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# **nucleardatapy**

***Release 0.1***

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**nucleardatapy** (/in short nuda/) is a Python library for nuclear physicists facilitating the access to theoretical or experimental nuclear data. It is specifically designed for equation of state practitioners interested in the modeling of neutron stars, and it offers *simple* and *intuitive* APIs.

All data are provided with their reference, so when using these data in a scientific paper, reference to data should be provided explicitly. The reference to this toolkit could be given, but it should not mask the reference to data.

This python toolkit is designed to provide: 1) microscopic calculations in nuclear matter, 2) phenomenological predictions in nuclear matter, 3) experimental data for finite nuclei.

Check out the [Usage](#) section for further information, including how to [install](#) the project.

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**Note:** This project is under active development.

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## CONTENTS

## 1.1 Usage

### 1.1.1 Installation

To use nucleardatapy, first download the .zip file from the git repository, or clone it in your local computer:

```
$ git clone https://github.com/jeromemargueron/nucleardatapy
```

If you have downloaded the .zip file, you can unzip it anywhere in your local computer:

```
$ unzip nucleardatapy.zip
```

Then, in all cases, you shall enter into the new folder */nucleardatapy*:

```
$ cd nucleardatapy
```

and launch the install script:

```
$ bash install.sh
```

This will copy the Python toolkit into `$HOME/mylib/` as well as a few samples. It will also give you the content of the global variable `NUCLEARDATAPY_TK`. If you edit `install.sh`, you can change the version (by default it is set to the latest one) as well as the destination folder (by default it is `$HOME/mylib`).

Finally, you will have to create the global variable `NUCLEARDATAPY_TK` with its right content. If you do not want to create it each time you open a new terminal, then you can define it in your `.profile` or `.zprofil` or `.bash` file as:

```
export NUCLEARDATAPY_TK=$HOME/mylib/nucleardatapy
```

---

**Note:** The exact path to write above is given at the end of the installation.

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### 1.1.2 Use nucleardatapy

Go to the folder *mylib/nucleardatapy/samples/nucleardatapy\_samples/* and try that:

```
$ python3 sample_SetupMicro.py
```

### 1.1.3 Test nucleardatapy

A set of tests can be easily performed. They are stored in *tests/* folder.

```
$ bash run_tests.sh
```

### 1.1.4 Get started

How to obtain microscopic results for APR equation of state:

```
import os
nucleardatapy_tk = os.getenv('NUCLEARDATAPY_TK')
sys.path.insert(0, nucleardatapy_tk)

import nucleardatapy as nuda

mic = nuda.SetupMicro( model = '1998-AM-APR' )

mic.print_outputs( )
```

## 1.2 API

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*nucleardatapy*

This module provides microscopic, phenomenological and experimental data constraints.

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### 1.2.1 nucleardatapy

This module provides microscopic, phenomenological and experimental data constraints.

## 1.3 Miscellaneous

### 1.3.1 Contributing

For the moment, contributions are based on co-optation among the team.

To make contribution easy, we all work in the *main* branch and we shall therefore remember to pull before working and pulling after, with a running version. For long developments, you can work in a local folder (in *mylib* for instance) and copy your contribution to the GitHub folder once you are sure it is functioning. So the final step should last less than 5 minutes, and can be safely done between a pull and before a push. Since we are not numerous, we hope that no one



will work in the same part of the code at the same time (i.e. between a pull and a push). It is probably the simpler way to proceed.

Once the toolkit is released, the rules to contribute will be changing. A team of developpers should be defined and a generic email to contact them should be created. Here is a suggestion to contribute after the release.

This file describes how new contributors to the project can start contributing.

**Two ways:**

You can provide your data and interacting with one of our developer.

You can also join the developing team and extend the functionality of this toolkit.

**Provide your data:**

Please contact the developer team directly by shooting an email to TBC.

Then you can interact directly with one of our developer and provide your data. You will not be able to push your data to the repository, but an updated version of the toolkit will contain your new data.

**Join the team:**

Please contact the developer team directly by shooting an email to TBC. Explain the reason why you wish to join the team and if you have ideas about extending the functionality of the toolkit.

Once in the team, a branch will be dedicated to your contribution. You could show it during our virtual meetings, and your contribution will be merged to the new version of the toolkit.

### **1.3.2 License**

TBC.

### **1.3.3 Report issues**

For the current version, we report issues chatting among us. Once this toolkit is released, we should setup a way that users could contact us and report issues or difficulties in installing or using the toolkit.

### **1.3.4 Thanks**

A special thanks to all contributors who accepted to share their results in this toolkit.



## COMPLEMENT

### 2.1 SetupMicro

**class** nucleardatapy.setup\_micro.**SetupMicro**(*model*='1998-VAR-AM-APR')

Instantiate the object with microscopic results choosen by the toolkit practitioner.

This choice is defined in *model*, which can chosen among the following choices: '1981-VAR-AM-FP', '1998-VAR-AM-APR', '2006-BHF-AM\*', '2008-BCS-NM', '2008-AFDMC-NM', '2008-QMC-NM-swave', '2010-QMC-NM-AV4', '2009-DLQMC-NM', '2010-MBPT-NM', '2012-AFDMC-NM-1', '2012-AFDMC-NM-2', '2012-AFDMC-NM-3', '2012-AFDMC-NM-4', '2012-AFDMC-NM-5', '2012-AFDMC-NM-6', '2012-AFDMC-NM-7', '2013-QMC-NM', '2014-AFQMC-NM', '2016-QMC-NM', '2016-MBPT-AM', '2018-QMC-NM', '2019-MBPT-AM-L59', '2019-MBPT-AM-L69', '2020-MBPT-AM', '2024-NLEFT-AM', '2024-BHF-AM-2BF-Av8p', '2024-BHF-AM-2BF-Av18', '2024-BHF-AM-2BF-BONN', '2024-BHF-AM-2BF-CDBONN', '2024-BHF-AM-2BF-NSC97a', '2024-BHF-AM-2BF-NSC97b', '2024-BHF-AM-2BF-NSC97c', '2024-BHF-AM-2BF-NSC97d', '2024-BHF-AM-2BF-NSC97e', '2024-BHF-AM-2BF-NSC97f', '2024-BHF-AM-2BF-SSCV14', '2024-BHF-AM-23BF-Av8p', '2024-BHF-AM-23BF-Av18', '2024-BHF-AM-23BF-BONN', '2024-BHF-AM-23BF-CDBONN', '2024-BHF-AM-23BF-NSC97a', '2024-BHF-AM-23BF-NSC97b', '2024-BHF-AM-23BF-NSC97c', '2024-BHF-AM-23BF-NSC97d', '2024-BHF-AM-23BF-NSC97e', '2024-BHF-AM-23BF-NSC97f', '2024-BHF-AM-23BF-SSCV14'

#### Parameters

**model** (*str*, *optional*.) – Fix the name of model. Default value: '1998-VAR-AM-APR'.

#### Attributes:

##### **init\_self()**

Initialize variables in self.

##### **model**

Attribute model.

##### **print\_outputs()**

Method which print outputs on terminal's screen.

**nucleardatapy.setup\_micro.models\_micro()**

Return a list with the name of the models available in this toolkit and print them all on the prompt. These models are the following ones: '1981-VAR-AM-FP', '1998-VAR-AM-APR', '2006-BHF-AM\*', '2008-BCS-NM', '2008-AFDMC-NM', '2012-AFDMC-NM-1', '2012-AFDMC-NM-2', '2012-AFDMC-NM-3', '2012-AFDMC-NM-4', '2012-AFDMC-NM-5', '2012-AFDMC-NM-6', '2012-AFDMC-NM-7', '2008-QMC-NM-swave', '2010-QMC-NM-AV4', '2009-DLQMC-NM', '2010-MBPT-NM', '2013-QMC-NM', '2014-AFQMC-NM', '2016-QMC-NM', '2016-MBPT-AM', '2018-QMC-NM', '2019-MBPT-AM-L59', '2019-MBPT-AM-L69', '2020-MBPT-AM', '2024-NLEFT-AM', '2024-BHF-AM-2BF-Av8p',

```

'2024-BHF-AM-2BF-Av18', '2024-BHF-AM-2BF-BONN', '2024-BHF-AM-2BF-CDBONN', '2024-BHF-AM-2BF-NSC97a',
'2024-BHF-AM-2BF-NSC97b', '2024-BHF-AM-2BF-NSC97c', '2024-BHF-AM-2BF-NSC97d', '2024-BHF-AM-2BF-NSC97e',
'2024-BHF-AM-2BF-NSC97f', '2024-BHF-AM-2BF-SSCV14', '2024-BHF-AM-23BF-Av8p', '2024-BHF-AM-23BF-Av18',
'2024-BHF-AM-23BF-BONN', '2024-BHF-AM-23BF-CDBONN', '2024-BHF-AM-23BF-NSC97a', '2024-BHF-AM-23BF-NSC97b',
'2024-BHF-AM-23BF-NSC97c', '2024-BHF-AM-23BF-NSC97d', '2024-BHF-AM-23BF-NSC97e', '2024-BHF-AM-23BF-NSC97f',
'2024-BHF-AM-23BF-SSCV14', '2024-BHF-AM-23BFmicro-Av18', '2024-BHF-AM-23BFmicro-BONNB',
'2024-BHF-AM-23BFmicro-NSC93' :return: The list of models. :rtype: list[str].

```

Here are a set of figures which are produced with the Python sample: `/sample/nucleardatapy_plots/plot_setupMicro.py`

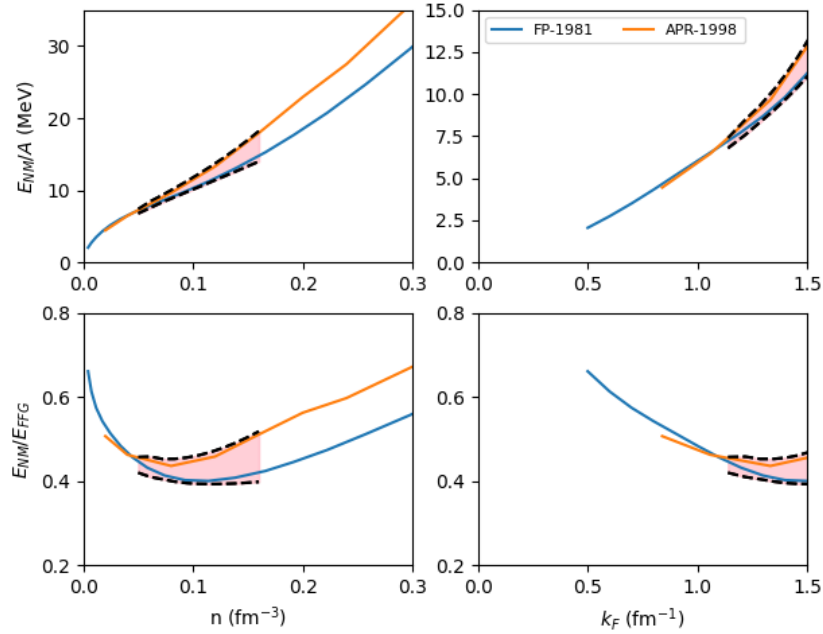


Fig. 1: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the variational models available in the nucleardatapy toolkit.

## 2.2 SetupMicroBand

```

class nucleardatapy.setup_micro_band.SetupMicroBand(models=['2016-MBPT-AM'], nden=10, ne=200,
                                                    den=None, matter='NM', e2a_min=- 20.0,
                                                    e2a_max=50.0)

```

Instantiate the object with statistical distributions averaging over the models given as inputs and in NM.

### Parameters

- **models** (*list.*) – The models given as inputs.
- **nden** (*int, optional.*) – number of density points.
- **ne** (*int, optional.*) – number of points along the energy axis.
- **den** (*None or numpy array, optional.*) – if not None (default), impose the densities.
- **matter** (*str, optional.*) – can be 'NM' (default), 'SM' or 'ESYM'.

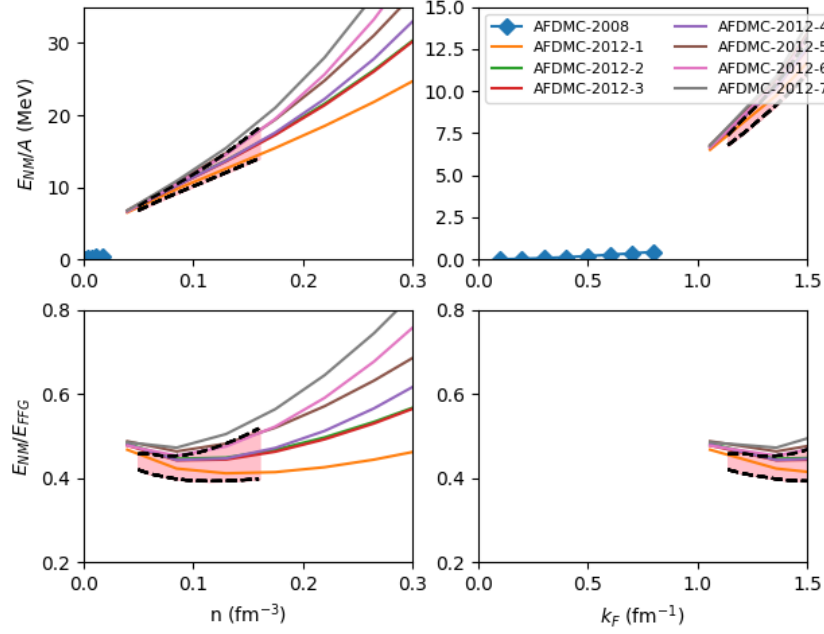


Fig. 2: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the AFDMC models available in the nucleardatapy toolkit.

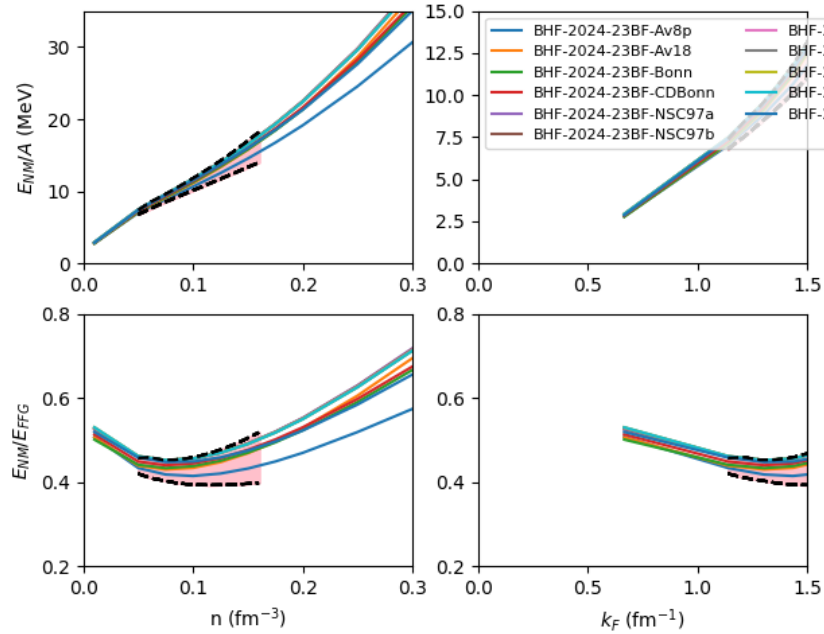


Fig. 3: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the BHF models available in the nucleardatapy toolkit.

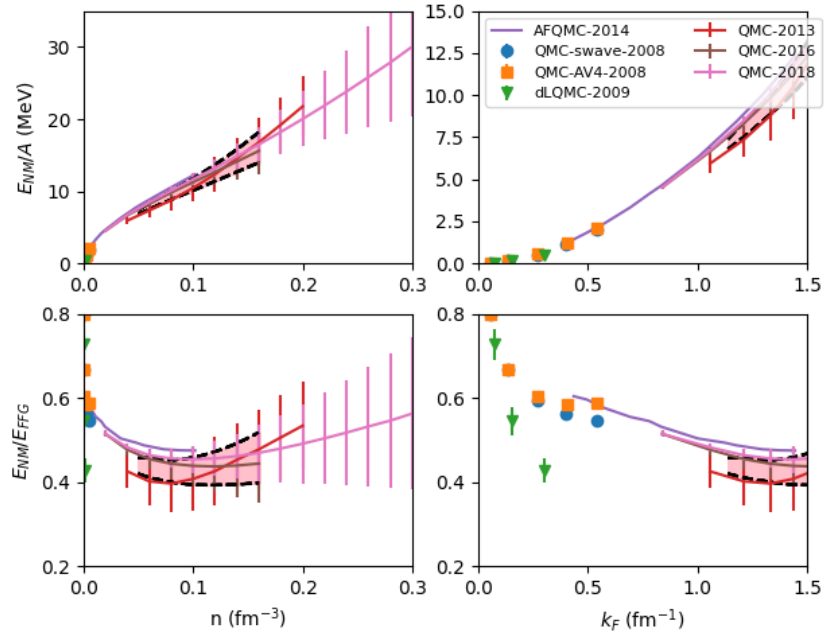


Fig. 4: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the QMC models available in the nucleardatapy toolkit.

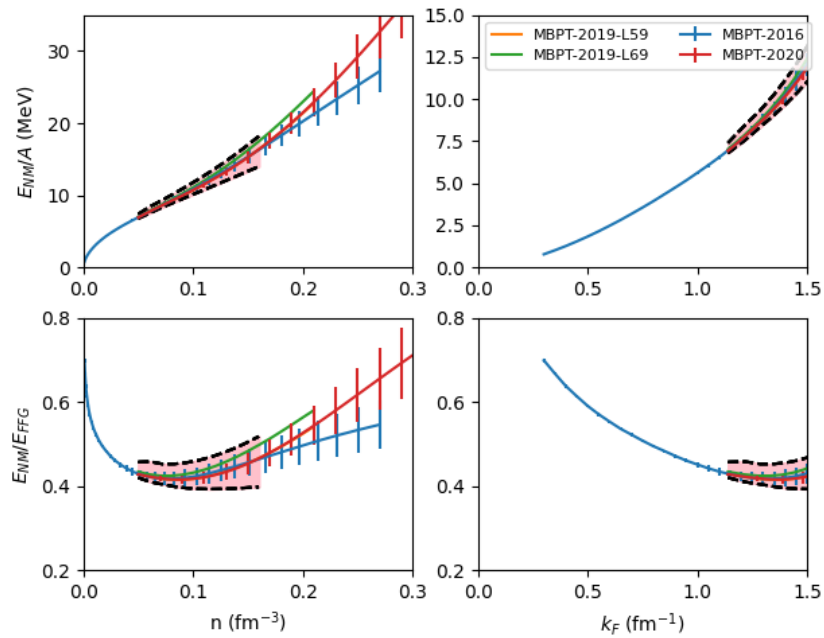


Fig. 5: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the MBPT models available in the nucleardatapy toolkit.

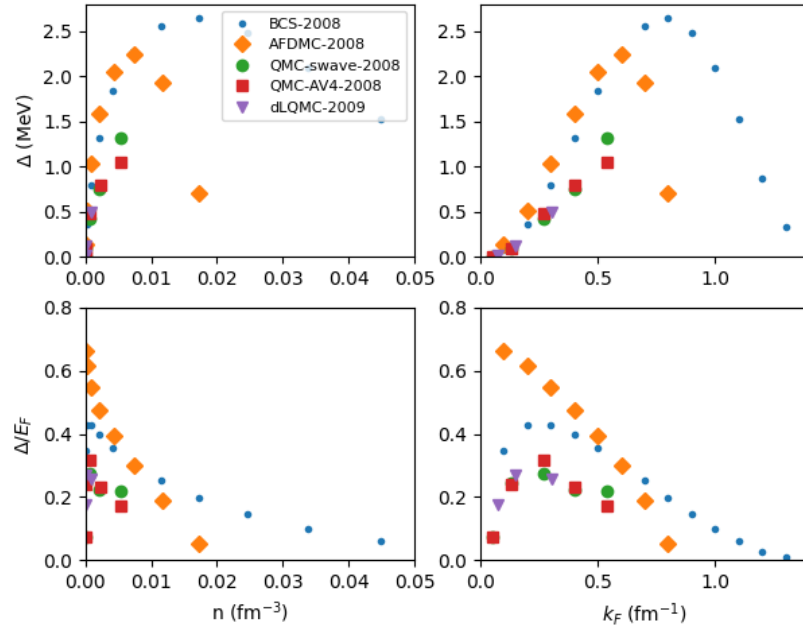


Fig. 6: This figure shows the pairing gap in neutron matter (NM) over the Fermi energy (top) and the pairing gap (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the models available in the nucleardatapy toolkit.

#### Attributes:

##### **den**

Attribute a set of density points.

##### **init\_self()**

Initialize variables in self.

##### **matter**

Attribute matter str.

##### **models**

Attribute model.

##### **nden**

Attribute number of points in density.

##### **print\_outputs()**

Method which print outputs on terminal's screen.

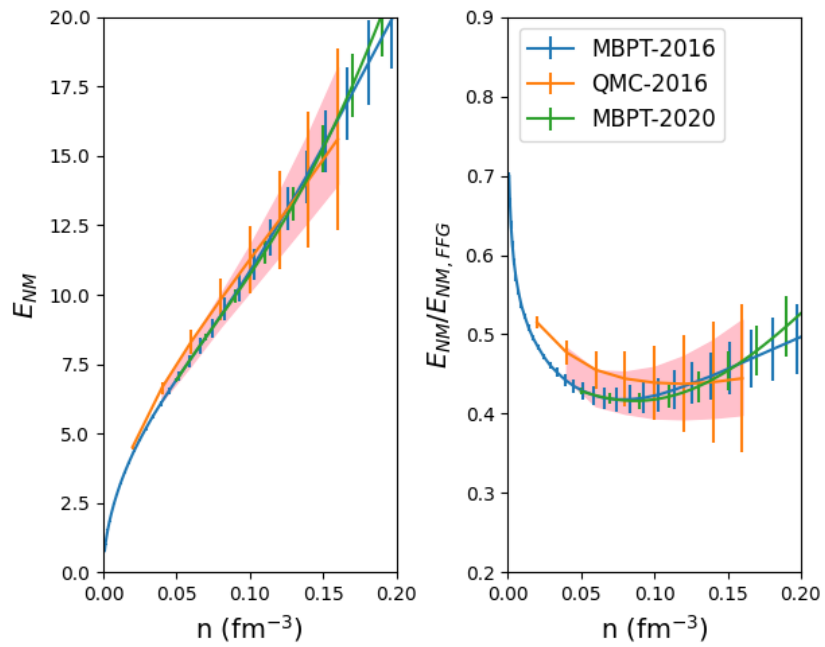


Fig. 7: Uncertainty band in NM obtained from the analysis of different predictions: MBPT-2016, QMC-2016 and MBPT-2020.

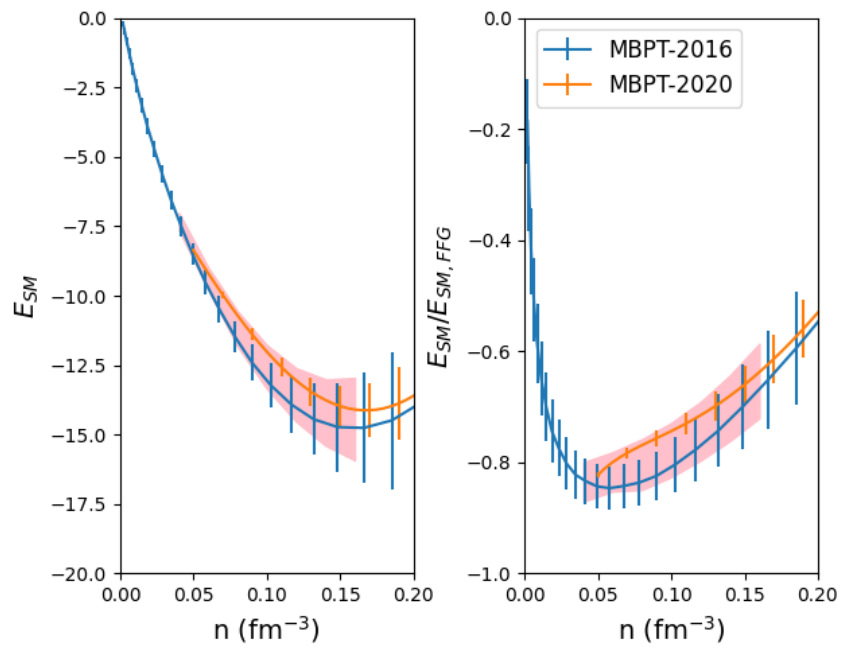


Fig. 8: Uncertainty band in SM obtained from the analysis of different predictions: MBPT-2016 and MBPT-2020.



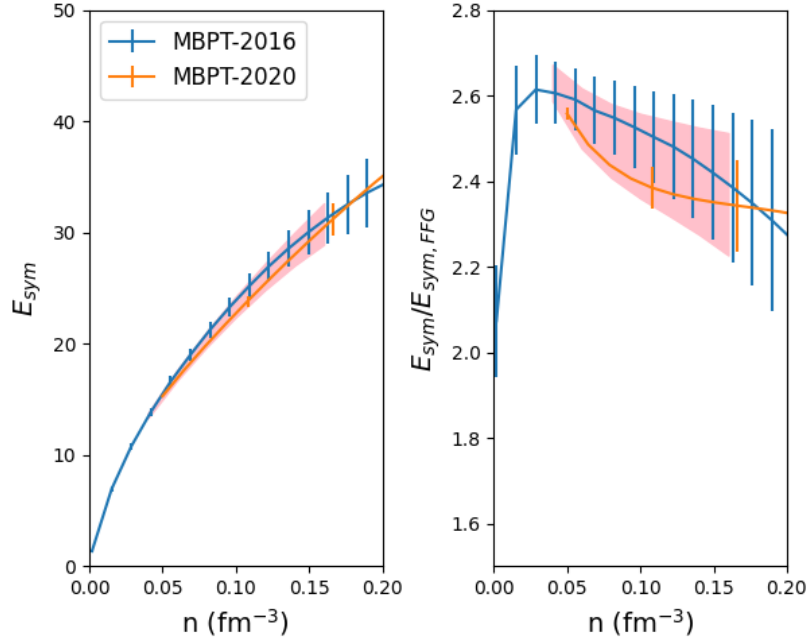


Fig. 9: Uncertainty band for the symmetry energy obtained from the analysis of different predictions: MBPT-2016 and MBPT-2020.

## 2.3 SetupPheno

**class** nucleardatapy.setup\_pheno.**SetupPheno**(*model*='Skyrme', *param*='SLY5')

Instantiate the object with results based on phenomenological interactions and chosen by the toolkit practitioner. This choice is defined in the variables *model* and *param*.

If *models* == 'skyrme', *param* can be: 'BSK14', 'BSK16', 'BSK17', 'BSK27', 'F-', 'F+', 'F0', 'FPL', 'LNS', 'LNS1', 'LNS5', 'NRAPR', 'RATP', 'SAMI', 'SGII', 'SIII', 'SKGSIGMA', 'SKI2', 'SKI4', 'SKMP', 'SKMS', 'SKO', 'SKOP', 'SKP', 'SKRSIGMA', 'SKX', 'Skz2', 'SLY4', 'SLY5', 'SLY230A', 'SLY230B', 'SV', 'T6', 'T44', 'UNEDF0', 'UNEDF1'.

If *models* == 'NLRH', *param* can be: 'NL-SH', 'NL3', 'NL3II', 'PK1', 'PK1R', 'TM1'.

If *models* == 'DDRH', *param* can be: 'DDME1', 'DDME2', 'DDMed', 'PKDD', 'TW99'.

If *models* == 'DDRHF', *param* can be: 'PKA1', 'PKO1', 'PKO2', 'PKO3'.

### Parameters

- **model** (*str*, *optional*.) – Fix the name of model: 'Skyrme', 'NLRH', 'DDRH', 'DDRHF'. Default value: 'Skyrme'.
- **param** (*str*, *optional*.) – Fix the parameterization associated to model. Default value: 'SLY5'.

### Attributes:

#### Esat

Attribute the NEP.

#### esym\_den

Attribute the density for the symmetry energy.

**esym\_e2a**

Attribute the symmetry energy.

**esym\_kf**

Attribute the Fermi momentum for the symmetry energy.

**label**

Attribute providing the label the data is references for figures.

**model**

Attribute model.

**nm\_cs2**

Attribute the neutron matter sound speed  $(c_s/c)^2$ .

**nm\_den**

Attribute the neutron matter density.

**nm\_e2a**

Attribute the neutron matter energy per particle.

**nm\_gap**

Attribute the neutron matter pairing gap.

**nm\_kfn**

Attribute the neutron matter neutron Fermi momentum.

**nm\_pre**

Attribute the neutron matter pressure.

**note**

Attribute providing additional notes about the data.

**param**

Attribute param.

**print\_outputs()**

Method which print outputs on terminal's screen.

**ref**

Attribute providing the full reference to the paper to be cited.

**sm\_cs2**

Attribute the symmetric matter sound speed  $(c_s/c)^2$ .

**sm\_den**

Attribute the symmetric matter density.

**sm\_e2a**

Attribute the symmetric matter energy per particle.

**sm\_gap**

Attribute the symmetric matter pairing gap.

**sm\_kf**

Attribute the symmetric matter Fermi momentum.

**sm\_kfn**

Attribute the symmetric matter neutron Fermi momentum.

**sm\_pre**

Attribute the symmetric matter pressure.

**nucleardatapy.setup\_pheno.models\_pheno()**

Return a list of models available in this toolkit and print them all on the prompt.

**Returns**

The list of models with can be 'Skyrme', 'NLRH', 'DDRH', 'DDRHF'.

**Return type**

list[str].

**nucleardatapy.setup\_pheno.params\_pheno(model)**

Return a list with the parameterizations available in this toolkit for a given model and print them all on the prompt.

**Parameters****model** (str.) – The type of model for which there are parametrizations. They should be chosen among the following options: 'Skyrme', 'NLRH', 'DDRH', 'DDRHF'.**Returns**The list of parametrizations. If *models* == 'skyrme': 'BSK14', 'BSK16', 'BSK17', 'BSK27', 'F-', 'F+', 'F0', 'FPL', 'LNS', 'LNS1', 'LNS5', 'NRAPR', 'RATP', 'SAMI', 'SGII', 'SIII', 'SKGSIGMA', 'SKI2', 'SKI4', 'SKMP', 'SKMS', 'SKO', 'SKOP', 'SKP', 'SKRSIGMA', 'SKX', 'Skz2', 'SLY4', 'SLY5', 'SLY230A', 'SLY230B', 'SV', 'T6', 'T44', 'UNEDF0', 'UNEDF1'. If *models* == 'NLRH': 'NL-SH', 'NL3', 'NL3II', 'PK1', 'PK1R', 'TM1'. If *models* == 'DDRH': 'DDME1', 'DDME2', 'DDMed', 'PKDD', 'TW99'. If *models* == 'DDRHF': 'PKA1', 'PKO1', 'PKO2', 'PKO3'.**Return type**

list[str].

Here are a set of figures which are produced with the Python sample: /sample/nucleardatapy\_plots/plot\_setupPheno.py

## 2.4 SetupEOSHIC

**class nucleardatapy.setup\_eoshic.SetupEOSHIC(constraint='DLL-2002')**

Instantiate the constraints on the EOS from HIC.

This choice is defined in the variable *constraint*.*constraint* can chosen among the following ones: [ 'DLL-2002', 'FOPI-2016' ].**Parameters****constraint** (str, optional.) – Fix the name of *constraint*. Default value: 'DLL-2002'.**Attributes:****init\_self()**

Initialize variables in self.

**print\_outputs()**

Method which print outputs on terminal's screen.

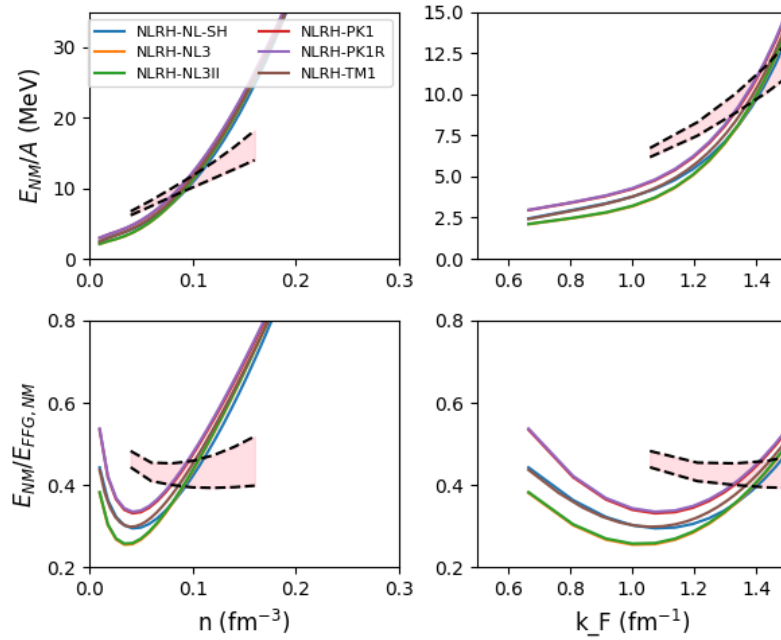


Fig. 10: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on non-linear meson(s) relativistic Hartree (NLRH) approach available in the nucleardatapy toolkit.

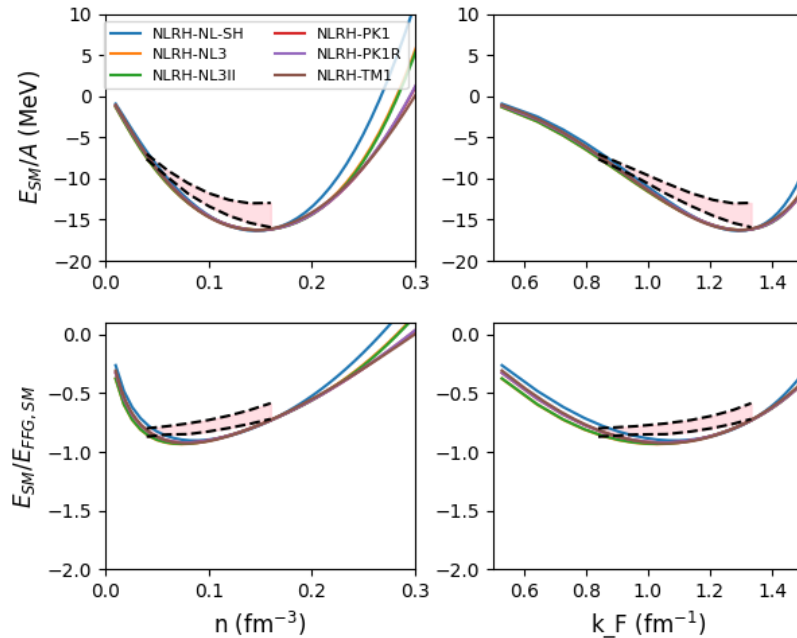


Fig. 11: This figure shows the energy in symmetric matter (SM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on non-linear meson(s) relativistic Hartree (NLRH) approach available in the nucleardatapy toolkit.

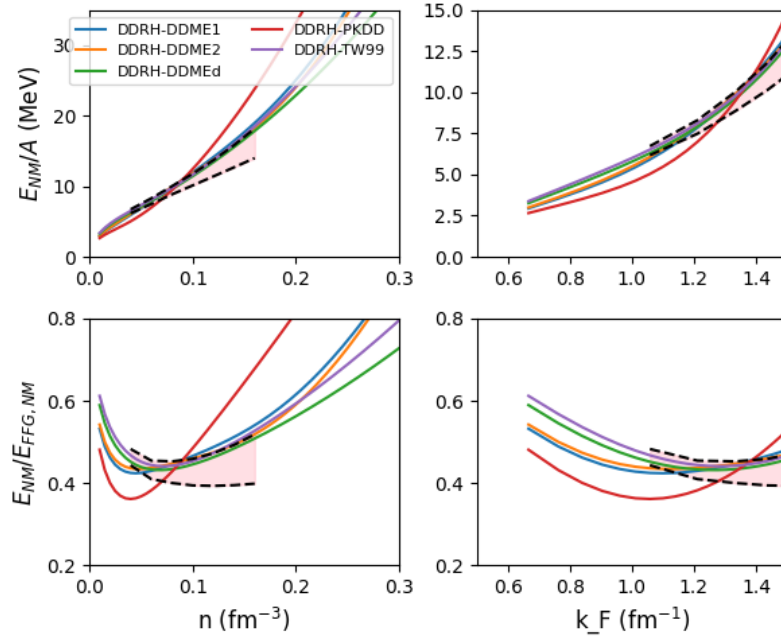


Fig. 12: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on density-dependent relativistic Hartree (DDRH) approach available in the nuclear-datapy toolkit.

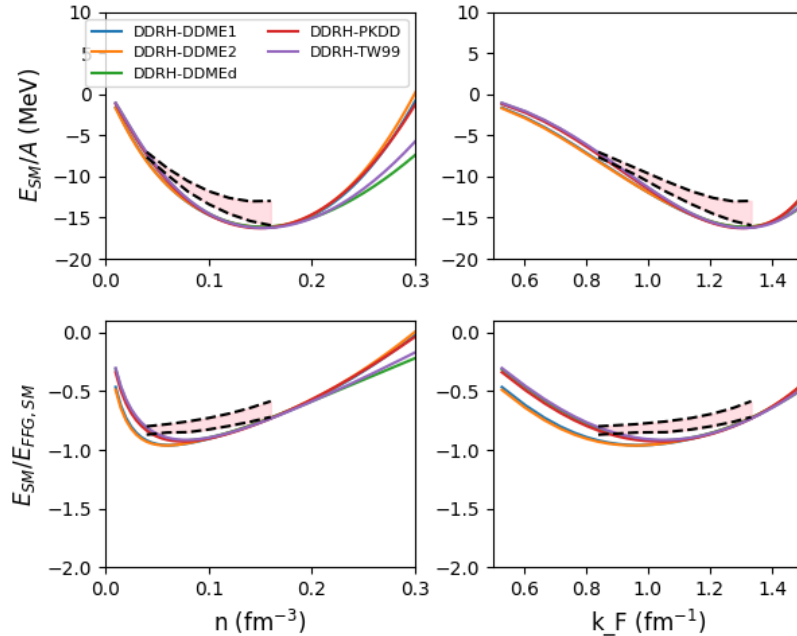


Fig. 13: This figure shows the energy in symmetric matter (SM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on density-dependent relativistic Hartree (DDRH) approach available in the nuclear-datapy toolkit.

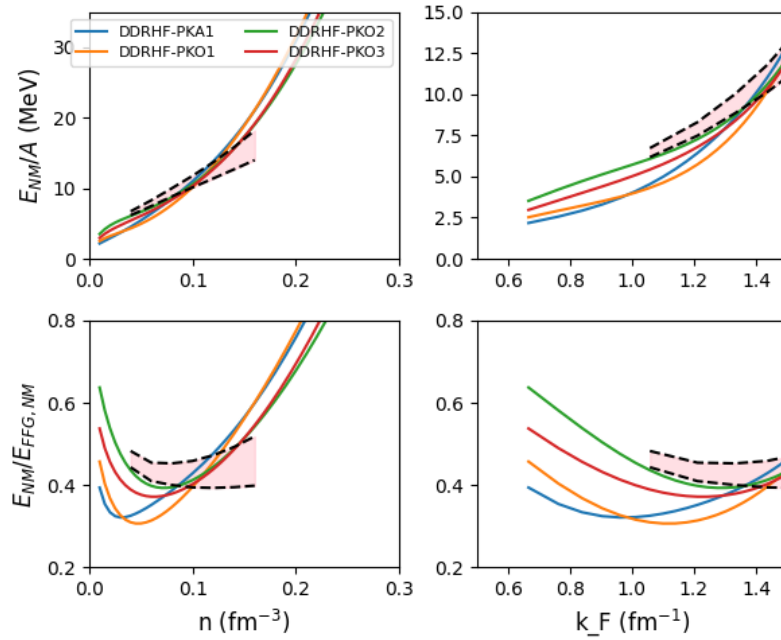


Fig. 14: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on density-dependent relativistic Hartree-Fock (DDRHF) approach available in the nucleardatapy toolkit.

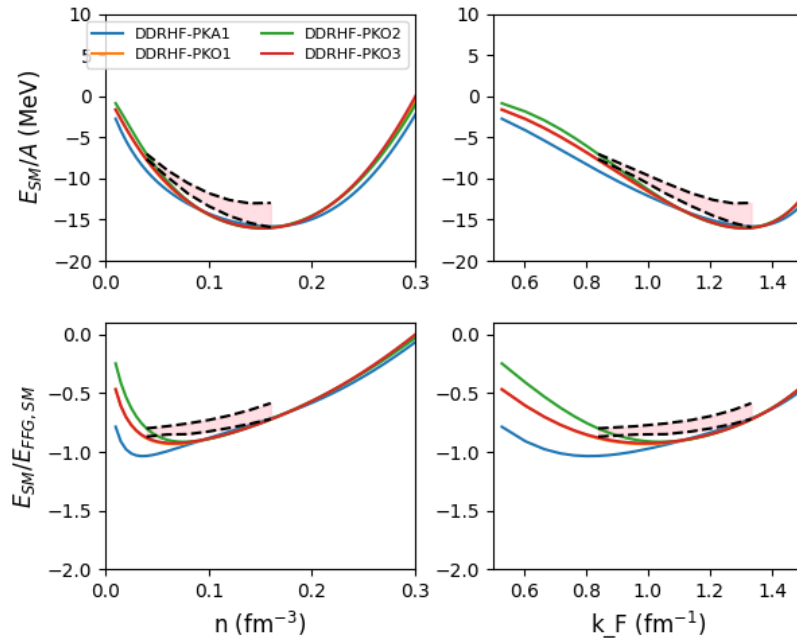


Fig. 15: This figure shows the energy in symmetric matter (SM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on density-dependent relativistic Hartree-Fock (DDRHF) approach available in the nucleardatapy toolkit.

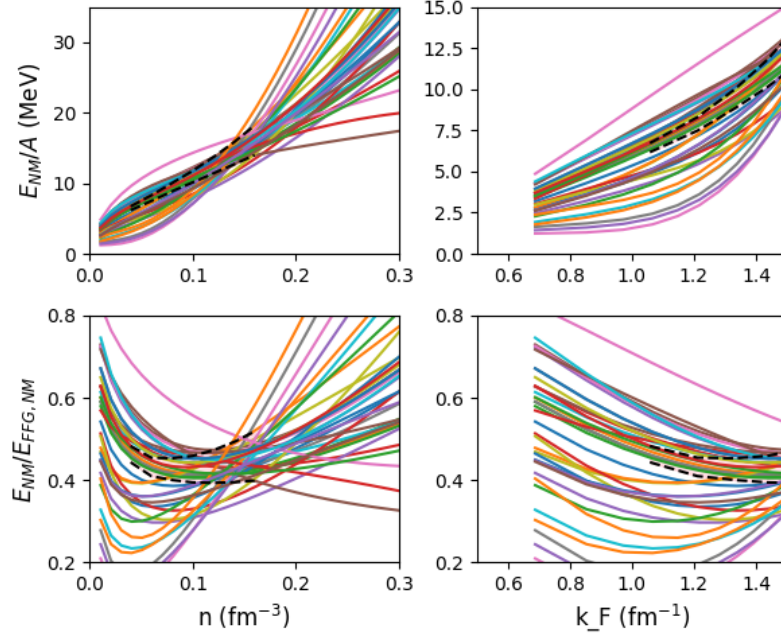


Fig. 16: This figure shows the energy in neutron matter (NM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on the standard Skyrme interaction available in the nucleardatapy toolkit.

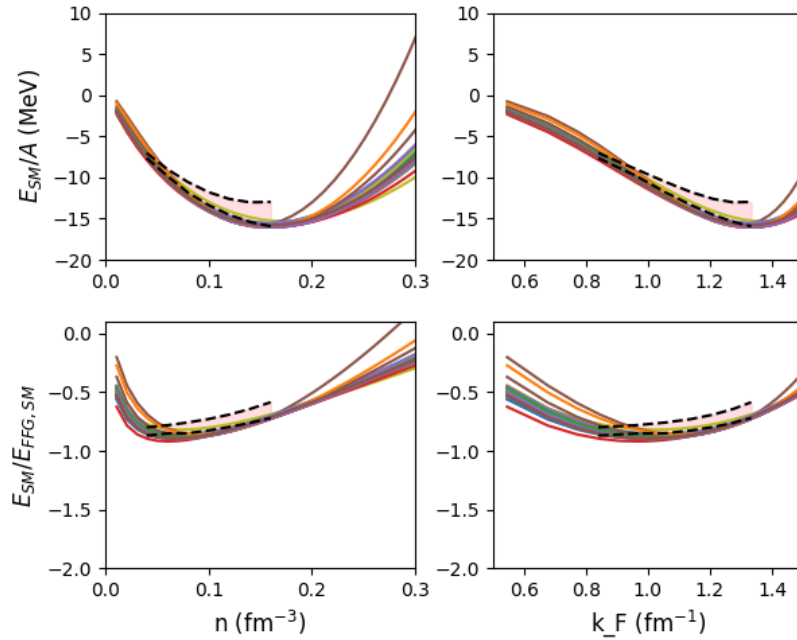


Fig. 17: This figure shows the energy in symmetric matter (SM) over the free Fermi gas energy (top) and the energy per particle (bottom) as function of the density (left) and the neutron Fermi momentum (right) for the complete list of phenomenological models based on the standard Skyrme interaction available in the nucleardatapy toolkit.

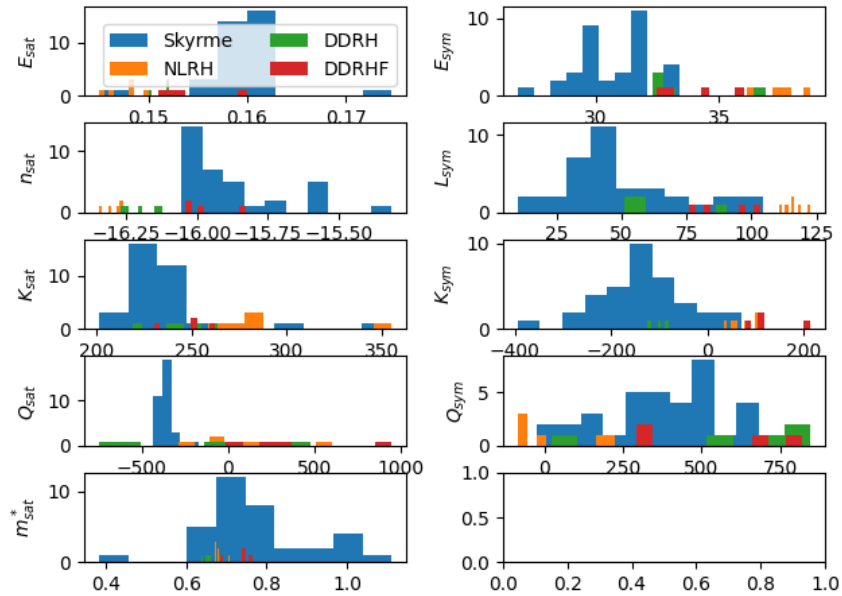


Fig. 18: Distribution of NEP for phenomenological models available in the nucleardatapy toolkit.

`nucleardatapy.setup_eoshic.constraints_EOSHIC()`

Return a list of the HIC constraints available in this toolkit for the equation of state in SM and NM and print them all on the prompt. These constraints are the following ones: [ 'DLL-2002', 'FOPI-2016' ].

**Returns**

The list of constraints.

**Return type**

list[str].

## 2.5 SetupCrust

`class nucleardatapy.setup_crust.SetupCrust(modcrust='Negele-Vautherin-1973')`

Instantiate the properties of the crust for the existing models.

This choice is defined in the variable *crust*.

*crust* can chosen among the following ones: 'Negele-Vautherin-1973'.

**Parameters**

**crust** (str, optional.) – Fix the name of *crust*. Default value: 'Negele-Vautherin-1973'.

**Attributes:**

**A**

Attribute A (mass of the nucleus).

**N**

Attribute N (total number of neutrons of the WS cell).



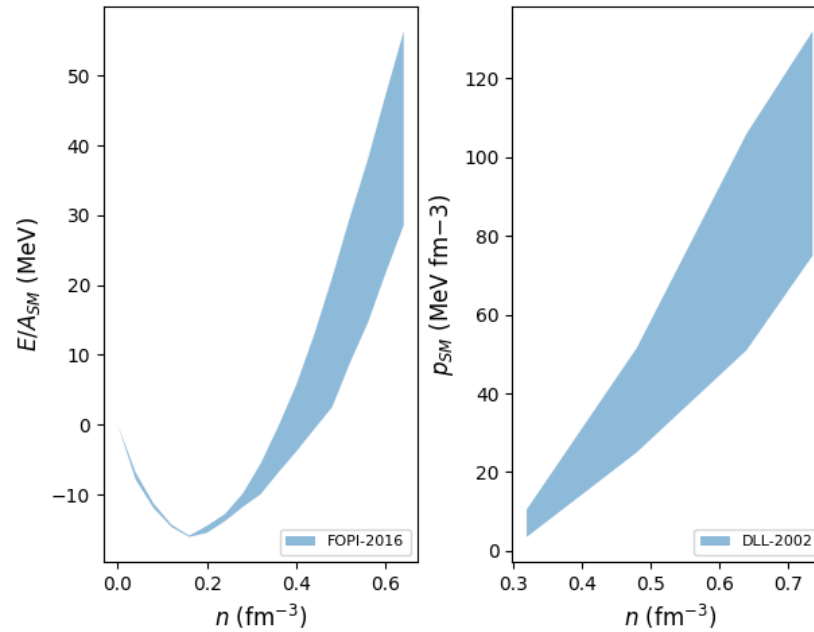


Fig. 19: HIC Experimental constraints for the energy per particle (left) and pressure (right) in SM as a function of the particle density for different analyses available in the *nuda* toolkit.

#### **N\_g**

Attribute N\_g (number of neutrons in the gas).

#### **RWS**

Attribute the radius of the WS cell (in fm).

#### **Z**

Attribute Z (charge of the nucleus).

#### **den**

Attribute the density of the system (in  $\text{fm}^{-3}$ ).

#### **den\_cgs**

Attribute the density of the system (in  $\text{cm}^{-3}$ ).

#### **den\_g**

Attribute the approximate density of neutron in the gas (in  $\text{fm}^{-3}$ ).

#### **e2a\_int**

Attribute the internal energy (in MeV).

#### **e2a\_int2**

Attribute the energy minus the neutron mass (in MeV).

#### **e2a\_int\_g**

Attribute the internal energy of the gas component (in MeV).

#### **e2a\_rm**

Attribute the rest mass energy (in MeV).

**mu\_n**

Attribute the neutron chemical potential (in MeV).

**mu\_p**

Attribute the proton chemical potential (in MeV).

**print\_outputs()**

Method which print outputs on terminal's screen.

**xn**

Attribute the fraction of neutrons.

**xn\_bound**

Attribute the fraction of bound neutrons.

**xp**

Attribute the fraction of protons.

**xpn\_bound**

Attribute the approximate ratio of proton to neutron in the nucleus.

**nucleardatapy.setup\_crust.models\_crust()**

Return a list of the tables available in this toolkit for the experimental masses and print them all on the prompt. These tables are the following ones: 'Negele-Vautheron-1973'.

**Returns**

The list of tables.

**Return type**

list[str].

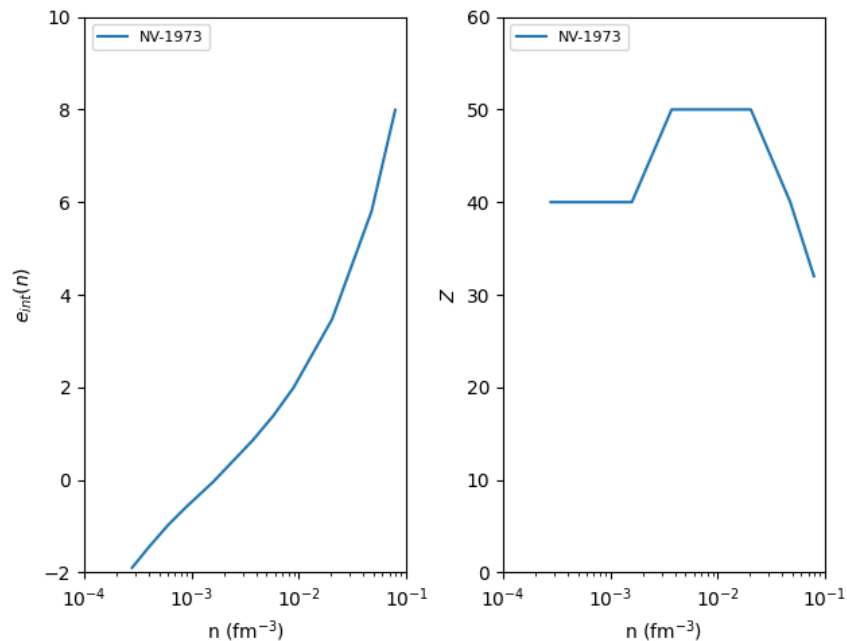


Fig. 20: Properties of the crust as given by the models available in the nuda toolkit.

## 2.6 SetupMassesExp

**class** nucleardatapy.setup\_masses\_exp.**SetupMassesExp**(*table*='AME', *version*='2020')

Instantiate the experimental nuclear masses from AME mass table.

This choice is defined in the variables *table* and *version*.

*table* can be chosen among the following ones: 'AME'.

*version* can be chosen among the following choices: '2020', '2016', '2012'.

### Parameters

- **table** (*str*, *optional*.) – Fix the name of *table*. Default value: 'AME'.
- **version** (*str*, *optional*.) – Fix the name of *version*. Default value: 2020'.

### Attributes:

#### Zmax

maximum charge of nuclei present in the table.

#### Type

Attribute Zmax

#### dist\_nbNuc

attribute number of nuclei discovered per year

#### dist\_year

attribute distribution of years

#### drip(*Zmax*=95)

Method which find the drip-line nuclei (on the two sides).

### Parameters

- **Zmax** (*int*, *optional*. Default: 95.) – Fix the maximum charge for the search of the drip line.

### Attributes:

#### flagI

Attribute I.

#### flagInterp

Attribute Interp (interpolation). Interp='y' is the nucleus has not been measured but is in the table based on interpolation expressions. otherwise Interp = 'n' for nuclei produced in laboratory and measured.

#### label

Attribute providing the label the data is references for figures.

#### nbLine

Attribute with the number of line in the file.

#### nbNuc

Attribute with the number of nuclei read in the file.

#### note

Attribute providing additional notes about the data.

**nucA**

Attribute A (mass of the nucleus).

**nucBE**

Attribute BE (Binding Energy) of the nucleus.

**nucBE\_err**

Attribute uncertainty in the BE (Binding Energy) of the nucleus.

**nucHT**

Attribute HT (half-Time) of the nucleus.

**nucN**

Attribute N (number of neutrons of the nucleus).

**nucStbl**

Attribute stbl. stbl='y' if the nucleus is stable (according to the table). Otherwise stbl = 'n'.

**nucSymb**

Attribute symb (symbol) of the element, e.g., Fe.

**nucYear**

Attribute year of the discovery of the nucleus.

**nucZ**

Attribute Z (charge of the nucleus).

**print\_outputs()**

Method which print outputs on terminal's screen.

**ref**

Attribute providing the full reference to the paper to be cited.

**select**(*Amin=0, Zmin=0, interp='n', state='gs', nucleus='unstable', every=1*)

Method which select some nuclei from the table according to some criteria.

**Parameters**

- **interp**(*str, optional. Default = 'n'.*) – If interp='n', exclude the interpolated nuclei from the selected ones. If interp='y' consider them in the table, in addition to the others.
- **state**(*str, optional. Default 'gs'.*) – select the kind of state. If state='gs', select nuclei measured in their ground state.
- **nucleus**(*str, optional. Default 'unstable'.*) – 'unstable'.

It can be set to 'stable', 'longlive' (with LT>10 min), 'shortlive' (with 10min>LT>1 ns), 'veryshortlive' (with LT< 1ns) :param every: consider only 1 out of every nuclei in the table. :type every: int, optional. Default every = 1.

**Attributes:****select\_year**(*year\_min=1940, year\_max=1960, state='gs'*)

Method which select some nuclei from the table according to the discovery year.

**Parameters**

- **year\_min** –
- **year\_max** –

- **state** (*str*, optional. Default 'gs'.) – select the kind of state. If state='gs', select nuclei measured in their ground state.

**Attributes:**

`nucleardatapy.setup_masses_exp.tables_masses_exp()`

Return a list of the tables available in this toolkit for the experimental masses and print them all on the prompt. These tables are the following ones: 'AME'.

**Returns**

The list of tables.

**Return type**

list[str].

`nucleardatapy.setup_masses_exp.versions_masses_exp(table)`

Return a list of versions of tables available in this toolkit for a given model and print them all on the prompt.

**Parameters**

**table** (*str*.) – The table for which there are different versions.

**Returns**

The list of versions. If table == 'AME': '2020', '2016', '2012'.

**Return type**

list[str].

Here are a set of figures which are produced with the Python sample: `/sample/nucleardatapy_plots/plot_setupMassesExp.py`

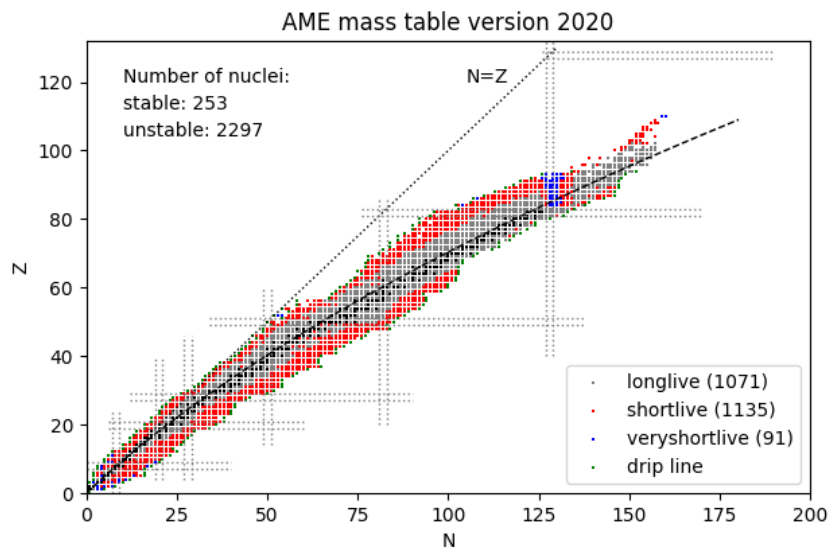


Fig. 21: The nuclear chart based on AME 2020 table. The different colors correspond to the different measured half-times of nuclei.

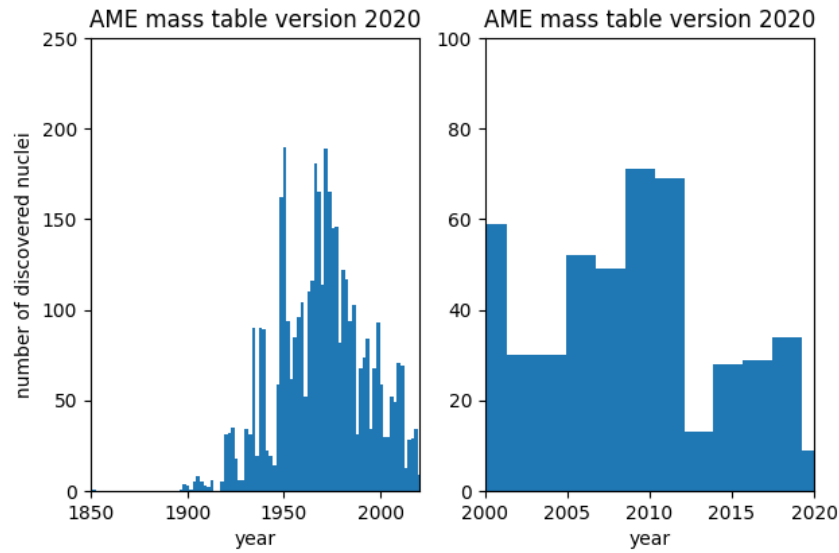


Fig. 22: Histogram showing the distribution of nuclei per discovery year, since the first one discovered in 1851.

## 2.7 SetupMassesTheory

**class** nucleardatapy.setup\_masses\_theory.SetupMassesTheory(*table*='1995-DZ')

Instantiate the theory nuclear masses.

This choice is defined in the variable *table*.

*table* can chosen among the following ones: [ '1988-MJ', '1995-DZ', '1995-ETFSI', '1995-FRDM', '2005-KTUY', '2007-HFB14', '2010-WS3', '2010-HFB21', '2011-WS3', '2013-HFB26' ]

### Parameters

**table** (*str*, *optional.*) – Fix the name of *table*. Default value: '1995-DZ'.

### Attributes:

**diff**(*table*, *Zref*=50)

Method calculates the difference between a given mass model and *table\_ref*.

### Parameters

- **table** (*str.*) – Fix the table to analyze.
- **Zref** (*int*, *optional.* *Default: 50.*) – Fix the isotopic chain to study.

### Attributes:

**diff\_exp**(*table\_exp*, *version\_exp*, *Zref*=50)

Method calculates the difference between a given experimental mass (identified by *table\_exp* and *version\_exp*) and *table\_ref*.

### Parameters

- **table** (*str.*) – Fix the table to analyze.
- **Zref** (*int*, *optional.* *Default: 50.*) – Fix the isotopic chain to study.

**Attributes:****drip**( $Z_{max}=95$ )

Method which find the drip-line nuclei (on the two sides).

**Parameters****Zmax** (*int, optional. Default: 95.*) – Fix the maximum charge for the search of the drip line.**Attributes:****init\_self**()

Initialize variables in self.

**print\_outputs**()

Method which print outputs on terminal's screen.

**nucleardatapy.setup\_masses\_theory.tables\_masses\_theory()**

Return a list of the tables available in this toolkit for the masses predicted by theoretical approaches and print them all on the prompt. These tables are the following ones: [ '1988-MJ', '1995-DZ', '1995-ETFSI', '1995-FRDM', '2005-KTUY', '2007-HFB14', '2010-WS3', '2010-HFB21', '2011-WS3', '2013-HFB26' ]

**Returns**

The list of tables.

**Return type**

list[str].

Here are a set of figures which are produced with the Python sample: `/sample/nucleardatapy_plots/plot_setupMassesTheory.py`

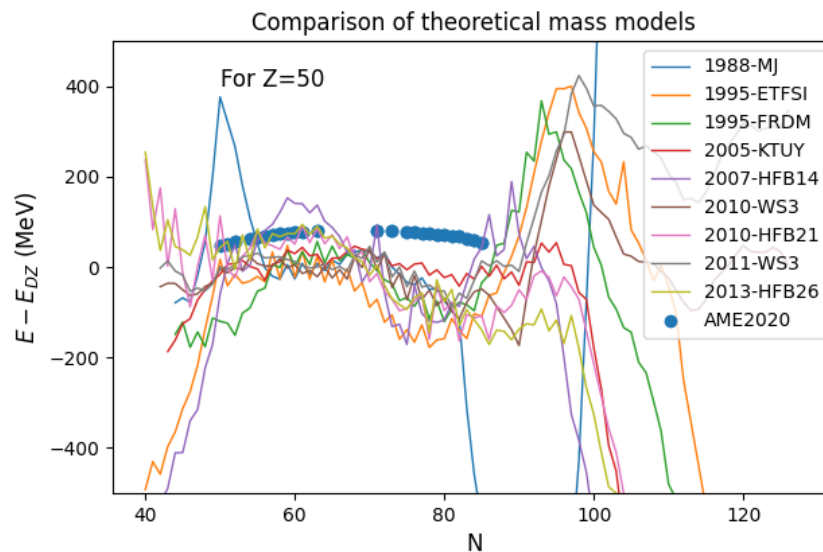


Fig. 23: Differences between binding energies predicted by different models with respect to the one predicted by Duflo-Zuker for  $Z = 50$ .

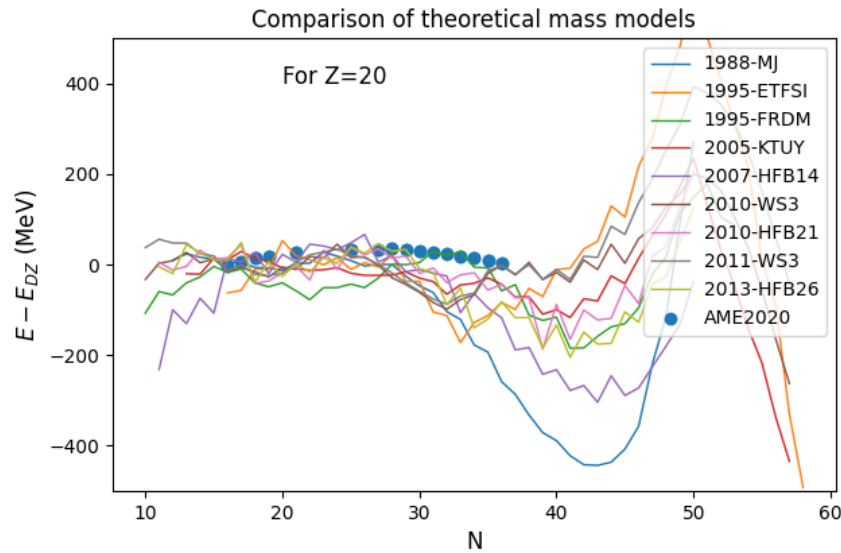


Fig. 24: Differences between binding energies predicted by different models with respect to the one predicted by Duflo-Zuker for  $Z = 20$ .

## 2.8 SetupRadCh

**class** nucleardatapy.setup\_rad\_ch.**SetupRadCh**(*table*='2013-Angeli')

Instantiate the object with charge radii choosen from a table.

This choice is defined in the variable *table*.

The tables can chosen among the following ones: '2013-Angeli'.

### Parameters

**table** (*str*, *optional*.) – Fix the name of *table*. Default value: '2013-Angeli'.

### Attributes:

#### R\_unit

Attribute radius unit.

#### RadCh\_isotopes(*Zref*=50)

This method provide a list if radii for an isotopic chain defined by *Zref*.

#### label

Attribute providing the label the data is references for figures.

#### note

Attribute providing additional notes about the data.

#### nucA

Attribute A (mass of the nucleus).

#### nucN

Attribute N (number of neutrons of the nucleus).



**nucRch**

Attribute R\_ch (charge radius) in fm.

**nucRch\_err**

Attribute uncertainty in R\_ch (charge radius) in fm.

**nucSymb**

Attribute symb (symbol) of the element, e.g., Fe.

**nucZ**

Attribute Z (charge of the nucleus).

**print\_outputs()**

Method which print outputs on terminal's screen.

**ref**

Attribute providing the full reference to the paper to be citted.

**nucleardatapy.setup\_rad\_ch.tables\_rad\_ch()**

Return a list of the tables available in this toolkit for the charge radius and print them all on the prompt. These tables are the following ones: '2013-Angeli'.

**Returns**

The list of tables.

**Return type**

list[str].

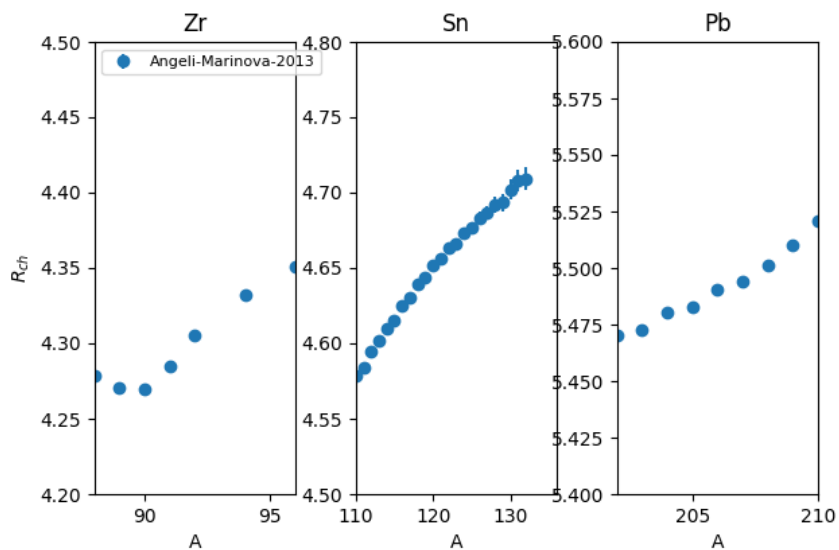


Fig. 25: Charge radii for Zn, Sn, and Pb isotopes and for the models available in the nuda toolkit.

## 2.9 SetupISGMR

**class** nucleardatapy.setup\_ISGMR.**SetupISGMR**(*table*='2018-ISGMR-GARG')

Instantiate the object with microscopic results choosen by the toolkit practitioner. This choice is defined in the variable *table*.

The *table* can chosen among the following ones: '2010-ISGMR-LI', '2018-ISGMR-GARG'.

**Parameters**

**table** (*str*, *optional*.) – Fix the name of *table*. Default value: '2018-ISGMR-GARG', '2018-ISGMR-GARG-LATEX'.

**Attributes:**

**E\_unit**

Attribute energy unit.

**label**

Attribute providing the label the data is references for figures.

**note**

Attribute providing additional notes about the data.

**nucA**

Attribute A (mass of the nucleus).

**nucM12Mm1\_cent**

Attribute energy centroid.

**nucM12Mm1\_errm**

Attribute (-) uncertainty in the energy centroid.

**nucM12Mm1\_errp**

Attribute (+) uncertainty in the energy centroid.

**nucSymbol**

Attribute the symbol of the element.

**nucZ**

Attribute Z (charge of the nucleus).

**print\_outputs()**

Method which print outputs on terminal's screen.

**ref**

Attribute providing the full reference to the paper to be citted.

**table**

Attribute table.

nucleardatapy.setup\_ISGMR.**tables\_isgmr**()

Return a list of tables available in this toolkit for the ISGMR energy and print them all on the prompt. These tables are the following ones: '2010-ISGMR-LI', '2018-ISGMR-GARG', '2018-ISGMR-GARG-LATEX'.

**Returns**

The list of tables.

**Return type**

list[str].

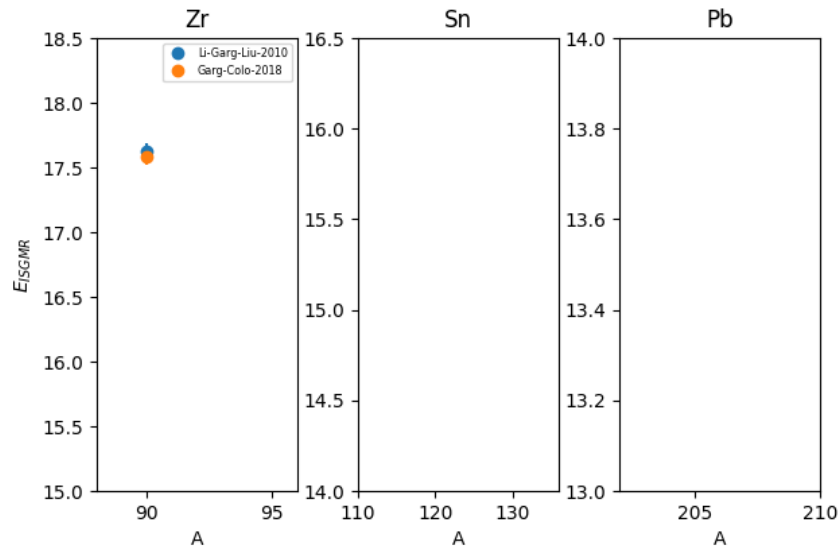


Fig. 26: ISGMR energies available in the nucleardatapy toolkit.

## 2.10 SetupEsymLsym

**class** nucleardatapy.setup\_EsymLsym.**SetupEsymLsym**(*constraint*='2014-IAS')

Instantiate the values of Esym and Lsym from the constraint.

The name of the constraint to be chosen in the following list: '2009-HIC', '2010-RNP', '2012-FRDM', '2013-NS', '2014-IAS', '2014-IAS+RNP', '2015-POL-208PB', '2015-POL-120SN', '2015-POL-68NI', '2017-UG', '2021-PREXII-Reed', '2021-PREXII-Reinhard', '2021-PREXII+CREX-Zhang'.

### Parameters

**constraint** (*str*, *optional*.) – Fix the name of *constraint*. Default value: '2014-IAS'.

### Attributes:

#### Esym

Attribute Esym.

#### Esym\_err

Attribute with uncertainty in Esym.

#### Esym\_max

Attribute max of Esym.

#### Esym\_min

Attribute min of Esym.

#### Lsym

Attribute Lsym.

#### Lsym\_err

Attribute with uncertainty in Lsym.

**Lsym\_max**

Attribute max of Lsym.

**Lsym\_min**

Attribute min of Lsym.

**alpha**

Attribute the plot alpha

**constraint**

Attribute constraint.

**label**

Attribute providing the label the data is references for figures.

**note**

Attribute providing additional notes about the constraint.

**print\_outputs()**

Method which print outputs on terminal's screen.

**ref**

Attribute providing the full reference to the paper to be citted.

**nucleardatapy.setup\_EsymLsym.constraints\_EsymLsym()**

Return a list of constraints available in this toolkit in the following list: '2009-HIC', '2010-RNP', '2012-FRDM', '2013-NS', '2014-IAS', '2014-IAS+RNP', '2015-POL-208PB', '2015-POL-120SN', '2015-POL-68NI', '2017-UG', '2021-PREXII-Reed', '2021-PREXII-Reinhard', '2023-PREXII+CREX-Zhang'; and print them all on the prompt.

**Returns**

The list of constraints.

**Return type**

list[str].

Here are a set of figures which are produced with the Python sample: `/sample/nucleardatapy_plots/plot_setupEsymLsym.py`

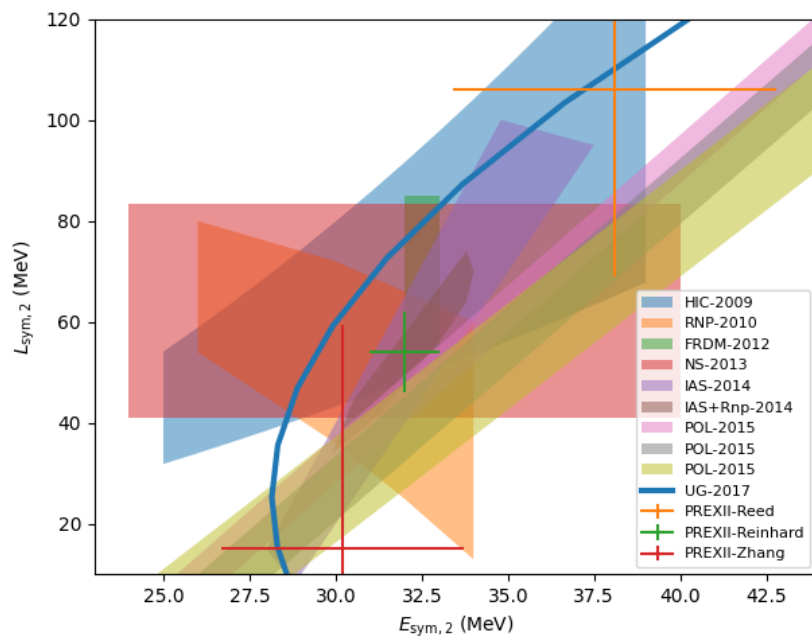


Fig. 27: This figure shows the  $E_{\text{sym},2}$  versus  $L_{\text{sym},2}$  correlation for the different constraints available in the nuclear-datapy toolkit.



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