Geant4 Installation Guide Documentation

Release 10.5

Geant4 Collaboration

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Scope of this Manual

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.

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 *Supported and Tested Platforms*.

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, C++ compiler type and version, CMake version, and any error messages. It also helps to list the sequence of commands you used so we can try and reproduce the issue.

If you feel you have found a genuine bug in the Geant4 CMake build, please report it 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.

CHAPTER

ONE

GETTING STARTED

1.1 OS/Software Prerequisites

The following source/software *must* be present to build Geant4:

- Geant4 Toolkit Source Code.
- C++ Compiler and Standard Library supporting the C++11 Standard:
  - Linux: GNU Compiler Collection 4.8.5 or higher.
    - It is strongly recommended to use the GCC compiler supplied by the package management system of your distribution unless this does not meet the minimum version requirement.
  - macOS: Apple Clang (Xcode) 8 or higher.
    - The command line tools must also be installed by running `xcode-select --install` from the terminal.
  - Windows: Visual Studio 2015, Community version or higher.

  The compiler and standard library need to support at least the following features of the C++11 Standard:
  - Template aliases, as defined in N2258.
  - Automatic type deduction, as defined in N1984.
  - Delegating constructors, as defined in N1986.
  - Enum forward declarations, as defined in N2764.
  - Explicit conversion operators, as defined in N2437.
  - Override control final keyword, as defined in N2928, N3206 and N3272.
  - Lambda functions, as defined in N2927.
  - Null pointer, as defined in N2431.
  - Override control override keyword, as defined in N2928, N3206 and N3272.
  - Range-based for, as defined in N2930.
  - Strongly typed enums, as defined in N2347.
  - Uniform intialization, as defined in N2640.
- CMake 3.3 or higher.

  On Linux, we recommend that you use CMake as provided through the package management system of your distribution, unless it does not meet the minimum version requirement. 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 macOS and Windows, CMake is not installed by default, so we recommend that you install it using the most recent Darwin64 dmg (macOS) or Win32 exe (Windows) installers supplied by the Kitware download site. On macOS, you may also use the Homebrew or Macports package managers to install the required version.

For more information on CMake, the CMake Help and Documentation should be consulted.

1.2 Supported and Tested Platforms

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

- Scientific Linux CERN 6 and Linux CentOS 7 with gcc >=4.8.4, >=4.9.3, >=5.4.0, >=6.3.0, >=7.3.0, >= 8.2.X 64bit

  The minimum required versions of GCC may be installed on SLC6 systems via the free Developer Toolset *(GCC 4.8), or* Software Collections 1.2 *(GCC 4.9).*

  Geant4 has been successfully compiled on other Linux distributions, including Debian, Ubuntu and openSUSE. The main requirement is that the system has a GCC of sufficient version to support C++11 installed. Please note that distributions other than SLC/CentOS are not officially supported. However, feedback and patches for non-SLC platforms are welcome!

- macOS 10.12 (Sierra) with Apple-LLVM (Xcode) 8, 10.13 (High Sierra) with Apple-LLVM (Xcode) 9, and 10.14 (Mojave) Apple-LLVM (Xcode) 10 , 64bit
- Windows 10 with Visual Studio 2017, 32/64bit.

The following platforms and compilers are also tested

- Scientific Linux CERN 6 with Intel C/C++ Compiler >=18.X. *Note that the Intel Compiler must be set up to use C++ headers and standard library supplied by GNU GCC >= 4.9 only to provide the required compatibility with the C++11 Standard.*
- Scientific Linux CERN 6 with clang 3.9/5.0.
- Ubuntu Linux 16 with gcc 5.4.0 (system compiler).
- macOS 10.11 (El Capitan) with clang 3.7/3.9

The Geant4 toolkit and applications can also be compiled for Intel Xeon Phi systems using the Intel C/C++ Compiler >=16.X. and Intel Manycore Platform Support Stack 3.4. Note that due to a bug in the MPSS GCC compatibility layer, only version 3.4 of MPSS can be used at the time of release. Though we cannot offer full support for the Xeon Phi architecture, a guide discussing our current experience with the platform is available separately.

1.3 Prerequisites for 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.

On Linux, we strongly recommend that you install these through the package management system of your distribution unless these do not meet the version and (for C++ packages) standard requirements listed. You should consult the documentation of your distribution for information on the packages that provide the needed software libraries and headers.

On macOS and Windows, we strongly recommend installing any required packages through binary dmg/exe installers supplied by the vendors of the packages. Installation and use of packages on macOS through Homebrew or MacPorts is not tested or supported, but you may build Geant4 using packages installed through these systems with that caveat.

1.3.1 CLHEP, Expat and zlib Support Libraries

Geant4 distributes minimal versions of the CLHEP , Expat and zlib sources with the toolkit to help cross-platform usage.

These internal versions are built and installed by default (*except for Expat on Linux and macOS Platforms*), but Geant4 can be configured to use existing installs of these packages if required (see *Geant4 Build Options* for details). If existing installs are used, they must meet the following version/standard requirements:

- CLHEP: 2.4.1.0 or higher, compiled against the same C++ Standard as Geant4 (C++11 by default)
- Expat: 2.0.1 or higher
- zlib: 1.2.3 or higher

1.3.2 GDML XML Geometry Support

To enable use of geometry reading/writing from GDML XML files, the Xerces-C++ headers and library >=3 must be installed, compiled against the same C++ Standard as Geant4 (C++11 by default)

1.3.3 User Interface and Visualization Drivers

In addition to the packages listed below for individual drivers, we strongly recommend installing the drivers for the video card on your system (e.g. NVIDIA).

- Qt User Interface and Visualization (*All Platforms*)
  - Qt4 (>=4.6) or Qt5 headers and libraries
    - On macOS, you should use Qt5.
    - Qt should preferably be compiled against the same C++ Standard as Geant4 (C++11 by default), but this is not required as its ABI is binary compatible between standards.
  - OpenGL or MesaGL headers and libraries.
- X11 OpenGL Visualization (*Linux and macOS*)
  - X11 headers and libraries (XQuartz on macOS).
  - OpenGL or MesaGL headers and libraries.
- WIN32 OpenGL Visualization (*Windows*)
  - OpenGL or MesaGL headers and libraries.
  - Visual Studio supplies a basic install of OpenGL.
- X11 RayTracer Visualization (*Linux and macOS*)
  - X11 headers and libraries (XQuartz on macOS).
- Open Inventor Visualization (*All Platforms*)
  - Coin3D libraries and headers with SoXt(SoWin) graphics binding on Linux/macOS(Windows), compiled against the C++11 standard.

- Motif User Interface and Visualization (*Linux and macOS*)
  - Motif headers and libraries.
  - X11 headers and libraries (XQuartz on macOS).
  - OpenGL or MesaGL headers and libraries.

1.3.4 Analysis Features and Backends

The Geant4 analysis library provides a lightweight interface for storing quantities and plots with various backends for persistency (e.g. plain text, XML). Whilst the choice of backend and linking is deferred to the user as required for their application, the following features require presence of additional software when compiling Geant4:

- Freetype Font Rendering Support (*Linux and macOS*)
  - Freetype headers and libraries.

1.3.5 Advanced/Experimental Features

Warning: These features are for advanced users only. Note that HDF5 and Wt support are experimental.

- VecGeom Replacements for Geant4 solids
  - VecGeom headers and libraries, compiled against the same C++ Standard as Geant4 (C++11 by default)
- TiMemory profiling for Geant4 kernel and applications
  - TiMemory headers and library, compiled against the same C++ Standard as Geant4 (C++11 by default)
- HDF5 Persistency for Geant4 Analysis module
  - HDF5 1.8 or higher C headers and libraries.
  - If Geant4 is built with multithreading support, then the used HDF5 install *must* have been compiled with thread safety enabled.
- Wt User Interface and Visualization Driver
  - Wt headers and libraries

1.4 Software Suggested for Use With Geant4 Applications

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

However, you may wish to install the third-party 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. Also note that Geant4 cannot provide support on installing or using these packages. Any issues here should be reported to the developers of the package.

- 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, JAS3 or rAIDA.
- gMocren volume visualizer for Geant4 medical simulations.

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

TWO

BUILDING AND INSTALLING

2.1 On Unix Platforms

Unpack the Geant4 source package `geant4.10.05.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/geant4.10.05
```

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 geant4.10.05-build
$ ls
geant4.10.05  geant4.10.05-build
```

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

```
$ cd /path/to/geant4.10.05-build
$ cmake -DCMAKE_INSTALL_PREFIX=/path/to/geant4.10.05-install /path/to/geant4.
↪10.05
```

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 *Geant4 Build Options* for details of these options. If you run CMake and decide afterwards you want to activate additional options, simply rerun CMake in the build directory, passing it the extra options plus the build directory path. For example, after running CMake as above, you may wish to activate the installation of Geant4's datasets, so you would run (in the build directory)

```
$ cd /path/to/geant4.10.05-build
$ cmake -DGEANT4_INSTALL_DATA=ON .
```

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/geant4.10.05-install /path/to/geant4.
↪10.05
-- The C compiler identification is GNU 4.9.2
-- The CXX compiler identification is GNU 4.9.2
```

```
-- Check for working C compiler: /usr/bin/gcc-4.9
-- Check for working C compiler: /usr/bin/gcc-4.9 -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Detecting C compile features
-- Detecting C compile features - done
-- Check for working CXX compiler: /usr/bin/g++-4.9
-- Check for working CXX compiler: /usr/bin/g++-4.9 -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Detecting CXX compile features
-- Detecting CXX compile features - done
-- Found EXPAT: /usr/lib64/libexpat.so (found version "2.0.1")
-- Looking for sys/types.h
-- Looking for sys/types.h - found
-- Looking for stdint.h
-- Looking for stdint.h - found
-- Looking for stddef.h
-- Looking for stddef.h - found
-- Check size of off64_t
-- Check size of off64_t - done
-- Looking for fseeko
-- Looking for fseeko - found
-- Looking for unistd.h
-- Looking for unistd.h - found
-- Pre-configuring dataset G4NDL (4.5)
-- Pre-configuring dataset G4EMLOW (7.7)
-- Pre-configuring dataset PhotonEvaporation (5.3)
-- Pre-configuring dataset RadioactiveDecay (5.3)
-- Pre-configuring dataset G4PARTICLEXS (1.1)
-- Pre-configuring dataset G4PII (1.3)
-- Pre-configuring dataset RealSurface (2.1.1)
-- Pre-configuring dataset G4SAIDDATA (2.0))
-- Pre-configuring dataset G4ABLA (3.1)
-- Pre-configuring dataset G4INCL (1.0)
-- Pre-configuring dataset G4ENSDFSTATE (2.2)
  *WARNING*
    Geant4 has been pre-configured to look for datasets
    in the directory:

    /path/to/geant4.10.05-install/share/Geant4-10.5.0/data

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

    G4NDL (4.5)
    G4EMLOW (7.7)
    PhotonEvaporation (5.3)
    RadioactiveDecay (5.3)
    G4PARTICLEXS (1.1)
    G4PII (1.3)
    RealSurface (2.1.1)
    G4SAIDDATA (2.0))
    G4ABLA (3.1)
```

```
    G4INCL (1.0)
    G4ENSDFSTATE (2.2)

    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:

    https://cern.ch/geant4-data/datasets/G4NDL.4.5.tar.gz
    https://cern.ch/geant4-data/datasets/G4EMLOW.7.7.tar.gz
    https://cern.ch/geant4-data/datasets/G4PhotonEvaporation.5.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4RadioactiveDecay.5.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4PARTICLEXS.1.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4PII.1.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4RealSurface.2.1.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4SAIDDATA.2.0.tar.gz
    https://cern.ch/geant4-data/datasets/G4ABLA.3.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4ENSDFSTATE.2.2.tar.gz

    and unpack them under the directory:

    /path/to/geant4.10.05-install/share/Geant4-10.5.0/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_USE_SYSTEM_EXPAT: Using system EXPAT library

-- Configuring done
-- Generating done
-- Build files have been written to: /path/to/geant4.10.05-build
```

The exact output will differ depending on the exact platform/compiler in use, but the last three lines should be the same to within path differences. 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/geant4.10.05-install/share/Geant4-10.5.0/data`. If any datasets are not found here, it will pre-configure the setup scripts for using

Geant4 (described in *Postinstall Setup*) 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 *Standard Options* 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 *Postinstall Setup*. 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 On Windows Platforms

The easiest way to build and install Geant4 from source on Windows platforms is to use the Windows command line program `cmd` plus CMake's command line interface to the MSBuild tool supplied with Visual Studio. Whilst the full Visual Studio GUI can be used, `cmd` and CMake/MSBuild provide a simpler interface and the commands can be used inside scripts. You can also use PowerShell instead of `cmd` if you prefer, and the instructions below should transfer barring minor syntax differences. Builds of Geant4 using Cygwin or MinGW with their own compilers or the Microsoft C++ Compiler are neither supported or tested, though the CMake system is expected to work under these toolchains. If you are using these tools via their native shells and with their own versions of CMake, then the instructions for building and installing on Unix platforms *On Unix Platforms* can be used.

To ensure that the appropriate Visual Studio paths and settings are set up for building, open a Visual Studio Developer `cmd` window from *Start → Visual Studio 201X → Visual Studio Tools → Developer Command Prompt for VS201X*. After running this, confirm that you have the MSVC compiler available by running the `cl` command, and you should see (NB, in the following, the `cmd` prompt is shown as a > for clarity):

```
> cl
Microsoft (R) C/C++ Optimizing Compiler Version 19.11.25547 for x86
Copyright (C) Microsoft Corporation.  All rights reserved.

usage: cl [ option... ] filename... [ /link linkoption... ]
```

The exact version number of `cl` may differ slightly, but for Visual Studio 17 the first element of the Compiler Version should be at least `19`.

To begin building Geant4, unpack the source package `geant4_10_05.zip` to a location of your choice. For illustration *only*, this guide will assume it's been unpacked in a directory named `C:\Users\YourUsername\Geant4`, so that the Geant4 source package sits in a subdirectory `C:\Users\YourUsername\Geant4\geant4_10_05`

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 %HOMEPATH%\Geant4
> dir /B
geant4_10_05

> mkdir geant4_10_05-build
> dir /B
geant4_10_05
geant4_10_05-build
```

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

```
> cd %HOMEPATH%\Geant4\geant4_10_05-build
> cmake -DCMAKE_INSTALL_PREFIX="%HOMEPATH%\Geant4\geant4_10_05-install" "
↪%HOMEPATH%\Geant4\geant4_10_05"
```

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. Paths should be quoted in case they contain spaces.

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 *Geant4 Build Options* for details of these options. If you run CMake and decide afterwards you want to activate additional options, simply rerun CMake in the build directory, passing it the extra options plus the build directory. For example, after running CMake as above, you may wish to activate the installation of Geant4's datasets, so you would run

```
> cd %HOMEPATH%\Geant4\geant4_10_05-build
> cmake -DGEANT4_INSTALL_DATA=ON .
```

On executing the CMake command, it will run to configure the build and generate Visual Studio Project files to perform the actual build. CMake has the capability to generate buildscripts for other tools, such as NMake and Ninja, but please note that *these are not supported for builds of Geant4 on Windows yet*. With Visual Studio 2017, you should see output similar to

```
> cmake -DCMAKE_INSTALL_PREFIX="%HOMEPATH%\Geant4\geant4_10_05-install" "
↪%HOMEPATH%\Geant4\geant4_10_05"
-- Building for: Visual Studio 15 2017
-- The C compiler identification is MSVC 19.11.25547.0
-- The CXX compiler identification is MSVC 19.11.25547.0
-- Check for working C compiler: C:/Program Files (x86)/Microsoft Visual␣
↪Studio/2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe
```

```
-- Check for working C compiler: C:/Program Files (x86)/Microsoft Visual␣
↪Studio/2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe --
↪ works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Check for working CXX compiler: C:/Program Files (x86)/Microsoft Visual␣
↪Studio/2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe
-- Check for working CXX compiler: C:/Program Files (x86)/Microsoft Visual␣
↪Studio/2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe --␣
↪works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Detecting CXX compile features
-- Detecting CXX compile features - done
-- Looking for dlfcn.h
-- Looking for dlfcn.h - not found
-- Looking for fcntl.h
-- Looking for fcntl.h - found
-- Looking for inttypes.h
-- Looking for inttypes.h - found
-- Looking for memory.h
-- Looking for memory.h - found
-- Looking for stdint.h
-- Looking for stdint.h - found
-- Looking for stdlib.h
-- Looking for stdlib.h - found
-- Looking for strings.h
-- Looking for strings.h - not found
-- Looking for string.h
-- Looking for string.h - found
-- Looking for sys/stat.h
-- Looking for sys/stat.h - found
-- Looking for sys/types.h
-- Looking for sys/types.h - found
-- Looking for unistd.h
-- Looking for unistd.h - not found
-- Looking for getpagesize
-- Looking for getpagesize - not found
-- Looking for bcopy
-- Looking for bcopy - not found
-- Looking for memmove
-- Looking for memmove - found
-- Looking for mmap
-- Looking for mmap - not found
-- Looking for 4 include files stdlib.h, ..., float.h
-- Looking for 4 include files stdlib.h, ..., float.h - found
-- Check if the system is big endian
-- Searching 16 bit integer
-- Looking for stddef.h
-- Looking for stddef.h - found
-- Check size of unsigned short
-- Check size of unsigned short - done
-- Using unsigned short
-- Check if the system is big endian - little endian
```

```
-- Looking for off_t
-- Looking for off_t - not found
-- Looking for size_t
-- Looking for size_t - not found
-- Check size of off64_t
-- Check size of off64_t - failed
-- Looking for fseeko
-- Looking for fseeko - not found
-- Looking for unistd.h
-- Looking for unistd.h - not found
-- Pre-configuring dataset G4NDL (4.5)
-- Pre-configuring dataset G4EMLOW (7.7)
-- Pre-configuring dataset PhotonEvaporation (5.3)
-- Pre-configuring dataset RadioactiveDecay (5.3)
-- Pre-configuring dataset G4PARTICLEXS (1.1)
-- Pre-configuring dataset G4PII (1.3)
-- Pre-configuring dataset RealSurface (2.1.1)
-- Pre-configuring dataset G4SAIDDATA (2.0))
-- Pre-configuring dataset G4ABLA (3.1)
-- Pre-configuring dataset G4INCL (1.0)
-- Pre-configuring dataset G4ENSDFSTATE (2.2)
  *WARNING*
    Geant4 has been pre-configured to look for datasets
    in the directory:

    /Users/YourUsername/Geant4/geant4_10_05-install/share/Geant4-10.5.0/data

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

    G4NDL (4.5)
    G4EMLOW (7.7)
    PhotonEvaporation (5.3)
    RadioactiveDecay (5.3)
    G4PARTICLEXS (1.1)
    G4PII (1.3)
    RealSurface (2.1.1)
    G4SAIDDATA (2.0))
    G4ABLA (3.1)
    G4INCL (1.0)
    G4ENSDFSTATE (2.2)

    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:

    https://cern.ch/geant4-data/datasets/G4NDL.4.5.tar.gz
    https://cern.ch/geant4-data/datasets/G4EMLOW.7.7.tar.gz
    https://cern.ch/geant4-data/datasets/G4PhotonEvaporation.5.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4RadioactiveDecay.5.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4PARTICLEXS.1.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4PII.1.3.tar.gz
    https://cern.ch/geant4-data/datasets/G4RealSurface.2.1.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4SAIDDATA.2.0.tar.gz
    https://cern.ch/geant4-data/datasets/G4ABLA.3.1.tar.gz
    https://cern.ch/geant4-data/datasets/G4ENSDFSTATE.2.2.tar.gz

    and unpack them under the directory:

    /Users/YourUsername/Geant4/geant4_10_05-install/share/Geant4-10.5.0/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:

-- Configuring done
-- Generating done
-- Build files have been written to: C:/Users/YourUsername/Geant4/geant4_10_
 ↪04-build
```

The output will differ slightly due to the source/build paths being for illustration only, but the last three lines at least should be the same to within path differences. 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 `C:\Users\YourUsername\Geant4\geant4_10_05-install\share\Geant4-10.5.0\data`. If any datasets are not found here, the message is emitted to advise you of 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 *Standard Options* 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 Visual Studio first. The default configuration of Geant4 is very simple, and provided CMake and Visual Studio are installed correctly, you should not see errors.

After the configuration has run, CMake will have generated Visual Studio Solution files for building Geant4. CMake itself can be used to run the build by executing the command:

```
> cmake --build . --config Release
```

Here, the `--build` argument takes the path to the build directory, in this case we are running from the build directory so it is just the current working directory. The `--config` argument takes the configuration we want to build (Visual Studio, unlike Make, can support multiple configurations in the same project) and `Release` is chosen to provide fully optimized libraries for best performance. If you are developing applications and require debugging information, then you should change this argument to `RelWithDebInfo`.

The build will now run, and will output information on the progress of the build and current operations. By default, Visual Studio Solutions do not enable parallel compilation of files for faster builds. Geant4's CMake system provides an option to enable this, so if you have a multicore system, you can add the option `-DGEANT4_BUILD_MSVC_MP=ON` to the arguments passed to CMake. Once the build has completed the headers, libraries and support files can be installed by running the command:

```
> cmake --build . --config Release --target install
```

This command may also be invoked immediately after configuration to build and install Geant4 in one step. The file and directory structure of the installation follows that of the Unix build, and is described in *Postinstall Setup*.

2.3 Geant4 Build Options

Both *On Unix Platforms* and *On Windows Platforms* give the minimal proceedure to build and install Geant4 on these platforms. Many additional options can be passed to CMake to adjust the way Geant4 is built and installed and to enable optional components.

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 install. Some options enable components of Geant4 which require external software (as listed in *Getting Started*). 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.

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-source
```

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

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). You can also *deactivate* a previously selected option to remove a component from the build. For example, if we had configured a build to enable GDML support and wanted to remove it, we could run:

```
$ cmake -DGEANT4_USE_GDML=OFF .
```

Note that this assumes we are running `cmake` in a previously configured build directory so we only need pass the current working directory rather than the full source directory path.

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 should build the `uninstall` target before reconfiguring to guarantee removal of these files.

CMake also provides Curses (UNIX only) and Qt (UNIX and Windows) based Terminal/GUI interfaces which may be used to browse and set options. Please see the CMake documentation for more information on these interfaces.

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. Where third-party software requirements are listed, please consult *Getting Started* for links and information on these packages.

- `CMAKE_INSTALL_PREFIX`
  - Sets the installation prefix for Geant4. Equivalent to `--prefix` in Autotools. The 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)`
  - Sets the type of build. It defaults to `Release` which gives a fully optimized build without debugging symbols. The most useful values are:

    `Release` : Optimized build, no debugging symbols

    `Debug` : Debugging symbols, no optimization

    `RelWithDebInfo` : Optimized build with debugging symbols

    See *Options for Changing the Compiler and Build Flags* for the compiler flags used in each mode.

    Note that if you use a build system which supports multiconfiguration builds (e.g. Xcode, Visual Studio), this variable has no effect. For these systems, all build types are available inside the CMake generated project and can be selected in the tool itself.
- `GEANT4_BUILD_MULTITHREADED : (DEFAULT : OFF)`
  - If set to `ON`, build Geant4 libraries with support for multithreading. At present, this is only supported on Unix systems.

    Requires: Compiler/C++ Standard Library with support for C++ Threading Support
- `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_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_USE_G3TOG4 : (DEFAULT : OFF)`
  - If set to `ON`, build the `G3ToG4` library for reading ASCII call list files generated from Geant3 geometries.
- `GEANT4_USE_GDML : (DEFAULT : OFF)`

  - If set to ON, build the G4persistency library with support for GDML.

    Requires: Xerces-C++ libraries and headers. See the XERCESC_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating Xerces-C.

- GEANT4_USE_QT (DEFAULT : OFF)
  - If set to ON, build Qt4/5 User Interface and Visualization drivers.

    Requires: Qt4 or Qt5 and OpenGL libraries and headers. Qt5 will be searched for first. If it is not found Qt4 will be searched for. This behaviour can be adjusted through the advanced option GEANT4_FORCE_QT4.

    See the QT_QMAKE_EXECUTABLE and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating Qt.

- 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_RAYTRACER_X11 (DEFAULT : OFF, Unix only)
  - If set to ON, build RayTracer visualization driver with X11 support.

    Requires: X11 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.

- 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.

    See the INVENTOR_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating Inventor.

    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_XM (DEFAULT : OFF, Unix Only)
  - If set to ON, build Motif User Interface and Visualization drivers.

    REQUIRES: Motif and OpenGL libraries and headers. See the MOTIF_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating Motif.

- GEANT4_USE_SYSTEM_CLHEP (DEFAULT : OFF)
  - 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 project's software uses CLHEP in other tools and requires consistent use of the same CLHEP across the software stack).

    Requires: CLHEP libraries and headers. See the CLHEP_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating CLHEP.

- GEANT4_USE_SYSTEM_EXPAT (DEFAULT : ON)

  - If set to ON, build Geant4 with an external install of Expat. Whilst Expat is installed on the vast majority of systems, it may be missing in certain instances. In these cases, simply switch this option to OFF and Geant4 will build and use its internal version of Expat.

    Requires: Expat library and headers. See the EXPAT_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating Expat.

- GEANT4_USE_SYSTEM_ZLIB (DEFAULT : OFF)
  - If set to ON, build Geant4 with an external install of zlib.

    Requires: Zlib library and headers. See the ZLIB_XXX and CMAKE_PREFIX_PATH *Advanced Options* if CMake has trouble locating ZLIB.

2.3.2 Advanced Options

Most installs should never need to touch these options, and are primarily to give advanced users more control over the build, enable experimental features, and to help CMake locate needed software packages. Advanced options and variables can be set like the standard ones listed earlier using -D arguments to cmake. In CMake's curses and GUI interfaces these options can be displayed by pressing t in ccmake, or clicking the 'advanced' check box in the CMake GUI.

In the list below, we only list those options most relevent for Geant4. Many additional core CMake variables are available, for which you should consult the Reference Documentation section of the main CMake documentation , and specifically the sections on Variables. The following list is presented in semi-alphabetical order, with grouping by task where appropriate.

- 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 Toolkit 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.
- 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.
- GEANT4_INSTALL_EXAMPLES : (DEFAULT : ON)

  - Set to OFF to prevent installation of the source code and documentation for the Geant4 examples.

- GEANT4_BUILD_CXXSTD : (DEFAULT : 11)
  - Compile Geant4 against given C++ standard (11, 14, or 17). Geant4 is written in C++11, and you should use this option if your application requires support for the newer standard. If you set the variable to a standard the compiler does not support, an error will be emitted.

    Requires: C++ Compiler with support for the requested standard. Use of C++17 requires CMake 3.8 or newer.

- GEANT4_BUILD_MSVC_MP : (Windows Only, DEFAULT : OFF)
  - If set to ON, add /MP to CMAKE_CXX_FLAGS to enable file level parallel compilation when using MSVC and MSBuild. Note that this only works when building Geant4 using Visual Studio Solutions.

- GEANT4_BUILD_TLS_MODEL : (DEFAULT : initial-exec)
  - If building Geant4 with multithreading support, use a specific model for Thread Local Storage (initial-exec, local-exec, global-dynamic, local-dynamic or auto). If you set the variable to a model unknown to the compiler, an error will be emitted.

    Geant4's default model of initial-exec is chosen to give the best performance under a wide variety of use cases.

    The special auto value leaves the choice of TLS model to the compiler.

    Requires: GEANT4_BUILD_MULTITHREADED set to ON

- 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_MUONIC_ATOMS_IN_USE : (DEFAULT : OFF)
  - Set to ON **only** if using Muonic Atom physics.

- 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.*

- 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_USE_FREETYPE : (DEFAULT : OFF)
  - If set to ON, build Geant4 Analysis library with support for Freetype font rendering.

    Requires: Freetype libraries and headers.

- GEANT4_USE_HDF5 : (DEFAULT : OFF)

  - If set to ON, build Geant4 Analysis library with support for HDF5 persistency.

    WARNING: use of HDF5 is experimental and should be used with caution.

    Requires: HDF5 C libraries and headers, compiled in threadsafe mode if Geant4 is built with multithreading support.

- GEANT4_USE_USOLIDS : (DEFAULT : OFF)
  - If set to ON, replace Geant4 solids with VecGeom equivalents.

    WARNING: the use of VecGeom is experimental and should be used with caution.

    Requires: VecGeom libraries and headers.

- GEANT4_USE_TIMEMORY : (DEFAULT : OFF)
  - If set to ON, build Geant4 with support for memory/CPU profiling with TiMemory.

    Requires: TiMemory library and headers.

- GEANT4_USE_WT : (DEFAULT : OFF)
  - If set to ON, build Geant4 Wt web based visualization driver.

    WARNING: this driver is experimental and should be used with caution.

    Requires: Wt libraries and headers, OpenGL libraries and headers, Boost headers and Boost signals library.

- CMAKE_PREFIX_PATH
  - If you have software packages required by Geant4 installed in custom locations, this variable can be set to list these prefixes to help CMake locate the packages. For example, if Xerces-C is needed and installed in /custom/xerces-c, then CMAKE_PREFIX_PATH could be set on the command line as:

    ```
    cmake -DCMAKE_PREFIX_PATH="/custom/xerces-c" <otherargs>
    ```

    Additional paths may be added, separated by semicolons, e.g.:

    ```
    cmake -DCMAKE_PREFIX_PATH="/A;/B;/C" <otherargs>
    ```

    CMAKE_PREFIX_PATH may also be set in the environment with paths separated by the appropriate element separator for the platform (":" on UNIX, ";" on Windows).

- XERCESC_ROOT_DIR
  - If CMAKE_PREFIX_PATH is not sufficient to locate, or you require a very specific version of, Xerces-C, 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 XERCESC_INCLUDE_DIR and XERCESC_LIBRARY.

    Setting this variable will automatically enable a build with support for GDML.

- 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

- GEANT4_FORCE_QT4 : (DEFAULT : OFF)

  - If set to ON, only search for a Qt4 installation. WARNING: This cannot be set after a Qt5 installation has already been found.

- 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).

    To locate Qt5 installations, the CMAKE_PREFIX_PATH variable should be used to point the installation prefix for the required Qt5.

- 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.

- 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

- GEANT4_USE_SYSTEM_CLHEP_GRANULAR (DEFAULT : OFF)
  - If set to ON, configure Geant4 to search for and use the Evaluator, Geometry, Random and Vector component libraries of CLHEP rather than the single CLHEP library.

    WARNING: This option should only be used if your project is locked into using the CLHEP granular libraries by other requirements. Use of the single CLHEP library is no different and simplifies the configuration and use of Geant4.

- 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 subdirectories 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.

    Setting this variable will automatically enable a build using the located system install of CLHEP.

- CLHEP_INCLUDE_DIR
  - 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 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 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 CMake cannot locate your external EXPAT installation, set this to the full path to the EXPAT library, e.g. /usr/lib/libexpat.so
- ZLIB_INCLUDE_DIR
  - If CMake cannot locate your external zlib installation, set this to the directory containing the zlib headers (e.g. if you have /foobar/zlib.h, then set this to /foobar).
- ZLIB_LIBRARY
  - If CMake cannot locate your zlib installation, set this to the full path to the zlib library, e.g. /usr/lib/libz.so

2.4 Options for Changing the Compiler and Build Flags

CMake will, by default, select the first C and C++ compilers it finds in your PATH. 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 use a full path should the compilers not be in the PATH or 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 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.

Geant4's CMake scripts configure a set of flags for use with each supported compiler as follows. CMAKE_CXX_FLAGS are always applied, with the CMAKE_CXX_FLAGS_<MODE> being appended when building in the given <MODE>

(e.g. "Release"). If you are using an unsupported or unrecognized compiler, CMake will default to a standard and very simple set of flags.

- GNU Compiler Collection
  - `CMAKE_CXX_FLAGS : -W -Wall -pedantic -Wno-non-virtual-dtor -Wno-long-long -Wwrite-strings -Wpointer-arith -Woverloaded-virtual -Wno-variadic-macros -Wshadow -pipe`
  - `CMAKE_CXX_FLAGS_RELEASE : -O3 -DNDEBUG -fno-trapping-math -ftree-vectorize -fno-math-errno`
  - `CMAKE_CXX_FLAGS_DEBUG: -g -DG4FPE_DEBUG`
  - `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 -Wno-variadic-macros -Wshadow -pipe -Qunused-arguments`
  - `CMAKE_CXX_FLAGS_RELEASE : -O3 -DNDEBUG -fno-trapping-math -ftree-vectorize -fno-math-errno`
  - `CMAKE_CXX_FLAGS_DEBUG: -g -DG4FPE_DEBUG`
  - `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_DEPRECATE`
  - `CMAKE_CXX_FLAGS_RELEASE: -MD -Ox -DNDEBUG`
  - `CMAKE_CXX_FLAGS_DEBUG: -MDd -Od -Zi`
  - `CMAKE_CXX_FLAGS_RELWITHDEBINFO: -MD -O2 -Zi`
- Intel
  - `CMAKE_CXX_FLAGS : -w1 -Wno-non-virtual-dtor -Wpointer-arith -Wwrite-strings -fp-model precise`
  - `CMAKE_CXX_FLAGS_RELEASE: -O3 -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++11 standard. This can be changed if the compiler version supports it by setting the `GEANT4_BUILD_CXXSTD` to the required standard, as described in *Advanced Options*.

When Geant4 is built with support for multithreading (`GEANT4_BUILD_MULTITHREADED` set to `ON`), the following additional flags are added to all build types for the GNU, Clang and Intel compilers:

- `-DG4MULTITHREADED -ftls-model=initial-exec -pthread`

Note that the model passed to the `-ftls-model` argument can be changed using the `GEANT4_BUILD_TLS_MODEL` option described in *Advanced Options*. The additional `auto` option to `GEANT4_BUILD_TLS_MODEL` does not set additional flags, leaving the selection of TLS model to the compiler.

Whilst we strongly recommend the default set of flags as described above, they may be modified. CMake is aware of the `CFLAGS` and `CXXFLAGS` variables, so these may be set on the command line or as environment variables like the `CC` and `CXX` options above. However, note that these 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. 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.

CHAPTER

THREE

POSTINSTALL SETUP

If you chose the default installation paths, then your install of Geant4 is completely contained under the directory passed to `CMAKE_INSTALL_PREFIX`, with hierarchy

```
+- CMAKE_INSTALL_PREFIX
   +- bin/
   |  +- geant4-config   (UNIX ONLY)
   |  +- geant4.csh      (UNIX ONLY)
   |  +- geant4.sh       (UNIX ONLY)
   |  +- G4global.dll    (WINDOWS ONLY)
   |  +- ...
   +- include/
   |  +- Geant4/
   |     +- G4global.hh
   |     +- ...
   +- lib{64}/
   |  +- libG4global.{so,a,dylib,lib}
   |  +- ...
   |  +- Geant4-10.5.0/
   |     +- Geant4Config.cmake
   |     +- ...
   |     +- {Linux,Darwin}-{g++,clang}  (UNIX ONLY)
   +- share
      +- Geant4-10.5.0
         +- examples/
         +- data/        (IF GEANT4_INSTALL_DATA WAS SET)
         +- geant4make/
            +- geant4make.csh
            +- geant4make.sh
            +- config/
```

3.1 Required Environment Settings on UNIX

If you wish to make the Geant4 Toolkit programs and libraries available via your `PATH` and library path (`LD_LIBRARY_PATH` on Linux) together with default environment variables for locating datasets, you should source the relevant script in `CMAKE_INSTALL_PREFIX/bin`. Please note that `DYLD_LIBRARY_PATH` is not set on macOS as this variable is not propagated to programs due to SIP. This should not affect general running of Geant4 applications as the default macOS settings link and install the libraries with suitable install names and RPATHs.

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 environment for Geant4 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 the C 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.

3.2 Required Environment Settings on Windows

On Windows, you should add the directory containing the Geant4 `.dll` files to your `PATH/Path` environment variable(s), and set the variables pointing to the datasets:

1. On Windows 7
   - Open the Windows Control Panel.
   - Open the *System* item in the Control Panel.
2. On Windows 10
   - In *Search*, search for and select *System (Control Panel)*
3. Click the *Advanced system settings* link
4. Click the *Environment Variables* button
5. Select the `PATH` (or `Path`) entry in the *User variables* list, and click the *Edit* button. If `PATH` or `Path` are not present, click the *New* button and create one or the other.
6. In the popup *Edit User Variable* window, add the directory in which the Geant4 dlls are installed to the Variable value entry of the `PATH` or `Path` variable (Note that on Windows, path entries are separated by semicolons). It's very important to keep any existing entries otherwise other programs may stop working correctly!
7. For each variable listed in *Environment Variables for Datasets*, create a new environment variable using the name and path listed there.
   - If you installed Geant4 with `GEANT4_INSTALL_DATA` set to `ON`, then the datasets will be present under `CMAKE_INSTALL_PREFIX/share/Geant4-10.5.0/data`.
   - Otherwise, set the paths to the locations you manually unpacked the datasets to.
7. Click *OK*, and then *OK* through remaining windows to close.

3.3 Environment Variables for Datasets

If you need to manually manage the datasets for the Geant4 data-driven physics models, zip/tarballs can be downloaded from the Geant4 distribution site. Simply unpack these to a location of your choice and set each environment variable listed below to the full path to the unpacked directory for the given dataset. You can use any method you like to set these variables.

Environment Variable	Value
G4ABLADATA	absolute path to the G4ABLA3.1 directory
G4ENSDFSTATEDATA	absolute path to the G4ENSDFSTATE2.2 directory
G4INCLDATA	absolute path to the G4INCL1.0 directory
G4LEDATA	absolute path to the G4EMLOW7.7 directory
G4LEVELGAMMADATA	absolute path to the PhotonEvaporation5.3 directory
G4NEUTRONHPDATA	absolute path to the G4NDL4.5 directory
G4PARTICLEXSDATA	absolute path to the G4PARTICLEXS1.1 directory
G4PIIDATA	absolute path to the G4PII1.3 directory
G4RADIOACTIVEDATA	absolute path to the RadioactiveDecay5.3 directory
G4REALSURFACEDATA	absolute path to the RealSurface2.1.1 directory
G4SAIDXSDATA	absolute path to the G4SAIDDATA2.0 directory

CHAPTER

FOUR

HOW TO USE THE GEANT4 TOOLKIT LIBRARIES

To build an application that uses the Geant4 Toolkit, it is necessary to include the Geant4 headers in the application C++ sources, and compile and link these to the Geant4 libraries. Full details on how to implement, build, and run a Geant4 application are provided in the Geant4 User's Guide for Application Developers.

Here we describe tools supplied with Geant4 to help with compilation and linking: a CMake `Geant4Config.cmake` config file and a UNIX-only command line program `geant4-config`. *A self-contained GNUmake system, "Geant4Make" is also supplied, but is deprecated since Geant4 10.0. Brief details on this are given in Using Geant4Make to build Applications.*

4.1 CMake Build System: Geant4Config.cmake

The `Geant4Config.cmake` file installed by Geant4 is designed to be used with CMake's `find_package` command. When used, 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 script is just to locate Geant4 with no requirements on its existence, version number or components

```
find_package(Geant4)
```

If Geant4 is an absolute requirement of the project, then you can use

```
find_package(Geant4 REQUIRED)
```

This will cause CMake to fail with an error should an install of Geant4 not be located. By default, CMake will look in several platform dependent locations for the `Geant4Config.cmake` file (see find_package for listings). If these are not sufficient to locate your install of Geant4, then the `Geant4_DIR` or `CMAKE_PREFIX_PATH` variables may be used. For example, if we have an install of Geant4 located in

```
+- opt/
   +- Geant4/
   +- lib/
      +- libG4global.so
      +- ...
      +- Geant4-10.5.0/
         +- Geant4Config.cmake
```

then we could pass the argument `-DGeant4_DIR=/opt/Geant4/lib/Geant4-10.5.0` (i.e. the directory holding `Geant4Config.cmake`) *or* `-DCMAKE_PREFIX_PATH=/opt/Geant4` to `cmake`.

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_CXX_FLAGS_<CONFIG>`

  The compiler flags recommended for compiling Geant4 and applications in mode `CONFIG` (e.g. Release, Debug, etc). Usually most important on Windows platforms.

- `Geant4_CXXSTD`

  The C++ standard, e.g. "`c++11`" against which this install of Geant4 was compiled.

- `Geant4_TLS_MODEL`

  The thread-local storage model, e.g. "`initial-exec`" against which this install of Geant4 was compiled. Only set if the install was compiled with multithreading support.

- `Geant4_USE_FILE`

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

- `Geant4_builtin_clhep_FOUND`

  A CMake boolean which is set to true if this install of Geant4 was built using the internal CLHEP.

- `Geant4_system_clhep_ISGRANULAR`

  A CMake boolean which is set to true if this install of Geant4 was built using the system CLHEP and linked to the granular CLHEP libraries.

- `Geant4_builtin_expat_FOUND`

  A CMake boolean which is set to true if this install of Geant4 was built using the internal Expat.

- `Geant4_builtin_zlib_FOUND`

  A CMake boolean which is set to true if this install of Geant4 was built using the internal zlib.

- `Geant4_DATASETS`

  A CMake list of the names of the physics datasets used by physics models in Geant4. It is provided to help iterate over the `Geant4_DATASET_XXX_YYY` variables documented below.

- `Geant4_DATASET_<NAME>_ENVVAR`

  The name of the environment variable used by Geant4 to locate the dataset with name `<NAME>`.

- Geant4_DATASET_<NAME>_PATH

  The absolute path to the dataset with name <NAME>. Note that the setting of this variable does not guarantee the existence of the dataset, and no checking of the path is performed. This checking is not provided because the action you take on non-existing data will be application dependent.

  You can access the Geant4_DATASET_XXX_YYY variables in a CMake script in the following way:

```
find_package(Geant4_REQUIRED)                    # Find Geant4

foreach(dsname ${Geant4_DATASETS})               # Iterate over dataset names
  if(NOT EXISTS ${Geant4_DATASET_${dsname}_PATH})  # Check existence
    message(WARNING "${dsname} not located at ${Geant4_DATASET_${dsname}_PATH}")
  endif()
endforeach()
```

  A typical use case for these variables is to automatically set the dataset environment variables for your application without the use of the shell scripts described in *Postinstall Setup*. This could typically be via a shell script wrapper around your application, or runtime configuration of the application environment via the relevant C/C++ API for your system.

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
```

When included, the Geant4_USE_FILE script performs the following actions:

1. Adds the definitions in Geant4_DEFINITIONS to the global compile definitions.
2. Appends the directories listed in Geant4_INCLUDE_DIRS to those the compiler uses for search for include paths, marking them as system include directories.
3. Prepends Geant4_CXX_FLAGS to CMAKE_CXX_FLAGS, and similarly for the extra compiler flags for each build mode (Release, Debug etc).

This use file is very useful for basic applications, but if your use case requires finer control over compiler definitions, include paths and flags you should use the relevant Geant4_NAME variables directly.

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

```
find_package(Geant4 10.0 REQUIRED)
```

would make CMake search for a Geant4 install whose version number is greater than or equal to 10.0. An exact version number may also be specified:

```
find_package(Geant4 10.4.0 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 installed 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 provides the Qt UI and visualization drivers, 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 components are found, any needed header paths, libraries and compile definitions required to use the component 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 OPTIONAL_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:

- `static`

  `Geant4_static_FOUND` is `TRUE` if the install of Geant4 provides static libraries.

  Use of this component forces the variable `Geant4_LIBRARIES` to contain static libraries, if they are available. It can therefore be used to force static linking if your application requires this, but note that this does not guarantee that static version of third party libraries will be used.

- `multithreaded`

  `Geant4_multithreaded_FOUND` is `TRUE` if the install of Geant4 was built with multithreading support.

  Note that this only indicates availability of multithreading support and activates the required compiler definition to build a multithreaded Geant4 application. Multithreading in your application requires creation and usage of the appropriate C++ objects and interfaces as described in the Application Developers Guide.

- `usolids`

  `Geant4_usolids_FOUND` is `TRUE` if the install of Geant4 was built with VecGeom replacing the Geant4 solids.

  Note that this only indicates that the replacement of Geant4 solids with VecGeom has taken place. Further information on the use of VecGeom applications is provided in the Application Developers Guide.

- `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. If so, the G3ToG4 library is added to `Geant4_LIBRARIES`.

- freetype

  Geant4_freetype_FOUND is TRUE if the install of Geant4 was built with Freetype support.

- hdf5

  Geant4_hdf5_FOUND is TRUE if the install of Geant4 was built with HDF5 support.

- ui_tcsh

  Geant4_ui_tcsh_FOUND is TRUE if the install of Geant4 provides the TCsh command line User Interface. Using this component allows use of the TCsh command line interface in the linked application.

- ui_win32

  Geant4_ui_win32_FOUND is TRUE if the install of Geant4 provides the Win32 command line User Interface. Using this component allows use of the Win32 command line interface in the linked application.

- motif

  Geant4_motif_FOUND is TRUE if the install of Geant4 provides the Motif(Xm) User Interface and Visualization driver. Using this component allows use of the Motif User Interface and Visualization Driver in the linked application.

- qt

  Geant4_qt_FOUND is TRUE if the install of Geant4 provides the Qt User Interface and Visualization driver. Using this component allows use of the Qt User Interface and Visualization Driver in the linked application.

- wt

  Geant4_wt_FOUND is TRUE if the install of Geant4 provides the Wt Web User Interface and Visualization driver. Using this component allows use of the Wt User Interface and Visualization Driver in the linked application.

- vis_dawn_network

  Geant4_vis_dawn_network_FOUND is TRUE if the install of Geant4 provides the Client/Server network interface to DAWN visualization. Using this component allows use of the Client/Server DAWN Visualization Driver in the linked application.

- vis_vrml_network

  Geant4_vis_vrml_network_FOUND is TRUE if the install of Geant4 provides the Client/Server network interface to VRML visualization. Using this component allows use of the Client/Server VRML Visualization Driver in the linked application.

- vis_raytracer_x11

  Geant4_vis_raytracer_x11_FOUND is TRUE if the install of Geant4 provides the X11 interface to the RayTracer Visualization driver. Using this component allows use of the RayTracer X11 Visualization Driver in the linked application.

- vis_opengl_x11

  Geant4_vis_opengl_x11_FOUND is TRUE if the install of Geant4 provides the X11 interface to the OpenGL Visualization driver. Using this component allows use of the X11 OpenGL Visualization Driver in the linked application.

- vis_opengl_win32

  Geant4_vis_opengl_win32_FOUND is TRUE if the install of Geant4 provides the Win32 interface to the OpenGL Visualization driver. Using this component allows use of the Win32 OpenGL Visualization Driver in the linked application.

- `vis_openinventor`

  `Geant4_vis_openinventor_FOUND` is `TRUE` if the install of Geant4 provides the OpenInventor Visualization driver. Using this component allows use of the OpenInventor Visualization Driver in the linked application.

- `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`.

4.1.1 Going further with CMake

The preceeding sections show the minimal CMake scripting required to configure, build and install an application linking against the Geant4 libraries. If your project requires more advanced configuration, CMake provides tools such as compiler/platform identification and location of additional libraries/executables to link to/use. As this document is specific to Geant4, we do not cover more advanced usage of CMake and recommend that you consult the online manuals and tutorials supplied by Kitware.

In particular, for the common use case of finding and using an external software package, see the documentation of the `find_package` command, overview of CMake's package location functionality, and the list of packages CMake knows about out of the box. Location and use of a required package works exactly as we have illustrated for Geant4. Simply add the required `find_package` call to your CMake script, and use the supplied variables or targets for headers paths and library linking, e.g.

```
find_package(Foo 1.2 REQUIRED)         # Find "Foo" of at least version 1.2
find_package(Bar 3.4 EXACT REQUIRED)   # Find "Bar" at exactly version 3.4

include_directories(${Foo_INCLUDE_DIRS}) # Foo's setup supplies a header path

add_library(MyLibrary SHARED MyLibrary.cc) # Define our library
target_link_libraries(MyLibrary            # Link it
  ${Foo_LIBRARIES}                         # Foo's setup supplies a library path
  Bar::Bar                                 # Bar's setup supplies an "IMPORTED" target
  )                                        # which sets header and library paths␣
↪automatically
```

You should consult the documentation of the packages your project requires to see if they supply suitable CMake configuration files. If they do not, then CMake provide documentation on writing modules to find packages that do not supply these files. Geant4 cannot provide support for any third party package your project uses, and any questions should be direct to that package's authors.

4.2 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 a Geant4 installation for locations and features. It is installed at:

```
+- 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 of the Geant4 installation:

```
$ ./geant4-config --help
Usage: geant4-config [OPTION...]
  --prefix                output installation prefix of Geant4
  --version               output version for Geant4
  --cxxstd                C++ Standard compiled against
  --tls-model             Thread Local Storage model used
  --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

  --datasets              output dataset name, environment variable
                          and path, with one line per dataset

  --check-datasets        output dataset name, installation status and
                          expected installation location, with one line
                          per dataset

  --install-datasets      download and install any missing datasets,
                          requires a network connection and for the dataset
                          path to be user writable

Known Features:
 staticlibs[no]
 multithreading[no]
 muonic_atoms[no]
 clhep[yes]
 expat[no]
 zlib[yes]
 gdml[no]
 usolids[no]
 freetype[no]
 hdf5[no]
 g3tog4[no]
 qt[no]
 motif[no]
 raytracer-x11[no]
 opengl-x11[no]
 openinventor[no]

Help options:
 -?, --help              show this help message
```

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```
--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. If the argument to `--has-feature` is known to Geant4 *and* enabled in the installation, `yes` will be printed to stdout, otherwise `no` will be printed.

The `--datasets` argument may be used to print out a table of dataset names, environment variables and paths. No checking of the existence of the paths is performed, as the action to take on a non-existing dataset will depend on your use case. The table is printed with one row per dataset, with space separated columns for the dataset name, environment variable name and path. As with `Geant4Config.cmake`, this information is provided to help you configure your application environment to locate the Geant4 datasets without a preexisting setup, if your use case demands this.

The `--check-datasets` argument may be used to check whether the datasets are installed in the location expected (as set by the configuration of Geant4). A table is printed with one row per dataset, with space separated columns for the dataset name, installation status and expected path. If the expected path is found, the status column will contain `INSTALLED`, otherwise it will contain `NOTFOUND`. Note that this check only verifies the existence of the dataset path. It does not validate that the dataset files are all present nor that the relevant environment variables are set.

If you did not use the `GEANT4_INSTALL_DATA` option to install data when Geant4 itself was installed, you can use the `--install-datasets` argument to perform this task at a later time. Running `geant4-config` with this argument will download, unpack and install each dataset to the location expected by the Geant4 installation. These steps require a working network connection, the local dataset installation path to be writable by the user running `geant4-config` and the presence of the `curl`, `openssl` and `tar` programs. Note that no changes to the environment are made by the data installation, so you may need to update this using the relevant scripts documented in *Postinstall Setup*.

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`.

CHAPTER

FIVE

HOW TO MAKE AN EXECUTABLE PROGRAM

The code for the user examples in Geant4 is placed in the subdirectory `examples` of the main Geant4 source package. This directory is installed to the `share/Geant4-G4VERSION/examples` (where `G4VERSION` is the Geant4 version number) subdirectory under the installation prefix. In the following sections, a quick overview will be given on how to build a concrete example, "ExampleB1", which is part of the Geant4 distribution, using CMake and the older, and now deprecated, Geant4Make system.

5.1 Using CMake to Build Applications

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

```
+- CMAKE_INSTALL_PREFIX
   +- lib/
      +- Geant4-G4VERSION/
         +- Geant4Config.cmake
```

which is designed for use with the CMake `find_package` command. Building a Geant4 application using CMake therefore involves writing a `CMakeLists.txt` script using this and other CMake commands to locate Geant4 and describe the build of your client application. Whilst it requires a bit of effort to write the script, CMake provides a very friendly yet powerful 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_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. Though the build of Geant4 itself requires CMake 3.3 and we recommend this version for your own projects, `Geant4Config.cmake` can support the 2.6 and 2.8 series. 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, and force setting of compiler flags and compiler definitions needed for compiling against 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 platform specific configuration or using other third party packages (via `find_package`).

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/macOS 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.

5.1.1 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-G4VERSION $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. This provides the most specific way to point CMake to the Geant4 install you want to use. You may also use the `CMAKE_PREFIX_PATH` variable, e.g:

```
$ cd $HOME/B1-build
$ cmake -DCMAKE_PREFIX_PATH=/home/you/geant4-install $HOME/B1
```

This is most useful for system integrators as it may be extended via the environment or command line with paths to the install prefixes of additional required software packages.

The second argument to CMake 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 and you will see output similar to

```
$ cmake -DGeant4_DIR=/home/you/geant4-install/lib64/Geant4-G4VERSION $HOME/B1
-- The C compiler identification is GNU 4.9.2
-- The CXX compiler identification is GNU 4.9.2
-- Check for working C compiler: /usr/bin/gcc-4.9
-- Check for working C compiler: /usr/bin/gcc-4.9 -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Detecting C compile features
-- Detecting C compile features - done
-- Check for working CXX compiler: /usr/bin/g++-4.9
-- Check for working CXX compiler: /usr/bin/g++-4.9 -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Detecting CXX compile features
-- Detecting CXX compile features - done
-- Configuring done
-- Generating done
-- Build files have been written to: /home/you/B1-build
```

The exact output will depend on the UNIX variant and compiler, but the last three lines should be identical to within the exact path used.

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

```
$ ls
CMakeCache.txt       exampleB1.in   Makefile      vis.mac
CMakeFiles           exampleB1.out  run1.mac
cmake_install.cmake  init_vis.mac   run2.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 `N` can be set to 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_vis.mac      run2.mac
CMakeFiles           exampleB1.in   Makefile          vis.mac
cmake_install.cmake  exampleB1.out  run1.mac
```

You can now run the application in place:

```
$ ./exampleB1
Available UI session types: [ GAG, tcsh, csh ]

*************************************************************
 Geant4 version Name: geant4-10-05 [MT]   (07-December-2018)
  << in Multi-threaded mode >>
                      Copyright : Geant4 Collaboration
                     References : NIM A 506 (2003), 250-303
                                : IEEE-TNS 53 (2006), 270-278
                                : NIM A 835 (2016), 186-225
                           WWW : http://geant4.org/
*************************************************************

<<< Reference Physics List QBBC
Visualization Manager instantiating with verbosity "warnings (3)"...
Visualization Manager initialising...
Registering graphics systems...
```

Note that the exact output shown will depend on how both Geant4 and your application were configured. Further output and behaviour beyond the `Registering graphics systems...` line 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 in your build directory with arguments:

```
$ cmake -DWITH_GEANT4_UIVIS=OFF .
```

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 must remember to rerun CMake to pick up the changes. This is another reason why Kitware recommend listing the sources explicitly.

5.1.2 Building ExampleB1 with CMake on Windows with Visual Studio

As with building Geant4 itself, the simplest system to use for building applications on Windows is a Visual Studio Developer Command Prompt, which can be started from *Start → Visual Studio 2017 → Developer Command Prompt for VS2017* (similarly for VS2015)

We'll assume, *for illustration only*, that you've copied the exampleB1 sources into a directory `C:\Users\YourUsername\B1` so that we have:

```
+- C:\Users\YourUsername\B1
   +- CMakeLists.txt
   +- exampleB1.cc
   +- include\
```

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```
   +- src\
   +- ...
```

Here, our *source directory* is `C:\Users\YourUsername\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*, `C:\Users\YourUsername\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, working from the Visual Studio Developer Command Prompt:

```
> cd %HOMEPATH%
> mkdir B1-build
```

We now change to this *build directory* and run CMake to generate the Visual Studio solution needed to build the B1 application. We pass CMake two arguments

```
> cd %HOMEPATH%\Geant4\B1-build
> cmake -DGeant4_DIR="%HOMEPATH%\Geant4-install\lib\Geant4-G4VERSION" "
↪%HOMEPATH%\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. As with the examples above, you can also use the `CMAKE_PREFIX_PATH` variable. 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 it to where you copied the B1 source directory. In both cases the arguments are quoted in case of the paths containing spaces.

CMake will now run to configure the build and generate Visual Studio solutions and you will see output similar to

```
-- Building for: Visual Studio 15 2017
-- The C compiler identification is MSVC 19.11.25547.0
-- The CXX compiler identification is MSVC 19.11.25547.0
-- Check for working C compiler: C:/Program Files (x86)/Microsoft Visual Studio/2017/
↪Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe
-- Check for working C compiler: C:/Program Files (x86)/Microsoft Visual Studio/2017/
↪Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Check for working CXX compiler: C:/Program Files (x86)/Microsoft Visual Studio/
↪2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe
-- Check for working CXX compiler: C:/Program Files (x86)/Microsoft Visual Studio/
↪2017/Community/VC/Tools/MSVC/14.11.25503/bin/Hostx86/x86/cl.exe -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Detecting CXX compile features
-- Detecting CXX compile features - done
-- Configuring done
-- Generating done
-- Build files have been written to: C:/Users/YourUsername/B1-build
```

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

```
> dir /B
ALL_BUILD.vcxproj
ALL_BUILD.vcxproj.filters
```

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```
B1.sln
B1.vcxproj
B1.vcxproj.filters
CMakeCache.txt
CMakeFiles
cmake_install.cmake
exampleB1.in
exampleB1.out
exampleB1.vcxproj
exampleB1.vcxproj.filters
init_vis.mac
INSTALL.vcxproj
INSTALL.vcxproj.filters
run1.mac
run2.mac
vis.mac
ZERO_CHECK.vcxproj
ZERO_CHECK.vcxproj.filters
```

Note the `B1.sln` solution file and that all the scripts for running the exampleB1 application we're about to build have been copied across. With the solution available, we can now build by running cmake to drive MSBuild:

```
> cmake --build . --config Release
```

Solution based builds are quite verbose, but you should not see any errors at the end. In the above, we have built the B1 program in `Release` mode, meaning that it is optimized and has no debugging symbols. As with building Geant4 itself, this is chosen to provide optimum performance. If you require debugging information for your application, simply change the argument to `RelWithDebInfo`. Note that in both cases you must match the configuration of your application with that of the Geant4 install, i.e. if you are building the application in `Release` mode, then ensure it uses a `Release` build of Geant4. Link and/or runtime errors may result if mixed configurations are used.

After running the build, if we list the contents of the build directory again we see:

```
> dir /B
ALL_BUILD.vcxproj
ALL_BUILD.vcxproj.filters
B1.sln
B1.vcxproj
B1.vcxproj.filters
CMakeCache.txt
CMakeFiles
cmake_install.cmake
exampleB1.dir
exampleB1.in
exampleB1.out
exampleB1.vcxproj
exampleB1.vcxproj.filters
init_vis.mac
INSTALL.vcxproj
INSTALL.vcxproj.filters
Release
run1.mac
run2.mac
vis.mac
Win32
ZERO_CHECK.vcxproj
```

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```
ZERO_CHECK.vcxproj.filters

> dir /B Release
exampleB1.exe
...
```

Here, the `Release` subdirectory contains the executable, and the main build directory contains all the `.mac` scripts for running the program. If you build in different modes, the executable for that mode will be in a directory named for that mode, e.g. `RelWithDebInfo/exampleB1.exe`. You can now run the application in place:

```
> .\Release\exampleB1.exe

*************************************************************
 Geant4 version Name: geant4-10-05 [MT]   (07-December-2018)
  << in Multi-threaded mode >>
                      Copyright : Geant4 Collaboration
                     References : NIM A 506 (2003), 250-303
                                : IEEE-TNS 53 (2006), 270-278
                                : NIM A 835 (2016), 186-225
                           WWW : http://geant4.org/
*************************************************************

<<< Reference Physics List QBBC
Visualization Manager instantiating with verbosity "warnings (3)"...
Visualization Manager initialising...
Registering graphics systems...
```

Note that the exact output shown will depend on how both Geant4 and your application were configured. Further output and behaviour beyond the `Registering graphics systems...` line will depend on what UI and Visualization drivers your Geant4 install supports.

Whilst the Visual Studio Developer Command prompt provides the simplest way to build an application, the generated Visual Studio Solution file (`B1.sln` in the above example) may also be opened directly in the Visual Studio IDE. This provides a more comprehensive development and debugging environment, and you should consult its documentation if you wish to use this.

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 in the Visual Studio IDE.

5.2 Using Geant4Make to build Applications

Please note that this system is deprecated, meaning that it is no longer supported and may be removed in future releases without warning. You should migrate your application to be built using CMake via the `Geant4Config.cmake` script, or any other build tool of your choice, using the `geant4-config` program to query the relevant compiler/linker flags.

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. 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-G4VERSION/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 commands:

```
$ cd CMAKE_INSTALL_PREFIX/share/Geant4-G4VERSION/geant4make
$ source geant4make.csh
```

or alternatively

```
$ source CMAKE_INSTALL_PREFIX/share/Geant4-G4VERSION/geant4make/geant4make.
↪csh \
CMAKE_INSTALL_PREFIX/share/Geant4-G4VERSION/geant4make
```

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
```

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```
.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, 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 is deprecated from Geant4 10.0.

CHAPTER

SIX

CMAKE 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.

6.1 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 a sequence of 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 named, say, `mysettings.cmake`. We could then pass this file to CMake to configure the build with these settings:

```
$ cmake -C /path/to/mysettings.cmake <otherargs>
```

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.

6.2 Using Different CMake Generators

CMake is a *buildsystem generator* that can create scripts for many buildsystems including Make, Ninja, 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. On Unix system we in fact **recommend** use of Ninja due to the significant performanace advantages it has over traditional Make. On the command line, one can select the buildsystem using the `-G` argument of CMake. For example, to generate and run a Ninja build:

```
$ mkdir -p /path/to/build-ninja
$ cd /path/to/build-ninja
$ cmake -G Ninja /path/to/geant4-dev.git
$ ninja
```

On macOS, an Xcode project for Geant4 using the example from *On Unix Platforms* may be generated via:

```
$ mkdir -p /path/to/build-xcode
$ cd /path/to/build-xcode
$ cmake -G Xcode /path/to/geant4-dev.git
```

The resulting `/path/to/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 *On Windows Platforms*), where it can be selected from a drop down list.

Note that in all cases, you can only have one buildsystem 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.

6.2.1 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-ofSource Builds`" section.

6.3 Command Line Help with Ninja/Make

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

```
$ 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 listed target individually, and it will be built together with all of its dependencies. CMake's generated Make/Ninja files only output minimal information by default, so if you need to see the full commands used, you can run `make` with the extra `VERBOSE` argument:

```
$ make VERBOSE=1
```

or `ninja` with the `-v` flag:

```
$ ninja -v
```

to output every command in full.

In Make only, 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.

6.4 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-dev.git
$ mkdir build-release build-debug
$ cd build-release
$ cmake -DCMAKE_BUILD_TYPE=Release ../geant4-dev.git

...output...

$ make -j8

...output...

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

...output...

$ make -j8

...output...
```

The above example uses Makefiles, but the same technique also works with Ninja. It may not seem to have gained you much, but when you edit and develop code that is living under `/path/to/geant4-dev.git`, you only need to rebuild in each directory:

```
... work on code ...
$ cd /path/to/build-release
$ make -j8
```

(continues on next page)

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```
... incremental build ...

$ cd /path/to/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.

6.5 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 `Geant4Config.cmake` (see *CMake Build System: Geant4Config.cmake*) and `geant4-config` (described in *Other Unix Build Systems: geant4-config*) 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 *How to Use the Geant4 Toolkit Libraries* to build your test applications *against a specific build tree*. You therefore don't need to install Geant4 everytime you make a small update. In the CMake case, simply set `Geant4_DIR` to the directory where you configured and built Geant4.

CHAPTER

SEVEN

STATUS OF THIS DOCUMENT

Guide for the installation and configuration of the Geant4 toolkit.

- Rev 1.0: First sphinx version implemented for Geant4 Release 10.4, 8th Dec 2017
- Rev 2.0: Updates and fixes in documentatio for GEANT4 Release 10.4, 15th May 2018
- Rev 3.0: GEANT4 Release 10.5, 11th December 2018
- Rev 3.1: GEANT4 Updates and fixes - especially to search functionality, 5th March 2019