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Large scale computing for designing plasma-based particle accelerators and related applications

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Plasma accelerators can enable accelerator based applications at the university campus or large hospital level thanks to their reduced footprint and relatively low acquisition and operation costs. The underlying physical processes are described by the Vlasov-Maxwell equations coupled to the Lorentz force equation, so that their design requires solving a system of highly non-linear, partial differential equations; moreover, the physical problem is multi-scale (from fraction of um up to meters). An estimation of emitted radiation, reaching up to the few hundreds keV energy range, may also be required in some situations.

Although fast reduced physics models do exist, the complete design of a plasma based facility and of the inherently plasma based applications (e.g. betatron radiation sources) require to run full 3D simulations with Particle-In-Cell (PIC) solvers in order to correctly evaluate the effects of jitters and (mostly inherently 3D) instabilities (e.g. hose instability). A sound design typically foresees a few hundreds runs, each worth up to 10^5 - 10^6 hours/core, and returns data for tens of terabytes requiring further analysis and, possibly, post-processing; moreover, the design process may also face unexpected, unwanted effects and must cope with strict project deadlines. Hence the need for a large scale, dedicated computational facility, efficient programming and adequate storage.

In this contribution, we showcase a selection of the numeric tools frequently used in the design of plasma based facilities and related experiments/applications, detailing the techniques employed to improve performances and numerical accuracy and focusing on the LNF-based EuPRAXIA and EuAPS projects.

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