Faster Simulation

HF GFLASH

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Outline

- Motivation & Introduction to HF Gflash
- Shower profile of HF Gflash
- Speed of HF Gflash
- Comparison to Test Beam Result
- Comparison to 7 TeV certified Collision Data
- Plan and Summary of HF Gflash

Motivations

- Why do we need GFLash?

  Full Geant4 simulation in colliders is really time consuming and

  you may need days to simulate 1 event

- Gflash can speed up full detector simulation significantly without sacrificing its precision
- Gflash package has been used in many experiments
- In this talk, I will explain ***HF GFlash***, an example of a successful application of Gflash in CMS Hadronic Forward Calorimeter (HF)that will be useful to save computing not only in CMS but also other physics experiments
- Reference: hep-ex/0001020v1 by G. Grindhammer & S. Peters
- CMS CR -2009/343 Parameterized Simulation of the CMS Calorimeter Using Gflash
- **"HF GFLASH", Phys.Procedia 37 (2012) 340-346 by Rahmat**

Introduction to GFlash

- The spatial energy distribution of EM showers is given by three Probability Distribution Functions (PDF) :

$$dE(\vec{r}) = E\ f(t)dt\ f(r)dr\ f(\phi)d\phi$$

where

- t = the longitudinal shower distribution
- r = the radial shower distribution
- ϕ = the azimuthal shower distribution (assumed to be distributed uniformly)

- The average longitudinal shower profile : (in units of radiation length)

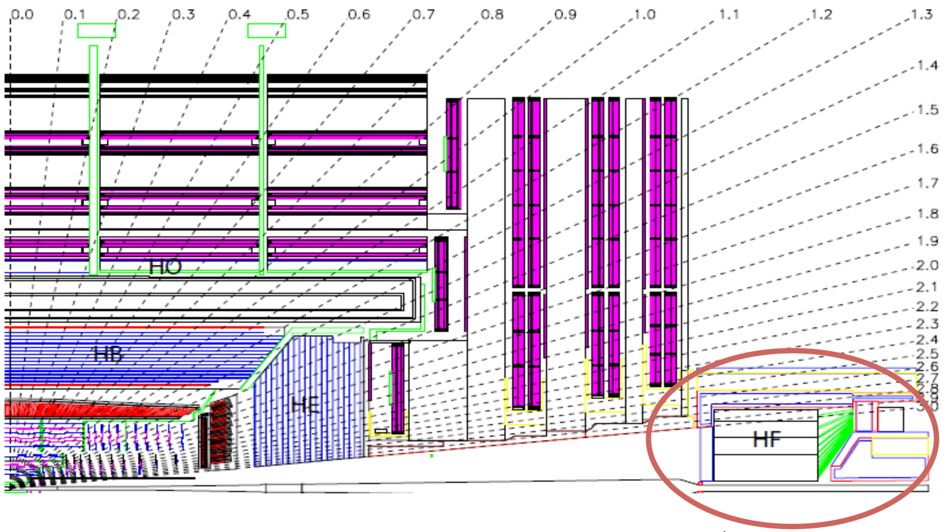
$$\langle \frac{1}{E}\frac{dEt}{dt} \rangle = f(t) = \frac{(\beta t)^{\alpha-1}\beta e^{-\beta t}}{\Gamma(\alpha)}$$

- The average radial energy profile : (in units of Moliere radius)

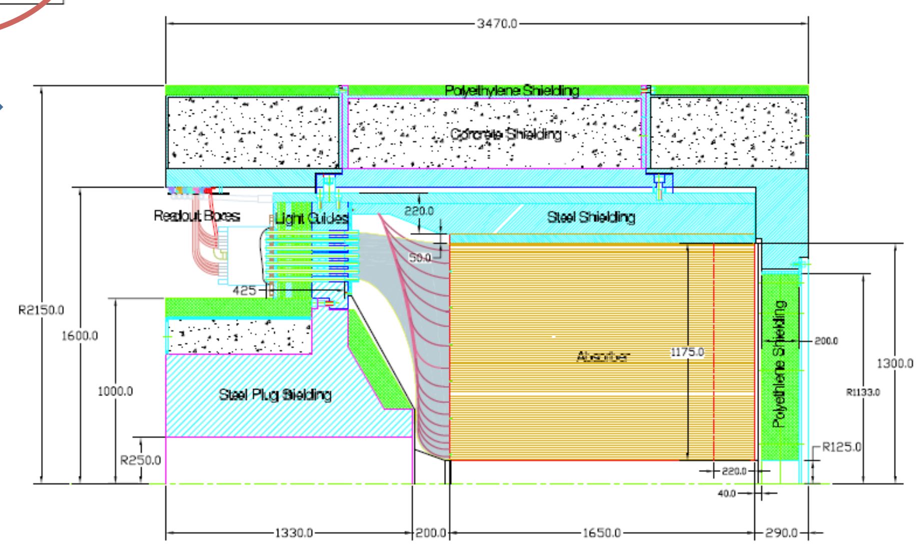
$$f(r) = \frac{1}{dE(t)}\frac{dE(t,r)}{dr}$$

Gflash is not a transport code, it simulates no underlying processes

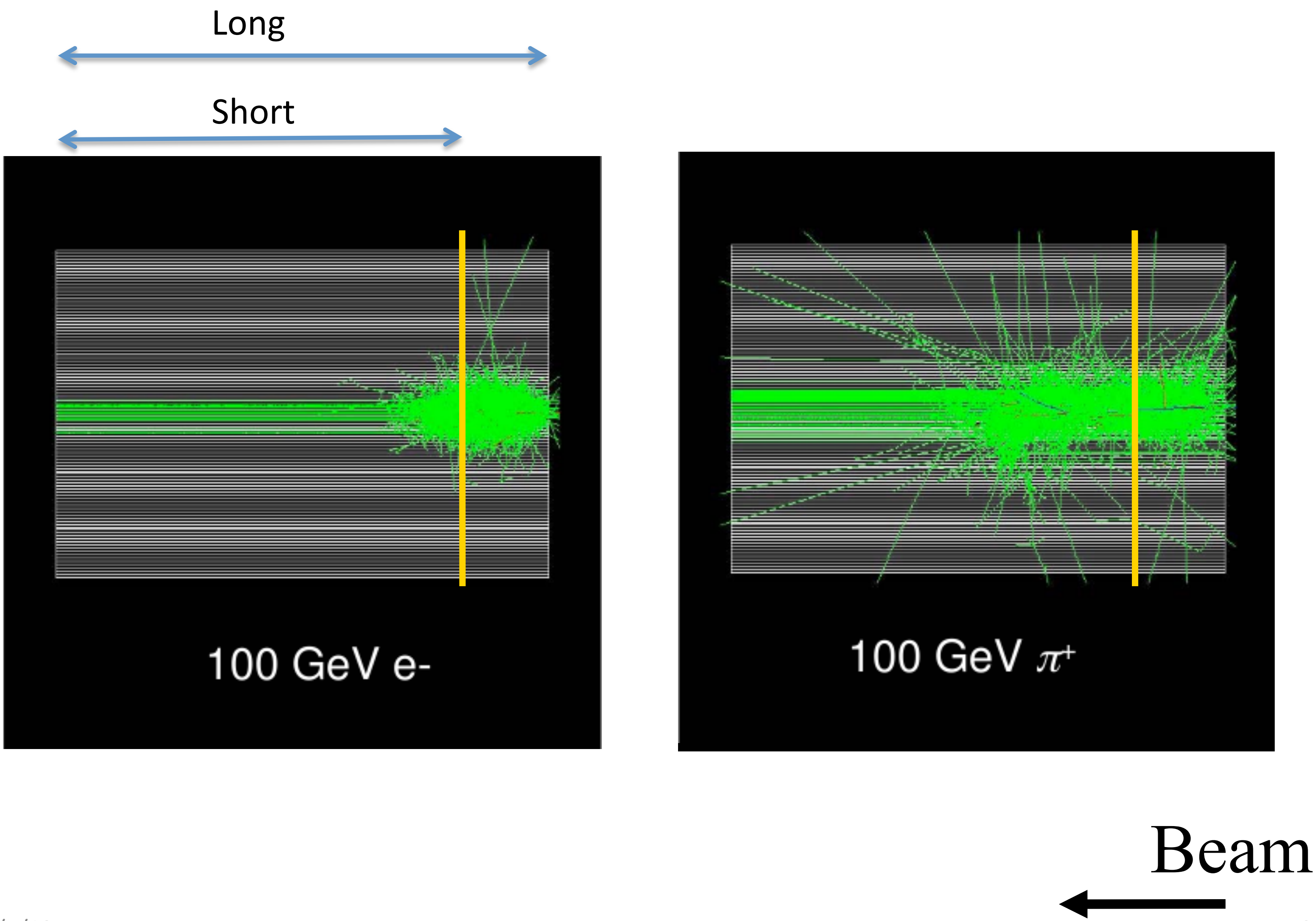
Hadronic Forward Calorimeter(HF)



Hadronic Forward Calorimeter(HF) is placed about 11 m from interaction point and has 3 <|η|< 5. There is no other calorimeter in front of HF so that HF is a very good place to study Gflash.



HF has **Long** and **Short** Fibers to differentiate shower from electromagnetic & hadronic particles



Hybrid GFlash Implementation for HF

For electromagnetic showers, in homogeneous or uniform sampling calorimeters, GFlash includes a powerful set of tools to provide initial guesses shower parameters. Can be used almost “out of the box”.

For hadronic showers there is little guidance available for tuning.

Implementation of HF GFlash is a hybrid that fast showers only Electromagnetic particles and performs full shower GEANT4 on Hadronics:

a) Necessary to properly model noise hits on the PMT windows by punch through pions.

b) Simplicity of tuning.

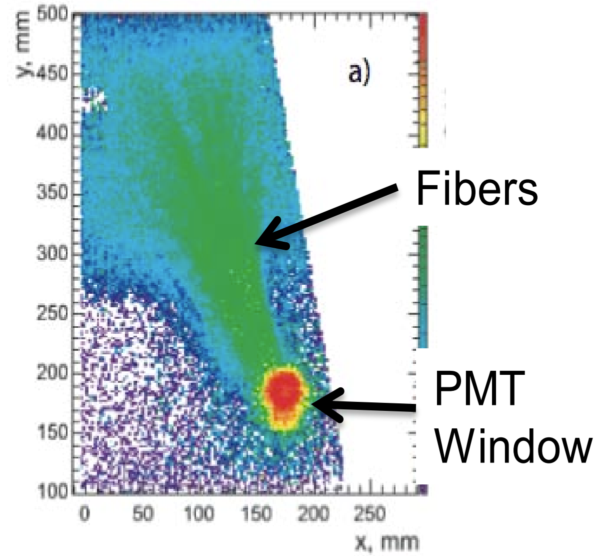
c) The hadronic fraction of the energy which is required to be full showered in GEANT4, drops strongly with the log of the incident hadron energy.

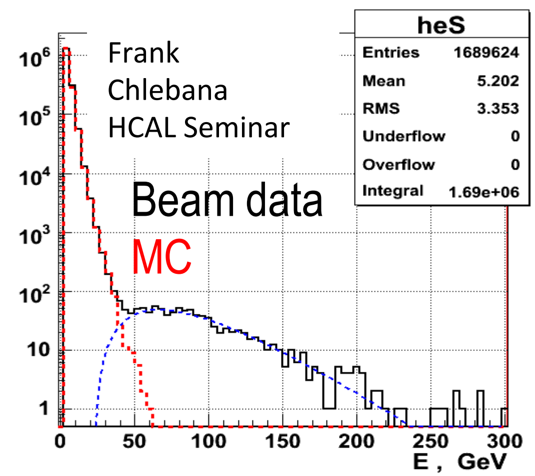
HF Noise

Anomalous signals were first observed in the 2004 test beam

Signals in HF L or S sections observed from particles interacting in the PMT window.

Eur.Phys.J. C53, 139-166 (2008)

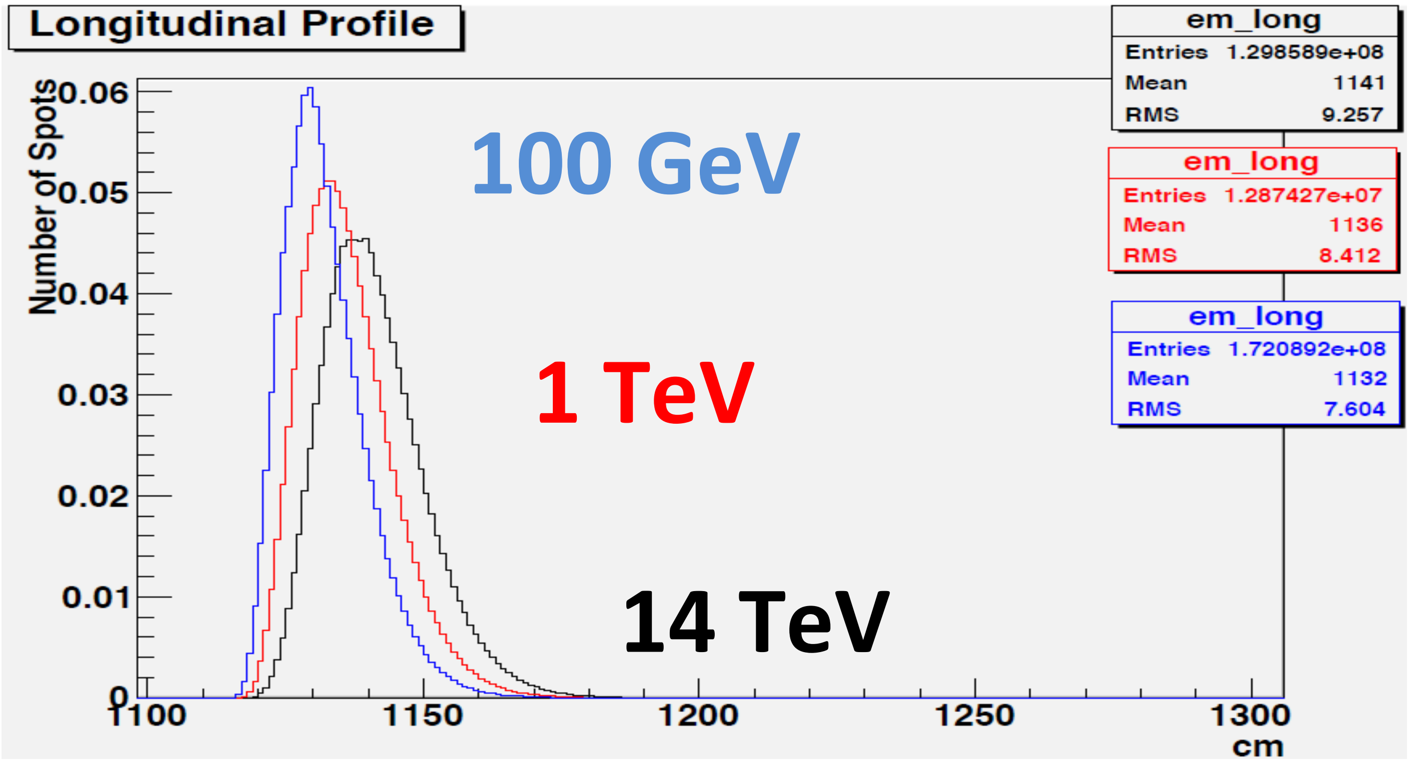




Previous CMS Simulation has a problem to simulate HF Noise because it killed particles immediately when they entered detectors.

HF GFlash was called to help simulate HF Noise produced by PMT Windows

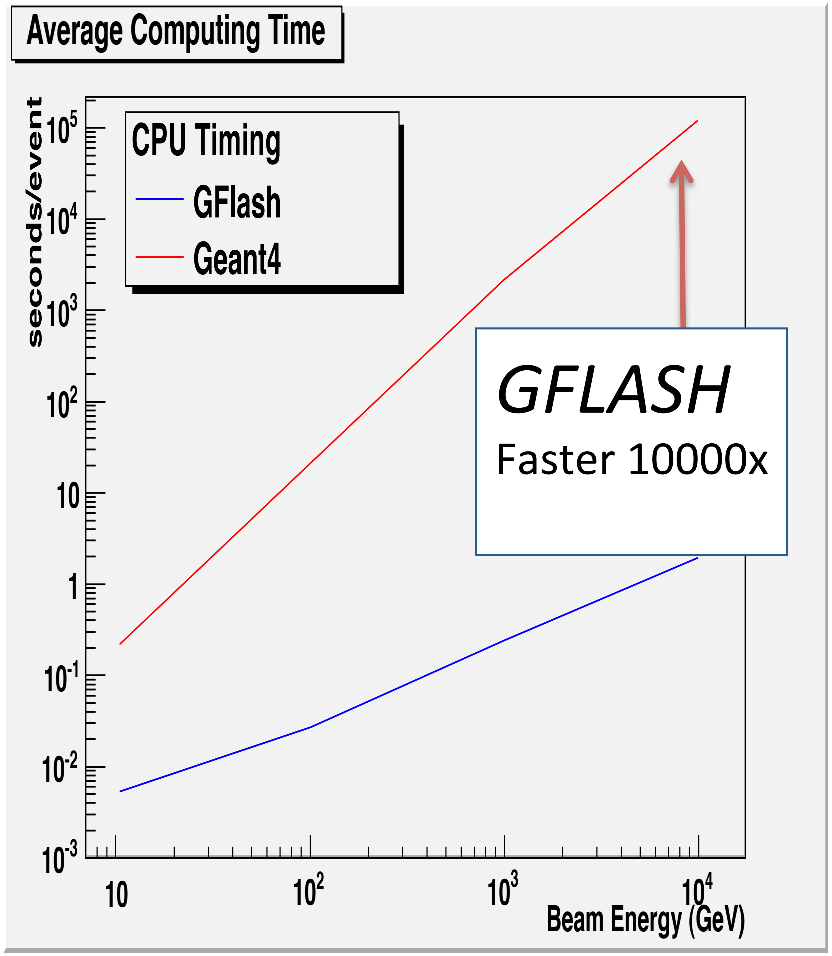
High Energy Longitudinal Profile



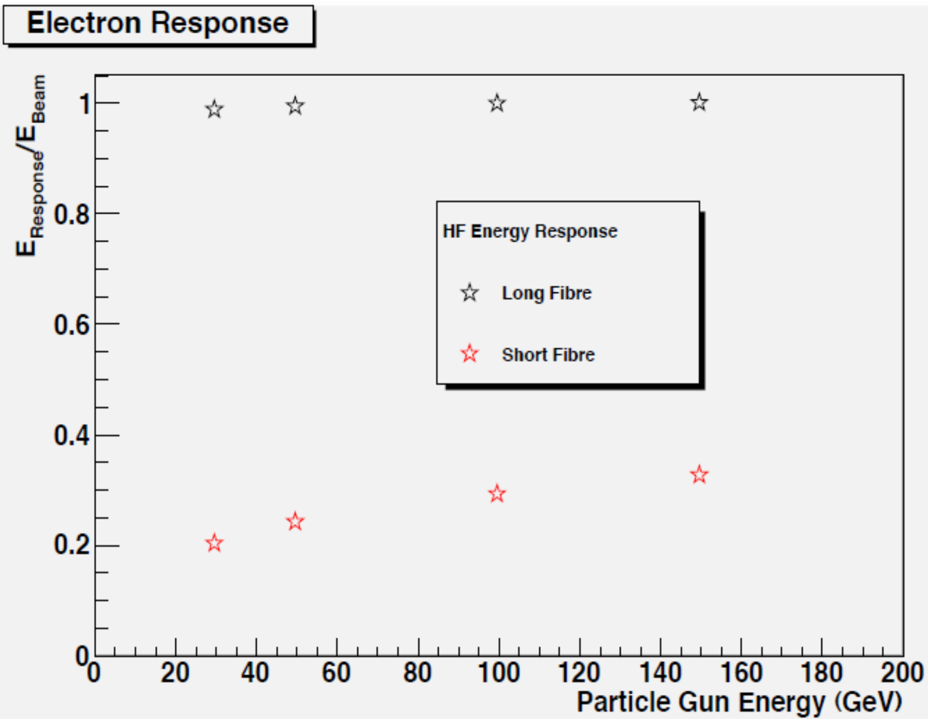
Geant4 will need days to simulate the shower profile of 1 TeV electron gun. Fortunately HF Gflash only need few seconds to simulate the interaction of very high energy particles with detector and gives good longitudinal profiles for very high energy particles(higher than 1 TeV)

GFlash saves computing time significantly

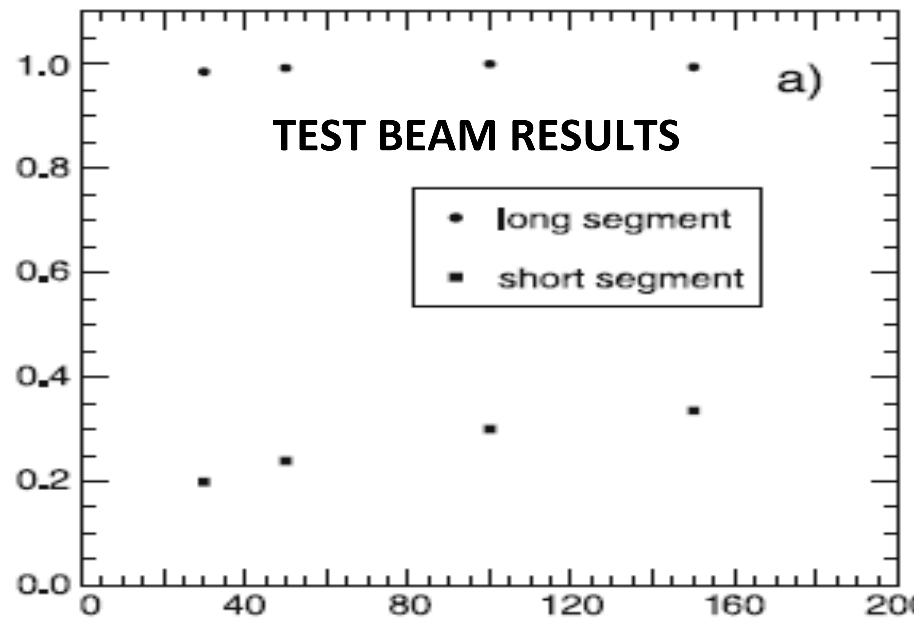
Gflash is not only can be directly tuned to data, but also can make simulation about 10000x faster than Geant4 for very high energy particles.



Response of Electron gun



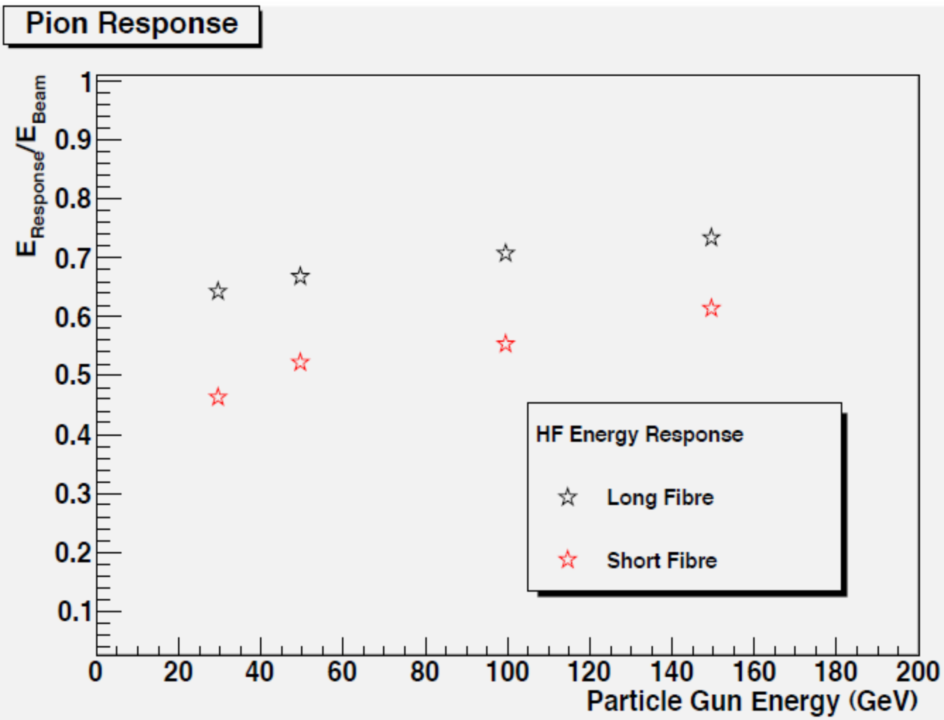
HFGflash(CMSSW_3_10_0_pre9)



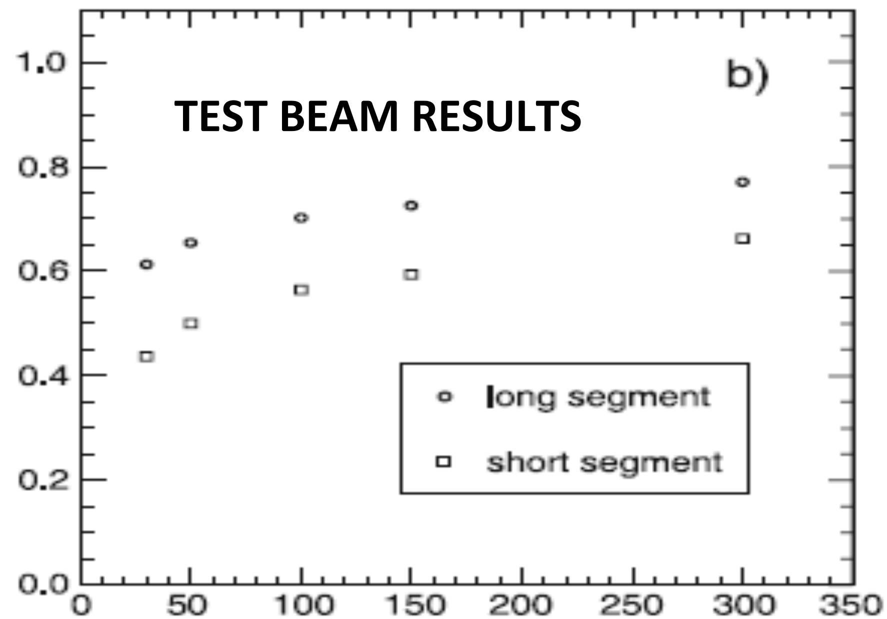
"Design, Performance, and Calibration of CMS Forward Calorimeter Wedges"
http://www.springerlink.com/content/f002u432m2453667/

Comparison of HF Gflash and TEST BEAM RESULTS: The normalized response to electrons(30, 50, 100 and 150 GeV) for long fibers are linear. **HF Gflash has good agreement to Test Beam Data.**

Pion Energy Response



HFGflash(CMSSW_3_10_0_pre9)



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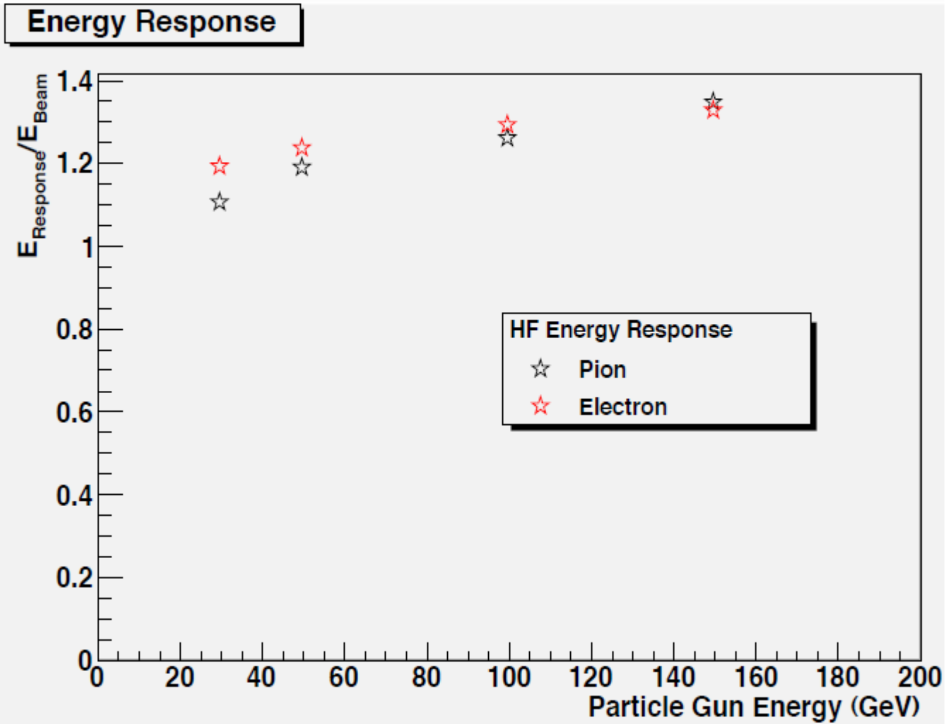
Comparison of HF Gflash and TEST BEAM RESULTS: The normalized response to pions(30, 50, 100 and 150 GeV). **HF Gflash has good agreement to Test Beam Data.**

Long+Short Energy Response



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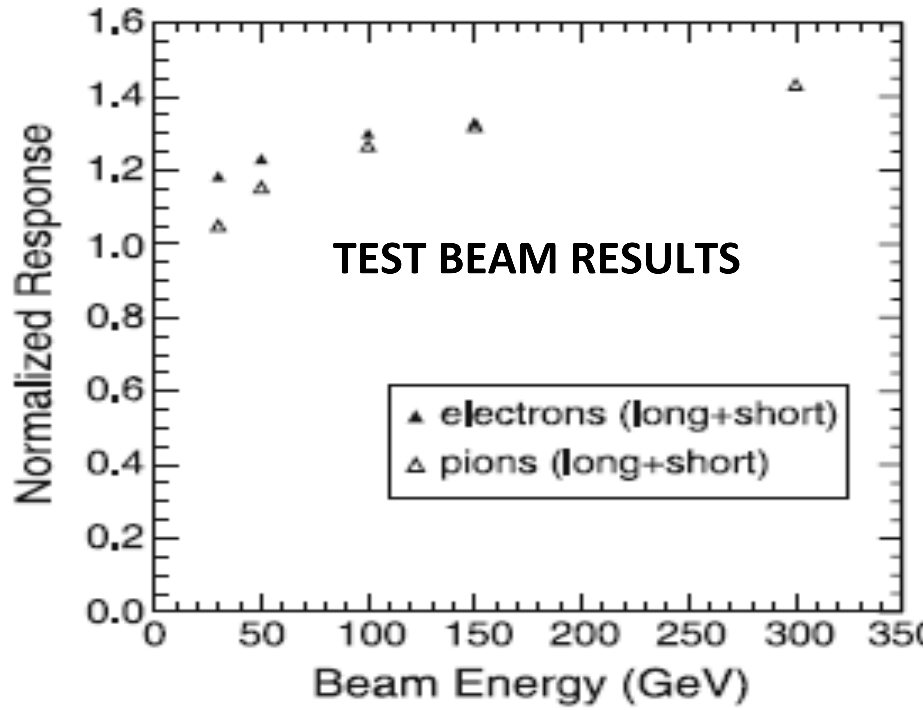

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Comparison of HF Gflash and TEST BEAM RESULTS: The normalized response to electrons and pions L+S(30, 50, 100 and 150 GeV). **HF Gflash has good agreement to Test Beam Data.**

50 GeV Pions and Electrons

	Gflash	Test Beam	Shower Library (Geant4)
Se/Le	**0.24**	0.24	0.20
Lp/Le	**0.67**	0.66	0.63
Sp/Le	**0.51**	0.50	0.51
Sp/Lp	**0.76**	0.76	0.80

Le = Energy deposited in Long Fiber from 10000 50-GeV electrons
Se = Energy deposited in Short Fiber from 10000 50-GeV electrons
Lp = Energy deposited in Long Fiber from 10000 50-GeV charged pions
Sp = Energy deposited in Short Fiber from 10000 50-GeV charged pions

HF Gflash has better agreement to experimental results compared to Shower Library(derived from Geant4)

100 GeV Pions and Electrons

	HF GFlash	Test Beam	Shower Library (Geant4)
Se/Le	**0.30**	0.30	0.25
Lp/Le	**0.70**	0.69	0.67
Sp/Le	**0.57**	0.55	0.56
Sp/Lp	**0.82**	0.80	0.84

Le = Energy deposited in Long Fiber from 10000 100-GeV electrons
Se = Energy deposited in Short Fiber from 10000 100-GeV electrons
Lp = Energy deposited in Long Fiber from 10000 100-GeV charged pions
Sp = Energy deposited in Short Fiber from 10000 100-GeV charged pions

HF Gflash has better agreement to experimental results compared to Shower Library(derived from Geant4)

150 GeV Pions and Electrons

	HF GFlash	Test Beam	Shower Library (Geant4)
Se/Le	**0.33**	0.34	0.28
Lp/Le	**0.71**	0.73	0.70
Sp/Le	**0.59**	0.60	0.56
Sp/Lp	**0.83**	0.82	0.80

Le = Energy deposited in Long Fiber from 10000 150-GeV electrons
Se = Energy deposited in Short Fiber from 10000 150-GeV electrons
Lp = Energy deposited in Long Fiber from 10000 150-GeV charged pions
Sp = Energy deposited in Short Fiber from 10000 150-GeV charged pions

HF Gflash has better agreement to experimental results compared to Shower Library(derived from Geant4)

Comparison with Certified Collision Data

- Using Collision Dataset with good condition
- PileUp was included implicitly
- Requiring good vertex
- Events passed muon trigger bit(HLT_Mu9)
  - Assuming muon is triggered outside HF
- **Most towers show HF Gflash has better agreement to Certified Collision Data compared to Shower Library**

Comparison with 36.1/pb good Collision Data from CMS

HF RecHit Energy at some iη towers

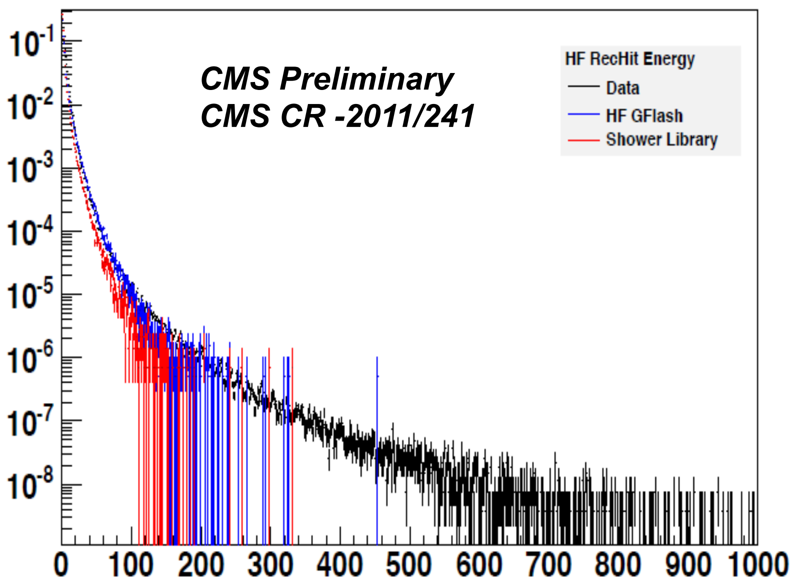
Muon Dataset triggered by muon (outside HF)

Collected certified integrated Luminosity 36 pb^{-1}

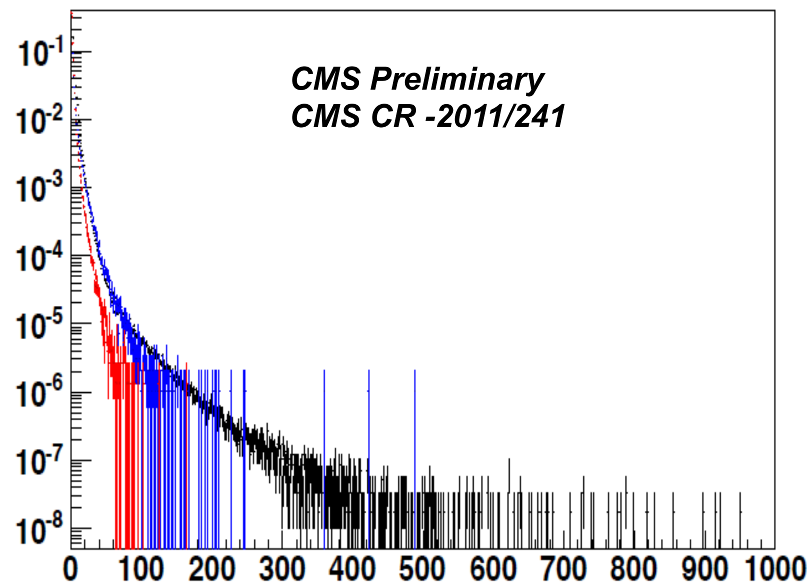
Requiring good vertex

Most towers show MC enhanced with HF GFlash has better agreement to Certified Collision Data compared to Shower Library

iη = 39

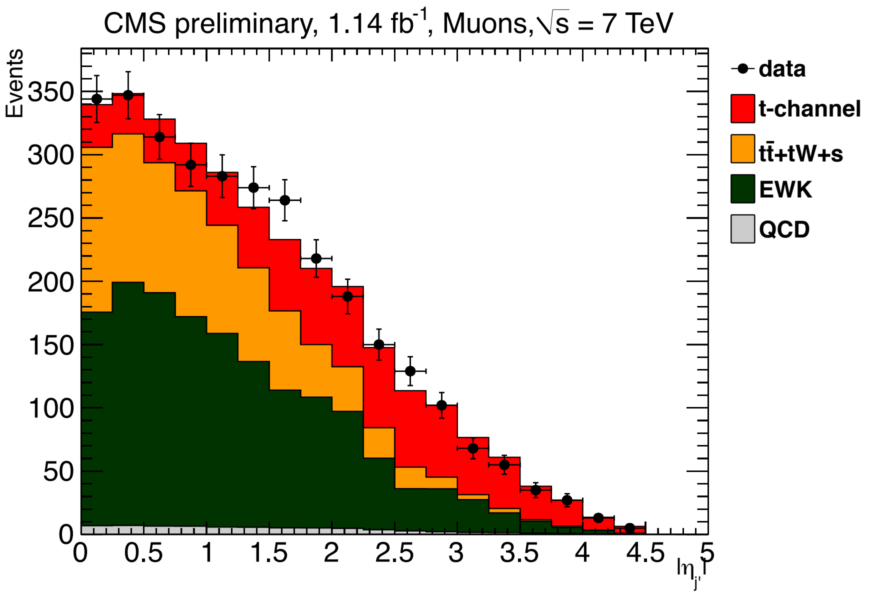


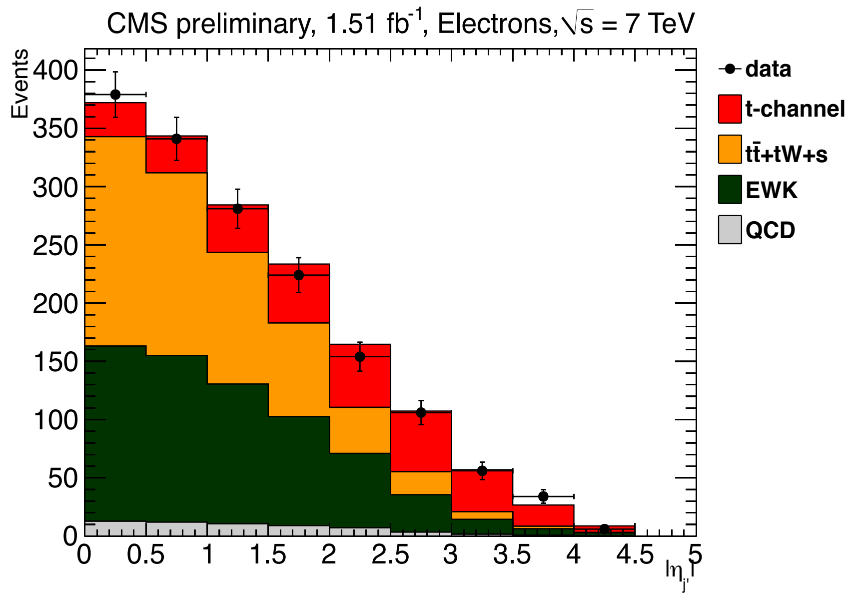
iη = -33



MC enhanced with HFGFlash has **better agreement** to 36 pb^{-1} Collision Data compared to previous simulation

Result from HFGFlash presented in many conferences





Good agreement between Data and MC (based on MC enhanced with **HFGFlash** for $3<|\eta_{jet}|<5$) of eta jet (η_{jet}) used in single top analysis (TOP-11-021)

HF Gflash Summary

We have tested HF Gflash against

1. Test Beam Data
2. Collision Data
3. Shower Library (previous HF CMS Simulation)

- HF Gflash has the ability to help Noises simulation
- HF Gflash has the ability to simulate very high energy particles
- HF Gflash has better agreement to Test Beam Data
- HF Gflash has good agreement to CMS Collision Data
- ***HF Gflash will be very useful for Super LHC and other experiments***