

BetaShape Status

X. Mougeot, CEA-LNHB (France)

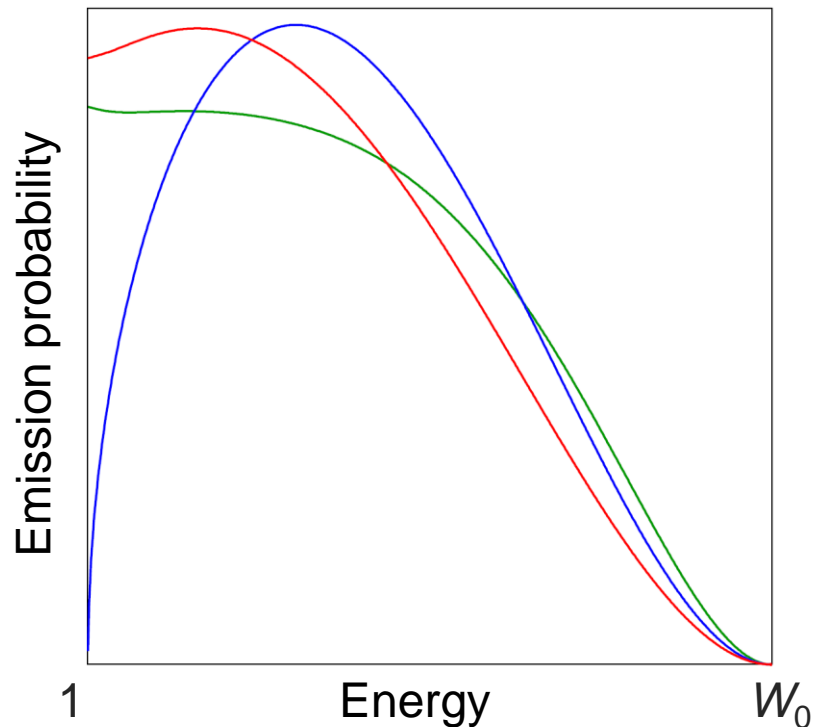
USNDP meeting 2025



Beta spectrum shape

Phase space Fermi function Shape factor

$$\frac{dP}{dW} \propto \boxed{pWq^2} \cdot \boxed{F(Z, W)} \cdot \boxed{C(W)}$$



W electron energy, W_0 transition energy

p electron momentum, q neutrino momentum

Allowed

$$C(W) = 1$$

First forbidden unique

$$C(W) = q^2 + \lambda_2 p^2$$

Second forbidden unique

$$C(W) = q^4 + \lambda_2 q^2 p^2 + \lambda_3 p^4$$

Third forbidden unique

$$C(W) = q^6 + \lambda_2 q^4 p^2 + \lambda_3 q^2 p^4 + \lambda_4 p^6$$

Etc.

- ✓ The BetaShape program (version 2.4) now replaces the LogFT code. Electron captures also treated.
- ✓ $F(Z, W)$ and λ_k parameters determined from the relativistic electron wave functions, obtained by numerical solving of the Dirac equation.
- ✓ Included: extended nucleus; atomic exchange, overlap and screening; radiative corrections; database of experimental shape factors.

For forbidden non-unique transitions, coupling with nuclear structure is necessary.

→ ξ -approximation possible but accuracy is questionable.

Version 2.3 (September 2023)



Technical

- ✓ Rounding limit can be changed via a simple option.
- ✓ Provision of f -values and average energy of emitted neutrinos (B and EC).
- ✓ Handling of branching ratios (BR and NB from N and PN records) and propagation of their uncertainties.
- ✓ Modification of forbiddenness assignment when J^π are ambiguous.

Physical model

- ✓ Tabulation of atomic screening and exchange effects from full numerical calculations.
- ✓ Inclusion of the atomic overlap correction in beta decays. Negligible influence except close to the end-point energy, which can appear lower by hundreds of eV.

Uncertainties

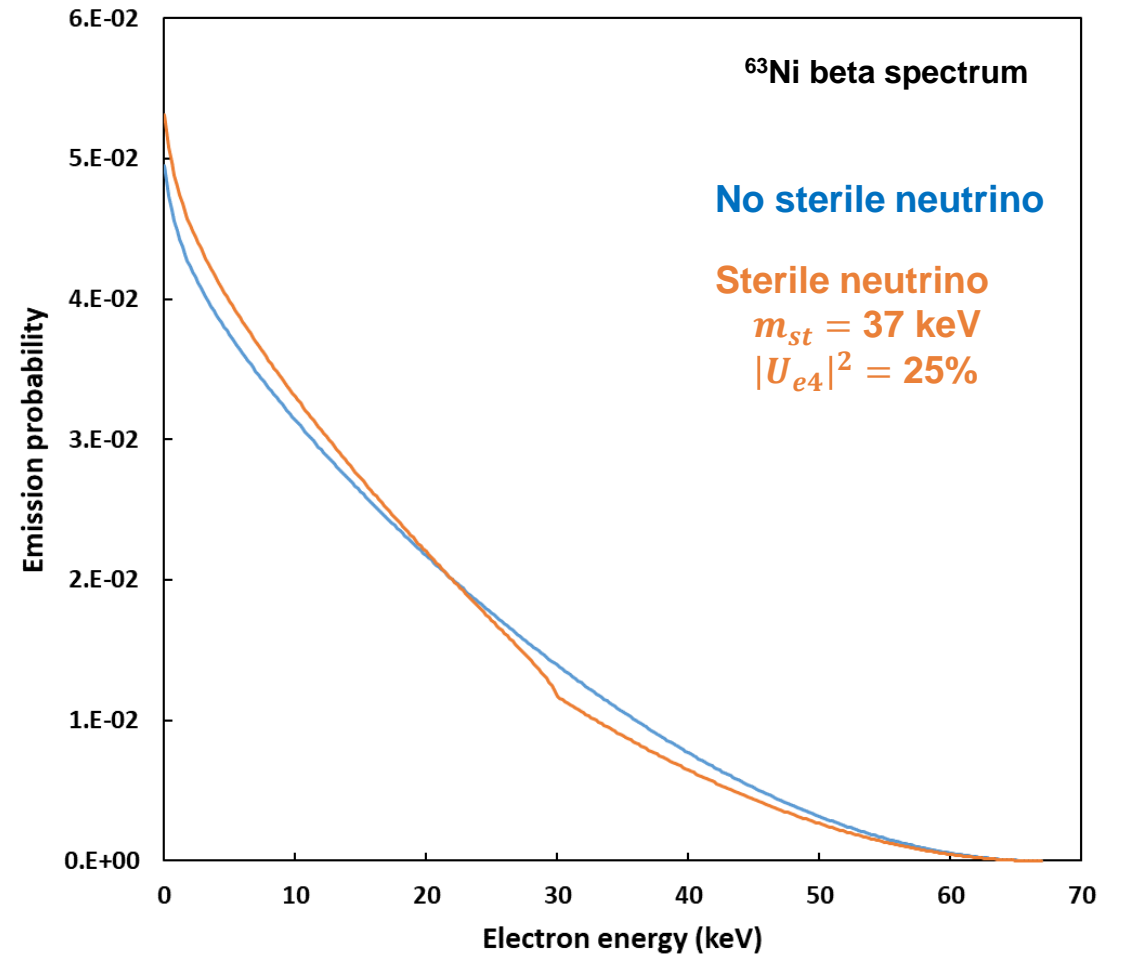
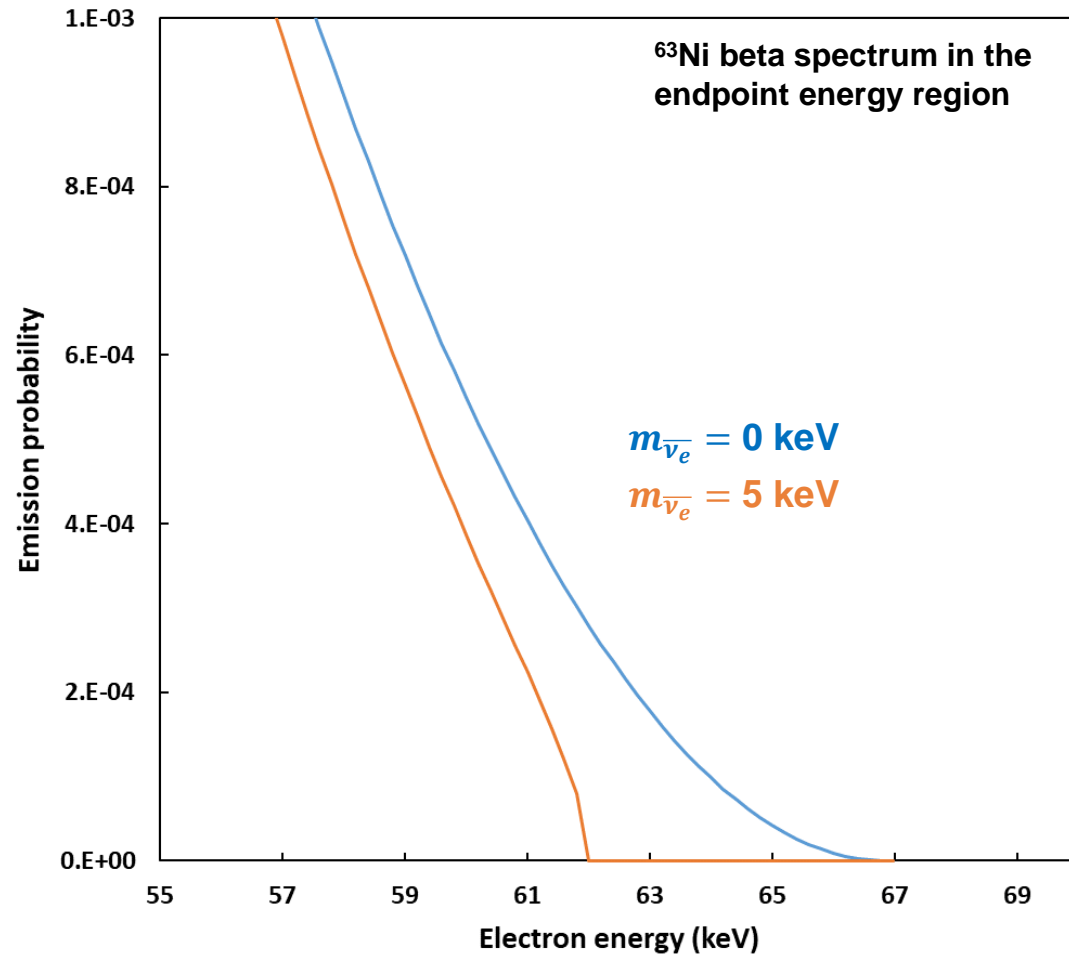
- ✓ Treatment of non-numeric uncertainties (AP, SY, GT, etc.). Up to version 2.2, treated as null.
- ✓ Treatment of asymmetric uncertainties. Important for large uncertainties on intensities and transition energies.

Developments for the recent versions

- ✓ Feedbacks at 2023 USNDP meeting → **Version 2.3.1** in December 2023.
 - A few bugs fixed in generated CSV files. Description of CSV format in a separate Microsoft Office Excel file.
 - Insertion of a comment line with the code version in updated ENSDF files.
- ✓ Feedbacks at 2024 NSSD meeting → **Version 2.4** in June 2024.
 - Acceleration of electron capture calculations by a factor of 50 via an extensive tabulation of wave function overlaps.
 - An environment variable (**BSINSTALL**) can be defined to run the code from any directory.
 - Validation of the code on the entire ENSDF database, archived version of January 2024.
- **Version 2.5** (in preparation)
 - Implementation of a “help” option to facilitate use.
 - EC decays: Provision of the atomic orbital energies and of the neutrino energies.
 - B decays: Possibility to define a non-zero mass to the neutrino, and to add a sterile neutrino (mass, amplitude).
 - Implementation ongoing: improved uncertainty propagation on BR and NB from N and PN records (following Jun Chen’s recommendations).

→ **Feel free to send me any bug report or suggestion of improvements.**

Massive neutrinos in beta decays



Where to get BetaShape

LNHB website

<http://www.lnhb.fr/rd-activities/spectrum-processing-software/>



Software and tools developed by the LNHB



BETASHAPE – BETA SPECTRA COMPUTING

The BetaShape program has been developed to improve nuclear data related to beta emission and electron capture properties. Use of the code, with options, and improvements over the previous versions are briefly described in the README.txt file.

Beta Transitions

Mean energies, log (ft) values, beta and neutrino spectra for single and multiple transitions are provided. A database of experimental shape factors is included and has been updated. The uncertainties provided by the input parameters are taken into account and propagated.

Electron captures

Capture probabilities and capture-to-beta-plus ratios are provided for each atomic subshell. The log(ft) value of each transition is calculated. For a given branch, the splitting between capture and beta plus transitions is also determined.

The spectra and capture probabilities pre-calculated with BetaShape are available on the [atomic and nuclear data](#) page, in the column 'ASCII files', by clicking on the 'B' button for the desired nuclide.

A dynamic display of these pre-calculated spectra can be found on this page: [BetaShape web](#).

REFERENCES:

– X. Mougeot, Applied Radiation and Isotopes 201 (2023) 111018
DOI : <https://doi.org/10.1016/j.apradiso.2023.111018>
– X. Mougeot, Applied Radiation and Isotopes 154 (2019) 108884
DOI : <https://doi.org/10.1016/j.apradiso.2019.108884>

Download BetaShape – Stable version: 2.4 (11/6/2024):

[BetaShape – Windows 10](#) (7z file, 14.8 Mo)
[BetaShape – Scientific Linux 6.4](#) (bz2 file, 11.2 Mo)
[BetaShape – Linux Ubuntu 20.04](#) (bz2 file, 30.8 Mo)
[BetaShape – Linux CentOS 8](#) (bz2 file, 22.4 Mo)
[BetaShape – macOS Sonoma \(M1\)](#) (bz2 file, 7.7 Mo)
[BetaShape – macOS Sonoma \(Intel\)](#) (bz2 file, 7.9 Mo)
[BetaShape – ReadMe](#) (Txt file)
[BetaShape – Manual](#) (Pdf file)
[BetaShape – CSV format details](#) (Excel file)

Warning: For Linux/macOS users, please read first the [README](#) file about the environment variable PATH.

IAEA-NSDD GitHub Repository

<https://github.com/IAEA-NSDDNetwork>

IAEA-NSDDNetwork / BetaShape (Public)

Couldn't load subscription status. [Retry](#) Fork 1 Star 5

<> Code Issues Pull requests Actions Projects Security Insights

main 1 Branch 3 Tags

Go to file

<> Code

About

Calculation of beta and electron capture decays

[www.lnhb.fr/rd-activities/spectrum-proc...](#)

Readme

CC0-1.0 license

Activity

Custom properties

5 stars

2 watching

1 fork

Report repository

Releases 3

v2.4 (Latest) on Jun 12, 2024

+ 2 releases

Packages

No packages published

Contributors 2

xavier-mougeot

mverpelli

BetaShape

The BetaShape program calculates **beta and electron capture decays**, and provides for each transition:

- Energy spectra of the emitted β and ν particles.
- Capture probabilities and capture-to-positron ratios for all subshells.
- Average β and ν energies.
- log-ft values.
- In case of multiple branches, total decay spectra are also generated for each type of particles.

All results are provided as formatted text files, including updated ENSDF files and CSV files.

BetaShape is part of the [ENSDF Analysis and Utility Programs](#). It is also made available on [LNHB website](#) as part of the Utility Programs of the [Decay Data Evaluation Project \(DDEP\)](#). Any question can be addressed to Xavier Mougeot: xavier.mougeot@cea.fr

Downloads

The **packages** directory contains the executables for Windows (10), macOS (Monterey M1 and Intel) and Linux (CentOS 8, Ubuntu 20.04.2 LTS, Scientific Linux 6.4).

Quick start

The program takes as input a formatted ENSDF file, for example [Ni63.txt](#) for ^{63}Ni decay. With default options, it is simply run in Windows typing:

ICRM2025 Conference

The CEA-LNHB organized the 24th International Conference on Radionuclide Metrology and its applications (ICRM2025).

This biannual conference is very structuring for our metrology community.

- ✓ > 220 participants from 33 countries of all the continents.
- ✓ Scientific Committee decision:
 - 43 Orals and 106 Posters.
 - 113 abstracts selected for an article in a Special Issue of Applied Radiation and Isotopes.
 - 16 abstracts as ICRM Technical Series.
- Edition part is not over yet. Still some articles under review.

CONFERENCE TOPICS

- Aspects of international metrology
- Intercomparisons
- Measurement standards and reference materials
- Radionuclide metrology techniques
- Alpha-particle and beta-particle spectrometry
- Gamma-ray spectrometry
- Liquid scintillation counting techniques
- Nuclear decay data
- Low-level measurement techniques
- Radionuclide metrology in life sciences
- Source preparation techniques
- Quality assurance and uncertainty evaluation in radioactivity measurements



**24th International Conference
on Radionuclide Metrology
and its applications**

19-23 May 2025
Paris
France

<https://icrm2025.org/>



ICRM 2025 · 19-23 May · Paris

ESNT Workshop

Organization of workshop within the Theoretical Nuclear Structure and reaction framework of CEA/Irfu (Fundamental Research Division).

Probing nuclear structure with beta-decay energy spectra

CEA Saclay, 7-10 July 2025

- ✓ Scientific organization with B.C. Rasco from ORNL.
- ✓ 21 participants from Canada, Germany, Italy, Spain, UK, USA, and France (Metrology, Strasbourg University, IJCLab, CEA/Irfu, CEA/DAM).
- ✓ Half theorists, half experimentalists.
- ✓ Very interesting for all the participants. Another edition is in preparation, most probably in September 2026.



Program and presentations available on the ESNT website:

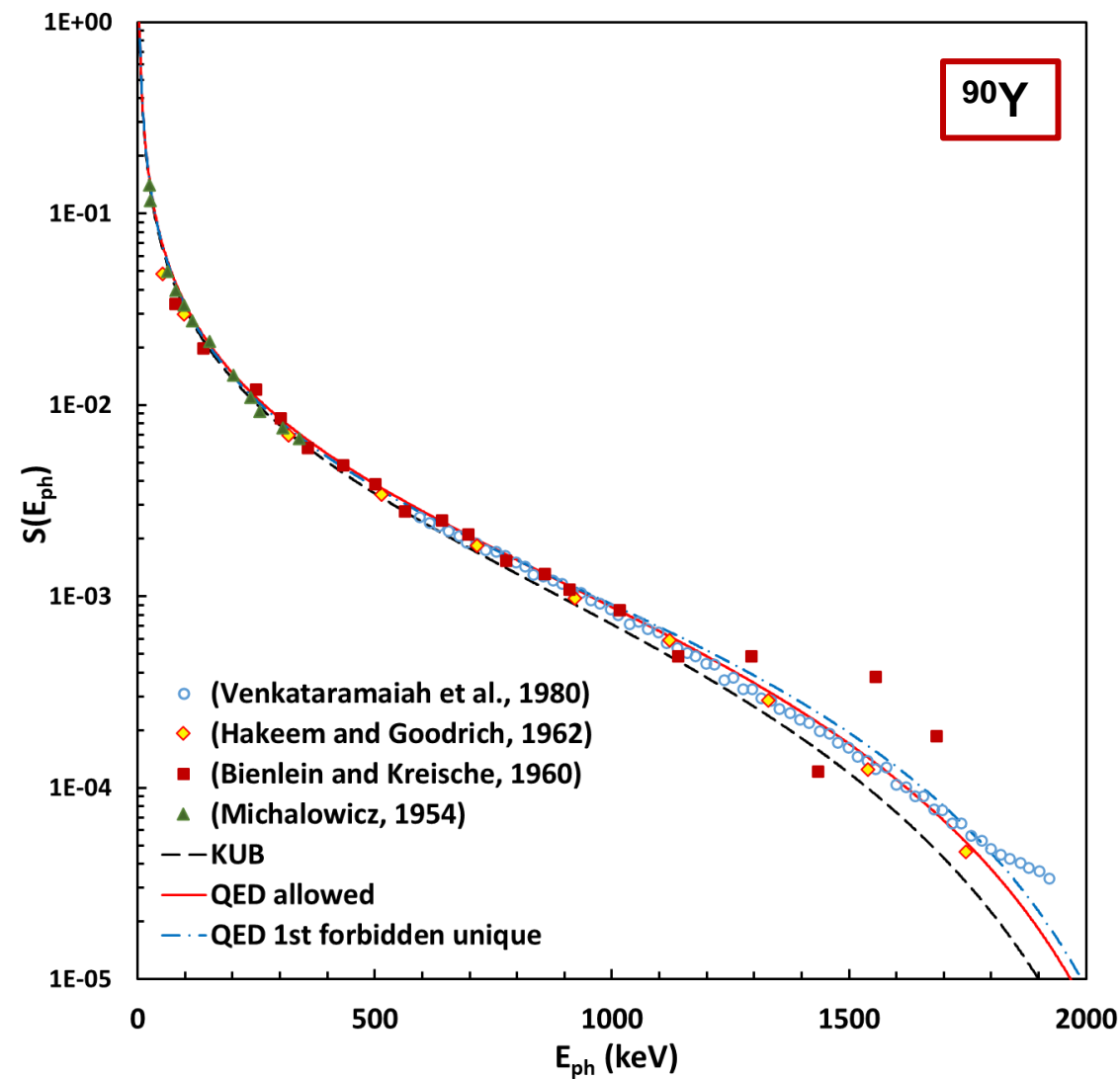
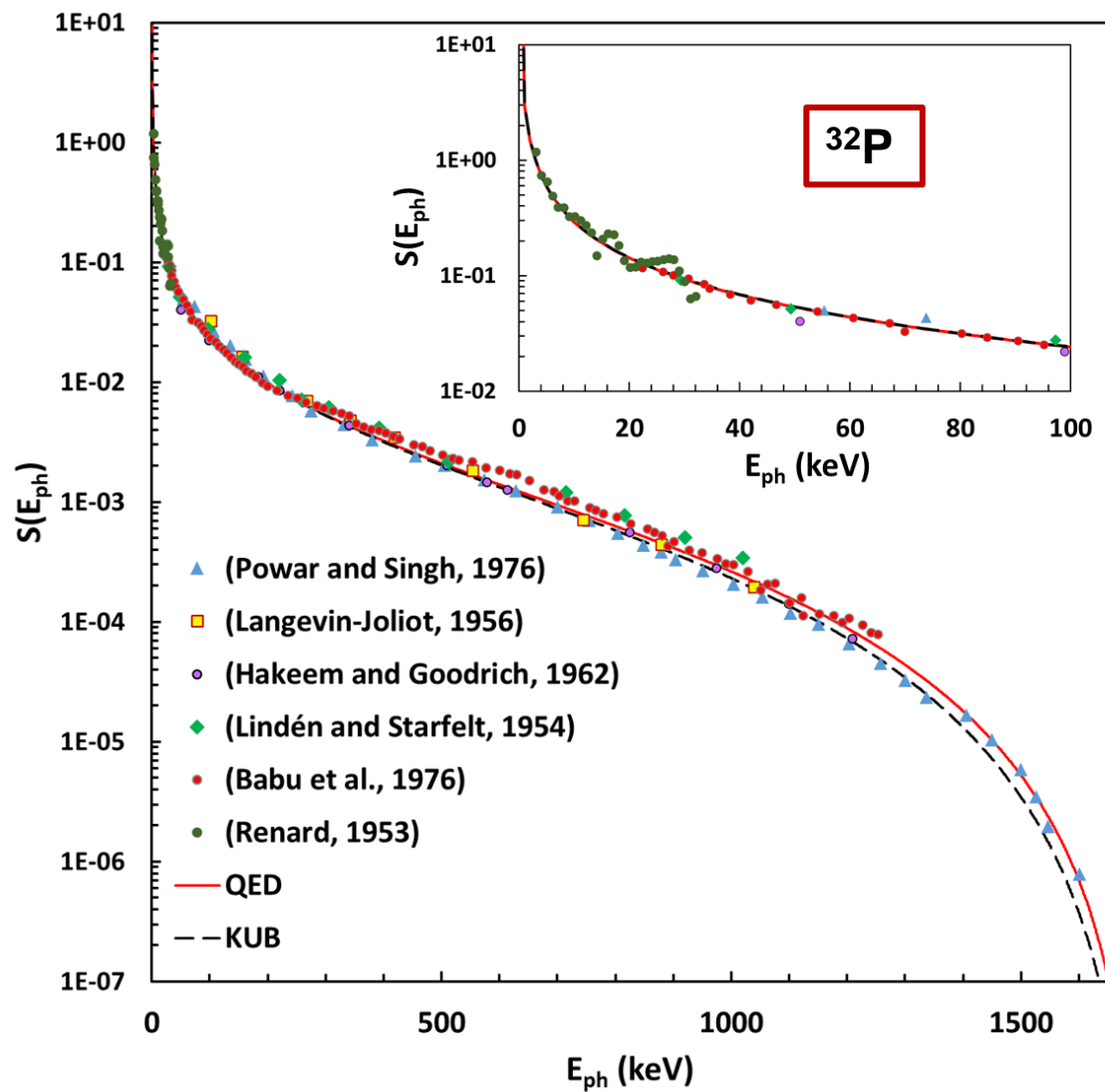
<https://esnt.cea.fr/Phoceia/Page/index.php?id=129>

Internal bremsstrahlung

This process is part of the radiative corrections, in which the **emitted soft photons** are assumed lost for the detection. In reality, these photons are **partially reabsorbed in the measurement**.

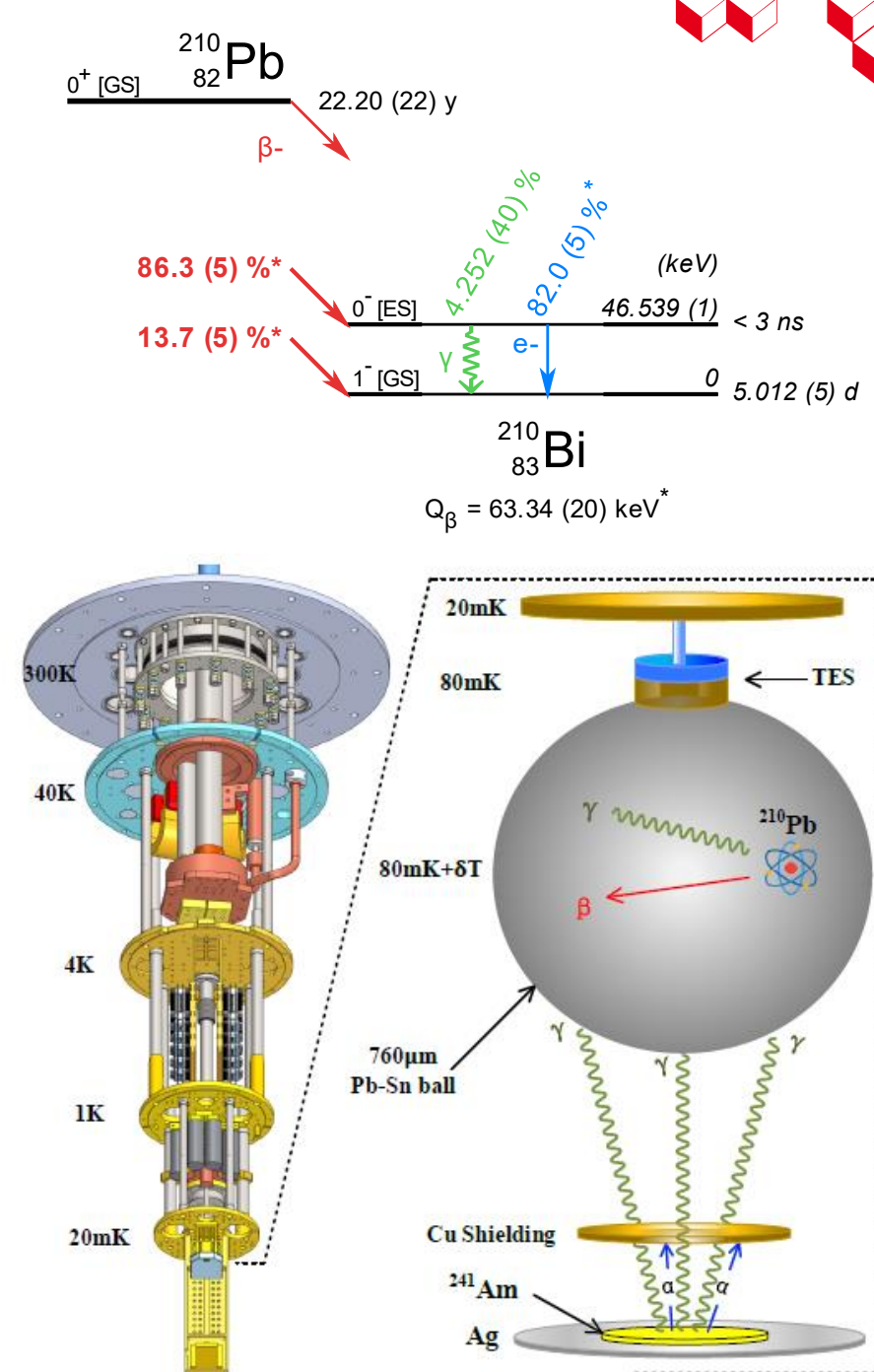
- ✓ Two theoretical formalisms studied, with specific work to ensure consistency of the observables:
 - The simplest from **KUB** (Knipp and Uhlenbeck, Bloch; 1936). No Coulomb effect.
 - The most accurate derived from **QED** (Ivanov et al., 2014). Coulomb effect and nucleus recoil.
- ✓ **Development of a dedicated code**, linked to BetaShape for the beta spectra.
- ✓ Review of the measurements available in the literature. Correction and selection of the most accurate.
- ✓ Validation of the theoretical predictions on ${}^6\text{He}$, ${}^{35}\text{S}$, ${}^{32}\text{P}$, ${}^{90}\text{Y}$. Allowed and first forbidden unique transitions.
- ✓ Realistic Geant4 Monte Carlo simulations to quantify the influence on the beta spectrum:
 - ${}^{32}\text{P}$ in an ultra-thin source measured with a 4π Si(Li) spectrometer.
 - ${}^{99}\text{Tc}$ in the gold absorber of a Metallic Magnetic Calorimeter.
- ✓ Very high statistics required for a significant effect (10^8 and 10^9 , respectively). Flexible method for any type of radionuclide and any type of experimental device.
- ✓ Published in Applied Radiation and Isotopes 226, 112197 (2025) within the ICRM2025 conference.

Internal bremsstrahlung



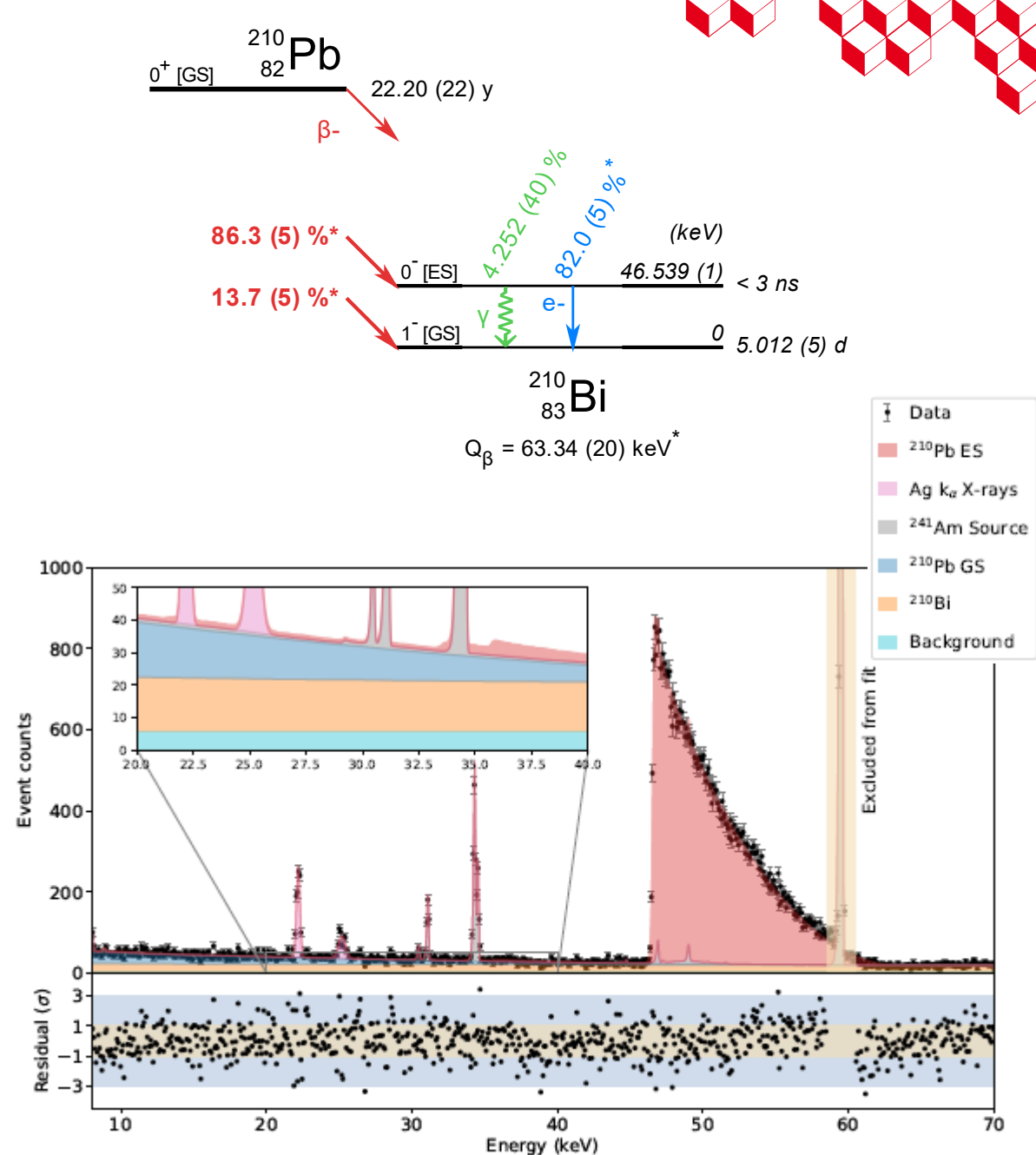
Atomic exchange effect

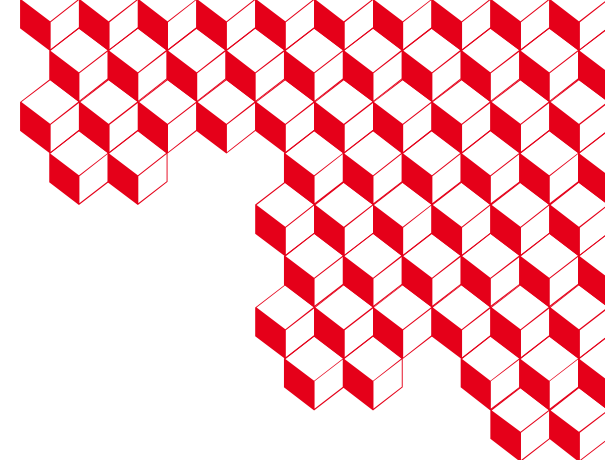
- ✓ High-precision measurement of the ^{210}Pb decay with a cryogenic Transition Edge Sensor at ShanghaiTech University. **Threshold-free.**
- ✓ Improvement of the atomic exchange modelling:
 - Accurate atomic model, based on RDFT and benchmarked on DF-MCDF calculations.
 - Consistent atomic and continuum electron wave functions.
- ✓ Significant influence of the atomic modelling. The one within BetaShape leads to worse agreement.
- ✓ Improved nuclear data (*): Q-value, branching ratios, and emission probability of the internal conversion electrons; γ transition admixture, $|\delta|$ and α_T deduced.
- S. Zhang et al., arXiv:2509.26390 (2025). Under review at Nature.



Atomic exchange effect

- ✓ High-precision measurement of the ^{210}Pb decay with a cryogenic Transition Edge Sensor at ShanghaiTech University. **Threshold-free.**
- ✓ Improvement of the atomic exchange modelling:
 - Accurate atomic model, based on RDFT and benchmarked on DF-MCDF calculations.
 - Consistent atomic and continuum electron wave functions.
- ✓ Significant influence of the atomic modelling. The one within BetaShape leads to worse agreement.
- ✓ Improved nuclear data (*): Q-value, branching ratios, and emission probability of the internal conversion electrons; γ transition admixture, $|\delta|$ and α_T deduced.
- S. Zhang et al., arXiv:2509.26390 (2025). Under review at Nature.





Thank you for attention

