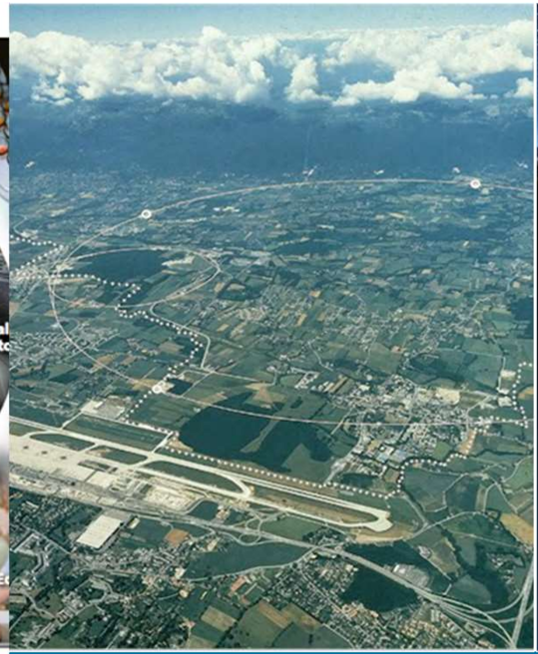
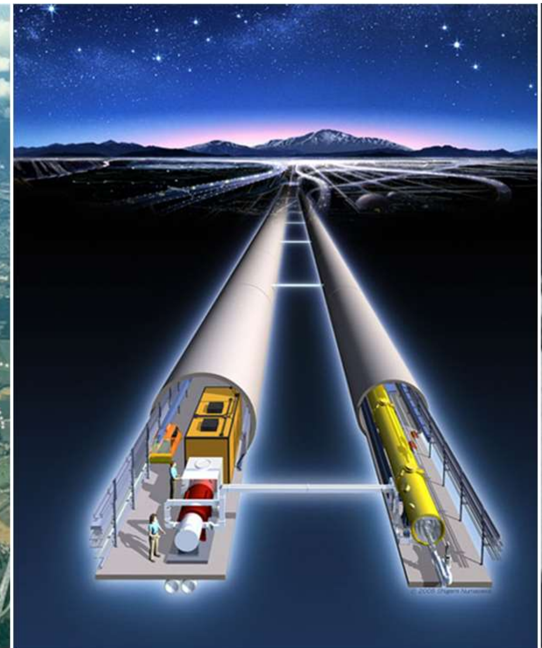


Particle-in-cell simulation of a Laser-Wakefield based High gradient accelerator

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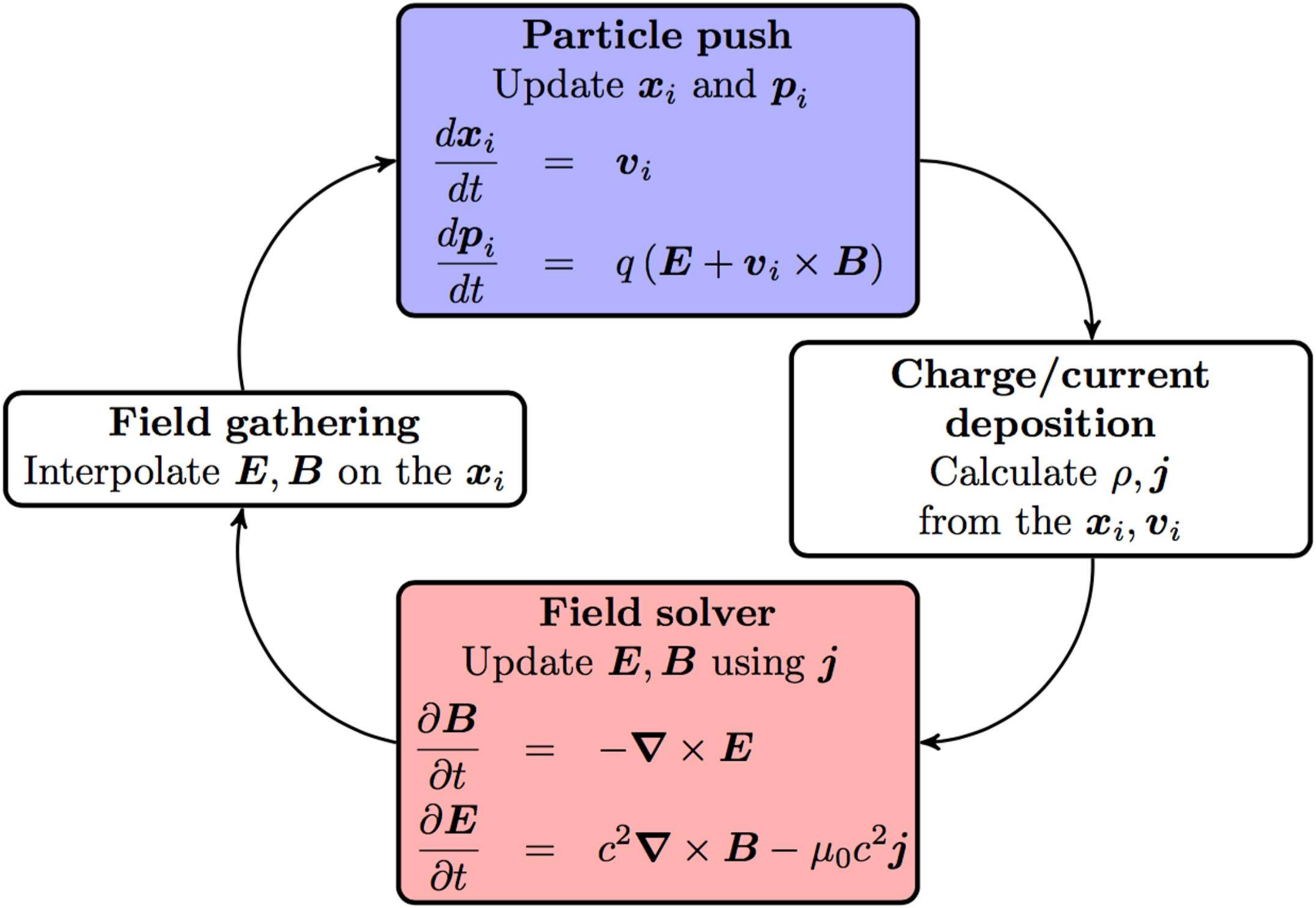
Introduction

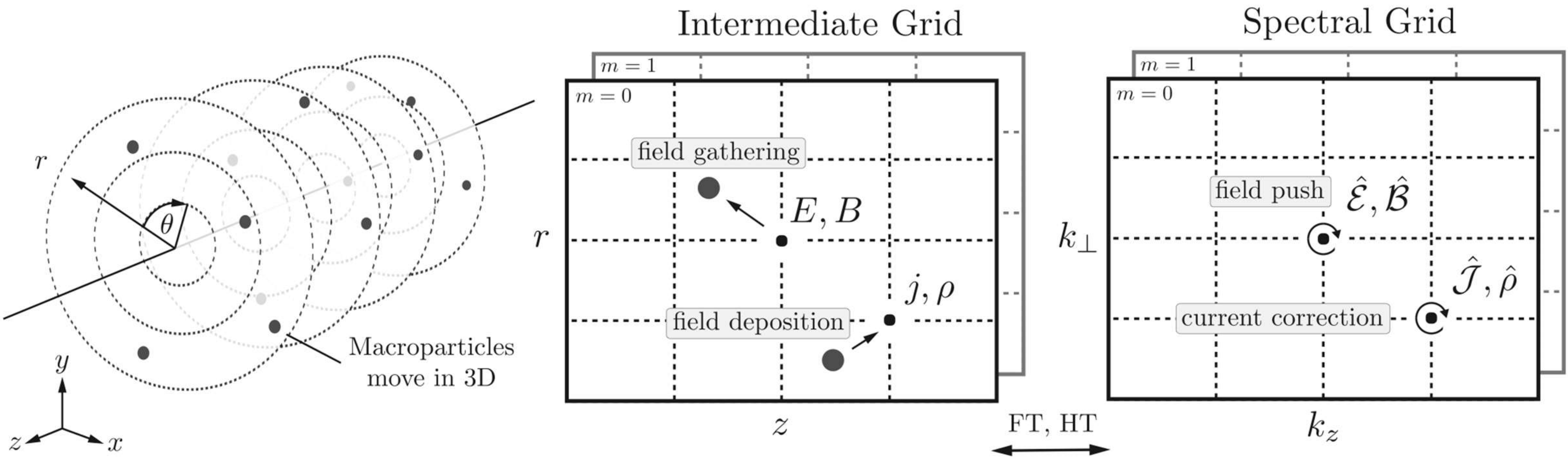
- We present Particle-in-cell simulation of a Laser-Wakefield based High gradient accelerator
- This study is carried out using FBPIC particle in cell code.
- FBPIC is a Specialized code, for plasma-based acceleration in nearly-cylindrical geometry

The Particle In Cell cycle

- The charged particles are represented by macroparticles (which lump together several physical particles), while the fields are represented on a grid.
- The time evolution of the system is simulated by taking discrete time steps.
- At each timestep:
  - The values of E and B are gathered from the grid onto the macroparticles.
  - The particles are pushed in time.
  - The charge and current of the macroparticles are deposited onto the grid.
  - The fields E and B are pushed in time.


Particle push
Update $\boldsymbol{x}_i$ and $\boldsymbol{p}_i$
$\frac{d\boldsymbol{x}_i}{dt} = \boldsymbol{v}_i$
$\frac{d\boldsymbol{p}_i}{dt} = q\left(\boldsymbol{E} + \boldsymbol{v}_i \times \boldsymbol{B}\right)$
Charge/current deposition
Calculate $\rho, \boldsymbol{j}$ from the $\boldsymbol{x}_i, \boldsymbol{v}_i$
Field solver
Update $\boldsymbol{E}, \boldsymbol{B}$ using $\boldsymbol{j}$
$\frac{\partial \boldsymbol{B}}{\partial t} = -\boldsymbol{\nabla} \times \boldsymbol{E}$
$\frac{\partial \boldsymbol{E}}{\partial t} = c^2 \boldsymbol{\nabla} \times \boldsymbol{B} - \mu_0 c^2 \boldsymbol{j}$
Field gathering
Interpolate $\boldsymbol{E}, \boldsymbol{B}$ on the $\boldsymbol{x}_i$

Cylindrical grid with azimuthal decomposition



- The fields are decomposed into azimuthal modes

$$F(r, z, \theta) = Re\left[\sum_{m=0}^{N_m - 1} \hat{F}_m(r, z) e^{im\theta}\right]$$

- m=0: purely cylindrical mode
- m=1: dipole mode
- m=2: quadrupole mode
- Each azimuthal mode is represented by a 2D r-z grid

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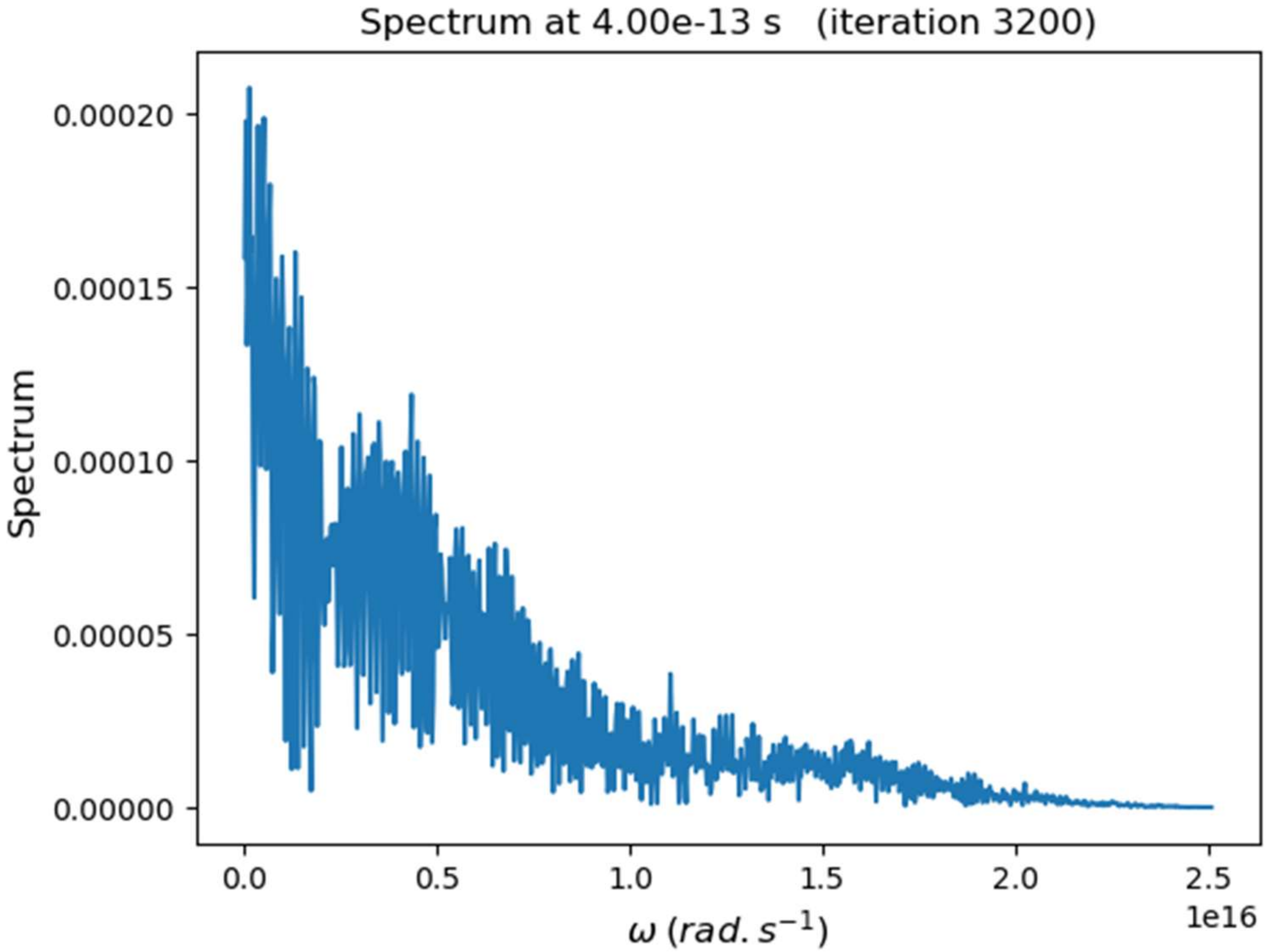
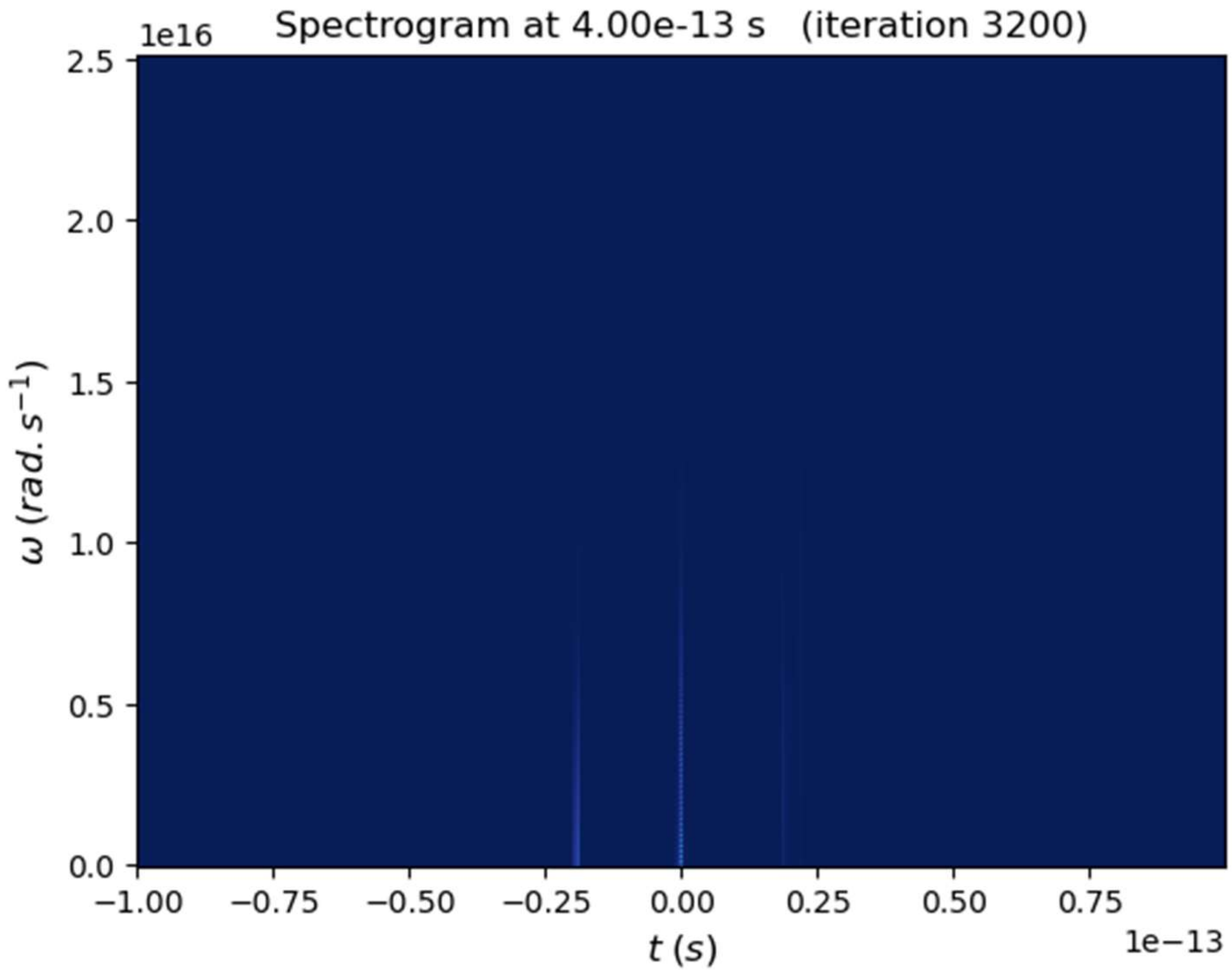
Input Parameters for FBPIC simulation

Electron density	10^{19} cm^{-3}
Laser amplitude	3.4
Laser beam waist	6.2 μm
Laser duration	7 fs

Spectrum of the Laser Field





time-frequency analysis of the laser

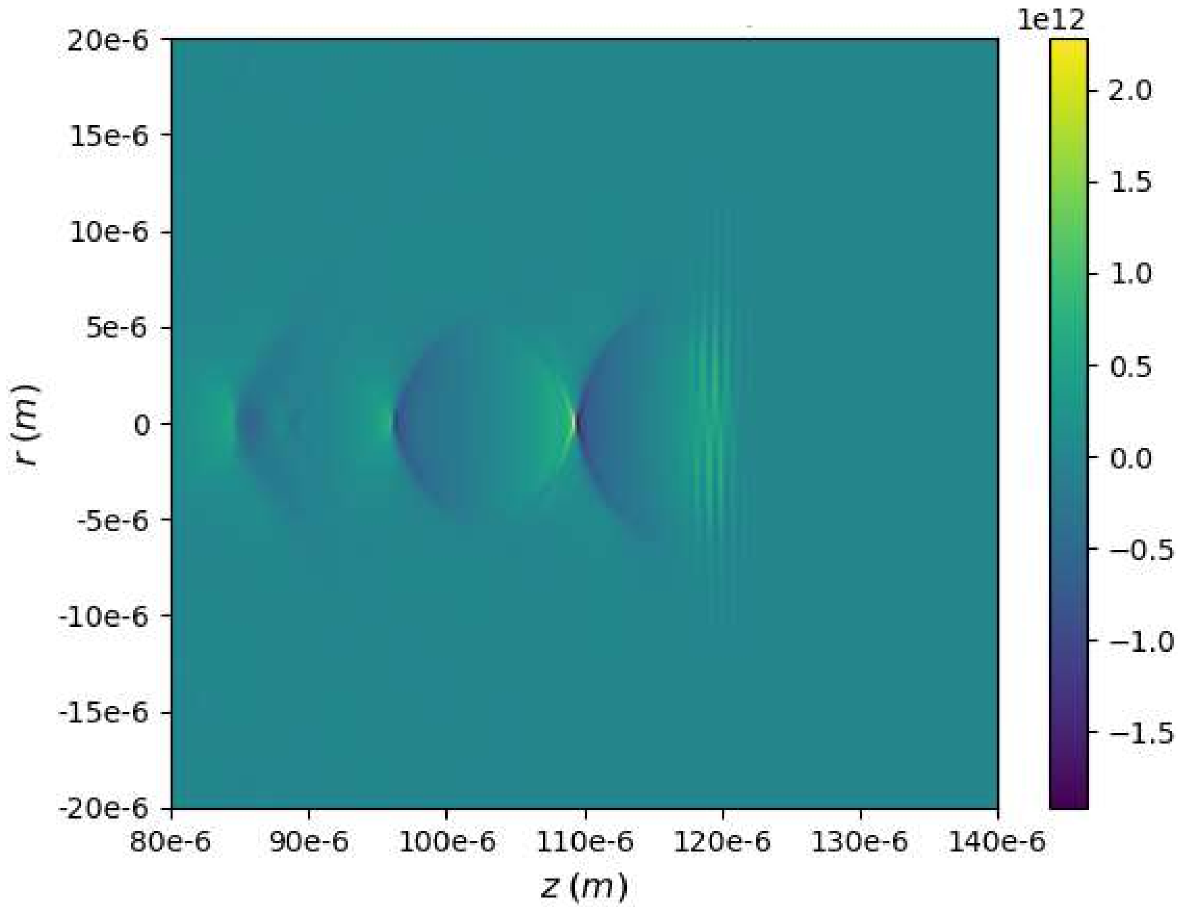


Fig. charge density, ρ illustrating the bubble regime.

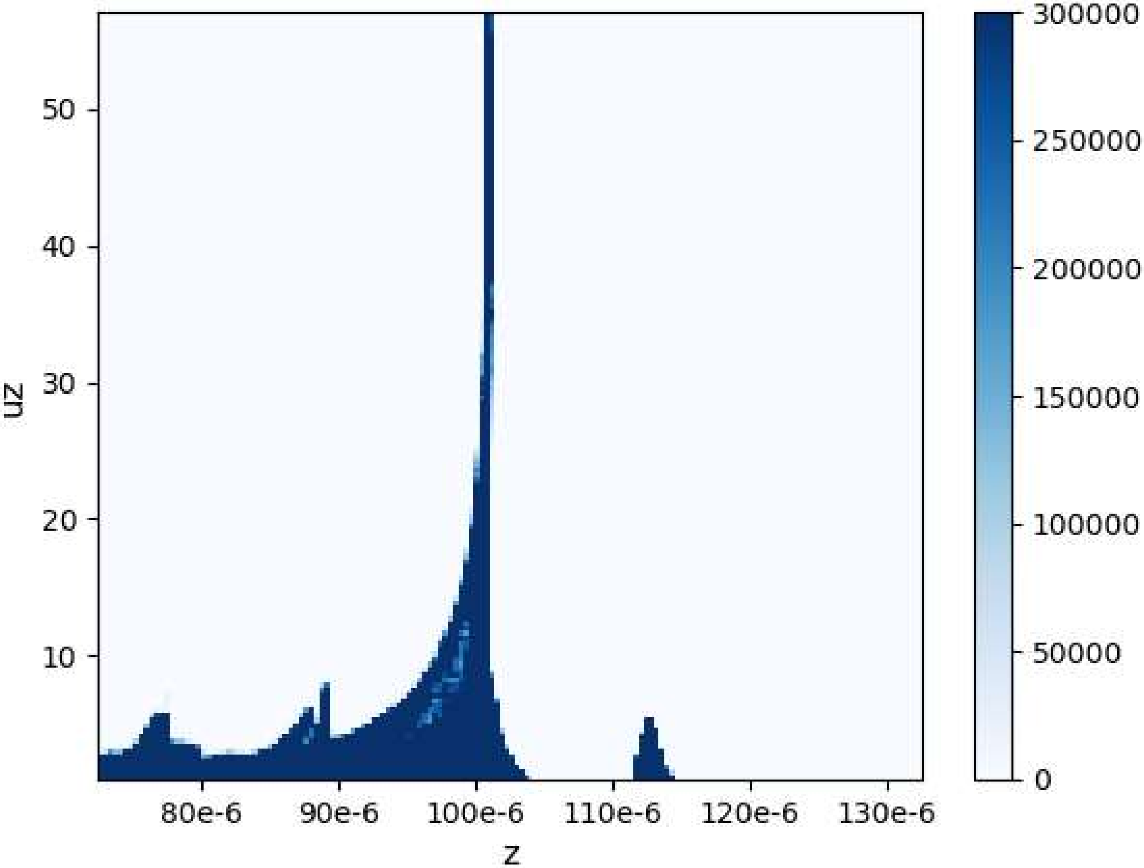
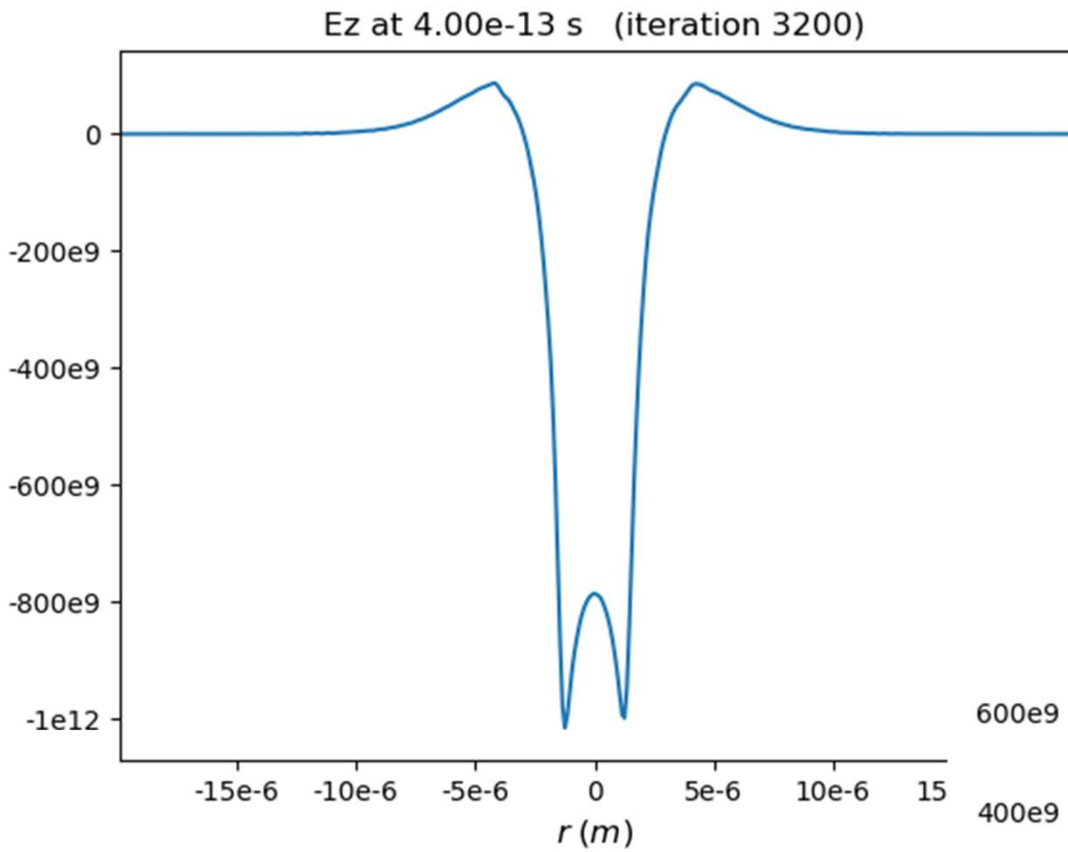
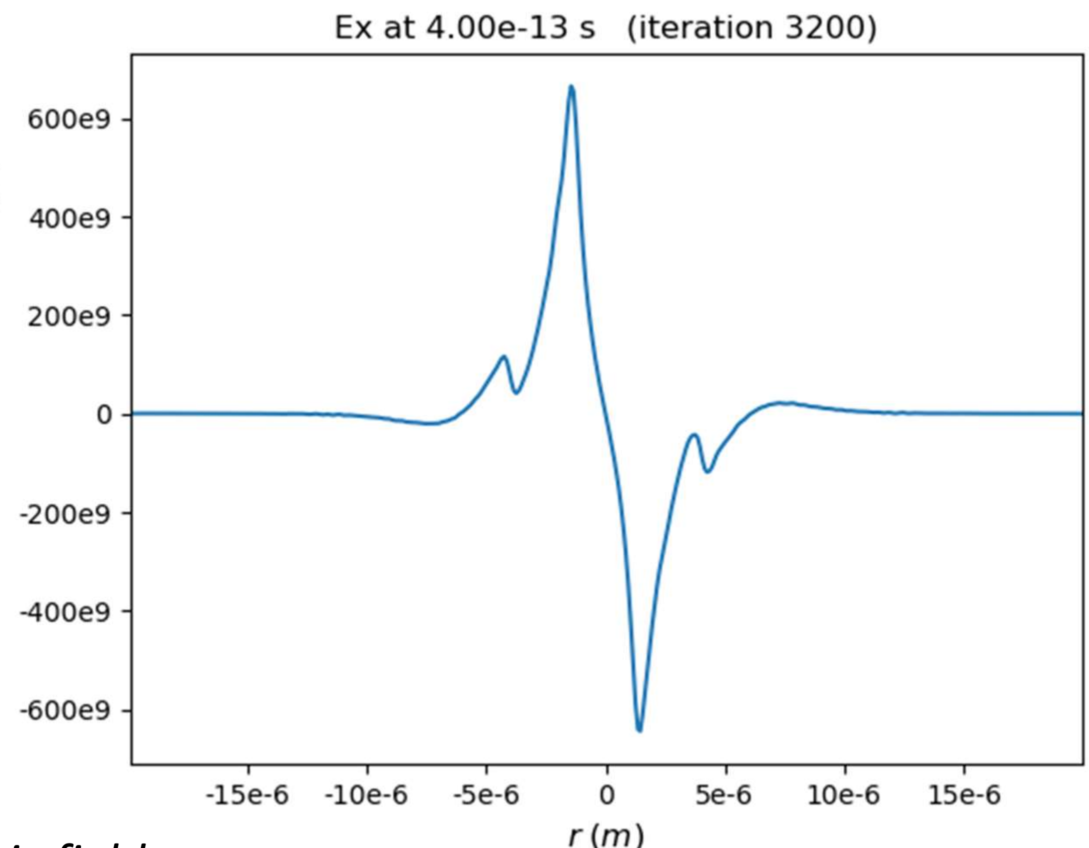


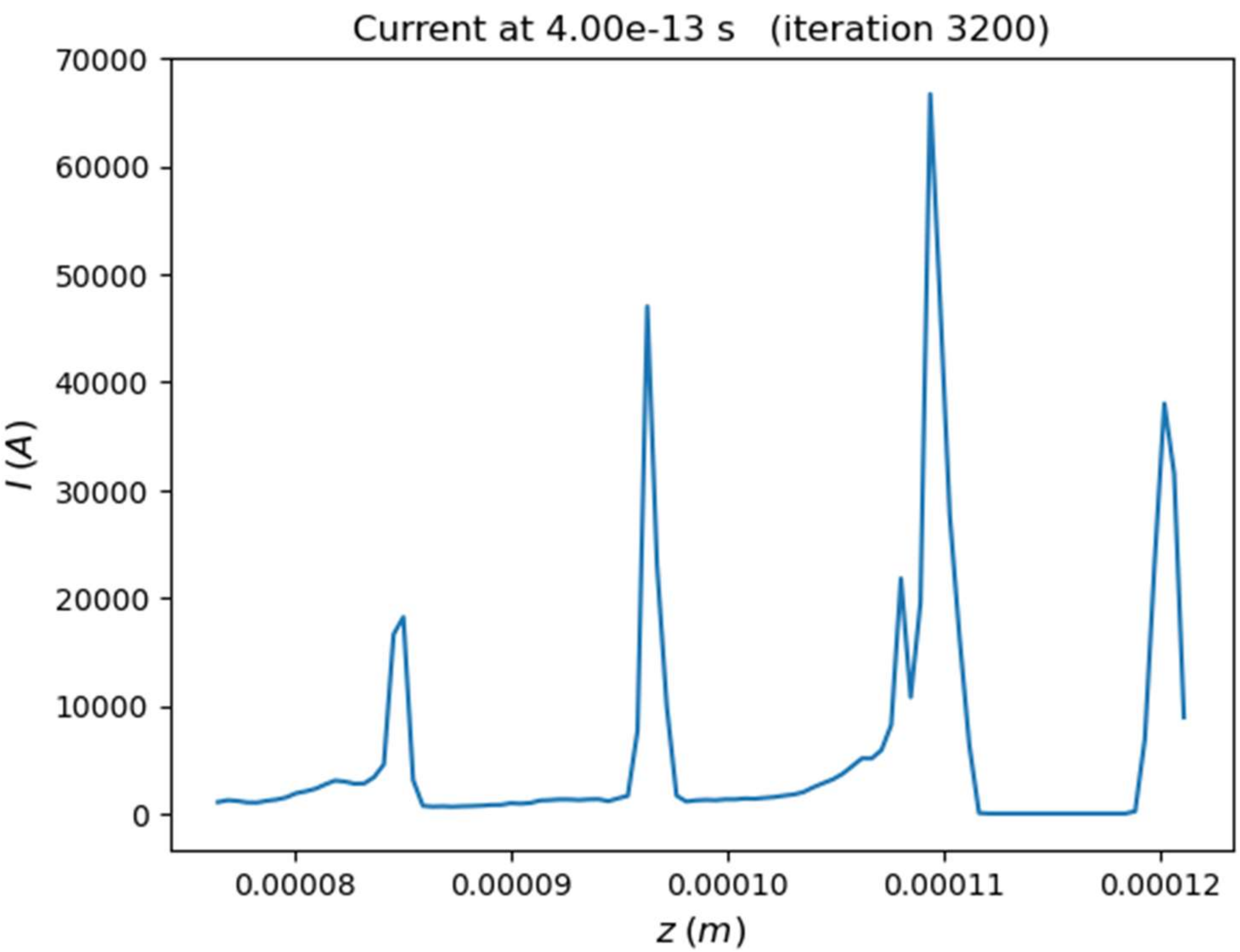
Fig. Phase space of electrons in the bubble regime.



electric field along the bubble



laser's electric field



Current at 4.00e-13 s (iteration 3200)
70000
60000
50000
40000
30000
20000
10000
0
I (A)
0.00008
0.00009
0.00010
0.00011
0.00012
z (m)

Fig. a charge density and corresponding longitudinal phase space before density modulation

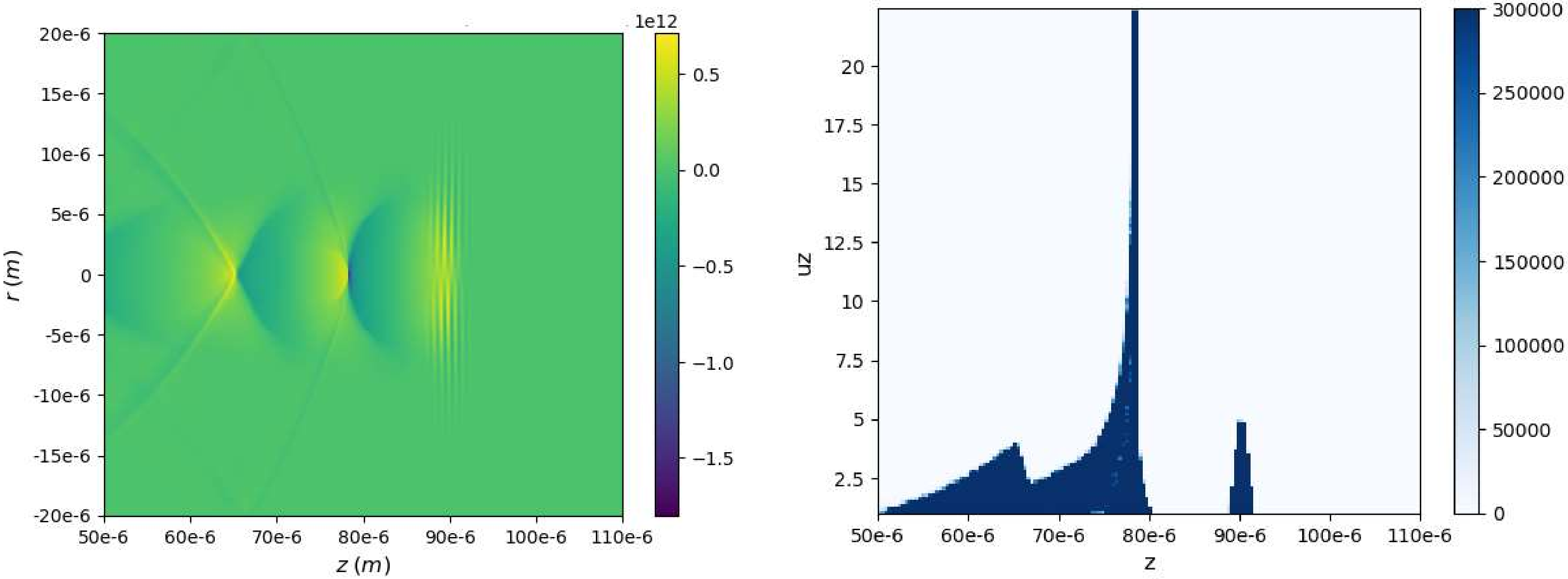
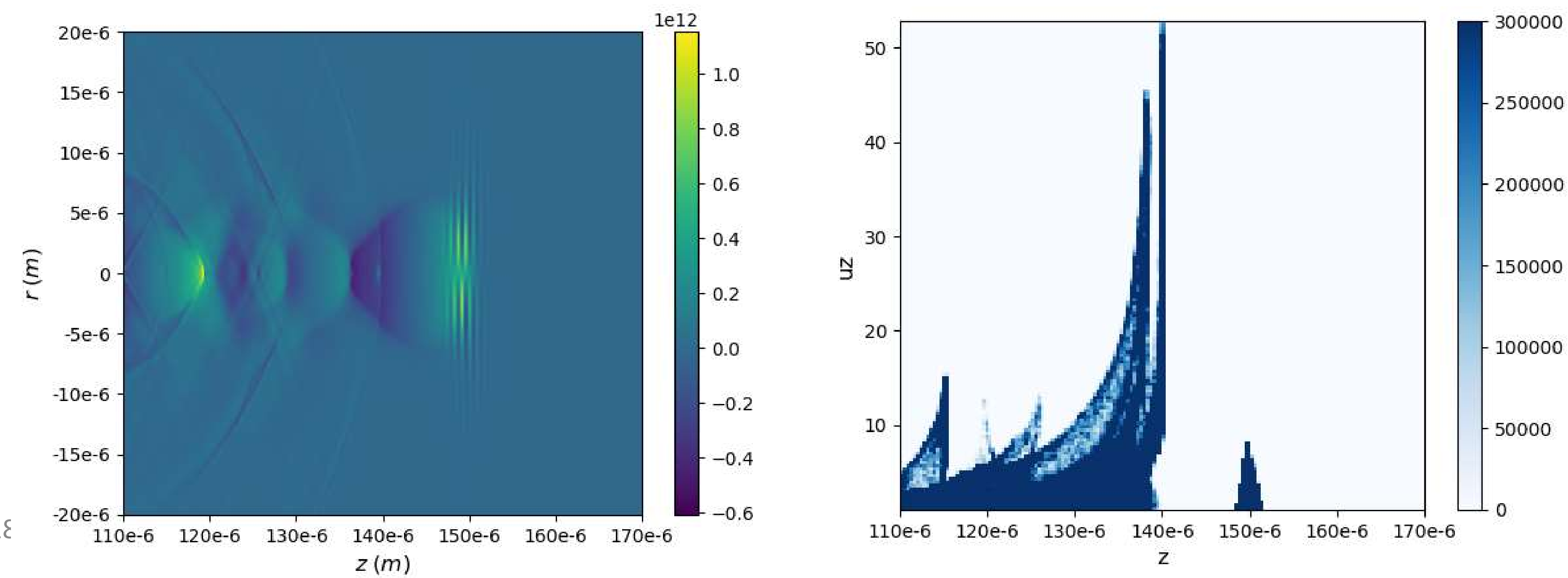


Fig. b charge density and corresponding longitudinal phase space after density modulation



Typical Output parameters

Peak particle Energy	About 35 MeV
Divergence	0.455 μrad
Current	50 kA
Emittance ε_x	14 μm
Emittance ε_y	6 μm

THANK YOU