

# Physics Lists

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# Physics lists task force

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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](http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/G4_Physics_Lists.html)

# Reference Physics Lists

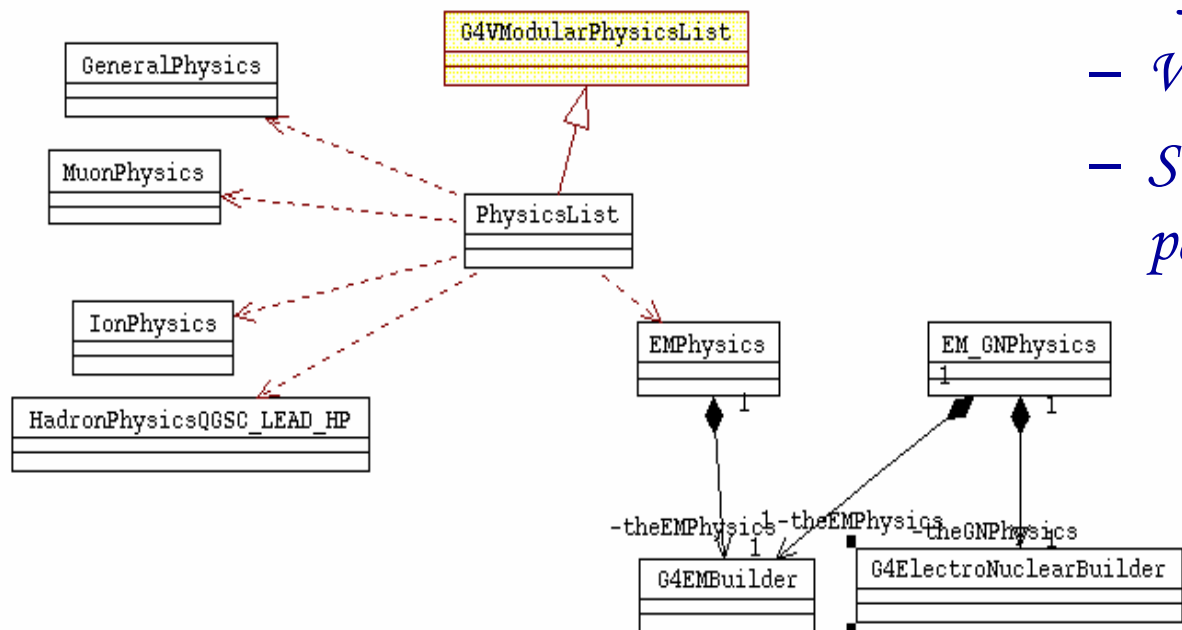
- *Wide choice of physics lists offered*
  - *more than 20 lists*
- *Cover wide range of use cases*
- *All lists cover all primary and secondary particles up to high energies ( $>TeV$ )*



# 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*
- *Solve configuration problem*
  - *Move physics lists into Geant4 source and build system*
  - *Integrates physics lists with Geant4*
- *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 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)*

# 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*

# 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*

# 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*
  - *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 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,  $\alpha$*
- *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  $\mu^-$ ,  $\pi^-$ , 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*

# 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](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*