GENE-X and BOUT++

ACH Annual Meeting
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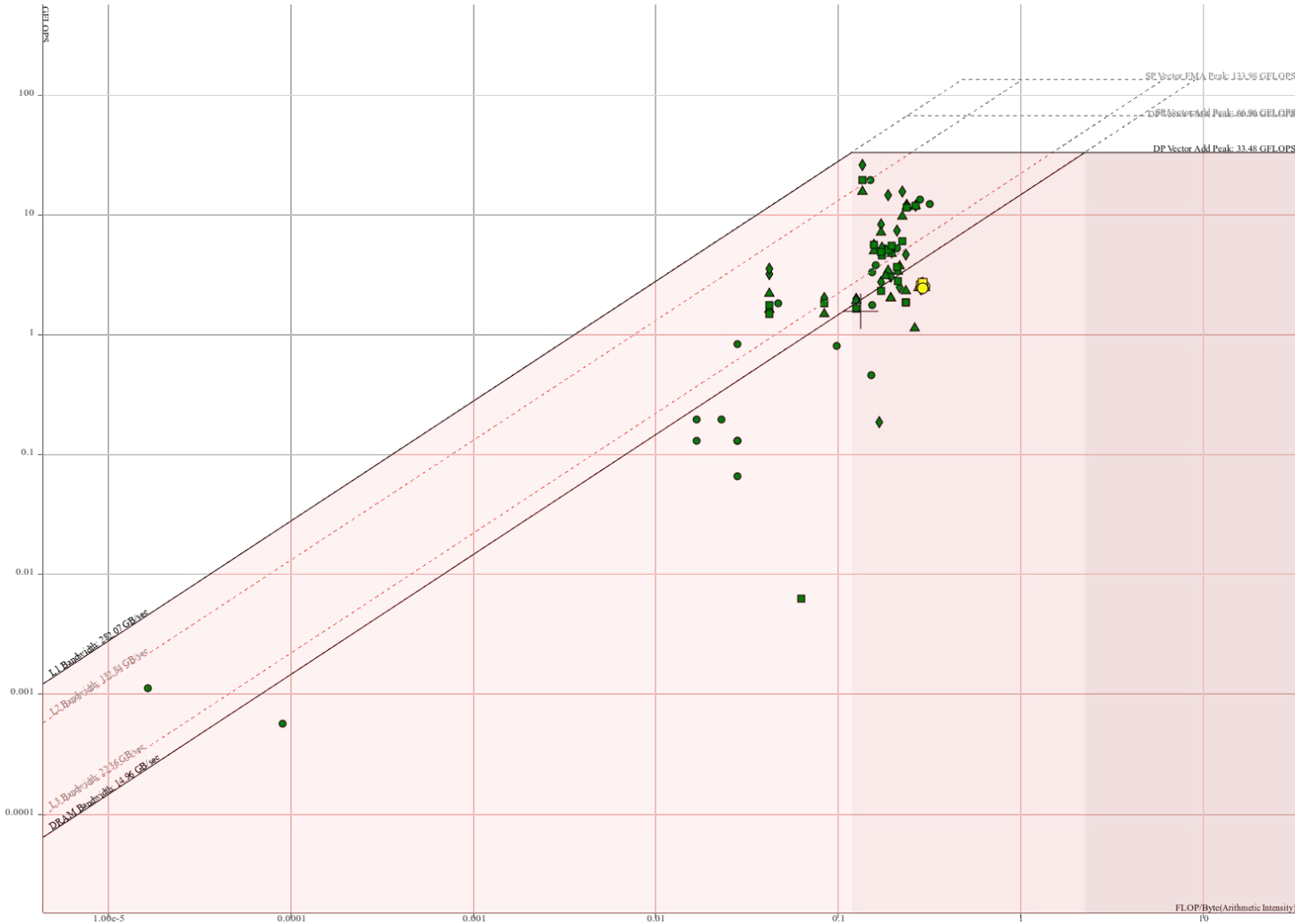# GENE-X

Gyrokinetic code to simulate plasma turbulence
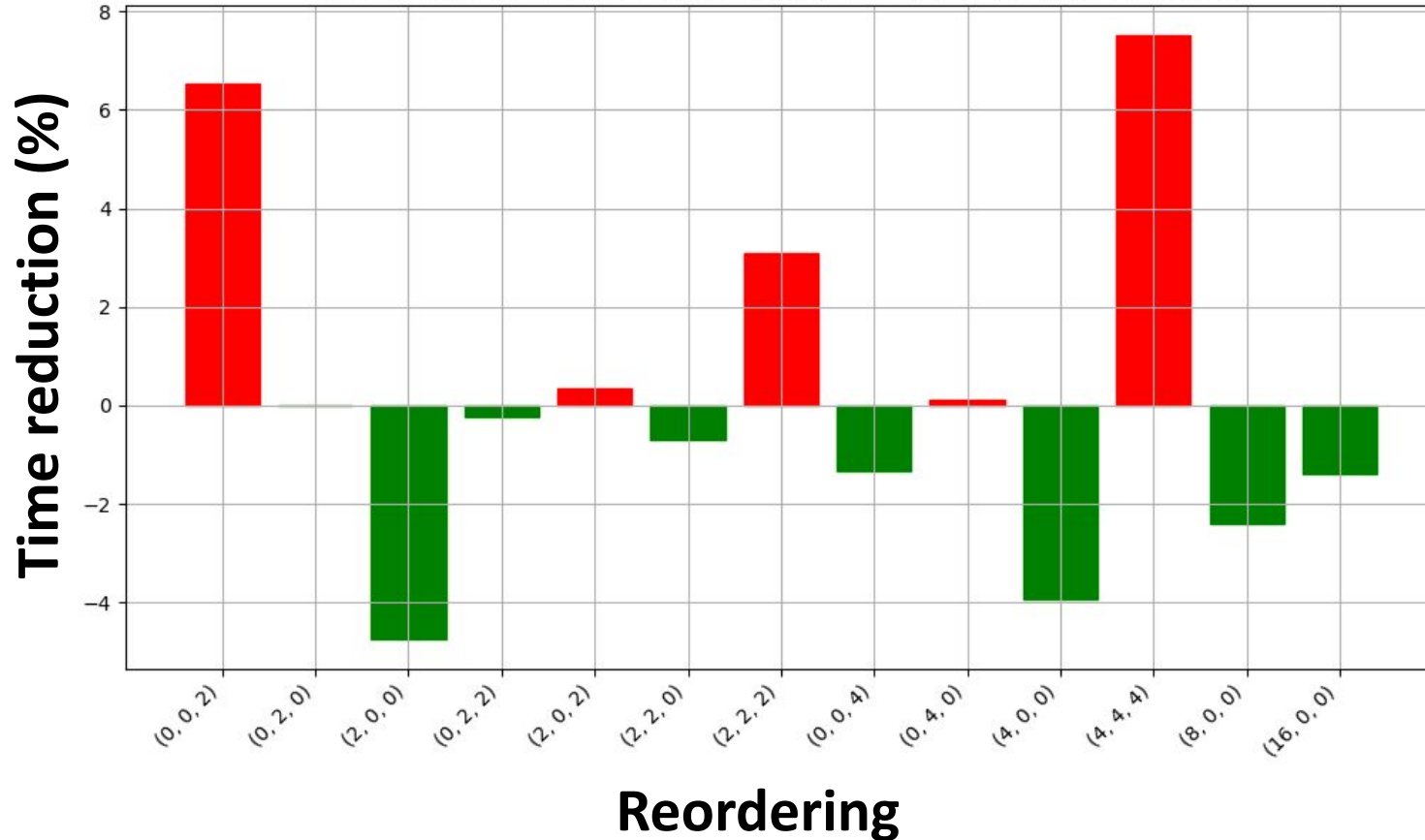in X-point geometries in tokamaks and stellarators.

Work required into ACH: Assessment of reordering algorithm using a
multigrid approach to increase cache efficiency and reduce simulation time.

MARENOSTRUM 4

- **Intel oneAPI** roofline model vectorized to identify the most compute-intensive routines:
  - Vlasov operator
  - Ampère's law
  - Ohm's law
  - Maxwell's equation

LOCAL MACHINE
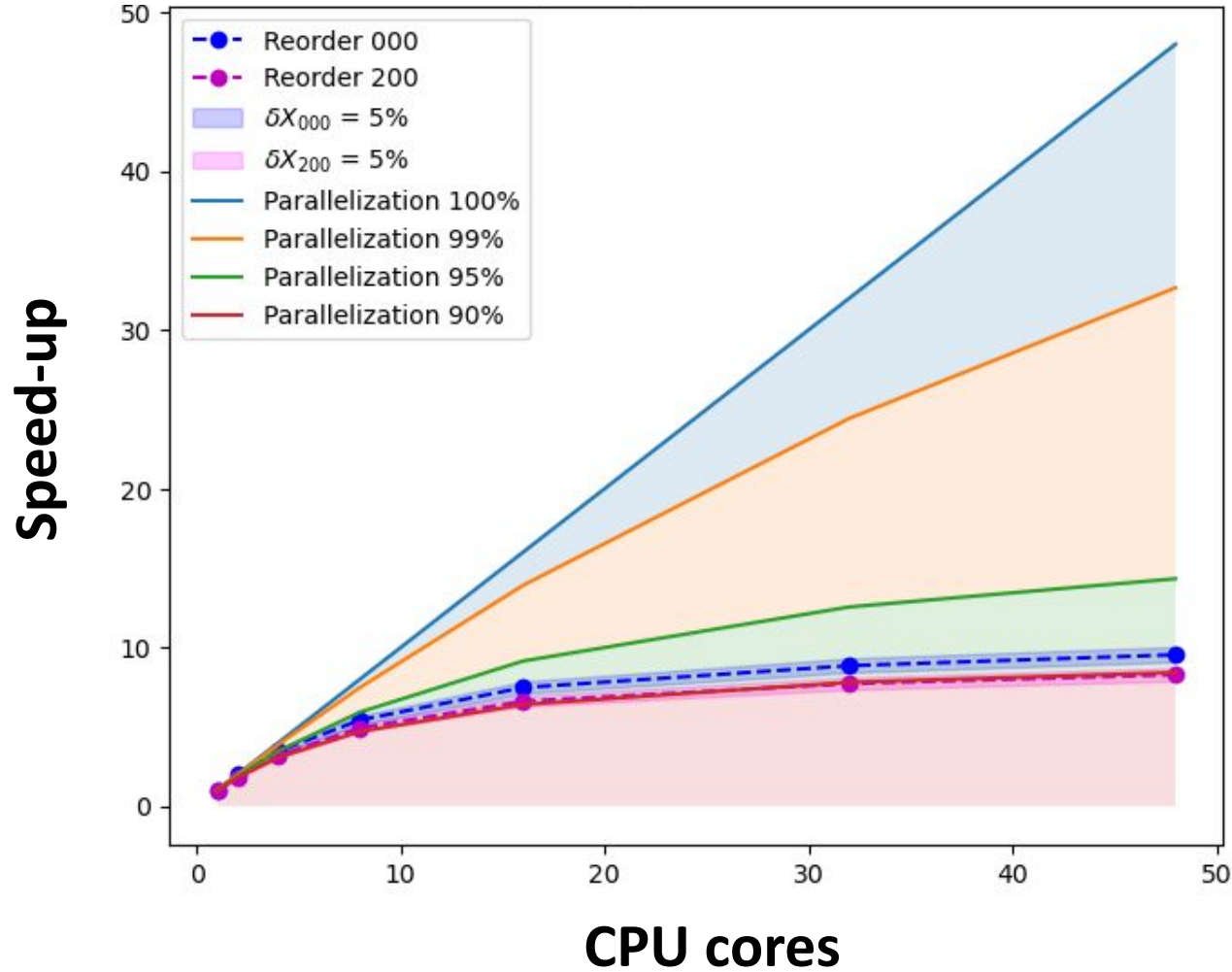
- **Geometry:** non-ITER case
- *benchmark* executable
- **Grid RZ = 0.005**

MARENOSTRUM 5

- **Geometry:** ITER case
- *genex* executable
- Grid RZ: **0.00136, 0.000398 and 0.00005**

MARCONI

- *genex* executable
- **OpenMP ON**
- Grid RZ: **0.001**
- **2 repetitions**
- **Parallelization :**
  - **close to 90%** compared to Amdahl's law.
 - needs a bigger case to obtain higher values.

GENE-X

Reordering (*n_levels = 4*)	[0 0 0 0]	[2 0 0 0]	[4 0 0 0]	[8 0 0 0]
Instructions	1	1	1	1
L3 Cache misses	1	0.34	0.33	0.34
Runtime	1	0.55	0.53	0.54
Relative speed-up	1x	1.81x	1.88x	1.85x
Average IPC	0,69	**1,26**	**1,31**	**1,28**

MARENOSTRUM 5

- **EXTRAE** is a dynamic instrumentation package to trace programs compiled and run with the shared memory model (OpenMP, pthreads), MPI or both.
- **Geometry:** ITER case
- ***benchmark-operators*** executable
- **IPC increase** with reordering in most compute-intensive operators (i.e. vlasov-static)

RZ spacing	n_levels
0.00136	4 5
0.000398	5
0.00005	5 6
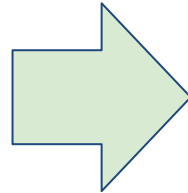
Reordering
00000
20000
40000
42000
80000
84000
84200

MARENOSTRUM 5

- **Geometry:** ITER case
- *genex* executable
- Grid RZ: **0.00136, 0.000398 and 0.00005**
  - **7 reorderings**
  - **3 spacings**
  - **3 multigrid levels.**

SOME PROBLEMS ENCOUNTERED

- **Convergence** of provided case was not appropriate.
- **Change** of main machine: **MareNostrum 4 to MareNostrum 5.**
  - **Compilation libraries** problems
  - **Intel Advisor (oneAPI)** problems in new machine
- **OpenMP parallelization** due to flag KMP_AFFINITY
- **Out Of Memory (OOM)** due to limited memory in standard nodes.
- **EXTRAE** incompatibility with newest GENE-X version.
- **Failed attempt to generalize** reordering vector.
- **Permissions revoked to Git** repositories and sub-repositories.
- **Compilation** via CMake requiring **internet access unavailable** at first stages of MareNostrum 5.
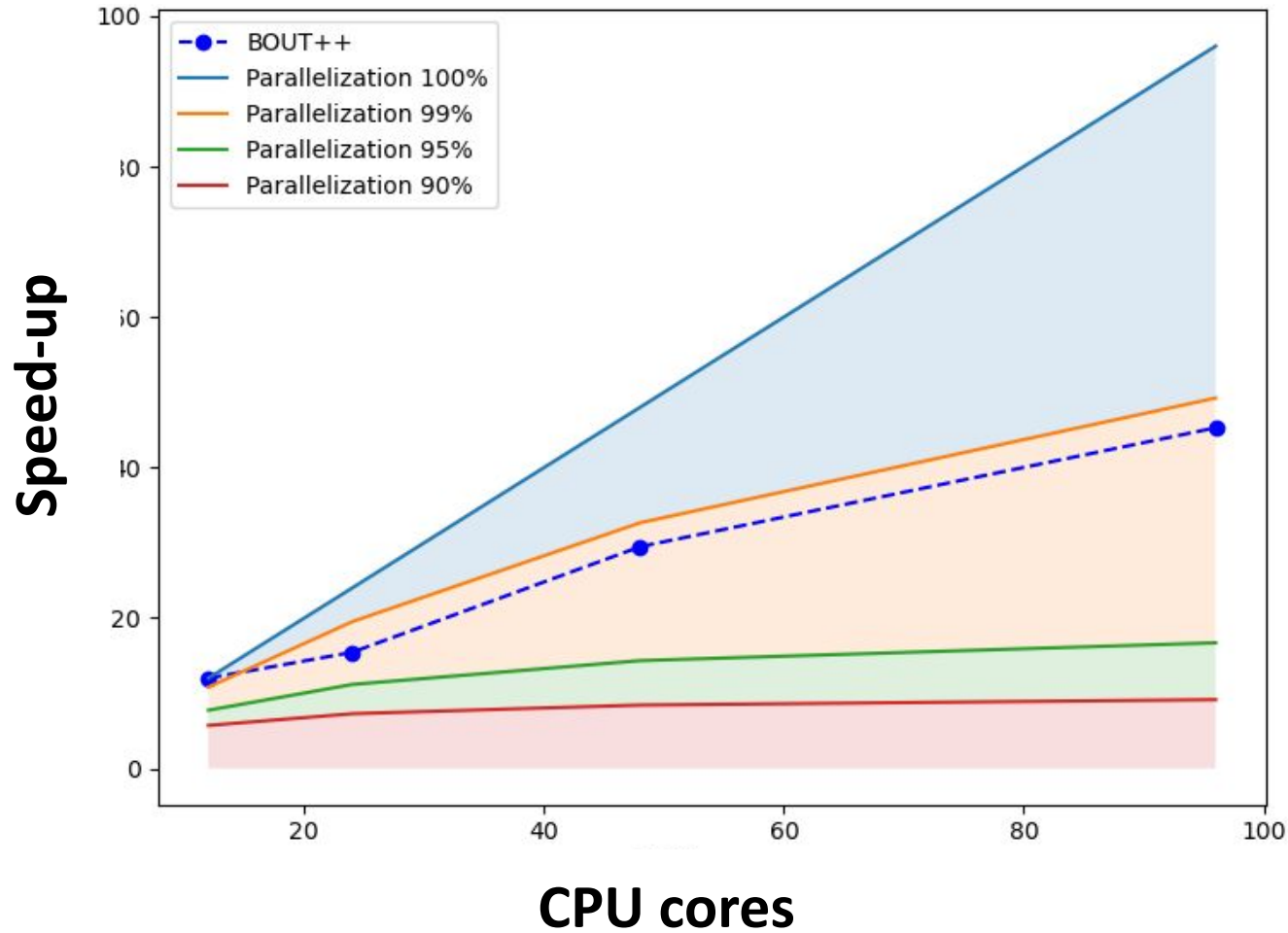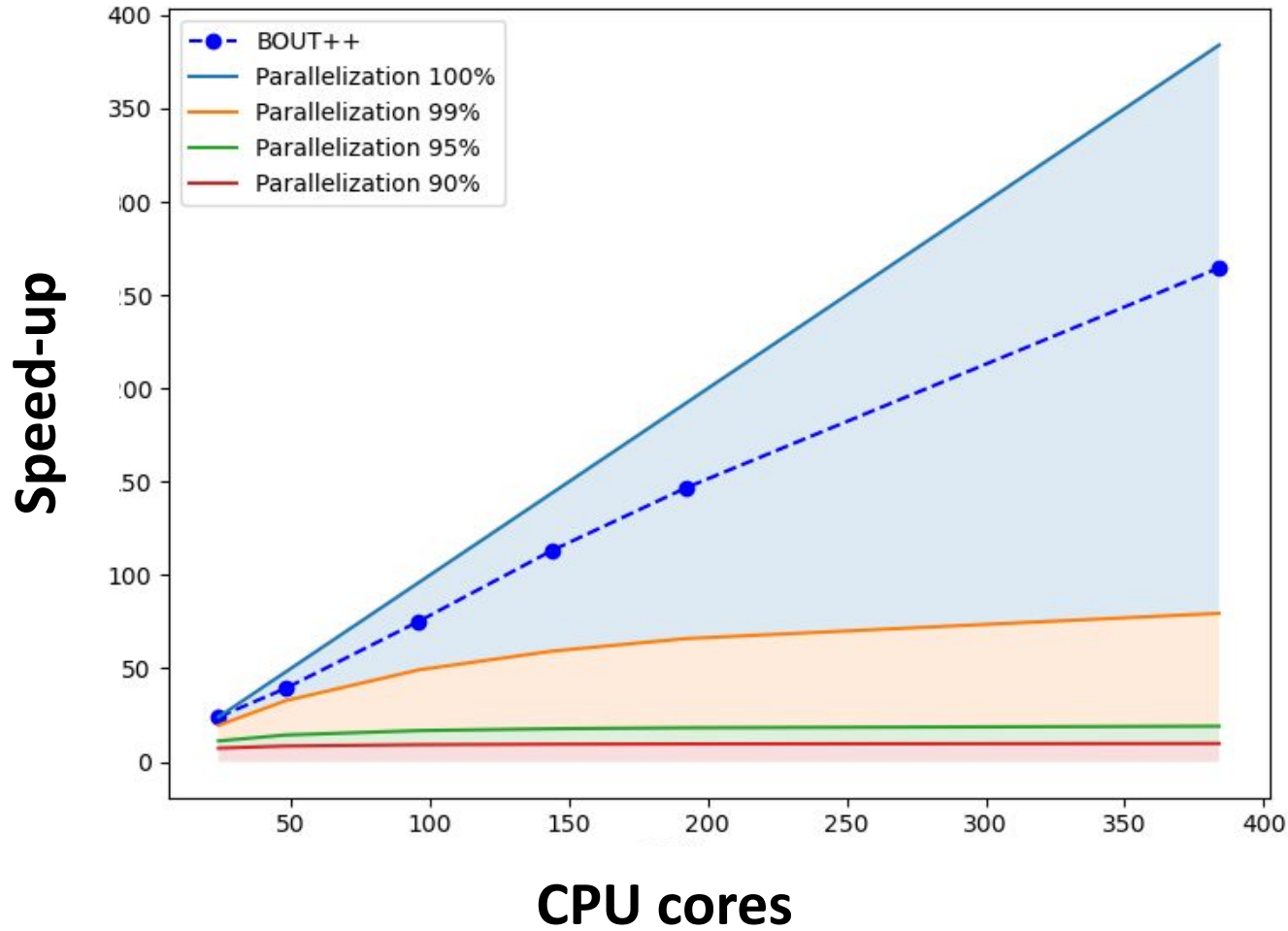
BOUT++

Uses finite difference methods to solve plasma fluid problems in curvilinear coordinates.

Work required into ACH: Test the performance of different PETSc solvers.
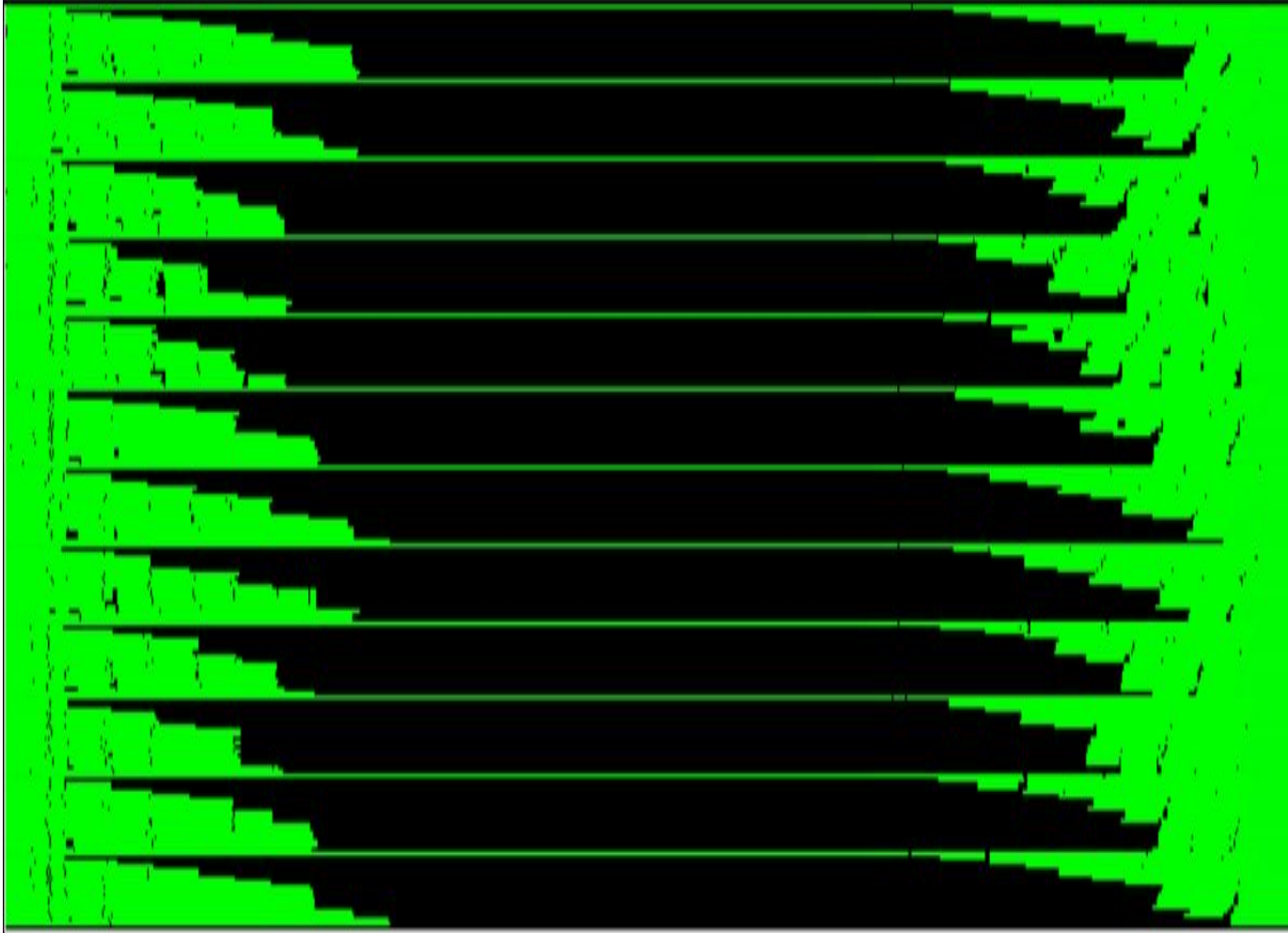
MARCONI

- *hermes-2* executable
- **MPI** scalability
- Grid RZ: **68x36x256**
- **Parallelization :**
  - **close to 99%** compared to Amdahl's law.

Speed-up vs CPU cores

MARCONI

- *hermes-2* executable
- **MPI** scalability
- Grid RZ: **724x72x256**
- **Parallelization :**
  - **close to 100%** compared to Amdahl's law.

MARENOSTRUM 5

- For every iteration we have a **time loss of 14%** due to **load imbalance:**
  - 86% load balance efficiency
- **12%** of the total load imbalance per iteration is due to: *VecScatterEnd_Internal*
- **Time improvement margin** per iteration of **12%:**
  - We could achieve a **1.1363x performance increase**

BOUT++

KSP Method
richardson
chebyshev
gmres

PC Method
Jacobi
SOR (and SSOR)
LU
Shell (user-defined)
Algebraic Multigrid

MARCONI

- Identification of PETSc implementation.

- Realization of tests:
  - Unit-tests: 100% passed
  - Integrated-tests: 74% passed

- Run with GRAFANA:
  - Inconclusive

SOME PROBLEMS ENCOUNTERED

- Runs with **Intel oneAPI cancelled** due to lack of answer from supporting colleagues.
- **Compilation in Marconi lost** due to machine decommissioning.
- Problems due to **high-memory** and **exclusive** flags for medium cases.
- **Unable to compile in Leonardo** - decision not to continue here.
- **Unable to identify** PETSc **matrix** to improve solver.
- **Medical leave** resumed by colleagues:
    - **Unable to install in MareNostrum 5 nor Leonardo.**

Thanks for your attention.

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