High Luminosity and Pile up effect

F. Machefert

Laboratoire de l'Accélérateur Linéaire

Calorimeter Upgrade Meeting

Outline

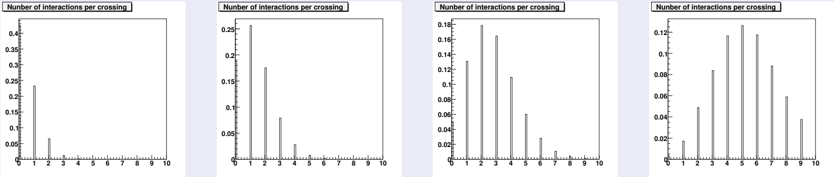
1. Introduction
2. The method based on real data
3. Results
   - $\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
   - $\mathcal{L} = 5 \times 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
   - $\mathcal{L} = 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
   - $\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$: Not foreseen for Phase I
4. Conclusion

This is very preliminary

Introduction
LHCb beam conditions

- The upgrade consists in increasing the luminosity at the LHCb IP.
- This has the side effect of increasing the number of interactions per bunch crossing.

$\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^2 \mathrm{s}^{-1}$ $\mathcal{L} = 5 \times 10^{32} \mathrm{cm}^2 \mathrm{s}^{-1}$ $\mathcal{L} = 10^{33} \mathrm{cm}^2 \mathrm{s}^{-1}$ $\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^2 \mathrm{s}^{-1}$



Number of interactions per crossing at different luminosities.

- Present "nominal" luminosity is $\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$
- Foreseen maximum luminosity for the phase 1 is $\mathcal{L} = 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$.

Introduction

Effect for physics signals

A direct consequence of the higher number of interactions per bunch crossing is that the event multiplicity is larger.

The events get piled-up and the energy/position reconstructed are overestimated/smeared.

This should be looked at with dedicated MC samples at the expected luminosities.

- We do not have them and producing those samples is not easy
  - Need to find someone in the calorimeter group to take care of this
  - but is needed (e.g. validation of the packing method for the readout) not only for the calorimeter

We want to have a rapid pile-up estimation before *upgrade* MC sample are produced.

This was the purpose of a previous study that indicated pessimistic results.

- A MC sample at 14TeV was used
- Digitization output was stored at various locations on the calorimeter surface
  - vertical and horizontal bands passing by the beam pipe
- The ADC spectrum was used to get random ADC configurations
- Average/RMS were extracted per cell (previous locations) and for groups of 9 cells $\rightarrow$*cluster*.

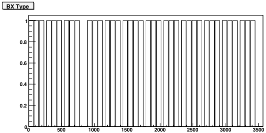
Here is a new study based on the real data events recorded since April, 2010.

The method based on real data

1. The ADC counts are extracted with present data (no pile-up)
    - for each calorimeter cell (3 areas)
        - do not simply perform calculation at a few positions
    - for each event recorded

   A large vector of 6016 integers is obtained per event
   Got more than 1 million event sample on disk.

2. The beam conditions (pile-up) at a certain luminosity are evaluated
    - the Poisson law to get the rate for a certain number n of interactions per crossing to occur
    - Use the LHC bunch structure to decide if bunches are crossing or not



   and permits to *generate* event conditions (pile-up) for a certain luminosity

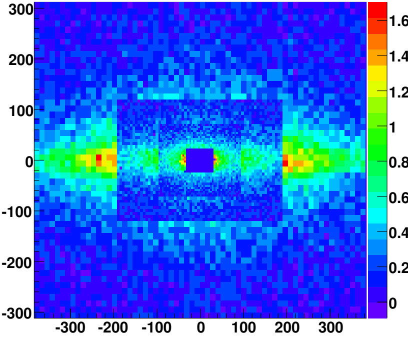
3. For a *high luminosity* add the generated number of events, i.e. add the 6016 rows of consecutively recorded vectors (real data events)

Pros/cons of the method :

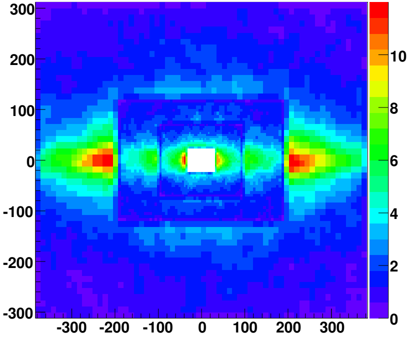
- Pros : based on real data
- Cons : 3.5 instead of 7TeV.

Calorimeter map - Average

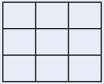
$\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



Cell averaged signal (ADC counts)

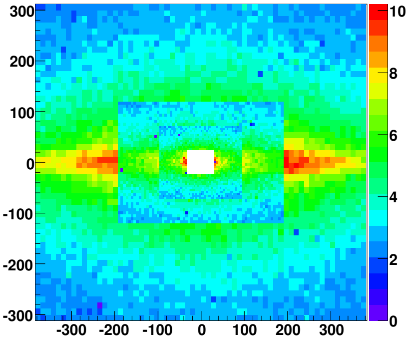


Cluster (9 cells) averaged signal (ADC counts)

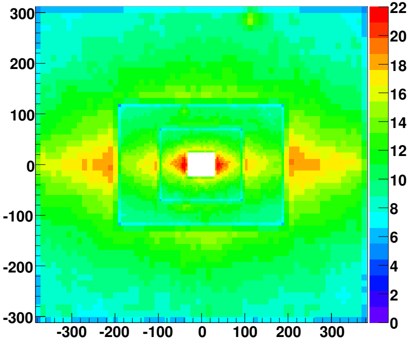
- A cluster (usually, see below) is made by a group of 9 cells 
- The 2D representation shows the cluster signal/RMS at the location of the central cell (seed)
  - border effect are clearly visible : some cluster are made by less than 9 cells.

Calorimeter map - RMS

$\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



Cell signal RMS (ADC counts)



Cluster signal RMS (ADC counts)

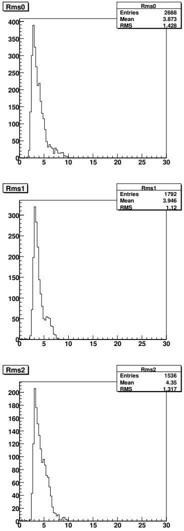
RMS per zone

$\mathcal{L} = 2 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$

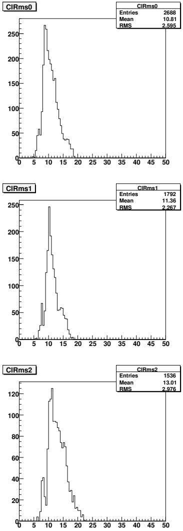
Outer

Middle

Inner



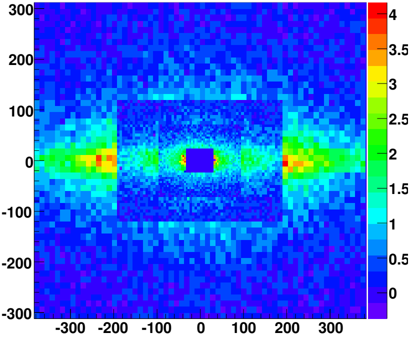
Cell RMS



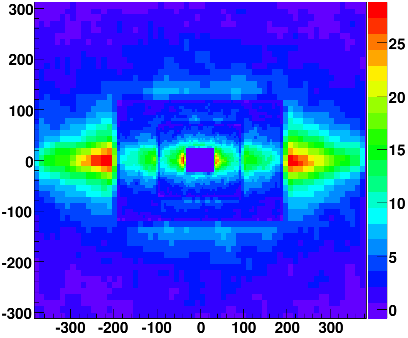
Cluster RMS

Calorimeter map - Average

$\mathcal{L} = 5 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



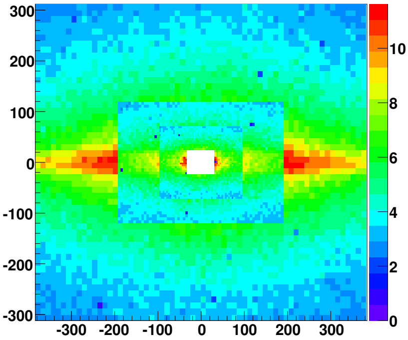
Cell averaged signal (ADC counts)



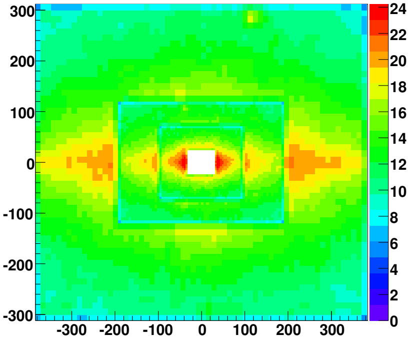
Cluster (9 cells) averaged signal (ADC counts)

Calorimeter map - RMS

$\mathcal{L} = 5 \times 10^{32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



Cell signal RMS (ADC counts)



Cluster signal RMS (ADC counts)

RMS per zone

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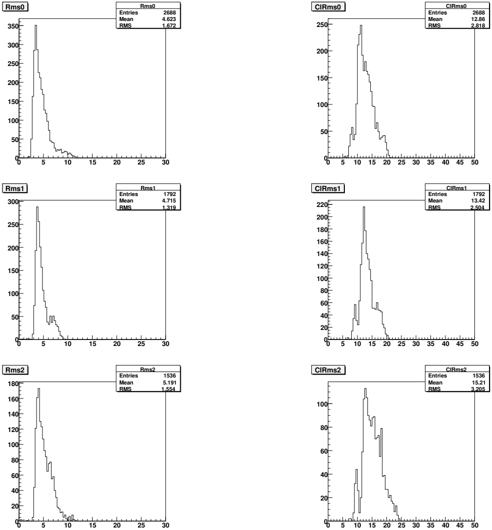
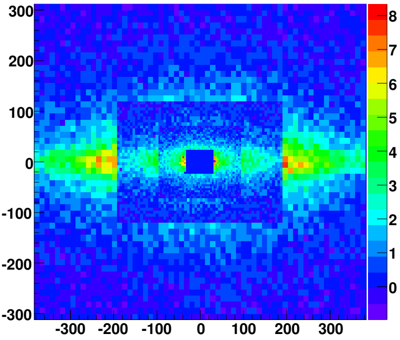


Cell RMS

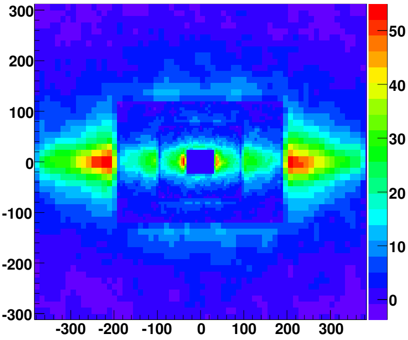
Cluster RMS

Calorimeter map - Average

$\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$



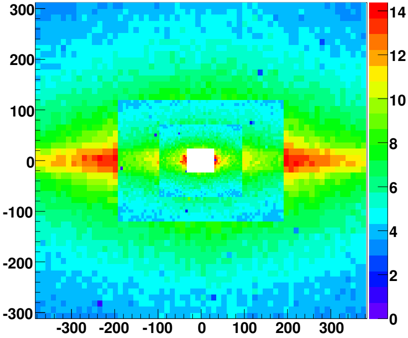
Cell averaged signal (ADC counts)



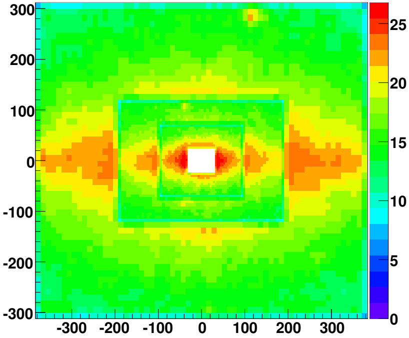
Cluster (9 cells) averaged signal (ADC counts)

Calorimeter map - RMS

$\mathcal{L} = 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



Cell signal RMS (ADC counts)



Cluster signal RMS (ADC counts)

RMS per zone

$\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

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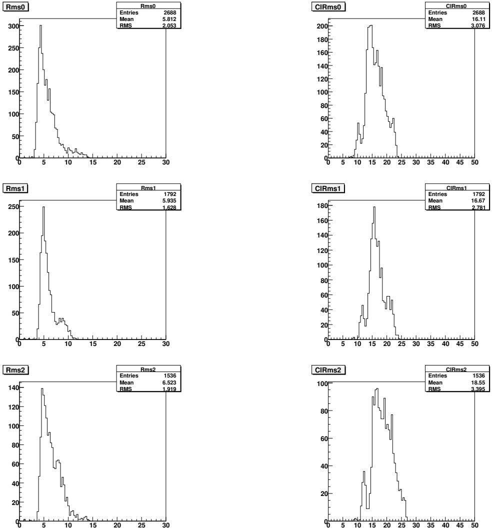
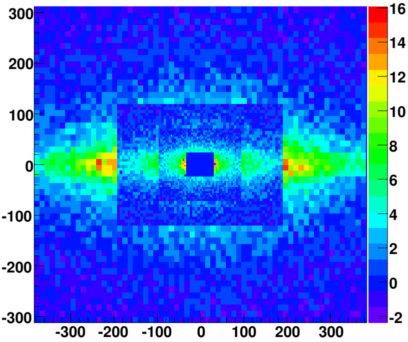


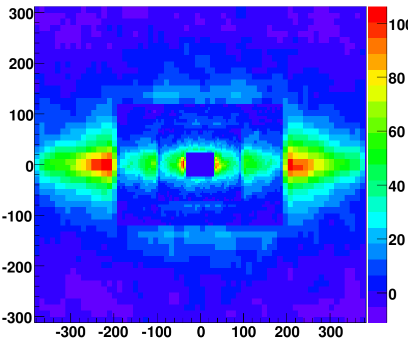
Cell RMS Cluster RMS

Calorimeter map - Average

$\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



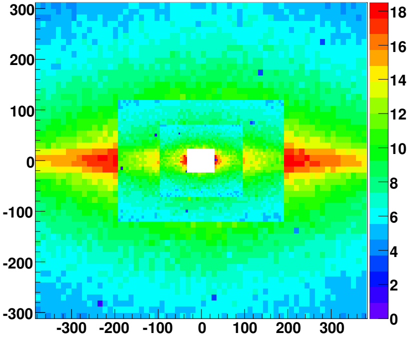
Cell averaged signal (ADC counts)



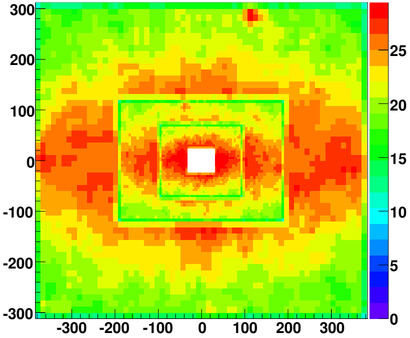
Cluster (9 cells) averaged signal (ADC counts)

Calorimeter map - RMS

$\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$



Cell signal RMS (ADC counts)

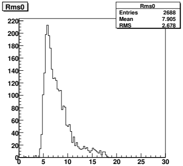


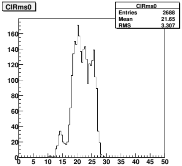
Cluster signal RMS (ADC counts)

RMS per zone

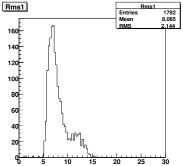
$\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$

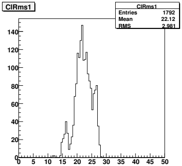
Outer



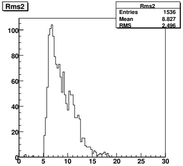


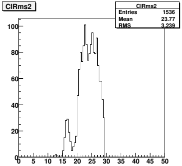
Middle





Inner





Cell RMS

Cluster RMS

Conclusion

The reason why the previous estimation was of the order of 2.5 times more pessimistic is unclear :

- average ADC counts per cell from MC min-bias events was clearly larger
- MC generation energy was 14 TeV (correct). Real data are recorded at 7 TeV.
- The estimation was made from an "average" of 12 positions
  - those position ($y = 0$ and $x = 0$ band) are probably more affected than the rest (pessimistic bias).
- The clusters are built from *uncorrelated* random ADC count generation.

A quantitative conclusion on the pile-up is difficult to get as the RMS obtained is widely spread and the average is not representative.
The energy of the real data sample used is twice too small

- This is clearly an optimistic assumption

Still if we try to take the average the calorimeter resolution could be expressed by

$$\frac{\sigma(E)}{E} = \frac{10\%}{\sqrt{E}} \oplus 1.5\% \oplus \frac{0.0025 \times RMS}{E\theta}(\mathrm{pile-up}) \oplus \frac{0.01}{E\theta}(\mathrm{electronics})$$

$\mathcal{L}$	$2\text{x}10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	$5\text{x}10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	$10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	$2\text{x}10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
RMS	12.	15.	18	22
$0.0025 \times RMS$	0.030	0.038	0.045	0.055

Need MC samples at the correct luminosity in order to feel confident.