Physics Lists

Gunter Folger

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Introduction

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

- Physics List is responsibility of user
- Users need guidance or help
- Geant4 provided physics lists offer starting points
- Responsibility of application developer
  - To choose and, if needed, further develop
  - To validate for his use case

Physics Lists: Why in G4 space

- Share code
  - Name and version number uniquely defines configuration used
- Share experience and improvements
  - Possible across different use cases
- Enable sharing of validation
  - E.g. HEP/LHC experiments
  - But more effort needed in other areas

Constructing a list

- Collaboration between user group and Geant4
- User input
  - Identify requirements
  - Provide feedback on quality of simulation
  - Evaluate possible alternative options
- Geant4 developers provide experience/knowledge
  - Physics performance of specific processes/models
  - Evolution of physics modeling and cross sections
  - Available new options

Physics modeling choices

- EM physics processes: default well documented 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 separate from model
- Optical photons
- Neutrino physics
- …

Why choice of physics 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. low energy neutrrons)

Supported lists

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

Novice & extended examples

- Novice
  - N04: usage of reference physics list
  - N05: demonstrates fast parameterization
  - N06: using optical photons
- Extended
  - Electromagnetic
  - Polarization
  - Radiative decay
  - Exotic physics

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)

Reference Physics Lists

- Evolution of 'Educated Guess 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 (>TeV)

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
  - Paratmeterized modeling for all hadronic interactions
  - Standard EM physics
- QGSP
  - QGS for high energy interaction, using Precompound for nuclear de-excitation
  - LEP for low energy (< 12-25 GeV)
  - LHEP models for particles other than proton, neutron, pion, Kaon
  - Elastic scattering was changing
  - Standard EM physics
- QGSP_BERT_HP
  - Radiation background studies – good modeling for neutron production and transport
  - Usage of LEP reduced by BERT for nucleons, pions, Kaons below 10 GeV
  - Add HP neutron transport for neutrons < 20MeV
- QGSC
  - Like QGSP with improved nuclear fragmentation provided by CHIPS
- FTFP
  - Alternative string model, under revision
- QGSP_EMV, LHEP_EMV
  - Alternate EM physics, using faster multiple scattering similar to 7.1

Inventory of Reference PL (G4 8.3)

- LHEP
- LHEP_EMV
- LHEP_BERT
- LHEP_BERT_HP
- *LHEP_BIC*
- *LHEP_BIC_HP*
- *LHEP_PRECO*
- LHEP_PRECO_HP
- *LHEP_HP*
- *LHEP_LEAD*
- *LHEP_LEAD_HP*

- QGSP
- QGSP_EMV
- QGSP_EMX
- QGSP_NQE
- QGSP_EMV_NQE
- QGSP_BERT
- QGSP_BERT_EMV
- QGSP_BERT_HP
- QGSP_BERT_NQE
- QGSP_BERT_TRV
- QGSP_BIC
- QGSP_BIC_HP
- *QGSP_HP*
- QGSP_QEL
-

- QGSC
- QGSC_EMV
- QGSC_EFLOW
- *QGSC_LEAD*
- *QGSC_LEAD_HP*

- LBE

- FTFC
- FTFP_EMV
- FTFP

- QBBC

Lists in italic deleted in 9.0

Improvements in Reference PL

- Evolution of physics modeling
  - New developments offered in experimental lists first
  - Adopt mature improvements
- Change key options
- Solve configuration problem
  - Move physics lists into Geant4 source and build system
  - Integrates physics lists with Geant4
- Obsolete and delete superfluous lists, or where better options exist
- Code cleanup and code migrations

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 CHIPS based 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 provided by CHIPS added to lists based string models (8.3)
  - New lists QGSP_NQE, QGSP_EMV_NQE, and QGSP_BERT_NQE without quasi-elastic for short term backward compatibility

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

Obsolete and removed Lists

- Starting with 8.2, declare several lists obsolete
- In 9.0, deleted the following:
  - All 4 lists using Mars leading particle bias …_LEAD
    - Due to removal of Mars code itsself
  - LHEP_BIC and LHEP_BIC_HP
    - use QGSP_BIC or QGSP_BIC_HP
  - LHEP_HP and QGSP_HP
    - use QGSP_BERT_HP or QGSP_BIC_HP
  - LHEP_PRECO
    - use QGSP_BIC

Plans

- **Improve Documentation**
  - draft pages available at
    http://cern.ch/geant4/support/proc_mod_catalog/physics_lists/physicsLists.shtml
  - Much still to be done
- Continue to provide new model developments
  - E.g. add quasi-elastic channel for string models
  - New options as new (experimental) physics lists
  - Adopt mature options
- Better integrate physics lists for communities like underground experiments, space users, …

Summary

- Reference Physics lists
  - User request for better integration in Geant4 implemented in 8.2
  - Structure has been improved with 8.0 and 8.1
    - Use standard builder for EM, remove TMP program
  - Improved or new models always made available
    - Gamma Nuclear is included by default
    - Improved elastic scattering
    - Revised stopping physics now using CHIPS model
- Advanced Examples physics list
  - Targeted to specific problems, often with validation

Backup slides.....

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 Ineleastic

Since 8.0

- G4EmStandardPhysics
  - **Standard EM physics list for all particles**
  - **Removes TMP file**
- G4EmExtraPhysics
  - Synchroton 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 Ineleastic

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-, pi-, 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

Updates in 8.3

- Add quasi-elastic scattering to all QGS physics lists
  - For backward compatibility and for testing, new temporary lists **without** quasi-elastic scattering: QGSP_NQE, QGSP_EMV_NQE, and QGSP_BERT_NQE
- QGSC lists use new CHIPS model for muon capture at rest
- Use HElastic model for all particles with kinetic energy T> 1GeV, except in Hydrogen
- Skin parameter of multiple scattering set to 0
  - No computation of linear distance to boundary
- FTFP and FTFC use revised FTF model
- New QGSP _BERT_TRV
  - Restrict use of Bertini cascade to particles with T<5.4GeV, by default it is used up to T=9.9 GeV

Updates in 9.0

- Rename components for EM physics
  - G4EMStandardPhysics, the default EM option
  - G4EMStandardPhysics_option1, used by _EMV variants
    - Was G4EMStandardPhysics71
  - G4EMStandardPhysics_option2, used by _EMX variants
    - Was G4EMStandardPhysics72
- Removed obsolete lists
- Threshold for use of FTF model lowered to 5GeV
  - FTF is under development

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