GFLASH -
Parameterised simulation of electromagnetic shower in Geant4.7.0

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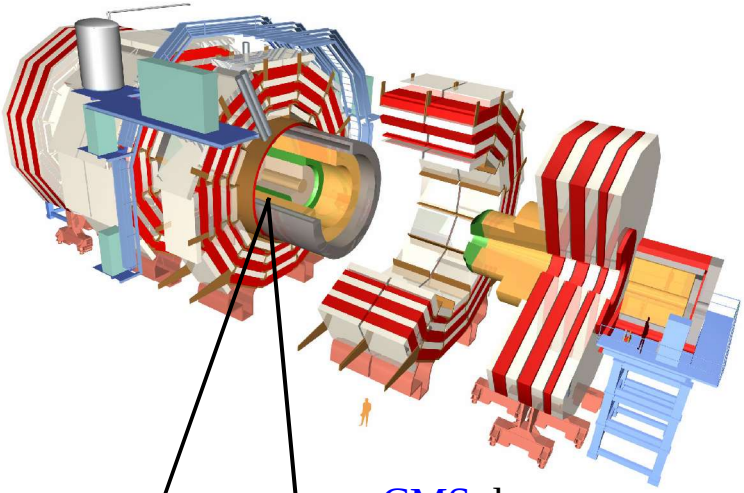
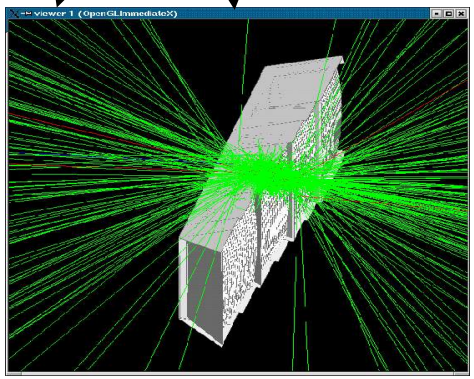
Why GFLASH ?



CMS detector



Geant4 simulation of 50 GeV shower in CMS ECAL super module (PbWO4 crystals)

Problem:

• Full simulation of LHC events is very time consuming (O (minutes/event)).

• Much CPU time is spend in simulating electromagnetic shower

Aim: Speed up full simulation (OSCAR) in electromagnetic calorimeter (ECAL)

A Solution: GFLASH package (used in H1): substitutes full tracking of high energy electrons/positrons in electromagnetic shower inside the ECAL with parametrized shower profile ->significant gain in speed, not much sacrifice in precision

Longitudinal Profile

Spatial energy distribution of electromagnetic showers is given by three probability density functions:
(hep-ex/0001020, Grindhammer & Peters)

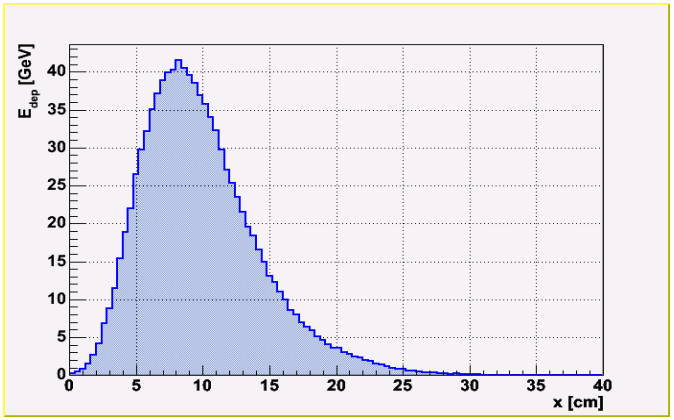
$$dE(\vec{r}) = E\, f(t)dt\, f(r)dr\, f(\phi)d\phi$$

In ϕ the energy is assumed to be distributed uniformly:

$$f(\phi) = 1/2\pi$$

Longitudinal profile parameterised by gamma function with parameters α and β:

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



Radial Profile

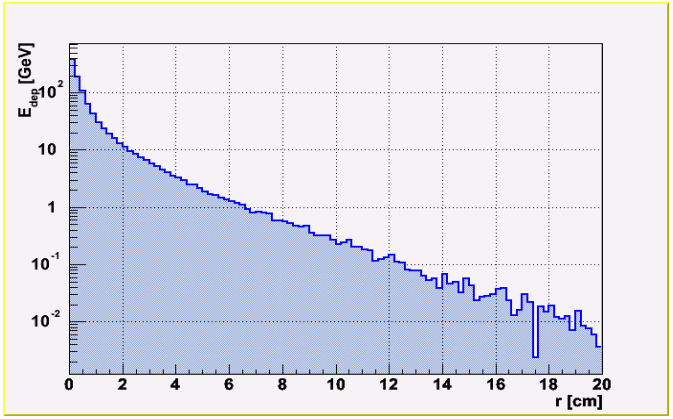
The average radial energy profile can be described by (with $0 \le p \le 1$):

$$< \frac{1}{dE(t)} \frac{dE(r,t)}{dr} > = f(r) = p \frac{2rR_{C(ore)}^2}{(r^2+R_{C(ore)}^2)^2} + (1-p) \frac{2r R_{T(ail)}^2}{(r^2+R_{T(ail)}^2)^2}$$

r := Transverse size of shower, measured in Moliere radius (R_M)

R_C (R_T) is the median of the core (tail) component

R_C (R_T) depends on the shower depth



GFLASH in Geant4

What will be available in Geant4.7.0?

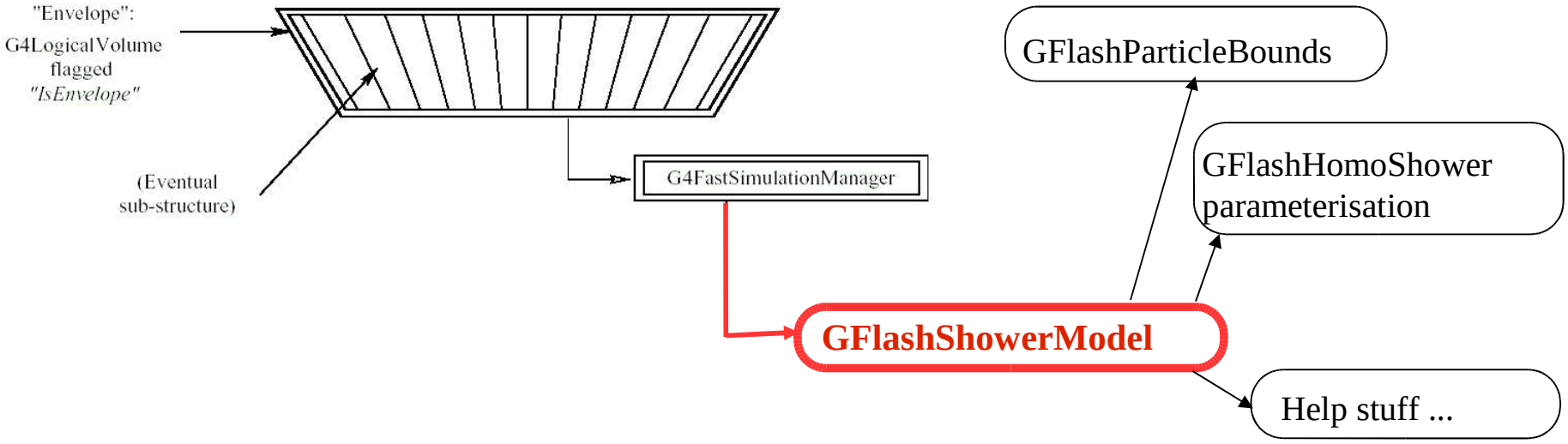
•(documented:) GFLASH library for homogeneous calorimeter & simple example how to use it

Main concept:

•Uses the Fast Shower Framework of Geant4

•Every time a particle enters envelope (G4LogicalVolume, e.g. calorimeter), trigger is called

•If certain criteria (energy bounds, particle type[@ moment: e-/e+], containment in volume) fulfilled, particle is killed and hits distributed according to calculated shower profile



Example of Use:

- In Detector Construction:

Assign GFLASH parameterisation to Envelope

```
theFastShowerModel =  new GflashShowerModel("GflashShowerModel",
                                                    calo_log);
theParameterisation = new GflashHomoShowerParamterisation
                                    (matManager->getMaterial(mat));
theFastShowerModel->SetParameterisation(*theParameterisation);
theFastShowerModel->SetParticleBounds(*theParticleBounds);
theFastShowerModel->SetHitMaker(*theHMaker);
```

- In Physics List: Add FastSimulationManagerProcess

```
G4FastSimulationManagerProcess* theFastSimulationManagerProcess
= new G4FastSimulationManagerProcess();
{
(Loop over particles and add to Process Manager)
}
```

Simple PbWO4 Cube

CPU time of full Geant 4.6.2 simulation and GFLASH shower parameterisation for a single electron (Pentium III @ 1Ghz) in an PbWO4 cube:

Electron Energy	Time / event full simulaton	Time / event GFLASH	Speed-up Factor
1 GeV	0.10	0.01	16
5 GeV	0.46	0.01	48
10 GeV	0.92	0.01	67
50 GeV	4.60	0.04	103
100 Gev	9.37	0.08	117
500 GeV	46.50	0.31	149
1000 GeV	91.75	0.57	162

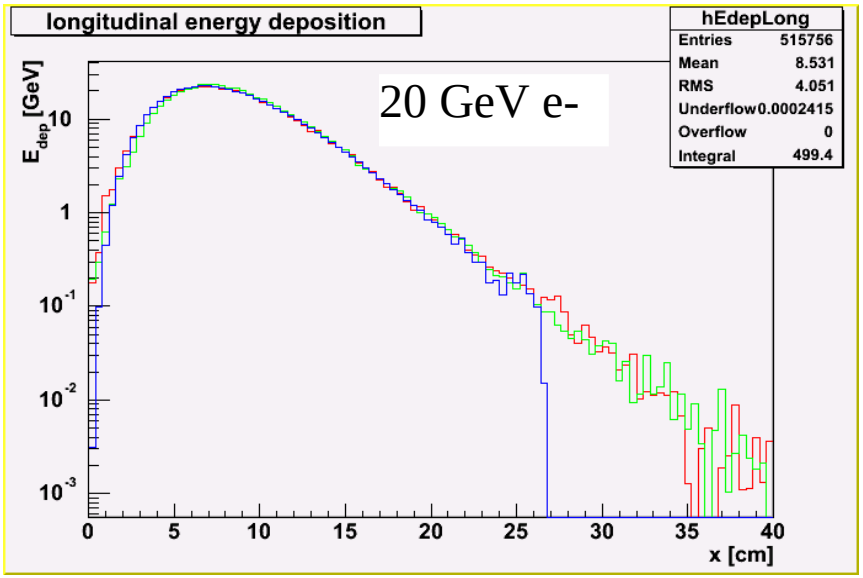
Results quite promising :-);

Simple PbWO4 Cube (2)

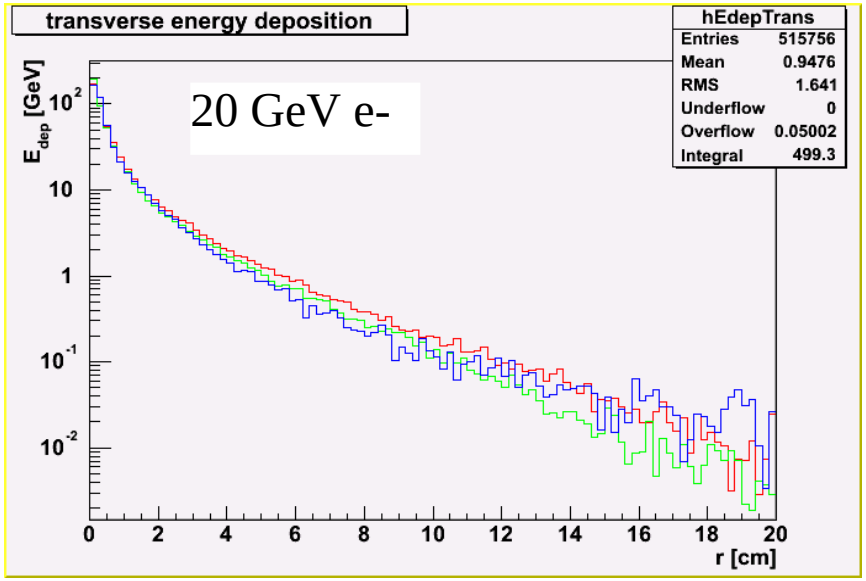
Only problem: GFLASH parameters obtained from Geant3.

-> For G(4)FLASH retuning can be necessary (radial profile).
For experiment specific geometries retuning often necessary anyway, therefore it is possible to pass user-tuned parameters:

*GFlashHomoShowerParamterisation(G4Material * aMat,*
*GVFlashHomoShowerTuning * aPar)*

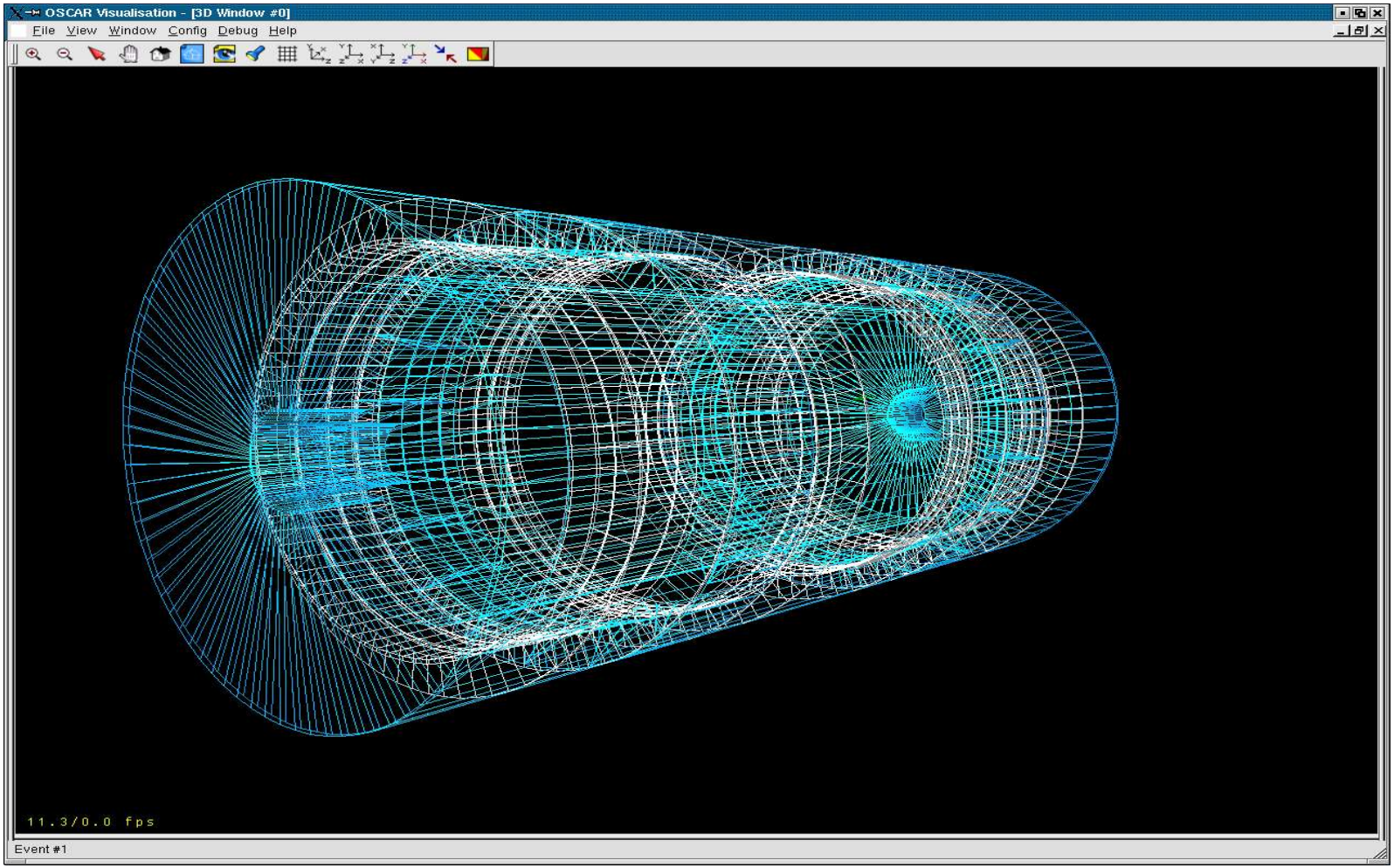


Geant 4.6.2 / Geant3 / GFLASH



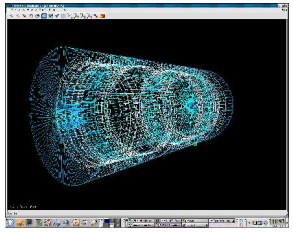
Geant 4.6.2 / Geant3 / GFLASH

OSCAR Simulation



Visualization of CMS ECAL with OSCAR / IGUANACMS
(http://cmsdoc.cern.ch/oscar, http://iguanacms.web.cern.ch/iguanacms)

CMS ECAL simulation



CPU time of full Geant 4.6.2 simulation and GFLASH shower parameterization for a single electron (Pentium III @ 1Ghz) inCMS ECAL simulation(OSCAR):

Electron Energy	Time / event full simulaton	Time / event GFLASH	Speed–up Factor
1 GeV	2.30	2.10	1
5 GeV	3.40	2.10	2
10 GeV	4.90	2.10	2
50 GeV	15.70	2.20	7
100 Gev	28.70	2.40	12
500 GeV	144.30	3.60	40
1000 GeV	281.90	4.83	58

Further plans

- Design iteration to extend for sampling calorimeter
(together with ATLAS group[E.Barberio])

- Setup of (partial) tuning infrastructure:
tuning means refit of (energy dependent) parameters in the shown equations for radial and longitudinal profile (details in *hep-ex/0001020*)
-> especially for radial profile not trivial :-(

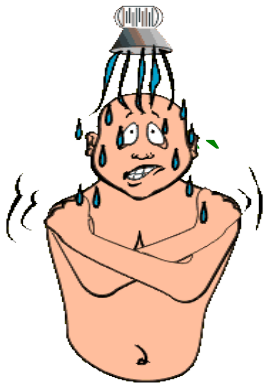
- Improved handling of sensitive detectors:
At the moment one should be careful with
ProcessHits(G4Step *aStep, G4TouchableHistory *)
(mandatory method invoked when step is composed in sensitive detector): Infos available with full tracking not available in fast parametrization e.g. track information (since there is no track...)
Possible solutions : Flag to check if parametrization active ...
-> Discussion about other solutions in progress

Conclusions

• (First) GFLASH implementation will be available in **Geant4.7.0**

• Is easy to use and provides the possibility to significantly speed up (electromagnetic) shower simulation

• For complicated geometries or if more precision necessary, GFLASH parameters should be tuned by the user
(tuning tools development in progress)



You are invited to try a GFLASH "Fast Shower" and give us Feedback!