Geant4 User Requirements from HEP Energy Frontier Experiments

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Outline

- ATLAS
- CMS
- LHCb
- ALICE
- CALICE

ATLAS

(Z. Marshall, J. Apostolakis)

ATLAS (1/3)

- Expect to be on SLC6 and coming to CC7 soon.
  Using gcc 4.7/8/9, and soon will test gcc 5. All 64-bit .
- Running production with G4 **9.6** using the **ISF** (Integrated Software Framework)
  Will move to production with G4 **10.1** by the end of 2015
- Crash rate of G4 10.1 is ~ 10^-5 / event , far too high
  - Long-standing navigation problems, likely fixed recently by J.A.
- Neutrons are taking a lot of CPU time
  - To be re-evaluated after fixing the navigation problems
  - Applying biasing techniques could be considered
- Memory consumption is significant but not a major concern
  - A very large number (**~600**) of materials is used
- Lazy initialization and use of many small files in some hadronic processes can cause problems for many-core jobs

ATLAS (2/3)

- Associate multiple sensitive detectors to a single logical volume (thanks to A. Dotti, included in G4 10.1.ref08); expect to have the same for user actions, *i.e.* support for multiple user actions
- Want a cheap method for the number of secondaries produced in a step
- Want to cheaply copy information from the mother to a secondary
- Pleased to see the CPU improvements in EM physics

ATLAS (3/3)

- Working to understand the EM-scale response changes of ~1% between G4 9.6 and 10.1
  - For both EM and HAD calorimeters in barrel only (no in end cap)

  also seen a change in EM shower shapes in the EM barrel
- Hope that the long-standing EM shower lateral shape problem can be resolved
  - Creating a dedicated stand-alone Geant4 test might be helpful

- As the LHC is now running at 13 TeV, we are working to understand the interactions of hadrons at very high energies (above a TeV) in the detector

CMS

(V. Ivanchenko)

Geant4 Status in CMS

- Production version of Geant4 for 2015
  - Geant4 version **10.0.p02** built in sequential mode
  - Production platform slc6_amd64_gcc491
  - Default physics list: QGSP_FTFP_BERT_EML
  - ~5 billion events already produced in 2015
    - This number will be increased for the end of the year
- Current development versions of Geant4 in CMSSW
  - Geant4 10.0.p03 + patch of Geant4e for threading is established
  - Multi-threaded Geant4 is fully integrated with CMS multi-threaded framework
    - Our goal is to use it in production 2016
  - Platform slc6_amd64_gcc493
  - Geant4 10.1.p02 is also available in development branches
  - Geant4 10.2 planned tobe our production version in 2017
- There are no urgent new CMS requirements to Geant4
  - Few suggestions to improve Geant4 are discussed in the following slides

CMS Open Issues (1/2)

- CMS is developing FastSim options using only Geant4 physics model classes for EM and hadronic sub-libraries
  - Initialisation of these models is performed concurrently, master thread does not exist
  - We would suggest to take into account this use-case to guarantee thread safety at initialisation of Geant4 physics in worker threads
- Working recently with CMS geometry we discover several problems which are not critical but can be considered:
  - Base geometry classes (G4VSolid, G4LogicalVolume, G4VPhysicalVolume) do not have stream operators
    - It may be useful to add stream operators to geometry classes if there will be no performance penalty
  - Overlap checks are done using the same number of points per volume regardless of their size
    - It would be good to add a new interface allowing, for example, logarithmic scaling of number of random points in an overlap check depending on volume size

CMS Open Issues (2/2)

There are issues which have been already discussed at Geant4 Technical Forum in January 2015

- Possible technical improvements
  - Provide proper destruction at exit for Geant4
    - Significant progress in 10.2.beta but still there are many objects which are not properly destructed
  - Review implementation of G4VERBOSE compile option (~2% CPU)
    - CMSSW is currently built with G4VERBOSE enabled in order to be able to trace back problems with tracking verbosity
- Physics studies
  - Evaluate accuracy of simulation of high energy hadronic interactions
    - Public FTFP/QGSP validation results are limited in Geant4 web :

      http://geant4.cern.ch/results/validation_plots/thin_target/hadronic/high_energy/index.shtml

      http://g4validation.fnal.gov:8080/G4WebAppNG/welcomePrimefaces.xhtml

LHCb

(G. Corti)

LHCb (1/2)

- The MC productions for the 2015 and 2016 data will be made with Geant4 **9.6.p04**
- We require bug fixes to be provided for issues we may observe in production (see next slide on support for Run 2)
- We will use **FTFT_BERT** hadronic physics with changes provided to us by Geant4 for Kaons cross sections
  - Further update may be needed once we have evaluated the effect in detail within physics analysis
- Proton/anti-proton asymmetries may become an issue in the future
- We would like our EM physics list, a no cut variation of Opt1 to be maintained by Geant4
- We will provide what we are currently using

LHCb (2/2)

- To produce few billions of MC events requires a big share of the Grid computing resources. Improvements in speed are and will be highly appreciated
- We are also looking into fast MC options
- Migration to Geant4 10 is THE major task in the simulation next year for LHCb
- Need to change the LHCb Gauss simulation framework in many places and carry out extensive tests
- Very fruitful discussion with A.Dotti and M.Asai
- We rely on support from Geant4
- Will not put it in production before the end of 2016

ALICE

(A. Morsch, I. Hrivnacova)

ALICE (1/2)

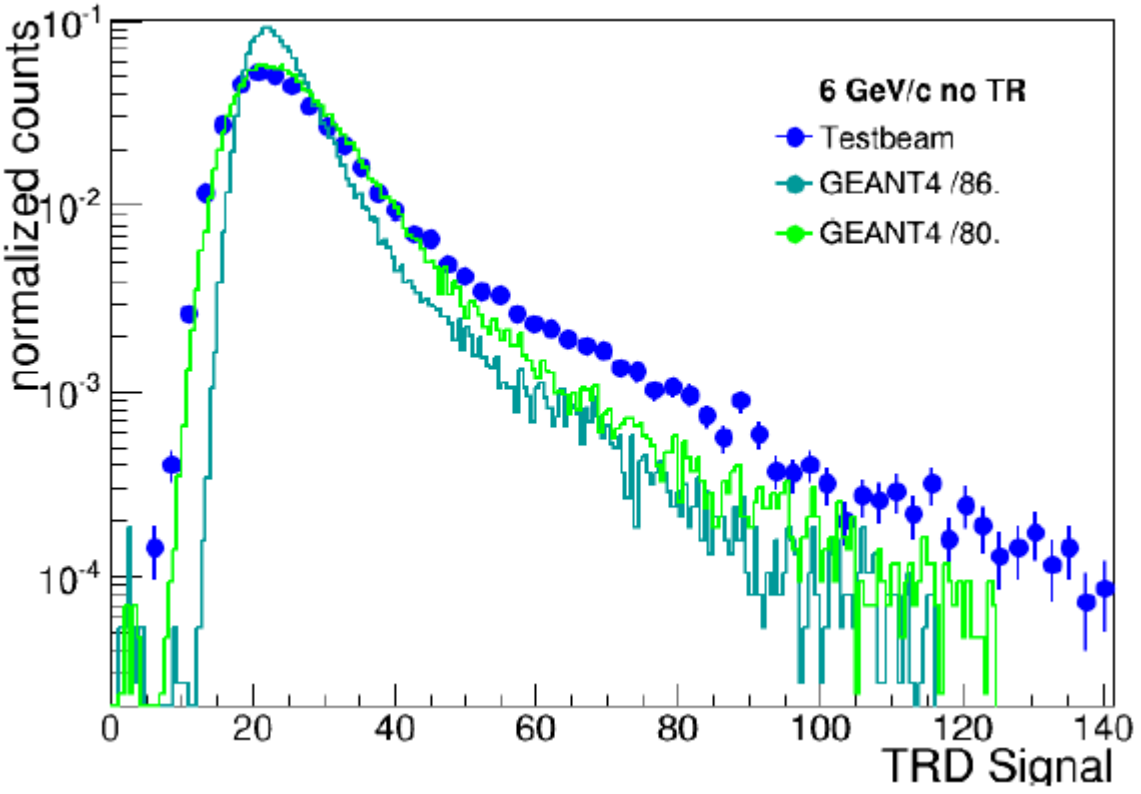
- Platform: SL(C)6, gcc 4.1.2
- Last G4 production run for special studies with G4 10.1 (in sequential mode)
  - Pb-Pb @2.76 TeV
  - Efficiency study for: (anti-)d, (anti-)t, (anti-)3He, (anti-)α
- In preparation general G4 production with G4 10.1.p02+fixes (in sequential mode)
- Using FTFP_BERT_EMV physics list
  - With PAI model only in the gas gap of TRD
  - With Standard EM only in ECAL

ALICE (2/2)

- Geant4 problems in ALICE encountered this year :
  - Fatal exceptions from G4MultiLevelLocator
    - Considering a new build of Geant4 libraries with the fix provided by the Geant4 geometry group; the fix is now being validated with ALICE geometry
  - Memory growth problem found in the development version
    - Fixed (hadronic reaction-products not properly deleted) in G4 **10.1.ref04**
  - Non-reproducibility issue found with light anti-nuclei
    - Fixed (ion-ionization) in G4 **10.1.ref07**
- Interested to try out VecGeom
  - Via TGeo because of VMC

ALICE TRD Simulation

- Energy deposition in the gas layer of the transition detector is not well simulated by Geant4 standard EM physics; Geant4 PAI model is closer to the test-beam data
  - V. Ivanchenko is studying it
- ALICE simulation uses successfully Geant4 PAI model only in the small gas gap of TRD, with negligible CPU overhead

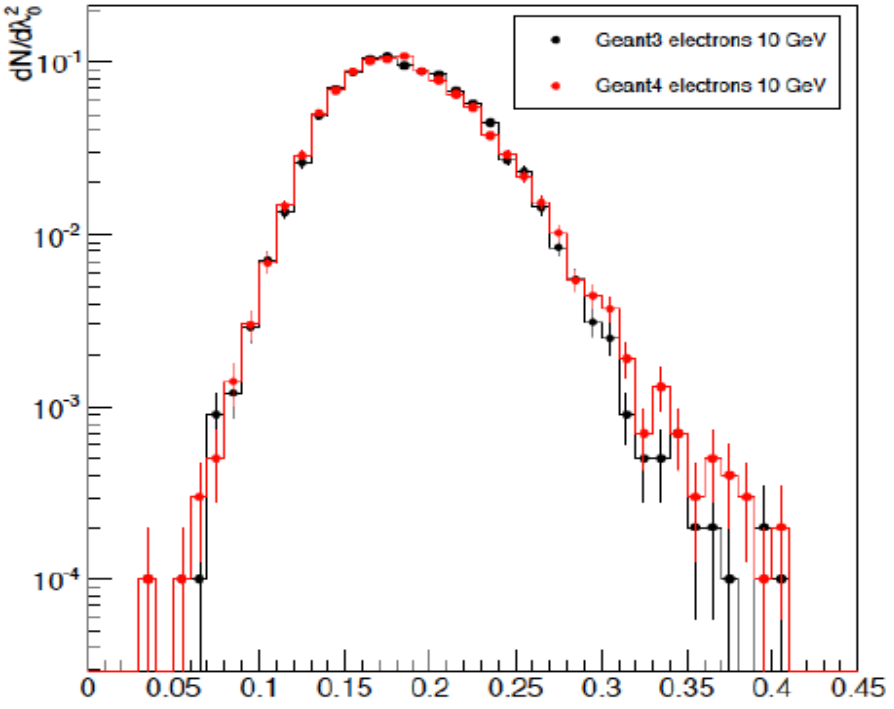


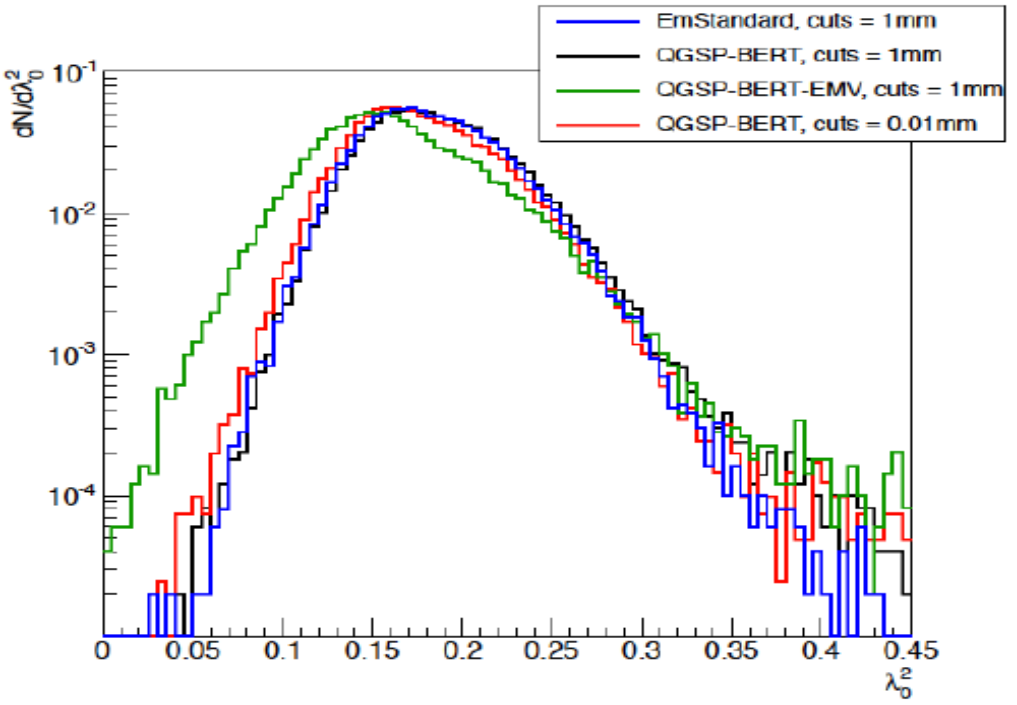
6 GeV/c e- on TRD
thickness 3.8 cm
85% Xe, 15% CO2

Test-beam data *vs.*
G4 Standard EM
G4 PAI model

EM Showers in ALICE ECAL

- The _EMV option works fine everywhere in ALICE except in the ECAL (Pb-Sci), where the standard EM is needed
  - Unfortunately, at level of G3, not better !
- To minimize the CPU overhead, ALICE uses _EMV everywhere, except in the ECAL, where the stdEM is used
  - Hack by V. Ivanchenko should no longer needed in G4 10.2





CALICE

(A. Dotti)

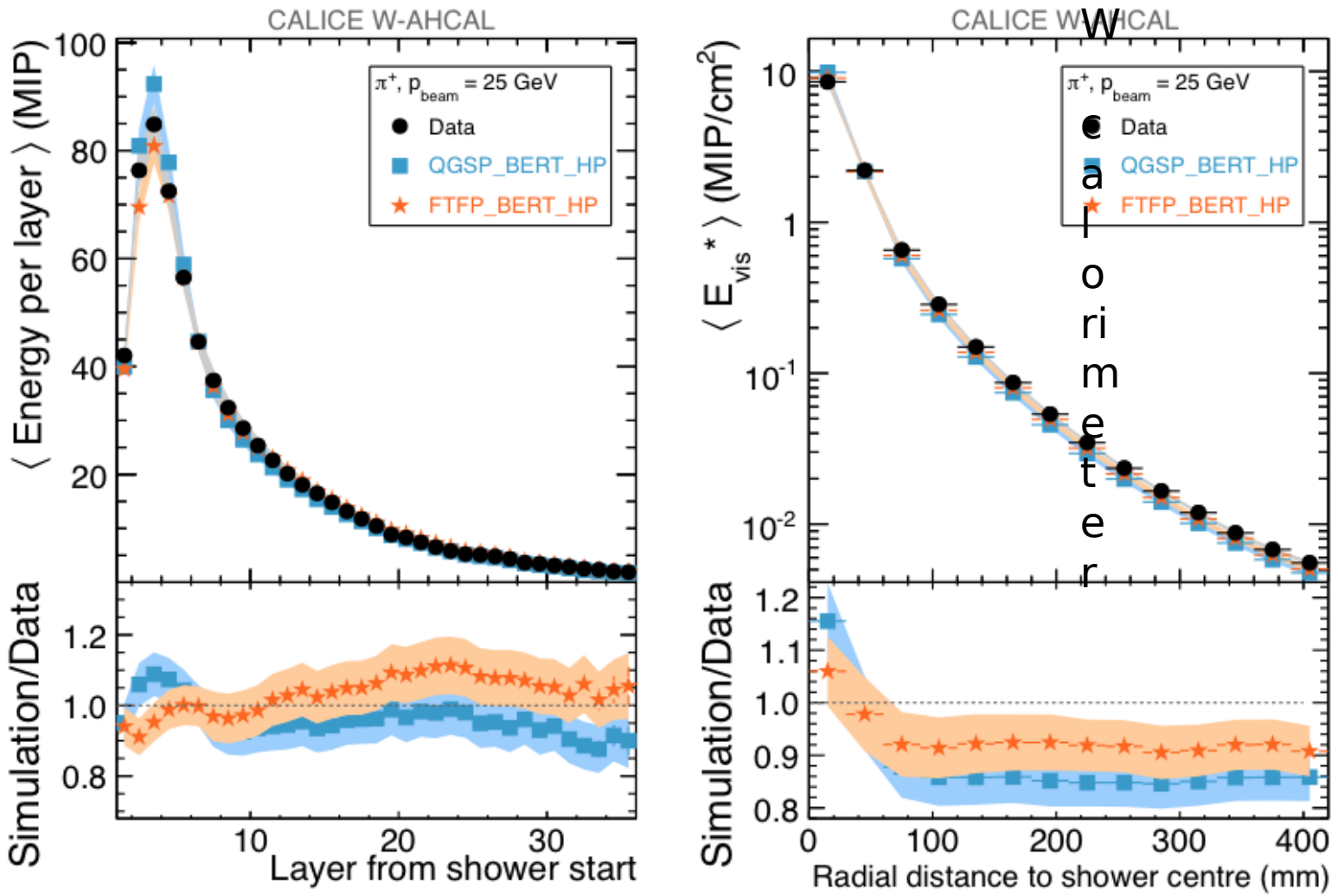
CALICE: Notes from the Collaboration Meeting

- See talk by A. Dotti at Parallel Session **7A**
- General improvement in the description of CALICE test-beam data with recent Geant4 versions
- But the recent FTF tuning in G4 10.2.beta goes in the wrong direction and is disfavored by CALICE test-beam data
- CALICE is a set of different calorimeters
  - Different materials (**Fe**, **W**) and technologies (**Si**, **Sci**, **RPC**)
- Conclusions do not always agree between CALICE setups
  - W/Sci ECAL (short, completely digitial Si active and W absorber)
  - For all other HCALs (Steel/RPC, W/Sci)

CALICE : Some Conclusions

- Indication of need for **wider** hadronic showers
  - BERT is doing in general better than FTF below 10 GeV, should we review the transition region?
- For the hadronic longitudinal shower shapes, the situation is less clear
  - ECAL SiW (< 10 GeV) indicates too short showers
  - HCAL calorimeters (> 10 GeV) indicate slightly too long showers
  - Experimental effects or two different FTF regimes?
- Response is too high close to the core of the shower : could FTF produce too many π° ?
  - Requires detailed discussion
  - Warning: effect will increase in G4 10.2, need action (!)

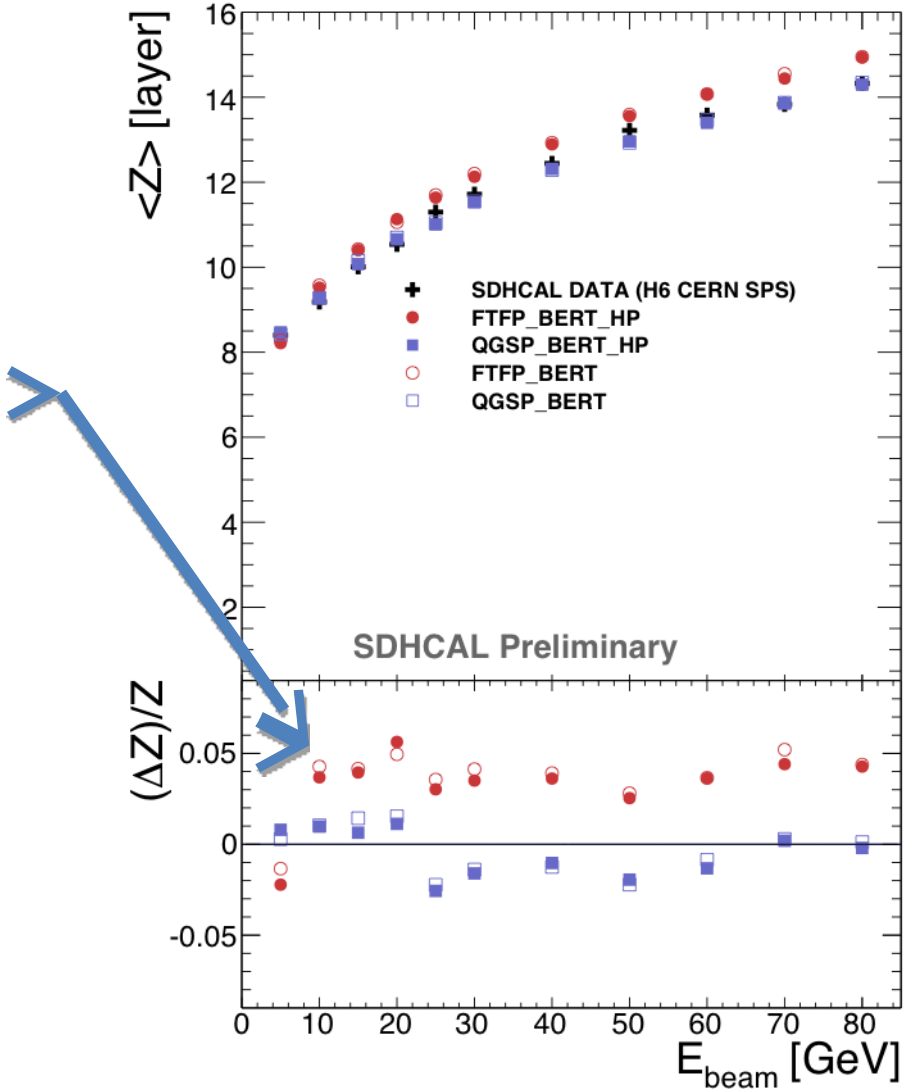
Pion shower profiles



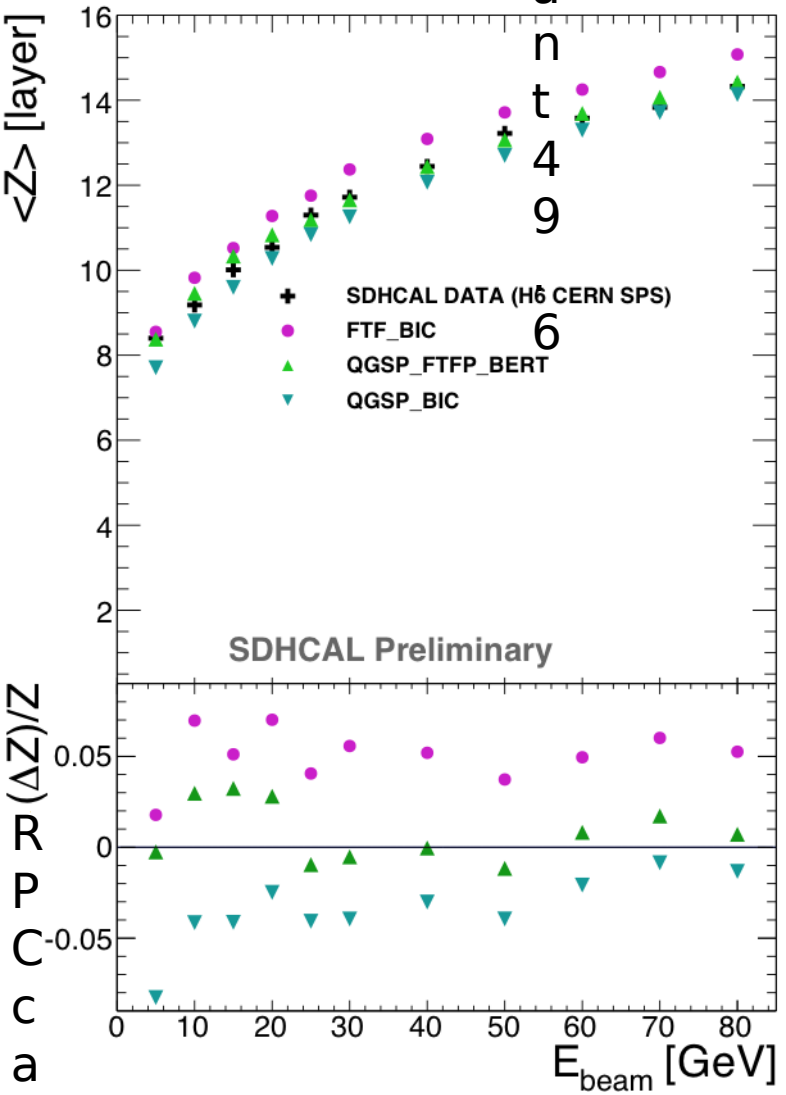
- Longitudinal profile (from shower start): QGSP_BERT_HP overestimates energy deposition in first part of shower, FTFP_BERT_HP overall slightly better
- Radial profile: Models overestimate energy density in shower core and underestimate the tails, FTFP_BERT_HP better than QGSP_BERT_HP

Hadronic longitudinal shower profile

- $< Z >= \frac{1}{N_{event}} \sum_{i=0}^{N_{event}} \sum_{k=0}^{48} k \frac{N_{k,i}}{N_{tot,i}}$

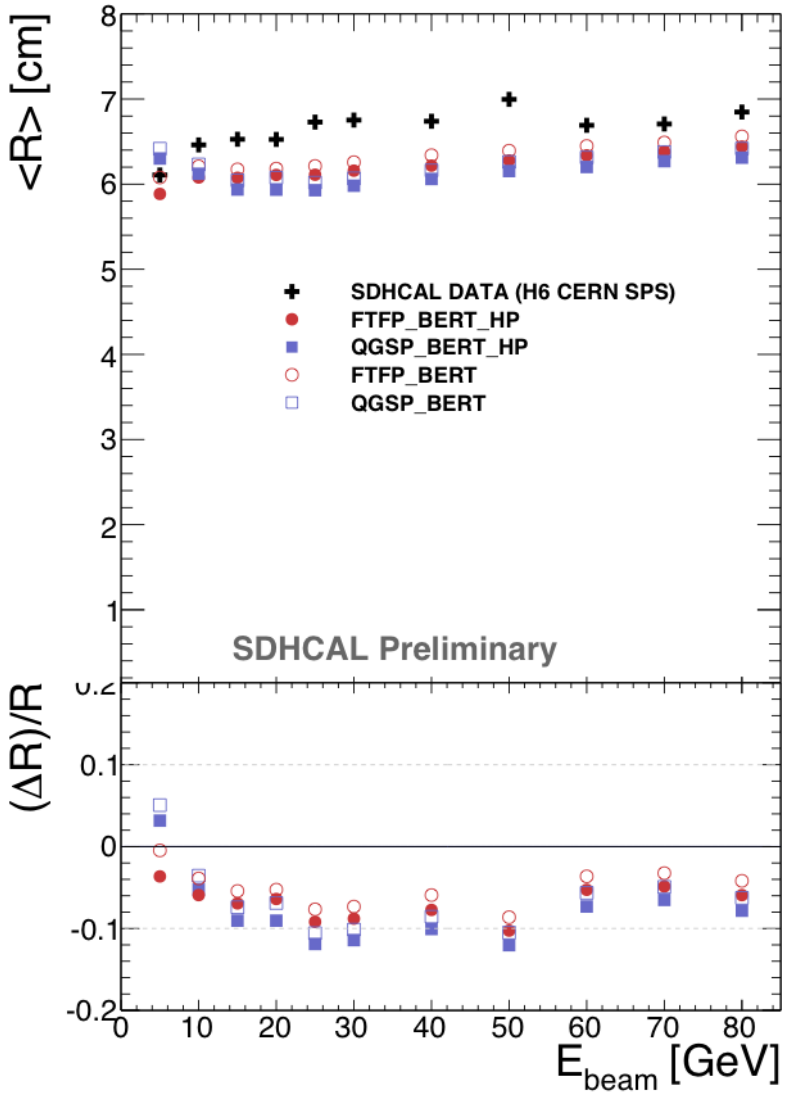


Geant4 9.6 vs RPCcal

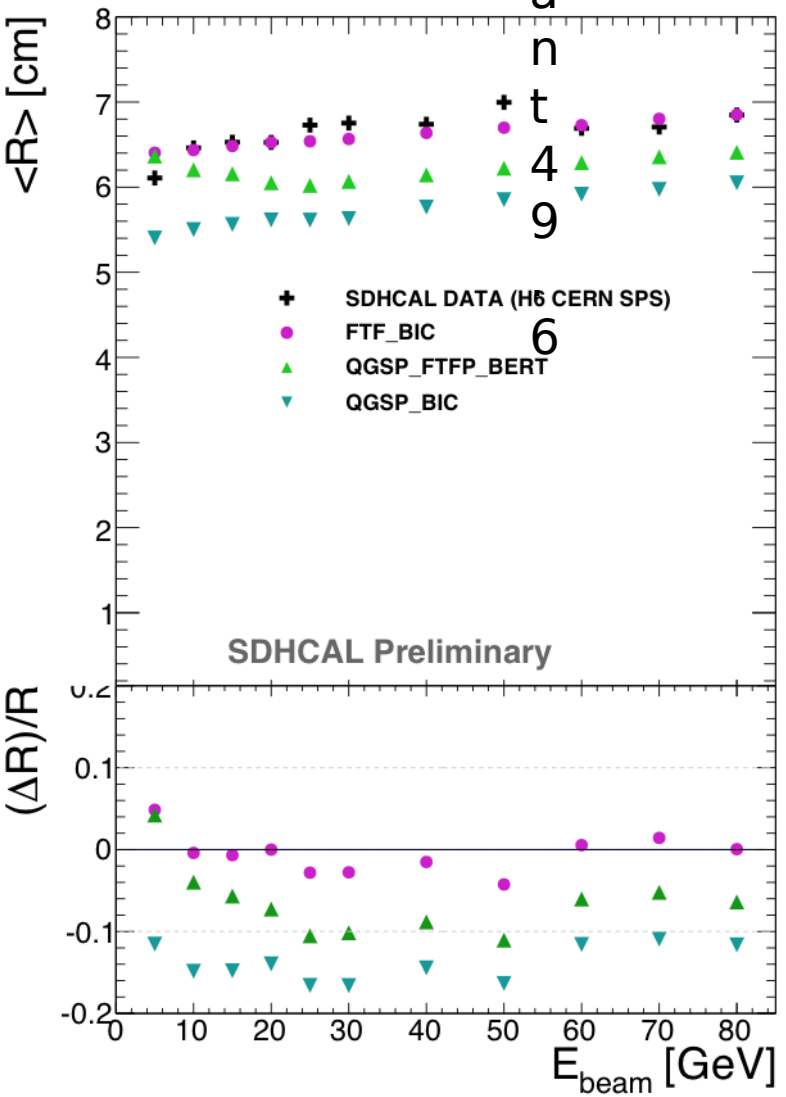


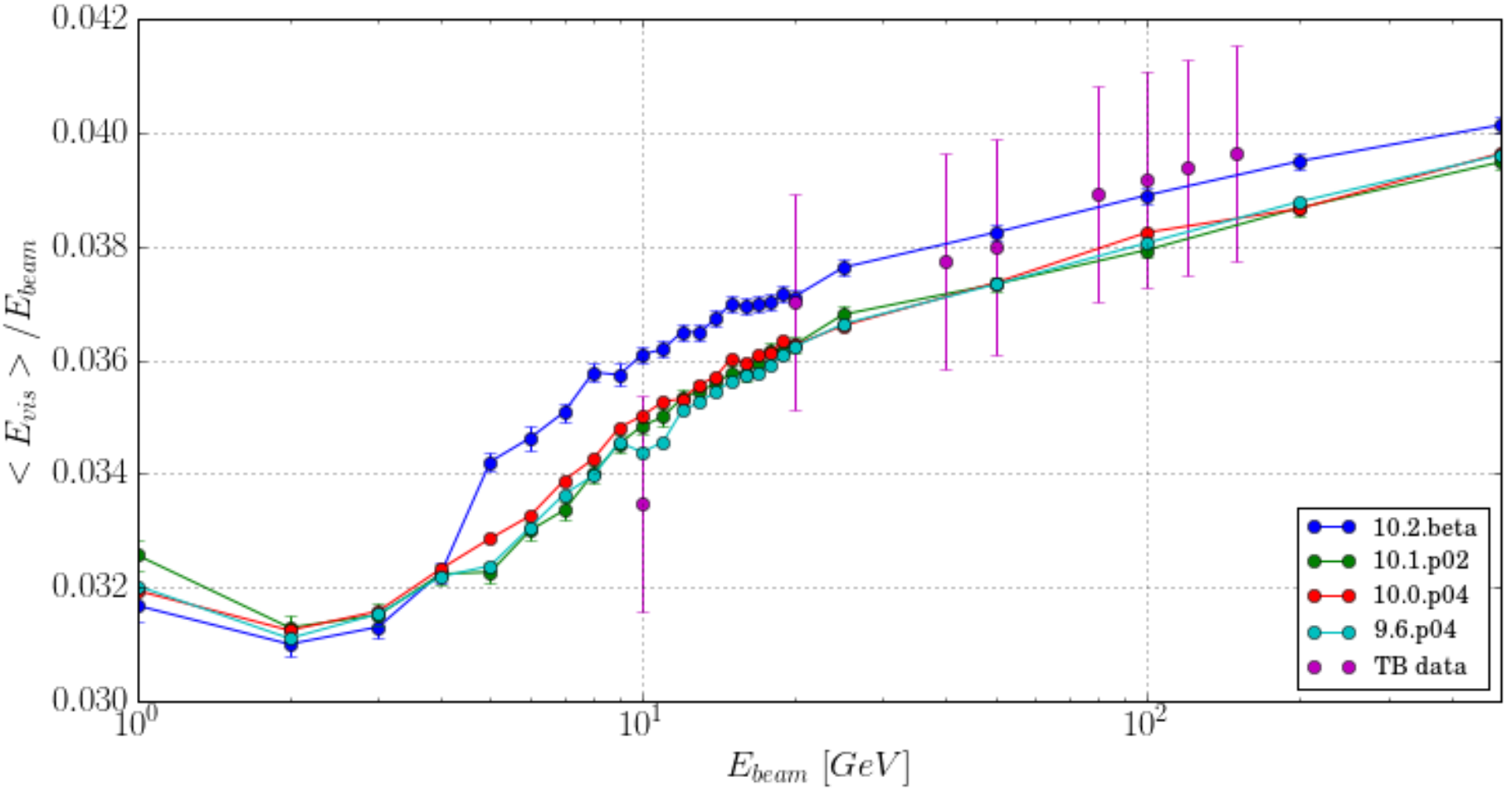
Hadronic radial shower profile

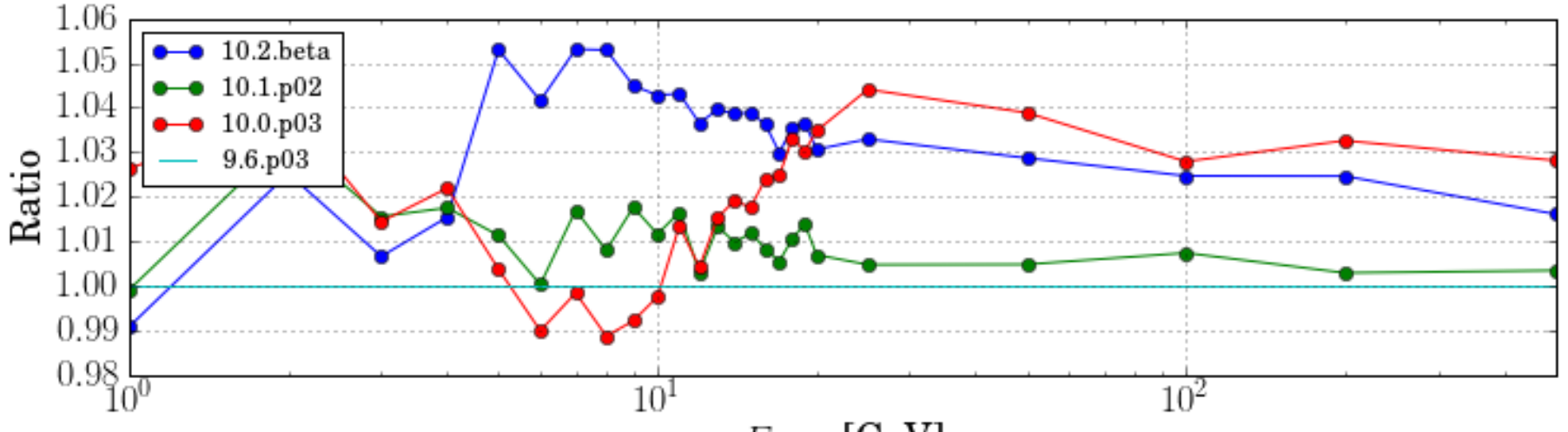
- $< R >= \sum_{i=0}^{N_{events}} \sum_{r=0}^{R_{max}} r \frac{N_{hit}(i,r)}{N_{hit}(i)}$



Geant4 9.6




0.042
0.040
0.038
0.036
0.034
0.032
0.030
$< E_{vis} > / E_{beam}$
10^0
10^1
10^2
E_{beam} $[GeV]$
10.2.beta
10.1.p02
10.0.p04
9.6.p04
TB data


1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
Ratio
10^0
10^1
10^2
10.2.beta
10.1.p02
10.0.p03
9.6.p03

Longitudinal shower profile

- During the analysis of the Si-W ECAL pion test beam data recorded at FNAL in 2008, we have observed that the longitudinal shower profile has deteriorated in G4.9.6 compared to G4.9.3
- Recently Geant4.10.1 became available for CALICE MC production (New data set thanks to Mathias Götze)
- Geant4.10.1 shows an improvement with respect to v9.6