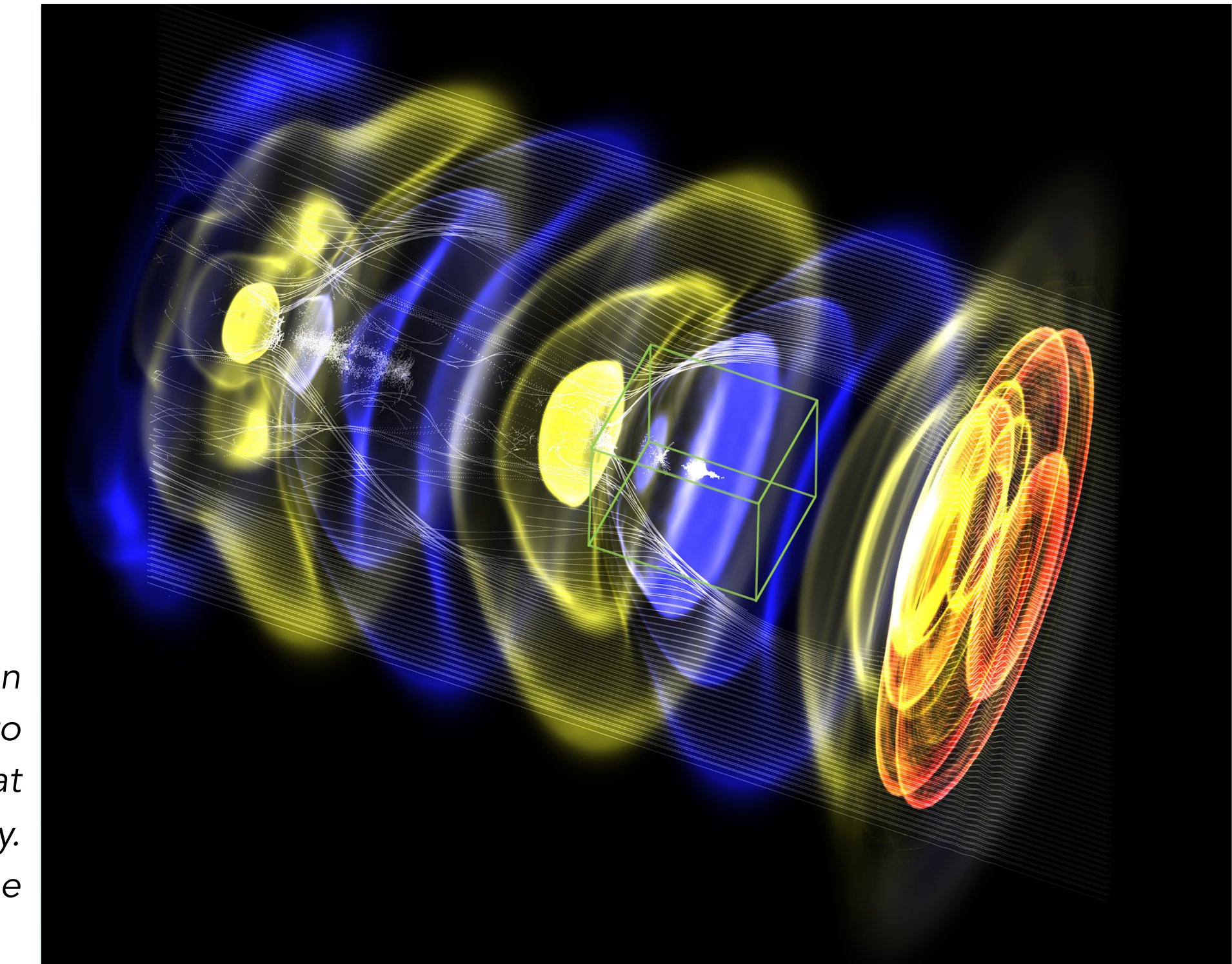


WarpX: Toward Exascale Modeling of Plasma Particle Accelerators



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Goal

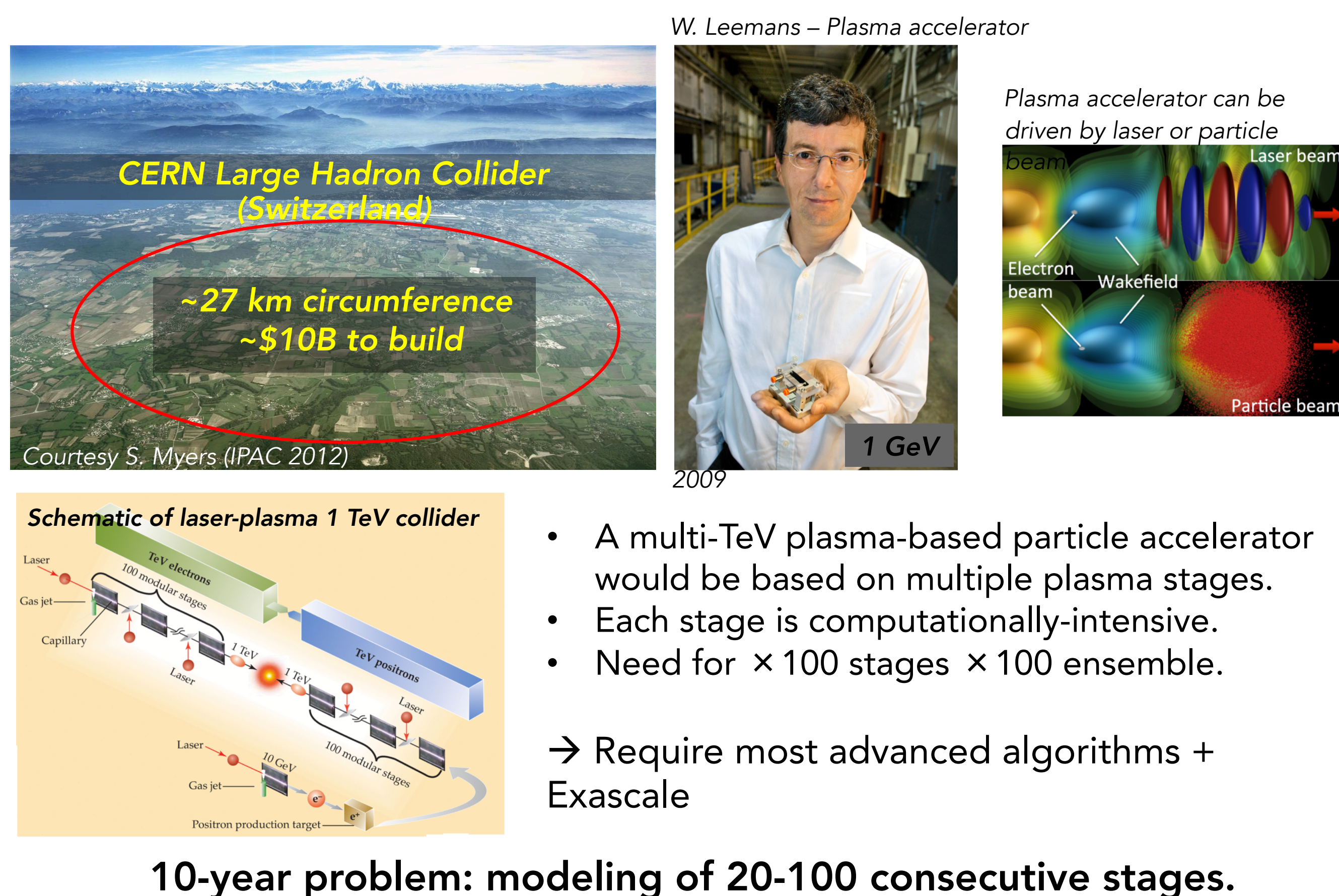
Particle accelerators are a vital part of the DOE-supported infrastructure of discovery science and applications, but we need game-changing improvements in the size and cost for future accelerators. Plasma-based particle accelerators stand apart in their potential for these improvements. Turning this from a promising technology into mainstream scientific tools depends critically on high-performance, high-fidelity modeling of complex processes.

Solution

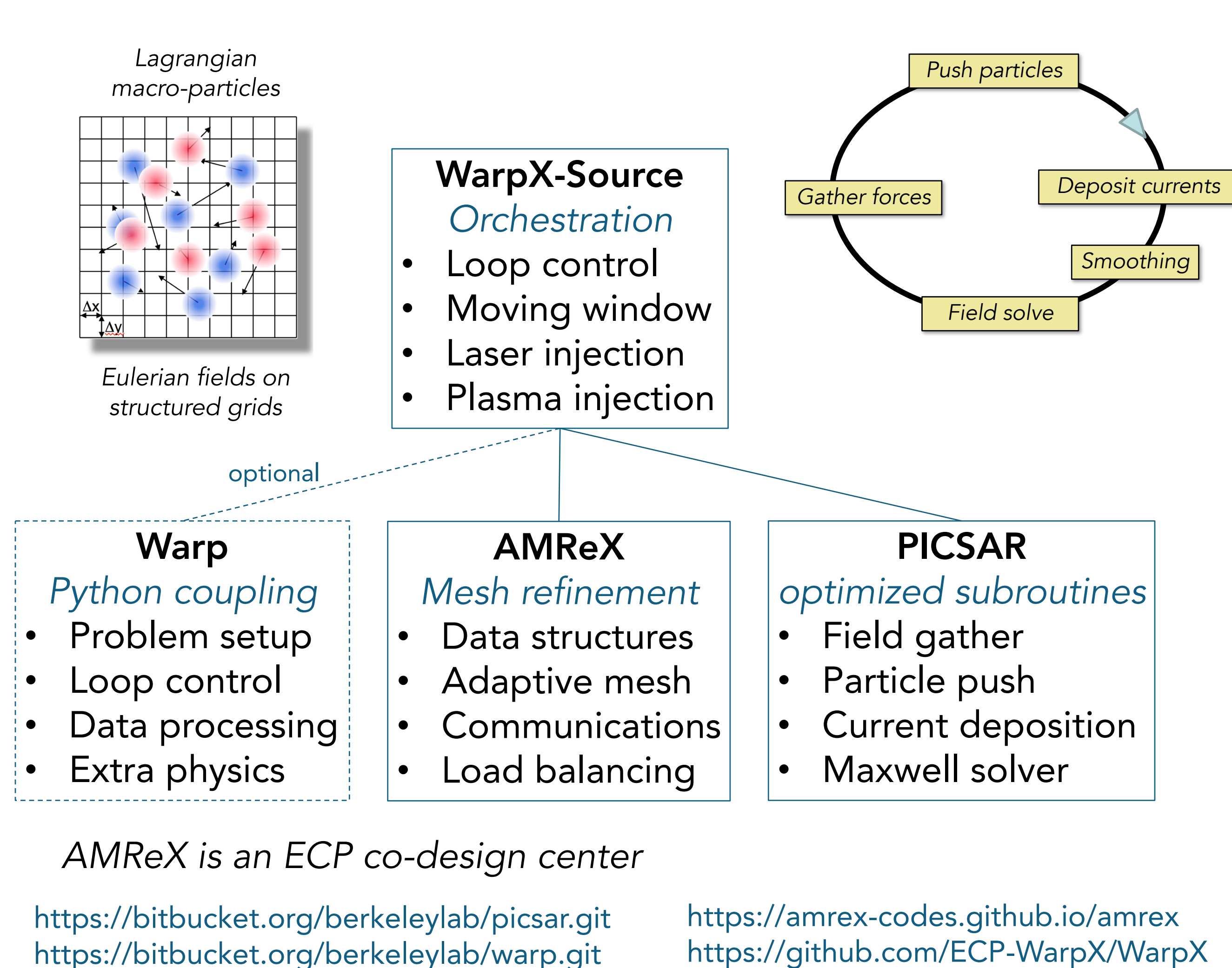
WarpX is an open-source particle-in-cell (PIC) code supported by the Exascale Computing Project (ECP) that is combining advanced algorithms with adaptive mesh refinement to allow challenging simulations of a multi-stage plasma-based TeV acceleration relevant for future high-energy physics discoveries.

Snapshot from a WarpX 3-D simulation of a laser-driven plasma accelerator. The laser (red) propagates from left to right and creates a plasma wake (yellow and blue) that accelerates a small electron beam (white) to high energy. A mesh refinement patch (green box) is used to increase the resolution and accuracy around the electron beam.

Application domain: plasma accelerators

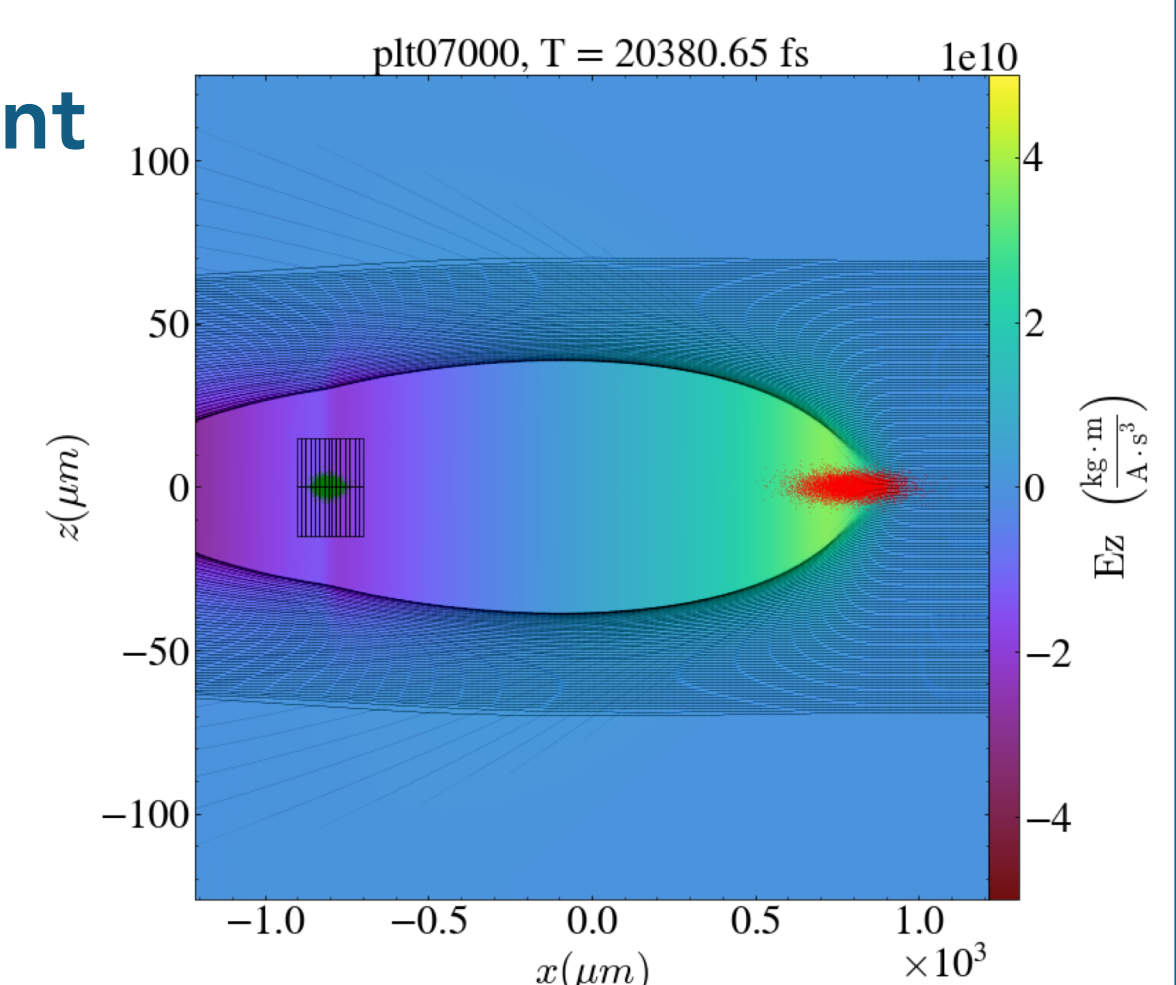
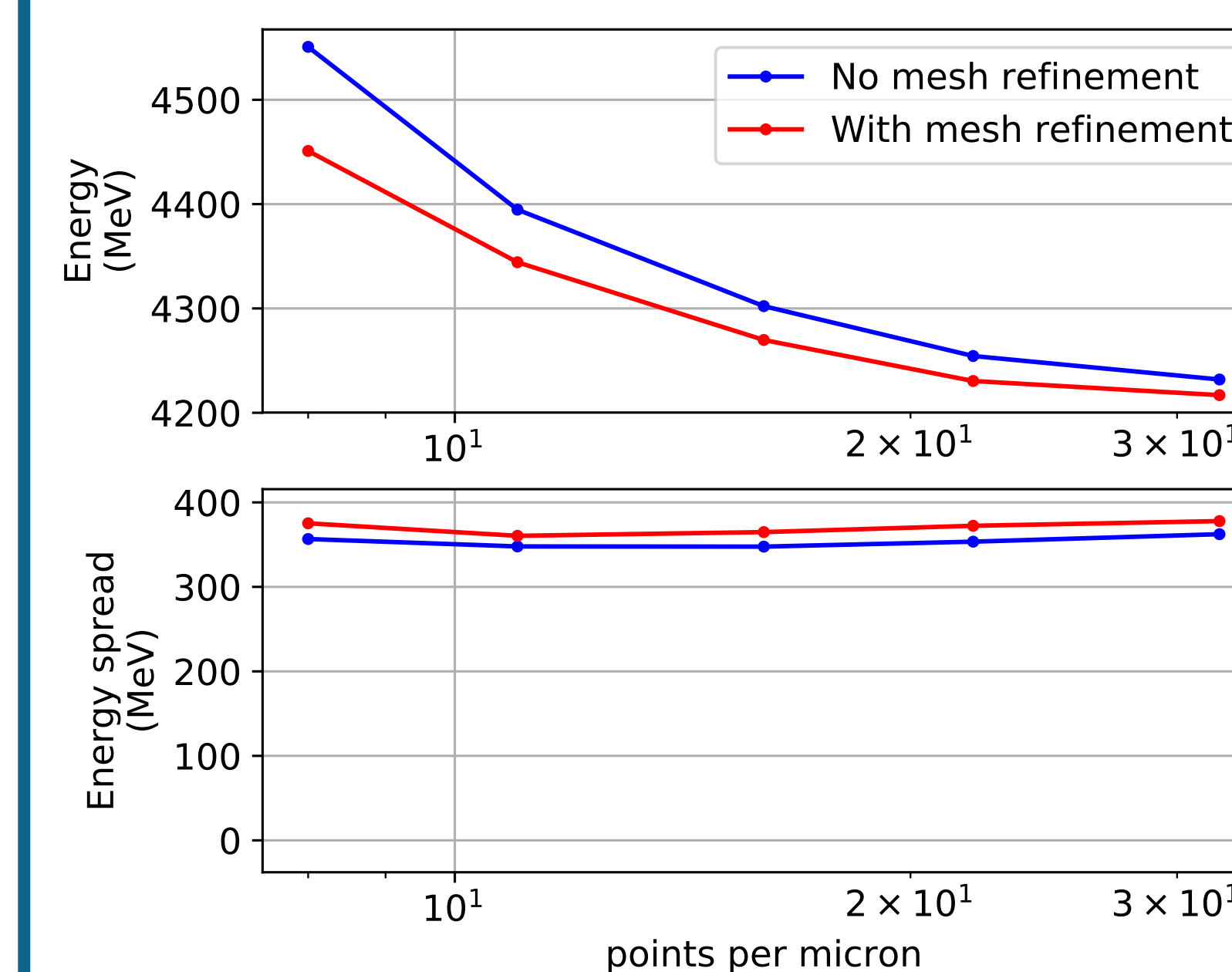


WarpX code structure and distribution: Open Source



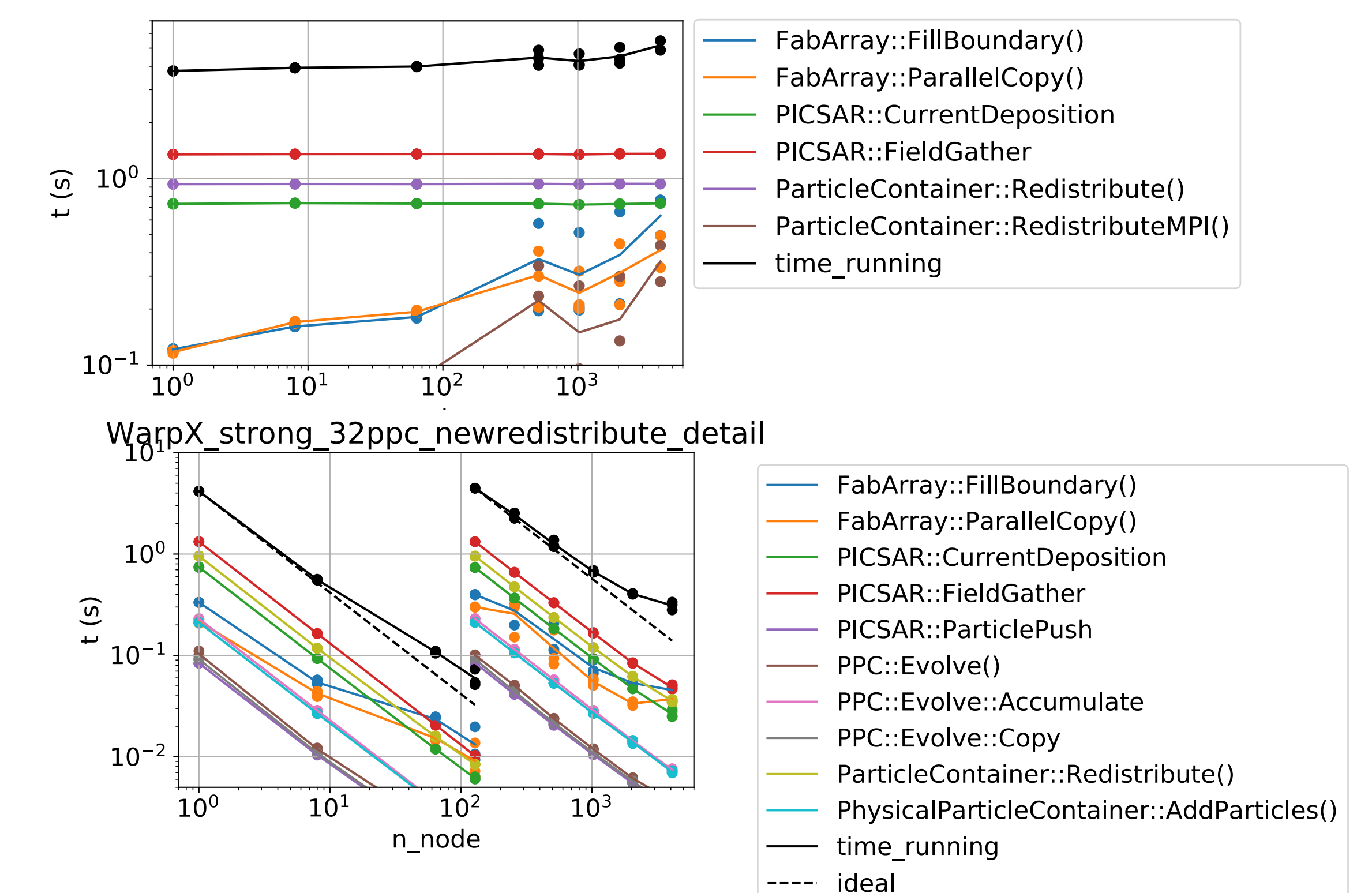
WarpX fulfilments and performances

Convergence tests with mesh refinement



First wakefield acceleration simulation with MR. Convergence tests performed on Cori KNL 384x384x3872 cells, refinement x2, 210 nodes.

Scalings on Cori KNL up to half-machine



WarpX is part of the Exascale Computing Project

The Exascale Computing Project (ECP) is focused on accelerating the delivery of a capable exascale computing ecosystem that delivers 50 times more computational science and data analytic application power than possible with DOE HPC systems.

WarpX challenges in the ECP:

- Mitigate spurious effects due to mesh refinement in electro-magnetic PIC codes (self-forces and wave reflection, numerical dispersion) → advanced algorithms.
- Demonstrate good performances and scalings with mesh-refinement capability (single-node to full-machine optimizations).
- Demonstrate portability on future architectures.

WarpX roadmap:

- 2018: model single accelerator stage + port to GPU
- 2020: model 10 consecutive 10 GeV-stages
- 2022: model 100 consecutive 10 GeV-stages



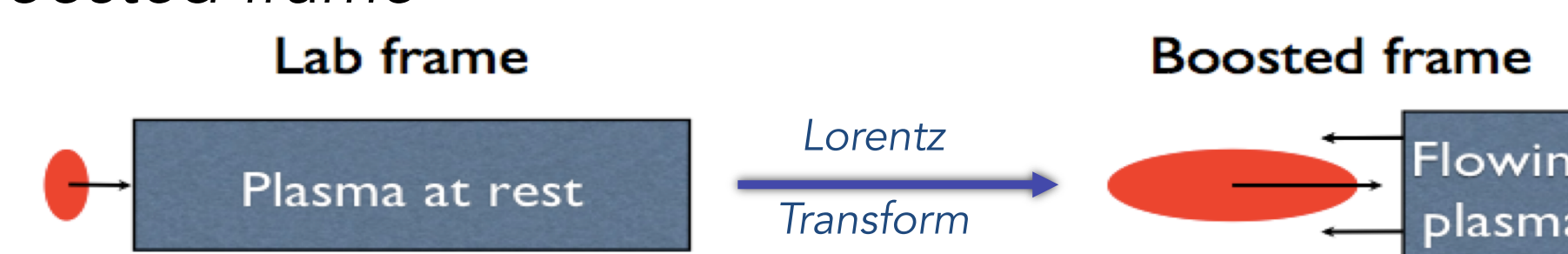
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J.-L. Vay, A. Almgren, J. Bell, L. Ge, D. P. Grote, M. Hogan, O. Kononenko, R. Lehe, A. Myers, C. Ng, J. Park, R. Ryne, O. Shapoval, M. Thévenet, W. Zhang "Warp-X: A new exascale computing platform for beam-plasma simulations", Nucl. Inst. Meth. A in press (2018) <https://doi.org/10.1016/j.nima.2018.01.035>

WarpX combines most advanced algorithms

Lower # time steps:

- optimal Lorentz boosted frame



Higher accuracy:

- Adaptive Mesh Refinement
- Arbitrary order & pseudo-spectral Analytical Maxwell solvers
- Sub-cycling

Higher stability

- Galilean T. to suppress Numerical Cherenkov Instability

Higher scalability

- FFT Maxwell solvers on local domains + domain decomposition

Dynamic load-balancing

Perspectives

- WarpX is the first electromagnetic particle-in-cell code combining adaptive mesh refinement and pseudo-spectral methods.
- WarpX shows good weak and strong scalings on Cori after 2-year development, and current active efforts are dedicated to porting to GPU architecture like Summit (OLCF-4).