The ALICE Geant4 Integration

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For the ALICE Collaboration

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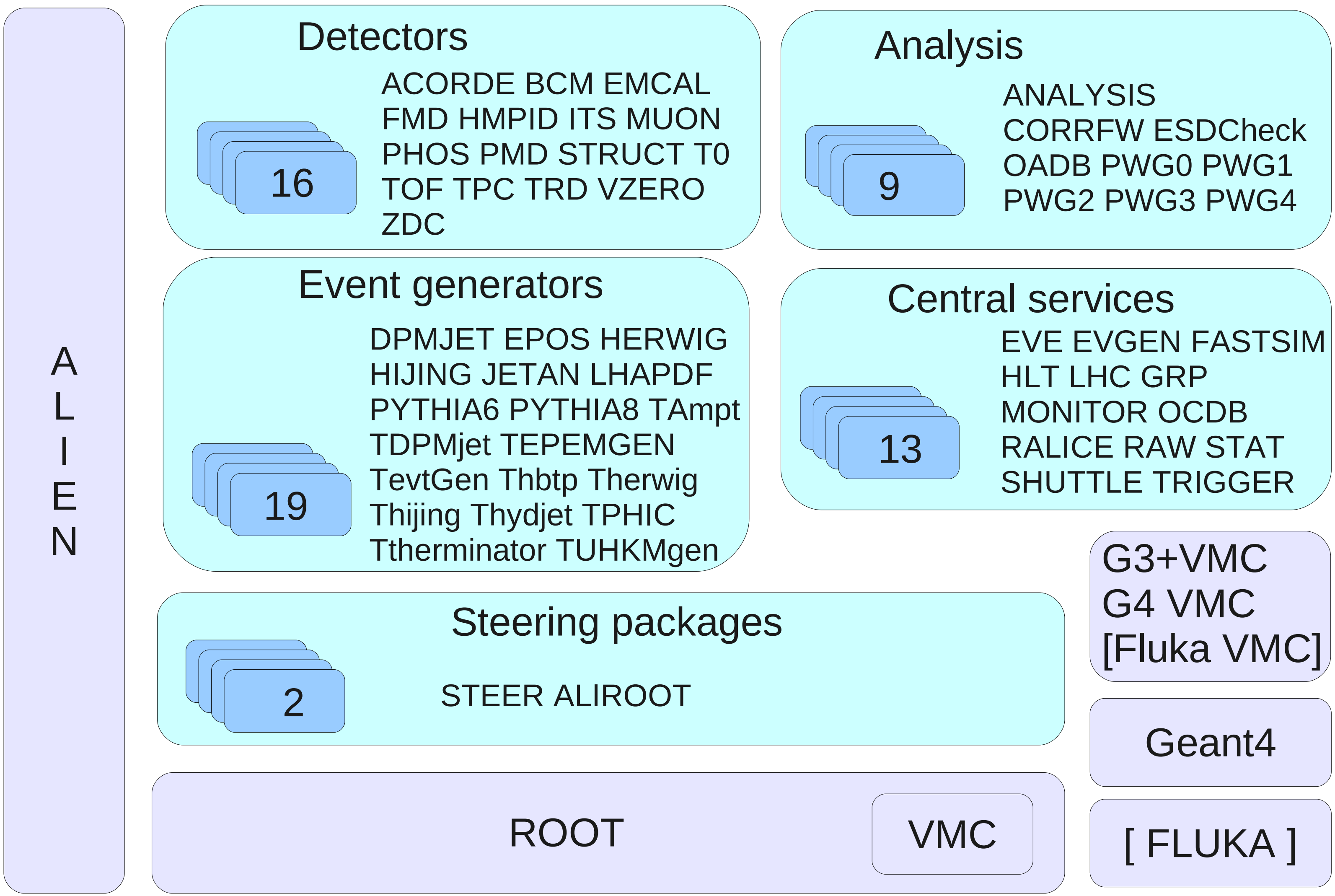
Outline

- ALICE simulation framework
- VMC and Geant4 VMC
- Geometry tools
- GRID deployment
- Remaining problems

The ALICE offline framework

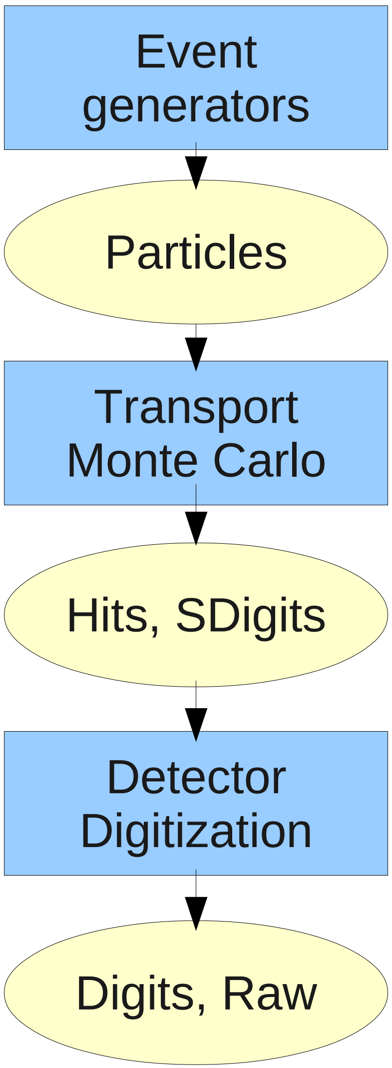
- AliRoot = the ALICE offline framework
  - the framework for simulation, reconstruction and analysis
  - uses the ROOT system as a foundation
  - based on the Object Oriented programming paradigm, and is written in C++ - except for large existing libraries, such as Pythia6, HIJING, and some remaining legacy code
  - 59 packages, 190 libraries

The AliRoot Layout



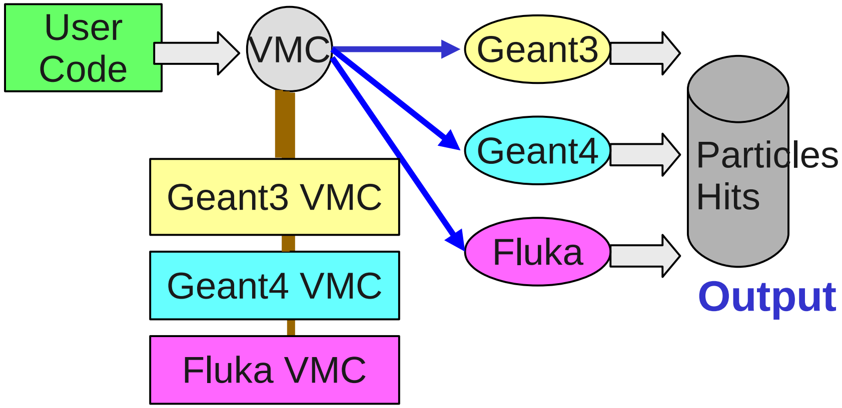
The ALICE Simulation Framework

- It covers:
  - the simulation of primary collisions and generation of the emerging particles
    - Via Event generator packages
  - the transport of particles through the detector
    - Via Monte Carlo packages
  - the simulation of energy depositions (hits) in the detector components, their response in form of so called summable digits
    - Via Detector packages steered by STEER
  - the generation of digits from summable digits with the optional merging of underlying events and the creation of raw data.
    - Via Detector packages steered by STEER



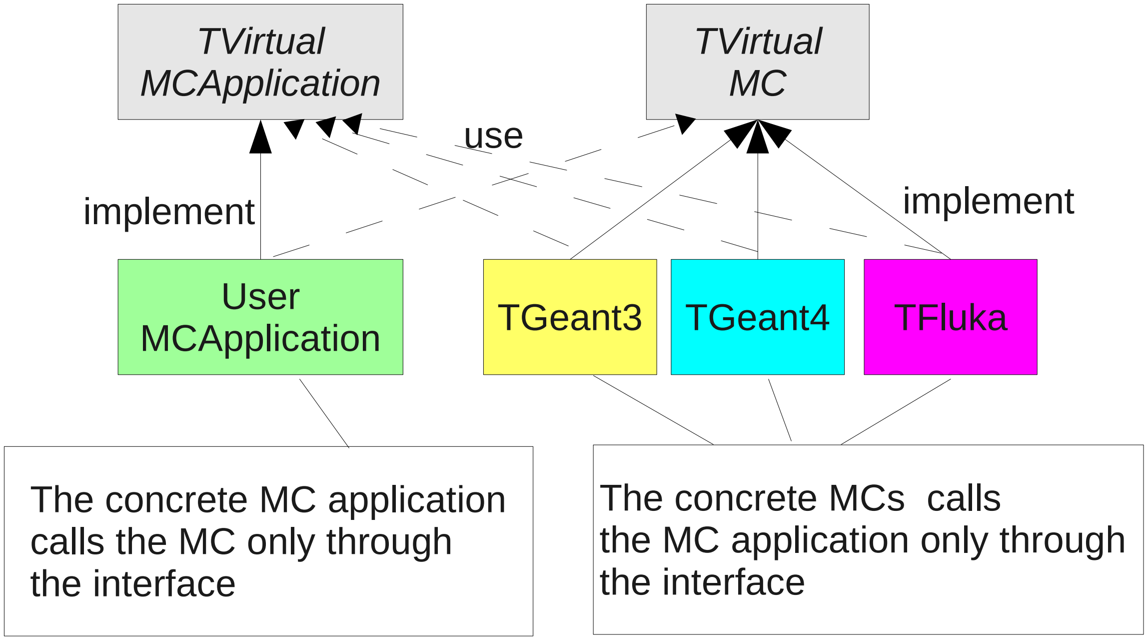
Virtual Monte Carlo

- ALICE has developed in the close collaboration with the ROOT team the Virtual Monte Carlo interface:
  - First, it allowed a smooth transition from GEANT3 based FORTRAN code to C++ and then it made possible to run the same code with three transport codes: GEANT3, Geant4 and FLUKA
- The VMC is distributed with ROOT since 2002 and now it is used in more experimental frameworks
  - http://root.cern.ch/drupal/content/vmc



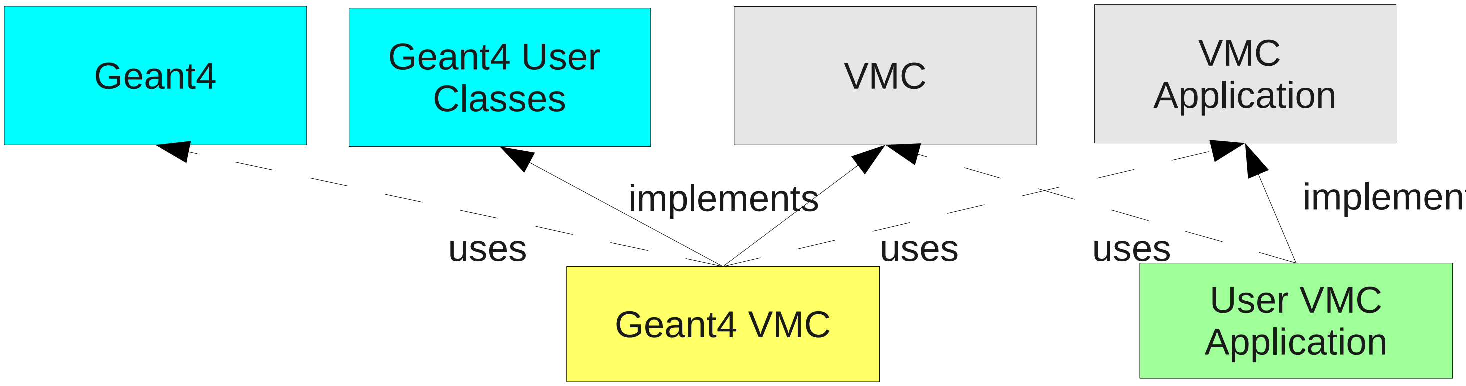
The VMC Design

- In VMC, we introduce the abstract interface both for the MC simulation program and for the user application
- In this way we decouple the dependence between the user code and the concrete MC



Geant4 VMC

- Geant4 VMC implements:
  - TVirtualMC interface - via calls to the Geant4 objects
  - Geant4 user classes - via calls to the VMC application interface



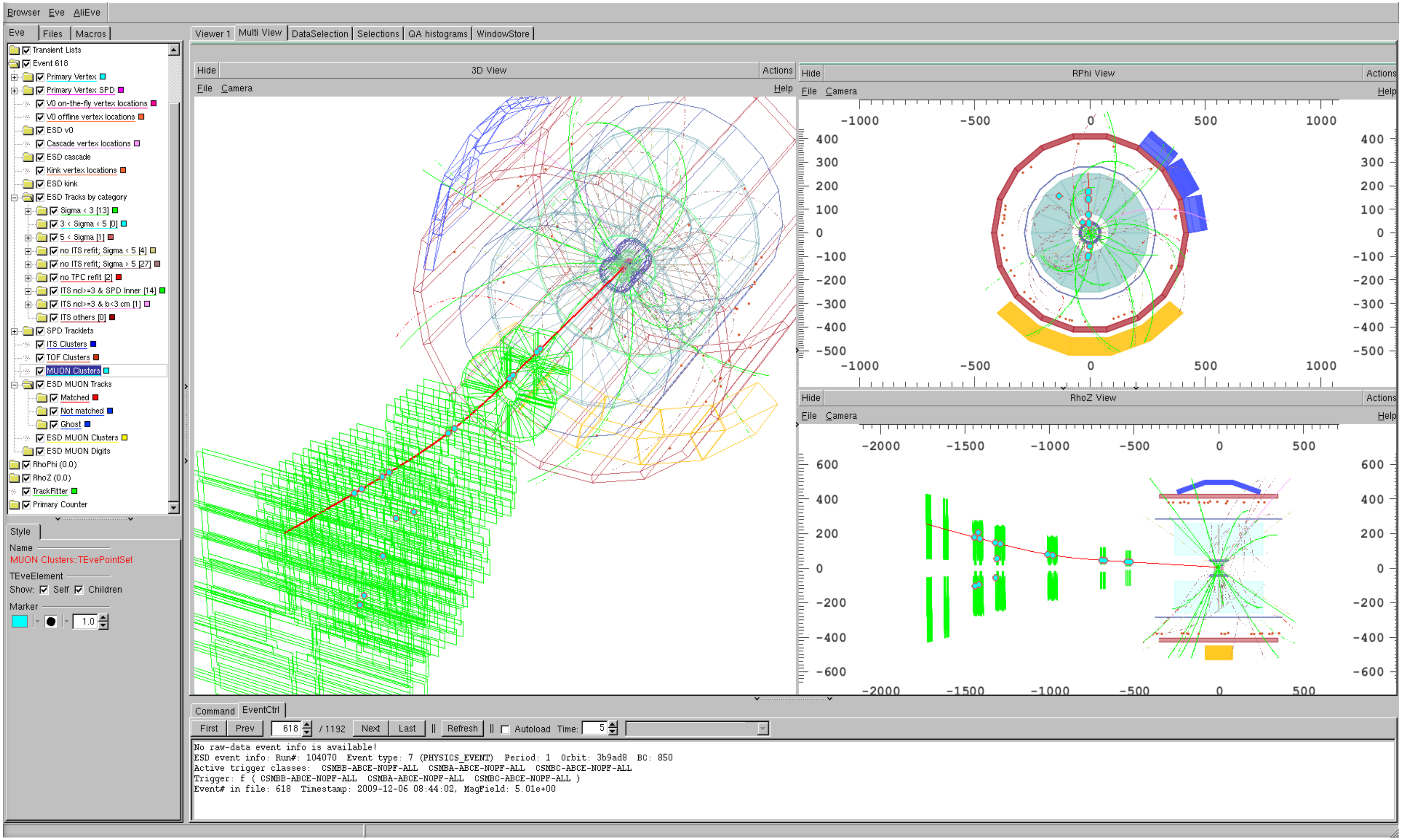
- Geant4 VMC is distributed as a stand-alone package via the ROOT site
  - http://root.cern.ch/drupal/content/geant4-vmc

Geant4 VMC
Geometry

- Geometry inputs
  - Root geometry (TGeo), VMC geometry, Geant4 geometry
- Navigation
  - Geant4 native navigation - if geometry defined via Root, a conversion from Root to Geant4 is performed via VGM (Virtual Geometry Model)
    - http://ivana.home.cern.ch/ivana/VGM.html
    - Conversion does not support all geometry features ("exotic solids", declared overlapping volumes)
  - G4Root navigation – for geometry defined via Root or VMC
- ALICE is using TGeo geometry + G4Root navigation
  - Geometry cannot be fully converted to Geant4 due to declared overlapping volumes

Geometry in ALICE: TGeo

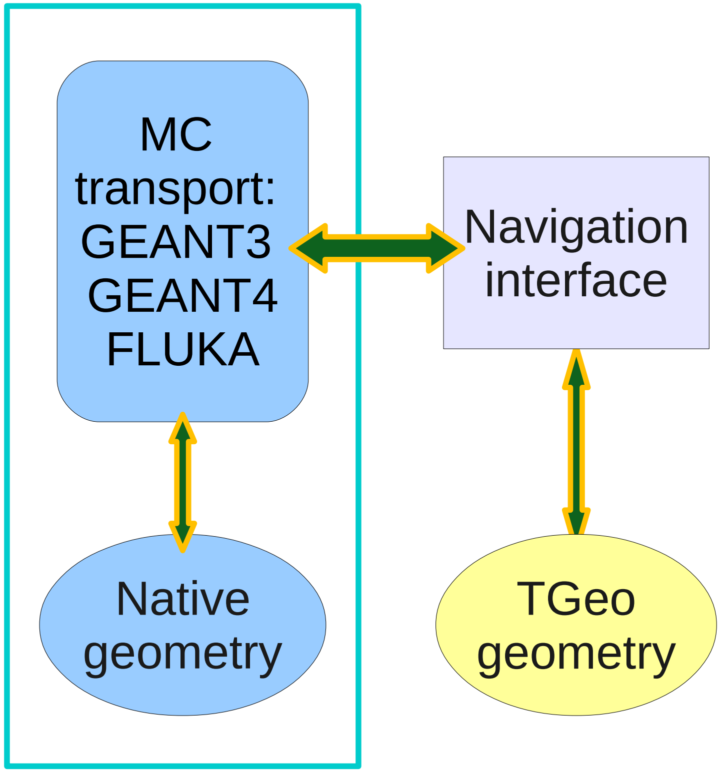
- ALICE geometry is defined via TGeo, the geometry toolkit inside ROOT
  - TGeo was developed following closely the needs of ALICE
  - Besides simulation, it is used also in reconstruction and event display
  - Performance was a design goal
  - It is used also by other experiments: PANDA, CBM, OPERA, STAR, ...
- It provides the full geometry description of the ALICE detector and:
  - Navigation functionality used in simulation.
  - Ability to store and directly use misalignment within the geometry itself
  - Built-in checking tools, geometry builder, visualization



ROOT geometry package is used as a single geometry source in simulation, reconstruction and event display, it is also used for misalignment, tracking and in some cases even to retrieve geometry information for analysis purposes.

Navigation Interfaces

- Particle transport MC's are using their own geometry
  - Transportation procedures are using own geometry navigation as ingredient
- The navigation interfaces had to be implemented to allow navigation using TGeo geometry modeller
  - Not only to test the principle, but actually to make the ROOT geometry work for simulation purposes
  - Several tests done in the development process to compare with results of native geometries (produced via conversion)



G4Root Interface (1)

- G4Root = the Root geometry navigation interface for Geant4, by A. Gheata, CERN
- Implements the G4VUserDetectorConstruction::Construct() interface to build a Geant4 native geometry skeleton with links to TGeo geometry objects:
  - Maps all shapes from a TGeo geometry from memory to a Geant4 alike solid using G4VSolid interface
  - Creates Geant4 elements and materials corresponding to ROOT ones
  - Creates a Geant4 volumes hierarchy (logical and physical volumes) needed by Geant4 physics
- Defines a user interface TVirtualUserPostDetConstruction that allows the user to hook up sensitive detectors and user cuts to the newly created G4 geometry tree
  - In VMC, this interface is implemented in Geant4 VMC

G4Root Interface (2)

- Implements the G4Navigator interface using TGeo navigation methods as the back-end
  - Navigation queries like: ComputeStep(), LocateGlobalPointAndSetup(), ComputeNormal(), ...
- Tested and benchmarked against Geant4 native geometry, shows comparable speed while giving the same results
- Besides its use in the VMC context, it can be also used in a standalone Geant4 application using TGeo as geometry
  - A test case based on Geant4 novice example N06 demonstrates using the native TGeo features in GEANT4 simulations
- Initially in ROOT, it is now part of Geant4 VMC
  - http://root.cern.ch/drupal/content/g4root

Geant4 VMC

Production thresholds & tracking cuts

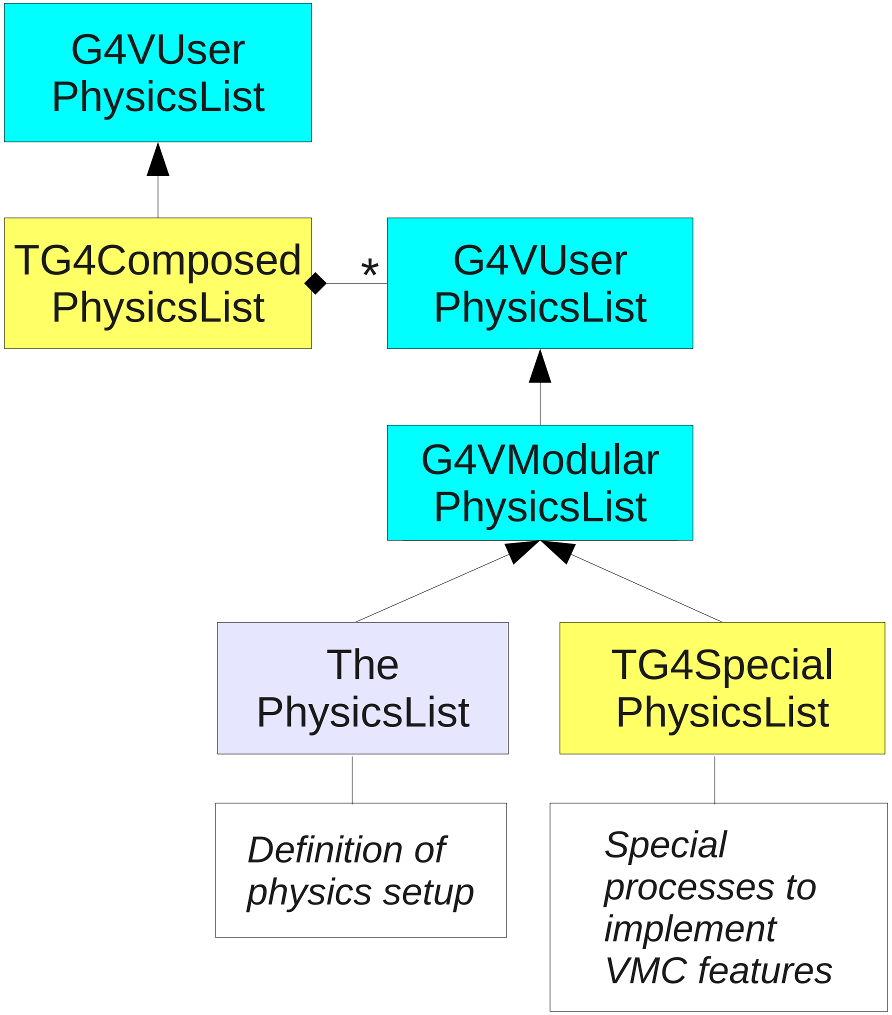
- VMC cuts = cuts in energy applied as both energy threshold and tracking cut per tracking medium
- In Geant4 VMC the VMC cuts in energy are converted in cuts in range and applied per regions
  - Defined for e-, e+, gamma; to be added: proton
  - The regions do not represent the detector sub-systems but the volumes with the same materials
- Tracking limits applied via G4UserLimits & Special cuts process
  - User has to activate the special cuts process in their configuration macro

Geant4 VMC

Physics Selection (1)

- Geant4 VMC defines a composed physics list, which combines registered physics lists together
- Typically, it includes:
  - A selected physics list provided by Geant4
  - The special physics list implementing the VMC features
- User selects the physics in a configuration macro:

```
void g4Config() {
  TG4RunConfiguration* runConfiguration
     = new TG4RunConfiguration(
             "geomRootToGeant4",
              "QGSP_BERT",
              "specialCuts");
  TGeant4* geant4
    = new TGeant4("TGeant4", "...",
              runConfiguration);
}
```



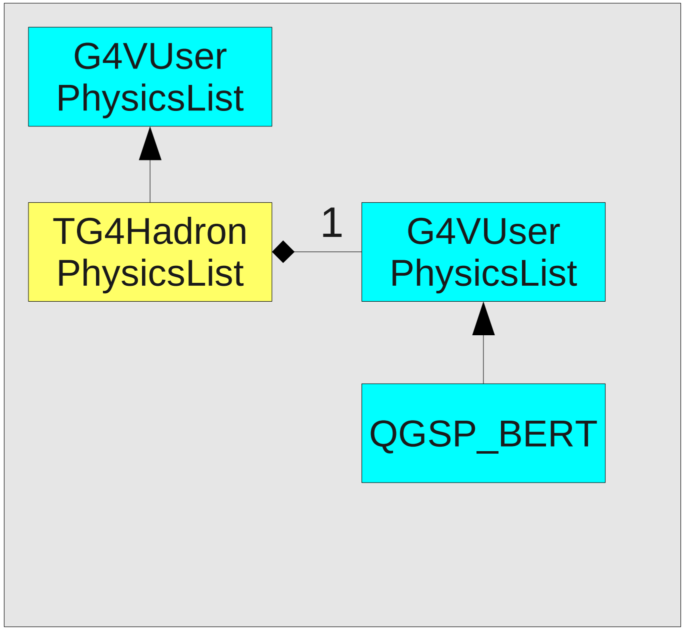
Geant4 VMC

Physics Selection (2)

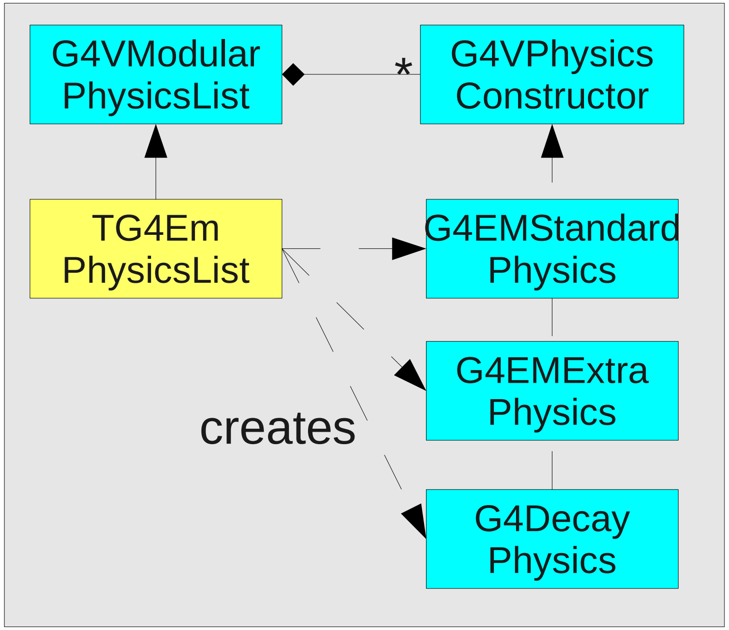
The PhysicsList

Users can select in a configuration macro any of Geant4 provided hadron physics lists, or EmStandard or include their own physics list

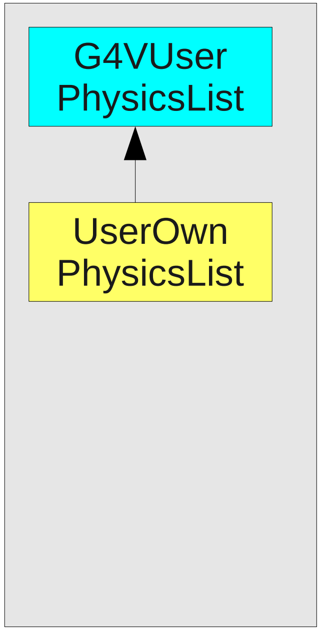
Hadron:
eg. "QGSP_BERT"



"EmStandard"



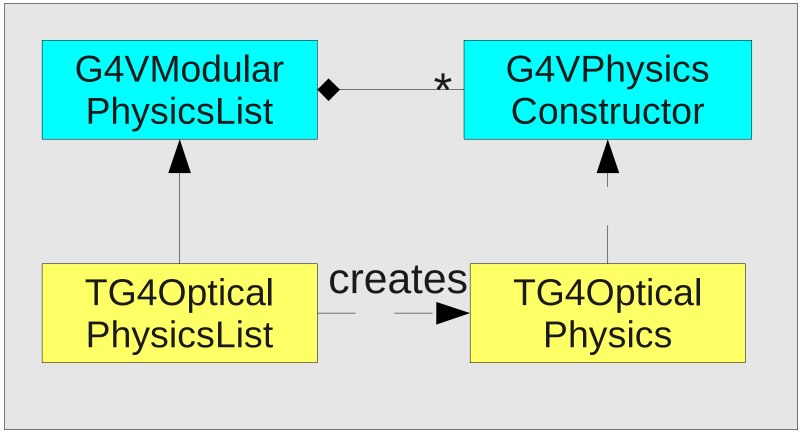
User own
physics list



Geant4 VMC

Physics Selection (3)

- The optical processes can be added to the selected physics
- TG4OpticalPhysics is the only physics builder in Geant4 VMC which defines itself physics from physics processes
  - The current G4OpticalPhysics does not allow not to build Scintillation (problem report #1216)
  - To be replaced with G4OpticalPhysics with Geant4 9.5 release




```
void g4Config() {
      TG4RunConfiguration* runConfiguration
       = new TG4RunConfiguration(
                 "geomRootToGeant4",
                  "QGSP_BERT+optical",
                  "specialCuts");
      TGeant4* geant4
        = new TGeant4("TGeant4", "...",
                    runConfiguration);
    }
```

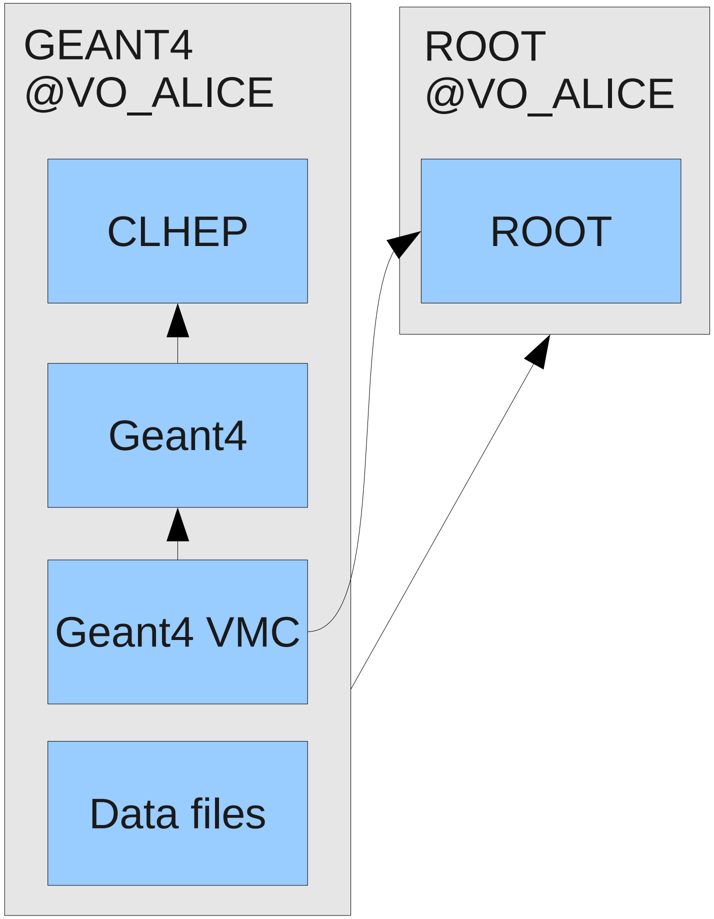
Geant4 VMC

Geant4 VMC represents the realisation of the Virtual Monte Carlo (VMC) for Geant4 . It can be also seen as a Geant4 application implemented via the VMC interfaces. It implements all Geant4 user mandatory classes and user action classes, which provide the default Geant4 VMC behaviour, that can be then customized by a user in many ways.

Contact: vmc@root.cern.ch
Page maintained by: Ivana Hrivnacova
Last update: 08/06/2009

The GRID: Geant4 Distribution

- ALICE packages in production: ROOT, Geant3, AliRoot, AliEn
- In test productions (since 2010): Geant4
- The complete Geant4 GRID package contains:
  - CLHEP, Geant4, Geant4 VMC and data files supplied by Geant4
  - Including Geant4 VMC inside the package makes it dependent on ROOT



The GRID: Deployment

- The distribution is built on various platforms and deployed on the ALICE GRID through the centralized AliEn (ALICE Environment) package manager.
- GRID users then simply specify the distribution version they want to use in their job description.
- Alternatively, using an automated script, users can install any available Geant4 distribution and its ROOT dependency on their local machine.

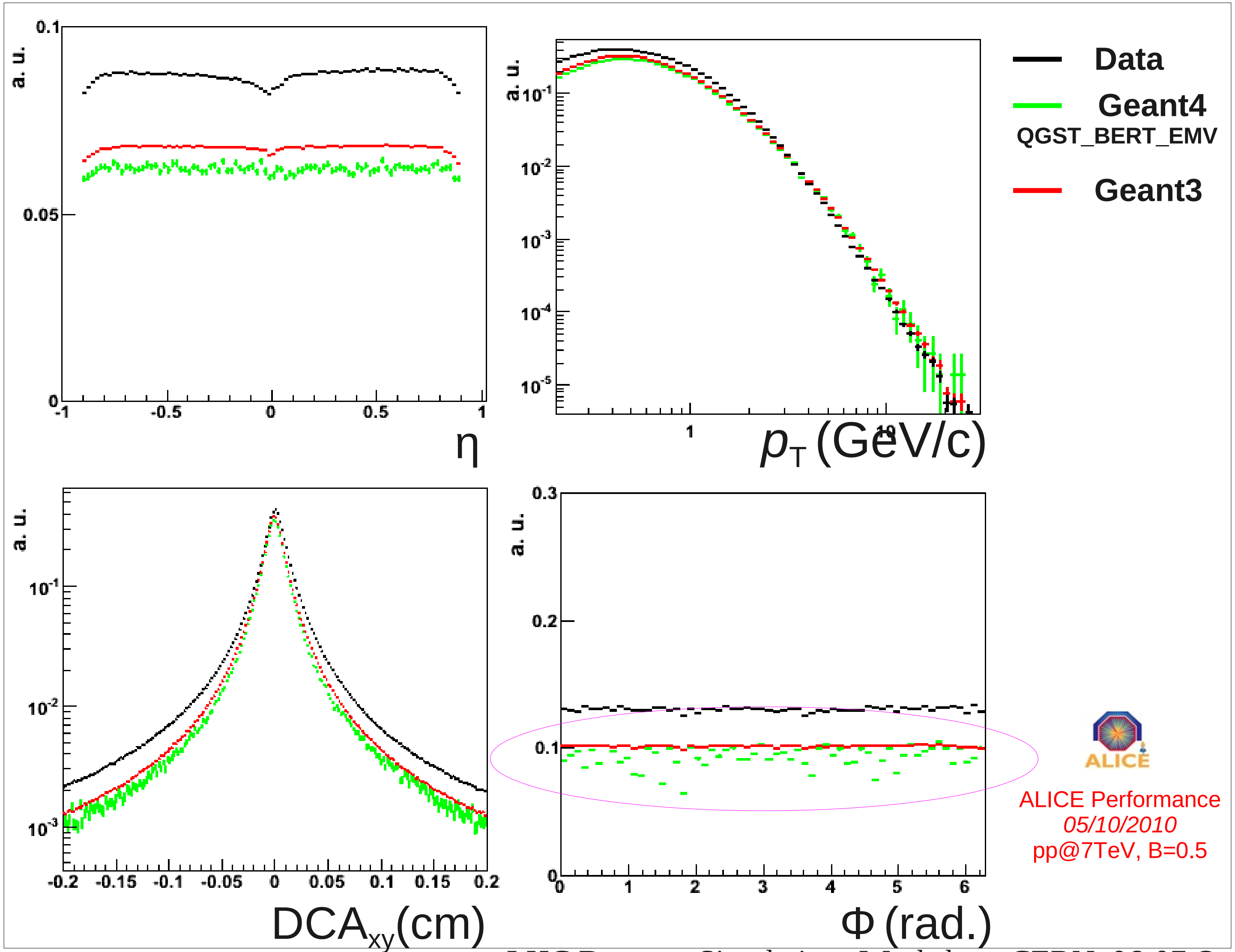
Packages available in Grid

Package name	Dependencies	Install
VO_ALICE@AliRoot::v4-18-Rev-23	VO_ALICE@ROOT::v5-26-00b-6,VO_ALICE@GEANT3::v1-11-12	Linux
VO_ALICE@AliRoot::v4-19-Rev-10	VO_ALICE@ROOT::v5-27-05-build3,VO_ALICE@GEANT3::v1-11-14	Linux
VO_ALICE@GEANT3::v1-11-14		Linux
VO_ALICE@GEANT3::v1-11-15		Linux
VO_ALICE@GEANT4::v9.3.p02_vmc.2.10	VO_ALICE@ROOT::v5-27-06	Linux
VO_ALICE@GEANT4::v9.3.p02_vmc.Rev512	VO_ALICE@ROOT::v5-26-00b-6	Linux

Test Productions

- In 2010
  - pp @ 7 TeV, Geant4 9.3.p02 and Geant4 9.4.b01
  - QGSP_BERT, QGSP_BERT_EMV, QGSP_BERT_CHIPS
- In July 2011:
  - pp @ 7 TeV,,Geant4 9.3.p02, QGSP_BERT_EMV
  - Serious bug in the TGeo interface
- In August 2011:
  - pp @ 7 TeV, Geant4 9.4.p02 and Geant4 9.5.b01
  - QGSP_BERT_EMV, QGSP_BERT_CHIPS, QGSP_FTFP_BERT
- In September 2011:
  - Nuclei cocktail production (LHC10d6g),
  - Geant4 9.5.b01, QGSP_FTFP_BERT

2010
Properties of Reconstructed Particles



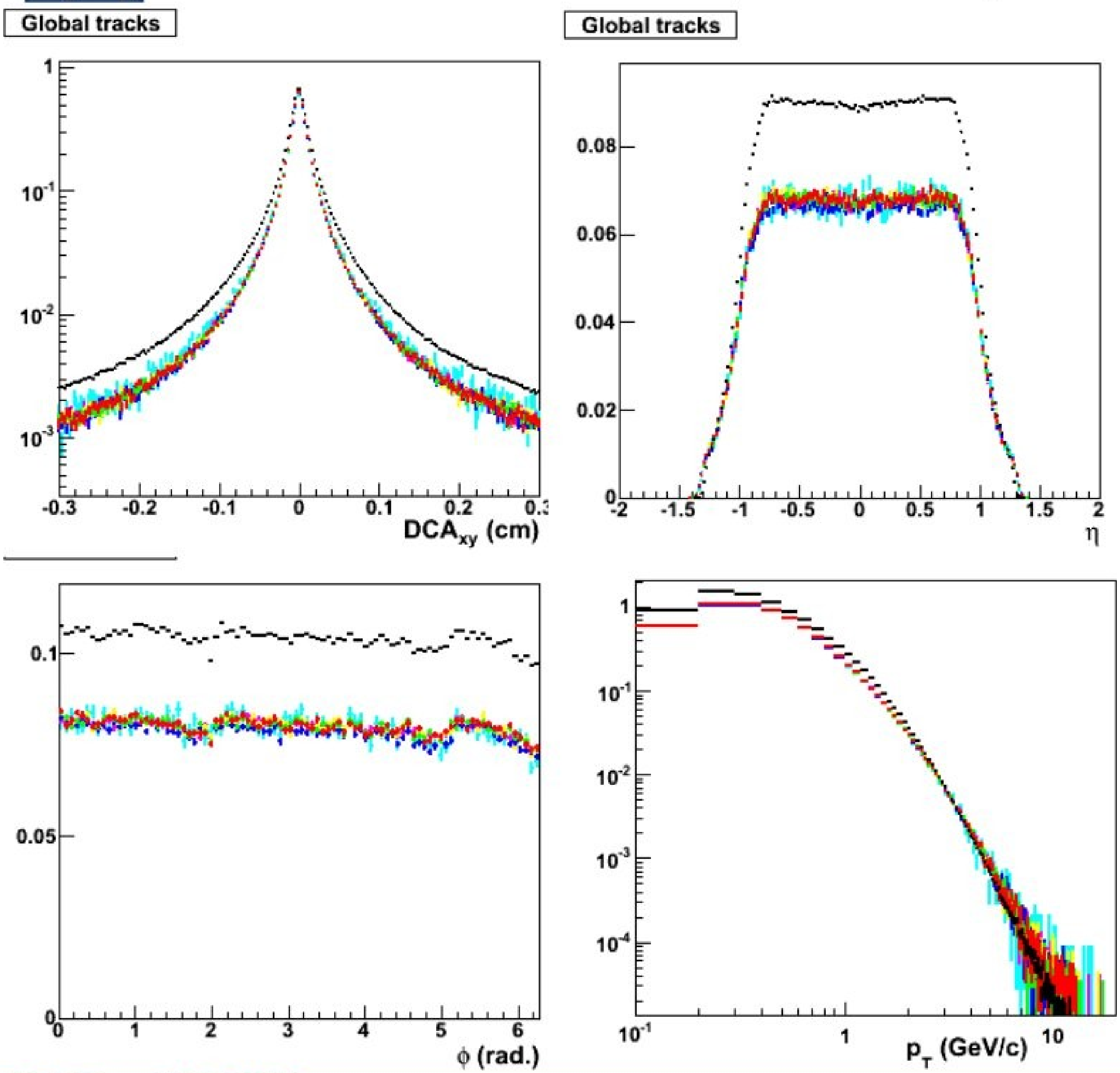
Global tracks after standard quality selection scaled to the number of events

Work in progress

Fixes in the last year

- In Geant4 VMC:
  - Fixed the time of flight returned via TVirtualMC::TrackPosition(): return the global track time instead of local track time
  - Fix in handling Geant4 particles which have no equivalent in TDatabasePDG: the particle is now added in TDatabasePDG without issuing an exception (needed for anti-nuclei)
  - Coverity defects
- In TGeo
  - Fix in TGeoEltu shape: track did not see a geometry boundary; all particles passing through some ITS structure were stopped
  - Fix in the reflection factory for assemblies
    - This factory hides reflection matrices inside the shape rather than the node so that CLHEP can live with it.
    - In case of assemblies there was a bug that was distorting tracks in TPC at positive eta (TPC is half reflected)

Track Properties (Global) 2011



- Properties of reconstructed tracks are similar in Geant3 and Geant4
- Event generator underestimates particle yield but shape of distribution is similar

Remaining Problems (1)

Besides the issues reported by validation of physics results

- Computing time
  - Evaluated from the GRID production in 2010
  - With fastest physics list (QGSP_BERT_EMV) the Geant4 simulation is by factor ~ 3 slower than Geant3

Production	MC	physics list	Run [s/ev]	RunSim [s/ev]	G4/G3 RunSim
LHC10d4	Geant3		107	65	
LHC10c9	9.4.b02	QGSP_BERT	360	311	4.7
LHC10c10	9.4.b02	QGSP_BERT_EMV	235	194	2.9
LHC10c11	9.4.b02	QGSP_BERT_EMV+optical	268	224	3.4
LHC10c12	9.4.b02	QGSP_BERT_CHIPS	325	280	4.3
LHC10c13	9.4.b02	CHIPS	403	365	5.6
LHC10f9a	9.3.p02	QGSP_BERT_EMV	218	178	2.7
LHC10f9b	9.3.p02	QGSP_BERT_EMV+otical	250	188	2.9

Remaining Problems (2)

- Geometry:
  - Looping tracks stopped after reaching maximum number of tracks trapped in between 2 volumes
    - Approximately 1 such killed track per 2 “ppbench” (test benchmark for pp collisions) events
  - Warnings from G4PropagatorInField:
    - 0 - 1 message per 10 events
    - *** G4Exception : GeomNav1002

      issued by : G4PropagatorInField::ComputeStep()

      Particle is stuck; it will be killed.

      Zero progress for 51 attempted steps.

Conclusions

- ALICE simulation is based on Root tools:
  - Virtual Monte Carlo, Root geometry modeller TGeo and G4Root navigation interface
- Geant4 is used as a second Monte Carlo, after GEANT3
- The test productions run on the Grid since July 2010
  - Intensive validation by detector sub-systems is ongoing
- Plans to start special productions with high statistics to be used for certain analysis.
- The complete transition to Geant4 will be performed during the long LHC shut-down. An optimization of the computing time will be necessary.