# Introduction to ROC-Profiler (rocprof)

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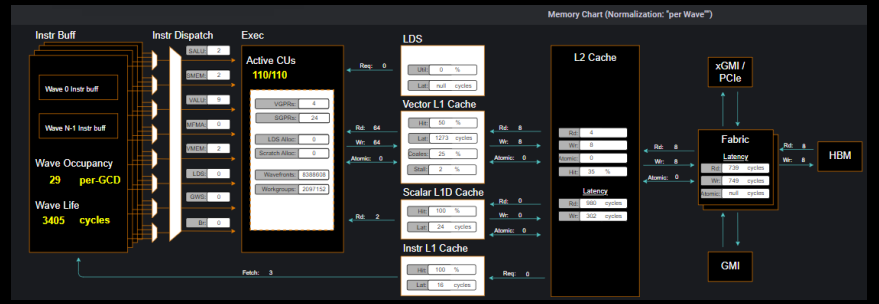
# What is ROC-Profiler?

- 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 `rocprof` can be visualized in the Chrome browser with Perfetto (https://ui.perfetto.dev/)

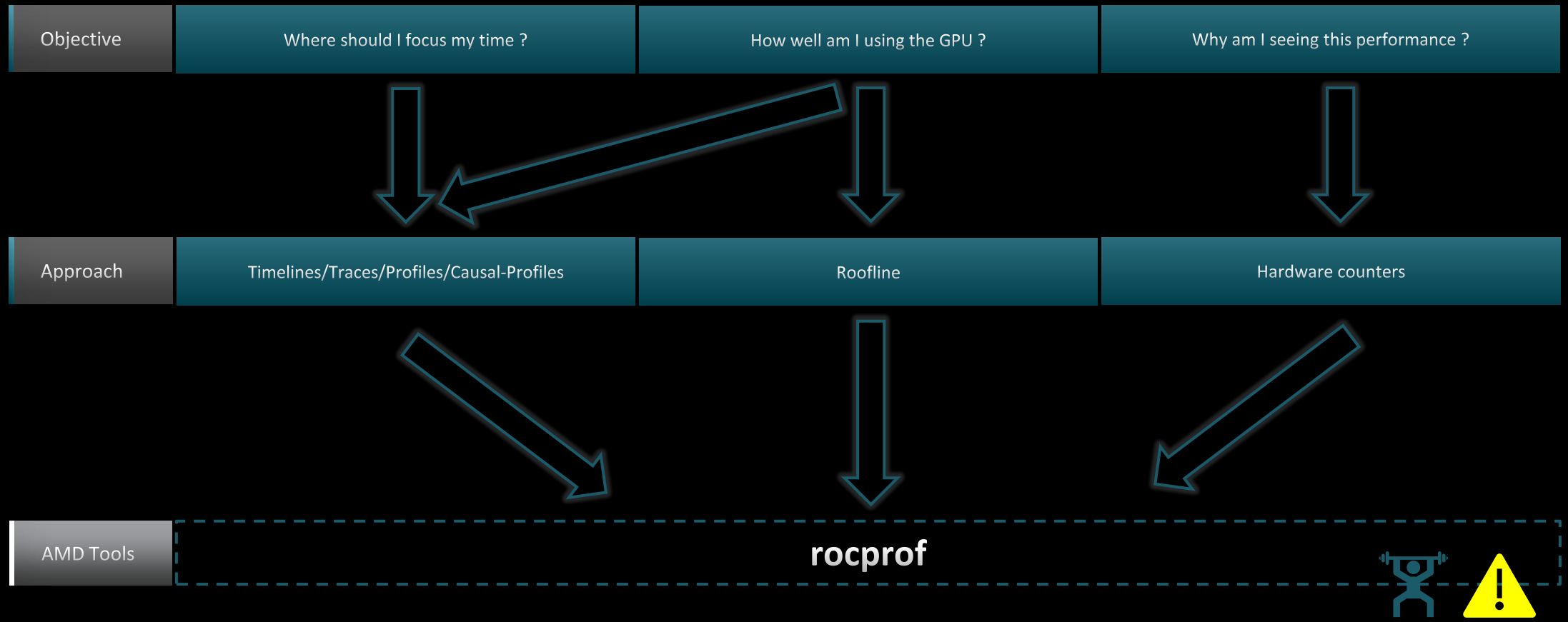
# Background – AMD Profilers

| | ROC-profiler (rocprof) | Omnitrace | Omniperf |
|---|---|---|---|
| Hardware Counters | Raw collection of GPU counters and traces<br>Counter collection with user input files<br>Counter results printed to a CSV | | |
| Trace collection | | Comprehensive trace collection<br>CPU<br>GPU | |
| Performance Analysis | | | Automated collection of hardware counters<br>Analysis<br>Visualisation |
| Traces and timelines | Trace collection support for<br>CPU copy<br>HIP API<br>HSA API<br>GPU Kernels | | |
| Supports | | CPU copy<br>HIP API<br>HSA API<br>GPU Kernels<br>OpenMP®<br>MPI<br>Kokkos<br>p-threads<br>multi-GPU | Speed of Light<br>Memory chart<br>Rooflines<br>Kernel comparison |
| Visualisation | Traces visualized with Perfetto | Traces visualized with Perfetto | With Grafana or standalone GUI |

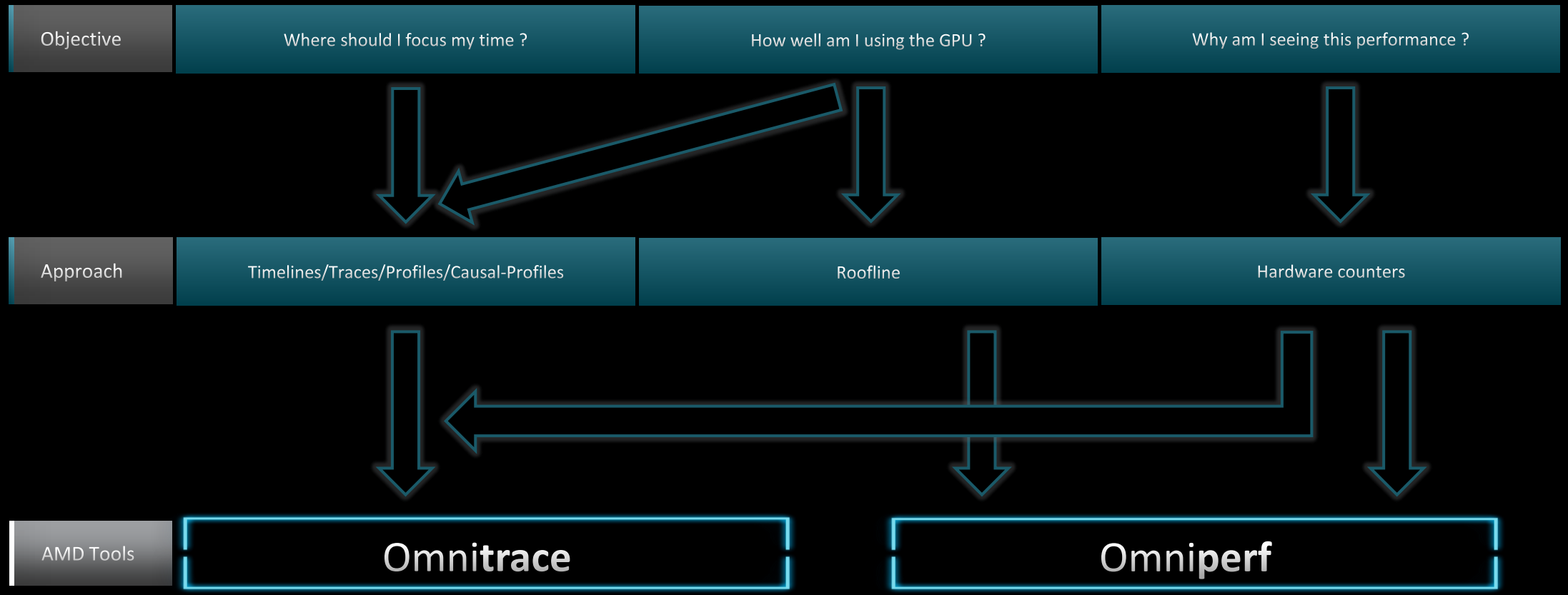
| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Name | Calls | TotalDura | AverageNs | Percentage |
| 2 | hipMemcpyAsync | 99 | 3.22E+10 | 3.25E+08 | 44.14872 |
| 3 | hipEventSynchronize | 330 | 2.42E+10 | 73394557 | 33.225 |
| 4 | hipMemsetAsync | 87 | 7.76E+09 | 89232696 | 10.64953 |
| 5 | 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 |



# Background – AMD Profilers



# Background – AMD Profilers



# rocprof: 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: 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: Collecting Application Traces

- rocprof can collect a variety of trace event types, and generate timelines in JSON format for use with Perfetto, currently:

| Trace Event | rocprof Trace Mode |
|---|---|
| HIP API call | `--hip-trace` |
| GPU Kernels | `--hip-trace` |
| Host <-> Device Memory copies | `--hip-trace` |
| CPU HSA Calls | `--hsa-trace` |
| User code markers | `--roctx-trace` |

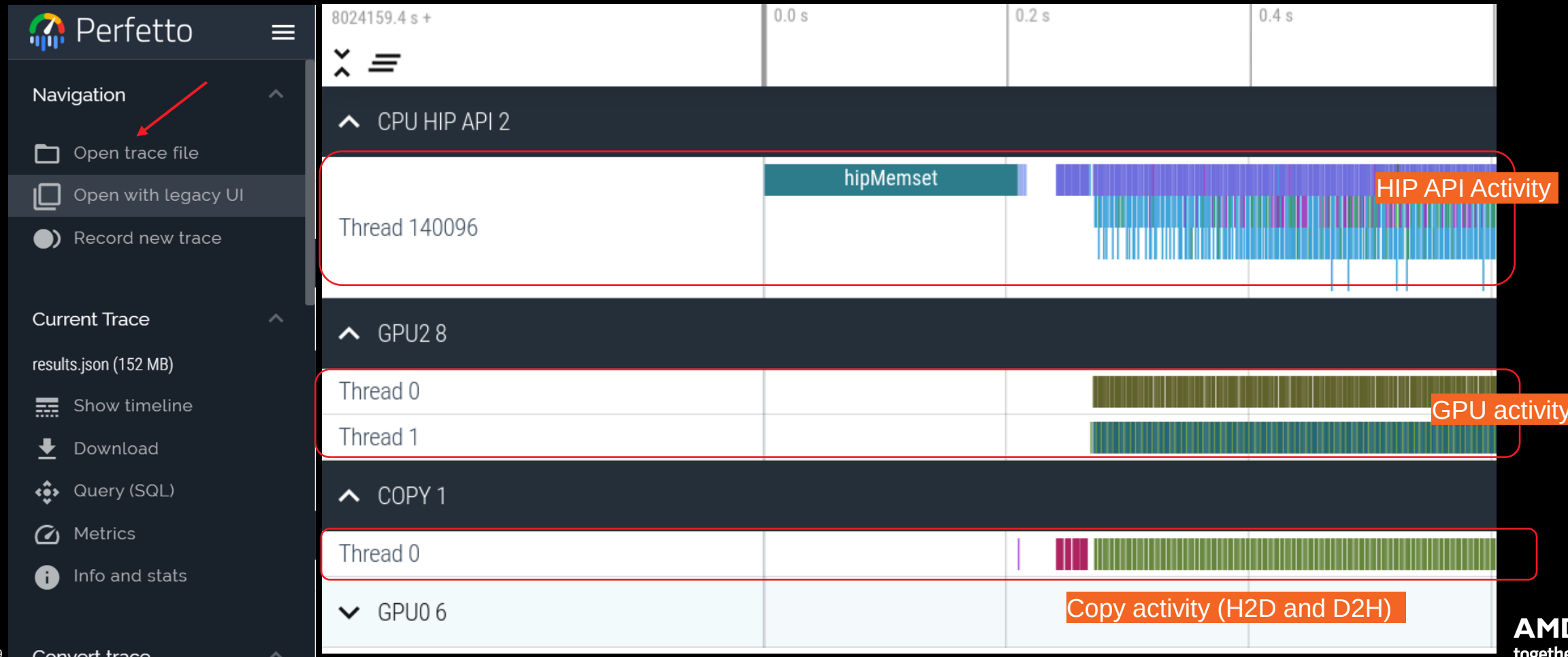
- You can combine modes like `--hip-trace --hsa-trace`
- If profiling OpenMP offload code, `--hsa-trace` is required to show HSA activity

# rocprof + Perfetto: Collecting and Visualizing Application Traces

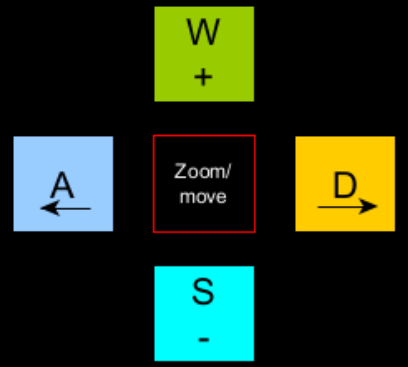
- rocprof can collect traces

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

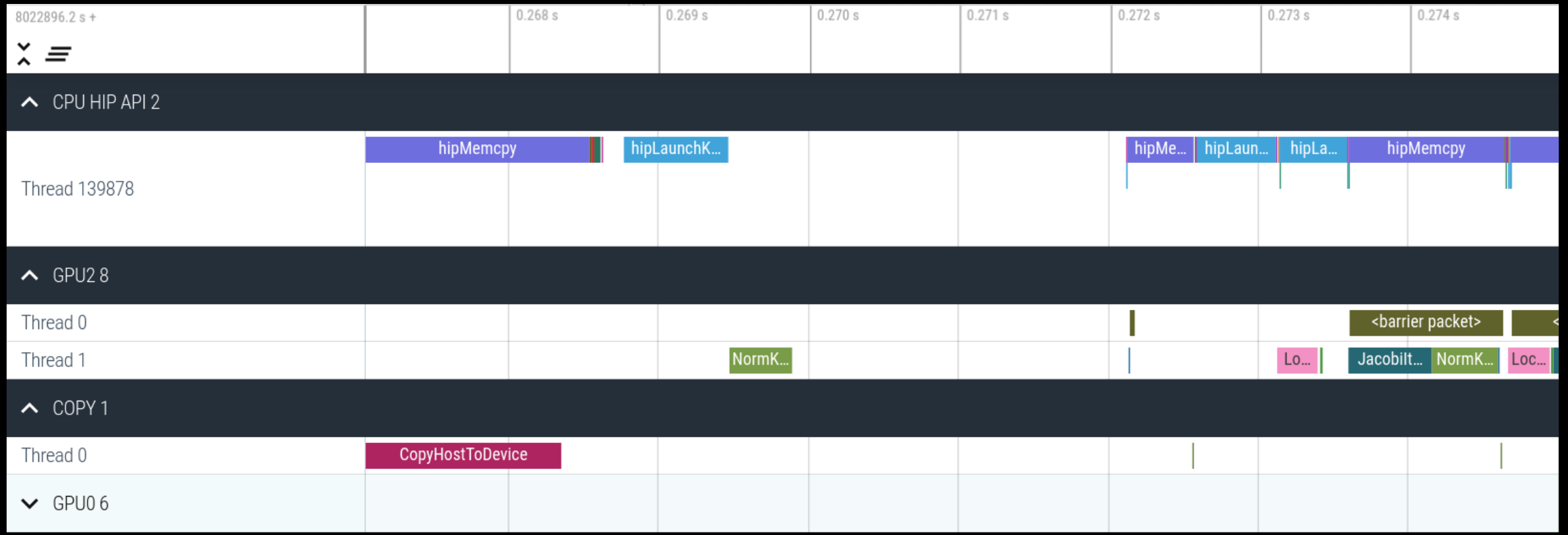
  This will output a .json file that can be visualized using the chrome browser and Perfetto ( https://ui.perfetto.dev/ )



# Perfetto: Visualizing Application Traces

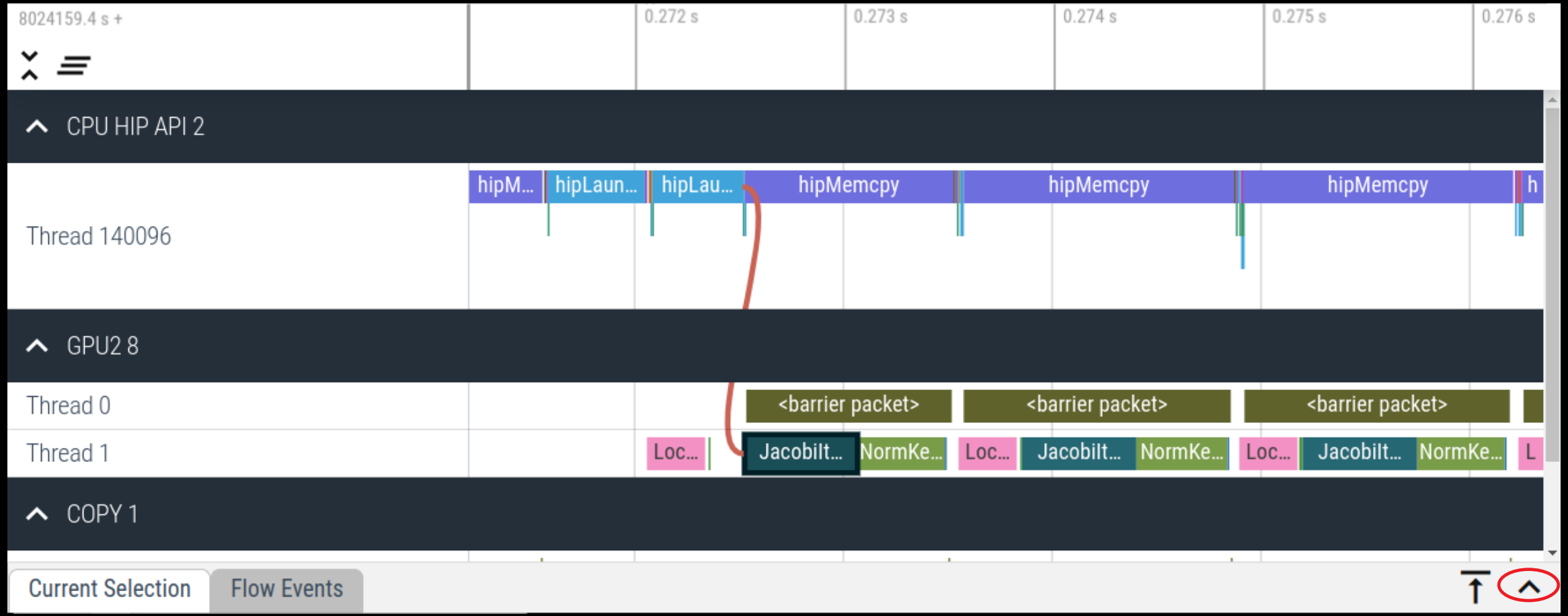



- Zoom in to see individual events
- Navigate trace using WASD keys

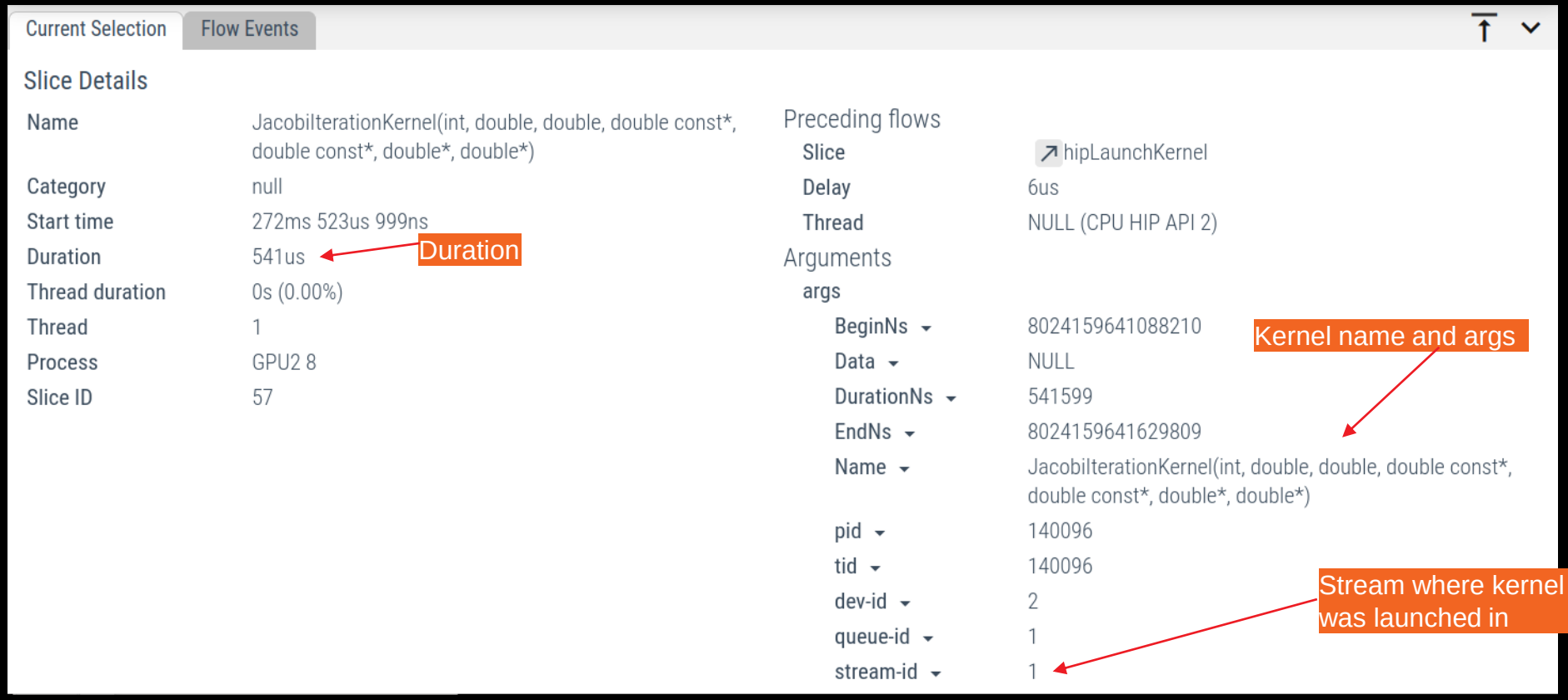


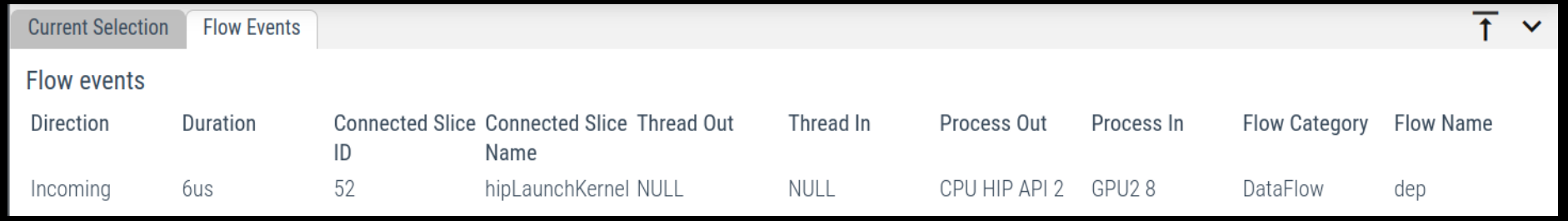
# Perfetto: Kernel Information and Flow Events

- 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)



# Perfetto: Kernel Information and Flow Events



# rocprof: Collecting Application Traces with rocTX Markers and Regions

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

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

- Annotate code with roctx markers:

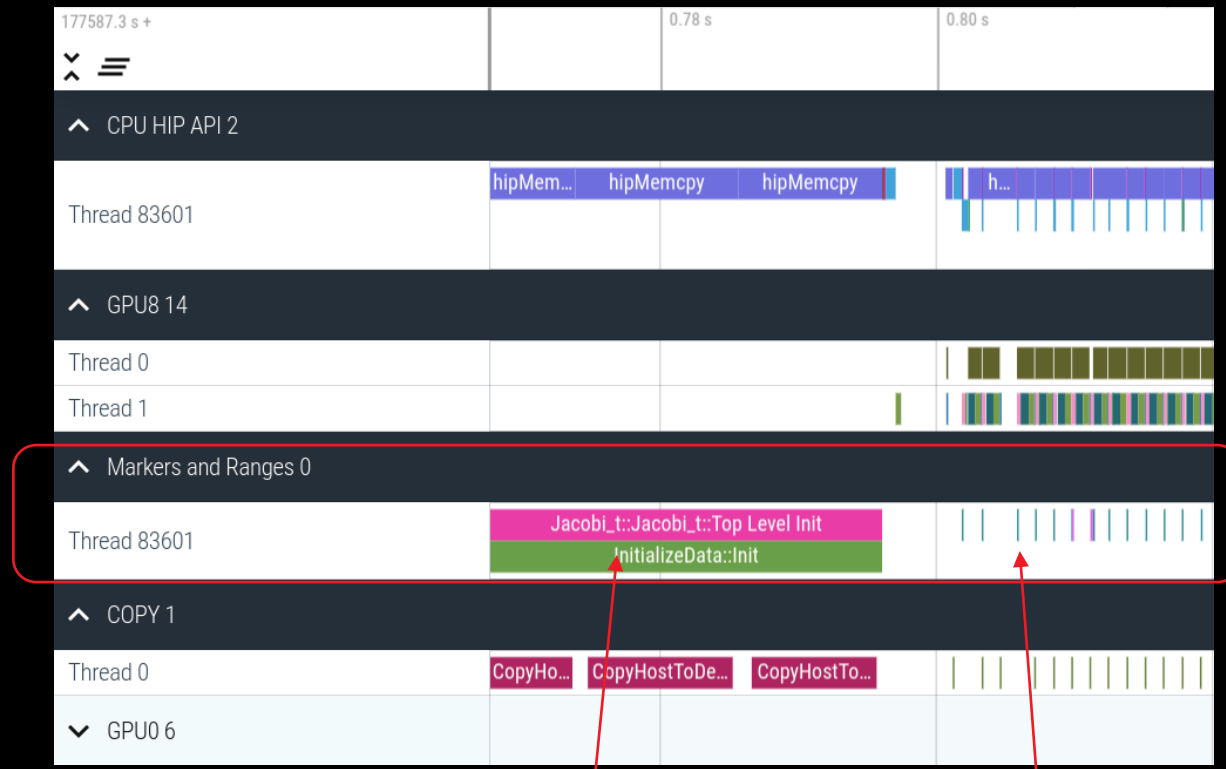
```
...
    roctxMark("start of some code");
    // some_code
    roctxMark("end of some code");
...
```

- Add roctx and roctracer libraries to link line:

```
-L${ROCM_PATH}/lib -lroctx64 -lroctracer64
```

- Profile with `--roctx-range` option:

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



# rocprof: Collecting Hardware Counters

- rocprof can collect a number of hardware counters and derived counters
  - `$ /opt/rocm/bin/rocprof --list-basic`
  - `$ /opt/rocm/bin/rocprof --list-derived`

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

```
pmc : Wavefronts VALUInsts VFetchInsts VWriteInsts VALUUtilization VALUBusy WriteSize
pmc : SALUInsts SFetchInsts LDSInsts FlatLDSInsts GDSInsts SALUBusy FetchSize
pmc : L2CacheHit MemUnitBusy MemUnitStalled WriteUnitStalled ALUStalledByLDS LDSBankConflict
```

  - 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

  - A csv file will be created containing all the requested counters for each invocation of every kernel

# rocprof: 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 |
| L2CacheHit | The percentage of fetch, write, atomic, and other instructions that hit the data in L2 cache |
| MemUnitBusy | The percentage of GPUTime the memory unit is active. The result includes the stall time |
| MemUnitStalled | The percentage of GPUTime the memory unit is stalled |
| WriteUnitStalled | The percentage of GPUTime the write unit is stalled |

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

# Performance Counters Tips and Tricks

- GPU Hardware counters are global
  - Kernel dispatches are serialized to ensure that only one dispatch is ever in flight
  - It is recommended that no other applications are using the GPU when collecting performance counters

- Use `--basenames on` which will report only kernel names, leaving off kernel arguments

- How do you time a kernel's duration?
  - `$ /opt/rocm/bin/rocprof --timestamp on -i rocprof_counters.txt <app with args>`
  - This produces four times: `DispatchNs, BeginNs, EndNs,` and `CompleteNs`
  - Closest thing to a kernel duration: `EndNs - BeginNs`
  - If you run with "`--stats`" the resultant results.stats.csv file will include a kernel duration column
    - Note: the duration is aggregated over repeated calls to the same kernel

# rocprof: Multiple MPI Ranks

- rocprof can collect counters and traces for multiple MPI ranks
- Say you want to profile an application usually called like this:

```
srun --ntasks=n ./Jacobi_hip -g <x> <y>
```

- Invoke the profiler by executing:

```
srun --ntasks=n rocprof <rocprof_options> ./Jacobi_hip -g <x> <y>
```

- By directing output files from each rank to different directories, we can collect traces for each rank separately
  - Use a helper script for this, and run your program as shown below:

```
srun --ntasks=n helper_rocprof.sh ./Jacobi_hip -g <x> <y>
```

- Multi-node profiling currently isn't supported

# Profiling Multiple MPI Ranks

$cat rocprof_wrapper.sh

```
#!/bin/bash
set -euo pipefail
# depends on ROCM_PATH being set outside;  input arguments are the output directory & the name
outdir="$1"
name="$2"
if [[ -n ${OMPI_COMM_WORLD_RANK+z} ]]; then
    # mpich
    export MPI_RANK=${OMPI_COMM_WORLD_RANK}
elif [[ -n ${MV2_COMM_WORLD_RANK+z} ]]; then
    # ompi
    export MPI_RANK=${MV2_COMM_WORLD_RANK}
elif [[ -n ${SLURM_PROCID+z} ]]; then
    export MPI_RANK=${SLURM_PROCID}
else
    echo "Unknown MPI layer detected! Must use OpenMPI, MVAPICH, or SLURM"
    exit 1
fi
rocprof="${ROCM_PATH}/bin/rocprof"

pid="$$"
outdir="${outdir}/rank_${pid}_${MPI_RANK}"
outfile="${name}_${pid}_${MPI_RANK}.csv"
${rocprof} -d ${outdir} --hsa-trace -o ${outdir}/${outfile} "${@:3}"
```

Output directory per rank

Filenames annotated with rank as well

Application and its arguments

# Larger Traces with Perfetto

- There is a memory limit in the Chrome browser. There is a way to read in the trace for the browser before starting it up.

Linux

- curl -LO https://get.perfetto.dev/trace_processor
- chmod +x ./trace_processor
- ./trace_processor –httpd <path to trace file>
- Open up Chrome browser and go to https://ui.perfetto.dev
- When prompted, click on "Yes, use loaded trace"

Windows

- Open up https://get.perfetto.dev/trace_processor in a browser to download the python script
- py trace_processor --httpd <trace file>
  - You may need to download and install python on your windows system
- Open up Chrome browser and go to https://ui.perfetto.dev
- When prompted, click on "Yes, use loaded trace"

# 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

# Summary

- rocprof is the open source, command line AMD GPU profiling tool distributed with ROCm
- Many other tools are built over rocprof
- rocprof provides tracing of GPU kernels, HIP API, HSA API and Copy activity
- rocprof can be used to collect GPU hardware counters with additional overhead
- JSON Traces can be viewed in Perfetto UI
- Other output files are in text/CSV format

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