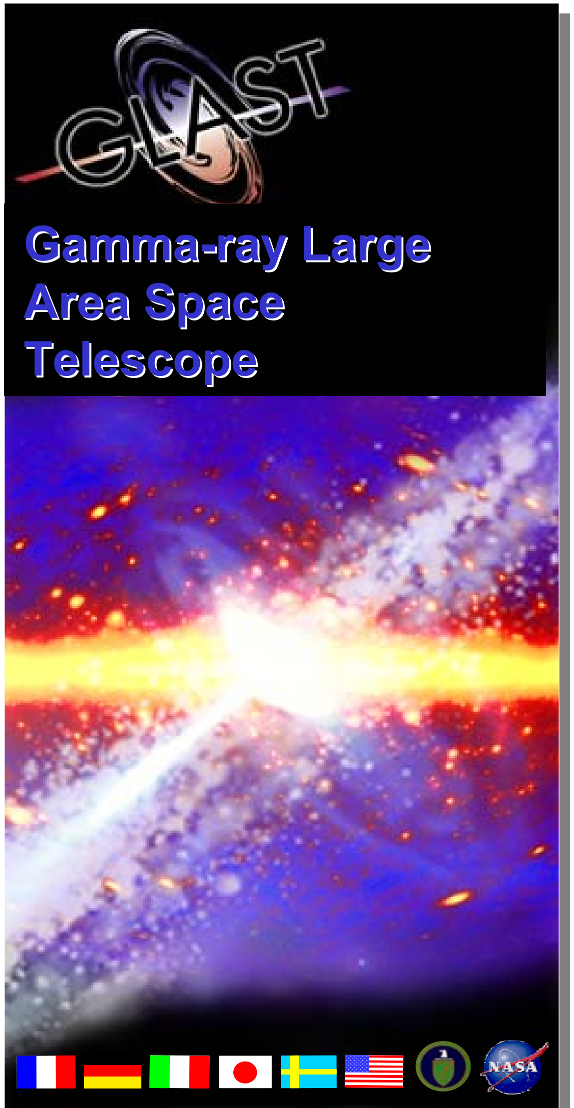

Geant4 Validation for DC1:

Status and Prospects

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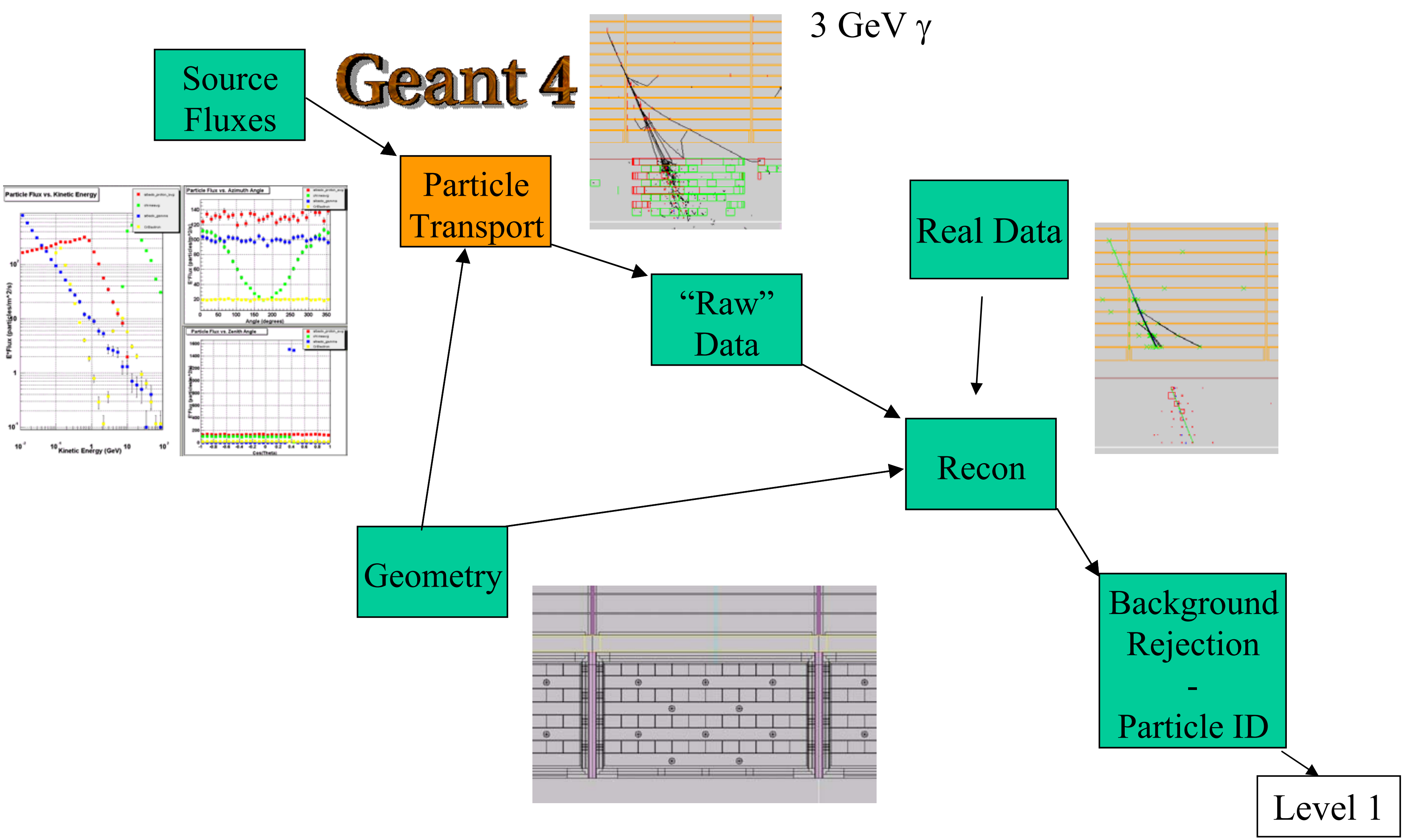
Thanks to:
P.Boinee, T.Burnett, C.Cecchi, J.Cohen-Tanugi, A.De Angelis, R.Dubois, R.Giannitrapani, T.Kamae, T.Koi, T.Mizuno, P.Nieminen, M.G.Pia, R.Rando, G.Santin, T.Usher, M.Verderi, J.P.Wellish

Outline

- Introduction to G4 simulation in the SAS framework
- The G4 toolkit and the Geant4 collaboration
- G4 EM physics
  - EM standard / EM low-energy
  - Processes treatment description
- G4 Hadronic: physics
  - A brief introduction
- G4 validation activities
- GLAST LAT validation suite for G4
  - EM physics
    - Procedure
    - Status on different processes
  - Hadronic physics
    - Procedure
- Preliminary results
- Summary

Geant4 simulation within the SAS framework

Level 1 Sim/Recon Chain

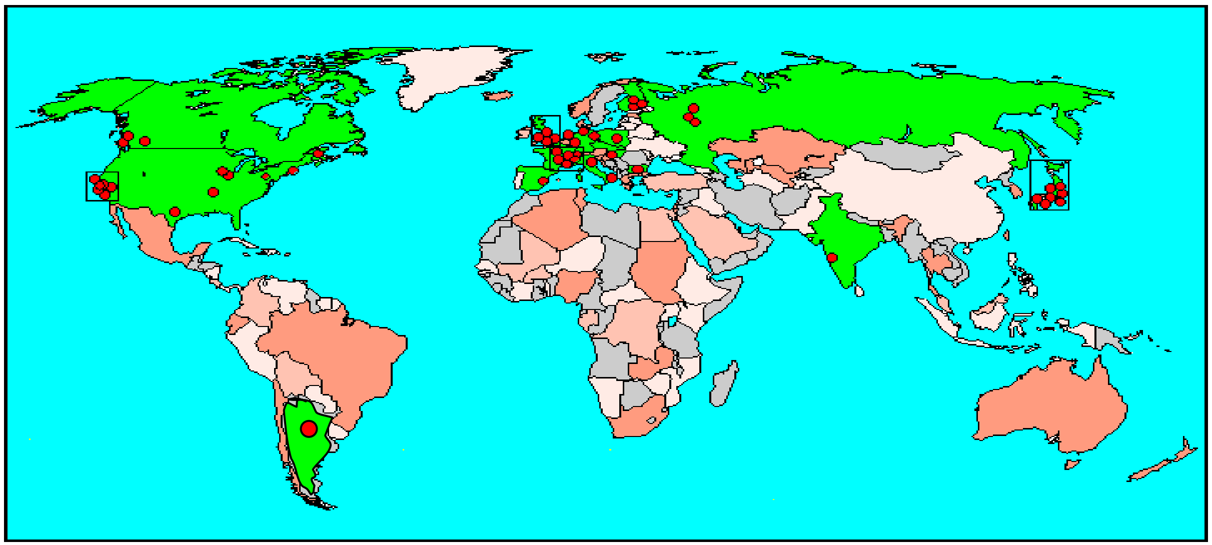


Simulation transition

	Past: Gismo	Now: detModel+Geant4	Benefits
Geometry Description	21 classes, 4380 loc one xml file, 250 lines	data: 6830 lines in 30 xml files code: 8200 loc	•Clean separation between data and code •Easy for different clients to have unique views
Simulation	Physics based on EGS4+Gheisha Supported by 1 person All physics, particle property code in 1 MB of code.	New physics code Supported by 100’s Physics and particle properties: 75 MB.	•Better support, documentation. •Becoming standard: many more users to validate physics.
Digitization	Hits turned immediately into digis during simulation	Hits in sensitive detectors, and perhaps all vols, accumulated for later processing	•Energy accounting •Tune digitization independently of simulation

T.Burnett LAT-PDR (2002)

G4 Collaboration



HARP

Lebedev

Univ. Barcelona

Helsinki Inst. Ph.

PPARC

Collaborators also from non-member institutions, including
Budker Inst. of Physics
IHEP Protvino
MEPHI Moscow
Pittsburg University
Cordoba University

G4 collaboration

- **Collaboration Board**
  - manages resources and responsibilities
- **Technical Steering Board**
  - manages scientific and technical matters
- **Working Groups**
  - do maintenance, development, QA

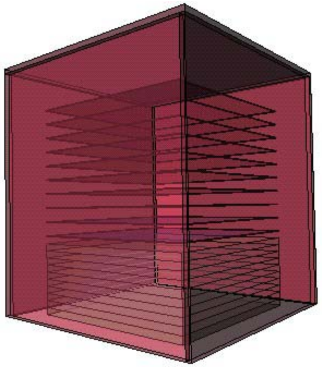
Members of National Institutes, Laboratories and Experiments participating in Geant4 Collaboration acquire the right to the Production Service and User Support

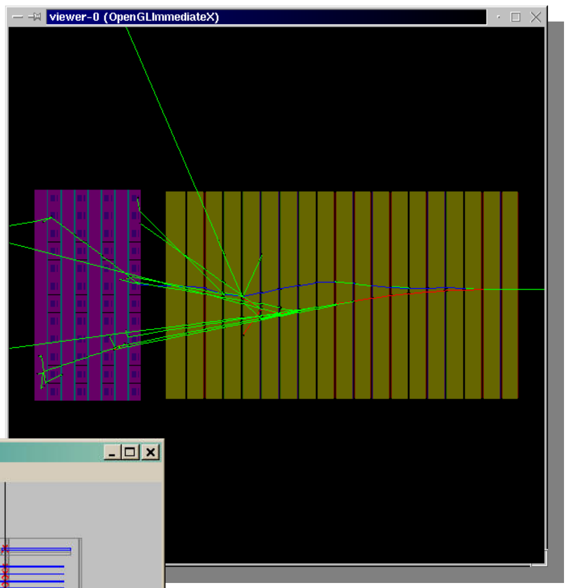
For others: free code and user support on best effort basis

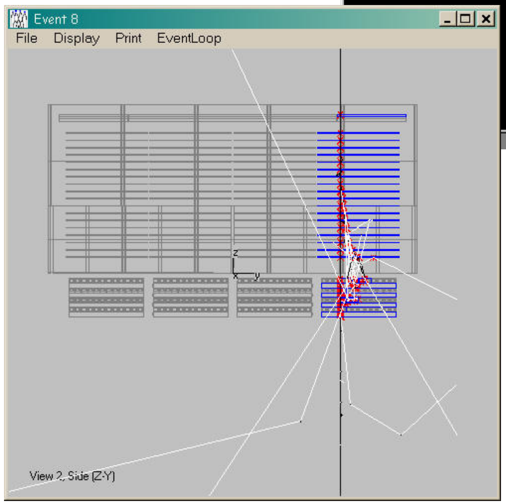
- **For G4 subdomains**
  - Run, Events & Detector Response
  - Tracking
  - Geometry & Transportation,
  - Generic Processes & Materials
  - Hadronic Physics,
  - E.M. Physics (“Standard”),
  - Low Energy EM Physics (since 2000)
  - User and Category Interfaces
  - Visualization
- **For software**
  - Software Management
  - Testing & QA
  - Documentation Management

G4Generator package History

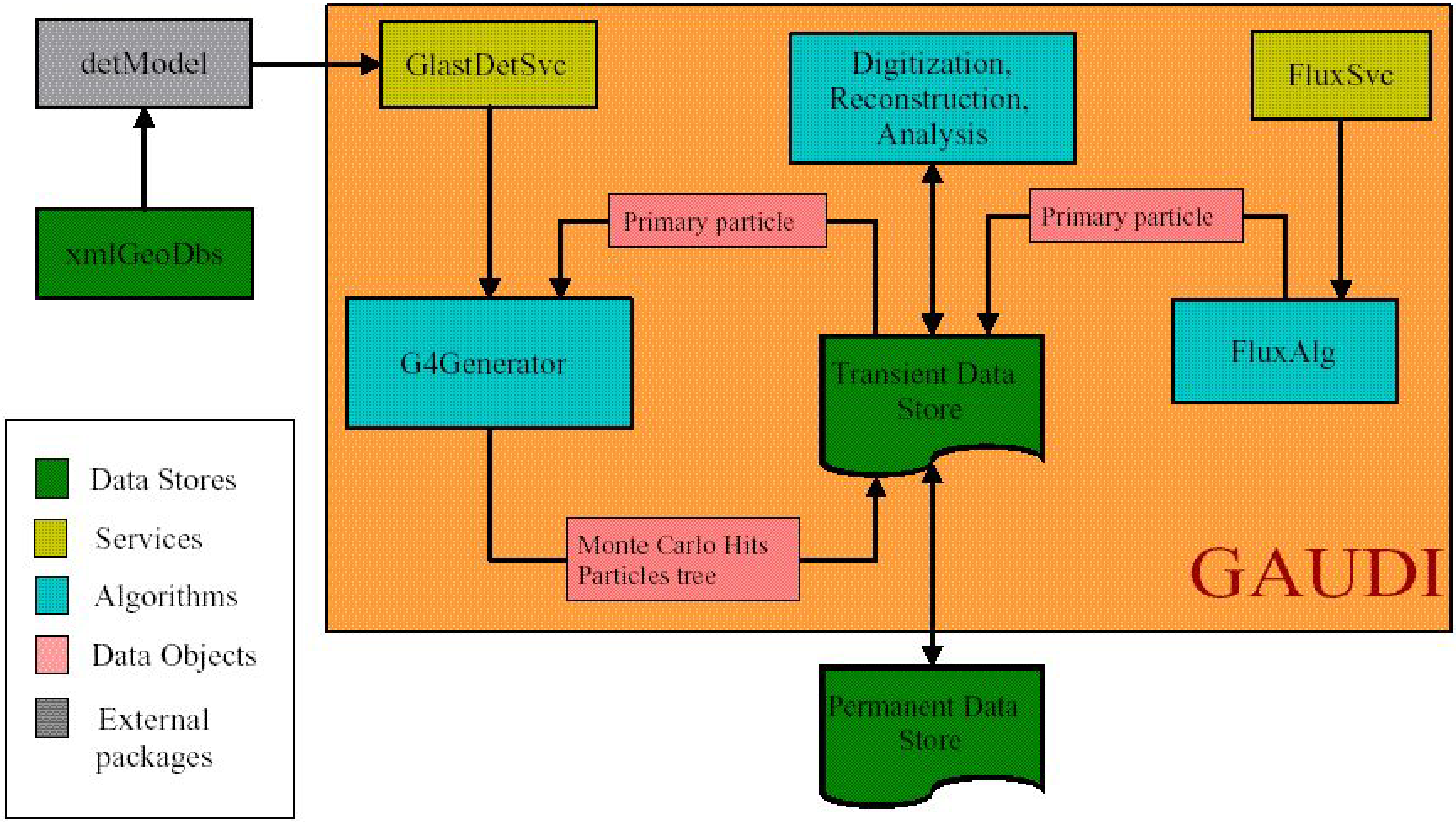
- G4 as proposed MC
- Learning G4 and development of GammaRayTel
- Standalone Packages
  - Test Beam 1999
  - Balloon Flight
- Geometry repository
- Gaudi integration
  - Managing the event loop
  - Source generation
  - Hit structure Filling
  - Digitization
- G4Generator review
- Gleam package released



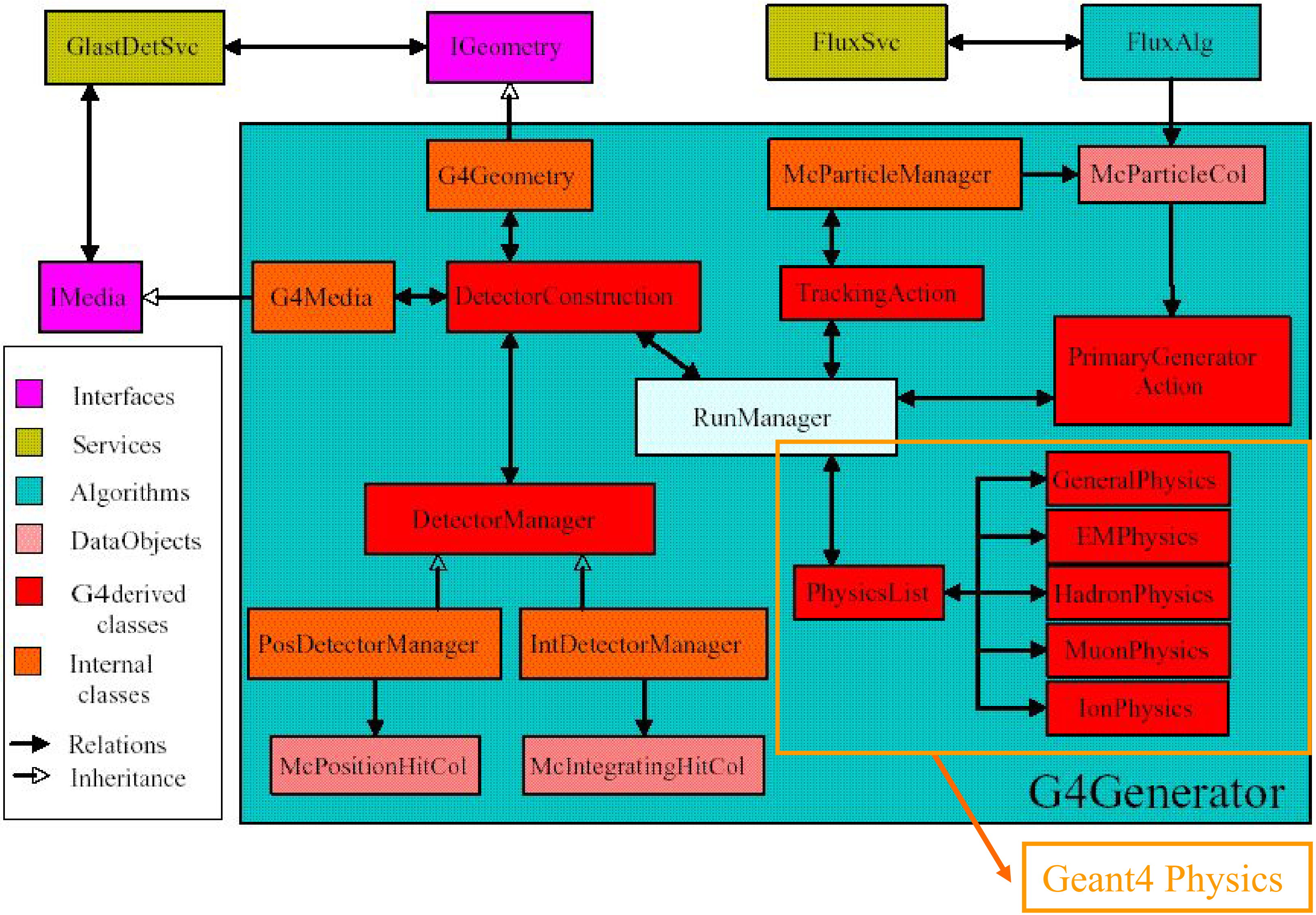




G4Generator implementation



G4Generator



G4 physics

Physics

From the Minutes of LCB (LHCC Computing Board) meeting on 21 October, 1997:

"It was noted that experiments have requirements for **independent, alternative physics models**. In Geant4 these models, differently from the concept of packages, allow the user to **understand** how the results are produced, and hence improve the **physics validation**. Geant4 is developed with a modular architecture and is the ideal framework where existing components are integrated and new models continue to be developed."

Geant4 requirements

Geant4 has adopted a rigorous approach to requirements

- *user requirements collected from the user communities in the initial phase*
- *continuously updated*

Geant4 User Requirements Document

CERN, European Laboratory for Particle Physics

GEANT4

OO Toolkit for Particle Detector Simulation

User Requirements Document

Version 5.0

Reference GEANT4-URD-v5.0
Created on 6 December, 1994
Last modified 31 October, 1995
Status Under Review

Prepared By Katsuya Amako
Giuseppe Ballocchi

Physics: general features

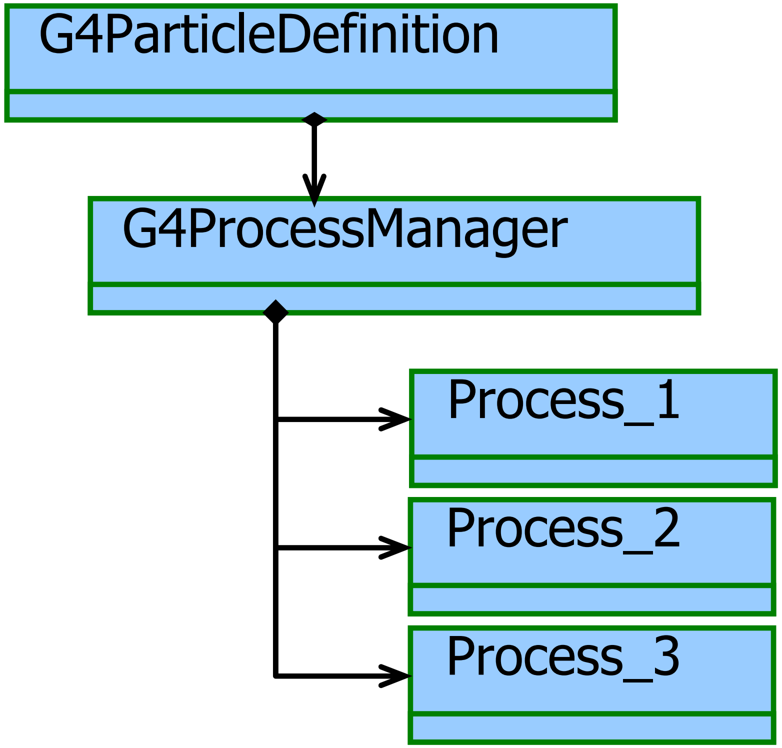
- Ample variety of physics functionalities
- Modular design, at a fine granularity, to expose the physics
- Uniform treatment of electromagnetic and hadronic processes
- Abstract interface to physics processes
  - tracking independent from physics
- Distinction between processes and models
  - often multiple models for the same physics process (complementary/alternative)
- Transparency (supported by encapsulation and polymorphism)
  - calculation of cross-sections independent from the way they are accessed (data files, analytical formulae etc.)
  - distinction between the calculation of cross sections and their use
  - calculation of the final state independent from tracking
- Open system
  - users can easily create and use their own models
  - users should validate “their” physics

G4Generator physics

- PhysicsList class
- Particles to be used: gamma, e+/e-, proton, muon, ions, …
- Physics Processes assigned to particles using a ProcessManager per Particle
- G4 capability
  - Hadronic and Electromagnetic Processes
  - Production Cuts per Region (EM physics)
- Modular Physics List (taken from `G4 novice/N04` example)
  - General: decay, transportation
  - EM: photon/electron processes
  - Muon: muon/tau physics
  - Hadron: EM and hadronic physics for hadrons
  - Ion: EM physics for ions, hadronics still missing…

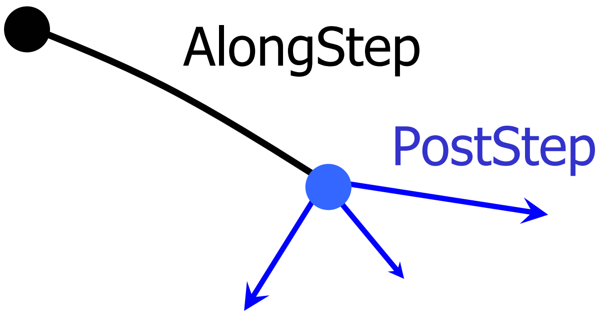
Particles in G4

- The particle types in GEANT4 are described by the G4ParticleDefinition class;
- Describes the « intrisic » particle properties:
  - Mass, width, spin, lifetime…
- Describes its « sensitivity » to physics:
  - This is realized by a G4ProcessManager;
  - Attached to the G4ParticleDefinition;
  - The G4ProcessManager manages the list of processes the user wants the particle to be sensitive to;
  - Note that G4ParticleDefinition doesn't know by itself its sensitivity to physics.



G4VProcess

- Abstract class defining the common interface of all processes in GEANT4:
  - Used by all « physics » processes
  - but is also used by the transportation, etc…
- Define three kinds of actions:
  - AtRest actions:
    - Decay, e+ annihilation …
  - AlongStep actions:
    - To describe continuous (inter)actions occuring along the path of the particle, like ionisation
  - PostStep actions:
    - For describing point-like (inter)actions, like decay in flight, hard radiation…
- The stepping makes the processes to:
  - Cooperate for AlongStep actions;
  - Compete for PostStep and AtRest actions;



G4VProcess (cont'd)

- **Each action defines two methods:**
  - **`GetPhysicalInteractionLength():`**
    - Used to ***limit the step size***:
      - either because the process « triggers » an interaction, a decay;
      - Or any other reasons, like fraction of energy loss;
      - geometry boundary;
      - user's limit …
  - **`DoIt():`**
    - Implements the actual action to be applied on the track and the related production of secondaries.

The cuts in GEANT4

- In GEANT4 there is no tracking cut:
  - Particles are tracked down to a zero range/kinetic energy;
- Only production cuts exist;
  - ie cuts allowing a particle to born or not;
- Why production cuts are needed ?
- Some electromagnetic processes involve infrared divergences:
  - This leads to an infinity[huge number] of smaller and smaller energy photons[electrons] (like in bremstrahlung, δ-ray productions);
  - Production cuts limit this production to particles above the threshold;
  - The remaining, divergent part is treated as a « net » continuous effect (ie « AlongStep » action);
- For other processes, production cuts can be an « option » to speed-up the simulation.

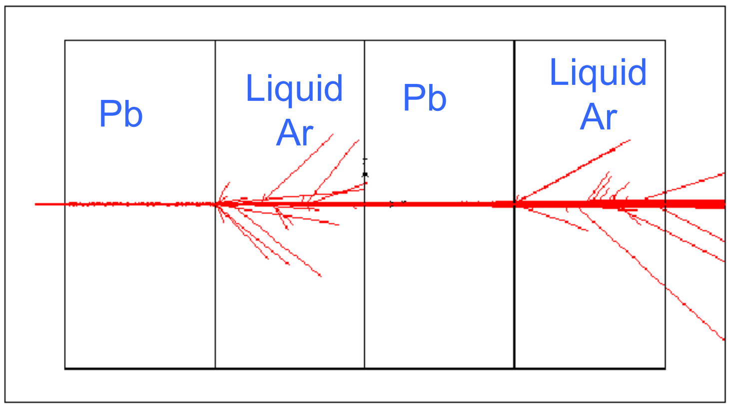
Range versus Energy production cuts

- The production of a secondary particle is relevant if it can be « visible » in the detector:
  - i.e. produce a signal -say an energy deposition- visible compared to the signal of the primary alone;
- Range cut allows to easily define such visibility:
  - « I want to produce particles able to travel at least 1 mm; »
  - Criteria which can be applied uniformly accross the detector;
- A same energy cut leads to very different ranges:
  - For the same particle type, depending on the material;
  - For the same material, depending on particle type;
- Range cut has been adopted by GEANT4;
- Actual input to cross-section is the energy threshold, but the conversion range-energy is done automatically in GEANT4;

Effect of production thresholds

Geant 4

500 MeV incident proton



Threshold in range: 1.5 mm

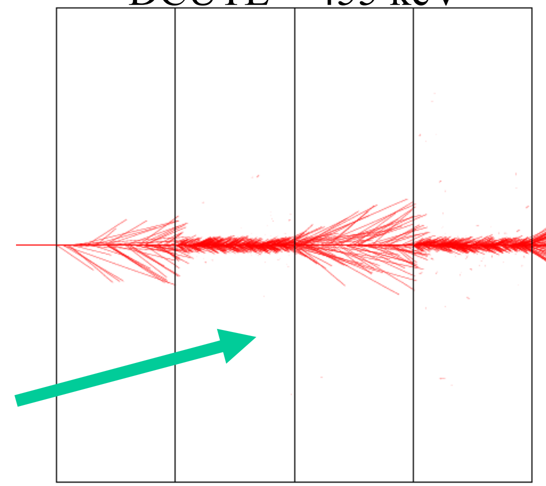
455 keV electron energy in liquid Ar

2 MeV electron energy in Pb

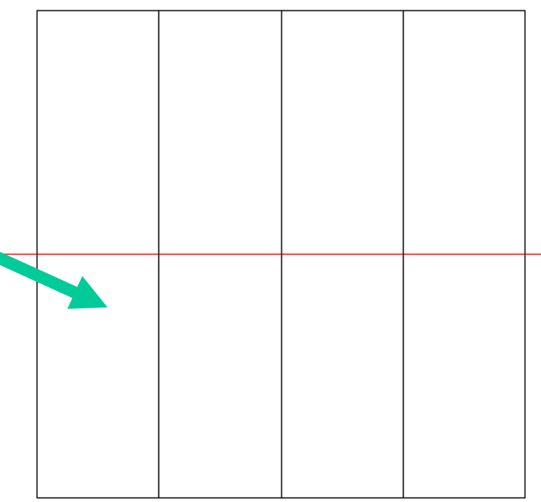
In Geant3

one must set the cut for delta-rays (DCUTE) either to the Liquid Argon value, thus producing many small unnecessary δ-rays in Pb,

DCUTE = 455 keV



or to the Pb value, thus killing the δ-rays production everywhere



DCUTE = 2 MeV

G4 physics List

- The « physics list » exposes, deliberatly, the user to the choice of physics (particles + processes) relevant for his/her application;
- This is a critical task, but guided by the framework;
- Examples have to be used as starting point;
- G4 “educated physics lists”: http://cmsdoc.cern.ch/~hpw/GHAD/HomePage/

Physics in G4Generator

- Cut per region (since 5.1)
- EM Physics
  - Processes
    - Pair Production
    - Compton
    - PhotoElectric
    - Bremsstrahlung
    - Multiple Scattering
    - Ionisation & Delta Ray Production
    - Positron Annihilation
  - Prospects
    - Low Energy
- Hadronic Physics
  - Hadron Processes
    - Elastic & Inelastic scatter
    - Ionisation
    - Multiple Scattering
    - Annihilation
  - Ion Processes
    - Multiple Scattering
    - Ionisation
  - Particle Decay
  - Prospects
    - Radioactive Decay
  - Other Hadronics

G4 electromagnetic physics

Standard EM processes

- The primary is assumed to have ≥ 1 keV
  - Atomic electrons are “quasi-free”
    - Binding energy neglected (except photoelectric)
  - Atomic nucleus “fixed”
    - Recoil momentum neglected
  - Matter described as
    - Homogeneous
    - Isotropic
    - Amorphous

Overview of the EM processes

- **Common to all**
  - Ionization
  - Coulomb scattering from nuclei
  - Cherenkov
  - Scintillation
  - Transition radiation
- **Muons**
  - e^+/e^- pair production
  - Bremsstrahlung
  - Nuclear interaction
- **Electrons and positrons**
  - Bremsstrahlung
  - e^+ annihilation

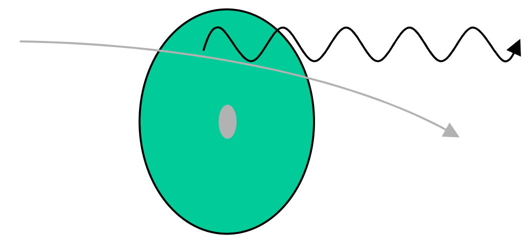
- Photons
  - Gamma conversion (~10 MeV →)
  - Incoherent scattering (~10 keV → ~10 MeV)
  - Photoelectric effect (← ~10 keV)
  - Coherent scattering (← ~100 keV)

- Optical photons
  - Reflection and refraction
  - Absorption
  - Rayleigh scattering

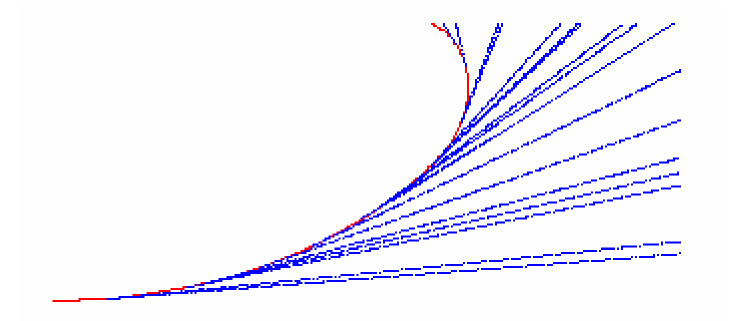
Ionisation

- Basic mechanism: Inelastic collisions with the atomic electrons of the material, ejecting off an electron from the atom
  - Small energy transfer in individual collisions
  - Large number of collisions
- Depending on the amount of matter
  - Energy loss can be strongly asymmetric (→ Landau tail)
- The cross section depends on the electron cut
  - Below the threshold, soft d-rays are only counted as continuous energy loss
  - High energy knock-on electrons are produced and tracked
- Both continuous energy loss (below the production cut) and d-ray energy spectrum
  - obtained integrating the differential cross section for the ejection of an electron
- Different processes for different particles
  - e.*g.* e^+/e^-
    - Möller or Bhabha cross sections
    - Integration → Berger-Seltzer dE/dx formula
  - Muons
    - Integration → Bethe-Bloch formula

Bremsstrahlung

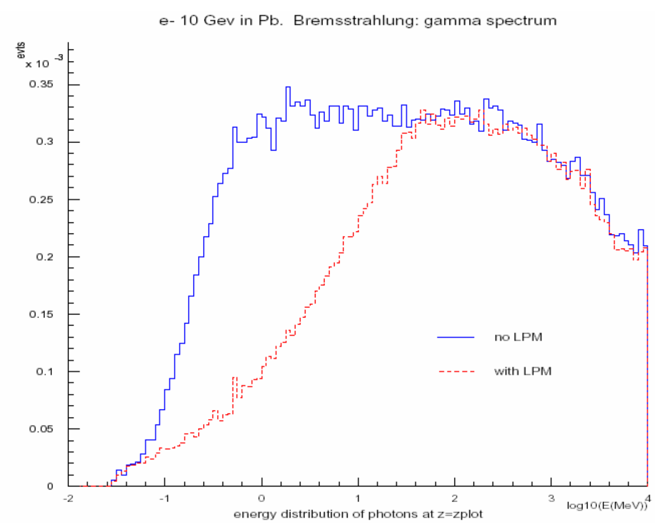


- Fast moving charged particles are decelerated in the atoms Coulomb field. A fraction of their kinetic energy is emitted in form of real photons
  - Probability ~$1/M^2$ (M = mass of the incident particle) and ~Z^2 (Z = atomic number of the material)



- High energy photons created and tracked above a given threshold k_{cut}

- Bethe-Heitler formula, corrected and extended
  - Screening, atomic electrons, polarization,…
  - Landau-Pomeranchuk-Migdal suppression effect

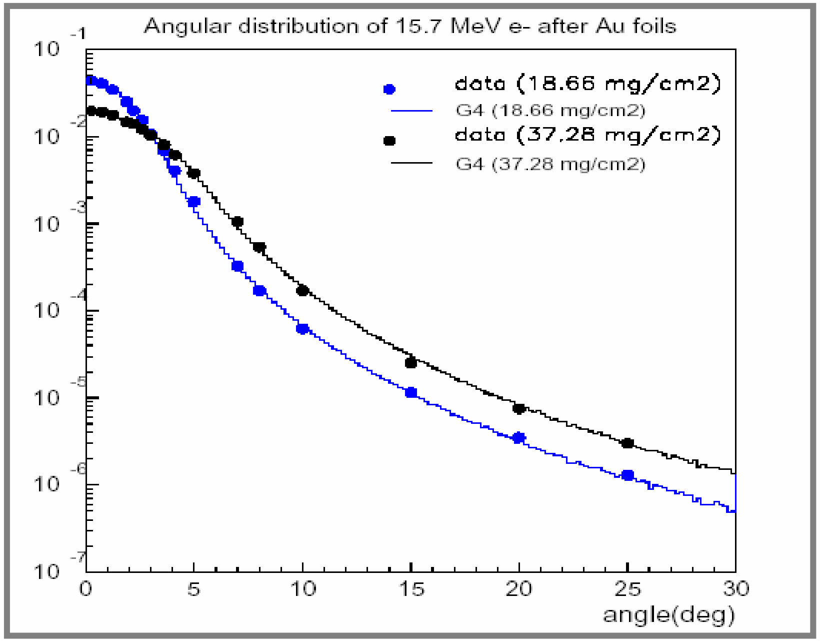


Multiple Scattering

- GEANT4 uses a new model (L.Urban) which simulates the scattering of the particle after a step, computes the mean path length correction and the mean lateral displacement
  - This model does not use the Moliere formalism

- New tuning in the 5.0 release
  - Good behavior both for high energy protons and low energy electrons
  - Backscattering well described

- Very weak dependence on the step limit
  - longitudinal (z) and tranverse (r) distances



Compton scattering

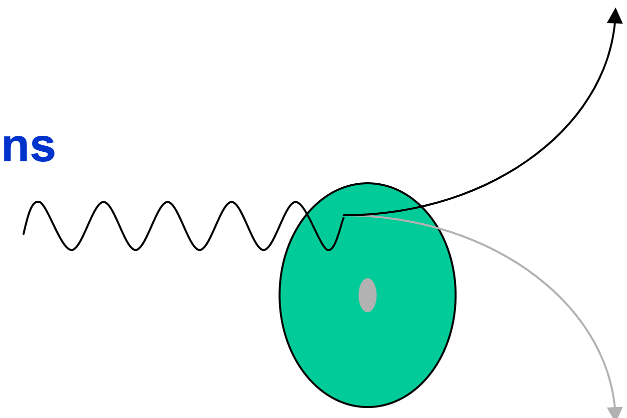
- **Parameterization based on the Klein-Nishina formula, corrected for low energy distortions**

$$\sigma(Z, E_\gamma) = \left[P_1(Z) \frac{\log(1+2X)}{X} + \frac{P_2(Z) + P_3(Z)X + P_4(Z)X^2}{1 + aX + bX^2 + cX^3} \right].$$

  - **Fit over 511 data points**
  - **1 ≤ Z ≤ 100**
  - **10 keV ≤ k ≤ 100 GeV**
- **The accuracy of the fit is estimated to be**
  - **dσ/σ =**
    - **~ 10 % for k ~10 keV → 20 keV**
    - **~ 5-6 % for k > 20 keV**

Gamma conversion in (e^+,e^-) pair

- **Transformation of a photon in a (e^+,e^-) pair in the Coulomb field of an atom (for momentum conservation)**
  - **Dominant process for Eγ ≥ few tens of MeV**
- **Differential cross section: Bethe-Heitler formula corrected and extended for various effects**
  - **Screening of nucleus field**
  - **Pair creation in the field of atomic electrons**
  - **Correction to the Born approximation**
  - **LPM suppression mechanism**
  - **…**



- **In Geant4: parameterized and fitted against data (Hubbel *et al.* 1980)**
  - **1 ≤ Z ≤ 100, Eγ: 1.5 MeV → 100 GeV**
  - **dσ/σ ≤ 5 % (with a mean value of 2.2 %)**

Low Energy EM processes

- A set of processes extending the coverage of electromagnetic interactions in Geant4 down to "*low*" energy
  - 250 eV *(in principle even below this limit)* for electrons and photons
  - down to the approximately the ionization potential of the interacting material for hadrons and ions
- A set of processes based on detailed models
  - shell structure of the atom
  - precise angular distributions
- Based on evaluated databases for cross sections and generation of final state:
  - EADL, EEDL, EPDL97(evaluated data libraries from LLNL, courtesy Dr. Red Cullen)
  - Other data Libraries
- Complementary to the "standard" electromagnetic package

Hadron and ion EM processes

- Variety of models, depending on energy range, particle type and charge
- Positive charged hadrons
  - Bethe-Bloch model of energy loss, E > 2 MeV
  - 5 parameterisation models, E < 2 MeV
    - *based on Ziegler and ICRU reviews*
  - 3 models of energy loss fluctuations

- Positive charged ions
  - Scaling: $S_{ion}(T) = Z_{ion}^2 S_p(T_p), \; T_p = T \frac{m_p}{m_{ion}}$
  - 0.01 < b < 0.05 parameterisations, Bragg peak
    - *based on Ziegler and ICRU reviews*
  - b < 0.01: Free Electron Gas Model

- Models for antiprotons
  - $\beta > 0.5$ Bethe-Bloch formula
  - $0.01 < \beta < 0.5$ Quantum harmonic oscillator model
  - $\beta < 0.01$ Free electron gas mode

G4 hadronic physics

Hadronic physics

- **Completely different approach w.r.t. the past**
  - **transparent**
  - **native, *no longer interface to external packages***
  - **clear separation between data and their use in algorithms**
- **Cross section data sets**
  - **transparent and interchangeable**
- **Final state calculation**
  - **models by particle, energy, material**
- **Ample variety of models**
  - **alternative and complementary models**
  - **it is possible to mix-and-match, with fine granularity**
  - **<u>data-driven, parameterised and theoretical models</u>**

Parameterised and data-driven models

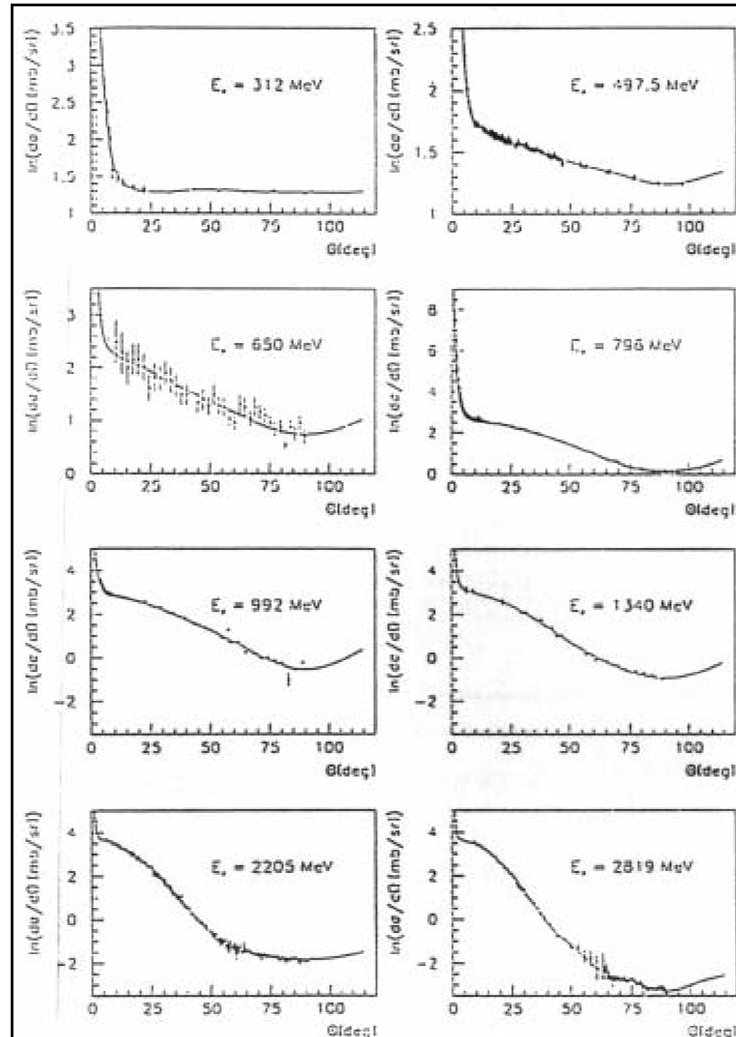
Based on experimental data

- Some models originally from GHEISHA
  - **completely reengineered into OO design**
  - **refined physics parameterisations**
- New parameterisations
  - **pp, elastic differential cross section**
  - **nN, total cross section**
  - **pN, total cross section**
  - **np, elastic differential cross section**
  - **πN, total cross section**
  - **πN, coherent elastic scattering**

Other models are completely new:

- **stopping particles (π^-, K^-)**
- **neutron transport**
- **isotope production**

p elastic scattering on Hydrogen



Theoretical models

- **They fall into different parts**
  - **the** *evaporation phase*
  - **the low energy range,** *pre-equilibrium,* **O(100 MeV),**
  - **the intermediate energy range, O(100 MeV) to O(5 GeV),** *intra-nuclear transport*
  - **the high energy range,** *hadronic generator* **régime**
- **Geant4 provides** complementary **theoretical models to cover all the various parts**
- **Geant4 provides** alternative **models within the same part**
- **Easy evolution: new models can be easily added, existing models can be extended**
- **Bibliography: e.g.** `nucl-th/0306006, nucl-th/0306007, nucl-th/0306008, nucl-th/0306012`

Radioactive Decay Module

- Handles α, β-, β+, ν and anti-ν, de-excitation γ-rays
  - can follow all the descendants of the decay chain
  - can apply variance reduction schemes to bias the decays to occur at user-specified times of observation
- Branching ratio and decay scheme data based on the Evaluated Nuclear Structure Data File *(ENSDF)*
- Geant4 photo-evaporation model is used to treat prompt nuclear de-excitation following decay to an excited level in the daughter nucleus
- Applications:
  - underground background
  - backgrounds in spaceborne γ-ray and X-ray instruments
  - radioactive decay induced by spallation interactions
  - brachytherapy
  - etc.

G4 Validation

G4 Validation

- EM Physics
  - Test Beam
  - Balloon Flight
  - Signal in Silicon and Cal
  - EM shower
  - Lot of data in energy Range
- High Level
  - Test Beam
  - Calibration
  - Balloon
- Low Level
  - Cross Section
  - Angular distribution
  - Implementation
  - Contact with G4 developers

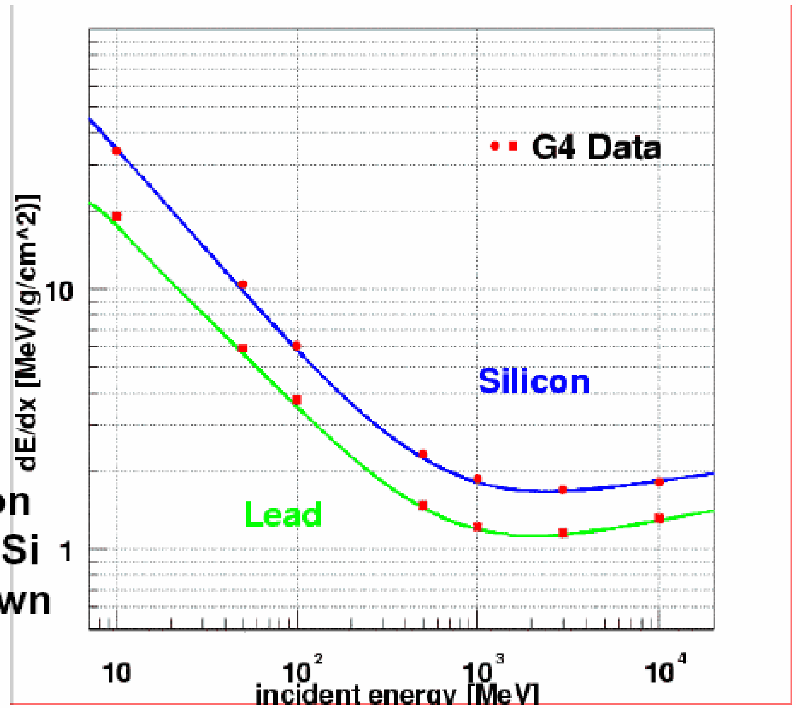
- Hadronic Physics
  - Test Beam data
  - Ion physics
  - Nuclear Interaction
  - CR induced processes
- High Level
  - Comparison with Literature
  - Test beam other detectors
- Low Level
  - Collaboration with Hadronic Working Group
  - Interaction
  - Energy Deposition
  - Activation
  - Radioactive Decay

G4 Validation

- Past Activities
  - Ogata's Thesis
  - BFEM simulation
  - TB99 simulation
  - MCS tests
  - Test and Analysis Project
  - Comparison projects
- Actual proposal
  - Unit tests on specific Processes
  - Extended EM examples (TestEM)
  - Physics tests on simplified geometry (Slab test)
  - System tests with full framework & simple geometry (G4testAlg)
  - Comparisons with TestBeam (EM?, BFEM?, …)

G4 physics validation

Bethe-Bloch formula for protons



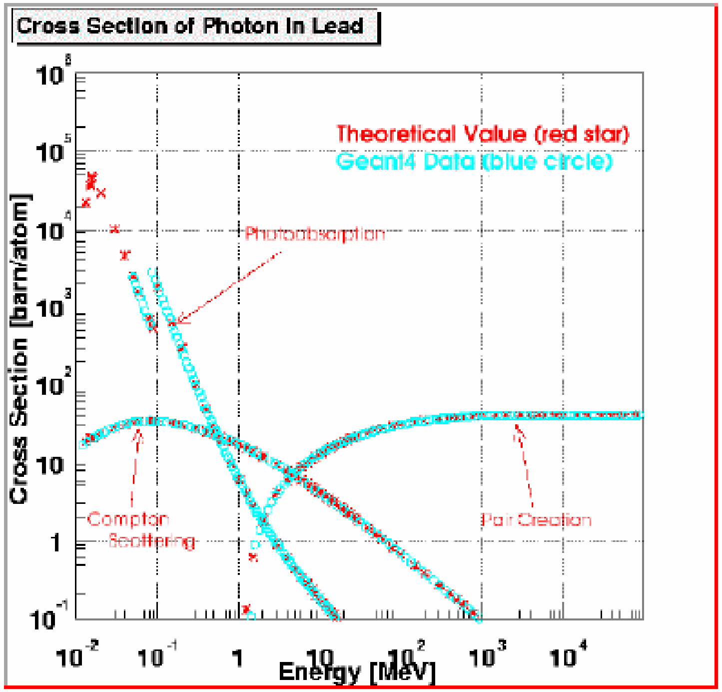
Geant4 well reproduces ionization energy loss in thick Si and Pb of proton down to 10 MeV

Kamae et al. 2002

G4 physics validation

Pair creation – cross section

Compare the cross section in Pb calculated by Geant4 with that of a reference (http://physics.nist.gov/PhysRefData/Xcom/Text)



Geant4 correctly calculates cross section down to ~100 keV

Kamae et al. 2002

Shower profile

EM Shower (G4 vs EGS4): Geometry1

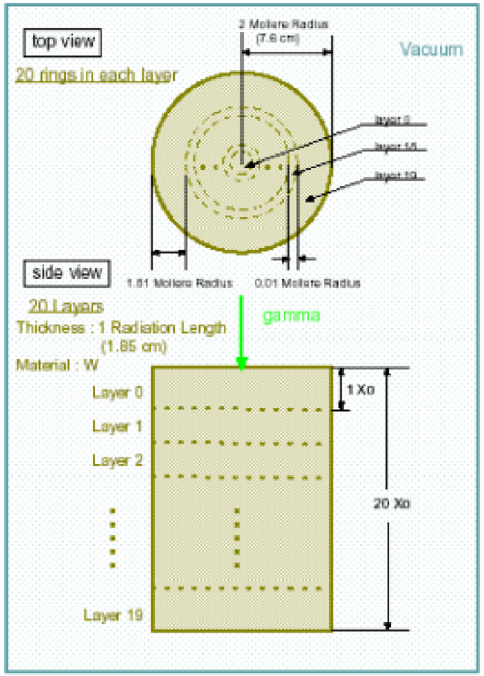
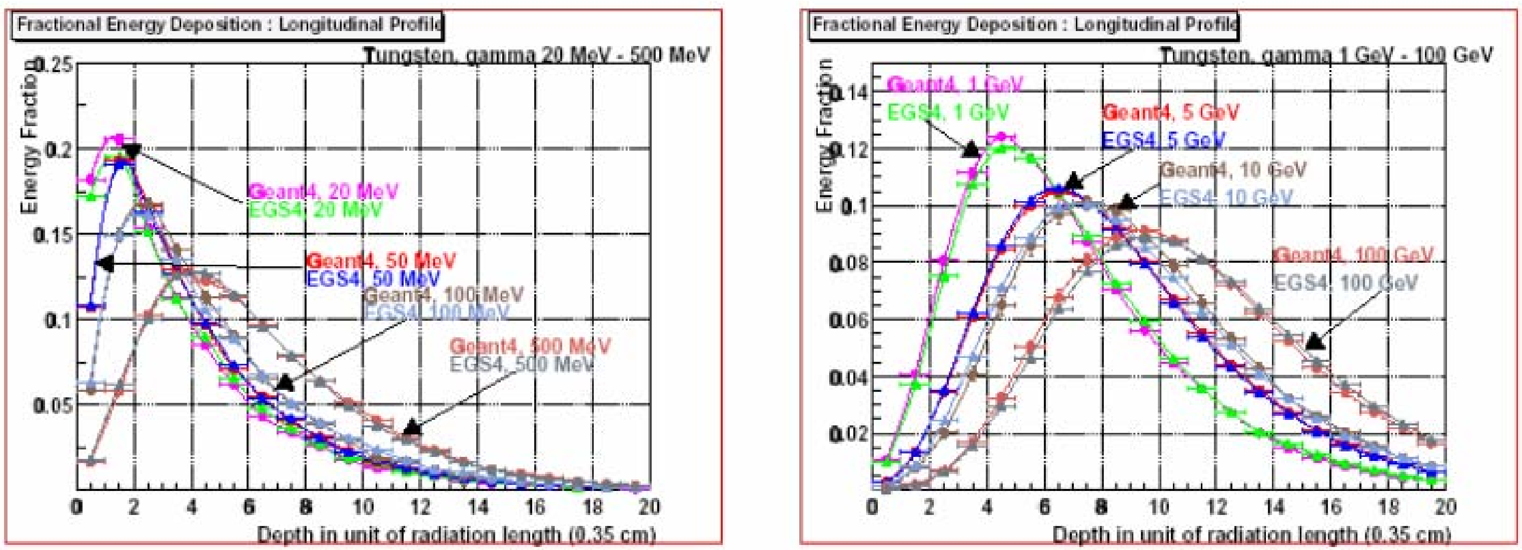


Figure 4.9: The geometry for the narrow CsI cylinder. The cylinder radius is 2 Moliere radius (7.6 cm) and the cylinder height is 20 Radiation length (37 cm).

Kamae et al. 2002

Shower profile

EM Shower (G4 vs EGS4): Longitudinal Profile No.1

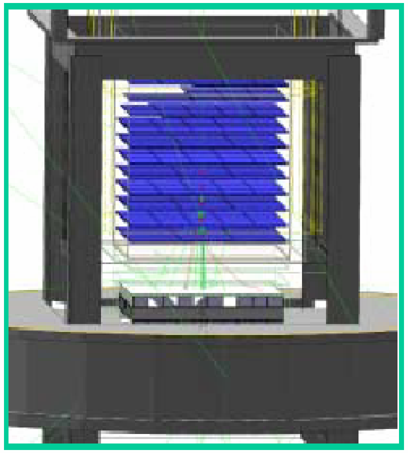


(a) From 20 MeV to 500 MeV gamma, Tungsten (b) From 1 GeV to 100 GeV gamma, Tungsten

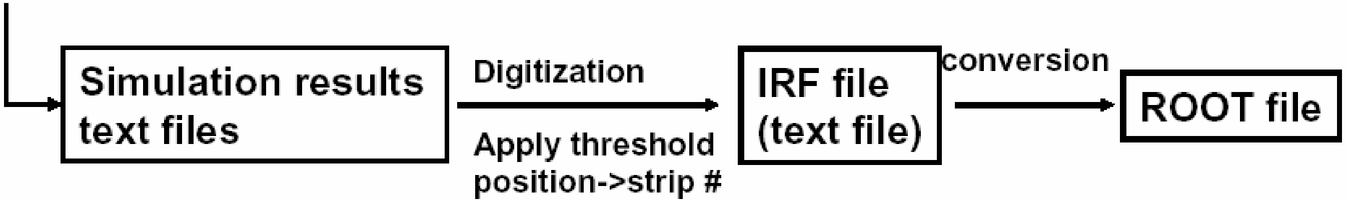
Kamae et al. 2002

Balloon Flight Simulation

Geant4 Simulator for the GLAST Balloon Flight (2)



- Physics process (example#4)
  - General process (decay)
  - Electromagnetic process
    (ionization, multiple scattering, photoelectric effect, compton scattering, pair creation, bremsstrahlung, annihilation)
  - Hadronic process
    elastic scattering, inelastic scattering
- Cutoff length
  - 0.4mm(e-), 0.1mm(others)



We ran typically 1M events for each particle type, and ~1% of them cause trigger.

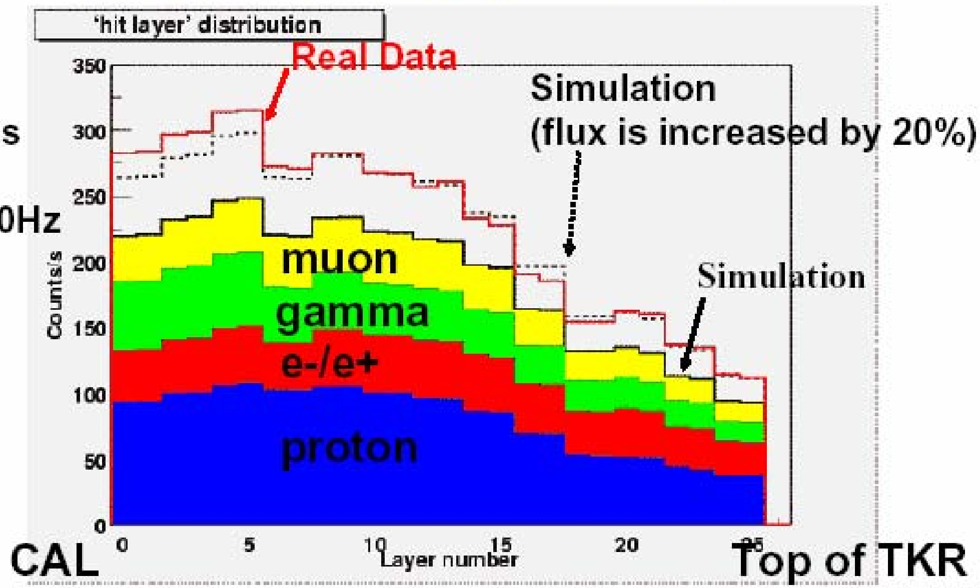
5

Mizuno et al. 2002

Balloon Flight Simulation

Hits in each layer for "charged" events (deposit energy in ACD)

Trigger rate of "charged" events
- data: ~440Hz
- simulation: ~350Hz

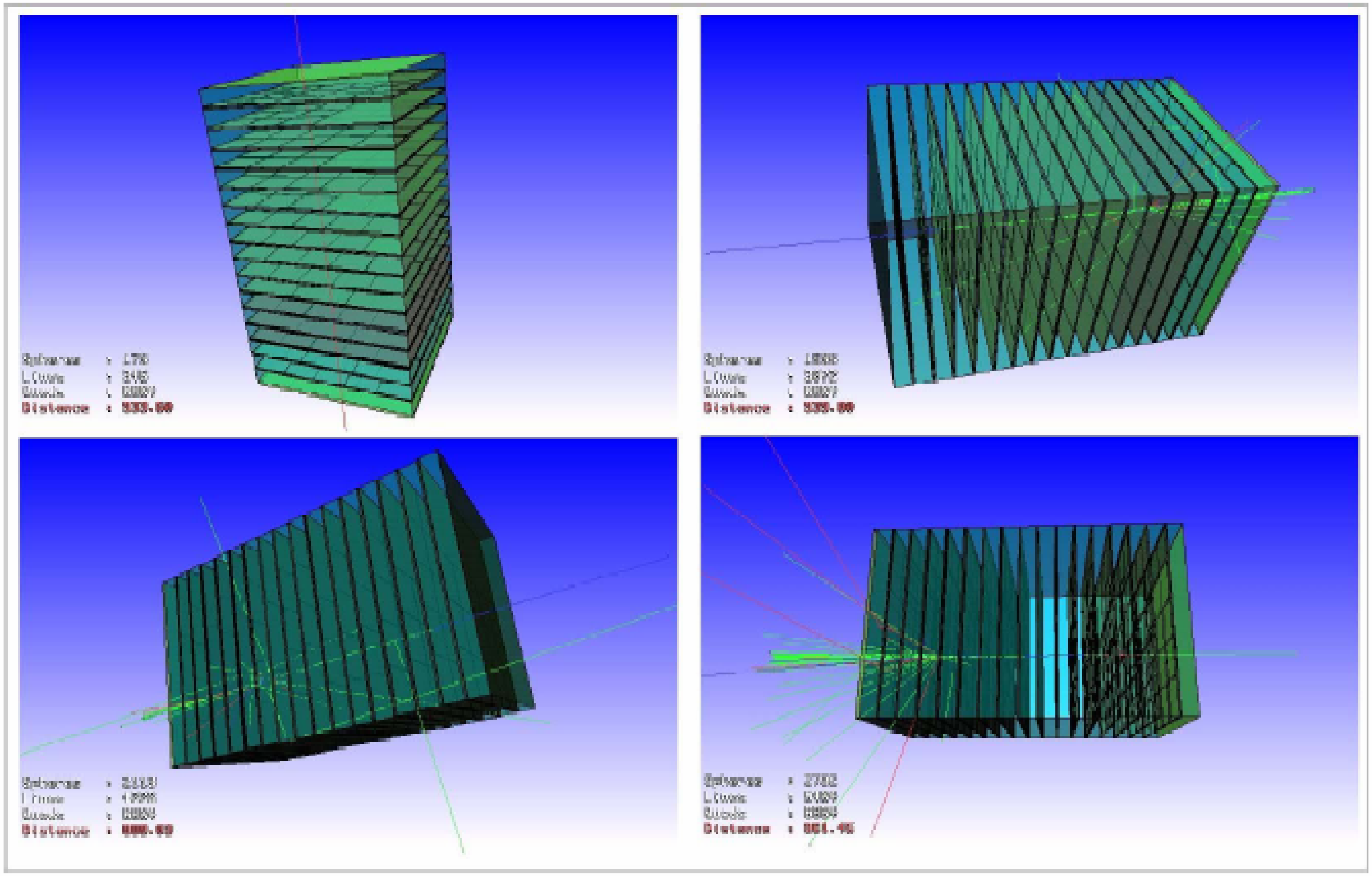


- The G4 BFEM simulator and cosmic-ray generators well reproduced hits in TKR (20% difference could be explained by He and the flux uncertainty.)
- small discrepancy is seen in layers near the CAL.

7

Mizuno et al. 2002

TestBeam 1999



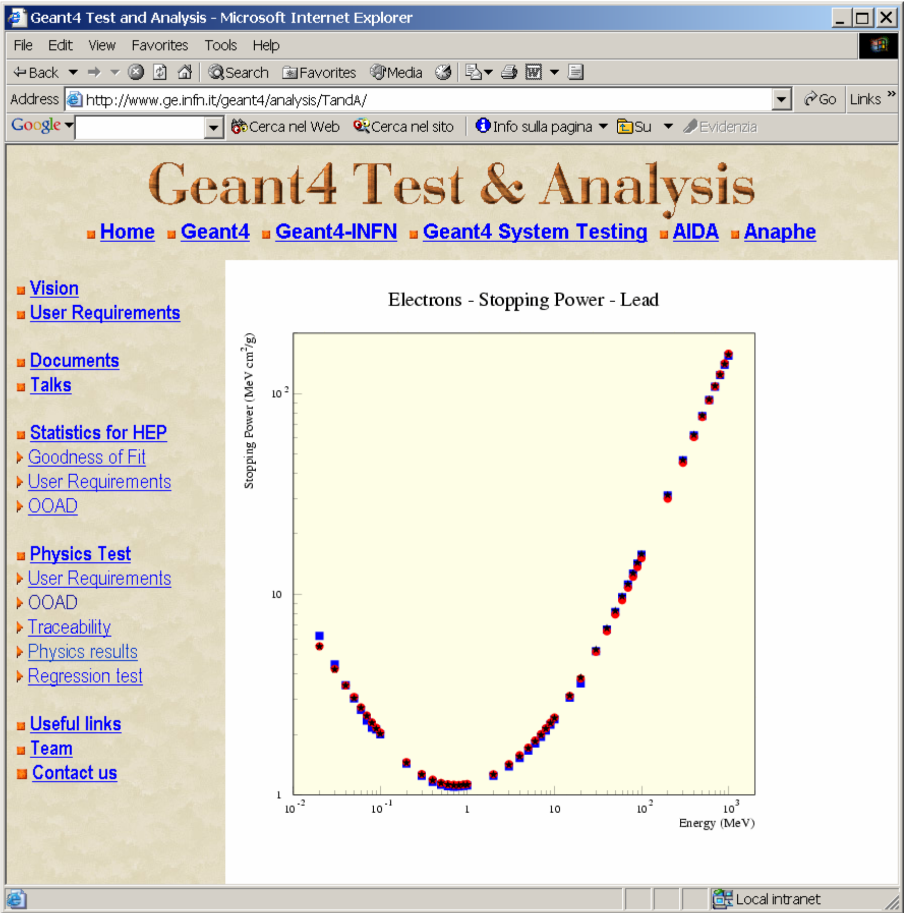
Cestellini & Cecchi 2002

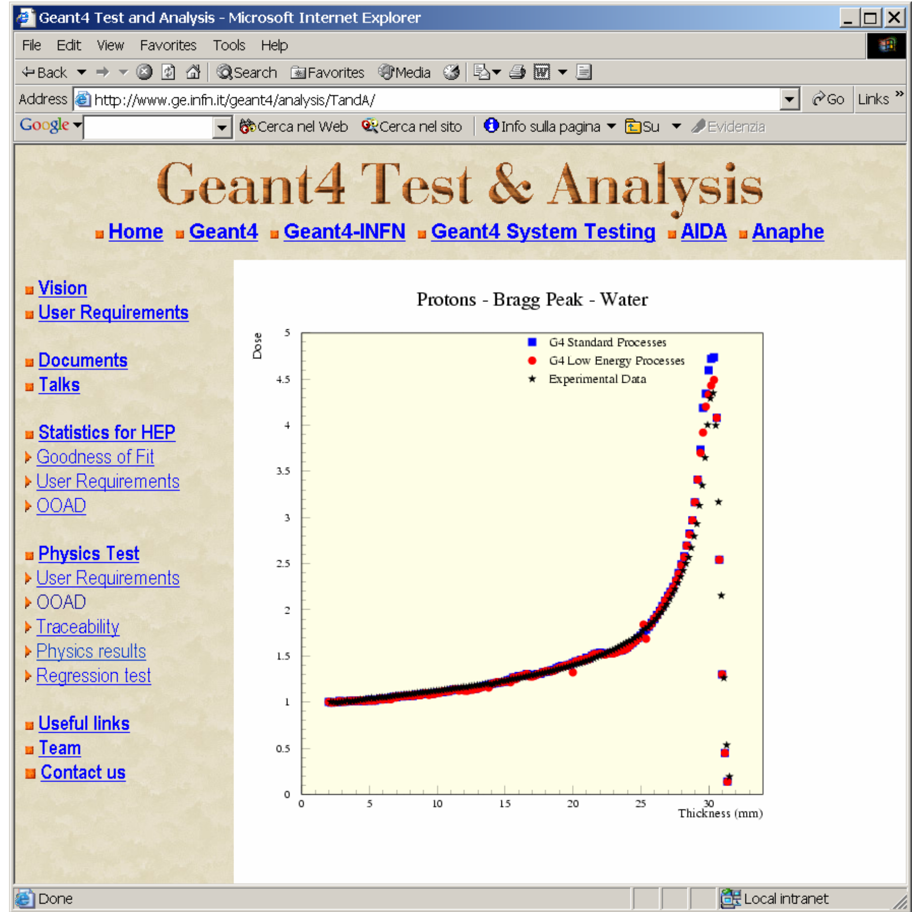
G4 Test&Analysis project

http://www.ge.infn.it/geant4/analysis/TandA

G4 Test&Analysis project

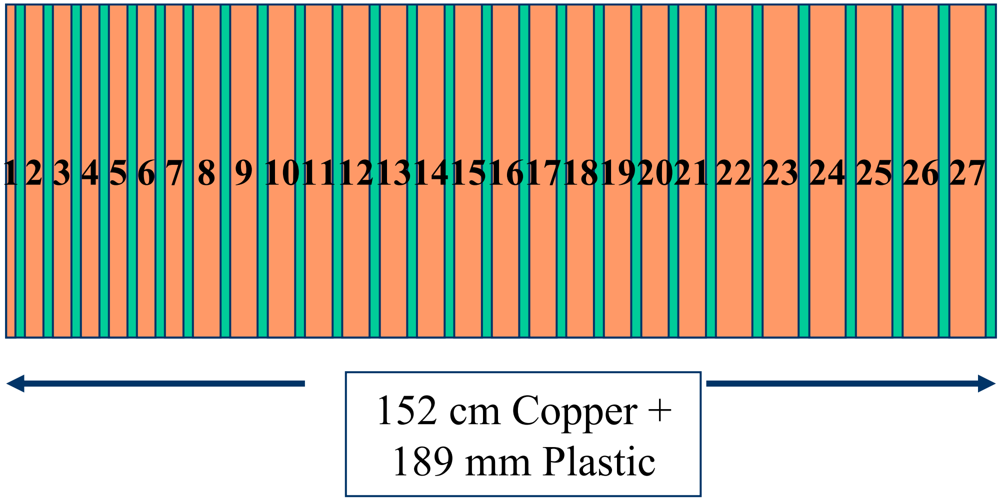
http://www.ge.infn.it/geant4/analysis/TandA

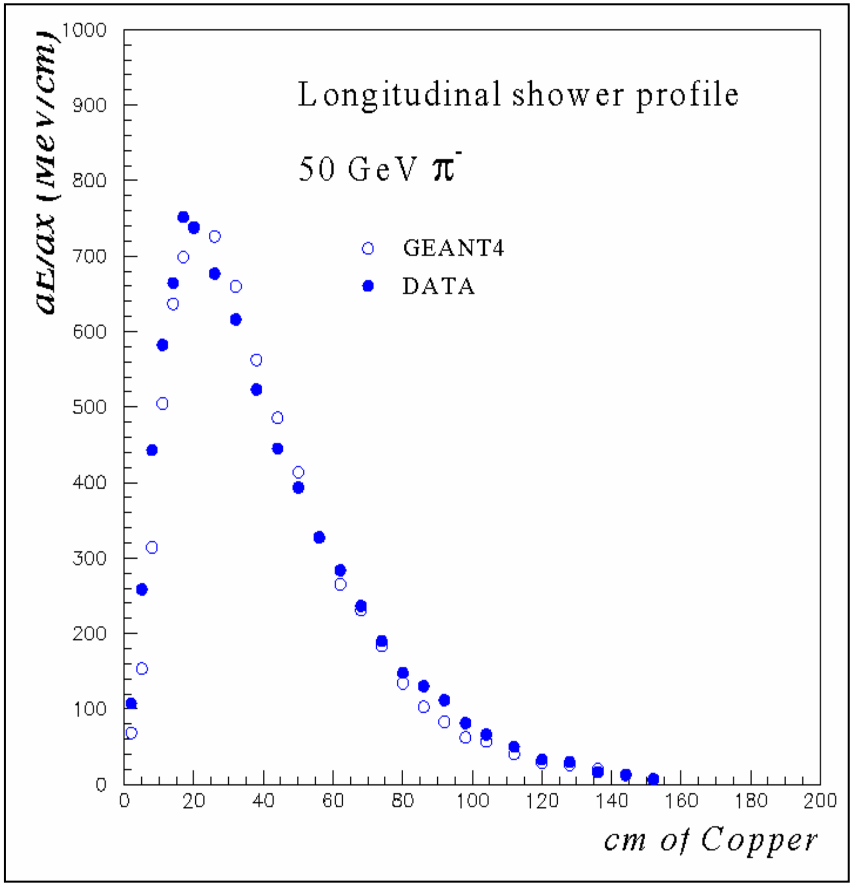




Comparison project

CMS HCAL Test-Beam Setup





Courtesy of CMS Collaboration

G4 physics validation

Quick test of G4 Multiple Scattering

Johann Cohen–Tanugi (INFN Pisa), Francesco Longo (INFN Trieste)

May 05th 2003

- **Recent switch to Geant 5.0: "Test suite" needed**
- **Pre –CDR request: see**
- **http://www-glast.stanford.edu/protected/mail/ana/0024.html**
- **This is preliminary: more to come...**

GLAST INFN

G4 physics validation

Setup for the study

- Script in userAlg uses MC information in TDS to retrieve deflection angle between initial and final direction of an normally incident charged track.
- Converting Volume is a Tungstene Slab:
  thin (0.105 mm) and thick (0.723mm)
- Projected angle is computed as: arcsin(p_f.x()/p_f.mag())
- Test is to compare its distribution to Moliere formula (pdg 26.10),
- 1 and 10 GeV mu and e, and 10 and 50GeV protons

GLAST INFN

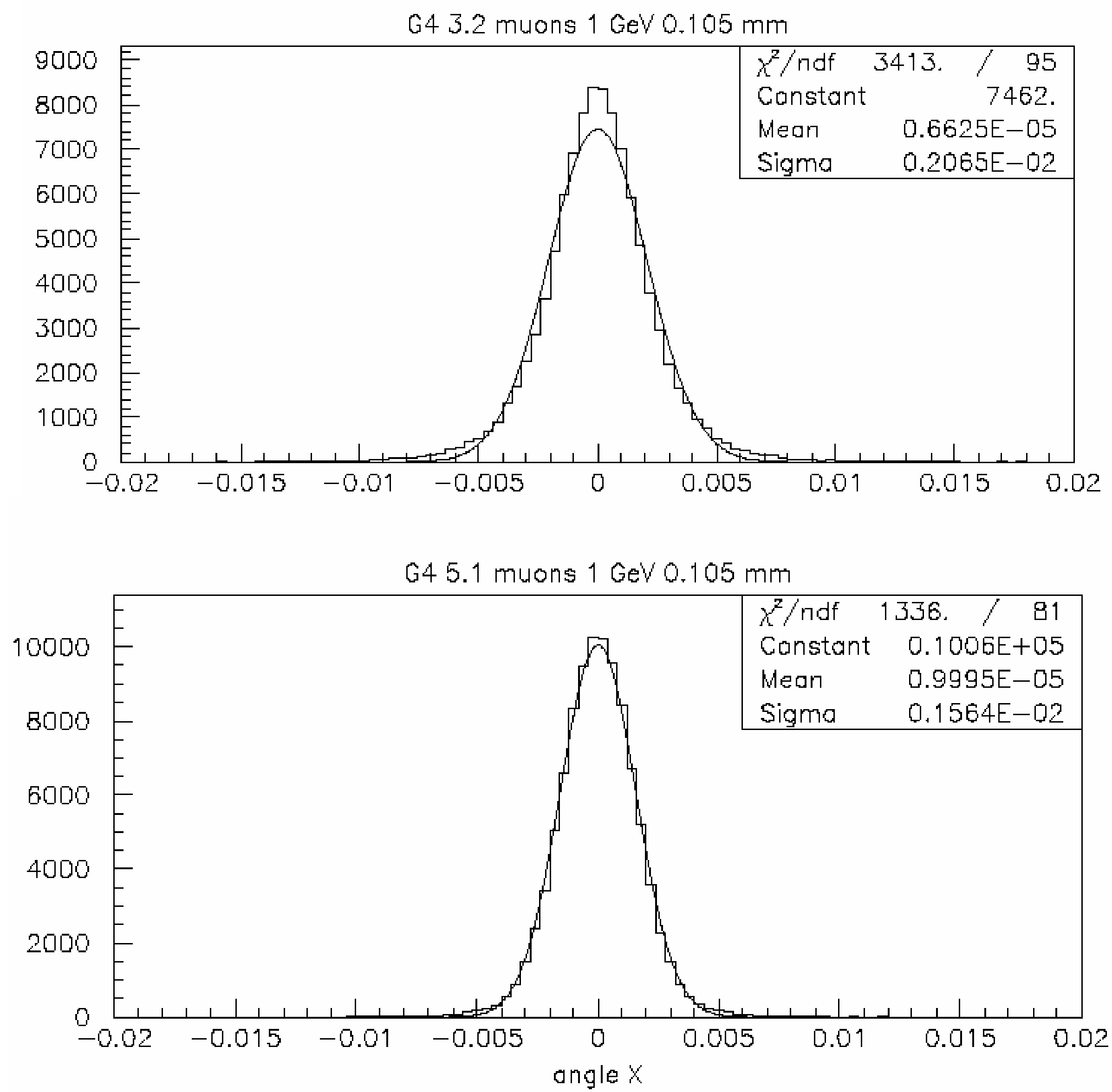
G4 physics validation

Conclusions

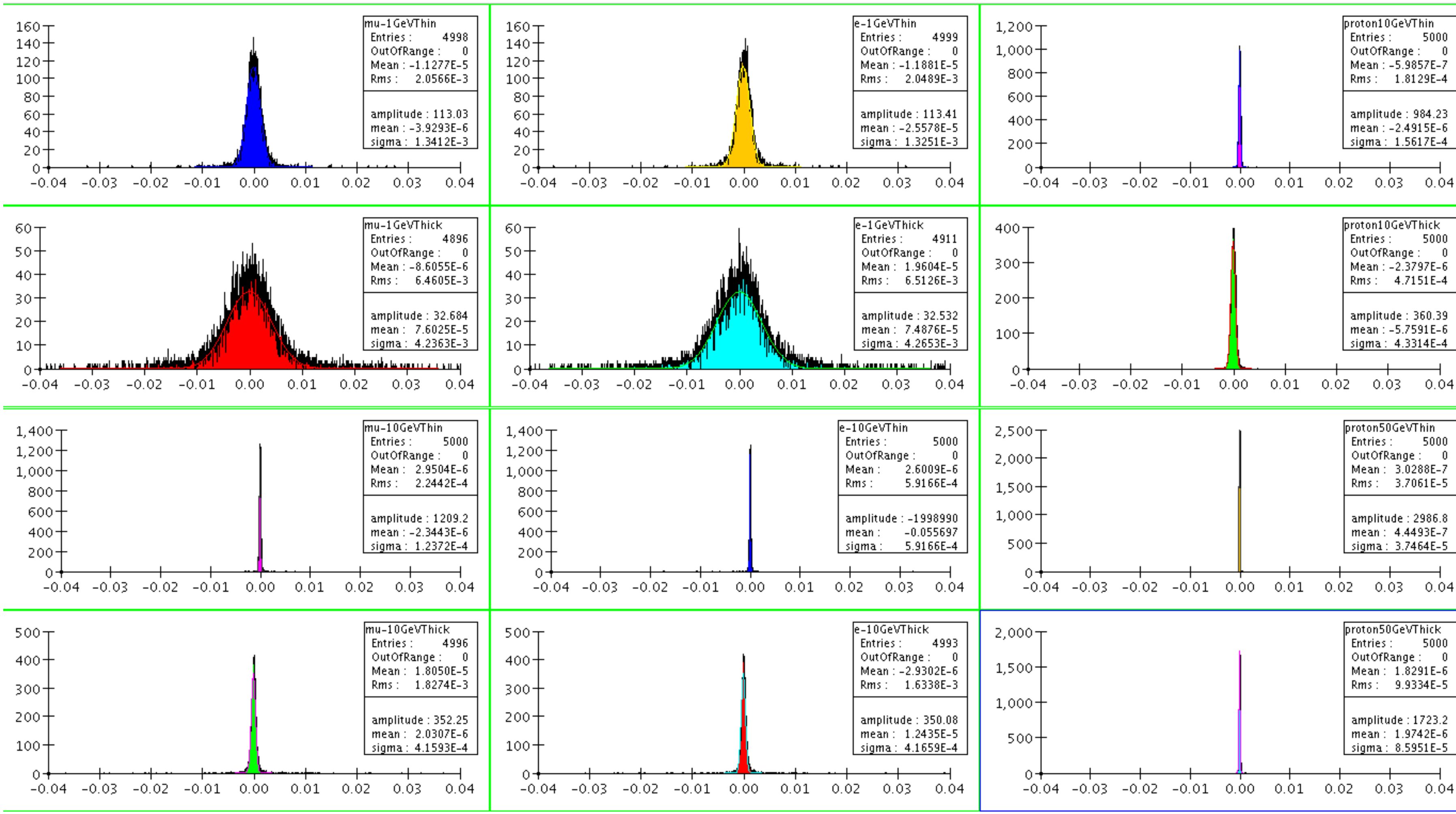
- Discrepancy at the 20–24% level
- Note that G4 does NOT use Moliere theory: see G4PhysicalReferenceManual
- Fits without tails don't improve significantly
- Francesco performed tests directly on G4 and obtained similar results
- Discussion with G4 developers. It seems they find correct values for 1mm Lead at different energies: more investigation on their side has been asked
- We will create a package from this userAlg. (Note today's creation of another package for G4 standalone tests: GEANT4TEST, same tests will be performed at both levels)
- More detailed studies to come....

GLAST INFN

G4 physics validation

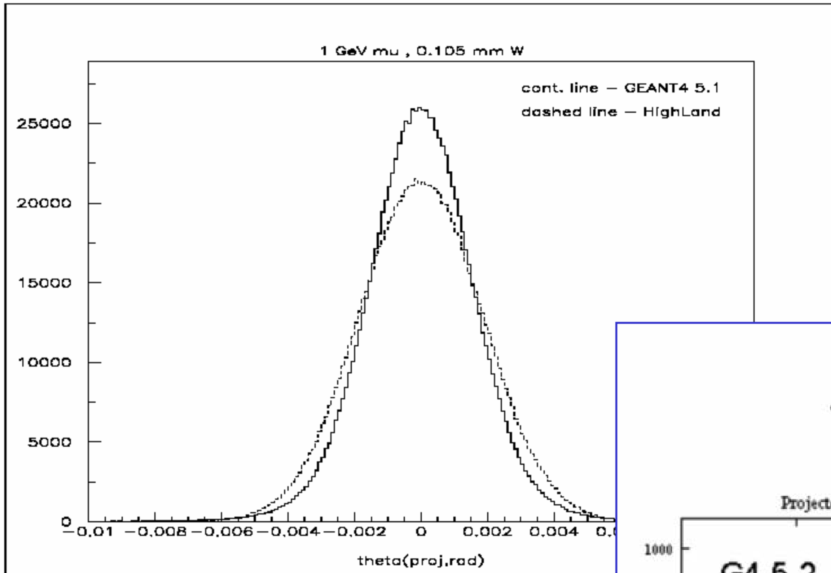


G4 physics validation

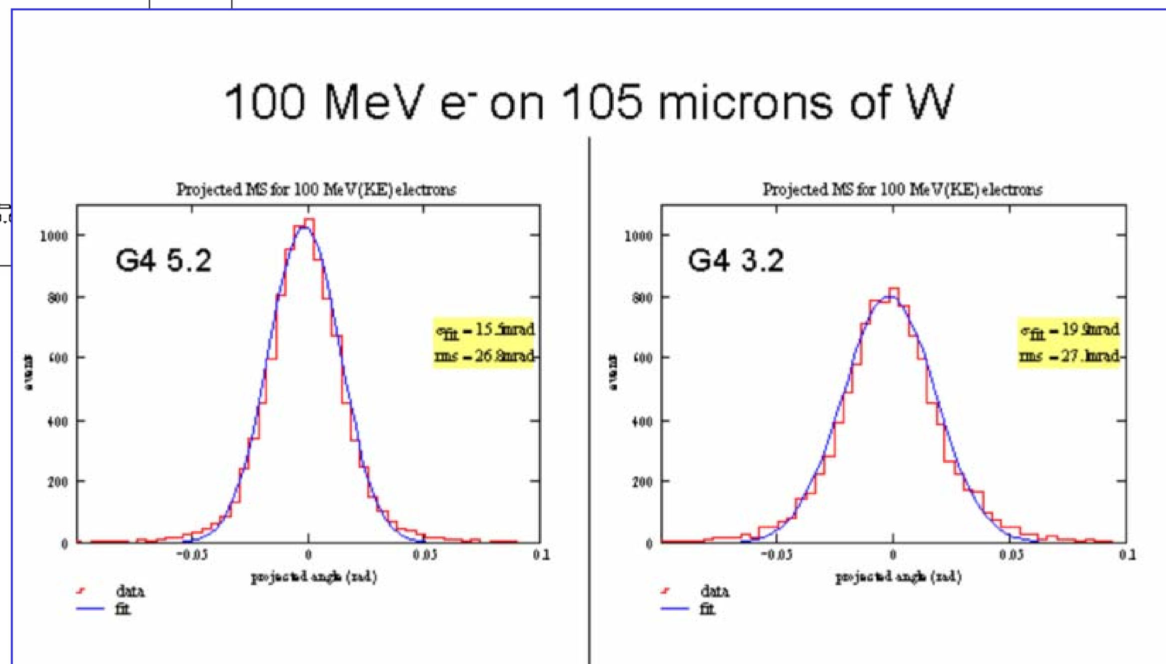


Koi 2003

G4 physics Validation



Urban 2003



Burnett et al. 2003

Multiple Scattering solution

- Decided to swith back to version 3.2 of G4 which was more accurate in evaluating the projected angle
- Comparison with G3, EGS4, other G4 versions
- Experimental tests are on-going

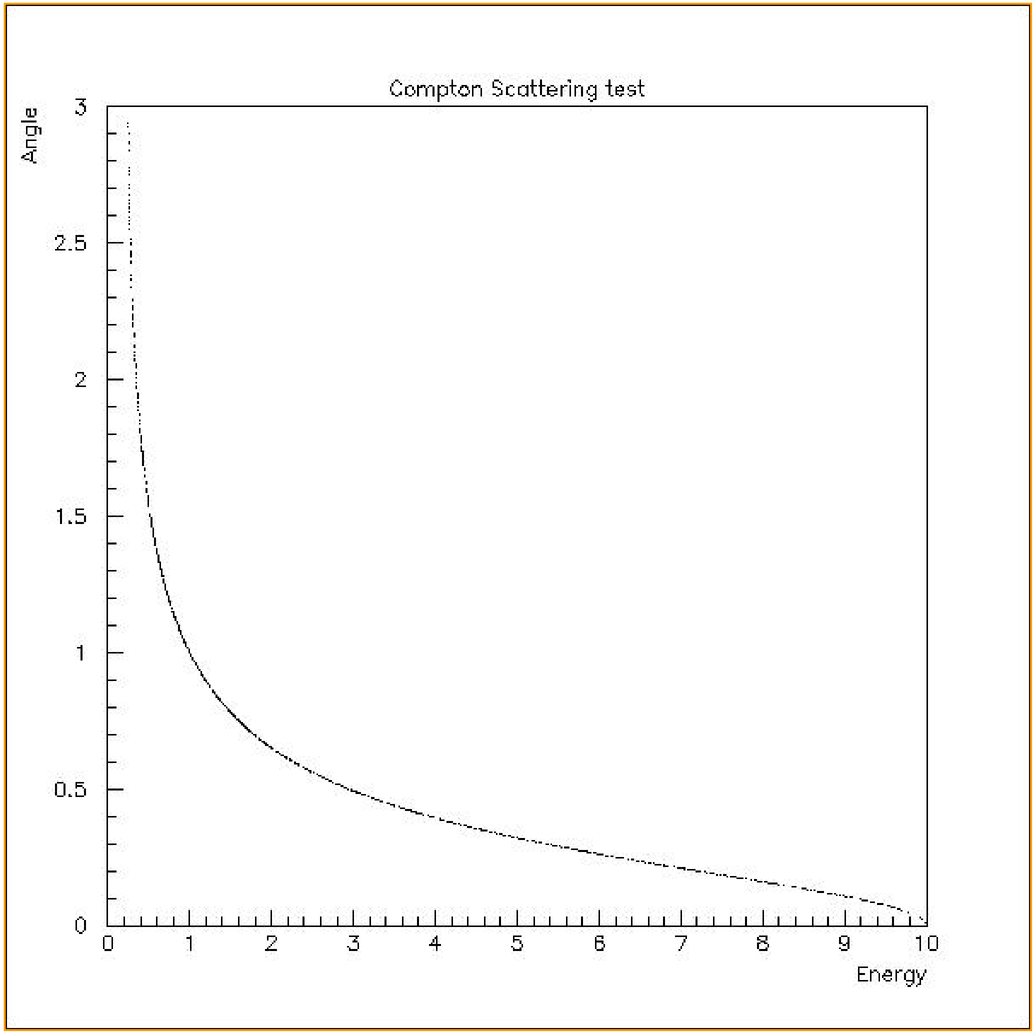
G4 validation for DC1

- Photon processes
  - Photoelectric, Compton, Pair production
    - Cross Section
    - Angular Distribution
    - Energy distribution
- Charged particle processes
  - Ionisation
    - Landau, Bethe Bloch
    - Range, Stopping Power, Straggling
  - Multiple Scattering
    - Projected Angle, Energy dependence
  - Bremsstrahlung
    - Cross Section, Angular Distribution, Energy Distribution
  - Delta ray production
    - Energy distribution, Multiplicity
  - Positron Annihilation
    - Cross section
- EM shower profile
- Ogata's thesis confirmation

Unit Test level

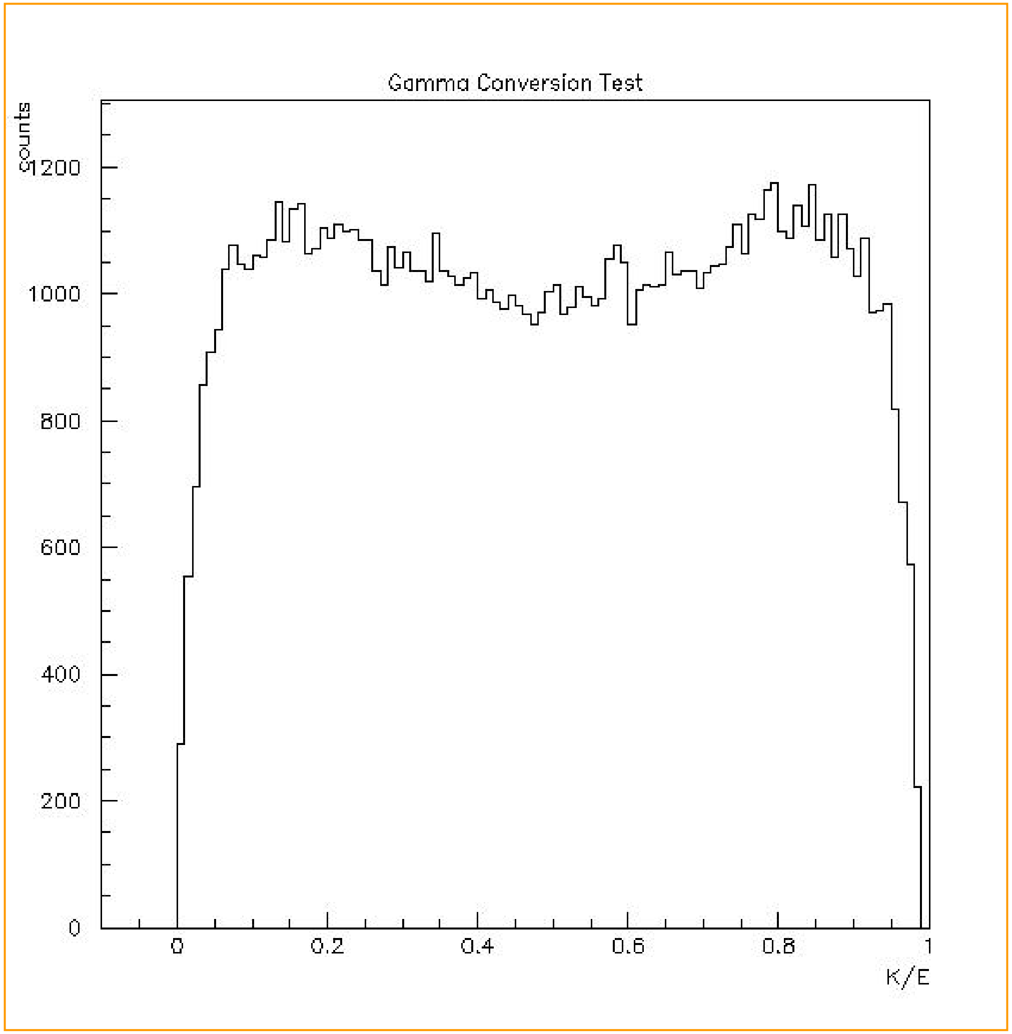
- Purpose: testing physics implementation of simple classes
- Actually done within the internal G4 tags to verify models and propose changes or bug fixes
- New unit tests suitable to GLAST purposes:
  - `G4EM_photonTest`: Photoelectric, Compton and Gamma Conversion classes
  - `G4EM_electronTest`: Ionisation and Bremsstrahlung
  - `G4EM_muonTest`: Muon ionisation
  - `G4EM_protonTest` : Proton and ion ionisation
  - `G4EM_mcsTest`: Multiple Scattering tests
  - …

Preliminary results



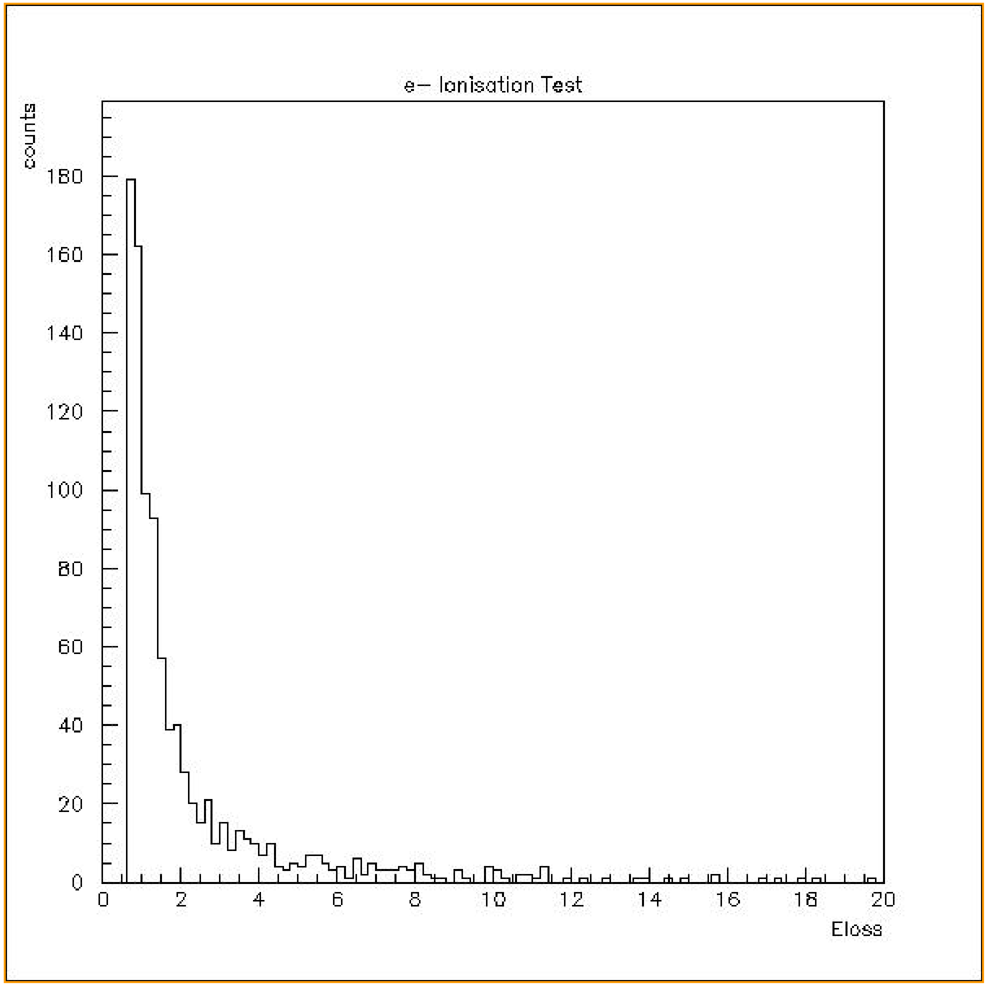
Theta – Energy relation in Compton

Preliminary results



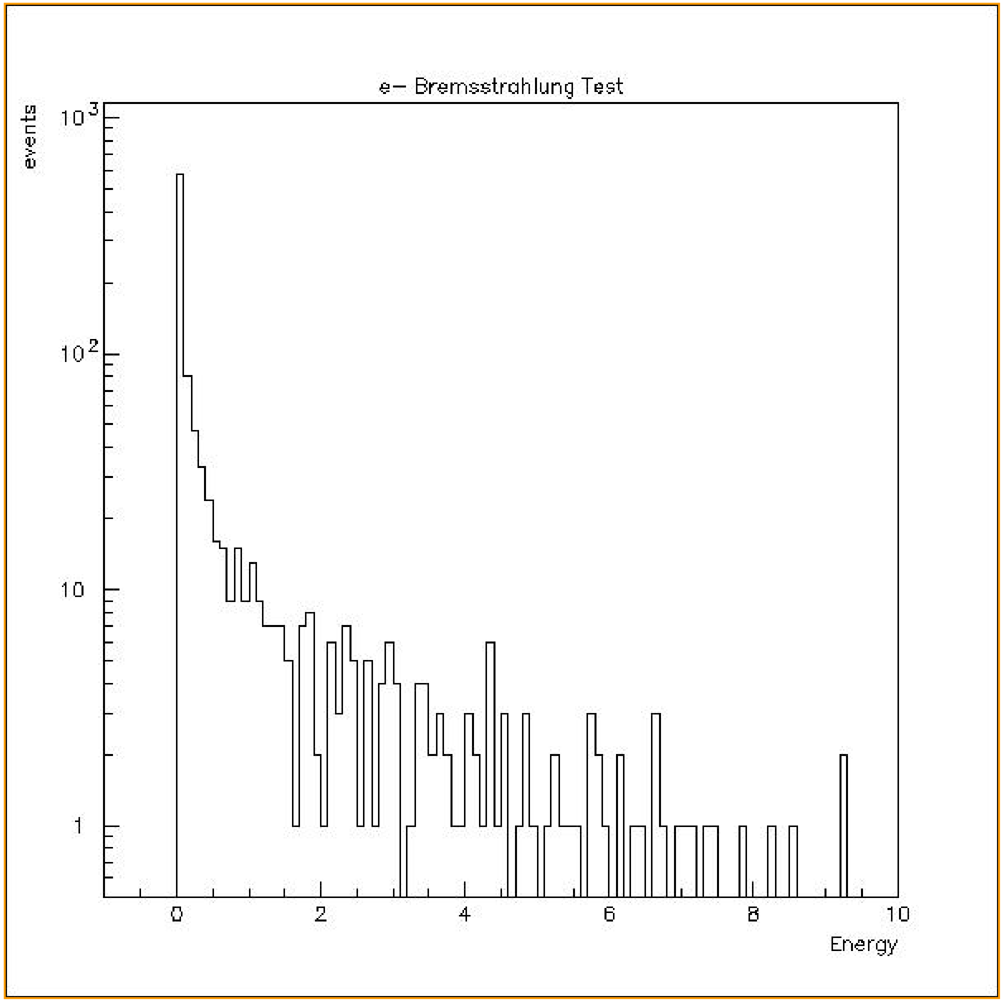
Energy distribution in Pair production

Preliminary results



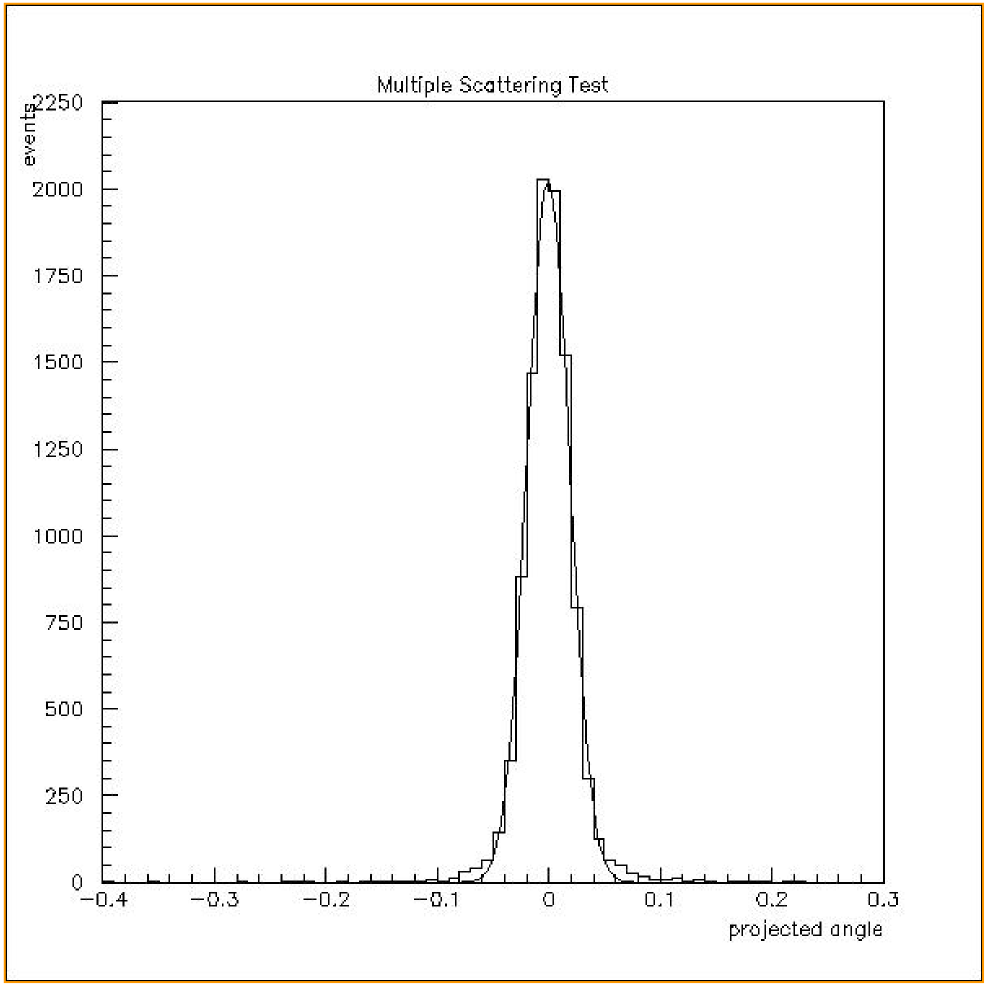
Ionisation in thin slabs

Preliminary results



Gamma spectrum from bremsstrahlung

Preliminary results

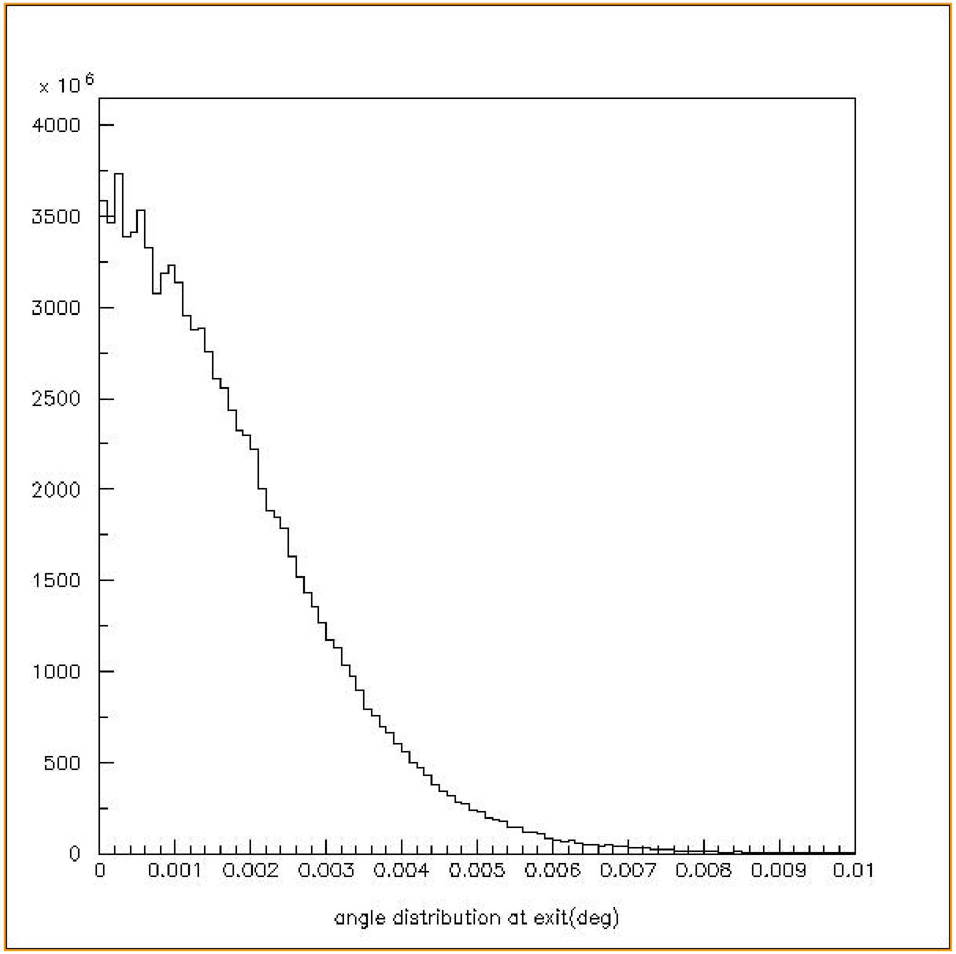


Theta scattering for MCS

G4 extended examples

- Purpose: testing physics implementation of simple classes
- EM physics testing and comparison to G3
  - `TestEM1` test on individual processes
  - `TestEM2` test on shower development
  - `TestEM3` simple Sampling Calorimeter setup
  - `TestEM4` Low energy EM physics
  - `TestEM5` simple Slab test
  - `TestEM6` gamma conversion to muons
  - `TestEM7` Bragg peak test
  - `TestEM8` Ionisation thin layers

Preliminary results

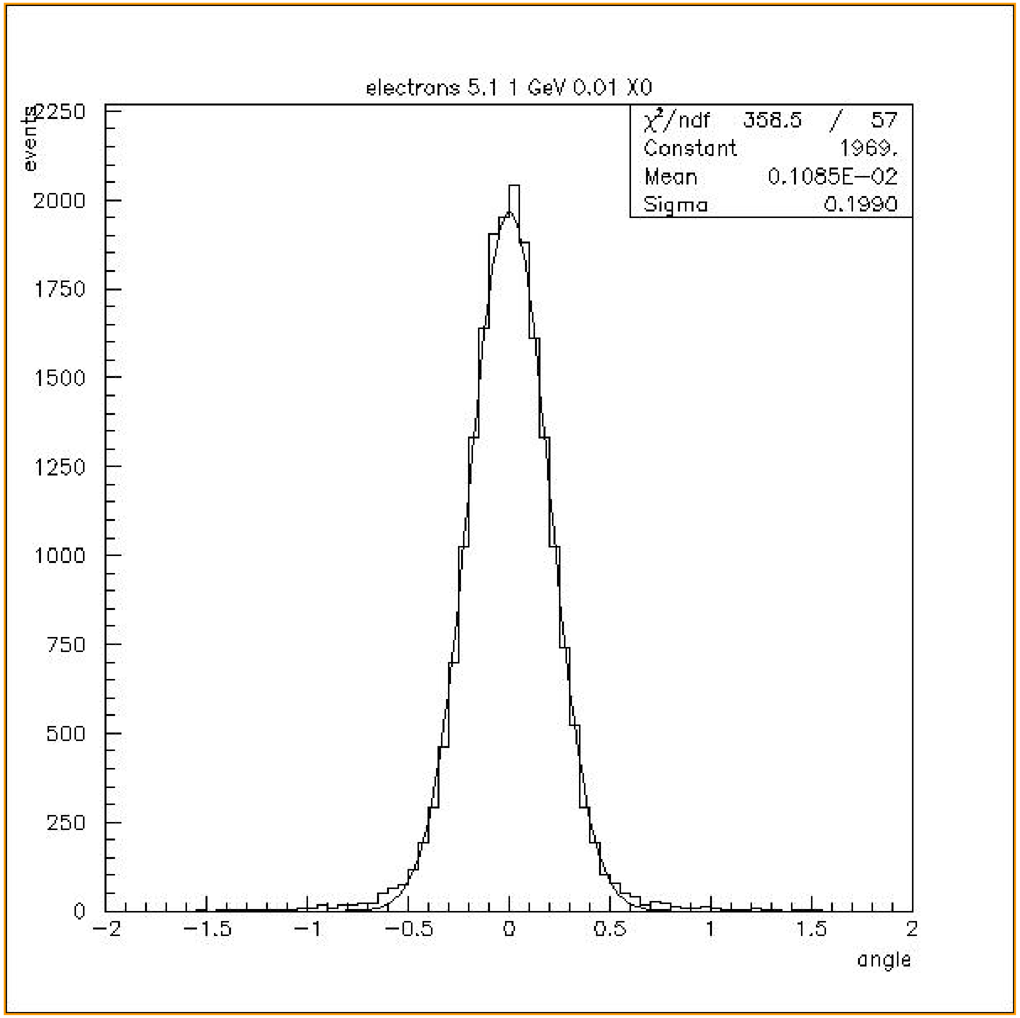


Exit angle from Slab (TestEM5)

Physics Test level (G4 standalone)

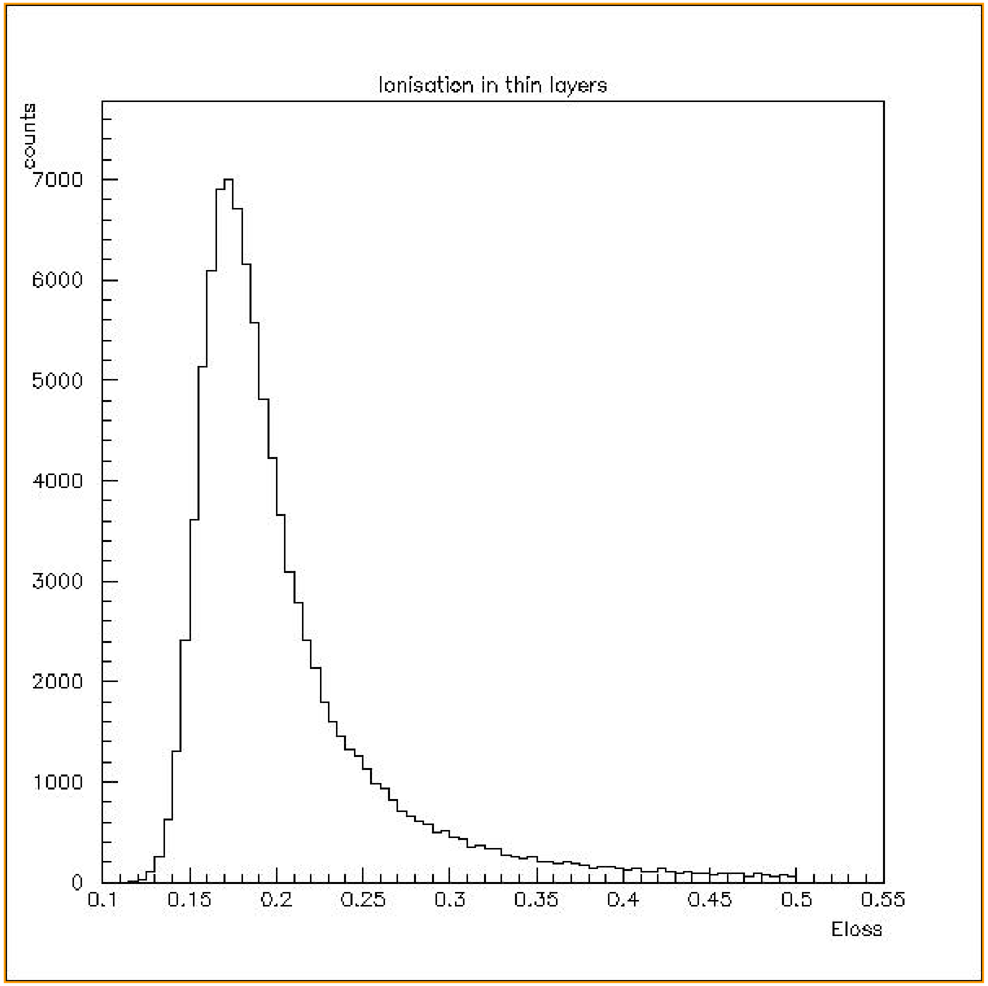
- Purpose: GLAST dedicated physics testing
- Simple geometries
- Complete EM physics: similar to Gleam's
- Tunable parameters
- Verification with other MC [G3, EGS4 (?)]
  - `MCStest`: Multiple scattering test
  - `IonTest`: Ionisation test
  - `BremTest`: Bremsstrahlung test
  - `PhotTest`: Cross section of photons, angular distribution
  - `HadrEMTest`: alpha, proton, ions ionisation
  - `Crannel` experiment simulation
- GEANT4TEST package in CVS repository
  - Test names, ROOT scripts, theoretical formulae

Preliminary results



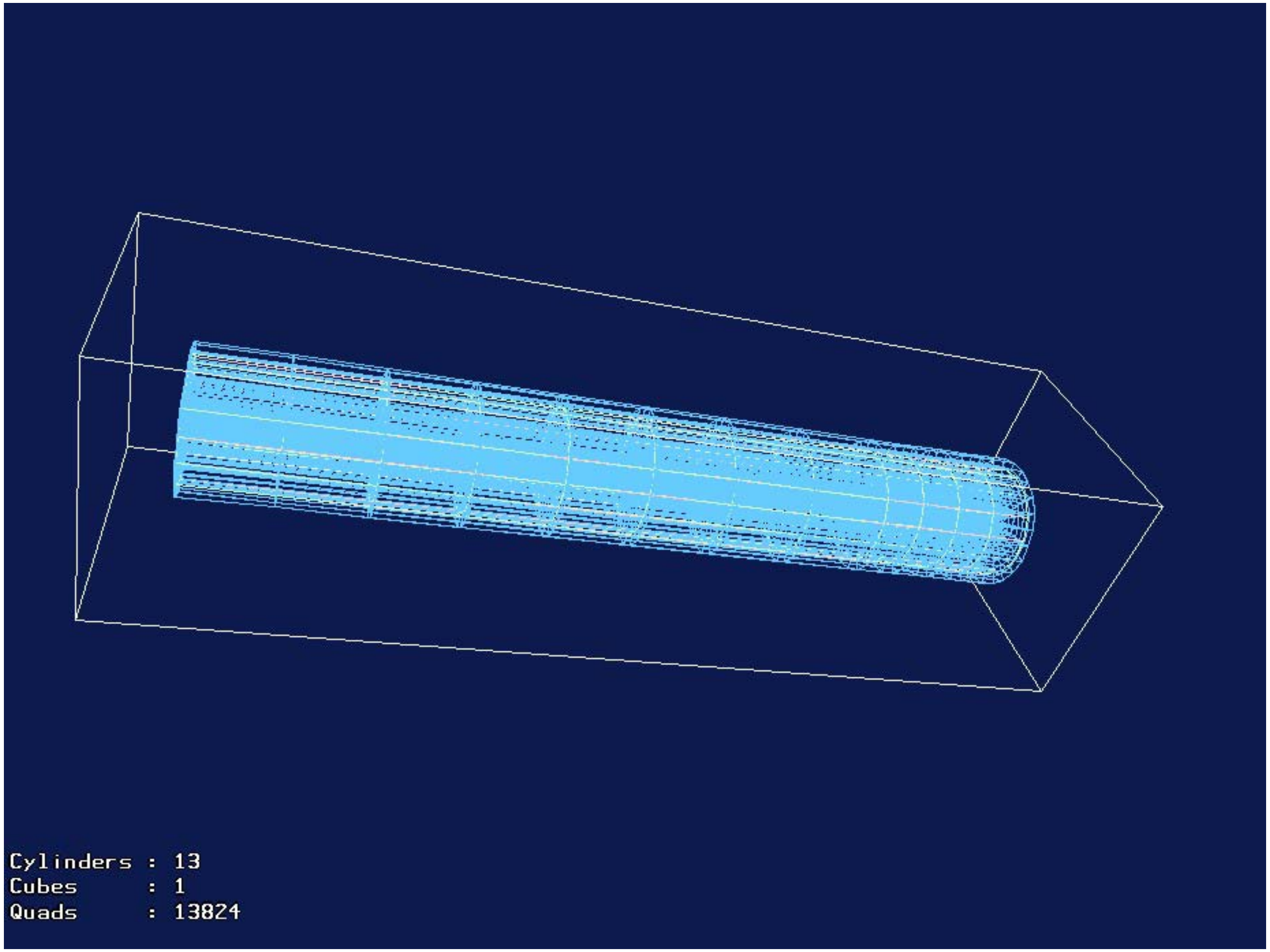
MCS angle (Thin Slab)

Preliminary results



Ionisation (Thin Slab)

Preliminary results



Crannell experiment setup

System Test level

- `G4TestAlg` package in CVS repository
- Full framework capabilities (Geometry, Sources, …)
- XML geometry definition
- XML library for sources definition
- Indirect Verification of goodness of framework (comparison with physics tests)
- Already proved with test on MCS run at 2 different levels

G4 hadronic validation

- Hadronics working group contacted
- Possible test beam comparison (for protons)
- Hadronic validation in progress also on G4 side
- Ion hadronic physics still missing
- Possible use of JQMD?

Schedule and Conclusions

- Working group on G4 validation
- EGS4, G3 comparisons
- EM physics validation on the list of processes presented
- Experimental data needed
- Contacts with previous validation efforts
- G4 developers contacted (visit at SLAC in September)
- Report on EM physics validation for mid August
- EM test suite to be developed and maintened at SLAC