Welcome to

Smile:)

4th User & Training Workshop

ELI Beamlines | November 8 - 10, 2023

eli beamlines

Today's program

09:00	Check-in & Welcome coffee		
09:30	Smilei: Project review	Mickael Grech	Status and perspectives
		Frederic Perez	Smilei's ecosystem
10:40	Coffee		
11:00	Contributed talks	Hyeon Kim	Numerical Simulation of High Harmonic Generation Using Liquid Flat-Jet Targets
		Pierce Giffin	Kinetic Simulations of Collisionless Shock Formation in the Dark Sector
		Jan Psikal	Sophisticated studies of laser-driven ion acceleration with SMILEI code
		Vojtěch Horný	Simulations on Particle and Radiation Sources at ELI NP
12:40	Lunch	+ Lab tour @ 13:20 (limited places)	
14:00	Smilei: Project review	Arnaud Beck	Supercomputing landscape
14:40	Contributed talks	Arnaud Beth	PIC simulation at boundaries of comets
		Francisco Javier Polanco Rodriguez	PIC simulations of electromagnetic emissions by solar radio bursts: a study of polarization characteristics of radiated waves
15:30	Coffee		
15:45	Contributed talks	Marianna Lytova	Scattered field formalism in the particle-in-cell method for tightly focused ultrashort laser beams
		Kevin Ambrogioni	Numerical Investigation of Laser-Driven Radiation Sources with Double-Layer Targets (DLTs) using Particle in-Cell (PIC) codes
		Yasmina Azamoum	Optical Probing of Ultrafast Laser-Induced Transitions from Solid to Overdense Plasma
		Mufei Luo	Kinetic modelling of autoresonant beat-wave excitation of plasma waves

Smile:)

Status and Perspectives

Mickael Grech, LULI

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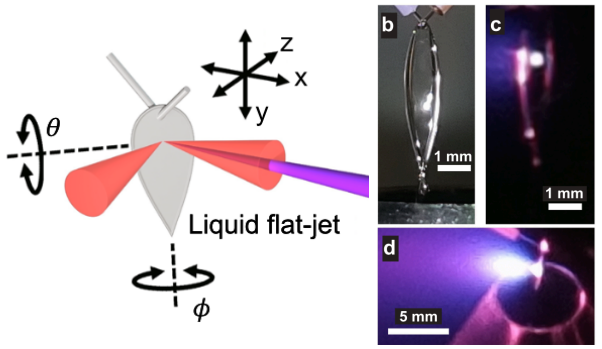
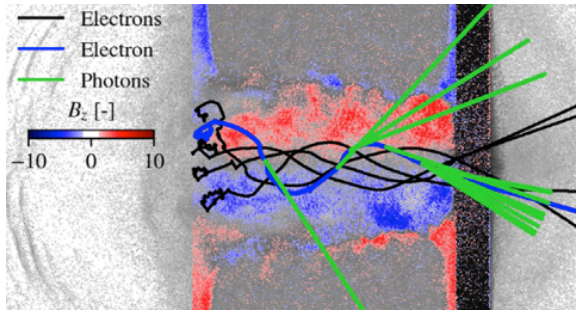
The Particle-In-Cell (PIC) simulation of plasmas

from Laboratory Plasmas …

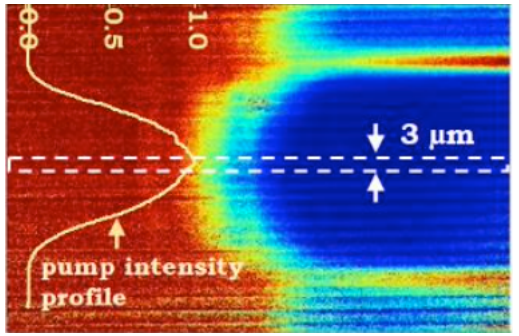
High-Harmonic Generation



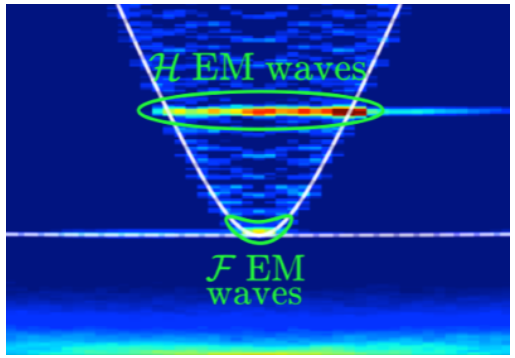
Radiation sources from DLT



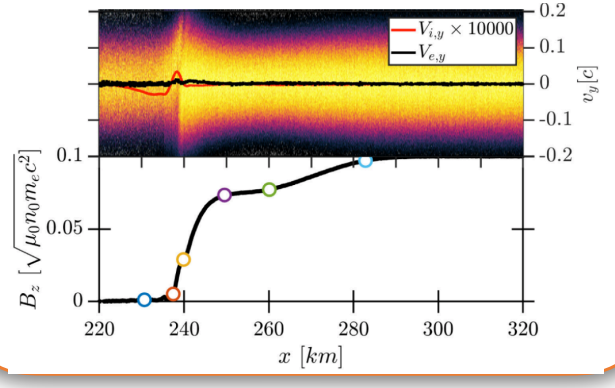
Solid to plasma transition



Solar radio-burst



Comet boundaries



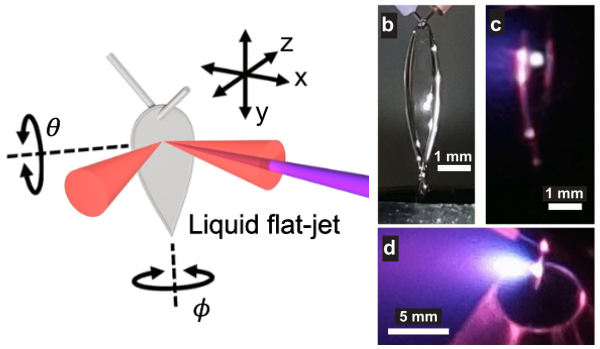
Collisionless shocks & Dark Matter

… to Space & Astrophysical Plasmas

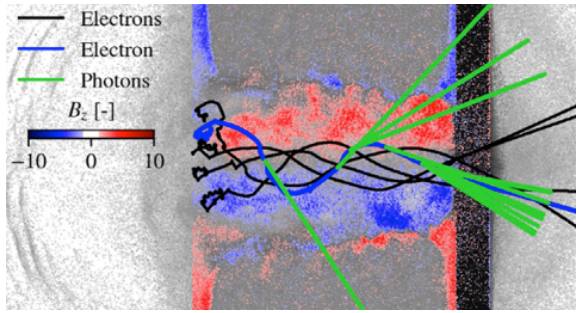
The Particle-In-Cell (PIC) simulation of plasmas

from Laboratory Plasmas …

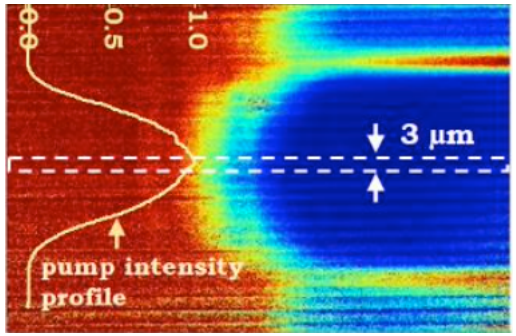
Hyeon Kim @ CoReLS | 11:00 AM



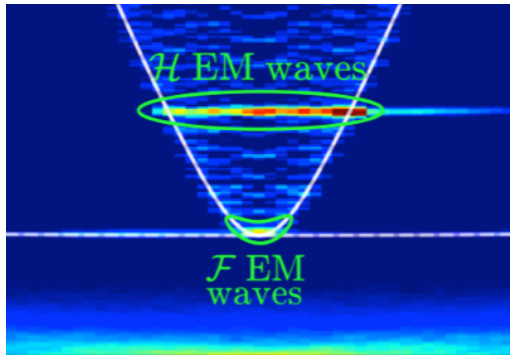
Kevin Ambrogioni @ Polimi | 11 AM



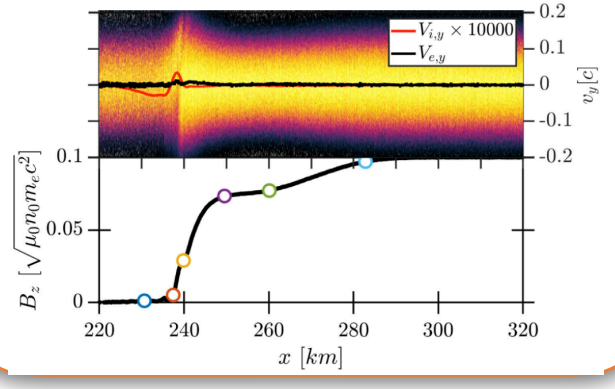
Yasmina Azamoun @ Jena | 04:35 PM



Francisco R. @ LPP | 03:05 PM



Arnaud Beth @ ICL | 02:40 PM



Pierce Giffin @ UCSC | 11:25 AM

… to Space & Astrophysical Plasmas

Smilei is an electromagnetic Particle-In-Cell (PIC) code

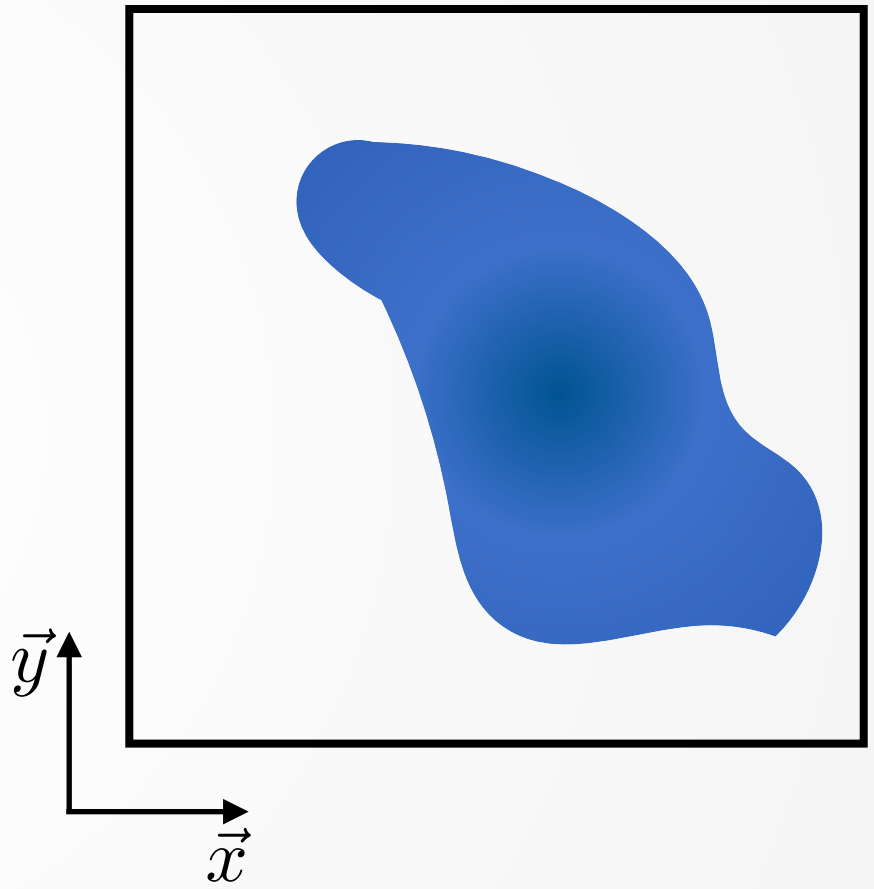
Maxwell Eqs - Electromagnetic Fields

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \qquad \partial_t \mathbf{E} = -\frac{1}{\epsilon_0}\mathbf{J} + c^2 \nabla \times \mathbf{B}$$

$$\nabla \cdot \mathbf{B} = 0 \qquad \partial_t \mathbf{B} = -\nabla \times \mathbf{E}$$

Vlasov Eq - Species of the plasma

$$\partial_t f_s + \frac{\mathbf{p}}{m_s \gamma} \cdot \nabla f_s + \mathbf{F}_L \cdot \nabla_p f_s = 0$$



Smilei is an electromagnetic Particle-In-Cell (PIC) code

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$\rho, \mathbf{J}$ ⟳ Δt ⟳ $\mathbf{F}_L$

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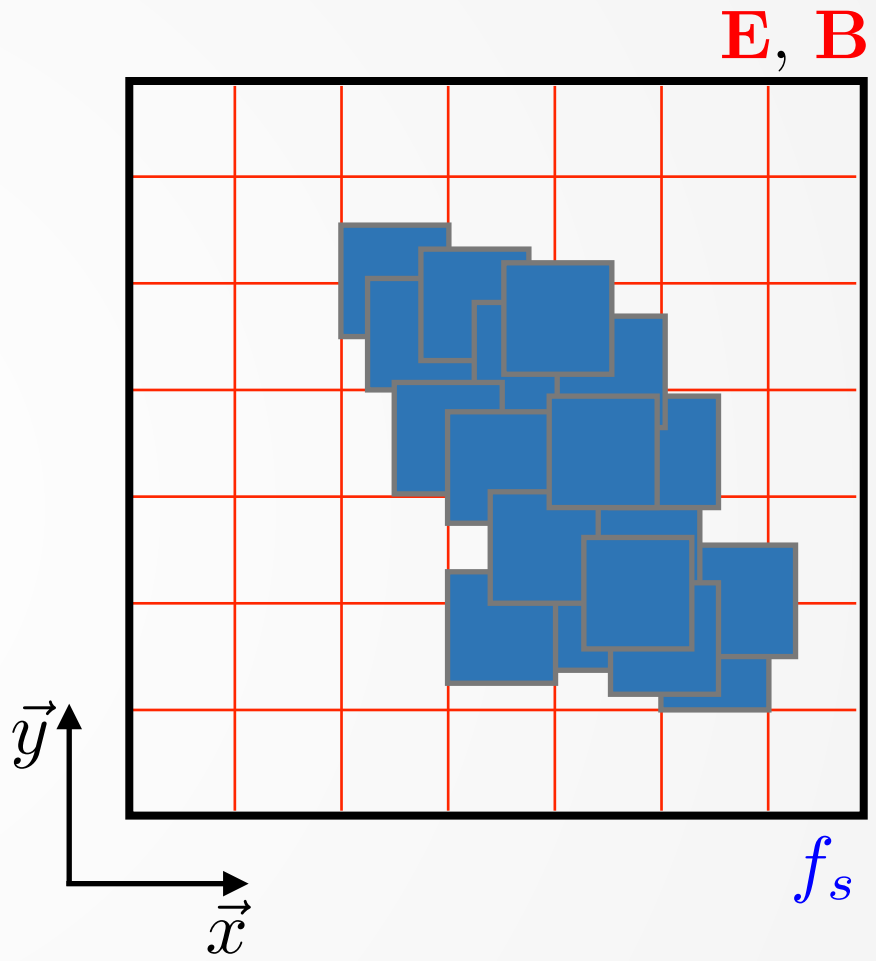

More on this in Fred's lecture tomorrow

Smilei allows for advanced physics simulation

Maxwell Eqs - Electromagnetic Fields

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \qquad \partial_t \mathbf{E} = -\frac{1}{\epsilon_0}\mathbf{J} + c^2 \nabla \times \mathbf{B}$$

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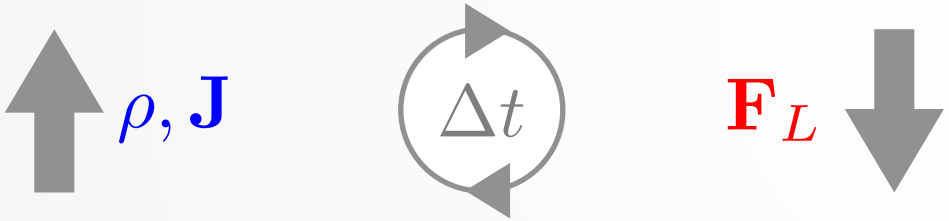


Vlasov Eq - Species of the plasma

$$\partial_t f_s + \frac{\mathbf{p}}{m_s \gamma} \cdot \nabla f_s + \mathbf{F}_L \cdot \nabla_p f_s = 0$$

Physics Modules

- collisions (Fokker-Planck)
- ionization (field & impact)
- fusion reaction (DD)
- inverse Compton scattering
- Breit-Wheeler pair production

  Francesco's lecture tomorrow

Advanced Models

- Azimuthal mode (AM) decomposition
- Laser envelope model
- Perfectly Matched Layers

  Guillaume's lecture tomorrow

Smilei in a nutshell

2013
Start of the project*

2014
Gitlab
release to co-dev

2016
1st physics studies & large scale simulations
Github

2018
Reference paper

*objective: develop the first open-source PIC code harnessing new paradigms of high-performance computing

Open-source & Community-Oriented

documentation • chat • online tutorials • post processing & visualization
training workshops • summer school & master trainings • issue reporting

Fred's review this morning

Multi-Physics & Multi-Purpose

advanced physics modules: geometries, collisions, ionization, QED
broad range of applications: from laser-plasma interaction to astrophysics

Francesco & Guillaume's lectures tomorrow

High-performance

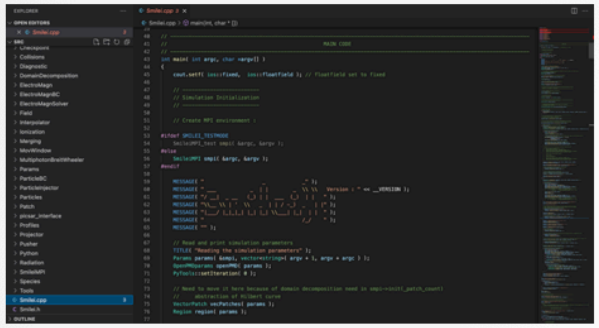
C++/Python • MPI/OpenMP/OpenACC/CUDA/HIP • SIMD • HDF5
designed for the latest architectures

Arnaud's review this afternoon & Charles' lecture tomorrow

What you get with Smilei

A high-performance PIC code

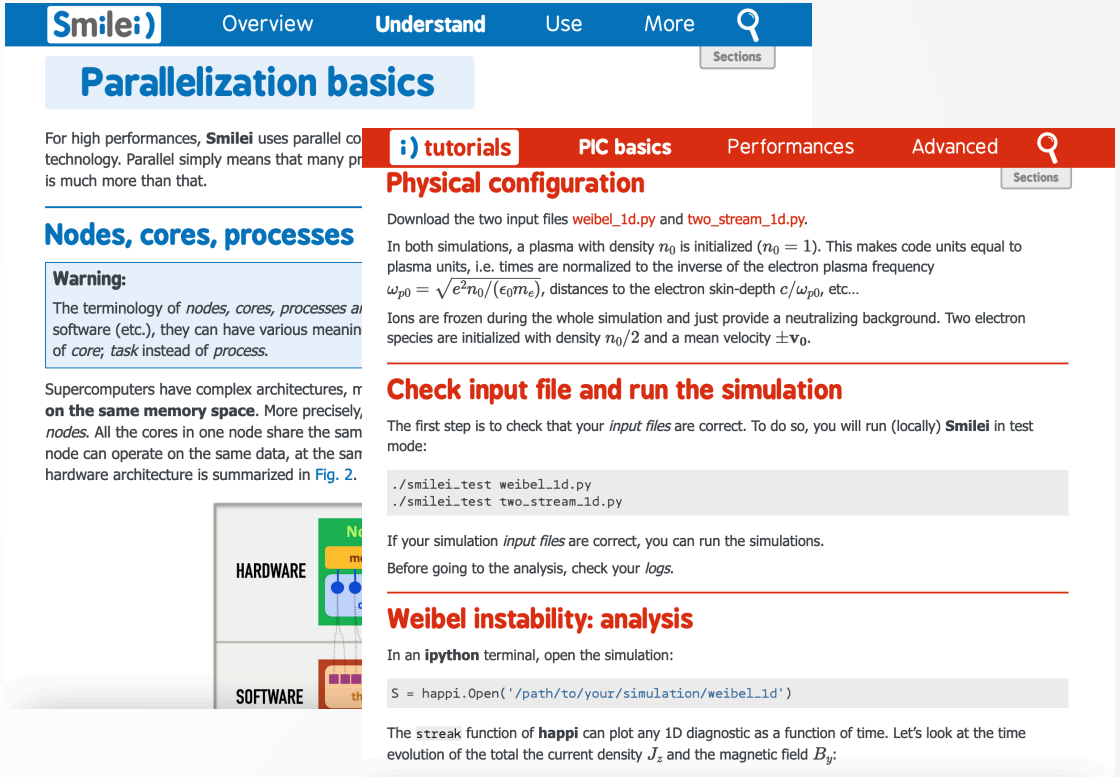
running on various supercomputers worldwide



with dedicated **post-processing tools** (Happi) and an ensemble of **benchmarks** (Easi, for continuous integration)

An extensive documentation

with online tutorials



and a collaborative community

Github
sources, issues

Element
chat

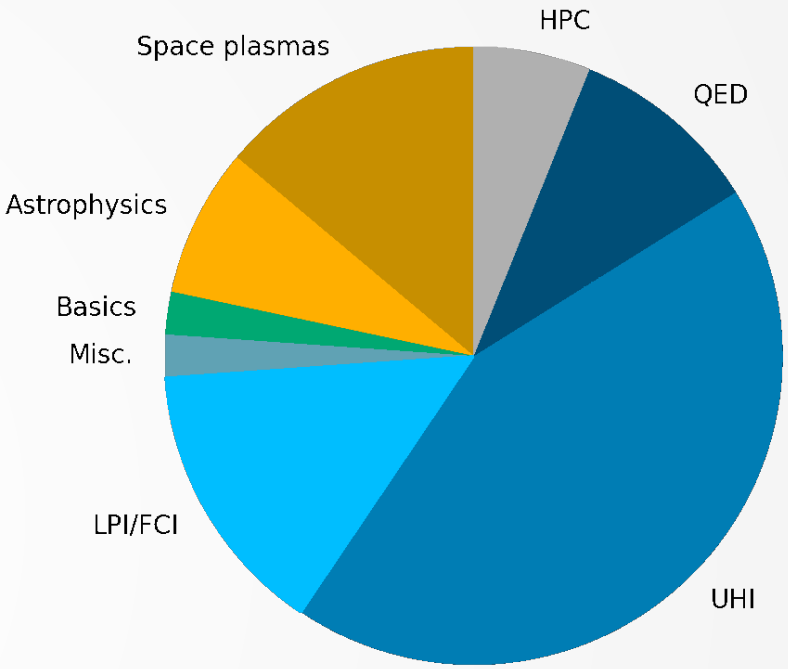
Smilei is a research & teaching platform

Scientific production is rich ...

130+ peer-reviewed papers have been published using Smilei
10+ PhD theses have already been defended

... and focuses on various applications

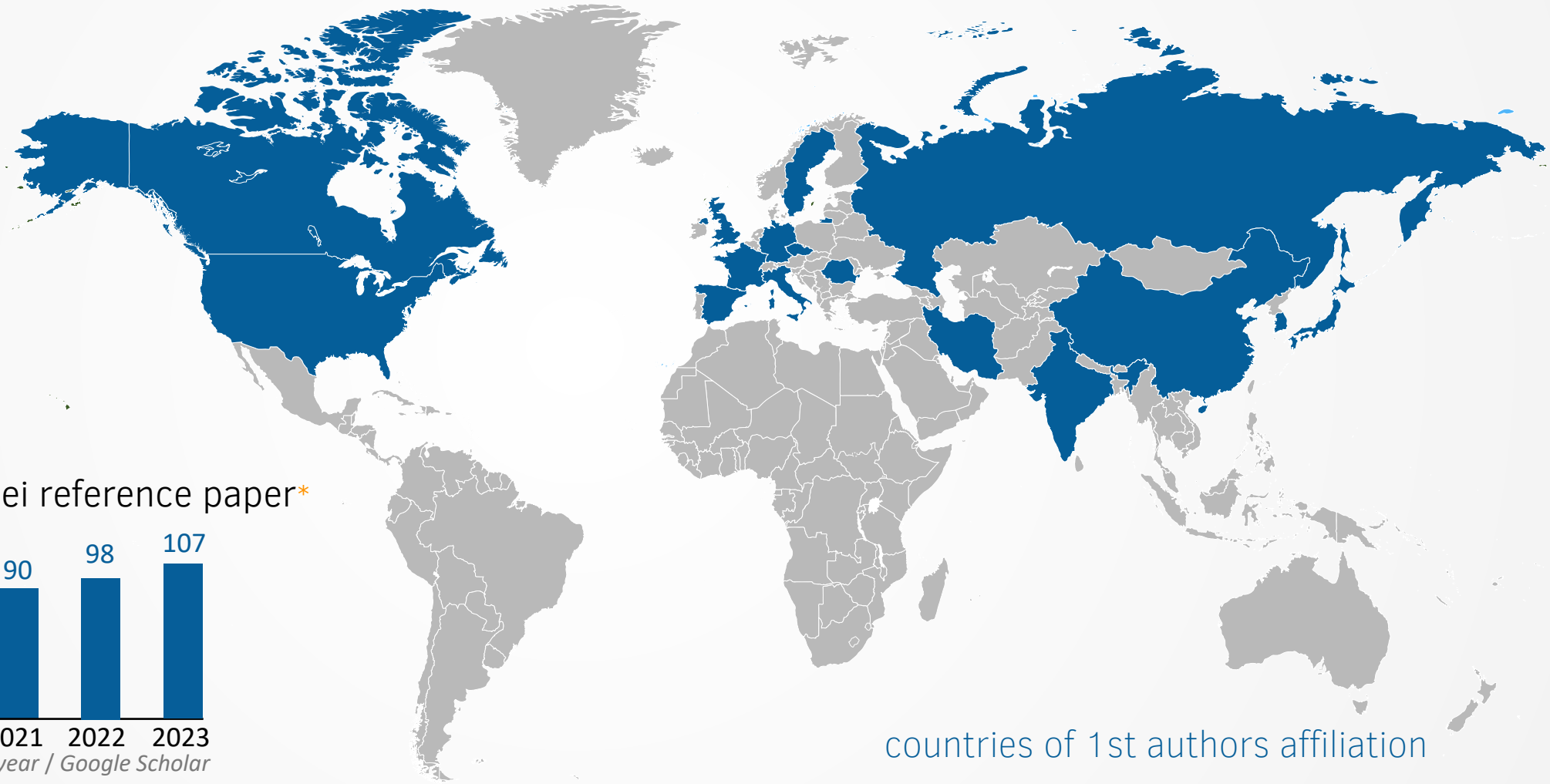
LPI/IFE : laser-plasma interaction / inertial fusion for energy
UHI : Ultra-high intensity
QED : Quantum electrodynamics (extreme light)
HPC : high-performance computing
Space plasmas & astrophysics



Teaching plasma physics

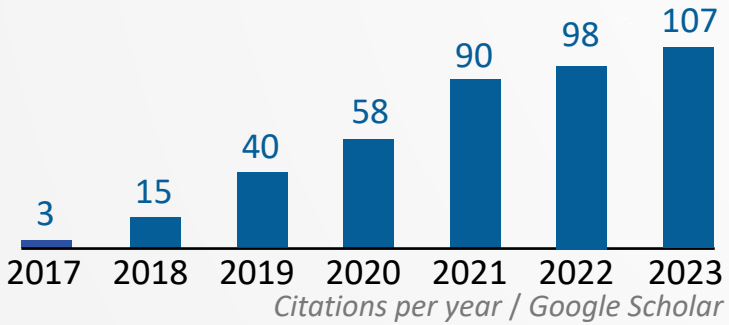
at the Master/doctoral levels in Europe
in various winter/summer schools
in user & training workshops
via online tutorials

Smilei's user community is international & steadily growing



countries of 1st authors affiliation

400+ citations for Smilei reference paper*



Citations per year / Google Scholar

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

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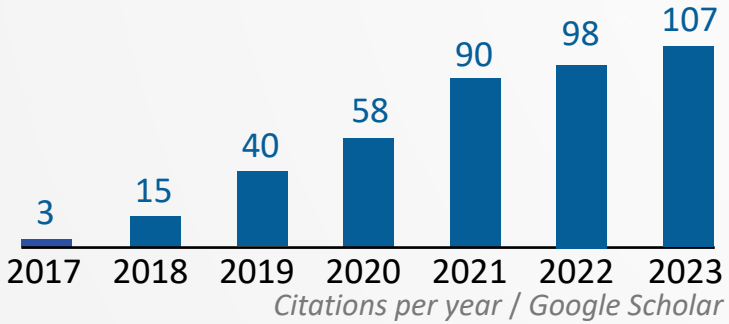


This year workshop welcomes participants from 10 countries!

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

A project anchored in the French & European HPC landscape

Integration in the French & European HPC landscapes

GENCI
Le calcul intensif au service de la connaissance

EuroHPC
Joint Undertaking

- running on all super-computers in France and many in Europe
- 10s millions computing hours every year via GENCI & PRACE/EuroHPC
- GENCI technological survey
- French Project NumPEX, Exascale project

Special/early access to various machines

2015 IDRIS/Turing BlueGene-Q
2016 CINES/Occigen
2018 TGCC/Irene-Joliot-Curie
2019 IDRIS/Jean Zay
2021 RIKEN/Fugaku
2022 CINES/Adastra (GPU)

A few recent highlights …

Code & HPC aspects

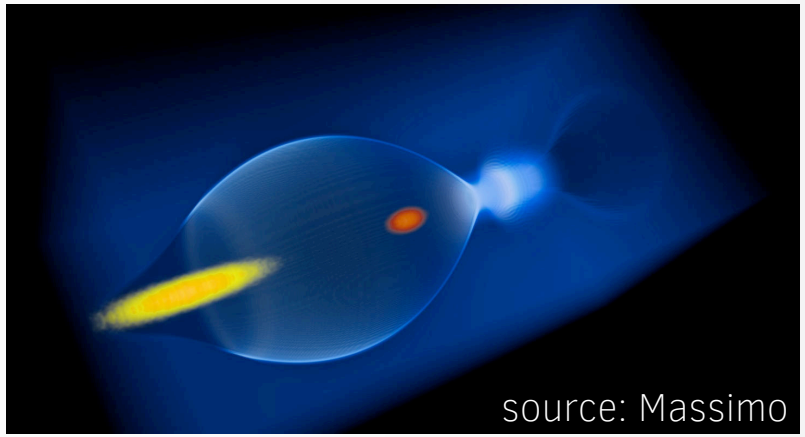
- optimization on ARM/RISC architectures*
- parallelization by task**

*Lobet et al., HPCAsia (2022) **Massimo et al., PASC (2022)

Additional physics modules (v4.7 and 4.8)

- upgrade of the Happi post-processing toolbox & diagnostic suit
- upgrade of the binary collision approach (nuclear reactions)
- advanced solvers for laser/particle-driven wakefield acceleration:
  - envelope models in various geometries & accounting for ionization
  - B-TIS3* interpolation scheme to mitigate numerical Cherenkov
- advanced boundary conditions:
  LaserOffset & Perfectly Matched Layers (also work with envelope)

*Bourgeois & Davoine, J. Plasma Phys. (2023)



More about it during Francesco's lecture tomorrow!

More also from our user community

- 30+ new articles published in peer-reviewed journal since our last workshop in March 2022!
- coupling with various codes / experimental data / Machine learning

... and a very big one!

Smilei 5.0 has just been released and it runs on NVIDIA & AMD GPUs !

NVIDIA OpenACC, CUDA

AMD OpenMP, HIP

Standard 2D and 3D simulations are supported

- extensive rewriting to run of both architectures & to insure performance!
- 2D and 3D cartesian geometries with various boundary conditions
- implementation is almost transparent to the user: `Main(..., gpu_computing=True)`
- porting of additional physics modules & advanced solvers is still work in progress
- additional releases will come regularly this year ... but there's already plenty you can do!

More info given during the workshop!

- see Francisco Rodriguez's contributed talk this afternoon (ADASTRA Grand Challenge)
- see also Arnaud's review this afternoon & Charles' lecture tomorrow
- you will try Smilei 5.0 on GPU during the tutorials on Friday!

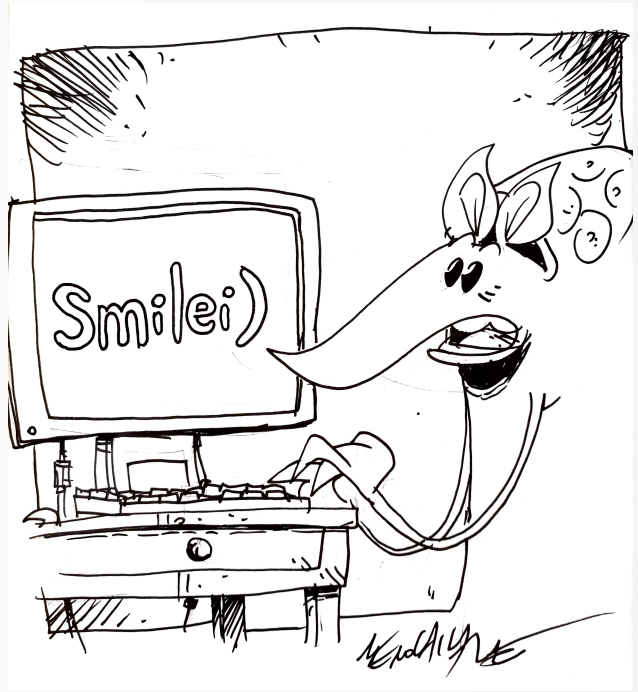
Perspectives

Code & HPC aspects

- GPU porting: AM geometry, adv. phys. modules, load-balancing
- parallelization by task, asynchronism
- advanced IO management (AI approach)
- refactoring / streamlining (200 000 lines of codes!)

Additional physics modules

- coupling with the strong-field QED ToolKit (collab. with MPIK, Heidelberg)
- additional atomic physics processes (Bremsstrahlung & Bethe-Heitler)
- advanced laser field injectors (collab. with ELI Beamlines & CEA/DAM)
- additional nuclear fusion processes (collab. with CELIA)



Keep on building & animating the user community

- encouraging new developers to join in
- developing an online teaching platform (beyond the tutorial approach)
- preparing next user & training workshop !

The Smilei dev-team

Co-development between HPC specialists & physicists

Charles Prouveur***
Mathieu Lobet*
Julien Derouillat
Haïthem Kallala, Juan Jose Silva Cuevas

Arnaud Beck*
Guillaume Bouchard (now at CEA)
Imène Zemzemi

Francesco Massimo*

Mickael Grech*
Frederic Perez*
Tommaso Vinci*
Marco Chiaramello, Anna Grassi

*permanent staff **Code architect
(CNRS DDOR, w.s.f. INP, INSU, IN2P3)

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Mickael Grech*
Frederic Perez*
Tommaso Vinci*
Marco Chiaramello, Anna Grassi

Olga Abramkina (also at MdlS)
Marie Flé

Etienne Malaboeuf

Asma Farjallah* (add NVIDIA)

Nicolas Aunai
Jérémie Dargent

Illya Plotnikov

Clément Caizergues
Emmanuel d'Humières

Paula Kleij
Michèle Raynaud

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*we need you: join the Smilei dev-team!

*permanent staff **Code architect
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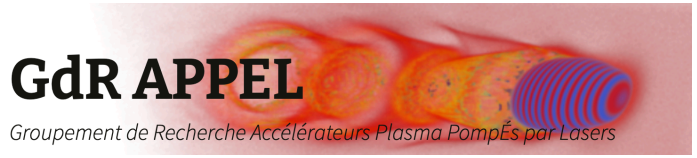
Thanks & Keep Smileing!)

Thanks for supporting this event!



Contributing labs, institutions & funding agencies