Machine Operation and Maintenance in CLS

WAO2010 in Daejeon, 2010-04-12

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Canadian Light Source

Where is Saskatoon?

CLS History

- Canadian Synchrotron Radiation Facility
  - Operated up to 3 beamlines at SRC in Madison since 1980’s
- 1991 – Canadian Institute for Synchrotron Radiation Proposal
  - 1.5 GeV for soft x-rays
  - Racetrack design with few ID’s
  - Superconducting “wiggle” bends
- 1994 – Design workshop at University of Saskatchewan
  - 1.5 GeV, 8-cell TBA lattice
  - 104 m circumference
  - Too few straights!
- 1995 – Revised proposal from U. of S.
  - 2.5 GeV, 12-cell DBA lattice
  - 127 m circumference
  - Budget estimate almost frozen
  - More ID’s, and 20 keV x-rays requested

CLS History

- CLS Project approved on 1999 March 31
  - 140.9 M $C to construct:
    - 2.9 GeV booster and third-generation storage ring
    - at least six beamlines
  - Only 22 staff at the start of the project, including:
    - 2 accelerator physicists
    - 1 mechanical engineer
    - 1 electrical engineer
    - 4-person group for IT, controls, diagnostics
    - 2 scientists
- Challenge:
  - Complete facility in ~ five years
  - Increase technical staff to ~60 or more
  - Build organization for operations and future R & D

CLS Accelerator Division

- CLS Accelerator Operations & Development Staff:
  - 2 accelerator physicists/engineers before 1999
  - +2 accelerator physicist/engineers in late 1999
  - +1 junior accelerator physicist/engineer in 2005
  - +1 junior accelerator physicist in 2006
  - +1 accelerator technician in 2006 (from Controls department)
  - 2008 reorganization:
    - +1 rf technician, +1 hardware controls and +1 software controls from Controls department
    - +1 electrical engineer from Engineering department
    - -1 accelerator engineer to Technical User Support
  - +2 junior accelerator physicists in 2009
- Total of 12 staff currently

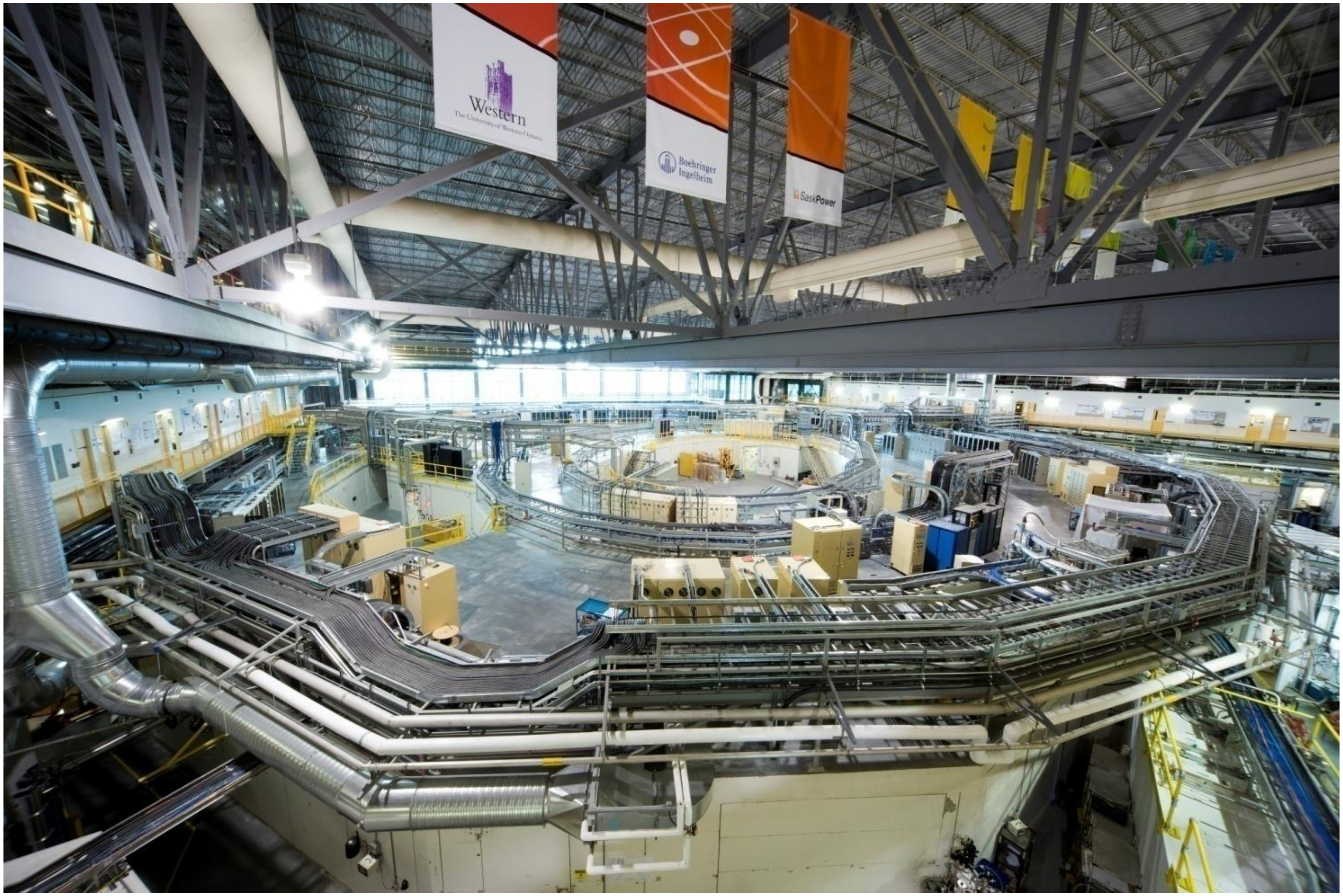
CLS Accelerator Division

- Responsibilities of group:
  - All accelerator operations
  - Physics design of accelerator modifications and upgrades
  - All routine accelerator maintenance during normal operations
- Additional support received from Controls and Engineering during maintenance shut-downs and major projects

Storage Ring Performance

	Achieved (2009-02-26)	Design Goals		
		Start (2003)	First 2 years (2004 – 2005)	Long-term (> 2009)
Horizontal Emittance (nm·rad)	15 18 normal setup	≤ 30	≤ 20	≤ 18*
Energy (GeV)	1.5, 2.9	2.9	2.9	≤ 2.9
X-Y Coupling	<0.1% to 0.3%	<10%	<1%	< 0.2%
Tunes (x / y) Alternate operating points:	(10.22 / 3.26) (10.22 / 4.32) ✓	(10.22 / 3.26)	(10.22 / 3.26) (10.22 / 4.26)	(10.22 / 3.26) (10.22 / 4.26) (11.22 / 3.26) *
RMS orbit stability (x / y) (μm)	0.5 / 0.3	50 / 10	40 / 3	30 / 1
RMS orbit position (x / y) (μm)	10 / 5	40 / 80	40 / 80	20 / 40
Maximum current (mA)	320 250 mA normal	100	200	500
Lifetime @ 100 mA (hours)	29	> 4	> 6	> 10 / Top-up*
Time Structure	210/280 bunches 1 bunch	Multi-bunch	Multi-bunch	Multi-bunch & single bunch

Storage Ring Overview



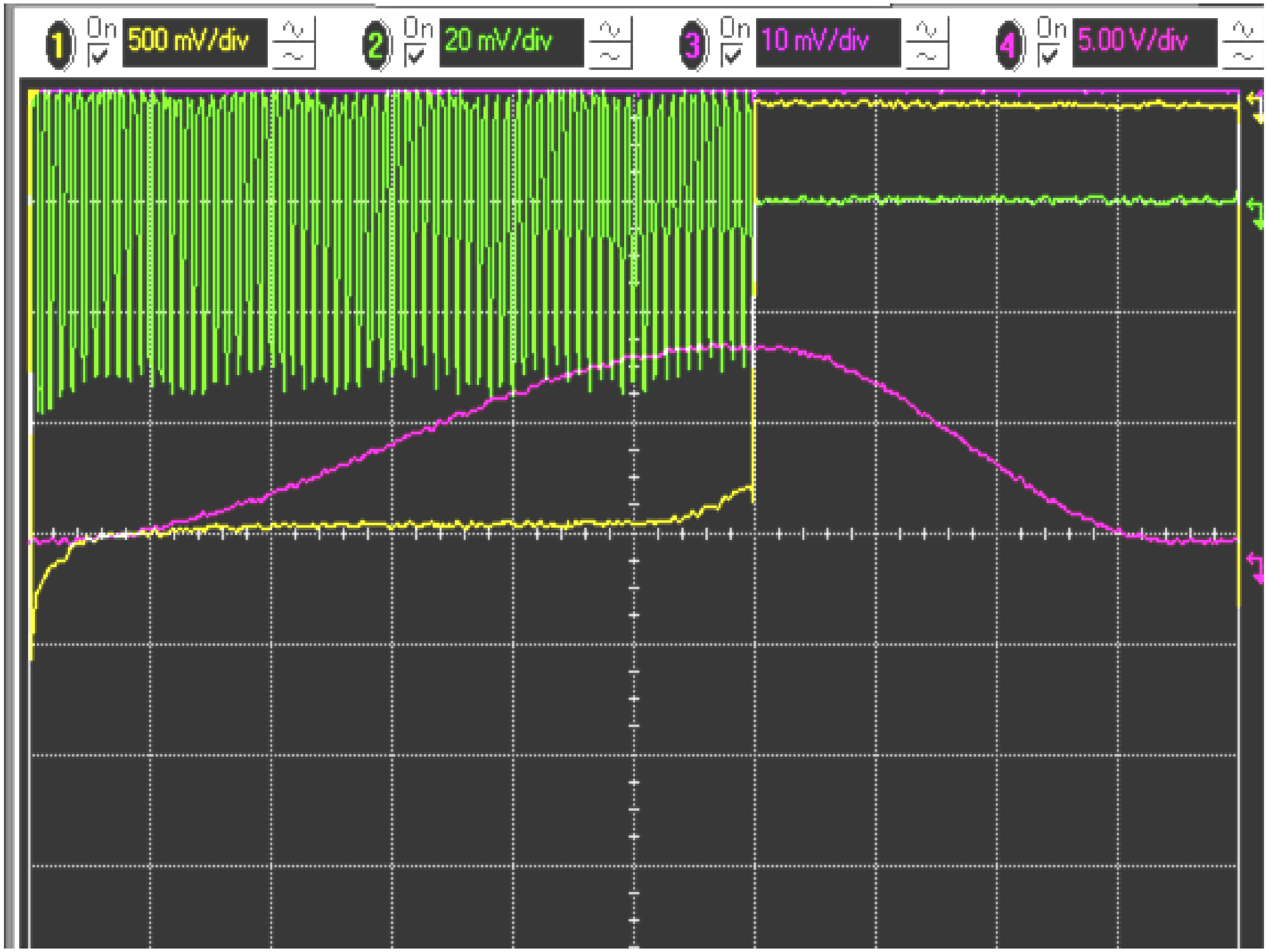
Storage Ring

2004 March 22

Booster Ring

Booster Commissioning– 2004

- Blue: Dipole Field
- Yellow: PCT average current – 8 mA
- Green: FCTpeak current – 40 mA injected, 20 mA extracted



2004 March 22

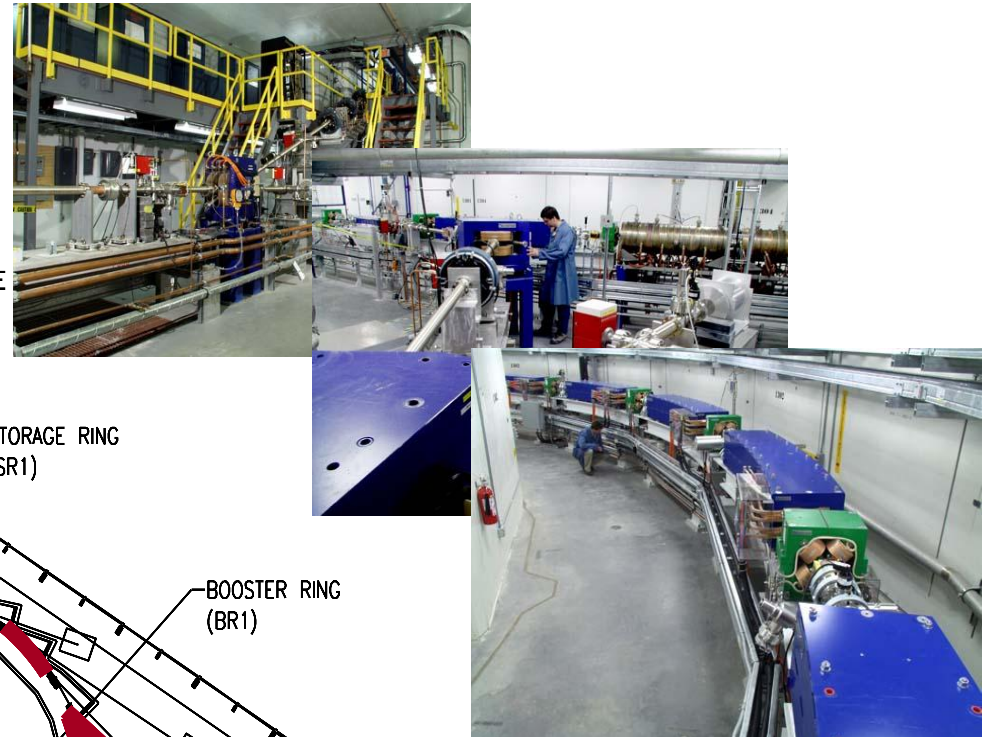
Run 1 - 2003 September

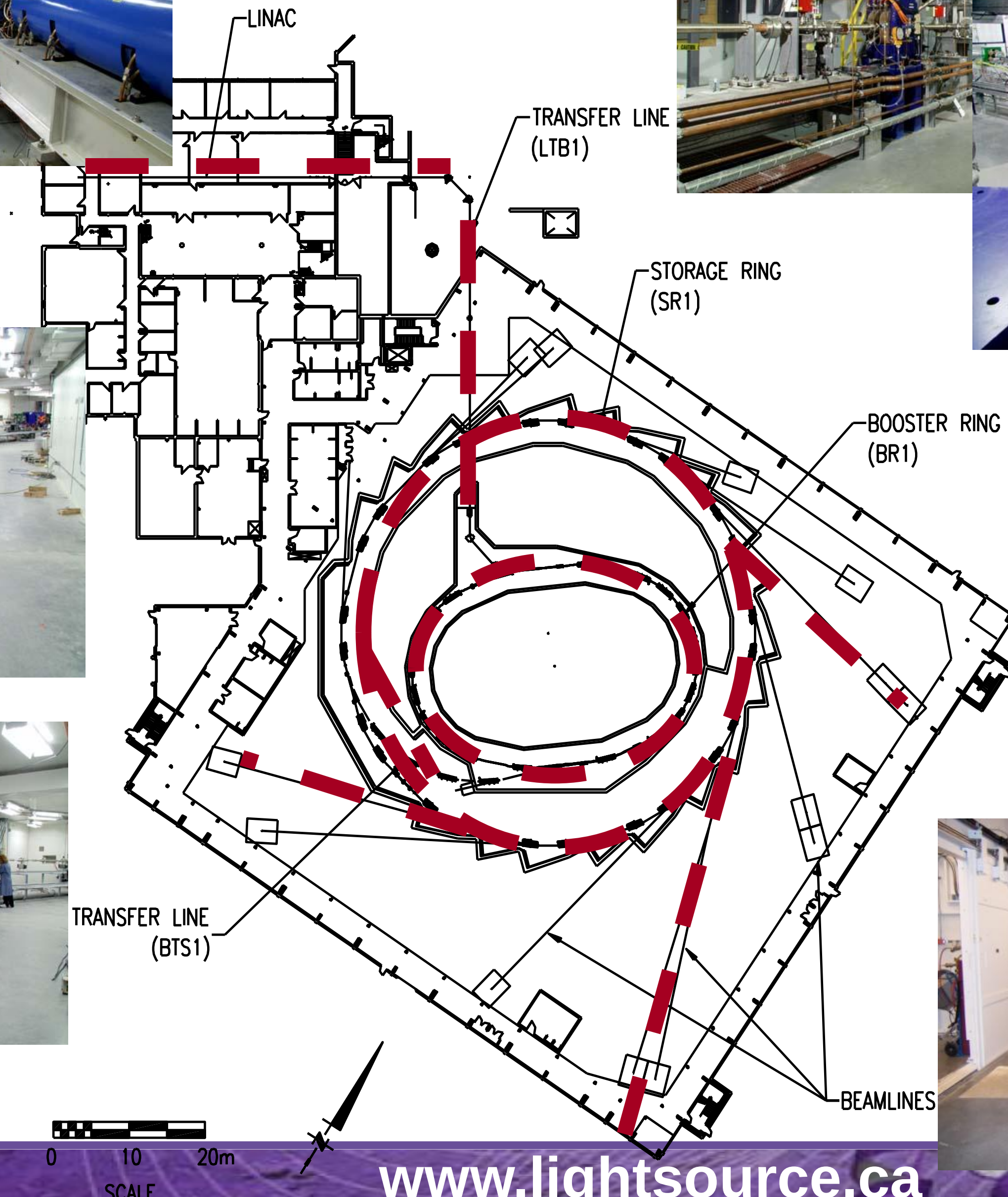
- Yellow: Storage Ring current at injection septum

Measured on 2003-09-26

Where is beam?– 2004 March

Machine Layout





Operator Interface – Control Room

- Hardware:
  - Quad Headed Scientific Linux workstations in the accelerator control room.
  - Dual Headed workstations on the beamlines.
- Operating System:
  - Scientific Linux (CERN/Fermilab)
- **Human Factors Engineering**
- EPICS Tools:
  - EDM (Display Manager)
  - Strip Tool (Data Trending)
- CLS Specific
  - Audio Alarm Annunciation
  - Legacy hard-wired controls from older Linac Equipment

Superconducting RF Cavity

Accel / Cornell “B” Design

Nb Cavity and waveguide

LHe and LN cooled

“HOM-free” cavity design

Commissioning Results

Q_0 = 8 E8 @ 2.4 MV

Q_{ext}= 192,000

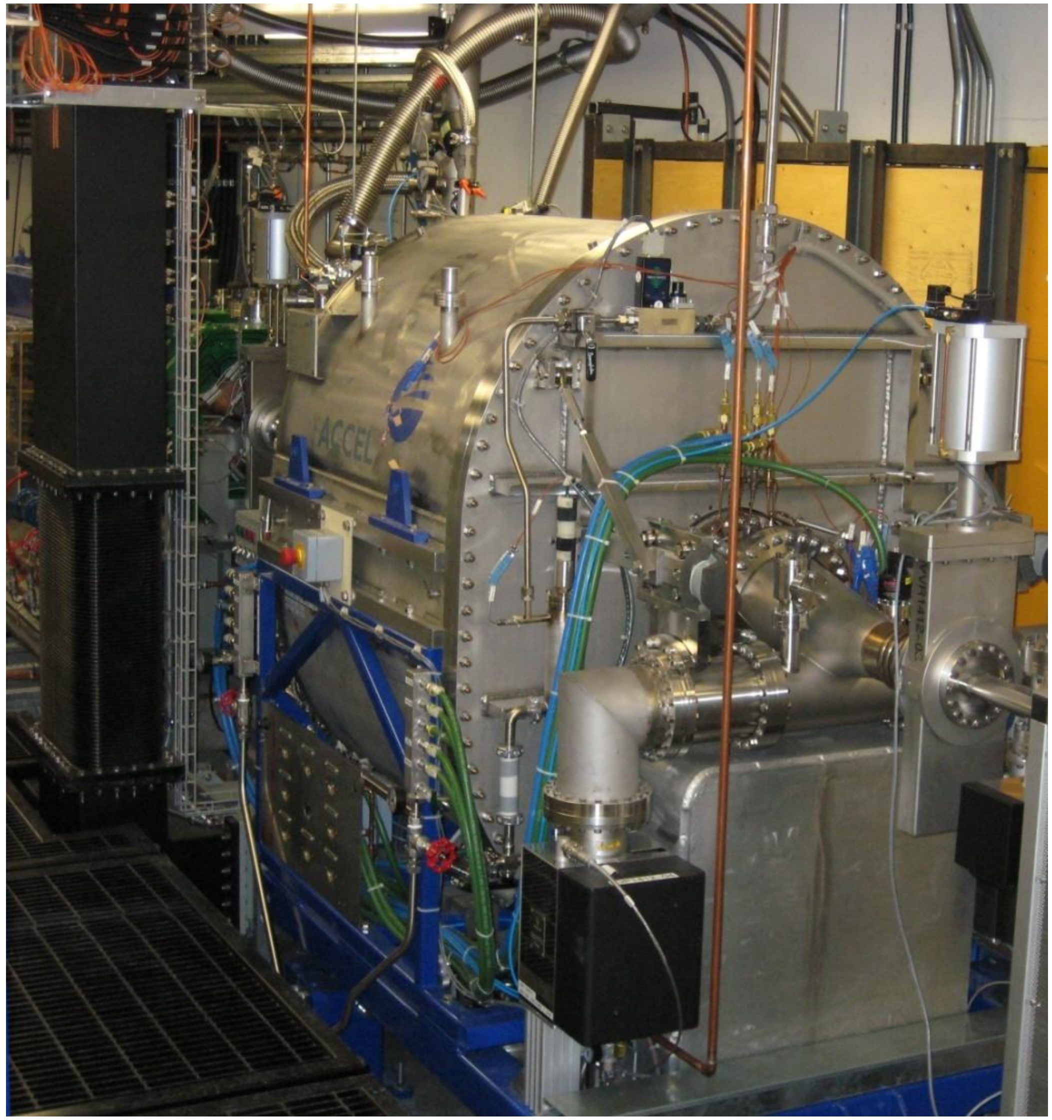
R/Q = 89 ohms

85 W P_{diss} @ V_{acc}= 2.4 MV

Operational Results

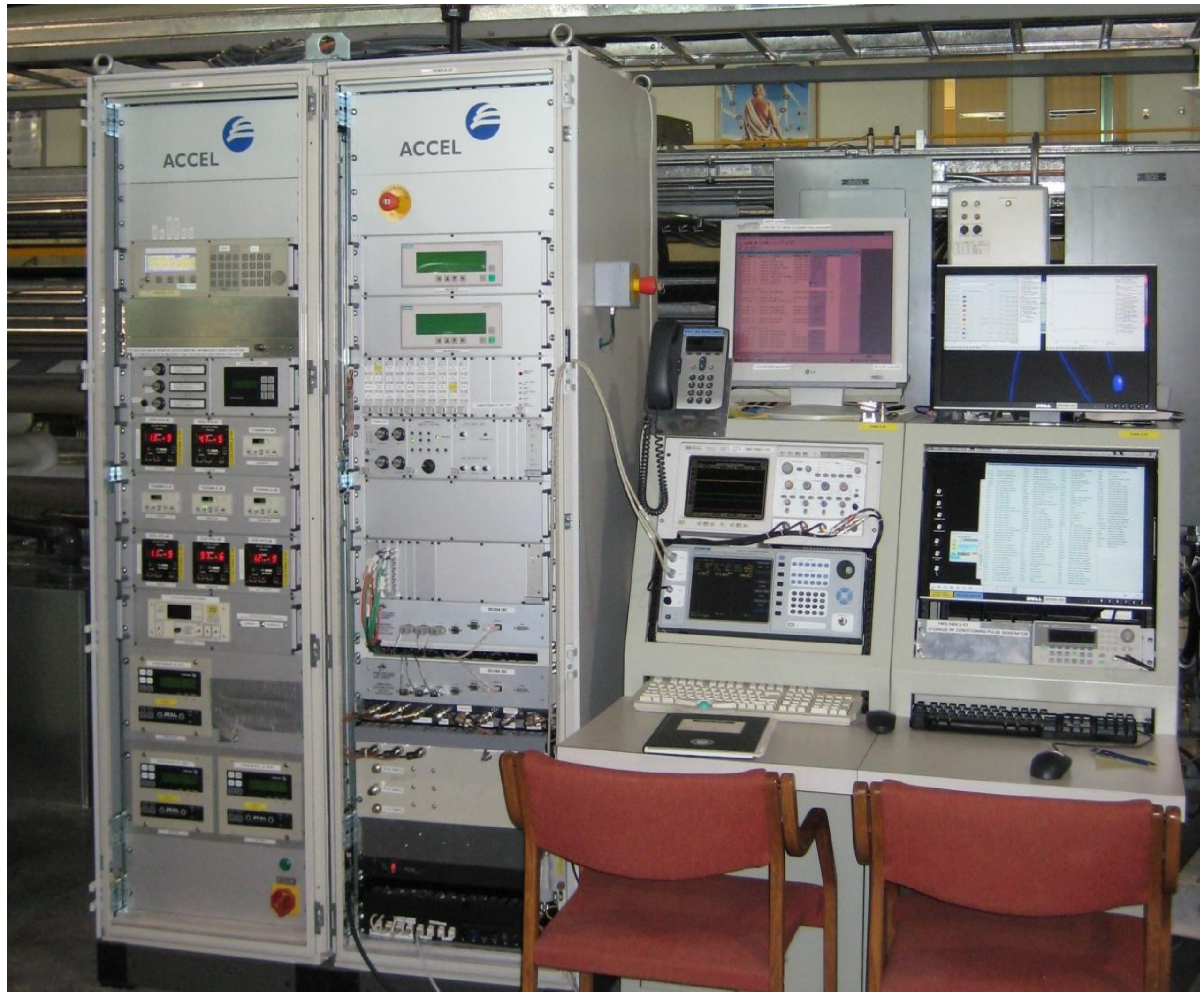
250 mA @ 2.9 Gev / 230 Kw RF

300 mA @ 2.9 GeV / 260 Kw RF



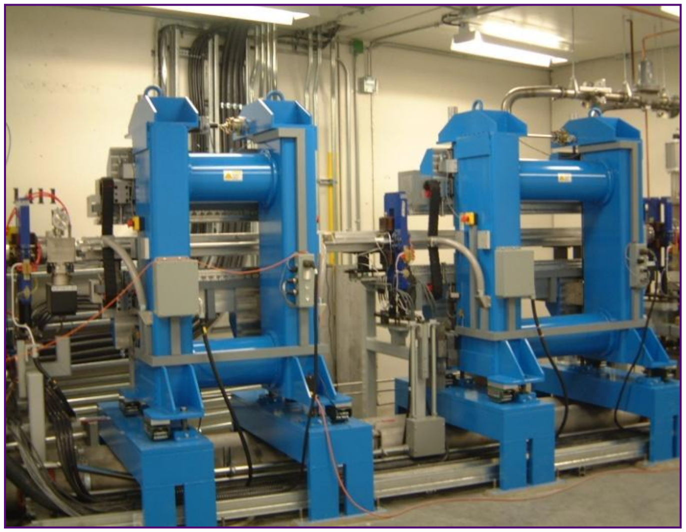
Superconducting RF Cavity Control

- Siemens S7 PLC Control
- Cryogenic Load Levelling
- Cryo Level and Pressure
- Cavity Temperatures
- Vacuum monitoring
- Personnel Safety
- Cavity Interlocks
- RF Control PC
- Remote VNC link
- RF Monitoring
- Cavity Conditioning Station



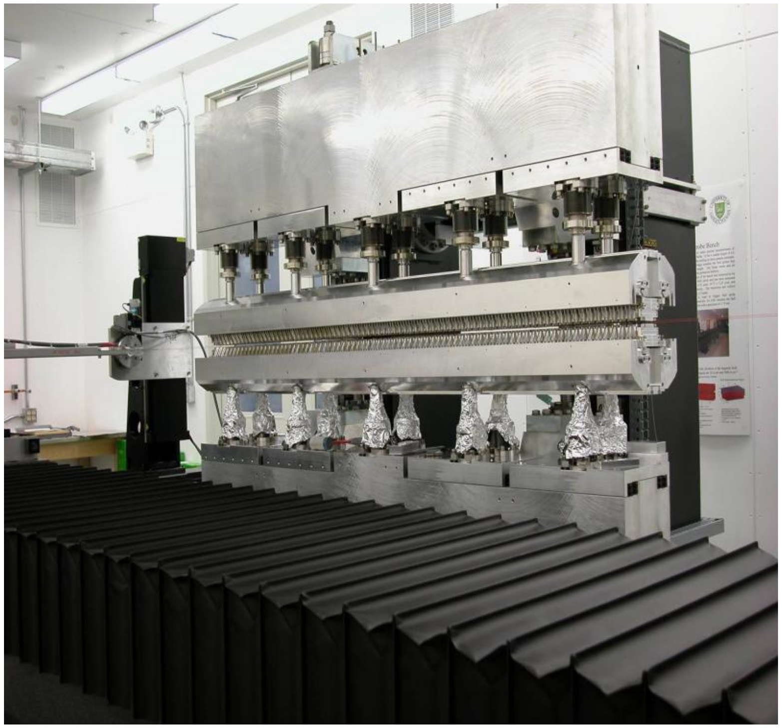
Existing Devices

- SGM & PGM planar devices
- 250eV-1900eV & 5-250eV
- Installed in January and May 2004 in section #11
  - Supports designed and built externally
  - Magnet assembly and shimming by CLS
  - 3 magnet chicane



Existing Devices

- CMCF in-vacuum undulator
- 6-18keV
- Installed in August 2005 in section #8
  - Supports designed and built externally
  - Magnet assembly and shimming by CLS
  - 3 magnet chicane

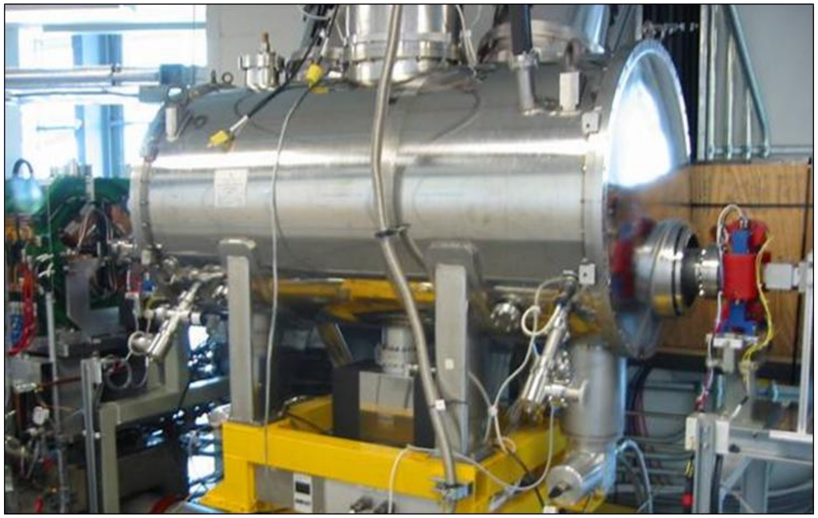


Existing Devices

- SM and REIXS elliptically polarized IDs
- Planar 100-4000eV, Circular 100-1000eV
- Installed in April 2006 and October 2007 in section #10
  - Same APPLE-II magnetic design for both IDs
  - SM Supports designed and built externally
  - REIXS supports are modified SM design built locally
  - Magnet assembly and shimming by CLS
  - 5 magnet chicane, with 2-in1 mode

Existing Devices

- HXMA and BMIT superconducting wigglers
- Critical Energy 10keV & 22keV
- Installed in January 2005 & October 2007 in section #6 & 5
  - Turnkey devices designed and built by BINP



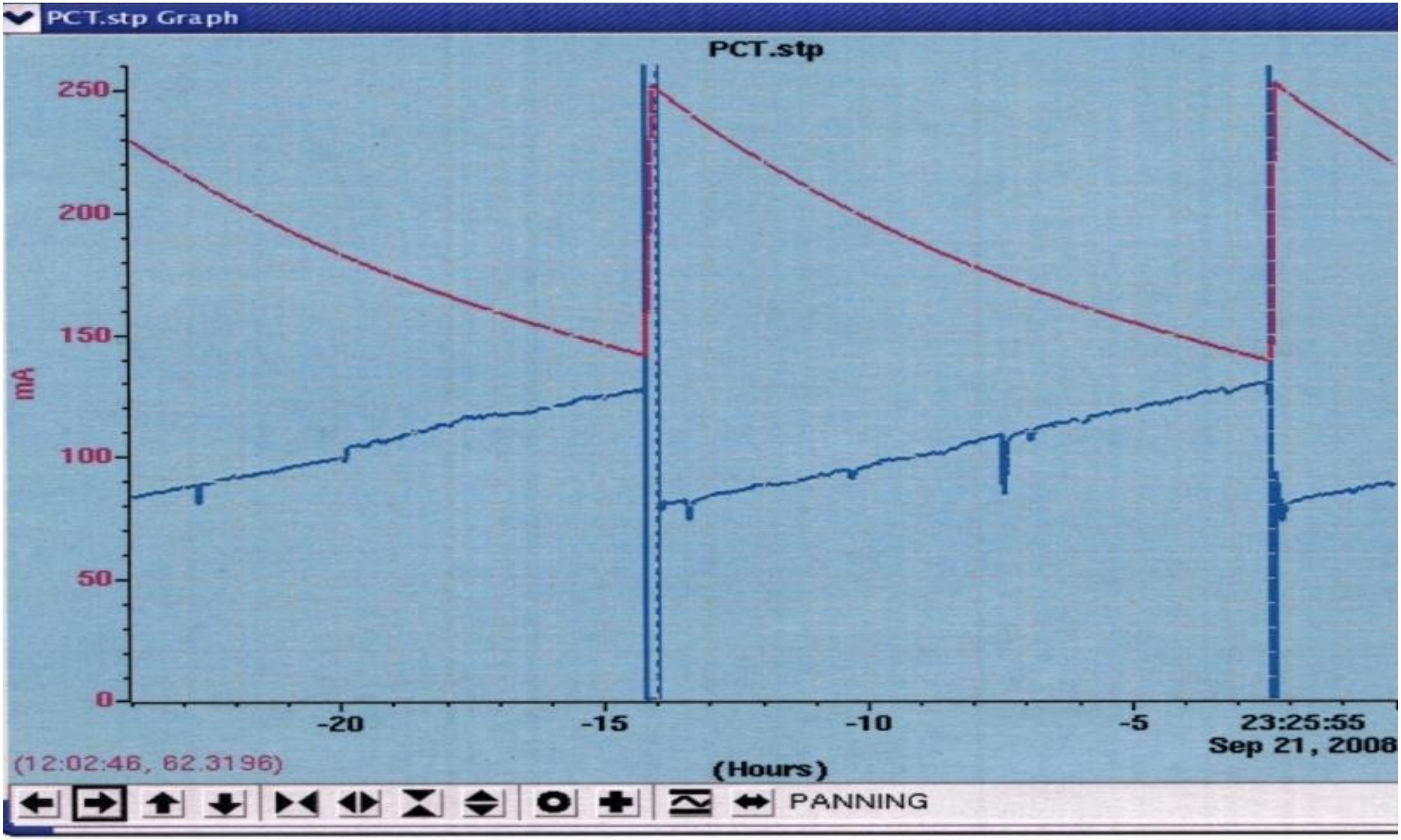
ID Overview

Beamline	PGM	SGM	CMCF	SM	HXMA	REIXS	BMIT
Location	11-2	11-1	8-1	10-1	6-2	10-1	5-2
Type of Device	PPM Planar Und	PPM Planar Und	In-Vac Hybrid Und	APPLE-II	SC Wiggler	APPLE-II	SC Wiggler
Photon Energy	5-250 eV	0.25-1.9 keV	6-18 keV	0.1-2keV	5-40keV Ec=10keV	0.1-2keV	20-100keV $E_{c=}$22keV
Polarization	Hor	Hor	Hor	Variable Lin & circ	Hor	Variable Lin & circ	Hor
Number of Poles	19	55	159	43	63	43	27
Total Length, m	1.66m	1.22m	1.58m	1.59m	-	1.59m	-
Peak Field, B(T)	0.71T	0.82T	1.17T	0.71T	1.94T	0.71T	4.3T
Period, (mm)	185mm	45mm	20mm	75mm	33mm	75mm	48mm
Effective K	12.3	3.5	2.2	5	6	5	18
Min. Gap (mm)	25mm	12.5mm	5mm	16mm	9.5mm aperture	16mm	10mm aperture
RMS Phase angle error	<2.0°	<1.6°	<4°	<6°	N/A	<4°	N/A
Magnet Material	Nd	Nd	Sm blks alloy poles	Nd	SC NbTi	Nd	SC NbTi
Installation Date	May-04	Jan-04	Aug-05	Apr-06	Jan-05	Dec-07	Oct-07

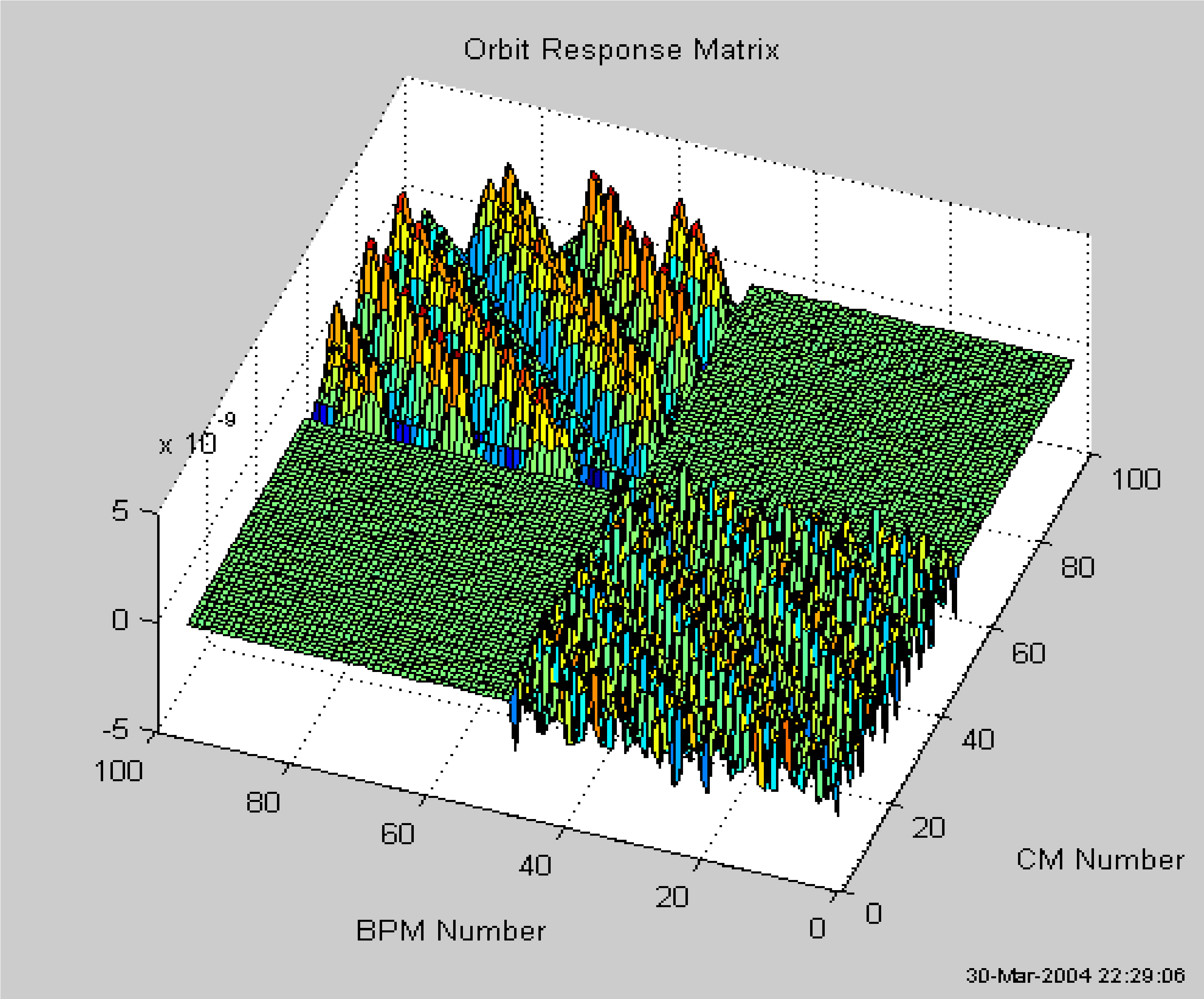
ID Overview

Beamline	Bio-Xas	Bio-Xas	QMSC	QMSC	Brock house	Brock house	Empty	Empty	Empty
Location	7-1	7-2	9-both	9-both	4-1	4-2	3-1	3-2	8-2
Type of Device	PM Hybrid Wig	In-Vac Hybrid Und	APPLE-II	APPLE-II	In-Vac Hybrid Und	SC Wiggler			
Photon Energy	Ec ~12keV	3-15 keV	15-200 eV	0.2-1 keV					
Polarization	Hor	Hor	Variable Lin & circ	Variable Lin & circ					
Number of Poles	22	167	33	145					
Total Length, m	~1.6m	~1.6m	~3.6m	~3.6m					
Peak Field, B(T)	2.1T	0.98T	0.41T	0.97T					
Period, (mm)	150mm	19.1mm	~225mm	~54mm					
Effective K	~35	1.75	8.6	4.9					
Min. Gap (mm)	11mm	5mm	25mm	12mm					
RMS Phase angle error	--	--	--	--					
Magnet Material	Nd blks alloy poles	Nd blks alloy poles	Nd	Nd					
Installation Date	2010	2010	2010+	2010+					

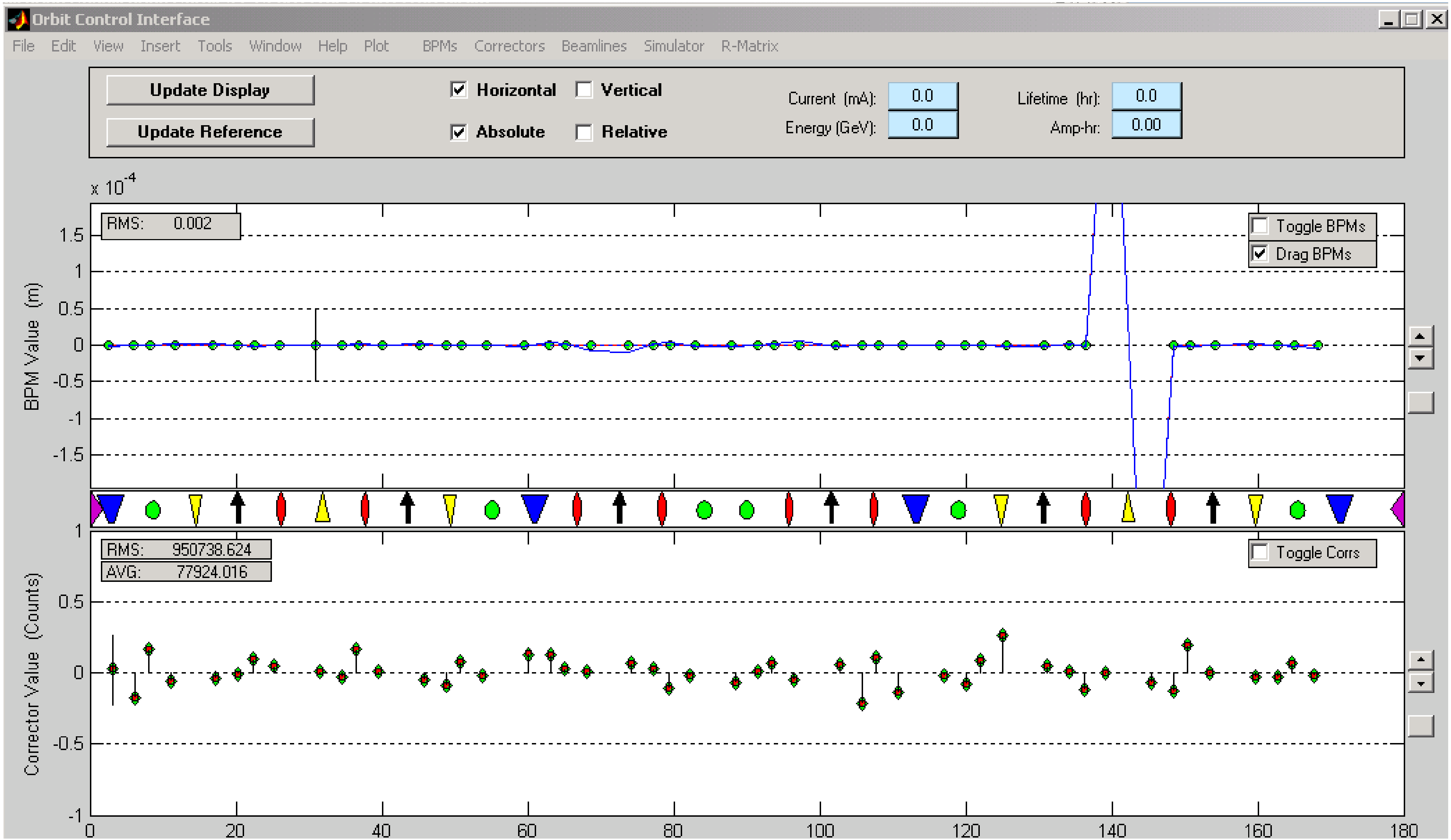
Routine Operation in Storage Ring



Orbit Response Matrix

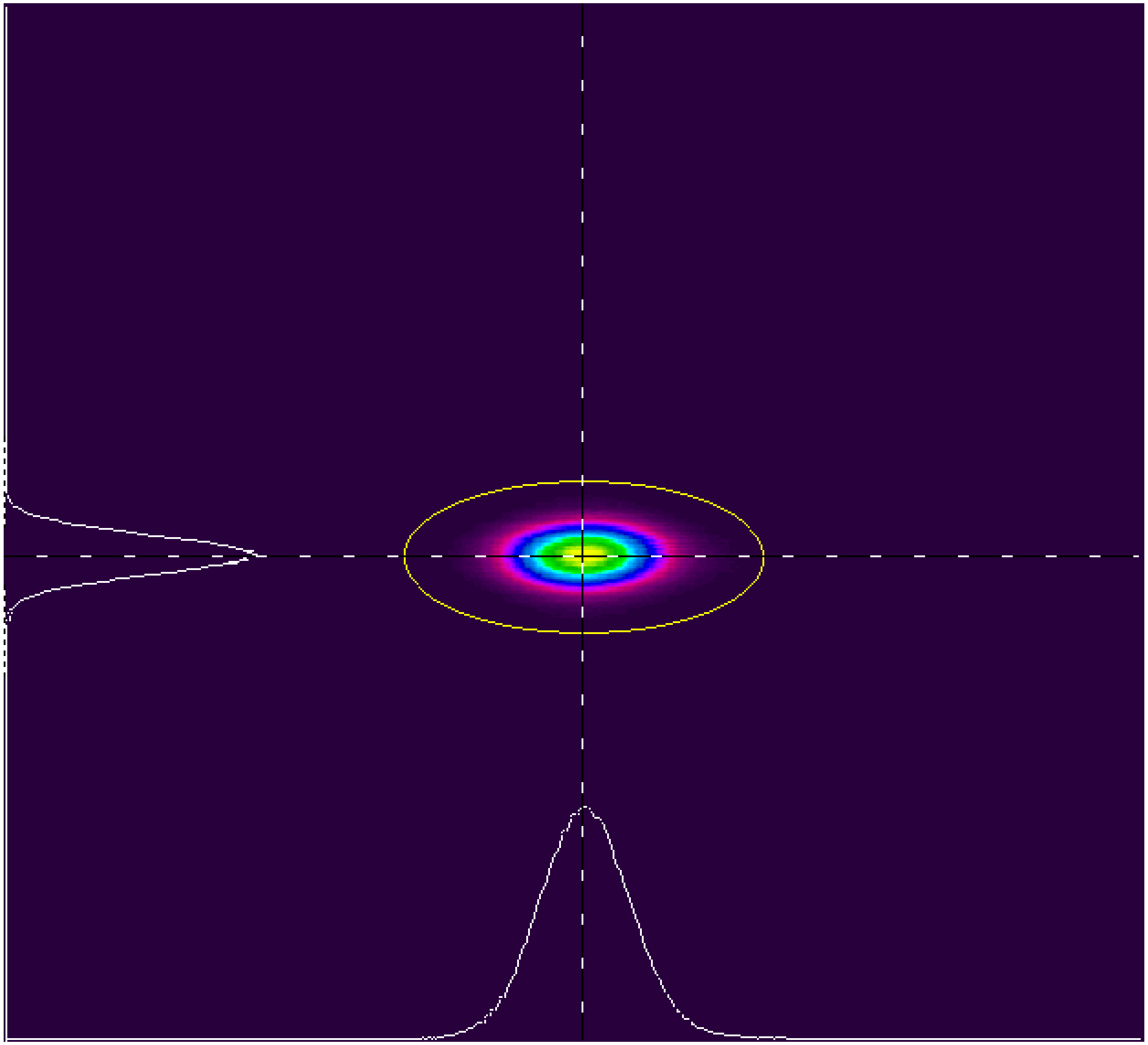


Corrected Horizontal Orbit



Beam Image from CCD Camera

CCD Camera - Beam Image [Spiricon Processing]



Canadian Light Source
Centre canadien de rayonnement synchrotron

Operations Schedule – 2010

	Su	Mo	T	W	Th	F	S
January, 2010						1 (stat)	2
00:00 - 08:00						X	X
08:00 - 16:00						X	X
16:00 - 24:00						X	X
	3	4	5 (Run 58)	6	7	8	9
00:00 - 08:00	X	M	M	M	NS	NS	NS
08:00 - 16:00	X	M	D	D	DS	NS	N
16:00 - 24:00	X	M	D	D	NS	NS	N
	10	11	12	13	14	15	16
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	17	18	19	20	21	22	23
00:00 - 08:00	N	N	DS- CSR	N	N	N	N
08:00 - 16:00	N	D	DS- CSR	N	N	N	N
16:00 - 24:00	N	DS- CSR	N	N	N	N	N
	24	25	26	27	28	29	30
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	31						
00:00 - 08:00	N						
08:00 - 16:00	N						
16:00 - 24:00	N						

	Su	Mo	T	W	Th	F	S
February, 2010		1	2	3	4	5	6
00:00 - 08:00		N	NS	N	N	N	N
08:00 - 16:00		D	DS	N	N	N	N
16:00 - 24:00		D	N	N	N	N	N
	7	8	9	10	11	12	13
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	14	15 (stat)	16	17 (Run 59)	18	19	20
00:00 - 08:00	N	N	N	M	NS	N	N
08:00 - 16:00	N	N	M	M	N	N	N
16:00 - 24:00	N	N	M	D	N	N	N
	21	22	23	24	25	26	27
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	28						
00:00 - 08:00	N						
08:00 - 16:00	N						
16:00 - 24:00	N						
00:00 - 08:00							
08:00 - 16:00							
16:00 - 24:00							

	Su	Mo	T	W	Th	F	S
March, 2010		1	2	3	4	5	6
00:00 - 08:00		N	NS	N	N	N	N
08:00 - 16:00		D	DS	N	N	N	N
16:00 - 24:00		D	N	N	N	N	N
	7	8	9	10	11	12	13
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	14	15	16	17	18	19	20
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	21	22	23	24	25	26	27
00:00 - 08:00	N	N	M	M	M	M	M
08:00 - 16:00	N	M	M	M	M	M	M
16:00 - 24:00	N	M	M	M	M	M	M
	28	29	30	31			
00:00 - 08:00	M	M	M	M			
08:00 - 16:00	M	M	M	M			
16:00 - 24:00	M	M	M	M			

	Su	Mo	T	W	Th	F	S
April, 2010					1	2 (stat)	3
00:00 - 08:00					M	M	M
08:00 - 16:00					M	M	M
16:00 - 24:00					M	M	M
	4	5	6	7	8	9	10
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	M	M
16:00 - 24:00	M	M	M	M	M	M	M
	11	12	13	14	15	16	17
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	M	M
16:00 - 24:00	M	M	M	M	M	M	M
	18	19	20	21	22	23 (Run 60)	24
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	D	D
16:00 - 24:00	M	M	M	M	M	D	D
	25	26	27	28	29	30	
00:00 - 08:00	M	NS	NS	NS	NS	NS	
08:00 - 16:00	D	D	DS	NS	NS	NS	
16:00 - 24:00	D	D	NS	NS	NS	NS	
00:00 - 08:00							
08:00 - 16:00							
16:00 - 24:00							

	Su	Mo	T	W	Th	F	S
May, 2010							1
00:00 - 08:00							NS
`							NS
16:00 - 24:00							NS
	2	3	4	5	6	7	8
00:00 - 08:00	NS	N	NS	SB	N	N	N
08:00 - 16:00	N	D	SB	N	N	N	N
16:00 - 24:00	N	D	SB	N	N	N	N
	9	10	11	12	13 (SAC)	14 (SAC)	15
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	16	17	18	19	20	21	22
00:00 - 08:00	N	N	DS- CSR	N	N	N	N
08:00 - 16:00	N	D	DS- CSR	N	N	N	N
16:00 - 24:00	N	DS- CSR	N	N	N	N	N
	23	24 (stat)	25 (Run 61)	26	27	28	29
00:00 - 08:00	N	N	M	NS	N	N	N
08:00 - 16:00	N	M	M	N	N	N	N
16:00 - 24:00	N	M	D	N	N	N	N
	30	31					
00:00 - 08:00	N	N					
08:00 - 16:00	N	D					
16:00 - 24:00	N	D					

	Su	Mo	T	W	Th	F	S
June, 2010			1	2	3	4	5
			NS	N	N	N	N
			DS	N	N	N	N
			N	N	N	N	N
	6	7	8	9	10	11	12
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	13	14	15	16	17 (AUM)	18 (AUM)	19
	N	N	N	N	N	D	NS
08:00 - 16:00	N	N	N	N	D	D	N
16:00 - 24:00	N	N	N	N	D	D	N
	20	21	22	23	24	25	26
00:00 - 08:00	N	NS	D	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	27	28	29	30			
00:00 - 08:00	N	N	N	N			
08:00 - 16:00	N	N	N	M			
16:00 - 24:00	N	N	N	M			

	Su	Mo	T	W	Th	F	S
July, 2010					1 (stat)	2	3
00:00 - 08:00					M	M	M
08:00 - 16:00					M	M	M
16:00 - 24:00					M	M	M
	4	5 (Run 62)	6	7	8	9	10
00:00 - 08:00	M	M	NS	N	N	N	N
08:00 - 16:00	M	D	N	N	N	N	N
16:00 - 24:00	M	D	N	N	N	N	N
	11	12	13	14	15	16	17
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	18	19	20	21	22	23	24
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	SB	N	N	N	N
16:00 - 24:00	N	D	SB	N	N	N	N
	25	26	27	28	29	30	31
00:00 - 08:00	N	N	NS	N	N	N	M
08:00 - 16:00	N	D	N	N	N	M	M
16:00 - 24:00	N	DS	N	N	N	M	M
00:00 - 08:00							
08:00 - 16:00							
16:00 - 24:00							

	Su	Mo	T	W	Th	F	S
August, 2010	1	2 (stat)	3 (Run 63)	4	5	6	7
00:00 - 08:00	M	M	M	NS	N	N	N
08:00 - 16:00	M	M	D	N	N	N	N
16:00 - 24:00	M	M	D	N	N	N	N
	Teacher's Workshop						
	8	9	10	11	12	13	14
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	15	16	17	18	19	20	21
00:00 - 08:00	N	N	DS-CSR	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	DS-CSR	N	N	N	N	N
	22	23	24	25	26	27	28
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	29	30	31				
00:00 - 08:00	N	N	NS				
08:00 - 16:00	N	D	N				
16:00 - 24:00	N	DS	N				

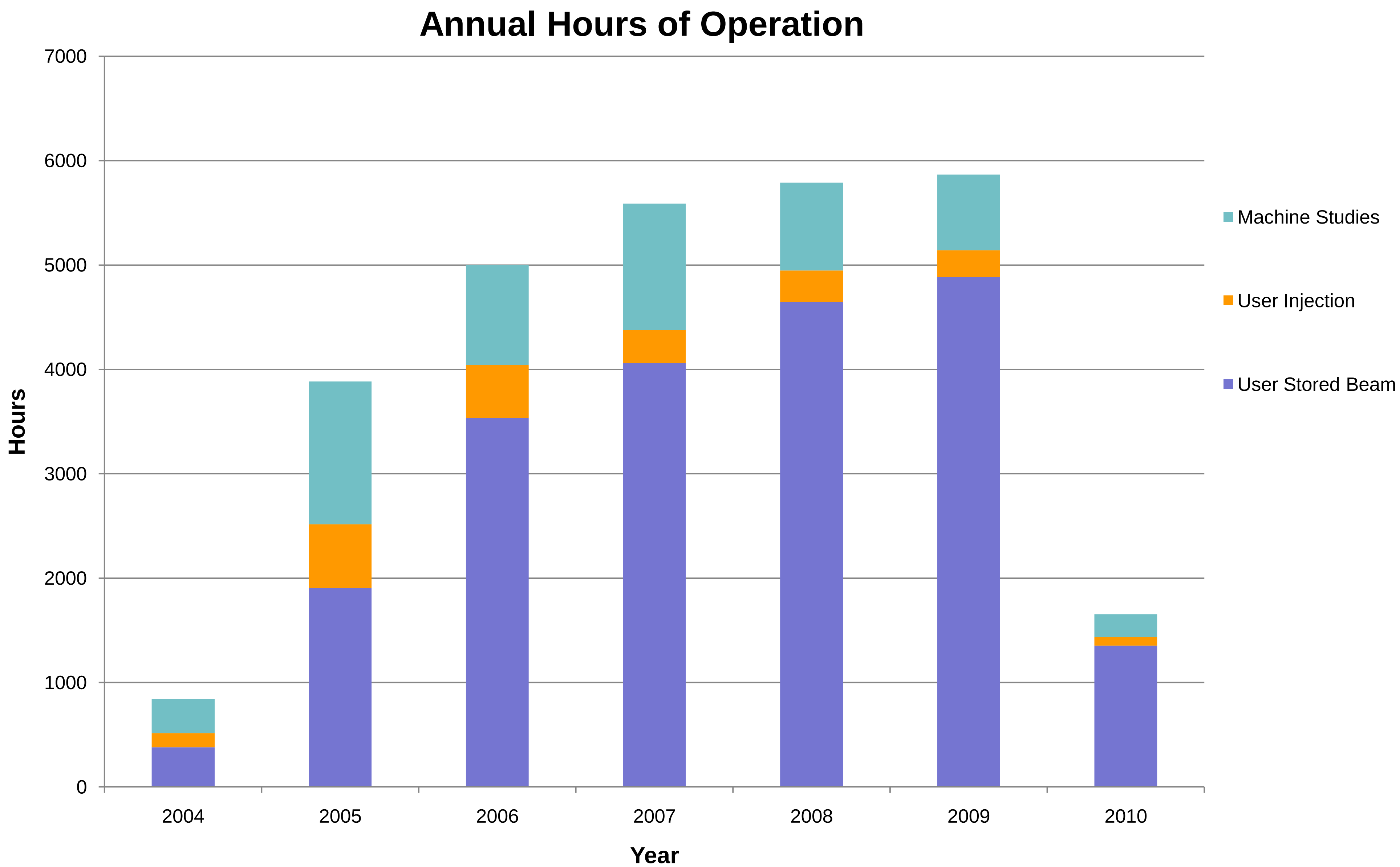
	Su	Mo	T	W	Th	F	S
September, 2010				1	2	3	4
00:00 - 08:00				N	N	N	M
08:00 - 16:00				N	N	M	M
16:00 - 24:00				N	N	M	M
	5	6 (stat)	7 (Run 64)	8	9	10	11
00:00 - 08:00	M	M	M	NS	N	N	N
08:00 - 16:00	M	M	D	DS	N	N	N
16:00 - 24:00	M	M	D	N	N	N	N
	12	13	14	15	16	17	18
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	19	20	21	22	23	24	25
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	DS	N	N	N	N	N
	26	27	28	29	30		
00:00 - 08:00	N	N	NS	N	N		
08:00 - 16:00	N	D	N	N	N		
16:00 - 24:00	N	D	N	N	N		

	Su	Mo	T	W	Th	F	S
October, 2010						1	2
00:00 - 08:00						N	N
08:00 - 16:00						N	N
16:00 - 24:00						N	N
	3	4	5 (PCaPAC)	6 (PCaPAC)	7 (PCaPAC)	8 (PCaPAC)	9
00:00 - 08:00	N	N	M	M	M	M	M
08:00 - 16:00	N	M	M	M	M	M	M
16:00 - 24:00	N	M	M	M	M	M	M
	10	11 (stat)	12	13	14	15	16
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	M	M
16:00 - 24:00	M	M	M	M	M	M	M
	17	18	19	20	21	22	23
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	M	M
16:00 - 24:00	M	M	M	M	M	M	M
	24	25	26	27	28	29 (PRC?)	30
00:00 - 08:00	M	M	M	M	M	M	M
08:00 - 16:00	M	M	M	M	M	M	M
16:00 - 24:00	M	M	M	M	M	M	M
	31						
00:00 - 08:00	M						
08:00 - 16:00	M						
16:00 - 24:00	M						

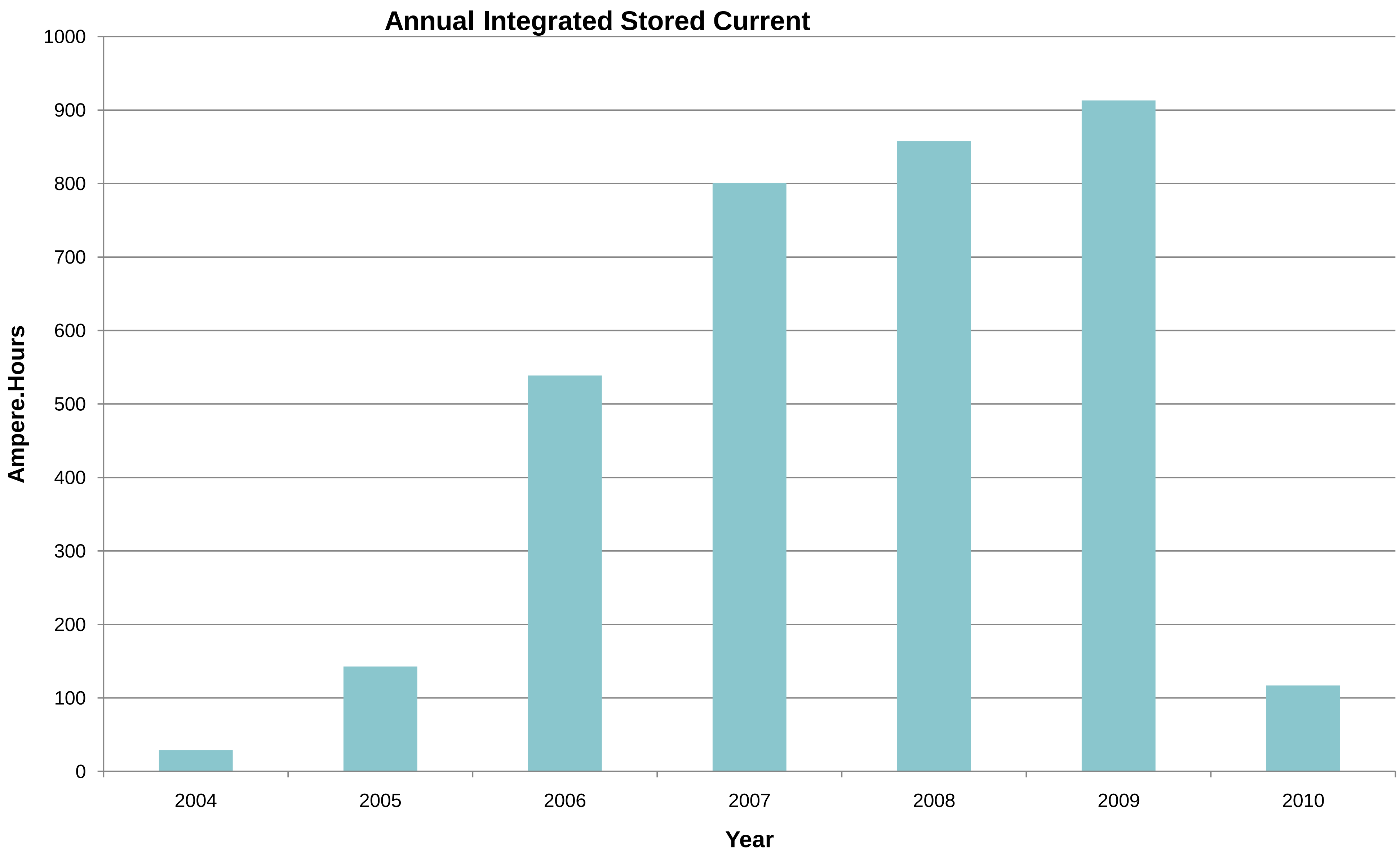
	Su	Mo	T	W	Th	F	S
November, 2010		1	2	3 (Run 65)	4 (SAC?)	5 (SAC?)	6
00:00 - 08:00		M	M	M	M	NS	NS
08:00 - 16:00		M	M	M	D	D	D
16:00 - 24:00		M	M	D	D	D	D
					(Stat)		
	7	8	9	10	11	12	13
	NS	NS	NS	N	N	N	N
08:00 - 16:00	D	D	N	N	N	N	N
16:00 - 24:00	D	DS	N	N	N	N	N
	14	15	16	17	18	19	20
00:00 - 08:00	N	N	DS-CSR	N	N	N	N
08:00 - 16:00	N	D	NS	N	N	N	N
16:00 - 24:00	N	DS-CSR	N	N	N	N	N
	21	22	23	24	25	26	27
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	N	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	28	29	30				
00:00 - 08:00	N	N	NS				
08:00 - 16:00	N	D	SB				
16:00 - 24:00	N	DS	SB				

	Su	Mo	T	W	Th	F	S
December, 2010				1	2 (BofD?)	3	4
00:00 - 08:00				N	N	N	N
08:00 - 16:00				N	N	N	N
16:00 - 24:00				N	N	N	N
	5	6	7	8	9	10	11
00:00 - 08:00	N	N	NS	N	N	N	N
08:00 - 16:00	N	D	DS	N	N	N	N
16:00 - 24:00	N	D	N	N	N	N	N
	12	13	14	15	16	17	18
00:00 - 08:00	N	N	NS	N	N	N	M
08:00 - 16:00	N	D	N	N	N	M	M
16:00 - 24:00	N	D	N	N	N	M	M
	19	20	21	22	23	24	25
00:00 - 08:00	M	M	M	M	M	M	X
08:00 - 16:00	M	M	M	M	M	X	X
16:00 - 24:00	M	M	M	M	M	X	X
	26	27	28	29	30	31	
00:00 - 08:00	X	X	X	X	X	X	
08:00 - 16:00	X	X	X	X	X	X	
16:00 - 24:00	X	X	X	X	X	X	

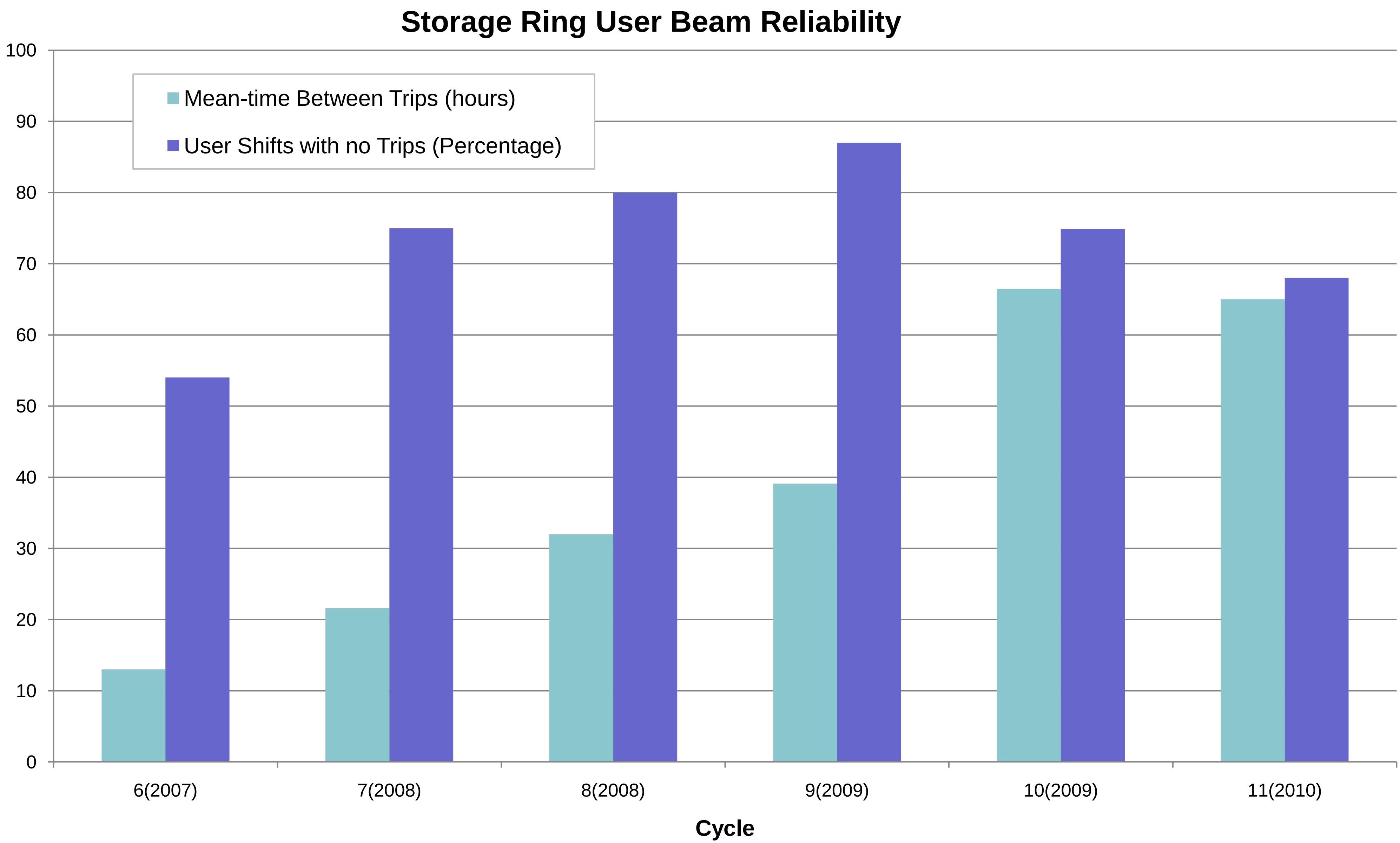
CLS Accelerator Operations



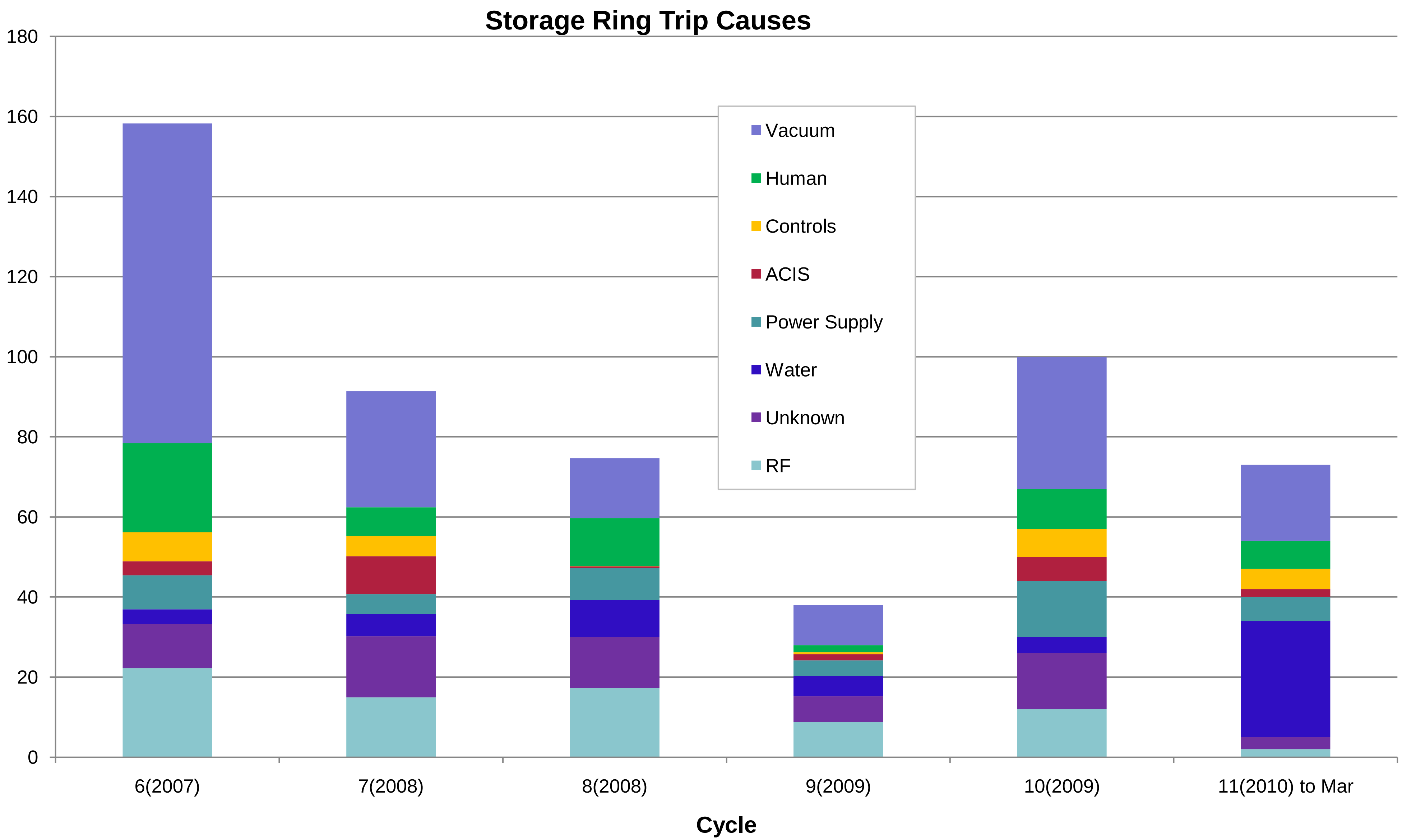
CLS Accelerator Operations



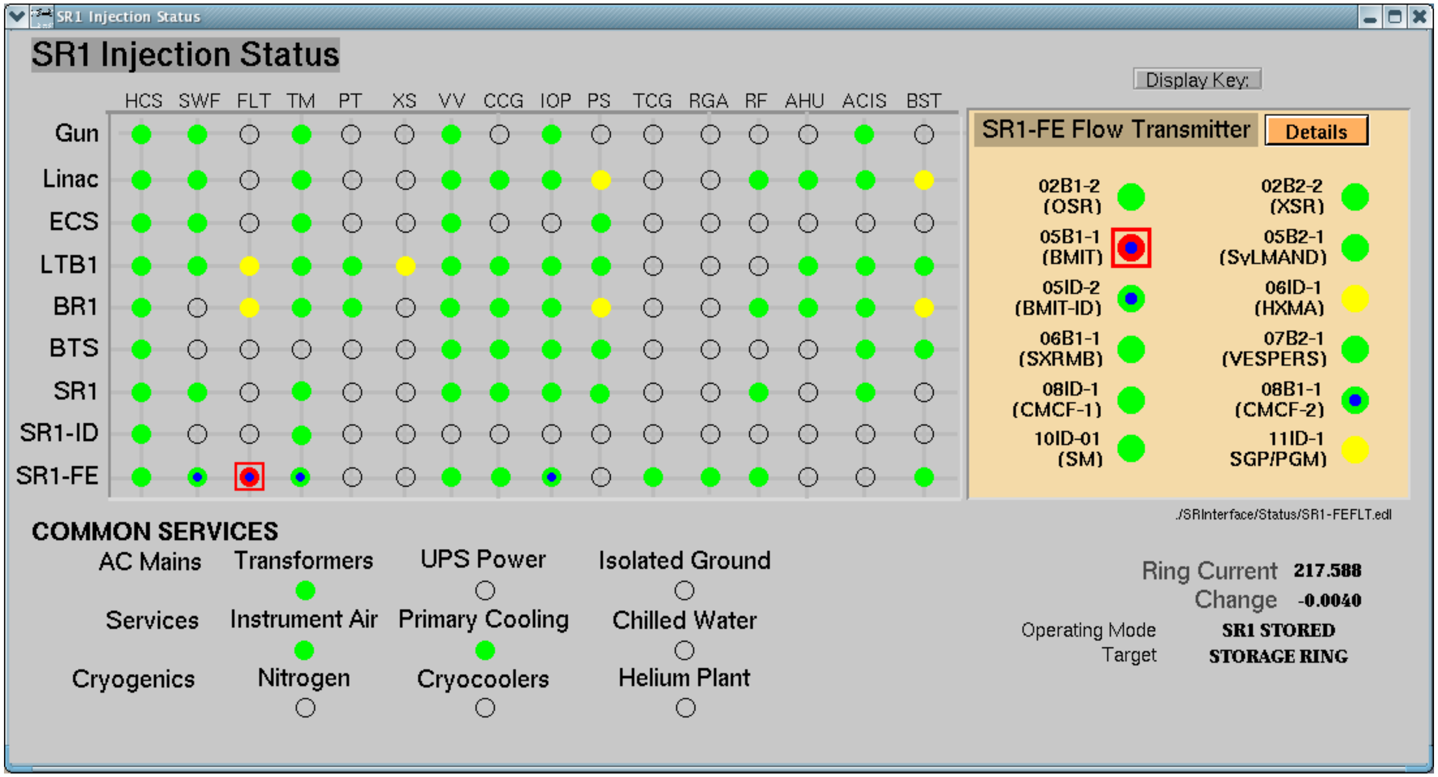
CLS Accelerator Reliability



CLS Accelerator Trips



Injection/Machine Status Screen

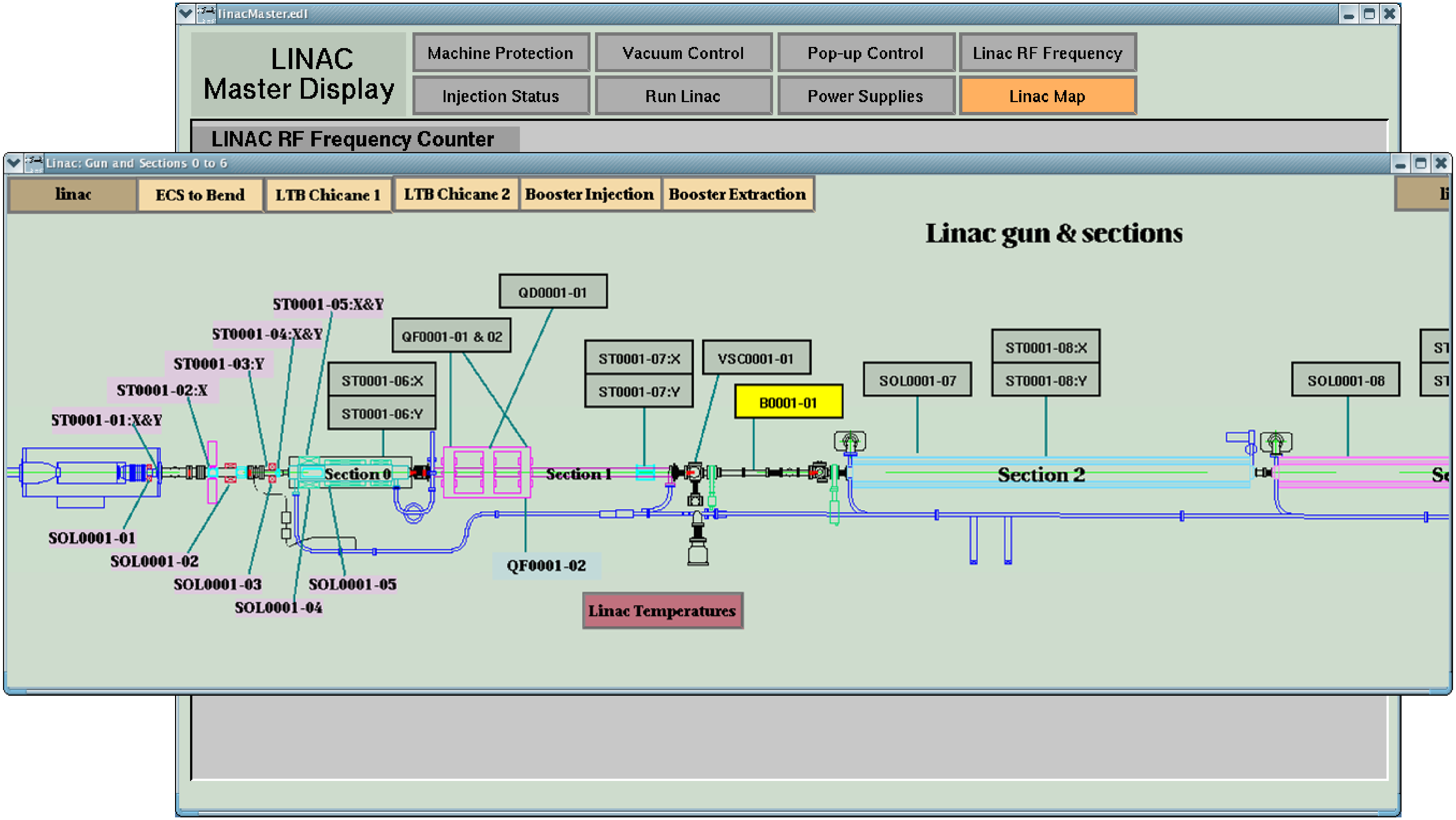


Status Screen Based on Grid Status Indicator Matrix

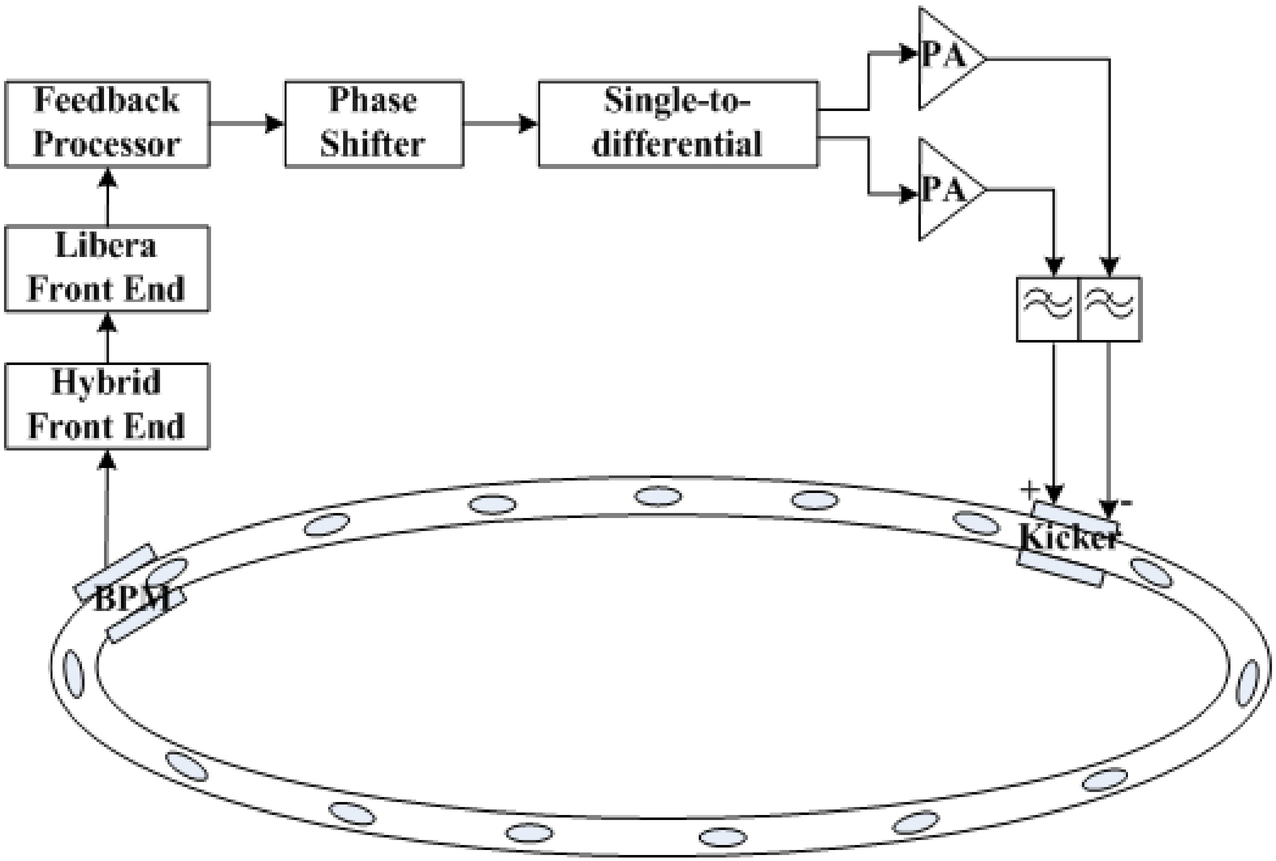
- Organizes thousands of process values in one screen
- Easy navigation through sub-system and components
- Color keys indicating device status
- Critical fault is latched for operator acknowledge/reset
- Useful tool for operator for monitoring/troubleshooting

Integrated master Display

- Tabbed window based master display integrates multiple control screens into one display
- Each tab button and the screen it brings up covers one specific aspect of LINAC operation
- Advantage: most LINAC operation can be performed from one central location

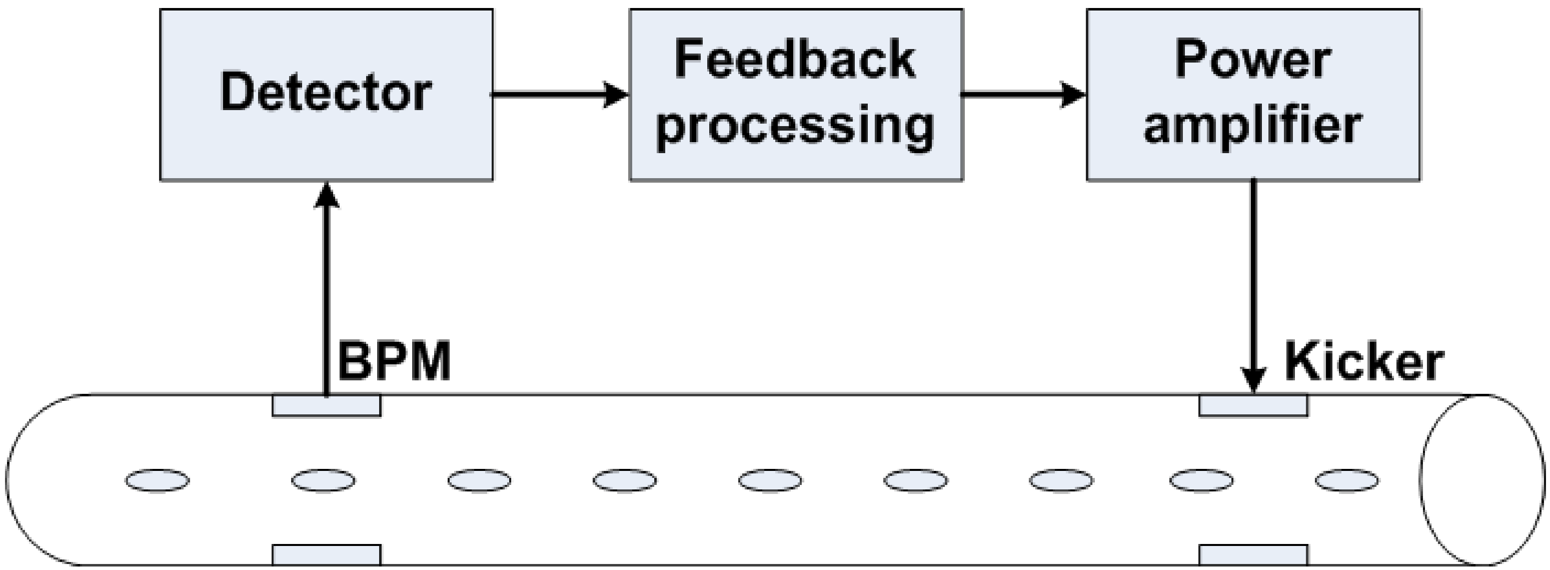


Timing Control Components



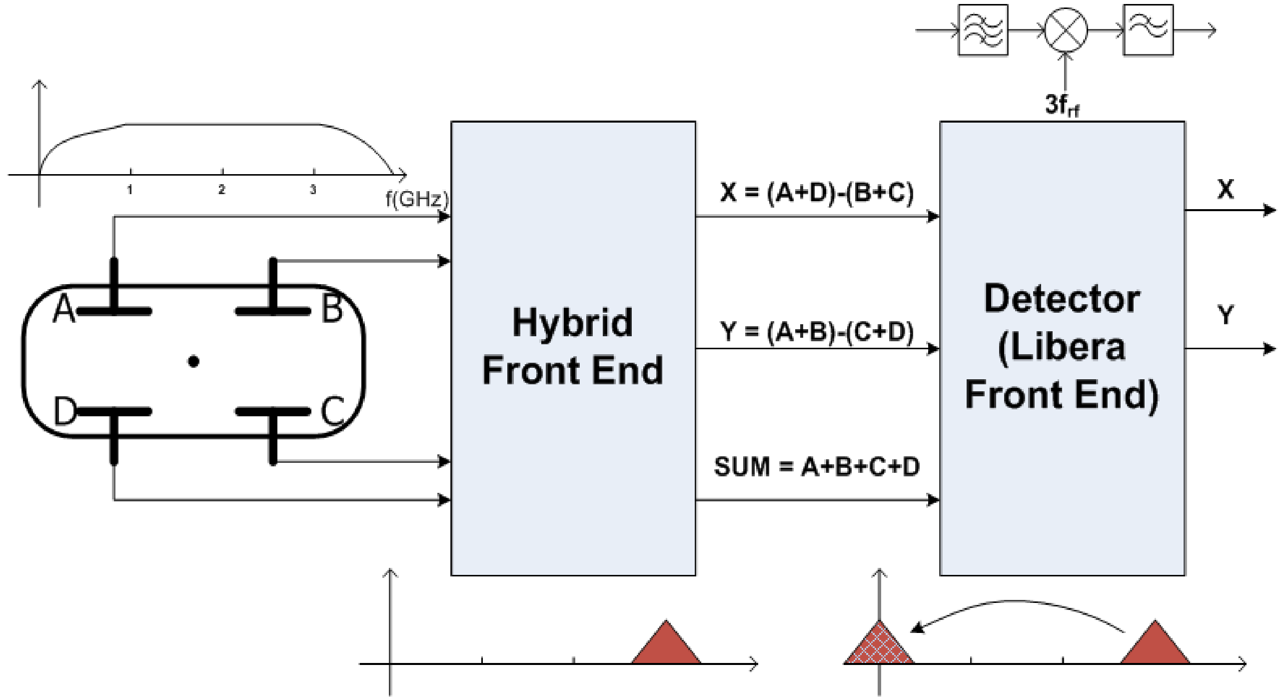
- It is important to adjust the timing of the signal to match the bunch arrival time
- Feedback processing unit can adjust delay at steps of 2ns
- The motorized phase shifter adjusts the fine output delay (0 to 2ns), with an accuracy of several ps.

TFBS Components



- BPM and detector → measure the beam oscillations
- Processing unit → generate the correction signal (bunch by bunch feedback @ CLS)
- PA and kicker → act on the beam

BPM and Detector



- Hybrid front end generates X, Y and SUM signals from the BPM button signals. It is working around the third harmonic ($3f_{rf}$), where the overall transfer function has maximum amplitude
- X and Y wideband signals are down converted into baseband (0 to $f_{rf}/2$) by Libera Front End (amplitude demodulation)

Future Plan for Operation

- Reduce superconducting wiggler quench
- Use fast orbit correctors
- Top-up mode Operation
- Improve the linac and booster stability
- Improve injection rate
- Injection with the wiggler full operation
- New superconducting RF cavity, goal: 500mA
- Trip less than 80/year

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CLS Accelerator Operations and Development

- Mark de Jong
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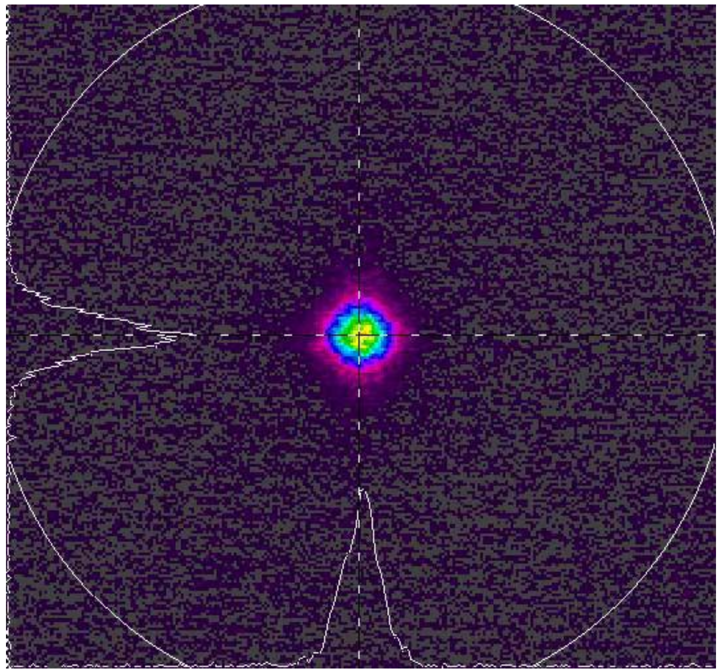
- Jonathan Stampe
- Morgan Bradford
- Don LaClair
- Xiaofeng Shen

The End



Computer-generated image of the first bunch of electrons stored in the CLS storage ring.

Thank you!