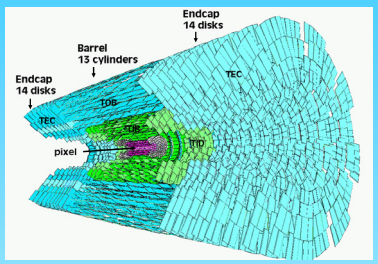
CMS TRACKER VISUALISATION TOOLS

M.S. MENNEA,[a] G. ZITO,[a] A. REGANO [a] AND I. OSBORNE [b]
[a] Dipartimento Interateneo di fisica di Bari & INFN sezione di Bari, Italy
[b] Northeastern University, Boston, USA

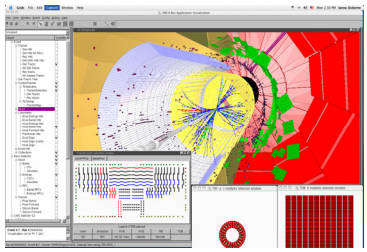
The CMS tracking system is a very complex sub-detector with more than 17000 modules each one a complete detector.

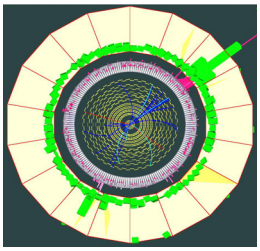
The designed goal of the central tracker system is to reconstruct isolated high Pt tracks with an efficiency of better than 95%, and high Pt tracks within jets with an efficiency of better than 90% over the rapidity range $\eta < 2.6$. Important discoveries may depend on the ability of the tracking system to perform efficient b-tagging even at the highest luminosity.



CMS experiment has chosen to build a visualisation tools for detector called IGUANACMS based on IGUANA, to provide basic 3D capabilities and integration within CMS framework. IGUANA provides an MDI (multi-document interface) GUI (graphical user interface) with:

- 3D representation of both detector and event objects.
- Standard projections of 3D
- Layered 2D projections

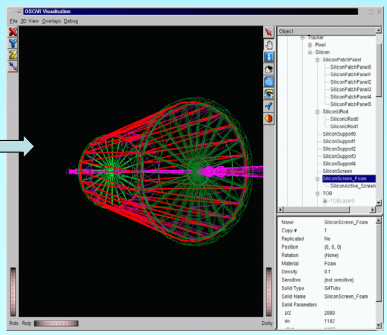




Visualisation tools are used for debug and monitor the CMS tracker sub-detector hardware, event simulation and reconstruction algorithms and also used for the test-beams and physics analysis

Tracker Geometry Visualisation

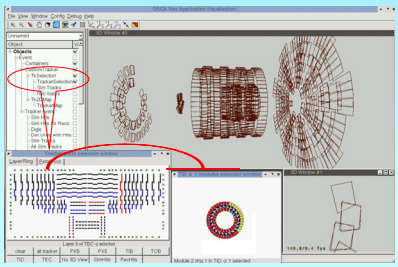
The CMS tracker geometry is fully described in DDD (detector description database) in XML format.This description is converted to the GEANT4 one and visualised whith OSCAR visualization in IGUANA. The description is very detailed such as materials, sensitive detectors and support structure as well as cables is available. The possibility to visualize volumes by material and other filters.



The standard CMS visualisation tools have been complemented with a detailed object model of the tracker and an additional 2D graphics objects for:

1 - tracker parts selection

2 - select single modules in a layer



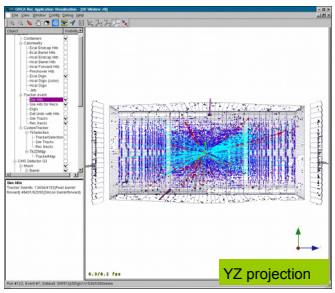
1 - Selection of tracker parts
Introducing a 2D schematic representation of the tracker parts,the user select each part (subdetector,layer,ring) by clicking on its representation on the image.One single bar represents a ring of a layer.The blue bars represent the rings with stereo modules. Whole parts of tracker can be selected with additionals buttons called PXB, PXE, TIB, …..

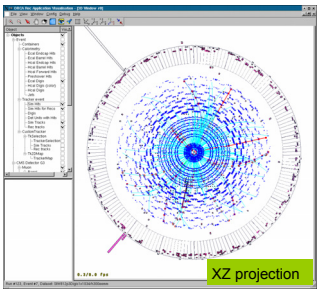
2 - Selection of single module
Window that can be used to select single modules in a layer. 2D representation of the barrel cylinder or endcap disk. The rings consisting of stereo modules are drawn with two different colors: yellow and blue, so the user can select both the modules in a stereo pair.

Simulated and Reconstructed Event Visualisation

The purpose of the simulated signal is to verify whether the data cards given to production produced correct results from the physicist point of view. It is also possible to verify the correctness of described tracker geometry by matching simulated data (sim hits) and sensitive detector units.
Simulated tracks are shown as straight lines connecting the sim hits (shown as dots) belonging to the simulated track. The simulated tracks contain color-coded information about particle type: muons are shown red, electrons - green, pions - blue, the rest of charged particles - cyan. This information comes from the first sim hit which knows about the particle id.

Event with high luminosity 10^{34} (signal event plus pileup)

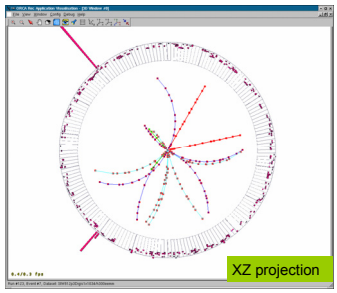




REDUCING EVENT COMPLEXITY

Simulated tracks and simulated hits can be filtered, the parameters of the filters are given interactively.
Both sim tracks and sim hits selected for visualisation use the same filters.

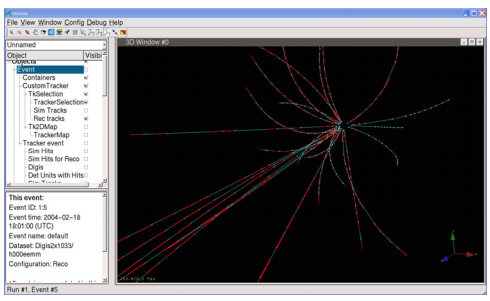
Higgs -> ZZ -> $e^+e^-\mu^+\mu^-$

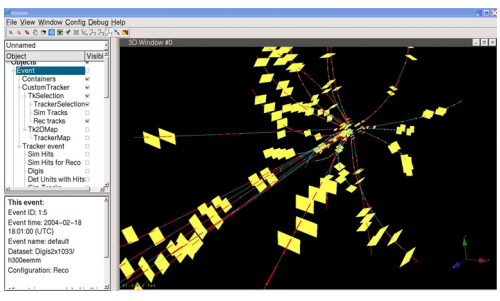


Visualisation of the reconstructed event for ORCA - CMS reconstruction project - is used for verication of the digitization and reconstruction algorithms. A user has a possibility to check that simulated data (sim hits) belong to the detector units and all detector units are active, e.g. all detector units have sim hits. In addition he can match the simulated data to digis (signal) and reconstructed data.

Reconstructed tracks are shown as straight lines connecting the measurements produced by reconstruction .

The rec hit is a reconstructed signal which is a point in space and for the stereo detector units it has a precise position in 3D. The rec hits from the rest of the detector units have a point with an error equal to the silicon channel length. We visualize the rec hit as a 3D point for the stereo detector units and a strip is shown for the rec hist which are not matched to the stereo detector units. During visualisation a user can zoom closely to see both a sim hit and a rec hit.





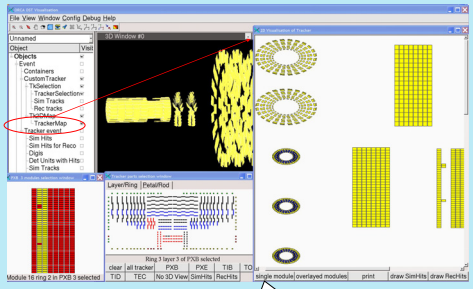
Module selection technique contribute to clarify also the most complex event.

CMS TRACKER VISUALISATION TOOLS

SCHEMATIC TRACKER REPRESENTATION

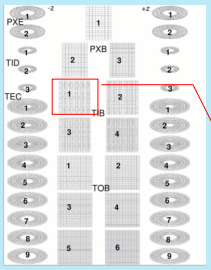
Need for a specialized representation for monitoring

Selecting "TrackerMap" twig a white windows frame will appear, where the user could visualize a **2D schematic representation** of each selected (by selection window) single layer of tracker.



Button in "All Tracker" mode

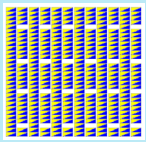
The **2D schematic representation** shows all modules at once in a single computer screen with single modules information coded in some way. We imagine to disassemble the whole tracker and to assemble it again on a flat surface putting the single modules in positions which are connected to their spatial position. The result is a kind of map of the whole tracker with each one of the 41 layers in a different position.



PXE pixel endcap
PXB pixel barrel
TID tracker inner disks
TIB tracker inner barrel
TEC tracker endcap
TOB tracker outer barrel

Two ways to represent the single modules.

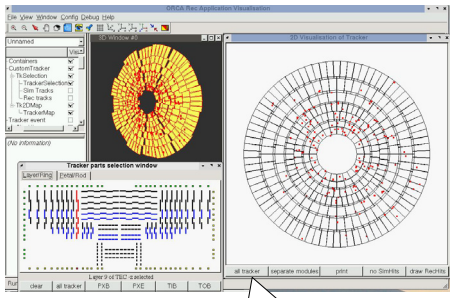
1 - Separated – by representing each module with a polygon in a different position . This is especially useful when you want to display separately the modules in a stereo pair (the yellow and blue triangles).



2 - Overlayed – by keeping the relative position of each module with its neighboring modules in order to show how modules overlap in space.

Going to the level of the single channel

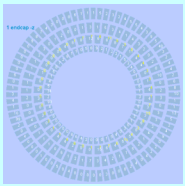
There are a few hundred channels for each module corresponding to strips or pixels.
The user can select (by selection window) a single layer of the 41 that form the tracker.



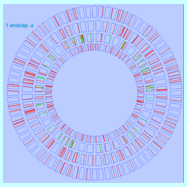
Button in "Single Module" mode

At this level it should be possible:

To write the value of the information represented: for example the number of the fired strips on the module



To represent fired strips

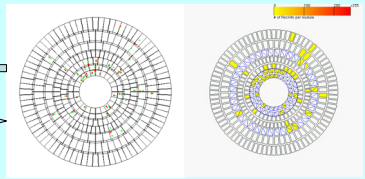


To represent reconstructed and simulated hits .In the overlayed mode they are represented by single points in red and green respectively.In the separated mode we represent them by using a color code proportional to the number of hits in the module

for barrel layer

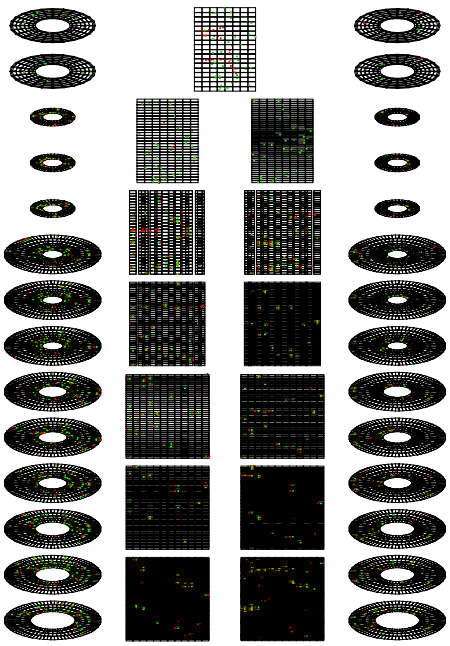
and

for endcap disk



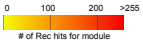
Tracker map use

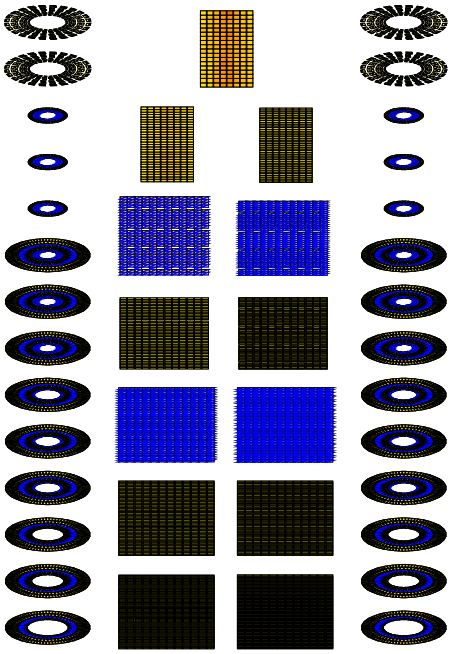
For event data: rec hits and sim hits visualisation



For monitoring: many events accumulation

This separated mode map for monitoring is obtained by accumulating the signal from one hundred events and coloring each module according the total number of hits in the module.Such a map can show quickly, during data taking, if there are problems by the presence of holes or increased activity. The same technique is used to monitor other detector running conditions, like temperature or voltages.





References

1. "*CMS Tracker Visualisation*" , Mennea,M.S; Regano,A; Zito,G. CMS-NOTE-2004-00 9; Geneva : CERN, 08Jun2004
2. "*IGUANA Architecture, Framework and Toolkit for Interactive Graphics*", G. Alverson, G. Eulisse, S. Muzaffar, I. Osborne, L.A. Tuura, L. Taylor - CHEP03, La Jolla, California March 24-28, 2003.