Object Oriented reconstruction of the CMS muon chambers

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Abstract

I present the Object Oriented Design of the software which performs the simulation and the reconstruction for the CMS muon chambers.

I illustrate the following phases of the process:

- requirements
- static design
- dynamic design
- code implementation

Persistency in an Objectivity database is introduced in order to save the products of the simulation and the GEANT hits informations.

The analysis of the data recorded using a prototype of a muon chamber layer during the test beam of Summer 1999, performed with the OO Muon code, is also discussed.

1 Introduction

The software for the simulation and the reconstruction used by the muon chambers of the Compact Muon Solenoid (CMS) experiment currently includes both C++ modules, integrated in the more general OO frame, and Fortran routines which allow the usage of the GEANT package for the simulation of the response of the detector to the generated physics events.

2 Software design

The main steps in the simulation of the response of the chamber and in the reconstruction of the track are:

- digitization: It is the detector response (time) to the ionization produced by a charged particle crossing the active volume of the chamber, i.e. the conversion of the *hits* from GEANT into *digi*;
- calibration: It is the conversion from the times (*digi*) to positions inside the detector;
- local reconstruction: It is the reconstruction of track segments inside a station;
- global fit: It is the combination, using a Kalman filter, of the local track segments with the evaluation of the relevant physics quantities of the charged particle (momentum, charge, direction).

As it is the chamber that have to deal with the first three actions, the "chamber" object was designed as shown in figure 1.

This ensures that the three actions (digitization, calibration and local reconstruction) under the "chamber" responsibility and demanded to the objects $DIGI\_CHAMBER$, $CALIB\_CHAMBER$ and $LOCAL\_CHAMBER$ are done only if required.

In a similar way the global fit is performed only on demand (figure 2).

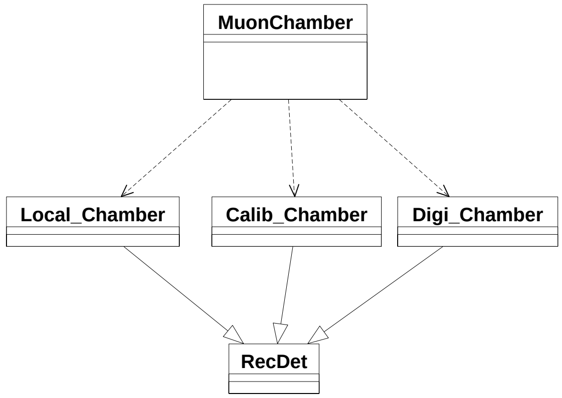

Figure 1: Muon Chamber design

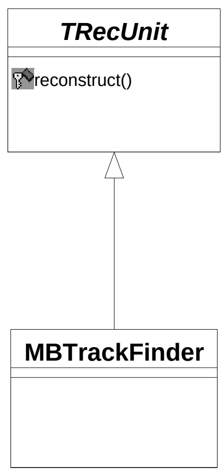

Figure 2: Muon Track Finder design

Finally the extensive use of patterns like abstract FACTORY and VISITOR, ensures a straightforward definition of different algorithms for each of the parts mentioned.

3 Results

The resolution on the track momentum of the fitted track is expressed in terms of $\Delta p_T/p_T$, i.e. in term of fractional error on p_T:

$$\frac{\Delta p_T}{p_T} = \frac{(1/p_T^{meas} - 1/p_T^{gen})}{1/p_T^{gen}} \tag{1}$$

In figure 3 the distribution of the residuals of $1/p_T$ fitted with a Gaussian for muon of $5-100$ GeV is shown (this fit procedure includes only the set of position measured by the muon system). The central value is greater than zero due to the energy loss (hard photon bremsstrahlung).

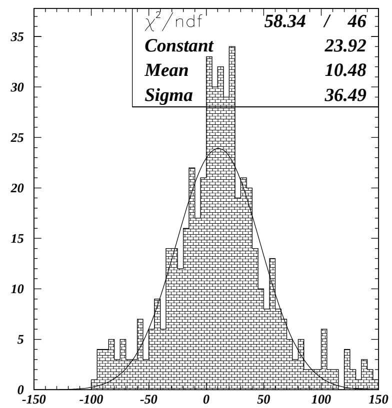

Figure 3: $1/p_T$ residual distribution for 100 Gev muons using only the muon system

Furthermore since the curvature decreases as $1/p_T$, at high momentum the bias in the central value of the residual leads to uncertainties in the assignment of the charge of the particle.

The momentum resolution as a function of p_T is shown in figure 4 (this estimate uses a constraint of the vertex point).

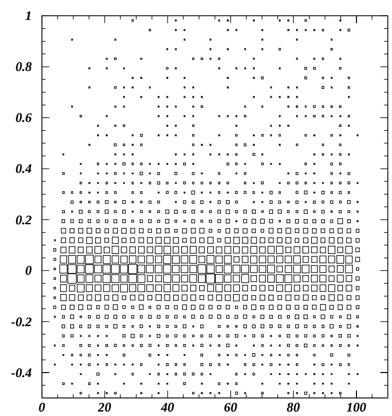

Figure 4: $\Delta p_T/p_T$ versus generated p_T using a vertex constrain

At low p_T the resolution on the track momentum is dominated by the multiple scattering. At high p_T, the error on the curvature, increasing linearly with p_T, becomes dominant.

The efficiency in the track reconstruction as a function of the momentum is shown in figure 5 in the range $5 < p_T < 100[GeV/c]$. This result was obtained using 10^4 events (prompt muons) generated in the overall detector acceptance ($|\eta| < 0.8$) but with no requirement on the trigger response in the event.

4 Developments

The first application of the OO reconstruction package for the muon chamber was the analysis of the data taken with a prototype chamber in a test beam performed at CERN SPS in August 1999, for which a program, with a structure equivalent to the one used for the analysis of the simulated data, was developed.

In November 1999 a production of Monte Carlo minimum bias events was performed using the software for the digitization capable to write the *digi* into an object database (Objectivity) and

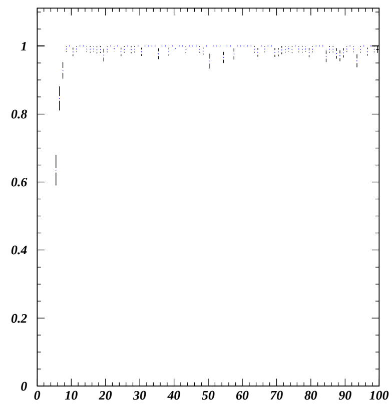

Figure 5: Efficiency versus generated p_T

then using the software described above for the reconstruction of the muon tracks up to the global fit.

This extensive use allowed to test, besides its performances, the versatility and the handiness of the software for the simulation and the reconstruction.

References

1 CMS Collaboration, “CMS - The Muon Ptoject - TDR”, 15 December 1997.