Physics with Exotic Nuclei and Exotic Atoms at Relativistic Energies

Hans Geissel

Euroschool Valencia, September 2003

- Introduction
- Momentum Measurements, Ion Optics, Spectrometers
- Atomic Interaction of Heavy Ions
- Exotic Atoms
- Production and Separation of Exotic Nuclei
- Halo and Skin Nuclei
- Precision Experiments with Stored Ions
- Discovery of a New Type of Radioactivity
- Next-Generation In-Flight Facilities

Physics with exotic nuclei and exotic atoms at relativistic energies

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Lecture I.

Introduction

Key topics in nuclear physics and nuclear astrophysics are to understand the structure of matter, the fundamental forces and interactions including the evolution and abundance of the elements in the universe.

What are exotic atoms?

What are exotic nuclei?

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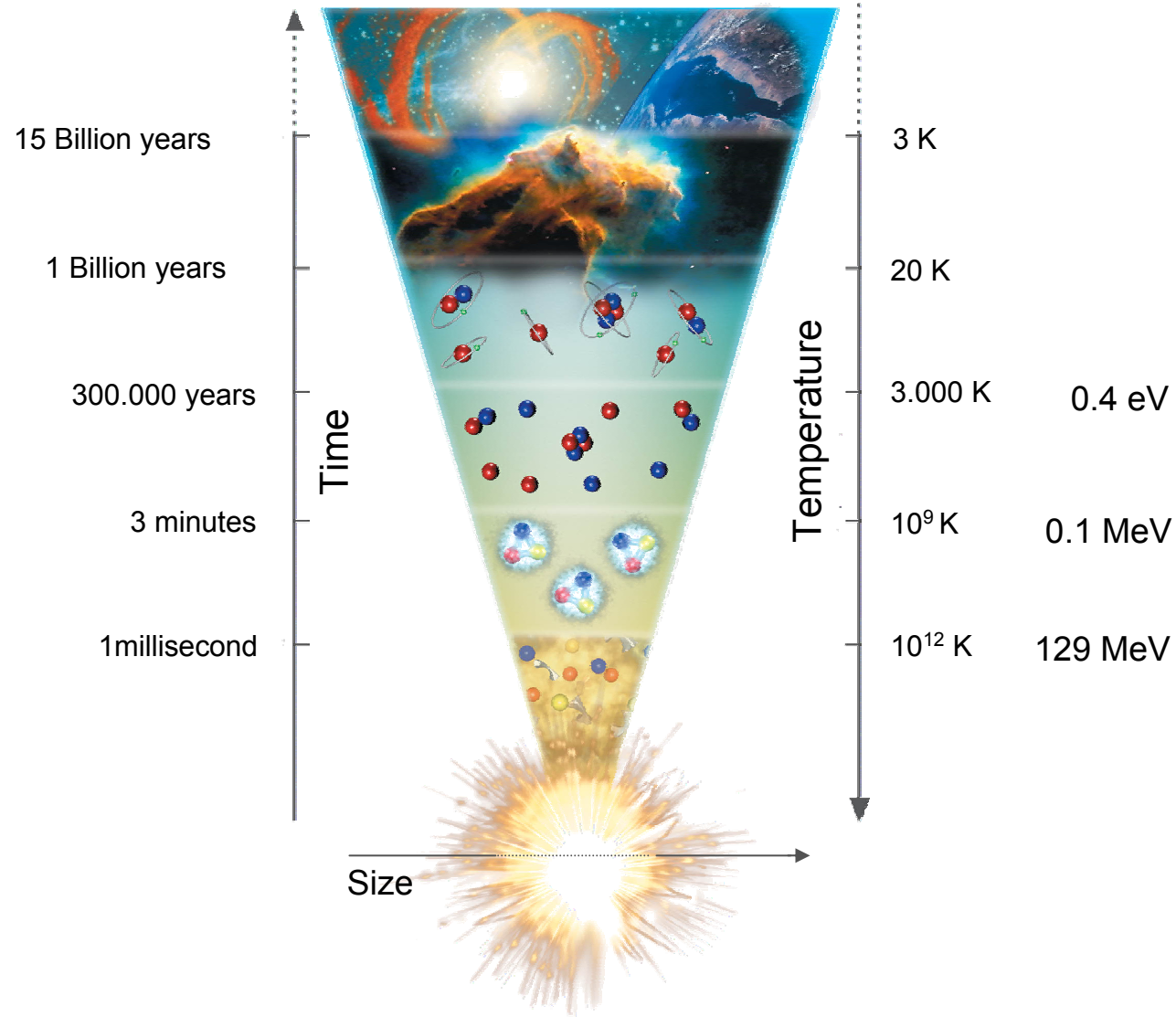
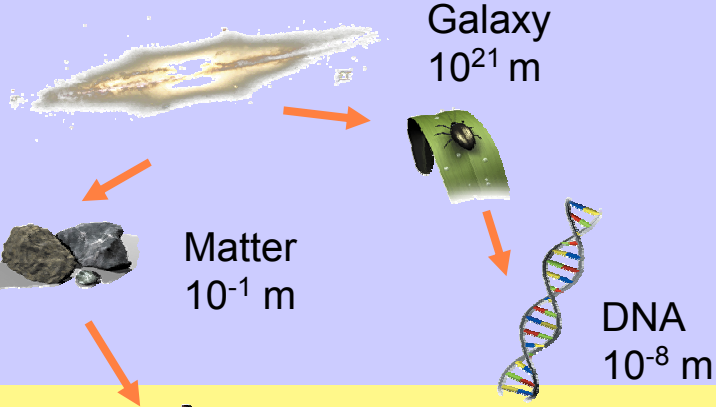
Evolution of Matter



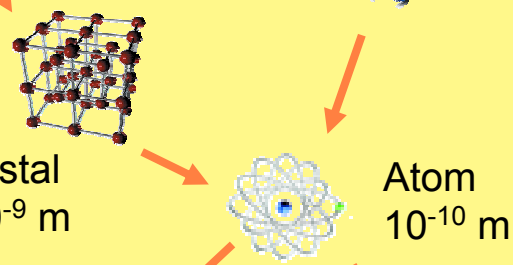
Matter and Forces

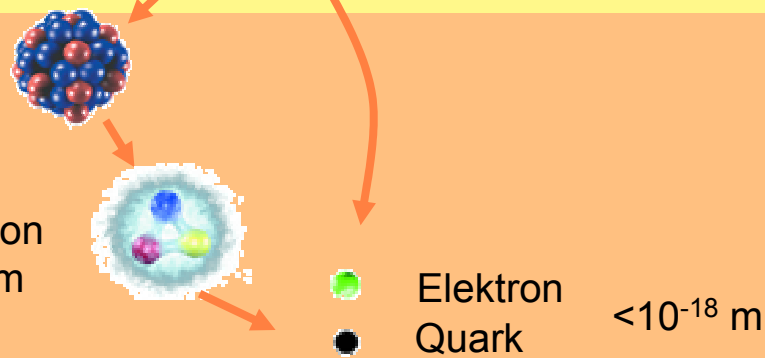
Gravitation
General Relativity



Elektromagnetic Force
QED

Weak Interaction
Standard Model





Strong Interaction
QCD

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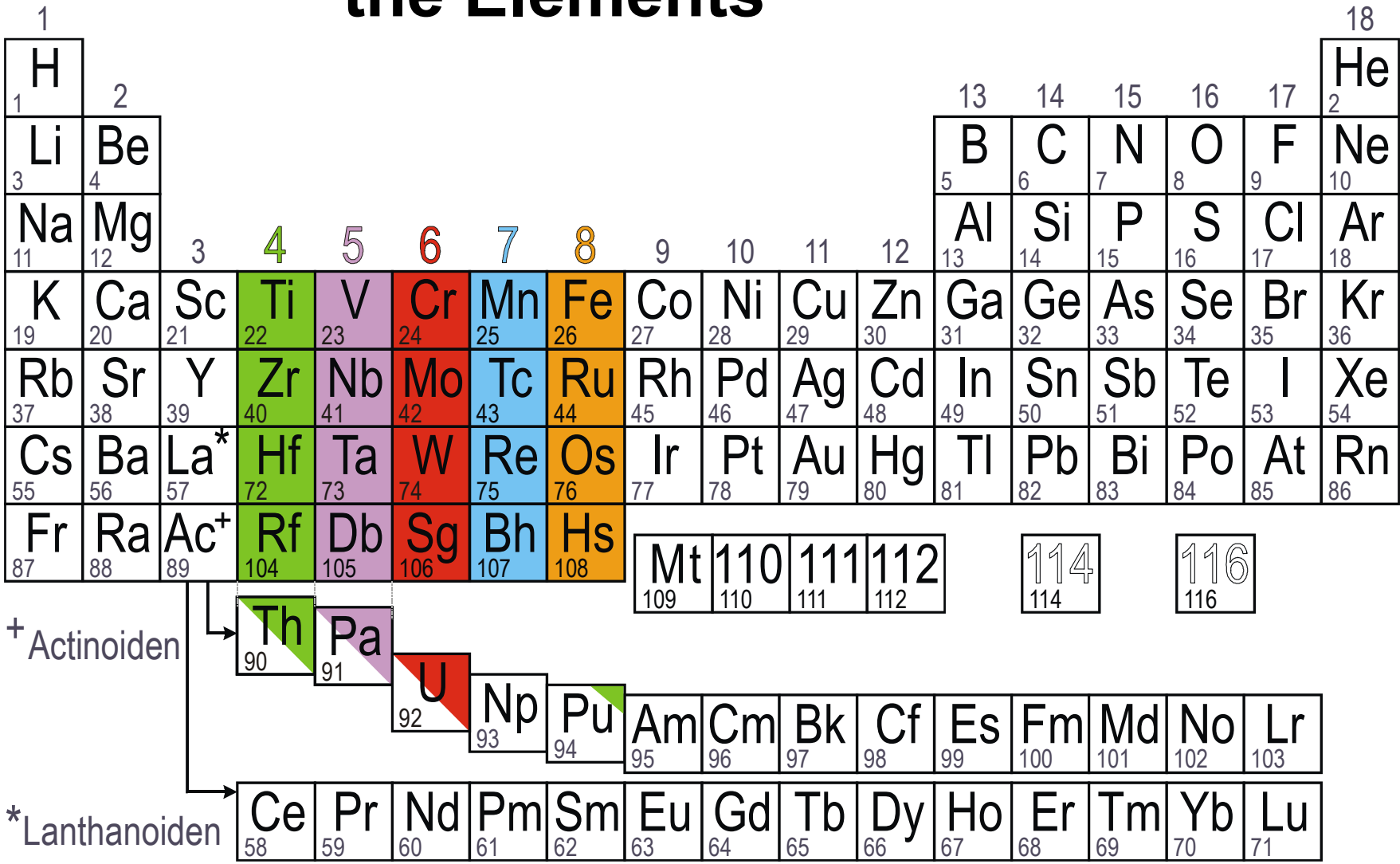
Periodic System of the Elements



Up to Hs chemistry is studied!

Solar System Abundances

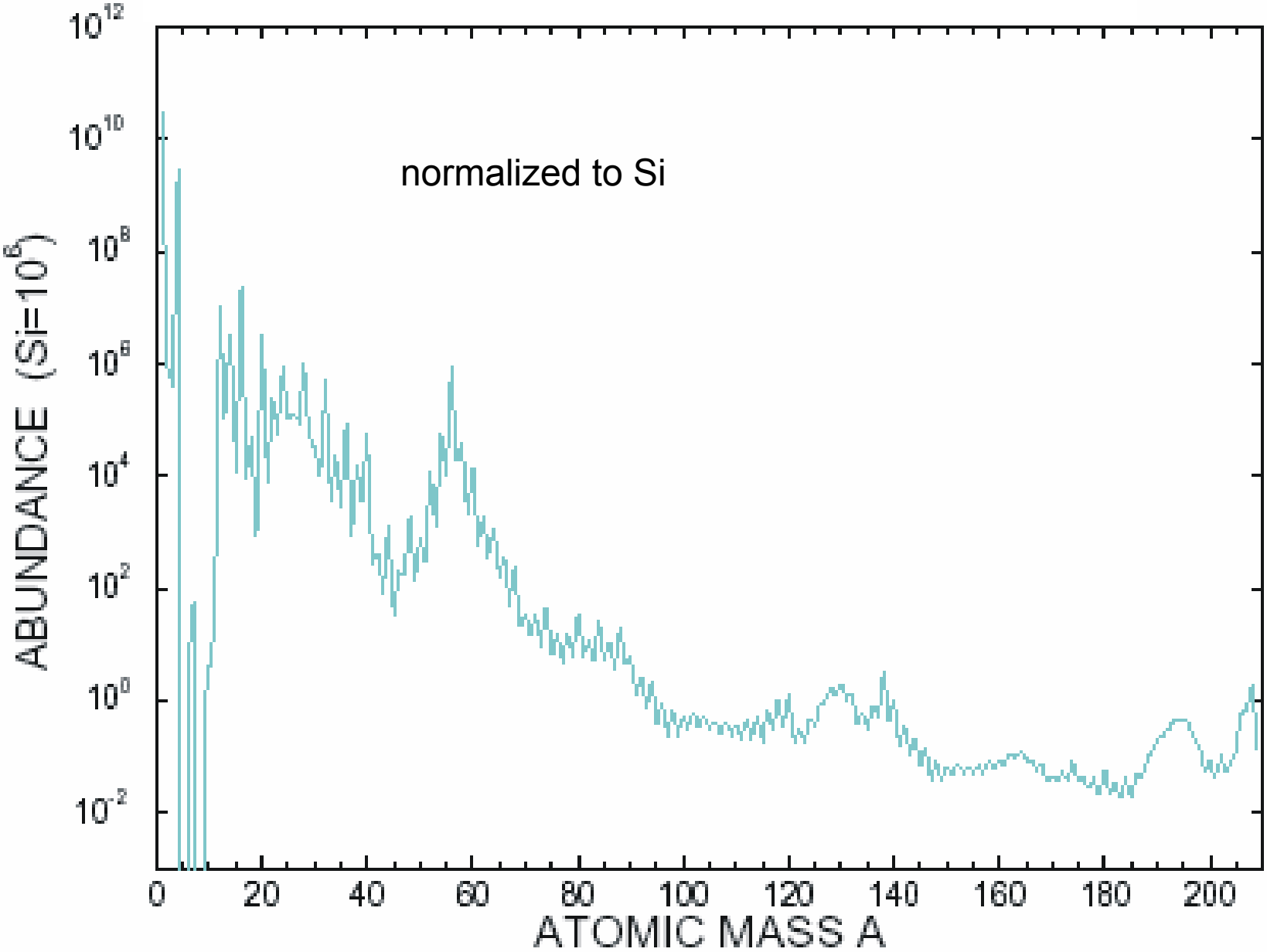
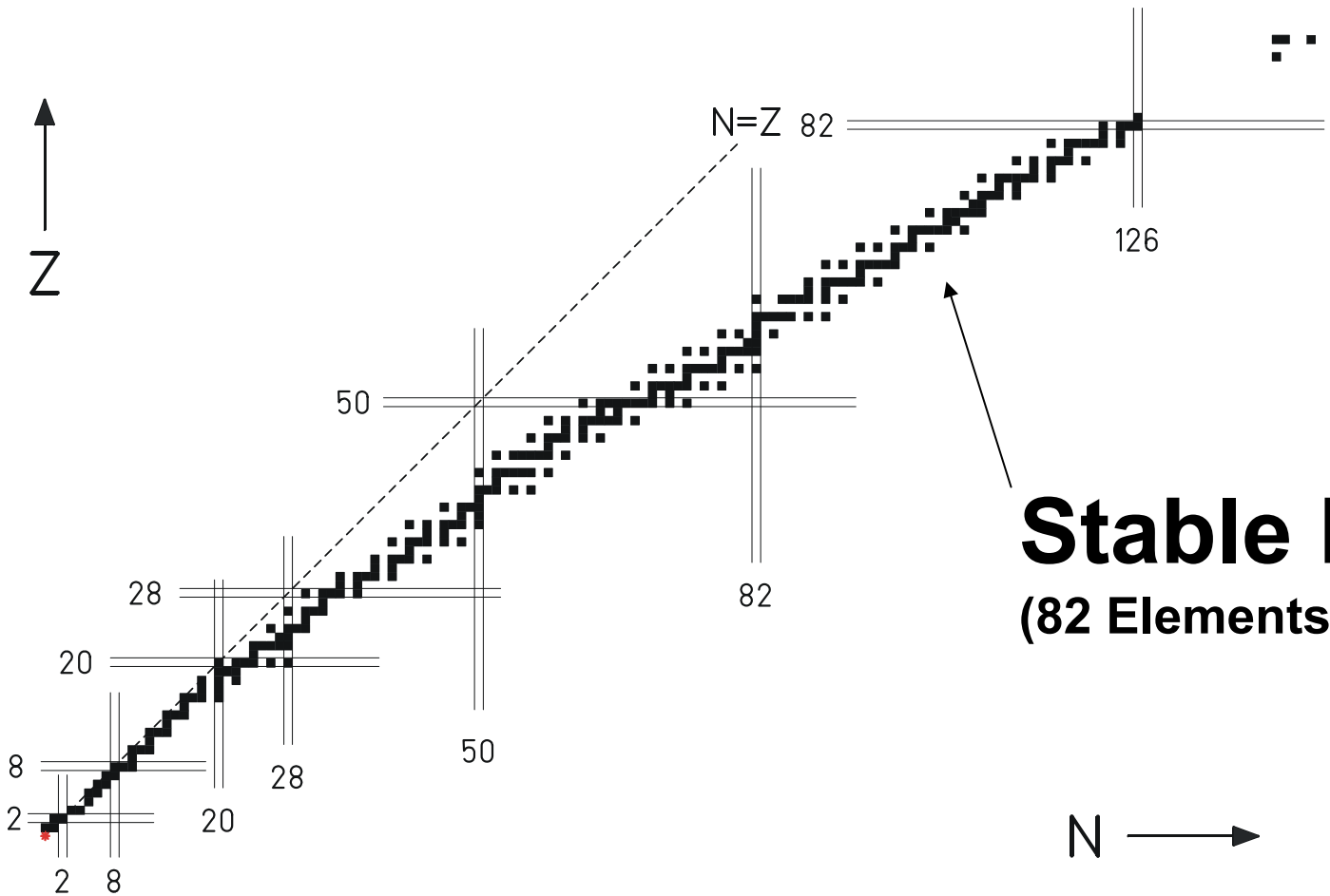


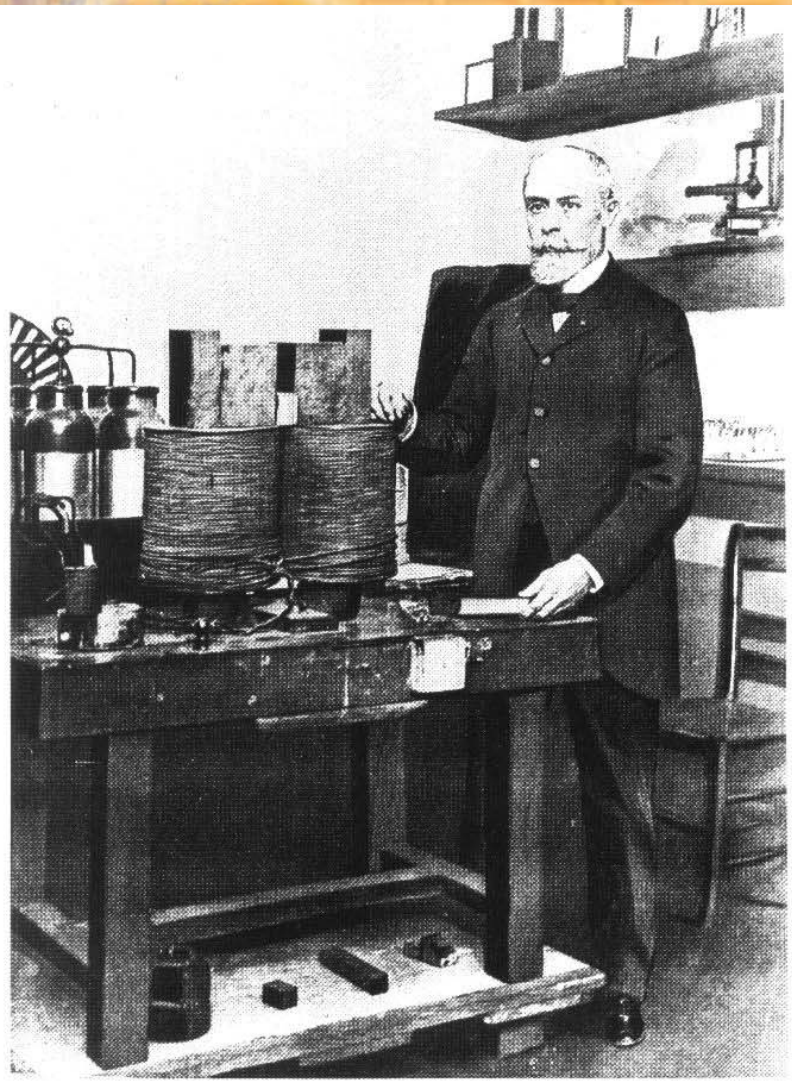
Chart of Nuclides



Stable Nuclei

(82 Elements, 272 Isotopes)

Discovery of the Radioactivity



Henri Becquerel, près d'un électro-aimant,
dans son laboratoire du Museum National d'Histoire Naturelle.

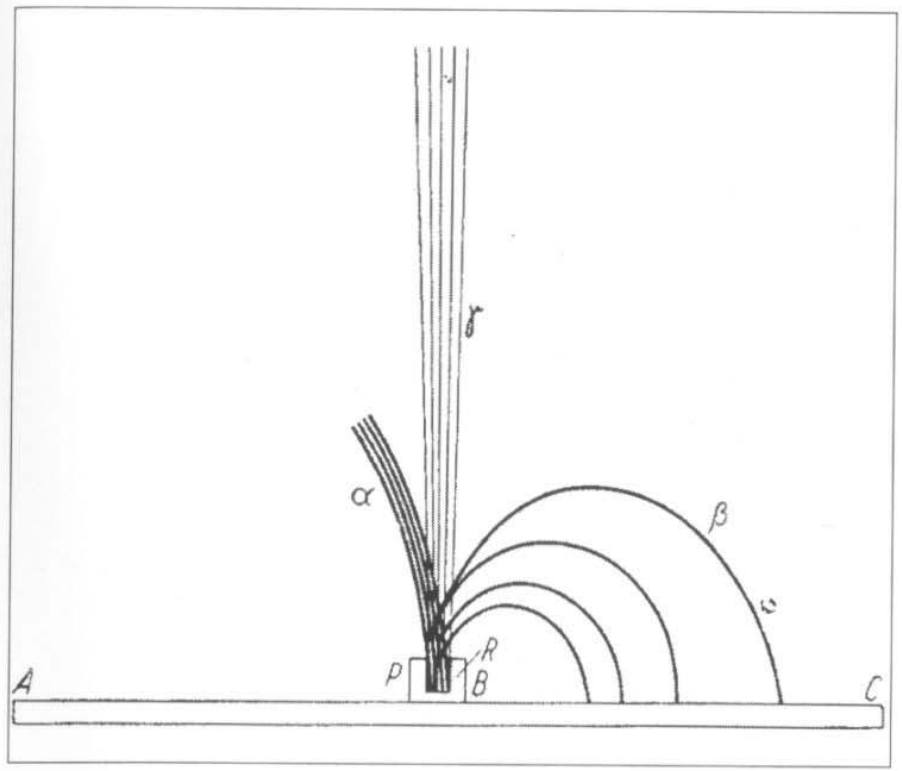
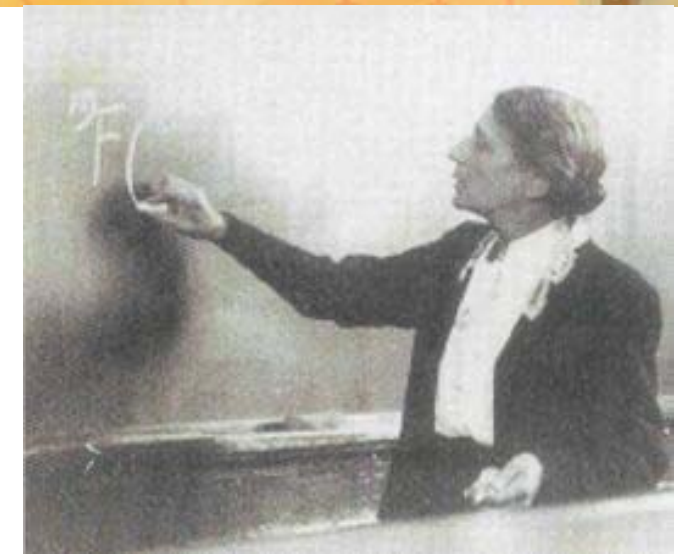


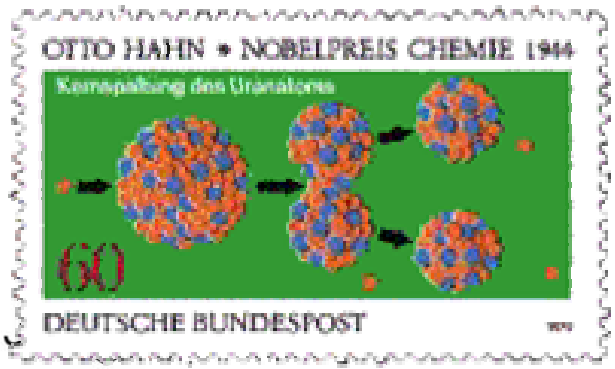
Schéma illustrant l'action d'un champ magnétique
sur les rayonnements de radioactivité (Marie Curie, thèse).

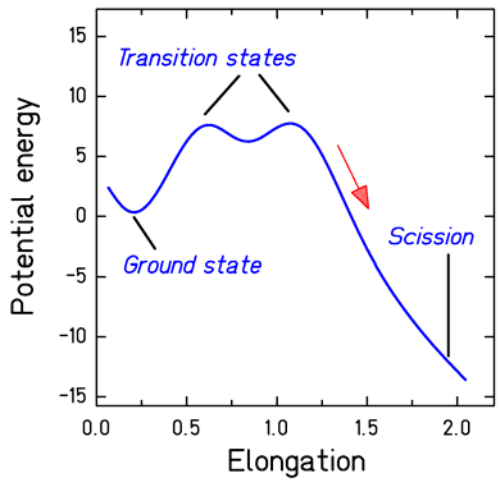
Discovery of Fission

O. Hahn, R. Straßmann
Naturwiss. 27 (1939) 11, 89



L. Meitner, O. Frisch, Nature 27 (1939) 239





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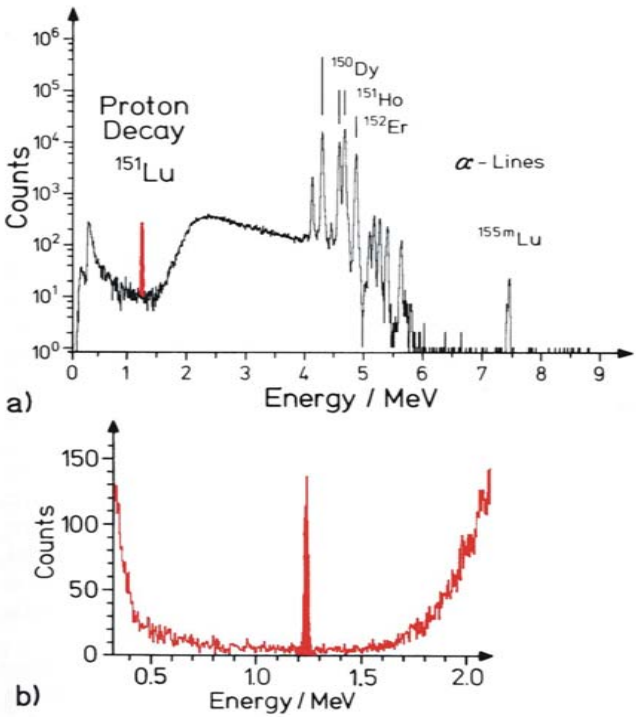
Discovery of the Proton Radioactivity

S. Hofmann et al. Z. Phys. A305, (1982) 111, 125



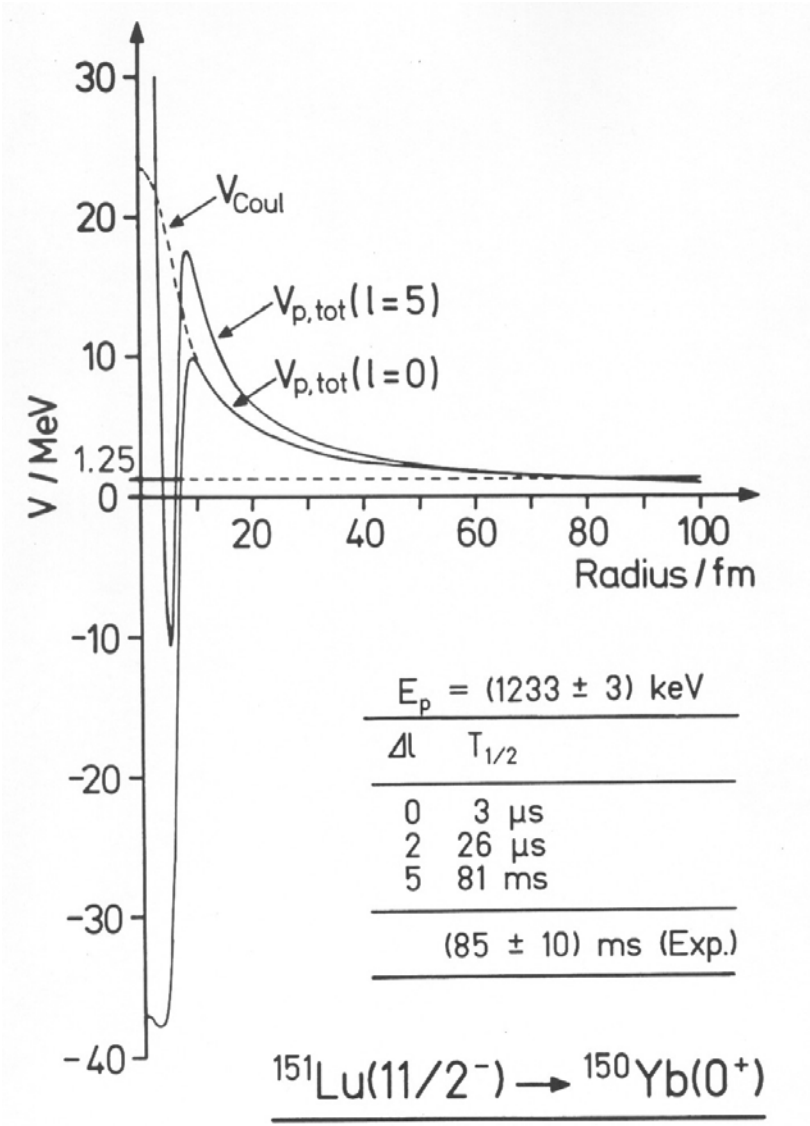
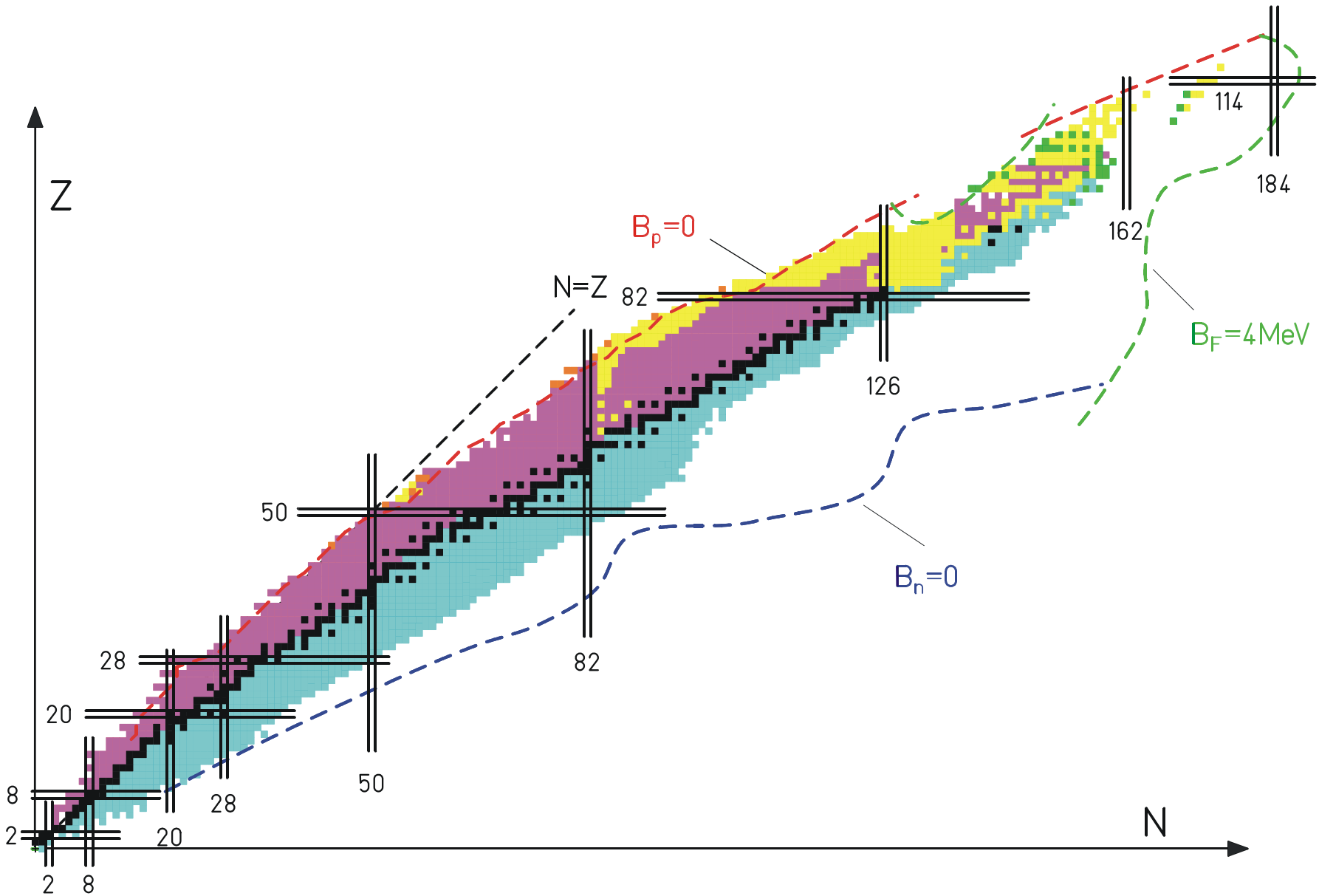
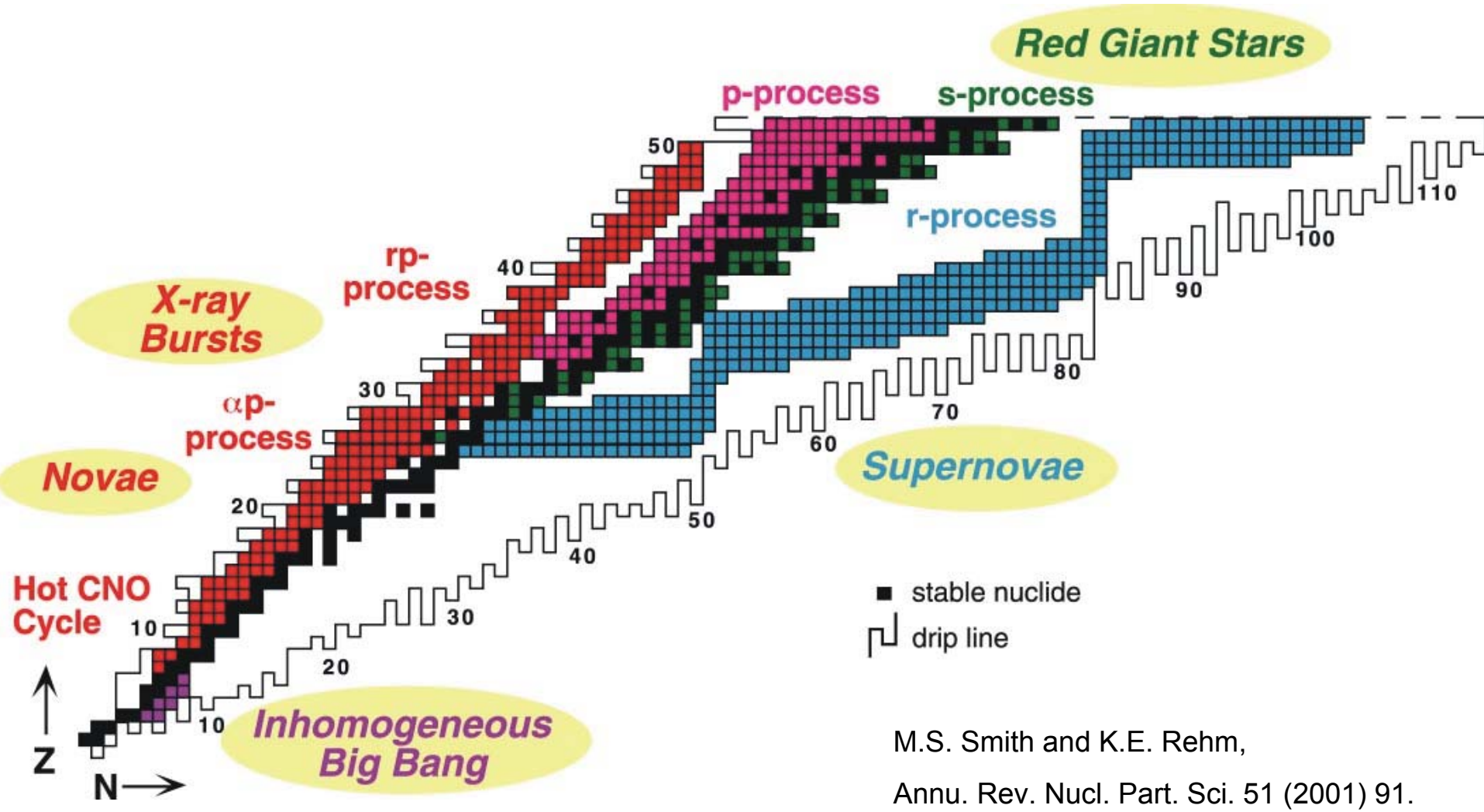


Chart of Nuclides



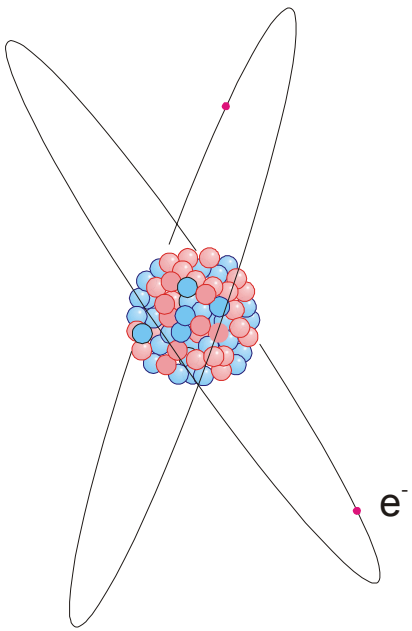
Knowledge on Exotic Nuclei is needed for Nuclear Structure and Astrophysics

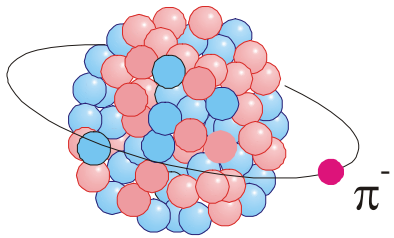


M.S. Smith and K.E. Rehm,

Annu. Rev. Nucl. Part. Sci. 51 (2001) 91.

Exotic Atoms





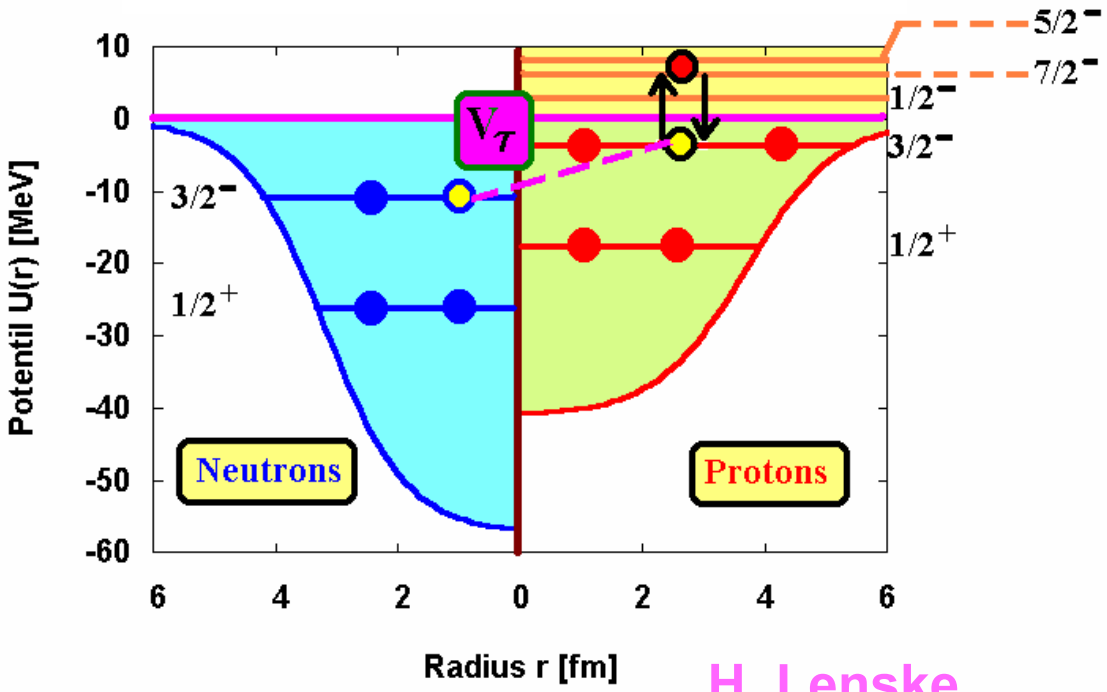
$$r_n \propto \frac{\hbar^2 n^2}{m e^2 Z}$$

Exotic atoms are unique traps for negative particles like μ^-, π^-, $\bar{p}$ and thus provide crucial tests of fundamental laws and properties.

- Probe nuclear charge distribution
- Study Strong Interaction (optical potential, in medium mass modification)

Exotic Nuclei
(Short-lived, Rare, Near the Driplines)

Exotic Nuclei are a Key to Our Universe



H. Lenske

- ❖ Weakly bound states close to the continuum
- ❖ Correlations are important
- ❖ Large radii and very dilute surface (halos, skins)
- ❖ Pairing and clustering
- ❖ New properties (excitation and decay modes, reaction, new shell structure)

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Exotic Nuclei and Exotic Atoms

Key topics:

How to produce exotic atoms and exotic nuclei?

How to separate and to investigate them?

What can we learn?