Gaussino - a Gaudi-based core simulation framework

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Motivation

- Starting point: general modernisation of LHCb software
- Main concept: separate core functionality for simulation
 - Experiment-independent framework: LHCb based algorithm built on top of that

- ~15 years old
- Single-threaded framework
- Memory usage becoming an issue
- Simulation based on Geant4
- Increase in CPU doesn't translate into an increase in memory

Main Features

- Keep the design choices of current Gauss, e.g.:
 - Integrated generation and simulation phase
- Include the following features:
 - Multi-threaded Gaudi
 - Can benefit from MT generators
 - HepMC3
 - Improve easy python configuration for jobs
 - Multi-threaded Geant4

Ref. [LHCB-TDR-017]

Gaussino

- A complete simulation framework following the basic Gauss architecture

Generator phase with Pythia8
interface implemented
Code migrated to HepMC 3

Simulation phase under
redesign with identification of
elements.
Aim to keep it 'simulation engine'
independent

Execution structure

Ref. [[Task based scheduler](#)]

Gaudi Functional

- Every Algorithm as task
- Constant execution
 - Random Engine created per call
- Fixed input/output, e.g.

```
/*output data*/ operator()(const /*input data*/) const
```

Multi-Threading

- Thread safety of generators
 - Production and decay tools
- Example in Gaussino: Pythia 8
 - Shared, locked
 - Thread local

Generation Phase Only!

Modular Simulation

- Take inspiration from the generation: modular!
- A simulation service managing different backends
- Flexible configuration, e.g. different setting for:
 - Pile-up - Spillover - Main Event
 - Signal - other particles
 - Fast Simulation

Simulation Interface

- Gaudi-Tools —————> factories
 - Easy python configuration of G4 settings
- Dynamic assignment possible
 - Entire Gaudi event
 - Split Gaudi Event into multiple G4 workloads
 - Plan to investigate new track based parallelism (in G4)

Truth Matching

Ref. [[HepMC](#)]

- Geant4 itself does not have any truth information

In current Gauss

- Writing HepMC structure keeping the history using G4 track actions
- Relying on global state for communications
- After simulation: converted to MCParticles (object storing the truth in LHCb Event Model)

For Future

- Redesign for multi-threading
- Simpler: directly write MCParticles

Detector Geometry

Ref. [[DD4Hep](#)]

- Move to **DD4Hep** for the detector wide translation
- Requires a bit redesign in simulation

User must provide:

- A Gaudi tool that provides the world pointer
- Logical volume to sensitive detector mapping (configurable via python)
- Basically python configurable UserDetectorConstruction
- DD4hep prototype being tested

Benefits

- Converter for loaded DD4Hep geometry to Geant4 already exists
 - Simplifies the GaussGeo conversion service
- Perform all modifications of geometry in DD4Hep

Future Gauss prototype

- Ported additional components
 - EvtGen
 - LHCb geometry description (DD4Hep in progress)
- Added to automatic LHCbPR testing (Ref. [[Link](#)])

Gauss + Gaussino

Migrated generation tools

- EvtGen (single, locking instance)
- Handles all decays
- Logic for signal generation
- LHCb specific generator cuts
 - Not affecting the performances

Generation Only $D^{*+} \rightarrow D^0 \pi^+$ with $D^0 \rightarrow K^- \pi^+$ events

Gauss + Gaussino + Geant4

Validation studies

- Performed in LHCbPR (the LHCb performance and regression monitoring tool)

Energy deposit (Generation + Simulation) $D^{*+} \rightarrow D^0 \pi^+$ with $D^0 \rightarrow K^- \pi^+$ events

Performances

- Tested with locking/thread-local generation phase
- Overall good scaling in throughput
- Very good scaling in memory usage

Tested with typical tagged D^0 decays with 2016 conditions

Generation + Simulation $D^{*+} \rightarrow D^0 \pi^+$ with $D^0 \rightarrow K^- \pi^+$ events

Conclusions

- Gaussino, an experiment-independent core framework developed in LHCb in very advanced state.
- Modular generation phase with Pythia8 example
- Gauss prototype built on top
- Interaction with Geant4 MT
- Encouraging first results, i.e.:
 - Performances not affected by LHCb specific tools
 - Almost perfect matching between old and new simulation
 - Higher throughput