



New software technologies in the LHCb Simulation

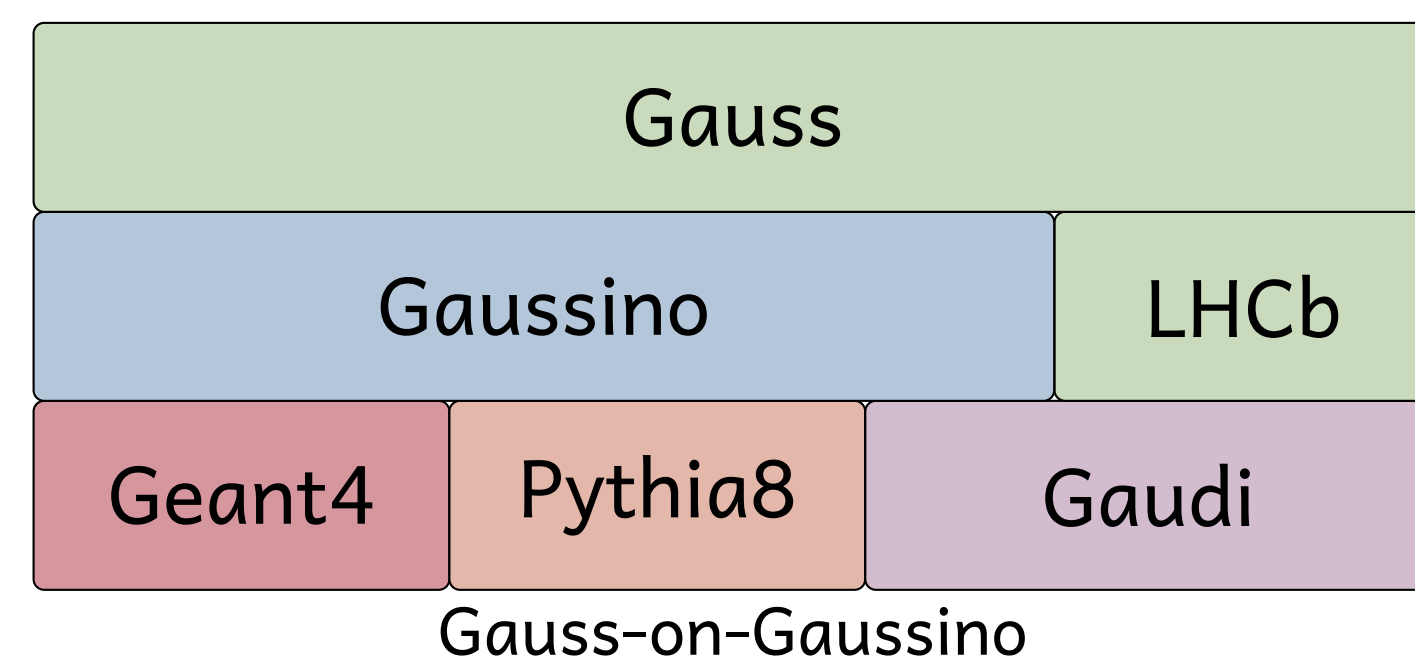
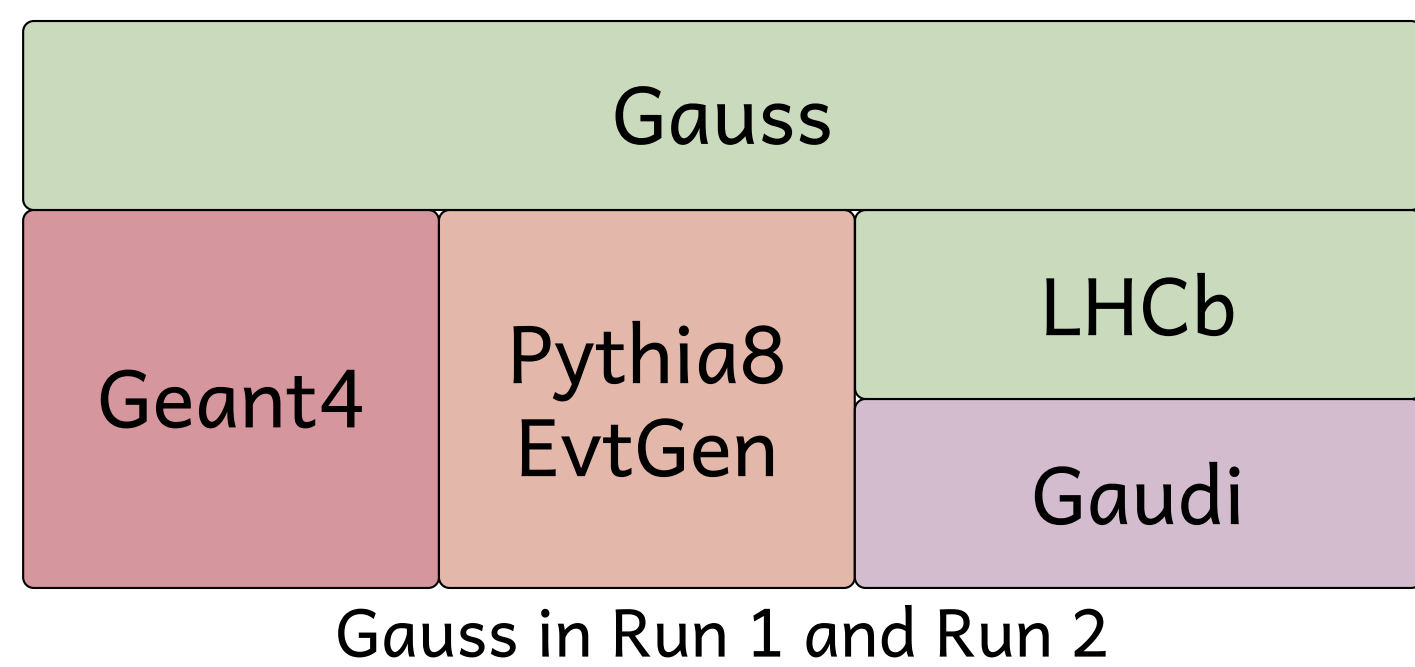
Gloria Corti¹ Adam Davis² Michal Kreps³ Michał Mazurek¹ Dmitry Popov^{1,4}
Benedetto Gianluca Sidi⁵

¹CERN, European Organization for Nuclear Research ²University of Manchester ³University of Warwick
⁴University of Chinese Academy of Sciences ⁵Università degli studi di Ferrara



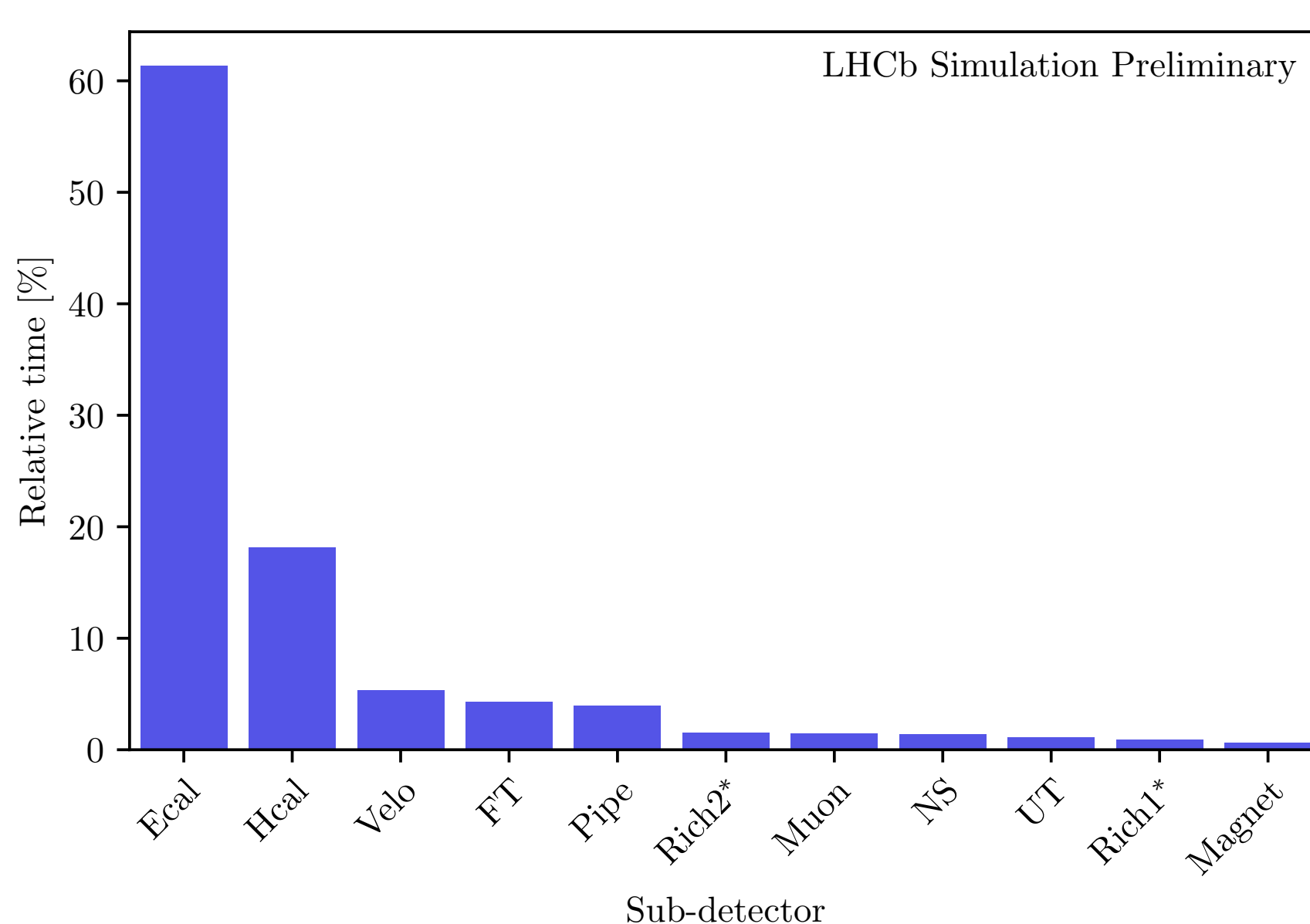
1. Gauss-on-Gaussino

- Gaussino** [1] is a new experiment-independent core simulation framework that:
 - is based on Gaudi's inter-event-based parallelism of the event loop;
 - marries it with Geant4 multi-threading;
 - provides infrastructure for a 'plug-in' of HEP generators.
- Gauss-on-Gaussino** is the newest version of the LHCb simulation framework, based on Gaussino.



2. Timing

- Around 80% [2] of the LHCb allocated CPU resources are used to produce Run 1 and Run 2 simulated samples.
- Particle showers in the electromagnetic calorimeter at LHCb dominate the time spent on simulation (RICH optical processes are turned off).

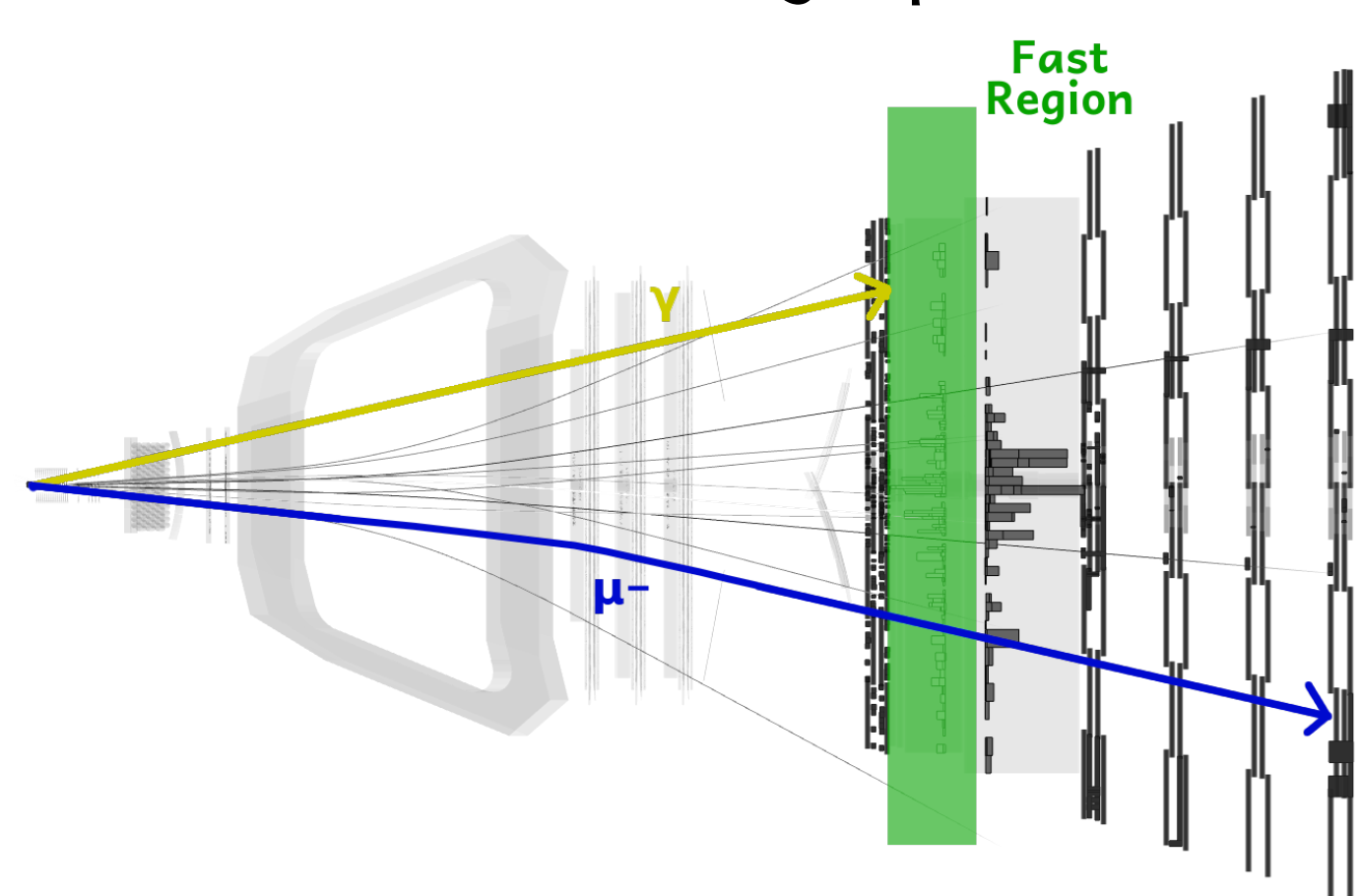


	Relative time [%]									
Velo	2.0	0.8	1.6	0.3	<0.1	0.2	0.2	<0.1	<0.1	0.4
Rich1*	0.3	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
UT	0.4	0.3	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Magnet	0.3	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
FT	2.1	1.4	0.4	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Rich2*	0.6	0.5	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
NS	0.4	0.6	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
Ecal	30.2	23.5	2.1	0.3	<0.1	0.9	3.6	<0.1	<0.1	0.5
Hcal	5.5	4.6	1.2	<0.1	<0.1	0.8	5.1	<0.1	<0.1	0.7
Muon	0.4	0.4	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	<0.1	<0.1
Pipe	1.8	1.7	0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1

Relative time [3] spent by given particles in a sub-detector with respect to the total time of the simulation

3. Fast simulations in Geant4

- The Geant4 [4] toolkit gives the possibility to replace its simulation of physics processes with a custom fast model.
- LHCb is introducing a palette of fast simulation models to complement the detailed simulation.

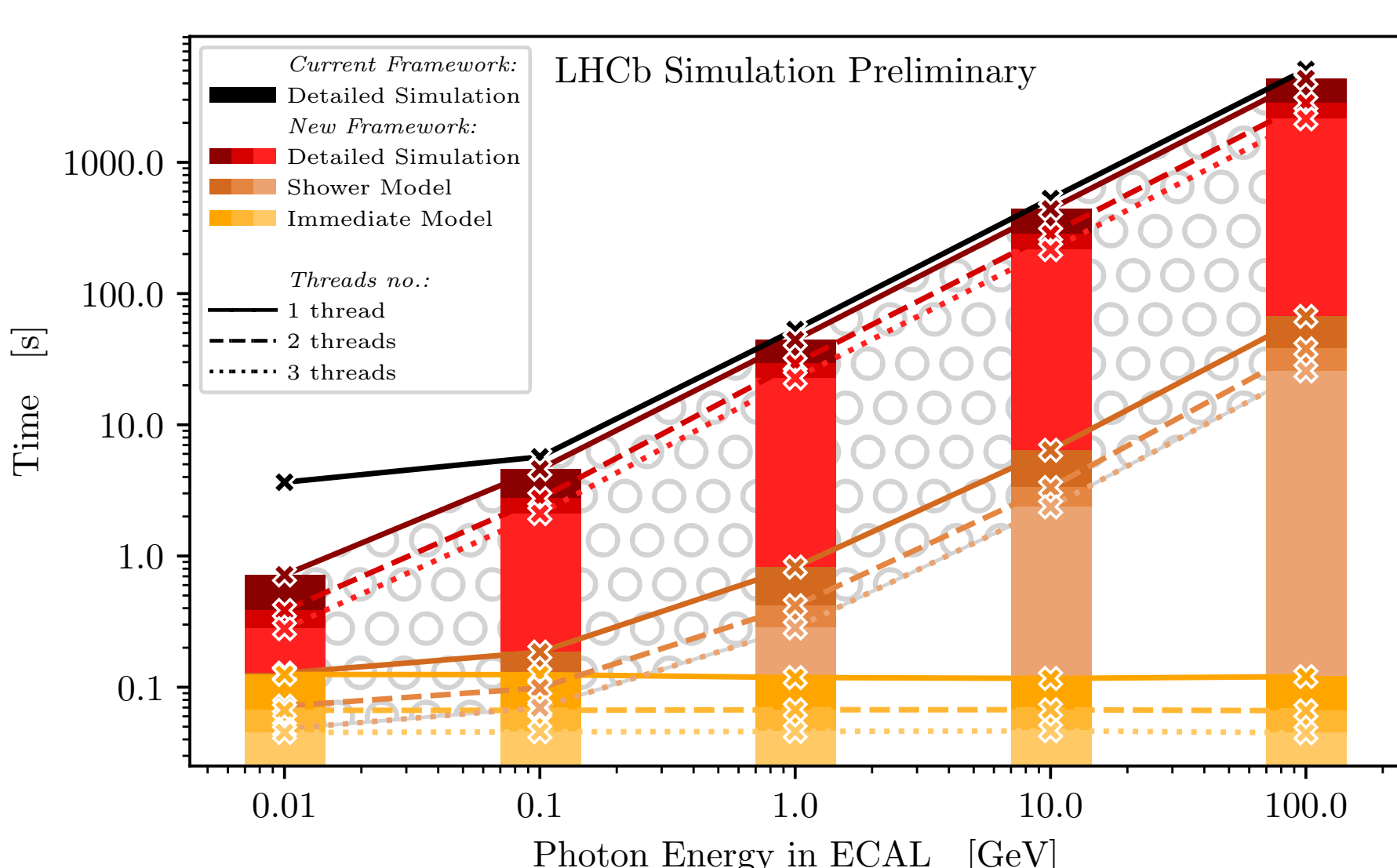


ECAL Fast Simulation with Geant4

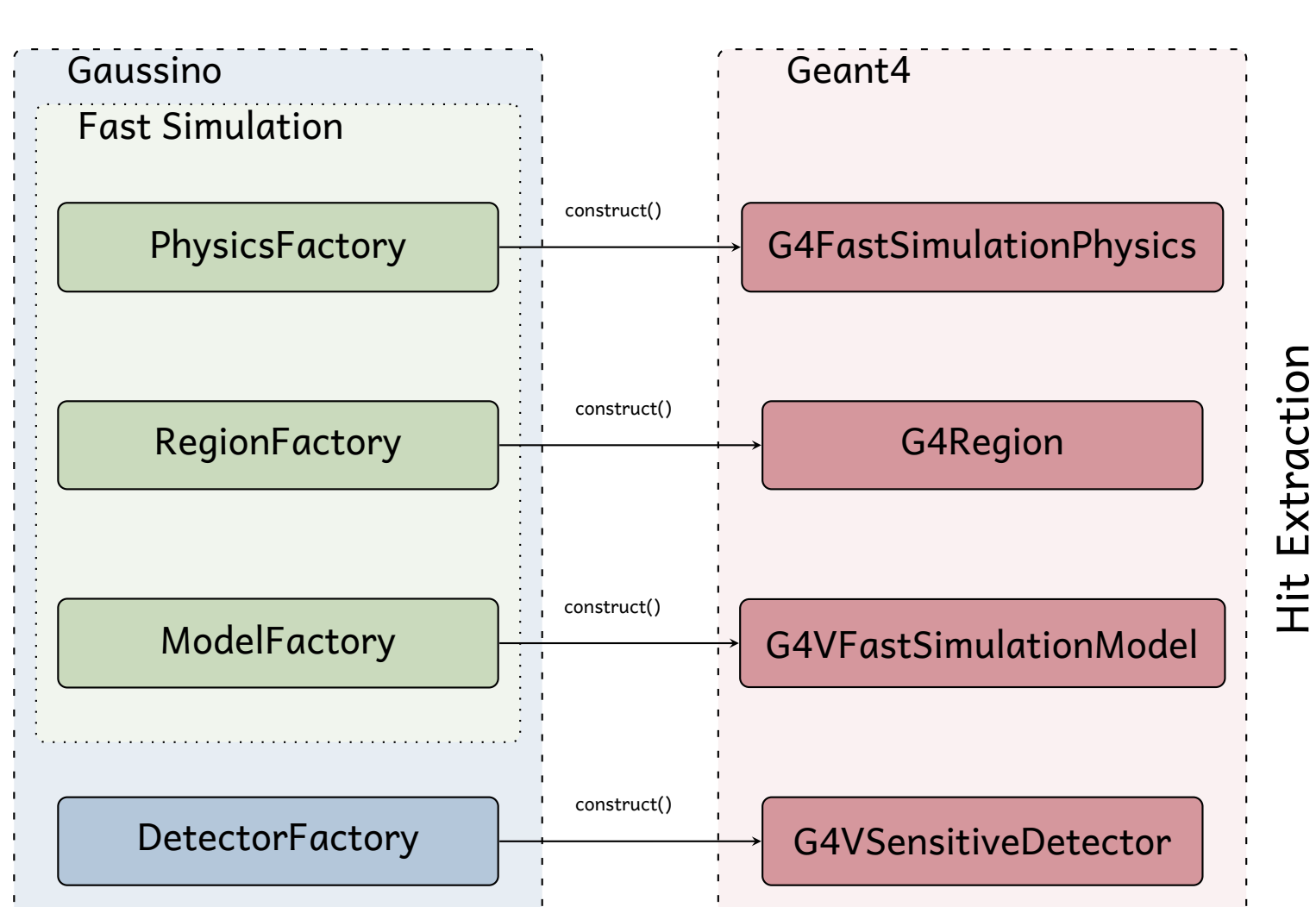
Model	Generation	Decay	Propagation	Migration to G-on-G
ReDecay [5]	✓	✓	✓	done
ParticleGun [6]	✓	✓	✓	done
SplitSim [6]	✓	×	✓	done
RICHless [6]	×	×	✓	in progress
TrackerOnly [6]	×	×	✓	in progress
Lamarr [7]	×	×	✓	to be done
Point lib [8]	×	×	✓	to be done
GAN [9]	×	×	✓	to be done

4. Fast Simulation Interface

- FastSimulation** interface provides a set of factories that configure the corresponding Geant4 objects at the right moment when running the application.
- Gaussino's implementation minimizes the work needed to implement fast simulation models and guarantees the integrity of the simulated data.

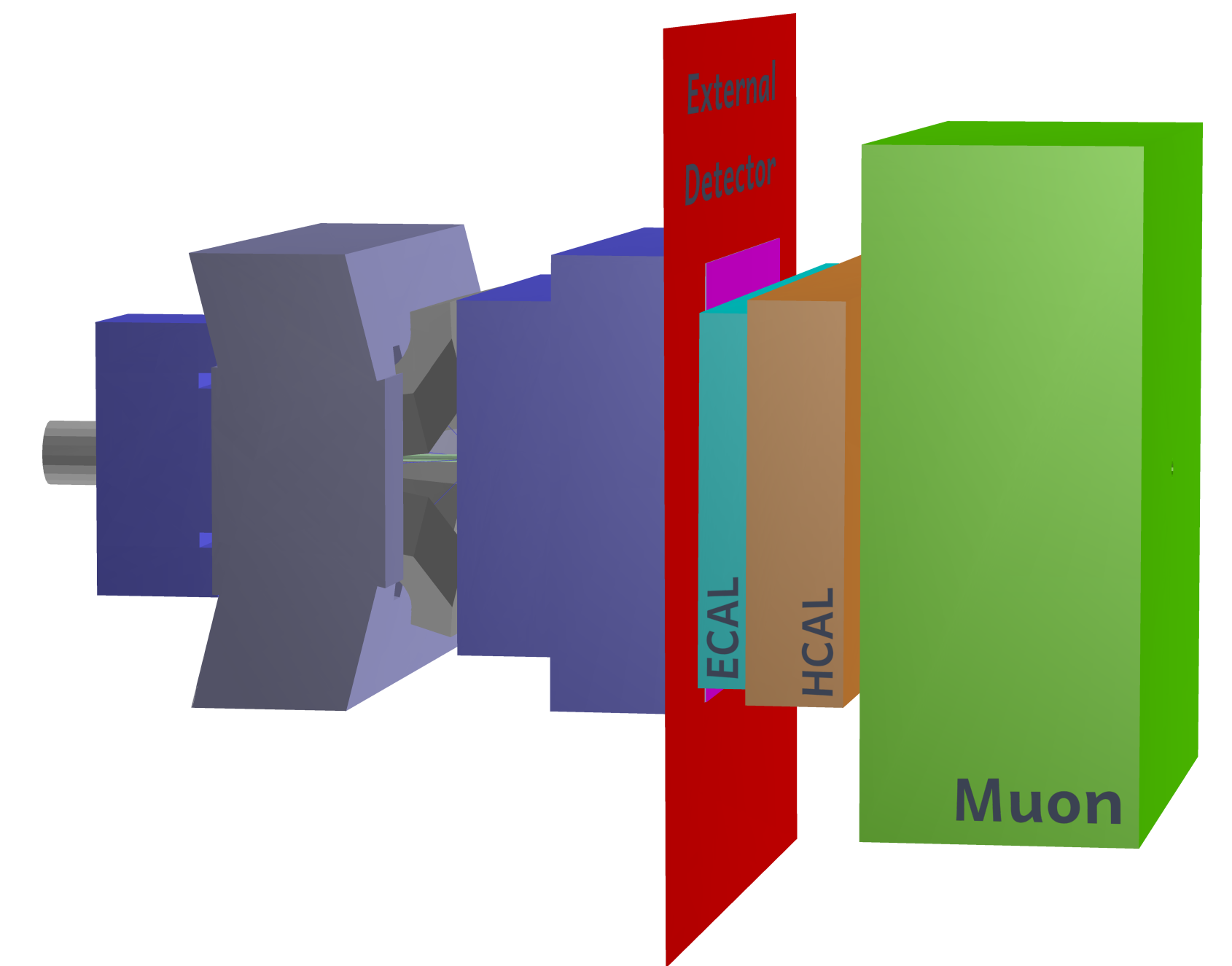


Time [3] spent by the infrastructure of the fast simulation interface with Geant4 10.7



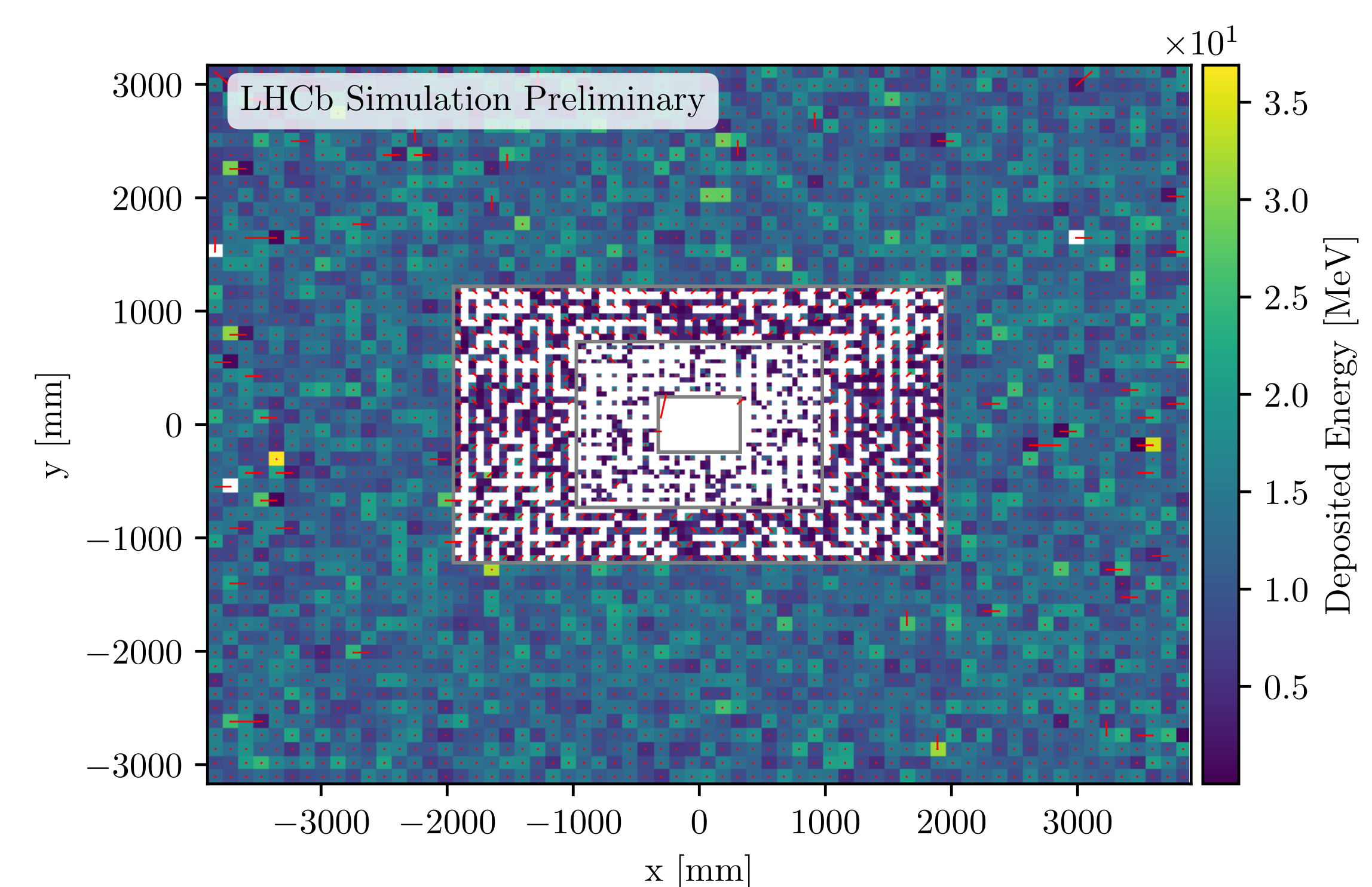
A simplified model [3] of the FastSimulation interface in Gaussino

5. External Geometry

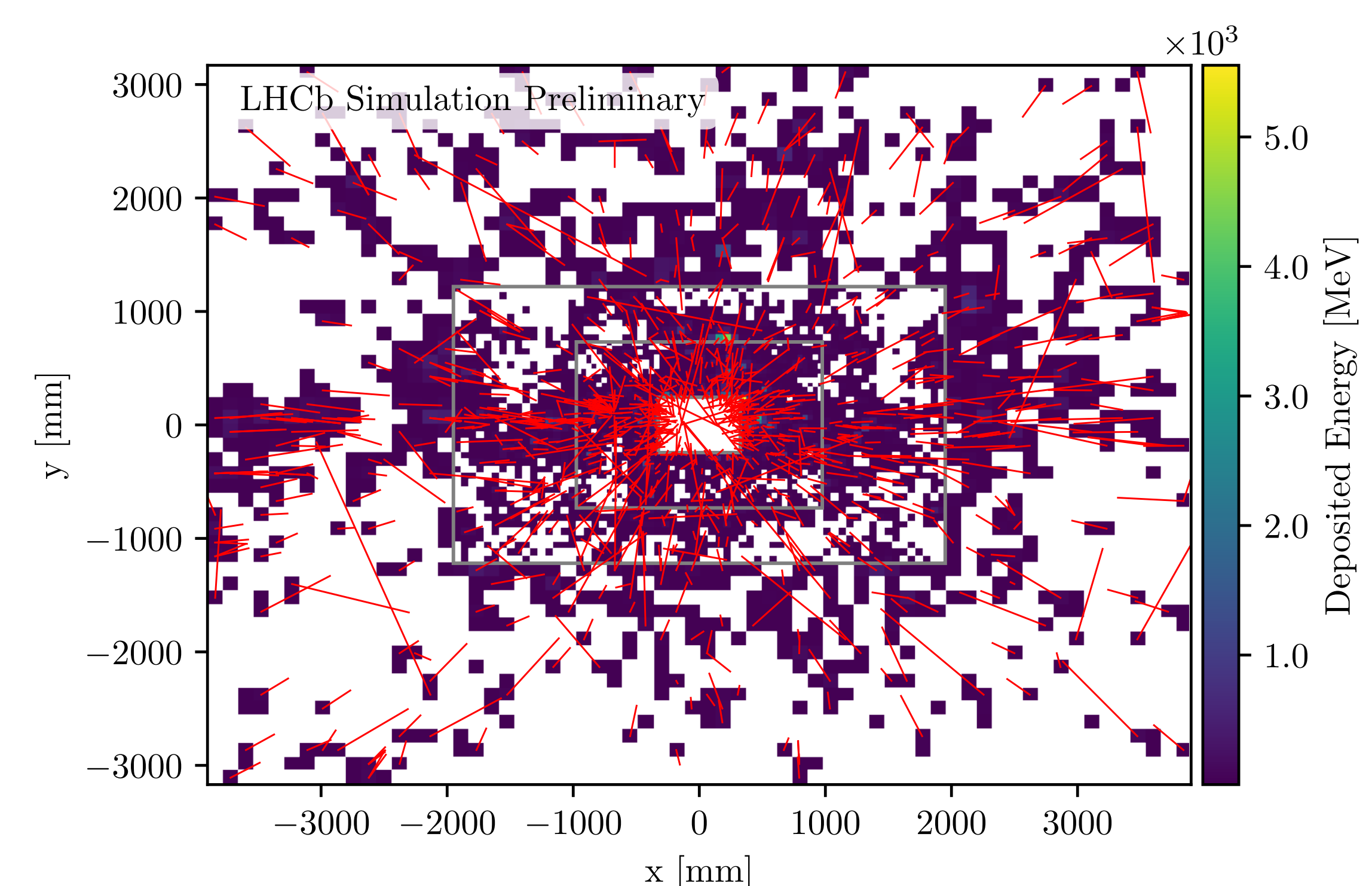


- ExternalDetector** is a new package in Gaussino that allows for abstract, sensitive volumes of any shape to be inserted.
- ParallelGeometry** is another special package that takes care of potential overlaps caused by extra volumes.
- These features allow to save custom information from detailed simulation needed to train and validate new models.

6. Examples of training samples



Energy deposition [3] in the LHCb ECAL from a training dataset produced with a grid of 3328 evenly-spaced 100 MeV photons



Energy deposition [3] in the LHCb ECAL from a training dataset produced by a minimum bias event with the beam conditions as foreseen in the Run 3 data-taking period

7. References

- B. G. Sidi and D. Müller. Gaussino - a gaudi-based core simulation framework. In 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), pages 1-4, 2019.
- LHCb collaboration. Computing Model of the Upgrade LHCb experiment. <http://cds.cern.ch/record/2319756>, 2018. CERN-LHCC-2018-014, LHCb-TDR-018.
- Michał Mazurek, Gloria Corti, and Dominik Müller. New Simulation Software Technologies at the LHCb Experiment at CERN. <https://cds.cern.ch/record/2790591>, Nov 2021. LHCb-PROC-2021-011.
- S. Agostinelli et al. Geant4: A simulation toolkit. Nucl. Instrum. Meth., A506:250, 2003.
- D. Müller, M. Clemencic, G. Corti, and M. Gersabeck. ReDecay: a novel approach to speed up the simulation at LHCb. <https://cds.cern.ch/record/2696310>, Oct 2019. LHCb-FIGURE-2019-017.
- Mark Peter Whitehead. A Palette of Fast Simulations in LHCb. <https://cds.cern.ch/record/2630475>, Jul 2018. LHCb-TALK-2018-302.
- Performance of the Lamarr Prototype: the ultra-fast simulation option integrated in the LHCb simulation framework. <https://cds.cern.ch/record/2696310>, Oct 2019. LHCb-FIGURE-2019-017.
- Matteo Rama. Fast calorimeter simulation in the LHCb Gauss framework. <https://cds.cern.ch/record/2725640>, Jul 2020. LHCb-TALK-2020-108.
- Fedor Ratnikov. Generative Adversarial Networks for LHCb Fast Simulation. <https://cds.cern.ch/record/2699549>, Nov 2019. LHCb-TALK-2019-403.