Luminosity measurement at CMS

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On behalf of the CMS Collaboration

Luminosity at CMS overview

\[ N = L \sigma + N_{bkgr} \]
\[ L = \frac{R_0(t)}{\sigma_{D}} \]

Absolute calibration: Van der Meer scan

The target physics quantity (fiducial)

Cross section analysis: extract the signal and estimate the efficiencies

The goal of the luminosity calibration is to determine the luminosity as a function of beam parameters. From this, the calibration constant $\sigma_D$ can be calculated. Luminosity calibration at CMS is done via a Van der Meer scan, during which the LHC beams are scanned across each other. The effective area of the beams can be determined from the data by scanning the luminosity system from full luminosity to zero luminosity with the help of a dedicated luminometer. The luminosity system must be calibrated in order to obtain reliable results.

Luminosity measurement at CMS overview

- 3 barrel layers, 2 endcap disks per side
- Total 165 mm radius
- >1,000,000 channels
- <0.1% missing occupancy
- Max missed rate: 10 kHz

The pixel detector is especially suited to luminosity measurement because of the high detection efficiency and low intrinsic noise. The luminosity measurement at CMS consists of several steps:

1. **Offline luminosity measurement: pixel cluster counting**
   - Several effects need to be accounted for during the analysis.
   - The relationship between number of pixel clusters and luminosity can be determined when pixel clusters belonging to more than one bunch are considered to be in the luminous region of the CMS detector. The luminosity is calculated from the number of pixel clusters in a given period of time, and the beam luminosity is determined from the number of pixel clusters per unit area.
   - The detector also has an effect on the material in the luminosity measurement, which is not well understood. However, the relationship between the luminosity and the number of pixel clusters is linear, and the uncertainty in the relationship is small.
   - In general, the uncertainty of the luminosity measurement in the CMS detector is about 1% to 2%.

2. **Stability of measurement**
   - The luminosity system must be calibrated to account for changes in the luminosity with time.
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3. **Upgrades to online luminometers**
   - After the upgrade, the online luminosity measurement system will include several more subsystems. This will introduce redundancy into the system, allowing for better performance in case one subsystem goes down. In addition, having multiple measurements in parallel can improve the accuracy of the measurement.
   - The Fast Beam Condition Monitor (BFM) will consist of 24 silicon strip detectors situated in two parallel planes on either side of the detector. These detectors will be used to measure the beam luminosity in real time. The luminosity system will include a dedicated luminometer to provide raw data to the BFMAU software system, which will monitor the luminosity measurement system for any anomalies.
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