Abstract: An unprecedented amount of energy will be stored in the circulating beams of LHC. The loss of even a very small fraction of a beam may induce a quench in the superconducting magnets or cause physical damage to machine components. A fast (one-turn) loss of 3·10^−5 and a constant loss of 3·10^−8 times the nominal beam intensity can quench a dipole magnet. A fast loss of 3·10^−7 times nominal beam intensity can damage a magnet. The stored energy in the LHC beam is a factor of 200 (or more) higher than in existing hadron machines with superconducting magnets (HERA, TEVATRON, RHIC), while the quench levels of the LHC magnets are a factor of about 5 to 20 lower than the quench levels of these machines. To comply with these requirements the detectors, ionization chambers (BLMI) and secondary emission monitors (BLMS) are designed very carefully. The stored energy in the LHC beam is a factor of 200 (or more) higher than in existing hadron machines with superconducting magnets (HERA, TEVATRON, RHIC), while the quench levels of the LHC magnets are a factor of about 5 to 20 lower than the quench levels of these machines. To comply with these requirements the detectors, ionization chambers (BLMI) and secondary emission monitors (BLMS) are designed very carefully.

LHC and its BLM System

- Circumference: 26.7 km
- Injection energy: 450 GeV
- Top energy: 7 TeV in two counter-rotating beams
- ~ 350 MJ stored energy per beam (can melt 600 kg of copper)
- ~ 11 GJ stored energy in the magnet system
- ~ 3·10^10 protons per beam
- Superconducting magnets
- Magnetic field 8.3 T (1.9 K)
- Factor 4 ~ 20 more sensitive to beam losses compared to existing hadron machines

Calibration of the BLM System

- Number of locally lost beam particles
- Detector response
- Hadronic showers
- Deposited energy in the machine component
- Quench and damage levels as function of loss duration (heat flow in machine component)
- Fraction of quench and damage level of the machine component

Detectors

Secondary Emission Monitor (SEM) design:
- Diameter = 9.9 cm
- Length = 60 cm
- Volume: 1.5 litre
- 60 Al disks, 0.5 mm
- Gain: Ni (1,1 bar)
- Bias voltage: 1500 V
- Gas: N_2, polarized, electron multiplication factor 4
- NEG pumping stripe (300 μm)
- Gas pressure: ≤ 1.1 bar
- Length: 60 cm

Ionization chamber design:
- Diameter = 9.9 cm
- Length: 60 cm
- Pressure: 10^−6 mbar
- 3 Ti electrodes (1 signal electrode), 0.25 mm
- Gain: Ni (1,1 bar)
- Bias voltage: 1500 V
- Gas: Ar
- Length: 60 cm
- Volume: 1.5 litre

Readout and Reliability

Probability of damage to magnet due to not detecting a dangerous loss, required: 10^−3 per year (SIL3)
- Calculated unavailability: 5·10^−5 per channel (satisfies SIL3 for 100 dangerous losses per year)
- Less than 20 false dumps per year required (SIL2), 10-17 false dumps per year calculated

System Test SPS Beam Dump

Test results of the BLM system (ionization chamber) over a large dynamic range with a pulsed beam at the SPS beam dump:
- At 1900 seconds: evolution of the radiation at the dump under normal fixed target operation.
- At 2000 seconds: full beam is dumped intentionally, showing immediately an increase in the remnant radiation level which is steadily decaying with time.
- Illustration of radiation measurement over 4 orders of magnitude.

System Test SPS Collimator

Beam loss at an LHC prototype collimator installed in the SPS. Signal vs time after a collimator component of 20 μs (corresponding to 10 ms)

Fast Fourier Transformation (FFT) of the BLM signal caused by the collimator movement (20 μs) of bunched and unbunched (“RF OFF”) beam. Blow-up of the lower frequencies in the bunched beam case.