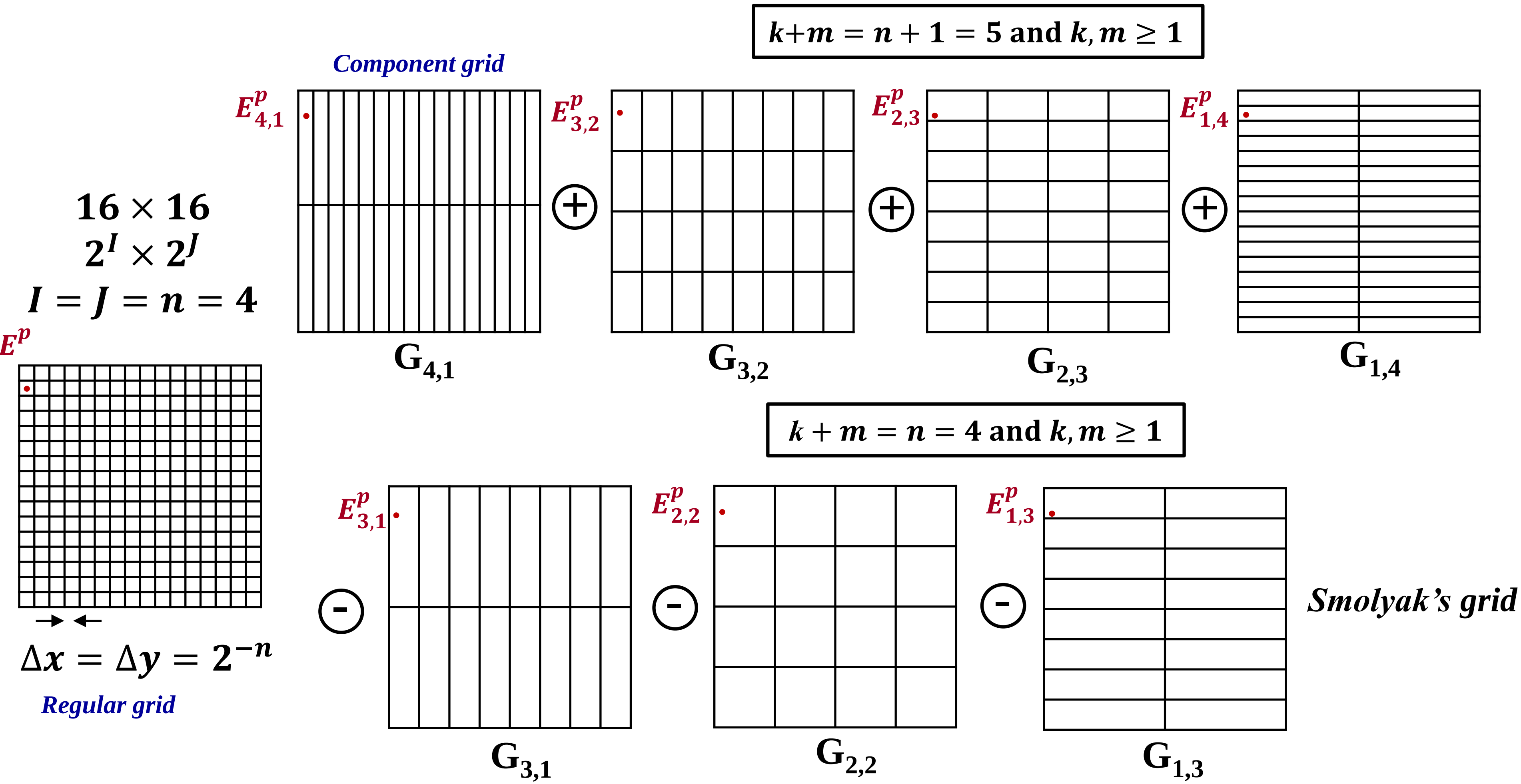
MATURATION :
Algorithmes PIC sur grilles parcimonieuses massivement parallèles pour la simulation des plasmas froids hors-équilibres
ANR-22-CE46-0012

CE46 - Modèles numériques, simulation, applications

DUREE : 2023 - 2026 (4 ANS)
BUDGET : 1 341 072 €
AIDE : 355 470 €

label

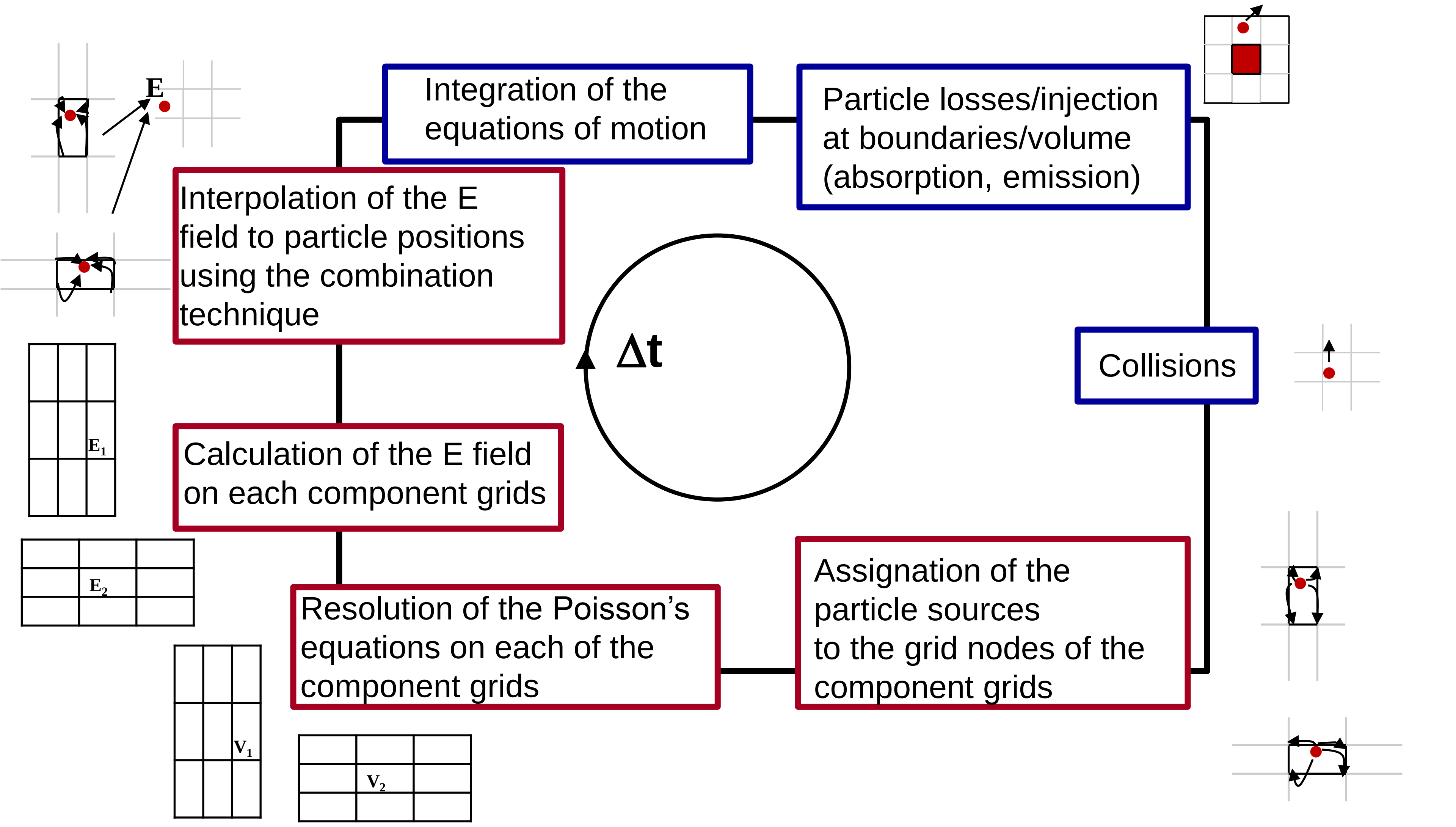
Décomposition en grilles de composantes



Combination technique

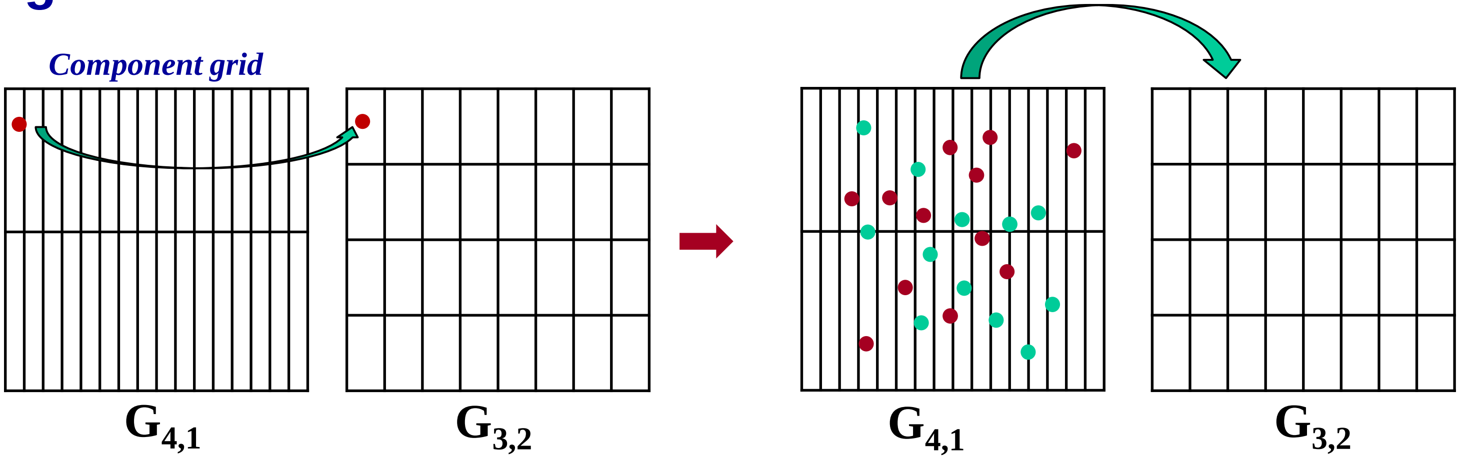
$$E^p \cong \sum_{k+m=n+1} E^p_{k,m} - \sum_{k+m=n} E^p_{k,m}$$

Cycle sparse-PIC



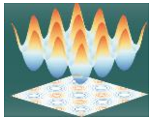
Base du code de Clément Guillet

- Code 3D en mémoire partagée (OpenMP)
- Recombinaison du potentiel sur la grille cartésienne
- Gestion optimisée dépôt de charge des particules sur les sous grilles

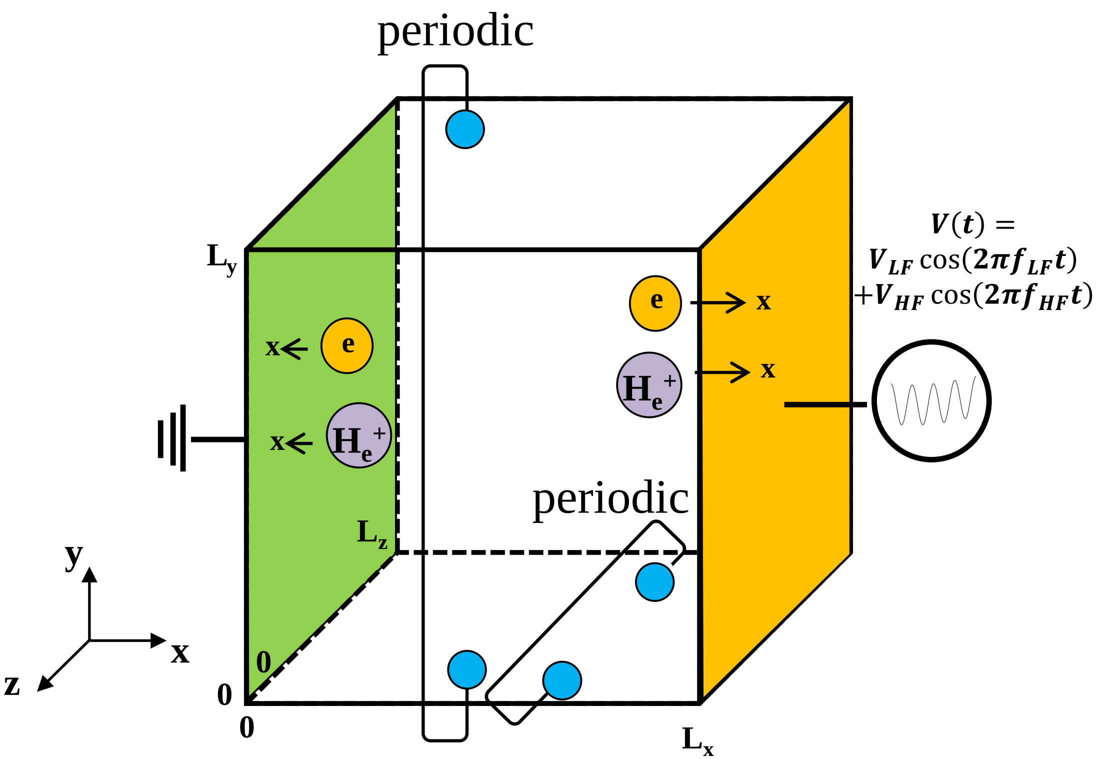


Modifications apportées - mineures

- **Atomic : reduction à la place (utile jusqu’à n = 9)**
- **Solveur Poisson (Pardiso) : solveur direct, meilleure maitrise**
- **Pusher: admensionnement des équations de transport**
- **Conditions aux limites Dirichlet**
- **Pertes aux parois (CdL non périodiques)**
- **Injection de particules**
- **Collisions**
- **Thermalisation des électrons**
- **Prise en compte d’un champ magnétique**
- **Application à un cas test – Olympe – 1 proc 18 cœurs (OpenMP)**



Simulations 3D quasi-1D



Discharge characteristics

electrons, Helium ions		
Initial electron temperature (eV)	3	3
Initial ion temperature (K)	300	300
Initial neutral temperature (K)	300	300
Frequency f_{LF} (MHz)	2	2
Frequency f_{HF} (MHz)	20	60
Electron-neutral collisions		
Ion-neutral collisions		
No SEE at the walls		

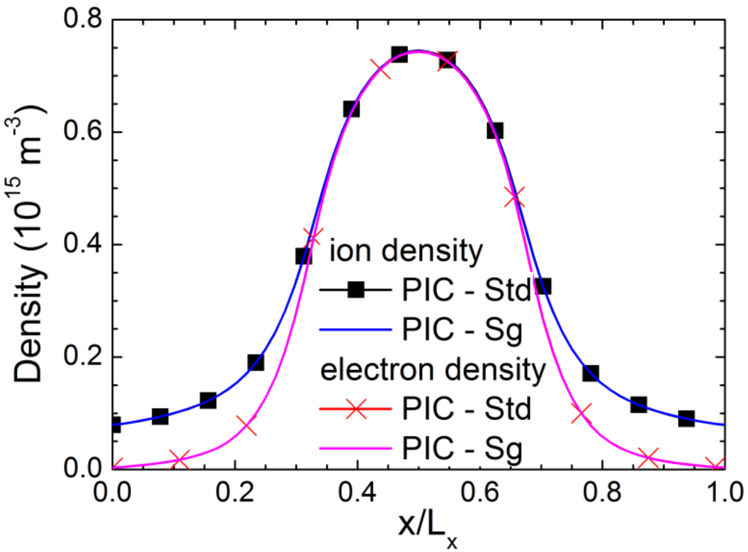
Initial conditions

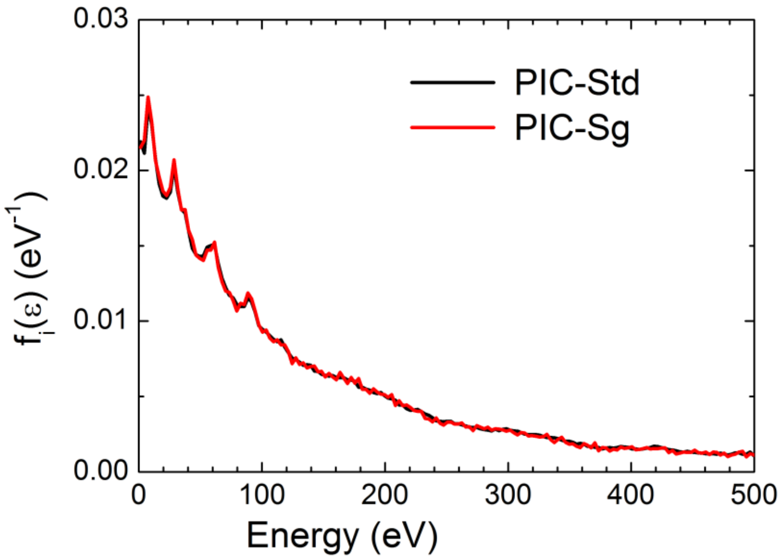
Neutral density (10^{21} m^{-3})	1.4	0.36
Pressure (Pa)	~6	~1.5
Initial plasma density (10^{14} m^{-3})	3.5	5.0
Voltage V_{LF} (V)	600	400
Voltage V_{HF} (V)	450	200

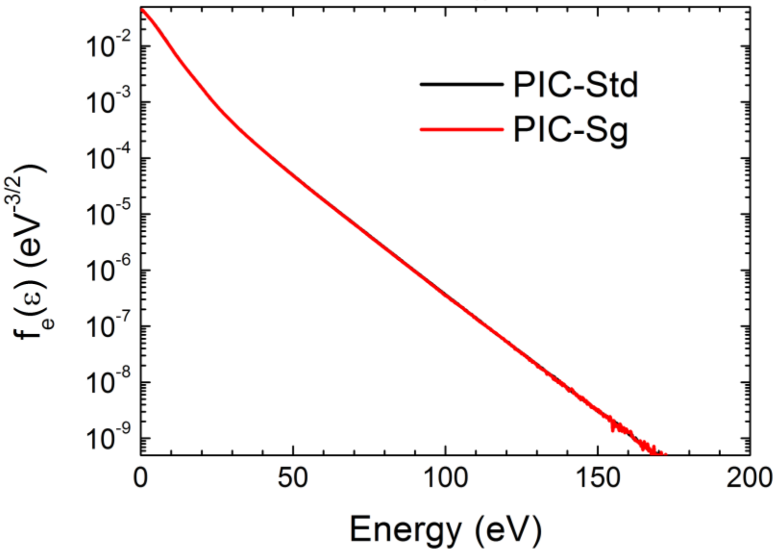
Simulation conditions

L_x, L_y, L_z (cm)	6.7	6.7
Number of grid cells (standard)	64^3	128^3
Time step (s^{-1})	$(800f)^{-1}$	$(200f)^{-1}$
N_{PC}	128	64
N_{total} standard (millions)	~ 34	~134
N_{total} sparse (millions)	~1.2	~1.7

Results @ 20 MHz





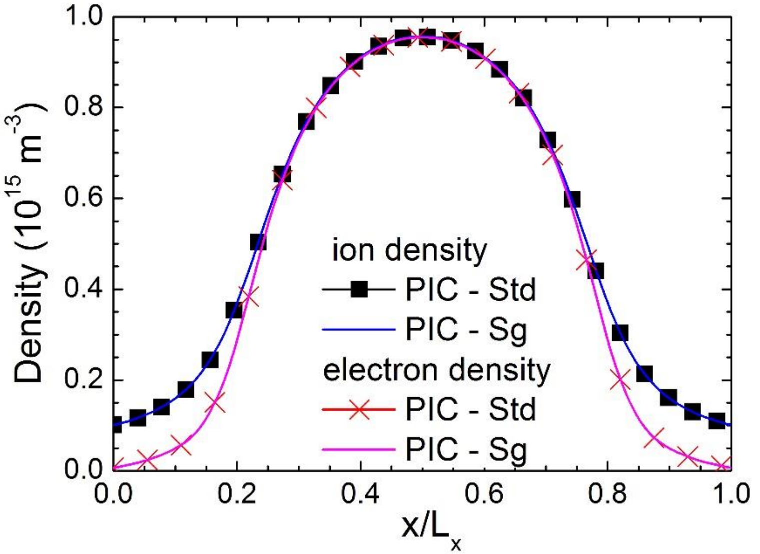


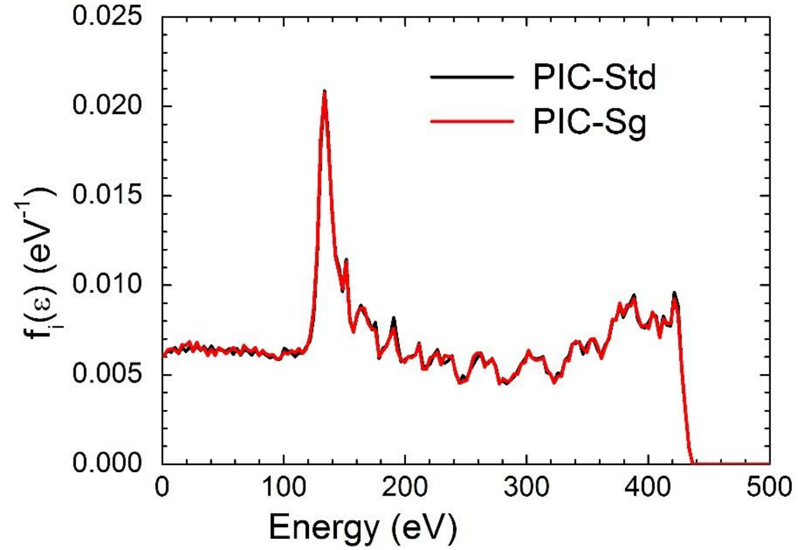
$$\epsilon(\varphi) = \frac{\|\varphi - \varphi_{\mathrm{ref}}\|_{L^2}}{\|\varphi_{\mathrm{ref}}\|_{L^2}} = \sqrt{\frac{\int |\varphi - \varphi_{\mathrm{ref}}|^2 \mathrm{du}}{\int |\varphi_{\mathrm{ref}}|^2 \mathrm{du}}}$$

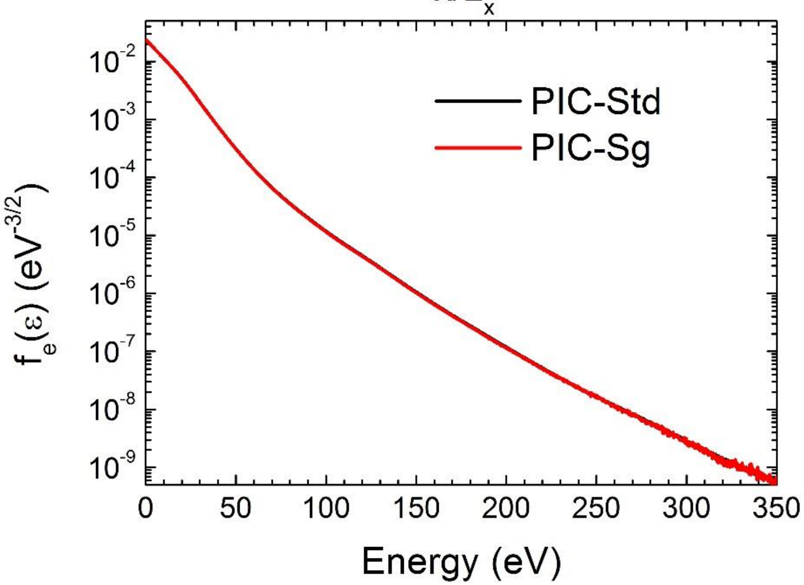
	Error (%)
n_i	0.18
n_e	0.19
$EEDF$	0.08
$IEDF$	0.26

Speed up ~ 5

Results @ 60 MHz





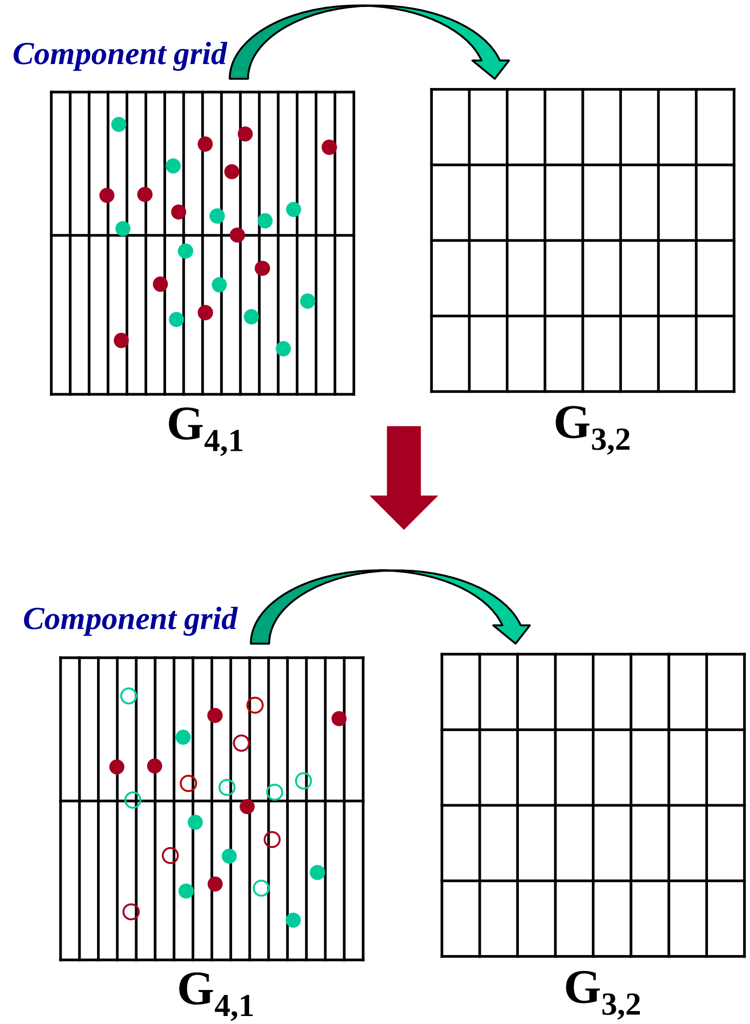


$$(\varphi) = \frac{\|\varphi - \varphi_{\mathrm{ref}}\|_{L^2}}{\|\varphi_{\mathrm{ref}}\|_{L^2}} = \sqrt{\frac{\int |\varphi - \varphi_{\mathrm{ref}}|^2 \mathrm{du}}{\int |\varphi_{\mathrm{ref}}|^2 \mathrm{du}}}$$

	Error (%)
n_i	0.4
n_e	0.5
$EEDF$	0.05
$IEDF$	0.23

Speed up ~ 15

Extension MPI/OpenMP du code 3D



Reduction en plus - MPI

Scaling – avec vectorisation projection, TGCC