Electron cloud study @LHC of November 17-19, 2010: BCT and FBCT

Expert (and big thanks to): Jean-Jacques Gras

Plan:

- Zoo of Beam Current Transformers
- BCT/FBCT @LHC
- TIMBER data
- MD runs, November 17-19, 2010

Beam current transformers (1/)

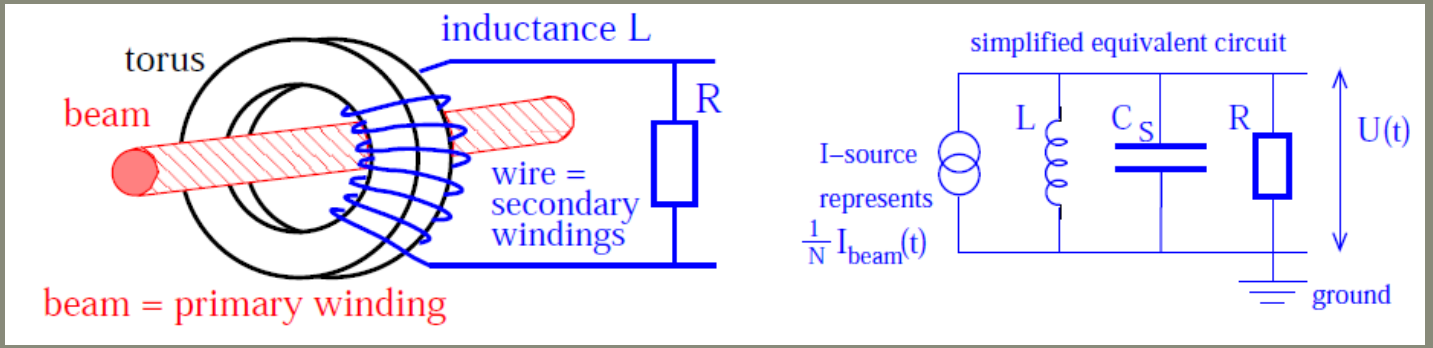
- General:
  - non-intercepting (non-destructive) method.
  - measures the magnetic field generated by the beam current.
- Electrical current formed by N particles of charge state q per unit of time t or unit of length l and velocity $\beta = v/c$:

$$I_{beam} = qeN/t = qeN\beta c/l$$

- From Biot-Savart law+cylindrical symmetry:

$$\vec{B} = \mu_0 I_{beam}/2\pi r \vec{e}_{\varphi}$$

- Torus with an insulated wire wound around guiding the field lines:



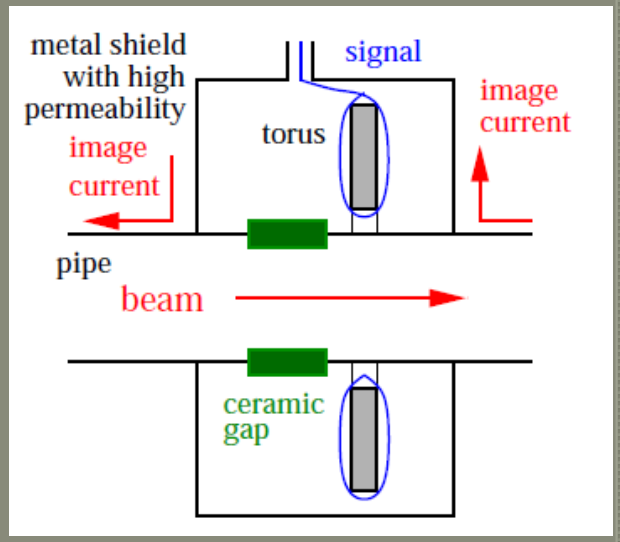
The electrical properties of the transformer and the electronics attached, have to be taken into account to determine the working region where the current measured can be correctly interpreted as a function of the beam current.

Lectures Notes on Beam Instrumentation and Diagnostics, P. Forck (GSI, Germany) – JUAS 2010

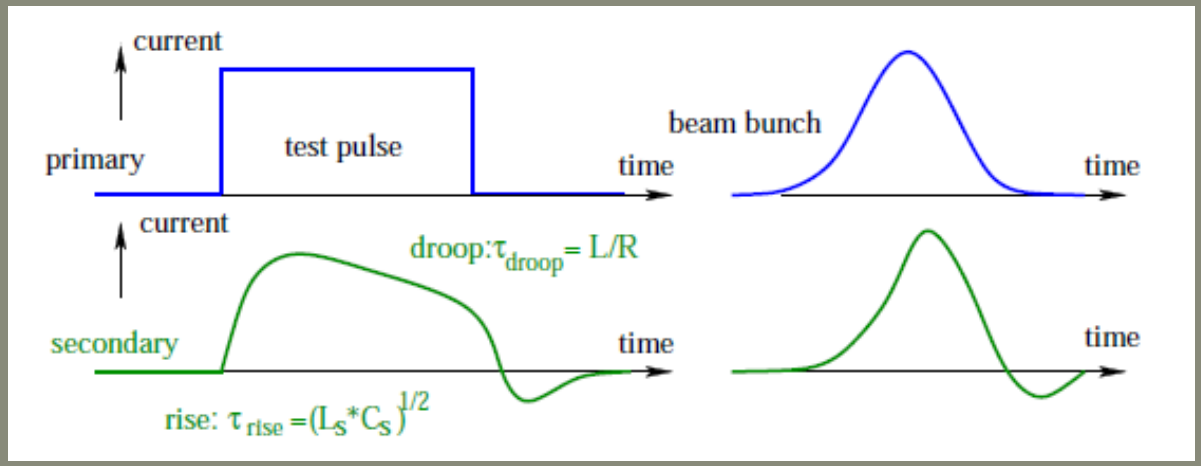
Beam current transformer (2/)

- Passive transformer:
  - mostly used for short beam pulses (1 ns – 10 μs ?)
  - can measure the bunch structure in time
  - bandwidth up to 500 MHz (~rise time < 1 ns ?)

- Need to interrupt the beam pipe close to the transformer to prevent the image current to flow through the torus.

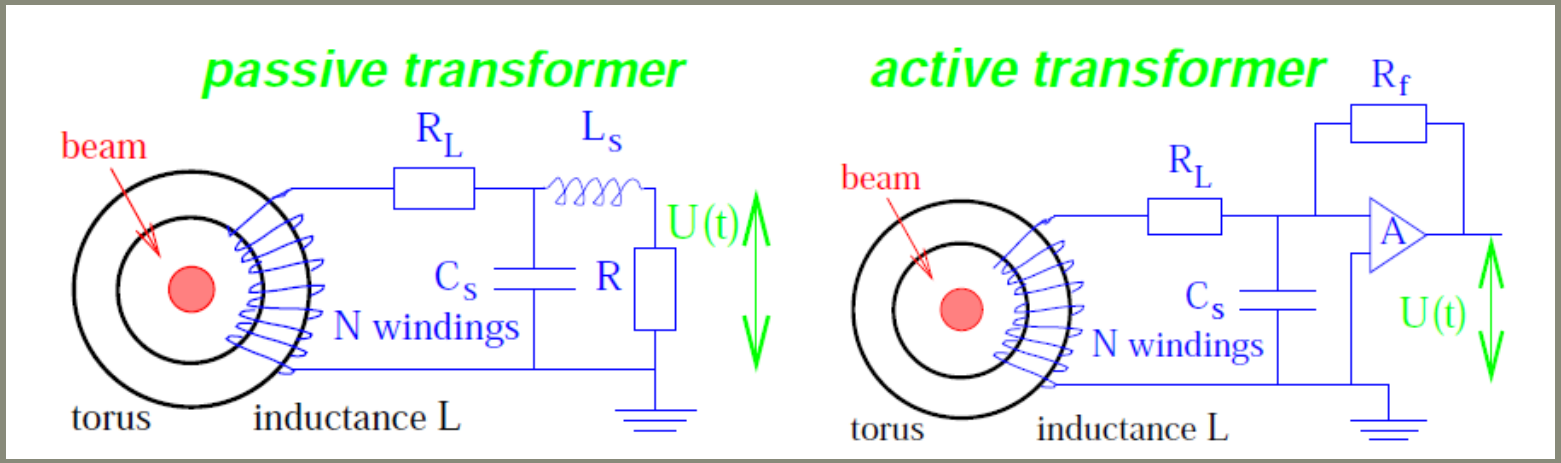


- Beam current measurement constrained by a droop constant:



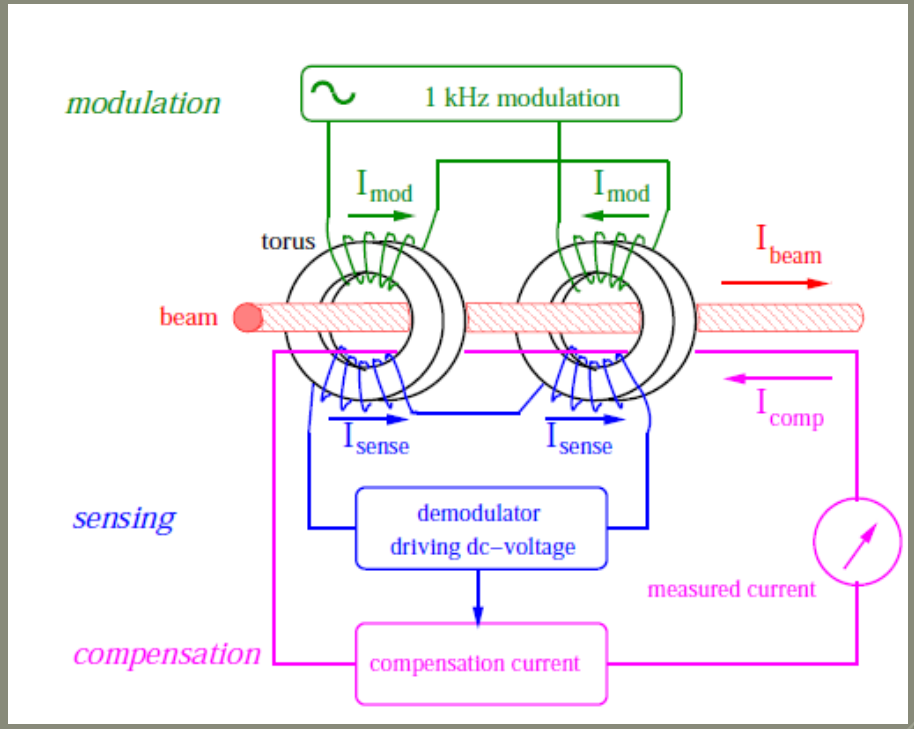
Beam Current transformer (3/)

- Active AC transformer:
  - used for beam pulses longer than several μs.
  - replace the resistance by a operational amplifier to increase the droop time constant to up to 1 s.
  - need an additional winding to compensate for the natural (?) droop introduced (not shown on the figure).



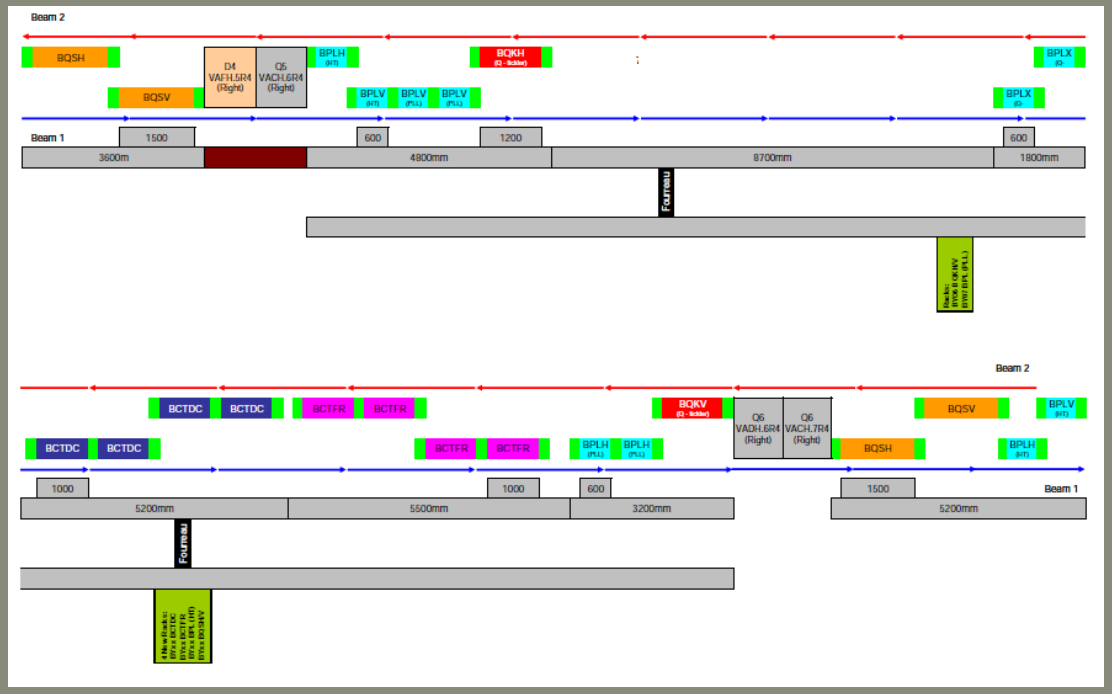
Beam Current transformer (4/)

- DC transformer:
  - measurement of a coasting (DC) beam current.
  - other devices worked only for pulsed beams (even if droop time constant can be increased to 1s).
  - two tori with three types of windings.
  - first winding of each torus with opposite orientation acts as modulator.
  - second winding with equal orientation acts as detector of the modulated signal.
  - third winding used to flow a feedback compensation current.



LHC BCT/FBCT (1/)

- All the BCT and FBCT are located in LSS4, a long straight section in Octant 4.
- 2 BCT (DC BCT) per beam.
- 2 FBCT (Fast BCT) per beam.



Layout database (Thanks Benoit !):
BCTDC.A6R4.B1
BCTDC.B6R4.B1
BCTDC.A6R4.B2
BCTDC.B6R4.B2

BCTFR.A6R4.B1
BCTFR.B6R4.B1
BCTFR.A6R4.B2
BCTFR.B6R4.B2

A operational one
B to diagnose problems

LHC BCT/FBCT (2/)

- DC BCT:
  - measures the current of the machine all bunches
  - what is the device type ?
  - sees everything that circulate.
- FBCT
  - measures the current bunch per bunch
  - what is the device type ?
  - will see the AC pattern bunch per bunch.
  - when particles are debunched or lost from the bucket cannot see it.
- Other specifications:
  - 680 bunches max. allowed in BCT/FBCT
  - FBCT 3564 values of intensity per slot of 25 ns.
  - BCT noise level bigger than in FBCT.
  - Precise timing needed for FBCT not for BCT.
  - FBCT has a low and a high bandwidth, nominal is high but for this to work it needs accurate timing. To make sure this is ok a low pass filter covers 16 bunch slots and look at the sum.

TIMBER data (1/)

- Two TIMBER databases:
  - measurement DB (get data in 20-30 s after measurement)
  - logging DB (get data in 20-30 min after measurement)

From the measurement DB some of the information is automatically filtered and moved into the logging DB. The rest of the information is lost if not saved by hand before 7 days after data-taking have passed.

- BCT/FBCT data
  - BCT intensity logged at 1 Hz in the logging DB.
  - FBCT bunch intensity logged at 1 Hz in the logging DB.
  - FBCT bunch vector only keep one array per minute in the logging DB.
  - Intensity (BCT & FBCT) can be seen as plots.
  - Bunch vector needs to be saved as a file (very slow readout from DB – 20 min long files OK).

Need to extract the data from TIMBER for the FBCT vector and save them

- Calibration:
  - If choosing "best now" will apply a data correction from background calibration (green if correction available).

MD runs (1/)

- 2010/11/17
  - 20H00 dumper study.
  - 20H35 ready for injection – both beams dumped.
  - 22H00 48 bunches injected - B1 & B2 – pb of losses on both beams.
  - 22H40 switched off the Abort Gap Cleaning (AGC).
  - 22H50 aborted – beam not captured.
  - 23H30 injecting 48 + 48 +…stopped after 4 x 48 because of beam losses on B2 again.
- 2010/11/18
  - 00H25 beam dumped due to beam losses.
  - 01H25 B1 & B2 pilot beam – orbit corrections - spacing the bunch injection to let the cryo system stabilize.
  - 02H35 working on the dumpers.
  - 03H10 dump B1/B2.
  - 03H25 injection restarted B1 & B2.
  - 04H40 beam dumped due to beam loss.
  - 04H50 pilot beam.
  - …
- Issues with data taken 17 night -18 morning:
  - Trigger of FBCT is 40 MHz (25 ns) beware of bunch separation.

MD runs (2/)

- Example plot of BCT/FBCT intensity:

- Data on DFS in Workspace\g\gprior\MD (ask me for access permissions).