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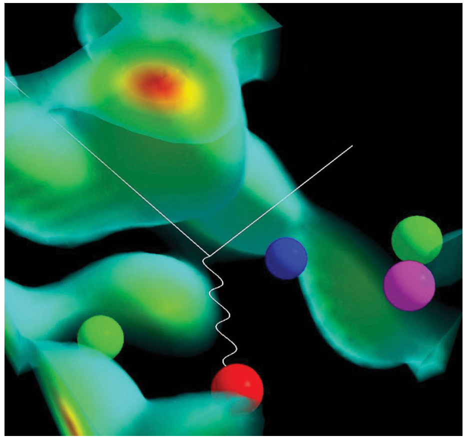
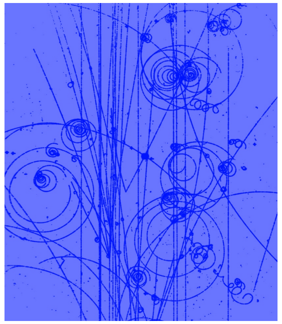
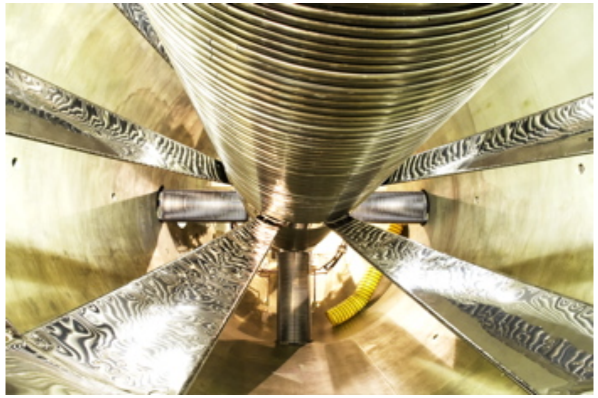
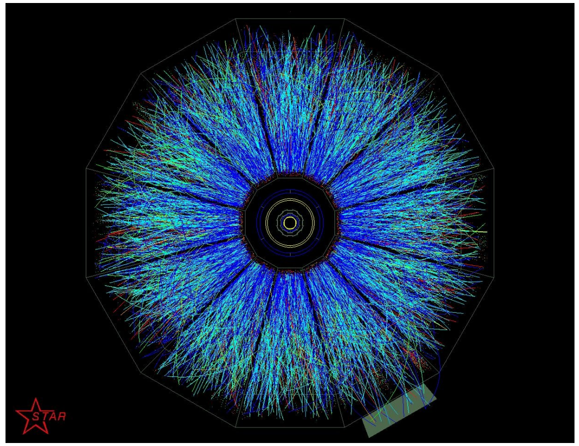
PC30121: Introduction to Nuclear and Particle Physics









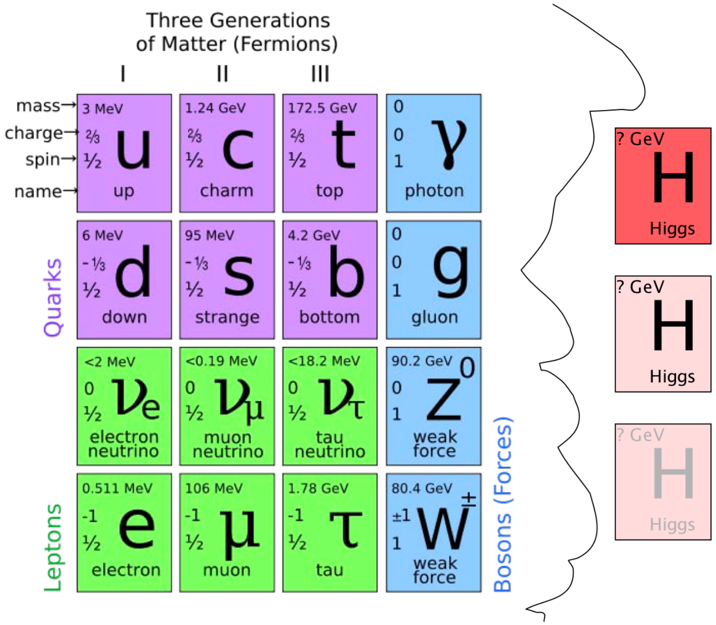
Prof Sean J Freeman *(Nuclei)* and Prof Fred K Loebinger *(Particles)*

Simplicity *AND* Complexity

PARTICLE PHYSICS

Quarks, leptons and gauge bosons are (currently) the most fundamental constituents.
Basic interactions.

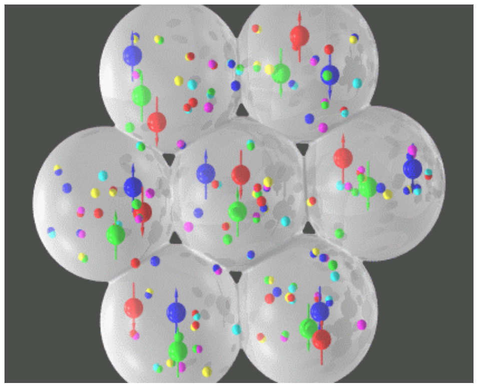
"Theories of everything"?



NUCLEAR PHYSICS

Hadrons and nuclei are simplest *complex* systems built from *fundamental* constituents.

Emergence of new physics in complex systems from correlations between constituents: collectivity, super fluidity…



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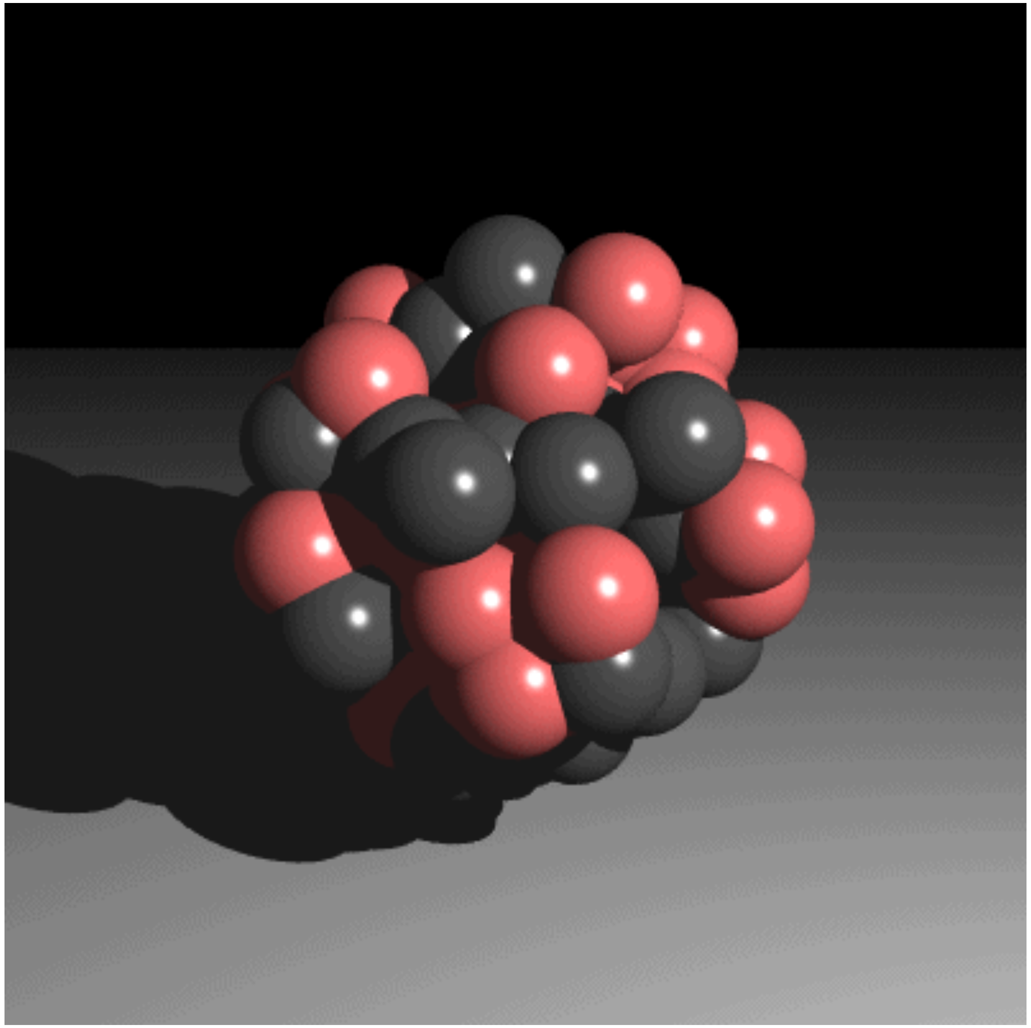
A nucleus?



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Concepts so far…

binding energy

mass-energy equivalence

definitions of atomic and nuclear mass

atomic mass scale

mass excess and defect

Q values

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Quick Tour of the Hydrogen Isotopes

Hydrogen, ${}^{1}_{1}\mathrm{H}_{0}$ or p:
99.985% of the Universe!
Stable…mean life τ > 1.6 × 10^{25} yr

Deuterium, deutron, diplon…. ${}^{2}_{1}\mathrm{H}_{1}$ or d.
Stable and 0.016% of all hydrogen atoms.

Tritium, triton… ${}^{3}_{1}\mathrm{H}_{1}$ or t.
Unstable, but naturally occurring.

Hydrogen isotopes out to ^{7}H have been artificially manufactured in nuclear reactions. All unstable with short lifetimes.

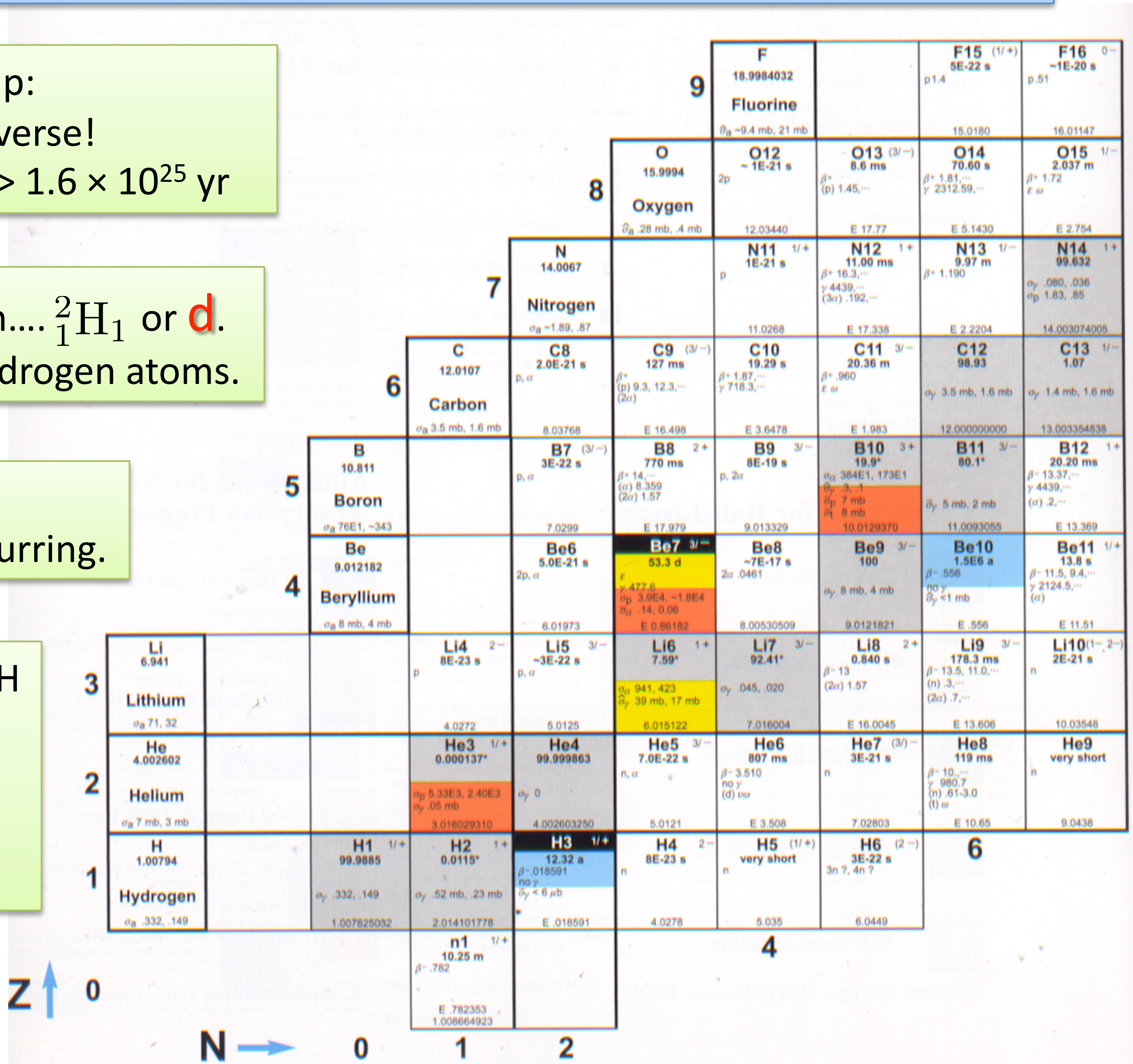
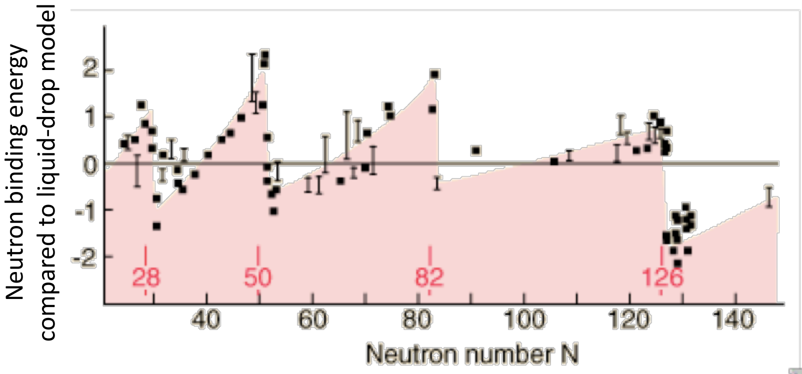
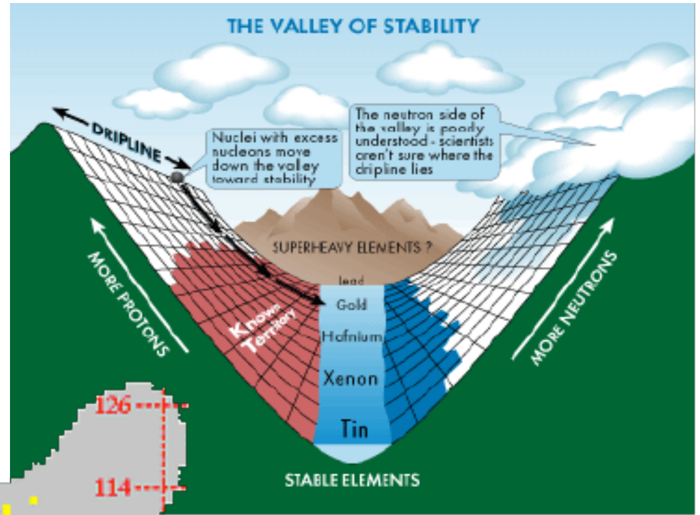
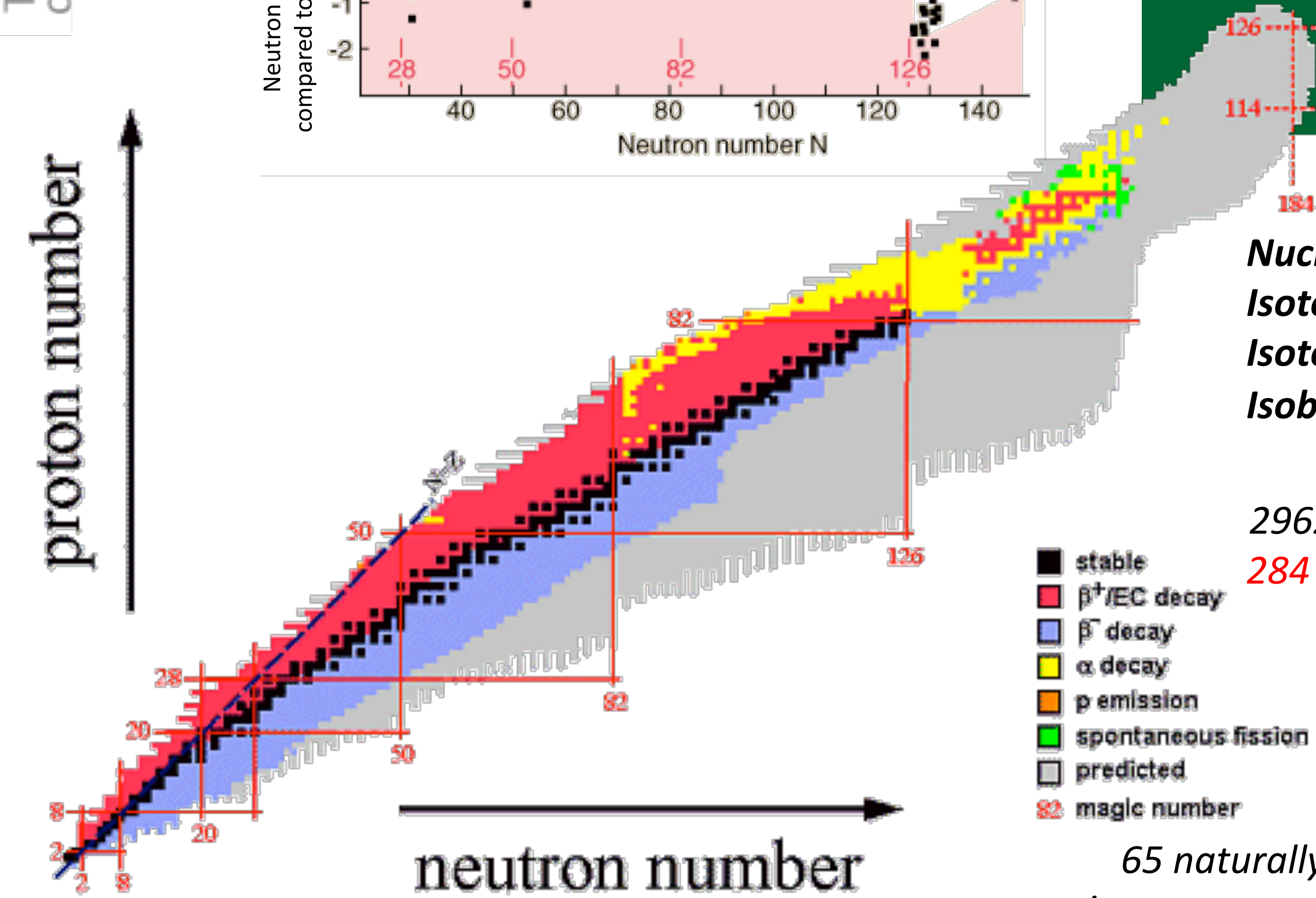


Chart of Nuclides







Nuclides: A=Z+N

Isotopes: Same Z, different N

Isotones: Same N, different Z

Isobars: Same A, different Z & N

2962 known nuclides (Aug 2006)

284 terrestrially occurring (1998)

>6000 potentially bound

65 naturally occurring radioactive isotopes: very long lived / cosmogenic and their daughters

Some things to think about

- how do you know if something is stable or just very long lived?
- there are naturally occurring radioactive nuclei with both long and short half lives; why?
- if the neutron is unstable, why do they exist in nuclei?
- if neutrons were just 800 keV/c^2 lighter, hydrogen atoms would be unstable and the world would be a dull place.

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Books: Read Them!

Books on Nuclear and Particle Physics:

Nuclear and Particle Physics by R.J. Blin-Stoyle (Chapman Hall 1991)

Nuclear and Particle Physics: An Introduction by Brian R. Martin (Wiley 2009)

Nuclear and Particle Physics by W. S. C. Williams (Cambridge 1991)

Nuclear and Particle Physics by W.E. Burcham and M. Jobes (Prentice Hall 1994)

Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by Eisberg and Resnick

Particles and Nuclei: An Introduction to the Physical Concepts
by Bogdan Povh, Klaus Rith, and Christoph Scholz (Springer 2008)

...plus many more.

Books on Nuclear Physics and Applications: Nuclear Physics: Principles and Applications by J.S. Lilley (Wiley 2001) Manchester Physics

Books on Nuclear Physics:

Introductory Nuclear Physics by Kenneth S. Krane (Wiley 1987)

An Introduction to Nuclear Physics by W. N. Cottingham and D. A. Greenwood (Cambridge 2001)

Introductory Nuclear Physics by P.E. Hodgson, E. Gadioli, and E. Gadiloi Erba, (Oxford 1997)

The Properties of Nuclei by G. A. Jones (Oxford 1987)

Nuclear Physics in a Nutshell by Carlos A. Bertulani (Princeton 2007)

...plus many more.

Important Ideas from Second-Year Quantum Mechanics

- Schrodinger equation and energy eignvalues/functions.
- Separable solutions in 3D potentials.
- Eigenvalues/functions of orbital angular momentum.
- Pauli principle.
- Parity.
- Potential barriers, steps and wells.
- Intrinsic spin and symmetry.
- Atomic shell structure.

PHYS20101: Introduction to Quantum Mechanics and PHYS20302: From Atoms to Solids

•A.C. Phillips *Introduction to Quantum Mechanics* Wiley
•R.M. Eisberg and R. Resnick *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* Wiley

Read the primer on Quantum Mechanics of Potential Wells