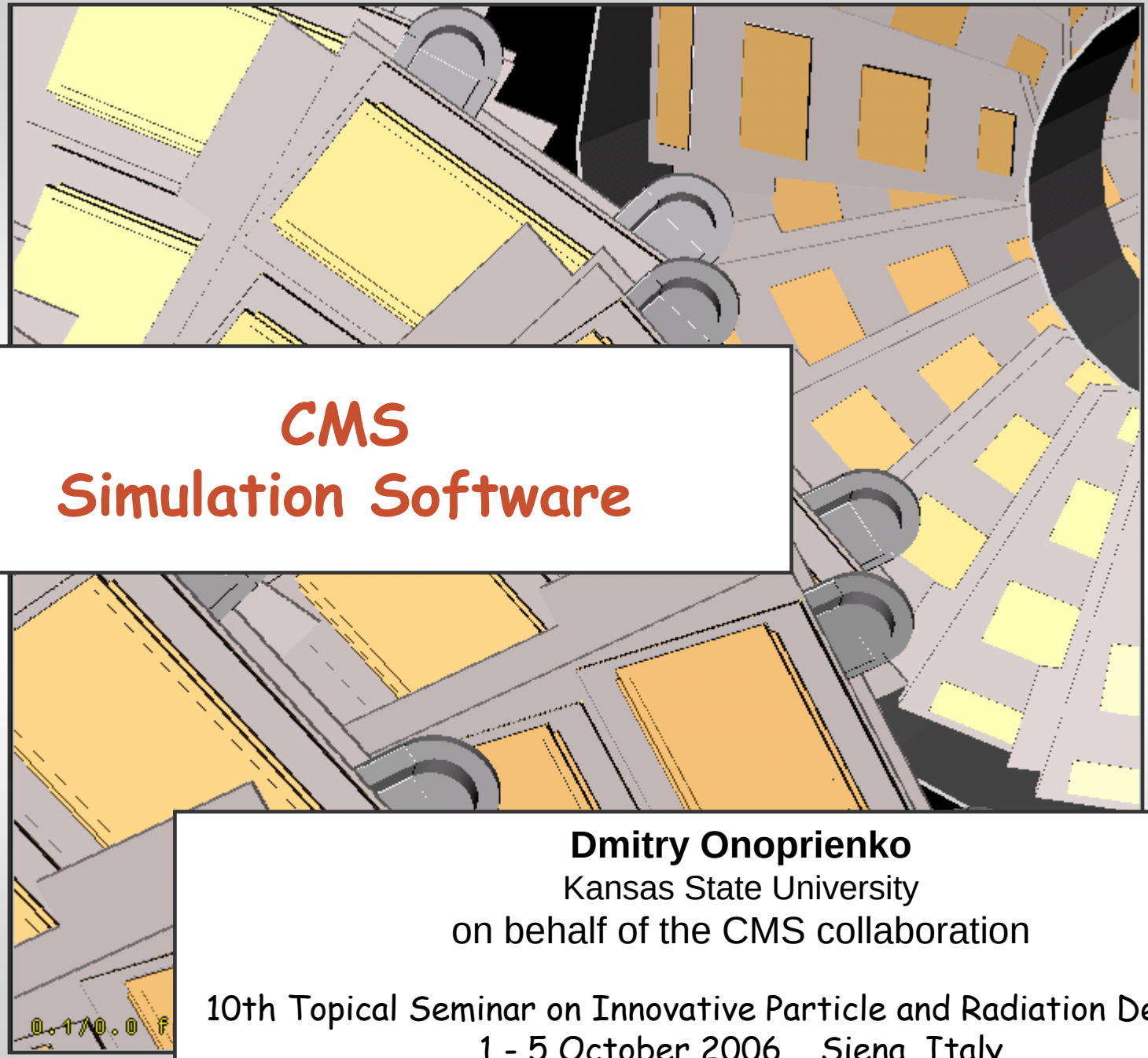

CMS Simulation Software

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Simulation role in physics experiments

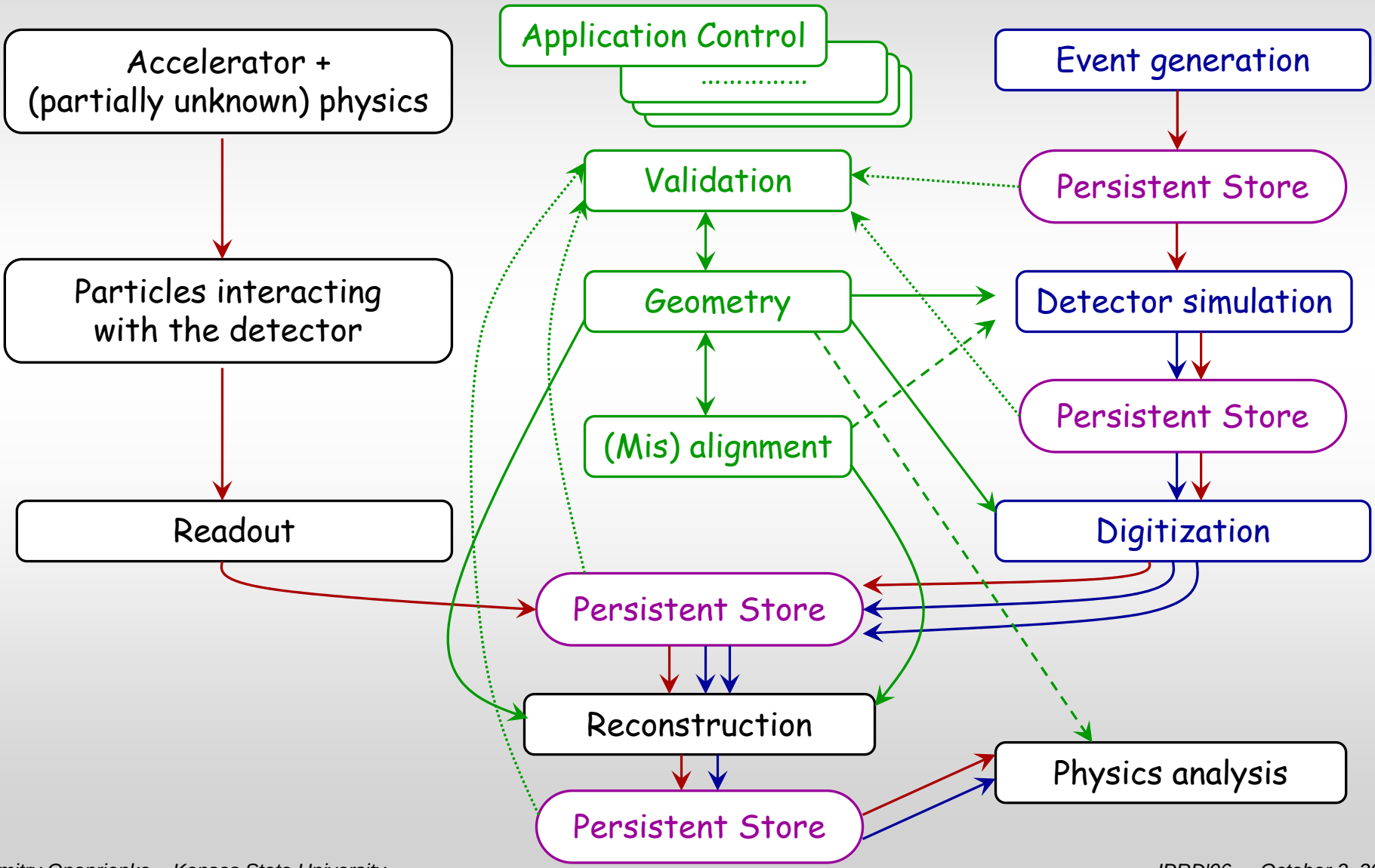
- conceptual design and technology choice for the detector
- physics sensitivity studies and background estimates
- detector optimization
- basis for reconstruction algorithms development
- basis for data quality monitoring
- **physics analysis :**
  - signal shape and background calculations
  - trigger and reconstruction efficiency estimates
  - accounting for detector hardware effects (acceptance, resolution, etc.)
  - … many other applications

Simulation software is a vital component of every HEP experiment.

It is also a live system – goals, requirements, and tools change throughout the lifetime of the experiment. Yet changing horses during a race is tricky and expensive – simulation suite we design today should be susceptible to changes required years from now…

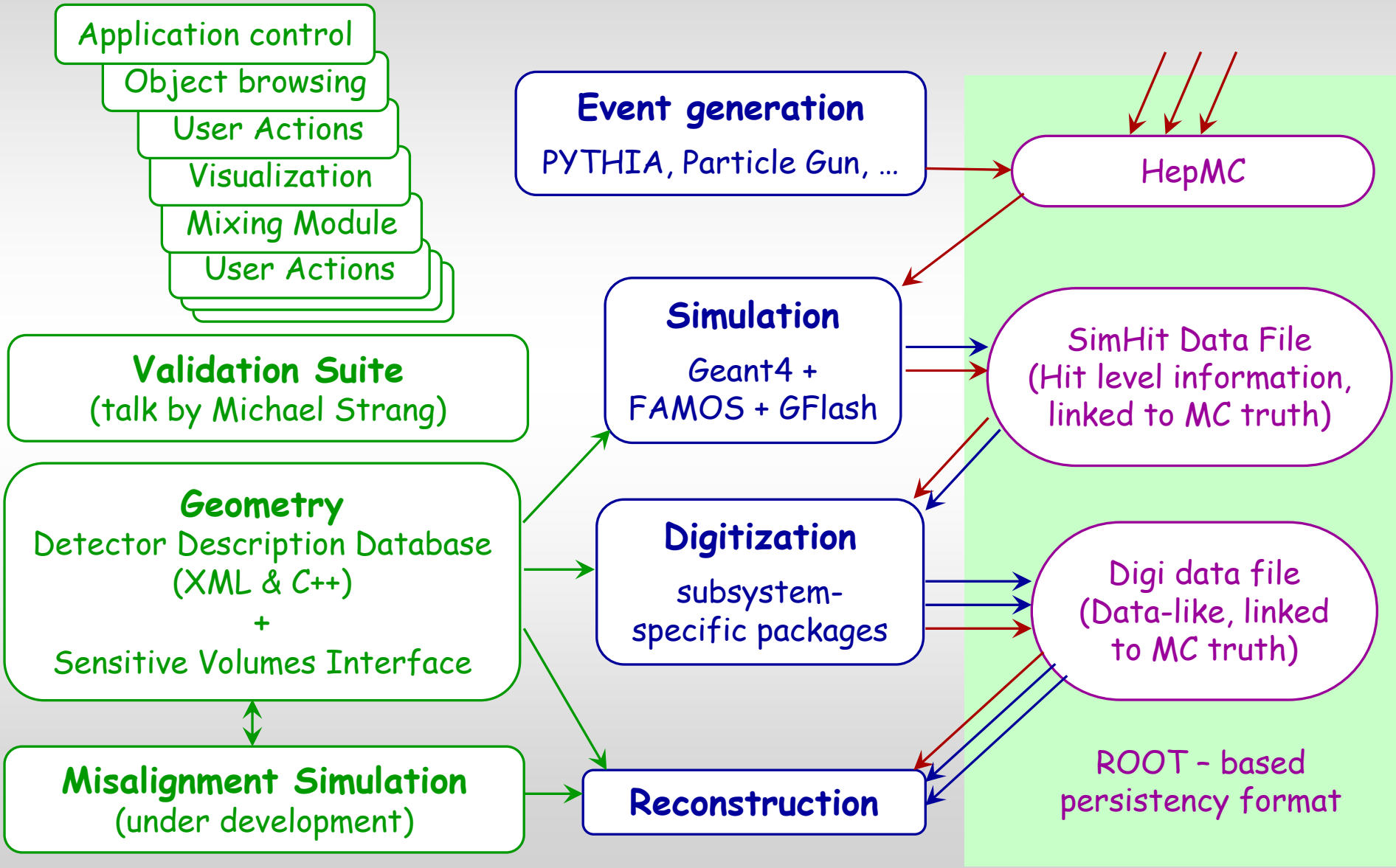
Simulation Software – What is needed ?

(Almost) everybody is using (mostly) Geant4.
Why does so much effort go into experiment specific simulation software ?



Simulation Software – CMS solutions

CMSSW – new CMS software framework – is used to tie all the pieces together



Geometry Description

XML based detector description language (DDL) developed by CMS :

- Mirrors most of Geant4 geometry description functionality
- Human readable, easy to modify without recompiling
- Flexible and easily extendable
- Arbitrary parameters can be attached to volumes

C++ "algorithms" (called from DDL) :

- Standard and custom.

CMSSW :

- uses XML configuration files to select components for the simulation job
- parses DDL and converts geometry to DDD internal object model
- interfaces DDD object model to Geant4, reconstruction, alignment, etc.
- reads/writes DDD objects to POOL Object Relational Access database

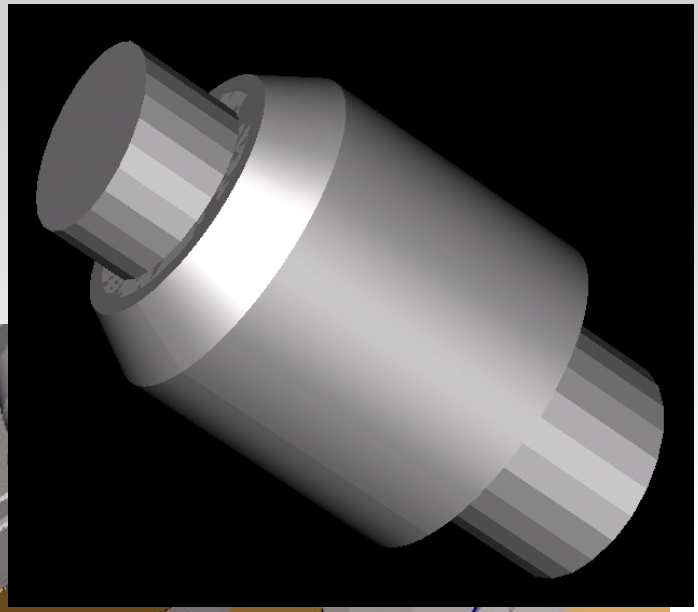
Sensitive detector hierarchy is described separately (XML file). It does not have to mirror volume hierarchy in the geometry description.

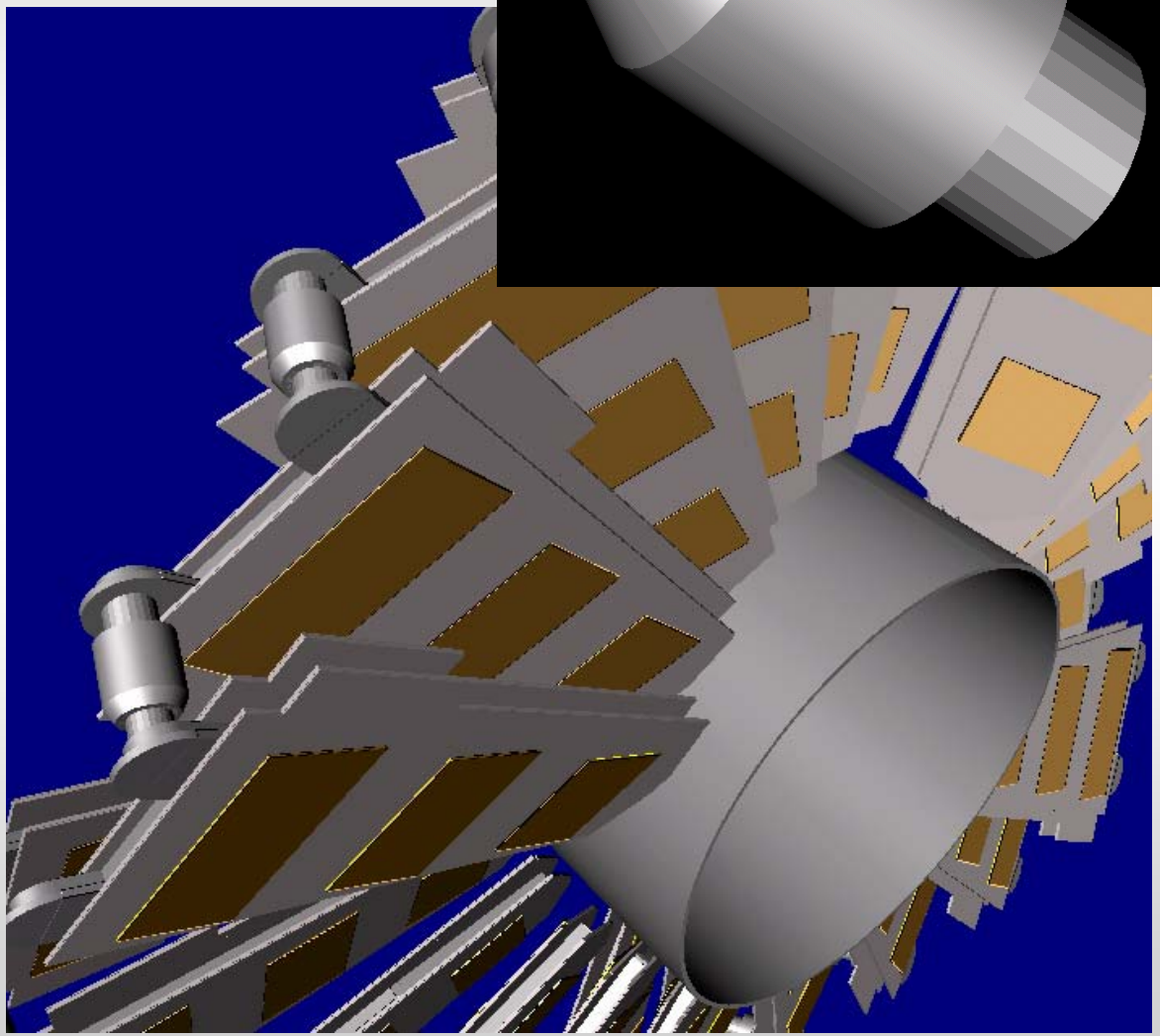
Readout components (sensitive detectors) are associated with geometrical volumes through configuration files (XML again) at run time. Geometry information becomes available to reconstruction software.

Visualization

IguanaCMS

(Interactive Graphics and User Analysis for CMS)





Based on Iguana C++ toolkit.

Used for geometry, reconstruction, and physics visualization.

Flexible and customizable.

Fetches geometry through the same interface the simulation does – excellent testing tool.

Caveat : shares Geant4 visualization drivers limitations.

Other Modules and Services

Mixing Module

Pileup simulation - overlays from a pool of pre-generated minimum bias events.

Configurable physics

Run-time choice of Geant4 physics list (standard or custom).

User actions (aka hooks)

Allows user access to Geant4 objects at any stage (run, event, step, etc.)

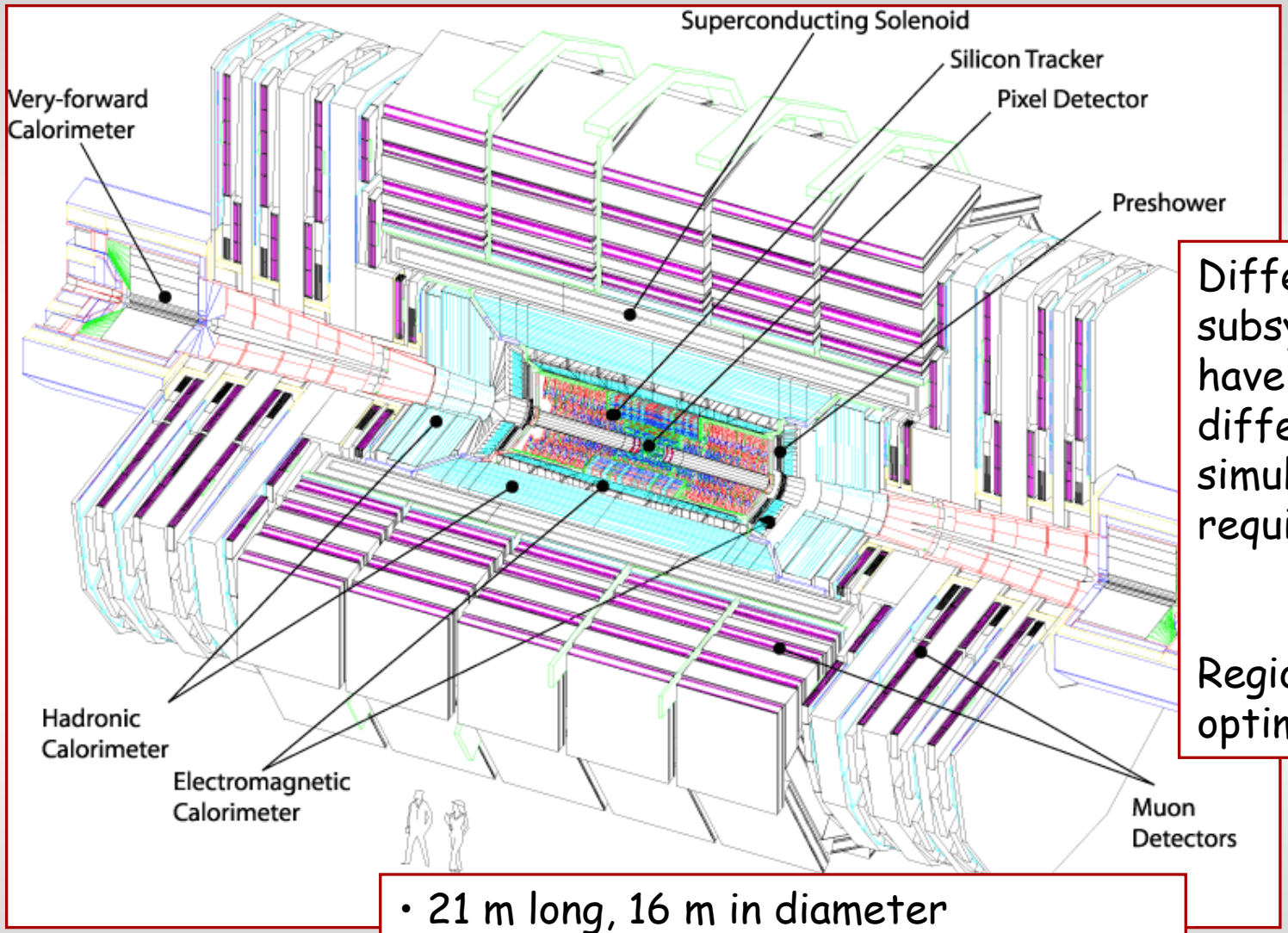
Used for tuning, diagnostics, custom bookkeeping, etc.

Allows direct use of various Geant4 tools.

Magnetic field

Based on dedicated geometry of "magnetic volumes".

CMS Detector



Different subsystems have different simulation requirements

⇓

Region based optimization

- 21 m long, 16 m in diameter
- Over a million geometrical volumes
- Many complex shapes

Detector Subsystems

Tracker :

Critical region, due both to its own physics significance, and to the effect on overall simulation accuracy.

Detailed geometrical description of both active and passive volumes. Level of detail in the "production" version of the geometry is determined by testing against physics requirements.

Detailed, persistent, and navigable Monte Carlo truth bookkeeping – required for testing reconstruction algorithms.

Extensive validation at hit level – single particle, minimum bias, and physics events.

Electromagnetic calorimeter :

Resolution is dominated by effects not included in shower simulation.

Excellent agreement between simulation and beam tests

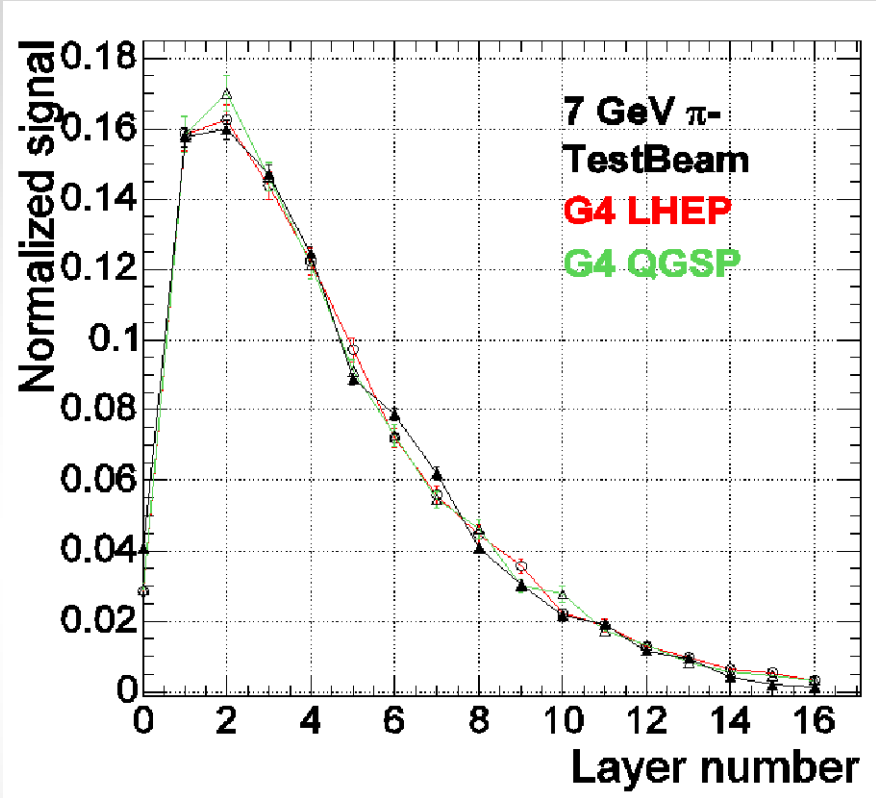
Highly sensitive to accuracy of tracker simulation.

Detector Subsystems

Hadronic calorimeter :

Sensitive to the accuracy of hadronic showers simulation by Geant4. Obvious dependence on the choice of physics models.

Beam tests data available (in 2002-2004, various HCAL modules, preceded by ECAL prototype, have been tested with e, π, and μ beams). Agreement with simulation has been observed within large systematic uncertainties of the data.



Muon system :

Good agreement with beam test – Geant4 seems to be doing a much better job than Geant3 did.

Forward detectors :

Simulation work / beam test data is analysis under way

Performance & Production

Over 60 million physics events simulated by the production team since July 2006 (new CMSSW framework).

Failure rate: once per 10^4 - 10^6 events.
Expected to improve now that we switch to Geant4.8.1

Speed (3.6GHz CPU, Geant 4.8.1, QGSP_EMV physics list) **very preliminary** :

Minimum bias events : 37 seconds per event

$H \rightarrow eeμμ$: 197 seconds per event

CMS strategy: equal number of simulated and real events (~ 1.5 x 10^9 per year)
Aim to achieve this with a mixture of full and fast simulation.

Summary and Outlook

CMS has successfully migrated from its earlier Geant3 based simulation suite to a Geant4 based object oriented simulation software. The new system has been extensively validated, and used for physics and detector studies.

Porting to a new CMSSW framework has been finished.

Geometry of all subsystems has been brought up to date.

CMS simulation software has proved to be powerful, flexible, and maintainable. We hope that tools developed and experience accumulated while working on this system will be useful outside CMS as well.

Further development is underway :

New features (GFlash, new ECAL geometry, …)

Performance improvements (Geant4.8.1 related changes, local magnetic field stepper implementation, …)