Testing and verification of the LHCb Simulation

From SW commissioning to testing and validation

Dmitry Popov on behalf of the LHCb Collaboration
Outline

Overall SW developing and testing in LHCb
Commissioning of SW applications in LHCb
    Nightly builds and checks
    Performance and Regression tests
Production Validation and MC Data Quality
Summary
Overall SW development and testing in LHCb

- All LHCb software applications dream to go into production …
  .. but it is a long way for any new version to get there...

- We have plenty of tools to help them reach the finish line

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Commissioning

- Make a new version of simulation application compile and run
  - May include new versions of compilers, building tools, MC generators
  - Updated underlying framework (Gaudi) and a new version of GEANT4
  - Make it all work together, some simple checks start here
    - Everything should build, run and finalise successfully
    - Some changes should not influence the behaviour
    - For geometry - checks for volumes overlaps apply
LHCb SW applications family

Simulation subgroup

- Event Generation
- Tracking particles through material
- Detector Response
- L0 Trigger Emulation

Data processing subgroup

- High Level Trigger
- Lower Level Trigger
- Reconstruction
- Stripping
- Analysis

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Commissioning Gauss

- Nightly builds: automatically apply changes and build projects
- Nightly tests kick in, red flags all over the dashboard…
  … even if it builds, because Gauss relies on random numbers
- Gauss managers review what should be tested, tests are customised
  - Each test checks a single entity, e.g. a specific event type
  - For some tests a new SW stack should not change the output
Commissioning Gauss

- We have been using many separate nightly builds (slots) in parallel recently
  - Support various simulation configurations
  - Experimenting with new GEANT4 versions
  - Legacy, upgrade, production and future development builds…
    - More details in the talk by S.Chitic (T5, 12 Jul)
Simulation Validation begins with PR

- LHCb PR2 steps in, closely coupled with the nightly build system
- Tests are flexibly scheduled: required frequency, specific nightly slots
- Many different types and configurations
  - GEANT4 standalone applications, Gauss + different MC generators
  - Various beam conditions/types of events, full simulation (small samples)
  - Record CPU consumption, memory footprint
- Results are processed and stored, accessed/compared in a web interface
  - A new version of the interface is being developed, working prototype
- More details in the poster by M. Szymanski (T5)
Validation begins: PR2 GEANT4 test example

Simple physics quantities

“Multiple Scattering in thin layers” test, results compared in PR2 for two different G4 versions
Validation begins: PR2 detailed timing test

“Detailed timing in volumes” results comparison in PR2

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Validation: LHCb’s list of PR2 tests for simulation

<table>
<thead>
<tr>
<th>GEANT4 tests</th>
<th>Gauss tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadronic X-section</td>
<td>Hadronic Multiplicities</td>
</tr>
<tr>
<td>Calorimeter</td>
<td>Radiation Length and Absorption Map</td>
</tr>
<tr>
<td>Multiple Scattering</td>
<td>Muon Multiple Scattering</td>
</tr>
<tr>
<td>Simplified RICH Simulation</td>
<td>dE/dx in Thin Layer</td>
</tr>
<tr>
<td></td>
<td>VELO Energy Deposits</td>
</tr>
<tr>
<td></td>
<td>Detailed Timing in Detector Volumes</td>
</tr>
<tr>
<td></td>
<td>Bremsstrahlung</td>
</tr>
<tr>
<td></td>
<td>CPU &amp; Memory Consumption</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gauss Sim Validation</td>
</tr>
</tbody>
</table>
Simulation Validation goals at this point

- Checks before starting larger validation
  - Verify that only the expected changes are observed
    - Physics, detector modelling
    - Small samples $O(1\text{Kevts})$ for full simulation
  - Verification of performance, keep track of its evolution
- Green light for validation by the physics working groups
Why we need one more layer: Data Quality for MC

- Nightly tests $O(5\text{evts})$, PR tests $O(1\text{Kevts})$, production validation $O(1\text{Mevts})$
- Some things are spotted only in large production
  - Jobs get stuck!
  - Reconstruction distributions make sense?
- DQ for MC allows to spot large discrepancies/problems faster
  - Validates simulation quality
  - Checks a subset of all productions jobs
  - Verifies configurations for each separate production
- Some of these we want to do automatically and this is the next step
An example from the current validation of Sim10*

- Sim10 brought many changes to Gauss, simulation conditions
  - New compilers, MC generators, latest GEANT4 version, frameworks updates
- Started out with nightly builds
- Continued with private test productions
  - Testing new versions of PYTHIA8, EvtGen, hadronic/EM physics lists
- Now ready to start central productions
  - Studies with particle guns, calibrations verification, etc.
  - Checks of effects on full reconstruction (tracking, calorimetry)
  - Systematic studies on trigger and physics analysis

*The next simulation production campaign for physics analysis
There were extensive checks on test production by working groups

The results were generally in good agreement

- Compared to the previous major simulation SW release
- Most of the reported differences were expected
  - Slightly higher multiplicities (new tuning, PYTHIA8 vs. PYTHIA6)
  - Small changes in $p_T$ distributions (new tuning, field map), etc.

Some problems in production were identified and fixed

- New validation productions verified the fixes

In the end we had to produce $\sim 50\,\text{Mevts}$ to complete the validation
Plans for Data Quality for MC for the next Simulation Campaign

- Would like to automate part of the work done by experts
- Experts define a set of distributions of interest, provide references
  - Such references depend on many things
    - From beam settings to event typology
- References are associated with productions
- Productions have a few processing steps
  - Every step produces and stores the distributions (histograms)
- Introduce MC DQ shifters to monitor the ongoing productions
  - Compare the produced distributions to the references
  - Decide to continue, hold or halt productions
Data Quality for MC: Interface example

*Credit A. Baranov, Yandex School of Data Analysis*
Summary

- Delivering reliable SW tools for physics analysis is a complicated task
  - Many stages from defining what goes into the new version
  - To prove that everything works as expected
- LHCb has adopted a multilevel verification system for simulation
  - Simple, not time consuming nightly tests
    - More complex LHCb PR2 checks
      - Validation in small productions
- Plans to introduce MC production Data Quality
- Together these steps help to spot the majority of potential problems
Thank you for your attention!