Luminosity measurement at CMS.

Analysis of the behavior of the polycrystalline diamond sensors of the BCM1F detector

DPG conference in Aachen 2019
March 27, 2019
What is luminosity

\[ R = \sigma \cdot L \]

Event rate: measured in experiment

cross section: to be determined as precisely as possible

luminosity
<table>
<thead>
<tr>
<th>Event rate: measured in experiment</th>
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<th>luminosity</th>
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<tbody>
<tr>
<td>hits/minute</td>
<td>hits/throws</td>
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\[ R = \sigma \cdot L \]
What is luminosity

- Measureing small cross sections requires high luminosity
- Luminosity integrated over time: ideal measure for amount of data
  → 1 fb\(^{-1}\): one event with cross section 1 fb.
- Run 2, with 13 TeV: 150 fb\(^{-1}\) in total
- Precise measurement: precise luminosity value needed
- Luminosity is often the largest uncertainty

\[ R = L \cdot \sigma \]
How is luminosity calibrated

\[ R = L \cdot \sigma \]

\[ L = \frac{N_1 \cdot N_2 \cdot f \cdot n_b}{2\pi \cdot \Sigma X \cdot \Sigma Y} \]

* \( N_1, 2, f, n_b \): known
* \( \Sigma X \) und \( \Sigma Y \) to be determined in calibration measurement: Van-der-Meer scan
* Van-der-Meer Scan: determines "visible cross section"* of a luminometer → instantaneous luminosity from rate via extrapolation to total luminosity

*how much of the total luminosity is seen by the luminometer?
on both sides at 1.8 m distance from the collision point around the beam pipe

This talk: 2017/18 (polycrystalline diamond sensors)

- 4 modules with 6 sensor chips each:
- Polycrystalline diamond sensors: used for the measurement of luminosity
- In addition: silicon sensor prototypes
Silicon sensors

> very good results: stable measurement, no dependencies on rate, history, etc.
> needs cooling

Polycrystalline diamond sensors (pCVD)

> radiation hard
> saturation effects: efficiency dependent on rate
⇒ Non-linear behavior during a fill: Correction necessary

luminosity measurement of pCVD und Si during a fill
The silicon sensors show no rate dependency – can be used as reference to measure non-linearity

Plot ratio between pCVD and Si over luminosity

Efficiency and nonlinearity are dependent on the total rate
⇒ Strong dependence on number of colliding bunches
Using fills April - June 18

Result: Dependence is approximate linear
⇒ simple linear correction sufficient to correct non-linear effects and false efficiency
Calibration of the pCVD sensors

Other corrections

VdM efficiency correction

> Rate in VdM scan lower than with nominal conditions → Efficiency higher

> need extrapolation to full machine efficiency
  ▶ Overall efficiency correction of approx. 8%

Long term detector stability

> efficiency changes during year (radiation damage, annealing, changed settings...)

> measure stability with short scans at beginning and end of every fill ("emittance scans")

> changes parametrised in stability plot and implemented using fits
BCM1F data now approximately independent of rate and linear

With calibration BCM1F is able to provide a comparable result – without cross calibration

Good results with silicon – will be main sensor type for Run 3
Thanks for your attention.