The Radiation Monitoring System for the LHCb Inner Tracker

Oleksandr Okhrimenko[1], V. Iakovenko[1], V. Pugatch[1], F. Alessio[2], G. Corti[2]

[1]Institute for Nucler Research, Kyiv, Ukraine, [2]CERN, Geneva, Switzerland

okhrimenko@kinr.kiev.ua

I Introduction

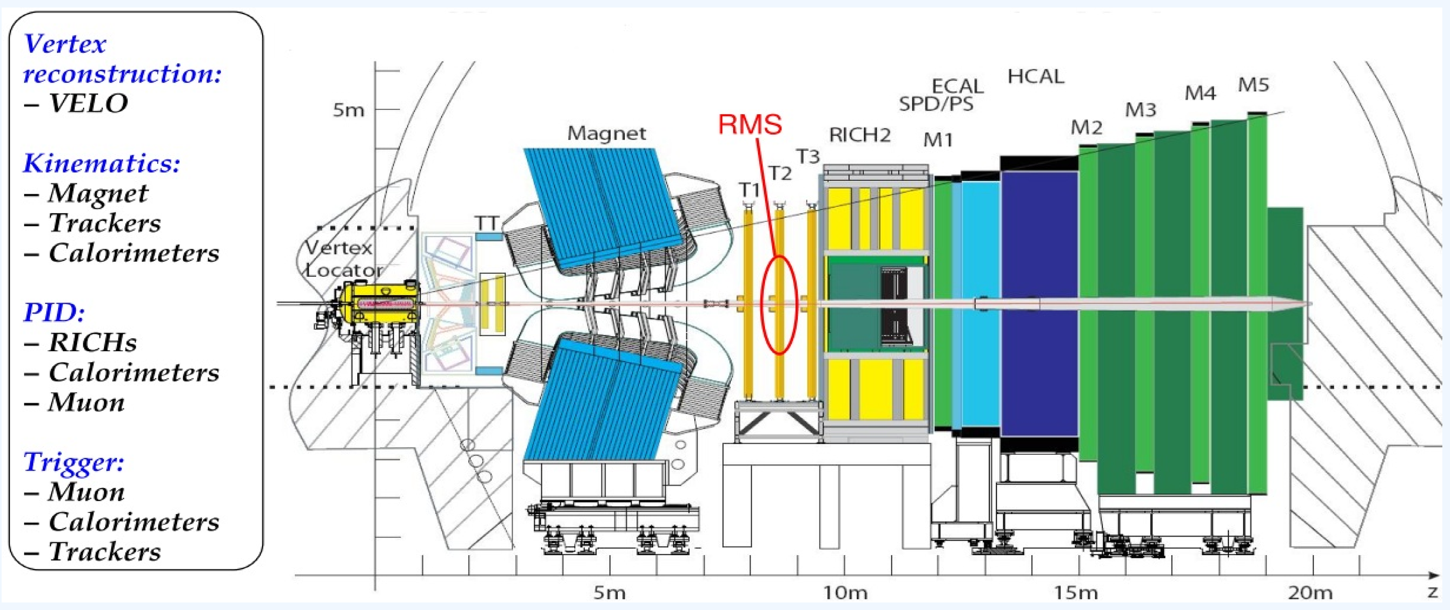

Fig. 1: The LHCb detector.

LHCb's main aim: CP-violation and rare B-decays.
pp-collisions, $E_{CM} = 1 \rightarrow 7 \rightarrow 14$ TeV, $L = 2\times10^{32}$ cm^{-2}s^{-1}.

Inner Tracker:
– Si-sensors (11×7.5 cm, 300 µm thick) with pitch 198 µm, spatial resolution is ~ 50 µm.
– Expected charged hadron fluxes ~ 10^4–10^5 cm^{-2}s^{-1}.

It requires radiation dose monitoring:
– Permanent measurement of the distribution of doses over Si-sensors with accurcy better then 10% during 10 years.
– On-line information with warning and alarm messages.
– On-line displaying as well as off-line storage.

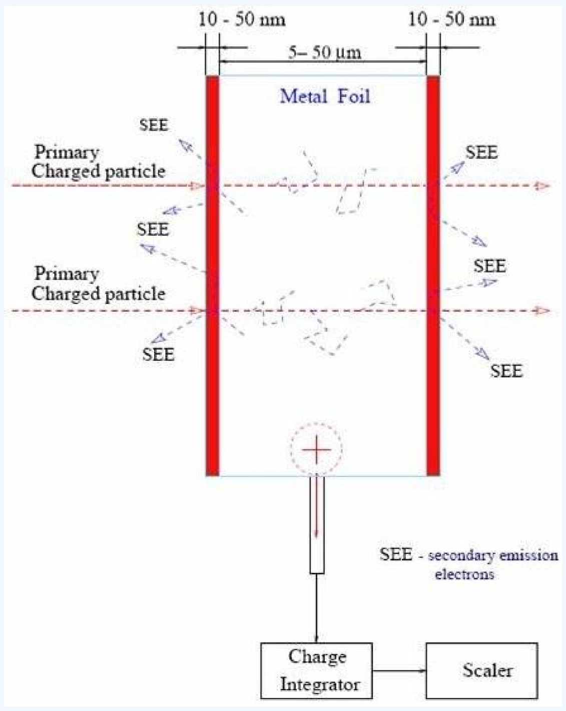

Fig. 2: Principle of MFD operation.

MFD comprises a metal foil connected to the sensitive Charge Integrator (ChI).
Principle of operation: Secondary Electron Emission (SEE) from metal foil surface (10–50 nm) caused by impinging particles.

MFD is an ideal detector for measuring charged particle fluxes excceding 5×10^3 s^{-1} per sensor

Advantages of MFD for radiation monitoring:
– High radiation tolerance: up to 1 MGy.
– Simple readout: ChI and scaler.
– Low mass: 5 Al-foils of 50 µm thick.
– Low operation voltage: 20 V.
– Low cost.

Radiation Monitoring System:
– 4 modules contain 7 MFD-sensors, as result 28 channels, in total.
– Sensor size: 11×7.5 cm.
– ChI is equipped by voltage-to-frequency converter—10^6 dynamic range.
– 250 pA calibration current causes 25 kHz base line.
– 300 MIP/cm^{2}s—10 Hz of signal.
– Linear response up to 1.2 MHz.

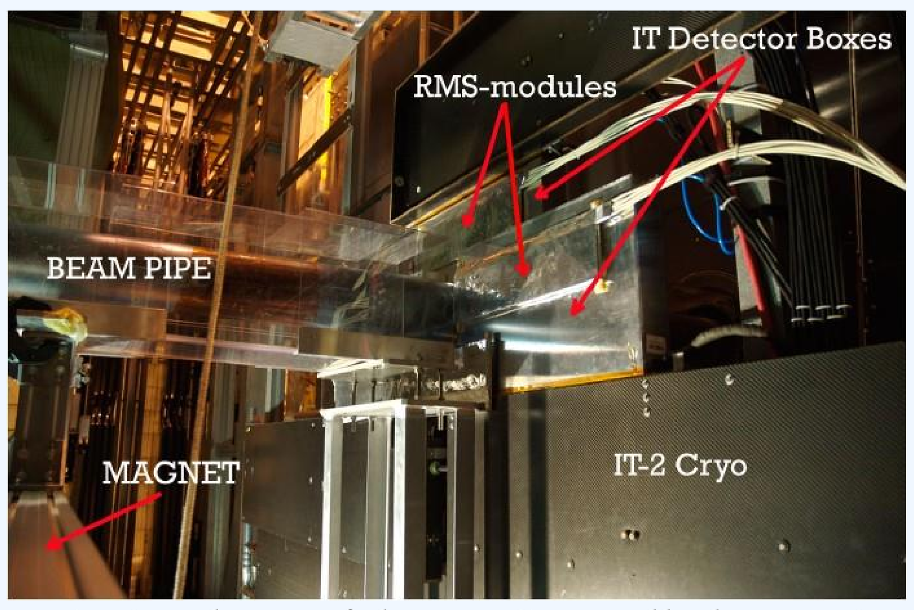

Fig 3: Photo of the RMS installed at IT-2.

II Dose Distribution and Luminosity Measured by the RMS

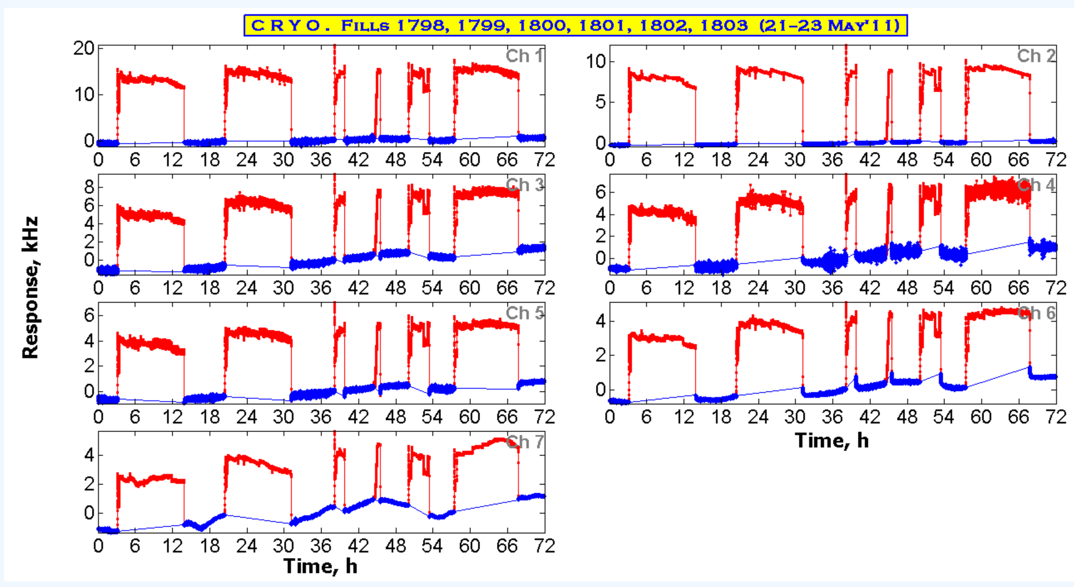

Fig. 4: RMS responce on pp-collisions at 7 TeV.

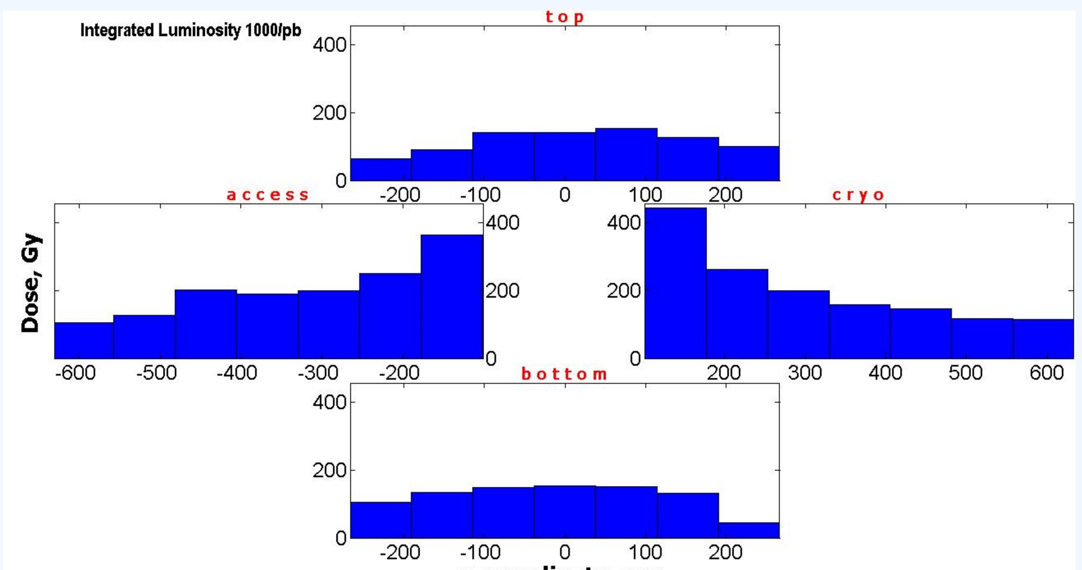

Fig. 5: Absorbed dose distribution over IT Si-sensors measured by the RMS in 2011 (1 fb^{-1}). The shape of the fluence and leakage current increasing distributions is similar to absorbed dose one.

– **RMS's main goal is to control of the radiation load on IT Si-sensors.**

– Formulae to calculate using RMS data the Fluence *f*, Absorbed Dose *D* and Leakage Currens Increasing *ΔI*, respectively:

- $f\,[MIP/cm^2] = 30\times Counts_{RMS}$;
- $D[Gy] = 0.266\times f\times10^{-9}$;
- $\Delta I[\mu A] = 2.5\times10^{-11}\times f\times V[cm^3]$.

– Estimation of the *f* and *ΔI* from *D* (see Fig. 5) resulting in **0.4–1.5×10^{12} MIP/cm^2** and **25–200 µA**, respectively.

– This requires Si-sensors **cooling down** and **bias voltage tuning** to keep reliable operation of the IT.

– The *D* and *ΔI* agree well with MC data and ST measurements, respectively.

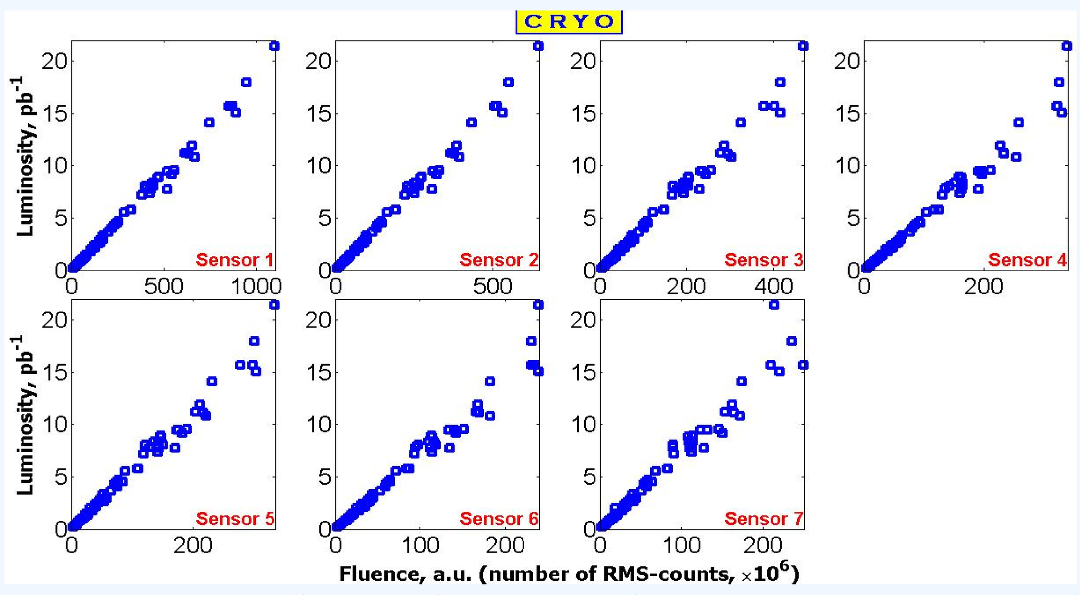

Fig. 6: Correlation between the RMS response and the LHCb measured integrated luminosity in 2011. The response from Cryo-module sensors is presented for illustration.

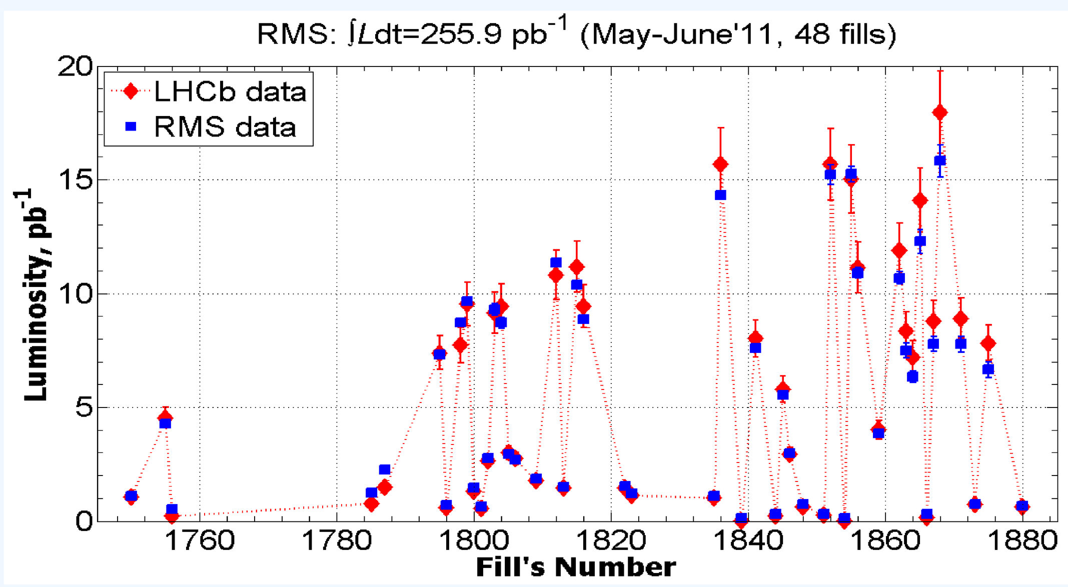

Fig. 7: Integrated luminosity measured by the RMS in comparison with LHCb's data.

– **The RMS's additional application is a Integrated Luminosity measurement.**

– In 2010 RMS data have shown linear correlation between RMS response and LHCb Luminosity (similar to as showed in Fig. 6)—**calibration of the RMS was done.**

– **It is planned to add RMS to on-line monitoring of the Integrated Luminosity.**

– RMS's Luminosity data are in good agreement with LHCb one.

III Monte-Carlo for the RMS

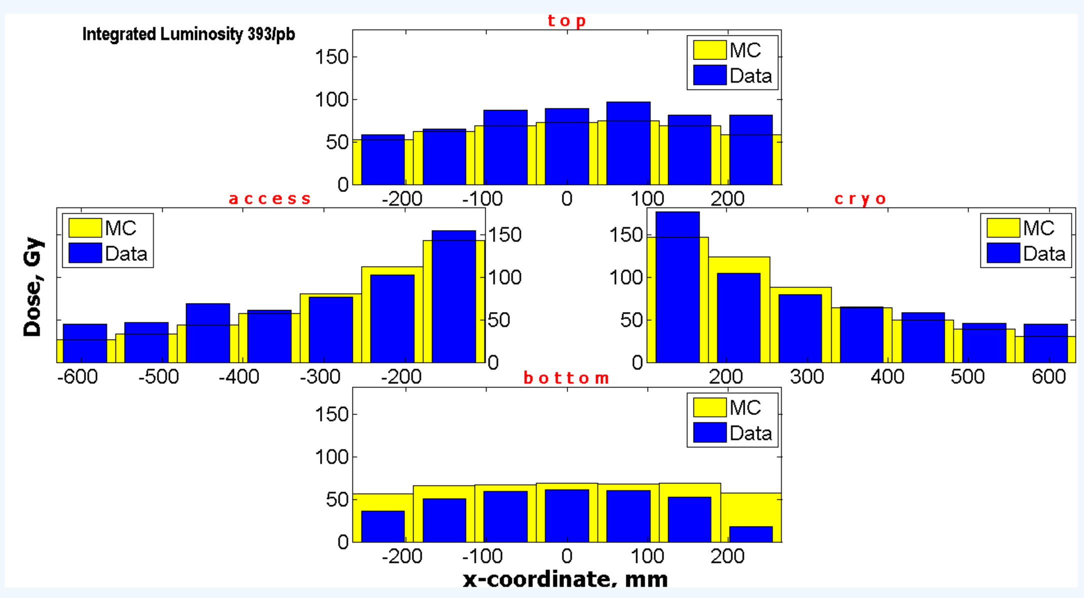

Fig. 8: Comparison between RMS real and MC simulated data.

Using standard LHCb software (**Gauss v38r9**) **10k events** under following condition were generated:
– E_{CM} = **7 TeV**;
– Magnet: **Up** and **Down**;
– ν = **1** and **2.5**;
– only **charged particles**.

Dose distributions are in the good agreement.

IV Summary and Outlook

- **The Radiation Monitoring System has provided monitoring of the radiation load on Si-sensors of the LHCb Inner Tracker in 2011.**
- **RMS data have allowed also to determine the integrated luminosity as well.**
- **The RMS data are in good agreement with data obtained by other detectors as well as with Monte-Carlo simulations.**

– These data are planned to be included into the on-line monitoring of the radiation load and integrated luminosity.

Acknowledgments: We would like to thank Silicon Tracker, Beam & Background groups and the LHCb Collaboration for exciting studies this year. Special thanks to F. Blanc, H. Voss, J. van Tilburg, M. Needham and R. Jacobsson!