Introduction to Rocprof Profiling Tool

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Developing Applications with the AMD ROCm Ecosystem

AMD GPU Profiling

- ROC-profiler (or simply 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 the collection of application tracing and counter collection
  - Under constant development
- Provided in the ROCm releases
- The output of rocprof can be visualized using the chrome browser with Perfetto (https://ui.perfetto.dev/)

rocProf: Getting started + useful flags

- To get help:
  - `$ /opt/rocm-5.2.0/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: 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

rocProf: Information about the kernels

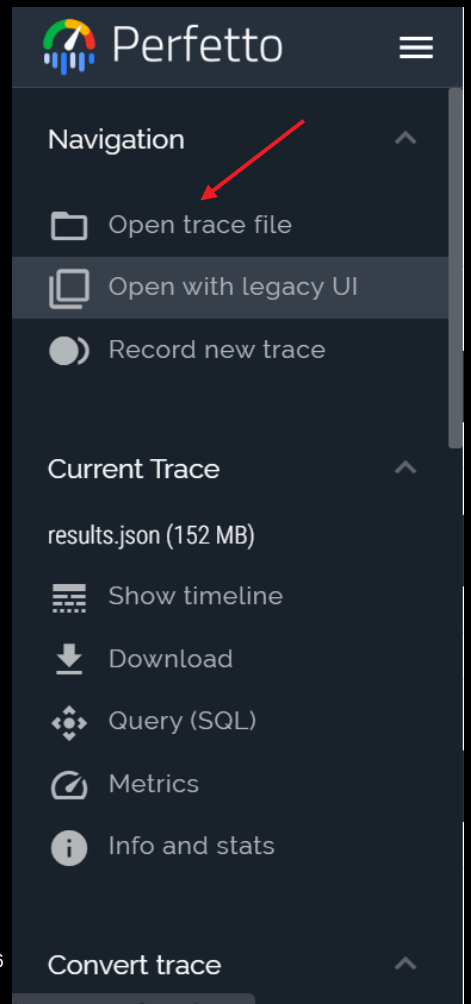
- rocprofiler can collect kernels information
  - **`$ /opt/rocm/bin/rocprof --stats --basenames on <app with arguments>`**
  - This will output two csv files, one with information per each call of the kenel *results.csv* and one with statistics grouped by each kernel *results.stats.csv.*
  - Content of results.stats.csv:

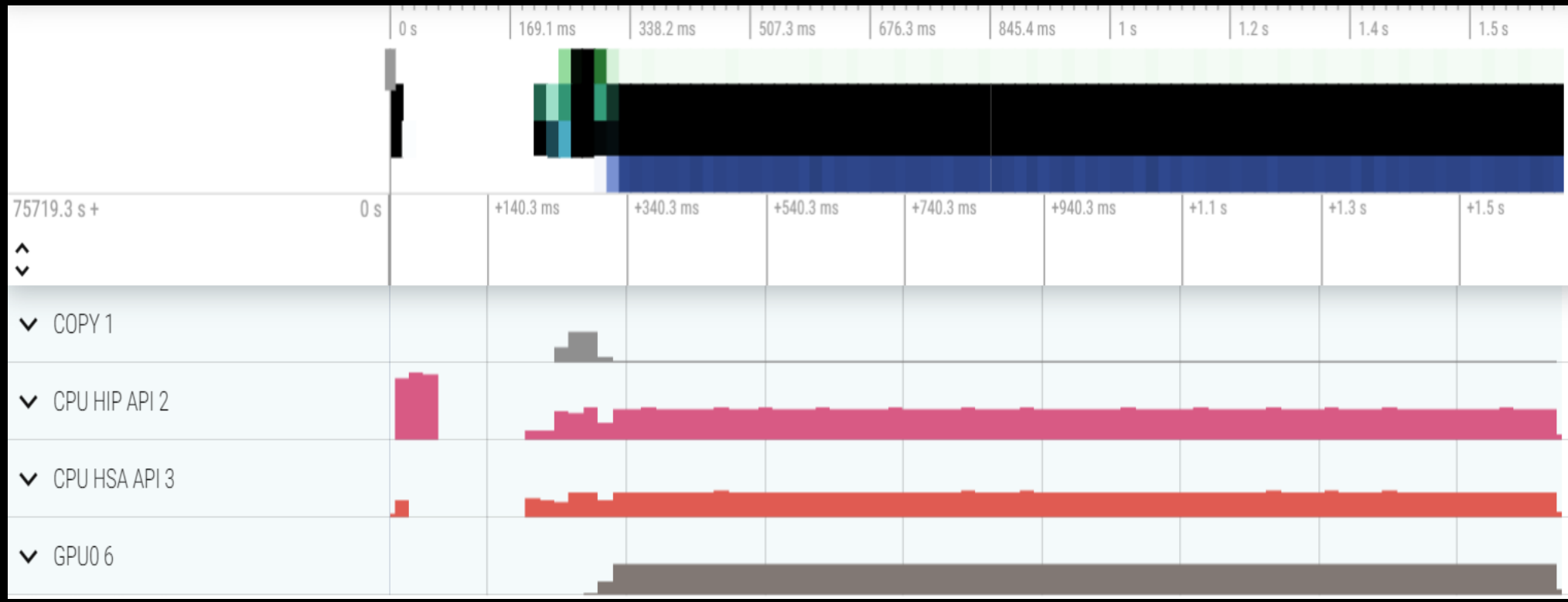
"Name",	"Calls",	"TotalDurationNs",	"AverageNs",	"Percentage"
"LocalLaplacianKernel",	1000,	817737586,	817737,	40.908259879301134
"JacobiIterationKernel",	1000,	699515425,	699515,	34.994060790890174
"NormKernel1",	1001,	454737348,	454283,	22.748756969583884
"HaloLaplacianKernel",	1000,	14561933,	14561,	0.7284773865206329
"NormKernel2",	1001,	12395374,	12382,	0.620092789636225
"__amd_rocclr_fillBufferAligned.kd",	1,	7040,	7040,	0.00035218406794656007

  - This way you know directly which kernels consume most of the time, it does not mean that the performance is slow, for now.

rocProf and Perfetto: Collecting and visualizing application traces

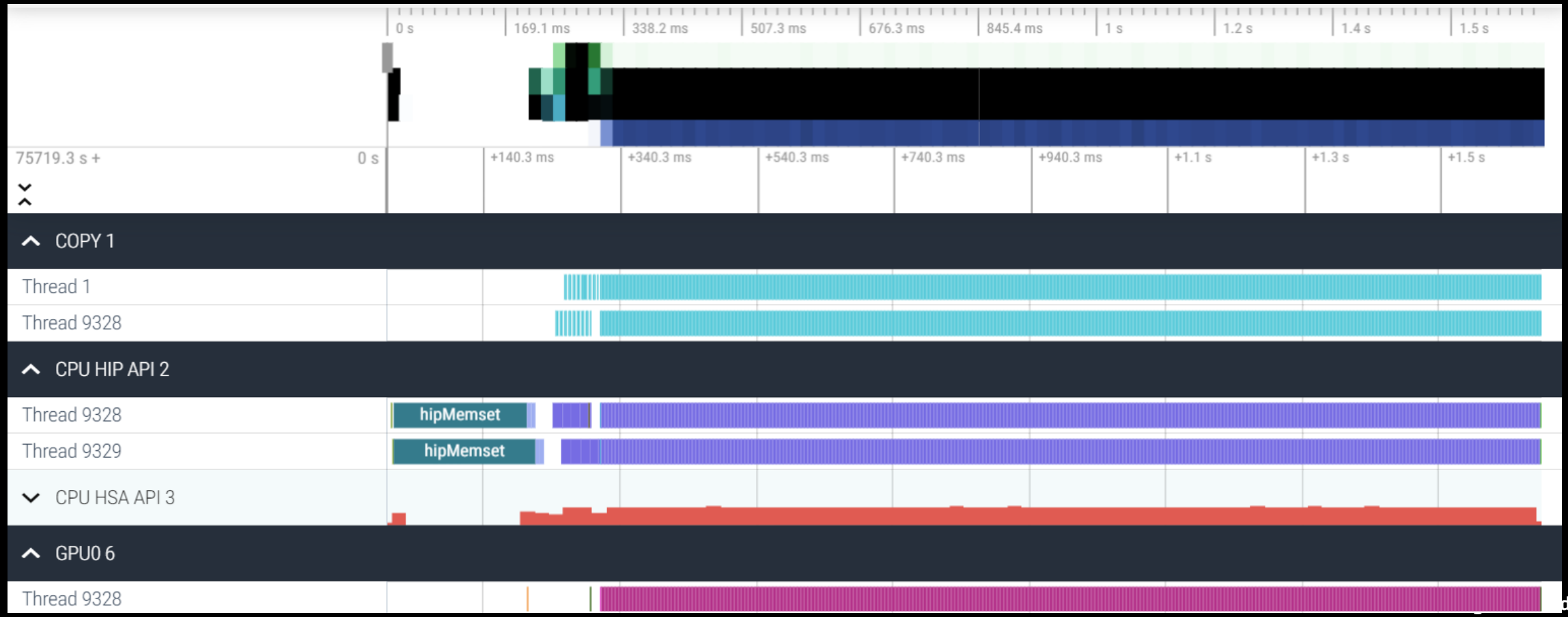
- rocprofiler can collect traces
  - `$ /opt/rocm/bin/rocprof --hip-trace --hsa-trace <app with arguments>`
  - This will output a .json file that can be visualized using the chrome browser and Perfetto (https://ui.perfetto.dev/)





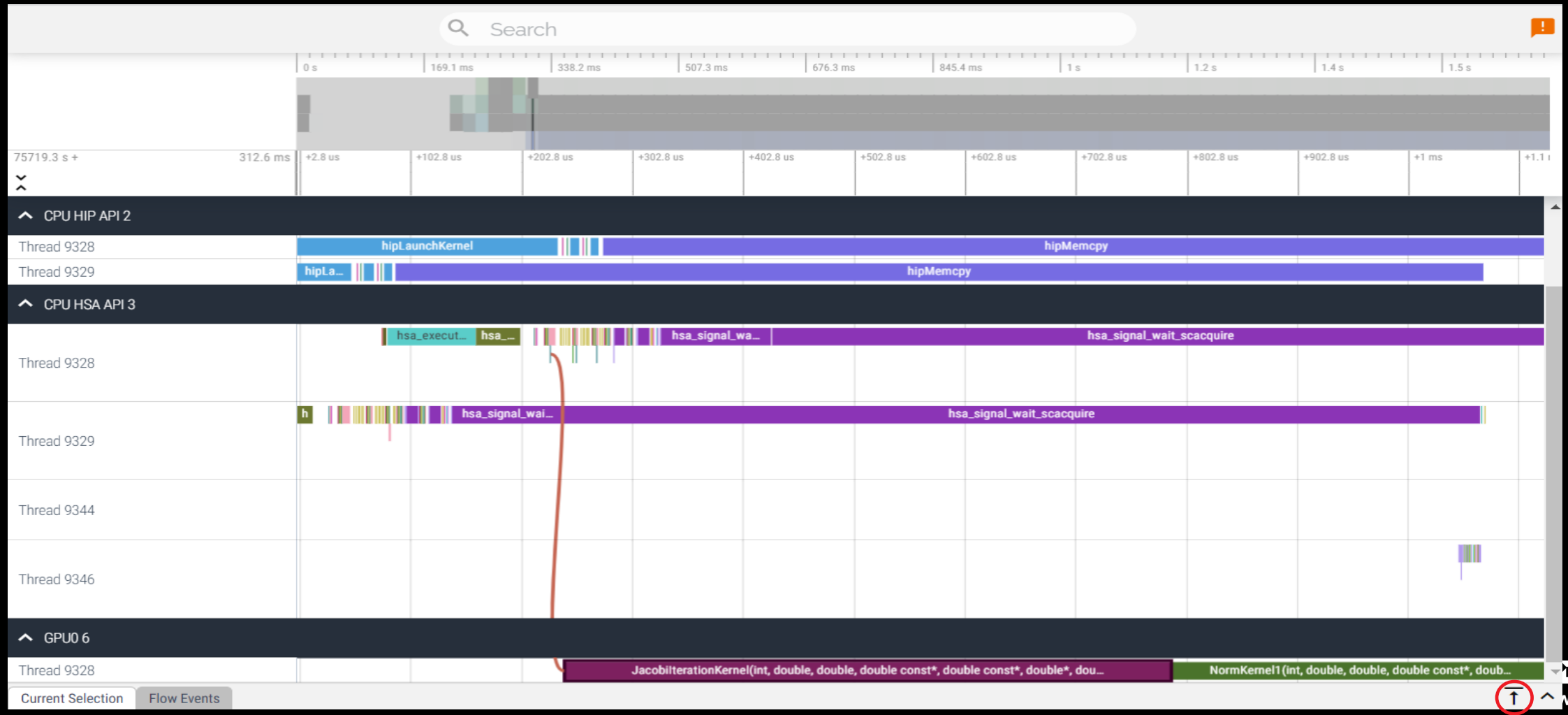
Perfetto: Visualizing application traces

- We have expanded the COPY 1, CPU HIP API 2 and GPU0 6
- X axis is time and it displays events or counters.
- Handle the zoom by keystrokes: W zoom, S zoom out, A move left, D move right

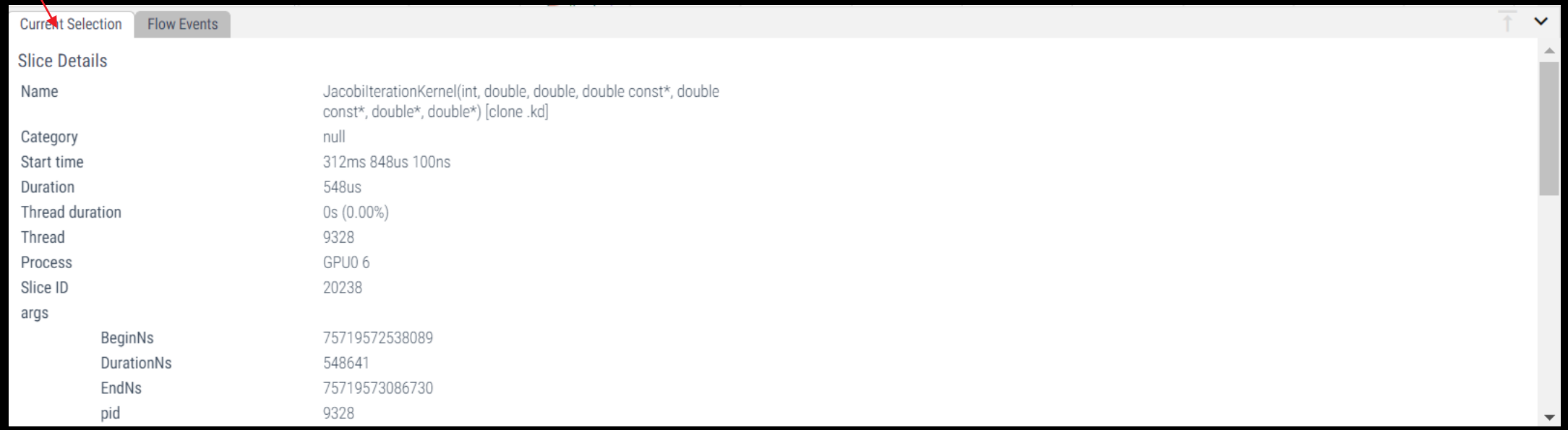


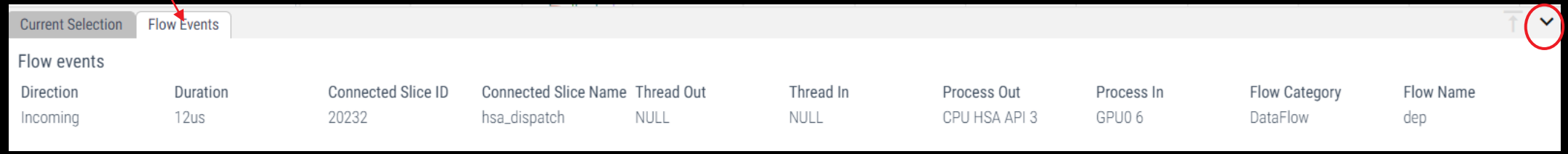
Perfetto: Kernel and flows

- Zoom and select a kernel, you can see the link to the HSA call enables the kernel
- Try to open the information for the kernel (button right down)



Perfetto: Information about kernels and flow events





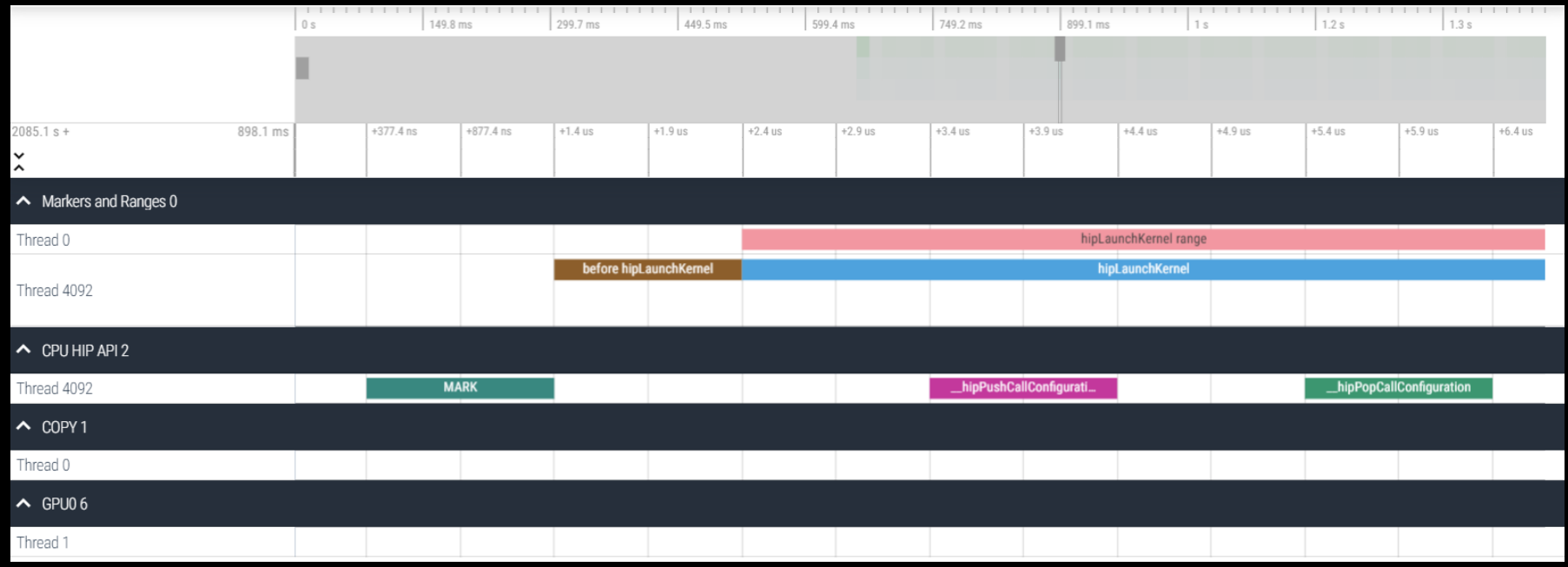
rocprof: Collecting application traces with markers

- Rocprof can collect user code-markers using rocTX
  - See MatrixTranspose.cpp example on roctracer GitHub page for sample in-code usage
  - **`$ /opt/rocm/bin/rocprof --hip-trace --roctx-trace <app with arguments>`**

```
roctracer_mark("before HIP
LaunchKernel");

roctxMark("before hipLaunchKernel");
int rangeId =
roctxRangeStart("hipLaunchKernel
range");

roctxRangePush("hipLaunchKernel");
hipLaunchKernelGGL(matrixTranspose,…)
;
roctracer_mark("after HIP
LaunchKernel");
 roctxMark("after hipLaunchKernel");
```



rocprof: Collecting hardware counters

- rocprofiler 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 by this command containing all of the requested counters

rocprof: Commonly Used 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 running that use 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 file will automatically include a column that calculates kernel duration
    - 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:
  - `mpiexec –np <n> ./Jacobi_hip –g <x> <y>`
  - Then invoke the profiler by executing:

```
mpiexec -np <n> rocprof --hip-trace ./Jacobi_hip -g <x> <y>
or
srun --ntasks=n rocprof --hip-trace ./Jacobi_hip -g <x> <y>
```

- This will produce a single CSV file per MPI process
- Multi-node profiling currently isn’t supported

Profiling Per MPI Rank: From Another Node(1)

- Let’s consider a 3-step run:
  - sbatch_profiling.sh with sbatch command line to launch the app
  - rocprof_batch.slurm This file contains sbatch parameters and the call to srun command line
  - rocprof_wrapper.sh calls rocprof command line with input parameters to run the application to be profiled

- $cat sbatch_profiling.sh
  - sbatch -p <partition> -w <node> rocprof_batch.slurm

- $cat rocprof_batch.slurm

```
#!/bin/bash
#SBATCH --job-name=run
#SBATCH --ntasks=2
#SBATCH --ntasks-per-node=2
#SBATCH --gpus-per-task=1
#SBATCH --cpus-per-task=1
#SBATCH --distribution=block:block
#SBATCH --time=00:20:00
#SBATCH --output=out.txt
#SBATCH --error=err.txt
#SBATCH -A XXXXX
cd ${SLURM_SUBMIT_DIR}
```

- **load necessary modules**
- **export necessary environment variables**

```
 make clean all
srun ./rocprof_wrapper.sh ${repository} triad_off_mpi triad_off_mpi
```

Profiling Per MPI Rank: From Another Node(2)

- $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}"
```

rocprof: Profiling Overhead

- As with every profiling tool that collects data, there is an overhead
- The percentage of the overhead depends on many aspects, for example if you try to instrument tiny tasks in a loop, this can take more time than tasks outside a loop
- If you try to collect many counters and especially ones that need more than one pass, then this could cause overhead if there a lot of related calls
- Also, if a lot of markers are added and especially in a loop then the roctx-trace can take significantly more time than the non instrumented execution time
- In general, more the data you collect, more the overhead can be, and it depends on the application.

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