MiniPIC

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Maison de la Simulation

CExA Kokkos Hackathon, January 12-16, 2026
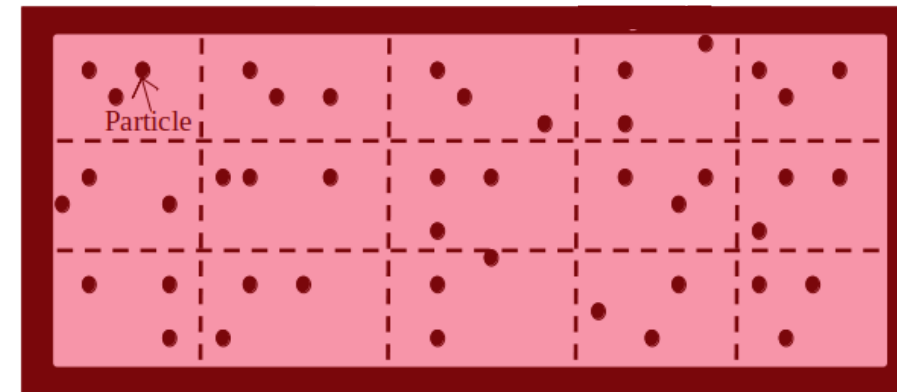
MiniPIC
Description

- MiniPIC: A Mini Application
- Based on Smilei, a simulation code for plasma physics
- Uses the **Particle-in-Cell (PIC)** model
- **Goal**: Explore new programming models

- C++ Code
- No distributed-memory parallelism across multiple nodes

- Several Programming Models Implemented: SYCL, Thrust, Kokkos, OpenMP, OpenMP Target, OpenACC and CUDA

- A Domain Consists of Two Data Structures:
  - ➤ **Particles:** Represent matter
  - ➤ **Grid:** Represents electromagnetic fields

- Interaction between particles and the grid
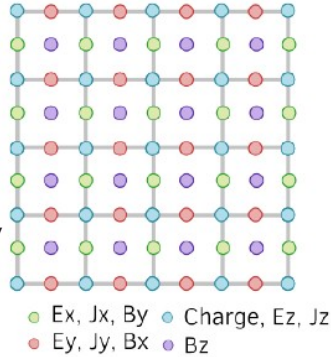
GPU
Domain

Particle

MiniPIC
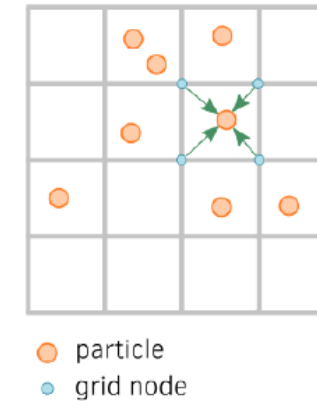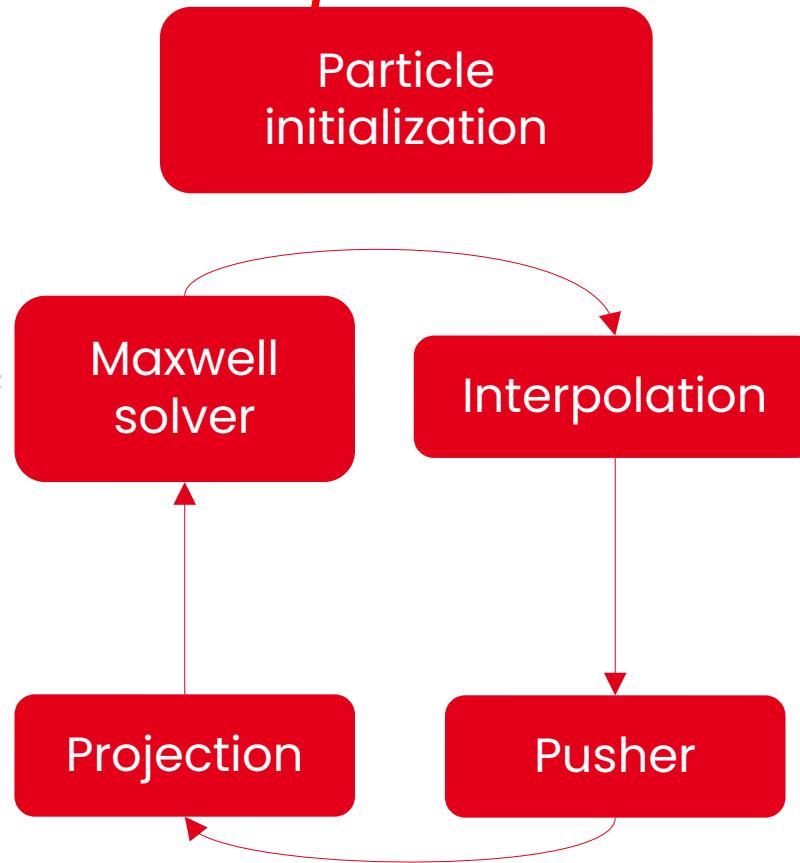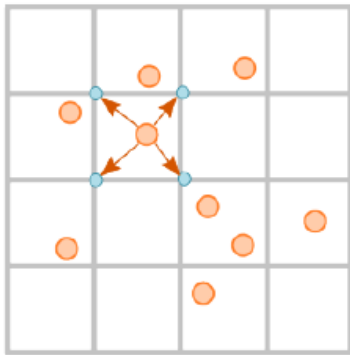## *PIC loop: The four main operators*

With the currents known, we update the E and B fields using Maxwell's equations
- ➢ Stencil problem
- ➢ Less computationally expensive

⇒ Parallelizes efficiently on GPU

Ex, Jx, By   Charge, Ez, Jz
Ey, Jy, Bx   Bz

Calculates the values of the electromagnetic fields at the position of each particle
- ➢ Random memory access on the grid
- ➢ Problem: Cache miss

particle
grid node

As particles move under the fields, they generate electric currents, which are computed and accumulated on the grid points
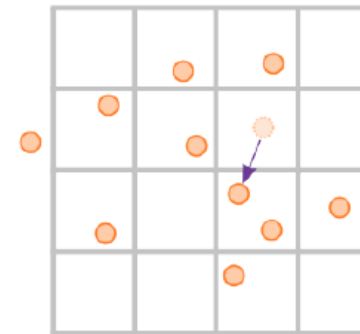- ➢ Random access
- ➢ Memory contention

Updates the momentum of the particles in response to the electric and magnetic fields
- ➢ Vector problem
- ➢ Indices are independent
- ➢ Contiguous memory access

⇒ Easy to port

Particle initialization

Maxwell solver
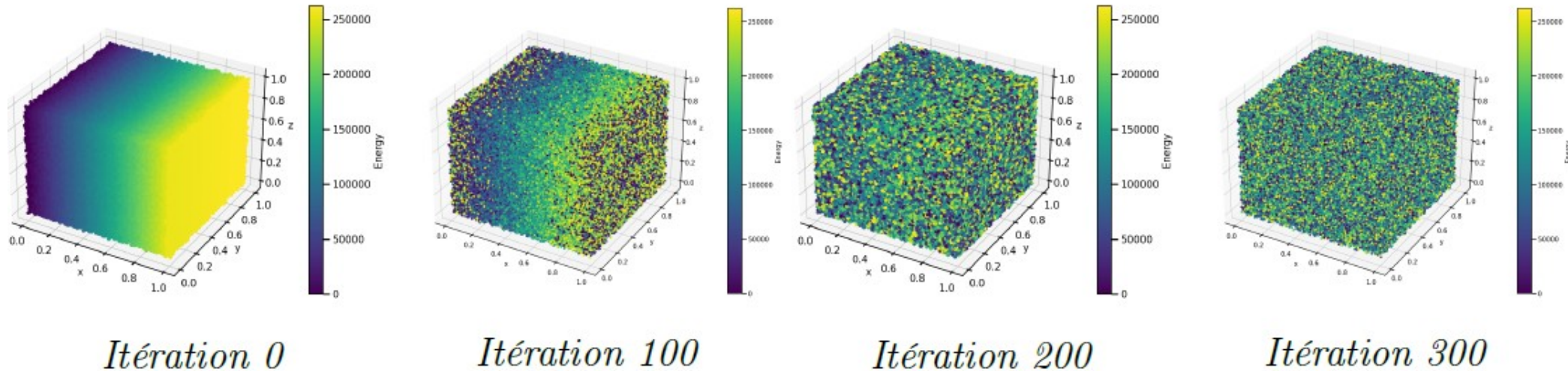
Interpolation

Projection

Pusher

MiniPIC
Methodology

- The case studied: Thermal plasma
- It consists of electrons and ions with a uniform charge distribution
- 64 cells per direction

- Comparison with :
  - Thrust
  - Kokkos
  - Thrust with UVM
  - Kokkos with UVM

GPU Name	CUDA/ ROCM Version	Compiler Version	Memory Size/Type	Memory Bandwidth (MB/s)	Double-Precision (TFLOPS)
NVIDIA V100 (PCIe 32GB)	12.2.1	nvc++ 23.7	32GB/HMB2	900	7
NVIDIA A100 (SXM 40GB)	12.2.1	nvc++ 23.7	40GB/HBM2	1555	9.7
NVIDIA H100 80GB	12.2.1	nvc++ 23.7	80GB/HBM3	3350	34
NVIDIA GH200 480GB	12.3	nvc++ 24.1	96GB/HBM3	4000	34
AMD MI250X	rocm-6.1.2	clang++ 17.0.0	128GB/HBM2e	3200	47.9
AMD MI300A	rocm-6.1.2	clang++ 17.0.0	128GB/HBM3	5300	61.3

MiniPIC
Example of results

Itération 0   Itération 100   Itération 200   Itération 300

Visualization of electron particles in a homogeneous and uniform thermal plasma