Conventional source developments (300Hz Linac scheme and the cost, Part-II)

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PosiPol-2012 at DESY Zeuthen

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0. Short review of 300Hz conventional positron source

From T. Omori et al. / NIMA 672 (2012) 52–56

The baseline choice of the ILC positron source is the helical undulator scheme. After accelerating the electron beam in the main linac, it passes a 150 m long helical undulator to create a circularly polarized photon beam, and goes to the interaction point [2]. The photon beam hits the production target and generates electron–positron pairs. The positrons are captured, accelerated to 5 GeV, damped, and then accelerated to the collision energy in the main linac. Thus the undulator based positron generation gives interconnection to nearly all sub-systems of the ILC.

The proposed ILC positron source contains risks only in the target area. Therefore, we concentrate to cure these risks in two ways:
(1)pulse stretching by 300 Hz generation; the proposed scheme creates 2600 bunches in about 60 ms, and
(2) optimized drive beam and target thickness parameters.

Following design is the backup for proposed ILC positron source.

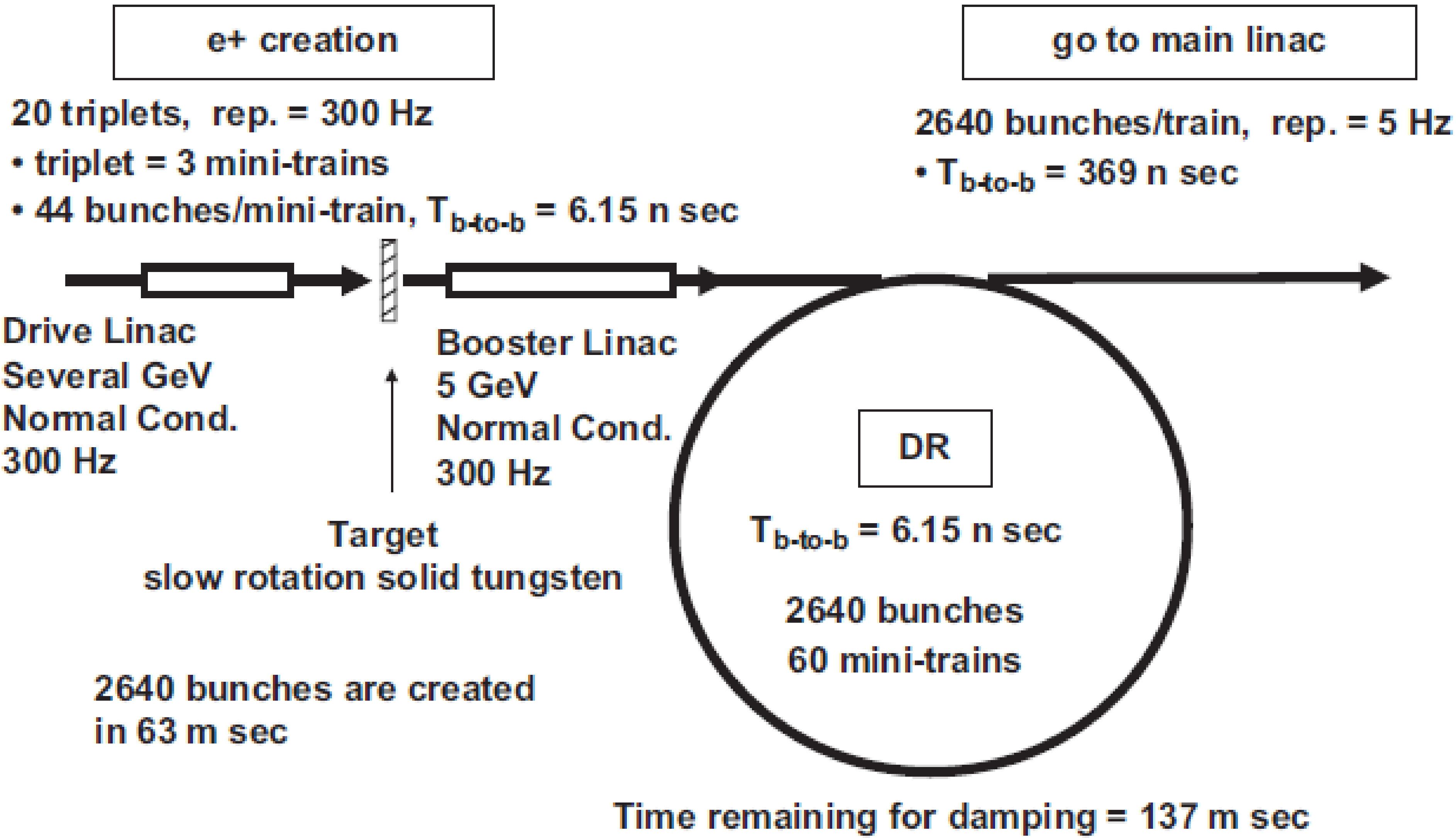
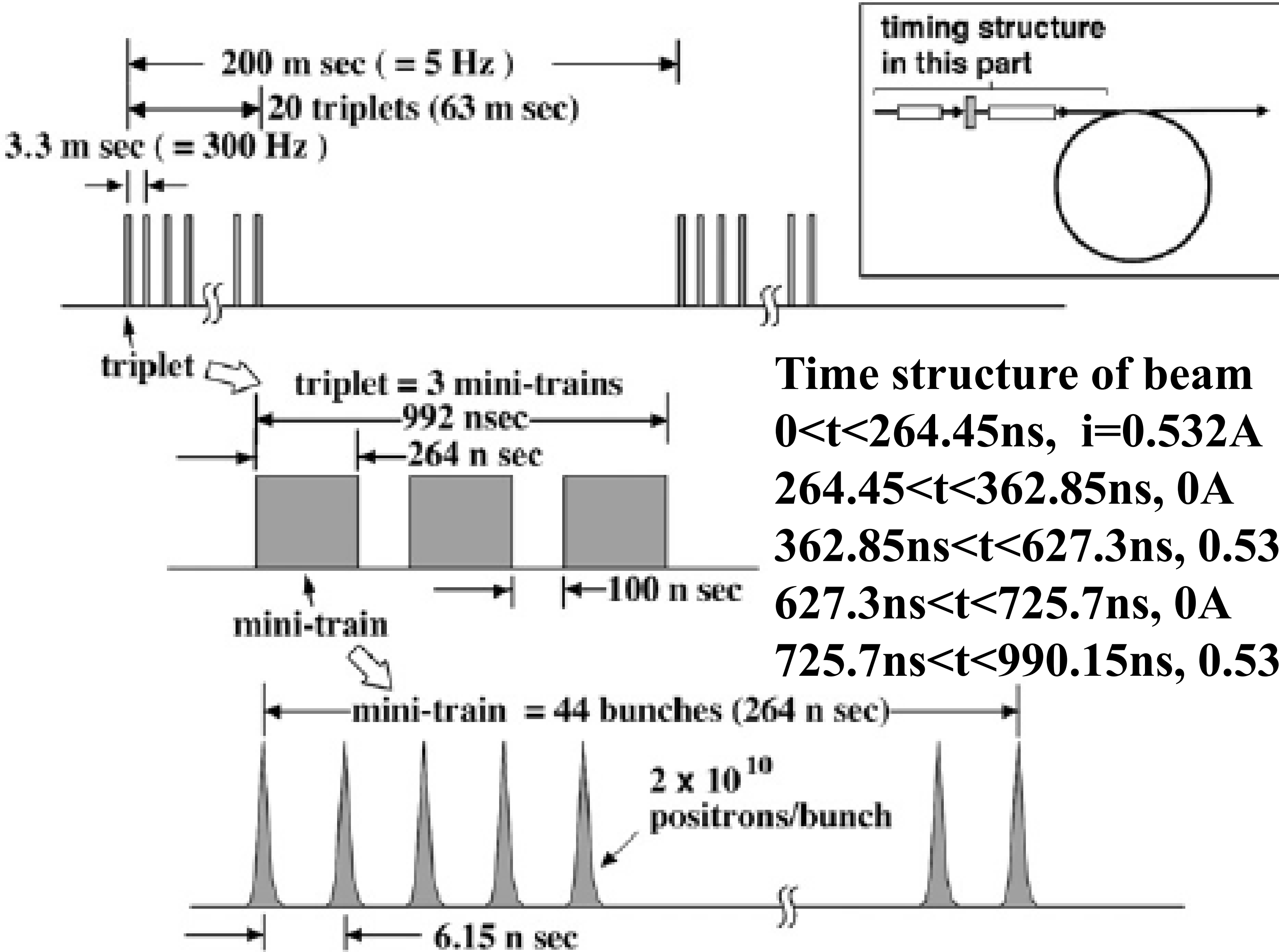


Fig. 1. Schematic view of the 300 Hz scheme.



Time structure of beam

0<t<264.45ns, i=0.532A

264.45<t<362.85ns, 0A

362.85ns<t<627.3ns, 0.532A

627.3ns<t<725.7ns, 0A

725.7ns<t<990.15ns, 0.532A

Fig. 2. Timing structure in the positron source and in the booster linac.

Bunch by bunch extraction from Damping Ring to make ILC beam train.

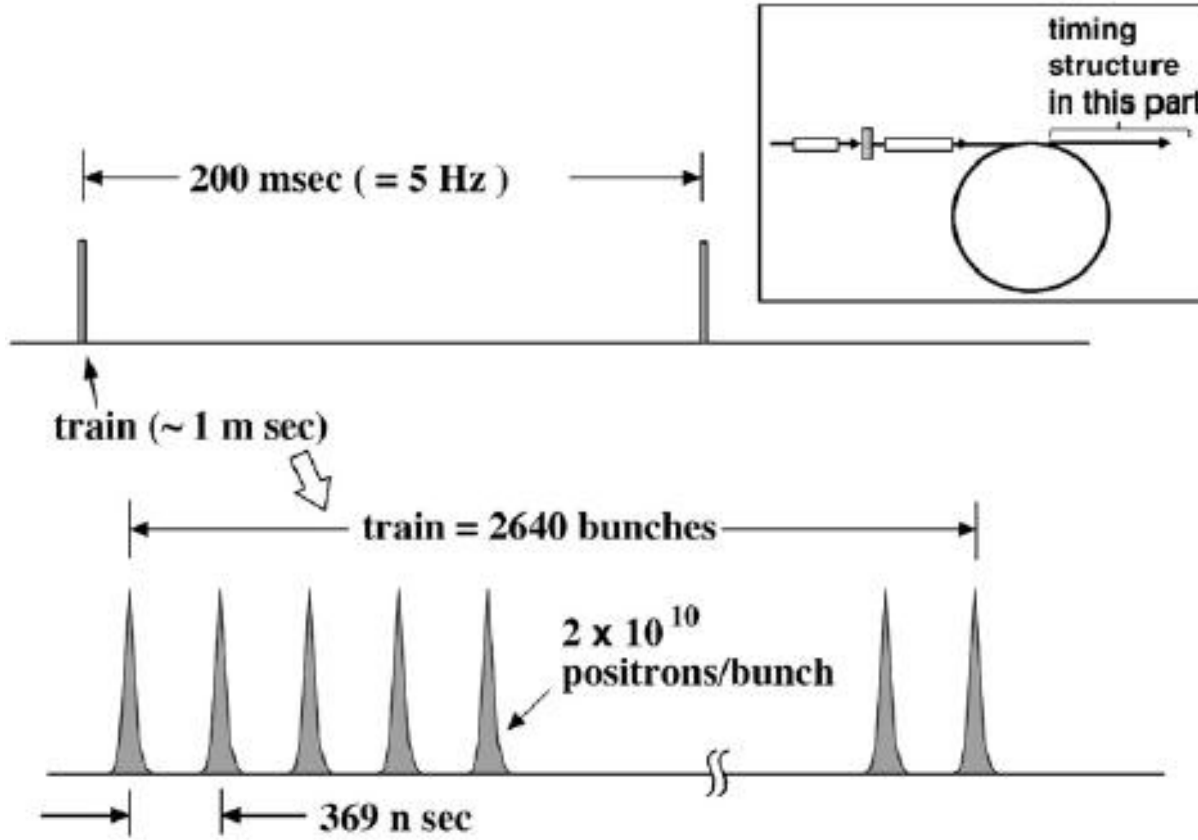
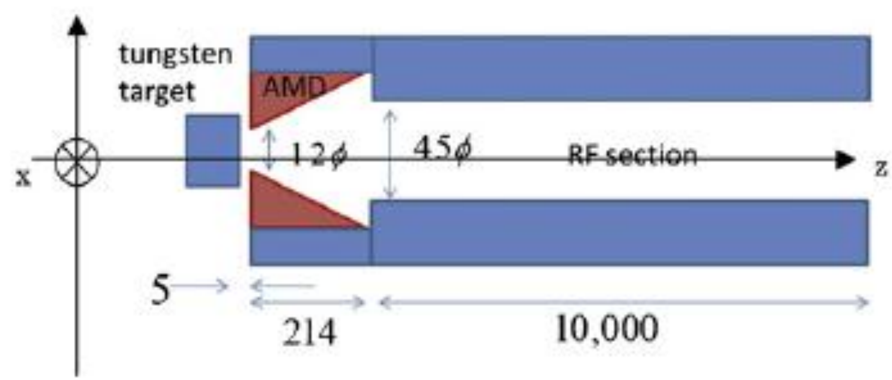


Fig. 4. Time structure after the damping ring.

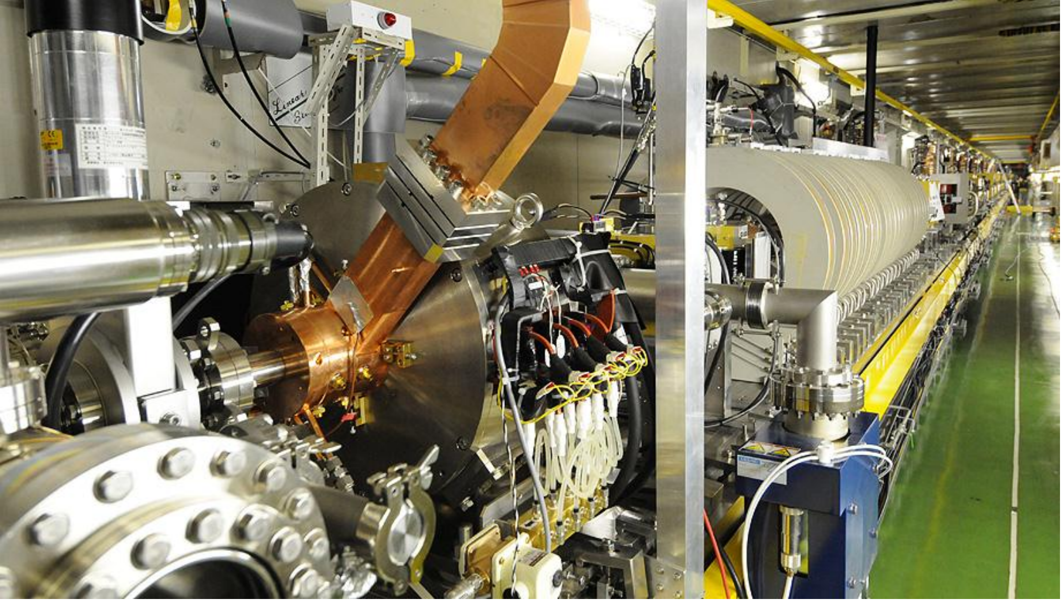
This is the model for positron target system to confirm the generation of ILC positron beam.



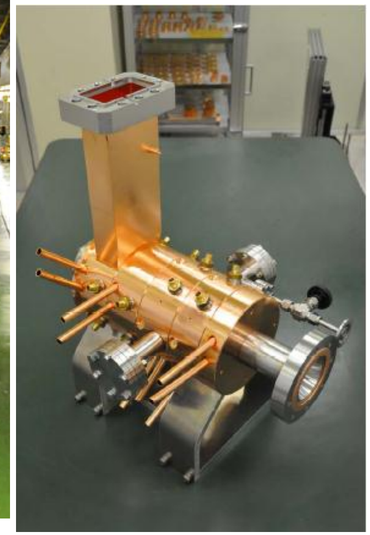
Abstract of the paper.

A possible solution to realize a conventional positron source driven by a several-GeV electron beam for the International Linear Collider is proposed. A 300 Hz electron linac is employed to create positrons with stretching pulse length in order to cure target thermal load. ILC requires about 2600 bunches in a train which pulse length is 1 ms. Each pulse of the 300 Hz linac creates about 130 bunches, then 2600 bunches are created in 63 ms. Optimized parameters such as drive beam energy, beam size, and target thickness, are discussed assuming a L-band capture system to maximize the capture efficiency and to mitigate the target thermal load. A slow rotating tungsten disk is employed as positron generation target.

Photo-cathode RF Gun



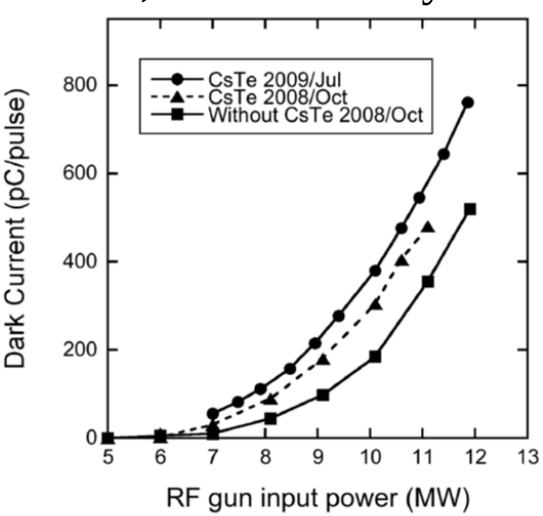
1.3GeV ATF Linac, results by 80MeV beam.

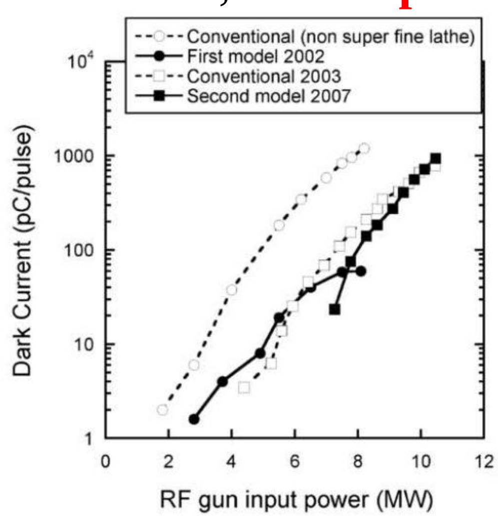


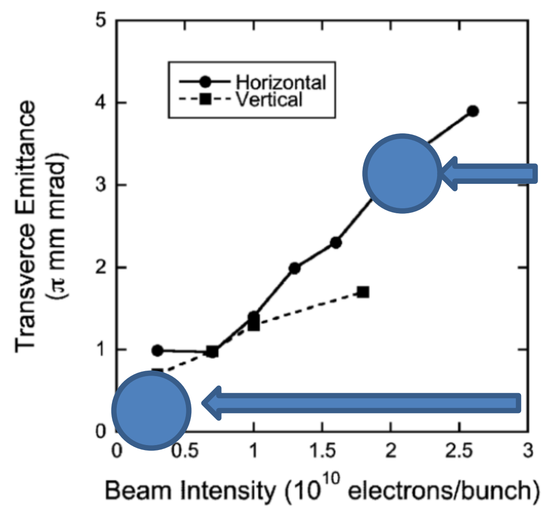
10MeV 3.6 cell gun

6MeV 1.6 cell gun

From 2002 onward, successive improvements have been incorporated into newer models of the RF gun. In 2008, a new gun incorporating all of the earlier modifications was produced for the ATF. A typical transverse emittance of **1.3 π mm·mrad** has been obtained under solenoid field of 0.18 T, beam intensity of **1.6nC/bunch**, and **RF power of 9 MW**.







$2x10^{10}$ electrons/bunch for ILC source

Study to reduce normalized emittance.
0.3 πmm-mrad at 0.1nC/bunch

From NIM A 560 (2006) 233–239.

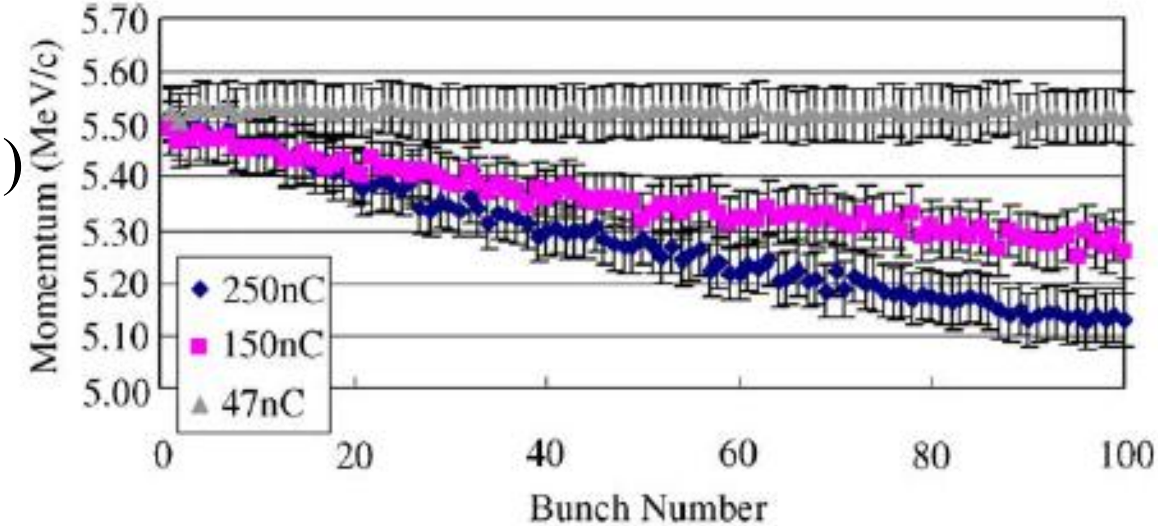


Fig. 11. Momentum of a multi-bunch beam at a laser injection timing of 1.703 μs.

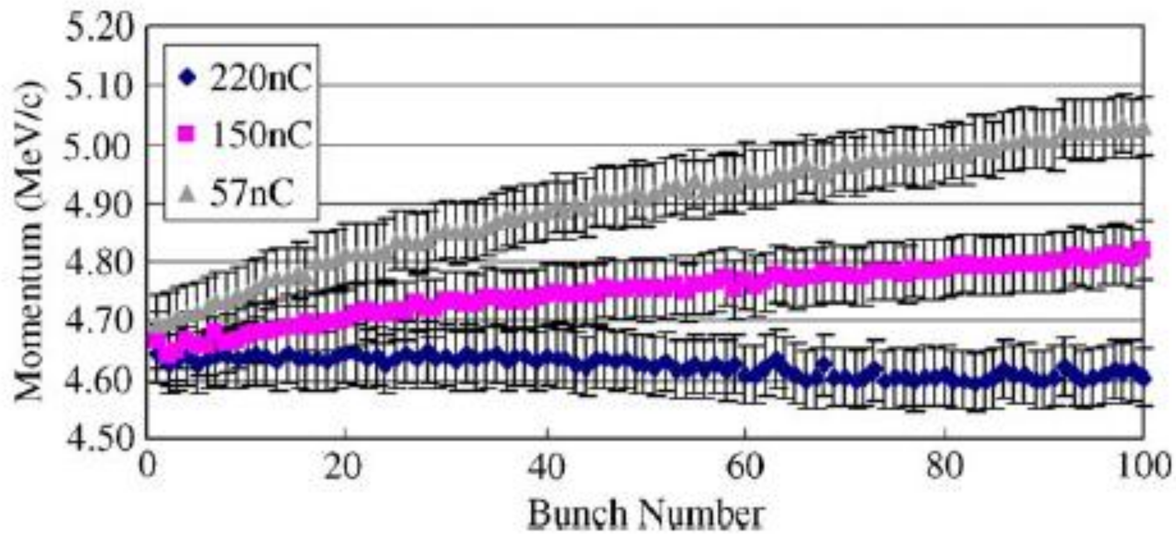
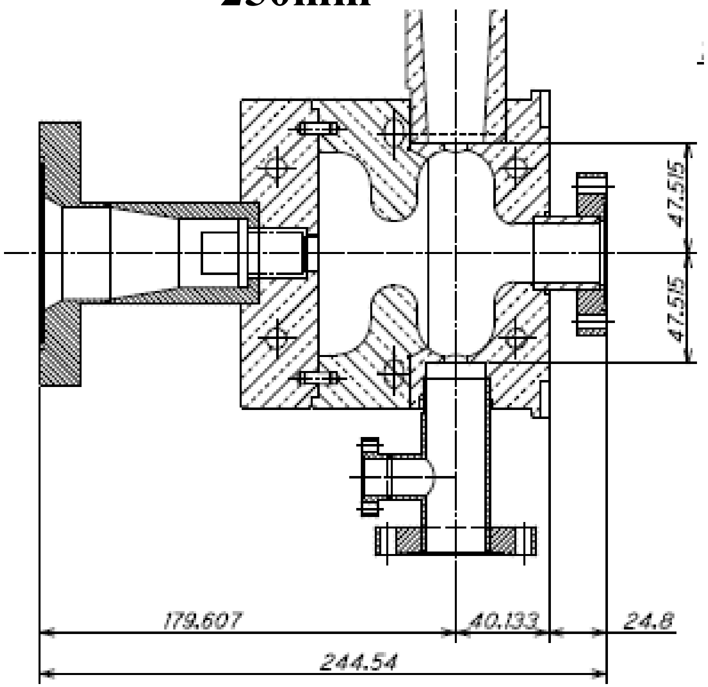


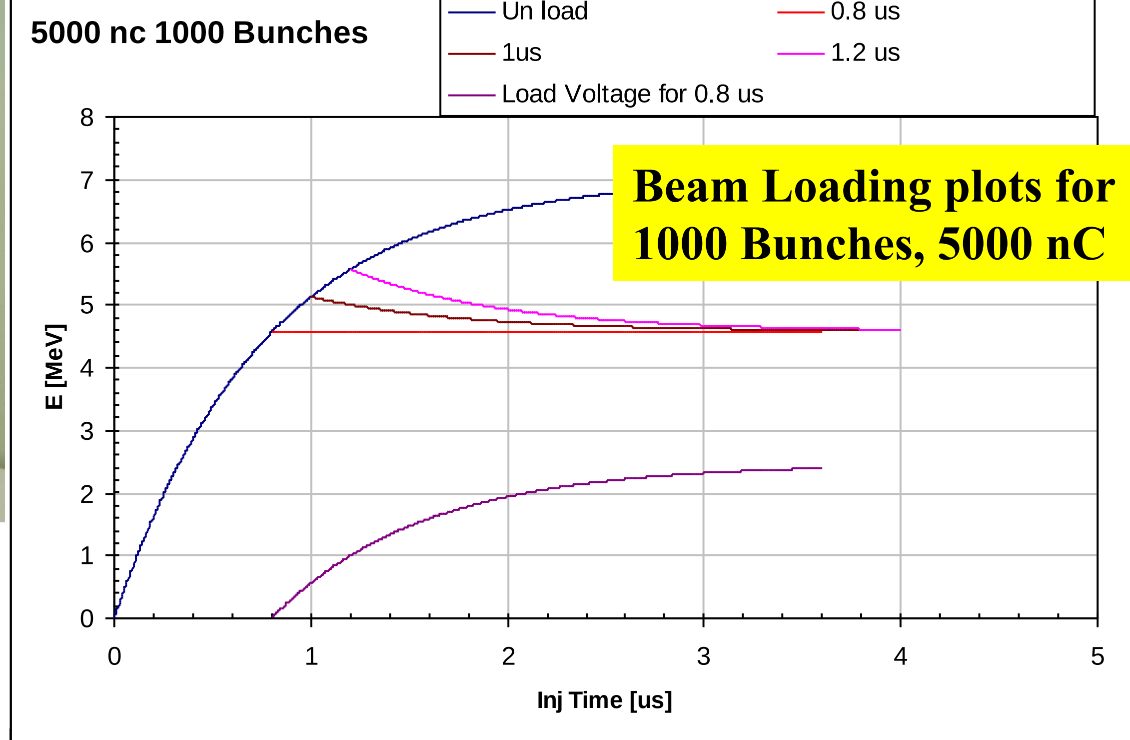
Fig. 12. Momentum of a multi-bunch beam at a laser injection timing of 0.906 μs.

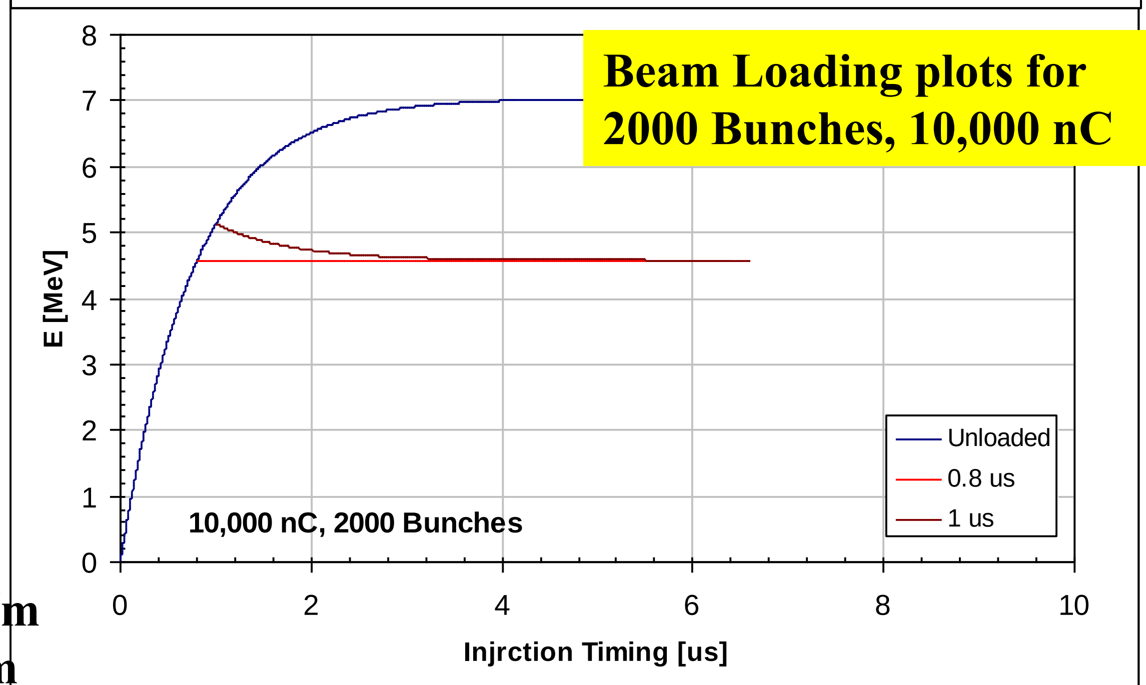
JFY2004
300nC achieved
Schedule
JFY 2012 to 2015
1000nC-8000nC
JFY 2012 to 2015
X-ray Gen.

250mm

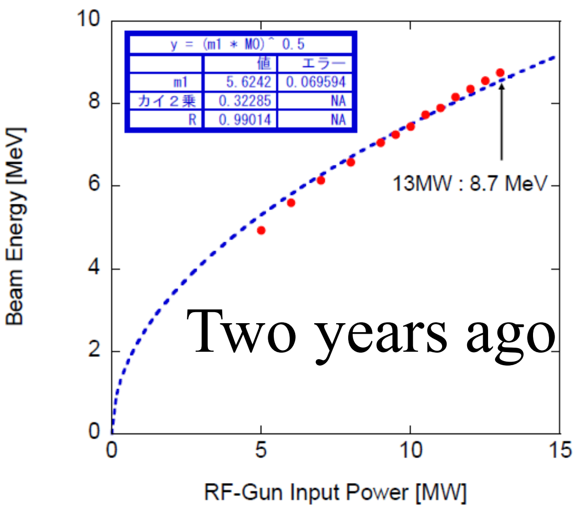


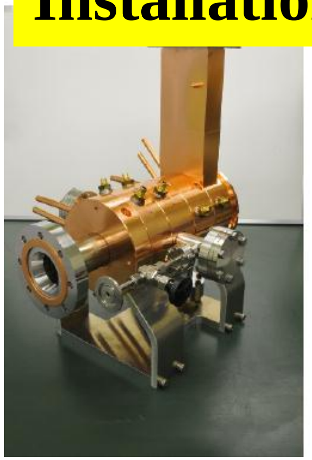
S-band RF Gun, more than 100MV/m
Operation:120MV/m,max.:140MV/m



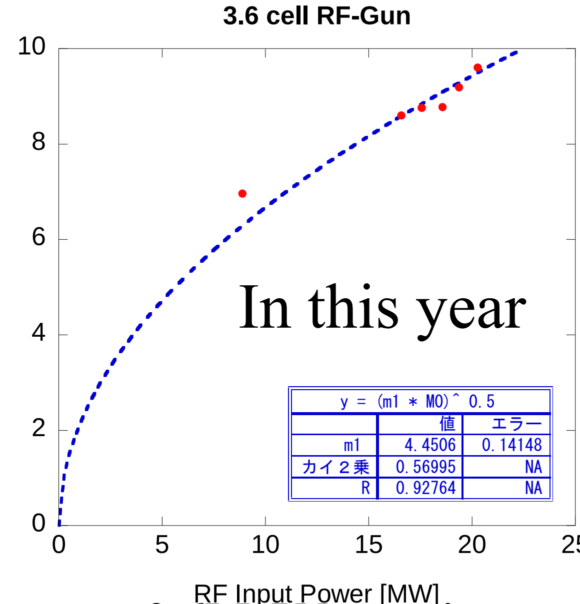


3.6 cell RF Gun Installation

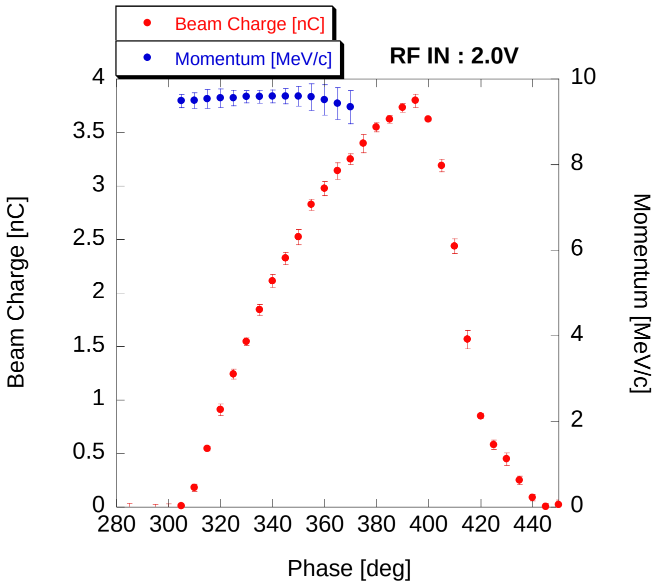


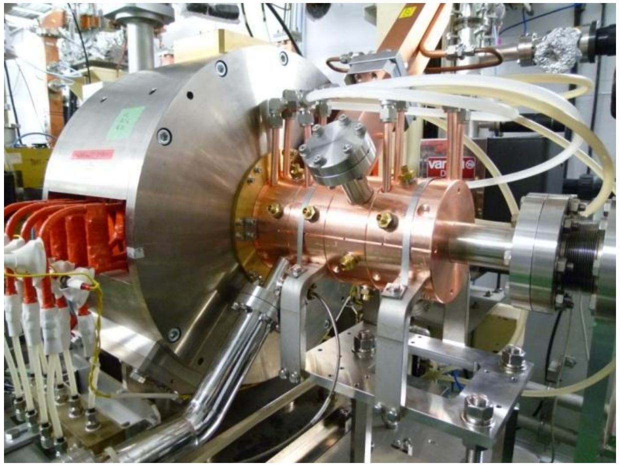


ATF インストールの様子



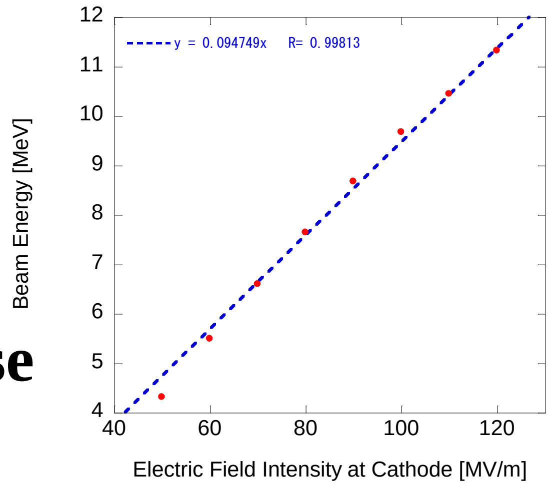
9.6MeV beam in a week RF aging with ~20.3MW RF input power





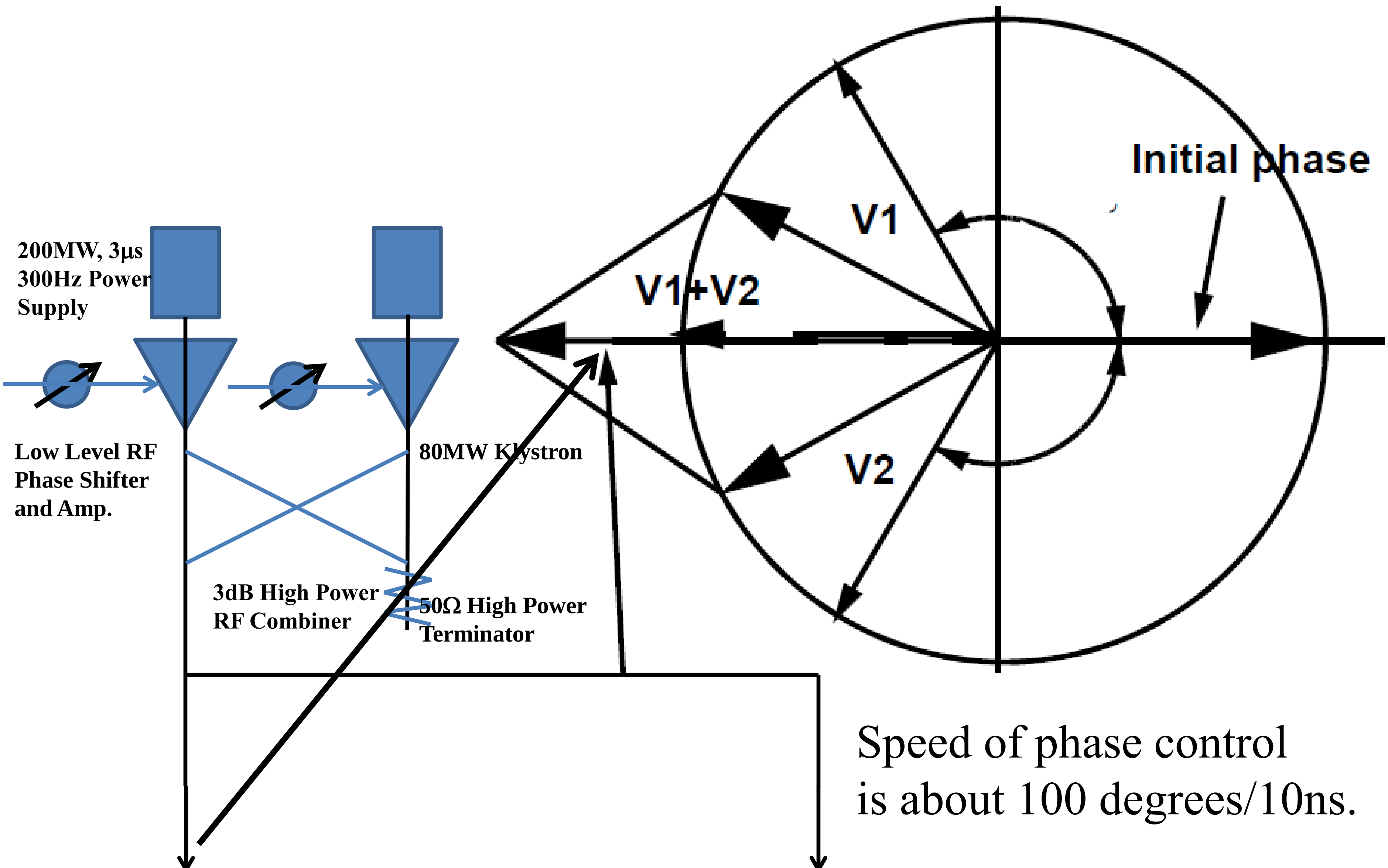
3.6 cell RF-Gun
Start of beam acceleration test from 1/11,2012.

PARMELA SIMULATION



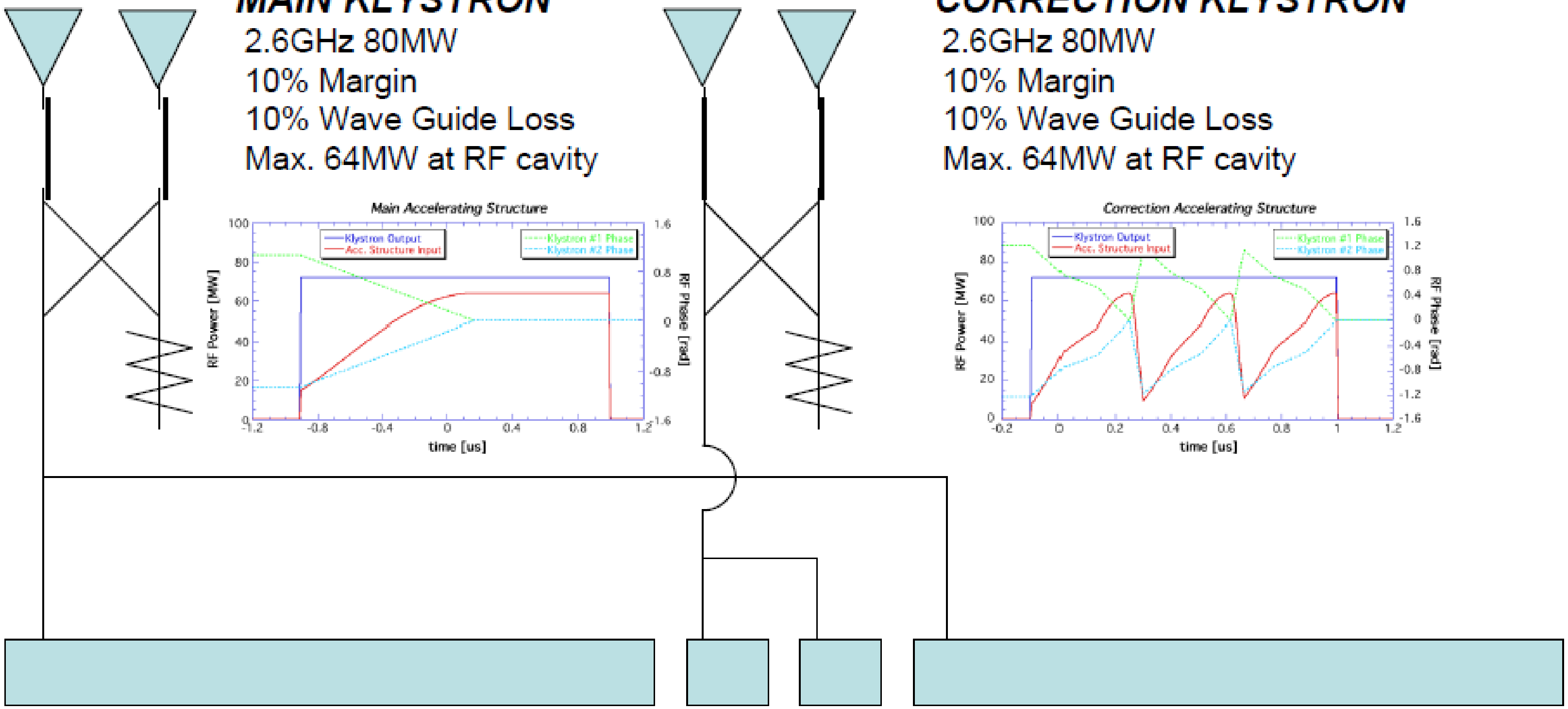
11MeV beam at 120MV/m, from 100bunches/pulse to 1000bunches/pulse beam generation

Phase to Amplitude Modulation Method for Beam Loading Compensation



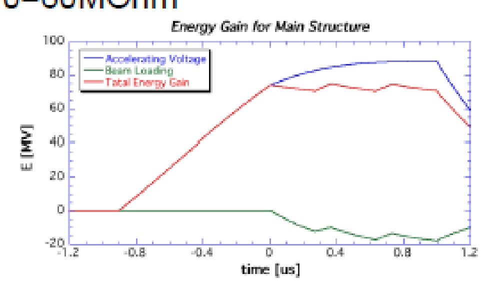
Speed of phase control is about 100 degrees/10ns.

Concept Design of Single RF Unit (Nb=2e10)



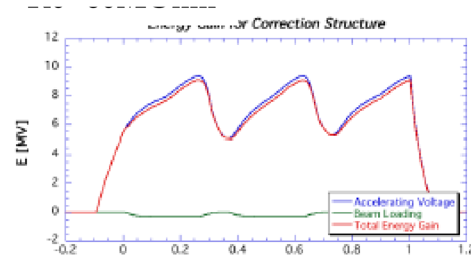
Main RF Cavity

L=3.00m (2.6GHz)
tf=906ns
Q0=13000
r0=60MOhm



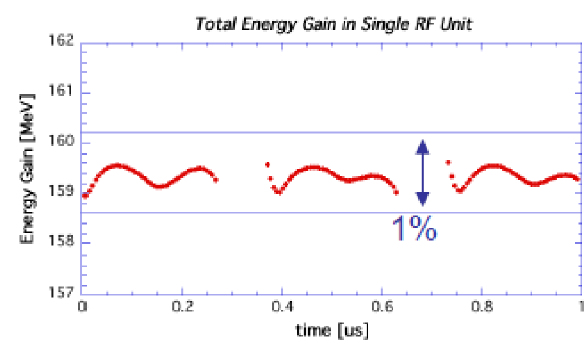
Correction RF Cavity

L=0.33m (2.6GHz)
tf=96ns

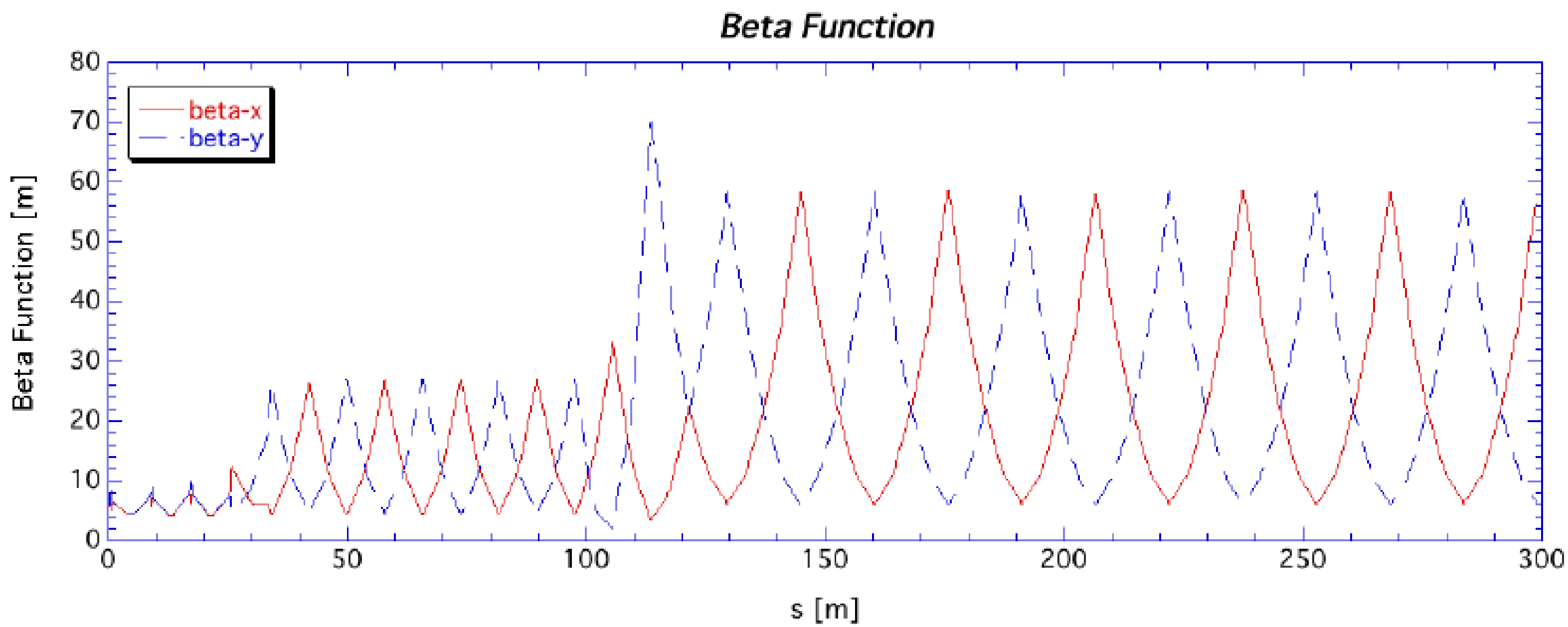


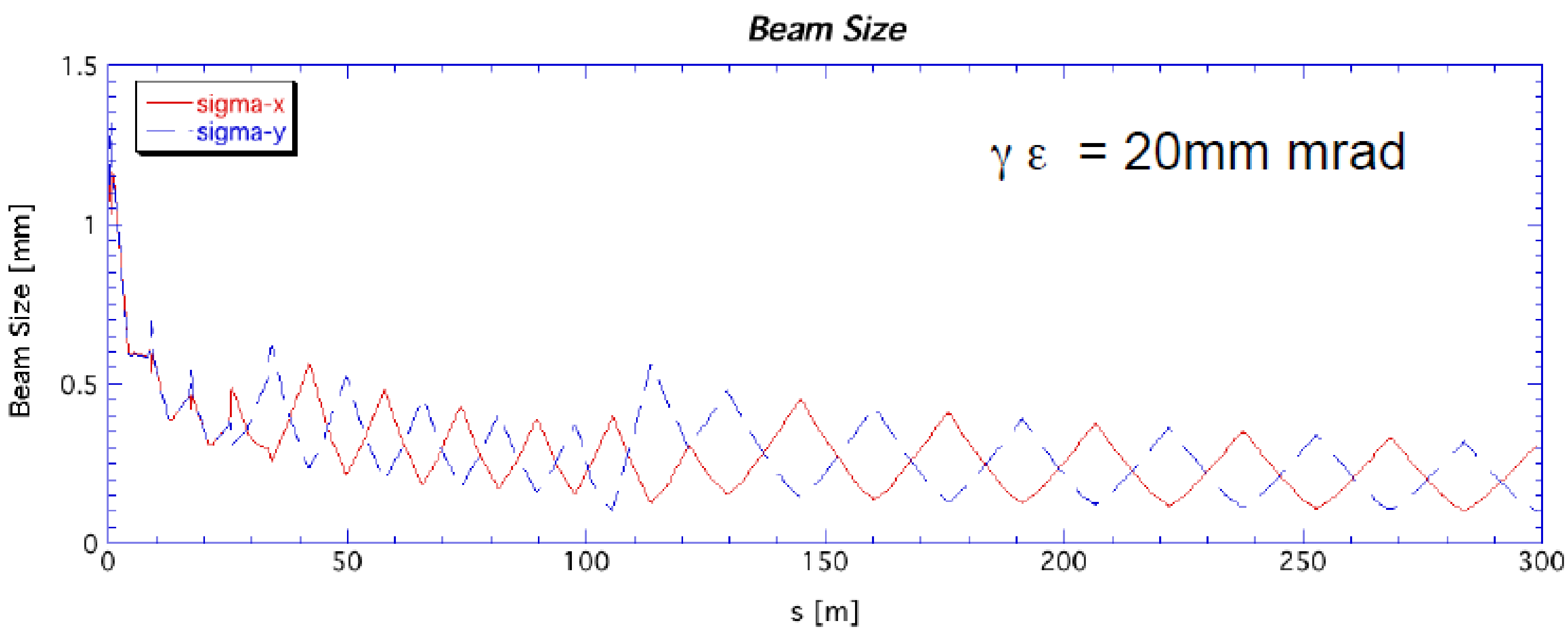
Total Energy Gain in 1 Unit

159.3MeV



Beam Optics Design for 6GeV Linac (Nb=2e10)





Device List for 6 GeV Linac (Nb=2e10)

Magnet List

35 quads
27 horizontal steerings
27 vertical steerings

Magnet Name	Effective Length [m]	dB/dx [T/m]
Q01.1	0.1	1.3332
Q02	0.1	-2.6201
Q01.2	0.1	1.3332
Q03.1	0.1	6.0686
Q04	0.1	-11.9069
Q03.2	0.1	6.0686
Q05.1	0.1	11.1410
Q06	0.1	-21.8199
Q05.2	0.1	11.1410
Q07	0.1	-13.9861
Q08	0.1	14.5026
Q09	0.1	11.9981
Q10	0.1	-14.1085
Q11.1	0.1	5.0587
Q12.1	0.1	-6.0110
Q11.2	0.1	6.9631
Q12.2	0.1	-7.9155
Q11.3	0.1	8.8675
Q12.3	0.1	-9.8199
Q11.4	0.1	10.7720
Q13	0.1	-14.7304
Q14	0.1	13.3063
Q15	0.1	-12.6623
Q16	0.1	14.5968
Q17.1	0.1	-9.1552
Q18.1	0.1	10.2777
Q17.2	0.1	-11.4002
Q18.2	0.1	12.5226
Q17.3	0.1	-13.6451
Q18.3	0.1	14.7676
Q17.4	0.1	-15.8901
Q18.4	0.1	17.0125
Q17.5	0.1	-18.1350
Q18.5	0.1	19.2575
Q17.6	0.1	-20.3800

RF section

RF Unit

Maximum Accelerating Volatage
(80MW Klystron Output) 170MV

Nominal Accelerating Voltage
(72MW Klystron Output) 159.3MV

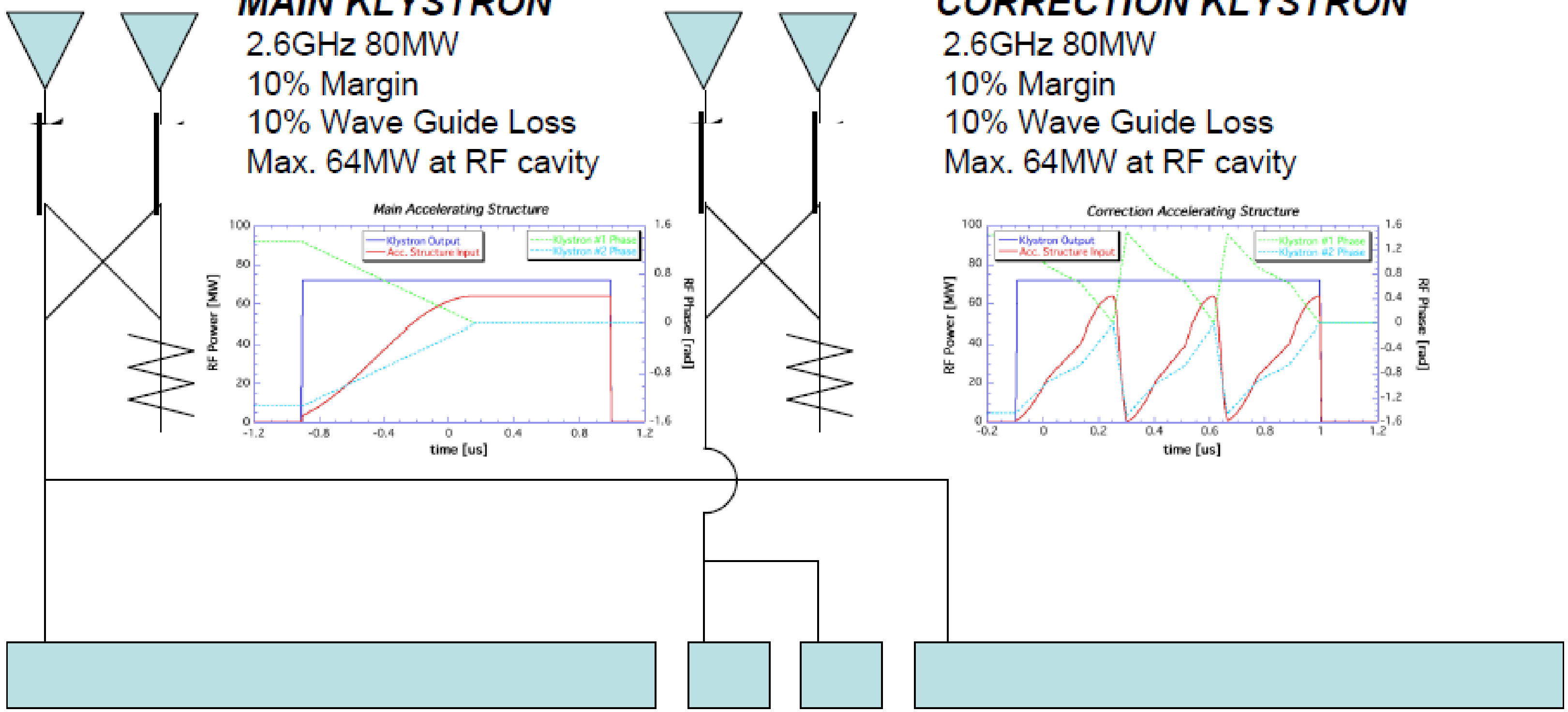
Number of Unit 38

Nominal Accelerating Voltage 6.05GeV

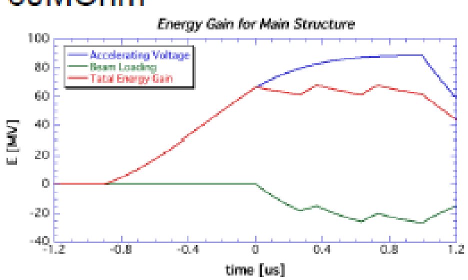
Concept Design of Single RF Unit (Nb=3e10)

MAIN KLYSTRON
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity

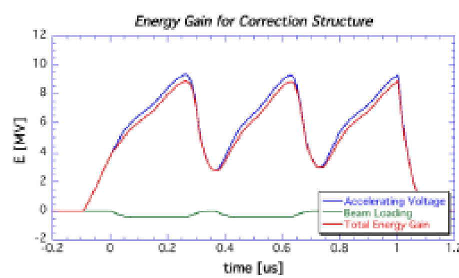
CORRECTION KLYSTRON
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity



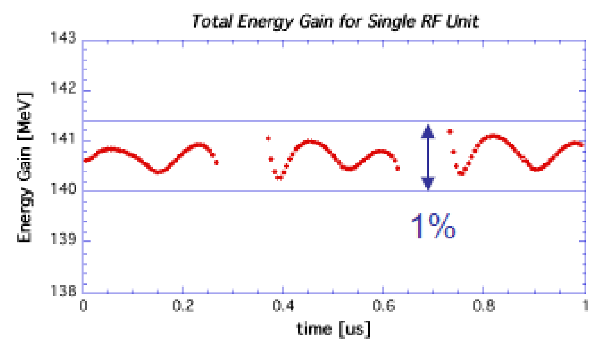
Main RF Cavity
L=3.00m (2.6GHz)
tf=906ns
Q0=13000
r0=60MOhm



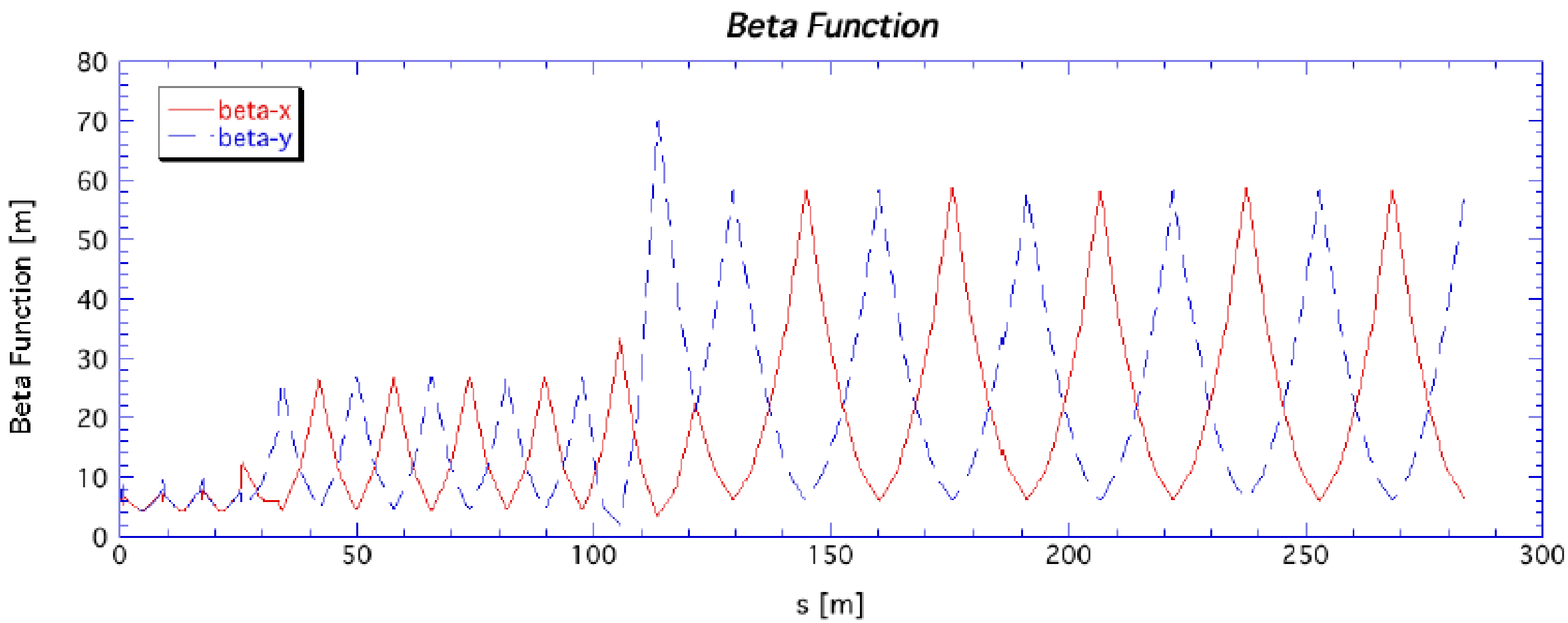
Correction RF Cavity
L=0.33m (2.6GHz)
tf=96ns

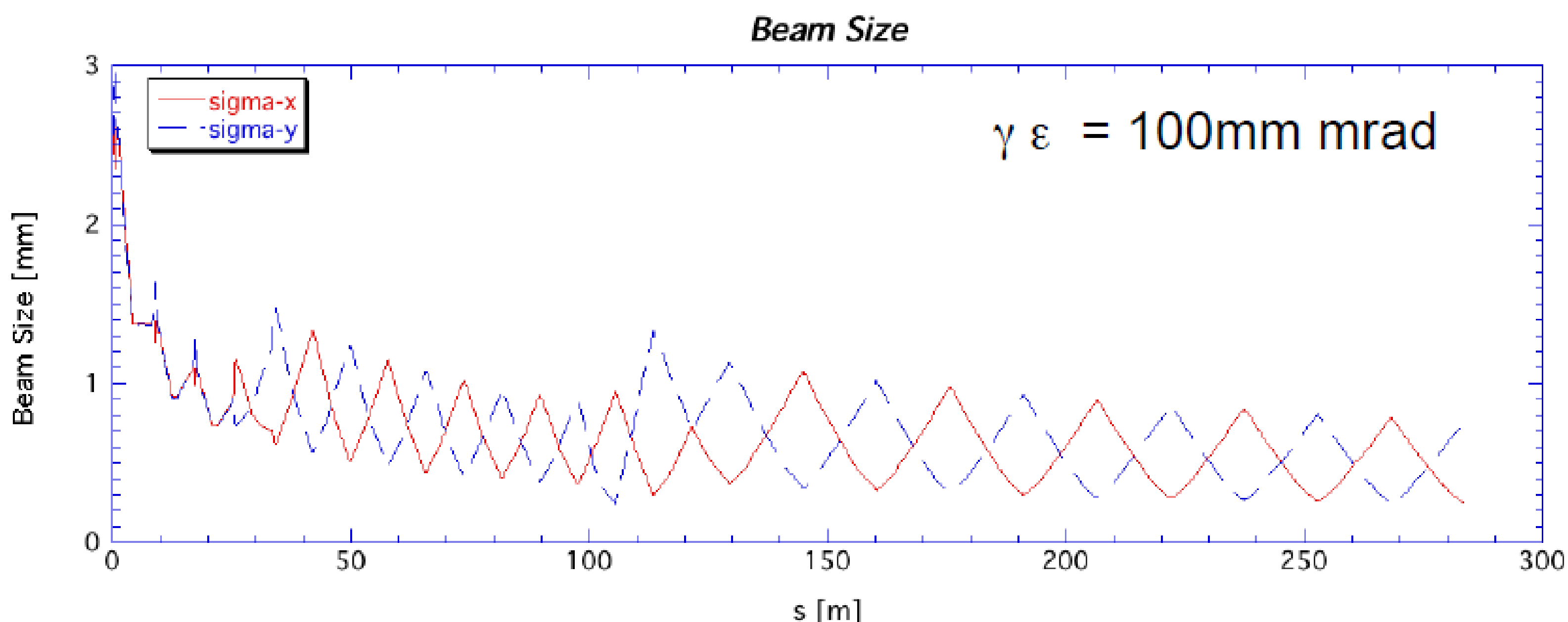


Total Energy Gain in 1 Unit
140.6MeV



Beam Optics Design for 5GeV Linac (Nb=3e10)





Device List for 5 GeV Linac (Nb=3e10)

Magnet List

34 quads
26 horizontal steerings
26 vertical steerings

Magnet Name	Effective Length [m]	dB/dx [T/m]
Q01.1	0.1	1.3391
Q02	0.1	−2.6322
Q01.2	0.1	1.3391
Q03.1	0.1	5.5491
Q04	0.1	−10.8851
Q03.2	0.1	5.5491
Q05.1	0.1	10.0016
Q06	0.1	−19.5879
Q05.2	0.1	10.0016
Q07	0.1	−12.4680
Q08	0.1	12.9311
Q09	0.1	10.6418
Q10	0.1	−12.5256
Q11.1	0.1	4.4933
Q12.1	0.1	−5.3325
Q11.2	0.1	6.1716
Q12.2	0.1	−7.0108
Q11.3	0.1	7.8498
Q12.3	0.1	−8.6892
Q11.4	0.1	9.5281
Q13	0.1	−13.0255
Q14	0.1	11.7631
Q15	0.1	−11.1916
Q16	0.1	12.8989
Q17.1	0.1	−8.0889
Q18.1	0.1	9.0780
Q17.2	0.1	−10.0672
Q18.2	0.1	11.0564
Q17.3	0.1	−12.0456
Q18.3	0.1	13.0348
Q17.4	0.1	−14.0239
Q18.4	0.1	15.0131
Q17.5	0.1	−16.0023
Q18.5	0.1	16.9915

RF section

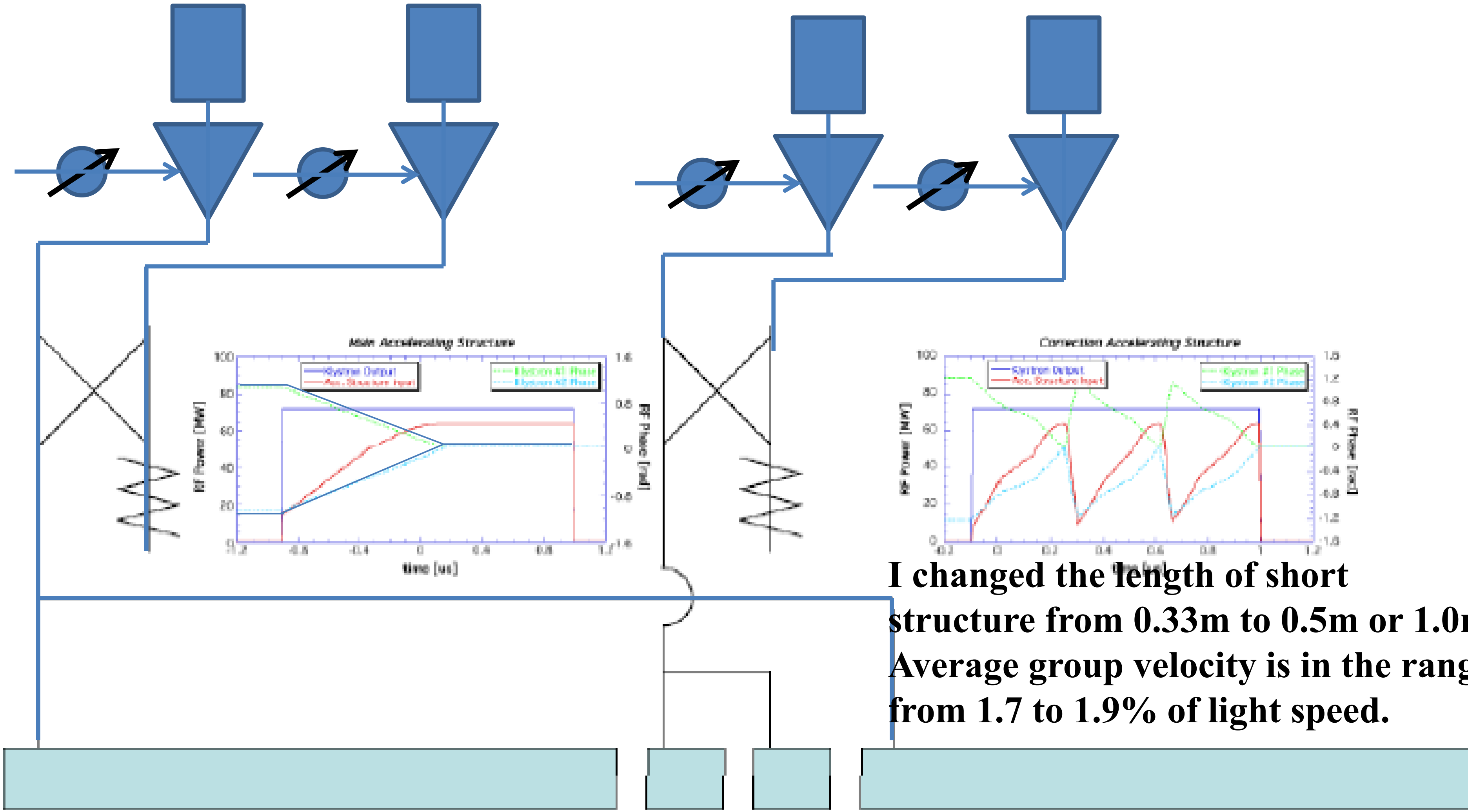
RF Unit

Maximum Accelerating Volatage (80MW Klystron Output)	148MV
Nominal Accelerating Voltage (72MW Klystron Output)	140.6MV
Number of Unit	36
Nominal Accelerating Voltage	5.06GeV

6GeV Drive Linac with 2x10E10 e/bunch	unit :M¥
38 RF units	
2 main klystrons x 38 with 10% margin and 10% loss	0
2.6GHz 64MW at RF cavity, total 76 Klystrons	1748
number of 3m long cavities, total 76 structures	1157
2 phase shifters x 38, total 76 phase shifters	38
HP combinor x 38	130
3dB divider x 38	70
waveguide x 38	20
2 modulators x 38, total 76 modulators	3952
Computor Control Unit x 38	30
2 correction klystrons x 38 with 10% margin and 10% loss	0
2.6GHz 64MW at RF cavity, total 76 Klystrons	1748
number of 0.33m long cavities, total 76 structures	468
2 phase shifters x 38, total 76 phase shifters	38
HP combinor x 38	130
3dB divider x 38	70
waveguide x 38	20
2 modulators x 38, total 76 modulators	3952
Computor Control Unit x 38	30
35 quads	35
27 horizontal steerings	10
27 vertical steerings	10
power supplies for magnets	50
beam monitor devices	50
	13756

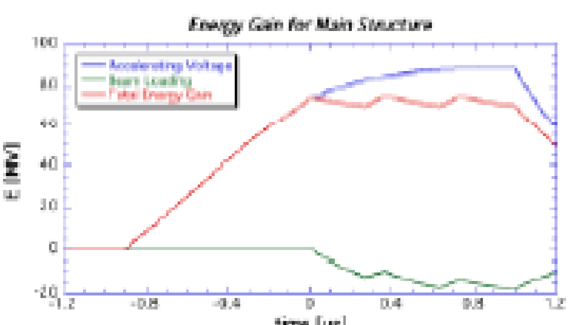
5GeV Positron Linac with 3x10E10 e/bunch	unit :M¥
36 RF units	
2 main klystrons x 36 with 10% margin and 10% loss	0
2.6GHz 64MW at RF cavity, total 72 Klystrons	1656
number of 3m long cavities, total 72 structures	1096
2 phase shifters x 36, total 72 phase shifters	36
HP combinor x 36	120
3dB divider x 36	66
waveguide x 36	20
2 modulators x 36, total 72 modulators	3744
Computor Control Unit x 36	30
2 correction klystrons x 36 with 10% margin and 10% lc	0
2.6GHz 64MW at RF cavity, total 72 Klystrons	1656
number of 0.33m long cavities, total 72 structures	443
2 phase shifters x 36, total 72 phase shifters	36
HP combinor x 36	120
3dB divider x 36	66
waveguide x 36	20
2 modulators x 36, total 72 modulators	3744
Computor Control Unit x 36	30
34 quads	34
26 horizontal steerings	10
26 vertical steerings	10
power supplies for magnets	50
beam monitor devices	50
	13037

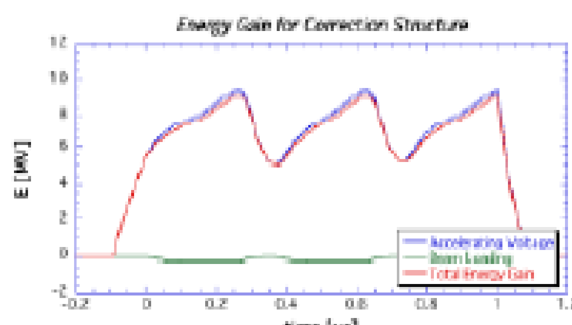
Total 26793MYen for 6GeV and 5GeV S-band 300Hz Linac

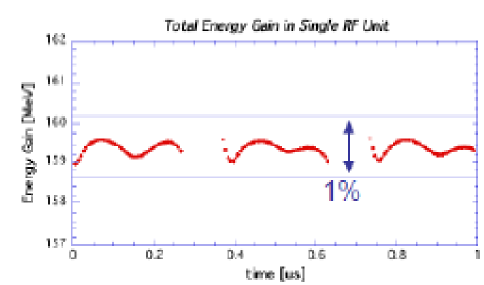


I changed the length of short structure from 0.33m to 0.5m or 1.0m. Average group velocity is in the range from 1.7 to 1.9% of light speed.

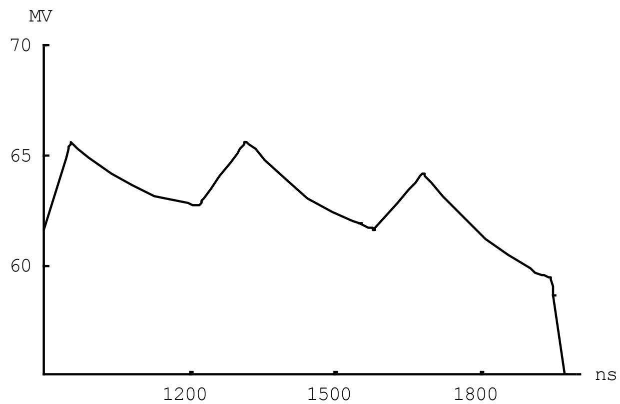
Total Energy Gain in 1 Unit
159.3MeV



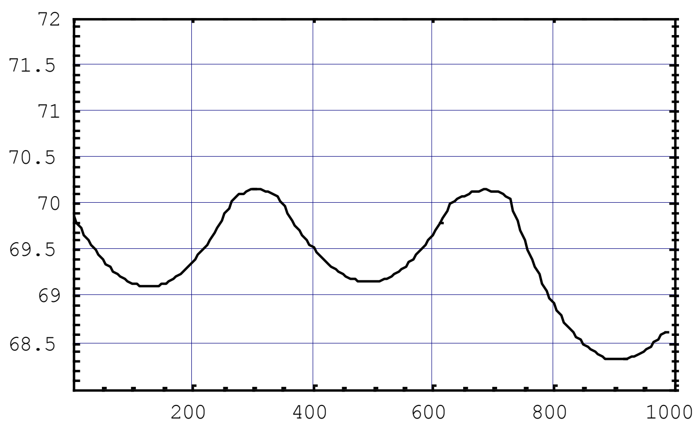




We can reduce the input power to the short structures from 64MW to 20MW. Then, one unit of RF source can feed the RF to three sets for correction accelerating structures.



Above shows the effect of beam loading in 3m long structure.



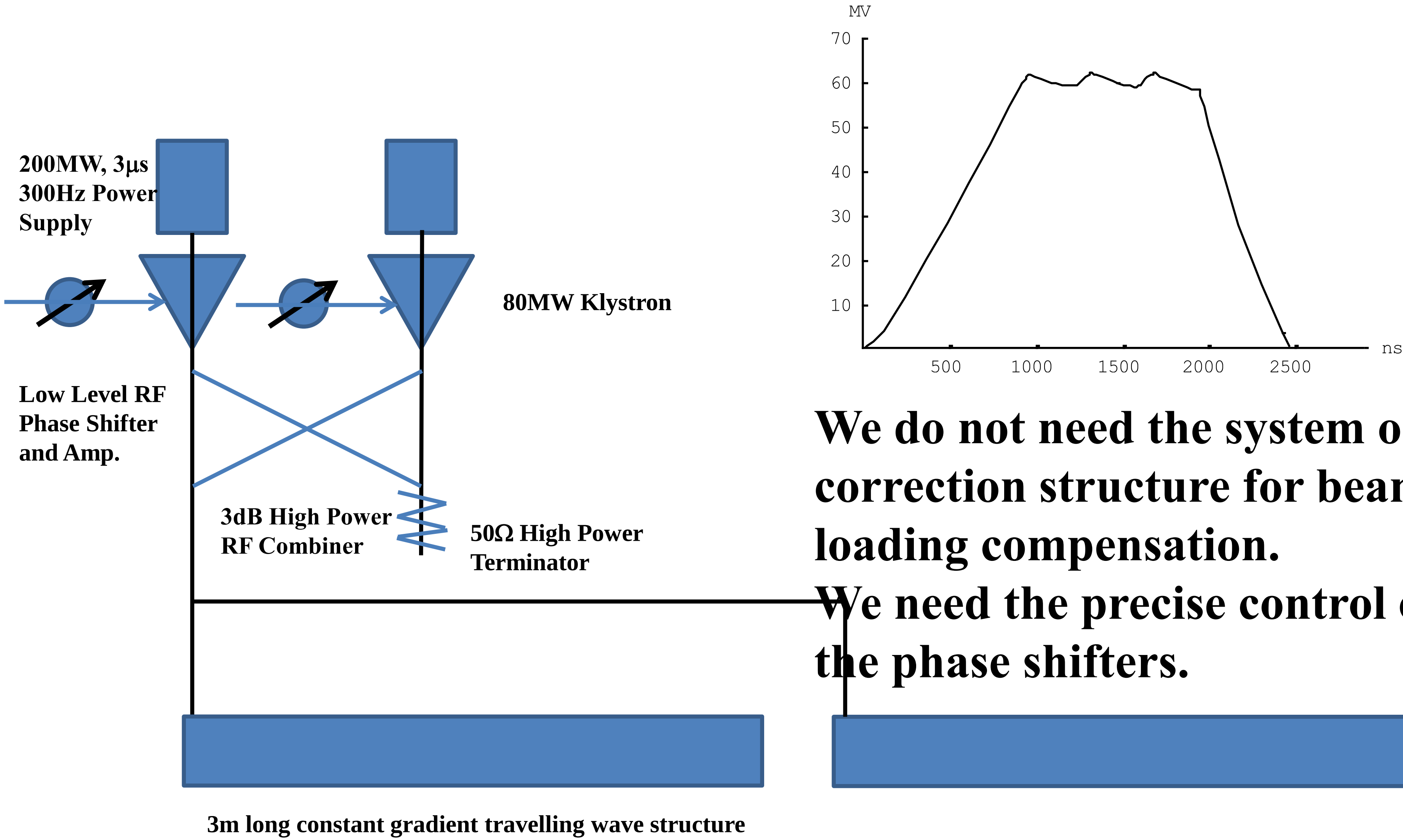
After adding correction structures, we can reduce the energy spread due to beam loading within +/- 0.5%.

6GeV Drive Linac with 2x10E10 e/bunch		unit :Myen
38 RF units		
2 main klystrons x 38 with 10% margin and 10% loss		0
2.6GHz 64MW at RF cavity, total 76 Klystrons		1748
number of 3m long cavities, total 76 structures		1157
2 phase shifters x 38, total 76 phase shifters		38
HP combinor x 38		130
3dB divider x 38		70
waveguide x 38		20
2 modulators x 38, total 76 modulators		3952
Computor Control Unit x 38		30
2 correction klystrons x 38 with 10% margin and 10% loss		0
2.6GHz 64MW at RF cavity, total 76 Klystrons		1748
number of 0.33m long cavities, total 76 structures		468
2 phase shifters x 38, total 76 phase shifters		38
HP combinor x 38		130
3dB divider x 38		70
waveguide x 38		20
2 modulators x 38, total 76 modulators	x1/3	3952
Computor Control Unit x 38		30
35 quads		35
27 horizontal steerings		10
27 vertical steerings		10
power supplies for magnets		50
beam monitor devices		50
		13756

5GeV Positron Linac with 3x10E10 e/bunch		unit :Myen
36 RF units		
2 main klystrons x 36 with 10% margin and 10% loss		0
2.6GHz 64MW at RF cavity, total 72 Klystrons		1656
number of 3m long cavities, total 72 structures		1096
2 phase shifters x 36, total 72 phase shifters		36
HP combinor x 36		120
3dB divider x 36		66
waveguide x 36		20
2 modulators x 36, total 72 modulators		3744
Computor Control Unit x 36		30
2 correction klystrons x 36 with 10% margin and 10% loss		0
2.6GHz 64MW at RF cavity, total 72 Klystrons		1656
number of 0.33m long cavities, total 72 structures		443
2 phase shifters x 36, total 72 phase shifters		36
HP combinor x 36		120
3dB divider x 36		66
waveguide x 36		20
2 modulators x 36, total 72 modulators	x1/3	3744
Computor Control Unit x 36		30
34 quads		34
26 horizontal steerings		10
26 vertical steerings		10
power supplies for magnets		50
beam monitor devices		50
		13037

20% cost down or more
Cost down is possible.

Total 26793MYen for 6GeV and 5GeV S-band 300Hz Linac → 21600MYen



We do not need the system of correction structure for beam loading compensation.
We need the precise control of the phase shifters.

Also, I am researching the time structure of RF power feeding to increase energy gain and decided 20% of the margin +wave guide loss is too much and we can reduce it to 10% because of the experience at ATF Linac.

6GeV Drive Linac with 2x10E10 e/bunch	unit :M¥
38 RF units	
2 main klystrons x 38 with **10% margin and 10% loss**	0
2.6GHz 64MW at RF cavity, total 76 Klystrons	1748
number of 3m long cavities, total 76 structures	1157
2 phase shifters x 38, total 76 phase shifters	38
HP combinor x 38	130
3dB divider x 38	70
waveguide x 38	20
2 modulators x 38, total 76 modulators	3952
Computor Control Unit x 38	30
2 correction klystrons x 38 with 10% margin and 10% loss	**0**
2.6GHz 64MW at RF cavity, total 76 Klystrons	**1748**
number of 0.33m long cavities, total 76 structures	**468**
2 phase shifters x 38, total 76 phase shifters	**38**
HP combinor x 38	**130**
3dB divider x 38	**70**
waveguide x 38	**20**
2 modulators x 38, total 76 modulators	**3952**
Computor Control Unit x 38	**30**
35 quads	35
27 horizontal steerings	10
27 vertical steerings	10
power supplies for magnets	50
beam monitor devices	50
	13756

5GeV Positron Linac with 3x10E10 e/bunch	unit :M¥
36 RF units	
2 main klystrons x 36 with **10% margin and 10% loss**	0
2.6GHz 64MW at RF cavity, total 72 Klystrons	1656
number of 3m long cavities, total 72 structures	1096
2 phase shifters x 36, total 72 phase shifters	36
HP combinor x 36	120
3dB divider x 36	66
waveguide x 36	20
2 modulators x 36, total 72 modulators	3744
Computor Control Unit x 36	30
2 correction klystrons x 36 with 10% margin and 10% loss	**0**
2.6GHz 64MW at RF cavity, total 72 Klystrons	**1656**
number of 0.33m long cavities, total 72 structures	**443**
2 phase shifters x 36, total 72 phase shifters	**36**
HP combinor x 36	**120**
3dB divider x 36	**66**
waveguide x 36	**20**
2 modulators x 36, total 72 modulators	**3744**
Computor Control Unit x 36	**30**
34 quads	34
26 horizontal steerings	10
26 vertical steerings	10
power supplies for magnets	50
beam monitor devices	50
	13037

26793M\-12571M\=14222M\, which is 142 Oku-Yen for 300Hz 6GeV Drive Linac and 5GeV positron Linac.

Complete calculation results will be presented at coming LCWS. Also, plan for beam loading compensation experiment at ATF will be presented.