



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA



CINECA

ETH zürich

# Monte Cimone v2: Down the Road of RISC-V High-Performance Computers

**Emanuele Venieri**<sup>1</sup>, Simone Manoni<sup>1</sup>, Giacomo Madella<sup>1</sup>, Federico Ficarelli<sup>2</sup>,  
Daniele Gregori<sup>3</sup>, Daniele Cesarini<sup>2</sup>, Luca Benini<sup>1,4</sup>, Andrea Bartolini<sup>1</sup>

<sup>1</sup>University of Bologna, Italy, <sup>2</sup>CINECA, Italy, <sup>3</sup>E4 Company S.p.A., <sup>4</sup>ETH Zürich Switzerland

[emanuele.venieri2@unibo.it](mailto:emanuele.venieri2@unibo.it)





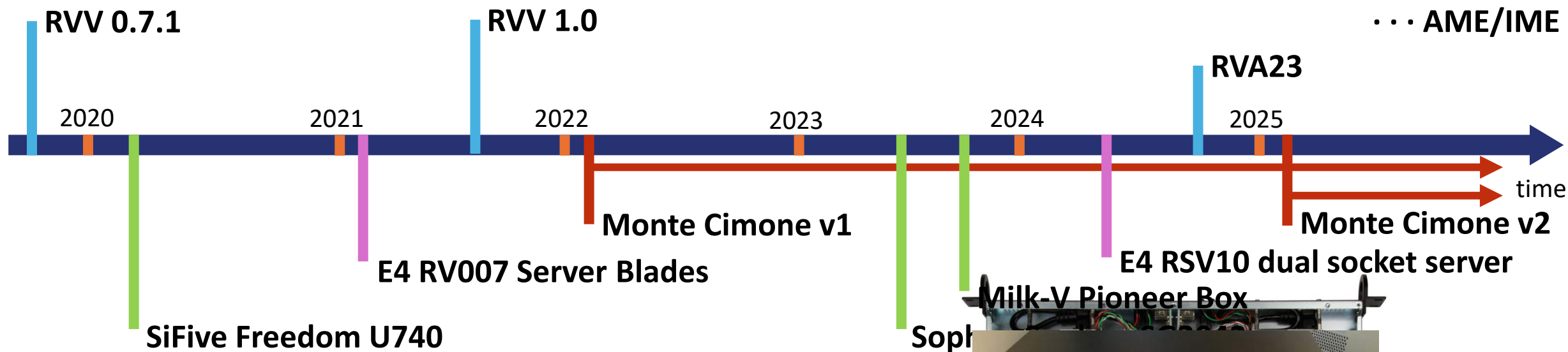
# Outline

- RISC-V & HPC
- Monte Cimone
- Performance evaluation
- BLAS vectorization
- Results

# RISC-V & HPC

- HPC platform requirements:
  - High core count + vector/matrix extensions
  - Large amount of system memory
  - PCIe support (accelerators, network cards, fast storage)
  - Software: OS, job schedulers, monitoring systems, packages and libraries
- RISC-V is mature in embedded domain
- How to foster RISC-V ISA uptake in HPC?

# RISC-V HPC timeline



## SiFive Freedom U740

- 16x PCIe-4
- 2x CCIX
- 512GT/s



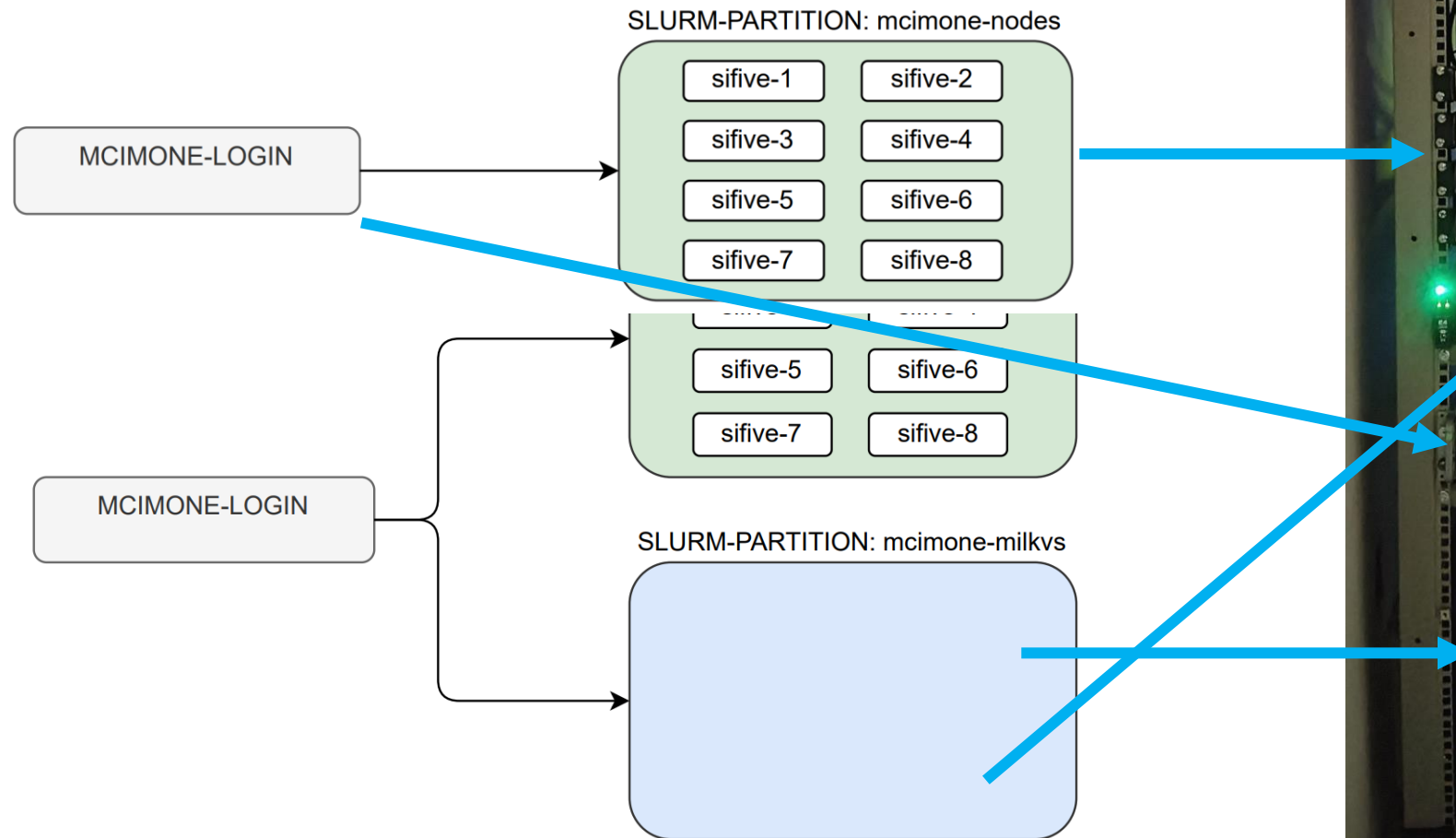
## E4 RSV10 dual socket server

- Single socket 1600W form
- 128GB RAM 54GC Op 7V
- 3-levels cache system
- ECC DDR4 memory
- 32 PCIe Gen 4 lanes



# Monte Cimone v2 bring up

Starting SLURM partition





# Cluster environment

- SLURM
- Examon
- Shared NFS
- Spack + new tools
  - New compilers:
    - Xuantie GNU Toolchain
    - GCC 14
  - New BLAS libraries:
    - OpenBLAS
    - BLIS with our optimized kernel

MCIMONE-LOGIN



Terminal output showing Spack module lists for SLURM:

```

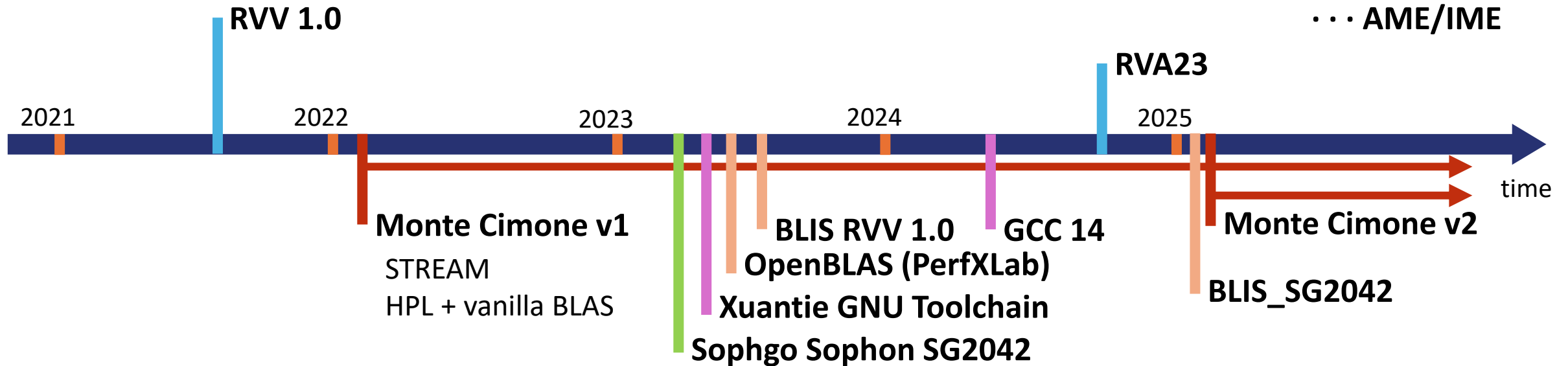
/opt/share/spack/modules/linux-f
-----
SLURM autoconf/2.69/gcc-13.1.1-qhn4yrq
      automake/1.16.3/gcc-13.1.1-7nxi645
      berkeley-db/18.1.40/gcc-13.1.1-lxhzsx5
      berkeley-db/18.1.40/gcc-13.2.1-hp5nxy
      bzip2/1.0.8/gcc-13.1.1-ng7qlnb
      bzip2/1.0.8/gcc-13.2.1-5ftm54j
      cmake/3.21.4/gcc-13.1.1-miqhn23
      cmake/3.21.4/gcc-13.2.1-gmkgtyz
      diffutils/3.8/gcc-13.1.1-rstfsbg
      diffutils/3.8/gcc-13.2.1-6ymjvui
      expat/2.4.1/gcc-13.2.1-psiody2
      fftw/3.3.10/gcc-13.1.1-openmpi-h7dvbht
      gdbm/1.19/gcc-13.1.1-vvnxcvx
      gdbm/1.19/gcc-13.2.1-poile56
      gettext/0.21/gcc-13.2.1-q4ysmpw
      gnuconfig/2021-08-14/gcc-13.1.1-ukvdjeo
      gnuconfig/2021-08-14/gcc-13.2.1-6e7nxx6
      gromacs/2021.3/gcc-13.1.1-openmp-openblas-openmpi-cppmmcj
      hpl/2.3/gcc-13.1.1-netlib-openmpi-2kp2xmy
      hpl/2.3/gcc-13.1.1-openblas-openmpi-l65lo5i
      hpl/2.3/gcc-13.1.1-openmp-openblas-openmpi-mlxx6me
      hwloc/2.6.0/gcc-13.1.1-gjnxly5
      hwloc/2.6.0/gcc-13.2.1-vdbjczp
      libbsd/0.11.3/gcc-13.2.1-zhfrago
      libedit/3.1-20210216/gcc-13.1.1-2xstcc7
      libedit/3.1-20210216/gcc-13.2.1-wyvqcir
      libevent/2.1.12/gcc-13.1.1-v6fvwbk
      libffi/3.3/gcc-13.2.1-ng3lwp7
      libiconv/1.16/gcc-13.1.1-5h2j62z
      libiconv/1.16/gcc-13.2.1-pl6wjmc
      libmd/1.0.3/gcc-13.2.1-6c34tq7
      libpciaccess/0.16/gcc-13.1.1-74m3dl+
      libpciaccess/0.16/gcc-13.2.1-4qgzgo
      libsigsegv/2.13/gcc-13.1.1-ershg6
      libsigsegv/2.13/gcc-13.2.1-lxya2dy
      libtool/2.4.6/gcc-13.1.1-4ez6fpq
      libtool/2.4.6/gcc-13.2.1-3t47ydt
      libxml2/2.9.12/gcc-13.1.1-7nxi645
      libxml2/2.9.12/gcc-13.2.1-6e7nxx6
      m4/1.4.19/gcc-13.1.1-7nxi645
      m4/1.4.19/gcc-13.2.1-6e7nxx6
      ncurses/6.2/gcc-13.1.1-7nxi645
      ncurses/6.2/gcc-13.2.1-6e7nxx6
      netlib-lapack/3.9.1/gcc-13.1.1-7nxi645
      netlib-scalapack/2.10.0/gcc-13.1.1-7nxi645
      numactl/2.0.14/gcc-13.1.1-lusuzino
      openblas-openmpi-jk64vvy
      openblas-openmpi-jk64vvy
      openmpi
      openssl
      openssl
      openssl
      pcre/8.44/gcc-13.1.1-7nxi645
      perl-data
      perl/5.34.0/gcc-13.1.1-7nxi645
      perl/5.34.0/gcc-13.2.1-6e7nxx6
      pkgconf
      pkgconf
      python/3.9.13/gcc-13.1.1-7nxi645
      readline
      readline
      slurm/22.02.0
      sqlite/3.39.0
      swig/4.0.1
      tar/1.34
      util-linux
      util-macros
      util-macros
      xz/5.2.5
      xz/5.2.5
      z3/4.8.10
      zlib/1.2.12
      zlib/1.2.12
  
```

Overlaid text and images:

- Cartoon cow with "GCC" text
- Matrix equation: 
$$\begin{bmatrix} Op \\ BL \end{bmatrix}^T \times \begin{bmatrix} en \\ AS \end{bmatrix}$$
- Sleeping kitten



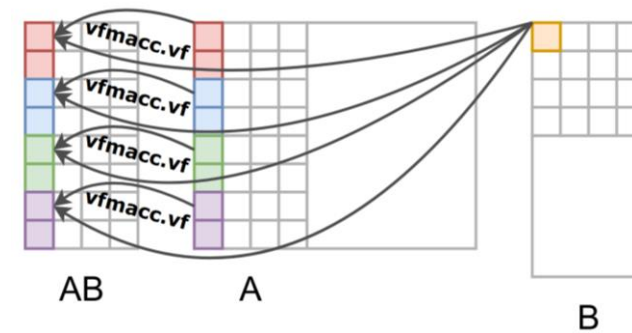
# Monte Cimone v2 benchmark



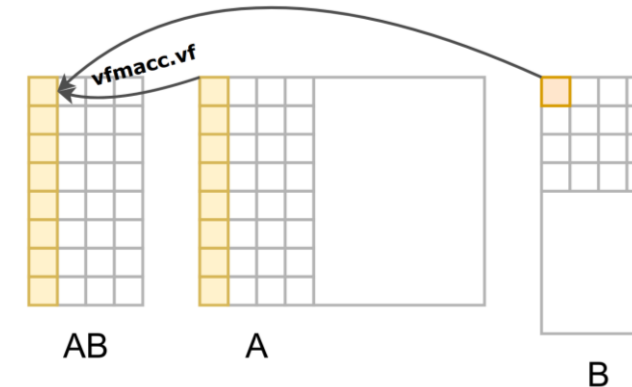
- **Performance assessment of new hardware:**
  - STREAM
  - HPL + OpenBLAS w/ Xuantie GNU Toolchain
- **BLIS library adapting and optimization:**
  - Developing an alternative for the community compilable with stock GCC 14
  - Improving found suboptimal micro-kernel

# BLIS kernels optimization

- BLIS comes with RVV 1.0 generic micro-kernels written in assembly for DGEMM
- SG2042 has an RVV 0.7.1 vector unit, GCC 14 supports it as theadvector
- Steps of our BLIS micro-kernel optimization:
  - Porting from RVV 1.0 to 0.7.1
  - First tests: suboptimal implementation
  - Optimization using register grouping



BLIS  
vectorization  
strategy



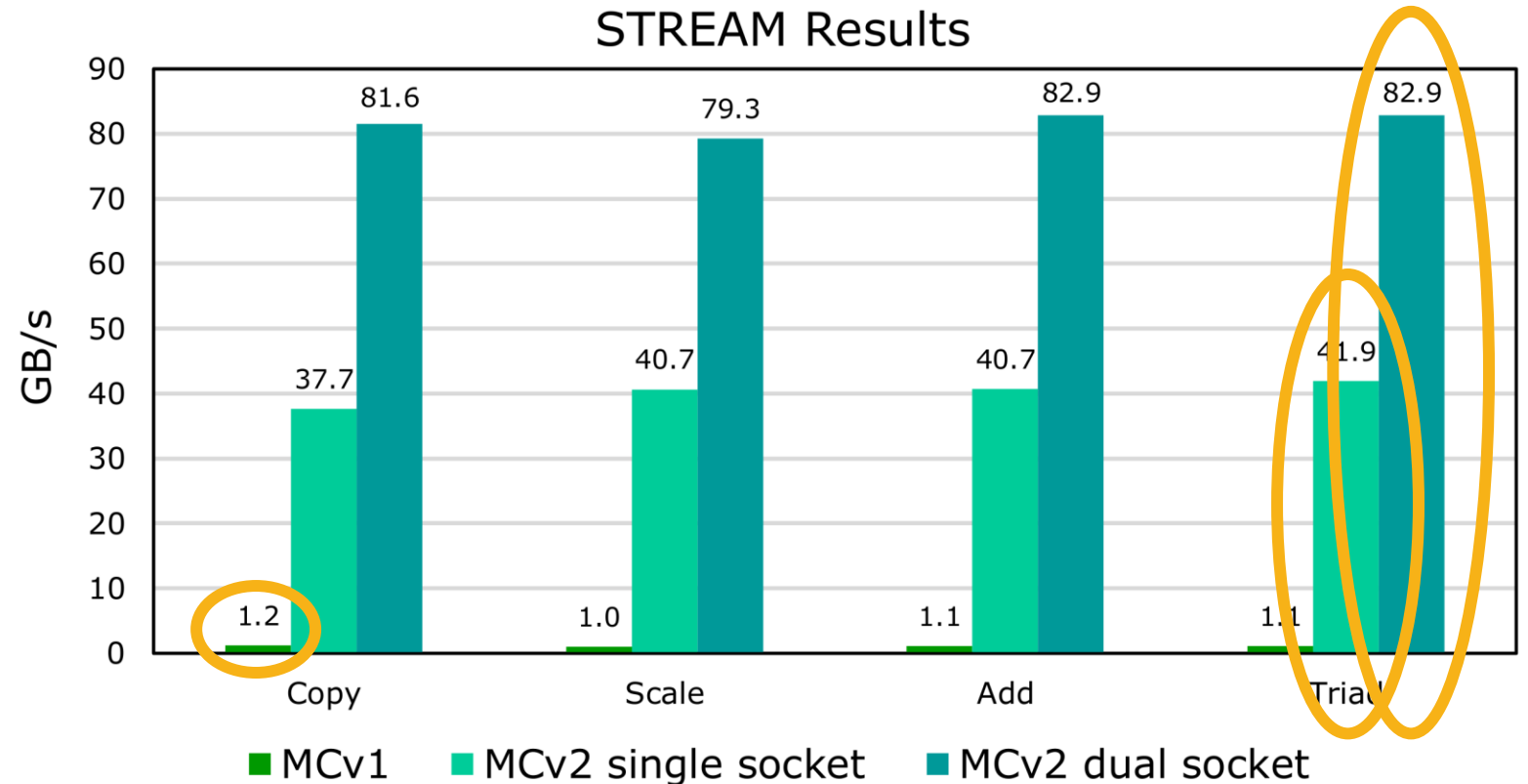
Our  
optimization  
strategy





# STREAM Results

- **Monte Cimone v1 node:**
  - Max: 1.2 GB/s
- **Milk-V Pioneer Box:**
  - 64 threads
  - 4 memory channels
  - Max: 41.9 GB/s
- **E4 RSV10 dual socket:**
  - 64 threads
  - 8 memory channels
  - Max: 82.9 GB/s



# HPL Results

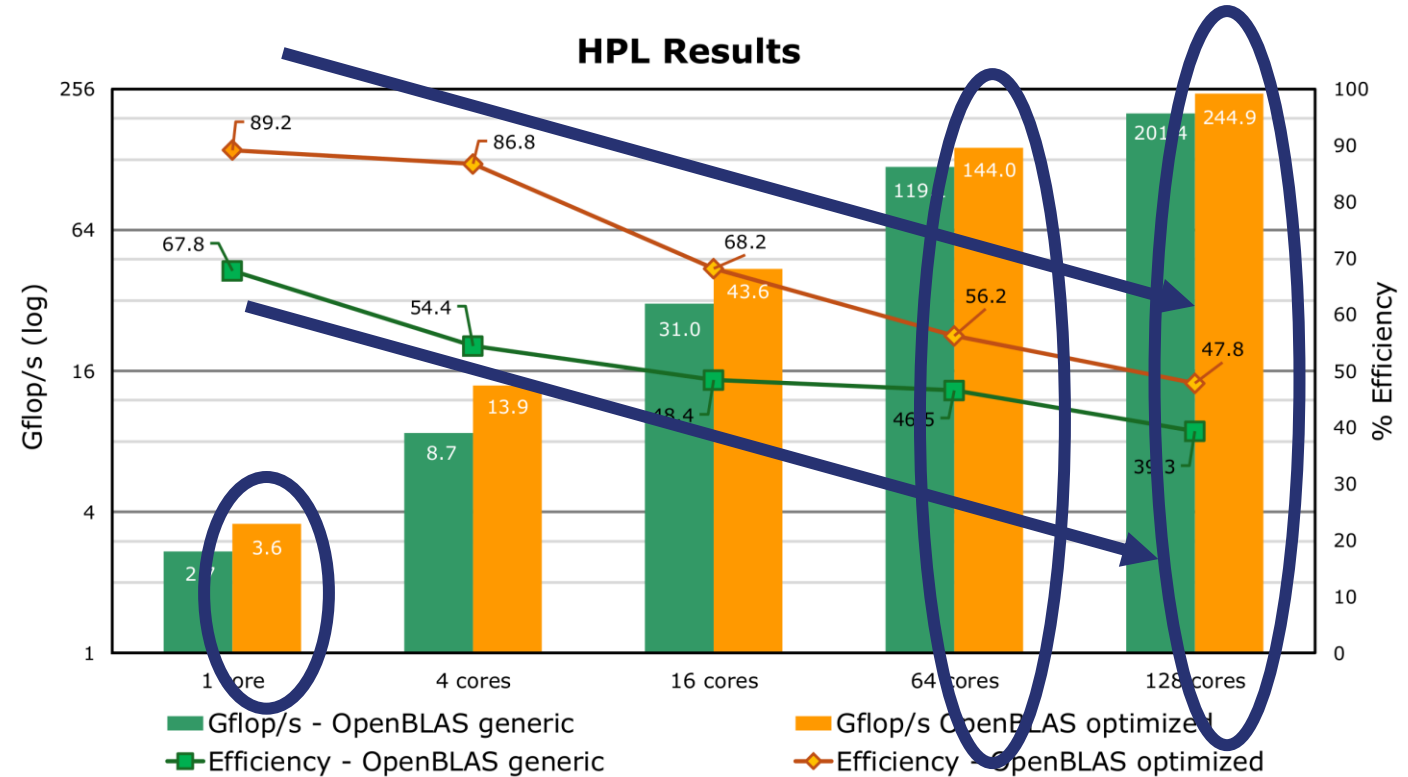
- **Reference results of SG2042:**

- HPL + vanilla OpenBLAS
- HPL + optimized OpenBLAS

- **Single nodes performance:**

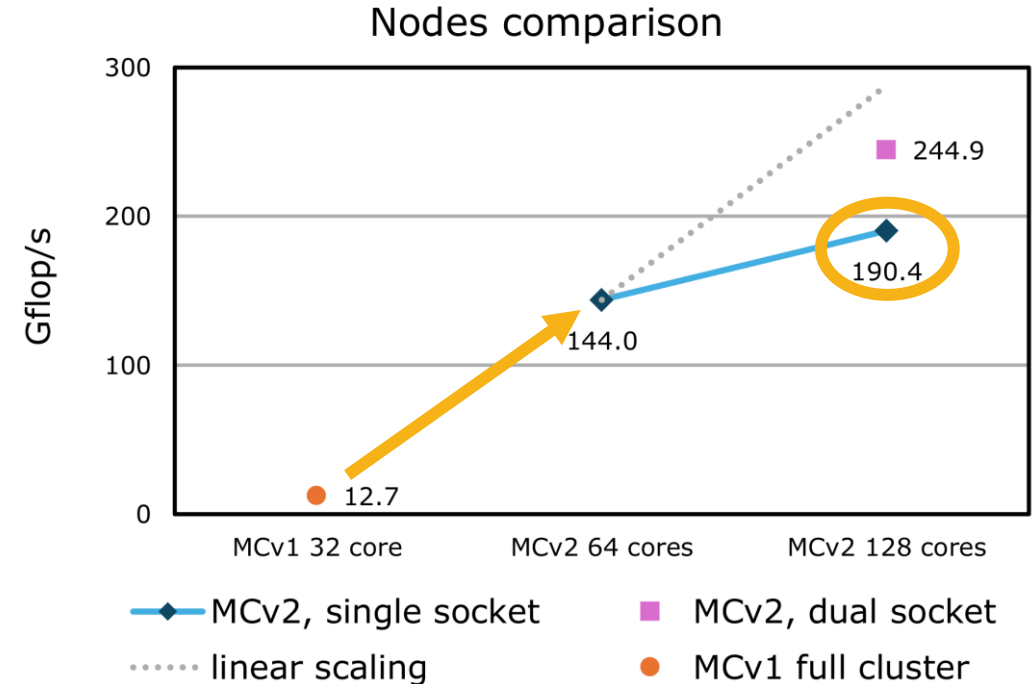
- 1 core:
  - 3.6 Gflop/s
- 64 cores:
  - 144 Gflop/s
- 128 cores:
  - 244.9 Gflop/s

- Decreasing efficiency with incremental core count
- Optimized OpenBLAS experience the same bottlenecks as vanilla ones
- The bottleneck was identified as the memory subsystem



# HPL Results

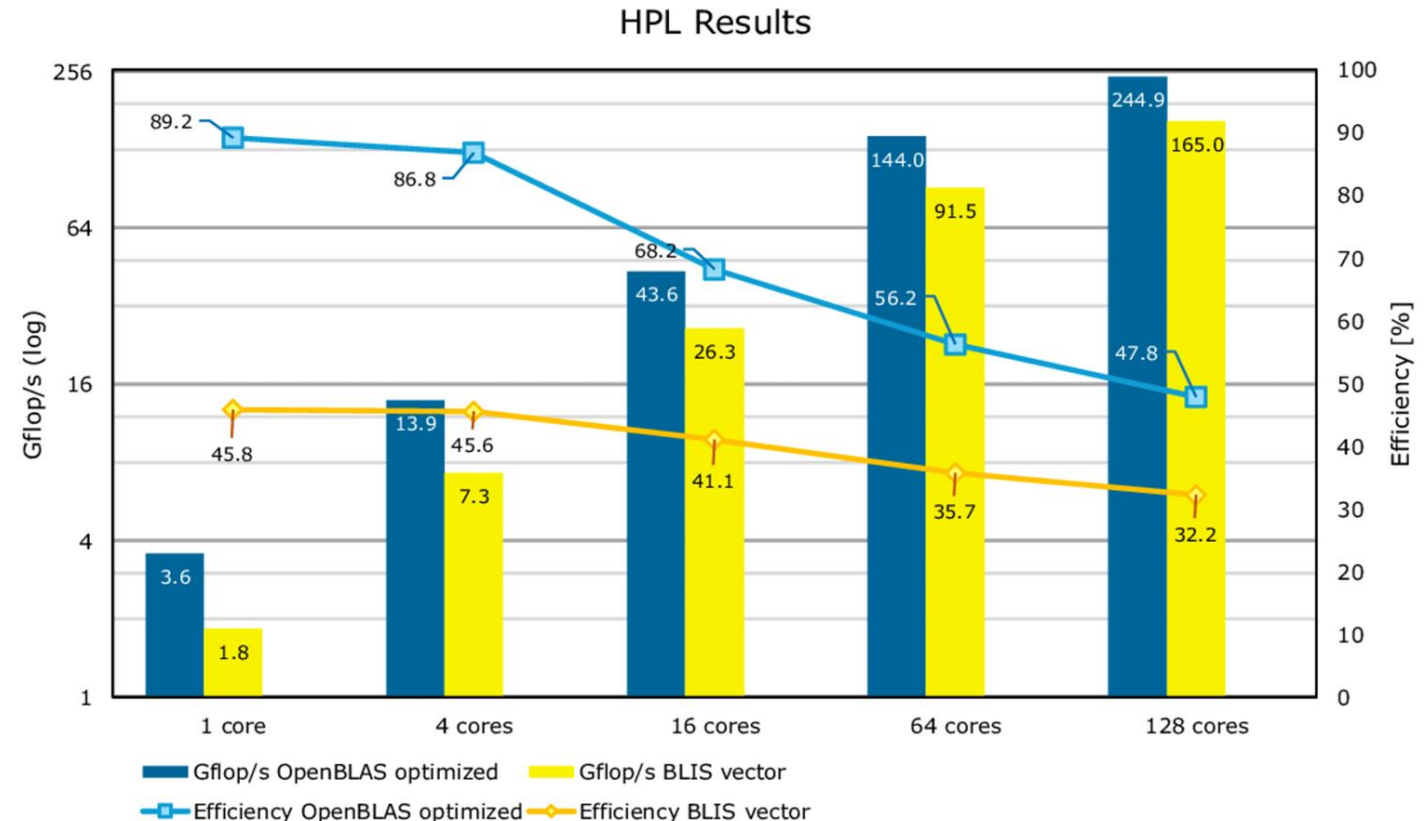
- **MCv1 full cluster:**
  - Linear scaling in multi node runs
  - HPL: 12.65 Gflop/s
- **MCv2 single node, single socket:**
  - 64 cores
  - HPL: 144.0 Gflop/s
- **MCv2 dual node, single socket:**
  - 128 cores
  - Ethernet 1Gbit/s network
  - HPL: 190.4 Gflop/s



- **MCv2 single node, dual socket:**
  - 128 cores
  - On board communication
  - HPL: 244.9 Gflop/s

# HPL BLIS Results

- The available vectorized BLIS micro-kernel performed poorly
- Boost in performance post optimization:
  - 49% w.r.t. original vectorized BLIS (dual socket and 128 core runs)
  - Performance on par with OpenBLAS
  - Effectiveness of register grouping



# Conclusions

- MCv1 vs. MCv2: rapidly evolving RISC-V ecosystem
  - Analysis of the first server style platforms
  - In two years a performance improvement obtained in average in eight years (Top500)
- BLIS library optimization:
  - Feasibility of enhancing RISC-V software ecosystem
  - Contributed to the HPC community

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