REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

ESR12: Accelerated Anomaly Detection

SMA HER

Pratik Jawahar

Supervisors: Caterina Doglioni, Jiri Masik, Alex Oh, Maurizio Pierini

Overview:

- Qualification Task -Heterogenous Tracking
- ML based Data Compression - Baler
- Misc. Activities







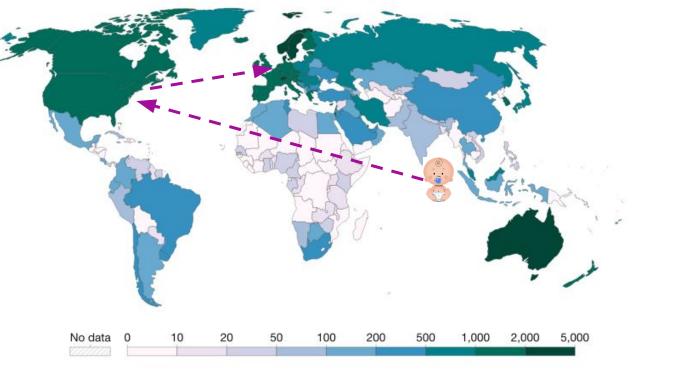
- BS: Mechanical Engineering (2019)
- MS: Robotics Engineering (2022)
- PhD: Robo.. *sike* Particle Physics
- Experience:
 - Summer student (CERN, 2018)
 - Control algorithms for GEM • detectors (CMS)
 - Technical student (CERN, 2021), DIANA HEP Fellowship (2020)
 - ML based anomaly detection • for new physics searches
- Website:

https://www.pratikjawahar.com/

Annual articles published in scientific and technical journals per million people, 2018



Includes physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.



Data source: World Bank (2022); United Nations (2022) Note: Articles are counted by the country of the author's institution. OurWorldInData.org/research-and-development | CC BY



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Qualification Task: Heterogenous Track Reconstruction

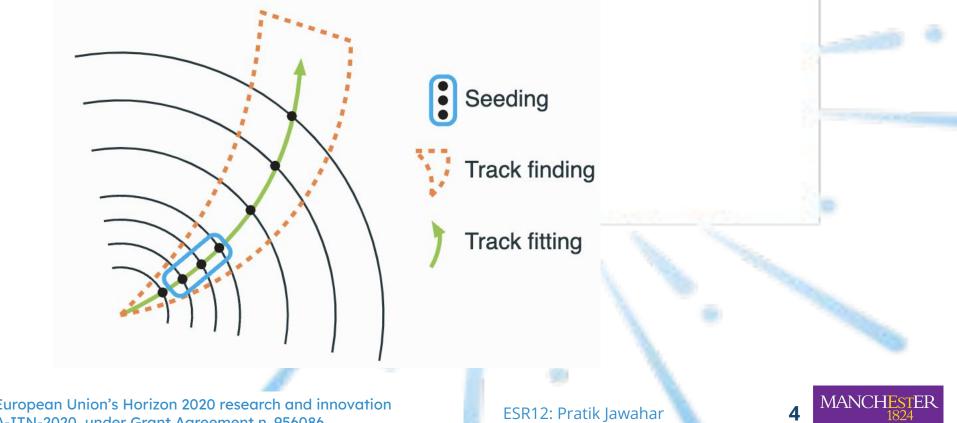






SMA HEP Track Reconstruction:

 Reconstruct trajectories of charged particles as they pass through different layers of the detector, subject to a magnetic field



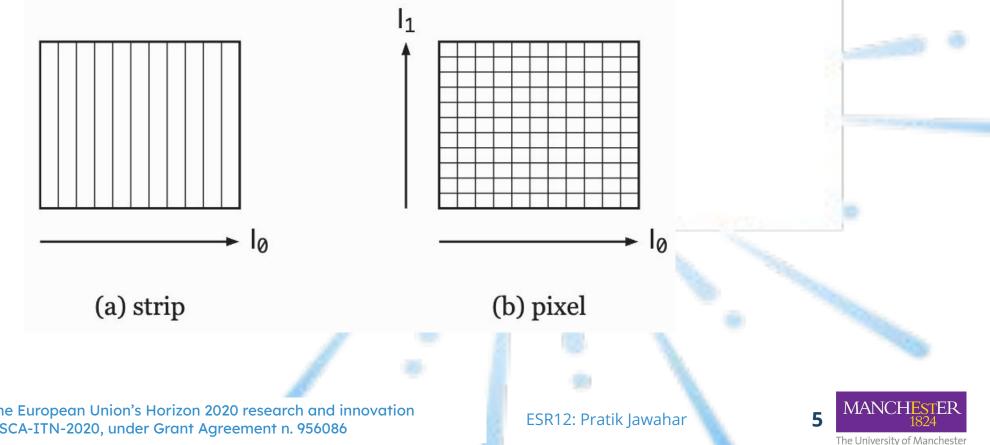
The University of Manchester





SMARTHEP Track Reconstruction:

- Step 1: Detect a charged particle when it passes through a layer
 - Ionization in semiconductors

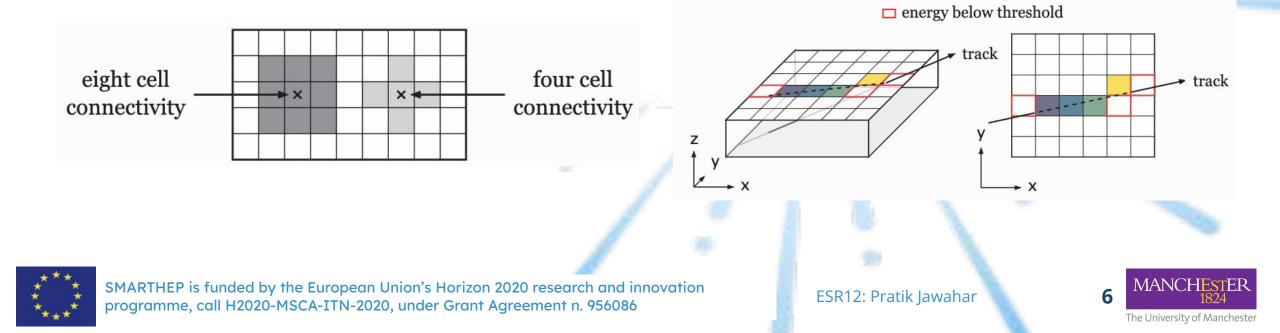






SMARTHEP Track Reconstruction:

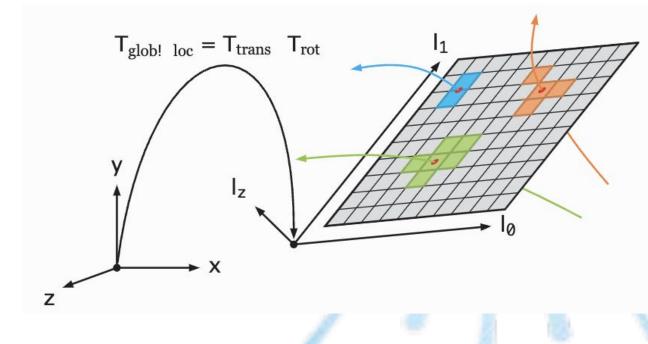
- Step 2: Clusterization
 - Depends on how you treat readout, detector design etc.
 - Connected Components Algo (CCA) iterated on edges





SMARHER Track Reconstruction:

- Step 3: Spacepoint Formation
 - Move from local sub-detector frame to global detector frame





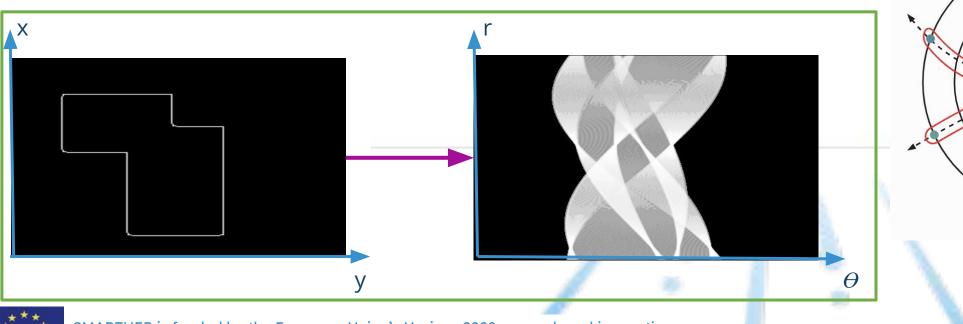
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SMARHEP Track Reconstruction:

- Step 4: Seeding
 - Find triplets of spacepoints that could potentially belong to the same track
 - **Conformal maps** => Hough Transform

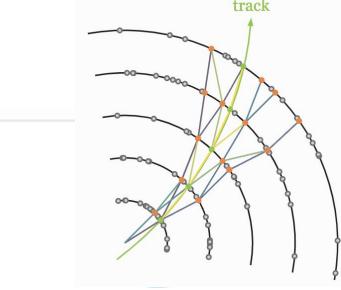








- Step 5: Track finding and fitting
 - Start from a seed
 - Kalman formalism (eg. Combinatorial KF) => Smoothing (eg. global χ^2 fit, or walk back with Kalman fit) => Ambiguity resolution track



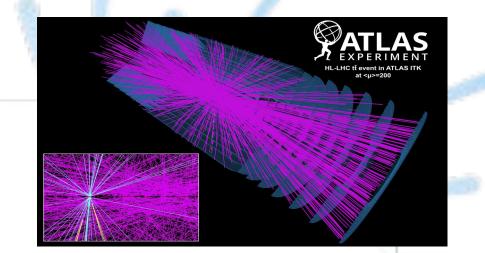


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- No. of tracks per event for HL-LHC, expected to increase 2.5x
- Current R&D: Use GPUs for speedup via parallel computation
- However, sequential algorithms like CKF do much better on CPUs than **GPUs!**



traccc

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aits.



Demonstrator tracking chain for accelerators.

Computing term for specific purpose architectures (eg. GPU, TPU, IPU etc.)



- Heterogeneous Track Reconstruction:
 - Step 1: Profiling CPU and GPU code to identify speed-up in inference time
 - Ideally without drop in tracking efficiency
 - Step 2: Identify bottlenecks
 - Points where one architecture outperforms the other
 - Step 3: Calculate data-transfer latencies at bottlenecks
 - Data transfer latencies between host (CPU) and device (GPU) eat up speed-up







Step 1: Ensure GPU computations do not decrease physics performance

D2H Calculations - CPU vs D2H CPU

D2H Calculations - CPU vs CUDA

<pre>Running seeding algo with CUDA spacepoints moved to host Number of D2H seeds: 28346 (host), 28346 (device) Matching rate(s):</pre>	<pre>Number of seeds: 28346 (host), 28346 (device) Matching rate(s):</pre>
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SMARHER CUDA Profiling - NSight Compute

Step 2: Profile code in as close-to-deployment conditions as possible

CUDA tools: NSight Compute, NSight Systems

ID	 Issues Detected 	Function Name	Demangled Name	Process	Device Narr Grid Size		Block Size		Cycles [cycle]	D	Ouration [msecond]	Compute T	hroughp Memory Throughput	[%] #	Registers [register/thread]	
	0 20	0 ccl_kernel	traccc::cuda::kernels::ccl_kernel(v	[1138765] tracc	Tesla T4	474, 1,	1	128, 1,	1	472435		0.81	43.75	43.72		49
	1 14	4 form_spacepoints	traccc::cuda::kernels::form_space	[1138765] tracc	Tesla T4	137, 1,	1	1024, 1,	1	95281		0.16	5.95	36.43		36
	2 1	1 count_grid_capacities	traccc::cuda::kernels::count_grid	[1138765] tracc	Tesla T4	545, 1,	1	256, 1,	1	18692	h.	0.04	22.31	50.49		20
	3 14	4 populate_grid	traccc::cuda::kernels::populate_gri	[1138765] tracc	Tesla T4	545, 1,	1	256, 1,	1	35039	1.	0.06	11.99	54.14		22
	4 1	5 fill_prefix_sum	traccc::cuda::kernels::fill_prefix_su	[1138765] tracc	Tesla T4	18, 1,	1	32, 1,	1	23989		0.04	7.45	26.34		28
	5 10	0 count_doublets	traccc::cuda::kernels::count_doubl	[1138765] tracc	Tesla T4	1131, 1,	1	64, 1,	1	848561		1.45	71.08	16.92		42
	6 1:	3 find_doublets	traccc::cuda::kernels::find_doublet	[1138765] tracc	Tesla T4	479, 1,	1	64, 1,	1 1	1211907		2.07	33.78	35.93		38
	7	9 count_triplets	traccc::cuda::kernels::count_triplet	[1138765] tracc	Tesla T4 2	24496, 1,	1	64, 1,	1 1	1957486	1	3.33	68.04	23.78		45
	8 1	5 reduce_triplet_counts	traccc::cuda::kernels::reduce_tripl	[1138765] tracc	Tesla T4	479, 1,	1	64, 1,	1	19298		0.03	2.52	11.65		16
	9 1	5 find_triplets	traccc::cuda::kernels::find_triplets([1138765] tracc	Tesla T4	720, 1,	1	64, 1,	1	294522	1	0.51	29.96	27.57		45
1	0 1	8 update_triplet_weights	traccc::cuda::kernels::update_tripl	[1138765] tracc	Tesla T4	930, 1,	1	64, 1,	1	18140		0.04	13.81	48.89		23
1	1 19	9 select_seeds	traccc::cuda::kernels::select_seed	[1138765] tracc	Tesla T4	479, 1,	1	64, 1,	1	102384		0.18	26.16	26.16		39
1	2 14	4 estimate_track_params	traccc::cuda::kernels::estimate_tra	[1138765] tracc	Tesla T4	443, 1,	1	64, 1,	1	78502		0.14	5.62	44.97		52



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SCIENCE AND INDUSTRY CUDA Profiling - NSight Compute

Uncoalesced Global Accesses

This kernel has uncoalesced global accesses resulting in a total of 5097660 excessive sectors (68% of the total 7519840 sectors). Check the L2 Theoretical Sectors Global Excessive table for the primary source locations uncoalesced device memory accesses.

Name Value Info derived_memory_l2_theoretical_sectors_global_excessive 5.09766e+06 memory_l2_theoretical_sectors_global > memory_l2_theoretical_sectors_global_ideal \odot

rce: clusterization_algorithm.cu		Source: ccl_kernel 🔻 🕒 Find	Navigation: Live Registers	▼	
igation: Live Registers 🔹 🗸 🧹 🔂 🖽 💆		# Address Source	e .	Registers	
	Live Instructions Warp Stall		LOP3.LUT R36, R27, 8xffff, RZ, 8xc8, IPT	34	1.51
# Source	Registers Executed (/		STS.U16 [R21+0x10], R30	34	
			IMAD.SHL.U32 R29, R27, 8x2, RZ	34	
/* * The algorithm executes in a loop of three distinct parallel			STS.U16 [R26+8x10], R31	33	
* The algorithm executes in a loop of three distinct parallel * stages. In this first one, a mix of stochastic and aggressive			LOP3.LUT R29, R29, 0x1fffe, RZ, 0xc0, IPT		
* stages. In this first one, a mix of stochastic and aggressive * hooking, we examine adjacent cells and copy their grand parents			STS.U16 [R23+0x10], R31		the second
* nooking, we examine adjacent cells and copy their grand parents * cluster ID if it is lower than ours, essentially merging the two			IMAD.IADD R30, R3, 8x1, R36		
* together.			LEA R30, R30, 0x10, 0x1		
*/			IMNMX.U32 R32, R34, 8x1, IPT		
<pre>- ^/ for (index_t tst = 0; tst < MAX_CELLS_PER_THREAD; ++tst) {</pre>			PRMT R31, R34, 0x7610, R31		
const index_t cid = tst * blckDim + tid;			LOP3.LUT R25, R32, 8x3, RZ, 8xc8, IPT		
. CONSE INDEX_C CIG - USC & DUCKDIM + CIG;			IADD3 R33, R32, -8x1, RZ		
builtin_assume(adjc[tst] <= 8);	<u> </u>		IMAD.MOV R35, RZ, RZ, -R25		1 M M
<pre>for (unsigned char k = 0; k < adjc[tst]; ++k) {</pre>	40 552(740)		LOP3.LUT R33, R33, 8xff, RZ, 8xc8, 1PT		and the second se
<pre>index_t q = gf[adjv[tst][k]];</pre>	44) 7(89,056)		PRMT R35, R35, 0x7710, RZ		
			BAR. SYNC 0x0		
<u>if</u> (gf[cid] > q) {	44) 937,256		ISETP.GE.U32.AND P1, PT, R33, 0x3, PT		
f[f[cid]] = q;	44 494,031		IMAD.IADD R27, R32, 0x1, R35		
f[cid] = q;	44 386,893		LOP3.LUT P2, RZ, R31, 0xff, RZ, 0xc0, IPT		
			BMOV.32.CLEAR RZ, B0 BSSY B0, 9x7fdba4fb1d20		
······································					
		 267 00007fdb a4fb16a0 268 00007fdb a4fb16b0 01P2 	PRMT R31, RZ, 9x7619, R31	39	
			BMOV.32.CLEAR RZ, B1		
/*			BSSY B1, 9x7fdba4fb1a70	39	
• Each stage in this algorithm must be preceded by a			ISETP.NE.AND P2, PT, R25, RZ, PT		
			PRMT R32, RZ, 0x7610, R32	39	
		272 00007fdb a4fb1700 01P1		30	
	34 15,864		PRMT R31, R27, 0x7610, R31	36	
			LOP3.LUT R33, R32, 0xff, RZ, 0xc0, IPT	37	
#pragma unroll		—	LDS.U.U16 R35, [R4]		
			IMAD R33, R33, 0x2, R0		



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No. of

Events

1

Old Version

Data File	Detector Geometry	
tml_full/ttbar_	tml_detector/trackml-	
mu300	detector	

New Version - with FastSV

GPU

Parent process

Container

Instantiation

File reading

Spacepoint Formation

Clusterization

Clusterization +

Track param est

Spacepoints

Seeding

		GPU		100 m	CPU			
Parent process	Duration [mu-sec]		Parent process	Duration [mu-sec]		Parent process	Duration [mu-sec]	
Container Instantiation	8			6		Container Instantiation	8	
File reading	1,720,207		File reading	NA		File reading	1,288,893	
Clusterization	40,197		Clusterization	NA		Clusterization	36,070	
Spacepoint Formation	6,078			NA		Spacepoint Formation	3,131	
Clusterization + Spacepoints	46,275			40,197			39,201	
Seeding	1,075,583		Seeding	80,072		Seeding	792,729	
Track param est	27,909		Track param est	2,651		Track param est	9,316	
	Parent process Container Instantiation File reading Clusterization Spacepoint Formation Clusterization + Spacepoints Seeding	Parent processDuration [mu-sec]Container InstantiationIContainer InstantiationISpacepoint Formation40,197SpacepointsIClusterization + SpacepointsISeedingIInstantiation + SpacepointsISeedingIInstantiation + SpacepointsIInstantiation + SpacepointsI </td <td>Parent processDuration [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-s</br></br></br></br></br></br></br></br></br></br></br></br></br></br></td> <td>Parent processDuration [mu-sec]Image: Constainer Image: Constainer InstantiationParent processContainer InstantiationImage: Constainer Image: Constainer Constainer Image: Constainer Image: Constainer Im</td> <td>Parent processDuration [mu-sec]Image: Constainer InstantiationDuration [mu-sec]Duration [mu-sec]Container InstantiationImage: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationFile reading1,720,207Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationClusterization40,197Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationSpacepoint Formation6,078Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationClusterization + Spacepoints1,075,583Image: Constainer Image: Constainer Image:</td> <td>Parent processDuration [mu-sec]Image: Container Image: Container InstantiationDuration [mu-sec]Duration [mu-sec]Container InstantiationImage: Container Image: Container InstantiationImage: Container Image: Container I</td> <td>Parent processDuration [mu-sec]Image: Container InstantiationDuration [mu-sec]Parent processDuration [mu-sec]Parent processContainer InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationFile reading1,720,207Image: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationFile reading1,720,207Image: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationSpacepoint Formation40,197Image: Container Image: Container FormationImage: Container Image: Container Image: Container FormationImage: Container Image: Con</td> <td>And the section of t</td>	Parent processDuration [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer [mu-sec]Image: Constainer 	Parent processDuration [mu-sec]Image: Constainer Image: Constainer InstantiationParent processContainer InstantiationImage: Constainer Image: Constainer Constainer Image: Constainer Image: Constainer Im	Parent processDuration [mu-sec]Image: Constainer InstantiationDuration [mu-sec]Duration [mu-sec]Container InstantiationImage: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationFile reading1,720,207Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationClusterization40,197Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationSpacepoint Formation6,078Image: Constainer InstantiationImage: Constainer InstantiationImage: Constainer InstantiationClusterization + Spacepoints1,075,583Image: Constainer Image:	Parent processDuration [mu-sec]Image: Container Image: Container InstantiationDuration [mu-sec]Duration [mu-sec]Container InstantiationImage: Container Image: Container InstantiationImage: Container Image: Container I	Parent processDuration [mu-sec]Image: Container InstantiationDuration [mu-sec]Parent processDuration [mu-sec]Parent processContainer InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationFile reading1,720,207Image: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationFile reading1,720,207Image: Container InstantiationImage: Container InstantiationImage: Container InstantiationImage: Container InstantiationSpacepoint Formation40,197Image: Container Image: Container FormationImage: Container Image: Container Image: Container FormationImage: Container Image: Con	And the section of t



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Duration

[mu-sec]

NA

NA

NA

2,433

11,686

411



SCIENCE AND INDUSTRY CUDA Profiling - NSight Compute

Old Version

Data File		No. of Events
	tml_detector/trackml- detector	1

New Version - with FastSV

# Address	Source	Registers	Dependencies	Dependencies	Dependencies Dependencies		#.
43 80807f68 c4fa63a	LOP3.LUT R18, R18, 8xfffffff8, RZ, 8xc8, IPT	14					9
44 00007f60 c4fa63b0	LOP3.LUT R19, R4, 8x7, RZ, 8xc8, 1PT	15					10
45 80007f60 c4fa63c6		15 4					11
46 80807f68 c4fa63d		16					12
47 80807f68 c4fa63e6	LDG.E.64.SYS R22, [R8+0x18]	18					13
48 80807f68 c4fa63f6		20					14
49 80807f68 c4fa6480		22					15
50 00007f60 c4fa6410	LDG.E.64.SYS R32, [R8+0x38]	24					16
51 80807f68 c4fa6420	IMAD.WIDE.U32 R14, R15, 8x18, R6	23 0 0					17
52 80007f60 c4fa6430		22 📢					18
53 80807f60 c4fa6448		22 4					19
54 00007f60 c4fa6450		21					20
55 80807f68 c4fa6466		23 👌					21
56 80807f60 c4fa6470		25 👂					22
57 80807f68 c4fa6480		27 0 0					23
58 80807f60 c4fa6490		25					24
59 80807f60 c4fa64a0		23 4 4					25
60 00007f60 c4fa64b0		24					26
61 00007f60 c4fa64c0		26					27
62 80807f68 c4fa64d0		24 🕨 🌾					28
63 80807f60 c4fa64e0		23 4					29
64 80807f68 c4fa64f6		22					30
65 80807f68 c4fa6580		23					31
66 00007f60 c4fa6510		22					32
67 80807f68 c4fa6520		22					33
68 80807f68 c4fa653		20					34
69 80807f68 c4fa6546		19					35
78 80807f68 c4fa6556							36
71 00007f60 c4fa6560							37
72 00007f60 c4fa6570							38
73 00007f60 c4fa6580							39
74 00007f60 c4fa6590							40
75 00007f60 c4fa65a0							41
76 80807f68 c4fa65b6		12					42
77 80807f68 c4fa65c6		12					43
78 00007f60 c4fa65d0		12					44
79 80807f68 c4fa65e0		12					45
88 80807f68 c4fa65f0	ST.E.64.SYS [R16+0x10]. R4	— 10				1000	46

# Address	Source	Registers	Dependencies	Dependencies	Dependencies	Dependencies	
9 80807f62 36faa380	LDG.E.SYS R9, [R2+8x18]						
10 00007f62 36faa390	MOV R4, BxaB						
11 00007f62 36faa3a0	LDG.E.SYS R8, [R2+8x8]						
12 00007f62 36faa3b0	LDG.E.SYS R11, [R2]						
13 00007f62 36faa3c0	LDG.E.SYS R29, [R2+8x8]						
14 00007f62 36faa3d0	LDG.E.SYS R31, [R2+8xc]						
15 00007f62 36faa3e0	IMAD.WIDE.U32 R4, R9, R4, c[8x8][8x188]						
16 00007f62 36faa3f0	LDG.E.SYS R7, [R4+0x18]						
17 00007f62 36faa400	LDG.E.SYS R15, [R4+8x1c]						
18 00007f62 36faa410	LDG.E.SYS R19, [R4+8x28]						
19 00007f62 36faa420	LDG.E.SYS R0, [R4+0x8]						
28 80007f62 36faa430	LDG.E.SYS R10, [R4+0xc]						
21 00007f62 36faa440	LDG.E.SYS R12, [R4+8x18]						
22 00007f62 36faa450	LDG.E.SYS R13, [R4+8x28]						
23 00007f62 36faa460	LDG.E.SYS R17, [R4+8x2c]						
24 00007f62 36faa470	LDG.E.SYS R21, [R4+8x30]						
25 00007f62 36faa480	LDG.E.SYS R23, [R4+8x38]	I 19 b b					
26 00007f62 36faa490	LDG.E.SYS R25, [R4+8x3c]	20					
27 00007f62 36faa4a0	LDG.E.SYS R27, [R4+8x40]	21					
28 00007f62 36faa4b0	MOV R33, 0x20	20 4					
29 00007f62 36faa4c0	FMUL R7, R7, R8	20					
30 00007f62 36faa4d0	FMUL R15, R8, R15	20					
31 00007f62 36faa4e0	FMUL R19, R8, R19						
32 00007f62 36faa4f0	FFMA R0, R0, R11, R7						
33 00007f62 36faa500	FFMA R10, R11, R10, R15	19					
34 00007f62 36faa510	FFMA R12, R11, R12, R19						
35 00007f62 36faa520	FFMA R0, RZ, R13, R0						
36 00007f62 36faa530	FFMA R10, RZ, R17, R10						
37 00007f62 36faa540	FFMA R12, RZ, R21, R12						
38 00007f62 36faa550	IMAD.WIDE.U32 R6, R6, R33, c[0x0][0x1a8]						
39 80807f62 36faa568	FADD R23, R0, R23						
40 00007f62 36faa570	FADD R25, R10, R25		•				
41 00007f62 36faa580	FADD R27, R12, R27		♥				
42 60007f62 36faa590	STG.E.SYS [R6+0xc], R11						
43 00007f62 36faa5a0	STG.E.SYS [R6+0x10], R8						
44 00007f62 36faa5b0	STG.E.SYS [R6+0x14], R29						
45 00007f62 36faa5c0	STG.E.SYS [R6+0x10], R31 STG.F.SYS [R6+0x1c], R9						

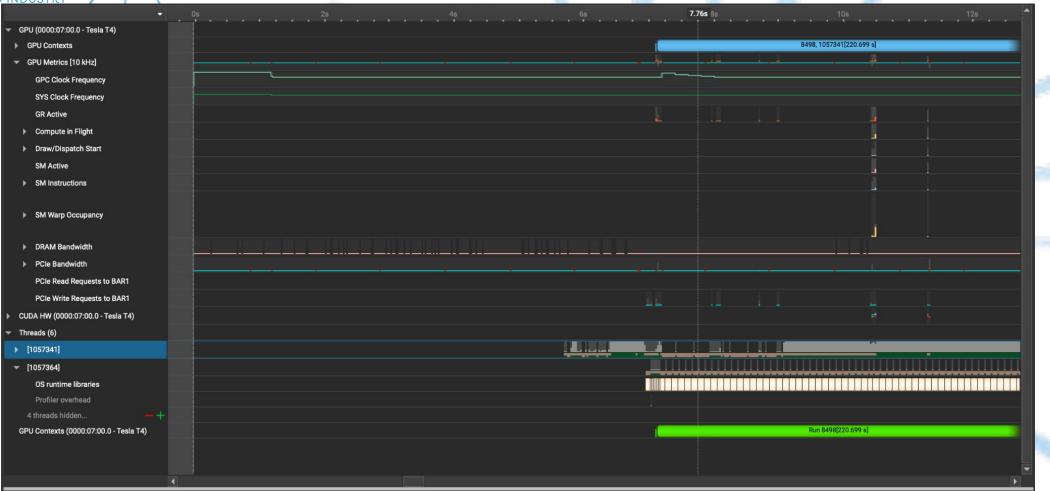


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SMA HEP CUDA Profiling - NSight Systems

REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY





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- POC feasibility example:
 - Clusterization, Spacepoint formation, Seeding are significantly faster on GPU
 - Considering Host-Device and Device-Host wall-time overheads,
 - there is still a speedup of ~O(800 msec)
- *Note* This is only an example for one event

	Data File	Detector Geometry	No. of Events		
		ml_detector/trackml detector	1		
CPU			GPU	3	a la
	Parent process	Duration [mu-sec]	Paren	t process	Duration [mu-sec]
	Container Instantiation	15	Conta Instan	iner tiation	5
	File reading	1,341,172	File re	ading	NA
	Clusterization	36,070	Cluste	rization	NA
	Spacepoint Formation	3,131	Space Forma	-	NA
de la constance	Clusterization + Spacepoints	39,201		rization + points	2,433
/	Seeding	814,789	Seedir	ıg	11,686
	Track param est	9,316	Track	param est	411







- POC feasibility example:
 - Clusterization, Spacepoint formation, Seeding are significantly faster on GPU
 - Considering Host-Device and Device-Host wall-time overheads,
 - there is still a speedup of ~O(800 msec)
- If CKF on GPU is considerably slower, it may still be feasible to run the first part of the chain on Device and move data to Host for CKF
 - Potential solution for net speedup in the tracking chain
- *Note* This is only an example for one event

Data File	Detector Geometry	No. of Events
tml_full/ttbar_ mu300	tml_detector/trackml- detector	1

CPU		GPU		
Parent process	Duration [mu-sec]		Parent process	Duration [mu-sec]
Host to Device [Cells]	3035		Device to Host [Cells]	NA
Host to Device [Spacepoints]	2,703		Device to Host [Spacepoints]	1087
Host to Device [Seeds]	781		Device to Host [Seeds]	349
Host to Device [Track params]	1,655		Device to Host [Track params]	1,161







- Extend studies to larger number of events with more realistic data (eg. mu=60, 140, 200 etc)
- Use seeds generated by traccc in ACTS CKF function to understand **Device-Host costs**
- Repeat overhead studies wrt other parameters such as Memory, GPU Occupancy etc.

Data File		No. of Events
tml_full/ttbar_ mu300	tml_detector/trackml- detector	1

CPU		GPU		
Parent process	Duration [mu-sec]		Parent process	Duration [mu-sec]
lost to Device [Cells]	3035		Device to Host [Cells]	NA
lost to Device Spacepoints]	2,703		Device to Host [Spacepoints]	1087
Host to Device [Seeds]	781		Device to Host [Seeds]	349
Host to Device [Track params]	1,655		Device to Host [Track params]	1,161







Baler: ML based Data Compression







Original

0.8 1.2 1.6

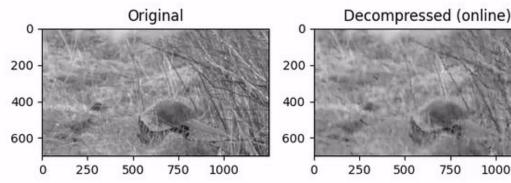
x [m]

y [m]

0.4

2.0

Baler: ML based Data Compression



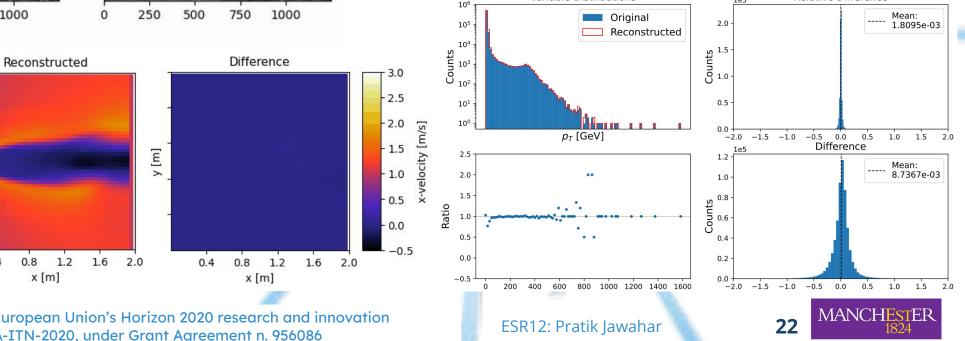
Paper: https://arxiv.org/abs/2305.02283 Code: https://github.com/baler-collaboration/baler

Variable Distributions



Relative Difference

The University of Manchester



0.4

2.0

1.6

ي 1.2 م _{0.8}

0.4



SMARHER Misc Activities

Side Quests:

- Helped lift new wire bonder into the Lund Uni clean room
- Working on DDMTD corrections for mu-CTP trigger chip for temperature variance with Kalman Filters

Hackathons:

- DL in HEP MIT
- Baler (Lund)

Workshops/Conferences:

- IOP APP&HEPP UK National Talk
- FastML Talk
- Hammers and Nails Poster

Schools:

- tCSC Split
- HASCO particle physics
- STFC UK theory summer school

Teaching/Outreach:

- Jupyter Notebooks Intro Lund
- Advanced C++ Manchester







SMARHER HER Conclusions & Future Work

- Track reconstruction may not scale to HL-LHC
 - R&D required to speed up track reconstruction
 - without loss in tracking efficiency
 - GPUs could be a viable option
 - GPUs may not be able to speed up the full chain due to sequential algo (eg. CKF)
 - Heterogeneous computing solutions may be feasible
 - POC studies show:
 - First half of the chain on GPUs, followed by offloading to CPUs for CKF, could show order of 100msec speedup per event
- Work on novel anomaly detection solutions?
- Contribute to the HLS4ML project?
- Analysis: Semi-visible jet signatures for dark sector searches ML based signal-background discrimination?
- TBD!









Questions?

People are hungry, just putting it out there :)

Feel free to chat later as well! :)



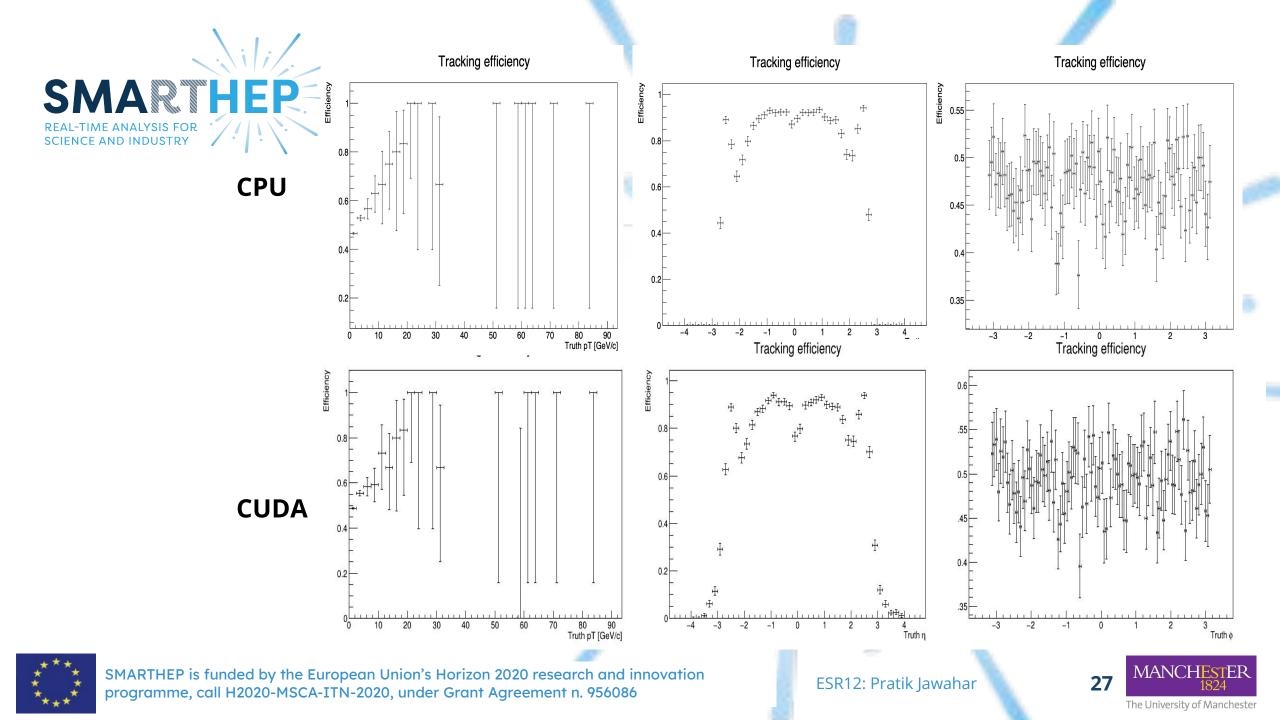


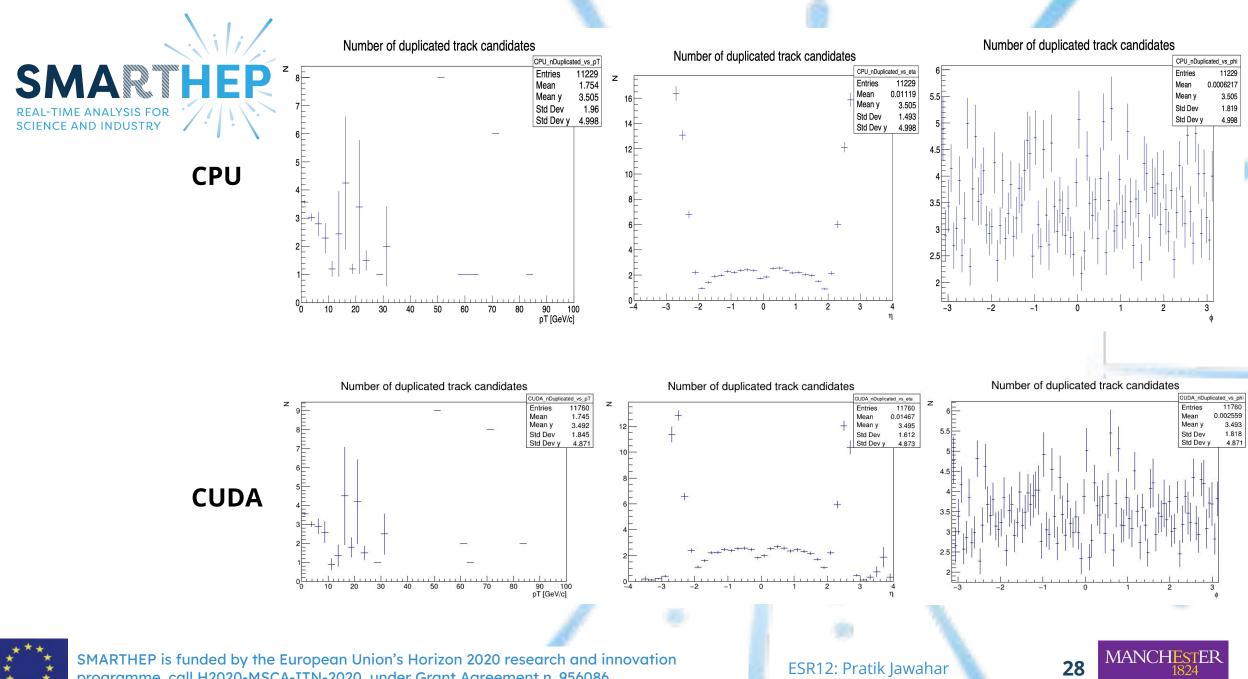


BACKUP









programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086

The University of Manchester



Old Version

- Seeding Synchronous kernel launches
 - fill prefix sum used for Ο

synchroniszation

ID 🔺	Issues Detected	Function Name	Demangled Name
0	2	find_clusters	traccc::cuda::kernels::find
1	2	fill_prefix_sum	traccc::cuda::kernels::fill_p
2	2	count_cluster_c	traccc::cuda::kernels::coun
3	2	connect_compo	traccc::cuda::kernels::conn
4	3	create_measure	traccc::cuda::kernels::creat
5	2	fill_prefix_sum	traccc::cuda::kernels::fill_p
6	2	form_spacepoints	traccc::cuda::kernels::form
7	2	fill_prefix_sum	traccc::cuda::kernels::fill_p
8	2	count_grid_capa	traccc::cuda::kernels::coun
9	2	populate_grid	traccc::cuda::kernels::popu
10	3	fill_prefix_sum	traccc::cuda::kernels::fill_p
11	2	count_doublets	traccc::cuda::kernels::coun
12	3	fill_prefix_sum	traccc::cuda::kernels::fill_p
13	2	find_doublets	traccc::cuda::kernels::find
14	3	fill_prefix_sum	traccc::cuda::kernels::fill_p
15	2	count_triplets	traccc::cuda::kernels::coun
16	3	fill_prefix_sum	traccc::cuda::kernels::fill_p
17	3	find_triplets	traccc::cuda::kernels::find
18	3	fill_prefix_sum	traccc::cuda::kernels::fill_p
19	3	update_triplet_w	traccc::cuda::kernels::upda
20	2	select_seeds	traccc::cuda::kernels::sele
21	2	estimate_track	traccc::cuda::kernels::esti

New Version - with FastSV

- Seeding Asynchronous kernel launches
 - Increases paralellization 0

ID	Issues Detected		Function Name	Demangled Name
	0	3	ccl_kernel	traccc::cuda::kernels::ccl_kernel(v
	1	3	form_spacepoints	traccc::cuda::kernels::form_space
	2	2	count_grid_capacities	traccc::cuda::kernels::count_grid
	3	2	populate_grid	traccc::cuda::kernels::populate_gri
	4	3	fill_prefix_sum	traccc::cuda::kernels::fill_prefix_su
	5	2	count_doublets	traccc::cuda::kernels::count_doubl
	6	2	find_doublets	traccc::cuda::kernels::find_doublet
	7	2	count_triplets	traccc::cuda::kernels::count_triplet
	8	2	reduce_triplet_counts	traccc::cuda::kernels::reduce_tripl
	9	3	find_triplets	traccc::cuda::kernels::find_triplets(
	10	3	update_triplet_weights	traccc::cuda::kernels::update_tripl
	11	3	select_seeds	traccc::cuda::kernels::select_seed
	12	2	estimate_track_params	traccc::cuda::kernels::estimate_tra

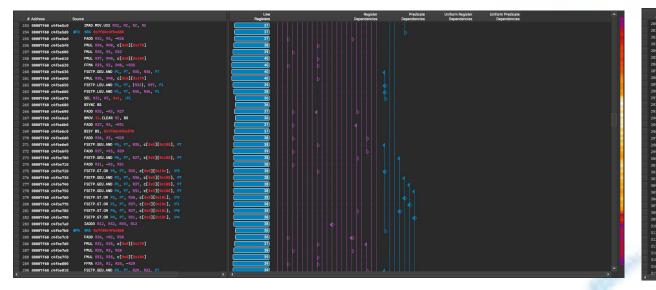




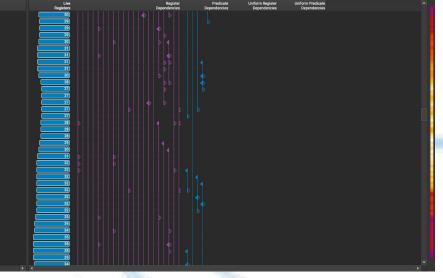
Old Version count_doublets()

Data File	Detector Geometry	Events
tml_full/ttbar_	tml_detector/trackml-	
mu300	detector	1

New Version - with FastSV count_doublets()



Address		Source	
00007f62			IMAD.IADD R12, R12, 0x1, R35
			BRA 9x7f6236fc5139
00007f62			FADD R2, -R6, R2
00007f62			FMUL R24, R34, c[8x8][8x178]
00007f62			FMUL R35, R7, R2
00087f62			FMUL R37, R34, c[8x8][8x184]
00007f62			FFNA R35, R6, R34, -R35
	36fc50e0		FSETP.GEU.AND P1, PT, R35, R24, PT
00007f62	36fc50f0		FMUL R24, R34, c[0x0][0x174]
00007f62	36fc5188		FSETP.LEU.AND P1, PT, [R2], R37, P1
00007f62	36fc5110		FSETP.LEU.AND P1, PT, R35, R24, P1
00007f62	36fc5120		SEL R24, RZ, 8x1, 1P1
00007f62	36fc5130		BSYNC B4
00007f62	36fc5140		IMAD.IADD R13, R13, 8x1, R24
00007f62			INAD.X R30, RZ, RZ, R19, P4
00007f62	36fc5160		
	36fc5170		LD.E.64.SYS R2, [R18+0x50]
00087f62	36fc5180		BMOV.32.CLEAR RZ, 84
00007f62	36fc5190		BSSY 84, 0x7f6236fc5300
00007f62	36fc51a0		IMAD.MOV.U32 R24, RZ, RZ, RZ
00007f62	36fc51b0		IMAD.MOV.U32 R35, RZ, RZ, RZ
00007f62	36fc51c0		FADD R32, R7, -R3
00007f62	36fc51d0		FADD R34, -R7, R3
00007f62	36fc51e0		IADD3 R3, P2, R18, 0x60, RZ
00007f62	36fc51f0		FSETP.GEU.AND P0, PT, R32, c[0x0][0x108], PT
00007f62	36fc5288		FSETP.GEU.AND P1, PT, R34, c[0x0][0x188], PT
00007f62	36fc5210		IMAD.X R30, RZ, RZ, R19, P2
00087f62	36fc5228		FSETP.GT.OR P0, PT, R32, c[0x0][0x18c], !P0
00007f62	36fc5230		FSETP.GT.OR P1, PT, R34, c[8x8][8x18c], 1P1
00007f62	36fc5240		
00007f62	36fc5250		FADD R26, R6, -R2
00007f62	36fc5260		FMUL R28, R32, c[0x0][0x170]
00007f62	36fc5270		FMUL R35, R7, R26
00087f62	36fc5280		FMUL R37, R32, c[0x0][0x184]
00007f62	36fc5290		FFNA R35, R6, R32, -R35
00007f62	36fc52a0		FSETP.GEU.AND PO, PT, R35, R28, PT
00007f62	36fc52b0		FMUL R28, R32, c[8x8][8x174]
00007f62	36fc52c8		FSETP.LEU.AND P0. PT. 1R261. R37. P0



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