

Development of the ISOLDE Yield Database

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Abstract

The CERN Summer Student Programme project was to continue the development of the ISOLDE Yield Database. The technologies used and the new features are described.

1 Introduction

The ISOLDE Yield Database serves as a source of information about extractable isotopes (yields) and beam intensities available at ISOLDE. The database is one of the most valuable tools for experiment planning at ISOLDE. The database was recently upgraded to a state of the art Oracle database. A web application [2] is serving as a graphical user interface (GUI) for the database. The development of a new web application was also started along with the upgrade of the database. The project task was to continue the development of the database and the website features.

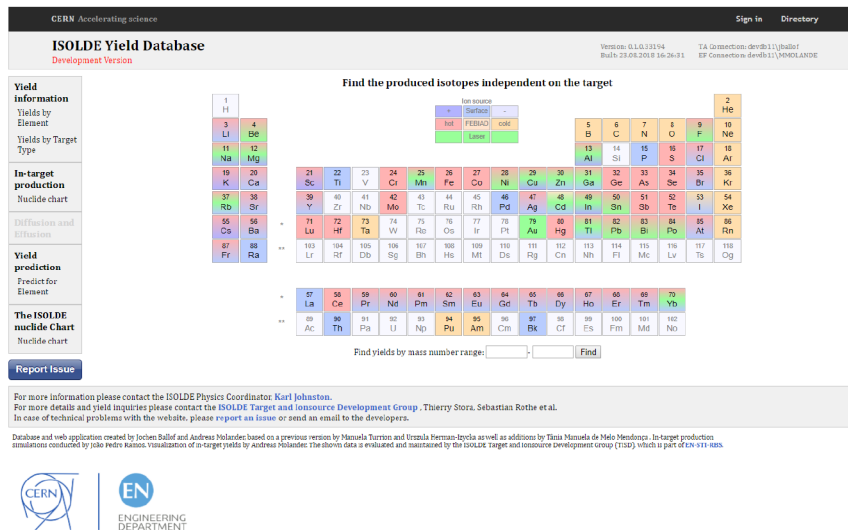


Figure 1: The GUI of the ISOLDE Yield Database.

2 Development

2.1 Implementation

The web application is built with the ASP.NET framework and is running on an IIS server hosted at CERN. The server side back end is written in C#, while the web pages and client side functionality is implemented using ASP.NET Web Pages and JavaScript. The connection to the database was initially handled by both ADO.NET DataTables and ADO.NET Entity Framework (EF), but during the project most of the DataTable connections were replaced by EF models.

2.2 Structure improvements

In the beginning of the project most of the database queries were written in the Code Behind of each web page. All queries to the database are now centrally stored in a disposable repository class to ease the use and access of data fetching and manipulation.

A comprehensive set of new interfaces and classes, corresponding to the data in the database were created to harmonize the structure of data returned by queries against the different database tables and views. These new classes also provide extended functionality to format and derive new information from the data in the database.

A controller providing a web API was implemented to provide data to client side functionality.

2.3 User interface improvements

While the website keeps the overall visual theme, some refactoring of the layout was made to improve the usability on different screen sizes and mobile devices. This was mainly achieved by replacing HTML tables used for layout design with divs, introducing the use of CSS Flexbox and upgrading deprecated content to the latest HTML5 equivalent.

3 New features

Due to the increasing demand of more exotic beams at ISOLDE, some new features of the database are needed to improve the process of planning experiments.

3.1 In-target production charts

A GUI was implemented for visualizing results of in-target isotope production simulations, i.e. the amount of produced isotopes inside a target at ISOLDE. Initially this new tool had to be able to show one nuclide chart per target type, with the nuclei representing the in-target production normalized to the proton current. The nuclide chart also provides information about the amount of produced nuclei per isotope, decay modes and half-life of the isotopes.

The nuclide chart was implemented in a generic way to be able to show any set of isotopes, not only simulation results of in-target production. It can also compare two different sets of isotopes and show the ratio of an isotope property, e.g. the yield, between the two sets.

The nuclide chart is generated by a single JavaScript function object on the client. The object takes as minimum two parameters, the nuclide chart container, in which the nuclide chart will be generated, and the data source. Then, taking use of the JavaScript library d3.js [1], a dynamic and interactive nuclide chart can be generated (figure 2).

3.1.1 In-target production calculations

Simulations of in-target produced isotopes have been conducted by João Pedro Ramos [7], using two different softwares, ABRABLA [5] and FLUKA [3] [4], for which the results had to be visualized in the nuclide chart. The nuclide chart shows the produced isotopes as isotopes per μC (of the primary proton beam), while the ABRABLA software gives the cross section of each isotope per target component and the FLUKA software gives the produces isotopes/ $\text{cm}^3/\text{proton}$.

The in-target production of the ABRABLA simulations were calculated as

$$Y_{\text{prod,ABRABLA}} = N \cdot \sigma \cdot n_{\mu\text{C}}, \quad (1)$$

where N is the amount of target atoms per area, σ is the cross section and $n_{\mu\text{C}}$ the amount of protons per μC . The FLUKA values just had to be normalized for the target volume and beam current

$$Y_{\text{prod,FLUKA}} = N_{\text{FLUKA}} \cdot V \cdot n_{\mu\text{C}}, \quad (2)$$

where N_{FLUKA} is the production given by the simulation and V the target volume. A tool for importing FLUKA simulation data into the database was also implemented.

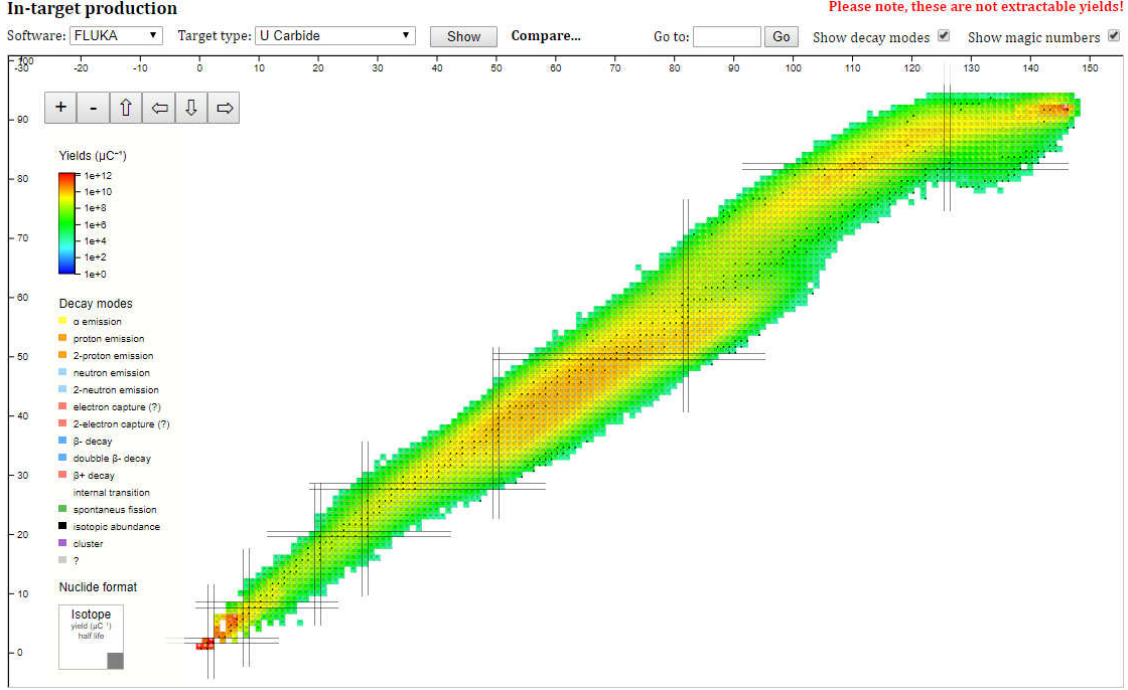


Figure 2: Visualization of in-target production simulation results for uranium carbide.

3.2 The ISOLDE yield chart

Using the same nuclide chart as for the in-target production, a visualization of the highest measured yields, independent of target material or other parameters, at ISOLDE was implemented.

3.3 Periodic tables

At the start page of the yield database website, a periodic table is shown. Each element is a link to a list of measured yields for that element. The elements are color coded based on the ion sources used for the yields. This periodic table was initially hard coded HTML, which meant that apart from being hard to modify it wasn't updated based on new data in the database.

A new periodic table was implemented using JavaScript that will generate the periodic table based on the data in the database. A similar new page, using the new periodic table, was also added for displaying available target elements, where each element is a link to the measured yields from a target containing the selected element.

3.4 Yield prediction tool

A tool for predicting unmeasured yields by extrapolating measured yields was also implemented. The yield of an isotope can be calculated like

$$Y = Y_{prod} \cdot \epsilon_{rel} \cdot \epsilon_{is} \cdot \epsilon_{sep} \cdot \epsilon_{transp} = Y_{prod} \cdot \epsilon_{rel} \cdot F, \quad (3)$$

where ϵ_{rel} [%] is the release efficiency, ϵ_{sep} [%] the separation efficiency, ϵ_{is} [%] the ionization efficiency and ϵ_{transp} [%] the transportation efficiency [7].

The release curve of a yield can be expressed like

$$P(t) = \frac{1}{A} (1 - e^{-\lambda_r t}) [\alpha e^{-\lambda_f t} + (1 - \alpha) e^{-\lambda_s t}], \quad (4)$$

where A is a normalization factor so that $\int_0^\infty P dt = 1$, λ_r the rise time constant, λ_f the fast fall time constant and λ_s is the slow fall time constant, α is a weighting factor between the fast and slow fall components [6]. For measured yields the release curve parameters, corrected for the half-life, are stored in the database.

The release efficiency ϵ_{rel} is a function of the isotope half-life ($t_{1/2}$) and can be calculated like

$$\epsilon_{rel}(t_{1/2}) = \int_0^\infty P(t)e^{-\lambda_i t} dt, \quad (5)$$

using the release curve P of a measured yield, where $\lambda_i = \ln(2)/t_{1/2}$ [7].

The rest of the efficiency parameters F , which are not $t_{1/2}$ dependent, are taken straight from a measured yield of the same element, and the yield can be predicted. In the tool the user is given the possibility to choose which measured yields he or she wants to use as reference points for calculating the efficiency parameters.

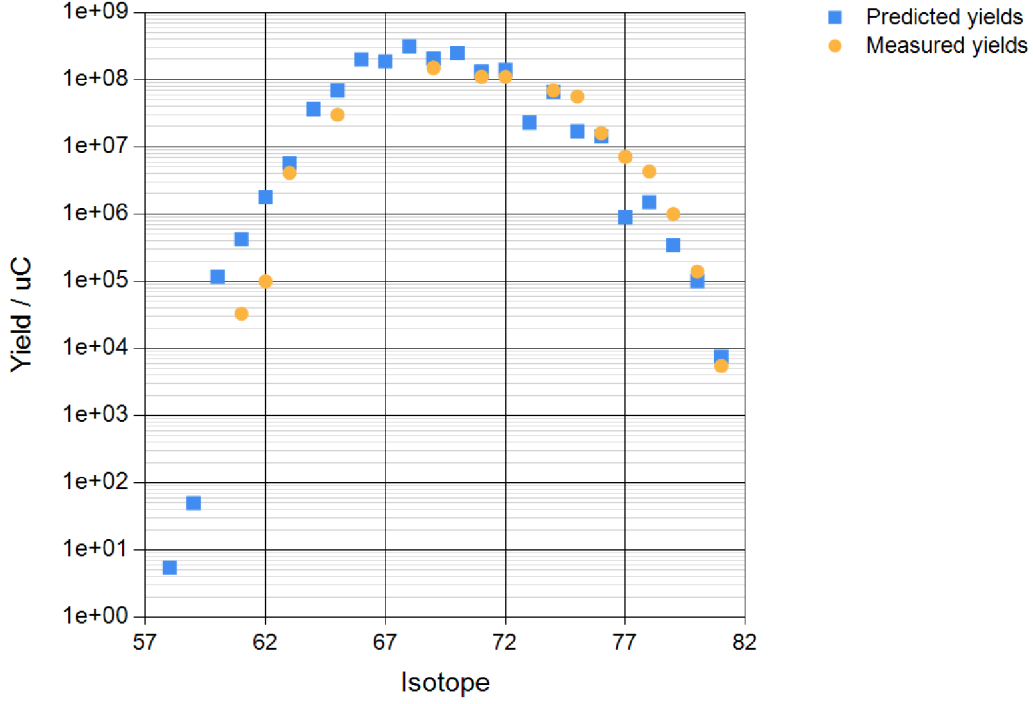


Figure 3: Yield prediction results of zinc from a uranium carbide target with a 1.4 GeV proton beam and FLUKA simulated in-target production.

References

- [1] d3.js. <https://d3js.org/>. Accessed: 2018-08-29.
- [2] The isotope yield database. <https://isoyields2.web.cern.ch/>. Accessed: 2018-08-29.
- [3] T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Ferrari, A. Fassò, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov, and V. Vlachoudis. The fluka code: Developments and challenges for high energy and medical applications. *Nuclear Data Sheets* 120, 211-214 (2014).
- [4] A. Ferrari, P.R. Sala, A. Fassò, , and J. Ranft. Fluka: a multi-particle transport code. *CERN-2005-10 (2005)*, INFN/TC_05/11, SLAC-R-773.
- [5] A. Kelic, M. Valentina Ricciardi, and K.-H. Schmidt. *ArXiv e-prints (2009)*.
- [6] J. Lettry, R. Catherall, P. Drumm, P. Van Duppen, A.H.M. Evensen, G.J. Focker, A. Jokinen, O.C. Jonsson, E. Kugler, and H. Ravn. Pulse shape of the isotope radioactive ion beams. *Nuclear Instruments and Methods in Physics Research B* 126 (1997) 130- 134.
- [7] Joao Pedro Ramos, Paul Bowen, and Thierry Stora. *Titanium carbide-carbon porous nanocomposite materials for radioactive ion beam production: processing, sintering and isotope release properties*. PhD thesis, EPFL, Lausanne, 2017.