Recent orientations in the particle-in-cell simulation software Smilei

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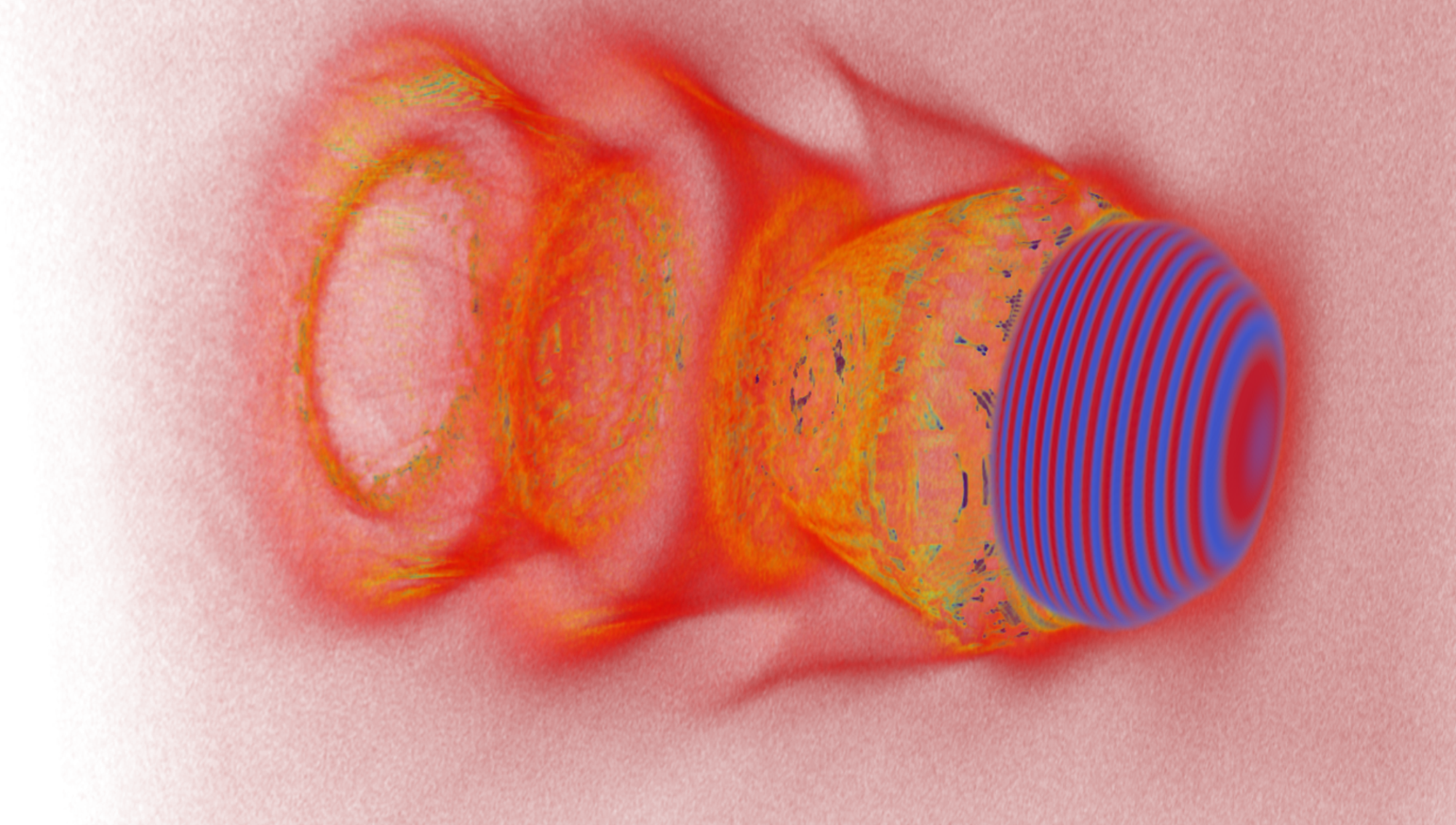


Smilei

Open-source
Particle-In-Cell code

Collaborative & User-Friendly

smileipic.github.io/Smilei

Educational resources

online documentation • tutorials

High-Performance Computing

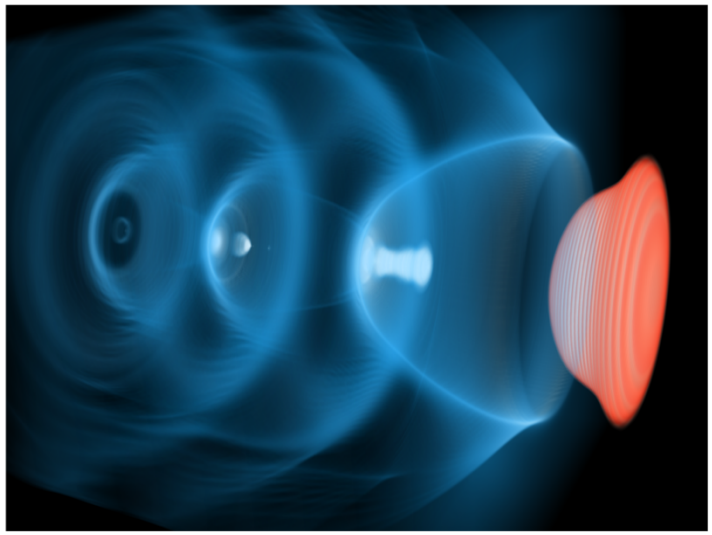
MPI-OpenMP • load balancing • vectorization

Advanced physics modules

ionisation • collisions • strong-field QED

Advanced solvers

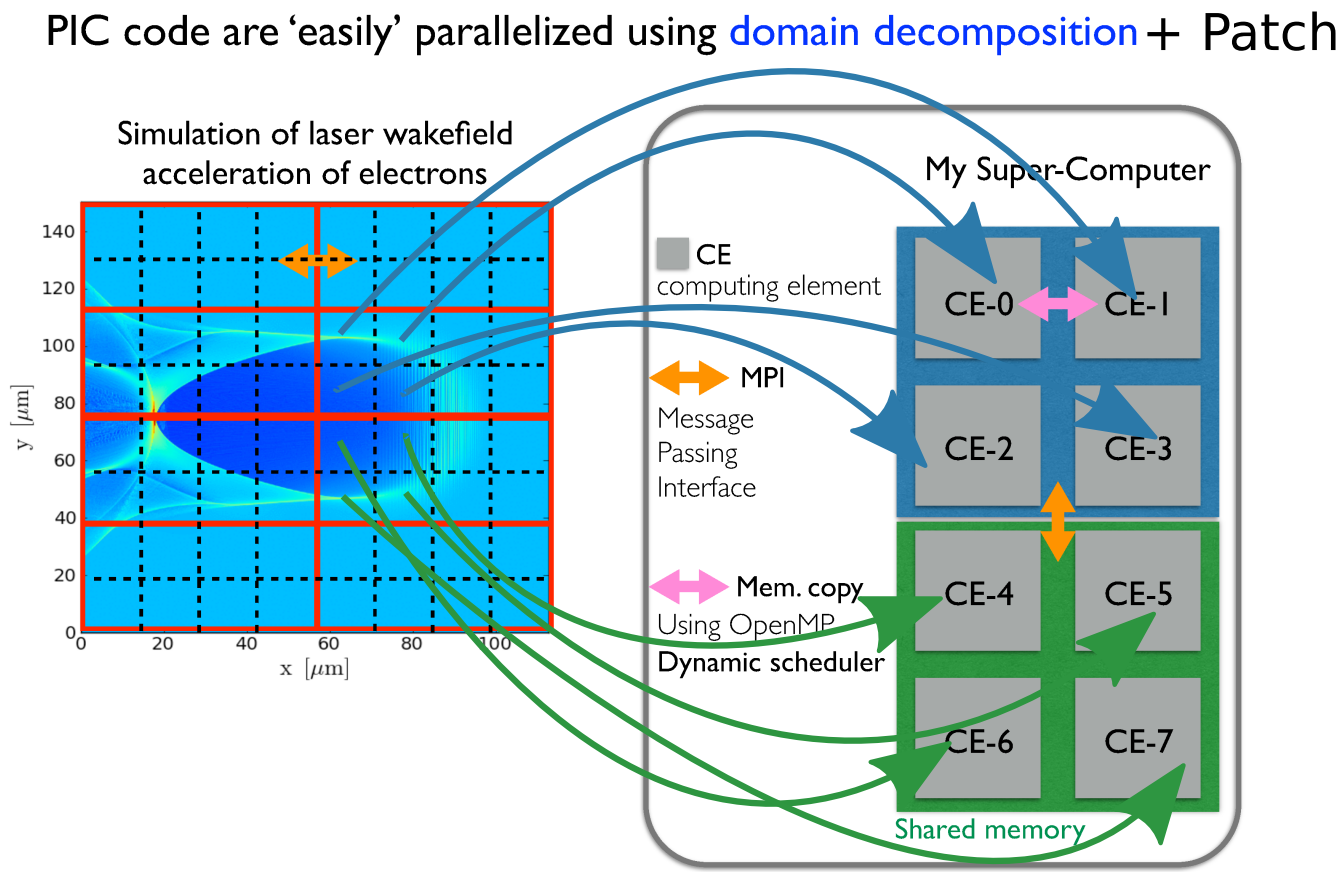
high-order FDTD • quasi-cylindrical • laser envelope



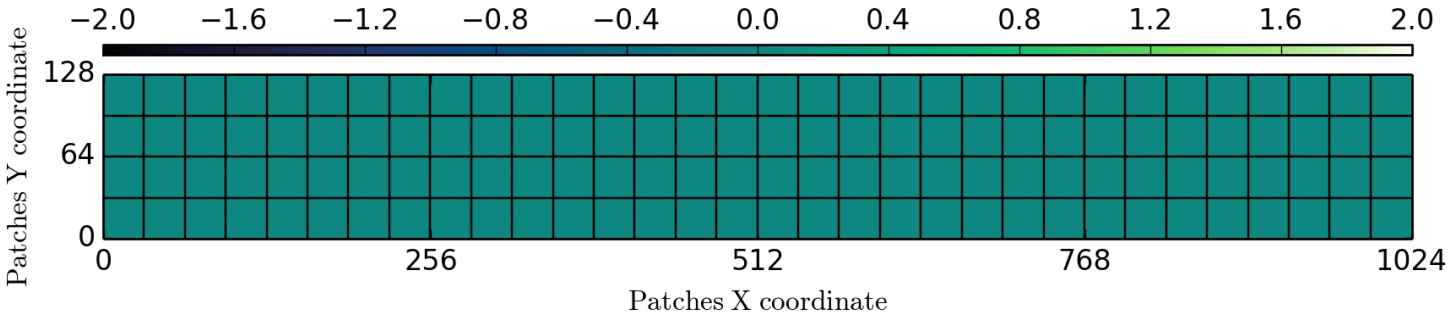
Derouillat *et al.*, Comp. Phys. Comm. **222**, 351 (2018)

Domain decomposition into “Patches“

Fine grain decomposition **exposes more parallelism** at the cost of more synchronizations.



Dynamic evolution of MPI domains

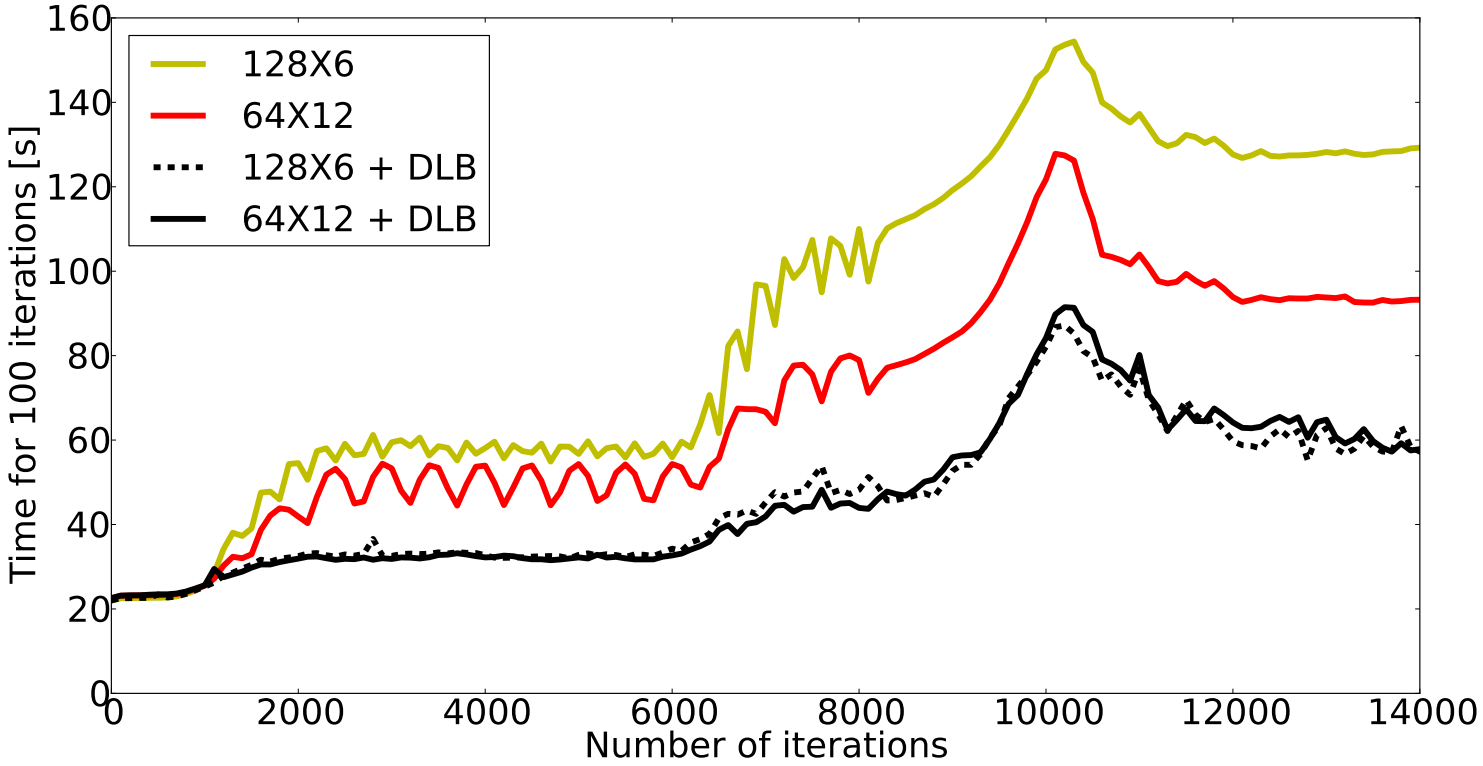


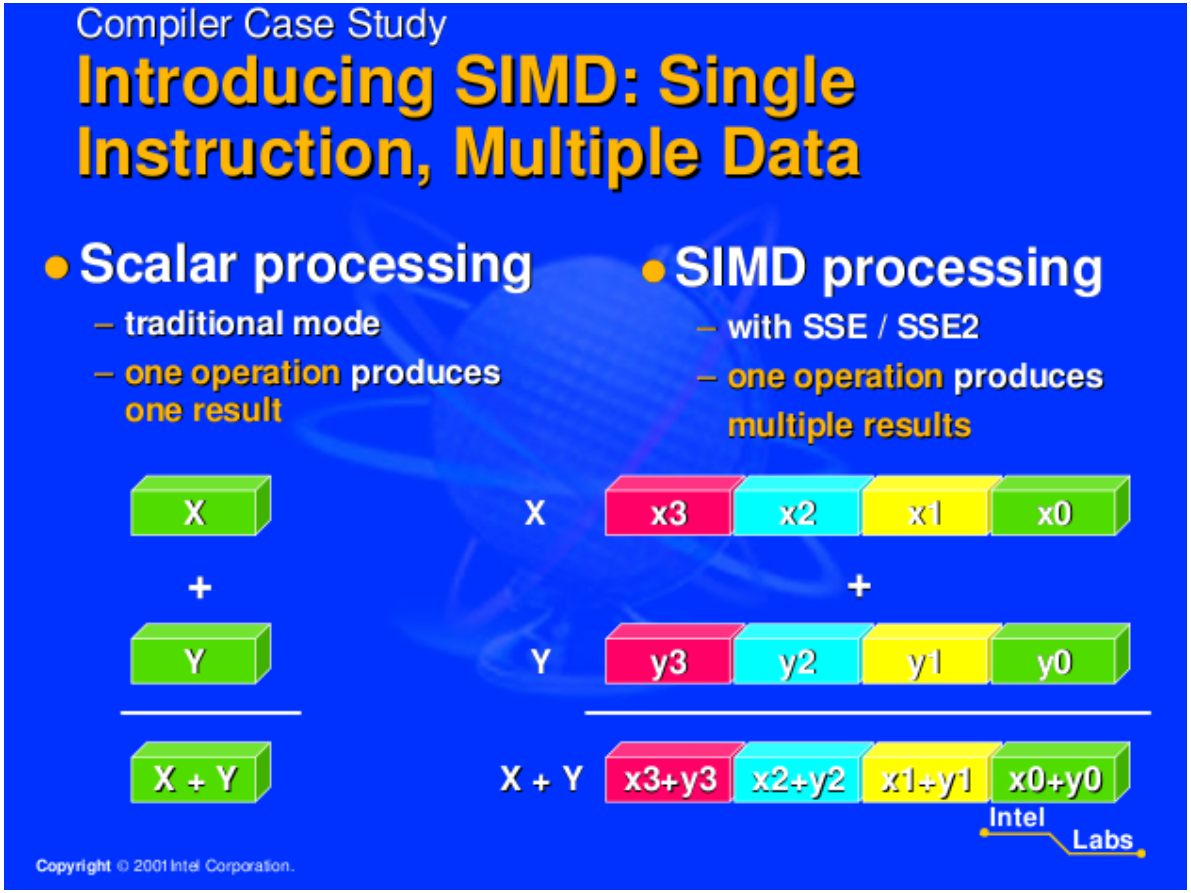
Color represents the local patch computational load imbalance

$$I_{loc} = \log_{10}\left(L_{loc}/L_{av}\right)$$

Mitigation of performance loss

MPI $\times$ *OpenMP*



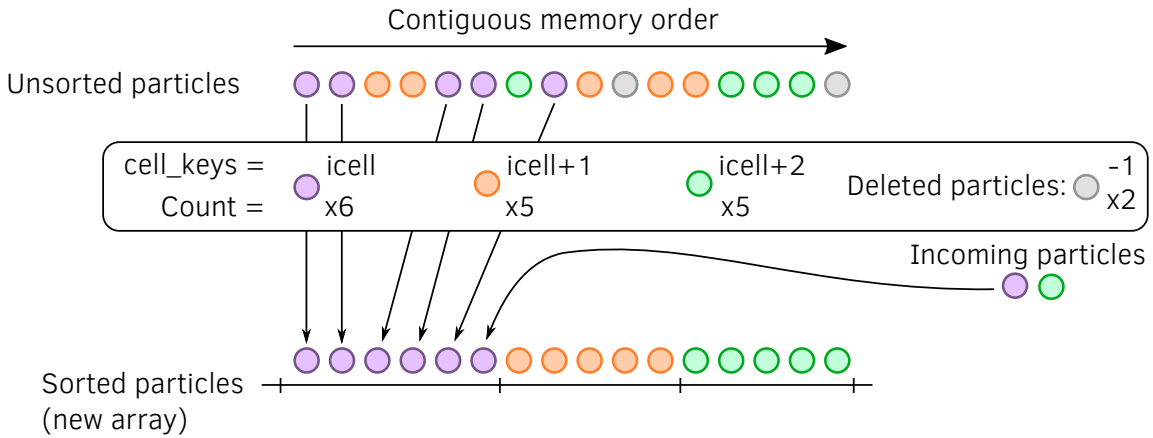


- Excellent potential speed up, very good power budget.
- Heavy constraints on data structure and algorithm.
- Difficult to use at its full extent in a PIC code.

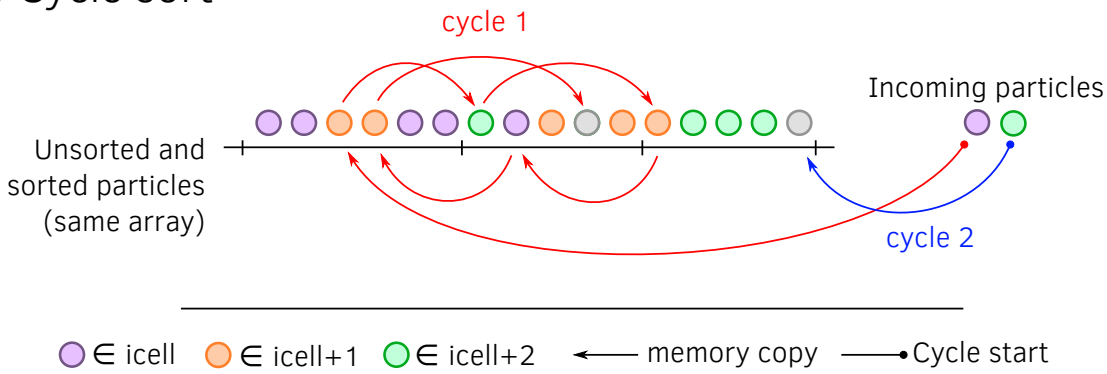
Sort per cell at all times

Particles do not move so much in a single time step.

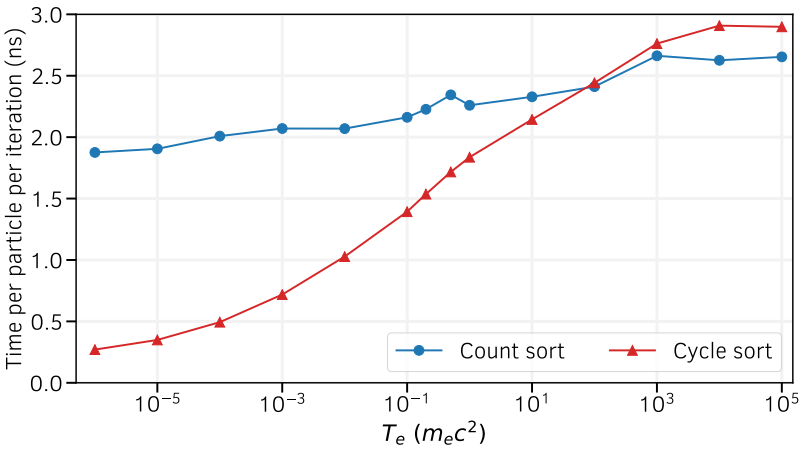
a) Count sort



b) Cycle sort

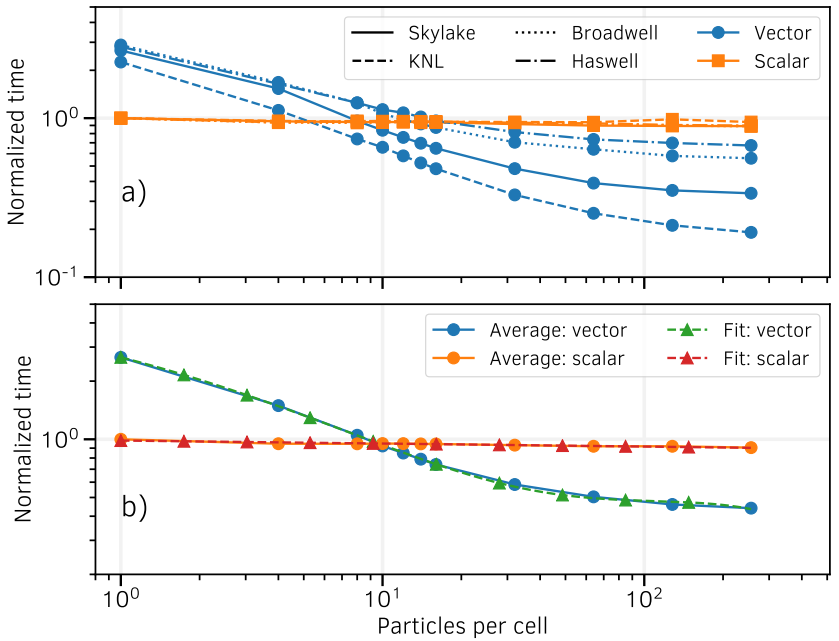


Sorting and SIMD efficiency



Particle sorting time V.S. Temperature

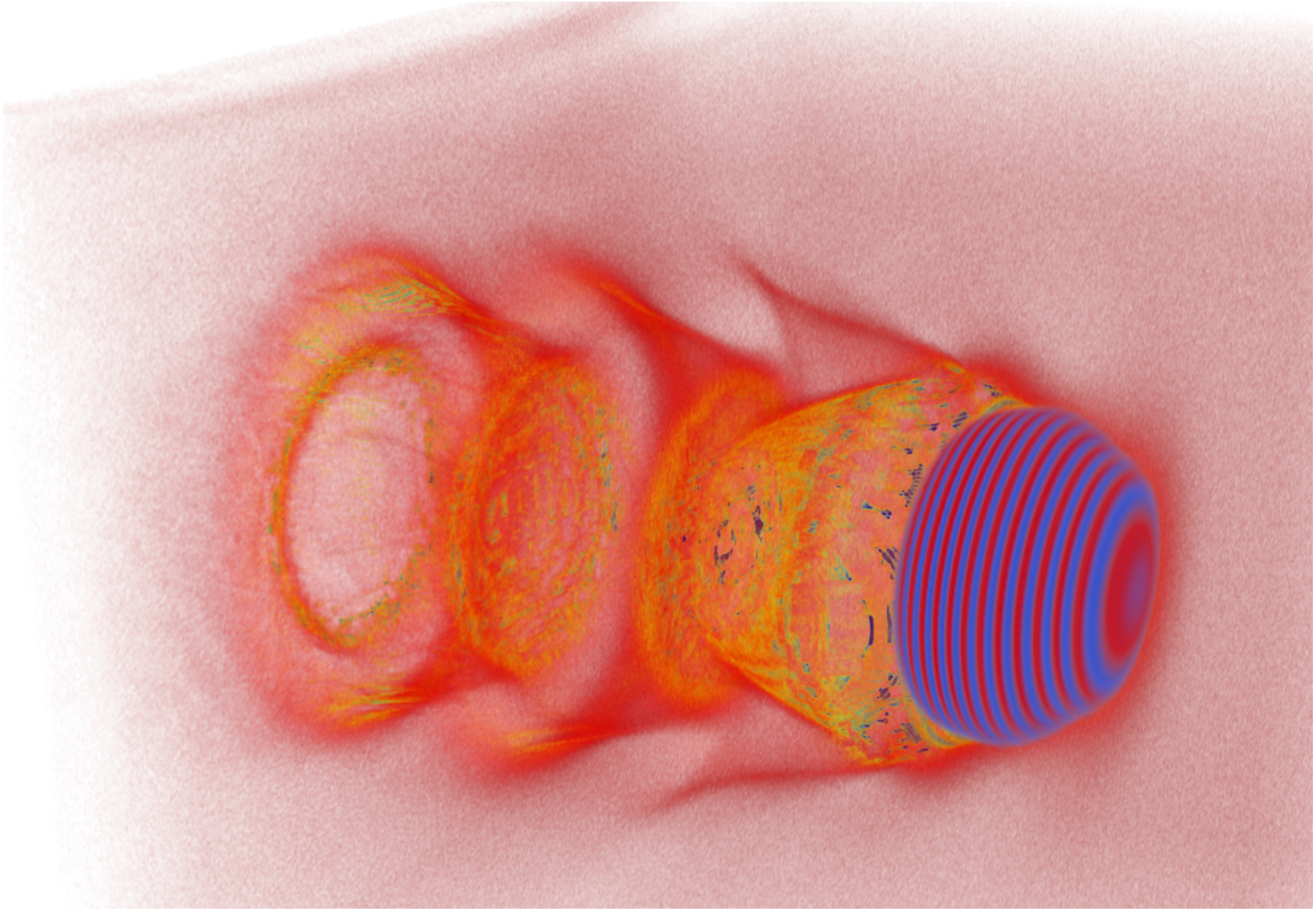
2 sets of operators



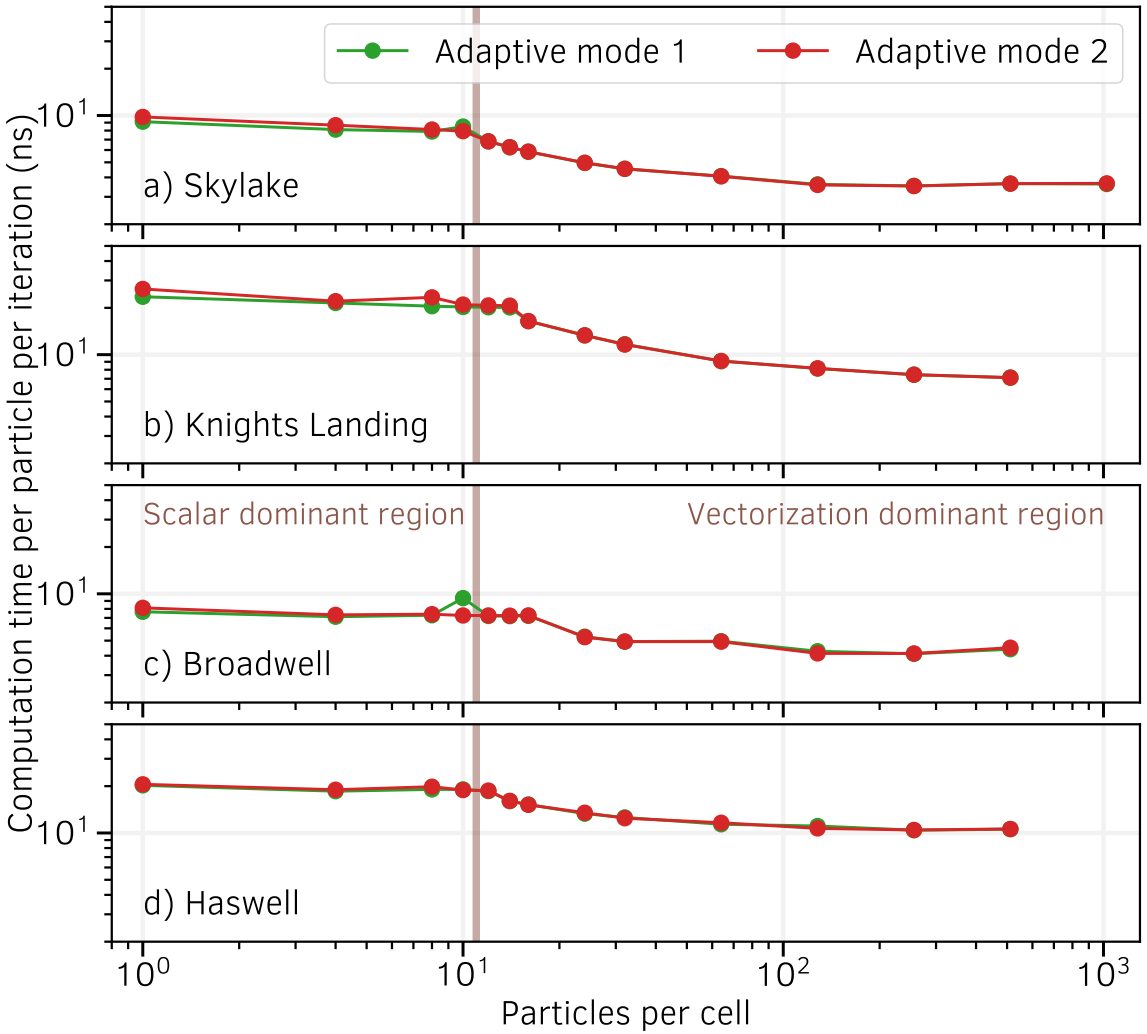
Particle push time V.S. number of PPC

The cycle sort is 2 to 4 times as efficient as a count sort for typical LWFA plasmas.
Sorting also benefits to collisions accuracy and performance.

Adaptive vectorization at play

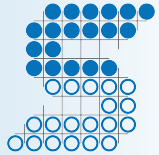


Adaptive vectorization performances



Bonus: free dynamic load balancing !

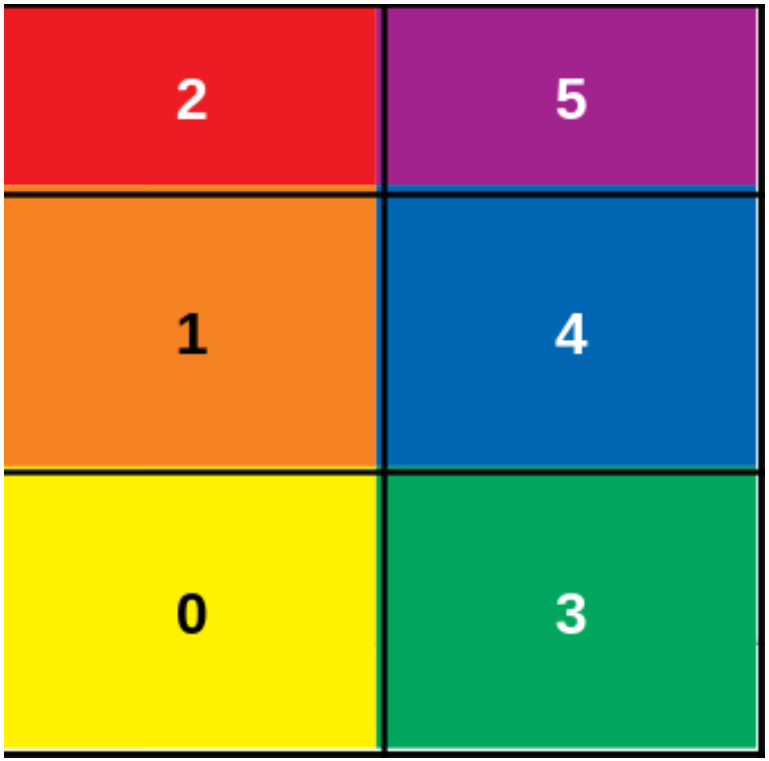
Patches are good but ...



- Additional synchronization costs.
- Too much particle load balancing end up unbalancing other sequences in the code.
- Fine grain is not adapted to spectral methods.
- Fields diagnostics are complicated.
- Variability of performances. Dependence on patches size which adds up to many other optimization variables.

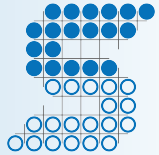
Single Domain Multiple Decompositions

Particles decomposition



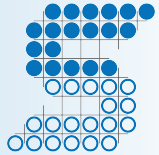
Fields decomposition

SDMD Interests and caveat



- Speeds up fields operations (Sync, Solvers, Filters ...)
- You can balance particles as much as you want with little impact on other sequences.
- Spectral solvers friendly structures.
- Exposes more parallelism and opportunities for openMP taskification.
- Caveat: A good strategy to optimize overlapping of the field decomposition with its corresponding patches is required.
- First rough estimations with scaling to only 128 MPI processes shows varying overheads of up to 7.5%.

Conclusions



- Robust code able to have good performances in wide range of real physics cases and for non expert users.
- Build a platform flexible enough to easily benefit from other developments.
- Contribute to code co-development via PICSAR and its coupling to SMILEI.

Acknowledgment

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Users community

for feedback, ideas, contributions and encouragements

For users and developpers

Smilei)

Training Workshop

Next edition coming up Fall 2020 !