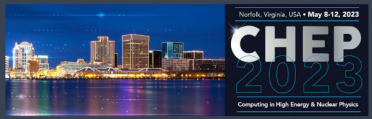
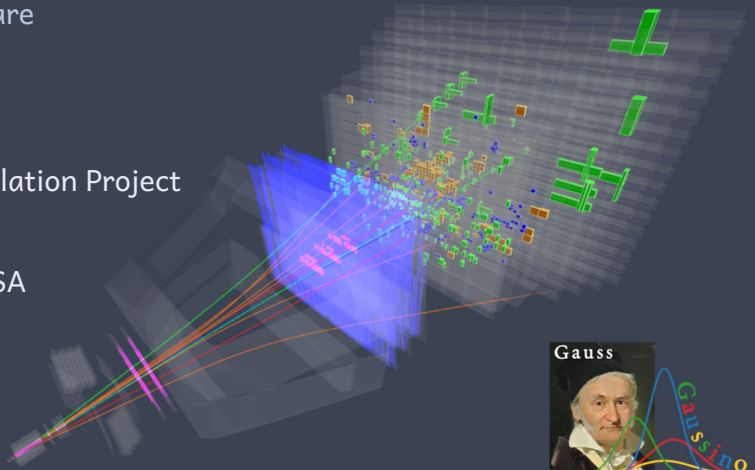


Gauss and Gaussino

the LHCb simulation software and its core framework

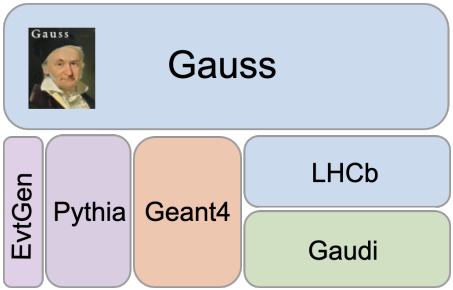
by **Michał Mazurek**
on behalf of the LHCb Simulation Project

on 11 May, 2023
CHEP 2023, Norfolk VA, USA



Simulation software in LHCb

LHCB-TDR-017



Gauss is the LHCb simulation framework:

- generates primary events,
- simulates the interaction with the detector,
- based on Gaudi as a core software framework.

Landscape for Run3 and future runs

- large increase in luminosity very challenging for computing,
- simulation for Run 2, takes up to 90% of the experiment computing resources,
- major rewrite of the software in LHCb.

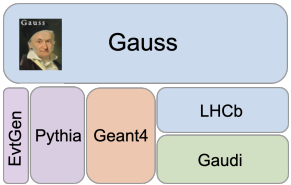
Simulation software upgrade needed!

- need for code optimization,
- clean up of 'dead' code,
- fix memory usage issues,
- use multi-threaded Gaudi and Geant4,
- extensive fast simulation models,
- new external software technologies.

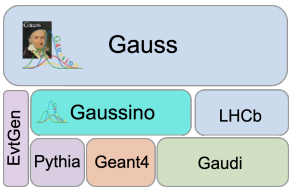
💡 **Separate simulation core functionalities!**

From Gauss to Gauss-on-Gaussino

💡 **Introduce an experiment-independent layer!**



(a) Gauss current dependencies



(b) Gauss-on-Gaussino dependencies

- Gaussino
  - new core simulation framework,
  - created by extracting experiment-independent components from Gauss,
  - ideal test bed for new developments,
  - idea came up in collaboration with the CERN SFT group / FCC,
  - 👉 **more on Gaussino** in the following talk!,
- Gauss-on-Gaussino
  - new version of LHCb simulation framework,
  - based on Gaussino's core functionalities,
  - adds LHCb-specific components and configurations,

What is the **status** of the new framework?

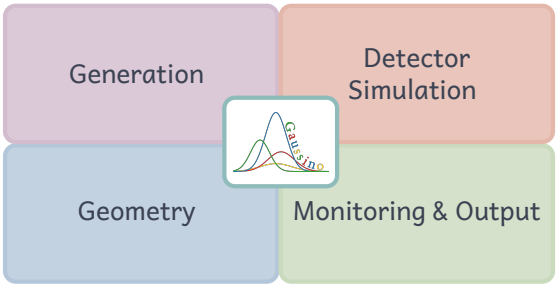
- 👉 multi-threading prototype,
- 👉 early benchmarks,
- 👉 first DD4hep sub-detectors,

- 👉 extensive testing,
- 👉 Gaussino standalone,
- 👉 configuration revisited,
- 👉 stable software,
- 👉 custom simulations,

- 👉 full testing,
- 👉 port all needed functionality from Gauss (Sim10). e.g. full generators palette,
- 👉 test productions with LHCbDirac,
- 👉 full scale physics validation,

Configuration

👉 python configurables steering C++ classes,
👉 modular structure with 4 main configurables, one for each module



- Gauss()
- GaussGeneration()
- GaussSimulation()
- GaussGeometry()
- \+ optional (ParticleGun, etc.)

👉 More on the Gaussino structure itself in the next talk!,

Generation phase

LHCB-FIGURE-2023-009

New features from Gaussino

- highly modular,
- thread safety of generators,
- HepMC3 as an exchange format,

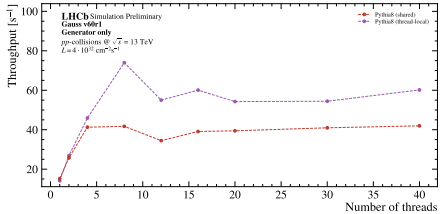
Structure

- **Gaussino:** Pythia8 and some particle guns,
- **Gauss:** EvtGen and specific LHCb settings,

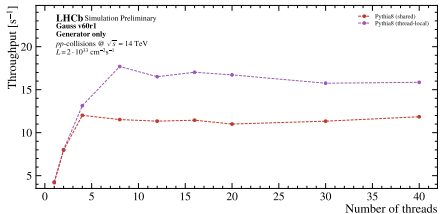
Performance

- shared (P8) vs. thread-local (P8MT) interface to Pythia8

👉 **Pythia 8 + EvtGen in Run 2 conditions**



👉 **Pythia 8 + EvtGen in Run 3 conditions**



Detector simulation phase

LHCB-FIGURE-2023-009

New features from Gaussino

- Geant4 10.7
- multi-threading,
- fast simulation hooks,

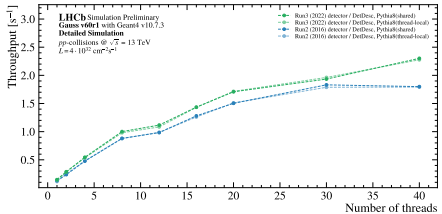
Structure

- **Gaussino:** interfaces to Geant4,
- **Gauss:** LHCb specific settings & models,

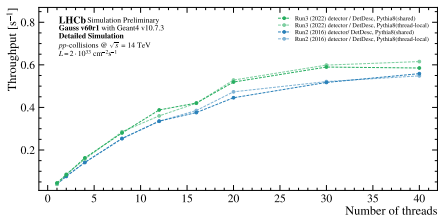
Performance

- Geant4 10.7 simulation with shared vs. thread-local interface to Pythia8

👉 **Geant4 10.7 in Run 2 conditions**



👉 **Geant4 10.7 in Run 3 conditions**



Fast simulations in LHCb

LHCB-FIGURE-2019-017
F. Ratnikov (CHEP, 2019)
M. Rama (ICHEP, 2020)

Model	Generation	Decay	Propagation	Status in G-on-G
ReDecay	✔	✔	✔	ported
ParticleGun	✔	✔	✔	ported
SplitSim	✔	✘	✔	ported
RICHless	✘	✘	✔	ported
TrackerOnly	✘	✘	✔	ported
Lamarr	✘	✘	✔	(**NEW**) in progress
Point library	✘	✘	✔	(**NEW**) in progress
GANs	✘	✘	✔	(**NEW**) in progress

In-house parametrizations

Lamarr

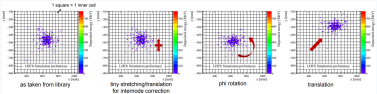
Idea: ultra-fast simulation option where not only the detector response, but also the reconstruction is parametrized

👉 **more on Lamarr** in M.Barbetti's talk

Fast simulation models with Geant4

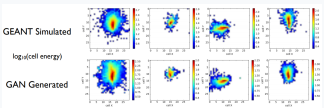
Point library

Idea: Extract points from a collection and transform them based on properties of the particle



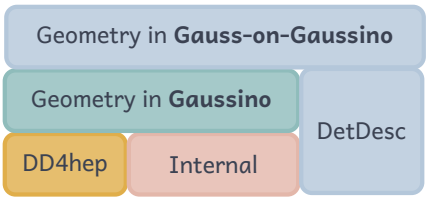
Generative Adversarial Networks (GANs)

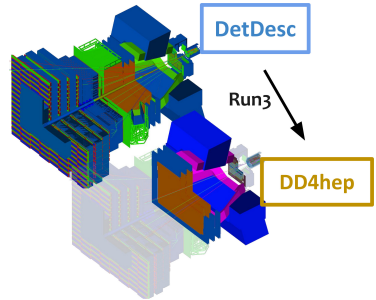
Idea: use GANs trained on the data produced by a detailed simulation to generate showers in ECAL

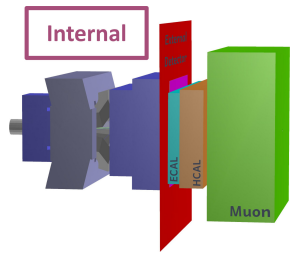


Geometry

- LHCb specific detector description tool used for Run 1, 2 & 3,
- LHCb description using DD4Hep toolkit for Run3 and beyond,
- Gaussino's internal geometry service for non-standard geometry setups (adding volumes at runtime, fast simulations, etc.)



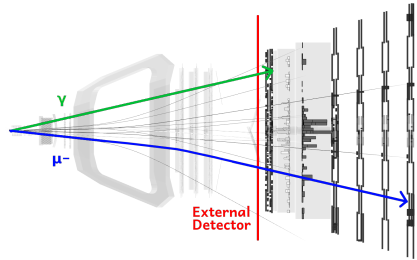


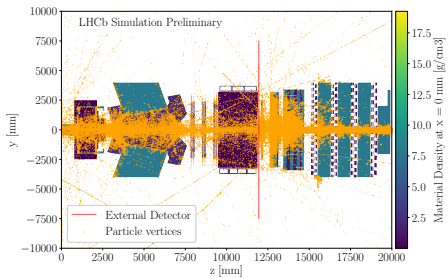


Example of using internal geometry service

LHCB-FIGURE-2021-004

- Required data for fast simulation models and other studies is not always present in the standard output.
- An abstract, external detector can be used as a collector of the required information at any position in the detector.
- A built-in mechanism can take care of potential volume overlaps by placing extra volumes in parallel geometries.

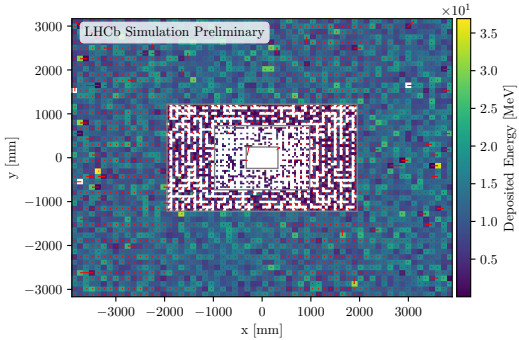




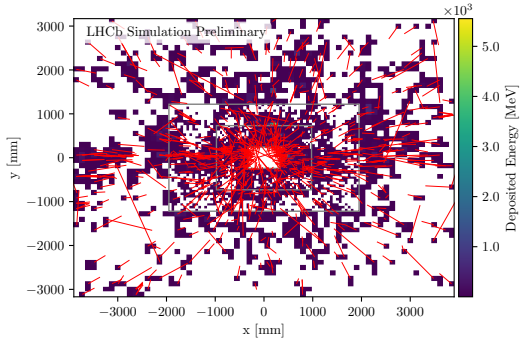
Example of custom datasets

LHCB-FIGURE-2021-004

💡 Crucial for fast simulation training datasets and sub-detector studies!
👉 example: external plane (incident particles info) 🔗 ECAL hits



Evenly-spaced grid of photons

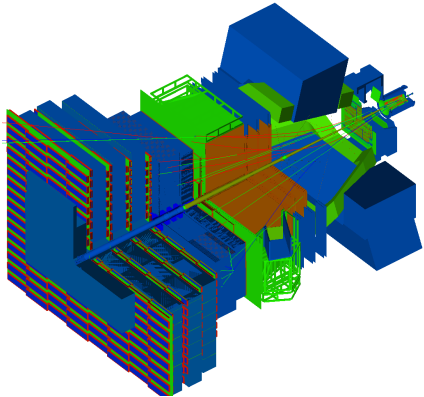


Minimum bias sample

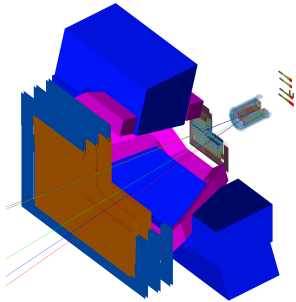
Visualizations in Geant4

CERN-STUDENTS-Note-2022-205

💡 available at runtime (in multi-threaded environment),
💡 crucial for validating geometries, overlap checks and the comparison of different description tools,



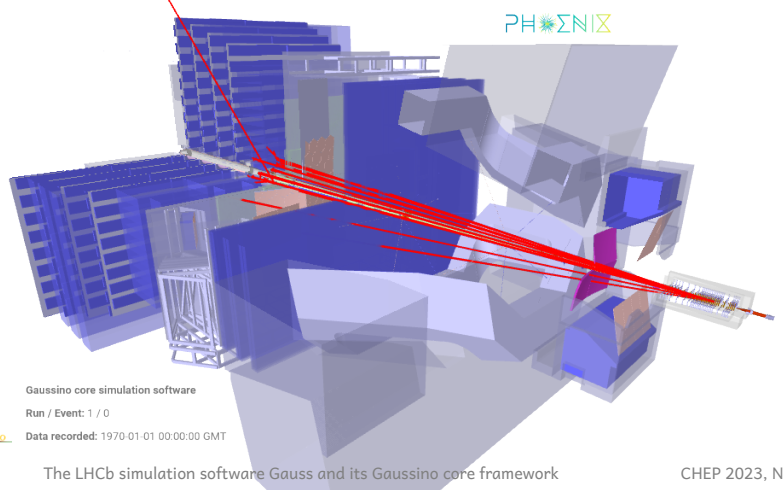
DetDesc (legacy)



DD4hep (new)

Visualizations in Phoenix

- 💡 available as an external tool based on data produced in the simulation,
  - 💡 simulation and reconstruction data comparisons possible,

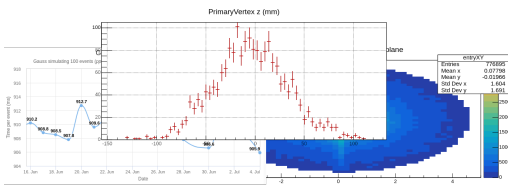


Monitoring & Output

D.Popov EPJ Web Conf., 214 (2019) 02043
M. Szymański, B. Couturier EPJ Web Conf., 214 (2019) 05014
LHCB-FIGURE-2021-004

Output files

- simulated data in the LHCb event model,
- monitoring histograms,
- custom n-tuples,



Monitoring and production tools

- **LHCb Nightly builds**: small jobs with validation of the code and checks on expected output, counter, etc.
- **LHCbPR**: provides statistical checks and comparisons on larger data samples,
- **LbMCSubmit**: new scriptable large submission system of large production requests of the simulation samples,

👉 **more on LbMCSubmit** in C. Burr's talk

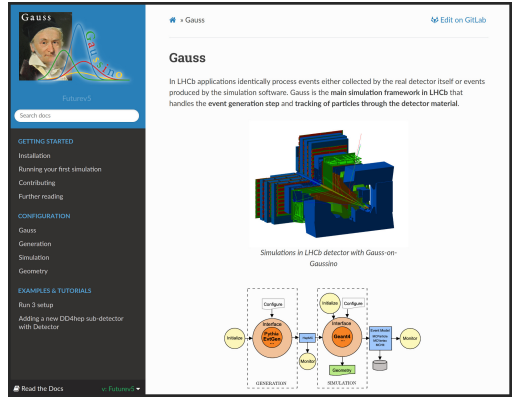
👉 **more on Simulation Data Quality in LHCb** in B. Couturier's talk

Documentation

https://gitlab.cern.ch/lhcb/Gauss

https://lhcb-gauss.docs.cern.ch/

- each new development in Gauss(-on-Gaussino) is documented,
- the documentation provides the description of:
  - how to install and run simulations,
  - high-level python configuration,
  - simple examples,
- versioning of the documentation.



Conclusions

- Simulation framework in LHCb had to be re-written to meet the requirements of Run3 and future runs.
- Gauss-on-Gaussino is the new version of Gauss based on Gaussino with LHCb-specific additions.
- 👉 More on Gaussino and its use for early detector studies and experiment-independent use in the next talk!,
- 🎉 Gauss-on-Gaussino is mature enough and is ready for its beta release!
- ⌛ First production tests and porting of the rest of the components soon!

Thank you!