THE BEAM ENERGY TRACKING SYSTEM OF THE LHC BEAM DUMPING SYSTEM

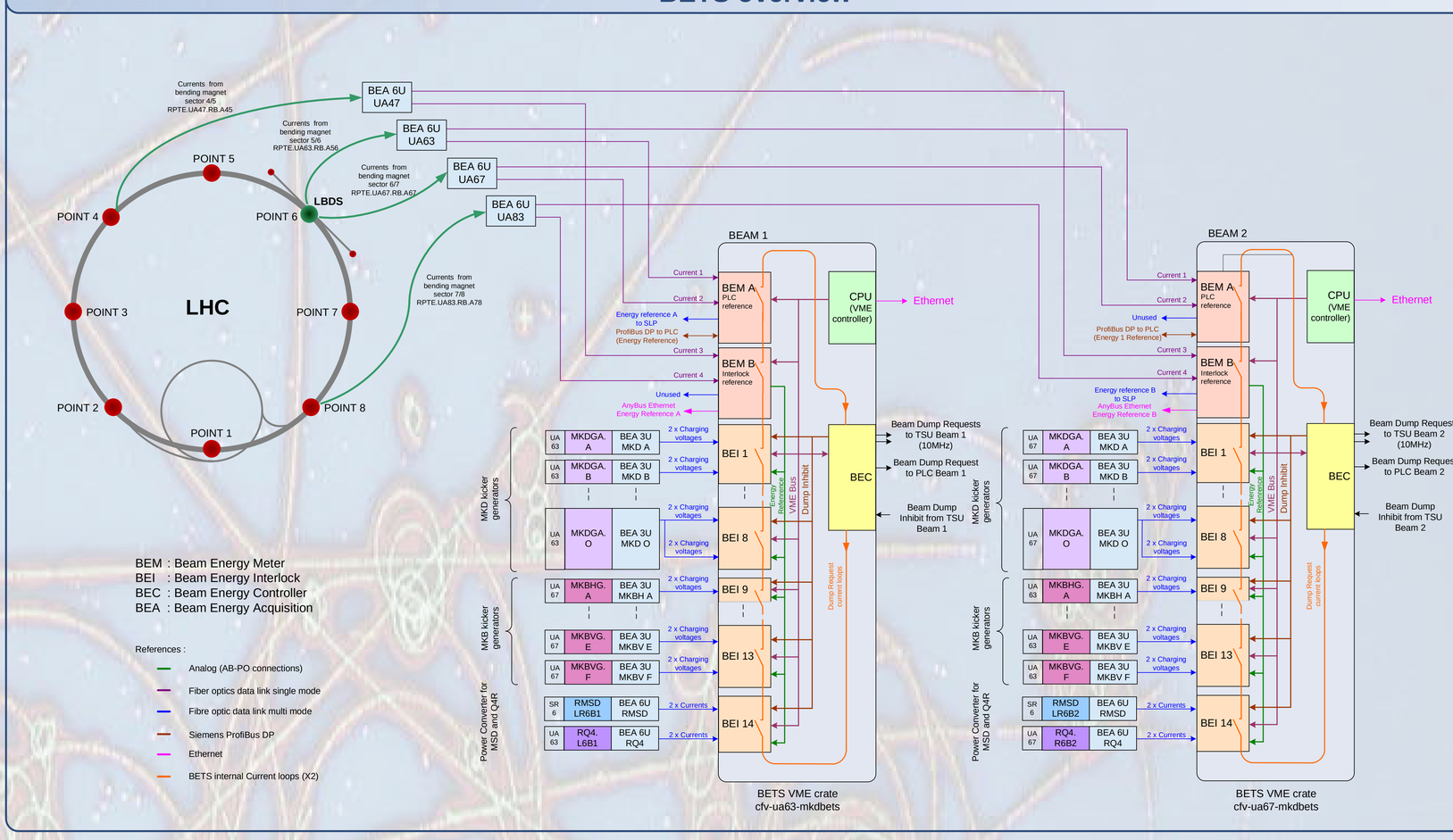
R.A.Barlow[1], P. Bobbio[1], E. Carlier[1], G. Gräwer[1], N. Voumard[1] and R. Gjelsvik[2]

[1]CERN, Geneva, Switzerland, [2]Bergen University College, Bergen, Norway

ABSTRACT

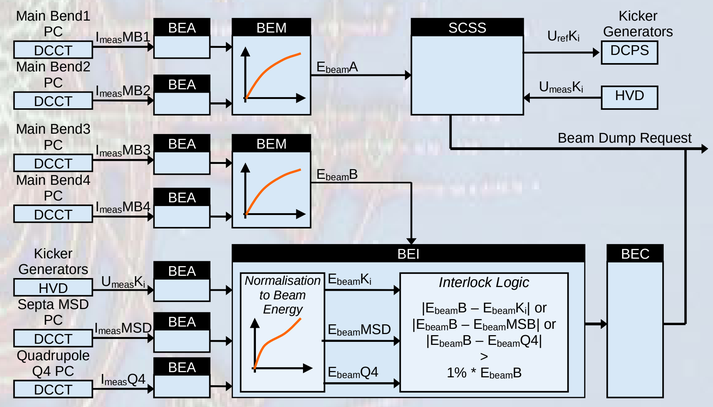
The LHC Beam Dumping System (LBDS) of the Large Hadron Collider (LHC), presently under construction at CERN, is installed around the straight section 6. It comprises per ring 15 horizontally deflecting extraction kickers (MKD), followed by 1 quadrupole (Q4), 15 vertically deflecting steel septum magnets (MSD), 10 dilution kickers (MKBH and MKBV) and, in a separate cavern several hundred meters away, an external absorber assembly. A beam dump request can occur at any time during the operation of the collider, from injection at 450 GeV up to top energy at 7 TeV. The Beam Energy Tracking System (BETS) monitors the deflection strength of each active element of the LBDS with respect to the beam energy in order to guarantee the correct extraction trajectory over the complete operational range and under all operational conditions. Its main functions are the acquisition of the beam energy, the generation of the kick strength reference signals for the extraction and dilution kickers, the continuous checking that the kicker high voltage generator capacitor charging voltages follow their references within predefined tolerance windows fixed by the extraction channel aperture, the continuous surveillance that the quadrupole and septum magnet currents are within predefined tolerance windows and the generation of a dump request after detection of and upcoming tracking fault. The beam energy reference is obtained through look-up tables from redundant real time measurements of the current in the LHC main bend dipoles. This paper describes the BETS reviews in detail its different functionality aspects.

BETS overview

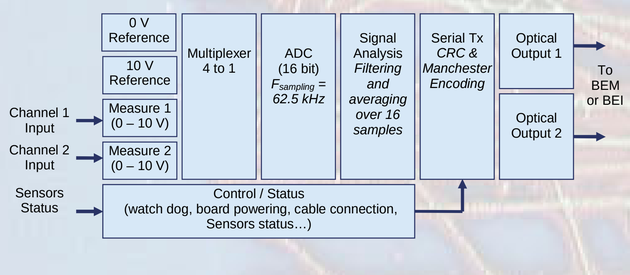


Two independent information of the beam energy, $E_{beam}A$ and $E_{beam}B$, are used within the BETS to control the correct tracking of the different LBDS sub-systems. $E_{beam}A$ is used as beam energy reference signal for the generation of the kick strength settings and $E_{beam}B$ is used as energy reference signal for the LBDS interlock logic.

The beam energy reference signals are obtained through two fully independent and redundant Beam Energy Meter (BEM) modules connected to 4 independent main bend power converters. Within each power converters, a Beam Energy Acquisition (BEA) module acquires with 16 bit resolution and 65 kHz sampling rate, the main bend current through high precision Direct-Current-Current-Transformer (DCCT). The acquired value is transmitted, after filtering, to the BEM modules via fibre-optic links. The BEM converts, through resident calibration look-up table, the physical measurement of the main bend current into an absolute normalised value proportional to the beam energy. This value is used as energy reference within the BETS for the LBDS kicker reference settings generation or for the LBDS tracking interlock logic.



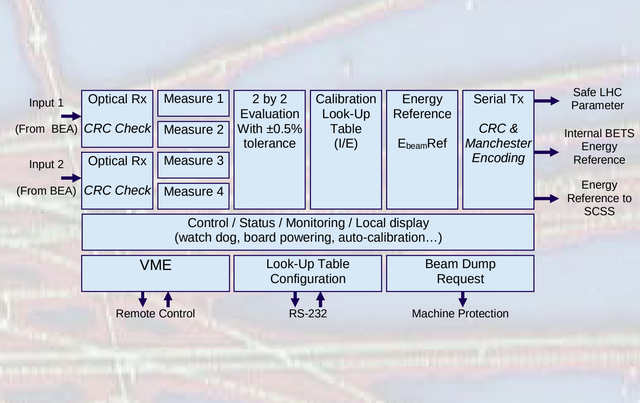
BEA (Beam Energy Acquisition)



The BEA module acquires and digitises 2 independent unipolar channels with 16bit resolution. Signals are digitally filtered before secure transmission through optical fibre. Two high precision reference signals are simultaneously digitised, modulated and transmitted in order to survey the linearity of the ADC and to probe the transmission.

In order to automatically compensate the ADC offset and to adjust its gain, two high precision reference signals are used within the BEA. Via a 4-to-1 analogue multiplexer, the BEA consecutively measures the two analogue input voltages as well as a high precision 10V reference voltage and a ground reference in order to generate full scale and zero reference signals. The analogue input range of the ADC extends from slightly below 0V to a little above 10V. In this way any possible offset and gain error of the ADC and the amplifier driving its input can be eliminated after conversion and the precision of the measurement depends only on the precision of the voltage references.

BEM (Beam Energy Meter)

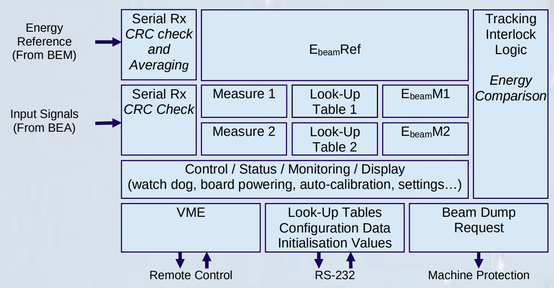


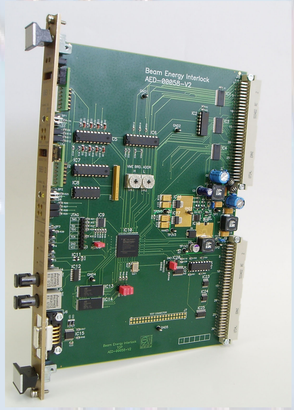
The BEM receives 4 Independent main bends DCCT measurements from two different BEA Modules placed in two main bends power converters.

These measurements are compared within the BEM two by two and Interlocks if a relative error between measurements is greater than ±0.5%.

The mean value of the 4 measurements is then converted into an absolute beam energy reference through a calibration look-up table. Calculated energy is then internally distributed within the BETS to the interlock logic and externally distributed to the SCSS for settings generation of the kick strength for the kickers generators and to the machine protection system for distribution around the LHC via the timing system.

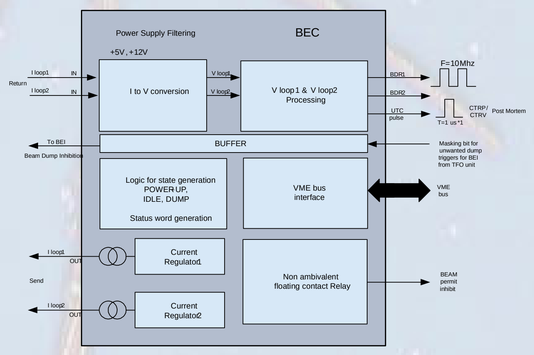
BEI (Beam Energy Interlock)

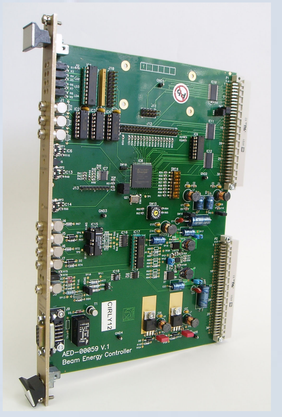




The Beam energy Interlock (BEI) receives the beam energy reference signal from One of the two BEM modules, lodged in the same crate, and two independent measurements from kicker generator HVDs, or from septa or quadrupole Q4 DCCTs. It normalises these measures to values proportional to the energy through independent calibration look-up tables. These normalised values are then compared with the beam energy reference signal and when a discrepancy larger than a predefined tolerance is detected, a beam dump request is issued.

BEC (Beam Energy Controller)





The BEC module interfaces the BEM and BEI modules to external systems through redundant fail safe connections. It produces the dump request signal that is fed to other systems for any failures detected within the BETS.

The BEC has a redundant pair of on board current loop generators that feeds all the BETS modules (BEMs and BEIs). The current loop is returned towards the BEC and the signals are then treated. When all the BETS modules operate correctly and are armed, the presence of a current in both current loops will be detected by the BEC and a 10 MHz frequency will be sent to the TSDS system. On the contrary, when one of the two current loops is broken, the 10 MHz signal disappears which produces a beam dump request (BDR) signal to the TSDS system. Simultaneously, a trigger signal is issued by the BEC to the LHC timing system in order to record the UTC time of the BDR action for post mortem analysis purposes.