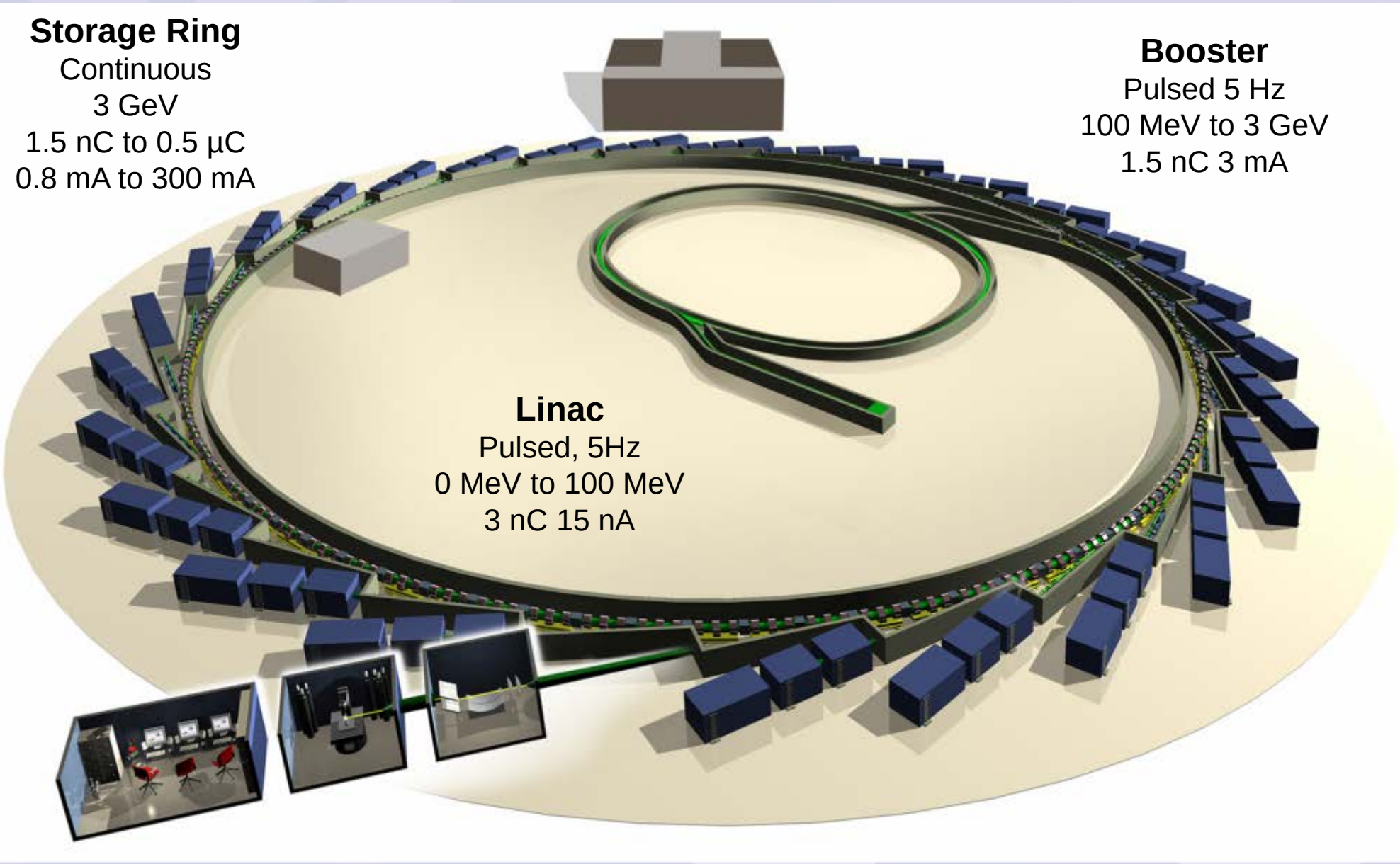
Diamond Light Source

Mark Heron

Head of Software and Computing

Diamond Accelerator Complex

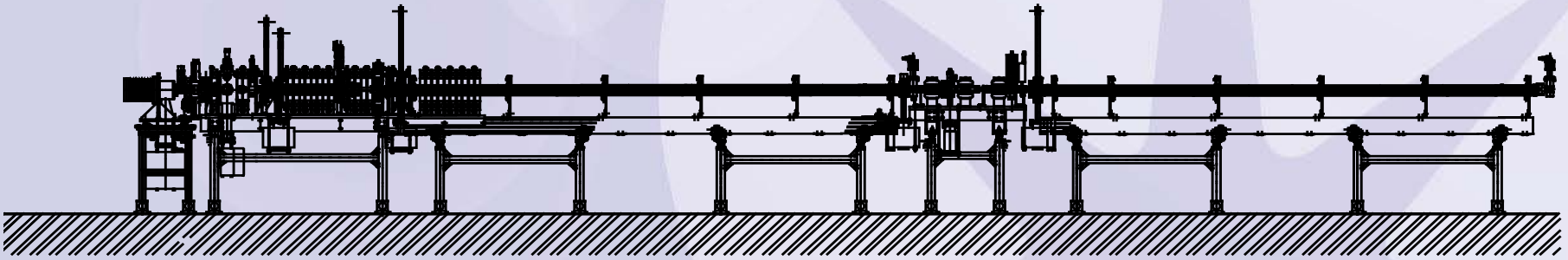


Linac

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

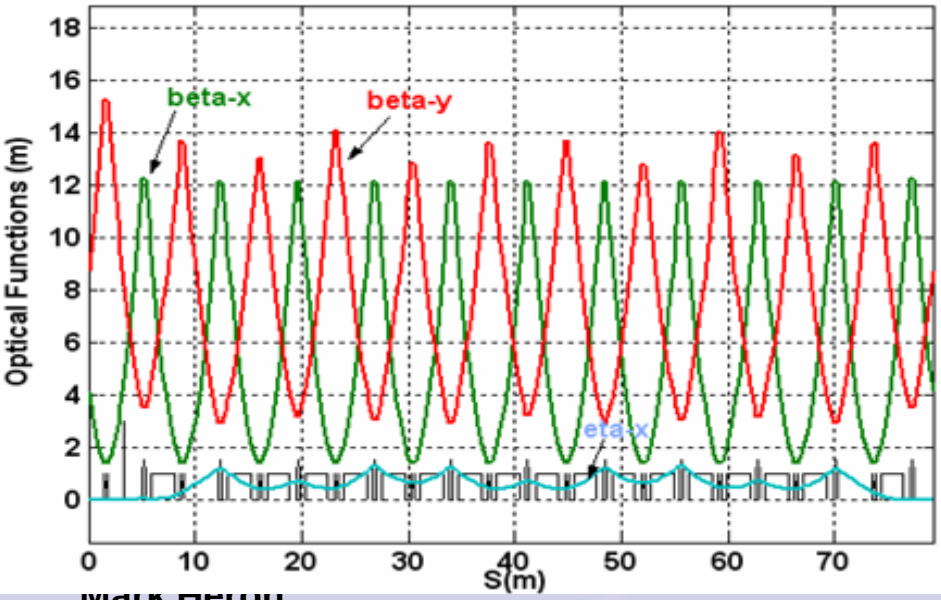
  (DLS supplied diagnostics, vacuum and control system components, and beam analysis software)

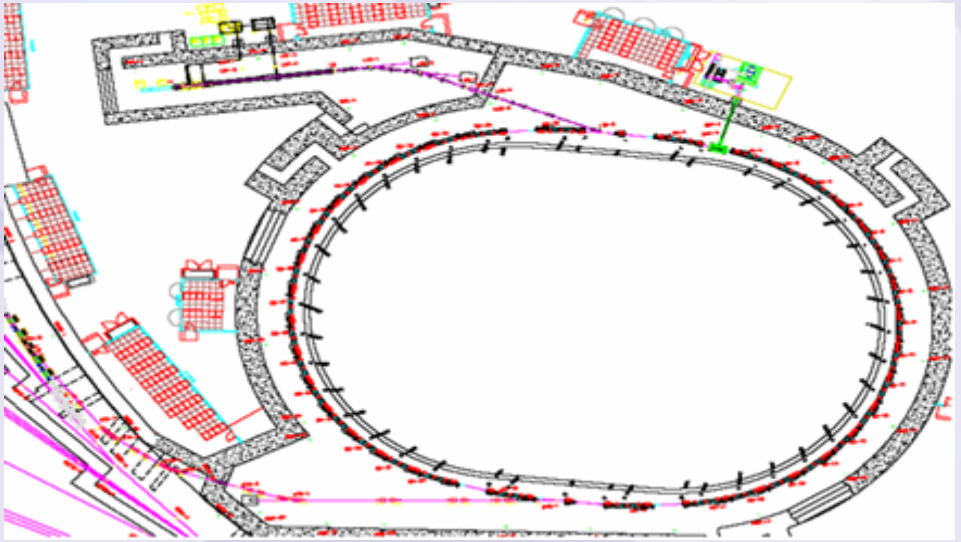
- Thermionic gun; short (< 1 ns) and long pulse (0.1-1 μs) modes
- 500 MHz sub-harmonic pre-buncher, 3 GHz primary buncher, 3 GHz final buncher
- Two 5.2 m constant gradient accelerating sections fed by independent klystrons



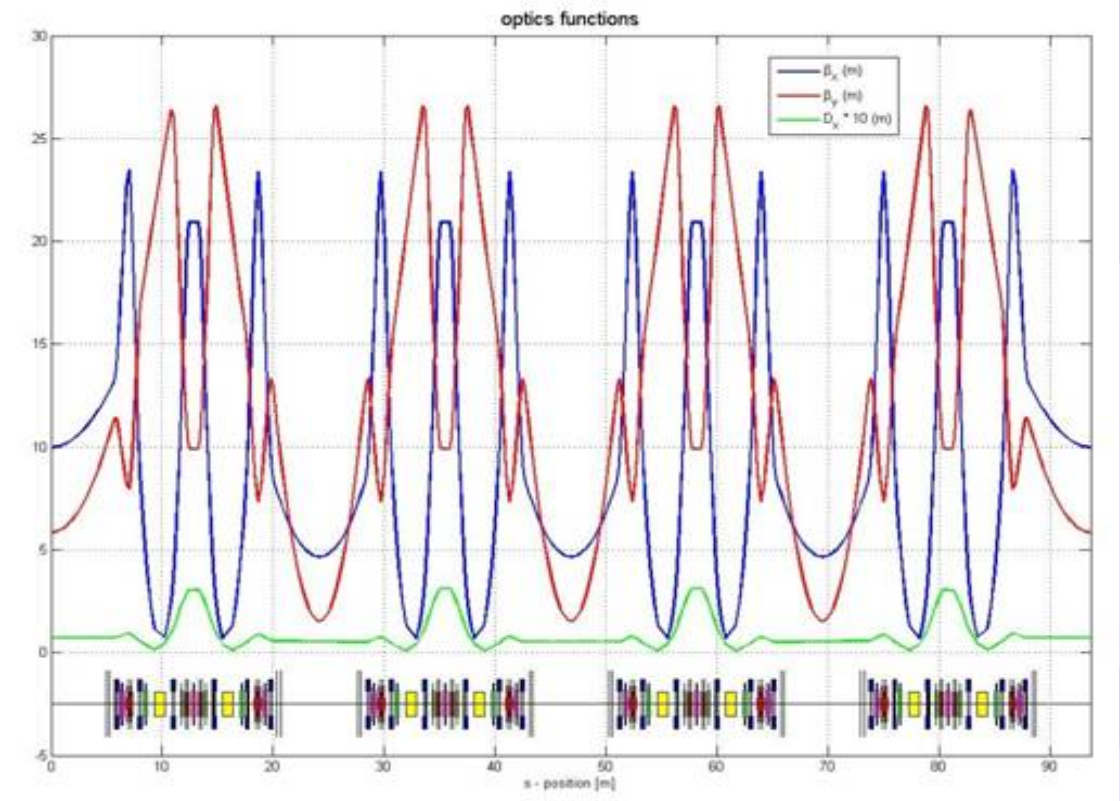
Booster

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





Storage Ring



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

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Diamond Light Source

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Storage Ring

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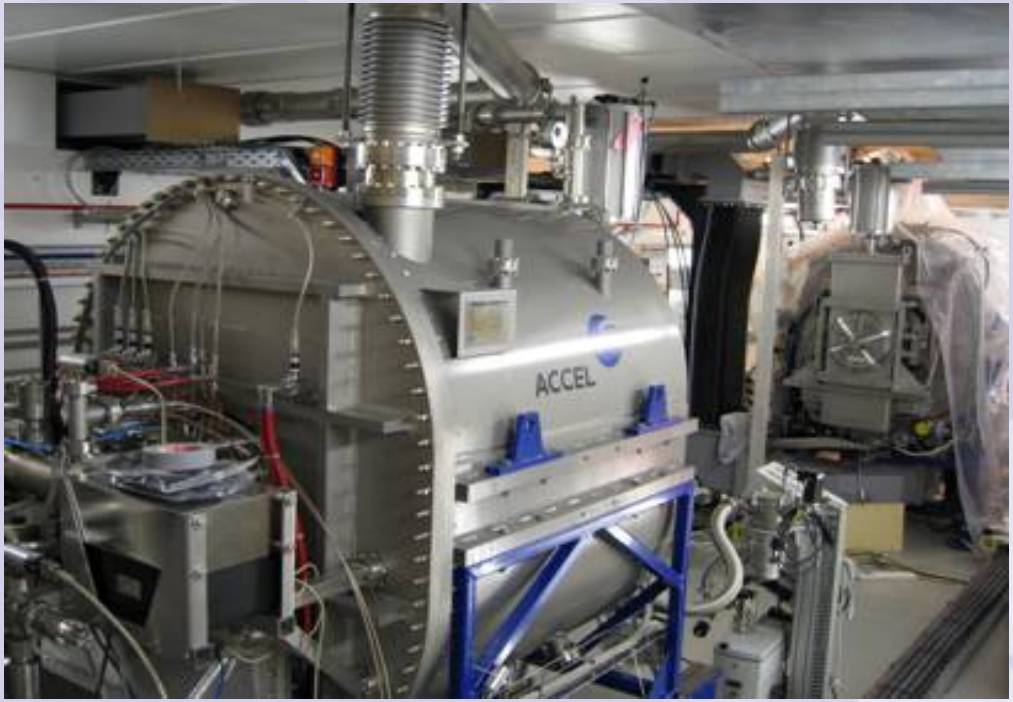
Diamond Installation and Commissioning

SR RF Cavity and Amplifier



SR RF: design os for 3 superconducting cavities in an 8m straight, 2 currently installed.

SR RF: Amplifier use 4x 80kW IOTs as the RF power source

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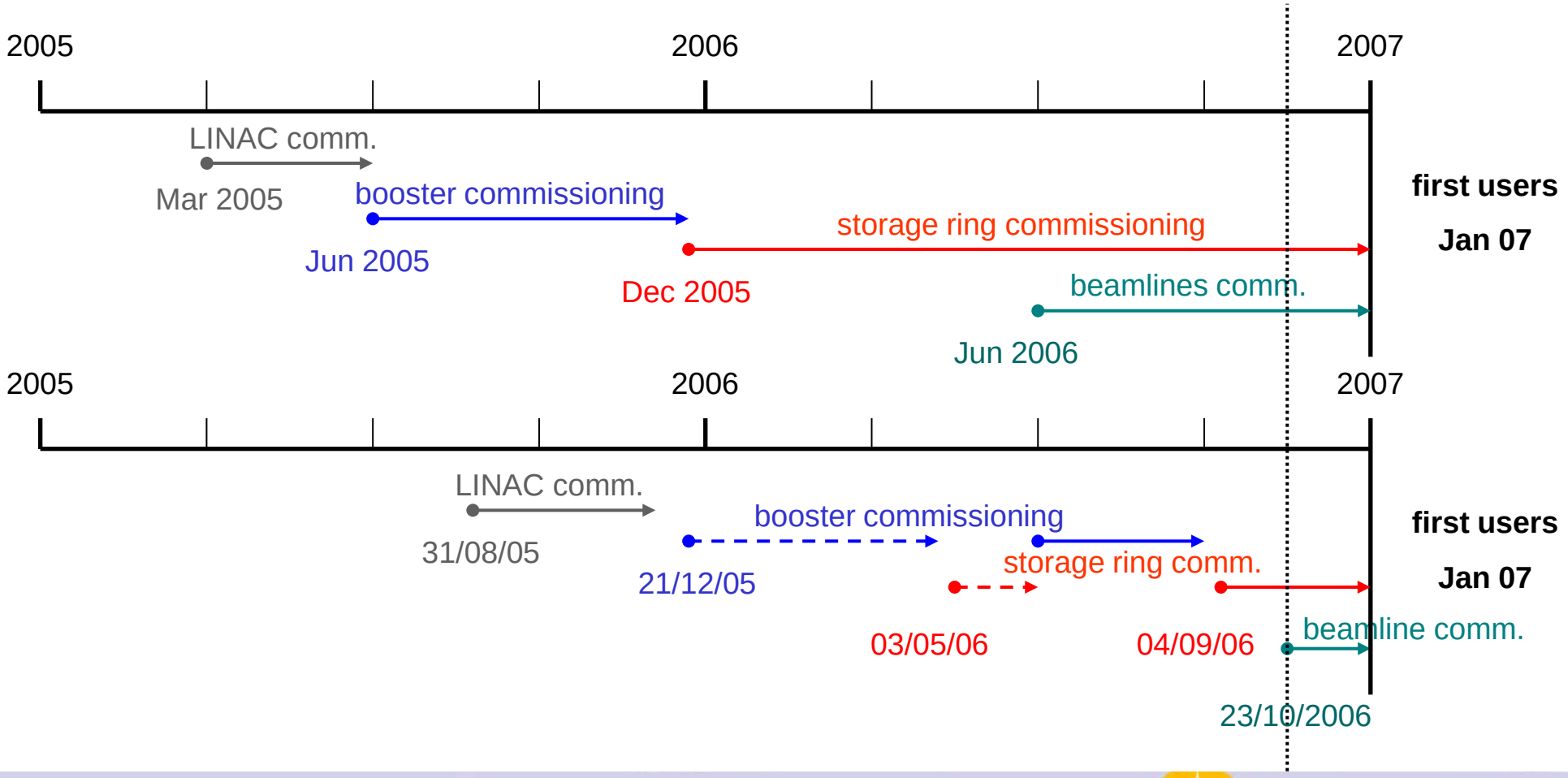
June 2004

May 2005

Celebrating First turns in the SR May 2006

Commissioning Schedule and Reality

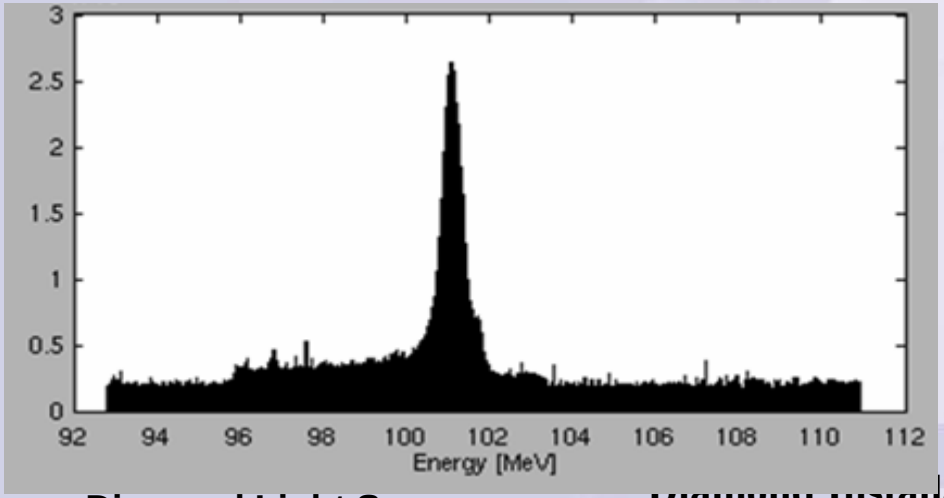


System Commissioning Effort

- Contract for commissioning staff in place for Nov 2004
- Commission of system used a mix of contract and in-house for Acc commissioning May 2005, Oct 2006

Tech System	Contract Techs	Tech Group Staff	Controls Staff
Linac	(turnkey ?)	1	0.5
PSUs	3	3	1
Vacuum	3	2	0.5 PLCs 0.5 CS
MPS	3		2 PLCs 0.5 CS
RF SR	(turnkey ?)	4	0.5
Diagnostics & FOFB	1	4	2.5
PSS	4	3	.5
Timing			0.5 HW 0.5 SW
IDs Turnkey	1	1	0.5
FEs	2	1 Elec	1 PLCs 0.5 CS
Girder Align	(turnkey ?)	0.5 Elec Eng	

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

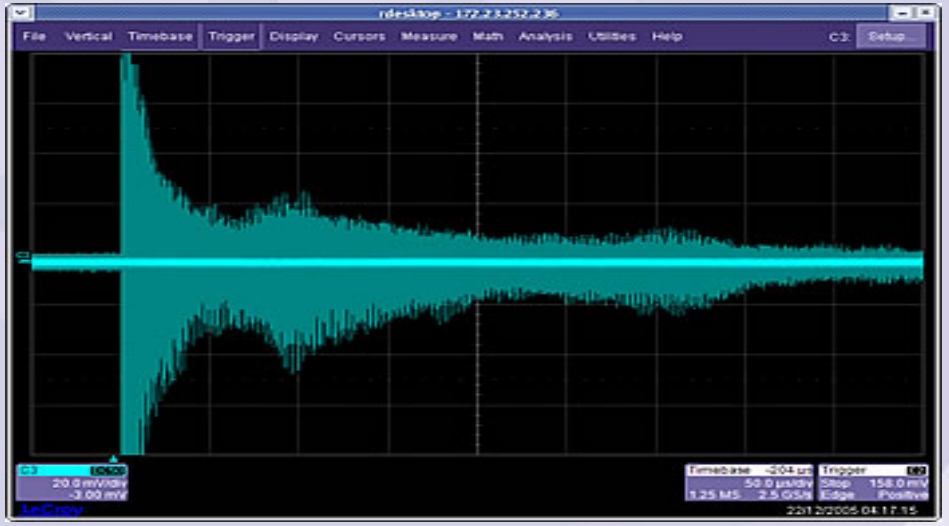
Temporary Cu Network
Local Timing Generator
Booting IOC of development servers
Temporary Control Room

Booster Commissioning

• Booster installation completed	December 2005
• First injection into booster from LTB	December 22nd 2005
• Capture of beam by booster RF	February 2006
• Acceleration to 700 MeV	March 3rd 2006
• First extraction from booster at 700 MeV	April 4th 2006
• First 700 MeV injection into storage ring	May 2006
• 3 GeV extracted	June 2006

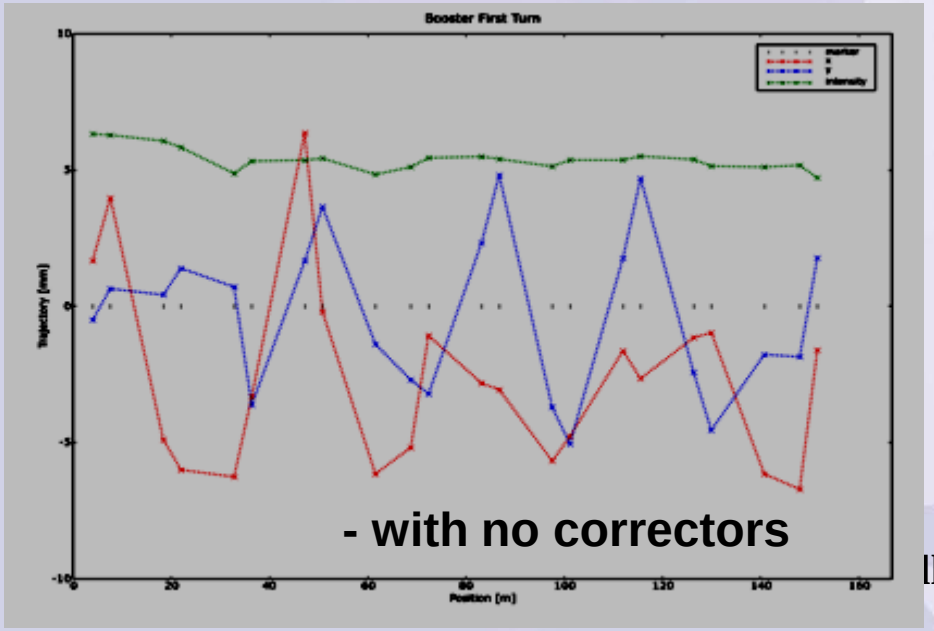
- Operational network and servers were installed because of building
- Timing EVG installed and timing distributed signal distributed over computer network
- 2nd temporary Control Room a Booster CIA

Booster Commissioning



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

Dec. 21st 2005



- with no correctors

llation and Commissioning

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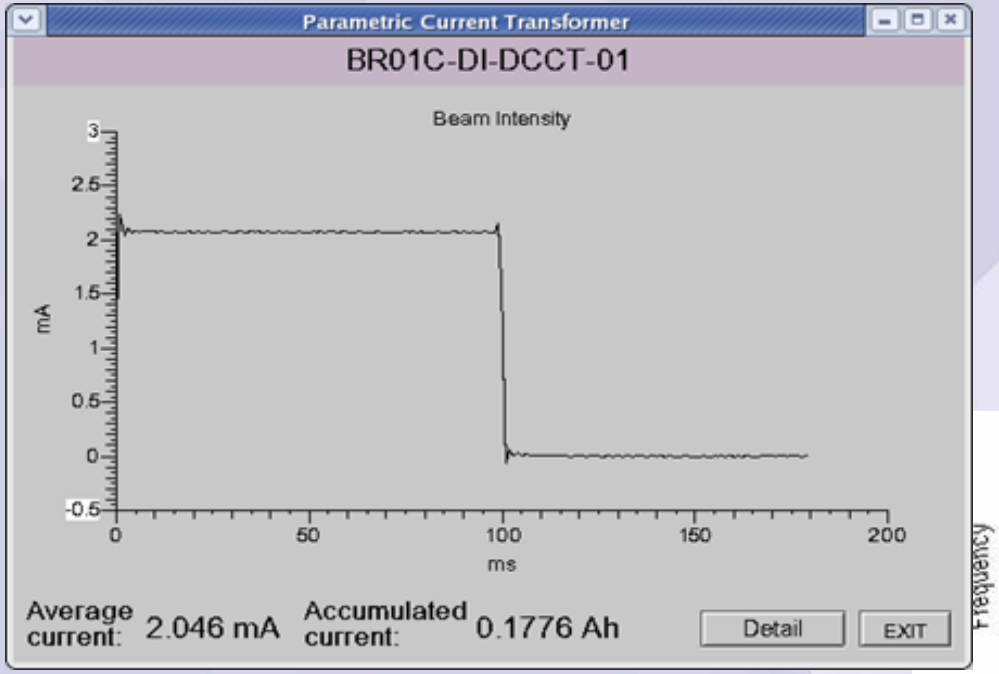
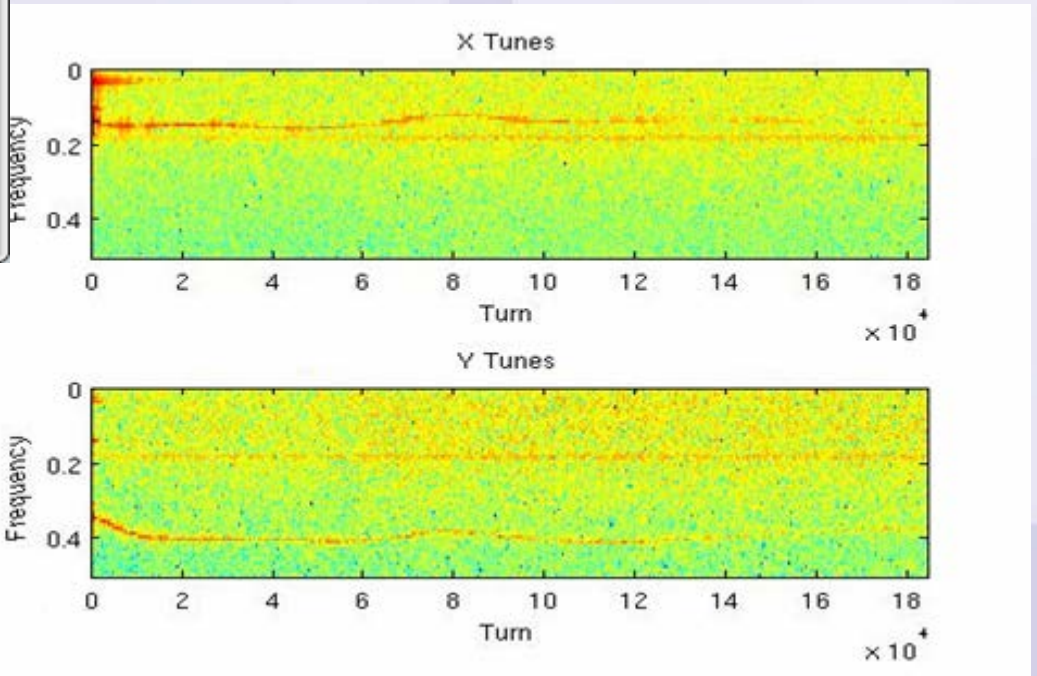
Booster Commissioning 3 GeV June 2006



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

Tunes corrected through the ramp



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Diamond Insta

- planned for current week	1			2			3			4			5			6			7			8			9			10			1
- due for completion previous week	10			1			2			3			4			5			6			7			8			9			10	
Activity \ Cell No.	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24								
Girder installation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									
Initial survey	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									
Correction of girders	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									
Qualification survey of girders	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									
Inter-girder vacuum connections	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									
Attach G1 PBPM to stand	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3										
Survey and adjust G1 PBPM	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3										
Attach G3 PBPM to stand	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Survey and adjust G3 PBPM	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Attach G1 Sector Valve to stand	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Attach G3 Sector Valve to stand	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
ID Make-up Straight Floor Plate		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		3	3	3	3	1										
ID Make-up vacuum connections		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		3	3	3	3	1										
ID Straight vacuum rack		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		3	3	3	3	1										
Sector Valve compressed air	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Sector Valve compressed air	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
ID Make-up vessel pipework		3	3																			1										
Balfour Handover	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Functional testing of vacuum racks;	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Functional testing of vacuum racks;	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Tunnel wall pipework installation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Trench pipework installation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Install off girder manifold	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Install girder flexibles	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Compressed air pipework installation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Pressure test pipework	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Flush and chemically clean pipework	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Pipework mechanical commissioning																						1										
MPS functional testing (without	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
MPS functional testing (with water)																						1										
MPS global testing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
Steerer Magnet PSU testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1										
Q&S Magnet PSU testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1										
SR Dipole PSU testing (for 700 MeV)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1										
Motion Control rack testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Diagnostics rack testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Ratchet Wall Shield Plug installation		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1										
Front end installation			3	3		3										3		3														
Front end rack testing			3	3		3										3		3														
Front End bakeout			3	3		3										3		3														
Front end commissioning			3	3		3										3		3														
Fit Girder 1 Access Steps	3	3	3	3		3	3	3	3	3	3	3	3									1										
Fit Girder 1 Step-ups for Access	3	3	3	3			3		3				3									1										
Fit Girder 3 Access Steps	3	3	3		3	3	3		3		3		3	3	3	3	3	3	3	3	3	3										
Fit Girder 3 Step-ups for Access	3	3	3		3	3	3		3		3		3	3	3	3	3	3	3	3	3	1										
Install lead and polythene beads -	3		3	3	3	3	3	3	3	3	3	3	3	3		3				3		1										
Install lead and polythene beads -	3	3	3	3	3	3	3	3	3	3	3	3	3	3		3				3		1										
Install lead and polythene beads -		3	3	3	3	3	3	3	3	3	3	3		3		3				3		1										
PSS Interface panel termination		3		3		3		3		3		3		3					3		3		3									
PSS Testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3								
PSS global testing	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3								
First Cavity Cooldown																	3															
First Cavity RF testing																	3															
Second Cavity installation																	3															
Second Cavity RF testing																	3															
Injection Straight	3																							3								
BTS2 installation	3																							3								

Storage Ring Technical Systems Commissioning

- Jan to April 2006
- Progressing final tasks to meet first beam, out of programme of 12k tasks
- Concentrated on ensuring commissioning
  - Coordinating multiple activities in the tunnel
- Progress Matrix
  - Tasks completed past weeks (Green)
  - Tasks not completed (Red)
  - Tasks for planned the current week (Blue)
- Progressed weekly

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Status in April 2006

- All Storage Ring technical systems required for beam system commissioned
  - Building not finished and no cooling
  - Only Night and weekend commissioning with beam
  - Ongoing day time installation of Building, Cooling, Frontends
- Booster and Storage Ring Commission in 2 phases
  - **1St Phase 700MeV**
    - Booster Dec 100MeV SR
    - Booster Jan – Feb 700MeV
    - SR April-May 2006
  - **2nd Phase 3GeV**
    - June 2006 Booster 3GeV (on temporary cooling)
    - SR Sept onwards 3GeV

Diamond Control Room

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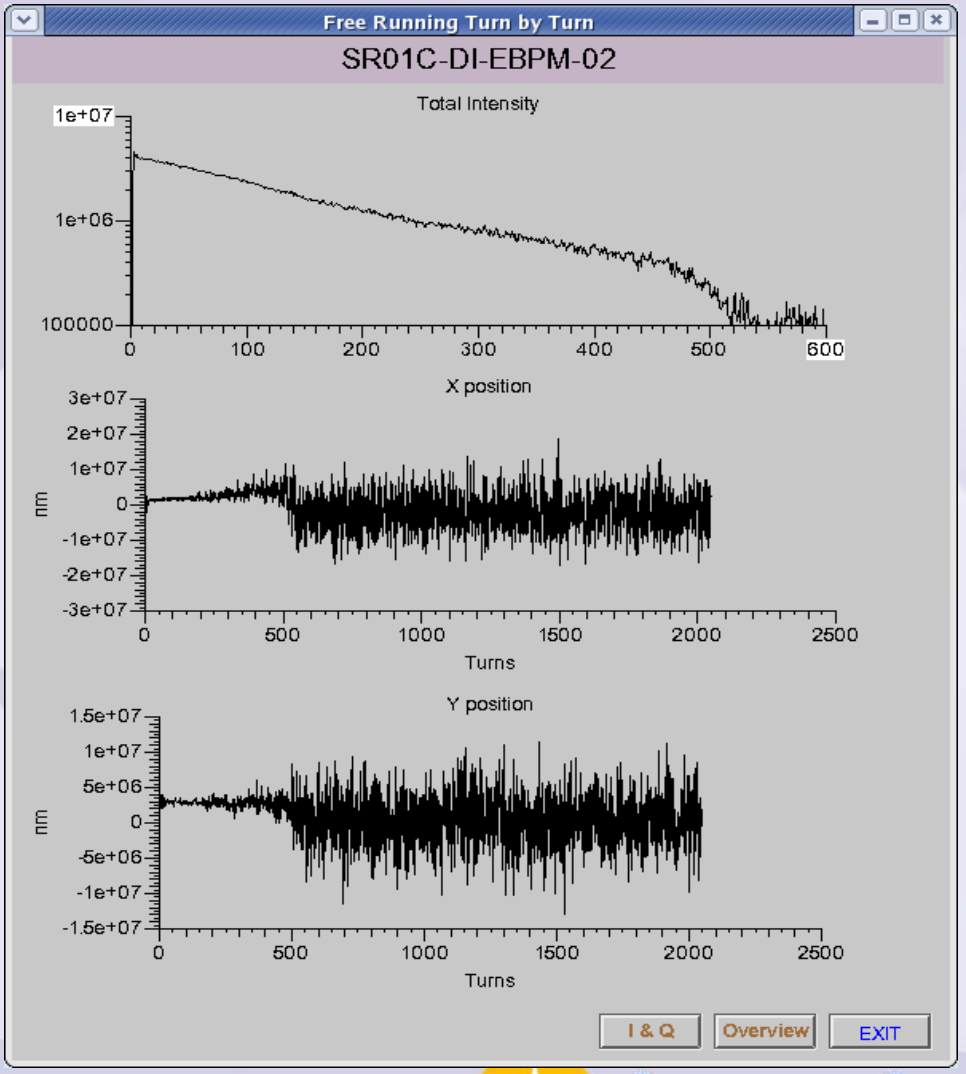
SR Commissioning at 700 MeV



- 1St beam,1 Turn on 5th May 2006
- Limited by a Quad with incorrect polarity

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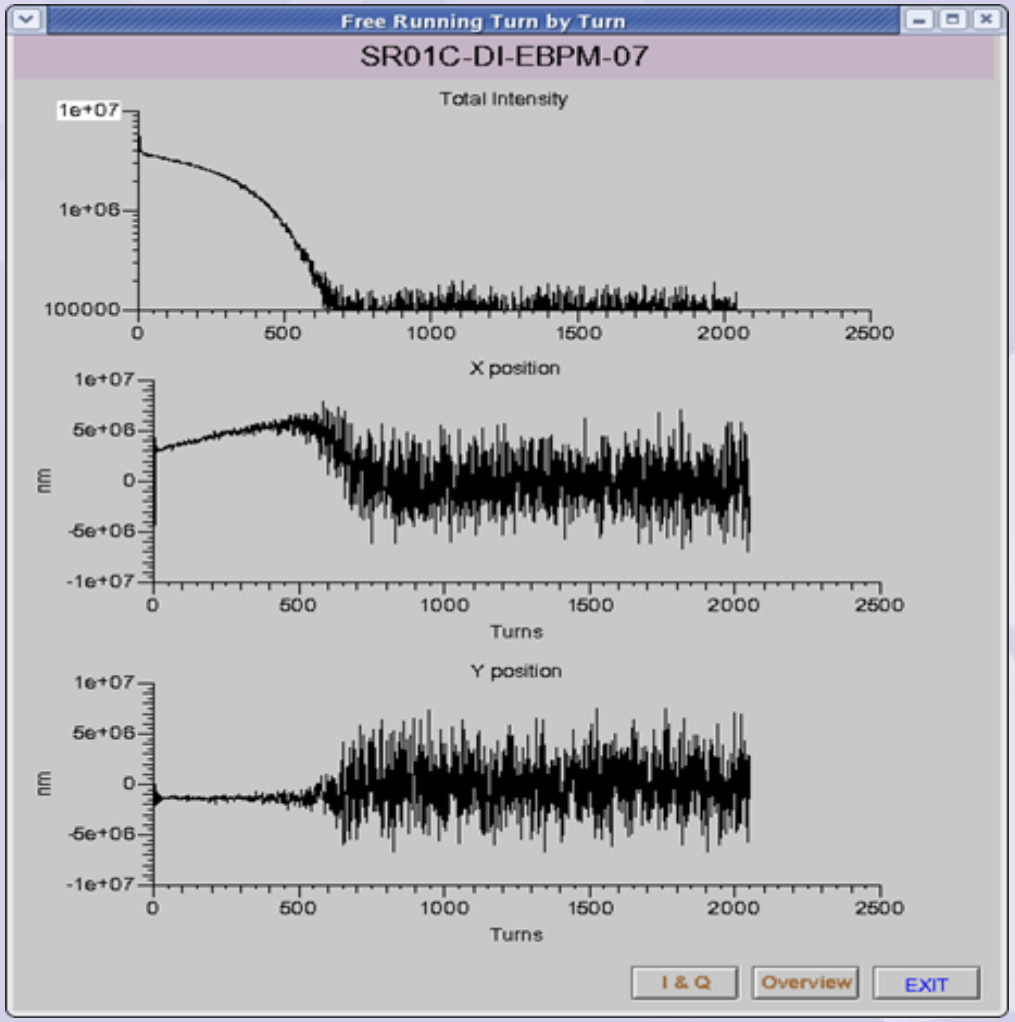
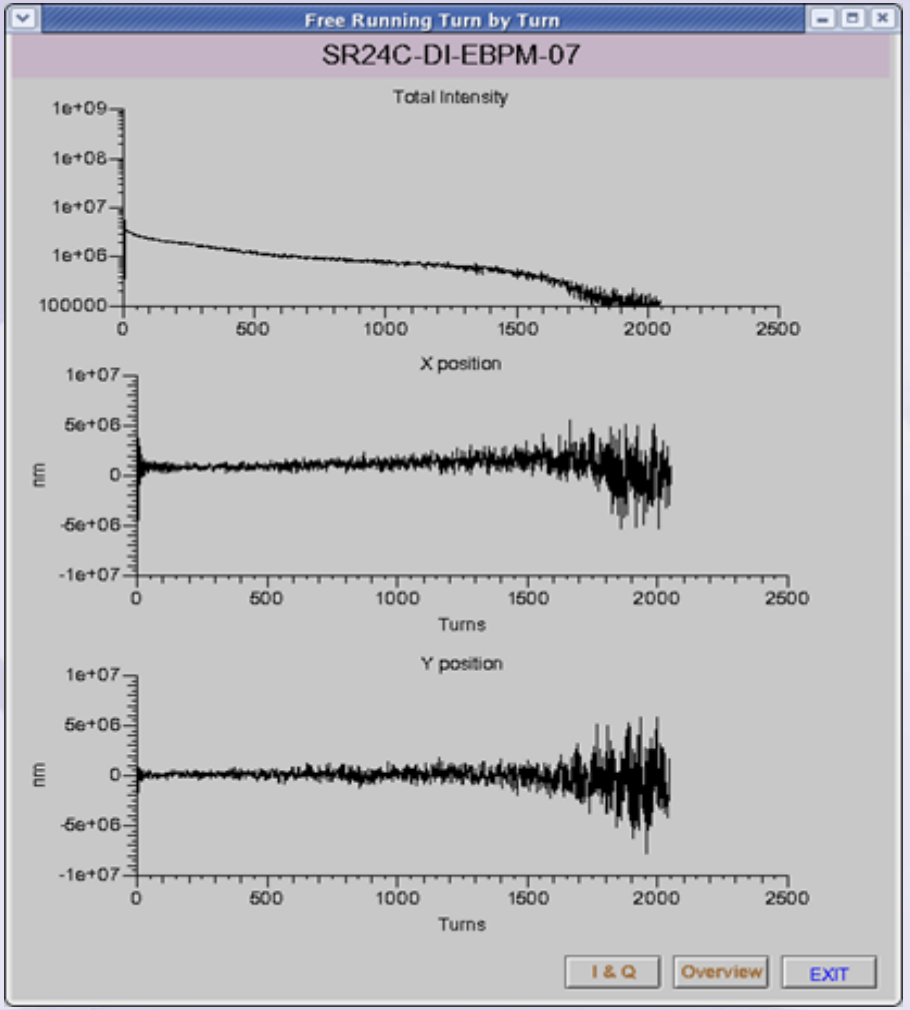
Diamond Installation and Commissioning

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



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



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Diamond Installation and Commissioning

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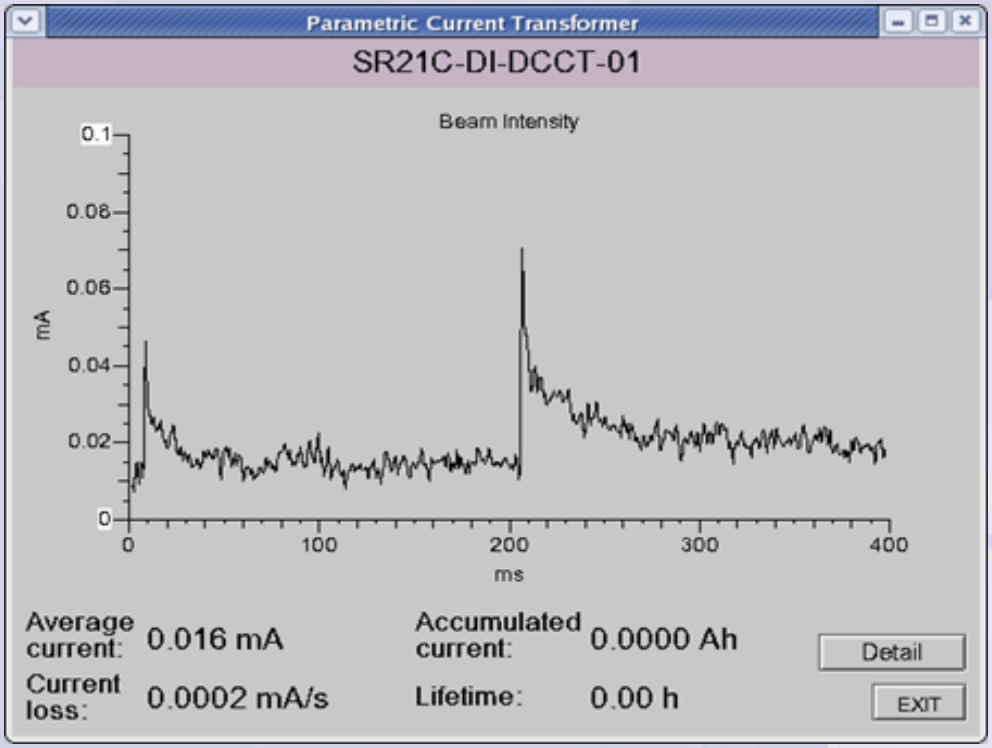
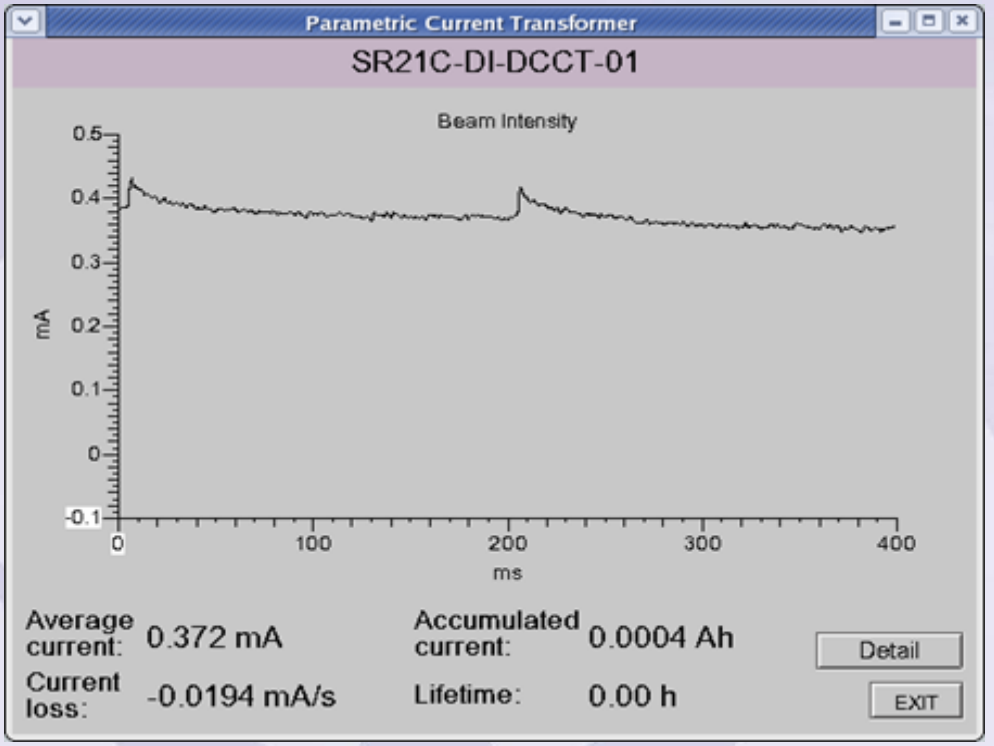
May 20th/21st:
106,764 turns !



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



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Diamond Installation and Commissioning

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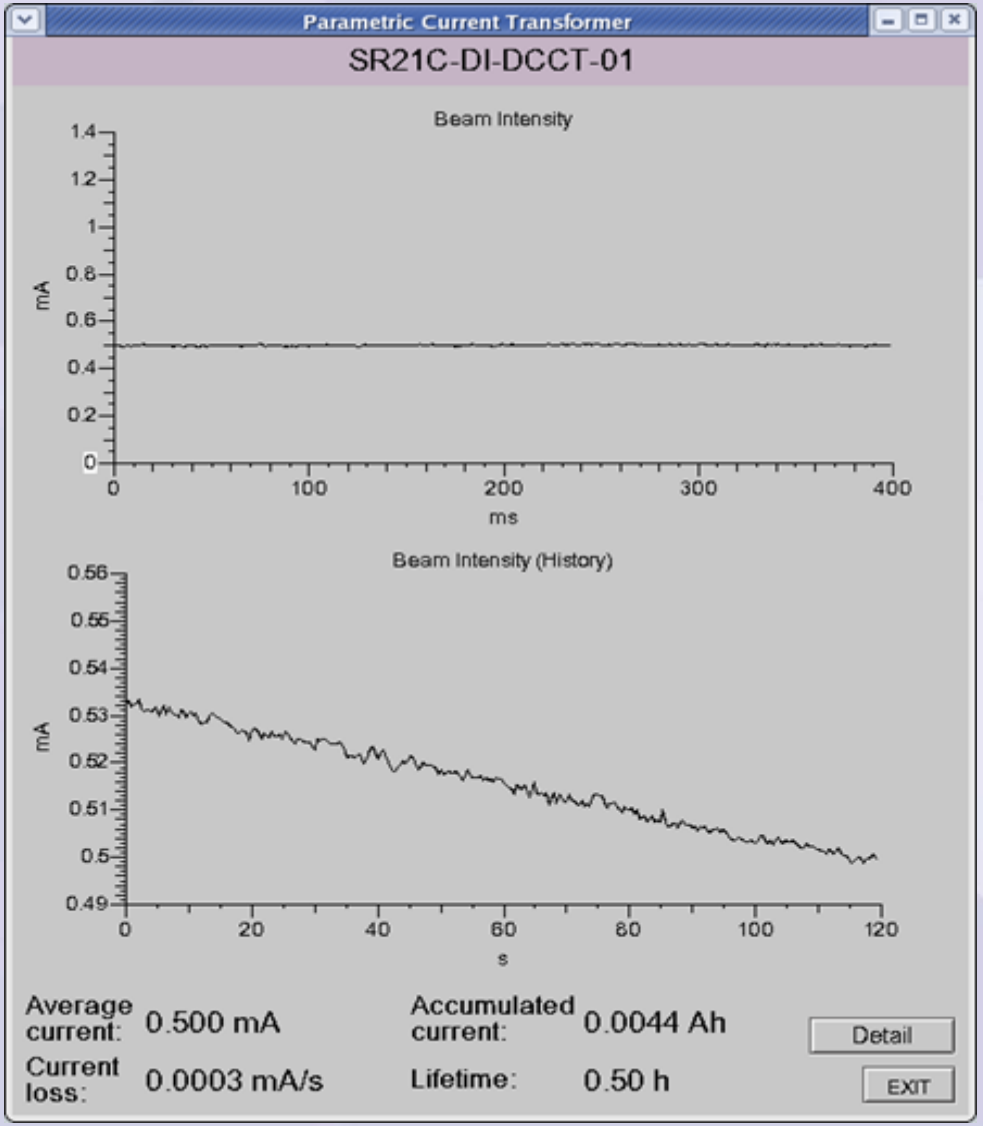
SR Commissioning at 700 MeV



First stored beam ! …

0.5 hour lifetime at 0.5 mA

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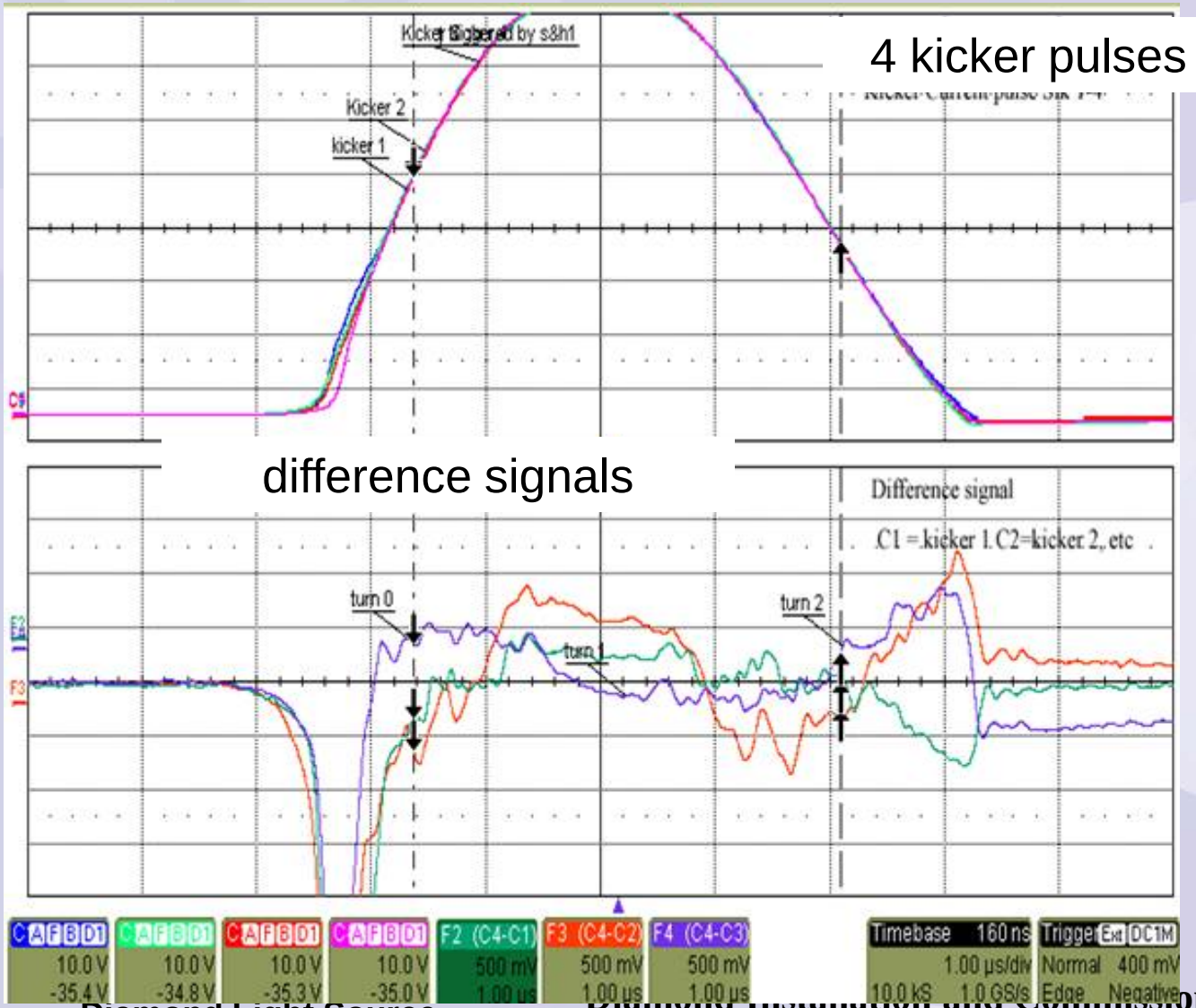
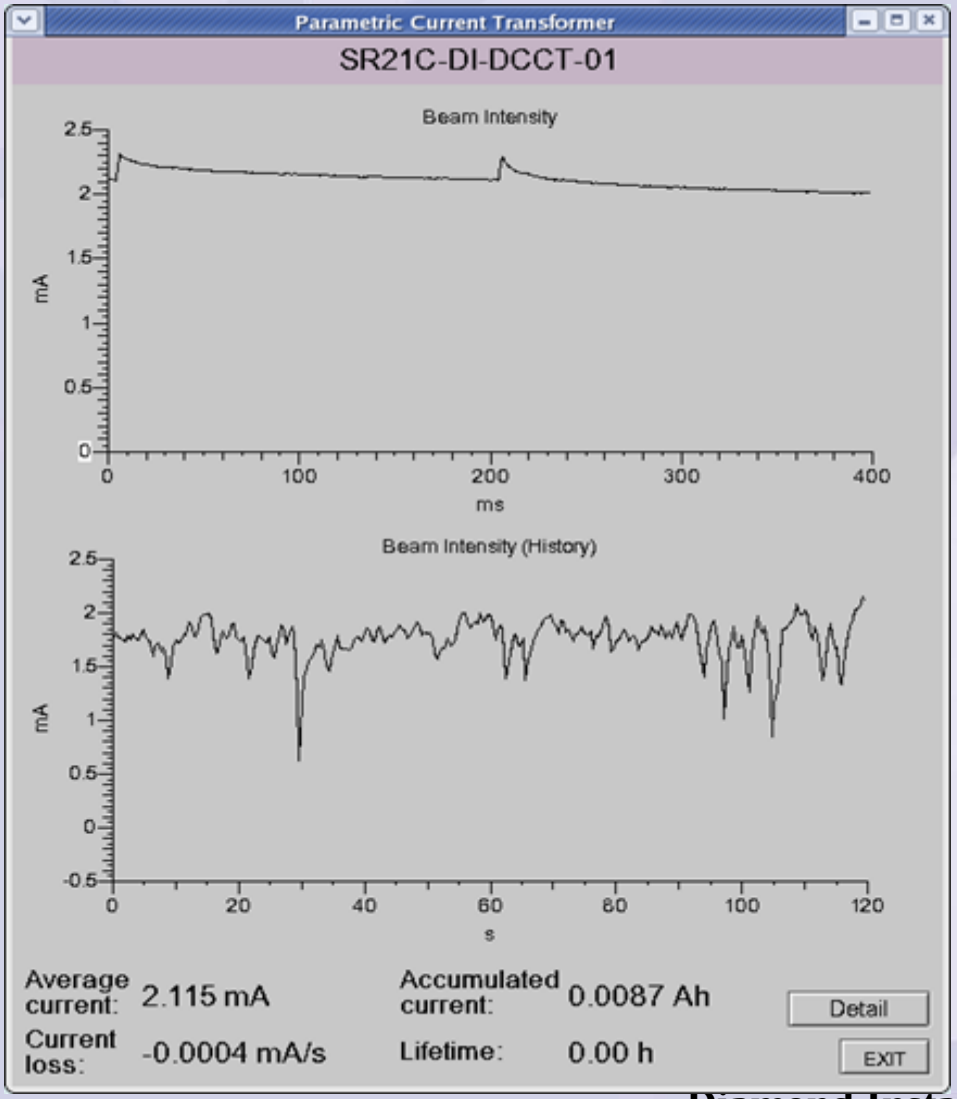
SR Commissioning at 700 MeV



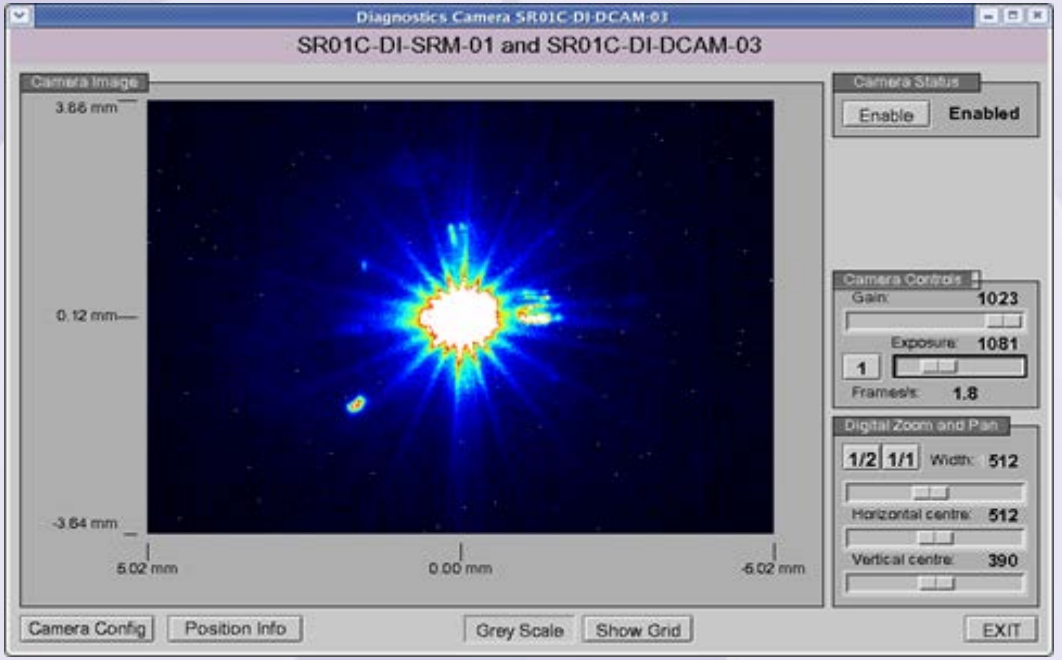
- But initially the beam did not accumulate
- Believed to be due to differences between the kicker pulse shapes (which were not tuned for operation at 700 MeV)
- After an optimisation procedure

…..

SR Commissioning at 700 MeV

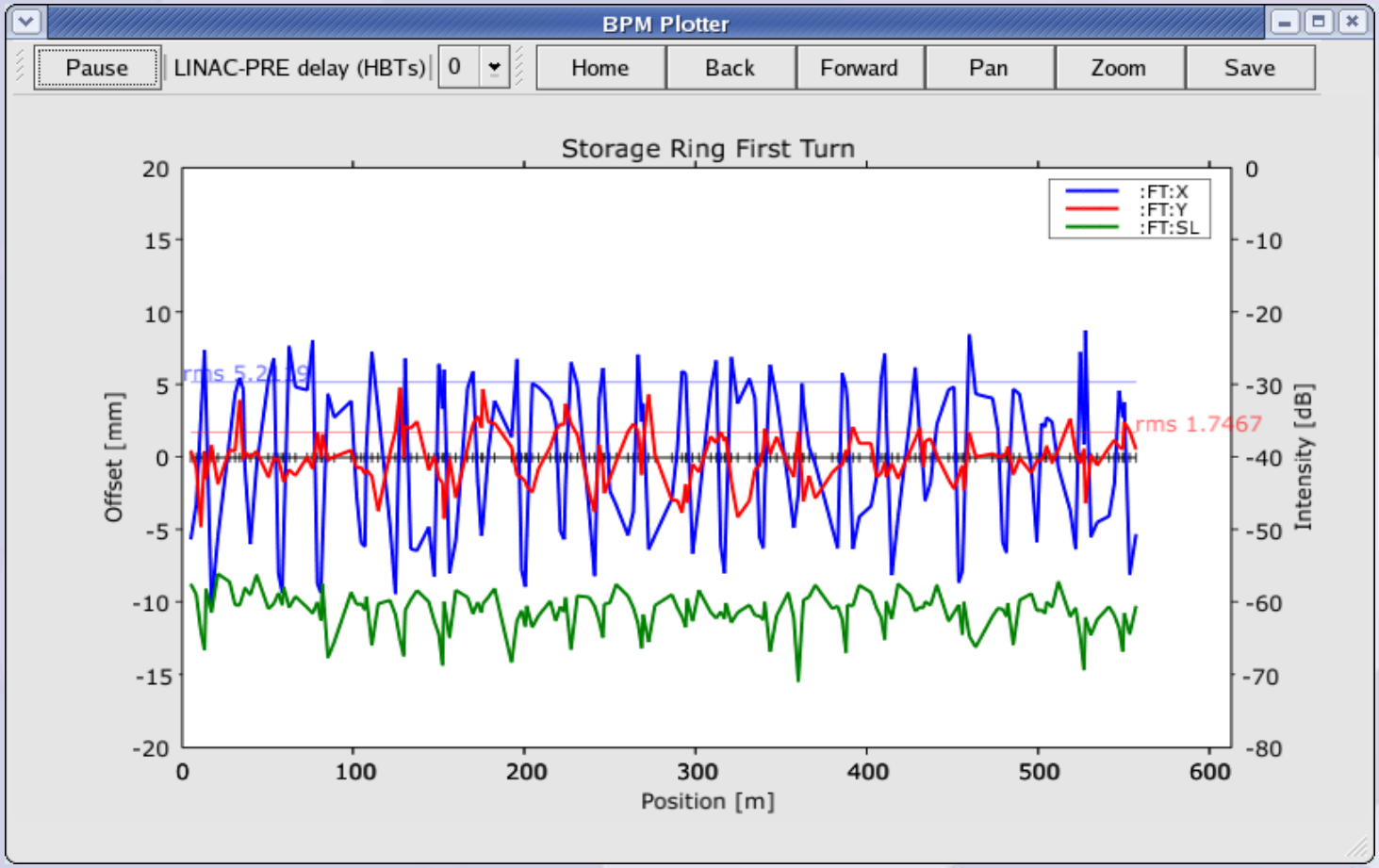


> 2 mA accumulated



SR visible on SLM

SR Commissioning at 3GeV:
1st Beam on 4th September 2006



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Diamond Installation and Commissioning

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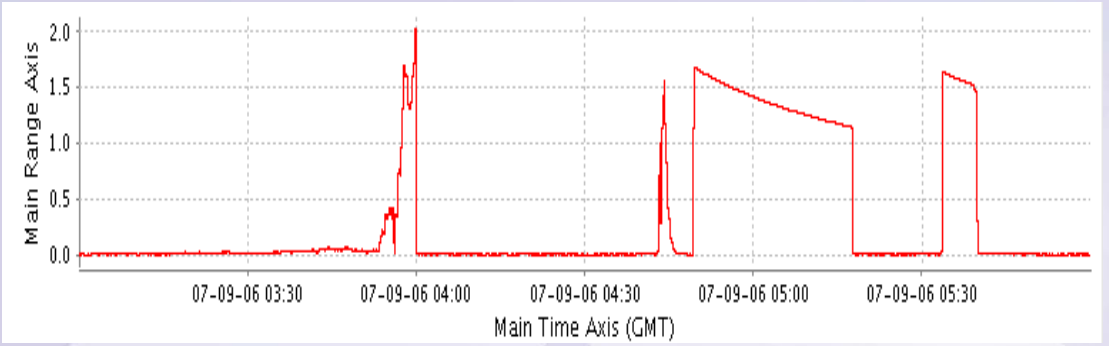
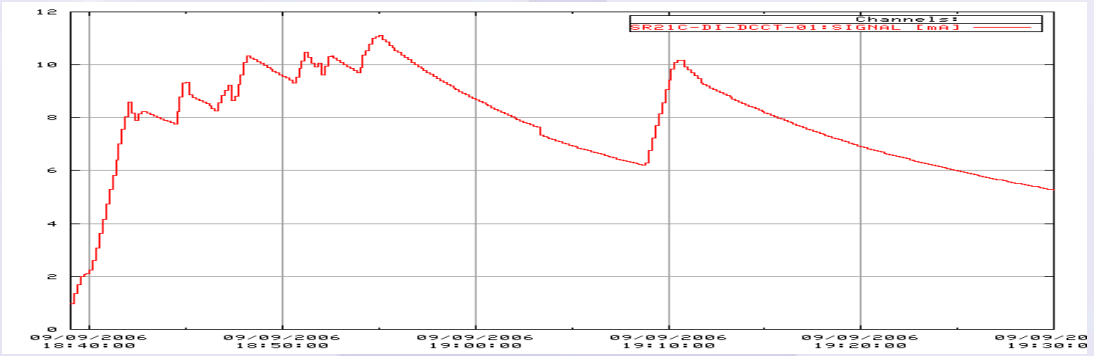
SR 3 GeV Commissioning

- Sep. 4th/5th – 5 turns, no correctors !
- Sep. 5th/6th – 120 turns, no RF on
- Sep. 6th/7th – RF On .. 2 mA stored;
- 2mA limit since absorber water flow interlocks not commissioned
- Sep. 9th – 10 mA
- 10mA limited since orbit interlock not commissioned
- Sep. 25th – 25 mA
- Oct. 2nd – 60 mA
- Oct. 10th – 90 mA





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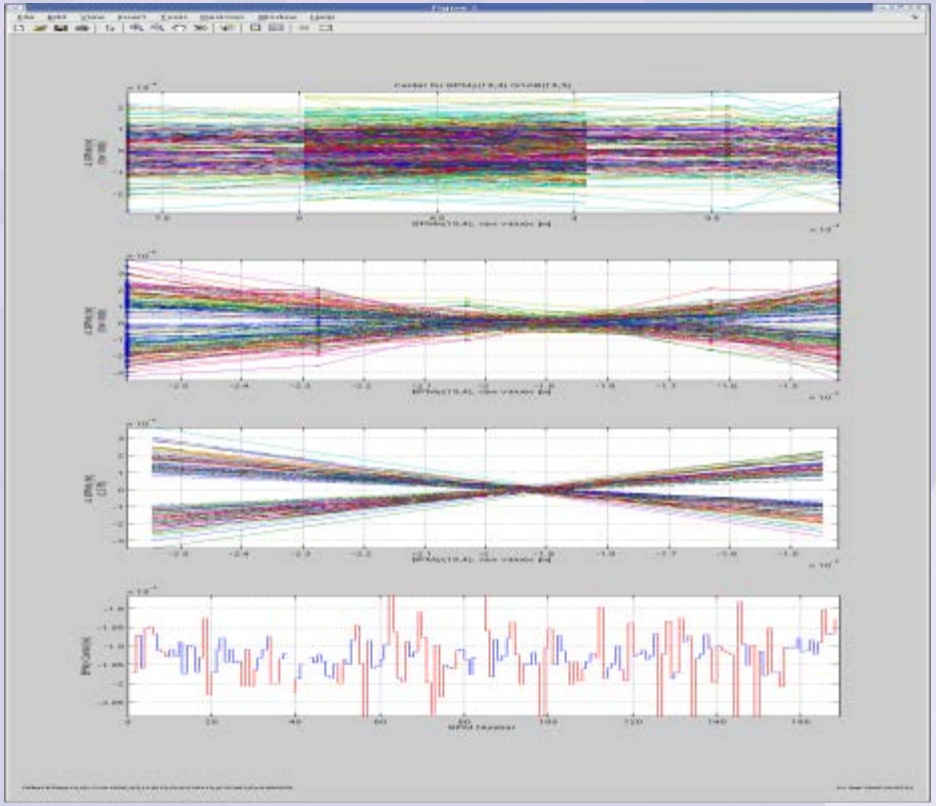
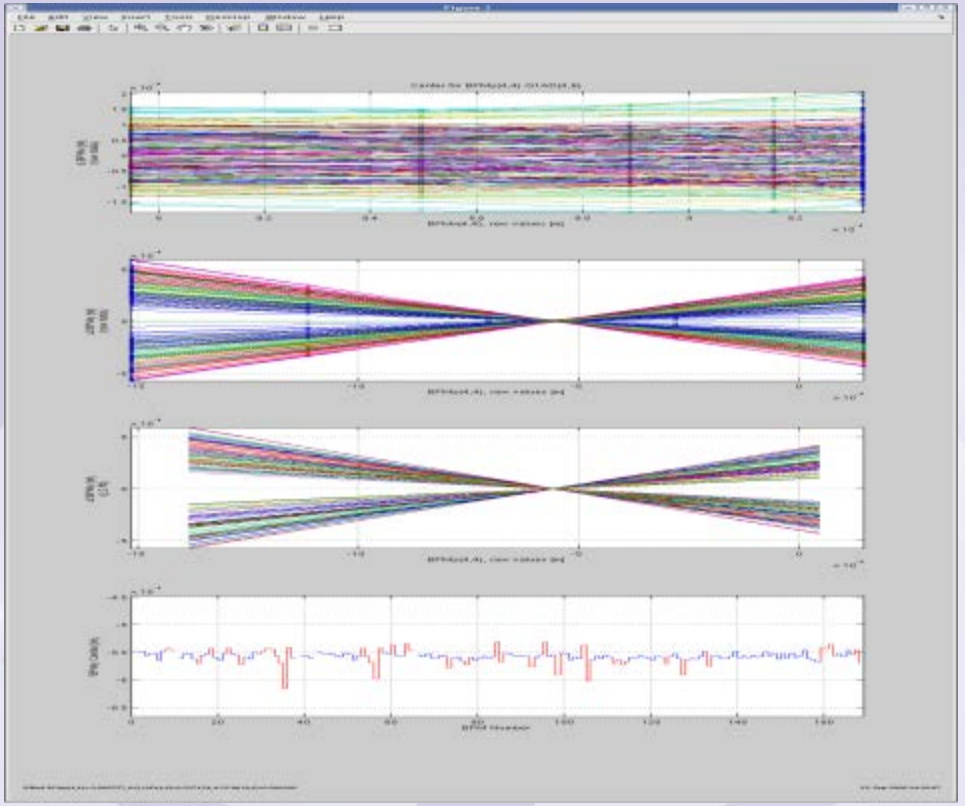
SR 3 GeV Commissioning

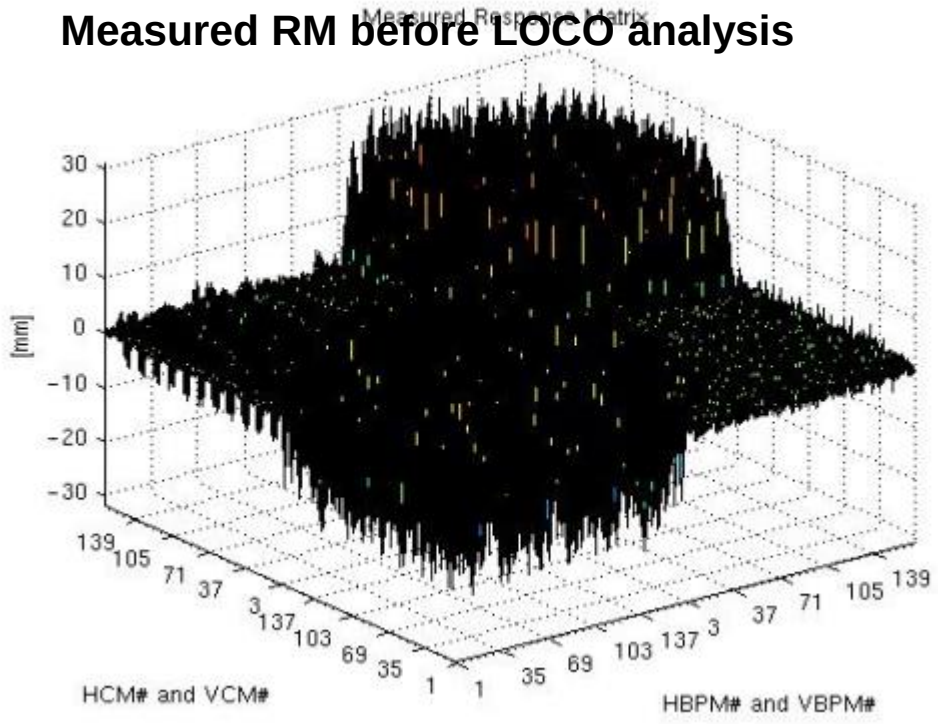




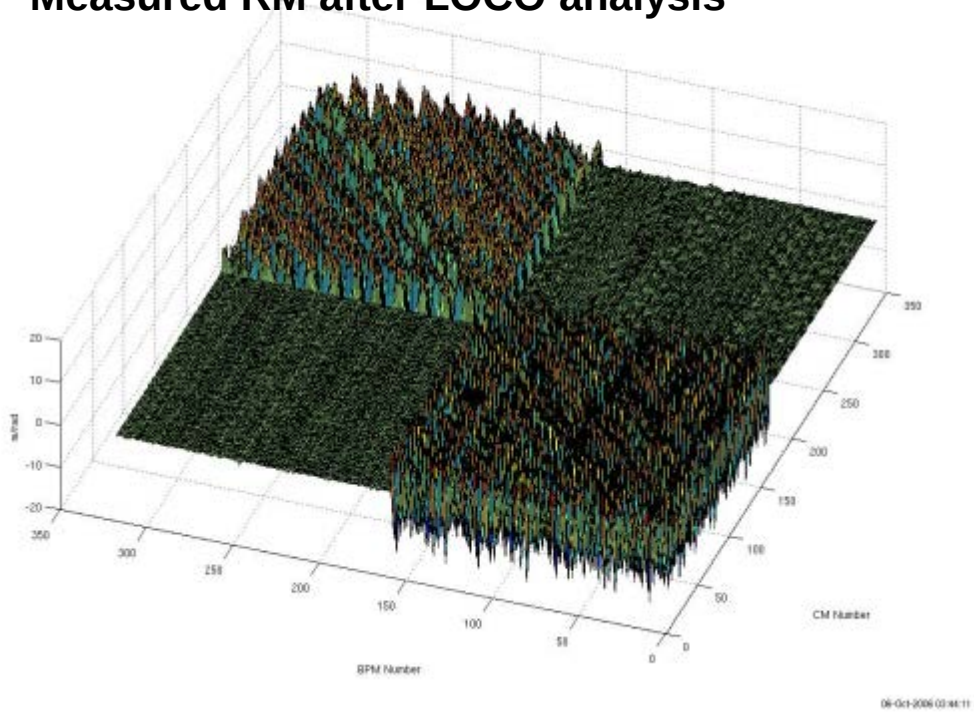
- Poor correction of closed orbit,
- Initial BBA measurement very noisy but offsets applied and subsequent measurement much cleaner
- Three BBA runs to establish BPM centres carried out, which improved orbit

SR 3 GeV Commissioning

Measured RM before LOCO analysis



Measured RM after LOCO analysis



- LOCO Measurement and correction applied to optics
- Initial Beta Beat 40%, was reduced in iterations to about 2%

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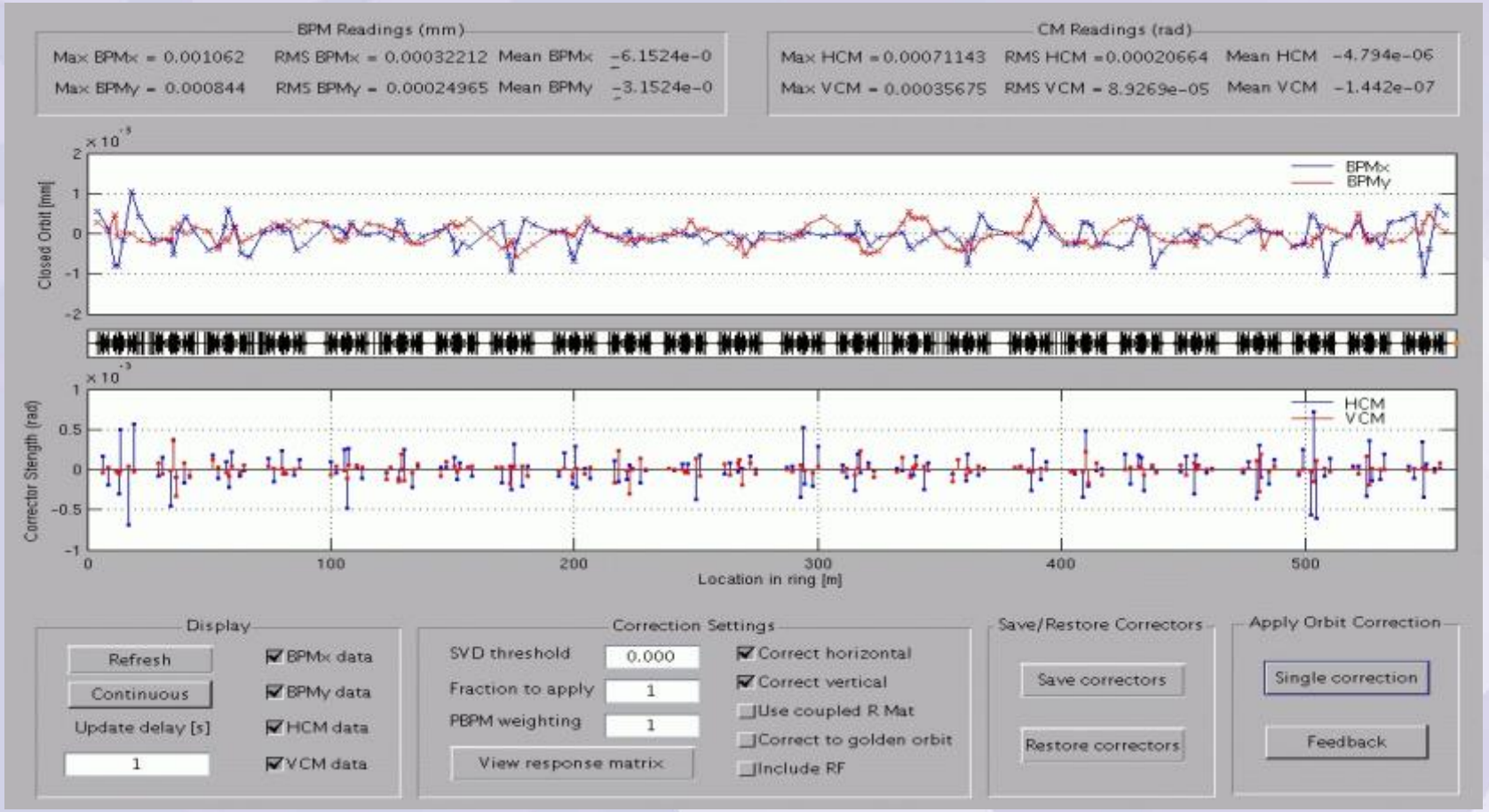
SR 3 GeV Commissioning



- SR orbit corrected to < 1um
- Slow orbit FB run in AT application

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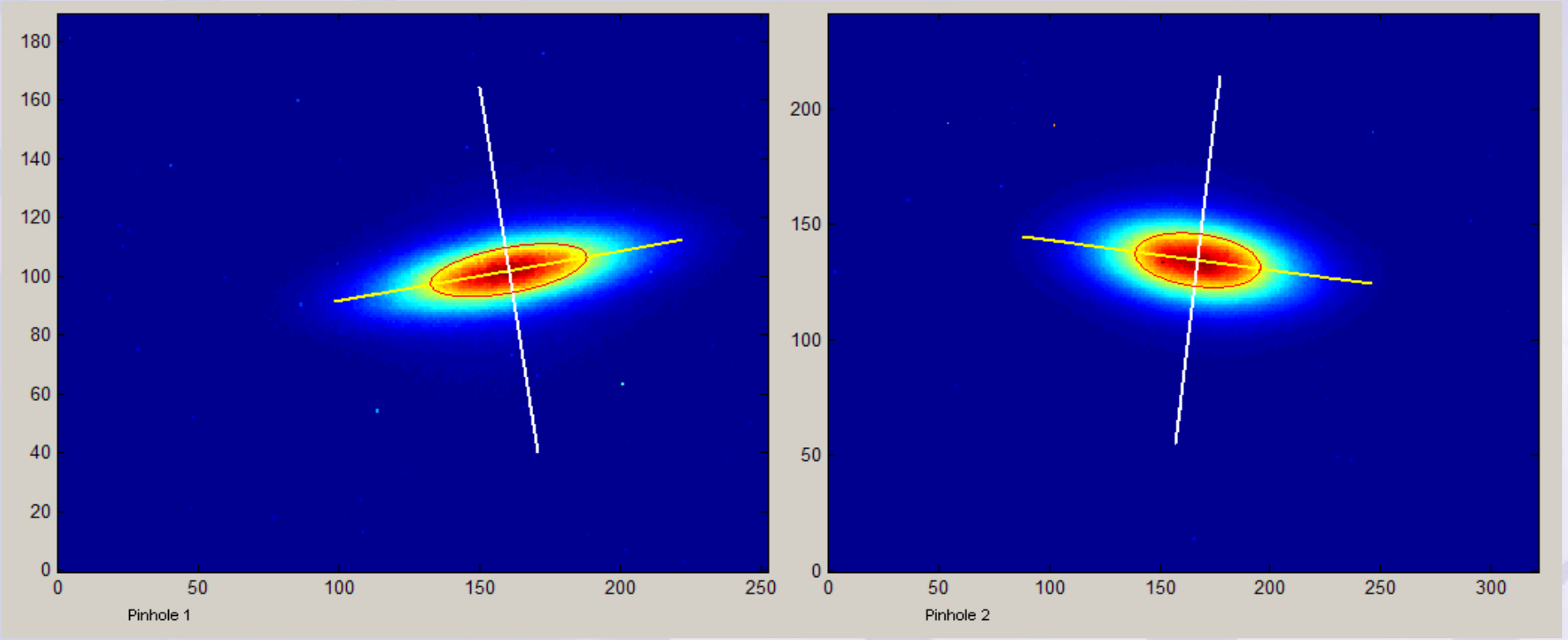
SR 3 GeV Commissioning



Pinhole camera #1	nominal:	Pinhole camera #2	nominal:
sigma-x = 56 μm	52 μm	sigma-x = 47 μm	45 μm
sigma-y = 14.5 μm	25 μm	sigma-y = 19 μm	25 μm

Best fit: emittance 3.2 nm, energy spread 0.014%, coupling 0.4%

Previous slides are a typical sanitised view of accelerator commissioning.

Commissioning Lessons : No 1

- Safety
- Electricity is one of the biggest hazards and hence a risk on the project
- Need robust process for a sub system to go from un-powered and safe to powered and potentially un-safe ie operational
  - It will not be clear cut and may need temporary power for vac pumps
- Need to know what systems are operational
- When a system is deemed operational, you need a system of work to make safe
  - Permit to Work
  - Lock Off Tag Off
- These Safety Processes are different from facility to facility
  - Staff and contractors need educating in them

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Commissioning Lessons : No 2

- **Be prepared for the unexpected**
  - Late deliveries from key suppliers (magnet suppliers in particular!!)
  - Buildings not finished, cables not installed (!) a major issue for us…
  - Football World Cup influenced commissioning of the Diamond SR
- **Be flexible**
  - Value from running equipment into dummy loads and powering up as soon as possible just to check things out and check they can be controlled by the control system
  - Cable check out is vital – we had many poorly fitted connectors in the storage ring
  - If services are not ready it might mean: hiring external pumping systems and water supplies (we did this for the booster); hiring generators if local power not available and running in temporary cables.

Commissioning Lessons : No 3

- **Establish an Operations Group**
  - Who champions the value of the beam in design reviews !
- **Start Operators on 24 hour Shift cover from when you switch on the first system**
  - Who responds to a fire alarm out of hours?
- **Have Operations coordinate commissioning**
  - Process for Technical groups to request subsystem commissioning time
- **For beam commissioning Operators carry and record status of systems at handover**
  - Ideal have some cross over from one shift to next
- **Managing**
  - Permits, Tools, Safety, On Call
- **Review objectives and progress daily/weekly with Technical groups**

Commissioning Lessons : No 4

- **Start tests as soon as the kit is ready for test**
  - Not to some arbitrary schedule.
- **Information gathered early is vital**
  - Document as you go along
- **Establish an operating mode for sub systems**
  - Avoid needing expert to switch On or Tune up system
  - Establish operating procedure
- **Establish routine running**
  - Bring out faults

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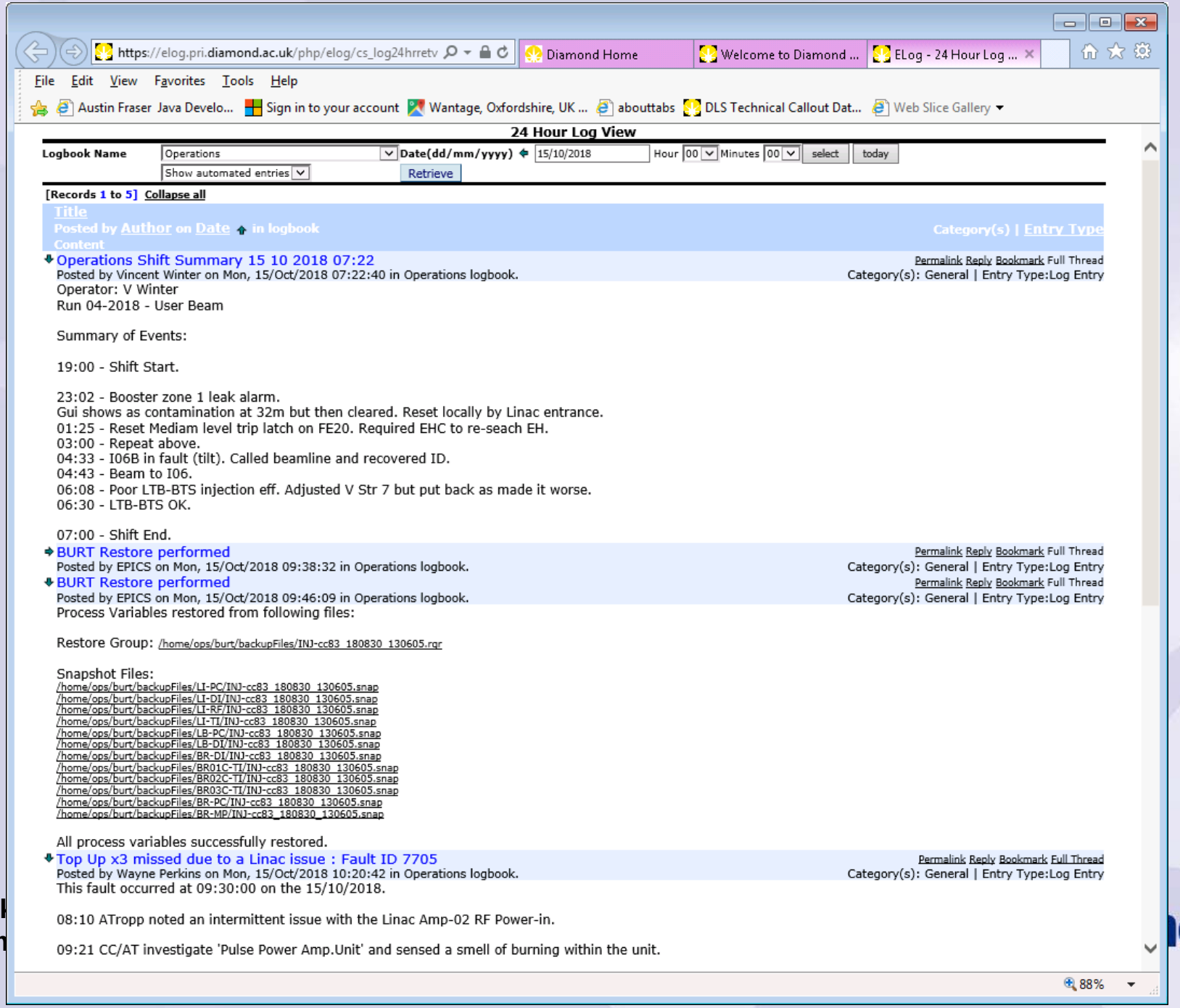
Commissioning Lessons : No 5

- **Have an Electronic Log Book system up and running from day one**
- **Insist everyone uses**
  - No private logs
- **Open access is available across all groups**
- **Capture**
  - Shift Aims
  - Shift Summary
  - System commissioning
  - Beam commissioning
  - Faults
  - Call-Ins
  - Status of the accelerator ie Backup and Restore



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Commissioning Lessons : No 6

- **You need two spares as a minimum**
  - Not always possible – especially with high value items
- **Why**
  - 1/ The in service component dies. Install the spare; it dies. More to point it was killed. Only then do you look to understand what the fault was
  - 2/ The first spare is dead
  - 3/ Having installed one of two spares, you now have one spare while you order/repair the failed component
- **Track all hardware through its life**
  - Purchased, onsite, in stock, installed, removed, ***faulty***, repaired, loaned
  - Know where spares are
  - Test spares
- **Remember spares are not development components**
  - Recipe for a dead spare

Commissioning Lessons : No 7

- **Checklists**
- **Drive things by pre agreed checklists for each technical area until some or all are ready for beam testing**
  - Gives clear visibility
- **Focus on the areas needed from day 1 of commissioning but never forget the individual subsystem testing without beam has to be cleared for ‘with beam testing ready’ to start**

Commissioning Lessons : No 8

- **Prepare for overnight working**
- **Likely you will need a system of working where technical systems are**
  - Worked on during the day
  - Powered and beam tested at night / weekends
- **Power up systems at the end of day in preparation for the night running**
  - You only see a system does not work when you switch it On
  - Greater probability of technical experts around during the day
- **Have experts On Call over night**
  - Available to come on and to address problem remotely ie access the control system hardware remotely

Commissioning Lessons : No 9

- **Contract management**
- **To keep a programme on track it might be necessary to take control of contracts**
  - Be prepared do the work yourselves
  - Address the contractual implication later
- **Diamond Linac commissioning was initially delayed due to only two Accel engineers were able to come to Diamond once every two weeks**
  - We took over and did the beam tests ourselves.

Commissioning Lessons : No 10

- Lateral thinking
- Diamond had a possible 6-month delay in cooling services for the storage ring
- Decided to run the completed storage ring at a low enough energy - 700MeV - to not need water-cooling and beam test that way
- The beam tests were difficult but all subsystems were checked with beam.
  - Bugs were spotted and corrected
- Ready for the full energy beam tests when the building cooling systems were available

Commissioning Lessons : No 11

- **Diamond planned for a year's commissioning time**
  - First 9 months will be making components work together under the control systems
  - Last 3 months on beam testing
- **75% of time the subsystem commissioning and 25% to beam test**

Commissioning Lessons : No 12

- **Be aware of hidden late systems**
  - "Everyone knows the building will be late so I am OK …."
- **It is clear what group or system is on or near to the critical path and running late**
  - You focus you effort on these systems
- **The concern is the group(s) or system(s) which are hiding behind the known late system or group**
  - Be concerned about optimistic reporting of progress
  - A water circuit only works when its 100% complete end-to-end.
- **Without focus these will hurt the programme**

Commissioning Lessons : No 13

- **Call a friend**
- **Beam commissioning team makeup**
  - Acc Physics
  - Controls/software
  - System expert
  - Lead
  - Technician
- **You need all these skills**
  - Invite friends from other projects with relevant experience to join in beam commissioning
- **Back seat drivers/ spectators are valuable**

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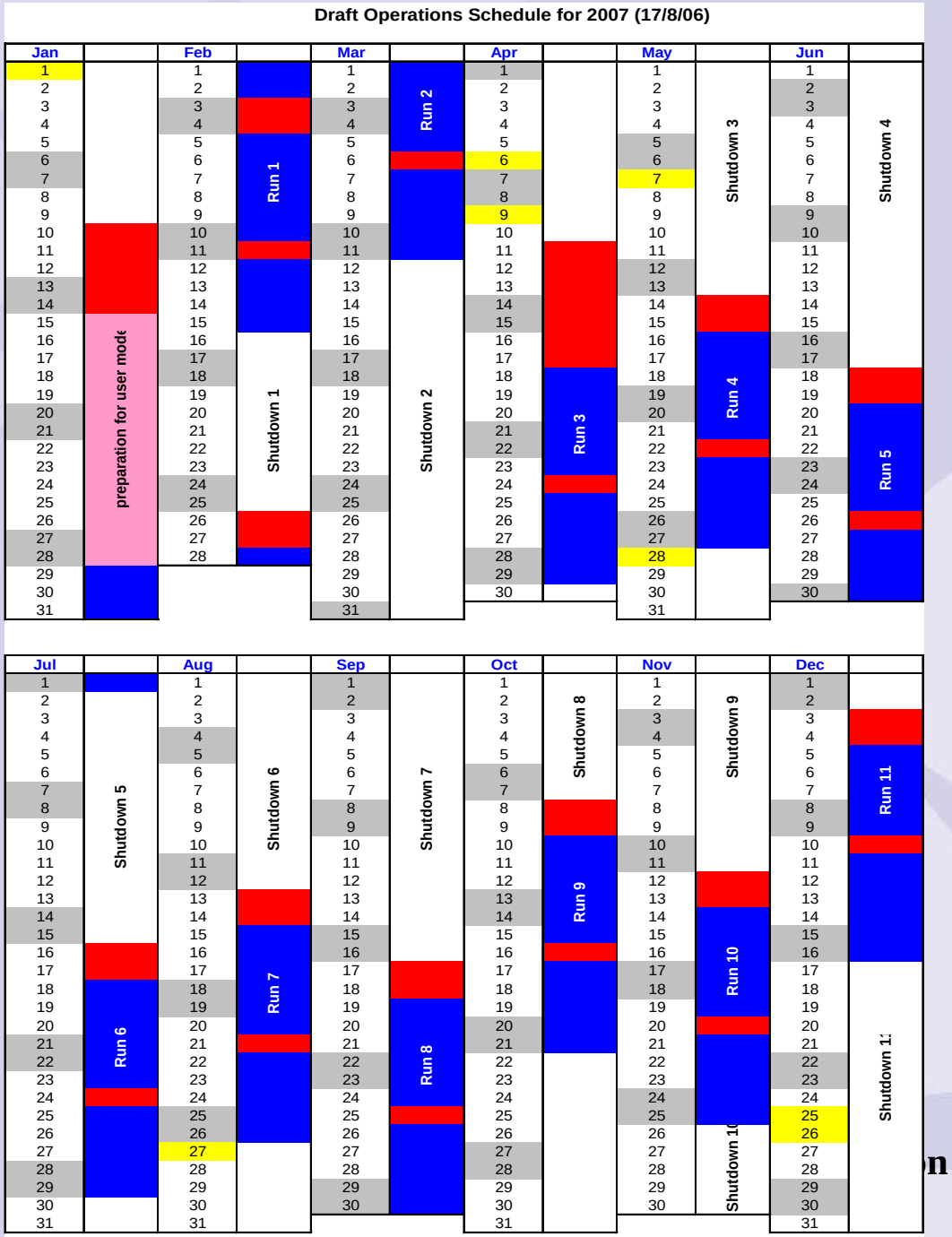
Commissioning Lessons : No 14

- **Restore machine settings**
- **Produce snapshot files during commissioning as way to go back to an operating point**
  - You need a naming convention to understand them
- **You need to know what operating point mode is loaded**
  - Operating/working point is often applicable to a campaign
- **Need a process to promote “an” operating/working point to “the” operating/working point**
- **Related to hand over from Acc Physics studies to Operations**
- **Key to establish repeatable operations**



Routine Operations

- Schedule 2007/2008
- 11 Runs of ~ 2 weeks
- 3000Hrs of Beamline Mode
- Ongoing commissioning (Red Blocks)
- Shutdowns 1½ - 4 weeks, for maintenance and installation:
  - 2nd RF cavity
  - ID6 module 2, ID11, ID24
  - FEs 11, 16, 19, 23, 24

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I am very grateful to Vince Kempson, Diamond Operations Manager, for discussion and input to commissioning lessons.

Mark Heron
Diamond Light Source

Thank You For Your Attention.

Mark Heron
Diamond Light Source