SAISINUC 2022 User Guide

English Version

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This document provides support and guidelines for all the users of the SAISINUC 2022 software. It is composed of three different sections:

1) A startup guide section, in which the basic description of the software, an installation guide, and some configuration advices are provided.
2) A step-by-step guide on how to complete an evaluation in SAISINUC.
3) A software overview in which all the components of SAISINUC 2022 are described.

The first section should be used to install properly the SAISINUC software on any computer. The second section has been written to focus only on the evaluation process and does not provide any technical details on the way to use the software. On the contrary, the third section has been written to be as exhaustive as possible regarding the SAISINUC software and its usage.

As a consequence it is recommended to newcomers to start with the second section to first have an overall idea on how to perform and evaluation with SAISINUC. Once the basic procedure is understood, the third section should provide enough technical details to guide any newcomer in each of the evaluation tasks previously mentioned.

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1 Startup guide

This section provides general concepts on SAISINUC 2022 and support for installation and configuration of the software.

1.1 Introduction to SAISINUC 2022

SAISINUC 2022 is a nuclear decay database and an associated editor developed by the LNE-LNHB since 1992. After many years of development, it has become the main software tool used by DDEP to perform evaluations and edition. The SAISINUC 2022 package is composed of two independent files:

- The DDEP database (usually named Donnees.mdb)
- The SAISINUC 2022 software (currently named Saisinuc_2022.mdb)

The Donnees.mdb file is a Microsoft Access database in which all the decay information of the various radioisotopes evaluated by DDEP are gathered. The file has no specific user interface and is a simple collection of tables for all the nuclear and atomic radiation properties of the decays. Each evaluator uses his own database to modify decay data when performing an evaluation or a study. The main database is maintained at LNHB and is handled by a single DDEP member (C. Dulieu) to avoid any consistency conflict. Once a new evaluation has been reviewed and validated for publication, a copy of the evaluator database is sent to LNHB in order to perform the update of the main DDEP database. At any time, a user can request an up-to-date copy of the main database.

The SAISINUC_2022.mdb file is a Graphical User Interface (GUI) developed with Microsoft Access to easily edit the database. All along the years, several decay data evaluation tools have been developed in order to perform DDEP evaluations. In particular, external programs like BrIcc, BetaShape, Emission, etc. have been integrated in the GUI in order to simplify the evaluation process. Finally, some nuclear and atomic databases (such as the latest Atomic Mass Evaluation database) are directly included in the software and provide an easy way to access the relevant information during an evaluation. Due to its historical development, the SAISINUC software can only be used with Microsoft Access 2000, the next versions of Access being not compatible (see the Installation guide for more details).

It is **strongly recommended** to all DDEP evaluators to use the SAISINUC 2022 software to perform the evaluation and update the database. Not only the package provides simple and comprehensive tools for the evaluation, but it also contains a large number of internal verification checks to ensure that data are properly formatted.

1.2 Installation guide

The installation of SAISINUC 2022 software and its external programs is presented below. The requirements for the installation are:

- Operating System: Windows 7 or 10

  Neither Linux distributions nor macOS are supported. Regarding the older versions of Windows OS, SAISINUC 2022 should work but no support will be provided by the LNHB local team. In the following manual all the examples and guides will be given assuming usage of Windows 10.
- Administrator rights on the computer during the installation process.
- Executable installer of
  - Microsoft Access 2000 Runtime
  - BetaShape
  - BrIcc
  - Emission

All the required packages for SAISINUC 2022 and external programs can be found online on a dedicated webpage accessible only to DDEP evaluators: http://www.lnhb.fr/nuclear-data/tools-for-evaluators. To have access to the webpage, please contact the DDEP coordinator (currently Xavier MOUGEOT).

In order to minimize the download time of the files, most of them have been compressed in zip format. The user needs then to extract the files first, by right clicking on each file and selecting the option *Extract All…* as displayed in Figure 1.

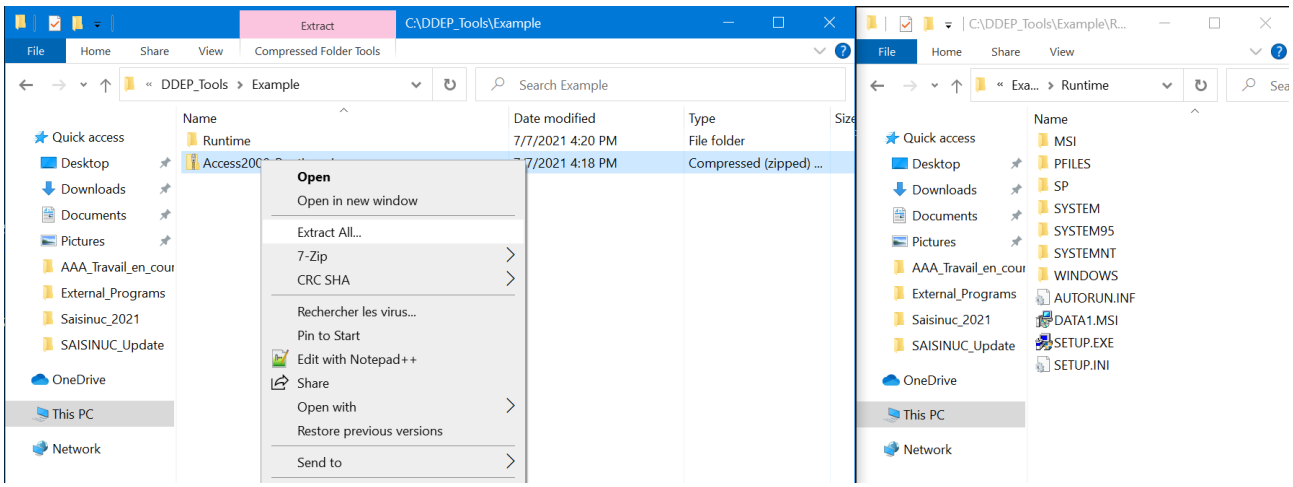


Figure 1: Extracting compressed files

Important notes:

- Some of the evaluation tools are similar with ENSDF ones (such as BrIcc for example). However, most tools had to be customized in order to be integrated in the SAISINUC 2022 software. Therefore, the most recent version available online (for example on ENSDF webpage) might not work with SAISINUC 2022. **We strongly recommend** to all the evaluators to use, for any DDEP evaluation, only the software and tools provided in the DDEP evaluators' webpage.

- Due to recurrent issues caused by Microsoft Office updates and by some SAISINUC updates **we strongly recommend to install** Microsoft Access 2000 Runtime, SAISINUC 2022 and all the external programs in a dedicated folder **outside** of C:\Program Files\ or C:\Program Files (x86)\. For example, if C: is the letter of the drive on which one wants to install SAISINUC 2022, we advise to install all tools in a new folder with the following path **C:\DDEP_Tools**. In the rest of the document, this path will the taken as an example for the installation.

- If the user is not using Windows as main Operating System, he might try to run Windows in a virtual machine and install SAISINUC on this virtual machine. Although this solution is not optimal it has been successfully performed few times.

Below, a step-by-step installation guide is provided to anyone wishing to have a fully operational version of SAISINUC 2022.

1.2.1 Microsoft Access 2000 Runtime

The first step is to install a functional version of Microsoft Access 2000. An installer of Microsoft Access 2000 Runtime is available on the DDEP evaluator's tools webpage (as mentioned previously, SAISINUC 2022 software will not work with newer versions of Access).

The runtime can be installed using the following guidelines:

- Download the file *Access2000_Runtime.zip* and unzip it to a temporary folder
- In the folder, run the *Setup.exe* executable
- Once the install setup has started, use the Configure option to select the desired installation path of the runtime by selecting the Customize… option (see Figure 2)
  In this example the installation directory has been chosen to be C:\DDEP_Tools\Access2000Runtime\
- Select *Install now*

After a few seconds, the installation should be completed. In some cases, error messages can pop up specifying missing files or components: they should be ignored. Once the installation is completed, Microsoft Access runtime can be used to read and edit existing database.

In case of an already existing version of Microsoft Access.

If ever another Microsoft Access version is already installed on the computer, it is still possible to install Access 2000 runtime version without damaging the current Access installation. However, one should be careful not to install the runtime on the same directory as the current Microsoft Access software.

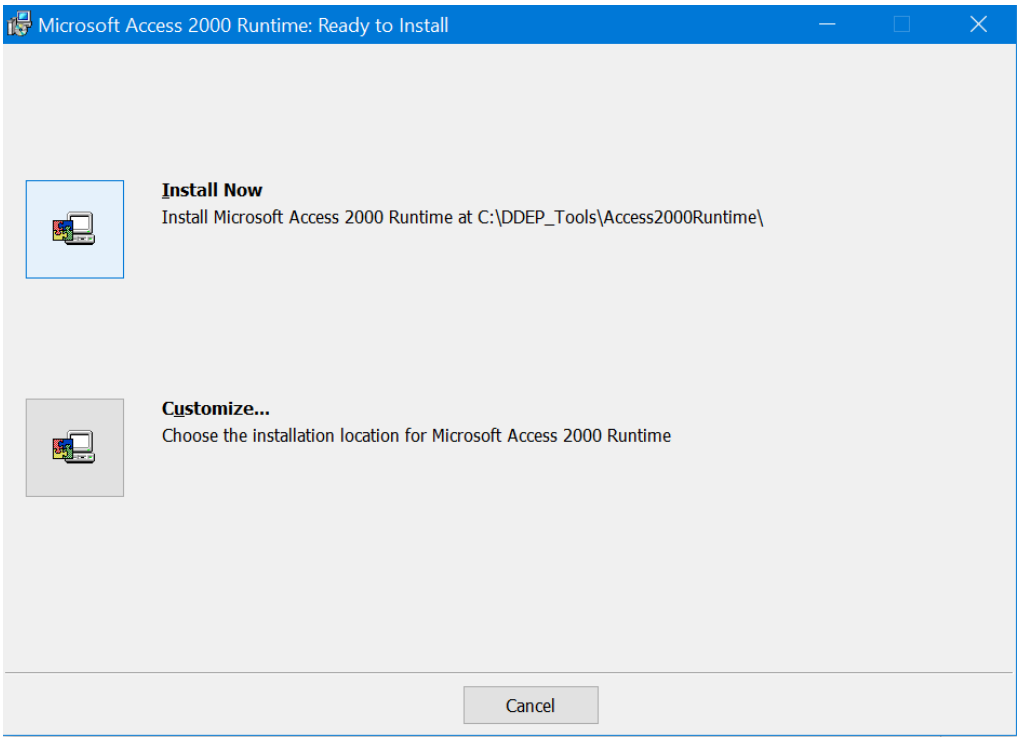


Figure 2: Installation setup of Microsoft Access 2000 Runtime

Important notice: If Microsoft Access 2000 Runtime was already installed on your computer, instead of the upper window, you should see one with two buttons: "**Repair Microsoft Access 2000 Runtime**" and "**Remove Microsoft Access 2000 Runtime**". You can then cancel this installation and proceed to the next step.

1.2.2 SAISINUC 2022 package

Once Microsoft Access Runtime is installed, the SAISINUC 2022 package can be used. The latest versions of the SAISINUC 2022 software and database can be obtained from the Tools for evaluators' webpage by downloading the SAISINUC_2022.zip file. The compressed file contains the following items:

- ***Saisinuc_2022.mdb***
  The evaluation program
- ***Donnees.mdb***
  A clean database for evaluator containing few examples.
- ***Comments***
  A folder containing the comments file associated with the example in the provided database.
- ***Help***
  A folder containing an explanation for setting the path to database.
- ***Saisinuc_2022.lnk***
  A shortcut for launching the SAISINUC 2022 program, if installed in the recommended directory. It can be edited to suit your needs if you installed the program in another location.
- ***Saisinuc_2022.ico***
  An icon to distinguish SAISINUC 2022 program (more explanations provided below)
- ***Saisinuc_2022_Installation guide.pdf***
  The installation guide of SAISINUC 2022
- ***Saisinuc_2022_UserGuide.pdf***
  The user guide of the SAISINUC 2022 program (this manual)

It is recommended to create a new directory to copy all these documents (for example C:\DDEP_Tools\Saisinuc_2022\). SAISINUC 2022 does not require any additional installation step. Once copied in the appropriate directory, the software can be directly used by double clicking on the provided link, or by opening the file *Saisinuc_2022.mdb* with Microsoft Access 2000. If the installation has been done correctly, the loading screen displayed in Figure 3 should appear, then the main window.

Note: The first time Microsoft Access Runtime is used, the user will be asked to register Name and Initial information in order to use the software. These information are not used any further and might be filled with any value.

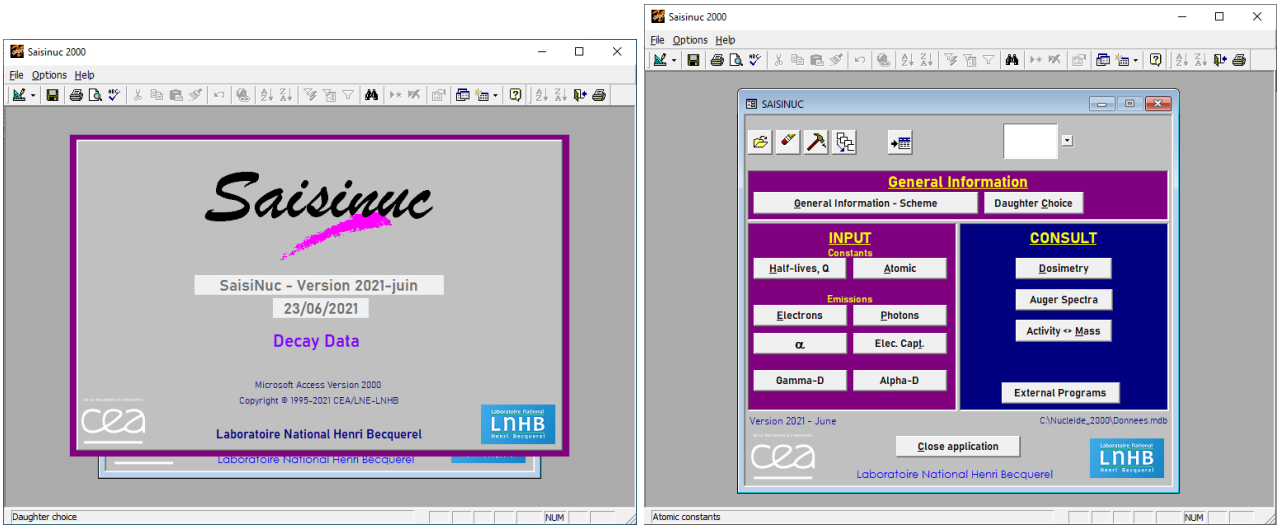


Figure 3: SAISINUC 2022 loading screen and main window

Finally, if the provided shortcut does not work, it can be useful and recommended to create one to launch SAISINUC 2022 from anywhere and set a dedicated icon to distinguish it more easily.

- To create a shortcut, right-click on the *Saisinuc_2022.mdb* file and select the field *create a shortcut*. By default, the created shortcut is named "*Saisinuc_2022.mdb – Shortcut (see* Figure 4*)*. The shortcut can be renamed as desired, for example *Saisinuc 2022*. It can be moved anywhere to use SAISINUC quickly (it is recommended to move it on the Desktop).

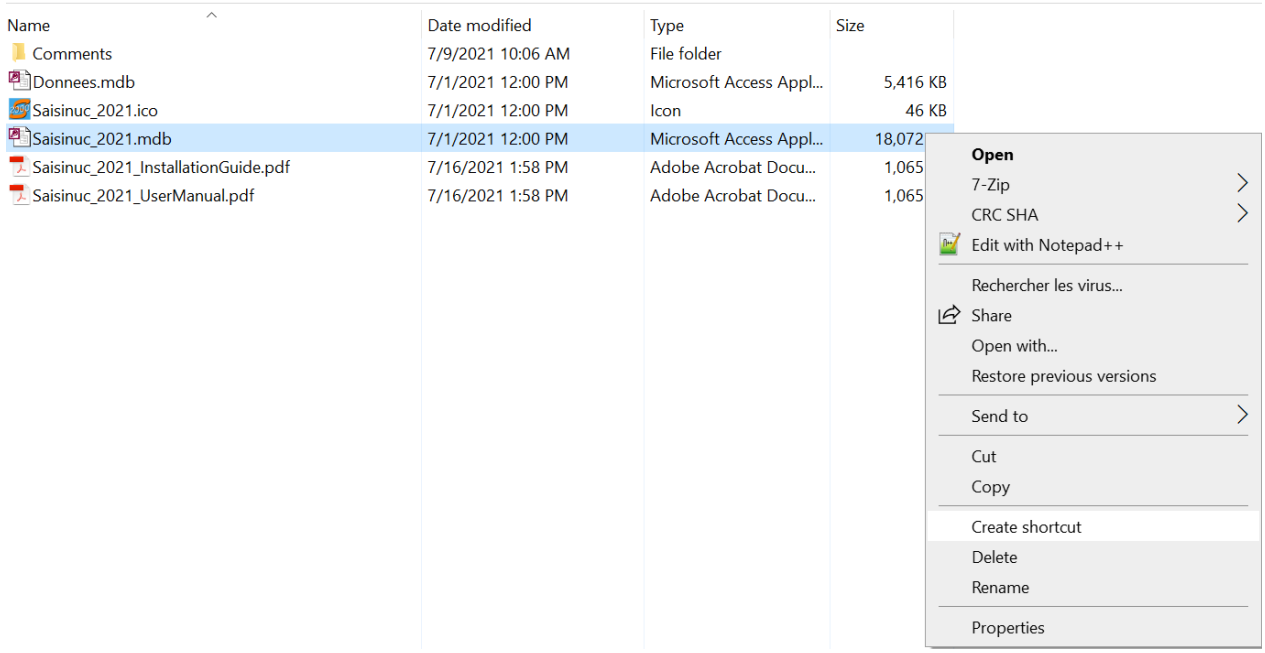


Figure 4: Creating a shortcut for SAISINUC

- To change the icon of the shortcut, right click on it and select the field *Properties*. In the newly opened window, select the tab *Shortcut* and click on the *Change Icon* Button. Then use the *Browse* option in the new window and finally select the Saisinuc_2022.ico file (this file is located in the same folder as the SAISINUC program). For a visual guide the user can refer to the Figure 5.

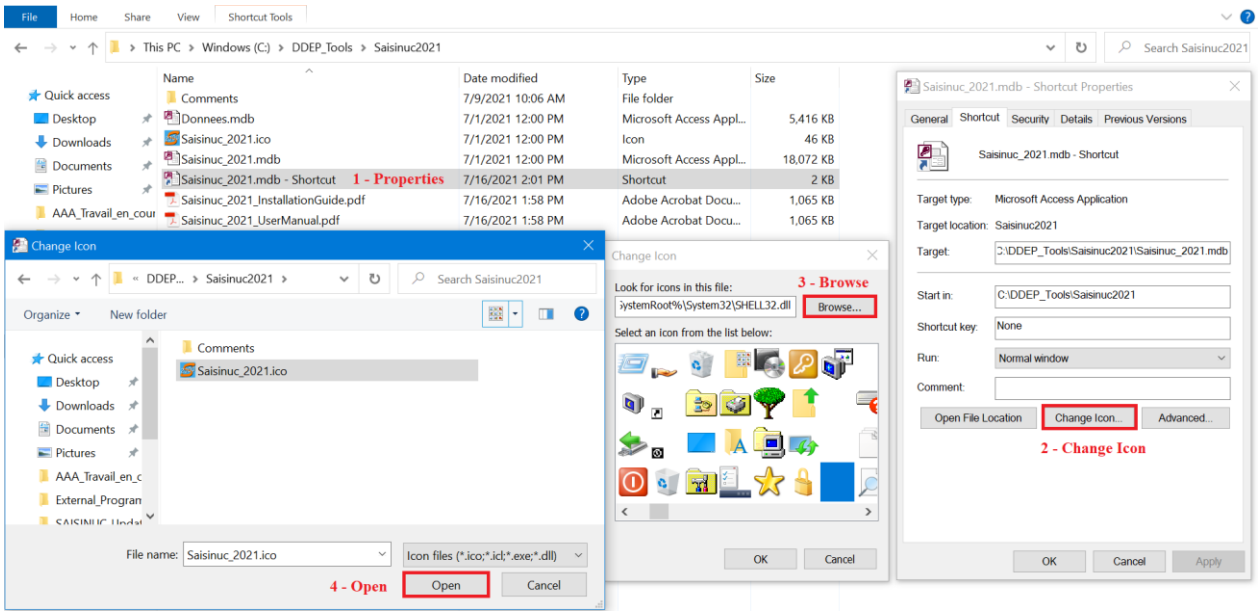


Figure 5: Defining a new icon for the shortcut

SAISINUC 2022 is now ready to use. As detailed in section 1.3, SAISINUC requires to be configured to use a specific database (usually named Donnees.mdb). A clean database (containing an example for each decay type) is provided during the installation process but a new one can be downloaded at anytime from the Tools for evaluators' webpage.

1.2.3 External programs

Once Microsoft Access 2000 and SAISINUC 2022 software have been installed, the user can start working on evaluations with SAISINUC. However, several external programs are mandatory in order to be able to perform some of the calculations required for an evaluation. These programs are however not necessary for accessing evaluation data. The list of all external programs is given below:

- ALPHAD_RadD
- AME2020
- BetaShape
- BrIcc
- Emission

In this section, a simple installation guide is provided for these external programs. Even if it is not mandatory, it is recommended to install all these programs in a dedicated directory, similar to the one used for SAISINUC.
In this guide, the tools are installed in the C:\DDEP_Tools\External_Programs\ directory. For each external program it is recommended to use a different subdirectory (named according to the program's name).

General case

Similarly to SAISINUC_2022.mdb, some of the external programs are already compiled and do not require any specific additional installation process. For such external programs, the users just need to download the executables from the Tools for evaluators' webpage and copy them in the directory of their choice. Later on, the program can be run from the provided executable.

The list of external programs requiring only a simple copy to a new folder is given below:

- ALPHAD_RadD
- AME2020
- BetaShape

For the others, the installation process is detailed below.

BrIcc program

BrIcc is a program mainly written by T. Kibédi. When no experimental data are available, DDEP recommends using the BrIcc software to evaluate the coefficients for internal conversion transitions. To simplify the evaluation process, a dedicated version has been developed for SAISINUC and provides an integrated way to calculate the internal coefficients.

To proceed to the installation of BrIcc within the SAISINUC framework, the requirements are:

- The installer of BrIcc for SAISINUC (BrIccSV23setup.exe)
- The administration rights on the computer

The BrIcc installer can be found on the dedicated Tools for evaluators' webpage. **Be careful,** the latest version of BrIcc available on the ENSDF evaluator tools webpage is not working with SAISINUC, **the users should use** the one provided by DDEP.

The installation of BrIcc is simply performed by executing the BrIcc installer. The user needs to follow all the steps of the installation, most notably by specifying the desired path of installation (C:\DDEP_Tools\External_Programs\BrIcc is recommended). Is also recommended to check the box to add BrICC to the system path (see Figure 6).

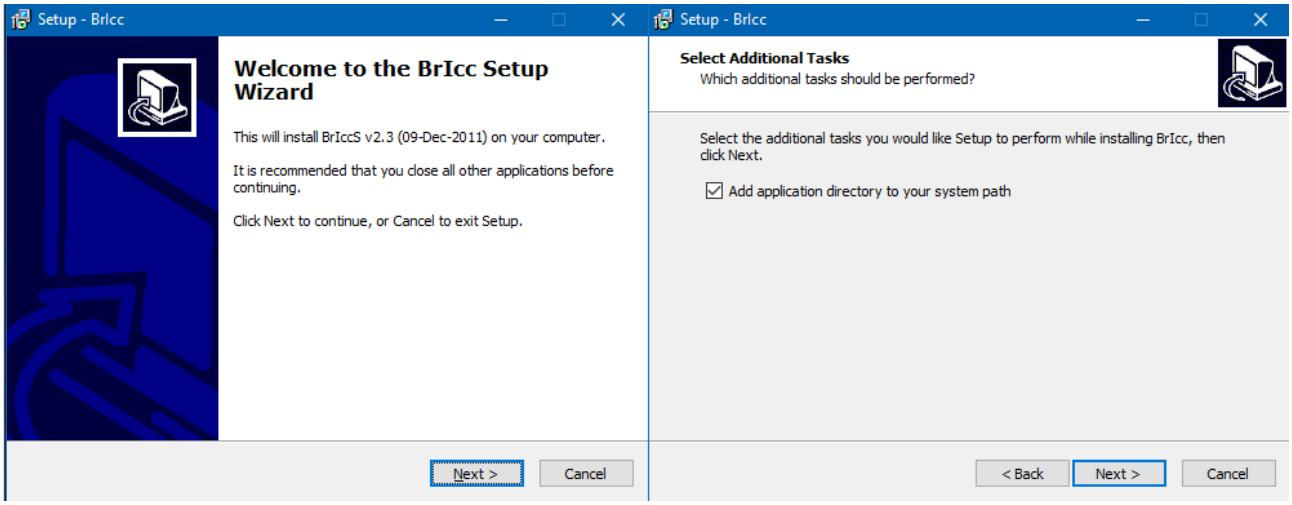


Figure 6: First and last window used during the BrICC installation

Once the installation is finished, the user can find all the BrICC installation files in the specified folder. The code can be directly used in the folder but, in most of the cases, further actions are required to integrate it in SAISINUC. If the user is not using a Windows account with administration rights, it is necessary to set up BrIcc environment variable to be able to use it in SAISINUC. To do so, a detailed explanation is given below for Windows 10.

- On the desktop press “Windows” and the “x” keys of the keyboard. It will open a list as displayed below in Figure 7.

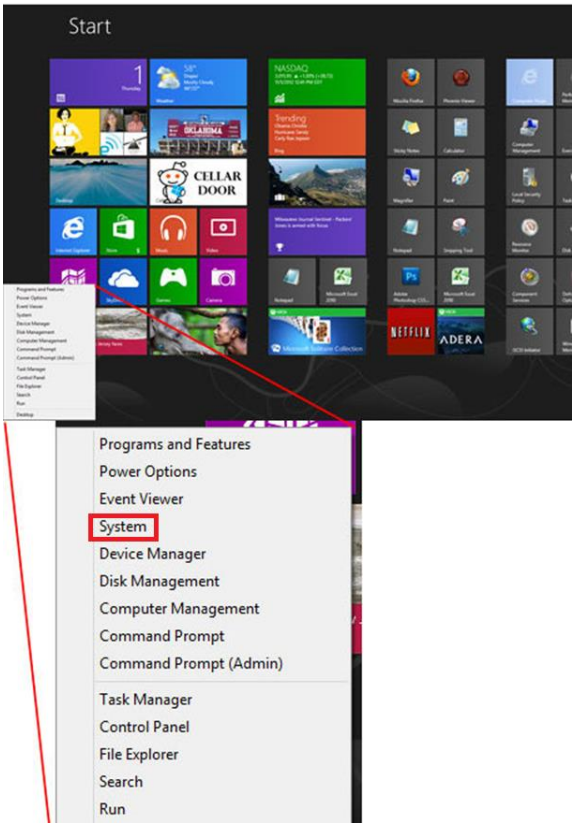


Figure 7: Windows system settings

- Select the *System* option from the list
- Type in the search bar (top left corner) *Edit environment variables for your account* and click on it.
- Create a new Variable called “BrIccHome” with the value equal to the path where BrIcc has been installed. An example is provided in Figure 8.

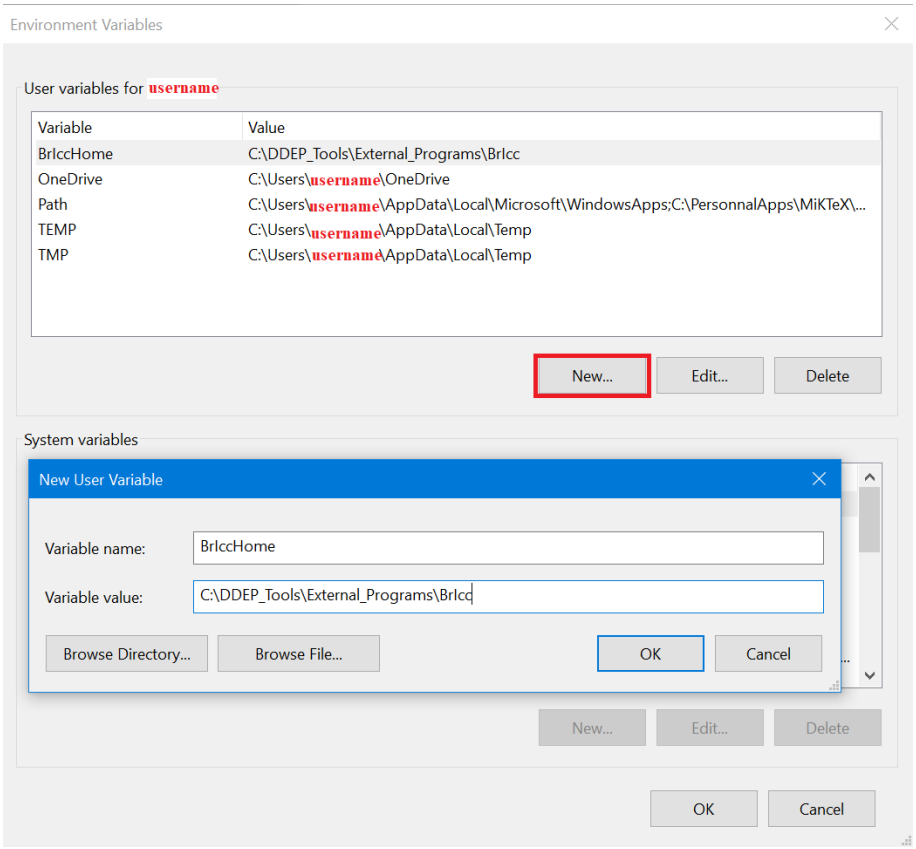


Figure 8: Adding a new environment variable for BrIcc

Emission

Emission, a code written at the PTB, is used in SAISINUC to calculate the X-ray and Auger electron emission probabilities from the atomic vacancies created by the nuclear processes.
The installation is very simple: the source directory “Emission_2013” can be downloaded from the Tools for evaluators’ webpage. To work with SAISINUC it is required to have an executable file entitled *emission.exe* in the folder. The folder already contains two compiled binary files: *emission_32.exe* and *emission_64.exe*, each of them being compiled for different system architecture (32 bits and 64 bits). One just have to copy the suitable file (depending on the system used to run SAISINUC) and rename it *emission.exe*. In case of a doubt, most recent computers are using 64-bit architecture. An example of the *Emission_2013* folder and how to handle the files inside is presented in Figure 9.

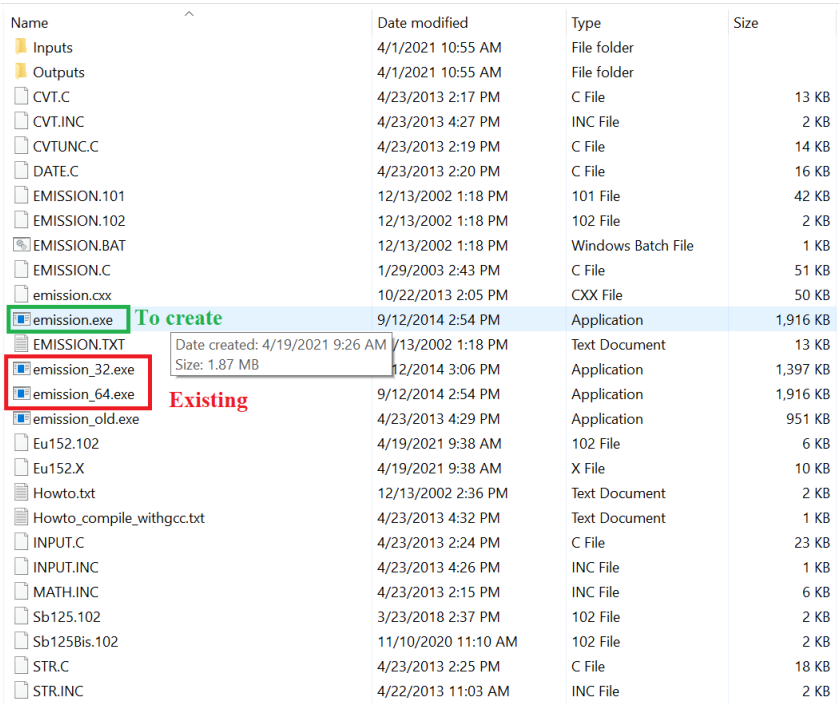


Figure 9: Emission software folder

1.3 SAISINUC configuration

Once all the external software programs have been installed, SAISINUC needs to be configured in order to specify the location of the external programs:

- Open SAISINUC
- Click on *External Programs* at the bottom right of the main window
- For each software, specify the installation path (an example is given in Figure 10)

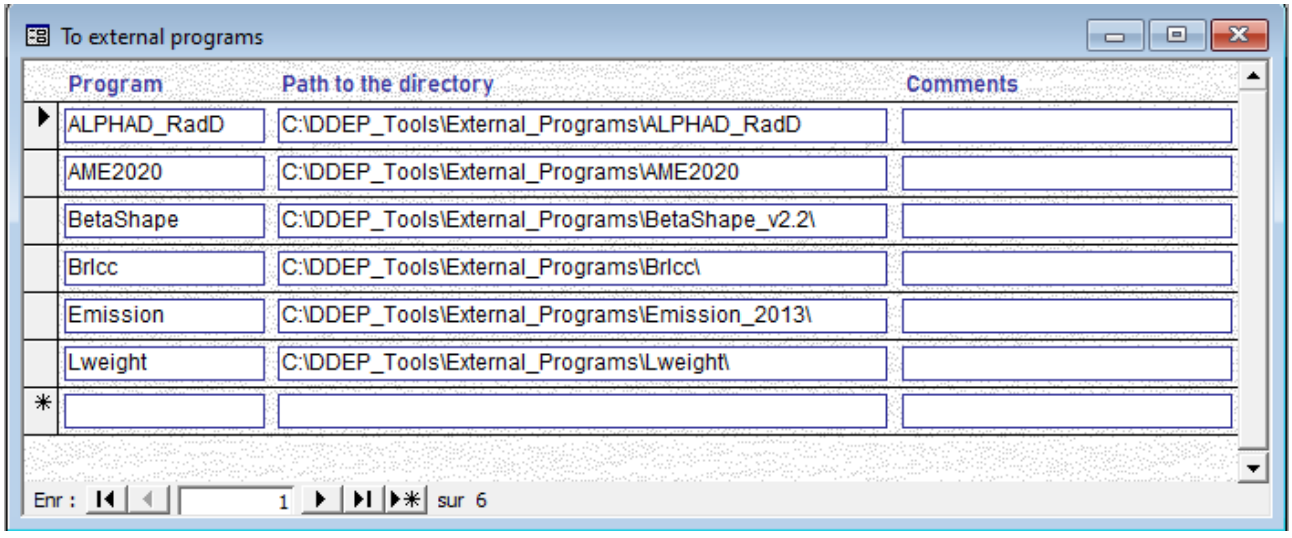


Figure 10 : SAISINUC external programs configuration

2 Completing an evaluation with SAISINUC step by step

This section describes briefly how to perform a DDEP evaluation using SAISINUC. As each evaluation is unique, it does not cover all the possible cases but rather focuses on the main steps of an evaluation. The guide has been written in order to help the user to finalize an evaluation using the SAISINUC software. In particular, an effort is made to specify the correct order in which the evaluated data should be entered in SAISINUC and how mistakes can be avoided. For more details on each function, the reader should refer to the third section of the guide.

Important note: As mentioned previously, it is critical to understand that the evaluation process using SAISINUC **requires** to be performed in a specific order. Several calculations depend on data provided by the user and will fail or will be incorrect if performed with an incomplete dataset. It is thus strongly advised to follow closely the procedure guide to avoid any problem. If at any point a user has to update the data at a given step, it is likely that the rest of the following steps have to be updated as well. For example, modifying the shell scheme level of a daughter nucleus will impact most of the following emissions.

2.1 General procedure on decay data evaluation

The general key ideas of a decay data evaluation are described in this section. For more details on how to evaluate data, the user can refer to the various publications, training and workshops performed by the DDEP collaboration. Some guidelines can also be found in the *Introduction to the Table of Radionuclides* available on the LNHB website.

The evaluation are generally sequentially performed in three steps: general decay properties, nuclear decay properties and finally atomic decay properties. The main idea is that the general properties of the decay are necessary to define properly the nuclear transitions of the decay, which are themselves mandatory to calculate the atomic emissions (which depends on the number and the type of vacancies in the atomic shell of the nucleus).

2.1.1 General information

To start the evaluation, it is first necessary to define a series of properties of the decay. In particular, it is critical to define the parent nucleus, the various decay modes and associated daughter nuclei. The branching ratios between the decay modes need to be evaluated and specified. Then, for each decay mode, it is necessary to define the Q-values and the properties (spin-parity and energy). of the nuclear levels of the daughter nucleus. Generally, the Q-value is calculated from the latest *Atomic Mass Evaluation* and the nuclear level properties from the ENSDF evaluation. However, in some cases, the evaluation can be performed by DDEP evaluator to include the latest measurements.

2.1.2 Properties of nuclear transitions

Once the general properties of the decay have been defined, the various nuclear transitions can be investigated. The first step is to define the decay scheme and the associated transitions (alpha, beta or gamma). The energy of these transitions, and the associated emissions, are automatically calculated based on the level properties previously defined.

Then, for each emission, the intensity probability needs to be evaluated. The evaluator should be careful to recommend a consistent and complete decay scheme as these emission intensities are correlated with each other. Usually, absolute intensity measurements are available for different type of nuclear emission (alpha, beta or gamma). In such case, the evaluator has to decide which transitions will be used to obtain a consistent decay scheme. Traditionally, the gamma emission intensities are preferred since the associated uncertainty are generally lower, but the DDEP evaluator might want to use the alpha emission intensities or the beta emission intensities in some cases. It is also possible to

make a weighted average of the different emissions after having properly propagated the associated uncertainties.

Once the emission intensities have been evaluated, nuclear transition intensities are directly calculated by SAISINUC. To complete the nuclear properties, some of them need to be calculated using external codes:

- The average energy and the logft of the beta minus, the beta plus and the internal conversion transitions are calculated using the BetaShape code.
- The hindrance factor of the alpha transitions, is calculated by the AlphaD-radD code.
- The internal conversion coefficients of the gamma transitions are calculated using the BrIcc code. It is recommended to compare the results to measurements if available. In case of a mixing of several polarities for one transition, the mixing ratio needs to be evaluated. If no measurement are available, a default value can be provided by BrIcc based on the multipolarity mixing considered.

2.1.3 Properties of atomic transitions

Once the nuclear transition data have been filled, the atomic transitions can be evaluated. It is critical to make sure beforehand that both the internal conversion and the electron capture have been estimated properly.

The fluorescence yields are usually taken from *E. Schönfeld et al, NIM A369 (1996) 257-533*, but the evaluator might modify these values if he wants to include more recent evaluated values. The X-ray (corresponding to the K-shell and L-shell) energies are both taken from atomic tables. The energy and intensity of the Auger electrons, as well as the intensity of the X-ray emission, are calculated using the Emission code.

2.2 Evaluation with SAISINUC

This sub-section deals with the procedure to follow in SAISINUC to complete an evaluation. All the possible actions are classified, depending on their importance, in two categories:

- ***Sequential***: the action will produce data which will be used during further calculations and thus must be performed when specified.
- *Independent*: the action is not related to any other actions in the evaluation process and can be performed at any time. Yet, the action is still necessary in order to complete the evaluation.

For simplicity, the guide is split in four independent parts corresponding to the four SAISINUC tabs available from the main menu. In order to help newcomers to identify the important steps of an evaluation, the ***Sequential*** and *Independent* actions are clearly distinguished for each section. The ***Sequential*** actions have been numbered to specify clearly in which order they should be performed. Additionally, to help the reader to identify in which tab/window the action needs be performed, the path to use, relative to the main menu, is given under the tag "Location".

2.2.1 General information

The first step is to create the radioisotope of interest in the database and to provide basic properties regarding the associated decay(s). The physical information provided are used later on to calculate some of the emission characteristics. Additionally, this first step can be an opportunity for the user to provide general information regarding the evaluation.

Sequential actions:

1. Location: *SAISINUC main page - Add new nuclide*
    - Specify element name and mass number
    - Specify if there is any equilibrium or isomeric state

2. Location: *SAISINUC main page / General Information - Scheme*
    - For each decay mode (alpha, beta, gamma…)
        - Specify the branching ratio and associated uncertainty
        - Specify the daughter nucleus
          Tips: The name of the daughter nucleus can be automatically filled by SAISINUC by double-clicking on the corresponding field.

   Important note: If the studied nucleus decays through several modes, most of the actions described in the following sections need to be performed for each daughter nucleus. Therefore, after finishing the previous step, the user needs to process the evaluation as follow:
   Location: *SAISINUC main page / Daughter Choice*
    - Select the daughter corresponding to the first decay mode
        - Proceed to step 3 up to step 11
    - Select the daughter corresponding to the second decay mode
        - Proceed to step 3 up to step 11
    - …

3. Location: *SAISINUC main page / General Information – Scheme / Levels*
    - Specify the level scheme of the daughter nucleus
4. Location: *SAISINUC main page / Half-lives, Q / Q*
    - Verify the Q value for the various decay modes. Modify the value if necessary.
      Tips: The Q-values are automatically calculated by SAISINUC at the creation of each decay mode using the latest Atomic Mass Evaluation available. When editing an old evaluation, one should be careful that the Q-value has been correctly updated using the latest mass evaluation.

Independent actions:
- Location: *SAISINUC main page / General Information - Scheme*
    - Specify the authors of the evaluation and associated affiliation
    - Specify the publication reference of the evaluation if any
    - Specify the half-life, uncertainty and associated unit
- Location: *SAISINUC main page / General Information - Scheme / Production*
    - Specify the main production modes
- Location: *SAISINUC main page / General Information - Scheme / Reference*
    - Specify the list of references used for this work
        - Tips: To increase productivity and save time, it is advised to use the import option.
- Location: *SAISINUC main page / General Information - Scheme / Fission*
    - Specify the number of neutrons per decay

2.2.2 Nuclear data

Once the basic decay properties have been defined, the user can start to work on the different emissions of the decay. It is important that the user completes first all the nuclear processes as they create vacancies in the electronic shells and thus, are necessary for the calculation of the atomic processes. The possible nuclear processes are: gamma emissions, beta / conversion electron emissions and alpha emissions. In the following guide, all the nuclear emissions are assumed for the sake of completeness:

Sequential actions:

5. Location: *SAISINUC main page / Electrons / Electron capture*
    - Run BetaShape code and input new values in the database
    - If necessary, modify some of the *Electron capture* parameters using experimental evaluations
    - Specify the nature of each of the transitions.

6. Location: *SAISINUC main page / Electrons / β^+*
    - If necessary, modify some of the β^+ parameters using experimental evaluations
    - Specify the nature of each of the transitions (be careful to be consistent with other electronic emissions).

    Note: The fields of the β^+ table are automatically updated when running BetaShape from the Electron capture table
7. Location: *SAISINUC main page / Electrons / β^-*
    - Run BetaShape code and input new values in the database
    - If necessary, modify some of the parameters using experimental evaluations
    - Specify the nature of each of the transitions (be careful to be consistent with other electronic emissions).
8. Location: *SAISINUC main page / Photons / Gamma*
    - For each gamma transition perform the following steps in the given order
        a. Specify initial and final level
        b. Specify number of photons per decay (or alternatively specify the relative intensity)
        c. If necessary correct the Multipolarity value proposed by SAISINUC
           Note: To recover the SAISINUC value, use the Button *Reset Multipolarity*
        d. In case of a mixture
            - Specify the mixing ratio
            - Specify the mixing ratio sign
            - Verify the calculated ratio by SAISINUC
        e. Run BrIcc calculation for the internal coefficients
        f. Run the conversion electron calculation
9. Location: *SAISINUC main page / Electrons / Conversion electron*
    - For each gamma transition
        - Verify that the conversion electrons have been calculated (from the previous step 8.f)

Independent actions:

- Location: *SAISINUC main page / Alpha*
    - For each alpha emission
        - Specify the initial and final level
        - Specify the mean energy and associated uncertainty
        - Specify the number of alphas per decay

          Note: The transition energy is automatically calculated by SAISINUC
    - Run alphaD-RadD to deduce the hindrance factor

2.2.3 Atomic data

Once the electronic vacancies created by the nuclear processes have been estimated, the user can work on the atomic processes.

Sequential actions:

10. Location: *SAISINUC main page / Photons / X_K*
    - Calculate the energy of each emission by using *Update of Energies* button
    - Modify energies according to experimental data if necessary
    - Use *Execute emission* button to calculate emission intensities
    - Modify intensities according to experimental data if necessary
11. Location: *SAISINUC main page / Photons / X_L*
    - Calculate the energy of each emission by using *Update of Energies* button
    - Modify energies according to experimental data if necessary

Note: The emission intensities should be calculated by running the *Emission code* during the step 10. If it is not available go back to *SAISINUC main page / Photons / X_K* and run again the *Execute Emission* button

2.2.4 Verifications

Once all the previous actions (critical and independent) have been performed, the evaluation is complete regarding SAISINUC database. Before submitting the evaluation, it is strongly recommended to check the data consistency. In particular, one should verify if the data has been entered correctly for:

- Half-life
- Q-value(s)
- Level scheme of daughter(s)
- Electron emissions & energies
- Gamma energies & intensities

Using the SAISINUC tools, the user can perform additional verifications. The most commonly used are:

- Decay rate summation
- Energy combination
- Intensities summation

2.3 Editing/updating an existing evaluation

When a user wants to update / correct / edit an existing evaluation, he has to take additional caution not to produce incoherent data. As mentioned previously many calculations are dependent on the input data of specific tables.

In general, update procedures are rather complicated, time consuming, and are very similar to make a new evaluation. Therefore, an update should be performed for specific cases for which only few entries need to be modified. This is typically the case when a new precise measurement has been performed for the half-life or when a typographic mistake has been discovered in a published evaluation. For cases in which several tables have to be updated, it is recommended to make a new evaluation.

Generally, if a user modifies one of the ***Sequential*** actions mentioned above, he has to remake all the following ***Sequential*** actions described in the guide. In case of a doubt, the user is encouraged to contact the LNHB team.

It is common that old evaluations were performed without using some of the modern external program (such as BrIcc or BetaShape). When updating such kind of dataset, the calculated information (intensities, energy, logft…) usually have to be updated using the recommended procedure of DDEP.

Finally, when performing an update, the user has to be careful about which daughter level scheme and which references are considered for the update. In case of a correction of a table, it is usually recommended not to include newest publication in order to have consistency between the cut off date of the information available in other tables.

3 Software overview

This section is dedicated to the description of all the different components of the SAISINUC software. A clear description of each component, function or macro is given, as well as the procedure to use it. As a consequence, the section might prove to be a bit tedious to read in one go and should be used as a reference to learn how to use a specific function.

The section is divided in four independents sub-sections each addressing different categories of the software as displayed in the Figure 11.

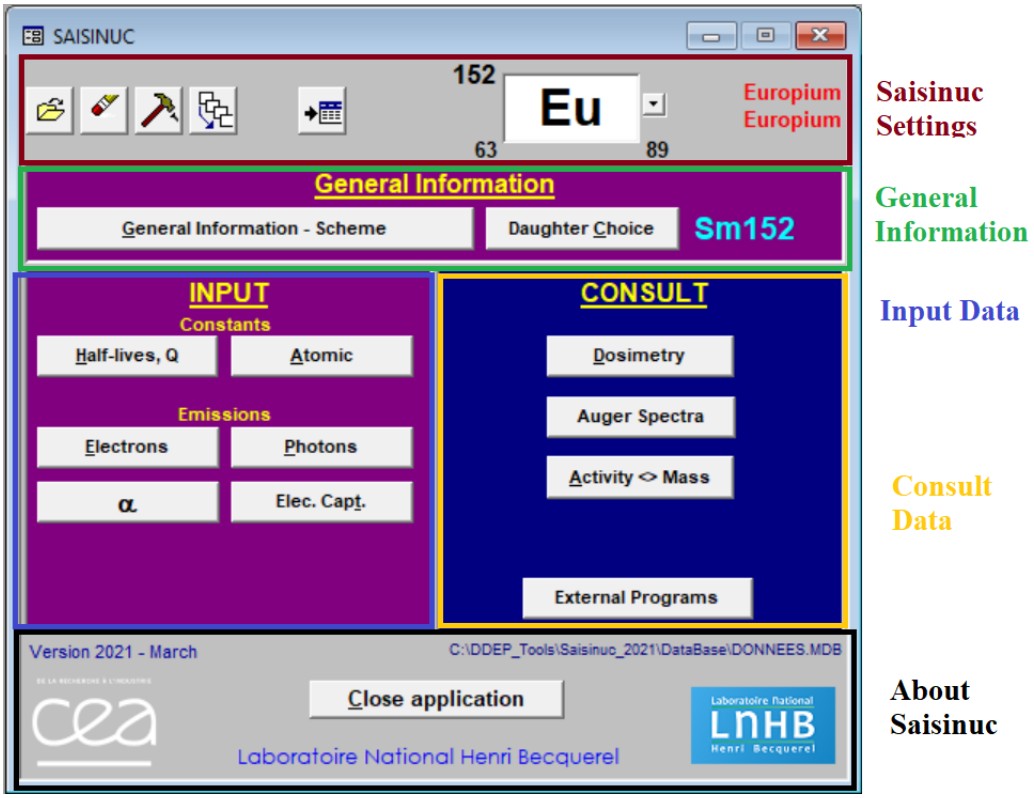
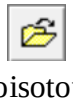


Figure 11 : SAISINUC Software main window

General note: All windows and panels of SAISINUC, provide a simple way to come back to the previous window by using the exit button. 

3.1 Settings

SAISINUC settings panel is available at the top of the main window of the program. The panel is mainly dedicated to the creation, edition and suppression of radioisotope in the database. Several options are available:

- ***Add new nuclide*** 
  Create a new radioisotope in the database. A new window opens in which the user can specify the name or the symbol of the element, the number of nucleons, and if the radioisotope is in equilibrium or if the entry is about an isomeric state. Note that the name of the element has to

be selected from the existing database. If the radioisotope already exists, a new entry will not be created.

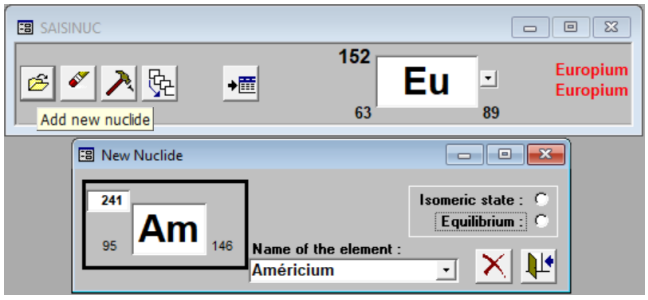


Figure 12: Radioisotope creation in SAISINUC

- ***Suppress a nuclide*** 
  Suppress the current/selected radioisotope. A confirmation window will open before suppression.

- ***Test of the data*** 
  Open a new window in which a large variety of tools is provided to the user to test the data consistency of the current radioisotope (see Figure 13). Most of these tools are designed to be used once the evaluation is finished, as a final verification before publication. In most cases, an option to print the verification is available.
  Note: most of the tests are performed for the selected daughter only. If several decay modes are available to the radioisotope, the tests have to be performed for each of them (see section 3.2.2 for more details).

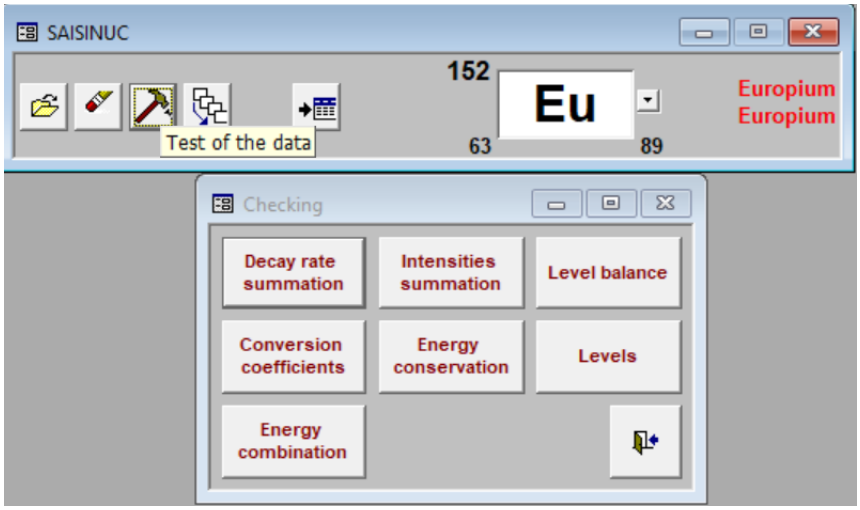


Figure 13 : Test of the data window

  - *Decay rate summation*
    Sum the probabilities of all the decays defined for one radioisotope.
  - *Conversion coefficients*
    List the calculated internal conversion coefficients for all the gamma transitions considered in the daughter. The relative difference between the total conversion coefficient and the sum of the individual conversion coefficients is also provided for each transition.
  - *Energy combination*
    Calculate the energy differences between each pair of levels in the considered daughter. All the possible pairs are listed by increasing energy.

- *Intensities summation*
  For a given daughter the input decay probability is compared to the sum of all the radiations (electron capture, beta and alpha). In order to detect more easily discrepancies, the deviation is given in percent.
- *Energy Conservation*
  A series of tools to investigate the energy conservation in various processes (see Figure 14).

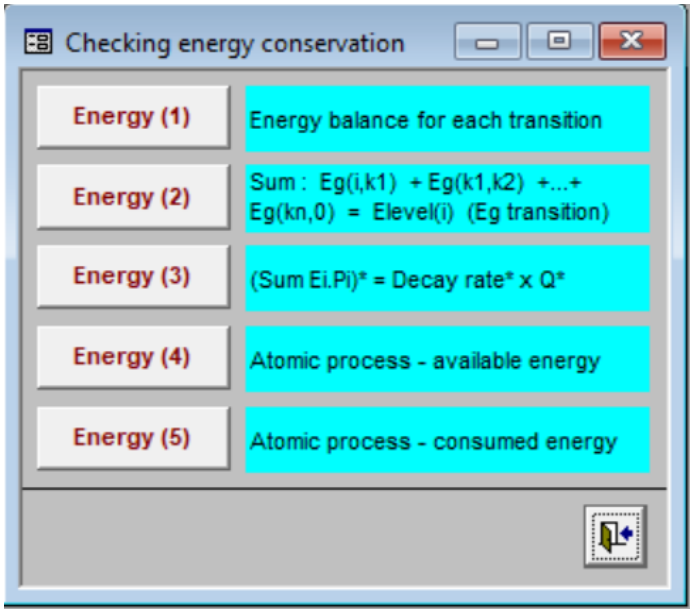


Figure 14: Menu for energy conservation verification

  - *Energy (1)*
    For a given decay mode, and for each type of transitions (beta, EC, alpha…), the energy of the transition is compared to the one calculated from the known Q-value and level scheme.
  - *Energy (2)*
    For a given decay mode, and using the energy level scheme defined for the daughter nucleus, as well as the associated gamma transitions information, all the possible decay paths from an initial state to the ground state of the nuclei are computed. The sum of the energy of all the considered transitions is compared to energy difference between the initial state and the ground state.
  - *Energy (3)*
    For each type of radiations emitted by the daughter, the sum of all the products between the probability and the energy of emission is calculated. The value is compared to the probability of the decay branch multiplied by the associated Q-value. The relative deviation as well as the associated uncertainty are computed.
  - *Energy (4)*
    For a given decay mode, and for each type of atomic electron emissions the products between the probability and the energy of an emission are calculated. The associated uncertainty to the calculation is computed.
  - *Energy (5)*
    For a given decay mode, and for each type of X-ray emissions the sum of the products between the probability and the energy of an emission is calculated. The associated uncertainty to the calculation is computed.
- *Level Balance*
  For each state of one given daughter nucleus, a comparison is made between all the transition intensities originating from the state and all the intensities feeding the state. The associated deviation and uncertainties are computed.

- *Levels*
  List all the nuclear states of the daughter nucleus for a given decay mode.

- ***Data extraction*** 
  Provides different ways to export the data of the current evaluation in different file formats (see Figure 15). Several options are provided:
  - *ENSDF*: export the current evaluation data in a single file using ENSDF 80-columns format. It is necessary to specify the name as well as the path of the output file.
  - *ASCII*: export the current evaluation data using ASCII format. Requires to specify the destination path. Create a folder with the name of the current radioisotope. In the folder are written text files containing all the evaluation information (decay emissions, references, production information…). The emissions (mainly gamma rays and X radiation) specific to the daughter nucleus are written in text files located in sub-folders named accordingly with the daughter nucleus.
  - *ENSDF All:* Export all the evaluations using the ENSDF 80-columns format. This process may take several minutes depending on the size of the database.
  - *GABS*: export the current evaluation data in a single file using the GABS format (ENSDF gamma intensities normalization tool). It is necessary to specify the name as well as the path of the output file.
  - *PENELOPE*: export the current radioisotope decay data in a single file to be used by the PENELOPE simulation code with the PENNUC module. It is necessary to specify the name as well as the path of the output file.

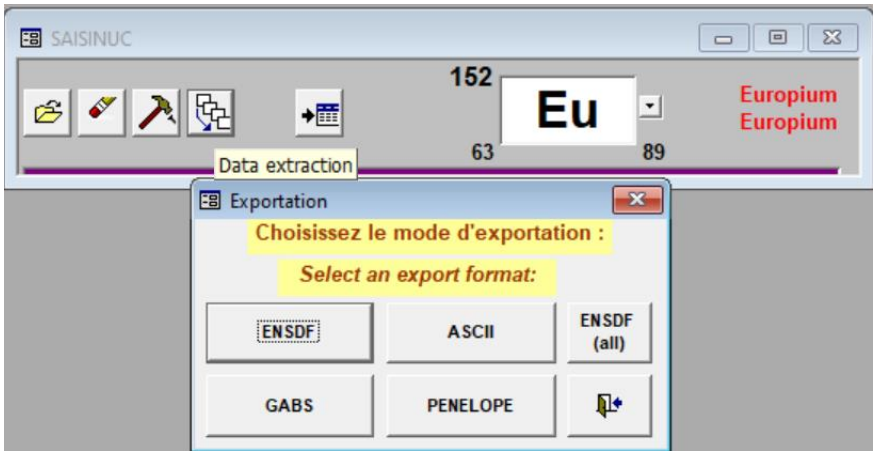


Figure 15: Data extraction with SAISINUC

- ***Access to the data table*** 
  Provides a simple way to specify the database to be read and updated by SAISINUC. Clicking on the *Access to the data table* opens a new window from which several choices can be made (see Figure 16).
  - The file localization can be chosen on a local disk or on a network (remote access).
  - *Option*  opens a new window (see Figure 16) in which the location path (local or network) and the name of the database can be specified using dedicated fields.
  - *Change confirmation*  will load into SAISINUC the database with the name and path specified in the *Option* window. Before loading a confirmation from the user is required.
  - A dedicated field text, below the previous options, is used to specify the current database opened with SAISINUC.
    Important note: To load a new database one has to specify the name and path of the

database in the *Option* window **AND** to confirm the loading by using the *Change confirmation* button.

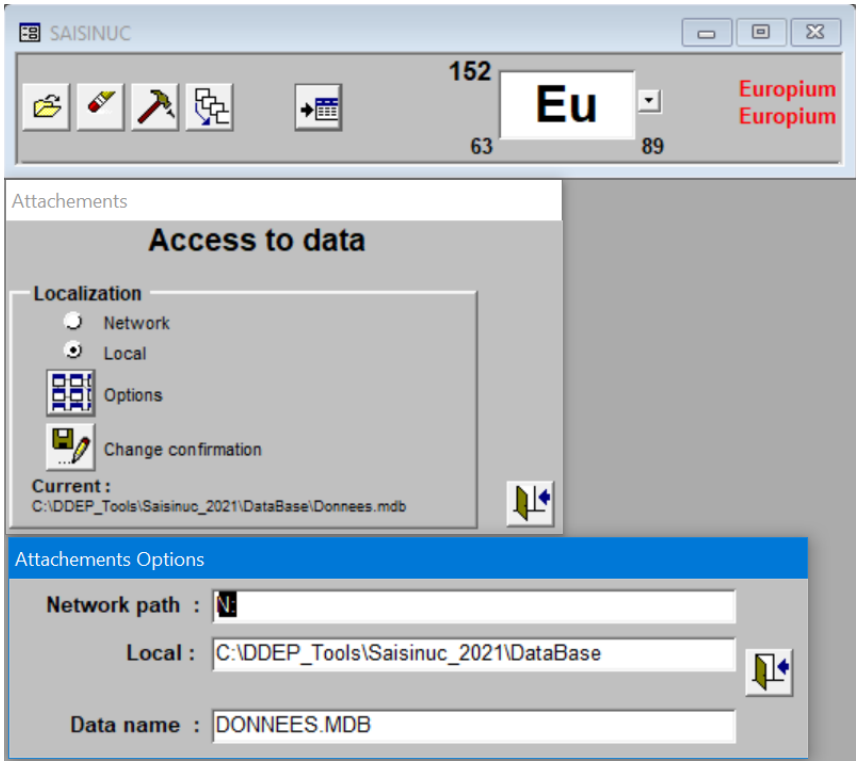


Figure 16: How to specify the SAISINUC database

Lastly, the nucleus of study can be specified using the drop down list on right side of the settings (as displayed in Figure 17). The drop down list displays a table of all entries of the selected database which are classified using: the entry identifier (Symbol of the element + mass number), the English and French name of the element. The entries are ordered alphabetically using the entry identifier.

Note: to simplify the selection of an element, the first letter(s) of one radioisotope can be inputted with the keyboard while scrolling the entries: the cursor will be automatically located on the first entry of the corresponding element.

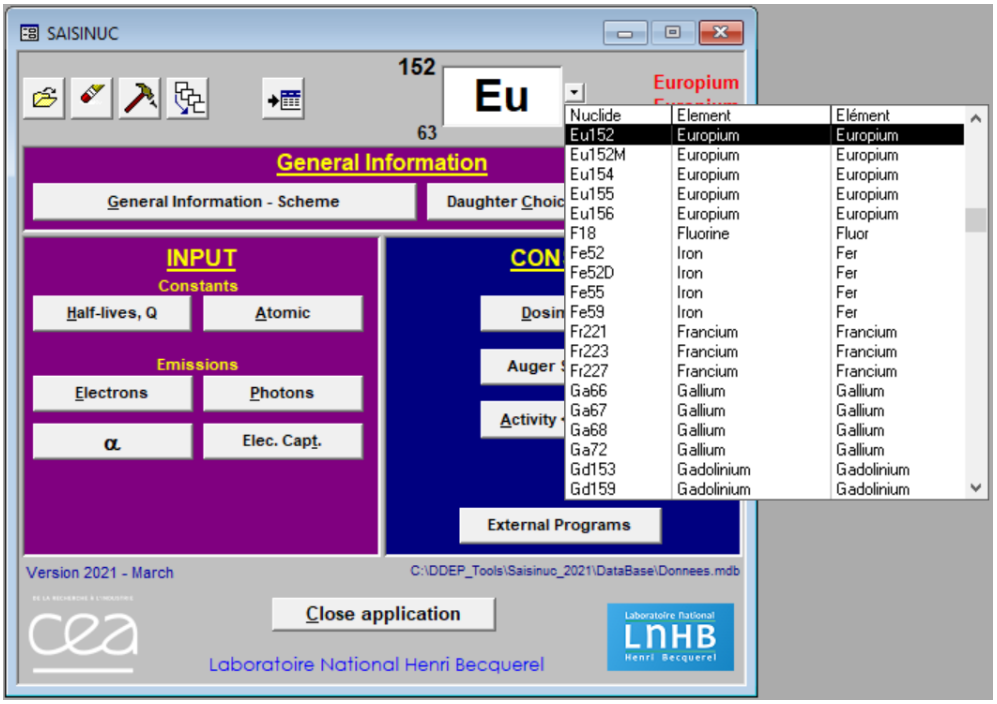


Figure 17: Selection of ^{152}Eu radioisotope in SAISINUC database

3.2 General Information

The *General Information* panel of SAISINUC software addresses the very basic information of the current selected radioisotope (as displayed Figure 18).



Figure 18: General Information menu

The *General Information – Scheme* section contains the following information:

- General details about the evaluation (authors, date, affiliation…)
- Half-life
- decay mode / type and branching ratio
- Daughter nucleus nuclear levels
- Decay level scheme

The *General Information – Daughter Choice* section is used to specify the daughter nucleus if several decay modes are available from the parent nucleus.

3.2.1 General Information – Scheme

The *General Information – Scheme* section contains various types of information that can be categorized in four types (as displayed in Figure 19):

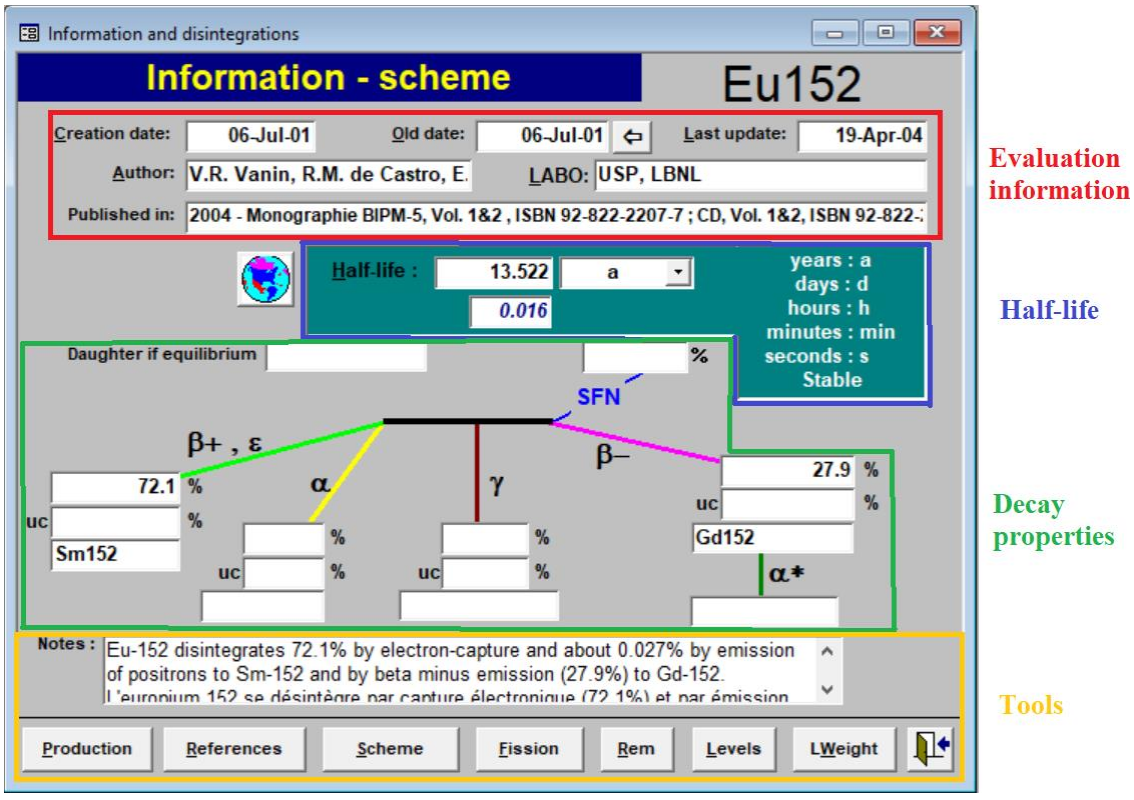


Figure 19: General Information – Scheme window for ^{152}Eu

- *Information about the evaluation*
  These data are for DDEP internal use for the publication in BIPM monography or for online publication
  - Date of creation is automatically filled. To notify an update of the evaluation the user can press the arrow button ⇦ (the changes will be automatically made by SAISINUC using the computer local date). Note: This action cannot be undone and thus should

be performed once all the update modifications are finalized. In case of a mistake, the fields can be modified manually.
    - The authors of the evaluation and the associated affiliation
    - The publication reference of this evaluation (if any)
- *Half-life of the considered radioisotope*
  The upper field is for the estimated value and the lower field for the associated uncertainty. The time scale unit can be chosen using the drop down list ranging from billion of years to microsecond.
- *Decay properties of the radioisotope*
  Up to five different decay modes can be specified: β^+/ε, α, γ (isomeric transition), β^- and fission. The daughter properties can be specified in case of an equilibrium. For each case, the first field (from the top) corresponds to the branching ratio, the second field to the uncertainty associated and finally the third field corresponds to the identifier of the daughter.
  Note: The identifier of the daughter nucleus is automatically filled when a double-click is performed on the field.
- *Tools*
  A collection of tools is available at the bottom of the window to provide additional information on the evaluations:
    - *Production* opens a new window in which the user can specify the main production modes of the radioisotope (as displayed in Figure 20). The reaction (initial nucleus, projectile and emissions) as well as the associated cross-section and the associated uncertainty can be specified in the dedicated fields.

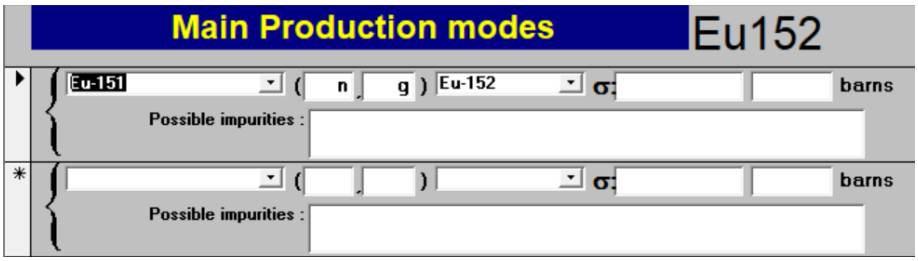


Figure 20: SAISINUC Production Mode window for ^{152}Eu

    - *References* opens a new window in which the user can specify the list of references used for the evaluation (see example in Figure 21). For each reference: the name of the authors and co-authors, the Journal details (name, date, volume, issue, pages…) and comments can be edited. Finally a field to indicate the corresponding NSR key (if any) is available. Both the Journal name and the authors can be automatically searched using SAISINUC internal base. Using the automatic completion is recommended to ensure the homogeneity between evaluations.
      On the bottom of the window three additional options can be used
        - *Journals Management*  provides the possibility to add a journal name to the SAISINUC database. The created journal becomes later on available for automatic completion.
        - *Authors management*  provides the possibility to add an author to the SAISINUC database. The created author becomes later on available for automatic completion.
        - *Import references* 

provides the possibly to automatically fill all the required information about references using a formatted txt file. The file should be formatted one line per reference using the following format: “Authors; Co-authors; Journal Name; Year; Page; Elements; Comments; NSR key”.

Note: once the path has been defined, click **only once** on Import before exiting the window (otherwise the references will be imported many times).

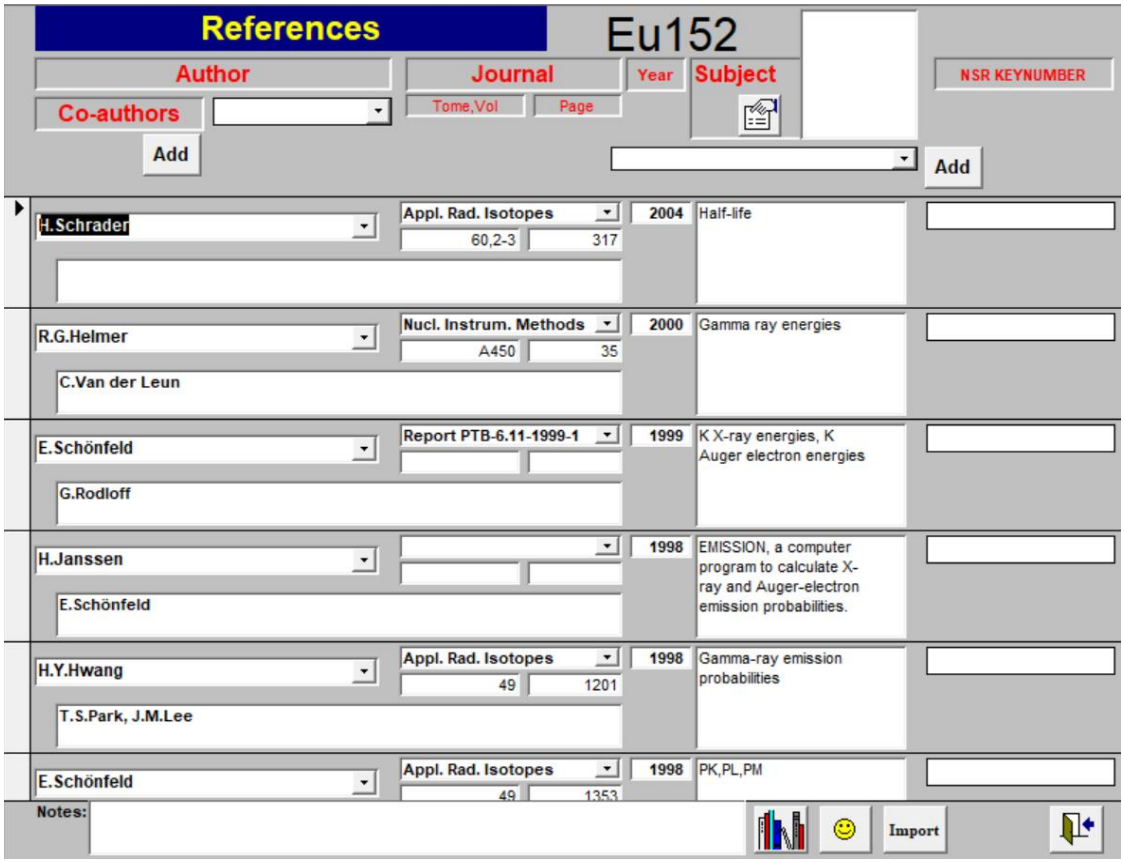
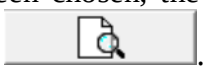


Figure 21: References in SAISINUC for ^{152}Eu

- *Scheme* provides a decay scheme builder in order to reconstruct all the possible emissions occurring during a decay. The decay scheme generated is the one used for the publication of the DDEP tables. A new window opens, summarizing the available decay modes, as well as the associated Q-value and branching ratios (see Figure 22). For each decay mode the number of generated pages is indicated. Before generating the scheme, additional conditions can be applied on the energy and intensity of each emission. To do so, the fields *Thresholds* have to be specified with non zero values: emission with energy or intensity below the values will not be used during the reconstruction of the spectrum. Once the conditions have been chosen, the decay scheme can be generated using the *Display print form button* .
  Important note: The scheme builder is based on the input evaluation and provides reasonable reconstruction only once the evaluation has been completed.
  Once the scheme pages have been generated, a new window opens. The pages can be displayed using the Decay scheme – navigation bar (see Figure 23) by selecting the decay mode and the page number of interest.
  Note: To update the display, it is required to click on the *Display* button

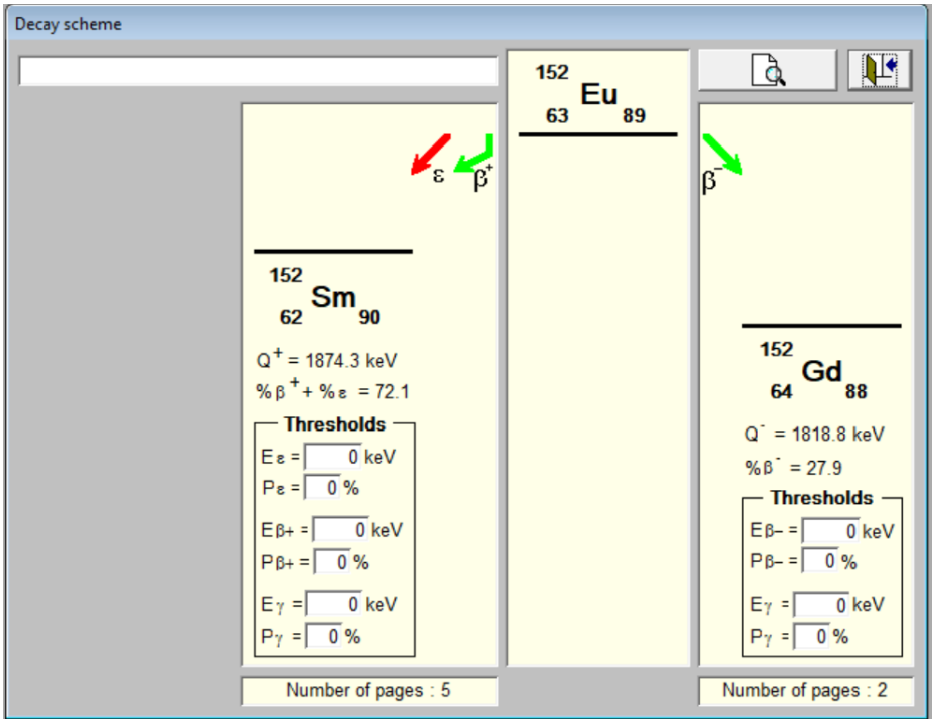


Figure 22: Decay scheme builder for ^{152}Eu

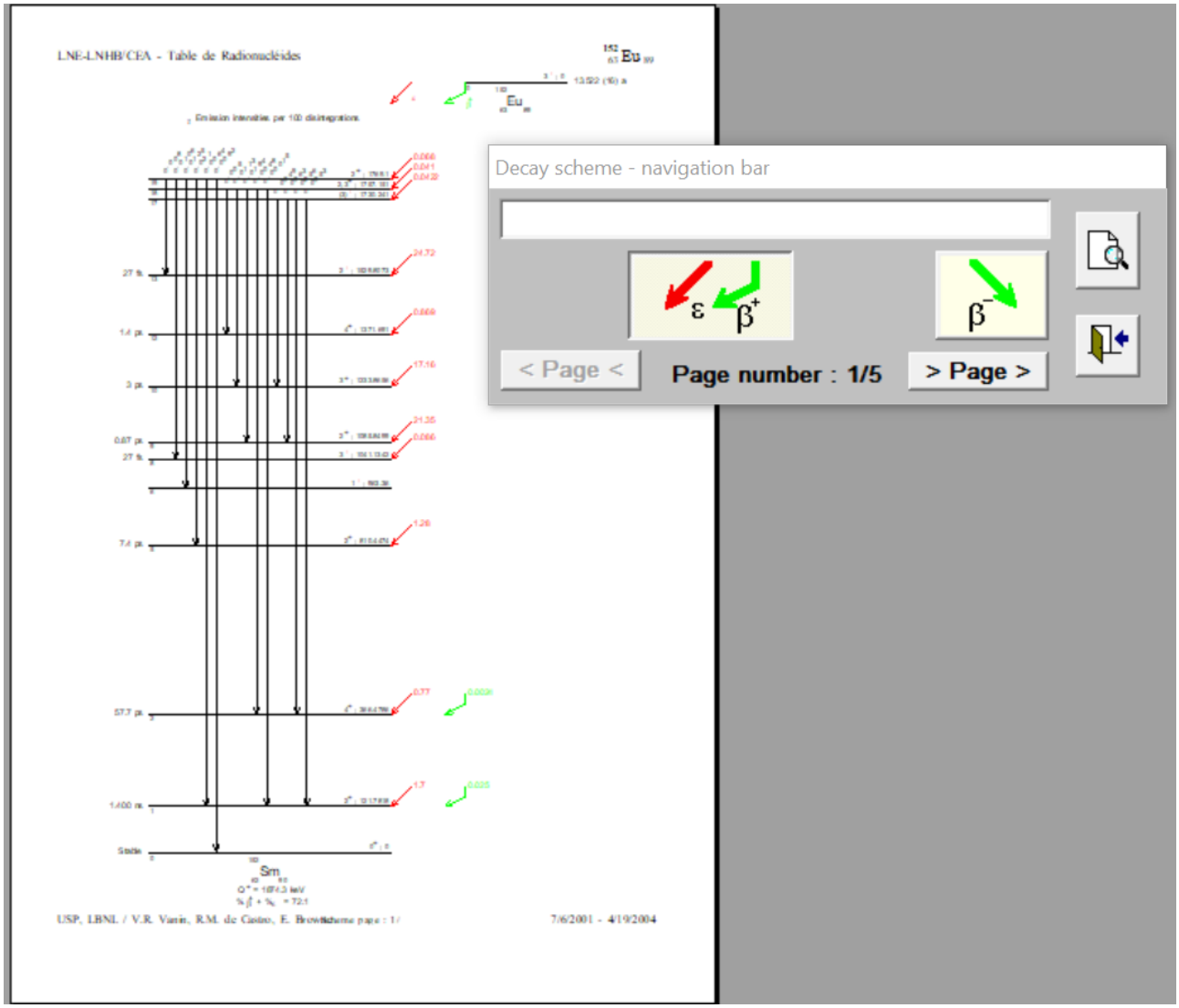


Figure 23 : Navigation bar for ^{152}Eu decay scheme

- *Spontaneous fission details* provides the user the possibility to specify fission neutron yields in case of a spontaneous fission. SAISINUC calculates the number of neutrons per 100 disintegrations using the input average number of neutrons per fission and the probability of spontaneous fission. These values can be inputted in dedicated fields with the new window as displayed in Figure 24.

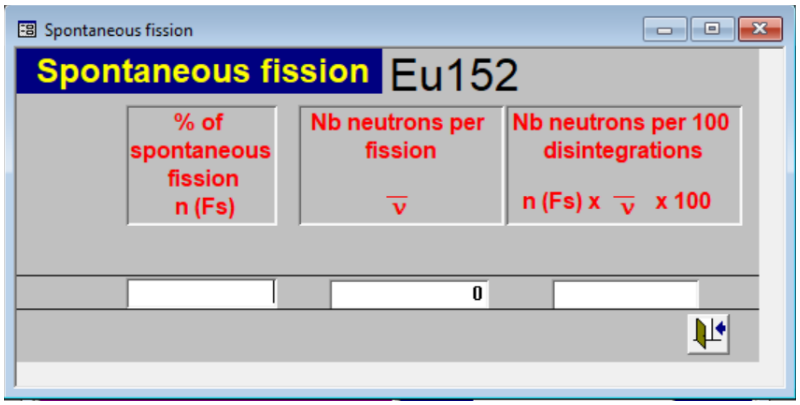


Figure 24 : Spontaneous fission specification

- *Comments on evaluation* (*Rem* button) opens the comment file (PDF format) associated with the selected nucleus (if there is any) in the SAISINUC directory. This function has little interest for most of the users and is mainly useful during the final LNHB verifications.
- *Levels* provides the possibility for the user to specify the levels scheme of the decay. In the case of the parent nucleus, only the initial state of the decay is required. Regarding the daughter nuclei (from different decay modes), all the levels that are directly or indirectly populated are required. For each level, various information can be specified: total angular momentum, parity, level index, energy of the level and associated uncertainty, half-life of the level and associated uncertainty (see Figure 25). Some of these parameters are mandatory and some others are not:
  - *Total angular momentum* is optional and can be specified with parenthesis when the assignment is not determined with certainty. The spin parity can be changed using the π button.
    Note*: Total angular momentum* will be used to pre-calculate some values such as gamma transitions polarity or beta transition nature.
  - The *level index* is mandatory and very important in SAISINUC as it is used in many emission calculations. The input index should be set according to the following rules: the ground state of a nucleus is defined as level 0; the excited states are numbered by increasing level energy (level index 1 corresponds to the first excited state, level index 2 corresponds to the second excited state…). Each index must be unique.
  - The *Level Energy* is mandatory and should be given in keV units. The top field corresponds to the level energy and the lower field to the associated uncertainty. In the case of the parent nucleus, the value is set by the defined Q-value and cannot be edited from this window.
  - The *Half-life* of the state is optional and can be given using the top field, and the associated uncertainty specified using the field below. The unit can be chosen in the drop down list.

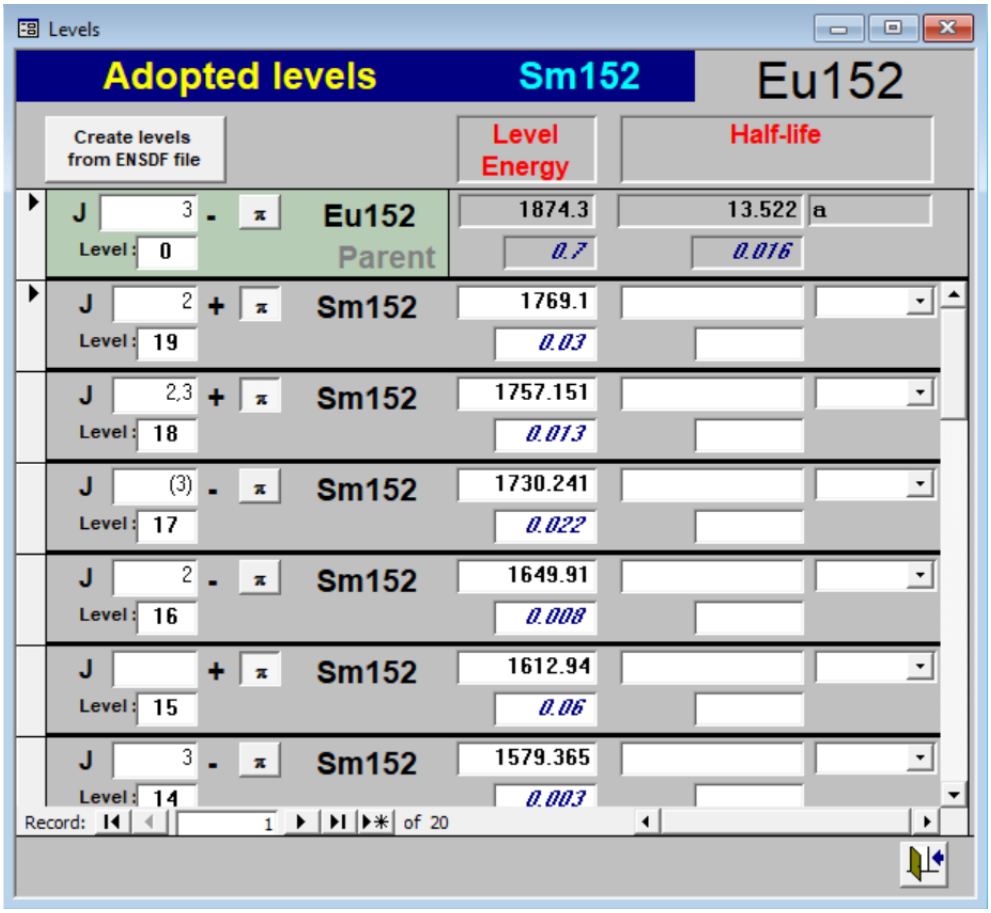


Figure 25 : Level scheme specification for the decay of ^{152}Eu

Important Note: Traditionally the level scheme used by DDEP evaluator is provided by ENSDF. Therefore, a tool has been designed to import automatically the level scheme of ENSDF from a file. The file needs to be formatted using the ENSDF 80 columns format.
Here is an example of the procedure used to obtain the levels involved in the beta minus decay from ^{152}Eu:

1 access the NNDC Nudat chart
2 access the Decay radiation information of the nucleus of interest
3 Download the ENSDF file for the Dataset of interest.

Once the file is downloaded, the import tool can be accessed from the top left button titled *Create levels from ENSDF file*. From the new window (see Figure 26), the name and path to the ENSDF file should be specified. The *Import Levels* button proceeds to the automatic import.

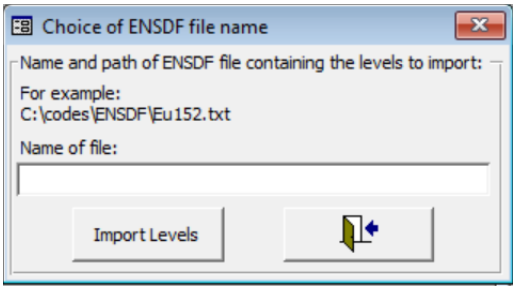


Figure 26: ENSDF level scheme automatic importation

- *Lweight* gives the possibility to process a Lweight calculation from an input file.

Finally, from the Information-scheme additional information and options regarding the evaluation can be accessed using the  button. This tool has been created for LNHB internal tracking and for publication purpose and is not relevant for most of the users. In the dedicated window (see Figure 27), the diffusion of the evaluation through different media can be specified by the user using the check boxes. The language of the evaluation can be also specified by editing the text field. Additionally, the status of the evaluation (available or unavailable) can be specified. Lastly, the evaluation history can be tracked using the  button.

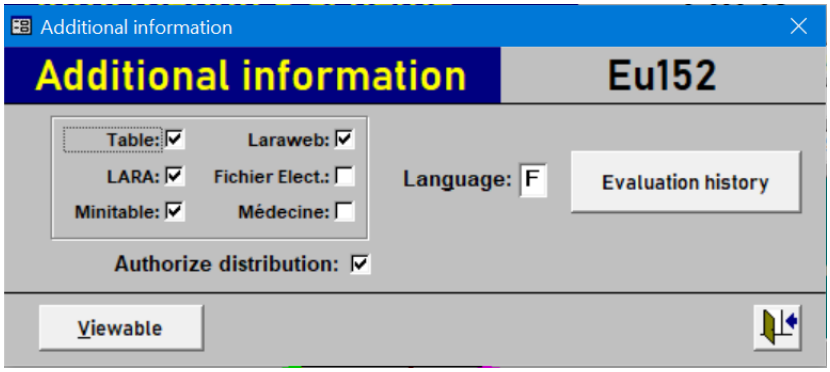


Figure 27: Additional information for ^{152}Eu decay evaluation

3.2.2 Daughter Choice

From the general information panel the second menu, *Daughter Choice* offers the possibility to select the decay mode to work on (see example in Figure 28). The list of all the decay modes defined in the menu *General Information – Scheme* are available. The selection can be performed by clicking on the desired daughter nucleus and then validating with the *OK* button.

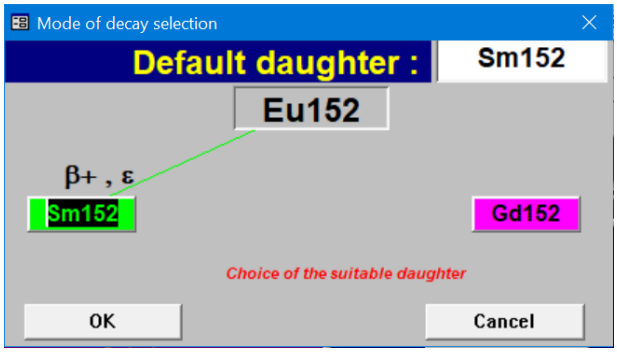


Figure 28: Decay mode selection for ^{152}Eu

3.3 Input data

The *Input Data* panel is the main panel in which the user fills or modifies the decay properties. The data are separated in two different categories: *Constants* and *Emissions*. The *Constants* category contains: half-life, Q-value and atomic parameters. The *Emissions* category is divided in different sub-categories depending on the type of radiation emission: Electrons, Photons (gamma or X), Alpha and Electron Capture.

The menu for the the *Input data* panel is displayed in Figure 29.

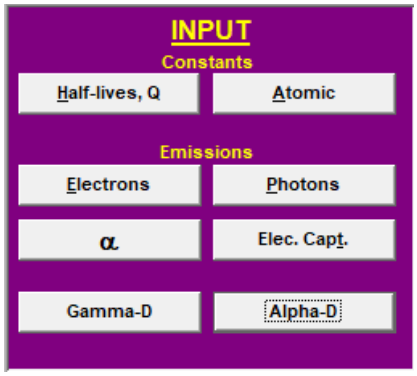


Figure 29: Input menu

In this panel, several pages have a specific button , which displays the data associated with the page in a printable format.

3.3.1 Half-life, Q

The first sub-section of the *Constants* category can be accessed by clicking on *Half-lives, Q* button. The window is dedicated to the half-life of the various nuclei involved in the decay process: both parent and daughter(s). In most cases, only the parent nucleus is radioactive. The value of the half-life, and the associated uncertainty can be specified in the dedicated fields. The time unit can be chosen using the drop down list (see example in Figure 30). If the nucleus is stable, a dedicated time unit *stable* is available.

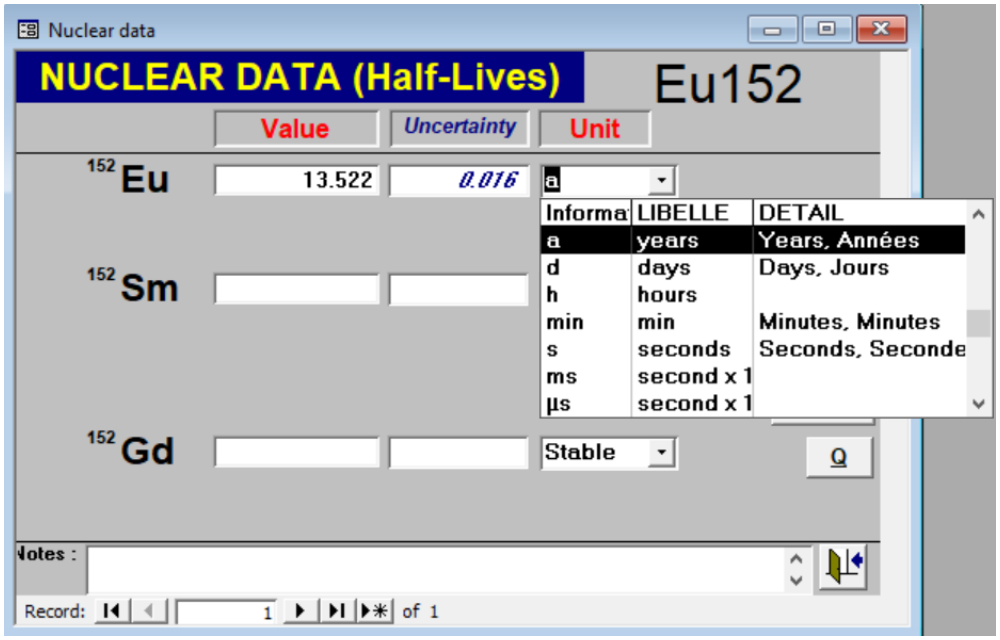


Figure 30: Half-life value of ^{152}Eu

From the same window, it is possible to specify the Q-value associated to the different decay modes with the  button (see example in Figure 31). In this window, each line corresponds to a different decay: the type of decay can be selected from the drop down list, then the value can be specified in the following field as well as the uncertainty and associated unit.

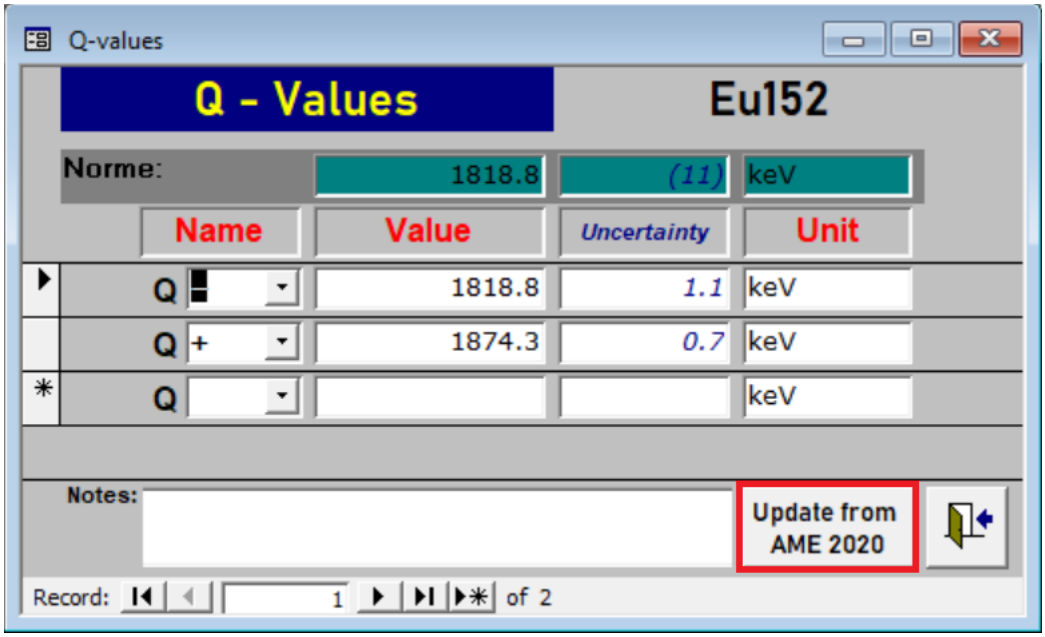
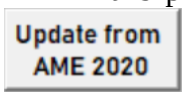


Figure 31: Q-values of the decay of ^{152}Eu.

It is possible to update automatically the Q-value of all decay modes by clicking on the 

button. The calculations will be performed using the recommendations from the AME2020.

3.3.2 Atomic

The second sub-section *Atomic*, corresponds to the fluorescence yields of the daughter nucleus and is automatically filled from SAISINUC database[1]. The default value can be viewed using the *Atomic* button. In the opened window, the user can modify the various fields directly (see for example Figure 32). Yet, for consistency purpose, it is **recommended** to the user to keep the SAISINUC value. The displayed values are the one corresponding to the daughter nucleus of the chosen decay mode.

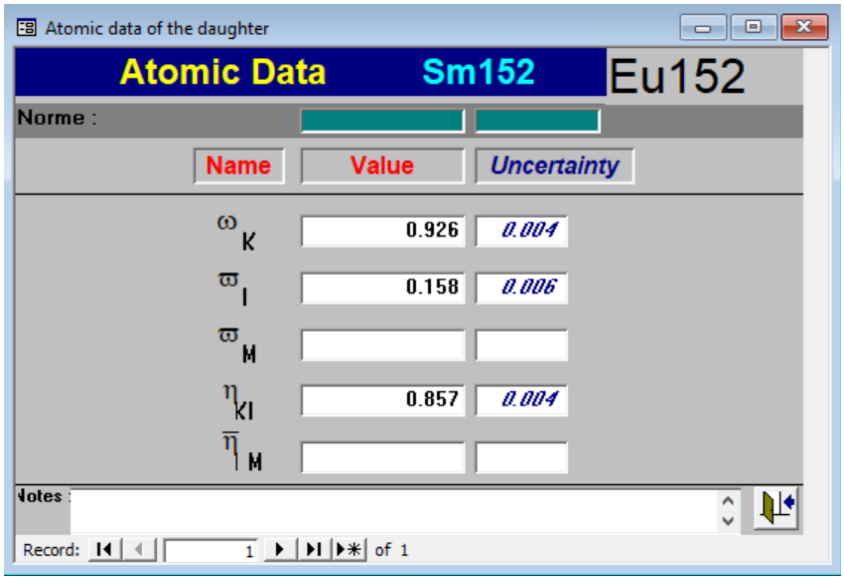


Figure 32 : Atomic parameters for Samarium (from ^{152}Eu decay)

[1] Taken from E. Schönfeld *et al.* NIM A369 (1996) 257-533

3.3.3 Electrons

The first sub-section of the *Emissions* category is the Electron emissions. Depending on the physical process involved, the electrons emitted are separated in different types: Beta electrons (β^+ and β^- are distinguished), Auger electrons and Conversion electrons. When using the *Electrons* Input category, the user is given the choice of the type of electrons emission through a new window. The available types depend on the selected decay mode (see example in Figure 33).

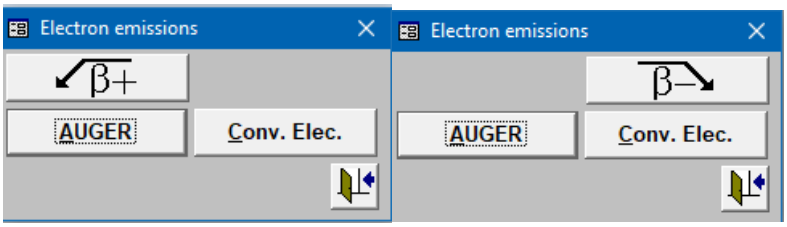


Figure 33: Different types of electron emissions for ^{152}Eu (depending on the chosen decay mode).

- The structure of the Beta panels are identical for β^+ and β^- : each transition is defined in a line of a large table (see Figure 34). From the left, the first two columns correspond to the index of the initial level (parent nucleus) and the index of the final level (daughter nucleus) involved during the electron emission. The third and fourth columns are related to the emission energy: the maximum energy of the emission (and the associated uncertainty) is on the upper field while the average value of the emission energy (and the associated uncertainty) is on the lower field. The remaining fields of the table are from left to right: the number of electrons per decay and its uncertainty, the nature of the Beta transition and finally the associated logft. All these fields can be calculated using the *BetaShape* program which can be accessed by clicking on the bottom right button.
  Note: In case of a β+ decay, the program cannot be launched from this window and will require the user to launch it from the electronic capture window (for more details see section 3.3.6).

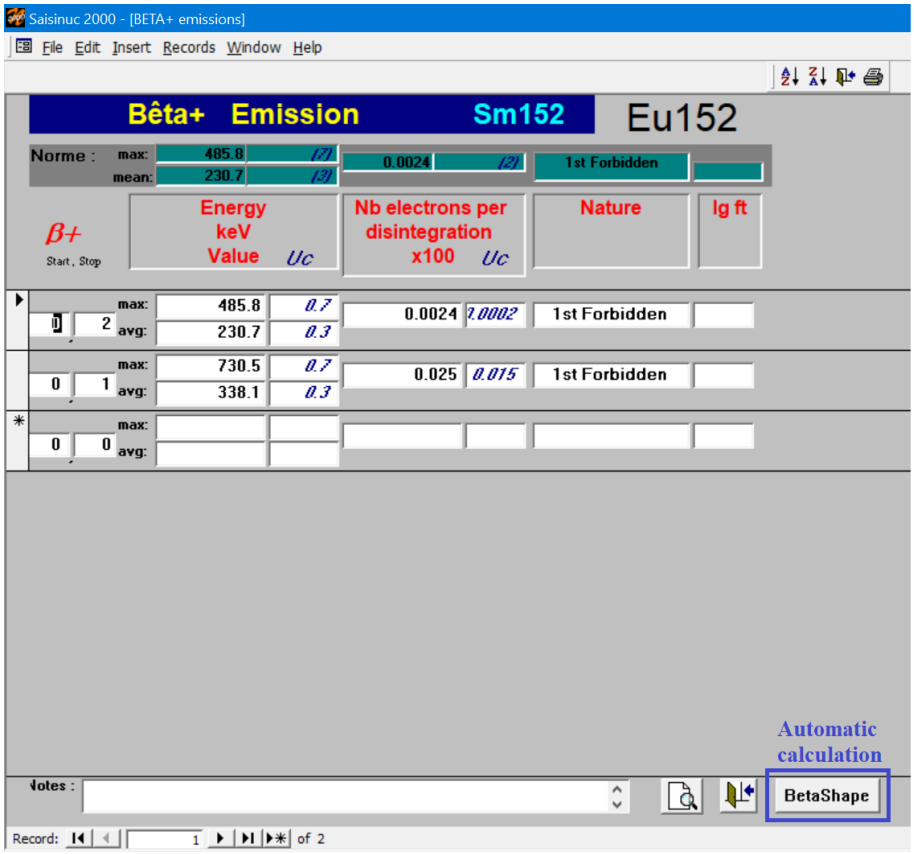


Figure 34: ^{152}Eu electron emission from β^+ decay

- *Auger emissions* are summarized in a single window accessible from the Electron emission menu (see Figure 35). In the table are listed the energy range for the different types of Auger emissions (KLL, KLX, KXY and L), the associated relative probability (relative to KLL), and the number of electrons per disintegration (with the associated uncertainty). All these fields can be modified by the user but are usually calculated by the Emission code.

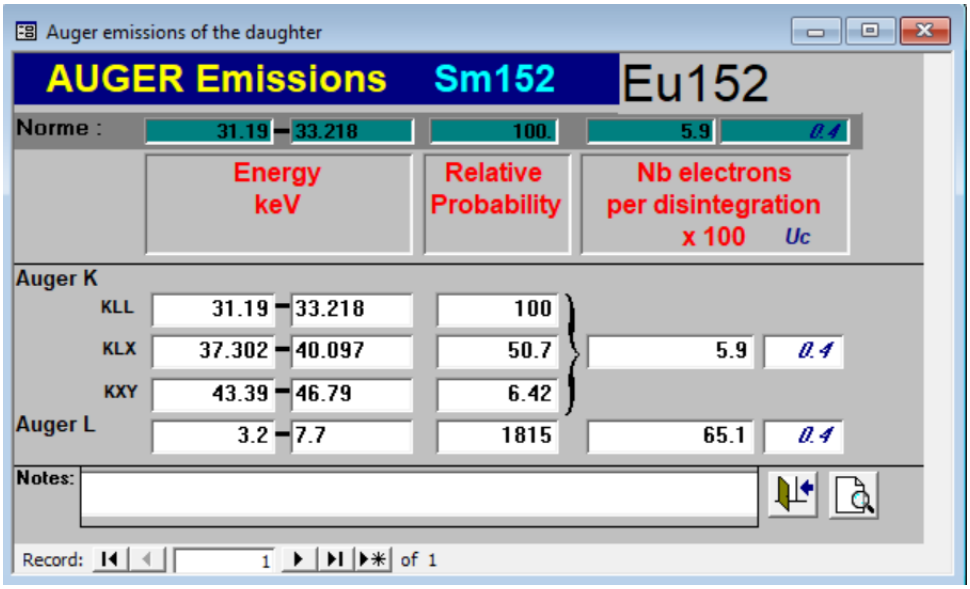


Figure 35: Auger emission of ^{152}Eu decay to ^{152}Sm

- The *Internal conversion electrons* emission can be found in a dedicated window which can be accessed from the Electron emission menu. For each gamma emission defined for the daughter nucleus, a dedicated page is defined (as displayed in Figure 36). On each page the structure is similar. From the left: the first column provides information regarding the corresponding gamma ray (initial and final levels, energy…), the second column provides the energy (and associated uncertainty) observed for the electron emission of the various atomic shells and finally the last column provides the number of electrons per decay (with the associated uncertainty). All these fields can be edited by the user but they can be automatically calculated by SAISINUC from the button *Conversion electron calculation* available in the gamma section (see the section 3.3.4 for more details).

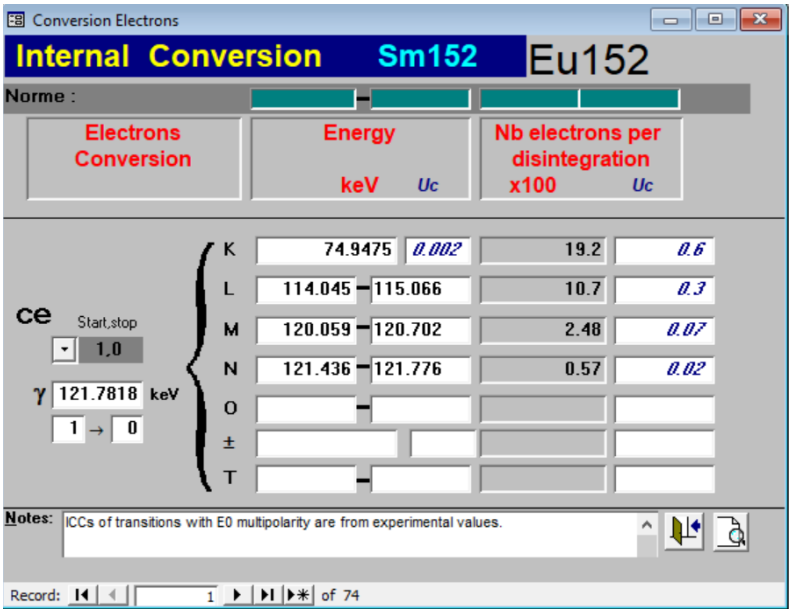


Figure 36 : Internal electron conversion in ^{152}Sm after the decay of ^{152}Eu

3.3.4 Photons

The second sub-section of the *Emissions* category is the *Photons* emissions. Three different categories of emissions are distinguished: gamma, X_K and X_L. Each of them can be accessed using the *Photons* menu (as displayed in Figure 37). Since these properties depend on the daughter nucleus, they have to be filled one by one for all the decay modes.

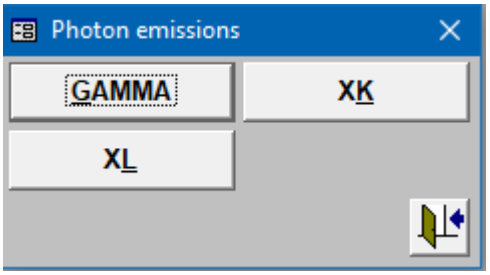


Figure 37: Photon emission menu

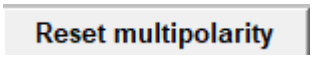
Gamma transition case

- The *GAMMA Emissions* window is composed of a large table containing the various physical properties of all the gamma transitions. In standard mode, the window displays only one single gamma transition (see Figure 38). The user can access to other transitions by using the scroll down bar accessible on the extreme right of the window. For one given gamma transition, the window is organized in a large table which can be divided in different parts as described below:
    - The first row is dedicated to generic information on the transition which are described below from left to right:
        - First and second columns: The initial and final nuclear level index of the daughter nucleus involved in the gamma transition. The fields have to be updated manually by the user in order to define the transition.

            Note: If there is an emission of 511 keV gamma due to electron-positron annihilation, the initial and final levels should be set to -1 ($\gamma_{-1,-1}$). The gamma emission is automatically created if a beta plus emission has been defined.

            Additional note: In case the initial and final levels are not known, the starting level of the transition should be set to -1 and the final to a number higher or equal to 0 ($\gamma_{-1,x}$). The later value (final level) is used as a label to sort the unknown gamma emissions. Therefore, if there is more than one: $\gamma_{-1,0}$ corresponds to the first unknown emission, $\gamma_{-1,1}$ corresponds to the second unknown emission… The indexes are usually assigned by increasing energy order.
        - Third and fourth columns correspond to the energy and associated uncertainty of the emission. The fields are automatically updated by SAISINUC once the initial and final level of the transitions have been defined.
        - The fifth and sixth columns are used to specify the absolute number of gammas observed per decay (in percent) and the associated uncertainty. The values have to be filled by the user manually.
        - The seventh and eighth columns correspond to the transition energy and associated uncertainty. The fields are automatically calculated by SAISINUC taking into account the nucleus recoil energy and cannot be modified by the user.
        - The ninth and tenth columns are used to display the transition probability and the associated uncertainty. The two fields are automatically updated by SAISINUC and cannot be edited by the user.
        - That last column is reserved for relative intensity usage. It should be filled if the user want to use relative intensity between gamma emissions. If so, one of

the transitions relative intensity should be set to 100 and the absolute intensity should be given for this specific transition. For the others transitions only the relative intensity value is required. SAISINUC will automatically calculate the absolute intensities of all transition from the specified information.

- The other three next rows of the table are composed of identical cells dedicated to information regarding the internal conversion coefficients. The cell structure is defined as follow:
  - In red caption the shell corresponding to the internal conversion is specified: K, L (L_1, L_2, L_3), M, N, O, T and π. The T symbol corresponds to the total internal conversion coefficient while the π stands for the pair creation.
  - The value of the internal conversion coefficient (in percent) and the associated uncertainty.
  - The value of the exponent used to express the value of the internal conversion coefficient.
- On the fourth and last row of the table, the two last cells are used to provide information regarding the multipolarity and mixing ratio of the considered transition.
  - The first cell (highlighted in green in Figure 38) is used to specify the multipolarity of the transition. The value is automatically filled by default by SAISINUC using the spin and parity information of the initial and final states. If the user wants to modify the multipolarity, it is recommended to select another value from the drop down list. If necessary, the user can edit manually the text field. To revert the value to the initial estimation of SAISINUC, the user can use the 

button.
  - The second cell is used for the mixing ratio associated with the multipolarity if the transition is mixed. In such case the user needs to provide the additional information (highlighted in orange in Figure 38) :
    - The sign of the mixing ratio if determined experimentally (**+** : positive, **-** : negative, **?** : unknown). The selection has to be performed among the three choices given in the first row of the cell (default is assumed as unknown).
    - Value of the mixing ratio and associated uncertainty (first and second fields of the second row).
    - SAISINUC will automatically calculate the relative component of the transition from the value entered by the user (as highlighted in blue in Figure 38).

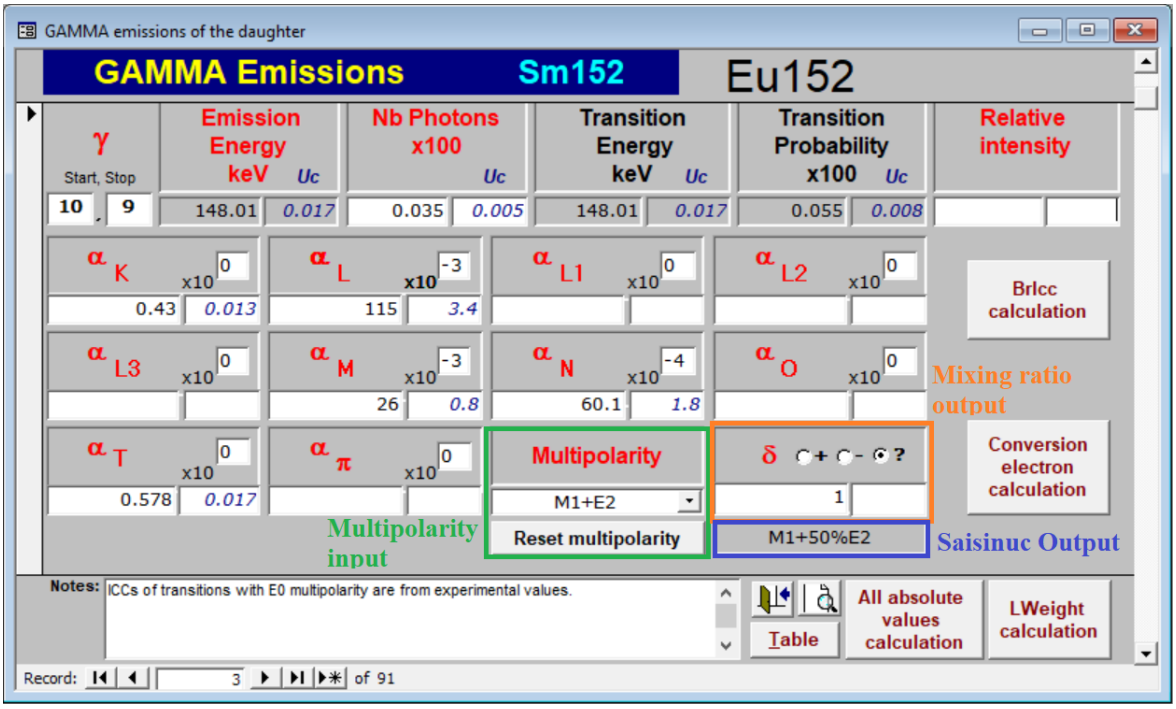
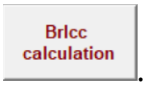
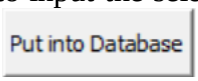


Figure 38: ^{152}Eu decay to ^{152}Sm – 148-keV photon emission properties

The internal coefficients can be specified manually but it is recommended to the user to use the BrIcc software for the estimation. The calculation is directly accessible through SAISINUC using the button 

. When used, the calculation is performed for the current transition and the results are displayed in a new window (see Figure 39). The top part of the window displays the results for each electron shells using two different extrapolation methods. The lower part of the window is providing the user different options to process the data:

- The left part (highlighted in red in Figure 39) provides the user the possibility to choose between interpolation method: *Frozen Orbital* or *No Hole*. It is strongly recommended to use only the default option *Frozen Orbital*.
- The middle part (highlighted in green in Figure 39) is dedicated to the path location for the output text file in which the calculations details are written. File path can be edited directly by the user using the dedicated text field. The file will be written whether the user decided to input, or not, the calculation results in SAISINUC.
  Important note: If ever a file with the same name already exists in the specified directory, it will be replaced.
- The right part can be used to input the selected result in the SAISINUC database. This can be achieved by clicking on the 

button. If the user doesn't want to input the newly calculated internal conversion coefficient, he can simply exit the window using the exit button.

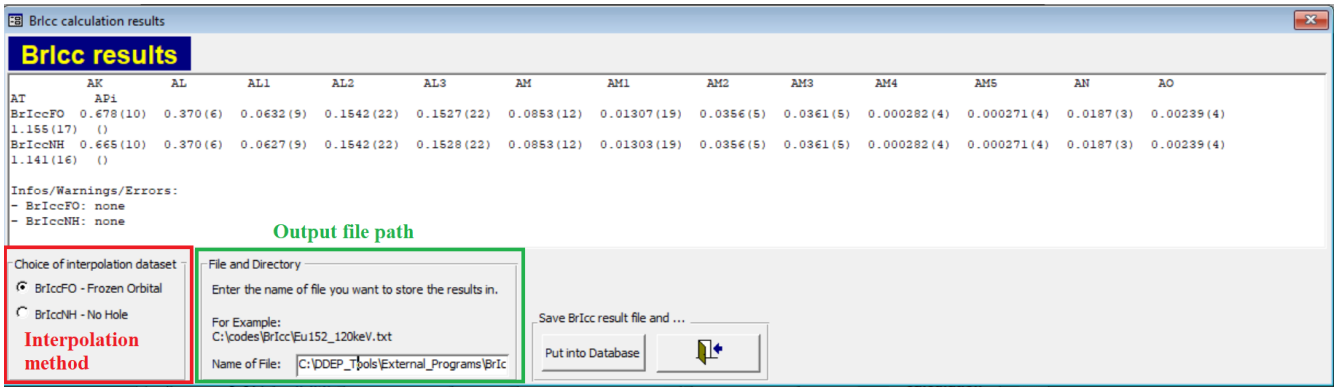


Figure 39: BrIcc calculation validation for the 148-keV photon emission from the ^{152}Eu decay to ^{152}Sm

Once the internal coefficients have been calculated it is possible to calculate the energies of the internal conversion electron emissions. To do so, the user is required to use the button Conversion electron calculation for each gamma transition.

Important note: Pressing the button *Conversion electron calculation* will not display any window or provide any acknowledgement of any kind, however the calculation will be made by SAISINUC. To make sure that the calculation has been performed properly the user needs to look at the window dedicated to conversion electron.

Finally, the user can access an overview of all the gamma transitions by using the Table button available at the bottom of the gamma emission window (see Figure 38). Once used, the window will switch to a large table in which all the information for all the transitions are compiled (see Figure 40). The fields can also be edited using this alternative view. To revert to the previous view the user needs to use the Table button once again.

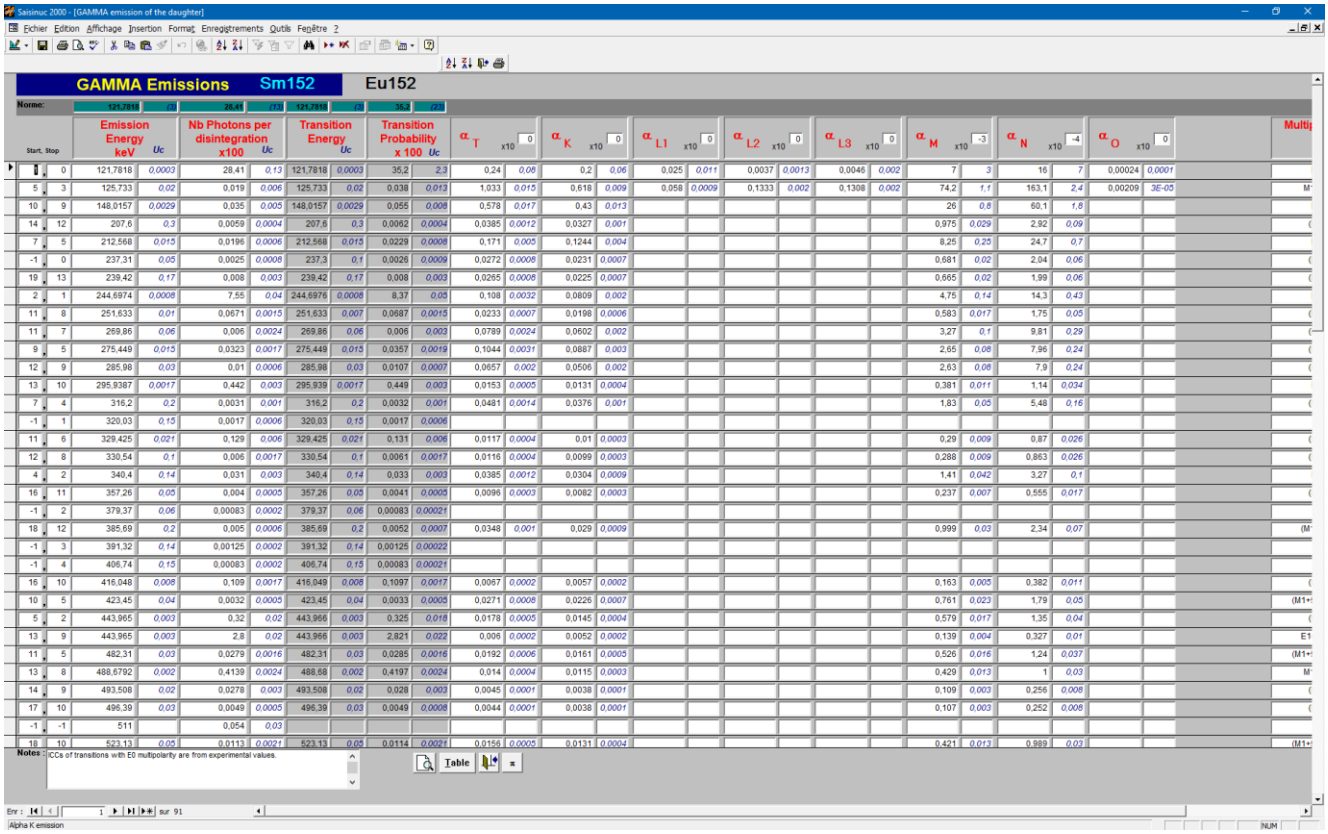


Figure 40: ^{152}Eu decay to ^{152}Sm - all gamma photon emissions

<u>X_K transition case</u>

- Regarding the X-ray emissions following the decay, they are separated into two different pages: X_K and X_L which can both be accessed from the *Photon Emissions* menu (see Figure 37). The two pages contain very similar information about X-ray emissions but with a slightly different organization.
    - Regarding the X_K page, all the emissions involving the K shell are summarized in a Table. Each line of the table represents a different sub-shell involved in the emission (see Figure 41). The different columns are presented below:
        - The first column of the table provides information on the two atomic shells involved in the transition (K plus another one) and cannot be edited by the user.
        - The second column of the table provides information on the energy of the considered emission (in keV) and can be edited directly by the user. Alternatively the user can update all the energy fields of the given element by using the Update of Energies button available on the right of the screen. In such case, the energies are automatically filled by SAISINUC using the fluorescence yields table.
        - The third column of the table is for the relative probability of each transition. The field should be edited by the user and needs to be calculated from the absolute probability of emission (if possible).
        - The fourth and fifth columns of the table are dedicated to the absolute emission probability and the associated uncertainty. The values can be directly edited by the user or can be calculated using the *Emission* code by clicking on the Execute Emission button. In such case, both value and uncertainty of all lines are updated from the calculation.
          <u>Important note</u>: using *Emission* code also updates the values and uncertainties of the XL emission table.

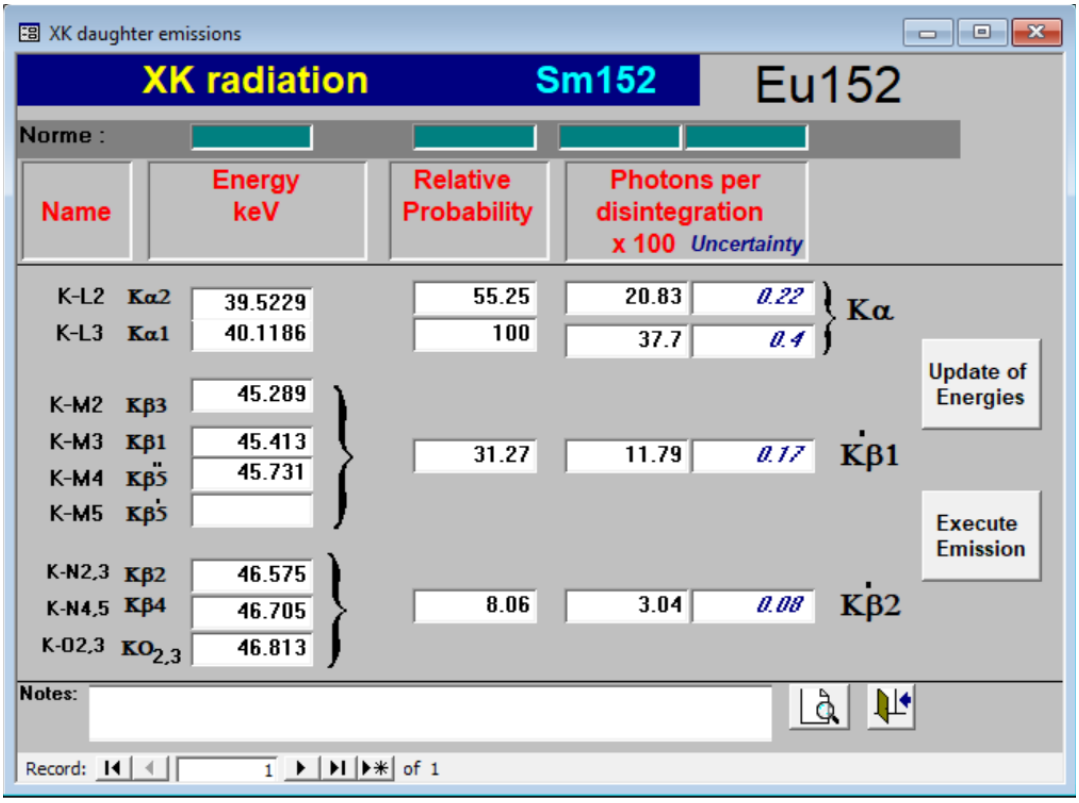
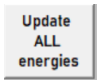


Figure 41: ^{152}Eu decay to ^{152}Sm X-ray (K-shell) emissions

<u>X_L transition case</u>

- The X_L emission are summarized in a table where each line corresponds to a different type of sub-shell transition (see Figure 42).
  - The first column of the table specifies the type of X_L emission and cannot be edited by the user.
  - The second column specifies the energy (or range of energies) associated with the emission type (in keV). The value can be directly modified by the user or can be automatically filled by SAISINUC from the atomic database. In order to do so, one has to use the dedicated button 

which will update <u>all</u> the energy fields.
  - Finally the third and fourth columns are used to specify the emission absolute probability and associated uncertainty. Both fields can be edited directly by the user or can be automatically filled if the *Emission* code is used.
    <u>Important note</u>: the *Emission* code cannot be run from the X_L page and the user needs to refer to the X_K page description to run the code in order to update both pages at once.

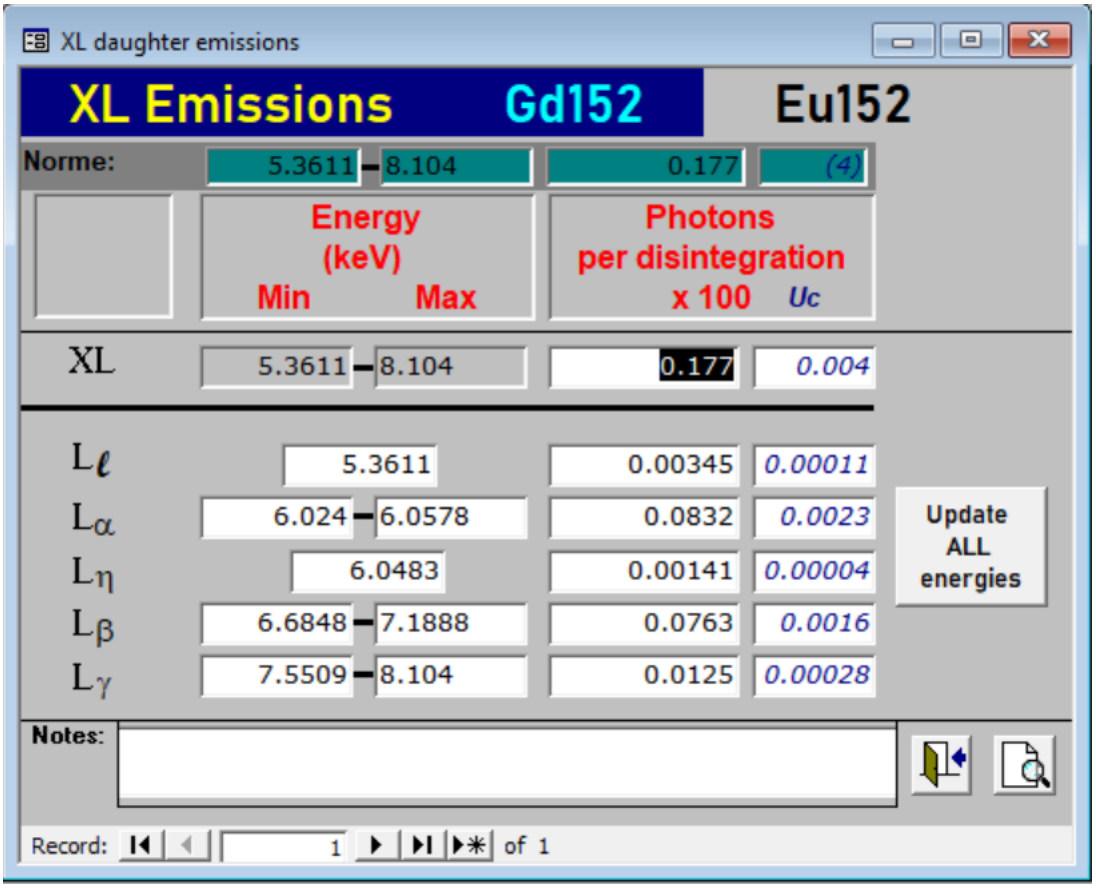
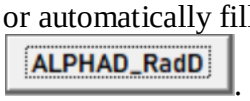


Figure 42: ^{152}Eu decay to ^{152}Gd X-ray (L-shell) emissions

3.3.5 Alpha

The *Alpha emissions* page is accessible though the *Emissions* menu. The page contains a single table listing all the possible alpha emissions occurring during the decay (see Figure 43). Each line of the table corresponds to a different alpha emission. Among the nine columns of the table, five different types of data can be distinguished:

- The first two columns (from the left) specify the initial state index in the parent nucleus and the final state in the daughter nucleus. Both fields have to be edited by the user in order to define a new transition.
- The two following columns (third and fourth) are directly editable by the user and used for the recommended energy of the emission as well as the associated uncertainty. The values are calculated from the level energy and thus depend on the index specified by the user in the first two columns.
- The columns number five and six are used to define the intensity of the emission and the associated uncertainty. The intensity is given per hundred disintegrations and has to be entered by the user.
- The seventh column corresponds to the Hindrance factor of the transition. It can be calculated by the user or automatically filled using the AlphaD-RadD calculation code by clicking on the button 

.
- The last two columns are not editable and are directly filled by SAISINUC. They correspond to the energy, and associated uncertainty, of the transition (taking into account the recoil energy of the parent nucleus).

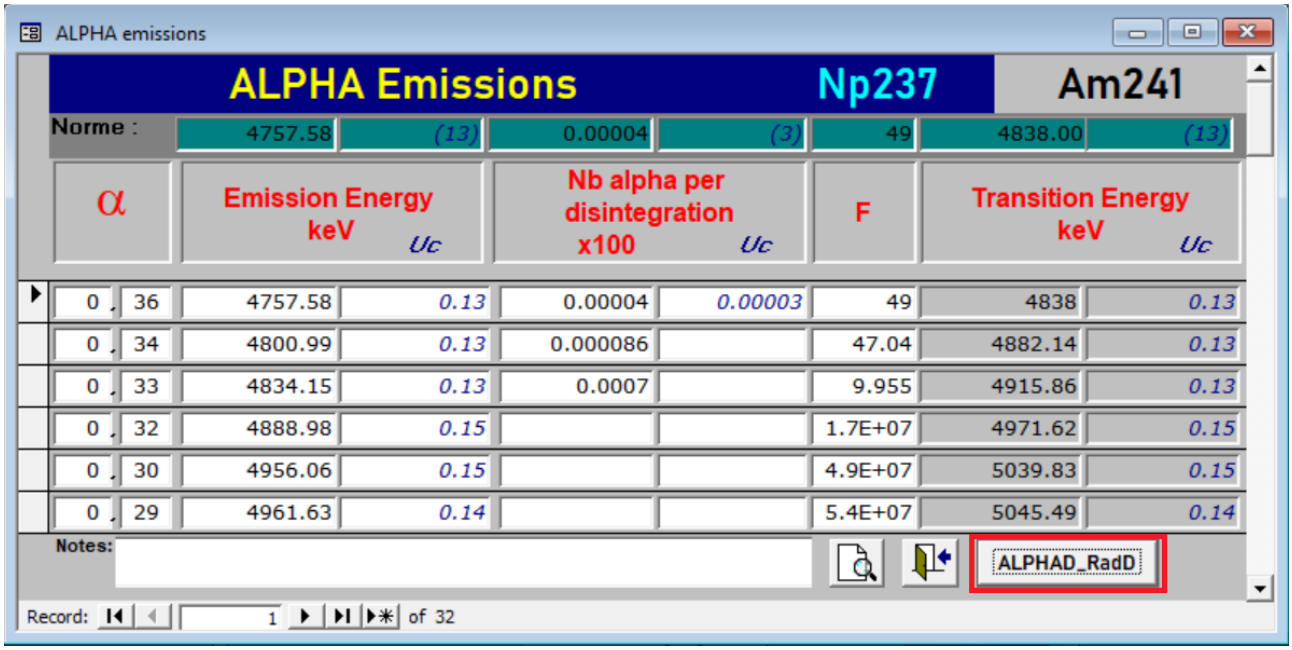
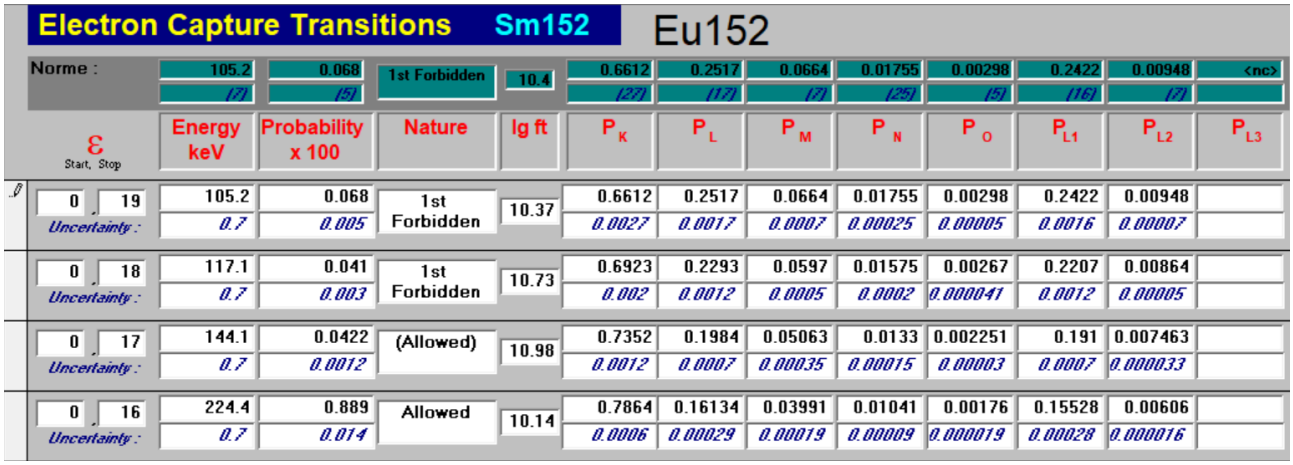


Figure 43: ^{241}Am decay Alpha emissions

3.3.6 Electron capture

The data page for the electron capture can be accessed through the menu of the Input Data menu. The page is composed of a large table (see Figure 44) for which each line corresponds to a different electron capture transition. The table is composed of fourteen different columns, which can be gathered in six different categories:

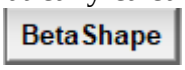
- First and second column (from the left) are used to specify the initial level (in the parent nucleus) and the final level (in the daughter nucleus). The values have to be edited directly by the user to define a new transition.
- The third column is dedicated to the energy, and associated uncertainty, of the electron capture transition. The upper field is used for the energy value and the lower one is for the associated uncertainty.
- The fourth column of the table corresponds to the intensity probability associated with the transition (in percent). The upper field is used for the probability value and the lower one is for the associated uncertainty.
- The fifth column is used to specify the nature of the transition. The value (text field) is automatically filled by SAISINUC based on the spin-parity properties of the levels involved in the transition but can be modified by the user if necessary.
- The sixth column is used to specify the logft of the electronic capture transition. The value can be specified by the user or by running the BetaShape code.
- The seventh to the fourteenth columns correspond to the relative capture probabilities associated with each atomic shell of the considered atom. The upper field is used for the probability value and the lower one is for the associated uncertainty. The field can be filled by the user or by running the BetaShape code.



Electron Capture Transitions Sm152 Eu152

Norme :		105.2 [7]	0.068 [5]	1st Forbidden	10.4	0.6612 [27]	0.2517 [17]	0.0664 [7]	0.01755 [25]	0.00298 [5]	0.2422 [16]	0.00948 [7]	<nc>
ε Start, Stop		Energy keV	Probability x 100	Nature	lg ft	P_K	P_L	P_M	P_N	P_O	P_{L1}	P_{L2}	P_{L3}
0 19		105.2	0.068	1st Forbidden	10.37	0.6612	0.2517	0.0664	0.01755	0.00298	0.2422	0.00948	
	Uncertainty :	0.7	0.005			0.0027	0.0017	0.0007	0.00025	0.00005	0.0016	0.00007	
0 18		117.1	0.041	1st Forbidden	10.73	0.6923	0.2293	0.0597	0.01575	0.00267	0.2207	0.00864	
	Uncertainty :	0.7	0.003			0.002	0.0012	0.0005	0.0002	0.000041	0.0012	0.00005	
0 17		144.1	0.0422	(Allowed)	10.98	0.7352	0.1984	0.05063	0.0133	0.002251	0.191	0.007463	
	Uncertainty :	0.7	0.0012			0.0012	0.0007	0.00035	0.00015	0.00003	0.0007	0.000033	
0 16		224.4	0.889	Allowed	10.14	0.7864	0.16134	0.03991	0.01041	0.00176	0.15528	0.00606	
	Uncertainty :	0.7	0.014			0.0006	0.00029	0.00019	0.00009	0.000019	0.00028	0.000016	

Figure 44: Part of the ^{152}Eu decay to ^{152}Sm Electron capture emissions

Most of the fields from the electron capture table can be automatically calculated using the BetaShape program. The later can be launched directly from the button 

located on the bottom of the page. If launched, BetaShape takes as input the level scheme of the parent and daughter nuclei to calculate the transitions, energies, intensity probabilities and log ft values. When launched the program will prompt two confirmation windows:

1 Before execution: to know if the ratio between β^+ and electron capture can be modified by the calculation.
2 After execution: the number of calculated transitions for both β^+ and electron capture will be specified. The user has to decide whether to input the calculation in the database or to keep the current values.
Important note: If the BetaShape code is used to calculate the electron capture transitions, it will also update the table of the β^+ transitions.

3.3.7 Gamma D

The gamma D page is only available for decay chains in equilibrium. In such cases, all the Photon emissions (both γ and X) of the parent nucleus and all the successive daughters are summarized in a single page (see Figure 45 for example). The page contains a single table for which each row corresponds to a new emission. The different columns of the table are:

- The first column corresponds to the energy of the emission (in keV)
- The second column corresponds to the uncertainty associated to the energy. In the specific case of an X_L transition, the value corresponds to the Maximum energy.
- The third column corresponds to the intensity probability of the transition (in percent).
- The fourth column corresponds to the uncertainty associated with the intensity.
- The fifth column indicates the daughter nucleus in which the emission is produced.
- The sixth and last column is used to specify the type of emission considered.

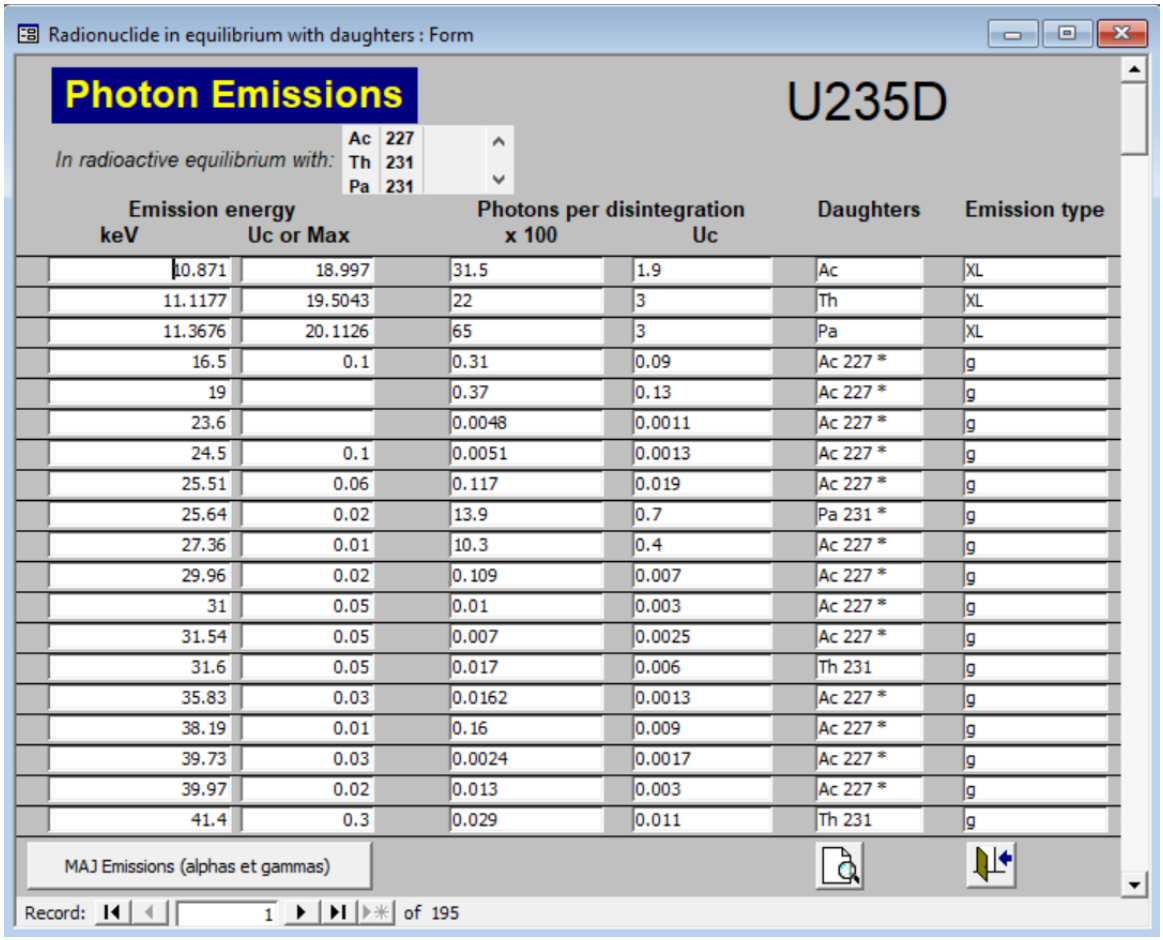


Figure 45: Photon emissions (X and γ) of ^{235}U decay chain in equilibrium

If all the fields from the table can be edited directly by the user, a tool is available to automatically update the fields using the decay data of the daughters.

Important note: This automatic importation requires that the decay data of all the nucleus from the decay chain is available in the database (Donnees.mdb) which is currently used.

To perform the automatic importation, the user needs to use the button on the bottom left of the page Update emissions (alpha & gamma). A new window (see Figure 46) is then opened and the importation can be completed in three steps:

- *Step 1*: Specify the nucleus of interest (using the field text), and find the available daughters using the Find the daughters button.
- *Step 2:* Select the daughter nucleus to import using the drop down list. The imported intensity data will be corrected by a scaling factor for which an associated uncertainty can be defined. By default the scaling factor is 1 and the associated uncertainty is 0. The value can be modified by updating the fields *Coeff. for intensities* and *Coeff. abs. uncertainty* respectively. Once the scaling factor and the associated uncertainty are set, the importation is performed using the Import daughter's emissions (intensity x coef.) button. The user has to repeat the procedure for each daughter nucleus of interest.
- *Step 3:* The user can update the table with all the defined daughter data by using the dedicated button Update database with emissions. The summary of the data to process is displayed in the text box located between step 2 and step 3.

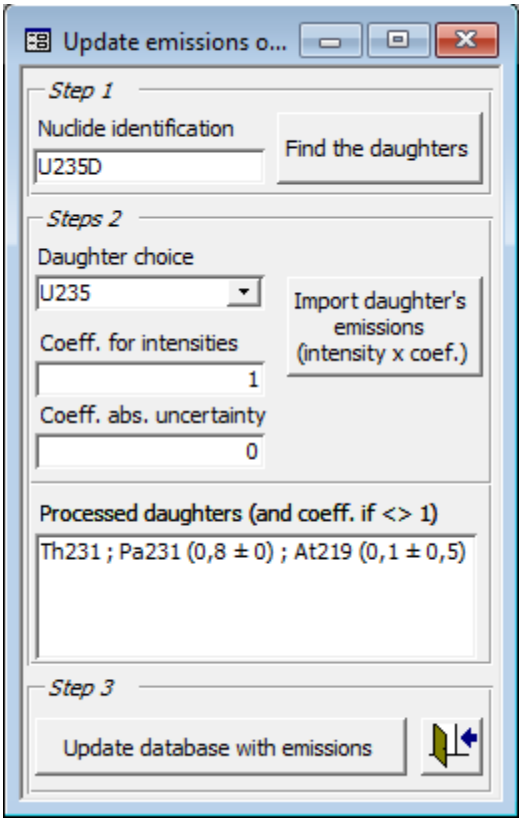


Figure 46: Automatic update of emissions database for ^{235}U decay chain in equilibrium

Important: The importation of data is performed for **both** the photons and the alpha emissions (see section below).

3.3.8 Alpha D

Like the Gamma D, the Alpha D page is only available for decay chains in equilibrium. In such cases, all the alpha emissions of the parent nucleus and all the successive daughters are summarized in a single page (see Figure 47 for example). The page contains a single table where each row corresponds to a new emission. The different columns of the table are:

- The first column corresponds to the energy of the emission (in keV)
- The second column corresponds to the uncertainty associated to the energy.
- The third column corresponds to the intensity probability of the transition (in percent).
- The fourth column corresponds to the uncertainty associated with the intensity.
- The fifth column indicates the parent nucleus from which the alpha is emitted.

Similarly to the Gamma D case, SAISINUC can automatically calculate the list of the various alpha emissions occurring for the selected decay chain. Such action is performed from the Gamma dedicated sub-section, in which the procedure is detailed.

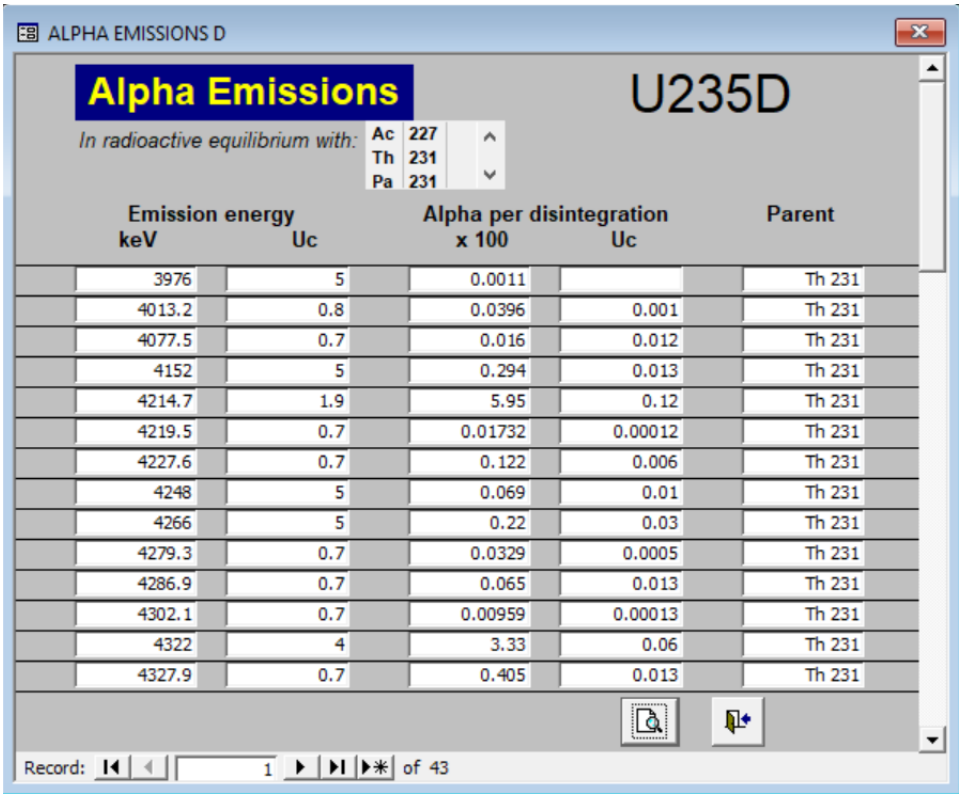


Figure 47: Alpha emissions of ^{235}U decay chain in equilibrium

3.4 Consult data

The *Consult* data panel, available from SAISINUC main page provides the user a simple way to access various information regarding the decay. The information are separated in the following three independent sections (see Figure 48):

- Dosimetry
- Auger Spectra
- Activity < > Mass

The *Consult* data section, and the previous three sections, are not mandatory to perform an evaluation and are usually not used by most of the users.

The last sections is independent from the others and is used during SAISINUC configuration.

- External programs

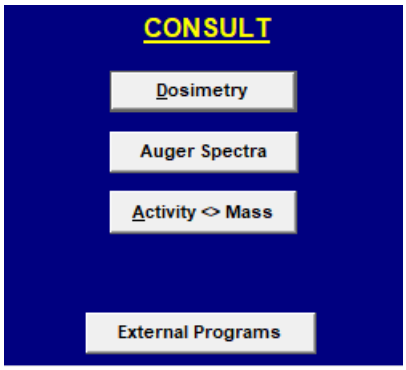


Figure 48: Consult data menu

3.4.1 Dosimetry

The dosimetry data provides a simple way to the user to have an estimation of the expected dose corresponding to the radiations emitted during the decay of the selected radioisotope. The user can consult the total dose corresponding to the sum of all the radiation types or, alternatively, the dose for each type of emission. The various cases can be accessed through the *Dosimetry* menu (Figure 49).

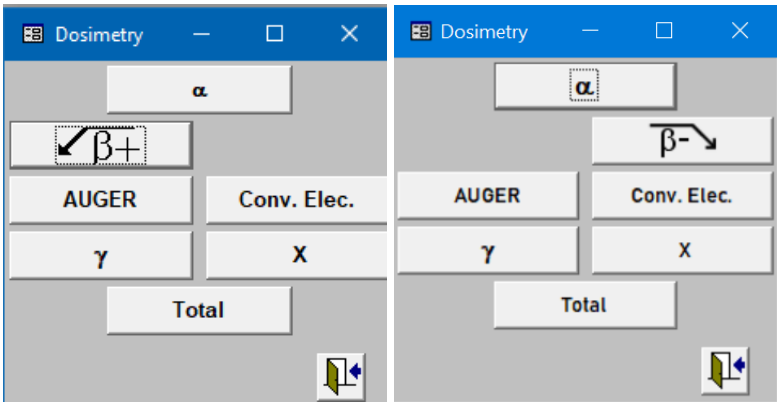


Figure 49: Dosimetry menus for ^{152}Eu depending on the decay mode

Regarding the dose corresponding to a single radiation, the user should select first the radiation type among the different possibilities:

- Alpha
- Beta +
- Beta –
- Auger
- Electron conversion
- Gamma
- X

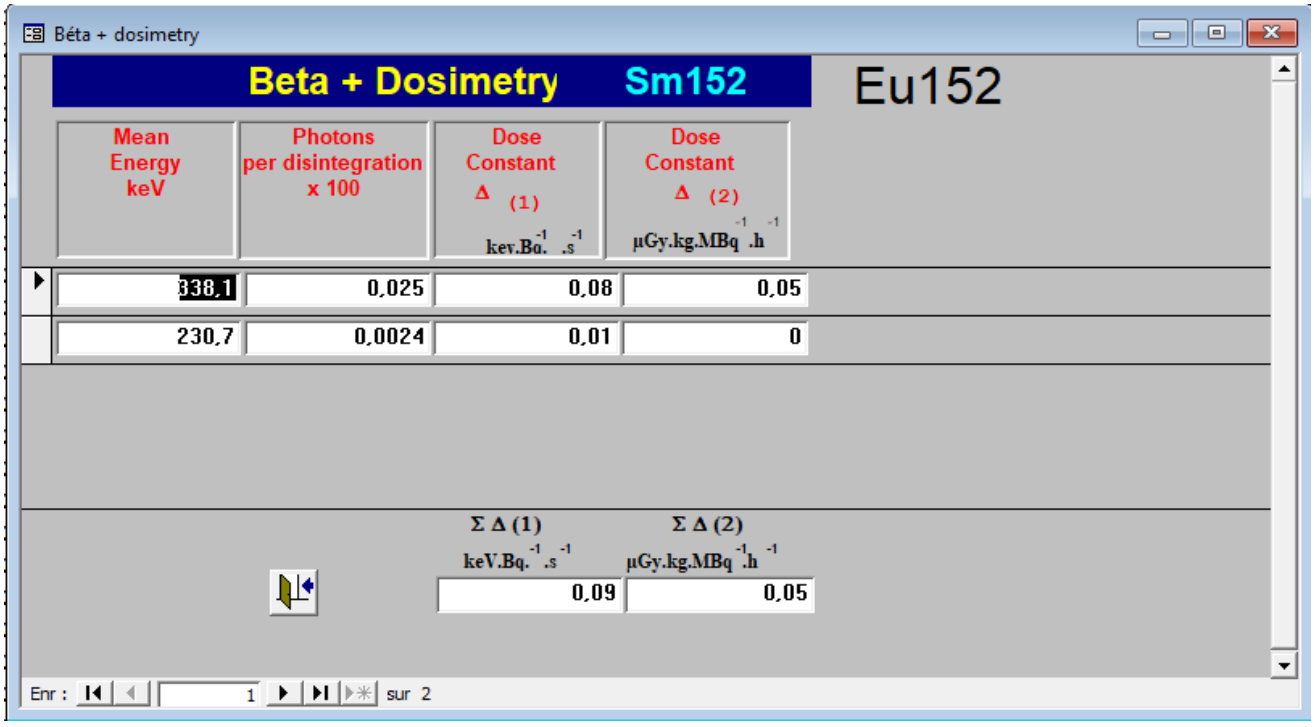


Figure 50: Dosimetry data for ^{152}Eu β^+ decay

After selection, a new window will present a table with the related dose information (see example in Figure 50). The table is composed of a number of rows equal to the number of transitions defined in the corresponding input table. For each row four columns are defined:

- The energy of the radiation (which will be used for the calculation). If the energy of the radiation follows a distribution, the mean value is taken.
- The intensity of the radiation (in percent)
- The *Dose Constant 1* which corresponds to the energy per decay for the given radiation
- The *Dose Constant 2* which corresponds to the dose (in µGy) per decay (in MBq) for one kg of water

At the bottom of the table, the two dose constants corresponding to the sum of the dose constants of all the radiations is performed. In the specific case of the photon emissions (gamma and X), an additional column is available: the corresponding Air Kerma Rate. All the values of the table can be specified by the user but are automatically calculated by SAISINUC based on the input data tables.

The summary of the dose corresponding to all the different types of radiations is available in the Total sub-section accessible through the dosimetry menu. In the sub-section, the dose constants and air kerma rate of all radiation types are listed in a single table.

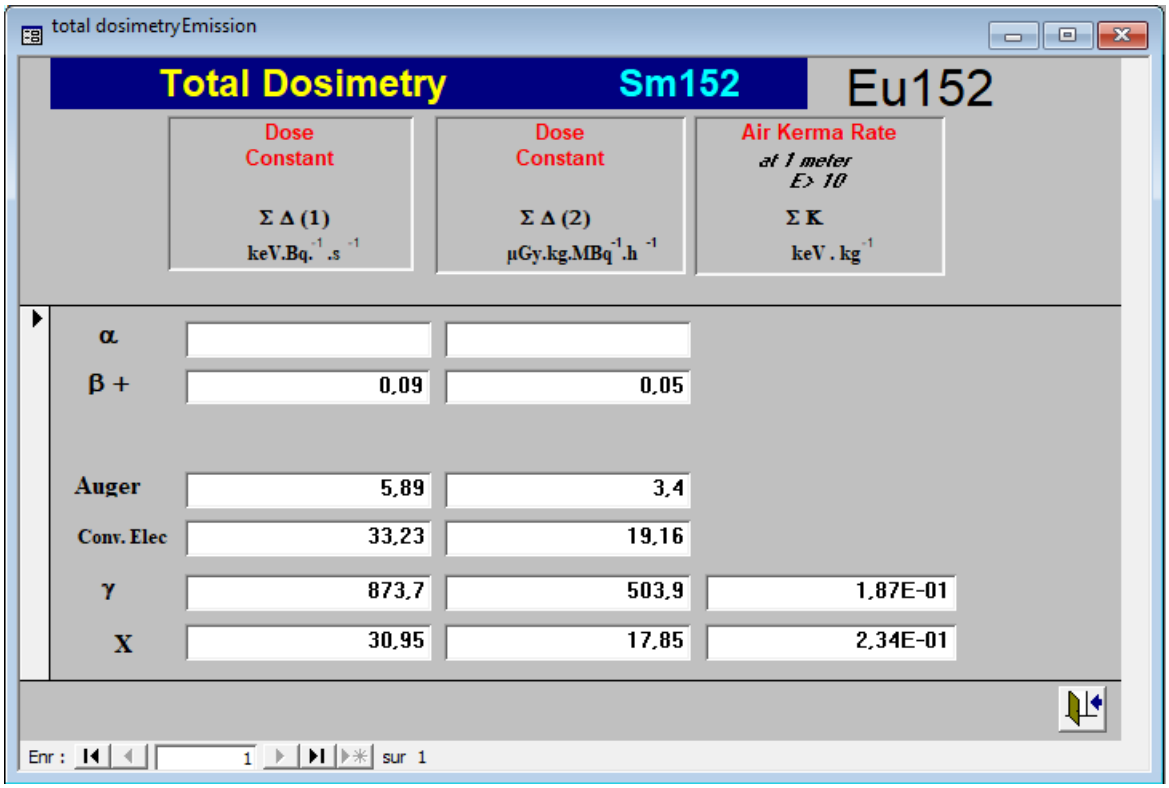


Figure 51: Total dosimetry data for ^{152}Eu

3.4.2 Auger spectra

From the *Consult* data menu, the user can also have access to detailed information regarding the Auger emissions and more precisely about the absolute intensity for each sub-shell involved in the process. The different types of distributions can be accessed using the *Auger Spectra* menu (see Figure 52). The menu provides the user the possibility to select the daughter of interest of the selected decay. From the menu, different types of Auger transitions are accessible depending on the sub-shell the user wants to study. In each case clicking on the button will pop-up a new window in which the

partitioning between the different sub-shells is detailed. The user can plot the corresponding graph by clicking on the button Show graph. An example is provided in Figure 53.

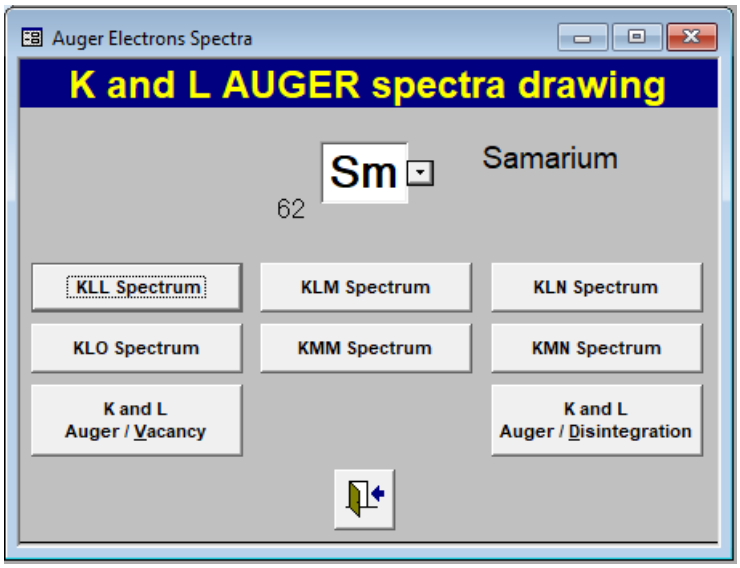


Figure 52: Auger spectra menu

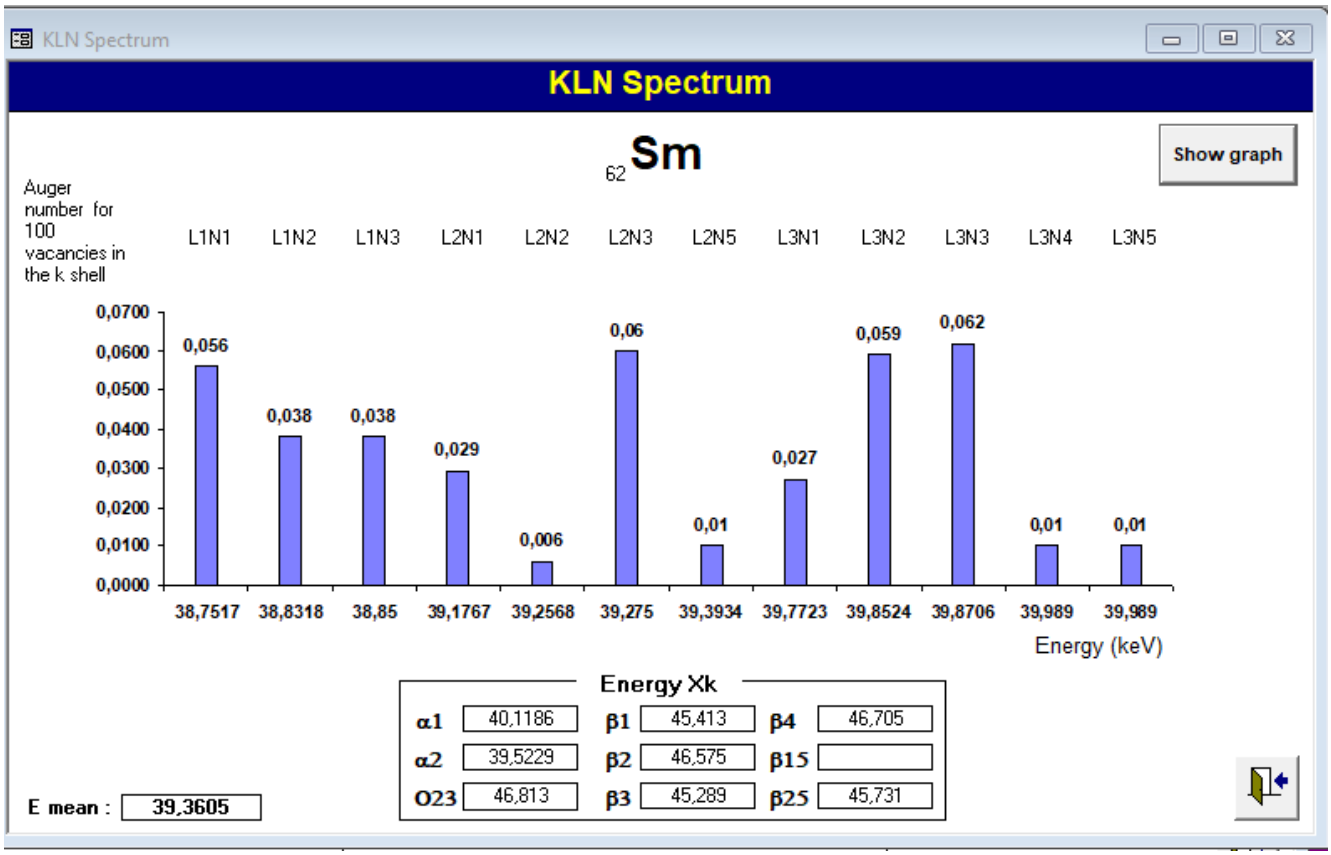


Figure 53: KLN Auger spectrum partitioning of Samarium following ^{152}Eu decay

3.4.3 Activity ↔ Mass

The last tool avalaible in the *Consult* data menu is the conversion between Activity and Mass for a given radioisotope. When selected by the user, a dedicated window appears (see example in Figure 54). From the window, the radioisotope of interest can be selected using the drop down list.

Once the radioisotope has been selected, the user should enter an activty (in Bq) or a mass (in µg) which needs to be converted. Finally, the conversion can be performed using the arrow button >> (or << depending on the case).

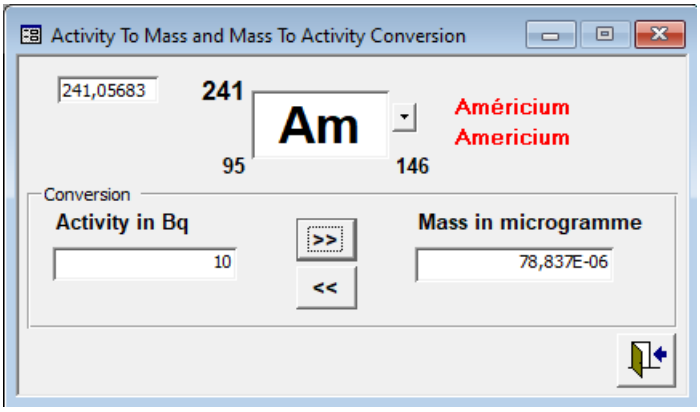


Figure 54: Activity to mass conversion menu

3.4.1 External programs

The external programs sub-section is dedicated to the setup of the different programs and external codes which are implemented in SAISINUC. For more details the reader can refer to the sub-section 1.2.3.