2deg_QH_SC

Release 3.0

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CONTENTS

Documentation of the code used in the paper "Geometrical effects on the downstream conductance in quantum-Hall–superconductor hybrid systems" available on arXiv and published in Phys. Rev. B. The code is available in a Github Repository.

Check the *Installation and Usage* section to install and use the code. The *Main Scripts* section includes the script *calculations.py* which can be used to run the different calculations and the script *manuscript_figures.py* that generates the manuscript figures. The *Modules* section describes the different modules used to run the calculations.

CHAPTER

ONE

INSTALLATION AND USAGE

Here we explain how to run the scripts. After following the steps below try to run some calculations with the script *calculations.py* or reproduce the manuscript figures with the script *manuscript_figures.py*.

1.1 Miniconda, GitHub repository and conda environment

Install miniconda , clone the repository and `cd` into the root directory *2deg_QH-SC-main* after unzipping. Then create the Conda environment that contains all dependencies with

```
conda env create -f environment.yml
```

You can now use this environment to run the scripts. Below is detailed how to run the scripts using the command line, Pycharm or Visual Studio Code.

1.2 Running the scripts by using the command line

To run a script from the terminal use the following command line:

```
<path_to_python_exe> <path_to_python_script>
```

The python executable should be located at :

~/opt/miniconda3/envs/2deg_QH-SC/bin/python (macOS)

~/miniconda3/envs/2deg_QH-SC/bin/python (Linux)

~/miniconda3/envs/2deg_QH-SC/python (Windows)

For example, if you are on macOS and you want to run the script *calculations.py* (while being in the root directory of the repo), use

```
~/opt/miniconda3/envs/2deg_QH-SC/bin/python calculations.py
```

Note: You can use a global shell variable to create a shortcut to the Python executable path. For that, open a terminal and modify the bash configuration file located in your HOME directory (the directory in which you are when you open the terminal) (.bashrc, .bash_profile, or .profile). For example on macOS

```
nano .bash_profile
```

Add the following in the file

```
export mypython=~/opt/miniconda3/envs/2deg_QH-SC/bin/python
```

and save it with `Ctrl+X` and `Y` and `Enter`. Then close the terminal and open a new one to make the modification effective. You can now use the variable `$mypython` for the path such that the above example reads

```
$mypython calculations.py
```

1.3 Running the scripts by using PyCharm

With PyCharm you can follow these steps :

1. Launch PyCharm and choose `Create New Project`
2. **Locate the project** at the root directory *2deg_QH-SC-main*.
3. Mark `Existing interpreter` (or `Previously configured interpreter`) and click on the selection icon `...`
4. Select `Conda Environment` and choose the location of the python executable. It should be located at :

   ~/opt/miniconda3/envs/2deg_QH-SC/bin/python (macOS)

   ~/miniconda3/envs/2deg_QH-SC/bin/python (Linux)

   ~/miniconda3/envs/2deg_QH-SC/python (Windows)
5. Click on `Ok` then on `Create` and select `Create from existing sources`
6. You are ready to run the scripts!
7. (Optional) You can see progress bars during the calculations by activating the `Emulate terminal in output console` option. For that, got to `Run->Edit Configurations` and check the option.

1.4 Running the scripts by using Visual Studio Code

With Visual Studio Code you can follow these steps :

1. Launch Visual Studio Code and install the *Python* extension if it's not done yet.
2. From the main page choose `Open...` , select the root directory *2deg_QH-SC-main*, and click on `Yes, I trust the authors`
3. Open the *Command Palette* with `Ctrl+Shift+P`, search `Python: Select Interpreter` and choose the one associated to the '2deg_QH-SC' environment.
4. You are ready to run the scripts!

1.5 Updating the documentation

The *documentation* directory contains a `pdf` and a local `html` version of the documentation. They can respectively be found at *documentation/build/latex/2deg_qh-sc.pdf* and *documentation/build/html/index.html*. You can update them by using

```
conda activate 2deg_QH-SC
cd documentation
make html
make latexpdf
```

Note: When you compile the documentation it runs the python scripts so make sure the calculations are commented before using `make html` or `make latexpdf`.

CHAPTER

TWO

MAIN SCRIPTS

The scripts present in the *main_code* directory are described in this section.

2.1 calculations.py

Calculations.

This script contains different sections, each of which generates the data and the plot of a calculation. Comment the quotation marks by using hashtags to run the calculations.

Contents:

- Visualization
  - Kwant system
  - Density u^2 - v^2
- Energy Spectrum
  - Tight-binding spectrum
  - Microscopic spectrum
  - Spectrum comparison
- Momentum at the Fermi level k0
  - k0 *v.s.* nu
  - k0 *v.s.* Z at various fillings
- Andreev Transmission and Hole Probability
  - tau *v.s.* theta_qh at various fillings
  - tau *v.s.* theta_sc at various fillings
  - tau *v.s.* mu_qh/Delta at various fillings
  - fh_p *v.s.* Z at various fillings
- Downstream conductance
  - Conductance comparison
- Track states
  - nu_crit *v.s.* mu_qh/delta
  - Asymptotic nu_crit *v.s.* mu_sc/mu_qh

  - Asymptotic nu_crit *v.s.* Z
- Finite-temperature
  - Momentum difference *v.s.* energy
  - tau *v.s.* energy
  - Finite-temperature tight-binding conductance *v.s.* L
  - Finite-temperature tight-binding conductance *v.s.* L at various temperatures

The resulting data and plots are saved in the ‘files‘ directory.

2.2 manuscript_figures.py

This script generates the figures as used in the manuscript.

To re-compute the data use the option from_data=False in the plot functions. Due to the option fig_name the plots are saved in the ‘figures‘ directory.

CHAPTER

THREE

MODULES

The different modules are described in this section.

3.1 functions.py

Definition of the functions required for the calculations.

modules.functions.**U**(*n*, *z*)

Definition of the parabolic cylinder function U(n, z) as defined in Abramowitz & Stegun book.

Parameters

- **n** (*float*) – First argument of the parabolic cylinder function.
- **z** (*float*) – Second argument of the parabolic cylinder function.

Returns The value of the parabolic cylinder function U(n, z).

Return type float

modules.functions.**U_m**(*x*, *E*, *k*, *m_qh*, *mu_qh*, *omega*)

Hole-like solution in QH region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_qh** (*float*) – Effective mass in the QH region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **omega** (*float*) – Cyclotron frequency.

Returns The value of the parabolic cylinder function associated to holes.

Return type float

modules.functions.**U_p**(*x*, *E*, *k*, *m_qh*, *mu_qh*, *omega*)

Electron-like solution in QH region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.

- **k** (*float*) – Momentum along the QH-SC interface.
- **m_qh** (*float*) – Effective mass in the QH region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **omega** (*float*) – Cyclotron frequency.

Returns The value of the parabolic cylinder function associated to electrons.

Return type float

modules.functions.**chi_m**(*x*, *E*, *k*, *m_qh*, *mu_qh*, *nu*)

Hole-like wave function in QH region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_qh** (*float*) – Effective mass in the QH region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **nu** (*float*) – Filling factor.

Returns The value of hole-like wave function in QH region.

Return type float

modules.functions.**chi_p**(*x*, *E*, *k*, *m_qh*, *mu_qh*, *nu*)

Electron-like wave function in QH region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_qh** (*float*) – Effective mass in the QH region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **nu** (*float*) – Filling factor.

Returns The value of electron-like wave function in QH region.

Return type float

modules.functions.**effective_tau**(*tau_0*, *L_b*, *v_b*, *mu_b*, *delta_b*, *phi_b*)

Compute the effective conversion probability at a QH-SS corner.

The value tau_0 is the one obtained from the microscopic model while the parameters labelled with '_b' correspond to the effective barrier.

Parameters

- **tau_0** (*str*) – Hole probability computed with the microscopic model.
- **L_b** (*str*) – Length of the barrier.
- **v_b** (*str*) – Velocity in the barrier.
- **mu_b** (*str*) – Chemical potential in the barrier.

- **delta_b** (*str*) – Superconducting gap of the barrier.
- **phi_b** (*str*) – Superconducting phase of the barrier.

modules.functions.**fermi_momenta**(*m_qh*, *m_sc*, *mu_qh*, *mu_sc*, *nu*, *delta*, *V_barrier*)

Positive momentum solutions of the secular equation f(E, k) = 0 at the Fermi level (i.e. at E = 0).

Parameters

- **m_qh** (*float*) – Effective mass in the QH region.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **nu** (*float*) – Filling factor.
- **delta** (*float*) – Superconducting gap.
- **V_barrier** (*float*) – Height of the delta-potential barrier.

Returns The positive solutions of the equation f(E=0, k) = 0.

Return type list

modules.functions.**hole_probability**(*m_qh*, *m_sc*, *mu_qh*, *mu_sc*, *nu*, *delta*, *V_barrier*)

Compute the hole content f_h^+ at the quasi-electron crossing, i.e., at k = -k0.

Parameters

- **m_qh** (*float*) – Effective mass in the QH region.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **nu** (*float*) – Filling factor.
- **delta** (*float*) – Superconducting gap.
- **V_barrier** (*float*) – Height of the delta-potential barrier.

Returns Hole probability at the quasi-electron crossing.

Return type float

modules.functions.**hopping**(*site1*, *site2*, *a*, *t*, *mu_qh*, *nu*)

Define hopping energies in QH and SC regions.

Parameters

- **site1** – Kwant site.
- **site2** – Kwant site.
- **a** (*float*) – Lattice spacing.
- **t** (*float*) – Hopping energy at zero field.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **nu** (*float*) – Filling factor.

Returns Hopping energy.

Return type float

modules.functions.**hopping_qh**(*site1*, *site2*, *a*, *t*, *mu_qh*, *nu*)

Define hopping energy in QH region.

Parameters

- **site1** – Kwant site.
- **site2** – Kwant site.
- **a** (*float*) – Lattice spacing.
- **t** (*float*) – Hopping energy at zero field.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **nu** (*float*) – Filling factor.

Returns Hopping energy.

Return type float

modules.functions.**hopping_sc**(*site1*, *site2*, *t*)

Define hopping energy in SC region.

Parameters

- **site1** – Kwant site.
- **site2** – Kwant site.
- **t** (*float*) – Hopping energy at zero field.

Returns Hopping energy.

Return type float

modules.functions.**kronecker_delta**(*x*)

Kronecker delta function.

Parameters **x** (*float*) – x-coordinate.

Returns

1. if x=0 and 0. otherwise.

Return type float

modules.functions.**onsite**(*site*, *a*, *t*, *mu_qh*, *mu_sc*, *delta*, *Z*)

Define onsite energies in QH and SC regions including a delta-potential barrier.

Parameters

- **site** – Kwant site.
- **a** (*float*) – Lattice spacing.
- **t** (*float*) – Hopping energy at zero field.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **delta** (*float*) – Superconducting gap.
- **Z** (*float*) – Barrier strength.

Returns Onsite energy.

Return type float

modules.functions.**onsite_qh**(*site*, *t*, *mu_qh*)

Define onsite energy in QH region.

Parameters

- **site** – Kwant site.
- **t** (*float*) – Hopping energy at zero field.
- **mu_qh** (*float*) – Chemical potential in the QH region.

Returns Onsite energy.

Return type float

modules.functions.**onsite_sc**(*site*, *t*, *mu_sc*, *delta*)

Define onsite energy in SC region.

Parameters

- **site** – Kwant site.
- **t** (*float*) – Hopping energy at zero field.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **delta** (*float*) – Superconducting gap.

Returns Onsite energy.

Return type float

modules.functions.**phi_m**(*x*, *E*, *k*, *m_sc*, *mu_sc*, *delta*)

Hole-like wave function in SC region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **delta** (*float*) – Superconducting gap.

Returns The value of hole-like wave function in SC region.

Return type float

modules.functions.**phi_p**(*x*, *E*, *k*, *m_sc*, *mu_sc*, *delta*)

Electron-like wave function in SC region.

Parameters

- **x** (*float*) – x-coordinate.
- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **delta** (*float*) – Superconducting gap.

Returns The value of electron-like wave function in SC region.

Return type float

modules.functions.**secular_equation**(*k*, *E*, *m_qh*, *m_sc*, *mu_qh*, *mu_sc*, *omega*, *delta*, *V_barrier*)

Value of f(k, E) used to compute the energy spectrum of the CAES and the Fermi momenta by solving the secular equation f(k, E) = 0.

Parameters

- **E** (*float*) – Energy measured from the Fermi level.
- **k** (*float*) – Momentum along the QH-SC interface.
- **m_qh** (*float*) – Effective mass in the QH region.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **omega** (*float*) – Cyclotron frequency.
- **delta** (*float*) – Superconducting gap.
- **V_barrier** (*float*) – Height of the delta-potential barrier.

Returns The value of f(k, E).

Return type float

modules.functions.**velocity**(*m_qh*, *m_sc*, *mu_qh*, *mu_sc*, *nu*, *delta*, *V_barrier*)

Compute the velocity of the CAES.

Parameters

- **m_qh** (*float*) – Effective mass in the QH region.
- **m_sc** (*float*) – Effective mass in the SC region.
- **mu_qh** (*float*) – Chemical potential in the QH region.
- **mu_sc** (*float*) – Chemical potential in the SC region.
- **nu** (*float*) – Filling factor.
- **delta** (*float*) – Superconducting gap.
- **V_barrier** (*float*) – Height of the delta-potential barrier.

Returns The value of the velocity.

Return type float

3.2 system.py

Classes constructing different Kwant's systems.

class modules.system.**Device**(*theta_1*, *theta_2*, *params*)

Construct a QH-SC junction with arbitrary QH angles and a rectangle-shaped SC.

Parameters

- **theta_1** (*float*) – First QH angle (in degrees).

- **theta_2** (*float*) – Second QH angle (in degrees).
- **params** (*dict*) – System's parameters.

make_system(*onsite*, *hopping*)

Make the (unfinalized) system.

Parameters

- **onsite** (*fun*) – Onsite energy function.
- **hopping** (*fun*) – Hopping energy function.

Returns Unfinalized Kwant system.

class modules.system.**DeviceInfinite**(*params*)

Construct a an infinite QH-SC interface (lead).

Parameters **params** (*dict*) – System's parameters.

make_system(*onsite*, *hopping*)

Make the (unfinalized) lead.

Parameters

- **onsite** (*fun*) – Onsite energy function.
- **hopping** (*fun*) – Hopping energy function.

Returns Unfinalized Kwant lead.

class modules.system.**DeviceSingleCorner**(*theta_qh*, *theta_sc*, *params*, *small=False*)

Construct a semi-infinite junction with a single corner.

Parameters

- **theta_qh** (*float*) – QH angle (in degrees).
- **theta_sc** (*str*) – SC angle (in degrees).
- **params** (*dict*) – System's parameters.
- **small** (*bool*) – Must be set to True when small dimensions are used, default to False.

make_system(*onsite*, *onsite_qh*, *onsite_sc*, *hopping*, *hopping_qh*, *hopping_sc*)

Make the (unfinalized) system.

Parameters

- **onsite** (*fun*) – Onsite energy function.
- **onsite_qh** (*fun*) – Onsite energy function in QH region.
- **onsite_sc** (*fun*) – Onsite energy function in SC region.
- **hopping** (*fun*) – Hopping energy function.
- **hopping_qh** (*fun*) – Hopping energy function in QH region.
- **hopping_sc** (*fun*) – Hopping energy function in SC region.

Returns Unfinalized Kwant system.

3.3 utils.py

Definitions of the functions used in *calculations.py*.

modules.utils.**compute_corner_transmissions**(*device*, *energy=0.0*)

Compute the corner transmission amplitudes with Kwant.

Parameters

- **device** (*object*) – The QH-SC corner.
- **energy** (*float*) – Value of the energy, default to 0.

Returns The normal and Andreev amplitudes : t_ee, t_he.

Return type list

modules.utils.**compute_delta_b_and_phi_b**(*device*, *L_b*, *v_b*, *mu_b*)

Compute the effective barrier parameters delta_b and phi_b.

Here have to give L_b, v_b, and mu_b as inputs.

Parameters

- **device** (*object*) – The QH-SC junction.
- **L_b** (*str*) – Length of the barrier.
- **v_b** (*str*) – Velocity in the barrier.
- **mu_b** (*str*) – Chemical potential in the barrier.

Returns The values of delta_b and phi_b.

Return type array

modules.utils.**compute_downstream_conductance_TB**(*device*)

Compute the (zero-temperature) downstream conductance with Kwant.

Parameters **device** (*object*) – The QH-SC junction.

Returns The value of the downstream conductance.

Return type float

modules.utils.**compute_momentum_difference**(*params*, *E*)

Compute the momentum difference dk.

Parameters

- **params** (*dict*) – The system's parameters.
- **E** (*float*) – The energy value.

Returns The value of dk.

Return type float

modules.utils.**compute_nu_crit**(*params*, *nu_min=1.0*, *nu_max=3.0*, *tol=1e-06*)

Compute the value of nu_crit.

Parameters

- **params** (*dict*) – The system's parameters.
- **nu_min** (*float*) – Lower bound, defaults to 1.

- **nu_max** (*float*) – Higher bound, defaults to 3.
- **tol** (*float*) – Precision of the returned value, defaults to 1E-6.

Returns The value of nu_crit.

Return type float

modules.utils.**plot_density**(*device*, *energy=0.0*, *fig_name=False*)

Plot the probability density $|u|^2 - |v|^2$ of the incoming electron.

Parameters

- **device** (*object*) – The device.
- **energy** (*float*) – Value of the energy (relative to the CAES Fermi level), default to 0.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_device**(*device*)

Plot the Kwant system.

Be carefull, the colors are badly defined for negative angles.

Parameters **device** (*object*) – The device.

modules.utils.**plot_downstream_conductance_comparison**(*Ls*, *device*, *device_1*, *device_2*, *L_b*, *v_b*, *mu_b*, *fig_name=False*, *from_data=True*)

Comparison between analytical and tight-binding conductance.

The analytical formula is shifted in order to recover the tight-binding simulation at large L. We we need to give L_b, v_b, and mu_b as inputs.

The shifted data and the plot are saved in the directory 'files/downstream_conductance/comparison'.

Parameters

- **Ls** (*list*) – The values of the interface's length.
- **device** (*object*) – The QH-SC junction.
- **device_1** (*object*) – The first QH-SC corner.
- **device_2** (*object*) – The second QH-SC corner.
- **L_b** (*str*) – Length of the barrier.
- **v_b** (*str*) – Velocity in the barrier.
- **mu_b** (*str*) – Chemical potential in the barrier.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **from_data** (*bool*) – If True the spectrum is plotted using existing data. If False the data are computed even if they exist.

modules.utils.**plot_fh_p_vs_Z_various_fillings**(*nus*, *Zs*, *params*, *fig_name=False*)

Plot the hole content f_h^+ vs Z for various values of the filling factor.

The plot is saved in the directory 'files/andreev_and_hole_prob/hole_probability/varying_Z/plots'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **Zs** (*list*) – The values of the barrier strength.
- **params** (*dict*) – The system's parameters.

- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_finite_T_conductance_TB_vs_L_various_temps**(*device*, *kTs*, *Ls*, *from_data=True*, *fig_name=False*)

Plot the finite-temperature downstream conductance versus the energy for various temperatures.

Here we use a full tight-binding calculation and we compare with the zero-temperature result.

The data and the plot are saved in the directory 'files/finite_temperature/downstream_conductance/varying_L/tight_binding'.

Parameters

- **device** (*object*) – The QH-SC junction.
- **kTs** (*list*) – The values of kB*T.
- **Ls** (*list*) – The values of the interface's length.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_k0_vs_Z_various_fillings**(*nus*, *Zs*, *params*, *fig_name=False*)

Plot the momentum k0 versus Z for various values of the filling factor.

The plot is saved in the directory 'files/momentum_k0/varying_Z/plots'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **Zs** (*list*) – The values of the barrier strength.
- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_k0_vs_nu**(*nus*, *params*, *fig_name=False*)

Plot the momentum at the Fermi level k0 versus nu.

The plot is saved in the directory 'files/momentum_k0/varying_nu/plots'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_momentum_difference_vs_energy**(*params*, *fig_name=False*)

Plot momentum difference *v.s.* energy.

The resulting plot is saved in the 'files/finite_temperature/momentum_difference/varying_energy' directory.

Parameters

- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_nu_crit_limit_vs_Z**(*params*, *from_data=True*, *fig_name=False*)

Plot the asymptotic value of nu_crit *v.s.* Z.

The resulting plot is saved in the 'files/track_states/varying_Z' directory.

Parameters

- **params** (*dict*) – The system's parameters.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist. Defaults to True.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_nu_crit_limit_vs_mismatch**(*params*, *from_data=True*, *fig_name=False*)

Plot the asymptotic value of nu_crit *v.s.* mu_sc/mu_qh.

The resulting plot is saved in the 'files/track_states/varying_mismatch' directory.

Parameters

- **params** (*dict*) – The system's parameters.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist. Defaults to True.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_nu_crit_vs_mu_qh_delta**(*params*, *from_data=True*, *fig_name=False*)

Plot nu_crit *v.s.* mu_qh/delta.

The resulting plot is saved in the 'files/track_states/varying_mu_qh_delta' directory.

Parameters

- **params** (*dict*) – The system's parameters.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist. Defaults to True.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_spectrum_TB**(*device*, *from_data=True*)

Plot tight-binding spectrum.

The data and plots are saved in the directory 'files/energy_spectrum/tight_binding'.

Parameters

- **device** (*object*) – Infinite QH-SC interface.
- **from_data** (*bool*) – If true the spectrum is plotted using the existing data. If False the data are computed even if they exist.

modules.utils.**plot_spectrum_comparison**(*device*, *params*, *fig_name=False*, *from_data=True*)

Comparison between microscopic and tight-binding spectrums.

The plots are saved in the directory 'files/energy_spectrum/comparison/plots'.

Parameters

- **device** (*object*) – Infinite QH-SC interface.
- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **from_data** (*bool*) – If true the spectrum is plotted using the existing data. If False the data are computed even if they exist.

modules.utils.**plot_spectrum_micro**(*params*, *from_data=True*, *fig_name=False*, *show_k0=False*, *qp_labels=False*)

Plot microscopic spectrum.

The data and plots are saved in the directory 'files/energy_spectrum/microscopic'.

Parameters

- **params** (*dict*) – The system's parameters.
- **from_data** (*bool*) – If true the spectrum is plotted using the existing data. If False the data are computed even if they exist.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **show_k0** (*str*) – Show the position of k0, default to False.
- **qp_labels** (*str*) – Show the quasiparticles labels, default to False.

modules.utils.**plot_tau_vs_energy**(*device*, *fig_name=False*, *from_data=True*, *tau_label=None*)

Plot the conversion probabilty tau vs energy.

The data and the plot are saved in the directory 'files/finite_temperature/scattering_probabilities/transmissions/'.

Parameters

- **device** (*object*) – The QH-SC junction.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist. Defaults to True.
- **tau_label** (*int*) – None, 1 or 2. Defaults to None.

modules.utils.**plot_tau_vs_mu_qh_delta_various_fillings**(*nus*, *deltas*, *theta_qh*, *theta_sc*, *params*, *from_data=True*, *fig_name=False*)

Plot the corner's Andreev transmission versus mu_{QH}/Delta for various values of the filling factor.

The data and plot are saved in the directory 'files/chapter3/andreev_transmission/varying_mu_qh_delta'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **deltas** (*list*) – The values of the SC gap.
- **theta_qh** (*float*) – The QH angle.
- **theta_sc** (*float*) – The SC angle.
- **params** (*dict*) – The system's parameters.
- **from_data** (*bool*) – If True the spectrum is plotted using the existing data. If False the data are computed even if they exist.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.

modules.utils.**plot_tau_vs_theta_qh_various_fillings**(*nus*, *thetas*, *device*, *fig_name=False*, *from_data=True*, *show_only_commensurate=False*)

Plot the corner's Andreev transmission versus the QH angle for various values of the filling factor.

The data and the plot are saved in the directory 'files/andreev_and_hole_prob/andreev_transmission/varying_theta'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **thetas** (*list*) – The values of the QH angle.
- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **from_data** (*bool*) – If True the spectrum is plotted using the stored data. If False the data are computed even if they exist.
- **show_only_commensurate** (*bool*) – If True only the commensurate angles are shown. Defaults to False.

modules.utils.**plot_tau_vs_theta_sc_various_fillings**(*nus*, *thetas*, *device*, *fig_name=False*, *from_data=True*, *show_only_commensurate=False*)

Plot the corner's Andreev transmission versus the SC angle for various values of the filling factor.

The data and the plot are saved in the directory 'files/andreev_and_hole_prob/andreev_transmission/varying_theta_sc'.

Parameters

- **nus** (*list*) – The values of the filling factor.
- **thetas** (*list*) – The values of the SC angle.
- **params** (*dict*) – The system's parameters.
- **fig_name** (*str*) – The name of the plot used for the manuscript, optional.
- **from_data** (*bool*) – If True the spectrum is plotted using the stored data. If False the data are computed even if they exist.
- **show_only_commensurate** (*bool*) – If True only the commensurate angles are shown. Defaults to False.

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