

Geant4 Installation Guide

Building and Installing Geant4 for Users and Developers

Version: geant4 9.6.0

Publication date 30th November, 2012

Geant4 Collaboration

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by Geant4 Collaboration

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Chapter 1. Getting Started

Geant4 uses CMake to configure a build system for compiling and installing the toolkit headers, libraries and support tools. This document covers the basics of using CMake to build and install Geant4 together with an overview of the most commonly used advanced features. We also provide a basic overview of how to build an application that uses Geant4. For more information on CMake itself, the CMake Help and Documentation should be consulted.

1.1. Supported and Tested Platforms

Geant4 is officially supported on the following operating system and compiler combinations:

- Scientific Linux CERN 5 with gcc 4.1.2 or 4.3.X, 32/64bit

Scientific Linux CERN 6 with gcc 4.6.X, 64bit

Geant4 has also been successfully compiled on other Linux distributions, including Debian, Ubuntu and openSUSE. Please note that distributions other than SLC are not officially supported. However, we welcome feedback and patches for non-SLC platforms!

- Mac OS X 10.7 (Lion) and 10.8 (Mountain Lion) with gcc 4.2.1 (Apple), 64bit.

Geant4 has also been successfully compiled on Mac OS X 10.6.8 (Snow Leopard) with gcc 4.2.1 (Apple), but this version of Mac OS X is not officially supported.

- Windows 7 with Visual Studio 10 (VS2010).

The following platforms and compilers are also tested, but not officially supported:

- Scientific Linux CERN 5 with gcc 4.7.X, 64bit.

Scientific Linux CERN 5 with Intel C++ 13, 64bit.

- Mac OS X 10.7 (Lion) and 10.8 (Mountain Lion) with Clang 3.1.
- Windows 7 with Visual Studio 9 (VS2008).

We welcome user feedback and/or bug reports via our HyperNews Forum and Bugzilla.

1.2. Software Required to Build Geant4

The following minimal set of software *must* be present to build Geant4:

- Geant4 Toolkit Source Code.
- CMake 2.6.4 or higher.

If you intend to use the Clang compiler, then you must use CMake 2.8.2 or higher in order to correctly identify this compiler.

We recommend version 2.8.X as this includes many extra useful features, but it is not required apart from the proviso on Clang usage above.

- C++ Compiler:
 - Linux: GNU Compiler Collection.
 - Mac OS X: GCC(g++) (Xcode 4).

In Xcode 4, you will also need to install the command line tools (*via Xcode->Preferences->Downloads*).

- Windows: Visual Studio 2010, either Express or Higher Editions.
- Linux/Mac only: Make

On Linux, we recommend that you use CMake as provided through the package management system of your distribution, unless this does not meet the minimum version requirement of CMake 2.6.4. In that case, we recommend you install it using the Linux binary installer for the latest version of CMake, available with instructions from the Kitware download site. This installer is highly portable and should work on the vast majority of distributions.

On Mac and Windows, CMake is not installed by default, so we recommend that you install it using the Darwin64 dmg (Mac) or Win32 exe (Windows) installers supplied by the Kitware download site.

On Linux and Mac, it is strongly recommended to use the g++ compiler supplied by the package management system of your distribution (Linux), or supplied with Xcode (Mac).

1.2.1. CLHEP Library

Geant4 distributes a minimal version of the CLHEP library sources with the toolkit to help cross-platform usage. This internal version of the CLHEP library is built and used by default, so having an external install of CLHEP is no longer a prerequisite for Geant4.

However, Geant4 can still be configured to use an existing install of CLHEP if required by your use case. This configuration is done by passing extra options to CMake, and if you require this feature you should consult Section 2.3.

1.3. Software Required to Build Optional Components of Geant4

Geant4 has several optional components which if enabled require further software to be preinstalled on your system. These components and their requirements are listed below.

- GDML Support (*All Platforms*)

Requires: Xerces-C++ headers and library.

- Qt4 User Interface and Visualization (*All Platforms*)

Requires: Qt4 headers and libraries, OpenGL or MesaGL headers and libraries.

On Mac OS X, you should use Qt 4.8.X.

- Motif User Interface and Visualization (*Linux and Mac OS X*)

Requires: Motif and X11 headers and libraries, OpenGL or MesaGL headers and libraries.

- X11 OpenGL Visualization (*Linux and Mac OS X*)

Requires: X11 headers and libraries, OpenGL or MesaGL headers and libraries.

On Mac OS X 10.8 (Mountain Lion), X11 can be obtained through the XQuartz project.

- WIN32 OpenGL Visualization (*Windows*)

Requires: OpenGL or MesaGL headers and libraries.

- Open Inventor Visualization (*All Platforms*)

Requires: Coin3D with SoXt(SoWin) graphics binding on Linux/Mac(Windows). Coin3D is a free implementation of Open Inventor.

- X11 RayTracer Visualization (*Linux and Mac OS X*)

Requires: X11 headers and libraries.

On Mac OS X 10.8 (Mountain Lion), X11 can be obtained through the XQuartz project.

On Linux, it is strongly recommend that you use the binary packages as supplied through the package management system of your distribution. If you require a component that uses OpenGL, we also recommend that you install the OpenGL package supplied for your video card (e.g. NVIDIA). You should consult the documentation of your distribution for information on the packages that provide the needed software libraries and headers.

On Mac and Windows, we strongly recommend installing any required packages through binary dmg/exe installers supplied through the vendor links above. Note that Mac OS X 10.7 already has OpenGL and X11 installed, and Visual Studio supplies an install of OpenGL on Windows. Mac OS X 10.8 supplies OpenGL, but if you need X11 you will need to install the XQuartz app. Installation and use of packages on Mac through MacPorts, fink or homebrew is not tested or supported, but you may build Geant4 using packages supplied by these package management systems with that caveat.

1.4. Software Suggested for Use With Geant4

Geant4 includes many cross-platform file-based visualization drivers, together with the lightweight inxlib for basic analysis. Geant4 does not require any additional software over and above that listed in Section 1.2 to *build and install* these components.

However, you may wish to install the software suggested below to make use of these components when running your Geant4 application. We again emphasize that you do not need these packages to build and install Geant4.

- DAWN postscript renderer (for use with DAWN visualization driver).
- HepRApp Browser (for use with HepRep visualization driver).
- WIRED4 JAS Plug-In (for use with HepRep visualization driver).
- VRML Browser (for use with VRML visualization driver).
- OpenScientist interactive environment for analysis.
- AIDA implementation such as OpenScientist, iAIDA, JAS3 or rAIDA.

For more details on Geant4's visualization and analysis components, you should consult the relevant sections in the Geant4 User's Guide for Application Developers.

Chapter 2. Building and Installing Geant4

2.1. Building and Installing on Unix Platforms

Unpack the Geant4 source package `geant4.9.6.tar.gz` to a location of your choice. For illustration *only*, this guide will assume it's been unpacked in a directory named `/path/to`, so that the Geant4 source package sits in a subdirectory

```
/path/to/geant4.9.6
```

We refer to this directory as the *source directory*. The next step is to create a directory in which to configure and run the build and store the build products. This directory should not be the same as, or inside, the source directory. In this guide, we create this *build directory* alongside our source directory:

```
$ cd /path/to
$ mkdir geant4.9.6-build
$ ls
geant4.9.6  geant4.9.6-build
```

To configure the build, change into the build directory and run CMake:

```
$ cd /path/to/geant4.9.6-build
$ cmake -DCMAKE_INSTALL_PREFIX=/path/to/geant4.9.6-install /path/to/geant4.9.6
```

Here, the CMake Variable `CMAKE_INSTALL_PREFIX` is used to set the *install directory*, the directory under which the Geant4 libraries, headers and support files will be installed. It must be supplied as an absolute path. The second argument to CMake is the path to the source directory. In this example, we have used the absolute path to the source directory, but you can also use the relative path from your build directory to your source directory.

Additional arguments may be passed to CMake to activate optional components of Geant4, such as visualization drivers, or tune the build and install parameters. See Section 2.3 for details of these options. If you run CMake and decide afterwards you want to activate additional options, simply rerun CMake and pass it the extra options.

On executing the CMake command, it will run to configure the build and generate Unix Makefiles to perform the actual build. CMake has the capability to generate buildscripts for other tools, such as Eclipse and Xcode, but please note that *we do not support user installs of Geant4 with these tools*. On Linux, you will see output similar to:

```
$ cmake -DCMAKE_INSTALL_PREFIX=/path/to/geant4.9.6-install /path/to/geant4.9.6
-- The C compiler identification is GNU
-- The CXX compiler identification is GNU
-- Check for working C compiler: /usr/bin/gcc
-- Check for working C compiler: /usr/bin/gcc -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- setting default compiler flags for CXX
-- Check for working CXX compiler: /usr/bin/c++
-- Check for working CXX compiler: /usr/bin/c++ -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Found EXPAT: /usr/lib64/libexpat.so
-- Pre-configuring dataset G4NDL (4.2)
-- Pre-configuring dataset G4EMLOW (6.32)
-- Pre-configuring dataset PhotonEvaporation (2.3)
-- Pre-configuring dataset RadioactiveDecay (3.6)
-- Pre-configuring dataset G4NEUTRONXS (1.2)
-- Pre-configuring dataset G4PII (1.3)
-- Pre-configuring dataset RealSurface (1.0)
-- Pre-configuring dataset G4SAIDDATA (1.1)
*WARNING*
  Geant4 has been pre-configured to look for datasets
  in the directory:
```

```
/path/to/geant4.9.6-install/share/Geant4-9.6.0/data
```

but the following datasets are NOT present on disk at that location:

```
G4NDL (4.2)
G4EMLOW (6.32)
PhotonEvaporation (2.3)
RadioactiveDecay (3.6)
G4NEUTRONXS (1.2)
G4PII (1.3)
RealSurface (1.0)
G4SAIDDATA (1.1)
```

If you want to have these datasets installed automatically simply re-run `cmake` and set the `GEANT4_INSTALL_DATA` variable to `ON`. This will configure the build to download and install these datasets for you. For example, on the command line, do:

```
cmake -DGEANT4_INSTALL_DATA=ON <otherargs>
```

The variable can also be toggled in `ccmake` or `cmake-gui`. If you're running on a Windows system, this is the best solution as CMake will unpack the datasets for you without any further software being required.

Alternatively, you can install these datasets manually now or after you have installed Geant4. To do this, download the following files:

```
http://geant4.cern.ch/support/source/G4NDL.4.2.tar.gz
http://geant4.cern.ch/support/source/G4EMLOW.6.32.tar.gz
http://geant4.cern.ch/support/source/G4PhotonEvaporation.2.3.tar.gz
http://geant4.cern.ch/support/source/G4RadioactiveDecay.3.6.tar.gz
http://geant4.cern.ch/support/source/G4NEUTRONXS.1.2.tar.gz
http://geant4.cern.ch/support/source/G4PII.1.3.tar.gz
http://geant4.cern.ch/support/source/RealSurface.1.0.tar.gz
http://geant4.cern.ch/support/source/G4SAIDDATA.1.1.tar.gz
```

and unpack them under the directory:

```
/path/to/geant4.9.6-install/share/Geant4-9.6.0/data
```

As we supply the datasets packed in gzipped tar files, you will need the 'tar' utility to unpack them.

Nota bene: Missing datasets will not affect or break compilation and installation of the Geant4 libraries.

```
-- The following Geant4 features are enabled:
GEANT4_BUILD_CXXSTD: Compiling against C++ Standard 'c++98'
GEANT4_USE_SYSTEM_EXPAT: Using system install of EXPAT

-- Configuring done
-- Generating done
-- Build files have been written to: /path/to/geant4.9.6-build
```

On Mac OS X, the output will have slight differences, but the last three lines at least should be the same. These indicate a successful configuration.

The warning message about datasets is simply an advisory. Due to the size of the datasets, Geant4 will try and reuse any datasets it can find under the data installation prefix, in our example case `/path/to/geant4.9.6-install/share/Geant4-9.6.0/data`. If any datasets are not found here, it will pre-configure the setup scripts for using Geant4 (described in Section 3.1 and Section 3.2) to point to this location and emit the message to advise you on the steps you need to take to manually install the datasets at a time of your convenience.

Datasets are *not* required to be present to build Geant4, but may be required to run your application, depending on the physics models you use. If you wish to download and install the datasets automatically as part of your build of Geant4, simply add the option `-DGEANT4_INSTALL_DATA=ON` to the arguments passed to CMake. Note that this requires a working network connection and will download around 0.5GB of data. If you already have the

datasets present on your system, you can point Geant4 to their location. See the `GEANT4_INSTALL_DATADIR` option described Section 2.3.1 for more details.

If you see any errors at this point, carefully check the error messages output by CMake, and check your install of CMake and C++ compiler first. The default configuration of Geant4 is very simple, and provided CMake and the compiler are installed correctly, you should not see errors.

After the configuration has run, CMake will have generated Unix Makefiles for building Geant4. To run the build, simply execute `make` in the build directory:

```
$ make -jN
```

where `N` is the number of parallel jobs you require (e.g. if your machine has a dual core processor, you could set `N` to 2).

The build will now run, and will output information on the progress of the build and current operations. If you need more output to help resolve issues or simply for information, run `make` as

```
$ make -jN VERBOSE=1
```

Once the build has completed, you can install Geant4 to the directory you specified earlier in `CMAKE_INSTALL_PREFIX` by running

```
$ make install
```

in the build directory. The libraries, headers and resource files are installed under your chosen install prefix in a standard Unix-style hierarchy of directories, described below in Section 3.1. If you are performing a staged install for packaging or deployment, the CMake generated Makefiles support the `DESTDIR` variable for copying to a temporary location. To uninstall Geant4 you can run

```
$ make uninstall
```

which will remove all installed files but not any installed directories.

2.2. Building and Installing on Windows Platforms

Unpack the Geant4 source package, `geant4.9.6.zip` to a location of your choice. For illustration *only*, this guide will assume it's been unpacked in a directory `C:\Users\Ben\Documents\geant4\`, so that the Geant4 source package resides in the subdirectory

```
C:\Users\Ben\Documents\geant4\geant4.9.6
```

We refer to this directory as the *source directory*.

Whilst CMake can be used from the Windows cmd program, we recommend using the CMake GUI for configuring the build. The steps required to use the CMake GUI and Visual Studio to build and install Geant4 are described below, and a slideshow of screenshots of the steps is provided.

- Step 1:

Open the CMake (`cmake-gui`) executable, and click on the *Browse Source...* button in the top right hand corner of the window. Use the file browser popup to locate the Geant4 source directory, and click *OK*.

- Step 2:

Now we create a directory in which to create the Visual Studio project files and hold the build products. This directory should not be the same as, or inside, the the source directory. Here we will create this *build directory* alongside our source directory.

Click on the *Browse Build...* button in the top right hand side of the CMake GUI window. Use the file browser popup to browse back to `C:\Users\Ben\Documents\geant4\`, and click on the *Make New Folder* button. Rename the created folder to *geant4.9.6-build*, and click on the *OK* button. The two text entries at the top of the GUI should now contain `C:/Users/Ben/Documents/geant4/geant4.9.6` and `C:/Users/Ben/Documents/geant4/geant4.9.6-build` respectively (*Note*: CMake always represents Windows paths with forward slashes).

- Step 3:

Click on the *Configure* button on the bottom left hand side of the GUI.

- Step 4:

In the popup window, select *Visual Studio 2010*. Ensure only the *Use default native compilers* radio box is checked. Then click on the *Finish* button.

- Step 5:

CMake will then run to check features and provide an initial configuration. All being well, you will see red highlighted entries in the main options window including *CMAKE* and *GEANT4* entries. Note that the red highlighting means CMake has not fully resolved all configuration variables yet, not that has been an error. On Express editions of Visual Studio, you may see a warning about missing system runtime libraries in the logging window at the bottom of the GUI, but this can be ignored for a standard install. Any other errors will be reported in this logging window.

- Step 6:

By default, CMake will configure the build to install Geant4 under `C:/Program Files/Geant4`. If you do not wish to use this directory, or do not have permission to install there, you can change the installation location. Click on the arrow next to the the *CMAKE* entry in the central options display to expand all CMake specific configuration options. Scroll down to locate the *CMAKE_INSTALL_PREFIX* entry. Click on the entry and edit the path directly or via the file browser popup. In this example we will modify this *install directory* to `C:/Users/Ben/Documents/geant4/geant4.9.6-install`.

- If you need to activate extra components of Geant4, click on the expansion arrow next to the *GEANT4* entry in the central options display to expand all Geant4 specific configuration options. We will not adjust any here, but they are all documented in Section 2.3. Simply click on the tick box next to an option to select it if you require.

- Step 7:

Once you have adjusted any options, click on the *Configure* button again. After this has finished, all the options listed in the central option display should be white. If you still have entries in red, click *Configure* to reconfigure until all entries are white.

- Step 8:

Now click on the *Generate* button to generate the Visual Studio project. All being well, CMake will generate the solution files and finally report *Configuring done*, *Generating done* in the logging window at the bottom of the GUI. You can now close the CMake GUI.

- Step 9:

Now start up Visual Studio, and choose *Open Project*. This guide is somewhat specific to Visual Studio 2010 Express, but the solutions should appear with the same names in other versions. Browse to your build directory, and open the `Geant4.sln` Microsoft Visual Studio Solution file. Note that it may take some time to fully configure,

open and parse all files in the solution. You may also use the MSBuild command line utility to build the solution directly if you are familiar with that tool, but we do not as yet document or support this.

- Step 10:

By default, the Visual Studio solution builds the Debug Configuration, so if you want an optimized build, you should select the *Release* option from the drop down *Solutions Configurations* menu in the toolbar (Visual Studio 2010).

- Step 11:

In the Solution Explorer, right click on the *INSTALL* solution, and select *Build* from the popup menu. The solution will now build and install to the directory you chose for `CMAKE_INSTALL_PREFIX` earlier. If you wish to build a different configuration (*Release* if you built *Debug* first, for example), then simply change the solution configuration as described in the previous paragraph, and build the *INSTALL* solution again.

- Step 12:

If you see a successful build, you can exit Visual Studio.

The file and directory structure of the installation follows that of the Unix build, and is described in Section 3.1.

2.3. Geant4 Build Options

Both Section 2.1 and Section 2.2 give the minimal procedure to build and install Geant4. Many additional options can be passed to CMake to adjust the way Geant4 is built and installed and to enable optional components.

On the command line, these options may be set by passing their name and value to the `cmake` command via `-D` flags, for example

```
$ cmake -DCMAKE_INSTALL_PREFIX=/opt/geant4 -DGEANT4_USE_GDML=ON /path/to/geant4.9.6
```

would configure the build of Geant4 for installation under `/opt/geant4` and compilation of support for GDML.

In the CMake GUI, the options are listed as textbox entries, and values may be set directly by clicking on the entry for the option and entering the requested information (for example, if a path is required, the GUI will pop up a file browser).

On Unix, CMake also provides a curses based interface, `ccmake`, which can be used to browse and set options in the terminal. Please see the CMake documentation for more information on this command.

If you have already created a build directory and used CMake to configure the build, you can always rerun CMake in that directory with new options to regenerate the buildscripts (Makefiles or IDE solutions). The curses based `ccmake` command is very useful in this case for browsing the current configuration and for updating it if required. In the CMake GUI, you should set the *Where is the source code*: path to that of your source directory, and the *Where to build the binaries*: path to that of the build directory you wish to reconfigure. You will then need to rebuild and reinstall to pick up the changes. You can also *deactivate* a previously selected option to remove a component from the build. For example, we could do

```
$ cmake -DCMAKE_INSTALL_PREFIX=/opt/geant4 -DGEANT4_USE_GDML=OFF /path/to/geant4.9.6
```

to explicitly remove support for GDML from a build (In the CMake GUI, we would simply uncheck the tick box for `GEANT4_USE_GDML`). Note however that if you reconfigure to *unset* an option and rebuild and reinstall, your install may contain files installed by the previously set option (for example headers). In this case, you may wish to build the `uninstall` target before reconfiguring.

Options are divided into *Standard* options, which any user or developer can set directly, and *Advanced* options, which in general are only needed by advanced users, developers or to give very fine control over the build and

and install. Some options enable components of Geant4 which require external software (as listed in Section 1.2). If these options are enabled, the required software will be searched for, and hence there are also options which control where CMake should look for these packages. If a required software package is not found, then CMake will exit with an error message detailing what was not found.

2.3.1. Standard Options

We list standard options here in logical order. If you use CMake's curses or GUI interfaces, they will be listed alphabetically.

- `CMAKE_INSTALL_PREFIX`

- Sets the installation prefix for Geant4. Equivalent to `--prefix` in Autotools. Its default is platform dependent:

Unix: `/usr/local`

Windows: `C:\Program Files\Geant4`

It should be supplied as an absolute path, otherwise CMake will interpret its value relative to your build directory.

See also the `CMAKE_INSTALL_XXXDIR` Advanced Options for fine control of installation locations.

- `CMAKE_BUILD_TYPE` : (DEFAULT : Release)

- Controls the type of build, at present only the additional flags passed to the compiler. It defaults to `Release` which gives an optimized build with no debugging symbols. The most useful values are:

`Release` : Optimized build, no debugging symbols

`Debug` : Debugging symbols, no optimization

`RelWithDebInfo` : Optimized build with debugging symbols

Note that if you use a build system which supports multiconfiguration builds (e.g. Xcode, Visual Studio), this variable has no effect as all build types are available inside the CMake generated project.

- `GEANT4_INSTALL_DATADIR` : (DEFAULT : `CMAKE_INSTALL_DATAROOTDIR`)

- Installation directory for Geant4 datasets. It can be supplied as a path relative to `CMAKE_INSTALL_PREFIX` or as an absolute path. It is always searched for existing datasets, which if present will be reused.

- `GEANT4_INSTALL_DATA` : (DEFAULT : OFF)

- If set to ON, download and install any Geant4 datasets missing from `GEANT4_INSTALL_DATADIR`. Each dataset will be unpacked and installed in the directory pointed to by `GEANT4_INSTALL_DATADIR`.

REQUIRES : A working network connection. It is highly recommended to switch this option on if you have a network connection to give the best integration with application development.

- `GEANT4_USE_GDML` : (DEFAULT : OFF | ON if `XERCESC_ROOT_DIR` is set)

- If set to ON, build the `G4persistence` library with support for GDML.

REQUIRES : Xerces-C++ libraries and headers, see the `XERCESC_ROOT_DIR` option.

- `XERCESC_ROOT_DIR`

- If your Xerces-C++ installation is in a non-standard location, set this variable to the root directory of the installation (i.e. the directory containing the `include` and `lib` subdirectories for Xerces-C++). If this is not

sufficient to locate Xerces-C++, see the Advanced `XERCESC_INCLUDE_DIR` and `XERCESC_LIBRARY` options.

- `GEANT4_USE_G3TOG4` : (DEFAULT : OFF)

- If set to ON, build the `G3TOG4` library for reading ASCII call list files generated from Geant3 geometries.

- `GEANT4_USE_QT` (DEFAULT : OFF)

- If set to ON, build Qt4 User Interface and Visualization drivers.

REQUIRES : Qt4 and OpenGL libraries and headers. See also the `QT_QMAKE_EXECUTABLE` option if CMake has trouble locating your Qt4 installation.

- `QT_QMAKE_EXECUTABLE`

- If your Qt4 installation is in a non-standard location, set this variable to point to the `qmake` executable of the Qt4 installation you wish to use. If you have a system install on Linux or the binary SDK install on other platforms, Qt4 will in general be found automatically (CMake should also honor the `QTDIR` environment variable).

- `GEANT4_USE_XM` (DEFAULT : OFF, Unix Only)

- If set to ON, build Motif User Interface and Visualization drivers.

REQUIRES : Motif and OpenGL libraries and headers. In most cases, these should be found automatically, but if not, see the Advanced `MOTIF_INCLUDE_DIR` and `MOTIF_LIBRARIES` options.

- `GEANT4_USE_OPENGL_X11` (DEFAULT : OFF, Unix Only)

- If set to ON, build the X11 OpenGL visualization driver.

REQUIRES : X11 and OpenGL libraries and headers.

- `GEANT4_USE_OPENGL_WIN32` (DEFAULT : OFF, Windows Only)

- If set to ON, build the Win32 OpenGL visualization driver.

REQUIRES : OpenGL libraries and headers. If you are using Visual Studio, then this should supply the needed headers and libraries.

- `GEANT4_USE_INVENTOR` (DEFAULT : OFF)

- If set to ON, build the OpenInventor visualization driver.

REQUIRES : Coin3D Open Inventor implementation, SoXt (Unix) or SoWin (Windows) binding, and OpenGL libraries and headers. CMake will use `coin-config` and `soxt-config` if present to locate the Coin3D and SoXt implementation respectively, and will honor the `COINDIR` environment variable. In case of issues with locating the Inventor implementation, see the Advanced `INVENTOR_INCLUDE_DIR`, `INVENTOR_LIBRARY`, `INVENTOR_SOXT_INCLUDE_DIR`, `INVENTOR_SOXT_LIBRARY` and `INVENTOR_SOWIN_LIBRARY` options.

KNOWN ISSUE : Use of clang compiler and Debug build mode will cause the Inventor driver build to fail with errors relating to Inventor specific debugging functions.

- `GEANT4_USE_RAYTRACER_X11` (DEFAULT : OFF, Unix only)

- If set to ON, build RayTracer visualization driver with X11 support.

REQUIRES : X11 Headers and Libraries.

- `GEANT4_USE_SYSTEM_CLHEP` (DEFAULT : OFF | ON if `CLHEP_ROOT_DIR` set)

- If set to ON, build Geant4 with an external install of CLHEP. You *should not* set this unless your usage of Geant4 mandates a specific external CLHEP installation (e.g. if your experiment's software uses CLHEP in other tools and requires consistent use of the same CLHEP across the software). If the CLHEP_ROOT_DIR option is not set, CLHEP will be searched for under standard system paths.

REQUIRES : CLHEP libraries and headers.

- CLHEP_ROOT_DIR

- If you wish GEANT4 to use a specific installation of CLHEP, set this variable to point to the root install directory of the CLHEP installation you wish to use. This directory should contain the `include` and `lib` sub-directories containing the CLHEP headers and library respectively. If this is not sufficient to locate CLHEP, see the Advanced CLHEP_INCLUDE_DIR and CLHEP_LIBRARY options.

- GEANT4_USE_SYSTEM_EXPAT (DEFAULT : ON)

- If set to ON, build Geant4 with an external install of Expat. In this case, the Expat headers and library will be searched for under the standard system paths. If these are not sufficient to locate the required Expat installation, see the Advanced EXPAT_INCLUDE_DIR and EXPAT_LIBRARY options/

REQUIRES : Expat library and headers.

2.3.2. Advanced Options

Most builds should never need to touch the advanced options, but should you need more control or CMake has problems locating needed software packages, they can be very helpful. We only list the options and variables most relevant for Geant4. For help on core CMake variables and options, you should consult the Reference Documentation section of the main CMake documentation , and specifically the sections on Variables.

Advanced options are not displayed by default in CMake's curses and GUI interfaces, but can be displayed by pressing `t` in `ccmake`, or clicking the 'advanced' check box in the CMake GUI. Note that displaying advanced options will also display a large number of options and variables used by CMake for build configuration and to cache the locations of Third Party packages. On the command line, advanced options and variables can be set like the standard ones listed earlier using `-D` arguments.

- GEANT4_USE_NETWORKDAWN : (DEFAULT : OFF, Unix Only)

- If set to ON, build network server/client support for DAWN visualization driver. You do *not* need this to view DAWN files.

- GEANT4_USE_NETWORKVRML : (DEFAULT : OFF, Unix Only)

- If set to ON, build network server/client support for VRML visualization driver. You do *not* need this to view VRML files.

- GEANT4_INSTALL_DATA_TIMEOUT : (DEFAULT : 1500)

- Sets the time in seconds allowed for download of each Geant4 dataset. The value can be increased if you are on a slow network connection and require more time to download.

REQUIRES : a working network connection.

- GEANT4_INSTALL_EXAMPLES : (DEFAULT : OFF)

- If set to ON, install Geant4 example application source code under CMAKE_INSTALL_DATAROOTDIR.

- BUILD_SHARED_LIBS : (DEFAULT : ON)

- If set to ON build Geant4 shared libraries.

- BUILD_STATIC_LIBS : (DEFAULT : OFF)

- If set to ON, build Geant4 static libraries.
- CMAKE_INSTALL_BINDIR : (DEFAULT : bin)
 - Installation directory for Geant4 executables. It can be supplied as a path relative to CMAKE_INSTALL_PREFIX or as an absolute path.
- CMAKE_INSTALL_INCLUDEDIR : (DEFAULT : include)
 - Installation directory for Geant4 C/C++ headers. It can be supplied as a path relative to CMAKE_INSTALL_PREFIX or as an absolute path. The headers will always be installed in a subdirectory of CMAKE_INSTALL_INCLUDEDIR named Geant4.
- CMAKE_INSTALL_LIBDIR : (DEFAULT : lib(+?SUFFIX))
 - Installation directory for object code libraries. It can be supplied as a path relative to CMAKE_INSTALL_PREFIX, or an absolute path. When the default is used, SUFFIX will be set to 64 on 64bit Linux platforms apart from Debian systems.
- CMAKE_INSTALL_DATAROOTDIR : (DEFAULT : share)
 - Installation directory for read-only architecture-independent data files. It can be supplied as a path relative to CMAKE_INSTALL_PREFIX, or an absolute path.
- XERCESC_INCLUDE_DIR
 - If CMake cannot locate your Xerces-C++ installation, set this to the directory containing the Xerces-C++ headers (e.g. if you have /foobar/xercesc/util/XercesVersion.hpp, then set this to /foobar).
- XERCESC_LIBRARY
 - If CMake cannot locate your Xerces-C++ installation, set this to the full path to the Xerces-C++ library, e.g. /usr/lib/libxerces-c.so
- MOTIF_INCLUDE_DIR
 - If CMake cannot locate your Motif installation, set this to the directory containing the Motif headers (e.g. if you have /foobar/Xm/Xm.h, then set this to /foobar).
- MOTIF_LIBRARIES
 - If CMake cannot locate your Motif installation, set this to the full path to the Motif library, e.g. /usr/lib/libXm.so
- INVENTOR_INCLUDE_DIR
 - If CMake cannot locate your OpenInventor installation, set this to the directory containing the Inventor headers (e.g. if you have /foobar/Inventor/So.h, then set this to /foobar).
- INVENTOR_LIBRARY
 - If CMake cannot locate your Inventor installation, set this to the full path to the Inventor library, e.g. /usr/lib/libCoin.so
- INVENTOR_SOWIN_LIBRARY (*Windows only*)
 - If CMake cannot locate your Inventor installation, set this to the full path to the Inventor SoWin binding library, e.g. C:\Program Files\Coin\sowin.dll.
- INVENTOR_SOXT_INCLUDE_DIR (*Unix only*)

- If CMake cannot locate your Inventor installation, set this to the directory containing the Inventor SoXt binding headers (e.g. if you have `/foobar/Inventor/SoXt/SoXt.h`, then set this to `/foobar`).
- `INVENTOR_SOXT_LIBRARY` (*Unix only*)
 - If CMake cannot locate your Inventor installation, set this to the full path to the Inventor SoXt binding library, e.g. `/usr/lib/libSoXt.so`.
- `CLHEP_INCLUDE_DIR` (*If `GEANT4_USE_SYSTEM_CLHEP` selected*)
 - If CMake cannot locate your external CLHEP installation, set this to the directory containing the CLHEP headers (e.g. if you have `/foobar/CLHEP/Vector/defs.h`, then set this to `/foobar`).
- `CLHEP_LIBRARY` (*If `GEANT4_USE_SYSTEM_CLHEP` selected*)
 - If CMake cannot locate your CLHEP installation, set this to the full path to the CLHEP library, e.g. `/usr/lib/libCLHEP.so`
- `EXPAT_INCLUDE_DIR` (*If `GEANT4_USE_SYSTEM_EXPAT` selected*)
 - If CMake cannot locate your external EXPAT installation, set this to the directory containing the EXPAT headers (e.g. if you have `/foobar/expat.h`, then set this to `/foobar`).
- `EXPAT_LIBRARY` (*If `GEANT4_USE_SYSTEM_EXPAT` selected*)
 - If CMake cannot locate your EXPAT installation, set this to the full path to the EXPAT library, e.g. `/usr/lib/libexpat.so`
- `GEANT4_BUILD_CXXSTD` : (DEFAULT : `c++98`, Unix Only)
 - Compile Geant4 against given C++ standard (`c++98`, including addenda, `c++0x`, or `c++11`. Geant4 is written in `c++98`, and you should use this option if your application requires support for the newer standards. If you set the variable to a standard the compiler does not support, and error will be emitted.

REQUIRES : GNU, Clang or Intel C++ compilers.
- `GEANT4_BUILD_STORE_TRAJECTORY` : (DEFAULT : ON)
 - If set to ON, store trajectories in event processing. It can be switched to OFF to give a degree of performance improvement, but you will *not* be able to visualize events.
- `GEANT4_BUILD_VERBOSE_CODE` : (DEFAULT : ON)
 - If set to ON, build Geant4 libraries with extra verbosity. It can be switched to OFF to give a degree of performance improvement, but you will not have as much information output should you run into problems or need to debug.
- `GEANT4_BUILD_GRANULAR_LIBRARIES` : (DEFAULT : OFF) (DEPRECATED)
 - If set to ON, build Geant4 libraries in granular mode. *WARNING*: this option is deprecated, intended for Geant4 developers only and does not provide a fully usable Geant4 install. *No support is, or will be, provided for user applications built with granular libraries.*
- `GEANT4_BUILD_EXAMPLES` : (DEFAULT : OFF)
 - If set to ON, build all Geant4 example applications using current Geant4 build. *WARNING*: this option is for Geant4 system testing only and is not intended for use by users studying and working on the examples. *No support is, or will be, provided for user builds of the examples using this option.*
- `GEANT4_ENABLE_TESTING` : (DEFAULT : OFF)

- If set to ON, build and run Geant4 testing suites. *WARNING*: this option is for Geant4 system testing only and is not intended for use by users. *No support is, or will be, provided for user builds with this option.*

2.3.3. Selecting a Different Compiler and Changing Flags

CMake will, by default, select the first C and C++ compilers it finds in your path. Geant4's CMake scripts configure a default set of flags based on the compiler identity, as follows

- GNU Compiler Collection
 - CMAKE_CXX_FLAGS : `-W -Wall -pedantic -Wno-non-virtual-dtor -Wno-long-long -Wwrite-strings -Wpointer-arith -Woverloaded-virtual -pipe`
 - CMAKE_CXX_FLAGS_RELEASE : `-O2 -DNDEBUG`
 - CMAKE_CXX_FLAGS_DEBUG : `-g`
 - CMAKE_CXX_FLAGS_RELWITHDEBINFO : `-O2 -g`
- Clang
 - CMAKE_CXX_FLAGS : `-W -Wall -pedantic -Wno-non-virtual-dtor -Wno-long-long -Wwrite-strings -Wpointer-arith -Woverloaded-virtual -pipe -Qunused-arguments`
 - CMAKE_CXX_FLAGS_RELEASE : `-O2 -DNDEBUG`
 - CMAKE_CXX_FLAGS_DEBUG : `-g`
 - CMAKE_CXX_FLAGS_RELWITHDEBINFO : `-O2 -g`
- Microsoft Visual C++
 - CMAKE_CXX_FLAGS : `-GR -EHsc -Zm200 -nologo -D_CONSOLE -D_WIN32 -DWIN32 -DOS -DXPNET -D_CRT_SECURE_NO_DEPRECATED`
 - CMAKE_CXX_FLAGS_RELEASE : `-MD -O2 -DNDEBUG`
 - CMAKE_CXX_FLAGS_DEBUG : `-MDd -Od -Zi`
 - CMAKE_CXX_FLAGS_RELWITHDEBINFO : `-MD -O2 -Zi`
- Intel C and C++ Compilers
 - CMAKE_CXX_FLAGS : `-w1 -Wno-non-virtual-dtor -Wpointer-arith -Wwrite-strings -fp-model precise`
 - CMAKE_CXX_FLAGS_RELEASE : `-O2 -DNDEBUG`
 - CMAKE_CXX_FLAGS_DEBUG : `-g`
 - CMAKE_CXX_FLAGS_RELWITHDEBINFO : `-O2 -g`

For the GNU, Clang and Intel compilers, an additional flag selecting the C++ standard to compile against will be set. By default, this will use the `c++98` standard. This can be changed if the compiler version supports it by setting the `GEANT4_BUILD_CXXSTD` to the required standard, as described in Section 2.3.2.

If you are using an unsupported or unrecognized (by Geant4) compiler, CMake will default to a standard and very simple set of flags for that compiler. We strongly recommend that you use the default compiler and flags, but both can be modified if your use case requires it. To specify the C and C++ compilers to be used, you can set the `CC` and `CXX` variables

```
... assuming clang/clang++ are in the PATH ...  
  
$ CC=clang CXX=clang++ cmake <otherargs>  
  
... or ...  
  
$ export CC=clang  
$ export CXX=clang++  
$ cmake <otherargs>
```

You can also specify a full path should the compilers not be in the `PATH`. You can also specify the C and C++ compilers via the `CMAKE_<LANG>_COMPILER` options:

```
$ cmake -DCMAKE_C_COMPILER=clang -DCMAKE_CXX_COMPILER=clang++ <otherargs>
```

Use of `CMAKE_<LANG>_COMPILER` will take precedence over any setting of `CC` or `CXX` in the environment or on the command line.

Whilst you *can* change the compiler after an initial configuration with CMake, it is not recommended as you may need to reset some variables by hand. If you do perform this step, it can only be done by rerunning CMake and passing the new compiler via the `CMAKE_<LANG>_COMPILER` argument(s), as the `CC` and `CXX` variables have no effect on subsequent runs of CMake in a given build directory. You may also need to remove the `CMakeCache.txt` file from the build directory before running CMake again. If you are building Geant4 using several compilers and/or versions, we strongly recommend creating one build directory per compiler system. Whilst this takes extra disk space, it provides a clean separation between different builds and also allows fast incremental builds against a single source directory.

Compiler flags can be interactively modified through the `ccmake` and CMake GUI interfaces. As compiler flags are an advanced option, you will need to activate viewing of advanced options. You may then edit the flags as you wish.

CMake is also aware of the `CFLAGS` and `CXXFLAGS` variables, so you may set these on the command line or as environment variables. However, note that this will only *prepend* extra flags to the default `CMAKE_<LANG>_FLAGS`.

If you need to completely change the compiler flags, then you can set `CMAKE_<LANG>_FLAGS` directly as a `-D` option to CMake. This will override all defaults set by Geant4's CMake scripts.

2.3.4. Using an Initial Cache File for Build Options

As Geant4, and CMake in general, has many configurable options, remembering and typing out the CMake command line can be tedious and potentially error prone once you start to use a significant number of options. To ease this task and provide reproducible builds, you can write options as CMake `set ()` commands into a so-called initial cache script. For example, to select Clang as the compiler and enable Qt support, we could write the following

```
set(CMAKE_C_COMPILER clang CACHE STRING "")  
set(CMAKE_CXX_COMPILER clang++ CACHE STRING "")  
set(GEANT4_USE_QT ON CACHE BOOL "")
```

into a file, say, `mysettings.cmake`. We could then pass this file to CMake to configure the Geant4 build with these settings:

```
$ cmake -C /home/me/mysettings.cmake /path/to/geant4.9.6
```

Any settings in the supplied script will take priority over the defaults, so this can be a useful way to manage different builds in a reproducible way. Note that the `set ()` commands must use the `CACHE` argument to ensure they are loaded into the CMake cache.

Chapter 3. Setting Up and Using an Install of Geant4

3.1. Geant4 Installation Locations

If you choose the default installation paths, then your install of Geant4 is completely contained under the directory you chose for `CMAKE_INSTALL_PREFIX`, with the structure

```
+-- CMAKE_INSTALL_PREFIX
|
|-- bin/
|   |-- geant4-config    (UNIX ONLY)
|   |-- geant4.csh      (UNIX ONLY)
|   |-- geant4.sh       (UNIX ONLY)
|   |-- G4global.dll    (WINDOWS ONLY)
|   |-- ...
|-- include/
|   |-- Geant4/
|   |   |-- G4global.hh
|   |   |-- ...
|   |   |-- CLHEP/      (WITH INTERNAL CLHEP ONLY)
|   |   |-- tools/
|-- lib/
|   |-- Geant4-9.6.0/
|   |   |-- Geant4Config.cmake
|   |   |-- Geant4ConfigVersion.cmake
|   |   |-- Geant4LibraryDepends.cmake
|   |   |-- Geant4LibraryDepends-Release.cmake
|   |   |-- UseGeant4.cmake
|   |   |-- Linux-g++   (OR Darwin-g++ UNIX ONLY SOFTLINK -> ..)
|   |   |-- Modules/
|-- share
|   |-- Geant4-9.6.0
|   |   |-- data/      (IF GEANT4_INSTALL_DATA WAS SET)
|   |   |-- geant4make/
|   |   |   |-- geant4make.csh
|   |   |   |-- geant4make.sh
|   |   |   |-- config/
```

To make the Geant4 binaries and libraries available on your `PATH` and library path (`LD_LIBRARY_PATH` on Linux, `DYLD_LIBRARY_PATH` on Mac OS X), you should source the relevant script in `CMAKE_INSTALL_PREFIX/bin`

On interactive bourne shells (e.g. `bash`), do (assuming you are in `CMAKE_INSTALL_PREFIX/bin`):

```
$ . geant4.sh
```

This command can also be used to setup the Geant4 environment in other Bourne shell scripts. You can also supply the full path to the script rather than changing to the directory containing it.

On interactive C shells, do (assuming you are in `CMAKE_INSTALL_PREFIX/bin`):

```
$ source geant4.csh
```

In an interactive session you can also supply the full path to the script rather than changing to the directory containing it. The C shell script cannot be sourced directly inside other shell scripts due to a limitation of this shell which prevents the script being able to locate itself. If you need to source the C shell script inside another, then you can use the command

```
cd CMAKE_INSTALL_PREFIX/bin ; source geant4.csh
```

where you should replace `CMAKE_INSTALL_PREFIX/bin` with the directory you installed `geant4.csh` in. You can also use the command

```
source CMAKE_INSTALL_PREFIX/bin/geant4.csh CMAKE_INSTALL_PREFIX/bin
```

where as above you should replace `CMAKE_INSTALL_PREFIX/bin` with the directory where `geant4.csh` is located.

On Windows, you should add the directory containing the Geant4 dll files to your `PATH` environment variable. On Windows 7/XP, this can be done via the Control Panel as follows

- Step 1:
Open the Windows Control Panel.
- Step 2:
Open the *System* item in the Control Panel.
- Step 3:
Click on the *Advanced system settings* link on the System window (on *Windows XP*, click on the *Advanced* tab).
- Step 4:
Click on the *Environment Variables* button in the System Properties window.
- Step 5:
Select the `PATH` entry in the *User variables* list, and click the *Edit* button. If `PATH` is not present, click on the *New* and create it.
- Step 6:

In the popup *Edit User Variable* window, append the directory in which the Geant4 dlls are installed to the Variable value entry of the `PATH` variable (Note that on Windows, path entries are separated by semicolons). It's very important to append the Geant4 dll path if you have an existing `PATH`, otherwise other programs may stop working correctly! If the Variable value entry of the `PATH` variable is empty, or you've just created it, you can simply set the value to the directory in which the Geant4 dlls are installed. Once you have edited, click *OK*.

3.2. Building Applications with Geant4

To build an application that uses the Geant4 toolkit, it is necessary to include Geant4 headers in the application sources and link the application to the Geant4 libraries. The details of how to implement source code for an application are described in detail in the Geant4 User's Guide for Application Developers. Here, we describe how you can build your sources into an application and compile and link it against Geant4.

We provide three main tools to help with building applications: a CMake "Geant4Config.cmake" config file, a GNUMake module "binmake.gmk" and a UNIX-only command line program "geant4-config". The following sections give an overview of each tool and how to use them to build a simple application.

3.2.1. Using CMake to build Applications: Geant4Config.cmake

Geant4 installs a file named `Geant4Config.cmake` located in:

```
+-- CMAKE_INSTALL_PREFIX
+-- lib/
+-- Geant4-9.6.0/
+-- Geant4Config.cmake
```

which is designed for use with the CMake scripting language `find_package` command. Building a Geant4 application using CMake therefore involves writing a CMake script `CMakeLists.txt` using this and other CMake commands to locate Geant4 and describe the build of your application against it. Whilst it requires a bit of effort to write the script, CMake provides a very powerful and flexible tool, especially if you are working on multiple platforms. It is therefore the method we recommend for building Geant4 applications.

We'll use Basic Example B1, which you may find in the Geant4 source directory under `examples/basic/B1`, to demonstrate the use of CMake to build a Geant4 application. You'll find links to the latest CMake documentation for the commands used throughout, so please follow these for further information. The application sources and scripts are arranged in the following directory structure:

```
+-- B1/
+-- CMakeLists.txt
+-- exampleB1.cc
+-- include/
|   ... headers.hh ...
+-- src/
    ... sources.cc ...
```

Here, `exampleB1.cc` contains `main()` for the application, with `include/` and `src/` containing the implementation class headers and sources respectively. This arrangement of source files is not mandatory when building with CMake, apart from the location of the `CMakeLists.txt` file in the root directory of the application.

The text file `CMakeLists.txt` is the CMake script containing commands which describe how to build the `exampleB1` application:

```
# (1)
cmake_minimum_required(VERSION 2.6 FATAL_ERROR)
project(B1)

# (2)
option(WITH_GEANT4_UIVIS "Build example with Geant4 UI and Vis drivers" ON)
if(WITH_GEANT4_UIVIS)
    find_package(Geant4 REQUIRED ui_all vis_all)
else()
    find_package(Geant4 REQUIRED)
endif()

# (3)
include(${Geant4_USE_FILE})
include_directories(${PROJECT_SOURCE_DIR}/include)

# (4)
file(GLOB sources ${PROJECT_SOURCE_DIR}/src/*.cc)
file(GLOB headers ${PROJECT_SOURCE_DIR}/include/*.hh)

# (5)
add_executable(exampleB1 exampleB1.cc ${sources} ${headers})
target_link_libraries(exampleB1 ${Geant4_LIBRARIES})

# (6)
set(EXAMPLEB1_SCRIPTS
    exampleB1.in
    exampleB1.out
    init.mac
    init_vis.mac
    run1.mac
    run2.mac
    vis.mac
)

foreach(_script ${EXAMPLEB1_SCRIPTS})
    configure_file(
        ${PROJECT_SOURCE_DIR}/${_script}
```

```
    ${PROJECT_BINARY_DIR}/${_script}
    COPYONLY
  )
endforeach()

# (7)
install(TARGETS exampleB1 DESTINATION bin)
```

For clarity, the above listing has stripped out the main comments (CMake comments begin with a "#") you'll find in the actual file to highlight each distinct task:

1. Basic Configuration

The `cmake_minimum_required` command simply ensures we're using a suitable version of CMake. The `project` command sets the name of the project and enables and configures C and C++ compilers.

2. Find and Configure Geant4

The aforementioned `find_package` command is used to locate and configure Geant4 (we'll see how to specify the location later when we run CMake), the `REQUIRED` argument being supplied so that CMake will fail with an error if it cannot find Geant4. The `option` command specifies a boolean variable which defaults to `ON`, and which can be set when running CMake via a `-D` command line argument, or toggled in the CMake GUI interfaces. We wrap the calls to `find_package` in a conditional block on the option value. This allows us to configure the use of Geant4 UI and Visualization drivers by `exampleB1` via the `ui_all vis_all "component"` arguments to `find_package`. These components and their usage is described later.

3. Configure the Project to Use Geant4 and B1 Headers

To automatically configure the header path, compiler flags and compiler definitions needed for linking to Geant4, we use the `include` command to load a CMake script supplied by Geant4. The CMake variable named `Geant4_USE_FILE` is set to the path to this module when Geant4 is located by `find_package`. We use the `include_directories` command to add the B1 header directory to the compiler's header search path. The CMake variable `PROJECT_SOURCE_DIR` points to the top level directory of the project and is set by the earlier call to the `project` command.

4. List the Sources to Build the Application

Use the globbing functionality of the `file` command to prepare lists of the B1 source and header files.

Note however that CMake globbing *is only used here as a convenience*. The expansion of the glob only happens when CMake is run, so if you later add or remove files, the generated build scripts will not know a change has taken place. Kitware strongly recommend listing sources explicitly as CMake automatically makes the build depend on the `CMakeLists.txt` file. This means that if you explicitly list the sources in `CMakeLists.txt`, any changes you make will be automatically picked when you rebuild. This is most useful when you are working on a project with sources under version control and multiple contributors.

5. Define and Link the Executable

The `add_executable` command defines the build of an application, outputting an executable named by its first argument, with the sources following. Note that we add the headers to the list of sources so that they will appear in IDEs like Xcode.

After adding the executable, we use the `target_link_libraries` command to link it with the Geant4 libraries. The `Geant4_LIBRARIES` variable is set by `find_package` when Geant4 is located, and is a list of all the libraries needed to link against to use Geant4.

6. Copy any Runtime Scripts to the Build Directory

Because we want to support out of source builds so that we won't mix CMake generated files with our actual sources, we copy any scripts used by the B1 application to the build directory. We use `foreach` to loop over the list of scripts we constructed, and `configure_file` to perform the actual copy.

Here, the CMake variable `PROJECT_BINARY_DIR` is set by the earlier call to the `project` command and points to the directory where we run CMake to configure the build.

7. If Required, Install the Executable

Use the `install` command to create an install target that will install the executable to a `bin` directory under `CMAKE_INSTALL_PREFIX`.

If you don't intend your application to be installable, i.e. you only want to use it locally when built, you can leave this out.

This sequence of commands is the most basic needed to compile and link an application with Geant4, and is easily extendable to more involved use cases such as using other third party packages (via `find_package`) or platform specific configuration.

With the CMake script in place, using it to build an application is a two step process. First CMake is run to generate buildscripts to describe the build. By default, these will be Makefiles on Unix platforms, and Visual Studio solutions on Windows, but you can generate scripts for other tools like Xcode and Eclipse if you wish. Second, the buildscripts are run by the chosen build tool to compile and link the application.

A key concept with CMake is that we generate the buildscripts and run the build in a separate directory, the so-called *build directory*, from the directory in which the sources reside, the so-called *source directory*. This is the exact same technique we used when building Geant4 itself. Whilst this may seem awkward to begin with, it is a very useful technique to employ. It prevents mixing of CMake generated files with those of your application, and allows you to have multiple builds against a single source without having to clean up, reconfigure and rebuild.

We'll illustrate this configure and build process on Linux/Mac using Makefiles, and on Windows using Visual Studio. The example script and Geant4's `Geant4Config.cmake` script are vanilla CMake, so you should be able to use other Generators (such as Xcode and Eclipse) without issue.

3.2.1.1. Building ExampleB1 with CMake on Unix with Makefiles

We'll assume, *for illustration only*, that you've copied the `exampleB1` sources into a directory under your home area so that we have

```
+-- /home/you/B1/  
  +- CMakeLists.txt  
  +- exampleB1.cc  
  +- include/  
  +- src/  
  +- ...
```

Here, our *source directory* is `/home/you/B1`, in other words the directory holding the `CMakeLists.txt` file.

Let's also assume that you have already installed Geant4 in your home area under, *for illustration only*, `/home/you/geant4-install`.

Our first step is to create a *build directory* in which build the example. We will create this alongside our `B1 source directory` as follows:

```
$ cd $HOME  
$ mkdir B1-build
```

We now change to this *build directory* and run CMake to generate the Makefiles needed to build the `B1` application. We pass CMake two arguments:

```
$ cd $HOME/B1-build  
$ cmake -DGeant4_DIR=/home/you/geant4-install/lib64/Geant4-9.6.0 $HOME/B1
```

Here, the first argument points CMake to our install of Geant4. Specifically, it is the directory holding the `Geant4Config.cmake` file that Geant4 installs to help CMake find and use Geant4. You should of course adapt the value of this variable to the location of your actual Geant4 install.

The second argument is the path to the *source directory* of the application we want to build. Here it's just the B1 directory as discussed earlier. You should of course adapt the value of that variable to where you copied the B1 source directory.

CMake will now run to configure the build and generate Makefiles. On Linux, you will see the output

```
$ cmake -DGeant4_DIR=/home/you/geant4-install/lib64/Geant4-9.6.0 $HOME/B1
-- The C compiler identification is GNU
-- The CXX compiler identification is GNU
-- Check for working C compiler: /usr/bin/gcc
-- Check for working C compiler: /usr/bin/gcc -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Check for working CXX compiler: /usr/bin/c++
-- Check for working CXX compiler: /usr/bin/c++ -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Configuring done
-- Generating done
-- Build files have been written to: /home/you/B1-build
```

On Mac OS X, you will see slightly different output, but the last three lines should be identical.

If you now list the contents of you build directory, you can see the files generated:

```
$ ls
CMakeCache.txt      exampleB1.in      init_vis.mac     run2.mac
CMakeFiles          exampleB1.out    Makefile         vis.mac
cmake_install.cmake  init.mac         run1.mac
```

Note the `Makefile` and that all the scripts for running the `exampleB1` application we're about to build have been copied across. With the `Makefile` available, we can now build by simply running `make`:

```
$ make -jN
```

CMake generated `Makefiles` support parallel builds, so can set `N` suitable for the number of cores on your machine (e.g. on a dual core processor, you could set `N` to 2). When `make` runs, you should see the output

```
$ make
Scanning dependencies of target exampleB1
[ 16%] Building CXX object CMakeFiles/exampleB1.dir/exampleB1.cc.o
[ 33%] Building CXX object CMakeFiles/exampleB1.dir/src/B1PrimaryGeneratorAction.cc.o
[ 50%] Building CXX object CMakeFiles/exampleB1.dir/src/B1EventAction.cc.o
[ 66%] Building CXX object CMakeFiles/exampleB1.dir/src/B1RunAction.cc.o
[ 83%] Building CXX object CMakeFiles/exampleB1.dir/src/B1DetectorConstruction.cc.o
[100%] Building CXX object CMakeFiles/exampleB1.dir/src/B1SteppingAction.cc.o
Linking CXX executable exampleB1
[100%] Built target exampleB1
```

CMake Unix `Makefiles` are quite terse, but you can make them more verbose by adding the `VERBOSE` argument to `make`:

```
$ make VERBOSE=1
```


If you now list the contents of your *build directory* you will see the exampleB1 application executable has been created:

```
$ ls
CMakeCache.txt      exampleB1      init.mac      run1.mac
CMakeFiles          exampleB1.in  init_vis.mac  run2.mac
cmake_install.cmake exampleB1.out  Makefile      vis.mac
```

You can now run the application in place:

```
$ ./exampleB1
+++ G4StackManager uses G4SmartTrackStack. +++

*****
Geant4 version Name: geant4-09-06-ref-00      (30-November-2012)
                    Copyright : Geant4 Collaboration
                    Reference  : NIM A 506 (2003), 250-303
                    WWW       : http://cern.ch/geant4
*****

<<< Reference Physics List QBBC
Checking overlaps for volume Envelope ... OK!
Checking overlaps for volume Shapel ... OK!
Checking overlaps for volume Shape2 ... OK!
WARNING: G4QInelastic is deprecated and will be removed in GEANT4 version 10.0.
### Adding tracking cuts for neutron TimeCut(ns)= 10000 KinEnergyCut(MeV)= 0
Visualization Manager instantiating with verbosity "warnings (3)"...
Visualization Manager initialising...
Registering graphics systems...
```

further output and behaviour will depend on what UI and Visualization drivers your Geant4 install supports. If you recall the use of the `ui_all vis_all` in the `find_package` command, this results in all available UI and Visualization drivers being activated in your application. If you didn't want any UI or Visualization, you could rerun CMake as:

```
$ cmake -DWITH_GEANT4_UIVIS=OFF -DGeant4_DIR=/home/you/geant4-install/lib64/Geant4-9.6.0 $HOME/B1
```

This would switch the option we set up to false, and result in `find_package` not activating any UI or Visualization for the application. You can easily adapt this pattern to provide options for your application such as additional components or features.

Once the build is configured, you can edit code for the application in its *source directory*. You only need to rerun make in the corresponding *build directory* to pick up and compile the changes. However, note that due to the use of CMake globbing to create the source file list, if you add or remove files, you need to rerun CMake to pick up the changes! This is another reason why Kitware recommend listing the sources explicitly.

3.2.1.2. Building ExampleB1 with CMake on Windows with Visual Studio

We'll assume, *for illustration only*, that you've copied the exampleB1 sources into a directory

```
C:\Users\Ben\Documents\examples\basic\B1
```

If you browse the contents of this directory you can see that it contains the `CMakeLists.txt` file. So our *source directory* is `C:\Users\Ben\Documents\examples\basic\B1`, in other words the directory holding the `CMakeLists.txt` file.

Let's now use the CMake GUI to configure the build and generate a Visual Studio solution for it, and then use Visual Studio to build the application from this solution. This process involves several steps, which we break down as follows, and which can also be viewed as a slide show .

- Step 1:

Open the CMake (cmake-gui) executable, and click on the *Browse Source...* button in the top right hand corner of the window.

- Step 2:

Use the file browser popup to locate the B1 *source directory*, and click *OK*.

- Step 3:

Now we create the *build directory* in which to create the Visual Studio project files and hold the build products. This directory should not be the same as, or inside, the *source directory*. Therefore, let's create this *build directory* alongside our source directory.

Click on the *Browse Build...* button in the top right hand side of the CMake GUI window. Use the file browser popup to browse back to `C:\Users\Ben\Documents\examples\basic`, and click on the *Make New Folder* button. Rename the created folder to *B1-build*, and click on the *OK* button. The two text entries at the top of the GUI should now contain `C:/Users/Ben/Documents/examples/basic/B1` and `C:/Users/Ben/Documents/examples/basic/B1-build` respectively (*Note*: CMake always represents Windows paths with forward slashes).

- Step 4:

Before we can configure the project, we need to tell CMake where to find Geant4. To do this, click on the *Add Entry* button in the top right corner of the CMake GUI.

- Step 5:

In the *Add Cache Entry* window that pops up, set the *Name* of the entry to *Geant4_DIR*. Set the *Type* to *PATH*.

- Step 6:

In the *Add Cache Entry* window, click the browse button on the right hand side of the *Value* to pop up the *Browse For Folder* window. Browse to find your install of Geant4, and select the folder which contains the `Geant4Config.cmake` file. This is generally located in the `lib/Geant4-X.Y.Z` (where `X.Y.Z` is the Geant4 version number) folder inside the directory in which you installed Geant4.

- Step 7:

With *Geant4_DIR* set, click on the *Configure* button in the bottom left hand corner of the GUI.

- Step 8:

In the pop up window, select *Visual Studio 10* (or 9 if you have that version installed) and ensure the *Use default native compilers* radio button is ticked. Click on the *Finish* button. CMake will run to check that your system can perform the build and that Geant4 can be found. It will output information on its status and any errors in the logging window at the bottom of the GUI.

- Step 9:

After a successful configuration, you will see *Configuring done* in the logging window at the bottom, and some red highlighted entries in the main window, including one for *CMake*. The red color does not always mean there has been an error, but denotes that CMake needs to rerun to resolve options it has found in the build. Simply relick the *Configure* button to rerun CMake.

- Step 10:

After a further successful configuration, you will see *Configuring done* in the logging window at the bottom, and there should be no red colored entries in the main window. Now click on the *Generate* button to create the Visual Studio solution.

- Step 11:

After generation, you should see *Configuring done*, *Generating done* in the logging window at the bottom of the GUI. CMake has run successfully, and a Visual Studio solution has been created. You can now exit the CMake GUI.

- Step 12:

Now start up Visual Studio and choose *Open Project*. This guide is somewhat specific to Visual Studio 2010 Express, but the solution files should appear with the same names in both 2008 and 2010. Browse to your build directory and open the `B1.sln` Microsoft Visual Studio Solution file. It may take some time for Visual Studio to fully open the project and parse all the sources.

- Step 13:

In the *Solution Explorer*, you can click on the *exampleB1* to view the sources for the project.

- Step 14:

To build the project, right click on `ALL_BUILD` in the *Solution Explorer* and click *Build* in the dialog box.

- Step 15:

Visual Studio will perform the build, and report on progress in *Output*.

- Step 16:

Whilst you can run the built application in Visual Studio, it can be tricky to set up all the paths correctly (see below). It's therefore easiest to open a `cmd.exe` window and `cd` to the *build directory* (the directory where the Visual Studio solution was generated). You can then run the built application directly from the command line. Note that because Visual Studio supports multiple configurations and builds in *Debug* mode by default, the application is located at `Debug\exampleB1.exe`.

- Step 17:

On execution, the *exampleB1* application should pop up a UI window, and a visualization window if your install of Geant4 was installed with OpenGL visualization.

As noted above, you can also run the application through the Visual Studio debugger, although we have seen issues with setting the directory to run incorrectly. The executable locates the macro files by assuming they are in the current working directory, so the executable must be run from a directory containing the macros.

One key CMake related item to note goes back to our listing of the *headers* for the application in the call to `add_executable`. Whilst CMake will naturally ignore these for configuring compilation of the application, it will add them to the Visual Studio Solution. If you do not list them, they will not be editable in the Solution.

3.2.1.3. Usage of Geant4Config.cmake

`Geant4Config.cmake` is designed to be used with CMake's `find_package` command. When found, it sets several CMake variables and provides a mechanism for checking and activating optional features of Geant4. This allows you to use it in many ways in your CMake project to configure Geant4 for use by your application.

The most basic usage of `Geant4Config.cmake` in a `CMakeLists.txt` file is just to locate Geant4 with no requirements on its existence, version number or components:

```
find_package(Geant4)
```

If you must find Geant4, then you can use

```
find_package(Geant4 REQUIRED)
```

This will cause CMake to fail should an install of Geant4 not be located.

When an install of Geant4 is found, the module sets a sequence of CMake variables that can be used elsewhere in the project:

- `Geant4_FOUND`

Set to CMake boolean true if an install of Geant4 was found.

- `Geant4_INCLUDE_DIRS`

Set to a list of directories containing headers needed by Geant4. May contain paths to third party headers if these appear in the public interface of Geant4.

- `Geant4_LIBRARIES`

Set to the list of libraries that need to be linked to an application using Geant4.

- `Geant4_DEFINITIONS`

The list of compile definitions needed to compile an application using Geant4. This is most typically used to correctly activate UI and Visualization drivers.

- `Geant4_CXX_FLAGS`

The compiler flags used to build this install of Geant4. Usually most important on Windows platforms.

- `Geant4_USE_FILE`

A CMake script which can be included to handle certain CMake steps automatically. Most useful for very basic applications.

The typical usage of `find_package` and these variables to configure a build requiring Geant4 is thus:

```
find_package(Geant4 REQUIRED) # Find Geant4
include_directories(${Geant4_INCLUDE_DIRS}) # Add -I type paths
add_definitions(${Geant4_DEFINITIONS}) # Add -D type defs
set(CMAKE_CXX_FLAGS ${Geant4_CXX_FLAGS}) # Optional

add_executable(myg4app myg4app.cc) # Compile application
target_link_libraries(myg4app ${Geant4_LIBRARIES}) # Link it to Geant4
```

Alternatively, the CMake script pointed to by `Geant4_USE_FILE` may be included:

```
find_package(Geant4 REQUIRED) # Find Geant4
include(${Geant4_USE_FILE}) # Auto configure includes/flags

add_executable(myg4app myg4app.cc) # Compile application
target_link_libraries(myg4app ${Geant4_LIBRARIES}) # Link it to Geant4
```

This is very useful for basic applications, but if you need fine control, you should use the variables directly.

By default, CMake will look in several platform dependent locations for the `Geant4Config.cmake` file (see `find_package` for listings). You can also specify the location yourself when running CMake by setting the `Geant4_DIR` variable to the path of the directory holding `Geant4Config.cmake`. It may be set on the command line via a `-D` option, or by adding an entry to the CMake GUI. For example, if we have an install of Geant4 located in

```
+-- opt/
   +- Geant4/
```

```
+-- lib/  
+-- libG4global.so  
+-- ...  
+-- Geant4-9.6.0/  
+-- Geant4Config.cmake
```

then we would pass the argument `-DGeant4_DIR=/opt/Geant4/lib/Geant4-9.6.0` to CMake.

You can also, if you wish, build an application against a build of Geant4 *without* installing it. If you look in the directory where you built Geant4 itself (e.g. on UNIX, where you ran `make`), you see there is a `Geant4Config.cmake` file. This is a perfectly valid file, so you can also point CMake to this file when building your application. Simply set `Geant4_DIR` to the directory where you built Geant4. This feature is most useful for Geant4 developers, but it can be useful if you cannot, or do not want to, install Geant4.

A version number may also be supplied to search for a Geant4 install *greater than or equal to* the supplied version, e.g.

```
find_package(Geant4 9.5.0 REQUIRED)
```

would make CMake search for a Geant4 install whose version number is greater than or equal to 9.5.0. An exact version number may also be specified:

```
find_package(Geant4 9.6.0 EXACT REQUIRED)
```

In both cases, CMake will fail with an error if a Geant4 install meeting these version requirements is not located.

Geant4 can be built with many optional components, and the presence of these can also be required by passing extra "component" arguments. For example, to require that Geant4 is found *and* that it support Qt UI and visualization, we can do

```
find_package(Geant4 REQUIRED qt)
```

In this case, if CMake finds a Geant4 install that does *not* support Qt, it will fail with an error. Multiple component arguments can be supplied, for example

```
find_package(Geant4 REQUIRED qt gdml)
```

requires that we find a Geant4 install that supports both Qt and GDML. If the component(s) is(are) found, any needed header paths, libraries and compile definitions are appended to the variables `Geant_INCLUDE_DIRS`, `Geant4_LIBRARIES` and `Geant4_DEFINITIONS` respectively. Variables `Geant4_<COMPONENTNAME>_FOUND` are set to `TRUE` if component `COMPONENTNAME` is supported by the installation.

If you want to activate options only if they exist, you can use the pattern

```
find_package(Geant4 REQUIRED)  
find_package(Geant4 QUIET COMPONENTS qt)
```

which will require CMake to locate a core install of Geant4, and then check for and activate Qt support if the install provides it, continuing without error otherwise. A key thing to note here is that you can call `find_package` multiple times to append configuration of components. If you use this pattern and need to check if a component was found, you can use the `Geant4_<COMPONENTNAME>_FOUND` variables described earlier to check the support.

The components which can be supplied to `find_package` for Geant4 are as follows:

- `gdml`

Geant4_gdml_FOUND is TRUE if the install of Geant4 was built with GDML support.

- g3tog4

Geant4_g3tog4_FOUND is TRUE if the install of Geant4 provides the G3ToG4 library.

- ui_tcsh

Geant4_ui_tcsh_FOUND is TRUE if the install of Geant4 provides the TCsh command line User Interface.

- ui_win32

Geant4_ui_win32_FOUND is TRUE if the install of Geant4 provides the Win32 command line User Interface.

- motif

Geant4_motif_FOUND is TRUE if the install of Geant4 provides the Motif(Xm) User Interface and Visualization driver.

- qt

Geant4_qt_FOUND is TRUE if the install of Geant4 provides the Qt4 User Interface and Visualization driver.

- vis_network_dawn

Geant4_vis_network_dawn_FOUND is TRUE if the install of Geant4 provides the Client/Server network interface to DAWN visualization.

- vis_network_vrml

Geant4_vis_network_vrml_FOUND is TRUE if the install of Geant4 provides the Client/Server network interface to VRML visualization.

- vis_opengl_x11

Geant4_vis_opengl_x11_FOUND is TRUE if the install of Geant4 provides the X11 interface to the OpenGL Visualization driver.

- vis_opengl_win32

Geant4_vis_opengl_win32_FOUND is TRUE if the install of Geant4 provides the Win32 interface to the OpenGL Visualization driver.

- vis_openinventor

Geant4_vis_openinventor_FOUND is TRUE if the install of Geant4 provides the OpenInventor Visualization driver.

- ui_all

Activates all available UI drivers. Does not set any variables, and never causes CMake to fail.

- vis_all

Activates all available Visualization drivers. Does not set any variables, and never causes CMake to fail.

Please note that whilst the above aims to give a complete summary of the functionality of Geant4Config.cmake, it only gives a sampling of the ways in which you may use it, and other CMake functionality, to configure your application. We also welcome feedback, suggestions for improvement and bug reports on Geant4Config.cmake.

3.2.2. Using Geant4Make to build Applications: binmake.gmk

Geant4Make is the Geant4 GNU Make toolchain formerly used to build the toolkit and applications. It is installed on UNIX systems (except for Cygwin) for backwards compatibility with the Geant4 Examples and your existing applications which use a GNUmakefile and the Geant4Make `binmake.gmk` file. However, please note that the system is *deprecated* and will not be supported in Geant4 10.0 and later.

The files for Geant4Make are installed under:

```
+-- CMAKE_INSTALL_PREFIX/  
  +- share/  
    +- geant4make/  
      +- geant4make.sh  
      +- geant4make.csh  
      +- config/  
        +- binmake.gmk  
        +- ...
```

The system is designed to form a self-contained GNUMake system which is configured primarily by environment variables (though you may manually replace these with Make variables if you prefer). Building a Geant4 application using Geant4Make therefore involves configuring your environment followed by writing a GNUmakefile using the Geant4Make variables and GNUMake modules.

To configure your environment, simply source the relevant configuration script `CMAKE_INSTALL_PREFIX/share/Geant4-9.6.0/geant4make/geant4make.(c)sh` for your shell. Whilst both scripts can be sourced interactively, if you are using the C shell and need to source the script inside another script, you must use the command:

```
cd CMAKE_INSTALL_PREFIX/share/Geant4-9.6.0/geant4make ; source geant4make.csh
```

or alternatively

```
source CMAKE_INSTALL_PREFIX/share/Geant4-9.6.0/geant4make/geant4make.csh CMAKE_INSTALL_PREFIX/share/Geant4-9.6
```

In both cases, you should replace `CMAKE_INSTALL_PREFIX` with the actual prefix you installed Geant4 under. Both of these commands work around a limitation in the C shell which prevents the script locating itself.

Please also note that due to limitations of Geant4Make, you *should not* rely on the environment variables it sets for paths into Geant4 itself. In particular, note that the `G4INSTALL` variable *is not equivalent to* `CMAKE_INSTALL_PREFIX`.

Once you have configured your environment, you can start building your application. Geant4Make enforces a specific organization and naming of your sources in order to simplify the build. We'll use Basic Example B1, which you may find in the Geant4 source directory under `examples/basic/B1`, as the canonical example again. Here, the sources are arranged as follows

```
+-- B1/  
  +- GNUmakefile  
  +- exampleB1.cc  
  +- include/  
    | ... headers.hh ...  
  +- src/  
    ... sources.cc ...
```

As before, `exampleB1.cc` contains `main()` for the application, with `include/` and `src/` containing the implementation class headers and sources respectively. You must organise your sources in this structure with these filename extensions to use Geant4Make as it will expect this structure when it tries to build the application.

With this structure in place, the GNUmakefile for exampleB1 is very simple:

```
name := exampleB1
G4TARGET := $(name)
G4EXLIB := true

.PHONY: all
all: lib bin

include $(G4INSTALL)/config/binmake.gmk
```

Here, `name` is set to the application to be built, and it must match the name of the file containing the `main()` program without the `.cc` extension. The rest of the variables are structural to prepare the build, and finally the core Geant4Make module is included. The `G4INSTALL` variable is set in the environment by the `geant4make` script to point to the root of the Geant4Make directory structure.

With this structure in place, simply run `make` to build your application:

```
$ make
```

If you need extra detail on the build, you append `CPPVERBOSE=1` to the `make` command to see a detailed log of the command executed.

The application executable will be output to `$(G4WORKDIR)/bin/$(G4SYSTEM)/exampleB1`, where `$(G4SYSTEM)` is the system and compiler combination you are running on, e.g. `Linux-g++`. By default, `$(G4WORKDIR)` is set by the `geant4make` scripts to `$(HOME)/geant4_workdir`, and also prepends this directory to your `PATH`. You can therefore run the application directly once it's built:

```
$ exampleB1
```

If you prefer to keep your application builds separate, then you can set `G4WORKDIR` in the GNUmakefile before including `binmake.gmk`. In this case you would have to run the executable by supplying the full path.

Further documentation of the usage of Geant4Make and syntax and extensions for the GNUmakefile is described in the FAQ and Appendices of the Geant4 User's Guide for Application Developers.

Please note that the Geant4Make toolchain is provided purely for convenience and backwards compatibility. We encourage you to use and migrate your applications to the new CMake and `geant4-config` tools. Geant4Make will no longer be supported in Geant4 10.0 and later.

3.2.3. Other Unix Build Systems: `geant4-config`

If you wish to write your own Makefiles or use a completely different buildsystem for your application, a simple command line program named `geant4-config` is installed on Unix systems to help you query the Geant4 installation. It is located in

```
+-- CMAKE_INSTALL_PREFIX
   +- bin/
   +- geant4-config
```

It may be run using either a full or relative path, or directly if `CMAKE_INSTALL_PREFIX/bin` is in your `PATH`.

This program provides the following command line interface for querying various parameters on the Geant4 installation:

```
$ geant4-config --help
Usage: geant4-config [OPTION...]
  --prefix           output installation prefix of Geant4
  --version          output version for Geant4
```



```
--libs                output all linker flags
--cflags              output all preprocessor
                    and compiler flags

--libs-without-gui    output linker flags without
                    GUI components
--cflags-without-gui  output preprocessor and compiler
                    flags without GUI components

--has-feature FEATURE output yes if FEATURE is supported,
                    or no if not supported

Known Features:
clhep[yes]
expat[no]
gdml[no]
g3tog4[no]
qt[no]
motif[no]
raytracer-x11[no]
opengl-x11[no]
openinventor[no]

Help options:
-?, --help            show this help message
--usage              display brief usage message
```

You are completely free to organise your application sources as you wish and to use any buildsystem that can interface with the output of `geant4-config`.

The `--cflags` argument will print the required compile definitions and include paths (in `-I<path>` format) to use Geant4 to stdout. Note that default header search paths for the compiler Geant4 was built with are filtered out of the output of `--cflags`. The `--libs` argument will print the libraries (in `-L<path> -lname1 ... -lnameN` format) required to link with Geant4 to stdout. Note that this may include libraries for third party packages and may not be reliable for static builds. By default, all the flags and Geant4 libraries needed to activate all installed UI and Visualization drivers are provided in these outputs, but you may use the `-without-gui` variants of these arguments to suppress this.

You may also check the availability of features supported by the install of Geant4 with the `--has-feature` argument.

Due to the wide range of possible use cases, we do not provide an example of using `geant4-config` to build an application. However, it should not require more than appending the output of `--cflags` to your compiler flags and that of `--libs` to the list of libraries to link to. We welcome feedback, suggestions for improvement and bug reports on `geant4-config`.

3.3. Note on Geant4 Datasets

If you built and installed Geant4 configured with the option `GEANT4_INSTALL_DATA` set, then the Geant4 datasets will have been downloaded and installed automatically.

In this case, the `geant4.(c)sh` and `geant4make.(c)sh` scripts will set up the needed environment variables required by Geant4 to locate these datasets. On Windows, you will need to set the needed environment variables listed below by hand. This can be done by opening the *Environment Variables* dialog, as described in Section 3.1, clicking on the *New* button, and entering the *Variable name* and *Variable value* using the names and paths described below.

If you chose not to install the datasets, but require them later, you will need to download and unpack them by hand to the location you specified for `GEANT4_INSTALL_DATADIR`. If you did not set this, it defaults to `CMAKE_INSTALL_PREFIX/share/Geant4-9.6.0/data`. Unpacking the datasets in this location will result in Geant4 automatically locating them once `geant4.(c)sh` or `geant4make.(c)sh` have been sourced.

If you have datasets in a different location, then you will need to manually set the following environment variables:

- `G4LEDATA`

Set to the path to the G4EMLOW6.32 dataset.

- G4LEVELGAMMADATA

Set to the path to the PhotonEvaporation2.3 dataset.

- G4NEUTRONHPDATA

Set to the path to the G4NDL4.2 dataset.

- G4NEUTRONXSDATA

Set to the path to the G4NEUTRONXS1.2 dataset.

- G4PIIDATA

Set to the path to the G4PII1.3 dataset.

- G4RADIOACTIVEDATA

Set to the path to the RadioactiveDecay3.6 dataset.

- G4REALSURFACEDATA

Set to the path to the RealSurface1.0 dataset.

- G4SAIDXSDATA

Set to the path to the G4SAIDDATA1.1 dataset.

Chapter 4. CMake and Build Tools For Geant4 Developers

Geant4 developers can make use of several powerful features of CMake to help with their work. The key concept and working practice is the separation of the *source directory*, which is where the sources you edit reside, and the *build directory*, where the buildscripts and compiled products reside. The reason for enforcing this separation is twofold:

- It provides separation of CMake generated files (e.g. Makefiles) from the Geant4 sources under revision control.
- It allows multiple builds against a single source directory, giving fast incremental builds without having to reconfigure.

4.1. Developing Geant4 using Make, Xcode, Visual Studio and Eclipse

CMake is a *buildsystem generator* that can create scripts for many buildsystems including Make, Xcode, Visual Studio and Eclipse, among others. To find out which systems your install of CMake can generate scripts for, consult the "GENERATORS" section of the CMake man page, or click on the "Generate" button in the CMake GUI. The resulting scripts can be used within the buildsystem of choice to perform the actual build, install and packaging.

Whilst we only support Make and Visual Studio for Unix and Windows user builds respectively, Geant4 developers are welcome, and encouraged, to use their buildsystem of choice. Scripts for developing Geant4 using these systems can be generated by choosing the CMake generator when running CMake for the first time.

On the command line, one can select the tool using the `-G` argument of CMake. For example, to generate an Xcode project for Geant4 using the example from Section 2.1:

```
$ mkdir -p /path/to/geant4.9.6-build-xcode
$ cd /path/to/geant4.9.6-build-xcode
$ cmake -G Xcode -DCMAKE_INSTALL_PREFIX=/path/to/geant4.9.6-install /path/to/geant4.9.6
```

The resulting `/path/to/geant4.9.6-build-xcode/Geant4.xcodeproj` project may be opened with Xcode.

In the CMake GUI, the generator will be asked for the first time you click on *Configure* button (see Section 2.2), where it can be selected from a drop down list.

Note that in all cases, you can only have one buildtool configuration in a given build directory (e.g. you cannot have Unix Makefiles alongside an Xcode project).

Support for these buildtools is still preliminary, so feedback is welcome, whether bug reports, guides or general comments.

4.1.1. Using the Eclipse IDE

Eclipse projects using Makefiles can be generated via the command:

```
$ cmake -G"Eclipse CDT4 - <TYPE> Makefiles" <otherargs>
```

where `<TYPE>` is platform dependent and one of `Unix`, `MinGW` or `NMake`. Note that only a single build mode is supported here because the projects are Makefile based. This means that you will need to supply CMake with the command line argument `-DCMAKE_BUILD_TYPE=<MODE>`, where `<MODE>`, is the required mode if you want to change the default mode. By default, Geant4 is built in "Release" mode.

With out-of-source builds enforced in Geant4, there are two issues that need to be worked around due to the way Eclipse expects project directories to be organised. These are to do with the integration of version control support and code editing/navigation/autocompletion. Both issues, together with their resolution are described in the CMake Wiki entry on Eclipse CDT4 under the "Out-of-Source Builds" section.

4.2. Command Line Help with Make

If you develop using the command line and Make, you can get information on the targets available by "building" the `help` target in your build directory:

```
$ make help
The following are some of the valid targets for this Makefile:
... all (the default if no target is provided)
... clean
... depend
.furthertargets.
```

You may build any target individually, and it will be built together with all of its dependencies. CMake's generated makefiles only output minimal information by default, so if you need to see the full commands used, you can run make with the extra `VERBOSE=1` argument:

```
$ make VERBOSE=1
```

to output every command in full.

If you want to quickly check that your target compiles, *without* checking and rebuilding any of its dependencies, you can append `/fast` to the target name, e.g.

```
$ make G4run/fast
```

This will finish with an error if any dependents of the target do not exist, but can be useful for rapidly checking that your sources simply compile.

4.3. Building Quickly and Efficiently with Multiple Build Directories

The many ways in which Geant4 can be configured with optional components can make compilation and testing under different configurations time consuming.

As the CMake generated scripts live in a *build directory* isolated from the *source directory*, one can create several build directories configured against the same source directory. Each directory can have a different configuration, for example

```
$ cd /path/to
$ ls
geant4.9.6
$ mkdir geant4.9.6-build-release geant4.9.6-build-debug
$ cd geant4.9.6-build-release
$ cmake -DCMAKE_BUILD_TYPE=Release ../geant4.9.6

...output...

$ make -j8

...output...

$ cd ../geant4-build-debug
$ cmake -DCMAKE_BUILD_TYPE=Debug ../geant4.9.6

...output...
```

```
$ make -j8  
...output...
```

The above example uses Unix Makefiles, but the same technique works on all platforms. It may not seem to have gained you much, but when you edit and develop code that is living under `/path/to/geant4.9.6`, you only need to rebuild in each directory:

```
... work on code ...  
$ cd /path/to/geant4.9.6-build-release  
$ make -j8  
  
... incremental build ...  
  
$ cd /path/geant4.9.6-build-debug  
$ make -j8  
  
... incremental build ...
```

The builds pick up the changes you make to the source and build separately *without needing reconfiguration*. This is particularly powerful if the different configurations you need to test (for example, different versions of an external package) would require significant recompilation if the configuration were changed. Naturally, this power comes at the cost of some disk space, so may not be ideal in all cases.

Note that whilst this technique works on all platforms and buildtools, some IDEs (Xcode or Visual Studio for example) automatically support multiple build modes such as Release and Debug. In this case, you do not need separate build directories as the IDE handles this for you. However, you would still need two separate build directories if you, for example, wanted to develop and test against two versions of an external package such as Xerces-C.

4.4. Building Test Applications Against Your Development Build

A key feature of Geant4's CMake scripts is that you *do not* need to install your current build to be able to use it. A typical use case here is that you have a simple testing application which you want to build against your latest development build of Geant4.

Versions of the `geant4cmake.(c)sh` (described in Section 3.2.2), `Geant4Config.cmake` (described in Section 3.2.1) and `geant4-config` (described in Section 3.2.3) scripts are created in the build directory. These versions are all configured to use the libraries as they exist in the build directory, and headers from the source directory, without installation.

You can therefore use these scripts as described earlier in Chapter 3 to build your test applications *against a specific build tree*. You therefore don't need to install Geant4 everytime you make a small update.

Chapter 5. Help And Support

5.1. Getting Help

Whilst every effort has been made to make the build of Geant4 robust and reliable, the multitude of platforms and system configurations mean we cannot guarantee that problems will not be encountered on platforms other than those listed in Section 1.1.

In case of issues with building and installing Geant4, we welcome questions as well as feedback via our HyperNews Forum. To help us deal with your problem as quickly as possible, please include as much detail as possible on the problem you have encountered. At minimum, you should let us know the platform and operating system version, your C++ compiler type and version, CMake version and any error messages. It also helps to have the sequence of commands you used so we can try and reproduce the issue.

Please note that as discussed earlier we can only support user installs on Unix via CMake and Unix Makefiles, and on Windows via CMake and Visual Studio. Developers however are welcome to try CMake and other buildtools like Xcode and Eclipse, and we welcome your feedback here.

If you feel you have found a genuine bug in the Geant4 CMake build, please report in to the CMake category on our Bugzilla. As with reports to HyperNews, please include as much information as possible so that we can triage the bug and track it down quickly. We also welcome general feature requests and feedback on the system.

5.2. Further Information

- [CMake Documentation](#)
- [CMake Wiki](#)
- [CMake Tutorial](#)