

Geant4 requirements from High Energy Physics (HEP)

A. Ribon

CERN PH/SFT

ATLAS and Geant4



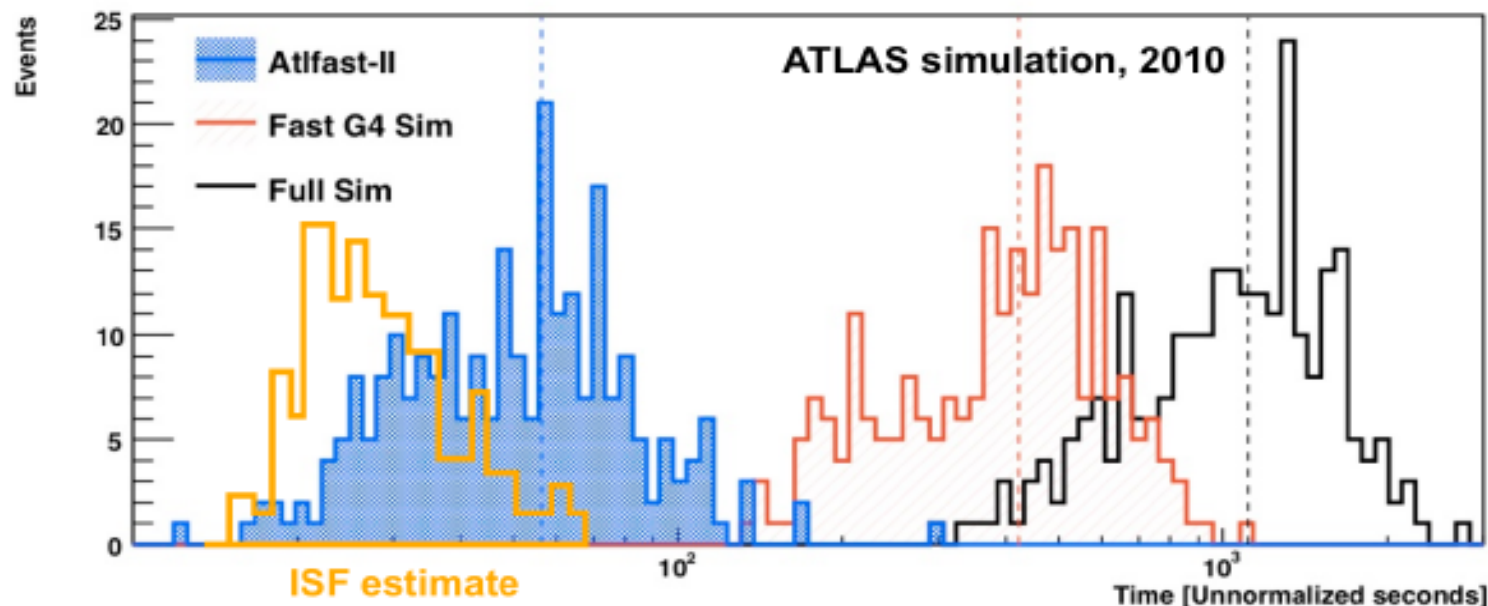
ATLAS Experience with Geant4

- ATLAS is currently using **Geant4 9.4.p04**
- very **robust performance**, crashes on the grid $O(10^{-6})$
- **good response** of Geant4 team to upcoming issues
 - improves overall stability (eg. energy non-conservation, navigation problems, ...)
- ATLAS is planning to skip Geant4 9.5 and **move to 9.6**, once released
- will use G4 hadronic interaction modules for Fatras fast simulation (ongoing)

ATLAS Points of Attention

- **shower shape** discrepancy between Geant4 and data
 - EM and hadronic G4 showers are laterally too narrow (model dependent)
- **bouncing particles** on volume boundaries
 - rate vastly reduced between G4 9.2 to G4 9.4.patch03
- **infinite loops** in G4SubtractionSolid volumes
 - seen in G4 9.4.patch01/03. 75% of instances fixed by patch back-ported from 9.6
- G4Navigator doesn't pick up that particle left volume already
 - particles end up 100m away from Interaction Point

Time for Something New



As a result of speeding up simulation

- number of ATLAS detector simulation engines increasing:
Geant4, FastCaloSim, Fatras, FrozenShowers, Parametrized Punch-Through
- partly complex and incompatible setups

The first Multi-Simulator ISF Run



Event Display Screenshot

- example simulation output generated by ISF
- one event, multiple simulators:
Fatras + Geant4 + FastCaloSim
 - Fatras: fast tracker simulation
 - FastCaloSim: parameterized calo simulation

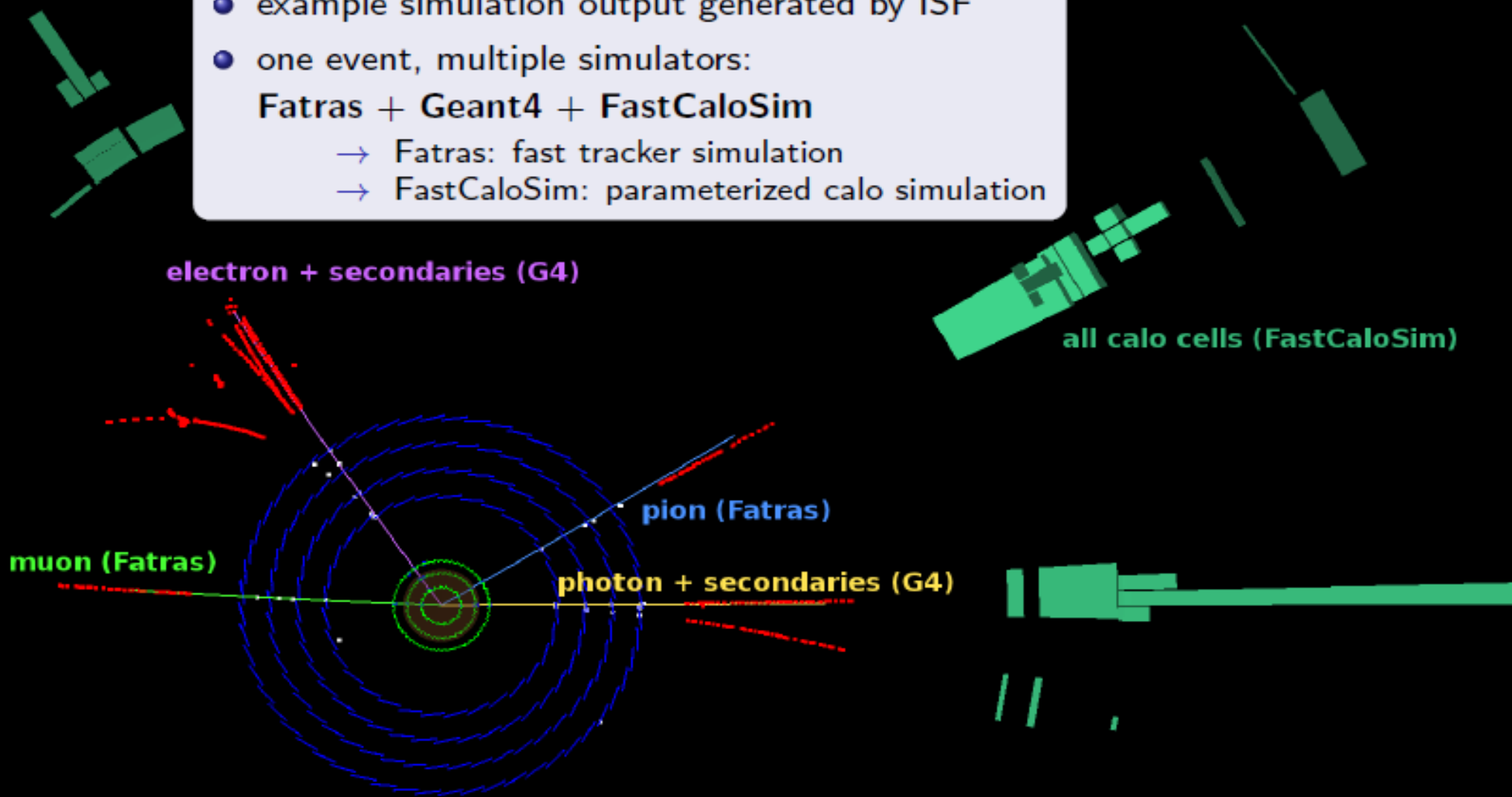
electron + secondaries (G4)

all calo cells (FastCaloSim)

muon (Fatras)

pion (Fatras)

photon + secondaries (G4)



ISF Implications on Geant4



ISF and Geant4

- ISF will become *the* future ATLAS simulation framework
 - Geant4 is one of many possible simulation engines within the ISF framework
 - shared SD hit collections, common sub-detector boundary definitions
 - ATLAS Event is now subdivided into multiple G4Events
 - new G4Event for each particle sent from ISF to Geant4
 - needed because G4 may not be the only simulation engine and it simplifies tracking of MC truth information
 - **request refinement** that enables G4SensitiveDetector NOT to finalize a HitsCollection at end of every G4Event
 - ongoing work for Geant4MT implementation within ISF
 - main objective: get it working in ATLAS framework
 - **sub-event level** parallelism with respect to ATLAS events
 - **event level** parallelism in a G4Event perspective
 - speedup studies to compare serial vs parallelized (eg: comparing against Geant4 alternative particle stacking approaches)
 - enable experiment parallel Run Manager to inherit from or use parts of G4MTParRunManager
- session on *Parallelization Efforts* this afternoon

ATLAS (6/8)

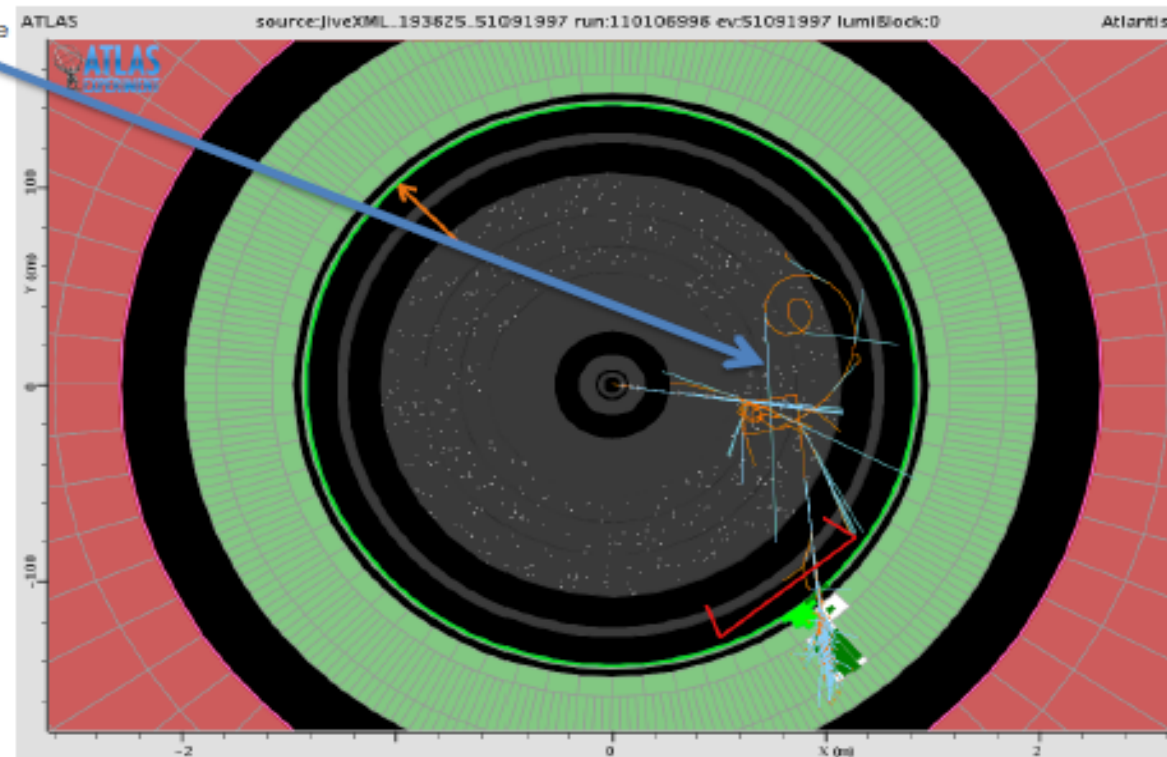
Physics Performance Status

- Now running “MC12”, the MC campaign for 2012 data analyses
- Similar situation to what we reported at the LPCC workshop last year:
 - <https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=144956>
- In MC12, using G4 9.4 with QGSP_BERT. May transition to G4 9.6 and FTFP_BERT for MC13.
- Continue to see the (long-standing) hadronic shower issues of too-good resolution and too-narrow showers (possibly related issues)
 - It is becoming very difficult, with the current pile-up situation, to disentangle simulation effects from generator effects.
- Cavern background simulation in G4 still progressing, though slowly
 - Currently some remaining discrepancies, but some geometry issues outstanding
 - No open geometry issues affect “standard” physics results (i.e. they affect forward shielding that changes ~only cavern background results)
 - Expect an update later this year, possibly including tests of the new neutron physics libraries

ATLAS (7/8)

EM Showers

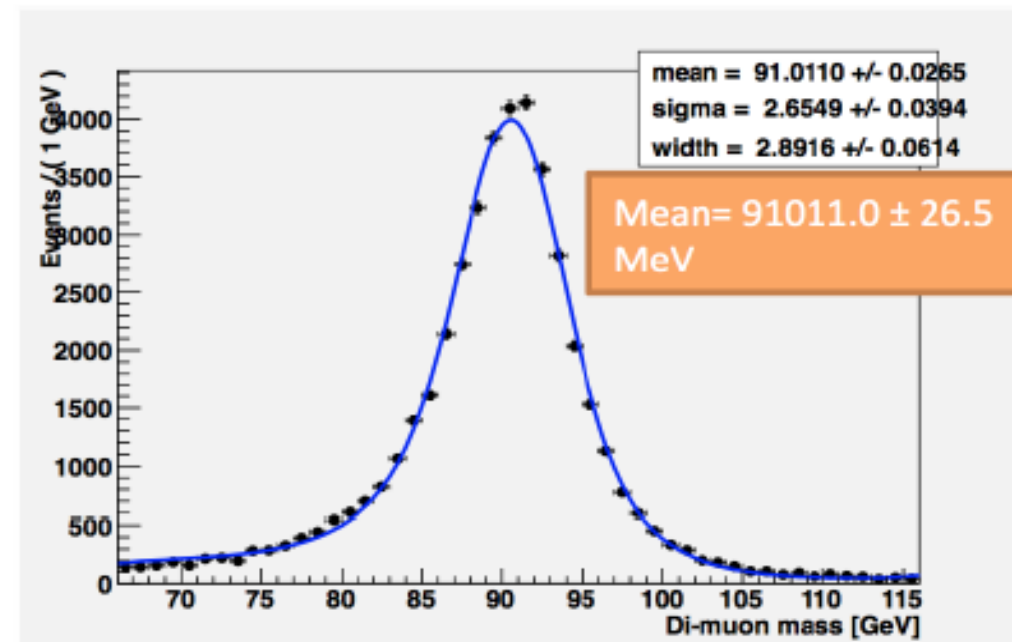
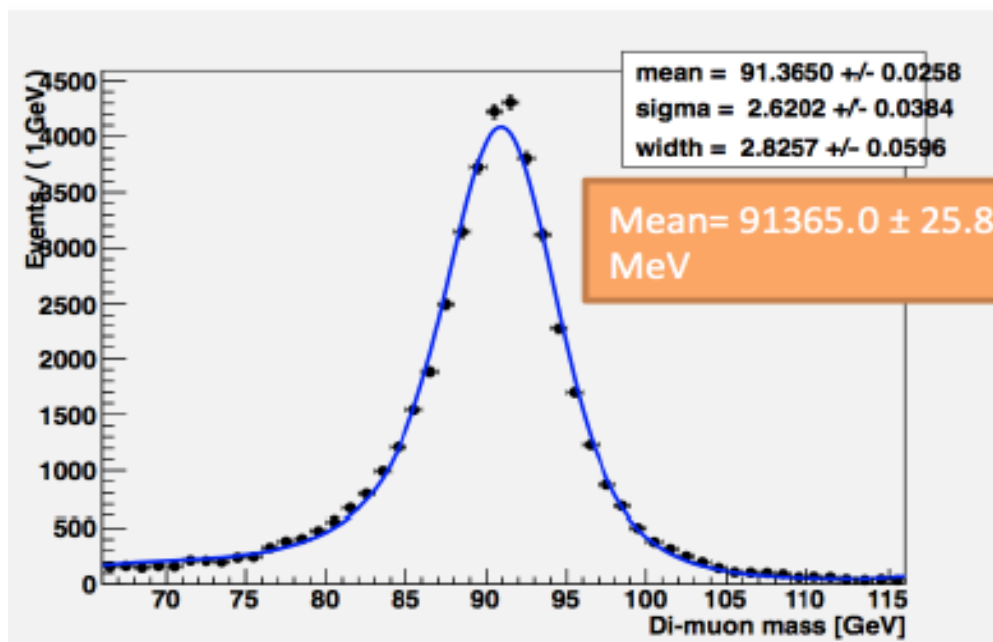
- We continue to see too-narrow EM showers
 - Reported a bug in EM multiple scattering earlier this year, where electrons were sharply kinking when taking small steps.
 - Bug much more common in certain setups that cause very small steps
 - Bugfix now in the system, unclear impact on EM shower shapes at the moment
 - Bugfix also seems to have resulted in a reduction in the number of very small steps, which has wide-ranging effects on number of hits, potentially sim time, etc.



ATLAS (8/8)

Muon Multiple Scattering

- Bugfix in muon multiple scattering earlier this year
 - Bug caused a shift in muon momentum scale when using `WentzelVI+Coulomb` scattering; solved by reverting to “old” G4 9.2 multiple scattering model
 - Still validating the move back to `Wentzel`
- Left: G4 9.4 default; right: G4 9.4 with `Urban93 MSC` model
 - 350 MeV shift in Z -mass peak



CMS (1/4)



Status of Monte Carlo Production for CMS

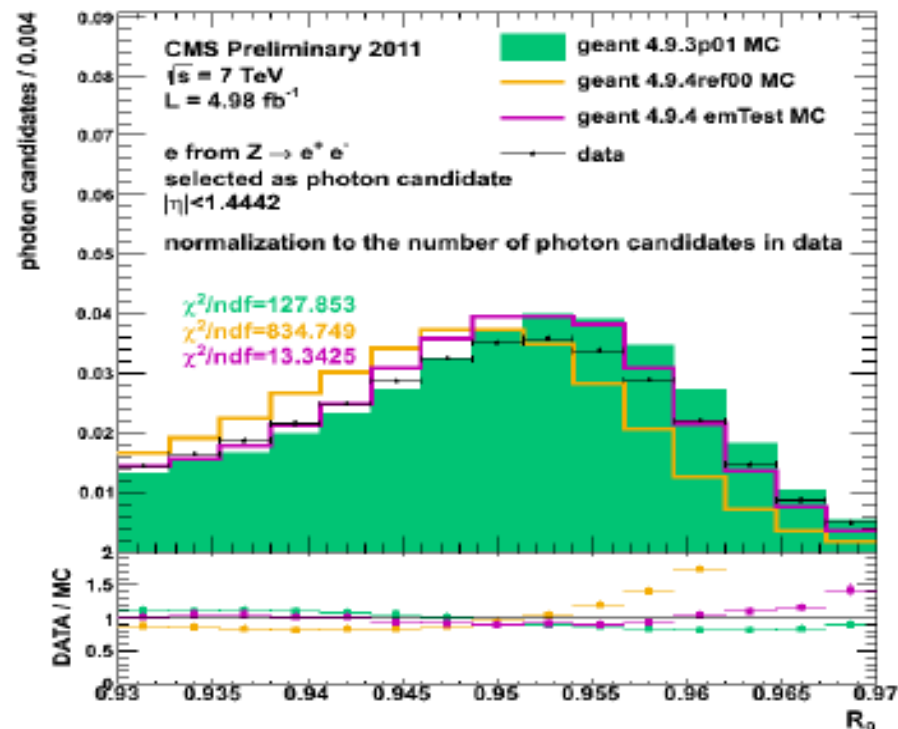
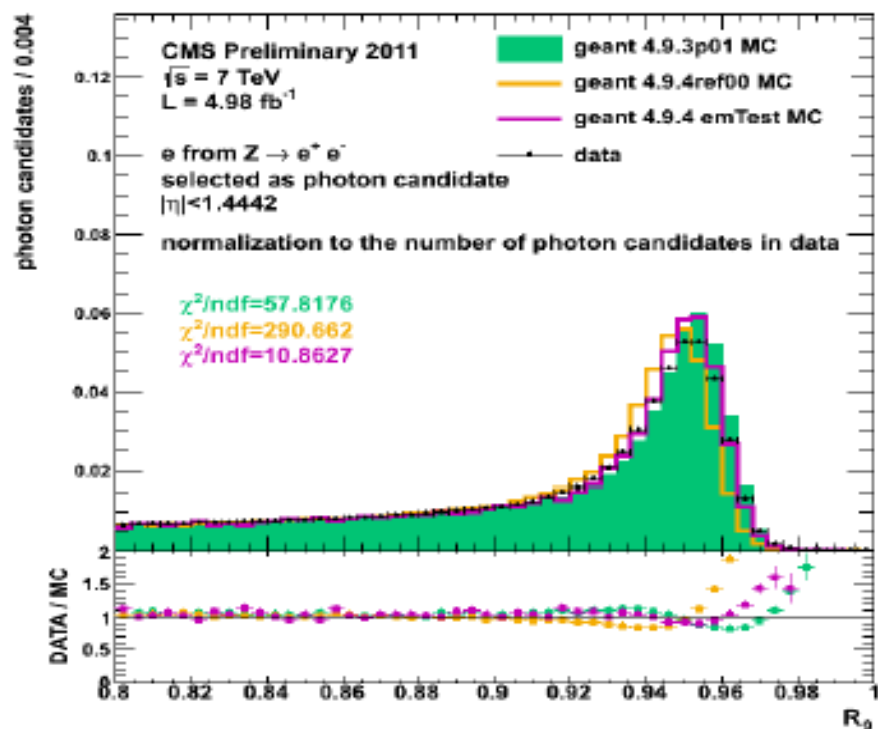
- 2011:
 - 7 TeV Monte Carlo production $3.5 \cdot 10^9$ events
 - Geant4 9.4 (+ few fixes)
 - Slc5_amd64_gcc434
- 2012 :
 - 8 TeV Monte Carlo production
 - $3.5 \cdot 10^9$ events requested, majority are already produced
 - Started with Geant4 9.4p03 + slc5_amd64_gcc434
 - Continues with slc5_amd64_gcc462 and CHIPS stopping fix
 - Main concern – EM shower shape in ECAL

CMS (2/4)



Distributions of R_9 in ECAL EB for $Z \rightarrow e^+e^-$ data and MC with three different G4 builds

O. Bondu, H. Brun, L. Sgandurra, S. Gascon-Shotkin, M. Lethuillier, IPN Lyon
J. Tao, H. Xiao, G. Chen, J. Fan, IHEP Beijing



Right-hand plot is zoom of peak region of left-hand plot

Points: $Z \rightarrow e^+e^-$ Data, $\text{Int}(L dt) = 4.98 \text{ fb}^{-1}$

Histograms: Green solid: $Z \rightarrow e^+e^-$ MC, Spring11, GEANT4.9.3p01

Orange open: $Z \rightarrow e^+e^-$ MC, Summer11, GEANT4.9.4ref00

Magenta open: $Z \rightarrow e^+e^-$ MC, High-statistics ReVal, CMSSW_5_0_0,

Seltzer-Berger bremsstrahlung model from GEANT4.9.5

No pileup in MC

CMS (3/4)



Status of CMS Monte Carlo

- **Geant4 9.5p01 have been approved for the current development version of CMSSW**
 - CLHEP 2.1.0.0
 - Geant4 9.5p01 + CMS private patch
 - G4NDL4.0-CMS
- **CMS private patch include modifications of Geant4 included in 9.6beta:**
 - Fix of CPU penalty in GHEISHA cross section (G4HadronCrossSection) and G4HadronicProcess class
 - Fix of time and weight for recoil nucleus in hadron elastic in the class G4WHadronElasticProcess
- **G4NDL4.0-CMS prepared privately by removal of thermal neutron data (1.4 GB -> 1.0 GB)**
- **CMS uses QGSP_FTFP_BERT_EML custom Physics List**
 - Multiple scattering for e+- Urban93
 - to keep HCAL response unchanged
 - Multiple scattering for muons Urban90
 - WentzelVI was not validated yet

CMS (4/4)



CMS Requirements

- **CMS requirement for 2012:**
 - Provide 9.5patch02 before mid October
 - include CMS private fixes
 - Needed fix of weight propagation to secondary particles
 - Desired official version of G4NDL for LHC
 - Needed possible fix of CPU penalty in hadronics cross sections
 - Both for 9.5p02 and 9.6
 - Geant4 9.6 should have compatible or better CPU performance and memory usage as 9.4
 - It is desired that in Geant4 9.6 one of reference Physics Lists is identical to CMS production Physics List
- **CMS requirements for 2013**
 - Geant4 MT to be compatible with CMS solution (TTB) – will be discussed at the next plenary and today parallel sessions

LHCb (1/3)



Sep 2012

Nigel Watson 1



Current Status

- Current MC in production
 - 9.4 vintage and tuning as in 2011 (still LHEP for hadronic PL)
 - Updated detector geometry and response for 2012
- Main productions for 2012/11 data to start Jan. 2013
 - Use G4 9.5.patch01, full scale validation tests starting ~now
 - Capacity for 150M events/month
- Disk space increasingly important issue for MC (and data)



Issues/Requirements

- Impact Parameter resolution has been a substantial issue for LHCb
- G4 developers provided us with EM builder using private EM PL to solve multiple scattering problems
 - `EmStandardPhysics_option1LHCb`, `WentzelVI` model for all species
- Did not improve IP resolution description of data
 - Underlies our decision to remain with `EmStandardPhysics_option1`
 - Discrepancy appears related to very complicated VELO RF foil geometry
 - Significant progress made using CAD imports/GDML
 - Will have conclusion of studies with improved material distribution in near future
 - Additional side-effects of using this EM PL seen in trackers, may be due to an inconsistent dE/dx treatment (by us)
- Modelling of cross-section and final states of hadronic interactions in thin layers important for LHCb physics
 - Kaons and Lambdas, and particle/antiparticle
- Can these be included in release regression tests
- Can changes to models which lead to significant changes be highlighted in release notes (or in models with revised names, or both)?

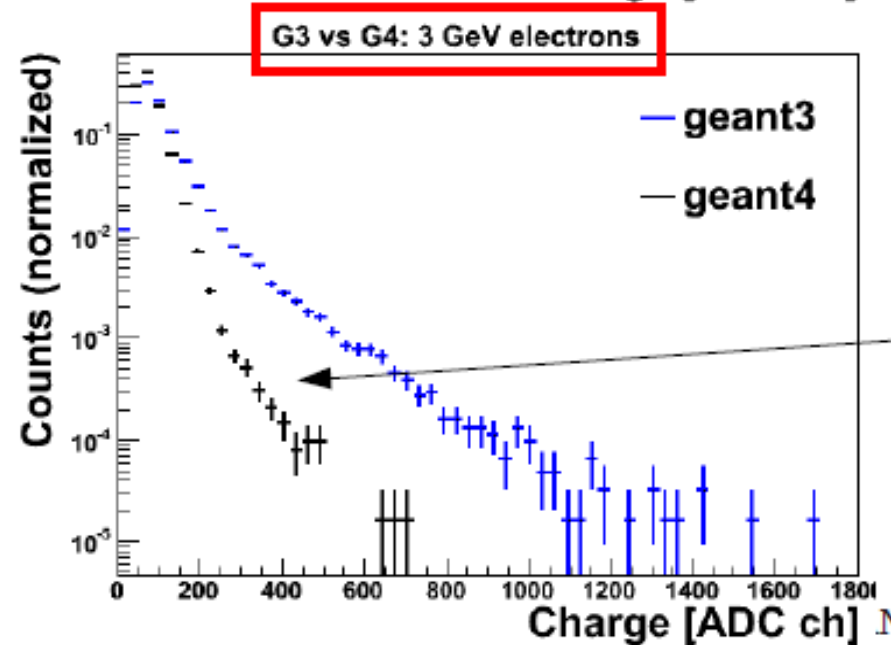
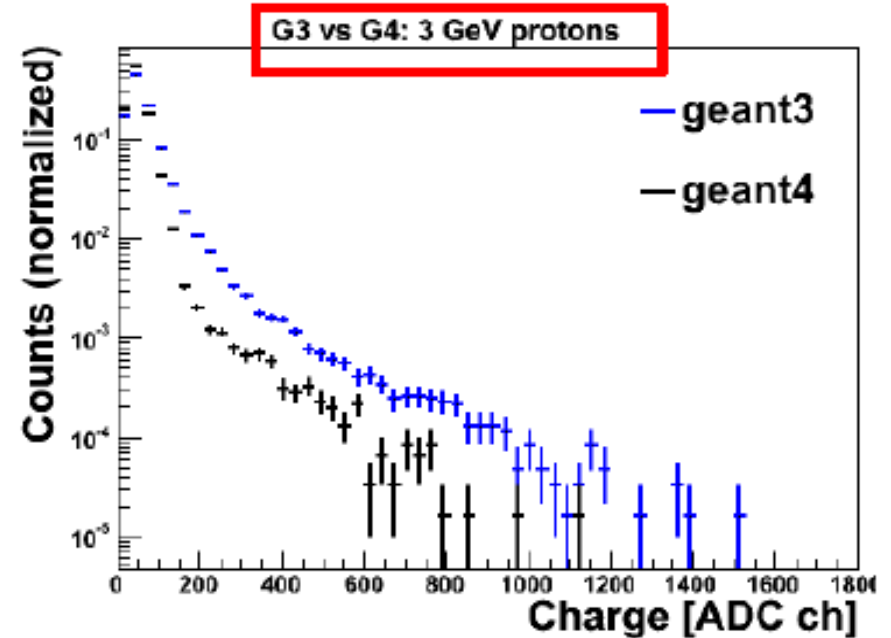


Plans

- During validation phase for next couple of months, prior to production start Jan. 2013
- Revisit EM physics model tests
 - Using improved VELO RF shield geometry
 - Consistent dE/dx
- LHEP obsolete and modelling of kaons important to us, so will investigate e.g. QGSP_BERT_CHIPS, FTFP_BERT
- Will resume multiplicity/cross-section tests
 - Aim to get optimised multiplicity response vs. cpu cost
- Results from technical comparisons of LHEP vs. newer/supported lists, choice for production

- Main concern of ALICE simulation with G4 is the **TPC response**
- G3 uses a special ALICE/NA49 model which describes well the test-beam data
- G4 has smaller fluctuations (tails) hence dE/dx resolution is too good
- Investigations are undergoing to understand the problem

GEANT3 and GEANT4 simulation



CALICE (1/4)

Study of shower decomposition

We want to decompose the shower in EM, charged hadron and neutron components.

Our definition of the neutron component:

1) Neutron capture:

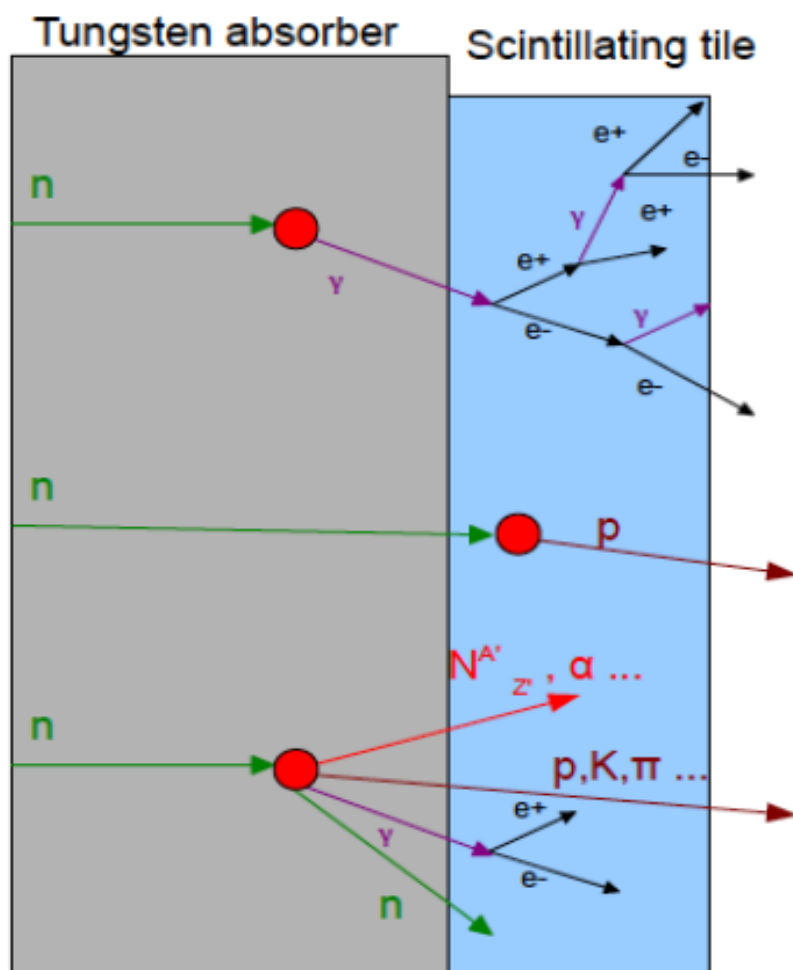
late nuclear de-excitation ($t_n \gg t_{EM}$)
gamma emission and pair production (also background to fEM)

2) Neutron elastic scattering with H nucleus proton emission

3) Neutron inelastic scattering with a nucleus

nuclear fragments, alpha particles ...
more gamma emission and delta electrons
protons, kaons, pions ... more neutrons

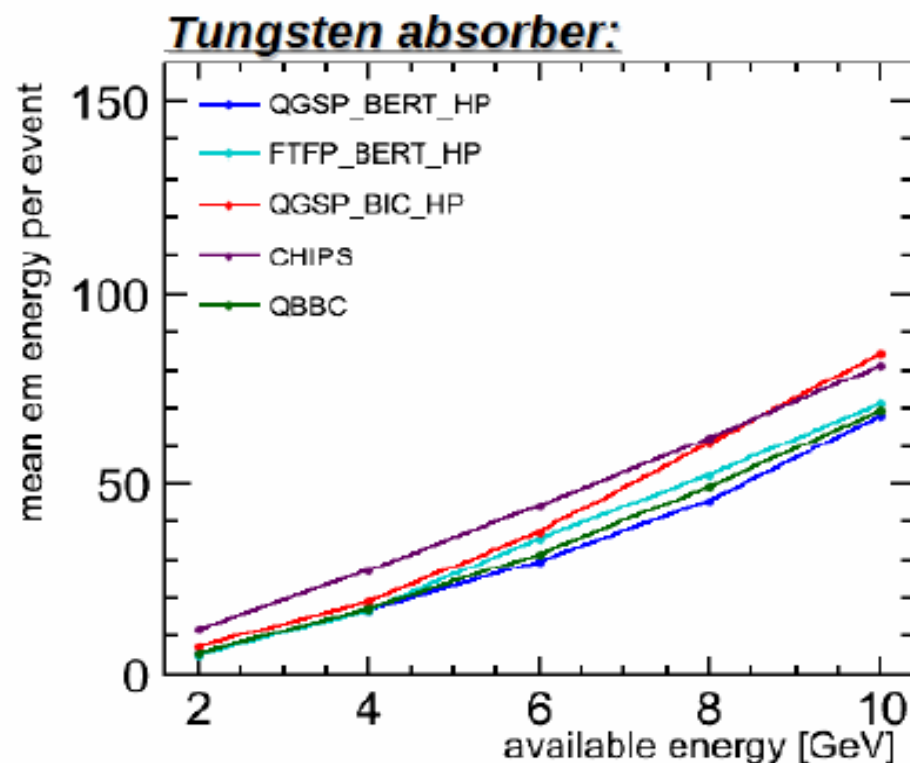
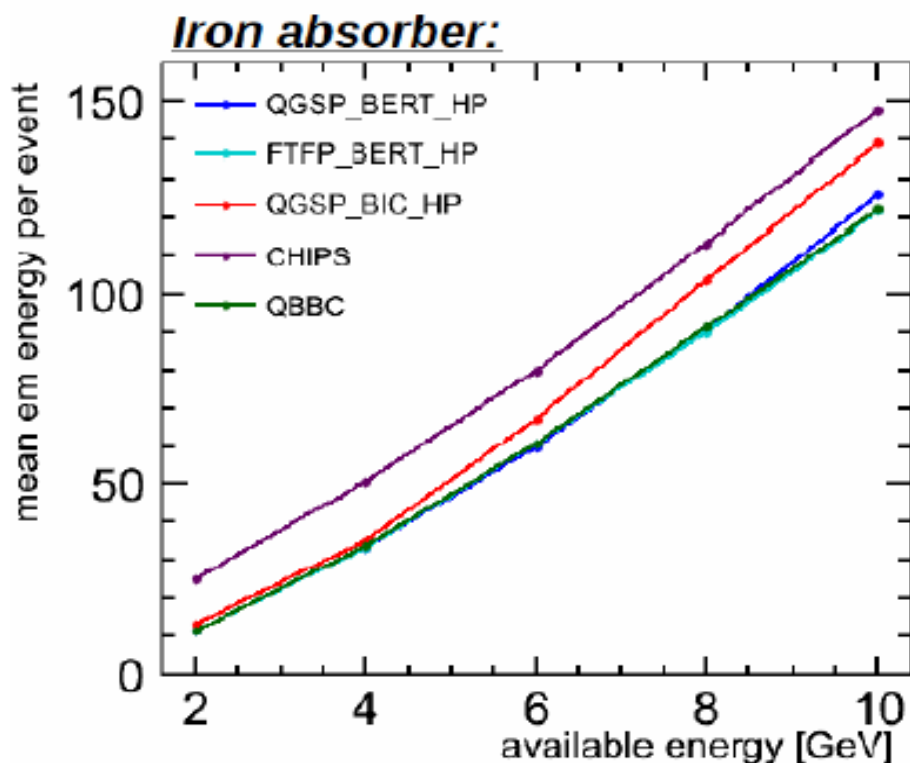
Would it be possible to provide a unique G4 tag for EM, neutron, charge hadron fraction of energy?



CALICE (2/4)

Study of shower decomposition

Electromagnetic component in the visible energy in 30 layers of AHCAL scintillator with two different absorbers

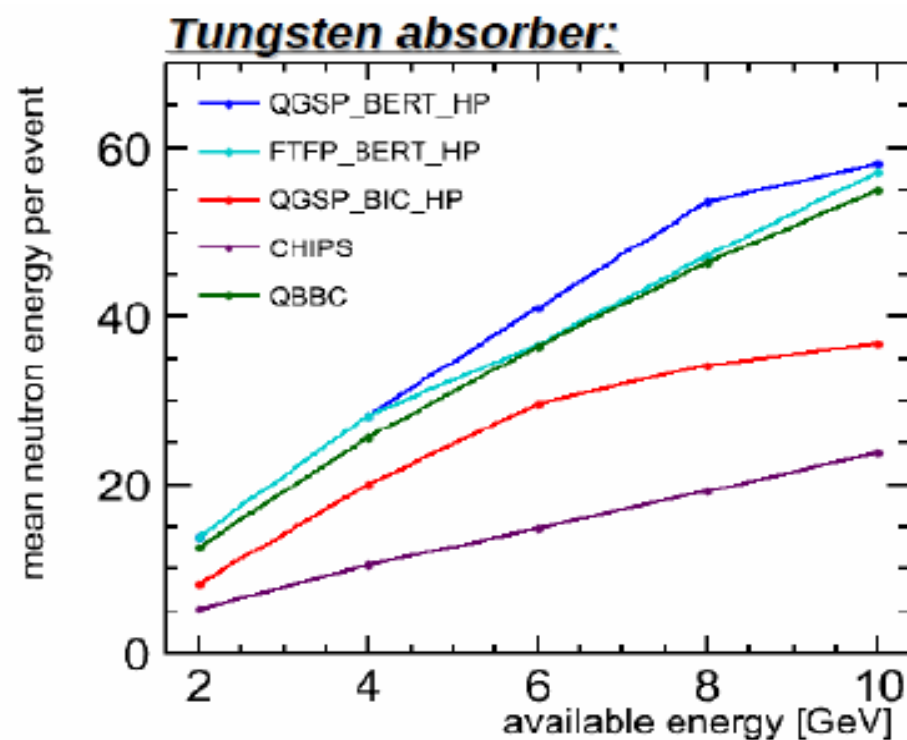
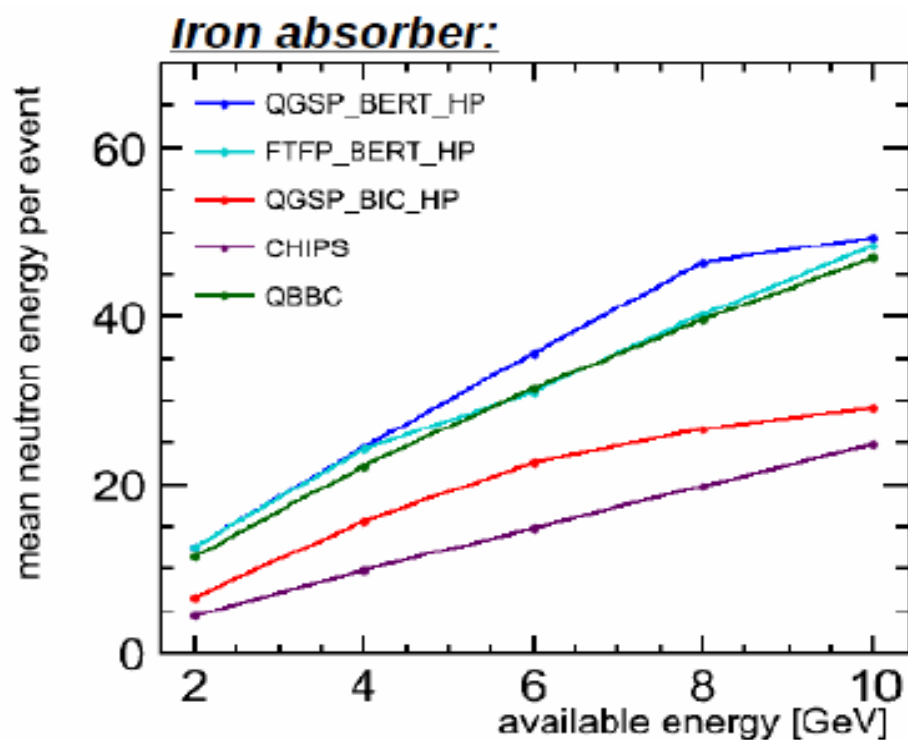


CALICE data will be first presented at the Cambridge collaboration meeting

CALICE (3/4)

Study of shower decomposition

Neutron component in the visible energy in 30 layers of AHCAL scintillator with two different absorbers



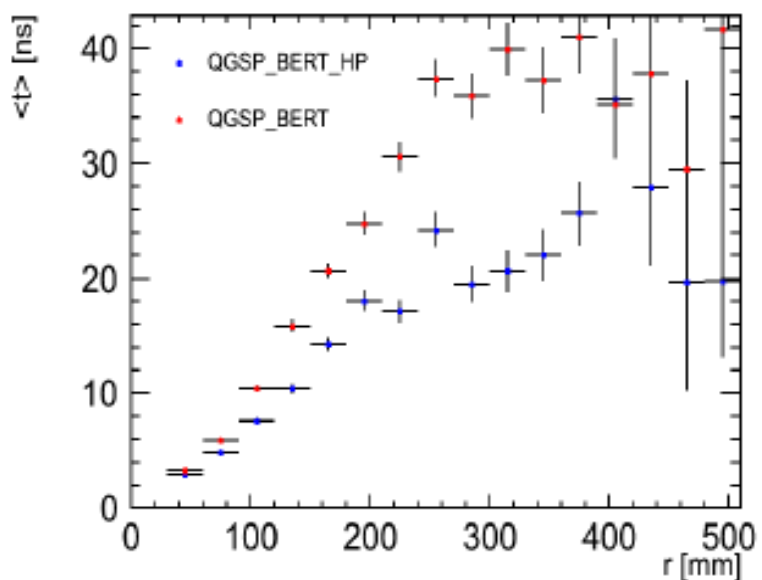
- Relatively small difference between Fe and W showers → is this expected?
- Factor 2 difference between models → why?

CALICE (4/4)

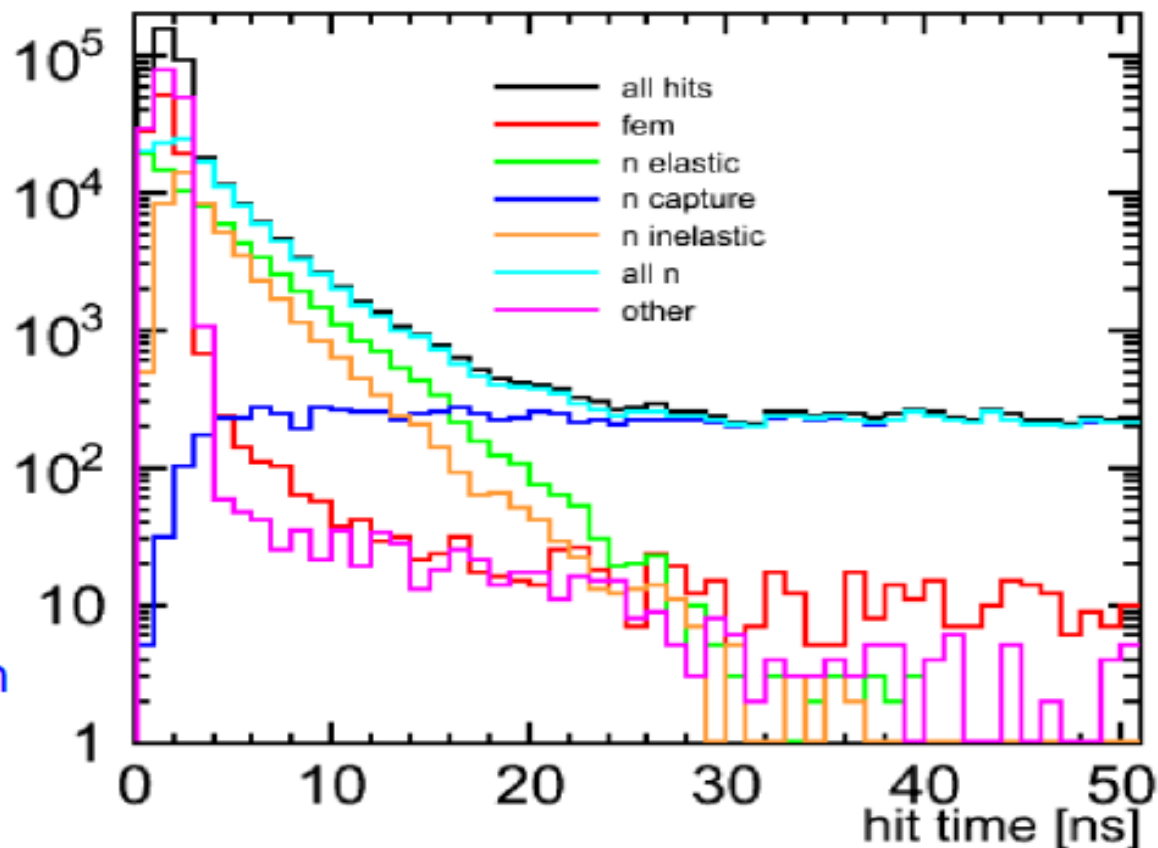
Timing structure of hadronic showers

Next generation of analog hadronic calorimeter provide time stamp capability ($\sim 1\text{ns}$) \rightarrow validate the late tail in hadronic showers development

Radial distribution of the average hit time after 4 lambda W



G4.9.4 QGSP_BERT_HP + Mokka + AHCAL digi



- Can we get a detailed description of the timing of the physics implemented in G4 (docu?)
- Other existing validation studies?

Thanks

Z. Marshall, E. Ritsch, A. Schaelicke, R. Harrington,
P. Clark, D. Froidevaux (ATLAS)

M. Hildreth , V. Ivanchenko (CMS)

N. Watson (LHCb)

P. Christiansen, A. Morsch (ALICE)

E. Garutti, C. Guenter, M. Ramilli, F. Sefkow (CALICE)