# Upgrading HFGFlash for Faster Simulation at Super LHC

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## Introduction

We have improved the performance of HF GFlash, a very fast simulation of electromagnetic showers using parameterizations of the profiles in Hadronic Forward Calorimeter. HF GFlash has good agreement to Collision Data and previous Test Beam results. In addition to good agreement to Data and previous Test Beam results, HF GFlash can simulate about 1000 times faster than Geant4.

We have developed HF GFlash, a fast simulation of electromagnetic showers using parameterizations of the profiles in Hadronic Forward Calorimeter. HF GFlash solves almost all problems of previous HF Simulation.

HF will experience unprecedented particle fluxes because on average, 760 GeV per proton proton interaction is deposited into the two forward calorimeters, compared to only 100 GeV for the rest of the detector. Due to this condition, CMS has changed the HF geometry for simulation because it will need very long computing time if we use full HF geometry for huge number of high energy particles.

The Gflash package allows the parameterization of electromagnetic showers in calorimeters and is based on the parameterization described by G. Grindhammer [2] . The spatial energy distribution of electromagnetic showers is given by:

$$dE(r) = E\, f(t)dt\, f(r)dr\, f(\varphi)d\varphi,$$

describing the longitudinal, radial, and azimuthal energy distributions. Here t denotes the longitudinal shower depth in units of radiation length, r measures the radial distance from the shower axis in Moliere units, and $\phi$ is the azimuthal angle. A gamma distribution is used for the parameterization of the longitudinal shower profile, f (t ). The radial distribution f (r ), is described by a two-component ansatz. In $\phi$ , it is assumed that the energy is distributed uniformly: $f(\phi) = 1/2\pi$ .

Using the results of energy response ratio from Team Beam data as the reference, we can check the performance of energy response ratio of HF GFlash compared to Shower Library.

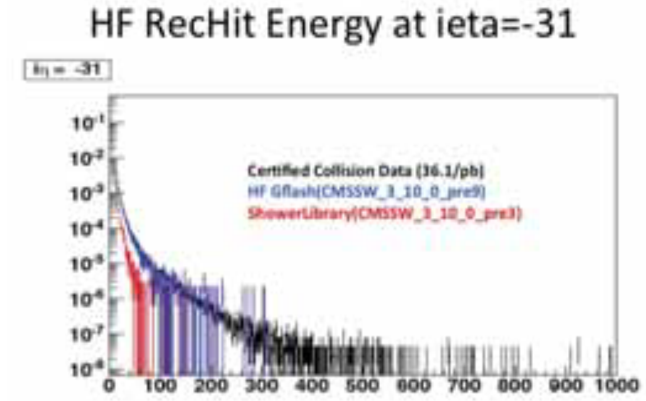
| | HF GFlash | Test Beam | Shower Library |
|---|---|---|---|
| $Se_{50}/Le_{50}$ | 0.24 | 0.24 | 0.20 |
| $Lp_{50}/Le_{50}$ | 0.67 | 0.66 | 0.63 |
| $Sp_{50}/Le_{50}$ | 0.51 | 0.50 | 0.51 |
| $Sp_{50}/Lp_{50}$ | 0.76 | 0.76 | 0.80 |

$Le_{50}$ = Energy deposited in Long Fiber from 10000 50-GeV electrons
$Se_{50}$ = Energy deposited in Short Fiber from 10000 50-GeV electrons
$Lp_{50}$ = Energy deposited in Long Fiber from 10000 50-GeV charged pions
$Sp_{50}$ = Energy deposited in Short Fiber from 10000 50-GeV charged pions

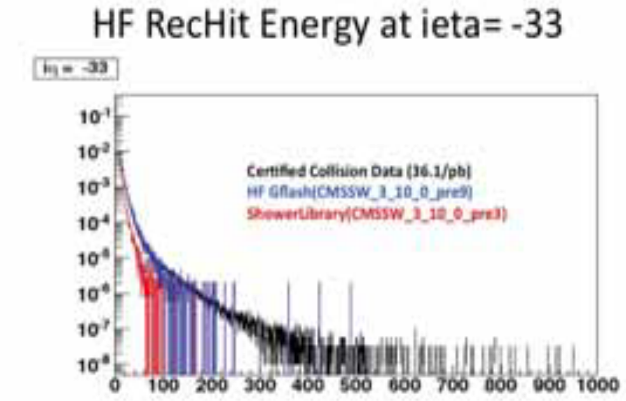
HF GFlash can handle not only low energy particles but also high energy particles. We can prove that HF GFlash can produce nice longitudinal profiles correctly for 1 TeV, 7 TeV and 14 TeV.

We also found that HFGFlash has good agreement with Collision Data that we collected in 2010.

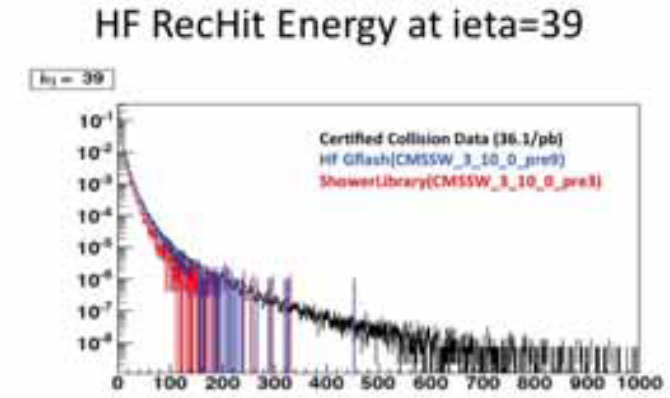
HF RecHit Energy at ieta=-31




HF RecHit Energy at ieta= -33




HF RecHit Energy at ieta=39




**Summary**

We have improved our simulation on earth that can handle very high energetic particles with better performance. HF GFlash has been compared and tested

1. Test Beam data
2. Shower Library
3. 36 $fb^{-1}$ Certified Collision Data

Due to its better performance, CMS Collaboration had chosen HF GFlash as the standard HF Detector simulation since 2011. HF GFlash has been tested and the tests showed that it is faster and more accurate so that HF GFlash will be a very useful simulation not only for Super Large Hadron Collider but also for other experiments, such as International Linear Collider, Muon Collider, etc.