GEANT4 GPU Port:

Test Report

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Contents

Revision History

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

Table 1: Revision History

Description of Changes	Author	Date
Initial draft of document	Matt, Rob, Victor, Stuart	2016-03-18
Template of document	Matt	2016-03-15

List of Figures

Tables and figures for specific unit tests have been omitted in order to keep this document readable.

Definitions and Acronyms

Table 2: Definitions and Acronyms

Term	Description
GEANT4	Open-source software toolkit used to simulate the passage of particles through matter
GEANT4-GPU	GEANT4 with some computations running on the GPU
GPU	Graphics processing unit, well-suited to parallel computing tasks
CPU	Computer processing unit, general computer processor well-suited to serial tasks
CUDA	Parallel computing architecture for general purpose programming on GPU, developed by NVIDIA
RHEL	Red Hat Enterprise Linux Server
OS X	Operating system developed by Apple

1 Introduction

1.1 Purpose of the Document

This document summarizes the testing and test conclusions of GEANT4-GPU. This document uses the implementation outlined in the test plan.

1.2 Scope of the Testing

1.3 Organization

In Section 4 we provide an introduction to this report. Section 5 describes the test cases which are carried out on each function. Section 6 describes system test cases that were carried out by our team. In section 7 traceability matrices to requirements and modules are documented. Section 8 provides a summary of changes made in response to the testing results.

1.4 Usability

GEANT4-GPU is a back end implementation of already existing GEANT4 modules. Therefore users will not be interacting with is directly. Since there is no direct user interaction with GEANT4-GPU. There are no usability test.

1.5 Robustness

The GEANT4-GPU functions are meant to mimic the already existing GEANT4 functions. Therefore the GEANT4-GPU functions must also mimic the the robustness of the GEANT4 functions. The accuracy section for unit tests has several unit tests designed to test the robustness of the functions.

2 Module Unit Testing

2.1 Use of Automated Testing

Our testing is semi-automated. Due to the nature of this implementation we need to recompile GEANT4-GPU from GPU to CPU in order to get the CPU results to compare against the GPU results. We have a unit test file which preforms all our unit tests and writes the results into a file. The user will then have to manually recompile GEANT4-GPU with GPU acceleration off. Once the unit test file is run again another results file is generated. The comparing of the results is automated by feeding them to an application that we created that will compare the test results against each other. The program outputs a summary of any differences between the two results, if there are any.

2.2 General variables used for Unit Testing

The following are variables that are used for multiple unit tests. Instead of defining them again for each unit test they are defined here only once. Other variables used for specific unit tests will be defined in their respective unit test sections
For all unit tests:

Table 3: General Unit Test Variables

Name #	Type	**Value**
n	G4double	length of the G4ParticleHPVector
r1	G4double	1.58
r2	G4double	513.18
Empty	G4ParticleHPVector	Empty
A	G4ParticleHPVector	66 entries
B	G4ParticleHPVector	1509 entries
C	G4ParticleHPVector	8045 entries
D	G4ParticleHPVector	41854 entries
E	G4ParticleHPVector	98995 entries
F	G4ParticleHPVector	242594 entries

2.3 Note about Performance testing

Tests on vectors A - F all behave the same. Showing accuracy for vectors A - F does not provide any extra useful information. Therefore only unit tests on vector D will be shown in the Unit Tests and Accuracy sections. Unit test interfaces for the other vectors will be omitted from this document in order to make it more readable. The unit tests were still performed on the other vectors. These unit tests on vectors of

different length are done to show how increasing the size of the vector increases the execution time of some functions

2.4 OperatorEquals

2.4.1 Unit Tests

Table 4: Unit Tests

Test #	Code	**Description**
1	Code goes here	Description goes here

2.4.2 Accuracy

Table 5: Accuracy

Test #	CPU	GPU
??	CPU time	GPU time

2.4.3 Performance

2.5 GetPoint

2.5.1 Unit Tests

Table 6: Unit Tests

Test #	Code	**Description**
2	Empty.GetPoint(-1)	Get a point at a negative index from an empty vector
3	Empty.GetPoint(0)	Get a point at a the first index from an empty vector
4	Empty.GetPoint(1)	Get a point at an index out of bounds from an empty vector
5	D.GetPoint(-1)	Get a point at a negative index
6	D.GetPoint(0)	Get a point at a the first index
7	D.GetPoint(n/2)	Get a point at an index within the vector
8	D.GetPoint(n-1)	Get a point at the last index
9	D.GetPoint(n)	Get a point at an index our of bounds

Table 7: Accuracy

Test #	CPU	GPU
2	CPU time	GPU time
3	CPU time	GPU time
4	CPU time	GPU time
5	CPU time	GPU time
6	CPU time	GPU time
7	CPU time	GPU time
8	CPU time	GPU time
9	CPU time	GPU time

2.5.2 Accuracy

2.5.3 Performance

2.6 GetX

2.6.1 Unit Tests

Table 8: Unit Tests

Test #	Code	**Description**
10	Empty.GetX(-1)	Set an xSec at a negative index of an empty vector
11	Empty.GetX(0)	Set an xSec at a the first index of an empty vector
12	Empty.GetX(1)	Set an xSec at an index out of bounds of an empty vector
13	D.GetX(-1)	Set an xSec at a negative index
14	D.GetX(0)	Set an xSec at a the first index
15	D.GetX(n/2)	Set an xSec at an index within the vector
16	D.GetX(n-1)	Set an xSec at the last index
17	D.GetX(n)	Set an xSec at an index our of bounds

Table 9: Accuracy

Test #	CPU	GPU
10	CPU result	GPU result
11	CPU result	GPU result
12	CPU result	GPU result
13	CPU result	GPU result
14	CPU result	GPU result
15	CPU result	GPU result
16	CPU result	GPU result
17	CPU result	GPU result

Table 10: Unit Tests

Test #	Code	**Description**
18	Empty.GetY(-1)	Get a point at a negative index of an empty vector
19	Empty.GetY(0)	Get a point at a the first index of an empty vector
20	Empty.GetY(1)	Get a point at an index out of bounds of an empty vector
21	D.GetY(-1)	Get a point at a negative index
22	D.GetY(0)	Get a point at a the first index
23	D.GetY(n/2)	Get a point at an index within the vector
24	D.GetY(n-1)	Get a point at the last index
25	D.GetY(n)	Get a point at an index our of bounds

Table 11: Accuracy

Test #	CPU	GPU
18	CPU result	GPU result
19	CPU result	GPU result
20	CPU result	GPU result
21	CPU result	GPU result
22	CPU result	GPU result
23	CPU result	GPU result
24	CPU result	GPU result
25	CPU result	GPU result

2.6.2 Accuracy

2.6.3 Performance

2.7 GetY

2.7.1 Unit Tests

2.7.2 Accuracy

2.7.3 Performance

2.8 GetXsec

2.8.1 Unit Tests

Table 12: Unit Tests

Test #	Code	**Description**
26	Empty.GetXsec(-1)	Get an xSec with a negative energy from an empty vector
27	Empty.GetXsec(0)	Get a xSec with an energy of zero from an empty vector
28	Empty.GetXsec(r1)	Get a xSec with a random energy from an empty vector
29	D.GetXsec(-1)	Get a xSec with a negative energy
30	D.GetXsec(0)	Get a xSec with a zero energy
31	D.GetXsec(r1)	Get a xSec with a random energy

2.8.2 Accuracy

Table 13: Accuracy

Test #	CPU	GPU
26	CPU result	GPU result
27	CPU result	GPU result
28	CPU result	GPU result
29	CPU result	GPU result
30	CPU result	GPU result
31	CPU result	GPU result

Table 14: Unit Tests

Test #	Code	**Description**
32	Empty.SetData(-1, r1, r2)	Set a point at a negative index of an empty vector
33	Empty.SetData(0, r1, r2)	Set a point at a the first index of an empty vector
34	Empty.SetData(1, r1, r2)	Set a point at an index out of bounds of an empty vector
35	D.SetData(-1, r1, r2)	Set a point at a negative index
36	D.SetData(0, r1, r2)	Set a point at a the first index
37	D.SetData(n/2, r1, r2)	Set a point at an index within the vector
38	D.SetData(n-1, r1, r2)	Set a point at the last index
39	D.SetData(n, r1, r2)	Set a point at an index our of bounds
40	D.SetData(0, -1, -1)	Set a point with a negative energy and xSec
41	D.SetData(0, 0, 0)	Set a point with a zero energy and xSec

2.8.3 Performance

2.9 SetData

2.9.1 Unit Tests

2.9.2 Accuracy

Table 15: Accuracy

Test #	CPU	GPU
32	CPU result	GPU result
33	CPU result	GPU result
34	CPU result	GPU result
35	CPU result	GPU result
36	CPU result	GPU result
37	CPU result	GPU result
38	CPU result	GPU result
39	CPU result	GPU result
40	CPU result	GPU result
41	CPU result	GPU result

Table 16: Unit Tests

Test #	Code	**Description**
42	Empty.SetEnergy(-1, r1)	Set an energy at a negative index of an empty vector
43	Empty.SetEnergy(0, r1)	Set an energy at a the first index of an empty vector
44	Empty.SetEnergy(1, r1)	Set an energy at an index out of bounds of an empty vector
45	D.SetEnergy(-1, r1)	Set an energy at a negative index
46	D.SetEnergy(0, r1)	Set an energy at a the first index
47	D.SetEnergy(n/2, r1)	Set an energy at an index within the vector
48	D.SetEnergy(n-1, r1)	Set an energy at the last index
49	D.SetEnergy(n, r1)	Set an energy at an index our of bounds
50	D.SetEnergy(0, -1)	Set an energy at an index within the vector to a negative value
51	D.SetEnergy(0, 0)	Set an energy at an index within the vector to a zero value

Table 17: Accuracy

Test #	CPU	GPU
42	CPU result	GPU result
43	CPU result	GPU result
44	CPU result	GPU result
45	CPU result	GPU result
46	CPU result	GPU result
47	CPU result	GPU result
48	CPU result	GPU result
49	CPU result	GPU result
50	CPU result	GPU result
51	CPU result	GPU result

2.9.3 Performance

2.10 SetEnergy

2.10.1 Unit Tests

2.10.2 Accuracy

2.10.3 Performance

2.11 SetXsec

2.11.1 Unit Tests

Table 18: Unit Tests

Test #	Code	**Description**
52	Empty.SetXsec(-1, r1)	Set an xSec at a negative index of an empty vector
53	Empty.SetXsec(0, r1)	Set an xSec at a the first index of an empty vector
54	Empty.SetXsec(1, r1)	Set an xSec at an index out of bounds of an empty vector
55	D.SetXsec(-1, r1)	Set an xSec at a negative index
56	D.SetXsec(0, r1)	Set an xSec at a the first index
57	D.SetXsec(n/2, r1)	Set an xSec at an index within the vector
58	D.SetXsec(n-1, r1)	Set an xSec at the last index
59	D.SetXsec(n, r1)	Set an xSec at an index our of bounds
60	D.SetXsec(0, -1)	Try to set a negative xSec
61	D.SetXsec(0, 0)	Try to set a zero xSec

Table 19: Accuracy

Test #	CPU	GPU
52	CPU result	GPU result
53	CPU result	GPU result
54	CPU result	GPU result
55	CPU result	GPU result
56	CPU result	GPU result
57	CPU result	GPU result
58	CPU result	GPU result
59	CPU result	GPU result
60	CPU result	GPU result
61	CPU result	GPU result

Table 20: Unit Tests

Test #	Code	**Description**
62	Empty.SetX(-1, r1)	Set an energy at a negative index of an empty vector
63	Empty.SetX(0, r1)	Set an energy at a the first index of an empty vector
64	Empty.SetX(1, r1)	Set an energy at an index out of bounds of an empty vector
65	D.SetX(-1, r1)	Set an energy at a negative index
66	D.SetX(0, r1)	Set an energy at a the first index
67	D.SetX(n/2, r1)	Set an energy at an index within the vector
68	D.SetX(n-1, r1)	Set an energy at the last index
69	D.SetX(n, r1)	Set an energy at an index our of bounds
70	D.SetX(0, -1)	Set a negative energy
71	D.SetX(0, 0)	Set a zero energy

Table 21: Accuracy

Test #	CPU	GPU
62	CPU result	GPU result
63	CPU result	GPU result
64	CPU result	GPU result
65	CPU result	GPU result
66	CPU result	GPU result
67	CPU result	GPU result
68	CPU result	GPU result
69	CPU result	GPU result
70	CPU result	GPU result
71	CPU result	GPU result

Table 22: Unit Tests

Test #	Code	**Description**
72	Empty.SetY(-1, r1)	Set an xSec at a negative index of an empty vector
73	Empty.SetY(0, r1)	Set an xSec at a the first index of an empty vector
74	Empty.SetY(1, r1)	Set an xSec at an index out of bounds of an empty vector
75	D.SetY(-1, r1)	Set an xSec at a negative index
76	D.SetY(0, r1)	Set an xSec at a the first index
77	D.SetY(n/2, r1)	Set an xSec at an index within the vector
78	D.SetY(n-1, r1)	Set an xSec at the last index
79	D.SetY(n, r1)	Set an xSec at an index our of bounds
80	D.SetY(0, -1)	Set a negative xSec
81	D.SetY(0, 0)	Set a zero xSec

Table 23: Accuracy

Test #	CPU	GPU
72	CPU result	GPU result
73	CPU result	GPU result
74	CPU result	GPU result
75	CPU result	GPU result
76	CPU result	GPU result
77	CPU result	GPU result
78	CPU result	GPU result
79	CPU result	GPU result
80	CPU result	GPU result
81	CPU result	GPU result

2.11.2 Accuracy

2.11.3 Performance

2.12 SetX

2.12.1 Unit Tests

2.12.2 Accuracy

2.12.3 Performance

2.13 SetY

2.13.1 Unit Tests

2.13.2 Accuracy

2.13.3 Performance

2.14 Init

2.14.1 Unit Tests

Table 24: Unit Tests

Test #	Code	**Description**
82	Code goes here	Description goes here

2.14.2 Accuracy

Table 25: Accuracy

Test #	CPU	GPU
82	CPU time	GPU time

Table 26: Unit Tests

Test #	Code	**Description**
83	Code goes here	Description goes here

Table 27: Accuracy

Test #	CPU	GPU
83	CPU time	GPU time

2.14.3 Performance

2.15 CleanUp

2.15.1 Unit Tests

2.15.2 Accuracy

2.15.3 Performance

2.16 SampleLin

2.16.1 Unit Tests

Table 28: Unit Tests

Test #	Code	**Description**
84	Empty.SampleLin()	Sample an empty Vector
85	D.SampleLin()	Sample a Vector

2.16.2 Accuracy

Table 29: Accuracy

Test #	CPU	GPU
84	CPU result	GPU result
85	CPU result	GPU result

Table 30: Unit Tests

Test #	Code	Description
86	Empty.Integrate()	Integrate an empty Vector
87	D.Integrate()	Integrate a Vector

2.16.3 Performance

2.17 Integrate

2.17.1 Unit Tests

2.17.2 Accuracy

Table 31: Accuracy

Test #	CPU	GPU
86	CPU result	GPU result
87	CPU result	GPU result

2.17.3 Performance

2.18 IntegrateAndNormalise

2.18.1 Unit Tests

Table 32: Unit Tests

Test #	Code	Description
88	Empty.IntegrateAndNormalise()	Integrate and normalize an empty Vector
89	D.IntegrateAndNormalise()	Integrate normalize a Vector

2.18.2 Accuracy

Table 33: Accuracy

Test #	CPU	GPU
32	CPU result	GPU result
32	CPU result	GPU result

2.18.3 Performance

2.19 Times

2.19.1 Unit Tests

Table 34: Unit Tests

Test #	Code	**Description**
90	Empty.Times(-1)	Times an empty vector by a negative factor
91	Empty.Times(0)	Times an empty vector by zero
92	Empty.Times(1)	Times an empty vector by 1
93	Empty.Times(r1)	Times an empty vector by a random factor
94	D.Times(-1)	Times a vector by a negative factor
95	D.Times(0)	Times a vector by zero
96	D.Times(1)	Times a vector by 1
97	D.Times(r1)	Times a vector by a random factor

2.19.2 Accuracy

Table 35: Accuracy

Test #	CPU	GPU
90	CPU result	GPU result
91	CPU result	GPU result
92	CPU result	GPU result
93	CPU result	GPU result
94	CPU result	GPU result
95	CPU result	GPU result
96	CPU result	GPU result
97	CPU result	GPU result

Table 36: General Unit Test Variables

Name	**Size**	Description
emptyBuff	0	Array with no queries
singleBuff	1	Array with a single query
smallbuff	50	Array with a small number of queries
normalBuff	1000	Array with a moderate number of queries
largeBuff	10000	Array with a large amount of queries
negBuff	50	Array of queries with negative values
zeroBuff	50	Array of queries with values of zero
highBuff	50	Array of queries with values larger than the highest energy in the vector

Table 37: Unit Tests

Test #	Code	**Description**
98	D.GetXsecBuffer(normalBuff, -1)	buffer with a negative size
99	Empty.GetXsecBuffer(emptyBuff, 0)	Empty buffer of xSec queries to an empty vector
100	Empty.GetXsecBuffer(normalBuff, 1000)	Normal buffer of xSec queries to an empty vecto
101	D.GetXsecBuffer(emptyBuff, 0)	Empty buffer of xSec queries
102	D.GetXsecBuffer(smalllBuff, 50)	Small number of queries
103	D.GetXsecBuffer(normalBuff, 1000)	Normal case
104	D.GetXsecBuffer(highBuff, 10000)	Large number of queries
105	D.GetXsecBuffer(negBuff, 1000)	Buffer of negative xSec queries
106	D.GetXsecBuffer(emptyBuff, 1000)	Buffer of zeros
107	D.GetXsecBuffer(highBuff, 0)	Buffer of high valued xSec queries

Table 38: Accuracy

Test #	CPU	GPU
98	CPU result	GPU result
99	CPU result	GPU result
100	CPU result	GPU result
101	CPU result	GPU result
102	CPU result	GPU result
103	CPU result	GPU result
104	CPU result	GPU result
105	CPU result	GPU result
106	CPU result	GPU result
107	CPU result	GPU result

2.19.3 Performance

2.20 GetXsecBuffer

2.20.1 Unit Tests

2.20.2 Accuracy

2.20.3 Performance

2.21 Dump

2.21.1 Unit Tests

Table 39: Unit Tests

Test #	Code	**Description**
108	Empty.Dump()	Dump an empty Vector
109	D.Dump()	Dump a Vector

2.21.2 Accuracy

Table 40: Accuracy

Test #	CPU	GPU
108	CPU result	GPU result
109	CPU result	GPU result

2.21.3 Performance

2.22 ThinOut

2.22.1 Unit Tests

Table 41: Unit Tests

Test #	Code	**Description**
110	Code goes here	Description goes here

Table 42: Accuracy

Test #	CPU	GPU
110	CPU time	GPU time

2.22.2 Accuracy

2.22.3 Performance

2.23 Sample

2.23.1 Unit Tests

Table 43: Unit Tests

Test #	Code	Description
111	Empty.Sample()	Sample an empty Vector
112	D.Sample()	Sample a Vector

2.23.2 Accuracy

Table 44: Accuracy

Test #	CPU	GPU
111	CPU result	GPU result
112	CPU result	GPU result

2.23.3 Performance

2.24 GetVectorLength

2.24.1 Unit Tests

Table 45: Unit Tests

Test #	Code	Description
113	Empty.GetVectorLength()	Get the length of an empty vector
114	D.GetVectorLength()	Get the length of a vector

Table 46: Accuracy

Test #	CPU	GPU
113	CPU result	GPU result
114	CPU result	GPU result

2.24.2 Accuracy

2.24.3 Performance

2.25 GetIntegral

2.25.1 Unit Tests

Table 47: Unit Tests

Test #	Code	Description
115	Code goes here	Description goes here

2.25.2 Accuracy

Table 48: Accuracy

Test #	CPU	GPU
115	CPU time	GPU time

2.25.3 Performance

2.26 SetPoint

2.26.1 Unit Tests

- "rPoint" is a random G4ParticleHPDataPoint
- "nPoint" is a negative G4ParticleHPDataPoint
- "zPoint" is a zero G4ParticleHPDataPoint

Table 49: Unit Tests

Test #	Code	**Description**
116	Empty.SetPoint(-1, rPoint)	Set a point at a negative index of an empty vector
117	Empty.SetPoint(0, rPoint)	Set a point at a the first index of an empty vector
118	Empty.SetPoint(1, rPoint)	Set a point at an index out of bounds of an empty vector
119	D.SetPoint(-1, rPoint)	Set a point at a negative index
120	D.SetPoint(0, rPoint)	Set a point at a the first index
121	D.SetPoint(n/2, rPoint)	Set a point at an index within the vector
122	D.SetPoint(n-1, rPoint)	Set a point at the last index
123	D.SetPoint(n, rPoint)	Set a point at an index our of bounds
124	D.SetPoint(0, nPoint)	Set a negative point
125	D.SetPoint(0, zPoint)	Set a zero point

Table 50: Accuracy

Test #	CPU	GPU
116	CPU result	GPU result
117	CPU result	GPU result
118	CPU result	GPU result
119	CPU result	GPU result
120	CPU result	GPU result
121	CPU result	GPU result
122	CPU result	GPU result
123	CPU result	GPU result
124	CPU result	GPU result
125	CPU result	GPU result

2.26.2 Accuracy

2.26.3 Performance

2.27 Merge

2.27.1 Unit Tests

Table 51: Unit Tests

Test #	Code	**Description**
126	Code goes here	Description goes here

2.27.2 Accuracy

Table 52: Accuracy

Test #	CPU	GPU
126	CPU time	GPU time

2.27.3 Performance

3 Specific System Tests

3.1 Summary of Tests Performed

3.2 System Tests Results

4 Traceability

The following section is used to highlight the relations of implemented test cases to requirements and modules. In doing so, we hope to draw clear reasoning upon the inclusion of such tests.

4.1 Requirements

Below is a traceability table outlining test cases and the requirements they are related to:

Table 53: Tests and Requirements Relationship

Test #	Description	Requirement
1	Performance test of functions	requirement
2	InitializeVector	requirement
3	SettersandGetters	requirement
4	GetXSec	requirement
5	ThinOut	requirement
6	Merge	requirement
7	Sample	requirement
8	GetBorder	requirement
9	Integral	requirement
10	Times	requirement
11	Assignment	requirement

4.2 Modules

Similarly, the following is a traceability table explicitly relating test cases to modules:

Table 54: Tests and Modules Relationship

Test #	Description	Module
1	Performance test of functions	module
2	InitializeVector	module
3	SettersandGetters	module
4	GetXSec	module
5	ThinOut	module
6	Merge	module
7	Sample	module
8	GetBorder	module
9	Integral	module
10	Times	module
11	Assignment	module

5 Changes after Testing