Geant-4
Status, Experience & Plans

John Apostolakis, CERN

for Geant4 collaboration

Context and Contents

- *Geant4's first production release*
  - *version 4.0.0 end 98*
  - *new Geant4 collaboration*
- *Brief overview of Geant4*
- *Experiences with Geant4.0.0*
- *Status and plans*

Geant4 Capabilities

- *Very powerful Geant4 kernel*
  - *tracking, stacks, geometry, hits, ..*
- *Extensive & transparent physics models*
  - *electromagnetic, hadronic, …*
- *Additional*
  - *persistency, visualization, …*
- *Surpasses Geant-3*
  - *in nearly every respect*

Geant4 kernel

- Tracking
  - general & flexible
- Event
  - powerful stacking at no cost
- Geometry
  - hierarchy or flat; voxels for speed.
- Hits: user-defined

Electromagnetic processes

All processes at least at level of Geant-3

- *New process: Transition radiation*
- *Multiple Scattering: new model*
  - *no path length restriction*
  - *added lateral displacement*
- *Energy Loss: two approaches*
  - *Integration of cross section over Energy*
    - *DE/E not constrained for e+/e-*
    - *hadronic resonances can be seen (future)*
- *Processes can produce secondaries below threshold near boundaries*

Hadronic processes

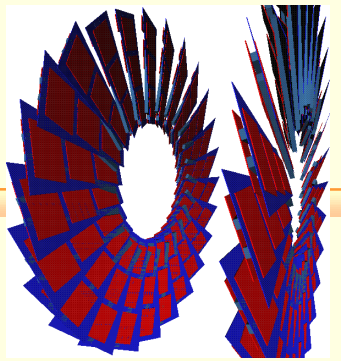
- *Distinguish process and model*
- *Separate model designs*
  - *for parameterized, data and theory driven*
- **Data driven models:** *Low energy neutron*
  - *Based on evaluated data*
    - *ENDF, Jef, JENDL, CENDL, ENSDF, etc..*
- **Parameterization driven models**, *e.g.*
  - *High E inelastic*
  - *Stopping particles:* p^- , K^-

Geant4 Experiences

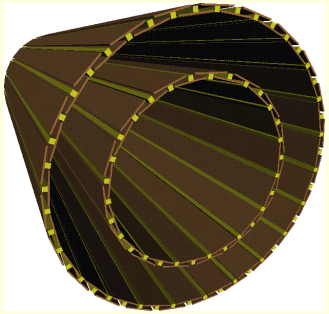
- *ATLAS: see following talks*
- *CMS from AIHENP99*
  - *Hcal, EM physics, ..*
- *Borexino*
- *BaBar: fast simulation*
- *Geant4 team*
  - *EM performance*

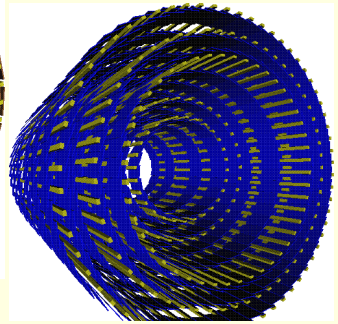
CMS Geometry in GEANT4

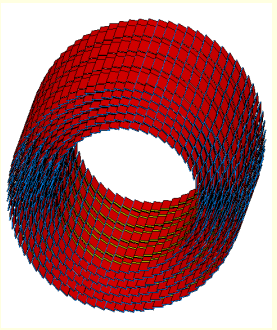
current status

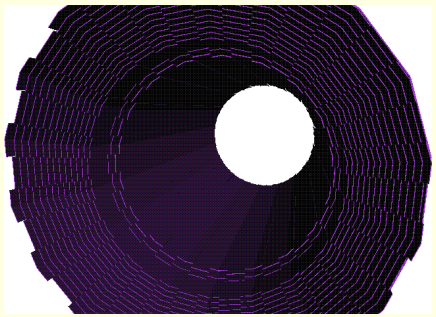


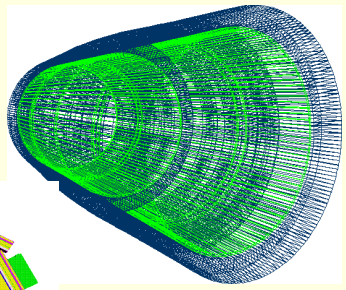
- **Beam Pipe**
- **Tracker**
  - Si Pixel Detectors
    - Barrel Si Pixel
    - Forward Si Pixel
  - Si Strip Detectors
    - Barrel Si Strip
  - MSGC
    - Barrel MSGC
- **Calorimeters**
  - Electromagnetic Calorimeter
    - Barrel ECAL
  - Hadron Calorimeter
    - Barrel HCAL
- **Muon System**
  - Barrel Muon

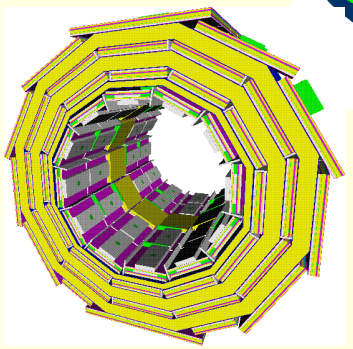




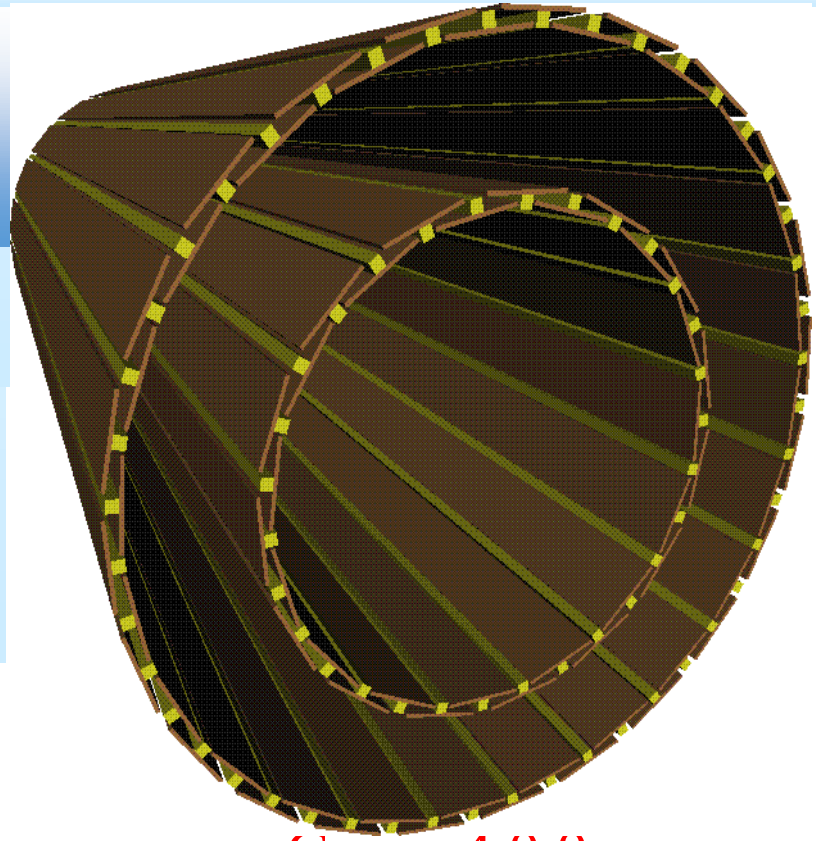


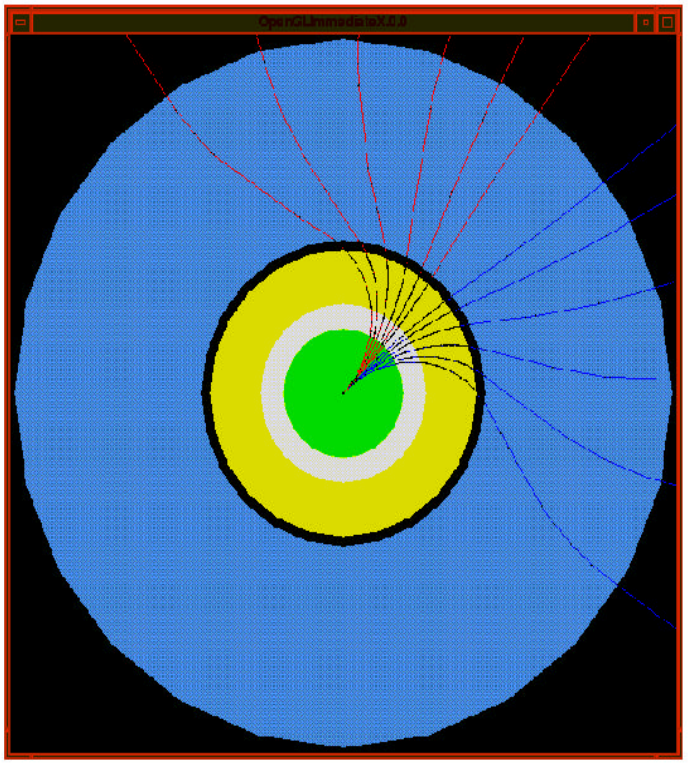






Barrel Si Pixel Magnetic Field





GEANT4.0.0

max. radius = 11 cm

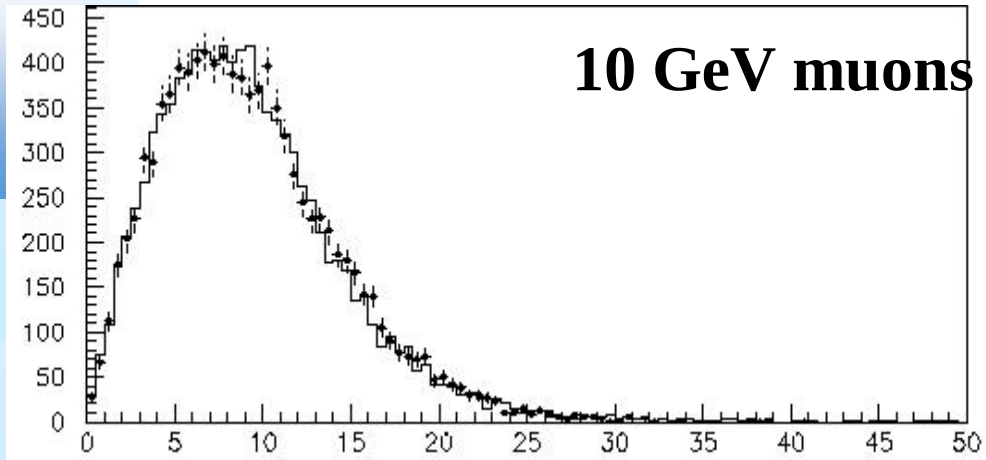
length = 60 cm

Muon Physics with GEANT4

Comparisons between GEANT3.21and GEANT4.0.0 for low/high energy muons going through 100 cm iron.

- *Good agreement for E~10 GeV*
- *Differences at E~100 GeV as expected:*
  - *limit of validity range of GEANT3, process missing, correction factors missing*
  - *GEANT4 uses more up-to-date cross-section values*
- *Results going to be compared with experimental data*

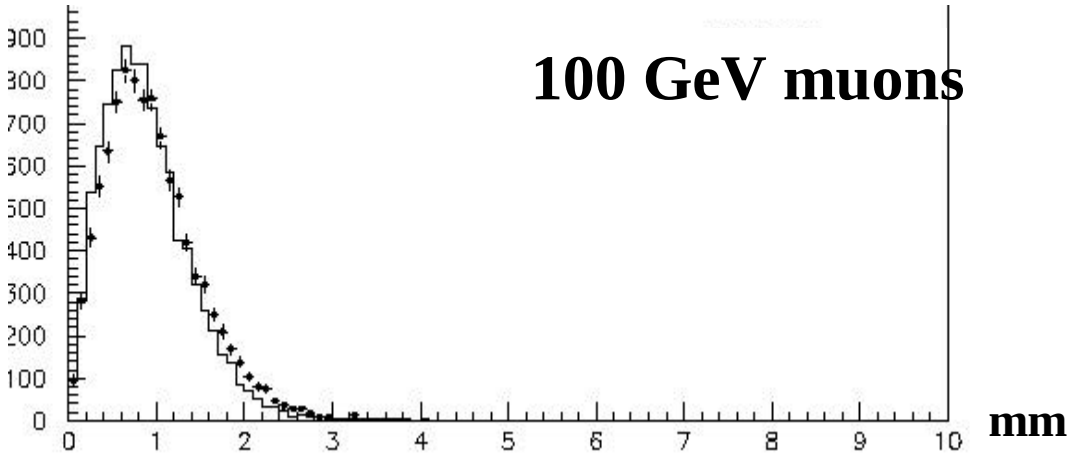
Muon mult. scattering



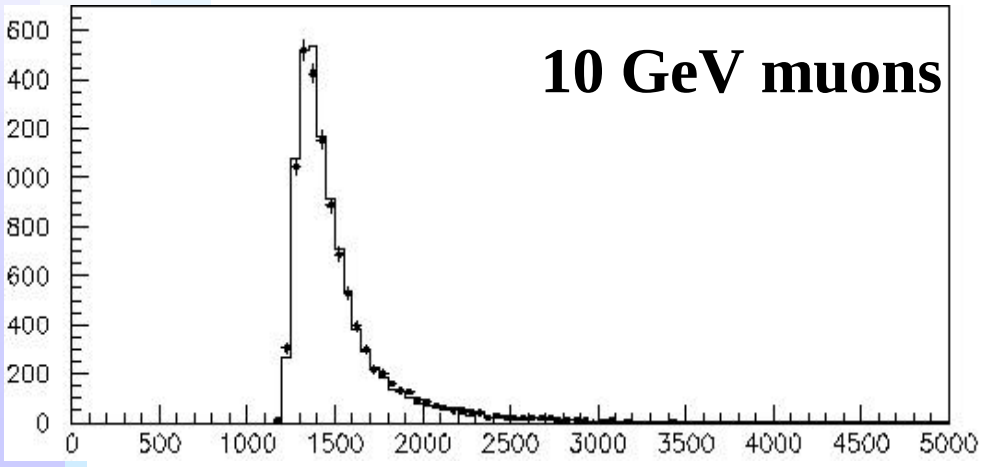
Transverse displacement after 100 cm iron

GEANT3.21 :—

GEANT4.0.0 :•



Muon energy loss

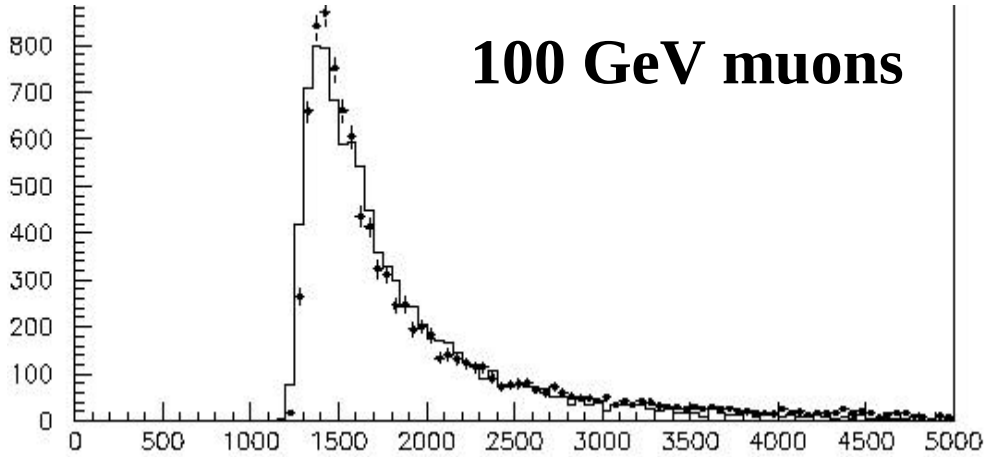


MeV

Energy loss in 100cm iron

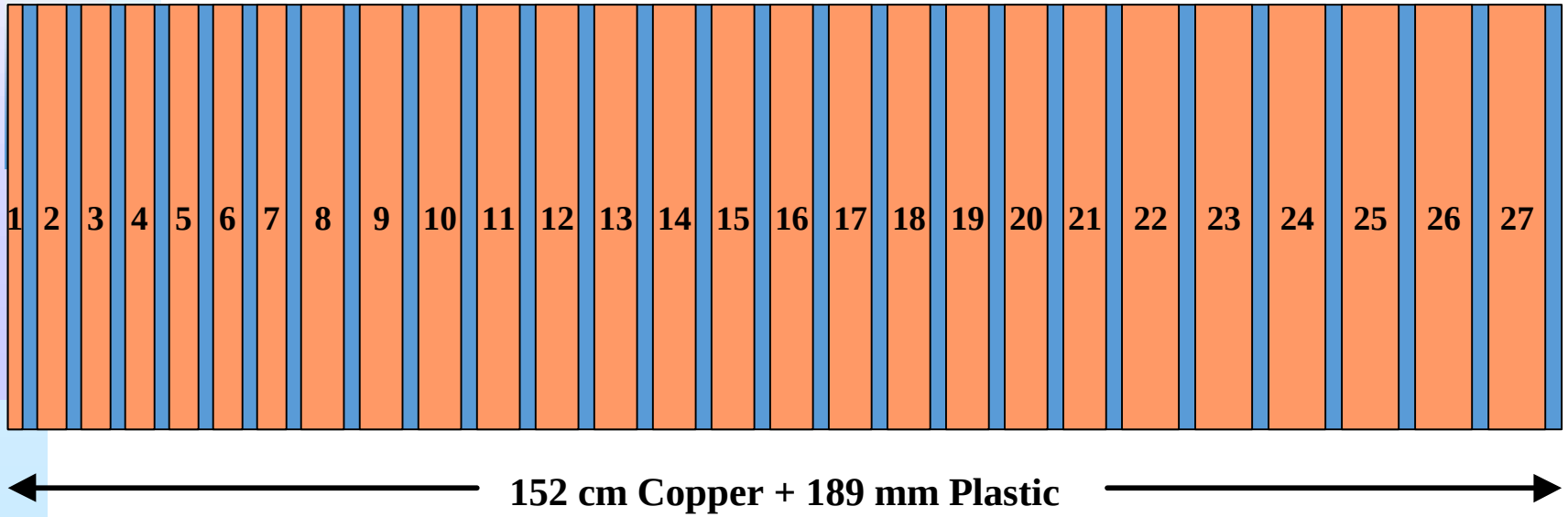
GEANT3.21 :—

GEANT4.0.0 :•



MeV

HCAL (H2 1996) Test-Beam Setup



Layer 1 : 2 cm Copper

Layers 2 to 7 : 3 cm Copper

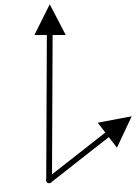
Layers 8 to 21: 6 cm Copper

Layers 22 to 27: 8 cm Copper

Scintillators: 2 mm passive Plastic

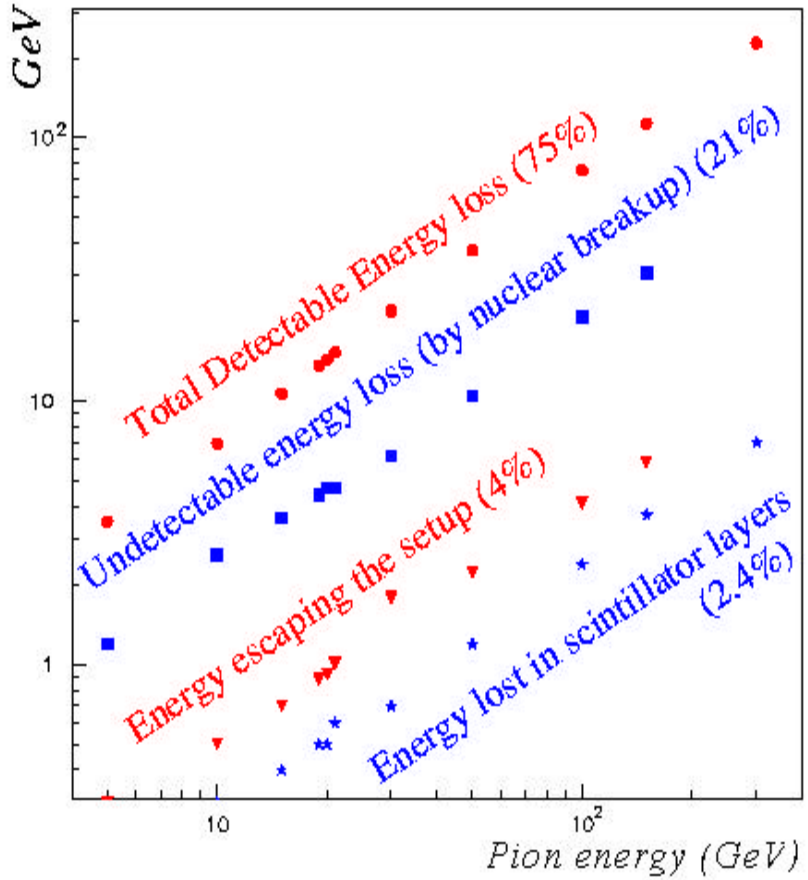
4 mm active Plastic

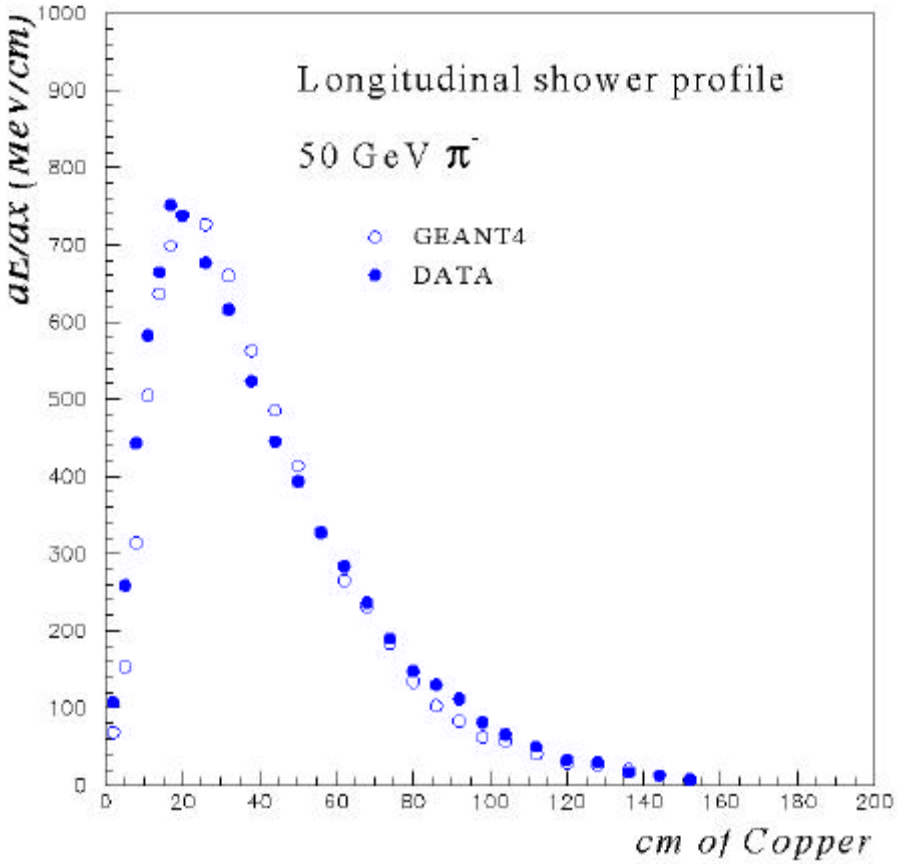
1 mm passive Plastic



64 cm x 64 cm

Geant4
Hadronic showers 50 GeV pion shower





AIHENP 99' Summary

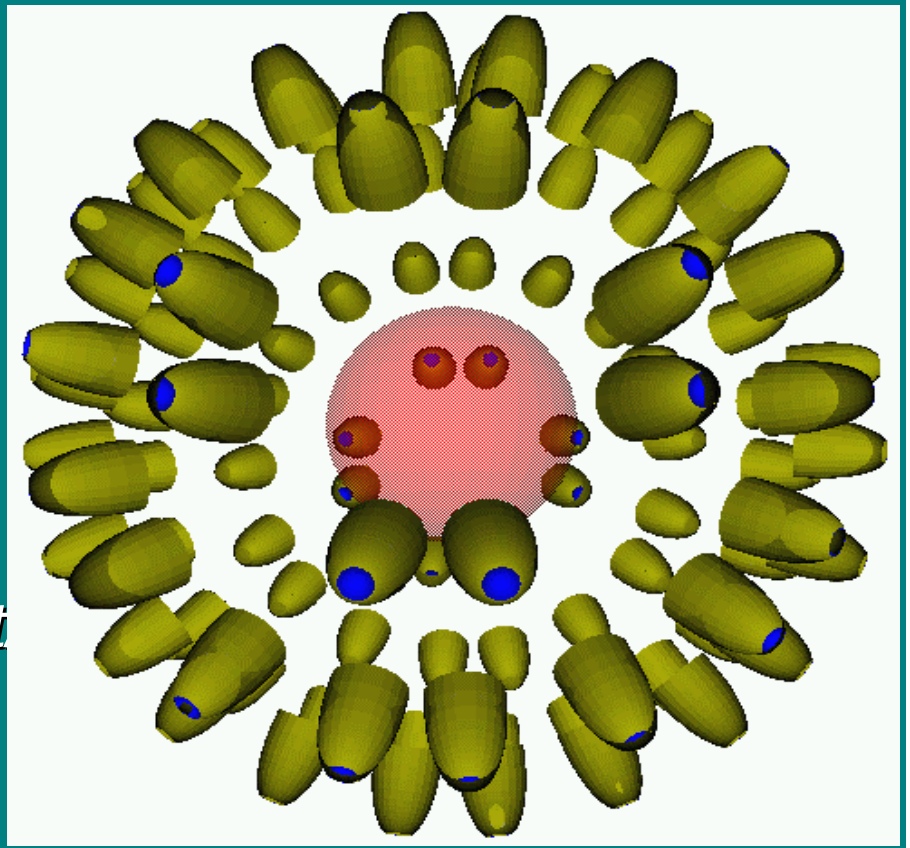
- CMS has close to 2 year experience with alpha, beta and first public releases of GEANT4
- GEANT4 will be used for full CMS simulation (OSCAR project)
- further validation tests of the physics processes simulated by GEANT4 will be performed using test-beam data

Borexino's detectors

- *Detector for Low Energy Solar Neutrinos*
- *1st phase*
  - *100 photomultipliers in 1m3 scintilator fluid*
- *Full detector: ~2000 ph.*
- *See http://almime.mi.infn.it*

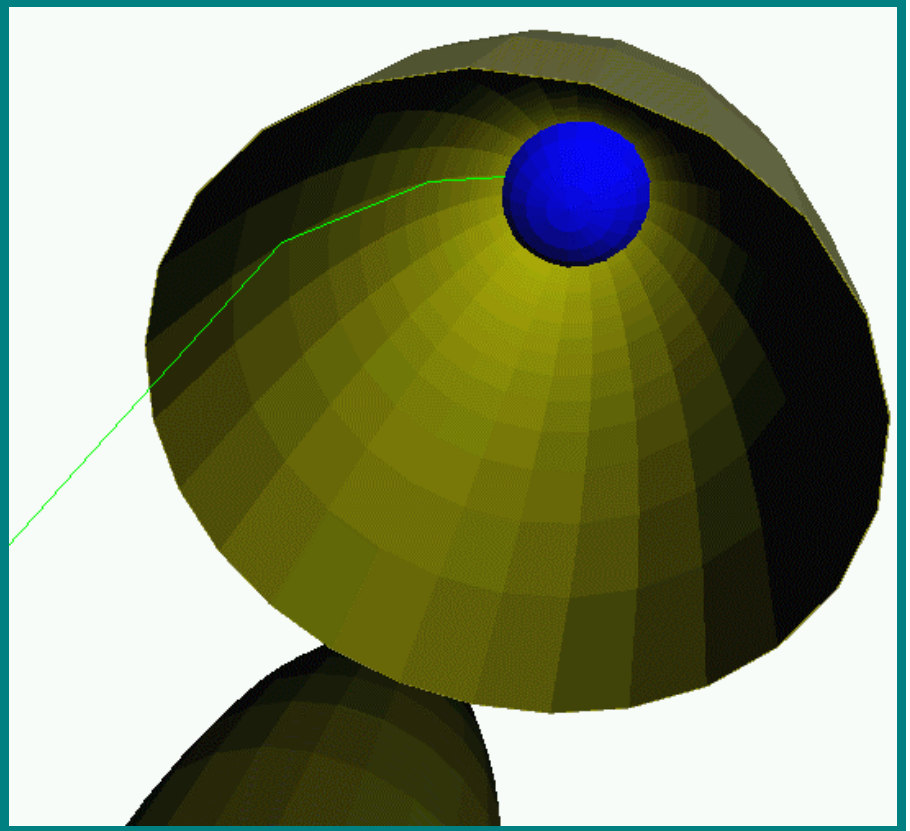
Thanks to

S.Magni, G.Pieri, INFN Milano



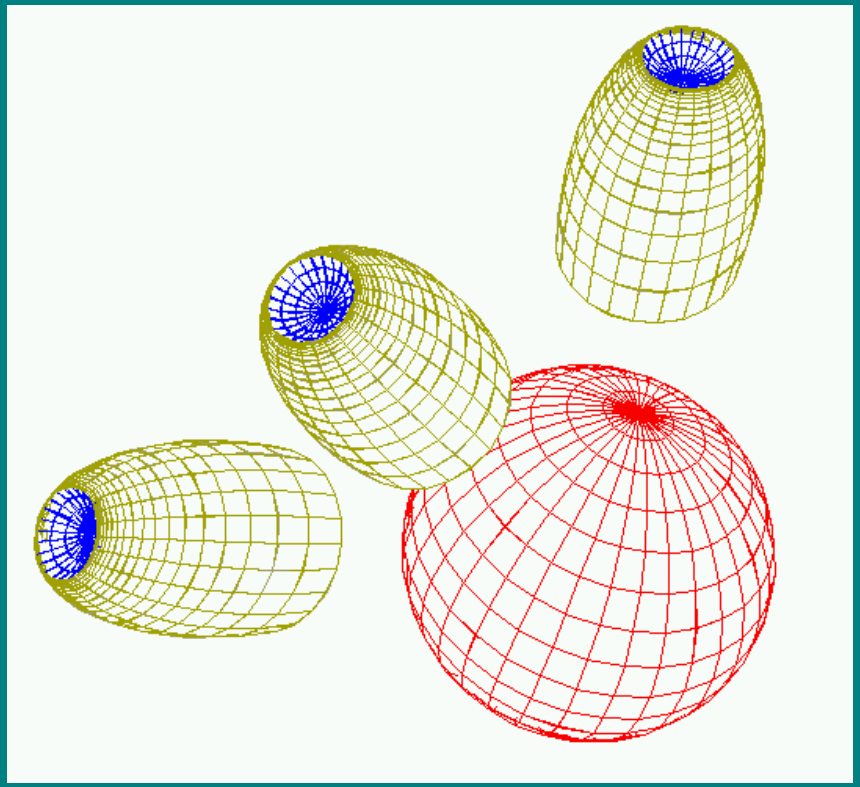
Simulation in Borexino

- Old code: ray tracer
  - simplified tracking
  - no reflections, phys.
- Geant4 code
  - reproduces results
  - photons tracked everywhere
  - flexible, extensible
  - immediate benefit: new under-standing



Benefits of Geant4 (Borexino)

- Full geometry
- All optical processes
  - reflection, refraction
- New process
  - for specialised physics of scintilator
    - scatter, absorption, re-emission

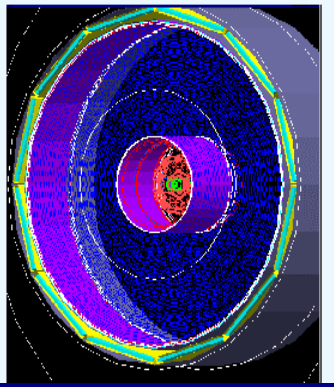


BaBar's Simulation: "Bogus"

- *Fast Simulation commisioned April 99*
- *Simple geometry*
- *Parameterisation processes*
  - *hits on detector elements create reconstruction objects*

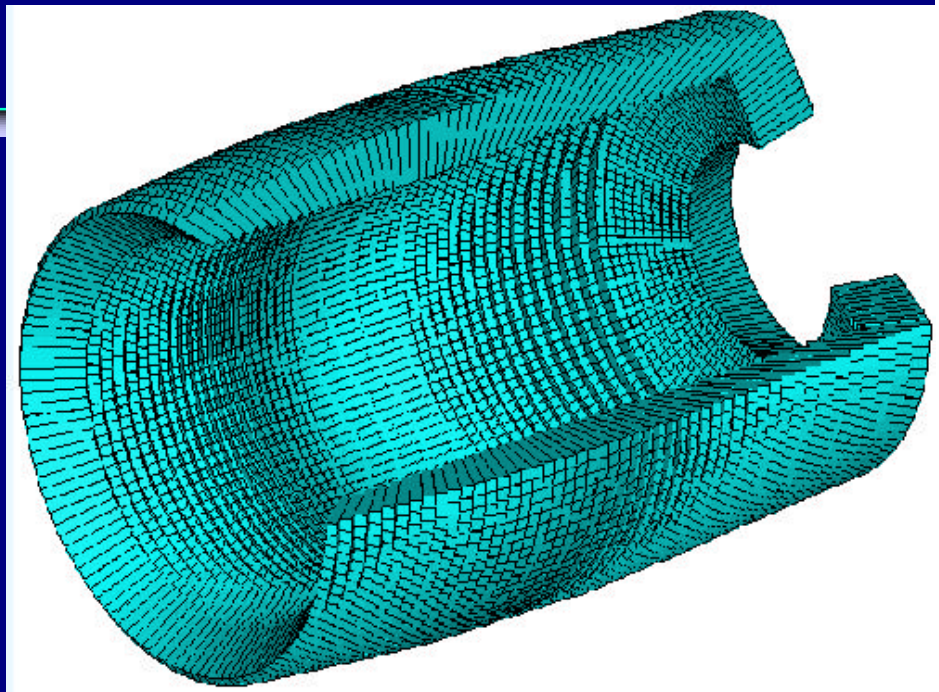
Fast Bogus Detector Geometry

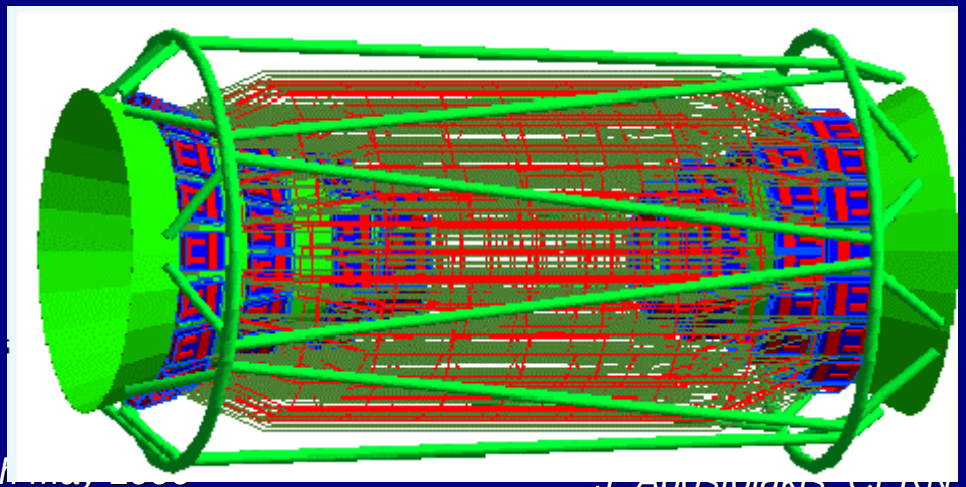
- OpenGL Screen dump
- Detector view from +z end with
  - PEP beam pipe
  - SVT
  - Support tube
  - Drift chamber (layer model)
  - DRC bars
- Currently testing
  - G4Polycone EMC mother volume
  - G4Polyhedra IFR mother volume



BaBar full simulation

- *Under development*
- *First full version of Geometry soon, e.g.*
  - *EMC from g3tog4*
    - *J. Allison*





- *SVT*
  - *N. Kuznetsova,UCSB*

Benchmarks: speed of EM physics

- Focus on EM physics performance
- Compares
  - speed at constant physics
  - physics at constant speed
- Two configuration:
  - thin silicon
  - model sampling calorimeter

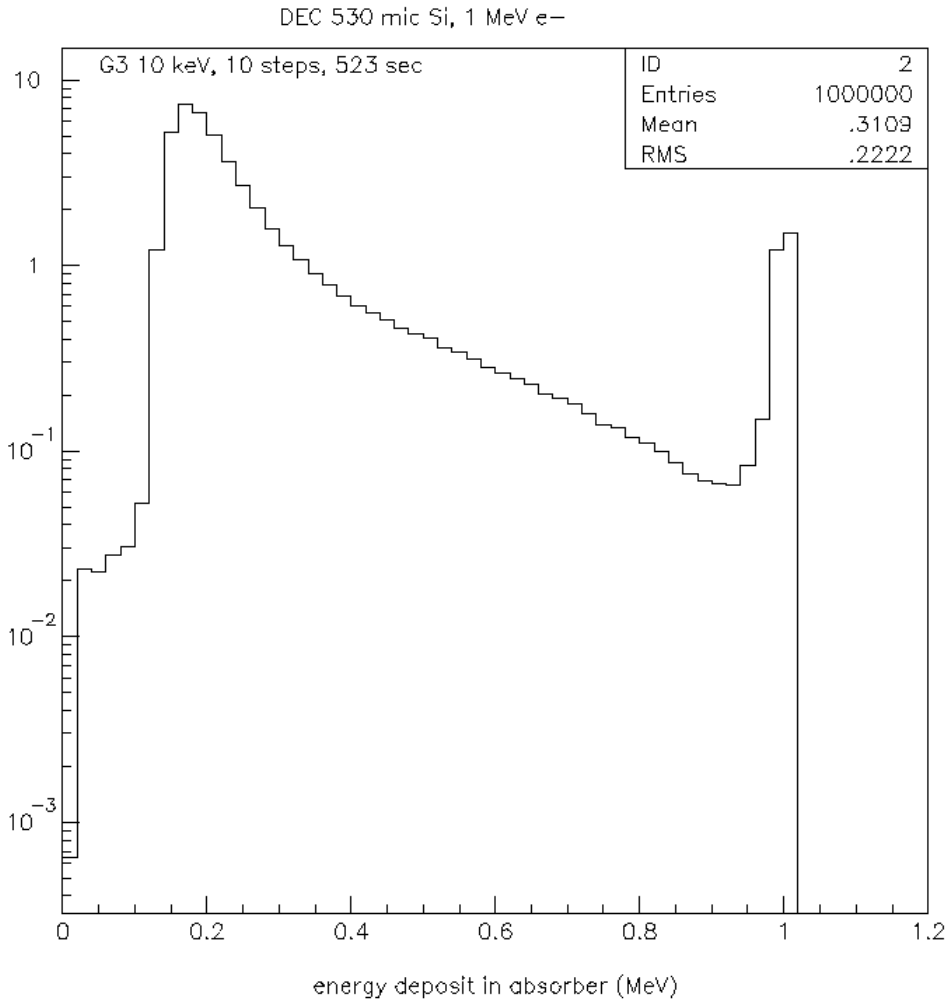
Benchmark 1 EM (sampling calorim.)

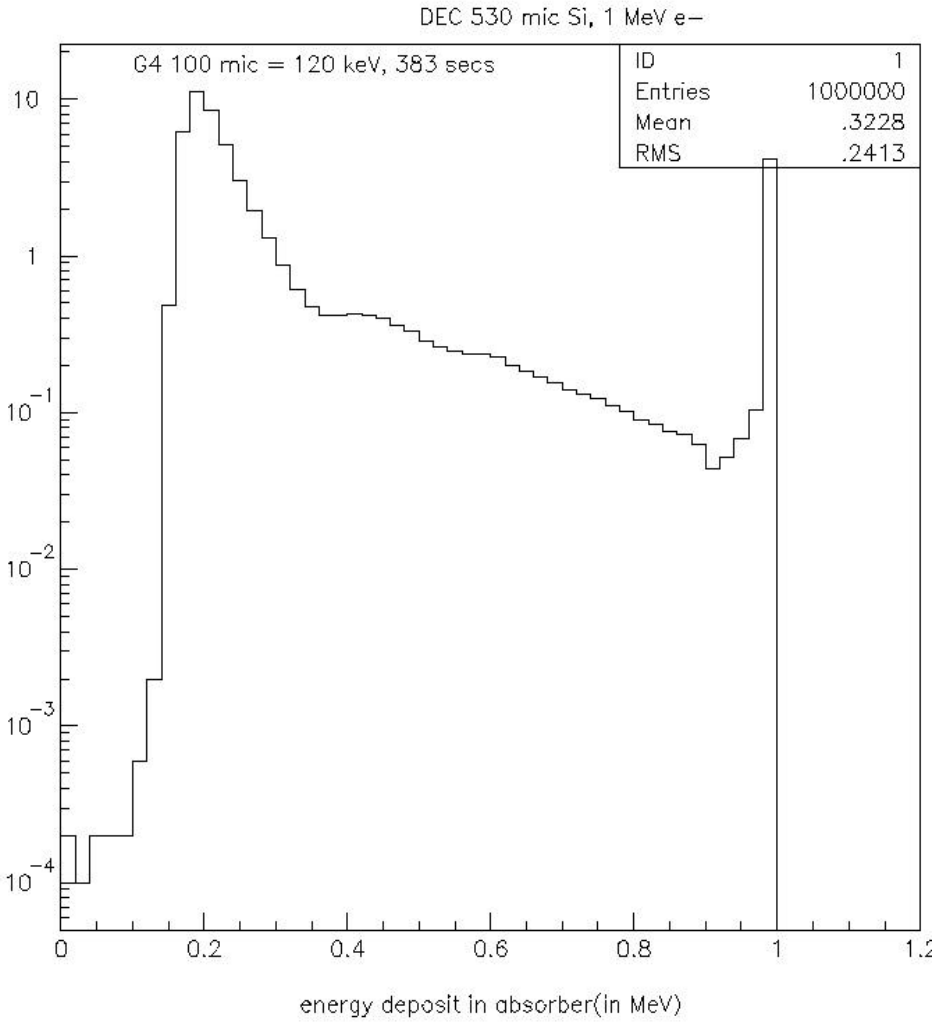
- Compares
  - speed at constant physics
- Focus on EM physics
  - so a single volume and material is selected,
    - the G4 geometry speed-up is not exploited
  - 530 um Si, 1 MeV electrons
  - 1,000,000 events

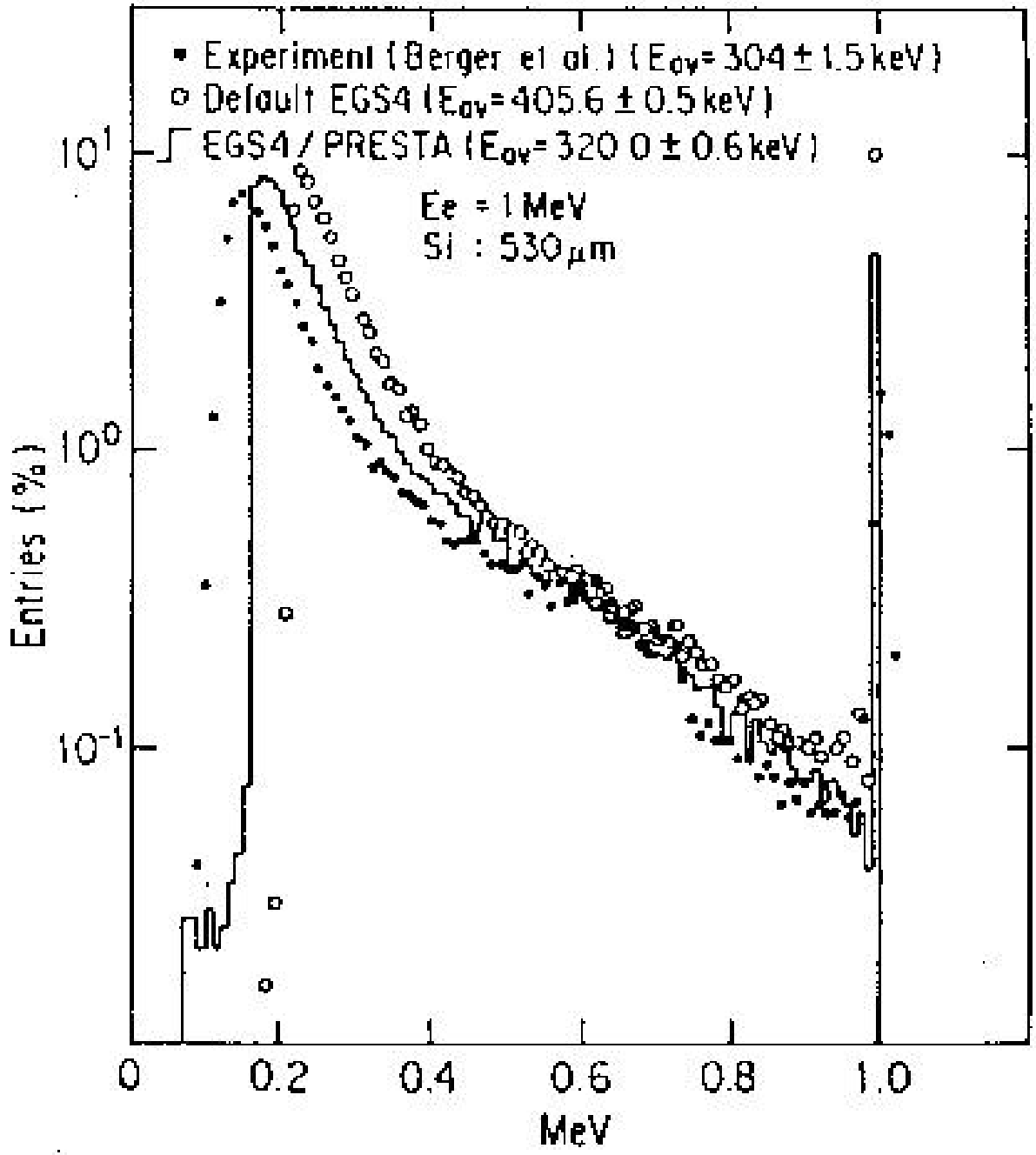
Benchmark 1 EM: thin silicon

- In order to agree with the data
  - and with EGS4 with the PRESTA option,
    - G3/G4 need to run in these configurations:
- Geant 3.21
  - cuts = 10 KeV, stemax = 53 micron, aban=0. ===> speed = 523 sec.
- Geant 4.0.1
  - cuts = 100 micron. ===> speed = 383 sec.

Benchmark 1: G3 & G4 plots






• Experiment (Berger et al.) (E_{av}= 304 ± 1.5 keV)
○ Default EGS4 (E_{av}= 405.6 ± 0.5 keV)
EGS4 / PRESTA (E_{av}= 320.0 ± 0.6 keV)
Ee = 1 MeV
Si : 530 μm
Entries (%)
10^1
10^0
10^{-1}
0
0.2
0.4
0.6
0.8
1.0
MeV

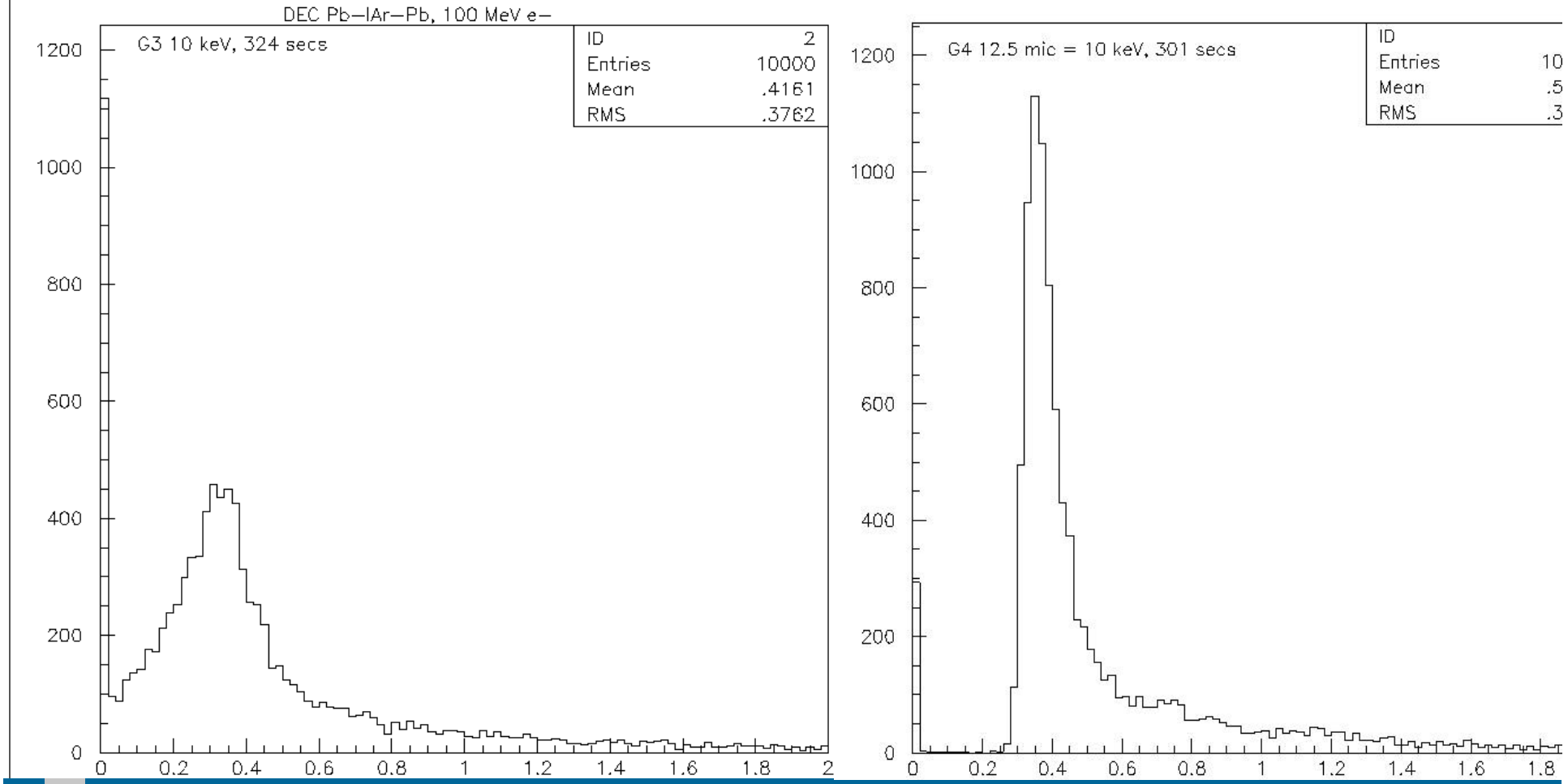
Benchmark 2 EM (sampling calorim.)

- Compares
  - speed at constant physics
  - physics at constant speed
- EM physics shower speed
  - model sampling calorimeter
  - Pb 0.5● - liquid Ar - Pb 19.5●
  - 100 MeV electrons

Fixed speed: quality of physics

- G3
  - cuts = 10 KeV, auto stepping, aban=0.
  - Time = 324 sec.
- G4
  - cuts = 12.5 micron (= 10 KeV in Lar).
  - Time= 301 sec.
- Plots show G4 is much better than G3

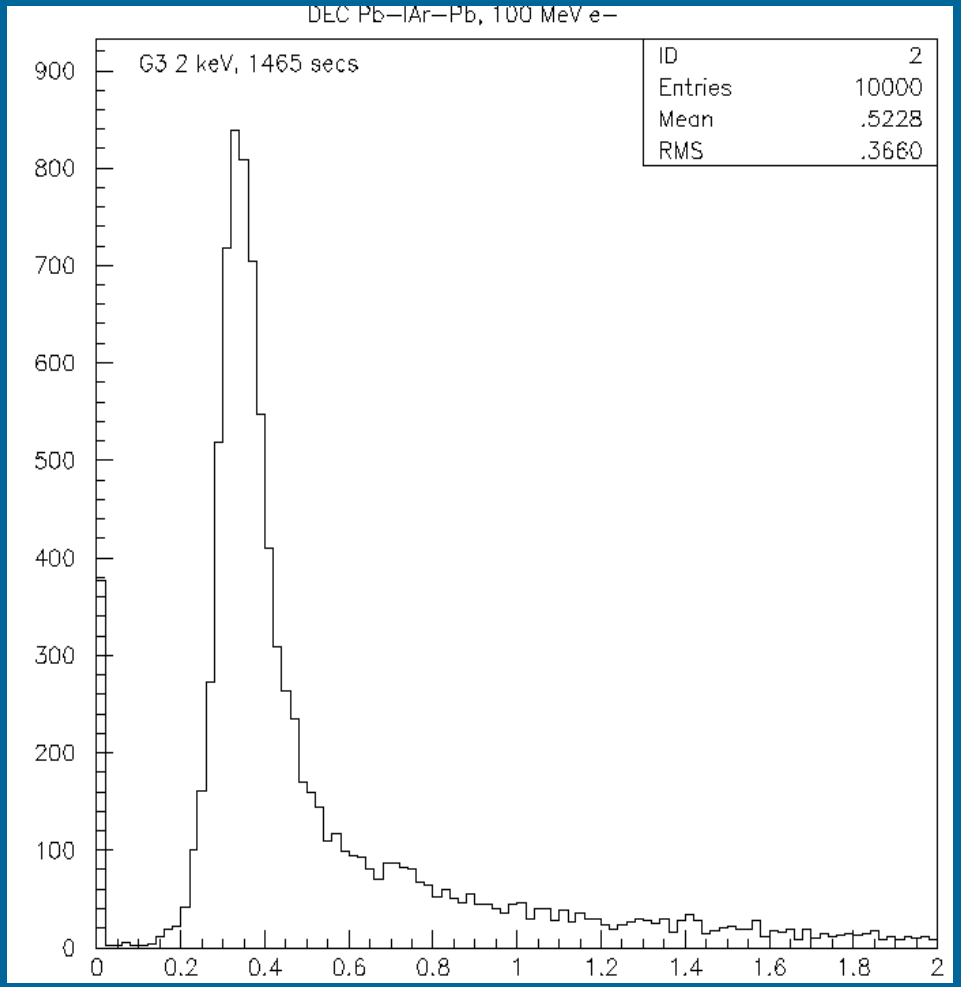
G3 vs G4: same speed (Pb-lAr)



Fixed physics: best speed

- Geant 3.21
  - cuts = 2 KeV, automatic stepping, aban=0.
    ===> Time = 1465 sec.
- Geant 4.0.1
  - cuts = 2.5 micron (= 2 KeV in Lar).
    ===> Time = 452 sec.

G3, best physics



Geant4 status & plans

- January 99 to now:
  - issued patches for urgent fixes
- Consolidation release 4.0.1
  - due end of May
  - It contains
    - fixes, minor improvements
    - a few models (e.g. low energy EM - ESA)
    - the ability to use STL instead of Rogue Wave

Geant4 plans

- *The next release is expected to be*
  - *4.1.0 at end-July*
  - *with additional physics models*
  - *with some new functionality*

Summary

- Production release in use
  - used, got feedback from >4 experiments
  - first results confirm G4 strengths
    - EM physics, geometry
  - First EM physics benchmarks
    - Geant4 gives better physics @ same speed
    - Geant4 gives better speed for same physics
- Consolidation release 4.0.1 imminent