Introduction to the LHC DCCT System

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Plan

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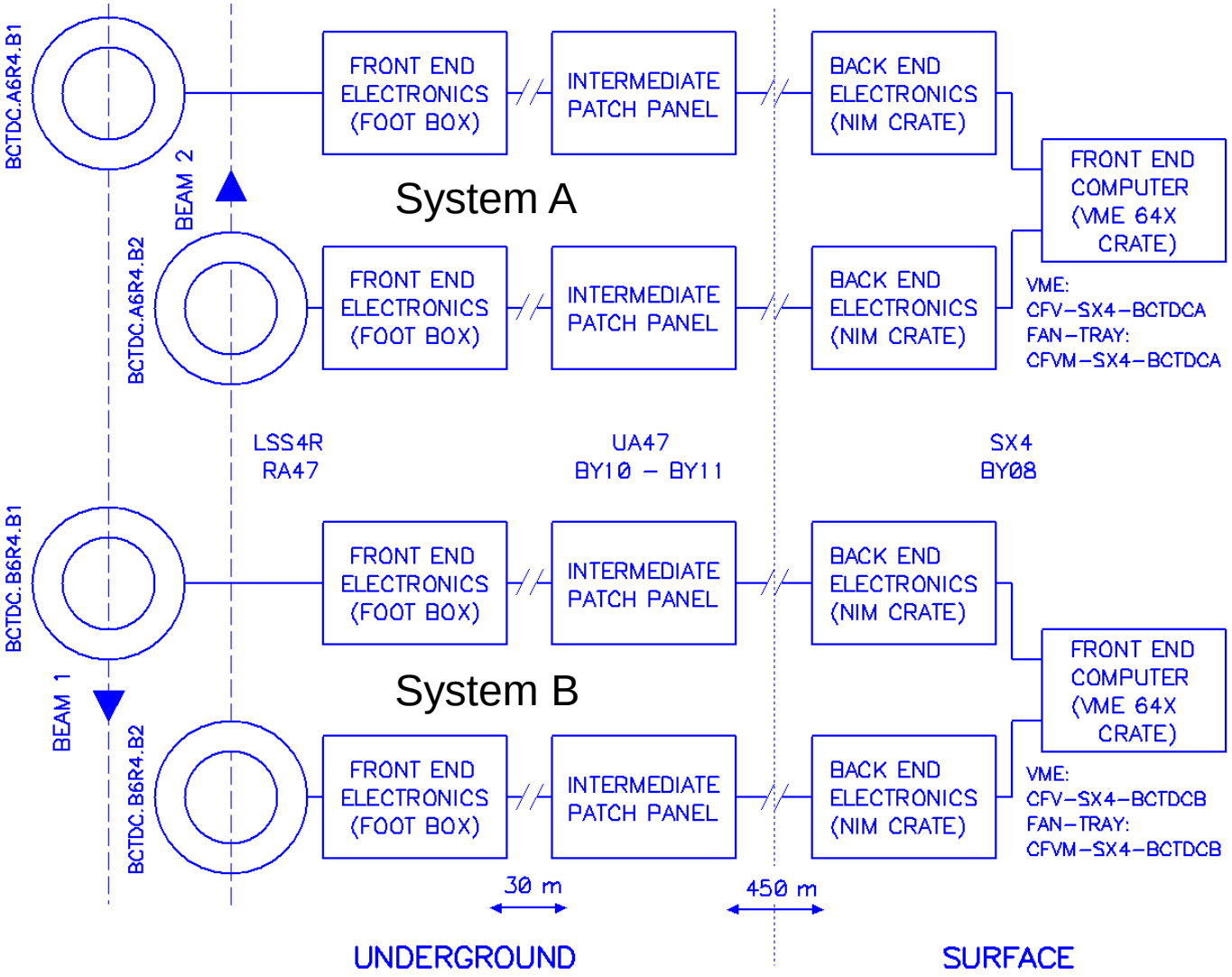
LHC parameters relevant for the beam intensity measurement

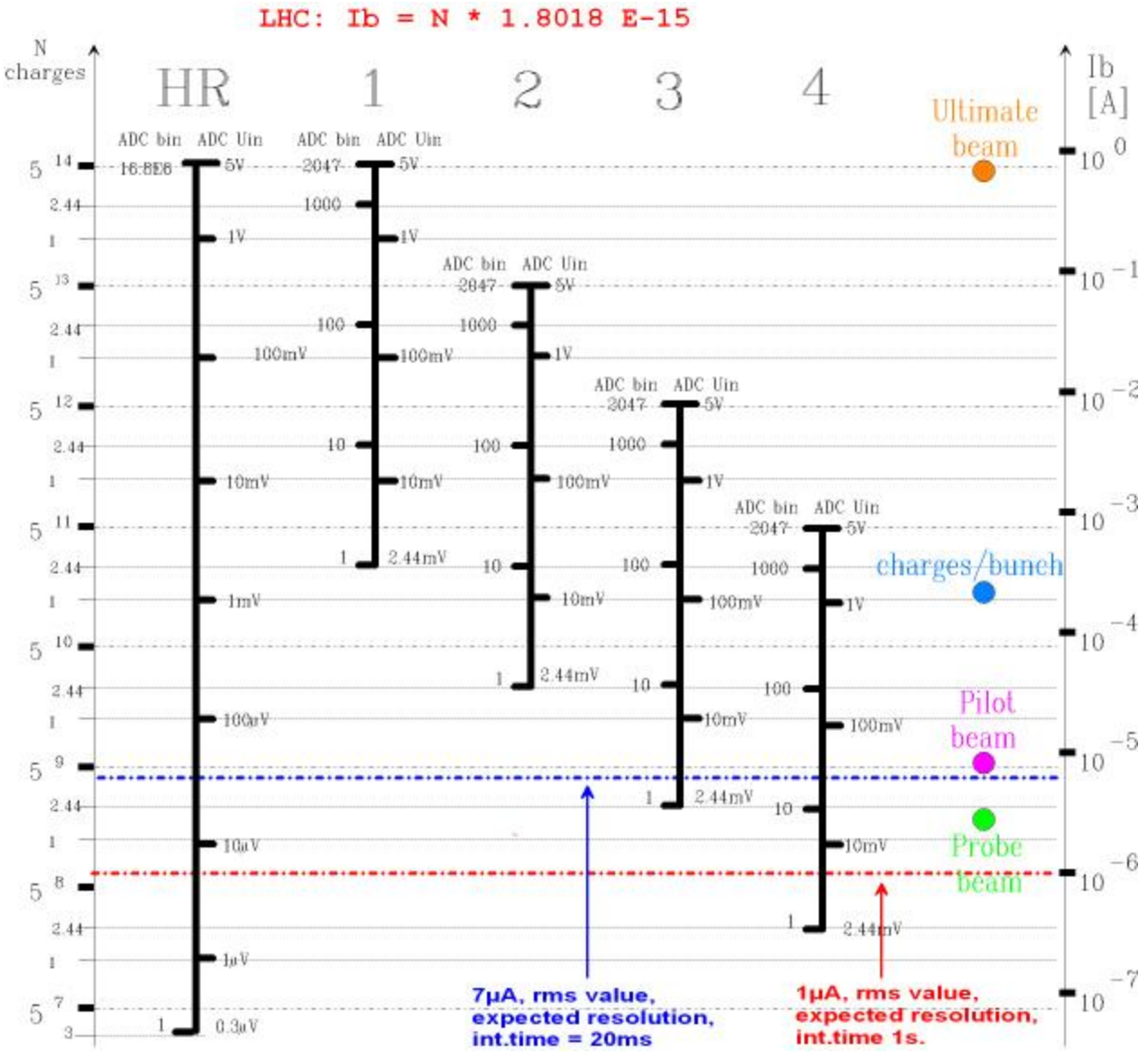
Ring circumference [m]			26659
Revolution period [μs]			88.9
Revolution frequency [kHz]			11.245
RF frequency [MHz]			400.8
Harmonic number			35640
Number of bunches			1 to 2808
bunch spacing [ns]			24.95 to 88925
Protons	Bunch charge	Probe [q]	2 E9
		Nominal [q]	1.15 E11
		Ultimate [q]	1.7 E11
	Circulating beam current	Probe [μA]	3.6
		Nominal [mA]	582
		Ultimate [mA]	860
Ions	Bunch charge	Early [q]	5.6 E8
		Nominal [q]	5.6 E9
	Circulating beam current	Early [mA]	6.4
		Nominal [mA]	0.64

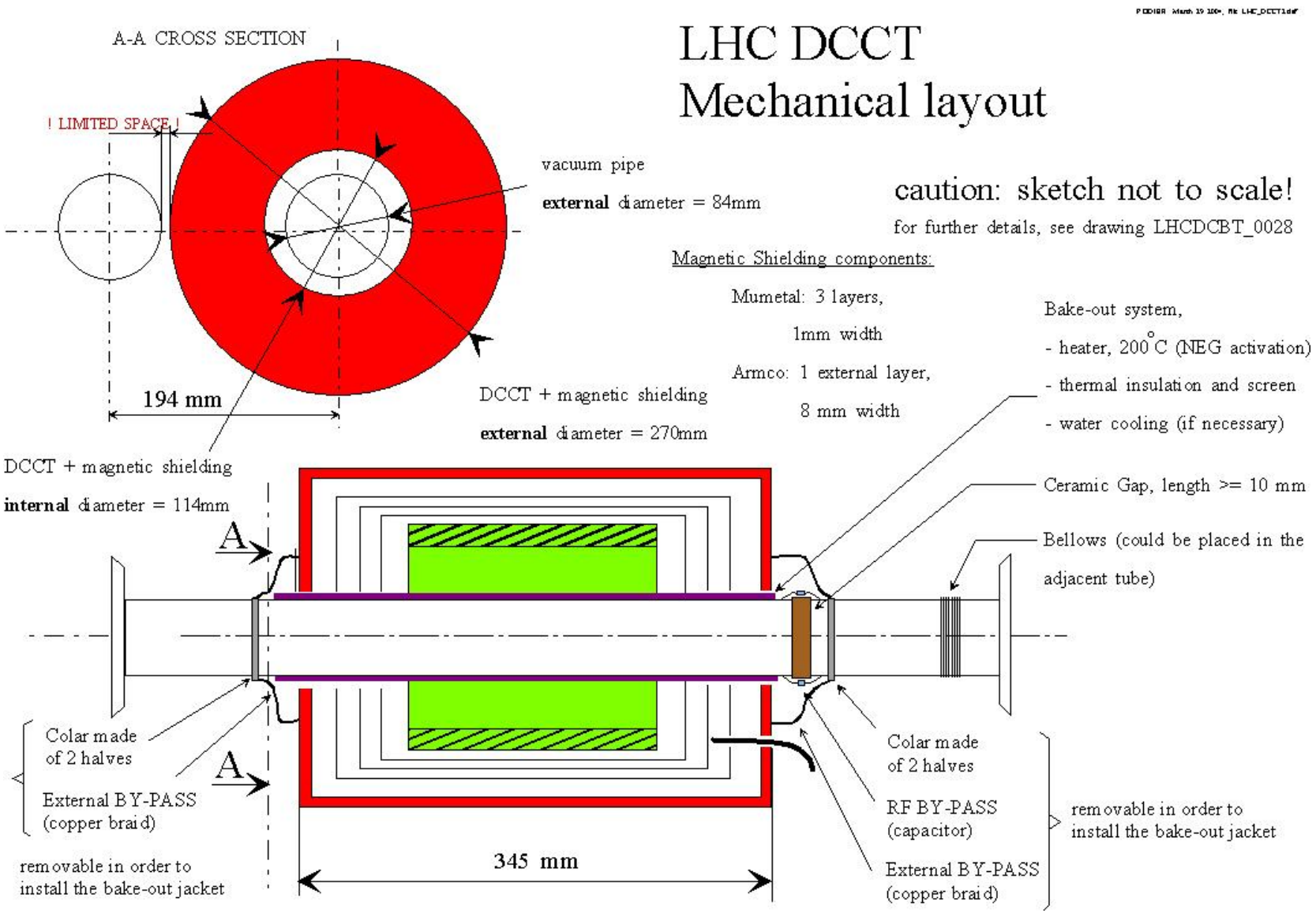
Large dynamic !

General layout

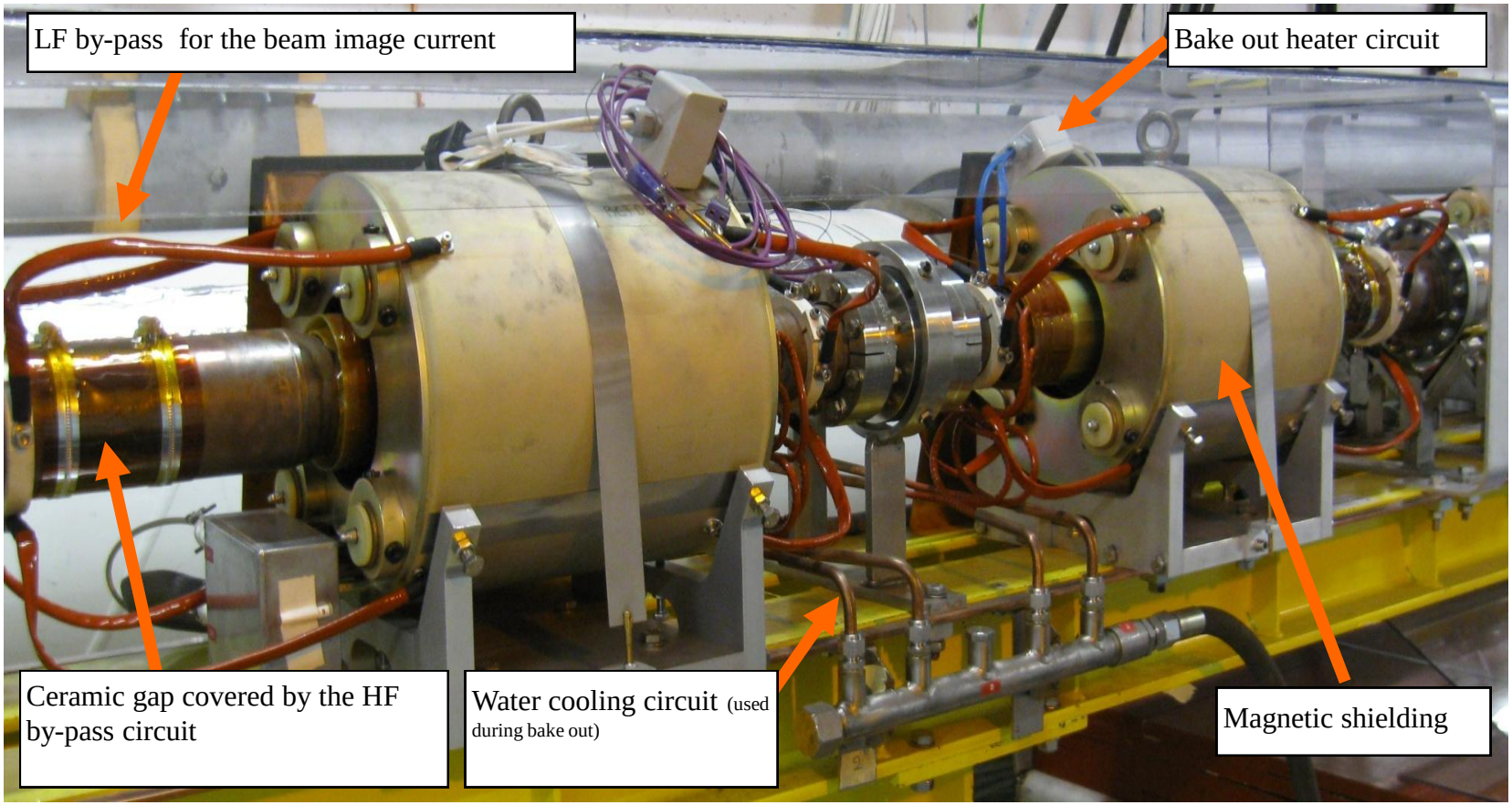


Distribution of the acquisition ranges



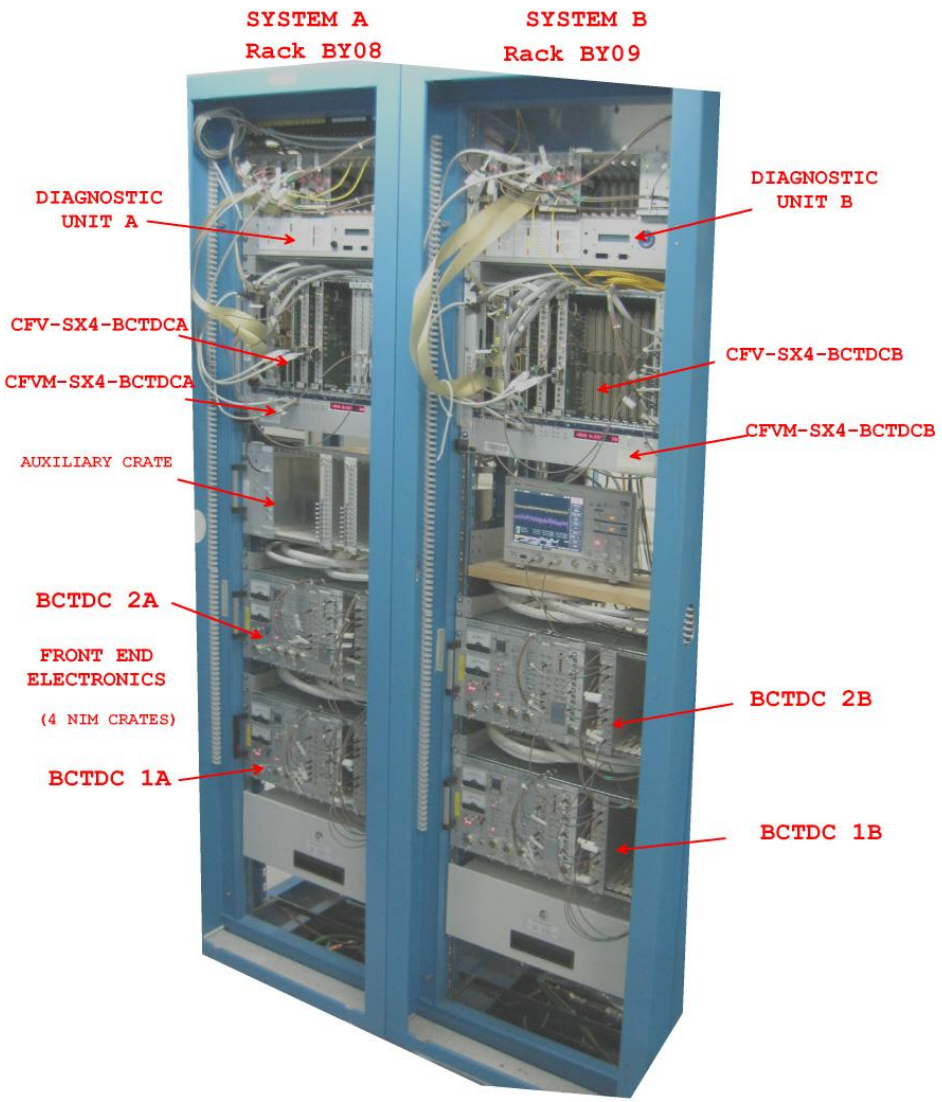

LHC DCCT
Mechanical layout
A-A CROSS SECTION
! LIMITED SPACE !
194 mm
vacuum pipe
external diameter = 84mm
caution: sketch not to scale!
for further details, see drawing LHCDCBT_0028
Magnetic Shielding components:
Mumetal: 3 layers,
1mm width
Armco: 1 external layer,
8 mm width
DCCT + magnetic shielding
external diameter = 270mm
DCCT + magnetic shielding
internal diameter = 114mm
Bake-out system,
- heater, 200°C (NEG activation)
- thermal insulation and screen
- water cooling (if necessary)
Ceramic Gap, length >= 10 mm
Bellows (could be placed in the adjacent tube)
A
A
Colar made of 2 halves
External BY-PASS (copper braid)
removable in order to install the bake-out jacket
345 mm
Colar made of 2 halves
RF BY-PASS (capacitor)
External BY-PASS (copper braid)
removable in order to install the bake-out jacket

Picture (1)



General view of DCCTs A et B on beam 1

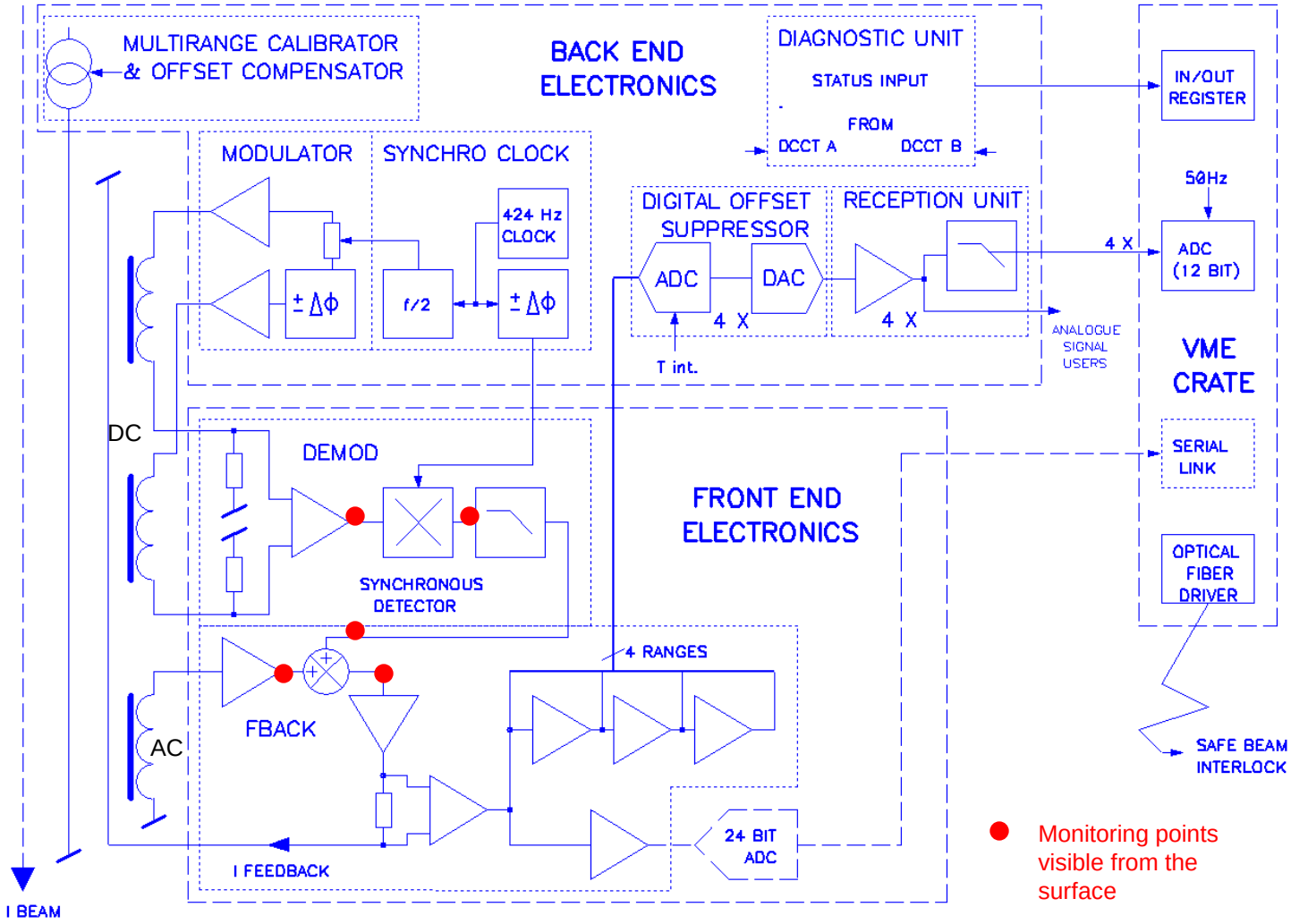
Picture (2)



Installation in SX4 (surface building)

Electronics

Simplified schematics



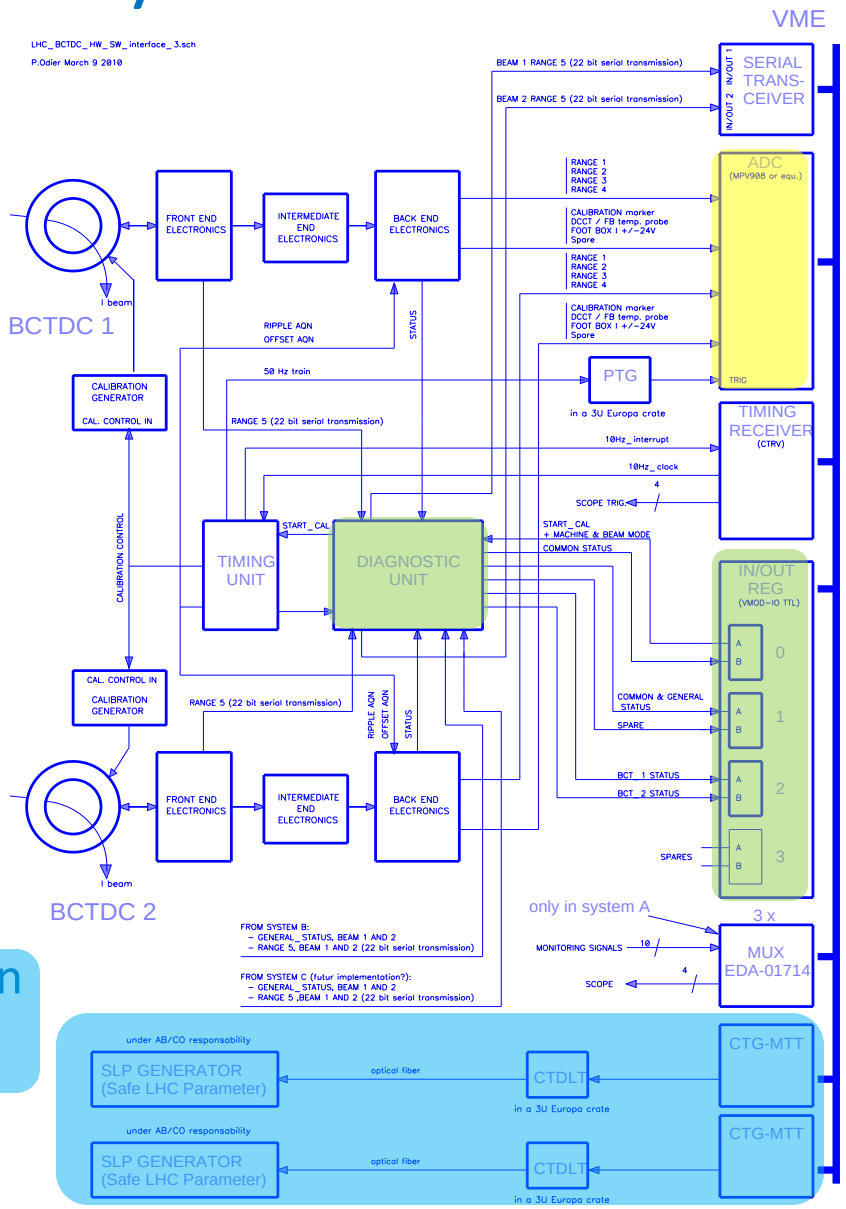
Acquisition system

Acquisition

- 50Hz ADC sampling rate, 8 channels/DCCT
- (4 ranges, temperature probes, etc.)

Real Time Program

- 10Hz interrupt
- ADC reading, autoranging
- 3 sets of scaling factors (precise, quick, theoretical)
- Status acquisition
- 10Hz and 1 Hz publishing results
- Interlock (Safe Beam Flag) based on Beam intensity and energy
- Logging (TIMBER) very convenient to analyze data afterwards



Quick check & calibration

- Quick check
  - A burst of 4 calibration pulses is systematically generated before each first injection (4E11, 4E12, 4E13 and 4E14 charges; 100ms per pulse; home made current generator)
  - Result evaluated by the CCC-sequencer agent

- Choice between 3 calibration modes, i.e. 3 different sets of scaling factors applied to the acquisitions:

  - Precise (used at the moment)

    Scaling factors determined after averaging of the acquisition performed during a few minutes with a known current (commercial current generator, accuracy better than 0.1%) applied to the calibration winding
  - Theoretical (used in case…)
  - Quick (used as a check)

    See above

Uncertainty-Resolution-Accuracy

Expected values based on measurements made in laboratory

calibrator accuracy	0.1%	Expected quality for the precise calibration
ADC #bit:	12	VME ADC used at the moment
noise (rms, 1s int.) [A]	2.0E-06	Conservative value (best case obtained is 1.3E-6)
Ib = N *	1.8E-15	Relationship: beam current vs Nb of circulating charges
temp. coef [A/°C]	5.0E-06	Typical temperature dependance (sensor + FEE); equ. to: 2.8E+09 [charges/°C]
HR ADC #bit	24	Future improvement

Range	SF [charges/V]	FS [charges]	1 bit equivalent [charges]	Noise (rms, 1s int.) [charges]	Dominent absolute uncetainty	Resolution (rms, 1s int.) [charges]	Accuracy at stable temperature ±(% of reading + charges)	Accuracy at variable temperature ±(% of reading + charges +charges/°C)
1	1.00E+14	5.00E+14	2.44E+11	1.1E+09	± 1 bit	2.44E+11	0.1 + 2.44E11	0.1 + 2.5E11 +2.8E9
2	1.00E+13	5.00E+13	2.44E+10	1.1E+09	± 1 bit	2.44E+10	0.1 + 2.44E10	0.1 + 2.5E10 +2.8E9
3	1.00E+12	5.00E+12	2.44E+09	1.1E+09	± 1 bit	2.44E+09	0.1 + 2.44E9	0.1 + 2.5E9 +2.8E9
4	1.00E+11	5.00E+11	2.44E+08	1.1E+09	noise	1.1E+09	0.1 + 1.1E9	0.1 + 1.1E9 +2.8E9
HR	1.00E+14	5.00E+14	5.96E+07	1.1E+09	noise	1.1E+09	0.1 + 1.1E9	0.1 + 1.1E9 +2.8E9

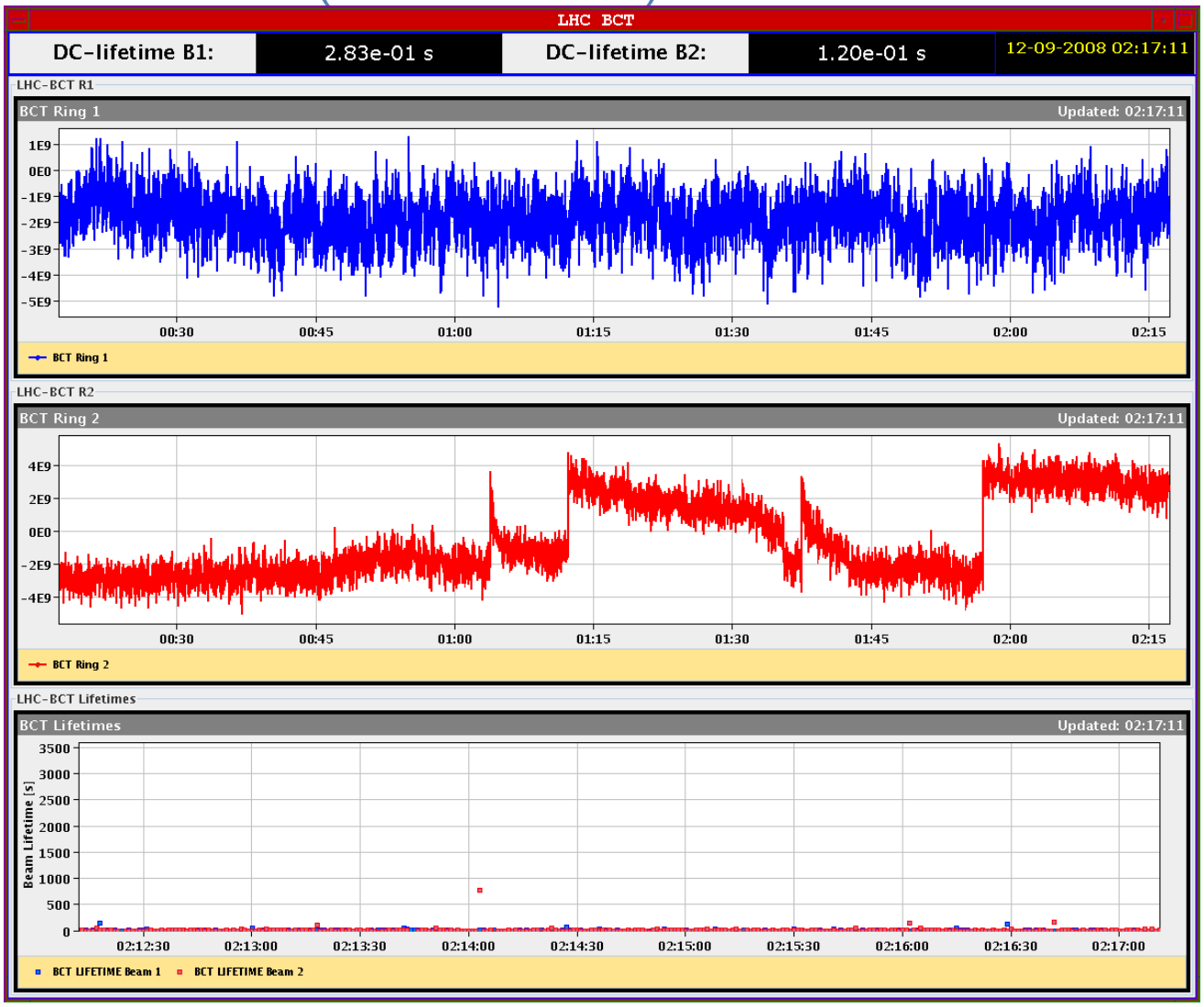
Note: the offset is considered suppressed

DCCT main specifications

DCCT size including the magnetic shielding · Internal diameter · External diameter · Length	 114mm 265mm 350mm
Vacuum pipe · External diameter · Distance between beam 1 and beam 2 axes	 64mm 192mm
Magnetic core Material Size (box) µi	 Nanocrystaline 168mm / 142mm / 23mm >100000
Dynamic range	1µA to 0.9A
Modulation frequency	212Hz
Acquisition sampling rate	50S/s
Noise measured during 1 hour with no beam (rms, 1s int. time) min. typ. max.	 1.3µA 2.1µA 3.0µA

Results (1)

First beam observed (December 2008)

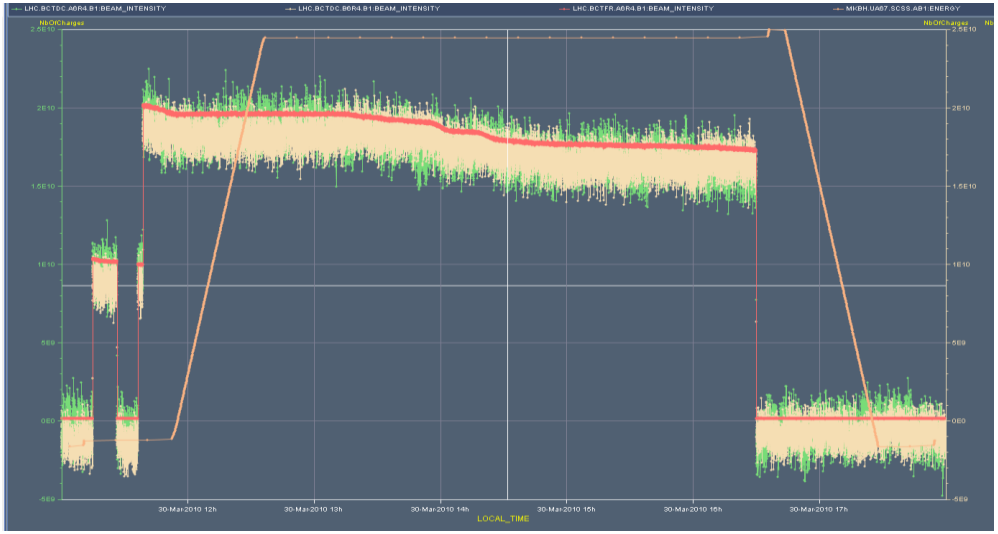


Results (2)

BCT signals during the first collision @ 3.5 TeV, March 30 2010 12h58 to 16h31

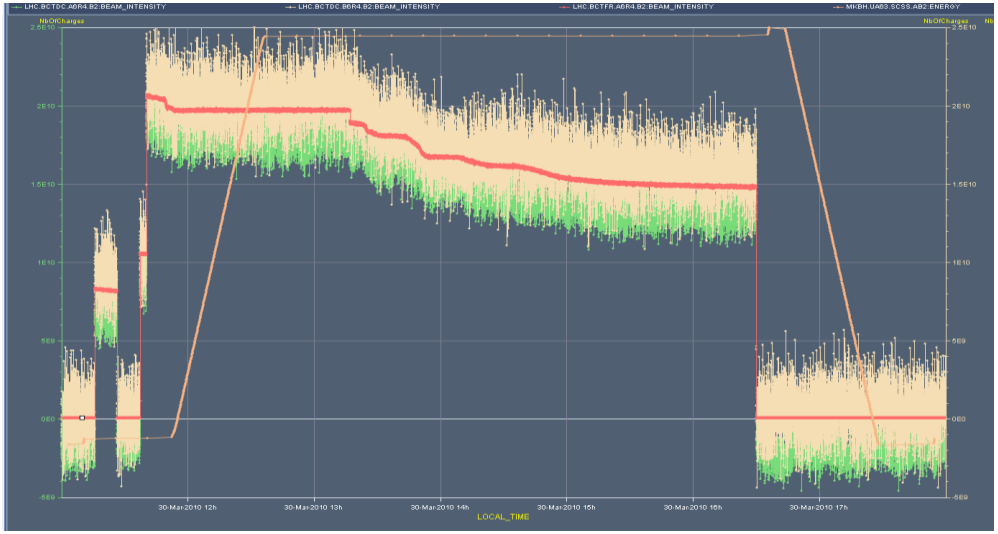
BEAM 1

2E10 charges



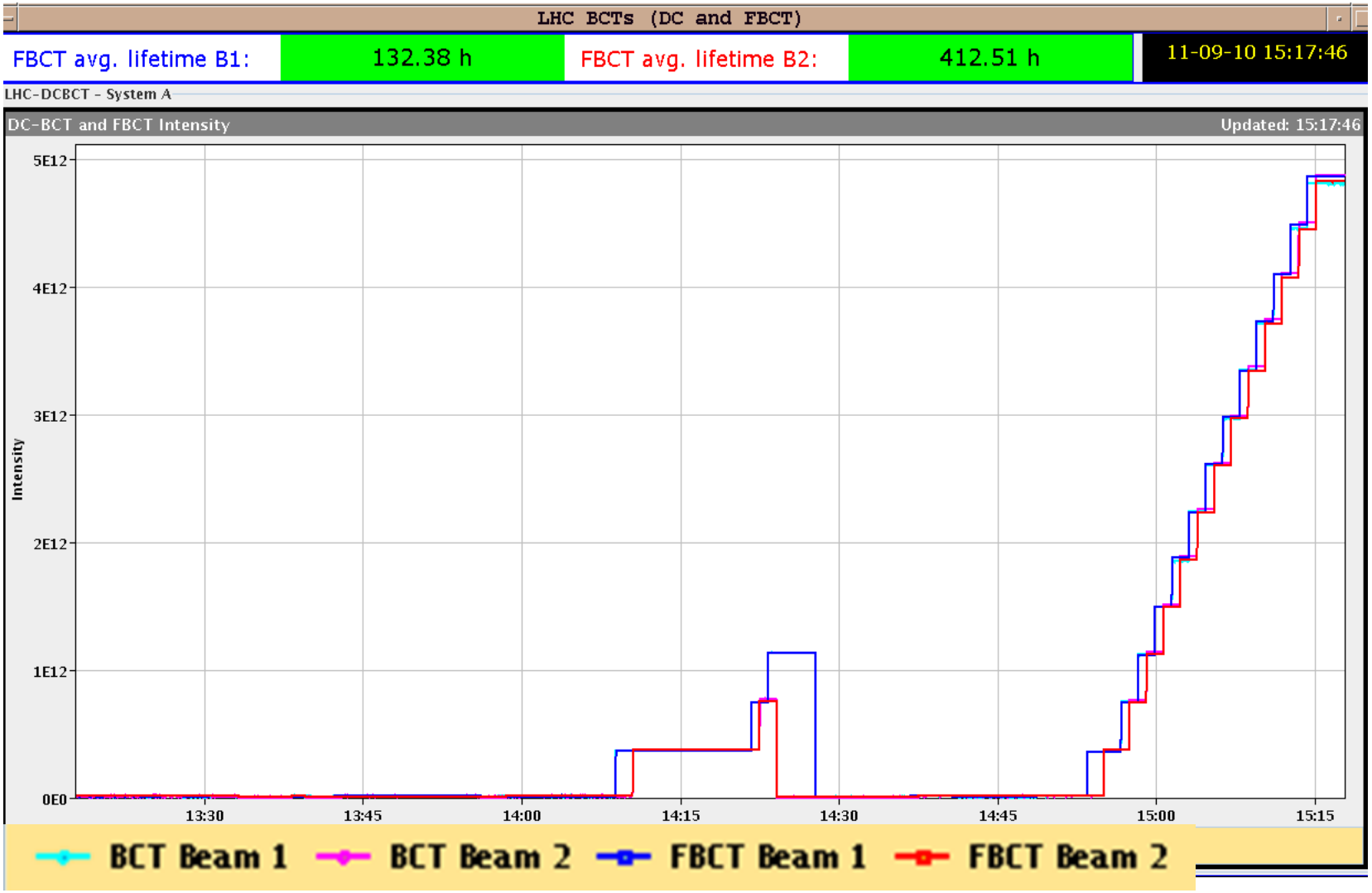
BEAM 2

2E10 charges



Results (3)

Multi injection (13), total: 5E12 (9mA)



Results (4)

Long term noise (December 2010, C.Barschel)