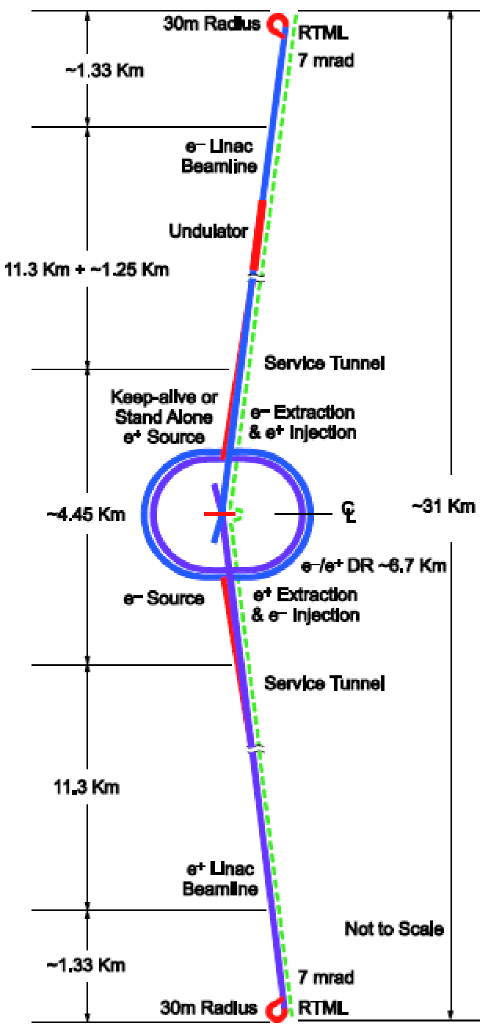
PoP experiment on beam loading for truly conventional positron source at ATF injector

ATF project meeting, 12-14 Feb. 2014
KEK, Junji Urakawa

Contents :

Proposed Design changes for TDR

RDR



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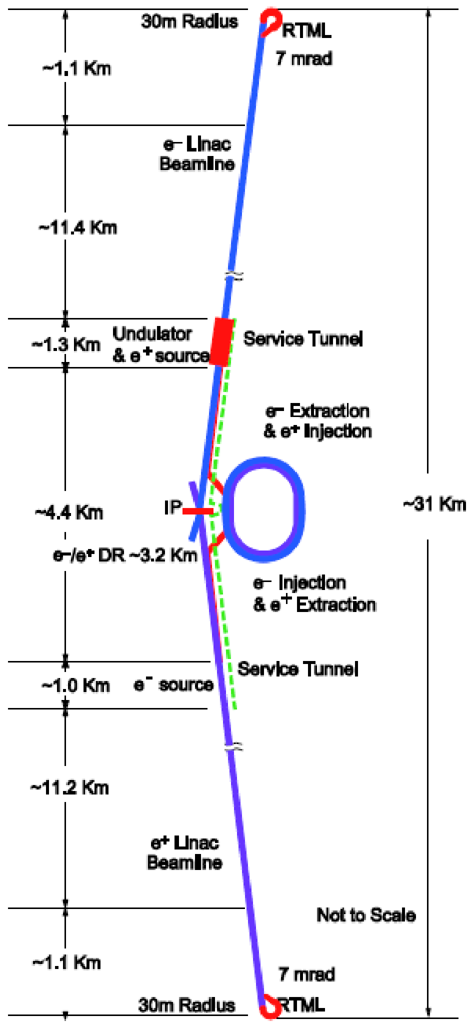


- **Single Tunnel for main linac**
- **Move positron source to end of linac *****
- **Reduce number of bunches factor of two (lower power) ****
- **Reduce size of damping rings (3.2km)**
- **Integrate central region**

Positron Source: Issues

- ILC positron source is challenging
  - Challenging hardware
    - **Rotating targets, undulators**
  - Risk for the electron beam
    - **Electron beam is sent through the smallest aperture**
    - **Significant energy loss for electrons (some GeV)**
    - **Will be hard to commission (compare to FEL)**
    - **Not clear about theoretical studies**
  - Positron beam quality is important
    - Will be hard to commission (comparable to proton source)
  - **Positron damping ring can only be fully commissioned if positron source is commissioned**
    - **Will come after commissioning of electron linac, i.e. late**
    - Positron damping ring is challenging because of electron cloud
  - Each step appears feasible but tough
  - Total is critical for overall commissioning
    - Adjust construction schedule for this?
  - Use a conventional positron source?

Some more efforts in theoretical studies appear necessary.
Should we take the risk?

- Hard to see an integrated system test
  - Can test components, as it has been done/is being done
  - Part tests from FEL, other sources

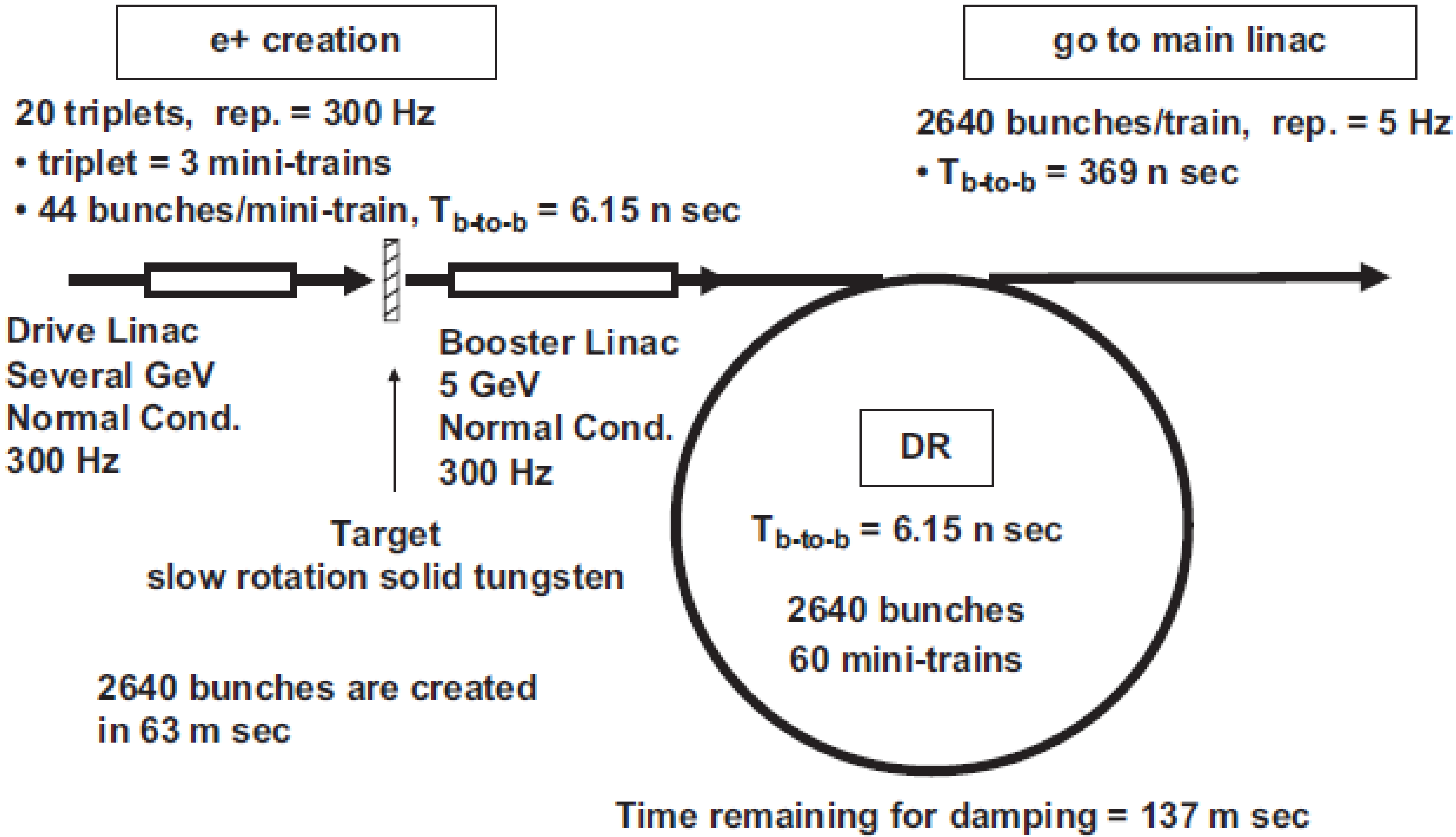
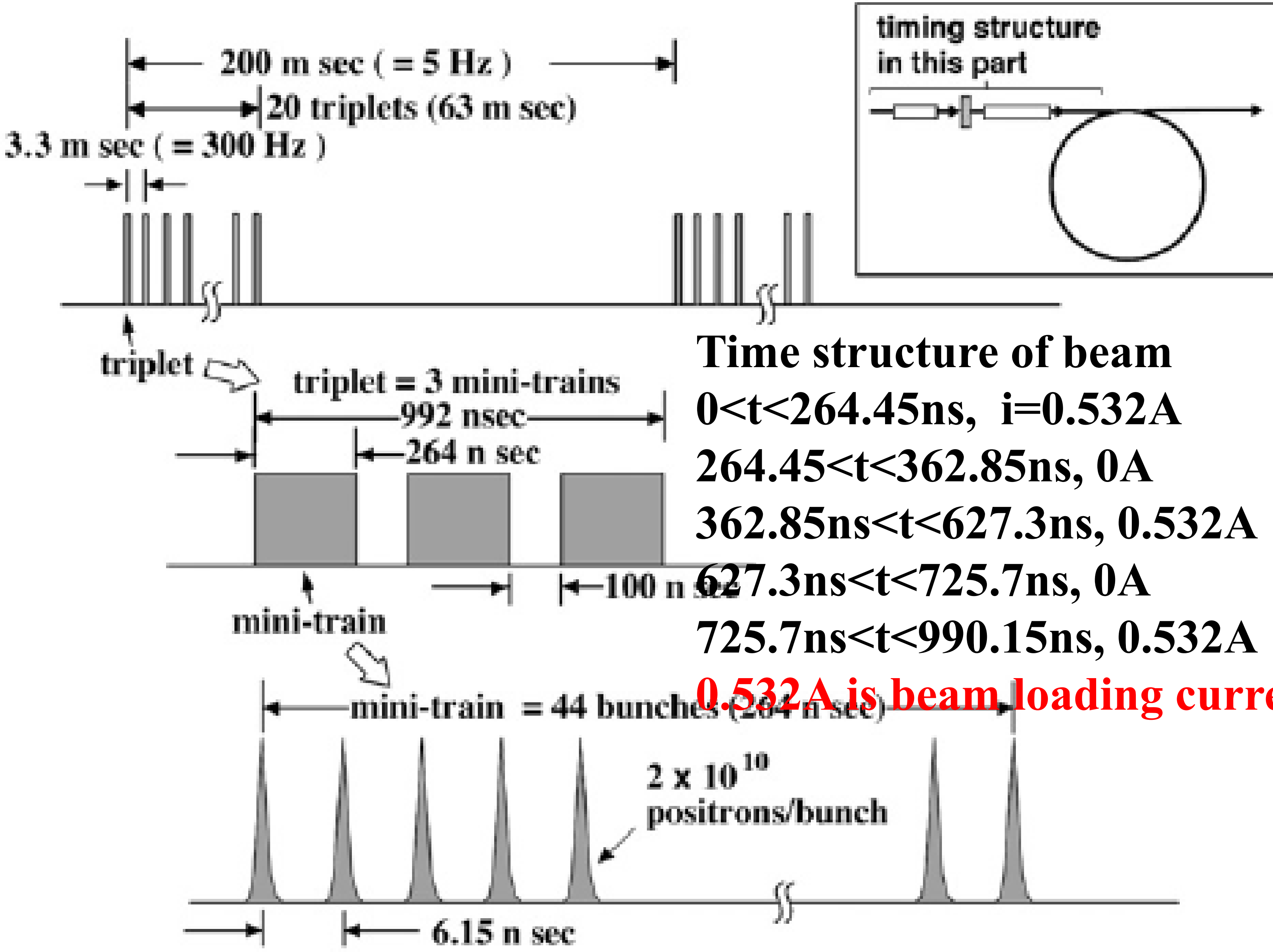


Fig. 1. Schematic view of the 300 Hz scheme.



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

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.

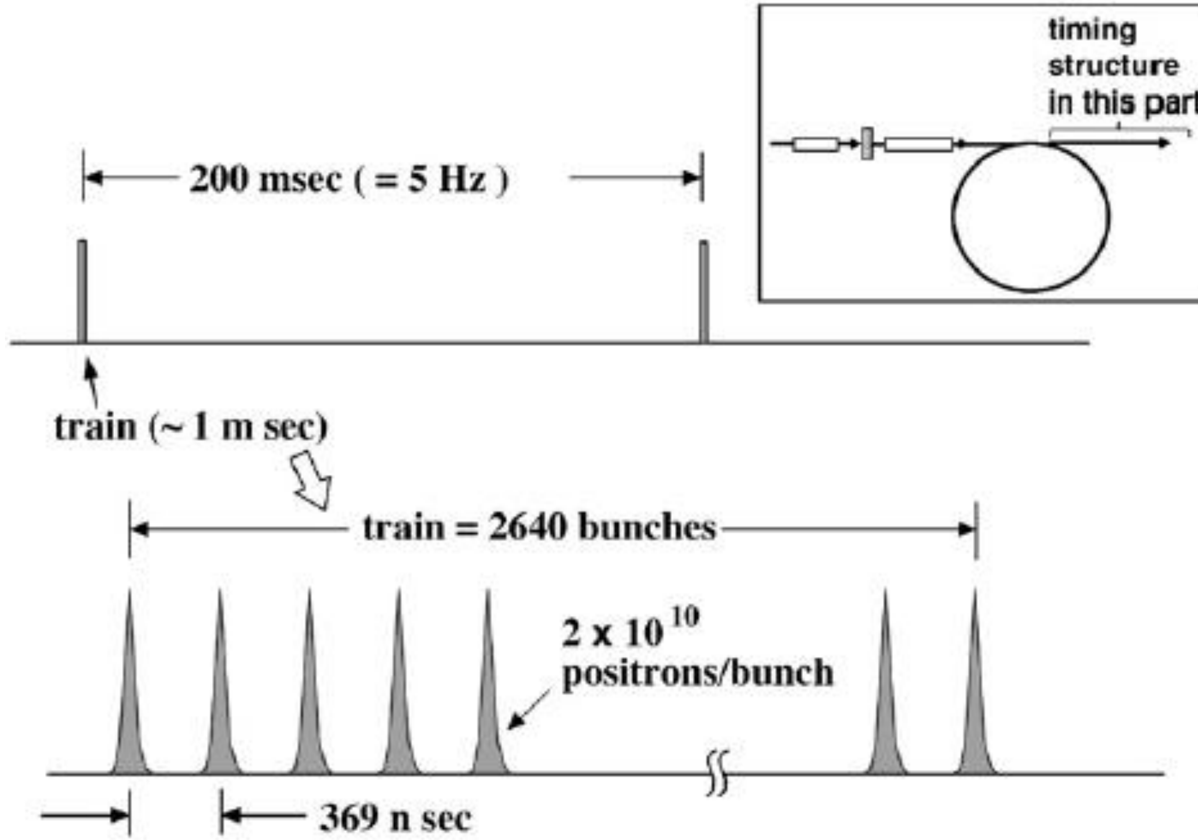
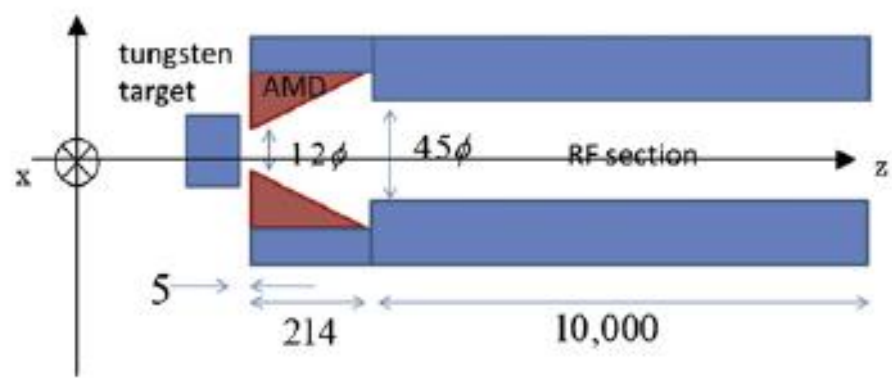


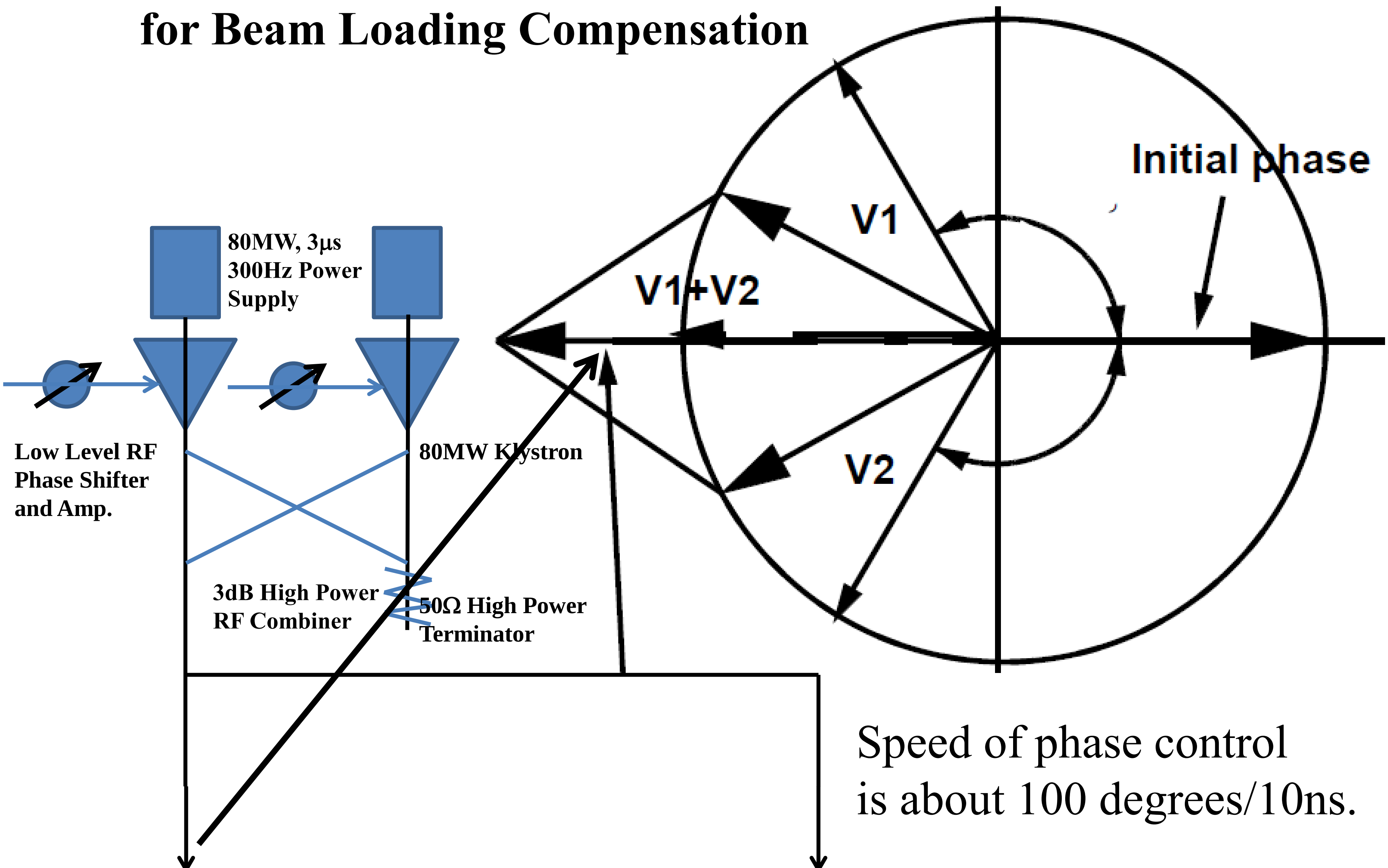
Fig. 4. Time structure after the damping ring.

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

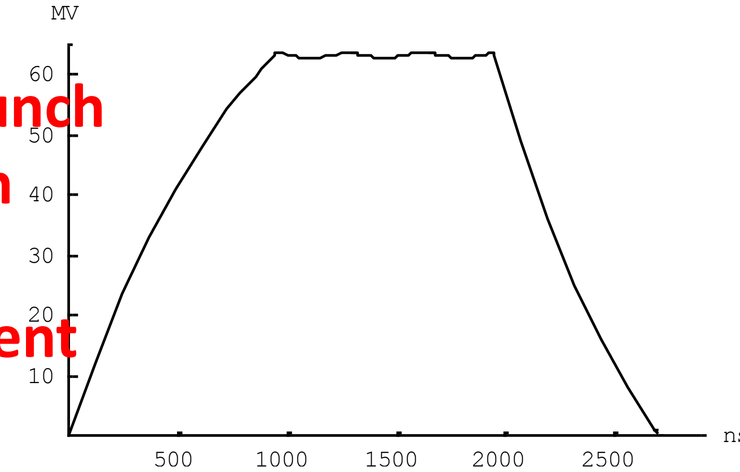


3. 300Hz Linac Scheme for Beam Loading Compensation

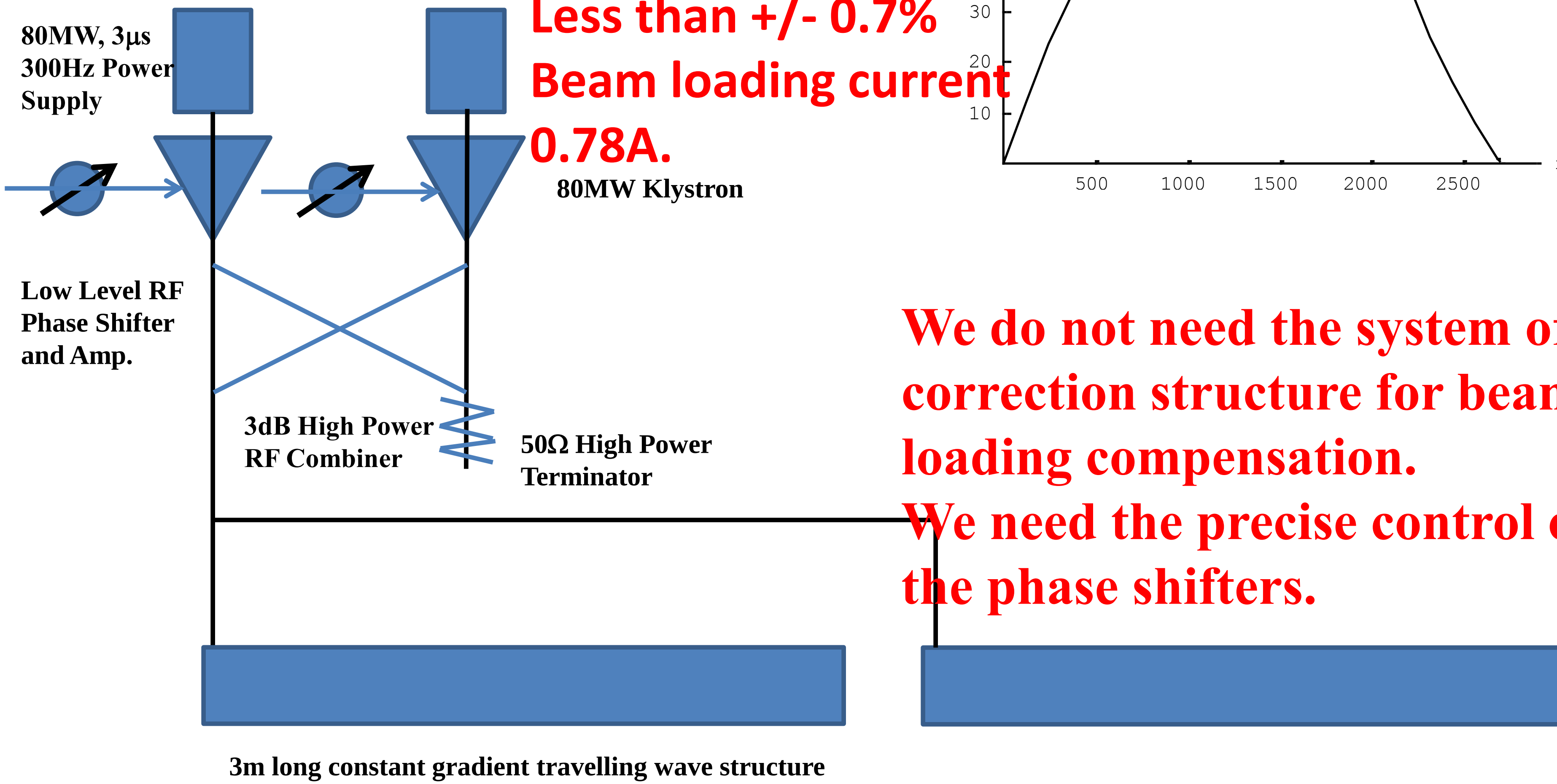
Phase to Amplitude Modulation Method for Beam Loading Compensation



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.

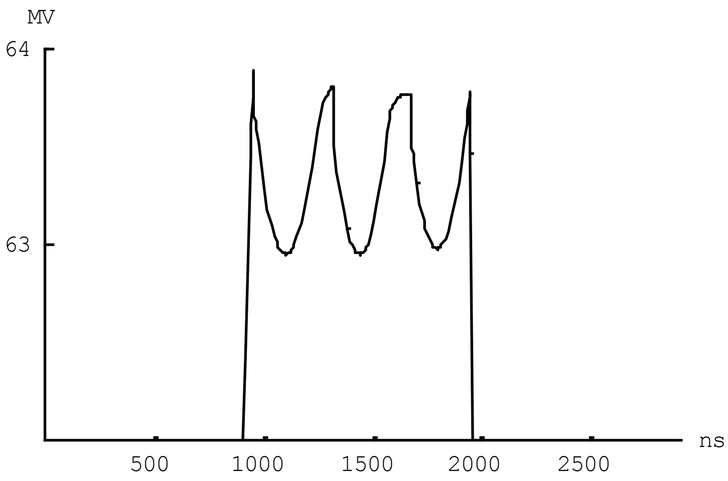


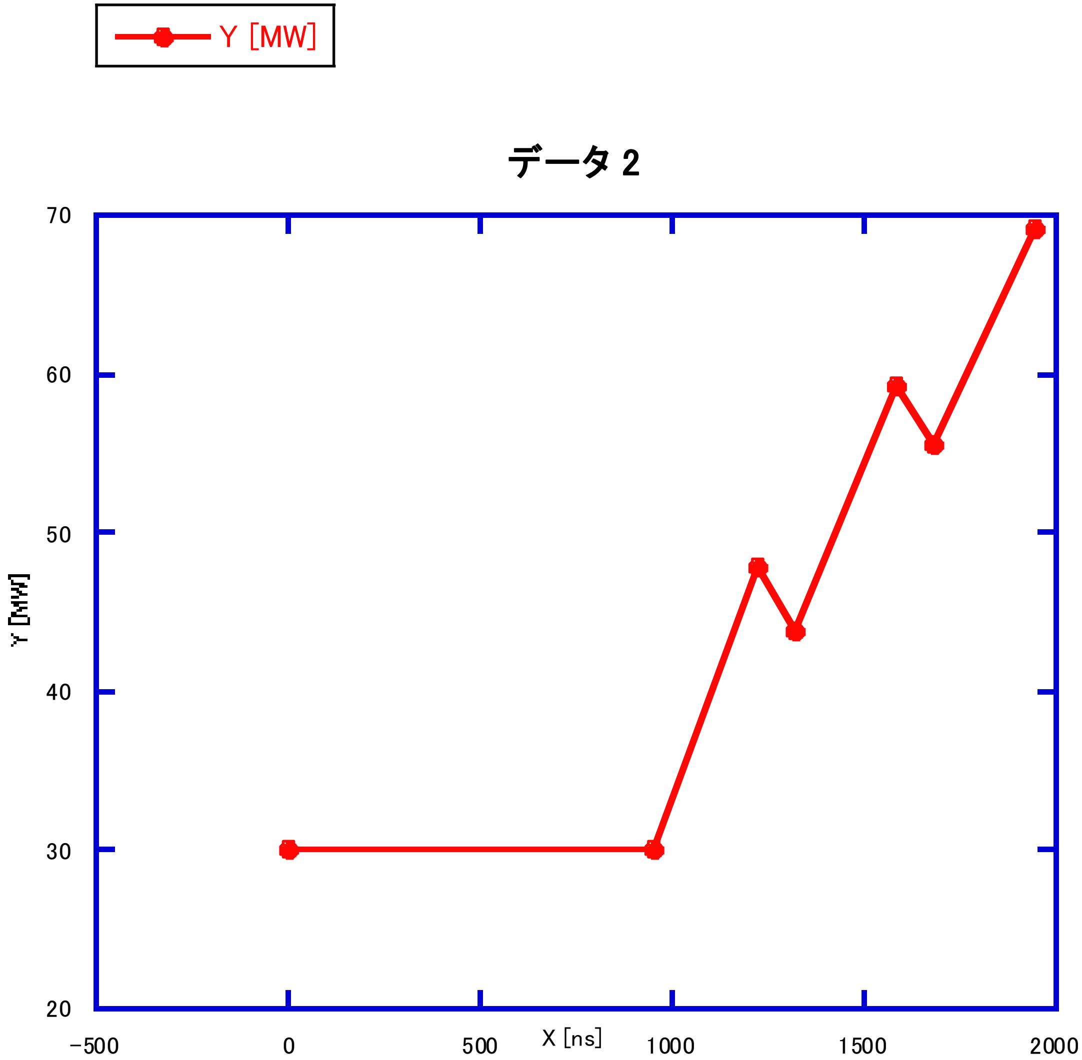
We do not need the system of correction structure for beam loading compensation.
We need the precise control of the phase shifters.

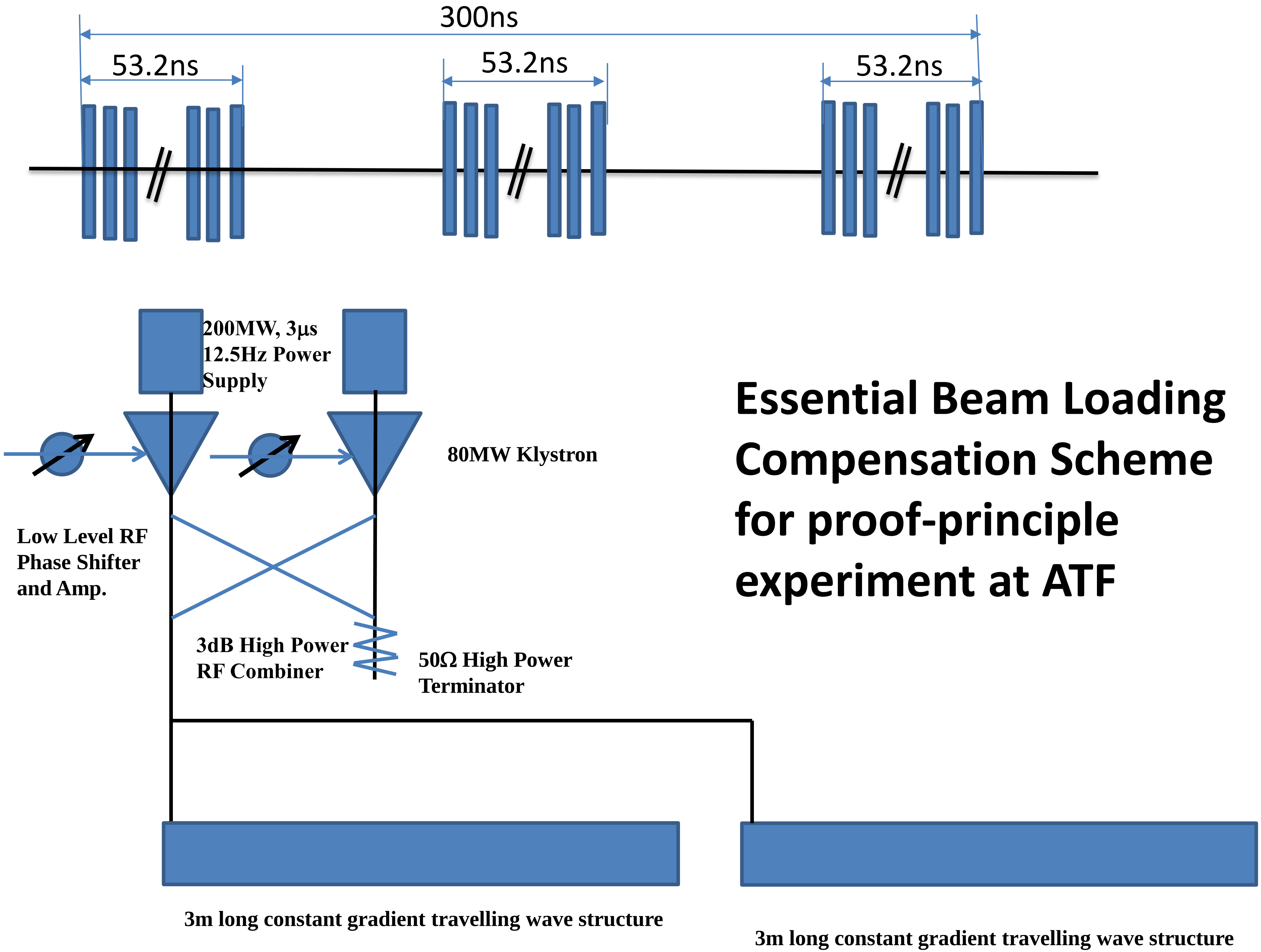
Also, I assume 10% margin as wave guide loss and so on because of the experience at ATF Linac. So, klystron output power 80MW and 3μs pulse width are necessary.

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.

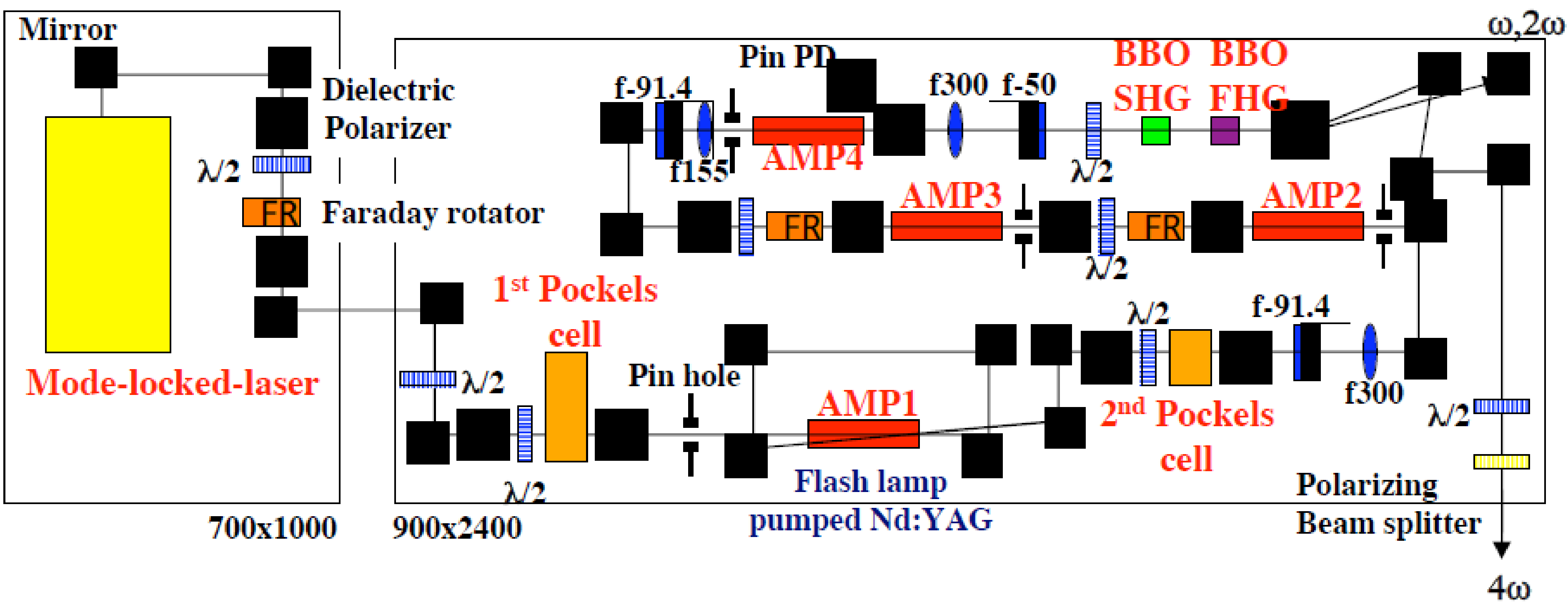




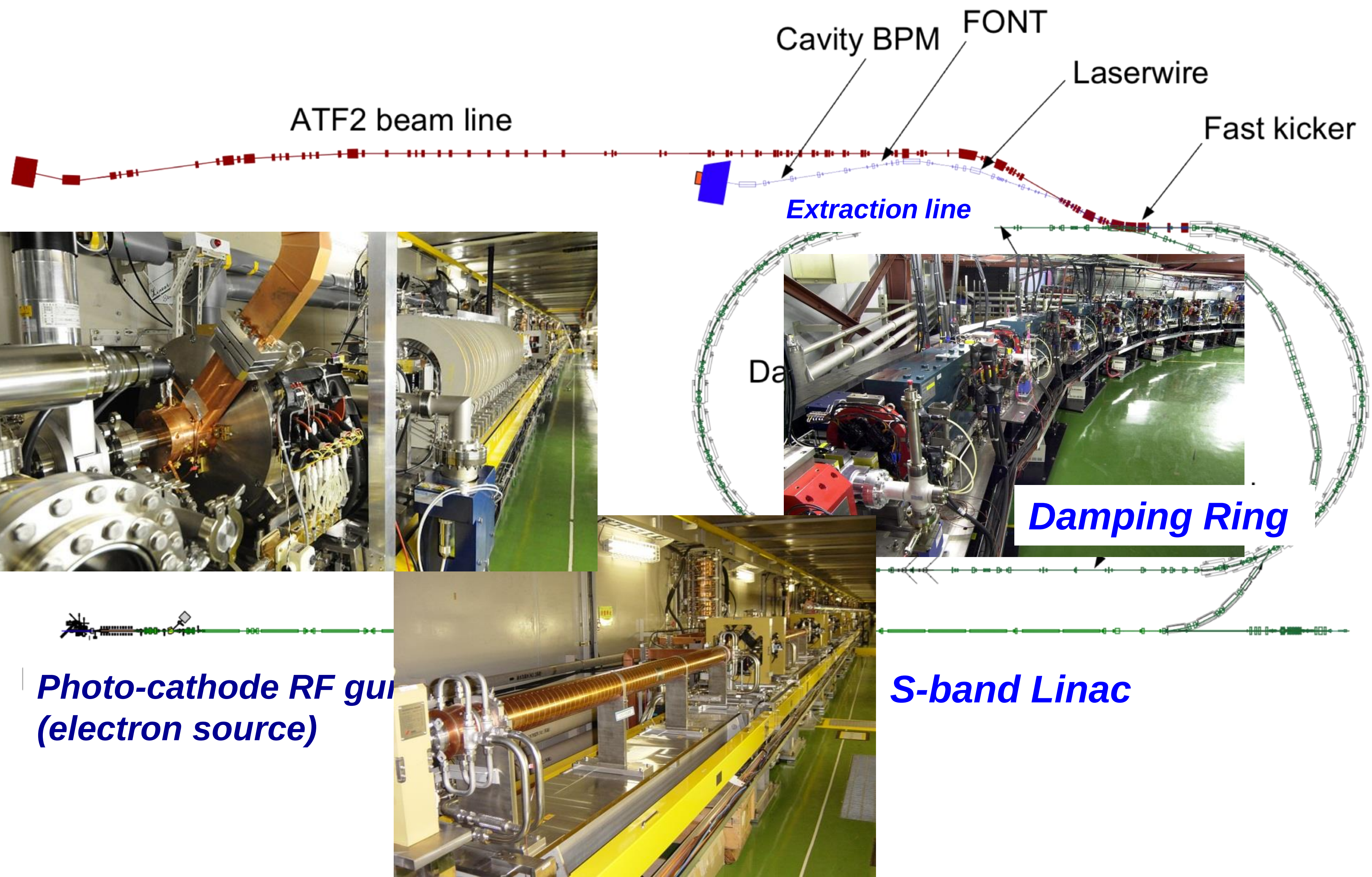

300ns
53.2ns
53.2ns
53.2ns
200MW, 3μs
12.5Hz Power
Supply
Essential Beam Loading
Compensation Scheme
for proof-principle
experiment at ATF
80MW Klystron
Low Level RF
Phase Shifter
and Amp.
3dB High Power
RF Combiner
50Ω High Power
Terminator
3m long constant gradient travelling wave structure
3m long 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**.

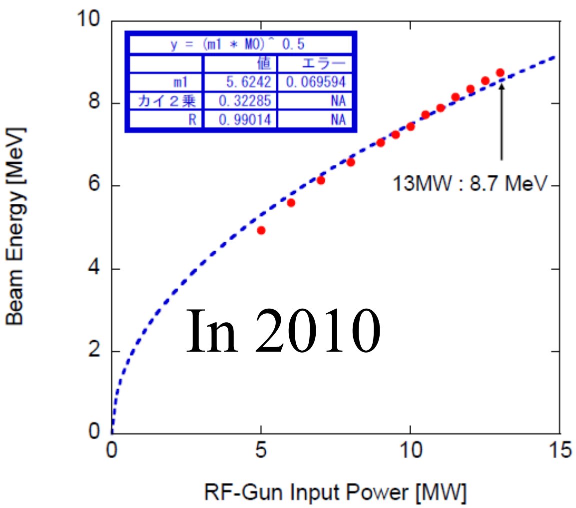
357MHz Laser oscillator	Pockels cell to make triplet laser pulse train	12.5Hz Amp.	4th higher harmonics generator (crystal:BBO)

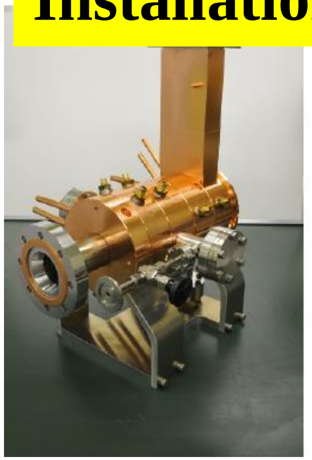


4. Plan for beam loading compensation experiment at ATF

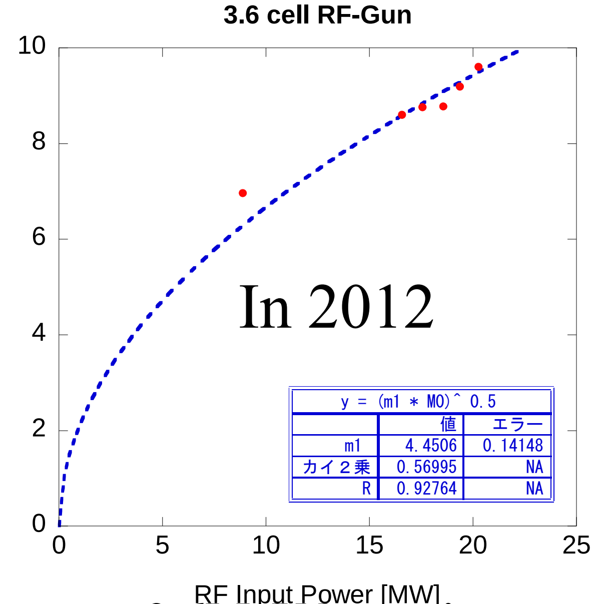


3.6 cell RF Gun Installation

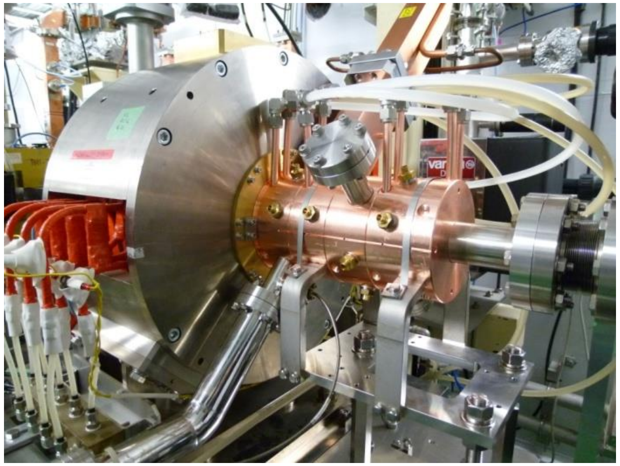




ATF インストールの様子

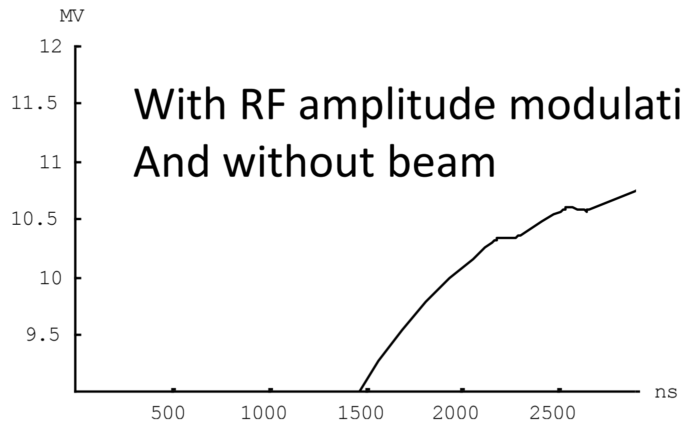


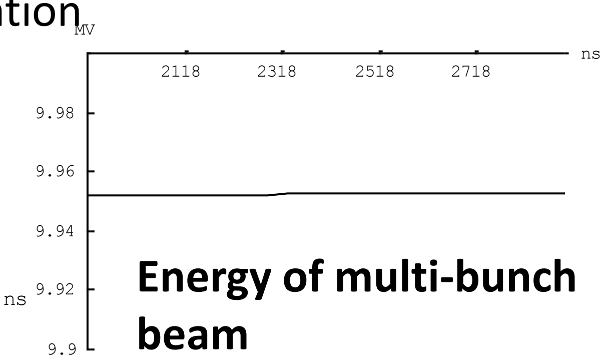
9.6MeV beam in one week RF aging with ~20.3MW RF input power



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

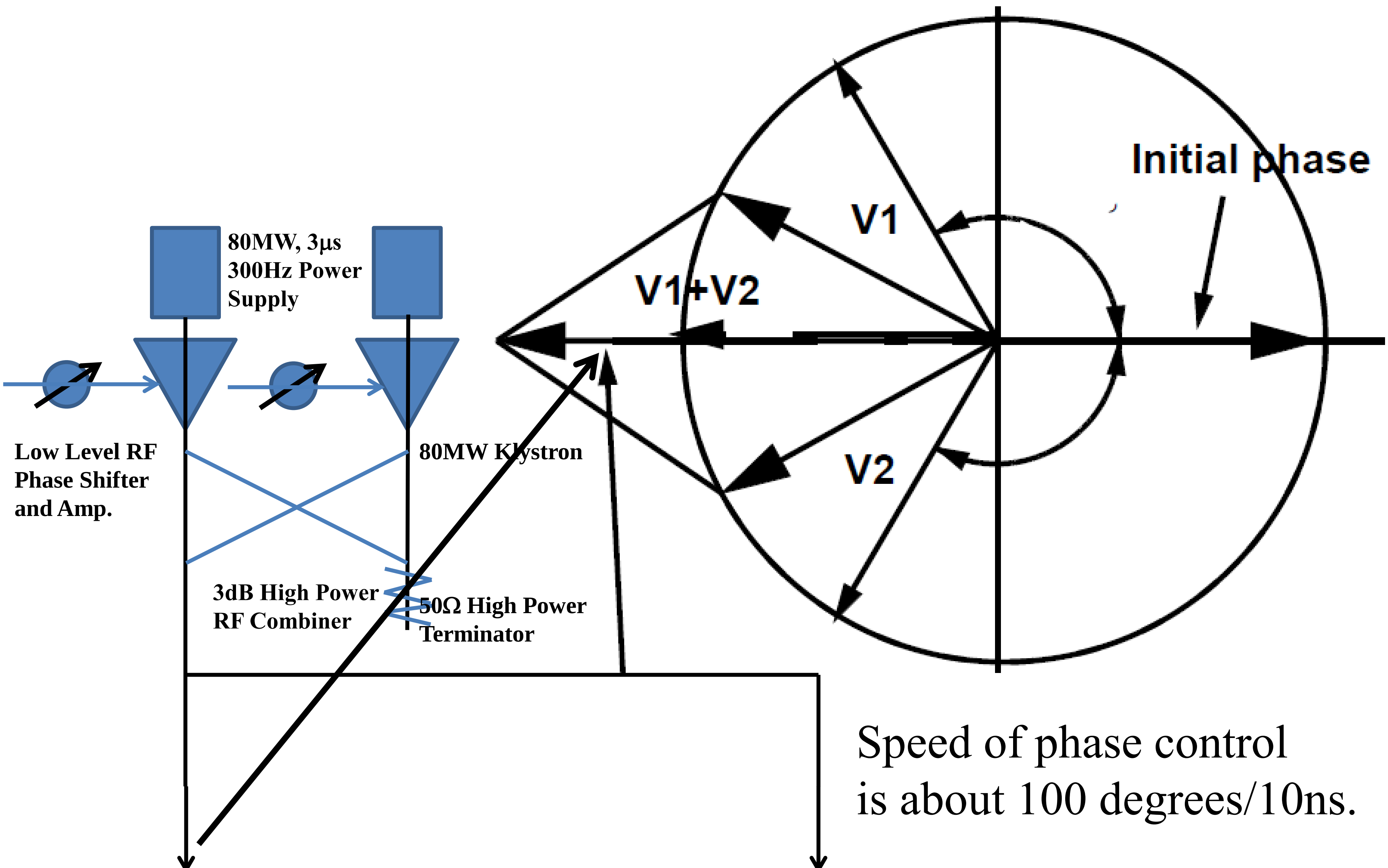
Now, 10MeV multi - bunch trains are generated and accelerated.





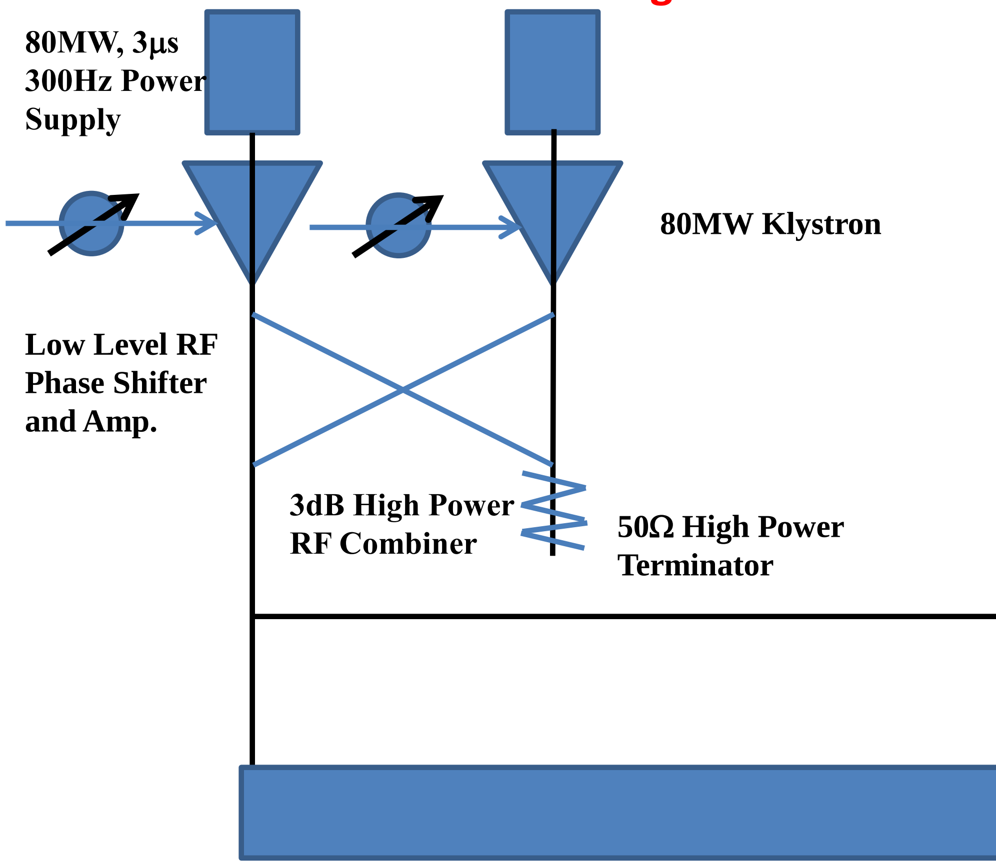
10MeV beam at 110MV/m, from 100 bunches/pulse to 500 bunches/pulse beam generation

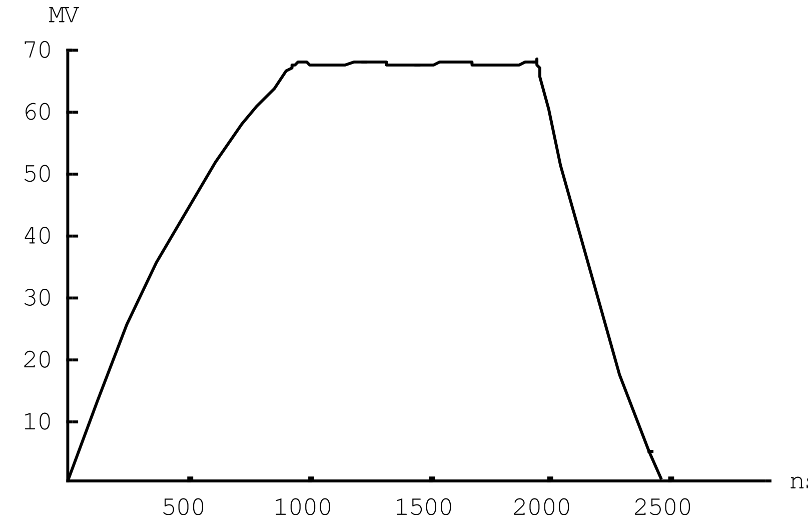
Phase to Amplitude Modulation Method for Beam Loading Compensation



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

1.4×10^{10} electrons/bunch
with 2.8nsec bunch spacing
and 2856MHz Linac
beam loading current: 0.78A

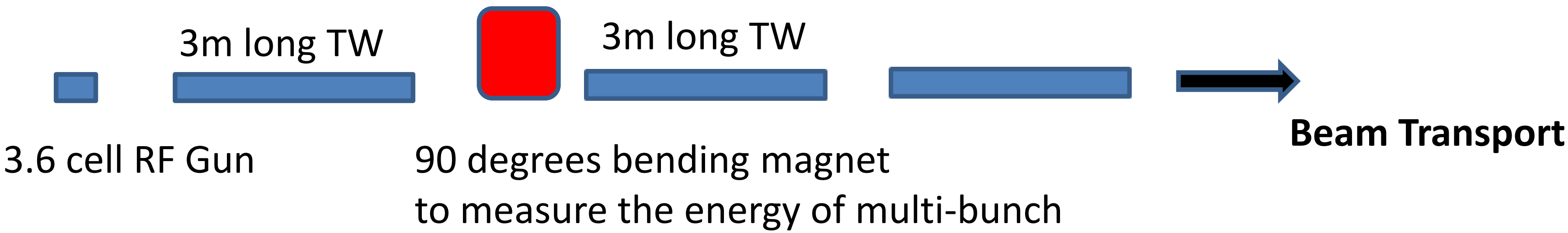




We do not need the system of correction structure for beam loading compensation.
We need the precise control of the low level phase shifters.

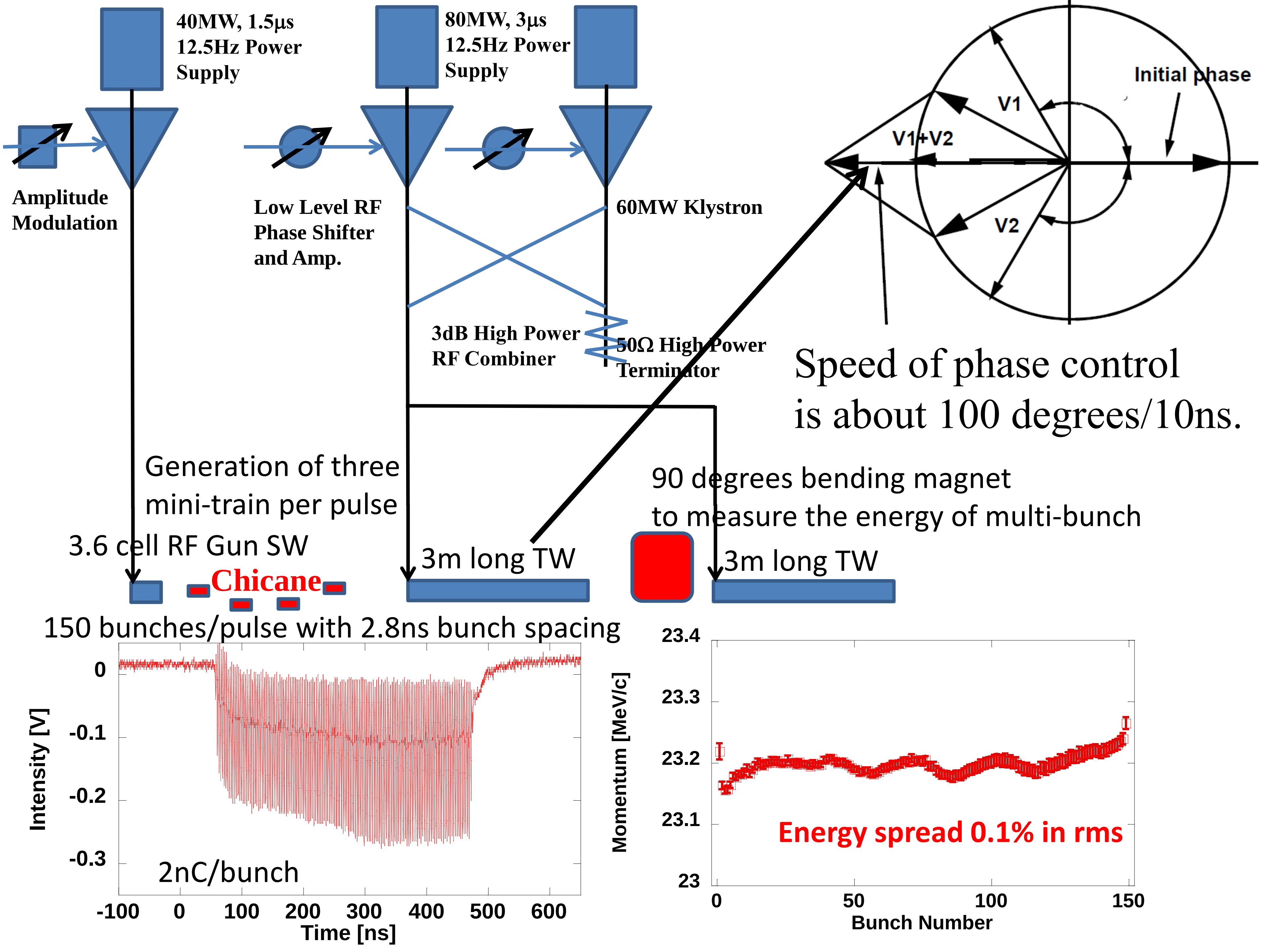
Also, I assume 10% margin as wave guide loss and so on because of the experience at ATF Linac. So, klystron output power 80MW and 3μs pulse width are necessary.

ATF Injector for 1.3 GeV ATF Linac will be modified for beam loading compensation experiment in this summer.



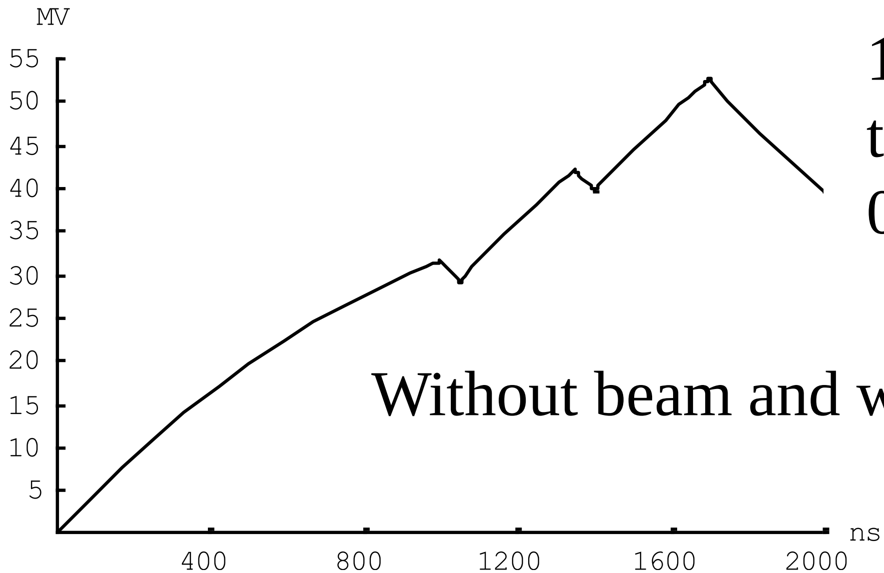
$3\mathrm{x}10^{10}$ with 6.15nsec bunch spacing corresponds to $1.4\mathrm{x}10^{10}$ in the case of 2.8nsec bunch spacing as same beam loading in multi-bunch trains.

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.

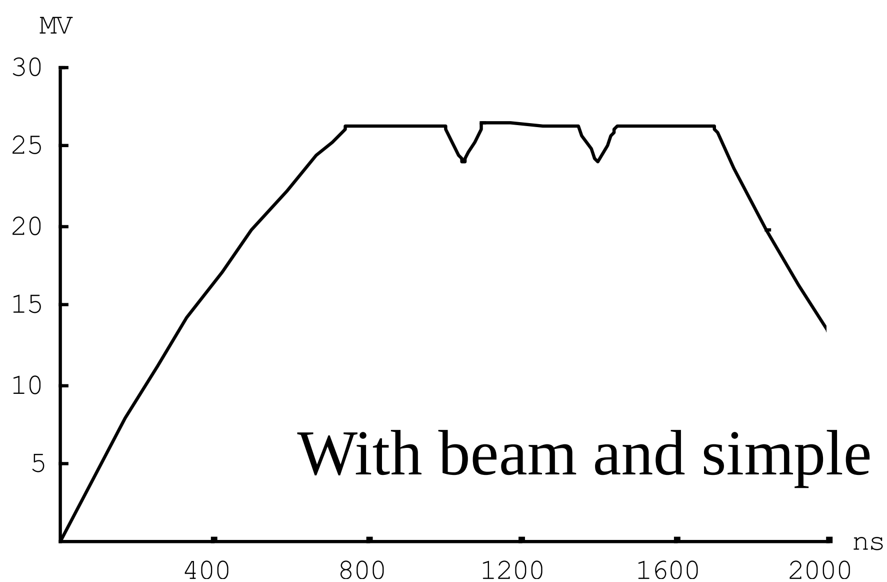

40MW, 1.5μs
12.5Hz Power
Supply
80MW, 3μs
12.5Hz Power
Supply
Initial phase
V1
V1+V2
V2
Amplitude
Modulation
Low Level RF
Phase Shifter
and Amp.
60MW Klystron
3dB High Power
RF Combiner
50Ω High Power
Terminator
Speed of phase control
is about 100 degrees/10ns.
Generation of three
mini-train per pulse
90 degrees bending magnet
to measure the energy of multi-bunch
3.6 cell RF Gun SW
Chicane
3m long TW
3m long TW
150 bunches/pulse with 2.8ns bunch spacing
0
-0.1
-0.2
-0.3
Intensity [V]
2nC/bunch
-100
0
100
200
300
400
500
600
Time [ns]
23.4
23.3
23.2
23.1
23
Momentum [MeV/c]
Energy spread 0.1% in rms
0
50
100
150
Bunch Number

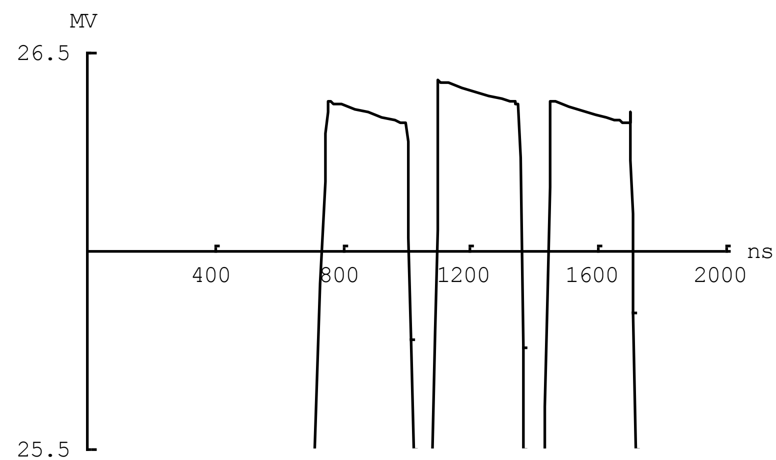
Rough beam loading compensation by simple simulation using standing wave accelerating structures (3.6 cell RF gun)

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

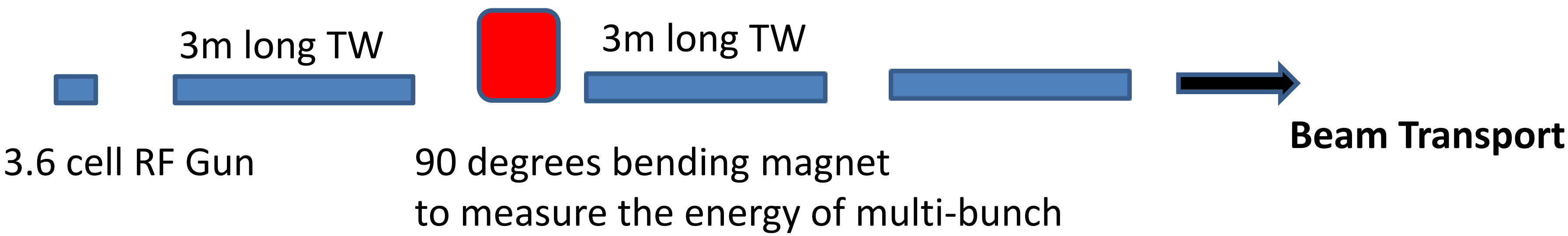




With beam and simple RF input power control

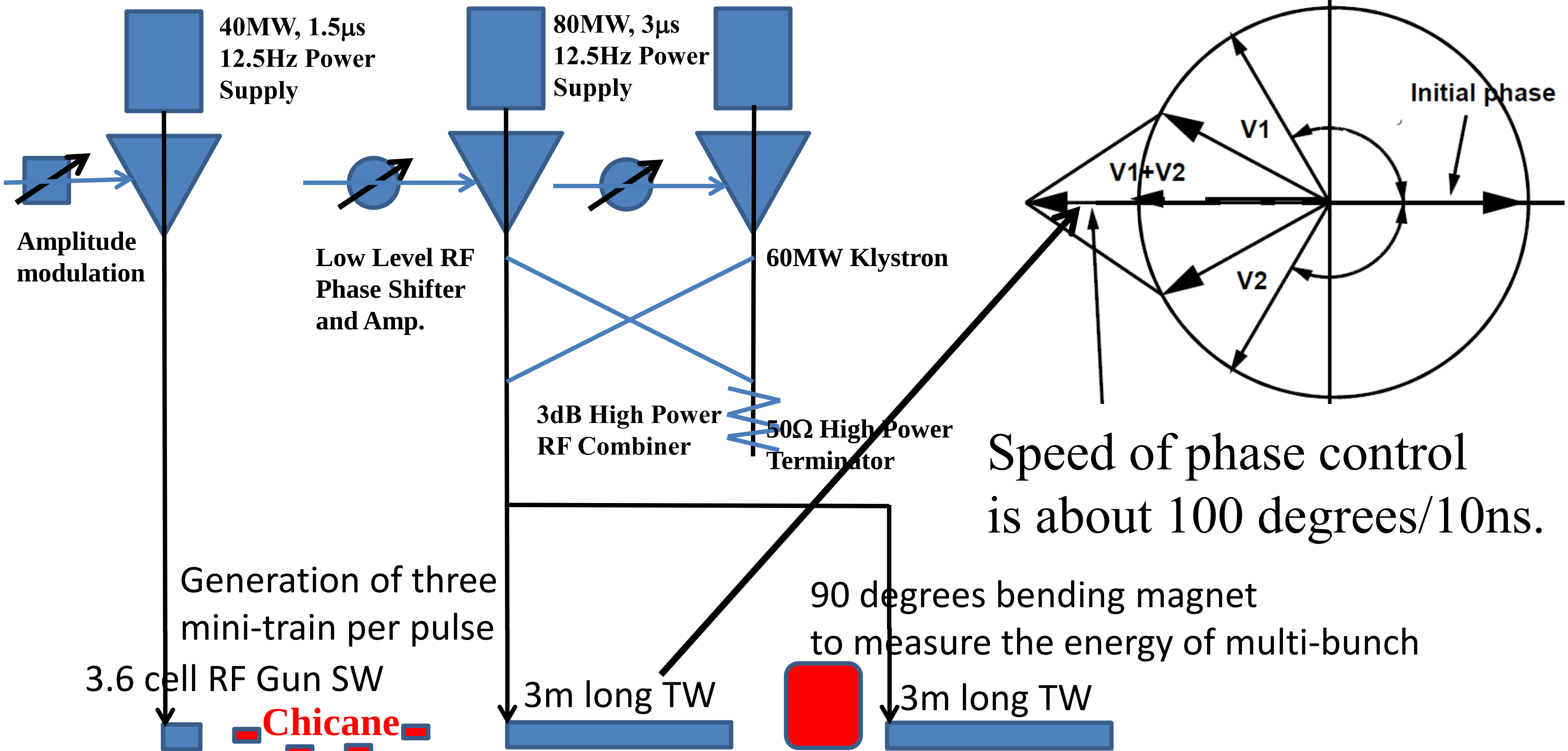
5. Summary

ATF Injector for 1.3GeV ATF Linac will be modified for beam loading compensation experiment in this summer.
Due to the lack of 2013 budget, we delayed this experiment.



$2x10^{10}$ with 6.15nsec bunch spacing corresponds to $0.9x10^{10}$ in the case of 2.8nsec bunch spacing as same beam loading in multi-bunch trains.

ATF Triplet Beam : 3x10 bunches/train with 30nsec train gap and 2.8nsec bunch spacing. (Since I want to have margin for the safety operation, I reduced half beam of former slide.)



150 bunches/pulse with 2.8ns bunch spacing