Which Physics List To Use

Geant4 PHENIICS & IN2P3 Tutorial,

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Orsay

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Choosing a Physics List

- Which physics list to use depends on the use-case
- It is convenient and recommended to start with one of the reference physics lists, which are routinely validated and updated with each Release
  - These should be considered only as starting points which you may need to validate or modify for your application
- There are also many physics lists in the examples, which you can copy and then eventually modify
  - These are often specific to a given use-case
- There are currently **19** packaged physics lists, of which **6** are reference physics lists
  - **FTFP_BERT**, **FTFP_BERT_HP**
  - **QGSP_BERT**, **QGSP_BERT_HP**, **QGSP_BIC**
  - **QGSP_FTFP_BERT**

Physics List Naming Convention

- The following acronyms refer to various hadronic options
  - FTF -> Fritiof string model (>~ 3 GeV)
  - QGS -> Quark Gluon String model (>~ 12 GeV)
  - BERT -> Bertini-style Cascade (~< 10 GeV)
  - BIC -> Binary Cascade (~< 10 GeV)
  - P -> Precompound model used for nuclear de-excitation (~< 150 MeV)
  - HP -> High Precision neutron model (< 20 MeV)
- EM options designated by
  - No suffix : standard EM physics
  - _EMV , _EMX : fast options for high-energy physics
  - _EMY , _EMZ , _LIV , _PEN : more precise options, for medical and space science applications

When the application starts…

- Large amount of information displayed by the physics list

```
…
FTFP_BERT : new threshold between BERT and FTFP is over the interval
 for pions :   3 to 12 GeV
 for kaons :   3 to 12 GeV
 for proton :  3 to 12 GeV
 for neutron : 3 to 12 GeV
…
conv:   for  gamma    SubType= 14  BuildTable= 1
      Lambda table from 1.022 MeV to 100 TeV, 18 bins per decade, spline: 1
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
        BetheHeitler :  Emin=        0 eV    Emax=       80 GeV
     BetheHeitlerLPM :  Emin=       80 GeV   Emax=      100 TeV
…
Hadronic Processes for anti_deuteron

  Process: hadElastic
        Model:              hElasticLHEP: 0 eV /n ---> 100.1 MeV/n
        Model:              AntiAElastic: 100 MeV/n ---> 100 TeV/n
     Cr_sctns:              AntiAGlauber: 0 eV  ---> 2.88022e+295 J
     Cr_sctns:            GheishaElastic: 0 eV  ---> 100 TeV

  Process: anti_deuteronInelastic
        Model:                      FTFP: 0 eV /n ---> 100 TeV/n
     Cr_sctns:              AntiAGlauber: 0 eV  ---> 2.88022e+295 J
     Cr_sctns:          GheishaInelastic: 0 eV  ---> 100 TeV

  Process: hFritiofCaptureAtRest
…
```

- The most up-to-date information you can find on a given physics list is here !

Reference Physics Lists (1/3)

- **FTFP_BERT**
  - Recommended by Geant4 for HEP
  - Contains all standard EM processes
  - Uses Bertini-style cascade for hadrons < 5 GeV
  - Uses Fritiof model for high energies > 4 GeV
  - Uses Precompound + evaporation for nuclear de-excitation
  - Includes neutron capture
  - Includes nuclear stopping at rest of negatively charged hadrons
  - Includes gamma- and electro-nuclear
  - No neutron-HP, radioactive decay, optical photons

Reference Physics Lists (2/3)

- **QGSP_FTFP_BERT**
  - All standard EM processes
  - Bertini-style cascade for hadrons < 8 GeV
  - Quark Gluon String model for high energies > 12 GeV
  - Fritiof model in between 6 – 25 GeV
- **QGSP_BERT**
  - All standard EM processes
  - Bertini-style cascade for hadrons < 9.9 GeV
  - Quark Gluon String model for high energies > 12 GeV
  - Fritiof in between 9.5 – 25 GeV
  - NB) We are working to extend QGS at lower energies, so that the transition with BERT can be done directly, without FTF (in this physics list)

Reference Physics Lists (3/3)

- **QGSP_BIC**
  - Same as QGSP_BERT, but replaces Bertini-style cascade with Binary cascade model (+ Precompound model)
  - Recommended for use at energies below 200 MeV
    - Many medical applications
    - Suggested EM option: _EMY or _EMZ
- **FTFP_BERT_HP (QGSP_BERT_HP)**
  - Same as FTFP_BERT (QGSP_BERT), but with the high-precision neutron model used for neutrons below 20 MeV
  - Significantly slower than FTFP_BERT (QGSP_BERT), especially when Doppler broadening on-the-fly is used
    - There is an option to turn this off
  - For radiation protection and shielding applications

Other Physics Lists (1/2)

- **Shielding**
  - Based on FTFP_BERT_HP with improved neutron cross sections from JENDL
  - Better ion nuclear interactions using QMD model
  - Radioactive decay model activated
  - Currently used by SuperCDMS dark matter search
  - Recommended for:
    - Shielding applications
    - Space physics
    - HEP
- **FTFP_INCLXX , FTFP_INCLXX_HP**
  - Like FTFP_BERT(_HP), but with Bertini-style cascade replaced by INCLXX (Liege) cascade model below 3 GeV

Other Physics Lists (2/2)

- **QBBC**
  - Uses both Bertini-style and Binary cascade models
  - Latest coherent elastic scattering
  - Neutron XS approach (fairly accurate, but faster then HP)
    - Since G4 10.0 adopted also in other non-HP physics lists
- **QGSP_BIC_HP**
  - Same as QGSP_BIC, but with the high precision neutron model used for neutrons below 20 MeV
  - Recommended for:
    - Radiation protection
    - Medical applications

Other Physics Lists (based on use-case)

- If primary particle energy in your application is < 5 GeV (for example, clinical proton beam of 150 MeV)
  - start with a physics list which includes BIC or BERT
  - e.g. **QGSP_BIC**, QGSP_BERT, FTFP_BERT, etc.

- If neutron transport is important
  - start with a physics list containing “HP”
  - e.g. QGSP_BIC**_HP**, FTFP_BERT**_HP**, etc.

- If you are interested in Bragg curve physics
  - use a physics list ending with **_EMY** or **_EMZ**
  - e.g. QGSP_BIC_EMY

- For detailed line emission from EM processes
  - EM options : **_EMY** , **_EMZ** , **_LIV** , **_PEN**

Using Geant4 Validation to Choose Physics Lists

- Ultimately you must choose a physics list based on how well its component processes and models perform
  - Physics performance
  - CPU performance
- Geant4 provides validation (comparison to data) for most of its physics codes
  - Validation is a continuing task, performed at least as often as each release
  - More validation tests added as time goes on
- To access these comparisons, go to
  - http://g4validation.fnal.gov:8080/DoSSiER/

DoSSiER

Database of Scientific Simulation and Experimental Results

Home | Geant4 | Geant4 Collaborators | GeantV | GENIE | Fermilab | CERN | Search

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Left

Main

- Display exp. data
- Display Geant4 data
- Display GeantV data
- Display GENIE data
- Display Statistics
- Display Dictionaries
- RESTful web service

Beam | Target | Secondary | Model | ParValues | Submit

Table | Default

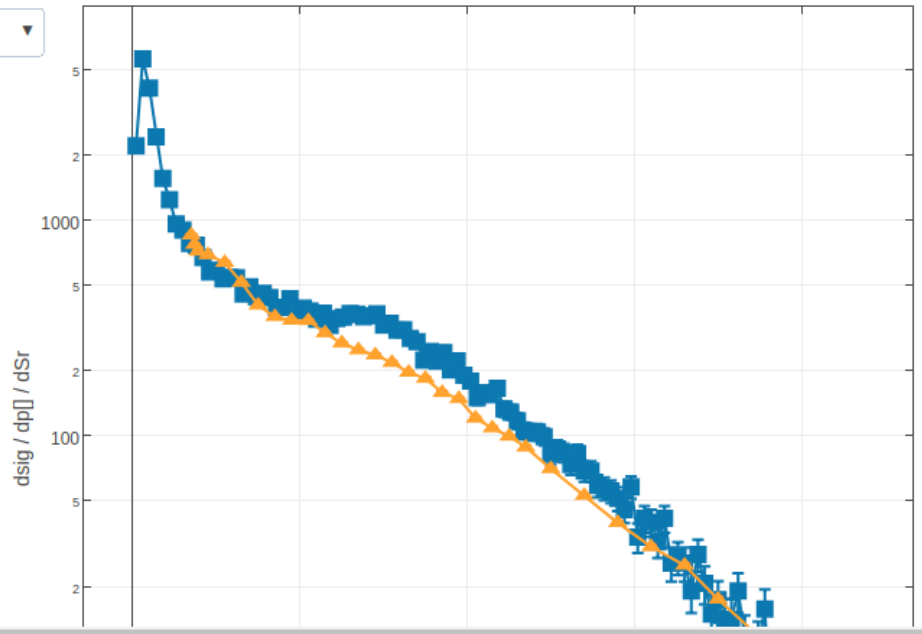
Print

INCLXX
BIC
Bertini

NEUTRON-INDUCED PRODUCTION OF PROTONS, DEUTERONS AN

Model:INCLXX,Beam:SIN Neutron beam [542MeV],Target:Cu,Secon
Ref: 20,Beam:SIN Neutron beam [542MeV],Target:Cu,Secondary:pro

log Y



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Summary

- Choosing a physics is a critical decision you have to make when building your application.
- Reference physics lists exist to guide your choice
  - They are continuously monitored
  - And are recommended to start with
- Physics lists can easily be customized using the G4PhysicsListFactory
  - Allowing you to compose your physics list using a few tags
- If you need to go to more specific physics, you will have to code your own physics lists
  - And numerous examples are demonstrating this