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Monte Carlo Simulation Tool Installation and Operation Guide

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NATIONAL LABORATORY

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Richland, Washington 99352

Summary

This document provides information on software and procedures for Monte Carlo simulations based on the Geant4 toolkit, the ROOT data analysis software and the CRY cosmic ray library. These tools have been chosen for its application to shield design and activation studies as part of the simulation task for the Majorana Collaboration. Included in this document are instructions for installation, operation and modification of the simulation code in a high cyber-security computing environment, such as the Pacific Northwest National Laboratory network. It is intended as a living document, and will be periodically updated. It is a starting point for information collection by an experimenter, and is not the definitive source. Users should consult with one of the authors for guidance on how to find the most current information for their needs.

Acronyms and Abbreviations

CRY	Cosmic-Ray Shower Library
Geant4	Geometry and Transport 4
HPGe	high-purity germanium
LHC	Large Hadron Collider
MJD	MAJORANA DEMONSTRATOR
PNNL	Pacific Northwest National Laboratory

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1.0 Introduction

Monte Carlo simulation tools play a key role in the design of detectors and radiation shield configurations. Monte Carlo methods use stochastic simulations, meaning that they use random numbers and probability statistics to examine a system. Geant4 is a tool kit that uses Monte Carlo methodology to simulate the passage of particles through matter. It has useful applications, in particle physics, nuclear physics, accelerator design, space engineering, and medical physics. Geant4 was specifically designed, using the C++ programming language, "to expose the physics models utilized, to handle complex geometries, and to enable its easy adaption for optimal use in different sets of applications" [Agostinelli et al. 2003]. In this report, the Geant4 based application will be set up to simulate hadronic processes to be applied to activation studies and transport shield design for the MAJORANA DEMONSTRATOR (MJD) [Aalseth et al. 2010].

When modeling hadronic interactions, the Geant4 toolkit spans over 15 orders of magnitude in energy, from thermal for neutrons interactions, to 7 TeV for Large Hadron Collider (LHC) experiments, and even higher for cosmic ray physics. The toolkit includes evaluation of cross-sections for the scattering of any incident meson or baryon off any stable or long lived nuclear isotope target; it also then includes models of these interactions. To allow for greater flexibility when running applications, the hadronic process category in Geant4 is made up of several families of classes. The *processes* class defines each process and provides connections to the cross-sections and models used in the process. The *management* class provides common properties of hadronic interactions and steering mechanisms of appropriate interactions. The *cross-section* class includes cross-section data and appropriate calculation methods. The *stopping* class provides information about particles stopping or at rest. The *models* class implements final state generation of a process for particles within specified energy ranges and contains sub-systems such as low energy, high energy, generator, radioactive decay, etc., and lastly, the *utility* class contains standardized computational methods for use by the models. The many options available in Geant4 allow for an application to be chosen that is well suited in energy range and particle types, among other characteristics, to create an appropriate simulation of the system and its interactions. [Agostinelli et al. 2003].

Geant4 was originally written for use under the Linux operating system environment, mainly using compiling utilities such as *make*. In this document, instructions are provided for the installation of Geant4 on the Windows operating system, and some notes on operating under the Linux environment. Windows has been selected to be the base system for this work simply because it is the widely available operating system at PNNL. A different operating system will require a PNNL user to undergo an installation process or the purchase of extra computing equipment. An example of the application of Geant4's Monte Carlo methods is shield design. Figure 1 shows a graphic capture of a 10,000 particle run through a 30 cm slab of concrete, under the Windows environment. Geant4 can display a live, three-dimensional image of the simulations being run by CRYbench (a cosmic ray code), or any other user application. Figure 2 shows a 3D screen capture generated by Geant4.

The first parts of this document, Sections 2 through 4, present a brief description of the tool set and some considerations when working under a highly secured computer environment. Appendices A and B present the installation and operation procedures, respectively, of a Geant4 based application in a step-by-step format.

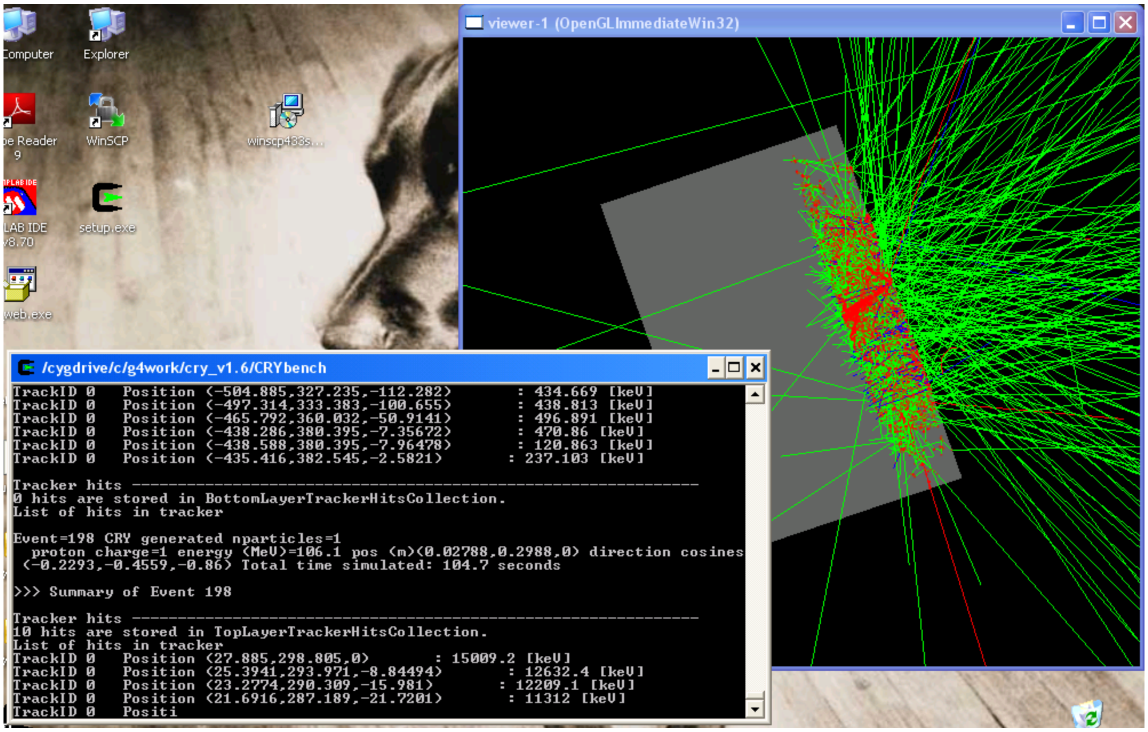

Figure 1. Screen shot of a 10,000 proton run through a 30 cm slab of concrete on a Windows desktop

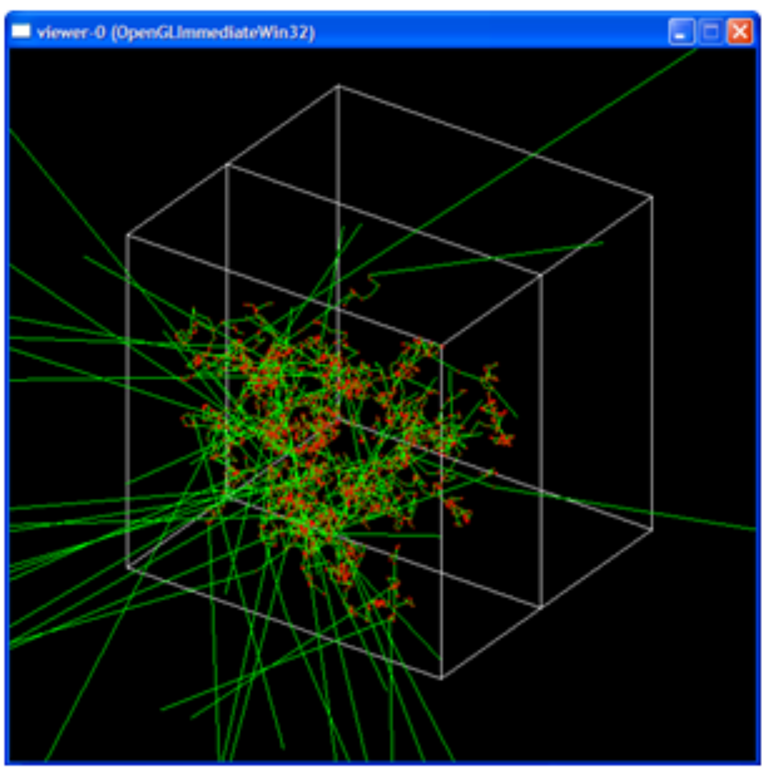

Figure 2. Geant4 simulation viewer screen shot

2.0 Cosmic ray shielding studies tool description

In order to have a complete Monte Carlo simulation tool, several pieces of software must be used, including at a minimum one for the physics simulation, one for the radiation source model and one for the data analysis. The sample tool developed by Majorana group at PNNL is used in this document as a reference design [Aguayo et al. 2010]. This tool is intended to simulate hadronic interaction of cosmic rays impinging on a radiation shield. The tool has three components:

- Geant4 Toolkit
- CRY library
- ROOT data analysis tool

Table 1. Software versions used in the development of this guide

	Version	Source
Geant4	9.3.4	Geant4.cern.ch
CRY	1.6	www.llnl.gov
ROOT	3.10/02	www-glast.slac. stanford.edu/software/root /walkthrough/install.htm
Cygwin	1.7.9-1	www.cygwin.com
Microsoft Visual Studio	2010 Express	http://www.microsoft.com/visualstudio/en-us/products/2010-editions/visual-cpp-express

In Table 1, the toolset for a Monte Carlo application based on Geant4 run in a Windows computing environment is described. The entries in the last two rows are required to run Geant4 under a Windows environment. The scripts necessary to reproduce our results, or in particular, root scripts, are available to future users at PNNL from the authors.

3.0 Installation notes for the PNNL secured network

Cyber security is a very complex issue at a national laboratory, and we must work in a secure computing environment. This section describes the considerations that were taken into account when installing the different software pieces that make up a Geant4 based simulation tool.

3.1 Cygwin installation

Cygwin is a program that executes a command prompt to emulate a Linux operating system. Cygwin allows a user who is in a Windows operating system environment to run applications that demand a Linux OS, and any other tool that operates under Linux. To install Cygwin, you will want to follow the instructions provided by Stanford Linear Accelerator web page [SLAC 2011]. A thorough explanation is given on the installation steps for Cygwin.

3.2 Geant 4 installation

The Geant4 installation instructions presented in this document are based on the instructions found in [SLAC 2011].

3.3 CRY installation

The Cosmic-Ray Shower Library (CRY) is a free software library produced by the Lawrence Livermore National Laboratory that is used to generate correlated cosmic-ray particle showers as either a transport or detector simulation code. It generates shower information for muons, neutrons, protons, electrons, and photons at one of three elevations (sea level, 2100 m and 11300 m) within a specified area (up to 300 m by 300 m). CRY also generates the time of arrival and the zenith angle of the secondary particles [Hagmann 2011].

The installation of CRY on Windows machines requires dealing with several security issues in the PNNL computing environment. While installing CRY, make sure to have Administrative Privileges for the computer to insure that you can run Cygwin elevated. To obtain Administrative Privileges at PNNL, email the Property Owner of the computer and have them send an email to the Help Desk (help.desk@pnl.gov) asking them to give you Administrative Privileges, make sure to include the Property Number of the computer. Then call the Help Desk (375-6789) and ask them to set up Administrative Privileges on the computer. After restarting your computer, and/or logging off and back on, you should now be able to right click on Cygwin and see the option "PM Run Elevated."

3.4 ROOT installation

ROOT [ROOT 2011] is a data analysis toolkit. In conjunction with Geant4, ROOT is used to create spectra of the data that is simulated with the toolkit. The large amount of data generated by these applications makes the use of a data analysis tools imperative. ROOT was developed at CERN to address the data analysis challenges of large data sets. To install version 5.30 of ROOT, go to the website http://root.cern.ch and select 'Download.' If you select the MSI installer, environment variables will be automatically set on installation. If you use tar, untar the file in C:/Root and follow the instructions to manually set the environment variables.

Figure 3 shows an example of a Muon spectrum generated using ROOT following the procedure described in Appendix B.

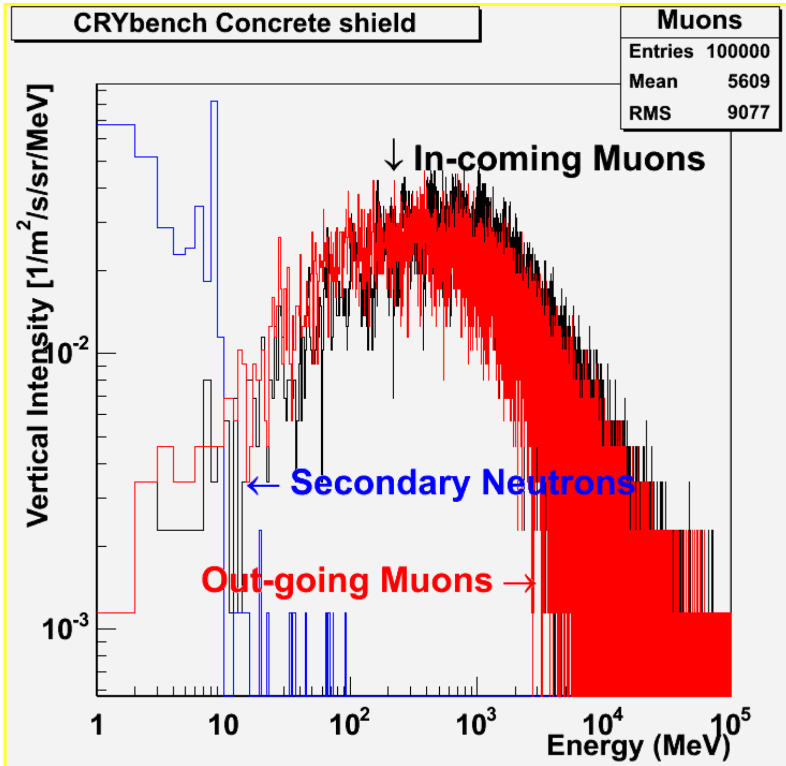

Figure 3. This is an example of a CRYbench spectrum of the simulation results of muons through 80 cm of concrete created using Root.

4.0 Conclusions and future work

The process for installing a state-of-the-art simulation toolkit, Geant4, in a highly secured computer environment under a Windows operating system has been described in detail. The result is a more efficient installation process for Geant4 users at PNNL without having to repeat the research performed by our group to get the tool up and running. This guide is intended to be a living document, in particular Appendix C, which will contain feedback from users. The code has been tested in Windows and Linux environments with equal results. Further work would involve the development of procedures to install Geant4 in a cluster and run several simulations using scripting techniques. We also plan to extend the guide to cover issues such as uninstalling the toolkit.

5.0 References

1. [Aalseth 2010] Aalseth CE, Aguayo E, Amman M, Avignone III FT, Backe HO, Bai X, Barabash AS, Barbeau PS, Bergevin M, Bertrand FE, Boswell M, V. Brudanin, W. Bugg, T.H. Burritt, M. Busch , G. Capps, Y-D. Chan, J.I. Collar, R.J. Cooper, R. Creswick, J.A. Detwiler, J. Diaz, P.J. Doe, Yu. Efremenko, V. Egorov, H. Ejiri, S.R. Elliott, J. Ely, J. Esterline , H. Farach, J.E. Fast, N. Fields, P. Finnerty , F.M. Fraenkle , V.M. Gehman, G.K. Giovanetti , M. Green, V.E. Guiseppe, K. Gusey, A.L. Hallin, G.C. Harper, R. Hazama, R. Henning , A. Hime, H. Hong, E.W. Hoppe, T.W. Hossbach, S. Howard, M.A. Howe , R.A. Johnson, K.J. Keeter, M. Keillor, C. Keller, J.D. Kephart, M.F. Kidd, A. Knecht, O. Kochetov, S.I. Konovalov, R.T. Kouzes, B.H. LaRoque, L. Leviner , J.C. Loach, P.N. Luke, S. MacMullin , M.G. Marino, R.D. Martin, D. Medlin, D.-M. Mei, H.S. Miley, M.L. Miller, L. Mizouni, A.W. Myers, M. Nomachi, J.L. Orrell, D. Peterson, D.G. Phillips II , A.W.P. Poon, O. Perevozchikov, G. Perumpilly, G. Prior, D.C. Radford, D. Reid, K. Rielage, R.G.H. Robertson, L. Rodriguez, M.C. Ronquest, H. Salazar, A.G. Schubert, T. Shima, M. Shirchenko, V. Sobolev, D. Steele, J. Strain , G. Swift , K. Thomas, V. Timkin, W. Tornow , T.D. Van Wechel, I. Vanyushin, R.L. Varner, K. Vetter, K. Vorren , J.F. Wilkerson, B.A. Wolfe, W. Xiang, E. Yakushev, H. Yaver, A.R. Young , C.-H. Yu, V. Yumatov and C. Zhang (The Majorana Collaboration). 2010a. "The MAJORANA Experiment*"*. In *Proceedings of the Neutrino Oscillation Workshop (NOW2010), September 4-11, 2010, Conca Specchiulla, Italy.*
2. [Agostinelli et al. 2003] Agostinelli, S "Geant4 – a simulation toolkit", Nucl. Instr. And Meth. A 506, 2003 pp. 250-303 (2003)
3. [Aguayo et al. 2010] Aguayo Navarrete E, Kouzes RT, Orrell JL, 2010. *Monte Carlo Simulations of Cosmic Ray Hadronic Interactions*. PNNL-20401, Pacific Northwest National Laboratory, Richland, WA.
4. [Hagmann 2011] Hagmann C, Lange D, Wright D "*Cosmic-ray Shower Library (CRY)"* LLNL UCRL-TM-229453 Lawrence Livermore National Laboratory. Avaliable at http://nuclear.llnl.gov/simulation/cry.pdf
5. [SLAC 2011] http://geant4.slac.stanford.edu/installation/. Accessed April 1, 2011
6. [ROOT 2011] ROOT European Center for Nuclear research (CERN) Accessed April 1, 2011 at http://*root.cern*.ch/root/*Reference*

Appendix A: Installation Procedures

A.1 Cygwin installation procedure

The instructions provided by Stanford do not cover a few PNNL security specific problems that a user could run into while trying to install Cygwin. It is possible to go through this section of the installation without running into problems until a later section, which leads to a lot of backtracking and lost time.

Before installing Cygwin, *make sure you have administrative privileges* on the computer on which you are installing it. Once you have been granted administrative privileges (you will need to log off and then log back on in order for this to take effect) be sure to take care of the installation as soon as possible, as these privileges can last a couple weeks, or only a couple hours. Aside from issues dealing with administrative privileges, there are not any other common problems with installing Cygwin, and the instructions from Stanford should walk you through to completion. Once installed, you will need to run Cygwin elevated. Go to Start →Run Program and type \pnl10\\hdtools\Elevated Shortcuts. Double click on the explorer icon and go to C:\Documents and Settings\All Users\ Desktop. If the Cygwin icon does not appear here, contact the Help Desk. Once the Cygwin icon does appear in this directory, you can open Cygwin from here each time you use it.

A.2 Geant4 installation procedure

To begin the Geant4 installation process, go to http://geant4.slac.stanford.edu/installation/, which is the website for the Stanford Linear Accelerator. Click on installing Geant4.9.4.p01 on Windows using Microsoft Visual C++ and Cygwin. From there, click on Getting Geant4. Installing Geant4 will take awhile. Expect to spend a few hours doing this.

A.3 CRY Installation Procedure

Step 1: Go to http://nuclear.llnl.gov/simulation/main.html

Step 2: Under the CRY section, click on 'Install from Source' (version 1.6)

Step 3: Save the file (cry_v1.6.tar.gz) to the g4work directory (c:/g4work). (If it automatically saves to some default directory you will need to copy/cut it and paste it in the c:/g4work directory.)

Step 4: Open Cygwin, either right click "PM Run Elevated" or open through Elevated Shortcuts.

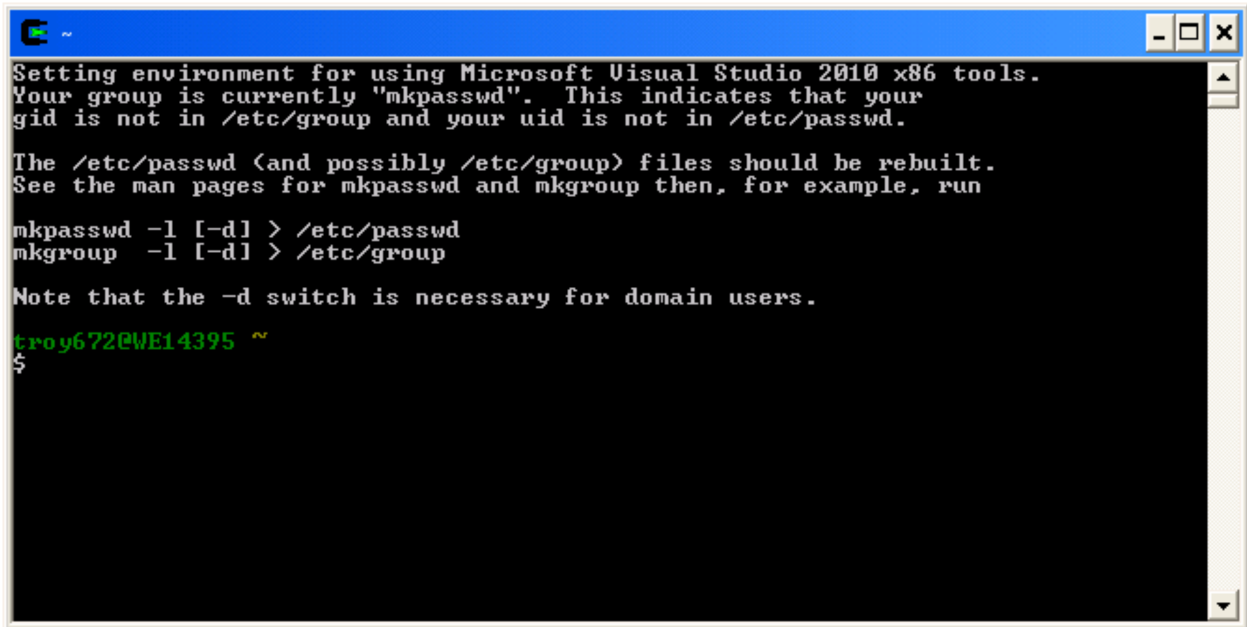

Figure 4. This is what Cygwin should look like when run elevated. (The lines about "mkpasswd" and "mkgroup" and the "-d switch" are not generally present when opened, however if they appear on you Cygwin, they will not affect the preformance).

Step 5: Type and enter the two individual commands below:

export G4WORKDIR=C:/g4work
source C:/Geant4/geant4_9_4_p01/env.sh

you must start with these commands each time a new Cygwin window is opened

Step 6: Go to the root dir. Enter (cd ..) twice to get there. **There is a space between the "d" and the period!!**

Step 7: Go to cygdrive/c/g4work (enter 'cd cygdrive/c/g4work' without quotes)

Step 8: Unpack the '.tar' file (enter 'tar -zxvf cry_v1.6.tar.gz' without quotes)

Step 9: Enter 'cd cry_v1.6/' without quotes (moves down to cry_1.6 directory)

Step 10: Before proceeding, several '.cc' files in the library must have two lines of source code added in order for CRY to load properly. Go to Windows directory navigation ('My Computer' for example), and navigate to the c:/g4work/cry_v1.6/src folder. The folder should include a number of pairs of '.cc' (C++) and '.h' (header) files.

Step 11: Thirteen of the '.cc' files (12 in the src folder, 1 in the test folder) need to be edited, they are listed below:

In the c:/g4work/cry_v1.6/src folder (12 files to edit), listed in the order they appear in the directory:

1. cry_fort.cc
2. CRYAbsFunction.cc
3. CRYAbsParameter.cc

4. CRYBinning.cc
5. CRYCosLatitudeFunction.cc
6. CRYData.cc
7. CRYFunctionDict.cc
8. CRYGenerator.cc
9. CRYParameter.cc
10. CRYParamI.cc
11. CRYPdf.cc
12. CRYSetup.cc

In the c:/g4work/cry_v1.6/test file (1 file to edit):

1. testMain.cc

At the top of each of these '.cc' files, there will be a list of commands that are in the format of '#include <stuff.h>' (where 'stuff' represents a variable). You will **add two command lines**: '#include <stdlib.h>' and '#include <string.h>', without the quotes, at the end of the '#include' command stack in each file.

The command stack will now look like:

```
#include <stuff.h>
#include <stdlib.h>
#include <string.h>
```

Depending on what version of Windows you are running, you may be able to do this in a WordPad (right click on the file, open with WordPad), but BE SURE to resave as '.cc' file, and NOT as a text file. If you cannot save as a '.cc' file, then you will have to open each of the '.cc' files in Microsoft Visual C++ and edit then resave the files there. Be sure to make this change in each of the above files.

Step 12: Go back to Cygwin and enter 'make' without quotes (NOT 'gmake')

Step 13: Go to the geant sub directory of cry_v1.6 (cd geant)

Step 14: Setup (source ../setup)

Step 15: Type Make (make) You will get an error: "Fatal error c1083: Cannot open include file: 'CRYSetup.h': No such file or directory". You will also get errors about G4PolarizedComptonScattering and G4MultipleScattering

Step 16: Go to C:\g4work\cry_v1.6\geant\src and open PhysicsList.cc with WordPad

Step 17: Using control + F, search for G4PolarizedComptonScattering. In front of every line that contains G4PolarizedComptonScattering, type "//" (without quotes) to keep the command from being executed, this will take care of the errors about G4PolarizedComptonScattering.

Step 18: Using control + F, search for G4MultipleScattering. If front of ever line that contains G4MultipleScattering, type "//" (without quotes) to keep the command from being executed; this will take care of the errors about G4MultipleScattering.

Step 19: Go to and open the setup.sh file found at C:\g4work\cry_v1.6 (Make sure to open in WordPad, NOT notepad…there is a difference!)

Step 20: Where you see "export CRYHOME=" make it look like
export CRYHOME=c:/g4work/cry_v1.6

Step 21: Where you see "export CRYDATAPATH=" make it look like
export CRYDATAPATH=c:/g4work/cry_v1.6/data

Save the file; this will take care of the error c1083.

Step 22: Back at your Cygwin window, enter the line export CRYHOME=c:/g4work/cry_v1.6

Step 23: Then enter CRYDATAPATH=c:/g4work/cry_v1.6/data

Step 24: Make (make), you'll get another error "error c2061: syntax error: identifier 'G4UItcsh'"

Step 25: Go to C:\g4work\cry_v1.6\geant in Windows and open the cosmic.cc file.

Step 26: At the bottom of the file, you'll see three lines of commands:

```
G4UIsession * theUIsession = new G4UIterminal(new G4UItcsh);
theUIsession->SessionStart();
delete theUIsession;
```

In front of **each** line, type "//" This will keep those commands from being executed.

Step 27: Save those changes, go back to Cygwin, and type make again (make)

Step 28: You get more errors, again.

Step 29: Open PrimaryGeneratorAction.cc located in C:\g4work\cry_v1.6\geant\src

Step 30: Near the top of the coding, under the command "using namespace std;" insert the commands below:

```
#include "CRYSetup.cc"
#include "CRYGenerator.cc"
#include "CRYParticle.cc"
#include "CRYUtils.cc"
#include "CRYPdf.cc"
#include "CRYBinning.cc"
#include "CRYPrimary.cc"
#include "CRYWeightFunc.cc"
#include "CRYData.cc"
#include "CRYAbsParameter.cc"
#include "CRYAbsFunction.cc"
#include "CRYFunctionDict.cc"
#include "CRYCosLatitudeFunction.cc"
#include "CRYPrimarySpectrumFunction.cc"
#include "CRYParamI.cc"
#include "CRYParameter.cc"
```

Save and go back to Cygwin.

Step 31: Now run make again (make), and there are going to be more errors. It will say something like “c:/g4work/cry_v1.6/src\CRYGenerator.cc(323) : error c2065: ‘M_PI’ : undeclared identifier.”

This error deals with “M_PI” the value of Pi, since Geant 4.9.4 is newer than CRY_v1.6, sometimes the coding doesn’t match up, and this case is one of them. So in all the files in which this error occurs, you will need to go in manually and replace “M_PI” with the value “3.1416.”

The error points you to the file that you must edit. In the case mentioned above, you would need to go to c:/g4work/cry_v1.6/src and open the file CRYGenerator.cc in Microsoft WordPad. You can expedite your search by hitting control + F and searching for “M_PI”

You will find it at the bottom of the file in a command line

```
double tphi=_utils->randomFlat()*2.0*M_PI;
```

Change that line to…

```
double tphi=_utils->randomFlat()*2.0*3.1416;
```

You will repeat this step for the other files with “Error: M_PI” (there should be three files with that error: CRYGenerator.cc, CRYPrimary.cc, and CRYCosLatitudeFunction.cc)

You will also run into an error that says…

“c:/g4work/cry_v1.6/src\CRYPdf.cc(259) : Error: c2668: ‘sqrt’…”

Go to that folder and search for this line

```
int divit=int(sqrt(((*_cdfs)[bin].size()));
```

Change this line to

```
int divit=int(sqrt(double((*_cdfs)[bin].size()));
```

Step 32: Now you can type “make” for the final time (make). There shouldn’t be any errors this time!

Step 33: Now go back a directory to /cygdrive/c/g4work/cry_v1.6/ by typing (cd ..). You are now ready to import your specific application into the cry_v1.6 folder and after installing ROOT you will be ready to run the application.

A.4 Root Installation

The MSI installer for the latest version of ROOT (5.30) will automatically set all necessary environment variables. If you need to install the tar file manually, here is the procedure:

Step 1: Download the .tar file from http://root.cern.ch/drupal/content/production-version-530.

Step 2: Move the file to C:/ROOT, and create the folder if necessary.

Step 3: From a fresh Cygwin window, as an administrator, change to the C:/ROOT folder and unpack the .tar file (enter ‘tar –zxvf (filename).tar.gz’)

Step 4: Call the file C:/ROOT/bin/thisroot.bat, to set up the required environment variables.

Step 5: To check that the variables have been set, go to Control Panel -> System -> Advanced System Settings -> Environment Variables, and check that under User variables, the variable PATH has the value C:\root\bin; %ROOTSYS%/bin; %ROOTSYS%/lib. Then check that the variable ROOTSYS has the value C:\root\; %ROOTSYS%/bin; %ROOTSYS%/lib. Change them to these values if necessary.

Step 6: Open ROOT by typing 'root' (without quotes) from a Cygwin terminal.

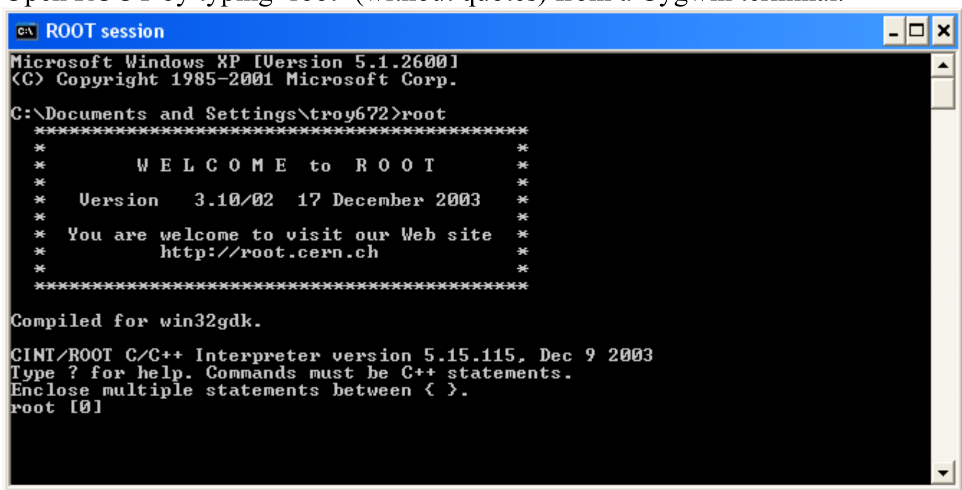

Figure 5. Screen shot of ROOT.

Appendix B: Operation Procedures

B.1 Running a Geant4 application

Geant4 operates similarly on Linux as on Windows, with just a few differences in commands. The instructions provided are specifically for simulating the shielding effects of various materials and thicknesses on neutrons, protons, and muons using CRYbench. CRYbench is a Geant4 program for cosmic radiation that simulates the particle flux through a simple slab of material. However, other simulations can be done by modifying the appropriate files accordingly and using the same steps provided with a few adjustments. It does not come packaged with the standard CRY library and must be downloaded separately.

B.1.1 Operating Geant4 under Linux

Step 1: Open a terminal located under Applications → System Tools → Terminal

Step 2: ENTER: cd G4work/cry_v1.5/CRYbench

Step 3: ENTER: export G4WORKDIR=~/G4work

Step 4: ENTER: export LD_LIBRARY_PATH=~/CLHEP/lib/:$LD_LIBRARY_PATH

Step 5: ENTER: source ~/geant4/geant4.9.3.p01/env.sh

Step 6: ENTER: source ../setup.sh

Step 7: Optional: change the material [See B.1.3]

Step 8: ENTER: make

Step 9: ENTER:[Work_directory]/G4WORK/bin/Linux-g++/CRYbench

Step 10: run/beamOn [desired number of events]

Step 11: Scroll up in the terminal window to "Event [desired number of events – 1]" and record the "Total Time Simulated"

Step 12: ENTER: exit

Step 13: Move the .txt and .dat files from the CRYbench file into the desired directory

NOTE You must exit out of the run application before moving the .txt and .dat files or the files will be for the incorrect simulation.

B.1.2 Operating Geant4 under Windows

Step 1: Launch Cygwin

Step 2: ENTER: cd ..
Repeat until in the C: drive

Step 3: ENTER: cd g4work/cry_v1.6/CRYbench

Step 4: ENTER: export G4WORKDIR=c:/g4work

Step 5: ENTER: source /cygdrive/c/Geant4/geant4_9_4_p01/env.sh

*Step 6: ENTER: source ../setup.sh

Step 7: Optional: change the material [See B.1.3]

Step 8: ENTER: make

Step 9: ENTER: /cygdrive/c/g4work/bin/WIN32-VC/CRYbench.exe

Step 10: run/beamOn [desired number of events]

Step 11: When using CRY, scroll up in the terminal window to "Event [desired number of events – 1]" and record the "Total Time Simulated"

Step 12: ENTER: exit

Step 13: Move the .txt and .dat files from the CRYbench file into the desired directory

NOTE You must exit out of the run application before moving the .txt and .dat files or the files will be for the incorrect simulation.

B.1.3 Interchanging files among Linux and Windows computers

When working with large Monte Carlo simulations, it is very useful to have the ability to exchange files among different computers in a efficient way through the network. Since this work was performed at a highly secured network, a file exchanging tool with secure protocols is required. The tool utilized for such purpose in this work is called WinSCP. This tool is free to use and can be downloaded from the web.

B.1.4 Example of modifying an application: changing the simulated material

These steps are done in a Cygwin window and start from the application directory, usually in the working directory of Geant4 (g4work directory).

Step 1: ENTER: cd src

Step 2: ENTER: vi DetectorConstruction.cc

Step 3: To make changes, use the down arrow key to get where you want, then press "i" to insert text and make the necessary changes
Note: The thickness is located beneath "Thickness of material" and is the "G4double LeadThick" while the material is located under "Material Slab" and is the "LogicPlastScint2"

Step 4: PRESS: Esc

Step 5: ENTER: :wq

Step 6: ENTER: cd ..

Step 7: Resume from Step 8 of Running an Application (under Linux or Windows)

Changing the materials or the thickness of the material is the same in Windows as it is in Linux with the only exception being there is no backspace key when editing a file in Windows from a Cygwin window. Rather, use the "x" key on the keyboard when not in the insert text mode in order to delete a character.

B.2 Generating graphs using ROOT

Graphs generated by Linux will have a different look than those generated by Windows, so keep that in mind, especially if comparing graphs of the same simulation but generated by different operating systems.

To generate graphs of the data simulated by Geant4, the Root application must be used.

Procedure:

1. First copy the file Cosmic2Root2PartWin.C, which should be located in a directory below the cry_v1.6, and paste that file in the directory containing the data that you wish to generate a graph of.

2. Open up windows Command Prompt. This can be found by clicking Start, All Programs, Accessories, Command Prompt.

3. Navigate to the directory where the data is stored. This is done using the same method that cygwin uses. To go down a directory, type (cd directory_name) and to go up a directory, type (cd ..).

   When moving down in directories don't forget that you can use Tab completion. This will save you a little time typing. To use Tab completion, type (cd directory_name) but instead of typing the full name of the directory you can type the first few letters then hit the tab button. This automatically completes the rest of the directory's name for you.

4. When you reach the correct directory on your prompt, type (root). This will open up the Root application.

5. To generate the graph, type (.x Cosmic2Root2PartWin.C). This will open a window containing the graph of the data in the current directory.

6. To save the graph, go up to the top of the window. Hit File and then save as .gif. This saves the file in your current directory.

B.2.1 Under Linux

Step 1: Copy and paste "Cosmic2root2part.C" from the CRYbench directory into the desired directory

Step 2: Edit the copy of "Cosmic2root2part.C"

Step 3: Open a terminal located under Applications → System Tools → Terminal

Step 4: ENTER: cd [desired directory]
Note: you may have to enter "cd .." a few times to get to the C: drive

Step 5: ENTER: source [Work_directory]/root/bin/thisroot.sh
Note: this only needs be done once for a fresh terminal

Step 6: ENTER: root

Step 7: ENTER: .x Cosmic2root2part.C

Step 8: Save the graph as a .gif

Step 9: ENTER: exit()

B.2.2 Under Windows

Step 1: Copy and paste "Cosmic2root2partWin.C" into the desired directory.

Step 2: Edit the copy of "Cosmic2root2partWin.C" [see B.2.3]

Step 3: Open Command Prompt located under Start → All Programs → Accessories → Command Prompt
Note: Right click the command prompt and select "PM – Run Elevated"

Step 4: ENTER: cd [desired directory]
Note: you may have to enter "cd .." a few times to get to the C: drive

Step 5: ENTER: root

Step 6: ENTER: .x Cosmic2root2partWin.C

Step 7: Save the graph as a .gif

Step 8: ENTER: exit()

B.2.3 Example of editing the ROOT script (Cosmic2root2partWin.C)

The file Cosmic2root2partWin.C can be edited much more than what is included in this document. What is included only covers the typical range of modifications that would need to be made using data from the CRYbench application.

Step 1: Line 21: Change “SimTime” to the appropriate Total Time Simulated

Step 2: Line 22: Change “Total_nu_of_particles” to the simulated number of events.

Step 3: Line 83/Col 29: Enter the appropriate particle

Step 4: Line 83/Col 37: Enter the appropriate title

Step 5: Line 108,114,120/Col 13: Enter h2 for neutrons, h3 for protons, or h4 for muons

Step 6: Lines 144-154: Adjust for the appropriate labels

Step 7: Save and close

Appendix C: Some Common Errors And Their Fixes

In installing *all* software packages, it is necessary to have been granted Administrator privileges on the machine. A Cygwin shell shortcut can be modified to have elevated privileges permanently by right-clicking, selecting Properties -> Advanced, and checking “Run as Administrator” in Windows 7.

Geant4 may appear to install successfully without administrative privileges, but it will fail to compile any code. Re-running /Configure -build from a Cygwin window with privileges will fix the issue. A similar error will occur if the CLHEP library is installed without administrative privileges, forcing a reinstall of CLHEP as well.

After installing the latest ROOT (v. 5.30.01), some machines will fail to start the program at first, giving the error message “MSVCP71.dll is missing. Try reinstalling the program and try again.” Reinstalling ROOT will *not* fix the problem, and the best solution is simply to download the required file from the internet. A Google search for “MSVCP71.dll” yielded a link to the website “dll-files.com”, where the replacement file can be found. Place the file in “C:/Windows/system32” or “C:/Windows/SysWOW64” if running on a 64-bit machine.

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