

How to create an interface between UrQMD and Geant4 Toolkit

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Abstract

An interface between the UrQMD-1.3cr model (version 1.3 for cosmic air showers) and the Geant4 transport toolkit has been developed. Compared to the current Geant4 (hybrid) hadronic models, this provides the ability to simulate at the microscopic level hadron, nucleus, and anti-nucleus interactions with matter from 0 to 10^{12} eV/A with a single transport code. This document provides installation requirements and instructions, as well as class and member function descriptions of the software.

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1 Introduction

Geant4 [1] use many transport codes to generate non-elastic reactions in macroscopic targets. The motivation was to provide a satisfactory level of description of final state hadron production for accurate and comprehensive simulations of particle detectors used in modern particle and nuclear physics experiments.

In Geant4 [1] there are mainly 4 codes which are frequently applied for simulating N-body collisions within the hadronic cascade models, namely, Binary [2], Bertini [3], FTF[4] and QGS[5]. The Geant4 Binary and Bertini cascade models implement large resonance collision term but multiparticle production through string formation and fragmentation is not considered, which sets the upper limit of model applicability in nucleon induced reactions to about 5 GeV/c incident momentum. In contrast to **Binary** and **Bertini** cascade models, **FTF** and **QGS**, takes multiparticle production into account, to handle interaction for particles above about 15-20 GeV/c.

For a reliable description of secondaries produced in high and low energy domains, Geant4 invoke **Binary** (**Bertini**) in the **FTF(QGS)** models. The corresponding hybrid model is called FTFB(QGSB).

To improve the simulation, it is worthwhile to supplement Geant4 toolkit with a single transport code which takes into account both resonance and multiparticle production. The UrQMD (Ultra relativistic Quantum Molecular Dynamics) model [6], which is first released in 1998, is designed to simulate (ultra) relativistic heavy ion collisions in a wide energy range from Bevalac and SIS up to AGS, SPS and RHIC. Thanks to the UrQMD collaborators, the UrQMD is provided as open source Fortran code on its website.

Geant4-UrQMD interface offers interactions of Protons, neutrons, pions and kaons (and their antiparticles) as well as light and heavy ions interactions with matter. It gives type, mass, energy, and momentum of all secondary

particles that are created in matter. Similar to CORSIKA-UrQMD [7] interface, the upper energy limit is recommended to be about several 100 GeV. For the simulation, the appropriate **UrQMD** cross sections (for determining the mean free path between interacting particles) are used. However, the probability for an interaction with matter at a given point is computed by the Geant4 cross sections classes.

This document provides installation requirements and instructions of the Geant4 -UrQMD interface. More details about validation with Geant4 cascade models can be found in Ref.[8]. This interface is sponsored by King Abdulaziz City for Science and Technology /National Center for Mathematics and Physics- Saudi Arabia under the contract number 31-465.

2 Brief description of UrQMD model

The UrQMD model version 1.3cr (for cosmic air shower) is a Monte Carlo event generator for simulating hadron-hadron, hadron-nucleus, nucleus-nucleus interactions from 0 to 10^6 MeV. The main goal is to gain understanding about Physical phenomena within a single transport mode. As such, it is relevant both to high-energy hadron/ion accelerators and cosmic radiation environments.

The UrQMD model is based analogous principles as the quantum molecular dynamic (QMD) model and the relativistic QMD (RQMD): the mean field potential applied to hadrons is treated similar to QMD, while the treatment of the collision term is similar to RQMD.

Compared with Geant4 simulation codes (e.g., Binary, Bertini, FTF, QGSM...), UrQMD has the following improvements to its physics (see Ref.[6] for full description):

- The collision term of the UrQMD treats 55 different baryon species (including nucleon, Δ, Λ, Σ, Ξ and Ω and their resonances with masses up to 2.25 GeV/c²) and 32 different meson species (including strange meson resonances with masses up to 1.9 GeV/c²) as well as their antiparticles and explicit isospin projected states. For excitations with higher masses than 2 GeV/c² the string model is used (The exited hadronic states can either be produced in inelastic *hh* collision, resonance decays or string decays).
- All of these hadronic states can propagate and re-interact in phase-space.
- A mean field potential can be applied for the scattered nucleons.

- An analytic expression for the differential cross section of in-medium NN elastic scattering derived from the collision term of the relativistic Boltzmann-Uehling-Uhlenbeck (RBUU) equation is used to determine the scattering angles between the outgoing particles in hh collisions.
- An introduction of the formation time and leading pre-hadron effects. For the leading pre-hadrons, a reduced cross section is adopted according to the constituent quark model.

UrQMD-1.3cr is freely available from the website http://urqmd.org/.

3 Installation requirements

The Geant4 interface to UrQMD-1.3cr (for cosmic air showers) uses the following software tools and packages:

- 1. UrQMD-1.3cr (available at http://urqmd.org/ website)
- 2. The following Geant4 versions:
 - *ver.9.3.p01* or *ver.9.5*

The interface and original UrQMD-1.3cr source code have been compiled and tested using:

• gcc 4.1.2 with g77 (FORTRAN77), gfortran (FORTRAN95) and GNUmake)

Operating systems used for this test is: Red Hat Linux 4.1.2-64

4 Interface design

The use of UrQMD-1.3cr physics in Geant4 has resulted in the introduction of a new event model (G4UrQMD1_3Model).

4.1 Logical description of G4UrQMD1_3Model

The general steps in the logical sequence of the design are:

1. Instantiation of G4UrQMD1_3Model

Upon instantiation of the UrQMD-1.3cr interface, the class constructor initialises variables associated with the class and the UrQMD-1.3cr FORTRAN model. The latter involves initialisation of a series of common-block variables from the C++ code, mimicking the initialisation process performed by the FORTRAN code when used in standalone mode.

2. Generation of the interaction events

In order to generate interaction events, the **ApplyYourself** member function of Geant4 is executed. The details of the projectile and target are determined (e.g., mass number, charge, projectile energy...).

If no data exist for the specific projectile-target combination, a "waning" is declared, and the program is stopped.

4.2 Class structure for model

The interface comprises **G4UrQMD1_3Model** class, which is derived from **G4HadronicInteraction**, and is defined within the Geant4 user physics list if access to **UrQMD1_3** physics is required. It controls initialisation of **UrQMD-1.3cr** through common block variables.

A small FORTRAN subroutine is included with the G4UrQMD distribution. This is required to ensure that block data initialisation in G4UrQMD-1.3c is performed (through FORTRAN EXTERNAL statements). Specifically the new FORTRAN subroutine is:

• g4urqmdblockdata.f

5 Instructions for software installation in geant4-9.3

5.1 Installing UrQMD-1.3cr and building the libG4hadronic_urqmd13 library

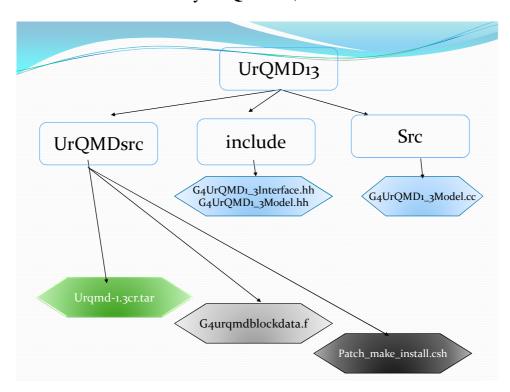
Copy the file **g4urqmd-1.3cr.2012.tar** (available at https://twiki.cern.ch/twiki/bin/view/Sandbox/Geant4UrQMDinterface) to the directory:

cd \$G4INSTALL/source/processes/hadronic/models

Unzip or untar the files, *e.g.*:

tar -xvzf g4urqmd-1.3cr.2012.tar

This creates the directory **UrQMD13**, which looks like:



Note that the header and C++ files (G4UrQMD1_3Interface.hh & G4UrQMD1_3Model.hh) and G4UrQMD1_3Model.cc are in UrQMD13/include and UrQMD13/src respectively.

Change directory:

cd UrQMD13/UrQMD13src

If the file **urqmd-1.3cr.tar** doesn't already exist in the directory, copy it from the web-site: http://urqmd.org/.

Execute the script **patch_make_and_install.csh** from a **csh/tcsh** environment. This initiates 2 steps:

1- All the relevant FORTRAN files are compiled in **UrQMD13src**, using

2- The object files are copied to the directory:

Change directory and execute **make** on the C++ source:

cd..

make

This will build the library:

\$G4LIB/\$G4SYSTEM/libG4hadronic_UrQMD13.a

but note that the **Gnumake** file of your application must explicitly identify this library and the **UrQMD1_3** headers. So in **GNUmake** file for you application, please add the following line:

CPPFLAGS += -I\$(G4BASE)/processes/hadronic/models/UrQMD13/include

Note that if you perform:

make clean

from UrQMD13 directory, this deletes the FORTRAN-compiled object files which UrQMD13/UrQMD13src from were \$G4TMP/\$G4SYSTEM/ libG4hadronic urgmd13. Therefore, you should either files. script re-copy the the or re-run

patch_make_and_install.csh before performing a make in directory
UrQMD13.

5.2 The main () program

Geant4 does not provide the **main()**. In the **main()**, one has to construct **G4ProcessManager**, in order to process a run for the interface.

Ensure that the **GNUmake** file for you application (in "**main**" directory) includes the following lines:

CPPFLAGS += -**I**\$(G4BASE)/processes/hadronic/models/UrQMD13/include

EXTRALIBS += -L\$(G4INSTALL)/lib/\$(G4SYSTEM) -lG4hadronic_UrQMD13

If you want to compile the Geant4-UrQMD interface from your "main" directory, please add these lines in GNUmake file:

EXTRA_LINK_DEPENDENCIES:= \$(G4INSTALL)/lib/\$(G4SYSTEM)/libG4hadronic_UrQMD13.so

\$G4INSTALL)/lib/\$(G4SYSTEM)/ libG4hadronic_UrQMD13.so: cd \$(G4BASE)/processes/hadronic/models/UrQMD13; \$(MAKE)

6 Class descriptions (summary)

Class G4UrQMD1_3Model

Public member functions

Private member functions

7 Class descriptions (full descriptions)

The following sub-sections describe in detail each of the new or modified classes introduced into Geant4 to treat the interface with UrQMD-1.3cr. The descriptions include the overall purpose of the class, the constructor, destructor, and private/public member functions of the classes, including identification of the arguments and quantities returned. It should be noted that, the *units of all inputted and returned quantities are default units used in Geant4*, *e.g.* lengths (such as nuclear radii) are stated in millimetres, areas (*e.g.* interaction cross-sections) in square-millimetres, and energies are stated in MeV.

7.1 Class G4UrQMD1_3Model

The **G4UrQMD1_3Model** class is the main class driving the UrQMD-1.3cr FORTRAN code and primarily acts as an event generator to Geant4 to determine the final state of an interaction. It is derived from **G4HadronicInteraction** class.

Public constructors, operators and member functions

```
G4UrQMD1_3Model(constG4String&name=UrQMD1_3");
```

public constructor which calls **InitialiseDataTables** (). This initialises all of the variables as required by UrQMD-1.3cr and held in FORTRAN common blocks based on the DEFAULT values, *i.e.* largely based on the UrQMD-1.3cr defaults, see CTParam(X) and CTOption(X) from Tables 5 and 6 of the UrQMD user guide (http://urqmd.org/).

~G4UrQMD1_3Model();

Class destructor.

virtual G4HadFinalState ***ApplyYourself** (**const** G4HadProjectile &*theTrack*, G4Nucleus &*theTarget*);

Member function to determine the **Final State** of the interaction process. The **Final state** is for the results of (and secondaries from) the projectile, described by **theTrack**, and **the target** nucleus, described by theTarget. This member function drives the UrQMD-1.3cr FORTRAN to enter information about an interaction event, and interprets the results into a product vector as a **G4HadFinalState** object.

Private constructors, operators and member functions

const G4UrQMD1_3Model& operator=(G4UrQMD1_3Model
&right);

Operator which is required by Geant4 physics lists.

void WelcomeMessage ();

Prints to standard output (stdout) the information about the G4UrQMD1_3Model when the class is instantiated.

void InitialiseDataTables ();

Initialises the UrQMD-1.3cr variables during the execution of either of the constructors. This is an initialisation process, primarily setting common block variables directly or through block data calls.

Gbool offshell;

Option to be fixed by the user:

true if nucleons are put "**off-mass-shell**" (default UrQMD option) and **false** if nucleons are "**on-mass-shell**" (recommended by the authors).

Note that this option strongly affects low energy cascade particles.

7.2 G4UrQMD1_3Interface: C++ --FORTRAN interface for common blocks and subroutines

Although not representing a class in itself, G4UrQMD1_3Interface.hh contains a series of structure definitions in order to permit access to FORTRAN common block variables. For each common block used by the Geant4 interface, there is an associated C/C++ struct. For example, common block **urqmdparams** becomes the variable **urqmdparams** of struct type ccurqmd13urqmdparams, and variables real*8 u_elab and common integer u_at in that block are designated urqmdparams_.u_elab and urqmdparams_.u_at respectively in the C/C++ interface.

The other function of **G4UrQMD1_3Interface.hh** is to define cross-references between the **UrQMD1.3cr** FORTRAN **subroutines** and C/C++ **subroutines**.

8 Changes to usage of geant4-9.5

In version 9.3.p01 (and older ones) the anti-nucleus characteristics and cross sections are not supplied with the geant4 source. Therefore, one has to install the most recent version of geant4 (9.5) in order to allow anti-nucleus interactions using UrQMD code. For installation, one has to use the so called **CMAKE** build system to compile and install the toolkit. **CMAKE** has been chosen to replace the old **Configure/Make** system. For more information on **CMAKE** itself, please visit http://www.cmake.org/.

8.1 Building and installing CMAKE

Unpack the **cmake-2.8.7.tar.gz** to a location of your choice. For illustration only, assume it is unpacked in a directory **/home/path,** so that the CMAKE source sits in the directory

\$ /home/path/make

\$tar -xvzf cmake-2.8.7.tar.gz

To configure the build:

\$./bootstrap

(The following step is not written in the CMAKE manual)

\$./configure - - prefix=/home/path/cmake

\$make

\$make install

Here the Configure variable prefix is used to set the install directory, the directory under which CMAKE libraries, binaries and headers are installed.

```
Finally you will get the directory "cmake" which contains:
+-cmake
+-Bin/
     1+-ccmake
     +-cmake
     |+-cpack
     +-ctest
+-cmake-2.8.7/
+-doc/
     |+-cmake-2.8/
+-man/
      |+-man1/
+-share/
      |+-alocal/
      |+-cmake-2.8/
 To make sure that everything is O.K., please write
 $ cmake -version
 You will get
 $cmake version 2.8.7
To run cmake in any path terminal, you have to add few lines in your
```

First open your .bash_profile:

.bash_profile as follows.

\$nano .bash_profile

Write

PATH=/home/path/cmake/bin:\$PATH

LD_LIBRARY_PATH=/home/path/cmake/lib:\$LD_LIBRARY_PATH

Save your .bash_profile.

Finally, execute:

\$source .bash_profile

8.2 Building and installing geant4.9.5

First make sure that there is no previous version of geant4 in your system.

To do this, please type:

\$ printenv | grep G4

Maybe you find something in your **.bash_profile**. If you do, go to main terminal and write

\$nano .bash_profile

Erase or mark anything starts with G4.

To ensure that everything is O.K., write:

\$source .bash_profile

\$printenv | grep G4

If you find no "G4" proceed as follows:

Unpack the **geant4.9.5.tar.gz** to the location **/home/path/geant4**, so that the geant4 "unpacked files" sits in the subdirectory

/home/path/geant4/geant4.9.5

The next step is to create a directory to configure and run the build and store the build products. This directory should be alongside your source directory (geant4-9.5):

\$mkdir geant4.9.4-build

\$ls

To configure and build, change into the build directory:

\$cd geant4.9.5-build

Since geant4 source is in /home/path/geant4/geant4.9.5, it is recommended to install it in /home/path/geant4/geant4.9.5-install by typing:

\$cmake -DCMAKE_INSTALL_PREFIX=/home/path/geant4/geant4.9.5-install ../geant4.9.5

When complete, do

\$make

\$make install

Finally, you will get "geant4.9.5-install" directory which contains

+-geant4.9.5-install

+-bin/

l+-geant4.csh

l+-geant4.sh

l+-geant4-config

+-include/

|+-Geant4/

l+-globals.hh

I+-G4ParticleDefinition.hh

```
|+-G4AntiDeuteron.hh
|+-...
|+-CLHEP/
|+-tools/
+-lib/
|+-libG4global.so
|+-...
+-share/
+-Geant4-9.5.0/
+-geant4make/
|+-config/
|+- geant4make.sh
|+-geant4make.csh
|+...
```

Finally, make sure that geant4 binaries and libraries are available on your path. This is done by writing (in your .bash_profile):

PATH=\$PATH:\$HOME/geant4_workdir/bin/Linux-g++/

Source /home/path/geant4/geant4.9.5-install/share/Geant4-9.5.0/geant4make/geant4make.sh

8.3 Building and installing Geant4-UrQMD interface for version 9.5

With version 9.5, you may have problems linking C++ geant4 code against FORTRAN-UrQMD code. In order to resolve these problems it is recommended to use **gfortran** instead of **g77**.

Thus go to the **GNUmake** file in the directory:

\$cd /home/path/geant4/geant4.9.5/source/processes/hadronic/models/UrQMD13

and make sure that these lines

FC = g77

LD=g77

FFLAGS=-g -Wall -Wsurprising -fbound -check

LDFAGS = -g

are replaced with:

FC=gfortran

LD=gfortran

FFLAGS=-Fpic

LDFLAGS="-L/usr/lib64 -lgfortran"

Also, it would be better to abandon the **patch_make_and_install.csh** environment and write few lines in **GNUmake** file:

```
.PHONY: all
all: urqmd lib
ifdef G4INCLUDE

CPPFLAGS += -I $(G4INCLUDE)
endif

UrQMDDIRNAME= UrQMDsrc
urqmd:
(cd ${URQMDDIRNAME} && \
tar -xzf urqmd-1.3cr.tar.gz && \
cp GNUmakefile urqmd-1.3cr && cp *.f urqmd-1.3cr && \
cd urqmd-1.3cr && ${MAKE} FFLAGS=-Fpic FC=gfortran LD=gfortran LDFLAGS="-L/usr/lib64-lgfortran");
```

(mv \${URQMDDIRNAME}/urqmd-1.3cr/obj_Linux/*.o \${G4TMPDIR});

This will:

1- Move the object files to the directory

\$/home/path/geant4_workdir/tmp/Linux-g++/G4hadronic_UrQMD13

2- Create UrQMD library in the directory:

\$/home/path/geant4/geant4-9.5.0/Linux-g++ libGhadronic_UrQMD13.so

If the linking is O.K. goto **UrQMD13** directory and type:

\$ make includes

This will move the include files (G4UrQMD1_3Interface.hh & G4UrQMD1_3Model.hh) to Geant4 directory:

/home/path/geant4/geant.9.5-install/include/Geant4

Finally in the **GNUmake** file of your "**main**()" application, make sure that this line:

EXTRALIBS += -L/{G4lib}/\${G4SYSTEM} -lG4hadronic_UrQMD13 is inserted.

9 The output file

```
Cascade Test (test30) Start =======
###### Start new run # 0 for 1 events #####
### NIST DataBase for Materials is used
Material is selected: G4_Zr
Test30Physics entry
Process is created; gen= UrQMD1_3
 ********
                            G4UrQMD_1.3
Interface to
                                               activated
Version number : 00.00.0B
                               File date : 25/01/12
 (Interface written by Kh. Abdel-Waged et al. for the KACST/NCMP)
 *****************
seed: 1097569630
New generator for material G4_Zr Nelm= 1 Nmat= 1 Target element: Zr
Secondary generator <UrQMD1_3> is initialized
Nucleus with N= 94 Z= 40 \overline{A}(amu) = 9.131840e+01Mass from G4NucleiProperties(GeV)= 8.745283e+01
The particle: anti\_deuteron
The material: G4\_Zr Z= 40 A= 94 Amax= 95
The step: 1.000000e-05 mm
The position: (0.000000e+00,0.000000e+00,0.000000e+00) mm
The direction: (0.000000e+00,0.000000e+00,1.000000e+00)
The time:
          0.000000e+00 ns
energy = 2.000000e+05 \text{ MeV}
                         RMS (MeV) = 0.000000e+00
emax = 2.500000e+01 MeV
pmax = 2.018669e+05 MeV
### Log10 scale from -2.000000e+00 to 2.000000e+00 in 80 bins
### Histo books 57 histograms in <UrQMD1_3.root>
Histograms are booked output file <UrQMD1_3.root>
### factor = 2.971747e-01### factora = 7.567491e+03### factorb = 2.377397e+03 cross(mb)=
2.377397e+03
Test rotation= (0.000000e+00,0.000000e+00,1.000000e+00)
### 0-th event start
creation of table, wait-----
 ##
       UrQMD 1.3 University of Frankfurt
                 urqmd@th.physik.uni-frankfurt.de
 ##
 ##
 ##
       please cite when using this model:
 ##
       S.A.Bass et al. Prog.Part.Nucl.Phys. 41 (1998) 225 ##
 ##
 ##
      M.Bleicher et al. J.Phys. G25 (1999) 1859 ##
 tabnameurqmd.tab
Generating table...
 (1/7) ready.
 (2/7) ready.
 (3/7) ready.
 (4/7) ready.
 (5/7) ready.
 (6/7) ready.
 (7/7) readv.
Writing new table...
0.K.
end to create table
UrQMDModel running-----
 (info) dsigma: calculating constants for ang. dist.
 (info) dsigma: calculation finished
 User=3.225000e+01s Real=3.319000e+01s Sys=3.000000e-02s
##### Save histograms
###### End of run # 0
                      ######
Next line #exit
     ##### End of test ####
```

Fig.2 Sample header of the output of Geant4-UrQMD interface

10G4UrQMD1_3.cc file

```
// *******************
// * License and Disclaimer
// *
// * The Geant4 software is copyright of the Copyright Holders of *
// * the Geant4 Collaboration. It is provided under the terms and *
// * conditions of the Geant4 Software License, included in the file *
// * LICENSE and available at http://cern.ch/geant4/license . These *
// * include a list of copyright holders.
// *
// * Neither the authors of this software system, nor their employing *
// * institutes, nor the agencies providing financial support for this *
// * work make any representation or warranty, express or implied, *
// * regarding this software system or assume any liability for its *
// * use. Please see the license in the file LICENSE and URL above *
// * for the full disclaimer and the limitation of liability.
// *
// * This code implementation is the result of the scientific and *
// * technical work of the GEANT4 collaboration.
// *
// * Parts of this code which have been developed by Abdel-Waged
// * et al under contract (31-465) to the King Abdul-Aziz City for
// * Science and Technology (KACST), the National Centre of
// * Mathematics and Physics (NCMP), Saudi Arabia.
// *
// * By using, copying, modifying or distributing the software (or *
// * any work based on the software) you agree to acknowledge its *
// * use in resulting scientific publications, and indicate your *
// * acceptance of all terms of the Geant4 Software license.
////
응
//
// MODULE: G4UrQMD1 3Model.hh
// Version:
              0.B
25/01/12
// Volume:
// Date:
25/01/12

// Authors:
Kh. Abdel-Waged and Nuha Felemban
// Revised by:
V.V. Uzhinskii
CHONGERED BY
                KACST/NCMP
// Customer:
                31-465
// Contract:
//
응
//
#include "G4UrQMD1_3Model.hh"
#include "G4UrQMD1_3Interface.hh"
//----
#include "globals.hh"
#include "G4DynamicParticle.hh"
#include "G4IonTable.hh"
#include "G4CollisionOutput.hh"
```

```
#include "G4V3DNucleus.hh"
#include "G4Track.hh"
#include "G4Nucleus.hh"
#include "G4LorentzRotation.hh"
#include "G4ParticleDefinition.hh"
#include "G4ParticleTable.hh"
//AND->
#include "G4Version.hh"
//AND<-
//----new_anti
#include "G4AntiHe3.hh"
#include "G4AntiDeuteron.hh"
#include "G4AntiTriton.hh"
#include "G4AntiAlpha.hh"
#include <fstream>
#include <string>
//////
G4UrQMD1_3Model::G4UrQMD1_3Model(const G4String& nam)
:G4VIntraNuclearTransportModel(nam), verbose(0)
 if (verbose > 3) {
   G4cout << " >>> G4UrQMD1_3Model default constructor" << G4endl;
// Set the minimum and maximum range for the UrQMD model
// SetMinEnergy(100.0*MeV);
// SetMaxEnergy(200.0*GeV);
//----
                         ----new_off shell
// It would be better to turn "MASS-SHELL" OFF !!
// because NUCLEONS should be "ON -MASS-SHELL".
// However, we turn it on to get default UrQMD options!
   offshell=true;
11
 WelcomeMessage();
CurrentEvent=0;
InitialiseDataTables();
```

```
//
//
// Destructor
G4UrQMD1_3Model::~G4UrQMD1_3Model (){}
G4ReactionProductVector* G4UrQMD1_3Model::Propagate(G4KineticTrackVector*,
                         G4V3DNucleus* ) {
 return 0;
}
//
// ApplyYourself
// Member function to process an event, and get information about the
products.
 G4HadFinalState *G4UrQMD1_3Model::ApplyYourself (
 const G4HadProjectile &theTrack, G4Nucleus &theTarget)
//anti_new
// -----define anti_light_nucleus
const G4ParticleDefinition* anti_deu =
 G4AntiDeuteron::AntiDeuteron();
const G4ParticleDefinition* anti_he3=
 G4AntiHe3::AntiHe3();
const G4ParticleDefinition* anti_tri=
 G4AntiTriton::AntiTriton();
const G4ParticleDefinition* anti_alp=
 G4AntiAlpha::AntiAlpha();
//
// The secondaries will be returned in G4HadFinalState &theResult -
// initialise this. The original track will always be discontinued and
// secondaries followed.
11
 theResult.Clear();
 theResult.SetStatusChange(stopAndKill);
 G4DynamicParticle* cascadeParticle=0;
//
//
// Get relevant information about the projectile and target (A, {\bf Z},
energy/nuc,
// momentum, etc).
//
 const G4ParticleDefinition *definitionP = theTrack.GetDefinition();
```

```
G4int id=definitionP->GetPDGEncoding(); //get particle encoding
// -----
 G4int AP1 = G4lrint(AP);
 G4int ZP1 = G4lrint(ZP);
 G4int AT1 = G4lrint(AT);
 G4int ZT1 = G4lrint(ZT);
// G4cout<<"----ap1--="<<AP1<<"---zp1---="<<ZP1<<"---id-=="<<id<<
G4endl;
//
//
*******************
// The following is the parameters necessary to initiate Uinit() and
UrOMD()
// -----
 urqmdparams_.u_sptar=0; //!0= normal proj/target, 1=special proj/tar
 urqmdparams_.u_spproj=1; // projectile is a special particle
//new_anti
 if (AP1>1 ||definitionP==anti_deu ||definitionP==anti_he3
          ||definitionP==anti_tri ||definitionP==anti_alp)
     urqmdparams_.u_ap=AP1;
     urqmdparams_.u_zp=ZP1;
     urqmdparams_.u_spproj=0;
     } else if (id==2212) {
                                 //!proton
      urqmdparams_.u_ap=1;
      urqmdparams_.u_zp=1;
     } else if(id==-2212){
                               //! anti-proton
      urqmdparams_.u_ap=-1;
      urqmdparams_.u_zp=-1;
     } else if(id==2112){
                                //! neutron
      urqmdparams_.u_ap=1;
      urqmdparams_.u_zp=-1;
     } else if(id==-2112){
                                //! anti-neutron
      urqmdparams_.u_ap=-1;
      urqmdparams_.u_zp=1;
     } else if(id==211) {
                                //! pi+
      urqmdparams_.u_ap=101;
      urqmdparams_.u_zp=2;
     } else if(id==-211) {
                                //! pi-
      urqmdparams_.u_ap=101;
      urqmdparams_.u_zp=-2;
                               //! K+
   } else if(id==321) {
      urqmdparams_.u_ap=106;
      urqmdparams_.u_zp=1;
                               //! K-
   } else if(id==-321) {
      urqmdparams_.u_ap=-106;
```

```
urqmdparams_.u_zp=-1;
   urqmdparams_.u_ap=106;
       urqmdparams_.u_zp=-1;
   } else if(id==-130 || id==-310){ // ! K0bar
       urqmdparams_.u_ap=-106;
       urqmdparams_.u_zp=1;
   } else {
     G4cout << " Sorry, No definition for particle for UrQMD::"<<id<<
"found" << G4endl;</pre>
     //AND->
#if G4VERSION NUMBER>=950
     //New signature (9.5) for G4Exception
     //Using G4HadronicException
     throw G4HadronicException(__FILE__,_LINE__, "Sorry, no definition for
particle for UrQMD");
#else
   G4Exception(" ");
#endif
  //AND<-
   } //end if id
 urqmdparams_.u_at=AT1; // Target identified
 urqmdparams_.u_zt=ZT1;
//----
// identify Energy
//
     G4ThreeVector Pbefore = theTrack.Get4Momentum().vect();
     G4double T = theTrack.GetKineticEnergy();
     G4double E = theTrack.GetTotalEnergy();
     G4double TotalEbefore = E*AP1 +
    theTarget.AtomicMass(AT1, ZT1) + theTarget.GetEnergyDeposit();
11
     if (AP1>1) {
     urgmdparams_.u_elab=T/(AP1*GeV); // Units are GeV/nuc for UrQMD
     E = E/AP1;
                          // Units are GeV/nuc
     } else {
     urqmdparams_.u_elab=T/GeV; //units are GeV
     TotalEbefore = E +
     theTarget.AtomicMass(AT1, ZT1) + theTarget.GetEnergyDeposit();
     }
// identify impact parameter
urqmdparams_.u_imp=-(1.1 * std::pow(G4double(AT1),(1./3.))); //units are
in fm for UrQMD;
//----
if (CurrentEvent==0)
G4cout << "\n creation of table, wait-----"<<G4endl;
```

```
G4cout << "\n"<<G4endl;
G4int io=0;
uinit_ (&io);
G4cout << "\n end to create table "<<G4endl;
CurrentEvent=1;
//#ifdef debug G4UrQMD1 3Model
G4cout << "UrQMDModel running----- << G4endl;
urqmd_ ();
//#endif
//G4cout <<"Number of produced particles: " <<sys_.npart<<G4endl;</pre>
               = sys_.npart; //no of produced particles
G4int n
if (n<2)
G4cout <<"Number of produced particles is very low: "
<<sys_.npart<<G4endl;
//AND->
#if G4VERSION_NUMBER>=950
//New signature (9.5) for G4Exception
//Using G4HadronicException instead of base class
throw G4HadronicException(__FILE__,_LINE__, "Number of produced particle is
very low");
#else
G4Exception(" "); //stop
#endif
//AND<-
} else {
 for (G4int i=0; i<n; i++)</pre>
G4int pid=pdgid_ (&isys_.ityp[i], &isys_.iso3[i]);
// Particle is a final state secondary and not a nucleus.
// Determine what this secondary particle is, and if valid, load dynamic
// parameters.
//
 G4ParticleDefinition* pd=
 G4ParticleTable::GetParticleTable()->FindParticle(pid);
//---new_offshell
```

```
if (offshell)
//////----- true off-shell!! --//
     if (pd)
     {
      G4double px
                       = (coor_.px[i]+ffermi_.ffermpx[i])* GeV;
//units are in MeV/c for G4
       G4double py = (coor_.py[i]+ffermi_.ffermpy[i])* GeV;
G4double pz = (coor_.pz[i]+ffermi_.ffermpz[i])* GeV;
       G4double et
                    = (coor_.p0[i]) *GeV;
            -----Use "Lorentz vector"-----
    G4LorentzVector lorenzvec = G4LorentzVector(px,py,pz,et);
    cascadeParticle = new G4DynamicParticle(pd, lorenzvec); //
    theResult.AddSecondary(cascadeParticle);
    }
     }else{
/////-better get rid of "off-mass-shell" nucleons-----//
     if (pd)
     if (coor\_.fmass[i] >= 0.938) //units in GeV (UrQMD)
                    = (coor_.px[i]+ffermi_.ffermpx[i])* GeV;
      G4double px
//units are in MeV/c for G4
       G4double py = (coor_.py[i]+ffermi_.ffermpy[i])* GeV;
G4double pz = (coor_.pz[i]+ffermi_.ffermpz[i])* GeV;
       G4double et = (coor_.p0[i]) *GeV;
//
       G4double mass = (coor_.fmass[i]) *GeV;
11
             -----Use "Lorentz vector"-----
    G4LorentzVector lorenzvec = G4LorentzVector(px,py,pz,et);
    cascadeParticle = new G4DynamicParticle(pd, lorenzvec); //
    theResult.AddSecondary(cascadeParticle);
     } //if mass
     } else { //particles other than nucleons
                  = (coor_.px[i]+ffermi_.ffermpx[i])* GeV;
       G4double px
//units are in MeV/c for G4
       G4double py = (coor_.py[i]+ffermi_.ffermpy[i])* GeV;
```

```
= (coor_.pz[i]+ffermi_.ffermpz[i])* GeV;
      G4double pz
                    = (coor_.p0[i]) *GeV;
      G4double et
//
                      = (coor_.fmass[i])*GeV;
       G4double mass
//
    -----Use "Lorentz vector"-----
    G4LorentzVector lorenzvec = G4LorentzVector(px,py,pz,et);
    cascadeParticle = new G4DynamicParticle(pd, lorenzvec); //
    theResult.AddSecondary(cascadeParticle);
    } //else
} //if pd
    } //else for off-shell
} //for
} //if warning
//
if (verbose >= 3) {
   G4double TotalEafter = 0.0;
   G4ThreeVector TotalPafter;
   G4double charge = 0.0;
   G4int baryon = 0;
   G4int nSecondaries = theResult.GetNumberOfSecondaries();
   for (G4int j=0; j<nSecondaries; j++) {</pre>
    TotalEafter += theResult.GetSecondary(j)->
      GetParticle()->GetTotalEnergy();
    TotalPafter += theResult.GetSecondary(j)->
      GetParticle()->GetMomentum();
    G4ParticleDefinition *pd = theResult.GetSecondary(j)->
      GetParticle()->GetDefinition();
    charge += pd->GetPDGCharge();
    baryon += pd->GetBaryonNumber();
   } //for secondaries
   G4cout <<"----"
        <<"----"
   G4cout <<"Total energy before collision = " <<TotalEbefore ///MeV
        <<" MeV" <<G4endl;
```

```
G4cout <<"Total energy after collision = " <<TotalEafter //MeV
       <<" MeV" <<G4endl;
   G4cout <<"-----"<<G4endl;
   G4cout <<"Total momentum before collision = " <<Pbefore
       <<" MeV/c" <<G4endl;
   G4cout <<"Total momentum after collision = " <<TotalPafter
                                                //MeV
       <<" MeV/c" <<G4endl;
   G4cout <<"-----
   if (verbose >= 4) {
    G4cout <<"Total charge before collision = " <<(ZP+ZT)*eplus
        <<G4endl;
    G4cout <<"Total charge after collision = " <<charge
        <<G4endl;
    G4cout <<"----"<<G4endl:
    G4cout <<"Total baryon number before collision = "<<AP+AT
        <<G4endl;
    G4cout <<"Total baryon number after collision = "<<baryon
        <<G4endl;
    G4cout <<"-----"<<G4endl;
   } //if verbose4
   G4cout <<"----"
       <<"----"
       <<G4endl;
 } //if verbose3
return &theResult;
} //G4hadfinal
//----
//-----
//
// WelcomeMessage
//
void G4UrQMD1 3Model::WelcomeMessage () const
 G4cout <<G4endl;
 G4cout <<"
******************
     <<G4endl;
 G4cout <<" Interface to G4UrQMD_1.3
activated"
     <<G4endl;
 G4cout <<" Version number : 00.00.0B File date : 25/01/12"
<<G4endl;
 {\tt G4cout} <<" (Interface written by Kh. Abdel-Waged et al. for the
KACST/NCMP)"
     <<G4endl;
 G4cout <<G4endl;
 G4cout <<"
******************
```

```
<<G4endl;
 G4cout << G4endl;
 return;
}
void G4UrQMD1_3Model::InitialiseDataTables ()
{
//
//
// The next line is to make sure the block data statements are
// executed.
g4urqmdblockdata_ ();
//G4int ranseed=-time_ ();
G4int ranseed=1097569630;
G4cout <<"\n seed: "<<ranseed<<G4endl;</pre>
sseed_ (&ranseed);
loginit_();
}
```

11 G4UrQMD1_3Model.hh file

```
//
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// *
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// *
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//
#ifndef G4UrQMD1_3Model_hh
#define G4UrOMD1 3Model hh
응
11
// MODULE:
           G4UrQMD1_3Model.hh
// Version:
                 0.B
// Date: 20/10/12
// Author: Kh. Abdel-Waged and Nuha Felemban
// Revised by: V.V. Uzhinskii
                 SPONSERED BY
// Customer:
// Contract:
                 KACST/NCMP
                  31-465
// Contract:
양
// Class Description
//
```

```
// Class Description - End
//
#include "G4Nucleon.hh"
#include "G4Nucleus.hh"
#include "G4VIntraNuclearTransportModel.hh"
#include "G4KineticTrackVector.hh"
#include "G4FragmentVector.hh"
#include "G4ParticleChange.hh"
#include "G4ReactionProductVector.hh"
#include "G4ReactionProduct.hh"
#include "G4IntraNucleiCascader.hh"
#include "G4Track.hh"
#include <fstream>
#include <string>
/////
class G4UrQMD1_3Model : public G4VIntraNuclearTransportModel {
public:
   G4UrQMD1_3Model(const G4String& name = "UrQMD1_3");
   virtual ~G4UrQMD1_3Model ();
//
   G4double GetMinEnergy( const G4Material *aMaterial,
//
                             const G4Element *anElement ) const;
//
    G4double GetMaxEnergy( const G4Material *aMaterial,
//
                             const G4Element *anElement ) const;
  G4ReactionProductVector* Propagate(G4KineticTrackVector*
  theSecondaries, G4V3DNucleus* theTarget);
   virtual G4HadFinalState *ApplyYourself
      (const G4HadProjectile &, G4Nucleus &);
  private:
  G4int operator==(G4UrQMD1_3Model& right) {
   return (this == &right);
  G4int operator!=(G4UrQMD1_3Model& right) {
```

```
return (this != &right);
  G4int verbose; //print options
  G4bool offshell; //nucleons on- or off-shell
  void InitialiseDataTables();
 G4int CurrentEvent;
 private:
  void WelcomeMessage () const;
   G4HadFinalState theResult;
} ;
// inline G4double G4UrQMD1_3Model::GetMinEnergy( const G4Material *,
// const G4Element * ) const
// {return theMinEnergy;}
/////
//
// inline G4double G4UrQMD1_3Model::GetMaxEnergy( const G4Material *,
// const G4Element * ) const
// {return theMaxEnergy;}
/////
//
   #endif
```

12 G4UrQMD1_3Interface.hh file

```
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// * for the full disclaimer and the limitation of liability.
// *
// * This code implementation is the result of the scientific and *
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// *
// * Parts of this code which have been developed by Abdel-Waged
// * et al under contract (31-465) to the King Abdul-Aziz City for
// * Science and Technology (KACST), the National Centre of
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// **********************
//
#ifndef G4UrQMD1_3Interface_hh
#define G4UrQMD1_3Interface_hh
응
//
// MODULE:
           G4UrQMD1 3Model.hh
//
// Version:
                 0.B
// Date: 20/12/12
// Author: Kh. Abdel-Waged and Nuha Felemban
// Revised by: V.V. Uzhinskii
SPONSERED BY
              20/12/12
// Date:
                 KACST/NCMP
// Customer:
// Contract:
                   31-465
//
응
11
// Class Description
//
//
// Class Description - End
```

```
#include "globals.hh"
// coms
//
const G4int nmax = 500;
const G4int nspl = 500;
const G4int smax = 500;
// comres
const G4int minnuc=1;
const G4int minmes=100;
const G4int maxmes=132;
const G4int numnuc=16;
const G4int numdel=10;
const G4int maxnuc=minnuc+numnuc-1;
const G4int mindel=minnuc+maxnuc;
const G4int maxdel=mindel+numdel-1;
const G4int minres=minnuc+1;
const G4int maxres=maxdel;
const G4int numlam=13;
const G4int numsig=9;
const G4int numcas=6;
const G4int numome=1;
const G4int minlam=mindel+numdel;
const G4int maxlam=minlam+numlam-1;
const G4int minsig=minlam+numlam;
const G4int maxsig=minsig+numsig-1;
const G4int mincas=minsig+numsig;
const G4int maxcas=mincas+numcas-1;
const G4int minome=mincas+numcas;
const G4int maxome=minome+numome-1;
const G4int minbar=minnuc;
const G4int maxbar=maxome;
const G4int offmeson=minmes;
const G4int maxmeson=maxmes;
const G4int maxbra=11;
const G4int maxbrm=25;
const G4int maxbrs1=10;
const G4int maxbrs2=3;
const G4int nsigs = 10;
const G4int itblsz= 100;
const G4int maxreac = 13;
const G4int maxpsig = 12;
//
//comwid
//
const G4int
            widnsp=120;
const G4double mintab=0.10;
const G4double maxtab1=5.0;
const G4double maxtab2=50.0;
           tabver=9;
const G4int
//
// options
//
const G4int numcto=400;
const G4int numctp=400;
const G4int maxstables=20;
//
```

```
// colltab (collision tables)
const G4int ncollmax = 100;
// inputs
//
const G4int aamax=300;
// newpart (new created particles)
const G4int mprt=200;
const G4int oprt=2;
// boxinc
//
const G4int bptmax=20;
// This next line is required as the default version of FORTRAN LOGICAL is
// four bytes long, whereas storage for G4bool is one byte.
//
// comnorm
const G4int n = 400;
// comstr
const G4int njspin=8;
//iso
const G4int jmax=7;
// This next line is required as the default version of FORTRAN LOGICAL is
// four bytes long, whereas storage for G4bool is one byte.
//
typedef G4int ftnlogical;
// Standard common block for UrQMD
// Common options for coms.f
// 20 commons
//
//
struct ccurqmd13urqmdparams
G4int u_at,u_zt,u_ap,u_zp;
G4double u_elab,u_imp;
G4int u_sptar,u_spproj;
};
struct ccurqmd13sys
G4int
        npart, nbar, nmes, ctag, nsteps, uid_cnt,
        ranseed, event, ap, at, zp, zt, eos, dectag,
        nhardres, nsoftres, ndecres, nelcoll, nblcoll;
} ;
struct ccurqmd13rsys
G4double time, acttime, bdist, bimp, bmin, ebeam, ecm;
```

```
} ;
struct ccurqmd13comseed
  ftnlogical
            firstseed;
};
struct ccurqmd13logic
  ftnlogical
            lsct[nmax], logSky, logYuk, logCb, logPau;
};
struct ccurqmd13mdprop
G4double
        r0_t[nmax], rx_t[nmax], ry_t[nmax], rz_t[nmax];
};
struct ccurqmd13cuts
  G4double
          cutmax, cutPau, cutCb, cutYuk, cutSky, cutdww;
};
struct ccurqmd13spdata
  G4double
          spx[nspl], spPauy[nspl], outPau[nspl],
          spCby[nspl], outCb[nspl],
          spYuky[nspl], outYuk[nspl],
          spSkyy[nspl], outSky[nspl],
          spdwwy[nspl], outdww[nspl];
};
struct ccurqmd13isys
{
G4int spin[nmax], ncoll[nmax], charge[nmax], ityp[nmax],
      lstcoll[nmax],
      iso3[nmax], origin[nmax], strid[nmax], uid[nmax];
} ;
struct ccurqmd13coor
G4double
        r0[nmax], rx[nmax], ry[nmax], rz[nmax],
        p0[nmax], px[nmax], py[nmax], pz[nmax],
        fmass[nmax], rww[nmax], dectime[nmax];
};
struct ccurqmd13frag
{
```

```
G4double
        tform[nmax], xtotfac[nmax];
struct ccurqmd13aios
G4double
        airx[nmax], airy[nmax], airz[nmax],
        aipx[nmax], aipy[nmax], aipz[nmax],
        aorx [4][nmax], aory[4][nmax], aorz[4][nmax],
        aopx[4][nmax], aopy[4][nmax], aopz[4][nmax];
} ;
struct ccurqmd13pots
G4double
       Cb0, Yuk0, Pau0, Sky20, Sky30, gamSky,
       gamYuk, drPau, dpPau, gw, sgw, delr, fdel,
       dt, da, db, dtimestep;
};
struct ccurqmd13scoor
G4double
     rOs[smax], rxs[smax], rys[smax], rzs[smax],
     p0s[smax], pxs[smax], pys[smax], pzs[smax],
     sfmass[smax];
};
struct ccurqmd13sisys
  G4int
      sspin[smax], scharge[smax], sityp[smax], siso3[smax],
     suid[smax];
} ;
struct ccurqmd13ssys
 G4int nspec;
};
struct ccurqmd13rtdelay
G4double
        p0td[nmax][2],pxtd[nmax][2],pytd[nmax][2],pztd[nmax][2],
        fmasstd[nmax][2];
};
struct ccurqmd13itdelay
G4int
    ityptd[nmax][2],iso3td[nmax][2];
struct ccurqmd13svinfo
{
```

```
G4int
     itypt[2], uidt[2], origint[2], iso3t[2];
struct ccurqmd13ffermi
G4double
       ffermpx[nmax], ffermpy[nmax], ffermpz[nmax];
};
struct ccurqmd13peq
G4double peq1, peq2;
};
//
// Definition for Collision Term
// Commons comres
// 4 commons
struct ccurqmd13versioning
char versiontag[45];
};
struct ccurqmd13resonances
{
      G4double massres[maxbar-minbar+1], widres[maxbar-minbar+1];
      G4double massmes[maxmes-minmes+1];
      G4double widmes[maxmes-minmes+1];
      G4double mmesmn[maxmes-minmes+1];
      G4double branres[maxdel-minnuc][maxbra+1];
      G4double branmes[maxmes-minmes][maxbrm+1];
      G4double branbs1[maxsig-minlam][maxbrs1+1];
      G4double branbs2[maxcas-mincas][maxbrs2+1];
      G4int bs1type[maxbrs1+1][4],bs2type[maxbrs2+1][4];
      G4int lbs1[maxsig-minlam][maxbrs1+1];
      G4int lbs2[maxcas-mincas][maxbrs2+1];
      G4int lbm[maxmes-minmes][maxbrm+1];
      G4int jres[maxbar-minbar+1];
      G4int jmes[maxmes-minmes+1];
      G4int lbr[maxdel-minnuc][maxbra+1];
      G4int brtype[maxbra+1][4];
      G4int pares[maxbar-minbar+1],pames[maxmes-minmes+1];
      G4int bmtype[maxbrm+1][4];
      G4int isores[maxbar-minbar+1], isomes[maxmes-minmes+1];
      G4int strres[maxbar-minbar+1], strmes[maxmes-minmes+1];
      G4int mlt2it[maxmes-minmes];
};
struct ccurqmd13sigtabi
G4int sigmaln[maxreac][2][maxpsig];
G4int sigmainf[20][nsigs];
```

```
};
struct ccurqmd13sigtabr
G4double sigmas[itblsz][nsigs], sigmascal[5][nsigs];
//comwid
struct ccurqmd13decaywidth
G4double tabx [widnsp];
G4double fbtaby [2] [maxbar-minbar+1] [widnsp];
G4double pbtaby[maxbra+1][maxbar-minbar+1][2][widnsp];
G4double fmtaby [2][maxmes-minmes+1][widnsp];
G4double pmtaby [maxbrm+1][maxmes-minmes+1][2][widnsp];
G4int
        wtabflg;
};
struct ccurqmd13brwignorm
G4double bwbarnorm[maxbar-minbar+1];
G4double bwmesnorm[maxmes-minmes+1];
struct ccurqmd13xsections
G4double tabxnd [widnsp];
G4double frrtaby[maxdel-1][2][2][widnsp];
};
struct ccurqmd13tabnames
char tabname[77];
};
//----
//
// options
//
struct ccurqmd13options
G4int CTOption[numcto];
G4double CTParam[numctp];
};
struct ccurqmd13optstrings
char ctodc[numcto][2];
char ctpdc[numctp][2];
struct ccurqmd13loptions
ftnlogical
```

```
fixedseed, bf13, bf14, bf15, bf16, bf17, bf18, bf19,
         bf20;
};
struct ccurqmd13stables
G4int nstable;
G4int stabvec[maxstables];
//colltab
struct ccurqmd13colltab
G4double
           cttime[ncollmax+1],ctsqrts[ncollmax],
           ctsigtot[ncollmax],tmin;
G4int
           cti1[ncollmax],cti2[ncollmax];
G4int.
           nct,actcol;
ftnlogical
           ctvalid[ncollmax];
G4int
           ctsav[ncollmax];
G4int
           nsav,apt;
G4double
           ctcolfluc[ncollmax];
};
// inputs
//
struct ccurqmd13inputs
G4int nevents, spityp[2], prspflg;
G4int trspflg, spiso3[2], outsteps, bflag, srtflag, efuncflag;
G4int nsrt, firstev, npb;
};
struct ccurqmd13input2
G4double srtmin, srtmax, pbeam, betann, betatar, betapro;
G4double pbmin, pbmax;
} ;
struct ccurqmd13protarints
{
G4int pt_iso3[2][aamax],pt_ityp[2][aamax],pt_spin[2][aamax];
G4int pt_charge[2][aamax],pt_aa[2],pt_uid[2][aamax];
struct ccurqmd13protarreals
G4double pt_r0[2][aamax],pt_rx[2][aamax],pt_ry[2][aamax],
         pt_rz[2][aamax],pt_fmass[2][aamax],pt_dectime[2][aamax];
G4double pt_p0[2][aamax],pt_px[2][aamax],pt_py[2][aamax],
```

```
pt_pz[2][aamax];
G4double pt_rho[2][aamax];
G4double pt_pmax[2][aamax];
};
// newpart
struct ccurqmd13inewpart
G4int itypnew[mprt], i3new[mprt], itot[mprt], inew[mprt], nexit;
G4int iline, strcount, pslot[oprt], nstring1, nstring2,
      sidnew[mprt],itypold[oprt],iso3old[oprt];
};
struct ccurqmd13rnewpart
G4double pnew[mprt][5], xnew[mprt][4], betax, betay, betaz,
          pold[oprt][5],p0nn,pxnn,pynn,pznn,pnn, mstring[2],
          pnnout,xtotfacold[oprt];
} ;
struct ccurqmd13fnewpart
G4double leadfac[mprt];
} ;
//
// boxinc
//
struct ccurqmd13boxic
G4int cbox;
G4int boxflag;
G4int mbox;
G4int bptityp[bptmax],bptiso3[bptmax],bptpart[bptmax];
G4int edensflag, para, solid, mbflag, mtest;
struct ccurqmd13boxrc
G4double bptpmax[bptmax];
G4double edens;
G4double lbox;
G4double lboxhalbe;
G4double lboxd;
G4double mbp0, mbpx, mbpy, mbpz;
};
// comnorm
struct ccurqmd13normsplin
G4double x_norm[n][4],y_norm[n][4];
G4double y2a[n][4], y2b[n][4], dx;
// comstr
struct ccurqmd13FRGSPA
G4double
          pjspns, pmix1s[njspin][3], pmix2s[njspin][3]
          , pbars, parqls, parrs;
struct ccurqmd13FRGCPA
G4double
```

```
pjspnc, pmix1c[njspin][3], pmix2c[njspin][3], pbarc;
} ;
struct ccurqmd13coparm
G4double parm[njspin];
struct ccurqmd13const
G4double pi;
} ;
//// freezeout
struct ccurqmd13frcoor
G4double frr0[nmax], frrx[nmax], frry[nmax], frrz[nmax],
         frp0[nmax], frpx[nmax], frpy[nmax], frpz[nmax];
} ;
// input
struct ccurqmd13values
G4double valint[1];
} ;
// cascinit
struct ccurqmd13ini
ftnlogical bcorr;
} ;
// iso
struct ccurqmd13factorials
G4double logfak[101];
};
struct ccurqmd13cgks
{
G4double cgktab[jmax+1][2*jmax+1][jmax+1][jmax+1];
} ;
// UrQMD
//
struct ccurqmd13energies
G4double ekinbar, ekinmes, esky2, esky3,
         eyuk, ecb, epau;
};
// urqmd
extern "C"
extern int time_ ();
extern void loginit_();
extern void sseed_ (int*);
extern void uinit_ (int*);
```

```
extern void urqmd_ ();
extern int pdgid_ (int*, int*); //ityp
extern void g4urqmdblockdata_ ();
// urqmdparams
extern struct ccurqmd13urqmdparams urqmdparams_;
//coms
extern struct ccurqmd13sys
                             sys_;
extern struct ccurqmd13rsys
                              rsys_;
extern struct ccurqmd13comseed comseed_;
extern struct ccurqmd13logic logic_;
extern struct ccurqmd13mdprop mdprop_;
extern struct ccurqmd13cuts
                             cuts_;
extern struct ccurqmd13spdata spdata_;
extern struct ccurqmd13isys isys_;
extern struct ccurqmd13coor
                             coor ;
extern struct ccurqmd13frag frag_;
extern struct ccurqmd13aios aios_;
extern struct ccurqmd13pots
                             pots_;
extern struct ccurqmd13scoor scoor_;
extern struct ccurqmd13sisys sisys_;
extern struct ccurqmd13ssys
                             ssys_;
extern struct ccurqmd13rtdelay rtdelay_;
extern struct ccurqmd13itdelay itdelay_;
extern struct ccurqmd13svinfo svinfo_;
extern struct ccurqmd13ffermi ffermi_;
extern struct ccurqmd13peq
//comres
extern struct ccurqmd13versioning versioning_;
extern struct ccurqmd13resonances resonances_;
extern struct ccurqmd13sigtabi sigtabi_;
extern struct ccurqmd13sigtabr sigtabr_;
//comwid
extern struct ccurqmd13decaywidth decaywidth_;
extern struct ccurqmd13brwignorm brwignorm_;
extern struct ccurqmd13xsections xsections_;
extern struct ccurqmd13tabnames tabnames_;
//options
extern struct ccurqmd13options
                               options_;
extern struct ccurqmd13optstrings optstrings_;
extern struct ccurqmd13loptions loptions_;
extern struct ccurqmd13stables
                                 stables ;
//colltab
extern struct ccurqmd13colltab colltab_;
//inputs
extern struct ccurqmd13inputs
                                 inputs_;
extern struct ccurqmd13input2
                                input2_;
extern struct ccurqmd13protarints protarints_;
extern struct ccurqmd13protarreals protarreals_;
//newpart
extern struct ccurqmd13inewpart
                                 inewpart_;
extern struct ccurqmd13rnewpart rnewpart_;
extern struct ccurqmd13fnewpart
                                  fnewpart_;
//bocinc
extern struct ccurqmd13boxic
                                 boxic_;
extern struct ccurqmd13boxrc
                                  boxrc_;
// comnorm
struct ccurqmd13normsplin normsplin_;
//comstr
```

```
struct ccurqmd13FRGSPA FRGSPA_;
struct ccurqmd13FRGCPA FRGCPA_;
struct ccurqmd13coparm coparm_;
struct ccurqmd13const const_;
// freezeout
struct ccurqmd13frcoor frcoor_;
//urqmd
extern struct ccurqmd13energies energies_;
//input
extern struct ccurqmd13values values_;
// cascinit
extern struct ccurqmd13ini ini_;
//iso
extern struct ccurqmd13factorials factorials_;
extern struct ccurqmd13cgks cgks_;
}
#endif
```

13 References

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