APC_524

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Contents

Chapter 1

Hierarchical Index

1.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 3

Class Documentation

3.1 BC_Factory Class Reference

`#include <bc_factory.hpp>`

Public Types

- typedef BC_Particle ∗(∗ **Factory**) (Domain ∗domain, int dim_Index, short isLeft, std::string type)

Public Member Functions

- BC_Particle ∗∗ **constructConditions** (Domain ∗domain, const char(∗bound)[32])
- void **declare** (const std::string &type, Factory factory)
- Factory **lookup** (const std::string &type)
- std::vector< const std::string ∗ > **types** () const

Static Public Member Functions

- static BC_Factory & **getInstance** ()

3.1.1 Detailed Description

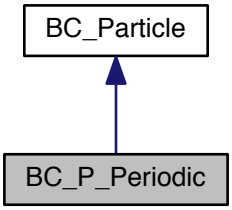
A singleton class to handle registration of particle boundaries

The documentation for this class was generated from the following file:

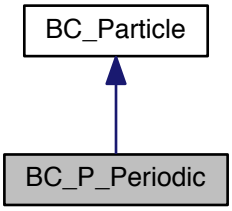
- src/boundaries/bc_factory.hpp

3.2 BC_P_Periodic Class Reference

Inheritance diagram for BC_P_Periodic:



Collaboration diagram for BC_P_Periodic:



Public Member Functions

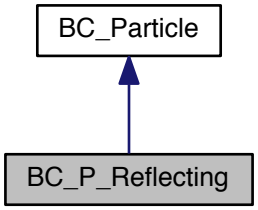
- **BC_P_Periodic** (Domain *domain, int dim_Index, short isLeft, std::string type)
- void **computeParticleBCs** (std::vector< Particle > pl)
- int **completeBC** (std::vector< Particle > pl)

The documentation for this class was generated from the following file:

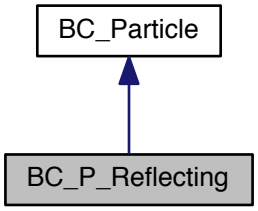
- src/boundaries/b_particles/bc_p_periodic.cpp

3.3 BC_P_Reflecting Class Reference

Inheritance diagram for BC_P_Reflecting:



Collaboration diagram for BC_P_Reflecting:



Public Member Functions

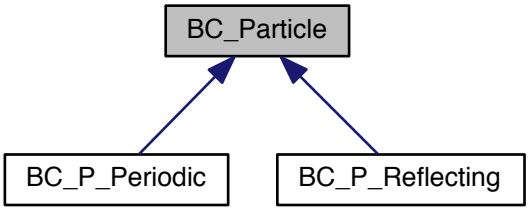
- **BC_P_Reflecting** (Domain *domain, int dim_Index, short isLeft, std::string type)
- void **computeParticleBCs** (std::vector< Particle > pl)
- int **completeBC** (std::vector< Particle > pl)

The documentation for this class was generated from the following file:

- src/boundaries/b_particles/bc_p_reflecting.cpp

3.4 BC_Particle Class Reference

Inheritance diagram for BC_Particle:



Public Member Functions

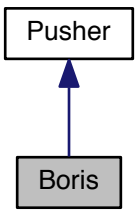
- void **computeParticleBCs** (std::vector< Particle > pl)
- virtual int **completeBC** (std::vector< Particle > pl)=0

The documentation for this class was generated from the following files:

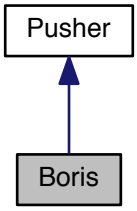
- src/boundaries/boundary_particles.hpp
- src/boundaries/boundary_particles.cpp

3.5 Boris Class Reference

Inheritance diagram for Boris:



Collaboration diagram for Boris:



Public Member Functions

- int **Step** (Particle ∗part, Field_part ∗field, double dt)

The documentation for this class was generated from the following files:

- src/pusher/boris.hpp
- src/pusher/boris.cpp

3.6 Depositor Class Reference

Public Member Functions

- void **deposit_particle_J** (Particle ∗part, double ∗lcell, double ∗cellverts, double ∗JObj)
- void **deposit_particle_Rho** (Particle ∗part, double ∗lcell, double ∗cellverts, double ∗RhoObj)

The documentation for this class was generated from the following files:

- src/particles/deposit.hpp
- src/particles/deposit.cpp

3.7 Domain Class Reference

Public Member Functions

- **Domain** (Input_Info_t ∗input_info)
- int **getnGhosts** (void)
- int ∗ **getnxyz** (void)
- int ∗ **getn2xyz** (void)
- double ∗ **getxyz0** (void)
- double ∗ **getLxyz** (void)

- double getmindx (void)

  Find minimum grid size.
- void mallocGhosts (int xgsize, int ygsize, int zgsize)

  Allocate ghost buffers for MPI.
- void **freeGhosts** (void)
- void PassFields (Grid *grids, Input_Info_t *input_info)

  Pass fields across MPI boundaries, or execute physical boundary conditions.
- int * **getnProcxyz** (void)
- int * **getmyijk** (void)
- int * **getNeighbours** ()
- int **getxl** (void)
- int **getyl** (void)
- int **getzl** (void)
- int **getxr** (void)
- int **getyr** (void)
- int **getzr** (void)
- int ijkToRank (int i, int j, int k)

  return rank for assigned i,j,k
- void RankToijk (int rank, int *myijk)

  assign value to allocated myijk[3]

3.7.1 Member Function Documentation

3.7.1.1 mallocGhosts()

```
void Domain::mallocGhosts (
            int xgsize,
            int ygsize,
            int zgsize )
```

Allocate ghost buffers for MPI.

xgsize : size of ghost buffer in x direction ygsize : size of ghost buffer in y direction zgsize : size of ghost buffer in z direction

The documentation for this class was generated from the following files:

- src/domain/domain.hpp
- src/domain/domain.cpp
- src/domain/ghosts.cpp
- src/domain/pass_fields.cpp

3.8 Field_part Struct Reference

Public Attributes

- double **e1**
- double **e2**
- double **e3**
- double **b1**
- double **b2**
- double **b3**

The documentation for this struct was generated from the following file:

- src/particles/particle.hpp

3.9 FieldBC Class Reference

Class for supplying boundary conditions to field grid.

`#include <fieldBC.hpp>`

Public Member Functions

- **FieldBC** (std::string &fieldStr, int dim, bool edge, double amp, double omega, double phase)
- void applyBCs (double t, Grid &grid)

  Apply boundary condition to grid.

3.9.1 Detailed Description

Class for supplying boundary conditions to field grid.

Boundary conditions are of form:
amp $*$ cos(omega $*$ t + phase)
along plane perpendicular to dimension dim (0 = x, 1 = y, 2 = z) on edge (false = low, true = high)
fieldStr one of Ex, Ey, Ez, Bx, By, Bz

3.9.2 Member Function Documentation

3.9.2.1 applyBCs()

```
void FieldBC::applyBCs (
            double t,
            Grid & grid )
```

Apply boundary condition to grid.

Uses setFieldAlongEdge method in grid to add field to grid.

The documentation for this class was generated from the following files:

- src/grid/fieldBC.hpp
- src/grid/fieldBC.cpp

3.10 Grid Class Reference

Class representing grid on which E and B fields and currents are defined.

`#include <grid.hpp>`

Public Member Functions

- Grid (int *nxyz, int nGhosts, double *xyz0, double *Lxyz)
  Grid constructor.
- virtual ~Grid ()
  Grid destructor.
- int evolveFields (double dt)
  Evolve Electric and Magnetic fields in time.
- void InitializeFields (int restart)
  Initialize E and B fields.
- void zeroJ ()
  sets all of J (Jx,Jy,Jz) to be identically zero
- int addJ (int cellID, double *Jvec)
  Add currents from particle to grid.
- int getFieldInterpolatorVec (int cellID, double *InterpolatorVec)
  Return vector for field interpolation.
- int getCellID (double x, double y, double z)
  Get cell ID based on particle position.
- int getCellVertex (int cellID, double *xyz)
  Returns vertex corresponding to cell ID.
- int getNumberOfCells ()
  Get total number of cells in grid.
- double getStepSize (int dimension)
  Get step size along dimension in grid.
- int setFieldAlongEdge (std::string &fieldStr, int dim, bool edge, double fieldVal)
  Set field along a certain edge.
- void updatePeriodicGhostCells ()
  updates ghost cells after evolving the field on physical points
- int getGhostVecSize ()
  returns size of ghost cell data to send
- void getGhostVec (const int side, double *ghostVec)
  bundles the data in the ghost cells to send
- void getGhostVecAlt (const int side, double *ghostVec)
  bundles the data in the ghost cells to send
- void setGhostVec (const int side, const double *ghostVec)
  unbundles the data sent from the ghost cells and puts it in the field
- void setGhostVecAlt (const int side, const double *ghostVec)
  unbundles the data sent from the ghost cells and puts it in the field
- void **setBoundaryVec** (const int side, const double *ghostVec)

Protected Member Functions

- double *** newField_ (int ifield)
  allocates memory for a single field
- void deleteField_ (double ***fieldPt, int ifield)
  frees memory for a single field
- int sideToIndex_ (const int side)
  function to convert -/+ 1 left/right side indicator to index in x direction
- void checkInput_ ()
  checks validity of input parameters for Grid constructor

- void sliceMatToVec_ (double ***const mat, const int side)
  slices a physical plane in the x direction (excludes ghosts)
- void unsliceMatToVec_ (double ***mat, const int side)
  unslices a physical plane in the x direction (excludes ghosts)
- int setFieldInPlane_ (int dim, int indx, double ***field, double fieldVal)
  Internal method to set field along a plane.

Protected Attributes

- const int **nx_**
- const int **ny_**
- const int **nz_**
- const int **nGhosts_**
- const int **nxTot_**
- const int **nyTot_**
- const int **nzTot_**
- const double **x0_**
- const double **y0_**
- const double **z0_**
- const double **Lx_**
- const double **Ly_**
- const double **Lz_**
- const int **iBeg_**
- const int **jBeg_**
- const int **kBeg_**
- const int **iEnd_**
- const int **jEnd_**
- const int **kEnd_**
- const double **dx_**
- const double **dy_**
- const double **dz_**
- const double **idx_**
- const double **idy_**
- const double **idz_**
- const int **nRealPtsYZPlane_**
- const int **nFieldsToSend_**
- const int **nFieldsTotal_**
- const int **ghostVecSize_**
- double *** **Ex_**
- double *** **Ey_**
- double *** **Ez_**
- double *** **Bx_**
- double *** **By_**
- double *** **Bz_**
- double *** **Bx_tm1_**
- double *** **By_tm1_**
- double *** **Bz_tm1_**
- double *** **Jx_**
- double *** **Jy_**
- double *** **Jz_**
- double *** **rhox_**
- double *** **rhoy_**
- double *** **rhoz_**
- double * **sliceTmp_**
- double * **fieldIsContiguous_**

3.10.1 Detailed Description

Class representing grid on which E and B fields and currents are defined.

Grid has ghost cells on each face. The ghost cell updating in y and z arises from periodic boundary conditions. x-direction ghost cells allow communication between MPI domains.

Following Yee (1966), electric fields and currents reside on edges, and magnetic fields on faces. Fields are updated using a set of finite-difference equations approximating Ampere's and Faraday's Laws.

A set of getters are available to allow particles to interpolate electric fields based on their position.

3.10.2 Constructor & Destructor Documentation

3.10.2.1 Grid()

```
Grid::Grid (
            int * nxyz,
            int nGhosts,
            double * xyz0,
            double * Lxyz )
```

Grid constructor.

Input arguments:
nxyz: integer array [nx,ny,nz] where nx is the total number of cells (physical + ghost) in the x direction in the simulation, and the same for ny,nz.
nGhosts: integer number of ghost cells on each side of the domain. This should always be at least 1. Currently the code does not support nGhosts>1, though it may in the future (to take advantage of higher order finite difference and interpolation methods, for instance).
xyz0: integer array [x0,y0,z0] where x0 is the initial x position, and the same for y0,z0
Lxyz0: double array [Lx,Ly,Lz] where Lx is the physical length of each cell in the x direction, and the same for Ly,Lz

3.10.2.2 ~Grid()

```
Grid::~Grid ( )  [virtual]
```

Grid destructor.

calls deleteField_ on each of the double*** fields

3.10.3 Member Function Documentation

3.10.3.1 addJ()

```
int Grid::addJ (
            int cellID,
            double * Jvec )
```

Add currents from particle to grid.

Currents added to cell with ID cellID via input vector of form:
[Jx((0,0,0) -> (1,0,0)), Jx((0,1,0) -> (1,1,0)), Jx((0,1,1) -> (1,1,1)), Jx((0,0,1) -> (1,0,1)),...
Jy((0,0,0) -> (0,1,0)), Jy((0,0,1) -> (0,1,1)), Jy((1,0,1) -> (1,1,1)), Jy((1,0,0) -> (1,1,0)),...
Jz((0,0,0) -> (0,0,1)), Jz((1,0,0) -> (1,0,1)), Jz((1,1,0) -> (1,1,1)), Jz((0,1,0) -> (0,1,1))]

3.10.3.2 checkInput_()

```
void Grid::checkInput_ ( )  [protected]
```

checks validity of input parameters for Grid constructor

asserts necessary conditions on each input (mainly positivity of many parameters). Terminates program if inputs are incorrect.

3.10.3.3 deleteField_()

```
void Grid::deleteField_ (
            double *** fieldPt,
            int ifield )  [protected]
```

frees memory for a single field

Uses fieldIsContiguous_ to determine contiguous or noncontiguous deltion method

3.10.3.4 evolveFields()

```
int Grid::evolveFields (
            double dt )
```

Evolve Electric and Magnetic fields in time.

Uses Yee algorithm to advance E and B fields. Assumes Gaussian-style Maxwell equation, with c = 1.

3.10.3.5 getCellID()

```
int Grid::getCellID (
            double x,
            double y,
            double z )
```

Get cell ID based on particle position.

Cell ID is uniquely given by (ny_∗nz_)∗ix + nz_∗iy + iz.
If particle is in a ghost cell or off the grid entirely, returns
-1 if off (-z), -2 if off (+z)
-3 if off (-y), -4 if off (+y)
-5 if off (-x), -6 if off (+x)

3.10.3.6 getFieldInterpolatorVec()

```
int Grid::getFieldInterpolatorVec (
            int cellID,
            double * InterpolatorVec )
```

Return vector for field interpolation.

Based on cellID, return relevant edge E and face B fields and cell origin, in format:
[x, y, z, ...
Ex(ix, iy, iz), Ex(ix, iy+1,iz), Ex(ix, iy+1, iz+1), Ex(ix, iy, iz+1), ...
Ey(ix, iy, iz), Ey(ix, iy, iz+1), Ey(ix+1, iy, iz+1), Ey(ix+1, iy, iz), ...
Ez(ix, iy, iz), Ez(ix+1, iy, iz), Ez(ix+1, iy+1, iz), Ez(ix, iy+1, iz), ...
Bx(ix, iy, iz), Bx(ix+1, iy, iz), ...
By(ix, iy, iz), By(ix, iy+1, iz), ...
Bz(ix, iy, iz), Bz(ix, iy, iz+1), ...]
where ix, iy, and iz are the row indices for each of the three dimensions (calculated from the cellID)

3.10.3.7 getGhostVec()

```
void Grid::getGhostVec (
            const int side,
            double * ghostVec )
```

bundles the data in the ghost cells to send

stores the data of the E,B,J fields at all of the ghost points along the domain interfaces (yz plane) into a 1D array of doubles to be sent with a single MPI call. ghostVec is an array of length ghostVecSize_ to store the data in. Side is -1 for left side of domain, +1 for right side. Sends (in order): Ex,Ey,Ez,Bx,By,Bz,Jx,Jy,Jz. This is a more elegant implementation than the one in getGhostVec, but may increase cache misses? Requires profiling.

3.10.3.8 getGhostVecAlt()

```
void Grid::getGhostVecAlt (
            const int side,
            double * ghostVec )
```

bundles the data in the ghost cells to send

stores the data of the E,B,J fields at all of the ghost points along the domain interfaces (yz plane) into a 1D array of doubles to be sent with a single MPI call. ghostVec is an array of length ghostVecSize_ to store the data in. Side is -1 for left side of domain, +1 for right side. Sends (in order): Ex,Ey,Ez,Bx,By,Bz,Jx,Jy,Jz. This is an alternative implementation to the one in getGhostVecAlt which is less elegant but might decrease cache misses? Requires profiling

3.10.3.9 getGhostVecSize()

```
int Grid::getGhostVecSize ( )
```

returns size of ghost cell data to send

this size is stored in the protected int ghostVecSize_

3.10.3.10 getNumberOfCells()

```
int Grid::getNumberOfCells ( )
```

Get total number of cells in grid.

Includes ghost cells.

3.10.3.11 getStepSize()

```
double Grid::getStepSize (
            int dimension )
```

Get step size along dimension in grid.

Returns step size along dimension according to; dimension = 0: x dimension = 1: y dimension = 2: z Returns -1 if invalid dimension.

3.10.3.12 InitializeFields()

```
void Grid::InitializeFields (
            int restart )
```

Initialize E and B fields.

Use restart file to set values of initial E,B,J fields

3.10.3.13 newField_()

```
double *** Grid::newField_ (
            int ifield )  [protected]
```

allocates memory for a single field

Returns double*** of size [nx_+1][ny_+1][nz_+1].
First attempts to allocate contiguously. If that fails, issues a warning and attempts to allocate with several calls to new.

3.10.3.14 setFieldAlongEdge()

```
int Grid::setFieldAlongEdge (
            std::string & fieldStr,
            int dim,
            bool edge,
            double fieldVal )
```

Set field along a certain edge.

Inputs:
fieldStr: string of format "Ex", "Bz", etc
dim: dimension along which to apply boundary condition
edge: side along which to apply boundary condition

3.10.3.15 setFieldInPlane_()

```
int Grid::setFieldInPlane_ (
            int dim,
            int indx,
            double *** field,
            double fieldVal )  [protected]
```

Internal method to set field along a plane.

Inputs:
dimension perpendicular to plane
indx along dimenstion perpendicular to plane
field to set along dimension
value to set field

3.10.3.16 setGhostVec()

```
void Grid::setGhostVec (
            const int side,
            const double * ghostVec )
```

unbundles the data sent from the ghost cells and puts it in the field

to be used in conjuction with getGhostVec or getGhostVecAlt. ghostVec is a 1D array storing each of the E,B,J field values at each of the ghost points along the domain interfaces (yz plane) of a single side. Side specifies which side this data should be set to. -1 corresponds to the left side of the domain (receiving data from the right ghost cells of the previous domain) and +1 to the right side (receiving data from the left ghost cells of the next domain). This is an alternate implementation of setGhostVecAlt. setGhostVec is more elegant but may increase cache misses (requires profiling).

3.10.3.17 setGhostVecAlt()

```
void Grid::setGhostVecAlt (
            const int side,
            const double * ghostVec )
```

unbundles the data sent from the ghost cells and puts it in the field

to be used in conjuction with getGhostVec or getGhostVecAlt. ghostVec is a 1D array storing each of the E,B,J field values at each of the ghost points along the domain interfaces (yz plane) of a single side. Side specifies which side this data should be set to. -1 corresponds to the left side of the domain (receiving data from the right ghost cells of the previous domain) and +1 to the right side (receiving data from the left ghost cells of the next domain). This is an alternate implementation of setGhostVec. setGhostVecAlt is less elegant but may reduce cache misses (requires profiling).

3.10.3.18 sideToIndex_()

```
int Grid::sideToIndex_ (
            const int side )  [protected]
```

function to convert -/+ 1 left/right side indicator to index in x direction

For use with ghost cell methods. side=-1 indicates operations on the left side of the domain, side=+1 indicates operations on the right side of the domain. This method converts side into the correct index i to reference ghost cells on that side of the domain. For instance, called by getGhostVec and setGhostVec. Generalizes to any number of ghost cells so long as iBeg_ and iEnd_ are initialized correctly.

3.10.3.19 sliceMatToVec_()

```
void Grid::sliceMatToVec_ (
            double ***const mat,
            const int side )  [protected]
```

slices a physical plane in the x direction (excludes ghosts)

mat is 3D array whose real (non-ghost) data on one side will be stored in sliceTmp_ as a 1D array. side is an integer +1 to indicate storage of the right hand side values and -1 to indicate storage of the left hand side. Complementary function to unsliceMatToVec_.

3.10.3.20 unsliceMatToVec_()

```
void Grid::unsliceMatToVec_ (
            double *** mat,
            const int side )  [protected]
```

unslices a physical plane in the x direction (excludes ghosts)

mat is 3D array whose real (non-ghost) data on one side will be set from the temporary 1D array sliceTmp_. side is an integer +1 to indicate setting of the right hand side values and -1 to indicate setting of the left hand side. Complementary function to sliceMatToVec_.

3.10.3.21 updatePeriodicGhostCells()

```
void Grid::updatePeriodicGhostCells ( )
```

updates ghost cells after evolving the field on physical points

For each of Ei_,Bi_,Ji_ (for i=x,y,z), updates the ghost cells in the y and z directions with periodic boundary conditions.
Updates of ghost cells in the x direction requires MPI calls due to 1D domain decomposition, and is handled in domain class, not here.
Currently this method requires nGhosts_=1 and will not perform correctly if nGhosts_ != 1 (it may not crash but will not update the ghost cells as desired).

3.10.3.22 zeroJ()

```
void Grid::zeroJ ( )
```

sets all of J (Jx,Jy,Jz) to be identically zero

Used during particle deposition.

The documentation for this class was generated from the following files:

- src/grid/grid.hpp
- src/grid/grid.cpp
- src/grid/oGrid.cpp
- src/grid/spookyGrid.cpp

3.11 Input_Info_t Struct Reference

Structure storing info in the input file.

`#include <IO.hpp>`

Public Attributes

- int **nCell** [3]
- int **nProc** [3]
- int **nt**
- int **restart**
- int **debug**
- long **np**
- double **t0**
- double **dens**
- double **temp**
- double **massratio**
- double **xyz0** [3]
- double **Lxyz** [3]
- char **distname** [50]
- char **parts_bound** [6][32]
- char **fields_bound** [6][32]

3.11.1 Detailed Description

Structure storing info in the input file.

The documentation for this struct was generated from the following file:

- src/IO/IO.hpp

3.12 Interpolator Class Reference

Public Member Functions

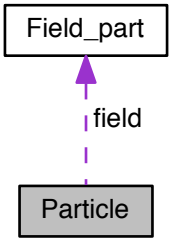
- void **interpolate_fields** (double ∗pos, double ∗lcell, double ∗cellvars, Field_part ∗field)

The documentation for this class was generated from the following files:

- src/particles/interpolate.hpp
- src/particles/interpolate.cpp

3.13 Particle Struct Reference

Collaboration diagram for Particle:



Public Attributes

- double **x** [3]
- double **v** [3]
- double **xo** [3]
- double **vo** [3]
- double **dx** [3]
- double **q**
- double **m**
- long **my_id**
- short **isGhost**
- Field_part **field**

The documentation for this struct was generated from the following file:

- src/particles/particle.hpp

3.14 Particle_Compare Class Reference

Public Member Functions

- **Particle_Compare** (Grid *grid)
- bool **operator()** (Particle const a, Particle const b) const

The documentation for this class was generated from the following file:

- src/particles/particle_utils.hpp

3.15 Particle_Handler Class Reference

Class that handles all particle-relevant operations.

`#include <particle_handler.hpp>`

Public Member Functions

- **Particle_Handler** (long np)
- void **Load** (Input_Info_t *input_info, Domain *domain)
- void **Push** (double dt)
- long **nParticles** ()
- void **incrementNParticles** (int inc)
- void **SortParticles** (Particle_Compare comp)
- void **setPusher** (Pusher *pusher)
- void **clearGhosts** ()
- void **InterpolateEB** (Grid *grid)
- void **depositJ** (Grid *grid)
- std::vector< Particle > **getParticleVector** ()
- double **maxVelocity** (void)
- void **setParticleBoundaries** (BC_Particle **bc)
- void **executeParticleBoundaryConditions** ()

3.15.1 Detailed Description

Class that handles all particle-relevant operations.

Particle handler handles all the particle operations. This includes deposition, boundary conditions, particle pushing, and communication between MPI nodes if needed

The documentation for this class was generated from the following files:

- src/particles/particle_handler.hpp
- src/particles/particle_handler.cpp

3.16 Poisson_Solver Class Reference

Public Member Functions

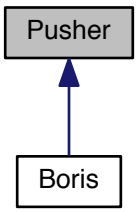
- void **run_poisson_solver** (Grid *grid, Domain *domain)

The documentation for this class was generated from the following files:

- src/poisson/poisson.hpp
- src/poisson/poisson.cpp

3.17 Pusher Class Reference

Inheritance diagram for Pusher:



Public Member Functions

- virtual int **Step** (Particle *part, Field_part *field, double dt)=0

The documentation for this class was generated from the following file:

- src/pusher/pusher.hpp

3.18 Random_Number_Generator Class Reference

Public Member Functions

- **Random_Number_Generator** (long seed)
- double **getUniform** ()
- double **getStandardNormal** ()
- double **getGaussian** (double mu, double sigma)
- RNG_State * **getRNGState** ()
- void **setRNGState** (RNG_State *state)

The documentation for this class was generated from the following files:

- src/utils/RNG.hpp
- src/utils/RNG.cpp

3.19 RegisterParticleBoundary Struct Reference

Public Member Functions

- **RegisterParticleBoundary** (const std::string &type, BC_Factory::Factory factory)

The documentation for this struct was generated from the following file:

- src/boundaries/bc_factory.hpp

3.20 RNG_State Struct Reference

Public Attributes

- long int **idum**
- long int **idum2**
- long int **iy**
- long int **iv** [RNG_NTAB]
- double **z0**
- double **z1**
- bool **generate**

The documentation for this struct was generated from the following file:

- src/utils/RNG.hpp