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The Argonne Nuclear Data Exploration Software (ANDES)

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Software

- Review
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Summary

The Argonne Nuclear Data Exploration Software (ANDES) is an open-source program that uses tools from the Event Visualization Environment (EVE) (Tadel, 2010), part of the ROOT data analysis framework (Brun & Rademakers, 1997). ANDES utilizes current nuclear databases, containing over 3000 experimentally determined nuclear masses from the atomic mass evaluation (AME) (Huang et al., 2021) and the evaluation of nuclear and decay properties (NUBASE) (Kondev et al., 2021), to plot basic nuclear physics quantities such as the two-proton (two-neutron) separation energy, S_{2p} (S_{2n}), the Q-values from α, β^{+} and β^{-} decays, the binding energy, etc.

The main output of the ANDES visualization tool is an interactive 3-dimensional plot of the nuclear chart (see figure below), where well-known phenomena such as nuclear shell closures and pairing effects naturally emerge. In addition, ANDES allows for a detail exploration of the presented *nuclear landscape* where even subtle nuclear structure phenonema, such as the quantum phase transition around the Zr ($Z = 40$) isotopes (Togashi et al., 2016), can be observed as deviations from the smooth patterns generated by the surrounding nuclei.

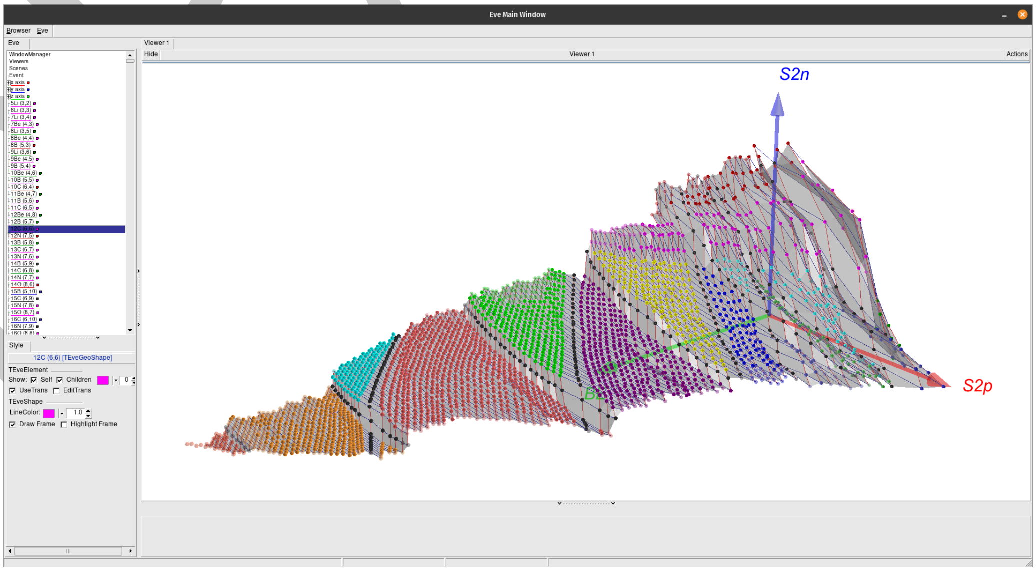

Figure 1: ANDES interactive window.

Statement of need

Emergent phenomena can be observed in atomic nuclei as the number of protons (Z) and neutrons (N) is varied. One of the most striking features of the nuclear force is that, when a nucleus is composed by 2, 8, 20, 28, 50, 82 or 126, protons or neutrons the energy binding the nucleons (protons and neutrons inside the nucleus) is much larger than for most other cases. The term *magic nuclei* was coined to refer to those special cases. In fact, this phenomenon can be explained in terms of the nuclear shell model, which had its inception from the thorough study of experimental data, e.g. from beta decay of radioactive nuclei around $Z = 20$ and $N = 120$ and from alpha decay around $N = 126$. It is worth noting that the discovery and explanation of the nuclear shell structure (Haxel et al., 1949; Mayer, 1949) by the independent works of Maria Goeppert Mayer and J. Hans D. Jensen awarded them the 1963 Nobel Prize in Physics.

In the spirit of the search for interconnections in nuclear data, as described in the Nobel lecture of Goeppert Mayer (Mayer, 1964), I have created the Argonne Nuclear Data Exploration Software (ANDES). The main output of the ANDES visualization tool is an interactive 3-dimensional plot of ground-state properties of atomic nuclei, where each point represents an nuclide. By using a control file to select the appropriate quantities to plot, well-known phenomena such as nuclear shell closures and pairing effects naturally emerge.

There are several 2D visualization tools commonly used in the fields of nuclear physics and nuclear chemistry, see for example NuDat3 (*NuDat3.0*, n.d.). However, the search for new patterns might require to *expand our view of the nuclear chart to new dimensions*, as it has been remarked for the periodic table of chemical elements (Francl, 2019). Interactive 3D plots of nuclear data allow the users to swiftly search for patterns across the entire nuclear chart in part due to the ability to rotate, zoom in or out, and translate the data points. Previous works presenting 3D plots of the nuclear chart and nuclear data include Livechart 3D (*Livechart 3D*, n.d.), a online tool created by the International Atomic Energy Agency, and the Colourful Nuclide Chart by (Simpson & Shelley, 2017).

The nuclear data visualizations enabled by ANDES, allow the user to quickly inspect the entire nuclear chart in search for new patterns that are otherwise not apparent when narrowing the search to few nuclei. The use mass differences and binding energies (which are also based on nuclear masses) in the 3D plots of ANDES is a natural selection given that nuclear masses are one of the more fundamental quantities of atomic nuclei. Masses are planned to be measured in the near future, for example in the region around $N = 126$. The tools presented here may help uncovering previously unobserved phenomena in such regions of the nuclear chart.

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