The Fast Beam Intensity Measurements for the LHC

The LHC FBCT day

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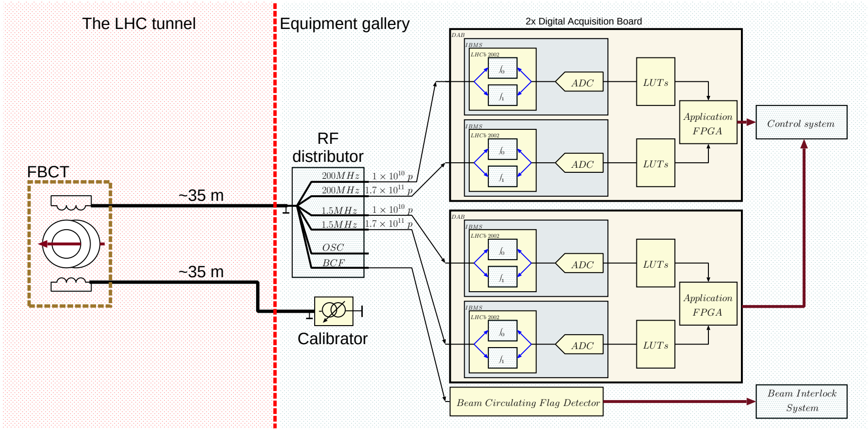
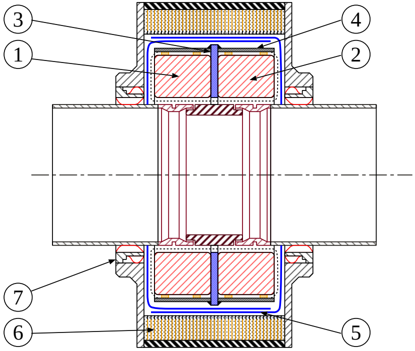
System overview



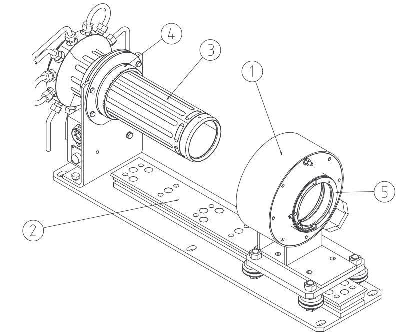
FBCT acquisition system

Integrator chip composed of 2 integrators working in time multiplex: different gains, offsets and integration times

The FBCT housing



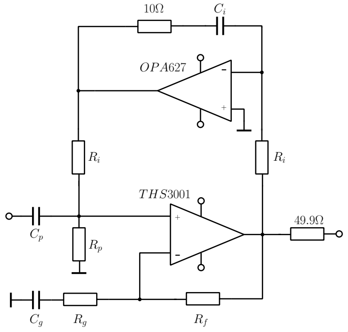
The FBCT



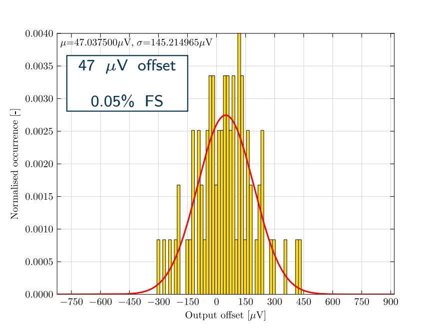
The FBCT CAE design

- Housing ARMCO + μMetal for static magnetic field protection (annealed)
- Principal toroid Bergoz Instrumentation 200 Hz-1.2 GHz
- Movable to provide cooling during NEG related bake-out

- Impedance controlled environment: FR4+RF substrate
- Provides filtering and amplification for measurement channels.
  - LOBW channels: active Sallen-Key configurations
  - HIBW channels: passive second order (≈200 MHz)
- Needed offset compensation to avoid integrator saturation

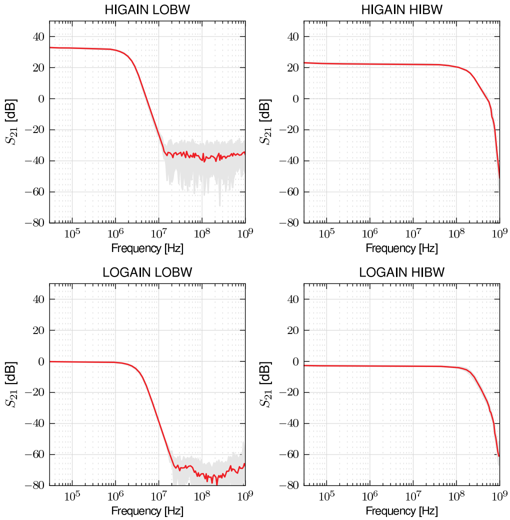


Offset suppression



Output offset measurements

RF distributor - bandwidth



Forward transmission coefficient s_{21}

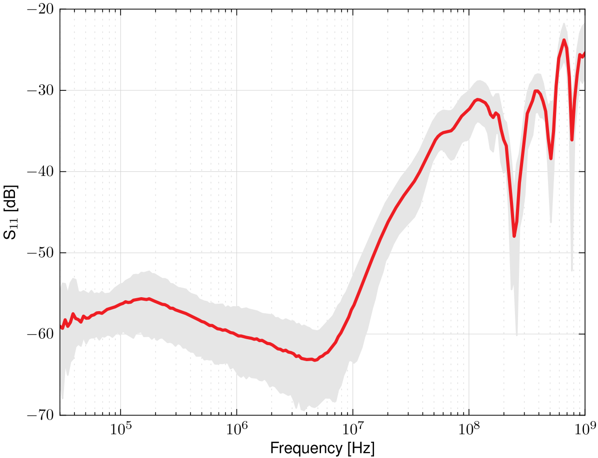
gain range:

-6 dB - 35 dB

gain scatter:

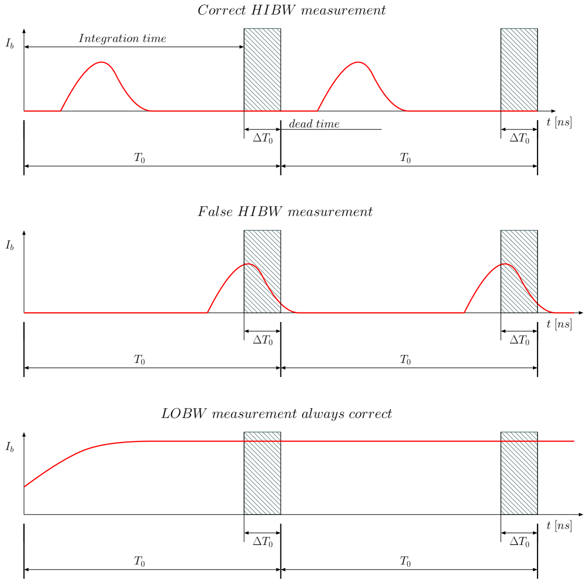
<1 dB

RF distributor - input reflection coefficient



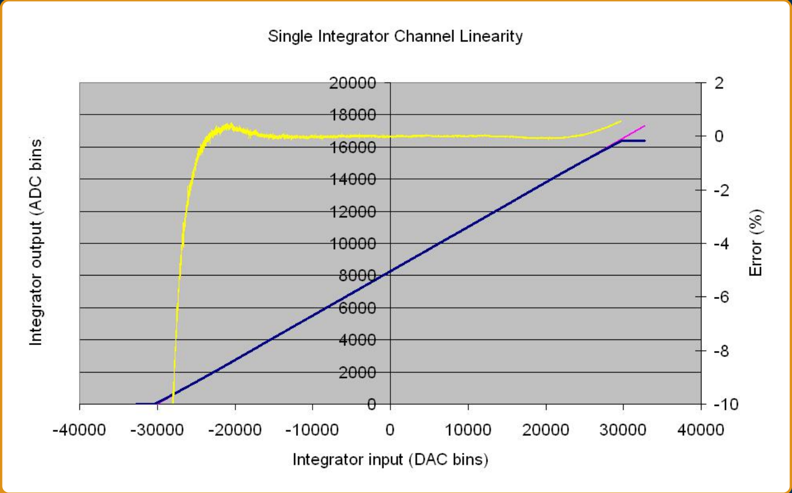
Input reflection coefficient s_{11}

Integration



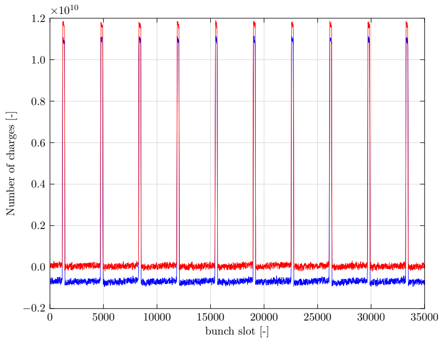
Bunch slot (25 fins) vs RF bunch (2.5 ns)

Integrator non-linearity



Measurement of integrator's non-linearity

Function of the base line restorer (BLR)



Base line signal restoration

- BLUE = signal from generator, synchronised with turn clock, and measured by the FBCT
- RED = signal with restored base line

Currently used base line restoration algorithm results in a small displacement of the base line

Question:

What is the main cause preventing further reduction of the systematic offset of 5×10^8 charges.

Answer:

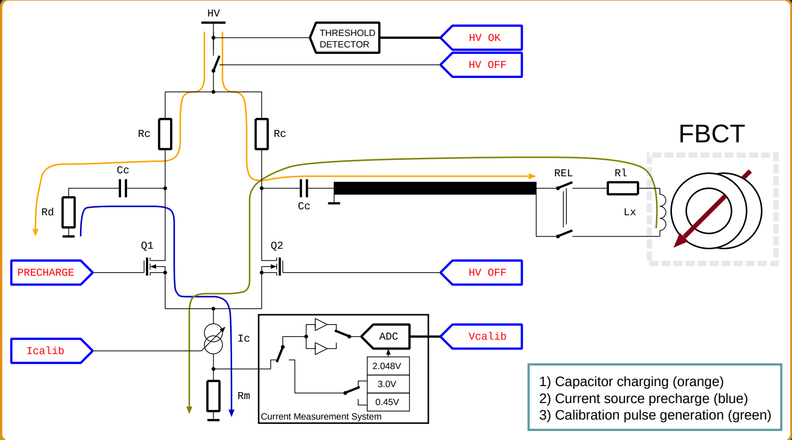
This offset is induced artificially by used base line restoration method. Current method:

- on-fly filter the integrated signal
- take a minimal measured value of the filtered signal from current measurement turn
- at the end of turn add this value to every measurement of the next turn

Peak noise is partially filtered to its 'rms' value, however as the minimum value is added (with respect to the mean value), it always results in a positive offset.

Cure: new base line restoration algorithm

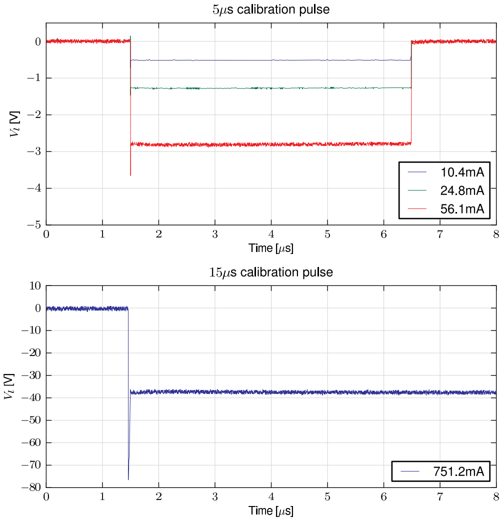
Device Calibration - Principle of Operation



Calibrator principle of operation

- generates a current pulse 10 mA to 800 mA, 5 μs to 200 μs
- transported into 8-branch parallel calibration turn using 7/8" coaxial transmission line

Device Calibration - Generated Pulse

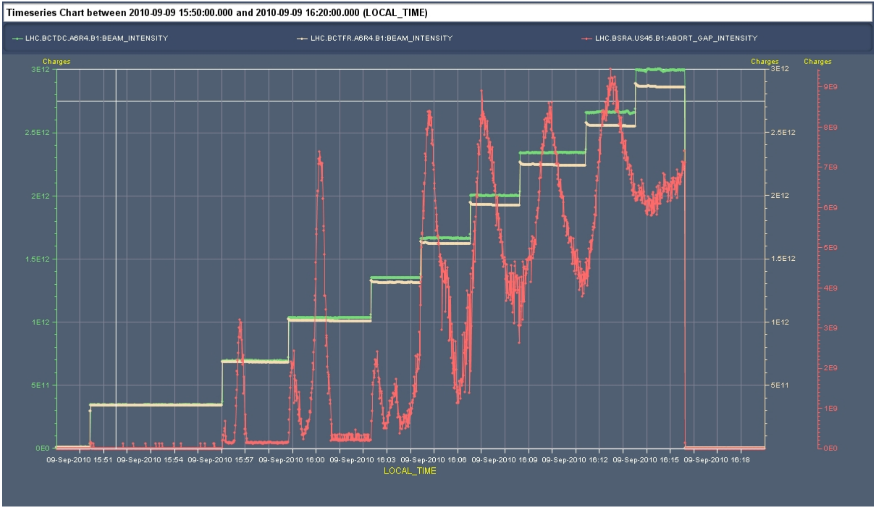


Generated calibration pulses

Typical noise floor of an installed FBCT (BLR off):

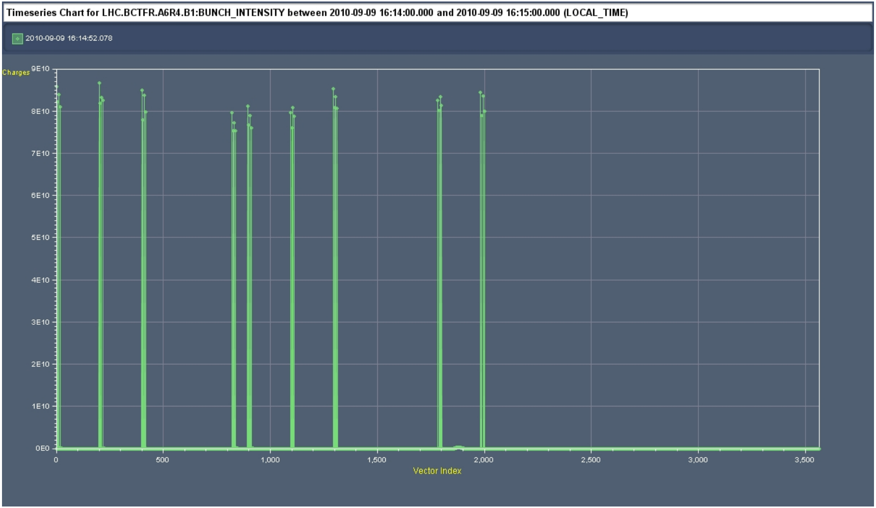
Channel	Mean value [-]	Standard deviation [-]	STD relative to real FS [%]
HIGAIN HIBW	-0.7×10^6	1.3×10^7	0.09
HIGAIN LOBW	0.6×10^6	6.2×10^7	0.42
LOGAIN HIBW	10.3×10^6	1.6×10^8	0.1
LOGAIN LOBW	-1.7×10^6	1.4×10^8	0.1

Uncaptured Beam Measurements 1/3



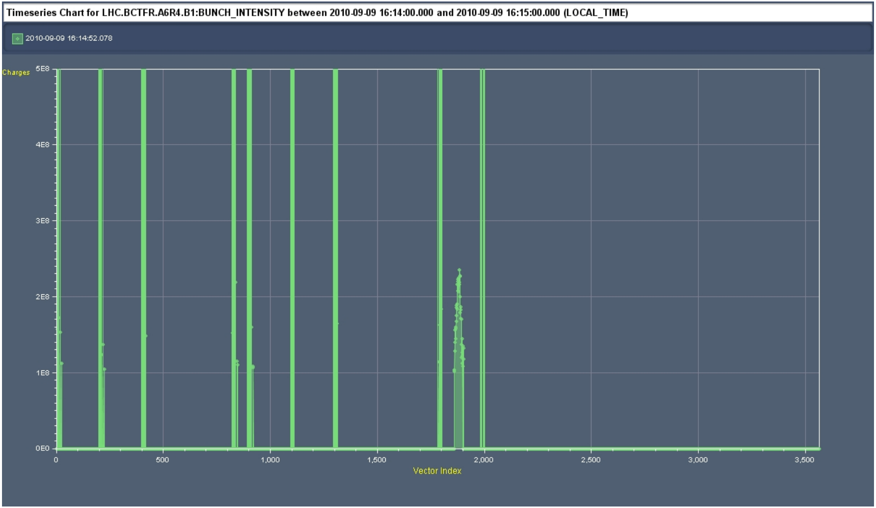
Number of particles - comparison DCCT, FBCT, BSRA

Uncaptured Beam Measurements 2/3



Number of particles - bunch resolution

Uncaptured Beam Measurements 3/3



Number of particles - bunch resolution, zoom

Droop is a basic property of the measurement method → can be lowered, but not suppressed. Toroid and all the transmission chain has complex frequency characteristics. It is not possible to achieve a perfect matching → there always will be some ringing observed on the measured signal. Such signal enters the integrator and if exceeding the bunch slot, then it is integrated into the next bunch slot. Bandwidth limitation results in tails leaking into next bunch slot get also integrated.

And what can be done about it:

- Minimum cable path: done
- Reasonable BW limit: done, 200MHz ≈1/3 of slot length
- Minimise reflections: tried hard
- Maybe improve FBCT impulse response? no idea how

Phase setting issue is related to previous slide. Possible causes:

- the FBCT+signal path impulse response longer that 25ns
- crosstalk somewhere in the integrator and/or electronics

Hard to be improved without further investigation. Difficult to do in the lab.

Phase stability is another issue:

- Phase is now tuned manually, when RF changes, modification is required
- If not: increased leak into next bunch, intensity measurement wrong

At certain moment the phase could be tuned manually e.g. by locking on the beam signal.

They get always integrated into the bunch slot.

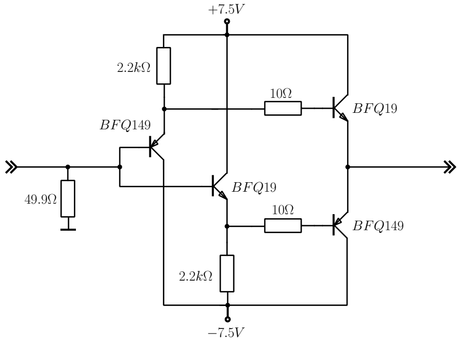
- Not suitable for luminosity calculation.
- The only way to avoid is to change the measurement method (e.g. using 40MHz signal component sampling).
- Requires lots of R&D, requires money and time. Certainly useless for 2011-2012.

No clear ideas here.

- First measurements looked like saturated amplifiers at the input of the RF distributor
- This was not confirmed, attenuating signal the same issue is observed
- Could it be caused by limited measurement bandwidth or slew rate of some amplifiers? (BL dependency observed at LOBW chains as well, less influence)
- Could it be caused by toroid beam position dependency? (more energy in position dependent band?)
- More info necessary

HIBW channel saturation @ high intensity

- Issue related to saturation of RF distributor input buffers.
- Understood, here we can improve by changing RF distributor design



Emitter follower in RF distributor

LOBW non-linear measurement region

Linked to the base-line restoration method. Can be improved using different BLR method.

- Could be a probable cause of following problems?
  - Charge measurement dependent of position
  - Maybe related to issues with calibration: HIBW gain calculated using 'DC' calibration pulse does not match 'AC' measurements
  - Maybe related to bunch length problem: shorter bunches contain more energy in bandwidth which is beam position dependent than longer pulses

Must be heavily studied and action taken. For the moment no 'quick hack' exists, majority of the attempts to improve results in opening of the vacuum chamber.