Validation and TestEm series

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What does Validation mean ?

- Comparison with well etablished data
  - from experiments
  - from evaluations
  - from other simulations

The data must be simple enough to be considered almost as single test unit

- Check internal coherence
  - verify that results of simulation are consistent with input data : cross_sections, stopping_power, …
- Book keeping
  - Keep track of the evolution of the physics versus Geant4 version

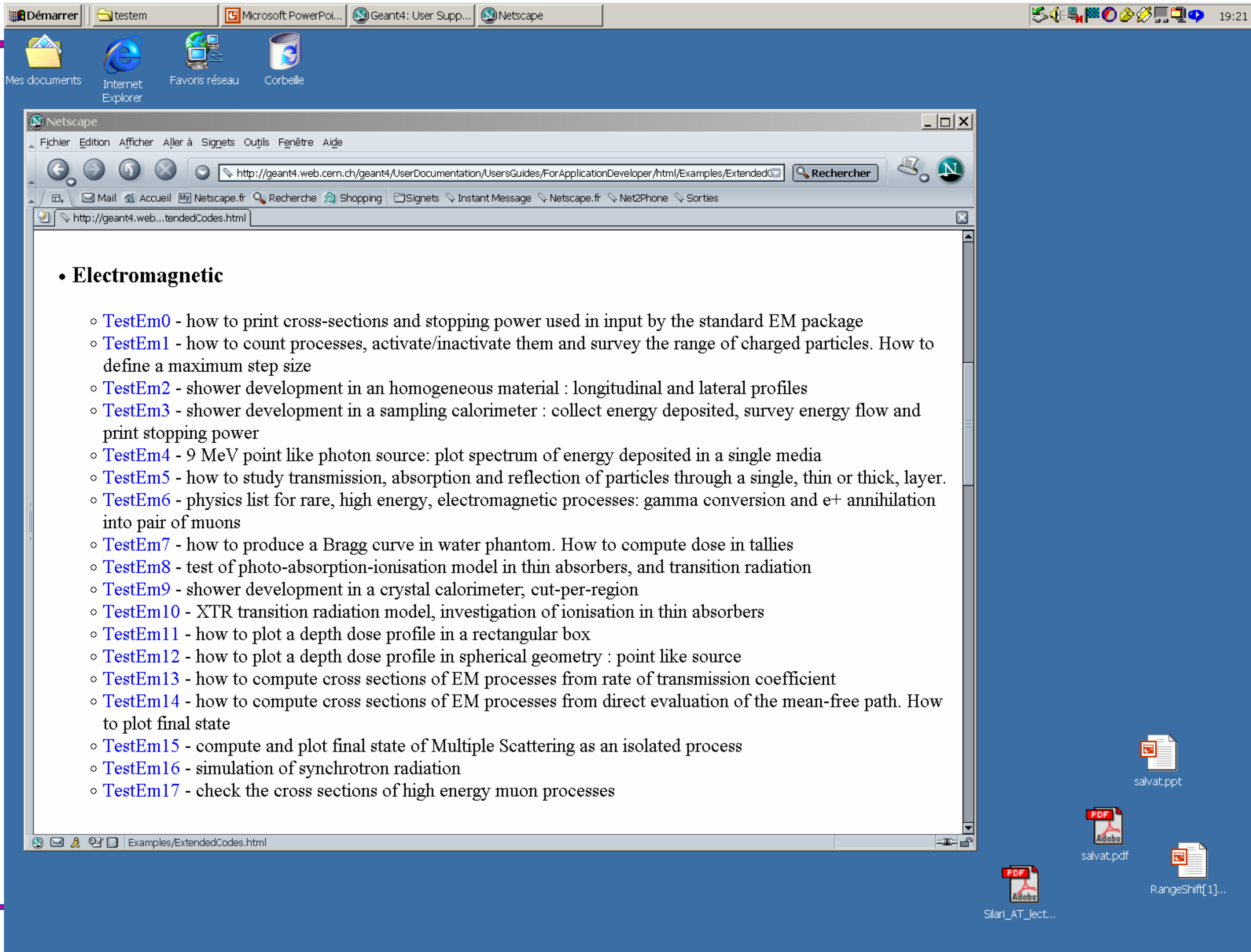
Two remarks of pratical importance

- The results of simulation must be simple enough to be analysed (understood …) easily and quickly
  - Not more than a few number of 1D histograms
- The results and the protocol to get them must be made public, in close connection with the source code distribution

User's applications : what to inspect ?

- Geometry
- Physics list
- What is recorded and how : tracking, stepping and stacking actions
  - very often the systematic use of hit/digit structures is not necessary; it may complicate the code for nothing
  - testEm series want to be a tutorial and a reference of what to do in this area
  - extended/medical/gammaTherapy and extended/optical/LXe have similar goal

TestEm series



- **Electromagnetic**
  - TestEm0 - how to print cross-sections and stopping power used in input by the standard EM package
  - TestEm1 - how to count processes, activate/inactivate them and survey the range of charged particles. How to define a maximum step size
  - TestEm2 - shower development in an homogeneous material : longitudinal and lateral profiles
  - TestEm3 - shower development in a sampling calorimeter : collect energy deposited, survey energy flow and print stopping power
  - TestEm4 - 9 MeV point like photon source: plot spectrum of energy deposited in a single media
  - TestEm5 - how to study transmission, absorption and reflection of particles through a single, thin or thick, layer.
  - TestEm6 - physics list for rare, high energy, electromagnetic processes: gamma conversion and e+ annihilation into pair of muons
  - TestEm7 - how to produce a Bragg curve in water phantom. How to compute dose in tallies
  - TestEm8 - test of photo-absorption-ionisation model in thin absorbers, and transition radiation
  - TestEm9 - shower development in a crystal calorimeter; cut-per-region
  - TestEm10 - XTR transition radiation model, investigation of ionisation in thin absorbers
  - TestEm11 - how to plot a depth dose profile in a rectangular box
  - TestEm12 - how to plot a depth dose profile in spherical geometry : point like source
  - TestEm13 - how to compute cross sections of EM processes from rate of transmission coefficient
  - TestEm14 - how to compute cross sections of EM processes from direct evaluation of the mean-free path. How to plot final state
  - TestEm15 - compute and plot final state of Multiple Scattering as an isolated process
  - TestEm16 - simulation of synchrotron radiation
  - TestEm17 - check the cross sections of high energy muon processes

General principles

- The examples try to be generic enough, to allow to handle similar situations without code modifications
  → always simple (trivial …) geometry
- Specific cases are defined *via* UI macros
- The source code is exposed to users. It wants to be a reference for how to compute and plot various physics quantities

Photon interactions

Unpolarized, no fluorescence

	Total cross sections, mean free paths …	Em0, Em13, Em14
DCS		
	Final state : ● energy spectra ● angular distributions	Em14

Charged particle interactions

Unpolarized, no fluorescence

	Total cross sections, mean free paths …	Em0, Em13, Em14
DCS	Stopping power, range … With cuts	Em0, Em1, Em5, Em11, Em12
	Final state : • energy spectra • angular distributions	Em14

Multiple Coulomb scattering

- As an isolated mechanism
  - mean free path
  - step limitation
  - true path length
  - angular distributions
  - lateral displacement
  - correlation

  } Em15

- As a result of particle transport
  - various distributions in
    - transmission
    - absoption
    - reflexion

  } Em5

More global verifications

Single layer : transmission, absorption, reflexion	Em5
Depth dose distribution, tallies Bragg curve	Em11, Em12 Em7
Shower shapes, Moliere radius	Em2
Sampling calorimeters, energy flow	Em3
Crystal calorimeters	Em9

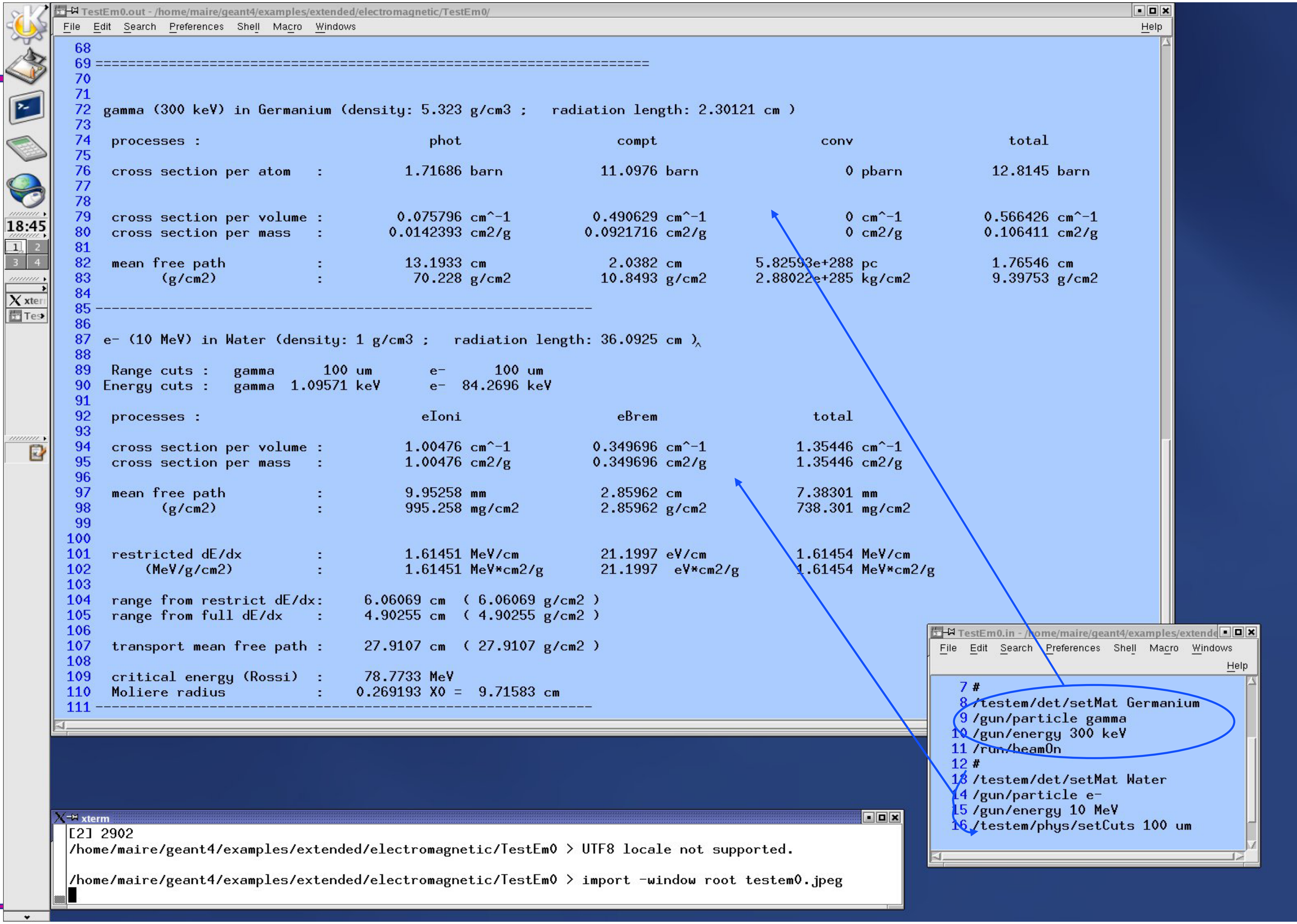
Other specialized programs

High energy muon physics	Em17
Other rare, high energy processes	Em6
Synchrotron radiation	Em16
Transition radiation	Em8
Photo-absorption-ionization model	Em10

Histograms management

- Creating histograms is always optional, under the control of G4ANALYSIS_USE
  → need at least one AIDA implementation
- A set of 1D histograms is predefined in an HistoManager class
  → only 1D histograms; no ntuples, no hits structures.
- Booking, Filling
  - a given histogram is selected and booked via UI command
  - his binning is defined via UI command
- Output
  - the name of the file and its format are defined via UI command
  → xml, root, hbook

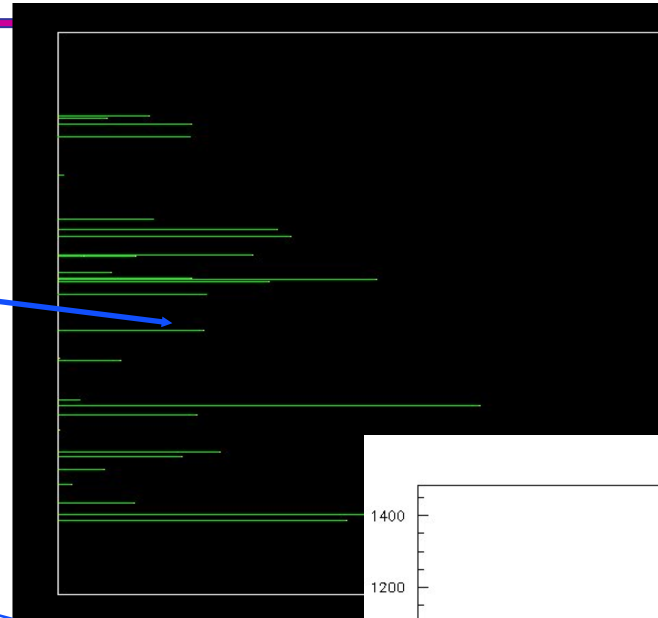
TestEm0 : Input data (via G4EmCalculator)

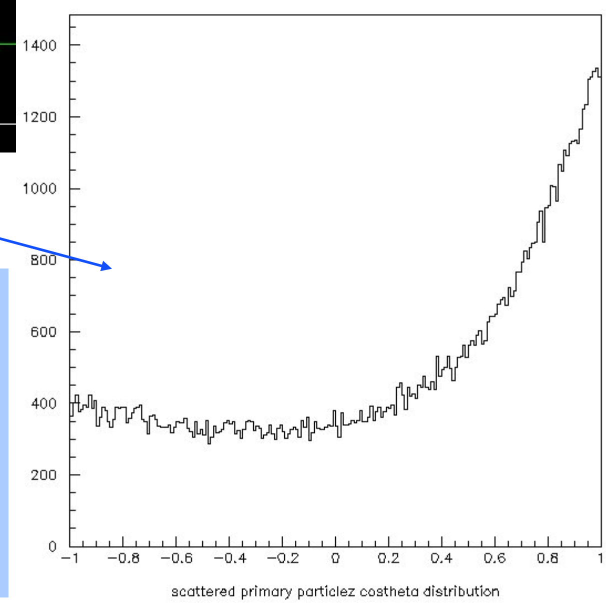


TestEm13 - 14 : cross sections and final state

```
# $Id: compton.mac,v 1.2 2006/05/10 11:15:33 maire Exp $
#
# Macro file for "TestEm14.cc"
# (can be run in batch, without graphic)
#
# photon 300 keV; compton
#
/control/verbose 2
/run/verbose 2
#
/testem/det/setMat Aluminium
#
/testem/phys/addPhysics standard
####/testem/phys/addPhysics livermore
####/testem/phys/addPhysics penelope
#
/run/initialize
#
/process/inactivate phot
/process/inactivate conv
/process/inactivate GammaToMuPair
#
/gun/particle gamma
/gun/energy 300 keV
#
/testem/histo/setFileName penel
/testem/histo/setFileType hbook
/testem/histo/setHisto 1  100 0. 300. keV      #energy  of primary
/testem/histo/setHisto 2  200 -1. +1. none     #costeta of primary
/testem/histo/setHisto 3  100 0. 300. keV      #energy  of ch. secondary
/testem/histo/setHisto 4  200 -1. +1. none     #costeta of ch. secondary
#
/run/beamOn 100000

```

Direct evaluation of the mean free path

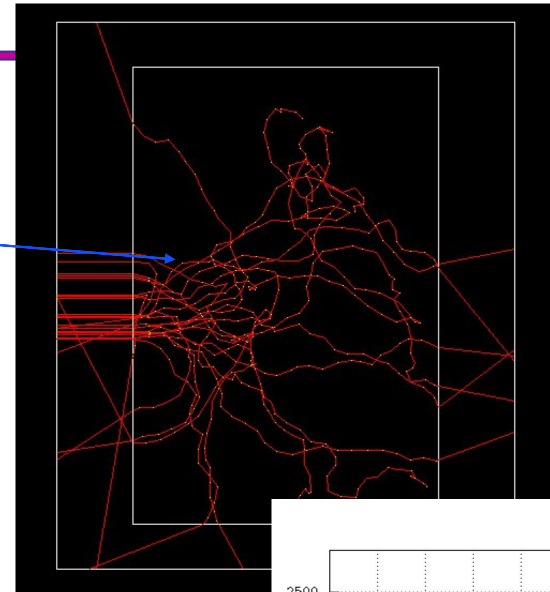




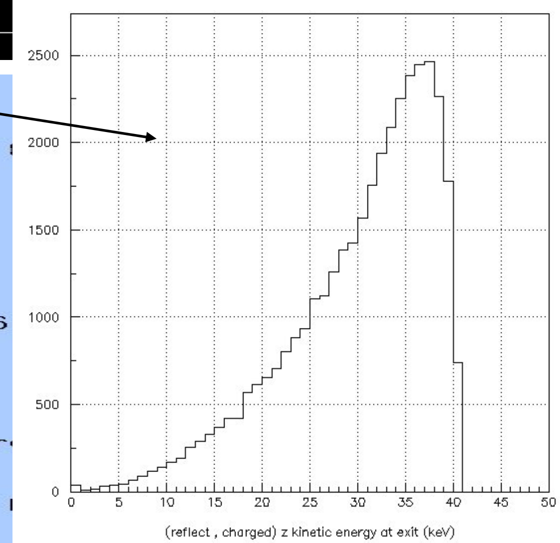

```
User=7.1s Real=7.5s Sys=0.06s

The run consists of 100000 gamma of 300 keV through 100 m   of Aluminium (density: 2.7 g/cm3 )

Process calls frequency --->   compt = 100000

MeanFreePath:  3.6444 cm  +- 3.6438 cm         massic: 9.84 g/cm2
CrossSection:  0.27439 cm^-1                   massic: 0.10163 cm2/g

Verification : crossSections from G4EmCalculator.
       compt= 0.10168 cm2/g    total= 0.10168 cm2/g
```

TestEm5 : low energy electron

```
#
# macro file for TestEm5.cc
#
# Back scattering of  41 keV electrons.
# H.J. Hunger and L. Kuchler Phys. Stat. Sol.(a) 56, K45 (1979)
#
/control/verbose 2
/run/verbose 2
#
/testem/det/setAbsMat Silver
/testem/det/setAbsThick 2 um
/testem/det/setAbsYZ    3 um
#
/testem/phys/addPhysics standard
###/testem/phys/addPhysics livermore
###/testem/phys/addPhysics penelope
#
/run/initialize
#
/testem/gun/setDefault
/gun/particle e-
/gun/energy 41 keV
#
/testem/histo/setFileName hunger
/testem/histo/setFileType hbook
/testem/histo/setHisto 11  50 0.0 50 keV        #energy reflected_charged
#
/run/beamOn 100000
```

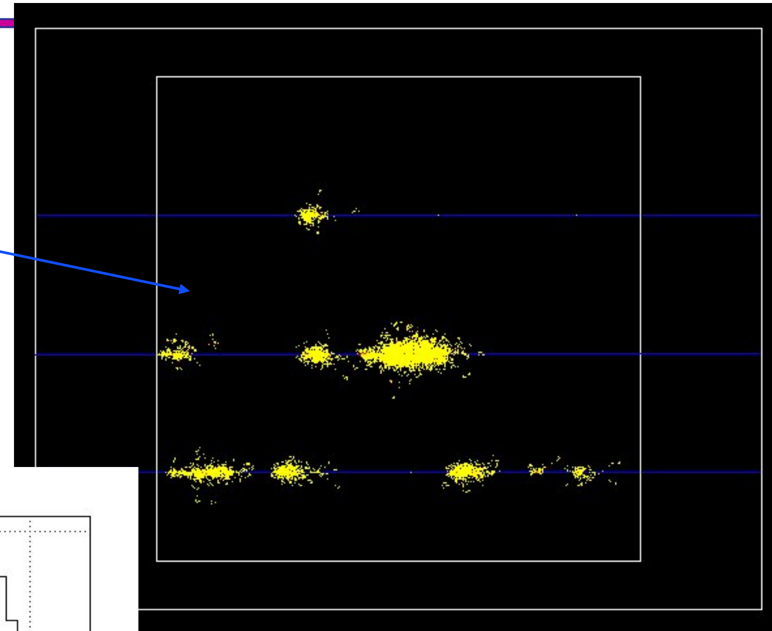


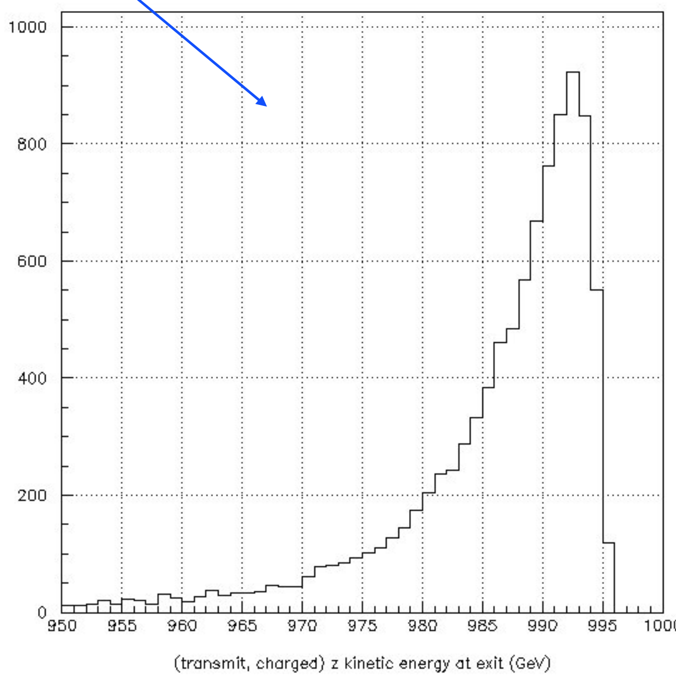
```

 ======================== run summary =======================

 The run was 100000 e- of 41 keV through 2 um  of Silver (density: 10.5 g

 Total energy deposit in absorber per event = 22.37 keV +- 46.67 eV
 -----> Mean dE/dx = 111.9 MeV/cm        (10.65 MeV*cm2/g)

 From formulas :
   restricted dEdx = 45.16 MeV/cm        (4.301 MeV*cm2/g)
   full dEdx       = 45.01 MeV/cm        (4.287 MeV*cm2/g)

 Total track length (charged) in absorber per event = 3.522 um  +- 5.186
 Total track length (neutral) in absorber per event = 0 fm  +- 0 fm

 Number of steps (charged) in absorber per event = 32.92 +- 7.201e-06
 Number of steps (neutral) in absorber per event = 0 +- 0

 Number of secondaries per event : Gammas = 0;   electrons = 0;   positr

 Number of events with the primary particle transmitted = 10.59 %
 Number of events with at least  1 particle transmitted (same charge as p

 Number of events with the primary particle reflected = 34.37 %
 Number of events with at least  1 particle reflected (same charge as primary) = 34.37 %

 =============================================================

 User=14.77s Real=110.67s Sys=95.14s
```



TestEm5 : high energy muon

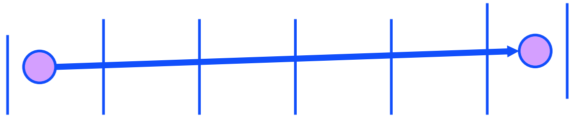
```
# 1 TeV mu+, transmitted through 3 m of iron
# Rev. of Particle Physics Eur. Phys. Jour. C (2000) page 172.
# Rev. of Particle Physics Letters B 592 (2004) page 251.
#
/testem/det/setAbsMat Iron
/testem/det/setAbsThick 3 m
/testem/det/setAbsYZ    3 m
#
/run/initialize
#
/testem/gun/setDefault
/gun/particle mu+
/gun/energy 1 TeV
#
/testem/histo/setFileName tramu
/testem/histo/setFileType hbook
/testem/histo/setHisto 4  50  950 1000 GeV      #energy at exit
#
/run/beamOn 10000
```





Energy deposited along step

- the physics computes a step length and a continuous energy loss along step, ΔE
- traditionally ΔE is treated as a spot at end of step
- the step length must be coherent with the desired precision to record or plot ΔE information
  - → by geometry : artificial volumes (voxels, tallies …)
  - → by step limiter : step size < histogram binning



- more natural solution : spread ΔE along step

```
point = prePoint+G4UniformRand()(postPoint–prePoint);
FillHisto (ΔE,point);
```

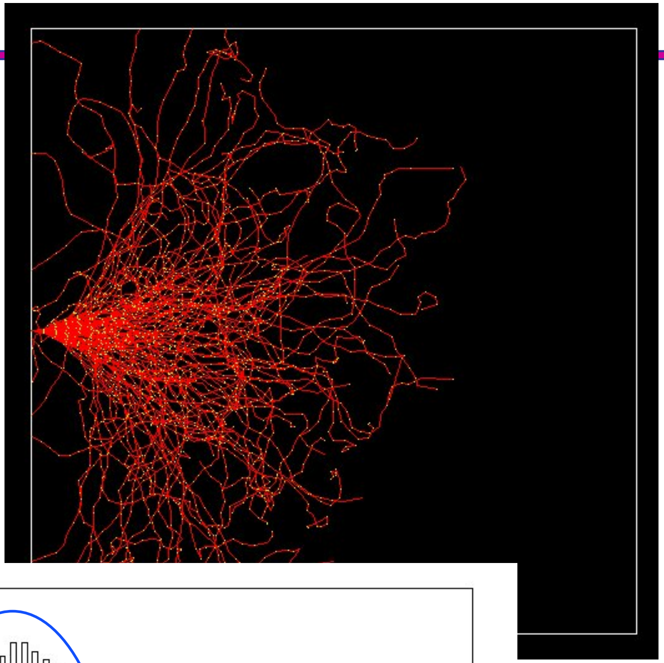
→ **user stepping action (for time being)**

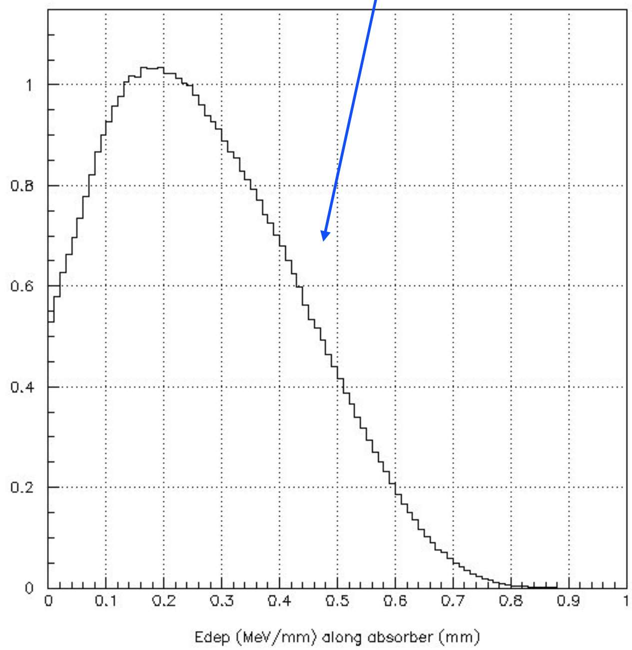
→ A variant of this idea can be found in examples/extended/medical/gammaTherapy

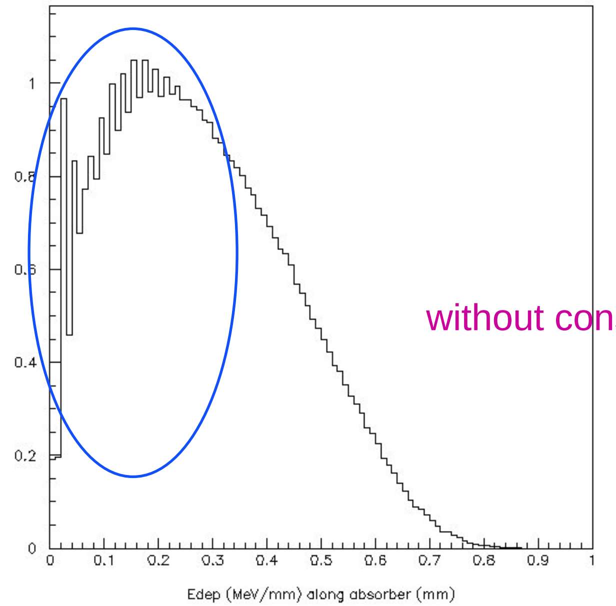
TestEm11 - 12 : depth dose distribution

```
#
/testem/det/setMat G4_Si
/testem/det/setSizeX  1 mm
/testem/det/setSizeYZ 1 mm
#
/testem/phys/addPhysics  standard       # em physics
#
/run/initialize
#
/gun/particle e-
/gun/energy 500 keV
#
/testem/histo/setHisto 1 100 0  1 mm    #edep profile
#
/run/beamOn 100000

```

bin = 10 um



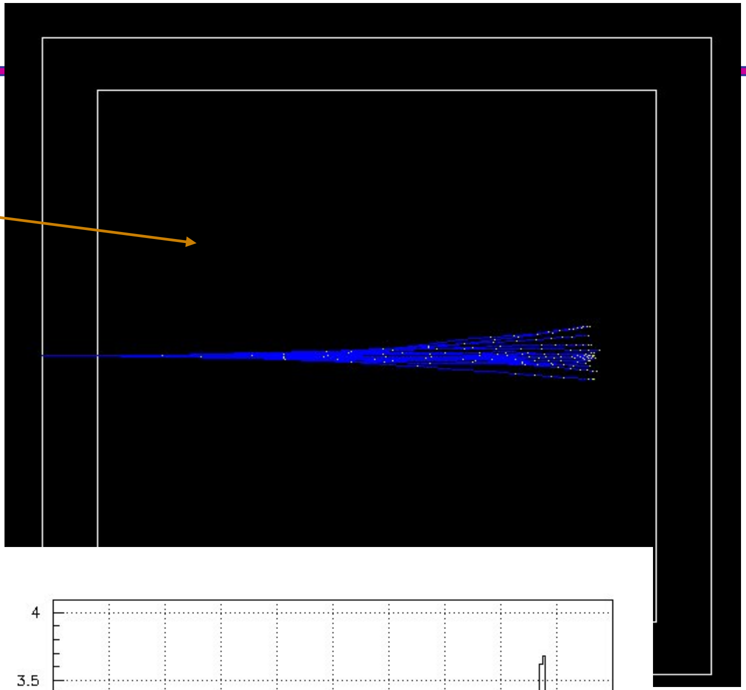


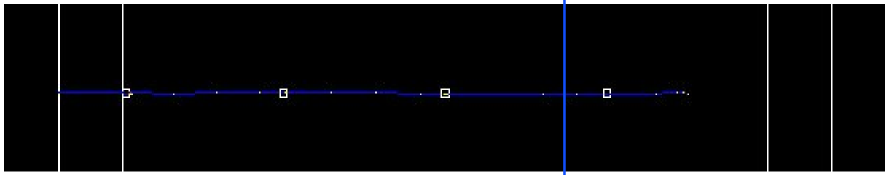


without constraint on step

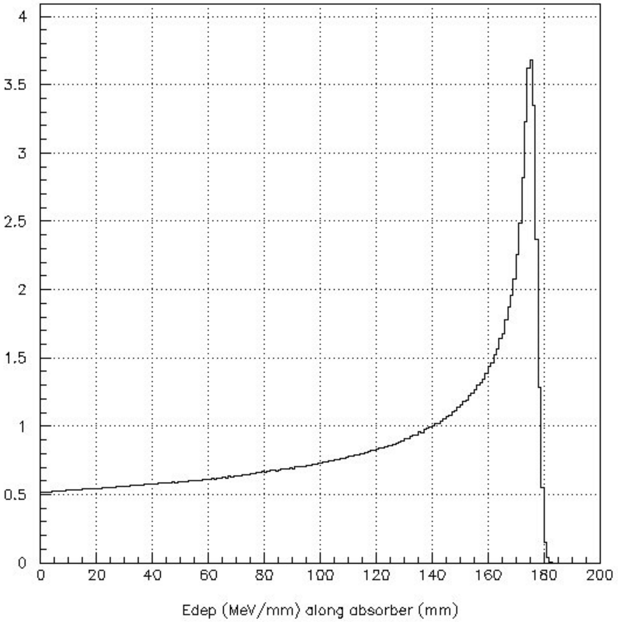
TestEm7 : Bragg curve and tallies

```
#
# Macro file for "TestEm7.cc"
# It shows how to introduce simple tallies
#
/testem/det/setMat Water
/testem/det/setSizeX  20 cm
/testem/det/setSizeYZ 20 cm
#
/testem/det/tallyMat Water
/testem/det/tallySize 2. 2. 2. mm
/testem/det/tallyPosition -9.9 0. 0. cm
/testem/det/tallyPosition -5.  0. 0. cm
/testem/det/tallyPosition  0.  0. 0. cm
/testem/det/tallyPosition  5.  0. 0. cm
#
/testem/phys/addPhysics  standard        # em physics
#
/run/initialize
#
/gun/particle proton
/gun/energy 160 MeV
#
# beam size
/testem/gun/rndm 3 mm
#
# limit the step size
/testem/stepMax 1 mm
#
/run/beamOn 10000
```





```
The run consists of 10000 proton of 160 MeV through 20 cm  of Water (density: 1 g/cm3 )

projected Range= 17.6828 cm     rms= 1.83303 mm

-------------------------------------------------------------
Cumulated Doses :        Edep            Edep/Ebeam         Dose
tally 0:                 4.56642 GeV     0.285401 %         9.14526e-05 Gy
tally 1:                 4.81323 GeV     0.300827 %         9.63956e-05 Gy
tally 2:                 2.79162 GeV     0.174476 %         5.59084e-05 Gy
tally 3:                 1.44142 GeV     0.0900885 %        2.88676e-05 Gy

-------------------------------------------------------------

 User=18.12s Real=54.15s Sys=35.19s
```



TestEm16 : synchrotron radiation

H. Burkhardt

```
#
# Macro file for "TestEm16.cc"
# (can be run in batch, without graphic)
#
#
/control/verbose 2
/run/verbose 2
/testem/det/setMat Vacuum
#
/run/initialize
#
# inactivate other processes to make Synchrotron
/process/inactivate msc
/process/inactivate eIoni
/process/inactivate eBrem
/process/inactivate phot
/process/inactivate compt
/process/inactivate conv
#
/testem/det/setField 1 tesla
/gun/particle e-
/gun/energy 9.9994890009 GeV
#
/run/beamOn 1000
```

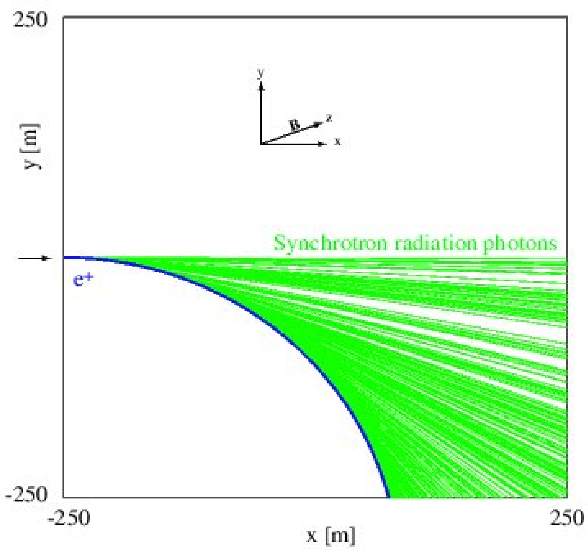


Figure 3: Geant4 display. 10 GeV e^+ moving initially in x-direction, bend downwards on a circular path by a 0.1 T magnetic field in z-direction.

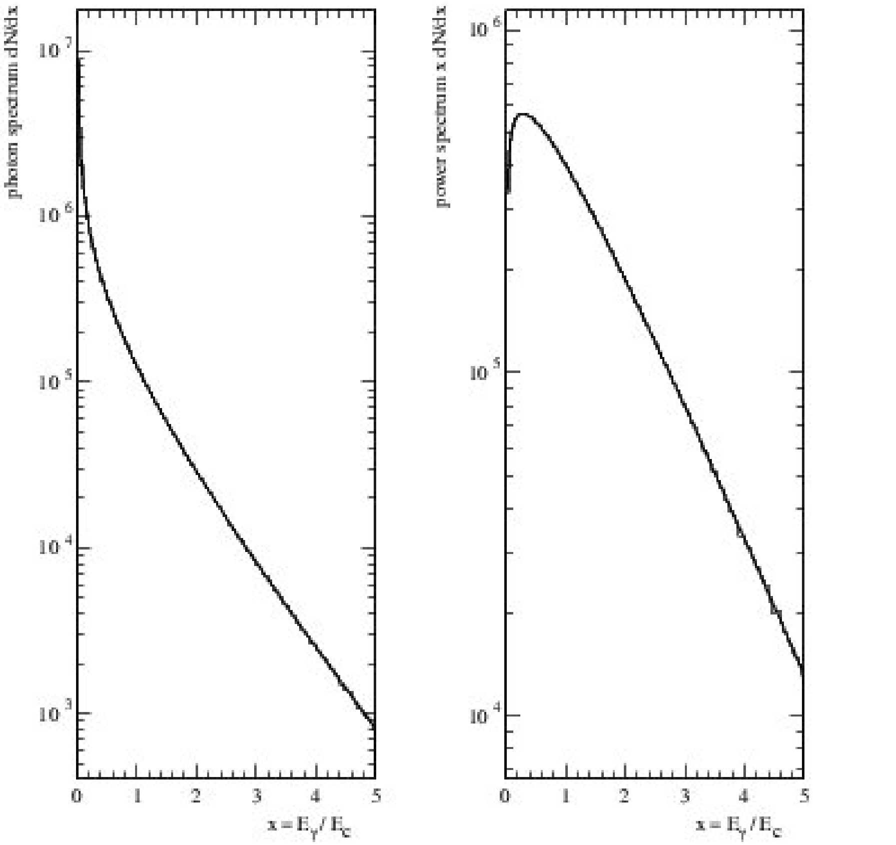


Figure 2: Comparison of the exact (smooth curve) and generated (histogram) spectra for 2×10^7 events. The photon spectrum is shown on the left and the power spectrum on the right side.

Interaction with users (1)

Base: Electromagnetic Processes

Keywords: backscattering, electron, energy dependence, GEANT4.7.0.p1.

Date: Wed, 12 Jul 2006 16:51:47 GMT

From: Ilya <ilya.kraev@fys.kuleuven.ac.be>

Dear all,

I'm trying to simulate backscattering of electrons on silicon and have some difficulties in reproducing the total backscattering probability coefficient as function of energy. The problem is that the coefficient that comes out from the simulation almost does not depend on the energy of incident electron. The energy of interest is in the range 100-800 keV. At the same time reference data obtained with semiempirical equation show that it should decrease by a factor of 1.4-1.5 for the energy increasing from 100 to 800 keV for normal incidence!!! (k_backscat(100 keV) = 13.8%, k_backscat(800 keV) = 9.9%). Angular dependence is more or less reproduced although for the higher incident angles (i.e. more "sliding") the backscattering coefficient is higher than the calculated one and fully looses energy dependence.

I already posted similar question about 1 year ago. The suggestion was to try to tune the facrange parameter i.e. to decrease it below ~0.01 (I'm using now GEANT4.7.0.p1 where the default value is 0.2). And also to play with a cut for secondaries value. I tried to use both STANDARD and LOW-ENERGY e/m physics lists but both of them do not reproduce the energy dependence of the backscattering probability coefficient. I varied facrange from 0.2 down to 0.0001 and cut for secondaries from 10 mum to 1 mum. It did not help too.

Can anybody suggest what else can solve the problem of the energy dependence of the backscattering coefficient??? Are there other parameters to be tuned? What precision can I expect from GEANT in such case? This is very imprtant issue for the physics we are doing and we really need to get a good grip on the backscattering of electrons.

Any help is welcome. If it's necessary I can provide the reference data that I'm using for the comparison of my results.

Best regards, Ilya.

Interaction with users (2)

Base: Electromagnetic Processes

Re: Re: simulation of bacscattering of e-'s on Silicon (Laszlo Urban)
Keywords: backscattering, electron, energy dependence, GEANT4.7.0.p1.
Date: Sat, 15 Jul 2006 10:23:29 GMT
From: michel maire <michel.maire@lapp.in2p3.fr>

User Laszlo Urban wrote:

```
>>   You have to use the latest GEANT4 version, GEANT4 8.1.Using TestEm5 I
>>  have got backscattering coefficients 13.1 % at 100 keV and 10.3 % at 800 keV. In the simulation
>>   I would not say that version 8.1 is perfect, but it is far better than the earlier versions...
>>
>>    best regards  Laszlo
>>

 It is even not necessary to play with cut. I ran Geant4 8.1 with default
 tracking parameters (see macro below).
 I got 13.78% and 10.14%, respectively.

       Michel

 # $Id: kraev.mac,v 1.1 2006/05/30 12:28:57 maire Exp $
 #
 # macro file for TestEm5.cc
 #
 # Back scattering of  100-800 keV electrons in Silicon.
 #
 #
 /control/verbose 2
 /run/verbose 2
 #
 /testem/det/setAbsMat Silicon
 /testem/det/setAbsThick 5 mm
 /testem/det/setAbsYZ    5 mm
 #
 /run/initialize
 #
 /testem/gun/setDefault
 /gun/particle e-
 /gun/energy 100 keV
 #
 /testem/histo/setFileName kraev
 /testem/histo/setFileType hbook
 /testem/histo/setHisto 11  100 0. 100. keV     #energy reflected_charged
 #
 /run/beamOn 100000
```

Interaction with users (3)

Base: Run Management
Keywords: random status
Date: Fri, 26 May 2006 20:37:00 GMT
From: Ioannis Sechopoulos <ioannis.sechopoulos@bme.gatech.edu>

I noticed that if you reset the random engine from a previously saved currentEvent.rndm using the above command, the next event will be the same than the last one that saved the currentEvent.rndm file, BUT after that, the following events are not the same. Specifically: I inserted a few HepRandom::showEngineStatus(); in different places (BeginOfRunAction, EndOfRunAction, BeginOfEventAction, EndOfEventAction, GeneratePrimaries) and then I turned on /random/setSavingFlag and performed a 10-event long run.

Then I exit and re-started the program, turned on /random/setSavingFlag again and performed a 4-event run. All the random engine status are equal with the previous run, as expected.

Then, I exit and re-start the program a third time, I use /random/resetEngineFrom currentEvent.rndm and perform /run/beamOn 6. As expected, the engine status outputs for the first event are equal to the last one of the previous run and the fourth of the first run, but the engine sta
after that (for the other 5 ev
event will be replicated?

I am trying to simulate the
seems that I won't get the s

Base: Run Management
Re: Problem with /random/resetEngineFrom ? (Ioannis Sechopoulos)
Keywords: random status
Date: Mon, 12 Jun 2006 17:53:14 GMT
From: michel maire <michel.maire@lapp.in2p3.fr>

```
I started with examples/extended/electromagnetic/TestEm4, because the
example and the output are simple, and the rndm saving and printing
is done by default.

I did 2 jobs : - 1 run of 10000 events
               - 2 runs : 4000 and 6001 events.

The rndm at the end of the 2 jobs is the same.

I attach the macros and the relevant part of the output.
-----------------------------------------------------------------------
```

Concluding comments

- The TestEm suite consists of 17 generic examples
  - →more than 100 macros covering various situations
- A subset of macros is part of the regular G4 system test
- Em physics lists : standard, penelope, livermore
- Many examples have a Geant3 equivalent
- Today, the suite covers almost all our basic needs; but it remains in continuous evolution
- Automatic running and book keeping must be developed