

# Choosing a Physics List

8<sup>th</sup> International Geant4 Tutorial in Korea

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# Outline

- Review
  - Physics lists, reference physics lists, naming convention
- Some application-based recommendations
- Using validation to choose your physics list
  - Example

# Physics List

- An object responsible for:
  - specifying all particles to be used in a simulation application
  - specifying physics processes and assigning them to each particle type
- One of three mandatory objects that the user must provide to the **G4RunManager** in any application
  - tells run manager what physics needs to be invoked and when
- Provides a very flexible way to set up the physics environment
  - user can choose and specify particles he wants
  - user can choose the physics (processes) to assign to each particle
- BUT, user must have a good understanding of the physics required to describe the problem
  - omission of relevant particles and/or physics interactions could lead to poor modeling results

# Reference Physics Lists

- Also called “Production Physics Lists”
  - used by larger groups like ATLAS, CMS, etc.
  - well-maintained and tested
  - very stable: not often changed and usually updated only for bug fixes
  - extensively validated inside and outside of Geant4
  - FTFP\_BERT, QGSP\_BERT, QGSP\_FTFP\_BERT\_EMV, FTFP\_BERT\_HP, QGSP\_BIC\_EMY, QGSP\_BIC\_HP, QBBC, Shielding
- Caveats:
  - these are provided as a “best guess” of the physics needed in certain use cases
  - intended as templates or starting points
  - if you decide to use them, you are responsible for validating them for your application
  - this may mean adding or removing physics or changing settings

# Reference Physics List Naming Convention

- **Hadronic options**
  - “QGS” Quark Gluon String model (>~ 15 GeV)
  - “FTF” FRITIOF String Model (>~ 5 GeV)
  - “BIC” Binary Cascade model (<~ 10 GeV)
  - “BERT” Bertini Cascade model (<~ 15 GeV)
  - “P” G4Precompound model used for de-excitation
  - “HP” High precision particle (neutrons and some charged particles (<~ 20 MeV))
- **Electromagnetic options**
  - no suffix: standard EM (default G4EmStandardPhysics constructor)
  - “EMV” G4EmStandardPhysics\_option1 (fast, less precise)
  - “EMY” G4EmStandardPhysics\_option3 (precise, used for medical and space)
  - “EMZ” G4EmStandardPhysics\_option4 (most precise, slower)
- **Name decoding: String\_Cascade\_Neutron\_EM**
- **Complete list of pre-packaged physics lists (with detailed descriptions) at**
  - <http://geant4-userdoc.web.cern.ch/geant4-userdoc/UsersGuides/PhysicsListGuide/html/index.html>

# Recommended Physics Lists for Some Applications

- **FTFP\_BERT**

- recommended for HEP applications
- FRITIOF string + Precompound deexcitation + Bertini cascade + standard EM
- can add \_HP if neutron flux is important

- **Shielding**

- for shielding and space applications
- very similar to FTFP\_BERT\_HP, but with better ion-ion interactions

- **QGSP\_BIC\_HP**

- recommended for medical applications
- Quark Gluon String + FRITIOF + Precompound + Binary cascade + high precision neutron + standard EM
- can add best precision EM by appending “EMZ”

# Changing the EM Physics in a Reference Physics List

- QGSP\_BIC\_HP\_EMZ

- QGSP\_BIC\_HP is a reference physics list with standard EM
- you can change this by using the G4PhysListFactory
  - knows all available reference physics lists and makes EM substitutions easy

```
212 // IM YOUR MAIN APPLICATION
213 //
214 // create your run manager
215 #ifdef G4MULTITHREADED
216   G4MTRunManager* runManager = new G4MTRunManager;
217   // number of threads can be defined via macro command
218   runManager->SetNumberOfThreads(4);
219 #else
220   G4RunManager* runManager = new G4RunManager;
221 #endif
222 //
223 // create a physics list factory object that knows
224 // everything about the available reference physics lists
225 // and can replace their default EM option
226 G4PhysListFactory physListFactory;
227 // obtain the QGSP_BIC_HP_EMZ reference physics lists
228 // which is the QGSP_BIC_HP reference list with opt4 EM
229 const G4String pName = "QGSP_BIC_HP_EMZ";
230 G4VModularPhysicsList* pList = physListFactory.GetReferencePhysList(pName);
231 // (check that pList is not nullptr, that I skip now)
232 // register your physics list in the run manager
233 runManager->SetUserInitialization(pList);
234 // register further mandatory objects i.e. Detector and Primary-generator
235 ...
```

# Choosing Your Physics List

- Ideally, user has a good understanding of the physics relevant to a given application
  - user can then build his own or decide on a pre-built one
  - in either case the physics list must be validated for the application
  - during the validation, some changes to the physics list may be required
- If your application fits within a well-defined area (e.g. medical)
  - user may choose a physics list used in that area as a starting point
- Procedure that always works, but is time-consuming
  - start with most accurate physics (e.g. EMZ for EM)
  - run the simulation with lower statistics to obtain the most accurate result
  - if desired, choose a less accurate, but faster, physics list and run some more simulation statistics
  - modify in a granular way the first physics list using the most accurate results as a guide

# Choosing Your Physics List

- Look at the advanced examples
  - many have physics lists custom-designed for a particular application area
  - if you are working in that area, try that list
    - space telescope
    - microelectronics
    - radioprotection
    - composite calorimeter
    - .....
- Look at the extended examples (optical, medical, EM, etc.)
  - examples/extended/electromagnetic – several different physics lists for testing specific EM processes
  - examples/extended/physicslists – how to use PhysicsListFactory

# Validation

- Physics list must always be chosen based on how well its components perform in your specific case
  - always balance physics accuracy with CPU performance
- Geant4 provides validation (comparison to data) for most of its physics codes
  - validation is a continuing task
  - performed at least with each release
  - more validations added with time
- Access these comparisons at the Geant4 website:
  - <https://geant4.web.cern.ch>
  - Click: **Validation of Geant4**
  - Choose **Validation and Testing** from the menu
  - today we'll look at the **Geant4 GRID-based testing results portal**



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Geant4

## Publications

Submitted by Anonymous (not verified) on Wed, 06/28/2017 - 11:23

### Geant4 main references for publications

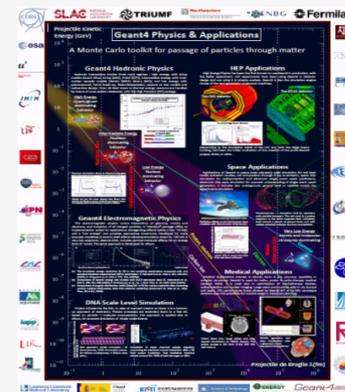
- [Recent Developments in Geant4](#) ,  
J. Allison et al., Nucl. Instrum. Meth. A 835 (2016) 186-225
- [Geant4 Developments and Applications](#) ,  
J. Allison et al., IEEE Trans. Nucl. Sci. 53 (2006) 270-278
- [Geant4 - A Simulation Toolkit](#) ,  
S. Agostinelli et al., Nucl. Instrum. Meth. A 506 (2003) 250-303

### Geant4 related publications

- [Geant4-DNA example applications for track structure simulations in liquid water: a report from the Geant4-DNA Project](#) ,  
S. Incerti et al., Med. Phys. 45 (2018) e722-e739
- [Electron backscattering simulation in Geant4](#) ,  
P. Dondero et al., Nucl. Instrum. Meth. B 425 (2018) 18-25
- [Eta and omega mesons as new degrees of freedom in the intranuclear cascade model INCL](#) 

### Related Links

- [Publications](#)
- [Reports and Presentations](#)
- [Validation and Testing](#)
- [Results from Experiments](#) 



## Testing And Validation

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This webpage is under redesign. Please, be patient.

### Physics Validation

This collection of links and resources covers the aspects of general interest for Geant4 physics validation.

The activities of this area are coordinated by the Physics Validation Task Force in the [Testing and Quality Assurance Working Group](#).

### Results and documents

- Geant4 Validation data-base: [geant-val](#) 
- FNAL Validation Data-Base: [DOSSIER](#) 
- GRID Testing: [Geant4 GRID-based testing results portal](#) 
- Electromagnetic physics. Results, publications, validation; HEP journals publications ; HEP conference proceedings ; HEP presentations
- [Electromagnetic Validation repository](#)
- [Hadronic Validation Web Pages](#)
- HEP experiments related notes [documents and notes](#)  (in collaboration with [LCG Physics Validation Project](#) )

### Technical documentation and resources

- [The Geant4 testing system](#) 
- [Validation Framework Design Proposal](#) 
- [LCG Physics Validation Project](#)  (focus on LHC experiments)
- The task force [twiki](#)  contains more information

# Geant Validation Portal

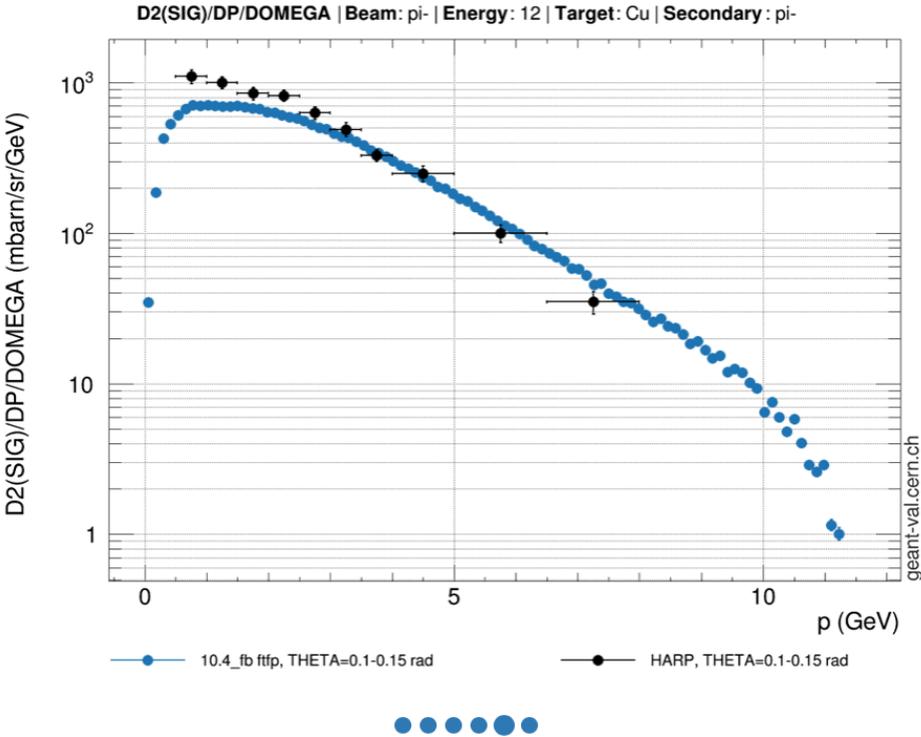
User layouts

**Stat comparison**

Record viewer

Reference data

Lookup tables



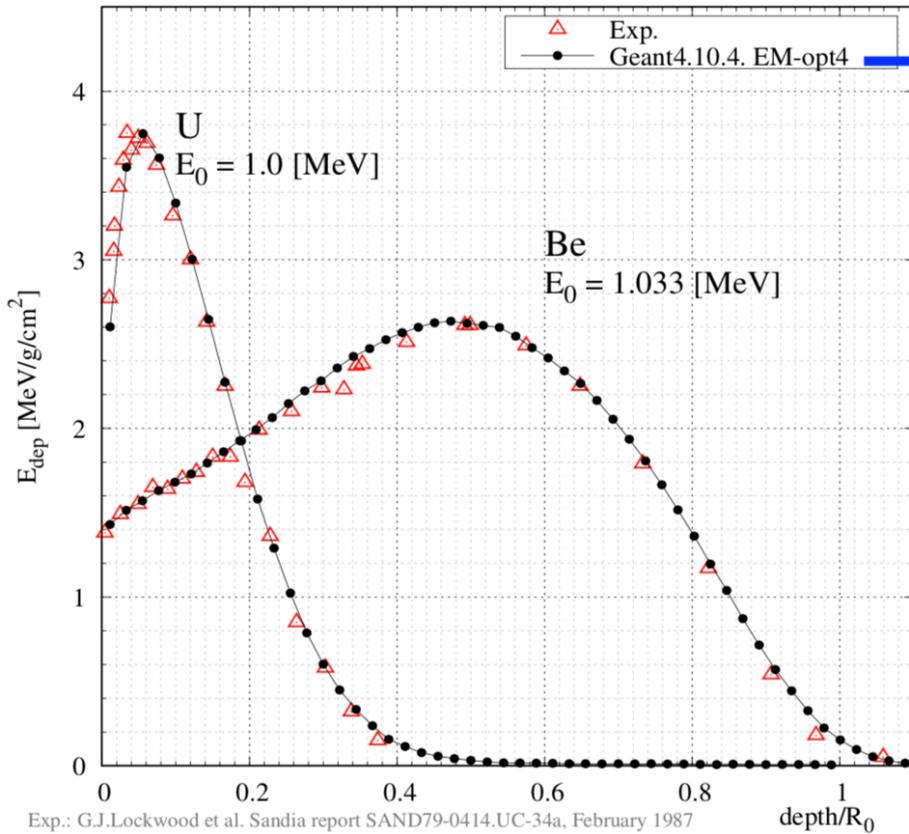
# Stat comparison

Test name	Project	Author	Description
<a href="#">BraggPeakGSI_MT</a>	GEANT4		
<a href="#">Bremsstrahlung</a>	GEANT4	B. Faddegon	Bremsstrahlung yield
<a href="#">CCCStest</a>	GEANT4	Chihiro Omachi	
<a href="#">ElecBackScat</a>	GEANT4		
<a href="#">ElectronScattering</a>	GEANT4	B. Faddegon	Electron scattering from foils at 13-20 MeV kinetic energies
<a href="#">FluctTest</a>	GEANT4	Vladimir Ivanchenko	Example for investigation of G4 fluctuation models is on the base of TestEm8 (ionisation in thin absorbers and gaseous detectors). Simulation data are ... <a href="#">Show more</a>
<a href="#">FragTest</a>	GEANT4	Susanna Guatelli, David Bolst	Validation of Geant4 fragmentation for Heavy Ion Therapy
<a href="#">LowEFrag</a>	GEANT4		
<a href="#">MscHanson</a>	GEANT4	Vladimir Ivanchenko	The tests simulates multiple scattering distributions of 15.7 MeV electrons transmitted through thin foils of the indicated materials.
<a href="#">NeutronYield</a>	GEANT4		

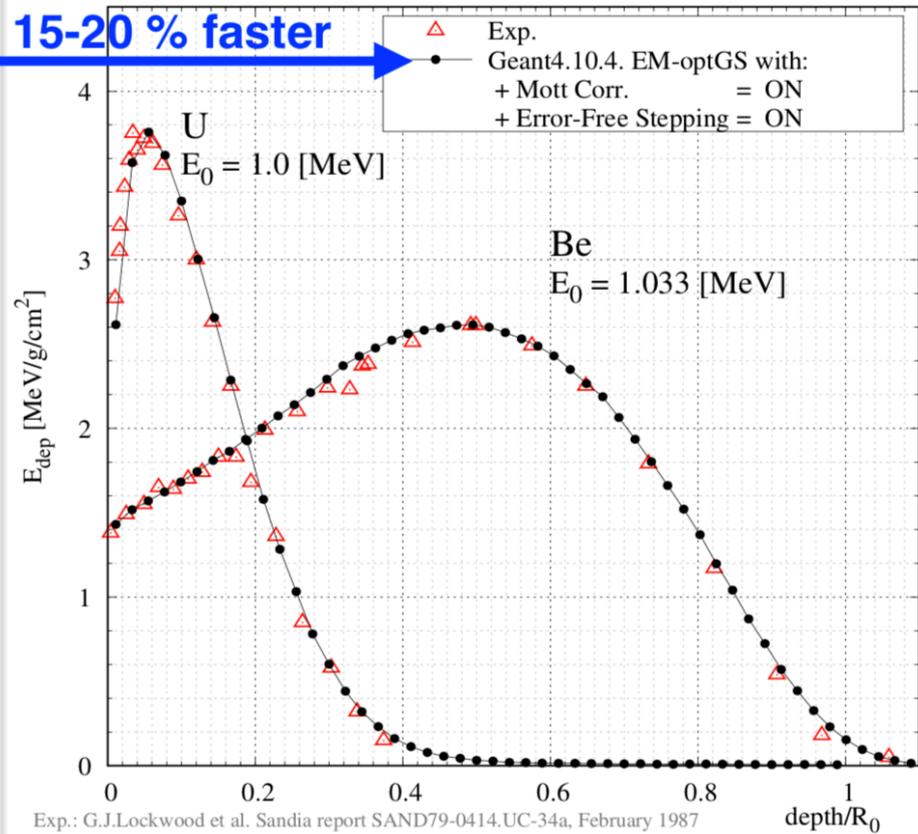
# Validation Example

- Simulating (EM) depth dose profile
  - energy deposit by energetic electrons as a function of penetration depth in both lighter and heavier materials
  - use Geant4 validation results from the Geant4 GRID-based testing results portal, especially test37, to choose an initial physics list
  - then adjust initial reference physics list to achieve maximum physics performance while improving computational efficiency
  - submit test

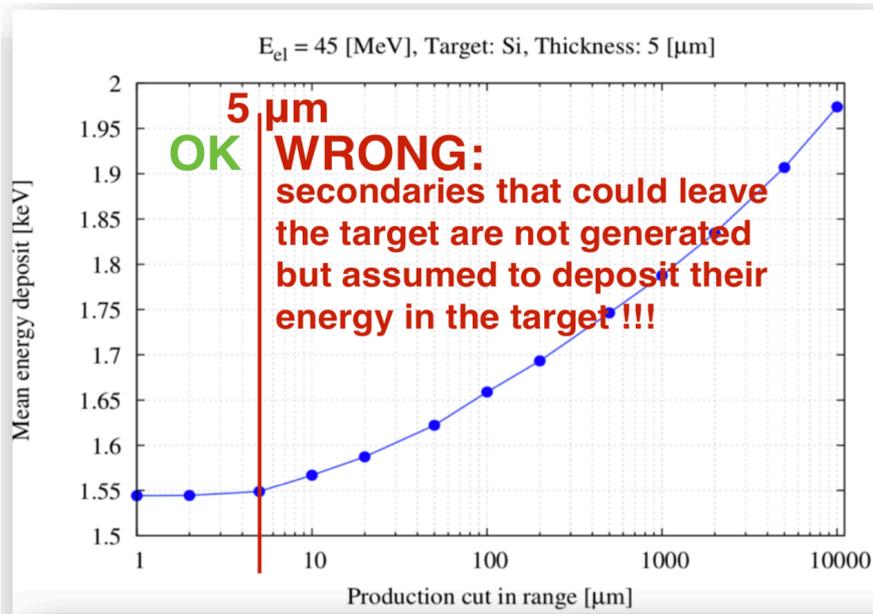
# Validation Example



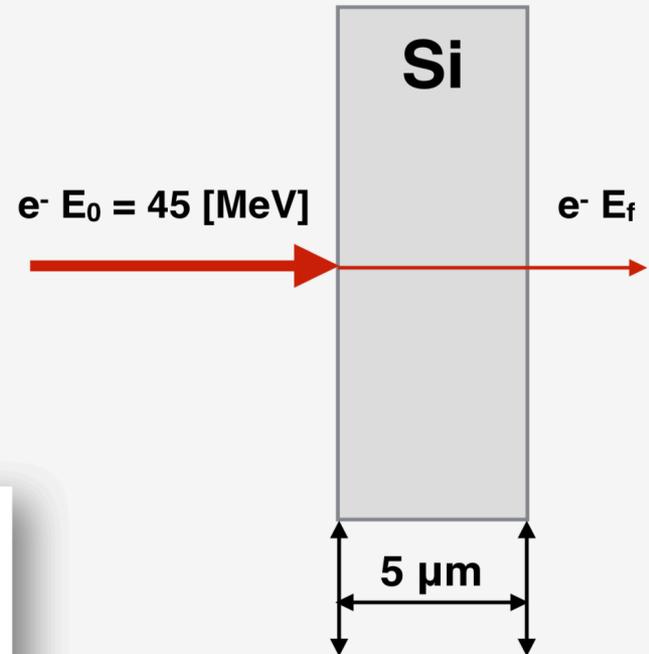
~ 15-20 % faster



# And Always Check the Production Threshold



Compute the mean of the energy deposit ( $E_f - E_0$ ) in the target



cut [ $\mu\text{m}$ ]	mean $E_{\text{dep}}$	rms $E_{\text{dep}}$	prod. thres. [keV]		mean num. sec.	
			$\gamma$	$e^-$	$\gamma$	$e^-$
1	1.54423	0.000573911	0.99	0.99	0.0006811	0.1018230
2	1.54443	0.000583879	0.99	2.9547	0.0006843	0.0316897
5	1.54882	0.000605834	0.99	13.1884	0.0006857	0.0068261
10	1.56717	0.000665733	0.99	31.9516	0.0006730	0.0028232
20	1.58734	0.000743473	1.08038	47.8191	0.0006651	0.0018811
50	1.62223	0.000912408	1.67216	80.7687	0.0006557	0.0011304
100	1.65893	0.001108240	2.32425	121.694	0.0006518	0.0007536
200	1.69338	0.001342180	3.2198	187.091	0.0006465	0.000477
500	1.74642	0.001774670	5.00023	337.972	0.0006184	0.0002617
1000	1.78751	0.002219870	6.95018	548.291	0.0006054	0.0001622
2000	1.83440	0.002861020	9.66055	926.09	0.0005786	9.3e-05
5000	1.90700	0.004243030	14.9521	2074.3	0.0005427	4.07e-05
10000	1.97378	0.006036600	20.6438	4007.59	0.000521	2.22e-05