Characterization of the LHC BLM detector

**Purpose:**
- Machine protection against damage of equipment and magnet quench
- Localization of beam losses and identification of loss mechanism
- Machine setup and studies

**Location:**
BLM mounted outside of cryostat (transverse tall of hadronic showers), six around each quadrupole

**Challenges:**
- Reliability (tolerable failure rate 10⁻³ per hour per channel)
- Large dynamic range (10⁻² to 10⁴ mA)

**Detector response simulation**

- Detailed detector simulation with Geant4 (4.8.1)
  - 9 different particle types
  - Kinetic energy range: 10 keV – 10 TeV
  - Transverse and longitudinal irradiation

**Verification Measurements**

1. Mixed radiation field measurements at CERN target area (CERN-HE High Energy Reference Field Facility), 5 positions:
   - Different particle composition and mean energy, simulation agrees with measurement, except position 1 (lower energy spectra, 21%).
   - Linearity of the detector verified over 1 order of magnitude

2. Protons at 400 GeV/GeV:
   - SPS extraction line at CERN, systematic error of 23% due to beam position uncertainty

3. Gamma Calibration at TSR-RP Calibration Laboratory for Radiation Protection Instruments (CERN), with Ca137 sources (662 keV)

4. Neutrons at 174 MeV:
   - Svobod Laboratory, Uppsala University (Sweden), intensity (0.7 to 4.6) 10⁻⁷ per second, assuming 11.2% gamma contribution to signal

**Space Charge Effect in Ionization Chamber**

- Above a critical ionization density a dead zone of thickness x = (d – F) / (1 + F m) will not form.
- Application of the formula to the HERA experiment

**Results**

- BLM detector response simulation with Geant4 and verification measurements:
  - Part of the BLM system certification
  - Difficulties:
    - ion chambers probe for tails of shower distribution (simulation uncertainties)
    - High flux of low energy neutrons and gammas
  - Preliminary Results:
    - Use of ionization chamber and physics modes, QGP, BH, closest to data (less than factor 2 in the peak)
    - Significant difference in absolute height and longitudinal shape between measurement and simulation. Backward and forward tails in the data are not represented in the simulation.
  - Successful long-term test of the complete LHC BLM System in real accelerator environment

**Hadronic Shower Measurements at HERA**

- HERA/DESY internal proton beam dump equipped with LHC type BLM system
- 6 detectors longitudinally spaced by ~1 m to cover the full range of correction factors at the HERA experiment

**Classification of the LHC BLM Ionization Chamber**

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**Abstract:** The LHC beam loss monitoring (BLM) system must prevent the vapor conducting magnets from quenching and protect the machine components from damage. The main monitor type is an ionization chamber. About 2000 of them will be installed around the ring. The lost beam particles initiate hadronic showers through the magnets and other machine components. These shower particles are measured by the monitors installed on the outside of the accelerator equipment.

For the calibration of the BLM system the signal response of the ionization chamber is simulated in GEANT4 for all relevant particle types and energies (keV to TeV range). For validation, the simulations are compared to measurements using protons, neutrons, photons and mixed radiation fields at various energies and intensities. This paper will focus on the signal response of the ionization chamber to various particle types and energies including recombination effects in the chamber gas at high ionization densities.

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**LHC and its BLM System**

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  - Localization of beam losses and identification of loss mechanism
  - Machine setup and studies

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- Challenges:
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**Calibration of the BLM System**

- Number of locally lost beam particles
- Hadronic showers
- Deposition energy in the machine component
- Quench and damage level of the machine component

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