

Physics Lists

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Gunter Folger

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Introduction

Physics List is a set of consistent physics models for each particle in application

- *Users need guidance or help*
- *Geant4 offers starting points*
- *Responsibility of application developer*
 - *To choose and, if needed, further develop*
 - *To validate for his use case*

Physics modeling choices

- *For EM physics, default set exists for standard EM*
 - *Low energy extensions*
- *Hadronic models only valid for specific energy range and specific particles*
 - *High energy: string models vs. parameterized*
 - *Medium/low energy: parameterized, cascade model, precompound model, data driven neutron transport model*
 - *Stopping particles: CHIPS, parameterized,*
 - *Elastic scattering*
- *Hadronic cross-sections*
- *Optical photons*
- *Neutrino physics*
- *...*

Why choice of models

- *Nature is exact and fast*
- *Simulation is attempt to approximate nature*
 - *Geant4 offers choice in level of approximation versus CPU performance (e.g. options for multiple scattering)*
- *Not all physics is relevant in given simulation (e.g. neutrino physics)*

Supported lists

- *Geant4 provides physics lists with source code*
 - *Reference Physics lists*
 - *Previously called ‘Educated Guess Physics Lists’*
 - *Examples*
 - *Advanced examples*
 - *Novice and extended examples*
- *Physics lists for specific communities, supported by SLAC*
 - http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/G4_Physics_Lists.html

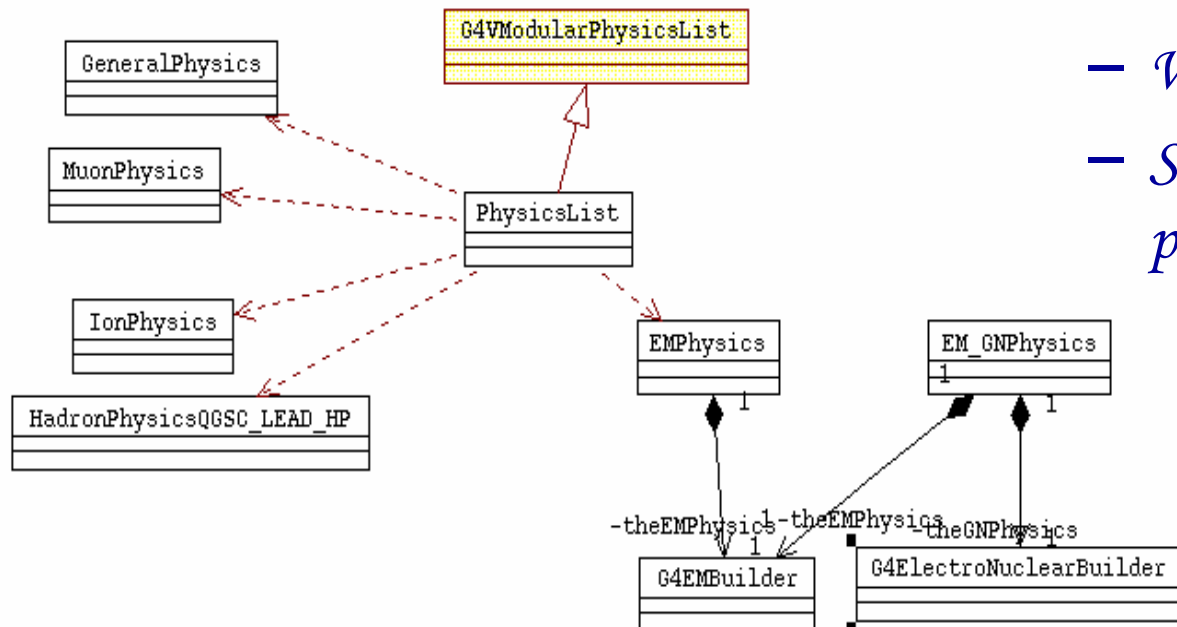
Reference Physics Lists

- *Wide choice of physics lists offered*
 - *more than 20 lists*
- *Cover wide range of use cases*
- *All lists cover all primary and secondary particles up to high energies ($> \text{TeV}$)*

Origin & Design

- *'Reference Physics lists'*
 - created starting 2002 by HP Wellisch as 'Educated Guess Physics Lists'

- *Problem domain oriented*
 - Covering 14 fields from HEP calorimetry to medical to low background experiments
 - Offering 21 physics lists
 - Web based guidance
 - Structured, re-use of common parts



Groups of lists – hadronic options

- *LHEP using parameterized models*
- *QGS/FTF series replaces parameterized high energy model*
 - *theory driven string model used for pion, protons, neutrons, Kaons*
 - *Improved cross-sections*
 - *Better description for stopping particles using CHIPS modeling*
 - *Revised elastic scattering*
- *Variations for modeling at medium and low energies (e.g. QGSP_BIC)*
 - *Cascade model, precompound model, CHIPS, low energy neutron transport*

Examples

- *LHEP:*
 - *fast, for shower simulation in calorimeter*
- *QGSP_BERT_HP*
 - *Radiation background studies – good modeling for neutron production and transport*
- *QGSC*
 - *Like QGSP with improved nuclear fragmentation*
- *FTFP*
 - *Alternative string model, under revision*
- *QGSP_EMV, LHEP_EMV*
 - *Providing faster multiple scattering similar to 7.1*

Improvements in Reference PL

- *Evolution of physics modeling*
 - *New developments offered in experimental lists first*
 - *Adopt mature improvements*
- *Change key options*

How to use

...

```
#include "QGSP.hh"
```

```
G4RunManager* runManager = new G4RunManager;  
runManager->SetUserInitialization( new myDetector );
```

```
QGSP * thePL = new QGSP;
```

```
//thePL->SetDefaultCutValue( 1.0*mm );
```

```
runManager->SetUserInitialization( thePL );
```

Advanced Examples: Physics Lists

- 17 (+4) *advanced examples*,
- *Targeted for specific use case*,
 - *Quantitative validation for this use case, seven of these published*
 - *Space applications*
 - *Medical*
 - *Underground experiments, low background physics*
- *Selection of Physics model adapted to use case*
 - *Several examples have lists with EM only, and/or using*
 - *low energy extension for EM*
 - *Optical photons, Scintillation, Cherenkov radiation*
 - *Restricted set of hadronic physics (particles, energy)*

Summary

- *Reference Physics lists*
 - *Improved or new models always made available*
 - *Gamma Nuclear is included by default*
 - *Improved elastic scattering*
 - *Revised stopping physics now using CHIPS model*
 - *Following evolution and improvements of Geant4*
- *Advanced Examples physics list*
 - *Targeted to specific problems, often with validation*

Backup slides.....

New developments

- *Alternative EM physics options*
 - *Default uses option for best physics in multiple scattering*
 - *_EMV variants providing multiple scattering similar to 7.1*
 - *_EMX variants offer new developments (eXperimental) from EM*
- *GN used by default (8.0)*
- *Improved elastic scattering (8.1 & 8.2)*
- *Improved processes for capture at rest (8.1)*
 - *All lists based on QGS and FTF*
- *QGSC_EFLOW using energy flow nuclear fragmentation(8.2)*
- *Quasi-elastic scattering added to lists based string models (new)*

Plans

- *Improve Documentation*
- *Continue to provide new model developments*
 - *E.g. add quasi-elastic channel for string models*
- *Introduce new options as new (experimental) physics lists*
- *Adopt mature options*

Physics list moved to G4 source

- *Integrate physics lists into Geant4 source code and build system, removes difficulties in using physics lists (8.2):*
 - *Avoid extra step to build physics list*
 - *Consistent environment, lists build by default*
 - *Simplified structure → only two libraries*
 - *One for 'lists', one for 'builders'*
 - *Libraries fully integrated with Geant4*
 - *No more problem to use granular/shared libraries*
 - *No need to misuse EXTRALIBS variable*

Cleanup: regrouping physics

Before 8.0

- *EMPhysics*
 - *Optionally including gamma-nuclear*
- *GeneralPhysics*
 - *Decay unstable particles*
- *MuonPhysics*
 - *EM physics for muons and tau*
 - *Capture at rest for mu-*
- *IonPhysics*
 - *Ionisation, Mult. Scattering, elastic for D, T, He and generic Ion*
 - *No inelastic hadronic process*
- *HadronPhysics..xyz*
 - *Hadron Inelastic*

Since 8.0

- *G4EmStandardPhysics*
 - *Standard EM physics list for all particles*
 - *Removes TMP file*
- *G4EmExtraPhysics*
 - *Synchrotron Radiation & GN Physics*
- *G4DecayPhysics*
- *G4Hadron(Q)ElasticPhysics*
 - *Hadron Elastic scattering*
- *G4(Q)StoppingPhysics*
 - *Stopping Physics from LHEP or CHIPS*
- *G4IonPhysics*
 - *Hadron Inelastic for d, t, α*
- *HadronPhysics..xyz*
 - *Hadron Inelastic*

Updates in 8.0

- *Use EM builder from EM standard*
 - *Removed template meta programming based class plist.tmp*
- *Gamma Nuclear physics enabled by default*
 - *Remove obsolete lists with gamma nuclear*
- *Added physics lists with 7.1 multiple scattering*
 - *QSQP_EMV and LHEP_EMV*
- *Added list for radiation studies*
 - *QGSP_BERT_HP*
- *Revision of particles*

Updates in 8.1

- *Added list with more performant em options QGSP_EMX*
- *Introduce Chips modeling for stopping particles in all physics lists based on QGS and FTF.*
 - *Replaces capture processes for μ^- , π^- , and K^-*
 - *Replaces annihilation at rest for anti-proton and anti-neutron*
- *Updated elastic scattering in all physics lists based on QGS and FTF using improved multiple scattering*
- *Use Bertini for Kaons in BERT lists*
- *Use Binary for ions in BIC lists*
- *New experimental physics list QBBC, minimizing use of LHEP models*

Updates in 8.2

- *Integrate physics lists into Geant4 source code and build system*
- *Neutron tracking cut*
- *New lists*
 - *QGSC_EFLOW using new CHIPS energy flow*
 - *QGSC_EMV*
 - *QGSP_BIC_HP*
 - *QGSP_QEL variant using CHIPS systematics for elastic scattering*
- *Declare several lists obsolete*
 - *LHEP: _HP, _BIC, _BIC_HP, _PRECO, and QGSP_HP*

Physics Lists supported by SLAC

- *Four lists supported for specific communities*
 - *BaBar, medium energy vertex/tracker/ calorimeter for B physics*
 - *GLAST, medium energy tracker/calorimeter for space applications*
 - *ILC, high energy tracker/calorimeter for colliders(ILC)*
 - *Space Electronics Physics List*
- *Simple and Fast Physics List – for getting started*
- *Distributed and documented via web page*
 - http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/G4_Physics_Lists.html
- *No code re-use between different lists*

Inventory of Reference PL

- *LHEP*
- *LHEP_EMV*
- *LHEP_BERT*
- *LHEP_BERT_HP*
- *LHEP_BIC_HP*
- *LHEP_BIC*
- *LHEP_HP*
- *LHEP_LEAD_HP*
- *LHEP_LEAD*
- *LHEP_PRECO_HP*
- *LHEP_PRECO*
- *LBE*
- *FTFP*
- *FTFC*
- *QGSP*
- *QGSP_EMV*
- *QGSP_EMX*
- *QGSP_BERT*
- *QGSP_BERT_HP*
- *QGSP_BIC*
- *QGSP_BIC_HP*
- *QGSC*
- *QGSC_EFLOW*
- *QGSC_EMV*
- *QGSP_QEL*
- *QGSC_LEAD_HP*
- *QGSC_LEAD*
- *QGSP_HP*
- *QBBC*