CHEP 2026 – 28th Conference on Computing in High Energy and Nuclear Physics

Deploying the new LHCb simulation framework based on Gaussino for distributed production of simulated samples

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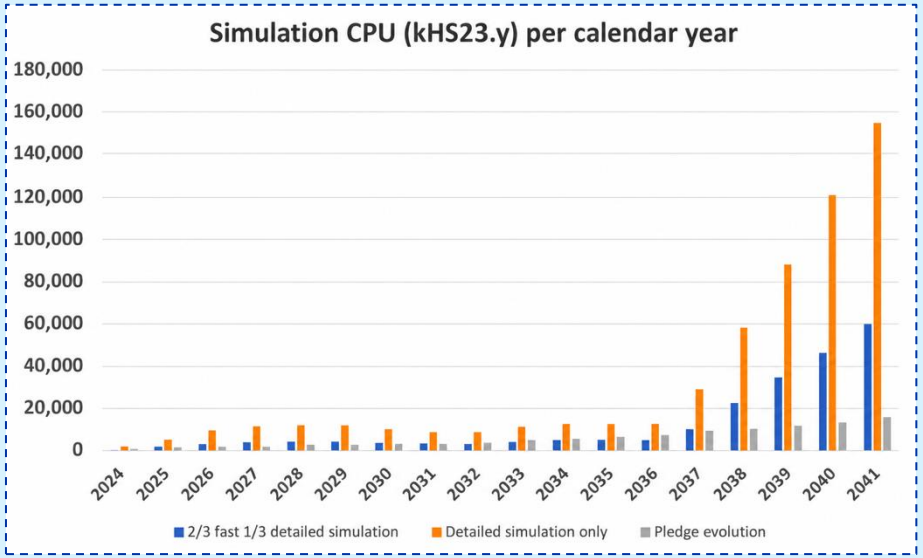
Motivation

Why does LHCb simulation framework need to evolve?

- Increasing luminosity requires significantly larger simulated datasets
  - simulation demands scale with increasing event rate
- Computing resources are becoming a major limitation
  - higher event complexity and pile-up increase CPU costs
- Future simulation framework must be both faster and scalable.
- Gaudi, Geant4 and the LHCb core software have evolved and modernized — The LHCb simulation must evolve with them
- New computing architectures and software technologies (MT, ML, GPUs, ...)

C. Bozzi (LHCb)

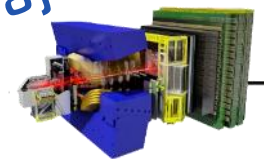


Current approaches are not sustainable in the long term!

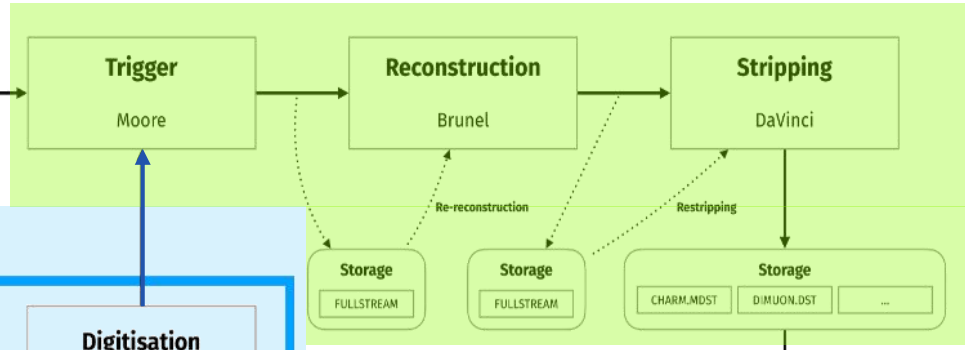
Up to ~ 95 % of LHCb's allocated distributed computing resources are used for Monte Carlo productions. Simulation MUST evolve!

Simulation data processing workflows in LHCb

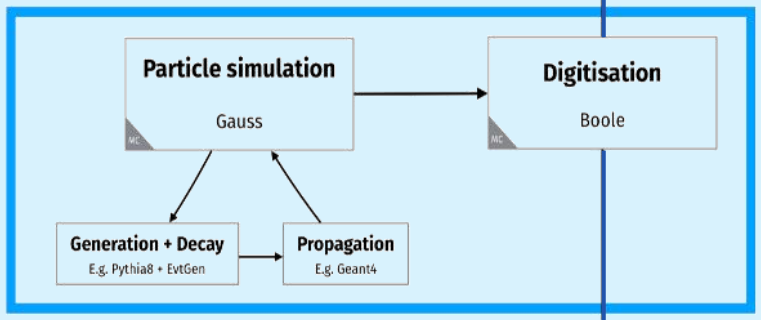
Run 1 & 2 (2011-2018)



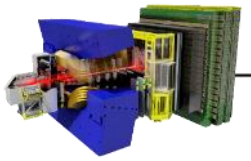
Run 1 & 2 Data Processing flow

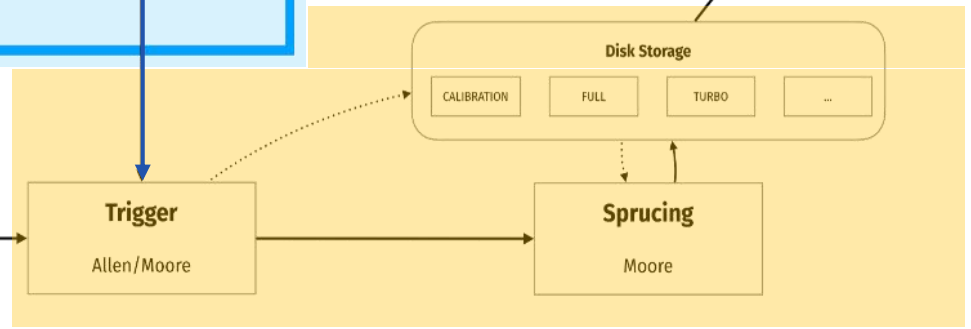


Simulation software



Run 3 (2023-2026)





Run 3 Data Processing flow

Simulation campaigns in LHCb are identified by labels of the form SimNN

- **Sim10**
  - Production campaign for Runs 1-3 (Gauss)
- **Sim11**
  - Production campaign starting for Upgrade 2 (Gauss-on-Gaussino)
  - Migration of Run3 productions underway
  - Eventually also Run 1-2

LHCb Simulation Software

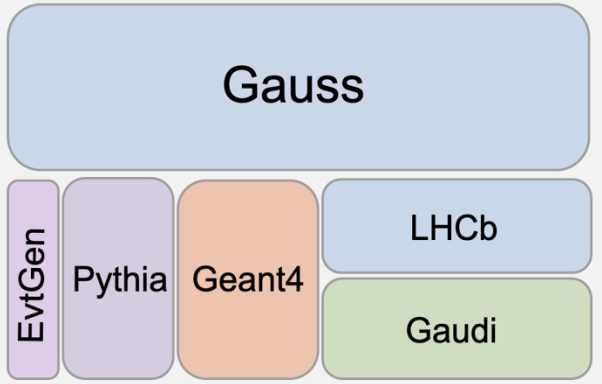
From Gauss to Gauss-on-Gaussino

- **Gauss (Sim10)** is the LHCb simulation framework integrating the full Monte Carlo chain, from event generation to detector simulation. Used at LHCb for Runs 1-3.
- **Gauss-on-Gaussino (Sim11)** is the next-generation LHCb simulation application that will replace Gauss by building the experiment-specific simulation stack on top of Gaussino. Already used for Upgrade 2 studies.
- **Gaussino** is a modular, experiment-independent simulation framework providing scalable and flexible detector simulation infrastructure based on Gaudi.

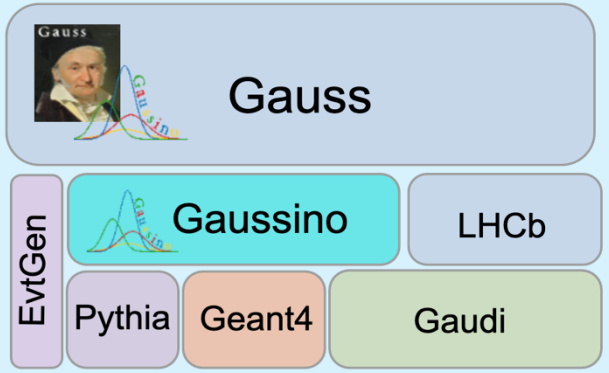
More at CHEP-2026

→ Wojciech Krupa et al., New developments in the experiment-independent **Gaussino** simulation software and its use in LHCb, 27 May 2026, 14:21 [🔗]

Gauss structure

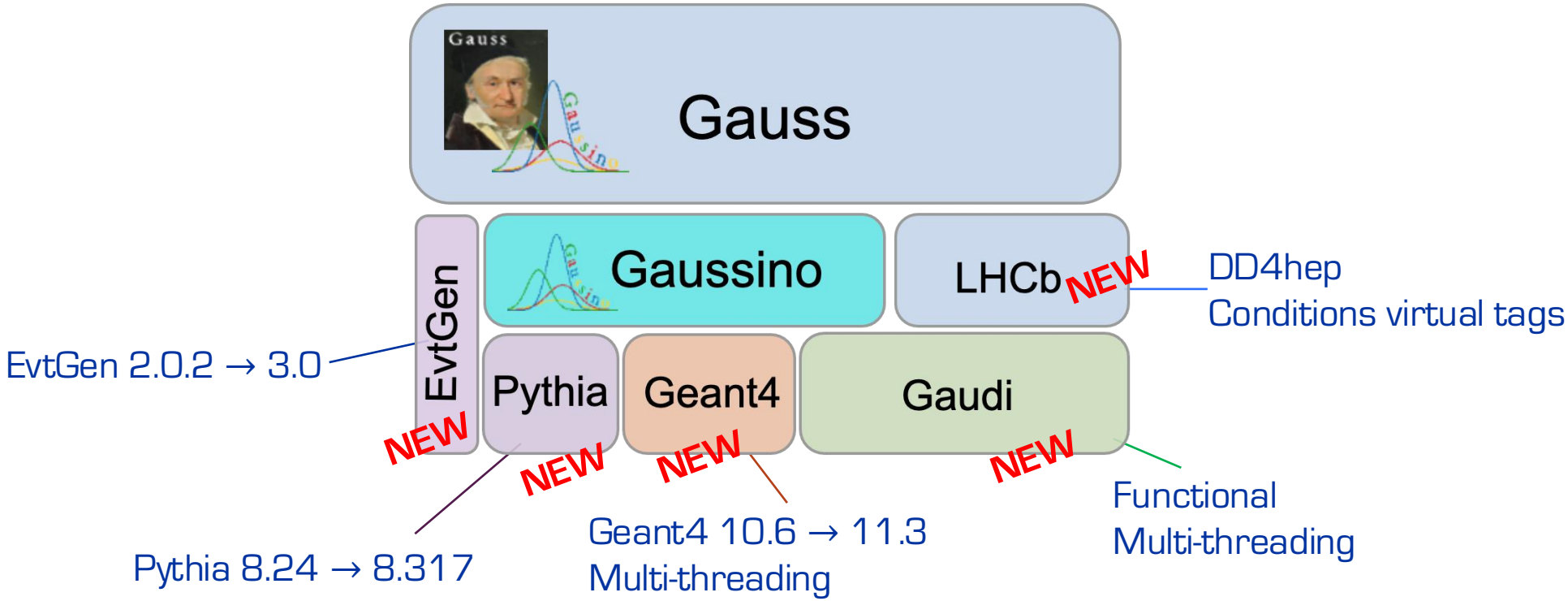


Gauss-on-Gaussino structure



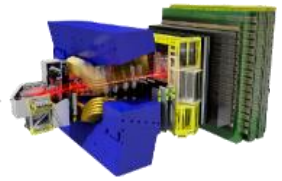
LHCb Simulation Software

From Gauss to Gauss-on-Gaussino - external software

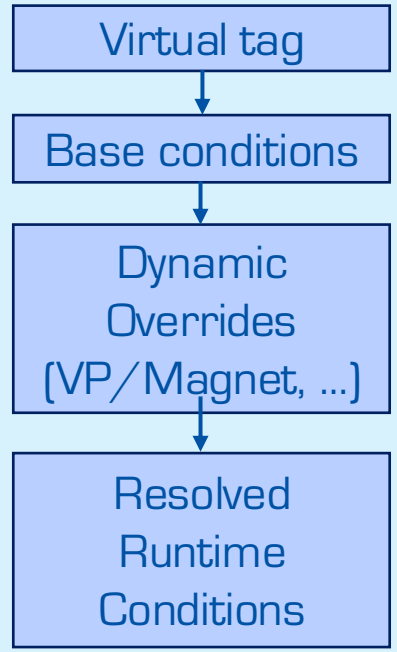


Virtual Conditions

A scalable, flexible and maintainable approach to detector conditions



- Each simulation campaign must accommodate multiple detector configurations.
- Old approach: many static condition tags → impossible to scale/manage
- New approach: **virtual tags** dynamic runtime condition composition → scalable production workflows
- Useful for local/offline studies and development workflows.
- Enabled dynamic overrides of key LHCb detector conditions: VELO alignment, magnet settings/polarity, and others.



Virtual Tag Resolution Workflow

Configuration example

```
<real-tag>-<virtual-tag>
sim{NN}-<data taking period>-<tag version>-[VELO position]-[magnetic field]-[…]
```

Challenges

Key challenges in deploying a new simulation framework

Physics

- → Ensure appropriate physics modelling and agreement with data
- → Regression against previous simulation campaigns

Software

- → Integration of new external software or versions, i.e. DD4Hep, Geant4, generators, ...
- → Dependency management
- → Release coordination and validation
- → Software modernisation, i.e. vectorisation, multi-threading, ...

Computing

- → Improve event throughput
- → Distributed production at large scale (DIRAC$^{\chi}$ THE INTERWARE)
- → Support multiple computing architectures

The deployment of a Gaussino-based simulation framework must preserve physics accuracy while delivering scalability and performance.

Deployment & validation of simulation s/w

Simulation software undergoes a long validation path before reaching production.

Commissioning

→ LHCb Nightly Builds
→ `ci-tests`

Production Validation

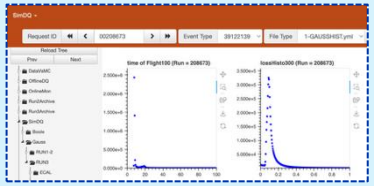
→ LHCb Nightly Builds
→ LHCbPR tests (GRID)

PRODUCTION

Performance & Regression

→ LHCbPR tests

Data Quality*



→ * MONET – LHCb Monitoring Framework for Data Quality and Simulation

Many tools are available to support this process.

Towards Sim11 in production

◊ Current Status

- ✓ Initial deployment of Gauss-on-Gaussino has been **successfully completed**.
- ✓ **Nightly validation** and **PR testing** infrastructure fully operational.
- ✓ Large-scale distributed **production commissioning** is **in progress.**
- ✓ Extensive physics and performance **validation campaigns** ongoing.

◊ Next Steps

- → Achieve **full feature parity with Sim10** workflows.
- → **Finalize DD4hep** detector geometry integration.
- → **Extend automated validation** with pytest-based infrastructure.
- → Prepare **Sim11** for **large-scale** Run 4-5 **production**.
- → Complete **migration of Run3** productions.

LHCb Nightly Builds

Validation of software integration at LHCb

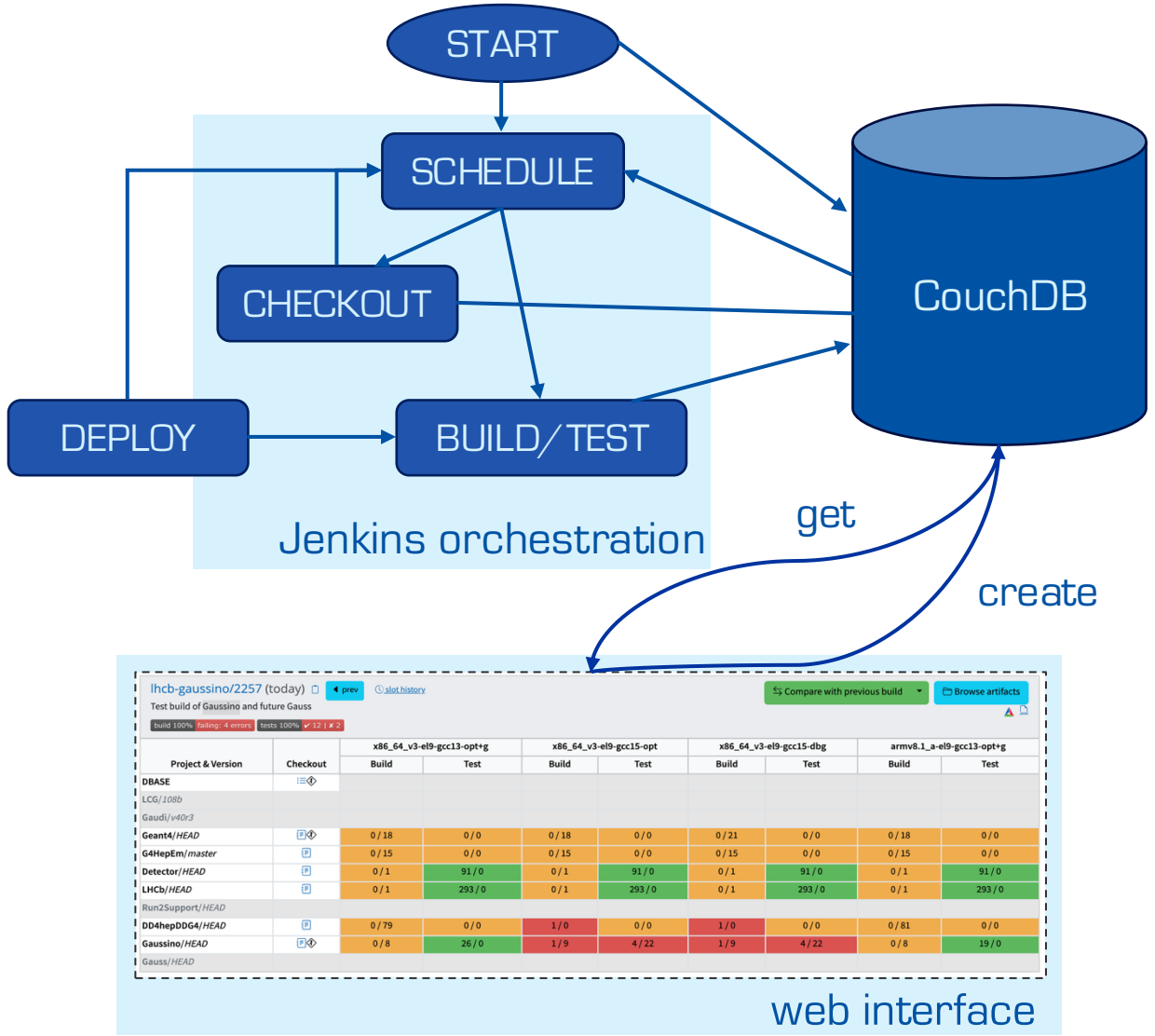
Commissioning

→ LHCb Nightly Builds

→ `ci-tests`

What is LHCb Nightly?

- A system for building and testing sets of interdependent software projects at **LHCb**.
- Steered by **Jenkins**
- Centralized state tracking via **CouchDB**
- Dynamic build configurations to test specific GitLab MRs (**ci-test**).



More?

→ Technical information about LHCb Nightly Builds can be found in the CHEP report

LHCb Nightly Builds

LHCb Nightly in Simulation workflow

Commissioning
→ LHCb Nightly Builds
→ `ci-tests`

- Key component for deployment and validation of **Sim11** releases.
  - Check software consistency, only *O*(10) events.
- Extensive automated validation for simulation workflows:
  - **generator-level** validation tests;
  - **detector** simulation checks;
  - **integration** tests across simulation stages;
- Transition to a **pytest**-based testing infrastructure for Sim11.

Sim11 nightly slots

Project & Version	Checkout	x86_64_v3-el9-gcc13-opt+g Build	x86_64_v3-el9-gcc13-opt+g Test	x86_64_v3-el9-gcc15-opt Build	x86_64_v3-el9-gcc15-opt Test	x86_64_v3-el9-gcc15-dbg Build	x86_64_v3-el9-gcc15-dbg Test	armv8.1_a-el9-gcc13-opt+g Build	armv8.1_a-el9-gcc13-opt+g Test	x86_64_v3-el9-gcc15+detdesc-opt+g Build	x86_64_v3-el9-gcc15+detdesc-opt+g Test	x86_64_v3-el9-gcc13-opt Build	x86_64_v3-el9-gcc13-opt Test	x86_64_v3-el9-gcc13-dbg Build	x86_64_v3-el9-gcc13-dbg Test
DBASE															
LCG/*108b*															
Gaudi/*v40r3*															
Geant4/*HEAD*		0 / 82	0 / 0	0 / 209	0 / 0	0 / 235	0 / 0	0 / 84	0 / 0	0 / 209	0 / 0	0 / 82	0 / 0	0 / 93	0 / 0
G4HepEm/*master*		0 / 17	0 / 0	0 / 17	0 / 0	0 / 17	0 / 0	0 / 17	0 / 0	0 / 17	0 / 0	0 / 17	0 / 0	0 / 17	0 / 0
Detector/*HEAD*		0 / 1	91 / 0	0 / 1	91 / 0	0 / 1	91 / 0	0 / 1	91 / 0	0 / 1	91 / 0	0 / 1	91 / 0	0 / 1	91 / 0
LHCb/*HEAD*		0 / 1	296 / 0	0 / 1	296 / 0	0 / 1	296 / 0	0 / 1	296 / 0	0 / 1	299 / 0	0 / 1	296 / 0	0 / 1	296 / 0
Run2Support/*HEAD*		0 / 2	46 / 0	0 / 2	46 / 0	0 / 2	46 / 0	0 / 2	46 / 0	0 / 2	6 / 0	0 / 2	46 / 0	0 / 2	46 / 0
DD4hepDDG4/*HEAD*		0 / 79	0 / 0	0 / 79	0 / 0	0 / 79	0 / 0	0 / 81	0 / 0	0 / 79	0 / 0	0 / 79	0 / 0	0 / 191	0 / 0
Gaussino/*HEAD*		0 / 7	26 / 0	0 / 8	26 / 0	0 / 8	26 / 0	0 / 7	19 / 0	0 / 8	9 / 17	0 / 7	26 / 0	0 / 7	26 / 0
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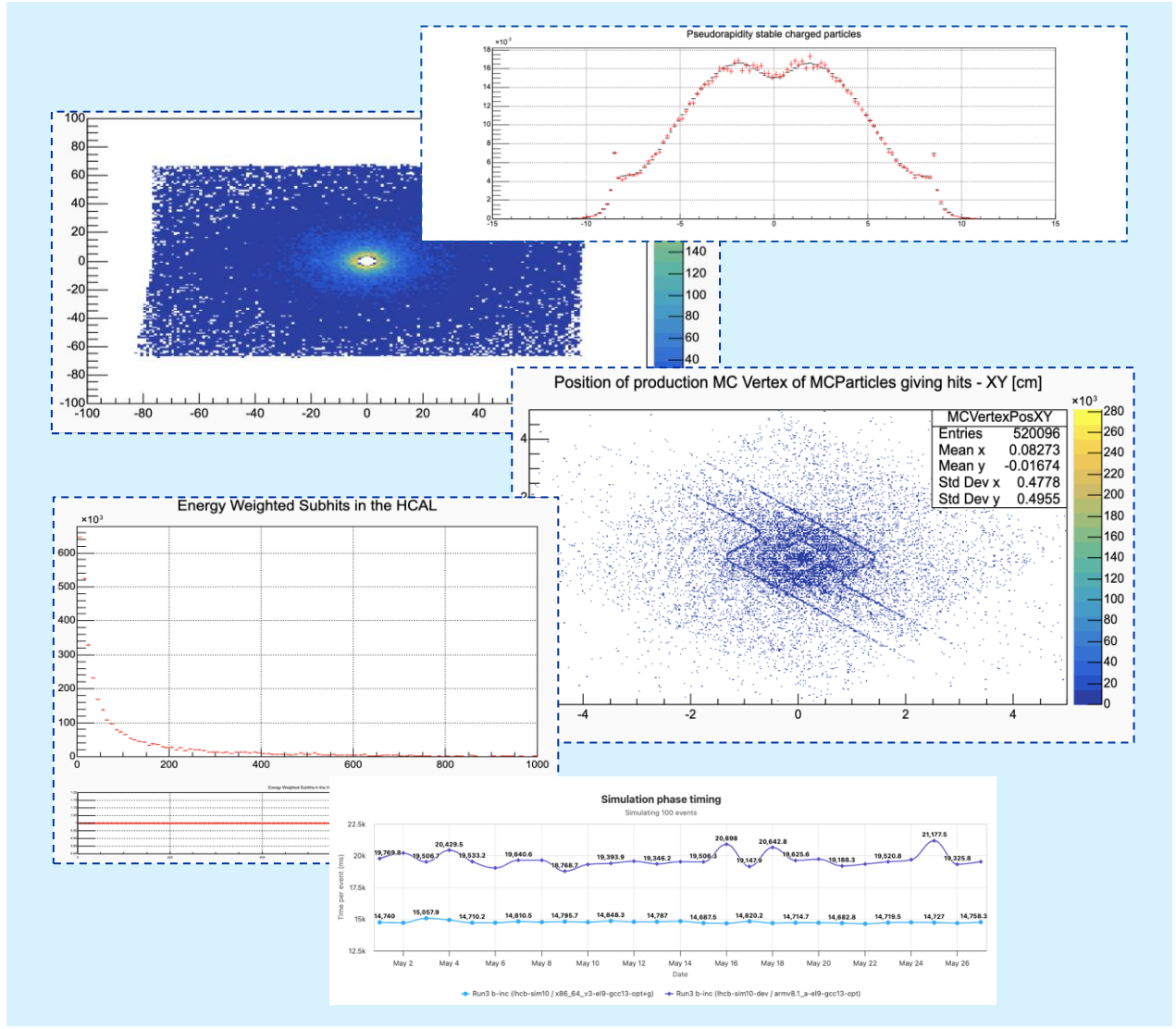
Boole/*HEAD*		0 / 1	15 / 0	0 / 1	15 / 0	0 / 1	15 / 0	0 / 1	15 / 0	0 / 1	15 / 0	0 / 1	15 / 0	0 / 1	15 / 0

LHCbPR tests

- ◊ **Performance and physics regression testing system at LHCb.**
- ◊ Results available through dedicated web application.
- ◊ Validation of technical performance and physics results.
- ◊ Monitoring of physics distributions and CPU/memory usage.
- ◊ Integrated with **GitLab CI** and nightly builds.
  - allow checking effect of each MR change

More?

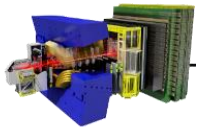
→ Technical information about LHCbPR tests can be found in the CHEP report



LHCbPR tests

LHCbPR tests for simulation

- Flexible configuration covering different simulation setups:
  - MC generators
  - beam conditions and data taking periods
  - detector geometry



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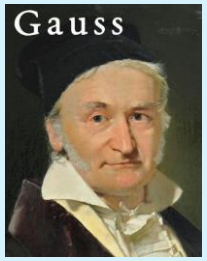
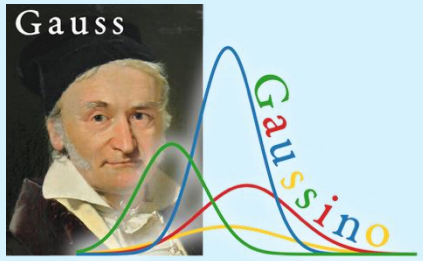
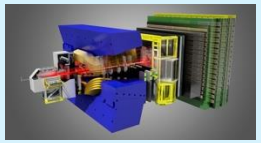
Gauss



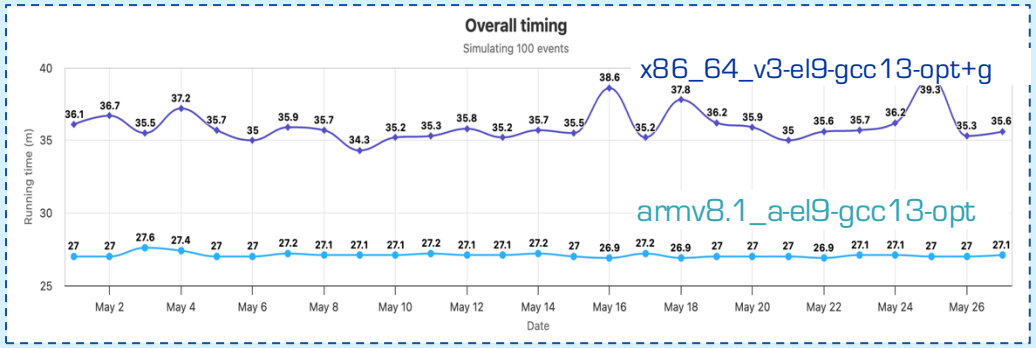
(Gauss on) Gaussino

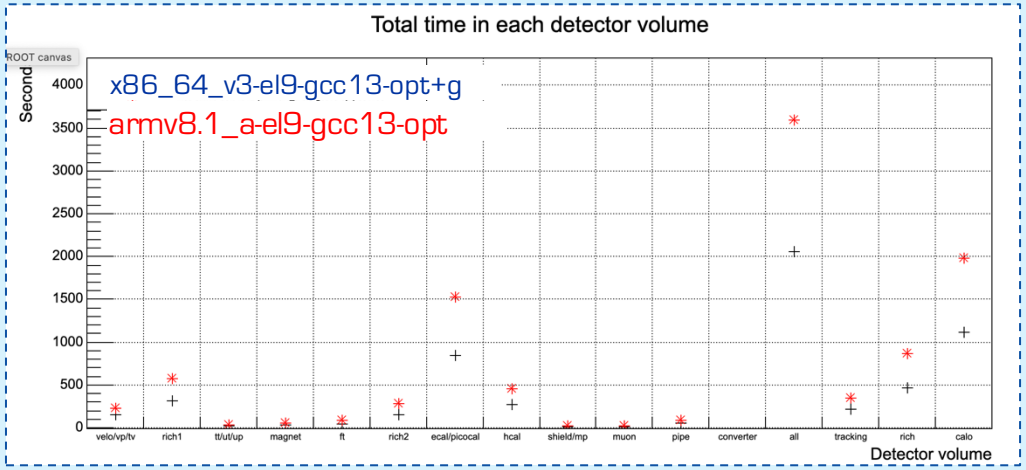


G4 & Other



Gauss timing

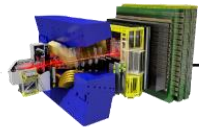




LHCbPR tests

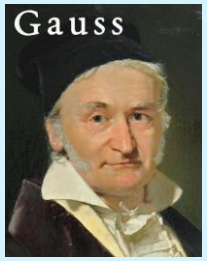
LHCbPR tests for simulation

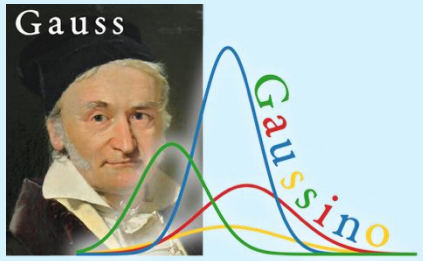
- Flexible configuration covering different simulation setups:
  - MC generators
  - beam conditions and data taking periods
  - detector geometry



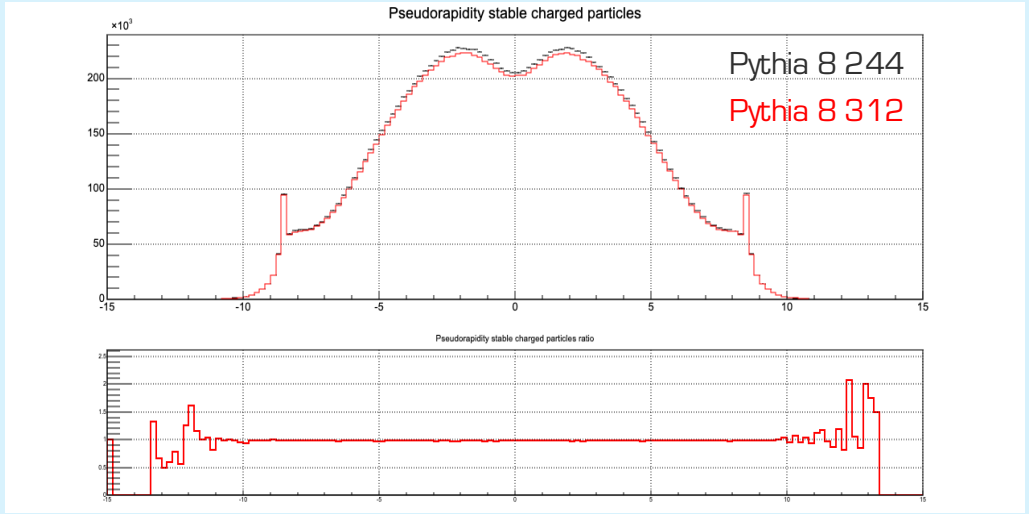
- Validation of histograms and physics observables.
- Large statistic samples … O(1000) on local machines and O(100k) on Grid for detailed physics analysis.
- Key component for developments and deployment of future releases.

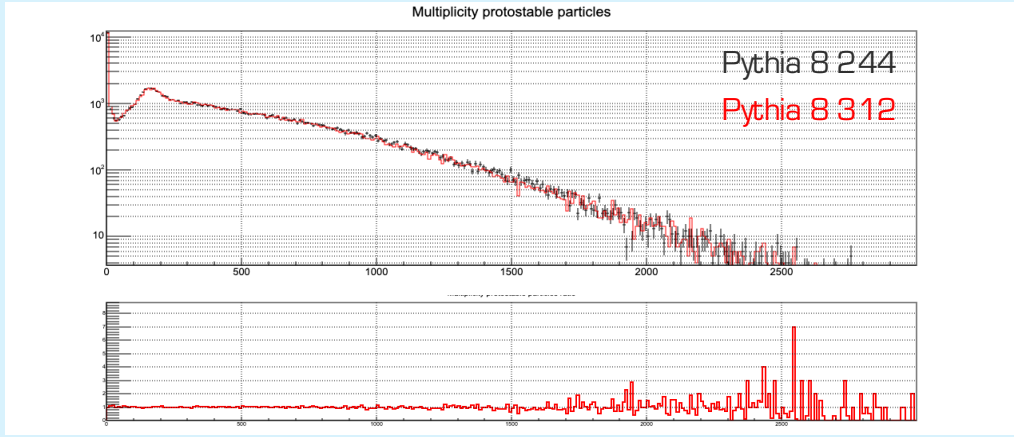
Gauss | **(Gauss on) Gaussino** | **G4 & Other**





Sim10 vs Sim11 – Pythia 8





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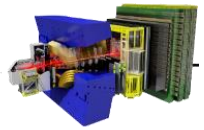

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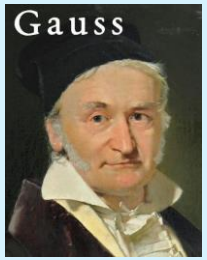
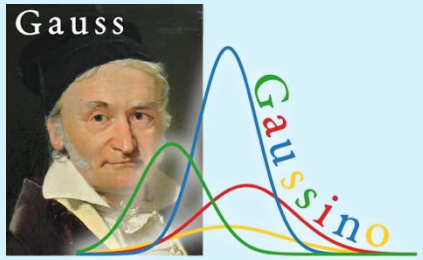
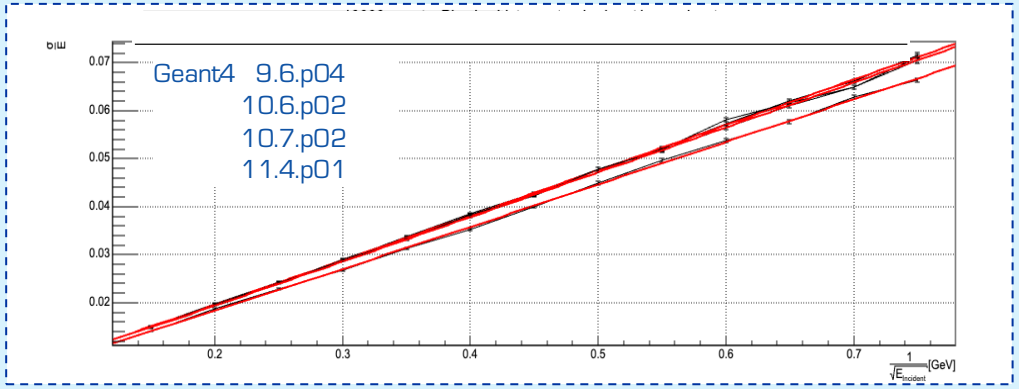
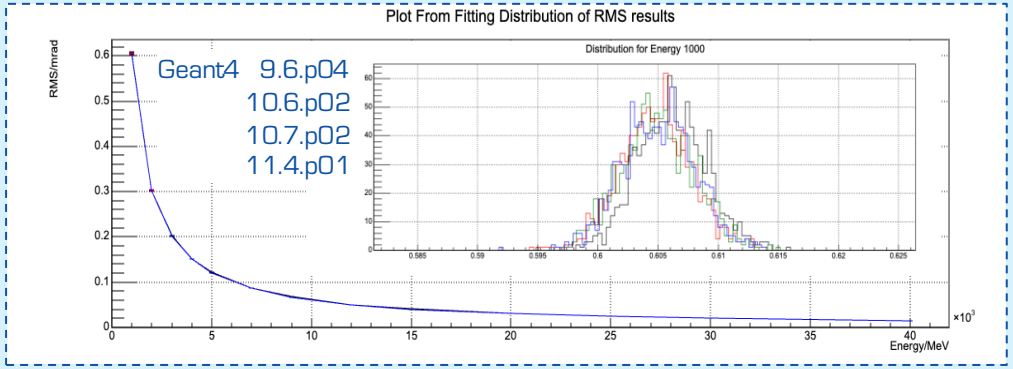




dE/dx in LHCb ECAL



Multiple Scattering angular resolution



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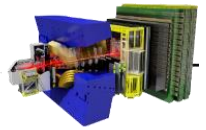

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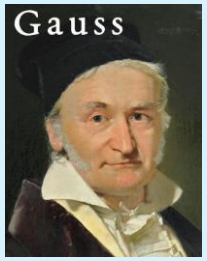

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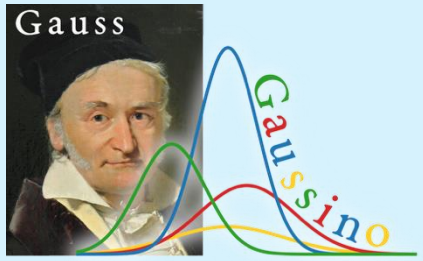
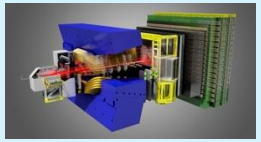
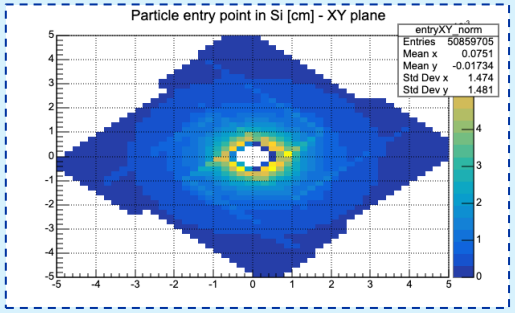


G4 & Other



Run3 VeLo - DetDesc



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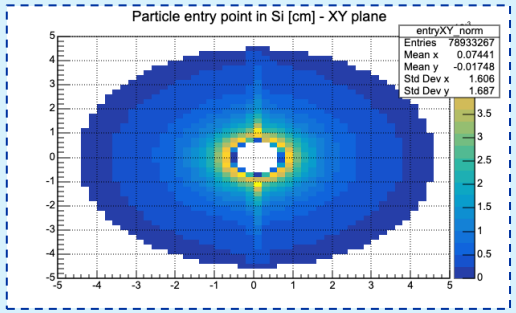
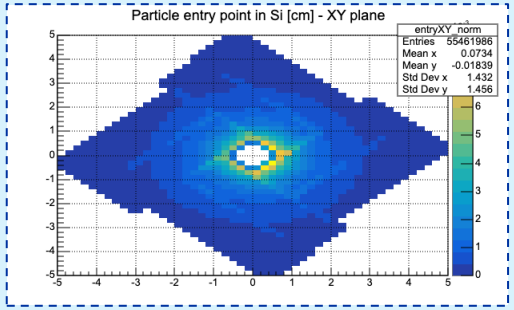
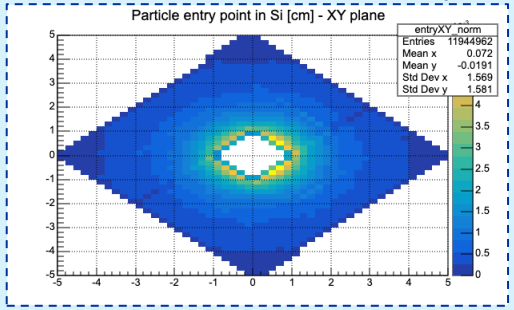


Run3 VeLo – DD4hep



Run5 VeLo – DD4hep



Towards physics production

PRODUCTION

Goal

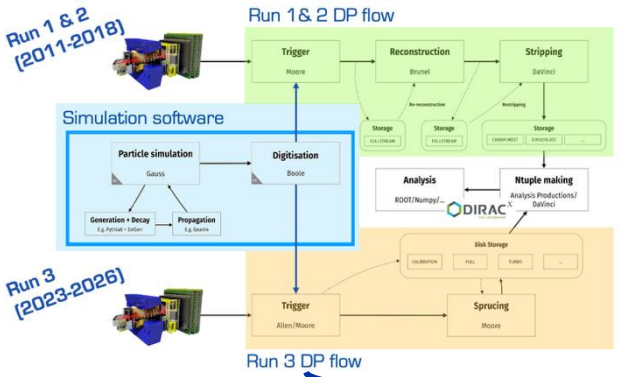
◊ Provide physicists with a wide variety of centrally produced MC samples.

◊ Validate the framework in large-scale production-scale distribution workflows.

◊ **Production deployment**
- CVMFS software distribution
- distributed GRID execution

◊ **Validation**
- excercise the whole simulation production chain
- production-scale commissioning
- large-statistics validation

◊ **Tooling**
- ProdConf, from DIRAC generic steering to specific applications configurations
- LbMCSubmit - submission of large-scale MC production



DIRAC

Gauss-on-Gaussino

CVMFS deployment

GRID distributed production

Large-scale MC campaigns

Gauss-on-Gaussino is entering large-scale distributed MC production

Conclusions

- **Gauss-on-Gaussino** establishes the next-generation simulation framework for **LHCb**
- Automated Nightly Builds and PR provide scalable validation and reproducibility
- Ongoing validation demonstrates compatibility with previous production campaigns
- The new framework enables scalable high-statistics Monte Carlo production for Run 4 and beyond

BACKUP