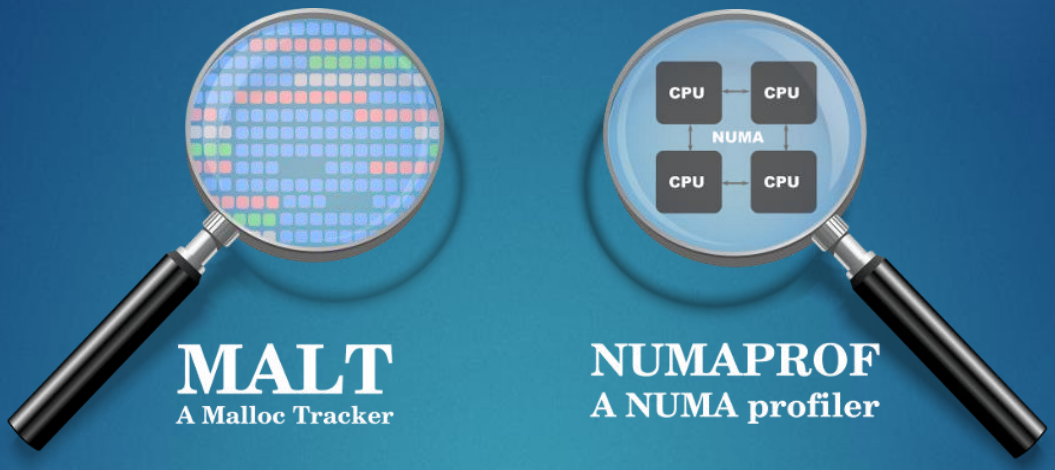


MALT & **NUMAPROF**, Memory Profiling for HPC Applications

SÉBASTIEN VALAT – FOSDEM 2019 – TRACK HPC

Origin of the tools

- **PhD.** on **memory management** for **HPC** (at CEA/UVSQ)
- **MALT**, post-doc at Versailles :

- **NUMAPROF**, side project post-doc work at :

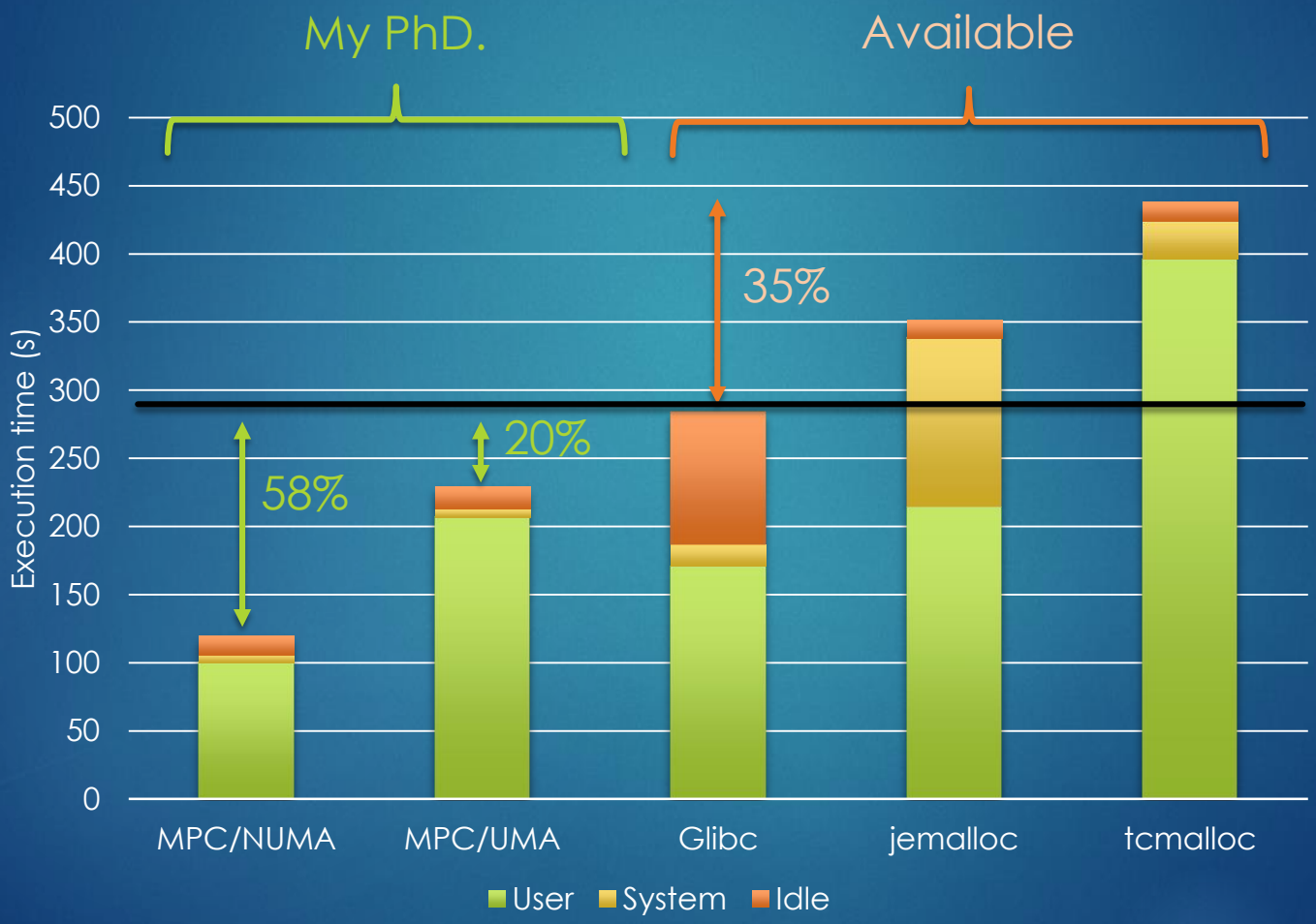
Motivation

- Lot of **issues** today :
  - **Huge** memory **space** to **manage** (~TB of memory)
  - **Lot more** distinct **allocations** (75 M in 5 minutes)
  - **Multi-threading** : 256 threads
  - **Hidden** into large (**huge**) C/C++/Fortran **codes** (**~1M** lines).
- Access:
  - **NUMA** (Non Uniform Memory Access)
  - **Memory wall** !

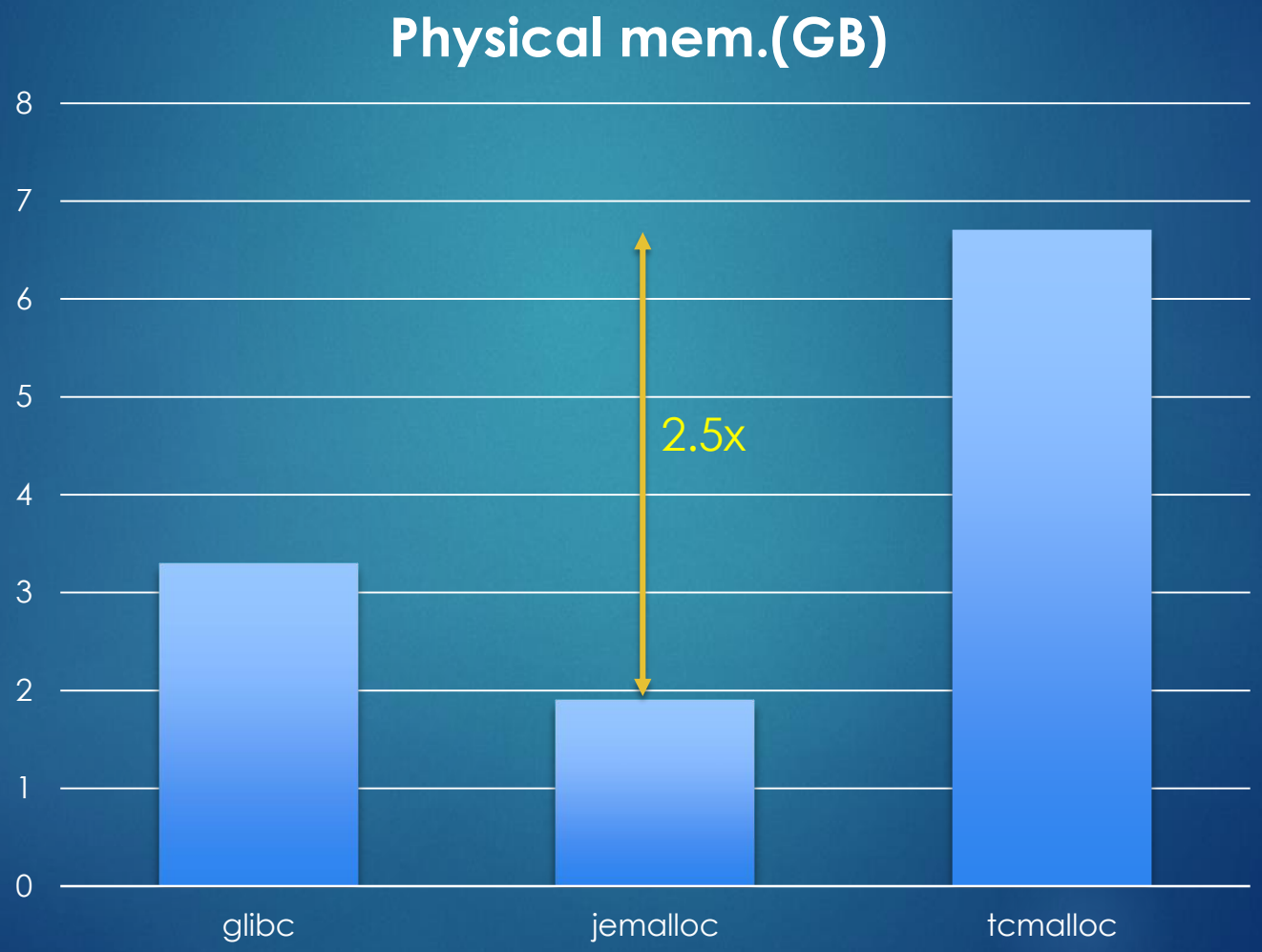
Key today

You need to
well understand memory behavior of your *(HPC)* application !

Eg: **>1M lines** C++ simulation. On **128** cores / **16** NUMA CPUs



Same about **memory consumption** on 12 cores

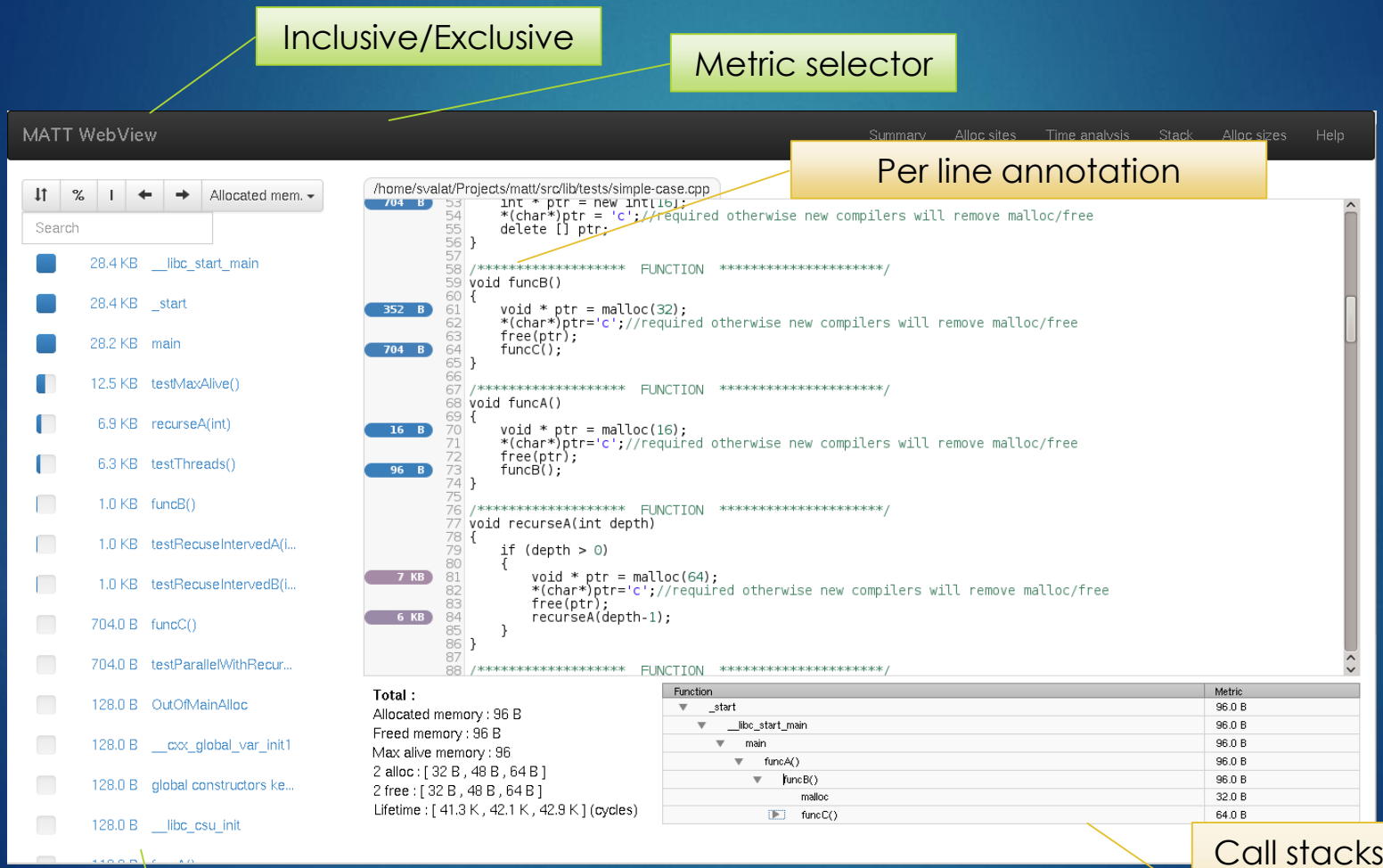


Tool 1 : **MALT**

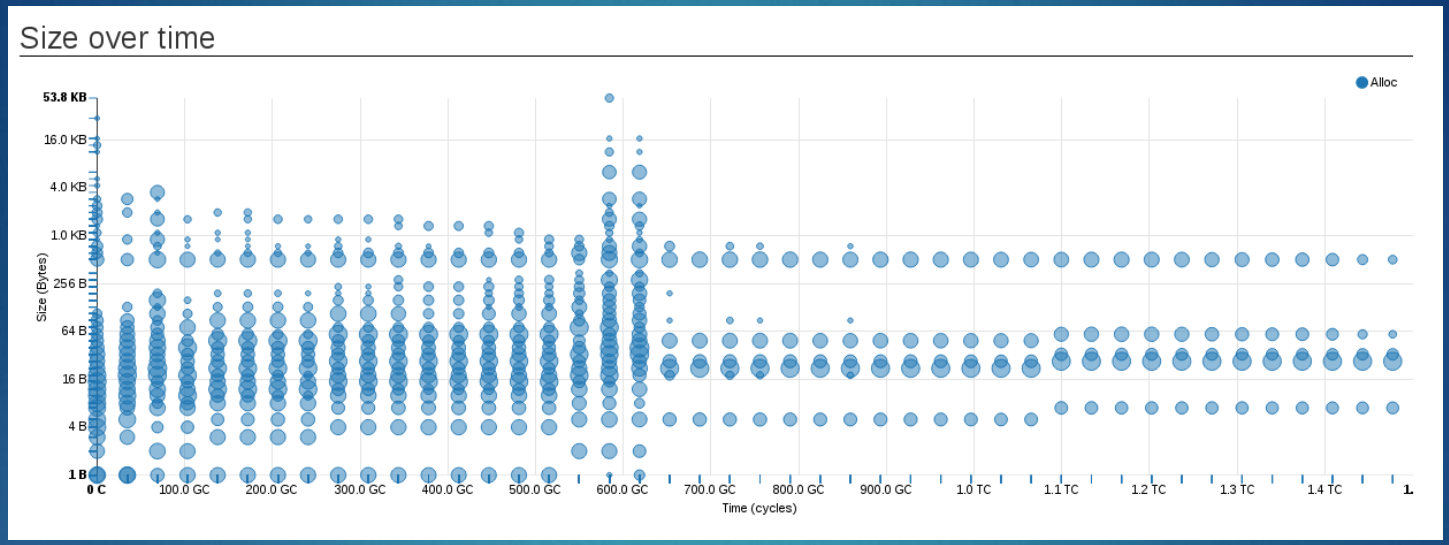
- **Memory management** can have **huge impact**
- Tool to **track mallocs**
- Report **properties** onto **annotated sources**

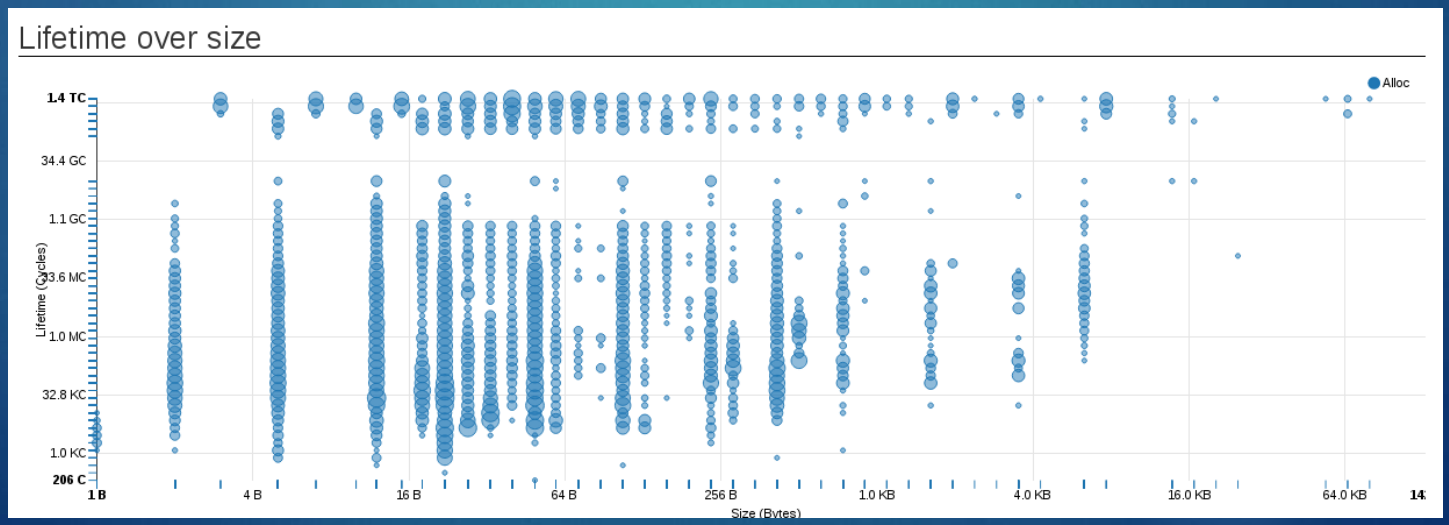
- Same **idea** than **valgrind/kcachegrind**
  - Annotated sources
  - Annotated call graphs
  - **+ Non additive metrics** (for inclusive costs, eg. lifetime)
  - **+ Time charts**
  - **+ Properties distribution (sizes….)**

Web based GUI



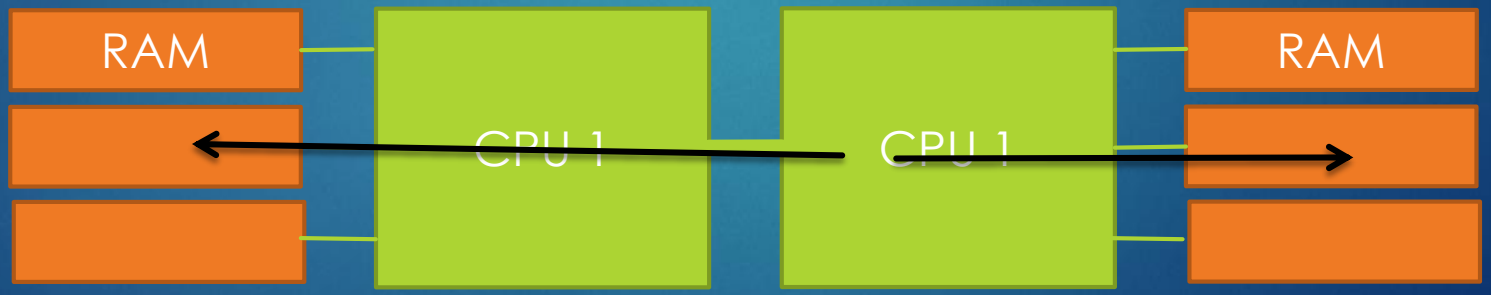
Example of time based view





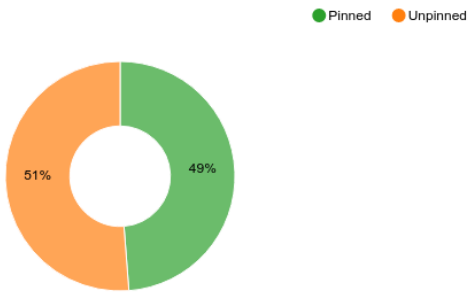
Tool 2 : **NUMAPROF**

- Based on MALT code
- But about **NUMA**
- How to **detect remote** memory **accesses**
- Unsafe & **uncontrolled memory binding**

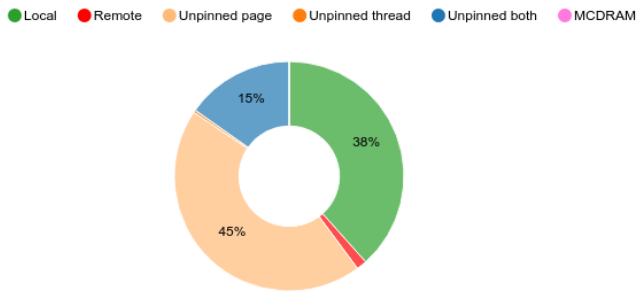


Some summary views

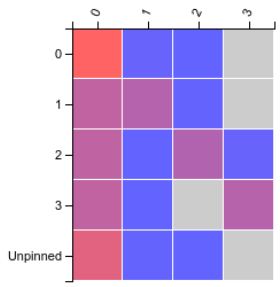
First touch



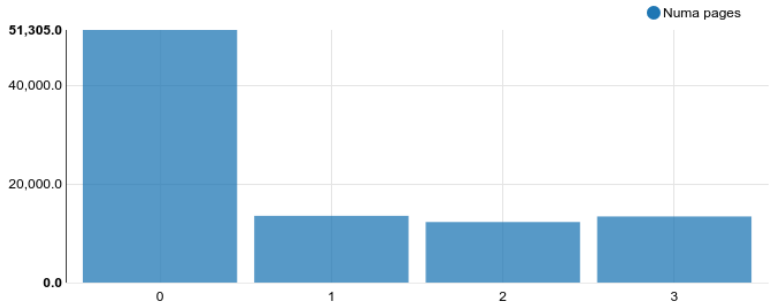
Memory access



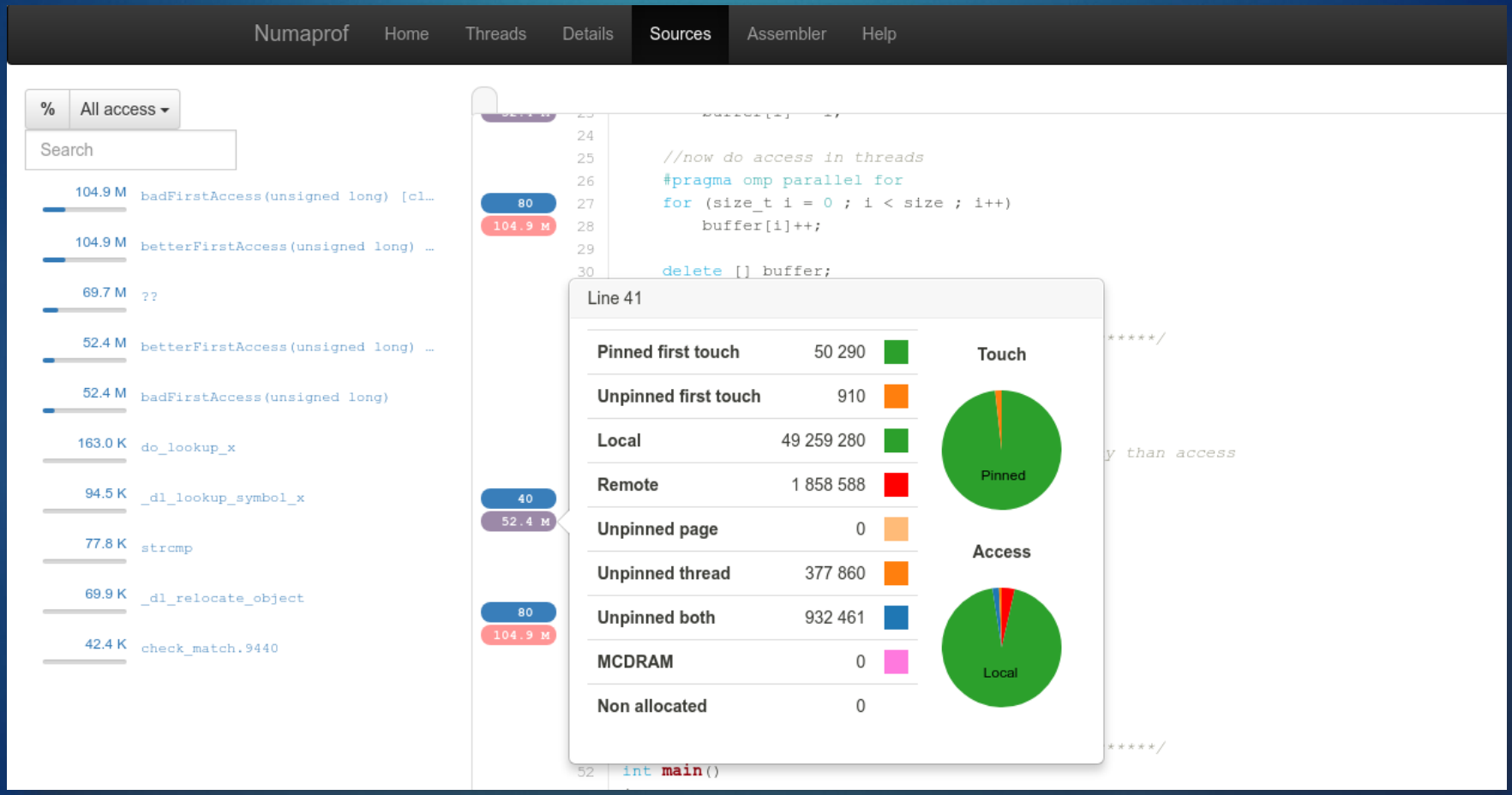
Access matrix



Peak allocated numa pages

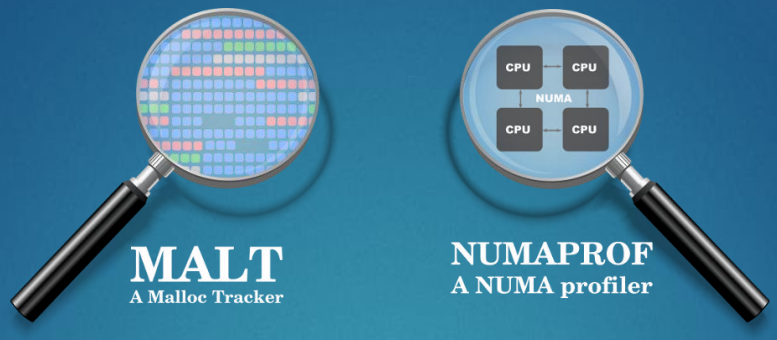


Still source annotation to understand code



Short success

- MALT
  - **20%** CPU saving on my **CERN 32 000** C++ code.
  - Improvement on **2 commercial simulation** codes
  - Profiled **CERN LHCb 1.5 million** line C++ code
- NUMAPROF
  - **20% perf in 20 minutes** on 8000 lines simu.
  - NUMA **Linux kernel policy bug** detected.
  - CERN PhD. code **NUMA correctness**



Questions

Both tools under CeCILL-C on http://memtt.github.io

My researches : http://svalat.github.io

Example of success MALT

- Reduce **CPU usage** of **30%** on the CERN app I was developing (mistake with C++11 `for(auto & it : lst)`) 32 000 C++ lines running on 500 servers.
- **Too large allocations** in a PhD. Student numerical simulation running on 500 cores while developing the tool.
- **Realloc pattern** in Fortran into **an industrial** R&D simulation code
- Unexpected **allocs generated** by GFortran **compiler** on another **industrial** R&D simulation **code**.
- Successfully ran on **CERN LHCb 1.5M lines** online analysis software

Example of success NUMAPROF

- **20% performance improvement** in 20 minutes on an unknown 8000 C++ lines simulation on Intel KNL
- **Linux Kernel bug** detected on NUMA management in conjunction with Transparent Huge Pages (while developing the tool).
  Was detected at same time by other way by Red-Hat…. But…..
- **Confirmation** of NUMA **correctness** on a CERN/OpenLab PhD. Student code on Intel KNL