A possible LHCb Luminosity Monitor based on the Muon System

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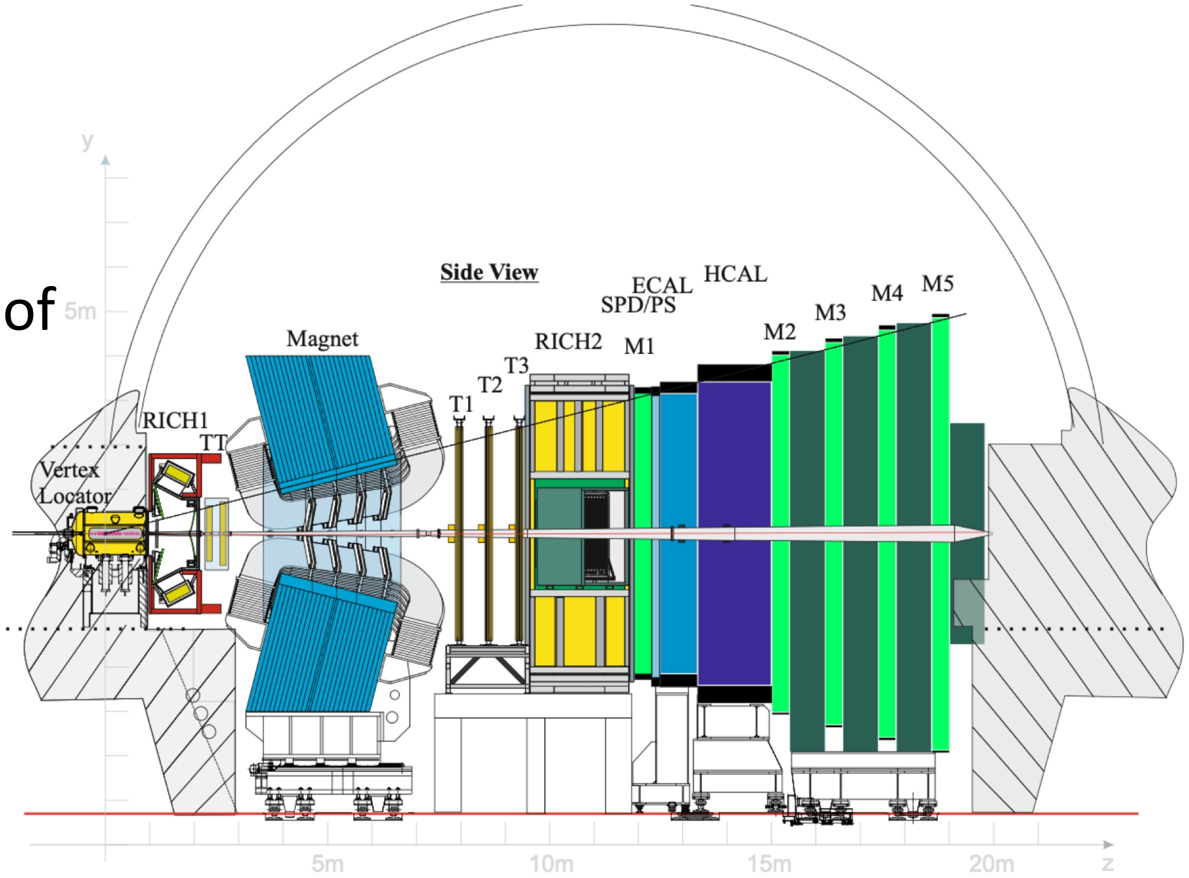
LHCb experiment: the past

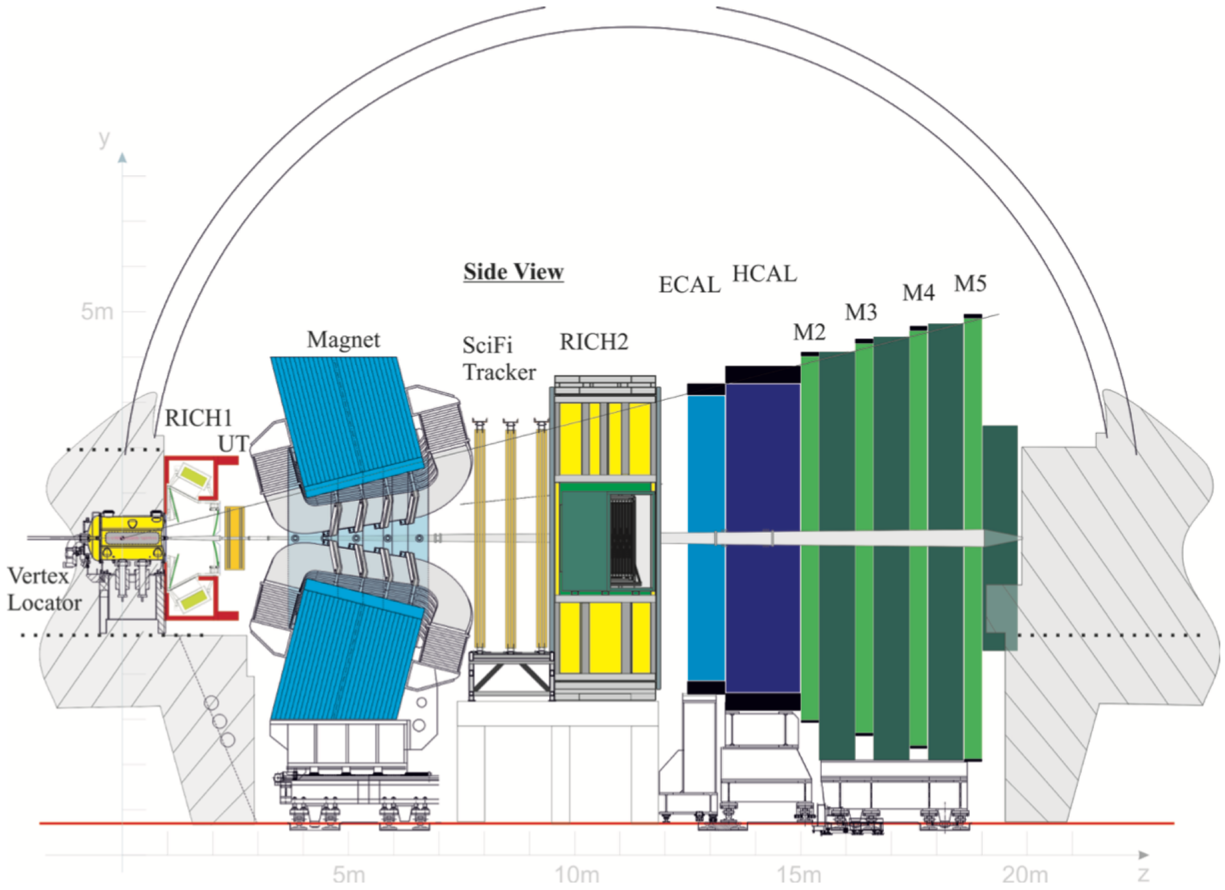
The LHCb detector is a single-arm forward spectrometer covering the pseudorapidity range $1.9 < \eta < 4.9$, designed for the study of particles containing *b* or *c* quarks.

Trigger system: L0 hardware trigger & High Level Trigger (HLT)



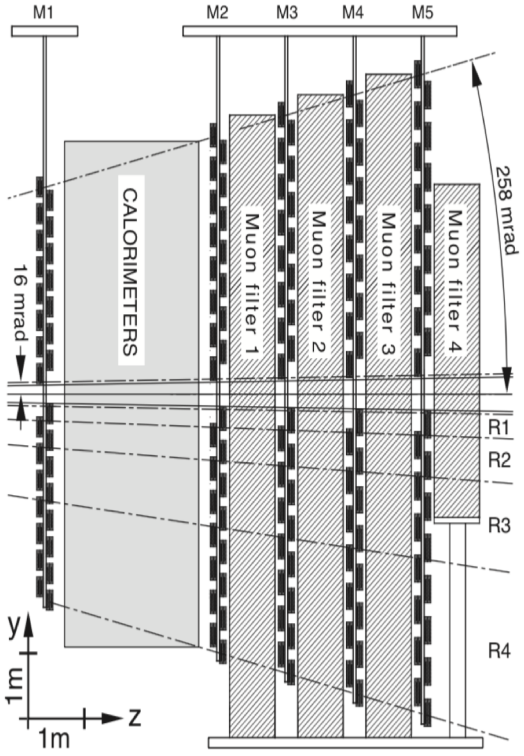
LHCb experiment: the future

The most sensitive part upgraded:
- New vertex locator
- New silicon strip detector
- New scintillating fibre detector
- New Front-End electronics
- No hardware trigger

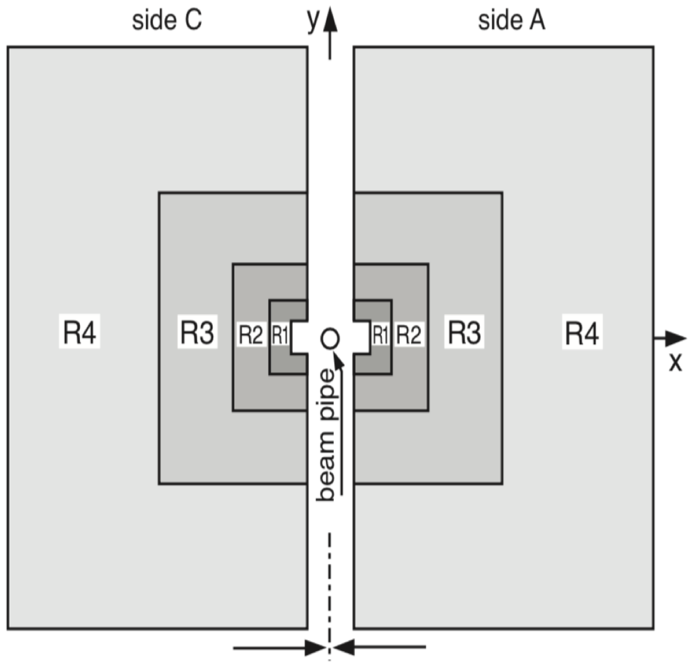


Muon system of LHCb detector

- The muon detector of the LHCb experiment consists of five stations, M1-M5 placed along the beam axis.
- Each station is divided into four regions, R1-R4, with increasing distance from the beam axis. The chambers are different in different regions.
- After the ongoing upgrade, muon system will be composed of 4 stations which comprise 1104 multi-wire-proportional-chambers (MWPC) with order of 100000 readout channels.



(a)

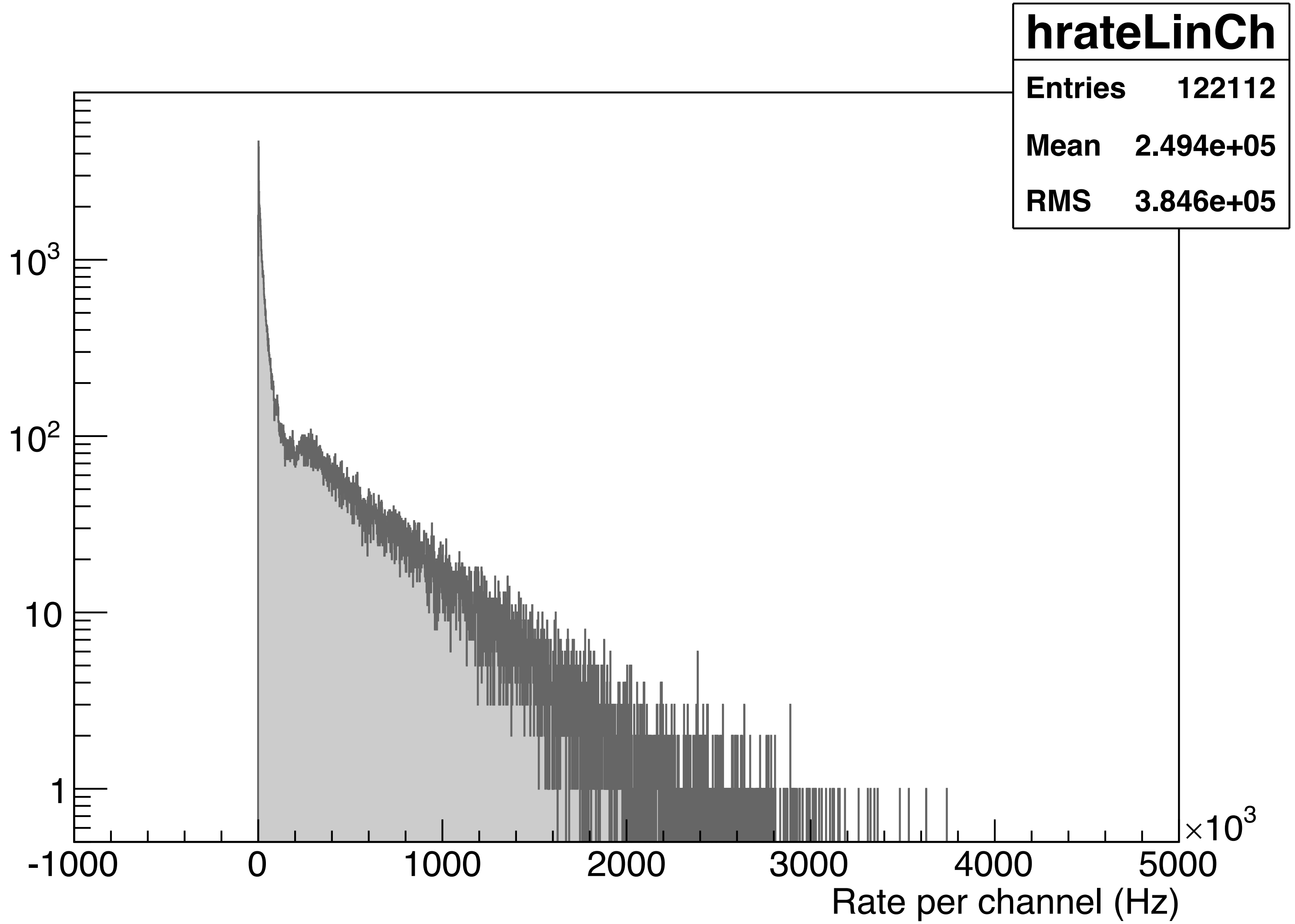


(b)

Muon front-end electronics

- CARDIAC readout board has 16 free-running scalers with preselectable gate
- The dead-time of the scalers is negligible compared with that of the CARDIAC
- Electronics deadtime depends on several parameters: C_{DET}, signal shape (i.e. ionization, gas gain...), and was estimated from direct measurements of particle rates

Rates of muon system



Correction of the deadtime inefficiency

The counting rate R^* of readout channel is: $R^* = R_{\text{part}}(1 - \delta_c R^*)$

where δ_c is the CARIOCA dead time and R_{part} is the rate of hitting particles.

The value of δ_c can be deduced from two measurements (R^*_i and R^*_j) performed at two different luminosities (L_i and L_j) :

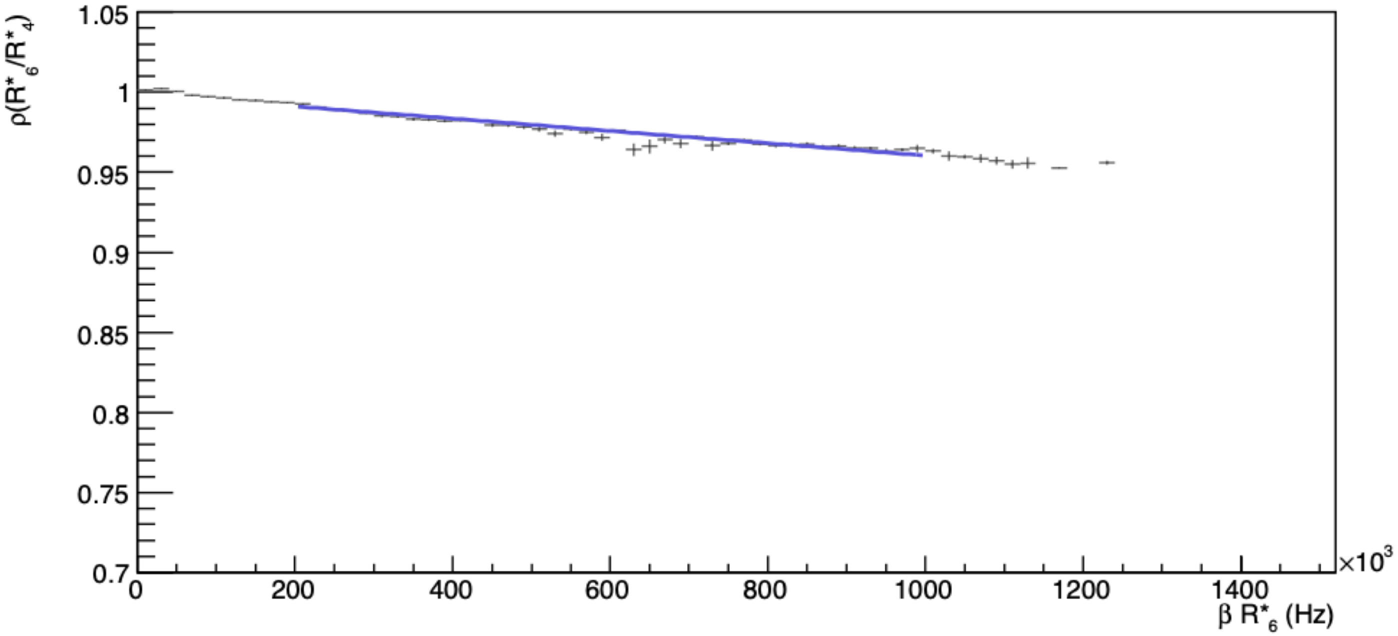
$$\begin{cases} R_i^* = R_{\text{part}}^{(i)}(1 - \delta_c R_i^*) \\ R_j^* = R_{\text{part}}^{(j)}(1 - \delta_c R_j^*) \end{cases}$$

For each readout channel the ratio ρ_{ij} , which can be evaluated from the experimental data

$$\rho_{ij} = \frac{R_j^*/L_j}{R_i^*/L_i}$$

We get $\rho_{ij} = 1 - \delta_c(1 - \beta_{ij})R_j^*$

$$(\beta_{ij} = L_i/L_j < 1)$$



Correction of the deadtime inefficiency

The detailed explanation of the deadtime correction method and results are given in dedicated paper

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Measurement of the front-end dead-time of the LHCb muon detector and evaluation of its contribution to the muon detection inefficiency

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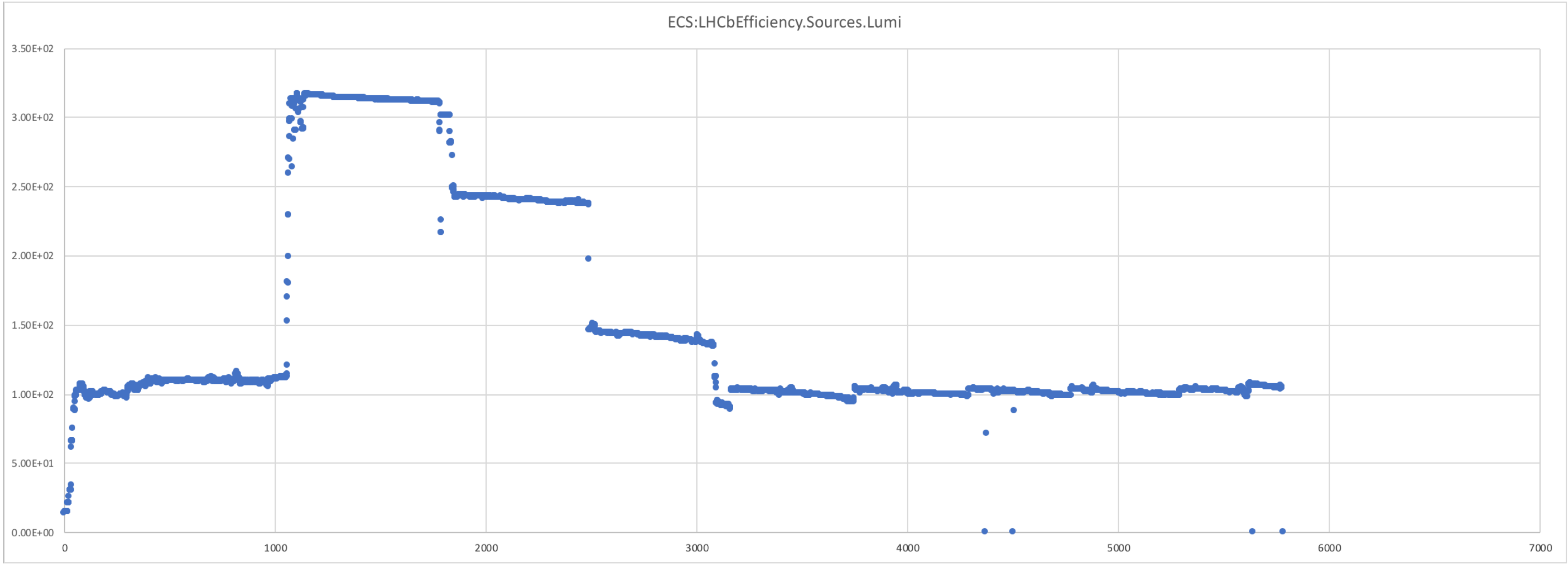
Dataset

- We took special “High Luminosities” runs in 2012 and 2018

Calo measured luminosity 2012	Estimated peak luminosity
$4 \times 10^{32}\ cm^{-2}s^{-1}$	$5.7 \times 10^{32}\ cm^{-2}s^{-1}$
$5 \times 10^{32}\ cm^{-2}s^{-1}$	$7.1 \times 10^{32}\ cm^{-2}s^{-1}$
$6 \times 10^{32}\ cm^{-2}s^{-1}$	$8.6 \times 10^{32}\ cm^{-2}s^{-1}$
$8 \times 10^{32}\ cm^{-2}s^{-1}$	$11.4 \times 10^{32}\ cm^{-2}s^{-1}$
$10 \times 10^{32}\ cm^{-2}s^{-1}$	$14.3 \times 10^{32}\ cm^{-2}s^{-1}$

Calo measured luminosity 2018	Estimated peak luminosity
$1 \times 10^{32}\ cm^{-2}s^{-1}$	$6.7 \times 10^{32}\ cm^{-2}s^{-1}$
$1.1 \times 10^{32}\ cm^{-2}s^{-1}$	$7.2 \times 10^{32}\ cm^{-2}s^{-1}$
$1.4 \times 10^{32}\ cm^{-2}s^{-1}$	$9.4 \times 10^{32}\ cm^{-2}s^{-1}$
$2.4 \times 10^{32}\ cm^{-2}s^{-1}$	$16 \times 10^{32}\ cm^{-2}s^{-1}$
$3.1 \times 10^{32}\ cm^{-2}s^{-1}$	$21 \times 10^{32}\ cm^{-2}s^{-1}$
$5.8 \times 10^{32}\ cm^{-2}s^{-1}$	$39 \times 10^{32}\ cm^{-2}s^{-1}$

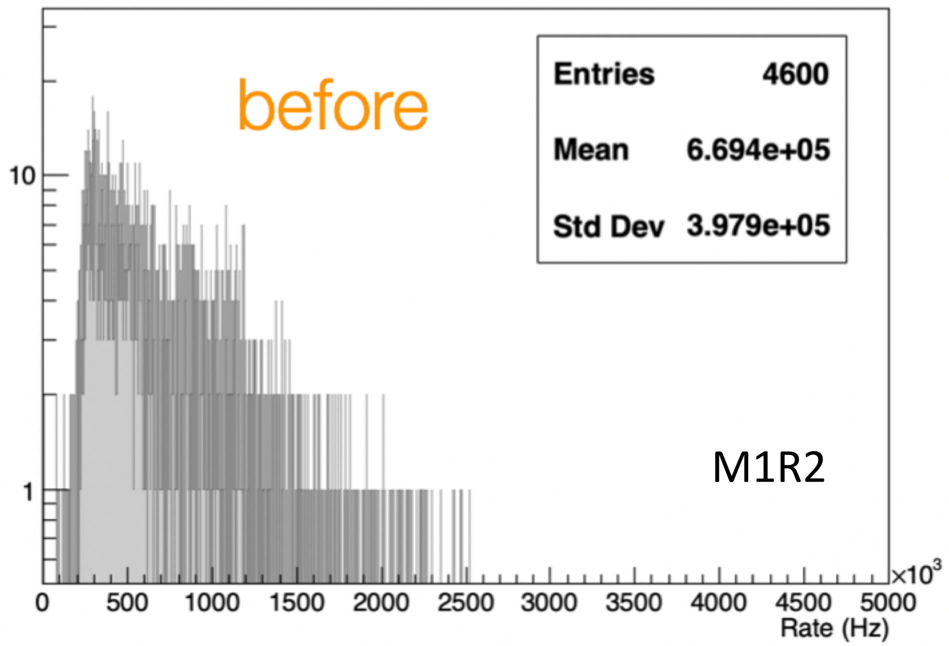
Luminosity measurements from calorimeter

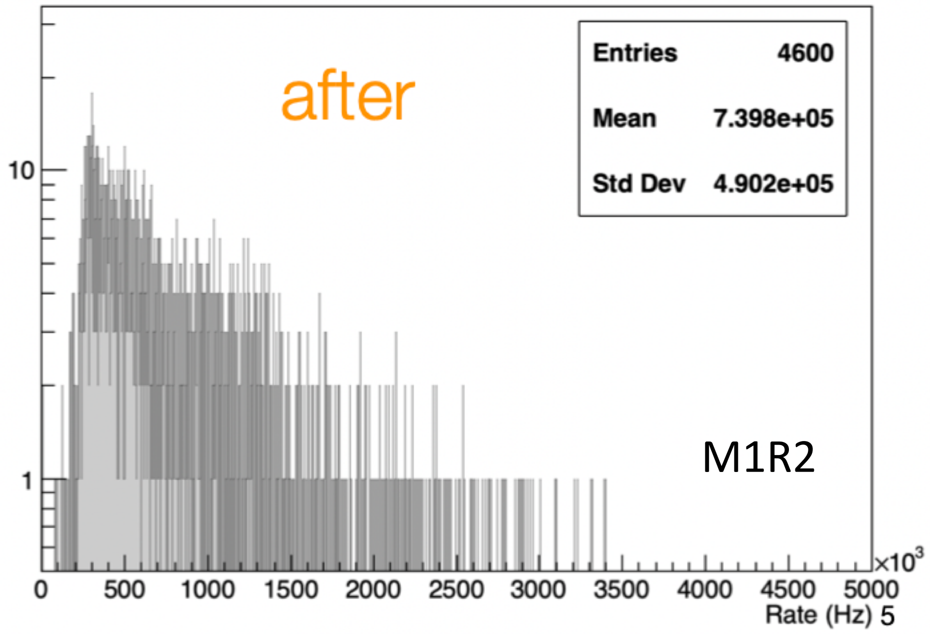


One of the fills of 2018

Rates distribution before & after deadtime correction

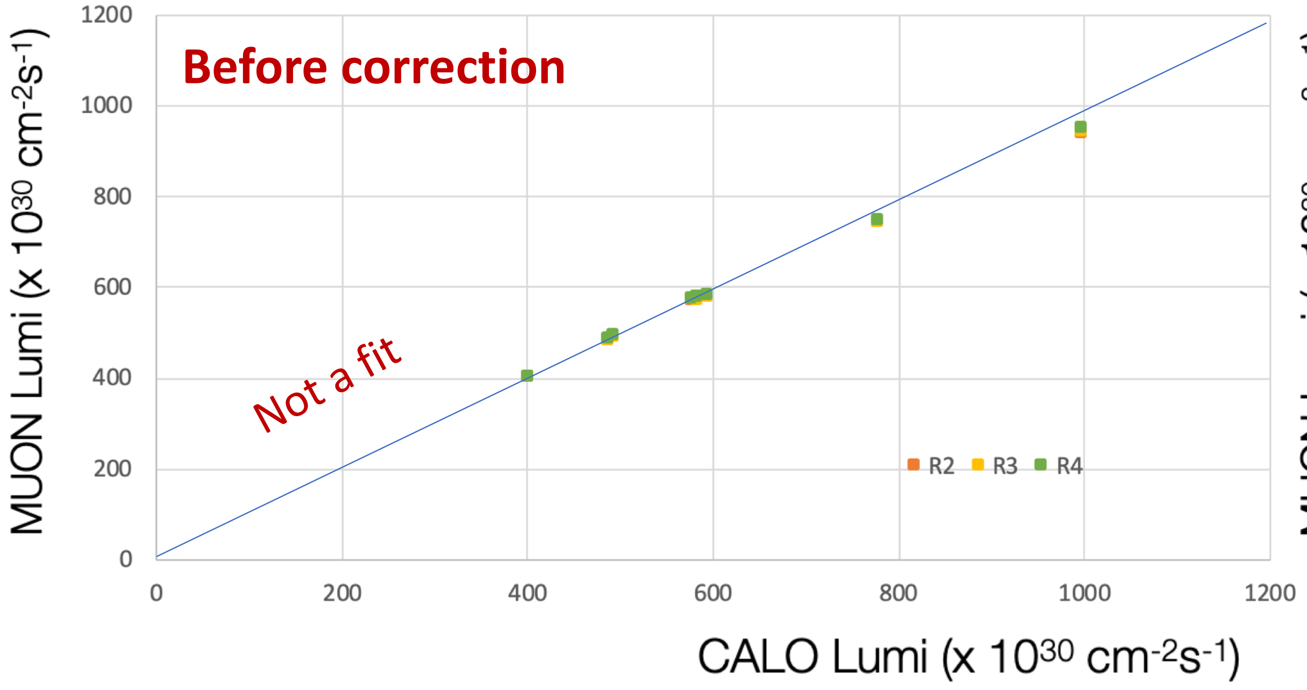
In order to take correctly into account the dead time effect, it has to be corrected channel-by-channel (not in average);

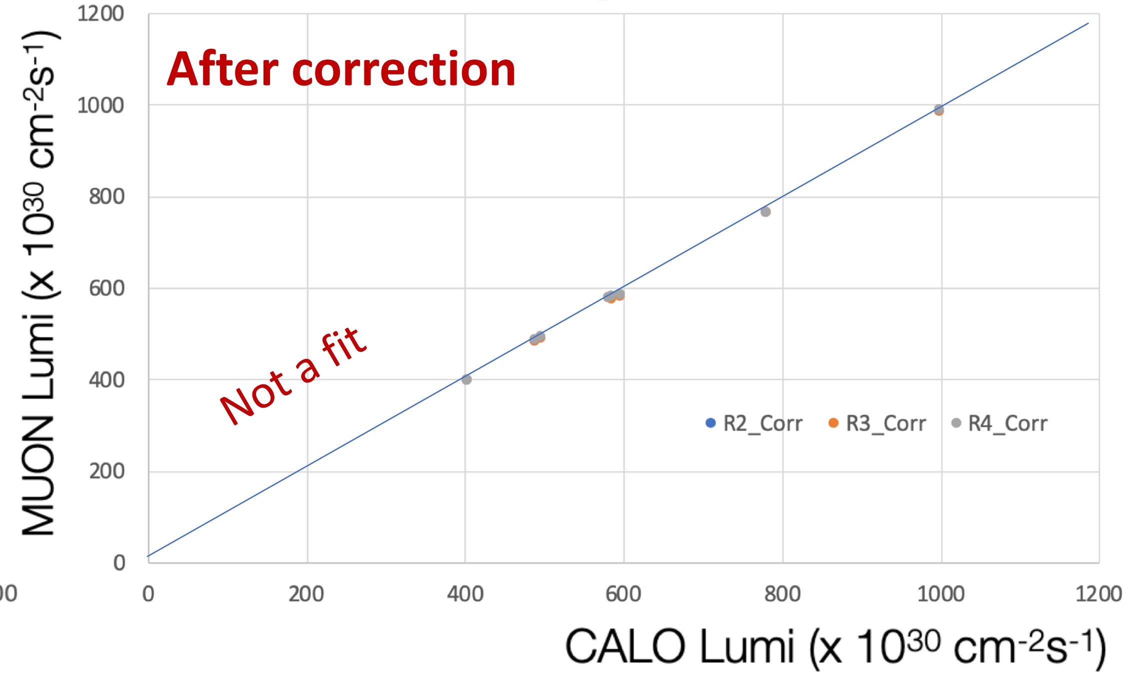




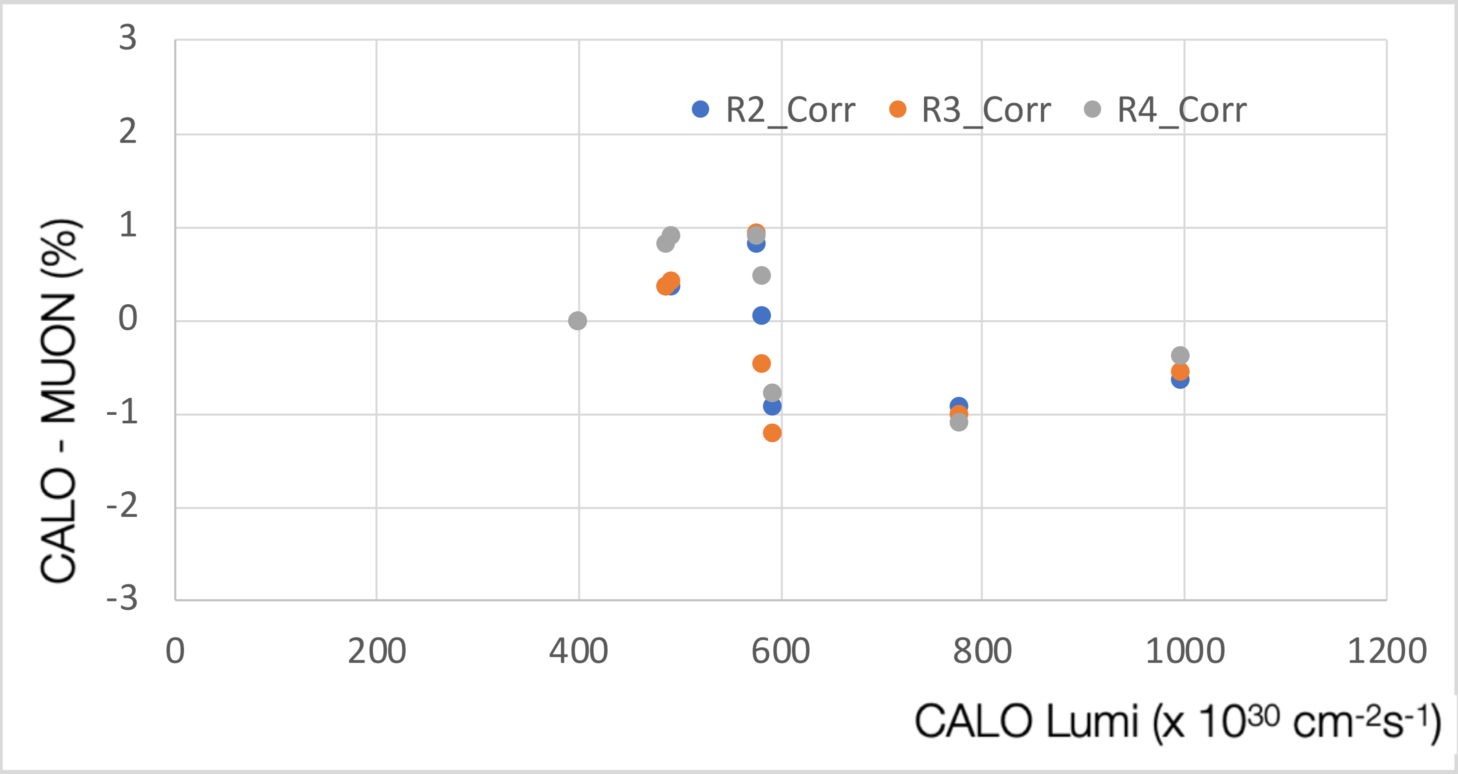
LHCb luminosity: MUON vs CALO

- The mean values of these distributions are plotted (before and after deadtime correction) w.r.t calorimeter measurements for M1 (2012)



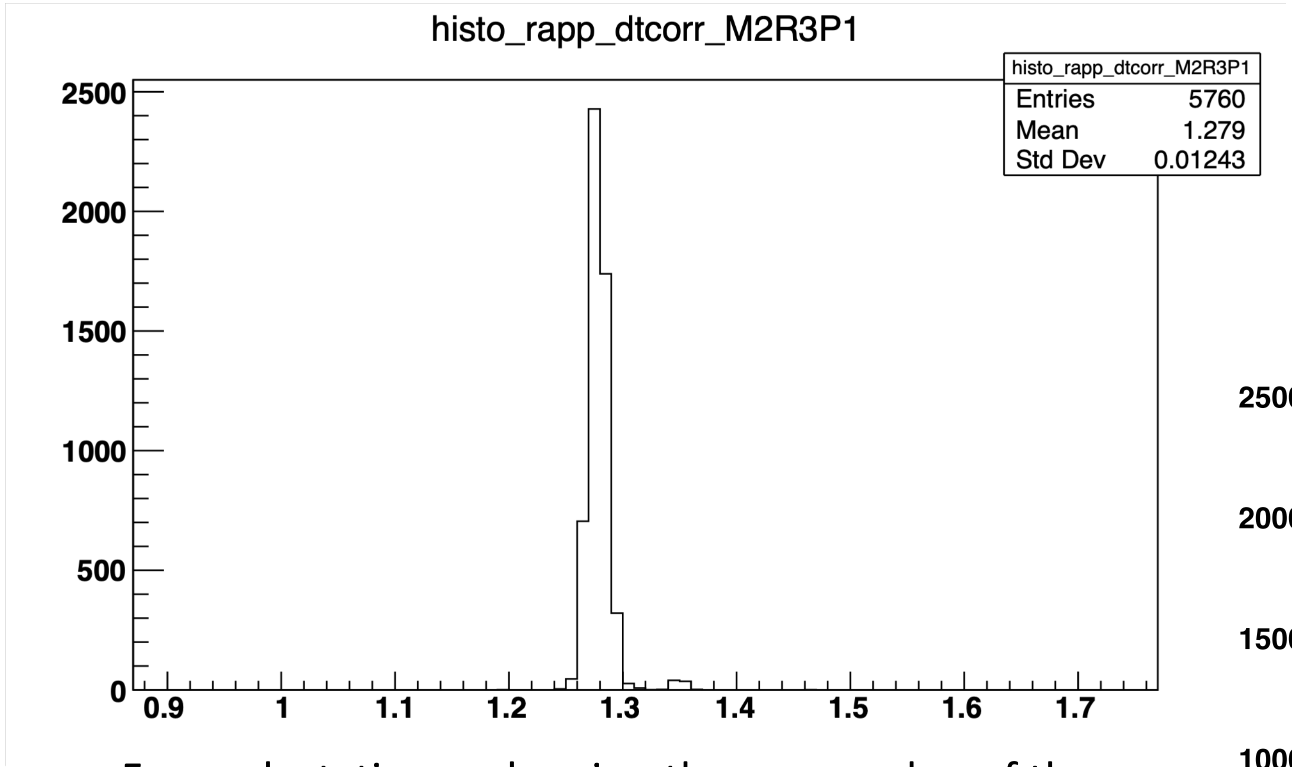


The difference (%) between the MUON and CALO measurements

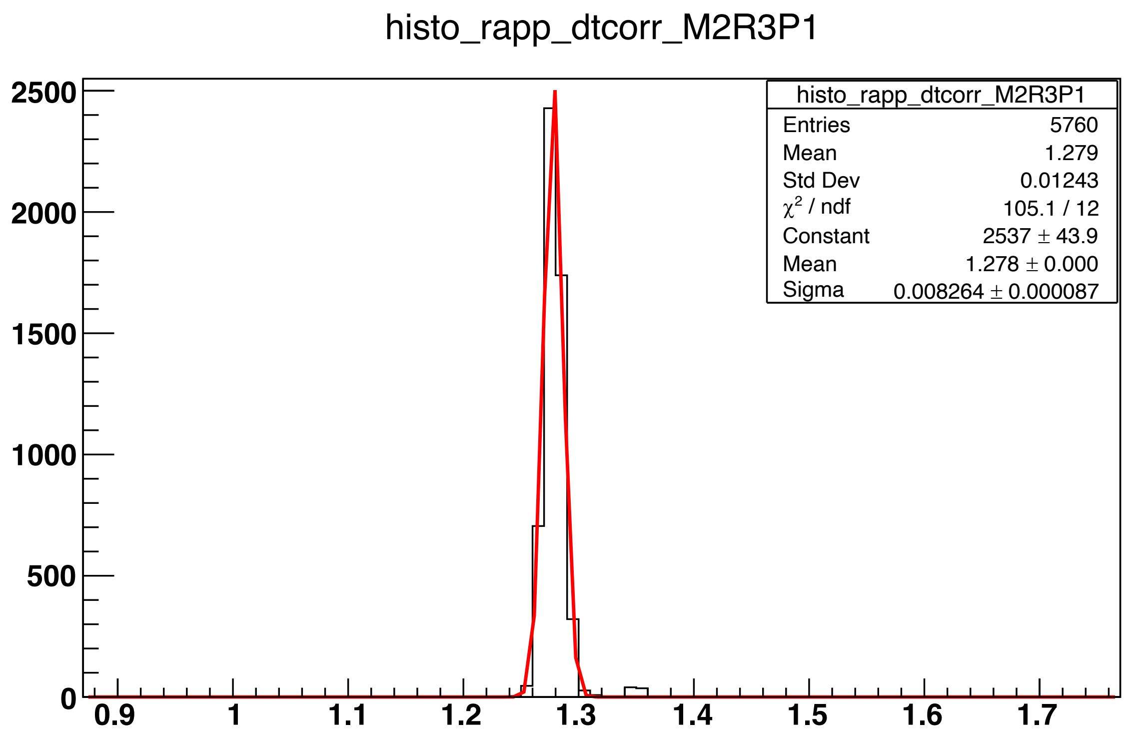


In the whole measured range, less than 1% difference

Self-consistency of the muon system

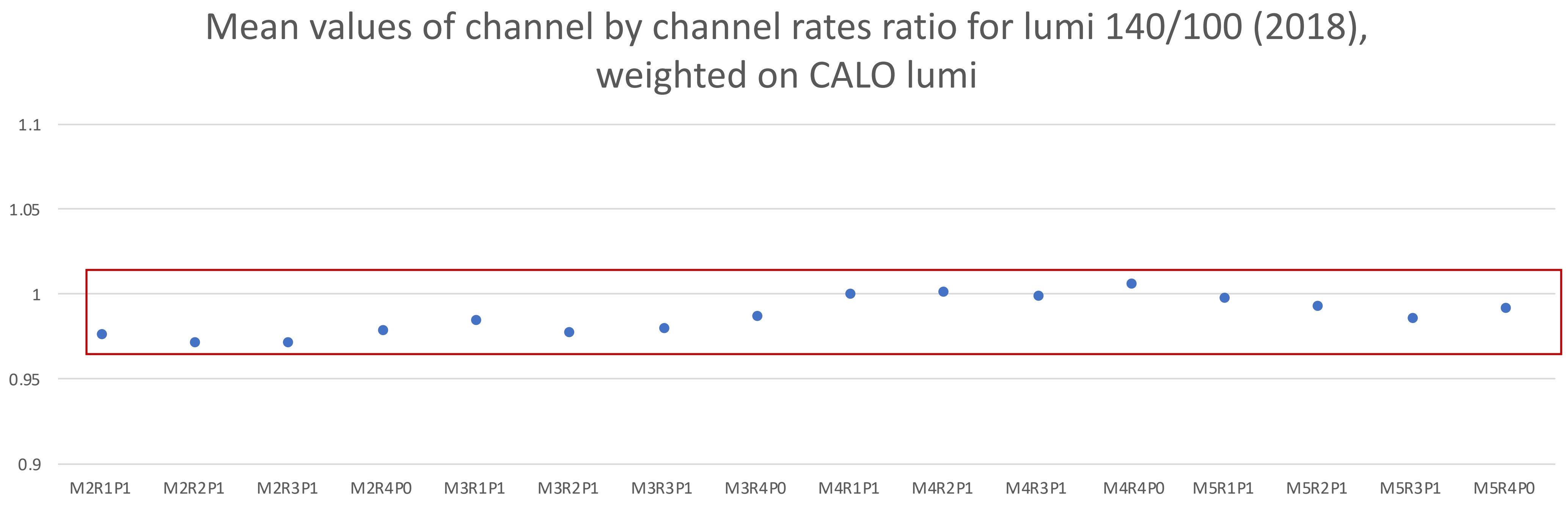


<-The method has a resolution of ~1%

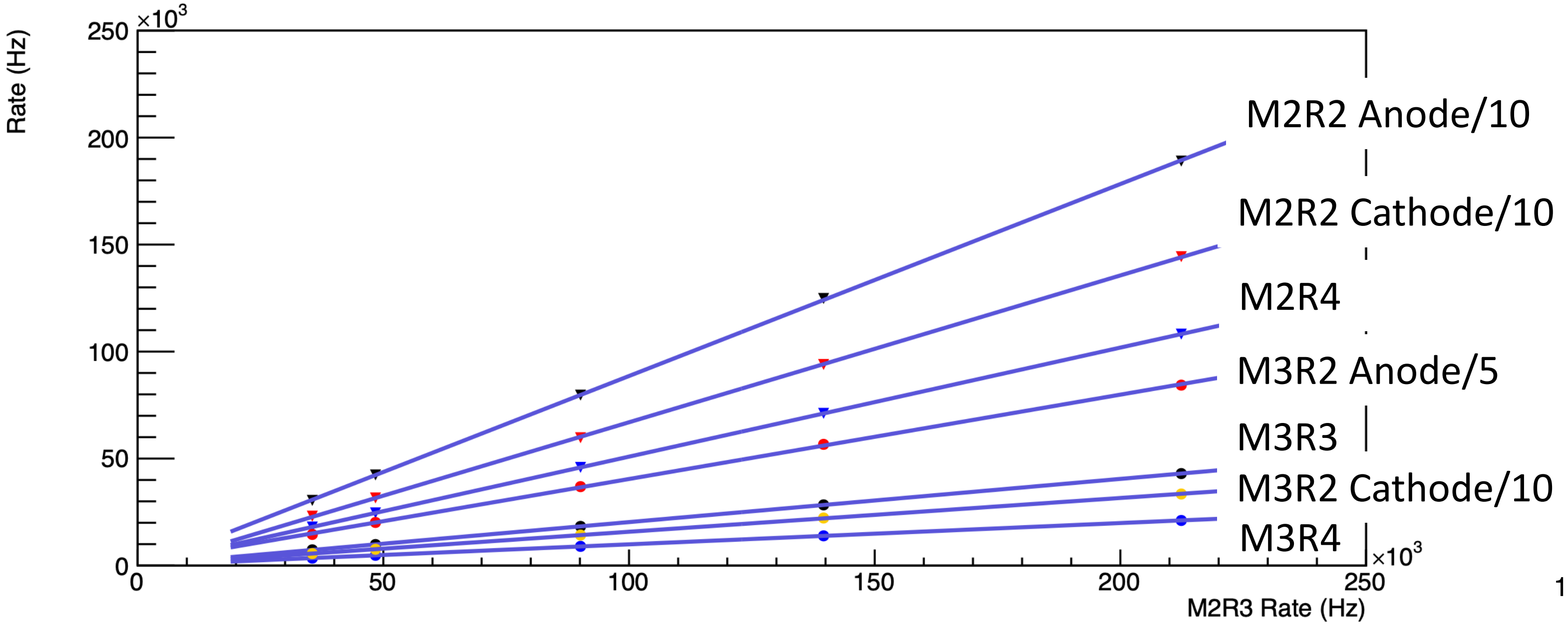


For each station and region the mean value of the channel by channel ratio of the rates taken at different luminosity for all regions.

Stability of the method in different regions

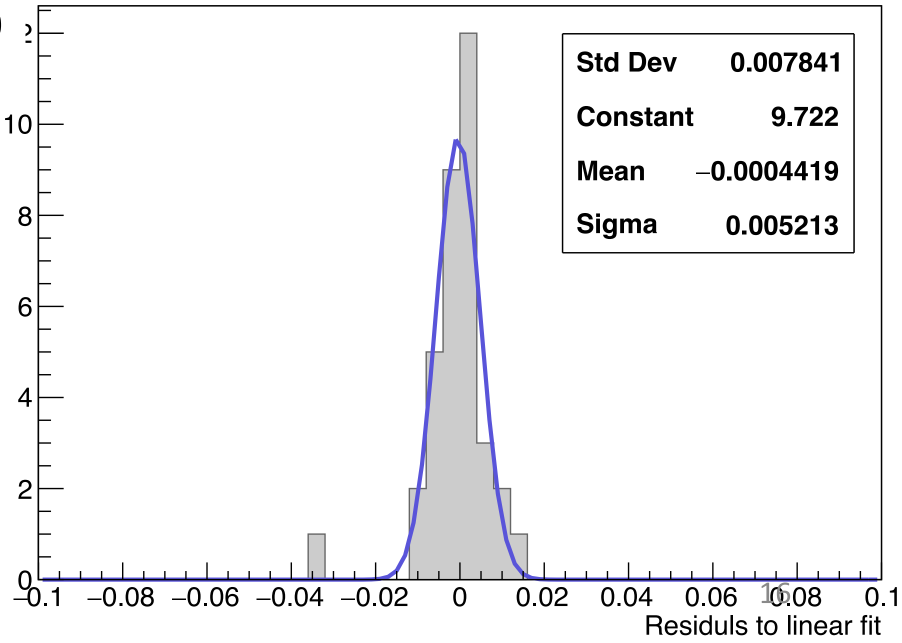


Self-consistency of the muon system



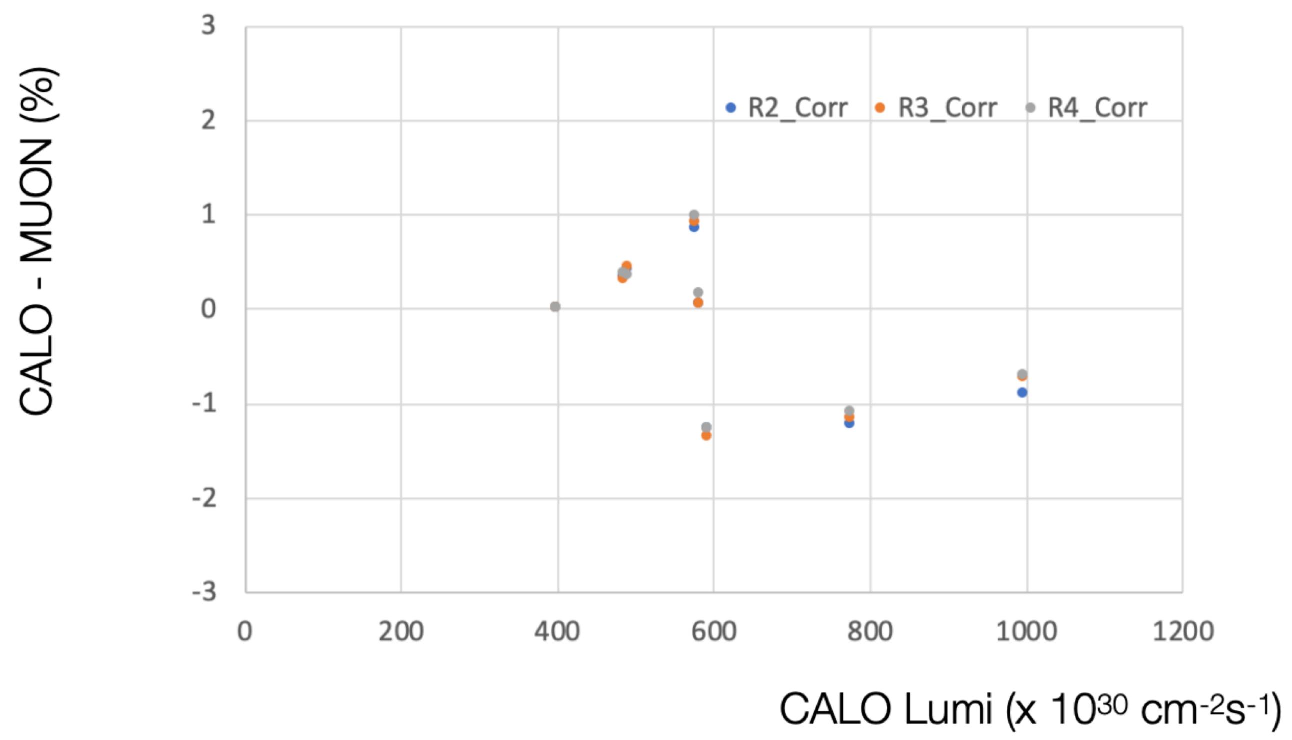
Correlation between measured rates at the different luminosities

The distribution of the relative difference between absolute rates and the linear fit



High speed measurement with a few chambers

- In order to have a fast version of the method, since the readout of the whole system takes ~20 minutes, we tried to analyze the data from only two chambers per region.
- Measured difference is around 1%



Conclusion and next steps

- In runs taken in 2012, the average rates in different regions (corrected for the dead time) are very good independent estimators of the LHCb Luminosity;
- The study of the 2018 data is ongoing
- The results are self-consistent within the whole muon system
- Even a few chambers can be used for these measurements

Next steps:

- Finish the analysis of 2018 data w.r.t CALO
- Perform a new scan in 2021