The Diamond Light Source

Richard P. Walker, Technical Director

diamond

What is Diamond ?

- The largest scientific facility to be built in the UK for 40 years
- The world’s largest medium energy, “third generation” synchrotron light source producing laser-like UV and X-ray light beams of exceptional brightness
- A series of ‘super microscopes’ for new research opportunities into the structure and properties of matter

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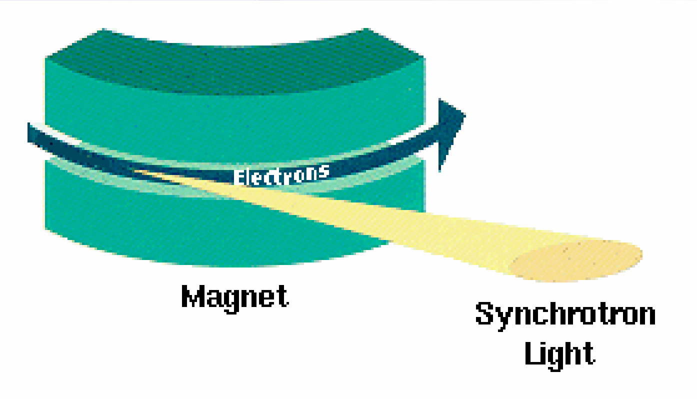
What is Synchrotron Light ?

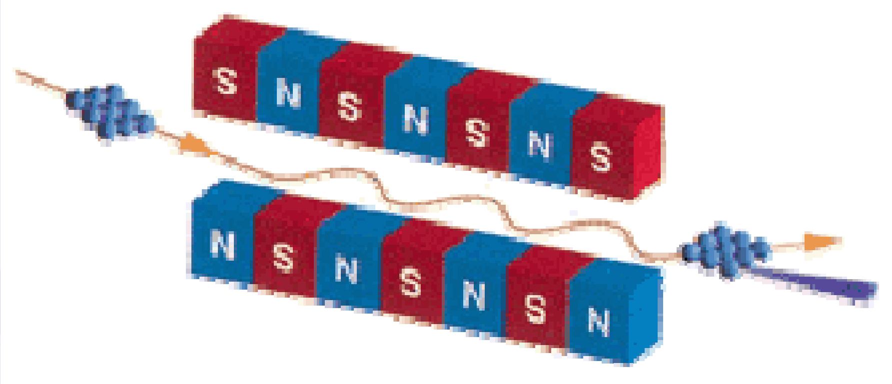
M1 © Caltech/Pasachoff/Malin
Photo from Hale 5mTelescope plates by David Malin

- Synchrotron Light is electromagnetic radiation emitted when a high energy beam of charged particles (electrons) is deflected by a magnetic field

a single bending magnet produces a wide fan of radiation



multiple bends in an "undulator" or "wiggler" magnet give higher intensity and brighter radiation

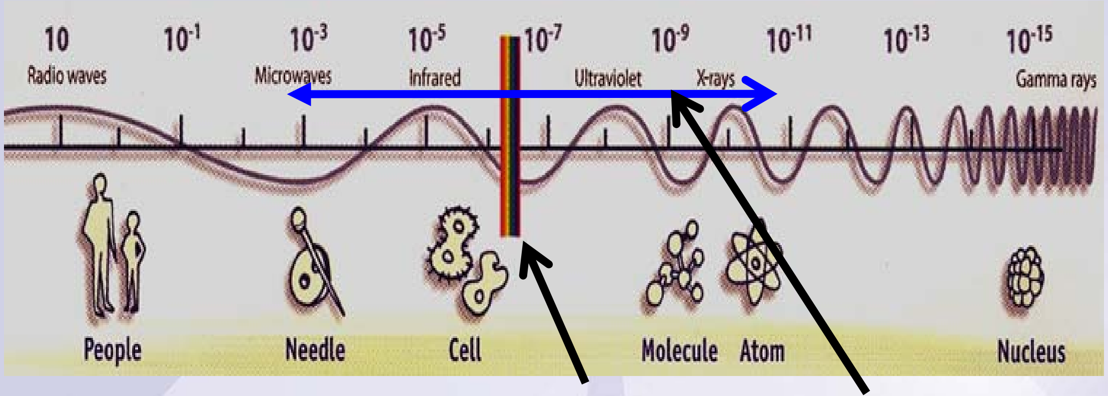


What's so special about Synchrotron Light ?

- **Covers the electromagnetic spectrum from microwaves to hard X-rays:**

  - can select the wavelength required for a given experiment

Wavelength (m)



visible light

synchrotron light

- **Extremely intense and well collimated:**

  - can be focused to sub-micron spot sizes, allows rapid experiments on small and dilute samples

- **Polarised:**

  - adjustable linear/circular polarisation

- **Pulsed time structure:**

  - allows dynamic studies of fast chemical or biological processes (10 -100 ps scale)

What can it be used for ?

Biomedical -	protein crystallography and cell biology;
Medical research -	microbiology, disease mechanisms, high resolution imaging;
Environmental science -	toxicology, atmospheric research, clean combustion and cleaner industrial production technologies;
Agriculture -	plant genomics, soil studies and plant imaging;
Advanced materials -	nanostructured materials, intelligent polymers, ceramics, light metals and alloys, electronic and magnetic materials;
Engineering -	imaging of industrial processes in real time, high resolution imaging of cracks and defects in structures, operation of catalysts in chemical engineering processes;
Forensic Science -	identification from extremely small and dilute samples.
Archaeometry -	ancient metalworking processes, identification of production sites etc.

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A Brief History of Synchrotron Light Sources :

- **Discovery:** 1947, General Electric 70 MeV synchrotron
- **First use for experiments:** 1956, Cornell 300 MeV synchrotron
- **1st generation:**

  machines built for other purposes, mainly High Energy Physics

  e.g. Synchrotron Radiation Facility at the NINA Synchrotron, Daresbury (1971-1977)
- **2nd generation:**

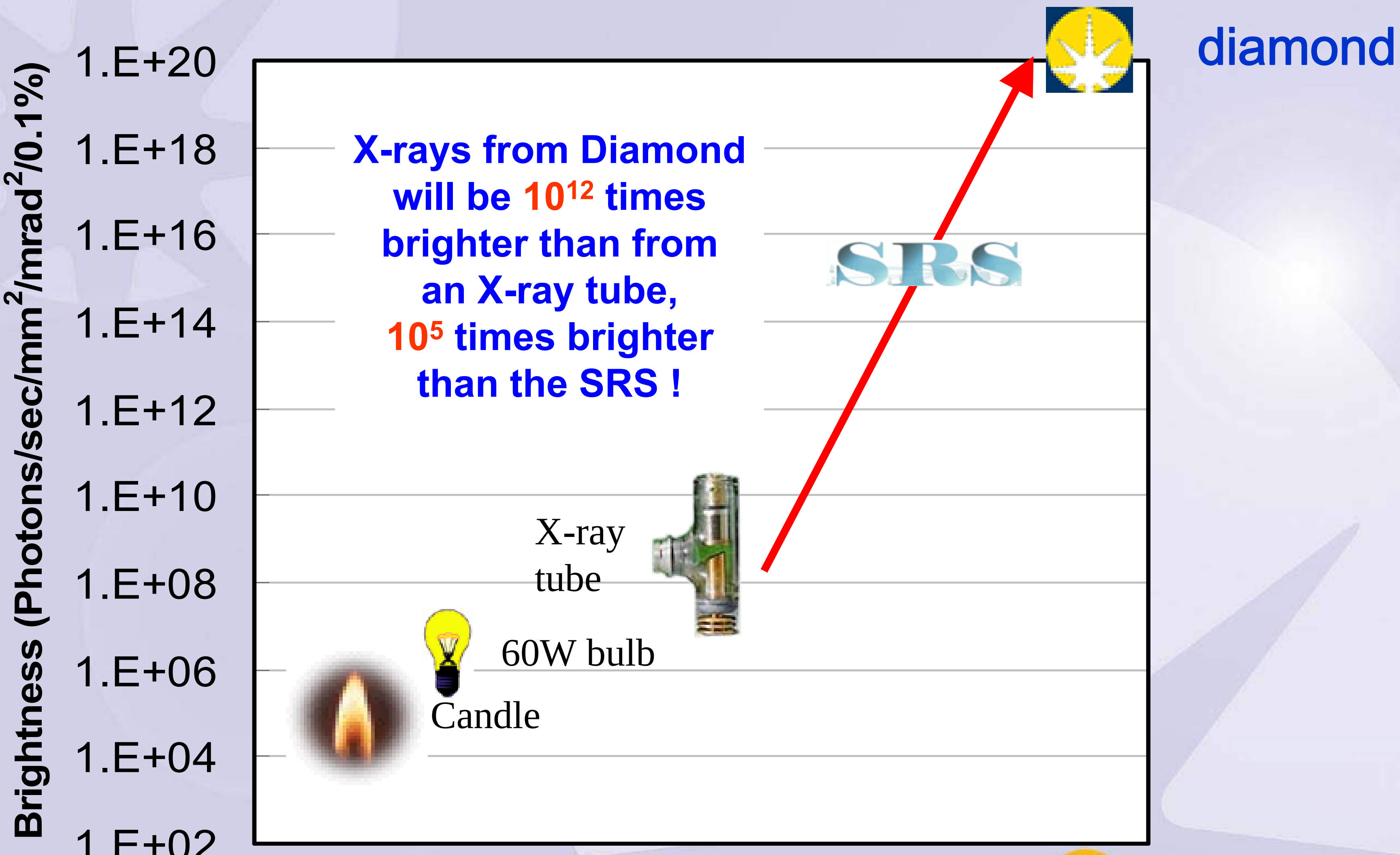
  purpose-built storage rings for synchrotron light

  e.g. the SRS at Daresbury, the world's first dedicated synchrotron X-ray source (1981-2008)
- **3rd generation:**

  higher brightness synchrotron light sources, using mainly undulators as the X-ray source

  e.g. ESRF, Diamond etc.

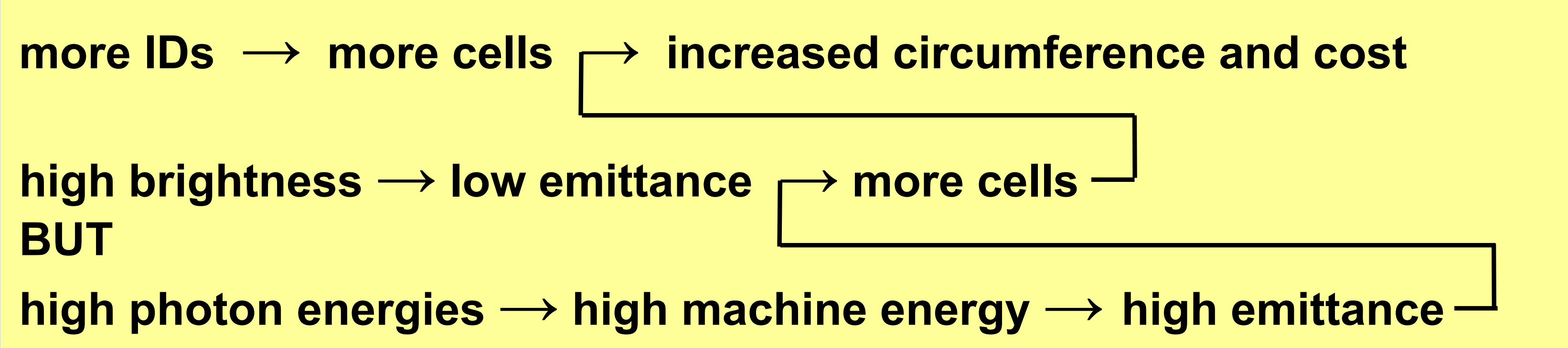
The figure-of-merit is Brightness …



X-rays from Diamond will be 10^{12} times brighter than from an X-ray tube, 10^{5} times brighter than the SRS !

Diamond Design Criteria

- Large number of Insertion Device beamlines
- High brightness from undulators optimised in the range
- 0.1-10 keV, extending to 15-20 keV
- High flux from wigglers from 20-100 keV
- Cost constraint



more IDs → more cells → increased circumference and cost

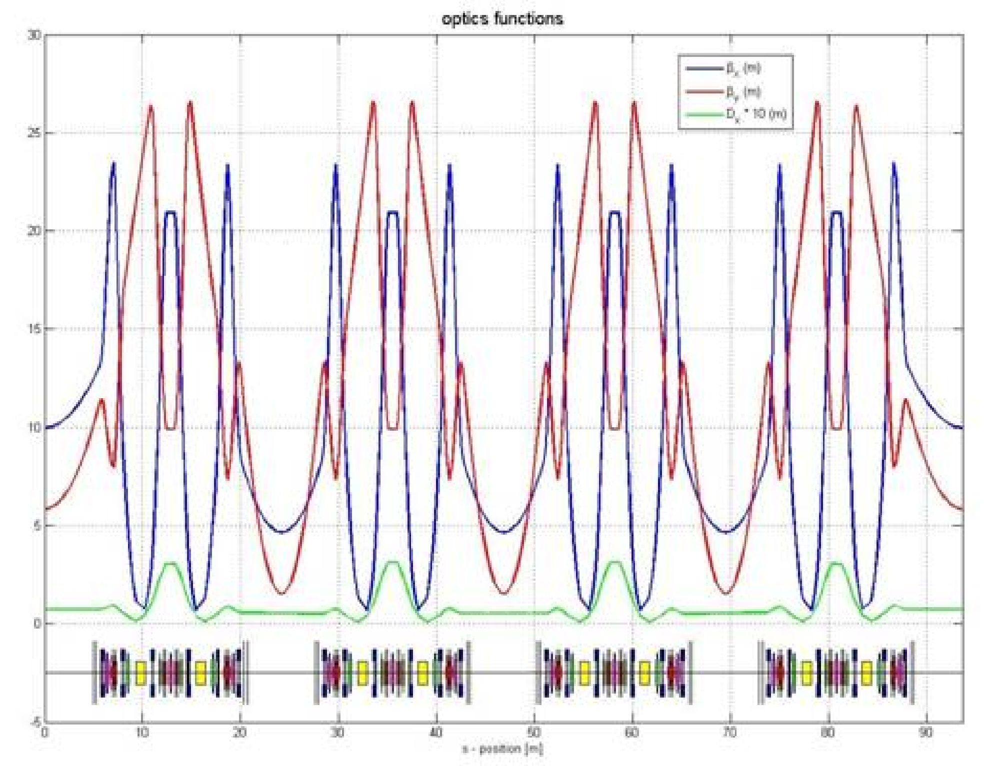
high brightness → low emittance → more cells

BUT

high photon energies → high machine energy → high emittance

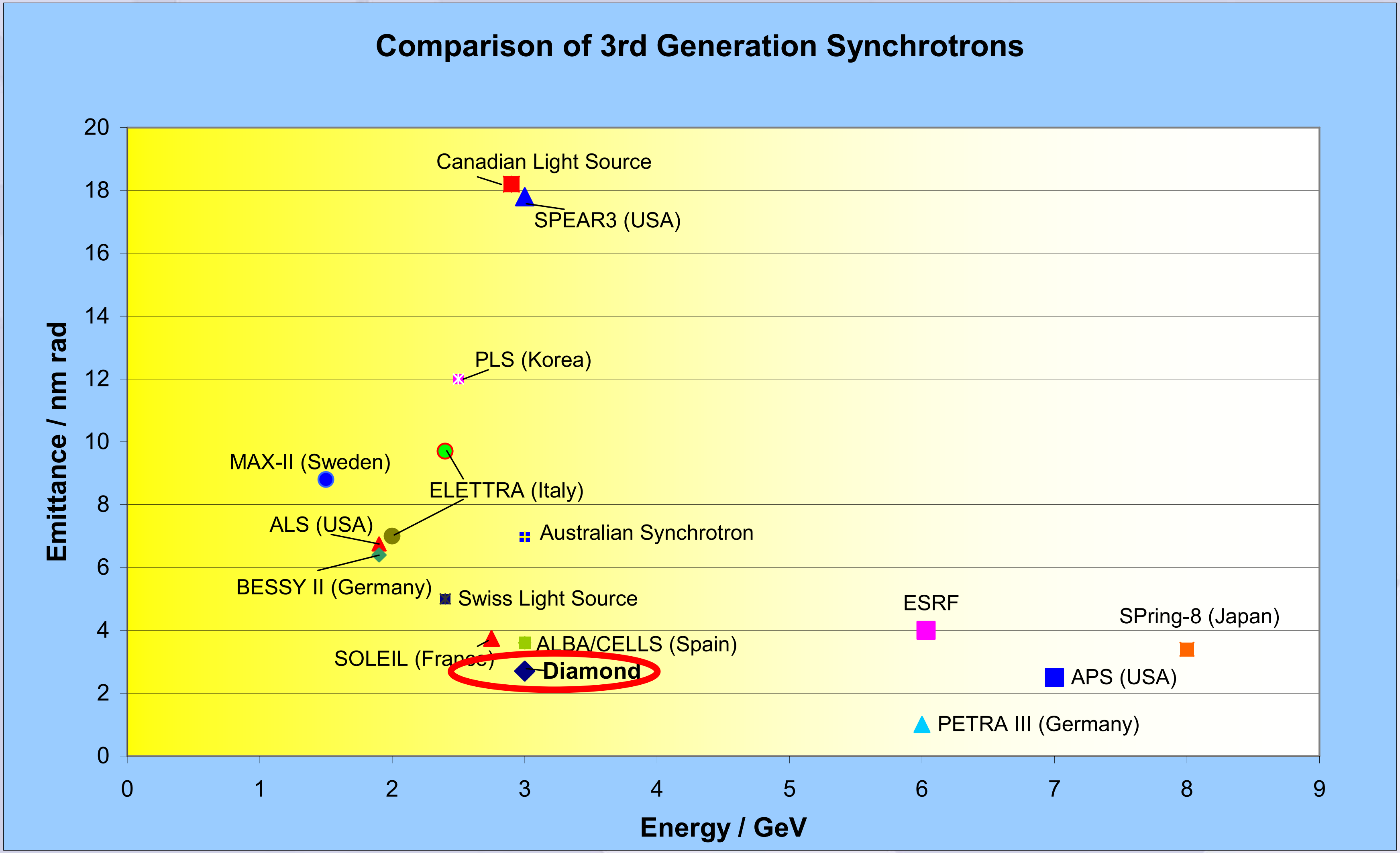
- "Medium" energy of 3 GeV
- Relatively large circumference (562 m) and no. of cells (24)
- Extensive use of in-vacuum undulators

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**
Emittance (h, v)	**2.7, 0.03 nm rad**
Lifetime	**> 10 h**
Min. ID gap	**7 mm**
Beam size (h, v)	**123, 6 μm**
Beam divergence (h, v) *(at centre of 5 m ID)*	**24, 4 μrad**

Comparison of 3rd Generation Synchrotrons
Emittance / nm rad
Energy / GeV
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
Canadian Light Source
SPEAR3 (USA)
PLS (Korea)
MAX-II (Sweden)
ELETTRA (Italy)
ALS (USA)
Australian Synchrotron
BESSY II (Germany)
Swiss Light Source
ESRF
SPring-8 (Japan)
ALBA/CELLS (Spain)
SOLEIL (France)
Diamond
APS (USA)
PETRA III (Germany)

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Diamond compared to SRS

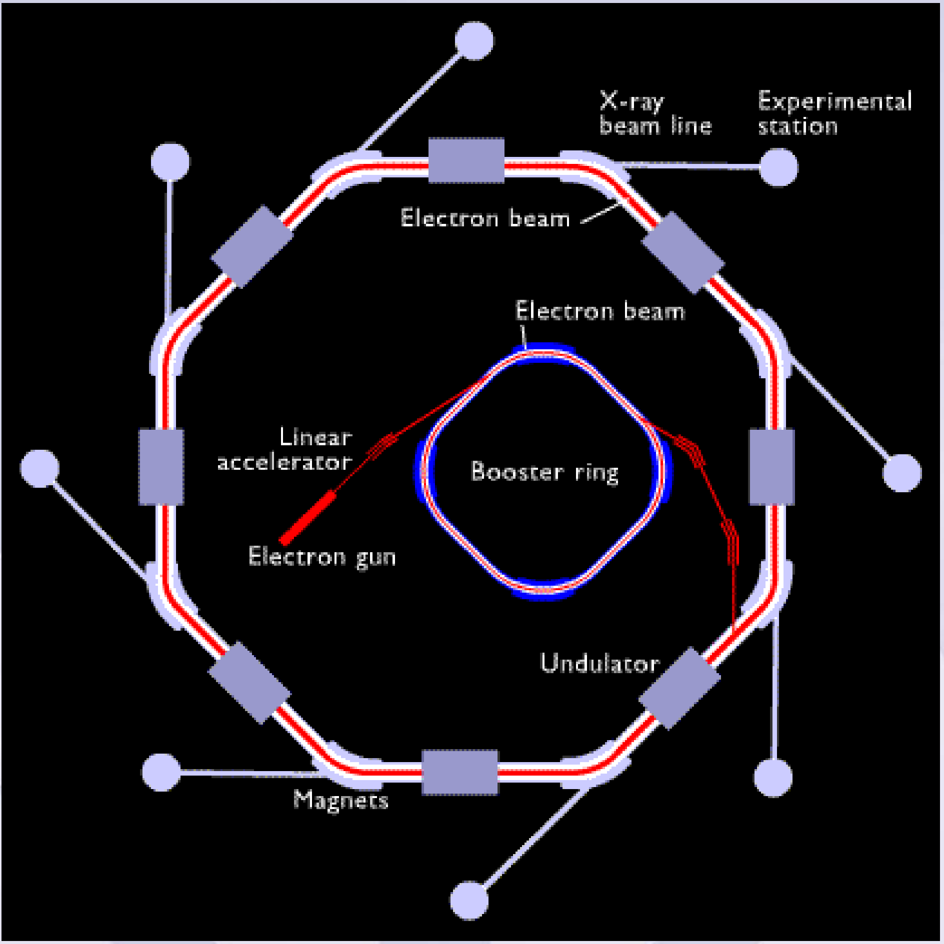
	SRS	Diamond
Electron Beam Energy	2 GeV	3 GeV
Storage ring circumference	96.0 m	561.6 m
Available space for Insertion Devices	6x1m	4x8m, 18x5m
Beam current	250 mA	300 mA
Emittance (hor., vert.) (nm rad)	190, 3.8	2.7, 0.03
Minimum ID gap	20 mm	7 mm
Electron beam sizes (hor., vert) (μm)	1000, 160	123, 6
Electron beam divergences (hor., vert)	590, 60	24, 4 μrad
Peak brightness*	$3\ 10^{15}$	$2\ 10^{20}$
Peak brightness* (1Å)	10^{14}	10^{19}

100,000 increase in brightness

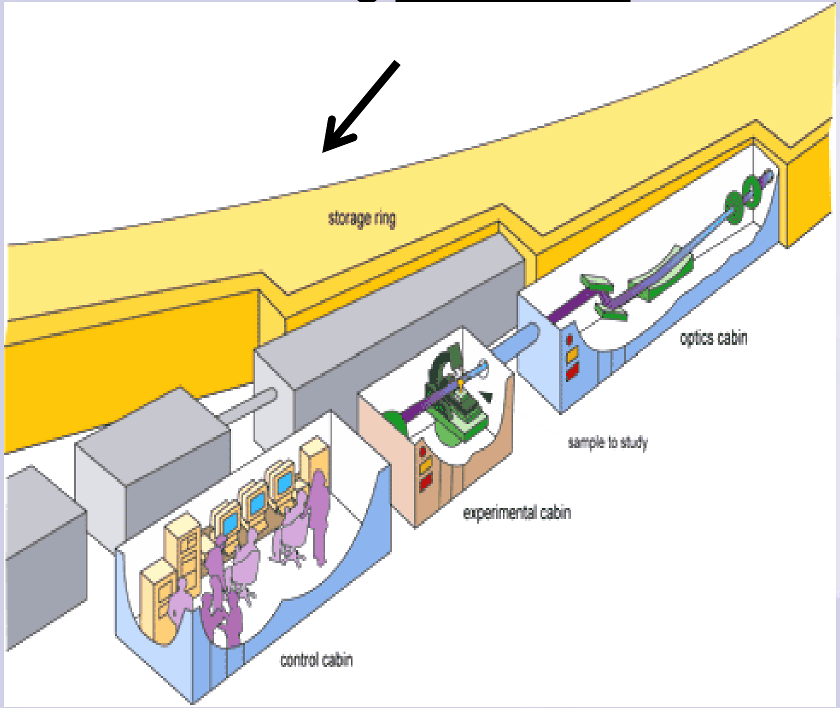
* photons/s/mrad^2/mm^2/0.1%bw

How does it work ?

A beam of electrons is accelerated in a linac, further accelerated in a booster, then accumulated in a storage ring.



The circulating electrons emit intense beams of synchrotron light that are sent along beamlines to the



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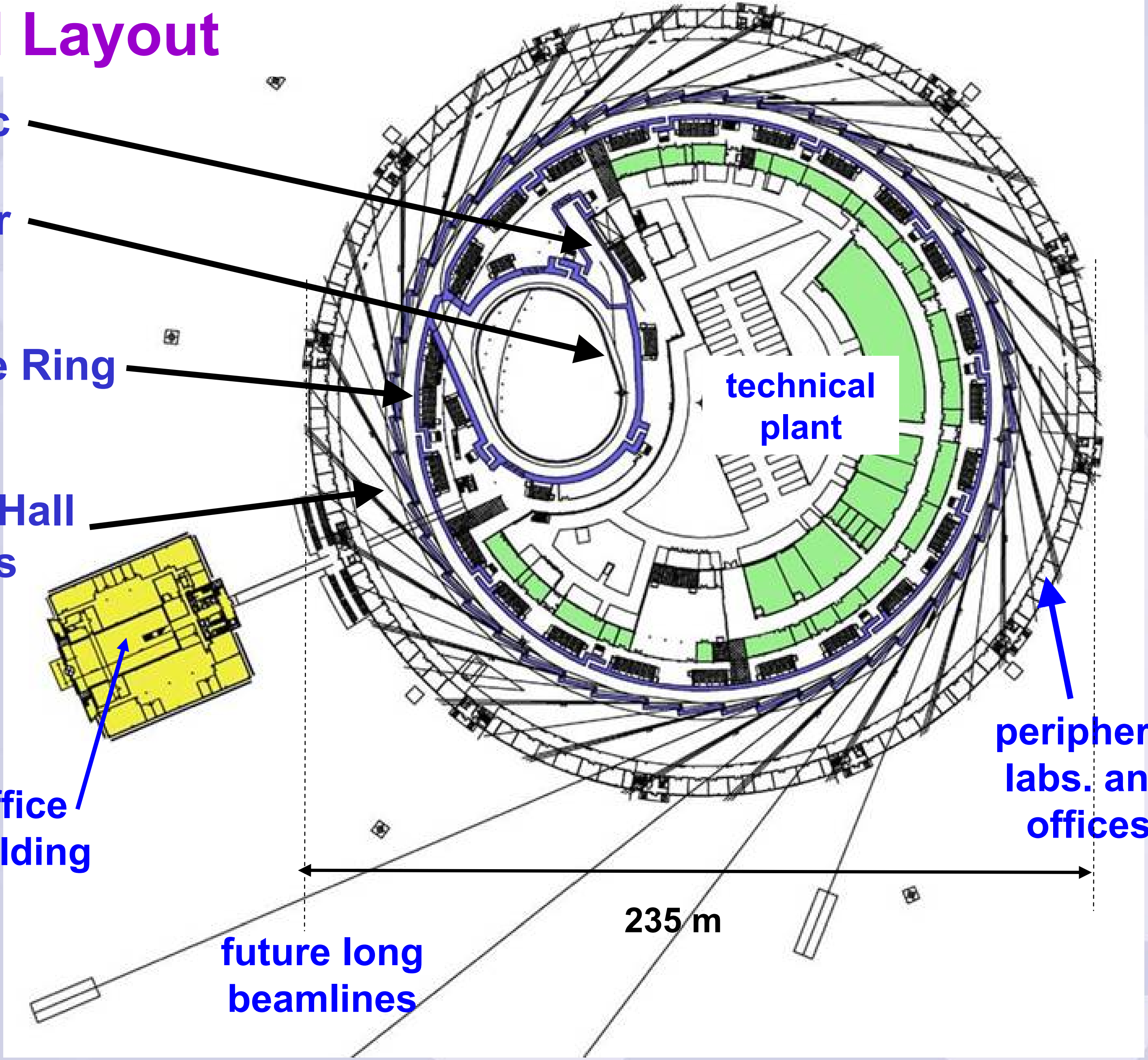
Diamond Layout



100 MeV Linac

3 GeV Booster
C = 158.4 m

3 GeV Storage Ring
C = 562.6 m

Experimental Hall and Beamlines

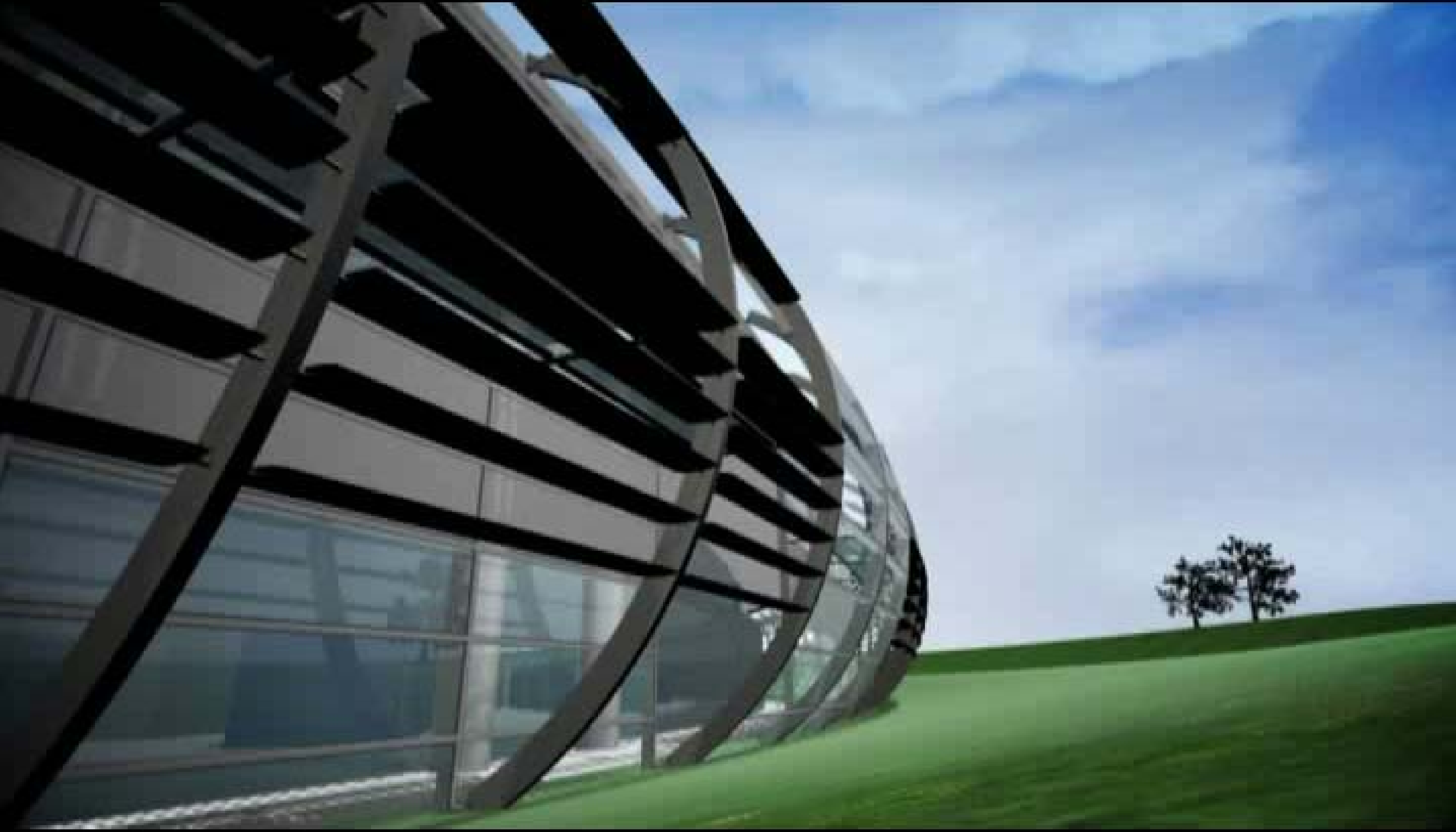
technical plant

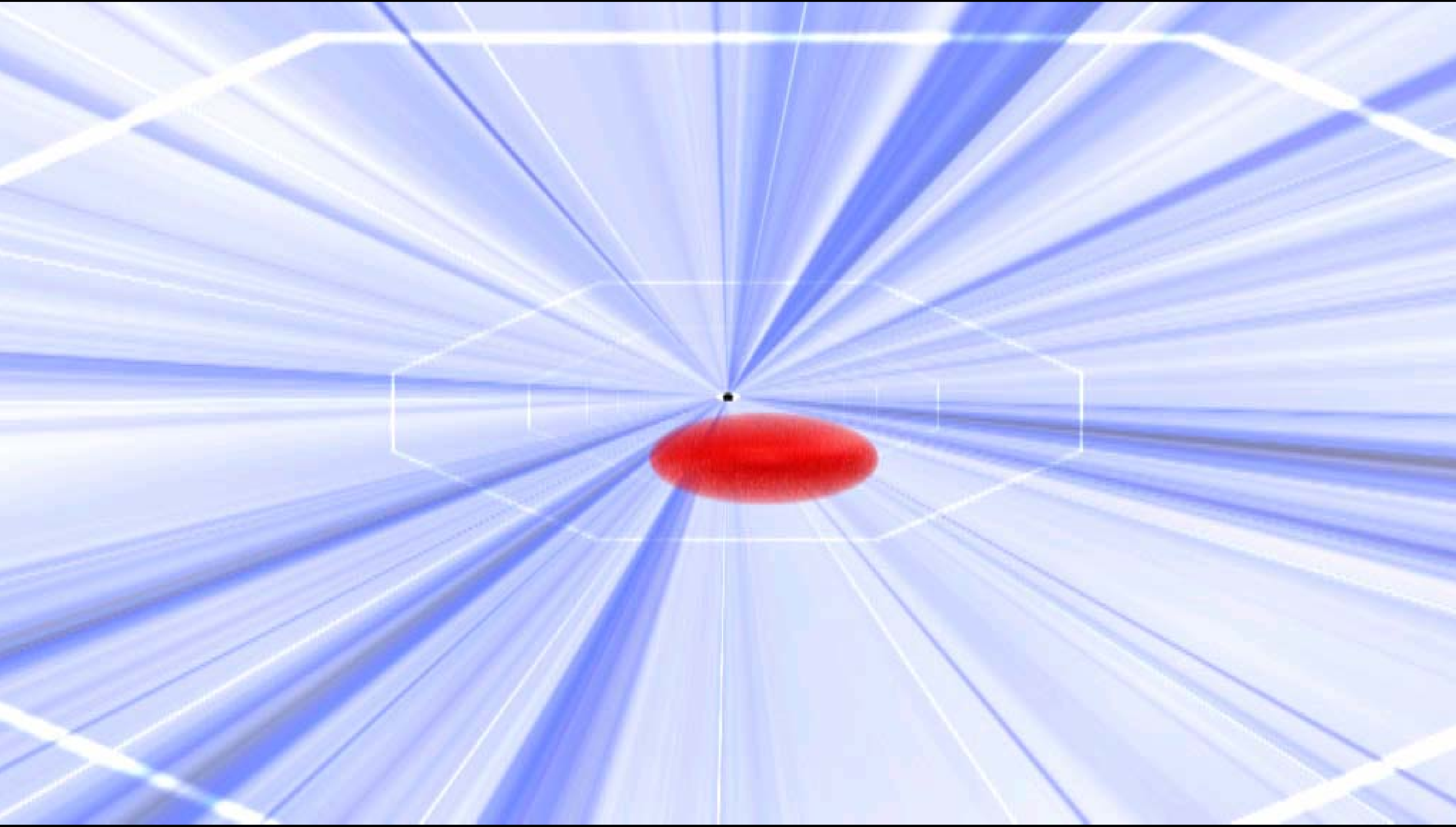
office building

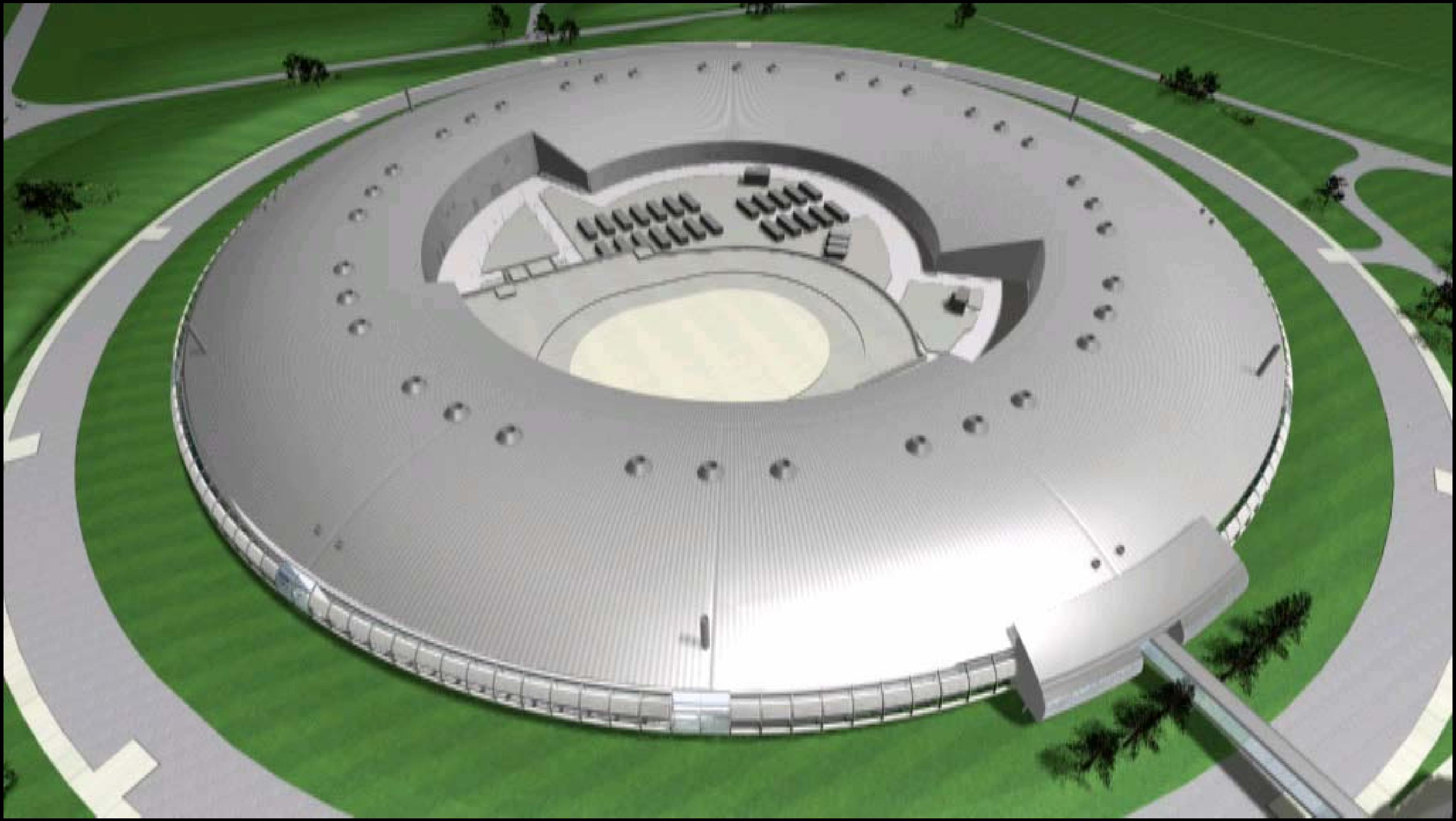
peripheral labs. and offices

future long beamlines

235 m







Diamond Key Dates

1993	Woolfson Review: new facility needed to replace the SRS
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
Jan. '07	Start of Operations
19th Oct. 2007	Official Opening

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Who we are:

Diamond Light Source Ltd. Shareholders

Science & Technology Facilities Council **86 %**

The Science and Technology Facilities Council is an independent, non-departmental public body of the Office of Science and Innovation, which is part of the Department of Trade and Industry. It was formed as a new Research Council on 1 April 2007.

wellcome trust **14 %**

The Wellcome Trust is an independent charity funding research to improve human and animal health. It is the UK's largest non-governmental source of funds for biomedical research.

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June 2003

Sep. 2003

June 2004

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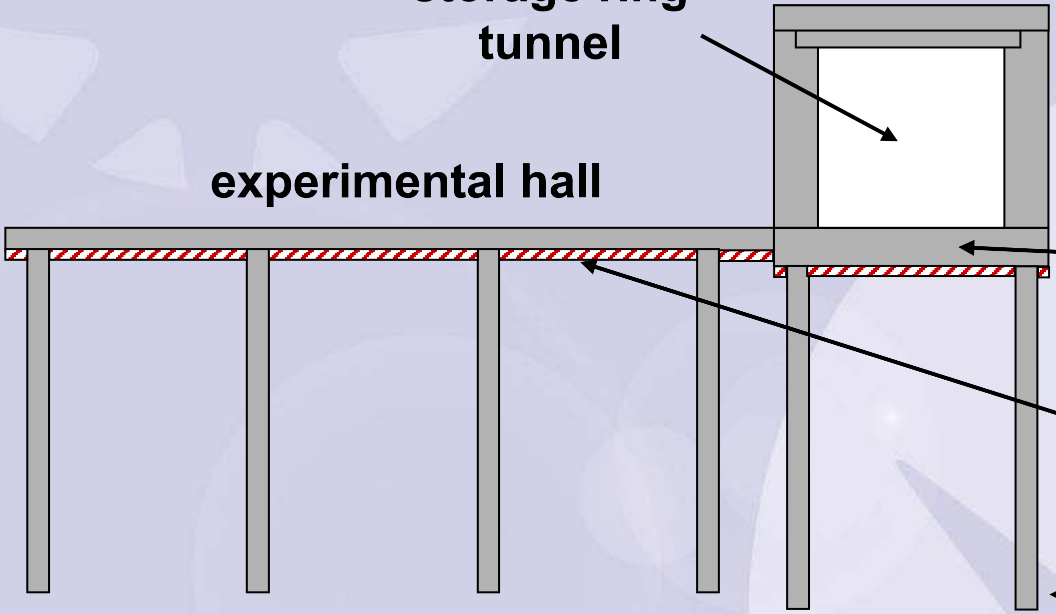
October 2005

Engineering Challenges

Foundations – designed to minimise ground movement, and transmission of vibrations

piling rig:



storage ring tunnel

experimental hall

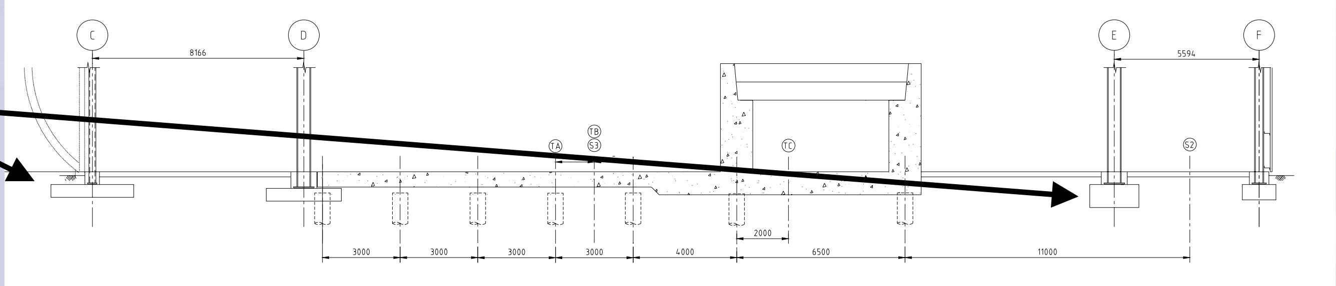
0.6-0.85 m thick concrete slab

void to isolate slab from the ground

1523 piles, 12-15 m deep

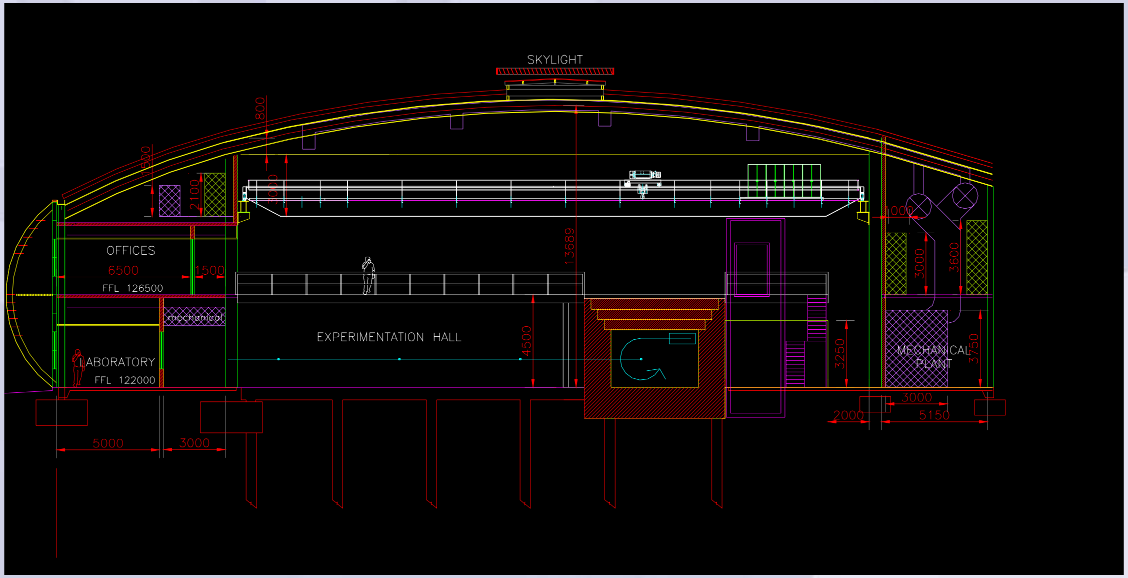
600 mm diam., 3 m apart

separate non-piled foundation for the building structure and plant rooms



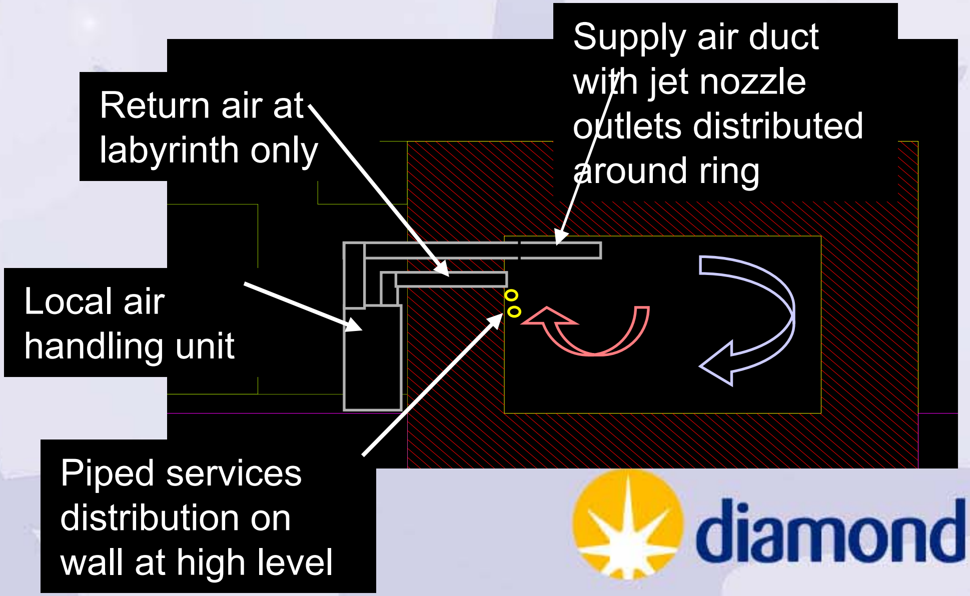
Concrete shielding walls cast to 5 mm tolerances :

Buildings and services: designed for thermal stability:



experimental hall +/- 1 °C

storage ring tunnel +/- 0.5 °C



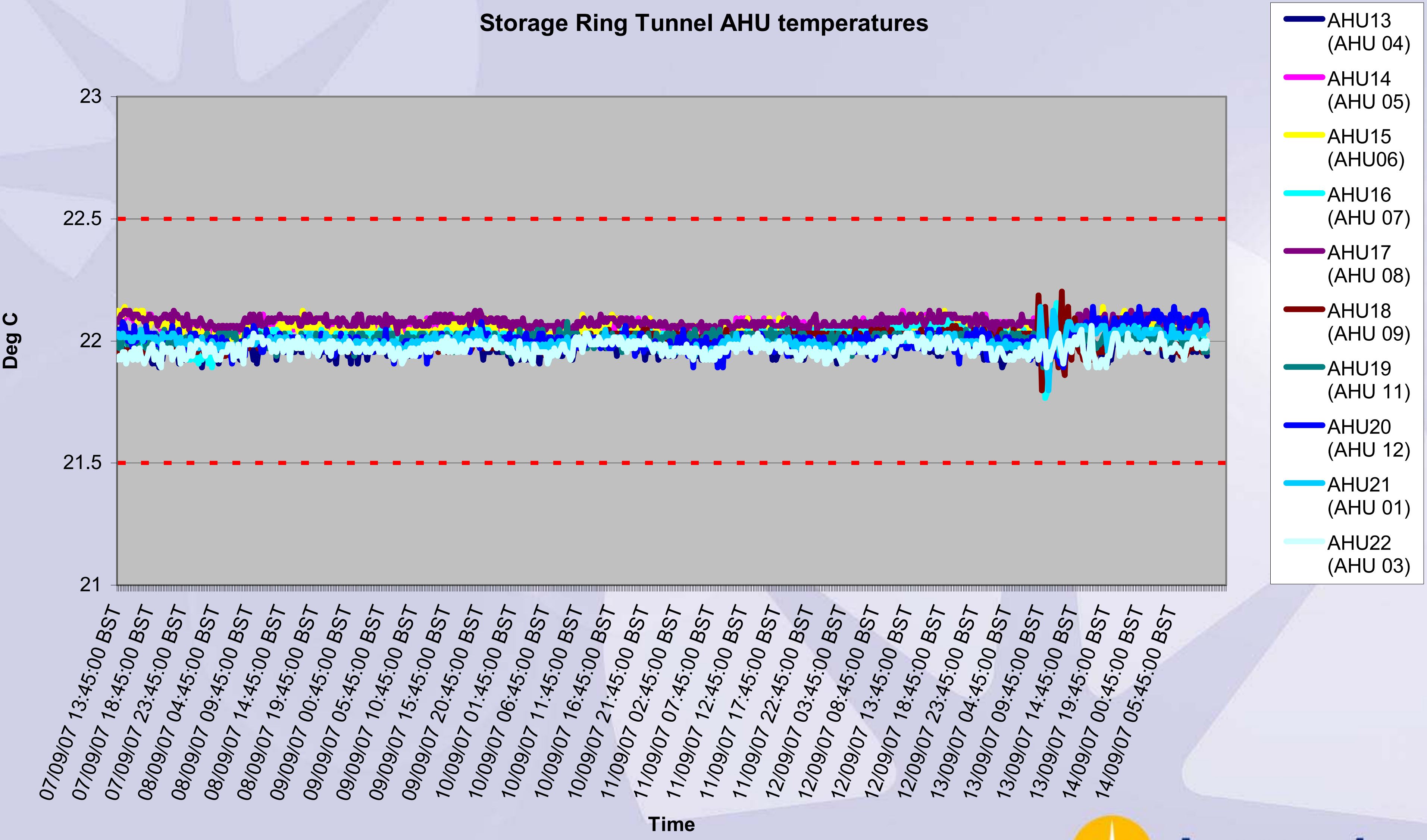
Return air at labyrinth only

Supply air duct with jet nozzle outlets distributed around ring

Local air handling unit

Piped services distribution on wall at high level

Courtesy of JacobsGibb Ltd.


Storage Ring Tunnel AHU temperatures
23
22.5
22
21.5
21
Deg C
Time
07/09/07 13:45:00 BST
07/09/07 18:45:00 BST
07/09/07 23:45:00 BST
08/09/07 04:45:00 BST
08/09/07 09:45:00 BST
08/09/07 14:45:00 BST
08/09/07 19:45:00 BST
09/09/07 00:45:00 BST
09/09/07 05:45:00 BST
09/09/07 10:45:00 BST
09/09/07 15:45:00 BST
09/09/07 20:45:00 BST
10/09/07 01:45:00 BST
10/09/07 06:45:00 BST
10/09/07 11:45:00 BST
10/09/07 16:45:00 BST
10/09/07 21:45:00 BST
11/09/07 02:45:00 BST
11/09/07 07:45:00 BST
11/09/07 12:45:00 BST
11/09/07 17:45:00 BST
11/09/07 22:45:00 BST
12/09/07 03:45:00 BST
12/09/07 08:45:00 BST
12/09/07 13:45:00 BST
12/09/07 18:45:00 BST
12/09/07 23:45:00 BST
13/09/07 04:45:00 BST
13/09/07 09:45:00 BST
13/09/07 14:45:00 BST
13/09/07 19:45:00 BST
14/09/07 00:45:00 BST
14/09/07 05:45:00 BST
AHU13 (AHU 04)
AHU14 (AHU 05)
AHU15 (AHU06)
AHU16 (AHU 07)
AHU17 (AHU 08)
AHU18 (AHU 09)
AHU19 (AHU 11)
AHU20 (AHU 12)
AHU21 (AHU 01)
AHU22 (AHU 03)

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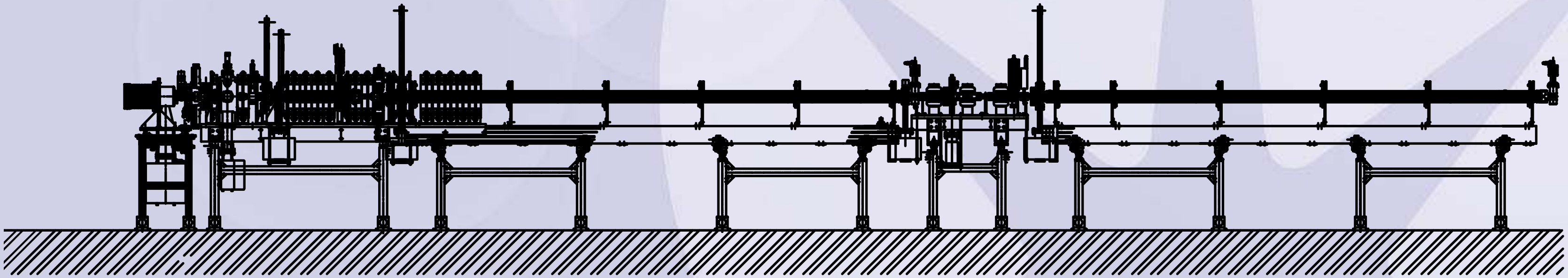
Linac

- 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



Linac Commissioning

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

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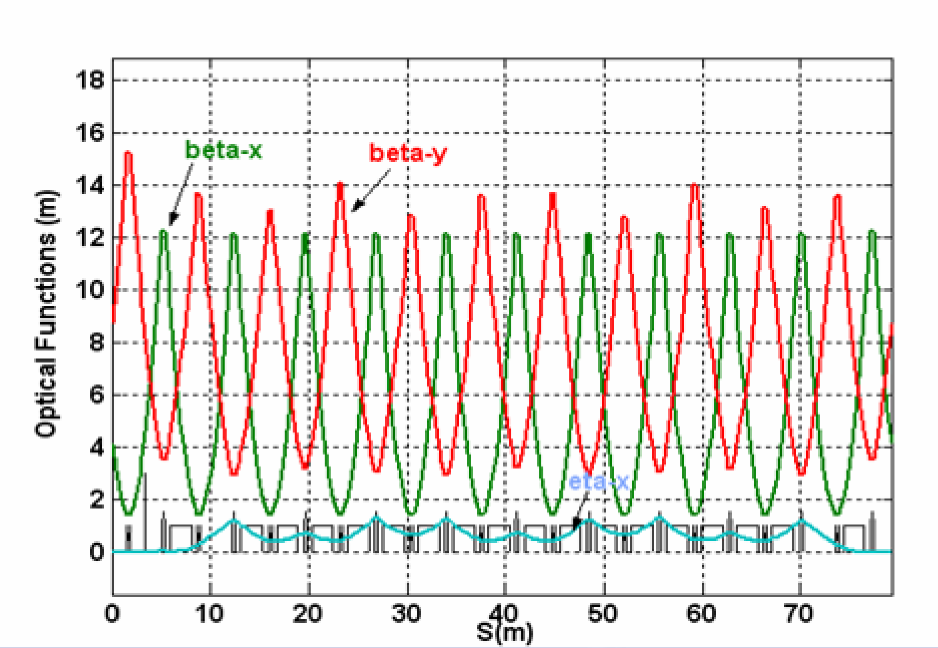
Linac Performance

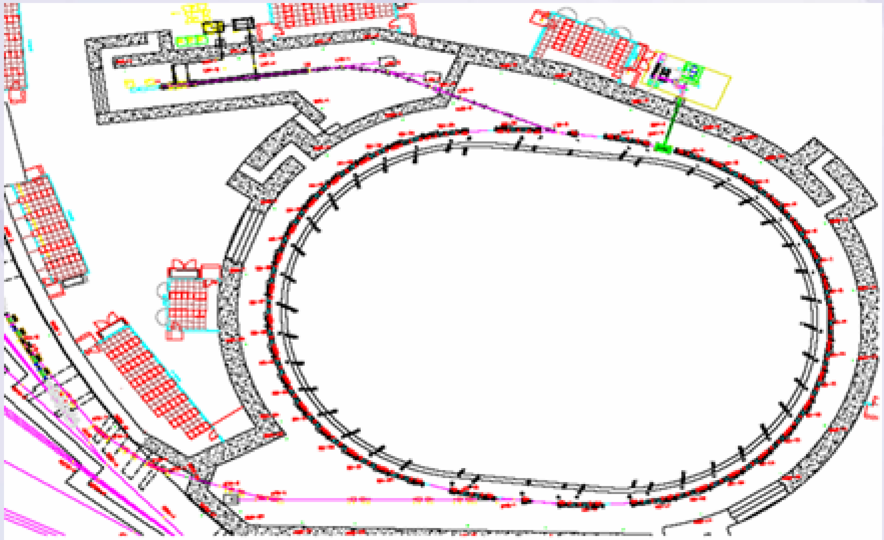
Parameter	**Specification**	**Single bunch**	**Multi bunch**
Energy [MeV]	> 100	103	103
x norm. emittance [π.mm.mrad]	< 50	18	16
y norm. emittance [π.mm.mrad]	< 50	27	11
Charge [nC]	> 1.5 / 3.0	2.1	4.8
Pulse width [ns]	< 1	~ 0.2 fwhm	~ 0.2 fwhm
Jitter [ps]	< 100	11	11
Energy variation [%]	< 0.25	0.05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

Booster

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





Booster Commissioning

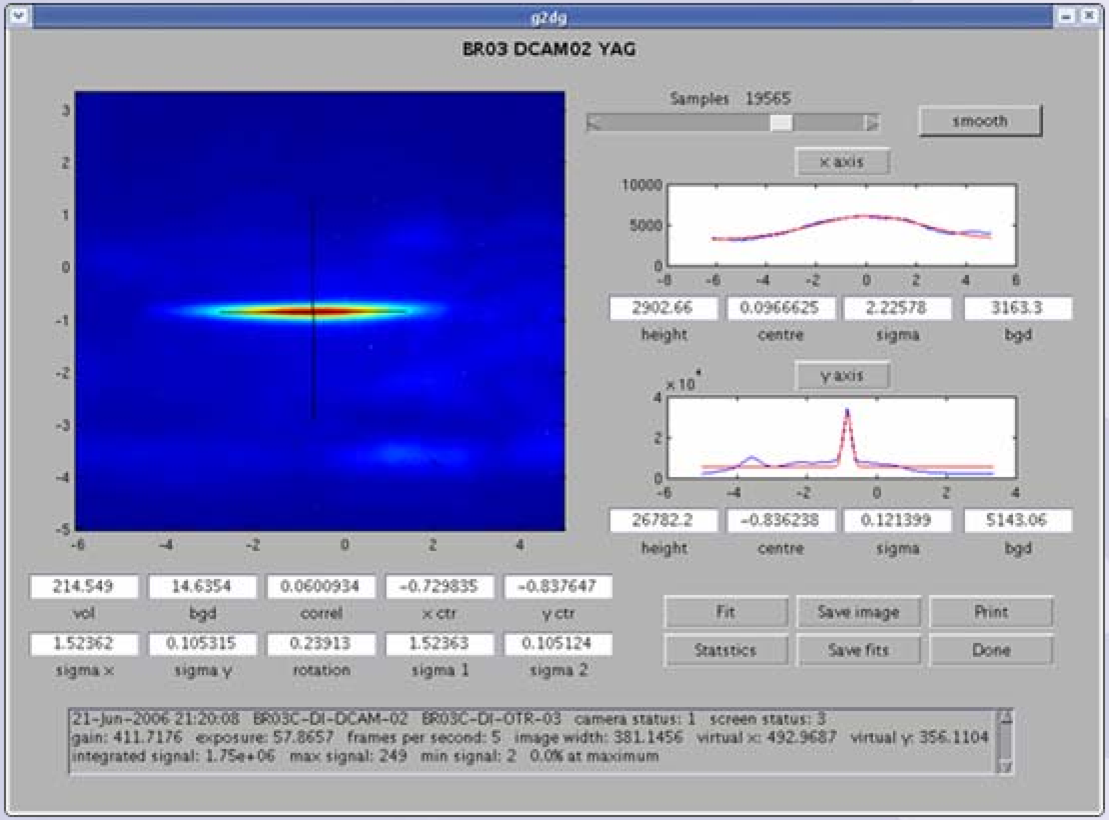
1st turn, 100 MeV: Dec. 21st 2005

Acceleration to 700 MeV: Mar. 10th 2006

Extraction at 700 MeV: Apr. 4th 2006

limited by lack of water cooling

Acceleration and extraction at 3 GeV: Jun. 9th 2006



2902.66	0.0966625	2.22578	3163.3
height	centre	sigma	bgd
26782.2	-0.836238	0.121399	5143.06
height	centre	sigma	bgd

214.549	14.6354	0.0600934	-0.729835	-0.837647
vol	bgd	correl	x ctr	y ctr
1.52362	0.105315	0.23913	1.52363	0.105124
sigma x	sigma y	rotation	sigma 1	sigma 2

```
21-Jun-2006 21:20:08   BR03C-DI-DCAM-02   BR03C-DI-OTR-03   camera status: 1   screen status: 3
gain: 411.7176   exposure: 57.8657   frames per second: 5   image width: 381.1456   virtual x: 492.9687   virtual y: 356.1104
integrated signal: 1.75e+06   max signal: 249   min signal: 2   0.0% at maximum
```

Extracted beam at 3 GeV

σ_x=1.5 mm

σ_y=0.11 mm

in agreement with theory (2% coupling)

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Storage Ring

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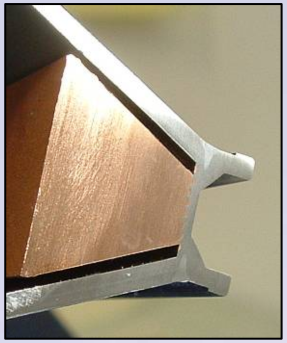
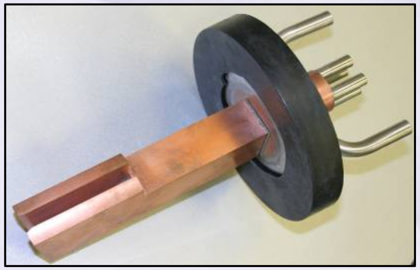
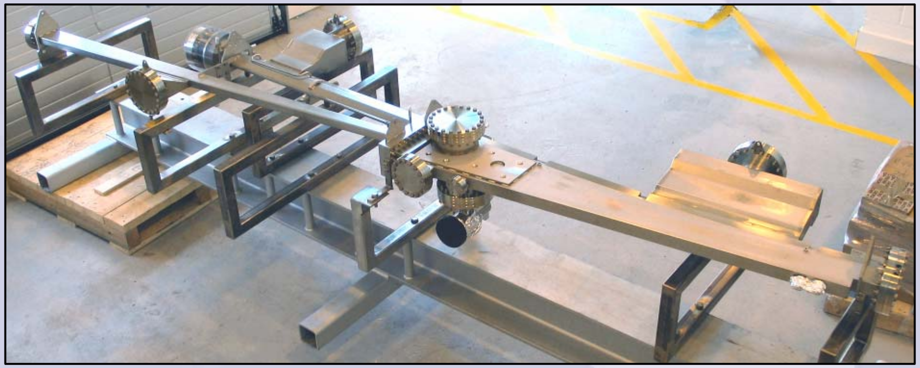
Vacuum System

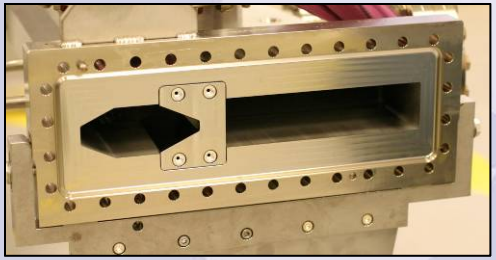


- **The 562 m circumference storage ring has to be maintained at a pressure of 10^{-9} mbar or lower (Ultra-High Vacuum) to reduce beam losses from collisions of circulating electrons with residual gas molecules.**

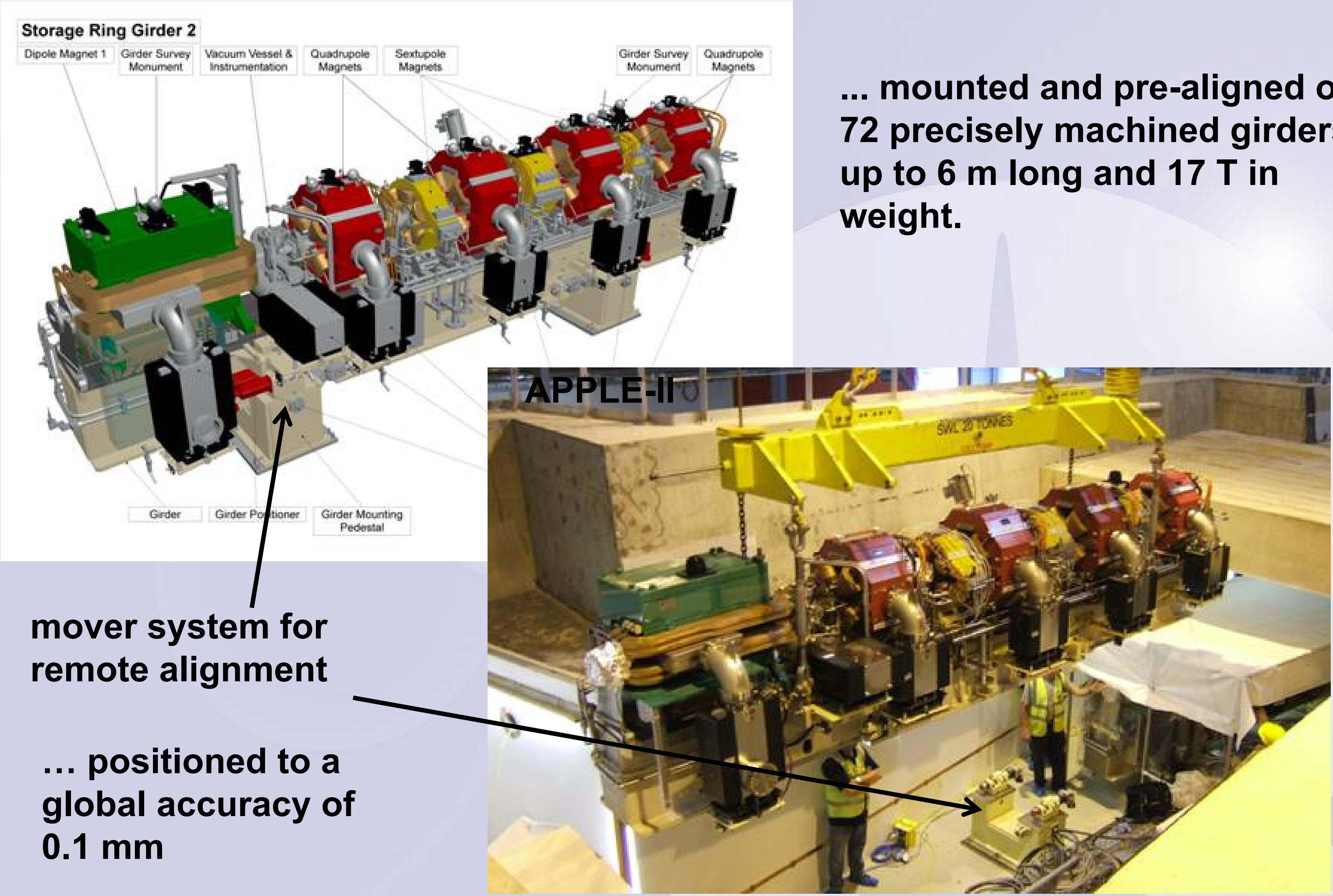


- **This sets a number of vacuum engineering challenges:**
  - **UHV compatible materials** (316LN stainless steel, OFHC copper, extruded aluminium)
  - **Reliable joining techniques** (TIG welding,electron beam welding, vacuum brazing, explosion bonding)
  - **Quality control** (material traceability, ultrasonic testing, radiography, helium leak testing etc.)
  - **Clean assembly and installation**





Magnets and Vacuum Chambers



... mounted and pre-aligned on 72 precisely machined girders, up to 6 m long and 17 T in weight.

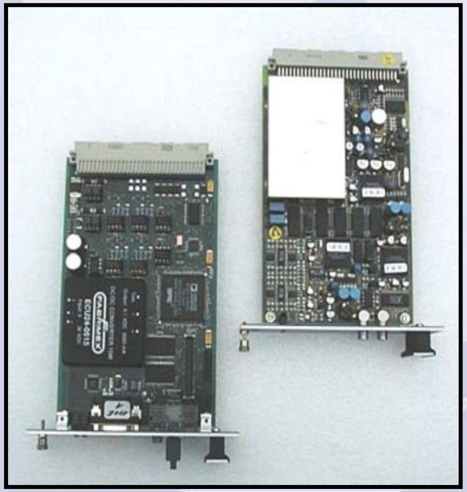
mover system for remote alignment

… positioned to a global accuracy of 0.1 mm

Power Converters

Type	Number	Current (A)	Voltage (V)	Bandwidth (Hz)
SR Dipole	1	1500	530	DC
Booster Dipole	1	1000	2000	5
Booster Quadrupole	2	200	421	5
Booster Sextupole	2	20	60	5
Medium Power Supplies	437	350/200/100	41/28/17	DC
Slow Corrector Type	544	5	20	50
LTB Quads.	10	20	55	1000*
Pulsed Power Supplies	10	85-15,000	100-23,000	Pulse

- **highly stable: 10ppm over 8 hours typically**
- **built in redundancy to improve reliability**
- **standardisation of types and modularity to reduce repair time**
- **common digital control interface for ease of commissioning and maintainability**



RadioFrequency System

Supercon-ducting cavities (2+1)

Liquid He plant

3 x IOT-based 300 kW amplifiers

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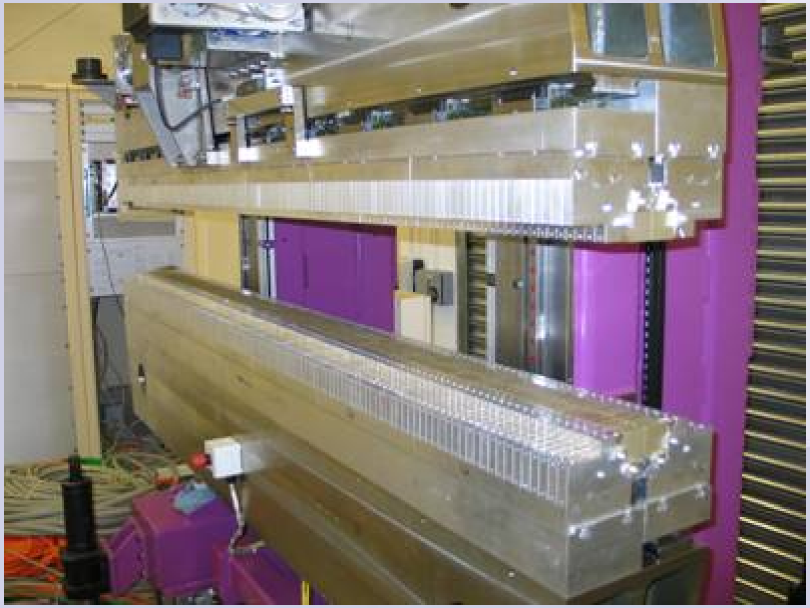
Insertion Devices

6 x in-vacuum devices

APPLE-II



3.5 T s/c wiggler

Control System

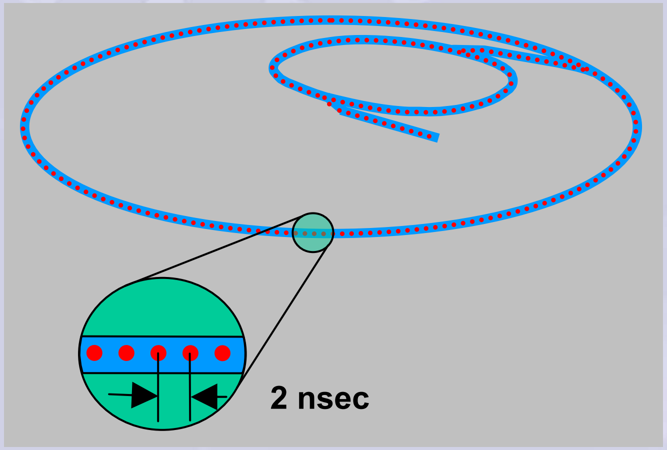
1 control room

265 embedded VME computer systems

450 19” racks

~ 10,000 physical devices

~ 500,000 control and monitoring points

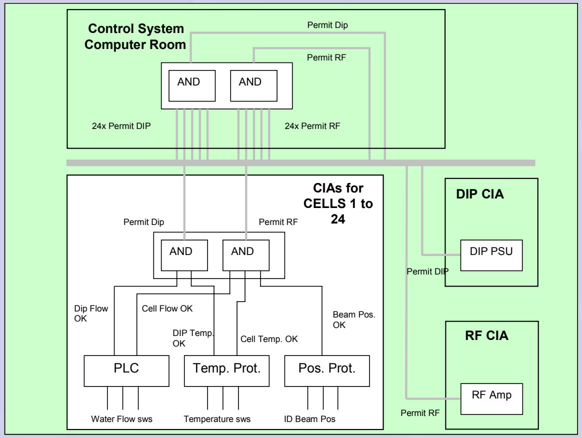


Timing System

Electrons contained in bunches separated by 2 ns

Storage ring contains 936 possible bunches

Timing system allows electrons to be injected reproducibly into any selected bunch



Protection System

> 300 kW of X-rays are produced

In the worst case, this could melt the vacuum chamber in ~ 10 ms

960 interlocks protect the machine, and can “kill” the beam in < 1 ms.

Storage Ring Commissioning – Phase I (700 MeV)

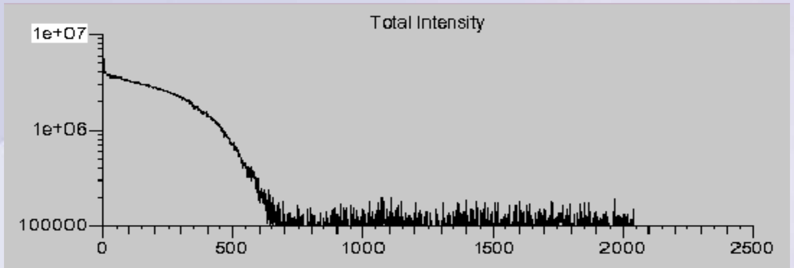
limited by lack of water cooling

May 4th 2006 - first injection in the storage ring

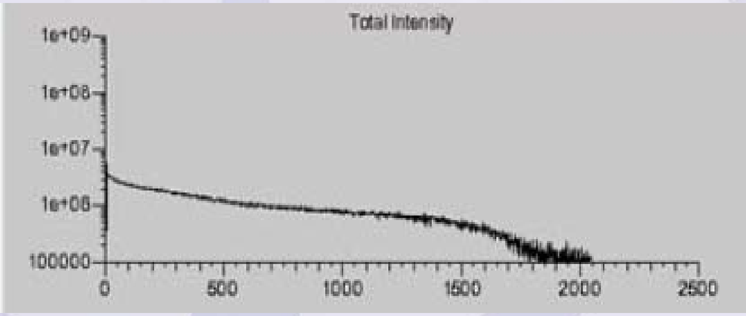
May 5th - first turn *(correctors off)*

May 6th - 4 turns

May 7th – 600 turns *(sext. off, RF off)*

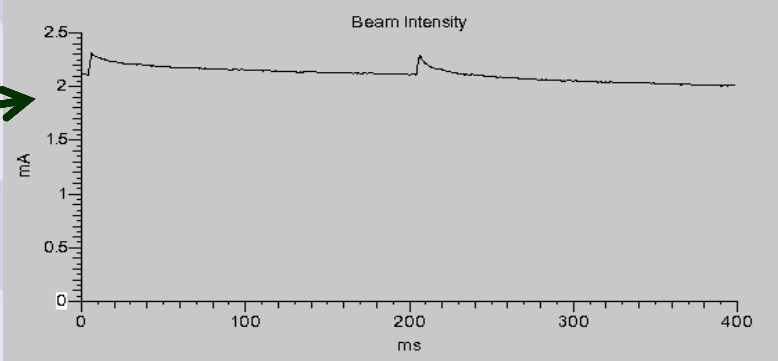


May 20th – 2000 turns *(sext. on, RF off)*



May 22nd – 0.5 mA stored beam (no accumulation)

May 30th – stacking to 2 mA

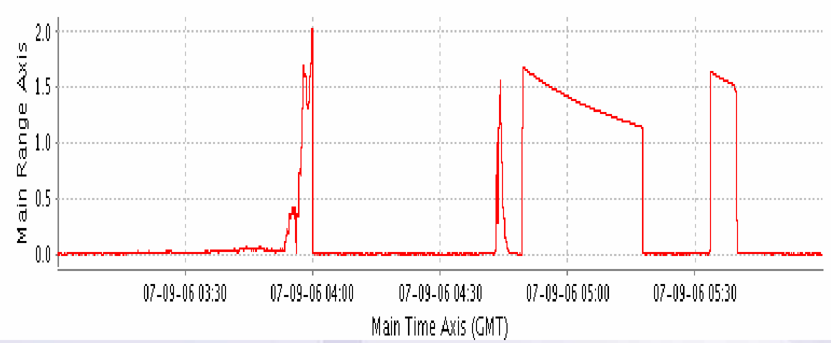


Storage Ring Commissioning – Phase II (3 GeV)

Sep. 4th 2006 – 5 turns, no correctors !

Sep. 5th – 120 turns, RF off

Sep. 6th – RF on .. 2 mA stored;
(limited since absorber water flow interlocks not commissioned ..)



Sep. 9th – 10 mA;
(limited since orbit interlock not commissioned ..)

Sep. 25th – 25 mA

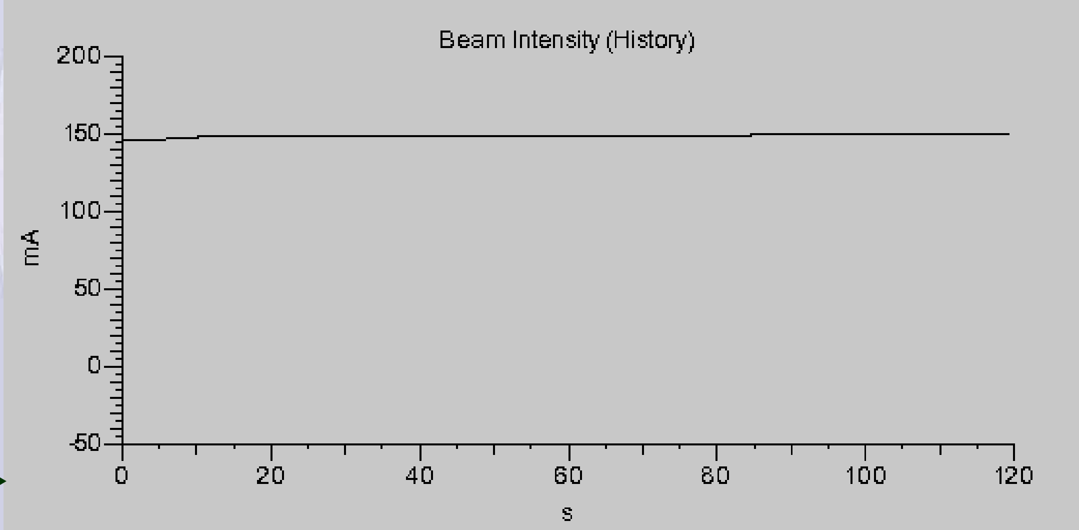
Oct. 2nd – 60 mA

Oct. 10th – 90 mA

Oct. 12th – Start of beamline commissioning

Nov. 11th – 100 mA

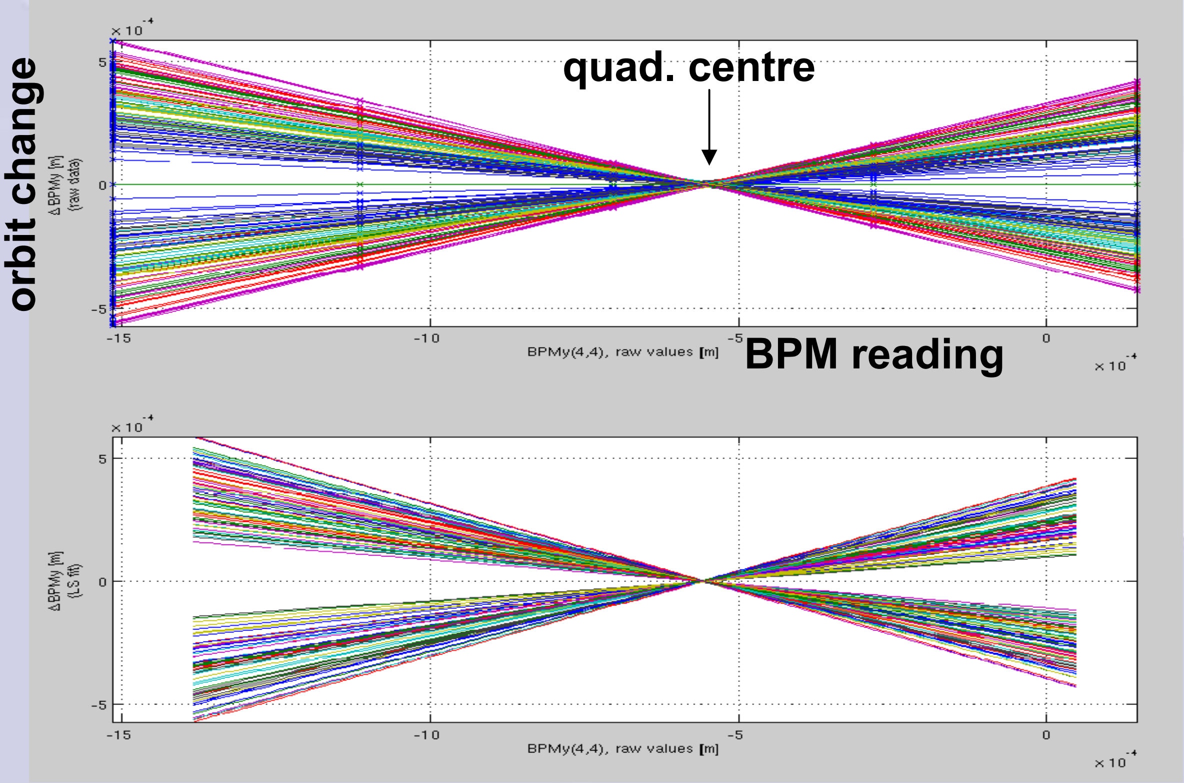
Jan. 12th 2007 – 150 mA



Closed Orbit

Closed orbit initially corrected to 0.7 mm rms in both planes, then “saturated”.

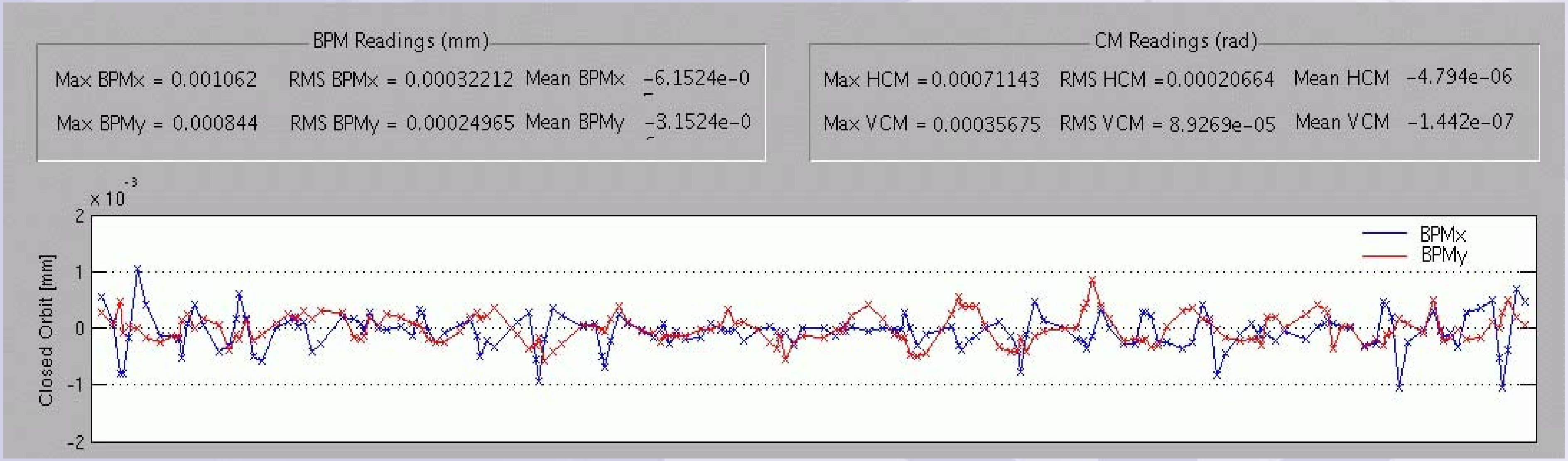
“Beam based alignment” carried out to determine offsets between the BPMs and quadrupole magnet centres.



corrector is varied to find the point that the beam passes through the centre of the adjacent quadrupole

G. Portmann, et al., “An Accelerator Control Middle Layer using MATLAB”, Proc. PAC 2005, p. 4009.

After the 5th iteration, the closed orbit could be corrected to < 1 μm rms (using all correctors):



BPM Readings (mm)

Max BPMx = 0.001062 RMS BPMx = 0.00032212 Mean BPMx -6.1524e-0

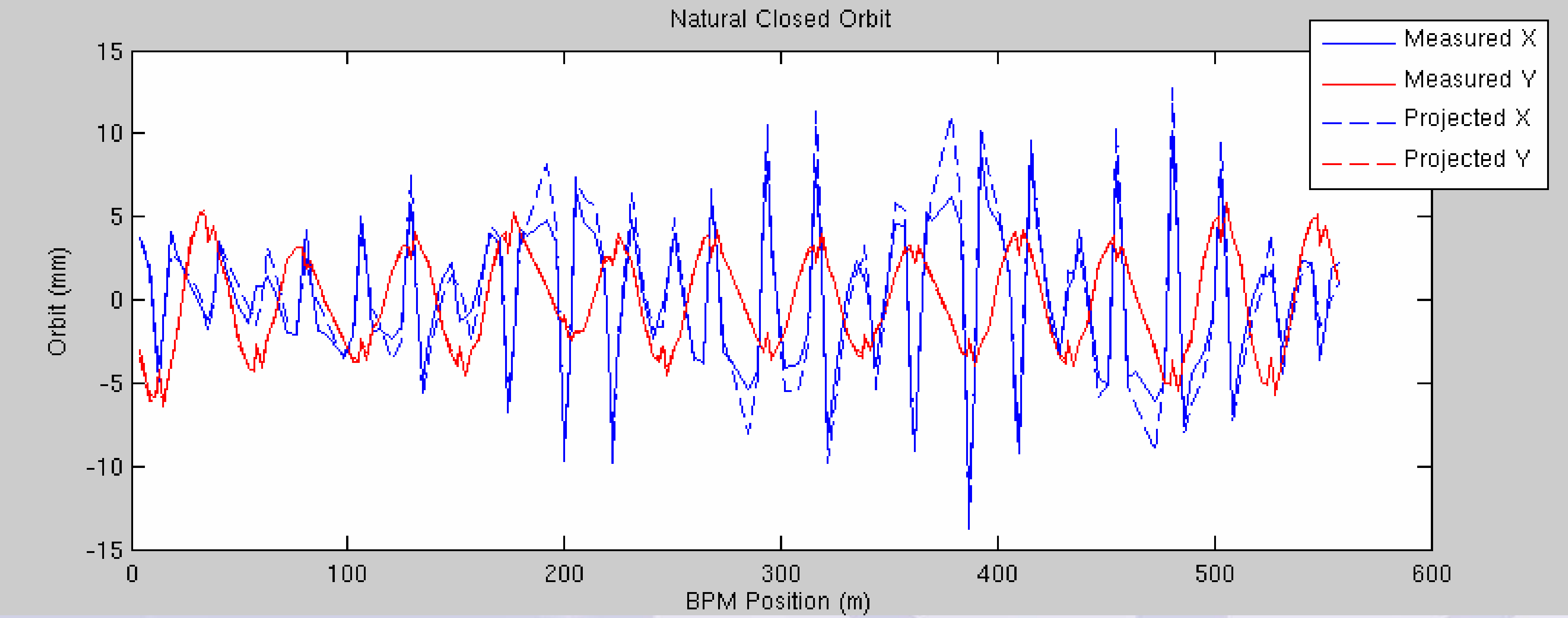
Max BPMy = 0.000844 RMS BPMy = 0.00024965 Mean BPMy -3.1524e-0

CM Readings (rad)

Max HCM = 0.00071143 RMS HCM = 0.00020664 Mean HCM -4.794e-06

Max VCM = 0.00035675 RMS VCM = 8.9269e-05 Mean VCM -1.442e-07

“Bare orbit” – correctors off

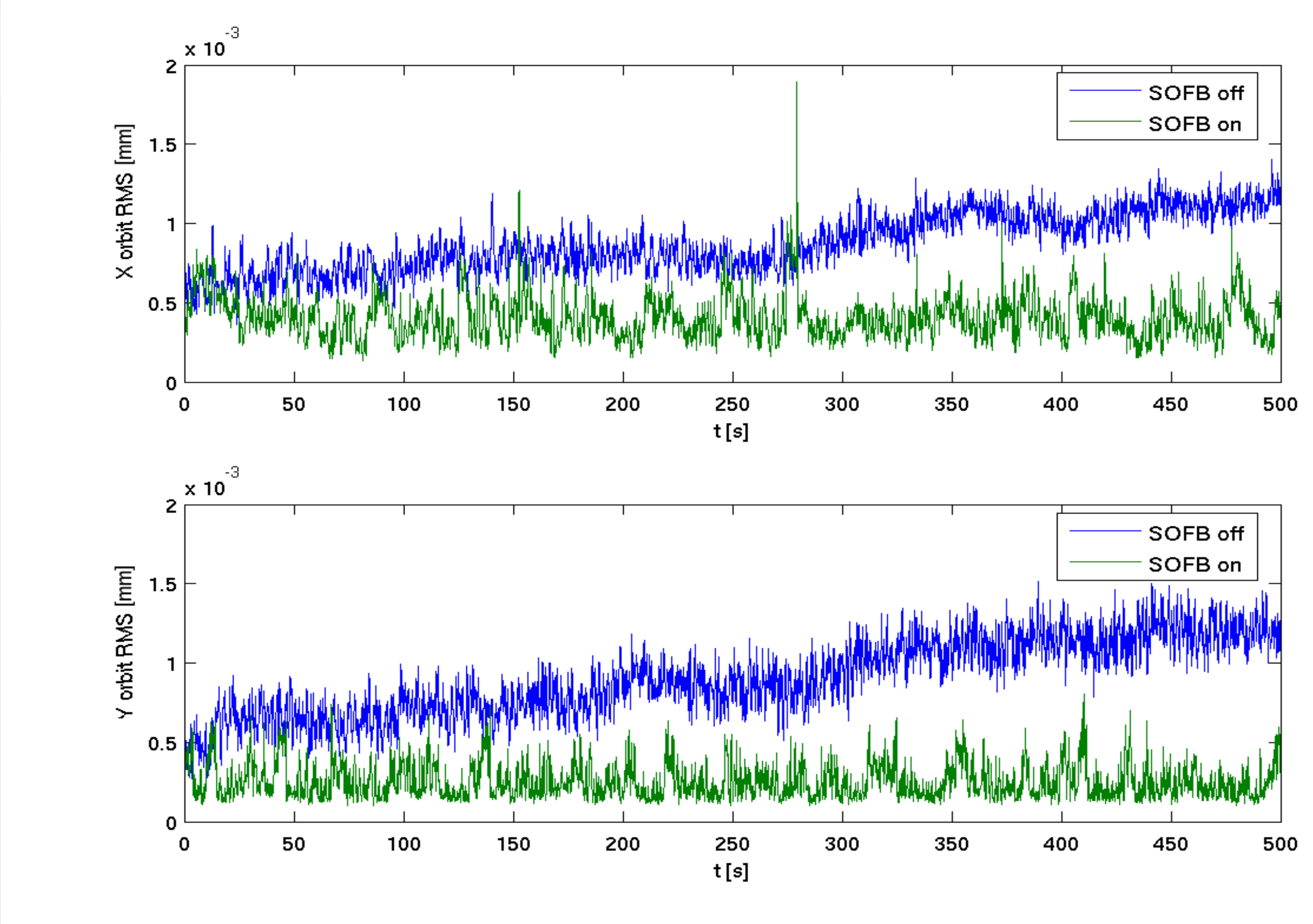


rms x = 4.8 mm, rms y = 3.1 mm

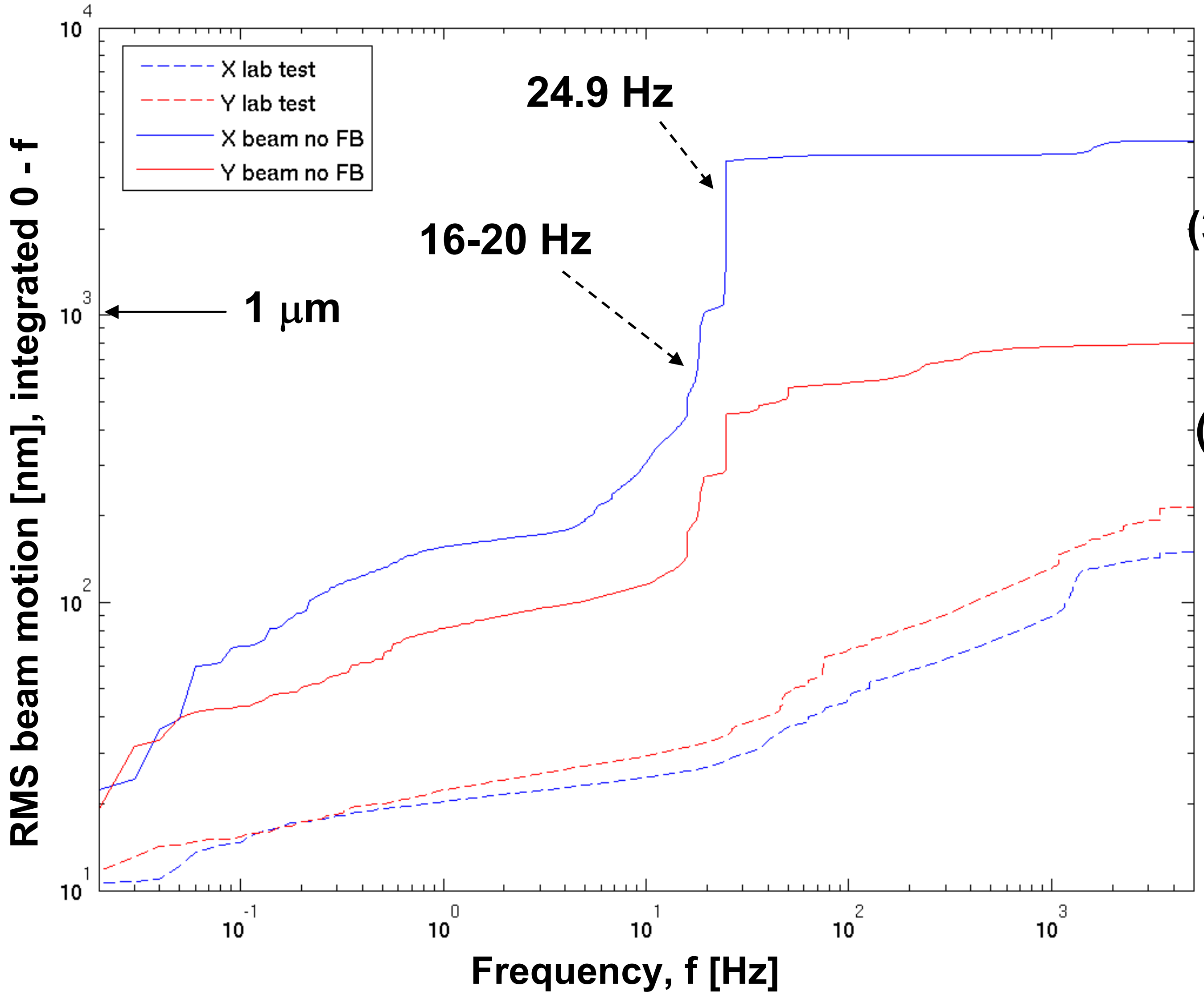
- reasonably consistent with specified 0.1 mm quadrupole positioning error

Orbit stability – long term

running from MATLAB, 0.2 Hz



Orbit stability – short term



24.9 Hz

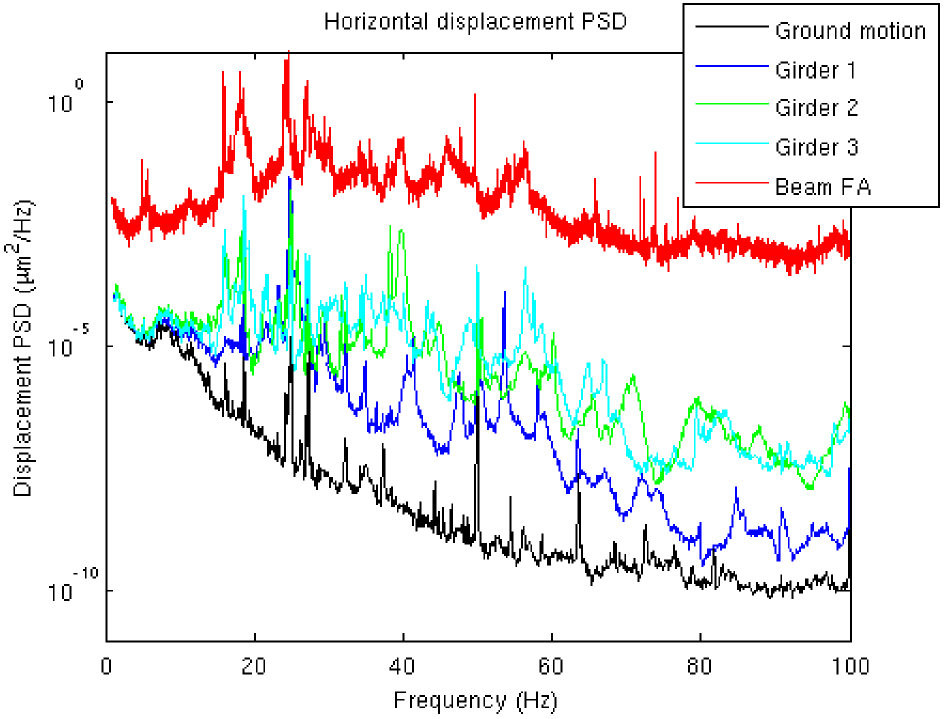
16-20 Hz

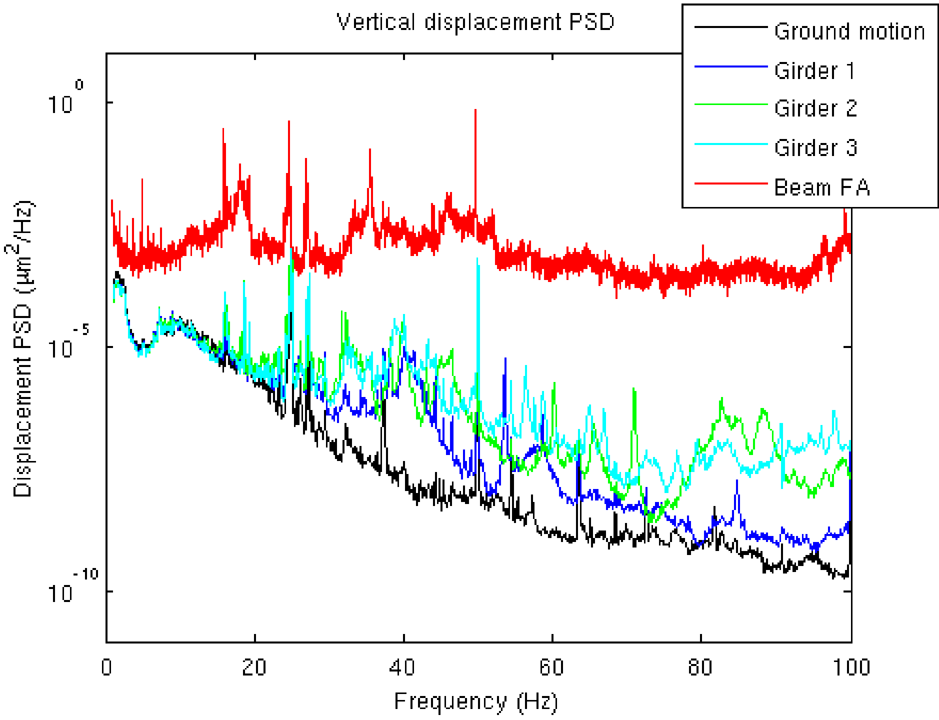
1 µm

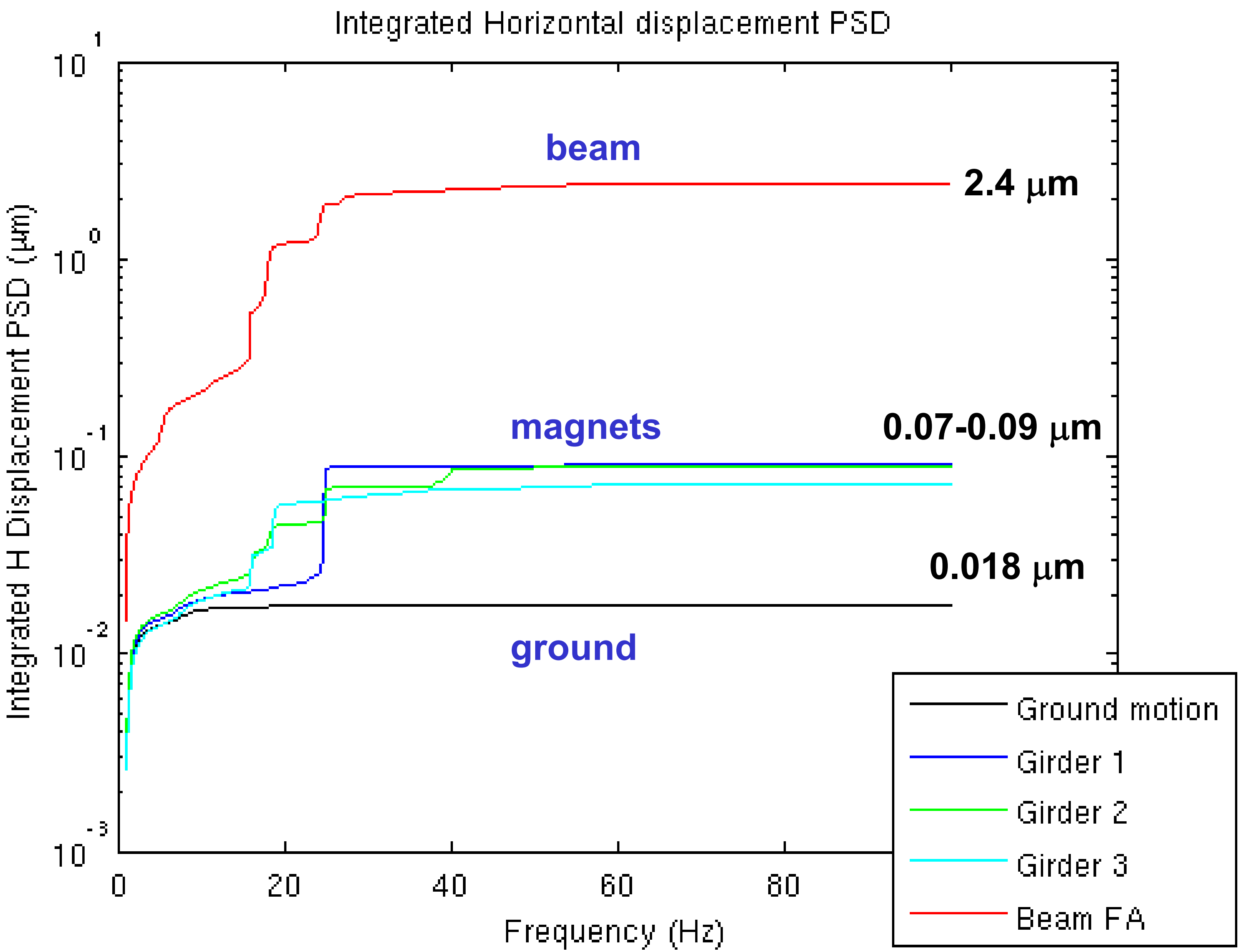
4 µm
Horiz.
(3% of σ_x)

0.8 µm
Vert.
(13% of σ_y)

Comparison of beam motion with that of the ground and the girders:







beam

2.4 µm

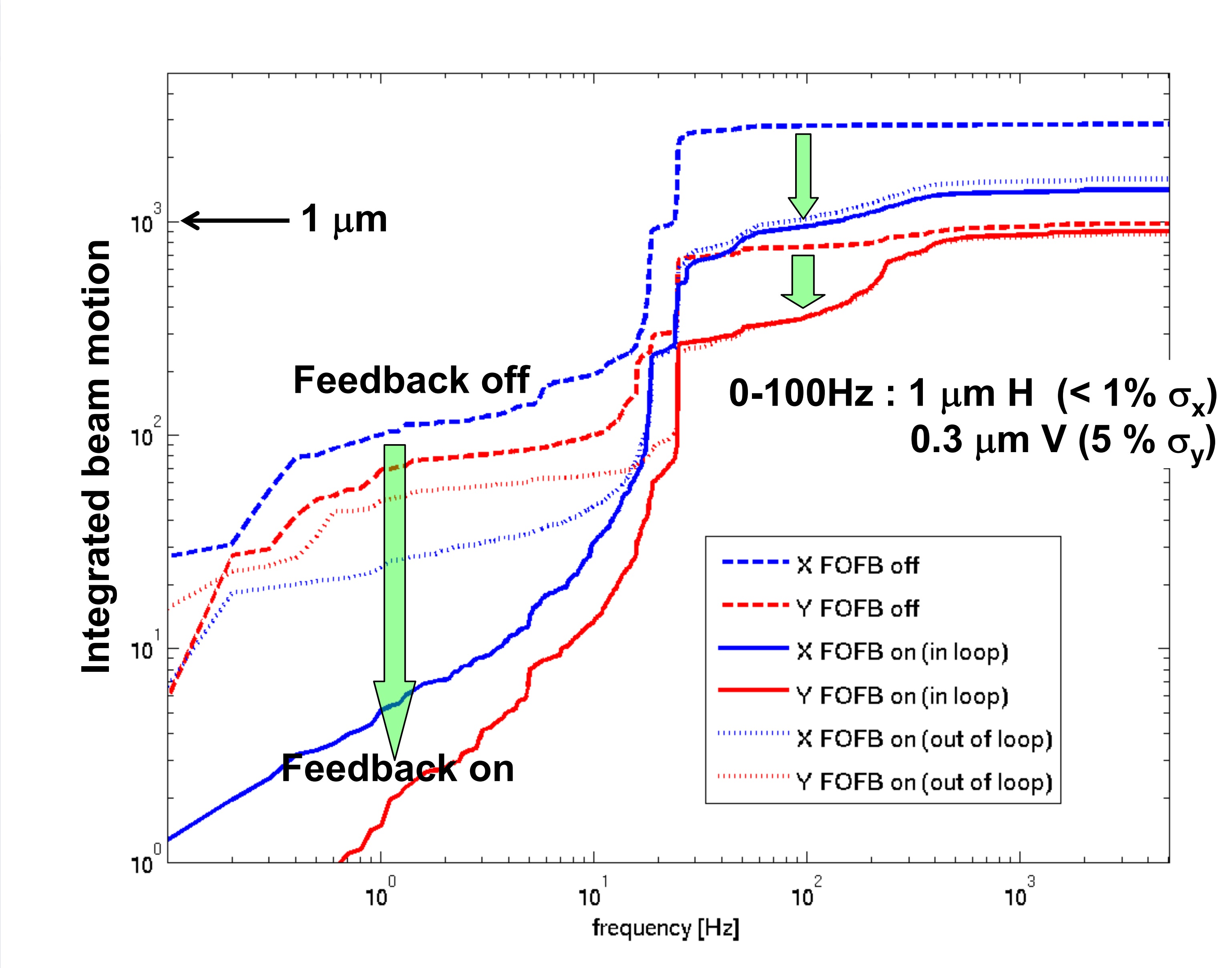
magnets

0.07-0.09 µm

0.018 µm

ground

Fast Orbit Feedback - in routine operation:



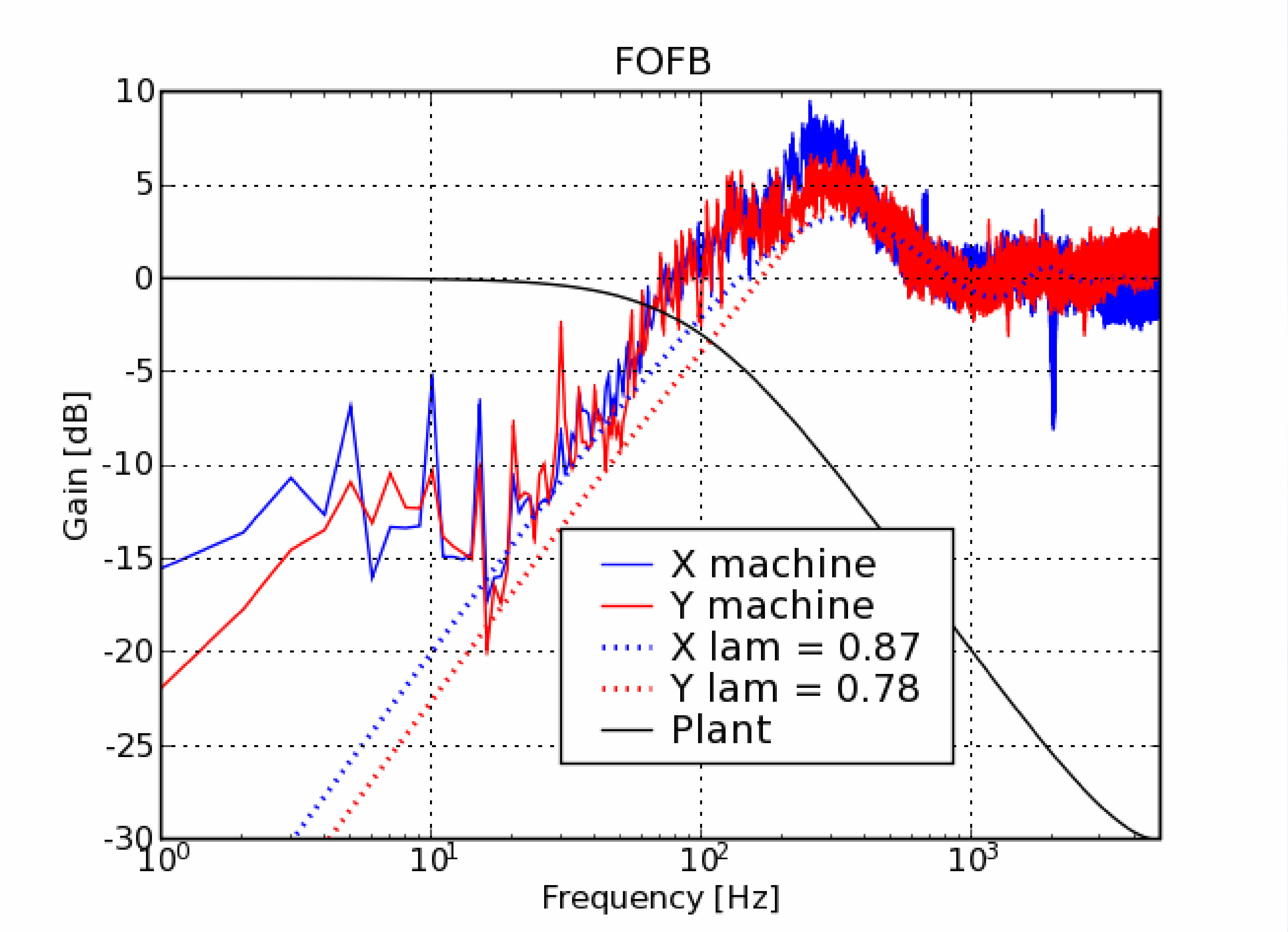
← 1 μm

Feedback off

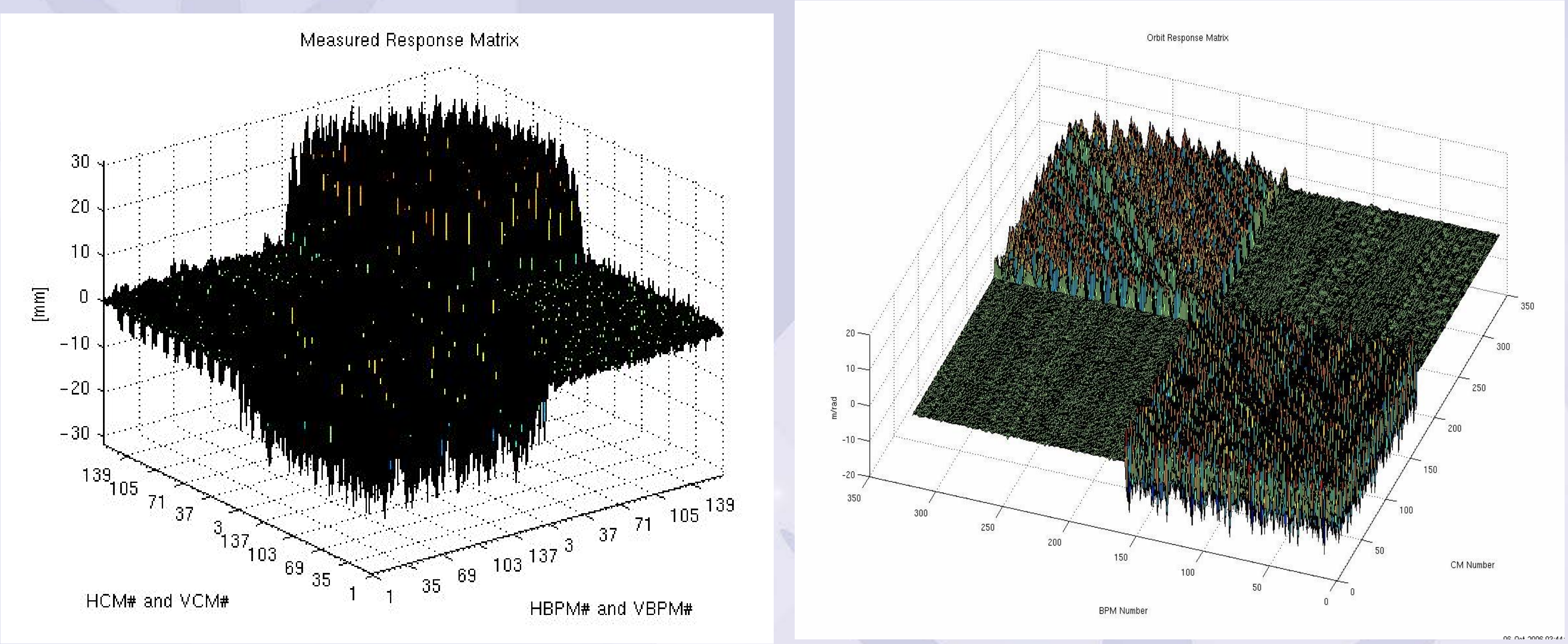
Feedback on

0-100Hz : 1 μm H (< 1% σ_x)

0.3 μm V (5 % σ_y)


FOFB
10
5
0
-5
-10
-15
-20
-25
-30
Gain [dB]
10^0
10^1
10^2
10^3
Frequency [Hz]
X machine
Y machine
X lam = 0.87
Y lam = 0.78
Plant

Optics Analysis and Correction (using LOCO*)

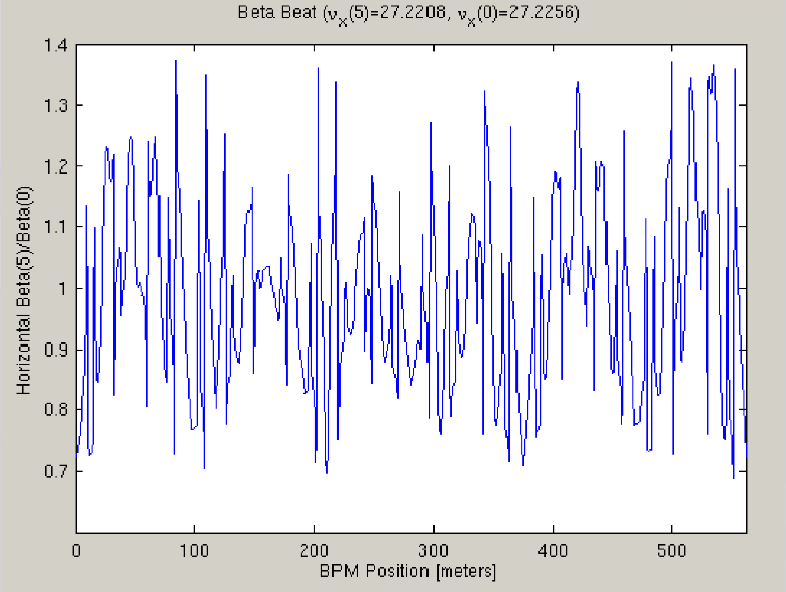


Measured Response Matrices (before and after LOCO analysis)

**J. Safranek, “Experimental Determination of Storage Ring Optics Using Orbit Response Measurements”, Nucl. Inst. Meth. A388, 27 (1997)*

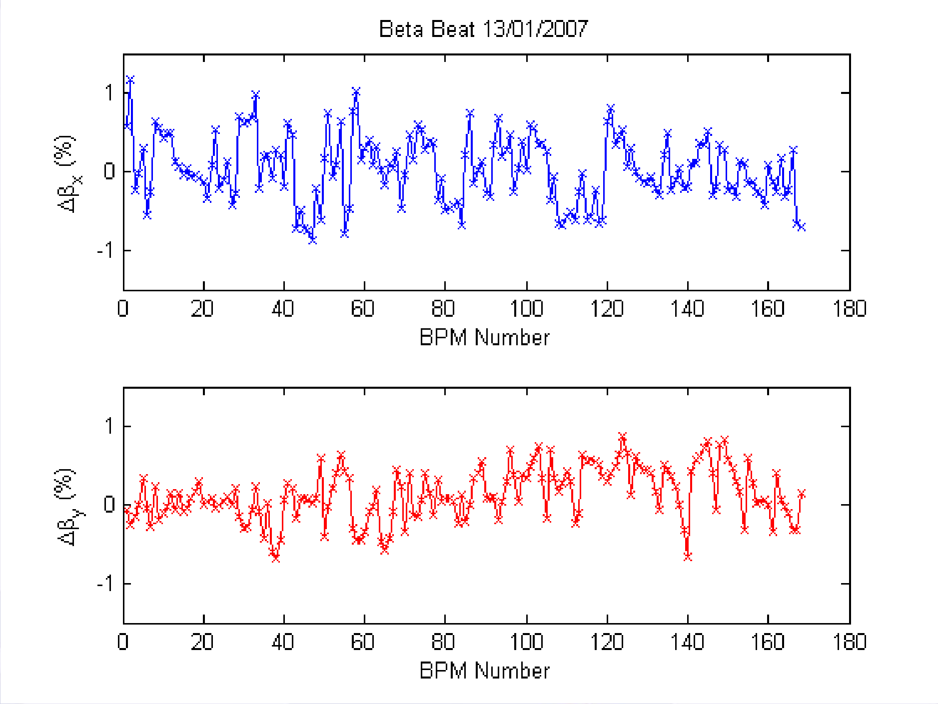
J. Safranek et al., “MATLAB based LOCO”, SLAC-PUB 9464, (2002).

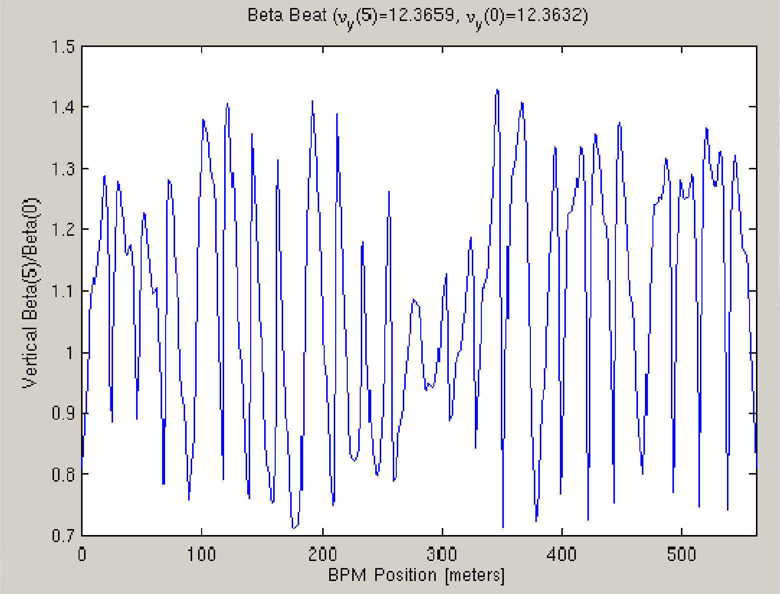
Beta-function – before and after LOCO correction



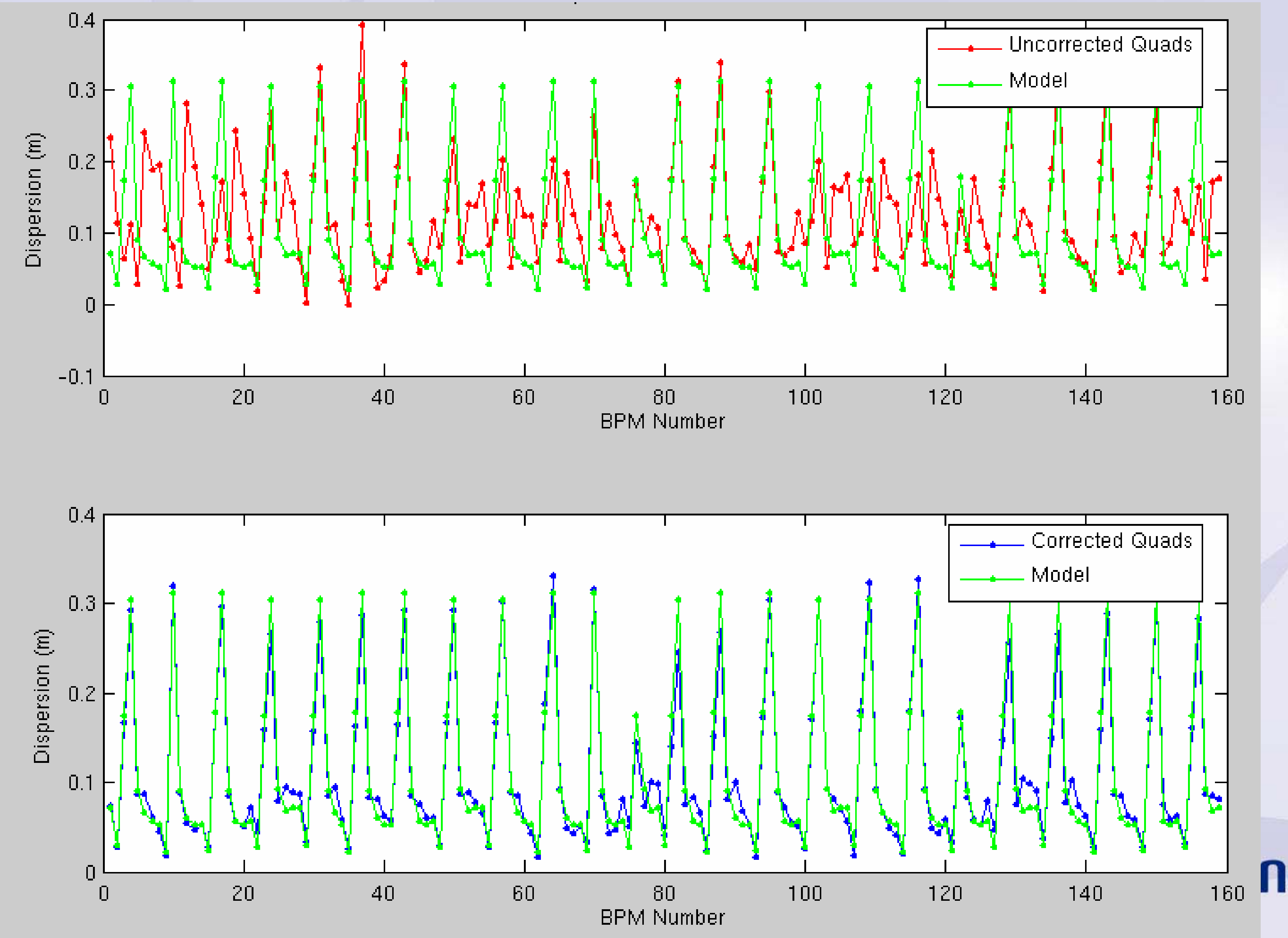
before correction ± 40%

after correction ± 1 %

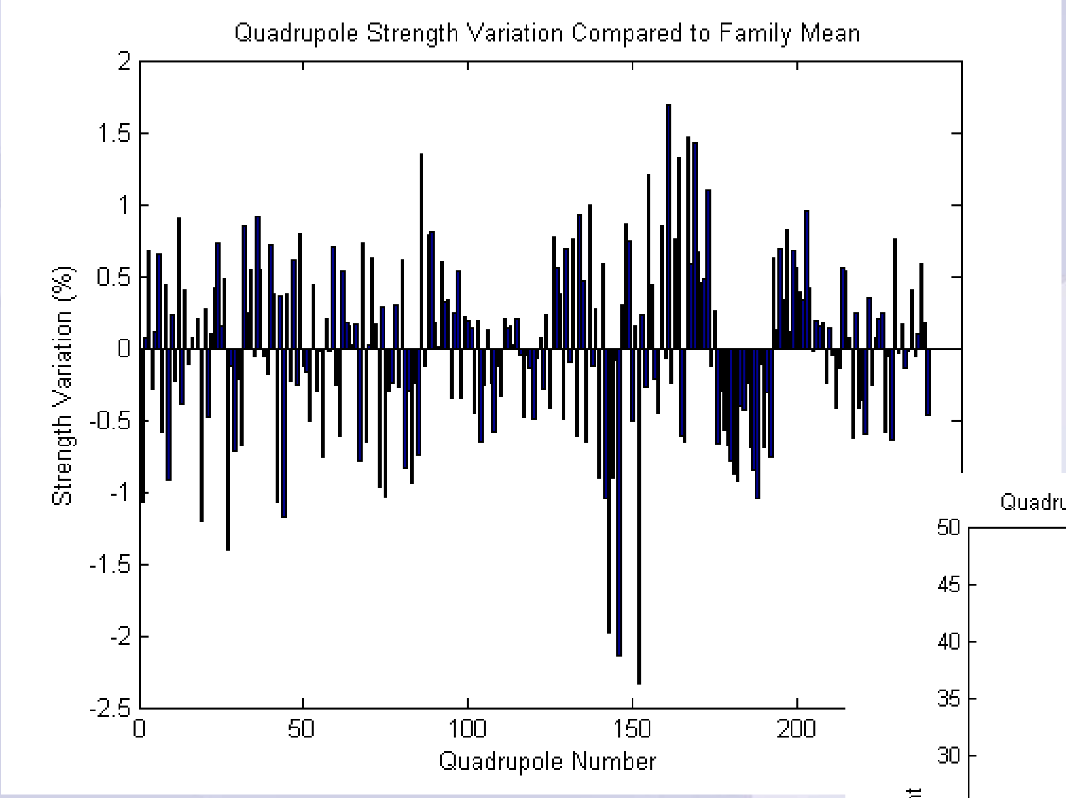




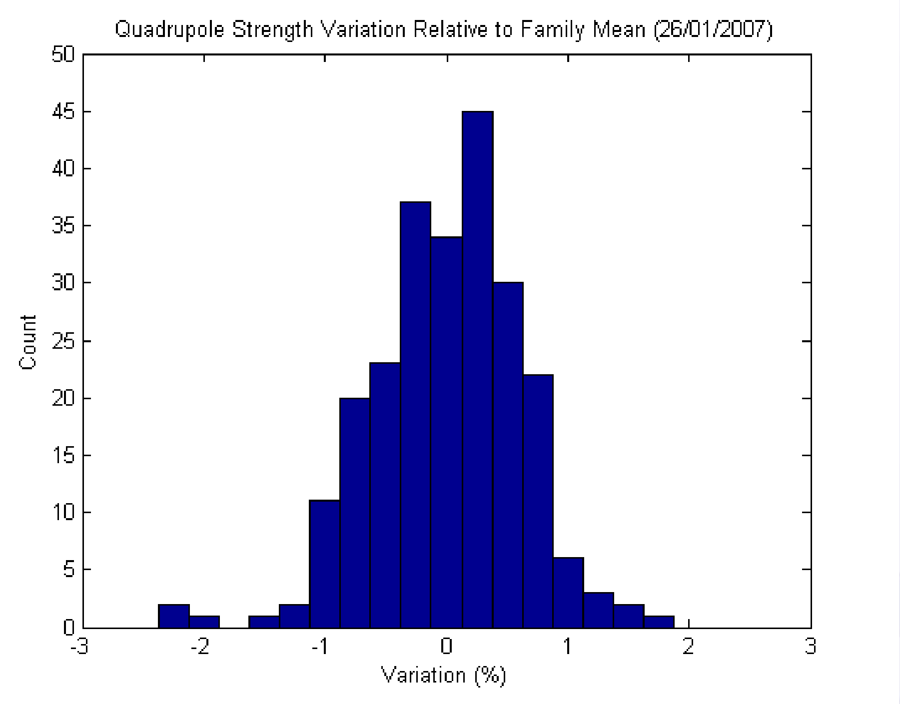
Dispersion – before and after LOCO correction



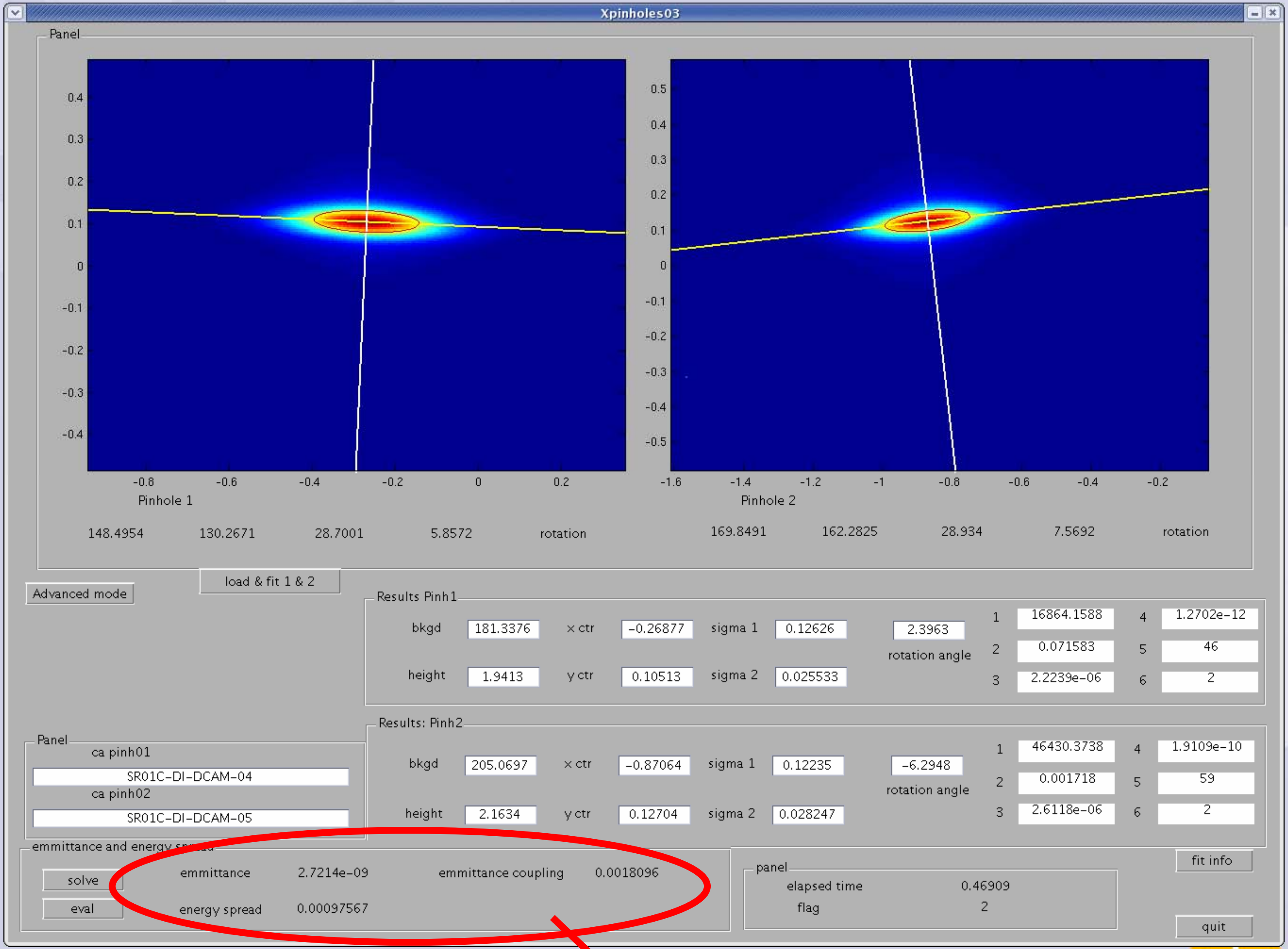
Quadrupole gradient corrections:



Up to 5 % with respect to the nominal calibration, but less than 2 % with respect to the mean for each quad. family



Emittance and Energy Spread agree with expectations:



148.4954 130.2671 28.7001 5.8572 rotation

169.8491 162.2825 28.934 7.5692 rotation

Results Pinh1

bkgd 181.3376
x ctr -0.26877
sigma 1 0.12626
height 1.9413
y ctr 0.10513
sigma 2 0.025533
2.3963 rotation angle
1 16864.1588
2 0.071583
3 2.2239e-06
4 1.2702e-12
5 46
6 2

Results: Pinh2

bkgd 205.0697
x ctr -0.87064
sigma 1 0.12235
height 2.1634
y ctr 0.12704
sigma 2 0.028247
-6.2948 rotation angle
1 46430.3738
2 0.001718
3 2.6118e-06
4 1.9109e-10
5 59
6 2

Panel

ca pinh01 SR01C-DI-DCAM-04
ca pinh02 SR01C-DI-DCAM-05

emittance and energy spread

emittance 2.7214e-09
emittance coupling 0.0018096
energy spread 0.00097567

panel

elapsed time 0.46909
flag 2

Automated measurement using two X-ray pinhole cameras

emittance 2.72 nm, energy spread 0.097%, coupling 0.18%

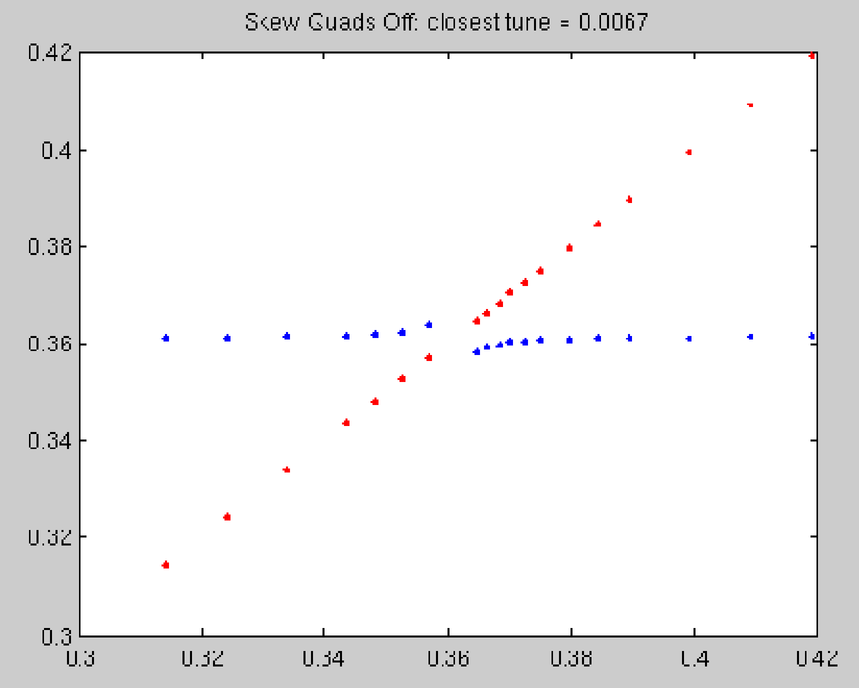
Linear coupling compensation using LOCO

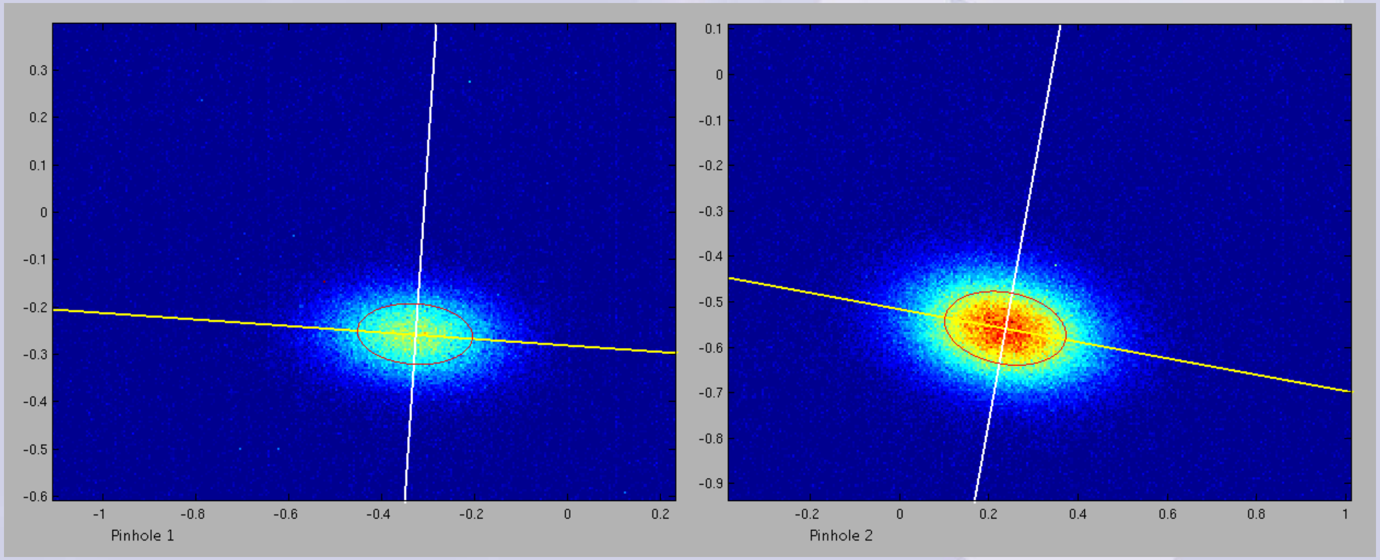
Skew-quads off:

Tune separation = 0.0067

Emittance ratio from betatron coupling at nominal WP = 0.13%

Measured emittance ratio = 1.3 %

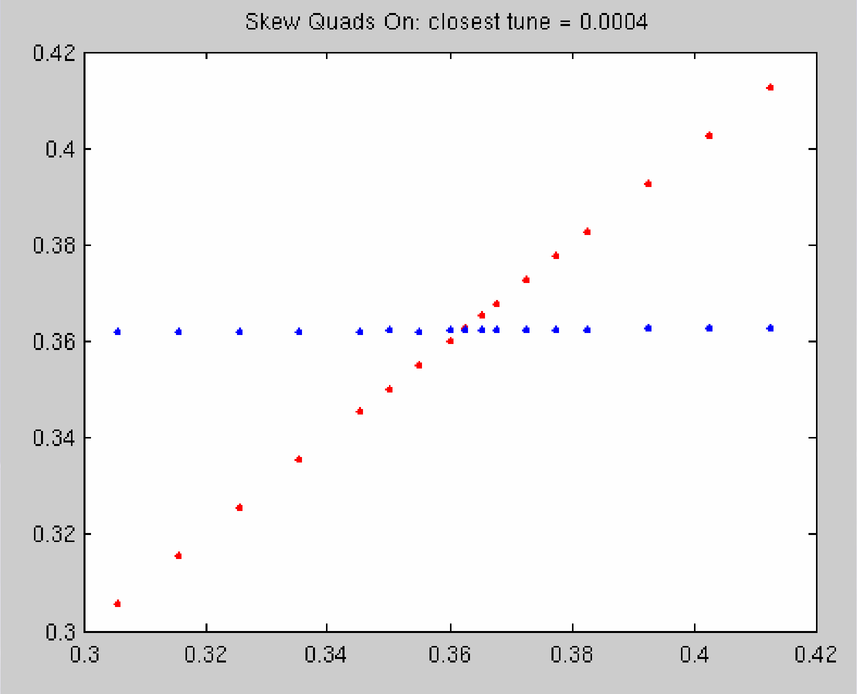




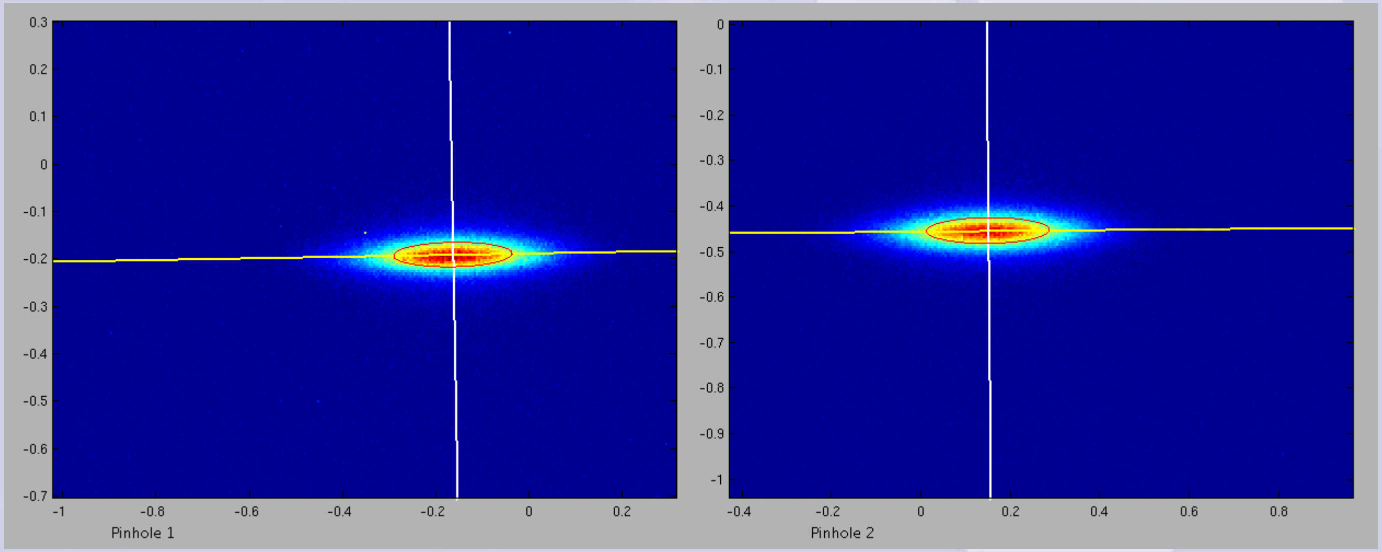
Skew-quads on:

Tune separation = 0.0004

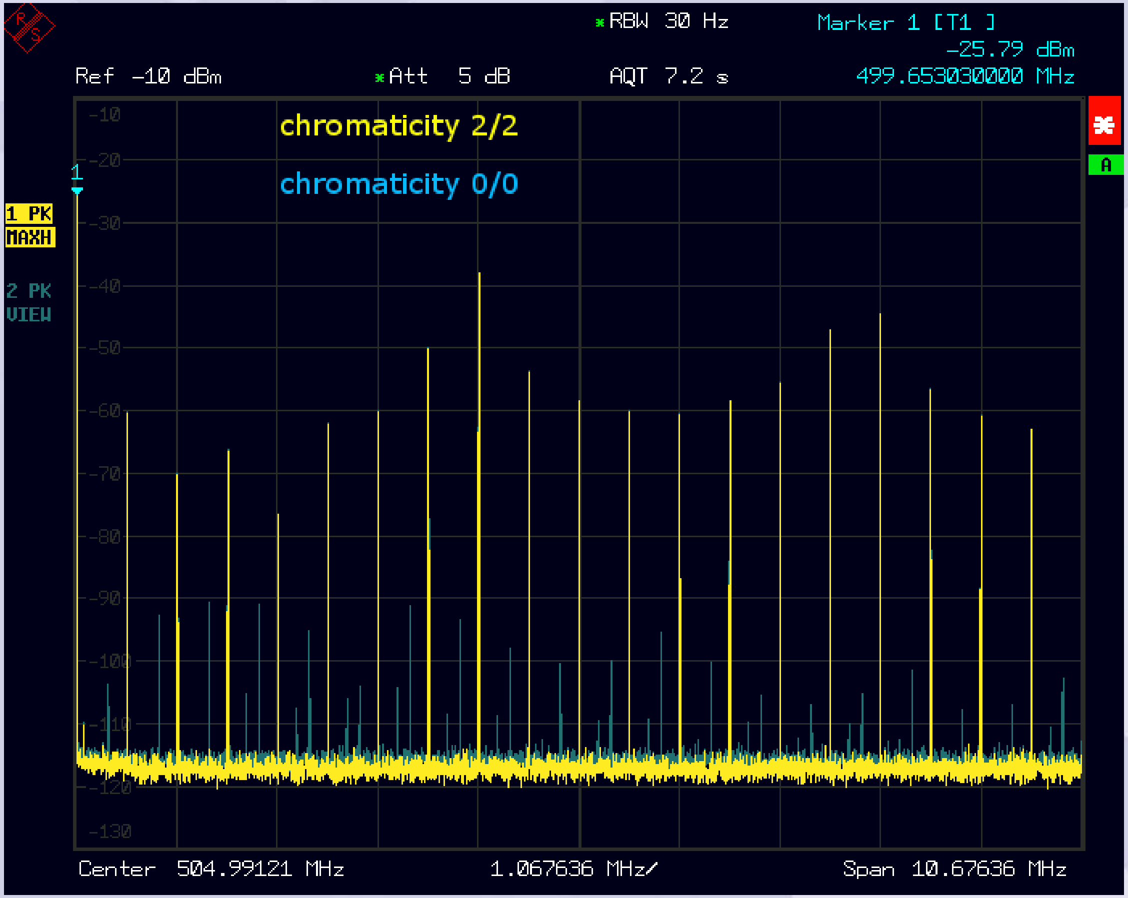
Emittance ratio from betatron coupling at nominal WP ~ 0%



Measured emittance ratio = 0.17 %



Instabilities



RBW 30 Hz

Marker 1 [T1]

-25.79 dBm

Ref -10 dBm

Att 5 dB

AQT 7.2 s

499.653030000 MHz

Center 504.99121 MHz

1.067636 MHz/

Span 10.67636 MHz

chromaticity 2/2

chromaticity 0/0

Vertical instability visible at 17 mA for zero chromaticity, lower than the predicted Resistive Wall Instability threshold (40 mA).

Increasing chromaticity counteracts the instability.

Beam is completely stable up to 250 mA with chromaticity ($\Delta Q/\Delta p/p$) = + 2 in both planes.

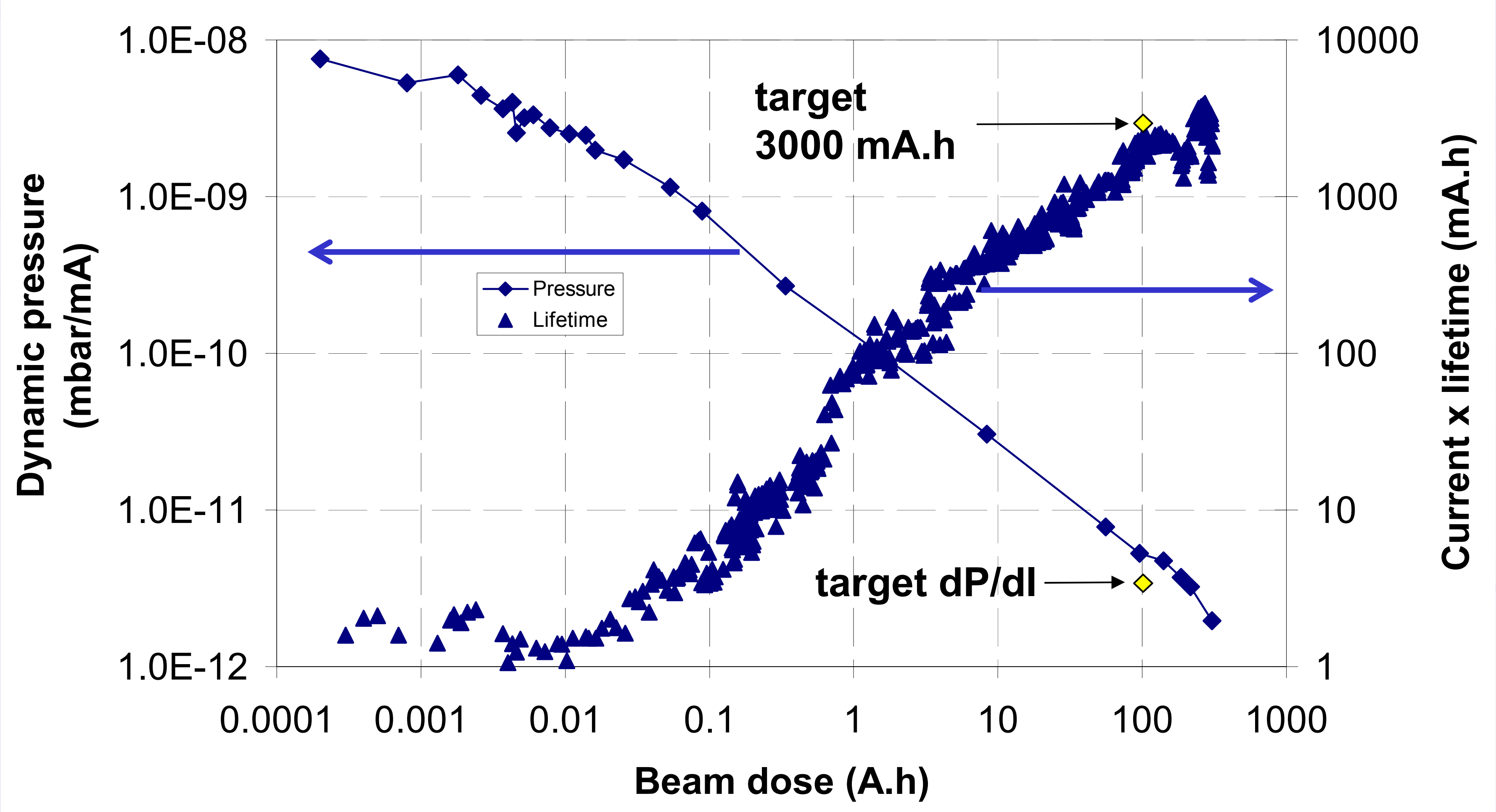
Eight Insertion Devices are Operational:

Beamline	ID	Type
I02	U23	In-vacuum
I03	U21	In-vacuum
I04	U23	In-vacuum
I06	HU64	APPLE-II
I15	SCW	3.5 T Superconducting Multipole Wiggler
I16	U27	In-vacuum
I18	U27	In-vacuum
I22	U25	In-vacuum

- In-vac undulators are operational to an initial minimum gap of 7 mm.
- Closed-orbit is corrected automatically to within 1-2 μm as a function of gap (and phase) using trim coils; fast orbit feedback does the rest.
- Users have control of ID gap
- No correction of focussing effects needed so far, including the superconducting wiggler.
- No significant changes in lifetime.

diamond

Vacuum Conditioning and Beam Lifetime



Static pressure = 3 10^{-10} mbar

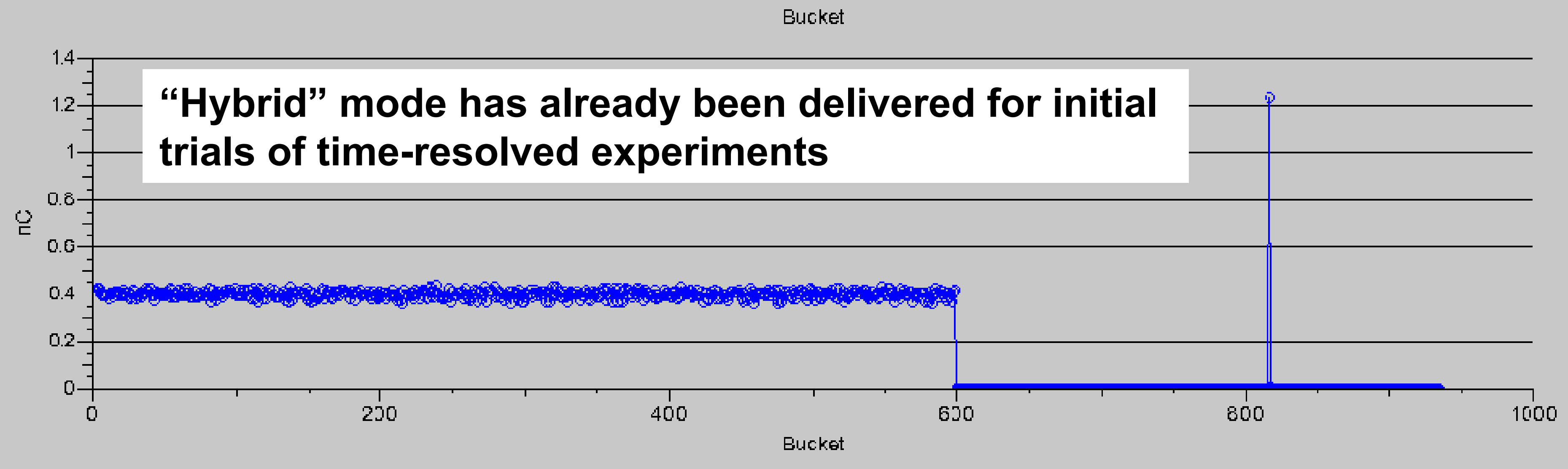
Dynamic pressure = 6 10^{-10} mbar at 125 mA, after 300 Ah

gas composition > 90% H no beam, > 80% H with beam

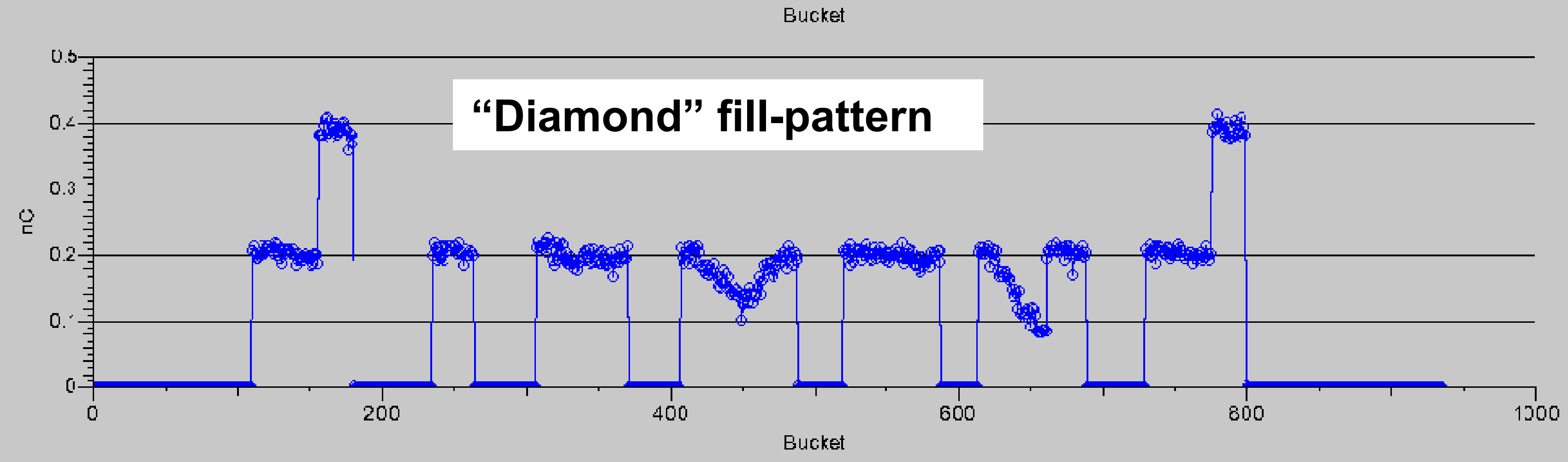
diamond

Time Structure

Single bunch injection allows any arbitrary filling pattern to be produced:



"Hybrid" mode has already been delivered for initial trials of time-resolved experiments



"Diamond" fill-pattern

Current Machine Status

	Target	**Achieved**	
Energy	**3 GeV**	**3 GeV**	
Beam current	**300 mA**	**300 mA**	***not yet with IDs operational***
Emittance			
- horizontal	**2.7 nm rad**	**2.7 nm rad**	
- vertical	**27 pm rad**	**4-50 pm rad**	***coupling can be varied 0.15-2%***
Lifetime	**> 10 h**	**12 h at 300 mA**	***still improving***
Min. ID gap	**7 mm**	**7 mm**	***all 6 in-vac IDs operational***

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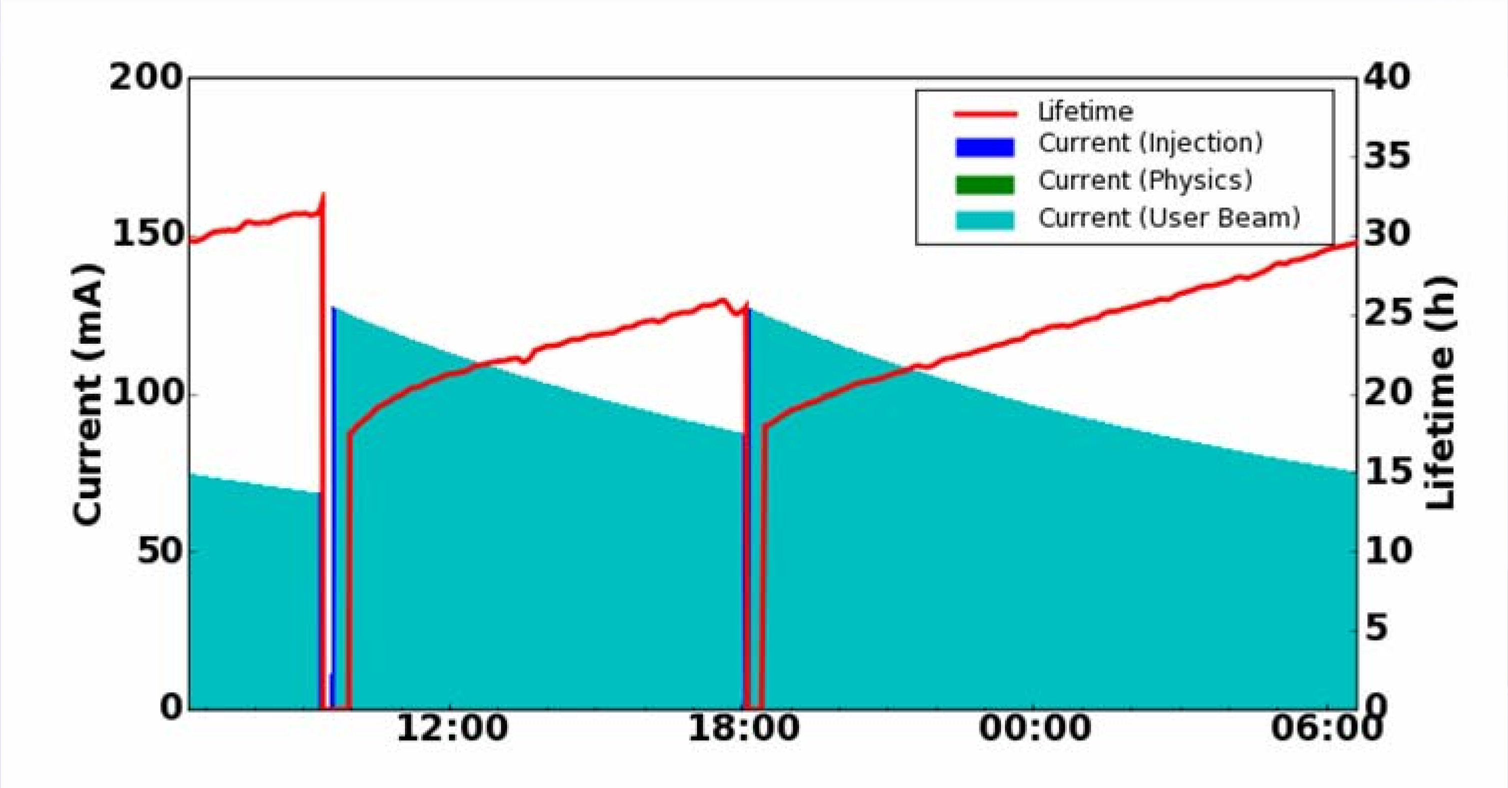
“User Mode” Operation

3000 h of User Operation in 2007, 4000h in 2008, 5000 h in 2009

current operation: 125 mA maximum, 2 injections/day

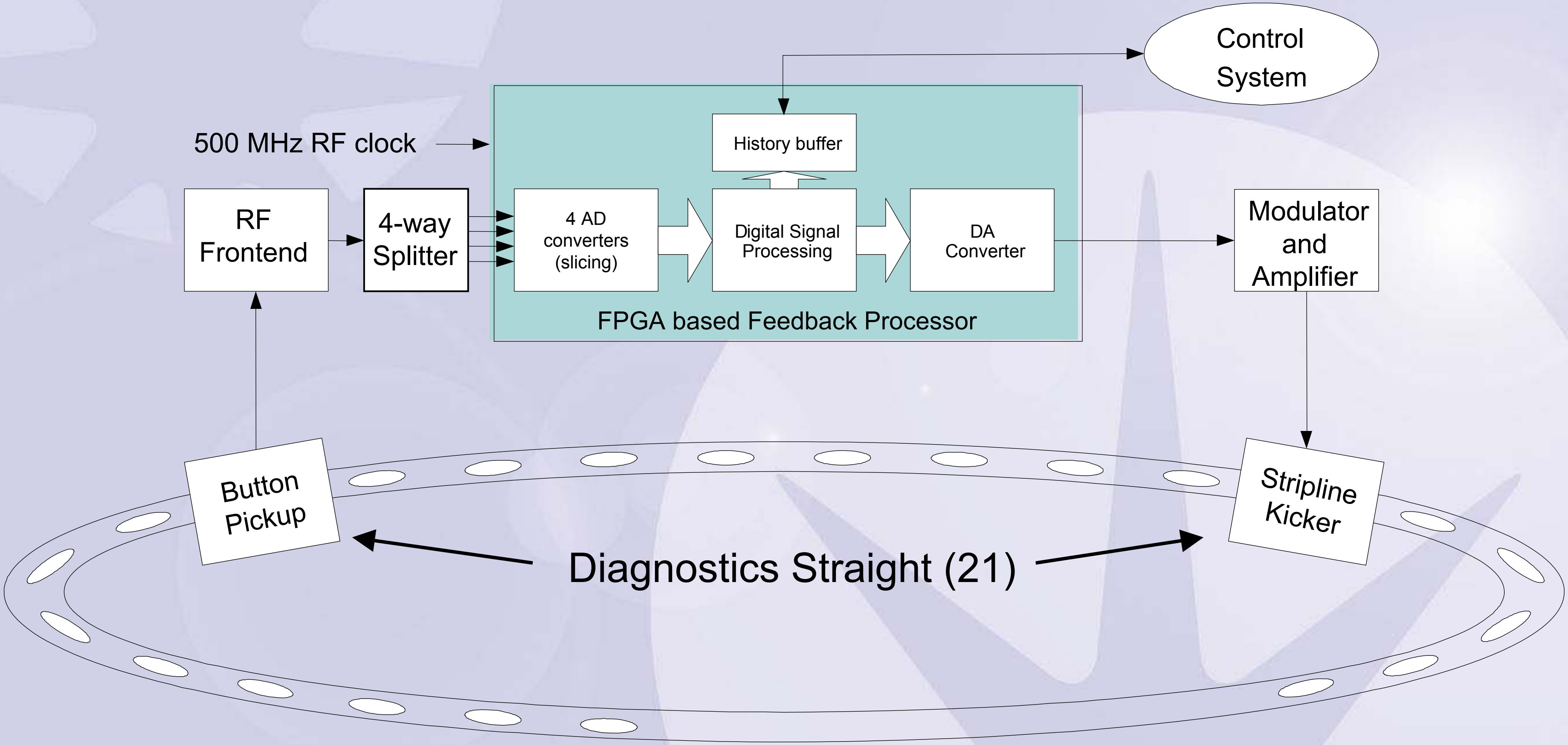


First 6 operating periods: 1944 hours of User Mode with 92% up-time

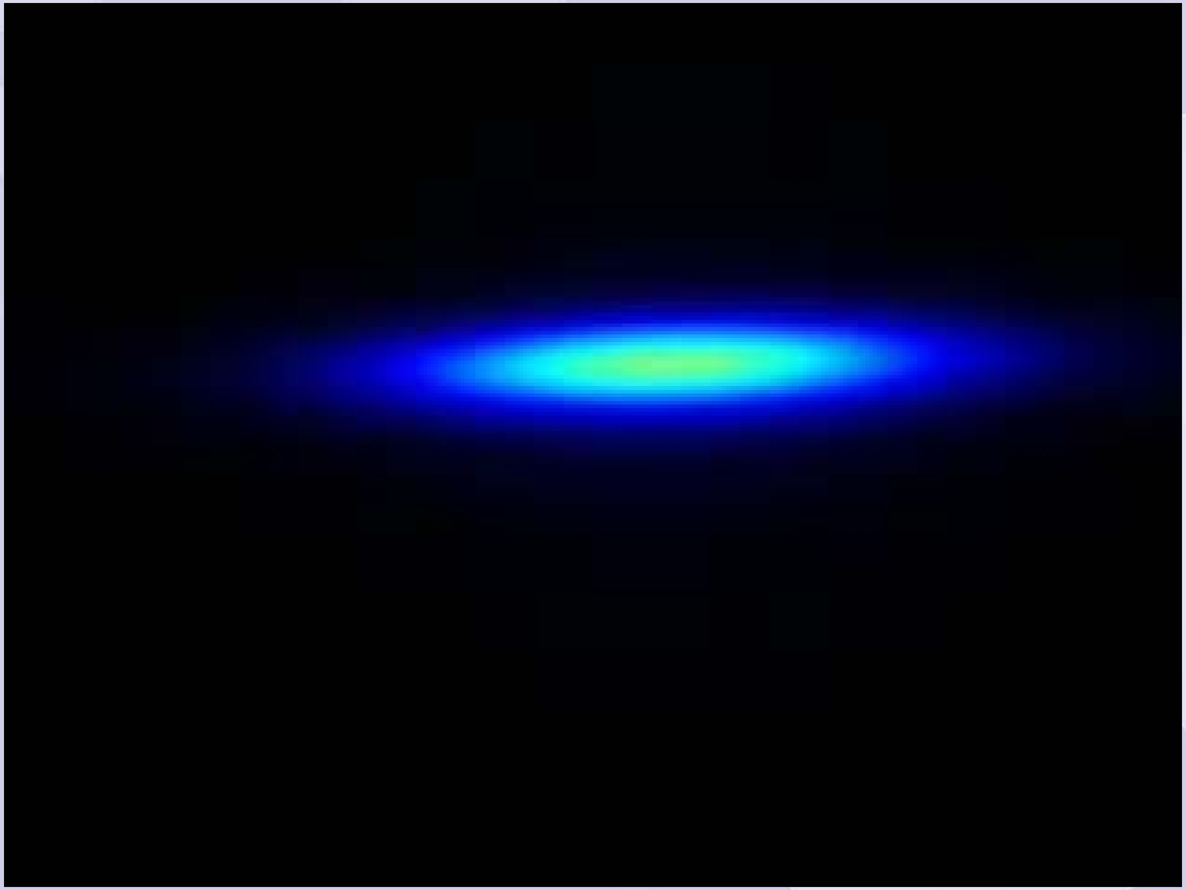
NB] injection counted as down-time

Under development:

Transverse Bunch-by-Bunch Feedback



Feedback tests:



Beam artificially made unstable in both planes:

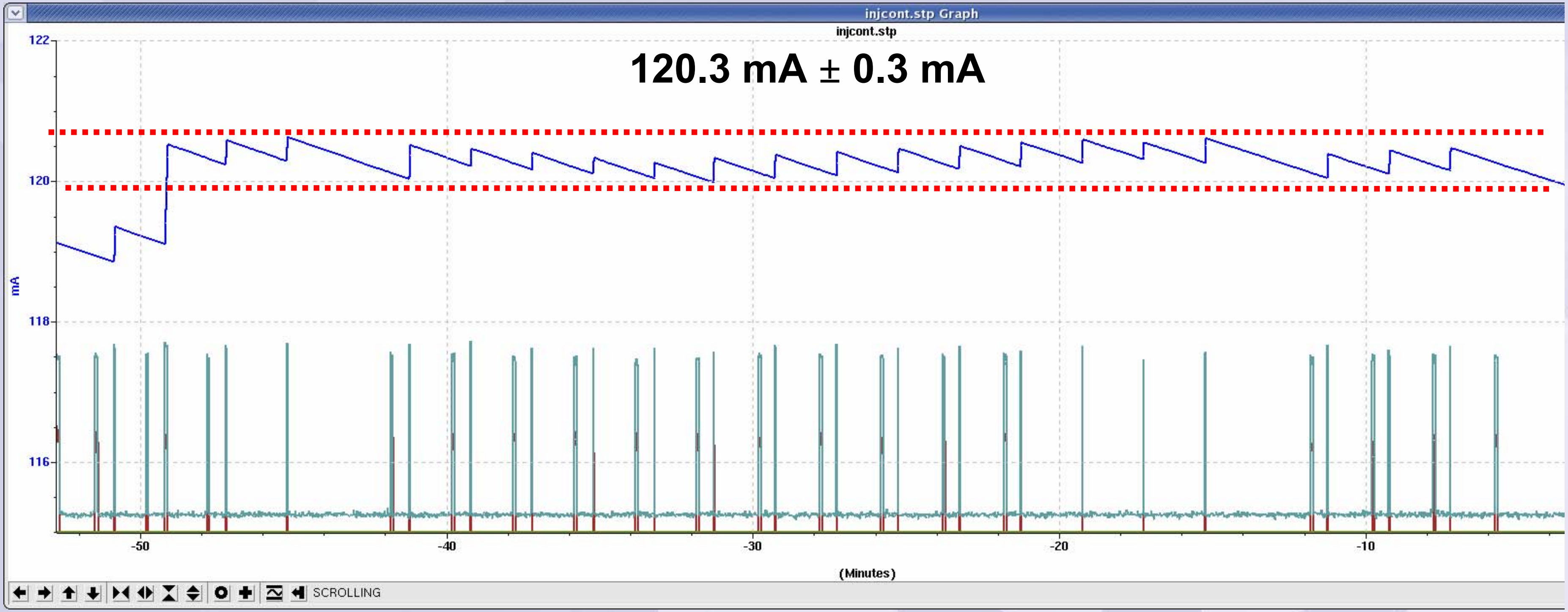
1) no feedback
→ horizontally unstable

2) feedback in horiz. plane only
→ vertically unstable

3) feedback in both planes
→ stable in both planes

Top-Up

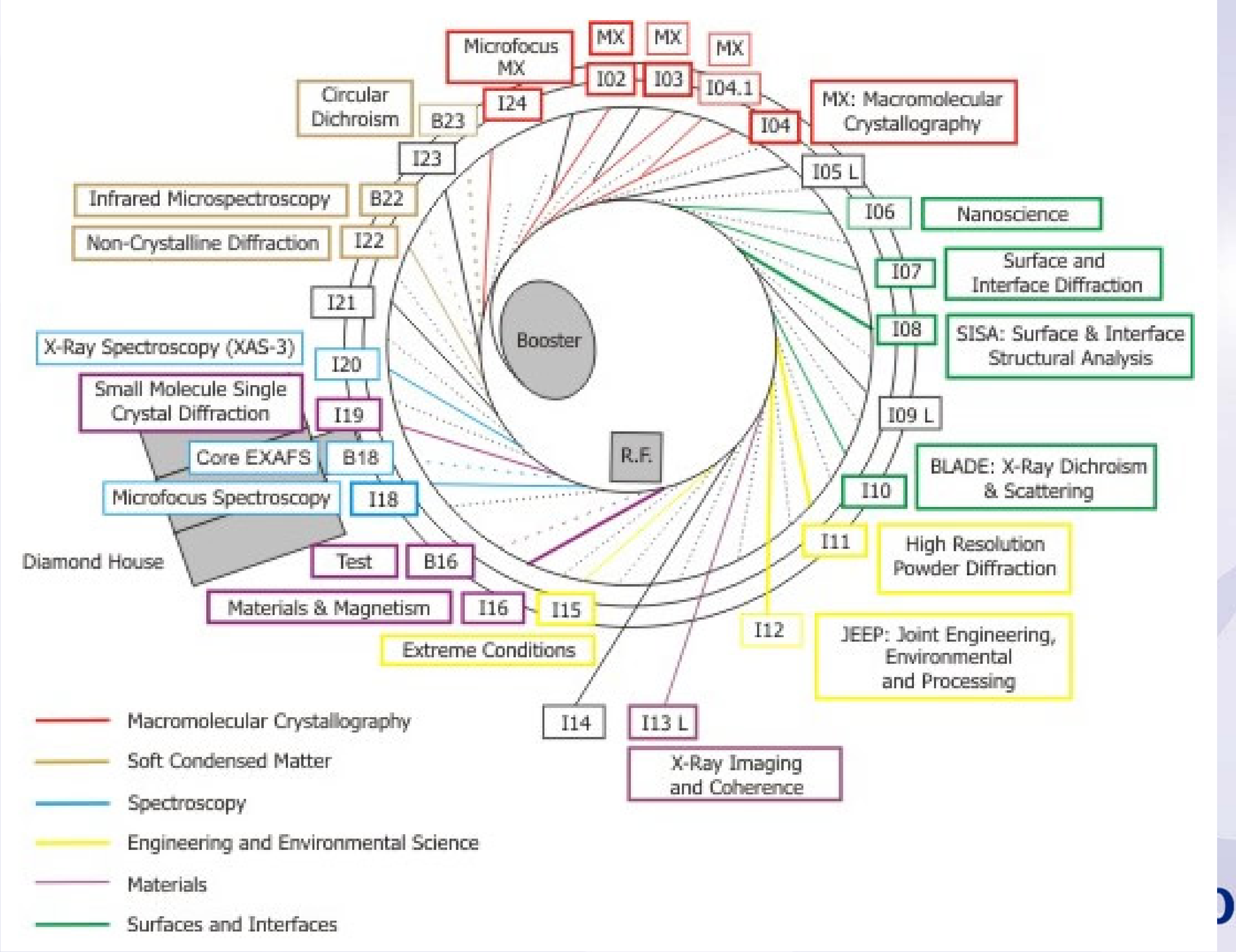
- all systems ready to deliver top-up operationally:



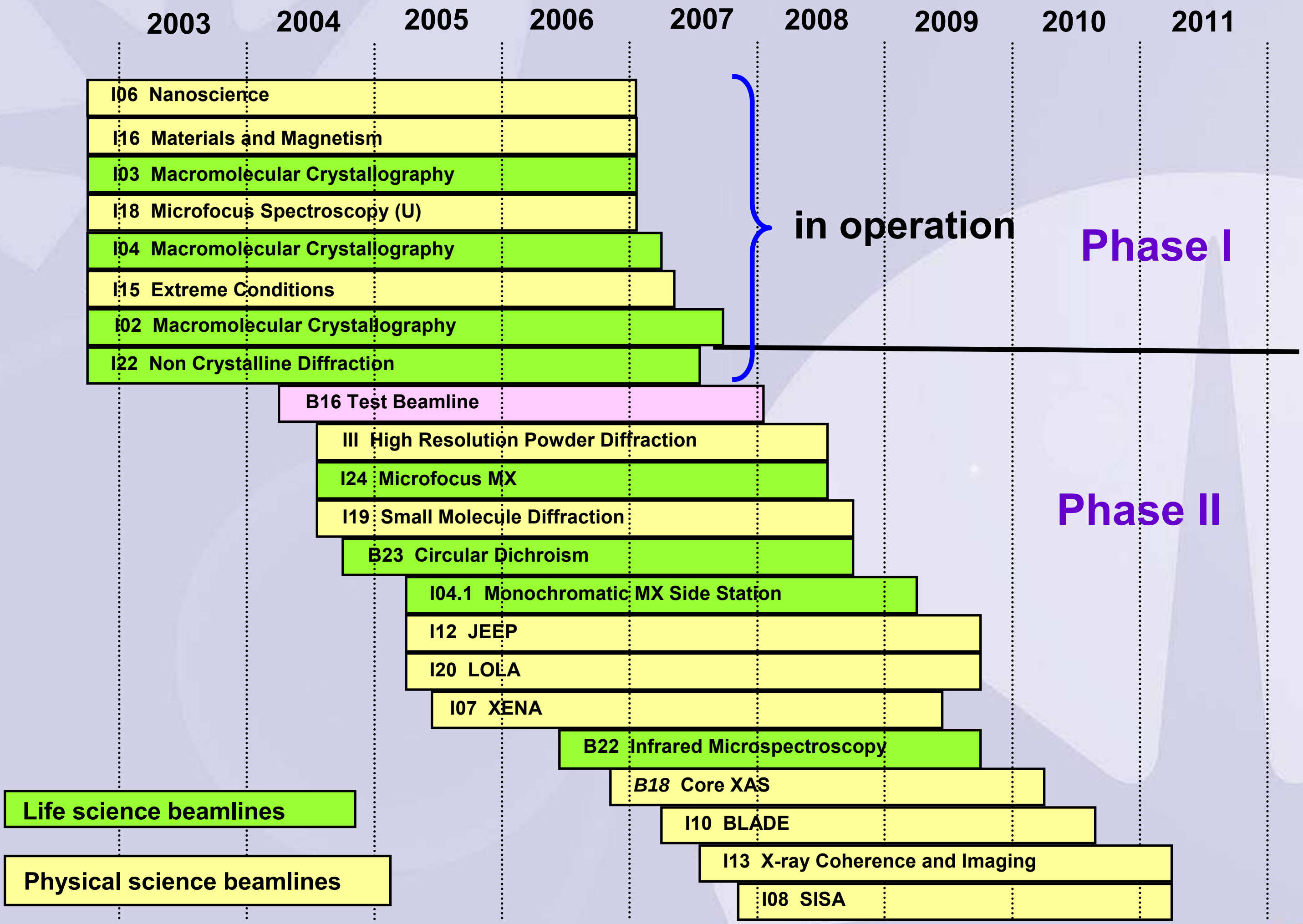
120.3 mA ± 0.3 mA

- User tests of the injection transient started
- Safety documentation being prepared

Beamlines – Science “Villages”



Beamline Programme



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Phase I Beamlines

- **I02,3,4 3-25 keV Macromolecular crystallography**

  For the determination of the structure of macromolecules with rapid sample through-put.

- **I06 80- 1500 eV Nanoscience**

  To study the morphology, chemical and magnetic state of nanostructures with <10 nm resolution.

- **I15 5-200 keV Extreme conditions**

  Study of materials at very high temperatures and pressures, typical of planetary interiors and industrial processes.

- **I16 3-25 keV Materials and magnetism**

  Study of materials including magnetic systems, high temperature superconductors.

- **I18 2-13 keV X-ray microfocus spectroscopy**

  Chemical imaging and structural studies of complex multicomponent systems with sub-micron resolution.

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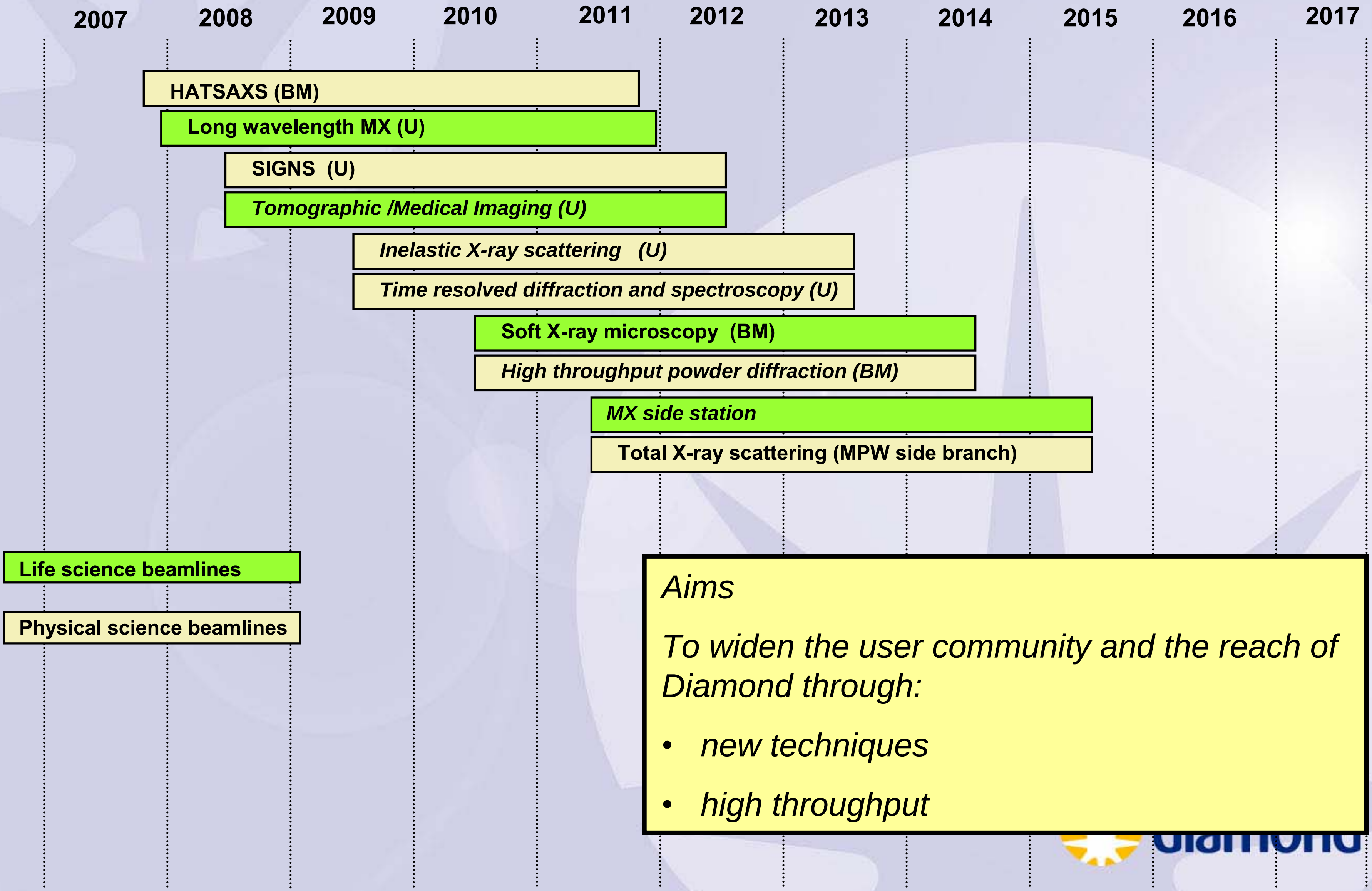
Proposed Phase III Beamline Programme:



Aims

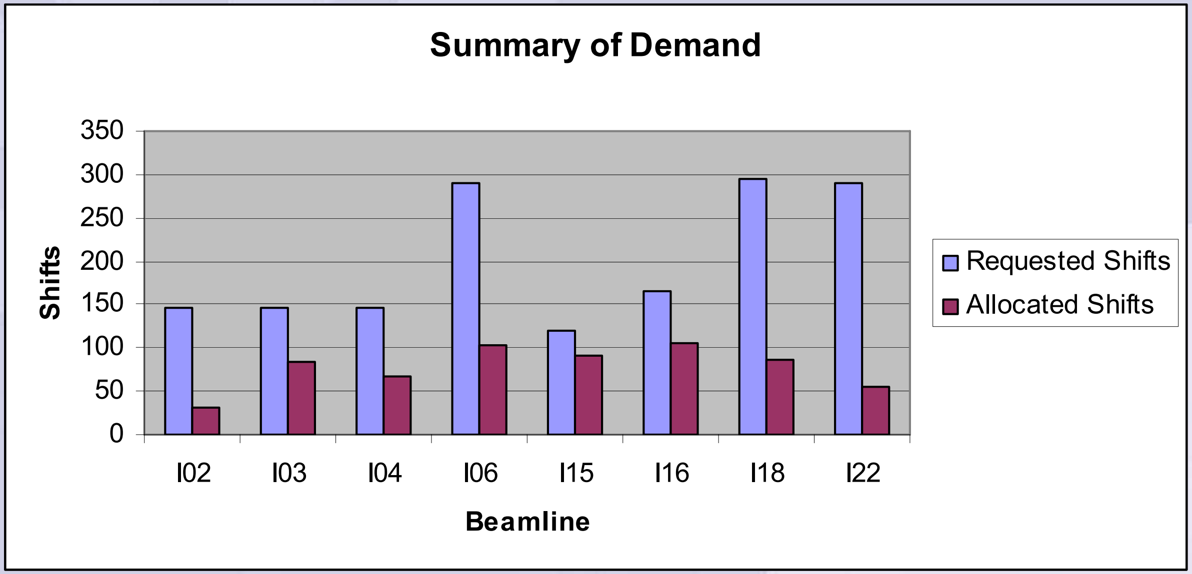
To widen the user community and the reach of Diamond through:

- *new techniques*
- *high throughput*

External Users

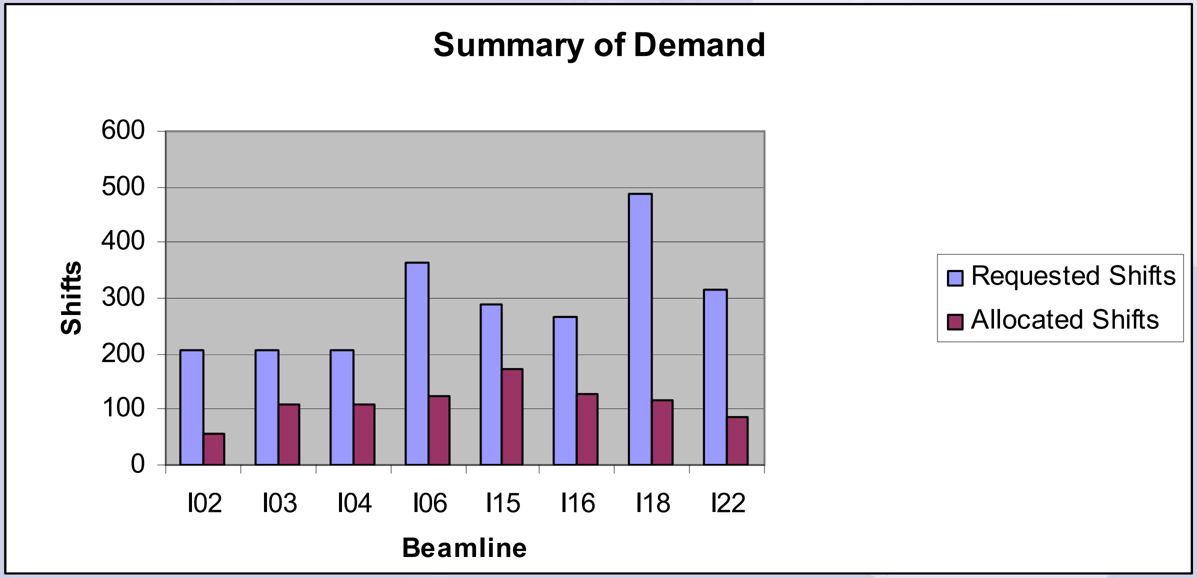
- **Optimisation phase with “experienced users”: Jan. – Sep. 2007**
- **First Users in Run#1 (Jan/Feb 2007):** Durham, Leicester, London, Oxford
- **Since Jan. ~ 50 sets of experiments have been conducted**
- **Second Call for Proposals: Apr 2007**
  (beamtime Oct. ’07 – Mar. ’08)

Beamtime Supply vs. Demand



Optimisation Phase:

Jan. - Sep. 2007



First Regular Operation Phase:

Oct. 2007 - Mar. 2008

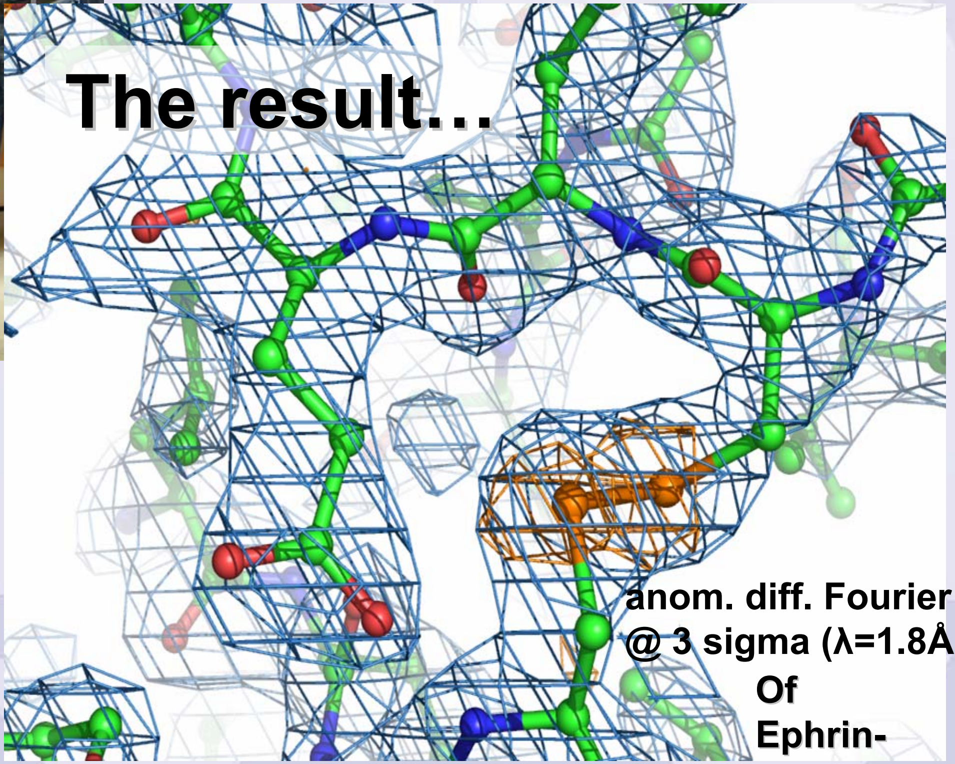
First Diamond Users – Jan./Feb. 2007

I03: Macromolecular Crystallography

Prof. Dave Stuart, University of Oxford

Determining the structure of a protein molecule (ephrin) that is linked to the development of cancer.

University of Oxford



The result…

anom. diff. Fourier
@ 3 sigma (λ=1.8Å)
Of
Ephrin-
EphR

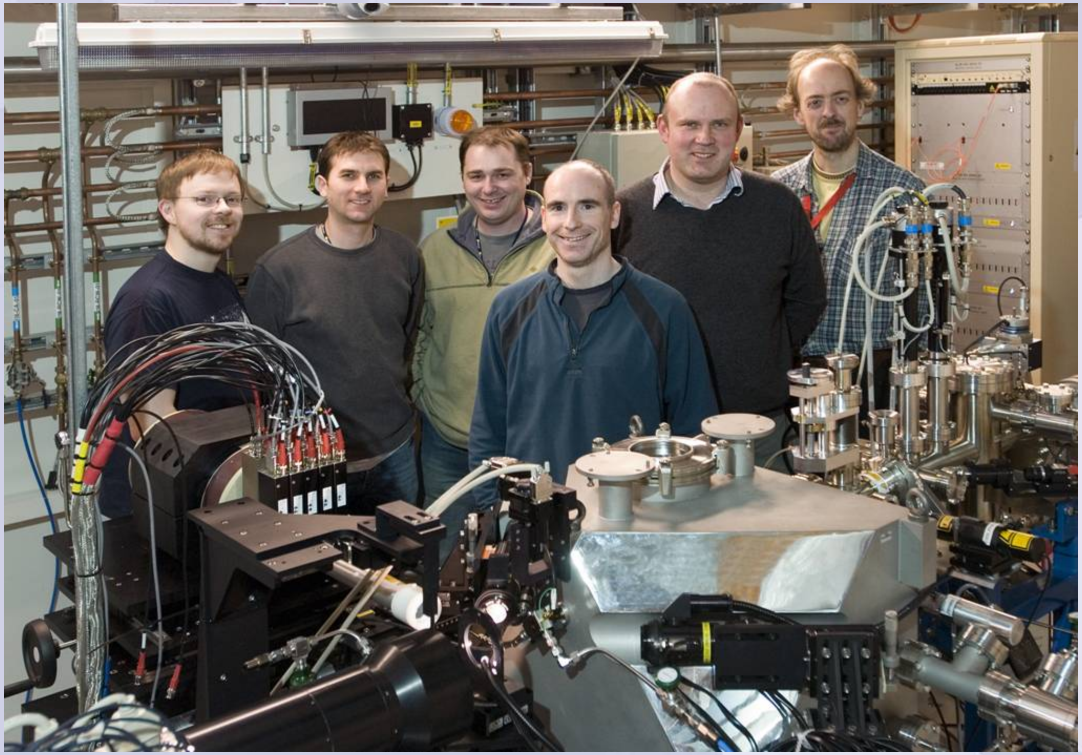
I16: Materials and Magnetism

Prof. Brian Tanner,
University of Durham

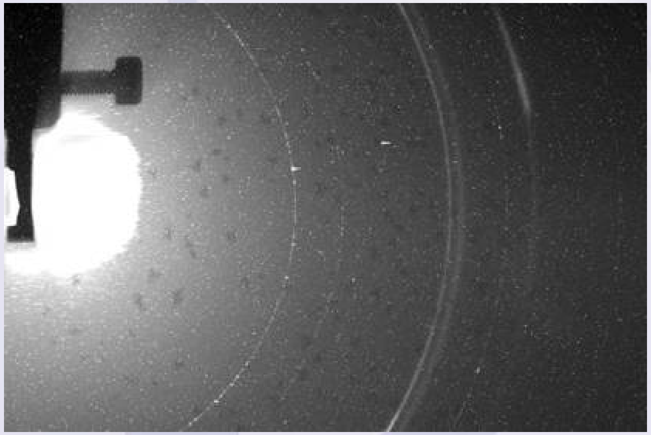
Examination of new thin-film magnetic sensors used in magnetic storage devices

Durham
University

I18: Microfocus Spectroscopy

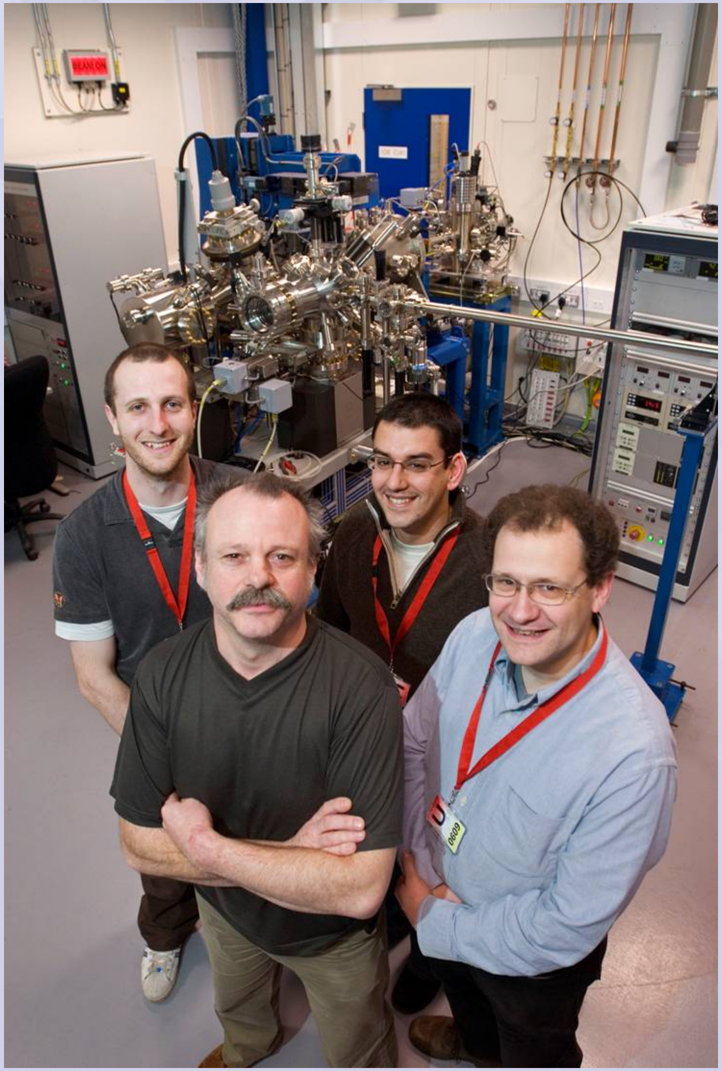


Dr Paul Schofield,
Natural History Museum



Examining the composition and structure of the Santa Catharine meteorite

I06: Nanoscience



Prof. Chris Binns,
University of Leicester

Studying the properties of magnetic materials with very high spatial resolution using a Photo-Emission Electron Microscope.

Media response….

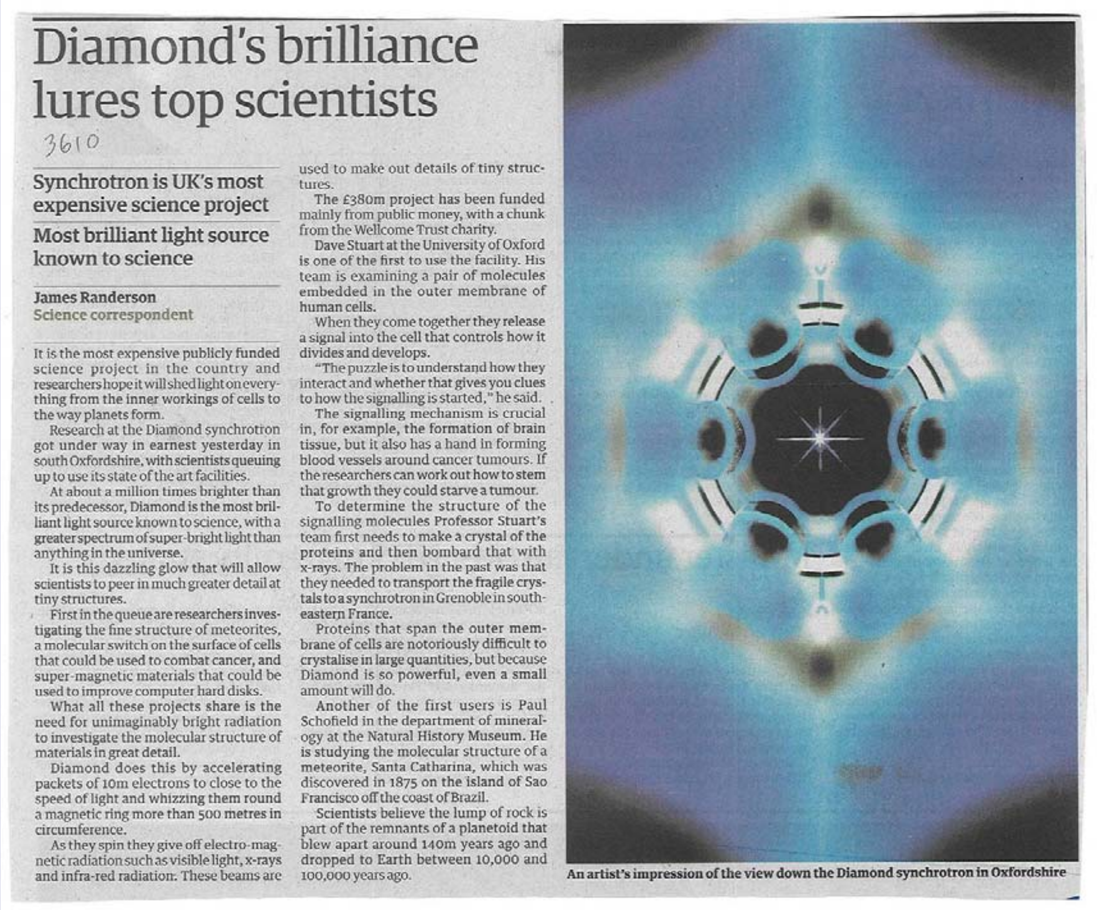
The Abingdon Herald Feb. 8th 2007

£260m project on time and budget

3610.

By Chris Buratta

The Guardian 7th February 2007



Diamond's brilliance lures top scientists

3610

Synchrotron is UK's most expensive science project

Most brilliant light source known to science

James Randerson
Science correspondent

It is the most expensive publicly funded science project in the country and researchers hope it will shed light on everything from the inner workings of cells to the way planets form.

Research at the Diamond synchrotron got under way in earnest yesterday in south Oxfordshire, with scientists queuing up to use its state of the art facilities.

At about a million times brighter than its predecessor, Diamond is the most brilliant light source known to science, with a greater spectrum of super-bright light than anything in the universe.

It is this dazzling glow that will allow scientists to peer in much greater detail at tiny structures.

First in the queue are researchers investigating the fine structure of meteorites, a molecular switch on the surface of cells that could be used to combat cancer, and super-magnetic materials that could be used to improve computer hard disks.

What all these projects share is the need for unimaginably bright radiation to investigate the molecular structure of materials in great detail.

Diamond does this by accelerating packets of 10m electrons to close to the speed of light and whizzing them round a magnetic ring more than 500 metres in circumference.

As they spin they give off electro-magnetic radiation such as visible light, x-rays and infra-red radiation. These beams are used to make out details of tiny structures.

The £380m project has been funded mainly from public money, with a chunk from the Wellcome Trust charity.

Dave Stuart at the University of Oxford is one of the first to use the facility. His team is examining a pair of molecules embedded in the outer membrane of human cells.

When they come together they release a signal into the cell that controls how it divides and develops.

"The puzzle is to understand how they interact and whether that gives you clues to how the signalling is started," he said.

The signalling mechanism is crucial in, for example, the formation of brain tissue, but it also has a hand in forming blood vessels around cancer tumours. If the researchers can work out how to stem that growth they could starve a tumour.

To determine the structure of the signalling molecules Professor Stuart's team first needs to make a crystal of the proteins and then bombard that with x-rays. The problem in the past was that they needed to transport the fragile crystals to a synchrotron in Grenoble in south-eastern France.

Proteins that span the outer membrane of cells are notoriously difficult to crystalise in large quantities, but because Diamond is so powerful, even a small amount will do.

Another of the first users is Paul Schofield in the department of mineralogy at the Natural History Museum. He is studying the molecular structure of a meteorite, Santa Catharina, which was discovered in 1875 on the island of Sao Francisco off the coast of Brazil.

Scientists believe the lump of rock is part of the remnants of a planetoid that blew apart around 140m years ago and dropped to Earth between 10,000 and 100,000 years ago.

An artist's impression of the view down the Diamond synchrotron in Oxfordshire

Daily Mail, Friday, February 9, 2007

It cost £260m, is the size of five football pitches and is the most remarkable British scientific project in decades

Magic doughnut: The new Oxfordshire lab will be able to study atoms in extraordinary detail

YOU CALL THAT A MICROSCOPE?

by Michael Hanlon
SCIENCE EDITOR

BY ONE reckoning this picture shows the most powerful torch in the world — a device that can create the brightest light in the known universe, ten billion times more brilliant than the sun.

It can produce a man-made beam of radiation so intense that it would be visible the other side of the cosmos, if it were to be pointed in the right direction.

Welcome to Diamond — the largest scientific instrument to be built in Britain for decades.

Constructed on the site of the old RAF Harwell airfield in Oxfordshire (from which the Pathfinder missions for D-Day took off), it has cost — so far — £260 million.

And after four years in construction it has finally opened for business, as scientists started the first of many research projects that will harness its astonishing capabilities to shed new light — quite literally — on the world around us.

Over the next 30 years, it is hoped that Diamond will revolutionise everything from the way that computer microchips are built to the manufacture of new drugs.

So what exactly is this giant building — the size of five football pitches — that sits like a beached flying saucer, near the little town of Didcot?

Well, to properly understand how the machine works you really need a degree in physics — preferably a doctorate.

Its official name is a 'synchrotron microscope' — the biggest, most expensive and most powerful of its kind on the planet.

But the very basic principles are simple enough. In essence, Diamond is a combination of a super-powerful torch and microscope.

It works by firing electrons, the sub-atomic particles that carry electrical charge, around a vast ring about 1,800ft in circumference. Inside this ring, they are then accelerated by gigantic powerful magnets until they are travelling at around 600 million mph — nearly the speed of light.

As the electrons reach these astonishing velocities, they are vibrated by more magnets, causing them to throw out intense and highly-focused beams of radiation — whether in the form of visible light, infra-red beams or X-rays.

These beams, just a fraction of a millimetre across, are then channelled away from the main ring down into adjacent research rooms, just like water being sent down aqueducts, where they are then used by scientists to illuminate whatever sample they want to study — for example, a human cell or a tiny dust particle.

To put it very simply, this super-bright light allows researchers to probe the most fundamental properties of the object being studied, right down to an atomic scale.

Diamond is certainly a versatile instrument. The first experiment, being conducted by scientists from Durham University, is using X-ray beams generated by the machine to find new ways of building silicon chips for machines like the iPod.

In future projects, the Natural History Museum has booked time to peer into the insides of meteorites, while police forces will be able to use Diamond as the most powerful forensic instrument in history.

A minute spatter of blood or a human hair from a crime scene can be analysed, atom by atom, to help scientists identify any evidence that conventional microscopes may have missed.

Because Diamond can peer with such precision, it will also be an invaluable tool for archaeologists.

SCIENTISTS at Cardiff University plan to examine the Domesday Book, the 11th-century Norman survey of England, to see what lies beneath the visible text. And the Dead Sea Scrolls, mysterious Biblical-era texts, will also fall under Diamond's needle-eyed scrutiny.

Jointly funded by the British taxpayer and by scientific charity the Wellcome Trust, it will also have numerous less arcane uses. Similar, less powerful, machines abroad have already been used to develop Aids drugs, and it is hoped that Diamond will be able to help analyse and develop vaccines and retroviral drugs.

Vast and costly as it may be, this is a landmark that has ushered in a whole new chapter in British scientific exploration.

Daily Mail, 9th February 2007

The Public Response …

Now this is what we should be spending money on, not the Dome, or an out of control Olympics, but cutting edge science.
Remember when Britain had something to be proud about, when we led the world in Industry and Science?
- Dino Fancellu, Epsom

What a nice change! Something the British can be proud of. Well done you boffins.
- Chris., Harlow, U.K.

Nothing short of a triumph. It's a great day for Britain and science.
- Steve Barker, Chippenham, Wiltshire

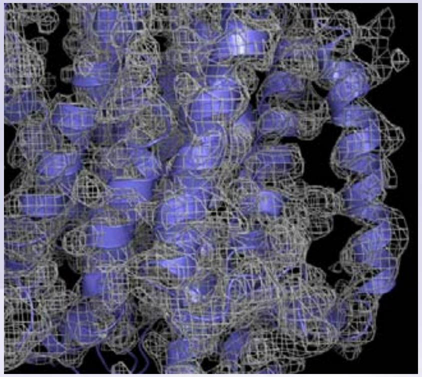
Probably built on time, to budget, and it works. That must mean an MP wasn't in charge of this project.
- Tony, Pontefract, West Yorkshire, UK

I03/I04 Feb-Sep. 2007 – 25 experiments performed

A multidrug efflux pump from pathogenic bacteria

Imperial College London and Diamond Membrane Protein Laboratory

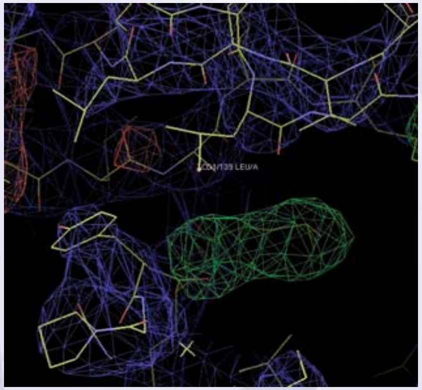
Bacteria that develop resistance to drugs cause great problems in the treatment of infection and disease worldwide. An early success at Diamond Light Source has been with crystals of **a multidrug efflux membrane protein** …



Inhibitors of Aurora-A Protein Kinase for the Treatment of Cancer

Institute of Cancer Research, London

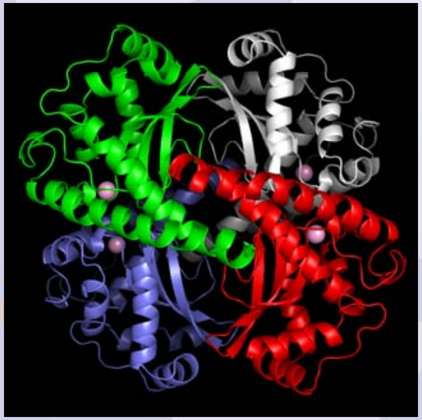
Aurora-A is an essential enzyme, which is required for human cells to multiply. Aurora-A has higher activity than normal in many human cancers and is **a target for the development of anti-cancer drugs** ….



Crystal structure determination of Superoxide Dismutase from *C. elegans.*

University of Leeds, University of Malta

Superoxide Dismutase (SOD) is **a key enzyme that is responsible for removing harmful oxygen radicals from cells** by catalysing their breakdown into hydrogen peroxide and water ….



I06: Nanoscience - 9 User Groups

Loss of long-range magnetic order in Fe nanoparticle thin films

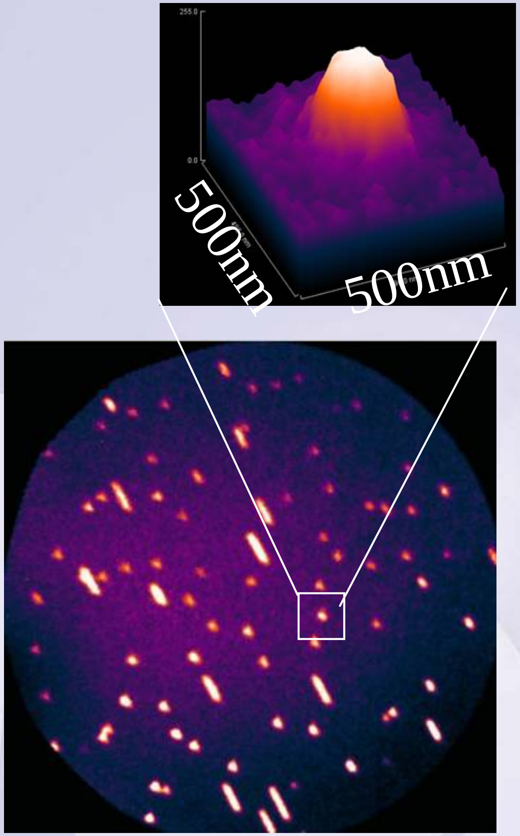
C. Binns, Univ. Leicester

Such films should find application in the recording industry …

Pd Nanoclusters and Nanowires grown on TiO2

G. Thornton, University College London

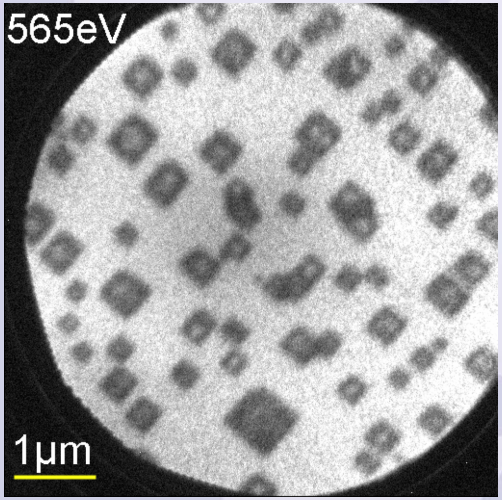
Conducting nanowires will form crucial components in nanoscale electronics …



Cr Clusters grown on W

R. Bennett, Univ. Reading

Chromium is important as an adhesion layer and the oxides find use in magnetic recording media, catalysts and gas sensors …



BBC NEWS

'Super-scope' to see hidden texts

By Liz Seward
Science reporter, York

Last Updated: Thursday, 13 September 2007

The hidden content in ancient works could be illuminated by a light source 10 billion times brighter than the Sun. The technique employs Britain's new facility, the Diamond synchrotron, and could be used on works such as the Dead Sea Scrolls or musical scores by Bach.
Intense light beams will enable scientists to uncover the text in scrolls and books without having to open - and potentially damage - them.
The research was presented at the British Association science festival.

> **"There are some parts of the Dead Sea scrolls which have not been unrolled"**
>
> Professor Tim Wess

Telegraph.co.uk

Diamond synchrotron to use x-rays to examine Dead Sea Scrolls

By Nic Fleming and Roger Highfield
Last Updated: 5:01pm BST 12/09/2007

more: http://www.diamond.ac.uk/News/LatestNews/press_release_13Sept.htm

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http://www.diamond.ac.uk