Mode Separated RF Photo Cathode Gun Work at LUCX

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Introduction

- It has been experimentally shown that for higher mode separation in rf photo cathode gun, lower emittance can be achieved [1]. Mode separation is the difference between Pi mode frequency and Zero mode frequency.
- LCLS (SLAC) changed the mode separation from 4 MHz to 15 MHz and recently LLNL [2] also shifted to 12 MHz mode separation
- Large mode separation is also desirable from stability point of view.
- With this motivation we re-designed the RF Gun at LUCX, KEK to achieve higher mode separation. We have designed cavities to achieve mode separation 8.6 MHz separation. The existing gun has separation of 3.5 MHz. [3][4]
- While re-designing the gun structure, the geometry was also optimized.

[1] C. Limborg et al., LCLS Tech Note, LCLS-TN-05-3

[2] Anderson et al, Proceedings of PAC 2007, TUPMS028

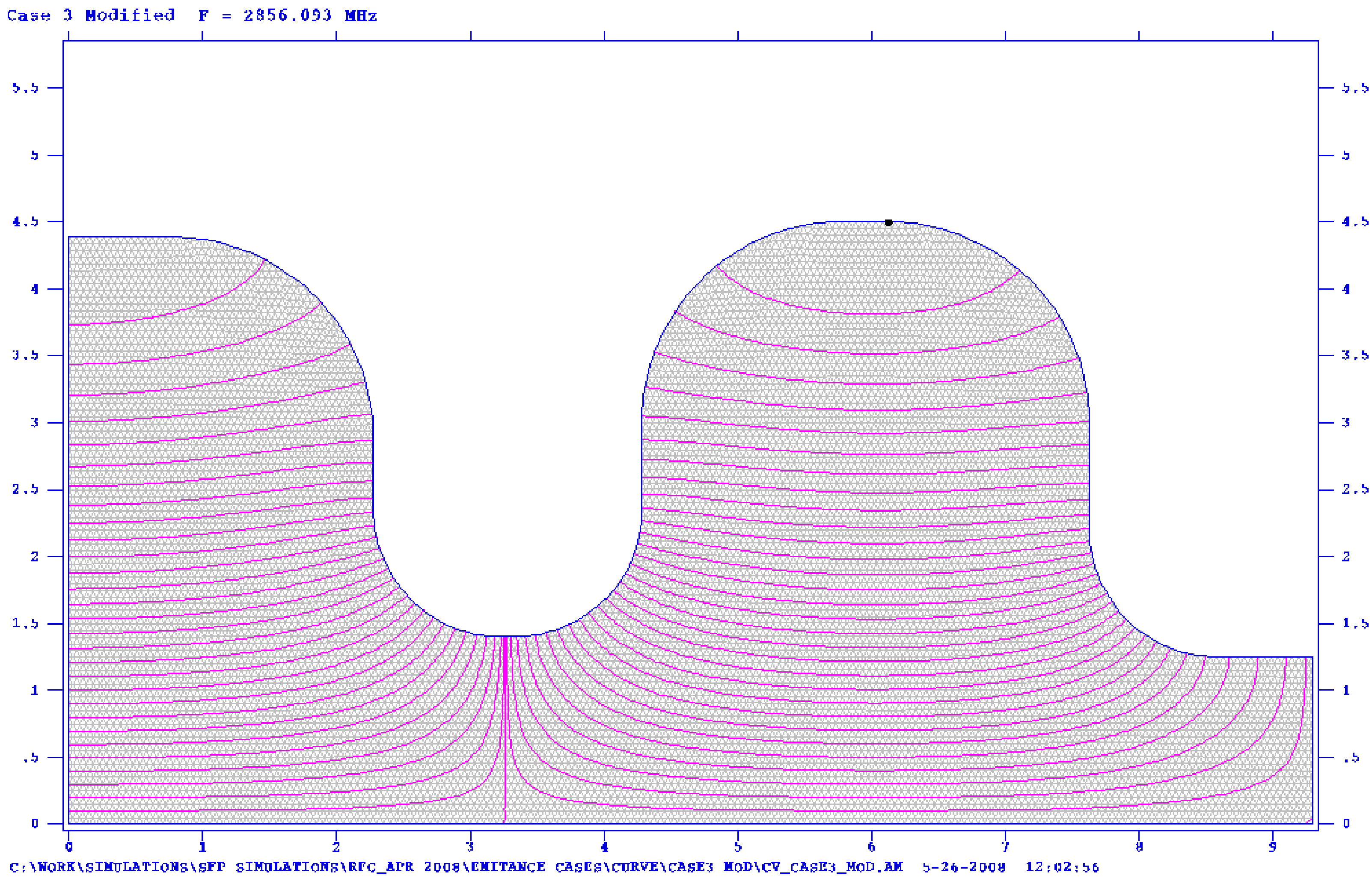
[3] K Hirano et al , NIM-A,560 (2006),233-239

[4] Abhay Deshpande, J Urakawa et al. NIM-A, in press, Jan 2009

Brief Summary of New Gun Design

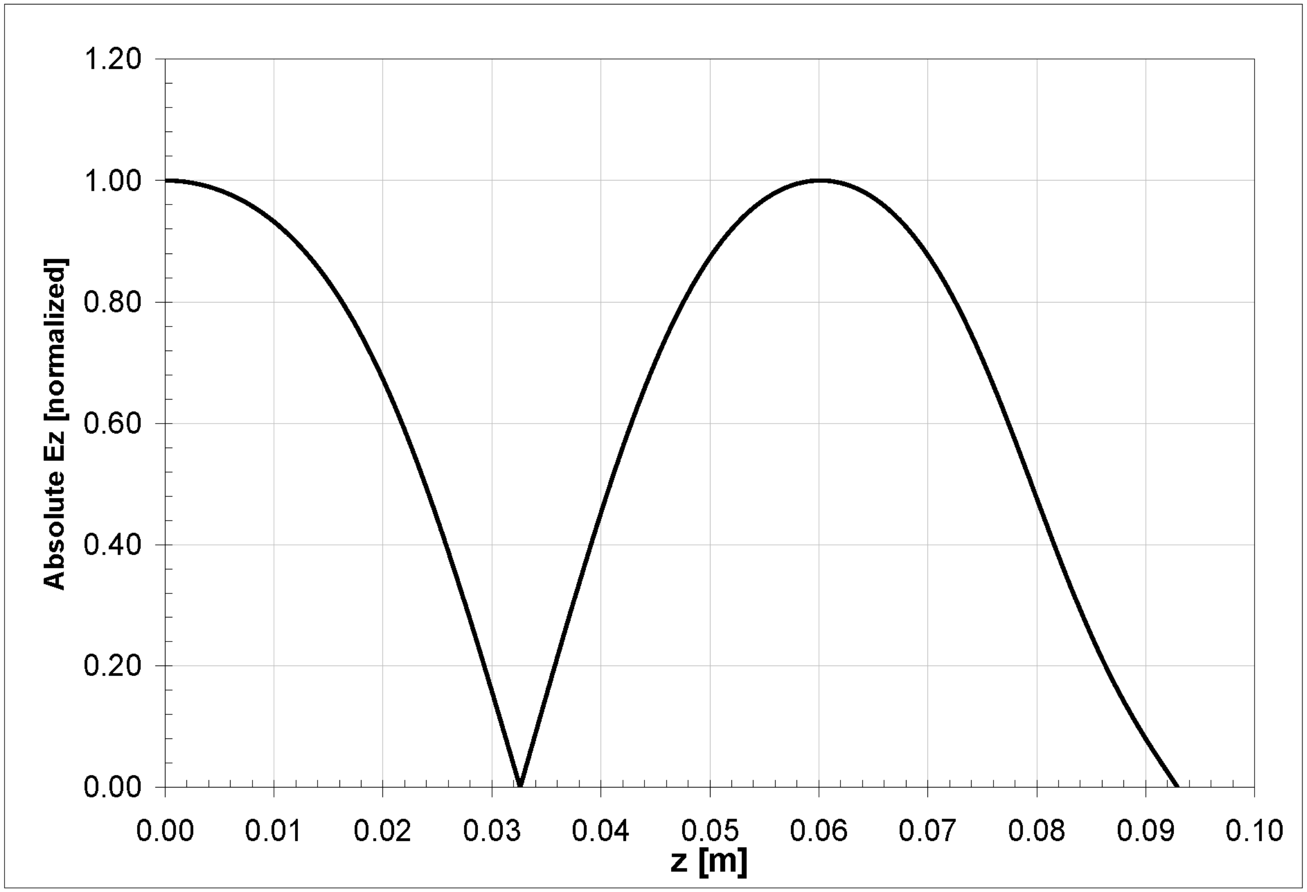
- Mode Separation : 8.6 MHz
- Inner Geometry : Curved surface
- Iris Diameter : 28 mm
- Expected Z : 34 MW/m
- Expected Q: 18,000
- The gun structure used has 1.625 cells.
- The other parameters are kept as close as the existing gun so as to reduce the re-designing issue for external attachments.

Cavity Profile



Field Pattern

- Field balance :1.0;
- The corresponding mode separation is 8.67 MHz



Surface Fields

- The curved geometry was chosen since this reduces surface fields with respect to earlier ATF gun by around 5% in the preliminary calculations.
- The reduction in surface fields will help in reducing the dark currents during the operation
- An elliptical drift region can further reduce the surface fields how ever at present from the machining point of view a circular profile is selected.

Comparison of Parameter

- Comparison with respect to existing Gun

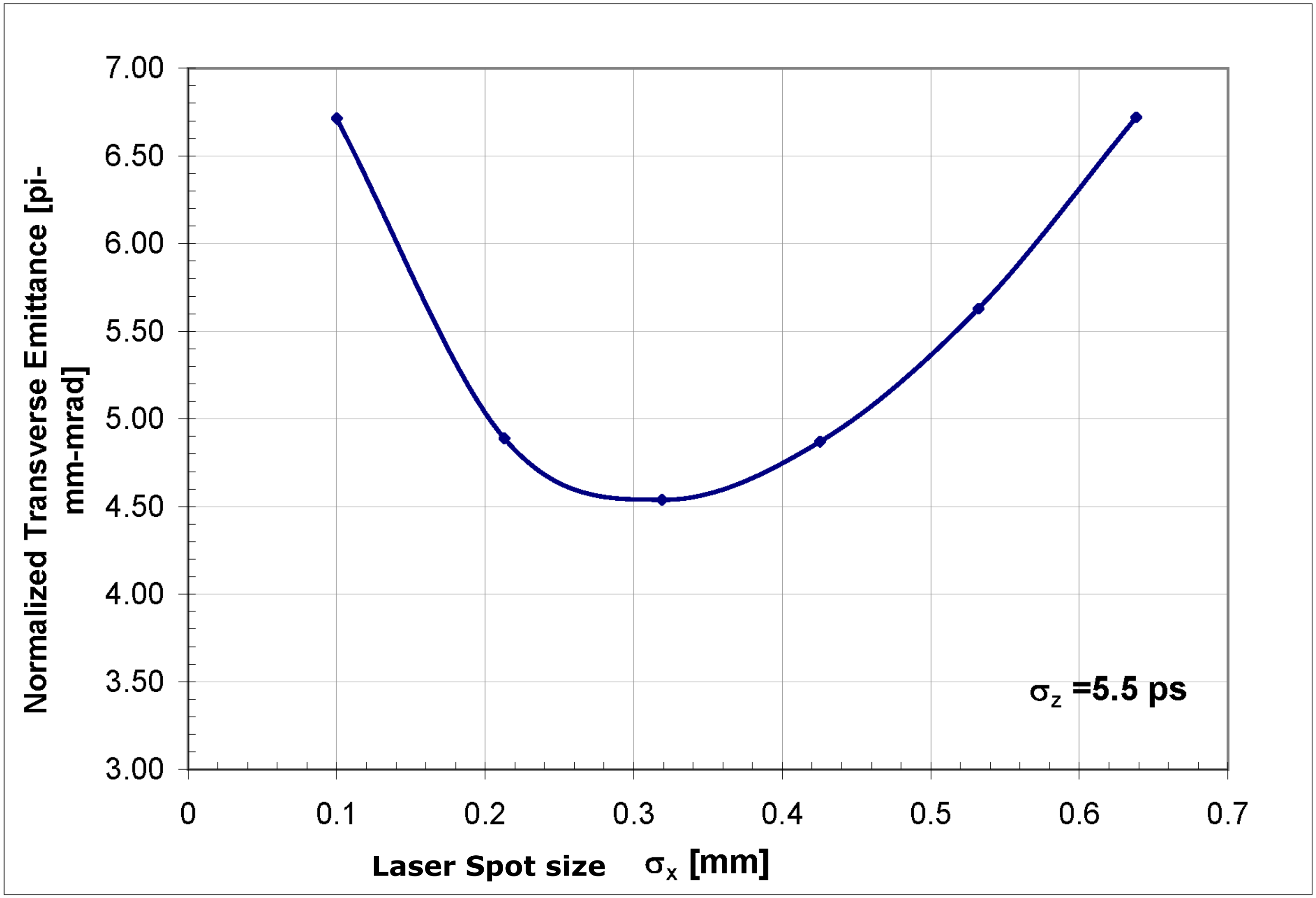
	Mode separation ΔF [MHz]	Q	Z [MW/m]
Existing ATF Gun Cavity	3.42	15913	29.69
Proposed cavity with High Q	8.67	18275	34.91

Beam Dynamics using: ASTRA

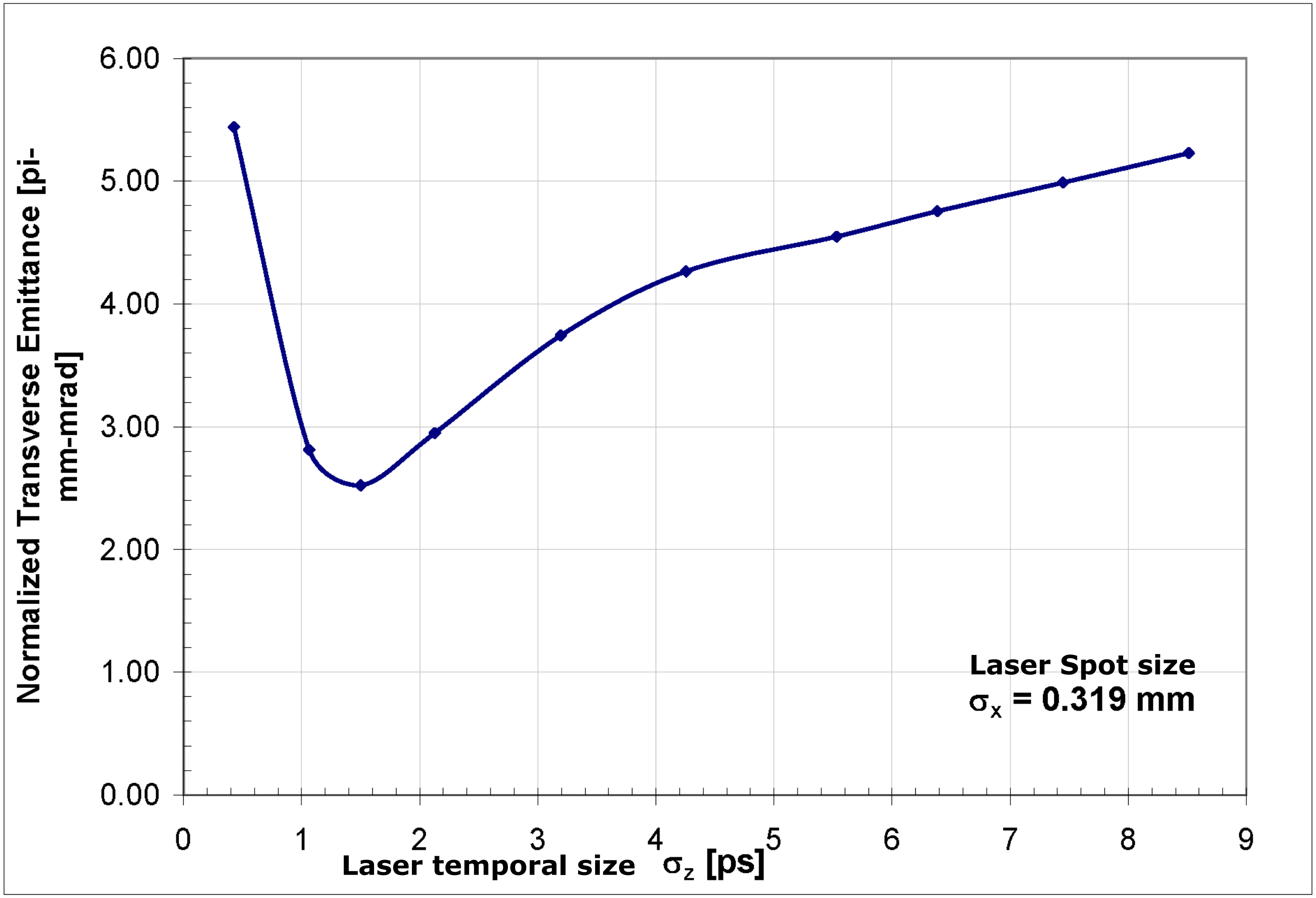
- A Space Charge Tracking Algorithm (ASTRA) code was used to study the emittance and other parameters for the above gun geometry.[5]
- Assuming the existing input parameters simulations were done to arrive at optimum operating parameters.
- ASTRA has in-built capability to simulate phase plot with Schottky effect. The charge at time of emission is determined using combined rf and space charge field and factors for field dependant emission process.

[5] K. Flöttmann, A Space Charge Tracking Algorithm, ASTRA, http://www.desy.de/~mpyflo/

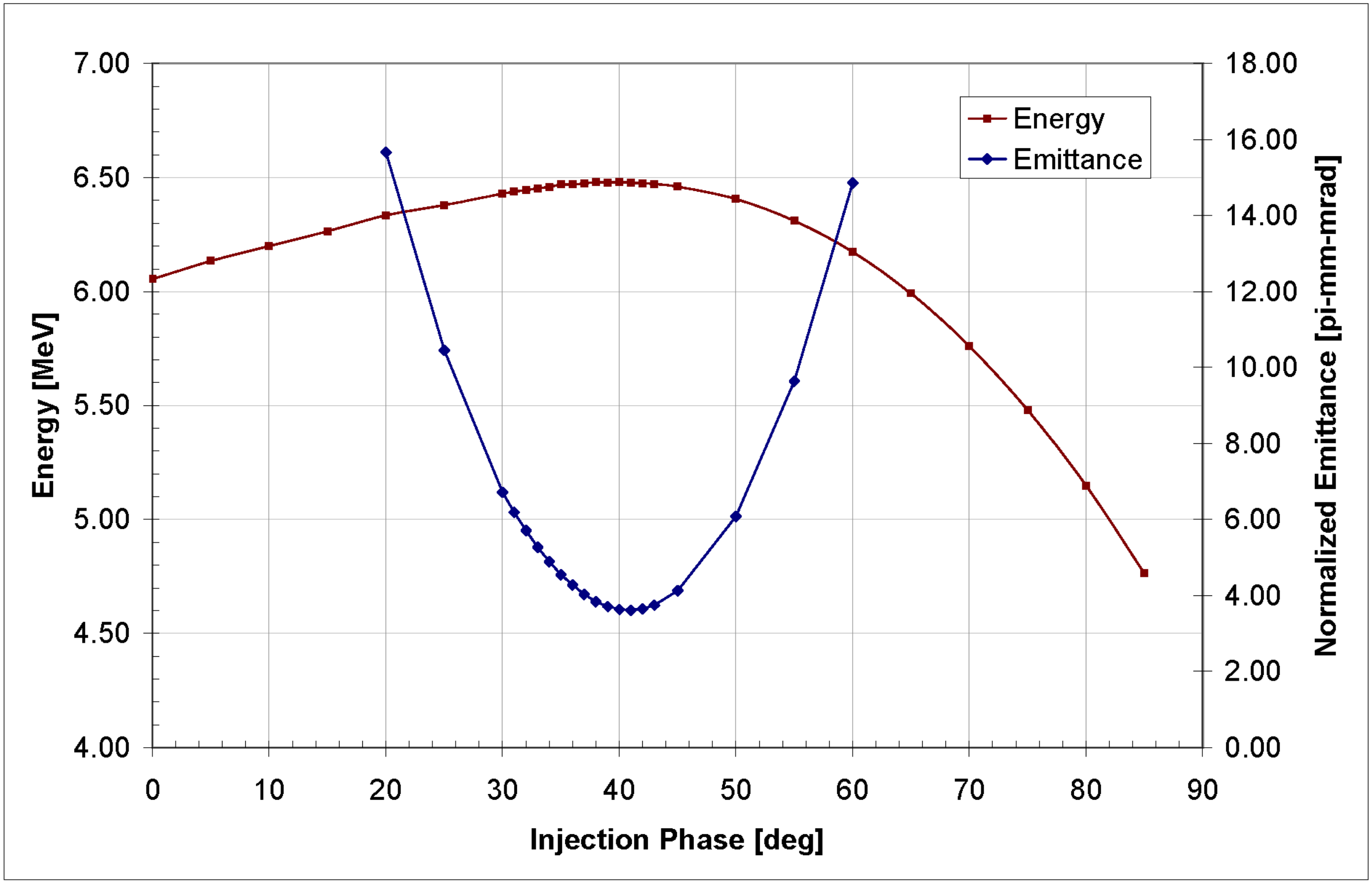
Variation of emittance with laser spot size



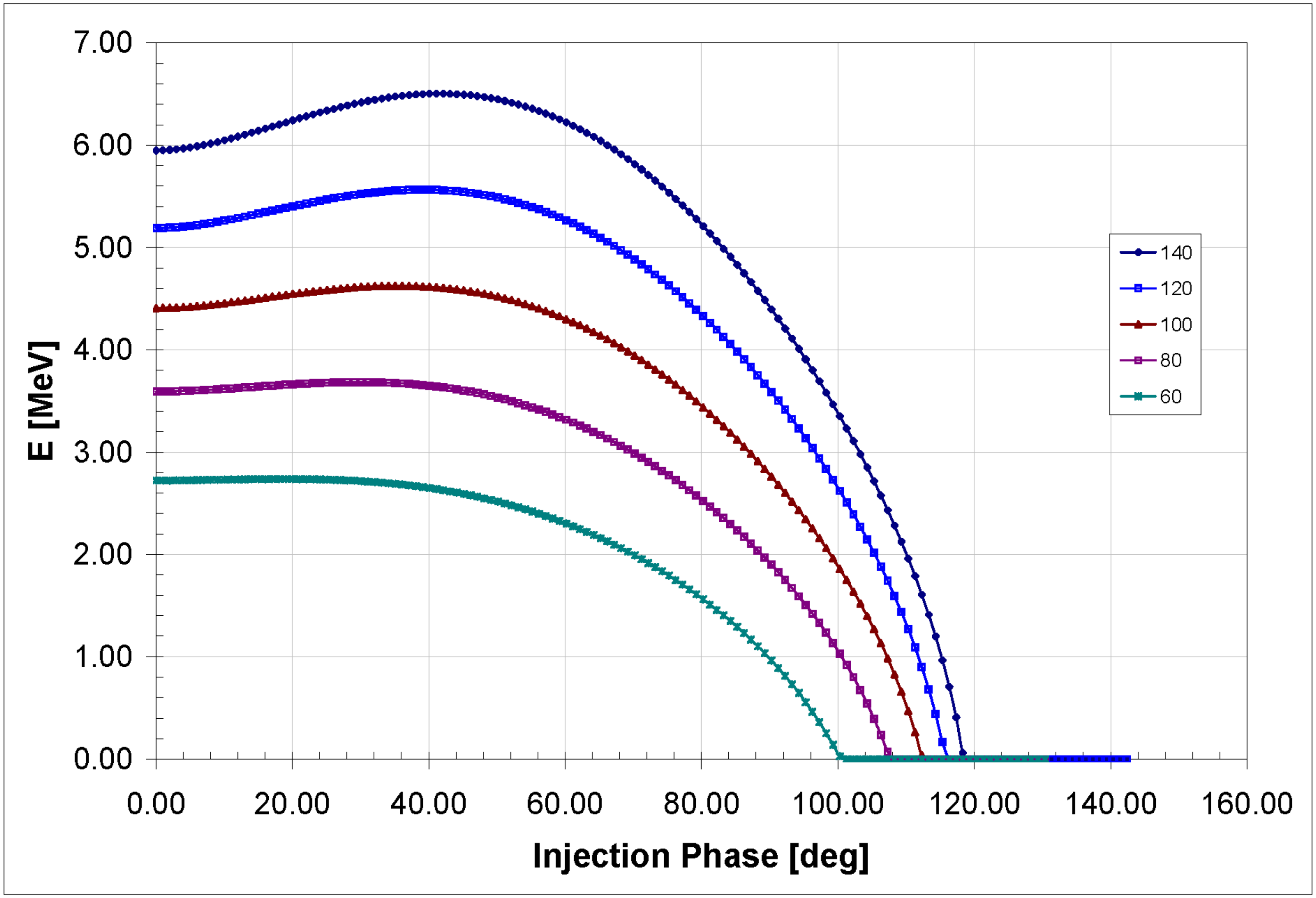
Variation of emittance with laser pulse length



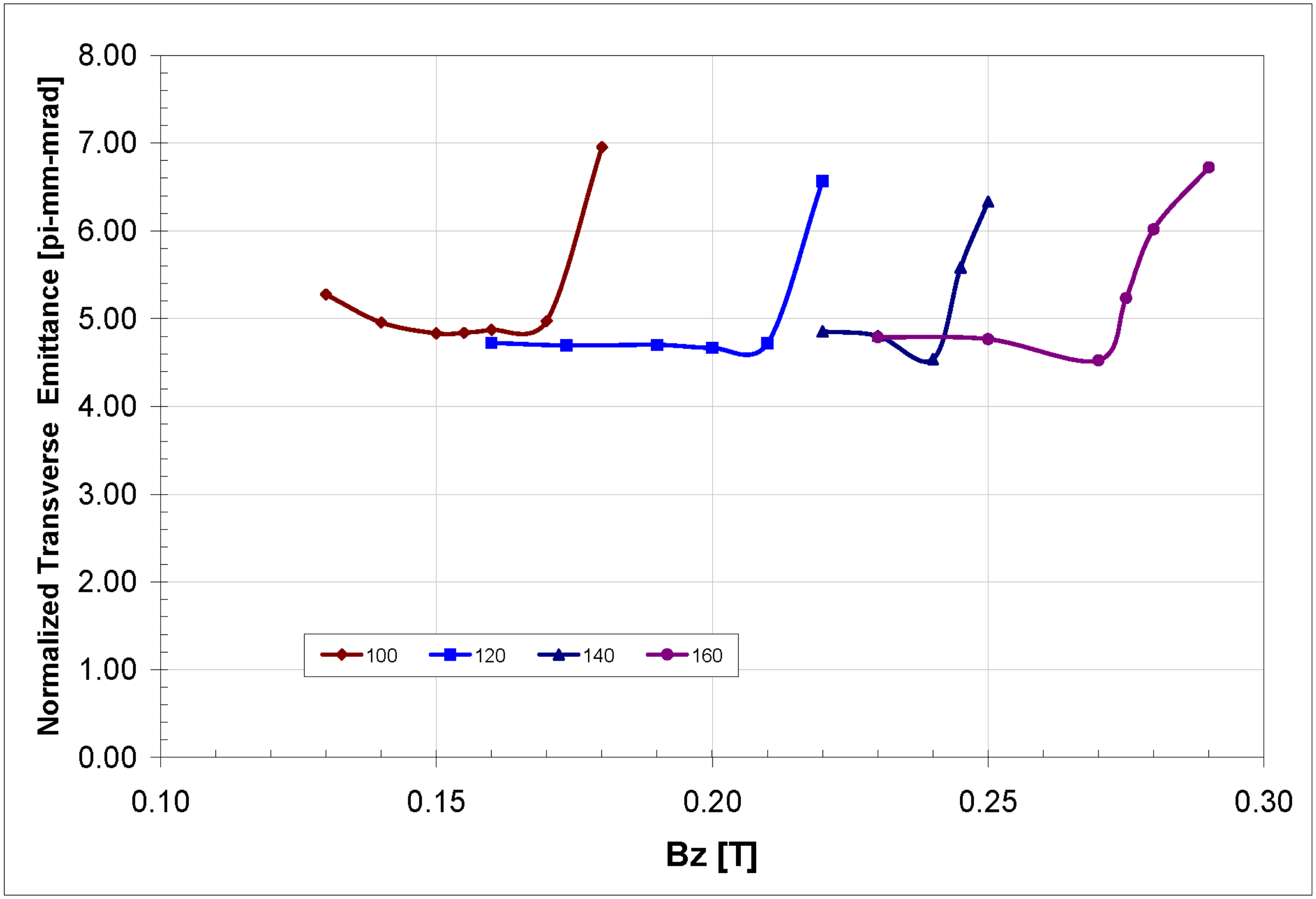
Phase vs Energy



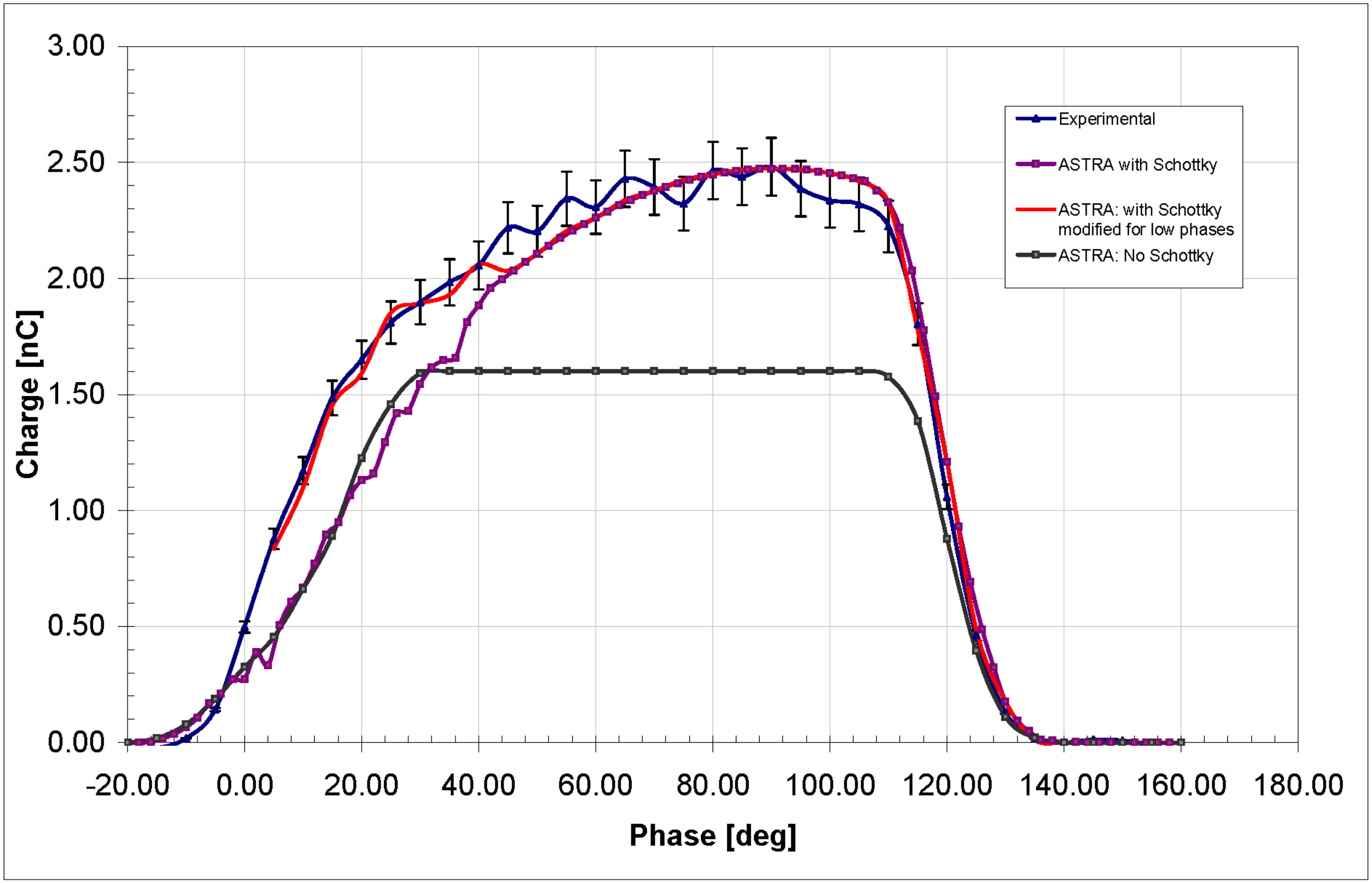
Phase vs Energy Gain for various field strength



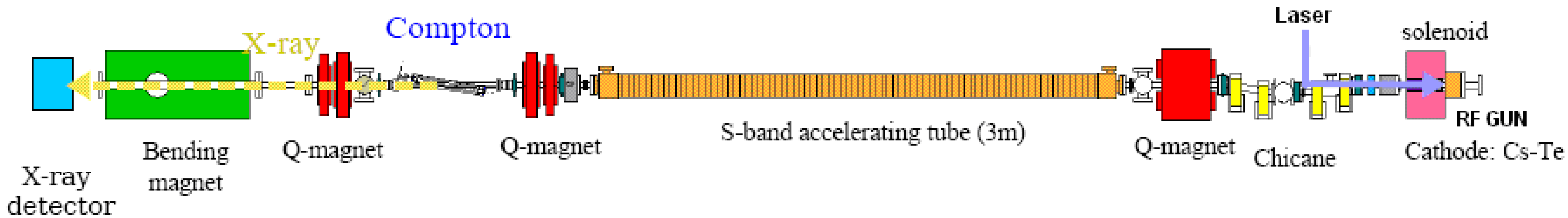
Optimization of Magnetic Field



Phase Plot using ASTRA



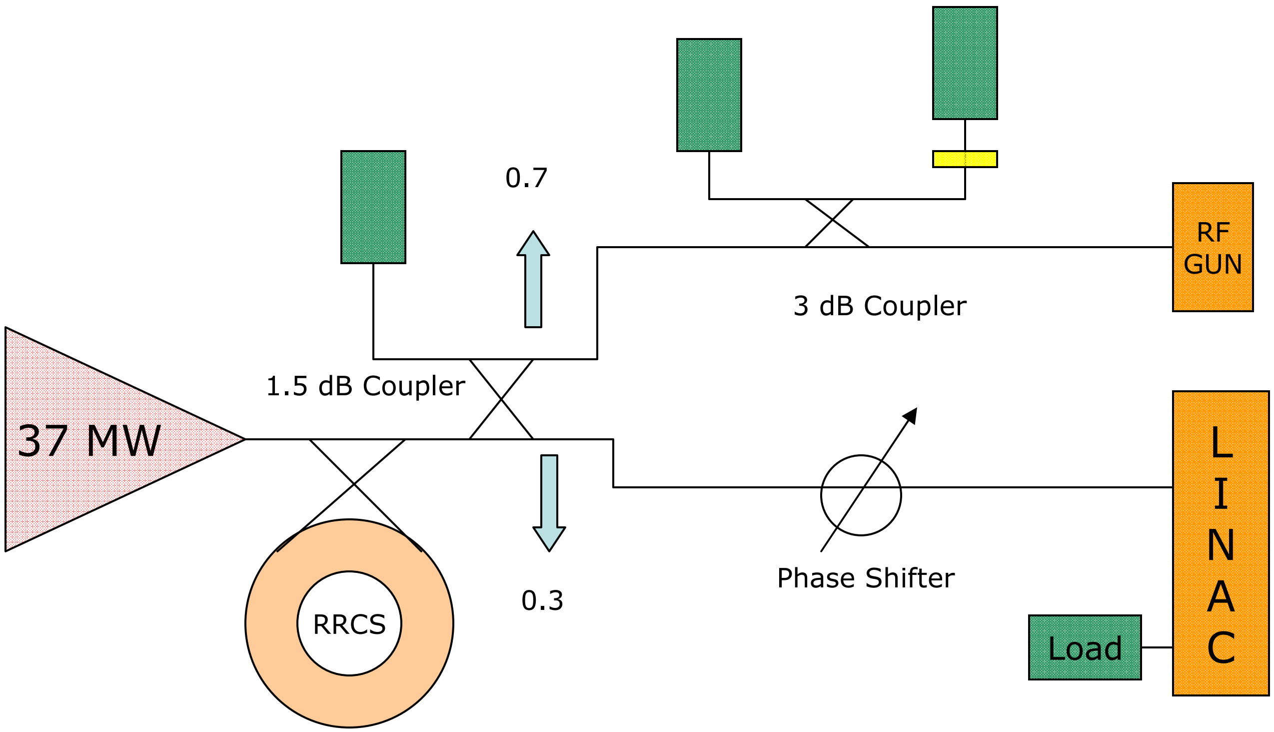
Test Bench LUCX Setup



- The experimentation will be done on existing Laser Undulator Compton X-ray (LUCX) setup.

- Provision is being made to remove the Linac to make the measurement of RF Gun output feasible.

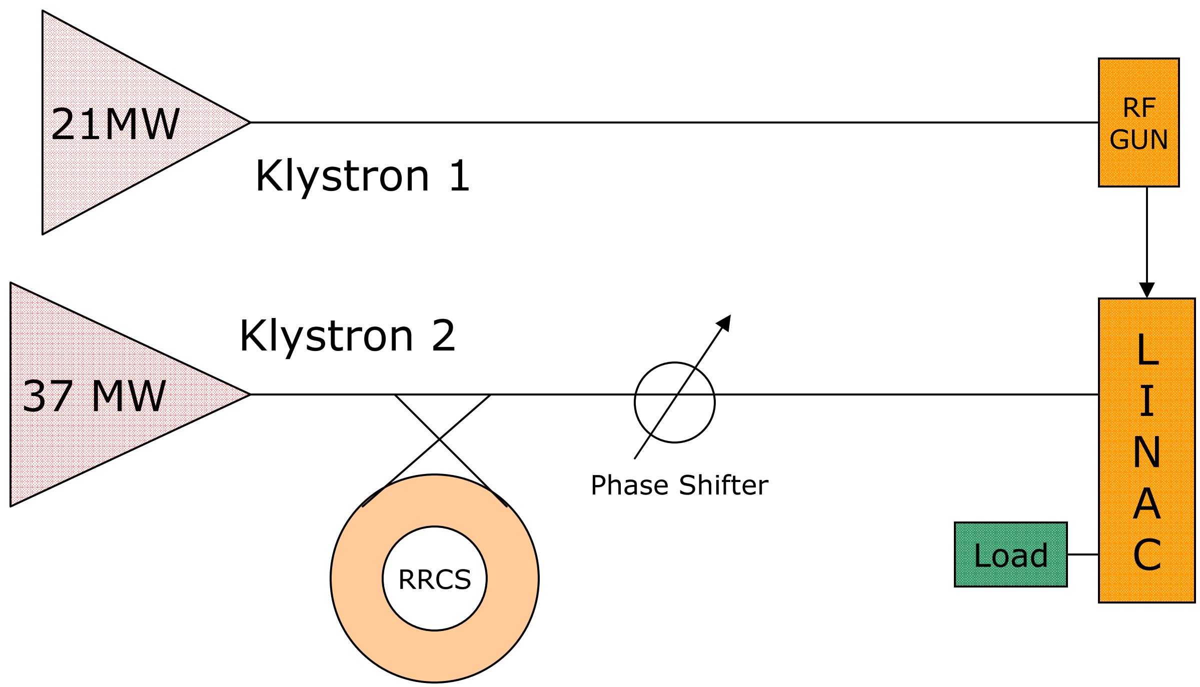
Existing Power Scheme



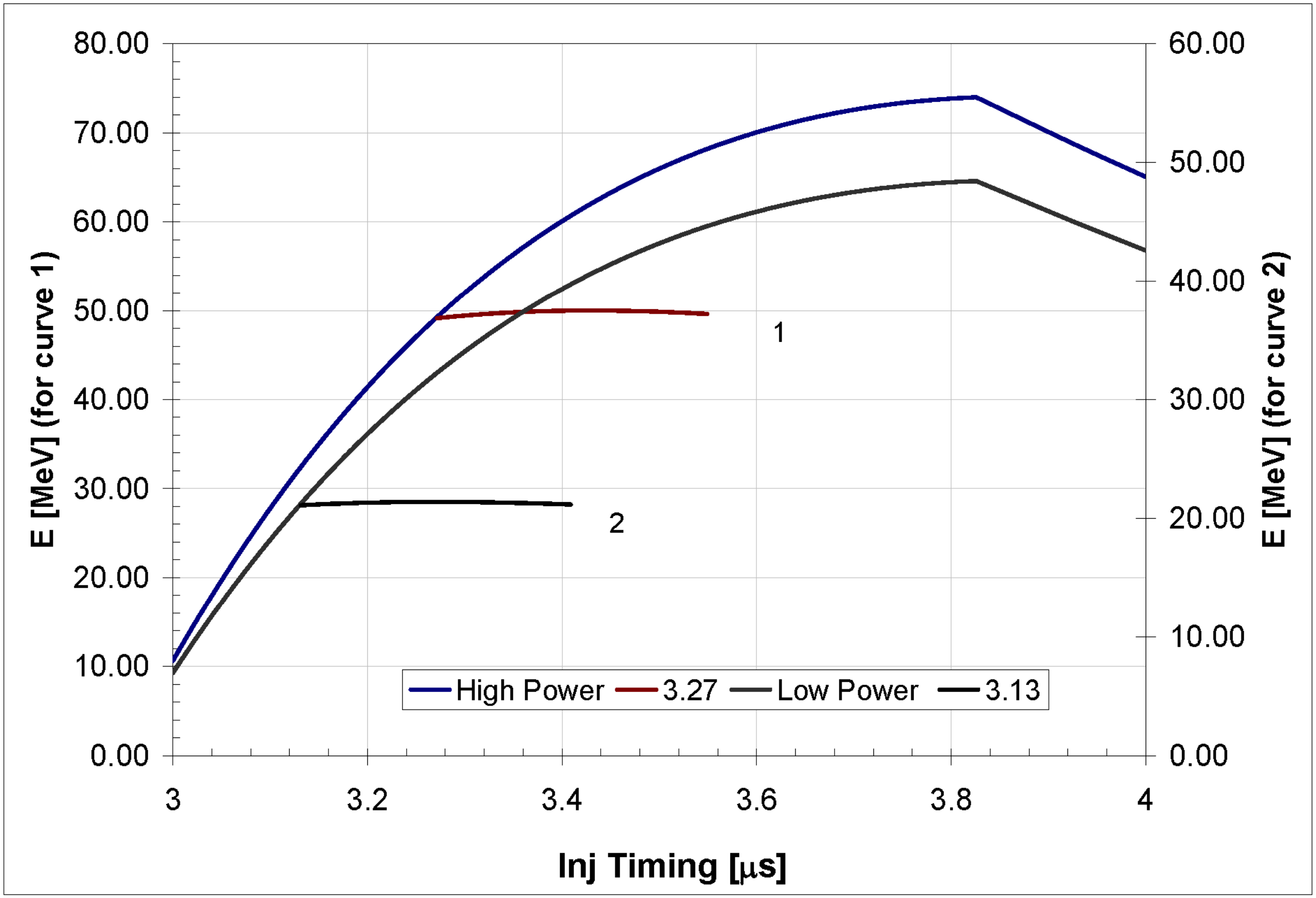
Demonstrated Beam: 40 nC in 100 bunches

200 nC in 100 bunches: New Power Scheme:

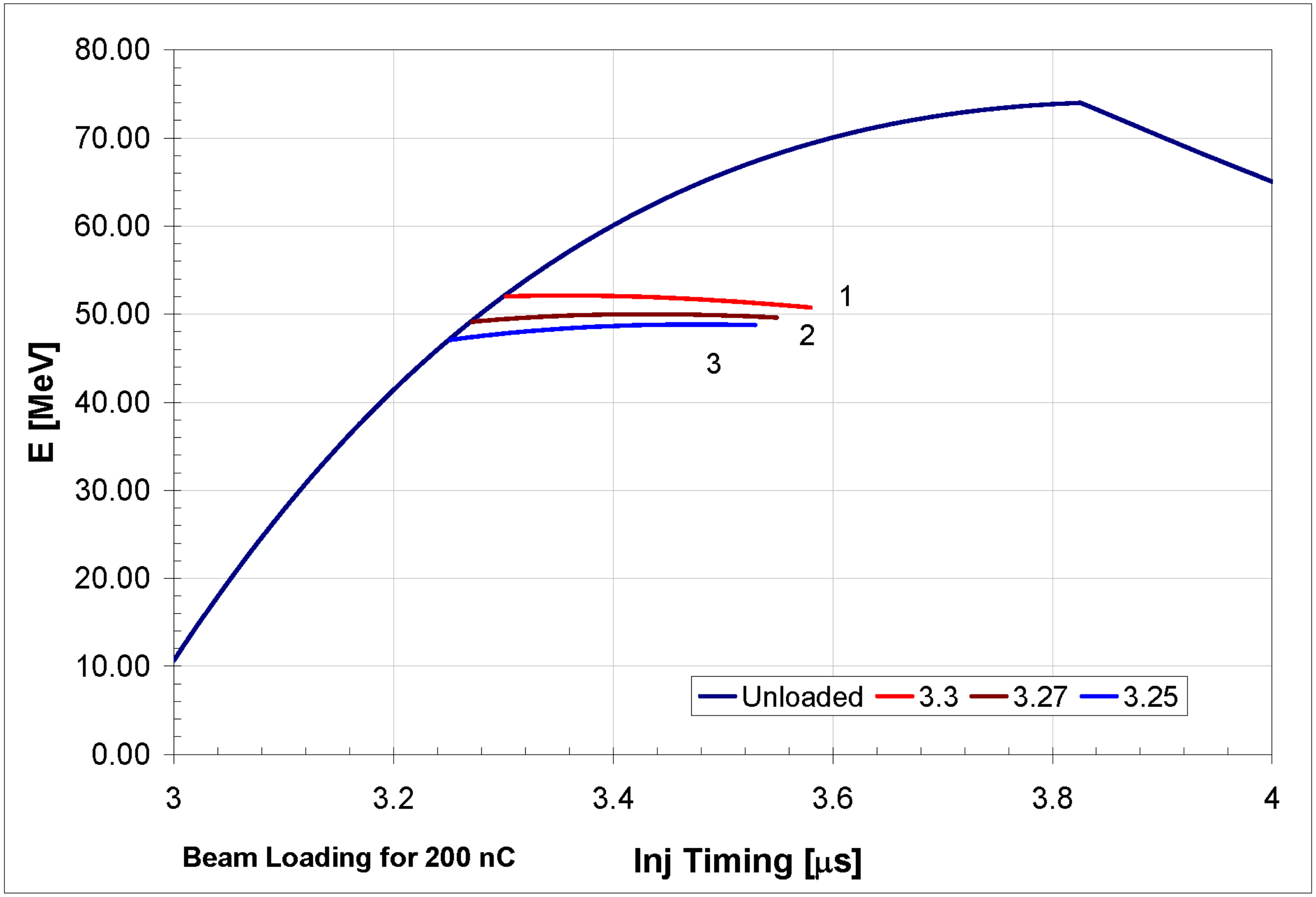
RF GUN	21. 0 MW	No SLED / RRCS
LINAC	86 MW	RRCS



200 nC in 100 bunches

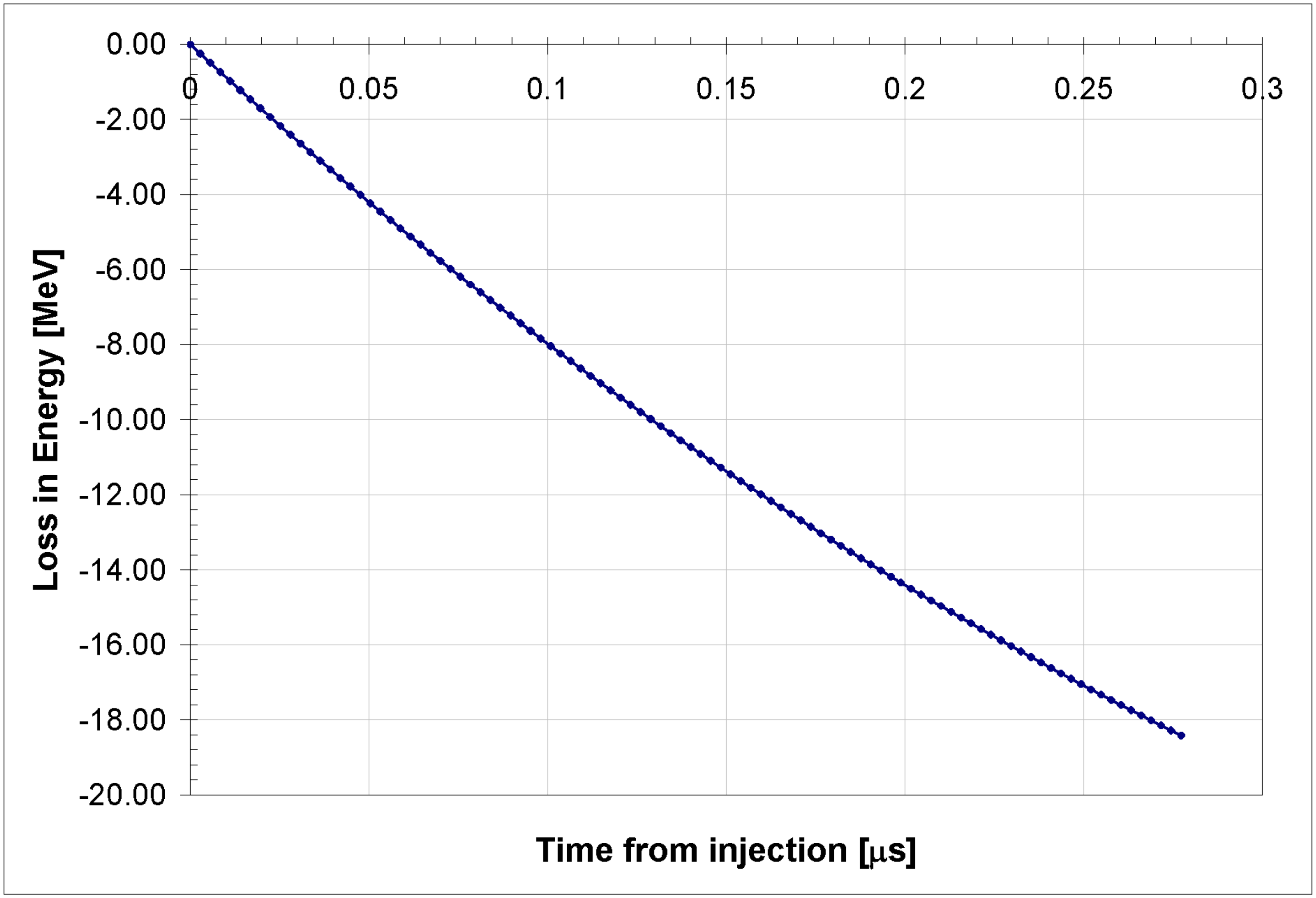


Beam Loading in Linac 100 bunches 200 nC [6]

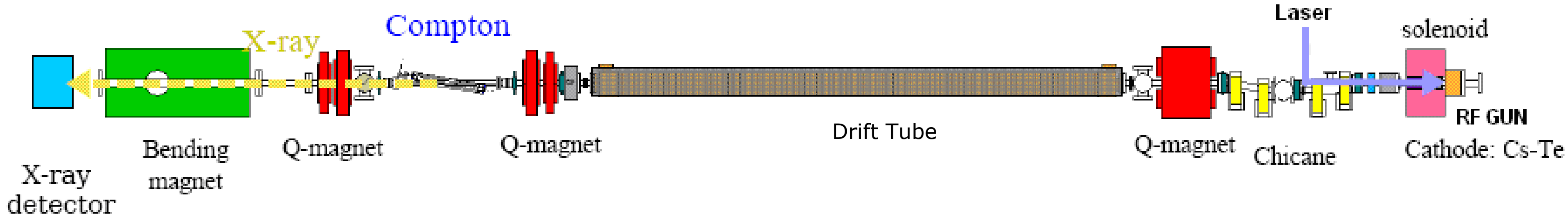


[6] S. Liu, J Urakawa et al. NIM-A 584 (2008) 1-8

Beam Loading in Linac 100 bunches 200 nC



Proposal for 5 MeV, 2 uC in 1000 bunches beam

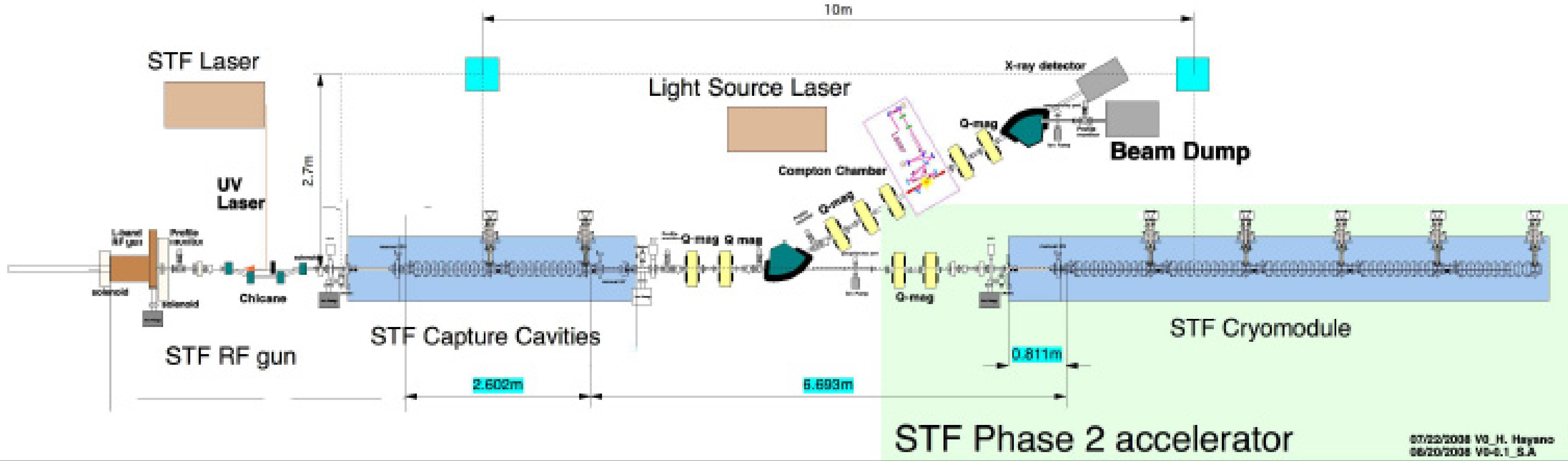


- We further plan to achieve 1000 bunches of 2 nC per bunch at the gun exit.
- This beam will cause severe loading problems in the linac, hence acceleration of such a beam using linac is not possible in current setup.
- By replacing the linac with a drift tube, it will be possible to achieve very high charge in the diagnostic region. In this way we will be able to use same diagnostic setup.
- This will make two mode possible in LUCX :
  a) 45 MeV, 200 nC in 100 bunches with use of LINAC (current setup)
  b) 5 MeV, 2 uC in 1000 bunches, No Linac, Only Gun (proposed)

Quantum Beam Technology Program (QBTP)

- The QBTP program uses part of the STF setup.
- L-Band photo cathode gun will be used as the source.
- We plan to use the STF Capture cavities for acceleration at 30 MV/m gradient to generate 48 uC beam in multi bunch mode.
- Simulations and parameter estimation is under progress.

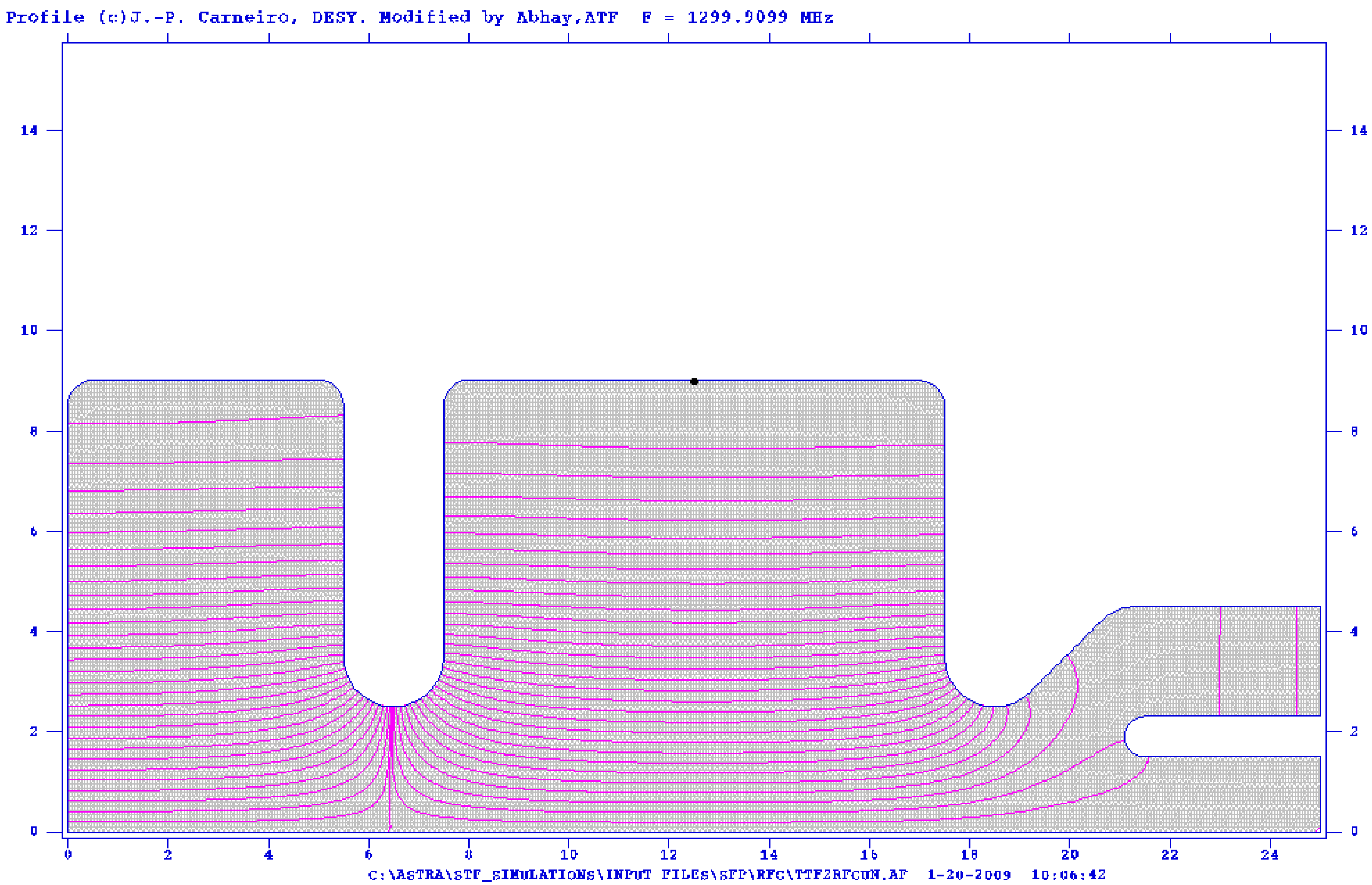
Layout



10m
STF Laser
Light Source Laser
X-ray detector
Q-mag
Beam Dump
Compton Chamber
UV
Laser
2.7m
Q-mag
Q mag
Chicane
Q-mag
STF Capture Cavities
STF RF gun
STF Cryomodule
0.811m
2.602m
6.693m
STF Phase 2 accelerator

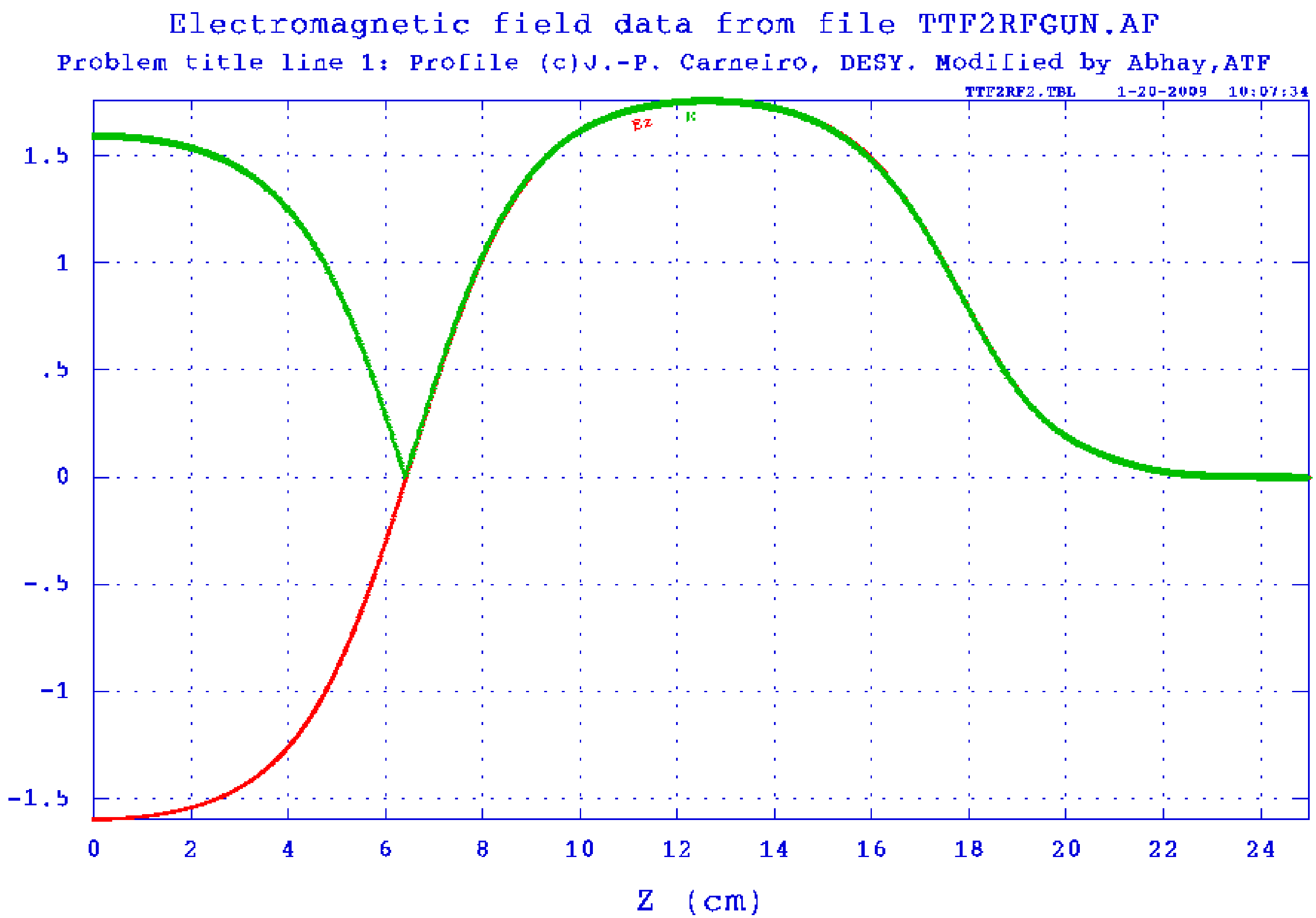
TESLA Type RF Gun

- Pi Mode Frequency : 1299.99 MHz
- Zero Mode Frequency : 1294.58 MHz
- Mode Separation : 5.41 MHz



TESLA Type RF Gun

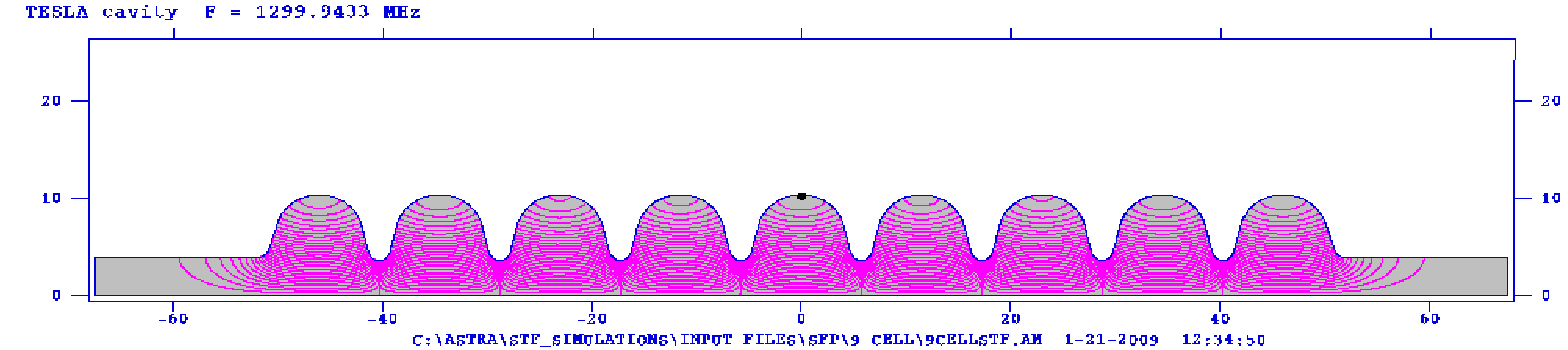
Max Field : ~ 30 MV/m

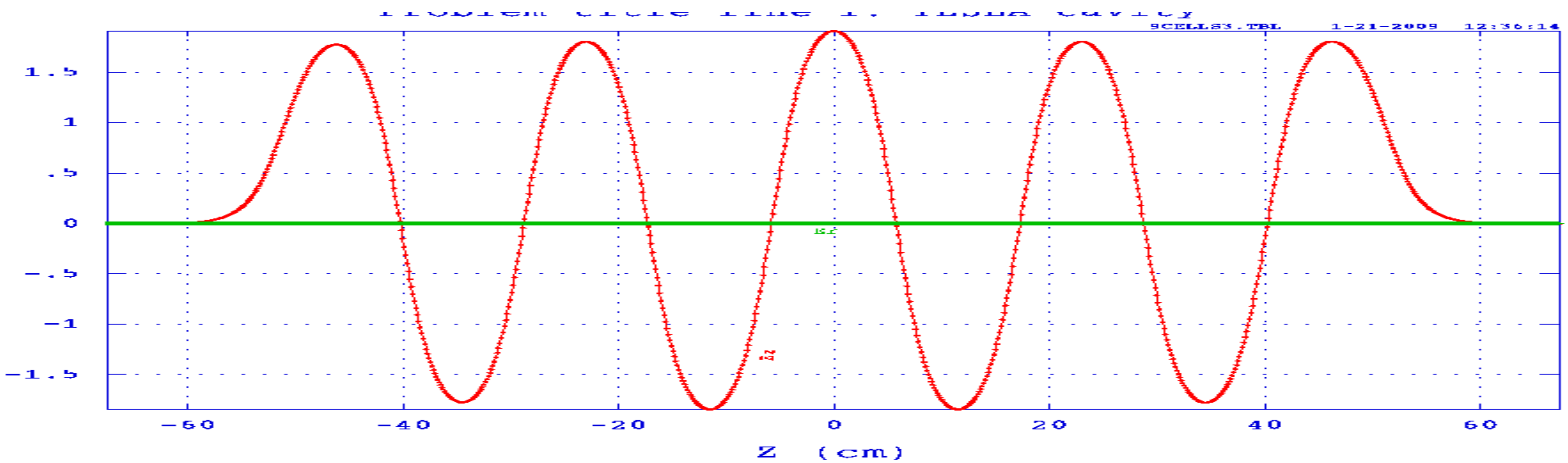


Comparison of RF Gun Cavities

	Q	R Mohm	ZTT MO/m	r/Q
ATF	15913	6.9739	29.6921	438.2518
ATF-MS	18275	7.5453	34.9091	412.8752
L Band	26690	13.7948	22.7550	514.6790

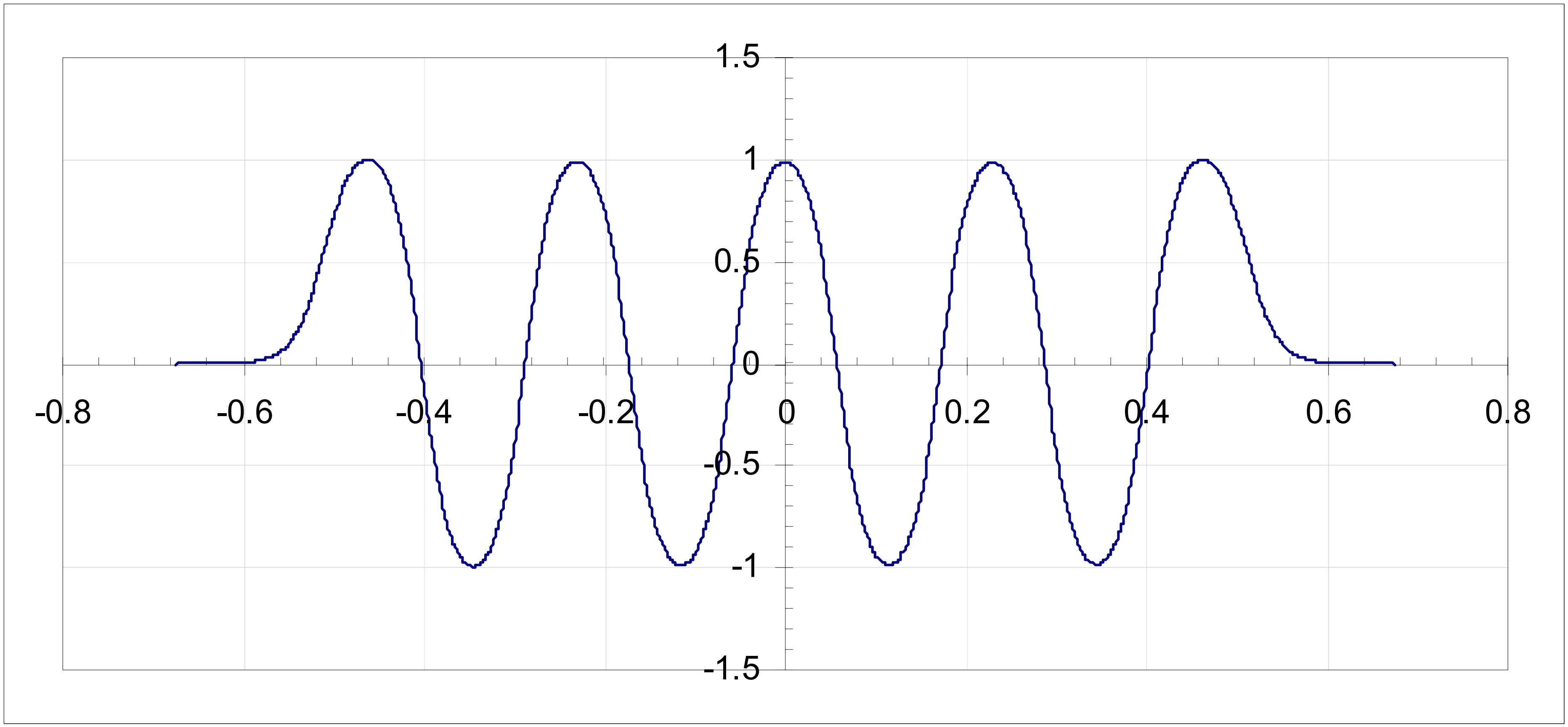
Main Linac : STF 9 Cell : 2 Cavities





STF 9 - Cell

- Axial field pattern



QBTP Test Bench Parameters

Beam Parameters
Charge : 300pC / Bunch
No of Bunches : 162,000 Bunches
Bunch Spacing : 6.15 ns
Bunch Train : 1 ms
Total Charge : 48 uC

RF Gun Parameters
F : 1.3 GHz
Q = 27,000
ΔF = 5.4 MHz
Field Balance = 1.0

9 Cell Cavity Parameters
F : 1.3 GHz
$Q_o = 1x10^{10}$
$Q_l = 1x10^6$
β =9999
Ez = 30 MV/m
No of Cavities : 2

Conclusions

- The new RF gun design , ATF-MS will increase the energy at gun output and decrease the emittance.
- The high mode separation will increase the stability range of the gun.
- With the upgrade of modulator and the change of power delivering scheme with 21 MW to RF Gun and 86 MW to Linac, the acceleration of 200 nC, 100 bunches can be realized.
- The Linac removal mechanism will make it possible to achieve Low Energy High Charge beam for at the Compton Cavity.
- The research work at STF will have a dedicated 48 uC beam of 40 MV in the diagnostic region of STF beam line.

Thank you for your attention.

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