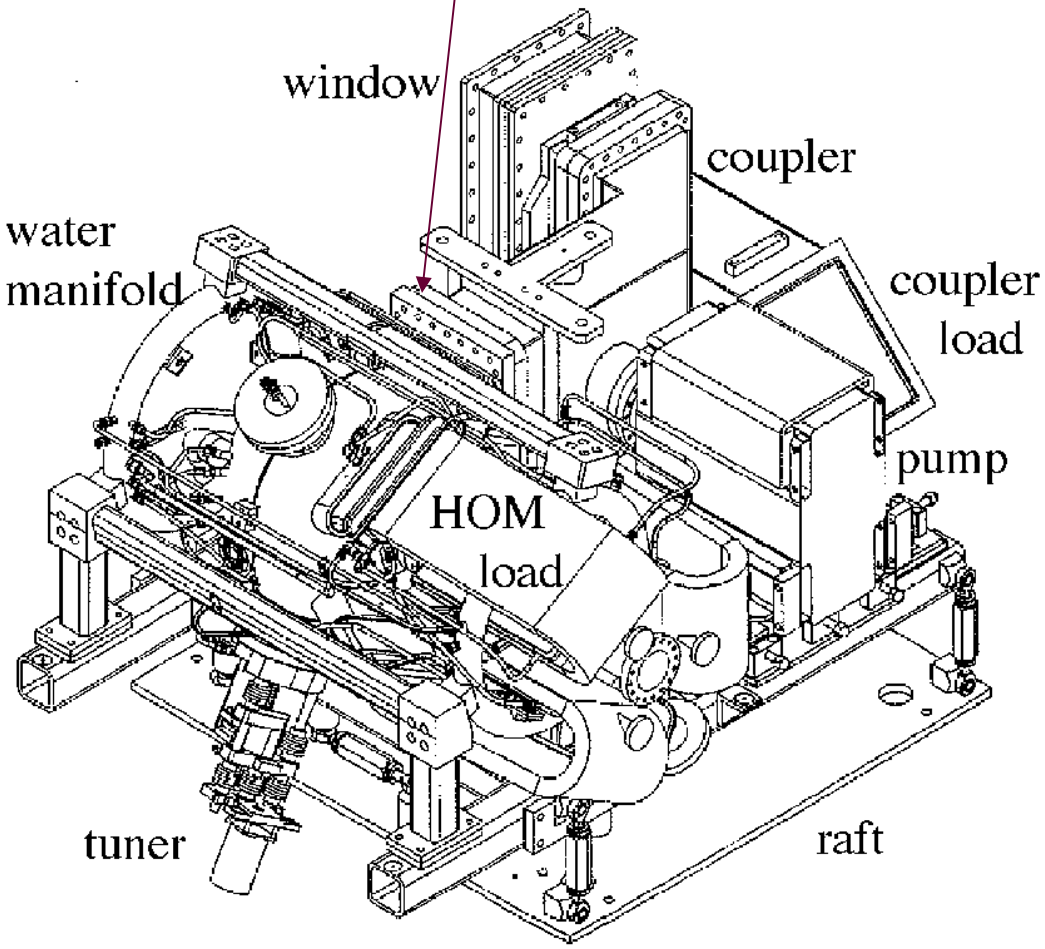
Super-B RF: Supply power 2009 in Frascati in July

Changing coupling from 3.6 to 8.0

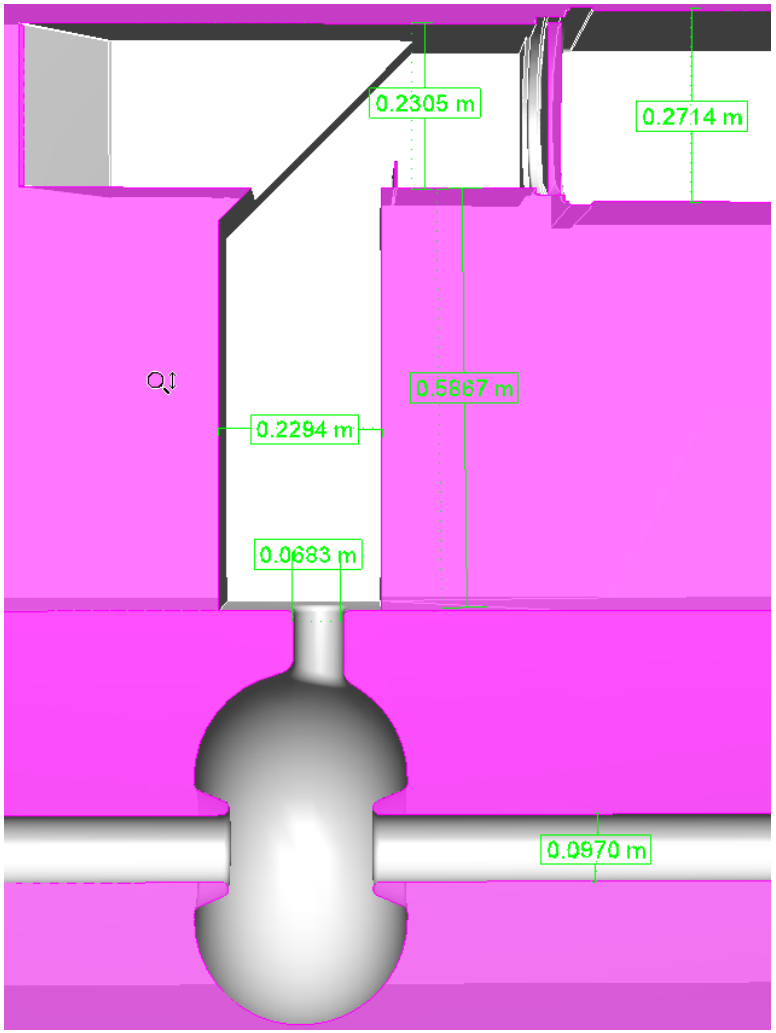
HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER+
		S.R. energy				Total	Zero I		Max	Number			Total	Total	Total	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Total
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	forward
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	5.7	5.0	4.2	0.4	14	4.3036	0.4611	0.58	0.1771	5.52	0.39	8.45
										7							
1E+36	6.7	2.12	2.03	4.0E-04	6.2E-04	7	4.5	4.2	0.5	14	4.3036	0.5411	0.875	0.0045	5.72	0.41	8.85
										7							
LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+ LER
		S.R. energy				Total	Zero I		Max	Number			Total	Total	Total	Power for	Supply
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	of	S.R.	HOM	cavity	reflected	forward	one	Power
	energy	current	per turn	tum com-	tum	voltag	length	spacing	er cavit	cavities	power	power	loss	power	power	cavity	eff.~50%
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	klystro	MW	MW	MW	MW	MW	MW	MW
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	4.1	5.0	4.2	0.65	6	1.7596	0.3836	0.7	0.0863	2.93	0.49	16.90
										3							
1E+36	4.18	2.12	0.83	4.2E-04	6.6E-04	5	4.5	4.2	0.65	8	1.7596	0.4694	0.781	0.1153	3.13	0.39	17.70
										4							

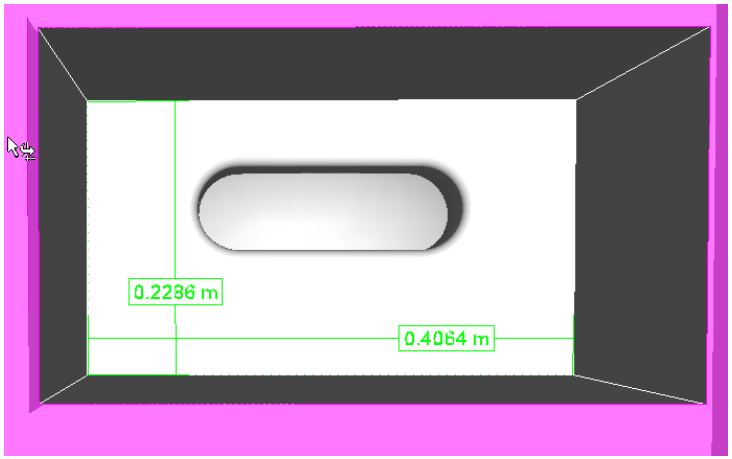
Sasha Novokhatski "RF/Impedance"

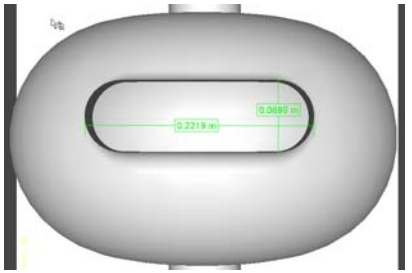
We may disconnect a coupler box



PEP-II cavity with a coupling box

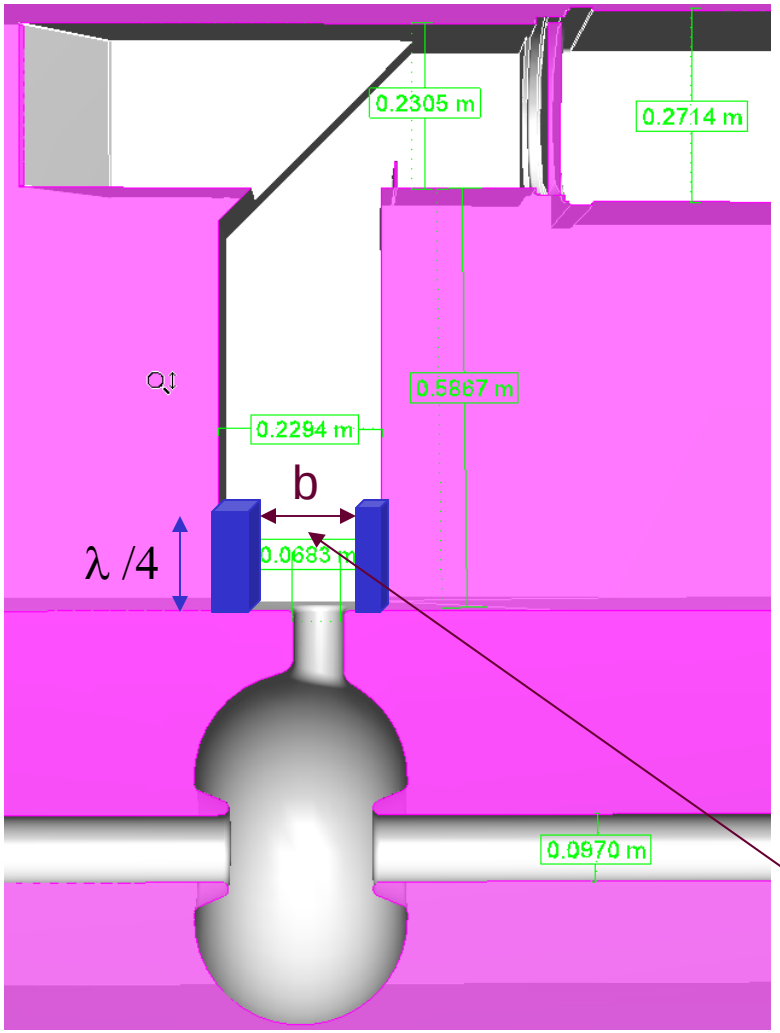


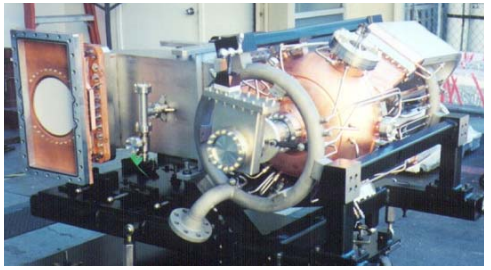


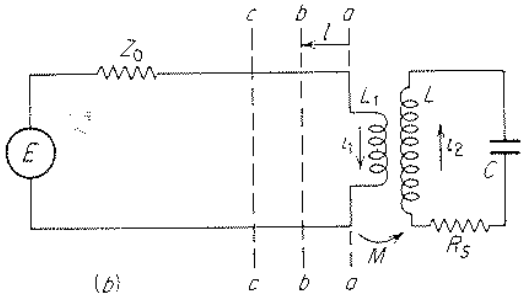


Changing the coupling factor β of the PEP-II cavity for a better RF performance at Super-B in Frascati

Sasha Novokhatski "RF/Impedance"







$$Q_L = \frac{Q_0}{1+\beta} \qquad Q_0 = \frac{\omega L}{R_s}$$

$$\beta = \frac{(\omega M)^2}{Z_0 R_s} \frac{1}{1+\left(\frac{\omega L_1}{Z_0}\right)^2}$$

$$Z_0 \sim b$$

Gap transient from K.Bertsche

Sasha Novokhatski "RF/Impedance"

From: Bertsche, Kirk
Sent: Tuesday, September 15, 2009 6:02 PM
To: Novokhatski, Alexander
Subject: New calculations

Sasha,

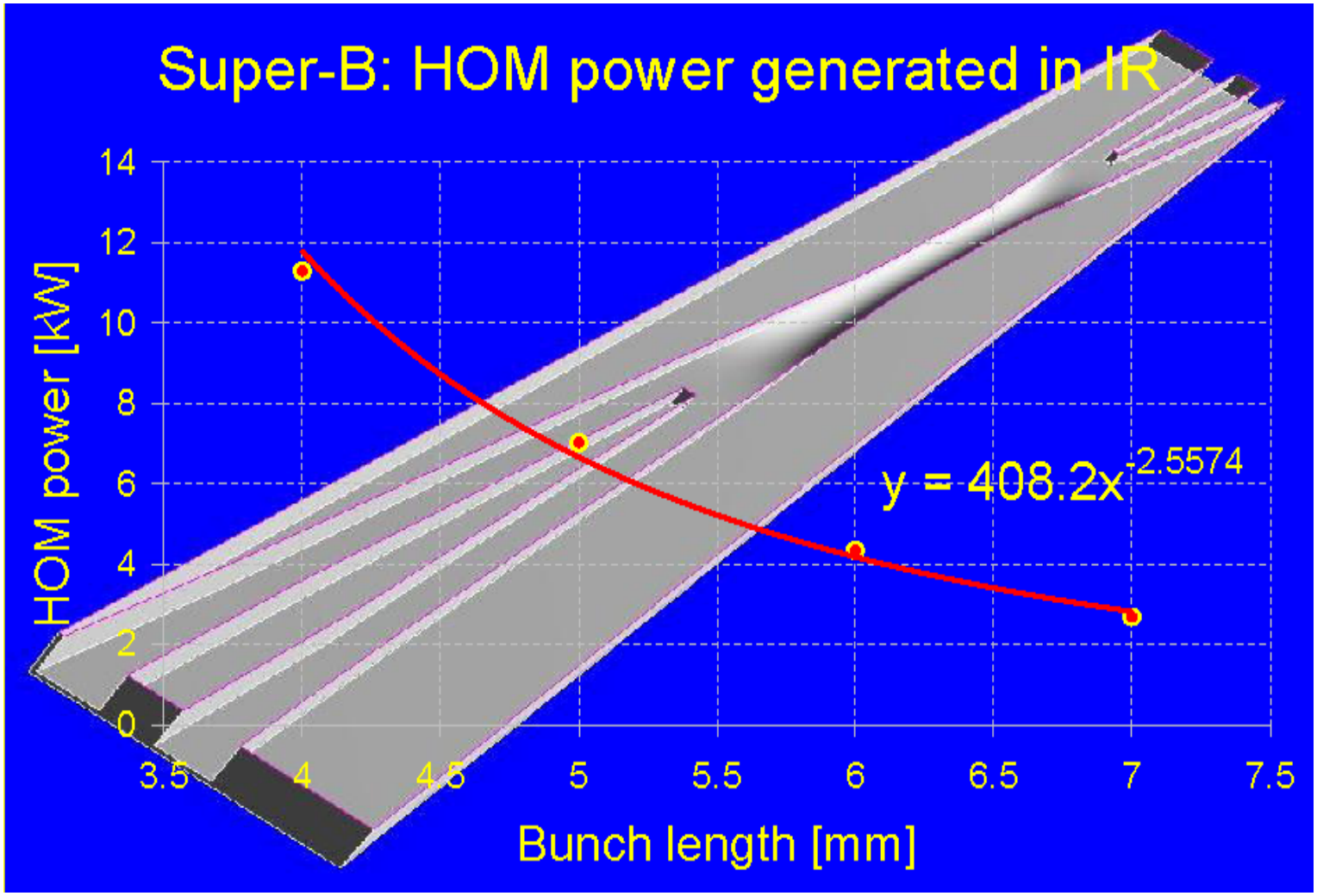
New suggestions:

HER 7MV, 12 cavities, change beta to 7.8 LER 5MV, 8 cavities, keep beta at 3.9
Phase transients mismatch ~0.8 deg (a bit large)

HER 5.7MV, 12 cavities, change beta to 7.8 LER 4.1MV, 6 cavities, keep beta at 3.9 Phase transients mismatch ~2.5 deg (too large)
BUT with 8 LER cavities it is back to ~0.8 deg

Kirk

Wake field simulations for the Super-B Interaction Region



News in wake field calculations

Sasha Novokhatski "RF/Impedance"

More results and details in S. Weathersby presentation

Summary

- A small modification of a coupler box of the PEP-II RF cavities will considerably improve the RF performance of the Super-B at the Frascati site.
- Final geometrical changes of a coupler box will be obtained using MAFIA simulations.
- A model and “cold measurement” may follow.