Geant4 simulation of the ATLAS liquid-argon calorimeters (LArG4)

- Evolution of the package
  - Four detectors -> one simulation
  - Athena/CMT and stand-alone
  - Complex geometries
- The next steps
  - GeoModel
  - Simulation speed
  - Calibration
- Related projects
  - test beam
  - ParticleGenerator

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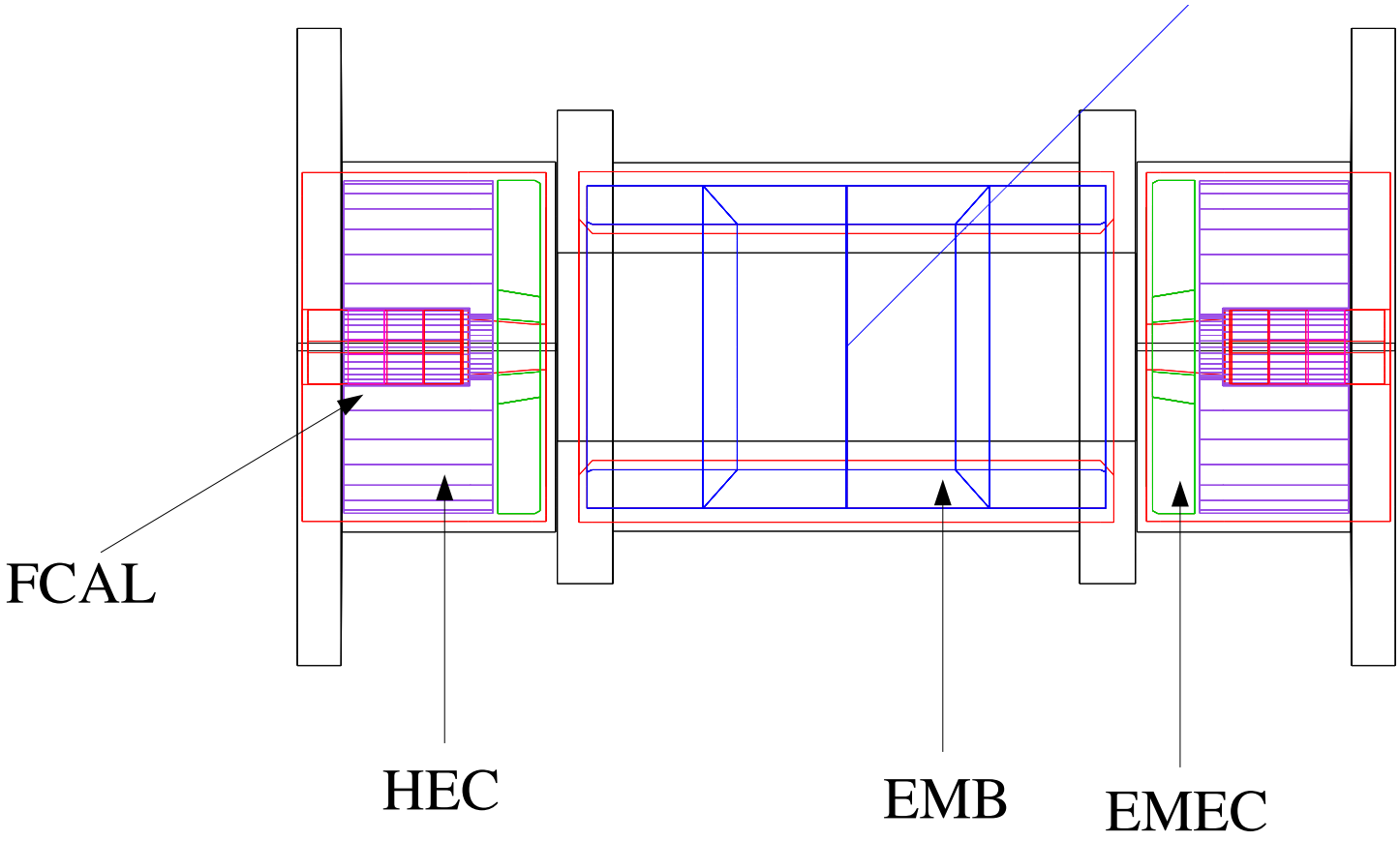
28-Aug-2003 ATLAS Software Conference at BNL

LAr Cryostats and Detectors



LArG4 development

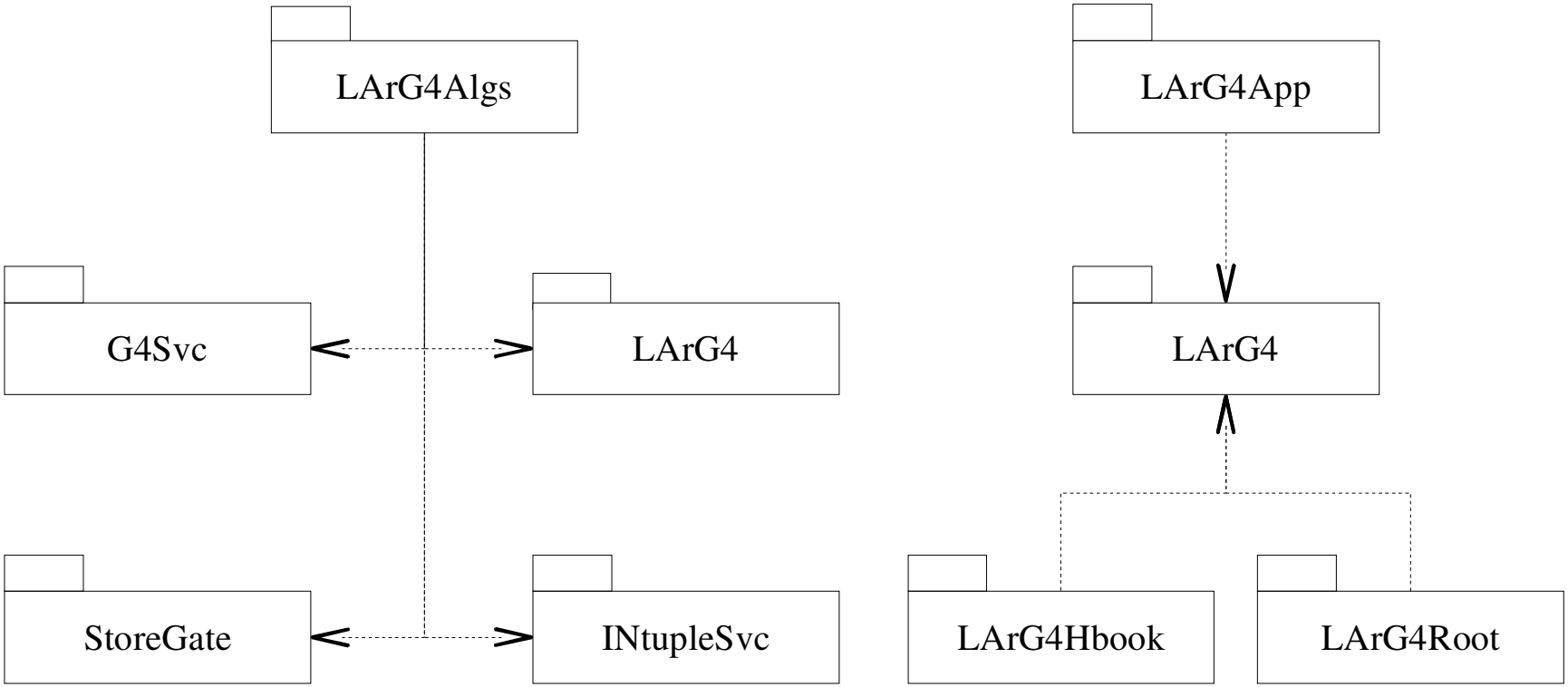
- The Geant4 development effort for the individual LAr detectors (FCAL, HEC, EMB, EMEC) were unified under one application package, LArG4.
- LArG4 standardizes the following, leaving the developers free to concentrate on geometry:
  - persistency (hits, n-tuples, histograms)
  - visibility (for G4 event displays)
  - database access (for parameters)
  - execution environment (Athena vs. stand-alone)

Some examples follow...

LArG4 execution: Athena and stand-alone

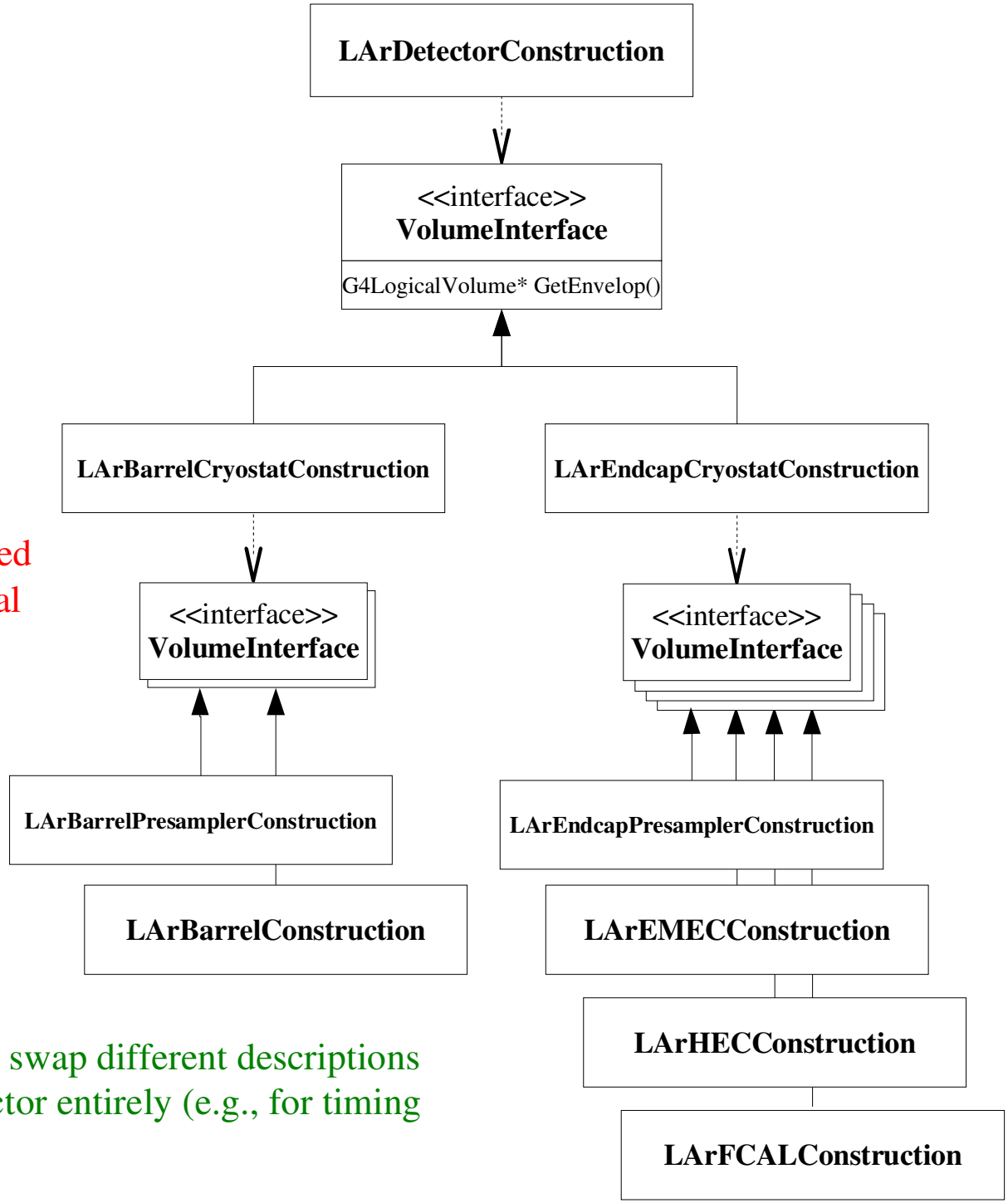
- Athena/CMT
  - provides access to other ATLAS physics packages, such as:
    - event generators (Pythia, ParticleGenerator [more on this later...])
    - Reconstruction
    - integration with full ATLAS detector simulation
- Stand-alone
    - fast development cycle
    - compatibility with previous HBOOK and ROOT studies
    - can compile and execute on many Linux versions, and on machines without network access (e.g., laptops)

One LArG4 package; two modes of execution



Documentation is available (in LArG4/doc) on how to use LArG4 and develop code in both these modes.

Unifying the geometries: the LArG4 detector construction classes



The class hierarchy is organized in the same way as the physical detector.

This approach makes it easy to swap different descriptions of a detector, or to omit a detector entirely (e.g., for timing studies)

Status

- Overall
  - The geometry definitions of the liquid-argon calorimeters in Geant4 are basically complete, including mechanical support structures.
  - The geometry definitions of the cryostats are also almost complete (still need some more detail on the back walls).
  - Endcap and barrel presamplers are present (some minor cleanup needs to be done).
  - All detectors can produce hits that can be passed into Athena Reconstruction. (Additional Digitization may come later.)

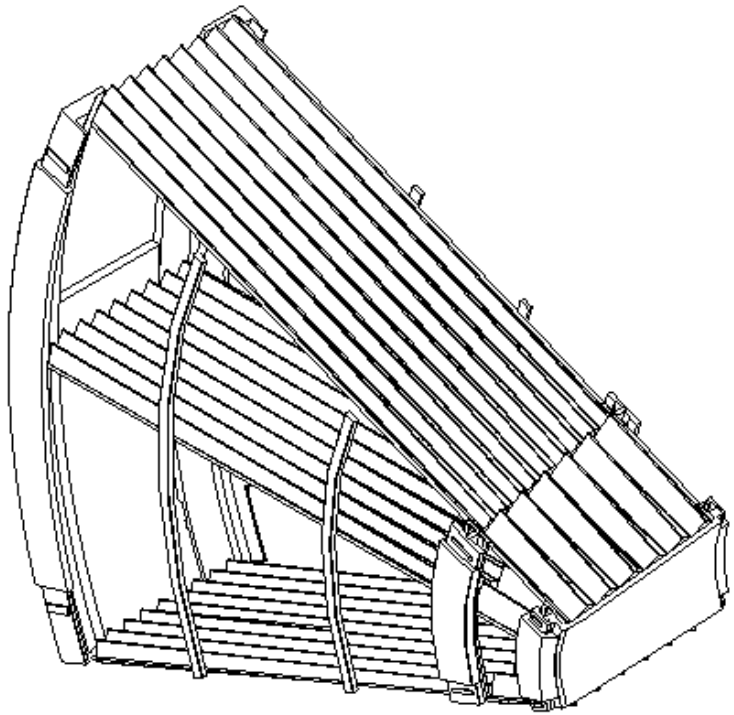
Status (continued)

- Milestones
  - FCAL
    - It's done!
  - HEC
    - Tie rods are included
  - EMB
    - Sagging of the accordion elements
    - Energy correction due to charge collection effects
  - EMEC
    - Energy correction due to charge-collection
    - Sagging not yet implemented (more on this in a little bit)

Why no pretty pictures?

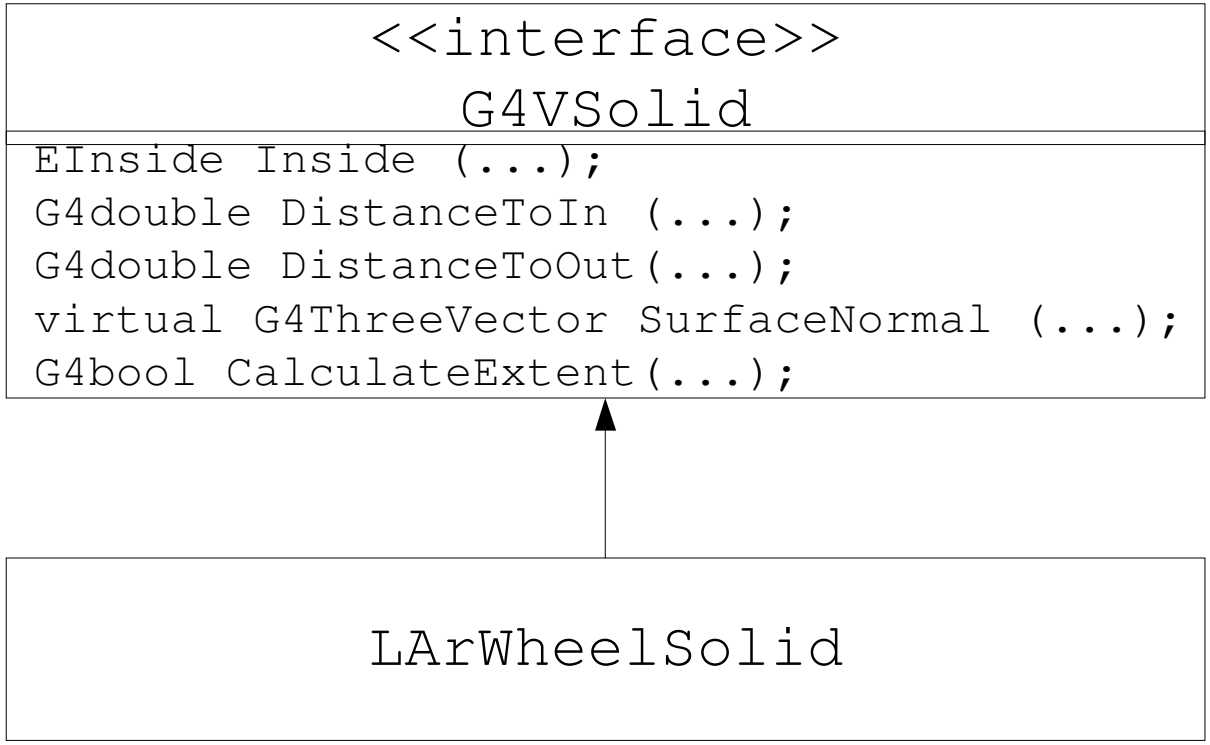
Geometry challenge: the EMEC (electro-magnetic endcap calorimeter)

The absorbers and electrodes have a complex fan-fold shape that varies as a function of radius.



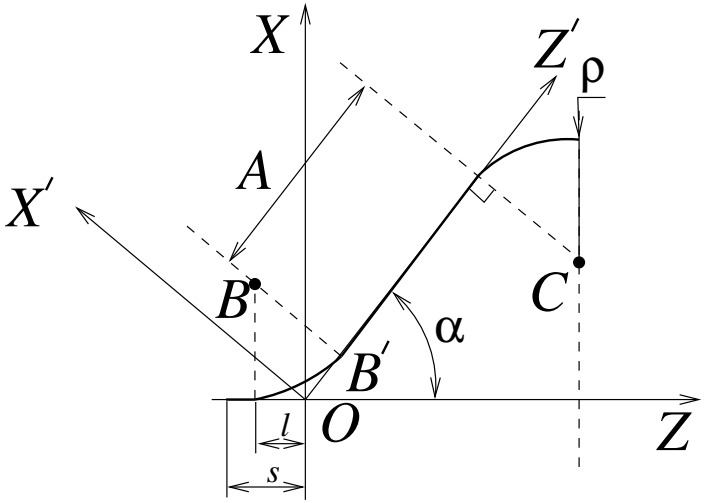
from the ATLAS TDR

One solution: implement a custom solid

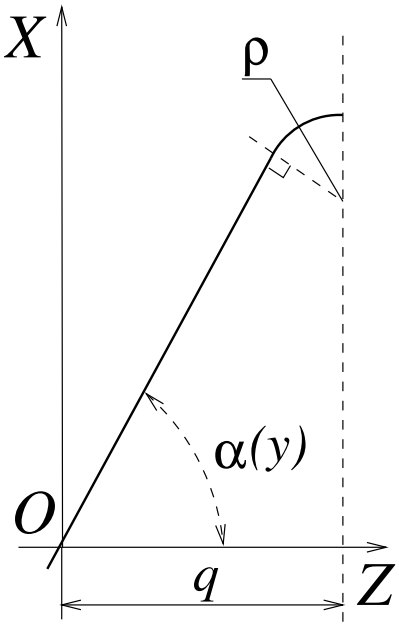


Unless you write the visualization code, custom solids won't be visualized.

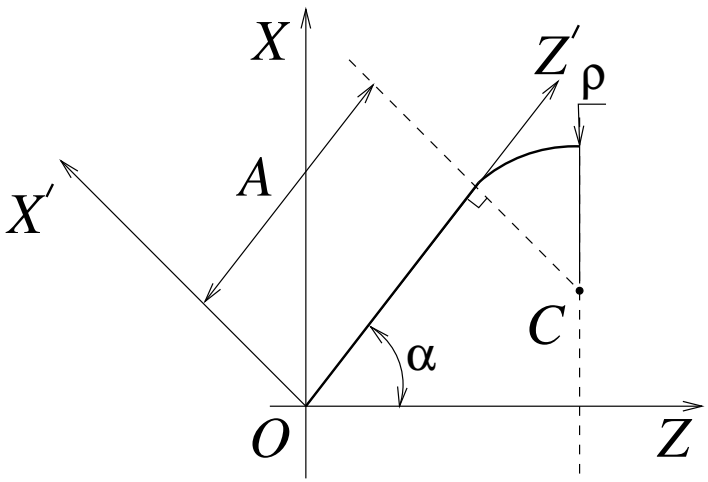
Some plots of the EMEC "shape"



initial quarter-wave at start of fan



typical quarter-wave



determining the distance
from an arbitrary point
to a typical quarter way

from A. Soukharev's paper in LArG4/LArG4EC/doc

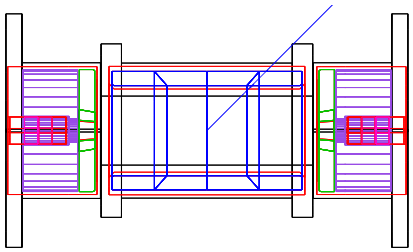
What's next? One project is...
GeoModel

- GeoModel is a package for describing detectors
  - shapes
  - materials
  - geometric hierarchies
  - alignable regions
- One geometry model will go to different clients
  - Simulation
  - Reconstruction
  - Visualization

An issue: GeoModel vs. Geant4

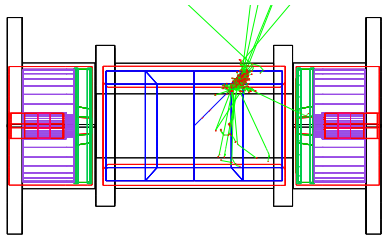
- GeoModel just describes geometry. Geant4 volumes have additional properties that aren't handled in GeoModel:
  - visualization
  - sensitivity to hits
  - fast-shower models (more on this later...)
  - e-m fields
  - voxelization parameters
  - custom shapes

Our solution: "Consultants"



GeoModel description
(LArGeoModel)

Geo2G4



Geant4 description
(LArGe4)

For each volume in the description, look up a property in the consultants

```
...
"LAr::FCAL::Module"
"LAr::FCAL::LiquidArgon"
"LAr::FCAL::Rod"
...
```

Shape consultant

Model consultant

Sensitive-detector consultant

Visual consultant

```
"LAr::FCAL::Module"
```

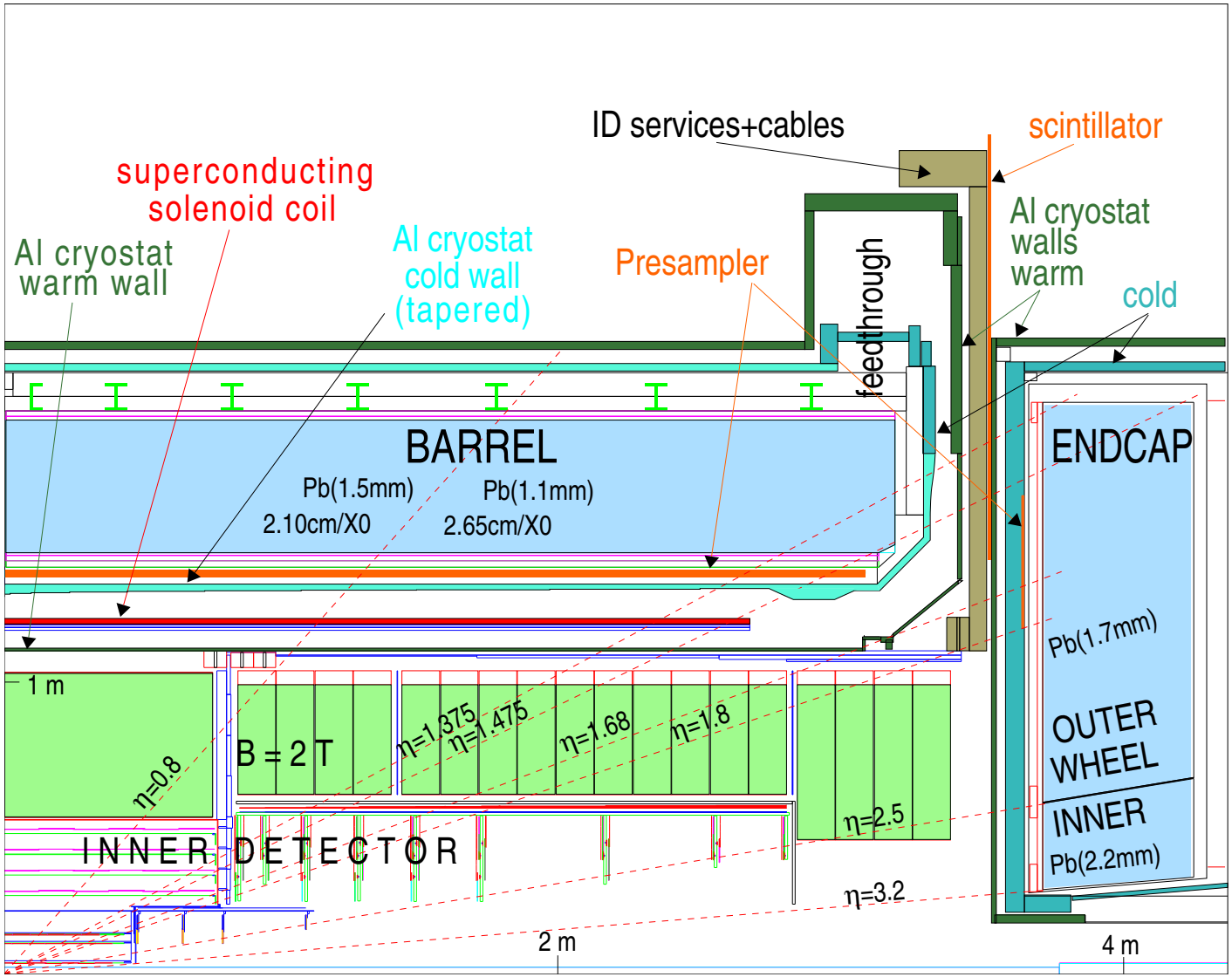
GeoModel conversion status

- All the necessary consultant classes have been created.
- The LArGeoModel application package has been created, with most of the control functionality of LArG4.
- Descriptions of the barrel and endcap cryostats have been placed into LArGeoModel.
- Work is currently in progress for the FCAL and EMB.
- Still need a Geo2G4 converter (just about to start this).
- We are co-ordinating with Reconstruction to fulfill their requirements, in addition to fulfilling the requirements for Simulation.

Another project: the Fast Shower Model

First, a reminder of η versus "calorimeter"

Note: the inner detector is not included in LArG4; the FCAL is not included in this diagram



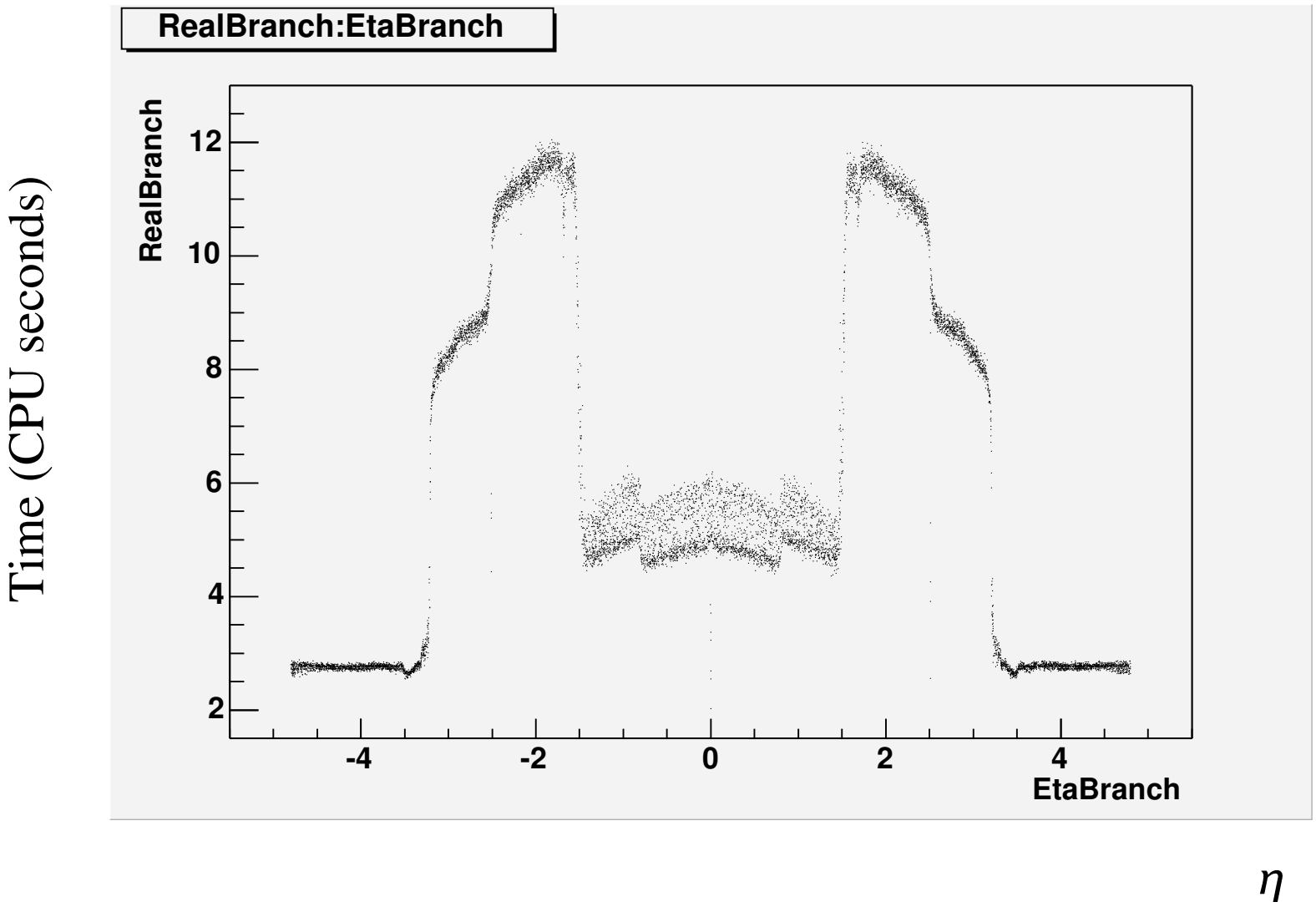
A rough guide

Detector	Range in η
EMB	0 to 1.5
EMEC outer wheel	1.5 to 2.5
EMEC Inner wheel	2.5 to 3.2
FCAL	3.2 to 4.9

from the ATLAS Performance TDR

LArG4 simulation time versus η for 20 GeV electrons

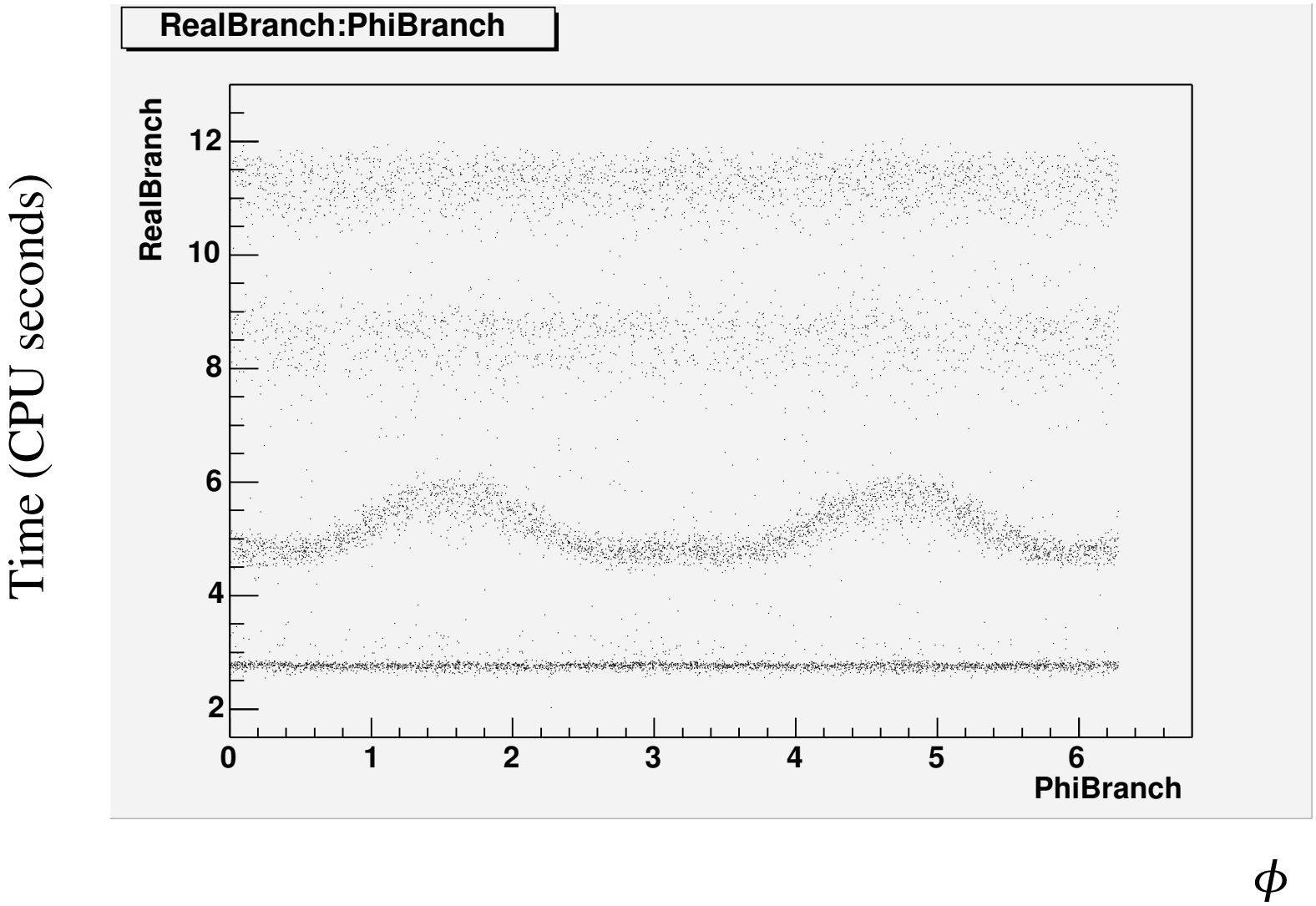
run with a 2.4 GHz Xeon processor running Redhat 8



If we parameterized the particle showers in the calorimeter, we could considerably speed up the simulation.

LArG4 simulation time versus ϕ for 20 GeV electrons

run with a 2.4 GHz Xeon CPU, cache size 512KB, Redhat 8



A quick Geant3 vs. Geant4 speed comparison

System: Pentium III, 0.8 GHz CPU, cache size 256KB, 10 GeV electrons

	Geant3 (atlsim)	Geant4 (LArG4)
EM Barrel	0.34 *sec/GeV*	0.64 *sec/GeV*
EM Endcap Outer Wheel (η=1.9)	0.56 *sec/GeV*	1.11 *sec/GeV*
EM Endcap Inner Wheel (η=2.8)	0.53 *sec/GeV*	0.82 *sec/GeV*

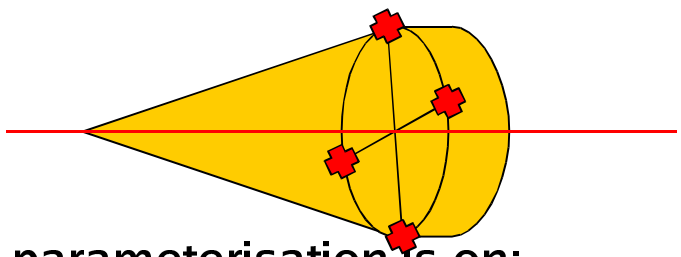
parameterisation mechanism

Procedure:

when a particle enters in the calorimeter is decided if the parameterisation is activated:

Particle type : e+/e-

Conditions : energy bounds for parameterisation validity, showers containment



Check if at Z(90%), R(90%) the shower is inside the calorimeter

when the parameterisation is on:

- the particle is killed
- energy spots are deposit along the particle direction according to the parameterised longitudinal & radial profile
- hits are deposit in the 'sensitive' detector

taken from E. Barberio's talk at the May 2003 ATLAS Software workshop

Status of Fast Shower Model

- The consultants and other infrastructure classes have been added to LArG4.
- The model parameters are being determined for the EMB by E. Barberio and A. Straessner.
- We are actively soliciting for people working the other LAr sub-systems to pursue this work.

Yet another LArG4 project: Calibration Hits

- Goal
  - To provide additional information from the simulation for use in calibration studies.
- Requirements
  - The additional information will be in the form of "hits", similar to the standard hits produced by the simulation.
  - Every volume in a detector must be made "sensitive" in the simulation in order to produce these "calibration hits" in Geant4.
  - All the energy from all the physics process must be recorded as part of the calibration hits.
- Status
  - Just starting.

Calibration hits

- LArHit
  - Readout identifier
  - Energy deposited in liquid argon
  - Time

- LArCalibrationHit (not final!)
  - "Dead material" identifier
    - equivalent to readout identifier in active detector regions
    - special code required for, e.g., cryostat walls
  - A separate energy field for each of the following:
    - e-m processes ($e^{\pm}$, γ)
    - ionization ($\pi^{\pm}$,$\mu^{\pm}$)
    - "invisible" processes (ν, stopped particles)

Work related to LArG4: Test Beam (package LArG4TB)

- The LArG4 code infrastructure is being used by the test-beam developers.
- The LArG4 detector-geometry classes are being shared with the test-beam code wherever possible.
- We're advising the test-beam developers in their use of the LArG4 code.

Work related to LArG4: ParticleGenerator

This is a simple event generator for use in Athena. It's a tiny 'programming language' that can be used to create to control particles for simulation studies.

Examples:

```
"PDGcode: constant 11",
"energy: constant 629",
"vertX: gauss 0.0 10",
"vertY: gauss 0.0 10",
"vertZ: gauss 0.0 50",
"targetX: constant 420",
"targetY: constant -4.2e+02",
"targetZ: fixed 52000E-01",
"Time=flat -1 1"
```

```
"id: constant 13",
"Et: histogram energydistribution4",
"eta: sequence 0.1 0.3 0.6 1.2 2.8 3.0 5",
"phi: Loop after Eta 0 6.283 .785398"
```

The documentation is in Generators/ParticleGenerator/doc

Conclusion

- LArG4 is a functional simulation of the liquid-argon calorimeters in Geant4.
- On-going development work includes:
  - ATLAS software infrastructure changes (e.g., GeoModel)
  - Fulfilling requirements for testbeam work
- We continue to work on the accuracy, speed, and usefulness of the package.
- For more infomation, take a look at the package itself in the ATLAS CVS Repository:
  <http://atlas-sw.cern.ch/cgi-bin/cvsweb.cgi/offline/LArCalorimeter/LArG4/>