Монте-Карло симуляції відгуку RMS-R3 на протон-протоні зіткнення у експерименті LHCb

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Motivation

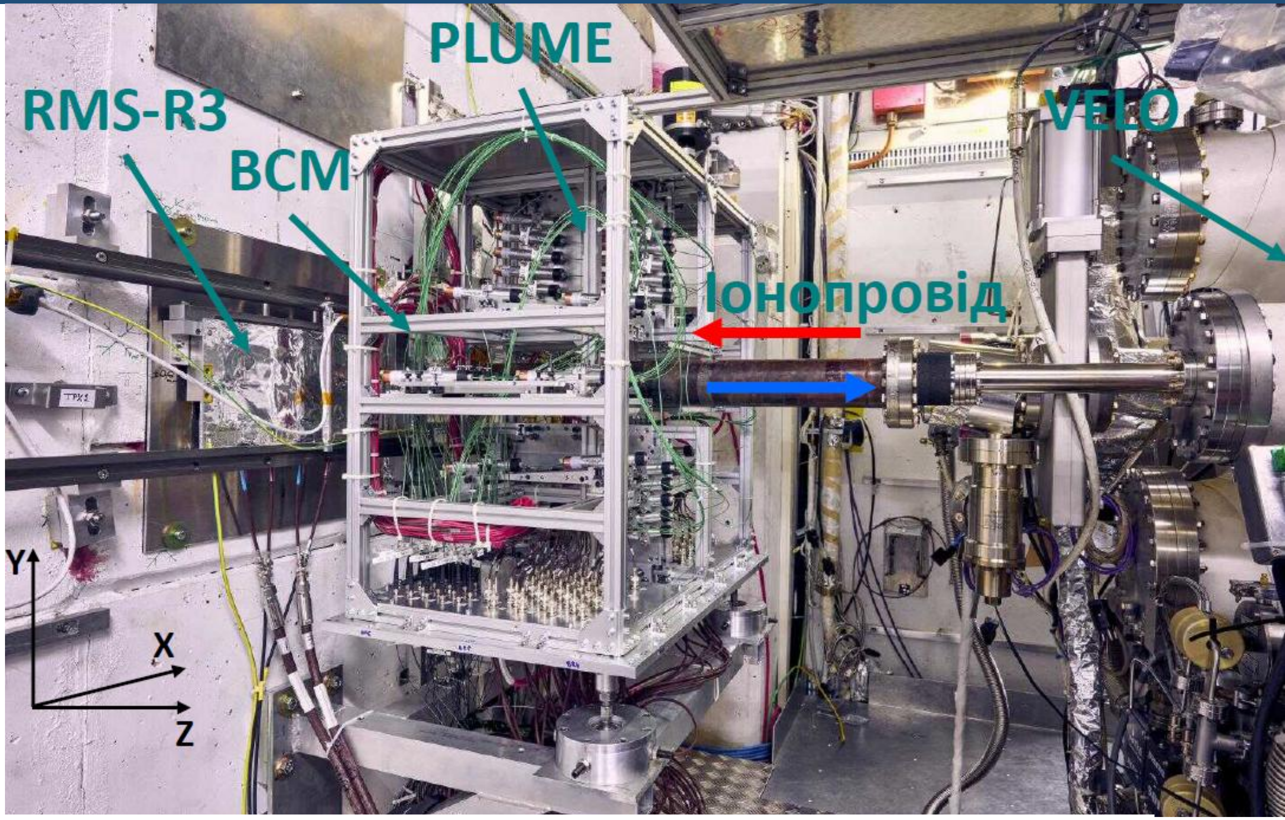
The increased instantaneous luminosity requires special measures for the safety and efficiency of data taking.

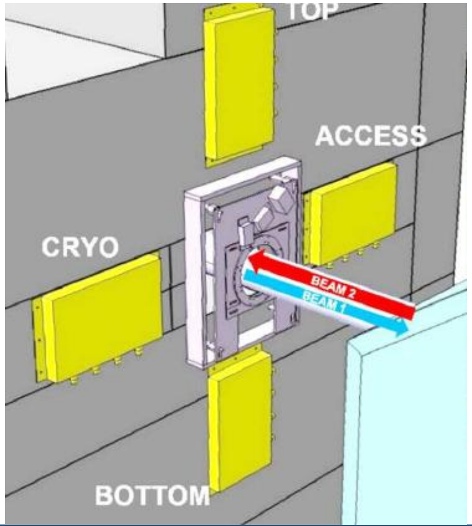
To ensure the successful operation of the LHCb detector, its Beam and Background monitoring systems were also upgraded.

They include the new online luminometer PLUME, the Beam Condition Monitors dumping the LHC beams in case of high backgrounds, and the Radiation Monitoring System (RMS-R3).

Simulations are needed to better understand and predict the response of the detectors to beam collisions.

$$A_{ij} = (R_i - R_j) / (R_i + R_j)$$





Ch1

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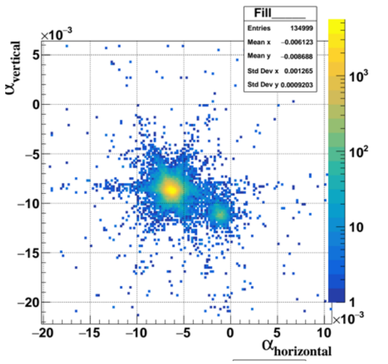

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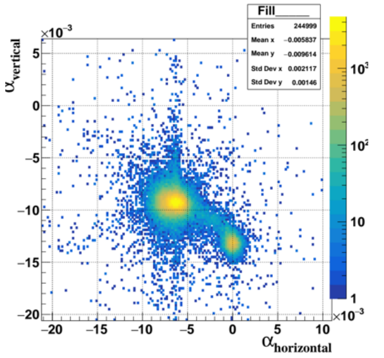

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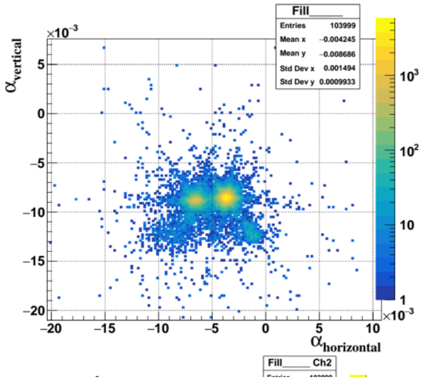
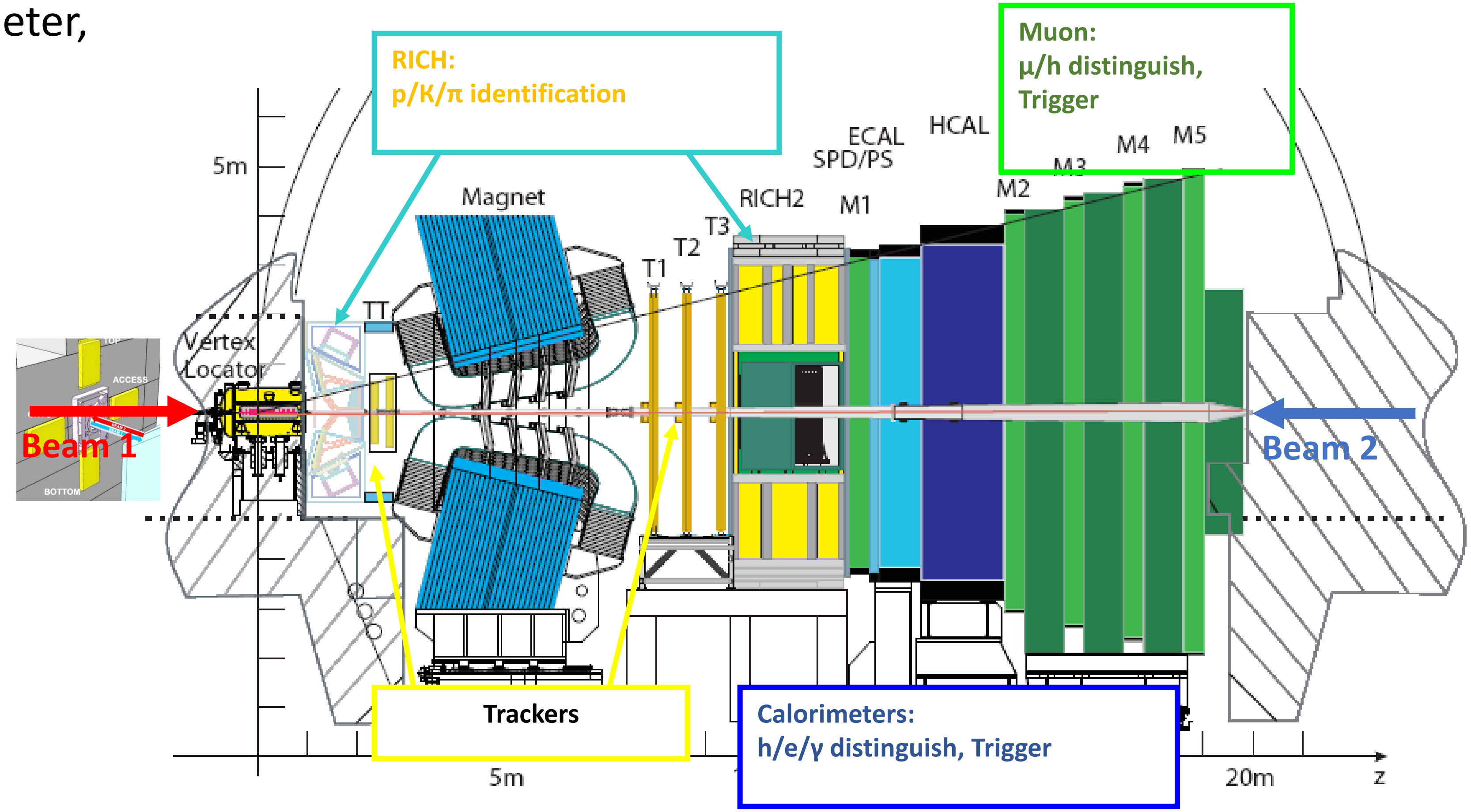


LHCb Experiment

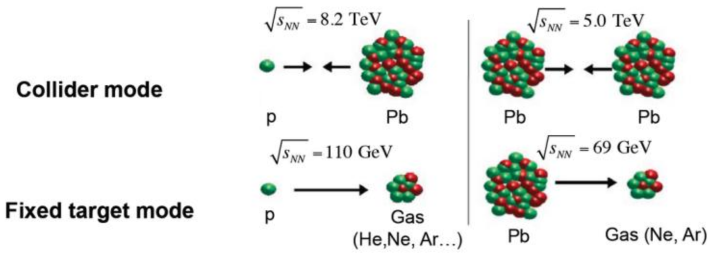
- **LHCb Run 2 [1]** – forward spectrometer, located at LHC.
- Acceptance **$2 < \eta < 5$**
- Proton-proton interaction at up to **$\sqrt{s}$ = 13 TeV,**
  $\mathcal{L} = 4{\cdot}10^{32}$ ($5{\cdot}10^{33}$) cm^{-2}s^{-1}.
- **Goal**: CP violation and rare decays of *B*-mesons.
- **Resolutions [2]:**
  - spatial (PV position): **~ 16 μm**;
  - decay time: **~ 50 fs**;
  - track's momentum: **0.5–0.4%**;
  - mass (FWHM): **~ 13 MeV (J/ψ)**;
  - particle identification: **~ 96%**.

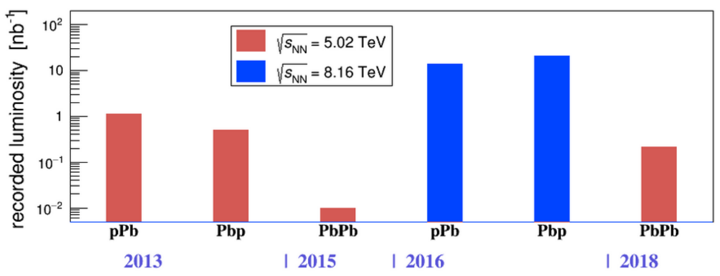


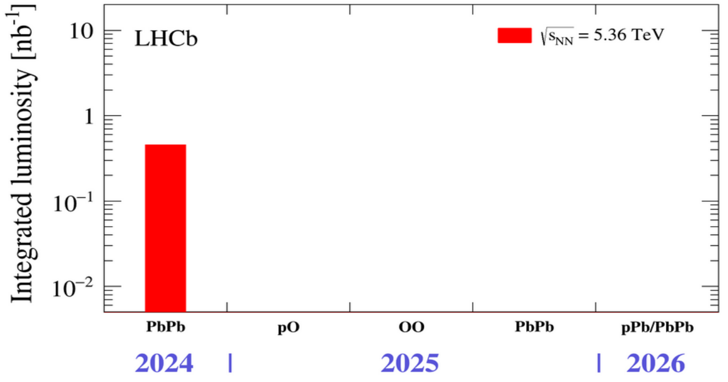
[1]. JINST 3 (2008) S08005.
[2]. Int. J. Mod. Phys. A 30 (2015) 15300227.

Proton-Ion setup at LHCb

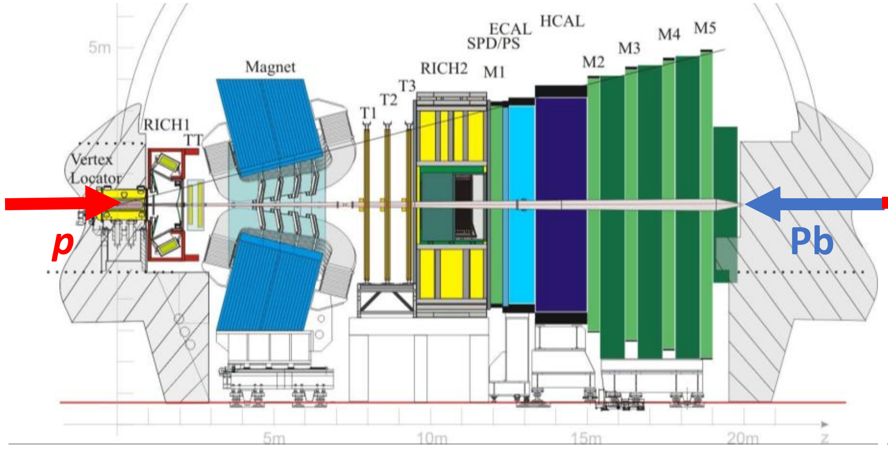
2013 heavy ion run:
Ion = ^{208}**Pb**, E_p = 4 TeV, E_{Pb} = 1.58 TeV →
$\sqrt{s_{NN}}$ **= 5.02** TeV,
$\mathcal{L}_{int}$: **1.1** nb^{-1} (Fwd), **0.5** nb^{-1} (Bwd)



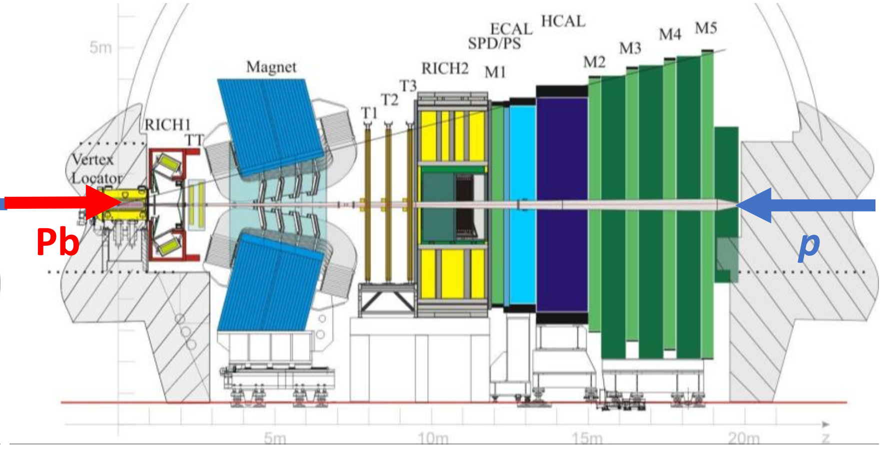


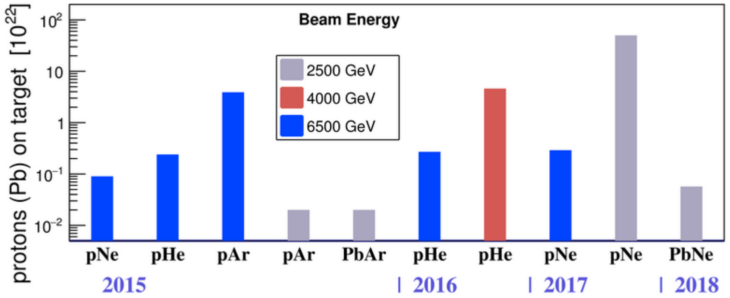


Forward (Fwd, p-Pb)



Backward (Bwd, Pb-p)





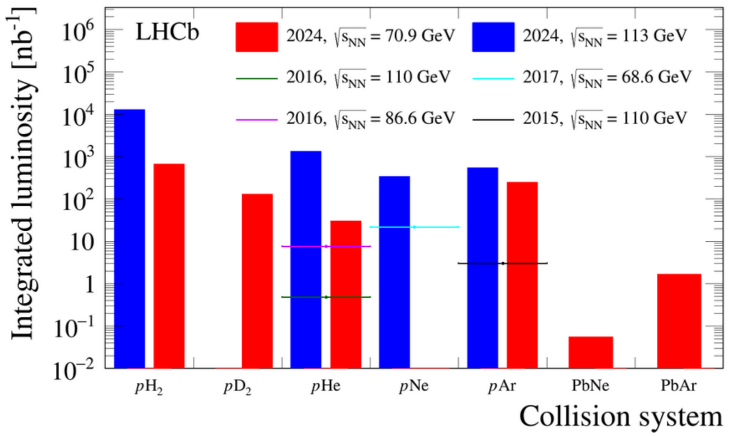
1.5 < y^* < 4.0

$y^* = y_{lab} - 0.465$

0.15 < p_T < 7.0 GeV/c

−5.0 < y^* < −2.5

$y^* = -(y_{lab} + 0.465)$

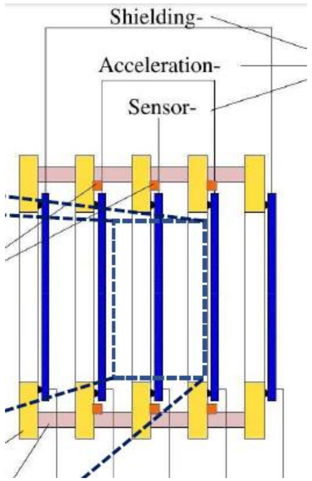


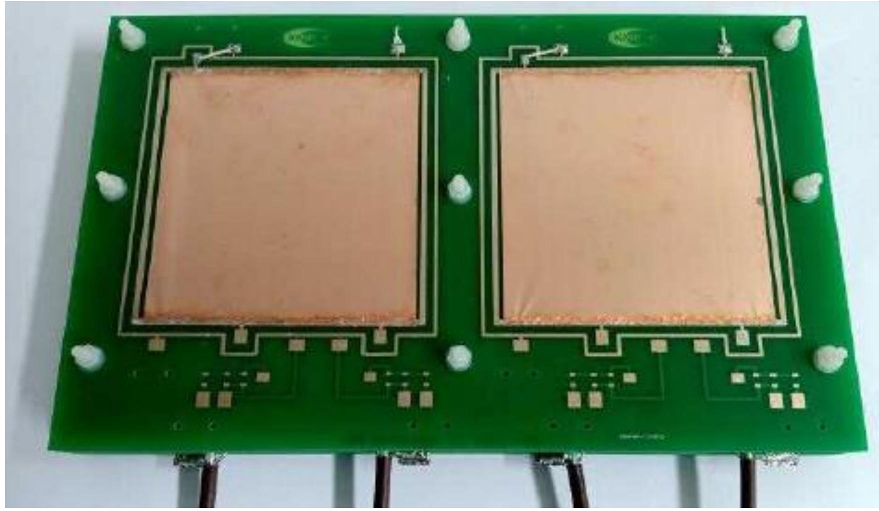
Monte Carlo samples:
20M Minimum Bias simulated events using **EPOS** generator under conditions similar to real ones. [1]

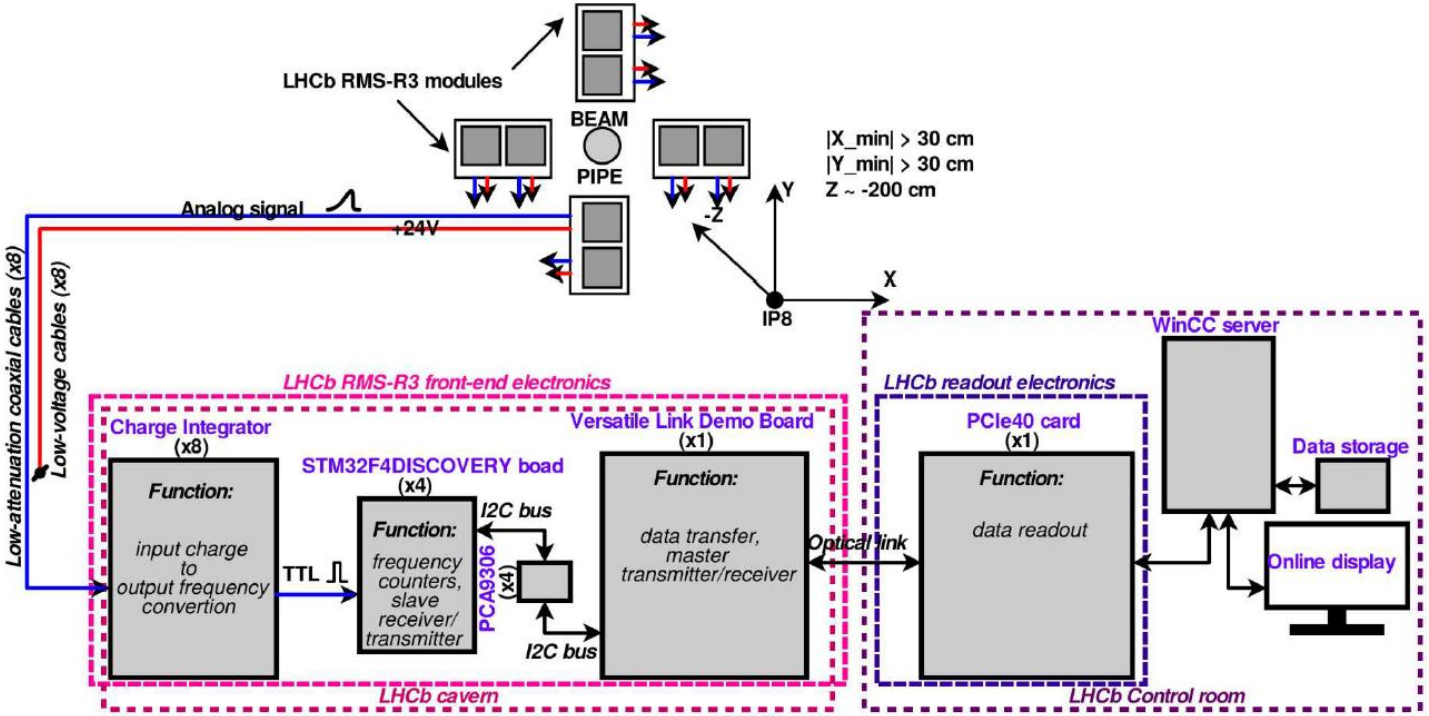
[1]. Phys. Rev. C92 (2015) 034906; arXiv:1306.0121.

RMS-R3 as a beam and background monitoring system

- Being integrated into the LHCb ECS, RMS-R3 responses are displayed online from the Beam & Background Control Panel
- It measures charged particle flux rates from 4 pairs of rad-hard Metal-Foil Detectors positioned symmetrically around the beam pipe on the wall behind the VELO (Z ≈ -2.2 m), while covering a backward acceptance of 7–14 degrees
- Potentially, it aims at measuring:
  - beams interaction rate (relative luminosity);
  - background stability and tendencies;
  - radiation loads
- Top-bottom and left-right 2D asymmetry maps are imaged to monitor reproducibility of the running conditions



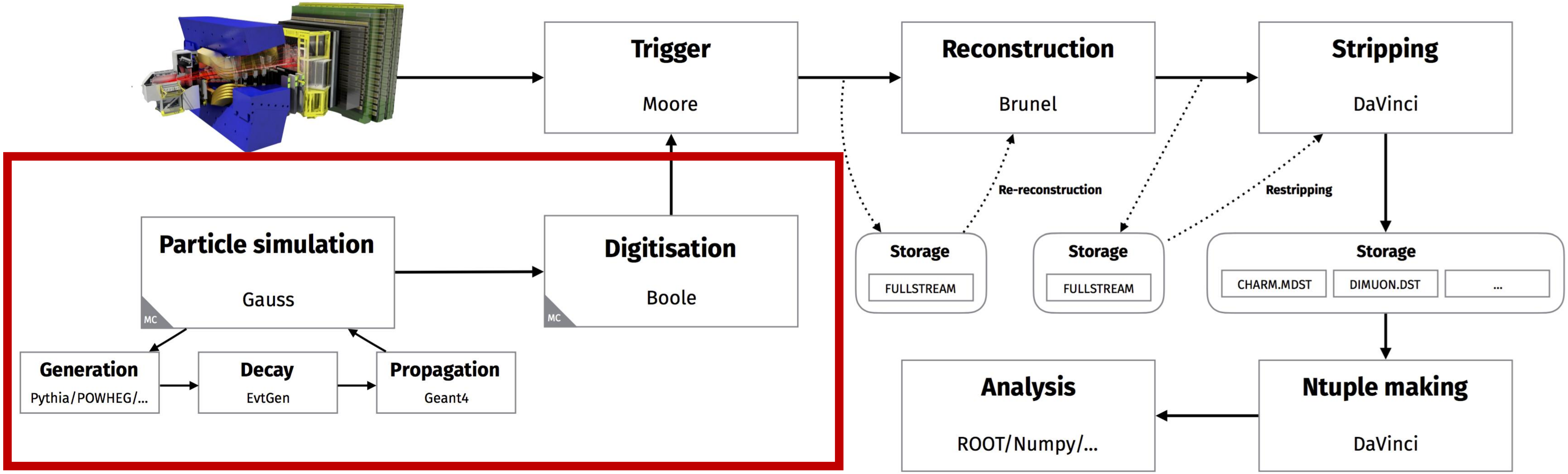




What are the prerequisites for simulations with **DD4hep**?

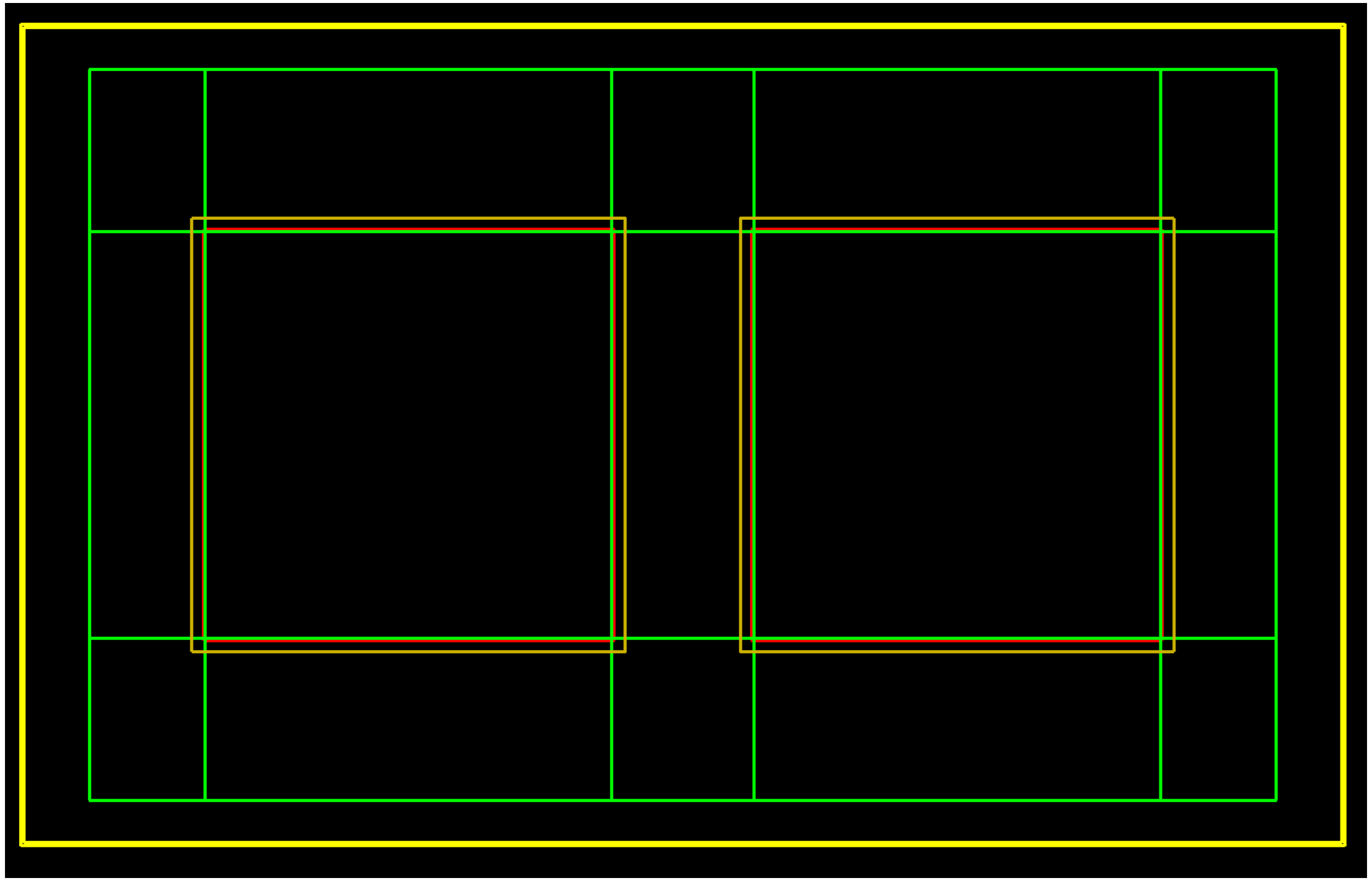
- **Detector project**
    - **xml** files in compact/trunk directory, detector elements with sensitive detector
- **Gauss-on-Gaussino**
    - **Python** configuration file in Sim/Gauss/python/Detectors

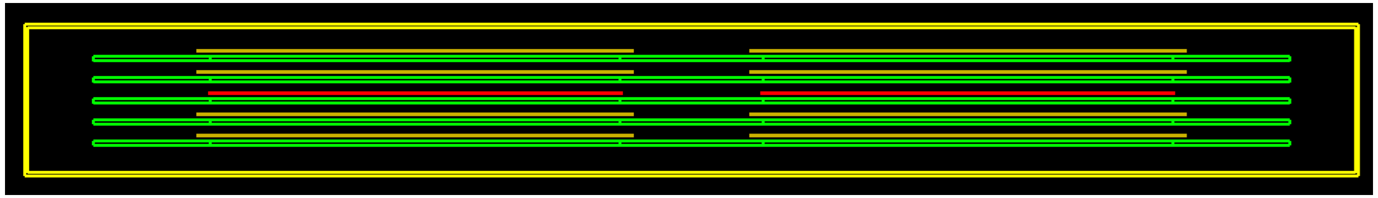
- What happens in Gauss-on-Gaussino?
    - Information from the **xml** files from compact/trunk is merged into one, temporary file and the loaded with **ROOT/TGeo**
    - The geometry gets converted to **Geant4** with DDG4/Geant4Converter



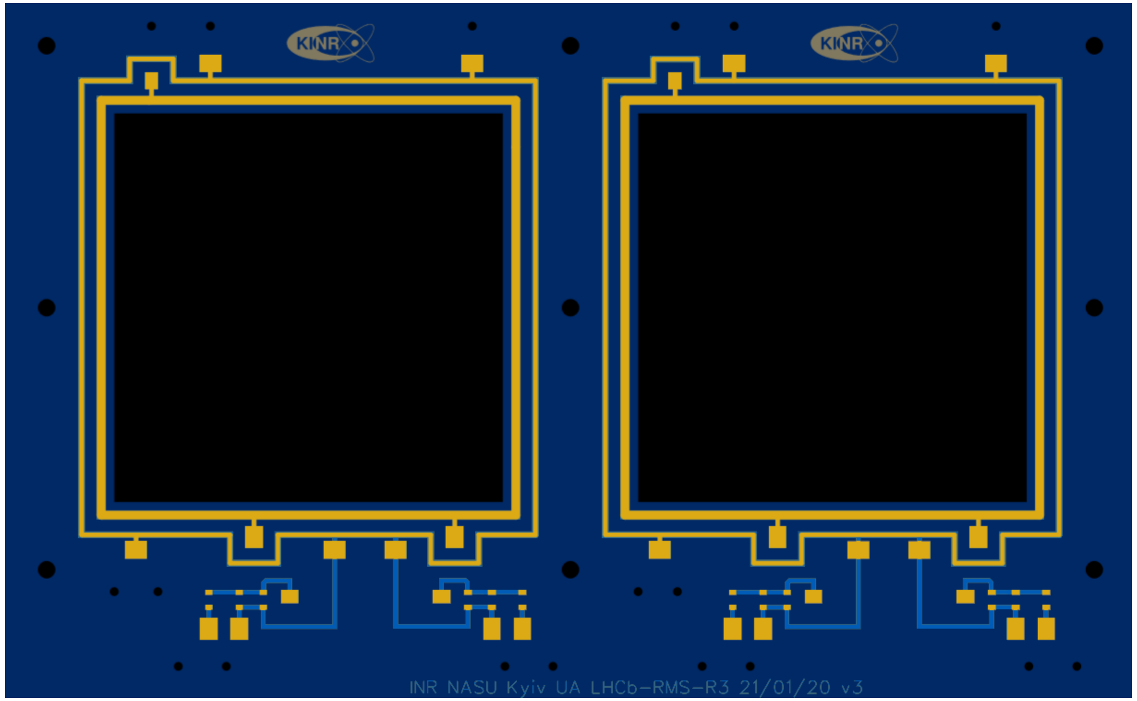
Simulations for the RMS-R3

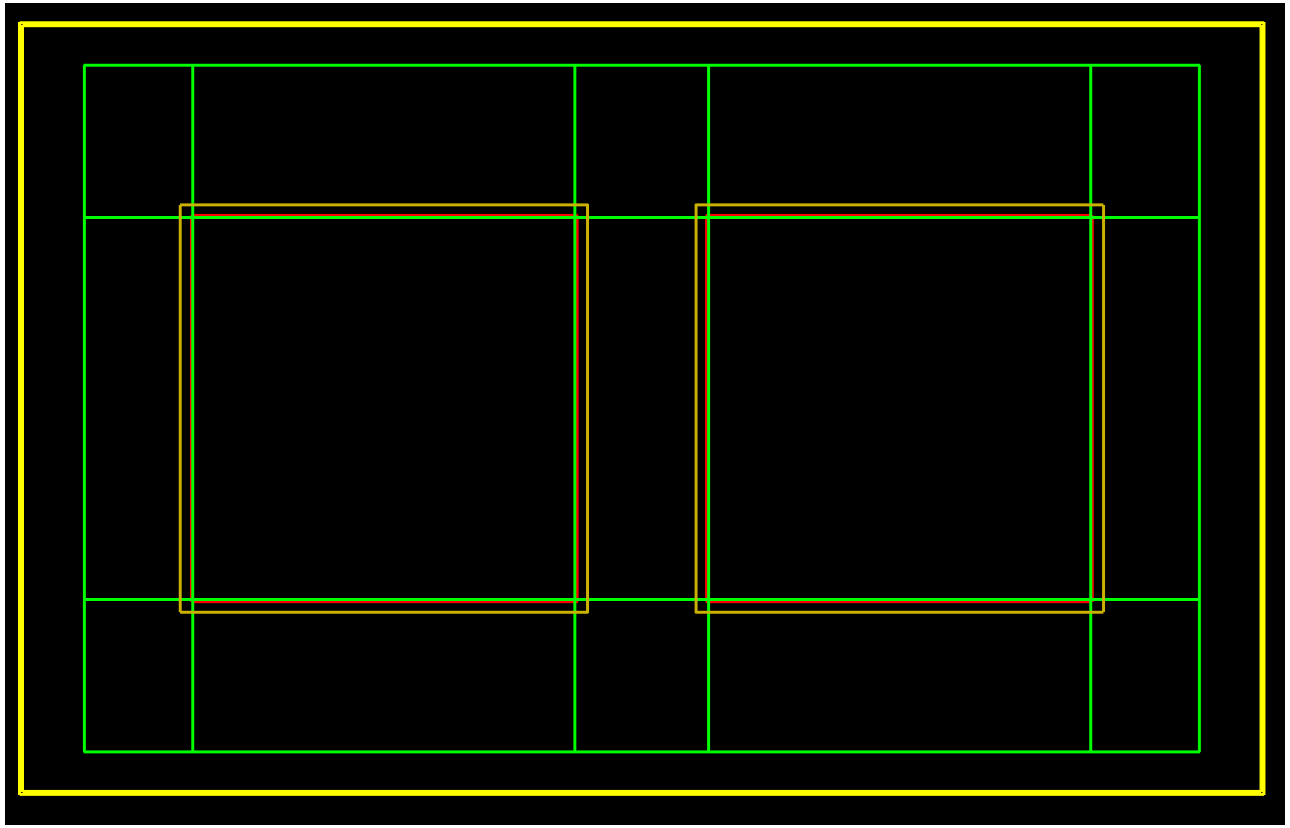
- **lhcb-stack is installed on lx+**
- **Detector** geometry in DD4Hep (Compact XML files in Detector/compact/components/Rms/trunk)
  - **Rms.xml** – **Done**
  - **parameters.xml** – **Done**
  - **detectors.xml** – **Done**
  - Detector/Detector/Infrastructure/src/ **Rms_geo.cpp** to load the compact XML-files – **Done**
- **Gauss** to simulate hits in detector
  - RMS.py is created and monitoring is added
  - __init__.py and Defaults.py are updated
- Both the **Detector** and the **Gauss** are under the merge request (pipeline is fixed)
  - https://gitlab.cern.ch/lhcb/Gauss/-/merge_requests/1142
  - https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/699
- The **Bool** to digitalize the RMS-R3 response

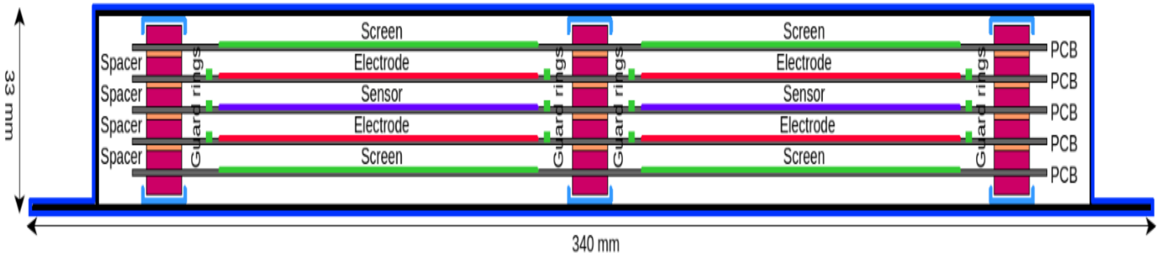


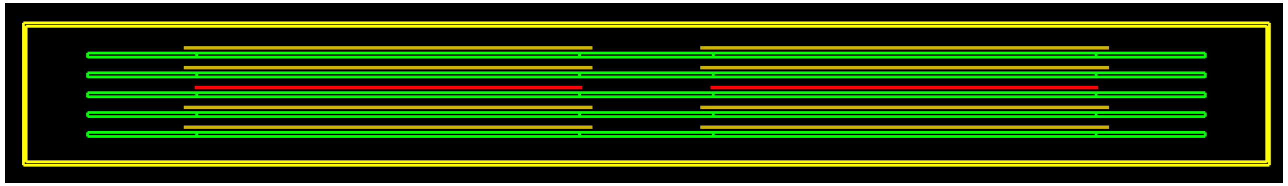


RMS-R3 Module geometry in Real and Simulation



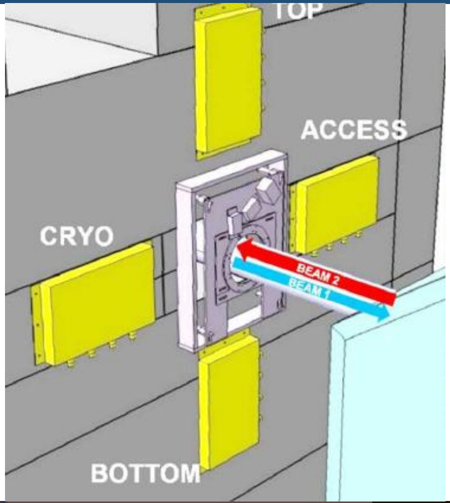


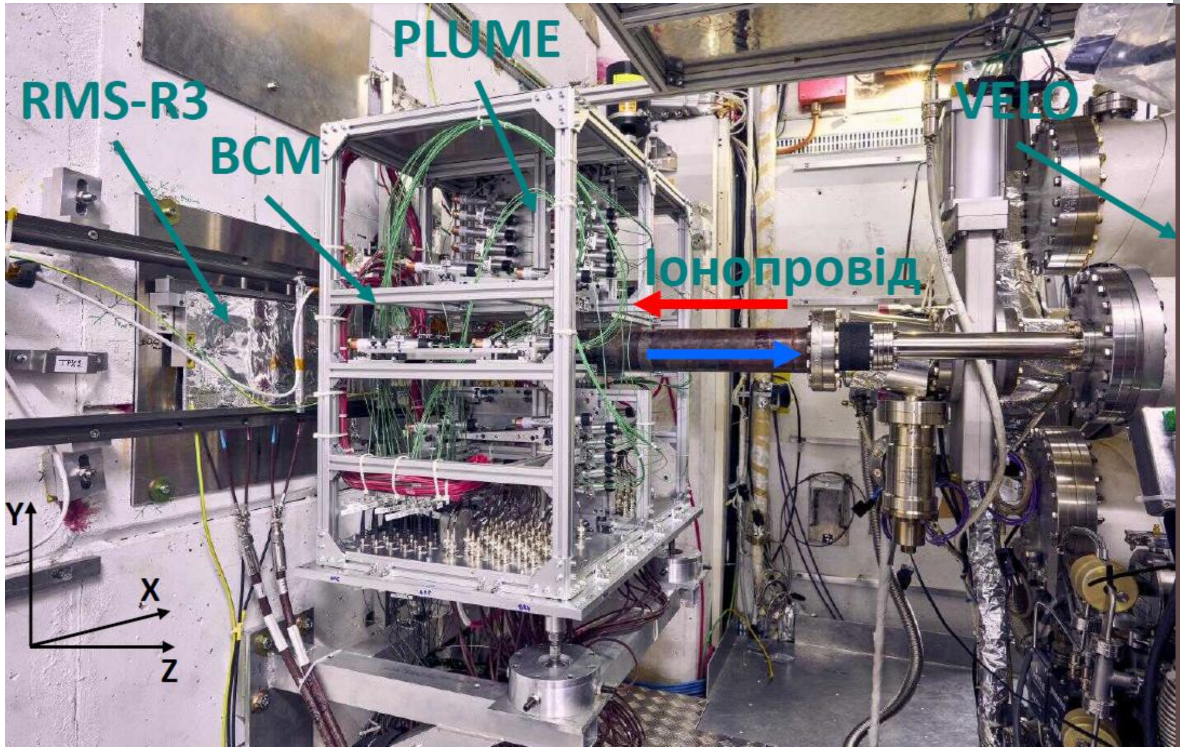


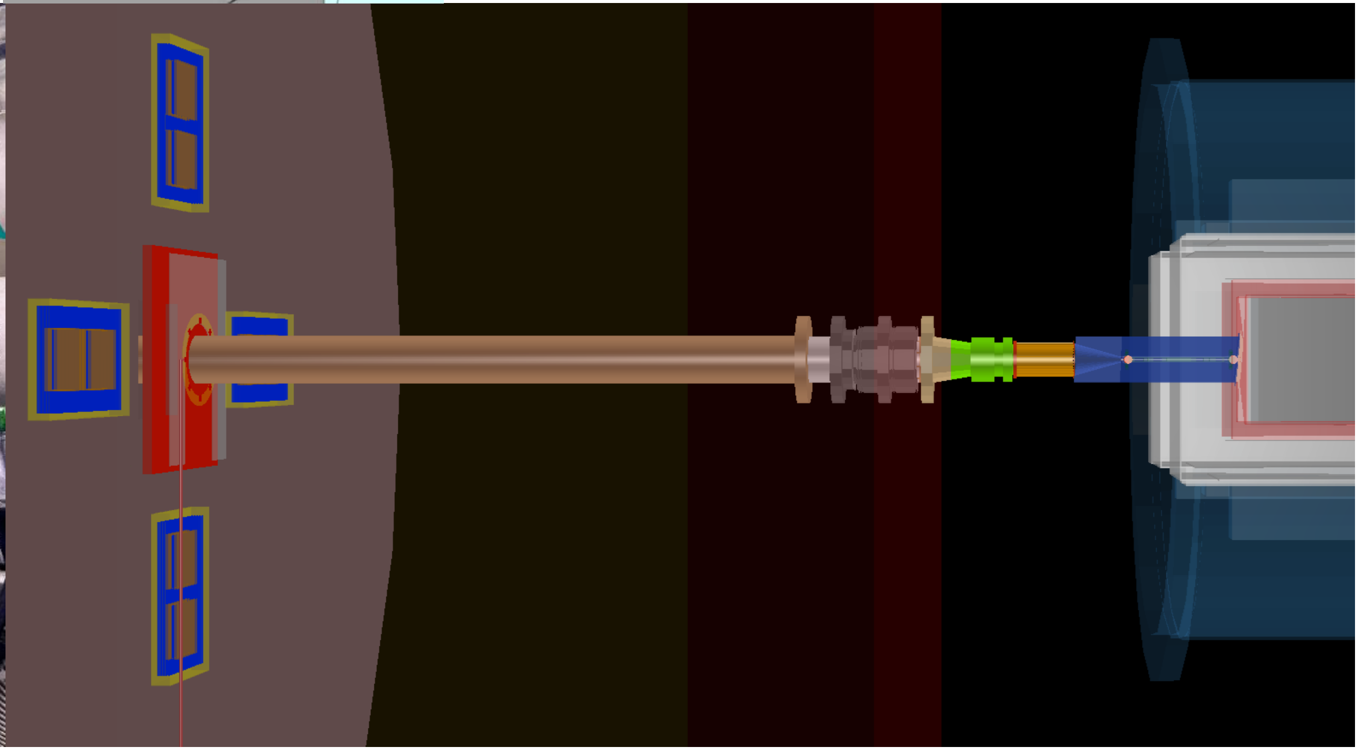


RMS-R3 Geometry in Real and Simulation

- BCM is fully implemented in the LHCb Simulations
- RMS-R3 and PLUME geometry are implemented locally.

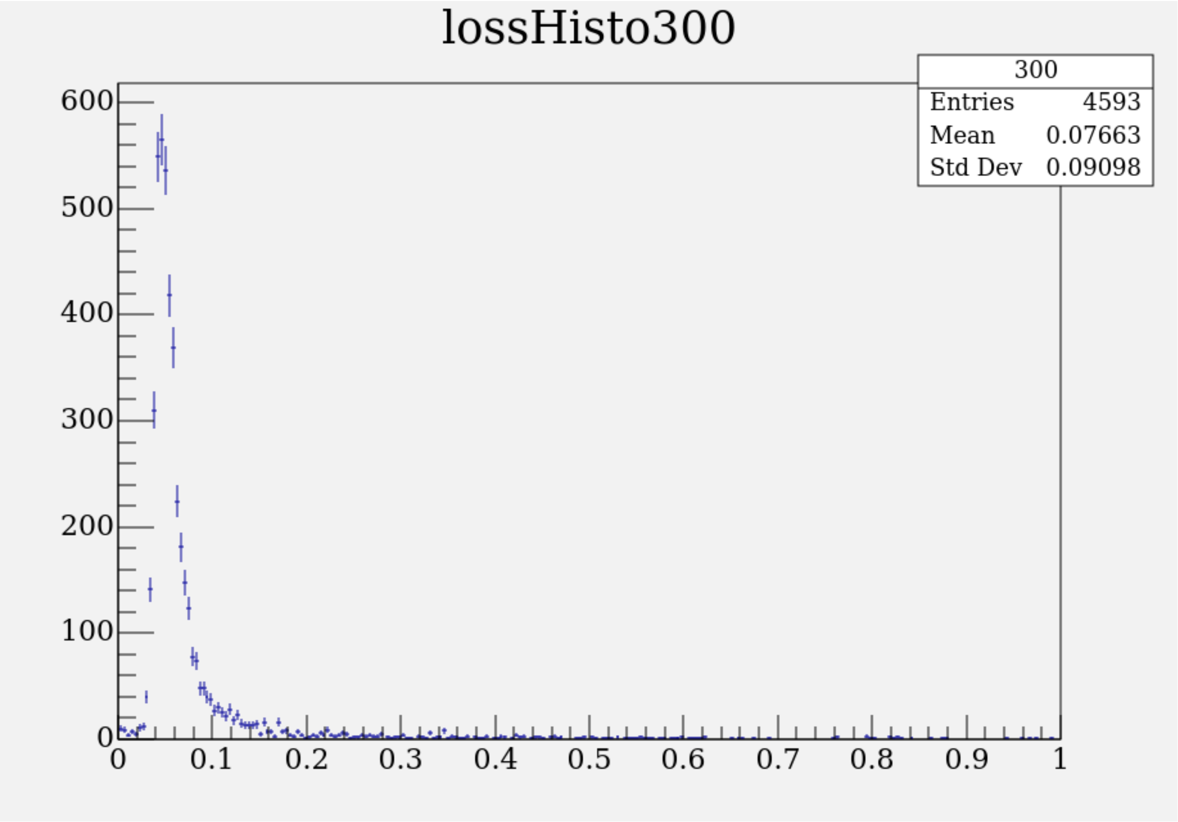






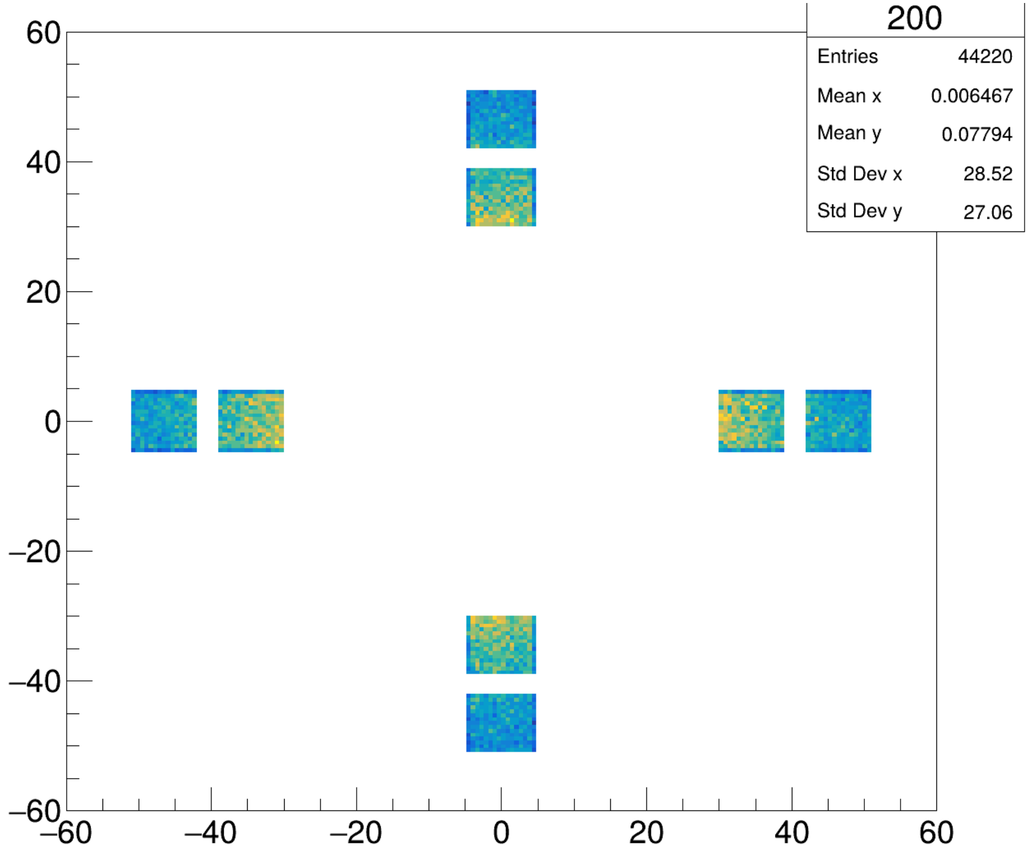
MCHits in RMS-R3 in the Simulation

Charged particle losses in the RMS-R3 sensors (1k events)



MCHits in the RMS-R3 sensors from 10k minimum bias simulated p-p events.

Beam7000GeV-md100-nu7.6-HorExtAngle.py



Work in progress to fully implement RMS-R3 in the LHCb Simulation project and estimate asymmetry function changes vs beam collision position…

Conclusions

- The first version of the RMS-R3 geometry is realized in DD4Hep and is on its way to be implemented in the general release of the Gauss
- The first simulations of the RMS response were performed locally to evaluate the changes in the asymmetry functions vs the beams' interaction point position.
- The work is ongoing to fully implement the RMS-R3 into LHCb simulations, simulate its response to different types of collisions (beam-beam, beam-gas, etc.), and simulate unexpected beam loss scenarios.

Acknowledgments

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Thank You for Your Attention!