



CMS studies on hadronic response simulation

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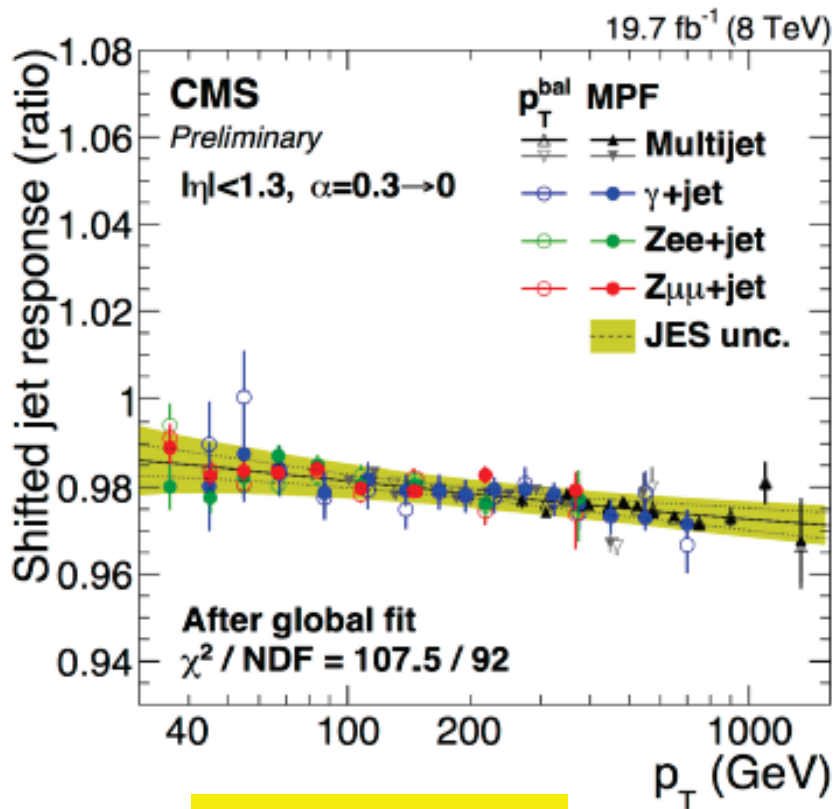
CMS simulation for 2017

- Production version of Geant4 for run-2 (2015-2016)
 - Geant4 version 10.0p02 built in sequential mode + private patches
 - Production platform slc6_amd64_gcc491
 - Default physics list: QGSP_FTFP_BERT_EML
 - ~10 billion events already produced
- CMS plan to switch from Geant4 10.0 to 10.2 for 2017 production because
 - It includes many fixes, in particular, for the MT mode
 - New version fully compliant with c++11 and new compilers
 - It includes VecGeom components which may be tested by CMS
- CMS had a problem to use 10.2:
 - Hadronic response changed compared to 10.0
- In order to better understand CMS calorimeter response for various Geant4 versions several studies are carried out
 - Restored combined ECAL+HCAL test-beam 2006
 - Standalone test46 of simplified ECAL+HCAL setup
 - Results of test46 studies will be presented in this talk

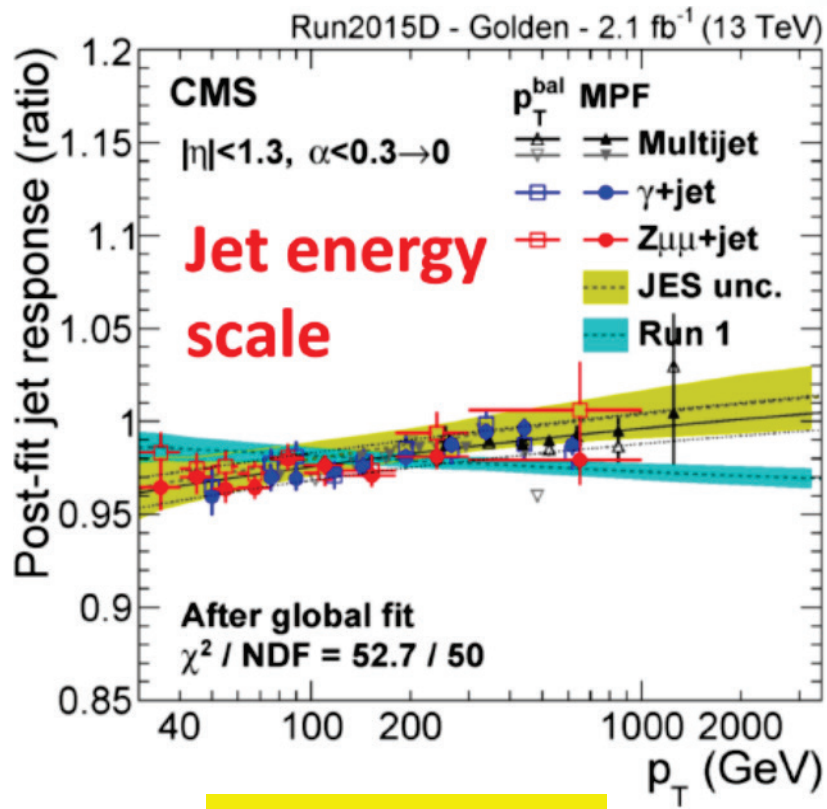
CMS jet energy scale



- Hadronic response for run-2 is different from one of run-1
- This difference may be due Geant4 and/or downstream software
 - Reconstruction was significantly changed for run-2
- In this study we only report Geant4 hadronic response evolution



Run-1 G4 9.4p03



Run-2 G4 10.0p02

New Geant4 Physics Lists for 10.2

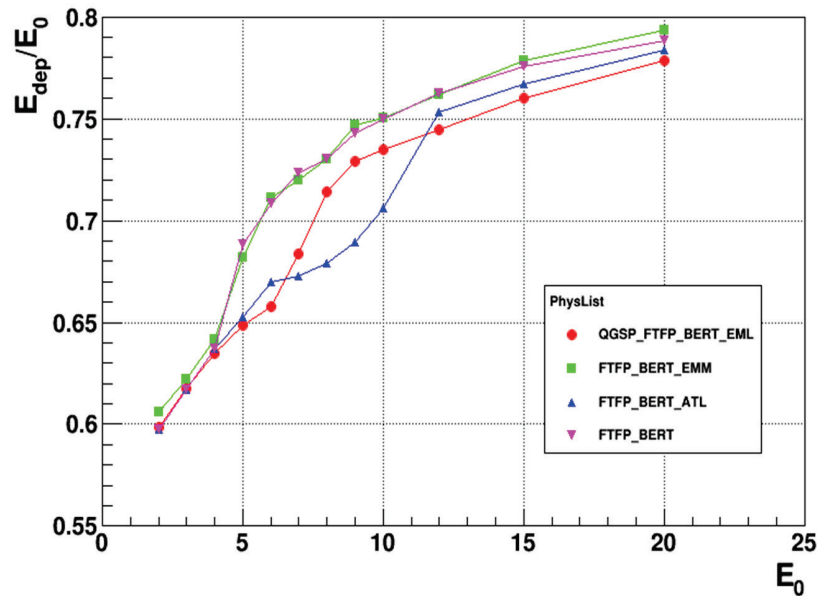
- **FTFP_BERT_ATL** – proposed for ATLAS some time ago
 - Shifting transition region from the Bertini cascade to FTFP model
 - FTFP_BERT – [4 - 5] GeV
 - FTFP_BERT_ATL – [9 - 12] GeV
 - QGSP_FTFP_BERT_EML – [6 - 8] GeV – previous CMS default
- **FTFP_BERT_EMM** – new EM configuration for CMS
 - A new Physics List for CMS with custom EM physics
 - Uses fast (as in EML) multiple scattering everywhere but more accurate (EM Opt0) within Hcal
 - TB2006 analysis shows that FTFP_BERT_EMM is closest to the data
- **FTF model**
 - CMS combined calorimeter response is very sensitive to FTF modifications
 - These effects were studied using test46 – standalone simplified combined calorimeter

Results with standalone test of combined calorimeter 10.2p01

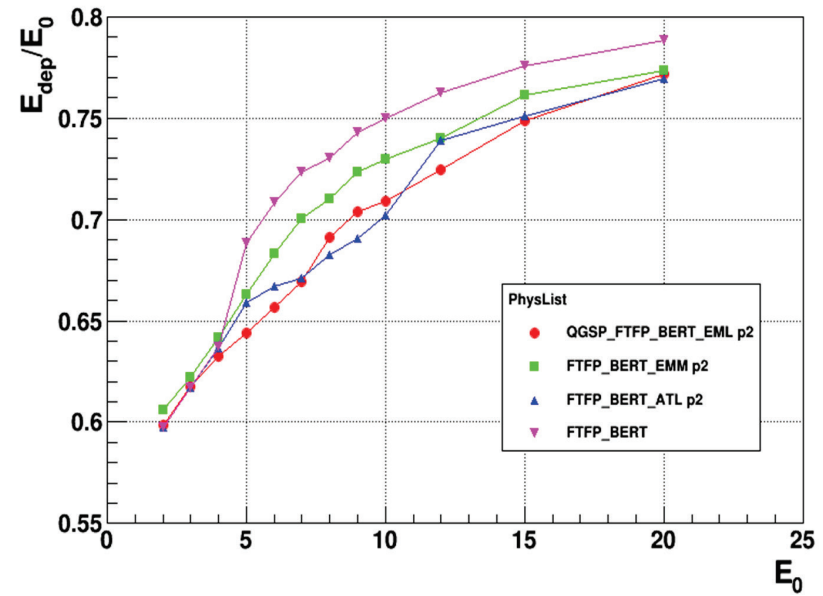
- We started to study effects of various Physics Lists configurations using test46 setup:
 - Simplified ECAL + HCAL
 - $E_{\text{vis}} = E_{\text{ECAL}} * f_{\text{ECAL}} + E_{\text{HCAL}} * f_{\text{HCAL}}$
 - $f_{\text{ECAL}} = 1.01, f_{\text{HCAL}} = 95.5,$
 - Beam energy of hadrons 2 – 20 GeV
 - Normalisation of HCAL response is done as in TB2006 using 50 GeV e- in HCAL only (ECAL removed)
- Simulation with 10.2p01 + patches to re-configure FTF provided by Alberto Ribon as a special tags for CMS
 - CMS private tag (p1): roll back correction for intermediate Z
 - CMS private tag (p2): roll back FTF configuration to 10.1
- **A comment:**
 - These re-configuration is transparent, because FTF model has a parameters class separated from algorithm implementations

Results with test46 for pi- Geant4 10.2p01 + p2

pi- mean energy deposition



pi- mean energy deposition

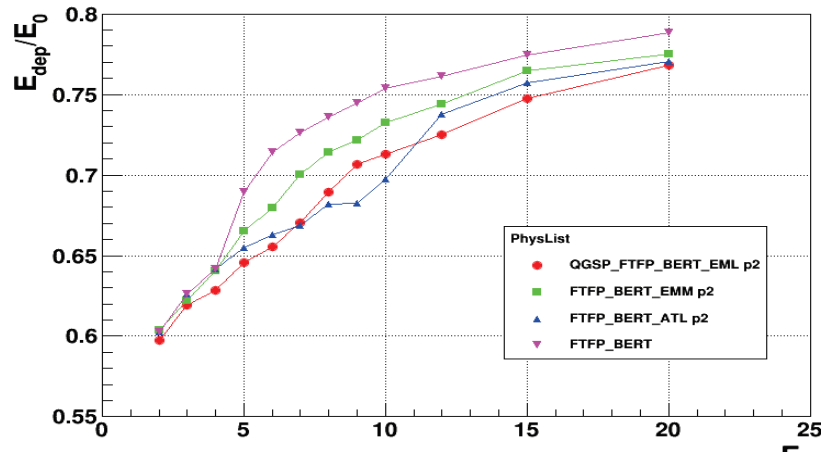


- No effect for p1
- Substantial reduction of the response using p2
- Higher response for FTFP_BERT
- Lower response for FTFP_BERT_ATL

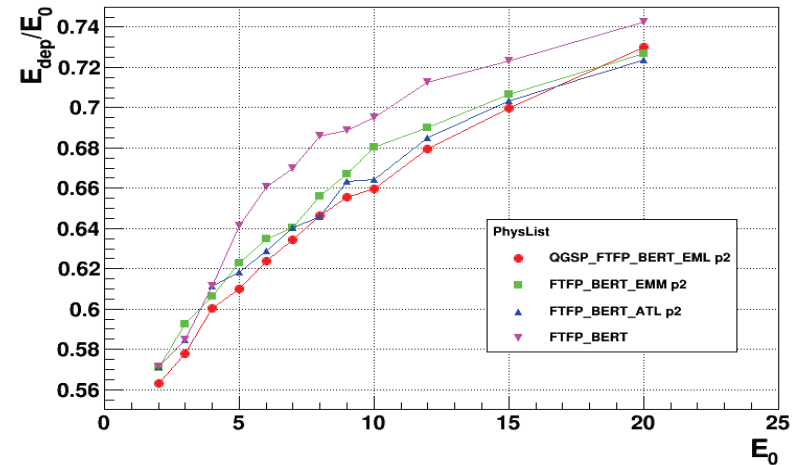
Results with test46 for π^+ , p , \bar{p} Geant4 10.2p01 + p2



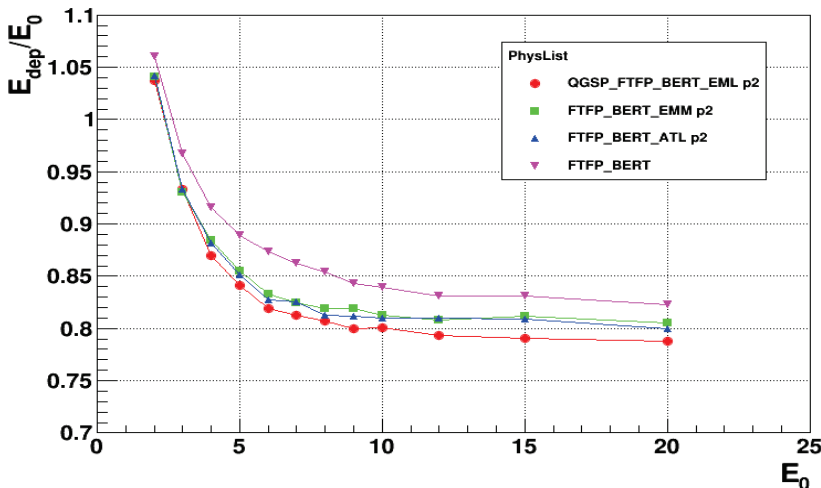
π^+ mean energy deposition



proton mean energy deposition



anti_proton mean energy deposition



- FTFP_BERT is very different from others due to HCAL calibration
- FTFP_BERT_ATL provides less regular shapes of the response

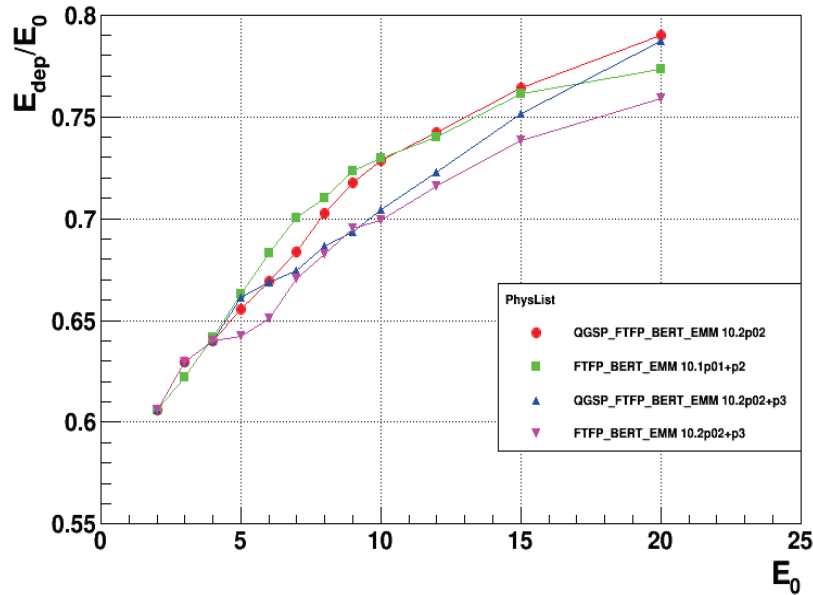
Configuration of FTFP on top of Geant4 10.2p02



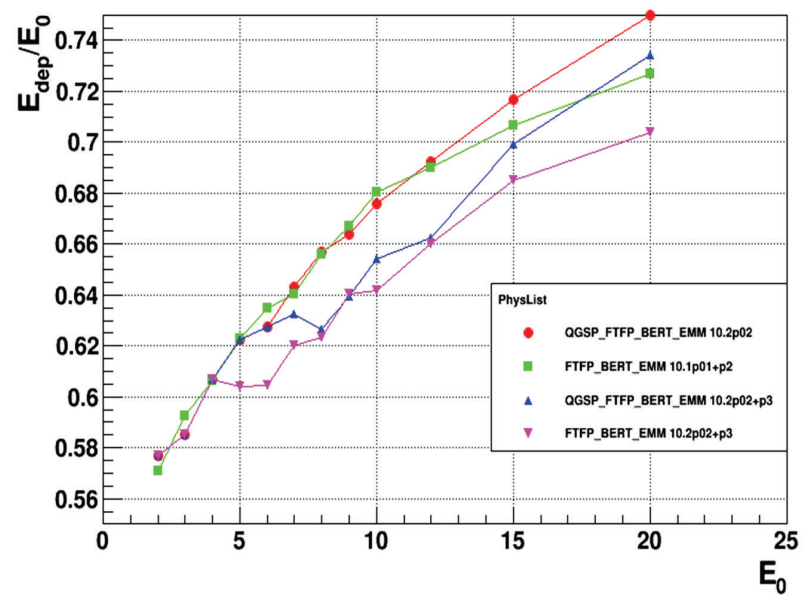
- CMS required 10.2p02 as a «technical patch» including fixes for the MT mode
- It turned out the this patch includes an update of the FTF model
 - backport fixed η and η' production
- Results using established with 10.2p01 FTF configuration became biased
- A new round of validation was performed using standalone test, which includes tests of several configurations:
 - 10.2p02
 - 10.2p02 + FTF p3 – merged modifications from p2 on top of 10.2p02
 - 10.2p02 + FTF p4 – discard FTF modifications in 10.2p02 and apply only p2
 - Selected plots are shown below

Results with test46 for pi- and p Geant4 10.2p03 + p3

pi- mean energy deposition



proton mean energy deposition

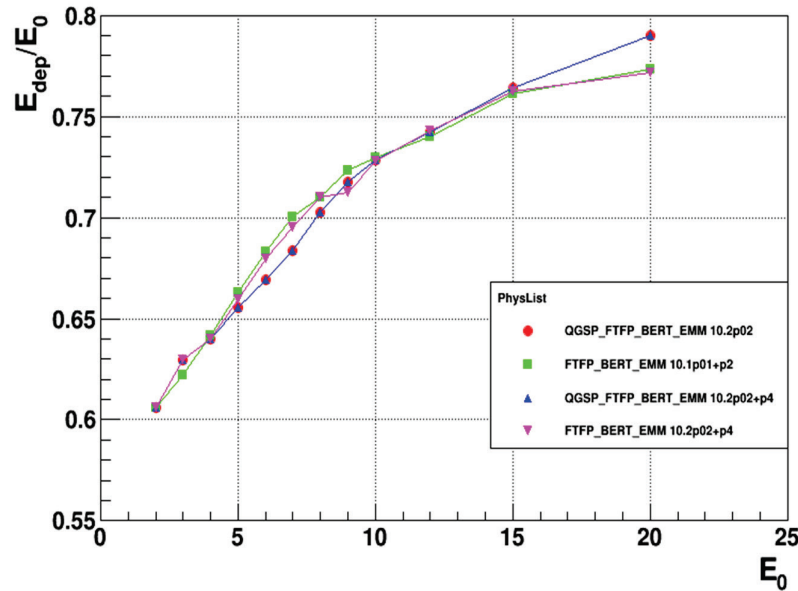


- Applying CMS p3 on top of 10.2p02 provides unphysical shape of the response and overreduced response for protons

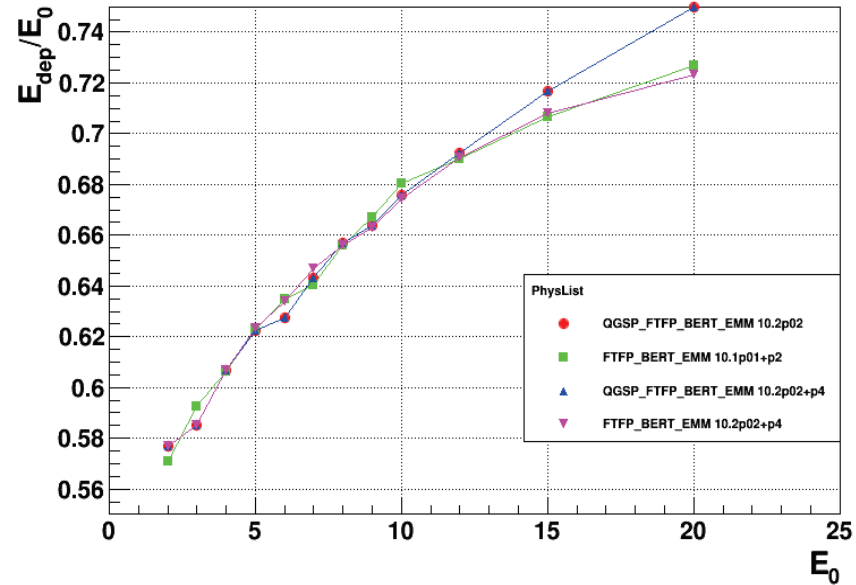
Results with test46 for pi- and p

Geant4 10.2p03 + p4

pi- mean energy deposition



proton mean energy deposition



- CMS final choice is to withdraw FTF changes for 10.2p02 (fixed η and η' production) and apply p2 only providing calorimeter response as it was in 10.1p03

Summary

- During this year CMS has performed set of validation studies in order to establish optimal Physics List for Geant4 10.2 to be used in 2017 production
 - FTFP_BERT_EMM is the current choice
- It turn our that two key aspects affect hadronic response for CMS calorimeters:
 - Configuration of EM physics – EMM option is added
 - Configuration of FTF model – CMS private patch is added
- CMS would suggest that combined calorimeter of CMS type is under regular validation by Geant4 team
 - Test46 software exist
 - Ideally such validations should be done before and not after official releases to avoiding private patches