Progress made with the LHC DCCT in 2010 & plans for 2011

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Plan

1. Introduction
2. Issue # 1. Incomplete saturation of the highest sensitivity ranges
3. Issue # 2. Offset reduction not sufficient after the Digital Offset Suppressor
4. Issue # 3. Dependence to the filling pattern
    - Beam frequency spectrum
    - Cause 1. The RF bypass
        - Principle
        - Improvements
    - Cause 2. The Electronics
        - Simulation
        - Bench test measurement
5. Beam simulation
6. Plans for 2011
7. Conclusions
8. Acknowledgments

Introduction

2010 Highlights

- Positive points

  The DCCT fulfill the specs for low intensity beams

  - Van der Meer scans used by the experiments to calibrate the luminosity measurement
  - Ions (~1E12 charges)
  - Debunched beams

  Observed no dependence to

  - calibration or beam position
  - bunch length

- Negative points
  - Issues related by JJG in the previous talk

Issue #1. Incomplete saturation of the highest sensitivity ranges

Symptoms

- The highest sensitivity ranges do not reach the foreseen saturation
- The ratio between the signals on different ranges is not proportional the ratio of the scaling factors (both for analogue signals & ADC raw data)

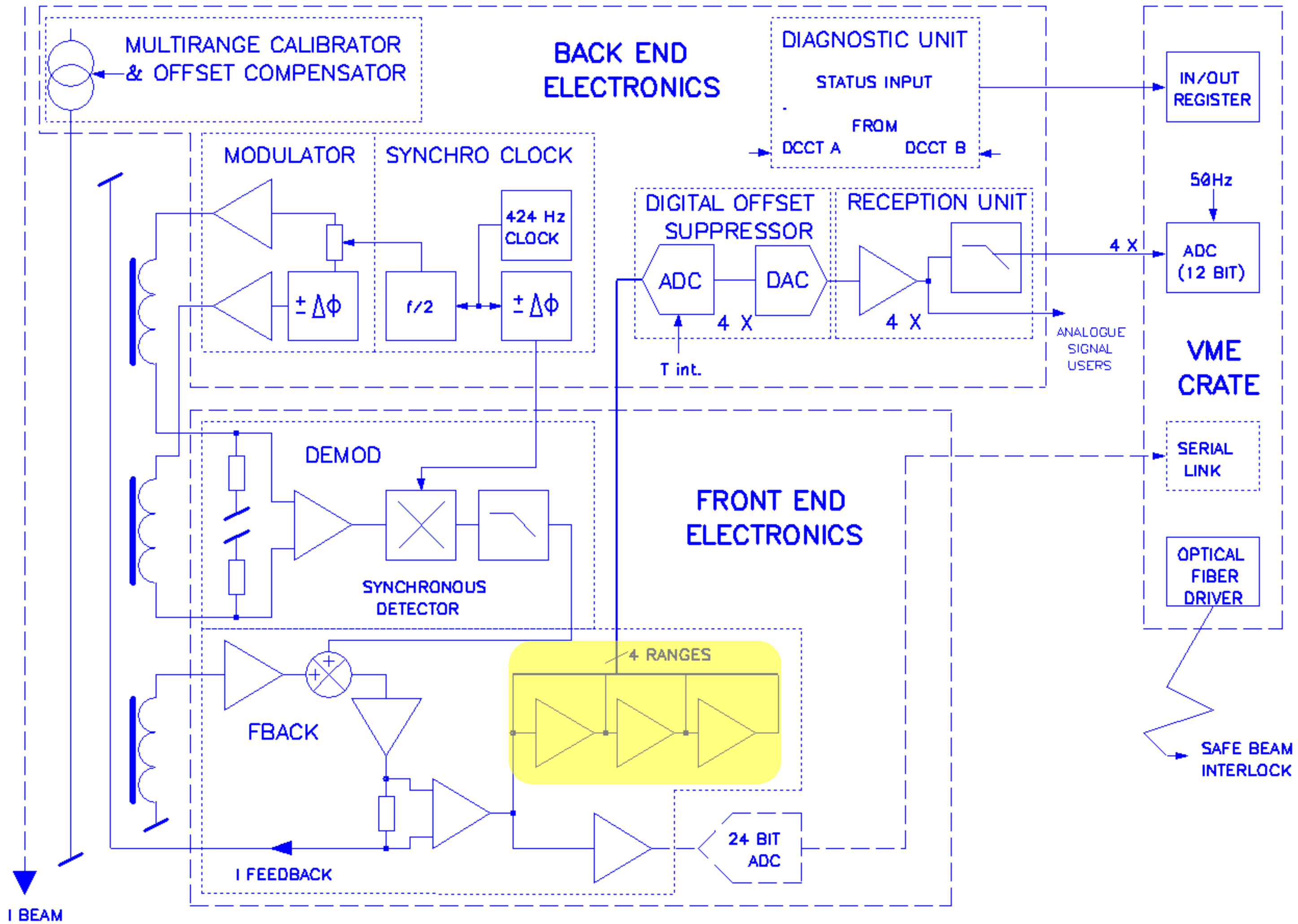
Cause

Strong AC component superimposed to the DC signal in the highest sensitivity range amplifiers located in the Front End Electronics.
Therefore the foreseen level of saturation is not reached.
Not visible on the signal transmitted to the surface (BW not sufficient)

Cures

1. Lowering the thresholds use for the autoranging SW
2. Filtering of the range amplifiers

Simplified schematics

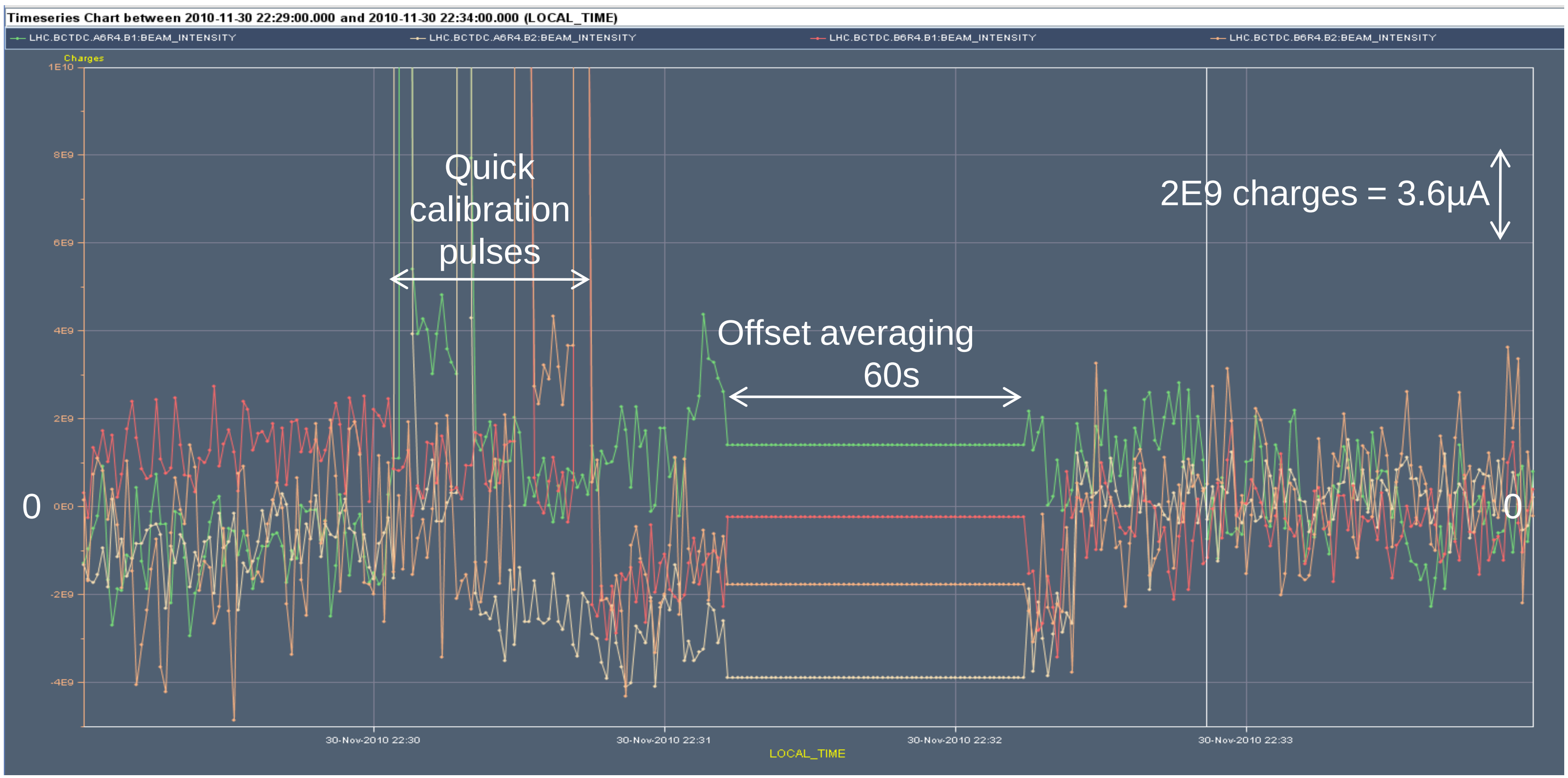


Issue #2. HW offset suppression not sufficient

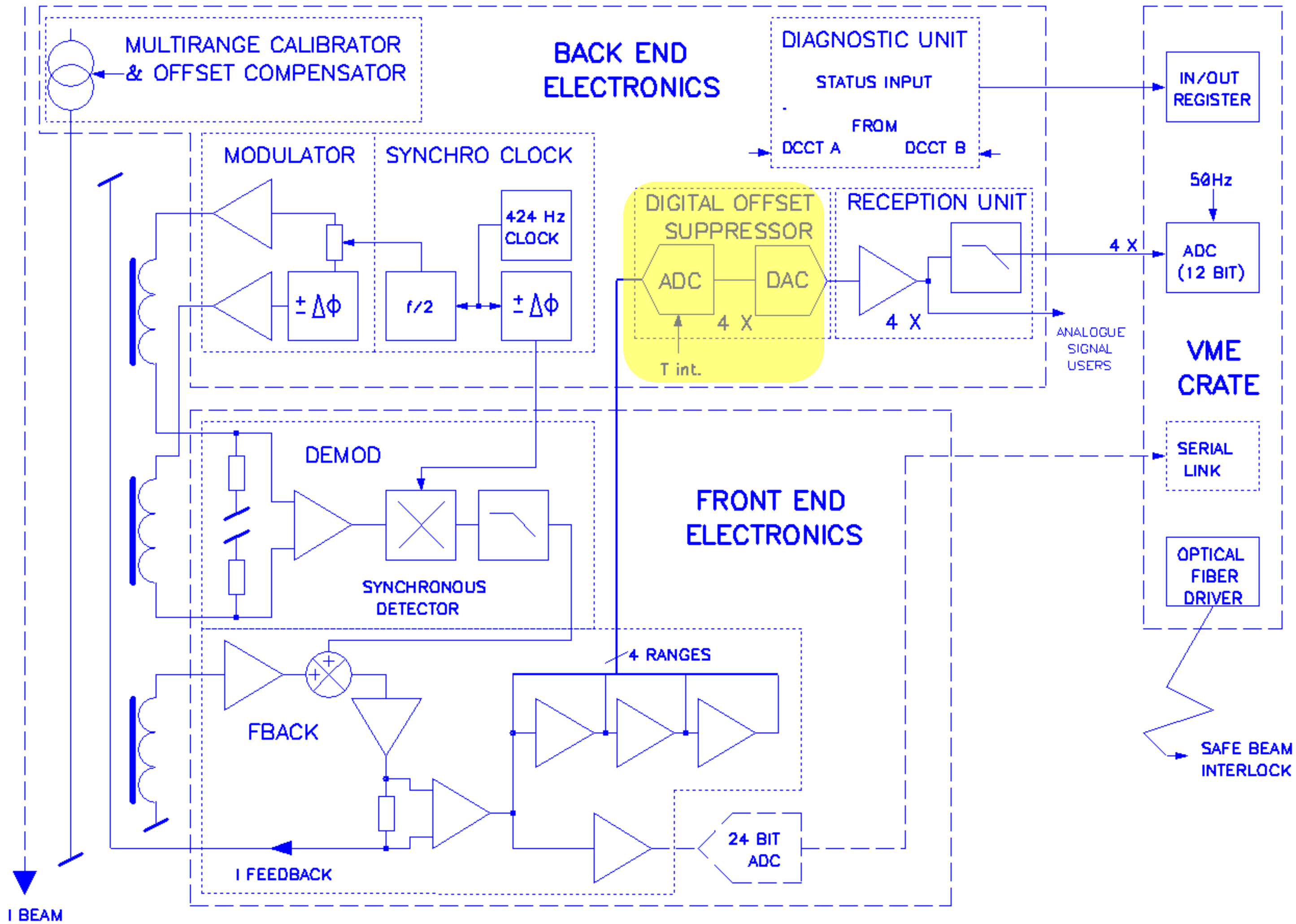
Symptom: the offset reduction by the HW module “DIGITAL OFFSET SUPPRESSOR” is not sufficient

Cause: integration time not long enough (80ms)

Cure: the HW offset suppression is complemented by a SW solution

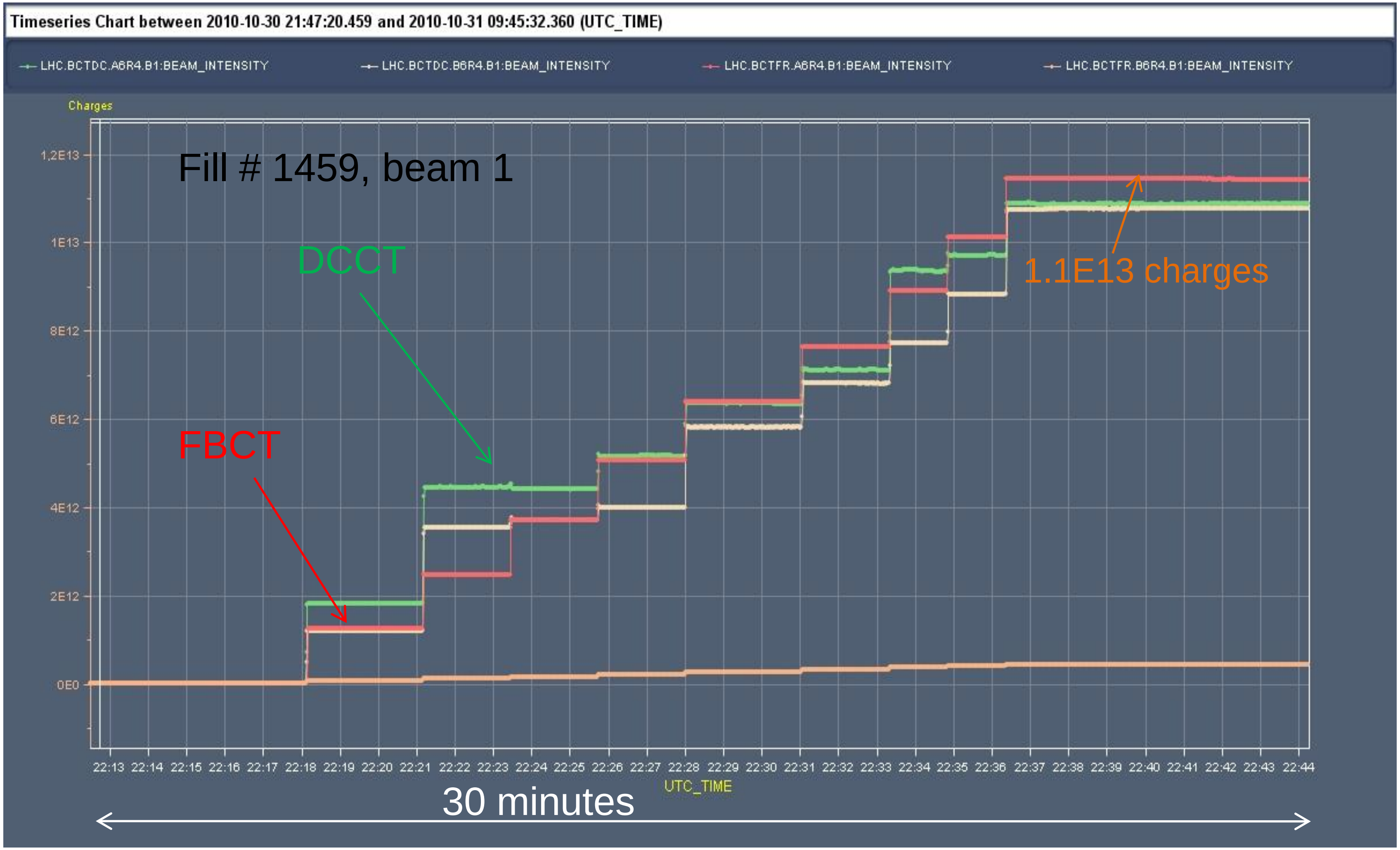


Simplified schematics



Issue # 3. The DCCT response depends on the filling pattern

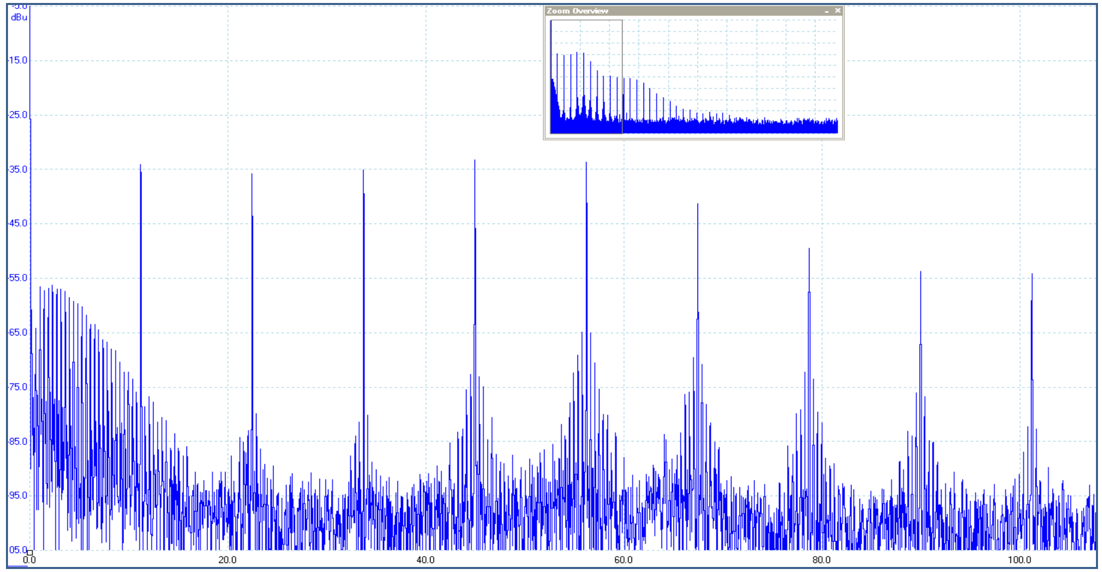
Symptom

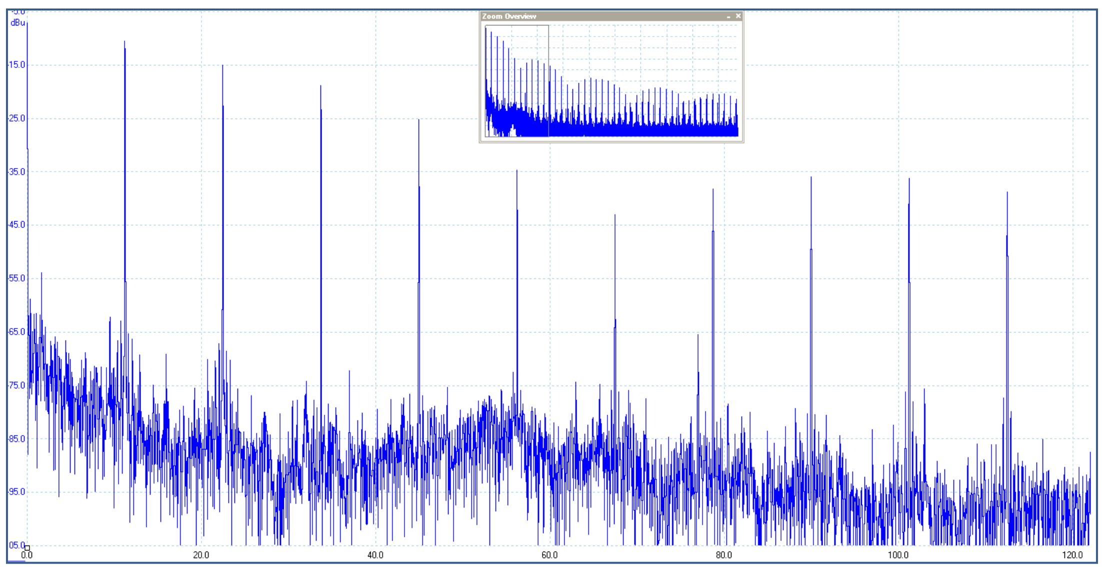


Beam frequency spectrum

f $_{rev}$ + harmonics (11.4kHz)

The relative amplitude of the harmonics (envelope) varies with the filling pattern

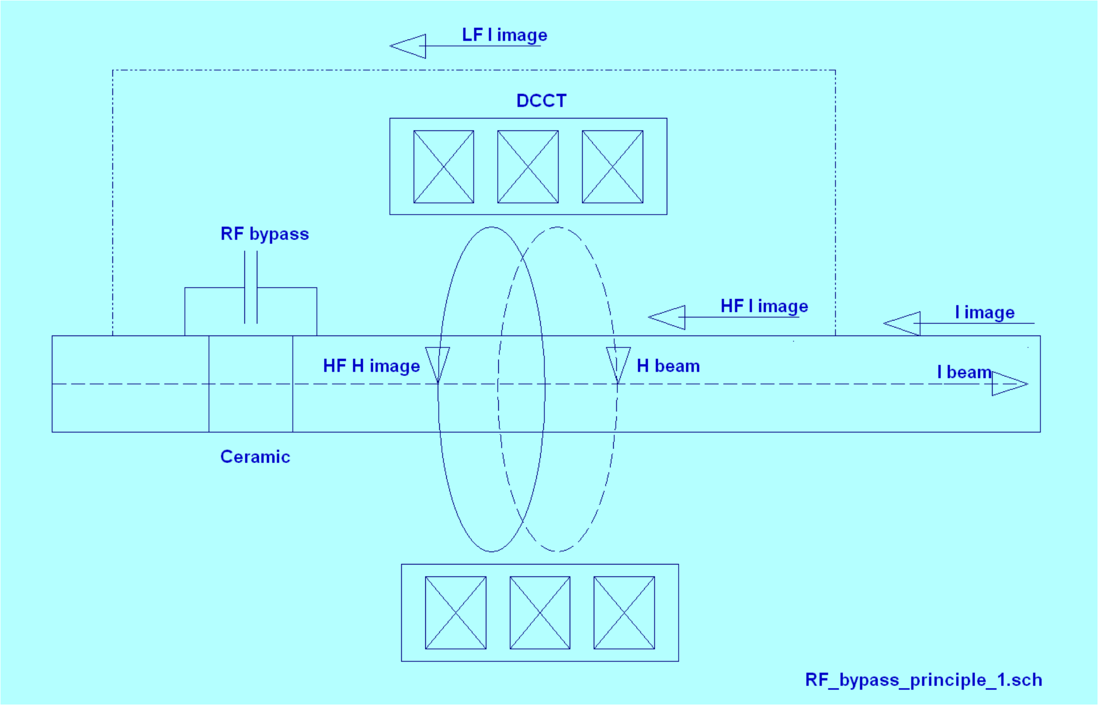




Issue #3. Cause 1, the RF bypass

RF bypass not good enough

Reminder: the purpose of this device is to low pass filter the magnetic field induced by the beam seen by the DCCT. It avoids non linear behavior of the LF amplifiers in presence of HF



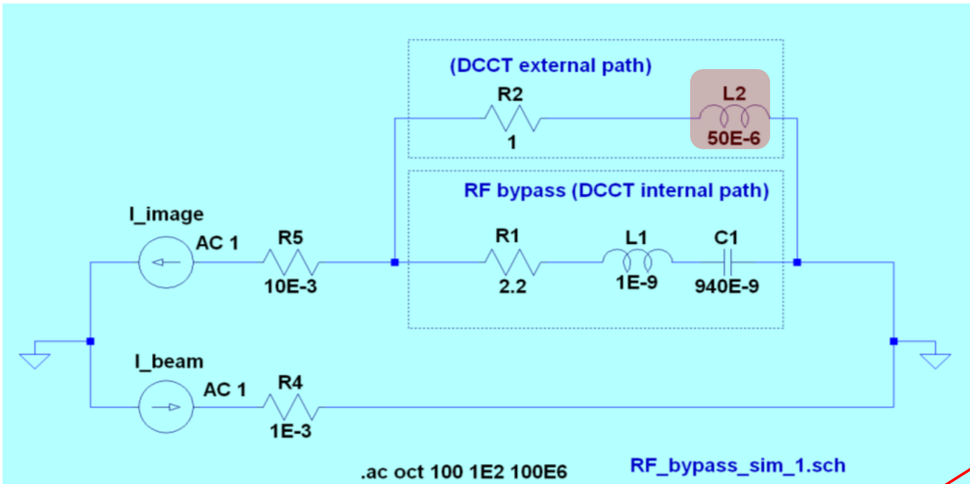
General principle:

RF bypass fc < DCCT fc ★

★ DCCT feedback fc not DCCT output fc

Many attempts were made to improve its efficiency

RF bypass, original version

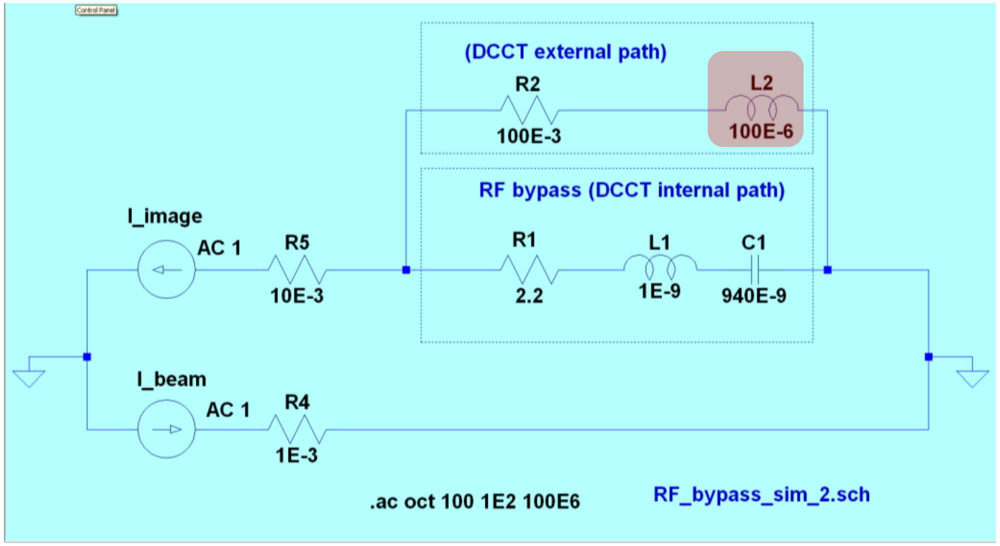


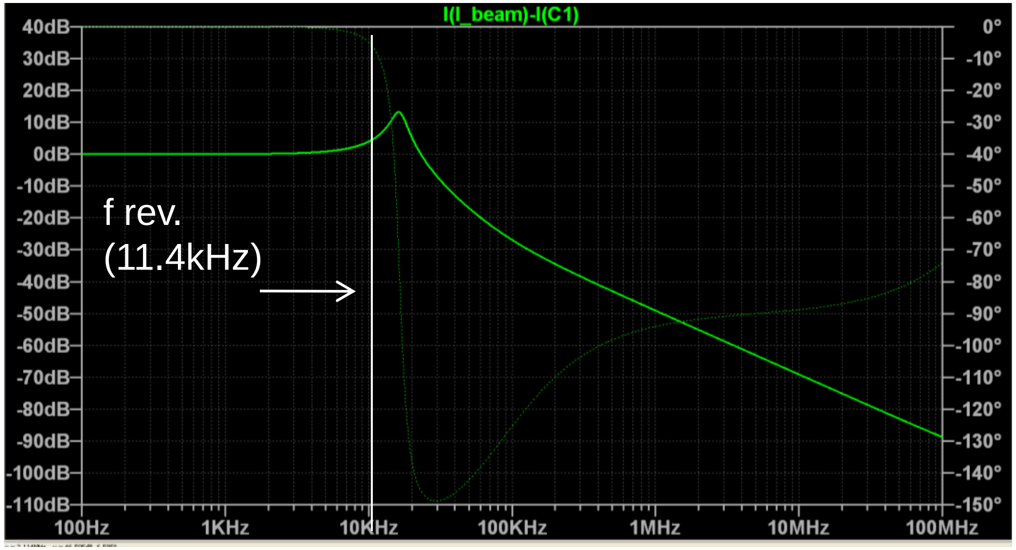
Expected attenuation (I_beam-I_RF bypass) according to the simulation

Actually measured on the bench test

Reason for the Δ: L2 value smaller than expected (zero-flux DCCT) and smaller at HF (μ decreasing with f)

RF bypass, first modification



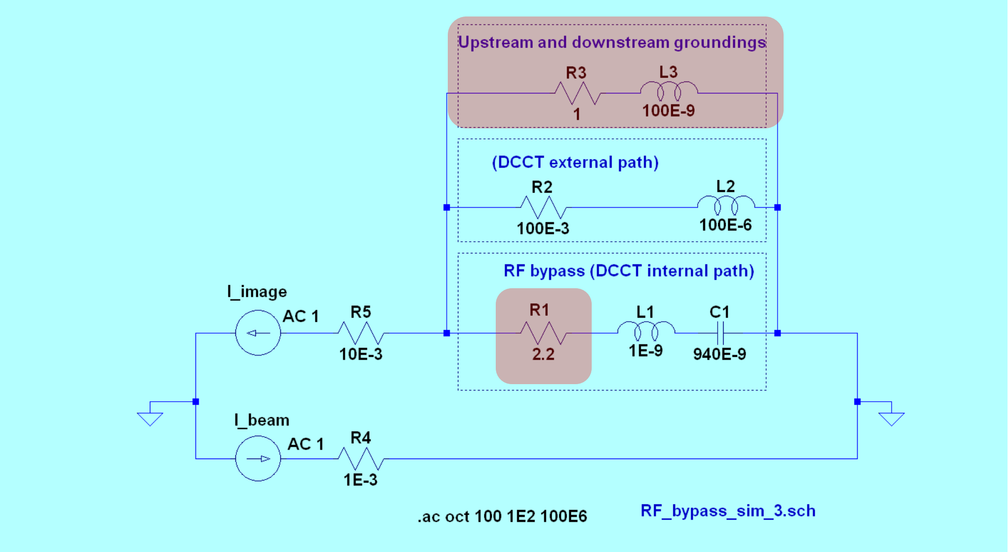


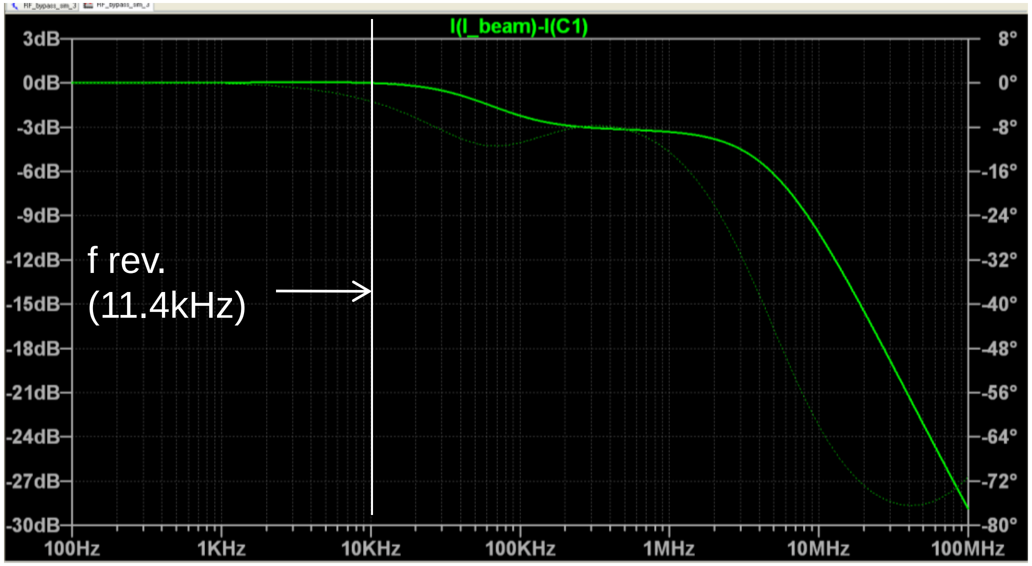
Added L2

Result:
Works pretty well on the bench test but inefficient in the machine

Reason?

RF bypass, reasons for the inefficiency of the first modification

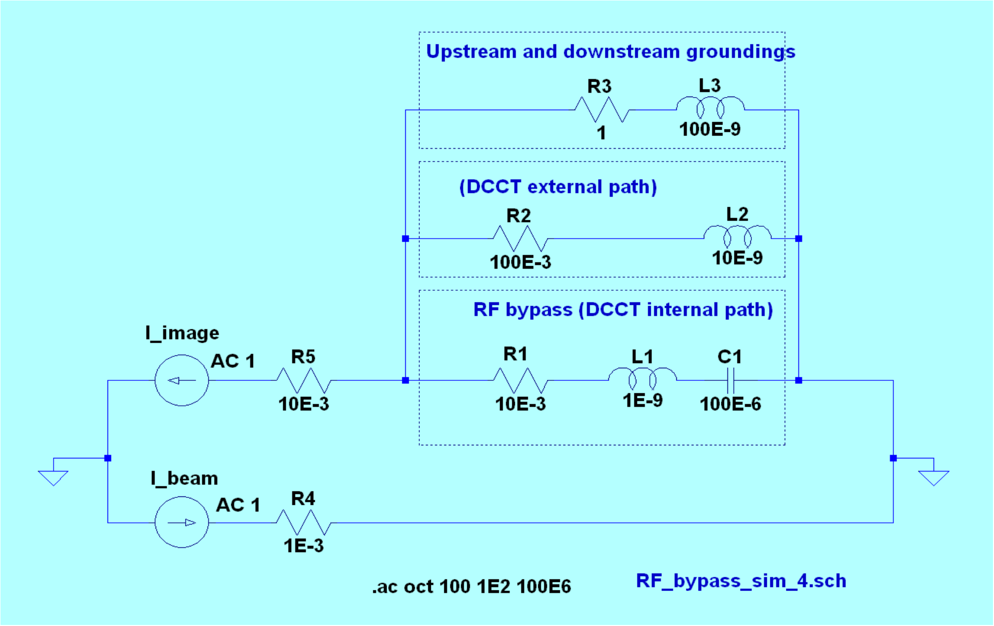


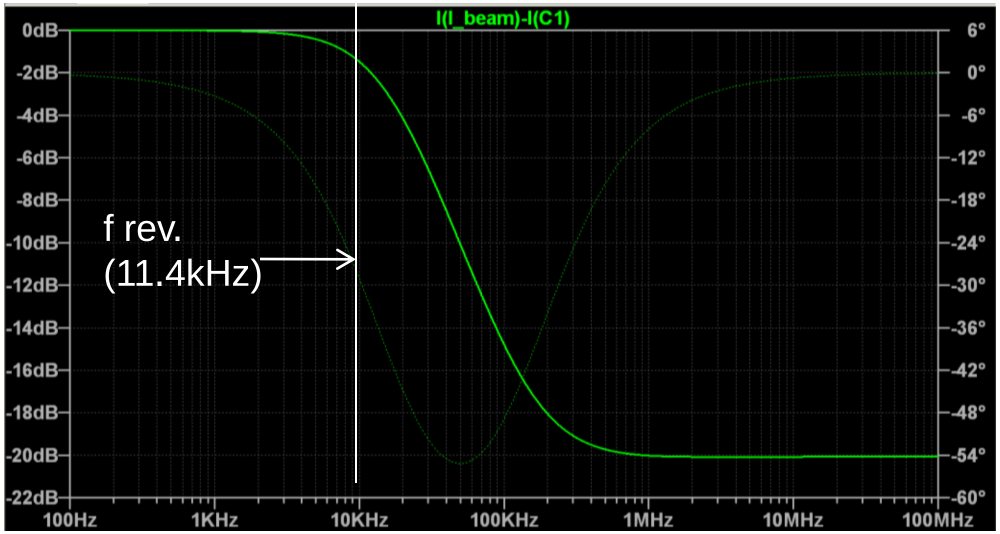


Upstream and downstream groundings short-circuit the added inductance
Unavoidable

+ damping resistor (R1) of the RF bypass
Can be suppressed

RF bypass, modification for 2011





- Increase the bypass capacitor C1 up to 100µF
- Suppress the damping resistor R1
- Suppress the added inductance L2

Works well on the bench test, upstream and downstream groundings simulated by a 1 meter copper braid connected on both ends of the bench test (believed to be worse than in the machine)

Will be hopefully as effective in the machine

Issue #3. Cause 2, the electronics

Tools to analyze the issue

- Simulation
  - Matlab/Simulink model (thanks to Steve Smith)
  - Spice

Have shown that amplitudes are too large within the AC loop

- Measurement on the bench test

Confirmation !

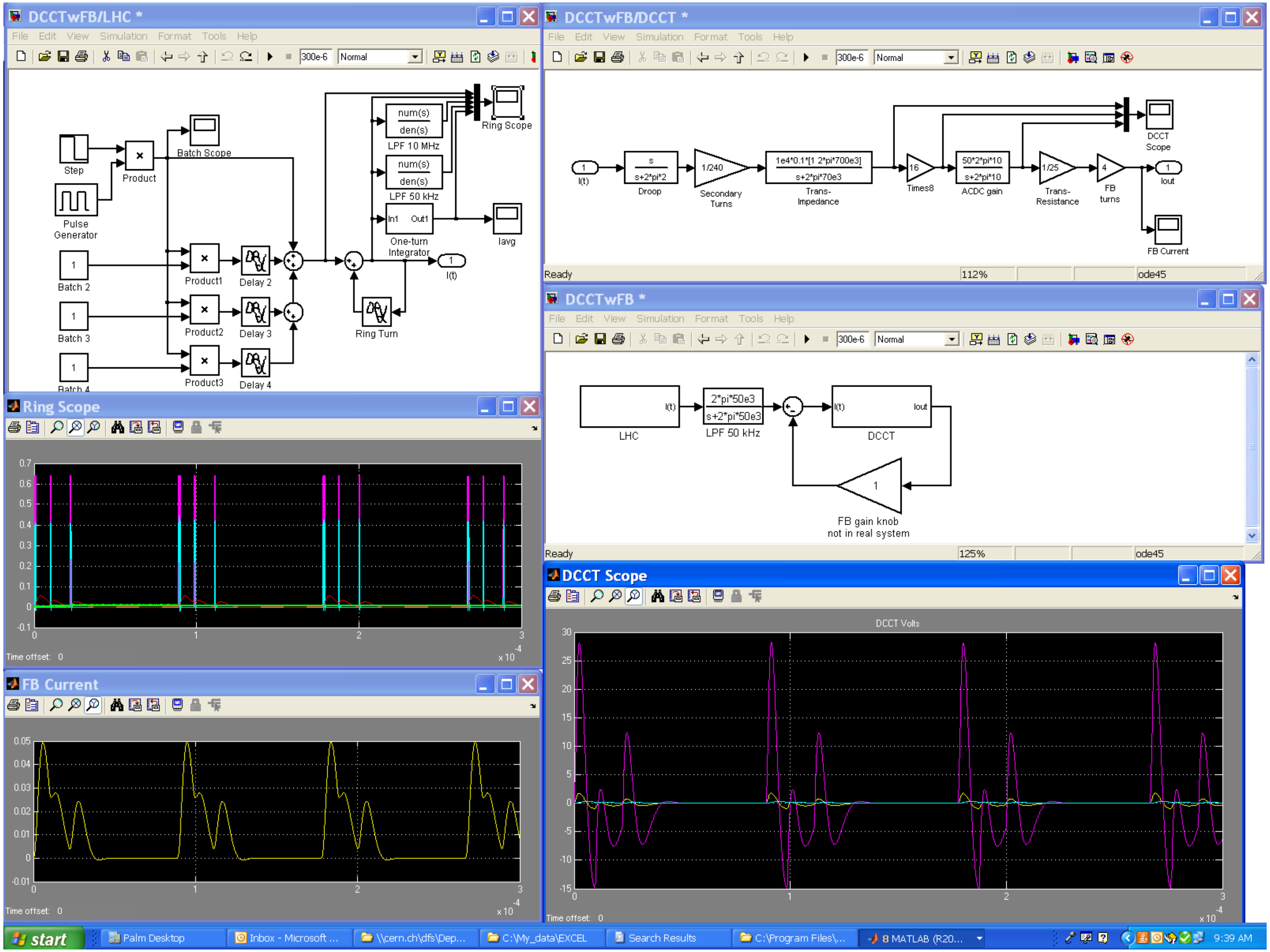
Cause of the filling pattern dependence:

Excessive amplitudes due to inappropriate gain partition associated with amp op limitations (current, voltage swing, slew-rate) induce **non linearity in the AC loop**

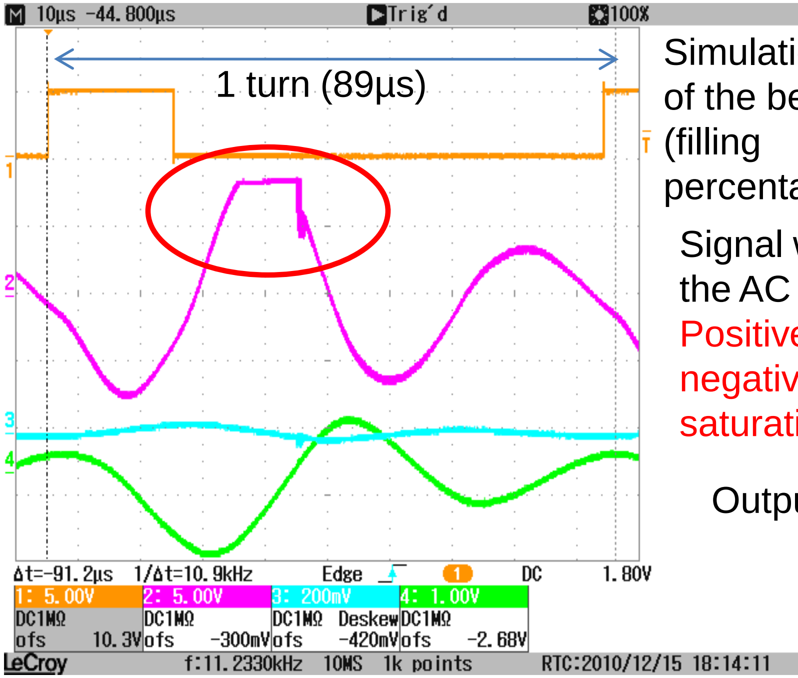
Design error

In addition the BW of the monitoring points available in surface was not sufficient to discover this effect in the machine

Matlab/Simulink model of the AC loop (Steve Smith)



Measurement on the bench test

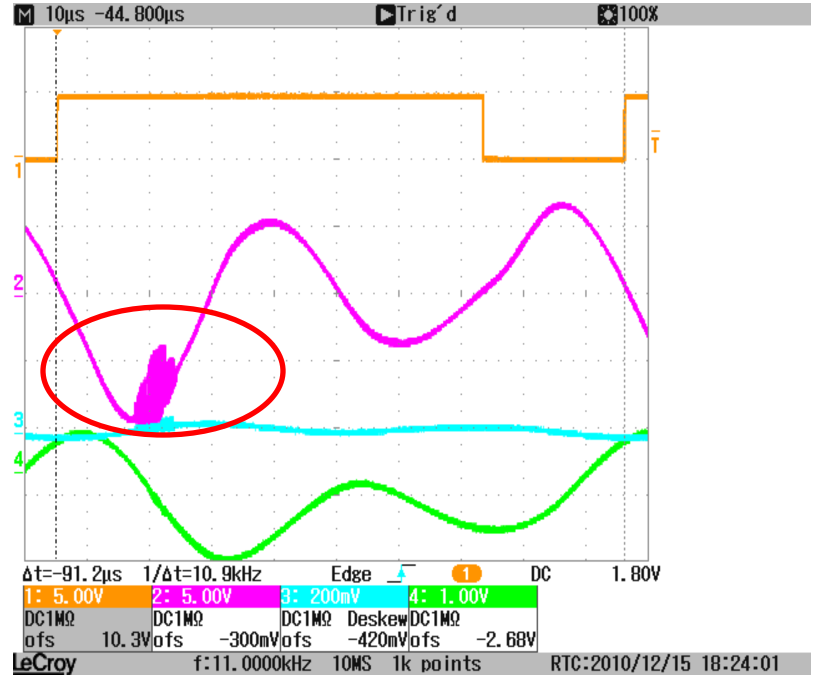


Simulation of the beam (filling percentage)

Signal within the AC loop

Positive or negative saturation

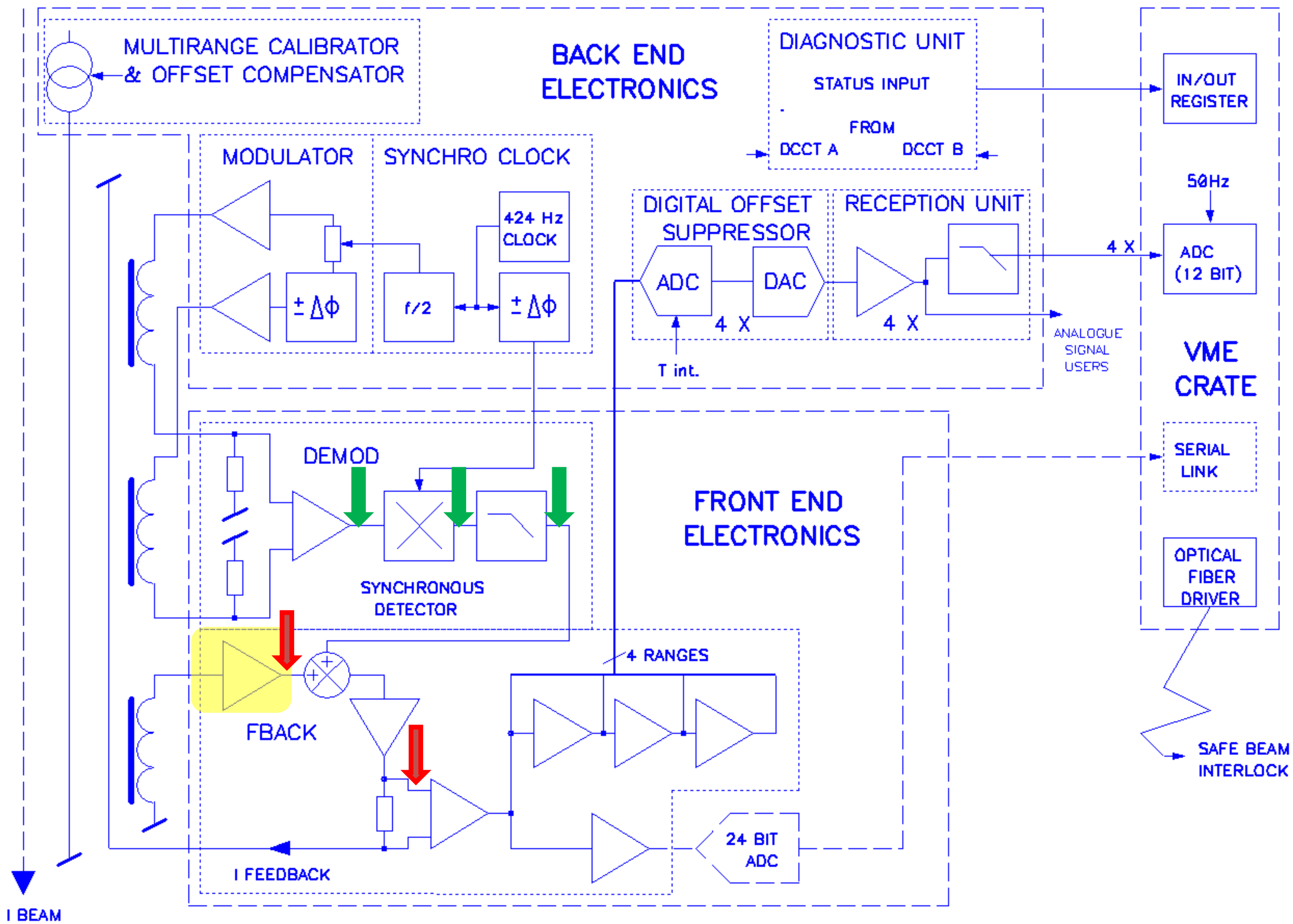
Output



Plan for January 2011:

- Modification of the AC loop gain partition before and after the dominant pole (compensation for loops stability)
- Use of higher speed amp op in the AC loop
- Increase of the monitoring points BW

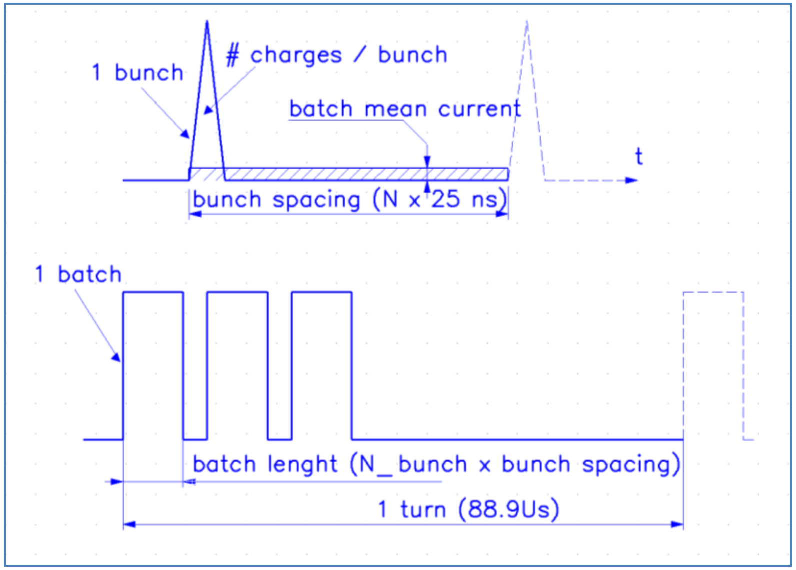
Simplified schematics



Beam simulation (1)

- DC level
  - 1 or many turns around the DCCT
  - DC Current source (home made or commercial)
- Batch level
  - Properly adapted antenna in the vacuum chamber
  - Pulser to generate pulses of current (single or train, 25ns to 89µs duration, repetition 11.4kHz) equivalent to the batch average current
  - Measurement of the average current in the antenna and of the DCCT average response (average obtained with a passive LP Filter)
- Bunch level
  - No quantitative test done so far
  - Check the insensitivity of the DCCT to RF, 100kHz to 400MHz CW injected into the antenna

Beam Simulation (2)



Tested with all batch combinations

I_mean_batch = #charges_per_bunch*elementary_charge/bunch_spacing

Elementary charge [C]: 1.60E-19

I_mean_batch [mA]			Bunch spacing [ns]				
			25	50	75	150	300
# charges/bunch	Pb min	5.60E+08	3.59	1.79	1.20	0.60	0.30
	Pb max	5.60E+09	35.88	17.94	11.96	5.98	2.99
	p nominal	1.15E+11	736.92	368.46	245.64	122.82	61.41
	p ultimate	1.67E+11	1070.14	535.07	356.71	178.36	89.18

To be tested

Plan for 2011

- January 2011
  - New RF bypass circuit
  - Modification of the Front End Electronics

- After January
  - Building a new pulser to simulate the ultimate beam (25ns bunch spacing, 1.7 E11 charges/bunch, 860mA)
  - Continue the simulation and measurement on the bench test (25ns spacing, HF, etc.), looking for the limits, phase margin, etc.
  - Complete the design of the 24 bit acquisition card
  - Study an improvement of the RF bypass made of a toroid. Anyway could not be implemented before the long shutdown foreseen for 2012 or 2013 (needs to open the vacuum)
  - Machine development sessions: observation of the bypass efficiency (requires DCCT in open loop)

Conclusions (1)

Progress made in 2010

- The independence of the calibration and beam position has been proved
- 2 Issues were discovered (non saturation and offset reduction) and corrected
- The cause of the third issue (non linearity) has been identified
  - The correction will be implemented before February 2011
  - The combined modifications of the RF bypass and the electronics reduce the amplitude of the signal within the AC loop by a large factor (~30 dB). This will be sufficient for the next 2 years of operation

What is different for the BCT at LHC:

- Uncommon low revolution frequency
- The DCCT is a part of the interlock system (reliability and availability requirements)
- Unusual long cables between the monitor and the back end electronics
- Rare opportunities to access therefore long iteration time for the modifications/improvements

Conclusions (2)

What we have learn from this project

- DCCT (not only FBCT) should be extensively tested on a good RF bench test
- The diagnostics tools, the monitoring points in our case, must be reliable
- We should concentrate our efforts on our field (design of the monitor, the electronics and the software) and outsource the others topic (design and follow up of the mechanics production and installation, etc.)
- A longer period of time should be dedicated to extensive tests of the whole system in the laboratory

"It would be great to anticipate unexpected issues"

Acknowledgements

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