Testing and verification of the LHCb Simulation

From SW commissioning to testing and validation

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Outline

Overall SW developing and testing in LHCb

Commissioning of SW applications in LHCb

Nightly builds and checks

Performance and Regression tests

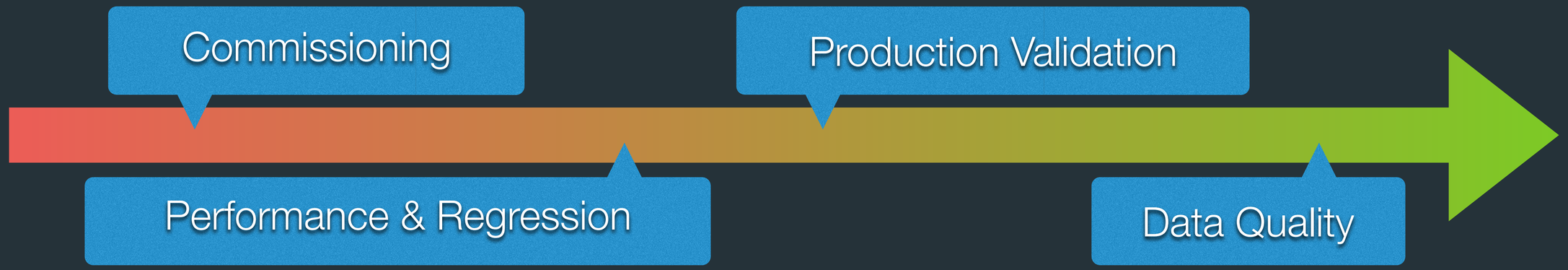
Production Validation and MC Data Quality

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…



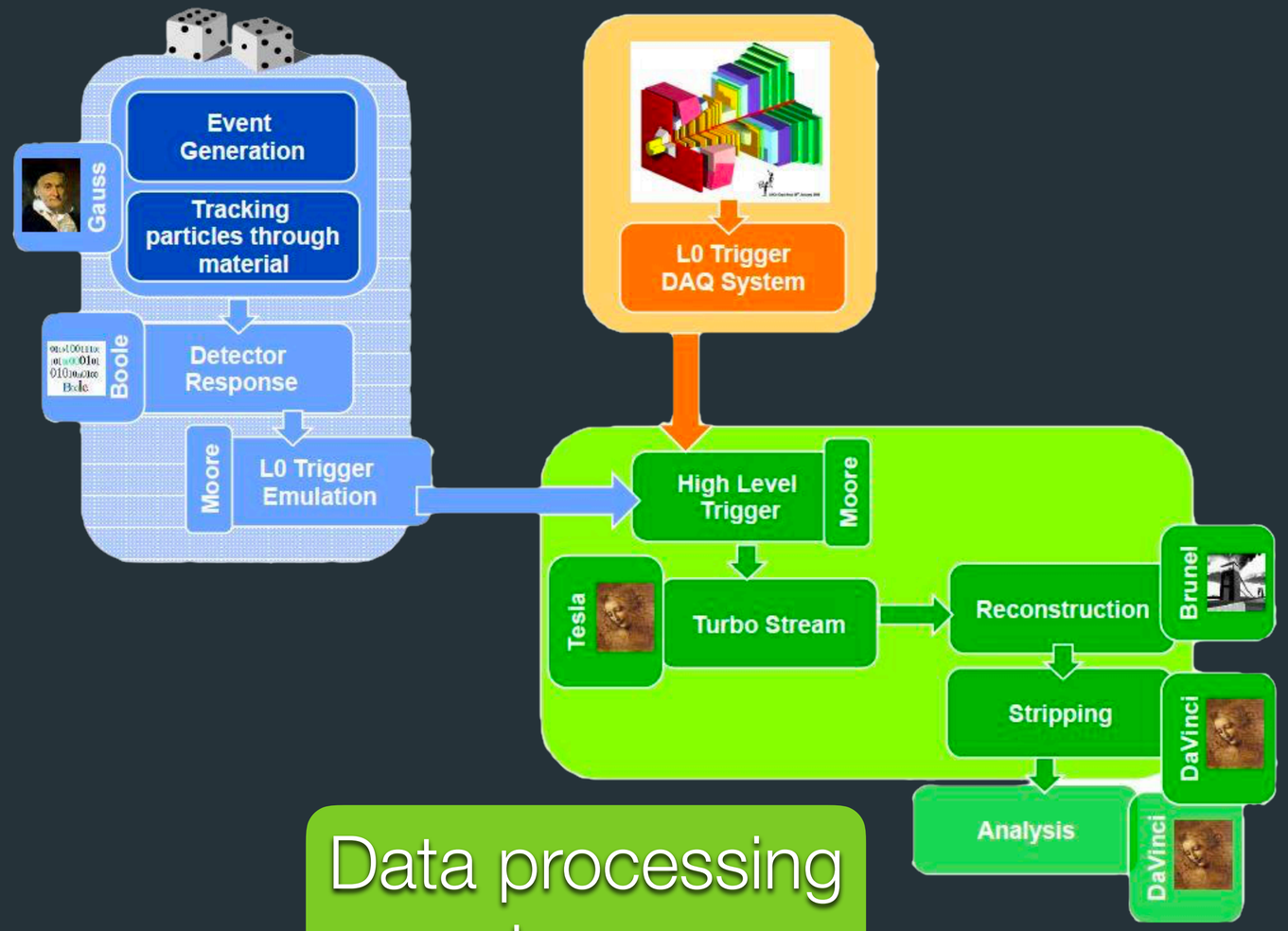
- We have plenty of tools to help them reach the finish line

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



Data processing subgroup

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)

Project	Version	x86_64-slc6-gcc62-opt Completed at 02:04:54 Platform diff		x86_64-slc6-gcc62-dbg Completed at 02:26:12 Platform diff		x86_64-centos7-gcc62-opt Completed at 02:18:08 Platform diff		x86_64-centos7-gcc62-dbg	x86_64-centos7-gcc7-opt
LCGCMT	93								
Gaudi	v29-patches	build	tests	build	tests	build	tests		
LHCb	2018-patches	build	tests	build	tests	build	tests		
Geant4	v104r2	build	tests (0)	build	tests (0)	build	tests (0)		
Gauss PR	HEAD	build (131789)	tests (8)	build (131781)	tests (0)	build (131789)	tests (13)		
DBASE	None	build		build		build			

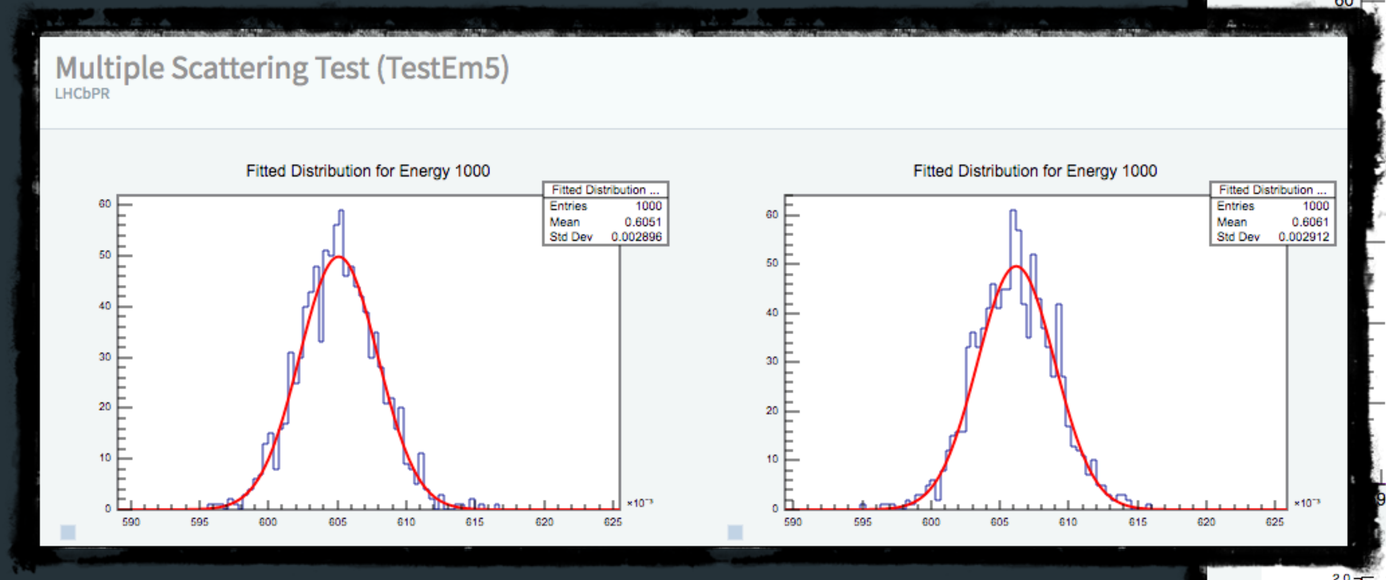
Project	Version	x86_64-slc6-gcc62-opt Completed at 02:01:43 Platform diff		x86_64-centos7-gcc62-opt Completed at 02:10:19 Platform diff	
LCGCMT	93				
Gaudi	v29-patches	build	tests	build	tests
LHCb	2018-patches	build	tests	build	tests
Geant4	HEAD	build (1)	tests (0)	build (1)	tests (0)
Gauss	a0927eee	build (131766)	tests (17)	build (131766)	tests (55)
DBASE	None	build		build	
PARAM	None	build		build	

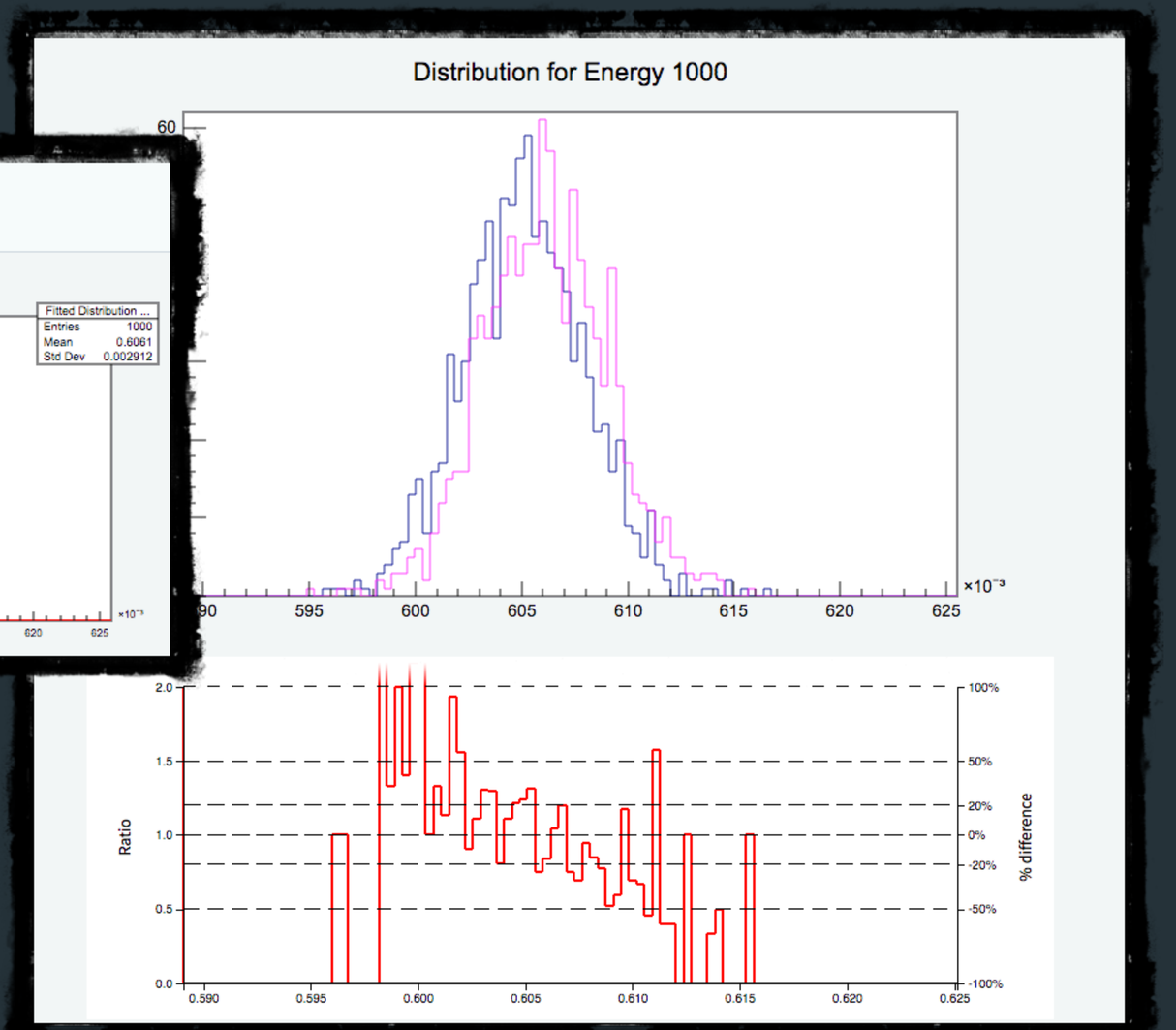
Simulation Validation begins with PR

- 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

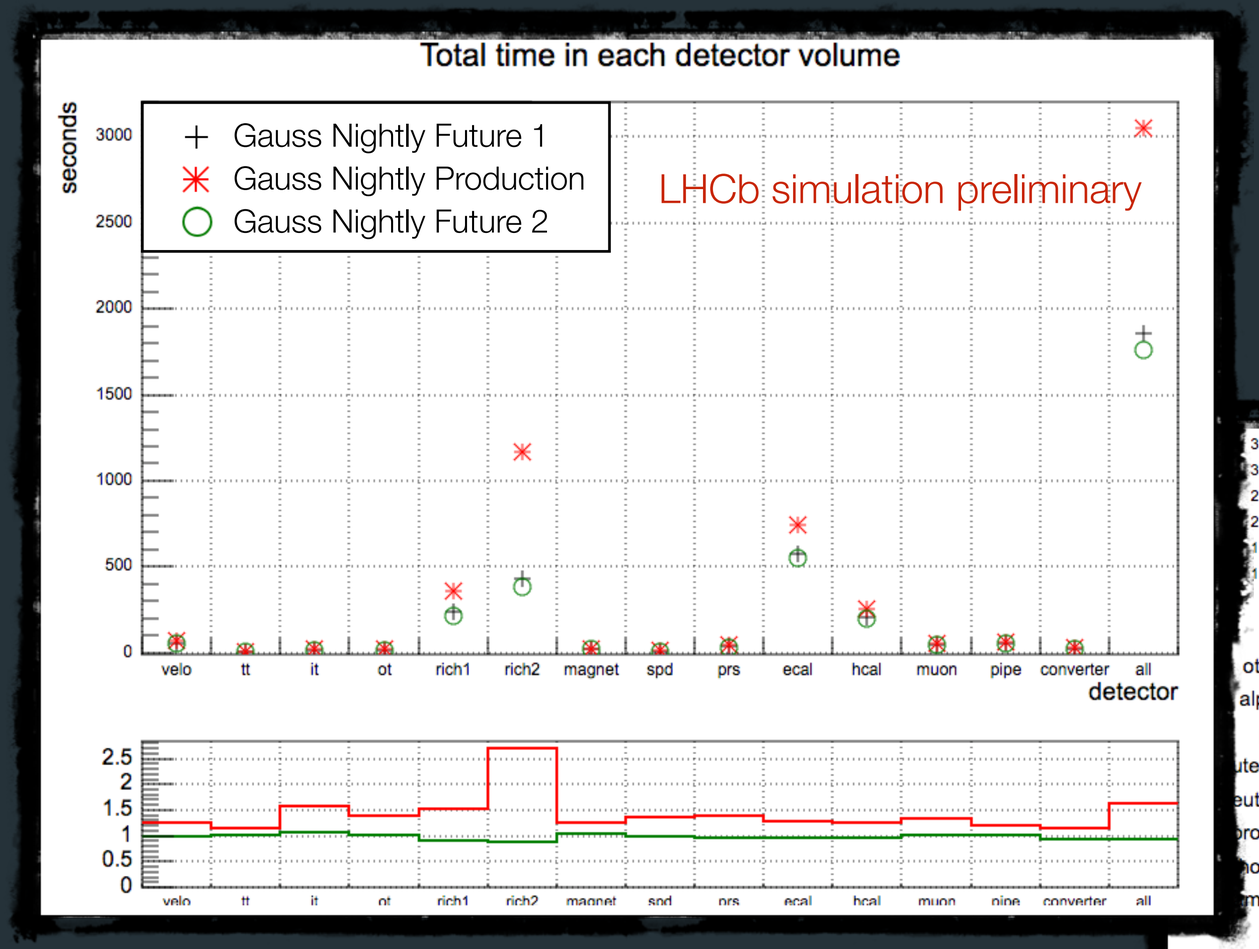
Simple physics quantities



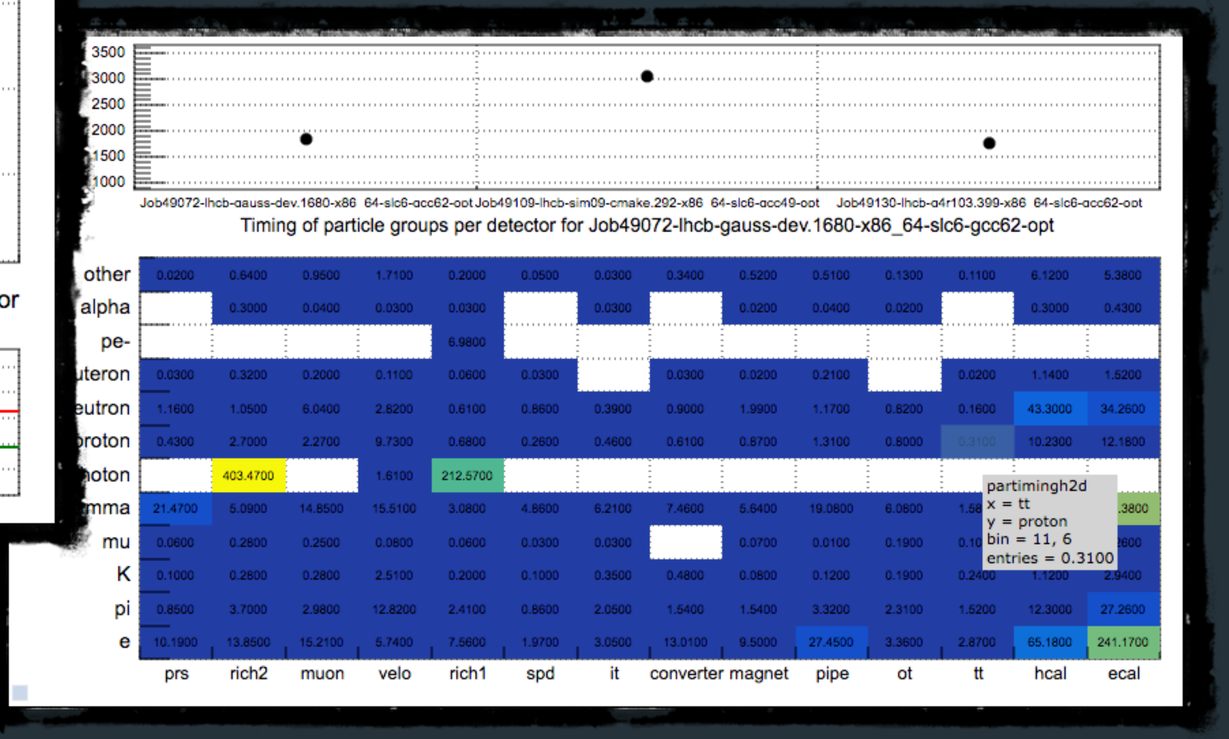


"Multiple Scattering in thin layers" test, results compared in PR2 for two different G4 versions

Validation begins: PR2 detailed timing test



"Detailed timing in volumes" results comparison in PR2



Validation: LHCb's list of PR2 tests for simulation

GEANT4 tests
Hadronic X-section
Calorimeter
Multiple Scattering
Simplified RICH Simulation

Gauss tests	
Hadronic Multiplicities	Radiation Length and Absorption Map
Muon Multiple Scattering	dE/dx in Thin Layer
VELO Energy Deposits	Detailed Timing in Detector Volumes
Bremsstrahlung	CPU & Memory Consumption
Gauss Sim Validation	

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`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(`5evts`), PR tests O(`1Kevts`), production validation O(`1Mevts`)
- 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*

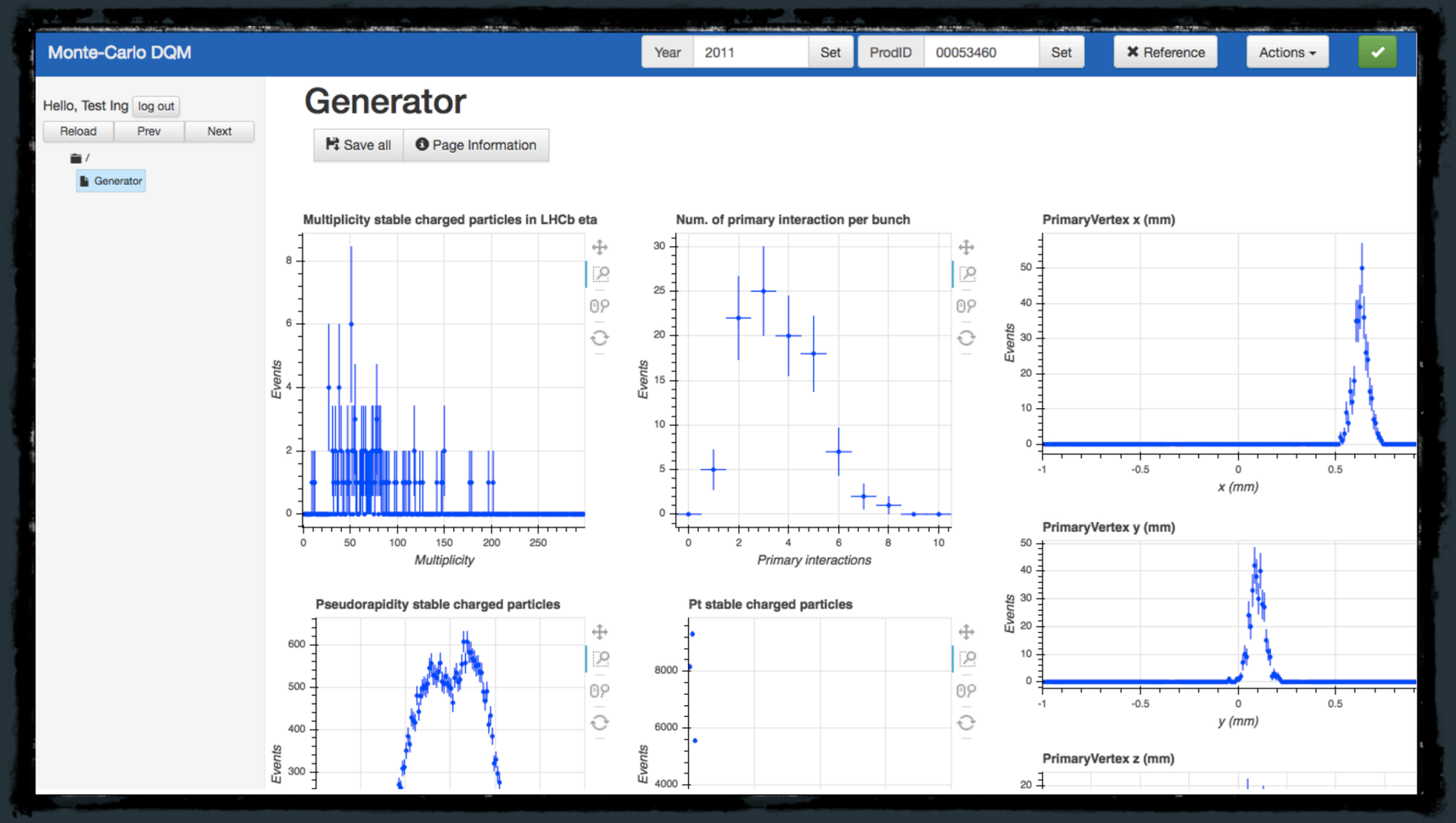
An example from the last major Sim validation

- 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 ~`50Mevts` 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!