Beam Dynamics Study of the SARAF beam loss along the linac based on the site RFQ tests

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SARAF, Soreq NRC

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1. Introduction
2. On site tests configuration
3. The RFQ proton beam on site tests combined with a beam dynamics study
4. Recommendations
5. Beam loss along the linac

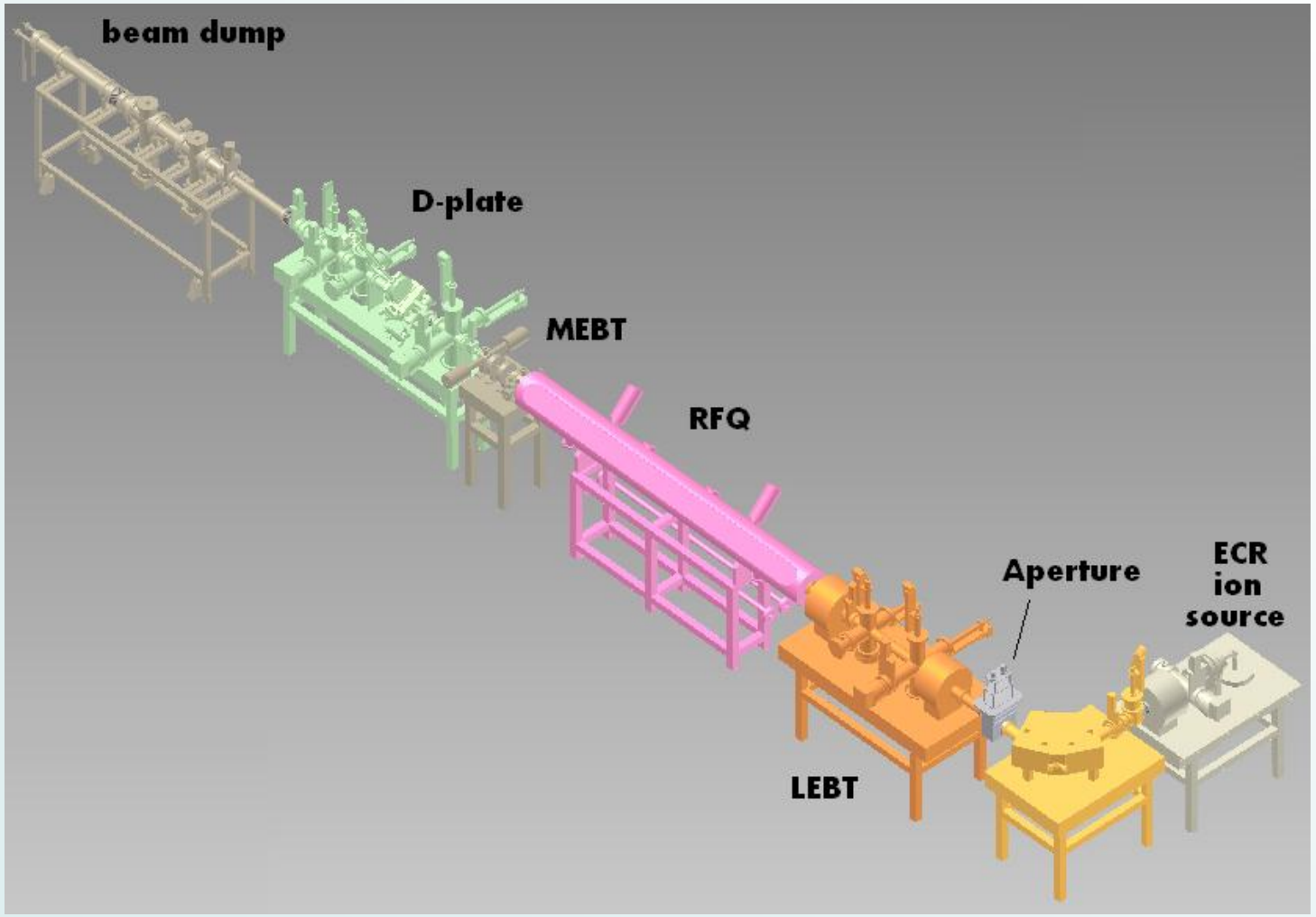
Introduction

- On site tests for the SARAF RFQ with a 0.5 mA and 3mA injected proton beam
- The RFQ electrode voltage was not measured explicitly
- The electrode voltage is derived by X-ray measurements (ANL, ISIS)
- Good agreement Beam Dynamics vs. Tests ISIS- nominal power, SNS- power range
- Beam dynamics study vs. RFQ on site tests for various applied RFQ powers correlates voltage to power
- The RFQ power is optimized for maximum transmission, minimum halo, low electrode voltage

* with the TRACK code, P. Ostroumov, ANL

The tests configuration

- The on site tests included the SARAF ECR, LEBT, RFQ, MEBT, D-Plate (to test the beam properties at the RFQ exit), and the Beam Dump



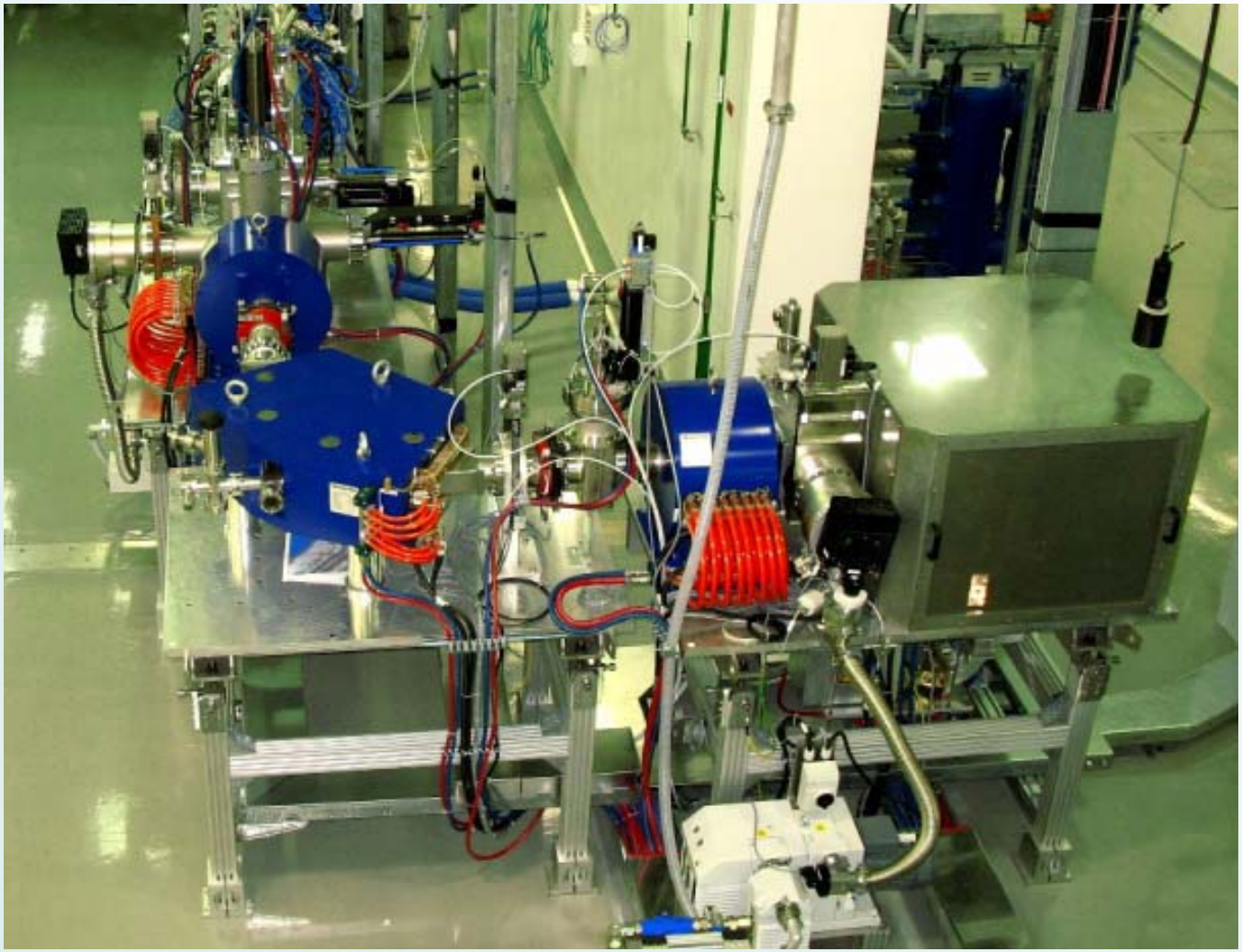
Tests Measurements

- A biased faraday cup to measure the RFQ injected current

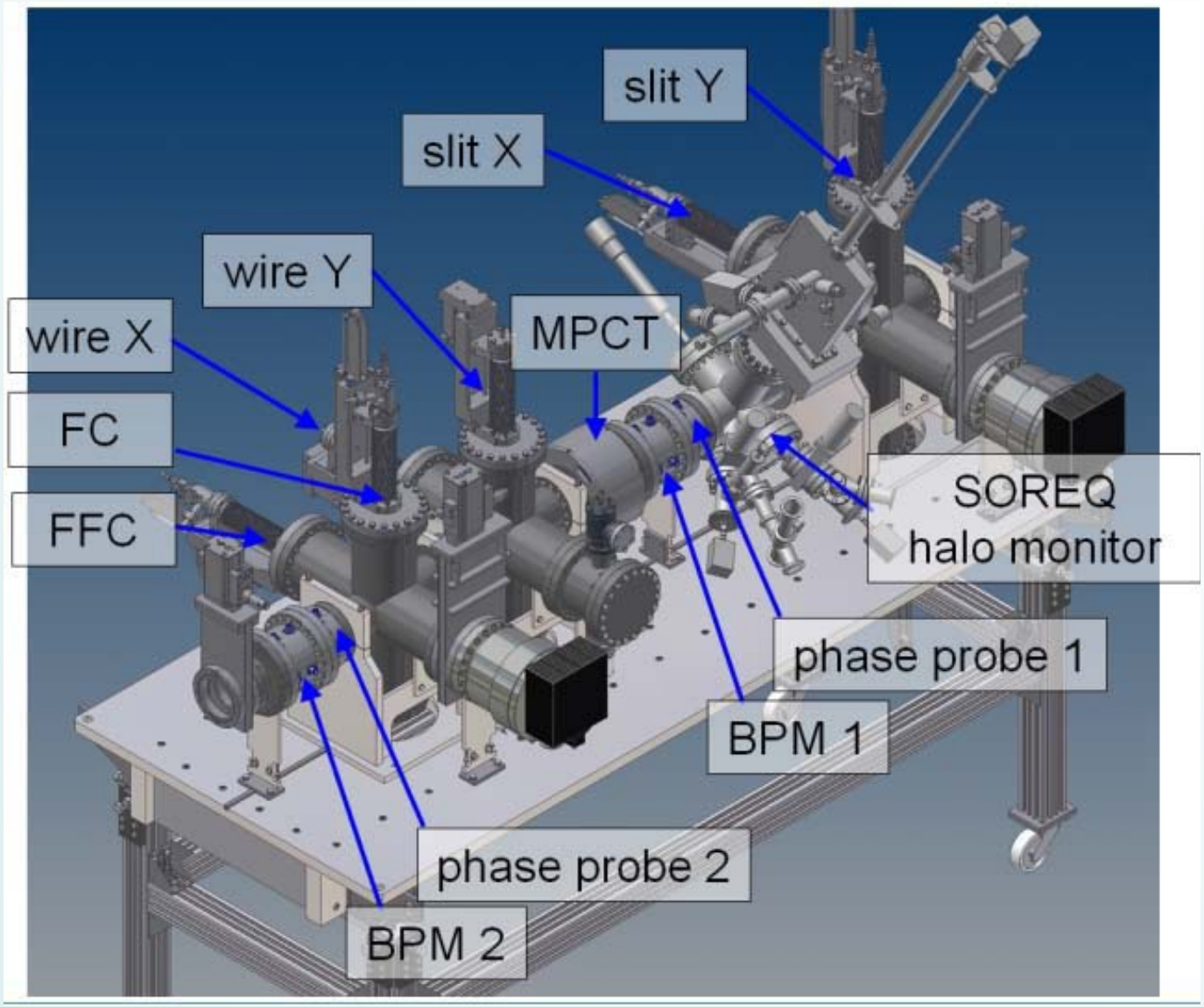
At the D-Plate there are:

- Two phase probes to test average bunch time of flight
- Two FFC positions at 1.0 m (the design position of the PSM buncher) and 2.6 m from the RFQ exit to measure the beam bunch profile
- A BPM- beam position monitor to test the beam current not calibrated to bunch length (the measured peak voltage is presented)
- A MPCT- a calibrated current transformer of BERGOZ to measure the RFQ exit current

ECR & LEBT (K. Dunkel PAC07)



D-Plate (C. Piel PAC07)



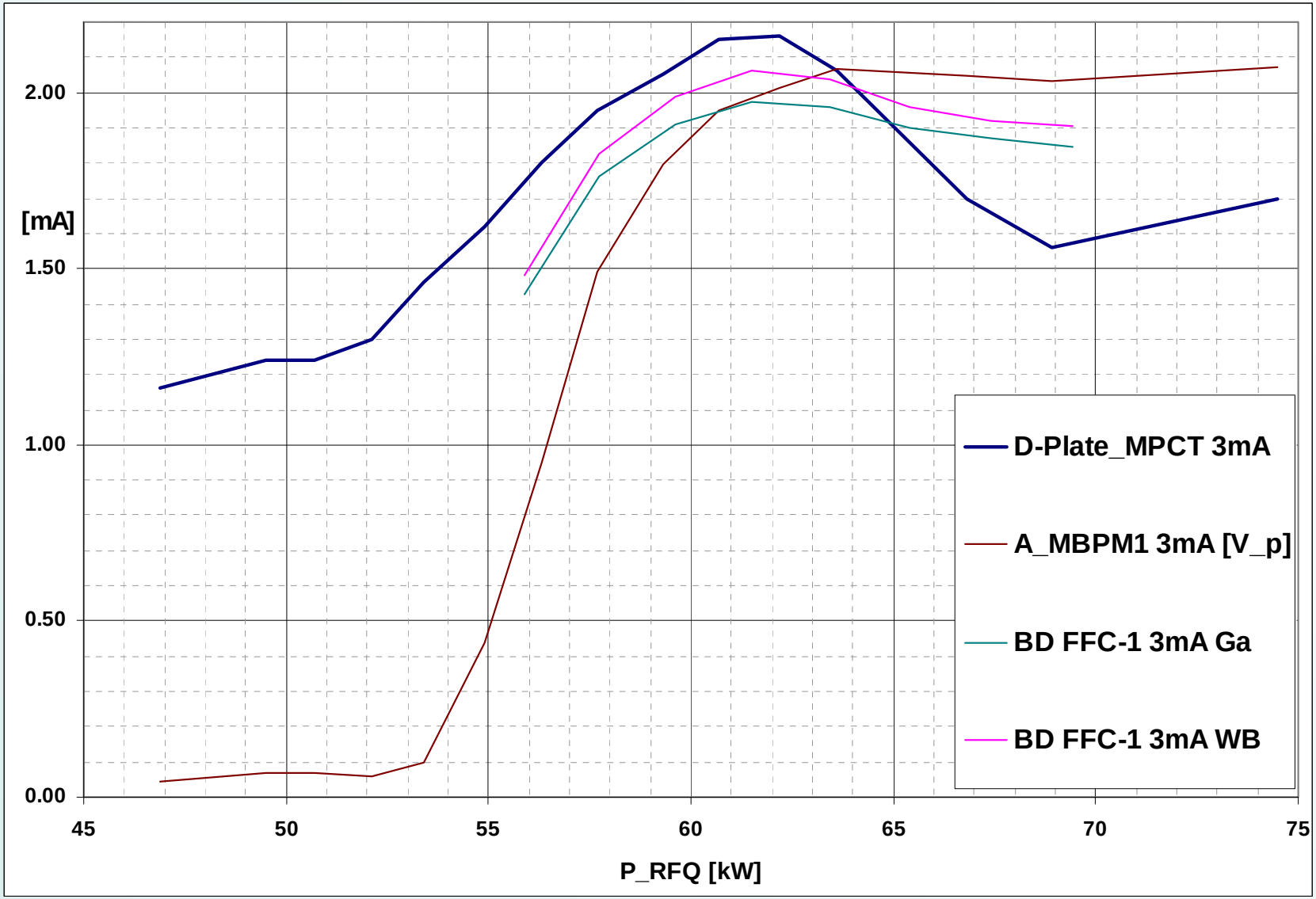
Tests Measurements

- The beam was tested for various RFQ operating power in the range of 47-74 kW
- At the first phase the LEBT aperture was partially closed- 0.5 mA injected current
- At the second phase the aperture was open- 3mA injected current
- The solenoids fields along the LEBT with an open aperture were: 1530, 1265, 1852 Gauss for the tests.
- The field at the third solenoid (near the RFQ) was reduced to 1779 Gauss when the aperture was partially closed

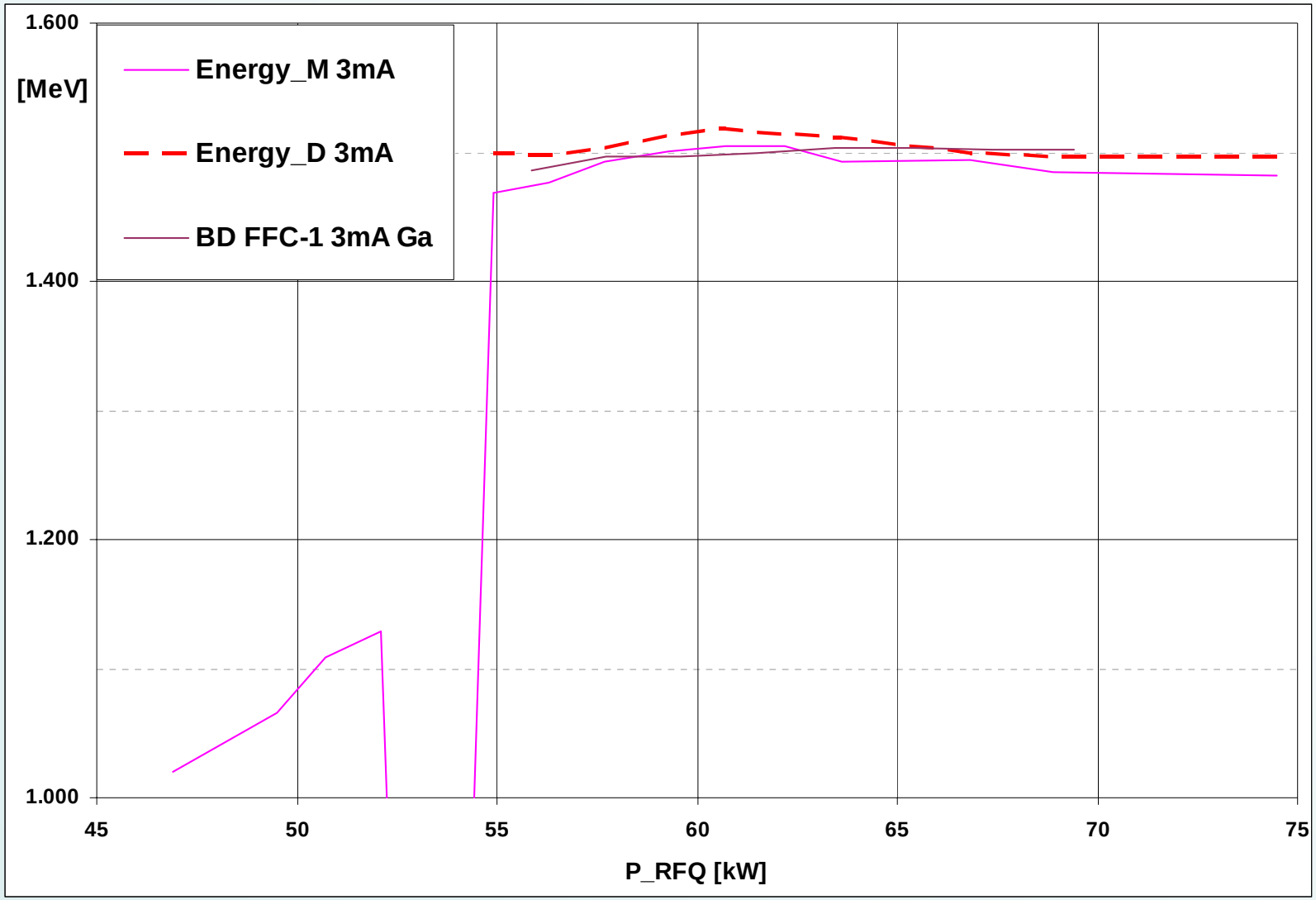
Beam dynamics simulations vs. tests

- The simulation fields are the same for the first and the second LEBT solenoids and with 8% higher amplitude for the third solenoid
- The CDR transverse Courant Snyder parameters at the ECR exit- alpha =0, beta=0.203 mm/mrad were used to generate the input data
- Both 40k 4D Gaussian and 4D WB initial input transverse distributions at the ECR exit were applied to simulate the 3 mA proton beam

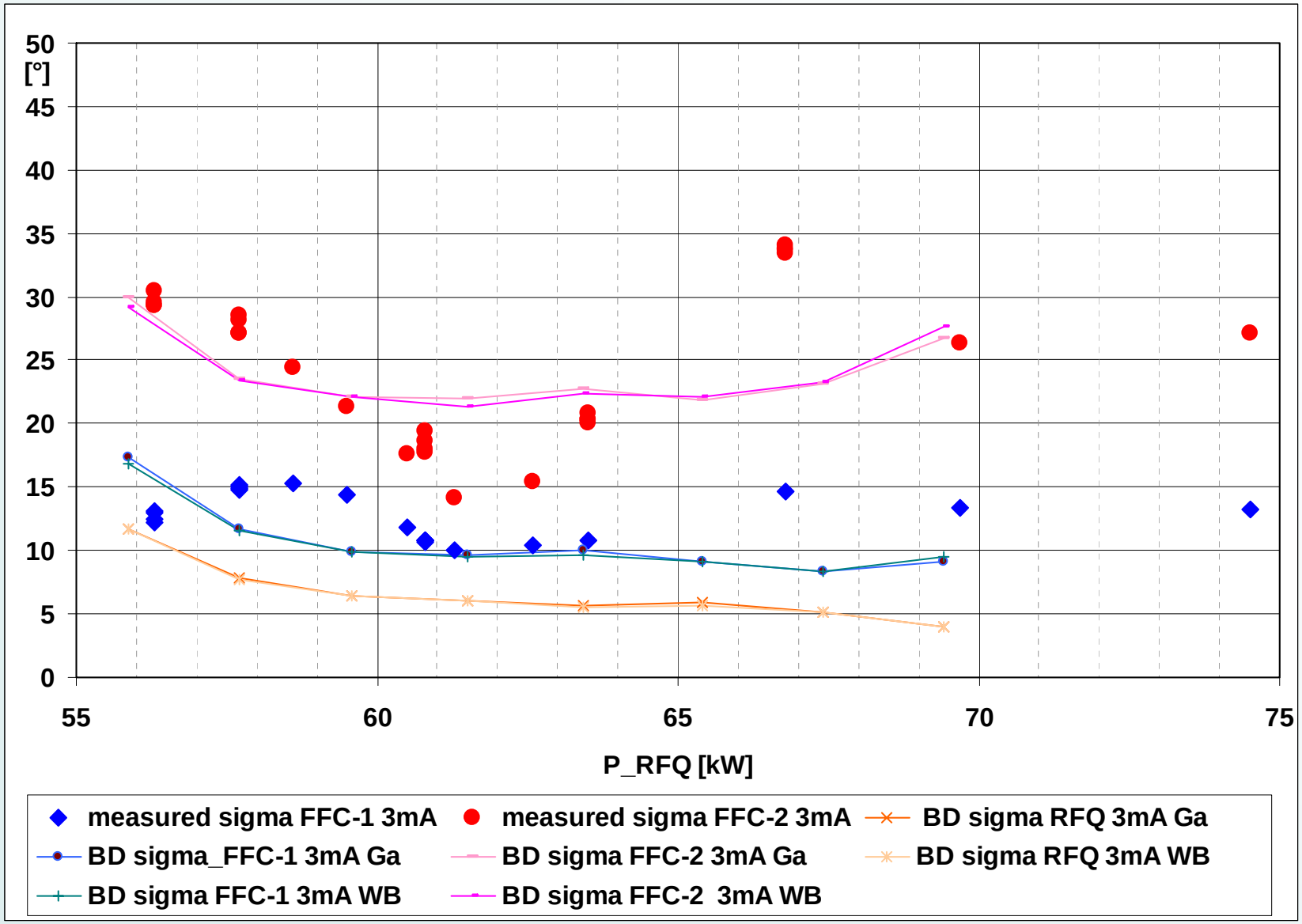
3 mA Current measurements vs. beam dynamics simulations



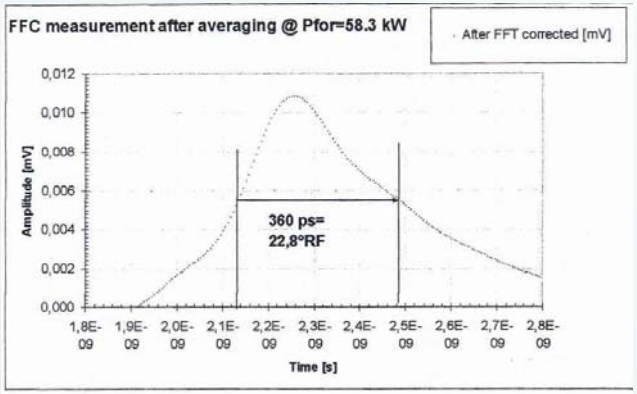
3 mA Energy measurements vs. beam dynamics simulations

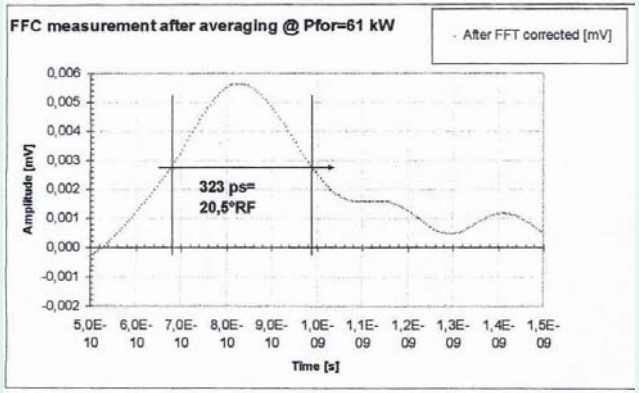


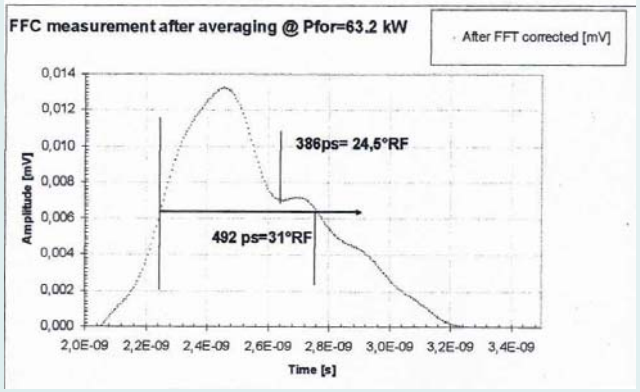
3 mA Bunch length measurements vs. beam dynamics simulations

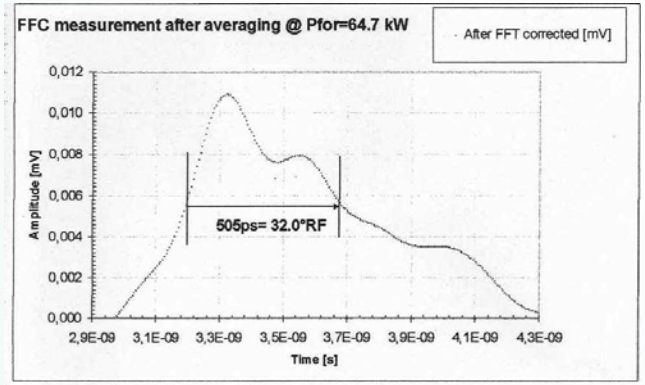


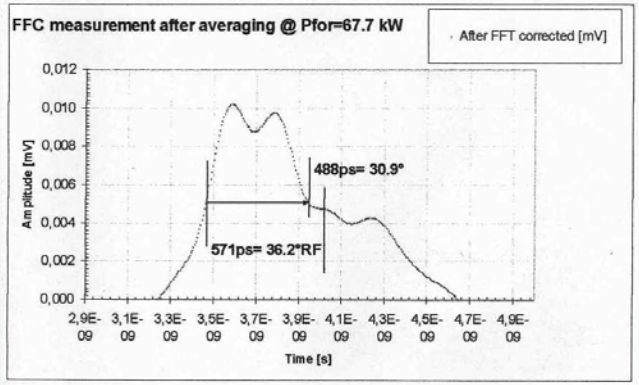
0.5 mA Tests bunch profile

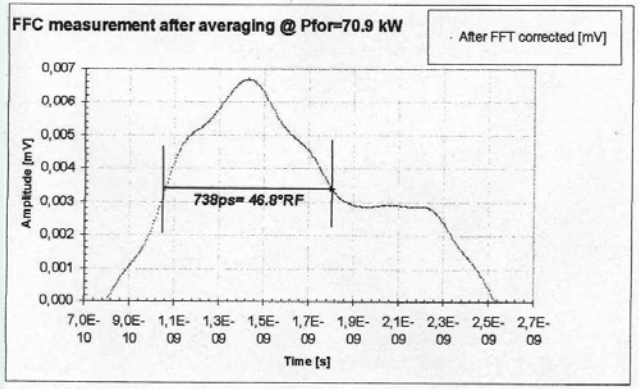






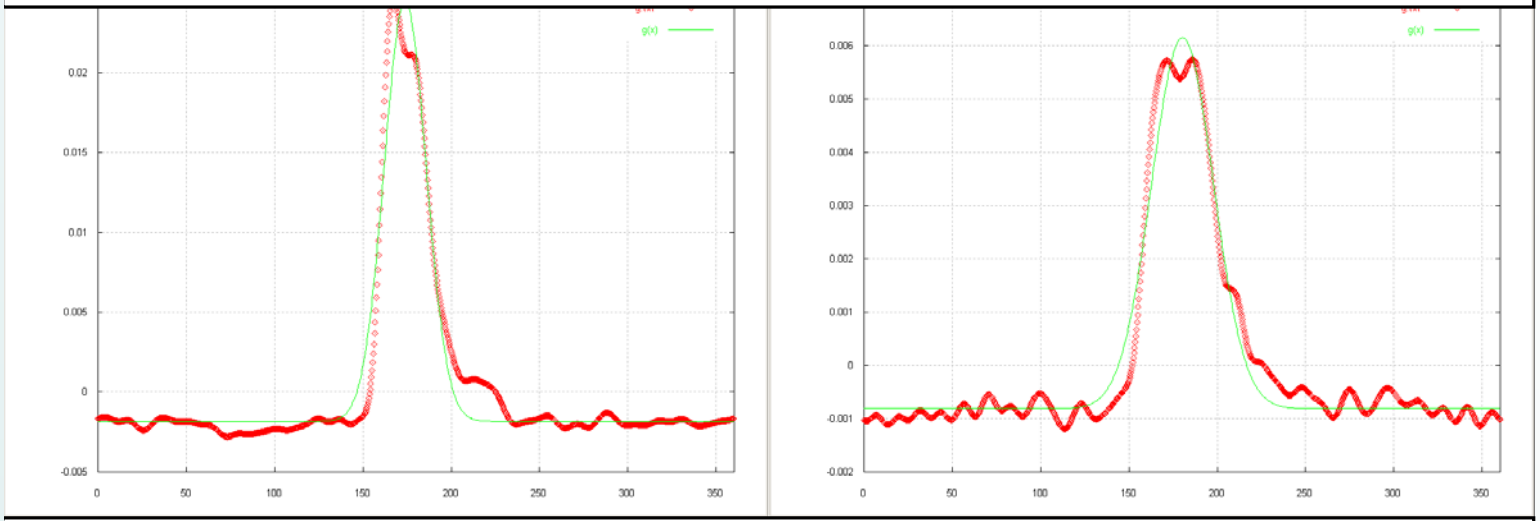




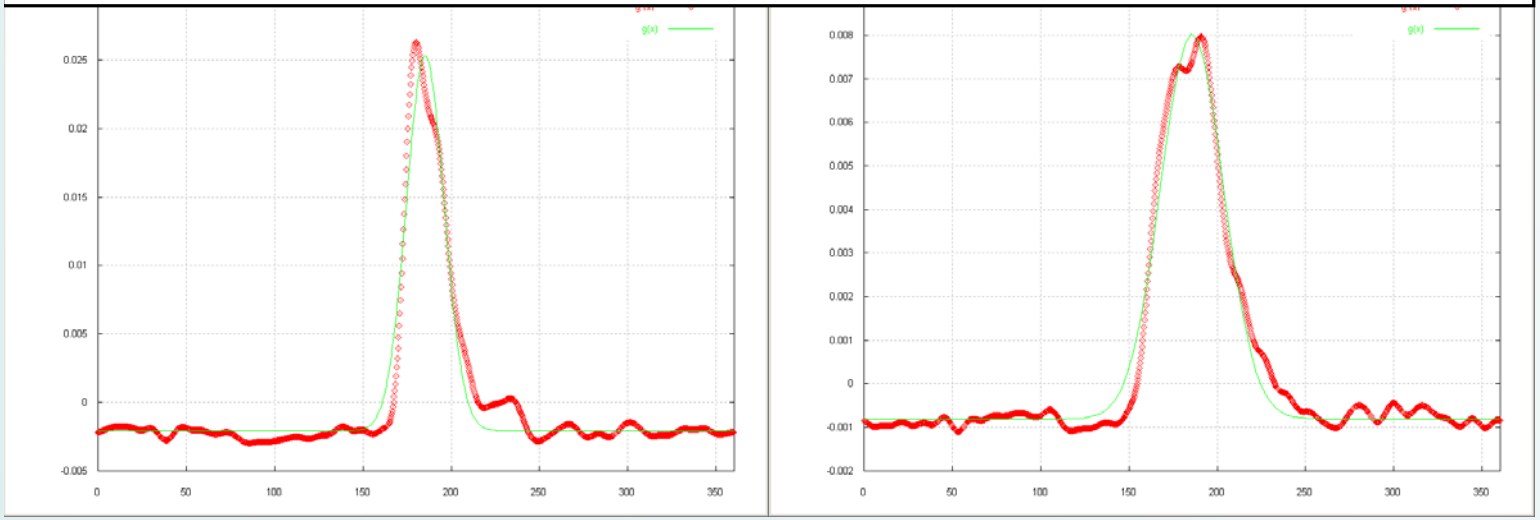


3 mA tests bunch profile

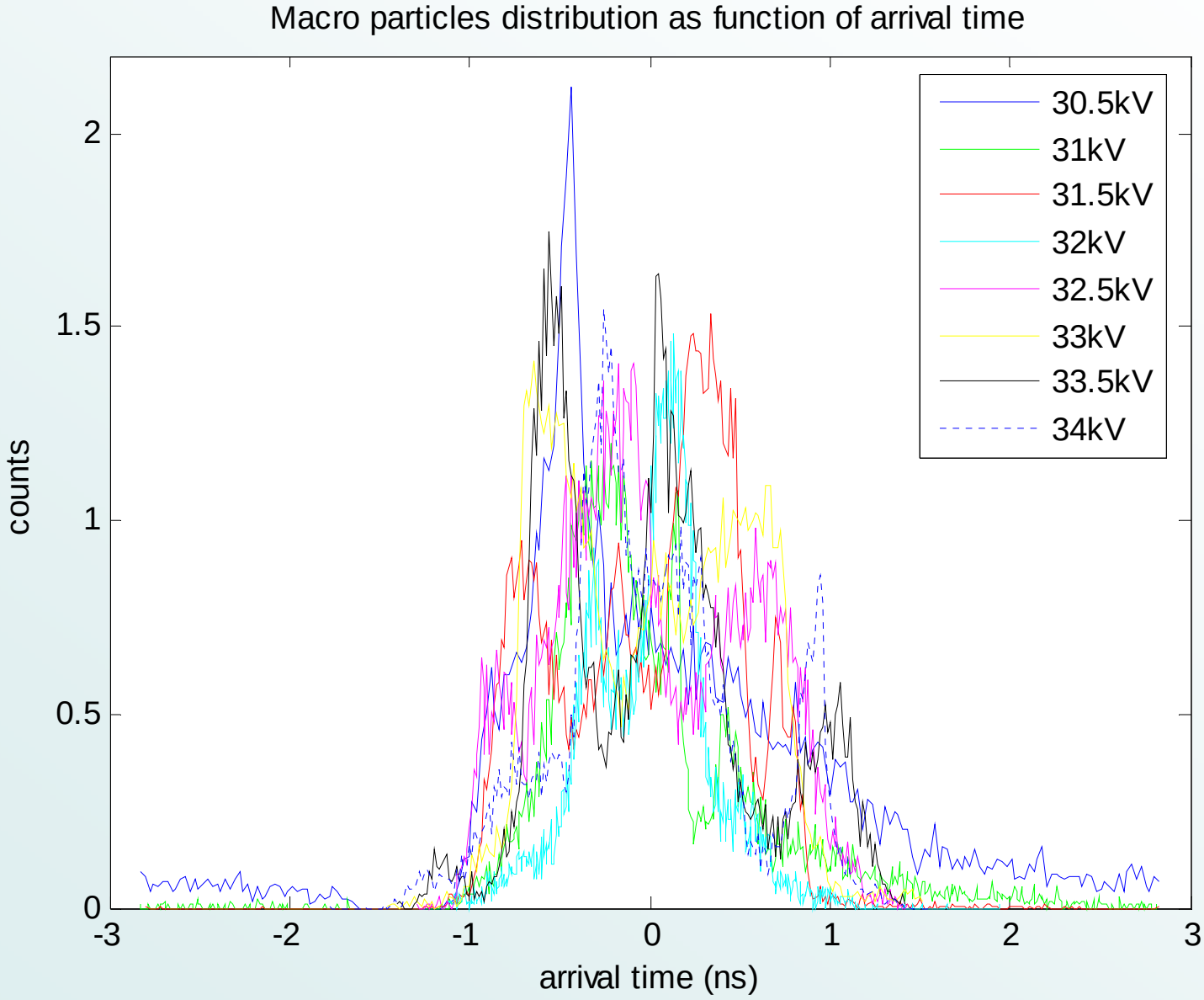
FFC-1 **P_RFQ = 60.5 kW** FFC-2



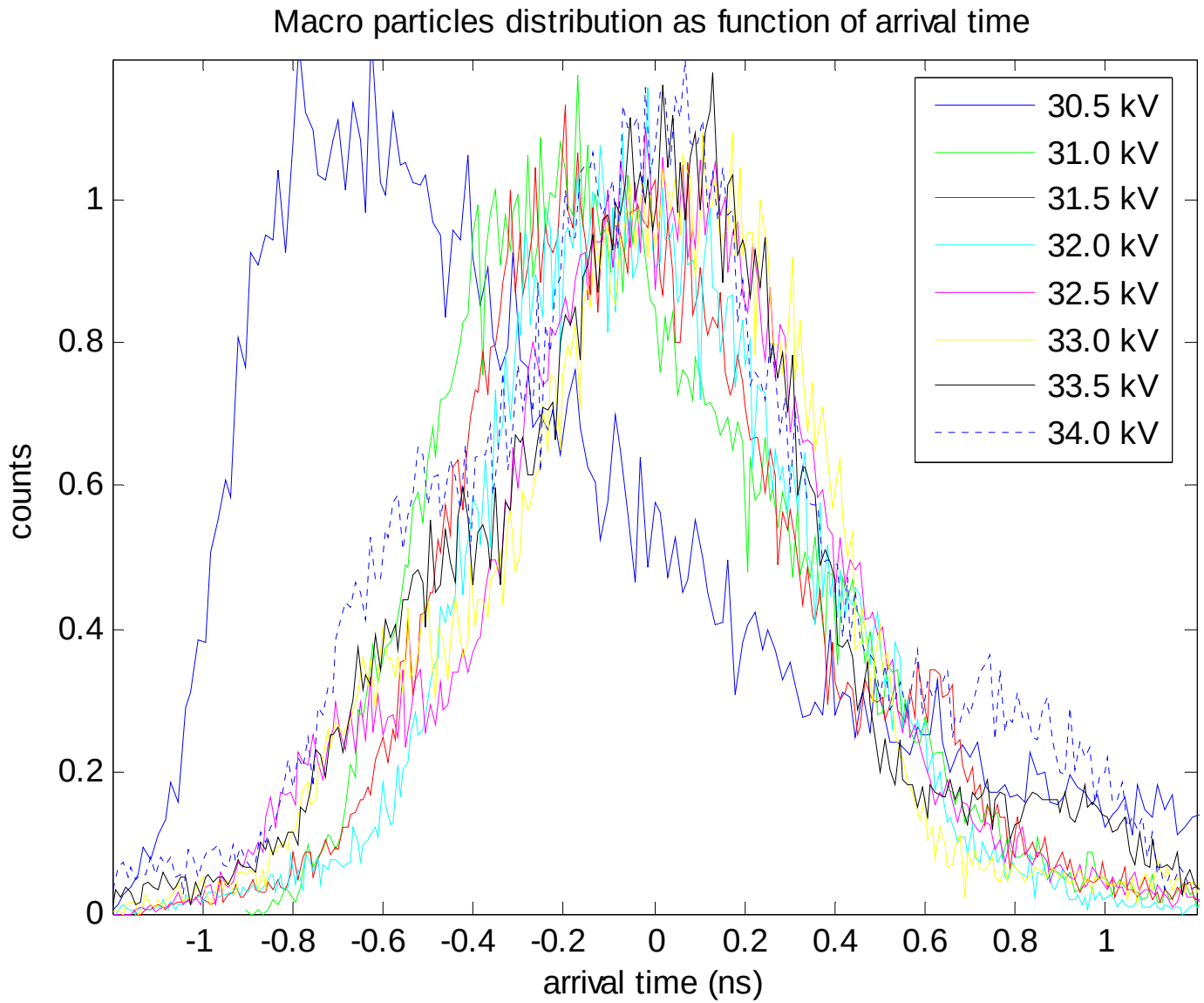
FFC-1 **P_RFQ = 60.8 kW** FFC-2



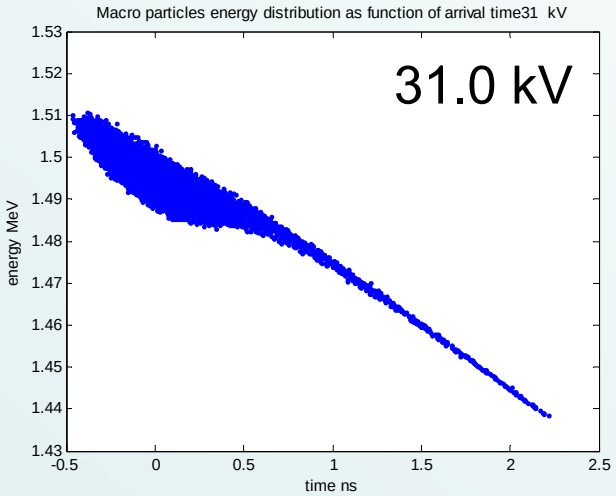
0.5 mA BD bunch profile at FFC-2

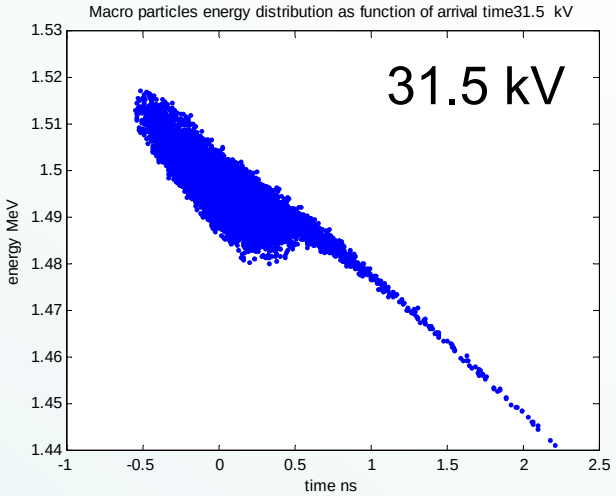


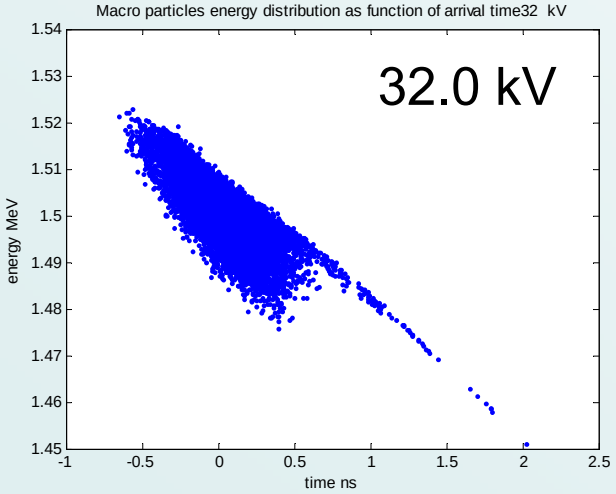
3 mA BD bunch profile at FFC-2

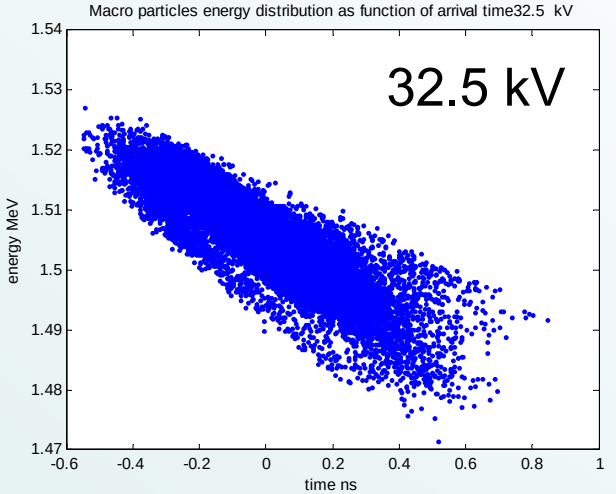


3 mA Bunch energy time phase space

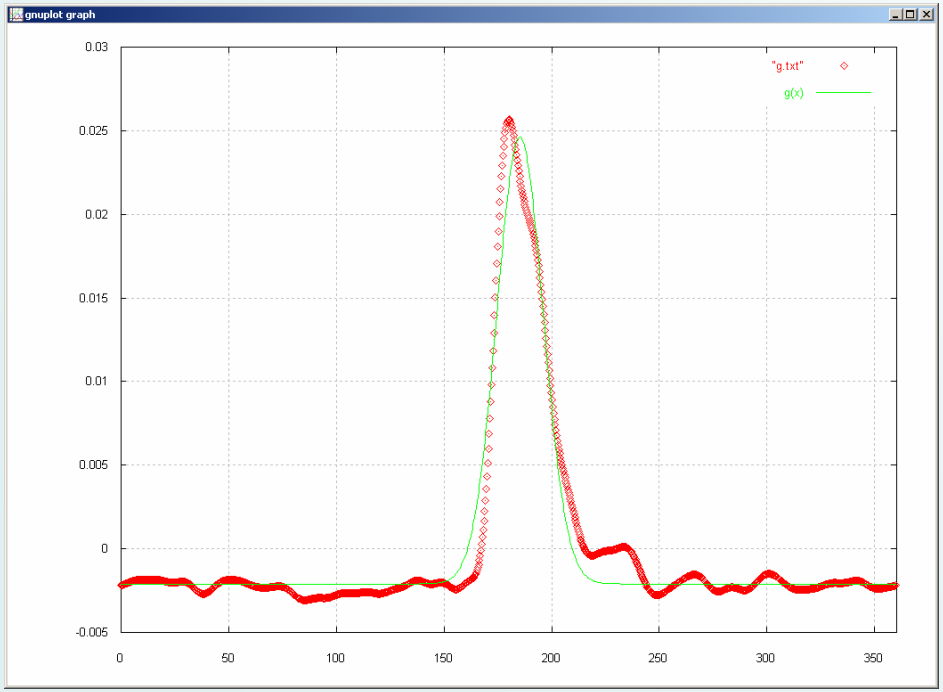


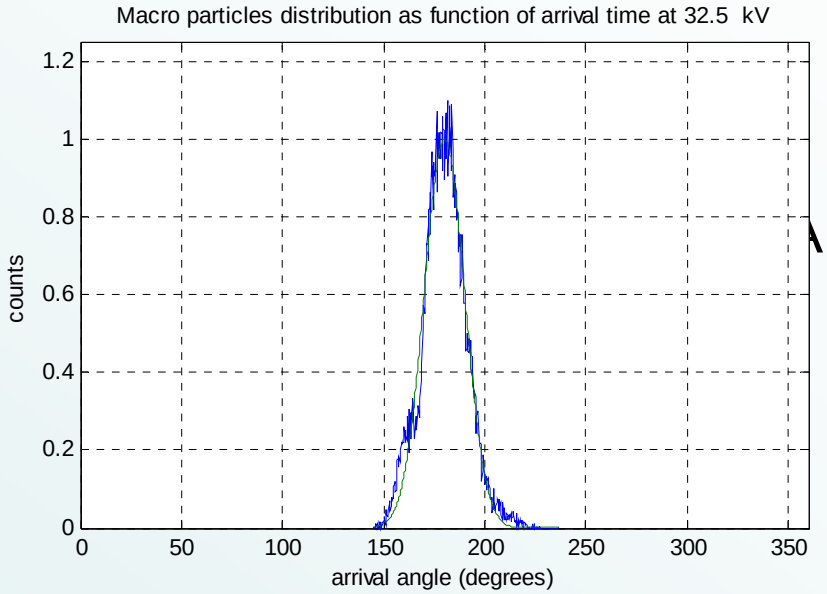




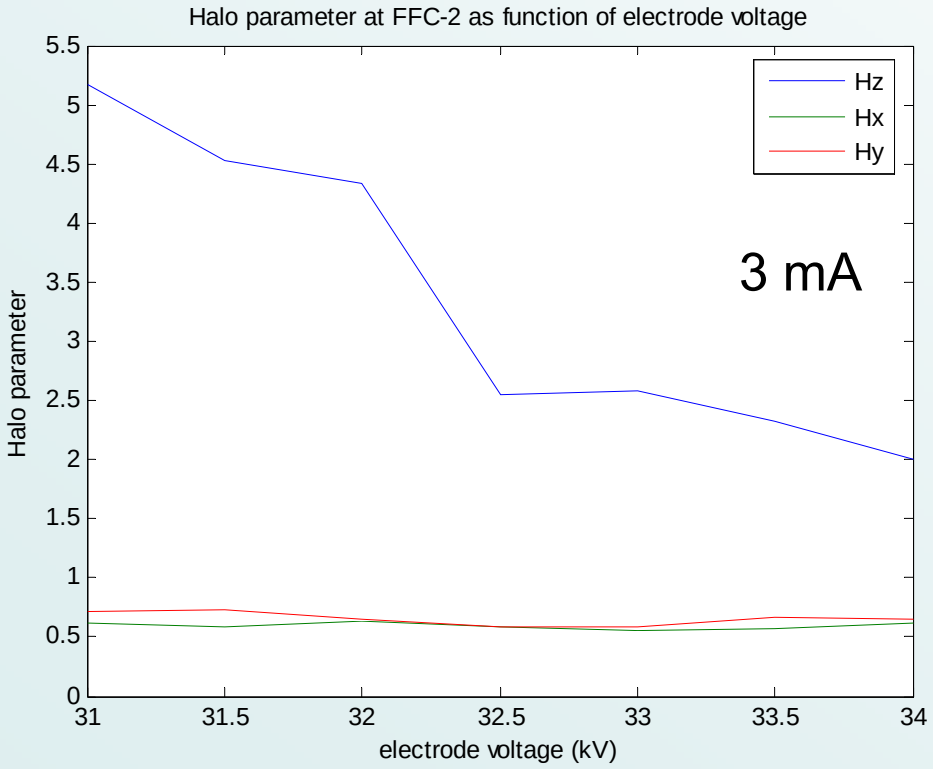


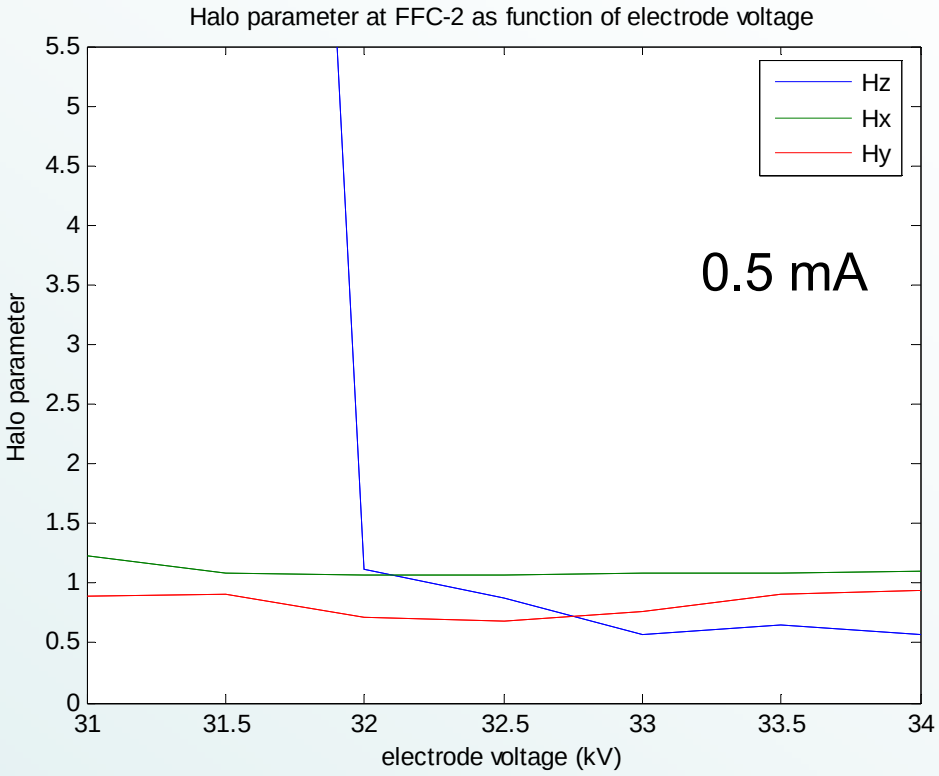
Longitudinal profile at FFC- 1 at 32.5 kV





Halo parameter as function of electrode voltage at FFC- 2





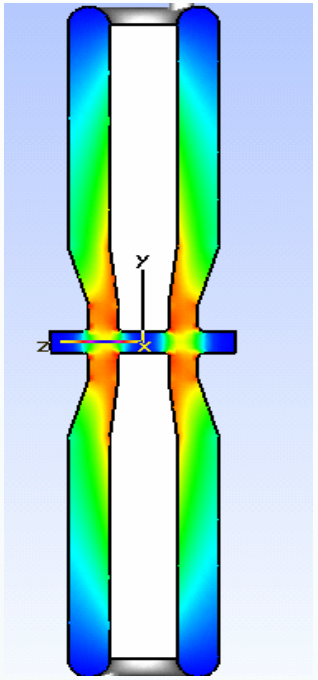
Recommendations

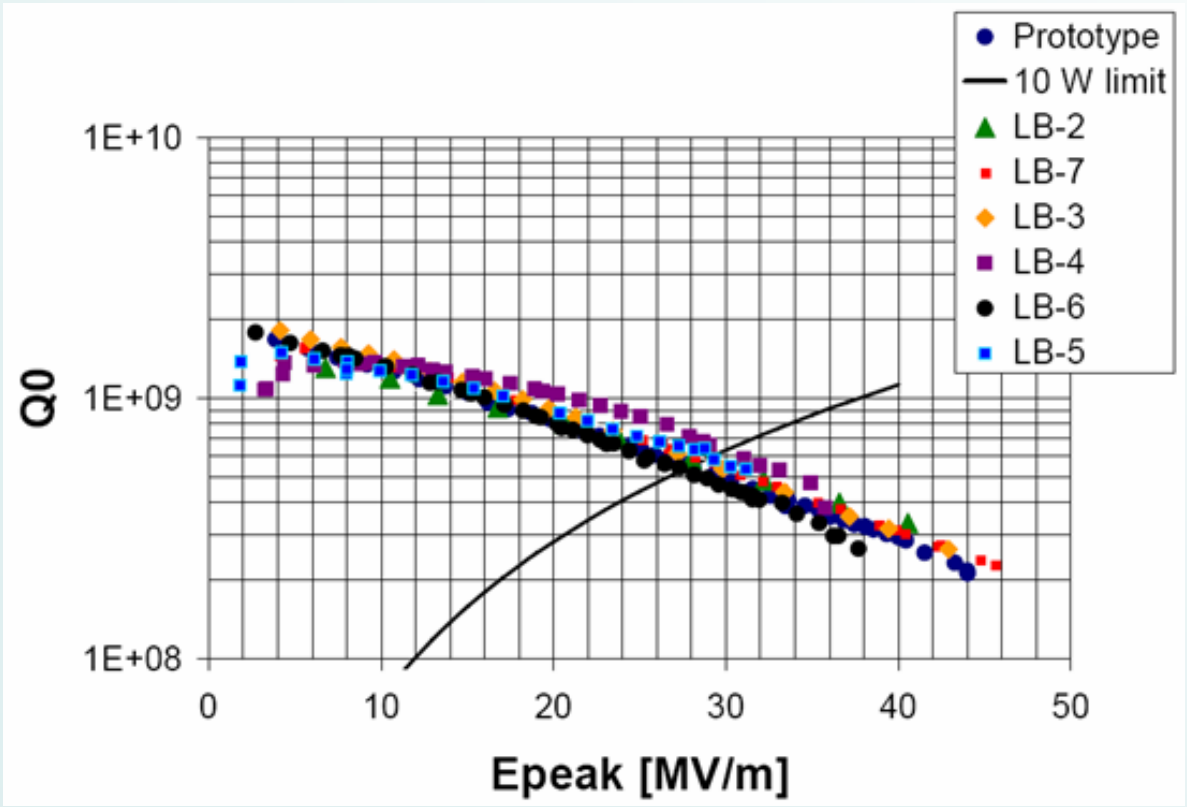
- Methods to test the bunch low energy tail at the RFQ exit as function of the electrode voltage including the use of the available D-Plate Soreq Halo Monitor for this task.
- Matching between the LEBT and the RFQ should be analyzed - the transmission from the LEBT to the RFQ is reduced from 90% to 70% as the injected proton beam is increased from 0.5 mA to 3 mA at the current tests.
- The LEBT beam dynamics transverse properties need to be updated with the applied optimized LEBT fields used to match the beam at the RFQ entrance.

Beam loss estimation based on the site RFQ tests Symmetric lattice versus Asymmetric lattice

HWR 176 MHz β_0 = 0.09, 0.15 EM field

- E_{peak}= 25 MV/m (for β_0=0.09 E_{acc}=4.9 MV/m, L_{acc}=0.22)
- Limits of HWR RF power supplies for 2 mA:
  - modules 1-2 energy gain per HWR ≤ 1. MeV
  - modules 3-6 energy gain per HWR ≤ 1.25 MeV

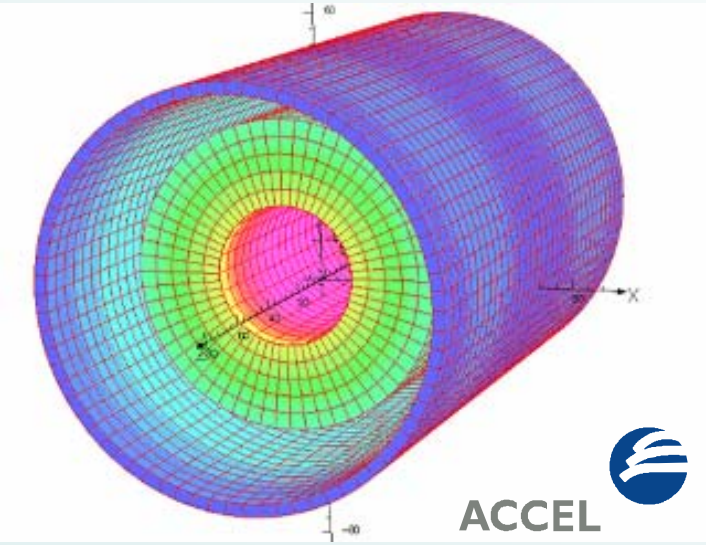




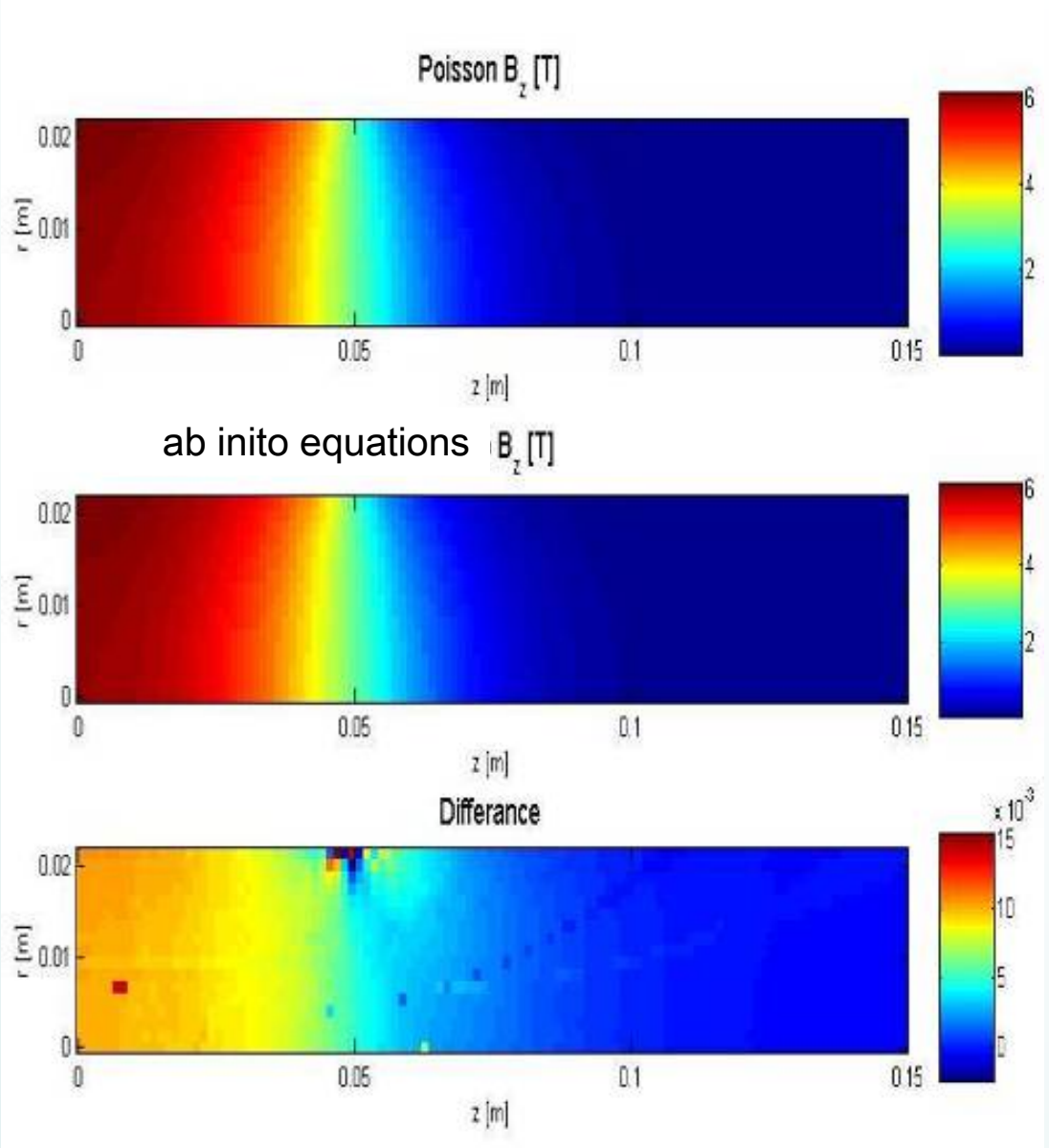
ACCEL

M. Pekeler LINAC 2006

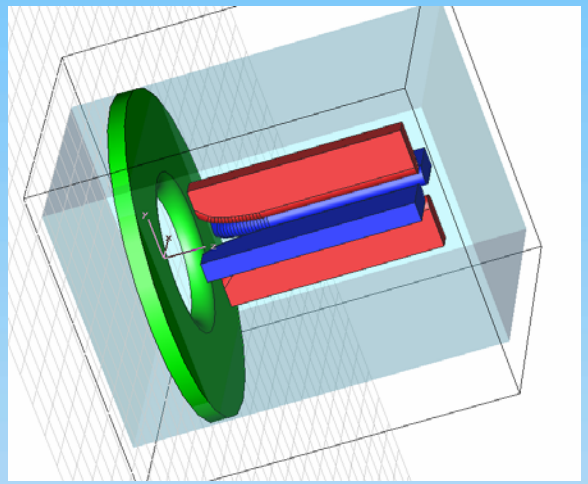
SC Solenoid – magnetic field calculation



The simulation uses 3D magnetic field calculation performed using ab-inito numerical integration of the vector of potential (good agreement with ACCEL cold test measurements).



Input particle distribution extracted from RFQ simulation, for linac lattice study



Calculated using the
RFQ geometry in
P. Fischer EPAC 2006

Lattice symmetry variations

symmetric

Comparison between symmetric and asymmetric presented in the EURISOL task meeting, CERN, November 2006

asymmetric

Lattice symmetry variations

symmetric

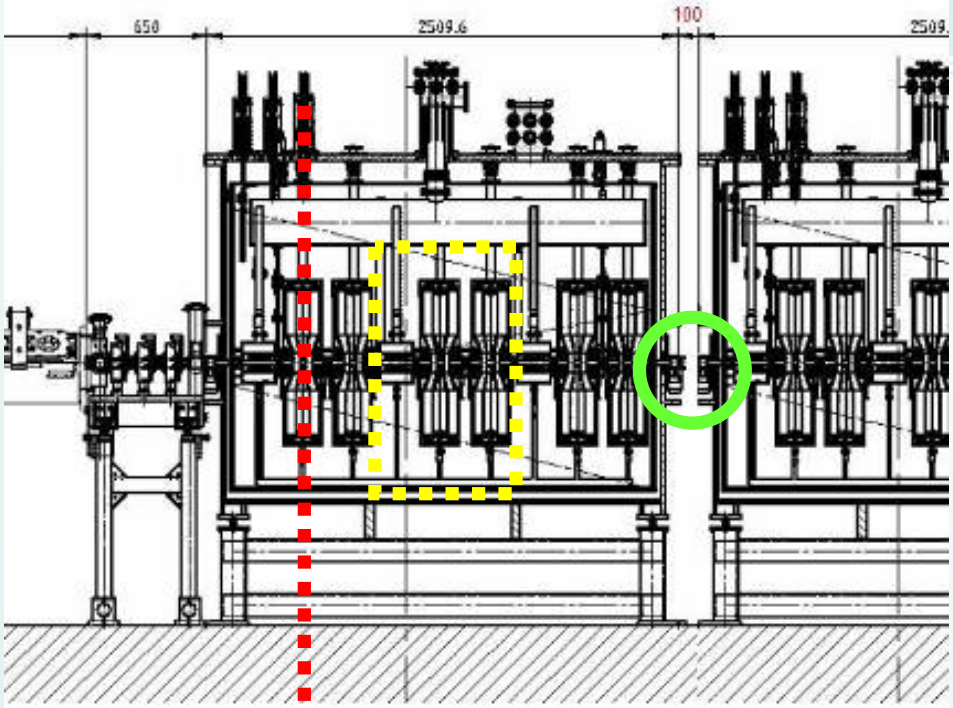
Comparison between symmetric and asymmetric presented in the EURISOL task meeting, CERN, November 2006

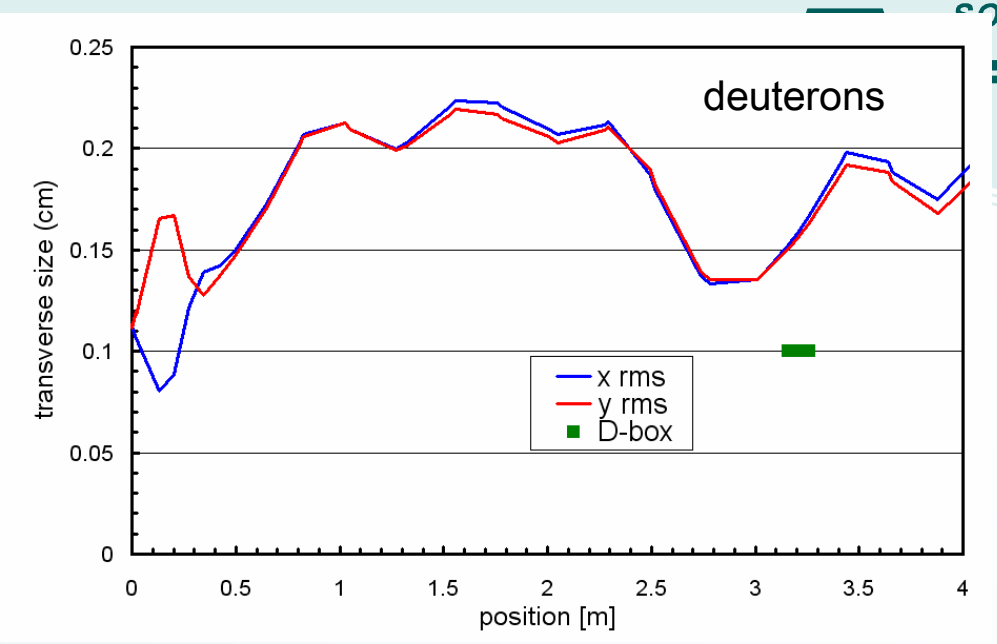
asymmetric

A new lattice combining the advantage of the asymmetric in bunching the initial beam and the advantage of the symmetric having diagnostics in beam waist

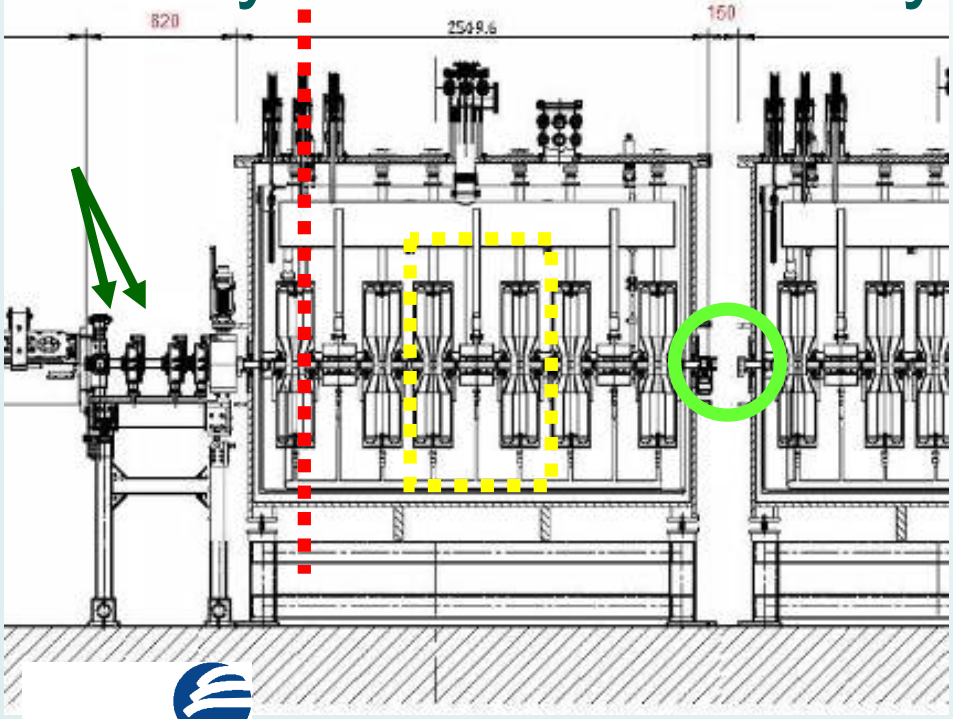
combined

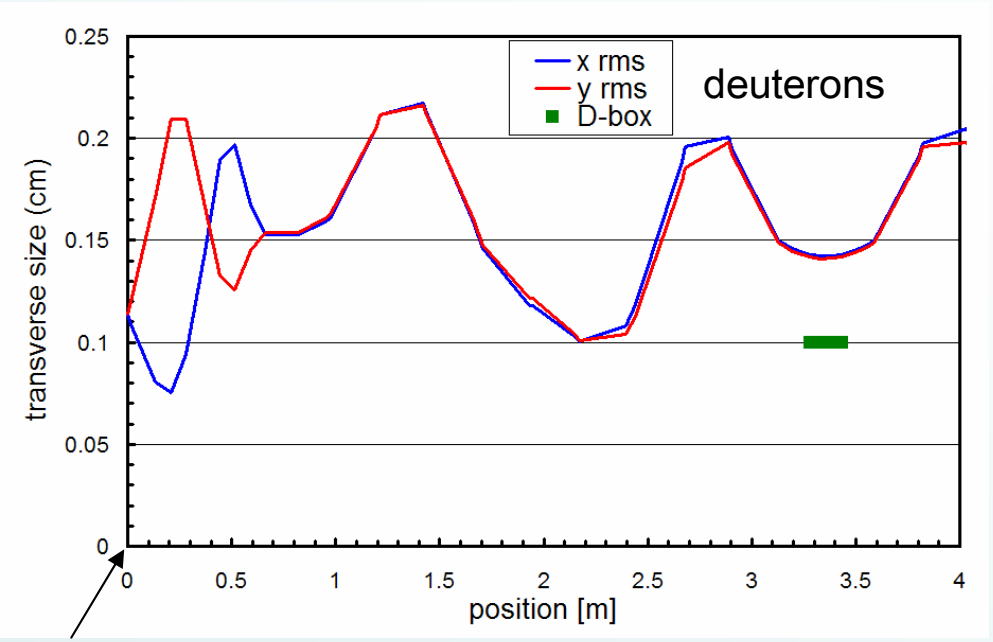
Simulated with the TRACK code, P. Ostroumov, ANL



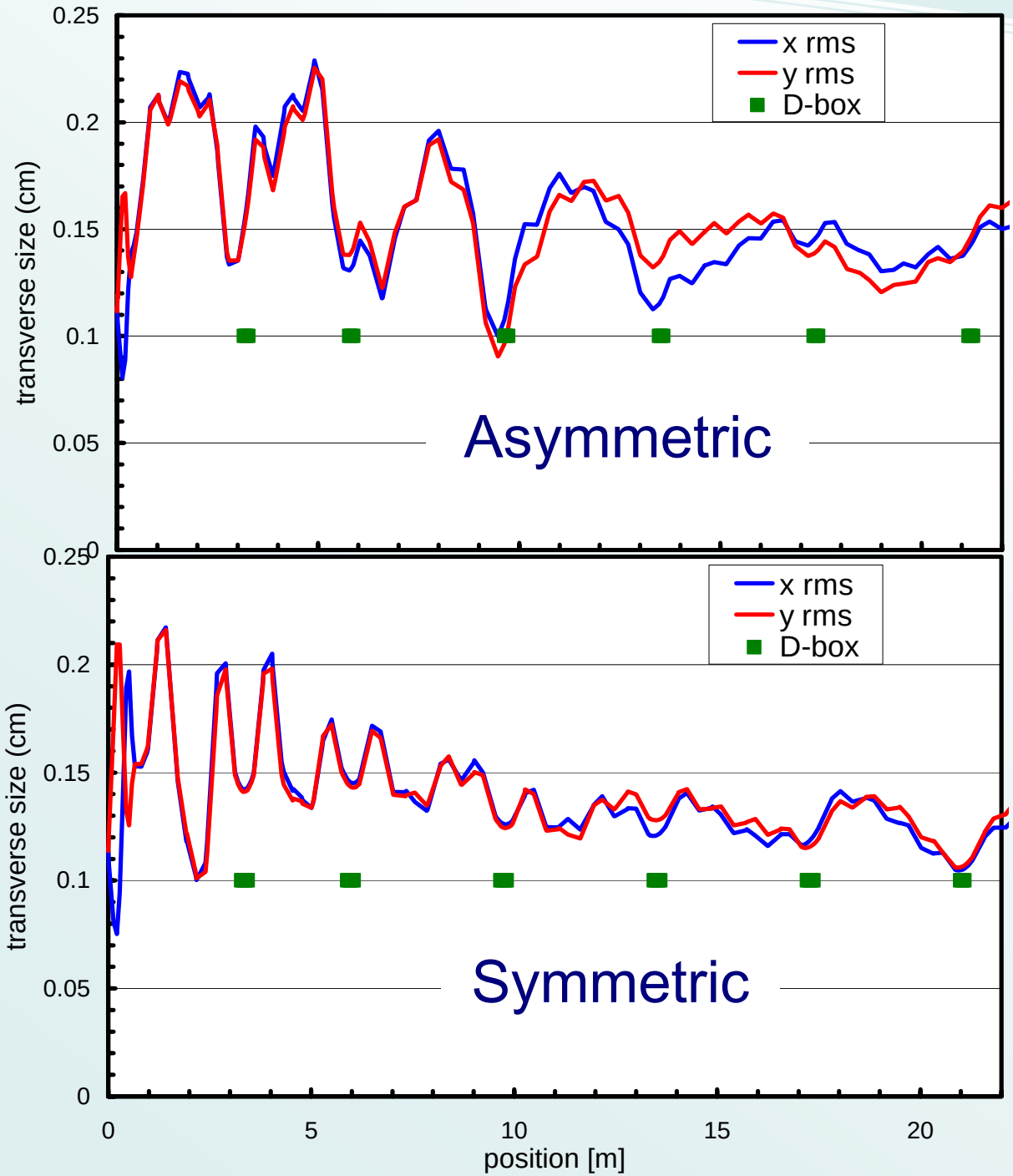


Symmetric versus Asymmetric lattice





RFQ exit



Diagnostic boxes / beam waist between modules

Symmetric lattice vs. Asymmetric lattice

- Extended MEBT space between quads 1&2
- Waist diagnostics
- Non HWR Vacuum trap
- Compact till first HWR 0.94 m
- Symmetric for transversal tune

- Fix space between the 3 quads
- Non waist diagnostics
- HWR Vacuum cold trap
- Larger Distance to HWR 1.07 m
- Non symmetric for transversal tune

SOREQ

Proton lattice comparison (excluding errors)

lattice	ε_{nx} growth (%)	ε_{ny} growth (%)	ε_{nz} growth (%)	Energy (MeV/u)
asymmetry				
symmetry	10	13	31	56.58
combined	8	3	19	58.75

Deuteron lattice comparison (excluding errors)

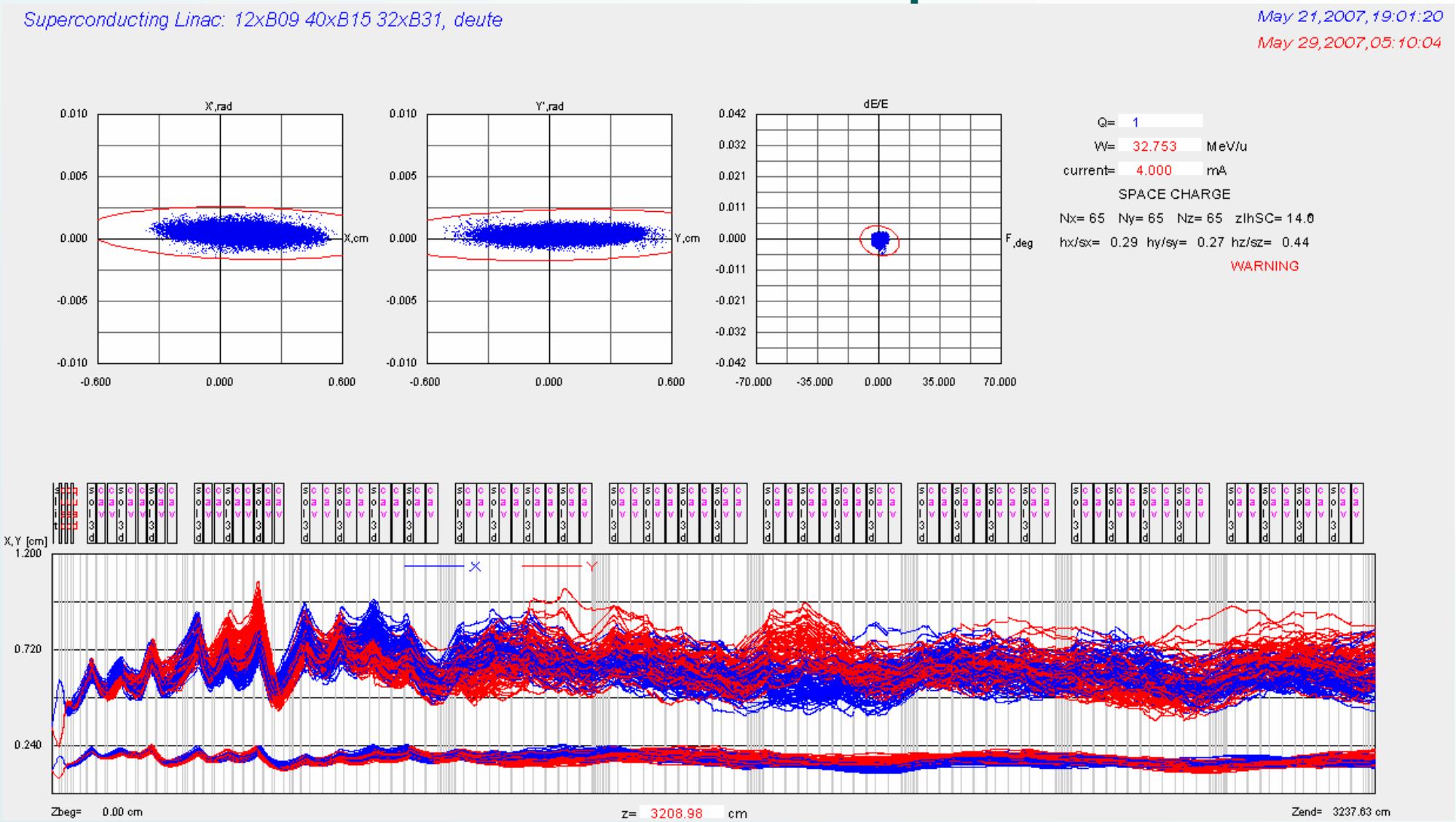
lattice	ε_{nx} growth (%)	ε_{ny} growth (%)	ε_{nz} growth (%)	Energy (MeV/u)
asymmetry	10	6	9	32.78
symmetry	10	10	18	32.48
combined	11	11	17	33.40

Fabrication, misalignment and operation errors

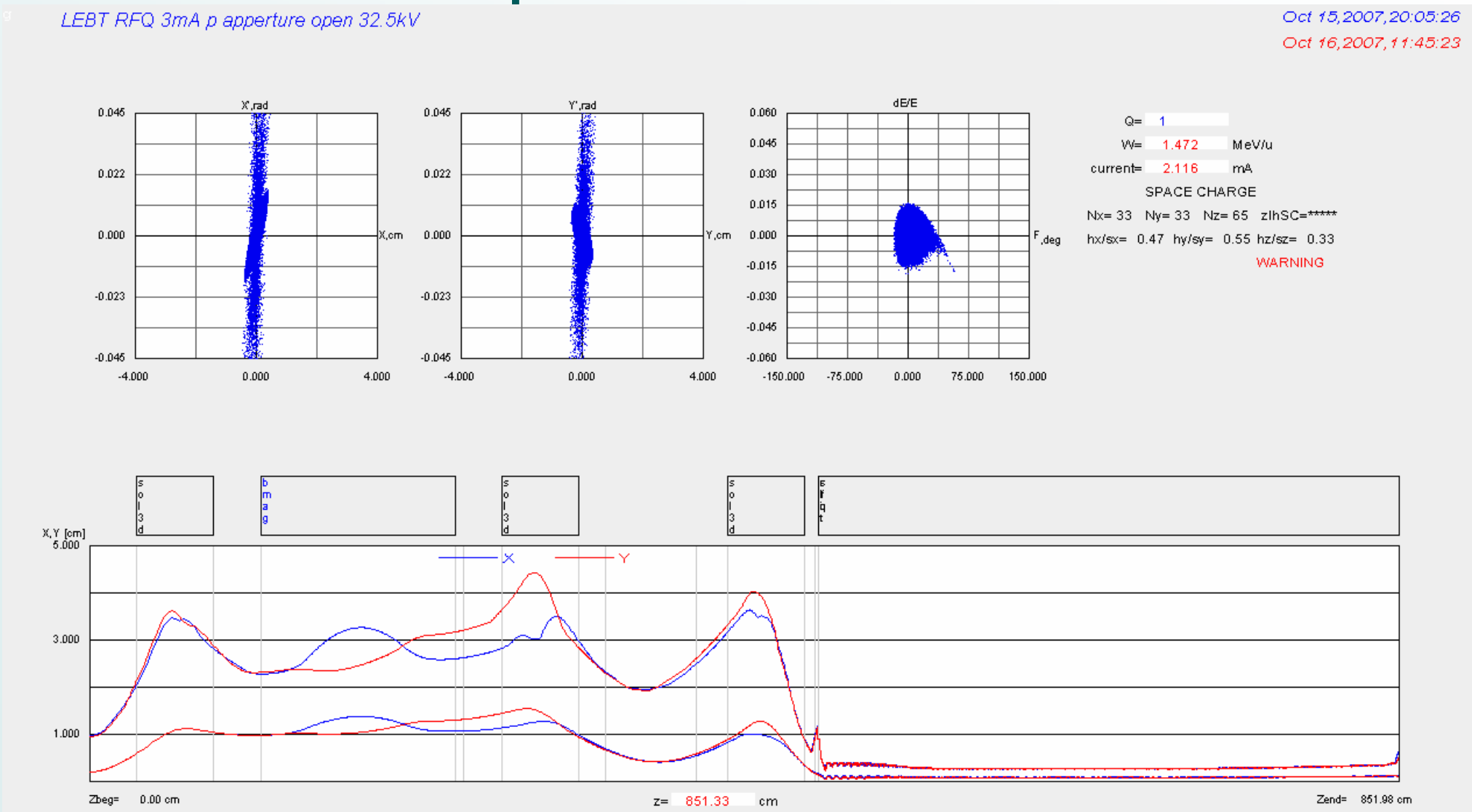
Error Type	Error range
Quadruples	
Misalignments [x,y,z] (mm)	[0.1, 0.1, 0.1]
Z rotation (mrad)	1.5
Field strength [static, dynamic] (%)	[1, 0.25]
HWR	(a half range at the 1th HWR)
Misalignments [x,y,z] (mm)	[0.2, 0.2, 0.2]
Z rotation (mrad)	3
Amplitude [static, dynamic] (%)	[1, 0.25]
Phase [static, dynamic] (deg)	[0.5, 0.125]
Solenoids	
Misalignments [x,y,z] (mm)	[0.1, 0.1, 0.1]
Field strength [static, dynamic] (%)	[1, 0.25]

M. Pekeler HPSL 2005. J. Rodnizki LINAC 2006

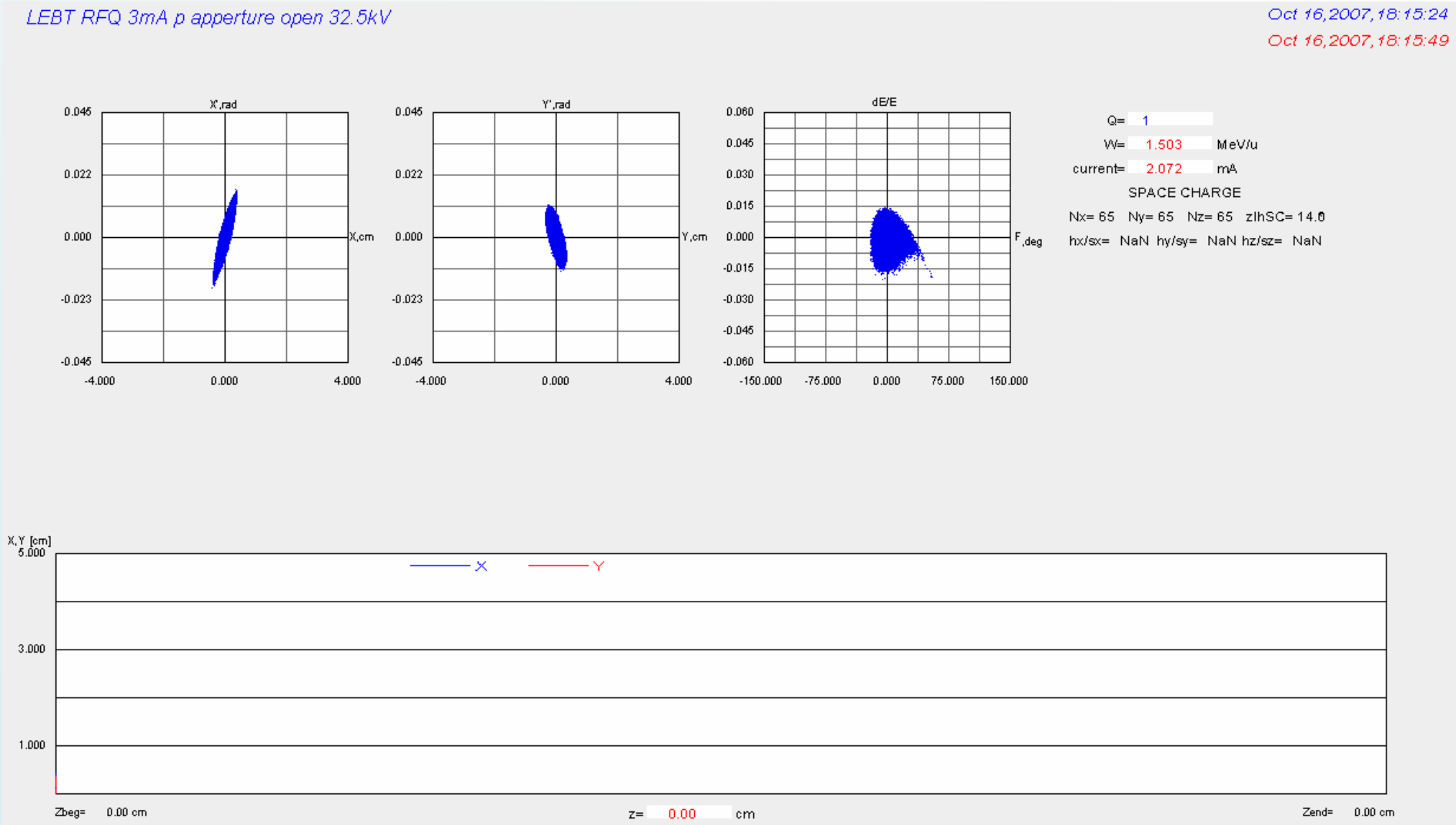
Asymmetry d 4mA 40k applying RFQ exit manufactured input



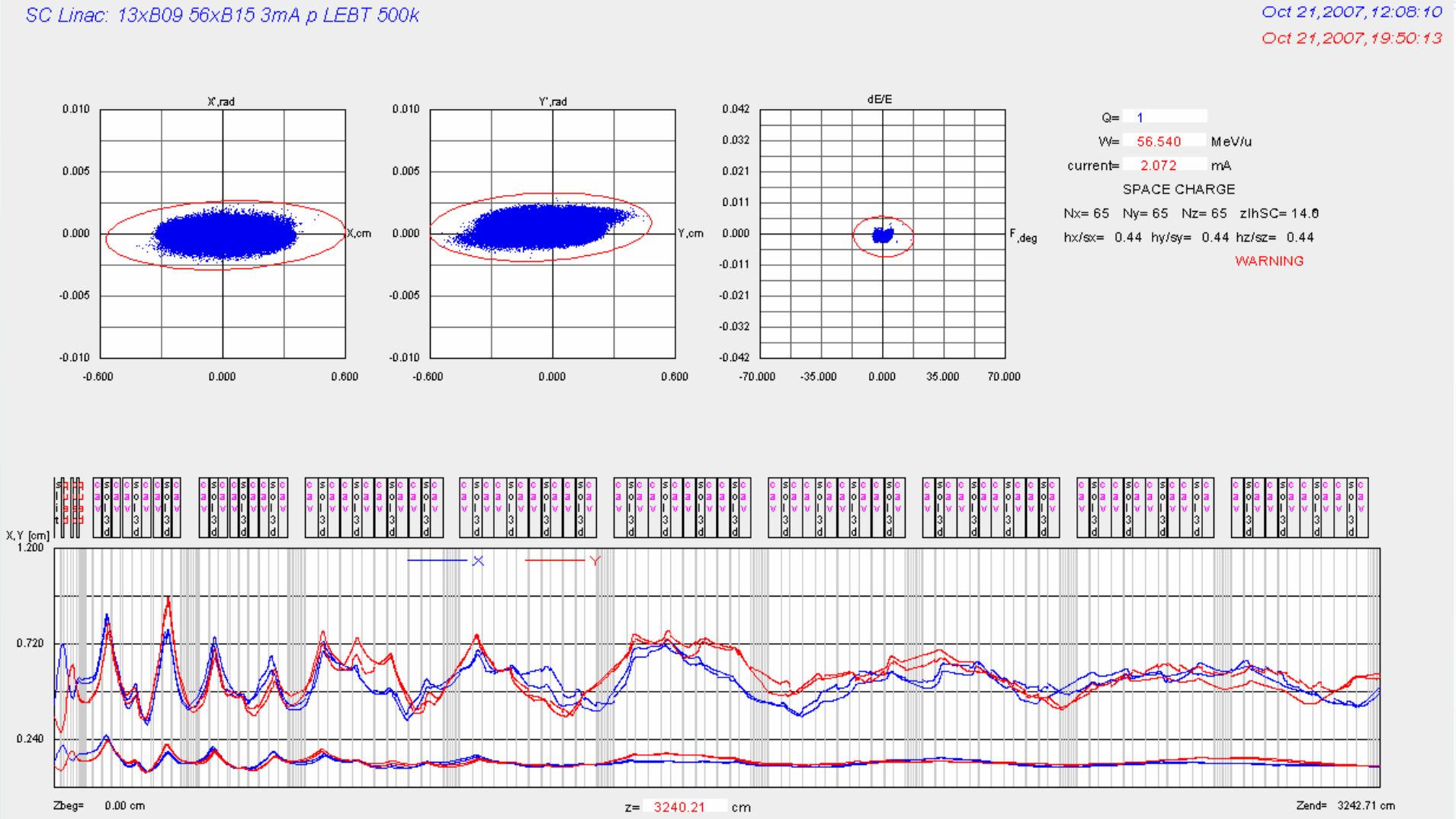
LEBT & RFQ p 2mA 500k



Cutting the low energy tail

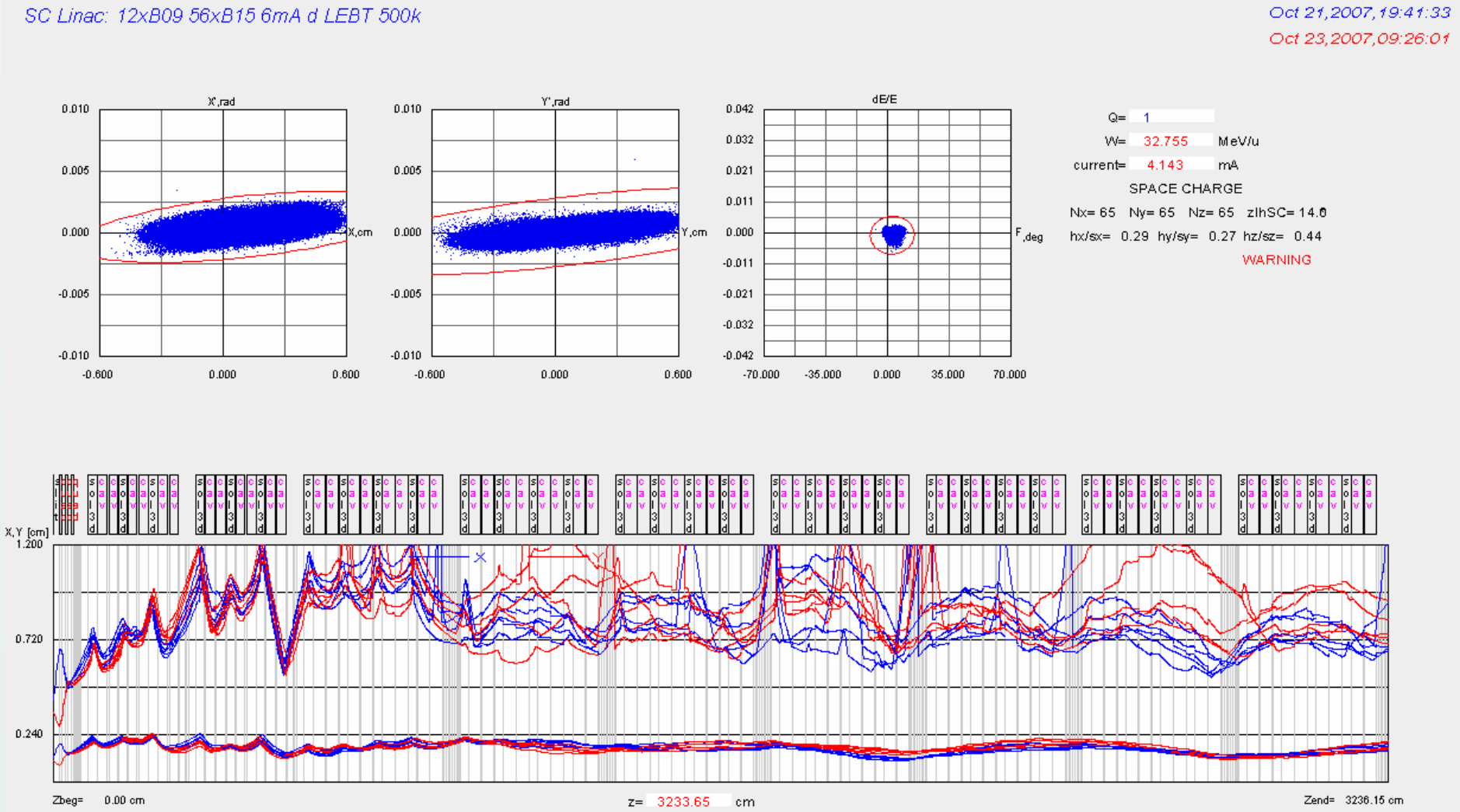


Symmetric lattice p 2mA 500k



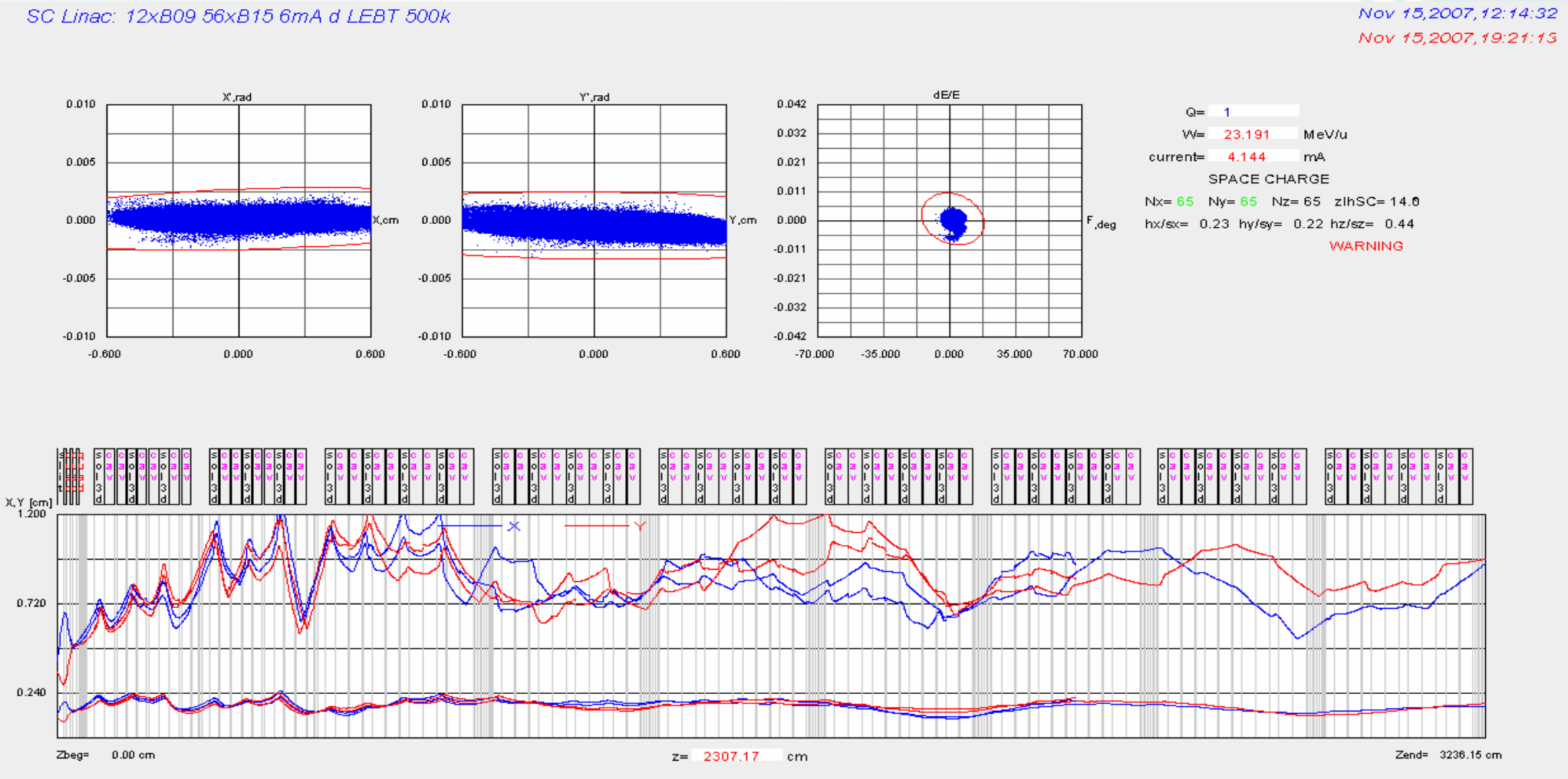
Use TRACK RFQ simulation as input for SC linac.
SC linac tuned with RFQ manufacturer 40k output.

Asymmetric lattice d 4 mA 500k



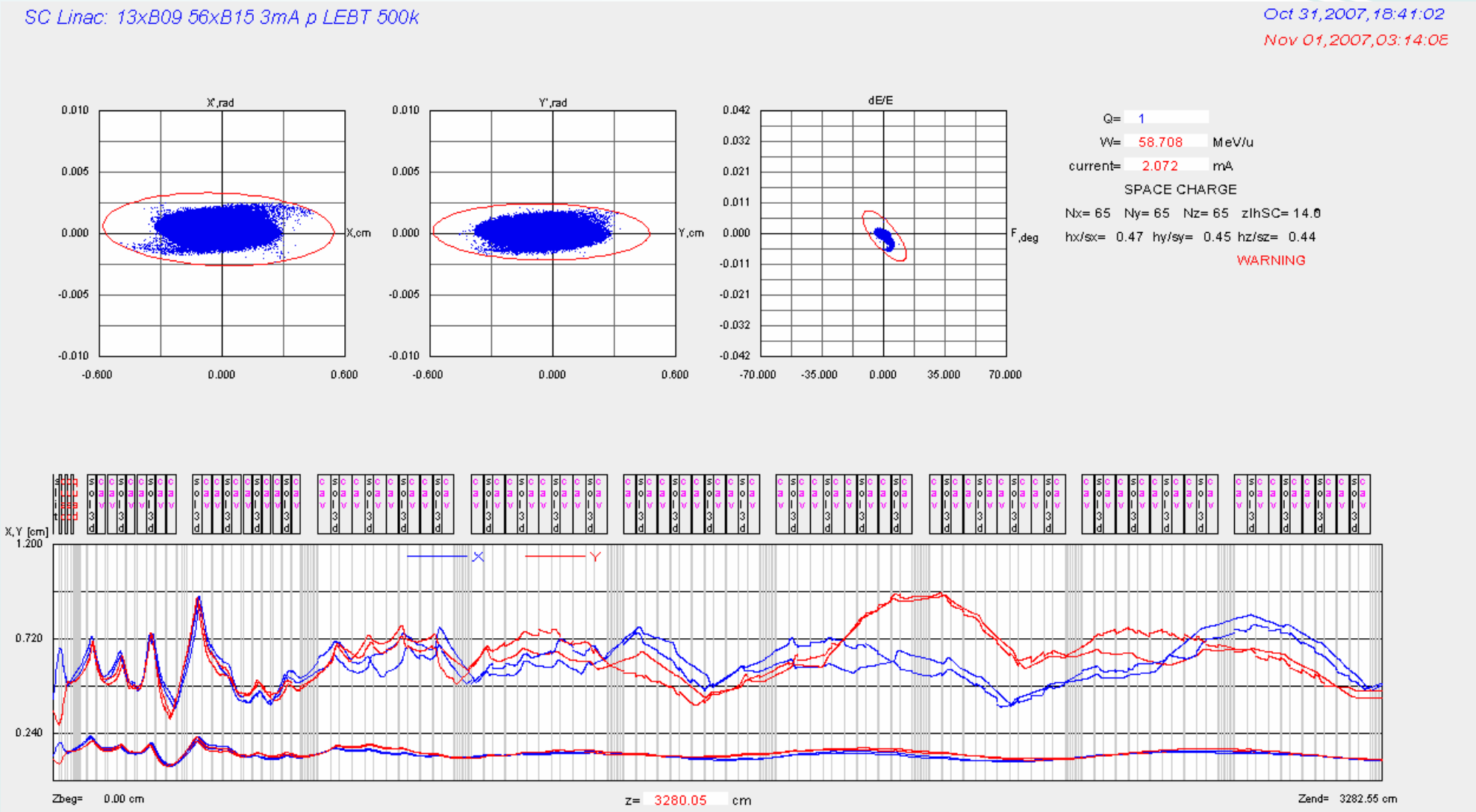
Use TRACK RFQ simulation as input for SC linac.
SC linac tuned with RFQ manufacturer 40k output.
Total beam loss per realization 30 nA (3 out of 500000).

Asymmetric 4 mA d 500k



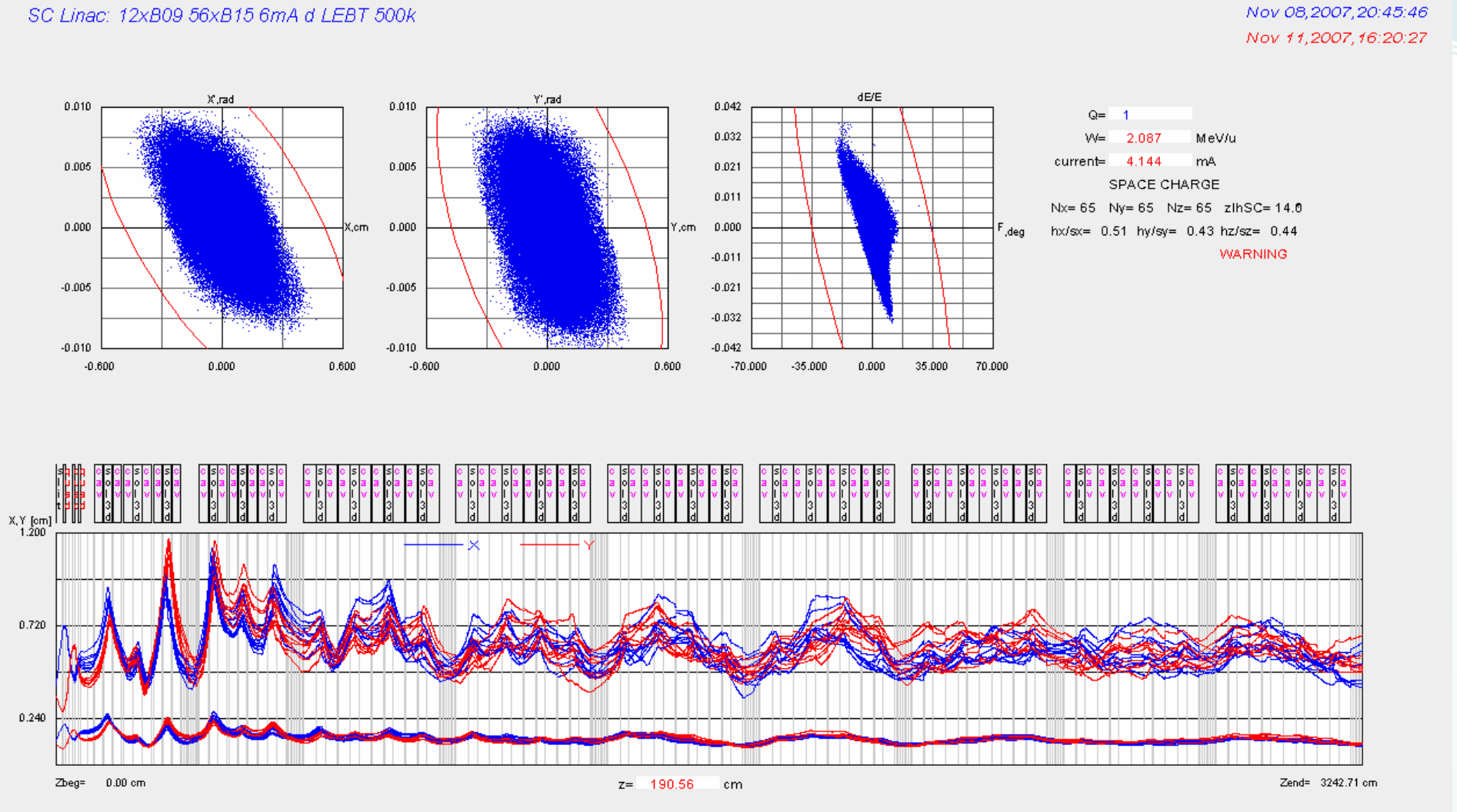
Use TRACK RFQ simulation as input for SC linac.
SC linac retuned with minor modifications.
No beam loss observed.

Combined lattice 2 mA p 500k



Use TRACK RFQ simulation as input for SC linac.
SC linac retuned with minor modifications.
No beam loss observed.

Symmetric lattice 4 mA d 500k



Use TRACK RFQ simulation as input for SC linac.
SC linac retuned with minor modifications.
No beam loss observed.

Collaboration

- Btzalel Bazak
- Dan Berkovits
- Gitai Feinberg
- Israel Hod
- Ran Rubin
- Asher Shor
- Yariv Yanay

- ACCEL
- Alberto Facco
- Peter Ostroumov

Related topics

- J. Rodnizki HB2006, LINAC06
- http://www.eurisol.org/site01/tasks_details.php

End