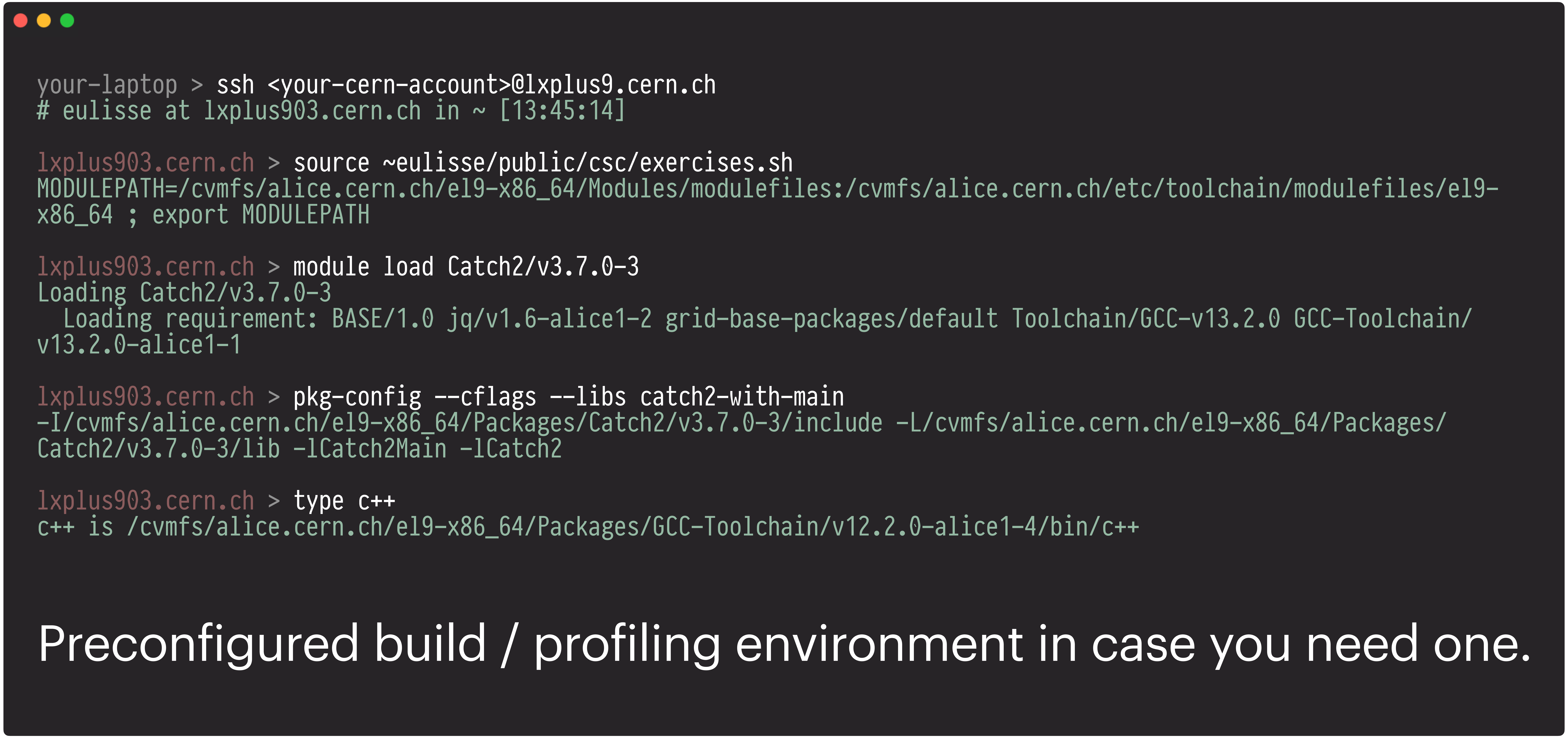
Benchmarking

Exercises

Giulio Eulisse

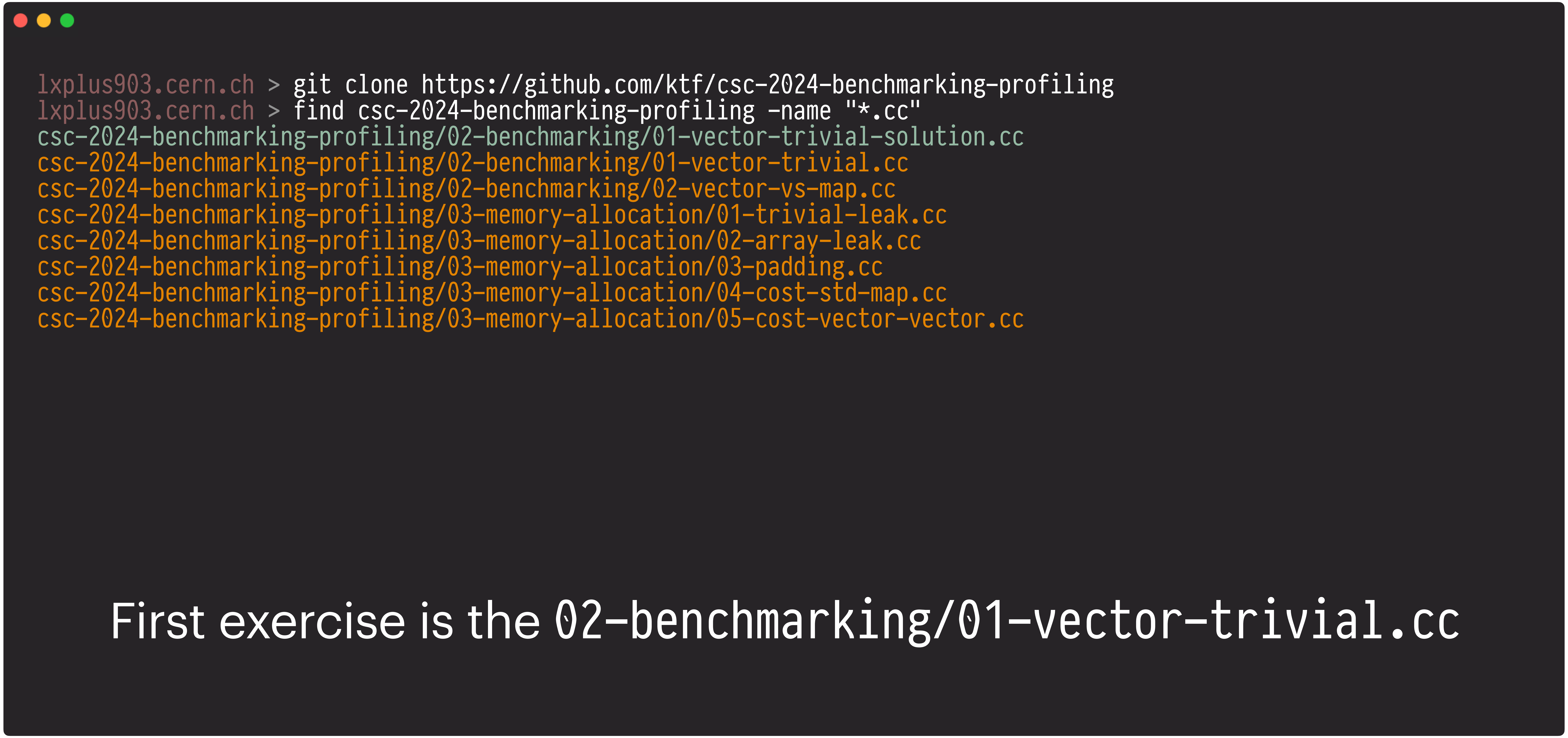
Getting Catch2 environment



```
your-laptop > ssh <your-cern-account>@lxplus9.cern.ch
# eulisse at lxplus903.cern.ch in ~ [13:45:14]

lxplus903.cern.ch > source ~eulisse/public/csc/exercises.sh
MODULEPATH=/cvmfs/alice.cern.ch/el9-x86_64/Modules/modulefiles:/cvmfs/alice.cern.ch/etc/toolchain/modulefiles/el9-
x86_64 ; export MODULEPATH

lxplus903.cern.ch > module load Catch2/v3.7.0-3
Loading Catch2/v3.7.0-3
  Loading requirement: BASE/1.0 jq/v1.6-alice1-2 grid-base-packages/default Toolchain/GCC-v13.2.0 GCC-Toolchain/
v13.2.0-alice1-1

lxplus903.cern.ch > pkg-config --cflags --libs catch2-with-main
-I/cvmfs/alice.cern.ch/el9-x86_64/Packages/Catch2/v3.7.0-3/include -L/cvmfs/alice.cern.ch/el9-x86_64/Packages/
Catch2/v3.7.0-3/lib -lCatch2Main -lCatch2

lxplus903.cern.ch > type c++
c++ is /cvmfs/alice.cern.ch/el9-x86_64/Packages/GCC-Toolchain/v12.2.0-alice1-4/bin/c++
```

Preconfigured build / profiling environment in case you need one.

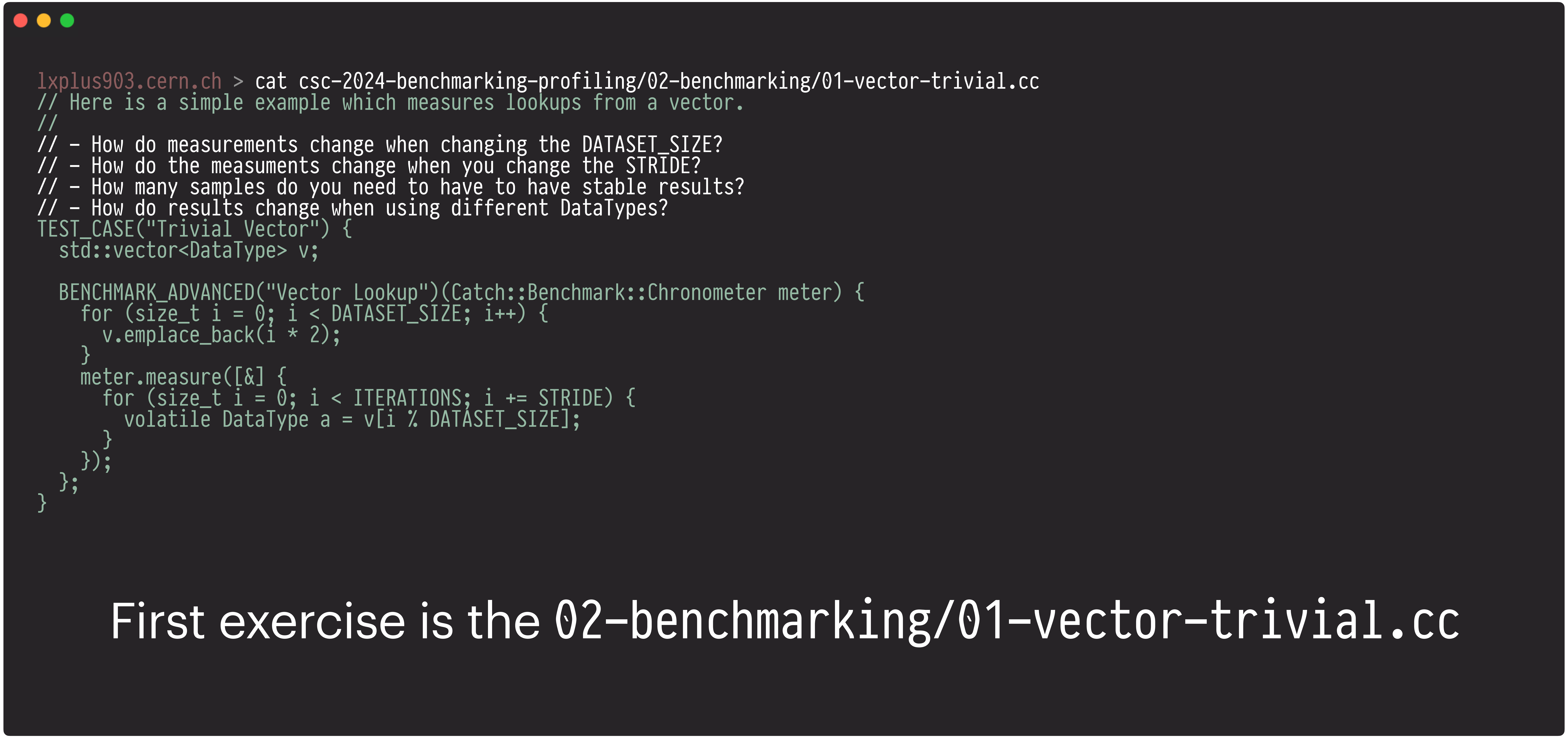
Getting the sources for the exercises



```
lxplus903.cern.ch > git clone https://github.com/ktf/csc-2024-benchmarking-profiling
lxplus903.cern.ch > find csc-2024-benchmarking-profiling -name "*.cc"
csc-2024-benchmarking-profiling/02-benchmarking/01-vector-trivial-solution.cc
csc-2024-benchmarking-profiling/02-benchmarking/01-vector-trivial.cc
csc-2024-benchmarking-profiling/02-benchmarking/02-vector-vs-map.cc
csc-2024-benchmarking-profiling/03-memory-allocation/01-trivial-leak.cc
csc-2024-benchmarking-profiling/03-memory-allocation/02-array-leak.cc
csc-2024-benchmarking-profiling/03-memory-allocation/03-padding.cc
csc-2024-benchmarking-profiling/03-memory-allocation/04-cost-std-map.cc
csc-2024-benchmarking-profiling/03-memory-allocation/05-cost-vector-vector.cc
```

First exercise is the `02-benchmarking/01-vector-trivial.cc`

Getting the sources for the exercises



```
lxplus903.cern.ch > cat csc-2024-benchmarking-profiling/02-benchmarking/01-vector-trivial.cc
// Here is a simple example which measures lookups from a vector.
//
// - How do measurements change when changing the DATASET_SIZE?
// - How do the measuments change when you change the STRIDE?
// - How many samples do you need to have to have stable results?
// - How do results change when using different DataTypes?
TEST_CASE("Trivial Vector") {
  std::vector<DataType> v;

  BENCHMARK_ADVANCED("Vector Lookup")(Catch::Benchmark::Chronometer meter) {
    for (size_t i = 0; i < DATASET_SIZE; i++) {
      v.emplace_back(i * 2);
    }
    meter.measure([&] {
      for (size_t i = 0; i < ITERATIONS; i += STRIDE) {
        volatile DataType a = v[i % DATASET_SIZE];
      }
    });
  };
}
```

First exercise is the `02-benchmarking/01-vector-trivial.cc`

To get you in the mood...

Farbrausch - fr-041: debris. [2160p60]
Breakpoint 2007 Demo Party Winner

https://www.youtube.com/watch?v=jY5Vrc5G0Ik

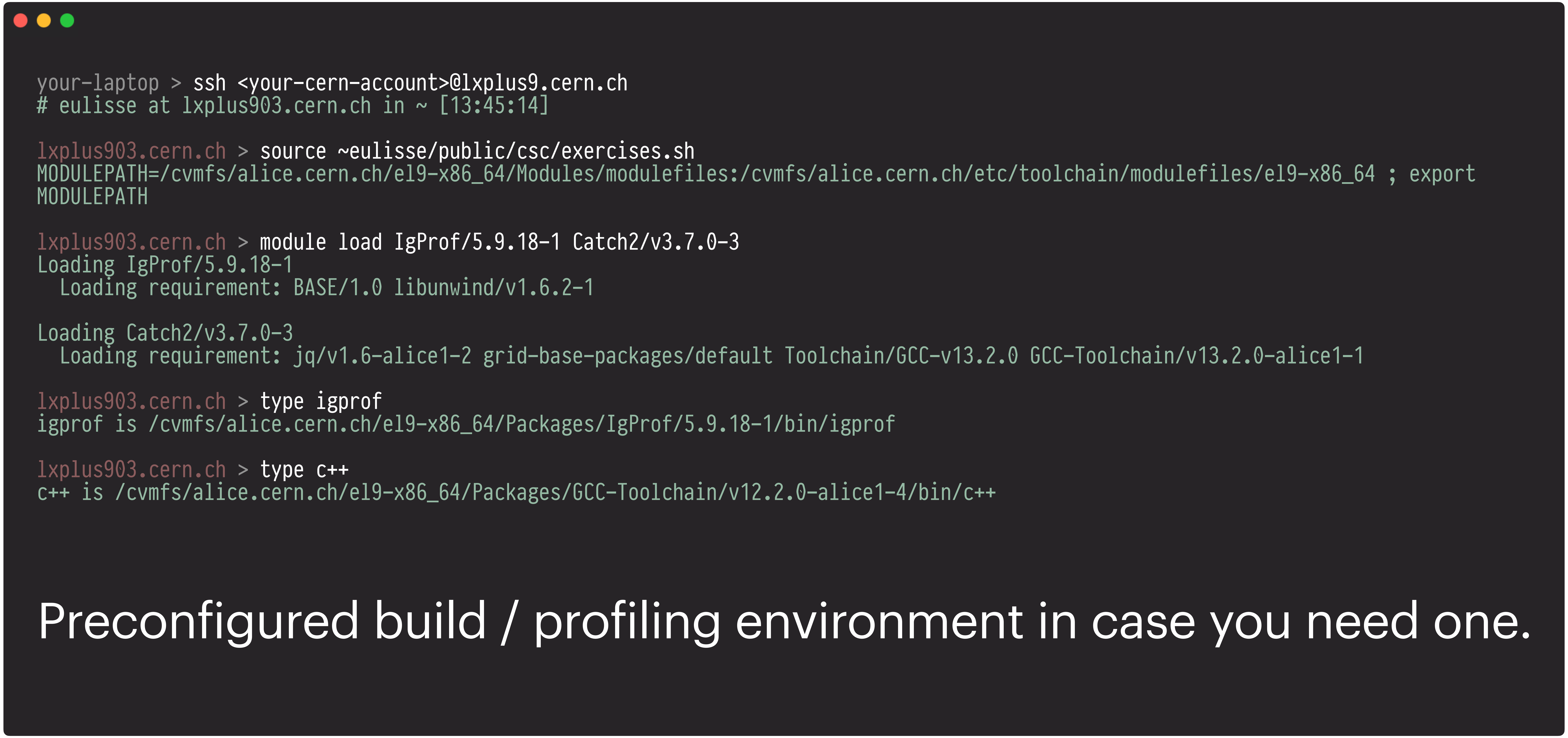
Procedurally generated in **177 kilobytes**

Profiling

Exercises

Giulio Eulisse

Getting IgProf environment

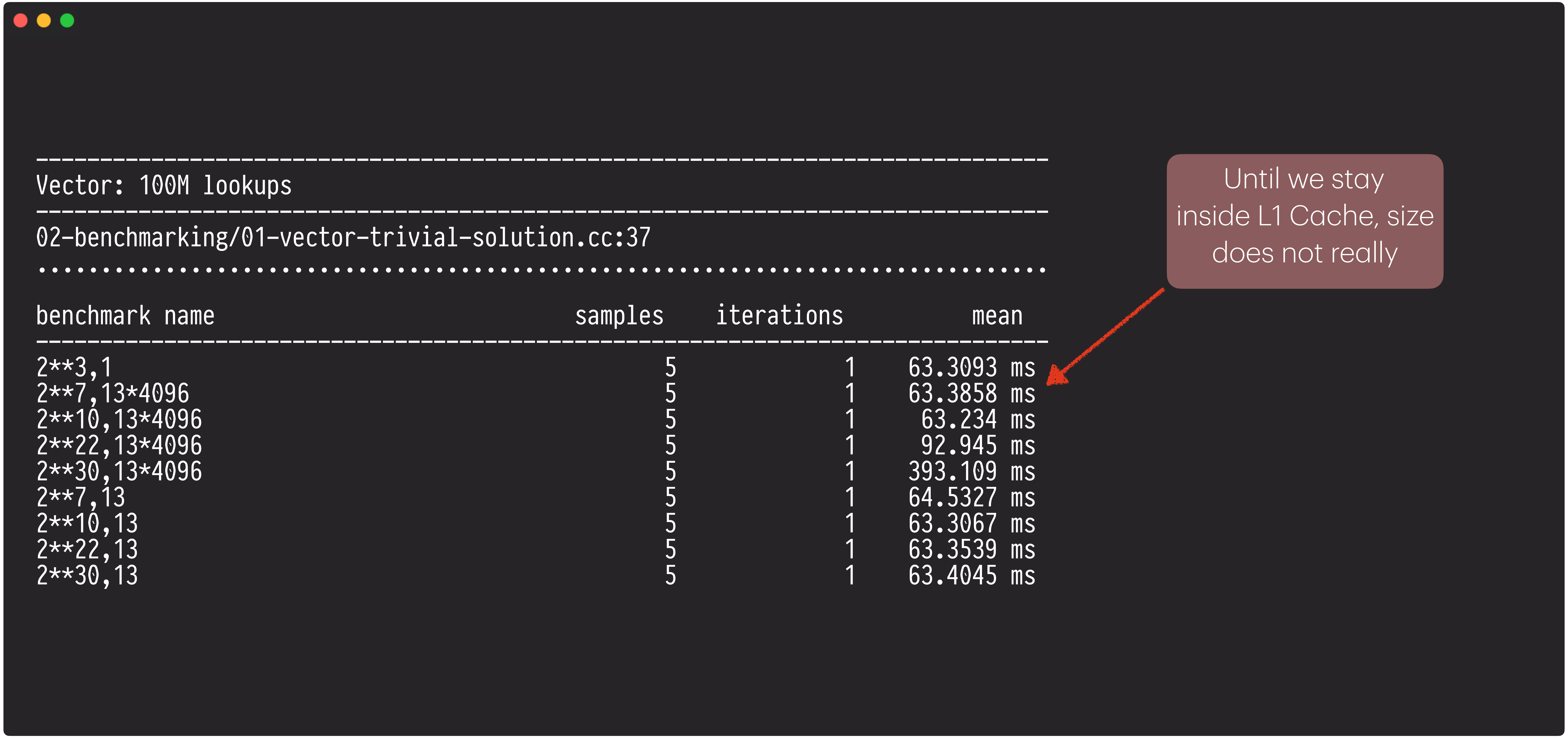


```
your-laptop > ssh <your-cern-account>@lxplus9.cern.ch
# eulisse at lxplus903.cern.ch in ~ [13:45:14]

lxplus903.cern.ch > source ~eulisse/public/csc/exercises.sh
MODULEPATH=/cvmfs/alice.cern.ch/el9-x86_64/Modules/modulefiles:/cvmfs/alice.cern.ch/etc/toolchain/modulefiles/el9-x86_64 ; export
MODULEPATH

lxplus903.cern.ch > module load IgProf/5.9.18-1 Catch2/v3.7.0-3
Loading IgProf/5.9.18-1
  Loading requirement: BASE/1.0 libunwind/v1.6.2-1

Loading Catch2/v3.7.0-3
  Loading requirement: jq/v1.6-alice1-2 grid-base-packages/default Toolchain/GCC-v13.2.0 GCC-Toolchain/v13.2.0-alice1-1

lxplus903.cern.ch > type igprof
igprof is /cvmfs/alice.cern.ch/el9-x86_64/Packages/IgProf/5.9.18-1/bin/igprof

lxplus903.cern.ch > type c++
c++ is /cvmfs/alice.cern.ch/el9-x86_64/Packages/GCC-Toolchain/v12.2.0-alice1-4/bin/c++
```

Preconfigured build / profiling environment in case you need one.

SPOILER ALERT!

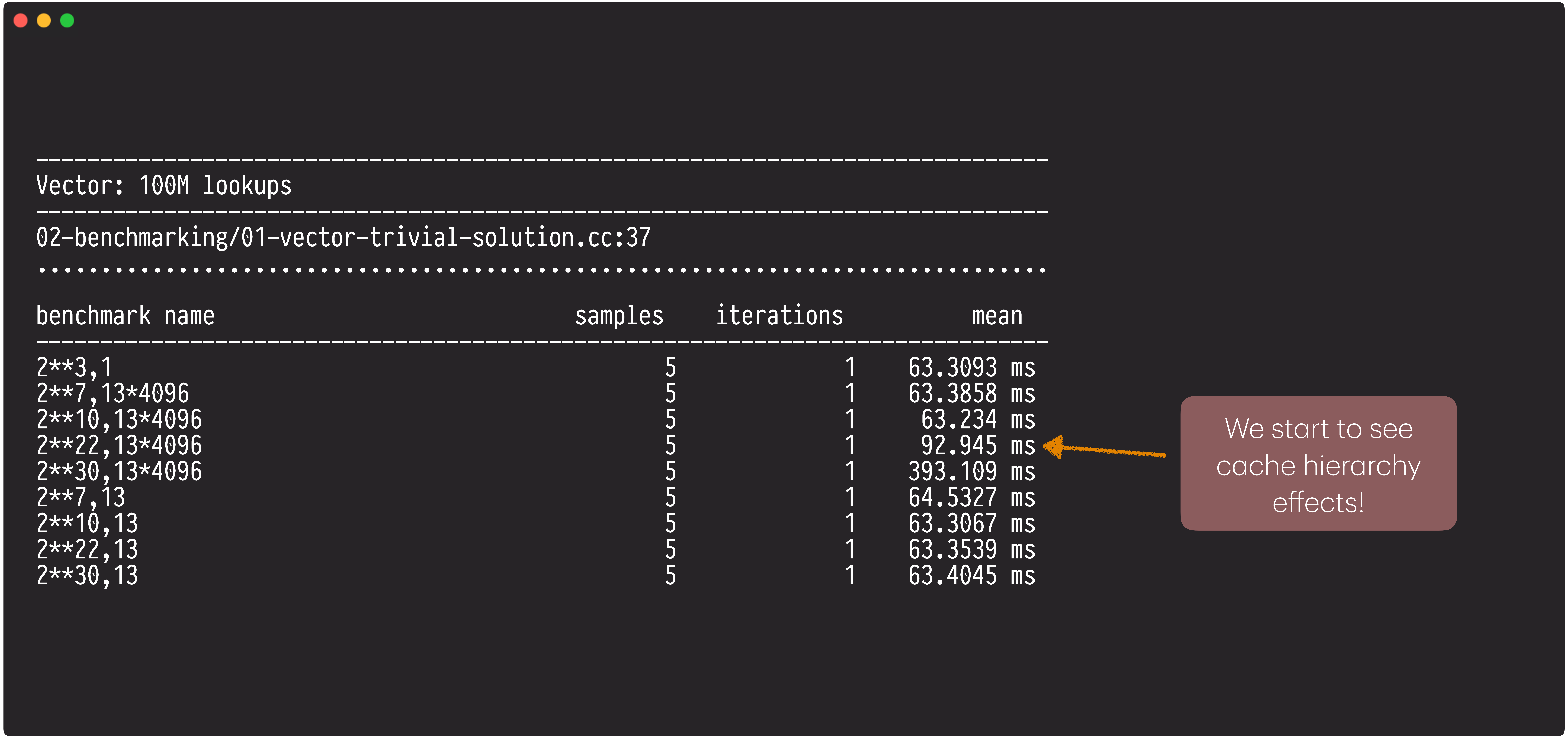
Ex 1: Trivial Vector benchmarking



```
-------------------------------------------------------------------------------
Vector: 100M lookups
-------------------------------------------------------------------------------
02-benchmarking/01-vector-trivial-solution.cc:37
...............................................................................

benchmark name                            samples    iterations          mean
-------------------------------------------------------------------------------
2**3,1                                           5             1    63.3093 ms
2**7,13*4096                                     5             1    63.3858 ms
2**10,13*4096                                    5             1     63.234 ms
2**22,13*4096                                    5             1     92.945 ms
2**30,13*4096                                    5             1    393.109 ms
2**7,13                                          5             1    64.5327 ms
2**10,13                                         5             1    63.3067 ms
2**22,13                                         5             1    63.3539 ms
2**30,13                                         5             1    63.4045 ms
```

Until we stay inside L1 Cache, size does not really

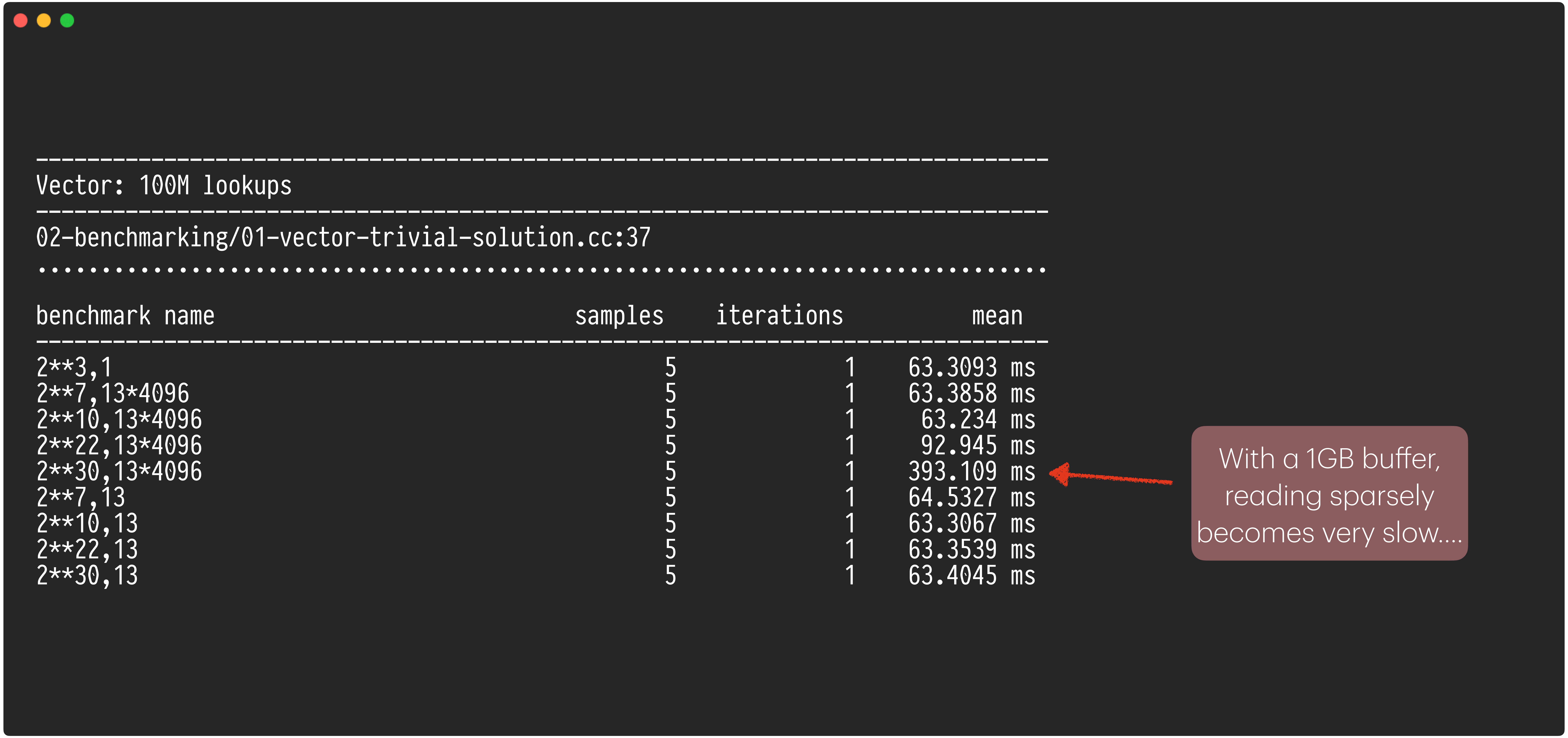
Ex 1: Trivial Vector benchmarking



```
-------------------------------------------------------------------------------
Vector: 100M lookups
-------------------------------------------------------------------------------
02-benchmarking/01-vector-trivial-solution.cc:37
...............................................................................

benchmark name                          samples    iterations          mean
-------------------------------------------------------------------------------
2**3,1                                        5             1    63.3093 ms
2**7,13*4096                                  5             1    63.3858 ms
2**10,13*4096                                 5             1     63.234 ms
2**22,13*4096                                 5             1     92.945 ms
2**30,13*4096                                 5             1    393.109 ms
2**7,13                                       5             1    64.5327 ms
2**10,13                                      5             1    63.3067 ms
2**22,13                                      5             1    63.3539 ms
2**30,13                                      5             1    63.4045 ms
```

We start to see cache hierarchy effects!

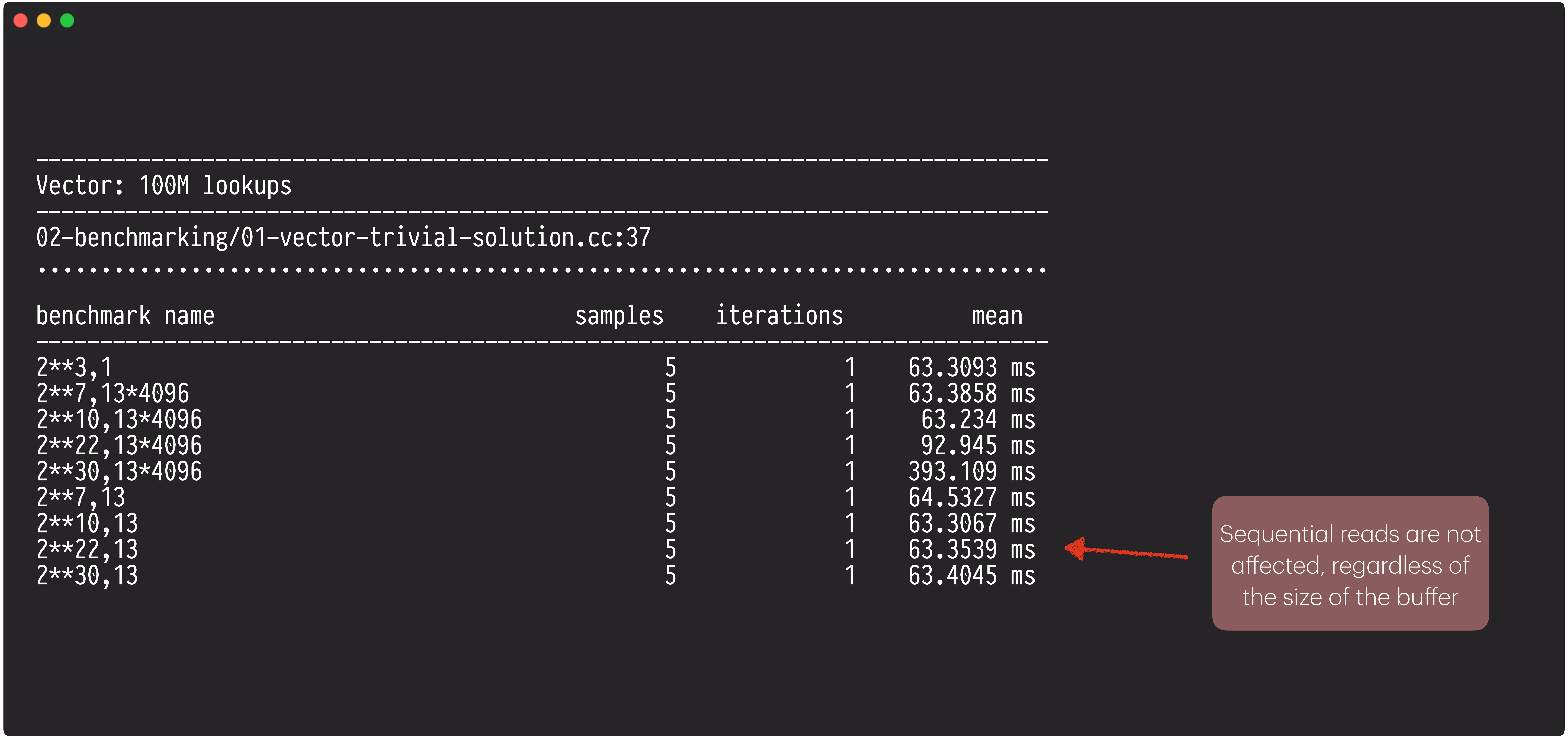
Ex 1: Trivial Vector benchmarking



```
-------------------------------------------------------------------------------
Vector: 100M lookups
-------------------------------------------------------------------------------
02-benchmarking/01-vector-trivial-solution.cc:37
...............................................................................

benchmark name                            samples    iterations          mean
-------------------------------------------------------------------------------
2**3,1                                           5             1    63.3093 ms
2**7,13*4096                                     5             1    63.3858 ms
2**10,13*4096                                    5             1     63.234 ms
2**22,13*4096                                    5             1     92.945 ms
2**30,13*4096                                    5             1    393.109 ms
2**7,13                                          5             1    64.5327 ms
2**10,13                                         5             1    63.3067 ms
2**22,13                                         5             1    63.3539 ms
2**30,13                                         5             1    63.4045 ms
```

With a 1GB buffer, reading sparsely becomes very slow....

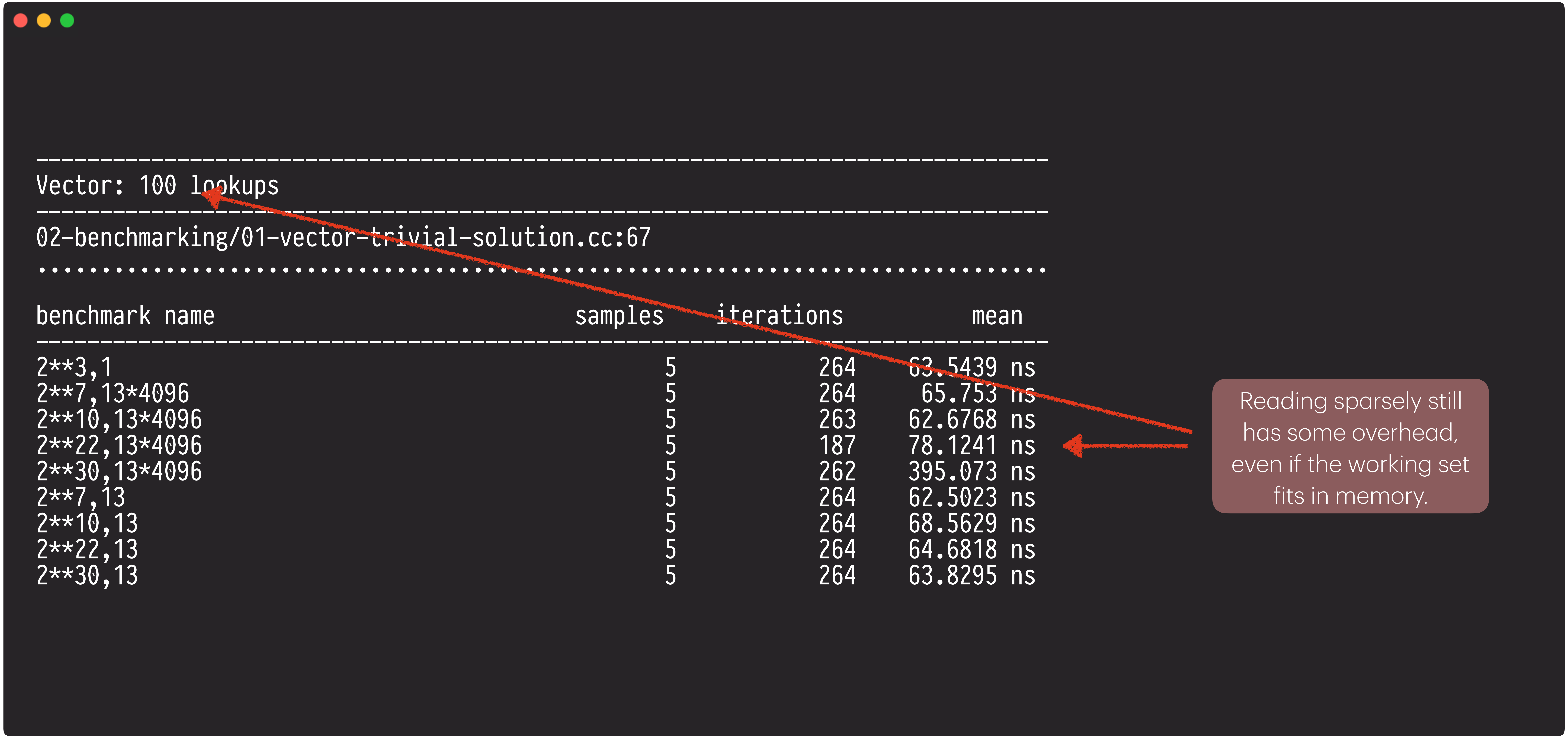
Ex 1: Trivial Vector benchmarking



```
-------------------------------------------------------------------------------
Vector: 100M lookups
-------------------------------------------------------------------------------
02-benchmarking/01-vector-trivial-solution.cc:37
...............................................................................

benchmark name                            samples    iterations          mean
-------------------------------------------------------------------------------
2**3,1                                           5             1    63.3093 ms
2**7,13*4096                                     5             1    63.3858 ms
2**10,13*4096                                    5             1     63.234 ms
2**22,13*4096                                    5             1     92.945 ms
2**30,13*4096                                    5             1    393.109 ms
2**7,13                                          5             1    64.5327 ms
2**10,13                                         5             1    63.3067 ms
2**22,13                                         5             1    63.3539 ms
2**30,13                                         5             1    63.4045 ms
```

Sequential reads are not affected, regardless of the size of the buffer

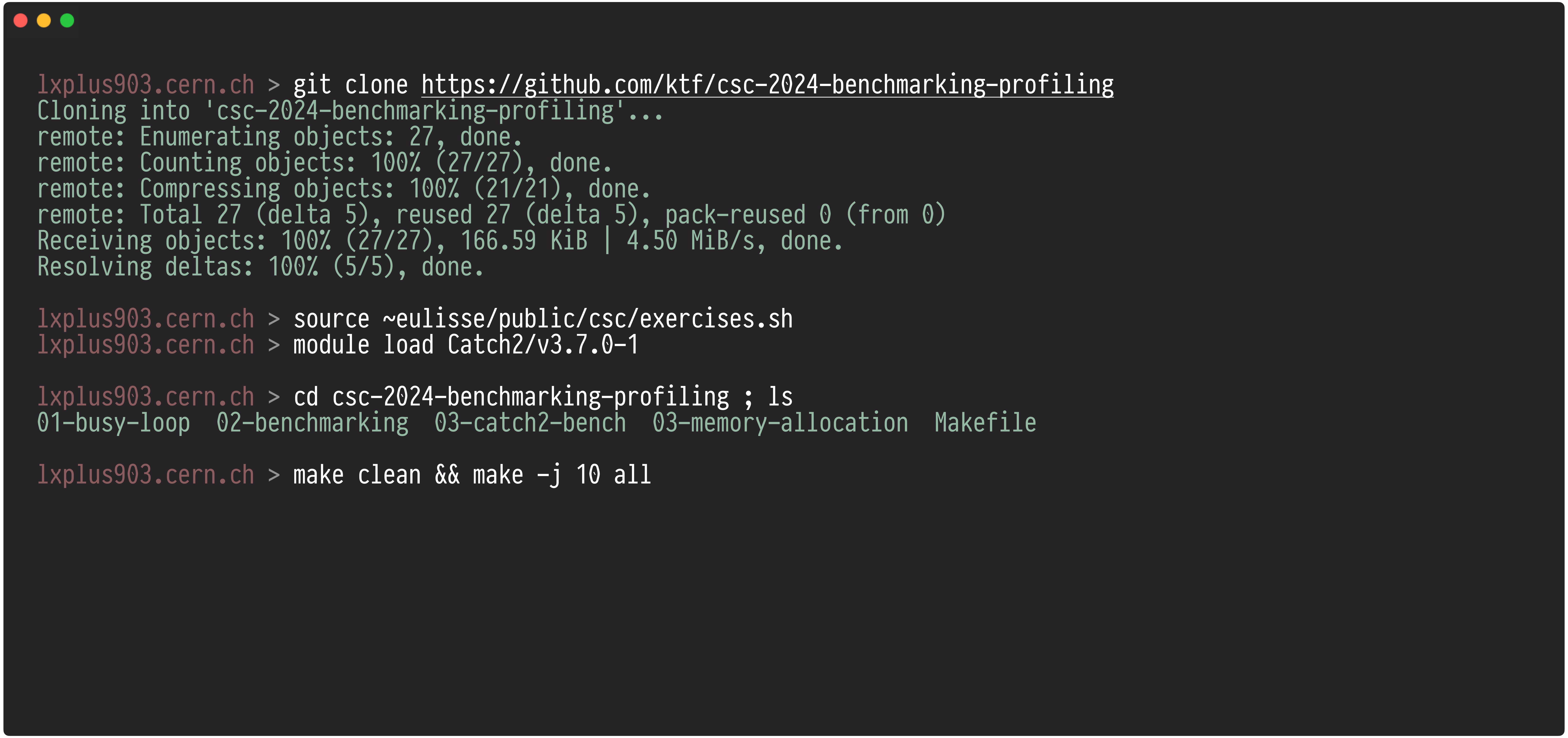
Ex 1: Trivial Vector benchmarking



```
-------------------------------------------------------------------------------
Vector: 100 lookups
-------------------------------------------------------------------------------
02-benchmarking/01-vector-trivial-solution.cc:67
...............................................................................

benchmark name                                  samples    iterations       mean
-------------------------------------------------------------------------------
2**3,1                                                5           264  63.5439 ns
2**7,13*4096                                          5           264   65.753 ns
2**10,13*4096                                         5           263  62.6768 ns
2**22,13*4096                                         5           187  78.1241 ns
2**30,13*4096                                         5           262  395.073 ns
2**7,13                                               5           264  62.5023 ns
2**10,13                                              5           264  68.5629 ns
2**22,13                                              5           264  64.6818 ns
2**30,13                                              5           264  63.8295 ns
```

Reading sparsely still has some overhead, even if the working set fits in memory.

Getting the sources for the exercises



```
lxplus903.cern.ch > git clone https://github.com/ktf/csc-2024-benchmarking-profiling
Cloning into 'csc-2024-benchmarking-profiling'...
remote: Enumerating objects: 27, done.
remote: Counting objects: 100% (27/27), done.
remote: Compressing objects: 100% (21/21), done.
remote: Total 27 (delta 5), reused 27 (delta 5), pack-reused 0 (from 0)
Receiving objects: 100% (27/27), 166.59 KiB | 4.50 MiB/s, done.
Resolving deltas: 100% (5/5), done.

lxplus903.cern.ch > source ~eulisse/public/csc/exercises.sh
lxplus903.cern.ch > module load Catch2/v3.7.0-1

lxplus903.cern.ch > cd csc-2024-benchmarking-profiling ; ls
01-busy-loop  02-benchmarking  03-catch2-bench  03-memory-allocation  Makefile

lxplus903.cern.ch > make clean && make -j 10 all
```