Numerical solution of the Vlasov-Poisson problem

April 7th. 2015

Source

- FTP ftp://ifts.zju.edu.cn under incoming/zonca15.

Part I
An Introduction to Chen Zhao's PIC1D Code

Formulation

- Equation of motion for electron

$$\begin{cases} \dfrac{dx_i}{dt} = v_i \\ \dfrac{dv_i}{dt} = -\dfrac{eE(x_i)}{m_e} \end{cases}$$

- Electric potential

$$E(x) = -\frac{d\phi(x)}{dx}$$

- Poisson equation

$$\frac{d^2\phi(x)}{dx^2} = -\frac{e}{\epsilon_0}[n_0 - n(x)]$$

Formulation

- Weight

$$S_x(x - x_{j\alpha}) = \begin{cases} \dfrac{h_x - |x - x_{j\alpha}|}{h_x^2} & |x - x_{j\alpha}| < h_x \\ 0 & \text{otherwise} \end{cases}$$

Part II
An Introduction to Wenjun Deng's PIC1D Code

Acquisition Code and Required Lib

- Code
  - You can easily get Wenjun Deng's PIC1D code from: https://github.com/wenjundeng/pic1dp
  - I suggest you setup the code on a Linux based system
- Required Lib
  - Compile & Run
    - Fortran 2003 compiler (e.g. GFortran)
    - MPI-2 (e.g. MPICH2 1.4+, OpenMPI 1.5+)
    - PETSc 3.1+
  - Visualization output results
    - Python 2.7
    - Numpy 1.4+
    - matplotlib 1.1+
    - Scipy (Optional, for calculating dispersion relation analytically)

Installation

- See the Simple Guide to Run Wenjun Deng's PIC1D Code.

Code Structure Overview

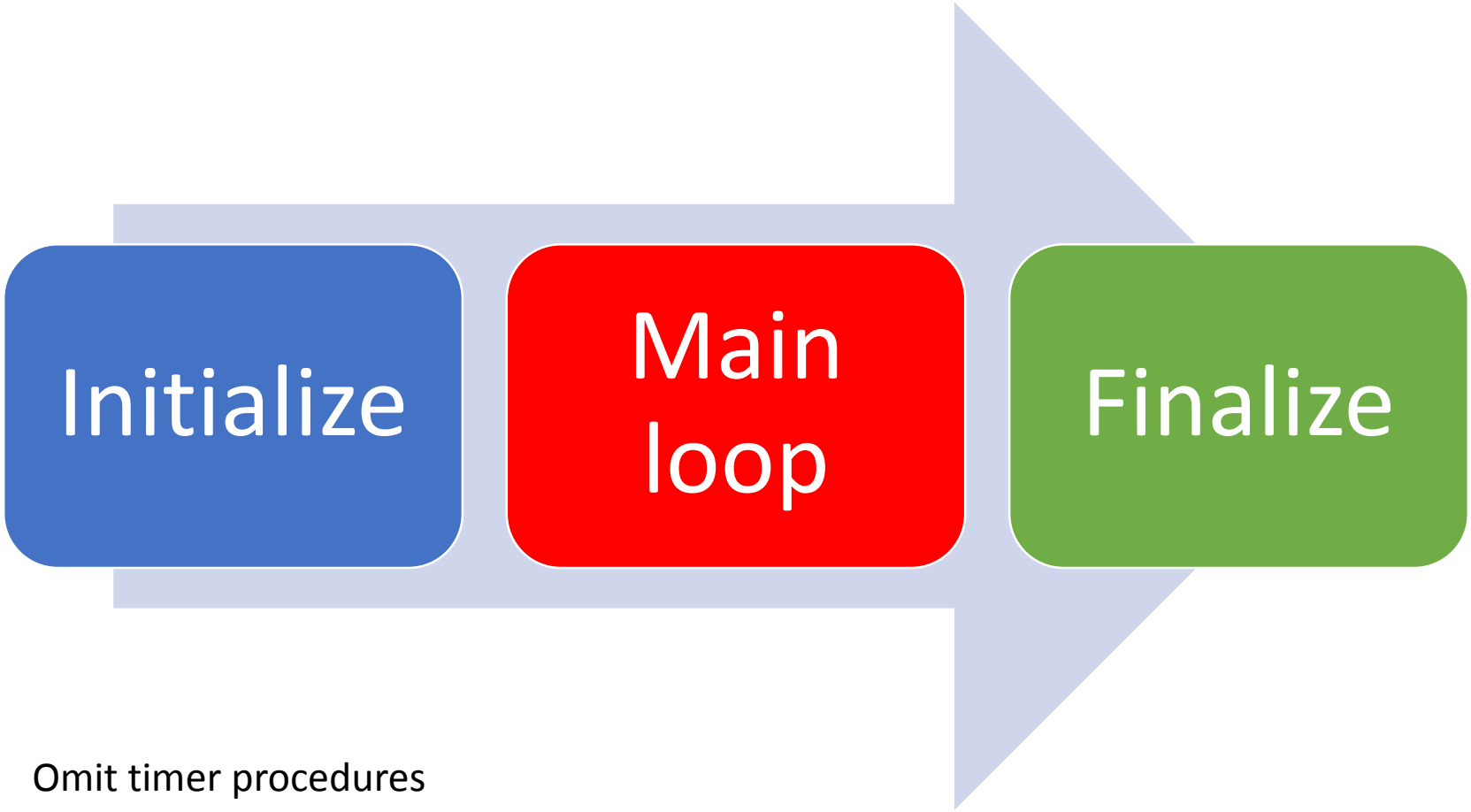
- All the functions / procedures are prefixed by the name of the source file that contained them.
- Most of the parameters are in src/pic1dp_input.F90 with detailed description.

Code Structure Overview
Source files

pic1dp.F90	The main program file.
pic1dp_global.F90	Module for managing global constants, variables and subroutines.
pic1dp_input.F90	Module for managing input parameters and functions. Change input parameters in this file.
pic1dp_particle.F90	Module for managing marker particles.
pic1dp_field.F90	Module for managing field quantities.
pic1dp_interaction.F90	Module for managing field-particle interactions.
pic1dp_output.F90	Module for managing output.
wtimer.F90	A wall clock timer using MPI_Wtime().
multirand.F90	A pseudo-random number generator.

Code Structure Overview

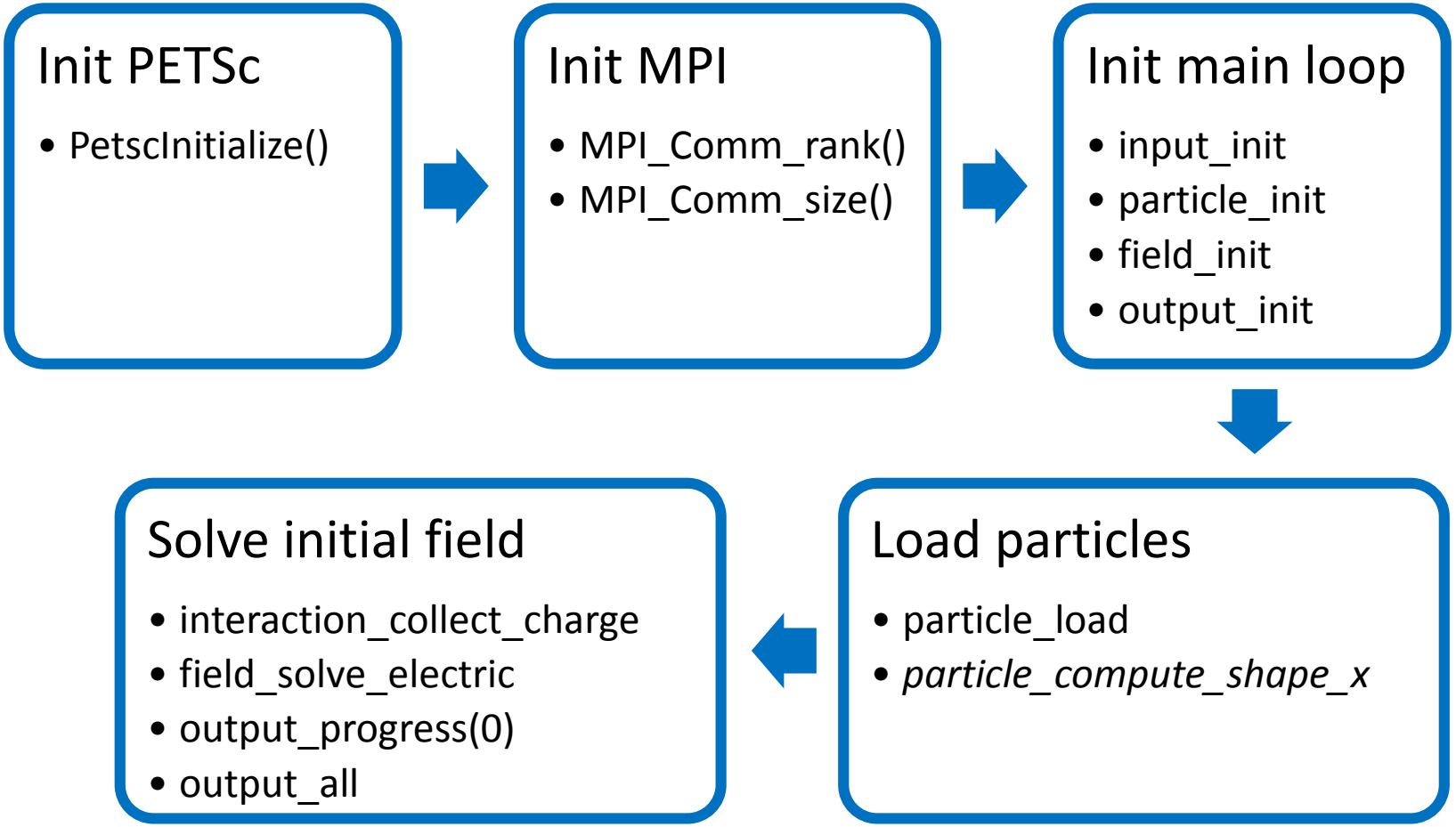
Execution flow



Omit timer procedures

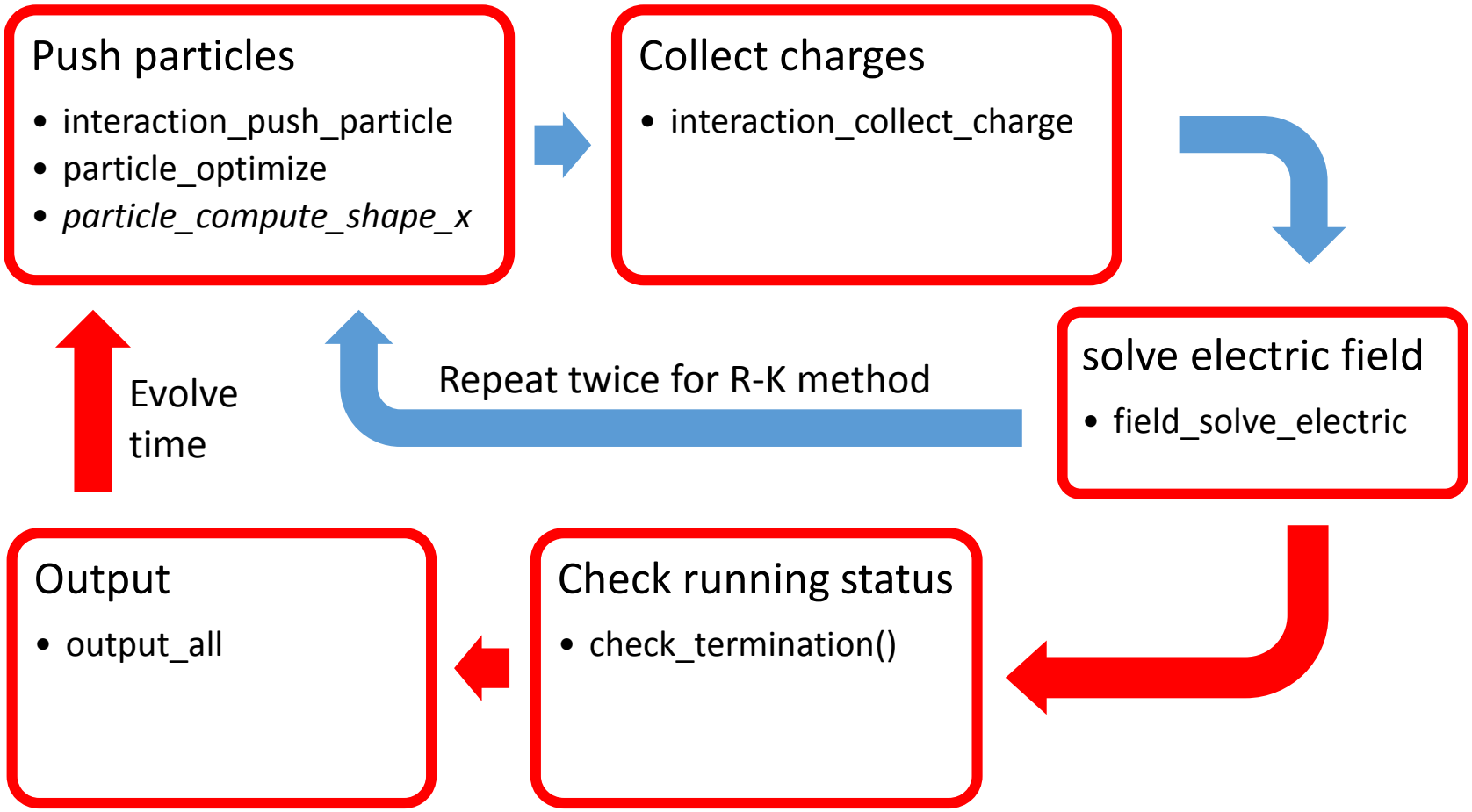
Code Structure Overview

Initialize



Code Structure Overview

Main loop



Code Structure Overview
Finalize

Finalize main loop

- particle_final
- field_final
- output_final

Finalize PETSc

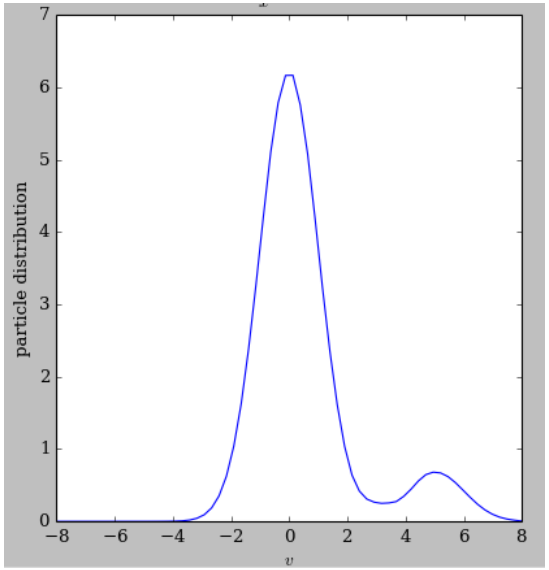
- PetscFinalize()

Basic Usage

- Modify input parameters
- Run
- Analyze output results

Basic Usage
Modify input parameters

- Take the default pic1dp_input.F90 file as an example
  - An electron bump-on-tail instability
  - Section V.A.2 in Siminos et al. (2011) PRE
  - http://dx.doi.org/10.1103/PhysRevE.83.056402



Basic Usage
Modify input parameters

termination conditions	physical parameters	initial condition	numerical parameters
• input_ntime_max • input_time_max	• input_linear • input_lx • input_iptcldist • input_nspecies • input_nspecies_xxx • input_nmode • input_modes	• input_init_nmode • input_init_mode • input_init_mode_cos • input_init_mode_sin	• input_deltaf • input_dt • input_nparticle_max • input_species_nparticle_init • input_imarker • input_v_max • input_nx • input_nv • input_iptclshape

Basic Usage
Modify input parameters

marker particle optimizations	random number generator (multirand) parameters	output parameters
• input_nmerge • input_tmerge • input_thshmerge • input_nremove • input_tremove • input_typeremove • input_thshremove • input_remove_frac • input_nsplit • input_tsplit • input_thshsplit • input_split_ngroup • input_split_dv_sig_frac	• input_multirand_al_int • input_multirand_seed_type • input_multirand_warmup • input_multirand_selftest	• input_verbosity • input_output_interval • input_nx_opd • input_nv_opd

Basic Usage
Run

- Compile
  - First time compile
    - Run make in the terminal
  - Otherwise
    - Run make cleanbuild first in the terminal, then run make
- Execute
  - On single machine
    - Run make run in the terminal
  - On cluster
    - Change the executive program name in the job script

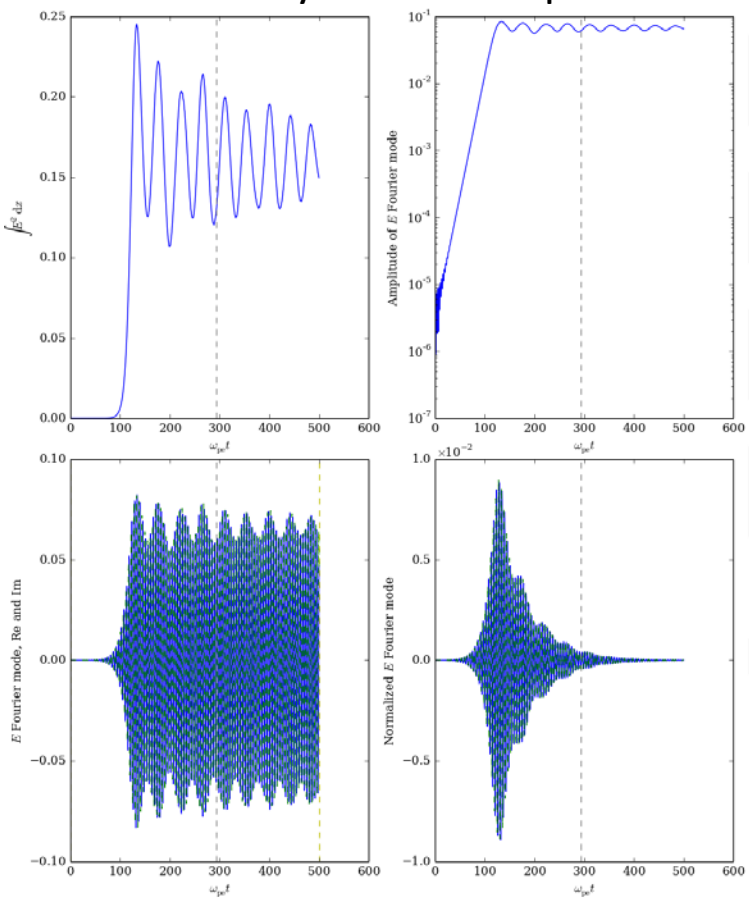
Basic Usage
Analyze output results

- The running progress is logged to run/pic1dp.log.
- The output data is written to run/pic1dp.out.
- To run the visualization app, execute make visual.

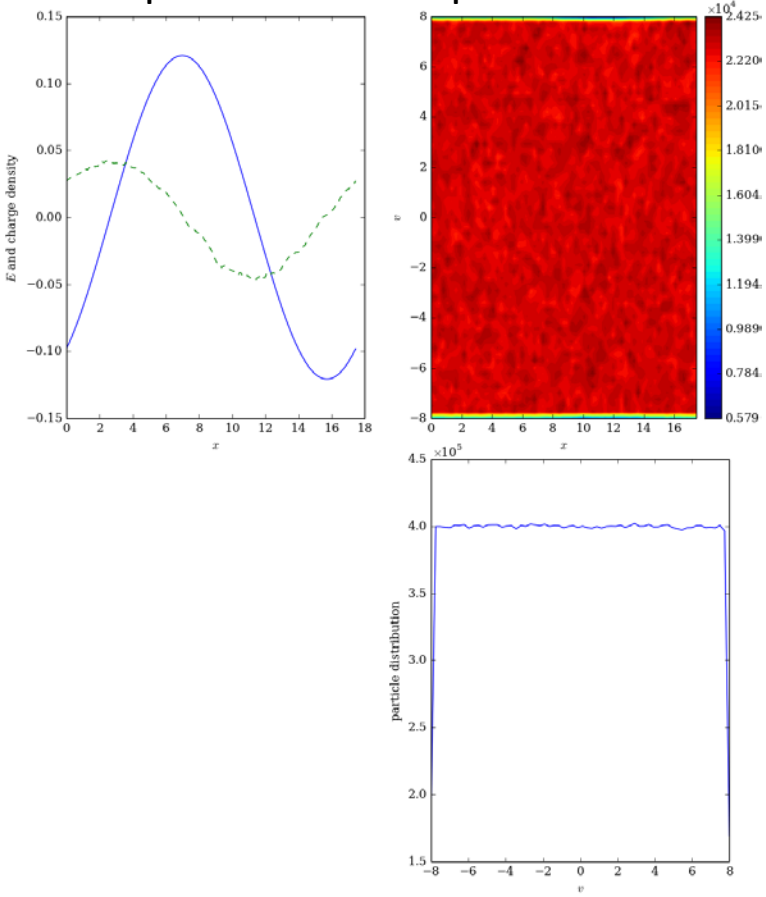
Basic Usage

Analyze output results

time history of various quantities



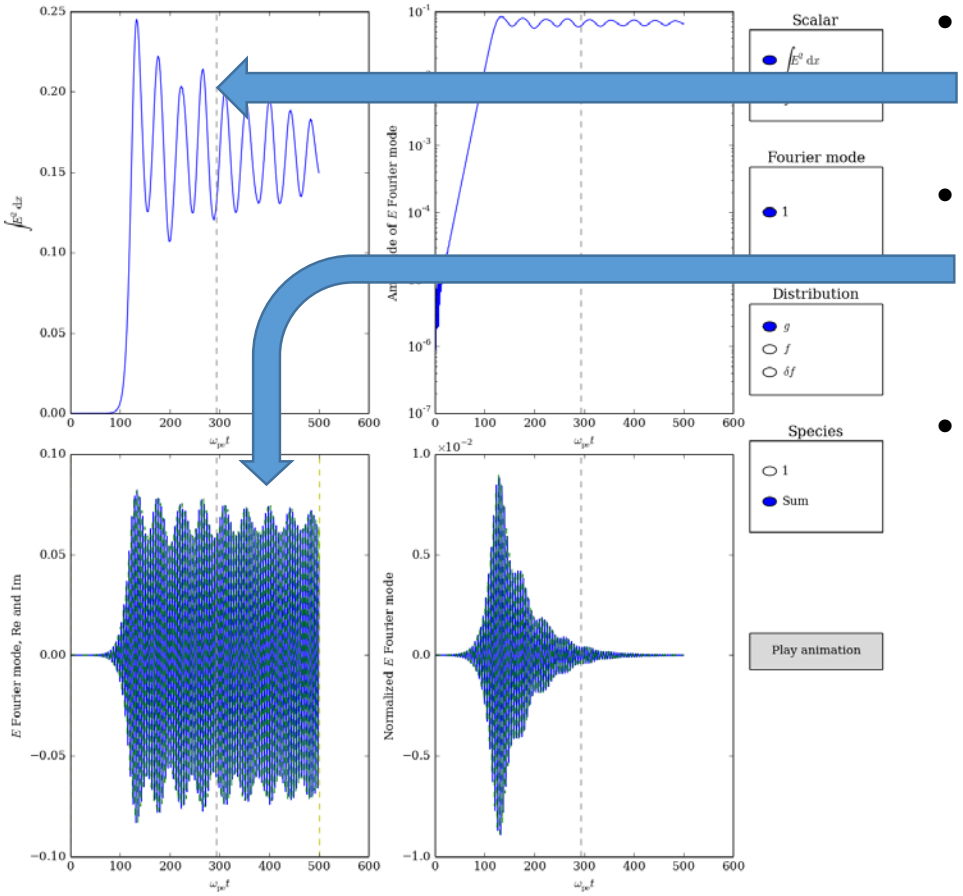
quantities on a specific time



Basic Usage

Analyze output results

time history of various quantities



- Clicking in the upper left panel changes the time for the right 3 panels.
- Clicking and dragging in the lower left panel chooses a time range for the 2 panels in the 2nd column.
- The growth/damping rate calculation is based on the plot end points of the 2nd column upper panel.

Formulation

- See 1D electrostatic δf particle-in-cell (PIC) formulation in vector-matrix form.