Talk dato al Software Workshop
di Roma 22/11/2001
con qualche aggiornamento

Simulation of the CMS Tracker

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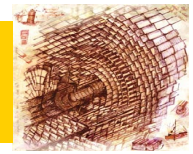
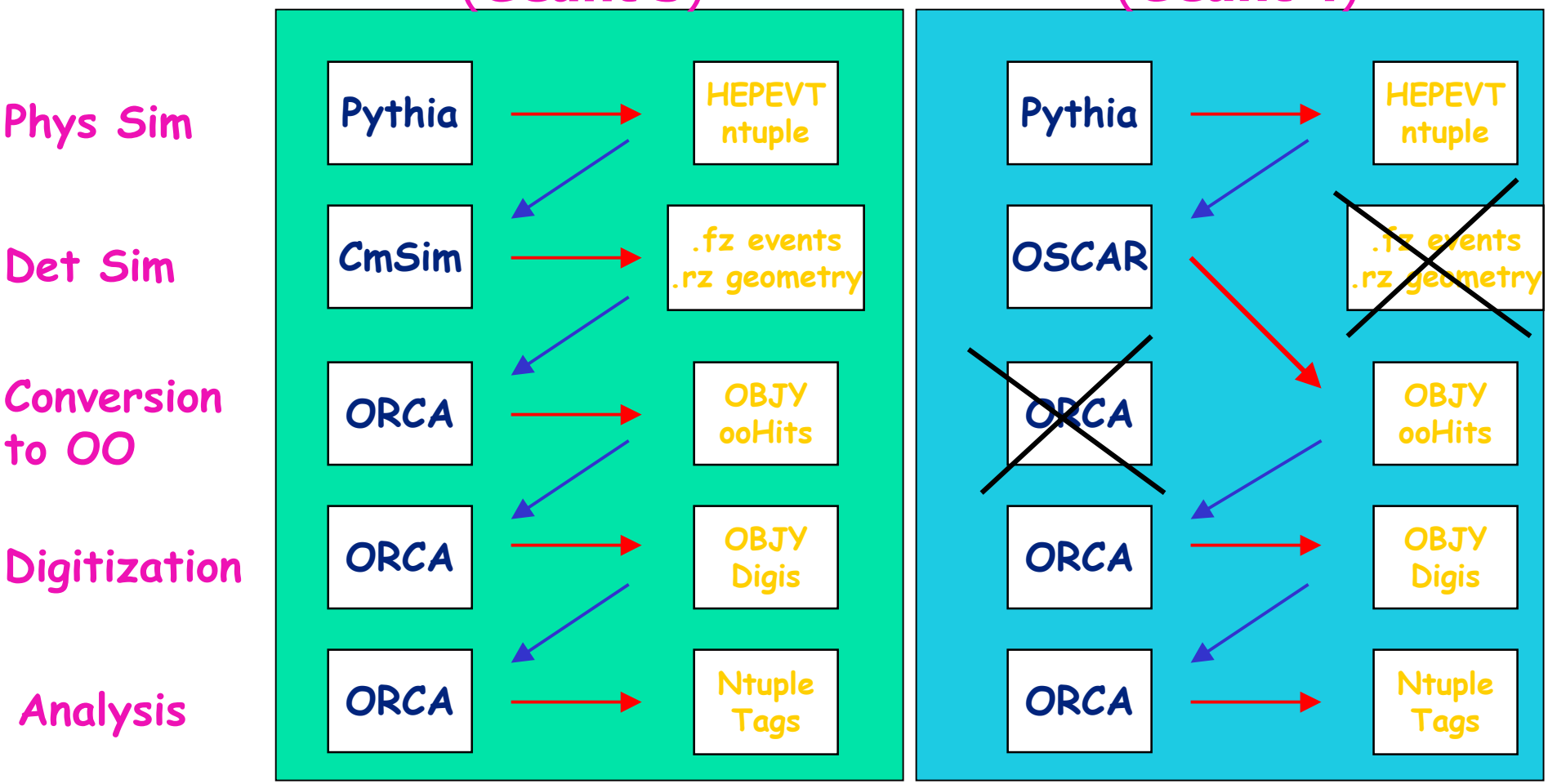
on behalf of the Tracker Simulation group

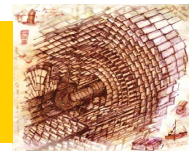
Contributions from: Ariane, Sunanda, Suchandra, Valeria, Lucia, Vitaliano, Danek, Matthias, Wolfgang, Ian, Teddy, Pedro …

The two-fold way





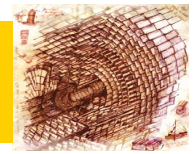
Detector Simulation



OSCAR/Geant4 is maturing fast, but the reference simulation is (and will be for quite a while) the fully working Cmsim/Geant3 system.

- **Cmsim:**
  - **Geometry description**
  - **Material budget**
  - **Pixel staging**
  - **Material cuts**
- **OSCAR:**
  - **Geometry description**
  - **Consistence with Cmsim**
  - **First complete tests**

Geometry



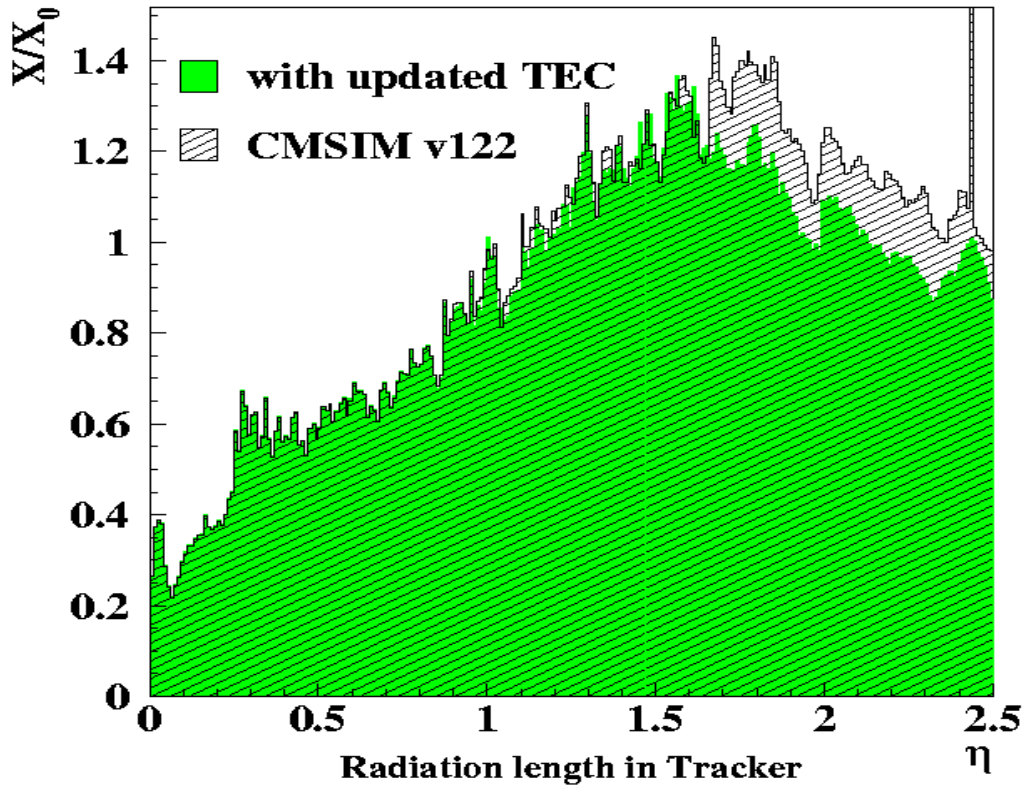
Cmsim 124 released:

- TEC and TID updated to the same level of accuracy of the barrel (both geometry and materials)
- Pixels: only 2 barrel layers and 1 forward disk; positions yet to be fixed (CMSIM125)
- **After that, the geometry should be "stable" and massive production can start!**
- **Production test already started**

Material Budget - EndCap

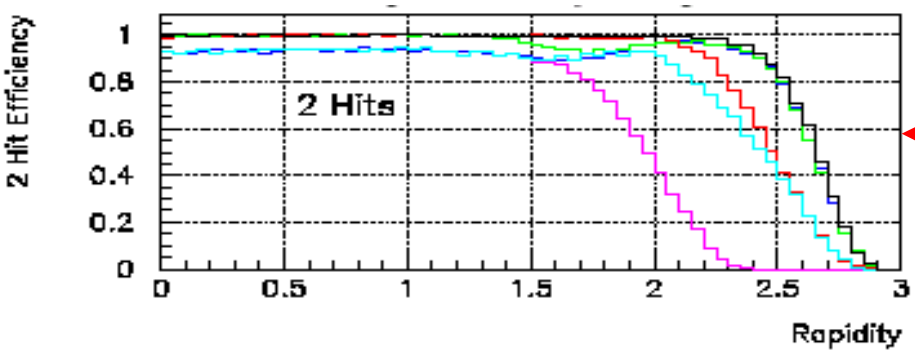
new TEC shows a lower MB!

(due mainly to cables and cooling)

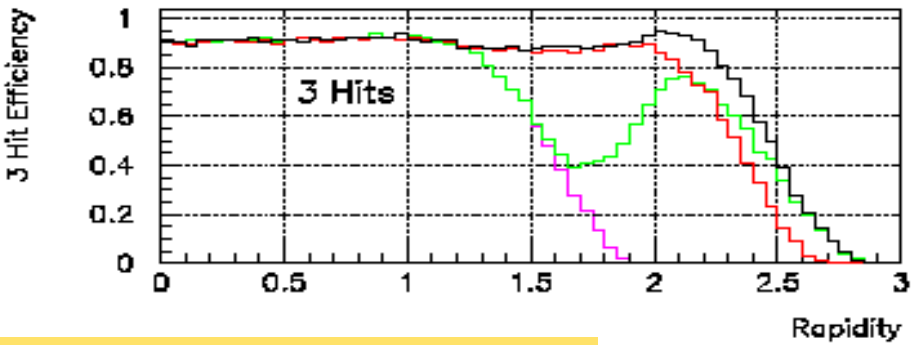


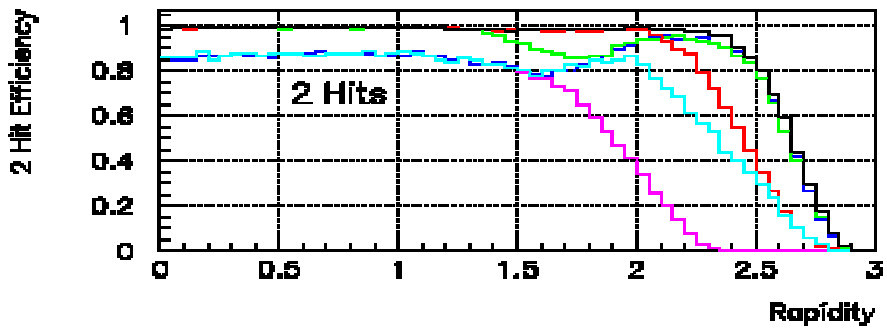
Pixel Staging

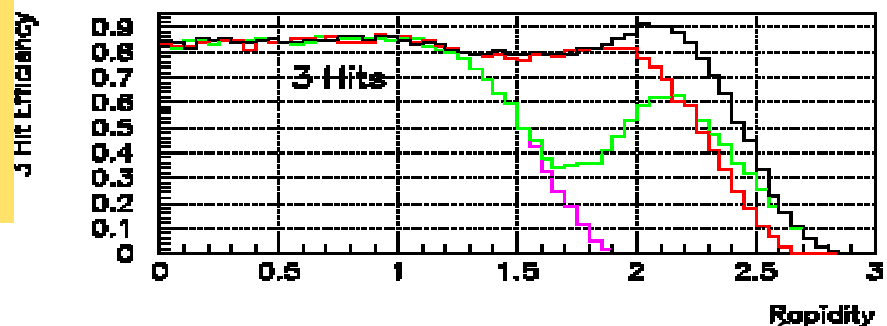
Efficiencies for 2/3 hits at different staging scenarios/Luminosity



$\mathcal{L} = 2\text{x}10^{33}$ $\mathcal{L} = 10^{34}$





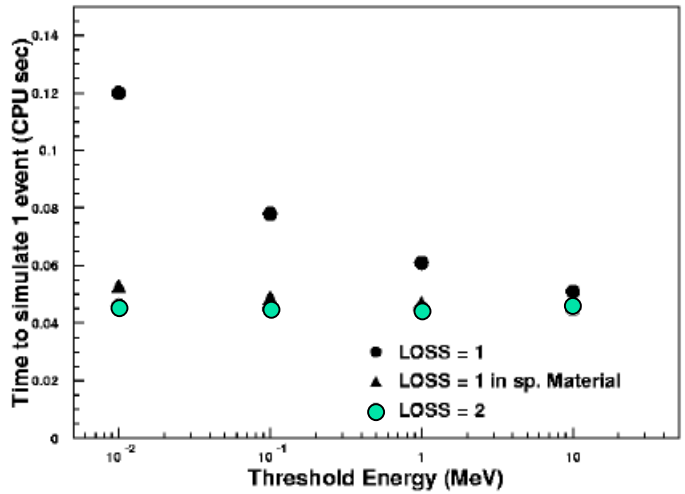


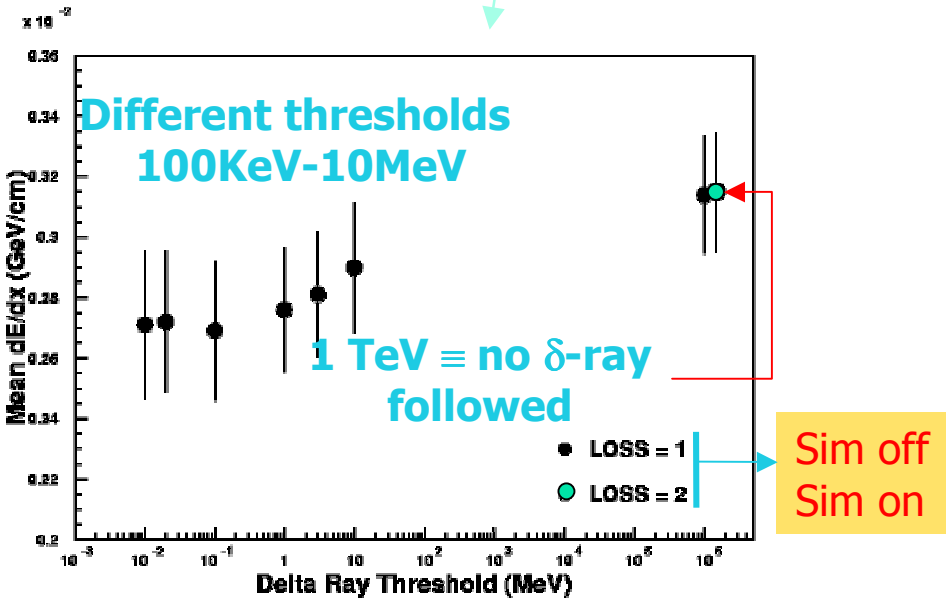
2 Barrels – 0 Disks
2 Barrels – 1 Disk
2 Barrels – 2 Disks
3 Barrels – 2 Disks (Optimized for 2Hit)
3 Barrels – 2 Disks (Optimized for 3Hit)
3 Barrels – 3 Disk

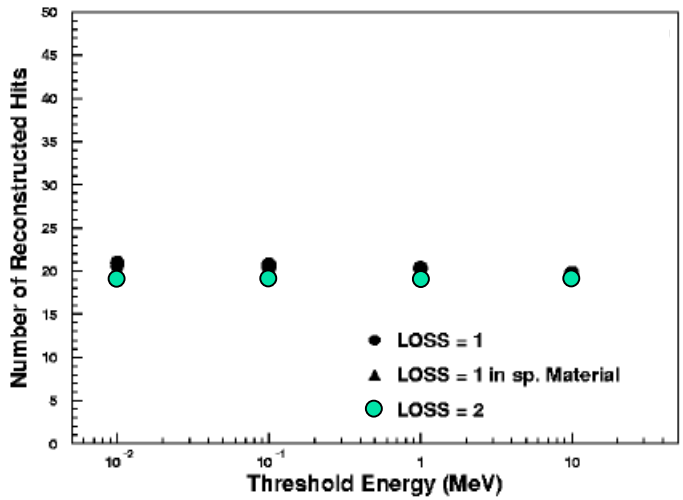
Remember: at the moment 2 Pixels hits are needed for Track Reco

Material Cuts - Cmsim

•Simulation of δ-rays and brem. photons by Cmsim can be switched on/off, and if on can be followed for photons up to a certain threshold. An accurate description to very low energy photons is needed to understand the dE/dx, and the impact on number of Sim/RecHits and on CPU time has been studied





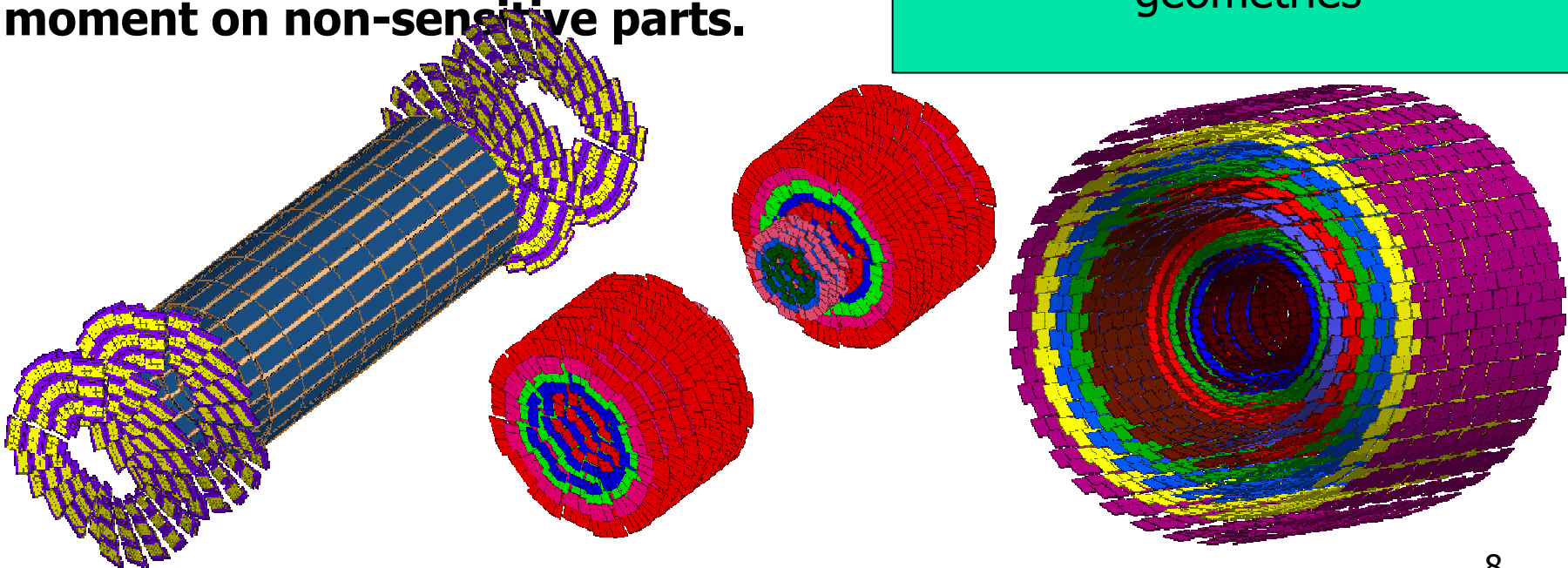


OSCAR – Status of geometry

- **Automatic tool to compare Cmsim/OSCAR geometry implemented. All the detectors (20280) are now within 5 μm and also the orientation is fine. Only the Tracker checked till now…**
- **No check performed at the moment on non-sensitive parts.**

but

Wait for the DDD era!
(April 2002?)
DDD (Detector Description Database) will ensure automatically the coherence of the various OSCAR/Cmsim/ORCA geometries

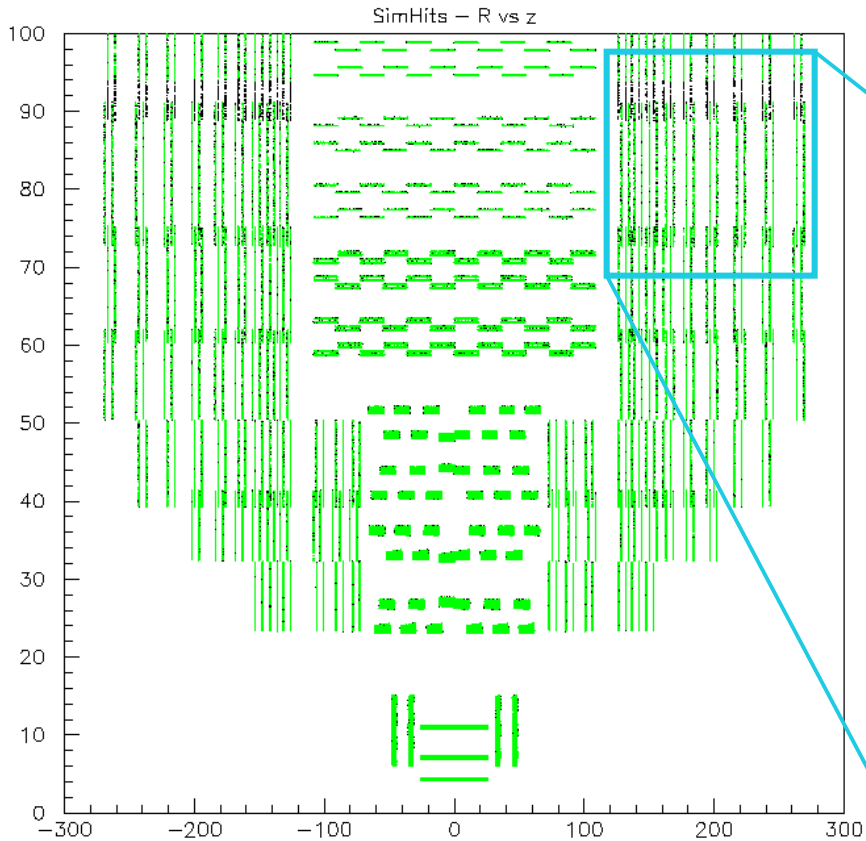


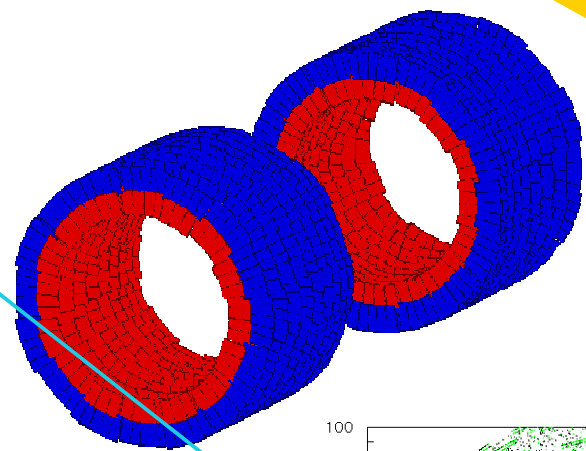
OSCAR/Cmsim comparisons

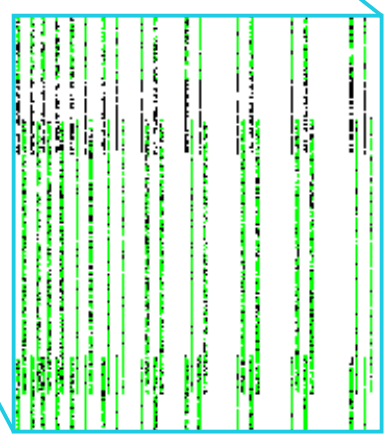
Plot SimHits in the Tracker, both from Cmsim and OSCAR

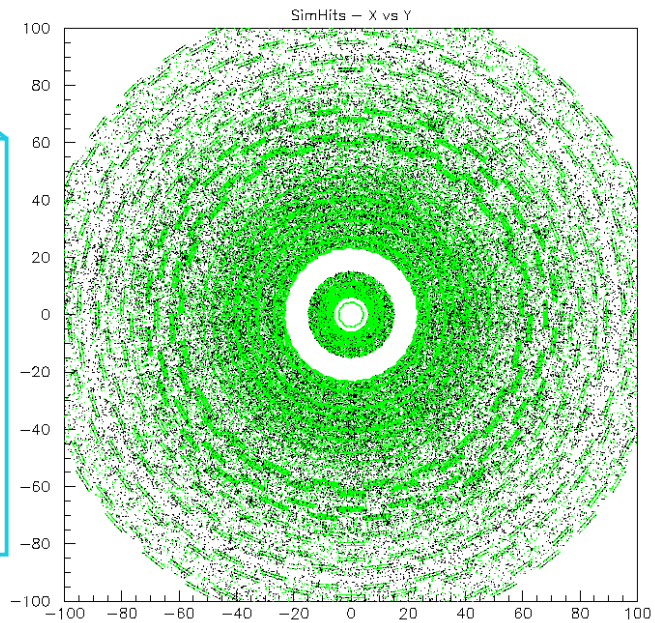
OK NOW!

Hole in the last ring of the TEC

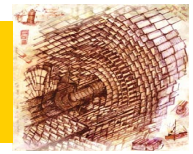




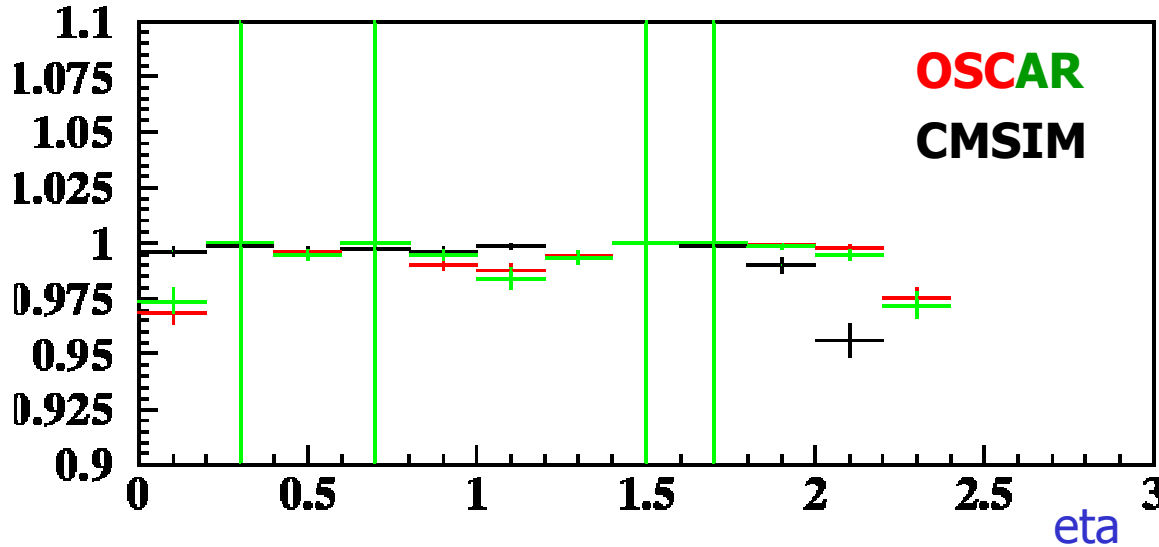




OSCAR/Cmsim comparisons



- **Tracking efficiency: differences at the % level; <u>not always worse on the OSCAR side!!</u>**



- Before you ask:

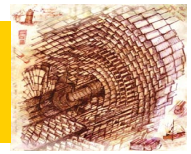
  Q: "Can we use <u>now</u> OSCAR for physics studies?"

  A: Not really:

  - Single muons are ok, more difficult topologies often drive to lockups (semi-infinite looping…) ➡ already addressed
  - Not all the detectors are at the same level of advancement/check

…but we are moving very fast towards a really usable system!

Digitization



✓A SimHit only knows about its entry and exit point in a detector (+ time of flight and energy deposit…)

✓The energy released is spread into the detector volume along the line connecting these into a number of smaller deposits, whose signals are drifted to the strip plane. Landau fluctuations are allowed for the deposits.

✓During the drift, Lorentz angle and diffusion are taken into account.

✓Charge is injected into the strips, taking into account the inter-strip capacitive couplings. We have the so called Digis!!!

✓Digis are clusterized and RecHits are made.

✓Different zero suppression algorithms can be applied.

Digitization parameters

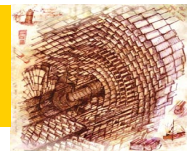
Some parameters still to be tuned:

- **capacitive couplings**
- **S/N**
- **diffusion**

Test-Beam analysis very important

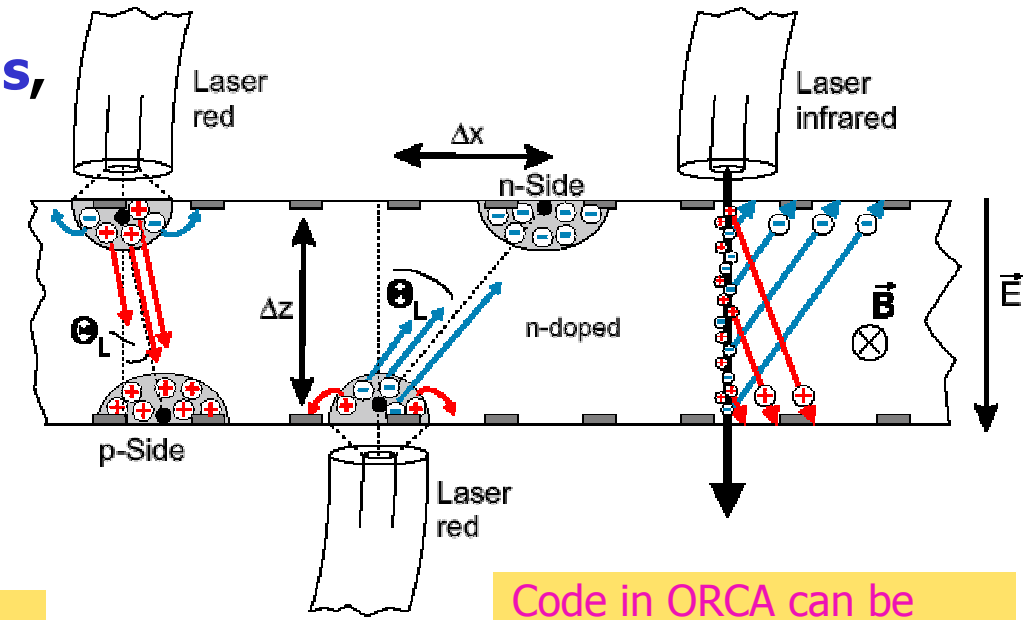
Maybe DDD needed for implementation

Tracker Detector Response



- **New and more reliable (from real tests in Karlsruhe) treatment of the Lorentz angle in silicon, as a function of bias, irradiation etc.**

- **Not yet implemented for pixels, where the modeling is more difficult (after irradiation, the depletion will not be complete…); wait for the optimization workshop**



Lorentz angle very important for hit resolution:

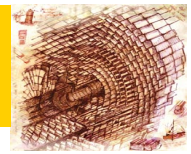
- Silicon: $\tan(\theta_L) = 0.12$ (~6° at 4T)
- Pixel: $\tan(\theta_L) = 0.53$ (~28° at 4T)

Code in ORCA can be adapted via configurables to any

- Irradiation conditions
- Temperature
- V bias
- Etc…

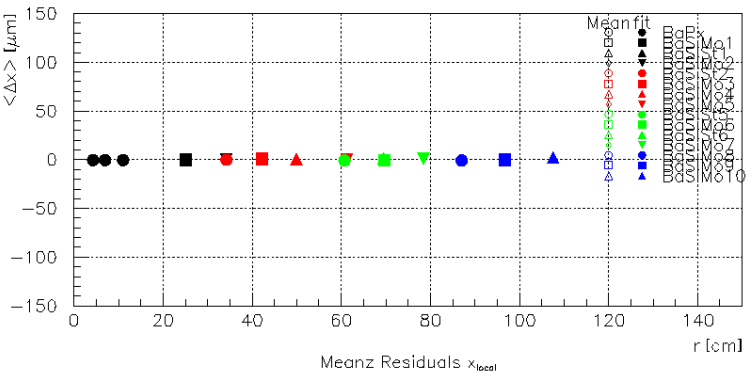
Silicon

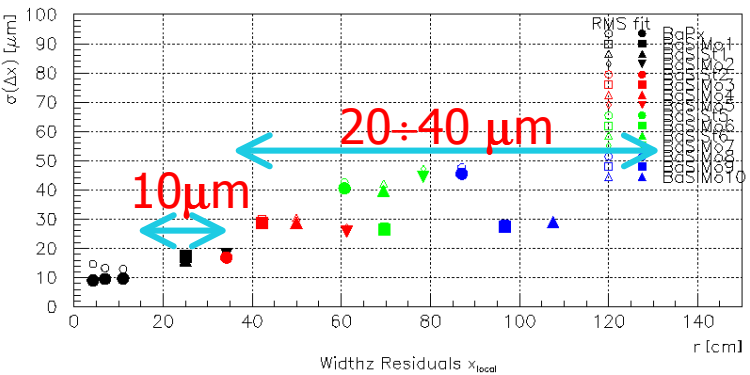
Tracker Detector Simulation



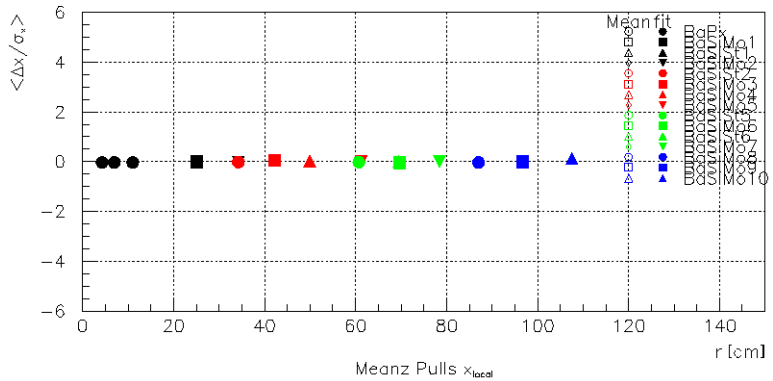
Given a set of Digitization parameters, the simulation is adjusted to parameterize correctly the estimated error on the residuals (pulls).

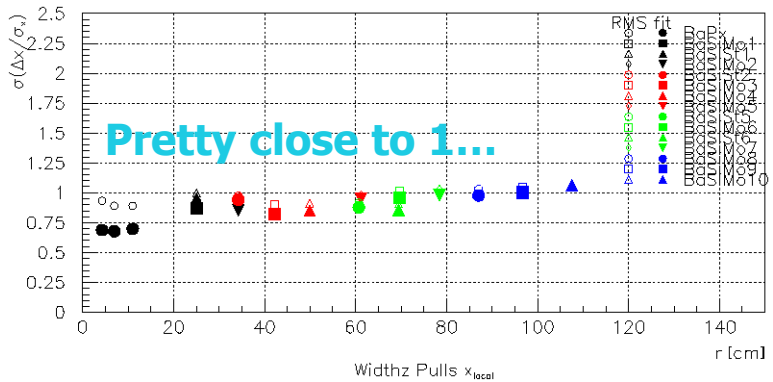
RecHit residuals (μm)



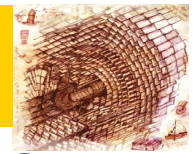


RecHit residuals (pulls)



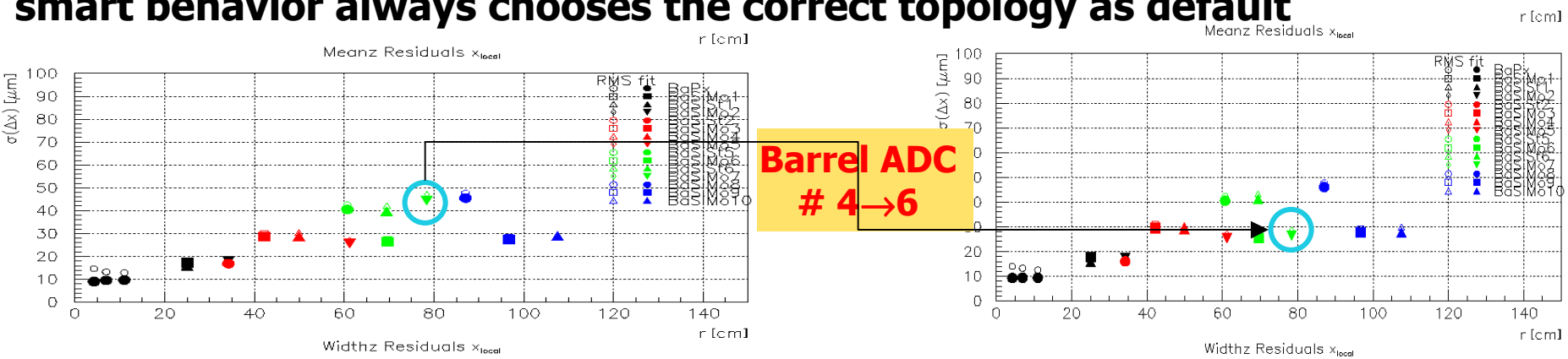


Detector Topology



- Detailed studies about the impact on reconstruction of the number of ADC per DetType has been performed.
- The standard setup is "take the strip topology from Cmsim title file". But in this way
  - The number of strips is not 128×#ADC, but a few % less
  - It is not feasible to re-simulate with Cmsim each time one changes the strip topology

- New approach: the topology is configurable at digitization time, via .orcarc; smart behavior always chooses the correct topology as default



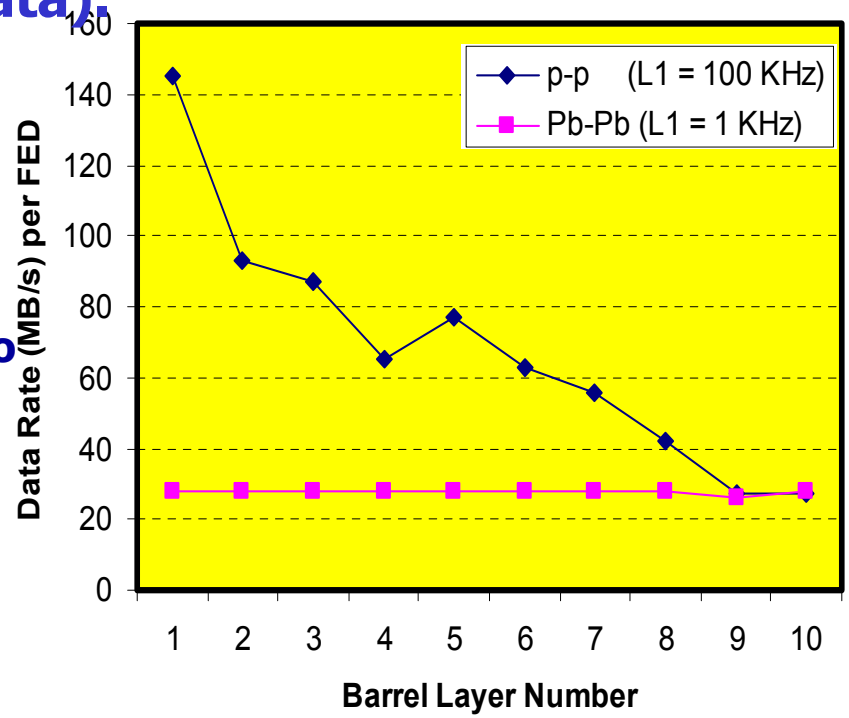
These studies could asset the impact of reducing the ADC# in the TOB by 1/3; decision accepted by the Steering Committee

Tracker Data Handling

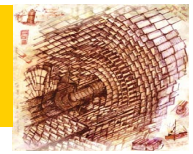
- Tracker will be read out by 442 (-16) FEDs.
- Detailed study made of expected data rates from each FED. (for DAQ TDR)
  - Covers p-p collisions (zero suppression) and Pb-Pb collisions (raw data).

- Data rates per FED less than capacity of DAQ inputs (200 MB/s) everywhere !
  - Comes from occupancy (strictly related to detector response)

Lorentz angle
Diffusion
Capacitive couplings
Tilt angle...

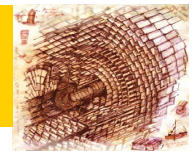


Plans



- **Cmsim: fix pixels in cmsim125 and start production**
- **OSCAR: integration with ORCA well on the way from the Tracker, some delay in integration and in other subdetectors. The time of OSCAR as a tool for physics analysis is close!**
- **Simulation of detector response: code existing & working but some tuning still needed.**
- **Detailed studies about Tracker Data Handling/Rate: we are "safely" in the bandwidth assigned to us.**

Pixel Inefficiencies



- Pixel detector will have substantial readout losses.
- These losses are due to highly stochastic nature of our events, the direct causes are: buffer overflows and dead times.
- Some type of losses affect single pixels, others whole pixel columns or even whole readout chips
- The inefficiency value depends on the occupancy (luminosity & radius) and the 1st level trigger rate.

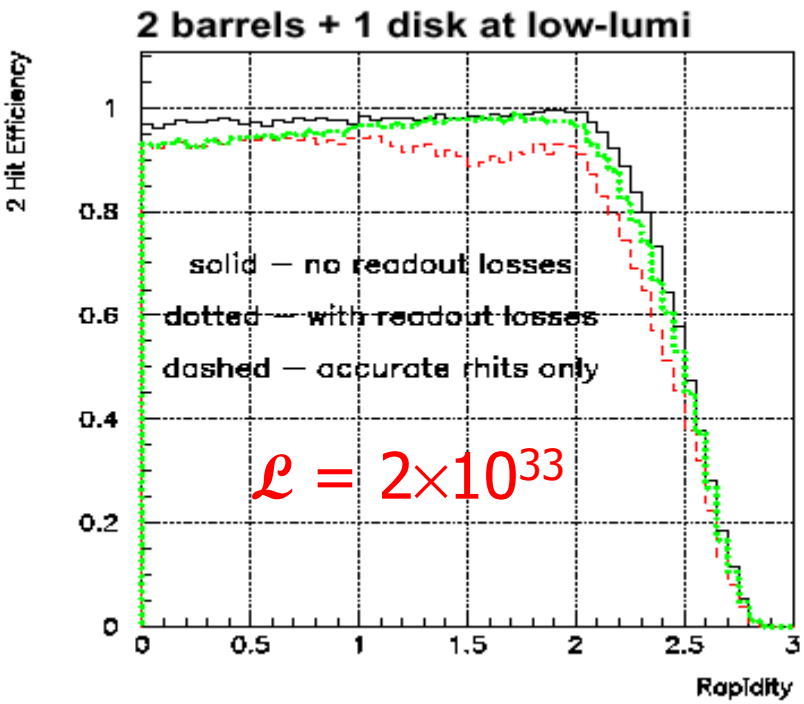
Net effect: lost pixel can

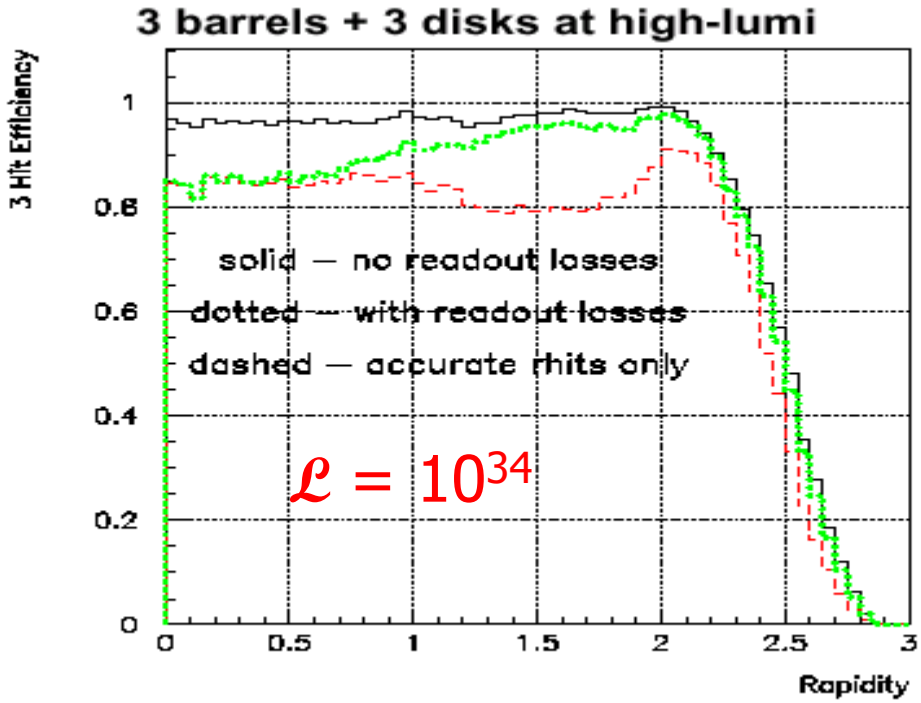
- Wipe out a RecHit
- Split a RecHit into 2

Remember: now pixel hits are at the base of tracking!
(it might change soon…)

Pixel Inefficiencies

Different staging/Lumi scenarios

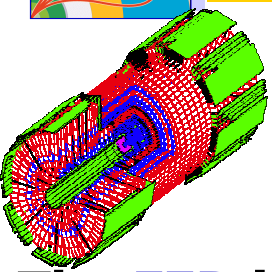




Expected Inefficiencies at $1/2/10 \times 10^{34}$

radius /cm/	pixels	columns	chips	total
4	1/1/1%	8.5/2.3/1.7%	0.3/0.3/0.3%	9.8/3.6/2.1%
7	1/1/1%	2.5/0.8/0.5%	0.3/0.3/0.3%	3.8/2.1/1.8%
11	1/1/1%	0.5/0.5/0.5%	0.3/0.3/0.3%	1.8/1.8/1.8%

Tracker Data Handling



APV → FED → DAQ

The FED is responsible for the selection of strips to be "saved" for offline analysis; only strips belonging to clusters should be passed along.

•Different zero suppression schemas have been tried (cut on S/N of the strip, of the whole cluster etc etc): Schema Number "2" chosen (remember: the algorithm must be simple enough to be implemented in FPGA!)

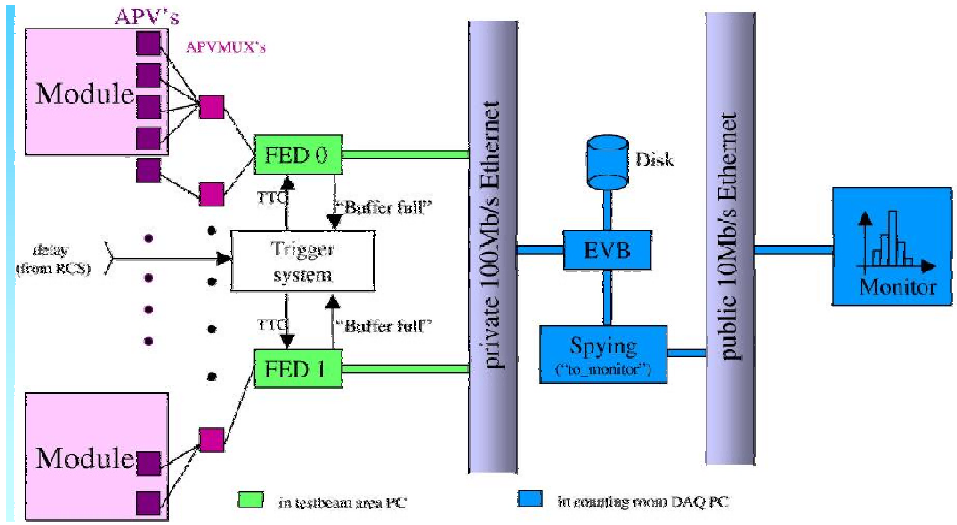
$S/N_{strip} > 2$
$S/N_{isolated\ strip} > 5$

•Cluster position (≡RecHit position in offline!) estimated using a simple median (less sensitive to the signal than the mean)

Test Beams

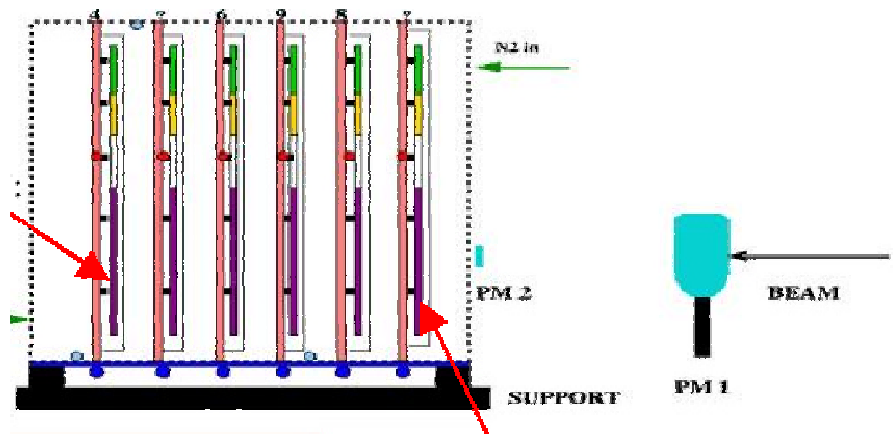
Activities in

- **DAQ**
- **Data taking**
- **Data analysis**
- **We are approaching the final module test:**

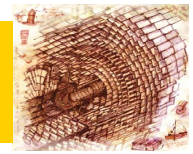


It is time to check all the DAQ components and to be sure we understand the modules!

- **General Framework for future studies (DAQ TDR); it will guide the full integration with ORCA and the first ORCA-based test on data handling**



Outline

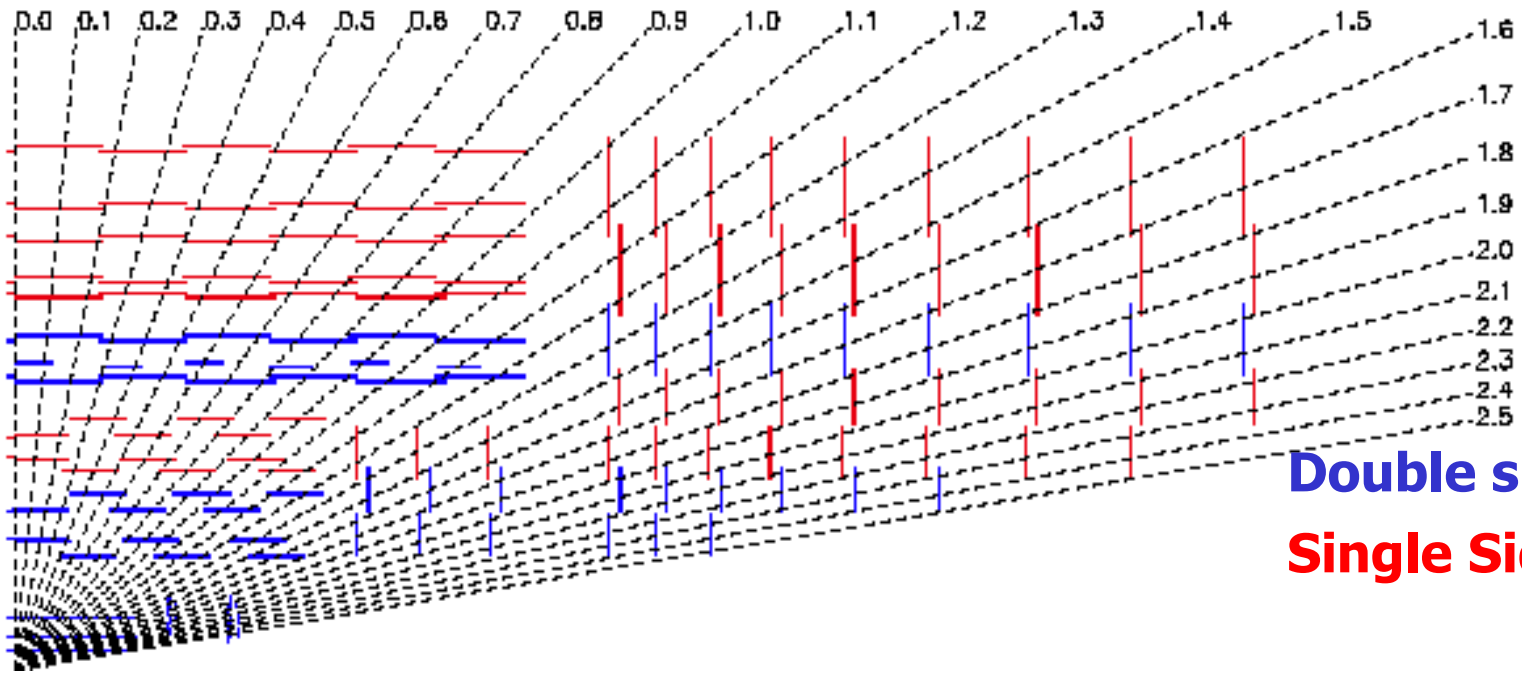


- **Responsibility of INFN at 70%!**

- **Flow of operations**
- **Simulation of geometry/materials (OSCAR/Cmsim)**
- **Simulation of the detectors**
- **Performance**
- **Plans**

Only 20 minutes, I will avoid any technicality…

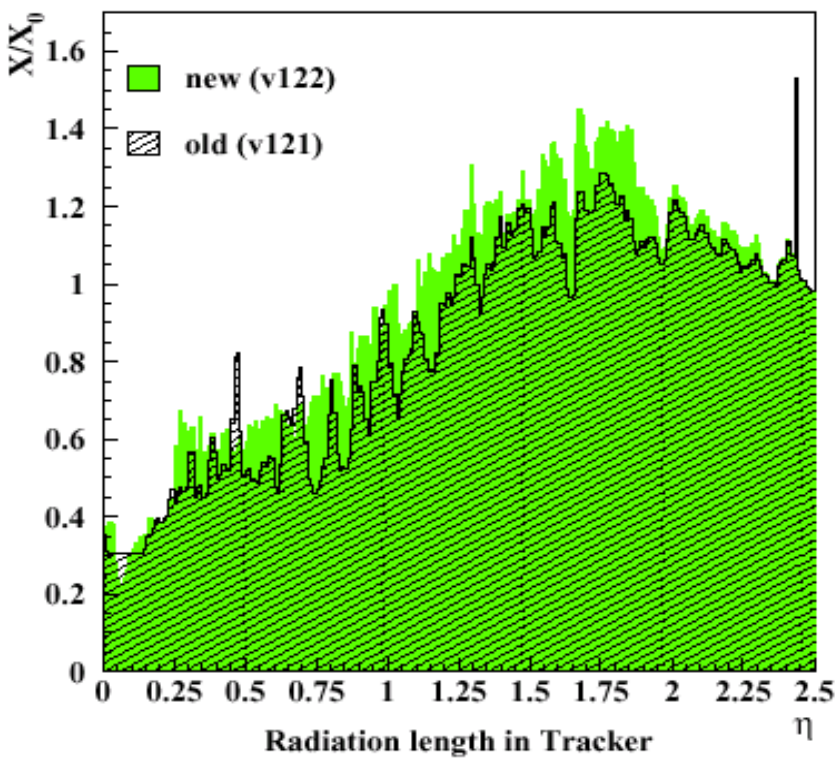
Sensor positions



- ✓Correct tilt for TIB (9 deg) and TOB (0 deg), they were 12 deg in Cmsim 121
- ✓Geometry position re-optimized

Compensate for Lorentz angle; lower data rate

Material Budget - Barrel



Increase
in radiation length
of about 10 %.

But is not surprising...

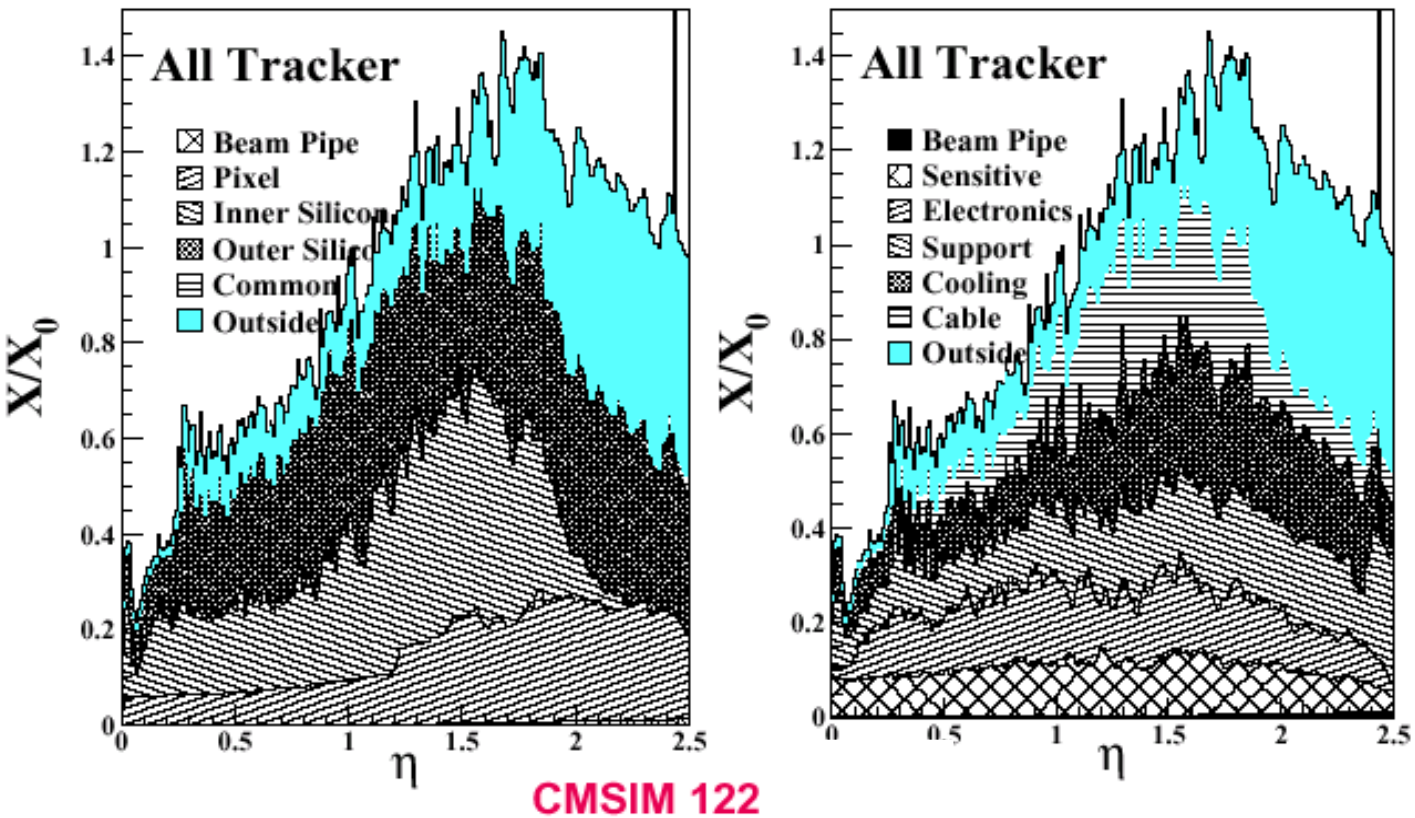
Remember:

Endcaps have not
been touched.

The changes in the barrel introduced a greater material budget (as usual, due to more detailed description), but…

Material Budget – cmsim122

Radiation length



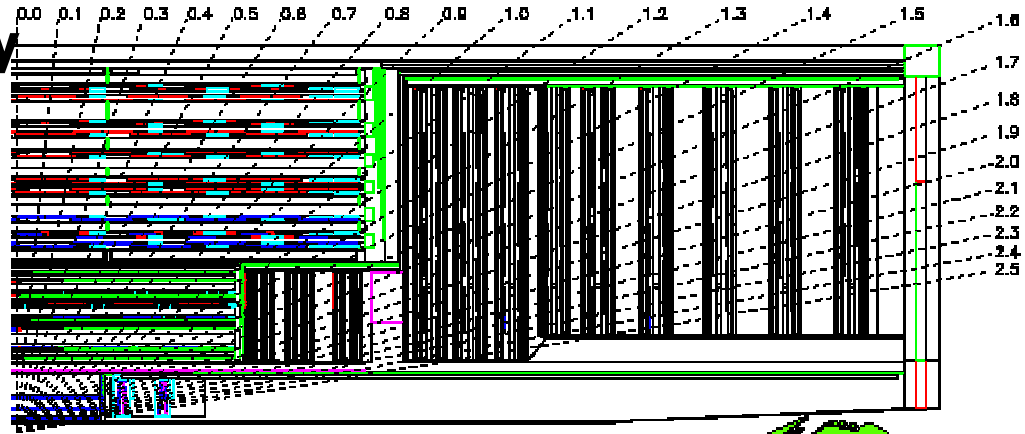
CMSIM 122

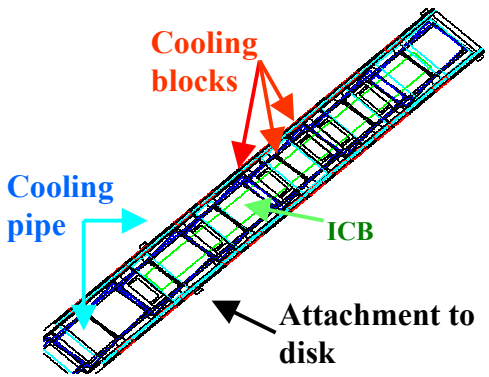
Detailed study on the source of the Material Budget, both for SubDet/Functional parts.

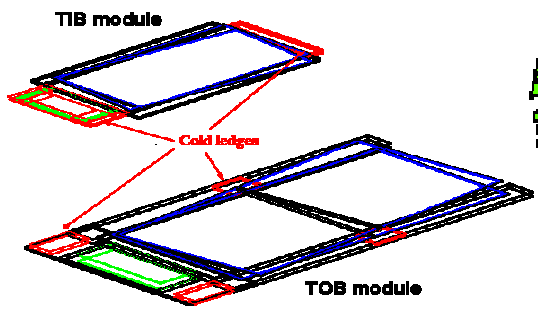
Geometry Description

Last release of Tracker Geometry is Cmsim 122(3), released June 2001.

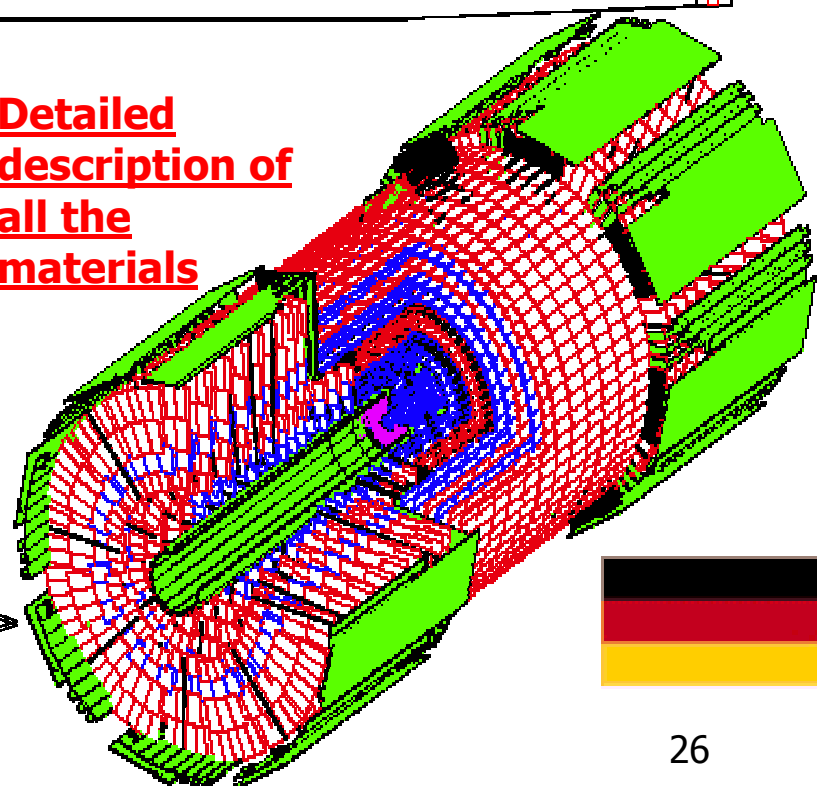
Currently "State of the art" for barrel (big jump from 121), TEC and TID changes foreseen by December release.



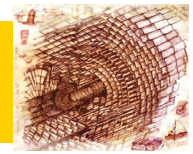




Detailed description of all the materials



OSCAR – Material cuts

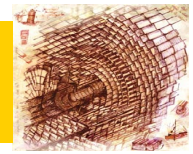


Now it is possible to tune the material cuts in the same way of Cmsim (needed our intervention on Geant 4 collaboration…)

For the moment, all the cuts are set to the tuned ones in Cmsim. It should be a good starting point!

Same work done on Cmsim needed, will start as soon as OSCAR is considerer "stable enough"

OSCAR – HitWriting



- **New and improved ReadOut Unit schema wrt to ORCA/Cmsim**

ORCA / Cmsim		OSCAR
1 ROU for all the Tracker	⇒	1 ROU for each SubDet

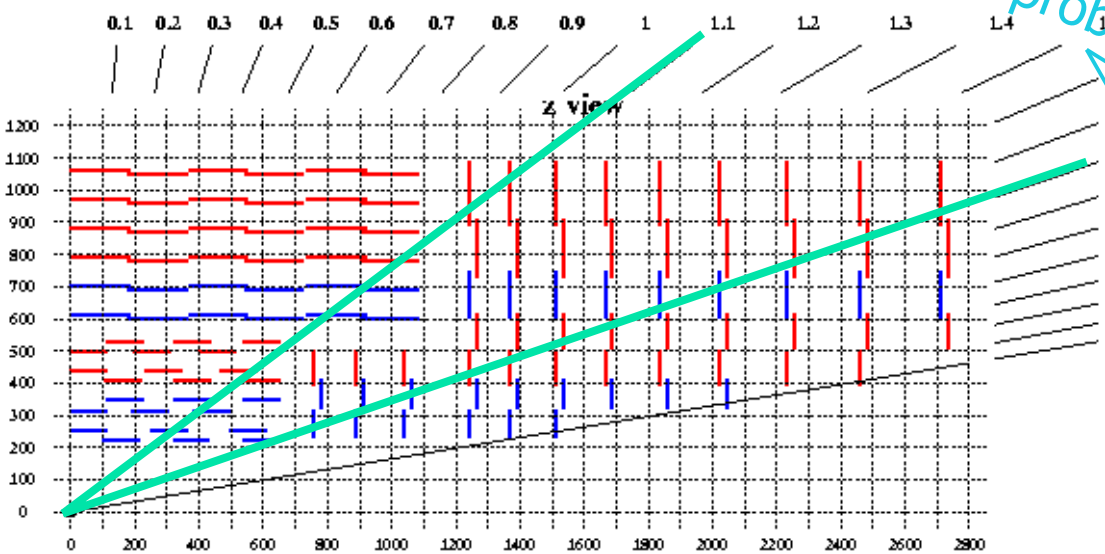
- **Tools to check the OSCAR/ORCA interface:**
  - Numbering schema ("Rosetta Stone" of the interface)
  - Local hit position (⇐ ability to read back the ooDB)
  - Global hit position (⇐ ability to reconstruct/convert the reference systems)

By the way: Cmsim was "bad"since it had more than one reference system. To my knowledge, the Tracker in OSCAR has 4 ref systems…

⇒ Again to be addressed by **DDD**

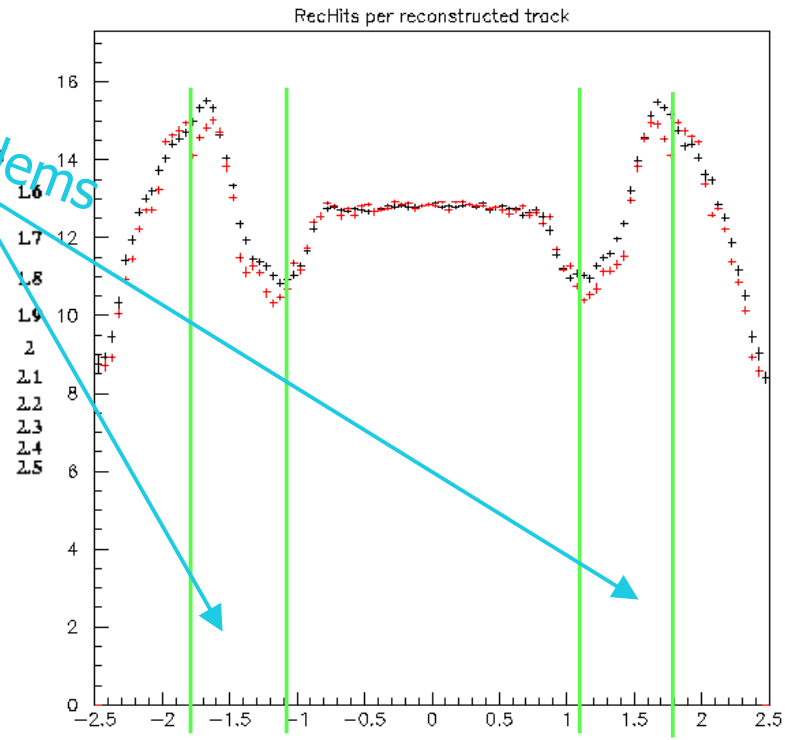
OSCAR/Cmsim comparisons

- The same happened in Cmsim ~1 year ago. Probably a "simple" problem with overlapping volumes.
- Does this mean we are now with OSCAR at the same level of refinement as Cmsim 1 year ago? Why not? Infact:

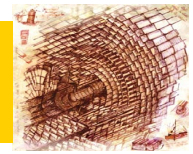


Expected problems

Reconstructed hits per reconstructed track



The OO project, OSCAR



- **Based on Geant4, promises better description of "all" the interactions (frankly speaking, to be proved…)**
- **Part of COBRA (Common Framework)**
- **Better speed (already proven for single tracks?)**
- **For what concerns specifically the Tracker, we need:**

1. Correct detector geometry
2. Correct material description (quantity + physics properties)
3. Correct interfacing to ORCA.

… or at least equal to Cmsim (for initial comparisons)