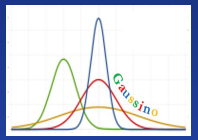
AIDAInnova Hackaton
Turnkey session
21 June 2022



Introduction to Gaussino & current status

With some examples of its use in new version of LHCb simulation framework/application Gauss-on-Gaussino

Gloria Corti, Michal Mazurek
CERN
on behalf of the LHCb Simulation Project

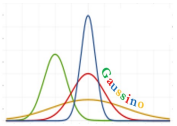
Motivation

- SFT/FCC exploration of existing software solutions in 2015-2016
  - Gauss (LHCb simulation framework) identified as a potential base for a production quality implementation
    - Generation rather straightforward to use
    - Despite the work required (parallelism, fast simulations, specific FCC pileup…) interested in picking up simulation part, too
  - Experiments need to follow development of Gaudi and Geant4

“We should join forces for an experiment independent Gauss-core”

Investigation, in B. Hegner talk at 6th LHCb Computing Workshop, Nov 2015, LPHNE Paris
First ideas, in B. Hegner talk at 8th LHCb Computing Workshop, Nov 2016, LPHNE Paris

Motivation, cont.

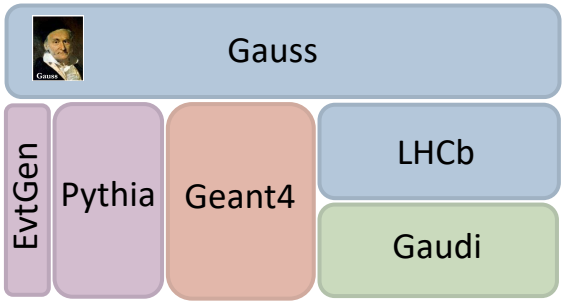


- General modernization of all LHCb software in view of Run3
  - LHCb large increase in luminosity very challenging for computing
  - Gaudi multi-threaded
  - Use of new external technologies, e.g. DD4Hep
- Necessary to update the simulation framework
  - ~ 15 years old
  - Purely single-threaded
  - Memory usage becoming an issue
  - Clean up of 'dead' code
  - Exploit new feature of external HEP simulation software, i.e. Geant4 MT

Main idea: Separate core functionality for simulation

LHCb Collaboration, Upgrade Software and Computing TDR, CERN-LHCC-2018-007

From Gauss to Gaussino

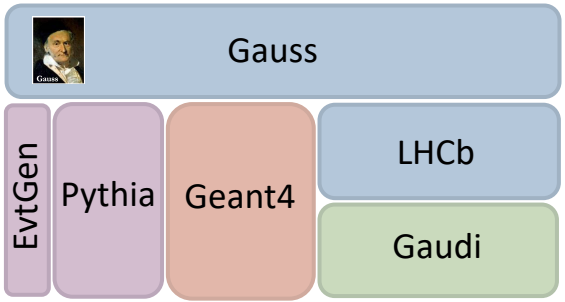


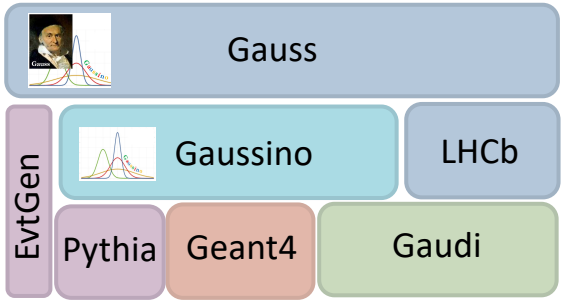
Restructure the code introducing an **experiment independent layer**

Gaussino core simulation framework

- provides the structure and hooks
- interfaces to generators
- controls the multi-threaded event loop
- ensure Geant4 and Gaudi threads play nice
- python configuration
- ideal test-bed for new developments

From Gauss to Gauss-on-Gaussino





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Gauss-on-Gaussino is the newest version of the LHCb simulation framework.

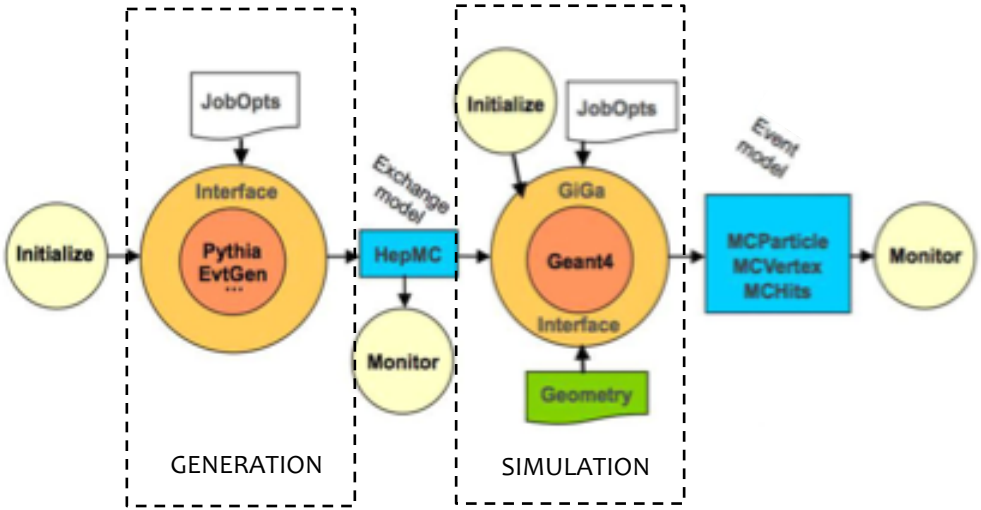
The evolution of Gauss based on Gaussino

Gaussino

A complete simulation framework following the basic Gauss architecture

Keep what is good:

- Modularity
- Integrated generation and simulation phase



Generator phase mostly as-is

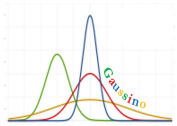
Pythia8 interface available

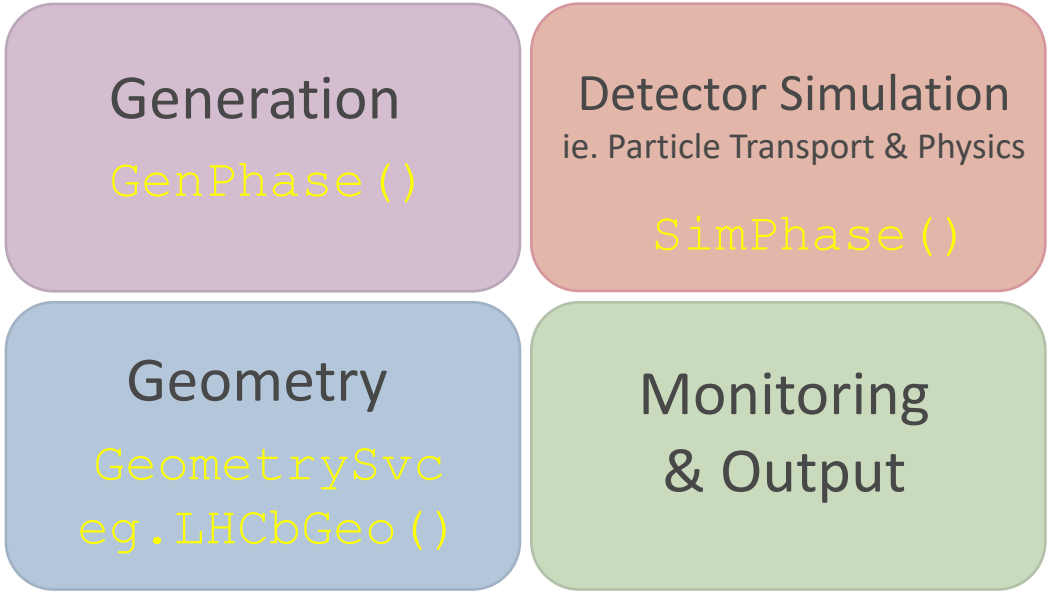
Code migrated to HepMC 3

Simulation phase redesigned following identification of elements

Keep it 'simulation engine' independent

Configurable building blocks

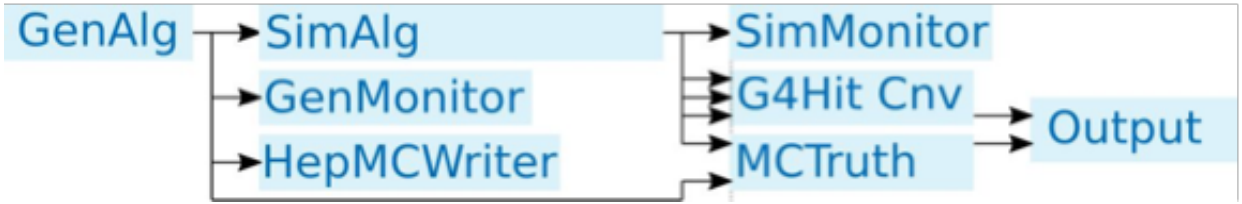




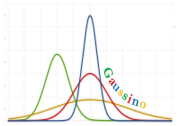
Details and examples in D. Muller talk at 13th LHCb Computing Workshop 2020

Execution structure

- Gaudi functional
  - Every algorithm as a ‘task’
  - Constant execution
    - Random engines created per call
  - Fixed input/output, e.g. `/*output data*/ operator()(/*const input data*/) const`



Random numbers

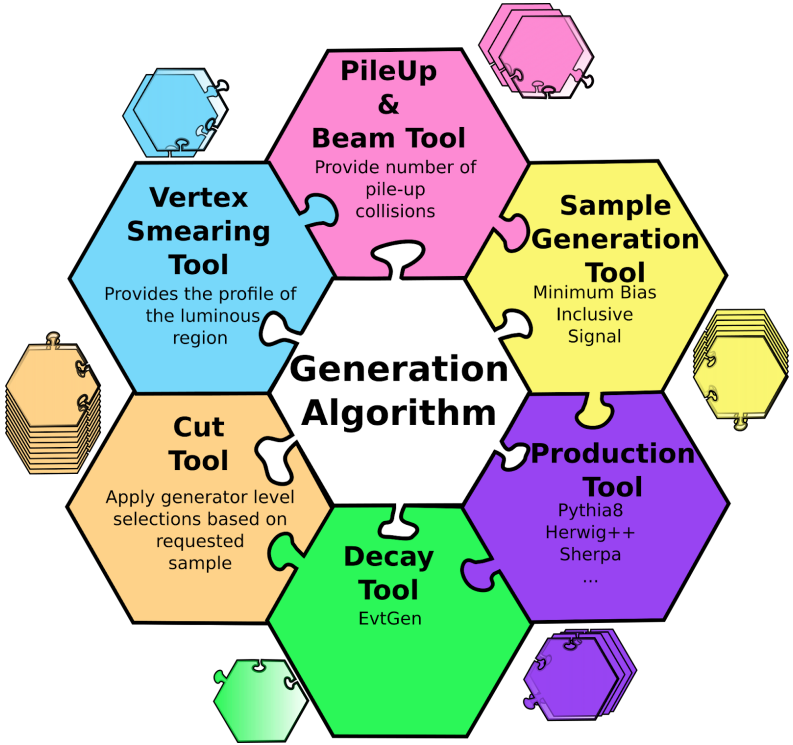


- We♡ Reproducibility
- A global singleton random engine won't work in MT!
- Solution
  - Largest predictable unit: algorithm execution
  - Create engine on the stack
  - Pass it around as reference
  - Or thread-local global only valid in algorithm
  - Seed initialized with each run #, event #, algorithm instance name and passed to external libraries

Generation phase

Structure from Gauss
Highly modular

HepMC3 as exchange format



Gaussino

- Pythia 8 and some Particle Guns

Gauss(-on-Gaussino)

- EvtGen and specific LHCb settings

Details at NSS2010 - CD Conference Record, N42-284; LHCb-PROC-2010-056

Generation

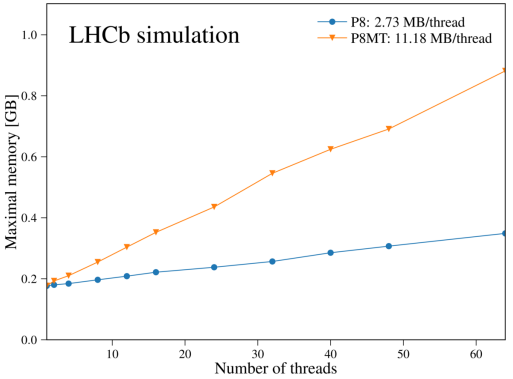
Structure from Gauss
Highly modular

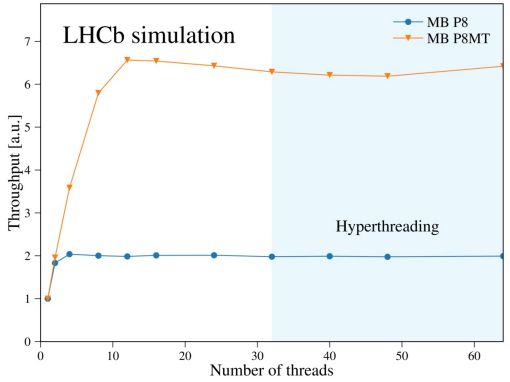
HepMC3 as exchange format

Thread safety of generators
- production and decay tool
- external generators shared between threads

Example in Gaussino: Pythia8
- Shared (locking)
- Thread-local (locking memory allocation)

Generation phase only, minimum bias, no LHCb-specific setting



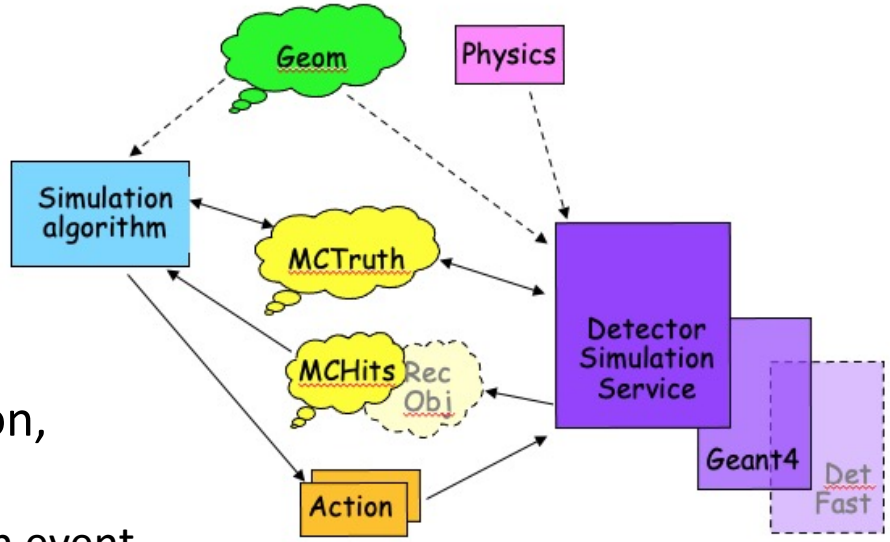


LHCB-FIGURE-2019-012

Simulation phase

Inspired from the generation
Modular!

Simulation Service managing
different backends



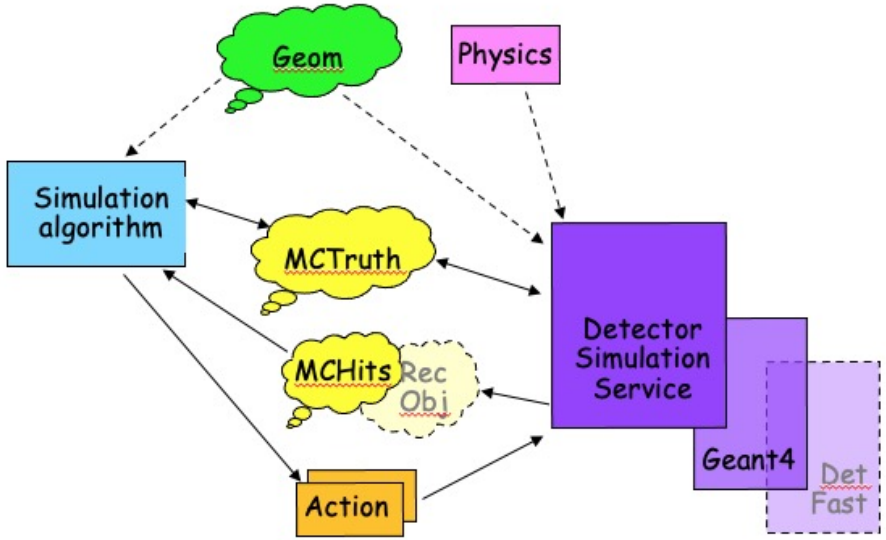
Enable flexible python configuration,
e.g. different settings for:

- In time – Out of time pile-up – Main event
- Signal – other particles
- Fast Simulation

Simulation phase

Inspired from the generation
Modular!

Simulation Service managing
different backends



Gaussino

- Geant4
- Fast simulation hook

Gauss[-on-Gaussino]

- LHCb specific settings

Next step

- Lamarr (ultra-fast simulation)

Interface to Geant4 MT

Keep Gaudi/Gauss as separate as possible from Geant4

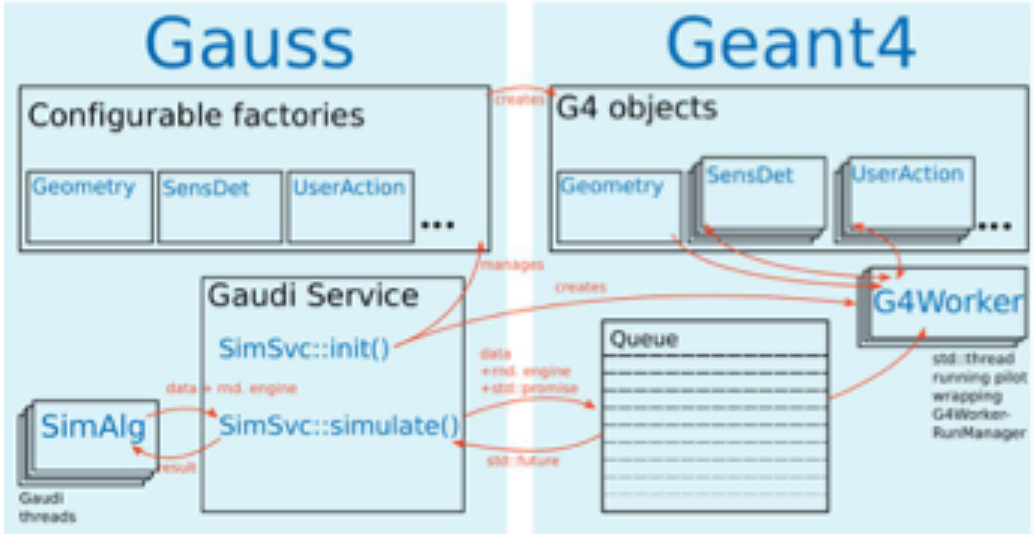
Gaudi-tools as factories for G4 objects

- python configuration of G4 settings
- G4 objects managed by G4

Run G4 workers in individual threads

Dynamic assignment possible

- Entire Gaudi event
- Split Gaudi event into multiple G4 workloads



Interface to Geant4 MT

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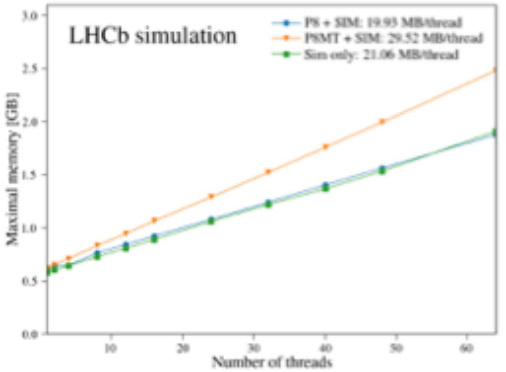
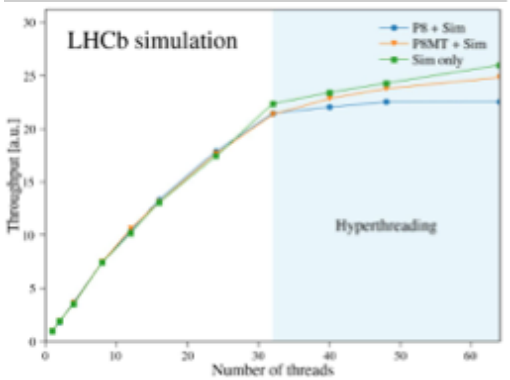
Simultion with LHCb 2016 conditions
Signal D^0 decays from minimum bias





Truth tracking

- Consistent MC truth for particles from
  - Generator level only
  - Generator level but modified by Geant4
  - Created in Geant4

```
omega(782) HepMC|G4Primary|G4Truth = 1|0|0 CONV  = MC
|--- pi- HepMC|G4Primary|G4Truth = 1|1|1 CONV  = G4
|---|--- e- HepMC|G4Primary|G4Truth = 0|0|1 CONV  = FROMG4
|--- pi+ HepMC|G4Primary|G4Truth = 1|1|1 CONV  = G4
|--- pi0 HepMC|G4Primary|G4Truth = 1|0|0 CONV  = MC
|---|--- gamma HepMC|G4Primary|G4Truth = 1|1|1 CONV  = G4
|---|---|--- e+ HepMC|G4Primary|G4Truth = 0|0|1 CONV  = FROMG4
|---|---|--- e- HepMC|G4Primary|G4Truth = 0|0|1 CONV  = FROMG4
|---|--- gamma HepMC|G4Primary|G4Truth = 1|1|1 CONV  = G4
```

- Keep the G4 history in HepMC3 structure while processes occur
- Linking of hits to particles
- Conversion to final event model
  - LHCb MCParticles, MCVertices, MCHits
  - Example for conversion to EDM exist in Gaussino – not checked in a while

Geometry

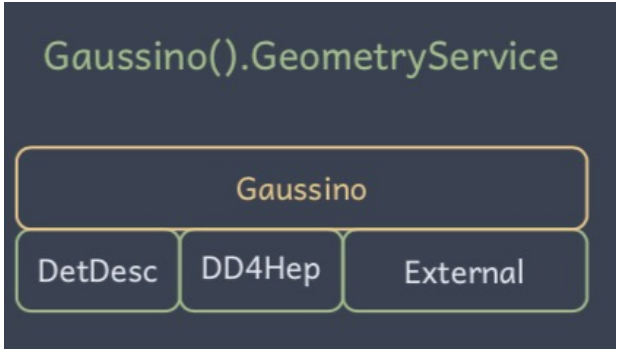
A geometry service managing different backends

- DD4hepCnvSvc (DD4Hep)
- experiment specific, e.g LHCb DetDesc

It is also equipped with a custom geometry service

- python configurable
- experiment-independent

allowing Gaussino to act as a stand-alone application



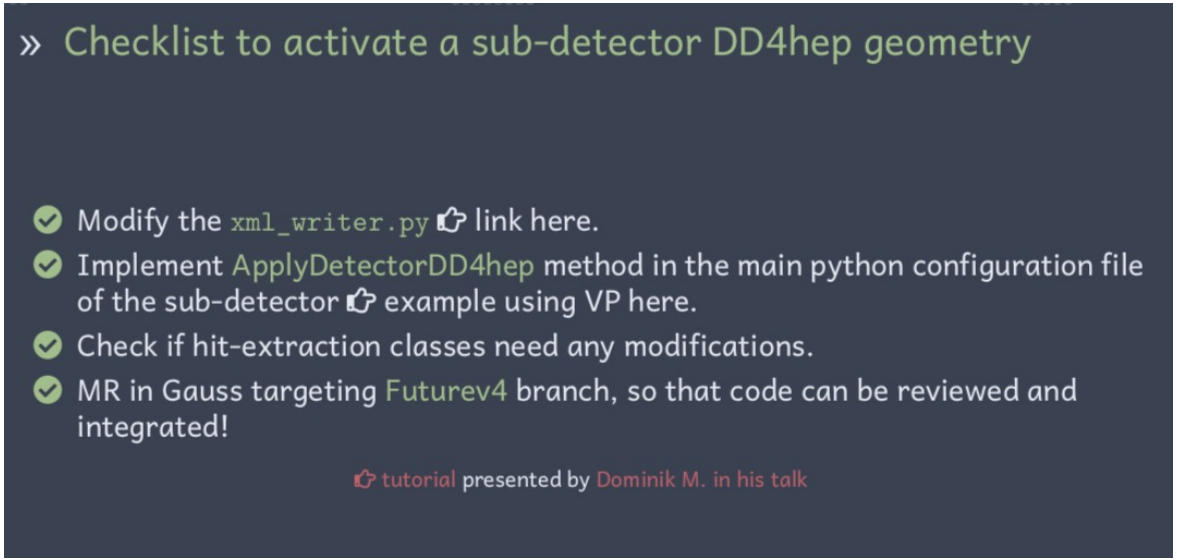
Gaussino can save the geometry in GDML

In LHCb a configurable high level service LHCbGeo() is responsible for coniguring the geometry and managing the readout and monitoring algorithms

Geometry from DD4Hep

Active volumes identified via DD4hep or manually specified
Actual sensitive detectors identical to those for DetDesc
Extraction of the volume IDs via DD4hep

The LHCb example



NB Gauss() writes a temporary top level DD4hep xml to select sub-detectors to simulate

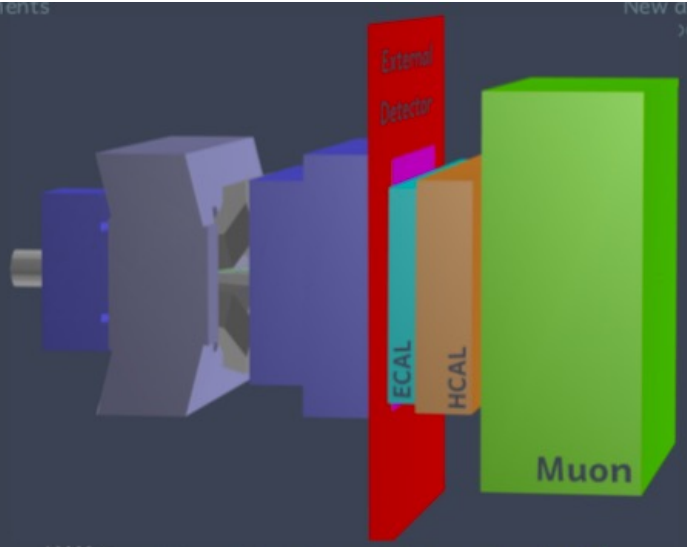
New Features

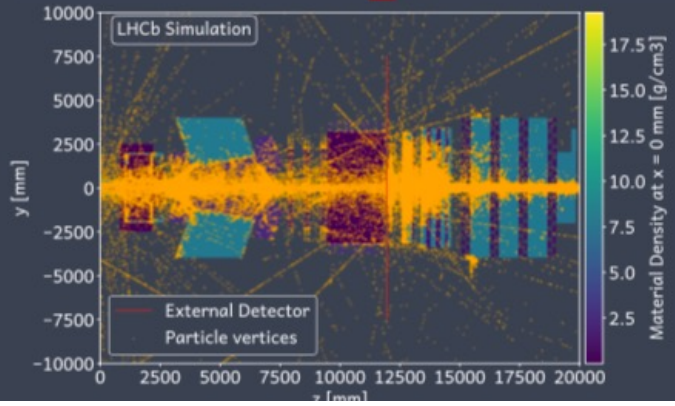
Status ○●○ Current developments ○○○○○○○○ New documentation ○○

» Abstract geometry

docs

- ExternalDetector is a new component in Gaussino that allows for abstract, sensitive volumes of any shape to be inserted at the configuration time.
- It can be mixed with any other geometry service.
- It is extensively used to test Gaussino infrastructure.





[6/20]

New Features, cont.

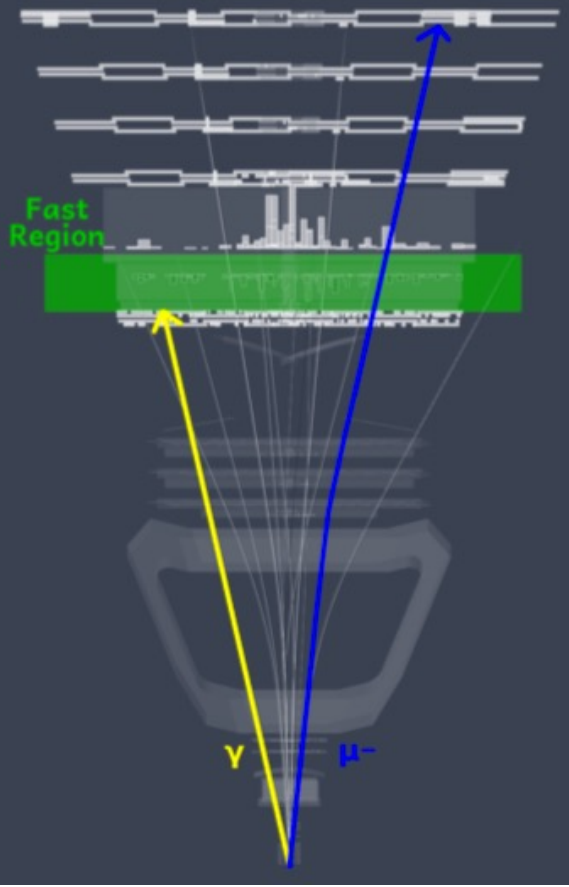
» Fast Simulation Interface

Gaussino!20 docs

Gaussino's hook to fast simulation directly in Geant4.

1. What?
   * what particles should be tracked,
2. Where?
   * region where the fast simulation takes place,
3. How?
   * particle conditions,
   * dynamics conditions,
   * fast hit generation algorithm,

more on fast simulations in Lucio's talk today



New Features, cont.

» Fast Simulation Interface

Implementation

Gaussino!20 docs

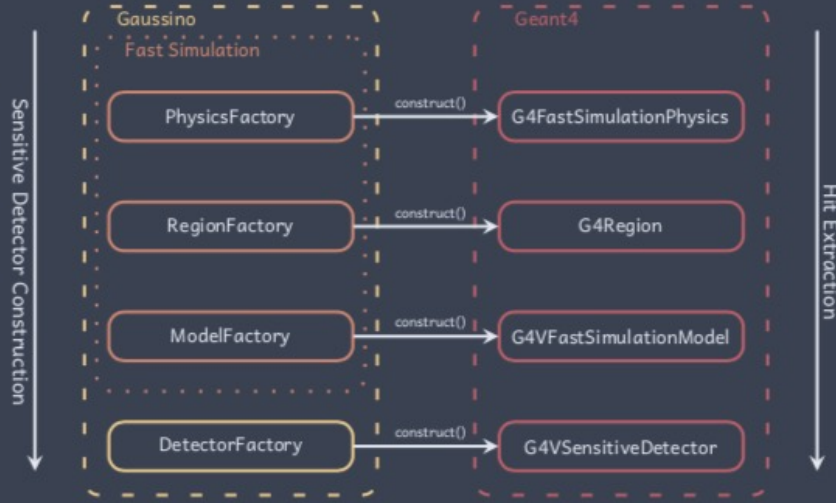


Figure: A simplified model of the FastSimulation interface with a set of dedicated factories that construct the corresponding Geant4 objects.

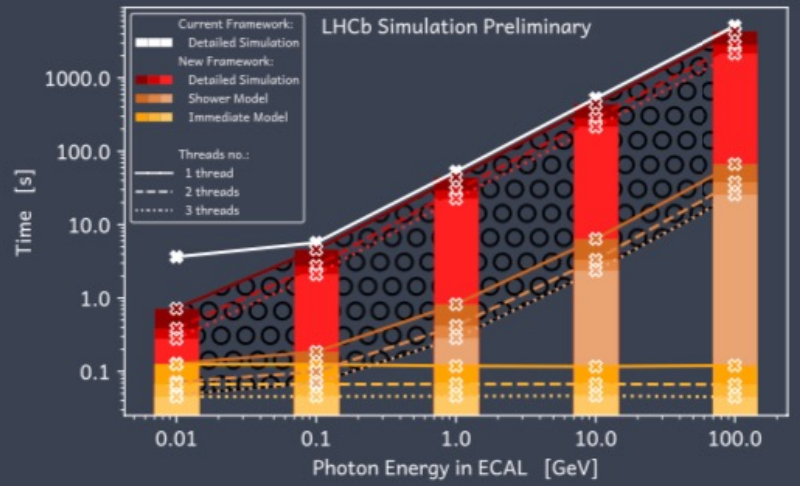


Figure: Comparison of the time spent by different fast simulation models (`ImmediateDeposit` and `ShowerDeposit`) and a detailed simulation with Geant4 in the electromagnetic calorimeter. In each of the models tested, a particle gun generates a grid of evenly-spaced photons of a particular energy. For the detailed simulation the time of the current version of Gauss is also given as reference.

LHCB-FIGURE-2021-004

[10/20]

Recent developments

» New CMake Configuration

* Based on the new CMake configuration in Geant4.
* Most of the packages are already ported.
* First successful tests.

- Gaussino!41 development of the new CMake in Gaussino,
- Geant4!79 Marco Cl. development of new CMake in Geant4.

lhcb-gaussino-new-cmake/84 (today) prev

Test build of new CMake in Gaussino

build 100% | passing: 10 warnings | tests 100% | ✔ 1758 | ✘ 4

Compare with previous build | Compare two slots | Restart | Abort | Browse artifacts

Project	Version	x86_64_v2-centos7-gcc11-opt		x86_64_v2-centos7-gcc11-dbg		x86_64_v2-centos7-gcc11+dd4hep-opt	
		build	tests	build	tests	build	tests
DBASE	None						
LCG	101						
Gaudi	HEAD	0 / 0	284 / 0	0 / 0	284 / 0	0 / 0	284 / 0
Geant4	HEAD	1043 / 0	0 / 0	1076 / 0	0 / 0	1043 / 0	0 / 0
Detector	HEAD	0 / 0	23 / 0	0 / 0	23 / 0	0 / 0	23 / 0
LHCb	HEAD	0 / 0	257 / 0	0 / 0	257 / 0	2 / 0	258 / 1
Run2Support	HEAD	0 / 0	6 / 0	0 / 0	6 / 0	0 / 0	6 / 0
Gaussino	HEAD	167 / 0	5 / 1	167 / 0	5 / 1	167 / 0	5 / 1
GaussinoExtLibs	HEAD	1 / 0	0 / 0	1 / 0	0 / 0	1 / 0	0 / 0

LHCb plans

Gauss[-on-Gaussino] to replace current Gauss for Run3 simulation this year and next year for Run1&Run2

* The first release of Gaussino and Gauss(-on-Gaussino) is tested in the lhcb-gaussino-prerelease nightly slot.

- Gaussino v0r1 - first version of Gaussino
- Gauss v60r0 - first version of Gauss(-on-Gaussino)

lhcb-gaussino-prerelease/31 (today) prev

Prerelease slot for Gauss-on-Gaussino

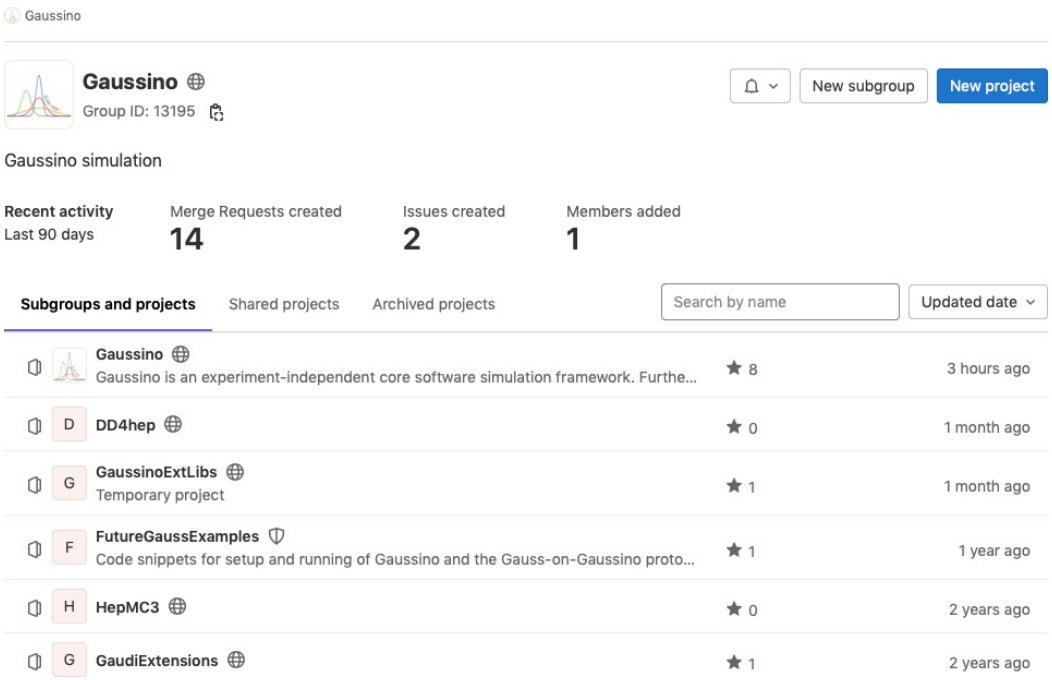
build 100% passing 10 warnings tests 100% ✔ 1763 | ✘ 23

Compare with previous build | Compare two slots | Restart | Abort | Browse artifacts

Project	Version	x86_64_v2-centos7-gcc11-opt		x86_64_v2-centos7-gcc11-dbg		x86_64_v2-centos7-gcc11+dd4hep-opt	
		build	tests	build	tests	build	tests
DBASE	None						
LCG	101						
Gaudi	master	0 / 0	284 / 0	0 / 0	284 / 0	0 / 0	284 / 0
Geant4	Sim10	1015 / 0	0 / 0	1015 / 0	0 / 0	1015 / 0	0 / 0
Detector	HEAD	0 / 0	23 / 0	0 / 0	23 / 0	0 / 0	23 / 0
LHCb	master	0 / 0	257 / 0	0 / 0	257 / 0	1 / 0	259 / 0
Run2Support	HEAD	0 / 0	6 / 0	0 / 0	6 / 0	0 / 0	6 / 0
Gaussino	HEAD	2 / 0	4 / 3	2 / 0	4 / 3	9 / 0	4 / 3
Gauss	Futurev4	5 / 0	2 / 5	2 / 0	2 / 5	6 / 0	3 / 4

Repository[-ies]

https://gitlab.cern.ch/Gaussino



For LHCb dedicated Gauss development branch, **`Futurev4`**

Documentation

https://gaussino.docs.cern.ch/gaussino

- Each new development in Gaussino is now documented
- Versioning of the documentation
- A simular website or Gauss[-on-Gaussino] is under construction
- Contents
  - Details on how to run Gaussino
  - Documentation of python configuration and their properties
  - Examples on how to use the configurations