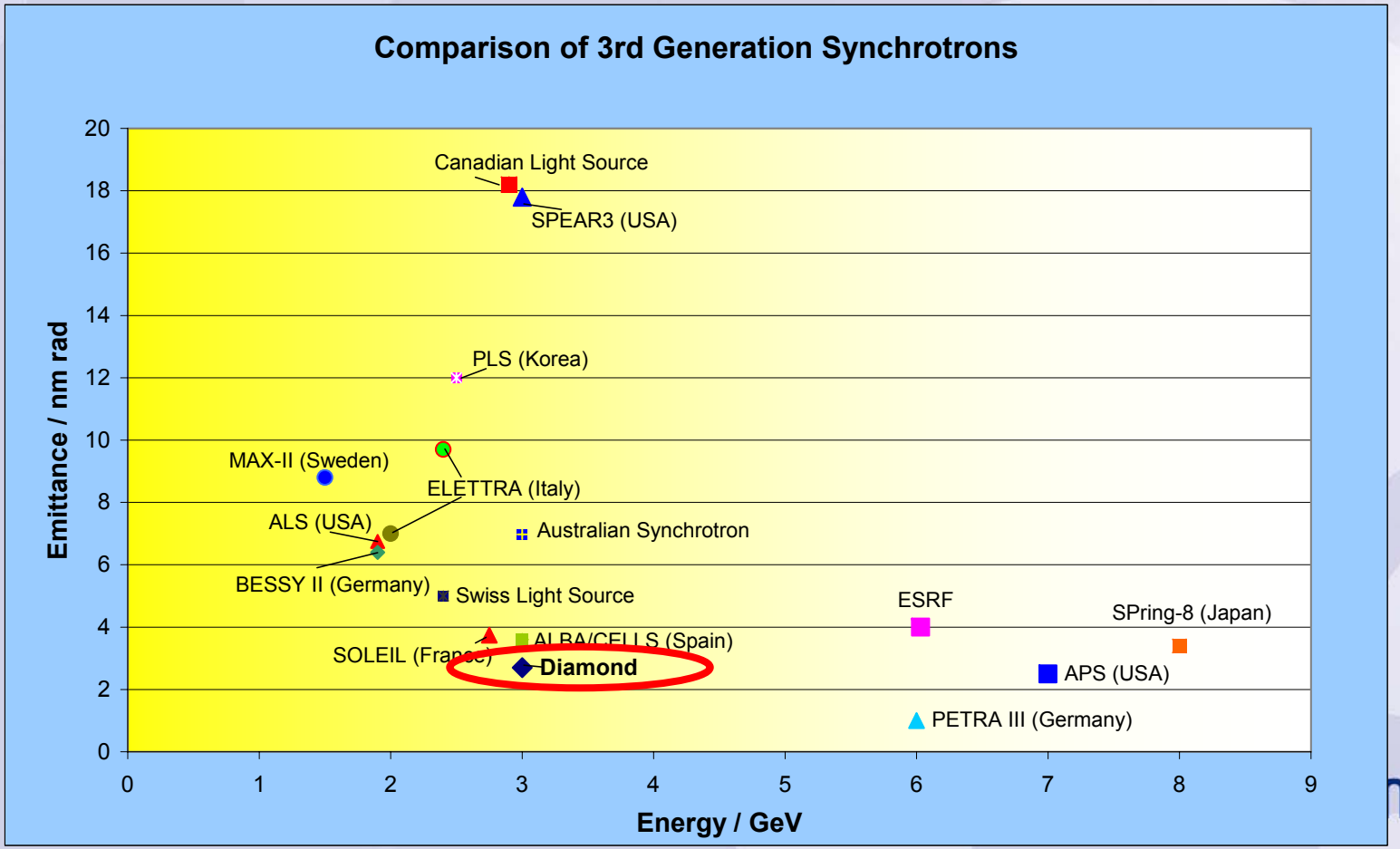
Diamond Light Source: Overview and Status

Richard P. Walker
on behalf of the Diamond Machine Project Team

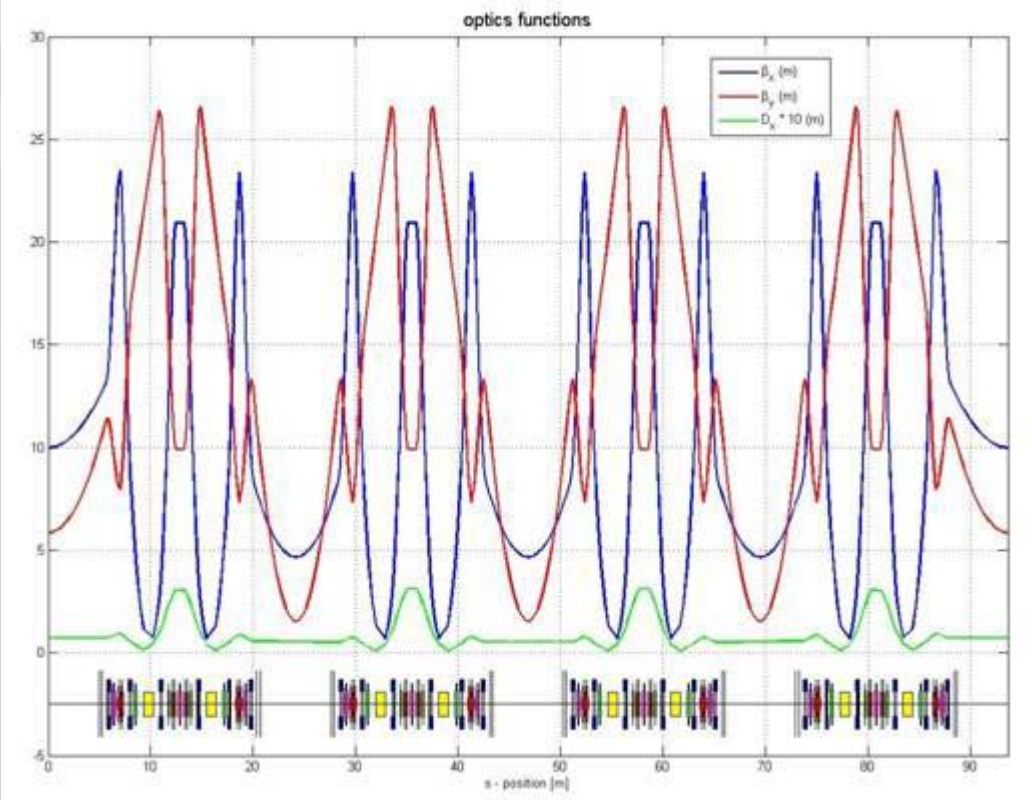
1. Introduction
2. Machine description
3. Commissioning
4. Status and future plan

Diamond is a new Medium Energy, 3rd Generation Light Source, to replace the SRS – the world's first purpose built high energy synchrotron radiation source (now 25 years old)

The largest accelerator project, and the largest scientific investment in the UK for over 30 years.



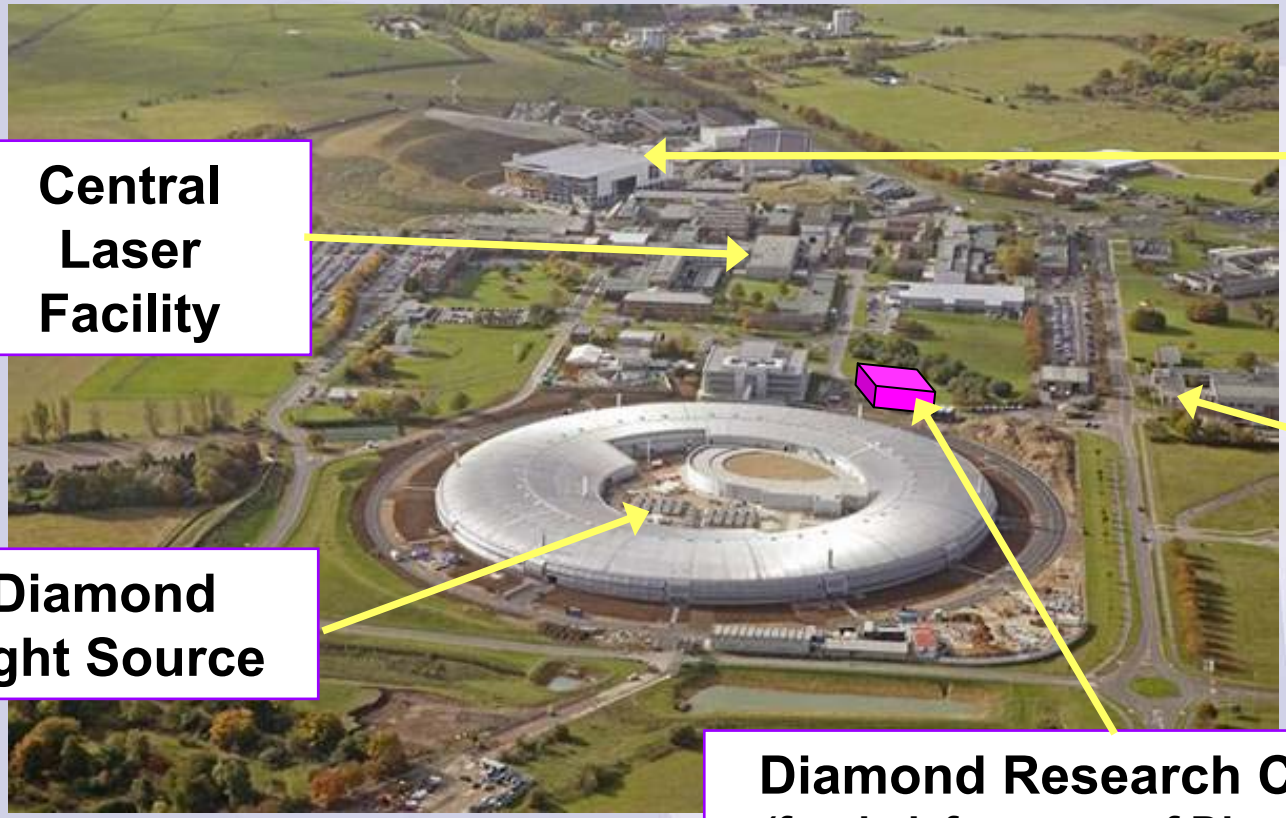
Diamond – Main Parameters



nominal, non-zero dispersion lattice

Energy	**3 GeV**
Circumference	**561.6 m**
No. cells	**24**
Symmetry	**6**
Straight sections	**6 x 8m, 18 x 5m**
Insertion devices	**4 x 8m, 18 x 5m**
Beam current	**300 mA (500 mA)**
Emittance (h, v)	**2.7, 0.03 nm rad**
Lifetime	**> 10 h**
Min. ID gap	**7 mm (5 mm)**
Beam size (h, v)	**80, 8 μm**
Beam divergence (h, v) *(at centre of 5 m ID)*	**35, 3 μrad**

Located at the Rutherford Appleton Laboratory, on the Harwell Science and Innovation Campus:



Central Laser Facility

ISIS
(Spallation Neutron Source)

Hostel
(open Sep. '06)

Diamond Light Source

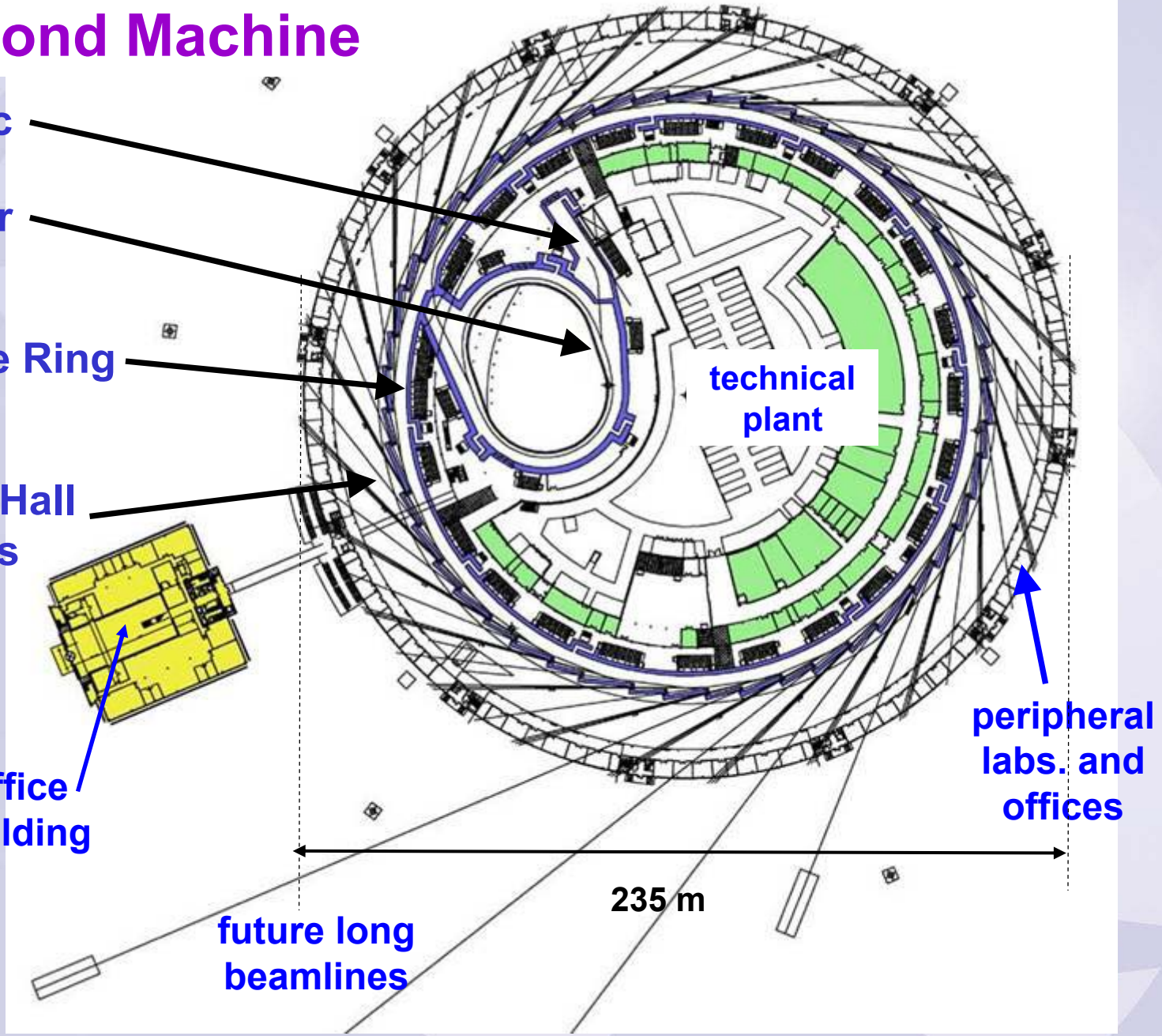
Diamond Research Complex
(funded, for users of Diamond, ISIS and CLF)

diamond

Diamond Project Evolution

1993	Woolfson Review: SRS to be replaced by a new medium energy machine
1997	Feasibility Study ("Red Book") published 3 GeV, 16 cells, 345 m circumference, 14 nm rads
1998	Wellcome Trust joins as partner
Mar. '00	Decision to build Diamond at Rutherford Appleton Lab.
Oct. '00	3 GeV, 24 cells, 560 m circumference design approved
Apr. '02	Joint Venture Agreement signed (UK Govt./WellcomeTrust) Diamond Light Source Ltd. established Design Specification Report ("Green Book") completed by CCLRC
Jan. '07	Start of Operations

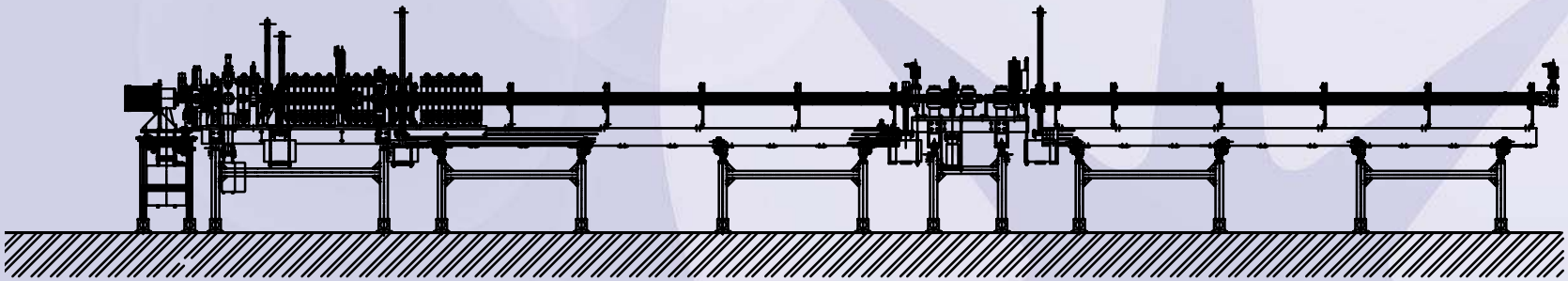
The Diamond Machine



Linac

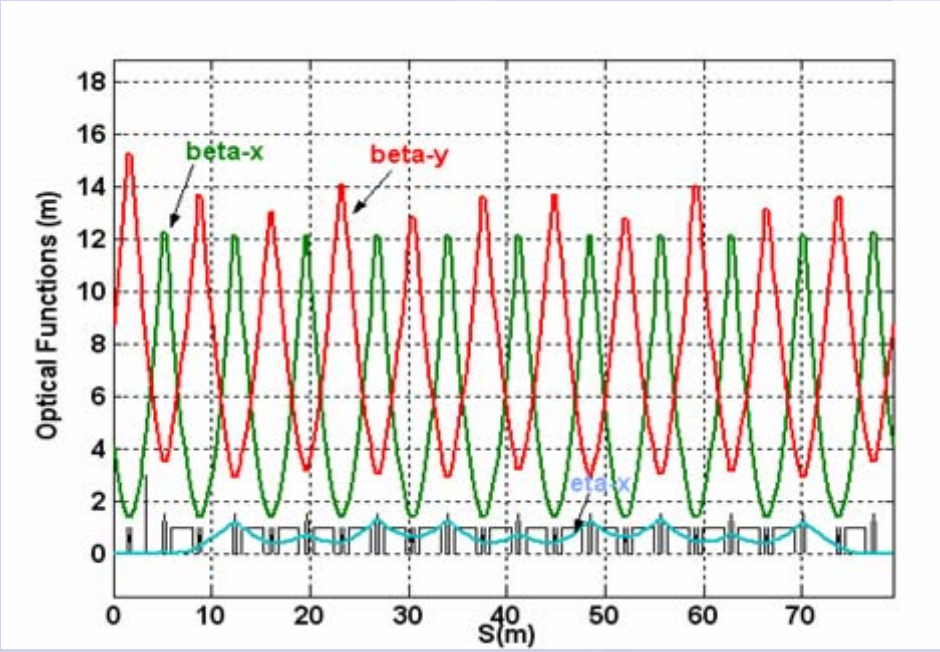
- 100 MeV Linac of the DESY S-band Linear Collider Type II design, supplied "turn-key" by Accel Instruments.

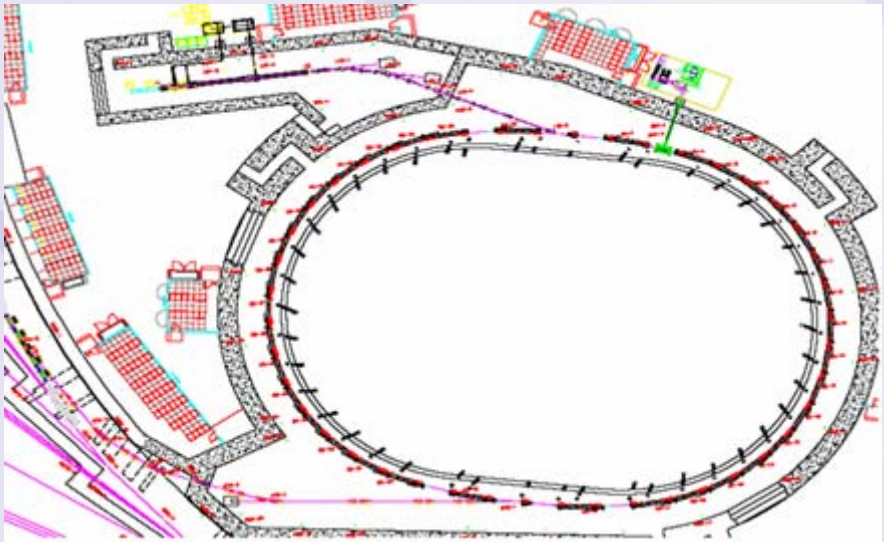
  (DLS supplied diagnostics, vacuum and control system components, and beam analysis software)
- thermionic gun; short (< 1 ns) and long pulse (0.1-1 μs) modes
- 500 MHz sub-harmonic pre-buncher, 3 GHz primary buncher, 3 GHz final buncher
- two 5.2 m constant gradient accelerating sections fed by independent klystrons



Booster

Energy	3 GeV
Circumference	158.4 m
Emittance	141 nm rad
Repetition rate	5 Hz
Lattice	FODO, missing dipole

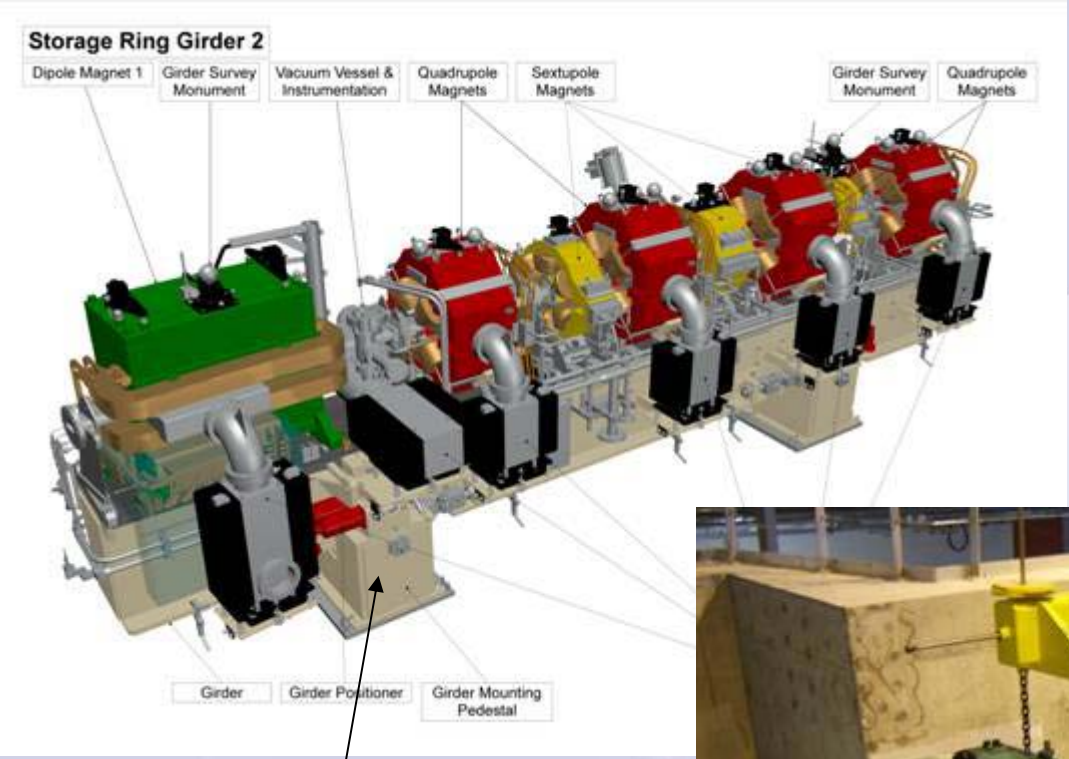




Storage Ring

diamond

Girders



Magnets and vacuum chambers mounted and pre-aligned on precisely machined girders, 3 per cell

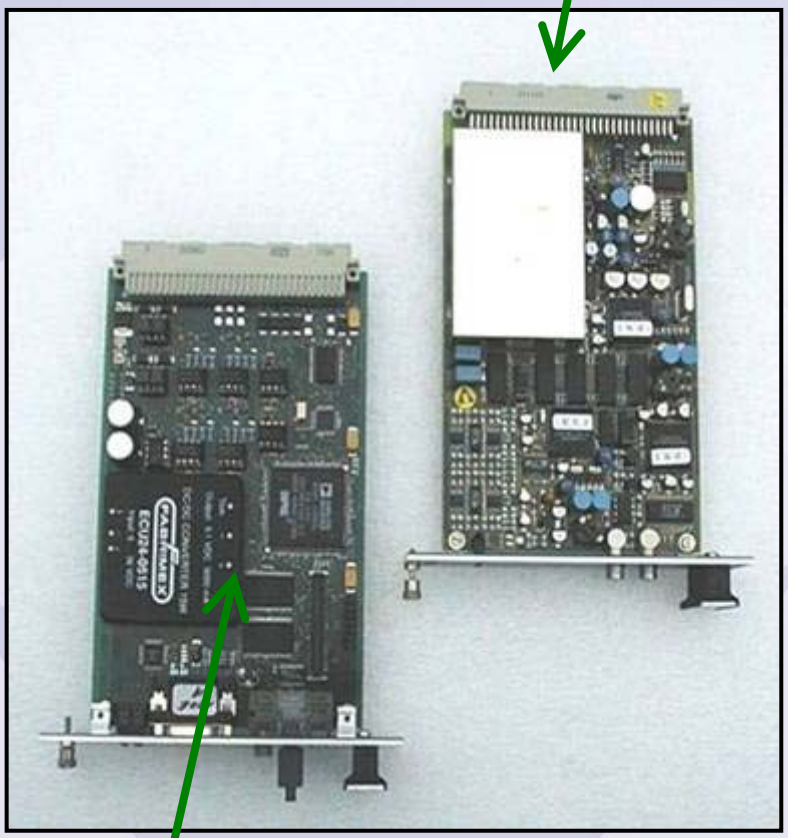
Up to 6 m long and 17 T in weight.

mover system allows remote alignment possibility

Power Supplies

Standardisation
- minimum no. of different types
- all 1038 power supplies use the same (PSI type) digital controller and ADC cards.

Maintainability and Reliability
- plug-in modules
- reduced component count
- redundancy of 24 V control power and power modules



RF System

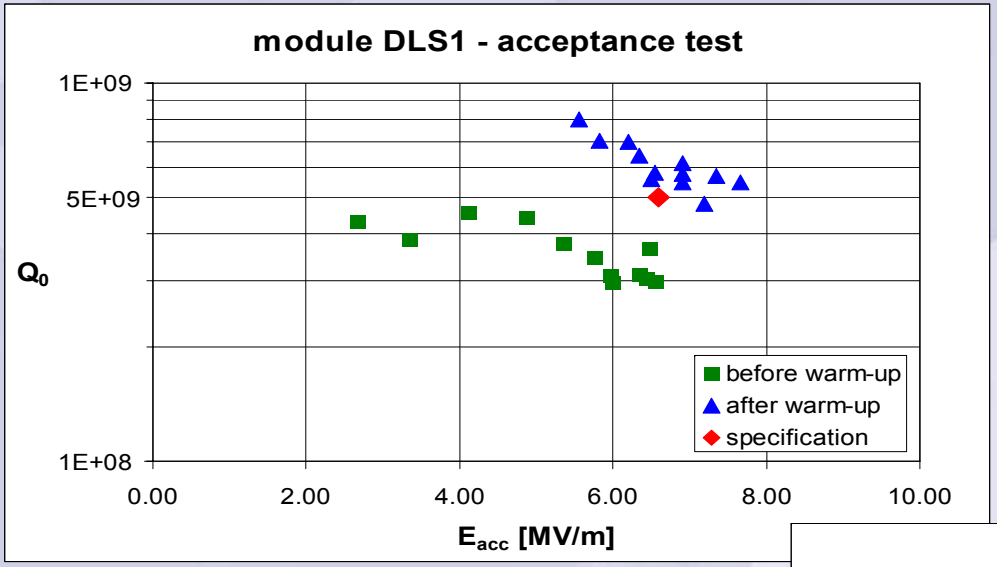
Supercon-ducting cavities (2)

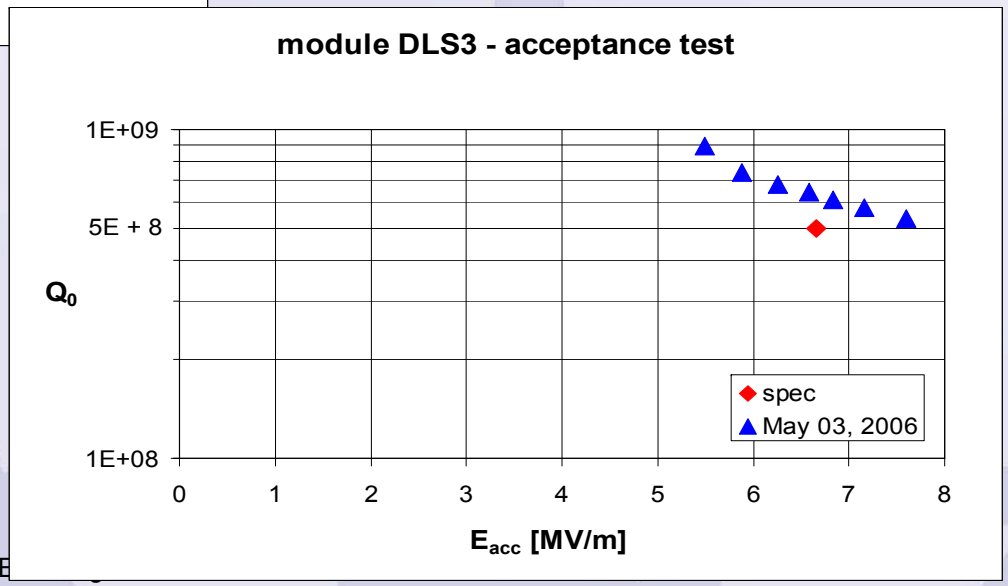
IOT-based 300 kW amplifiers

Liquid He plant

diamond

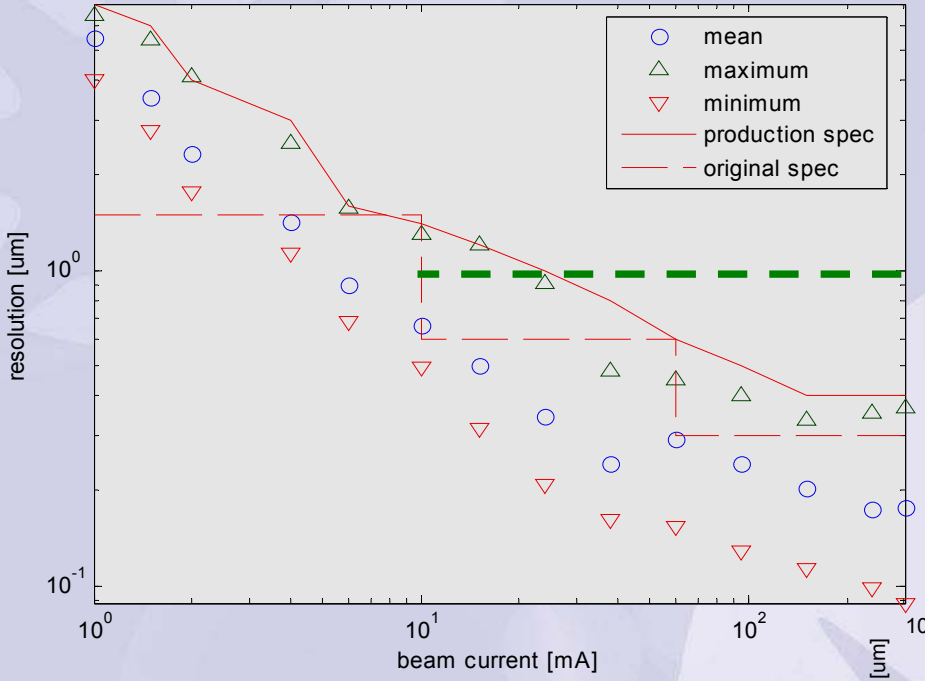
Both cavities conditioned above the nominal 2 MV accelerating voltage, meeting the specified Qo:





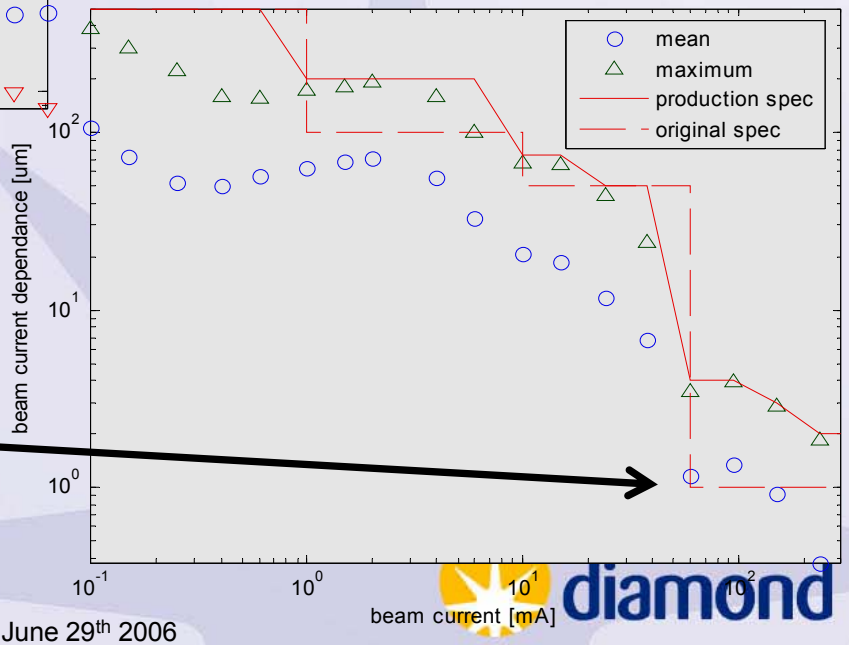
Digital Beam Position Monitor Electronics

(Libera, integrated in EPICS)



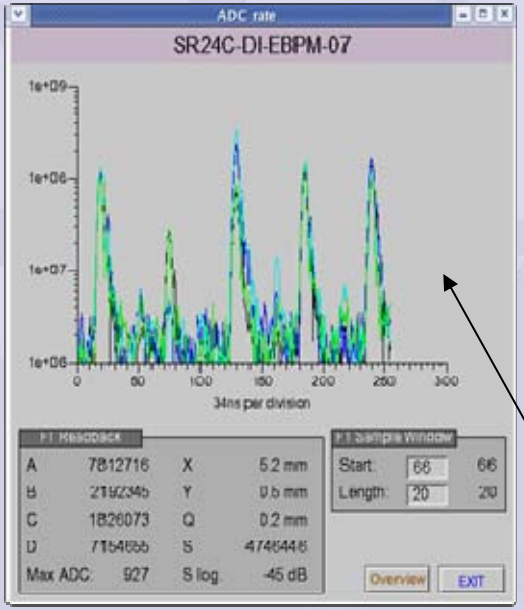
Resolution in 2 kHz Bandwidth:
<1 μm at >10 mA

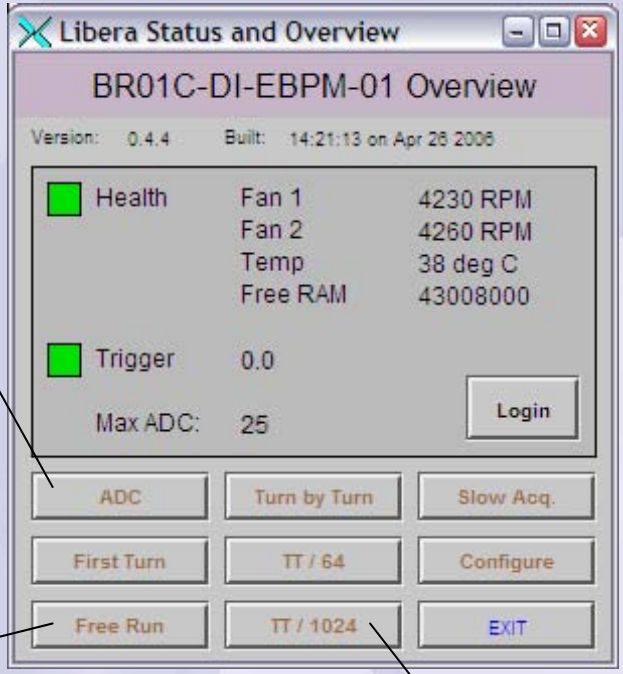
Turn-by-turn (1 MHz b.w.):
~ 100 μm at 1 mA

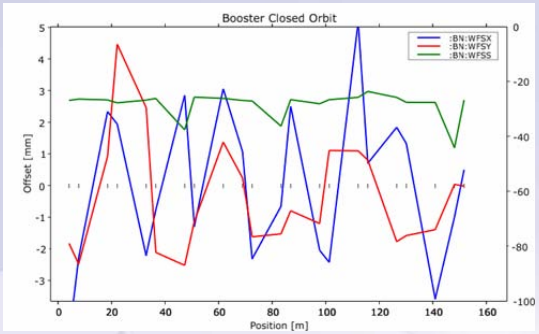


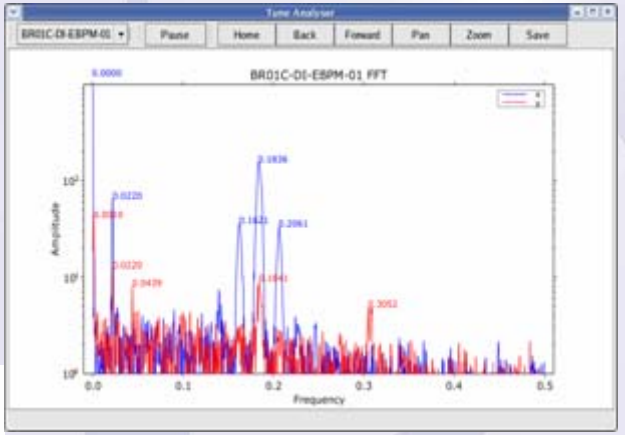
Beam Current Dependence
< 1 μm at 60-300 mA

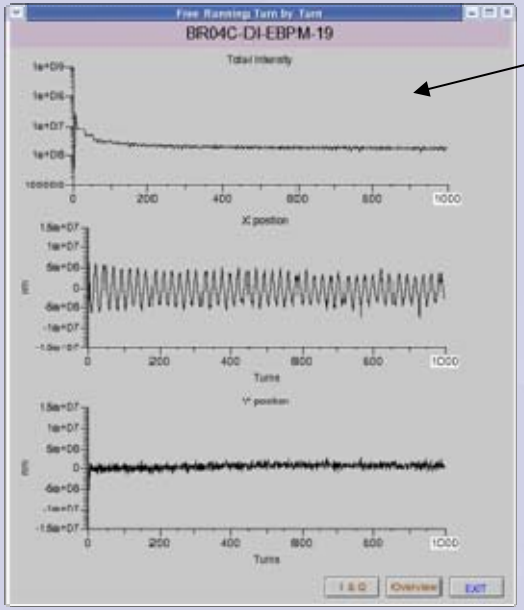
provides many different data streams, simultaneously

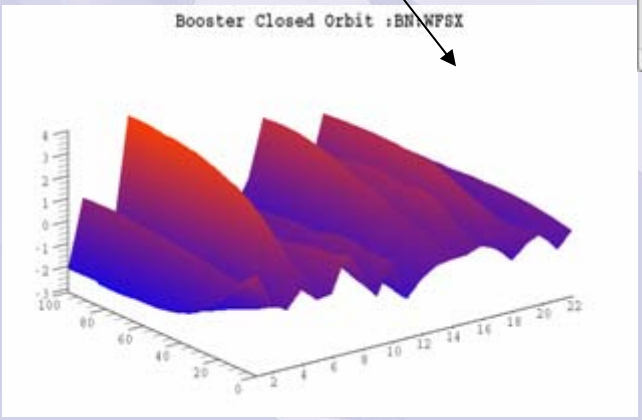


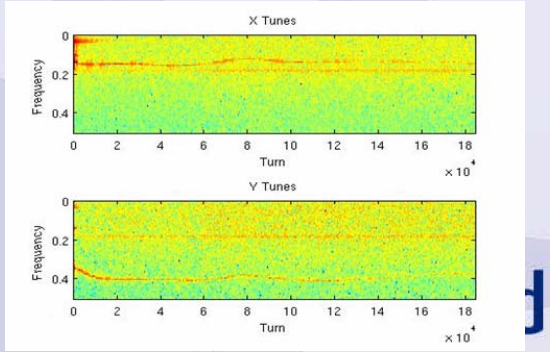










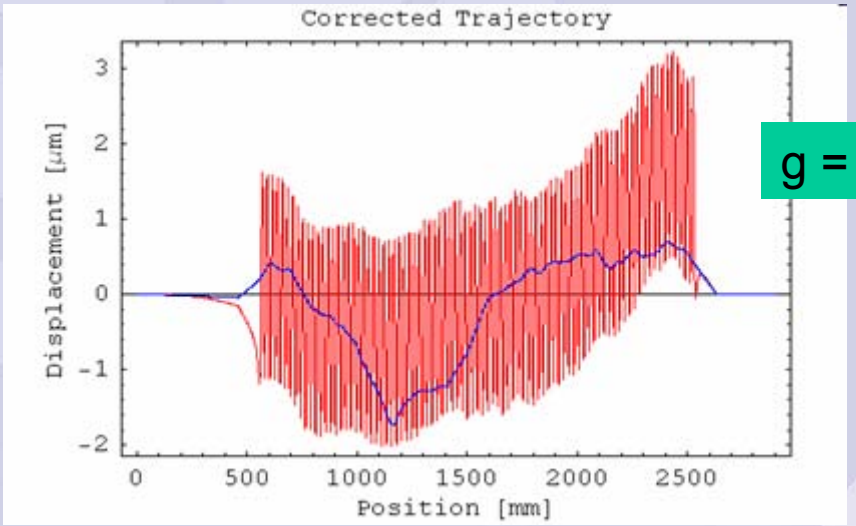


Phase I Insertion Devices

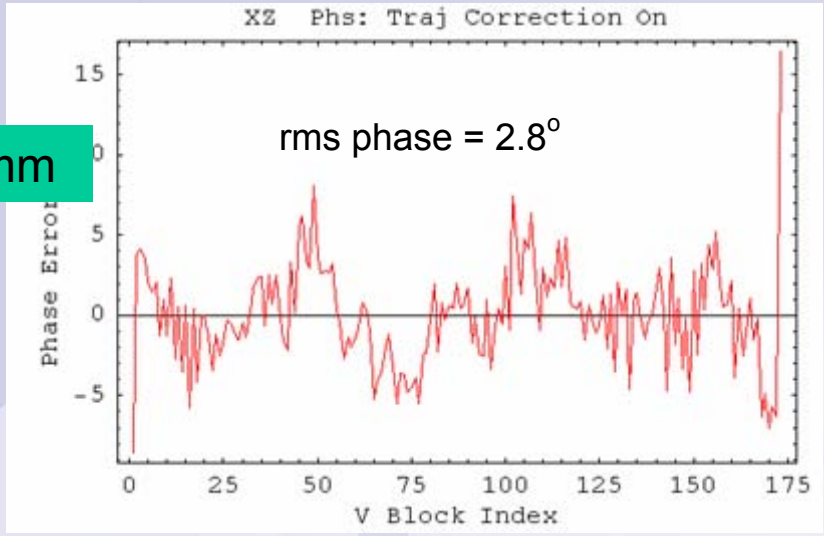
Beam -line	ID	Type	Status
I02	U23	In-vacuum	ready for vacuum assembly
I03	U21	In-vacuum	under bake-out
I04	U23	In-vacuum	**installed**
I06	HU64	APPLE-II	ready for installation
I15	SCW	Superconducting Multipole Wiggler	**installed**
I16	U27	In-vacuum	ready for vacuum assembly
I18	U27	In-vacuum	under assembly

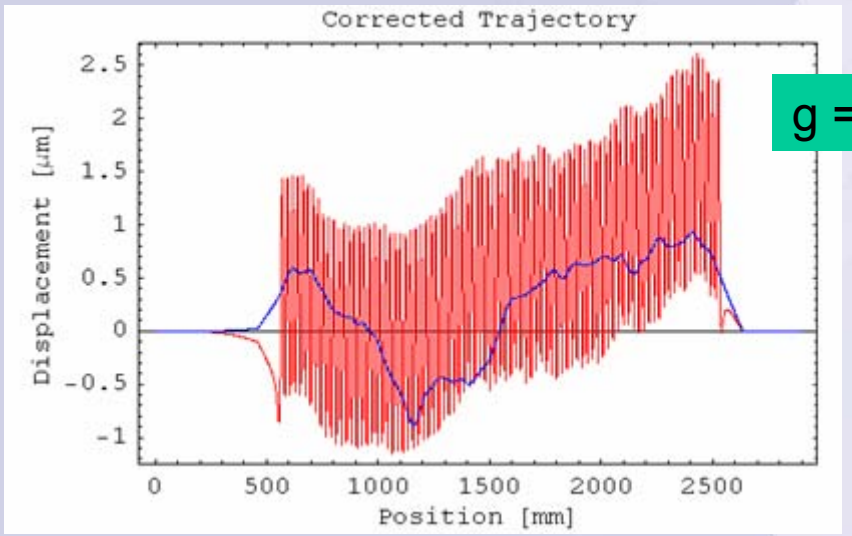
diamond

U23 trajectory and phase errors

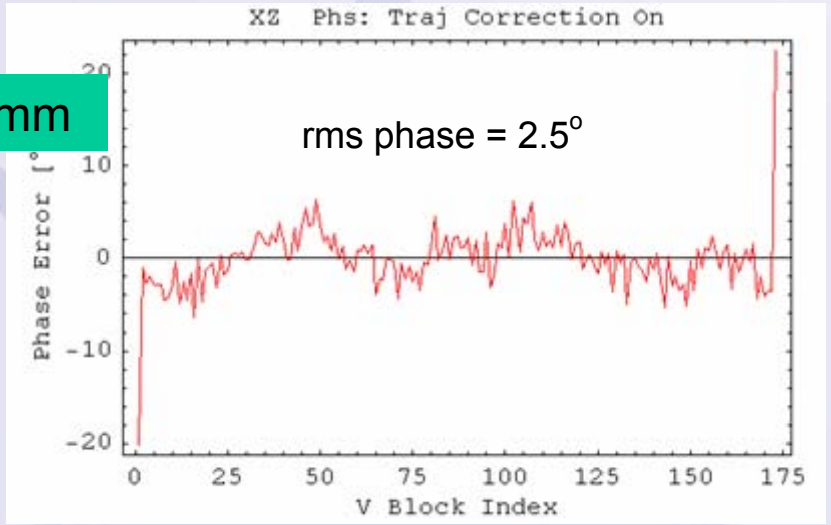


g = 5 mm

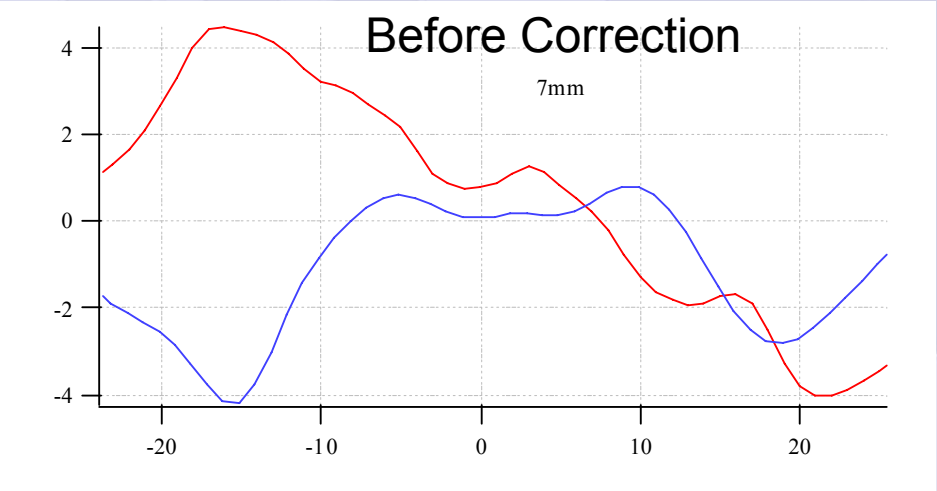


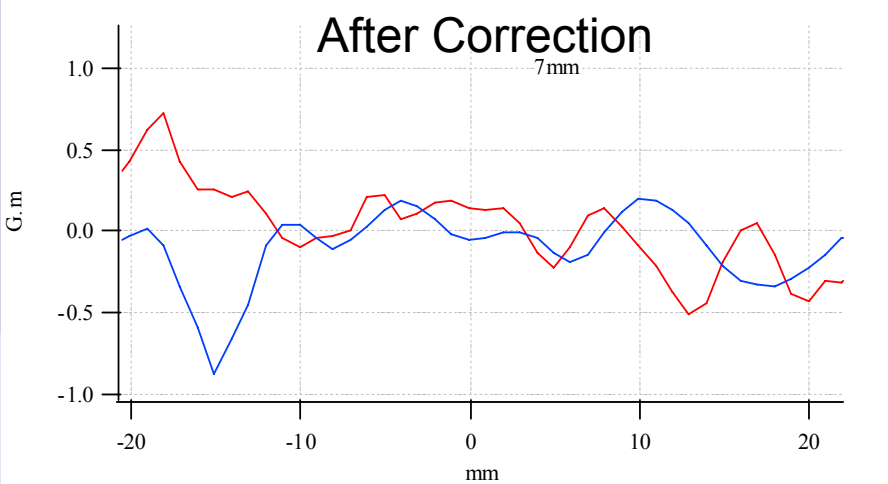


g = 7 mm



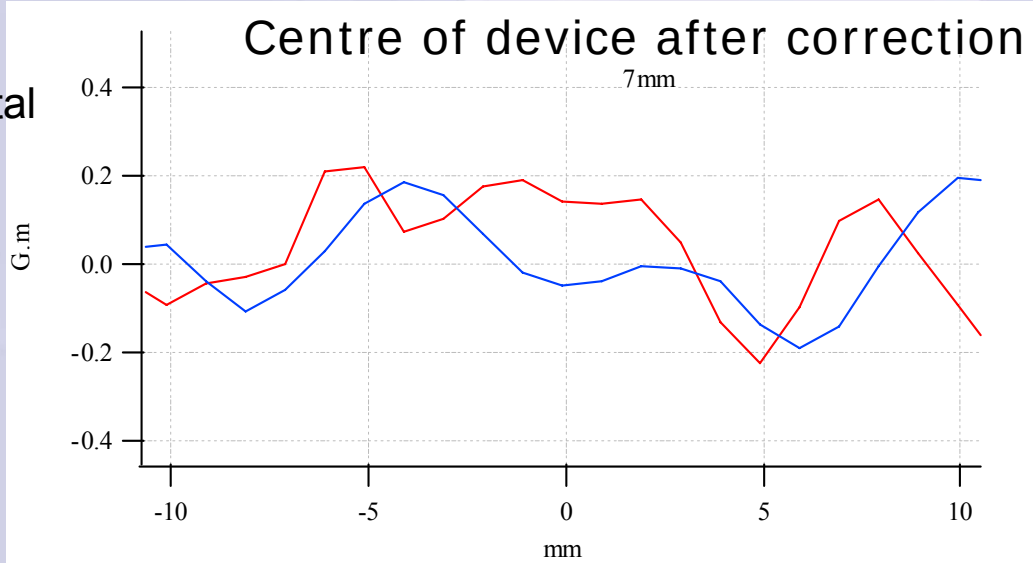
U23 field Integrals





Vertical

Horizontal

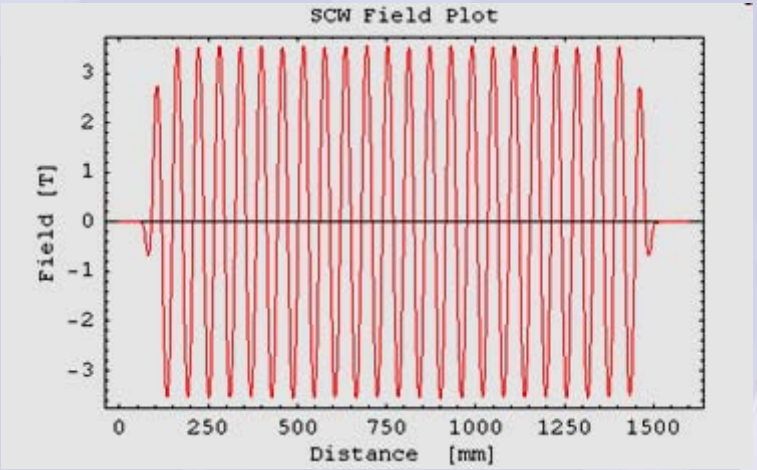


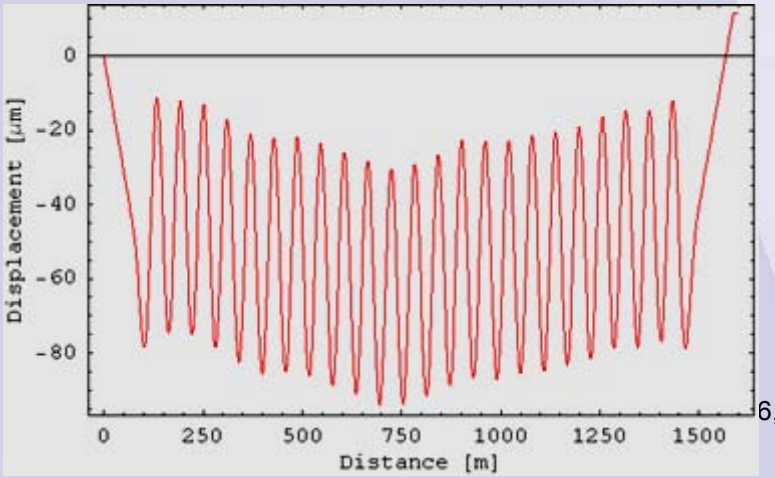
Richard P. Walker

diamond

Superconducting Wiggler

Field	**3.5 T**
Period	**60 mm**
No. full poles	**45**
Vertical aperture	**10 mm**

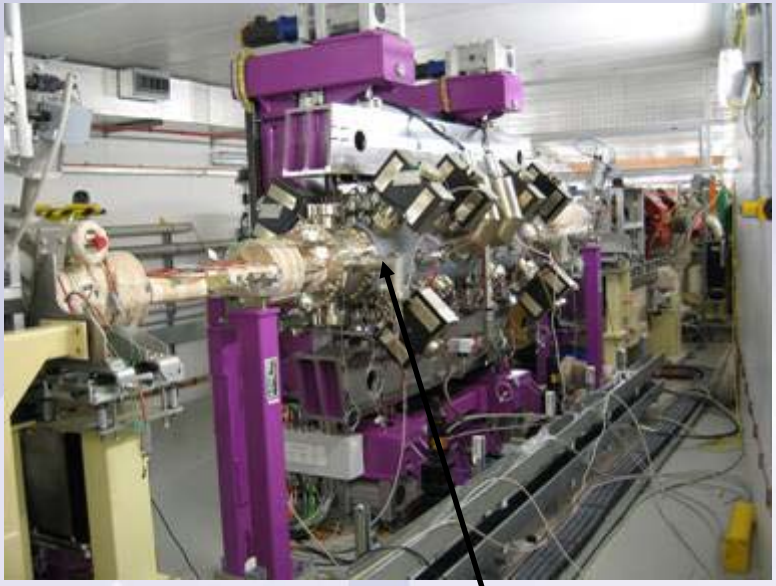




SCW under test on the experimental hall floor

ID Installation Status

5m long narrow gap vessel for APPLEII undulator



in-vacuum undulator

superconducting wiggler

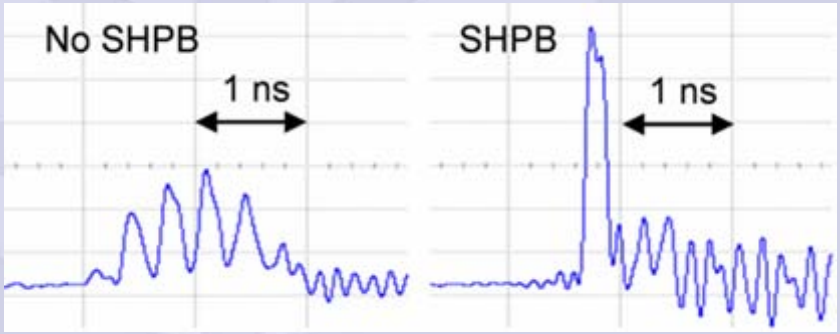
diamond

Machine Commissioning: Linac

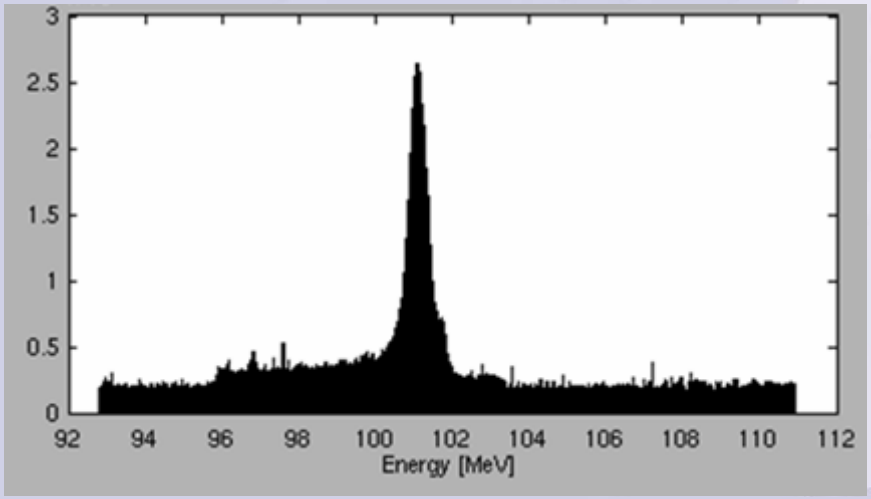
Installation complete:	**Aug. 3rd 2005**
1st beam from gun:	**Aug. 31st 2005**
1st 100 MeV beam:	**Sep. 7th 2005**
Acceptance test complete:	**mid-Oct. 2005**

diamond

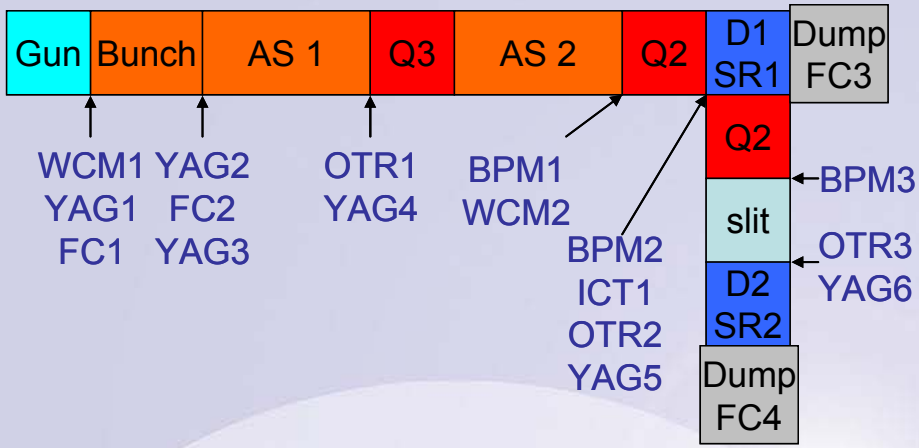
Linac Diagnostics



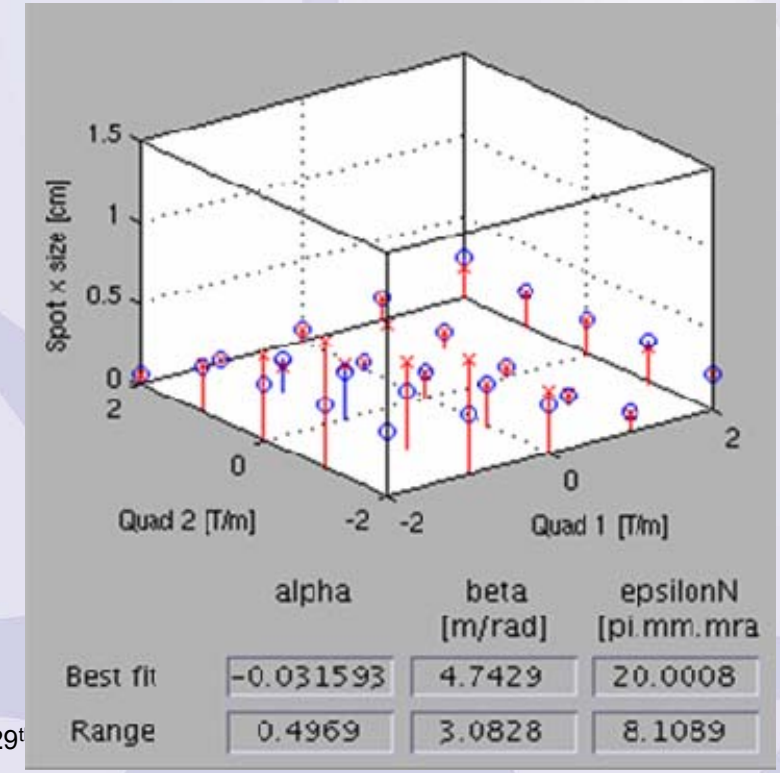
effect of the sub-harmonic pre-buncher (wall current monitor and 10 GHz oscilloscope)



energy spread measurement



emittance measurement:



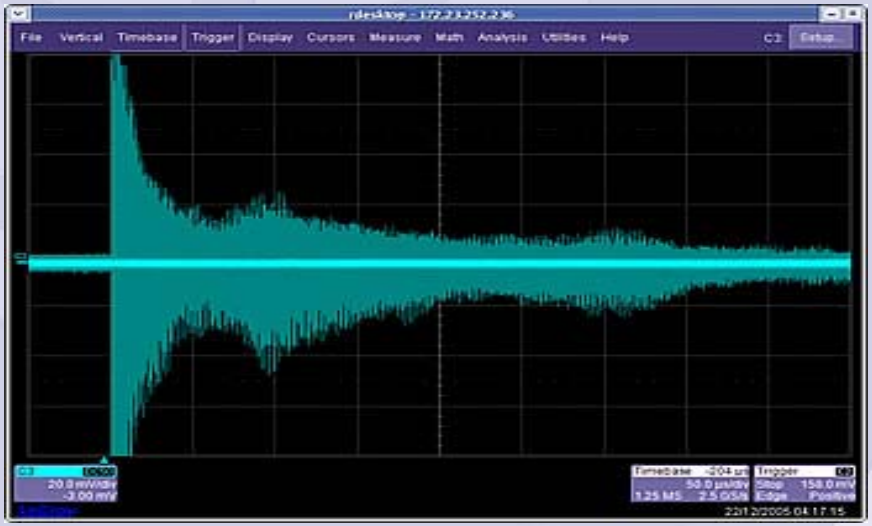
Linac Performance

Parameter	Specification	Single bunch	Multi bunch
Energy [MeV]	> 100	103	103
x norm. emittance [π.mm.mrad]	< 50	18	16
y norm. emittance [π.mm.mrad]	< 50	27	11
Charge [nC]	> 1.5 / 3.0	2.1	4.8
Pulse width [ns]	< 1	~ 0.2 fwhm	~ 0.2 fwhm
Jitter [ps]	< 100	11	11
Energy variation [%]	< 0.25	0.05 rms, 0.21 full	0.05 rms, 0.16 full
Energy spread [%]	< 0.5	< 0.2	0.2

(Same at 1 Hz or 5 Hz)

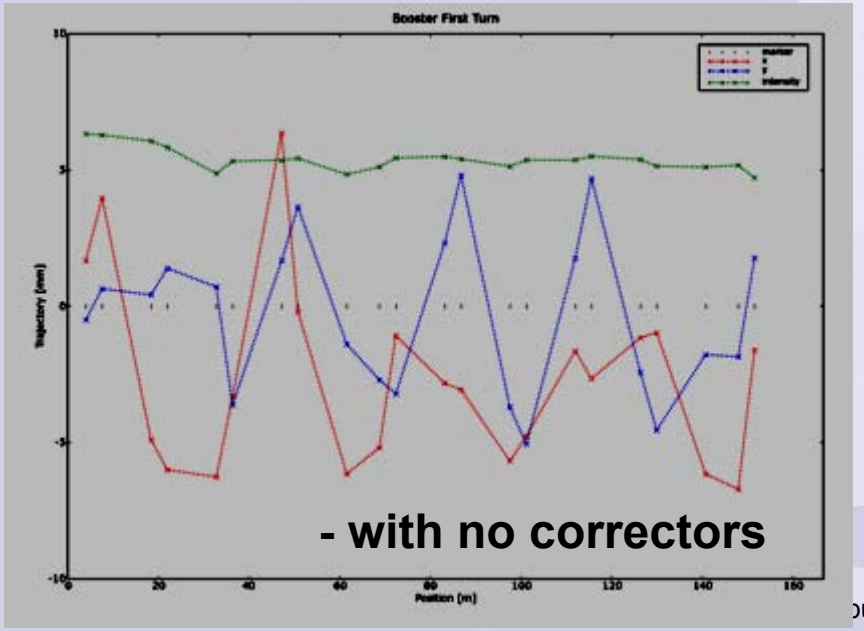
diamond

Booster Commissioning



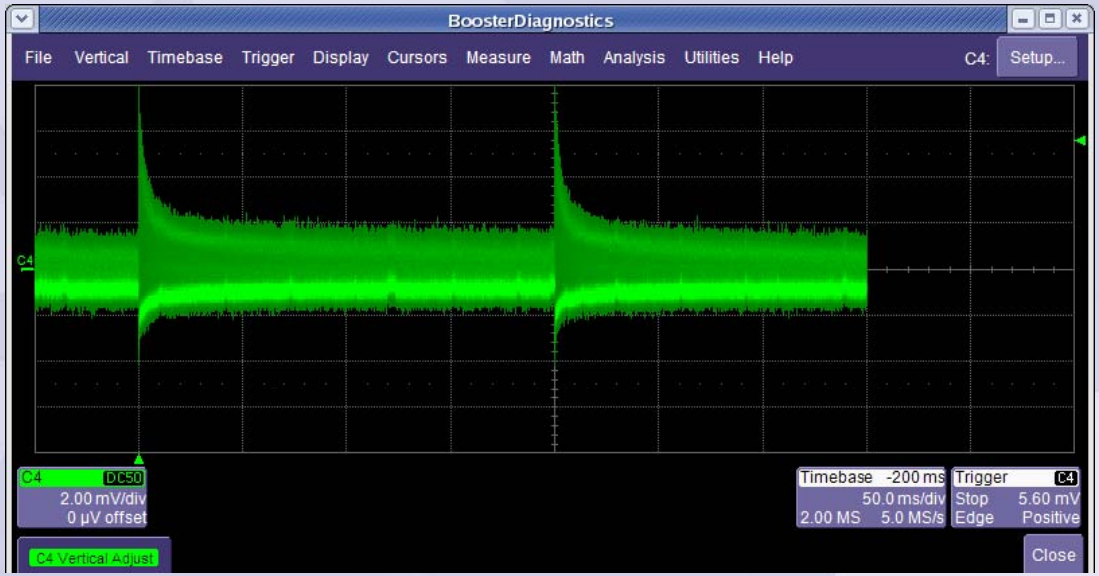
First beam in the Booster (100 MeV, no RF)

Dec. 21st 2005

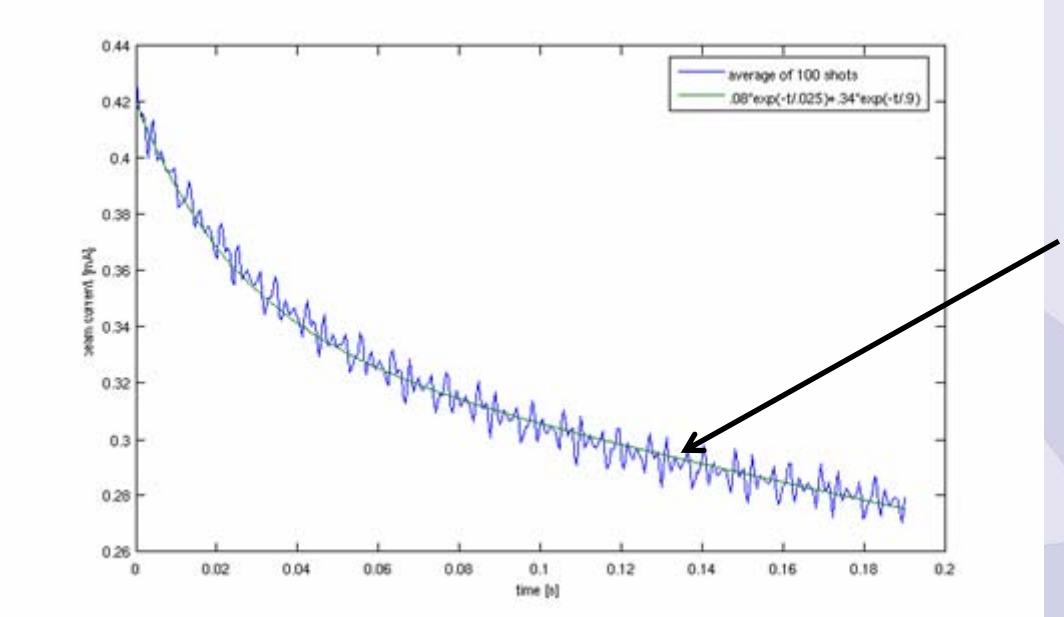


- with no correctors

diamond

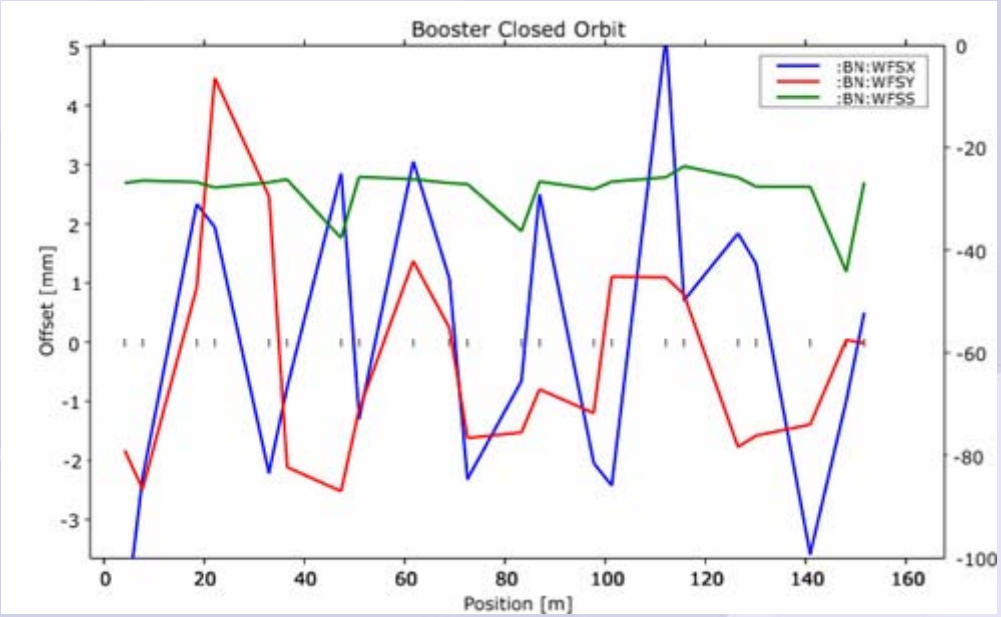


Feb. 13th:
Beam surviving for 200 ms between injections at 100 MeV (RF on)

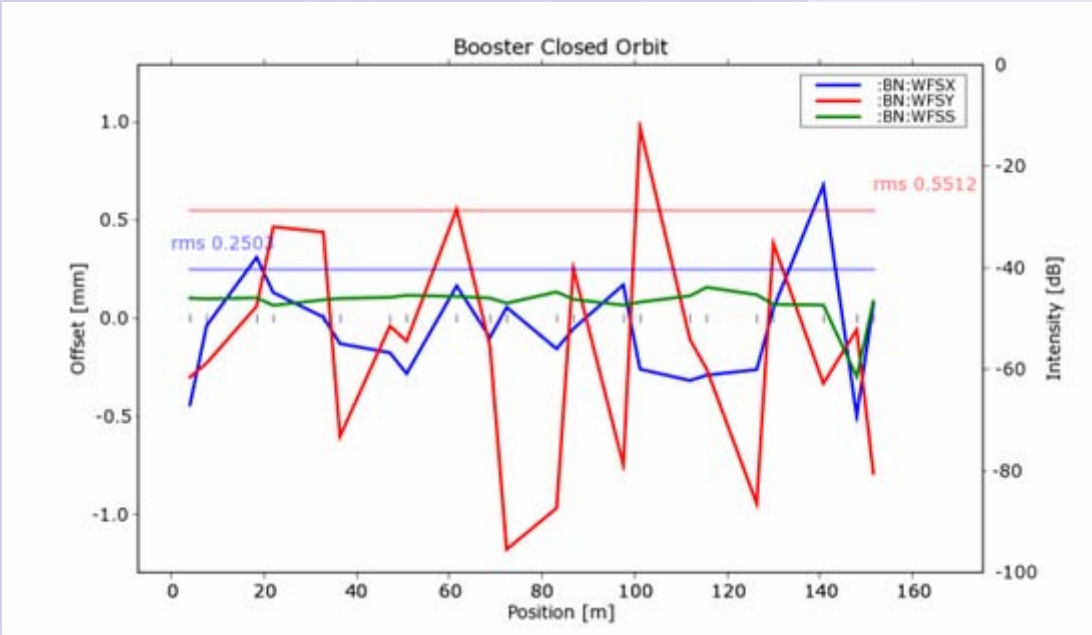


1/e lifetime = 1 s

Closed orbit

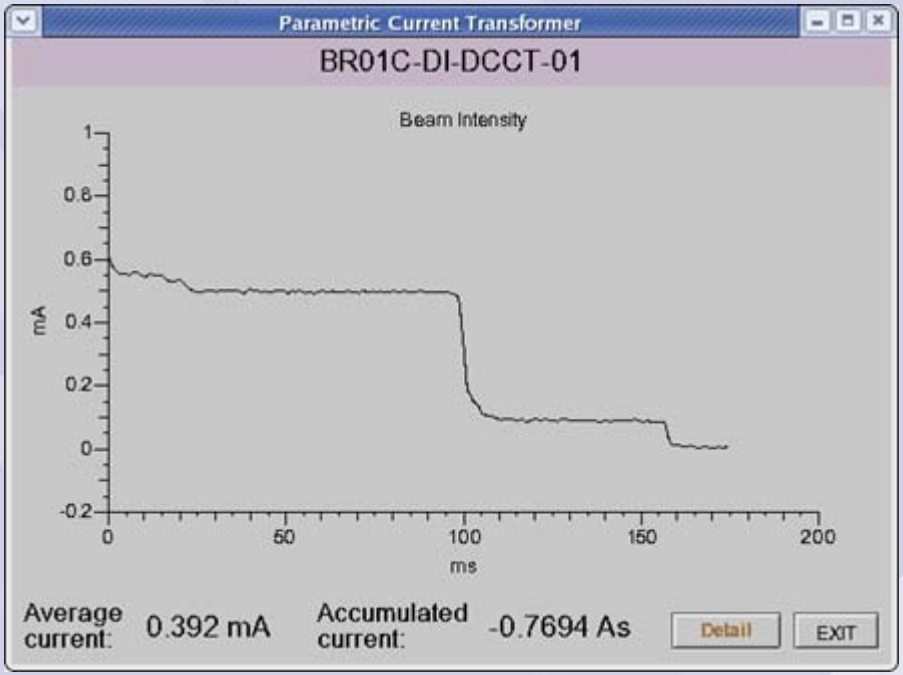


within +/- 5 mm,
with no correctors powered

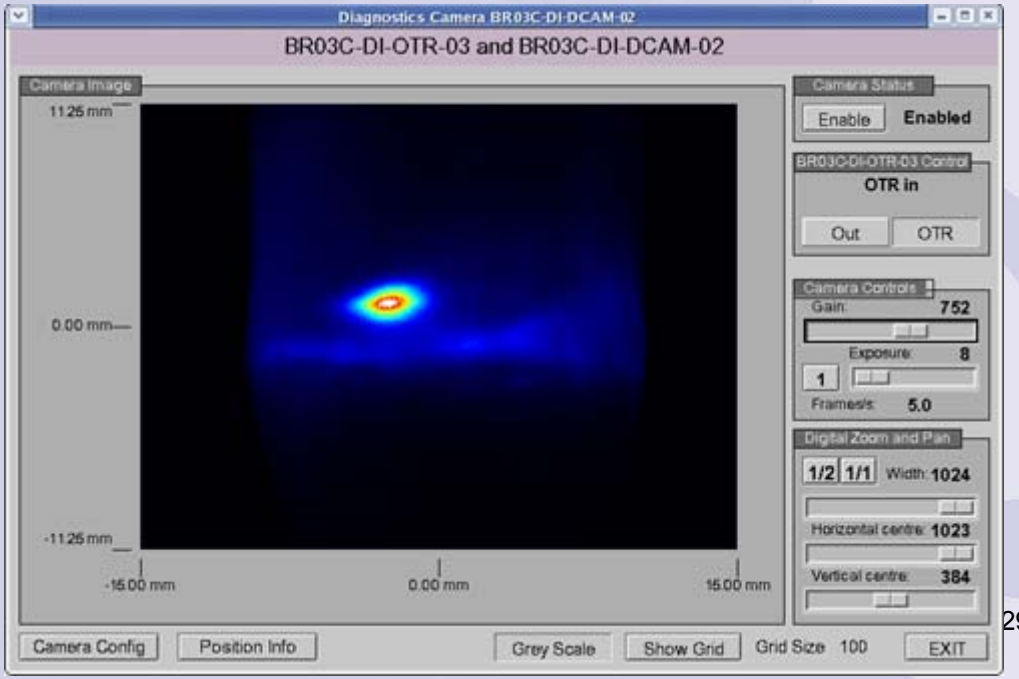


First orbit correction Feb. 17th

within +/- 1 mm



First acceleration to 700 MeV, March 10th



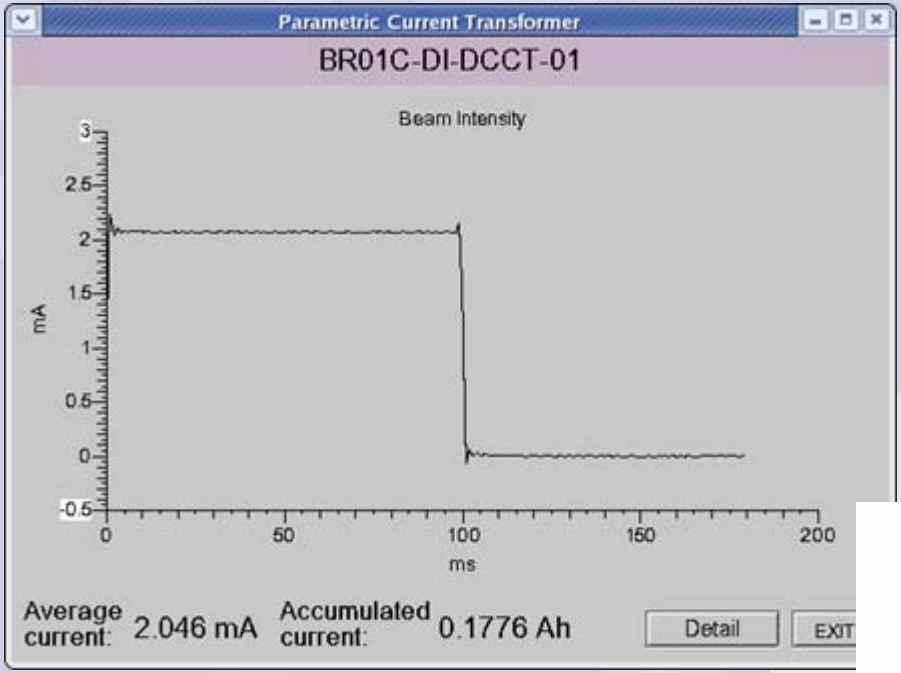
First extraction at 700 MeV, April 4th

Why 700 MeV ?

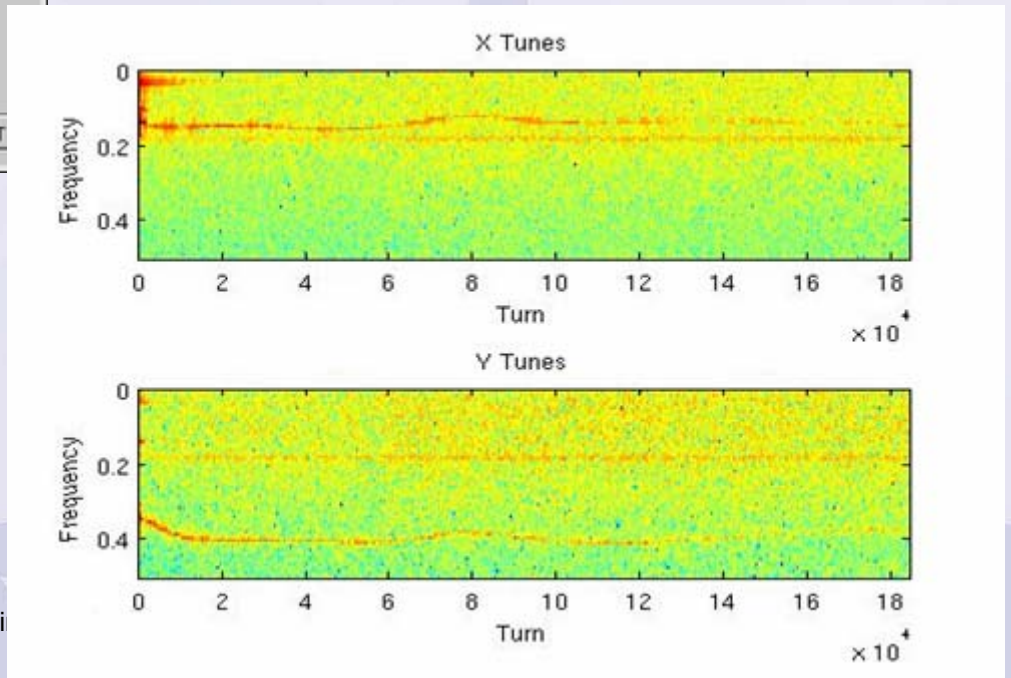
Water cooling system (part of the Buildings contract) not available.

Temporary systems set up for Linac, Booster RF, Storage ring RF, but not initially for the magnets.

Booster optimisation (April '06)



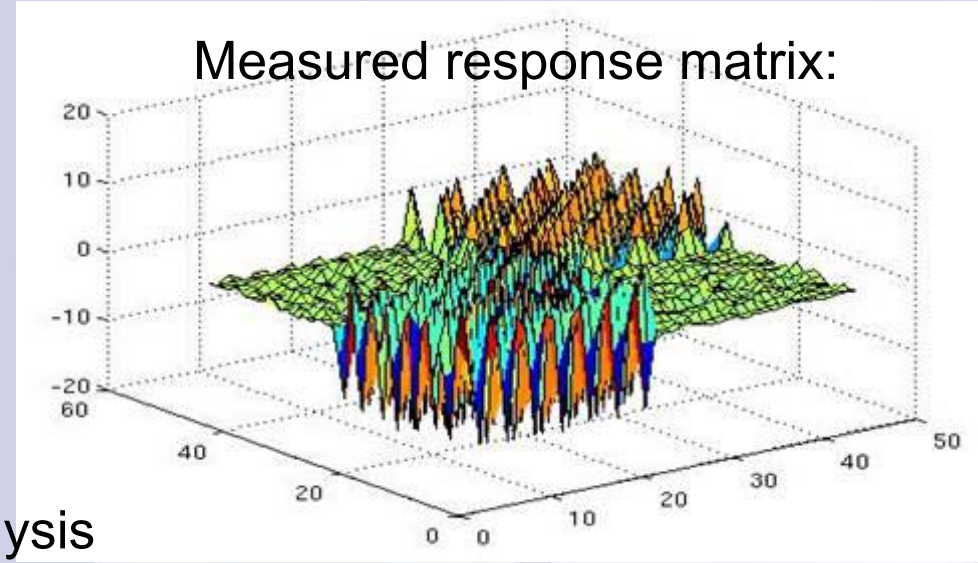
Tunes corrected through the ramp



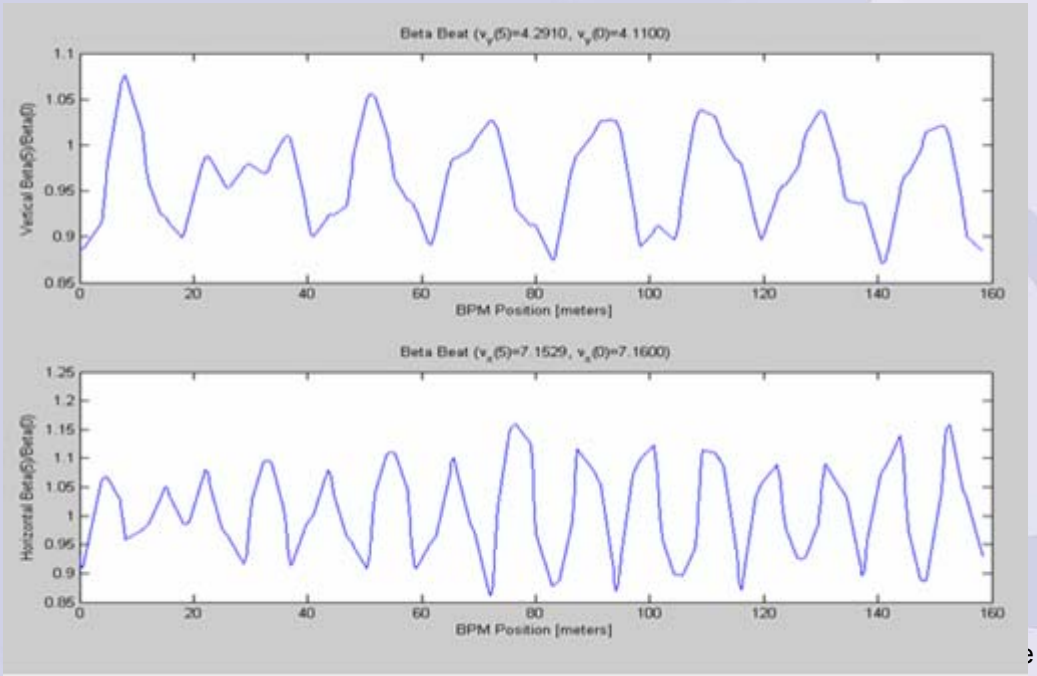
2 mA typical, with ~ 70 % transfer efficiency from before injection to after extraction.

Optics measurements

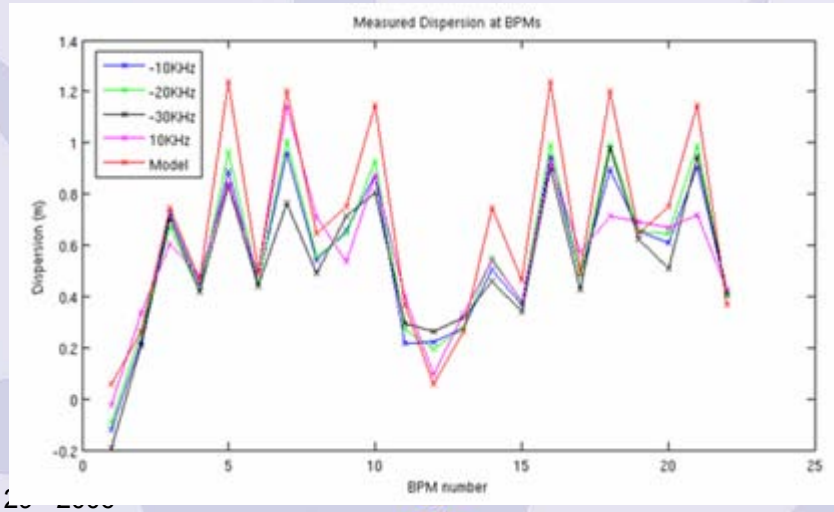
Measured response matrix:



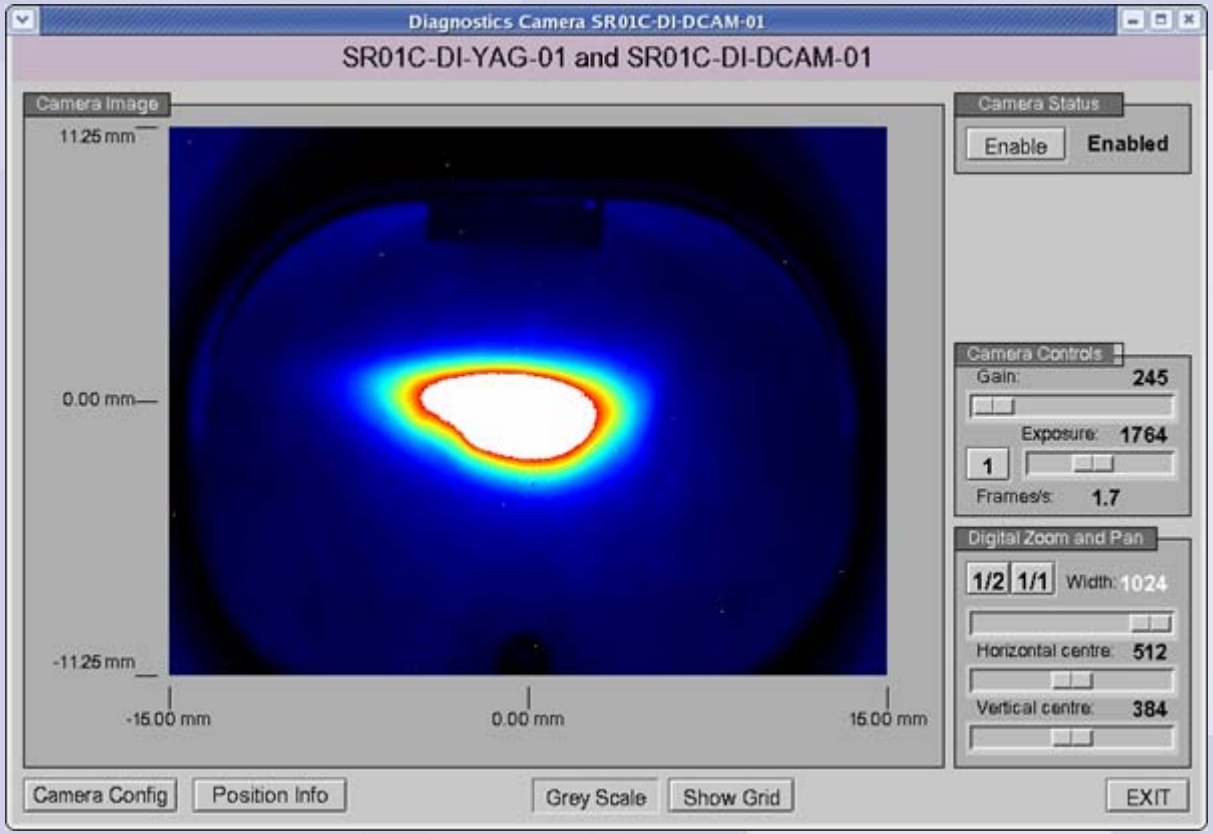
Predicted β-beat from LOCO analysis within ±15 % Horiz., ±10 % Vert.:



dispersion measurement:

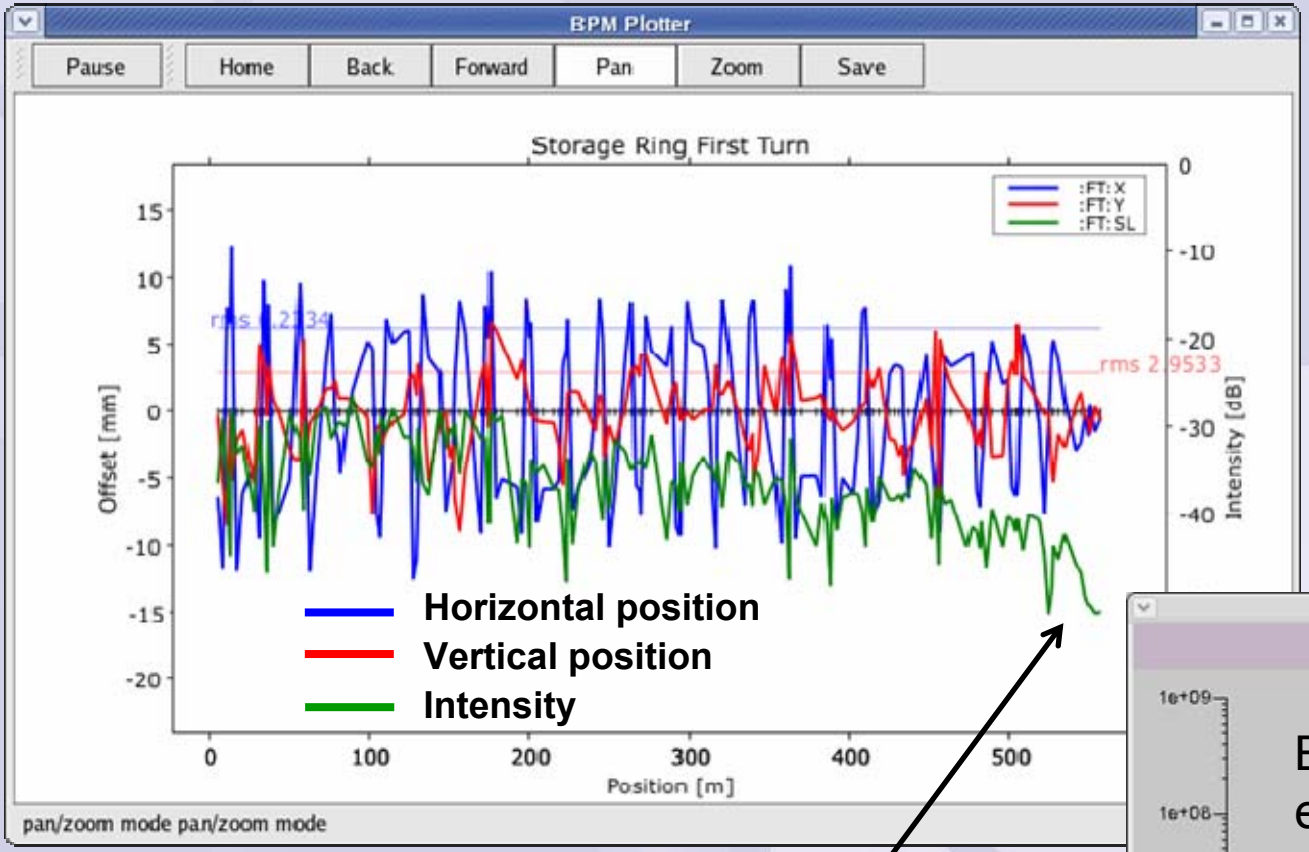


Storage Ring:
Phase I Commissioning (700 MeV)



May 3rd/4th:

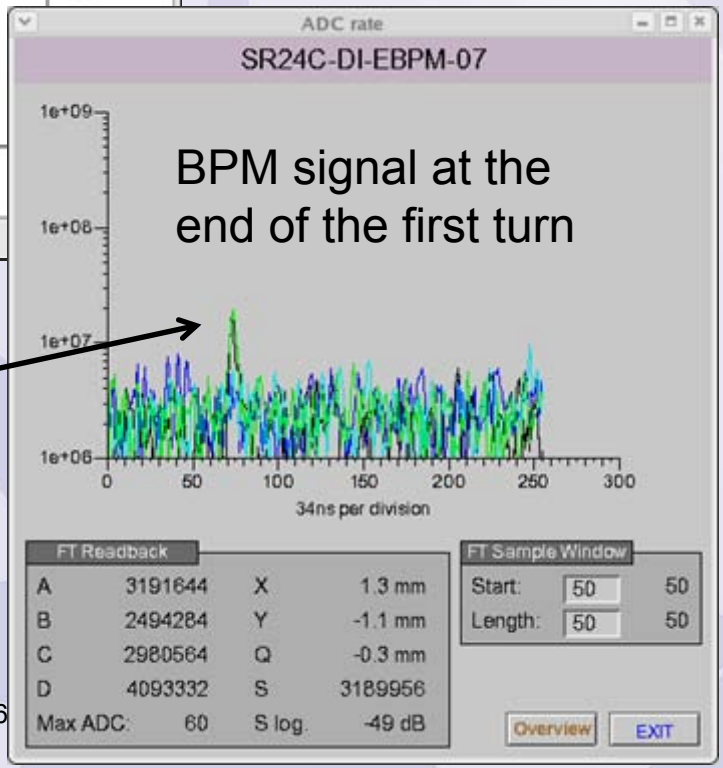
First beam in the storage ring – immediately after the septum



May 4th/5th:

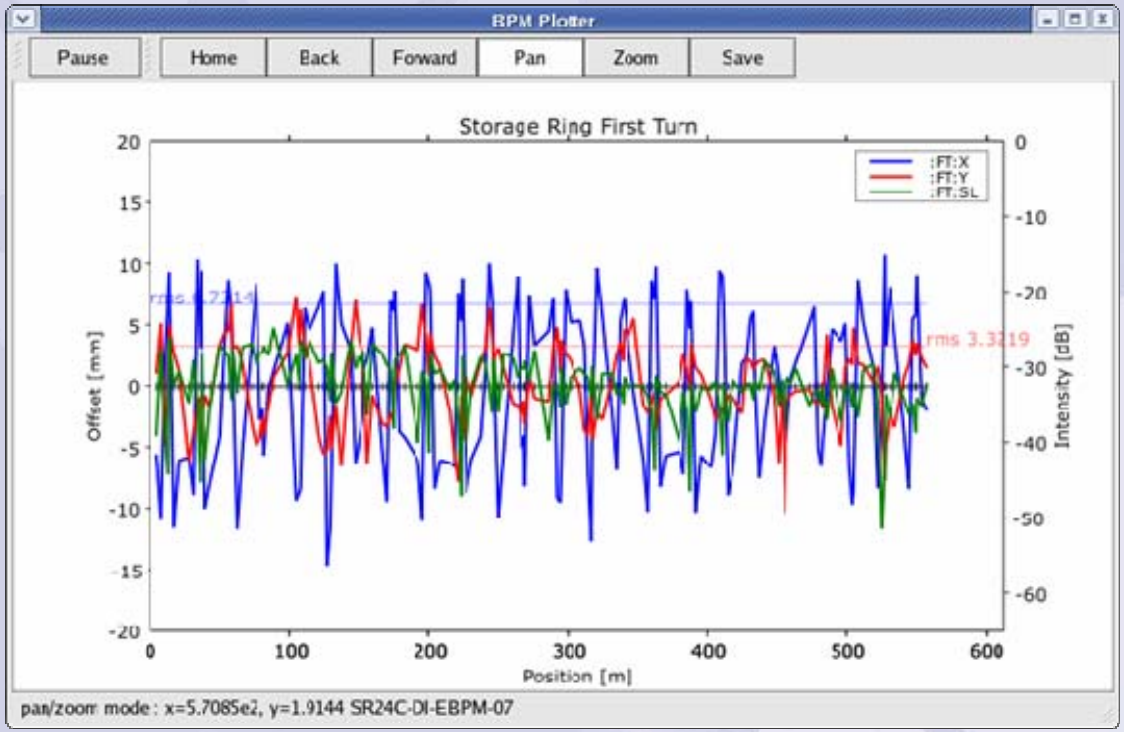
First turn !

Correctors off

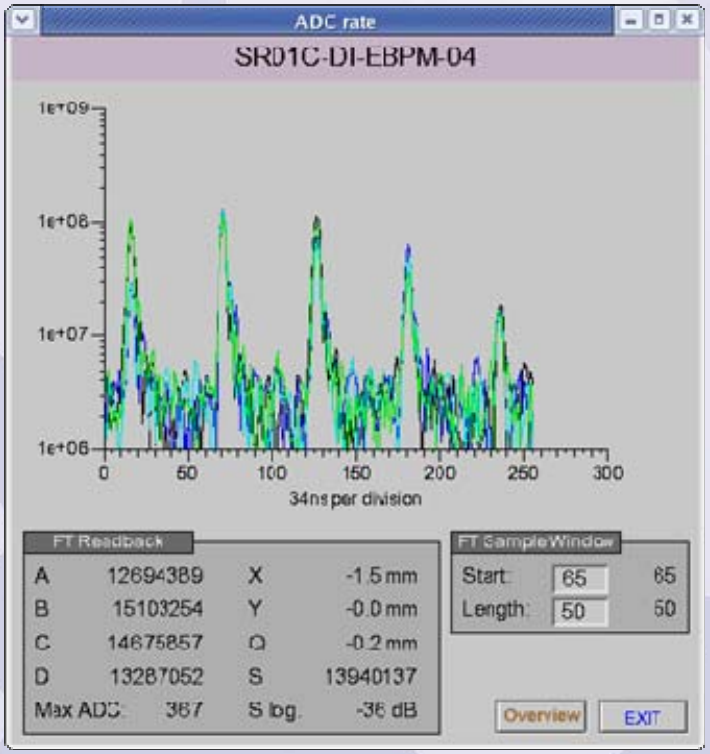


low intensity due to two quadrupoles with inverted polarity

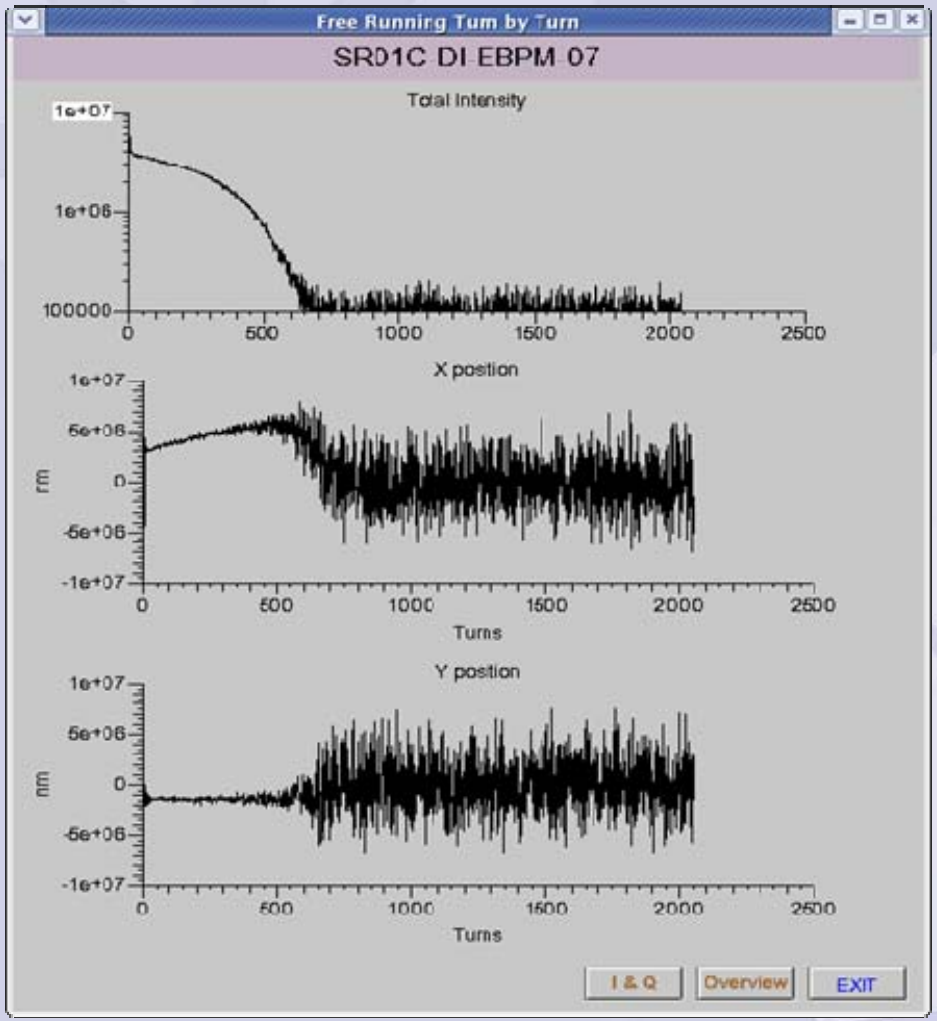
Celebrating the First Turn! – 03:00 May 5th 2006



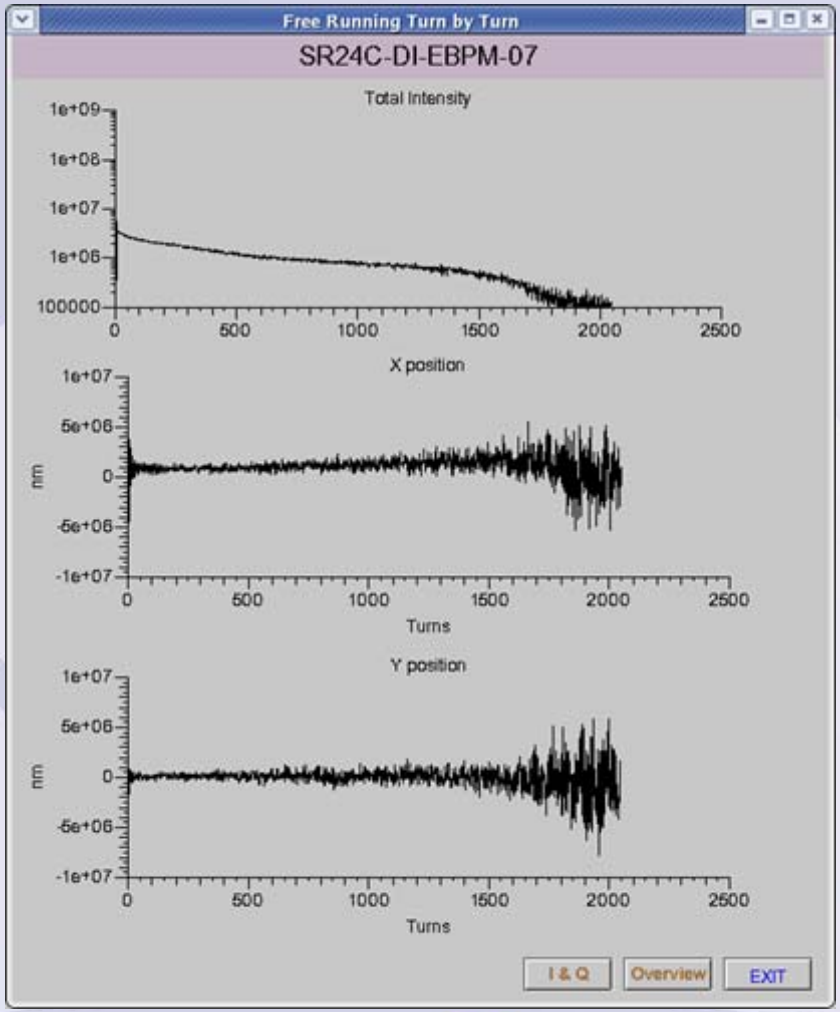
May 5th/6th: 4 turns



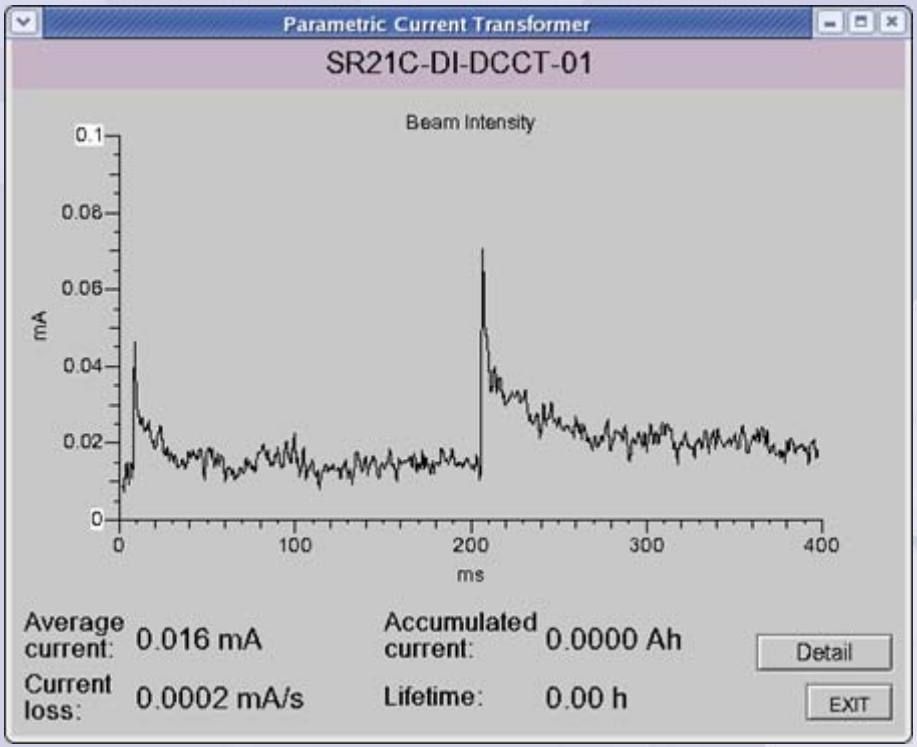
May 6th/7th: 600 turns (sextupoles off, RF off)



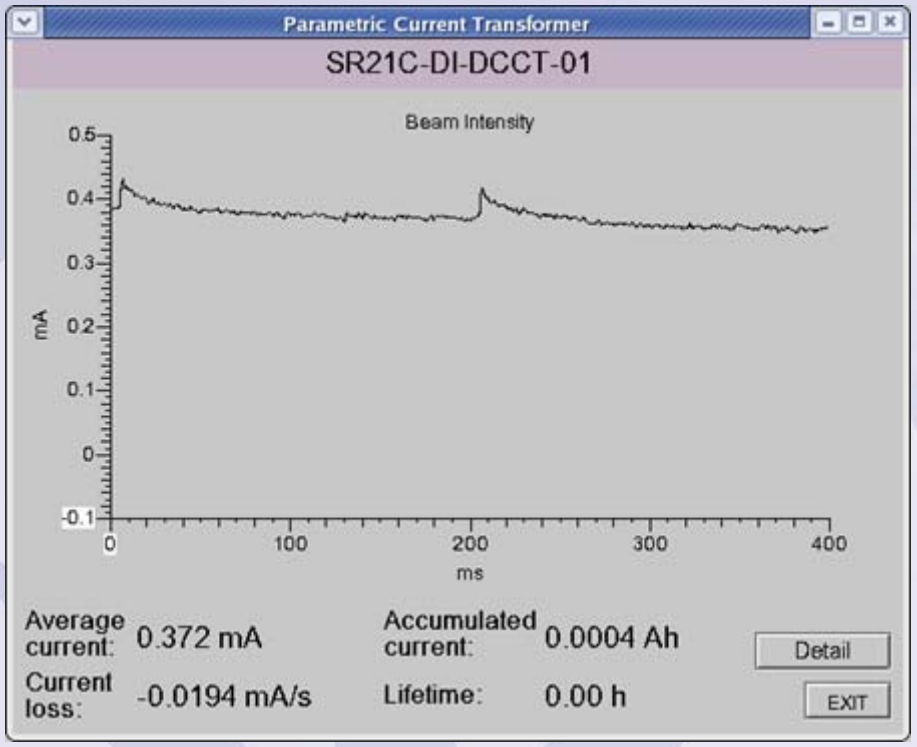
May 19th/20th: 2000 turns (sextupoles on, RF off)



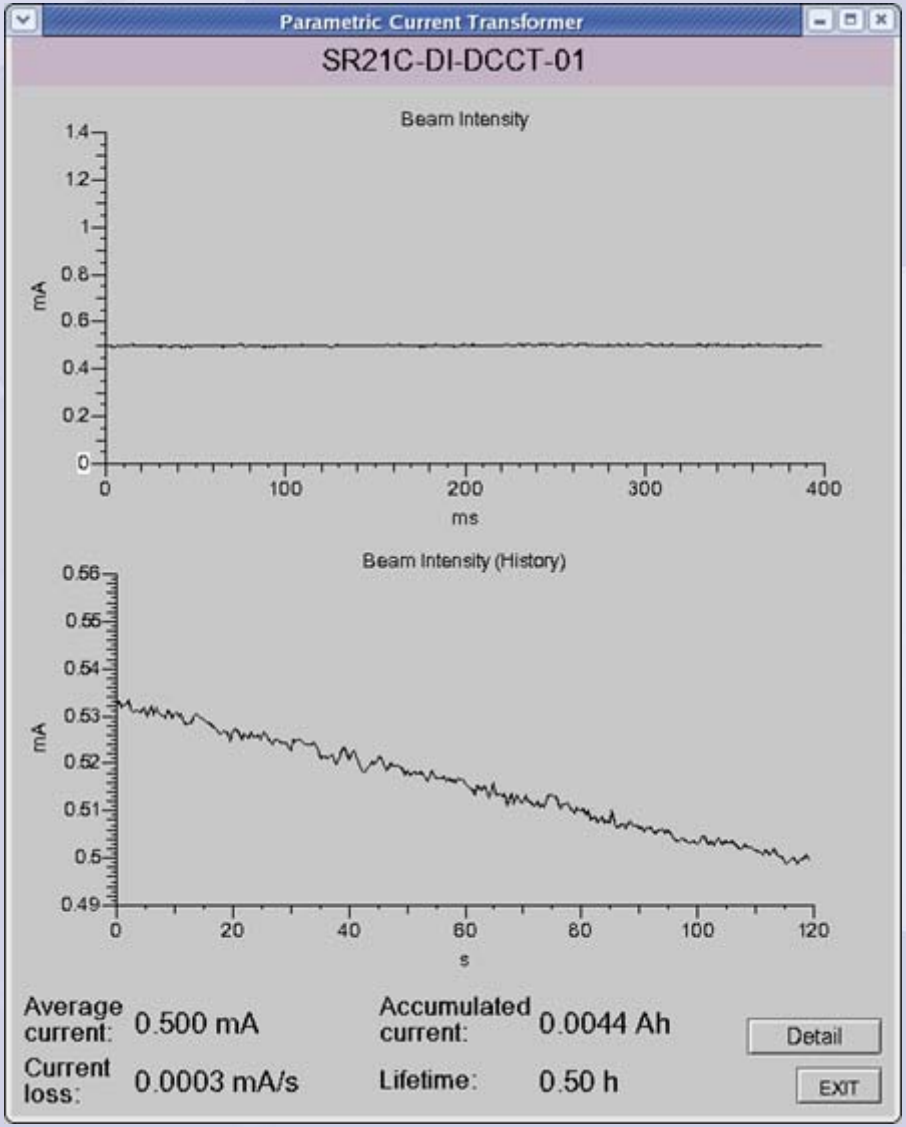
May 20th/21st:
106,764 turns !



May 21st/22nd:
0.4 mA, 70% injection efficiency

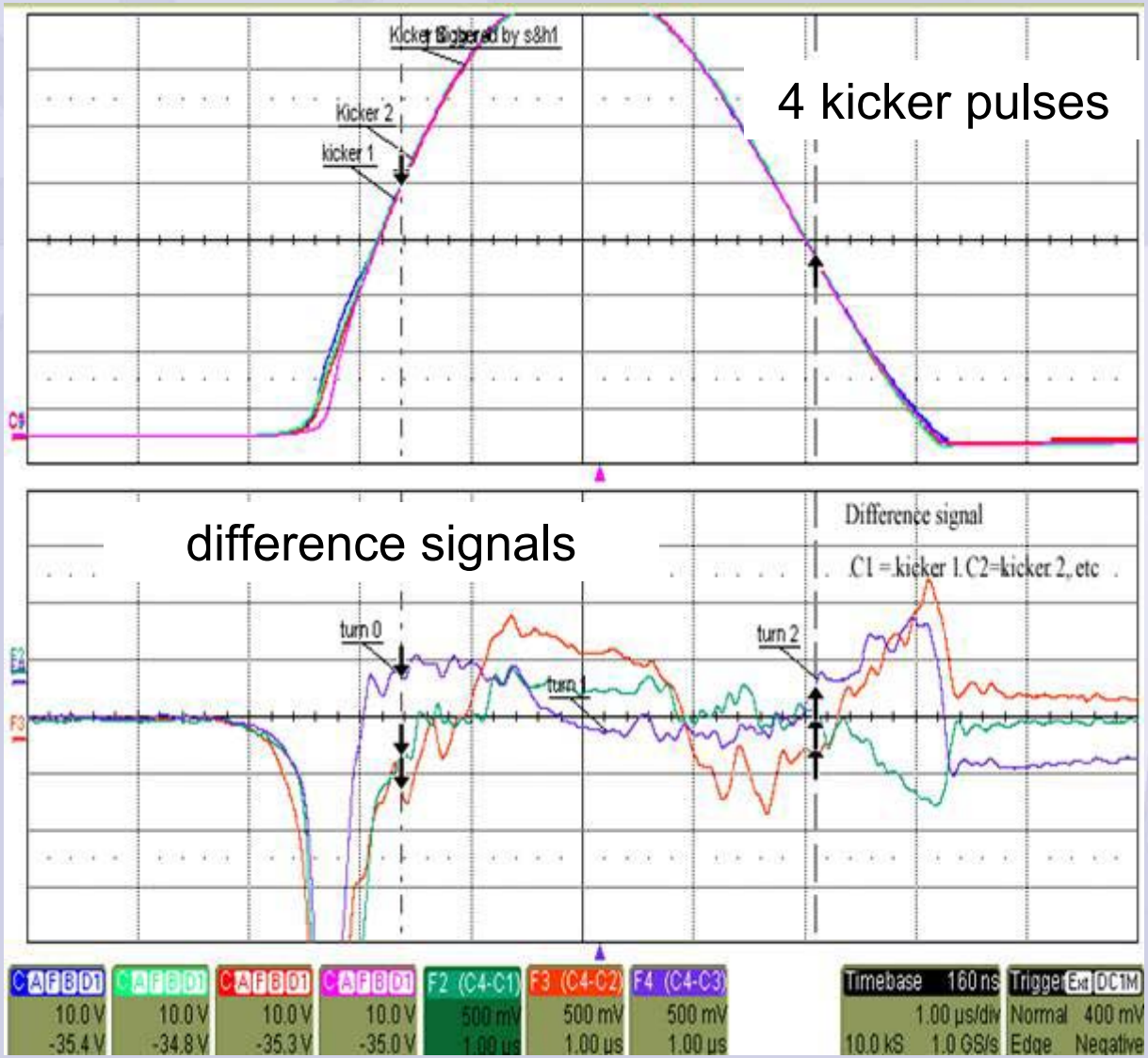


First stored beam ! …



0.5 hour lifetime at 0.5 mA

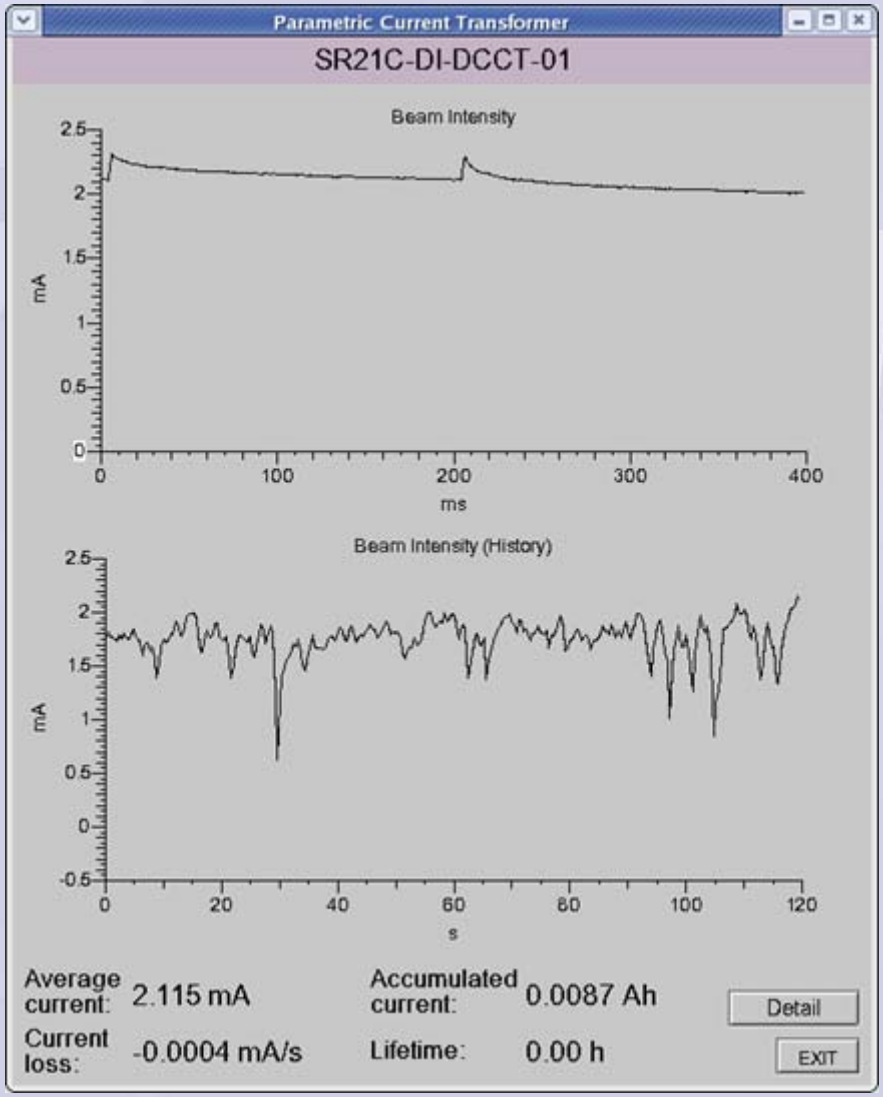
But initially the beam did not accumulate …



- believed to be due to differences between the kicker pulse shapes (which were not tuned for operation at 700 MeV)

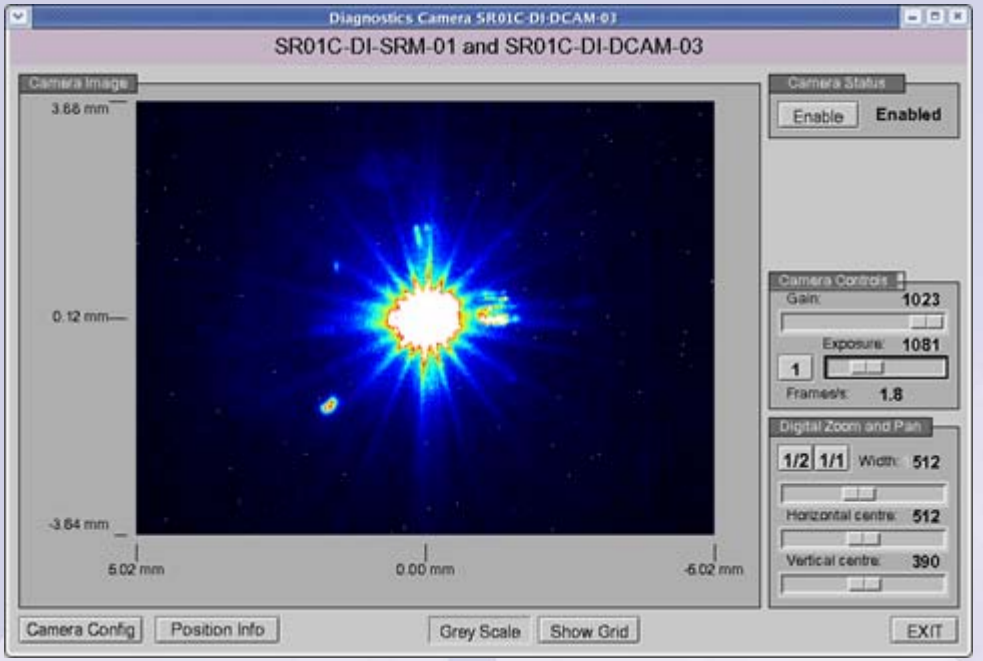
then after an "optimisation procedure" …..

> 2 mA accumulated

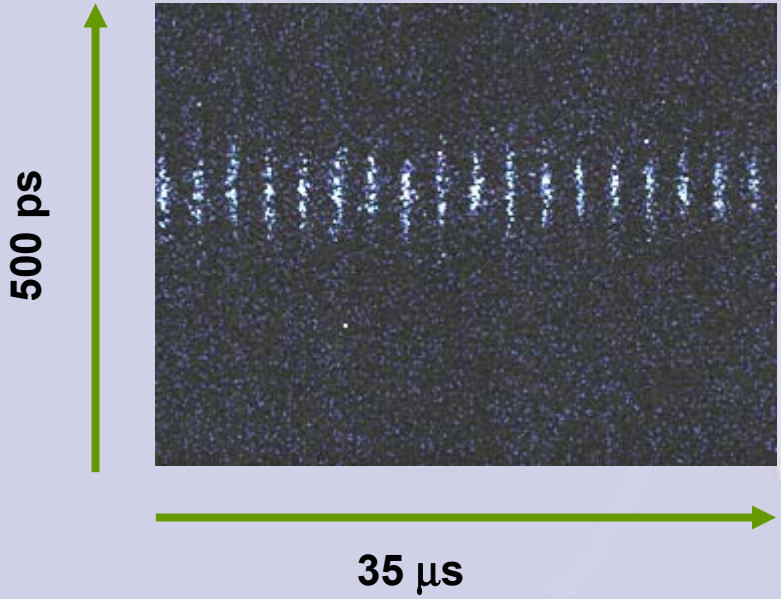


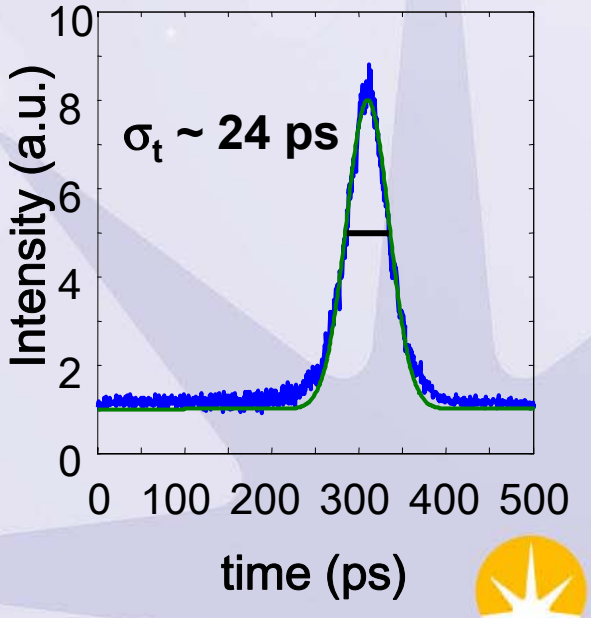
First Synchrotron Light !

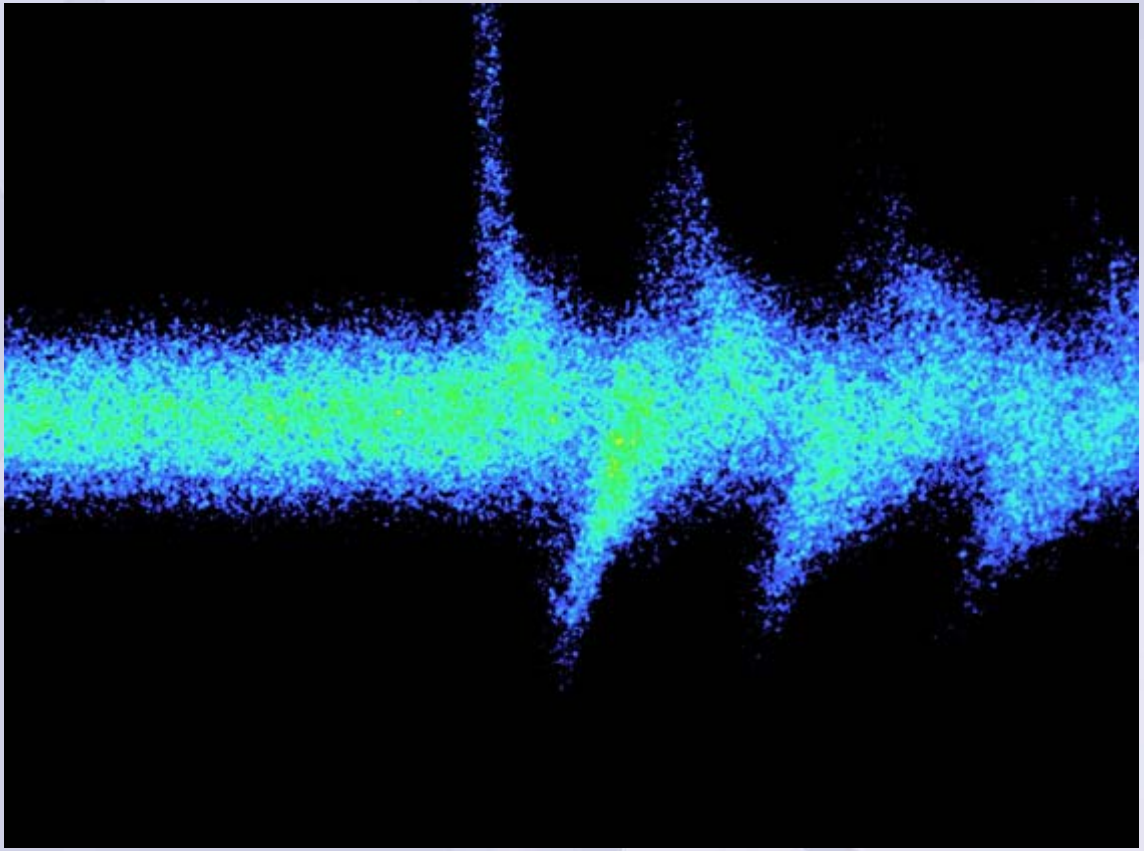
- from the visible Synchrotron Light Monitor



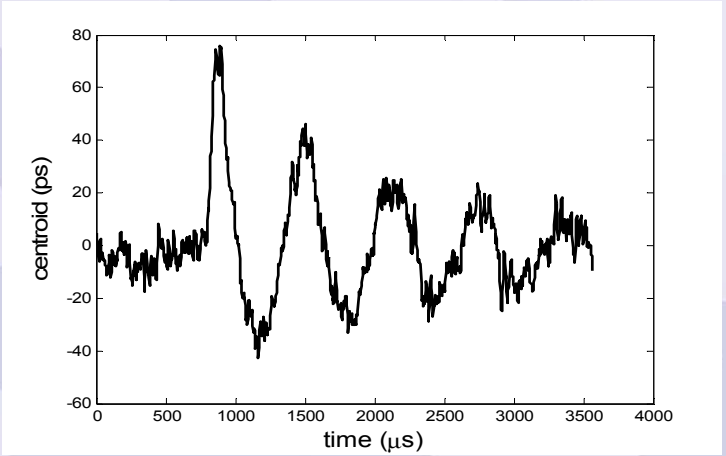
First use of the streak camera:



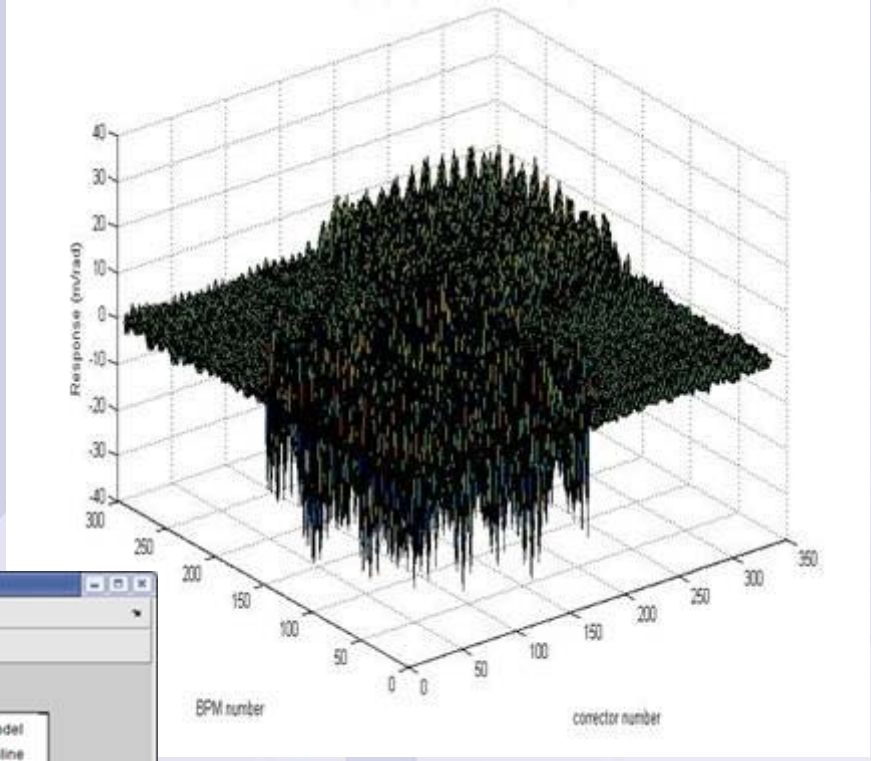


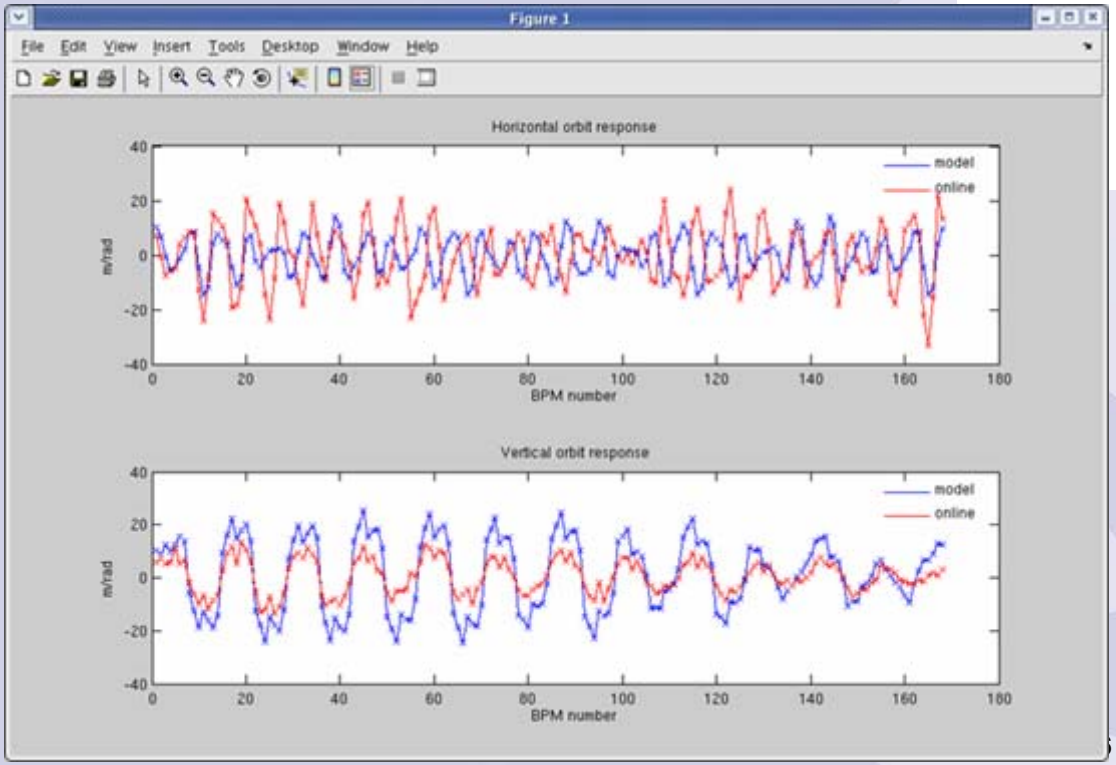


synchrotron oscillations at injection



Response matrix measurement





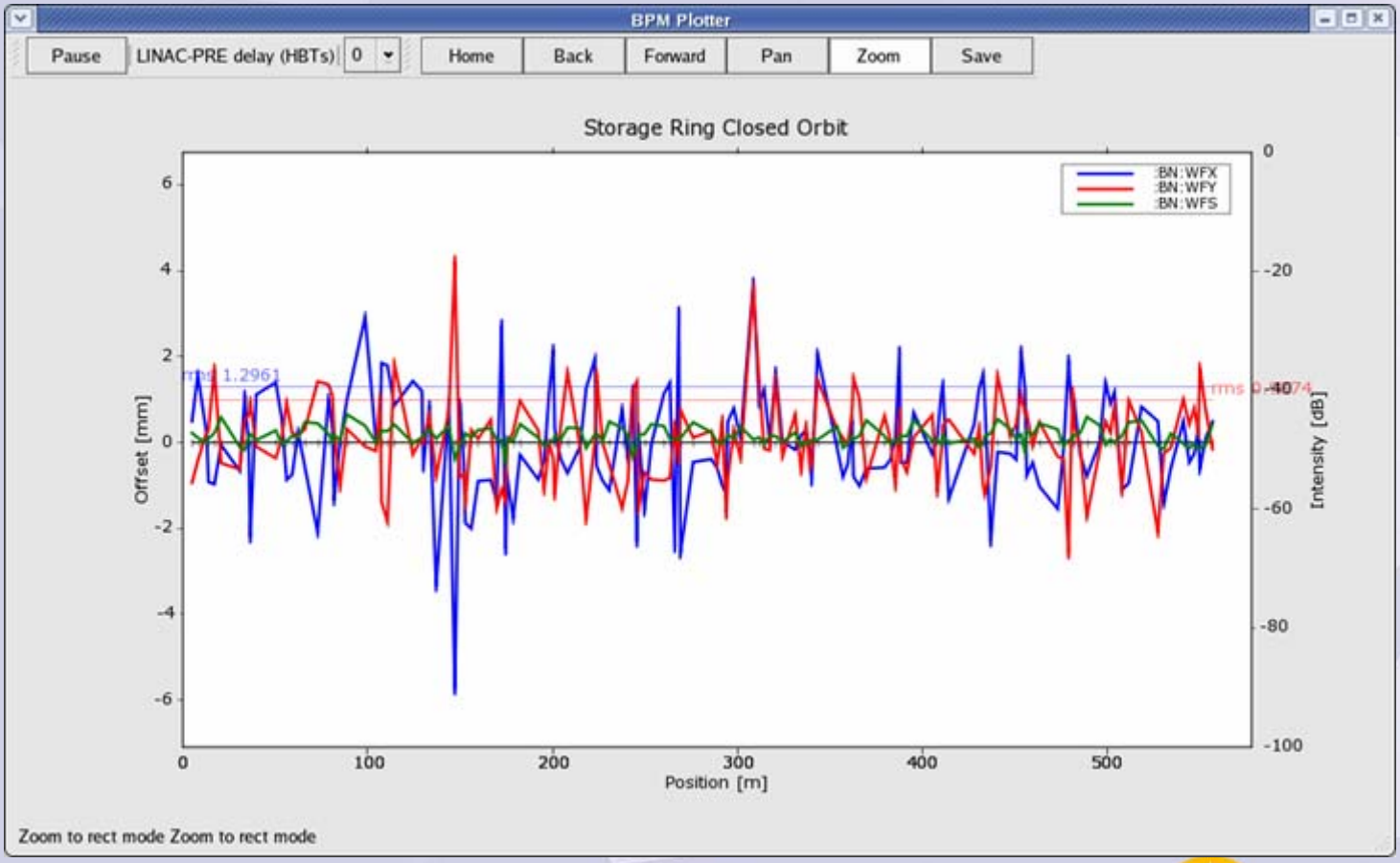
tunes generally within 0.4-0.5 of the model

diamond

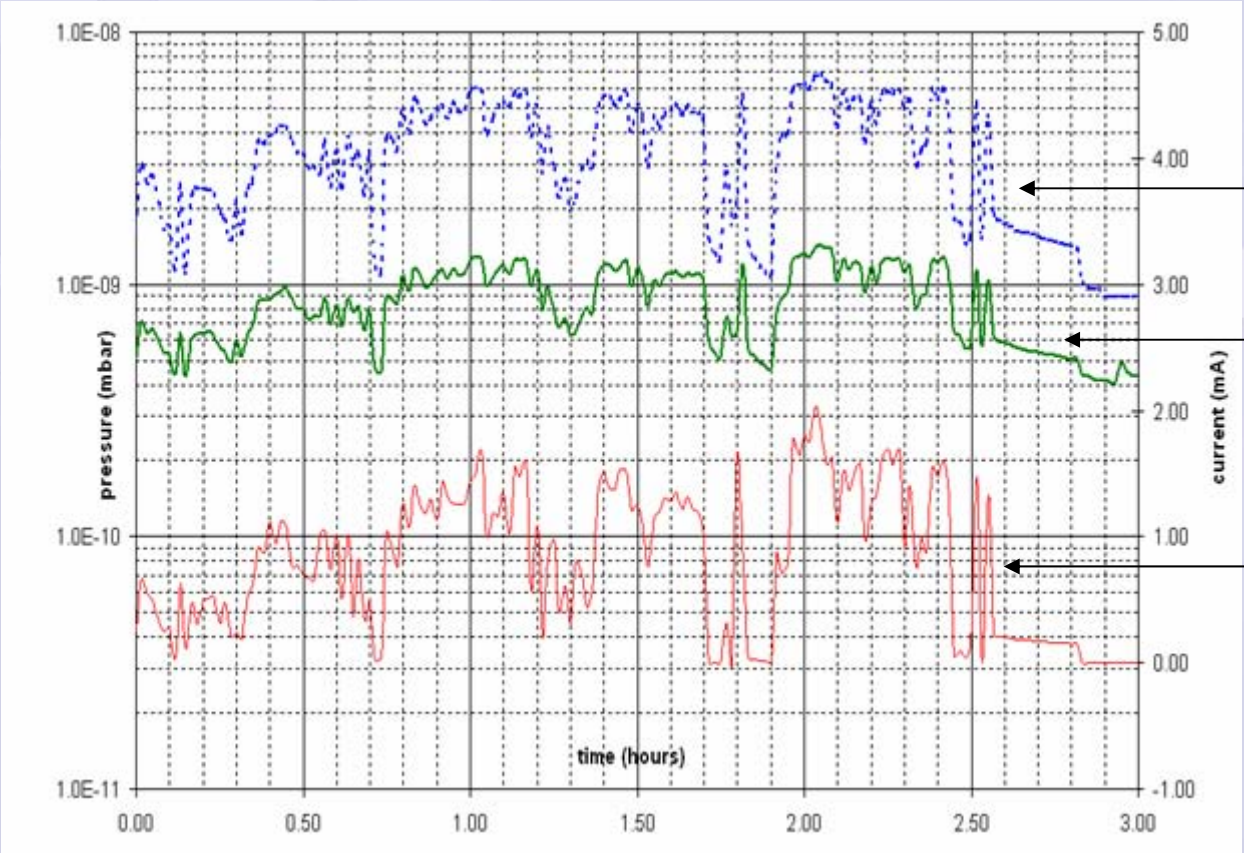
Closed orbit correction

Best achieved: σ_x = 1.3 mm, σ_y = 0.9 mm

- reasonable given the uncorrected girder and BPM positional errors



Vacuum: first observations of photo-stimulated desorption



pressure in the SR beam port

pressure in the e-beam chamber

beam current

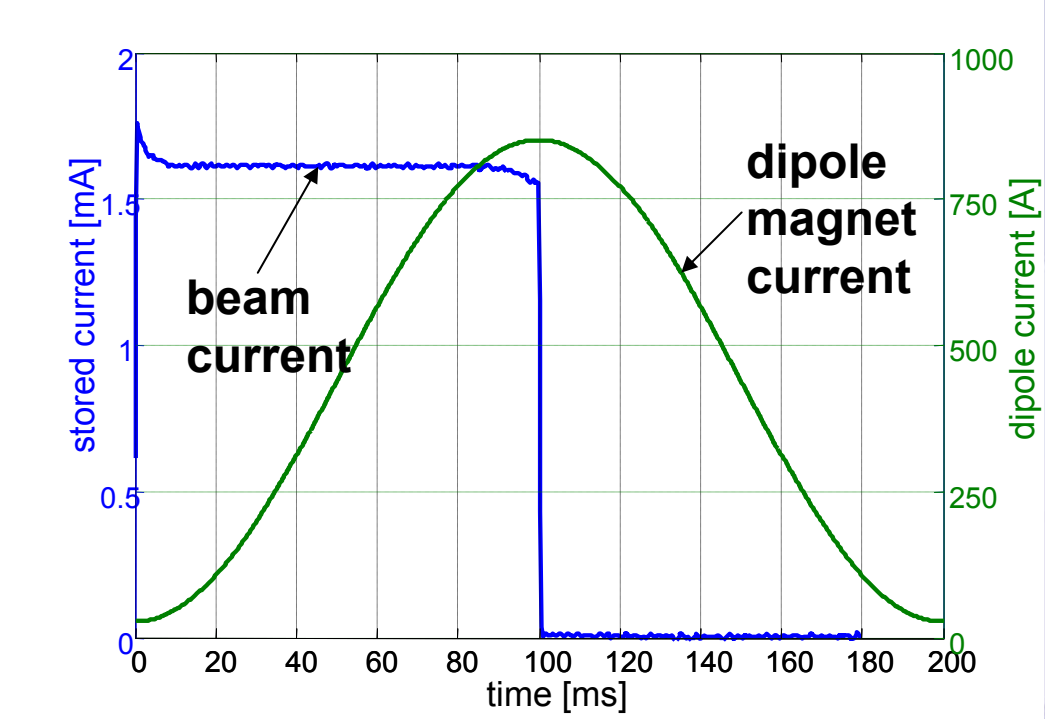
Average base pressure 5 10^{-10} mbar

Dynamic pressure 1.5 10^{-9} at 2 mA

Consistent with desorption rate of 10^{-3} molecules/photon (as expected for a pre-baked, stainless steel system)

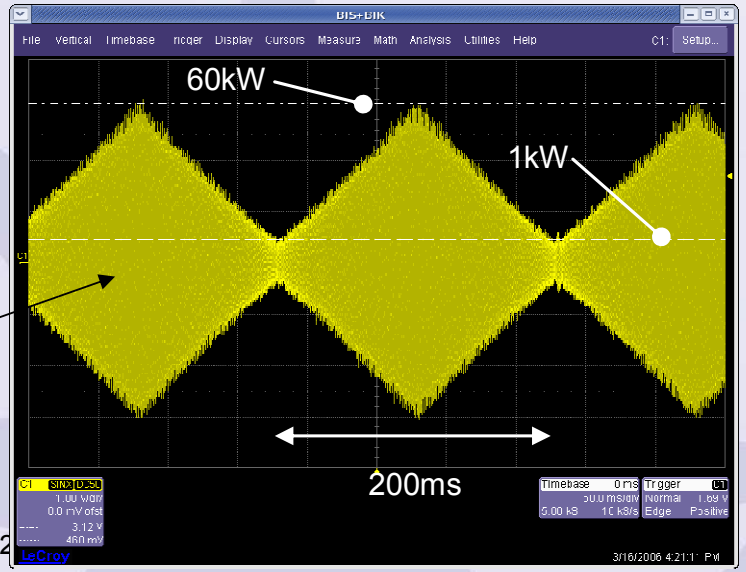
diamond

Booster 3 GeV Commissioning (June '06)

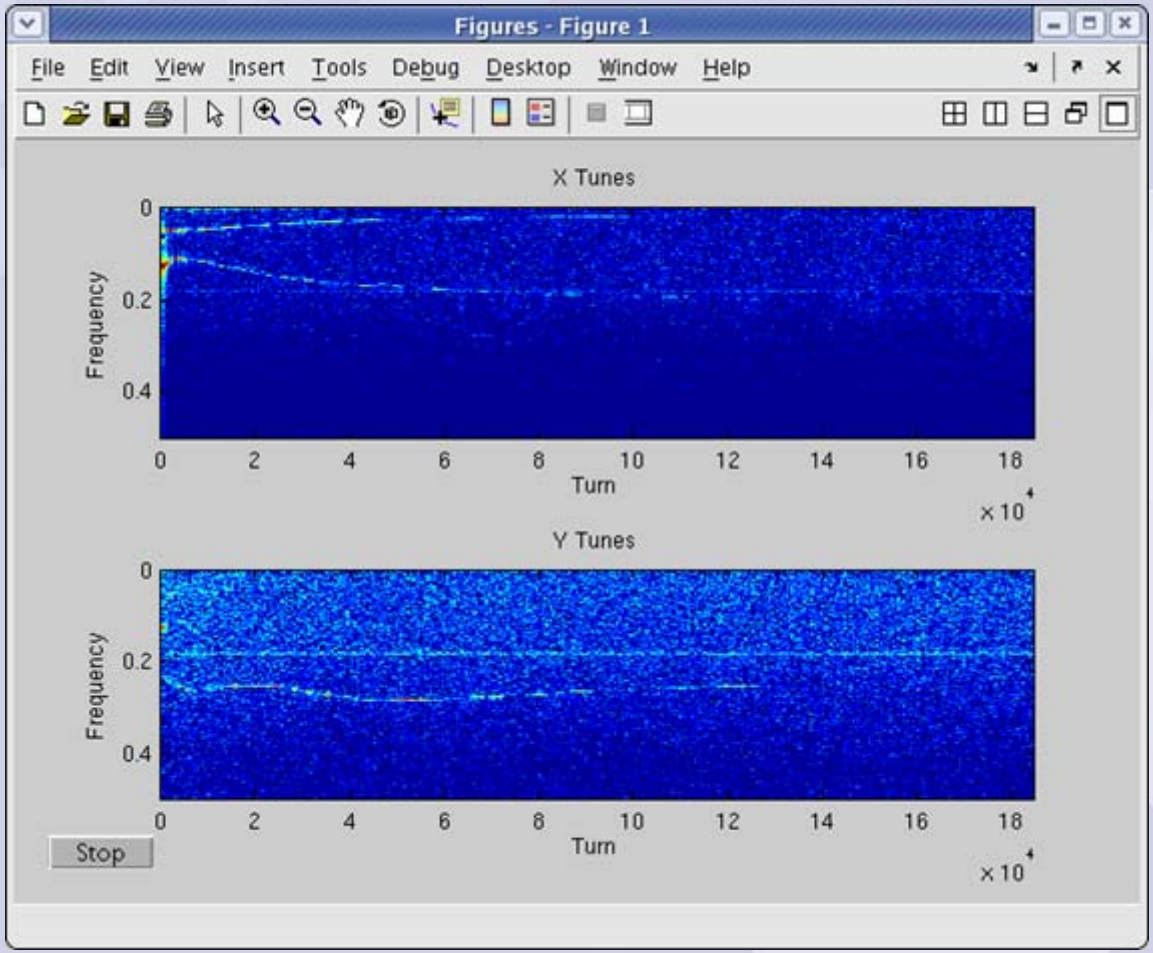


- Started 3 GeV trials on June 7th
- First beam to 3 GeV on June 9th

linear ramp of rf power



Tunes

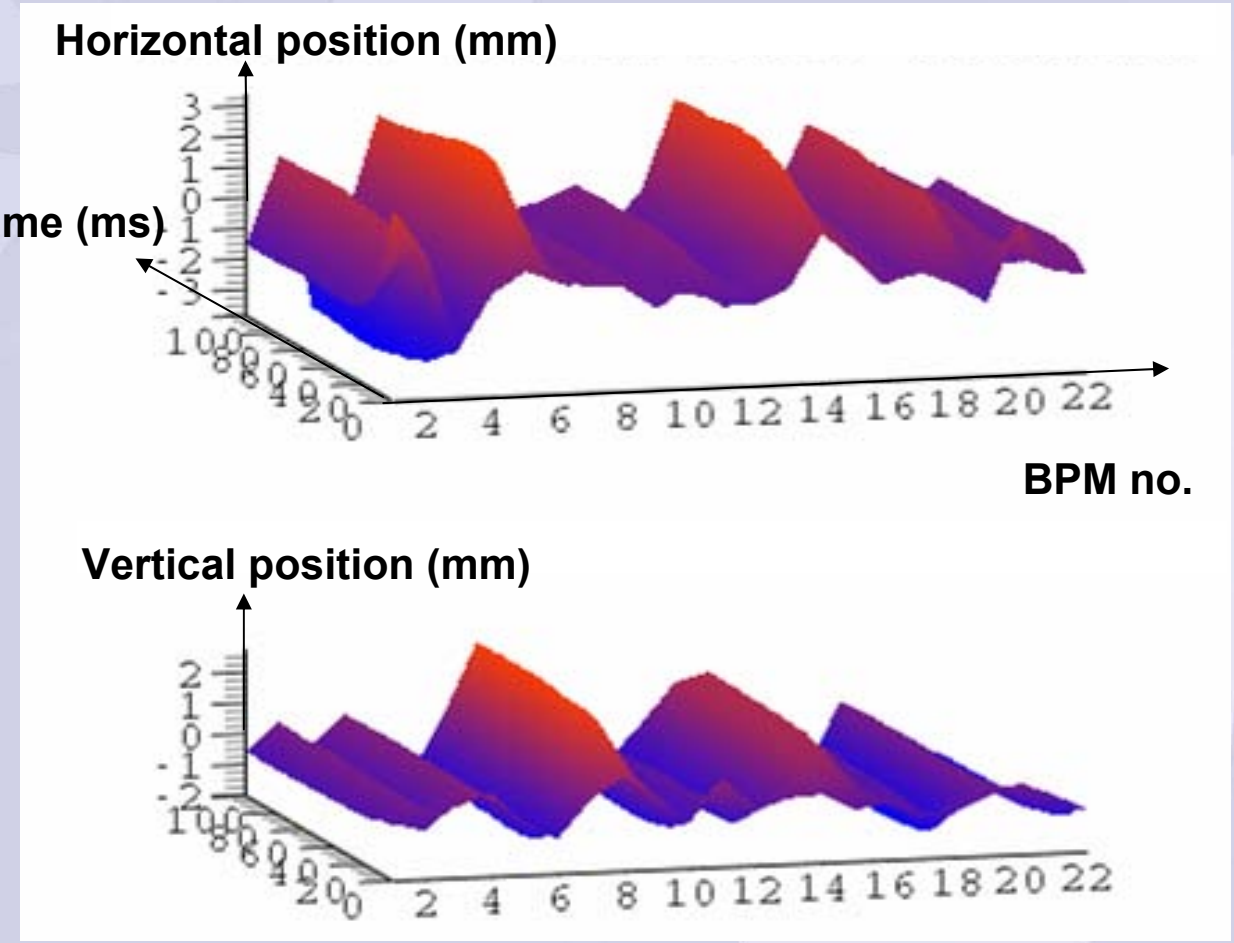


Tunes constant to
$\Delta Q_x = 0.07$,
$\Delta Q_y = 0.05$

- without corrections to the sinusoidal ramps

diamond

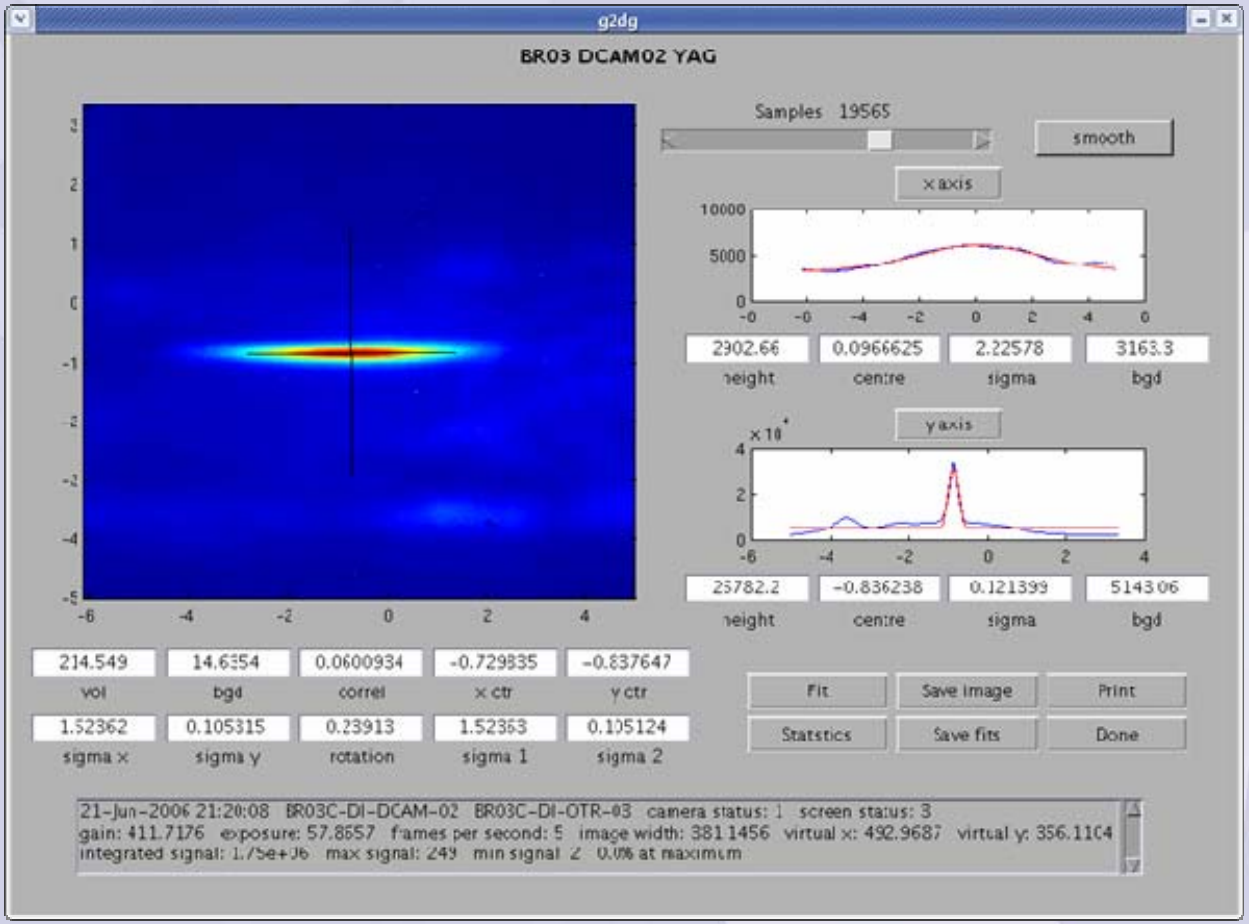
Closed orbit



Closed orbit can be corrected during the ramp, but is not needed.

After 400 MeV stays constant, within ± 3 mm.

Extracted Beam at 3 GeV



σ_x=1.5 mm

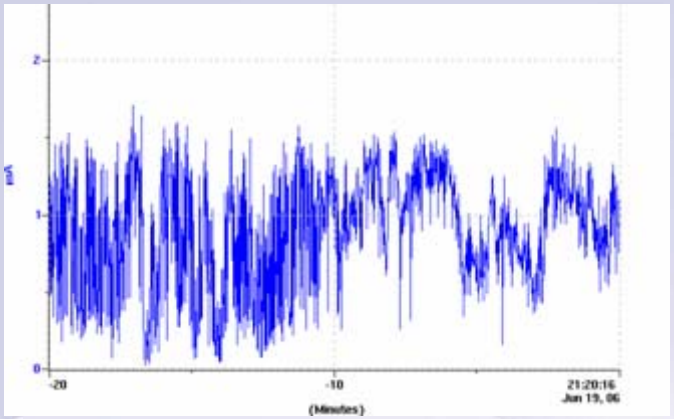
σ_y=0.11 mm

in agreement with theory (2% coupling)

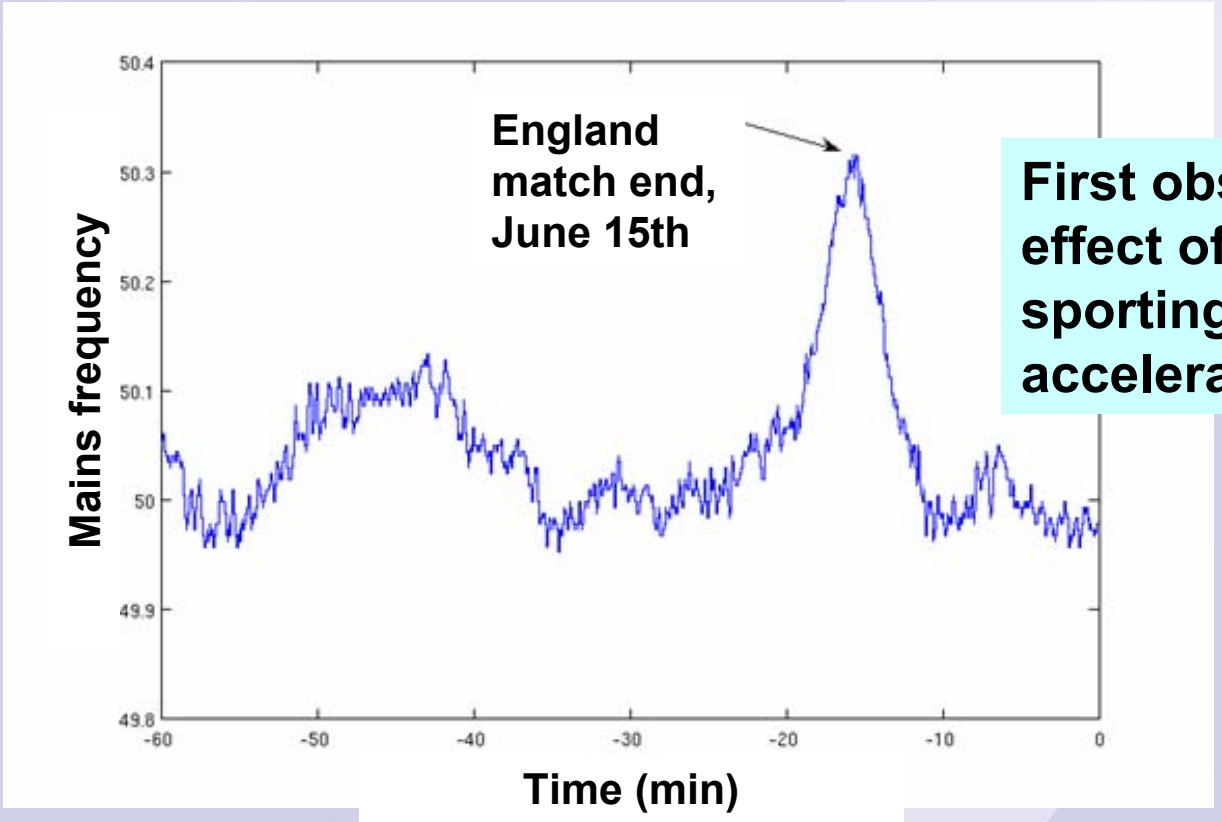
diamond

Booster is now ready to inject into the storage ring at 3 GeV.

Stability has however deteriorated, and has been linked in part to mains frequency variations ….which are being investigated



It should however improve after the World Cup !



First observation of the effect of a major sporting event on accelerator operation ?

diamond

Summary and Future Plan

- **Phase I storage ring commissioning at 700 MeV has been a success:**
  - all systems operational
  - beam stored and accumulated
  - optics in reasonable agreement with theory
- **Booster commissioned at 3 GeV – ready for the next stage**
- **Installation of IDs and FEs in progress**
- **Storage ring commissioning will resume in September, when water cooling is expected to be available.**
- **Beamline commissioning in parallel during October-December**
- **Start of Operational Phase - first external users, assisting with beamline optimisation - as original target: January 2007**

Thanks to the Machine Construction and Commissioning Teams,

& thank you for your attention.

diamond