Geant4 VMC
Recent Developments

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Outline

- Geant4 VMC
- ALICE geometry with respect to Geant4 simulation
- VMC cuts and Geant4 cuts
- Recent developments & bug fixes
- Geant4 macros in AliRoot
  - How to run AliRoot with Geant4

Geant4 VMC

- Implements the VMC interfaces defined in Root for Geant4
- A stand-alone package
  - Distributed from the Root site:
  - http://root.cern.ch/drupal/content/download
- The list of external packages needed to run AliRoot with Geant4:
  - CLHEP, Geant4, geant4_vmc
    - *Forgotten in the ALICE Installation Offline web pages*
- Since February 2010 it includes also G4Root package which was moved from Root
  - This allows to keep Root installation independent from Geant4

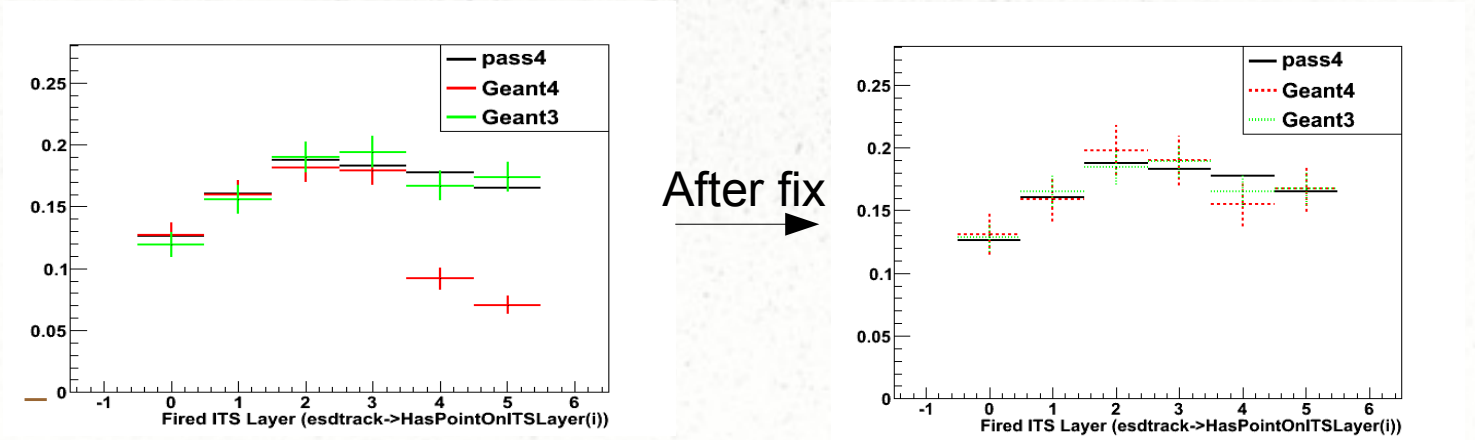
ALICE geometry with respect to Geant4 simulation

Geometry ALICE way

- ALICE choice:
  - Geometry Definition – via **TGeo** (Root geometrical modeller)
  - Navigation in Geometry – via **G4Root** (Root Geant4 navigator directly accessing TGeo objects)
- Other possibilities in Geant4 VMC:
  - Geometry Definition
    - Via VMC (in Geant3 way) - for backward compatibility
    - Via Geant4 - working but not really used (it was an option for PANDA experiment, but they decided later to move to Root geometry definition)
  - Geant4 native navigation
    - Via converting Root geometry in Geant4 using VGM tool – this option is in use by FAIR experiments (in parallel with G4Root)

Geant4 Native Navigation ?

- Why AliRoot with Geant4 navigation ?
  - A powerful tool for geometry verification
  - G4 geometry model & native navigation is already in use by a big number of users, while TGeo, and especially G4Root, not yet
- Geometry problems may have a significant impact to the physics results: Clusters in ITS



  - Long way to understand the problem, to reproduce it (it did not manifest on all platforms), and fix it (thanks to Andrei!)

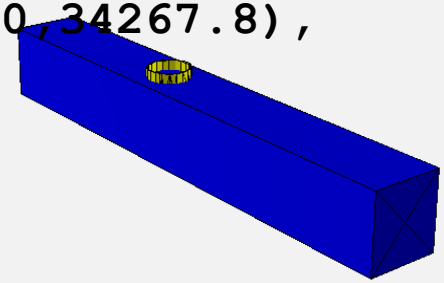
ALICE Geometry in Geant4 ?

- However ALICE geometry is not completely Geant4 compliant
  - Due to using *features not supported* or *not allowed* in Geant4
- When excluding the parts of geometry with these unsupported features we still can get most of geometry in Geant4
  - 4580840 nodes/ 5161 volume UID's => 3869297 nodes/ 5014 volume UID's in ALICE geometry
    - 85% nodes, 97% volumes
  - Not useful for simulation, of course, but can be used for geometry verification
- What can we do then ?
  - Run Geant4 checking tools
  - Compare tracking with both navigators and spotting differences
    - The differences may point at problem in navigation tools but also in geometry

Checking Overlaps

- Geant4 geometry can be built with activating checking overlaps with existing volumes
  - In G4PVPlacement(..., G4bool pSurfChk=false) constructor
- The list of overlaps sent to Andrei and Andreas
  - Overlaps volumes with composite shapes not spotted by TGeo tool; just one example of found overlap:

```
WARNING - G4PVPlacement::CheckOverlaps()
      Overlap is detected for volume &HALL_1%HHC1
      with its mother volume ALIC
      at mother local point (2791.14,25000,34267.8),
      overlapping by at least: 5 m
```



  - But also false reports
    - Some can be eliminated by setting a tolerance limit in checking

Tracking with 2 navigators

- The list of problems from comparing tracking of geantinos
  1) One difference comes from volumes which are closed to each other but do not touch: here Root does not make a step in between the volumes, while Geant4 does.
  2) We have some volumes sequences which are missing on one side
  3) G4Root is looping, track is stopped after maximum number of steps reached

Geometry Not Compliant With Geant4

- Not (yet) supported features:
  - **Arb8 shape** with twisted sides – 4 such shapes in ITS
    - In the Geant4 geometry group work plan for 2010
- Not allowed features: overlapping volumes
  - They can be defined in TGeo either with using **MANY** or **TGeoVolume::AddNodeOverlap**()
    - MANY: in T0, MUON, PMD, TOF
    - AddNodeOverlap: in ITS
  - *Continuing in this direction will close the possibility to use the Geant4 tools which are used (and so tested) by a large number of users*

Geometry
Pending Problems

- Steps in assemblies (should never happen):
  - **`I-TGeoShapeAssembly::DistFromInside: Cannot compute distance from inside the assembly (but from a component)`**
  - Code to facilitate debugging added in geant4_vmc
- http://root.cern.ch/drupal/content/known-problems
  - #4: Tracking location wrong in G4Root. A particle may end-up outside the setup giving the error message: "No physical volume found at track vertex: (107635,-190901,-638802)".
    - Reported by G. Terracciano, M. Al-Turany

VMC & Geant4 Cuts

VMC cuts != Geant4 cuts

- VMC cuts = cut in energy applied as both energy threshold and tracking cut per tracking medium
- Geant4 cuts = cut in range applied as energy threshold per region (region is usually a detector sub-system or structure)
  - The same spatial precision of energy deposition within a region
  - For e+, e-: the stopping range defined via integrating the energy loss due to ionization and Bremstrahlung for each G4Element of the material
  - For gamma: an approximate empirical formula is used to compute the absorption cross section of a photon in an element, absorption cross section means the sum of the cross sections of “destructive” processes for photons: the gamma conversion, Compton scattering and photoelectric effect
    - Absorption length = 5. / absorption cross section

VMC cuts
Old Implementation

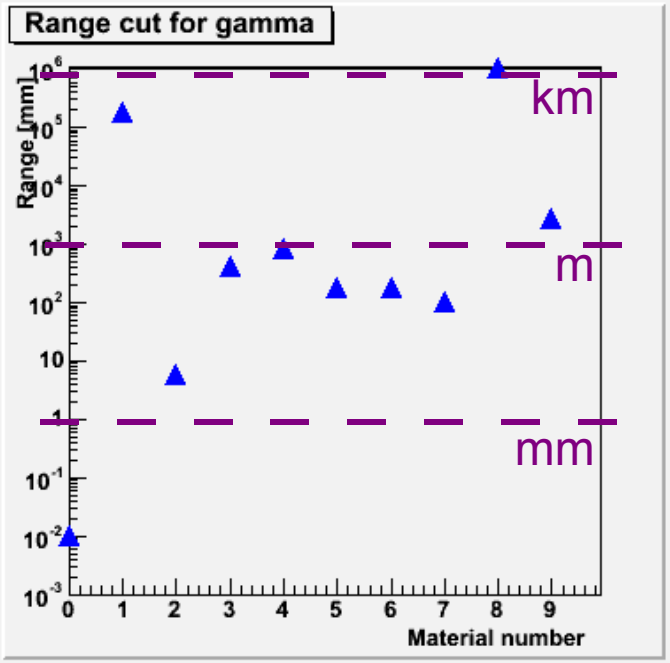
- Using G4UserLimits & Special cuts process:
  - Cuts in energy applied as tracking limits: if the energy of particle goes beyond cut, the particle is stopped and its remaining energy is released
  - If a particle is produced with energy beyond cut it is stopped in its first step
- Problem with this approach: memory explosion when running ALICE ppbench test: all particles produced were put to the stack and “purified” after finishing a primary track
  - Reported by E. Sicking at the ALICE Offline Week in June 2009

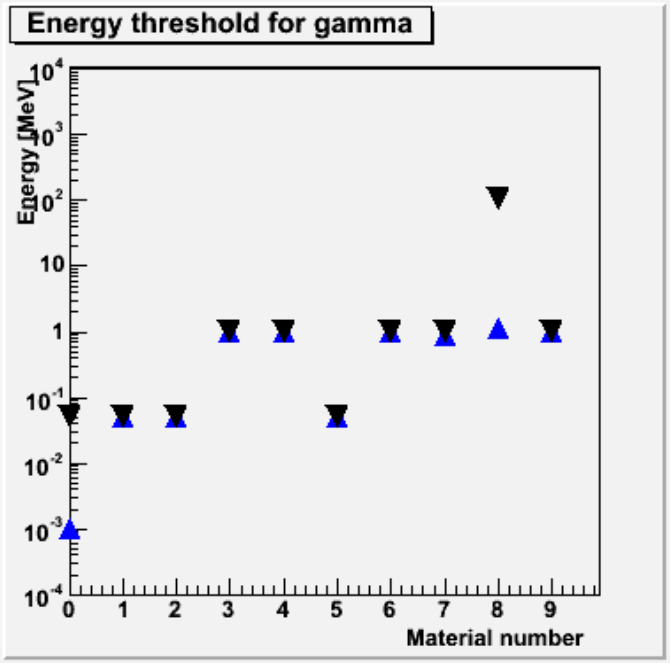
VMC cuts
New Implementation

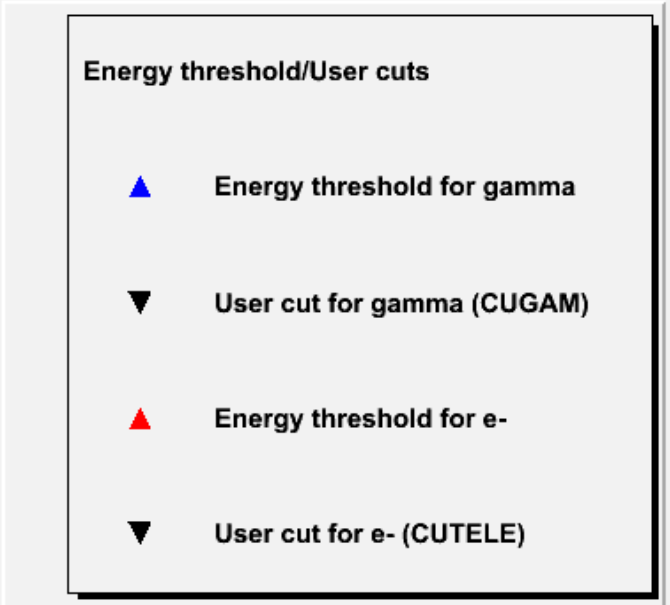
- Using G4Regions to define production threshold (in addition to use of G4UserLimits and Special cuts process)
  - *The regions are not used in the way as they were designed for*: the ranges do not really represent the detector sub-systems but are collections of volumes which may be spread over the detector with the same materials
- A tricky procedure as Geant4 provides only range to energy conversion but not energy to range
  - Iterating within a given range interval up to a given precision
  - User can customize the precision (the default is 2 orders of magnitude)
- Several verbosity levels are available to control the procedure

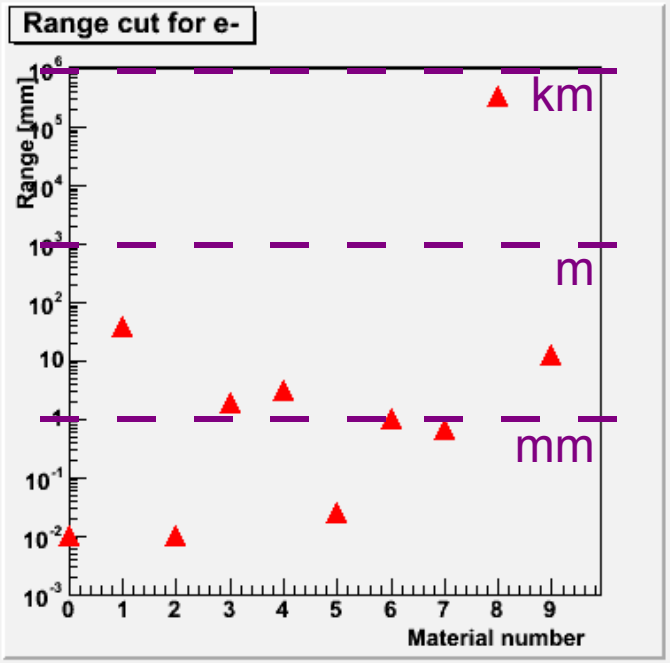
Reviewing Cuts in AliRoot

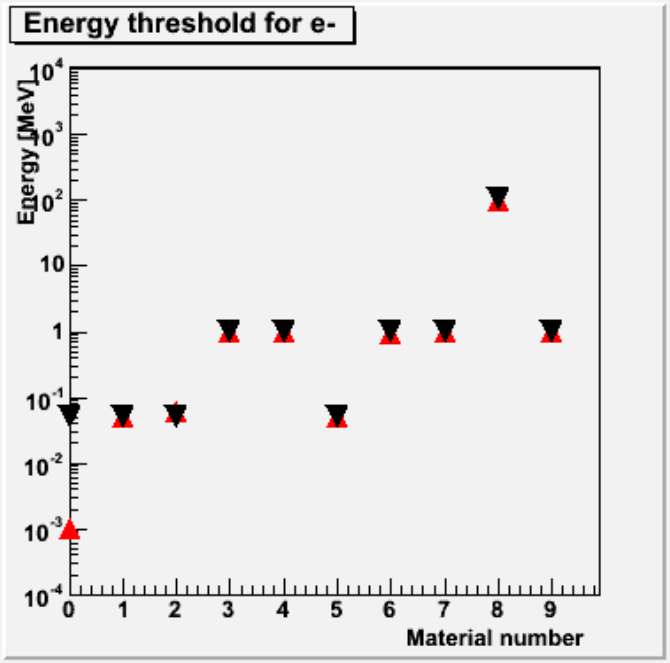
- cuts.cxx program in $ALICE_ROOT/test/vmctest/scripts
  - Reads the output from Geant4 VMC, activated with /mcRegions/print true command and generates plots with cuts values (range cuts, energy threshold computed from range cut and VMC cut set by user) per ALICE sub-system

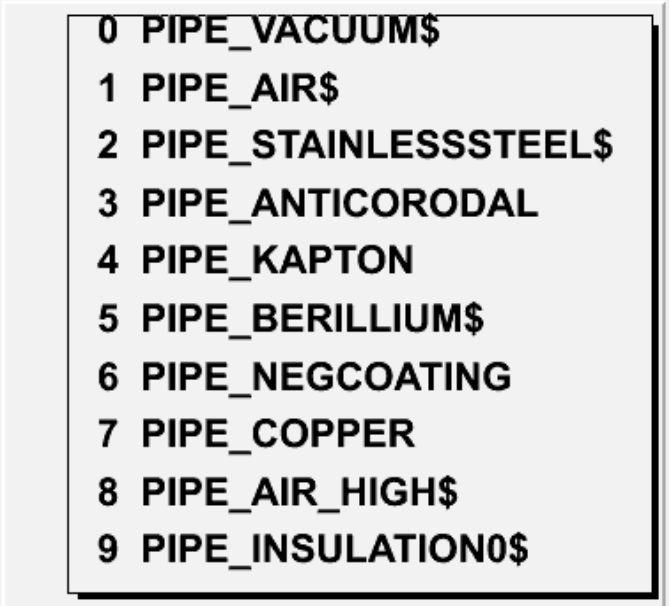

Range cut for gamma
Range [mm]
km
m
mm
Material number


Energy threshold for gamma
Energy [MeV]
Material number

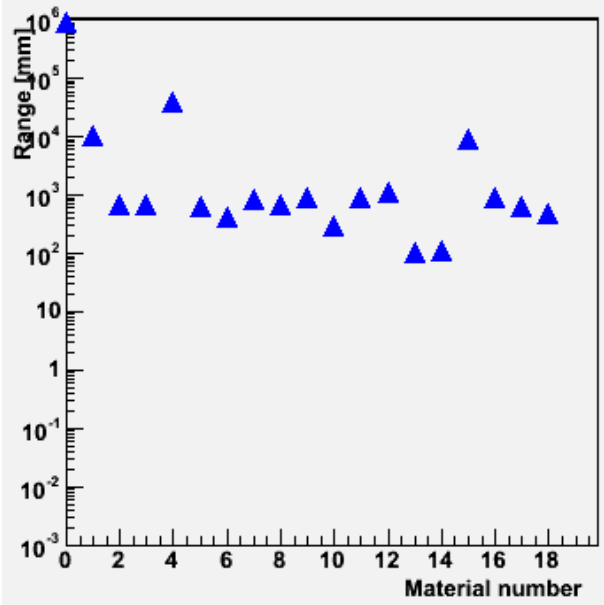

Energy threshold/User cuts
Energy threshold for gamma
User cut for gamma (CUGAM)
Energy threshold for e-
User cut for e- (CUTELE)


Range cut for e-
Range [mm]
km
m
mm
Material number

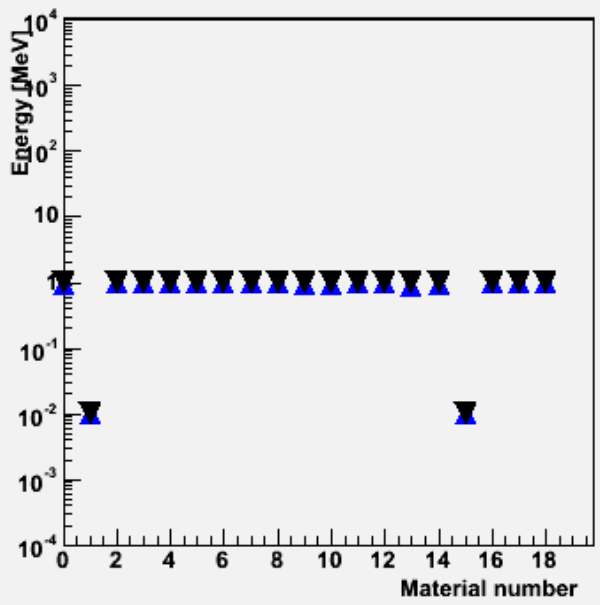

Energy threshold for e-
Energy [MeV]
Material number


0 PIPE_VACUUM$
1 PIPE_AIR$
2 PIPE_STAINLESSSTEEL$
3 PIPE_ANTICORODAL
4 PIPE_KAPTON
5 PIPE_BERILLIUM$
6 PIPE_NEGCOATING
7 PIPE_COPPER
8 PIPE_AIR_HIGH$
9 PIPE_INSULATION0$

Range cut for gamma



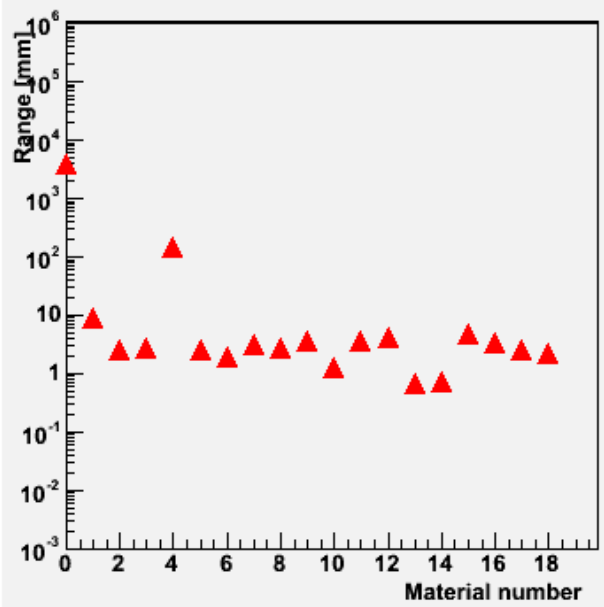
Energy threshold for gamma



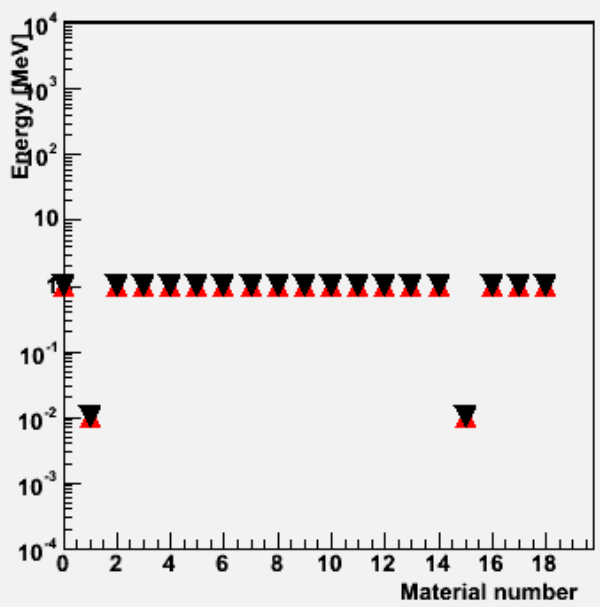
Energy threshold/User cuts

- Energy threshold for gamma
- User cut for gamma (CUGAM)
- Energy threshold for e-
- User cut for e- (CUTELE)

Range cut for e-



Energy threshold for e-



0 TPC_Air
1 TPC_Ne-CO2-N-2
2 TPC_Tedlar
3 TPC_Prepreg3
4 TPC_NOMEX
5 TPC_Prepreg2
6 TPC_Al
7 TPC_Mylar
8 TPC_G10
9 TPC_Makrolon
10 TPC_Alumina
11 TPC_Peek
12 TPC_Water
13 TPC_Cu
14 TPC_Brass
15 TPC_CO2
16 TPC_Epoxy
17 TPC_Prepreg1
18 TPC_Si

Uniform range cut ?

- In standard Geant4 applications the effect of cuts can be studied by running simulation with a uniform range cut (1mm) and then comparing the results with simulation were the higher cuts were applied (cut in range in some regions or tracking cuts via user limits)
  - In Geant4 VMC - the VMC cuts can be switched off and simulation can be run with a range cut defined in user physics list
  - In general, this is feasible, “only” it takes time
  - In AliRoot, we ran out of memory due to storing all secondaries in AliStack (and releasing them later)

Uniform range cut ?

- A possible solution (tested on ppbench test):
  - To pass the flag “keepCurrentTrack” to MC:

```
virtual Bool_t TVirtualMCStack::GetKeepCurrentTrack()
virtual void TVirtualMCStack::PushTrack(
   Int_t toBeDone, Int_t parent, ..., Int_t is,
   Bool_t overwrite) = 0;
```

  - If the track is not flagged to be kept and if it did not produced secondaries it will be replaced it in the stack with the next track
- But the change in the VMC stack requiring migration of user code
  - The code committed in geant4_vmc with a compilation option STACK_WITH_KEEP_FLAG
  - Modification of the interface depends on the interest from user side in having this possibility

Recent Developments
Bug Fixes

Magnetic Field

- The propagation of tracks inside the magnetic field in Geant4 can be performed to a user-defined accuracy, user can also choose from several integration methods.
- In VMC application, the user magnetic field is in VMC defined via **TVirtualMagField** interface and by default, the Geant4 default integration method and the default accuracy parameters are used
- Since recently, **user can choose another integration method and Customize the accuracy parameters** with a set of dedicated commands, see more details at:
  - http://root.cern.ch/drupal/content/magnetic-field

Geant4 VMC Fixes (1)

- Several bug fixes thanks to the ALICE testing, most of feedback by Eva Sicking
- In v2.7. (July 09)
  - Fix in applying special controls (the original processes activation was not always restored when particle got out from a given tracking medium or stopped).
  - Fix in applying SetMaxStep (the original step limit was not always restored when particle got out from a given tracking medium or stopped).

Geant4 VMC Fixes (2)

- In v 2.8 (January 10):
  - More fixes in applying VMC cuts:
    - Fixed processes names in TG4G3CutVector
    - Fix in applying PPCUTM: the cut is now applied as a limit to the total energy of e+e- pair produced by muon; the cut is not applied for e+e- pair from gamma conversion
  - Fix in handling feedback photons: keep the feedback photon PDG encoding which is different from opticalphoton
  - Fix in applying max step limit
- For the complete list of fixes and improvements see:
  - http://root.cern.ch/root/vmc/geant4_vmc_versions.txt

How to run AliRoot with Geant4

Installation

- There is nothing ALICE special, however VMC requires Geant4 configuration with some options not activated by default
- Follow the VMC web page and install: CLHEP, Geant4 and Geant4 VMC:
  - http://root.cern.ch/drupal/content/installing-geant4vmc
- *Instructions on the ALICE offline Web pages are outdated (old version of packages) and incomplete – to be avoided*

How to start

- $ALICE_ROOT/macros/g4menu.C


```
root [0] .x g4menu.C
Loading Geant4 libraries ...
...
Loading geant4vmc library ...

************************************************************
  To run simulation:
  First select <Geometry> to build geometry.root file.
  Then re-run aliroot and select <Run> button

  The <Init> button is kept for debugging purposes,
  it itializes MonteCarlo but it does not itialize
  completely ALICE framework. That's why to run simulation,
  you have to re-run aliroot and select Run button.

  The menu enables to start Geant4 interactive session:
  Select <Geant4UI> button and use Geant4 interactive commands
  To go back to Root UI, type exit.
************************************************************
```

vmctest directory

- $ALICE_ROOT/test/vmctest/
  - New directory added in November 2009
  - gun and ppbench tests adapted for running with both G3/G4
  - scripts – macros and scripts to produce plots with digits for several detector subsystems (by E. Sicking)

Configuration Macros

- No single Config.C but a set of configuration macros
  - genConfig.C, genGunConfig.C – macros for generating primary events in an external file
  - g3Config.C - steering configuration macro for G3
  - g4Config.C - steering configuration macro for G4
    - Only G3/G4 specific code, all common setting is done via common macros calls from both g3Config.C and g4Config.C
  - commonConfig.C, genExtFileConfig.C, – common setting (event generator, detectors, magnetic field etc.)
- Most of macros identical in gun and ppbench test
  - Different only the primary generator

g3Config.C
g4Config.C

```
void Config()
{
  cout << "Running g3Config.C ... " << endl;

  // AliRoot setup
  gROOT->LoadMacro("commonConfig.C");
  commonConfig(kFALSE);

  // Geant3/ Geant4 specific code
  // Loading libraries
  // Creating TGeant3/TGeant4
  // Setting Geant4 specific options (in g4Config.C)

  // AliRoot event generator
  // (it has to be created after MC, as it may use decayer via VMC
  gROOT>LoadMacro("genExtFileConfig.C");
  genExtFileConfig();

  cout << "Running g3Config.C finished ... " << endl;

}
```

Configuration Macros (cont.)

- Why not just one configuration macro for each MC?
  - We avoid code duplication (we have already a duplication of code from $ALICE_ROOT/test)
  - It is very important to follow the order of building objects (event generator, detectors, field, etc.) as defined in the current macros
  - Decomposing the macros into the blocks should make adapting macros for other use cases easier and avoid problems in Geant4 initialization

Conclusions

- Problems in geometry and geometry tools should get the top priority (*with wrong geometry we cannot trust the results)*
- The detector experts can run their benchmarks with both G3/G4, check the results and report on problems:
  - The macros to run with Geant4 are available in AliRoot
  - The installation of all tools is standard and well documented
  - Help can be get in the VMC mailing list: **vmc@root.cern.ch**