8.701

Introduction to Nuclear and Particle Physics

Markus Klute - MIT

9. Nuclear Physics

9.1 Introduction

Terminology

A given atom is specified by the number of

- neutrons: N
- protons: Z
- electrons: there are Z electron in neutral atoms

Atoms of the same *element* have same atomic number Z. They are not all equal, however. *Isotopes* of the same element have different # of neutrons N .
Isotopes are denoted by ${}^{A}_{Z}X_{N}$ or more often by

$$\boxed{{}^{A}_{Z}X}$$

where X is the chemical symbol and $A = Z + N$ is the mass number. E.g.: ${}^{235}_{92}U$,${}^{238}U$ [the Z number is redundant, thus it is often omitted].

Terminology

When talking of different nuclei we can refer to them as

- Nuclide: atom/nucleus with a specific N and Z.
- Isobar: nuclides with same mass # A ($\neq Z, N$).
- Isotone: nuclides with same N, $\neq Z$.
- Isomer: same nuclide (but different energy state).

Nuclear radius:

$$R = R_0 A^{1/3}$$

Chart of Nuclides

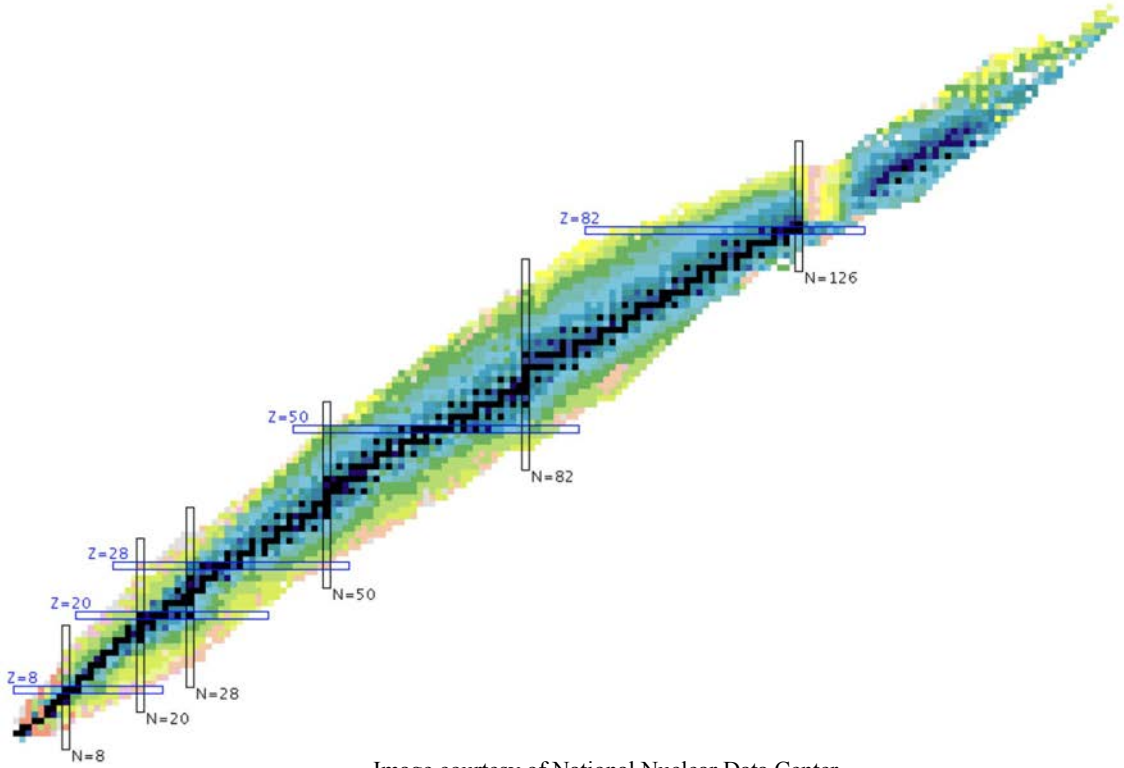

Image courtesy of National Nuclear Data Center.

Chart of Nuclides

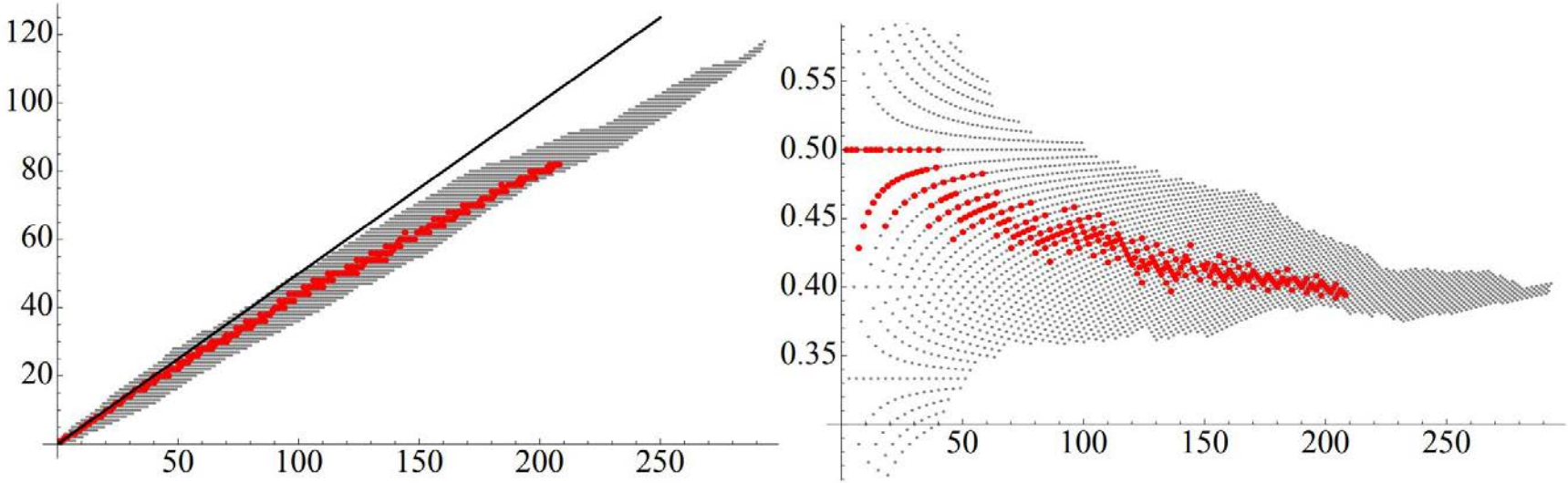

Fig. 4: Nuclide chart (obtained with the software Mathematica). Left: Z vs. A, Right: Z/A vs. A. In red, stable nuclides. The black line represents $Z = A/2$.

Radioactive Decays

Radioactive decay is the process in which an unstable nucleus spontaneously loses energy by emitting ionizing particles and radiation. This decay, or loss of energy, results in an atom of one type, called the **parent nuclide**, transforming to an atom of a different type, named the **daughter nuclide**.

$$\frac{dN}{dt} = -\lambda N(t)$$

We can also define the **mean lifetime**

$$\tau = 1/\lambda$$

and the **half-life**

$$t_{1/2} = \ln(2)/\lambda$$

8.701 Introduction to Nuclear and Particle Physics
Fall 2020