



Simulation Effort in CMS

Outline

- Introduction
- CMS Test Beam Data
- Early Tuning
- Recent progress
- Summary



Simulation in CMS

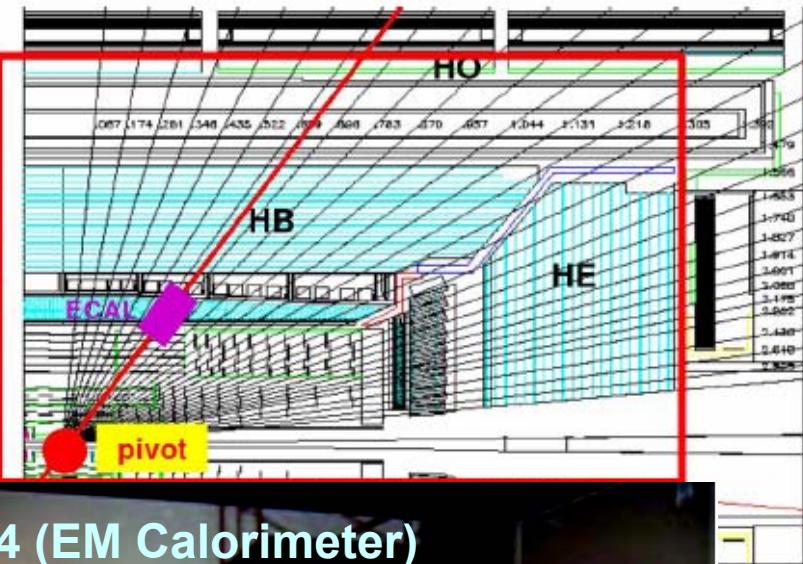


- CMS plans to use 3 complementary approaches for simulation:
 - Start from first principles (**Full Simulation**)
 - Replace the calorimeter simulation inside **FullSim** by a set of parameterizations
 - Use a fast parameterization (**Fast Simulation**)
- In all these approaches, the quality of simulation is dictated by its agreement with data
- The current implementations are tuned to **test beam data**.
- Emphasis is given to response of electrons, photons as well as of hadrons.
- Noise simulation is validated with Cosmic data (**CRAFT**)

CMS Test Beam Efforts



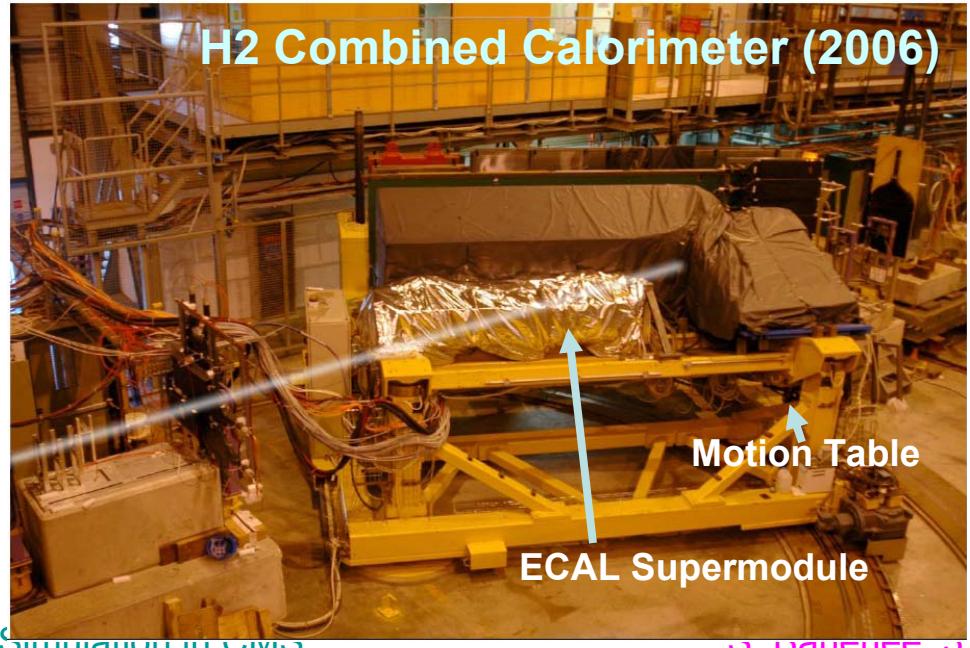
CMS



H4 (EM Calorimeter)



H2 Combined Calorimeter (2004)



Motion Table

ECAL Supermodule



Measurements & Comparison

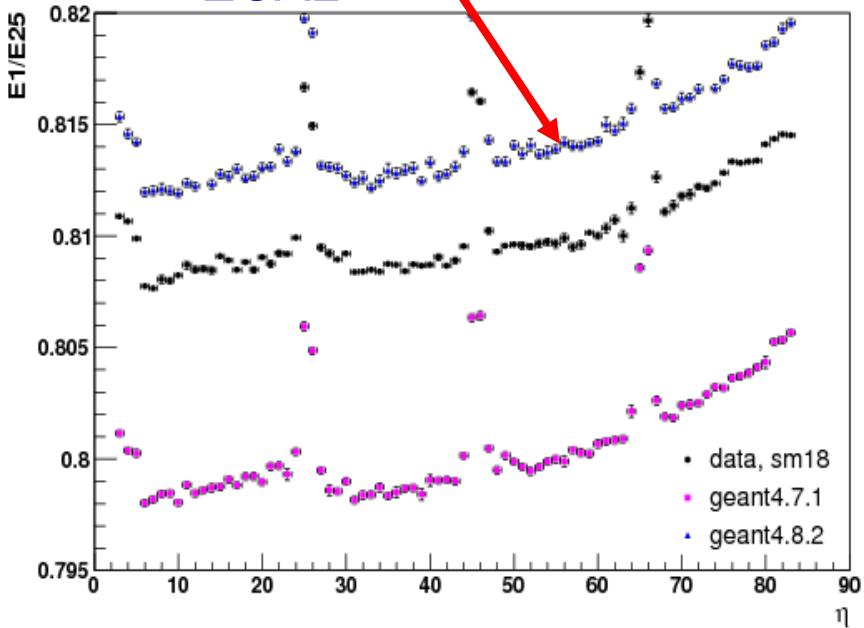


- Use **electron** beams at different energies in H4 test beam area to ECAL super-modules
 - Measure energy response, energy resolution, lateral shower profile, energy containment and leakage
- Use **electron**, **muon** and **hadron** beams at different energies in H2 test beam area to a combined calorimeter system
 - Measure energy response, energy resolution, shower shapes, energy sharing between ECAL and HCAL
- Both setups use modules on a motion table to mimic incidence at different angles
- Use sophisticated beam line detectors to **monitor beam qualities**, to carry out **offline particle ID** and to measure the beam profiles.
- For matching simulation to data, the test beam setup is described in detail and use the **Standard Simulation** code for all three applications.

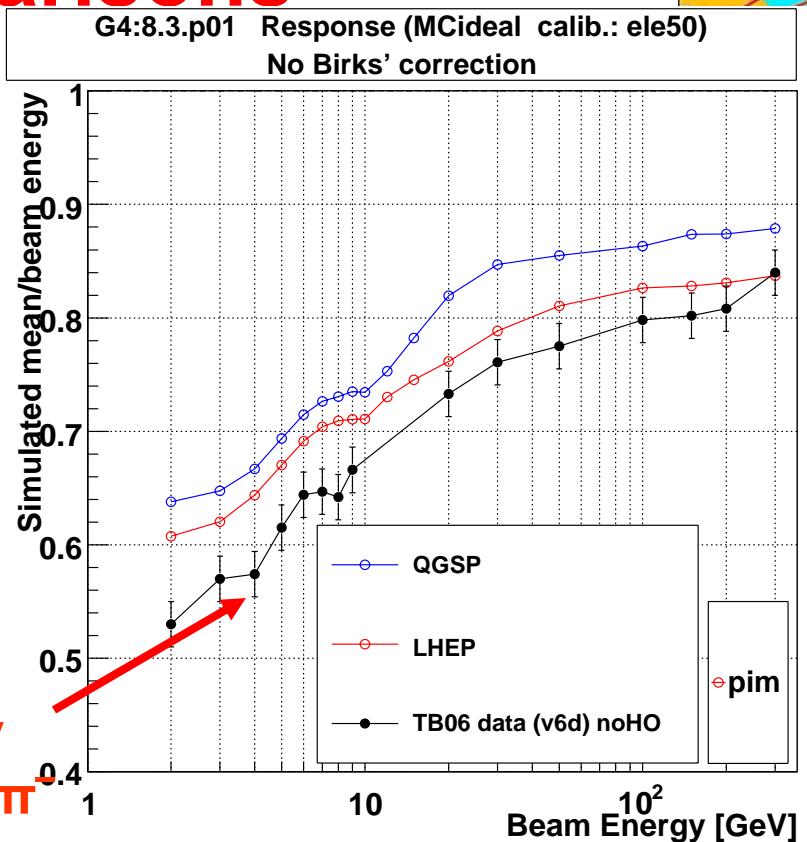


Lateral shower
profile of e^- in
ECAL

First Comparisons



Mean energy
response of π

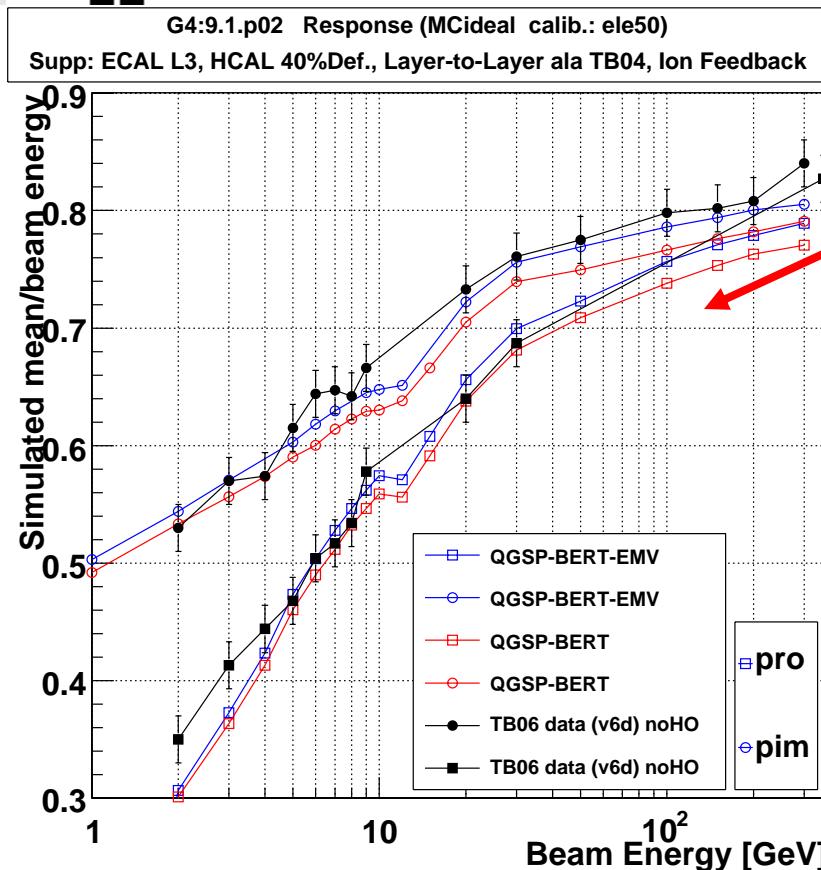


- EM showers are well reproduced in Monte Carlo
- Hadron showers are not well explained

→ Tune Birk's law and change in Physics List

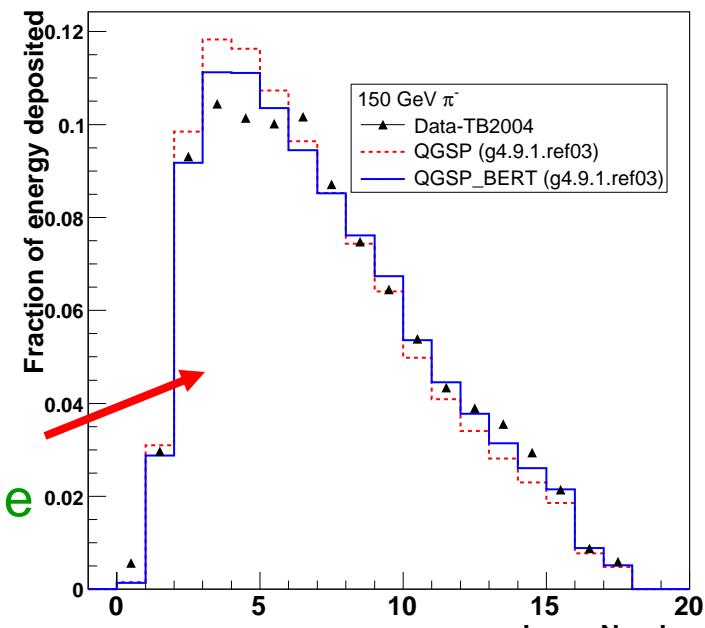


Results of the Tuning

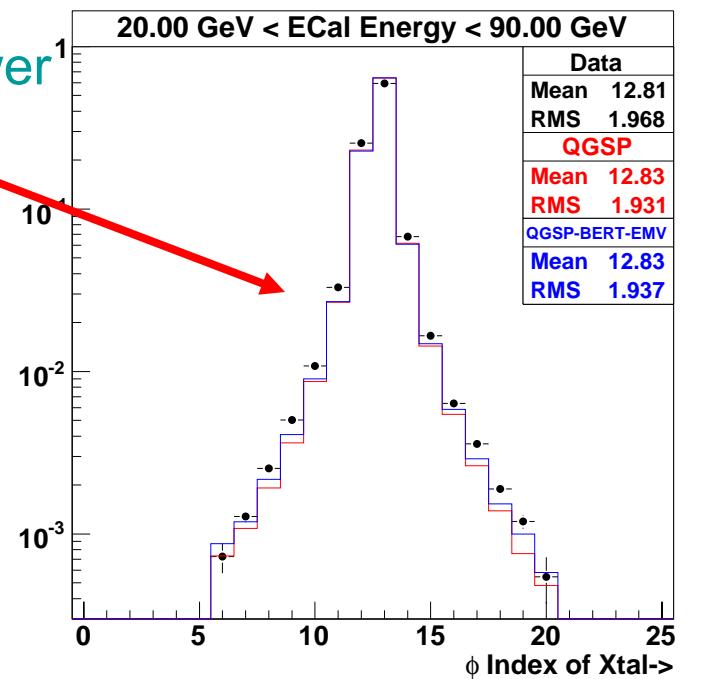


Mean energy response of π^- and p

Longitudinal shower profile for π^-



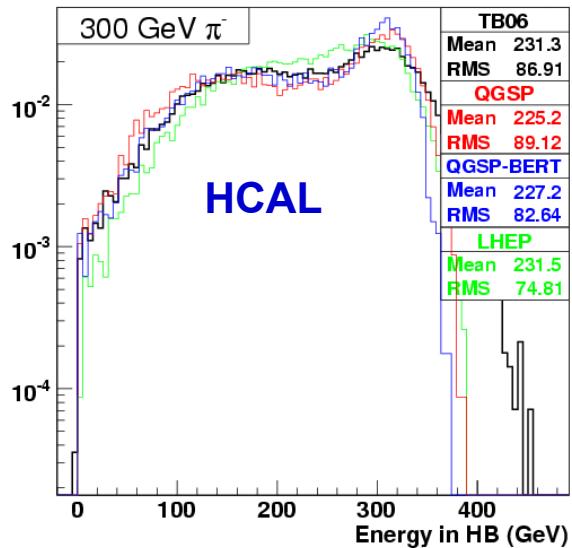
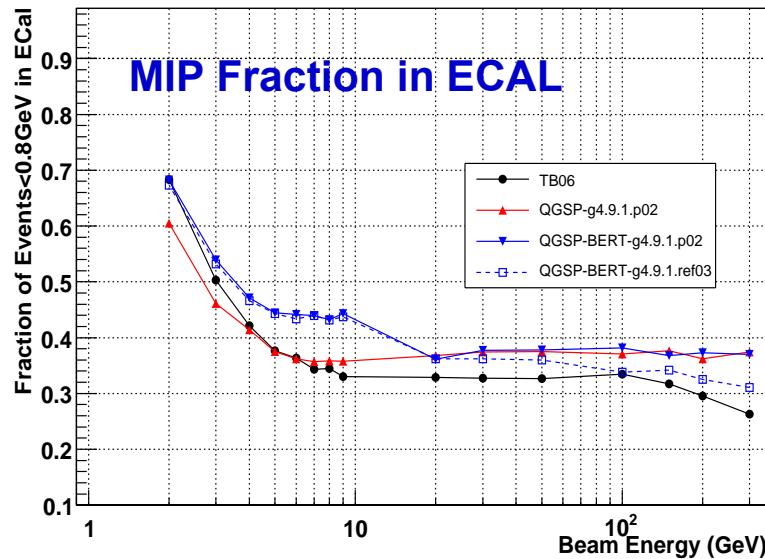
Lateral shower profile for π^-



- Reasonable agreement with hadron beam data
- But a few concerns



Main Issues in Past Simulation



- ❑ MIP Fraction in PbWO_4 too large at 5-9 GeV. Could be due to treatment of quasi-elastics in Bertini cascade model. The drop at high energy is due to bremsstrahlung of hadrons.
- ❑ Energy deposit in HCAL (non-interacting in PbWO_4) have a sharper cut off at high energies (above 100 GeV) – causes better energy resolution in G4 predictions
- ❑ The agreement in the lateral profile for electrons in PbWO_4 degraded from 0.4% to 1.0%.



Performance Issues



	Minimum Bias	t-tbar	$Z \rightarrow e^+e^-$
CPU Time (s)			
QGSP_EMV	1.00	1.00	1.00
QGSP	1.16	1.20	1.17
QGSP_BERT_EMV	1.41	1.46	1.36
QGSP_BERT	1.58	1.69	1.53
Event size (Mb)			
QGSP_EMV	1.00	1.00	1.00
QGSP	1.01	1.03	1.00
QGSP_BERT_EMV	1.52	1.77	1.60
QGSP_BERT	1.52	1.72	1.58

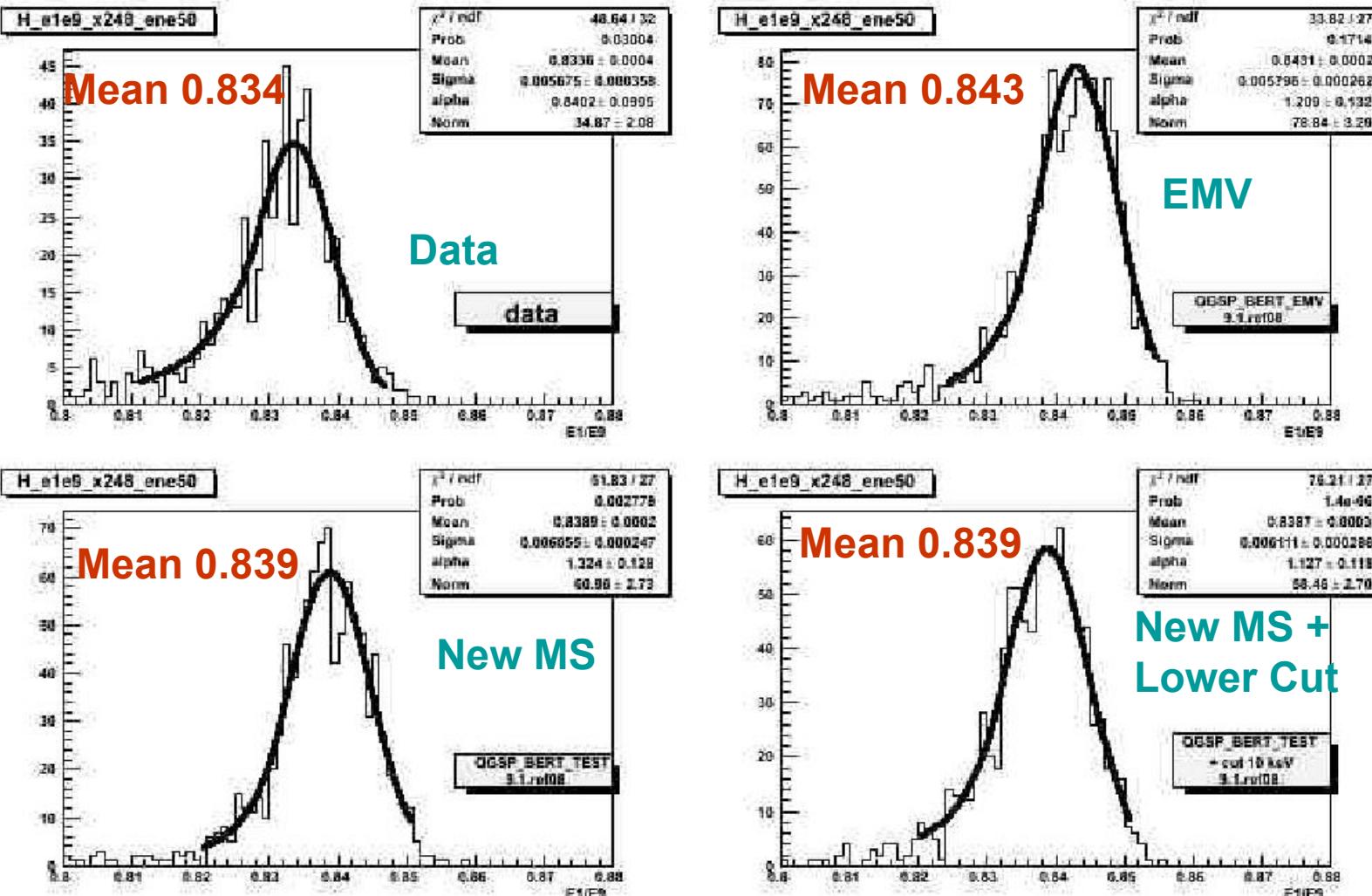
- ❑ Possible increase by ~40% in CPU time, ~(50-80)% in Event size (depending on physics channel), ~(5-10)% increase in memory usage as a result of moving from QGSP_EMV to QGSP_BERT_EMV



Change in EM Pysics



- Geant4.9.2 came with improvements in multiple scattering for electrons and positrons. This together with better interpolation of physics table improve the situation of lateral shower profile in EM calorimeter.



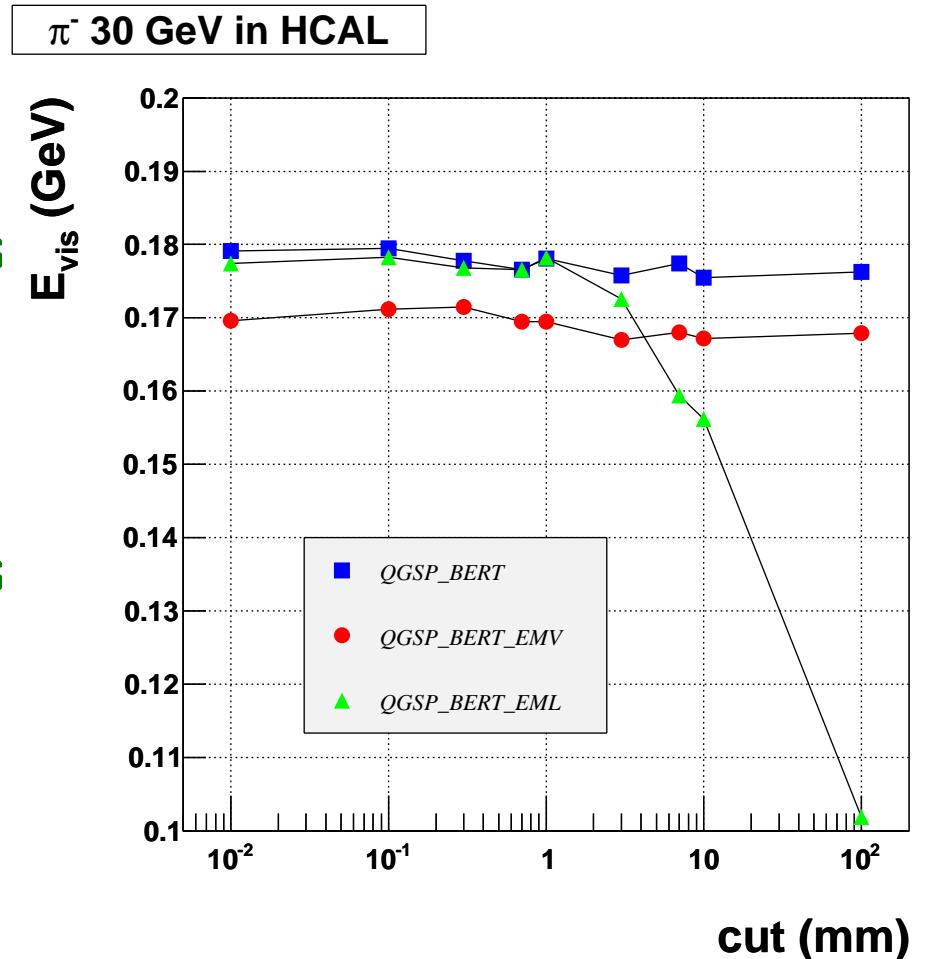
Difference drops by factor of 2



More on EM Physics



- By default production threshold in Geant4 are applied to ionization and bremsstrahlung. Extend this to other processes like Compton scattering, PE effect, ... → **Apply Cuts**
- No change in physics if cuts are small enough. Gain in CPU time by ~25%



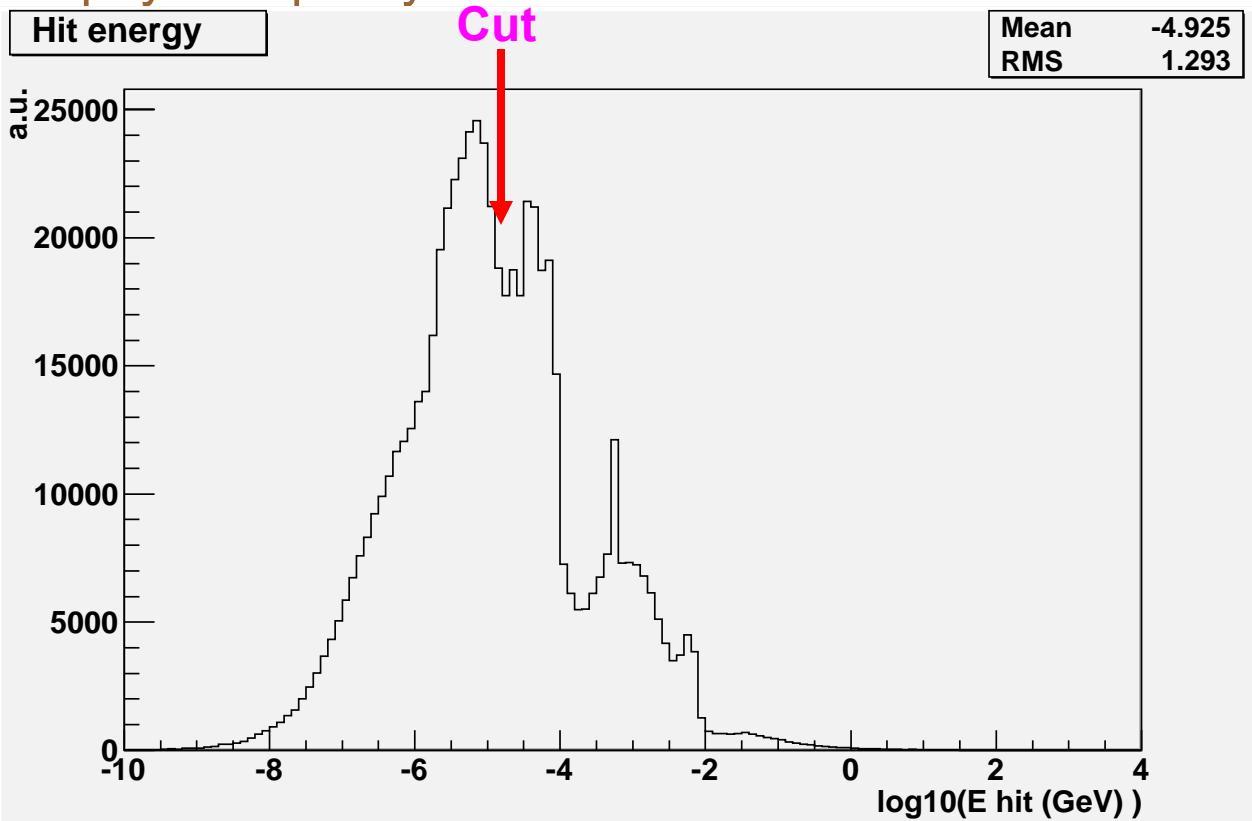
New CMS specific physics list **$QGSP_BERT_EML$**



Recover Space & Time



- All detector components have signal integration time significantly smaller than default time cut in Geant4. Make region specific cut on timing (SteppingAction and StackingAction)
- Many very low energy hits with Bertini cascade model. Study cut on energy deposit in a cell. Applicable to barrel and endcap calorimeter → calorimeter hit storage drops by a factor of 2. No impact on physics quality.



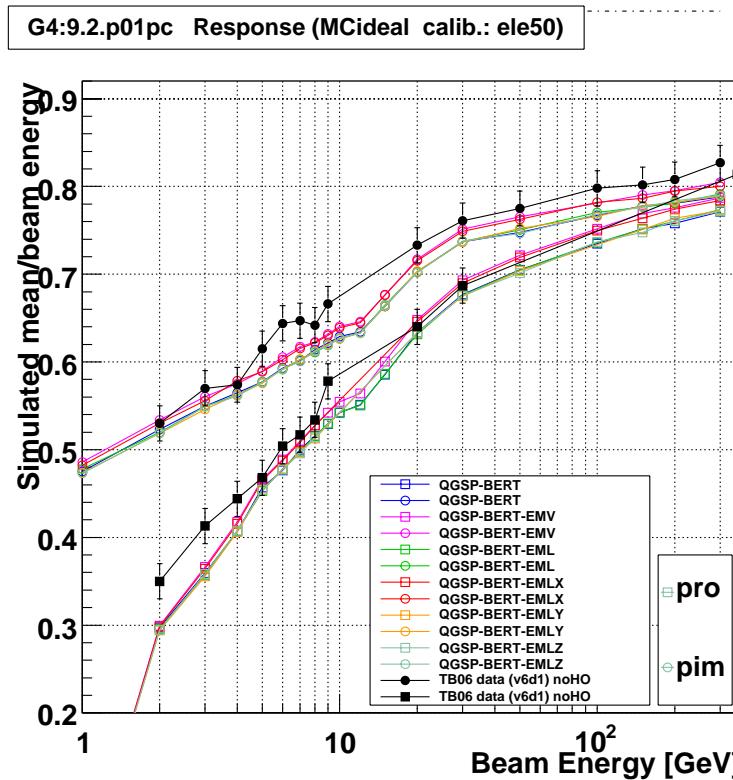
These measures
+ improvements
in the Bertini
cascade code
recovered all the
grounds lost in
switching physics
list.



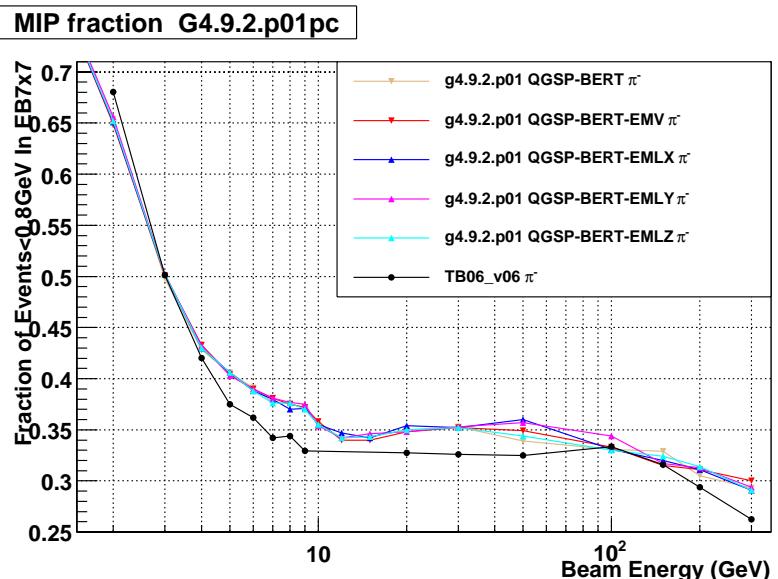
Hadron Response with 9.2



- Bertini cascade model had several improvements in version 9.2.p01
 - incorporation of Coulomb barrier
 - treatment of quasi-elastic scattering
- Bremsstrahlung of charged hadrons are allowed in EM physics list
- Possibility of having different multiple scattering models to electrons in different regions – included in CMS specific EM physics list (EML)



Use of **UrbanMscModel2** for special regions (HCAL) gives slightly smaller response (EMLY or EMLZ)



Standard EM Physics gives similar smaller response

Charged hadron brems. explains the drop above 100 GeV

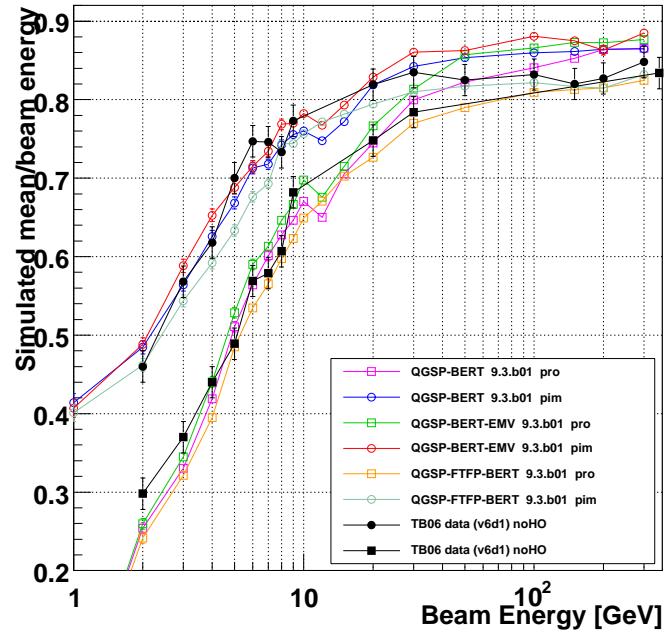


New Physics List in 9.3.b01

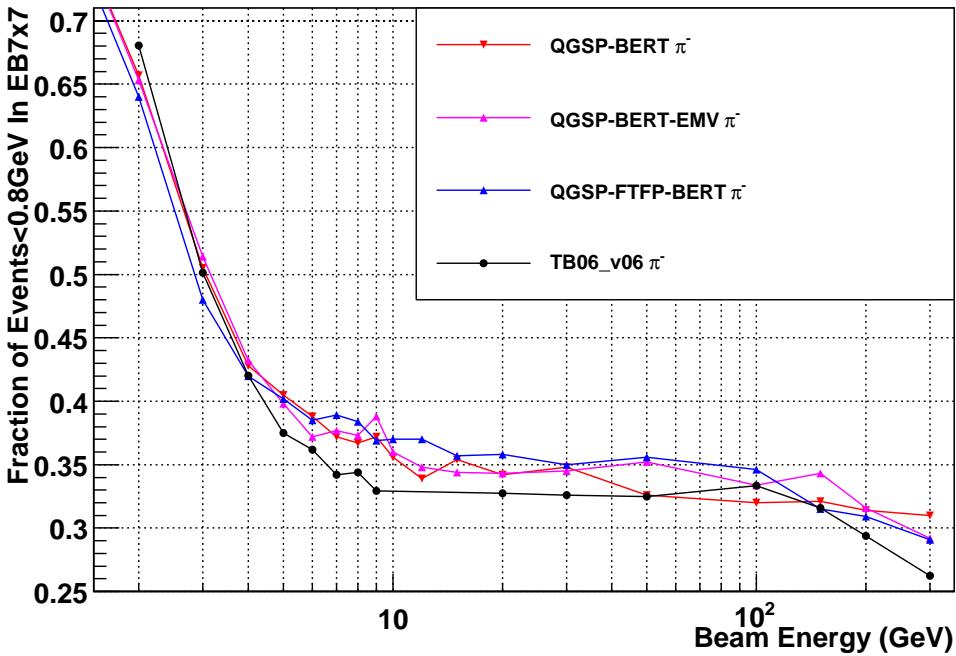
- 9.3.beta01 version gave 3 new physics lists out of which **QGSP_FTFP_BERT** looks rather promising

- Transition around 5 GeV is still not very smooth
- MIP fraction for FTF is higher than LEP

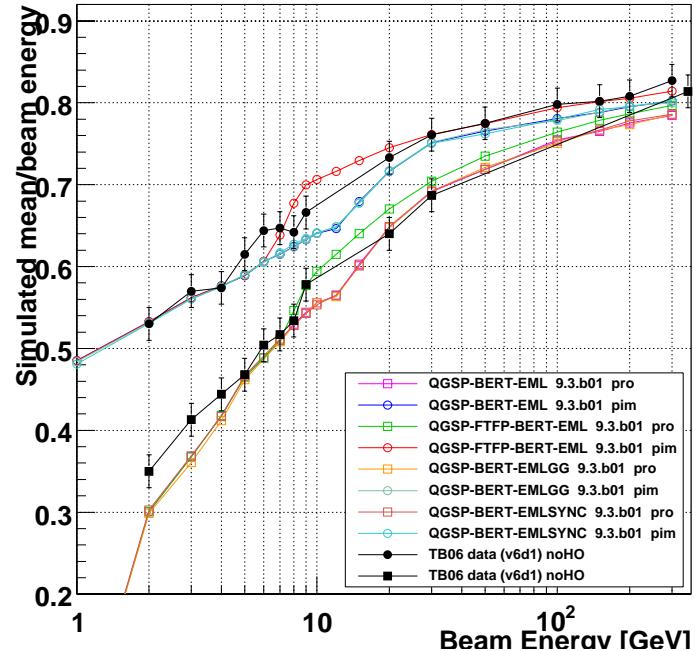
Calo Response (MCidealMIP calib.: ele50)



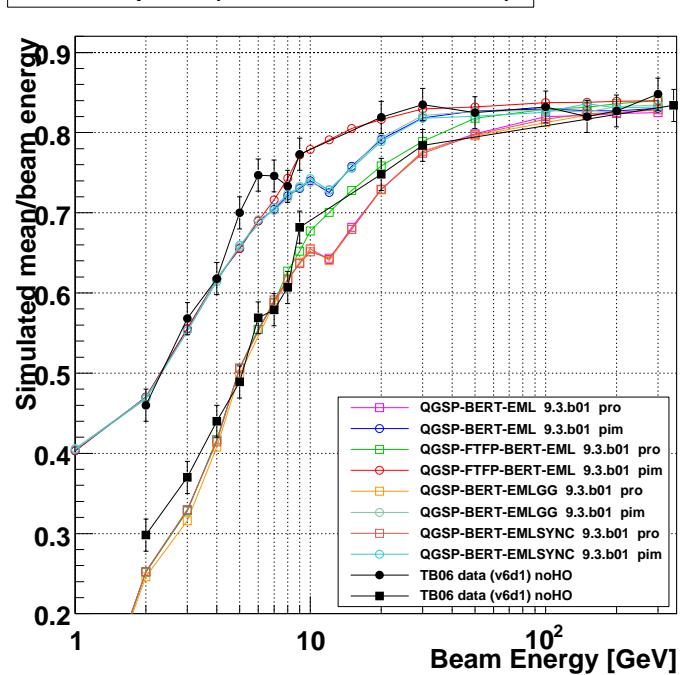
MIP fraction G4.9.3.b01



Other Attempt(s)



Calo Response (MCidealMIP calib.: ele50)



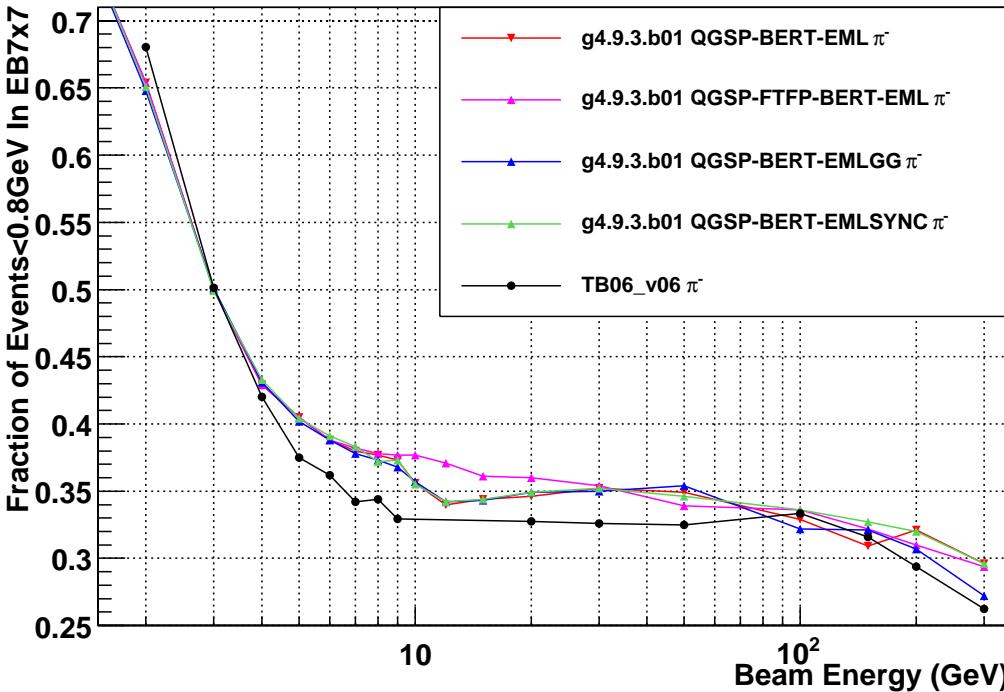
- Use Glauber-Gribov cross section parametrization

- No impact on hadron response
 - MIP fraction agrees better at high E_T

- ❑ Use Synchrotron radiation – see impact on electron ID

- No impact on hadron response or MIP

MIP fraction C4.9.3.b01





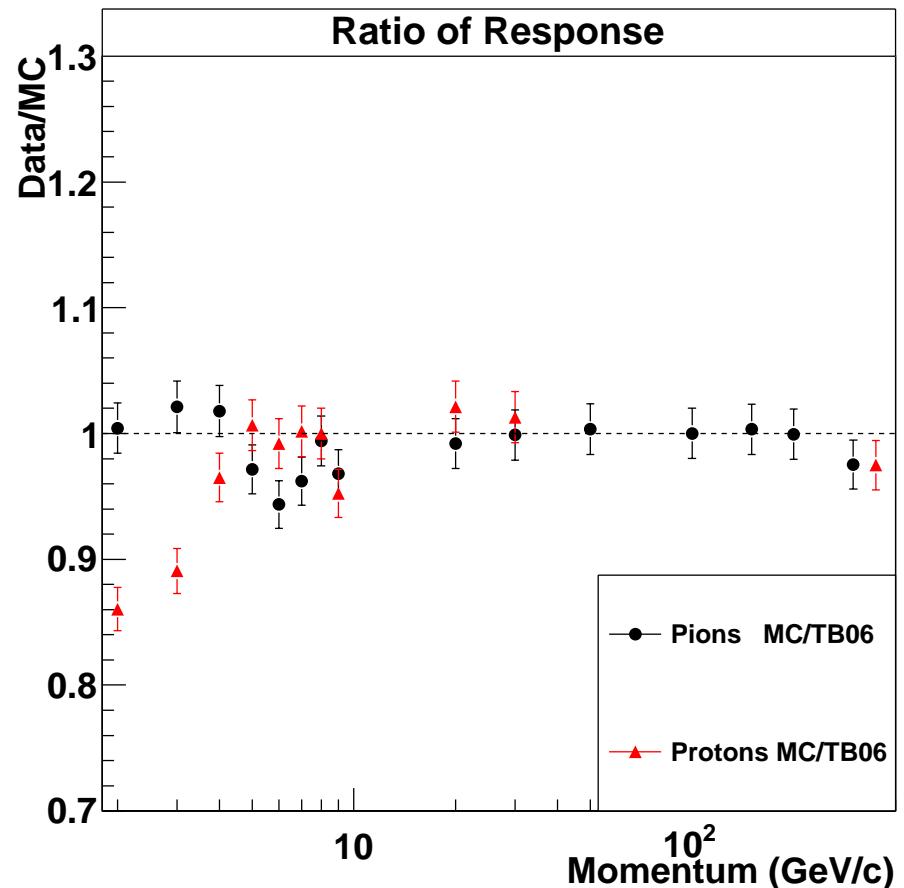
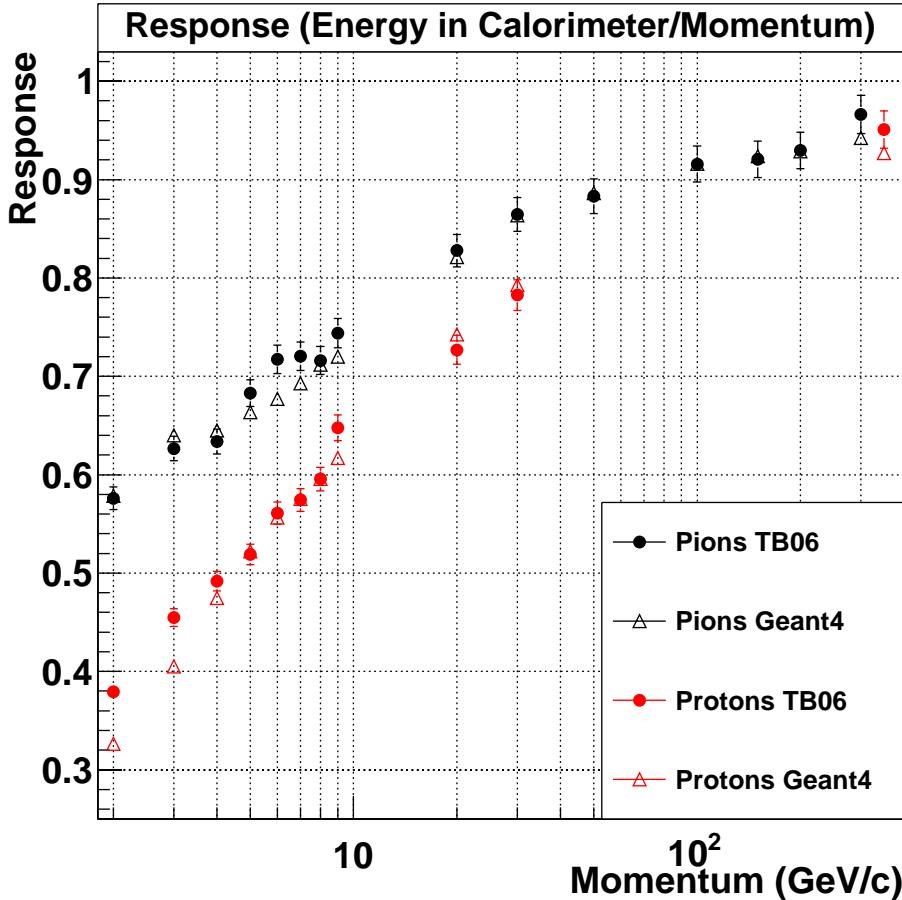
Summary



- ❑ CMS simulation is guided by (test beam) data in the choice of physics list
- ❑ There has been a continuous suggestion and feedback from the Geant4 team to improve the quality of the simulation.
- ❑ The current production version (9.2.p02) of Geant4 and **QGSP_BERT_EML** physics list are the current defaults of CMS simulation.
- ❑ Looking forward to improvements which will provide a smoother energy dependence on energy response (or MIP fraction)
- ❑ CMS is preparing to tune all these simulation codes to collision data from LHC.
- ❑ CMS plans to overlay zero bias data on MC signal for modeling noise/pileup with right luminosity profile.



Current Status



- ☐ Level of agreement on mean response is acceptable except for low energy protons. Still open issues on resolution and energy evolution of quantities like MIP fraction