Introduction to ROC-Profiler (`rocprof`)

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LUMI Comprehensive Training
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Background – AMD Profilers

ROC-profiler (rocprof)

Hardware Counters
- Raw collection of GPU counters and traces
- Counter collection with user input files
- Counter results printed to a CSV

Traces and timelines
- Trace collection support for
- CPU copy
- HIP API
- HSA API
- GPU Kernels

Visualisation
- Traces visualized with Perfetto

	A	B	C	D	E
1	Name	Calls	TotalDura	AverageNs	Percentage
2	hipMemcpyAsync	99	3.22E+10	3.25E+08	44.14872
3	hipEventSynchronize	330	2.42E+10	73394557	33.225
4	hipMemsetAsync	87	7.76E+09	89232696	10.64953
5	hipHostMalloc	9	5.41E+09	6.01E+08	7.415198
6	hipDeviceSynchronize	28	1.32E+09	47006288	1.805515
7	hipHostFree	17	1.05E+09	61534688	1.435014
8	hipMemcpy	41	8.11E+08	19791876	1.113161
9	hipLaunchKernel	1856	58082083	31294	0.079676
10	hipStreamCreate	2	46380834	23190417	0.063625
11	hipMemset	2	18847246	9423623	0.025854
12	hipStreamDestroy	2	15183338	7591669	0.020828
13	hipFree	38	8269713	217624	0.011344
14	hipEventRecord	330	2520035	7636	0.003457
15	hipMalloc	30	1484804	49493	0.002037
16	__hipPopCallConfigura	1856	229159	123	0.000314
17	__hipPushCallConfigur	1856	224177	120	0.000308
18	hipGetLastError	1494	100458	67	0.000138
19	hipEventCreate	330	76675	232	0.000105
20	hipEventDestroy	330	64671	195	8.87E-05
21	hipGetDevicePropertie	47	51808	1102	7.11E-05
22	hipGetDevice	64	11611	181	1.59E-05
23	hipSetDevice	1	401	401	5.50E-07
24	hipGetDeviceCount	1	220	220	3.02E-07

Omnitrace

Trace collection
- Comprehensive trace collection
- CPU
- GPU

Supports
- CPU copy
- HIP API
- HSA API
- GPU Kernels
- OpenMP®
- MPI
- Kokkos
- p-threads
- multi-GPU

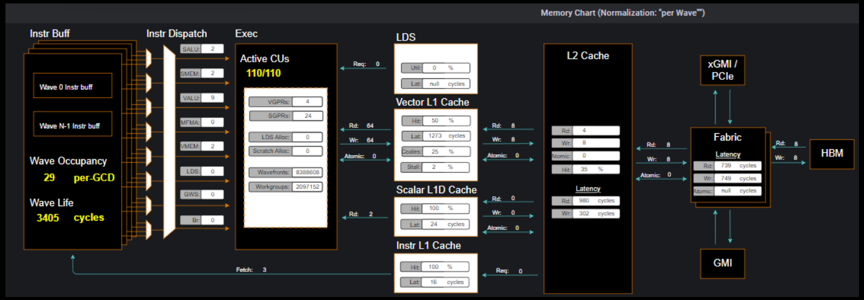
Visualisation
- Traces visualized with Perfetto

Omniperf

Performance Analysis
- Automated collection of hardware counters
- Analysis
- Visualisation

Supports
- Speed of Light
- Memory chart
- Rooflines
- Kernel comparison

Visualisation
- With Grafana or standalone GUI



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Background – AMD Profilers

Objective	Where should I focus my time ?	How well am I using the GPU ?	Why am I seeing this performance ?
Approach	Timelines/Traces/Profiles/Causal-Profiles	Roofline	Hardware counters
AMD Tools	rocprof		

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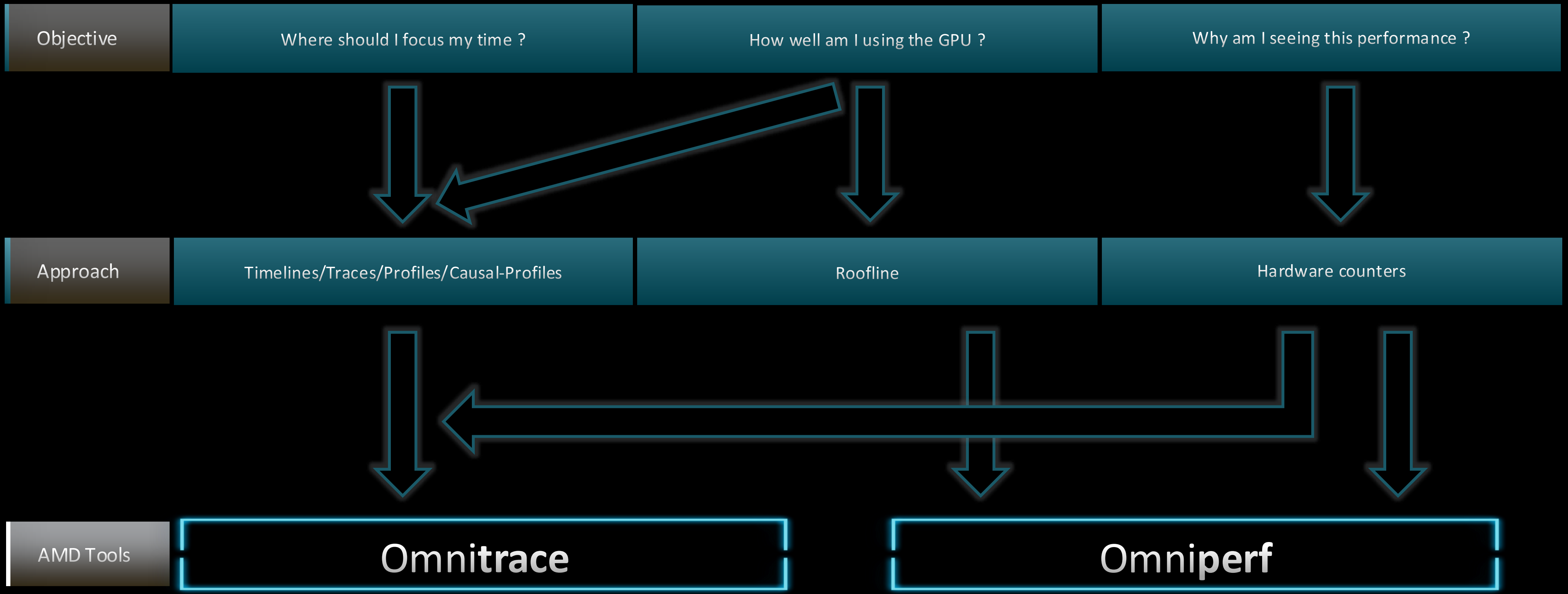
[Public]

Background – AMD Profilers



ROCm on LUMI

AMD ROCm

5.7.3 (Dec 2023)

Meant to support older version of apps and frameworks

Facilitate transition

GPU address sanitizer (beta)

Data pre-processing capabilities (MIVisionX)

GPU-Aware MPI

6.0.3 (Mar 2024)

Default version

Officially supported

Recommended for debugging

Improved sparse matrix operations

6.1.3 (Jun 2024)

Latest Pytorch and other AI frameworks require this version

Introduced many performance improvements

6.2.1 (Sep 2024)

ROCPROF V3

Many stability and performance improvements for performance libraries

Improved support for lower precisions

Best tunned for AI inference workloads

Integration of profiling tools Autocast (mixed-precision)

Native OpenXLA support

User level	5.7.3	**6.0.3**	6.1.3	6.2.1	… ?	… ?
	Dec 2023	Mar 2024	Jun 2024	Sep 2024	…	…
Driver		**6.0.3**				

We'll likely be abusing the driver soon

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What is ROC-Profiler (v1-v2-v3)?

- ROC-profiler (also referred to as `rocprof`) is the command line front-end for AMD's GPU profiling libraries
  - Repo: https://github.com/ROCm-Developer-Tools/rocprofiler
- rocprof contains the central components allowing application traces and counter collection
  - Under constant development
- Distributed with ROCm
- The output of `rocprofv1` can be visualized in the Chrome browser with Perfetto (https://ui.perfetto.dev/)
- There are ROCProfiler V1 and V2 (roctracer and rocprofiler into single library, same API)
- ROC-profiler-SDK is a profiling and tracing library for HIP and ROCm application. The new API improved thread safety and includes more efficient implementations and provides a tool library to support on writing your tool implementations. It is still in beta release.
- rocprofv3 uses this tool library to profile and trace applications.

rocprof (v1): Getting Started + Useful Flags

- To get help:
  `${ROCM_PATH}/bin/rocprof -h`
- Useful housekeeping flags:
  - `--timestamp <on|off>` - turn on/off gpu kernel timestamps
  - `--basenames <on|off>` - turn on/off truncating gpu kernel names (i.e., removing template parameters and argument types)
  - `-o <output csv file>` - Direct counter information to a particular file name
  - `-d <data directory>` - Send profiling data to a particular directory
  - `-t <temporary directory>` - Change the directory where data files typically created in /tmp are placed. This allows you to save these temporary files.
- Flags directing rocprofiler activity:
  - `-i input<.txt|.xml>` - specify an input file (note the output files will now be named input.*)
  - `--hsa-trace` - to trace GPU Kernels, host HSA events (more later) and HIP memory copies.
  - `--hip-trace` - to trace HIP API calls
  - `--roctx-trace` - to trace roctx markers
  - `--kfd-trace` - to trace GPU driver calls
- Advanced usage
  - `-m <metric file>` - Allows the user to define and collect custom metrics. See rocprofiler/test/tool/*.xml on GitHub for examples.

rocprof (v1): : Kernel Information

- rocprof can collect kernel(s) execution stats

  `$ /opt/rocm/bin/rocprof --stats --basenames on <app with arguments>`

- This will output two csv files:
  - `results.csv:` information per each call of the kernel
  - `results.stats.csv:` statistics grouped by each kernel
- Content of results.stats.csv to see the list of GPU kernels with their durations and percentage of total GPU time:

```
"Name","Calls","TotalDurationNs","AverageNs","Percentage"
"JacobiIterationKernel",1000,556699359,556699,43.291753895270446
"NormKernel1",1001,430797387,430367,33.500980655394606
"LocalLaplacianKernel",1000,280014065,280014,21.775307970480817
"HaloLaplacianKernel",1000,14635177,14635,1.1381052818810995
"NormKernel2",1001,3770718,3766,0.2932300765671734
"__amd_rocclr_fillBufferAligned.kd",1,8000,8000,0.0006221204058583505
```

- In a spreadsheet viewer, it is easier to read:

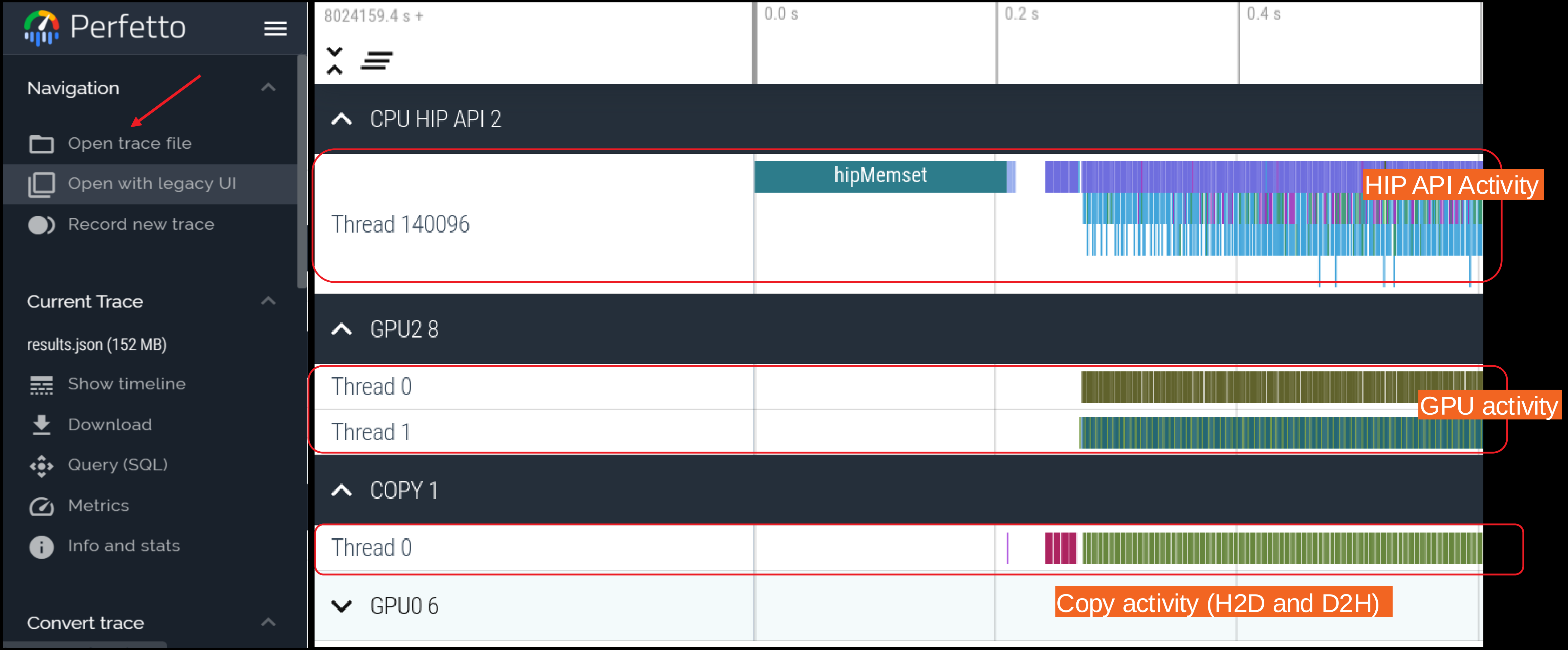
	A	B	C	D	E
1	Name	Calls	TotalDurationNs	AverageNs	Percentage
2	JacobiIterationKernel	1000	556699359	556699	43.2917538952704
3	NormKernel1	1001	430797387	430367	33.5009806553946
4	LocalLaplacianKernel	1000	280014065	280014	21.7753079704808
5	HaloLaplacianKernel	1000	14635177	14635	1.1381052818811
6	NormKernel2	1001	3770718	3766	0.293230076567173
7	__amd_rocclr_fillBufferAligned	1	8000	8000	0.000622120405858

rocprof (v1): + Perfetto: Collecting and Visualizing App Traces

- rocprof can collect traces

```
$ /opt/rocm/bin/rocprof --hip-trace <app with arguments>
```

This will output a .json file that can be visualized using the Chrome browser and Perfetto (https://ui.perfetto.dev/)



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rocprofv3: Getting Started + Useful Flags

- To get help:
  `${ROCM_PATH}/bin/rocprofv3 -h`
- Useful housekeeping flags:
  - `--hip-trace` For Collecting HIP Traces (runtime + compiler)
  - `--hip-runtime-trace` For Collecting HIP Runtime API Traces
  - `--hip-compiler-trace` For Collecting HIP Compiler generated code Traces
  - `--marker-trace` For Collecting Marker (ROCTx) Traces
  - `--memory-copy-trace` For Collecting Memory Copy Traces
  - `--stats` For Collecting statistics of enabled tracing types
  - `--hsa-trace` For Collecting HSA Traces (core + amd + image + finalizer)
  - `--hsa-core-trace` For Collecting HSA API Traces (core API)
  - `--hsa-amd-trace` For Collecting HSA API Traces (AMD-extension API)
  - `--hsa-image-trace` For Collecting HSA API Traces (Image-extenson API)
  - `--hsa-finalizer-trace` For Collecting HSA API Traces (Finalizer-extension API)

rocprofv3: Getting Started + Useful Flags (II)

- Useful housekeeping flags:
  - -s, --sys-trace For Collecting HIP, HSA, Marker (ROCTx), Memory copy, Scratch memory, and Kernel dispatch traces
  - -M, --mangled-kernels Do not demangle the kernel names
  - -T, --truncate-kernels Truncate the demangled kernel names
  - -L, --list-metrics List metrics for counter collection
  - -i INPUT, --input INPUT Input file for counter collection
  - -o OUTPUT_FILE, --output-file OUTPUT_FILE
    For the output file name
  - -d OUTPUT_DIRECTORY, --output-directory OUTPUT_DIRECTORY
    For adding output path where the output files will be saved
  - --output-format {csv,json,pftrace} [{csv,json,pftrace} ...]
    For adding output format (supported formats: csv, json, pftrace)
  - --log-level {fatal,error,warning,info,trace}
    Set the log level
  - --kernel-names KERNEL_NAMES [KERNEL_NAMES ...]
    Filter kernel names
  - --preload [PRELOAD ...]
    Libraries to prepend to LD_PRELOAD (usually for sanitizers)

  - rocprofv3 requires double-hyphen (--) before the application to be executed, e.g.

```
$ rocprofv3 [<rocprofv3-option> ...] -- <application> [<application-arg> ...]
$ rocprofv3 --hip-trace -- ./myapp -n 1
```

  - Instructions: https://rocm.docs.amd.com/projects/rocprofiler-sdk/en/docs-6.2.1/how-to/using-rocprofv3.html

rocprofv3: Kernel Information

- rocprof can collect kernel(s) execution stats

  `$ /opt/rocm/bin/rocprofv3 --stats --kernel-trace –T -- <app with arguments>`
- This will output four csv files (XXXXX are numbers):
  - `XXXXX_agent_info.csv: information for the used hardware APU/GPU and CPU`
  - `XXXXX_kernel_traces.csv: information per each call of the kernel`
  - `XXXXX_kernel_stats.csv: statistics grouped by each kernel`
  - `XXXXX_domain_stats.csv: statistics grouped by domain, such as KERNEL_DISPATCH, HIP_COMPILER_API`
- Content of results.stats.csv to see the list of GPU kernels with their durations and percentage of total GPU time:

```
"Name","Calls","TotalDurationNs","AverageNs","Percentage","MinNs","MaxNs","StdDev"
"NormKernel1",1001,365858158,365492.665335,53.49,360561,449240,3460.551681
"JacobiIterationKernel",1000,171479968,171479.968000,25.07,162040,205241,10113.842491
"LocalLaplacianKernel",1000,135771713,135771.713000,19.85,130400,145121,3349.580100
"HaloLaplacianKernel",1000,7777189,7777.189000,1.14,7000,12120,349.399610
"NormKernel2",1001,3107927,3104.822178,0.4544,2200,138681,6466.048652
"__amd_rocclr_fillBufferAligned",1,2720,2720.000000,3.977e-04,2720,2720,0.00000000e+00
```

- In a spreadsheet viewer, it is easier to read:

	A	B	C	D	E	F	G	H
1	Name	Calls	TotalDurationNs	AverageNs	Percentage	MinNs	MaxNs	StdDev
2	NormKernel1	1001	365858158	365492.665	53.49	360561	449240	3460.552
3	JacobiIterationKernel	1000	171479968	171479.968	25.07	162040	205241	10113.84
4	LocalLaplacianKernel	1000	135771713	135771.713	19.85	130400	145121	3349.58
5	HaloLaplacianKernel	1000	7777189	7777.189	1.14	7000	12120	349.3996
6	NormKernel2	1001	3107927	3104.82218	0.4544	2200	138681	6466.049
7	__amd_rocclr_fillBufferAligned	1	2720	2720	3.98E-04	2720	2720	0

rocprofv3: Collecting Application Traces

- rocprof can collect a variety of trace event types, and generate timelines in JSON format for use with Perfetto, currently, however better use the pftrace output format (*--output-format pftrace*):

Trace Event	rocprof Trace Mode
HIP API call	`--hip-trace`
GPU Kernels	`--kernel-trace`
Host <-> Device Memory copies	`--hip-trace or` --memory-copy-trace
CPU HSA Calls	`--hsa-trace`
User code markers	`--marker-trace`
Collect HIP, HSA, Kernels, Memory Copy, Marker API	`--sys-trace`
Scratch memory operations	`--scratch-memory-trace`

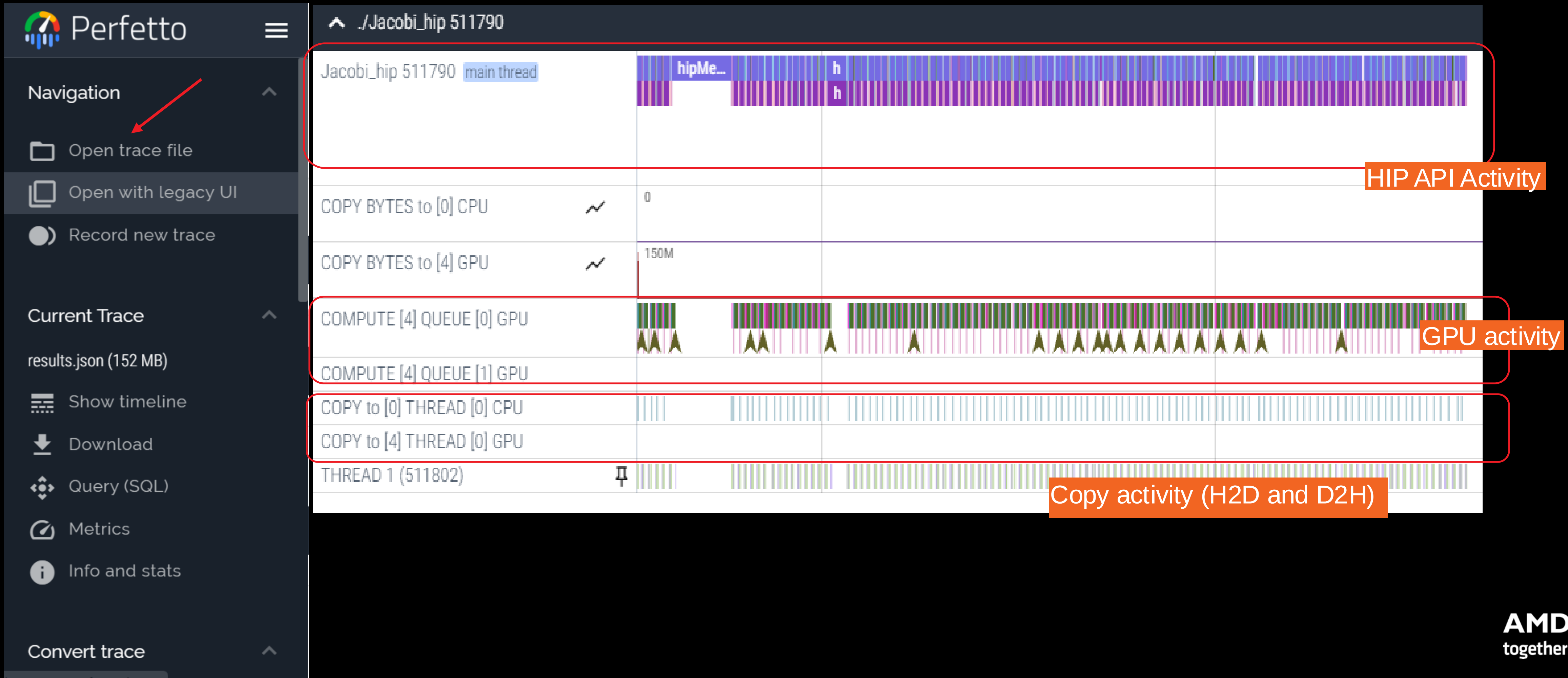
- You can combine modes like --stats `--hip-trace --hsa-trace --output-format pftrace`

rocprof + Perfetto: Collecting and Visualizing Application Traces

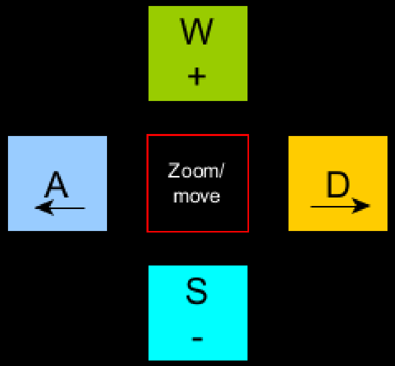
- rocprof can collect traces

```
$ /opt/rocm/bin/rocprof --hip-trace --output-format pftrace -- <app with arguments>
```

This will output a pftrace file that can be visualized using the chrome browser and Perfetto (https://ui.perfetto.dev/)



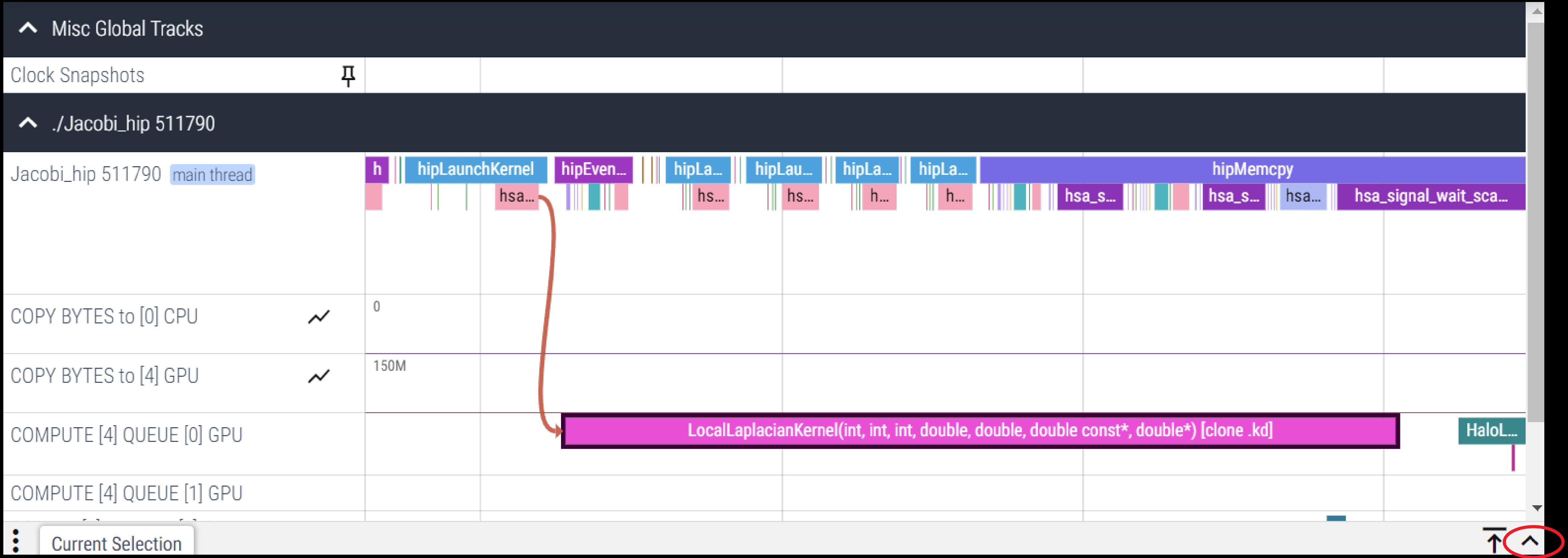
Perfetto: Visualizing Application Traces



- Zoom in to see individual events
- Navigate trace using WASD keys

Perfetto: Kernel Information and Flow Events

- Zoom and select a kernel, you can see the link to the HIP call launching the kernel
- Try to open the information for the kernel (button at bottom right)



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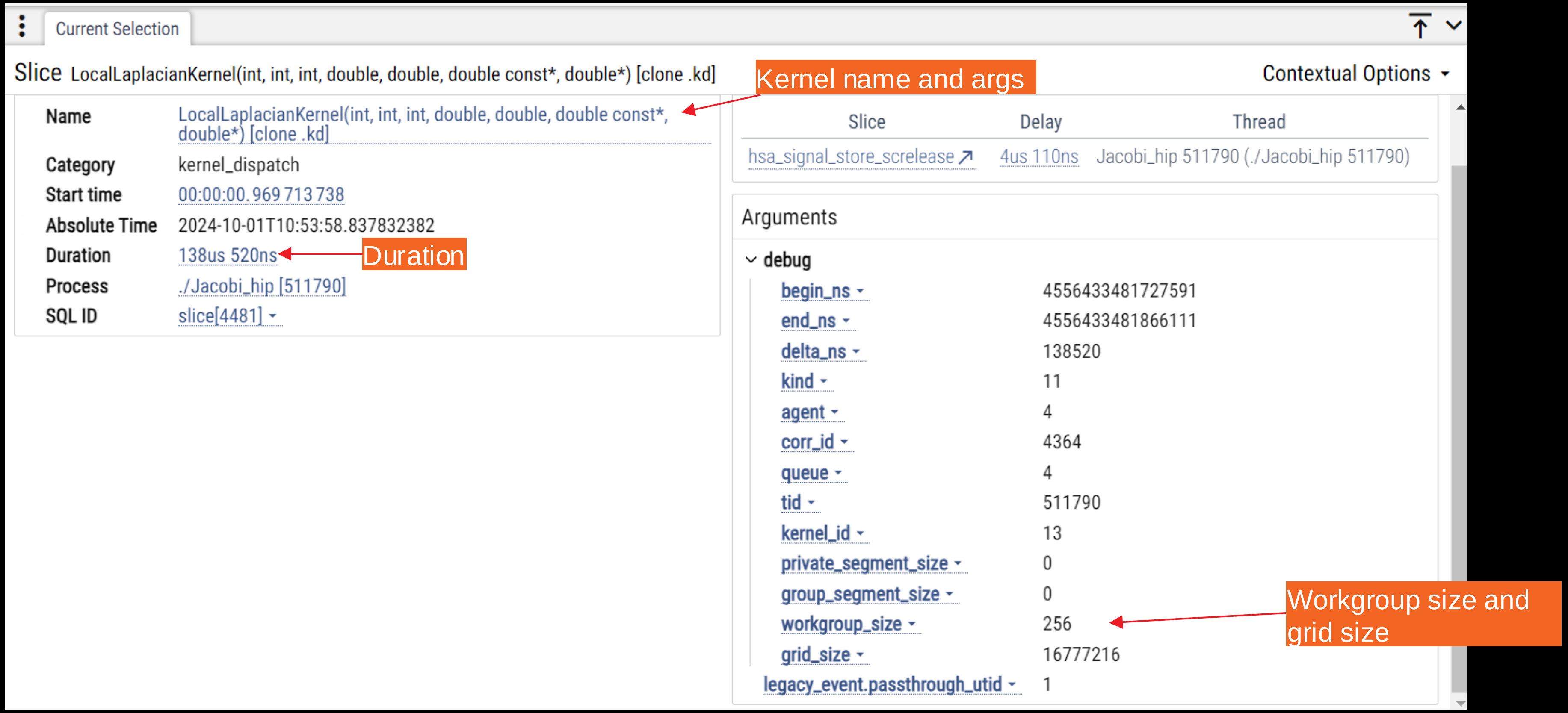
Perfetto: Kernel Information



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Rocprofv3: OpenMP Offloading

- The option --kernel-trace provides information of the OpenMP kernels, good to use --hsa-trace if you want information from HSA layer

- For example:

mpirun -n 1 rocprofv3 --stats --kernel-trace --output-format pftrace -- <app with arguments>

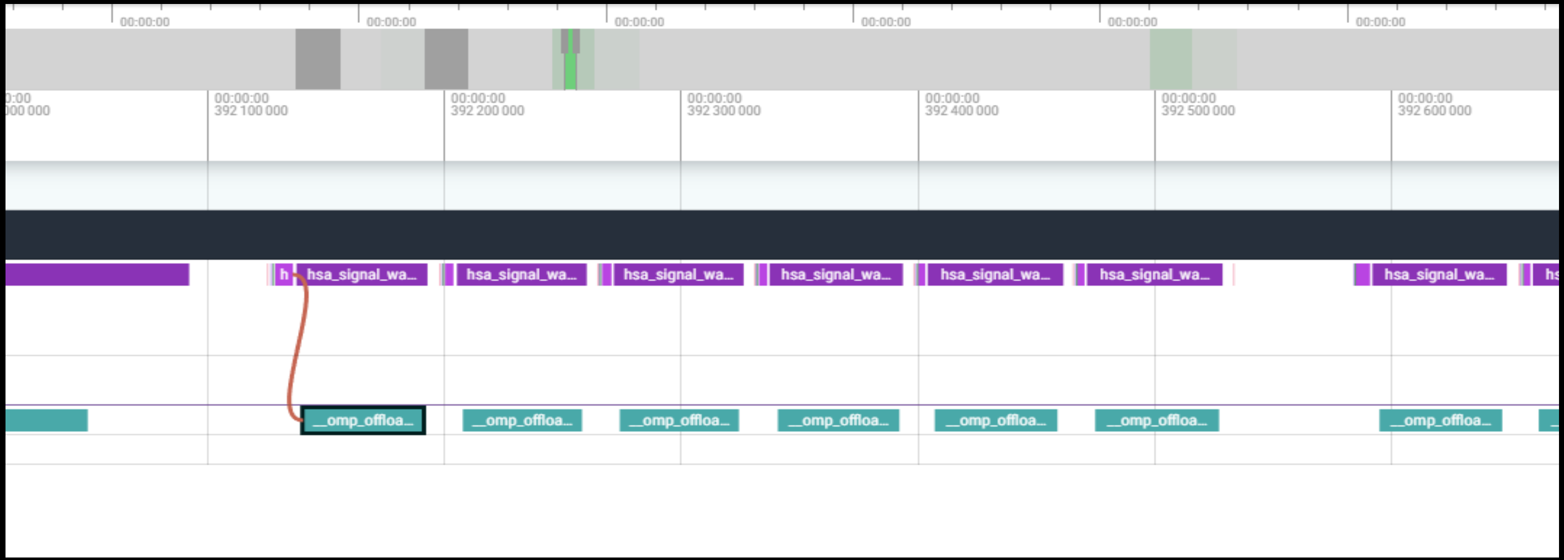
Content of XXXXX_kernel_stats.csv:

```
"Name","Calls","TotalDurationNs","AverageNs","Percentage","MinNs","MaxNs","StdDev"
"__omp_offloading_32_7f7a__Z6evolveR5FieldS0_dd_l24",500,45818062,91636.124000,100.00,49840,19483408,868965.767084
```

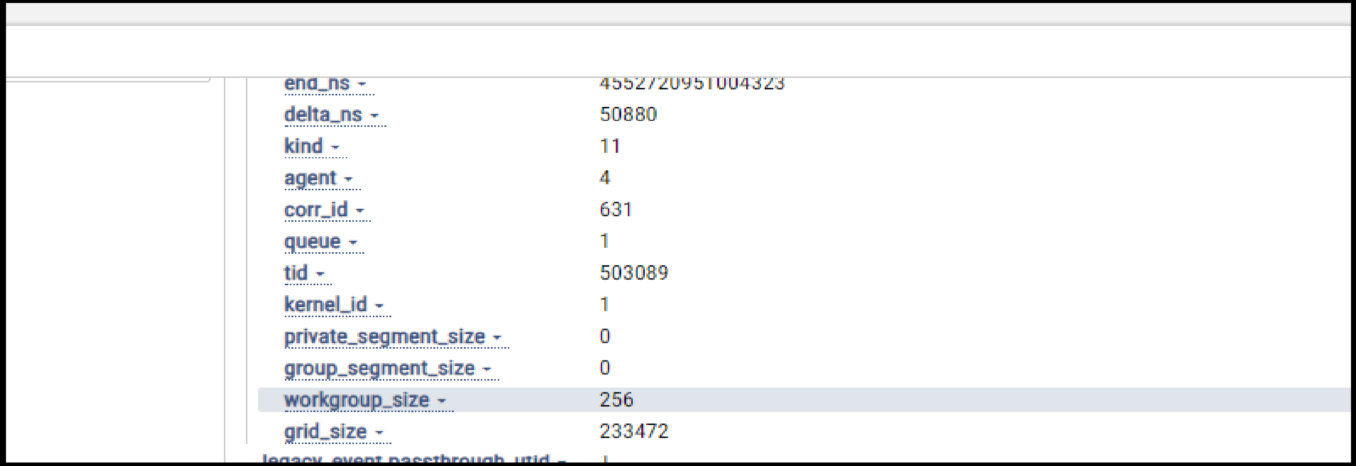
Content of XXXXX_kernel_trace.csv

```
"Kind","Agent_Id","Queue_Id","Kernel_Id","Kernel_Name","Correlation_Id","Start_Timestamp","End_Timestamp","Private_Segment_Size","Group_Segment_Size","Workgroup_Size_X","Workgroup_Size_Y","Workgroup_Size_Z","Grid_Size_X","Grid_Size_Y","Grid_Size_Z"
"KERNEL_DISPATCH",4,1,1,"__omp_offloading_32_7f7a__Z6evolveR5FieldS0_dd_l24",1,4547852833814530,4547852853297938,0,0,256,1,1,233472,1,1
"KERNEL_DISPATCH",4,1,1,"__omp_offloading_32_7f7a__Z6evolveR5FieldS0_dd_l24",2,4547852853393869,4547852853446789,0,0,256,1,1,233472,1,1
"KERNEL_DISPATCH",4,1,1,"__omp_offloading_32_7f7a__Z6evolveR5FieldS0_dd_l24",3,4547852853461519,4547852853514599,0,0,256,1,1,233472,1,1
…
```

Perfetto and OpenMP visualization



- Using: *--sys-trace --output-format pftrace*
- We can use: *--kernel-trace --output-format pftrace*



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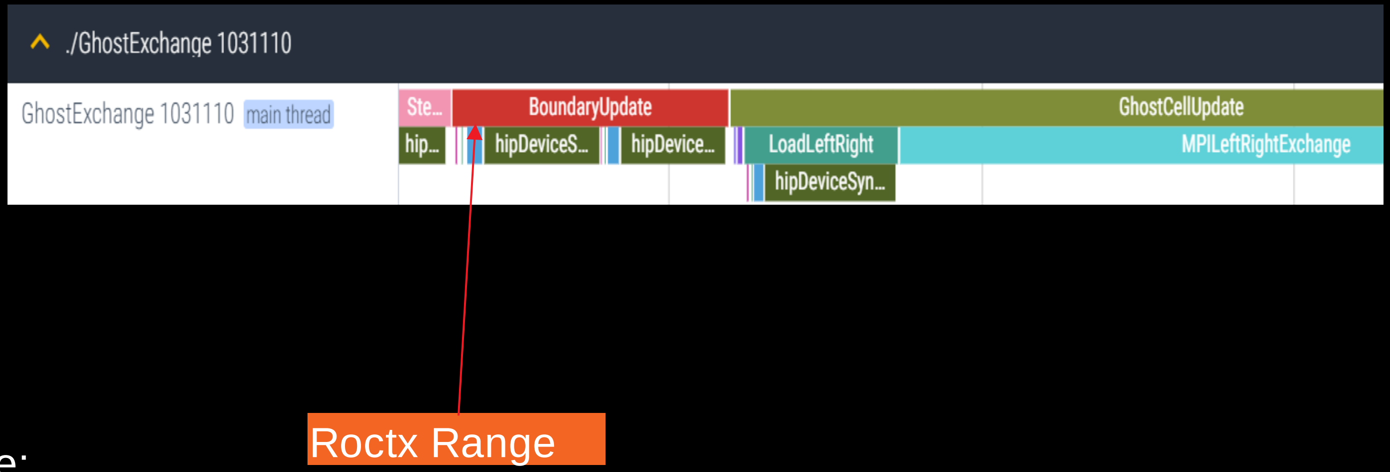
rocprofv3: Collecting Application Traces with rocTX Markers and Regions

- rocprofv3 can collect user defined regions or markers using rocTX
- Annotate code with roctx regions:

```
#include <rocprofiler-sdk-roctx/roctx.h>
...
    roctxRangePush("reduce_for_c");
    reduce_function ();
    roctxRangePop();
...
```



- Annotate code with roctx markers:

```
...
    roctxMark("start of some code");
    // some_code
    roctxMark("end of some code");
...
```

- Add roctx and roctracer libraries to link line:
  `-L${ROCM_PATH}/lib -lrocprofiler-sdk-roctx -lroctracer64`
- Profile with `--roctx-range` option:

```
$ /opt/rocm/bin/rocprofv3 --hip-trace --marker-trace -- <app with arguments>
```

- Important: There is some difference regarding roctx between rocprof and rocprofv3

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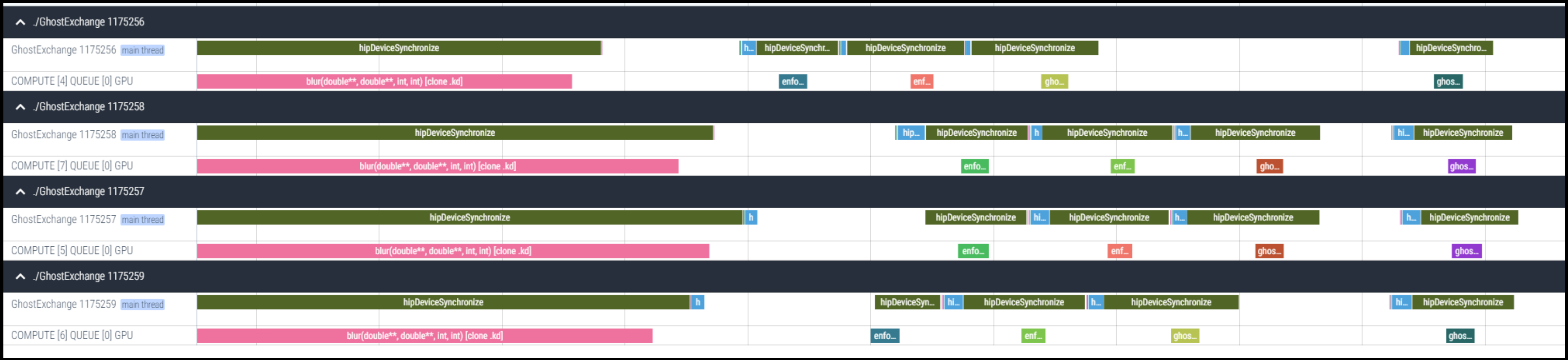
Rocprofv3: Merge traces

- When you have one pftrace per MPI processes you can merge them as follows:
  - For example cat XXXXX_results.pftrace > all_ghostexchange.pftrace
  - Then visualize the file called all_ghostexchange.pftrace



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rocprofv3: Commonly Used GPU Counters

VALUUtilization	The percentage of ALUs active in a wave. Low VALUUtilization is likely due to high divergence or a poorly sized grid
VALUBusy	The percentage of GPUTime vector ALU instructions are processed. Can be thought of as something like compute utilization
FetchSize	The total kilobytes fetched from global memory
WriteSize	The total kilobytes written to global memory
MemUnitStalled	The percentage of GPUTime the memory unit is stalled
CU_OCCUPANCY	The ratio of active waves on a CU to the maximum number of active waves supported by the CU
MeanOccupancyPerCU	Mean occupancy per compute unit
MeanOccupancyPerActiveCU	Mean occupancy per active compute unit

Full list at: https://github.com/ROCm-Developer-Tools/rocprofiler/blob/amd-master/test/tool/metrics.xml

rocprofv3: Collecting Hardware Counters

- rocprofv3 can collect a number of hardware counters and derived counters
  - `$ /opt/rocm/bin/rocprofv3 -L`

- Specify counters in a counter file. For example:
  - `$ /opt/rocm/bin/rocprofv3 -i rocprof_counters.txt -- <app with args>`
  - `$ cat rocprof_counters.txt`

```
pmc: VALUUtilization VALUBusy FetchSize WriteSize MemUnitStalled
pmc: GPU_UTIL CU_OCCUPANCY MeanOccupancyPerCU MeanOccupancyPerActiveCU
```

  - A limited number of counters can be collected during a specific pass of code
    - Each line in the counter file will be collected in one pass
    - You will receive an error suggesting alternative counter ordering if you have too many / conflicting counters on one line

  - One directory per pmc line will be created, for example pmc_1 and pmc_2 for the two lines in the file with the counters.
  - One agent_info and one counter_collection csv file per MPI process will be created containing all the requested counters for each invocation of every kernel

rocprof: Profiling Overhead

- As with every profiling tool, there is an overhead
- The percentage of the overhead depends on the profiling options used
  - For example, tracing is faster than hardware counter collection
- When collecting many counters, the collection may require multiple passes
- With rocTX markers/regions, tracing can take longer and the output may be large
  - Sometimes too large to visualize
- The more data collected, the more the overhead of profiling
  - Depends on the application and options used
- rocprofv3 has less overhead than rocprof (v1) on various examples with extensive ROCm calls

Summary

- rocprofv3 is the open source, command line AMD GPU profiling tool distributed with ROCm 6.2 and later
- rocprofv3 provides tracing of GPU kernels, through various options, HIP API, HSA API, Copy activity and others
- rocprofv3 can be used to collect GPU hardware counters with additional overhead
- Perfetto seems to visualize pftrace files without significant issues
- Other output files are in text/CSV format

Hands-on exercises

https://hackmd.io/@sfantao/lumi-training-ams-2024#Rocprof

We welcome you to explore our HPC Training Examples repo:

https://github.com/amd/HPCTrainingExamples

A table of contents for the READMEs if available at the top-level **README** in the repo

Relevant exercises for this presentation located in **Rocprof** directory.

Link to instructions on how to run the tests: **Rocprof/README.md and subdirectories**

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