The fast simulation for FCC in GEANT, first experience integrating ATLAS tracker tool

LHeC Workshop
25 June, 2015

Anna Zaborowska
Federico Carminati, Benedikt Hegner, Alberto Ribon

Fast simulation

- Physics studies: analyses to determine the detector performance;
- Detector performance studies: testing the detector models;

Fast simulation

- Physics studies: analyses to determine the detector performance;
- Detector performance studies: testing the detector models;

Geant4

- Geant4 is a ready framework for **full** simulation studies.
- It is important to have both **fast** and **full** simulation together in one framework, so they could share common blocks.

with Geant4 group (Federico, Alberto, ...)

Fast simulation

- Physics studies: analyses to determine the detector performance;
- Detector performance studies: testing the detector models;

Geant4

- Geant4 is a ready framework for **full** simulation studies.
- It is important to have both **fast** and **full** simulation together in one framework, so they could share common blocks.

with Geant4 group (Federico, Alberto, ...)

GAUDI

- common software framework

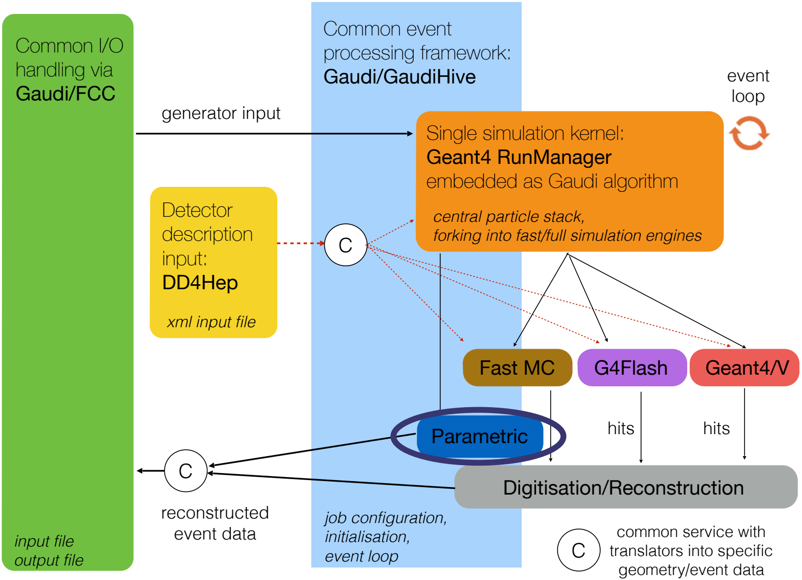
with FCC Software group (Benedikt, ...)

DD4hep

- geometry

Julia Hrdinka and Andi Salzburger

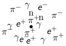
Common software framework



A. Salzburger

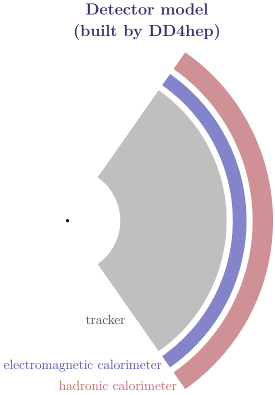
Basic concept of fast simulation

Event generation
(HepMC)



- Particle generation (PID, energy, vertex momentum and position);

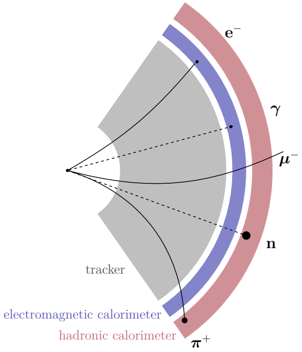
Basic concept of fast simulation



- Particle generation (PID, energy, vertex momentum and position);

Basic concept of fast simulation

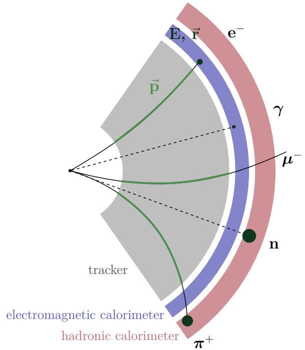
Particle propagation



- Particle generation (PID, energy, vertex momentum and position);
- Propagation of particles in the magnetic field;

Basic concept of fast simulation

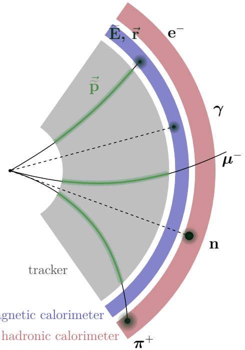
Momentum, energy deposit and position



- Particle generation (PID, energy, vertex momentum and position);
- Propagation of particles in the magnetic field;
  - Information on the true particle $\boldsymbol{p}$;
  - Information on the true energy deposits $\boldsymbol{E_{emcal}}$ and $\boldsymbol{E_{hcal}}$;

Basic concept of fast simulation

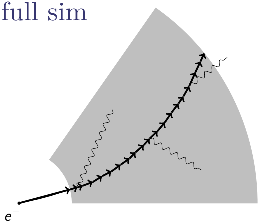
Smearing momentum and energy deposit



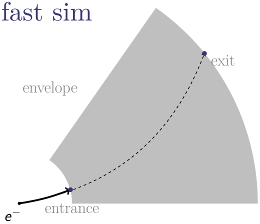
- Particle generation (PID, energy, vertex momentum and position);
- Propagation of particles in the magnetic field;
  - Information on the true particle $\boldsymbol{p}$;
  - Information on the true energy deposits $\boldsymbol{E_{emcal}}$ and $\boldsymbol{E_{hcal}}$;
- Smearing of $\boldsymbol{p}$, $\boldsymbol{E_{emcal}}$ and $\boldsymbol{E_{hcal}}$ (gaussian);
  - Keep track of a resolution $\boldsymbol{\sigma}$ used for smearing each track in all cases;

Geant 4

full sim



fast sim



full simulation:

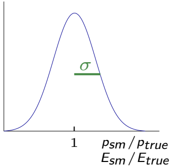
- normal transportation (step by step, taking into account possible physics processes);

fast simulation:

- G4FastSimulationModel attached to each G4Region (envelope)
- G4FastSimulationManagerProcess takes over ordinary transportation at the entrance point to the G4Region:
  - calculation of the position at the exit using G4PathFinder (G4CoupledTransportation)
  - proposing new, smeared momentum:
    - Smearing using given resolutions (I);
    - Smearing using more complex resolutions (dependent on the detector model) - reusing AtlFast approach (II);

ATL-PHYS-98-131

(I) Resolutions for momentum/energy smearing



To determine how resolutions affect physics analyses.

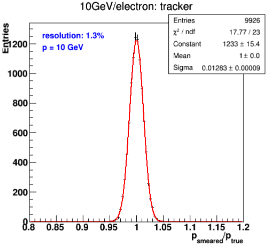
Smearing of the momentum in the tracker and energy in the calorimeter.
$\boldsymbol{\sigma}$ - standard deviation of the smearing distribution (resolution).

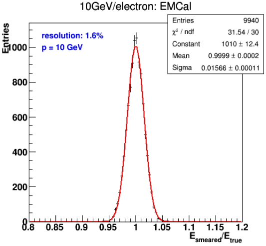
$$\boldsymbol{\sigma} = \boldsymbol{\sigma}\left(|\vec{\boldsymbol{p}}|, \mathrm{PDG}, \mathrm{detector}\right)$$

Example resolutions:
CMS-like

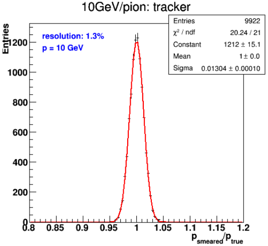
Tracker	1.3%
EM calorimeter	$\frac{3\%}{\sqrt{\mathrm{E}}} \oplus \frac{12\%}{\mathrm{E}} \oplus 0.3\%$
Hadron calorimeter	$\frac{110\%}{\sqrt{\mathrm{E}}} \oplus 9\%$

(I) Smearing results using CMS resolutions



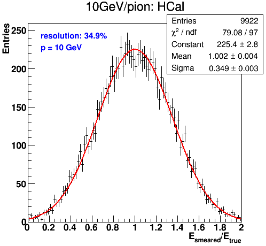


Electrons
10k e^-
10 GeV



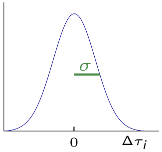
Pions
10k π^+
10 GeV

For now, assuming shower only in HCAL; Early showering in ECAL to be addressed;



Example of smearing in a standalone G4 fast-sim

(II) Resolutions from AtlFast



To test the detector models.

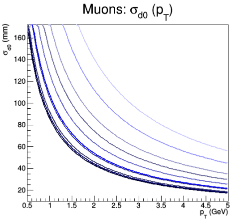
Smearing of the track perigee parameters.

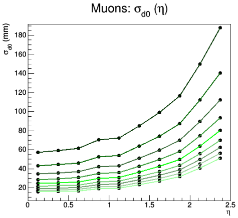
$$\tau_i = \{d_0, z_0, \phi_0, cot\theta, q/p_T\}$$

d_0 transverse impact parameter;
z_0 longitudinal impact parameter;
ϕ_0 azimuth angle at point of closest approach;
$cot\theta$ polar angle;

q/p_T charge over transverse momentum magnitude;

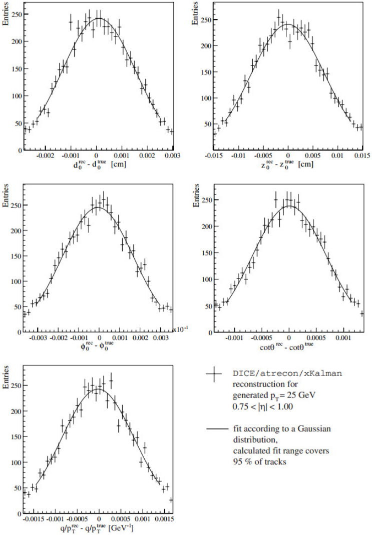
Example resolutions - parametrised in data files (detector dependent):



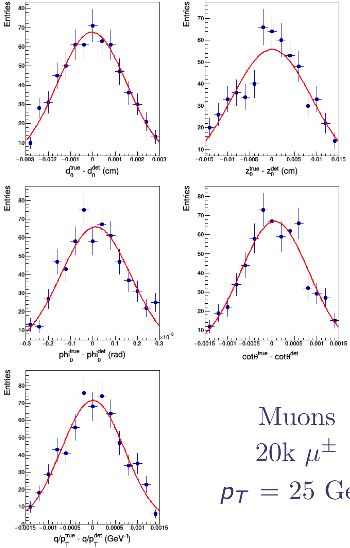


Resolutions valid for ATLAS Inner Detector

(II) Residuals of track parameters: Δd_0, Δz_0, $\Delta\phi_0$, $\Delta\cot\theta$,$\Delta q/p_T$ using AtlFast resolutions



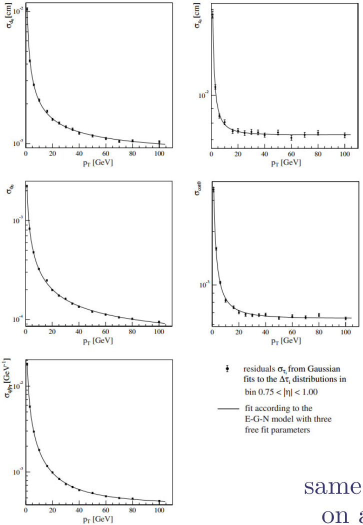
CERN-THESIS-2004-051 Fig. 6.3.



Example of smearing in a standalone G4 fast-sim
20k muons , $|\eta| < 5.5$

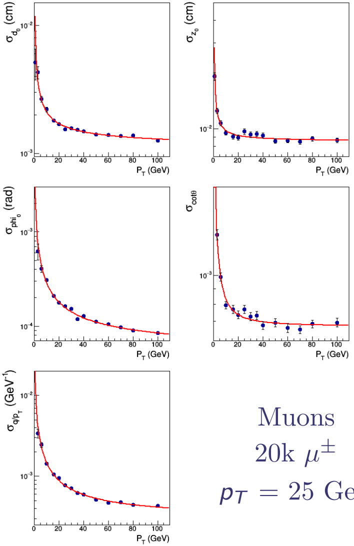
Muons
20k $\mu^\pm$
$p_T = 25$ GeV

(II) Gaussian standard deviations $\sigma_{\tau_i}(p_T)$ obtained from fits to the residual functions $\Delta\tau_i$



CERN-THESIS-2004-051 Fig. 6.5.

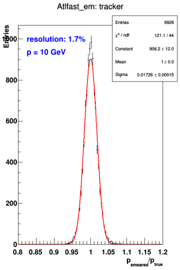
same scale on axes



Example of smearing in a standalone G4 fast-sim
20k muons , $|\eta| < 5.5$

Muons
20k $\mu^{\pm}$
$p_T = 25$ GeV

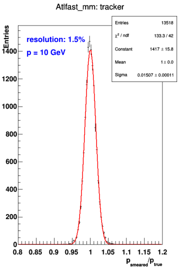
(II) Smearing results using AtlFast resolutions



Electrons

10k e^-

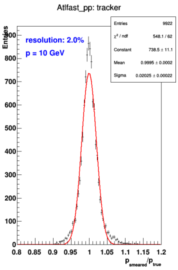
10 GeV



Muons

10k μ^-

10 GeV



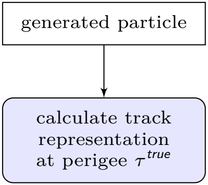
Pions

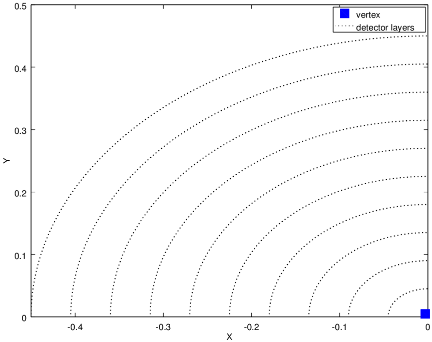
10k π^+

10 GeV

Example of smearing in a standalone G4 fast-sim

(II) Obtaining resolutions



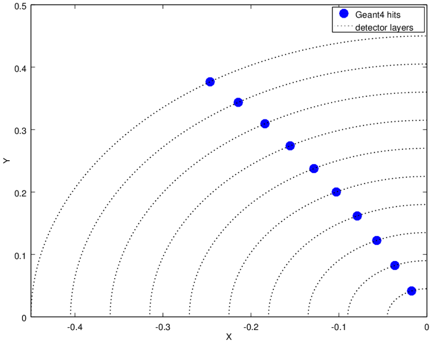


(II) Obtaining resolutions

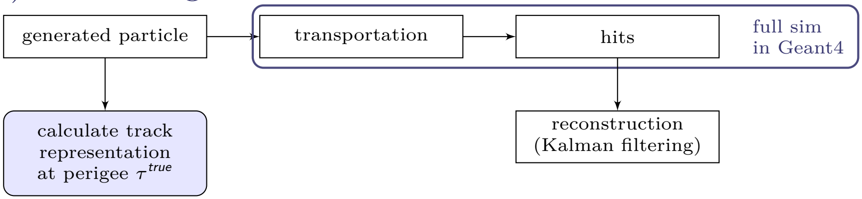
generated particle → transportation → hits (full sim in Geant4)

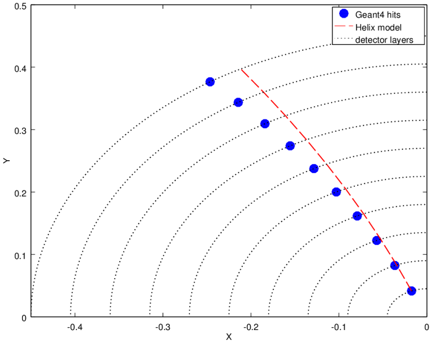
generated particle ↓

calculate track representation at perigee τ^{true}

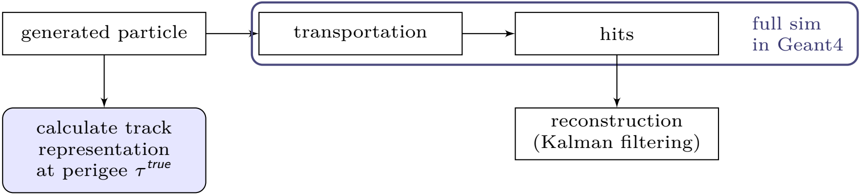


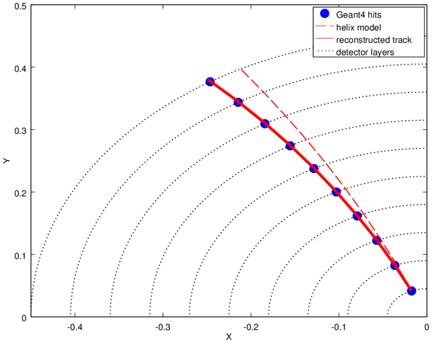
(II) Obtaining resolutions



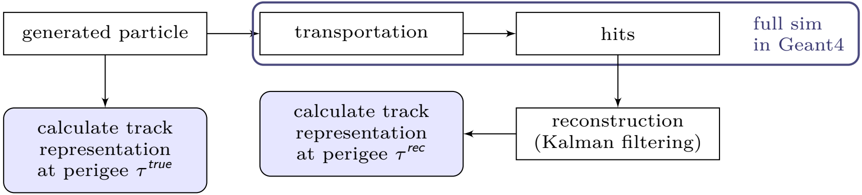


(II) Obtaining resolutions

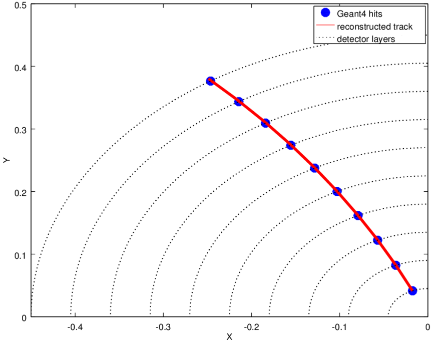




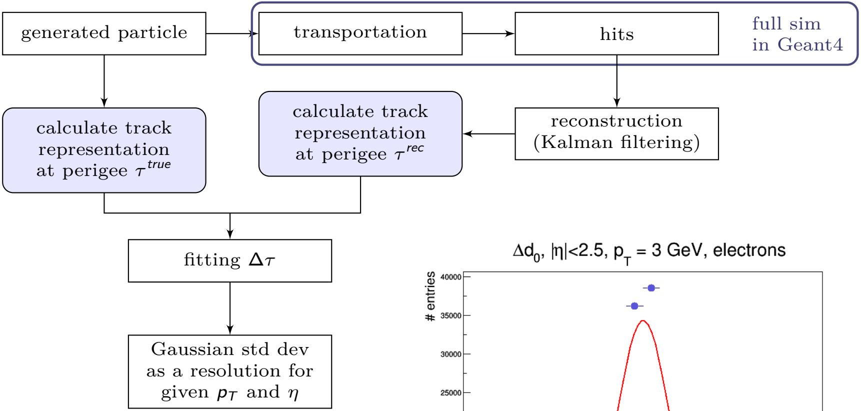
(II) Obtaining resolutions



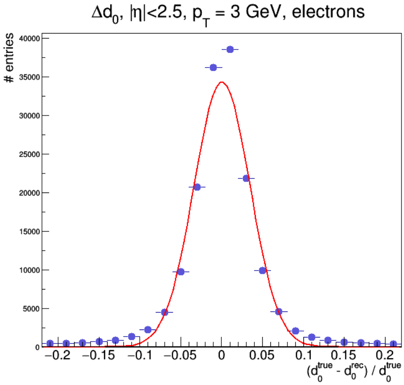
Single-particle reconstruction



(II) Obtaining resolutions



Single-particle reconstruction



Tracker & calorimeters

Kalman reconstruction from hits in the tracker layers takes into account:

a interaction with matter: *multiple scattering*;

b detector *intrinsic resolution*;

Tracker & calorimeters

Kalman reconstruction from hits in the tracker layers takes into account:

a interaction with matter: *multiple scattering*; ⟶ affects the particle

b detector *intrinsic resolution*; ⟶ affects the measurement

The resolution (a) should be disentangled from (b).

Only resolution (a) should be taken into account to calculate the position and momentum at the entrance to the calorimeter.

Summary

- FCC fast simulation with Geant4: first working prototype:
  - standalone Geant4 (using GDML as detector input and Pythia8 + HepMC as particle generator);
  - integration into the common software framework (GAUDI);
- two possible types of smearing:
  - (I) using pre-defined pT-dependent resolutions (eg. as in CMS, ATLAS or ALEPH);
  - (II) using AtlFast-like resolutions read from data files;
- progress reported (and discussed) on frequent basis in informal FCC weekly SW meetings;

On-going work:

- single particle reconstruction based on Kalman filtering to adress the second smearing approach;
- building the tool to generate the data files used for parametric smearing;

Plans:

- integration of single-particle reconstruction into GAUDI;
- extending the fast (parametric) simulation (efficiency, misidentification, separation in the calorimeters ...);