

DOS extraction

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# Chapter 1

## Index

### 1.1 Introduction

This program allows to extract the Density of States (DoS), assessed by means of capacitance-voltage measurements, in an organic semiconductor device. Simulated values are fitted to experimental data.

Source and header files are written in C++11 language.

The software is intended to be used on a Unix-like operating system.

### 1.2 Dependancies

The program requires the following software to be installed on your system:

- **CMake** (version 2.8 or above), a cross-platform configuration tool;
- **Make** (version 3.8.1 or above), a utility to build executables;
- **GCC** (version 4.8 or above), the GNU Compiler Collection;
- **Eigen** (version 3.2 or above), to handle with matrices, vectors and linear algebra;
- **Gnuplot** (version 4.6.4 or above), a graphical utility to generate plots (the package **gnuplot-x11**, a terminal for X servers, is also required for the interactive interface);
- **Boost** (version 1.50 or above), a set of libraries used by **gnuplot-iostream**;
- **Doxygen** (version 1.8.6 or above), a documentation generator (not compulsory).

It also uses the following libraries, shipped in the *include/* folder:

- **GetPot** (version 1.1.18), to parse command-line and configuration files;
- **gnuplot-iostream** (version 2), a C++ interface for **Gnuplot**.

Parallel computing capabilities are provided through the **OpenMP** library, shipped together with **GCC**.

### 1.3 Compile

In order to generate a test executable, first open the *CMakeLists.txt* file (in the top-level folder) and, if necessary, edit it to your needs.

Then create a build directory and move into it:

```
$ mkdir build
$ cd build
```

Now you're ready to configure your system:

```
$ cmake ..
```

#### Note

or, if you want the compiler to produce also debug symbols:

```
$ cmake -DCMAKE_BUILD_TYPE=Debug ..
```

Finally, start building the project:

```
$ make
```

This will generate the *test\_filename* (as specified in the **TARGET\_NAME** variable in *CMakeLists.txt*) executable.

Repeat these steps for each test source file you want to compile.

The following command will generate the present documentation, if [Doxygen](#) is found to be installed, under the *doc/* folder (or the one specified in *CMakeLists.txt*), :

```
$ make doc
```

## 1.4 Set up the configurations

#### Note

The default configuration directory is *config/*.

Before you can run an executable, you have to set up the configuration file (default: *config.pot*). Within it you can find a list of parameters, each of which is commented out to explain what modifying it will entail.

Particularly, the variables *input\_params* and *input\_experim* can be set, i.e. the filenames where to find input fitting parameters and experimental data respectively. It's recommended (but not compulsory) to put these files in the same directory as the configuration file (otherwise you can specify a relative or absolute path to them).

#### Warning

The program never checks that the input values are numeric but will always cast them to floating point numbers, then please pay attention while setting up the variable *skipHeaders*.

You can create multiple configuration files, each with different parameter values: the one you aim to use can be specified in the command-line before running.

## 1.5 Run!

Executables are placed under the *bin/* directory (or the one specified in *CMakeLists.txt*).

To run by using the default configuration filename (*config.pot*) simply move into the *bin/* directory and execute:

```
$ ./test_filename
```

To specify a different configuration file previously saved in the configuration directory:

```
$ ./test_filename -f configuration_filename
```

or:

```
$ ./test_filename --file configuration_filename
```

The variable *configuration\_filename* should **not** contain the path.

#### Warning

Furthermore, if you run the program from a different folder than *bin/* or if you chose a different configuration directory, you have also to manually specify the path to the configuration directory (either absolute or relative to the current directory) by using:

```
$ ./test_filename -d configuration_directory
```

or:

```
$ ./test_filename --directory configuration_directory
```

Once complete, the results of the simulation(s) will be saved in the output directory (relative to the current folder) specified in the configuration file (default: *output*).

[Gnuplot](#) scripts are saved too for later re-use under the *gnuplot/* subdirectory; you can run them through:

```
$ gnuplot name_of_the_script
```



## Chapter 2

# Namespace Index

### 2.1 Namespace List

Here is a list of all documented namespaces with brief descriptions:

<a href="#">constants</a>	Numerical constants . . . . .	13
<a href="#">numerics</a>	Namespace for generic numeric algorithms . . . . .	13
<a href="#">utility</a>	Namespace for utilities and auxiliary functions . . . . .	16



## Chapter 3

# Hierarchical Index

### 3.1 Class Hierarchy

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

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GaussianCharge . . . . .	37
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NonLinearPoisson1D . . . . .	44
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GaussLaguerreRule . . . . .	41
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GaussHermiteRuleFactory . . . . .	36
GaussLaguerreRuleFactory . . . . .	43





## Chapter 4

# Class Index

### 4.1 Class List

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

<a href="#">Bim1D</a>	Class derived from <a href="#">PdeSolver1D</a> , providing a finite volume Box Integration Method (BIM) solver	19
<a href="#">Charge</a>	Abstract class providing methods to calculate total electric charge (the rhs in the Poisson equation) . . . . .	21
<a href="#">ChargeFactory</a>	Abstract factory to handle the constitutive relation for the Density of States . . . . .	23
<a href="#">CsvParser</a>	Class providing methods to read <b>numeric</b> content from a .csv file and to store it in <a href="#">Eigen</a> matrices or vectors . . . . .	24
<a href="#">DosModel</a>	Class providing methods to process a simulation to extract the Density of States starting from a parameter list . . . . .	28
<a href="#">ExponentialCharge</a>	Class derived from <a href="#">Charge</a> , under the hypothesis that Density of States is a single exponential	31
<a href="#">ExponentialChargeFactory</a>	Concrete factory to handle a single exponential DoS constitutive relation . . . . .	34
<a href="#">GaussHermiteRule</a>	Class derived from <a href="#">QuadratureRule</a> providing the Gauss-Hermite quadrature rule . . . . .	35
<a href="#">GaussHermiteRuleFactory</a>	Concrete factory to handle a Gauss-Hermite quadrature rule . . . . .	36
<a href="#">GaussianCharge</a>	Class derived from <a href="#">Charge</a> , under the hypothesis that Density of States is a combination of gaussians . . . . .	37
<a href="#">GaussianChargeFactory</a>	Concrete factory to handle a multiple gaussians DoS constitutive relation . . . . .	40
<a href="#">GaussLaguerreRule</a>	Class derived from <a href="#">QuadratureRule</a> providing the Gauss-Laguerre quadrature rule . . . . .	41
<a href="#">GaussLaguerreRuleFactory</a>	Concrete factory to handle a Gauss-Laguerre quadrature rule . . . . .	43
<a href="#">NonLinearPoisson1D</a>	Provide a solver for a non-linear Poisson equation . . . . .	44
<a href="#">ParamList</a>	Class providing methods to handle a list of parameters . . . . .	46
<a href="#">PdeSolver1D</a>	Abstract class providing methods to assemble matrices to solve one-dimensional PDEs . . . .	48
<a href="#">QuadratureRule</a>	Abstract class providing a quadrature rule . . . . .	51

[QuadratureRuleFactory](#)

Abstract factory to handle a quadrature rule . . . . . [52](#)

## Chapter 5

# File Index

### 5.1 File List

Here is a list of all documented files with brief descriptions:

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/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/ <a href="#">dosModel.cc</a> . . . . .	57
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## Chapter 6

# Namespace Documentation

### 6.1 constants Namespace Reference

Numerical constants.

#### Variables

- const [Real Q](#) = 1.602176530000000e-19  
*Electron charge [C].*
- const [Real Q2](#) = [Q](#) \* [Q](#)  
*Electron charge squared [C<sup>2</sup>].*
- const [Real K\\_B](#) = 1.380650500000000e-23  
*Boltzmann's constant [J · K<sup>-1</sup>].*
- const [Real EPS0](#) = 8.854187817e-12  
*Vacuum electrical permittivity [C · V<sup>-1</sup> · m<sup>-1</sup>].*
- const [Real T](#) = 300  
*Reference temperature [K].*
- const [Real V\\_TH](#) = [K\\_B](#) \* [T](#) / [Q](#)  
*Threshold voltage [V].*
- const [Index PARAMS\\_NO](#) = 26  
*Number of parameters required in input file.*
- const [Real PI](#) = M\_PI  
 $\pi$ .
- const [Real SQRT\\_PI](#) = std::sqrt([PI](#))  
 $\sqrt{\pi}$ .
- const [Real PI\\_M4](#) = 0.7511255444649425  
 $\pi^{-\frac{1}{4}}$ .
- const [Real SQRT\\_2](#) = std::sqrt(2)  
 $\sqrt{2}$ .

#### 6.1.1 Detailed Description

Numerical constants.

### 6.2 numerics Namespace Reference

Namespace for generic numeric algorithms.

## Functions

- `template<typename ScalarType >  
VectorX< ScalarType > sort (const VectorX< ScalarType > &vector)`  
*Function to sort [Eigen](#) vectors.*
- `template<typename ScalarType >  
VectorXpair< ScalarType > sort_pair (const VectorX< ScalarType > &vector)`  
*Function to sort [Eigen](#) vectors, keeping track of indexes.*
- `Real trapz (const VectorXr &x, const VectorXr &y)`  
*Function to compute approximate integral of y with spacing increment specified by x, using trapezoidal rule.*
- `Real trapz (const VectorXr &y)`  
*Compute the approximate integral of y with unit spacing, using trapezoidal rule.*
- `VectorXr deriv (const VectorXr &, const VectorXr &)`  
*Compute the numeric derivative:  $\frac{dy}{dx}$ .*
- `Real interp1 (const VectorXr &, const VectorXr &, const Real &)`  
*Linear 1D interpolation. Interpolate y, defined at points x, at the point xNew.*
- `VectorXr interp1 (const VectorXr &, const VectorXr &, const VectorXr &)`  
*Linear 1D interpolation. Interpolate y, defined at points x, at the points xNew.*
- `Real error_L2 (const VectorXr &, const VectorXr &, const VectorXr &, const Real &)`  
*Compute the  $L^2$ -norm error between simulated and interpolated values, using trapz.*

### 6.2.1 Detailed Description

Namespace for generic numeric algorithms.

### 6.2.2 Function Documentation

#### 6.2.2.1 `VectorX< ScalarType > sort ( const VectorX< ScalarType > & vector )`

Function to sort [Eigen](#) vectors.

Template Parameters

<i>ScalarType</i>	: the scalar type.
-------------------	--------------------

Parameters

<i>in</i>	<i>vector</i>	: the vector to be sorted.
-----------	---------------	----------------------------

Returns

the sorted vector.

Definition at line 101 of file numerics.h.

#### 6.2.2.2 `VectorXpair< ScalarType > sort_pair ( const VectorX< ScalarType > & vector )`

Function to sort [Eigen](#) vectors, keeping track of indexes.

Template Parameters

<i>ScalarType</i>	: the scalar type.
-------------------	--------------------

**Parameters**

in	<i>vector</i>	: the vector to be sorted.
----	---------------	----------------------------

**Returns**

an [Eigen](#) vector of pairs: (sorted value, corresponding index in the unsorted vector).

Definition at line 110 of file numerics.h.

**6.2.2.3 Real trapz ( const VectorXr & x, const VectorXr & y )**

Function to compute approximate integral of *y* with spacing increment specified by *x*, using trapezoidal rule.

**Parameters**

in	<i>x</i>	: the vector of the discrete domain;
in	<i>y</i>	: the vector of values to integrate.

**Returns**

the approximate integral value.

Definition at line 15 of file numerics.cc.

**6.2.2.4 Real trapz ( const VectorXr & y )**

Compute the approximate integral of *y* with unit spacing, using trapezoidal rule.

**Parameters**

in	<i>y</i>	: the vector of values to integrate.
----	----------	--------------------------------------

**Returns**

the approximate integral value.

Definition at line 31 of file numerics.cc.

**6.2.2.5 VectorXr deriv ( const VectorXr & y, const VectorXr & x )**

Compute the numeric derivative:  $\frac{dy}{dx}$ .

**Parameters**

in	<i>y</i>	: the vector of values to differentiate;
in	<i>x</i>	: the vector of the discrete domain.

**Returns**

a vector of the same length as *y* containing the approximate derivative.

Definition at line 36 of file numerics.cc.

**6.2.2.6 Real interp1 ( const VectorXr & x, const VectorXr & y, const Real & xNew )**

Linear 1D interpolation. Interpolate *y*, defined at points *x*, at the point *xNew*.

**Parameters**

in	<i>y</i>	: the vector of values to interpolate;
in	<i>x</i>	: the vector of the discrete domain;
in	<i>xNew</i>	: the point to interpolate at.

**Returns**

a scalar containing the interpolated value.

Definition at line 56 of file numerics.cc.

**6.2.2.7 VectorXr interp1 ( const VectorXr & x, const VectorXr & y, const VectorXr & xNew )**

Linear 1D interpolation. Interpolate *y*, defined at points *x*, at the points *xNew*.

**Parameters**

in	<i>y</i>	: the vector of values to interpolate;
in	<i>x</i>	: the vector of the discrete domain;
in	<i>xNew</i>	: the vector of points to interpolate at.

**Returns**

a vector of the same length as *xNew* containing the interpolated values.

Definition at line 77 of file numerics.cc.

**6.2.2.8 Real error\_L2 ( const VectorXr & interp, const VectorXr & simulated, const VectorXr & V, const Real & V\_shift )**

Compute the  $L^2$ -norm error between simulated and interpolated values, using *trapz*.

**Parameters**

in	<i>interp</i>	: the interpolated values;
in	<i>simulated</i>	: the simulated values;
in	<i>V</i>	: the vector of the electric potential;
in	<i>V_shift</i>	: shift to the electric potential.

**Returns**

the value of the  $L^2$ -norm error.

Definition at line 92 of file numerics.cc.

## 6.3 utility Namespace Reference

Namespace for utilities and auxiliary functions.

**Functions**

- std::string [full\\_path](#) (const std::string &, const std::string &)  
*Auxiliary function to return the full path to a file.*
- void [print\\_block](#) (const char \*, std::ostream &=std::cout)  
*Auxiliary function to print a string inside a block.*
- void [print\\_done](#) (std::ostream &=std::cout)  
*Auxiliary function to print a "DONE!" string.*



### 6.3.1 Detailed Description

Namespace for utilities and auxiliary functions.

### 6.3.2 Function Documentation

#### 6.3.2.1 `std::string full_path ( const std::string & filename, const std::string & relative_directory )`

Auxiliary function to return the full path to a file.

##### Parameters

in	<i>filename</i>	: the filename;
in	<i>relative_ - directory</i>	: the directory for a relative path.

##### Returns

the variable *filename*, if it contains an absolute path; otherwise returns the concatenation of *relative\_directory* and *filename* (i.e. the relative path to *filename*).

Definition at line 15 of file typedefs.cc.

#### 6.3.2.2 `void print_block ( const char * string, std::ostream & os = std::cout )`

Auxiliary function to print a string inside a block.

##### Parameters

in	<i>string</i>	: the string to print;
out	<i>os</i>	: output stream.

Definition at line 20 of file typedefs.cc.

#### 6.3.2.3 `void print_done ( std::ostream & os = std::cout )`

Auxiliary function to print a "DONE!" string.

##### Parameters

out	<i>os</i>	: output stream.
-----	-----------	------------------

Definition at line 45 of file typedefs.cc.



## Chapter 7

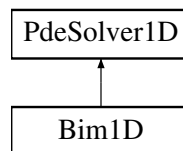
# Class Documentation

### 7.1 Bim1D Class Reference

Class derived from [PdeSolver1D](#), providing a finite volume Box Integration Method (BIM) solver.

```
#include <solvers.h>
```

Inheritance diagram for Bim1D:



#### Public Member Functions

- [Bim1D](#) ()=delete  
*Default constructor (deleted since it is required to specify the mesh).*
- [Bim1D](#) ([VectorXr](#) &)  
*Constructor.*
- virtual [~Bim1D](#) ()=default  
*Destructor (defaulted).*
- virtual void [assembleAdvDiff](#) (const [VectorXr](#) &, const [VectorXr](#) &, const [VectorXr](#) &, const [VectorXr](#) &) override  
*Assemble the matrix for an advection-diffusion term.*
- virtual void [assembleStiff](#) (const [VectorXr](#) &, const [VectorXr](#) &) override  
*Assemble the matrix for a diffusion term.*
- virtual void [assembleMass](#) (const [VectorXr](#) &, const [VectorXr](#) &) override  
*Assemble the matrix for a reaction term.*

#### Static Public Member Functions

- static [VectorXr](#) [log\\_mean](#) (const [VectorXr](#) &, const [VectorXr](#) &)  
*Compute the element-wise logarithmic mean of two vectors.*
- static std::pair< [VectorXr](#),  
[VectorXr](#) > [bernoulli](#) (const [VectorXr](#) &)  
*Compute the values of the Bernoulli function.*

## Additional Inherited Members

### 7.1.1 Detailed Description

Class derived from [PdeSolver1D](#), providing a finite volume Box Integration Method (BIM) solver.

Matrices are held in a sparse format.

Definition at line 115 of file solvers.h.

### 7.1.2 Constructor & Destructor Documentation

#### 7.1.2.1 Bim1D ( VectorXr & mesh )

Constructor.

Parameters

<code>in</code>	<code>mesh</code>	: the mesh coordinates.
-----------------	-------------------	-------------------------

Definition at line 18 of file solvers.cc.

### 7.1.3 Member Function Documentation

#### 7.1.3.1 VectorXr log\_mean ( const VectorXr & x1, const VectorXr & x2 ) [static]

Compute the element-wise logarithmic mean of two vectors.

$$M_{log}(x_1, x_2) = \frac{x_2 - x_1}{\log x_2 - \log x_1} = \frac{x_2 - x_1}{\log \left( \frac{x_2}{x_1} \right)}.$$

Parameters

<code>in</code>	<code>x1</code>	: the first vector;
<code>in</code>	<code>x2</code>	: the second vector.

Returns

the vector of the logarithmic means.

Definition at line 21 of file solvers.cc.

#### 7.1.3.2 std::pair< VectorXr, VectorXr > bernoulli ( const VectorXr & x ) [static]

Compute the values of the Bernoulli function.

$$\mathfrak{B}(x) = \frac{x}{e^x - 1}.$$

Parameters

<code>in</code>	<code>x</code>	: the vector of the values to compute the Bernoulli function at.
-----------------	----------------	--

Returns

the pair  $(\mathfrak{B}(x), \mathfrak{B}(-x))$ .

Definition at line 52 of file solvers.cc.

**7.1.3.3** `void assembleAdvDiff ( const VectorXr & alpha, const VectorXr & gamma, const VectorXr & eta, const VectorXr & beta ) [override],[virtual]`

Assemble the matrix for an advection-diffusion term.

Build the Scharfetter-Gummel stabilized stiffness matrix for:  $-\nabla \cdot (\alpha \cdot \gamma (\eta \nabla u - \beta u)) = f$ .

Parameters

in	<i>alpha</i>	: $\alpha$ , an element-wise constant function;
in	<i>gamma</i>	: $\gamma$ , an element-wise linear function;
in	<i>eta</i>	: $\eta$ , an element-wise linear function;
in	<i>beta</i>	: $\beta$ , an element-wise constant function.

Implements [PdeSolver1D](#).

Definition at line 111 of file solvers.cc.

**7.1.3.4** `void assembleStiff ( const VectorXr & eps, const VectorXr & kappa ) [override],[virtual]`

Assemble the matrix for a diffusion term.

Build the standard finite element stiffness matrix for the diffusion problem:  $-\nabla \cdot (\varepsilon \cdot \kappa \nabla u) = f$ .

Parameters

in	<i>eps</i>	: $\varepsilon$ , an element-wise constant function;
in	<i>kappa</i>	: $\kappa$ , an element-wise linear function.

Implements [PdeSolver1D](#).

Definition at line 171 of file solvers.cc.

**7.1.3.5** `void assembleMass ( const VectorXr & delta, const VectorXr & zeta ) [override],[virtual]`

Assemble the matrix for a reaction term.

Build the lumped finite element mass matrix for the reaction problem:  $\delta \cdot \zeta u = f$ .

Parameters

in	<i>delta</i>	: $\delta$ , an element-wise constant function;
in	<i>zeta</i>	: $\zeta$ , an element-wise linear function.

Implements [PdeSolver1D](#).

Definition at line 180 of file solvers.cc.

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

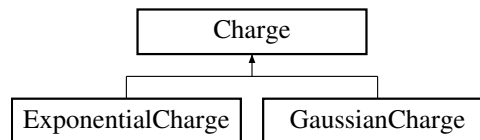
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[solvers.h](#)
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[solvers.cc](#)

## 7.2 Charge Class Reference

Abstract class providing methods to calculate total electric charge (the rhs in the Poisson equation).

```
#include <charge.h>
```

Inheritance diagram for Charge:



## Public Member Functions

- `Charge ()=delete`  
*Default constructor (deleted since it is required to specify a [ParamList](#) and a [QuadratureRule](#)).*
- `Charge (const ParamList &, const QuadratureRule &)`  
*Constructor.*
- `virtual ~Charge ()=default`  
*Destructor (defaulted).*
- `virtual VectorXr charge (const VectorXr &phi)=0`  
*Compute the total charge density.*
- `virtual VectorXr dcharge (const VectorXr &phi)=0`  
*Compute the derivative of the total charge density with respect to the electric potential.*

## Protected Attributes

- `const ParamList & params_`  
*Parameter list handler.*
- `const QuadratureRule & rule_`  
*Quadrature rule handler.*

### 7.2.1 Detailed Description

Abstract class providing methods to calculate total electric charge (the rhs in the Poisson equation).

Definition at line 28 of file charge.h.

### 7.2.2 Constructor & Destructor Documentation

#### 7.2.2.1 `Charge ( const ParamList & params, const QuadratureRule & rule )`

Constructor.

Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

Definition at line 17 of file charge.cc.

### 7.2.3 Member Function Documentation

#### 7.2.3.1 `virtual VectorXr charge ( const VectorXr & phi ) [pure virtual]`

Compute the total charge density.

## Parameters

<code>in</code>	<code>phi</code>	: the electric potential $\varphi$ .
-----------------	------------------	--------------------------------------

## Returns

the total charge density  $q(\varphi)$   $[C \cdot m^{-3}]$ .

Implemented in [ExponentialCharge](#), and [GaussianCharge](#).

## 7.2.3.2 virtual VectorXr dcharge ( const VectorXr &amp; phi ) [pure virtual]

Compute the derivative of the total charge density with respect to the electric potential.

## Parameters

<code>in</code>	<code>phi</code>	: the electric potential $\varphi$ .
-----------------	------------------	--------------------------------------

## Returns

the derivative:  $\frac{dq(\varphi)}{d\varphi}$   $[C \cdot m^{-3} \cdot V^{-1}]$ .

Implemented in [ExponentialCharge](#), and [GaussianCharge](#).

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

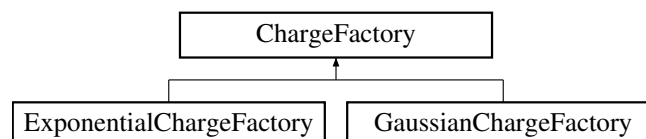
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.cc](#)

## 7.3 ChargeFactory Class Reference

Abstract factory to handle the constitutive relation for the Density of States.

```
#include <factory.h>
```

Inheritance diagram for ChargeFactory:



## Public Member Functions

- [ChargeFactory](#) ()=default  
*Default constructor (defaulted).*
- virtual [~ChargeFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [Charge](#) \* [BuildCharge](#) (const [ParamList](#) &params, const [QuadratureRule](#) &rule)=0  
*Factory method to build an abstract [Charge](#) object.*

## 7.3.1 Detailed Description

Abstract factory to handle the constitutive relation for the Density of States.

Definition at line 28 of file [factory.h](#).

### 7.3.2 Member Function Documentation

7.3.2.1 `virtual Charge* BuildCharge ( const ParamList & params, const QuadratureRule & rule )` [pure virtual]

Factory method to build an abstract [Charge](#) object.

#### Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

#### Returns

a pointer to [Charge](#).

Implemented in [ExponentialChargeFactory](#), and [GaussianChargeFactory](#).

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

- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[factory.h](#)

## 7.4 CsvParser Class Reference

Class providing methods to read **numeric** content from a .csv file and to store it in [Eigen](#) matrices or vectors.

```
#include <csvParser.h>
```

### Public Member Functions

- [CsvParser](#) ()=delete  
*Default constructor (deleted since it is required to specify at least a filename).*
- [CsvParser](#) (const std::string &, const bool &=true)  
*Constructor: load the input file and check its compatibility with the code.*
- virtual [~CsvParser](#) ()  
*Destructor: close the input file.*
- [RowVectorXr importRow](#) (const [Index](#) &)  
*Method to import a row from the input file.*
- [MatrixXr importRows](#) (const std::initializer\_list< [Index](#) > &)  
*Method to import multiple rows from the input file.*
- [MatrixXr importFirstRows](#) (const [Index](#) &)  
*Method to import the first nRows rows from the input file.*
- [VectorXr importCol](#) (const [Index](#) &)  
*Method to import a column from the input file.*
- [MatrixXr importCols](#) (const std::initializer\_list< [Index](#) > &)  
*Method to import multiple columns from the input file.*
- [MatrixXr importFirstCols](#) (const [Index](#) &)  
*Method to import the first nCols columns from the input file.*
- [Real importCell](#) (const [Index](#) &, const [Index](#) &)  
*Method to import a single cell from the input file.*
- [MatrixXr importAll](#) ()  
*Method to import the whole input file.*

### Getter methods

- const [Index](#) & **nRows** () const
- const [Index](#) & **nCols** () const



## Private Member Functions

- void [reset](#) ()  
*Reset all the flags for input\_ and go back to the beginning of file (possibly by ignoring headers).*

## Private Attributes

- bool [hasHeaders\\_](#)  
*bool to determine if first row contains headers or not.*
- [Index](#) [nRows\\_](#)  
*Number of rows in the input file.*
- [Index](#) [nCols\\_](#)  
*Number of columns in the input file.*
- [std::ifstream](#) [input\\_](#)  
*Input stream to input\_filename.*
- [std::string](#) [line\\_](#)  
*Auxiliary variable to store currently processed line.*
- char [separator\\_](#)  
*The separator character detected.*

### 7.4.1 Detailed Description

Class providing methods to read **numeric** content from a .csv file and to store it in [Eigen](#) matrices or vectors.  
Definition at line 32 of file csvParser.h.

### 7.4.2 Constructor & Destructor Documentation

#### 7.4.2.1 CsvParser ( const [std::string](#) & *input\_filename*, const bool & *hasHeaders* = `true` )

Constructor: load the input file and check its compatibility with the code.

##### Parameters

<a href="#">in</a>	<i>input_filename</i>	: the name of the input file;
<a href="#">in</a>	<i>hasHeaders</i>	: bool to specify if first row contains headers or not; if <b>true</b> , first row is always ignored.

Definition at line 22 of file csvParser.cc.

### 7.4.3 Member Function Documentation

#### 7.4.3.1 RowVectorXr importRow ( const [Index](#) & *index* )

Method to import a row from the input file.

##### Parameters

<a href="#">in</a>	<i>index</i>	: the row index.
--------------------	--------------	------------------

##### Returns

a row vector containing the content read.

Definition at line 94 of file csvParser.cc.

#### 7.4.3.2 **MatrixXr** importRows ( const std::initializer\_list< **Index** > & *indexes* )

Method to import multiple rows from the input file.

**Parameters**

<i>in</i>	<i>indexes</i>	: initializer list containing the row indexes (e.g. something like {1, 3, 4}).
-----------	----------------	--

**Returns**

a matrix containing the content read (row by row).

Definition at line 127 of file csvParser.cc.

**7.4.3.3 MatrixXr importFirstRows ( const Index & nRows )**

Method to import the first *nRows* rows from the input file.

**Parameters**

<i>in</i>	<i>nRows</i>	: the number of rows to import.
-----------	--------------	---------------------------------

**Returns**

a matrix containing the content read (row by row).

Definition at line 144 of file csvParser.cc.

**7.4.3.4 VectorXr importCol ( const Index & index )**

Method to import a column from the input file.

**Parameters**

<i>in</i>	<i>index</i>	: the column index.
-----------	--------------	---------------------

**Returns**

a column vector containing the content read.

Definition at line 158 of file csvParser.cc.

**7.4.3.5 MatrixXr importCols ( const std::initializer\_list< Index > & indexes )**

Method to import multiple columns from the input file.

**Parameters**

<i>in</i>	<i>indexes</i>	: initializer list containing the column indexes (e.g. something like {1, 3, 4}).
-----------	----------------	---

**Returns**

a matrix containing the content read (column by column).

Definition at line 187 of file csvParser.cc.

**7.4.3.6 MatrixXr importFirstCols ( const Index & nCols )**

Method to import the first *nCols* columns from the input file.

**Parameters**

<code>in</code>	<code>nCols</code>	: the number of columns to import.
-----------------	--------------------	------------------------------------

**Returns**

a matrix containing the content read (column by column).

Definition at line 204 of file csvParser.cc.

**7.4.3.7 Real importCell ( const Index & rowIndex, const Index & colIndex )**

Method to import a single cell from the input file.

**Parameters**

<code>in</code>	<code>rowIndex</code>	: the cell row index.
<code>in</code>	<code>colIndex</code>	: the cell column index.

**Returns**

a scalar containing the value read.

Definition at line 218 of file csvParser.cc.

**7.4.3.8 MatrixXr importAll ( )**

Method to import the whole input file.

**Returns**

a matrix containing the content read (cell by cell).

Definition at line 226 of file csvParser.cc.

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

- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/csvParser.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/csvParser.cc](#)

## 7.5 DosModel Class Reference

Class providing methods to process a simulation to extract the Density of States starting from a parameter list.

```
#include <dosModel.h>
```

**Public Member Functions**

- [DosModel](#) ()  
*Default constructor.*
- [DosModel](#) (const [ParamList](#) &)  
*Explicit conversion constructor.*
- virtual [~DosModel](#) ()=default  
*Destructor (defaulted).*
- const [ParamList](#) & [params](#) () const

*Getter method.*

- void [simulate](#) (const GetPot &, const std::string &, const std::string &, const std::string &, const std::string &)

*Perform the simulation.*

- void [post\\_process](#) (const GetPot &, const std::string &, std::ostream &, std::ostream &, const [Real](#) &, const [Real](#) &, const [VectorXr](#) &, const [VectorXr](#) &, const [VectorXr](#) &, const [VectorXr](#) &)

*Perform post-processing.*

- void [gnuplot\\_commands](#) (const std::string &, std::ostream &) const

*Defines commands to generate [Gnuplot](#) output files.*

- void [save\\_plot](#) (const std::string &, const std::string &, const std::string &, const std::string &) const

*Save the [Gnuplot](#) output files.*

## Private Attributes

- bool [initialized\\_](#)

*bool to determine if [DosModel](#) param\_ has been properly initialized.*

- [ParamList](#) [params\\_](#)

*The parameter list.*

- [Real](#) [V\\_shift\\_](#)

*Peak shift between experimental data and simulated values [V].*

### 7.5.1 Detailed Description

Class providing methods to process a simulation to extract the Density of States starting from a parameter list.

Definition at line 40 of file dosModel.h.

### 7.5.2 Constructor & Destructor Documentation

#### 7.5.2.1 [DosModel](#) ( const [ParamList](#) & *params* ) [explicit]

Explicit conversion constructor.

Parameters

<i>in</i>	<i>params</i>	: a parameter list.
-----------	---------------	---------------------

Definition at line 22 of file dosModel.cc.

### 7.5.3 Member Function Documentation

#### 7.5.3.1 void [simulate](#) ( const GetPot & *config*, const std::string & *input\_experim*, const std::string & *output\_directory*, const std::string & *output\_plot\_subdir*, const std::string & *output\_filename* )

Perform the simulation.

Parameters

<i>in</i>	<i>config</i>	: the GetPot configuration object;
<i>in</i>	<i>input_experim</i>	: the file containing experimental data;
<i>in</i>	<i>output_directory</i>	: directory where to store output files;

in	<i>output_plot_subdir</i>	: sub-directory where to store <a href="#">Gnuplot</a> files;
in	<i>output_filename</i>	: prefix for the output filename.

Definition at line 25 of file dosModel.cc.

**7.5.3.2** void post\_process ( const GetPot & config, const std::string & input\_experim, std::ostream & output\_fitting, std::ostream & output\_CV, const Real & A\_semic, const Real & C\_sb, const VectorXr & x\_semic, const VectorXr & dens, const VectorXr & V\_simulated, const VectorXr & C\_simulated )

Perform post-processing.

Parameters

in	<i>config</i>	: the GetPot configuration object;
in	<i>input_experim</i>	: the file containing experimental data;
out	<i>output_fitting</i>	: output file containing infos about fitting experimental data;
out	<i>output_CV</i>	: output file containing infos about capacitance-voltage data;
in	<i>A_semic</i>	: area of the semiconductor;
in	<i>C_sb</i>	: stray border capacitance (see <a href="#">ParamList</a> );
in	<i>x_semic</i>	: the mesh corresponding to the semiconductor domain;
in	<i>dens</i>	: charge density $[C \cdot m^{-3}]$ ;
in	<i>V_simulated</i>	: simulated voltage values;
in	<i>C_simulated</i>	: simulated capacitance values.

Definition at line 271 of file dosModel.cc.

**7.5.3.3** void gnuplot\_commands ( const std::string & output\_CV\_filename, std::ostream & os ) const

Defines commands to generate [Gnuplot](#) output files.

Parameters

in	<i>output_CV_filename</i>	: output CV filename;
out	<i>os</i>	: output stream.

Definition at line 362 of file dosModel.cc.

**7.5.3.4** void save\_plot ( const std::string & output\_directory, const std::string & output\_plot\_subdir, const std::string & output\_CV\_filename, const std::string & output\_filename ) const

Save the [Gnuplot](#) output files.

Parameters

in	<i>output_directory</i>	: directory where to store output files;
in	<i>output_plot_subdir</i>	: sub-directory where to store <a href="#">Gnuplot</a> files;
in	<i>output_CV_filename</i>	: output CV filename;
in	<i>output_filename</i>	: prefix for the output filename.

Definition at line 396 of file dosModel.cc.

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

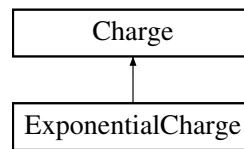
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/dosModel.h
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/dosModel.cc

## 7.6 ExponentialCharge Class Reference

Class derived from [Charge](#), under the hypothesis that Density of States is a single exponential.

```
#include <charge.h>
```

Inheritance diagram for ExponentialCharge:



### Public Member Functions

- [ExponentialCharge](#) ()=delete  
*Default constructor (deleted since it is required to specify a [ParamList](#) and a [QuadratureRule](#)).*
- [ExponentialCharge](#) (const [ParamList](#) &, const [QuadratureRule](#) &)  
*Constructor.*
- virtual [~ExponentialCharge](#) ()=default  
*Destructor (defaulted).*
- virtual [VectorXr](#) charge (const [VectorXr](#) &) override  
*Compute the total charge density.*
- virtual [VectorXr](#) dcharge (const [VectorXr](#) &) override  
*Compute the derivative of the total charge density with respect to the electric potential.*

### Private Member Functions

- [Real](#) n\_approx (const [Real](#) &, const [Real](#) &, const [Real](#) &) const  
*Compute electrons density (per unit volume).*
- [Real](#) dn\_approx (const [Real](#) &, const [Real](#) &, const [Real](#) &) const  
*Compute the approximate derivative of electrons density (per unit volume) with respect to the electric potential.*

### Private Attributes

- [Real](#) NO\_  
*Parameter of the exponential density.*

### Additional Inherited Members

#### 7.6.1 Detailed Description

Class derived from [Charge](#), under the hypothesis that Density of States is a single exponential.

Provide methods to compute total electric charge and its derivative under the hypothesis that Density of States is a single exponential, whose parameter is got by the constructor, of the form:

$$\frac{N_0}{\lambda} \exp\left(-\frac{(\cdot)}{\lambda}\right).$$

Definition at line 125 of file charge.h.

## 7.6.2 Constructor & Destructor Documentation

### 7.6.2.1 ExponentialCharge ( const ParamList & *params*, const QuadratureRule & *rule* )

Constructor.



## Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

Definition at line 110 of file charge.cc.

### 7.6.3 Member Function Documentation

#### 7.6.3.1 VectorXr charge ( const VectorXr & *phi* ) [override],[virtual]

Compute the total charge density.

## Parameters

in	<i>phi</i>	: the electric potential $\varphi$ .
----	------------	--------------------------------------

## Returns

the total charge density  $q(\varphi)$   $[C \cdot m^{-3}]$ .

Implements [Charge](#).

Definition at line 141 of file charge.cc.

#### 7.6.3.2 VectorXr dcharge ( const VectorXr & *phi* ) [override],[virtual]

Compute the derivative of the total charge density with respect to the electric potential.

## Parameters

in	<i>phi</i>	: the electric potential $\varphi$ .
----	------------	--------------------------------------

## Returns

the derivative:  $\frac{dq(\varphi)}{d\varphi}$   $[C \cdot m^{-3} \cdot V^{-1}]$ .

Implements [Charge](#).

Definition at line 153 of file charge.cc.

#### 7.6.3.3 Real n\_approx ( const Real & *phi*, const Real & *N0*, const Real & *lambda* ) const [private]

Compute electrons density (per unit volume).

## Parameters

in	<i>phi</i>	: the electric potential $\varphi$ ;
in	<i>N0</i>	: the exponential $N_0$ ;
in	<i>lambda</i>	: the exponential $\lambda$ .

## Returns

the electrons density  $n(\varphi)$   $[m^{-3}]$ .

Definition at line 113 of file charge.cc.

#### 7.6.3.4 Real dn\_approx ( const Real & *phi*, const Real & *N0*, const Real & *lambda* ) const [private]

Compute the approximate derivative of electrons density (per unit volume) with respect to the electric potential.

## Parameters

in	<i>phi</i>	: the electric potential $\varphi$ ;
in	<i>N0</i>	: the exponential $N_0$ ;
in	<i>lambda</i>	: the exponential $\lambda$ .

## Returns

the derivative:  $\frac{dn(\varphi)}{d\varphi} [m^{-3} \cdot V^{-1}]$ .

Definition at line 127 of file charge.cc.

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

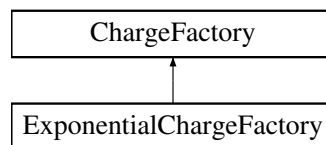
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.h
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.cc

## 7.7 ExponentialChargeFactory Class Reference

Concrete factory to handle a single exponential DoS constitutive relation.

```
#include <factory.h>
```

Inheritance diagram for ExponentialChargeFactory:



## Public Member Functions

- [ExponentialChargeFactory](#) ()=default  
*Default constructor (defaulted).*
- virtual [~ExponentialChargeFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [Charge](#) \* [BuildCharge](#) (const [ParamList](#) &, const [QuadratureRule](#) &) override  
*Factory method to build a concrete [Charge](#) object.*

### 7.7.1 Detailed Description

Concrete factory to handle a single exponential DoS constitutive relation.

Definition at line 82 of file factory.h.

### 7.7.2 Member Function Documentation

**7.7.2.1** [Charge](#) \* [BuildCharge](#) ( const [ParamList](#) & *params*, const [QuadratureRule](#) & *rule* ) [override],  
[virtual]

Factory method to build a concrete [Charge](#) object.

## Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

## Returns

a pointer to [ExponentialCharge](#).

Implements [ChargeFactory](#).

Definition at line 20 of file `factory.cc`.

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

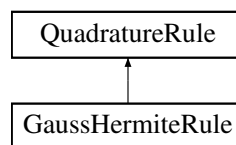
- `/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.h`
- `/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.cc`

## 7.8 GaussHermiteRule Class Reference

Class derived from [QuadratureRule](#) providing the Gauss-Hermite quadrature rule.

```
#include <quadratureRule.h>
```

Inheritance diagram for GaussHermiteRule:



## Public Member Functions

- [GaussHermiteRule](#) ()=delete  
*Default constructor (deleted since it is required to specify the number of nodes).*
- [GaussHermiteRule](#) (const [Index](#) &)  
*Constructor.*
- virtual [~GaussHermiteRule](#) ()=default  
*Destructor (defaulted).*
- virtual void [apply](#) () override  
*Apply the quadrature rule in order to compute the nodes and weights.*
- virtual void [apply](#) (const [GetPot](#) &) override  
*Apply the quadrature rule reading parameters from a configuration file.*
- void [apply\\_iterative\\_algorithm](#) (const [Index](#) &=1000, const [Real](#) &=1.0e-14)  
*Compute nodes and weights using an adapted version of the algorithm presented in: William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery. 2007. Numerical Recipes: The Art of Scientific Computing (3rd edition). Cambridge University Press, New York, NY, USA.*
- void [apply\\_using\\_eigendecomposition](#) ()  
*Compute nodes and weights using an eigendecomposition-based algorithm.*

## Additional Inherited Members

### 7.8.1 Detailed Description

Class derived from [QuadratureRule](#) providing the Gauss-Hermite quadrature rule.

Compute nodes and weights for the  $nNodes\_$ -points approximation of:

$$\int_{-\infty}^{+\infty} w(x)f(x) \, dx$$

where  $w(x) = e^{-x^2}$ .

Definition at line 92 of file quadratureRule.h.

### 7.8.2 Constructor & Destructor Documentation

#### 7.8.2.1 GaussHermiteRule ( const Index & $nNodes$ )

Constructor.

Parameters

<i>in</i>	<i>nNodes</i>	: the number of nodes to be used for the quadrature rule.
-----------	---------------	---

Definition at line 26 of file quadratureRule.cc.

### 7.8.3 Member Function Documentation

#### 7.8.3.1 void apply ( const GetPot & *config* ) [override], [virtual]

Apply the quadrature rule reading parameters from a configuration file.

Parameters

<i>in</i>	<i>config</i>	: the GetPot configuration object.
-----------	---------------	------------------------------------

Implements [QuadratureRule](#).

Definition at line 34 of file quadratureRule.cc.

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

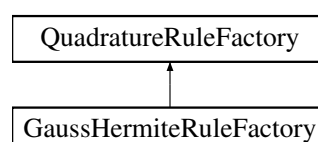
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.cc](#)

## 7.9 GaussHermiteRuleFactory Class Reference

Concrete factory to handle a Gauss-Hermite quadrature rule.

```
#include <factory.h>
```

Inheritance diagram for GaussHermiteRuleFactory:



## Public Member Functions

- [GaussHermiteRuleFactory](#) ()=default  
*Default constructor (defaulted).*
- virtual [~GaussHermiteRuleFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [QuadratureRule](#) \* [BuildRule](#) (const [Index](#) &) override  
*Factory method to build a concrete [QuadratureRule](#) object.*

### 7.9.1 Detailed Description

Concrete factory to handle a Gauss-Hermite quadrature rule.

Definition at line 135 of file [factory.h](#).

### 7.9.2 Member Function Documentation

#### 7.9.2.1 [QuadratureRule](#) \* [BuildRule](#) ( const [Index](#) & *nNodes* ) [override],[virtual]

Factory method to build a concrete [QuadratureRule](#) object.

##### Parameters

<i>in</i>	<i>nNodes</i>	: the number of nodes to be used for the quadrature rule.
-----------	---------------	---

##### Returns

a pointer to [GaussHermiteRule](#).

Implements [QuadratureRuleFactory](#).

Definition at line 25 of file [factory.cc](#).

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

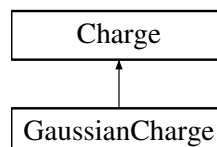
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.cc](#)

## 7.10 GaussianCharge Class Reference

Class derived from [Charge](#), under the hypothesis that Density of States is a combination of gaussians.

```
#include <charge.h>
```

Inheritance diagram for GaussianCharge:



## Public Member Functions

- [GaussianCharge](#) ()=delete

*Default constructor (deleted since it is required to specify a [ParamList](#) and a [QuadratureRule](#)).*

- [GaussianCharge](#) (const [ParamList](#) &, const [QuadratureRule](#) &)

*Constructor.*

- virtual [~GaussianCharge](#) ()=default

*Destructor (defaulted).*

- virtual [VectorXr charge](#) (const [VectorXr](#) &) override

*Compute the total charge density.*

- virtual [VectorXr dcharge](#) (const [VectorXr](#) &) override

*Compute the derivative of the total charge density with respect to the electric potential.*

## Private Member Functions

- [Real n\\_approx](#) (const [Real](#) &, const [Real](#) &, const [Real](#) &) const

*Compute electrons density (per unit volume).*

- [Real dn\\_approx](#) (const [Real](#) &, const [Real](#) &, const [Real](#) &) const

*Compute the approximate derivative of electrons density (per unit volume) with respect to the electric potential.*

## Additional Inherited Members

### 7.10.1 Detailed Description

Class derived from [Charge](#), under the hypothesis that Density of States is a combination of gaussians.

Provide methods to compute total electric charge and its derivative under the hypothesis that Density of States is a linear combination of multiple gaussians, whose parameters are read from a [ParamList](#) object, of the form:

$$\frac{N_0}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(\cdot)^2}{2\sigma^2}\right).$$

Definition at line 74 of file charge.h.

### 7.10.2 Constructor & Destructor Documentation

#### 7.10.2.1 [GaussianCharge](#) ( const [ParamList](#) & *params*, const [QuadratureRule](#) & *rule* )

Constructor.

Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

Definition at line 20 of file charge.cc.

### 7.10.3 Member Function Documentation

#### 7.10.3.1 [VectorXr charge](#) ( const [VectorXr](#) & *phi* ) [override],[virtual]

Compute the total charge density.

## Parameters

<i>in</i>	<i>phi</i>	: the electric potential $\varphi$ .
-----------	------------	--------------------------------------

## Returns

the total charge density  $q(\varphi)$   $[C \cdot m^{-3}]$ .

Implements [Charge](#).

Definition at line 51 of file charge.cc.

### 7.10.3.2 VectorXr dcharge ( const VectorXr & phi ) [override], [virtual]

Compute the derivative of the total charge density with respect to the electric potential.

## Parameters

<i>in</i>	<i>phi</i>	: the electric potential $\varphi$ .
-----------	------------	--------------------------------------

## Returns

the derivative:  $\frac{dq(\varphi)}{d\varphi}$   $[C \cdot m^{-3} \cdot V^{-1}]$ .

Implements [Charge](#).

Definition at line 78 of file charge.cc.

### 7.10.3.3 Real n\_approx ( const Real & phi, const Real & N0, const Real & sigma ) const [private]

Compute electrons density (per unit volume).

## Parameters

<i>in</i>	<i>phi</i>	: the electric potential $\varphi$ ;
<i>in</i>	<i>N0</i>	: the gaussian mean $N_0$ ;
<i>in</i>	<i>sigma</i>	: the gaussian standard deviation $\sigma$ .

## Returns

the electrons density  $n(\varphi)$   $[m^{-3}]$ .

Definition at line 23 of file charge.cc.

### 7.10.3.4 Real dn\_approx ( const Real & phi, const Real & N0, const Real & sigma ) const [private]

Compute the approximate derivative of electrons density (per unit volume) with respect to the electric potential.

## Parameters

<i>in</i>	<i>phi</i>	: the electric potential $\varphi$ ;
<i>in</i>	<i>N0</i>	: the gaussian mean $N_0$ ;
<i>in</i>	<i>sigma</i>	: the gaussian standard deviation $\sigma$ .

## Returns

the derivative:  $\frac{dn(\varphi)}{d\varphi}$   $[m^{-3} \cdot V^{-1}]$ .

Definition at line 37 of file charge.cc.

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

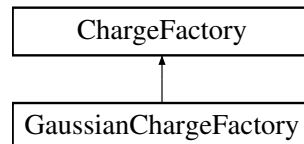
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.cc](#)

## 7.11 GaussianChargeFactory Class Reference

Concrete factory to handle a multiple gaussians DoS constitutive relation.

```
#include <factory.h>
```

Inheritance diagram for GaussianChargeFactory:



### Public Member Functions

- [GaussianChargeFactory](#) ()=default  
*Default constructor (defaulted).*
- virtual [~GaussianChargeFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [Charge \\* BuildCharge](#) (const [ParamList](#) &, const [QuadratureRule](#) &) override  
*Factory method to build a concrete [Charge](#) object.*

#### 7.11.1 Detailed Description

Concrete factory to handle a multiple gaussians DoS constitutive relation.

Definition at line 55 of file factory.h.

#### 7.11.2 Member Function Documentation

**7.11.2.1** [Charge \\* BuildCharge](#) ( const [ParamList](#) & *params*, const [QuadratureRule](#) & *rule* ) [[override](#)], [[virtual](#)]

Factory method to build a concrete [Charge](#) object.

##### Parameters

in	<i>params</i>	: the list of simulation parameters;
in	<i>rule</i>	: a quadrature rule.

##### Returns

a pointer to [GaussianCharge](#).

Implements [ChargeFactory](#).

Definition at line 15 of file factory.cc.

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

- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.cc](#)

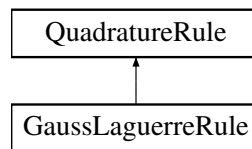


## 7.12 GaussLaguerreRule Class Reference

Class derived from [QuadratureRule](#) providing the Gauss-Laguerre quadrature rule.

```
#include <quadratureRule.h>
```

Inheritance diagram for GaussLaguerreRule:



### Public Member Functions

- [GaussLaguerreRule](#) ()=delete  
*Default constructor (deleted since it is required to specify the number of nodes).*
- [GaussLaguerreRule](#) (const [Index](#) &)  
*Constructor.*
- virtual [~GaussLaguerreRule](#) ()=default  
*Destructor (defaulted).*
- virtual void [apply](#) () override  
*Apply the quadrature rule in order to compute the nodes and weights.*
- virtual void [apply](#) (const [GetPot](#) &) override  
*Apply the quadrature rule reading parameters from a configuration file.*
- void [apply\\_iterative\\_algorithm](#) (const [Index](#) &=1000, const [Real](#) &=1.0e-14)  
*Compute nodes and weights using an adapted version of the algorithm presented in: William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery. 2007. Numerical Recipes: The Art of Scientific Computing (3rd edition). Cambridge University Press, New York, NY, USA.*
- void [apply\\_using\\_eigendecomposition](#) ()  
*Compute nodes and weights using an eigendecomposition-based algorithm.*

### Static Public Member Functions

- static [Real](#) [log\\_gamma](#) (const [Real](#) &)  
*Auxiliary function to compute  $\log \Gamma(x)$ .*

### Additional Inherited Members

#### 7.12.1 Detailed Description

Class derived from [QuadratureRule](#) providing the Gauss-Laguerre quadrature rule.

Compute nodes and weights for the  $nNodes\_$ -points approximation of:

$$\int_0^{+\infty} w(x) f(x) \, dx$$

where  $w(x) = e^{-x}$ .

Definition at line 135 of file [quadratureRule.h](#).

## 7.12.2 Constructor & Destructor Documentation

### 7.12.2.1 GaussLaguerreRule ( const Index & *nNodes* )

Constructor.

## Parameters

in	<i>nNodes</i>	: the number of nodes to be used for the quadrature rule.
----	---------------	---

Definition at line 146 of file quadratureRule.cc.

### 7.12.3 Member Function Documentation

#### 7.12.3.1 Real log\_gamma ( const Real & x ) [static]

Auxiliary function to compute  $\log \Gamma(x)$ .

## Parameters

in	<i>x</i>	: the point to compute the function at.
----	----------	---

## Returns

the natural logarithm of the gamma function evaluated at *x*.

Definition at line 149 of file quadratureRule.cc.

#### 7.12.3.2 void apply ( const GetPot & config ) [override],[virtual]

Apply the quadrature rule reading parameters from a configuration file.

## Parameters

in	<i>config</i>	: the GetPot configuration object.
----	---------------	------------------------------------

Implements [QuadratureRule](#).

Definition at line 182 of file quadratureRule.cc.

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

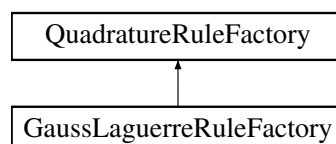
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[quadratureRule.h](#)
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[quadratureRule.cc](#)

## 7.13 GaussLaguerreRuleFactory Class Reference

Concrete factory to handle a Gauss-Laguerre quadrature rule.

```
#include <factory.h>
```

Inheritance diagram for GaussLaguerreRuleFactory:



### Public Member Functions

- [GaussLaguerreRuleFactory](#) ()=default  
*Default constructor (defaulted).*

- virtual [~GaussLaguerreRuleFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [QuadratureRule](#) \* [BuildRule](#) (const [Index](#) &) override  
*Factory method to build a concrete [QuadratureRule](#) object.*

### 7.13.1 Detailed Description

Concrete factory to handle a Gauss-Laguerre quadrature rule.

Definition at line 161 of file factory.h.

### 7.13.2 Member Function Documentation

#### 7.13.2.1 [QuadratureRule](#) \* [BuildRule](#) ( const [Index](#) & *nNodes* ) [override],[virtual]

Factory method to build a concrete [QuadratureRule](#) object.

Parameters

<i>in</i>	<i>nNodes</i>	: the number of nodes to be used for the quadrature rule.
-----------	---------------	---

Returns

a pointer to [GaussLaguerreRule](#).

Implements [QuadratureRuleFactory](#).

Definition at line 30 of file factory.cc.

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

- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[factory.h](#)
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[factory.cc](#)

## 7.14 NonLinearPoisson1D Class Reference

Provide a solver for a non-linear Poisson equation.

```
#include <solvers.h>
```

### Public Member Functions

- [NonLinearPoisson1D](#) ()=delete  
*Default constructor (deleted since it is required to specify the solver to be used).*
- [NonLinearPoisson1D](#) (const [PdeSolver1D](#) &, const [Index](#) &=100, const [Real](#) &=1.0e-6)  
*Constructor.*
- virtual [~NonLinearPoisson1D](#) ()=default  
*Destructor (defaulted).*
- void [apply](#) (const [VectorXr](#) &, const [VectorXr](#) &, [Charge](#) &)  
*Apply a Newton method to the equation and then discretize it using the solver specified.*

### Getter methods

- const [VectorXr](#) & [phi](#) () const
- const [VectorXr](#) & [norm](#) () const
- const [Real](#) & [qTot](#) () const
- const [Real](#) & [cTot](#) () const

## Private Member Functions

- [SparseXr computeJac](#) (const [VectorXr](#) &) const  
*Compute the Jacobi matrix.*

## Private Attributes

- const [PdeSolver1D](#) & [solver\\_](#)  
*Solver handler.*
- [Index](#) [maxIterationsNo\\_](#)  
*Maximum number of iterations.*
- [Real](#) [tolerance\\_](#)  
*Tolerance.*
- [VectorXr](#) [phi\\_](#)  
*The electric potential.*
- [VectorXr](#) [norm\\_](#)  
*Vector holding  $L^\infty$ -norm errors for each iteration.*
- [Real](#) [qTot\\_](#)  
*Total charge.*
- [Real](#) [cTot\\_](#)  
*Total capacitance.*

### 7.14.1 Detailed Description

Provide a solver for a non-linear Poisson equation.

A Newton method is applied in order to solve:

$$-\frac{d}{dz} \left( \epsilon(z) \cdot \frac{d\varphi}{dz}(z) \right) = -q \cdot \frac{N_0}{\sqrt{\pi}} \int_{-\infty}^{+\infty} \exp(-\alpha^2) \left( 1 + \exp \left( \frac{\sqrt{2}\sigma\alpha - q\varphi(z)}{K_B \cdot T} \right) \right)^{-1} d\alpha .$$

Definition at line 192 of file solvers.h.

### 7.14.2 Constructor & Destructor Documentation

#### 7.14.2.1 NonLinearPoisson1D ( const [PdeSolver1D](#) & *solver*, const [Index](#) & *maxIterationsNo* = 100, const [Real](#) & *tolerance* = 1.0e-6 )

Constructor.

Parameters

in	<i>solver</i>	: the solver to be used;
in	<i>maxIterationsNo</i>	: maximum number of iterations desired;
in	<i>tolerance</i>	: tolerance desired.

Definition at line 202 of file solvers.cc.

### 7.14.3 Member Function Documentation

#### 7.14.3.1 void apply ( const [VectorXr](#) & *mesh*, const [VectorXr](#) & *init\_guess*, [Charge](#) & *charge\_fun* )

Apply a Newton method to the equation and then discretize it using the solver specified.

**Parameters**

in	<i>mesh</i>	: the mesh;
in	<i>init_guess</i>	: initial guess for the Newton algorithm;
in	<i>charge_fun</i>	: an object of class <a href="#">Charge</a> specifying how to compute total electric charge.

Definition at line 209 of file solvers.cc.

#### 7.14.3.2 SparseXr computeJac ( const VectorXr & x ) const [private]

Compute the Jacobi matrix.

**Parameters**

in	<i>x</i>	: the vector where to start from.
----	----------	-----------------------------------

**Returns**

the Jacobi matrix in a sparse format.

Definition at line 330 of file solvers.cc.

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

- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[solvers.h](#)
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[solvers.cc](#)

## 7.15 ParamList Class Reference

Class providing methods to handle a list of parameters.

```
#include <paramList.h>
```

**Public Member Functions**

- [ParamList](#) ()=default  
*Default constructor (defaulted).*
- [ParamList](#) (const [RowVectorXr](#) &)  
*Explicit conversion constructor.*
- virtual [~ParamList](#) ()=default  
*Destructor (defaulted).*

**Getter methods**

- const [Index](#) & **simulationNo** () const
- const [Real](#) & **t\_semic** () const
- const [Real](#) & **t\_ins** () const
- const [Real](#) & **eps\_semic** () const
- const [Real](#) & **eps\_ins** () const
- const [Real](#) & **Wf** () const
- const [Real](#) & **Ea** () const
- const [Real](#) & **NO** () const
- const [Real](#) & **sigma** () const
- const [Real](#) & **NO\_2** () const
- const [Real](#) & **sigma\_2** () const
- const [Real](#) & **shift\_2** () const
- const [Real](#) & **NO\_3** () const
- const [Real](#) & **sigma\_3** () const

- const [Real](#) & **shift\_3** () const
- const [Real](#) & **N0\_4** () const
- const [Real](#) & **sigma\_4** () const
- const [Real](#) & **shift\_4** () const
- const [Real](#) & **N0\_exp** () const
- const [Real](#) & **lambda\_exp** () const
- const [Real](#) & **A\_semic** () const
- const [Real](#) & **C\_sb** () const
- const [Index](#) & **nNodes** () const
- const [Index](#) & **nSteps** () const
- const [Real](#) & **V\_min** () const
- const [Real](#) & **V\_max** () const

### Private Attributes

- [Index](#) **simulationNo\_**  
*Simulation number index.*
- [Real](#) **t\_semic\_**  
*Thickness of the semiconductor layer [m].*
- [Real](#) **t\_ins\_**  
*Thickness of the insulator layer [m].*
- [Real](#) **eps\_semic\_**  
*Relative electrical permittivity of the semiconductor layer [ ].*
- [Real](#) **eps\_ins\_**  
*Relative electrical permittivity of the insulator layer [ ].*
- [Real](#) **Wf\_**  
*Work-function (normalized by  $Q$ ) [V].*
- [Real](#) **Ea\_**  
*Electron affinity (normalized by  $Q$ ) [V].*
- [Real](#) **N0\_**  
*1st gaussian  $N_0$  [ $m^{-3}$ ].*
- [Real](#) **sigma\_**  
*1st gaussian standard deviation  $\sigma$  (normalized by  $K_B \cdot T$ ) [ ].*
- [Real](#) **N0\_2\_**  
*2nd gaussian  $N_0$  [ $m^{-3}$ ].*
- [Real](#) **sigma\_2\_**  
*2nd gaussian standard deviation  $\sigma$  (normalized by  $K_B \cdot T$ ) [ ].*
- [Real](#) **shift\_2\_**  
*2nd gaussian shift with respect to the 1st gaussian electric potential (normalized by  $-Q$ ) [V].*
- [Real](#) **N0\_3\_**  
*3rd gaussian  $N_0$  [ $m^{-3}$ ].*
- [Real](#) **sigma\_3\_**  
*3rd gaussian standard deviation  $\sigma$  (normalized by  $K_B \cdot T$ ) [ ].*
- [Real](#) **shift\_3\_**  
*3rd gaussian shift with respect to the 1st gaussian electric potential (normalized by  $-Q$ ) [V].*
- [Real](#) **N0\_4\_**  
*4th gaussian  $N_0$  [ $m^{-3}$ ].*
- [Real](#) **sigma\_4\_**  
*4th gaussian standard deviation  $\sigma$  (normalized by  $K_B \cdot T$ ) [ ].*
- [Real](#) **shift\_4\_**  
*4th gaussian shift with respect to the 1st gaussian electric potential (normalized by  $-Q$ ) [V].*
- [Real](#) **N0\_exp\_**  
*Exponential  $N_0$  [ $m^{-3}$ ].*

- [Real lambda\\_exp\\_](#)  
*Exponential  $\lambda$  (normalized by  $K_B \cdot T$ ) [ ].*
- [Real A\\_semic\\_](#)  
*Area of the semiconductor [m<sup>2</sup>].*
- [Real C\\_sb\\_](#)  
*Equivalent capacitance of the series semiconductor-insulator (stray-border capacitance) [F].*
- [Index nNodes\\_](#)  
*Number of nodes that form the mesh.*
- [Index nSteps\\_](#)  
*Number of steps to simulate.*
- [Real V\\_min\\_](#)  
*Minimum voltage [V].*
- [Real V\\_max\\_](#)  
*Maximum voltage [V].*

## Friends

- class **GaussianCharge**
- class **ExponentialCharge**
- class **DosModel**

### 7.15.1 Detailed Description

Class providing methods to handle a list of parameters.

It can include up to 4 gaussians (later combined to compute total charge) and an exponential.

Definition at line 28 of file paramList.h.

### 7.15.2 Constructor & Destructor Documentation

#### 7.15.2.1 ParamList ( const RowVectorXr & list ) [explicit]

Explicit conversion constructor.

Parameters

in	list	: a row vector containing a list of parameters (for example got by a <a href="#">CsvParser</a> object). Parameters should be sorted in the same order as specified above.
----	------	---

Definition at line 17 of file paramList.cc.

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

- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[paramList.h](#)
- /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/[paramList.cc](#)

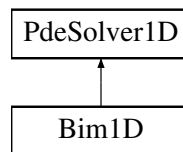
## 7.16 PdeSolver1D Class Reference

Abstract class providing methods to assemble matrices to solve one-dimensional PDEs.

```
#include <solvers.h>
```

Inheritance diagram for PdeSolver1D:





## Public Member Functions

- [PdeSolver1D](#) ()=delete  
*Default constructor (deleted since it is required to specify the mesh).*
- [PdeSolver1D](#) ([VectorXr](#) &)  
*Constructor.*
- virtual [~PdeSolver1D](#) ()=default  
*Destructor (defaulted).*
- virtual void [assembleAdvDiff](#) (const [VectorXr](#) &alpha, const [VectorXr](#) &gamma, const [VectorXr](#) &eta, const [VectorXr](#) &beta)=0  
*Assemble the matrix for an advection-diffusion term.*
- virtual void [assembleStiff](#) (const [VectorXr](#) &eps, const [VectorXr](#) &kappa)=0  
*Assemble the matrix for a diffusion term.*
- virtual void [assembleMass](#) (const [VectorXr](#) &delta, const [VectorXr](#) &zeta)=0  
*Assemble the matrix for a reaction term.*

## Getter methods

- const [SparseXr](#) & **AdvDiff** () const
- const [SparseXr](#) & **Stiff** () const
- const [SparseXr](#) & **Mass** () const

## Protected Attributes

- [VectorXr](#) [mesh\\_](#)  
*The mesh.*
- [Index](#) [nNodes\\_](#)  
*Number of nodes that form the mesh.*
- [SparseXr](#) [AdvDiff\\_](#)  
*Matrix for an advection-diffusion term.*
- [SparseXr](#) [Stiff\\_](#)  
*Stiffness matrix.*
- [SparseXr](#) [Mass\\_](#)  
*Mass matrix.*

## Friends

- class **NonLinearPoisson1D**

### 7.16.1 Detailed Description

Abstract class providing methods to assemble matrices to solve one-dimensional PDEs.

Matrices are held in a sparse format.

Definition at line 34 of file solvers.h.

## 7.16.2 Constructor & Destructor Documentation

### 7.16.2.1 PdeSolver1D ( VectorXr & mesh )

Constructor.

Parameters

<code>in</code>	<code>mesh</code>	: the mesh.
-----------------	-------------------	-------------

Definition at line 15 of file solvers.cc.

## 7.16.3 Member Function Documentation

### 7.16.3.1 virtual void assembleAdvDiff ( const VectorXr & alpha, const VectorXr & gamma, const VectorXr & eta, const VectorXr & beta ) [pure virtual]

Assemble the matrix for an advection-diffusion term.

Build the matrix for the advection-diffusion problem:  $-\nabla \cdot (\alpha \cdot \gamma (\eta \nabla u - \beta u)) = f$ .

Parameters

<code>in</code>	<code>alpha</code>	: $\alpha$ , an element-wise constant function;
<code>in</code>	<code>gamma</code>	: $\gamma$ , an element-wise linear function;
<code>in</code>	<code>eta</code>	: $\eta$ , an element-wise linear function;
<code>in</code>	<code>beta</code>	: $\beta$ , an element-wise constant function.

Implemented in [Bim1D](#).

### 7.16.3.2 virtual void assembleStiff ( const VectorXr & eps, const VectorXr & kappa ) [pure virtual]

Assemble the matrix for a diffusion term.

Build the matrix for the diffusion problem:  $-\nabla \cdot (\epsilon \cdot \kappa \nabla u) = f$ .

Parameters

<code>in</code>	<code>eps</code>	: $\epsilon$ , an element-wise constant function;
<code>in</code>	<code>kappa</code>	: $\kappa$ , an element-wise linear function.

Implemented in [Bim1D](#).

### 7.16.3.3 virtual void assembleMass ( const VectorXr & delta, const VectorXr & zeta ) [pure virtual]

Assemble the matrix for a reaction term.

Build the mass matrix for the reaction problem:  $\delta \cdot \zeta u = f$ .

Parameters

<code>in</code>	<code>delta</code>	: $\delta$ , an element-wise constant function;
<code>in</code>	<code>zeta</code>	: $\zeta$ , an element-wise linear function.

Implemented in [Bim1D](#).

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

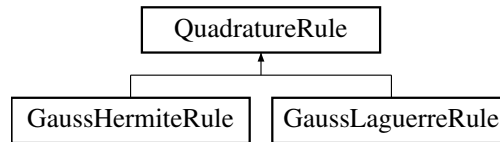
- </home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/solvers.h>
- </home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/solvers.cc>

## 7.17 QuadratureRule Class Reference

Abstract class providing a quadrature rule.

```
#include <quadratureRule.h>
```

Inheritance diagram for QuadratureRule:



### Public Member Functions

- [QuadratureRule](#) ()=delete  
*Default constructor (deleted since it is required to specify the number of nodes).*
- [QuadratureRule](#) (const [Index](#) &)  
*Constructor.*
- virtual [~QuadratureRule](#) ()=default  
*Destructor (defaulted).*
- virtual void [apply](#) ()=0  
*Apply the quadrature rule in order to compute the nodes and weights.*
- virtual void [apply](#) (const [GetPot](#) &config)=0  
*Apply the quadrature rule reading parameters from a configuration file.*

### Getter methods

- const [Index](#) & **nNodes** () const
- const [VectorXr](#) & **nodes** () const
- const [VectorXr](#) & **weights** () const

### Protected Attributes

- [Index](#) **nNodes\_**  
*Number of nodes of quadrature.*
- [VectorXr](#) **nodes\_**  
*Vector containing the computed nodes coordinates.*
- [VectorXr](#) **weights\_**  
*Vector containing the computed weights.*

### Friends

- class **GaussianCharge**
- class **ExponentialCharge**

### 7.17.1 Detailed Description

Abstract class providing a quadrature rule.

Approximate the integral:

$$\int_a^b f(x) \, dx$$

with the finite sum:

$$\sum_{i=1}^{nNodes} w_i \cdot f(x_i)$$

where  $\{x_i\}_{i=1}^{nNodes}$  and  $\{w_i\}_{i=1}^{nNodes}$  are called respectively nodes and weights.

Definition at line 32 of file quadratureRule.h.

### 7.17.2 Constructor & Destructor Documentation

#### 7.17.2.1 QuadratureRule ( const Index & nNodes )

Constructor.

Parameters

<code>in</code>	<code>nNodes</code>	: the number of nodes to be used for the quadrature rule.
-----------------	---------------------	---

Definition at line 17 of file quadratureRule.cc.

### 7.17.3 Member Function Documentation

#### 7.17.3.1 virtual void apply ( const GetPot & config ) [pure virtual]

Apply the quadrature rule reading parameters from a configuration file.

Parameters

<code>in</code>	<code>config</code>	: the GetPot configuration object.
-----------------	---------------------	------------------------------------

Implemented in [GaussLaguerreRule](#), and [GaussHermiteRule](#).

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

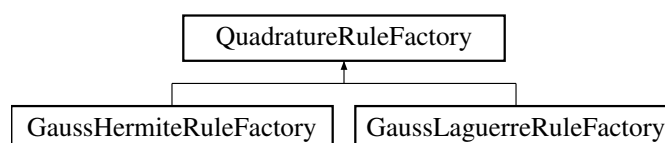
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.h](#)
- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.cc](#)

## 7.18 QuadratureRuleFactory Class Reference

Abstract factory to handle a quadrature rule.

```
#include <factory.h>
```

Inheritance diagram for QuadratureRuleFactory:



## Public Member Functions

- [QuadratureRuleFactory](#) ()=default  
*Default constructor (defaulted).*
- virtual [~QuadratureRuleFactory](#) ()=default  
*Destructor (defaulted).*
- virtual [QuadratureRule](#) \* [BuildRule](#) (const [Index](#) &nNodes)=0  
*Factory method to build an abstract [QuadratureRule](#) object.*

### 7.18.1 Detailed Description

Abstract factory to handle a quadrature rule.

Definition at line 109 of file [factory.h](#).

### 7.18.2 Member Function Documentation

**7.18.2.1** virtual [QuadratureRule](#)\* [BuildRule](#) ( const [Index](#) & *nNodes* ) [pure virtual]

Factory method to build an abstract [QuadratureRule](#) object.

#### Parameters

<i>in</i>	<i>nNodes</i>	: the number of nodes to be used for the quadrature rule.
-----------	---------------	---

#### Returns

a pointer to [QuadratureRule](#).

Implemented in [GaussLaguerreRuleFactory](#), and [GaussHermiteRuleFactory](#).

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

- [/home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.h](#)



## Chapter 8

# File Documentation

### 8.1 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.cc File Reference

```
#include "charge.h"
```

#### 8.1.1 Detailed Description

##### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

##### Date

2014

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Definition in file [charge.cc](#).

### 8.2 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/charge.h File Reference

Classes for computing total electric charge.

```
#include "paramList.h"  
#include "quadratureRule.h"  
#include "typedefs.h"
```

#### Classes

- class [Charge](#)  
*Abstract class providing methods to calculate total electric charge (the rhs in the Poisson equation).*
- class [GaussianCharge](#)  
*Class derived from [Charge](#), under the hypothesis that Density of States is a combination of gaussians.*
- class [ExponentialCharge](#)  
*Class derived from [Charge](#), under the hypothesis that Density of States is a single exponential.*

### 8.2.1 Detailed Description

Classes for computing total electric charge.

#### Author

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#### Date

2014

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Definition in file [charge.h](#).

## 8.3 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/csvParser.cc File Reference

```
#include "csvParser.h"
```

### 8.3.1 Detailed Description

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [csvParser.cc](#).

## 8.4 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/csvParser.h File Reference

Tools to store content from a .csv file in matrices or vectors.

```
#include "typedefs.h"  
#include <fstream>  
#include <sstream>  
#include <string>  
#include <utility>
```



## Classes

- class [CsvParser](#)

*Class providing methods to read **numeric** content from a .csv file and to store it in [Eigen](#) matrices or vectors.*

### 8.4.1 Detailed Description

Tools to store content from a .csv file in matrices or vectors.

#### Author

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#### Date

2014

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Definition in file [csvParser.h](#).

## 8.5 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/dosModel.cc File Reference

```
#include "dosModel.h"
```

### 8.5.1 Detailed Description

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [dosModel.cc](#).

## 8.6 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/dosModel.h File Reference

Mathematical model for Density of States extraction.

```
#include "charge.h"
#include "csvParser.h"
#include "factory.h"
#include "numerics.h"
#include "paramList.h"
#include "quadratureRule.h"
#include "solvers.h"
#include "typedefs.h"
#include "gnuplot-iostream.h"
#include <chrono>
#include <iomanip>
#include <limits>
```

## Classes

- class [DosModel](#)

*Class providing methods to process a simulation to extract the Density of States starting from a parameter list.*

### 8.6.1 Detailed Description

Mathematical model for Density of States extraction.

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [dosModel.h](#).

## 8.7 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.cc File Reference

```
#include "factory.h"
```

### 8.7.1 Detailed Description

#### Author

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#### Date

2014

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Definition in file [factory.cc](#).

## 8.8 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/factory.h File Reference

Abstract factory design patterns.

```
#include "charge.h"  
#include "paramList.h"  
#include "quadratureRule.h"
```

### Classes

- class [ChargeFactory](#)  
*Abstract factory to handle the constitutive relation for the Density of States.*
- class [GaussianChargeFactory](#)  
*Concrete factory to handle a multiple gaussians DoS constitutive relation.*
- class [ExponentialChargeFactory](#)  
*Concrete factory to handle a single exponential DoS constitutive relation.*
- class [QuadratureRuleFactory](#)  
*Abstract factory to handle a quadrature rule.*
- class [GaussHermiteRuleFactory](#)  
*Concrete factory to handle a Gauss-Hermite quadrature rule.*
- class [GaussLaguerreRuleFactory](#)  
*Concrete factory to handle a Gauss-Laguerre quadrature rule.*

### 8.8.1 Detailed Description

Abstract factory design patterns.

#### Author

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#### Date

2014

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Definition in file [factory.h](#).

## 8.9 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/numerics.cc File Reference

```
#include "numerics.h"
```

### 8.9.1 Detailed Description

#### Author

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#### Date

2014

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Definition in file [numerics.cc](#).

## 8.10 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/numerics.h File Reference

Generic numeric algorithms.

```
#include "typedefs.h"
#include <limits>
```

### Namespaces

- [numerics](#)

*Namespace for generic numeric algorithms.*

### Functions

- `template<typename ScalarType >  
VectorX< ScalarType > sort (const VectorX< ScalarType > &vector)`  
*Function to sort [Eigen](#) vectors.*
- `template<typename ScalarType >  
VectorXpair< ScalarType > sort_pair (const VectorX< ScalarType > &vector)`  
*Function to sort [Eigen](#) vectors, keeping track of indexes.*
- `Real trapz (const VectorXr &x, const VectorXr &y)`  
*Function to compute approximate integral of y with spacing increment specified by x, using trapezoidal rule.*
- `Real trapz (const VectorXr &y)`  
*Compute the approximate integral of y with unit spacing, using trapezoidal rule.*
- `VectorXr deriv (const VectorXr &, const VectorXr &)`  
*Compute the numeric derivative:  $\frac{dy}{dx}$ .*
- `Real interp1 (const VectorXr &, const VectorXr &, const Real &)`  
*Linear 1D interpolation. Interpolate y, defined at points x, at the point xNew.*
- `VectorXr interp1 (const VectorXr &, const VectorXr &, const VectorXr &)`  
*Linear 1D interpolation. Interpolate y, defined at points x, at the points xNew.*
- `Real error_L2 (const VectorXr &, const VectorXr &, const VectorXr &, const Real &)`  
*Compute the  $L^2$ -norm error between simulated and interpolated values, using trapz.*

### 8.10.1 Detailed Description

Generic numeric algorithms.

#### Author

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#### Date

2014

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Definition in file [numerics.h](#).

## 8.11 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/paramList.cc File Reference

```
#include "paramList.h"
```

### 8.11.1 Detailed Description

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

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Definition in file [paramList.cc](#).

## 8.12 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/paramList.h File Reference

Interface to process a list of simulation parameters.

```
#include "typedefs.h"
```

### Classes

- class [ParamList](#)  
*Class providing methods to handle a list of parameters.*

### 8.12.1 Detailed Description

Interface to process a list of simulation parameters.

#### Author

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#### Date

2014

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Definition in file [paramList.h](#).

## 8.13 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/physicalConstants.h File Reference

Physical constants.

```
#include "typedefs.h"
```

### Namespaces

- [constants](#)

*Numerical constants.*

### Variables

- const [Real](#) Q = 1.602176530000000e-19  
*Electron charge [C].*
- const [Real](#) Q2 = Q \* Q  
*Electron charge squared [C<sup>2</sup>].*
- const [Real](#) K\_B = 1.380650500000000e-23  
*Boltzmann's constant [J · K<sup>-1</sup>].*
- const [Real](#) EPS0 = 8.854187817e-12  
*Vacuum electrical permittivity [C · V<sup>-1</sup> · m<sup>-1</sup>].*
- const [Real](#) T = 300  
*Reference temperature [K].*
- const [Real](#) V\_TH = K\_B \* T / Q  
*Threshold voltage [V].*

### 8.13.1 Detailed Description

Physical constants.

#### Author

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#### Date

2014

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Definition in file [physicalConstants.h](#).

## 8.14 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.cc File Reference

```
#include "quadratureRule.h"
```

### 8.14.1 Detailed Description

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

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Definition in file [quadratureRule.cc](#).

## 8.15 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/quadratureRule.h File Reference

Quadrature rules.

```
#include "typedefs.h"
```

## Classes

- class [QuadratureRule](#)  
*Abstract class providing a quadrature rule.*
- class [GaussHermiteRule](#)  
*Class derived from [QuadratureRule](#) providing the Gauss-Hermite quadrature rule.*
- class [GaussLaguerreRule](#)  
*Class derived from [QuadratureRule](#) providing the Gauss-Laguerre quadrature rule.*

### 8.15.1 Detailed Description

Quadrature rules.

#### Author

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#### Date

2014

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Definition in file [quadratureRule.h](#).

## 8.16 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/solvers.cc File Reference

```
#include "solvers.h"
```

### 8.16.1 Detailed Description

#### Author

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#### Date

2014

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Definition in file [solvers.cc](#).



## 8.17 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/solvers.h File Reference

Generic solvers for PDEs.

```
#include "charge.h"
#include "typedefs.h"
#include <utility>
#include <limits>
```

### Classes

- class [PdeSolver1D](#)  
*Abstract class providing methods to assemble matrices to solve one-dimensional PDEs.*
- class [Bim1D](#)  
*Class derived from [PdeSolver1D](#), providing a finite volume Box Integration Method (BIM) solver.*
- class [NonLinearPoisson1D](#)  
*Provide a solver for a non-linear Poisson equation.*

### 8.17.1 Detailed Description

Generic solvers for PDEs.

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [solvers.h](#).

## 8.18 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/typedefs.cc File Reference

```
#include "typedefs.h"
```

### 8.18.1 Detailed Description

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [typedefs.cc](#).

## 8.19 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/src/typedefs.h File Reference

Typedefs and utility functions.

```
#include <Eigen/Dense>
#include <Eigen/Sparse>
#include "GetPot "
#include <iostream>
#include <fstream>
#include "physicalConstants.h"
```

## Namespaces

- [constants](#)  
*Numerical constants.*
- [utility](#)  
*Namespace for utilities and auxiliary functions.*

## Macros

- #define [Real](#) double  
*Pre-processor macro for real numbers.*
- #define [Index](#) ptrdiff\_t  
*Pre-processor macro for indexing variables.*

## Typedefs

- typedef Matrix< [Real](#), Dynamic, Dynamic > [MatrixXr](#)  
*Typedef for dense real-valued dynamic-sized matrices.*
- typedef Matrix< [Real](#), Dynamic, 1 > [VectorXr](#)  
*Typedef for dense real-valued dynamic-sized column vectors.*
- typedef Matrix< [Real](#), 1, Dynamic > [RowVectorXr](#)  
*Typedef for dense real-valued dynamic-sized row vectors.*
- typedef SparseMatrix< [Real](#) > [SparseXr](#)  
*Typedef for sparse real-valued dynamic-sized matrices.*
- template<typename ScalarType >  
using [VectorX](#) = Matrix< ScalarType, Dynamic, 1 >  
*Template alias for [Eigen](#) vectors.*
- template<typename T >  
using [VectorXpair](#) = [VectorX](#)< std::pair< T, [Index](#) > >  
*Template alias for an [Eigen](#) vector of pairs: (ScalarType, Index).*

## Functions

- `std::string full_path` (const std::string &, const std::string &)  
*Auxiliary function to return the full path to a file.*
- void `print_block` (const char \*, std::ostream &=std::cout)  
*Auxiliary function to print a string inside a block.*
- void `print_done` (std::ostream &=std::cout)  
*Auxiliary function to print a "DONE!" string.*

## Variables

- const `Index PARAMS_NO` = 26  
*Number of parameters required in input file.*
- const `Real PI` =  $M\_PI$   
 $\pi$ .
- const `Real SQRT_PI` = `std::sqrt(PI)`  
 $\sqrt{\pi}$ .
- const `Real PI_M4` = 0.7511255444649425  
 $\pi^{-\frac{1}{4}}$ .
- const `Real SQRT_2` = `std::sqrt(2)`  
 $\sqrt{2}$ .

### 8.19.1 Detailed Description

Typedefs and utility functions.

#### Author

Pasquale Claudio Africa [pasquale.africa@gmail.com](mailto:pasquale.africa@gmail.com)

#### Date

2014

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Definition in file [typedefs.h](#).

### 8.19.2 Typedef Documentation

#### 8.19.2.1 using `VectorX = Matrix<ScalarType, Dynamic, 1>`

Template alias for [Eigen](#) vectors.

#### Template Parameters

---

<i>ScalarType</i>	: the scalar type.
-------------------	--------------------

Definition at line 44 of file typedefs.h.

8.19.2.2 using `VectorXpair = VectorX<std::pair<T, Index> >`

Template alias for an [Eigen](#) vector of pairs: (*ScalarType*, *Index*).

Template Parameters

<i>ScalarType</i>	: the scalar type.
-------------------	--------------------

Definition at line 51 of file typedefs.h.

## 8.20 /home/elauksap/Dropbox/Progetto-PACS/C++/Source/test/simulate\_dos.cc File Reference

A test file.

```
#include "src/dosModel.h"
```

### Functions

- int [main](#) (const int argc, const char \*const \*argv, const char \*const \*envp)  
The *main* function.

### 8.20.1 Detailed Description

A test file.

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Date

2014

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Definition in file [simulate\\_dos.cc](#).

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