Beam loading compensation 300Hz positron generation

(Hardware Upgrade ??? Due to present Budget problem)

LCWS2013 at Tokyo Uni., 11-15 Nov. 2013

KEK, Junji Urakawa

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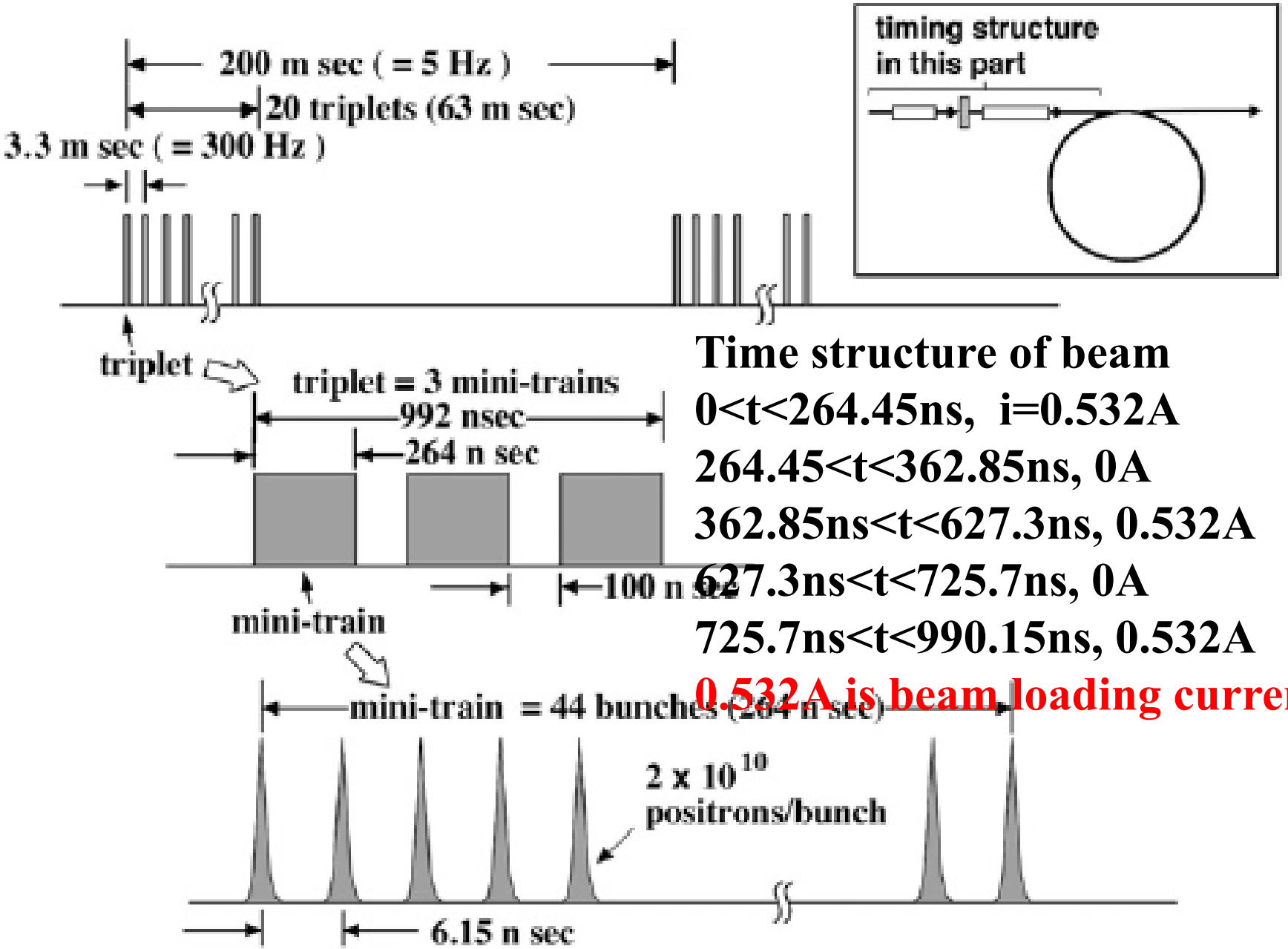


Time structure of beam

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

0.532A is beam loading current.

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.

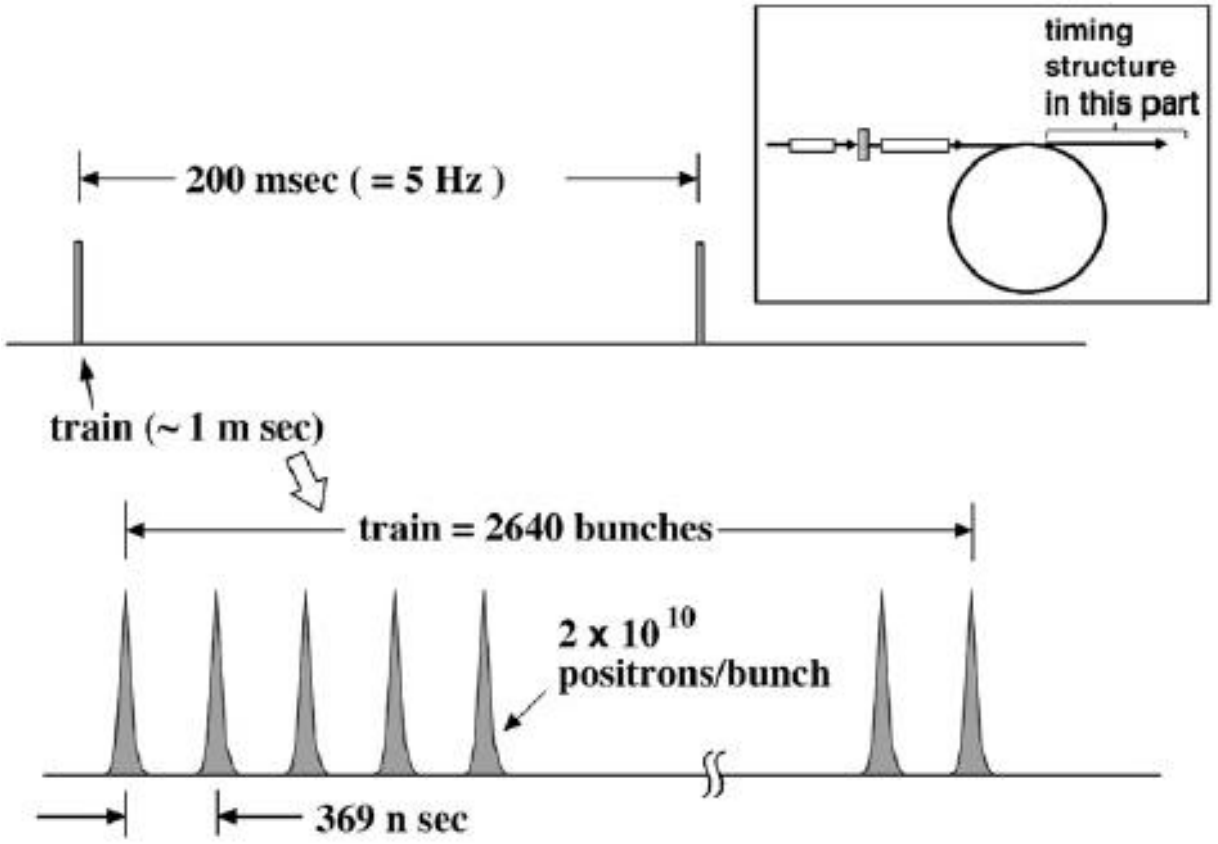
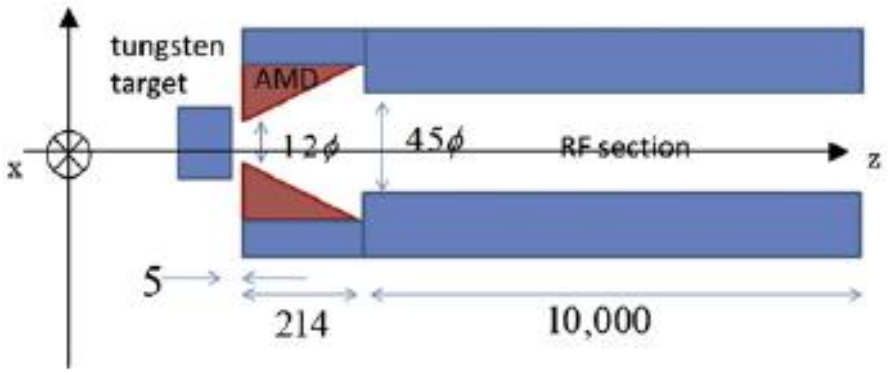


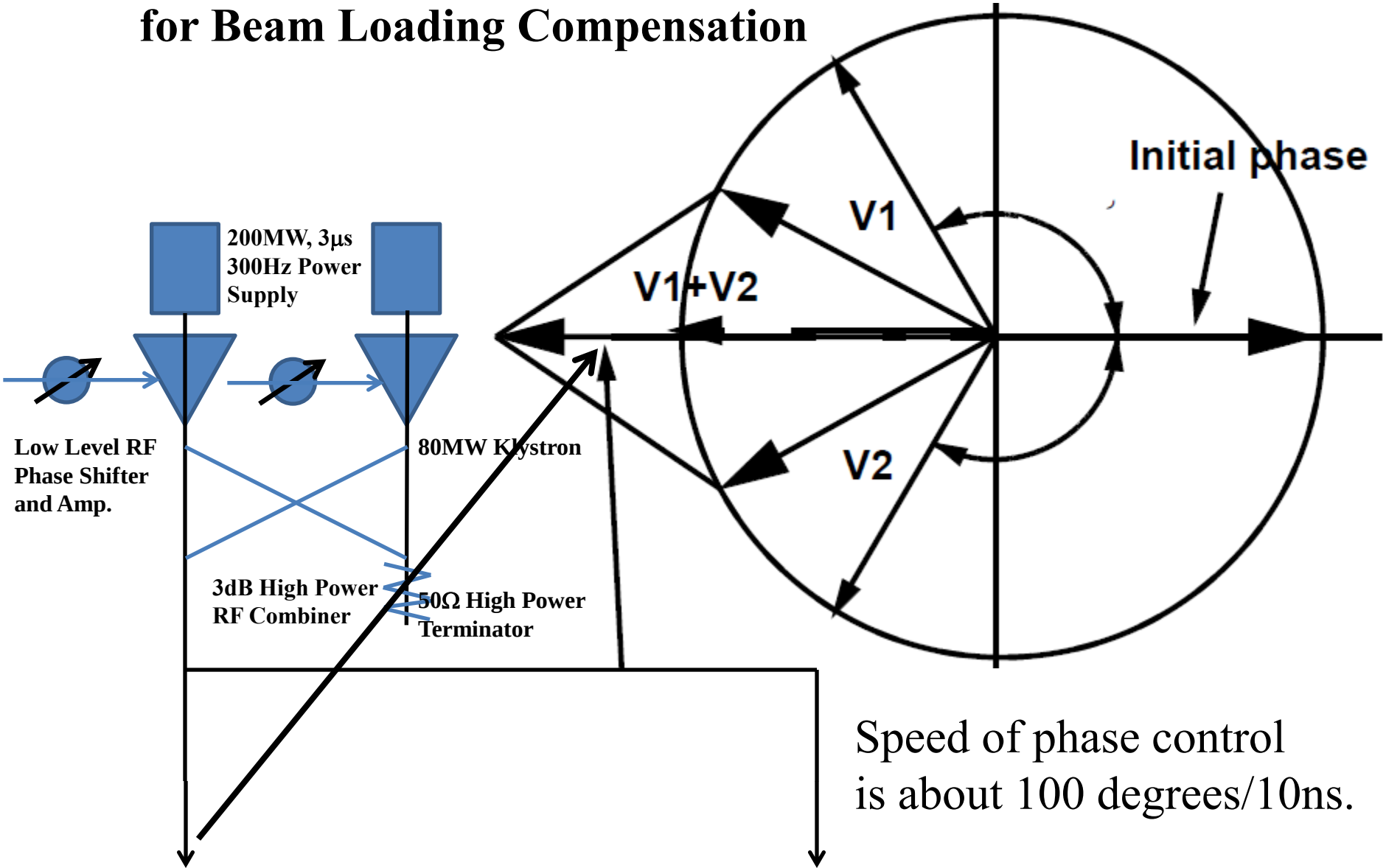
Fig. 4. Time structure after the damping ring.

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

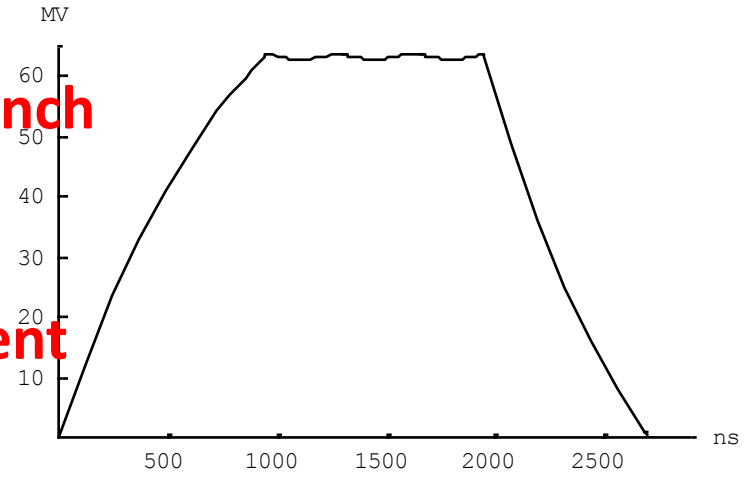


1. 300Hz Linac Scheme for Beam Loading Compensation

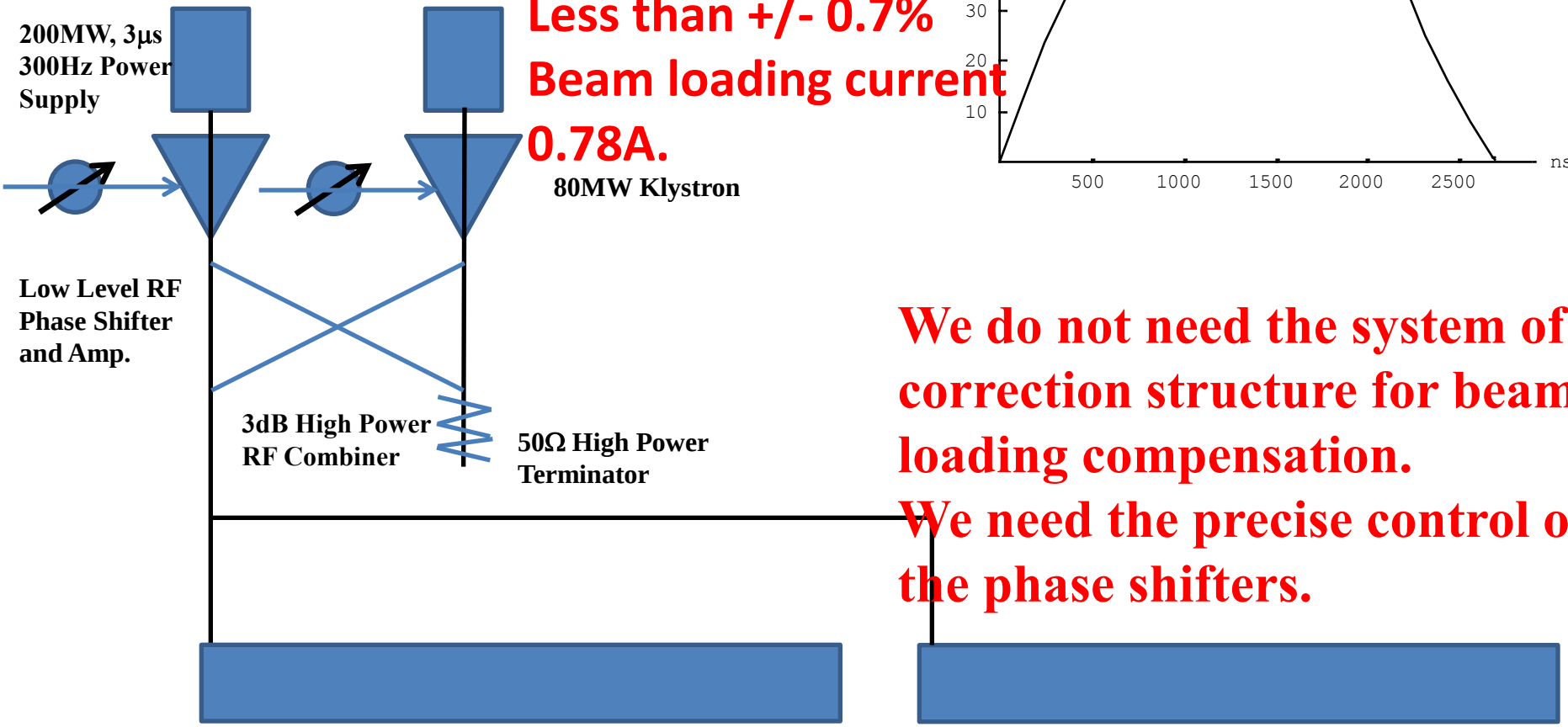
Phase to Amplitude Modulation Method for Beam Loading Compensation



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



3x10^{10} positron/bunch
300Hz triplet beam
Less than +/- 0.7%
Beam loading current 0.78A.

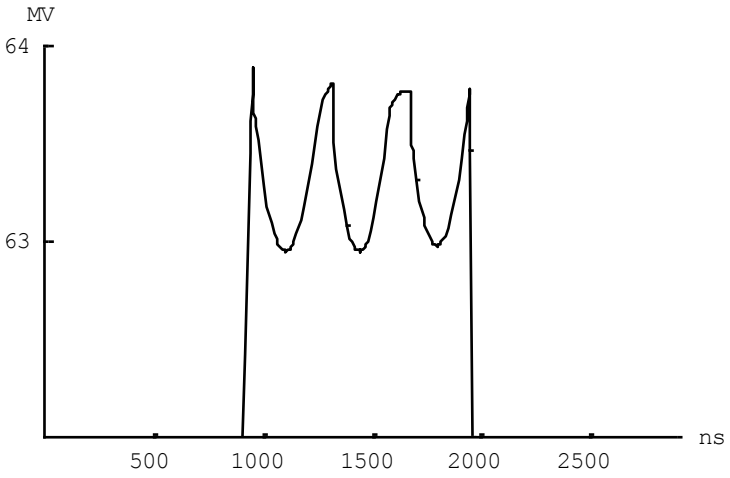


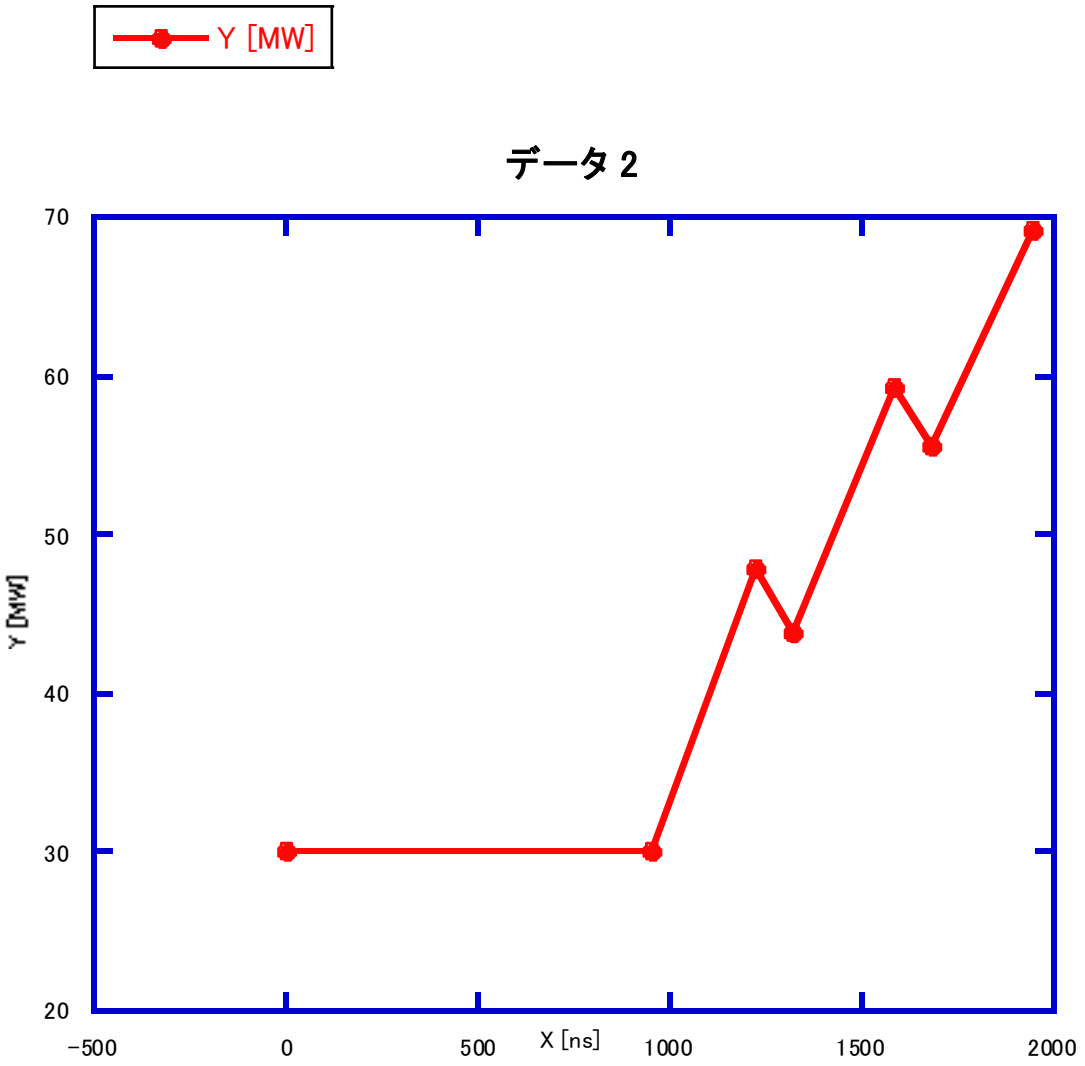
We do not need the system of correction structure for beam loading compensation.
We need the precise control of the phase shifters.

Also, I assume 10% margin as wave guide loss and so on because of the experience at ATF Linac. So, klystron output power 80MW and 3μs pulse width are necessary.

Control of input RF power by phase shifters

Detail of beam loading compensation:
Less than ±0.7% is possible
For ILC 300Hz multi-bunch beam.

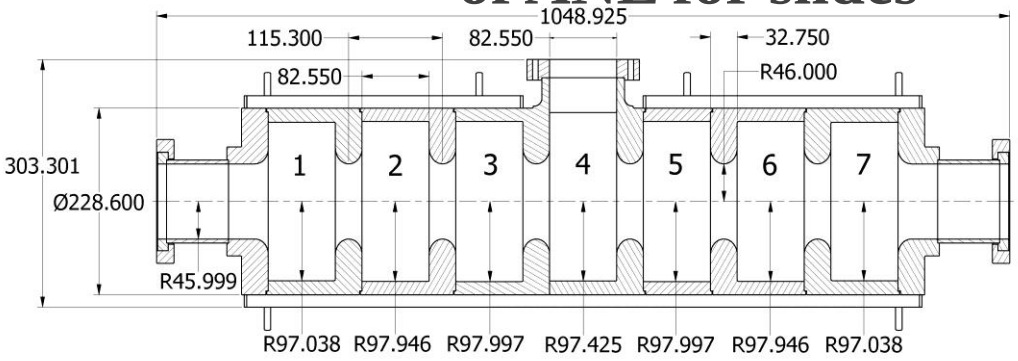




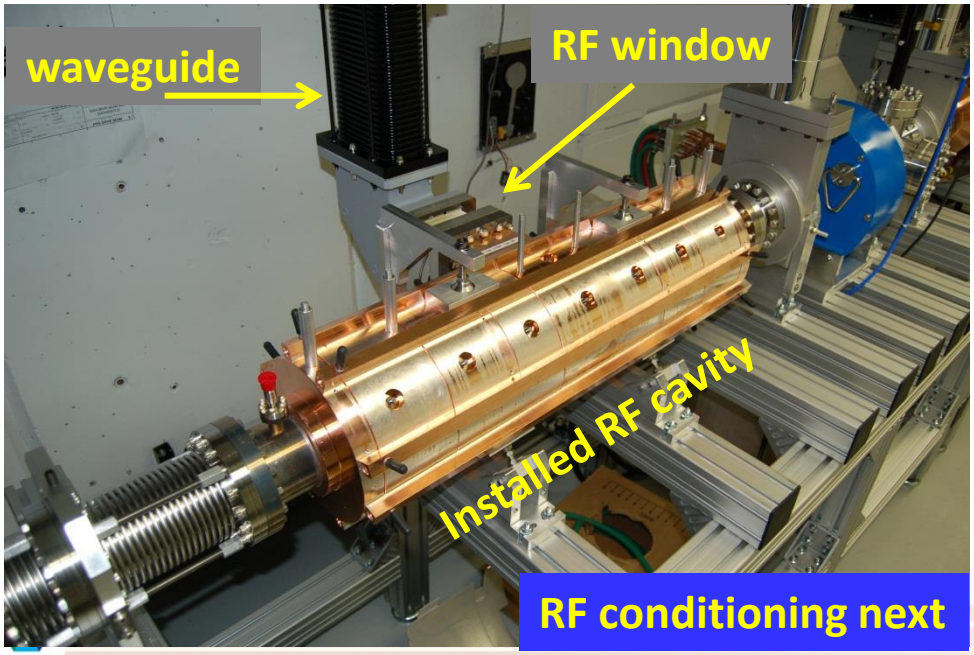
1300 MHz rf cavity

from design …

Thank to J. Power of ANL for slides



…to installed in beamline



Parameter (unit)	Value
unloaded voltage gain, V (MV)	**11.8**
$\varepsilon = U_b/U_0$ @ 1 μC (%)	43.15
energy droop along beam[1] (%)	27
σ = rms energy spread due to wakes[1] (keV)	159
μ = mean energy loss due to wakes[1] (keV)	394
E_{surf} (MV/m)	33.5
H_{surf} (kA/m)	58.8
pulsed heat temp. rise (°C)	1.5
Q_0	25147
U_0 (J)	**27.49**
coupling parameter, β	1.28
mode separation (MHz)	14.7
power flow phase shift (°)	0.17

[1]for P_{in} = 10 MW and Q_b = 100 nC, σ_z = 2 mm.

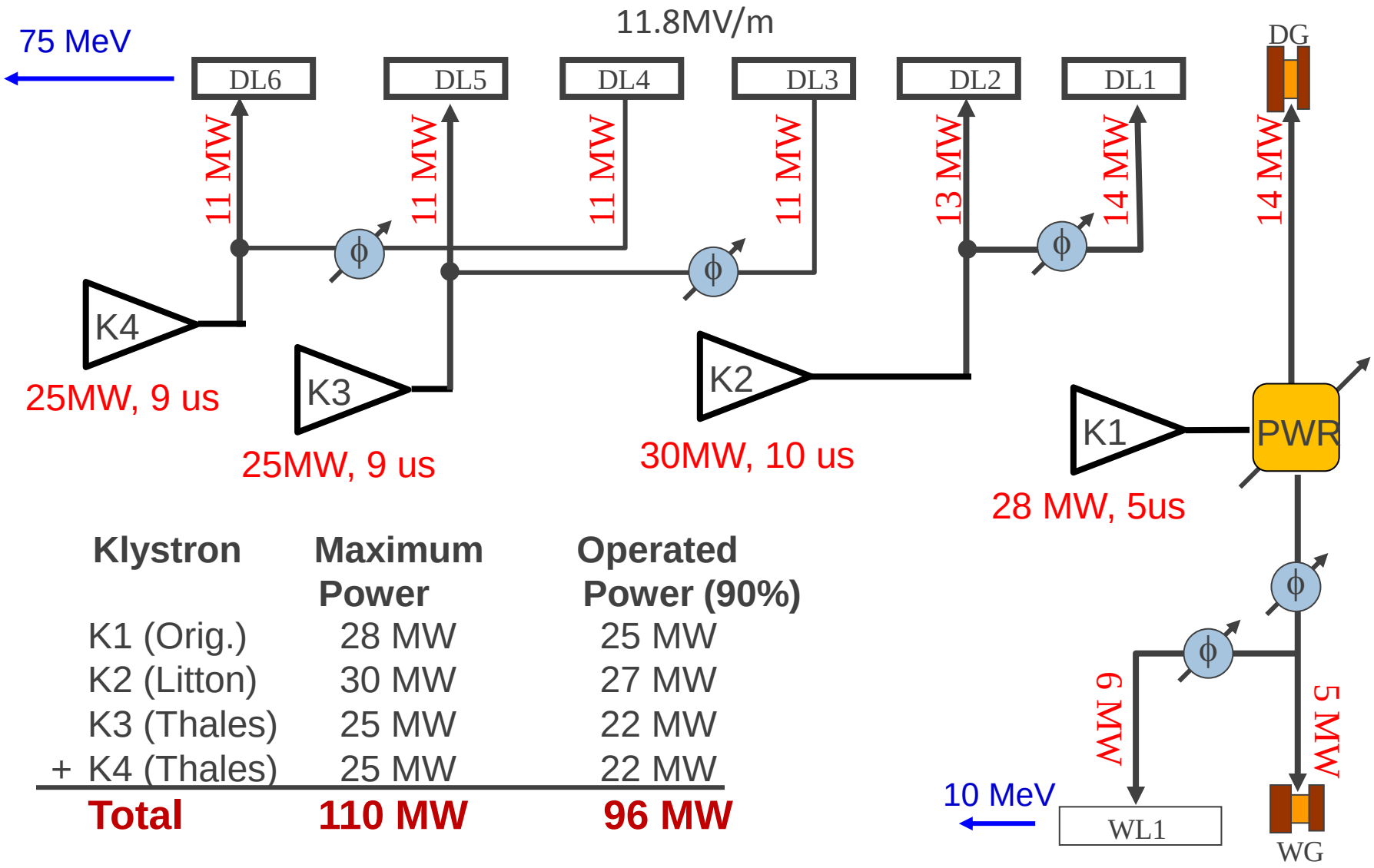
*Designed by ANL/SLAC

*fabrication by local vendor (Hi Tech)

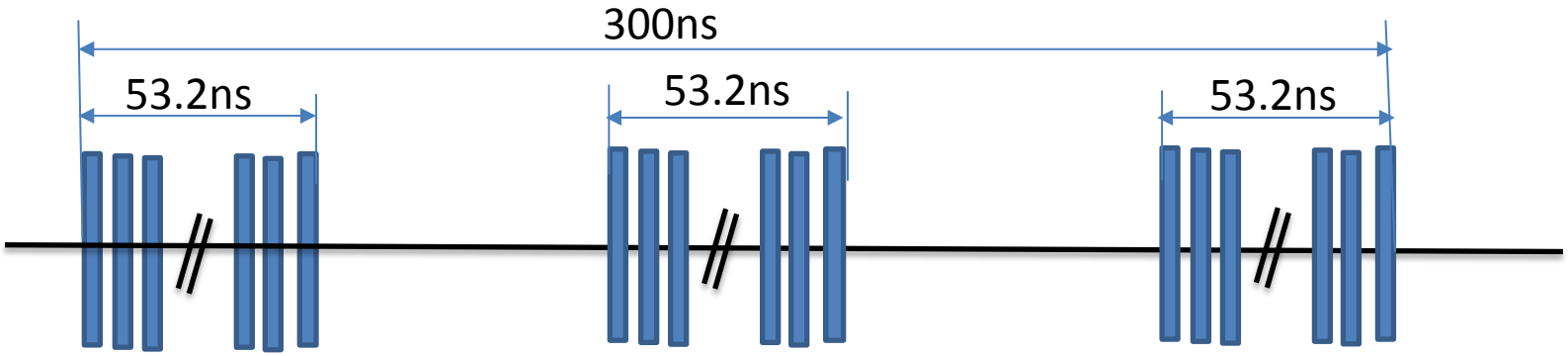
*tuned and balanced at Argonne

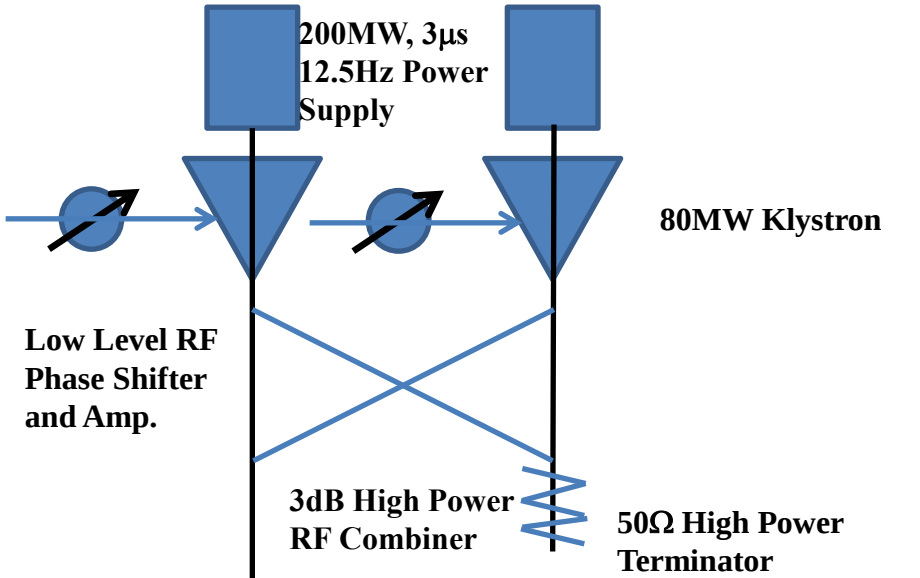
RF power distribution

Total Power Budget = 96 MW

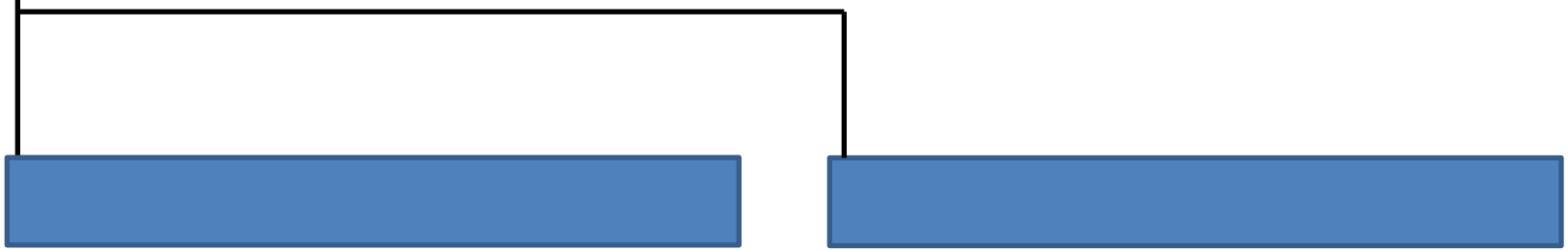


Klystron	Maximum Power	Operated Power (90%)
K1 (Orig.)	28 MW	25 MW
K2 (Litton)	30 MW	27 MW
K3 (Thales)	25 MW	22 MW
+ K4 (Thales)	25 MW	22 MW
Total	**110 MW**	**96 MW**





Essential Beam Loading Compensation Scheme for proof-principle experiment at ATF

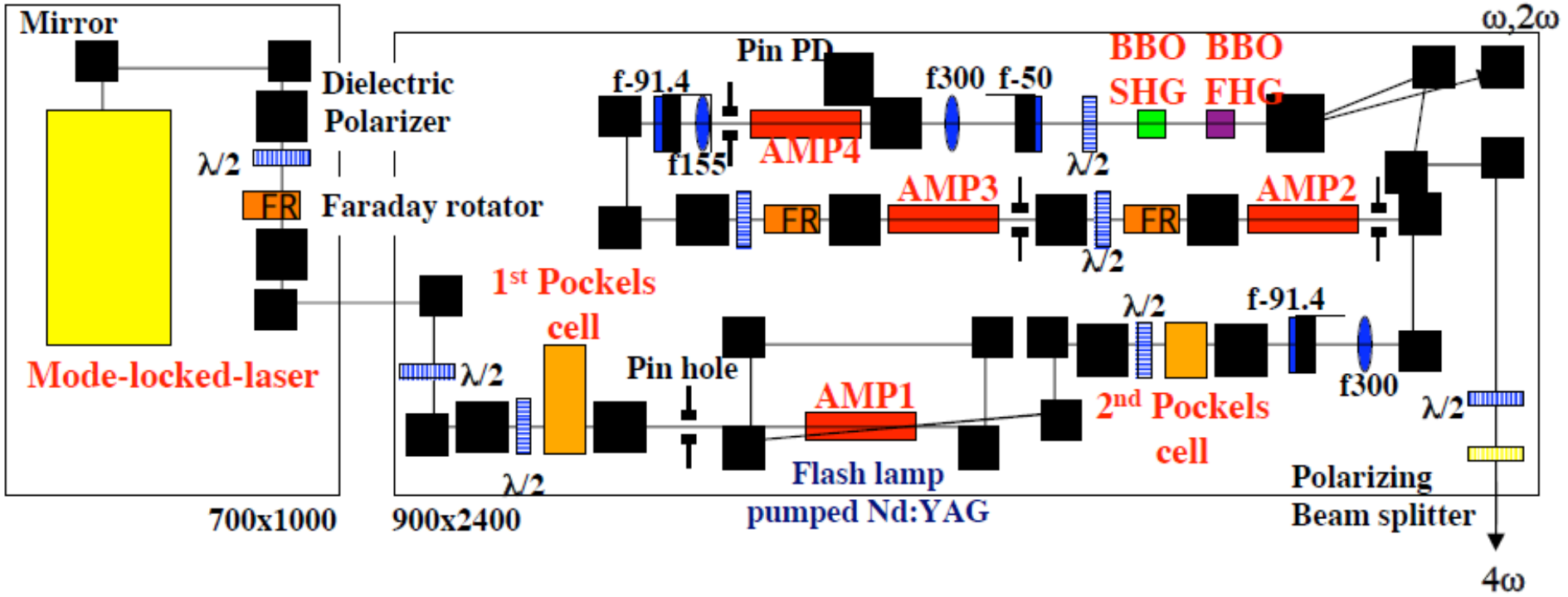


3m long constant gradient travelling wave structure

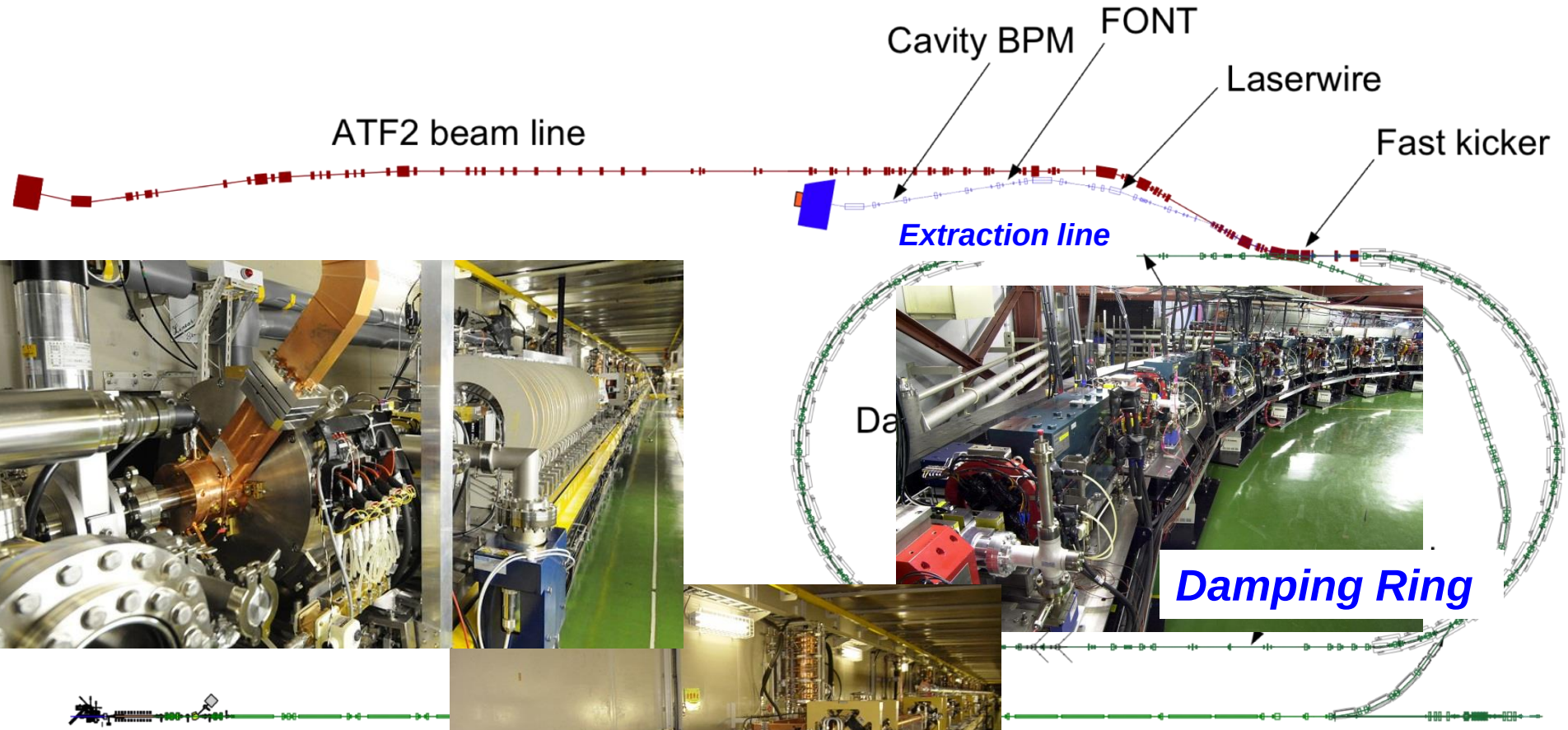
3m long constant gradient travelling wave structure

ATF laser system for photo-cathode RF Gun can generate triplet laser beam of 20 pulse with 2.8ns bunch spacing and about 100ns gap by minor modifications.

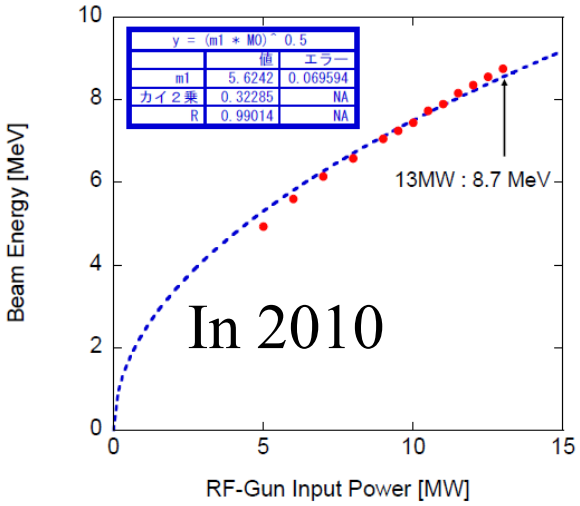
357MHz Laser oscillator	Pockels cell to make triplet laser pulse train	12.5Hz Amp.	4th higher harmonics generator (crystal:BBO)

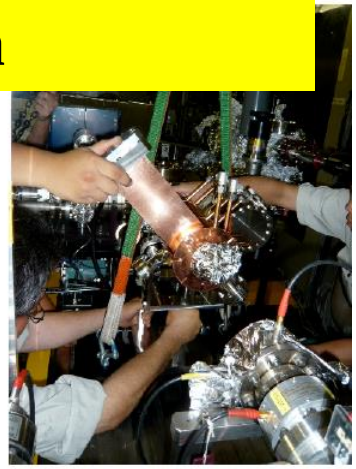


2. Plan for beam loading compensation experiment at ATF

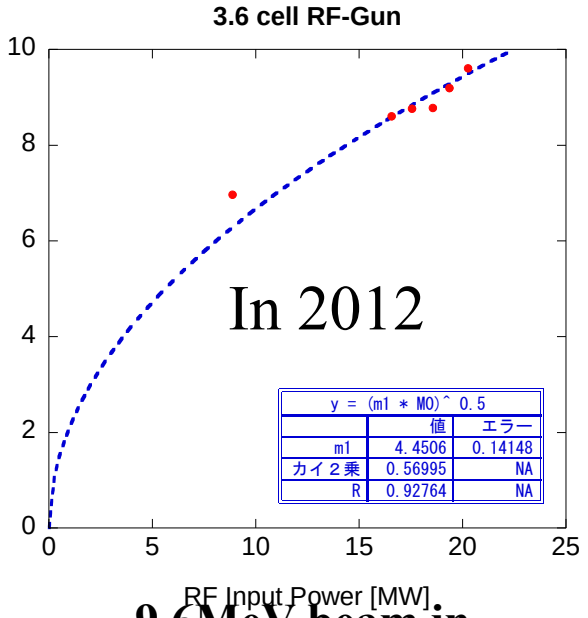


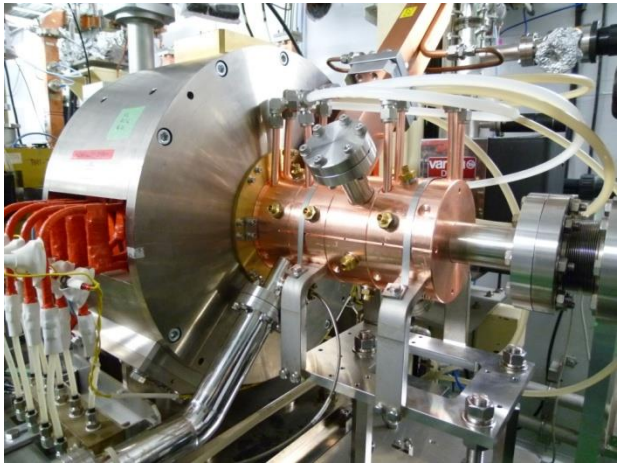
3.6 cell RF Gun Installation





ATF インストールの様子

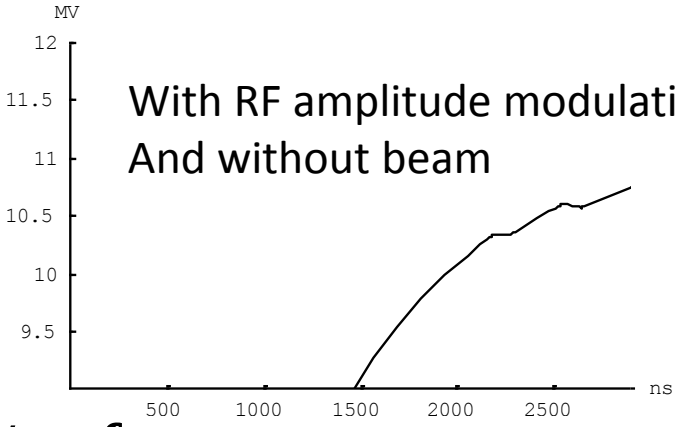


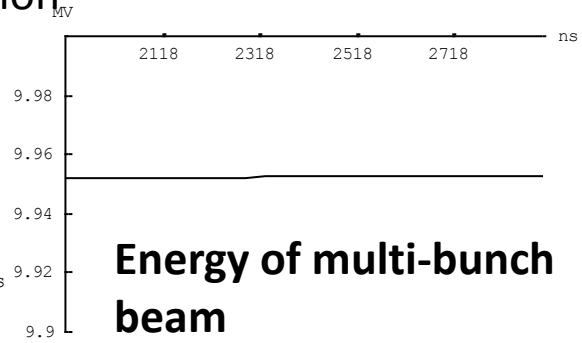


Now, 10MeV multi - bunch trains are generated and accelerated.

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

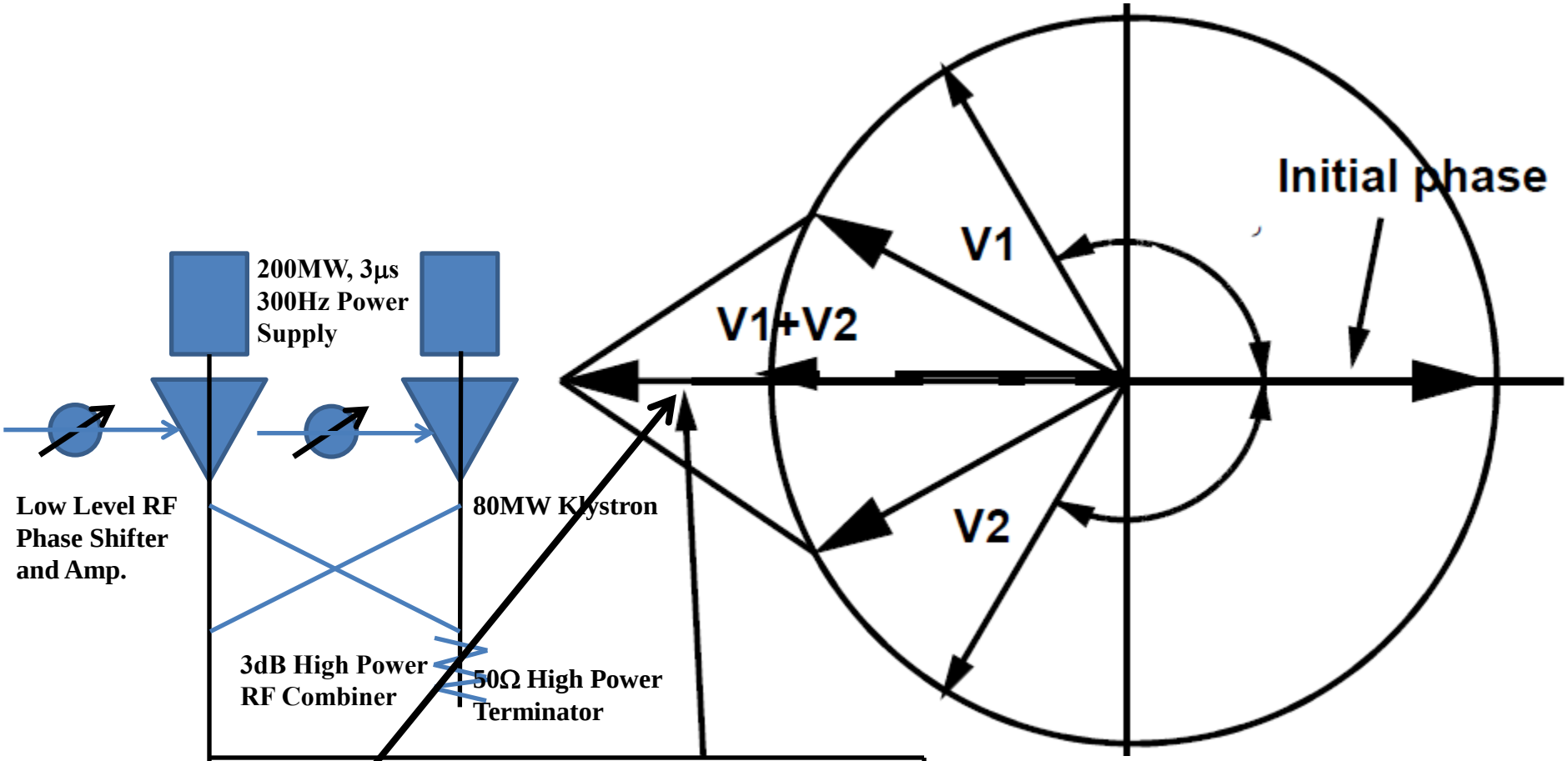
3.6 cell RF-Gun started beam acceleration test from 1/11,2012.





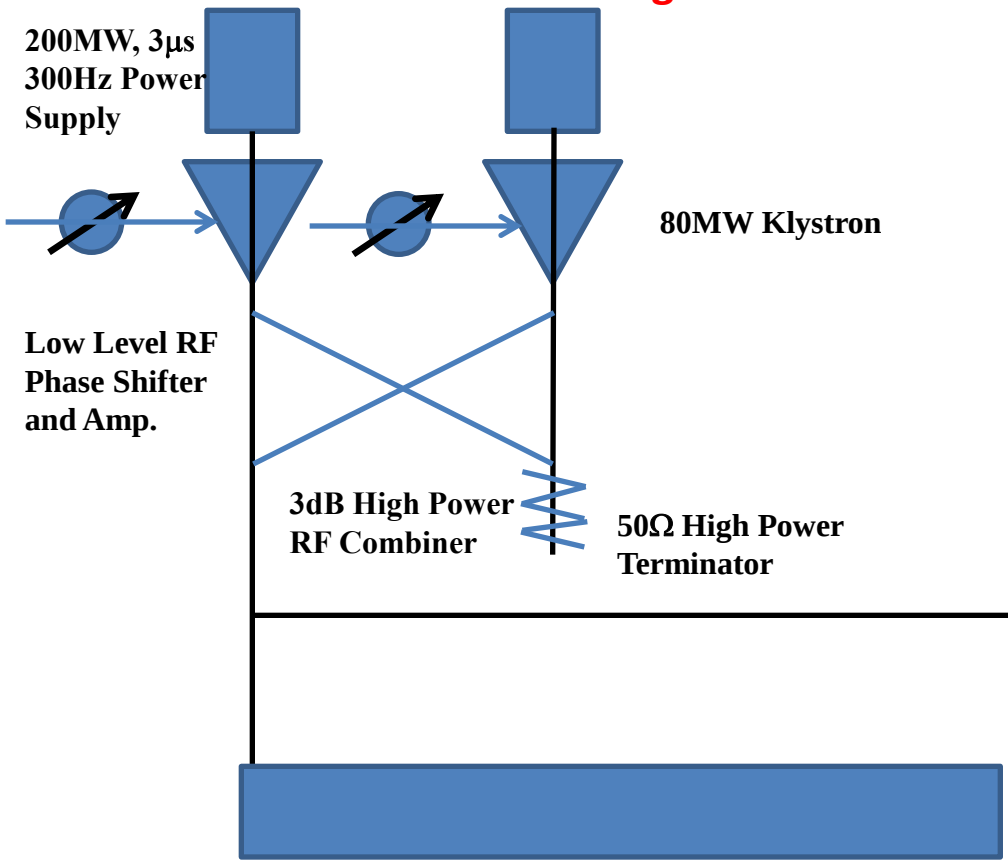
11MeV beam at 120MV/m, from 100bunches/pulse to 500bunches/pulse beam generation

Phase to Amplitude Modulation Method for Beam Loading Compensation



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

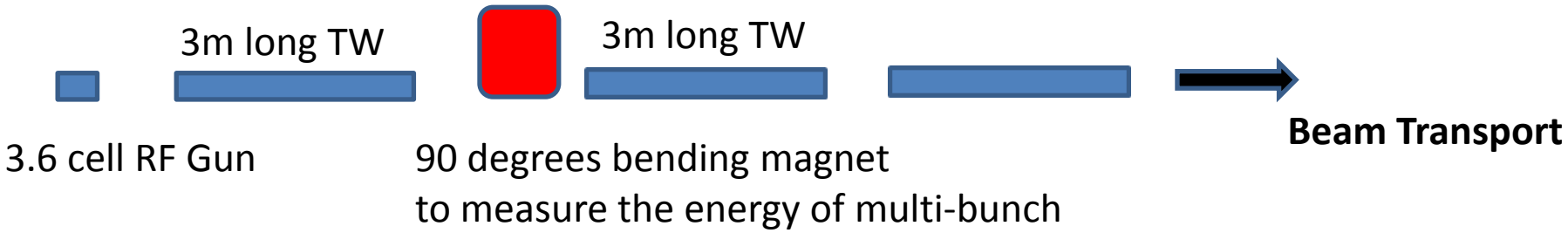
1.4x10^{10} electrons/bunch
With 2.8nsec bunch spacing
And 2856MHz Linac
Beam loading current: 0.78A



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

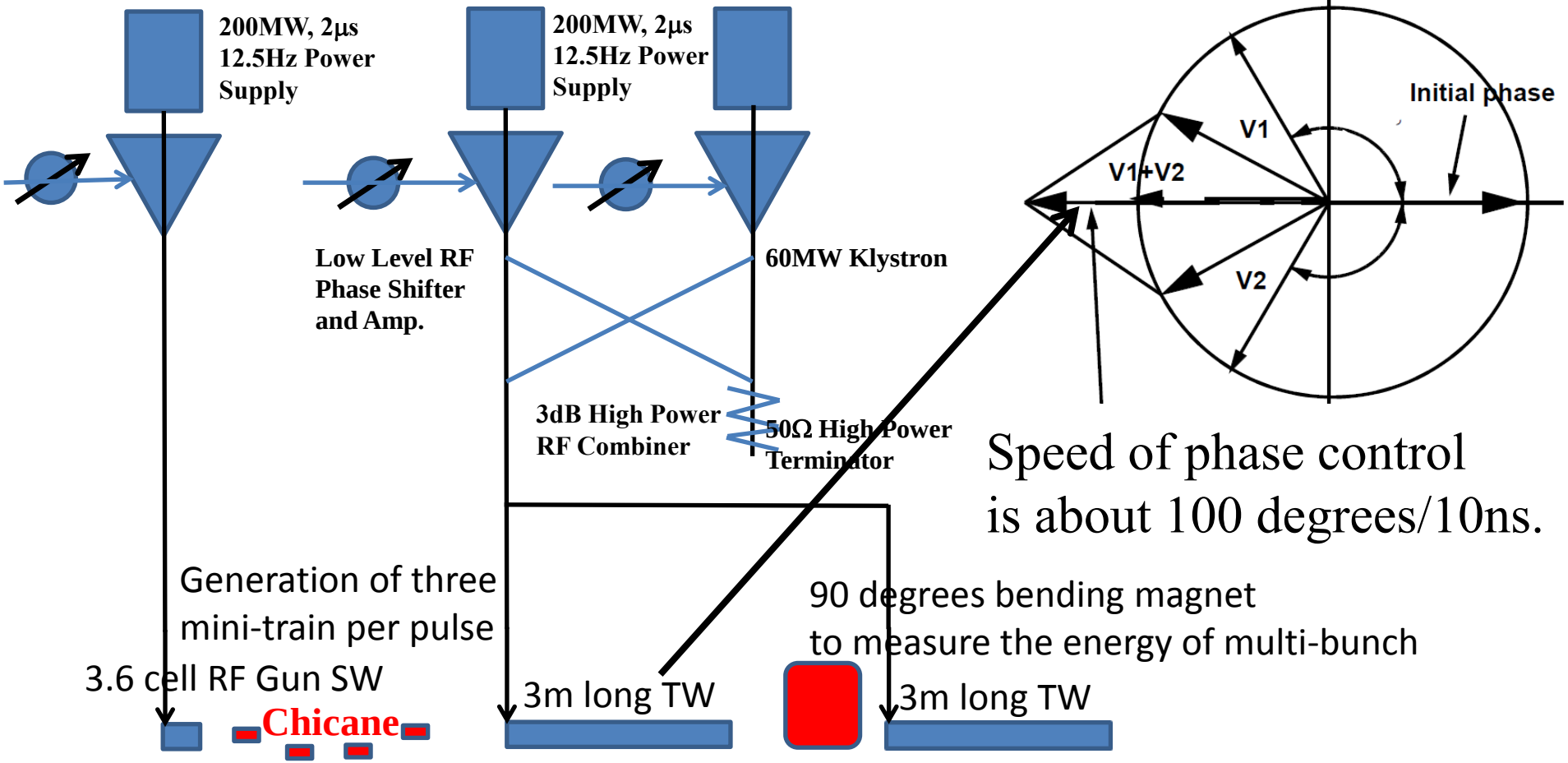
Also, I assume 10% margin as wave guide loss and so on because of the experience at ATF Linac. So, klystron output power 80MW and 3μs pulse width are necessary.

ATF Injector for 1.5GeV ATF Linac will be modified for beam loading compensation experiment in next year. However, due to the lack of 2013 budget, we delayed this experiment.

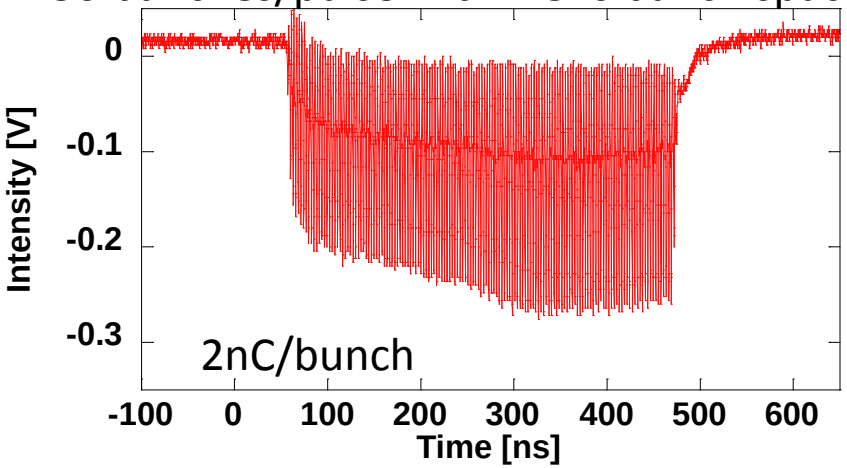


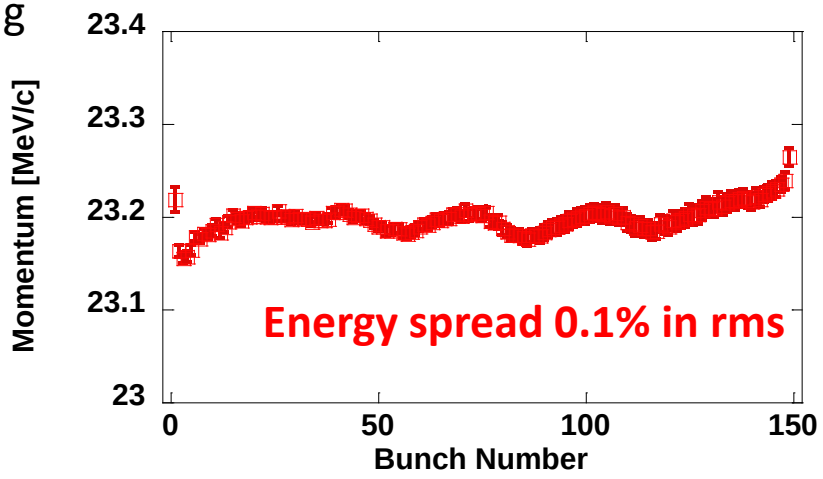
$3x10^{10}$ with 6.15nsec bunch spacing corresponds to $1.4x10^{10}$ in the case of 2.8nsec bunch spacing as same beam loading in multi-bunch trains.

ATF Triplet Beam : 3x20 bunches/train with 60nsec train gap and 2.8nsec bunch spacing. This operation is possible in the safety of the radiation for ATF accelerator.

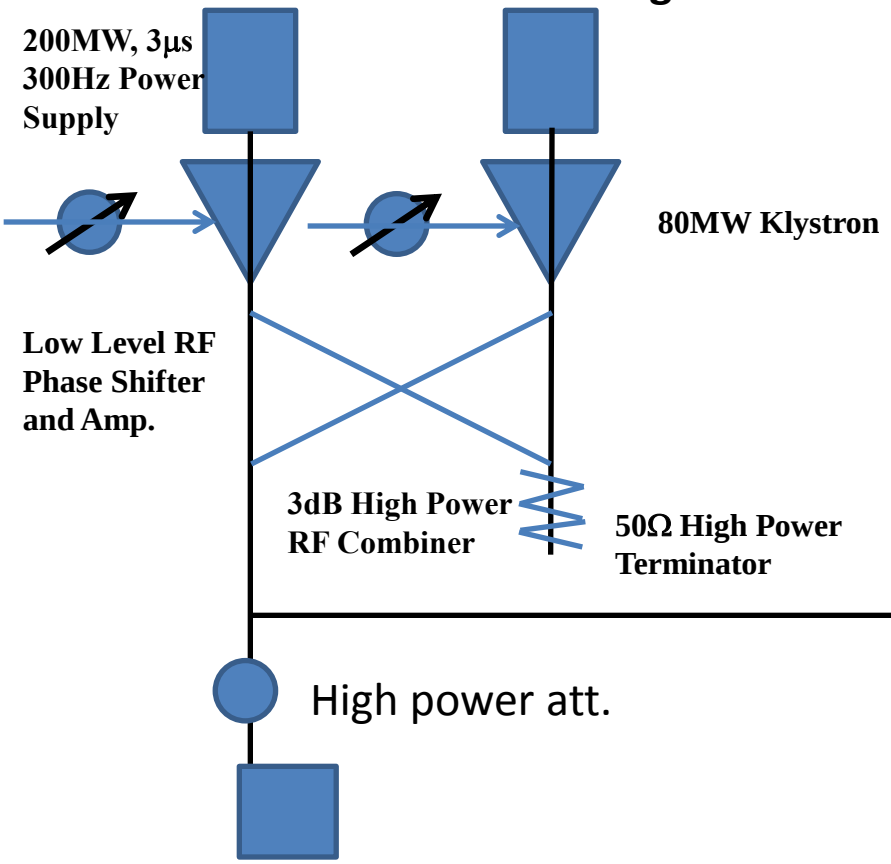


150 bunches/pulse with 2.8ns bunch spacing





1.4×10^{10} electrons/bunch
With 2.8nsec bunch spacing
And 2856MHz Linac
Beam loading current: 0.78A



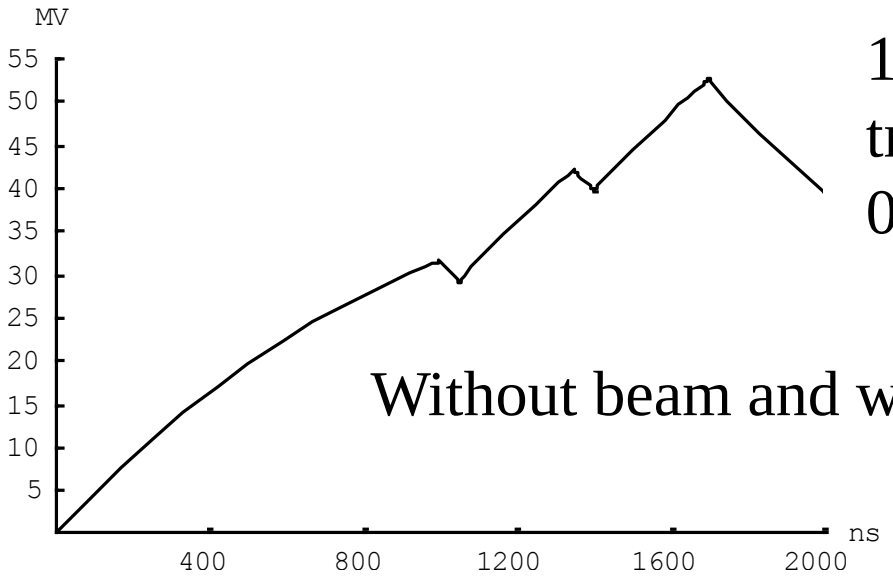
3.6 cell RF Gun

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

A0 3m long constant gradient travelling wave structure

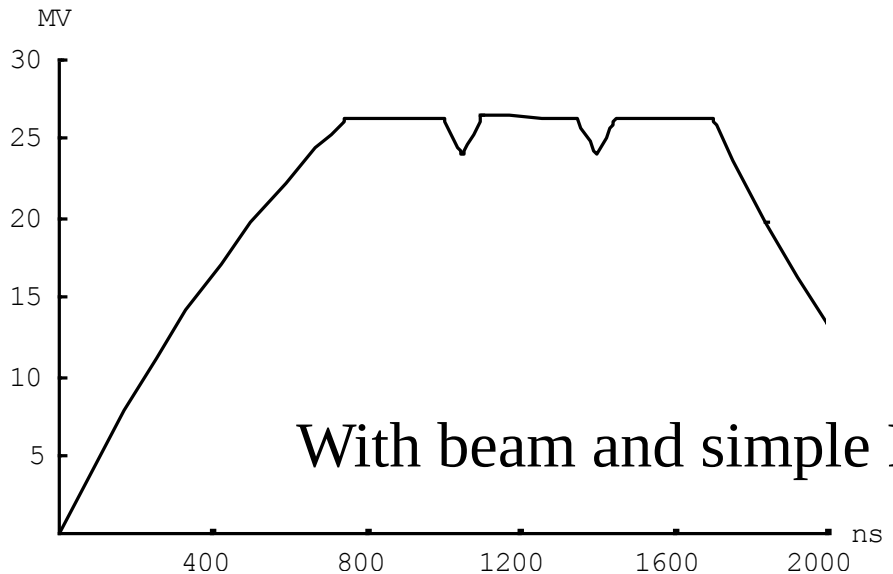
Considering the cost reduction for this experiment now.
Single bunch beam loading compensation can be done using off crest Acceleration on which we have a lot of experience.

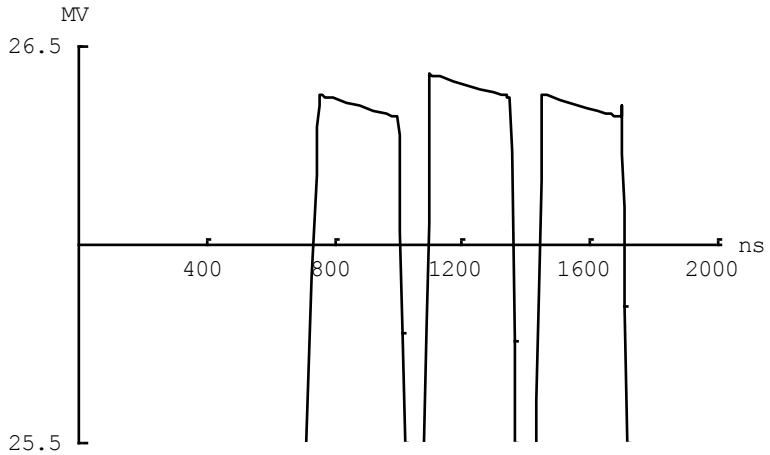
Rough beam loading compensation by simple simulation using standing wave accelerating structures



100ns beam gap and 3 x 250ns bunch train with 6.15ns bunch spacing and 0.78A beam loading

Without beam and with simple RF input power control

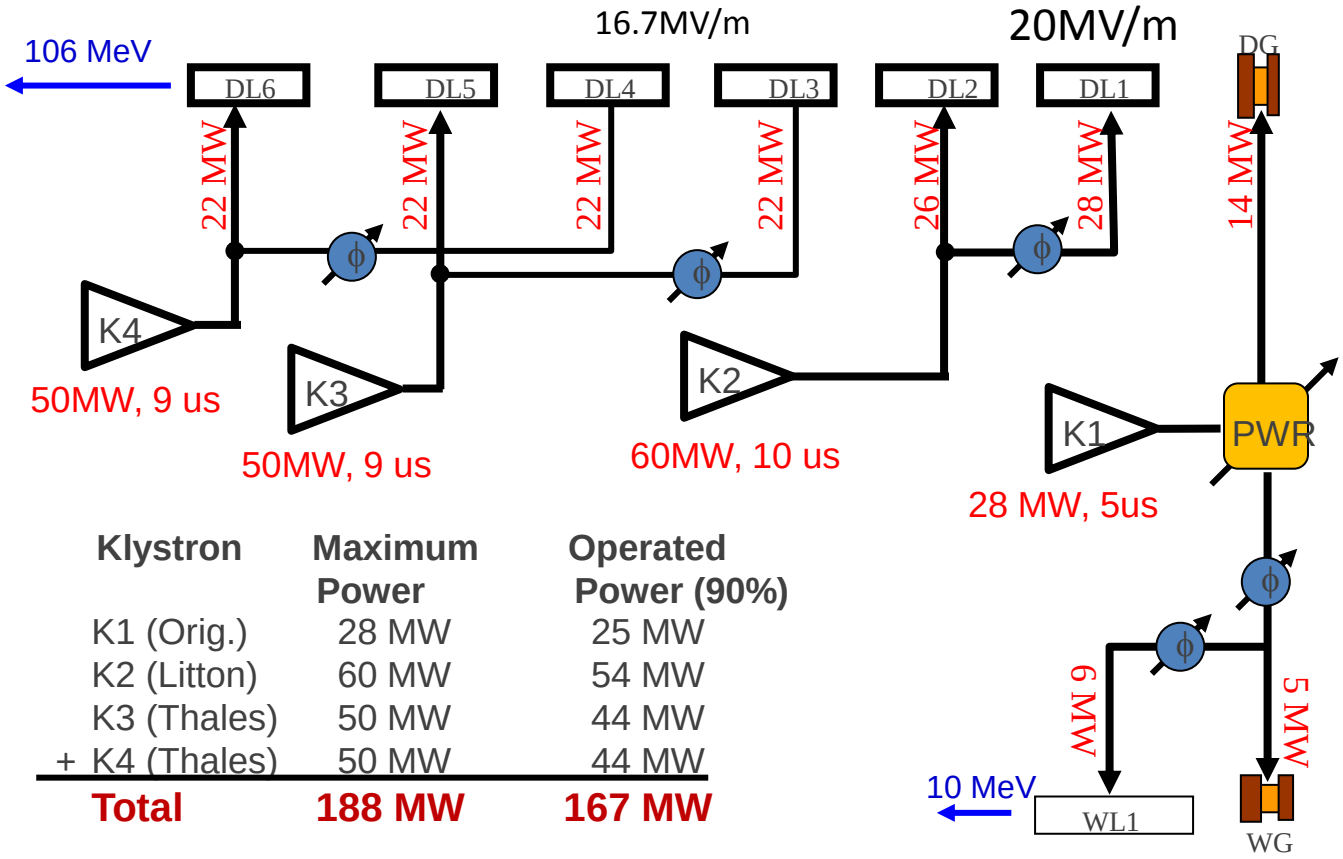




With beam and simple RF input power control

RF power distribution

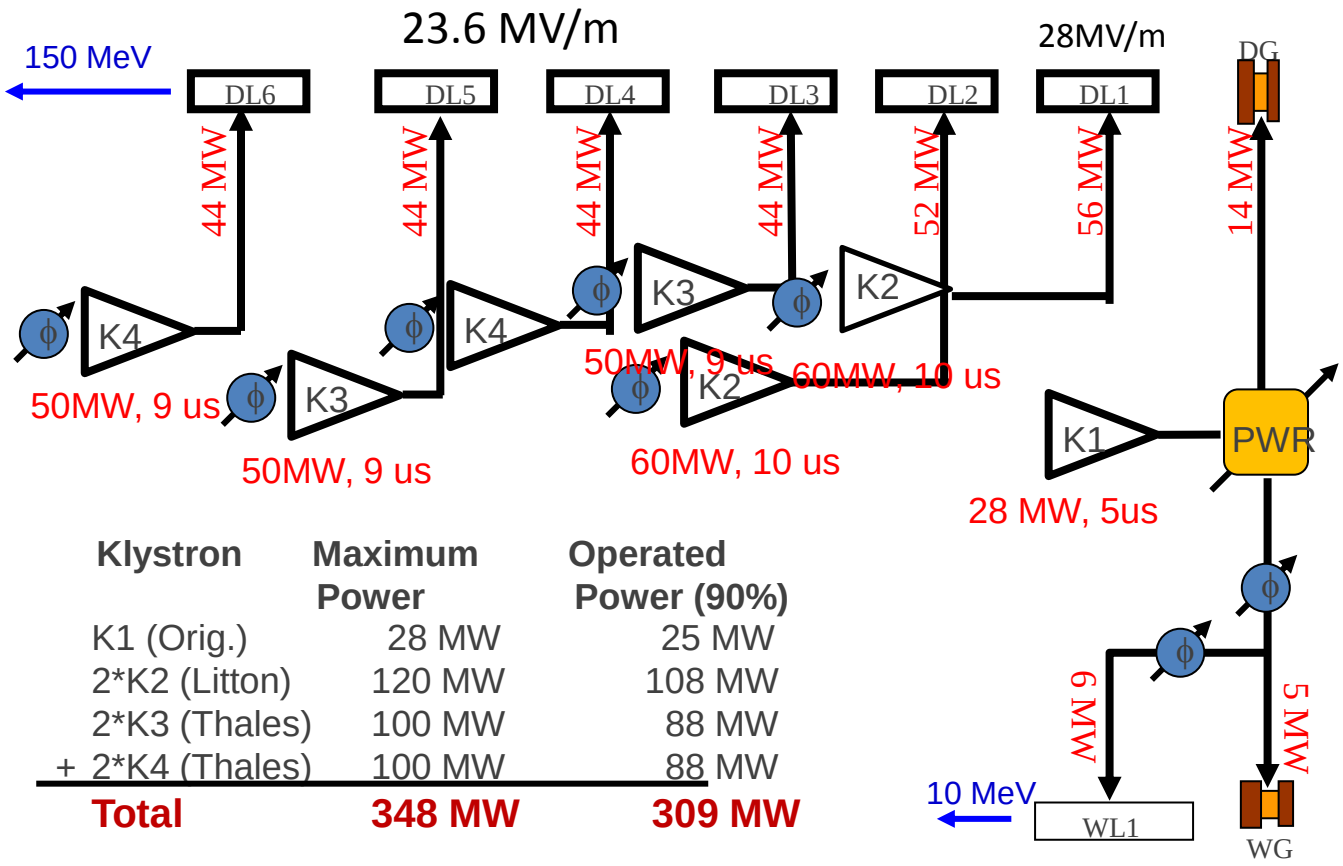
Total Power Budget = 167 MW



Klystron	Maximum Power	Operated Power (90%)
K1 (Orig.)	28 MW	25 MW
K2 (Litton)	60 MW	54 MW
K3 (Thales)	50 MW	44 MW
+ K4 (Thales)	50 MW	44 MW
Total	**188 MW**	**167 MW**

RF power distribution

Total Power Budget = 309 MW



Klystron	Maximum Power	Operated Power (90%)
K1 (Orig.)	28 MW	25 MW
2*K2 (Litton)	120 MW	108 MW
2*K3 (Thales)	100 MW	88 MW
+ 2*K4 (Thales)	100 MW	88 MW
Total	**348 MW**	**309 MW**

Increase accelerating gradient to 40MV as unloaded one, then we will make the design of 30MV/m as loaded one with $3x10^{10}$ positrons/bunch and 6.15ns bunch spacing.
We need the reduction of accelerator structure iris diameter from 46mm to ~40mm.

I hope ANL L-band standing wave tube with minor modification will be applicable to ILC positron booster Linac.

3. Summary

Beam dynamics simulation from the target to DR is necessary.

Target R&D is necessary at KEK.

Simple beam loading compensation experiment is necessary at ATF.

We have a budget problem on these urgent R&D.
I hope Japanese Gov., US DOE and European friends help us as soon as possible.