

+ / # "

! "#\$%&' ("#\$) & "#\$*"

+ , , + - -

+ . / "#"* 0

+ , ! ! ! -

!

!

-

2 3 + 1 ! 4 !

+ + + "#"*

! ! 5 2

! +

! 2 0 6 ! -

1 + 7 +

(! ! ! 7 ! -

! 8 -

7 + 6 9 !

! 1 , : 7 + 5 2 5

! 0 +

+

4 3

5 ! -

"#"* (+

& + !

,

;

+

!

+ , +

<

!

= 0 < +

< 2

">?"@6 "#"*

+ 4

/' # /9 %/ ' ' */# #(:"/ " *% # / 1
 \$ 0 + 1 !
 3 - + +
 ! ! &
 " + 1 !
 * , & ,
 !- ,
 + ! + *\$ -
 \$ -
 ! !
 + ! (3 < =
 (= + 5 3 9 95=9 <
 6/=9
 ,
 + , ! -
 " + -
 + + 20
 ! ! ! ! /9 ! !
 * + ! "#"*

3.1. Advances in the Shift GPU solver

Steven Hamilton, Oak Ridge National Lab

| | | | | | | | | | |
|----|---|-----|------|----|-----|-------|---|---|---------|
| < | | - | ! | | | "#\$@ | < | + | ! |
| 6, | / | = | 9 | ! | ! | | | | |
| | 1 | | ! | | | | | # | |
| ! | # | + | | | | | | | |
| | | | | | | | # | | & |
| ! | | 1 | 9 | 1: | | | | | . |
| \$ | + | !"3 | | | | | | | 4 |
| 1; | 1 | # | | 1 | 911 | 1: | | | 8 |
| 1 | # | | 1 | 91 | 1: | | | | . |
| | | | | !" | 9 | : | | | 4 |
| | | 1 | 9 | 1: | | | | , | |
| | | | " | 9 | : | | | , | |
| < | ! | | 1 | 9 | 1: | | | | 8 |
| ! | | | " | 9 | : | | | | 6 |
| | | 1 | 9 | 1: | | | | | 4 |
| | | " | 9 | : | | | | | 4 |
| " | | = | # | ! | 9 | : | | | 4 |
| " | | \$# | 9\$: | | | | | | , 64 |
| | | " | + | | | | | | |

; / # "

| & | | ! | ,-,6 | | ## + | | |
|------|--|-----------|-------|--|-------|--|-----|
| | | | & | | & # " | | \$ |
| | | %& | '# | | 1 | | , |
| # | | 1 1 | 1 ! | | 1 1 | | 6 |
| & ! | | ! | # ? < | | 1 1 | | 3 @ |
| > | | %& & | > " / | | 11 1 | | . |
| 11 1 | | | ; | | \$; | | A |
| %& | | | (| | 1 | | |
| '! | | !" &" | | | | | |
| %& 2 | | Celeritas | # C " | | / | | 3\$ |
| 3\$ | | ' B 2 (# | ? | | 9 3 : | | 8 / |
| / " | | %& ! | (## | | 1 | | 8 |
| | | 2 & # | | | | | 3 @ |
| | | & | | | | | |
| C \$ | | \$ %& | | | | | |
| | | ! | \$ | | % " | | 3 @ |
| | | 1 | & ? < | | 1 | | ,4 |
| & | | @ | # | | " | | D |
| | | | | | " | | |

| | | | | | | | |
|-------|--|-----|----------|--|------------------|--|---------|
| # " | | 1 + | ## | | " | | = |
| ; | | # | " 9 | | ": | | & # " 1 |
| | | | \$ | | via | | + +! |
| (" | | | " | | E | | |
| > | | | " | | E | | |
| " | | | " | | E | | |
| | | & | 9 B : | | ! + #3 # = 3 # | | |
| %& ! | | | 9 : | | ! + #3 #3 # | | |
| %& | | | 9 : | | ! + #3! "3 #3 3 | | |
| ,4 | | | " | | E | | |
| 3\$ | | | 9? \$=6: | | ! + #3 =& &3 \$ | | |
| ' # B | | | 9? \$=6: | | ! + #3 =& &3 # B | | |
| | | | 9 ,+:- | | ! + #3 =) 3 | | |

+ !- + -
! !
- ' "#"\$ 8 -
!

, -
! -
1 -
< ! -
4

6 - - ! 0

0
2
'!
!

/' # /9 %/ ' */# #(:/" "% # / ,
 < + 05 ' -
 2 ! '2 = 5 0
 ! '2 = 5 0 &
 + ! =
 , + 05 /6 5 2 <
 , < -
 + 5 0
 ! -
 ! , + ! -
 /6 + -
 /6 , !
 + + !
 + + <
 ! ! + /6 ! -
 , - !-, ,
 6 0
 0 5 0 2">#A + + 0 + 0
 1 B\$## + 1
 \$>#?"##
 + < + , -
 3 - +

3.2. Implicit Monte Carlo at LANL—progress and challenges

Alex Long, Los Alamos National Laboratory

C! $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ 2 2
 ! ; , \$)%\$ -
 C! ! ; 5 2
 ! ! , "#"\$
 ! ! D E 9 5 ">! +
 C! + + ! :
 ! C! + 1 :
 + +! : -
 + < +
 D E + ! F

. / # "

+ + C!
6 +
4

< ! \$"G !
! GG! &

5 + !
!&

/ &
2 1 -
0 0 00

/ 8 , &
, + =
/6

-) 2 -
@ +
* @ +

5 ! G ! +
! !

+ C! + + , -
! 1 , +

"# \$

5 , 5 H
9 5 = 9 5 "#\$>

! !- -
, /! <+ ! "#\$G /!
3 2

! +
! G# 2 + +
! \$>?" /!

5 ! -
! ! , <
! ! -
+ - ! ! -

/' # /9 %/ ' */# #(:/" "% # / 7
 \$#?"# = B\$## 2
 A + 5 H
 - ! 2 -
 2 2 2
 \$% , \$I

3.4. LLNL Monte Carlo Transport GPU status

Scott Mc inley ! S"a#n \$a#son, La#rence Livermore National Laboratory
 ! ! "\$\$@ - -

! ! 2
 ! "\$\$) + 2
 ! G#J + ! +
 99=9
 : !
 ! 2 + -
 , < (H !
 "\$\$) 6
 "\$"*
 ! ! 2 = -
 3 5 0 (-
 5 0- 99=9
 ! via D E
 +
 3 !
 + ! 3
 6 1 ! 3 + -
 8 3
 !
 + ! !
 + !
 ! /5C5 , "\$\$) ! !
 99=9&+ ! /5C5
 + !
 8 99=9
 ! 3
 +
 +
 ! +
 = ! ! +

< / # "

' + ! 2 !
 , "#"
 + !
 ! ! 2 + + ! -
 ! ! 1
 +
 !7 !- ,
 ! ! ,

< - + + ! -
 4

5 D E + ,
<
5!
9 , 6 + = 7 "#?*>J

>
* @ <
0 ! 2
 ! !
202 ! !
5 0
 !
99=97 ' , +
 , +
202 , & 99=97 -
 ! -
 ! + ! 2
05 /6 4

9 , 6 , + /6 &
 + , 05 + , -
 + /6 < ,
 + + &
=B , 05 '2 !
 /6 , ! <
&

/' # /9 %/ ' */# #(:/" *% # / =

1 /6

2 + ,

+ &

6 ! 2

= =B > - -

*@- 2 A ! ! +

!

3.5. High energy physics Monte Carlo on GPUs: Celeritas

Set " % "nson, Oak Ridge National Laboratory

3

9 ! 9 ' '9-9' (/=

"#" !

9' 5 D ,E ! '9-

"##" & + -

'9-9' 3 1 -

! -

! : , !

| '9-9' -

! - !

+ 1

+ +

'9-9' 1 !

& ,

+ 0

+ , !

+ , + ! , -

, ! , + ! -

-,

!

E + , -

3 ! | 3 +

+ +

>0

/ # "

6/5= ("#"# 6 , / 5 ! 8 5 , (! 6/5= (! , 0 + 6 + + *#?|# & + 6/5= (B 6/5= (- + , "#J + "#J + ! (+ ! " 8 ! ! 9 ! (/= , + , 6 , / = 1 , ! ! ! & ! + , !

3.6. MC/DC¹ Harmonize: JIT compilation & asynchronous GPU scheduling

¶ "am 'ariansya" ! Braxton (uneo, (enter)or *xascale Monte (arlo Neutron Trans+ort

0! K0 ! - + (3 = <0-* B ! "#"* K0 ! + - + ! ! 3 - - 2 + ! ! - 1 ! - 8 ! ! ! 3 K0 + 4 ! ! ! ! &

/'# /9 %/' '*/# #(:/" "% # / >>

! ! --+

=C6. &

! , - , 1 < -

- &

;3 - - k- &

+ 2&

+ = - 05 ' &

0 &

! ! !

- / = /=

K0 !

2 ! ,

! , 3 !

! "##* ;(5 "##\$ <

! !

1

5 2 ,

! ! K0 ! -

= + 9 < "##\$> 5 -

! + 99B

! + ! K

0 3 ! 1

!H,, 5 5+ "##\$!6 9 ! 05 H •,

"##\$ = + -

+ = ! "##"

K0 !

! 5 6

- H !

< = ! "##\$ 2 - > %

"##\$% - + + - ! 5 -

3

2 - ! K0

!*

=

!@"

!

>+ / # "

K0 + ! 3 -

! 8 ! K0 7 -

, = 1

! +

8

! ! ! F:

8 ! -

' + , 3

' ! "#"* ! ! + , -

, 3 ! 2 ! +

+ , 3 +!

;

- ! - & + ' !

! !

1 K0

! ! !

+ ! + ! !

3 1 - K0 B ! "#""

! 1 k-

"#"* "#"* "#"|

"#""

+ + + B !

- ! 1

"#"*

1 ! F

3 5

K0 ,

+ ,

3.7. OpenMC at exascale: performance portable Monte Carlo particle transport on Intel, Nvidia, and AMD GPUs

% 'n Tramm, Argonne National Laboratory

6 -

/ ; "#\$* ; ! 6

/'# /9 %/ ' */# #(:/" "% # / >1

6 7 - ! + 2

! "#!"

6 6 > -

! + - !

! &

D E 1 -

! +

6 !

< !

0 + + 6 + -

6 & + ,

3 !

2 + , -

6 -

6 +

6 + ,

2 - ! 6

, 2

A G"@# + IG 2 !

6

>| = 5\$## % #

5 0 2">#A \$" G 2 B

2 6 + ! -

! H,, /5C5 /5C5

!

6 , + 1 ! <. 9 '2

! -

+ ! , ! !

+ 1 3

6 !-

:

+ - ,

- , + ! 3 , -

! , + + +

+ 3 , -

, +

+ +

3 ,

1 +

+ + +

```

>; / # "

! ' + -

5 ! 2
, 1 ,! -
& 2
! 5 0 =
0 6
' - + ! + -
6 2 + -
!
! ! + ! + ! 8
+ +
& + ! !
! 0 + &
+ 52 + +
+ ! ! + -
+ +

```

3.8. Experience adapting OpenMC to CUDA

, avin Ridley, Massac"ussetts Institute o) Tec"nology

```

2 5 = 9 ! 6
2
! + ! 05
/ ! ; "#$ + -
- ! 5 ># ###
! 1/4 1/2 +
! + , ! - , 1
6 - 6 + ,
6 2 + !
6 3 ! 3 + ! -
05 ! 2
-1 ! + < 9 + + 2
+ 05 2 +
std::unique_ptr
+!

```

```

/ ' # /9 %/ ' */# #( :/" "% # / >,
5 std::vector + + -
1
+ !
: 3 !
6
3
-
2 6 1 + , ! 5 ! -
+ + - 4 -
+
6 1 3 !
+ 2 ! 05 ! -
! ! 5 !
+ ! 05 , ! 3 !
1 ! !
1
3 1 +
8 3 + - - !
!- - !
!- - >J -
5 ! -
! 6 ! "#"" +
! !
05-
+ + 6 +
+
! < 1 + ! 3 -

```

3.9. Monte Carlo research at NNL

-./.0. 1aul Burke, Naval Nuclear Laboratory

```

"$ = = 9 !7 ! 2
! ! ! ! !
+ !
"#> "$ 4
- ! &

```

> . / # "

;3 &

= &

; 3 ! ! +

&

2 - , K' A +

! &

! ! - D E

+ + !&

2 - ! &

8 -+ + +

+ "\$! 3

+ ! !

"\$! ' "\$ -

! 6 2 ==9 "\$ -

A - ! 2

- 8 "\$

! + - , ! !

! ! - , , H 3 + "#"\$

, ! , + -

! 3 8 -

+ - , - + + *#J *slowdown* \$#J *speedup*

6 ! !

"\$ ==97 -

B2L + , -

/! 5 1

! + - +

2 ! /! !

, + *via* : 3

5 ! ! 3

: ! !

! 5 /! +

! ! ! + -

, + 3 ! +

' 1 ! + +

+ 1 ! !

structures of arrays

+ "\$!

+ , + +

<

1 !- - + , +

!

!

+

0

==<5 95=9 99=9 <=9

+ ! +

+ + \$# + \$\$\$

"\$ + !

!

"\$ -

+

!

K

-

+ !

-

5 ! ! -

,

,

+

;

+

!

<

2 + + , -

+

+

>< / # "

! , ' +
+ + & ! -
, ! + ,
+ + -
+ 5 + !
+ + -

5 +
+ ,
! 2 1 , !
+ F , 3 5 + , + 6 ! + ,
4 , + +
+ < ! -
3 -
+ ! -
- ! -

! 5 = < ! 7
0 ! 2 < +
3 !
: ! +
< +

+ *benchmark problem* +
challenge problem +
! 0 ==<5 -
! + 6 , / -
! : ! -
! - ! > % -

' "#\$%
5 + 4
& + !
6 , / 5 = 9 ! +
5 - -
+ + &

2 : , + ! + +
!

/' # /9 %/ ' */# #(:/" "% # / >=

! !

+ 5 0 2 3 -

-

+ !

+

5 !

+

!

!

:

+ +

+ 3

!

!

+

!

,

+

-

5 + -

,

+

!

6

+!

+

-

(=

<

3

! "

8 + , , - 5 3

9 < ' , , ! = 0

=0 (!

C

!

9 5 - = 9 ! + 0 5 0 !

5 H 5

#

= + !

\$ "

+ , + ! (3 - =

(= <55 -222 : ! 0 (! = 4 0(-

=5##*)@%

+0 / # "

%& #

C 4KK K####-##*-\$*%)->I*\$
5 3 4KK K####-##\$->#))-#"**
< 9 4KK K####-##*-\$*)\$-\$I%\$
H! (= ! 4KK K####-##*-II">-%#)%

%

5 < = C <+ ! 5 L, C ! < /
5 + "\$\$> , 5 H Ann. Nucl. Energy. G"4I\$?%
4\$# \$\$\$@K: "\$I #G #I%
5 < C5 H 5 , C5 , ' 5 : 5 5 0 53
< : "##* IF5 , Nucl. Instrum.
Methods Phys. Res., Sect. A. >#@* 4">#?*" 4\$# \$\$\$@K<#\$@G-)##" #* #*\$@G-G
5 5+ = < L "\$\$ 5 ! + ,
! Int. Conf. Supercomput. I@%?%G 4\$# \$\$\$I>K*II%G\$G *I@#*%@
5 / C5 : 5 , C + C-< C ! B 0 .
0 5 ; H "\$\$;(4 5
! Comput. Math. Appl. G\$4I"?%I 4\$# \$\$\$@K: + "## # @ ##)
! < < 5 ! , ; 5 < C + H
#"* (< K 56 / 5=9-"\$K*) ? / *"# 5
= 9 !
, 5 C ; C < 0 / ,:, / 0 '
"## 4 5 - 3 -
! IBM J. Res. Dev. @I *KI 4##4\$?##4\$#4\$# \$\$\$I%KC/0 "\$\$) ")>II#*
, 0 5 C , / ' C 8 H 6 5 CH
/ < /!: / 8 < "\$\$) /5C54
- 2 IEEE/ACM international workshop on performance,
portability and productivity in HPC (P3HPC) %\$?G\$ 6 2((K5
! < / < 5 0+ = 5 < H ! C 6
"\$\$\$% 99=9
/ 9+ 9 = 9 99=9
9 5 <
! = 9 H ! 67 C 8 "\$\$) 5 +
!
2 Proceedings of the American Nuclear Society; Mathematics and
Computation (M&C) 2019 6 <5
! < 0+ < H ! 6 0 , H
5 ! "\$\$@ 99=9 ! : ! 6 < ; /
/ 9+ 9 = 9 4KK+++ K K
\$">@I#
H 5 C 6 "##* ! !
2 International Conference on Mathematics and
Computational Methods Applied to Nuclear Science and Engineering = ;
6
! "##* 0
+ - ! ACM Trans. Model. Comput. Simul. *I \$ 4\$?">
4\$# \$\$\$I>K*@"@)>%

; , C5 C0 \$)%\$5
 1 ! Comput. Phys. G * 4*\$*?
 I" 4\$# \$#\$@K##"\$-)))\$ %\$)##\$>->
 0 0 ; / = < ' < ! < 0 0
 ' (' C "\$\$> "\$ @#? 5 -
 ! + ,
 Ann. Nucl. Energy. G"4")?l# 4\$# \$#\$@K: "\$\$! #G #"
 ' < ("\$\$) - !
 < Ann. Nucl. Energy. \$"G4"*@?l% 4\$# \$#\$@K: "\$\$)
 # \$ #"
 ' < (H (/! (0 "\$#\$ 0 -
 - < Ann. Nucl. Energy. \$@ 4\$#G@G%
 4\$# \$#\$@K: "\$#\$G@G%
 ' CCH = 2 B ; ! 5 ; , "\$\$\$6(0K=(5 -
 - +
 Nucl. Eng. Des. *\$%4\$%%?G 4\$# \$#\$@K: "\$\$%#" ##G
 H 3 5 H (/ ! = 0 (, 5 "\$#\$
 5 ! - , -
 2 Proceedings of the American Nuclear Society; Mathematics and
 Computation (M&C) 2021 / =
 H •, 5 = . 9 2 5 ; "\$\$! 05
 !6 94 5 - - Parallel
 Comput. *G * 4\$>%?%l 4\$# \$#\$@K: "\$\$\$ #) ##\$
 H ! H = < . = ! "\$\$\$ *0 -
 + Prog. Nucl. Energy. *) " 4\$\$)?
 II +++ K K 4\$# \$#\$@K<#\$\$-)\$)%# # \$ #####->
 9 < H 5 < < "\$\$> = 4 5 99B - ! C2
 2 Proceedings of the Second Workshop on the LLVM Compiler Infrastructure in HPC
 5 A 5 4KK K K\$# \$\$\$!>K"G**\$>% "G**\$@"
 / C "\$"* "\$"* < 4\$#
 >"G\$K "\$#"%%#@l
 H ! / ! < 0 + 67 0 /
 "\$\$) < 99=9 < 2 Proceedings of the
 American Nuclear Society; Mathematics and Computation (M&C) 2019
 6 <5
 C < H (= ! "\$"" (3 ! - -
 + 2 Transactions of
 the American Nuclear Society \$"@\$G?"# 5 5 <54 5 =
 < ! 4\$# \$*\$G"K \$"@-*G\$*%
 ! < / C (0 < ' 5
 ! "\$\$@2 , < ! -
 Comput. Phys. *#G4"*?)%" 4\$# \$#\$@K: :
 "\$\$> \$" #*%
 < 2 B ! H ! / "\$\$!
 -M - M -
 + -
 4KK 3 K K"l#\$ #l#")
 < 2 B ! H ! / "\$"* M 4 2 1 -
 + H ! , -

++ / # "

2 International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering = ; 6 4\$# \$#G#K##")>@*)

"#" "\$I*%#I

< 2 B ! H ! / "#"* 5 1 -
+ H !

Nucl.

Sci. Eng. \$)% @ 4\$\$>)?%* 4\$# \$#G#K##")>@*) "#"\$ "\$I*%#I

= 5 5 5 5 ' < / < / "#\$*

0

-

2

05

Progress in

Nuclear Energy (New Series) @>4GG?)I4\$# \$\$\$@K: "#\$* # #G

/ ! < 0 + H ! 5 /

67 "#"* 99=9 =

2 International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering = ; 6

/ ! ; "#"\$ 0 6

2 ANS Winter Conference 8 0

/ H ; "#\$* 6

Ann. Nucl. Energy. >\$ 4"%I?G\$ 4\$# \$\$\$@K: "\$\$ # @ #I#

<+ ! C("\$G\$ 5 - !-

Comput. Phys. *% "4I" @?I> 4\$# \$\$\$@K: : "\$G\$ # @ #"

H 5 5 / 9 H 9 / 8 / !/

H ! "#"\$ C ! ! \$ # ? 5

/ 9 5 = 9 95=9

9 5 =

< (9 5 9 9 < / C < . C B /

H / "#"\$ 4 -

' (! ! 3 / ;

= 5 ; ! 6 , / = 9 4\$# IG>>#K A ""#* #)I@%

C/ H . H / "#"* + ! 4 5

-

2 The International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C 2023) = ; 6

C / C 0 5 9 < + 5 < / ! 5

"#" + 6

2 Proceedings of the international conference on physics of reactors -

PHYSOR "%*I?"%I* 5

B ! 2 / "#"\$ 5 !

1

- Nucl. Sci.

Eng. \$)@ \$\$ 4\$"G#?*#> 4\$# \$#G#K##")>@*) "#"\$ #) \$)#@

B ! 2 / "#"\$ 5 1

2 International Conference on Physics of

Reactors ! <5

B ! 2 C H (= ! / "#"* 0

K0 4 5 ! - -

2 International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering = ; 6

8 < C 5 , "#"\$ 5 B I

EPJ Web Conf. "I>4#"#I 4\$# \$#>\$K : K#"#"I>#"#I