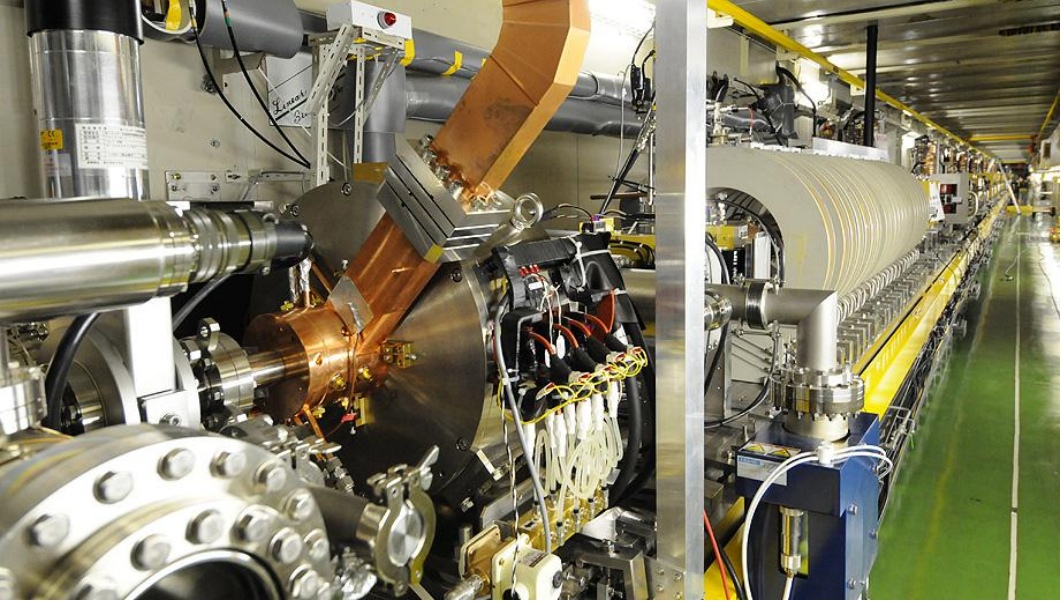
# 300Hz Conventional Linac/RF-gun scheme and cost

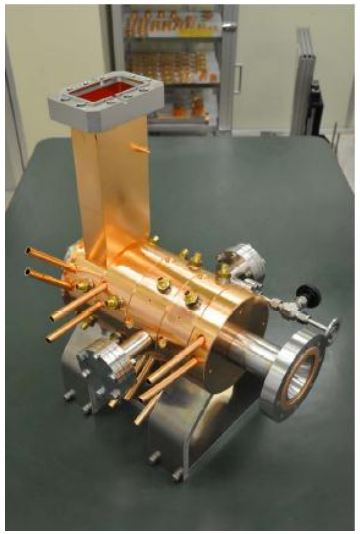
Junji Urakawa , KEK

300Hz Linac design is a tentative one for heavy beam loading.
After some discussion on the scheme for the heavy beam loading, we almost found to reduce the cost by ~30%. We still need a time to make a optimum design for the heavy beam loading compensation.

**Contents :**

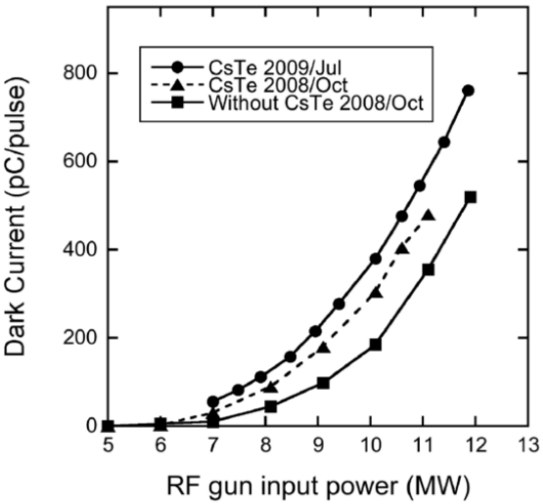
# Photo-cathode RF Gun

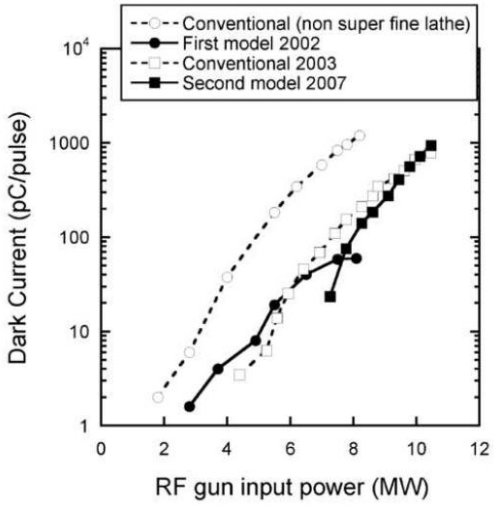


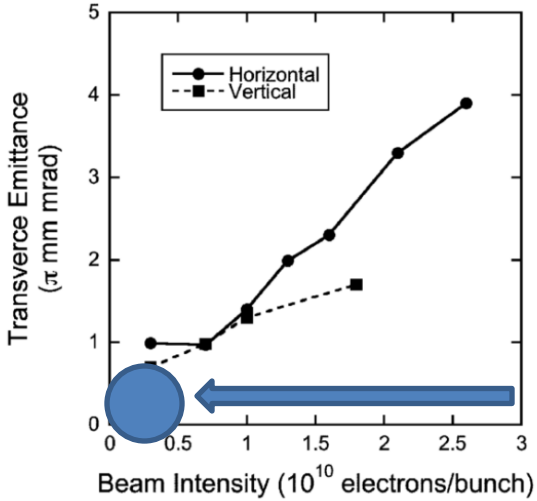


**1.3GeV ATF Linac, results by 80MeV beam.** **10MeV 3.6 cell gun** **6MeV 1.6 cell gun**

**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**.




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

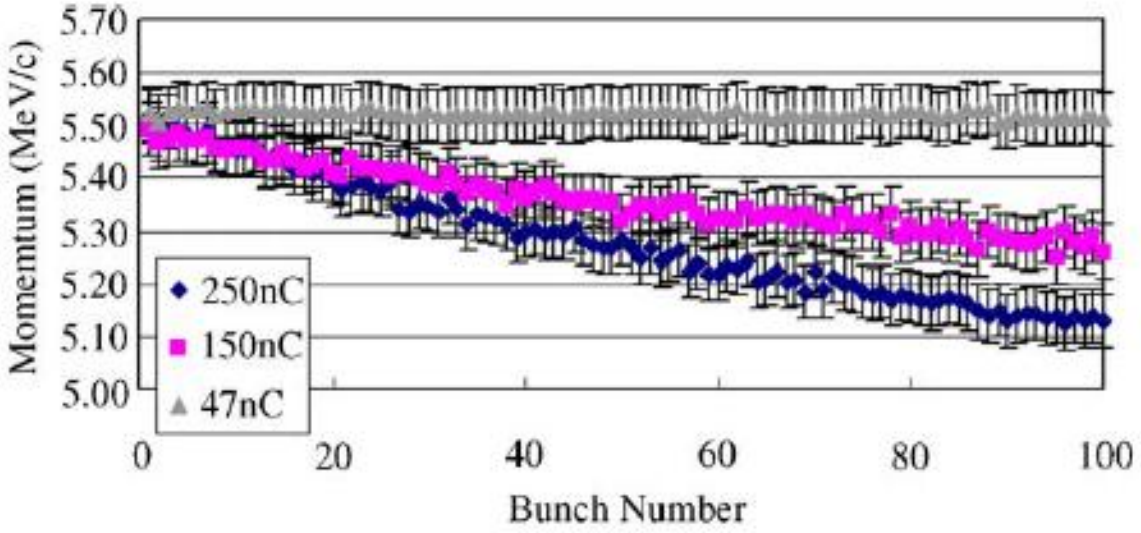



Fig. 11. Momentum of a multi-bunch beam at a laser injection timing of 1.703 μs.

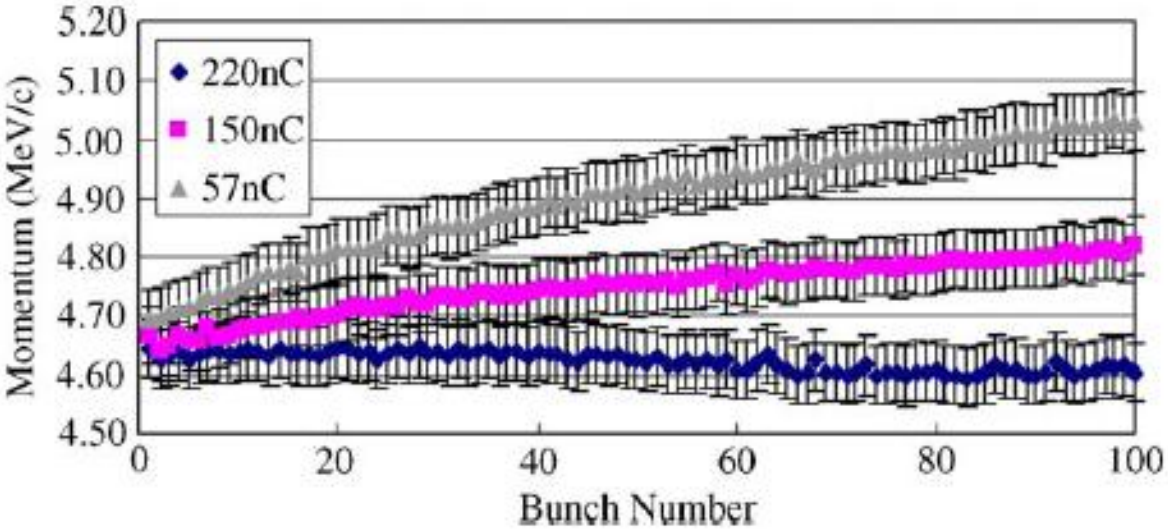
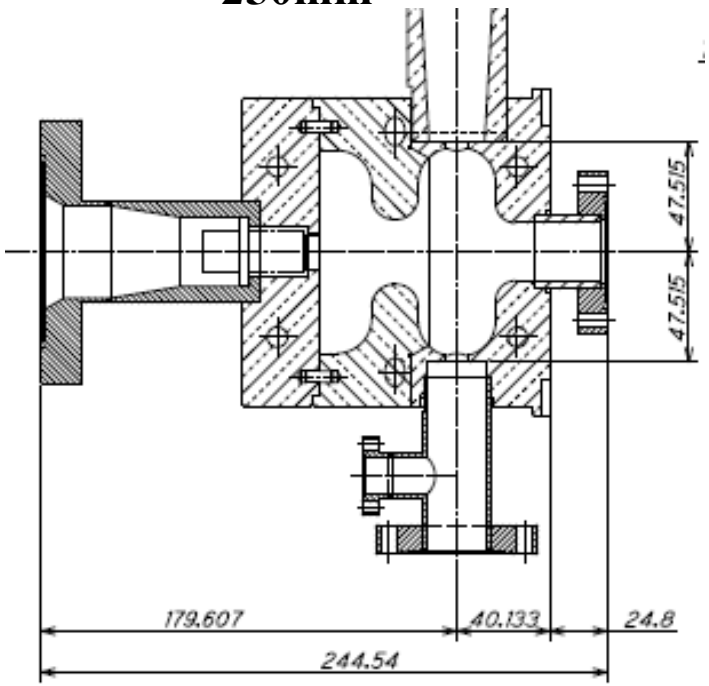



Fig. 12. Momentum of a multi-bunch beam at a laser injection timing of 0.906 μs.

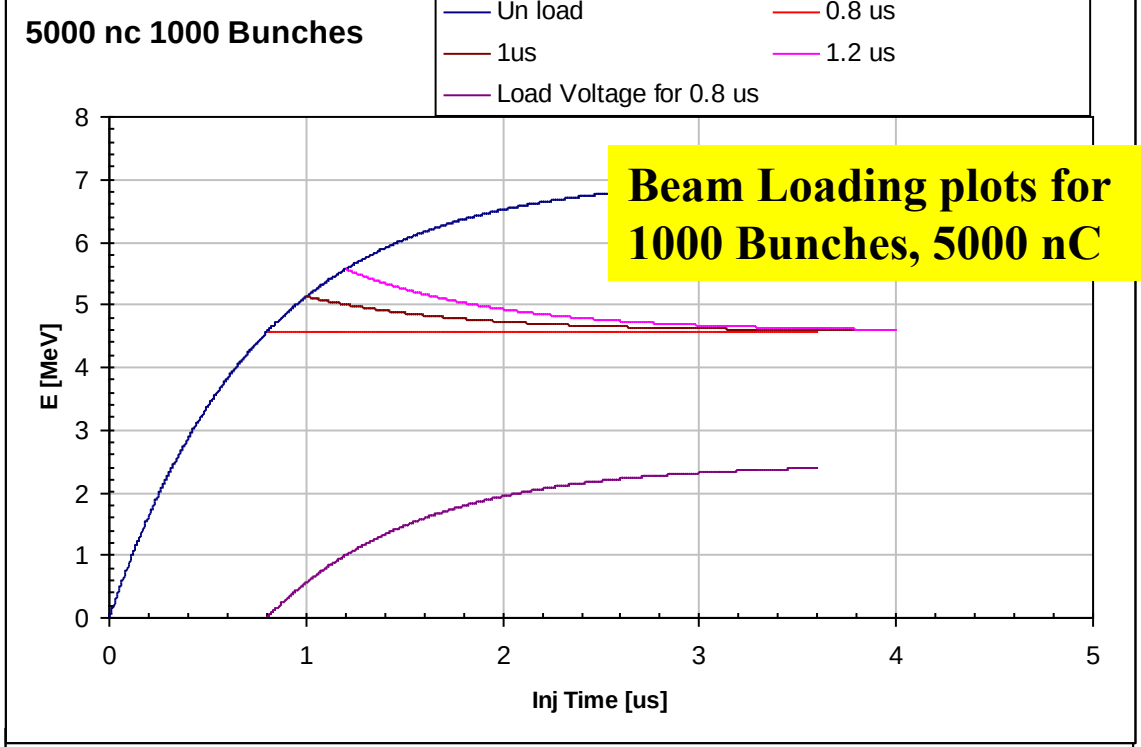
**JFY2004**
**300nC achieved**

**Schedule**
**JFY2012**
**1000nC-10000nC**
**And X-ray Gen.**

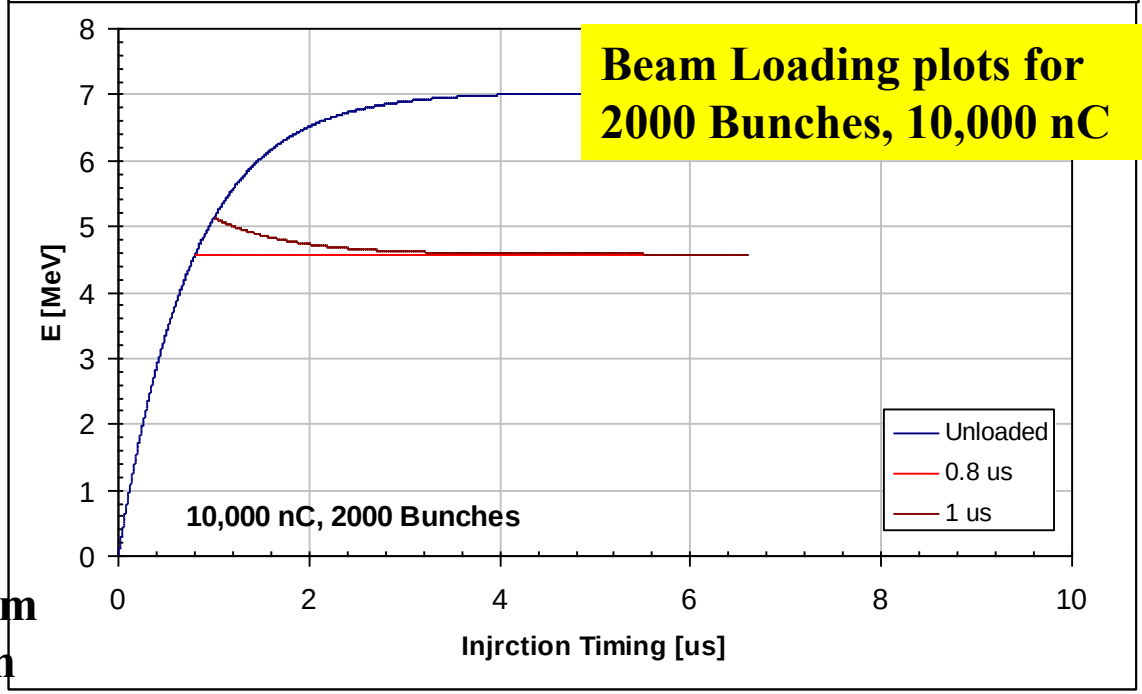
**250mm**




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



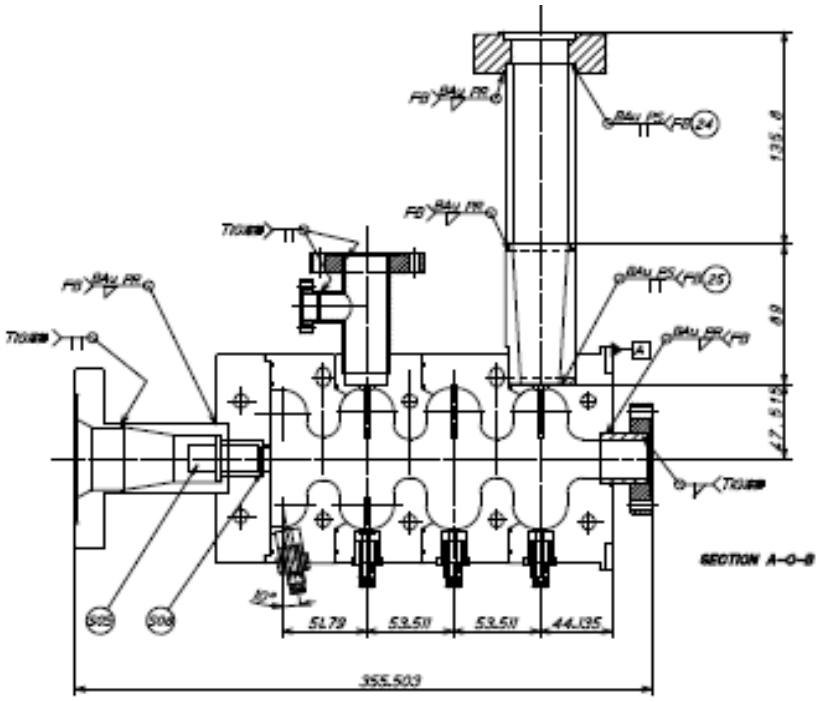

**Beam Loading plots for 1000 Bunches, 5000 nC**



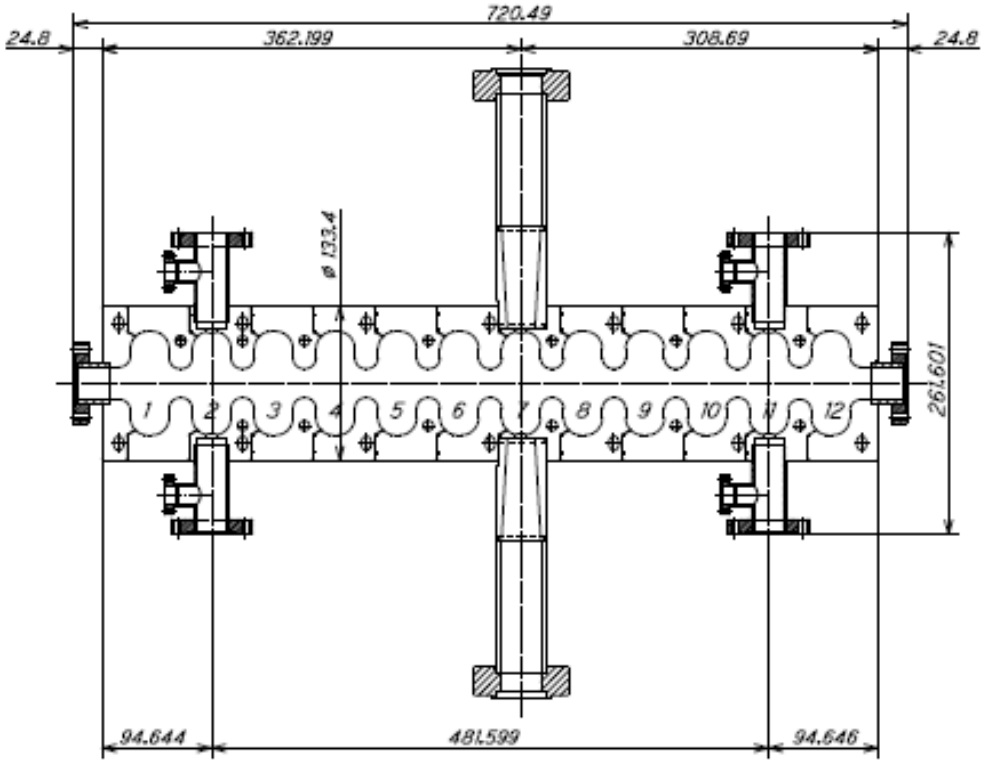

**Beam Loading plots for 2000 Bunches, 10,000 nC**

# Advanced Photo-cathode RF Gun and accelerator R&D

360mm




720mm




**S-band 3.6 cell RF Gun ~ 12MeV**

**S-band 12 cell booster linac to get 50MeV.**

# Comparison of various parameters of 1.6 cell RF Gun

| | Simulated | Measured | |
|---|---|---|---|
| | New Gun | New Gun | Old Gun |
| Frequency MHz | 2855.64 | 2855.61 | 2855.74 |
| Mode Separation MHz | 8.67 | 8.63 | 3.52 |
| Field Balance | 1.0 | 0.98 | 1.3 |
| Quality Factor Q | 18000 | 14,700 | 7900 |
| Coupling β | 1.0 | 1.0 | 0.6 |

| RF Gun | Q |
|---|---|
| BNL (original) | 7900 |
| LUCX (original) | 7900 |
| ATF ( modified) | 12600 |
| BNL (modified) | 12780 |
| LUCX New (Curved Profile) | 14,700 |
| LCLS (modified) | 13,900 |

# 3.6 cell RF Gun perfect machining and tuning

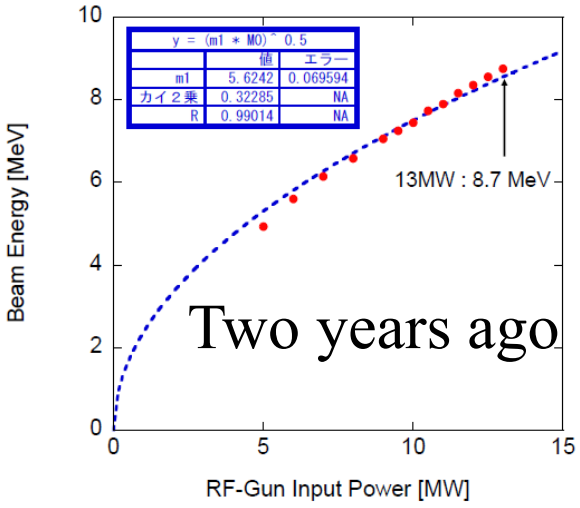
| Resonance mode | 3pi/3 | 2pi/3 | 1pi/3 | 0pi/3 |
|---|---|---|---|---|
| Measurement [MHz] | 2855.63 | 2852.82 | 2846.59 | 2841.55 |
| Target [MHz] | 2855.65 | 2852.82 | 2846.57 | 2841.65 |

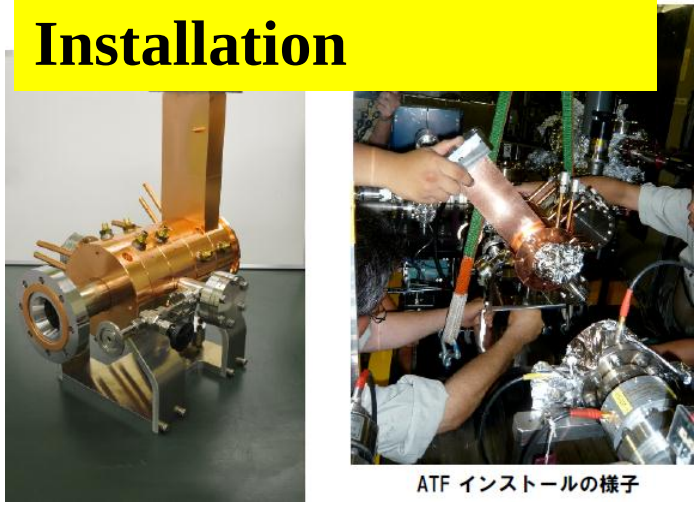
| Cell | Half cell | Full cell-1 | Full cell-2 | Full cell-3 |
|---|---|---|---|---|
| Measurement [MHz] | 2848.97 | 2848.06 | 2847.64 | 2851.82 |
| Target [MHz] | 2848.85 | 2848.10 | 2847.45 | 2851.70 |

**Machining on 12 cell booster structure is on going.**
**We will replace 3m TW structure to this booster soon.**

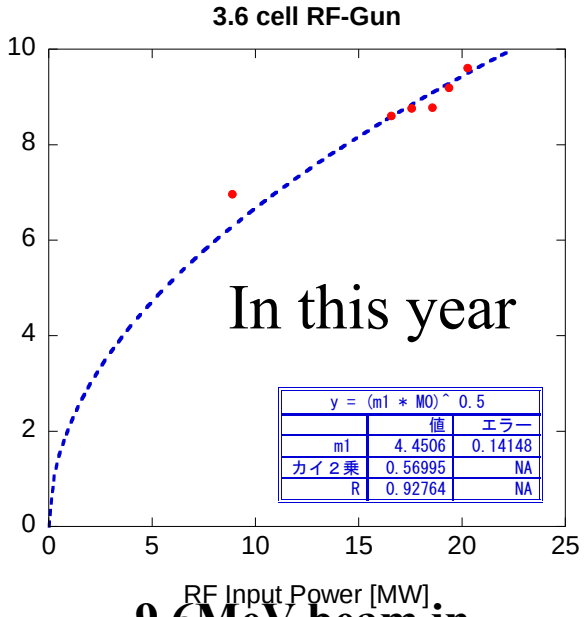
4 cell Test

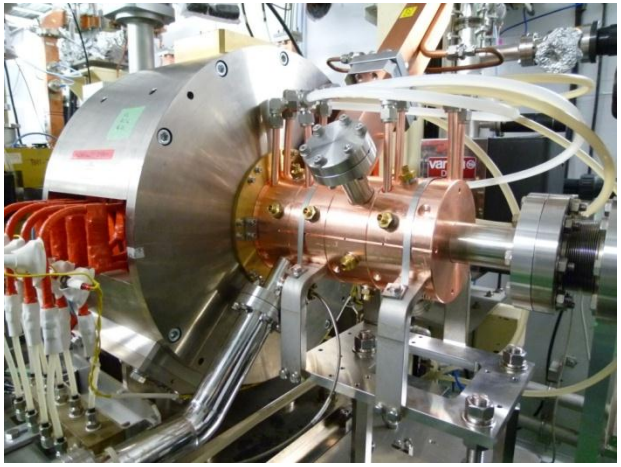
# 3.6 cell RF Gun Installation



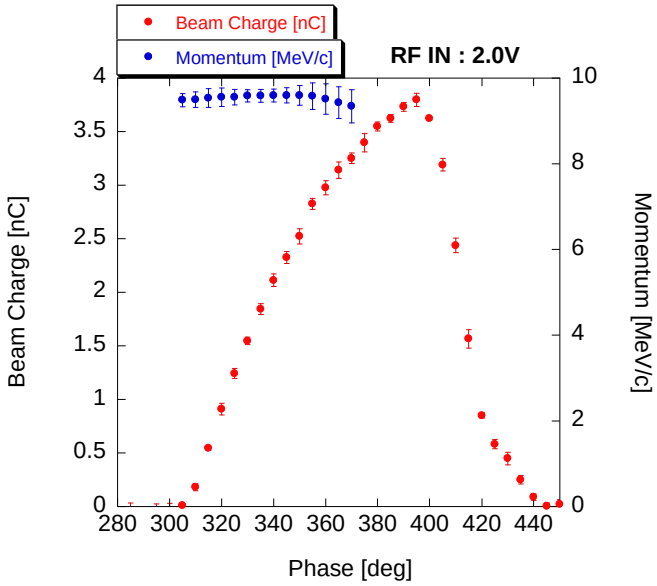



ATF インストールの様子



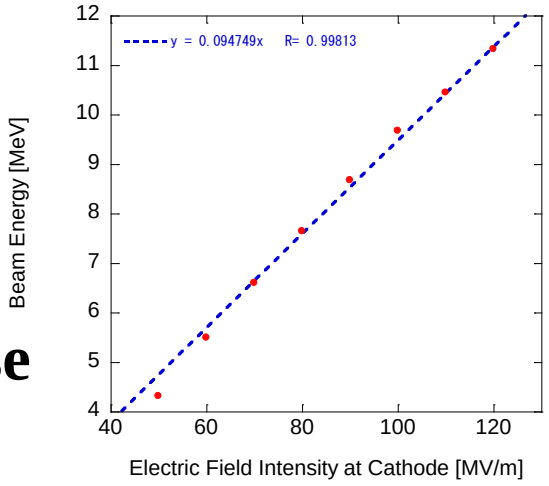



**9.6MeV beam in a week RF aging with ~20.3MW RF input power**




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

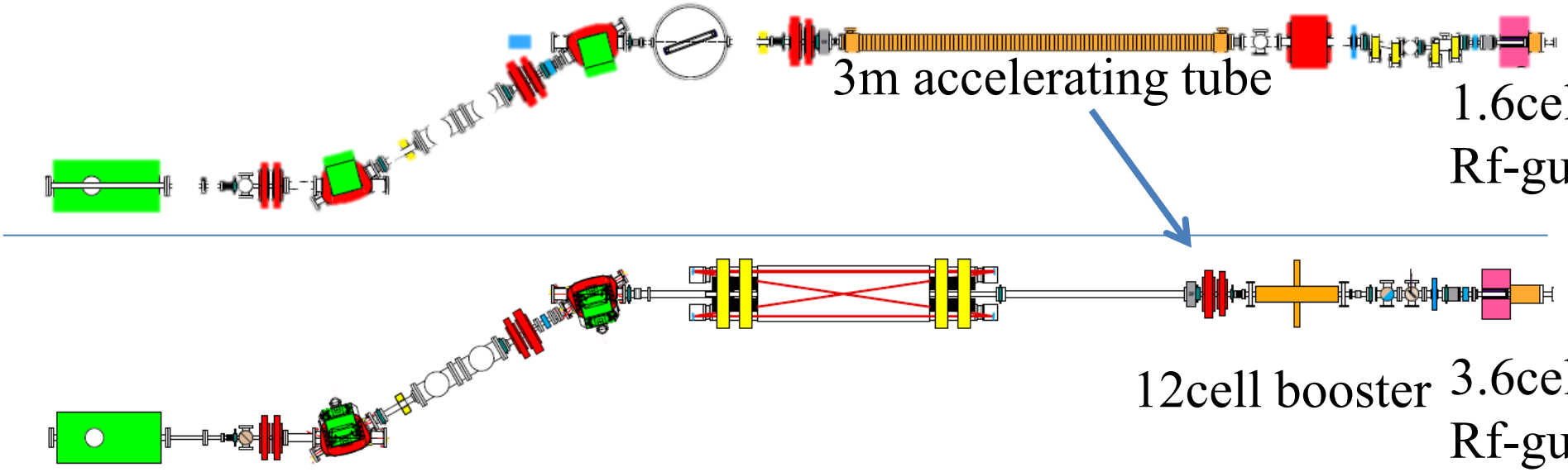
**PARMELA SIMULATION**



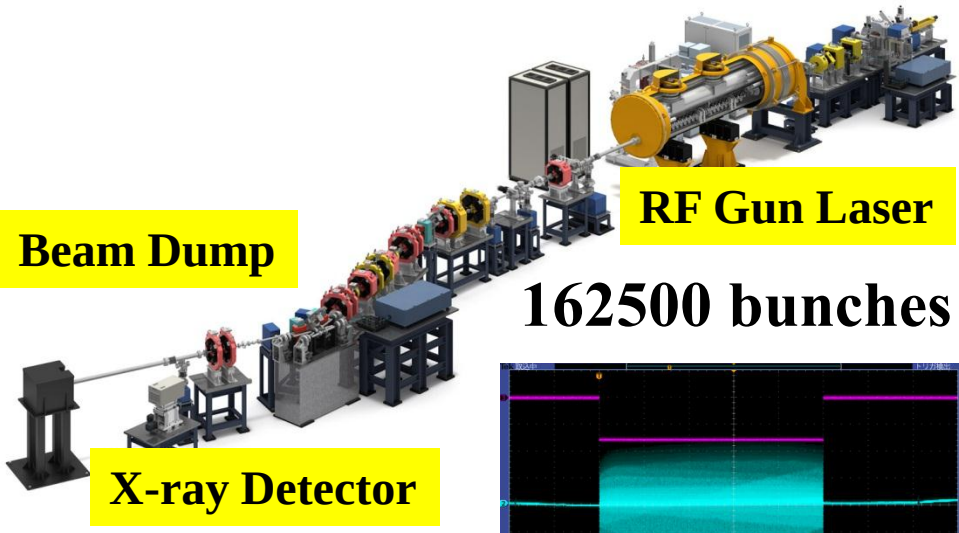

**11MeV beam at 120MV/m, from 100bunches/pulse to 1000bunches/pulse beam generation**

# Future plan for LUCX accelerator

- To downsize the accelerator, we have planed to install a 3.6cell rf-gun and a 12cell booster.
  - 3.6cell rf-gun
    - Beam test has been started from Jan 2012.
  - 12cell booster
    - This booster is making now.

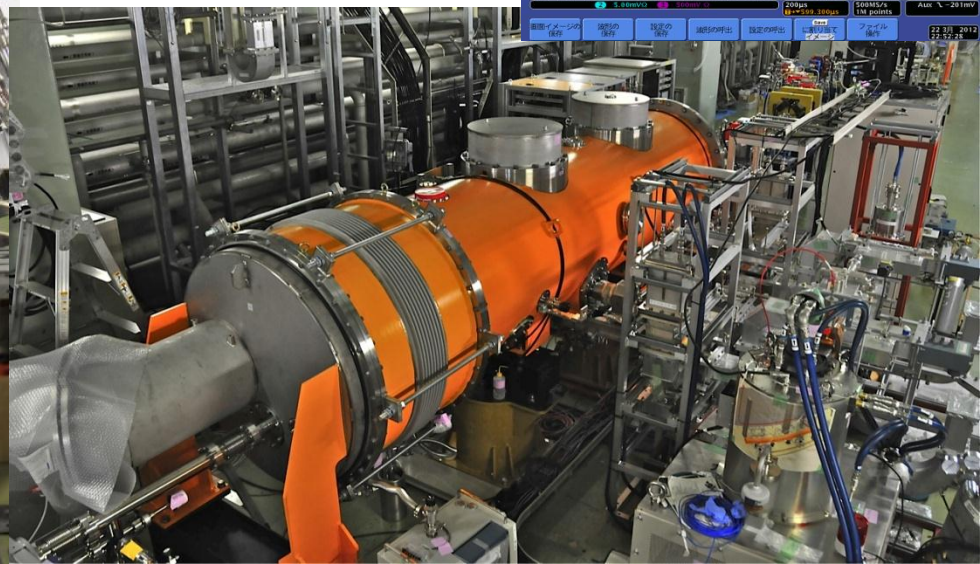


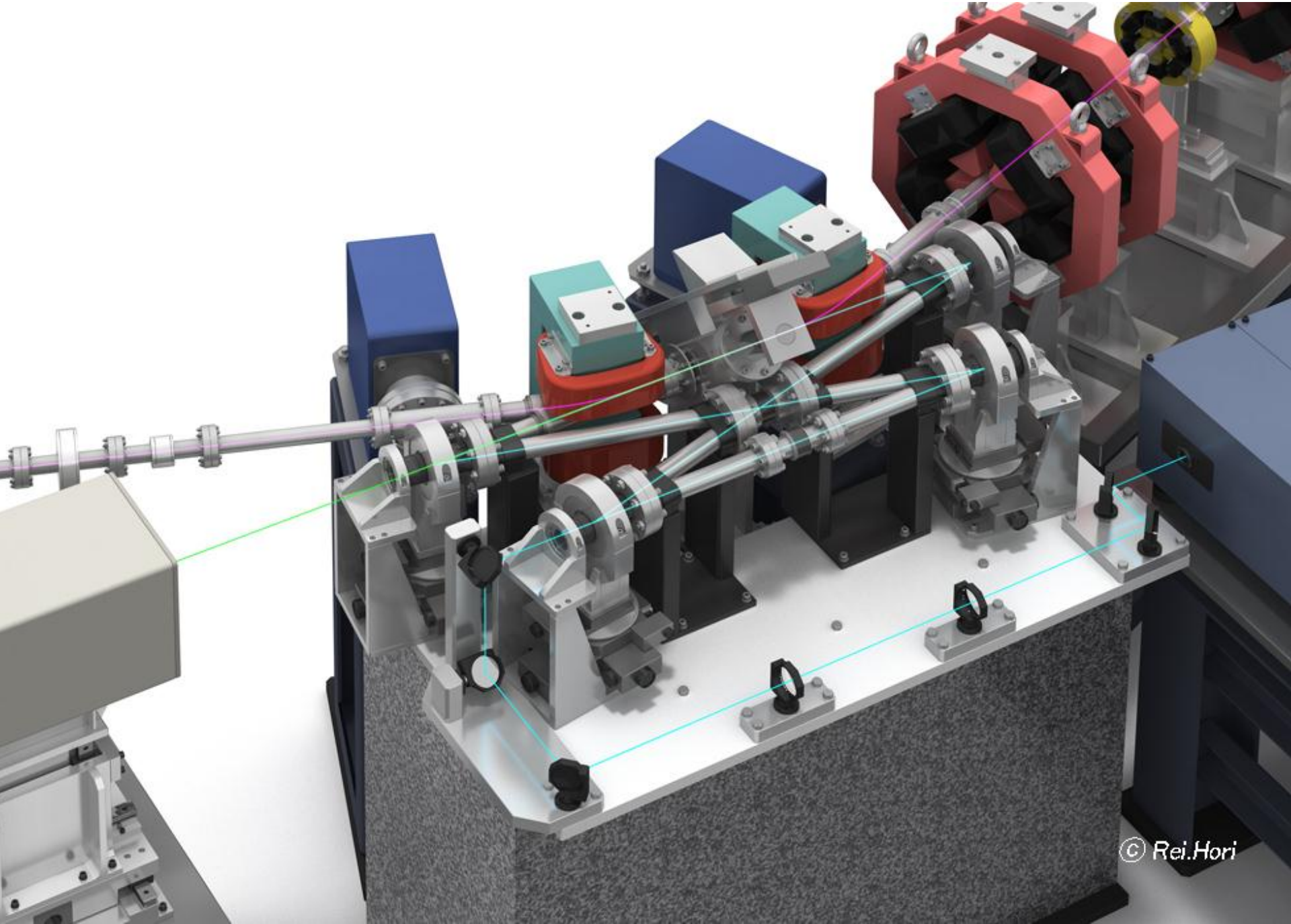
# View of QBTP from Beam Dump



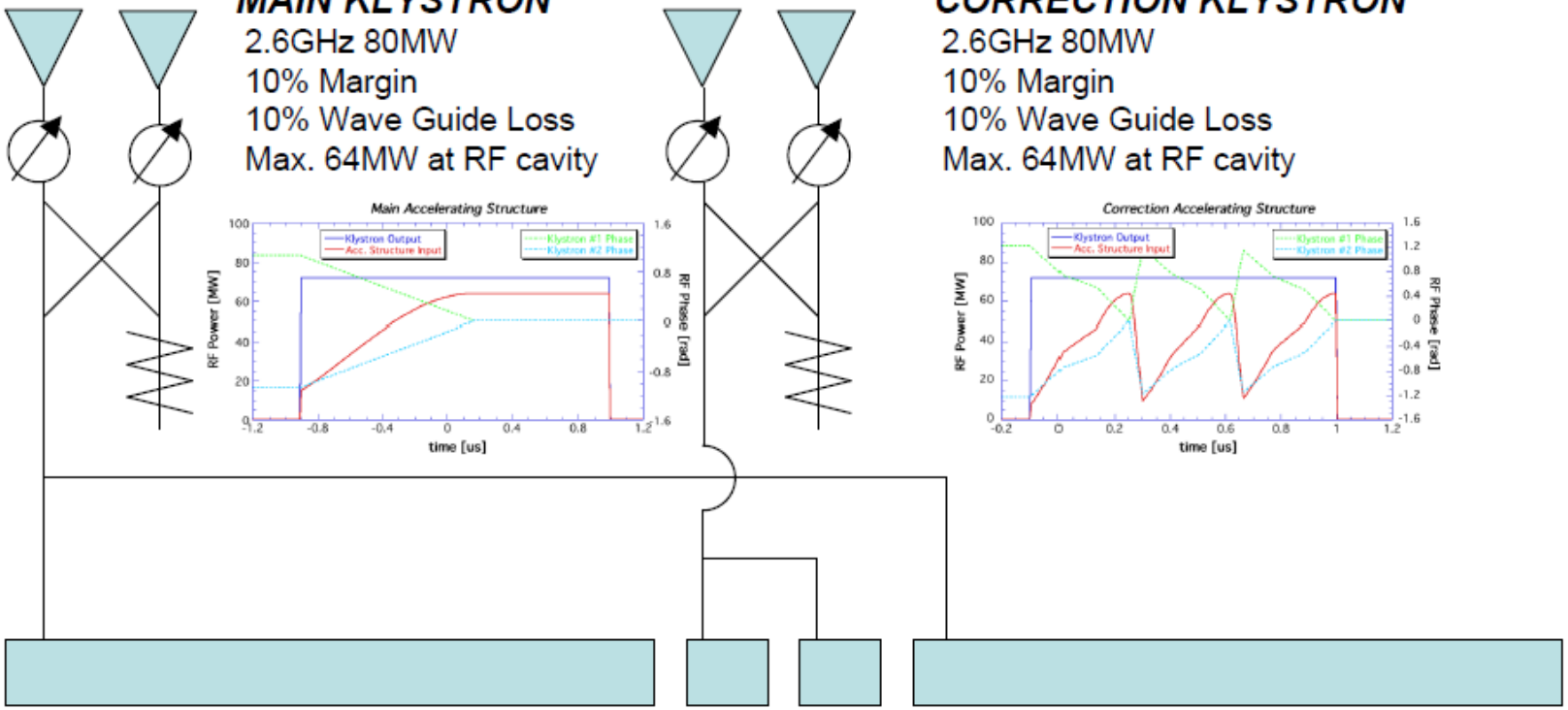

**162500 bunches**






© Rei.Hori

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



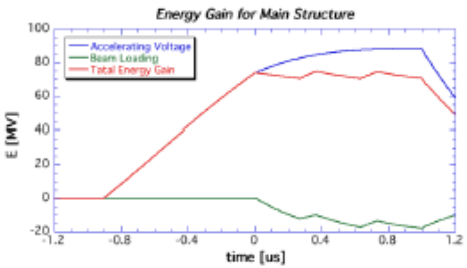
### MAIN KLYSTRON
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity



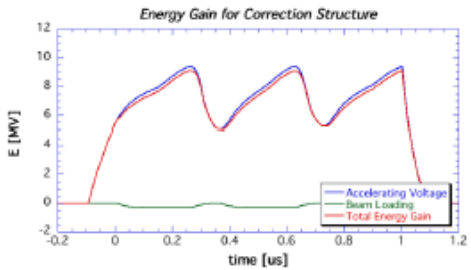

### CORRECTION KLYSTRON
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity



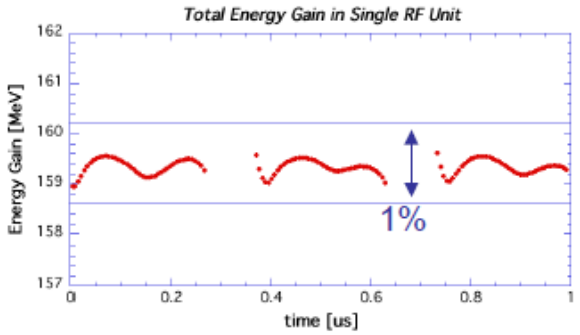

### Main RF Cavity
L=3.00m (2.6GHz)
tf=906ns
Q0=13000
r0=60MOhm



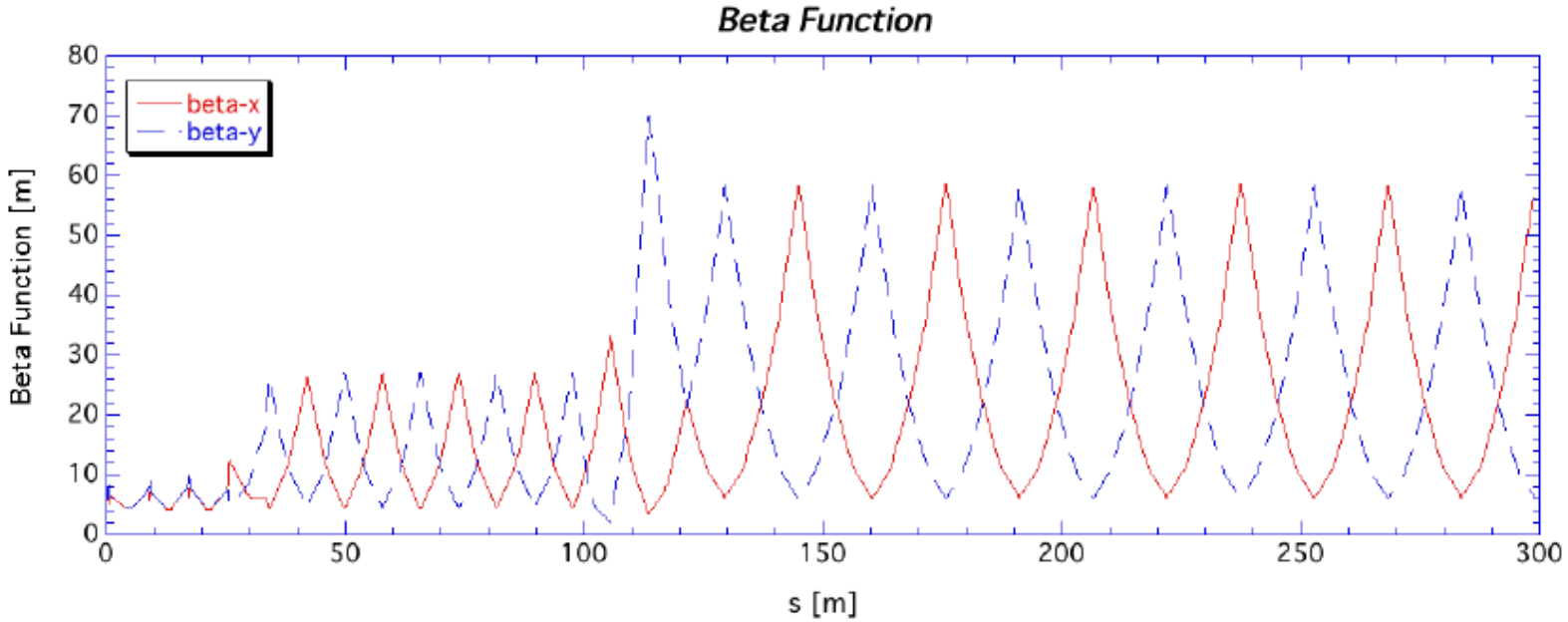

### Correction RF Cavity
L=0.33m (2.6GHz)
tf=96ns
Q0=850
r0=5.3MOhm

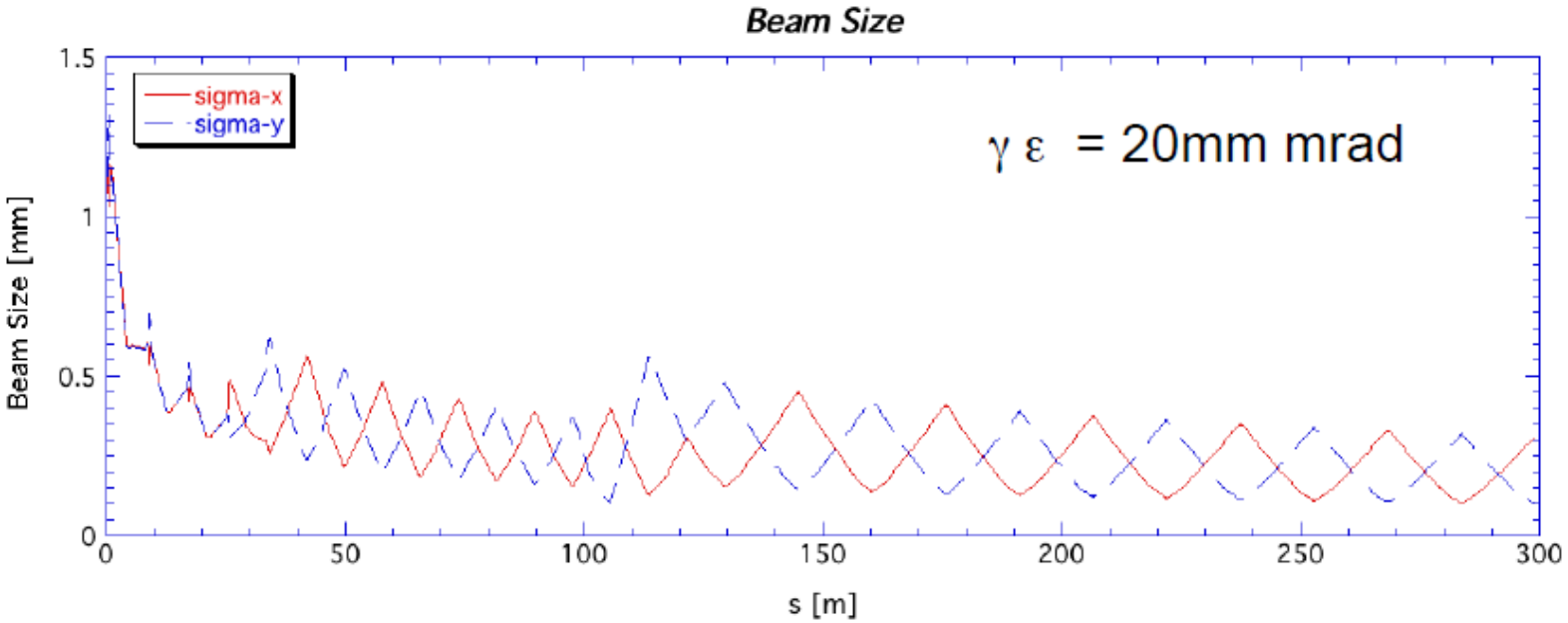



### Total Energy Gain in 1 Unit
**159.3MeV**



# 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

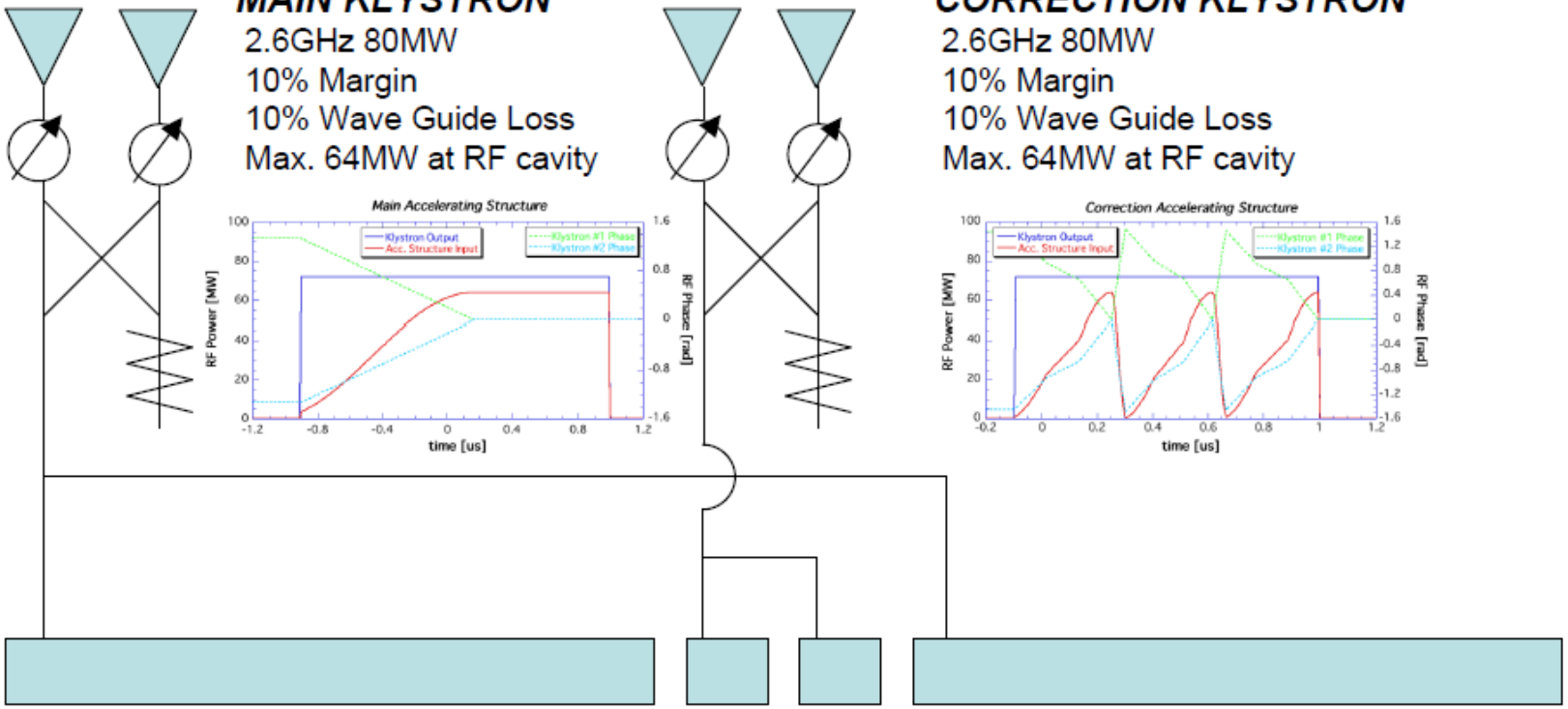
| Magnet Name | Effective Length [m] | dB/dx [T/m] |
|---|---|---|
| Q01.1 | 0.1 | 1.3332 |
| Q02 | 0.1 | −2.6201 |
| Q01.2 | 0.1 | 1.3332 |
| Q03.1 | 0.1 | 6.0686 |
| Q04 | 0.1 | −11.9069 |
| Q03.2 | 0.1 | 6.0686 |
| Q05.1 | 0.1 | 11.1410 |
| Q06 | 0.1 | −21.8199 |
| Q05.2 | 0.1 | 11.1410 |
| Q07 | 0.1 | −13.9861 |
| Q08 | 0.1 | 14.5026 |
| Q09 | 0.1 | 11.9981 |
| Q10 | 0.1 | −14.1065 |
| 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)



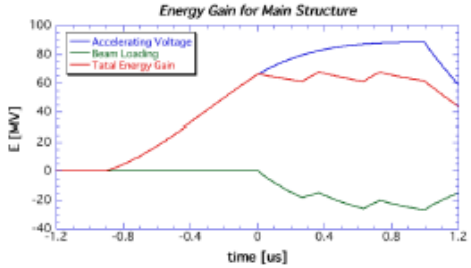
### *MAIN KLYSTRON*
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity



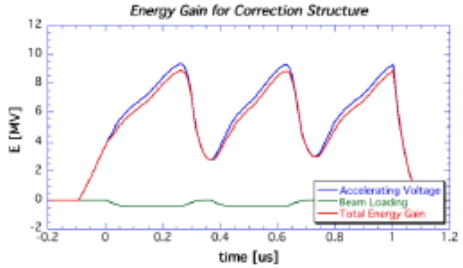

### *CORRECTION KLYSTRON*
2.6GHz 80MW
10% Margin
10% Wave Guide Loss
Max. 64MW at RF cavity



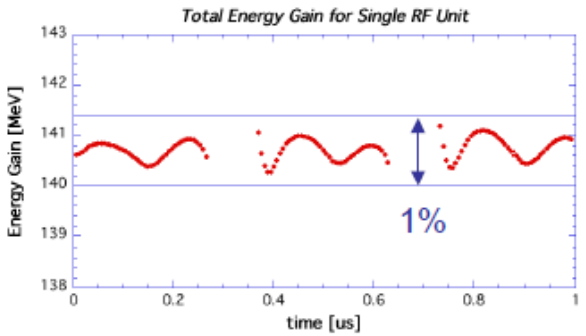

### *Main RF Cavity*
L=3.00m (2.6GHz)
tf=906ns
Q0=13000
r0=60MOhm



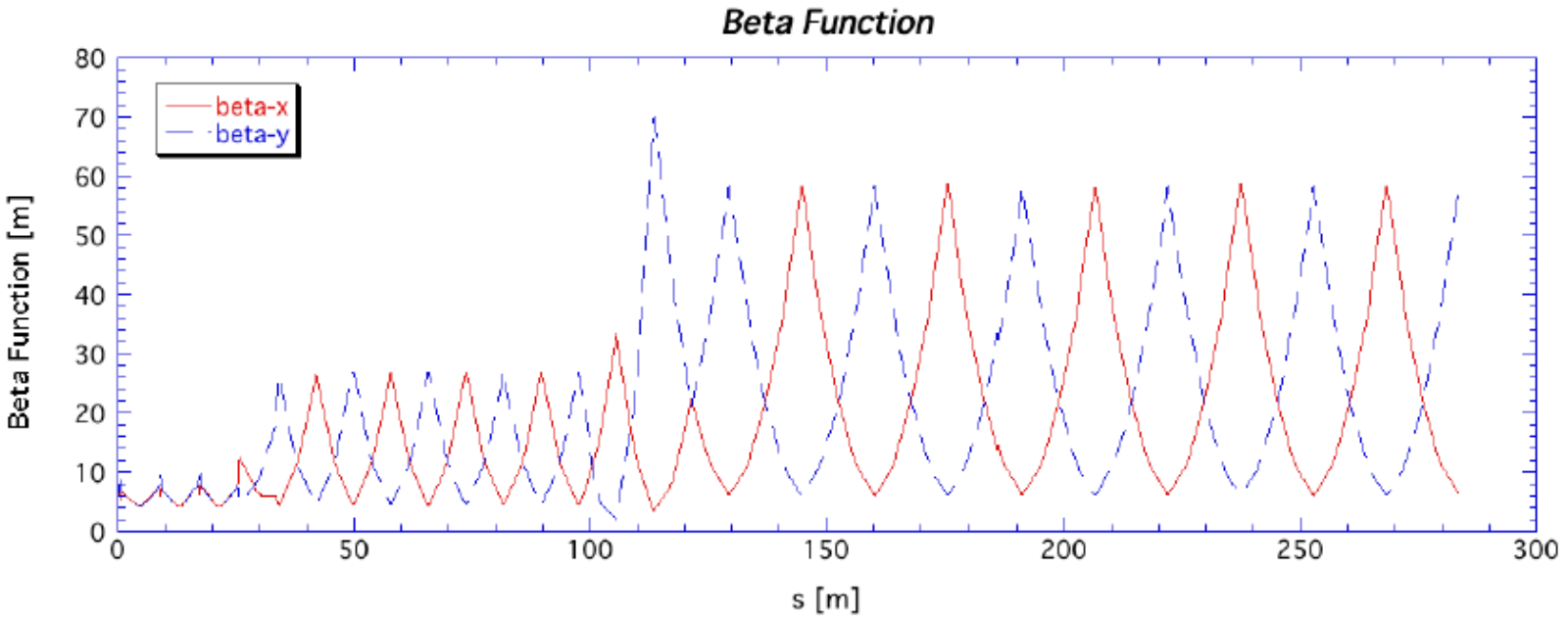

### *Correction RF Cavity*
L=0.33m (2.6GHz)
tf=96ns
Q0=850
r0=5.3MOhm

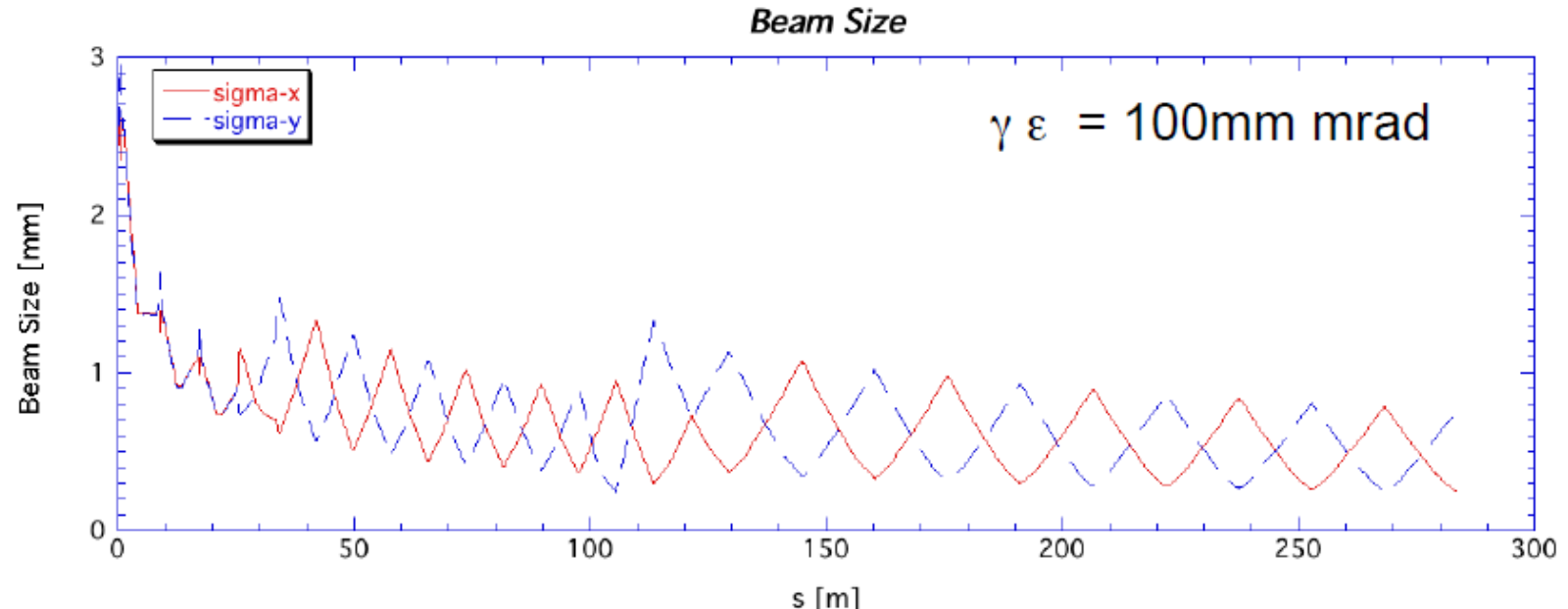



### *Total Energy Gain in 1 Unit*
***140.6MeV***



# 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 |

**~170M$**
**For 6GeV**

| | | |
|---|---|---|
| 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 | | 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 |

**~160M$ For 5GeV**

**Total ~330M$**

**by ~30% Optimization Effort ~230M$**

| 5GeV Positron Linac with 3x10E10 e/bunch | unit :Myen | Electron Source |
|---|---|---|
| 36 RF units | | |
| 2 main klystrons x 36 with 10% margin and 10% loss | 0 | less than 200MYen |
| 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 | |
| Total 26793MYen for 6GeV and 5GeV S-band 300Hz Linac | | |
| Electron source system, Total 26993 Myen | | |

# Summary

**300Hz Linac Technologies are no problem for conventional positron source.**

**Rough Total Cost ~230M$ with cost-down of ~30%**

**300Hz Linac design is a tentative one for heavy beam loading.**

**After some discussion on the scheme for the heavy beam loading, we almost found to reduce the 300Hz Linac cost by ~30%.**

**We still need a time to make a optimum design for the heavy beam loading compensation.**