

APC\_524

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# Chapter 1

## Hierarchical Index

### 1.1 Class Hierarchy

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

BC_Particle . . . . .	5
Domain . . . . .	6
Field_part . . . . .	7
Grid . . . . .	7
Input_Info_t . . . . .	13
Interpolator . . . . .	14
Particle . . . . .	14
Particle_Compare . . . . .	15
Particle_List . . . . .	15
Pusher . . . . .	16
Boris . . . . .	5



## Chapter 2

# Class Index

### 2.1 Class List

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

BC_Particle	5
Boris	5
Domain	6
Field_part	7
Grid	
Class representing grid on which E and B fields and currents are defined	7
Input_Info_t	
Structure storing info in the input file	13
Interpolator	14
Particle	14
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## Chapter 3

# Class Documentation

### 3.1 BC\_Particle Class Reference

#### Public Member Functions

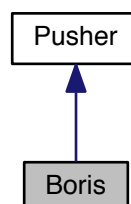
- virtual void **computeParticleBCs** ()=0
- virtual void **completeBC** ()=0

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

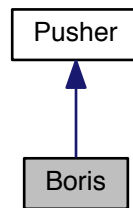
- `src/boundaries/boundary_particles.hpp`

### 3.2 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](#)

## 3.3 Domain Class Reference

### Public Member Functions

- **Domain** (int size, int rank, [Input\\_Info\\_t](#) \*input\_info)
- int **getnGhosts** (void)
- int \* **getnxyz** (void)
- double \* **getxyz0** (void)
- double \* **getLxyz** (void)
- double [getmindx](#) (void)

*Find minimum grid size.*

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

- [src/domain/domain.hpp](#)
- [src/domain/domain.cpp](#)

## 3.4 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

## 3.5 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.*
- 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 [getNumberOfCells](#) ()  
*Get total number of cells.*
- double [getStepSize](#) (int dimension)  
*Get number of cells along dimension in grid.*
- void [updateGhostCells](#) ()  
*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*

## Protected Member Functions

- double \*\*\* [newField\\_](#) ()  
*allocates contiguous block of memory for a single field*
- void [deleteField\\_](#) (double \*\*\*fieldPt)  
*frees contiguous block of 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)*

## Protected Attributes

- const int **nx\_**
- const int **ny\_**
- const int **nz\_**
- const int **nGhosts\_**
- 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 **nFields\_**
- 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 \* **sliceTmp\_**

### 3.5.1 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.

### 3.5.2 Constructor & Destructor Documentation

#### 3.5.2.1 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

#### 3.5.2.2 ~Grid()

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

[Grid](#) destructor.

calls deleteField\_ on each of the double\*\*\* fields

### 3.5.3 Member Function Documentation

#### 3.5.3.1 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.

### 3.5.3.2 deleteField\_()

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

frees contiguous block of memory for a single field

Deletes double\*\*\* of size [nx+1][ny+1][nz+1]

### 3.5.3.3 evolveFields()

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

Evolve Electric and Magnetic fields in time.

Uses Yee algorithm to advance E and B fields.

### 3.5.3.4 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)

### 3.5.3.5 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)

**3.5.3.6 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.

**3.5.3.7 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

**3.5.3.8 getGhostVecSize()**

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

returns size of ghost cell data to send

this size is stored in the protected int ghostVecSize\_

**3.5.3.9 getStepSize()**

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

Get number of cells along dimension in grid.

Returns number of cells along dimension according to; dimension = 0: x dimension = 1: y dimension = 2: z Returns -1 if invalid dimension.

**3.5.3.10 InitializeFields()**

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

Initialize E and B fields.

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

### 3.5.3.11 newField\_()

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

allocates contiguous block of memory for a single field

Returns double\*\*\* of size [nx\_+1][ny\_+1][nz\_+1]

### 3.5.3.12 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 conjunction 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).

### 3.5.3.13 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 conjunction 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).

### 3.5.3.14 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.



**3.5.3.15 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\_.

**3.5.3.16 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\_.

**3.5.3.17 updateGhostCells()**

```
void Grid::updateGhostCells ( )
```

updates ghost cells after evolving the field on physical points

For each of Ei\_,Bi\_,Ji\_ (for i=x,y,z), copies the value of the field on the outermost physical grid points onto their adjacent ghost grid points. 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).

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

**3.6 Input\_Info\_t Struct Reference**

Structure storing info in the input file.

```
#include <IO.hpp>
```

## Public Attributes

- int **nx**
- int **nt**
- int **restart**
- long **np**
- double **t0**
- double **dens**
- double **temp**
- char **distname** [50]

### 3.6.1 Detailed Description

Structure storing info in the input file.

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

- src/IO/IO.hpp

## 3.7 Interpolator Class Reference

### Public Member Functions

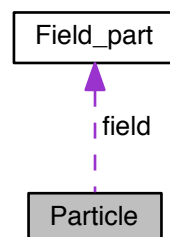
- void **interpolate\_fields** (double \*pos, double \*lcell, double \*cellvars, [Field\\_part](#) \*field)

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

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

## 3.8 Particle Struct Reference

Collaboration diagram for Particle:



### Public Attributes

- double **x** [3]
- double **v** [3]
- double **xo** [3]
- double **vo** [3]
- double **q**
- double **m**
- int **my\_id**
- short **isGhost**
- [Field\\_part](#) \* **field**

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

- src/particles/particle.hpp

## 3.9 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

## 3.10 Particle\_List Class Reference

### Public Member Functions

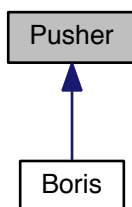
- **Particle\_List** (long np)
- void **Load** (int restart)
- void **Push** (double dt)
- void **Pass** ()
- long **nParticles** ()
- void **SortParticles** ([Particle\\_Compare](#) comp)
- void **setPusher** ([Pusher](#) \*pusher)
- void **InterpolateEB** ([Grid](#) \*grid)
- void **depositCurrent** ([Grid](#) \*grids)
- void **depositCharge** ([Grid](#) \*grids)
- double **maxVelocity** (void)

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

- src/particles/particle\_list.hpp
- src/particles/particle\_list.cpp

### 3.11 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`