Feedback from HEP Experiments

Geant4 Collaboration Meeting - Catania, 19 Ottobre 2009

A. Dotti for the Geant4 Collaboration

Content

- Emerging requirements on physics performance
- Feedback and requests for software robustness and performance
- LHCb Feedback

Hadronic Issues

Issues reported, in order of decreasing "impact" on data

- Discontinuities in some calorimeter observables as a function of the beam energy, due to the transition between hadronic models
  - It can affect the simulation of jets
  - It can affect the hadronic calibration of ATLAS calorimeters
- Proton longitudinal shower profiles are shorter than data in QGS-based Physics Lists, due to diffraction
  - It can affect the simulation of jets
- Lateral shower profiles are a bit narrower than data
  - Probably not a big issue for LHC experiments, but for ILC it could be a serious problem (very granular calorimeters)
- Energy resolution a bit too good in simulation
- Energy response a few % too high in simulation

See A. Ribon's Presentation Friday

Additional Feedback/Requests

- Hadron response in W:
  - Initial studies from CLIC report unphysical response to hadrons in a tungsten block: bi-modal response (under study), much probably related to the "transition region" effect
- Visualization of Boolean solids (CMS)
- Physics lists per G4Region:
  - This would allow to optimize performance Vs accuracy for systems with different calorimeters (homogeneous Vs sampling). This is important for CMS
- Muon Multiple Scattering:
  - Correlation between angle and displacement is lost after LHCb Absorbers. Due to long G4Steps limited only by volume boundaries, displacement is not correctly simulated
- Physics lists potential issues for LHCb (LHEP)
  - LHCb requires that interactions of pions and kaons in thin (Si) layers is well described: dE/dx but also cross-sections
- CMS: Interest in use of Glauber-Gribov cross section above 90-100 GeV
- BESIII: poor anti-proton simulation (cross sections)

See LHCb material

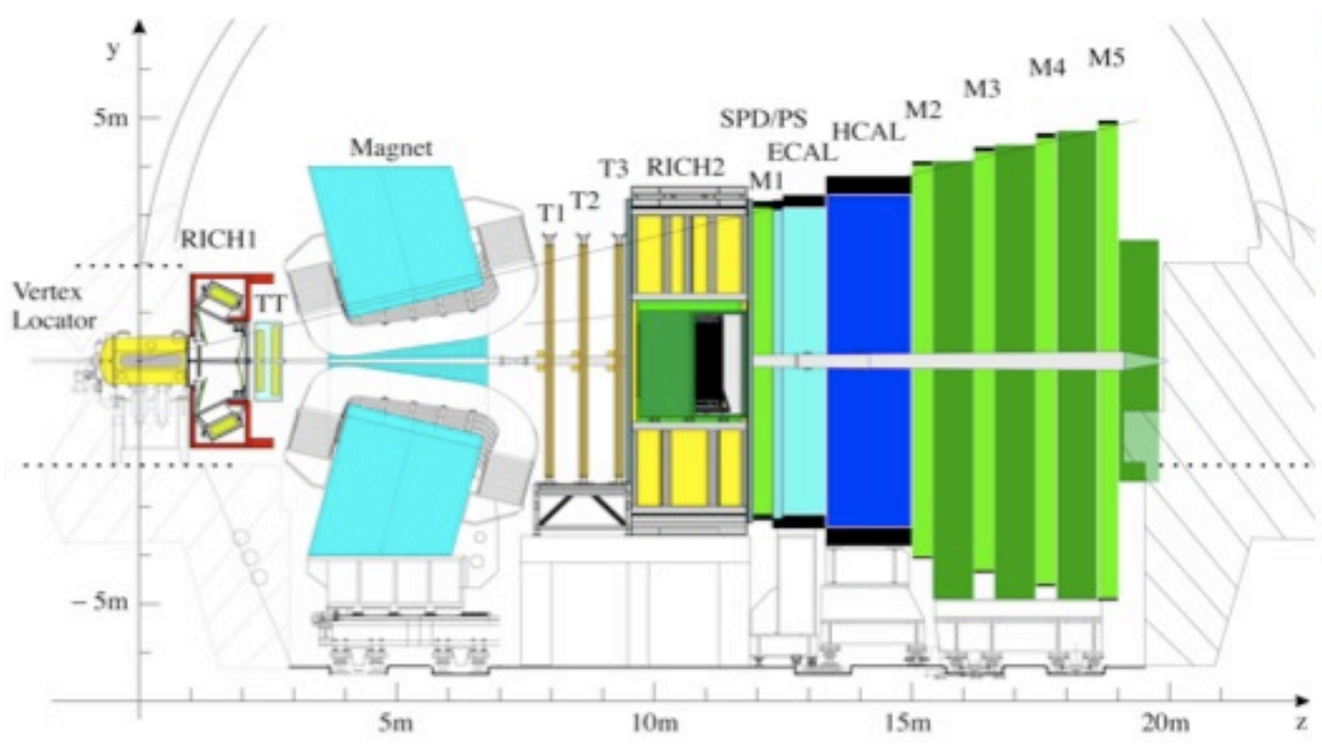
Performance/Robustness Issues

- Bugs/Crashes:
  - No major reports. Report from ATLAS: crash in hadronics with G4 9.2 (under study). Since October '08 produced over $650*10^6$ events (plus additional $500*10^6$ events w/o calorimeters)
- Robustness:
  - Stuck tracks: ATLAS reports 0.1%-1% jobs (=1/5000-50000 events or $1/\sim10^{11\text{-}12}$ Steps) with one track making very small steps(but big enough to prevent warnings), track processing takes very long and the job is eventually aborted
  - LHCb report: potential overlaps from rounding issues. Two exactly equal numbers in geometry-database may differ ($\Delta<<\mu m$) after geometry transformations are applied. Can G4 geometry module improve checks to reduce these cases?
- Reproducibility:
  - CMS reports that history of same job with gcc345 and gcc432 differs. Example: inelastic interaction producing two different final states (under study)
- Use of Memory:
  - LHC experiments report high use of memory, improvements are possible optimizing code and reducing memory fragmentation

LHCb Contribution

The LHCb experiment

- Designed to make precision measurement of CP violation and other rare phenomena in the b system at the LHC
- Trigger and reconstruct many different B decay modes to make independent and complementary measurements
- LHCb is a single arm forward spectrometer
- Forward production of bb, correlated



- Amount of material in tracker area kept as low as possible ($0.6X_0$ up to RICH2)
- HCAL used mainly for trigger purpose

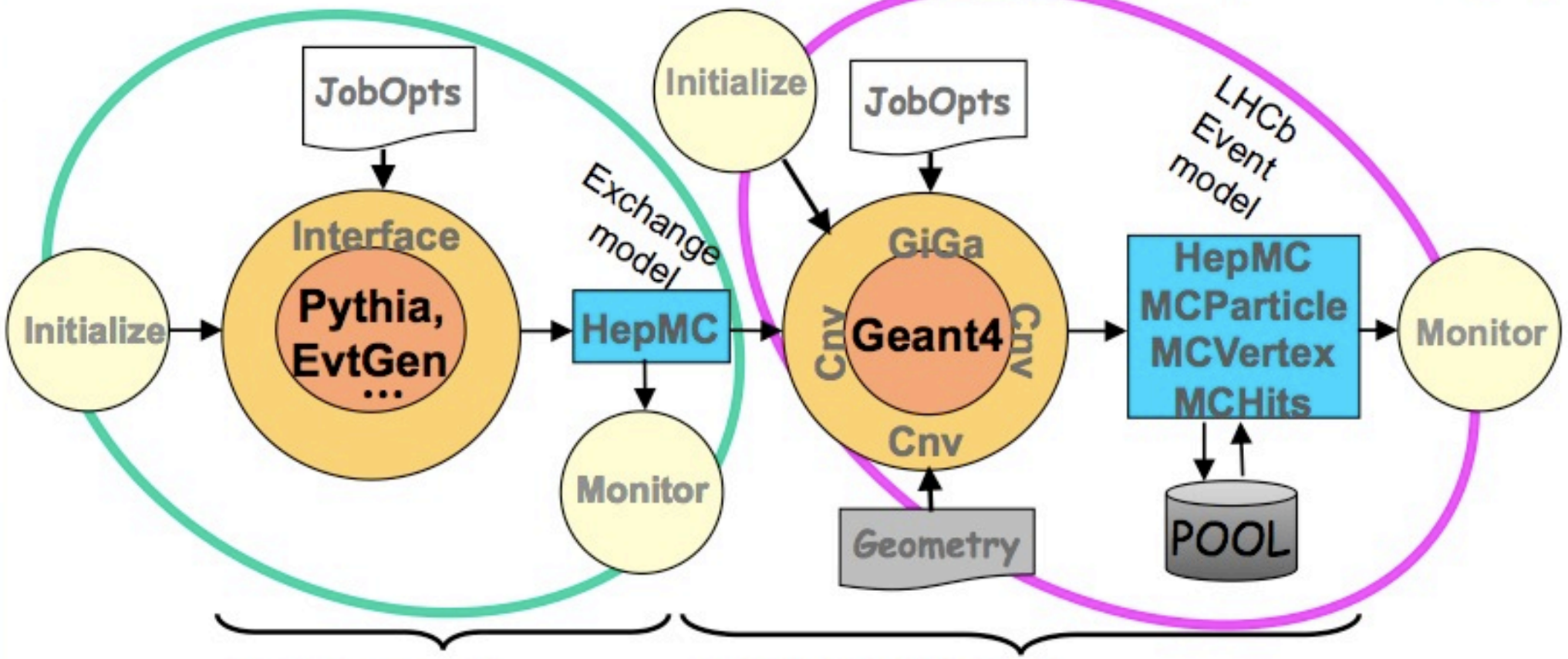
12 mrad < θ < 300 (250) mrad

i.e. 2.0 < η < 4.9

The Gauss Application

Gauss is the LHCb simulation application

Two INDEPENDENT phases normally run in sequence in a single job



Event Generation

primary event generator
specialized decay package
pile-up generation

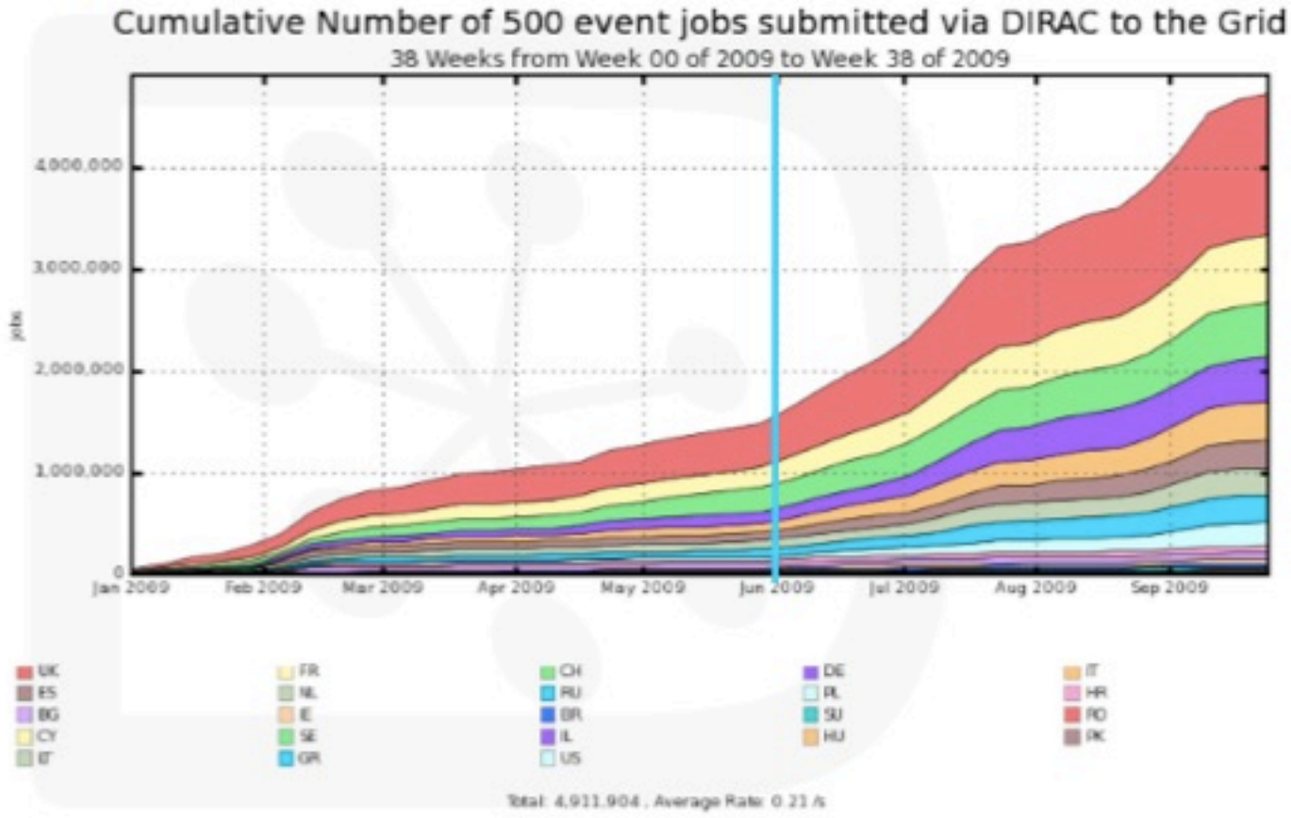
Detector Simulation

geometry of the detector (LHCb → Geant4)
tracking through materials (Geant4)
hit creation and MC truth information (Geant4 → LHCb)

Gauss in production: MC09

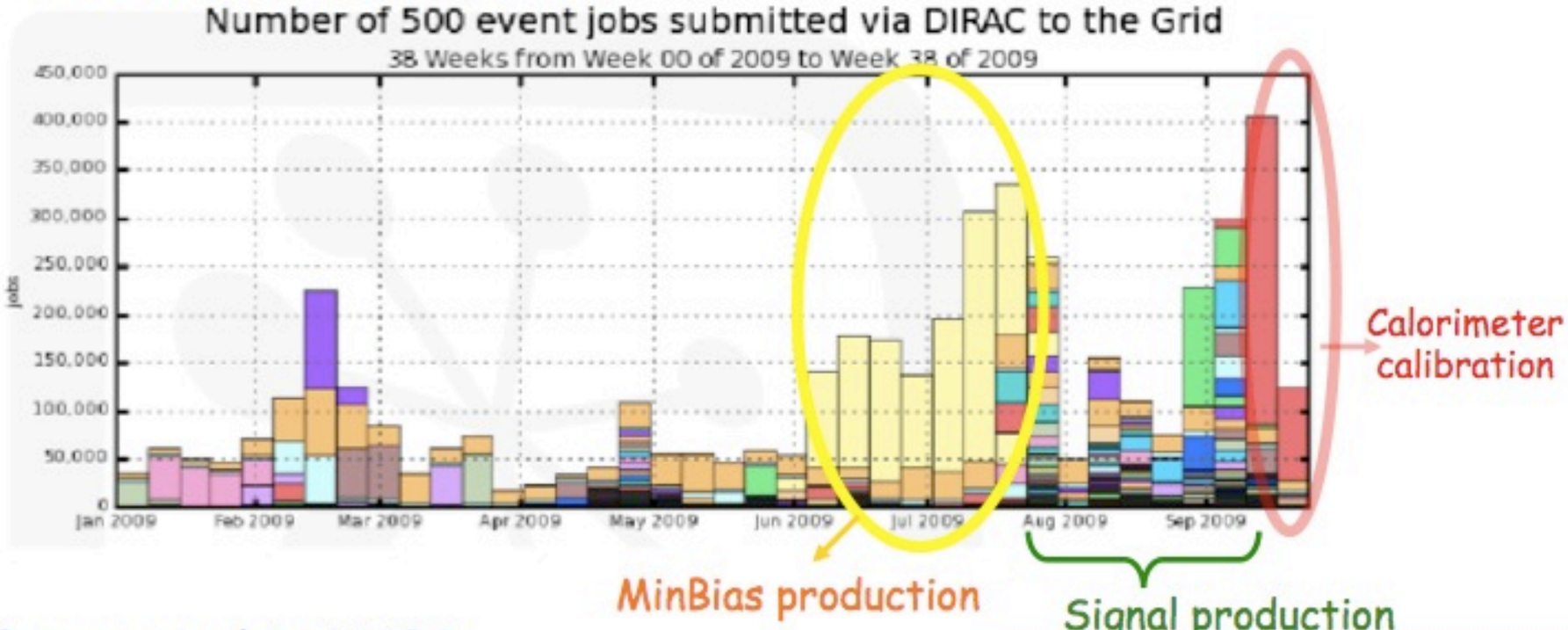
- LHCb latest major production (MC09) started at beginning of June:
  - exercise physics selection over 10^9 MinBias events
  - massive production of signal
  - production over the Grid
  - two phases:
    - production: MC simulation and reconstruction
    - stripping: event pre-selection

- 3M jobs run
- 45000 jobs/day



Gauss in production: MC09

- 10^9 MinBias events, few hundreds Millions of signal events (b,c,Z,Higgs...) produced
- No Spillovers simulation



- Gauss used in MC09:
  - Pythia 6 418.2 for pp-collision
  - EvtGen with latest merge from different experiments for B decays
  - Geant4 9.1r3 for detector simulation

G4 Range cuts applied:

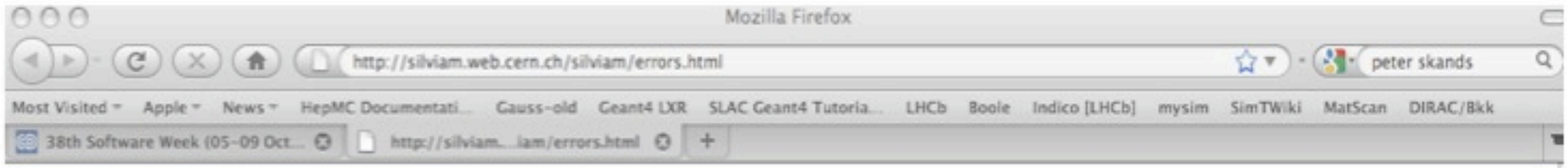
10 mm for gamma's

5 mm for e+

10 km for e- to have delta-rays off in trackers but affect dE/dx (see later)

Debugging Gauss in production

- Important to trace back reason of crashes and problems not leading to crashes (event aborted) during production:
  - impossible to look trough 45000 job log files /day
  - G4 errors detected at job level during production and combined for a given sample
  - dump of error messages together with RunNr,EventNr -> full reproducibility of event (random seed reset every event)
  - in final commissioning phase, will provide info relative to MC09 in near future



ERROR TYPE	COUNTER	DUMP OF ERROR MESSAGES
ERROR - G4	4	• Evt 2122 Run 483005 -->ERROR - G4Navigator::ComputeStep() Track stuck, not moving for 25 steps in volume -/dd/Structure/LHCb/DownstreamRegion/Hcal- at point (-63.4387,157.394,13842.9) direction: (0.643763,0.26705,0.717115). • Evt 2322 Run 483005 -->ERROR - G4Navigator::ComputeStep() Track stuck, not moving for 25 steps in volume -/dd/Geometry/BeforeMagnetRegion/Velo2Rich1/lvVelo2Rich1#VTa6- at point (-35.328,-10.2059,893.111) direction: (0.067896,0.327578,0.942381). • Evt 2390 Run 483005 -->ERROR - G4Navigator::ComputeStep() Track stuck, not moving for 25 steps in volume -/dd/Structure/LHCb/DownstreamRegion/Ecal- at point (119.652,105.414,12854) direction: (0.521036,-0.581958,0.624377). • Evt 2490 Run 483005 -->ERROR - G4Navigator::ComputeStep() Track stuck, not moving for 25 steps in volume -/dd/Structure/LHCb/DownstreamRegion/Ecal- at point (158.886,-24.0533,12977.2) direction: (-0.124053,-0.853045,0.506878).
ERROR Gap not found!	6	• Evt 2015 Run 483005 -->ERROR Gap not found! • Evt 2020 Run 483005 -->ERROR Gap not found! • Evt 2087 Run 483005 -->ERROR Gap not found! • Evt 2258 Run 483005 -->ERROR Gap not found!

Debugging Gauss in production

Main G4 problems encountered during production:

1) jobs hanging in production (~ several%)

- ν or n of few MeV ping-ponging between Universe and an upstream volume (protection has been introduced to kill these particles)
- charged particles of zero steps (G4 pushing them) in the same volume (protection introduced)

```
WARNING - G4PropagatorInField::ComputeStep():
  Zero progress for 51 attempted steps.
```

- investigation with G4 crew revealed:
  - due to precision problem there was an overlap between the volume (a Polycone) and its mother.
  - loss in precision of one of the planes of the Polycone

- this Overlap was not appearing if checked with G4 David Tool, detected with overlap check in G4PVPlacement.

2) in ~0.5% of events aborted by G4 due to:

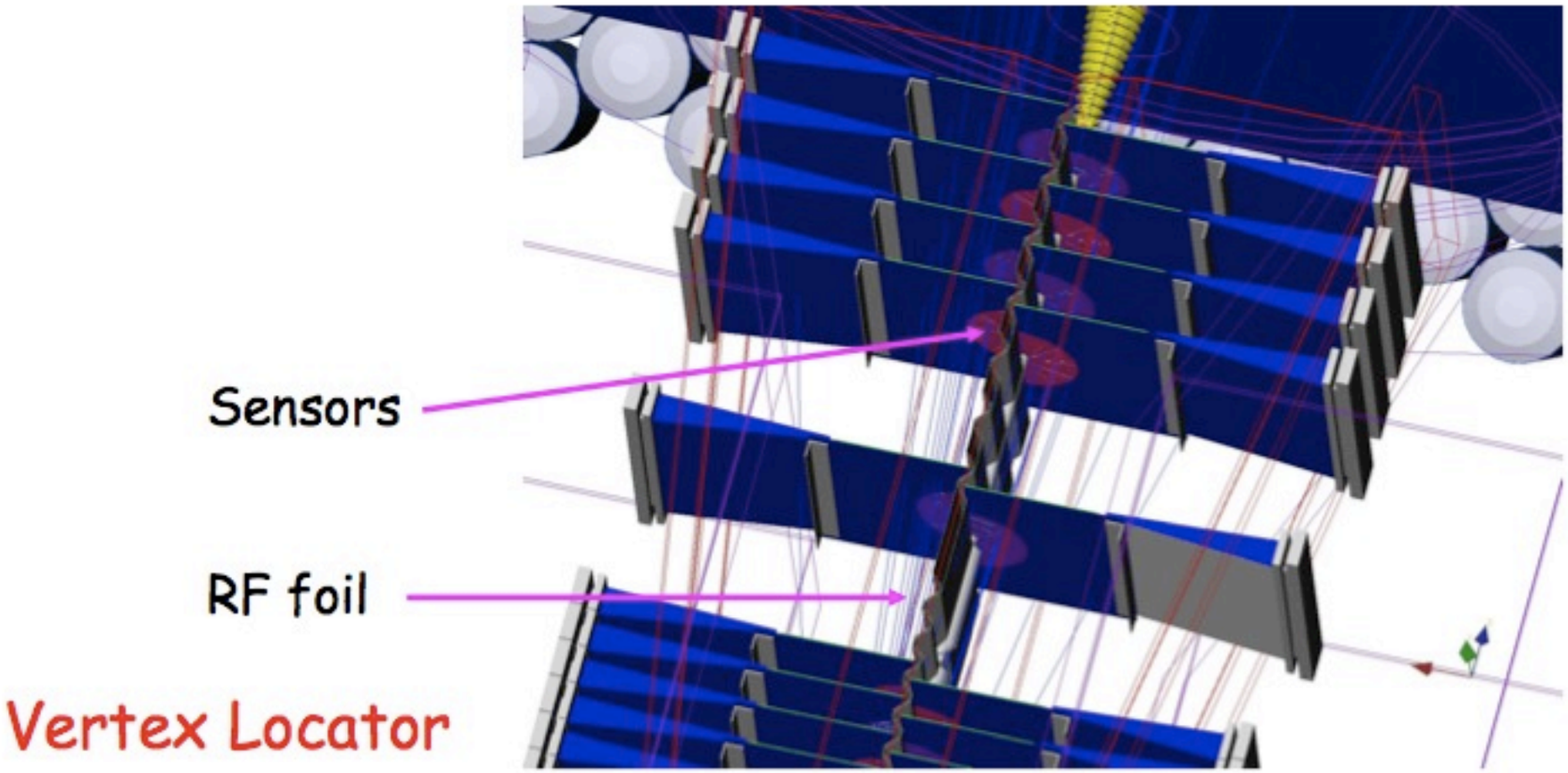
```
G4Exception : StuckTrack issued by : G4Navigator::ComputeStep()
Stuck Track: potential geometry or navigation problem
```

- track stuck message but G4 returning "no overlaps found" in check

Physics tuning studies

Two main simulation issues:

- G4 description of dE/dx in thin Si detectors
- G4 Multiple Coulomb Scattering simulation in case of large step sizes and dense material

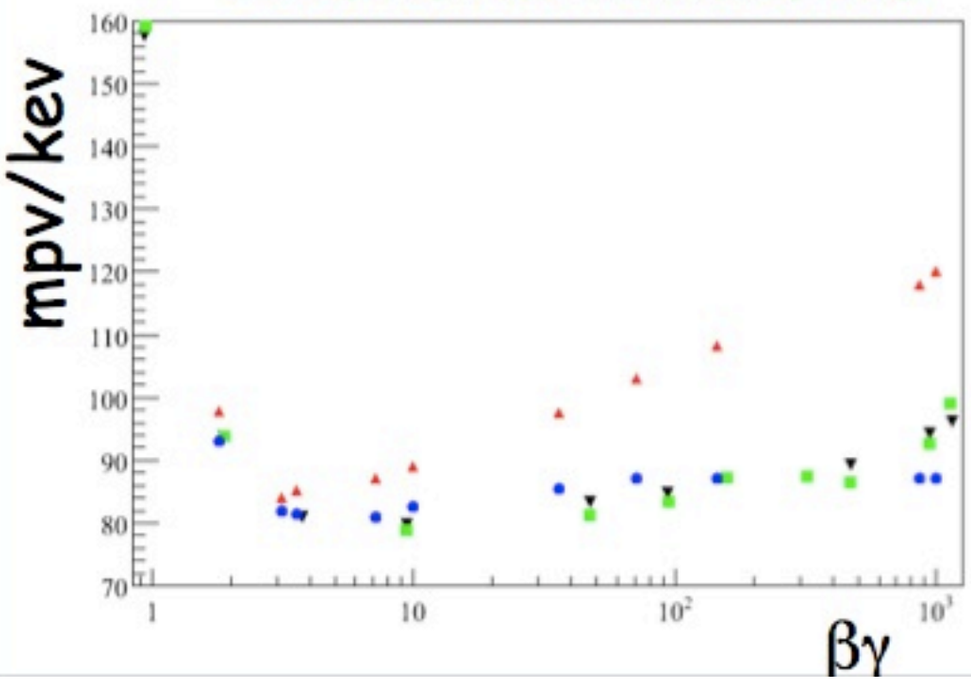


dE/dx in thin Si Detectors

- 3 detectors in LHCb use Si of different thickness (220μm,400μm, 600μm)
- Particle guns (50k muons at fixed Energy) studies performed
- Results of simulation compared to simple model describing data

Recent G4 versions -> much better agreement

- Landau + smearing for atomic binding
- G4 7.1.p03 (DC06)
- G4 8.3.p01 + EMOpt1
- G4 9.1.p01/p02/p03 + EMOpt1 (MC09)



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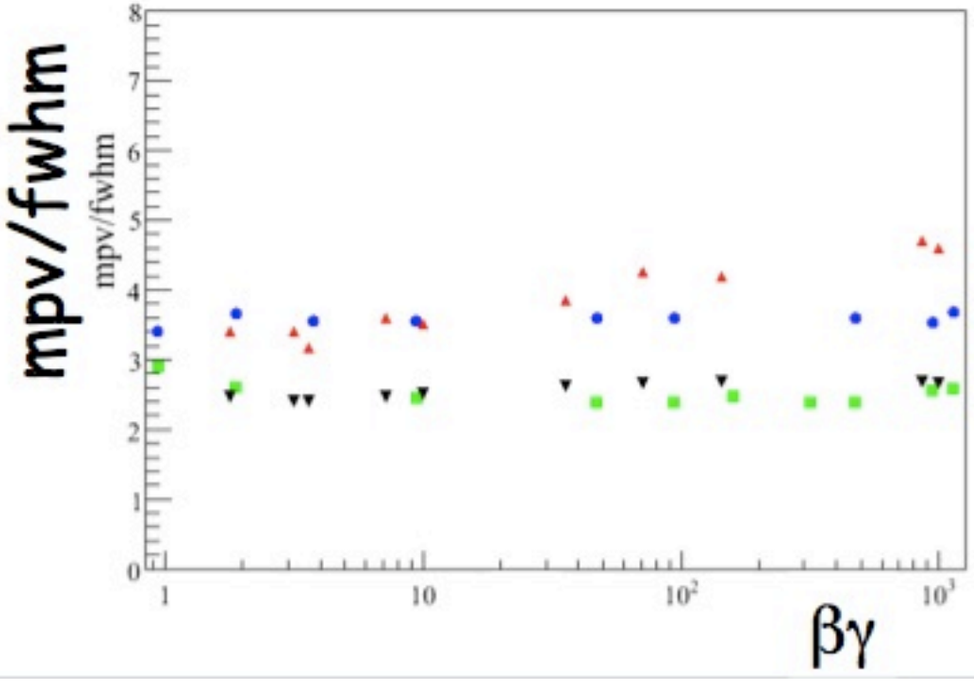
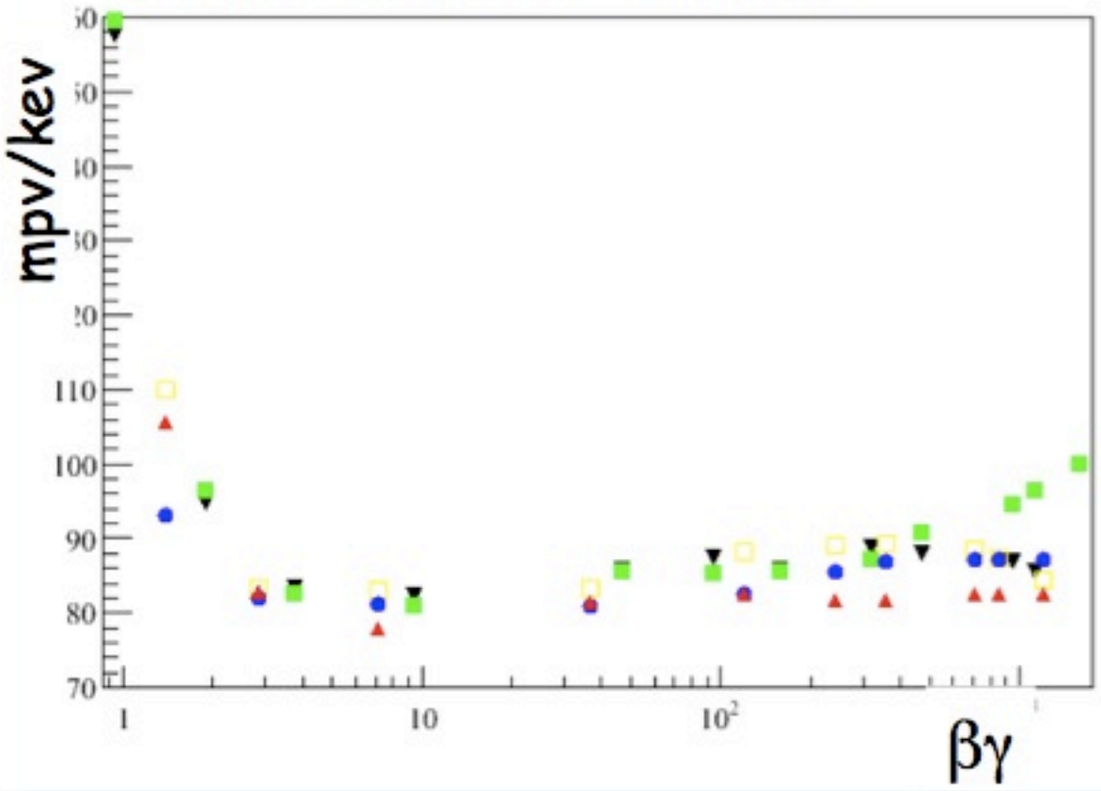


dE/dx in thin Si Detectors

- in G4 7.1.p03 the dE/dx intrinsic width was too small (atomic binding correction was missing) -> in digitization phase smearing was applied
- in G4 9.1 the atomic binding is simulated (width is close to expectation) -> correction no longer needed.
- the width seems to be a bit overestimated w.r.t. theory (~5% for 400μmSi)
- still remain problem in vertex detector (220μm Si) simulation: Landau width too wide w.r.t. test beam data

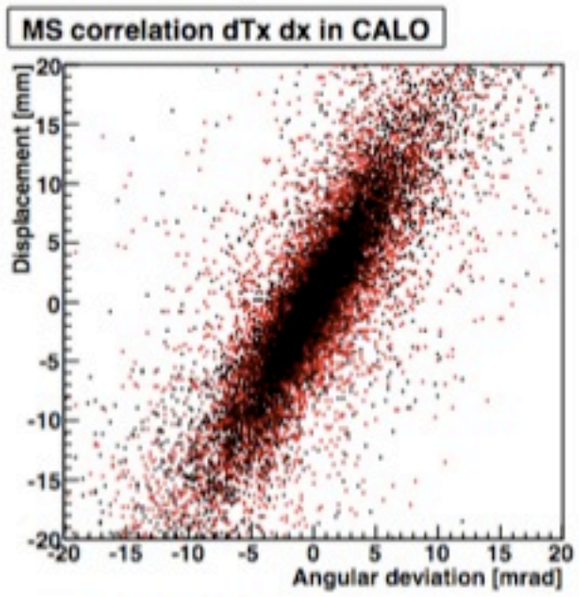


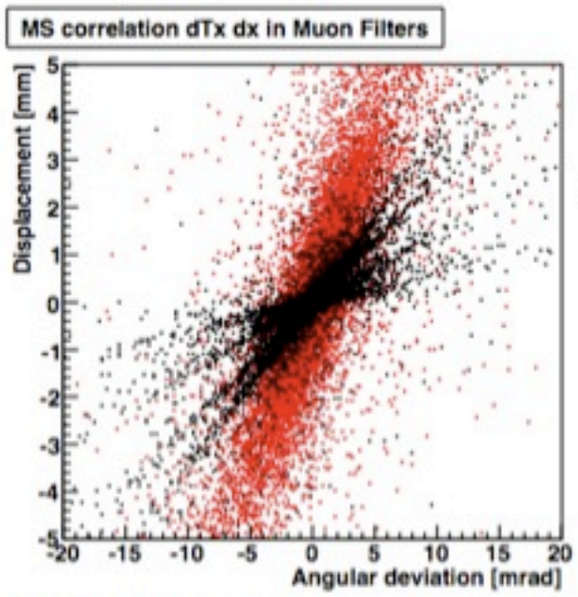
- better agreement with δ-rays on
  - still problem at high βγ for muons
- unphysical differences between muons and pions?

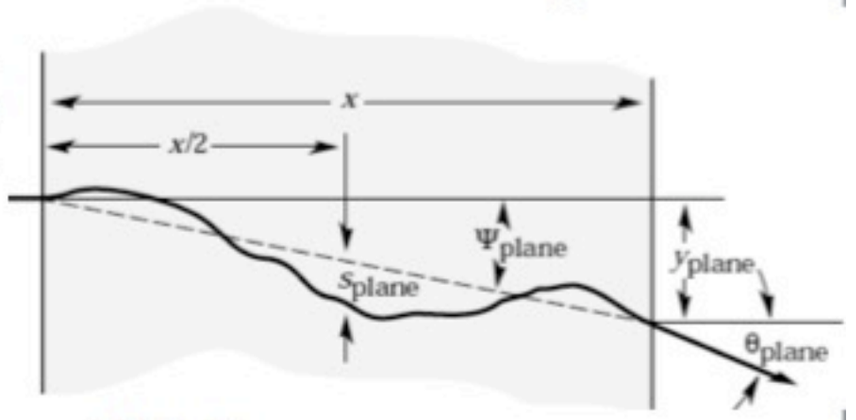
- **Landau + smearing for atomic binding**
- **G4 9.1.p01/p02/p03 (pions)**
- **G4 9.1.p01/p02/p03 (mu with δ-rays ON)**
- **G4 9.1.p01/p02/p03 (muons)**
- **G4 9.1.p01/p02/p03 (pions with δ-rays ON)**

MCS in LHCb MUON system

- Muon trajectories are dominated by multiples scattering interactions in the Calorimeters and Muon Filters
- The MCS in G4 is not correctly simulated in case of dense material and large step sizes (MUON Filters are a perfect example!) -> correlation between displacement and angular deviation not maintained.
- Step size not constrained by other factors (no B field simulated in that region)





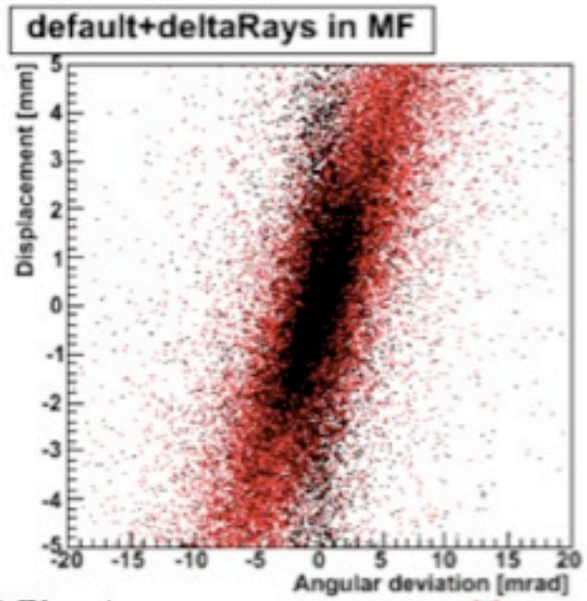


- G48.0
- PDG

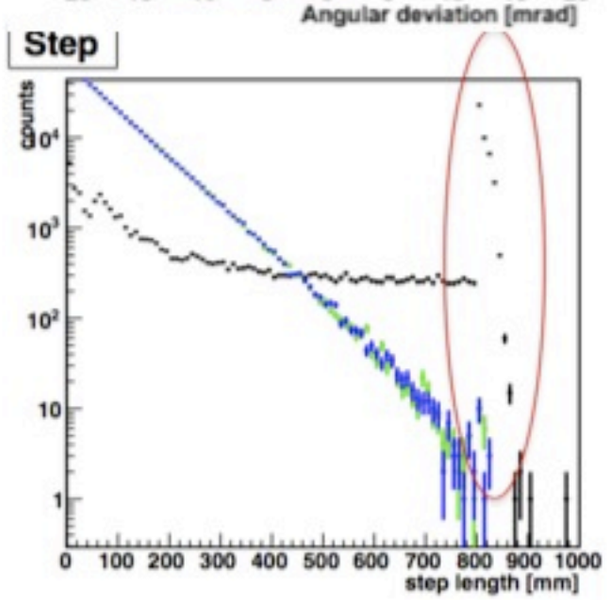
- MCS problem may affects also the momentum measurement in the track fit when propagation of track over large distances (e.g. Magnet) -> poor q/p parameter pull.
- Situation improved in current production but still the q/p pull is worse than the other track parameters.

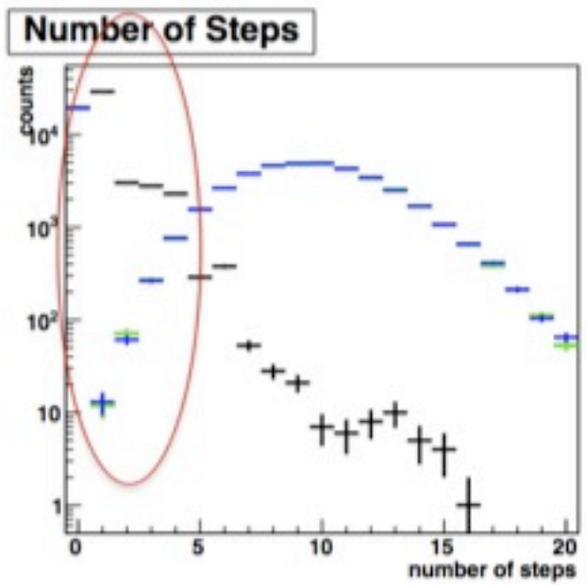
MCS in LHCb MUON system

• in future productions activation of δ-rays. Side effect G4 reduces the step length -> correct description of correlation (still slightly differences with PDG)



• G49.1p03
• PDG

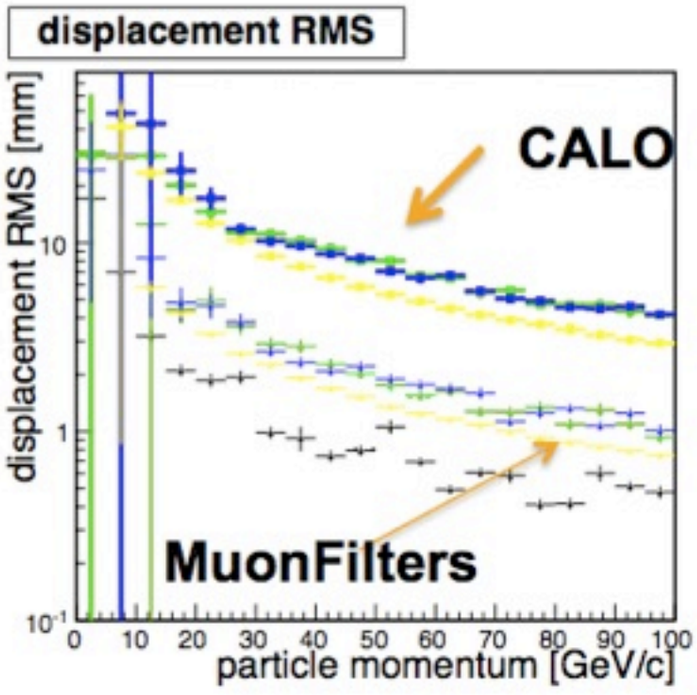


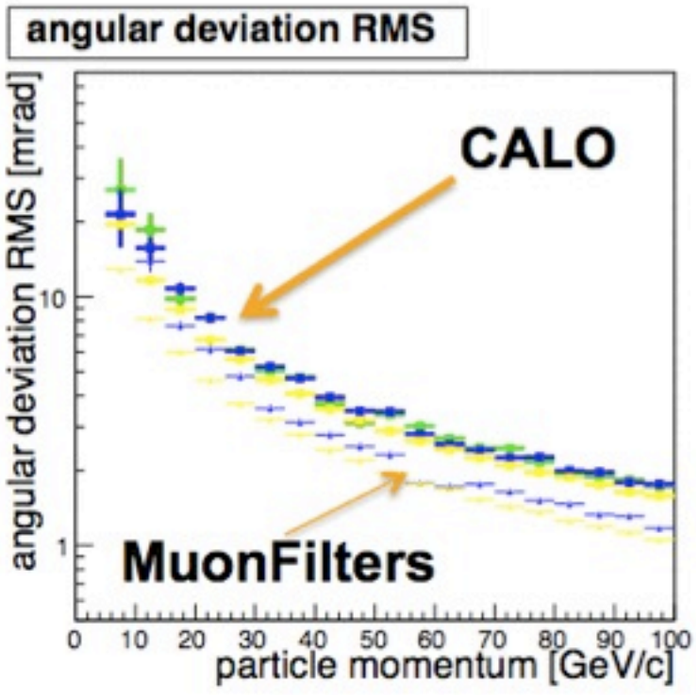


• default (δ-rays OFF)
• with δ-rays ON

MCS in LHCb MUON system

- MCS description in G49.1p03 (G4MuMscModel) slightly improved w.r.t. G4 8.2 (G4MuMultipleScattering), independently of δ-rays.
- Still slight differences with PDG
- Set up monitoring plots specific for MCS, to be investigated with Gauss based on G49.2p2 (being commissioned)





- Default
- δ-rays in ALL LHCb
- δ-rays in MUON Filters
- PDG

Conclusions

- Major issues under investigation are on hadronic simulation
- No major issues on the technical side, however, since the experiment sw is becoming mature and stable more and more emphasis is put on performance/robustness (especially use of memory and reproducibility)
- Geant4 9.2.pXX will be the simulation code for ATLAS, CMS and LHCb first runs: we can expect many new comparison (and requests) with first data in 2010

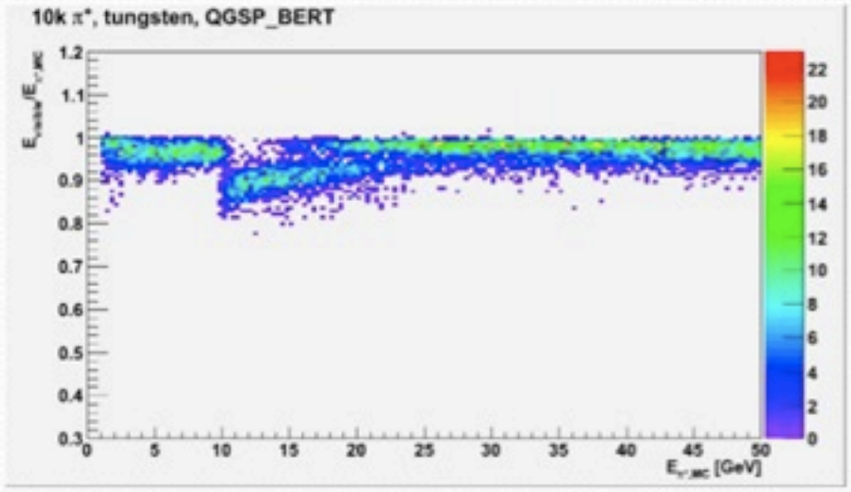
Backup Material

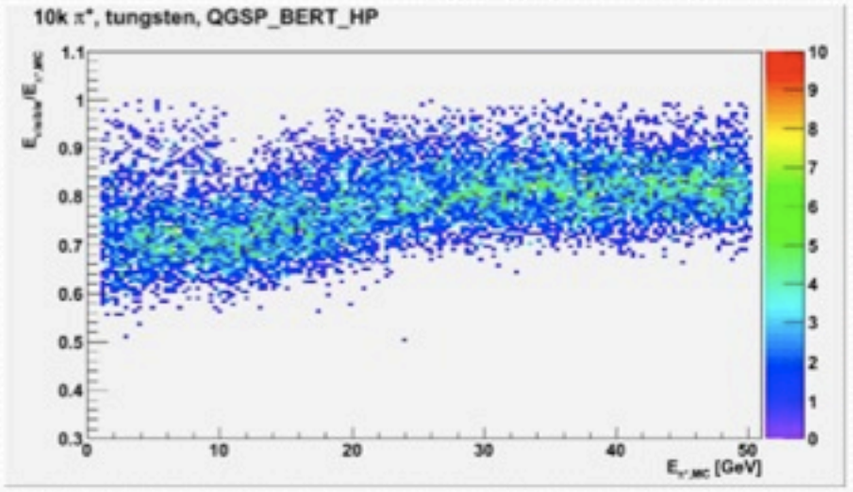
Pion Response In W

tungsten simulation issues (on big block of tungsten)

QGSP_BERT **QGSP_BERT_HP**

- large differences of deposited energies
- much narrower distribution without HP neutron model



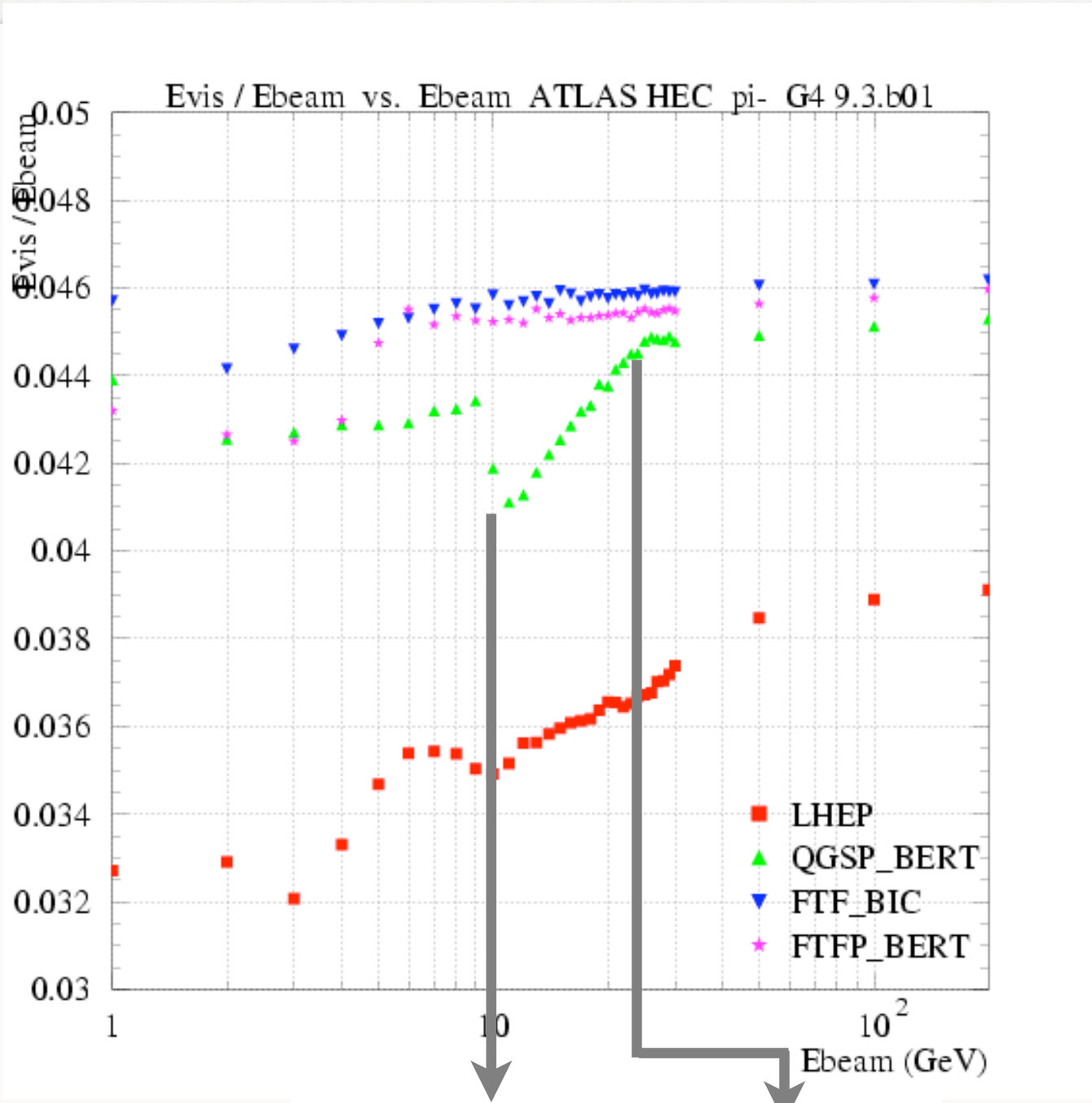


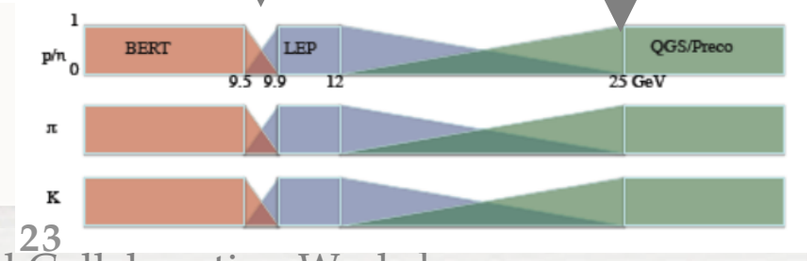
Memory Usage

- Example from ATLAS:
  - G4Transportation alloc/dealloc lot of memory
  - Default stepper (RK4) access memory ten times per step
  - An ATLAS custom stepper reduces access to B-field and adds caching of values
- Similar problem in BERTINI code (many alloc/dealloc):
  - Some patches done to improve code
- Smaller number of alloc/dealloc improves also performances: ATLAS reduction of 1.3GB/event of alloc/dealloc saves 10% CPU

Energy Response Discontinuities

Energy response
in simplified Cu-LAr
calorimeter





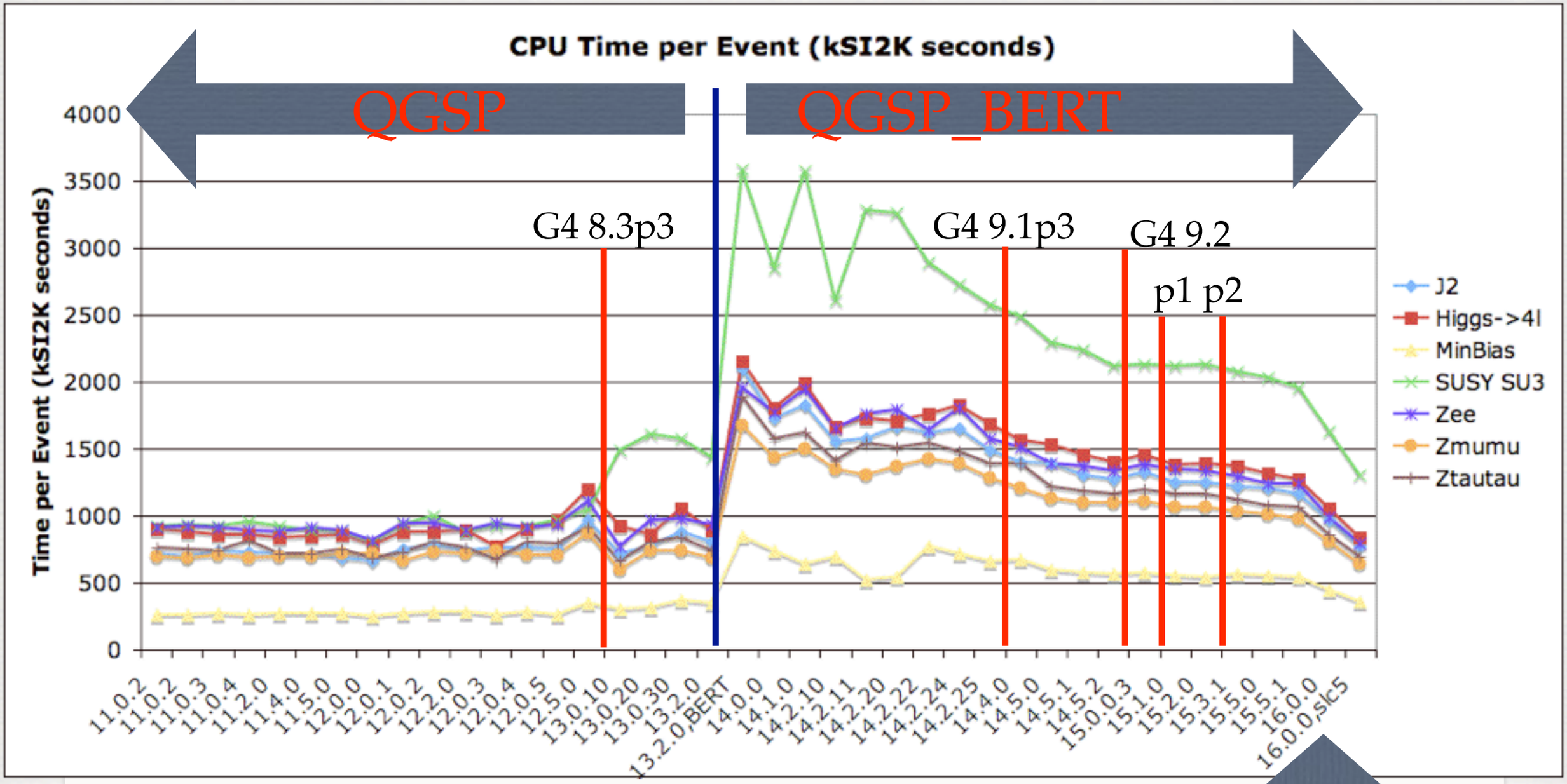
QGSP_BERT transitions

K/π In Thin Layers (LHCb)

- Cross sections used at the moment:
  - $\sigma_{\pi N}$ (LHEP): GEISHA cross-section
  - $\sigma_{\pi N}$ (OTHERS): Barashenkov cross-section data
  - σ_{KN} : GEISHA cross-section from πN with scaling factor

    probably non optimal
  - σ_{pN}(LHEP): GEISHA cross-section data
  - σ_{pN} (OTHERS): Wellish-Axen cross-section
- Different models for cross sections under validation, will increase flexibility / precision

Performance: ATLAS

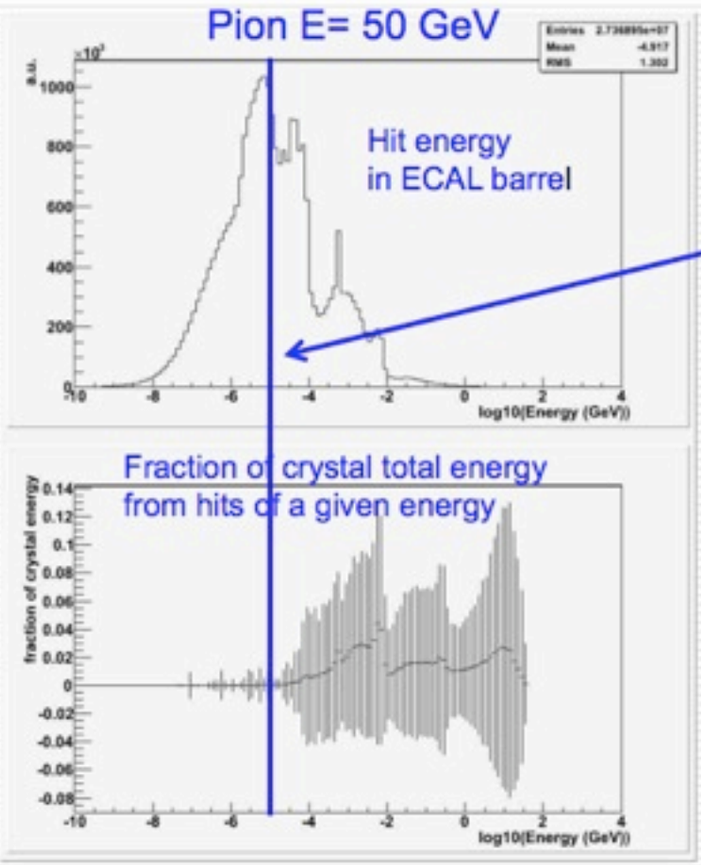


WARNING: timing of ATLAS sw, not only G4 code

-20% with slc5/gcc4.3

Simulation Optimization (CMS)

Performance optimization



- Main problem in Bertini: many very low energy hits
  - Cut those with no impact on observable energy
  - Reduce by 20-30% overall simulation output size
- Move the track and calorimeter hits management on a primary-by-primary basis
  - Reuse of memory released at every new track/hit
  - Gain in memory footprint: O(> 50 MB) on TTbar run

F. Cossutti CHEP09 Prague, 24/3/2009 21

Tuning and optimization of the CMS simulation software; F. Cossutti; CHEP 2009