Introduction to CMS Software

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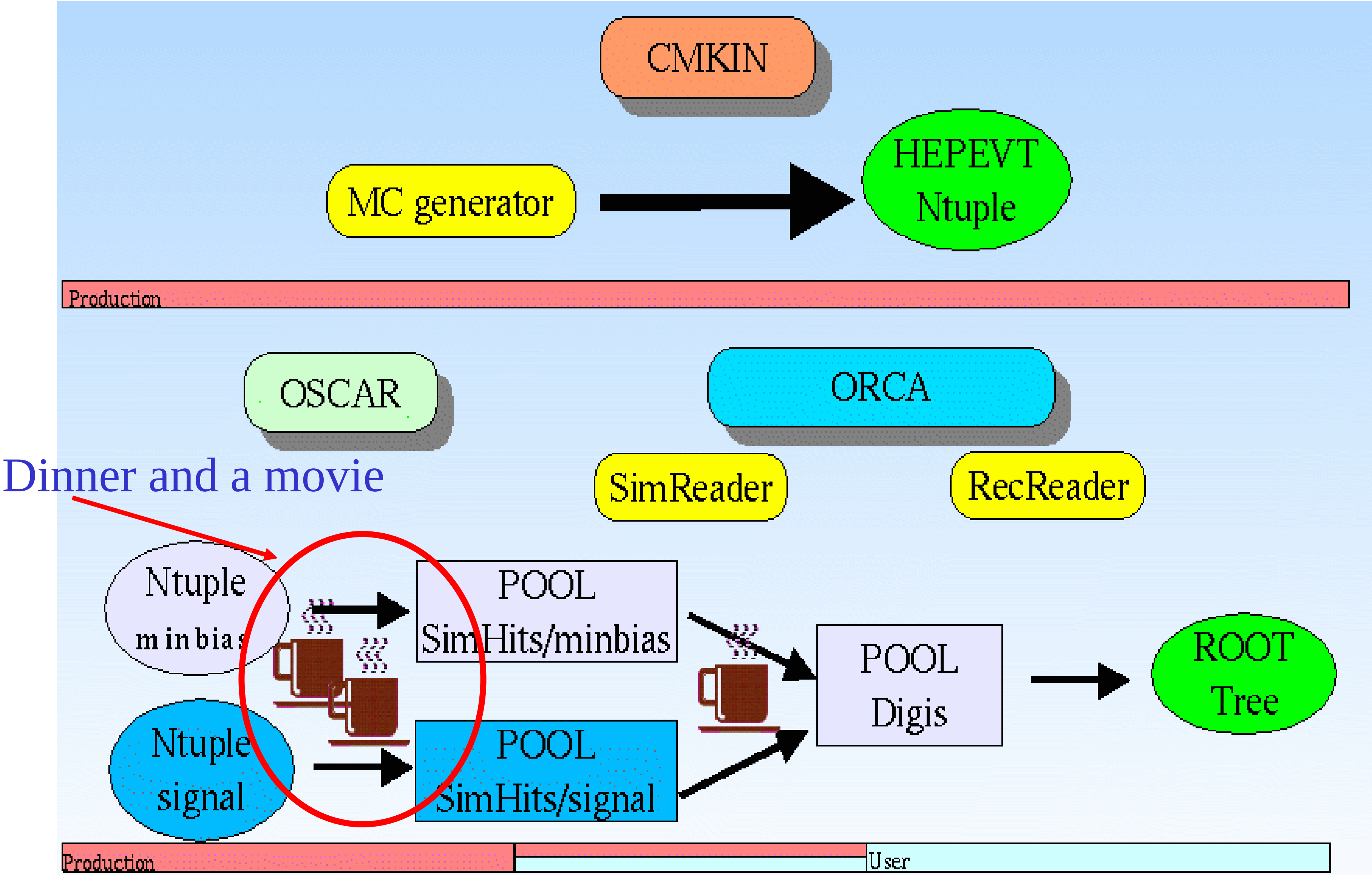
(Mostly Stolen from Hans Wenzel)

- CMS Software Overview
- New versus Old Framework
- Tutorials/Getting Started
- Reconstruction Algorithms

The Analysis chain (current/old framework)



Software Projects

CMKIN:
Interface to Generators

COBRA:
Software
Framework

OSCAR:
Geant-4 Simulation of
Particle Interaction with
Detector Material

FAMOS:
Parameterized (Fast)
Simulation

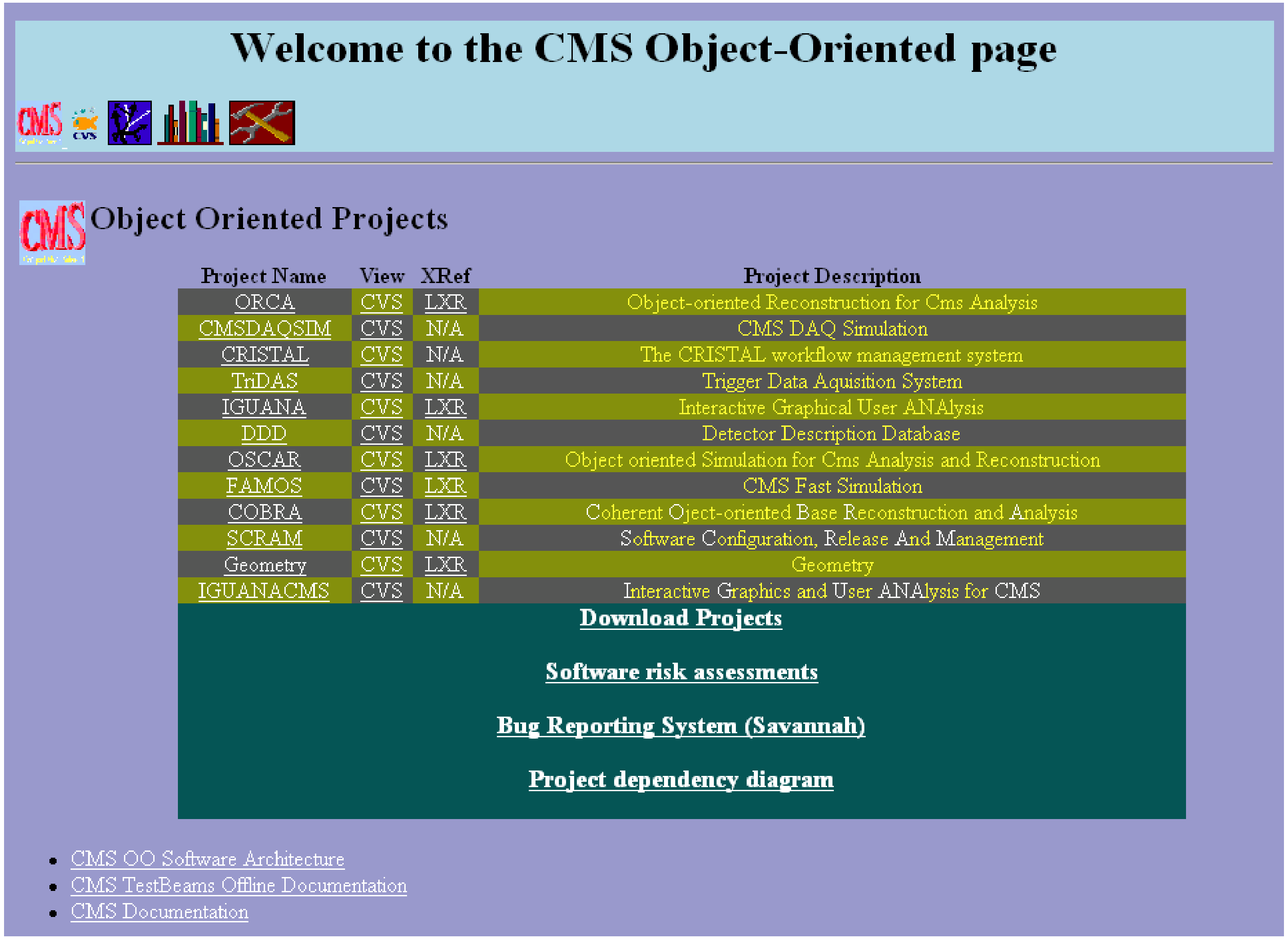
IGUANA:
Visualization Framework
(Event Display)

ORCA:
Simulation of Electronic
Signals and Event
Reconstruction

Geometry
XML
description

Code Browsers

http://cmsdoc.cern.ch/cmsoo/cmsoo.html



Welcome to the CMS Object-Oriented page

Object Oriented Projects

Project Name	View	XRef	Project Description
ORCA	CVS	LXR	Object-oriented Reconstruction for Cms Analysis
CMSDAQSIM	CVS	N/A	CMS DAQ Simulation
CRISTAL	CVS	N/A	The CRISTAL workflow management system
TriDAS	CVS	N/A	Trigger Data Aquisition System
IGUANA	CVS	LXR	Interactive Graphical User ANAlysis
DDD	CVS	N/A	Detector Description Database
OSCAR	CVS	LXR	Object oriented Simulation for Cms Analysis and Reconstruction
FAMOS	CVS	LXR	CMS Fast Simulation
COBRA	CVS	LXR	Coherent Oject-oriented Base Reconstruction and Analysis
SCRAM	CVS	N/A	Software Configuration, Release And Management
Geometry	CVS	LXR	Geometry
IGUANACMS	CVS	N/A	Interactive Graphics and User ANAlysis for CMS

Download Projects

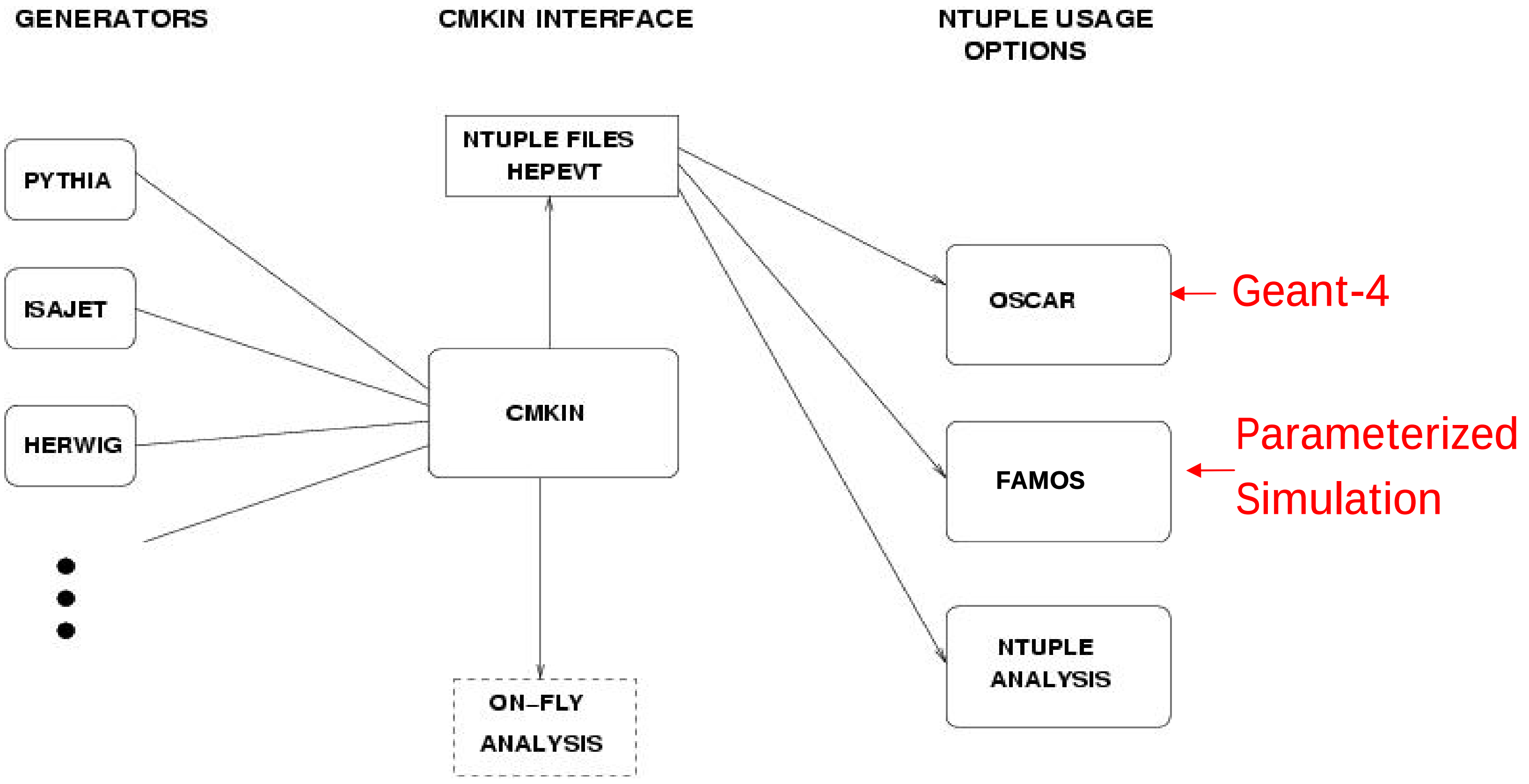
Software risk assessments

Bug Reporting System (Savannah)

Project dependency diagram

- CMS OO Software Architecture
- CMS TestBeams Offline Documentation
- CMS Documentation

Event Generation: CMKIN



GEANT4 Simulation : OSCAR

- Reads events from CMKIN produced Ntuple.
- Uses GEANT4 to simulate particle trajectories and their interactions with detector material.
- Creates collection of SimHits representing particle energy losses at fixed space points.
- Stores RawParticles, SimTracks, SimVertices and SimHits in POOL data files (in COBRA framework).
- Depending on the complexity of input events can take up to 100-200 s/event. Output is typically 1-2 MB/event.

Event Reconstruction : ORCA

- Object Oriented Reconstruction for CMS Analysis
- Also used to simulate the electronic signals from the detector (Digis).
- Raw Data is also converted to Digis (using separate software) for input to reconstruction.
- Can take 20-30 s/event (mostly tracking).
- ORCA is the program that provides input point to physics beyond analysis of ntuples.

ORCA

Raw Data

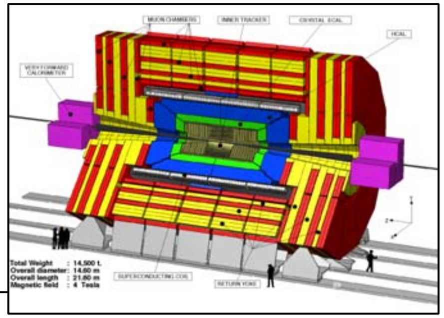
SimHits
Pileup Events

SimHits
Signal Event

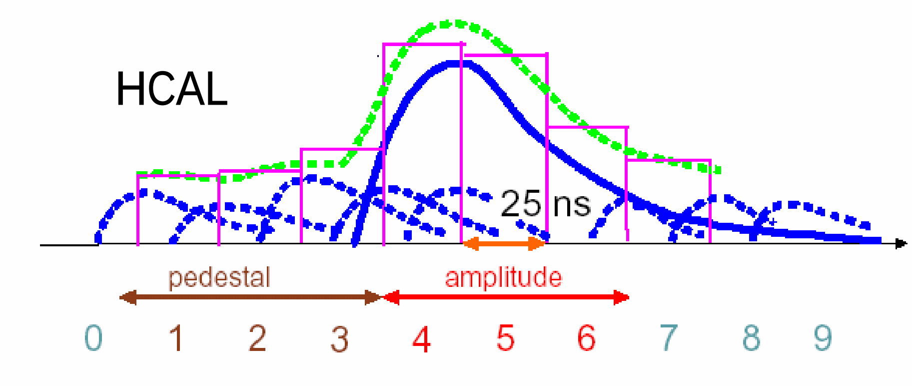
Simulation of
Electronics

Tracker
Calorimeter
Muon Det.
Trigger

DIGI's
RecHits



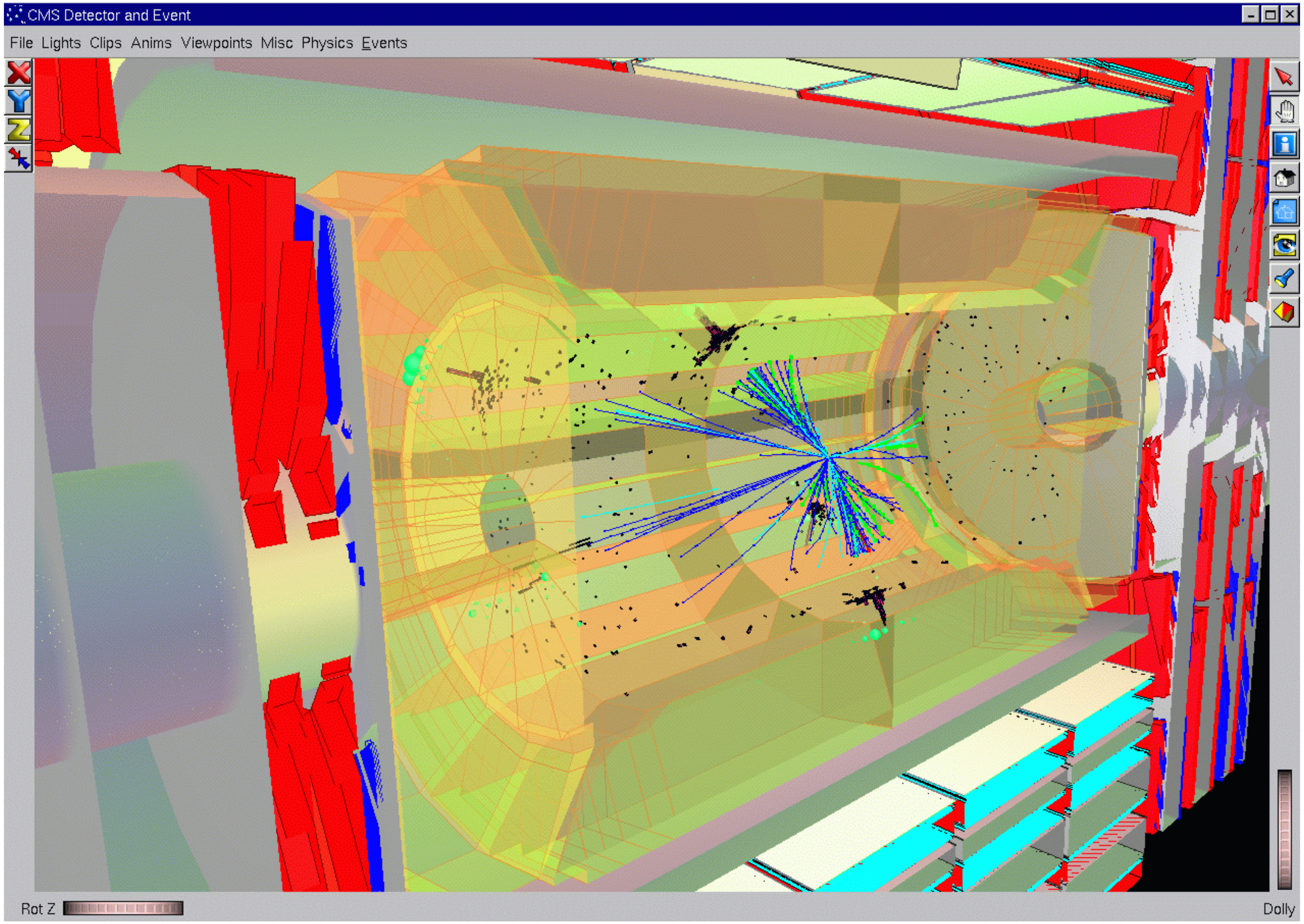
- 20 interactions/ crossing
- 25 ns crossing time: faster than detector response – read out (simulate) crossings –5;+3
- 200 pileup events per 1 signal event!



Tracks, Jets,
Muons, Vertices,
MET, Electrons,
Photons, b-tags,
etc…

High-level Reconstruction
and Analysis

Event Display : IGUANA



Old versus New Framework

Most Important Differences :

Events in the new framework are self-contained

Events are stored in a root compatible format

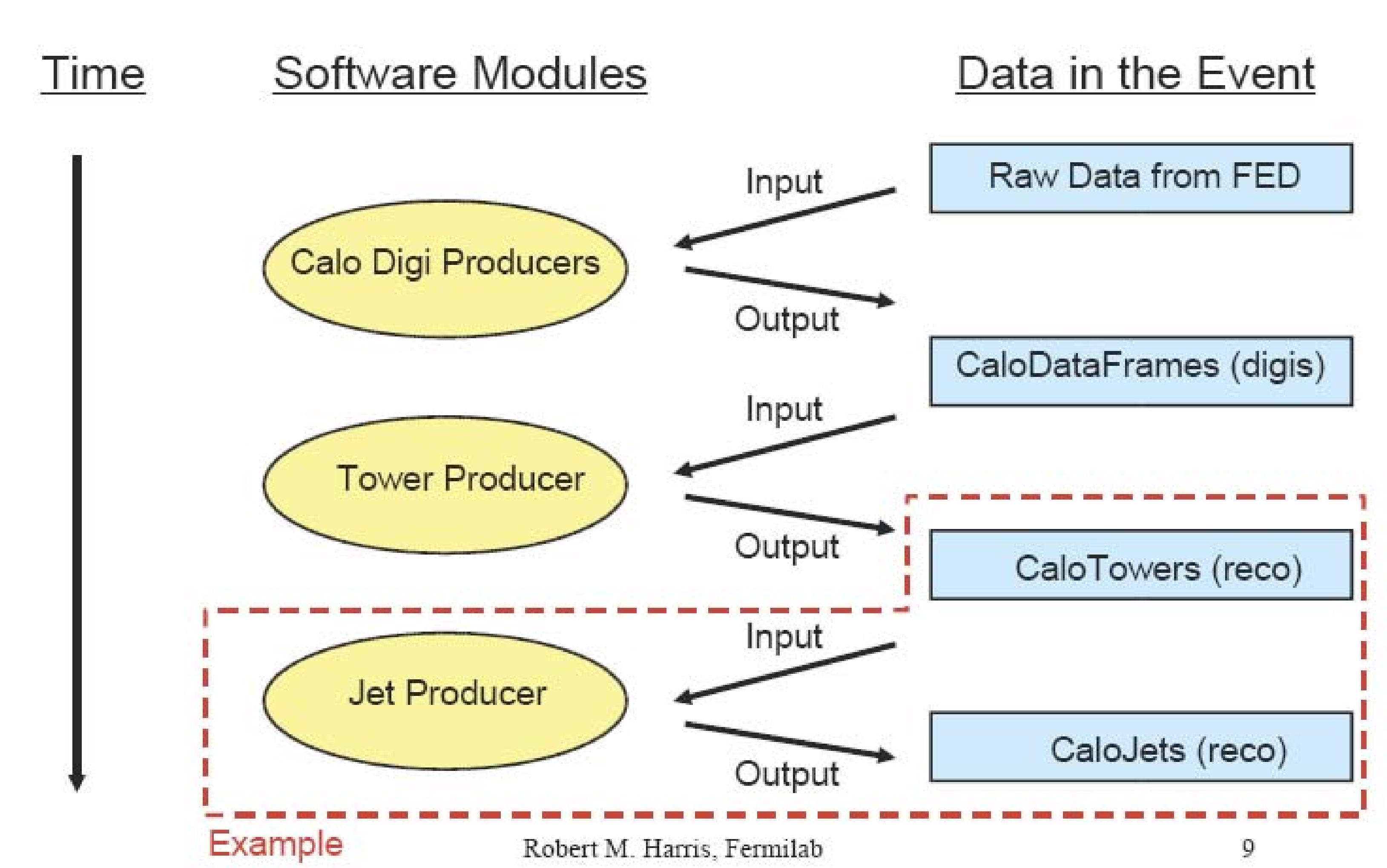
Events can be asked what information they contain

Jobs are based on a well-defined set of modules

Modules are run in a well-defined order

Events can be analyzed with subset of code libraries

New Framework (Example)



Framework Co-existence

- Old/Current Framework is being used for algorithm development and TDR physics studies while new framework is under development.
- CMS goal is to move to new framework for cosmic ray slice test in spring/summer of 2006.

LPC Tutorials

Old Framework :

See http://www.uscms.org/SoftwareComputing/UserComputing/NewTutorial.html

Also serves as great intro for running on UAF.

New Framework :

See http://agenda.cern.ch/askArchive.php?base=Agenda&categ=a055467&id=a055467s12t2/actionlist

Other CMS Tutorials

http://cmsdoc.cern.ch/cms/software/tutorials/

CMS OO Software Tutorials

Special Tutorials

- Introduction and DST reading (CPT week 11/2004)

2nd series: starting 19. Mar. 2004

- Introduction to CMS software - The Basics: slides (use ORCA_873 and replace tag Tutorial040319 by Tutorial050303)
- Simulation and Reconstruction - The Full Chain: slides
- Reconstruction and DST Analysis: slides
- Analysing Data with PAX: slides
- Muon and MuonReco software: slides
- Tracker and TrackerReco software: slides
- ECAL and ElectronPhoton software: slides
- HCAL and JetMET software: slides
- Visualisation software: slides
- Vertex software: slides
- b-tagging software: slides
- Visualisation software (2): slides
- Analysis Job Submission (CRAB) and the PHYSH tool: slides
- Analysis Tool: Root Tree Maker slides

1st series: 11. Nov. 2003 - 30. Jan. 2004

- New User Tutorial (basic introduction): slides, video
- The Full Simulation/Reconstruction Chain Tutorial: slides, video

ExRootAnalysis

Making a root ntuple : See

http://lynx.fnal.gov/runjob/MCPS_20ExRootAnalysis

List of available files : See

http://cmsdoc.cern.ch/cms/production/www/html/general/

Definitions of ntuple variables : See

http://cmsdoc.cern.ch/swdev/viewcvs/viewcvs.cgi/ORCA/

Examples/ExRootAnalysis/doc/RootTree.html?rev=1.3

Getting Help

Take advantage of experts at LPC

In particular, Patrick Gartung runs LPC help desk

Send email to helpdesk at fnal.gov or call x3832

Subscribe to lpc-howto mailing list :

Send email to listserv at fnal.gov with “subscribe lpc-howto” in message body (subject line blank)

USCMS Software and Computing Webpage

http://www.uscms.org/SoftwareComputing/index.html

CMS Tracker

Outer Barrel (TOB): 6 layers
- Thick sensors (500 mm)
- Long strips

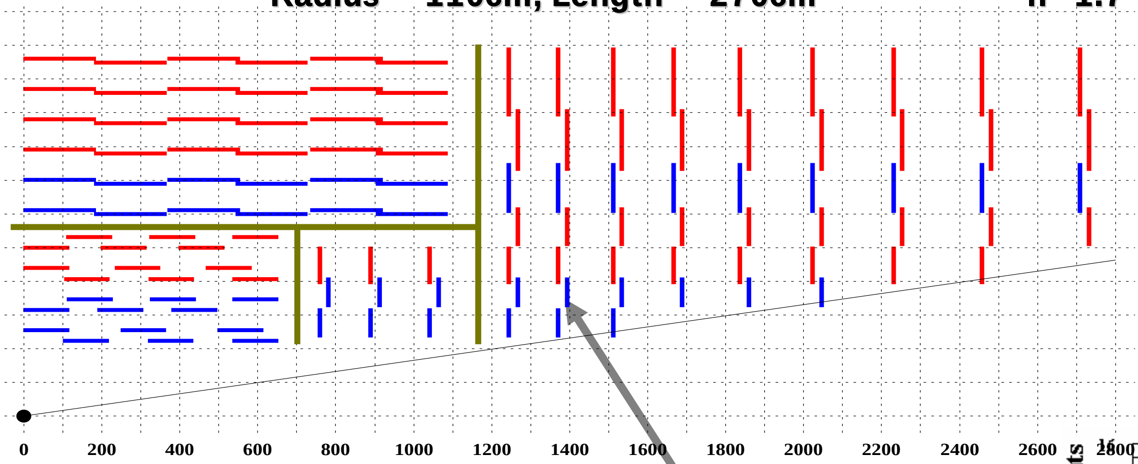
Endcap (TEC): 9 Disk pairs
- r < 60 cm thin sensors
- r > 60 cm thick sensors

Radius ~ 110cm, Length ~ 270cm

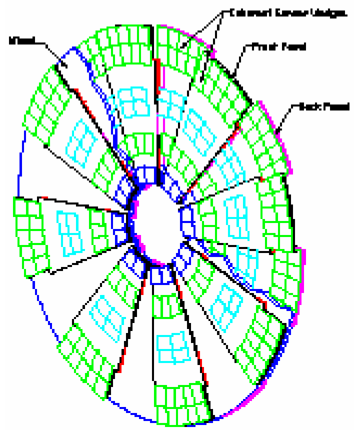
h~1.7

6 layers TOB

4 layers TIB



h~2.4



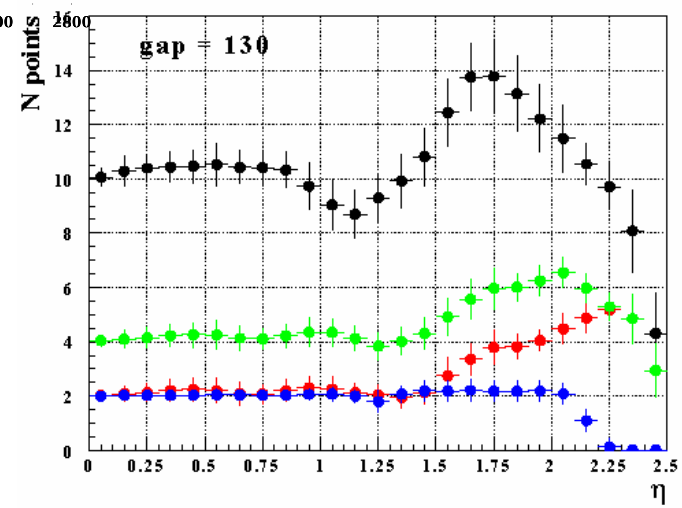
3 disks TID

9 disks TEC

Inner Barrel (TIB): 4 layers
- Thin sensors (320 mm)
- Short strips

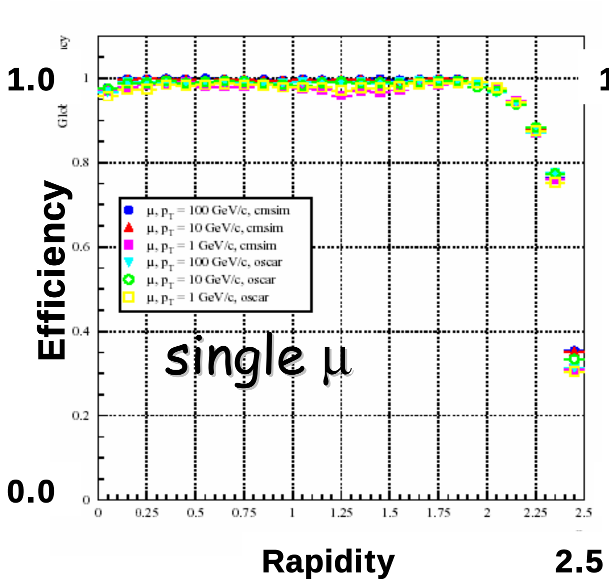
Inner Disks (TID): 3 Disk pairs
- Thin sensors

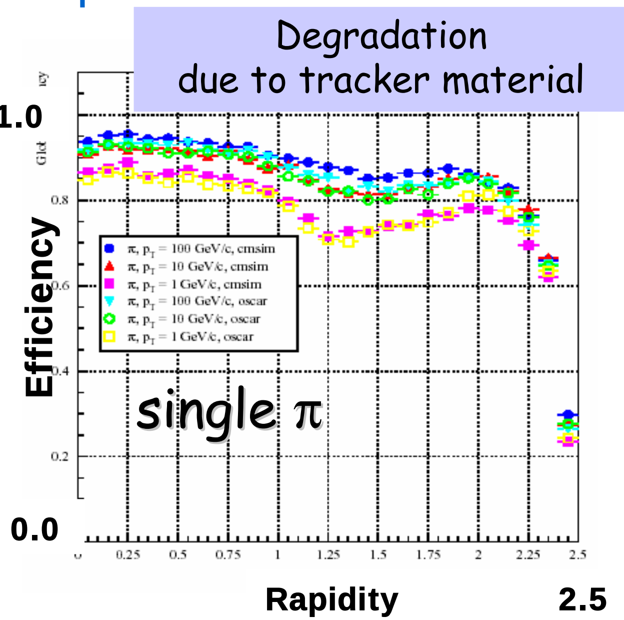
Black: total number of hits
Green: double-sided hits
Red: ds hits - thin detectors
Blue: ds hits - thick detectors



Tracking

- Very few measurements per track
  - very precise
  - very low occupancy: 10^{-4} in pixels, <5% in strips
- A lot of material in the tracker
  - 0.5-1.5 X_0: electrons brem, photons convert
  - 0.1-0.4 λ: pions interact
- Track inside out: start in pixels and extrapolate to strips
  - Can use external seeds (i.e. a pixel hit and an EM cluster)





Electrons and Photons

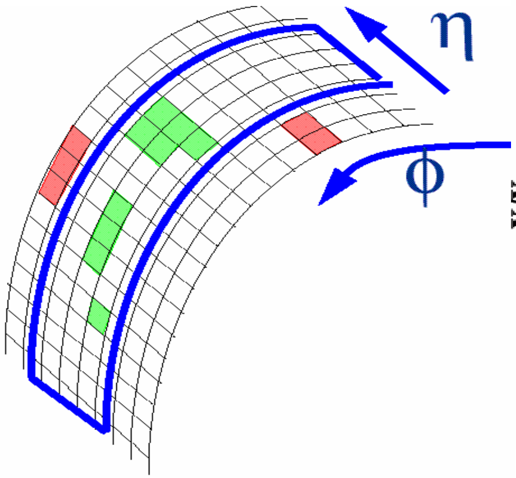
- Lead Tungstate crystals $\Delta\varphi\times\Delta\eta \sim 0.02\times0.02$
- Biggest challenge is the amount of material in front of the ECAL

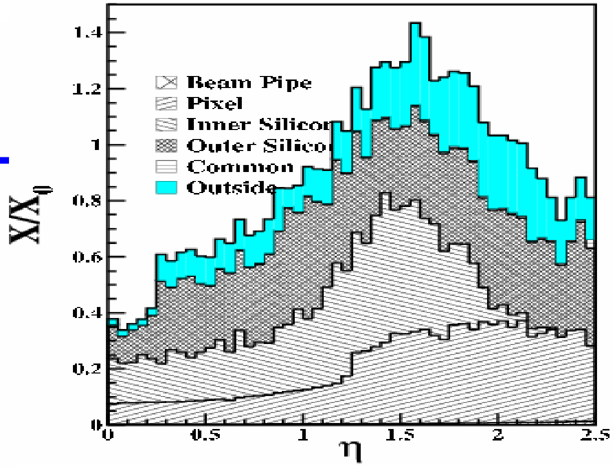
Cluster Reconstruction:

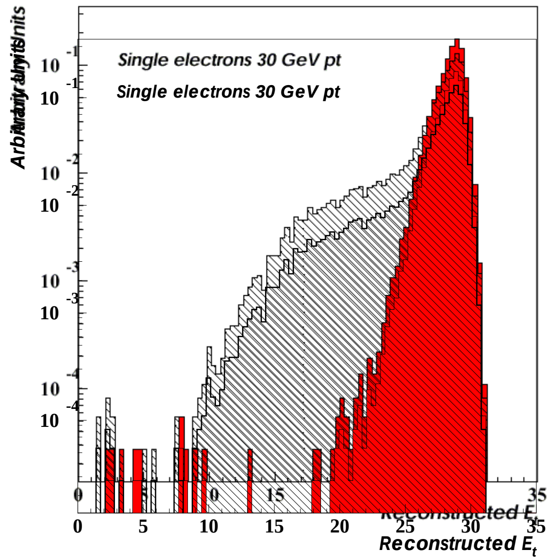
- find bumps in calorimeter
- cluster the bumps
- approximate window size $\Delta\varphi\times\Delta\eta \sim 0.8\times0.06$

Corrections:

- containment, cracks, energy loss in the tracker material





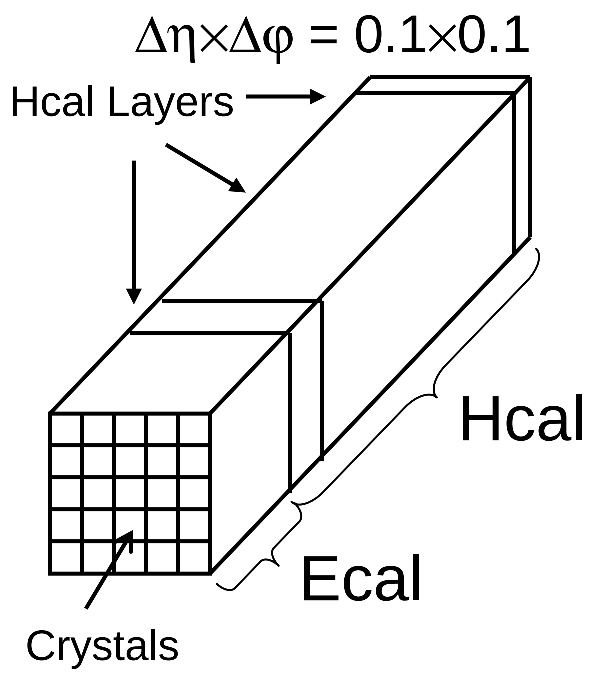


Electrons and photons propagate differently

- electron continuously looses energy via Bremsstrahlung
- photons propagate intact until the first conversion
- Energy scales are different and depend on detector region (both rapidity and azimuth) – measuring amount of material *in situ* is needed

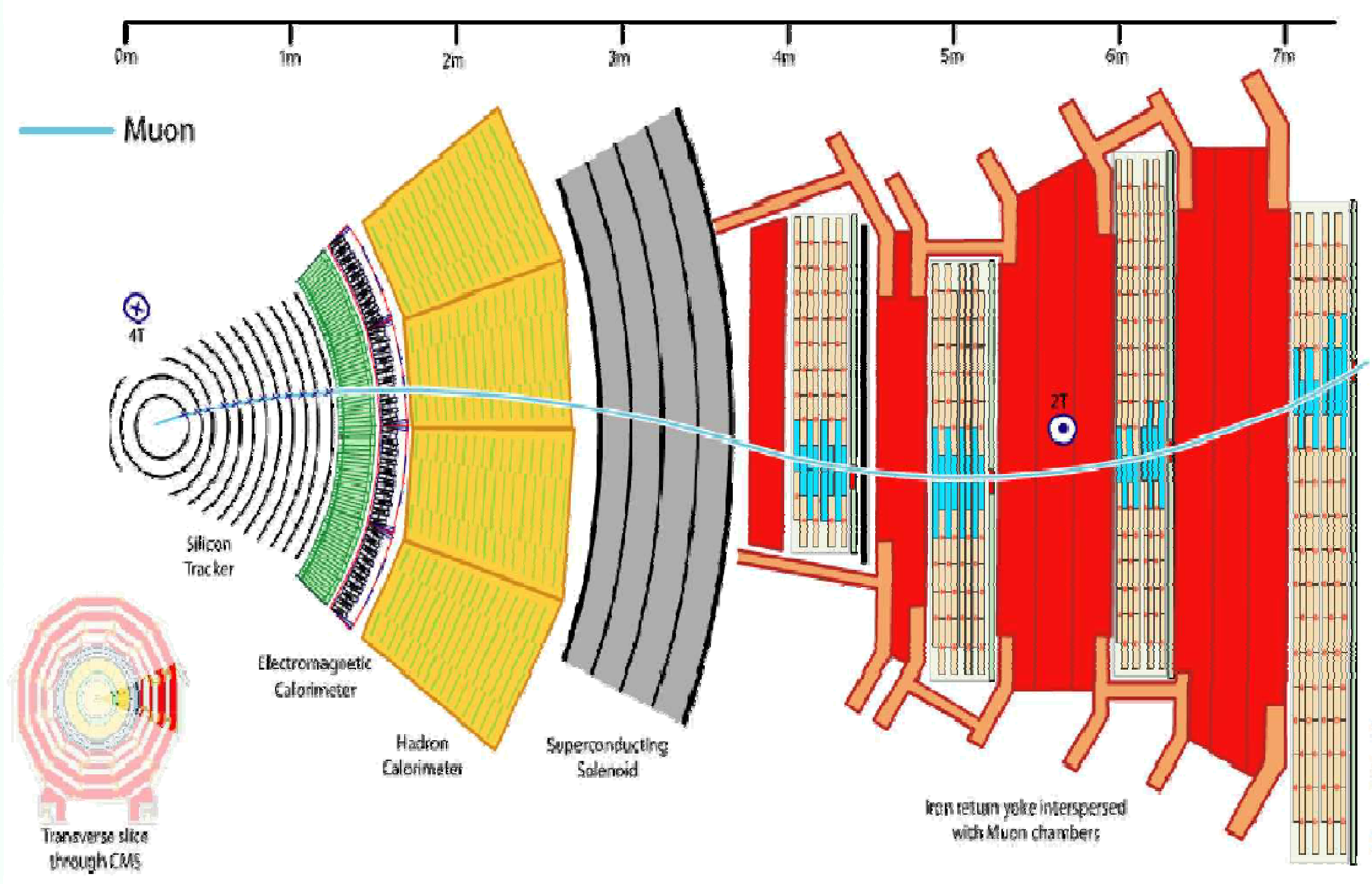
Jets & Missing E_T

- Biggest challenges:
  - calorimeter non-compensation and pile-up
- High Level Trigger: EcalPlusHcalTowers
  - Correspond to HCAL $\eta - \varphi$ towers
  - One HCAL tower matches 5x5 ECAL crystals (approximately in EC)
- Offline
  - Use both longitudinal and transverse segmentation (RecHits)
  - Refine jets and MET with tracks and muons



- Jet Algorithms available:
  - Cluster based:
    - Inclusive kT
    - Exclusive kT(d_{cut})
  - Cone based:
    - Simple Cone
    - Iterative Cone
    - MidPoint Cone

Muon Reconstruction



Global Muon Reconstruction

- Start with a local muon (~10% resolution @ 100 GeV)
- Extrapolate to the interaction point and find track seeds
  - can have many track seeds per muon
  - build a track propagating out, including hits in muon system
  - resolve ambiguities and do a final fit