Physics List Documentation

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Two Approaches

- Auto-generated
  - html-generating code embedded in almost all hadronic models, cross sections and processes
  - one html file generated at initialization time (when physics list is instantiated)
  - user parameter to turn this on/off

- Write custom physics list descriptions
  - concentrate on general focus or meaning
  - fewer details
  - not automatic

Auto-generated Descriptions

- Virtual methods implemented in class
  - CrossSectionDescription()
  - ModelDescription()
  - ProcessDescription()

- Description should be 4-10 lines of text with format:
  - outfile << " This model simulates X by using Y and .. \n"
    << " It is valid for energies.. and particles.. \n";

- Class name string should be set in constructor and becomes the title of the description in html

Auto-generated Descriptions

- G4HadronicProcessStore::DumpHtml() collects the various html description and assembles them into one file
- Maintainer of each cross section, model or process is responsible for updating descriptions as needed

- html file generated only when running application
  - user must specify two environment variables:
    - G4PhysListDocDir – where to put the html
    - G4PhysListName – name of the physics list

Sample Physics List HTML File

Summary of Hadronic Processes, Models and Cross Sections for Physics List Test

- **proton**

process : hadElastic
- G4HadronElasticProcess handles the elastic scattering of hadrons by invoking the following hadronic model(s) and hadronic cross section(s).
- **models :**
  - **hElasticCHIPS from 0 GeV to 100000 GeV**
- **cross sections :**
  - **ChipsProtonElasticXS from 0 GeV to 100000 GeV**

process : protonInelastic
- This process handles the inelastic scattering of protons from nuclei by invoking one or more hadronic models and one or more hadronic cross sections.
- **models :**
  - **FTFP from 3 GeV to 100000 GeV**
  - **BertiniCascade from 0 GeV to 12 GeV**
- **cross sections :**
  - **Barashenkov-Glauber from 0 GeV to 100000 GeV**

Sample Physics List HTML File

- **neutron**

process : hadElastic
- G4HadronElasticProcess handles the elastic scattering of hadrons by invoking the following hadronic model(s) and hadronic cross section(s).
- **models :**
  - **hElasticCHIPS from 0 GeV to 100000 GeV**
- **cross sections :**
  - **G4NeutronElasticXS from 0 GeV to 100000 GeV**

process : neutronInelastic
- This process handles the inelastic scattering of neutrons from nuclei by invoking one or more hadronic models and one or more hadronic cross sections.
- **models :**
  - **FTFP from 3 GeV to 100000 GeV**
  - **BertiniCascade from 0 GeV to 12 GeV**
- **cross sections :**
  - **G4NeutronInelasticXS from 0 GeV to 100000 GeV**
  - **Barashenkov-Glauber from 0 GeV to 100000 GeV**

process : nCapture
- This process handles the capture of neutrons by nuclei by invoking one or more hadronic models and one or more hadronic cross sections.
- **models :**
  - **nRadCapture from 0 GeV to 100000 GeV**
- **cross sections :**
  - **G4NeutronCaptureXS from 0 GeV to 100000 GeV**

Sample Physics List HTML File

- **pi+**

process : hadElastic
- G4HadronElasticProcess handles the elastic scattering of hadrons by invoking the following hadronic model(s) and hadronic cross section(s).
- **models :**
  - **hElasticLHEP from 0 GeV to 1.0001 GeV**
  - **hElasticGlauber from 1 GeV to 100000 GeV**
- **cross sections :**
  - **Barashenkov-Glauber from 0 GeV to 100000 GeV**

process : pi+Inelastic
- This process handles the inelastic scattering of pi+ from nuclei by invoking one or more hadronic models and one or more hadronic cross sections.
- **models :**
  - **FTFP from 3 GeV to 100000 GeV**
  - **BertiniCascade from 0 GeV to 12 GeV**
- **cross sections :**
  - **G4CrossSectionPairGG from 0 GeV to 100000 GeV**

- **pi-**

process : hadElastic
- G4HadronElasticProcess handles the elastic scattering of hadrons by invoking the following hadronic model(s) and hadronic cross section(s).
- **models :**
  - **hElasticLHEP from 0 GeV to 1.0001 GeV**
  - **hElasticGlauber from 1 GeV to 100000 GeV**
- **cross sections :**
  - **Barashenkov-Glauber from 0 GeV to 100000 GeV**

process : pi-Inelastic
- This process handles the inelastic scattering of pi- from nuclei by invoking one or more hadronic models and one or more hadronic cross sections.
- **models :**
  - **FTFP from 3 GeV to 100000 GeV**
  - **BertiniCascade from 0 GeV to 12 GeV**
- **cross sections :**
  - **G4CrossSectionPairGG from 0 GeV to 100000 GeV**

Custom-Written Descriptions

- Difficult/impossible to have automated process write good prose summarizing the physics list from existing html files
  - current html files have too much information for most users
  - they do not express the capability, application and motivation of the physics list as a whole

- Both auto-generated and custom-written descriptions are needed
  - some short, custom-written descriptions exist, need to be longer
  - Geant4 home page->User Support->Physics lists hadronic-> Reference Physics Lists

Custom-Written Descriptions

String model based physics lists

These Physics lists apply a **string model** for the modeling of interactions of high energy hadrons, i.e. for protons, neutrons, pions and kaons above ~(5-25) GeV depending on the exact physics list. Interactions at lower energies are handled by one of the intranuclear cascade models or the precompound model. Nuclear capture of negative particles and neutrons at rest is handled using either the Chiral Invariant Phase Space (CHIPS) model or the Bertini intranuclear cascade. Hadronic inelastic interactions use:

- a tabulation of the Barashenkov pion cross sections
- the Axen-Wellisch parameterization of the proton and neutron cross sections

The physics lists are:

- **QGSP and QGSP_EMV**
  QGSP is the basic physics list applying the quark gluon string model for high energy interactions of protons, neutrons, pions, and Kaons and nuclei. The high energy interaction creates an exited nucleus, which is passed to the precompound model modeling the nuclear de-excitation.

  QGSP_EMV is identical to QGSP, but parameters of electromagnetic processes tuned to yield better cpu performance with only slightly less precision.

- **QGSC and QGSC_EMV**
  As QGSP except applying CHIPS modeling for the nuclear de-excitation. In comparison to thin target experiments, this improves simulation of the nuclear de-excitation part of the interaction, resulting in slightly increased production of relatively low energy secondary protons (and neutrons).

  QGSC_EMV is identical to QGSC, but parameters of electromagnetic processes tuned to yield better cpu performance with only slightly less precision.

- **QGSP_EFLOW**
  This variant of QGSC uses a different algorithm setting up the excited nucleus created by the high energy interaction resulting in a good description of target fragmentation products; comparisons to thin target data well reproduce the proton production rate in the nuclear fragmentation region.
- **QGSP_BERT and QGSP_BERT_EMV**
  Like QGSP, but using Geant4 Bertini cascade for primary protons, neutrons, pions and Kaons below ~10GeV. In comparison to experimental data we find improved agreement to data compared to QGSP which uses the low energy parameterised (LEP) model for all particles at these energies. The Bertini model produces more secondary neutrons and protons than the LEP model, yielding a better agreement to experimental data.

  QGSP_BERT_EMV is like QGSP_BERT, but parameters of electromagnetic processes tuned to yield better cpu performance with only slightly less precision.

  Both QGSP_BERT and QGSP_BERT_EMV are less CPU performant as QGSP.

Extensions

- EM processes/models and other “non-hadronic” processes (e.g. radioactive decay)
  - no automated descriptions currently available
  - not derived from G4HadronicProcess
  - recently added virtual ProcessDescription() method to G4VProcess
    - now non-hadronic processes can be accommodated

- Added GenericIon to current html printout

Challenges

- Generating all lists at once
  - makes life easier for documentation coordinator
  - generate dummy main() for each physics list
  - develop script to run all mains at once and deposit them in given directory

- Tying physics list docs to release
  - docs to be generated for each release
  - script mentioned above could add string indicating release
- Enforcing updates
  - good will of maintainer ?

Challenges

- Auto-generating the Process/Model Catalog
  - need to use html snippets generated by physics lists and re-assemble them in catalog format
  - develop script which scans output of all physics lists docs and puts snippets into appropriate directories?

- Going beyond G4HadronicProcessStore
  - not general enough for expanded coverage
  - cannot current include things like RDM without generating circular dependency

- Propagating documentation machinery to EM code

To Do

- Produce a few, longer custom-written physics list docs as examples for future work
- Look for alternative to G4HadronicProcessStore for assembling html docs
- Develop scripts to run, then sort and re-arrange, physics list documentation snippets
  - also need set of “documentation mains”
- Write embedded documentation for a few major EM processes
  - multiple scattering, bremsstrahlung