BCM1F Detector Performance Plots for online luminosity measurement as presented at ICHEP 2012

CMS Collaboration

Abstract

Detector performance as presented for the ICHEP July 2012 conference

1) The feasibility of BCM1F as an online luminosity monitor - Bunch-by-bunch beam sigma measurements from Van der Meer Scan - Comparison to HF and pixel measurements from Van der Meer Scan - Extraction visible cross section (of calibration factor) from Van der Meer Scan measurements

2) The detector response features, that contribute to sources of inefficiencies - Peaking time of frontend amplifier - Response of frontend electronics chain after a saturated event
BCM1F Detector Performance Plots for online luminosity measurement as presented at ICHEP 2012

On behalf of the CMS Collaboration
Detected performance as presented for the ICHEP July 2012 conference

1) The feasibility of BCM1F as an online luminosity monitor
   - Bunch-by-bunch beam sigma measurements
   - Comparison to HF and pixel measurements
   - Extraction visible cross section (of calibration factor) from Van der Meer Scan measurements

2) The detector response features, that contribute to sources of inefficiencies
   - Peaking time of frontend amplifier
   - Response of frontend electronics chain after a saturated event
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An example of the measured overlap distribution of the two beams in the x-plane for the first Van der Meer scan, for the first bunch crossing in the train. The Double Gaussian distribution is used to best describe the data which is the OR rate measured by BCM1F normalized to the product of the bunch current, measured at each scan position, delta x.

On the plot:
- The black dots are the data points.
- The blue is the baseline contribution of the fit.
- The red and the green curves are the two single Gaussian contributions.
- The black curve is the total fit function, described in the function below

\[
\mu_x(x) = \mu_{x,\text{peak}} \left( \frac{f_1 \Sigma x}{\sigma_1} e^{\frac{(x-x_0)^2}{2\sigma_1^2}} + (1 - \frac{f_1 \Sigma x}{\sigma_1}) e^{\frac{(x-x_0)^2}{2\Sigma_x^2 \left(1-f_1\right)^2 \left(1-\frac{f_1 \Sigma x}{\sigma_1}\right)^2}} \right) + \mu_{x,0}
\]

\[\chi^2 / \text{ndf} = 86.06 / 18\]
\[\Sigma = 0.03146 \pm 4.213 \times 10^{-5}\]
\[\sigma_1 / \sigma_2 = 1.293 \pm 0.09057\]
\[\text{Amplitude} = 0.5739 \pm 0.001017\]
\[\text{Fraction} = 0.8778 \pm 0.05495\]
\[\text{Mean} = -0.000202 \pm 3.133 \times 10^{-5}\]
\[\text{Constant} = 0.0001305 \pm 2.454 \times 10^{-5}\]
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An example of the measured overlap distribution of the two beams in the y-plane for the first Van der Meer scan, for the first bunch crossing in the train. The Double Gaussian distribution is used to best describe the data which is the OR rate measured by BCM1F normalized to the product of the bunch current, measured at each scan position, delta y.

On the plot:
- The black dots are the data points.
- The blue is the baseline contribution of the fit.
- The red and the green curves are the two single Gaussian contributions.
- The black curve is the total fit function, described in the function below

\[
\mu(x) = \mu_{x,\text{peak}} \left( \frac{f_1 \Sigma X}{\sigma_1} e^{\frac{(x-x_0)^2}{2\sigma_1^2}} + (1 - \frac{f_1 \Sigma X}{\sigma_1}) e^{\frac{(x-x_0)^2}{2\Sigma_X^2}} (1-f_1)^2 (1 - \frac{f_1 \Sigma X}{\sigma_1}) \right) + \mu_{x,0}
\]
An example of the measured overlap distribution of the two beams in the x-plane for the first Van der Meer scan, for all bunch crossings using BCM1F.

The measurements of BCM1F is compared to the measurements obtained by the HF and the pixel detectors.

The measurements for all bunch crossings agree within better than 1.5%.

(Note: The a transverse beam size variation as a function of bunch number has also been measured with LHC beam instrumentation, and hence does not necessarily point to an error in the bunch by bunch variation in our measurements)
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The difference in percent between the overlap distribution of the two beams, in the x-plane for the first Van der Meer scan, as measured using the various luminosity techniques.

The beam overlap distributions are comparable to within 1.5% for all detectors. The BCM1F seems to systematically measure a 1% smaller overlap region than the other detectors. The origin for this effect is not yet understood.
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An example of the measured overlap distribution of the two beams in the y-plane for the first Van der Meer scan, for all bunch crossings using BCM1F. The measurements of BCM1F is compared to the measurements obtained by the HF and the pixel detectors.

The measurements agree with within xxx for a particular bunch crossing

Note: The a transverse beam size spread as a function of bunch number is intrinsic to the the LHC and has been measured with LHC beam instrumentation
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The difference in percent between the overlap distribution of the two beams, in the y-plane for the first Van der Meer scan, as measured using the various luminosity techniques.

The beam overlap distribution in y are comparable to within 1.2% for all detectors. The BCM1F detector measures a smaller overlap region than HF. The origin of this effect is not yet understood.
The visible cross section as measured by BCM1F for various bunch crossings. As shown in the equation below, the inputs in extracting the visible cross section are:

- the product of the extracted over lap region in x and y;
- the bunch current for beam 1 and beam 2;
- And the average peak amplitude

The average visible cross section is used to extract a calibration factor for the luminosity

\[
\sigma_{\text{vis}} = \pi \sum_Y \sum_X \frac{(\mu_{X,\text{peak}} + \mu_{Y,\text{peak}})}{N_1 N_2}
\]
An example of a MIP signal as measured by BCM1F, using the ADC.

The plot shows the peaking time of the preamplifier to be 25 ns and the total pulse length before returning to baseline to be about 120 ns, as expected from the design of the preamplifier. The plot shows also the baseline of the signal and the threshold over which a hit is counted. The region in red, is defined as the “time over threshold”.
Another example of a MIP signal as measured by BCM1F, using the ADC. The plot shows the data points as measured by the ADC in blue, and a fit to a Landau distribution in red.

The shape of the pulse is dominated by the shaping parameters of the front end preamplifier.
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An example of the ADC pulse height distribution for BCM1F using the ADC.

The plot shows the noise, the threshold of the discriminator, the peak corresponding to 1 MIP signal and the saturation in ADC counts is caused by the linear laser driver dynamic range, at about 75 ADC counts for this BCM1F channel.
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A histogram of the time over threshold as measured by BCM1F during a typical LHC fill.

The peak of the distributions, corresponds to the time over threshold of a typical MIP event, which is about 50 ns.

The tail of events, with large time over thresholds corresponds to events with larger deposited charge and events where the front end pre-amplifier is saturated.
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The measured single hit probability per bunch crossing for BCM1F as a function of the instantaneous online luminosity measured by HF.

This distribution is calculated using the ADC, and counting the frequency of an amplitude above threshold, per bunch crossing.

The distribution is calculated from LHC fill 2646, using the first bunch in the LHC orbit.

From this plot, the linearity with instantaneous luminosity shows an insensitivity to pileup.

The single bunch probabilities is used as input in the Monte Carlo.
From a **measurement in the laboratory**, an example of an injection of sufficient charge to saturate the BCM1F front end.

The region in “over-shoot” is fit with an exponential, and the time constant is consistent with what is expected in the preamplifier circuit.
From a measurement in LHC fill, where there is sufficient charge to saturate the BCM1F preamplifier. The time over threshold in this distribution is larger than that for a typical MIP. Following the saturation, the pulse goes into a “over-shoot” period and baseline shifts. The detection of following pulse is consequently inefficient, while the preamplifier is in recovery.
From a measurement in the laboratory, the overshoot amplitude is measured as a function of the time over threshold.

The measurement is done by injecting a variable amount of charge into the input capacitor to the preamplifier.

This illustrates, that by measuring the time over threshold, the overshoot amplitude, which is proportional to the maximum baseline shift, can be calculated.
From a measurement using the data from the BCM1F. From a profile histogram, the time in overshoot is measured as a function of the time over threshold.

The functional form of the correspondence between the time over threshold and the time in overshoot, is used as input in the Monte Carlo to simulate the dead time and resulting inefficiencies.
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Using the following inputs from the 8 BCM1F diamonds into the Monte Carlo:

- measured single hit probability distribution
- The time over threshold distribution
- The time in overshoot as a function of time over threshold
- The time to return to baseline after an overshoot; the probability of an OR hit is calculated.

This distribution is compared to the distribution as measured using the PLT FED as a function of bunch crossing ID.

Bunch-by-bunch emittance variations are not taken into account in this Monte Carlo simulation.

The full orbit is shown.
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Using the following inputs from the 8 BCM1F diamonds into the Monte Carlo:

- measured single hit probability distribution
- The time over threshold distribution
- The time in overshoot as a function of time over threshold
- The time to return to baseline after an overshoot; the probability of an OR hit is calculated.

This distribution is compared to the distribution as measured using the PLT FED as a function of bunch crossing ID.

Bunch-by-bunch emittance variations are not taken into account in this Monte Carlo simulation.

A zoom in on the first 400 bunch crossings.
From a measurement with beam, the pulse amplitude is plotted as a function of the time over threshold. Events saturating the preamplifier, corresponding to > 50 ADC counts, correspond qualitatively to a long time over threshold. This confirms that the saturated events are a source of deadtime.