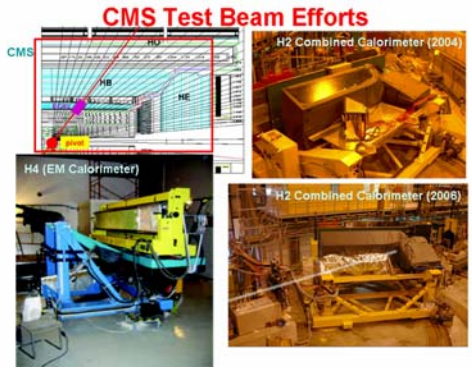
Data Driven Approach to Calorimeter Simulation

Sunanda Banerjee (on behalf of CMS Collaboration)

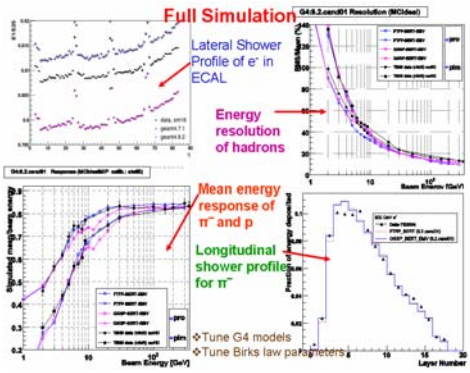
- CMS started simulation effort using GEANT3 more than a decade ago
- It has evolved to its current design through several generations
- Three complementary approaches are available
  - Start from first principles (Full Simulation)
  - Replace the calorimeter simulation inside FullSim by a set of parameterizations
  - 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.
- CMS is preparing to tune all these simulation codes to collision data from LHC.

CMS Test Beam Efforts

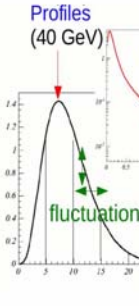


- Use electron beams at different energies in H4 test beam area to ECAL super-modules
  - Measure energy response, energy resolution, lateral shower profile, energy containment and leakage
- Use electron, muon and hadron beams at different energies in H2 test beam area to a combined calorimeter system
  - 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.

Full Simulation

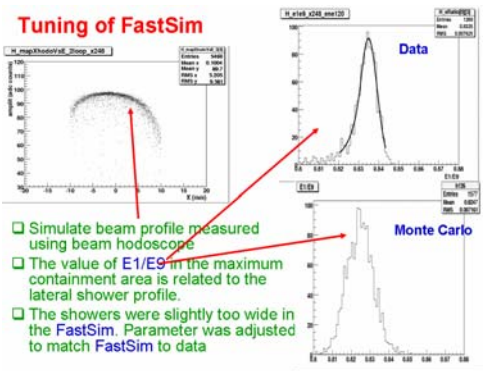


Shower Parametrization



- Showers of all particles reaching the calorimeter are simulated individually using a shower parameterization similar to GFlash approach
- Each shower is made of a number (proportional to E) of spots distributed by shower profiles
  - Generate a longitudinal slice taking care of fluctuations
  - Distribute spots using lateral profile (uniform in φ)
- Exact parameterization depends on type of initial particle (EM/Hadron)
- Map the spots to the detailed geometry to take care of all geometric effects

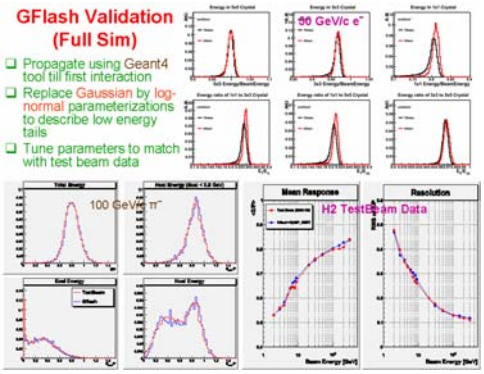
Tuning of FastSim



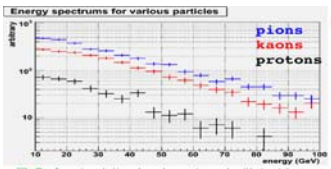
- Simulate beam profile measured using beam hodoscope
- The value of E1/E9 in the maximum containment area is related to the lateral shower profile.
- The showers were slightly too wide in the FastSim. Parameter was adjusted to match FastSim to data

GFlash Validation (Full Sim)

- Propagate using Geant4 tool till first interaction
- Replace Gaussian by log-normal parameterizations to describe low energy tails
- Tune parameters to match with test beam data



Collision Data



Combine Jet Trigger with unbiased Trigger

- So far simulation has been tuned with test beam condition without B-field and some special setups
- Need to tune simulation to collision data with LHC environment
- Isolated charged particles (pixel tracks) in collision data can be used to tune simulation (full as well as fast)
  - Low p_t (< 5 GeV): Zerobiased trigger + AlCaIsoTracks
  - Intermediate p_t (5-30 GeV): Dedicated HCAL isolated track trigger (Normal runs)
  - High p_t (> 30 GeV): worth considering only for $L > 10^{33}$ cm^{-2}s^{-1}. Dedicated HCAL isolated track trigger are considered using tracks from pixel+strip detectors
- Studies from 1 pb^{-1} and 10 pb^{-1} runs at 10 TeV, would give adequate statistics for tuning for energies up to 50 GeV.