

GEANT-4 GPU Port:

Design Document: Detailed Design

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Detailed Design: Version 0

January 10, 2016

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1 Introduction

1.1 Revision History

All major edits to this document will be recorded in the table below.

Table 1: Revision History

Description of Changes	Author	Date
Set up sections and filled out Introduction section	Matthew	2015-12-15
Added sections for Errors and Key Algorithms	Stuart	2016-01-08

1.2 Document Structure & Template

The design documentation for the project is broken into two main documents.

The system architecture document details the system architecture, including an overview of the modules that make up the system, analysis of aspects that are likely and unlikely to change, reasoning behind the high-level decisions, and a table showing how each requirement is addressed in the proposed design.

This detailed design document covers the specifics of several key modules in the project. For each module, an MIS is given fully detailing the interface of the module. Then, the methods for handling errors within the module are discussed, and finally the main algorithms and data structures used by the module are presented.

1.3 List of Tables

Table #	Title
1	Revision History
2	G4NeutronHPDataPoint – access program syntax
3	G4NeutronHPDataPoint – access program semantics
7	G4NeutronHPDataPoint – state variables
5	G4NeutronHPVector – access program syntax
6	G4NeutronHPVector – access program semantics
7	G4NeutronHPVector – state variables
8	CMake Files – state variables

1.4 Note About G4 variables

Geant4 uses its own basic types for standard C++ types (G4int, G4bool, G4double, etc). These types are currently just `typedefs` to the respective type as defined in the system libraries.

2 G4NeutronHPDataPoint

2.1 Description

This class encapsulates all of the data as well as the accessor and mutator methods that each point requires. The points contain two private variables used to store the xSec and the energy as doubles. This class also contains the constructors needed to instantiate this data type.

2.2 MIS (Module Interface Specification)

2.2.1 Access Program Syntax

Table 2: G4NeutronHPDataPoint – access program syntax

Routine Name	Input	Output	Exceptions
G4NeutronHPDataPoint			
G4NeutronHPDataPoint =	G4double, G4double G4NeutronHPDataPoint		
GetEnergy		G4double	
GetXsection		G4double	
SetEnergy	G4double		
SetXsection	G4double		
GetX		G4double	
GetY		G4double	
SetX	G4double		
SetY	G4double		
SetData	G4double, G4double		

2.2.2 Access Program Semantics

Note that hyphens in routine names and inputs are just for linebreaks due to the table size. The actual routine names and inputs do not have hyphens.

Table 3: NeutronHPDataPoint – access program semantics

Routine Name	Input	Semantics
G4NeutronHPDataPoint		instantiates the class, setting energy and xSec to 0
G4NeutronHPDataPoint	G4double, G4double	instantiates the class with the inputted energy and xSec
=	G4NeutronHP- DataPoint	sets the energy and xSec of the instance to those of the input
GetEnergy		returns energy of the instance
GetXsection		returns the xSec of the instance
SetEnergy	G4double	sets energy of instance to the argument
SetXsection	G4double	sets xSec of instance to the argument
GetX		returns the energy of the instance
GetY		returns the xSec of the instance
SetX	G4double	sets energy of instance to the argument
SetY	G4double	sets xSec of instance to the argument
SetData	G4double, G4double	sets instance's energy and xSec to the passed arguments

2.2.3 State Variables

The following variables maintain state for the class, and are all private to the module.

Table 4: G4NeutronHPDataPoint – state variables

Variable	Type	Description
energy	G4double	the energy of the particle
xSec	G4double	the cross-section of the particle

2.2.4 Environment Variables

There are no environment variables for this module.

2.2.5 Assumptions

It can be assumed that the class will be initialized. As such, all getter methods will return a non-null value.

2.3 Error Handling

NA

2.4 Key Algorithms

NA

3 G4NeutronHPVector

3.1 Description

G4NeutronHPVector

3.2 MIS (Module Interface Specification)

Note that hyphens in routine names, inputs, outputs, and exceptions are just for line-breaks due to the table size. The actual routine names, inputs, outputs, and exceptions do not have hyphens.

3.2.1 Access Program Syntax

Table 5: G4NeutronHPVector – access program syntax

Routine Name	Input	Output	Exceptions
G4NeutronHPVector			
G4NeutronHPVector	G4int		
=	G4NeutronHPVector&	G4NeutronHPVector&	
+	G4NeutronHPVector&, G4NeutronHPVector&	G4NeutronHPVector&	
SetVerbose	G4int		
Times	G4double		
SetPoint	G4int, G4NeutronHPDataPoint		
SetData	G4int, G4double, G4double		
SetX	G4int, G4double		
SetEnergy	G4int, G4double		

SetY	G4int, G4double	
SetXsec	G4int, G4double	
GetEnergy	G4int	G4double
GetXsec	G4int	G4double
GetXsec	G4double	G4double
GetXsec	G4double,G4int	G4double
GetX	G4int	G4double
GetY	G4double	G4double
GetY	G4int	G4double
GetVectorLength		G4int
GetPoint	G4int	const G4NeutronHPDataPoint&
Hash		
ReHash		
InitInterpolation	istream	
Init	istream,G4int, G4double, G4double	
Init	istream, G4double,G4double	
ThinOut	G4double	
SetLabel	G4double	
GetLabel		G4double
CleanUp		
Sample		G4double
Debug		G4double *
Merge	G4NeutronHPVector *, G4NeutronHPVector *	
Merge	G4InterpolationScheme, G4double, G4NeutronHPVector *, G4NeutronHPVector *	
SampleLin		G4double
IntegrateAndNormalise		
Integrate		
GetIntegral		G4double
SetInterpolationManager	const G4InterpolationManager &	
SetInterpolationManager	G4InterpolationManager &	

SetScheme	G4int,const G4InterpolationScheme &	
GetScheme	G4int	G4InterpolationScheme
GetMeanX		G4double
GetBlocked		vector<G4double>
GetBuffered		vector<G4double>
Get15percentBorder		G4double
Get50percentBorder		G4double

3.2.2 Access Program Semantics

Note that hyphens in routine names and inputs are just for linebreaks due to the table size. The actual routine names and inputs do not have hyphens.

Table 6: G4NeutronHPVector – access program semantics

Routine Name	Input	Description
G4NeutronHPVector		A constructor for the G4NeutronHPVector class. Instantiates the class with no parameters
G4NeutronHPVector	G4int	A constructor for the G4NeutronHPVector class. Instantiates the class with one parameter, determines the value of the nPoints variable based on input
=	G4NeutronHPVector&	Sets the current instance to the passed instance
+	G4NeutronHPVector&, G4NeutronHPVector&	Returns the vector addition of the two passed vectors.
SetVerbose	G4int	sets the Verbose to the input
Times	G4double	Multiplies theData array's y-values by the input, does the same with the corresponding integral
SetPoint	G4int, G4NeutronHP- DataPoint	sets theData[G4int] to the passed in Data-Point
SetData	G4int, G4double,G4double	sets theData[G4int] to the passed in G4double values
SetX	G4int, G4double	sets theData[G4int]'x value to the passed in G4double value

SetEnergy	G4int, G4double	sets theData[G4int]'s x value to the passed in G4double value
SetY	G4int, G4double	sets theData[G4int]'s y value to the passed in G4double value
SetXsec	G4int, G4double	sets theData[G4int]'s y value to the passed in G4double value
GetEnergy	G4int	Returns theData[G4int]'s current x value
GetXsec	G4int	Returns theData[G4int]'s current x value
GetXsec	G4double	Returns theData's y value corresponding to the x section starting at G4int
GetX	G4int	Returns theData[G4int]'s current x value
GetY	G4int	Returns theData[G4int]'s current y value
GetVectorLength		Returns the length of the vector, which is stored in nEntries
GetPoint	G4int	Returns theData[G4int]'s current value
Hash		sets theHash's value based on theData
ReHash		clears theHash and re-evaluates it based on theData
InitInterpolation	istream	calls Init on the istream input
Init	istream, G4int, G4double, G4double	Initializes the data in theHash of length G4int
Init	istream, G4double, G4double	Initializes the data in theHash of length that is read in from a file
ThinOut	G4double	Thins out theData() by removing unnecessary elements and calls ReHash
SetLabel	G4double	Sets the Label value to G4Double
GetLabel		Returns the current Label value
CleanUp		Sets the length of theData to 0, clears the integral and clears theHash
Sample		Samples X according to distribution Y
Debug		Returns theIntegral
Merge	G4NeutronHPVector*, G4NeutronHPVector*	interpolate between labels, continue in unknown areas by subtraction of the last difference.
Merge	G4Interpolation-Scheme, G4double, G4NeutronHPVector*, G4NeutronHPVector*	interpolate between labels according to G4InterpolationScheme, cut at G4double, continue in unknown areas by subtraction of the last difference.
SampleLin		Samples X according to distribution Y, linear int

IntegrateAndNormalise		Calculates the integral for every entry in <code>theIntegral</code> and normalizes each calculation
Integrate		Calculates the integral for every entry in <code>theIntegral</code>
GetIntegral		Linear interpolation over <code>theIntegral</code>
+SetInterpolation-Manager	const G4Interpolation-Manager&	sets <code>theManager</code> to the input
SetInterpolation-Manager	G4Interpolation-Manager&	sets <code>theManager</code> to the input
SetScheme	G4int, G4Interpolation-Scheme&	Appends the G4Interpolation-Scheme to <code>theManager</code>
GetScheme	G4int	Returns the current G4Interpolation-Scheme associated with <code>theManager</code>
GetMeanX		Returns the average x value of all data points in <code>theData</code>
GetBlocked		Returns the current value of <code>theBlocked</code>
GetBuffered		Returns the current value of <code>theBuffered</code>
Get15percentBorder		gets the integral from each data point to the last data point and returns the first one within 15% of the last data point
Get50percentBorder		gets the integral from each data point to the last data point and returns the first one within 50% of the last data point

3.2.3 State Variables

The following variables maintain state for the class, and are all private to the class.

Note that hyphens in variable names and types are just for linebreaks due to the table size. The actual variable names and types do not have hyphens.

Table 7: G4NeutronHPVector – state variables

Variable	Type	Description
<code>theLin</code>	G4NeutronHP-Interpolator	the linear interpolator for sampling data
<code>totalIntegral</code>	G4double	integral over all data points from <code>theData</code>
<code>theData</code>	G4NeutronHP-DataPoint*	array of G4NeutronHPDataPoint, stores all data points in vector
<code>theManager</code>	G4Interpolation-Manager	manages the interpolation schemes, knows how to interpolate data
<code>theIntegral</code>	G4double*	array of integrals where <code>theIntegral[i]</code> is the integral of all data points from <code>theData</code> up until <i>i</i>
<code>nEntries</code>	G4int	the number of data points to consider when performing calculations over <code>theData</code>
<code>nPoints</code>	G4int	the number of data points in <code>theData</code>
<code>label</code>	G4double	number
<code>theInt</code>	G4Neutron-Interpolator	the interpolator for sampling data (may not be linear)
<code>Verbose</code>	G4int	verbosity level, some statements will only print to console with higher values
<code>isFreed</code>	G4int	only used for debugging, 1 if class has been destructed 0 otherwise
<code>theHash</code>	G4NeutronHP-Hash	stores the <i>x</i> and <i>y</i> value of every tenth data point from <code>theData</code> to speed up getting the minimum index in <code>theData</code> of a data point with <i>X</i> larger than a given value
<code>maxValue</code>	G4double	maximum value of <i>Xsec</i> or <i>Y</i> passed in SetData, SetY, or SetXSec so far. Initialized to <code>-DBL_MAX</code> (min representable double).
<code>theBlocked</code>	vector <G4double>	deprecated: vector still exists in class but data never added to it
<code>theBuffered</code>	vector <G4double>	stores buffer of samples to speed up sampling the vector
<code>the15percent-BorderCash</code>	G4double	the <i>X</i> value of the first data point with an integral no more than 15% smaller than the integral of the last data point
<code>the50percent-BorderCash</code>	G4double	the <i>X</i> value of the first data point with an integral no more than 50% smaller than the integral of the last data point

3.2.4 Environment Variables

There are no environment variables for this Module.

3.2.5 Assumptions

It can be assumed that the module will be initialized before other functions are called.

3.3 Error Handling

G4HadronicException

3.4 Key Algorithms

4 CMake Files

4.1 Description

4.2 MIS (Module Interface Specification)

4.2.1 Access Program Syntax

NA

4.2.2 Access Program Semantics

NA

4.2.3 State Variables

Table 8: CMake Files – state variables

Variable	Type	Description
useCuda	Boolean	if set to true, the makefiles generated by CMake will include directives to compile and link the CUDA code and will execute ported procedures on the GPU. Default is false.

4.2.4 Environment Variables

- NeutronHPVectorGPU.cu : CUDA file with GPU code

4.2.5 Assumptions

No assumptions need to be made for CMake.

4.3 Error Handling

4.4 Key Algorithms