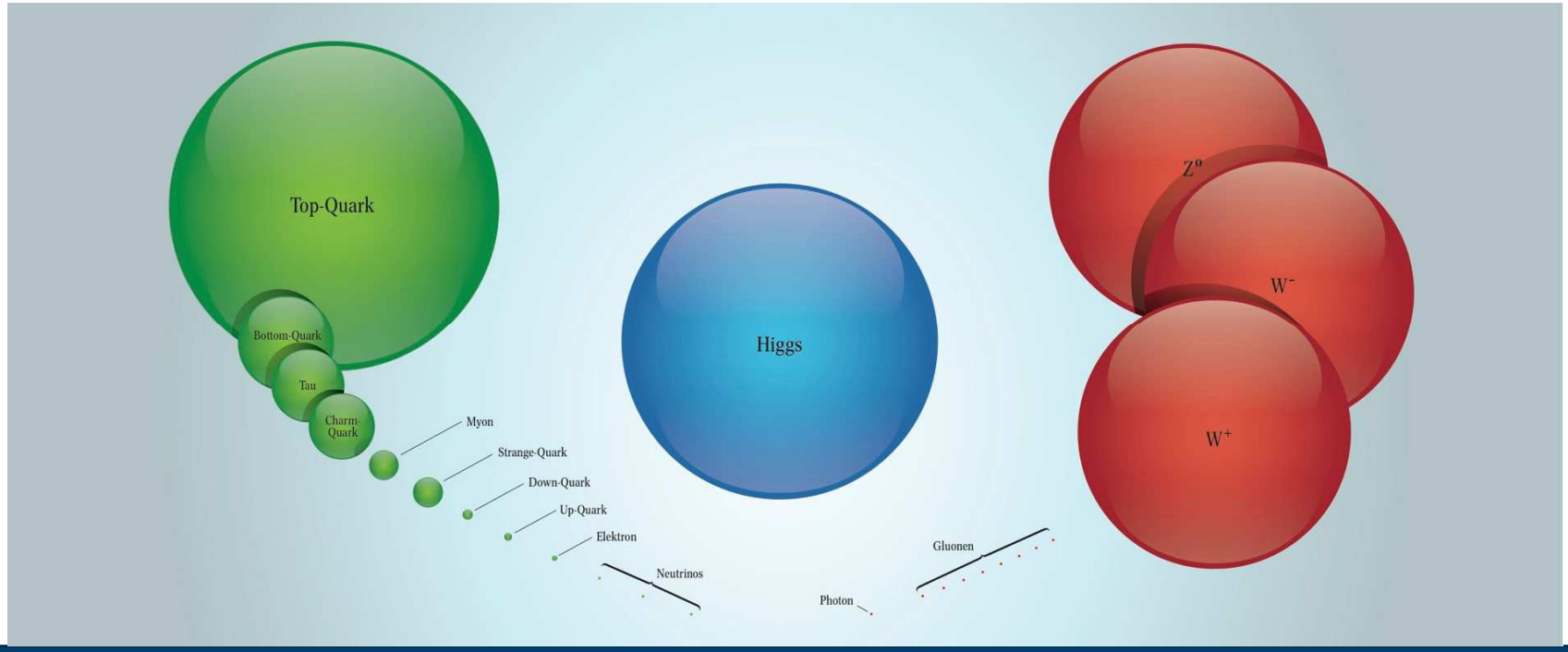


ELEMENTARY PARTICLE PHYSICS

A BRIEF INTRODUCTION (PART I)

APRIL 2020 I HANS STRÖHER (FZ JÜLICH, UNIVERSITY OF COLOGNE)

Mitglied der Helmholtz-Gemeinschaft

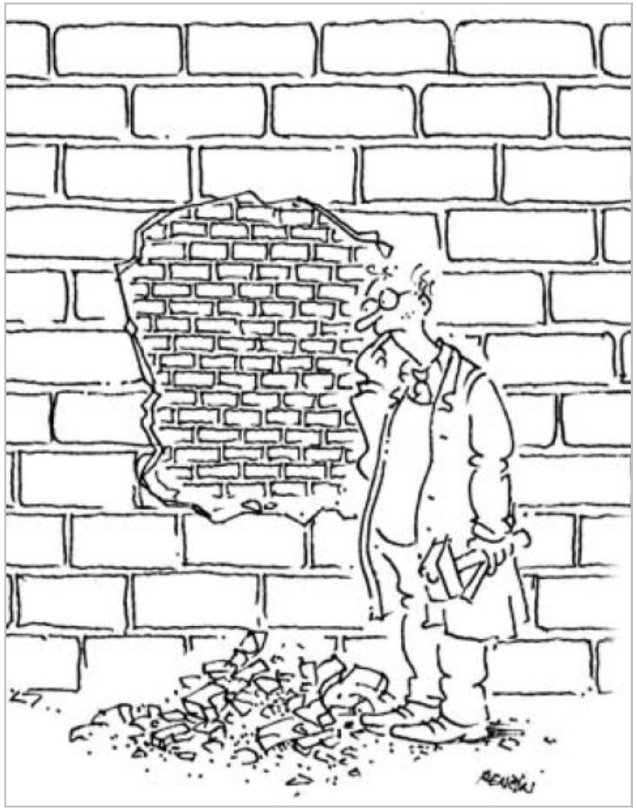
JÜLICH
Forschungszentrum

Outline – EPP Video Lectures

- An introduction of Elementary Particle Physics (EPP) via video
- Lecturers: Hans Ströher, Irakli Keshelashvili, Detlev Gotta
- Time: Monday & Friday @ 2 pm (Jülich time) → 4 pm (Tbilisi)
- Outline:
  - A brief **introduction** (history …)
  - The **tools** (accelerators, targets, detectors … kinematics, …)
  - The **particles** (hadrons, baryons, mesons)
  - The ***fundamental* particles** (quarks, leptons)
  - The **forces** (gravitation, nuclear forces)
  - The ***fundamental* interactions** (strong and electro-weak IA)
  - The **Standard Model** of EPP
  - Physics **Beyond the Standard Model** (BSM)
  - Spin-offs – **Applications** of EPP

Overall Information

Introduction – Prelude



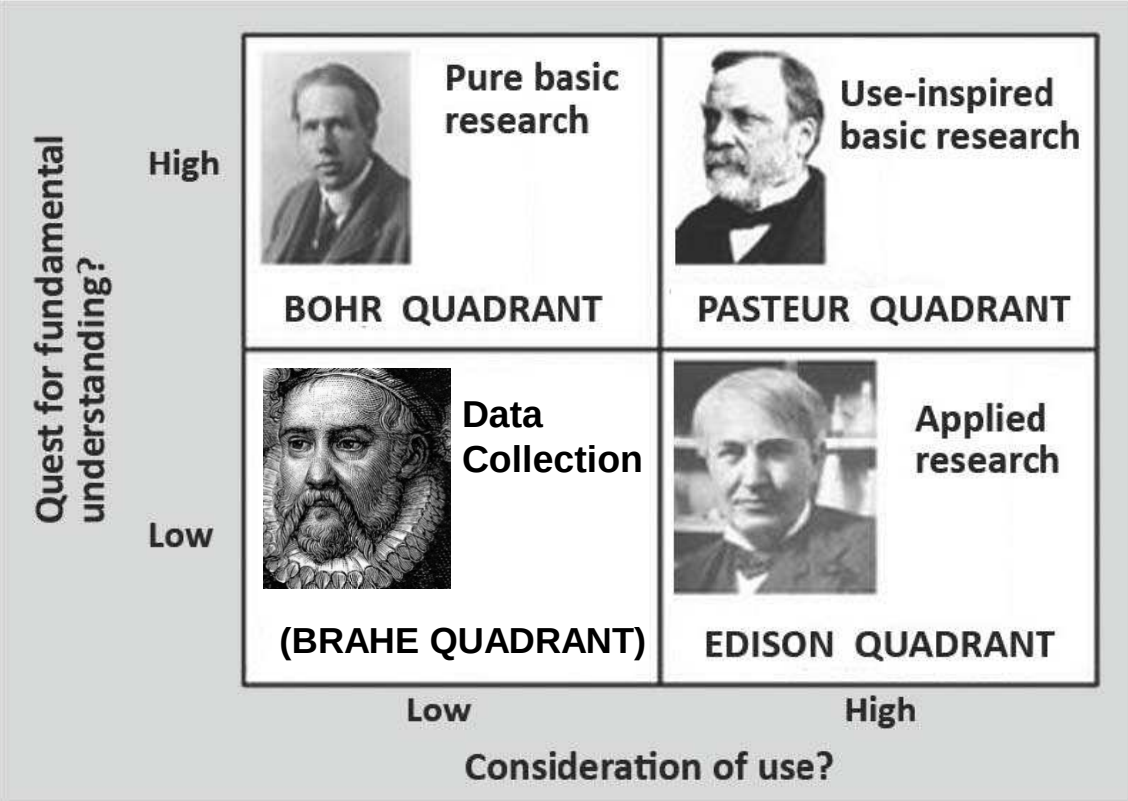
Science is driven by curiosity

Introduction – Prelude

- What we would like to know:
  - What are the **fundamental building blocks** of Nature?
  - Why are there **three generations** of fermions?
  - Are **neutrinos** their own antiparticle?
  - What are the **interactions** between the building blocks?
  - Do all **forces unify**?
  - Where does the **mass of the particles** originate?
  - What is **Dark Matter**? What is the origin of Dark Matter?
  - Or even **Dark Energy**?
  - Why is **antimatter** different from matter?
  - What is the origin of the **matter-antimatter asymmetry**?
  - Is the **proton** (ordinary matter) **stable**?
  - …

Fundamental questions

Introduction – Prelude



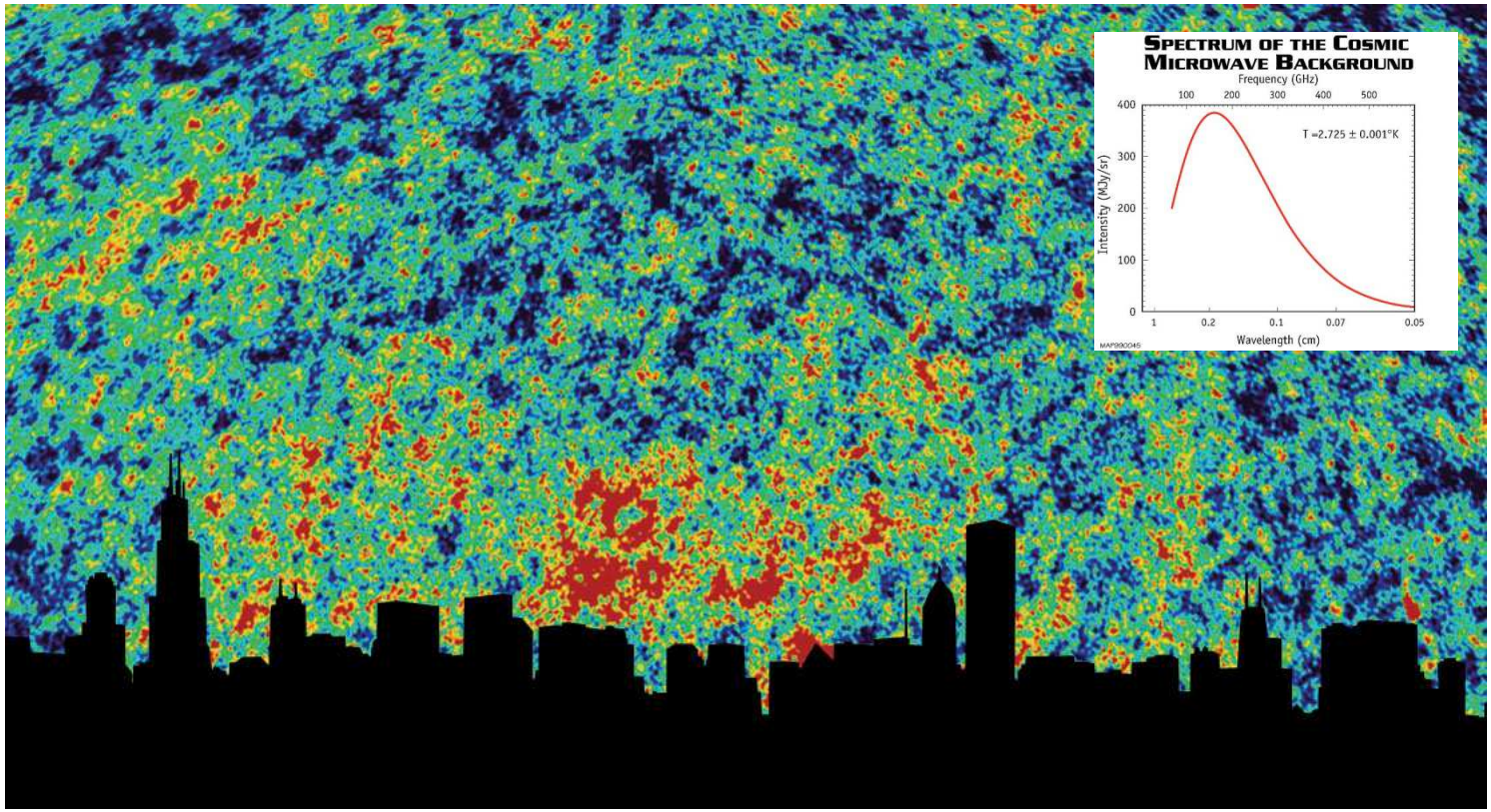
Curiosity-driven *vs.* use-inspired (basic) research

Introduction – Prelude

The *Milky Way* over monument valley

Mankind strives to understand **Nature** – from the very large …

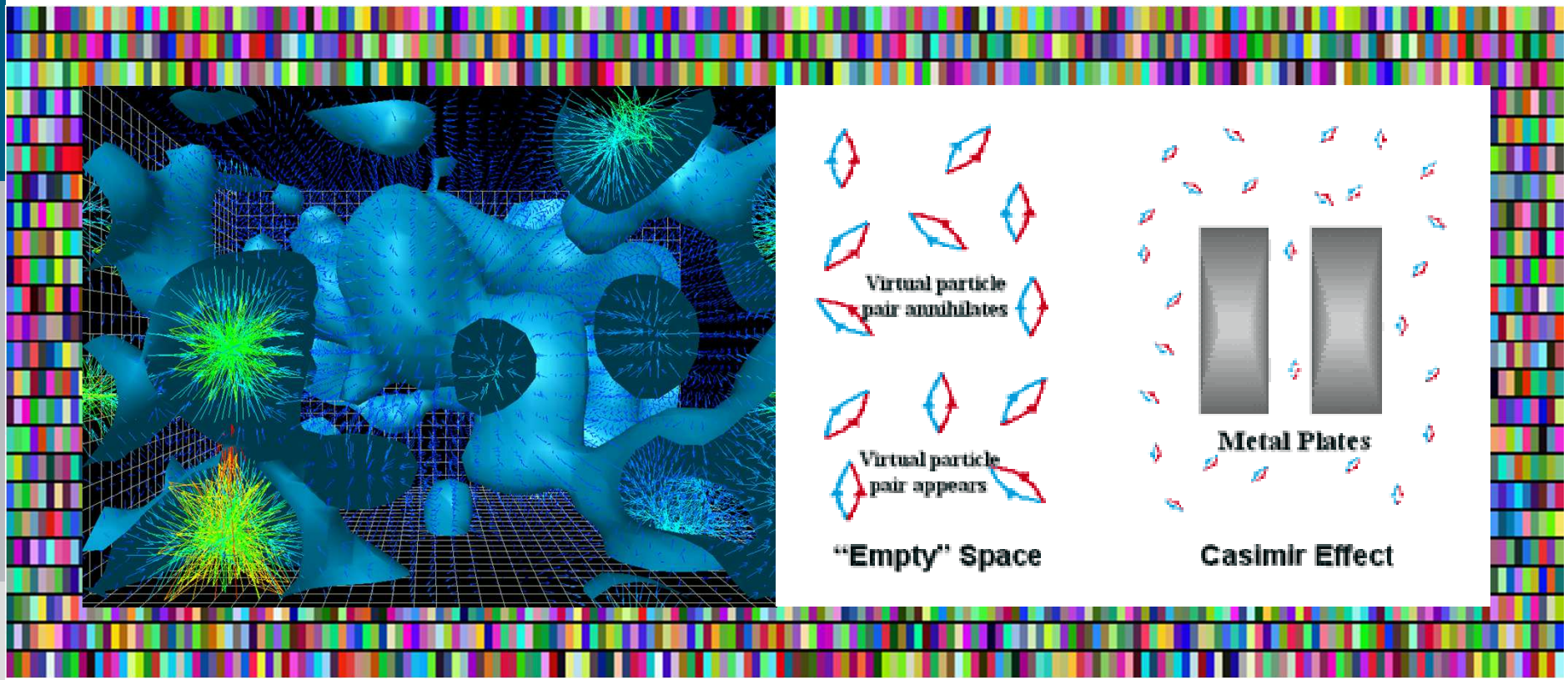
Introduction – Prelude



The *Cosmic Microwave Background* (CMB)

Mankind strives to understand **Nature** – from the very large …

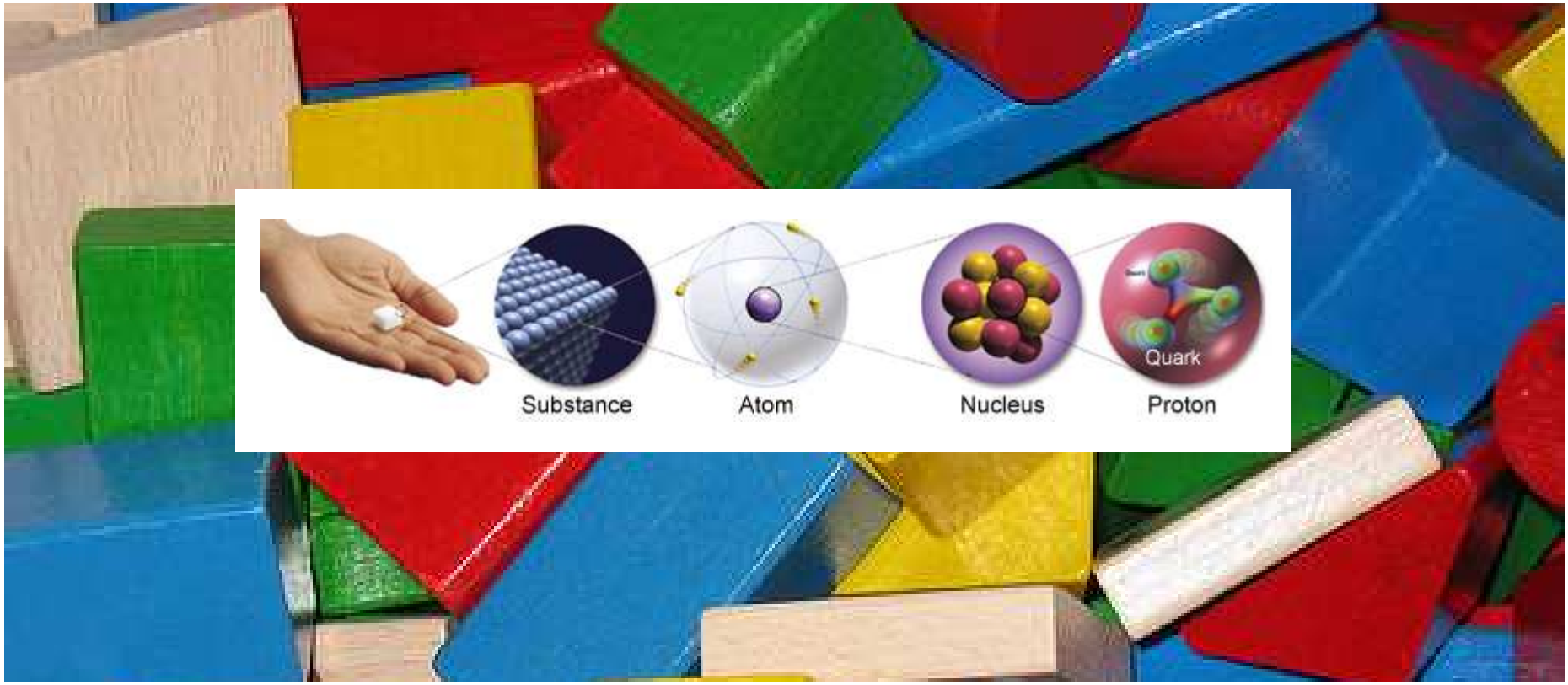
Introduction – Prelude



Vacuum Fluctuations (Simulation)

Mankind strives to understand **Nature** – from the very large to the very small

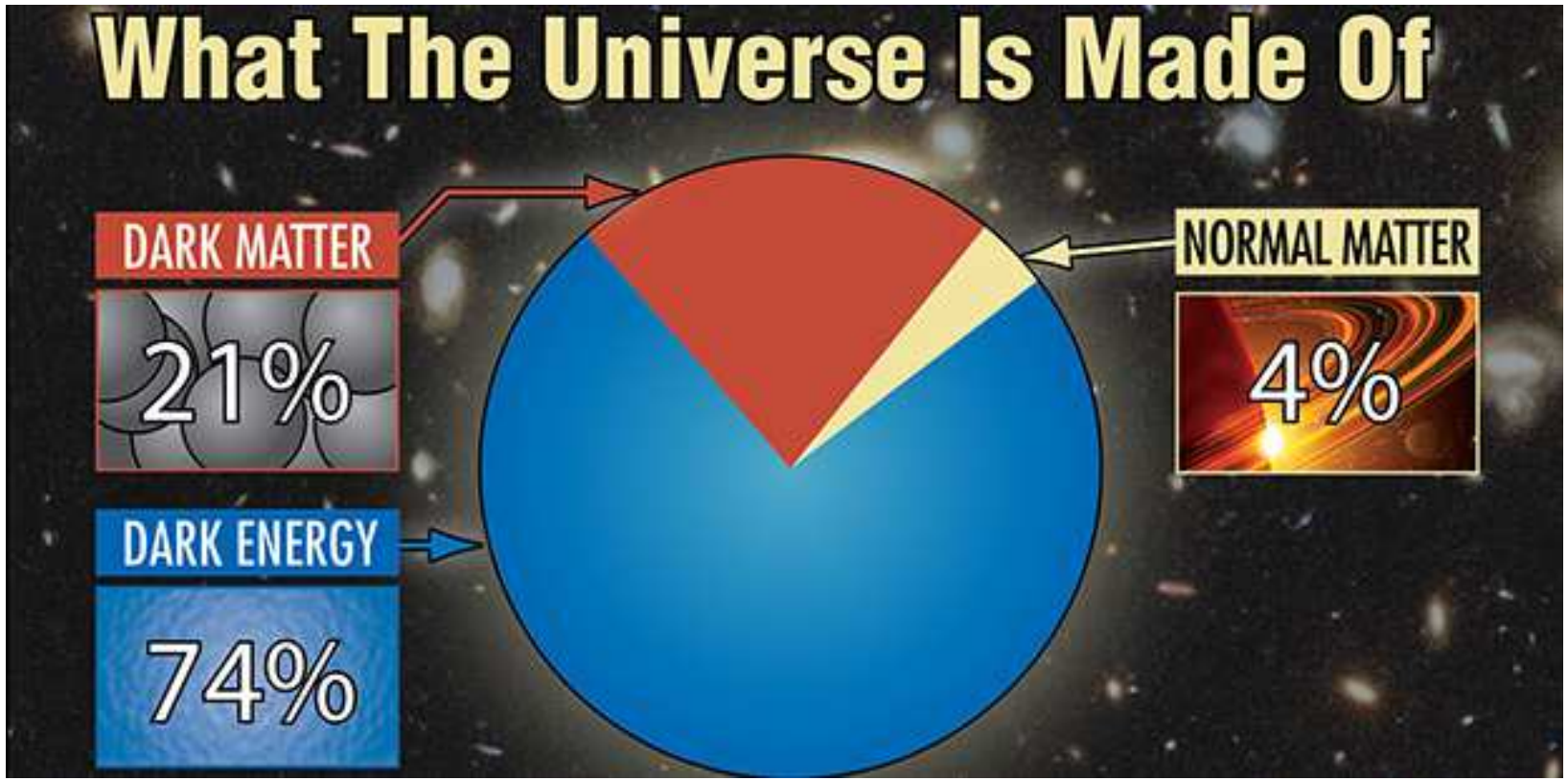
Introduction – Prospect



The building blocks of matter

There is a **connection** between the *very large* and the *very small*

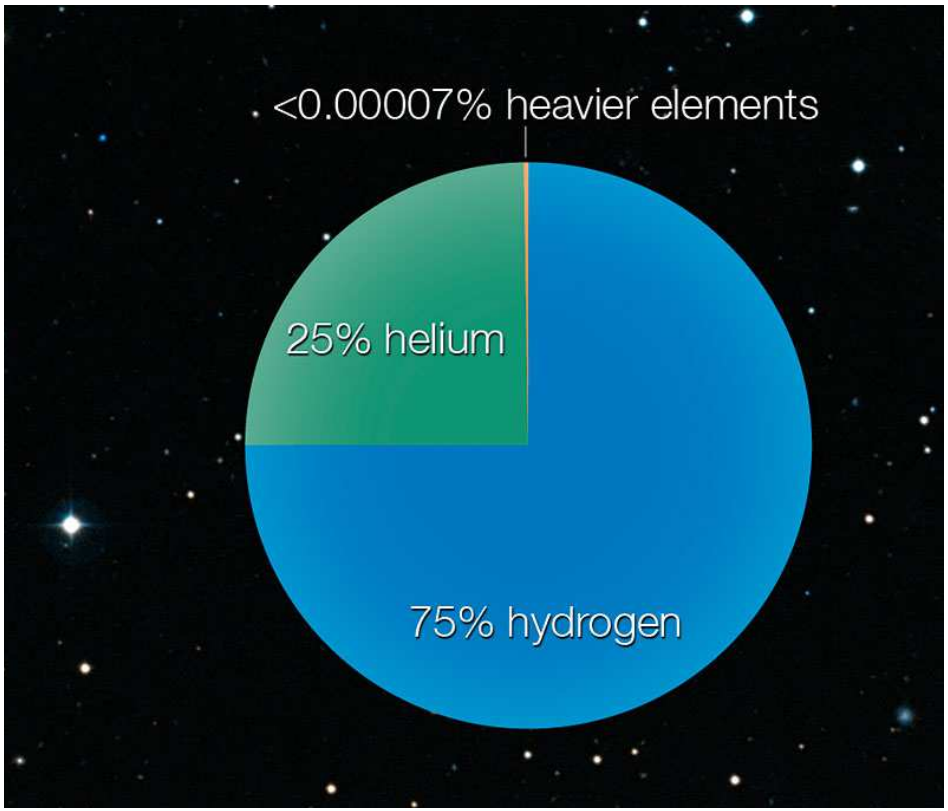
Introduction – Prospect



What we know and what we don´t know

This talk is only about a **tiny fraction** of the energy content of the Universe

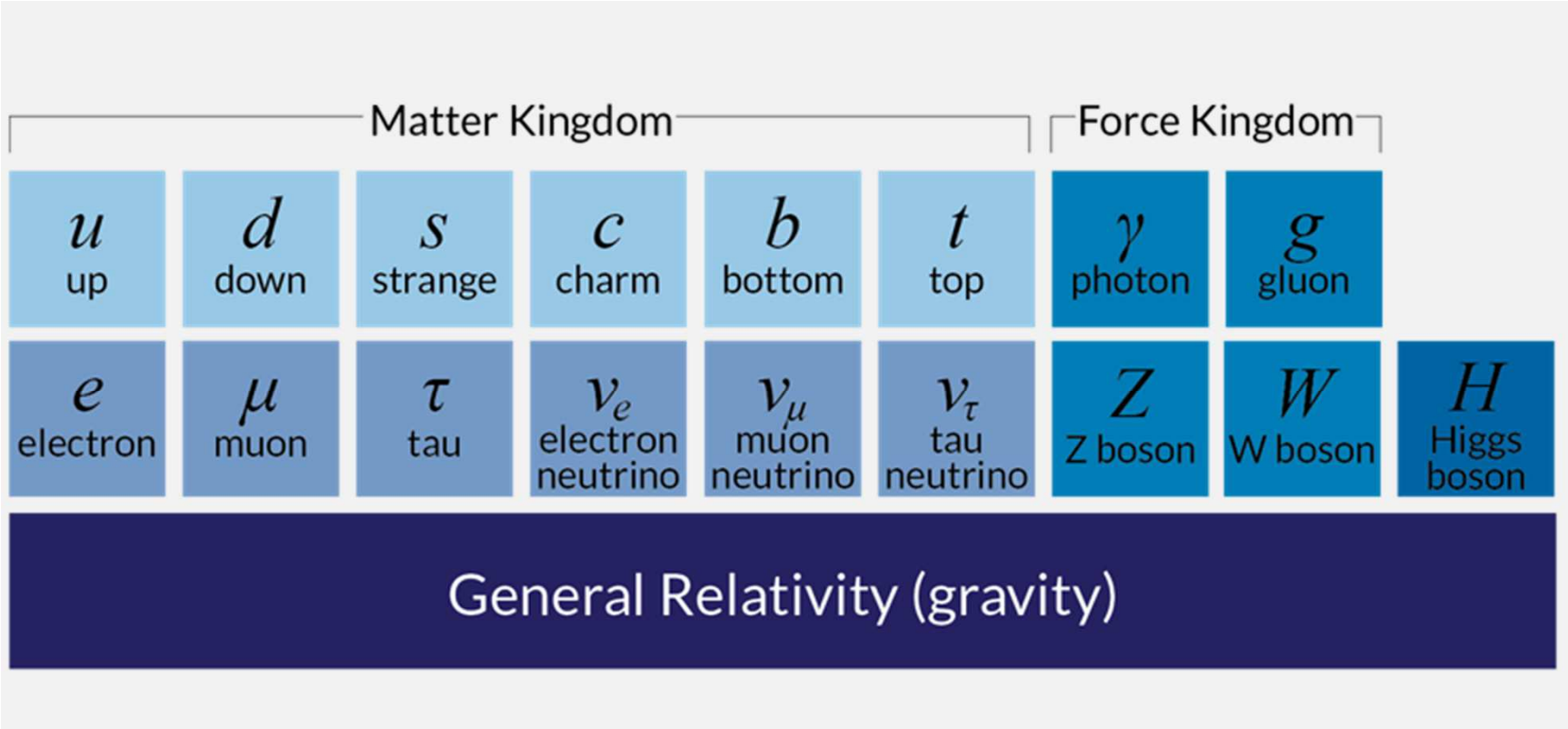
Introduction – Prospect



What we know and what we don´t know

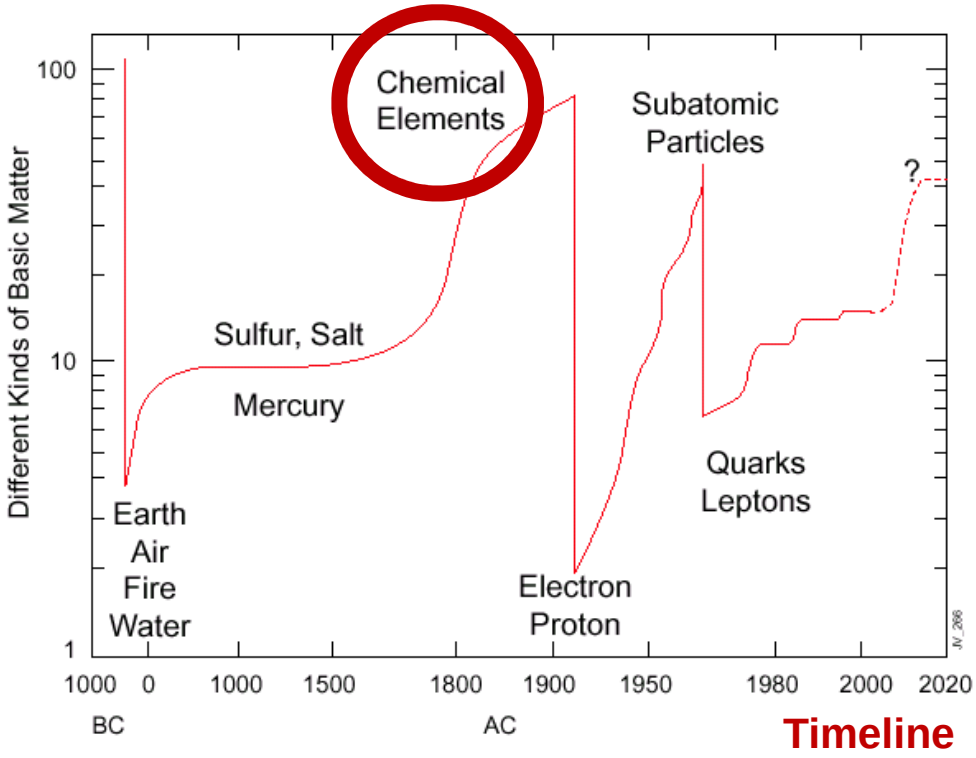
Matter is **essentially hydrogen** and helium (+ a tiny fraction of heavy nuclei)

Introduction – Prospect



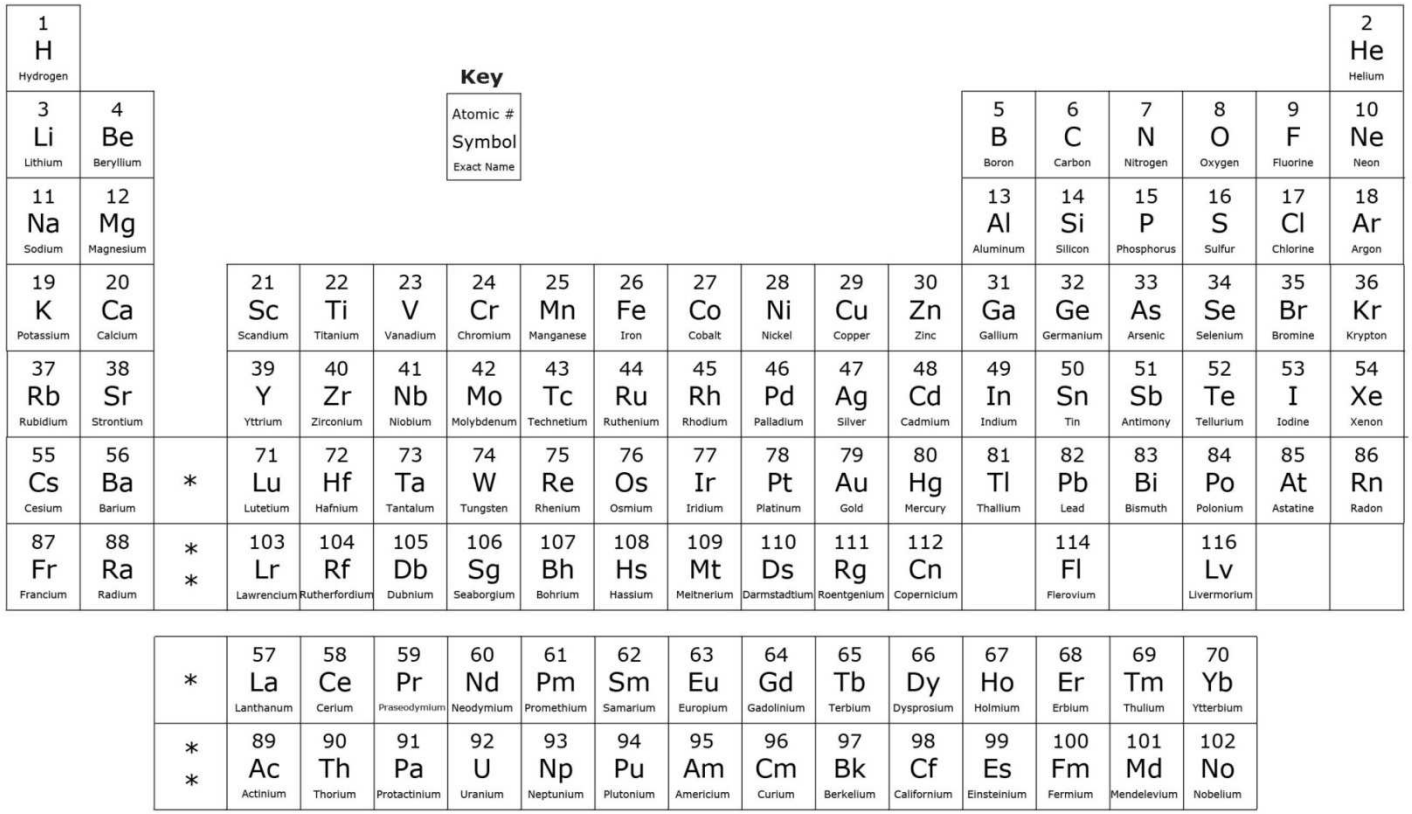
F. Wilczek (Nobel Laureate Physics 2004): „**Core Theory**“ of physics

Introduction – History



A historical account of the number of **matter-constituents**

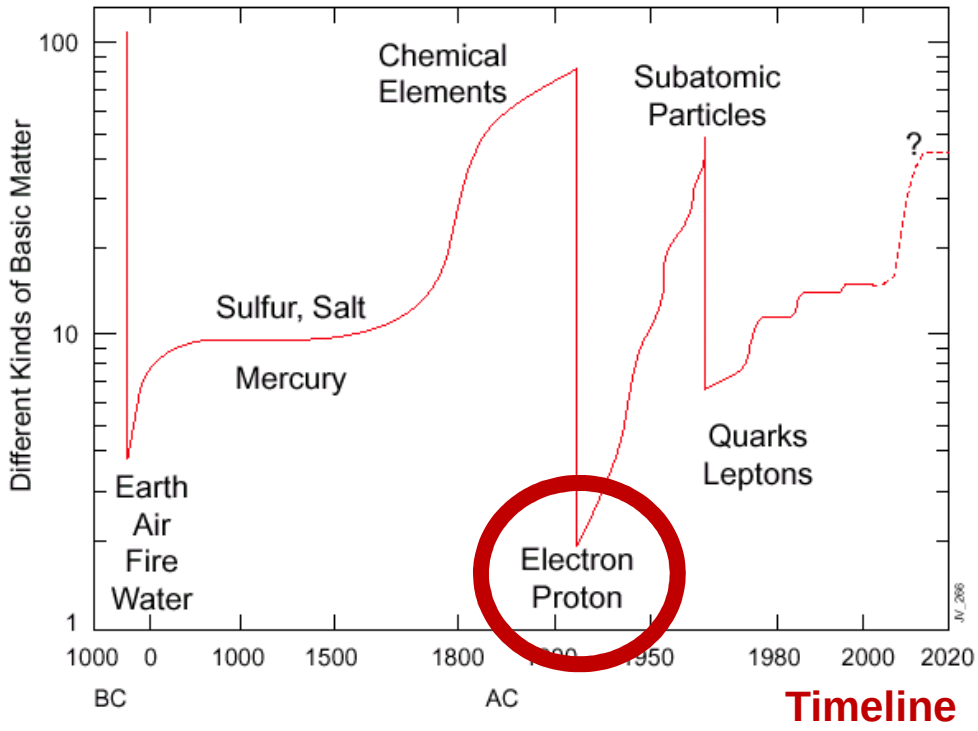
Introduction – History



Pauli-principle at work

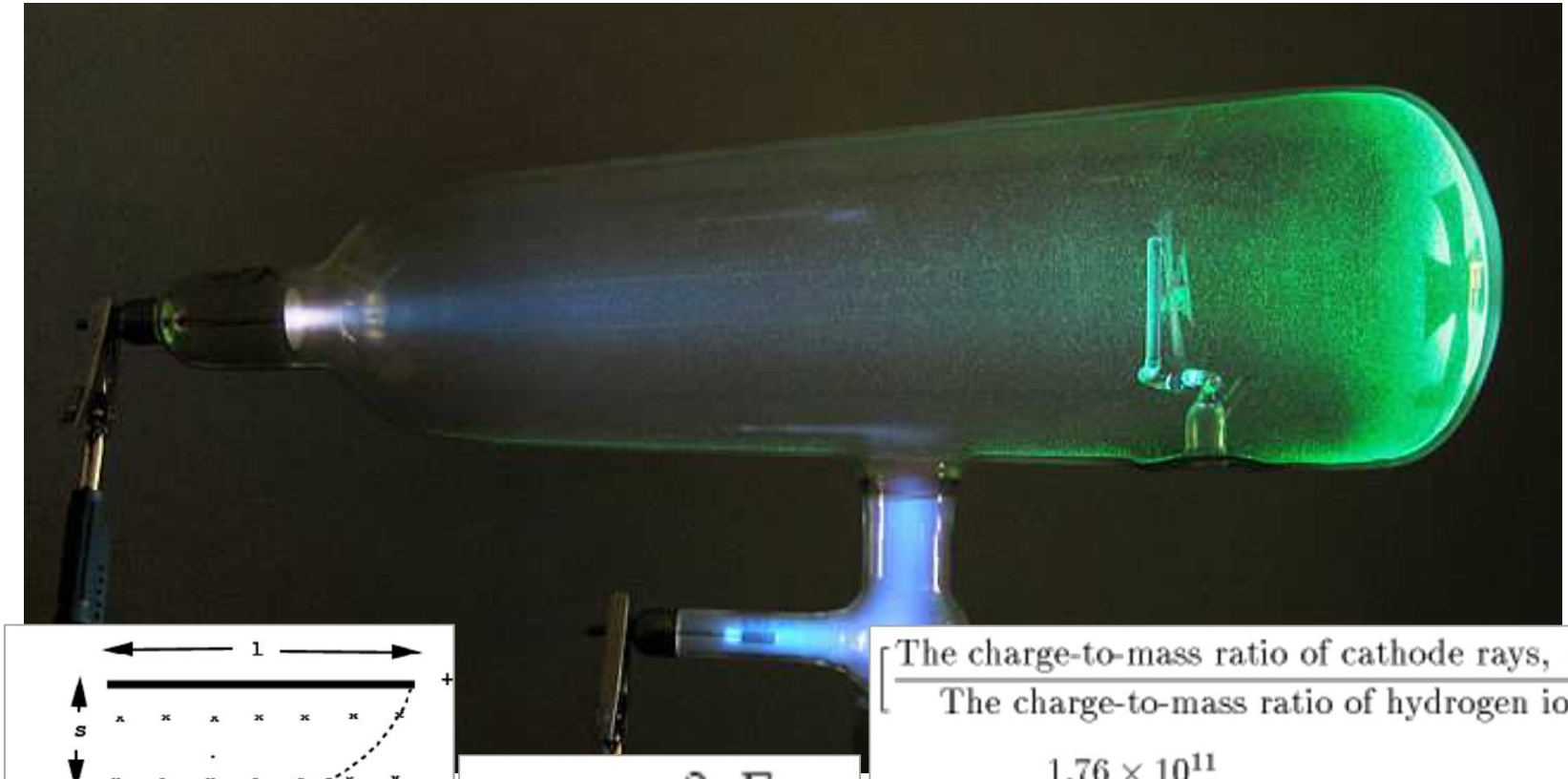
Periodic **Table of Elements**

Introduction – History



The up´s and down´s in the number of matter constituents

Introduction – History

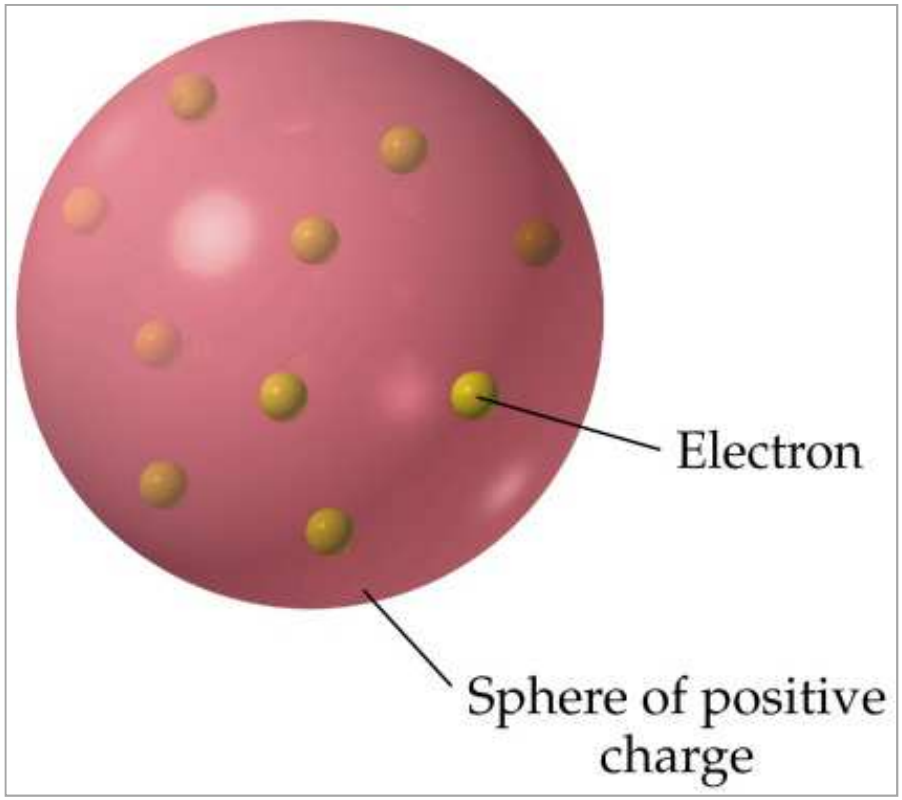


$$\frac{e}{m} = \frac{2sE}{l^2H^2}$$

$$\left[\frac{\text{The charge-to-mass ratio of cathode rays, } e/m}{\text{The charge-to-mass ratio of hydrogen ion}}\right] = \frac{1.76 \times 10^{11}}{9.65 \times 10^{7}} \approx 1800.$$

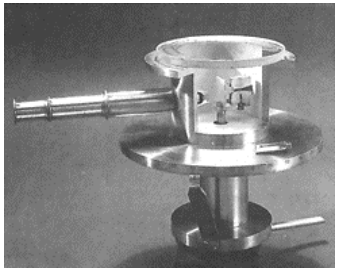
„Cathode rays“ → discovery of the **electron**

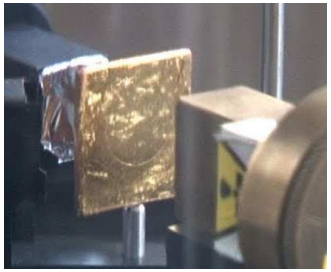
Introduction – History

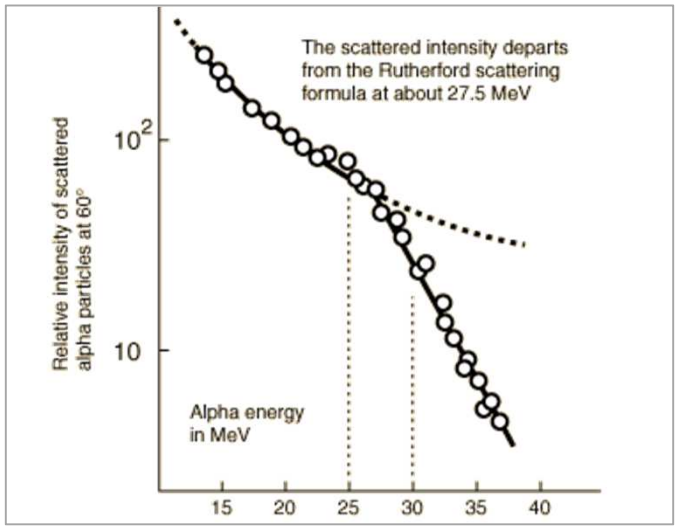


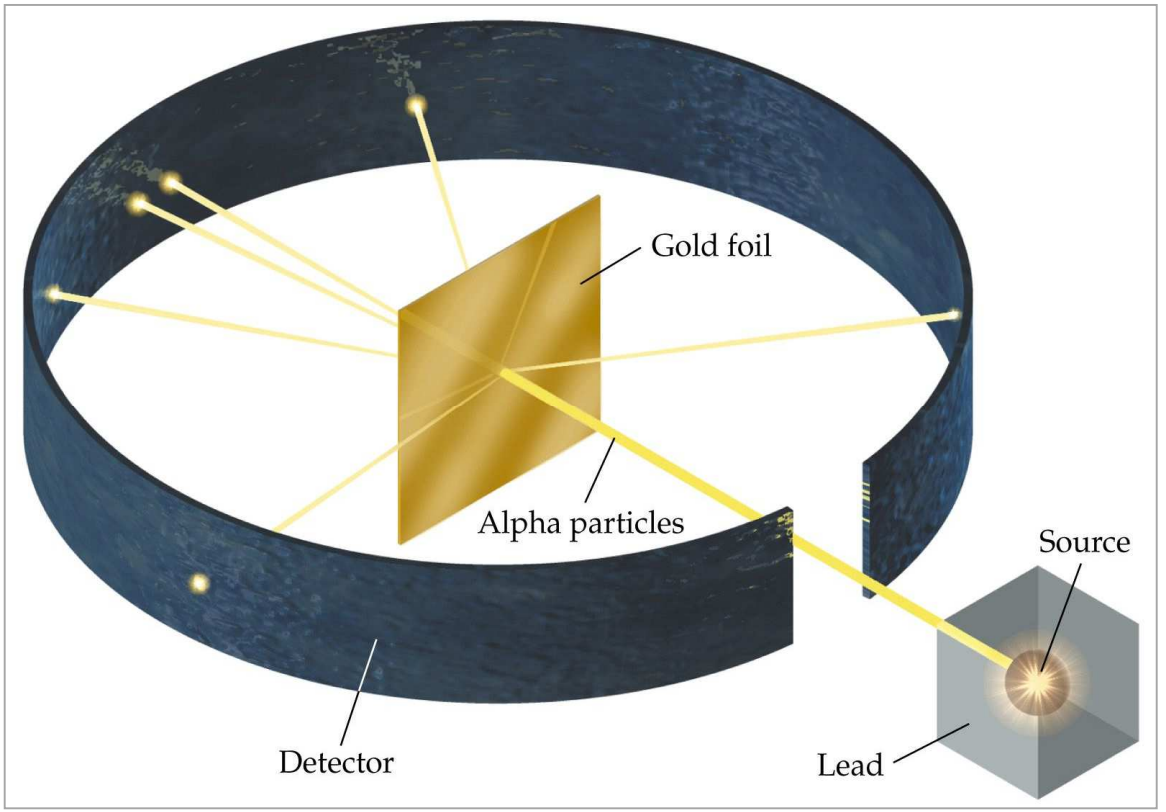
Discovery of the **electron** (J.J. Thomson, 1897) → Thomson´s atom-model

Introduction – History



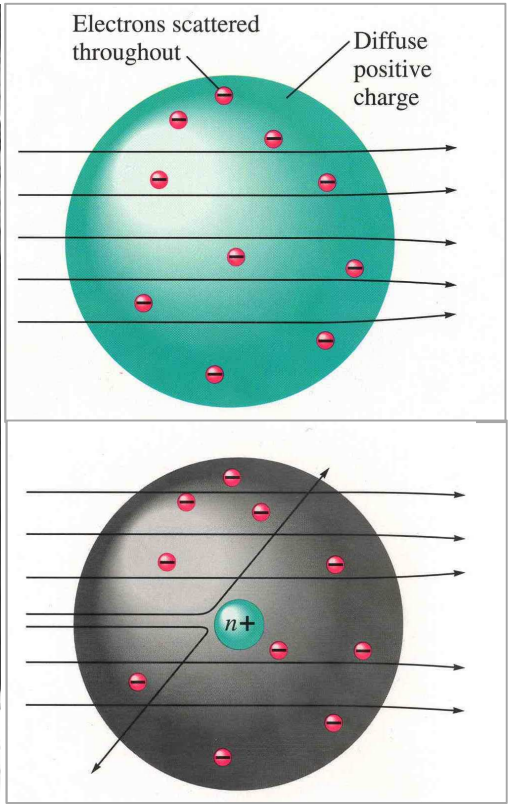


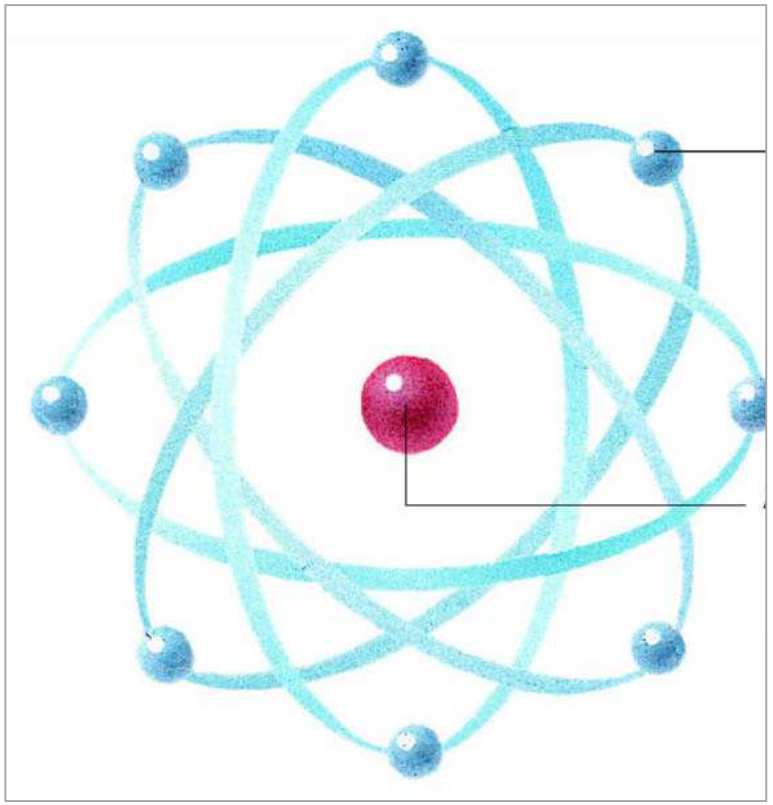




Discovery of the atomic **nucleus** (E. Rutherford, 1911) → new atomic model

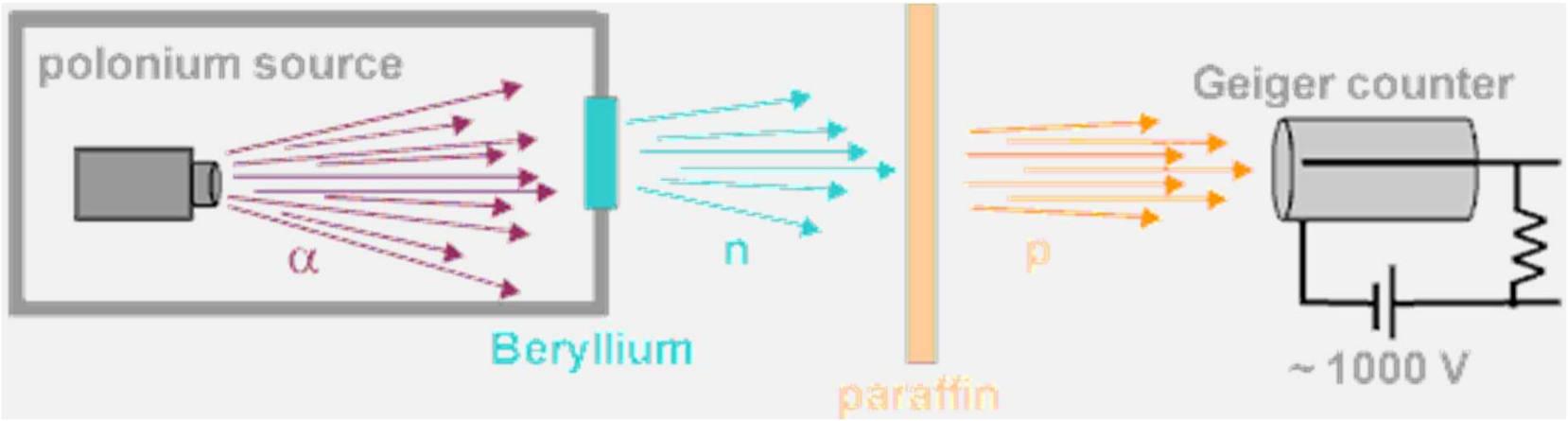
Introduction – History





Discovery of the atomic **nucleus** (E. Rutherford, 1911) → new atomic model

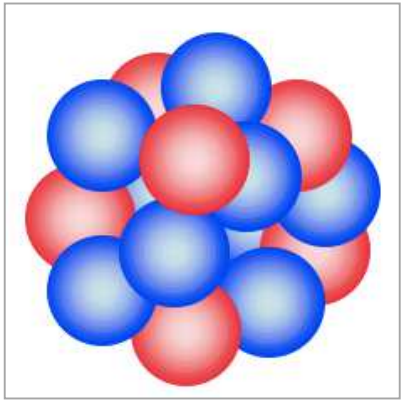
Introduction – History

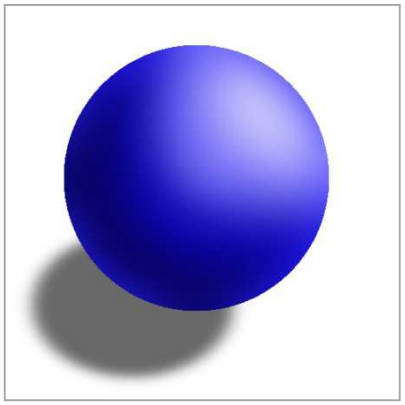


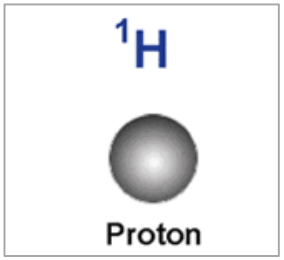
$$^{4}_{2}\mathrm{He} + ^{9}_{4}\mathrm{Be} \rightarrow ^{12}_{6}\mathrm{C} + ^{1}_{0}\mathrm{n}$$

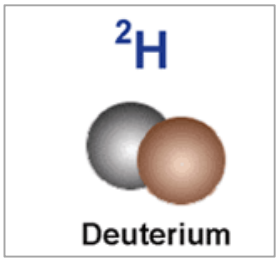
Discovery of the **neutron** (J. Chadwick, 1932) → structure of the nucleus

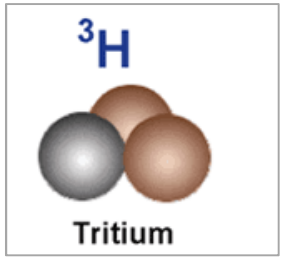
Introduction – History





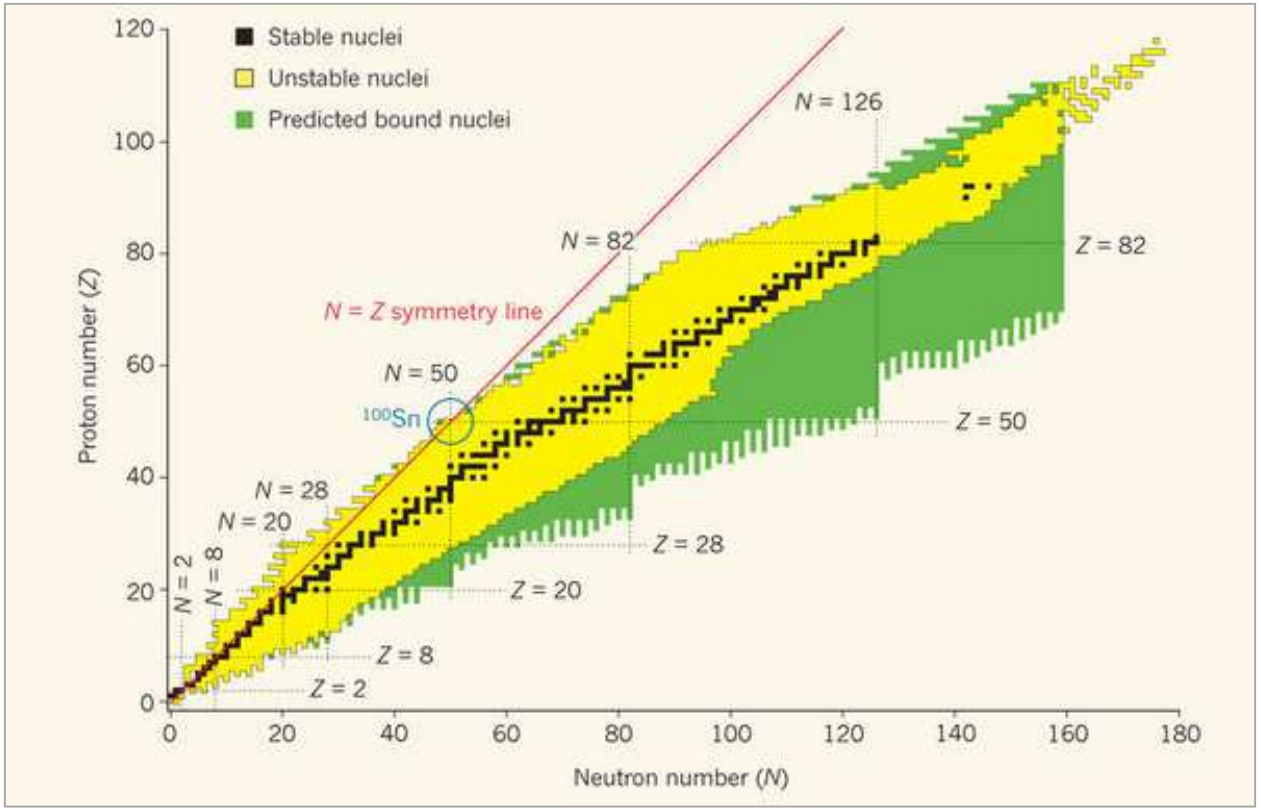






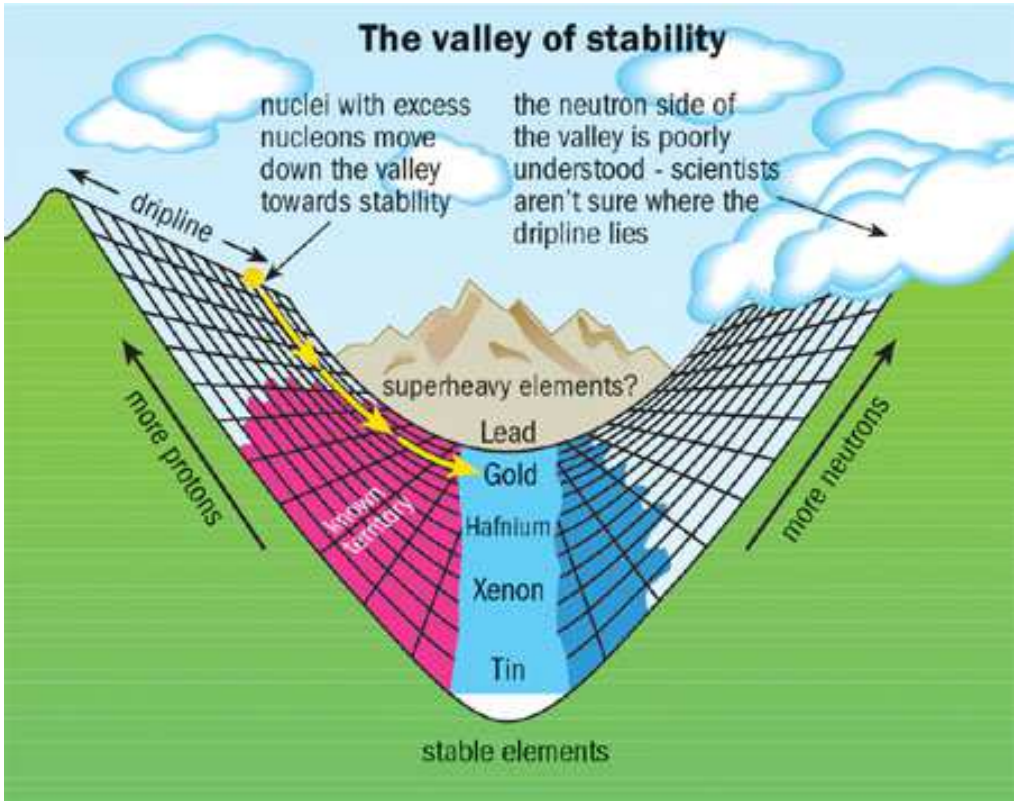
Discovery of the **neutron** (J. Chadwick, 1932) → isotopes

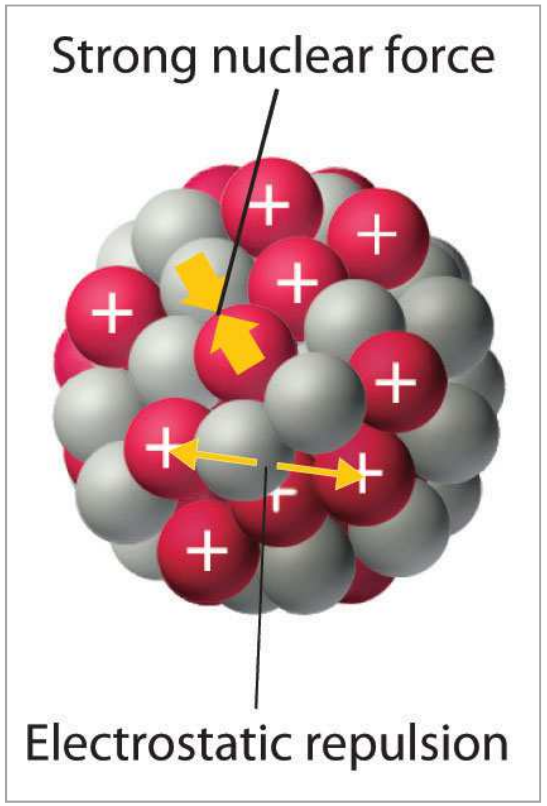
Introduction – History



The „**Table of Isotopes**“

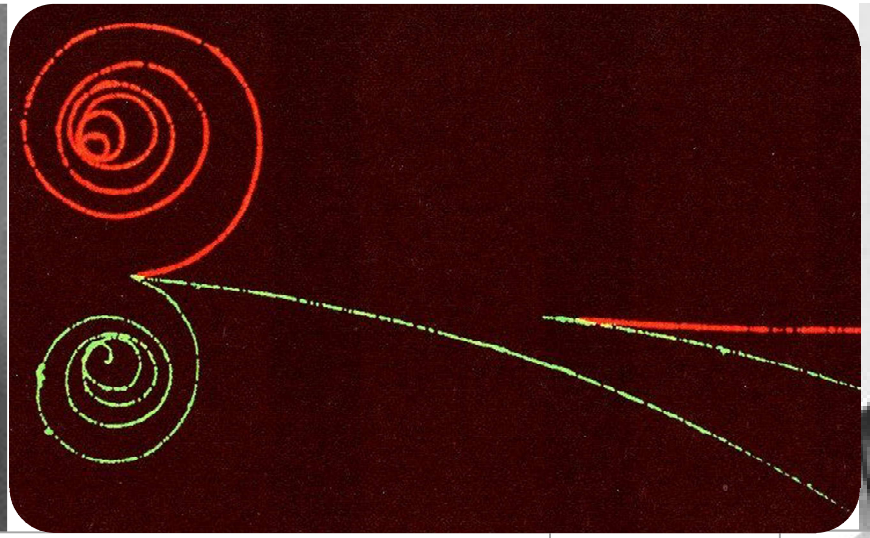
Introduction – History



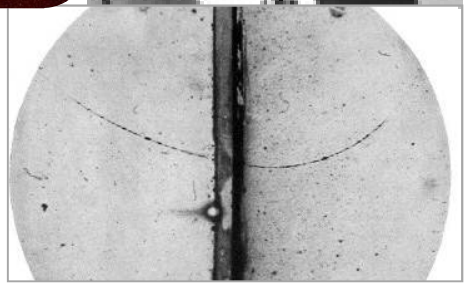


The „**Valley of Stability**“

Introduction – History

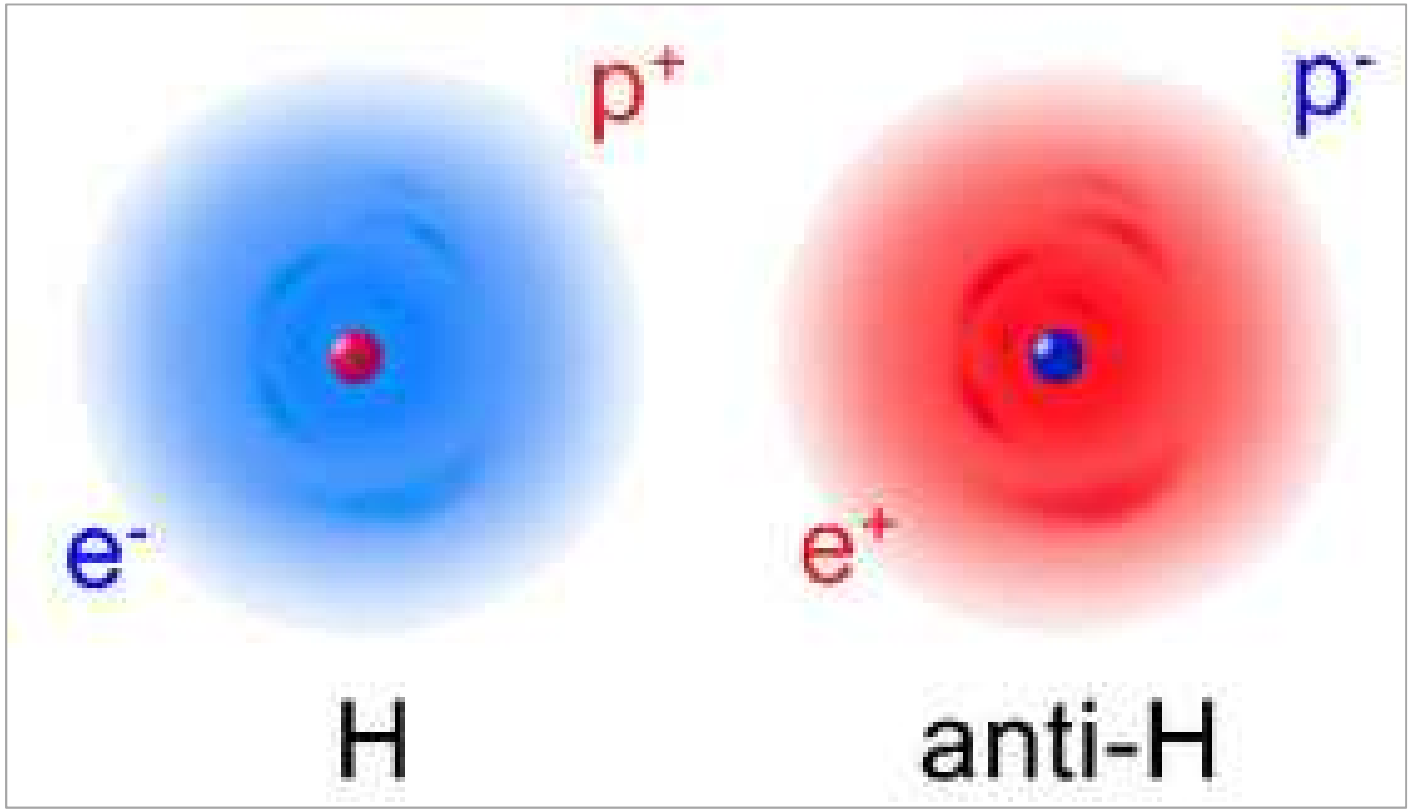


$$(i\gamma\cdot\partial - m)\psi = 0$$



Discovery of **antiparticles** (P.A.M. Dirac, 1928, C.D. Anderson, 1932)

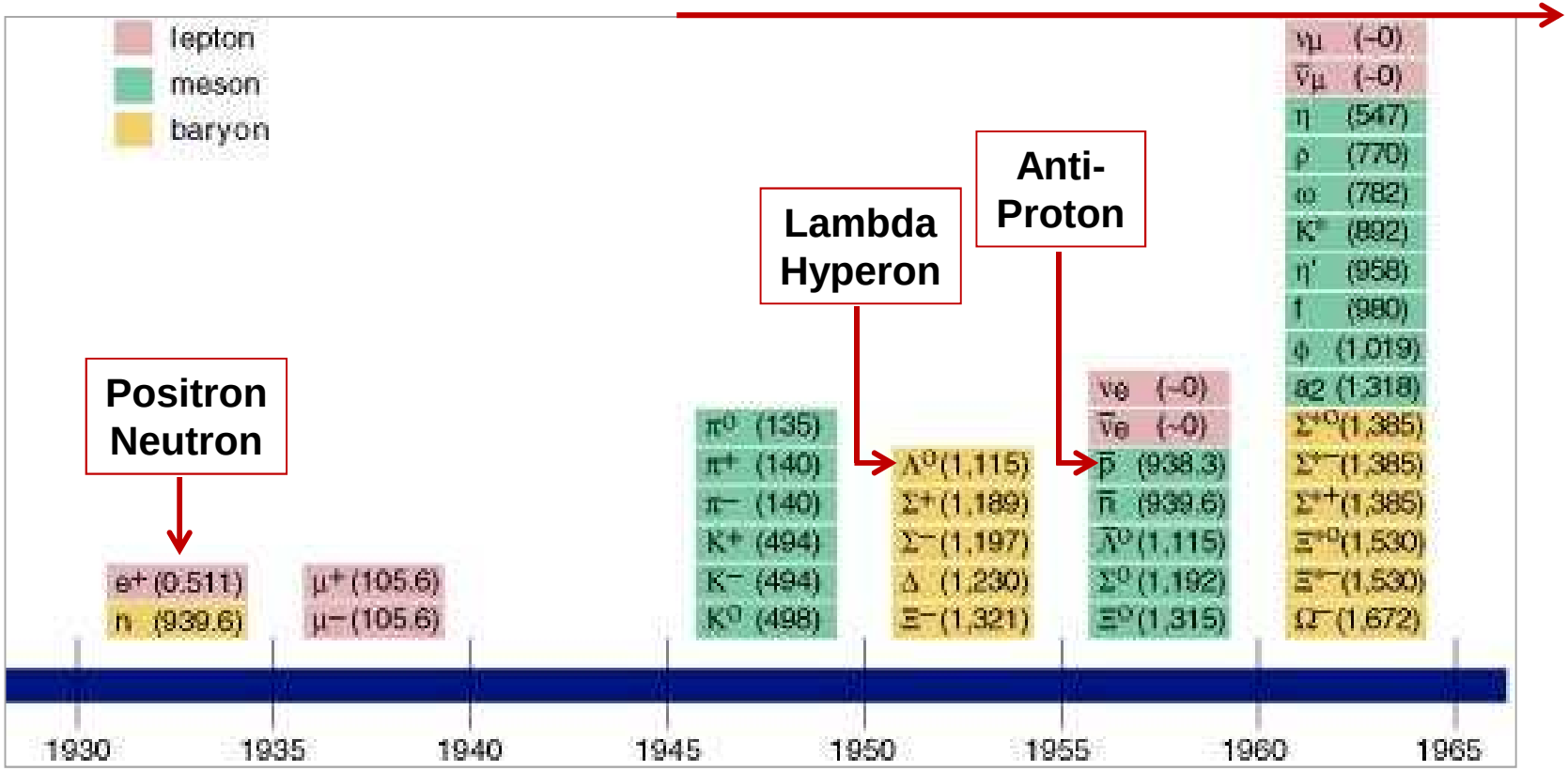
Introduction – History



Duplication: **matter** and **anti-matter**

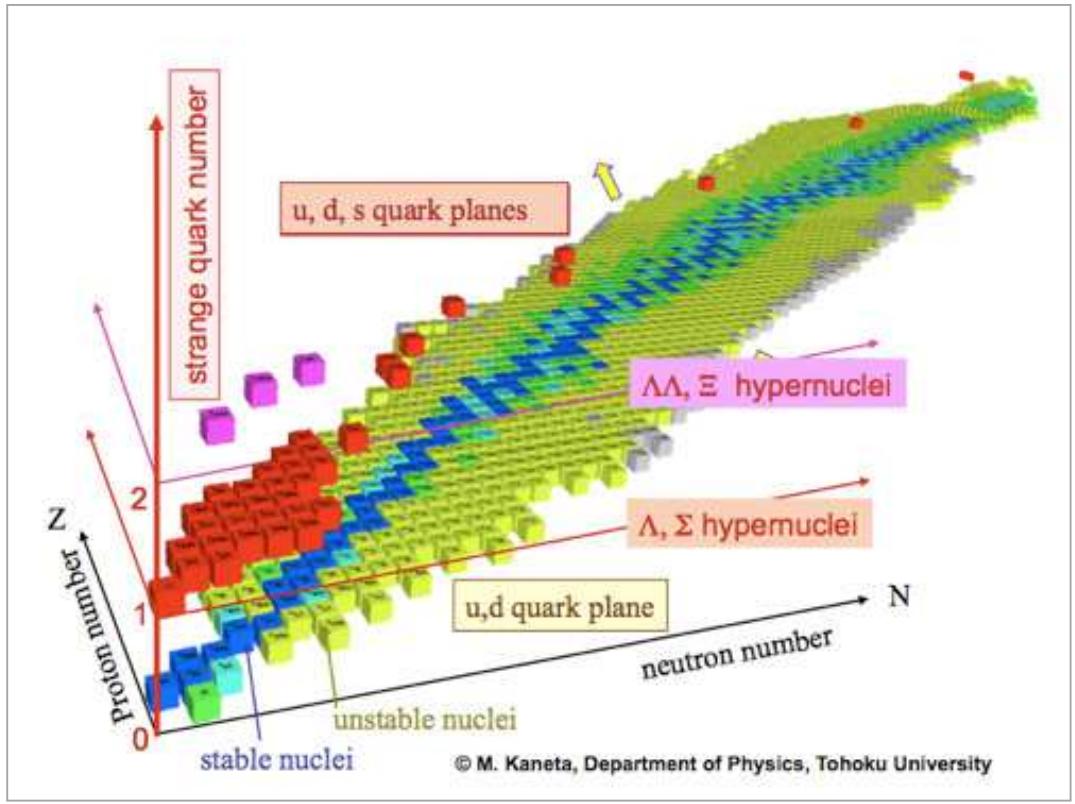
Introduction – History

The era of accelerators …



Observation of a „**zoo**“ of sub-atomic particles and anti-particles

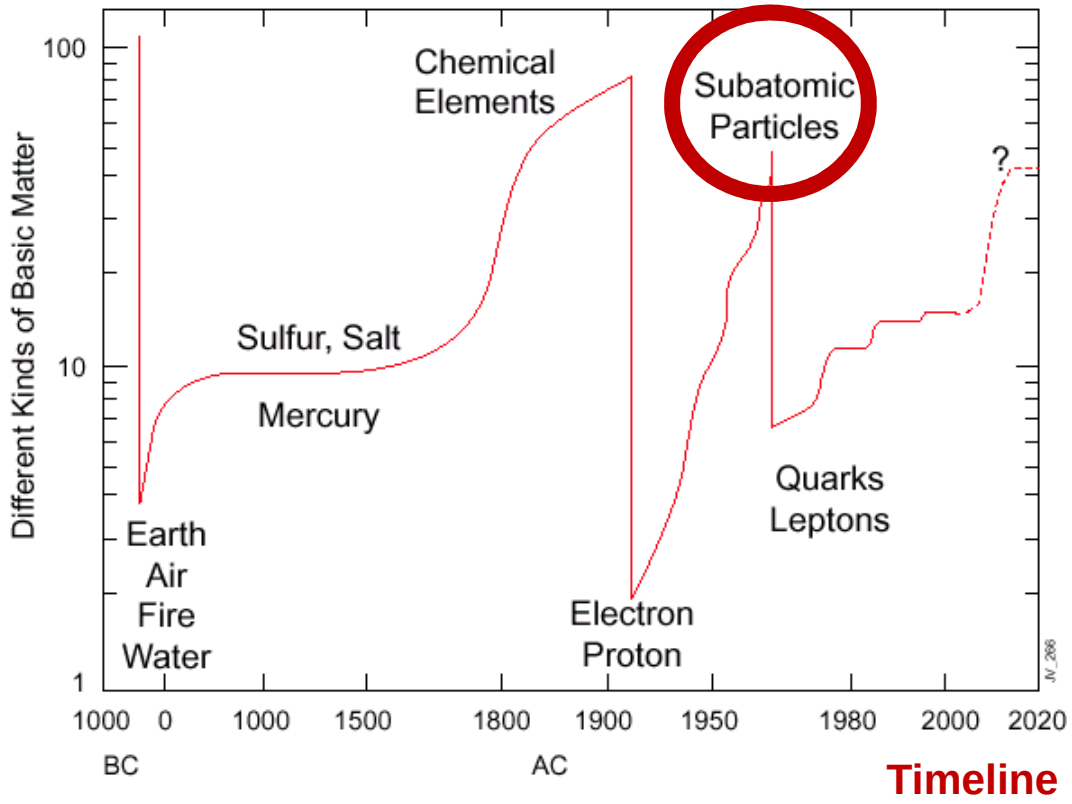
Introduction – History



“Hypernuclei”

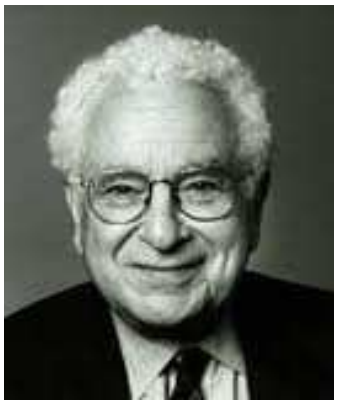
The extended „Table of Isotopes“

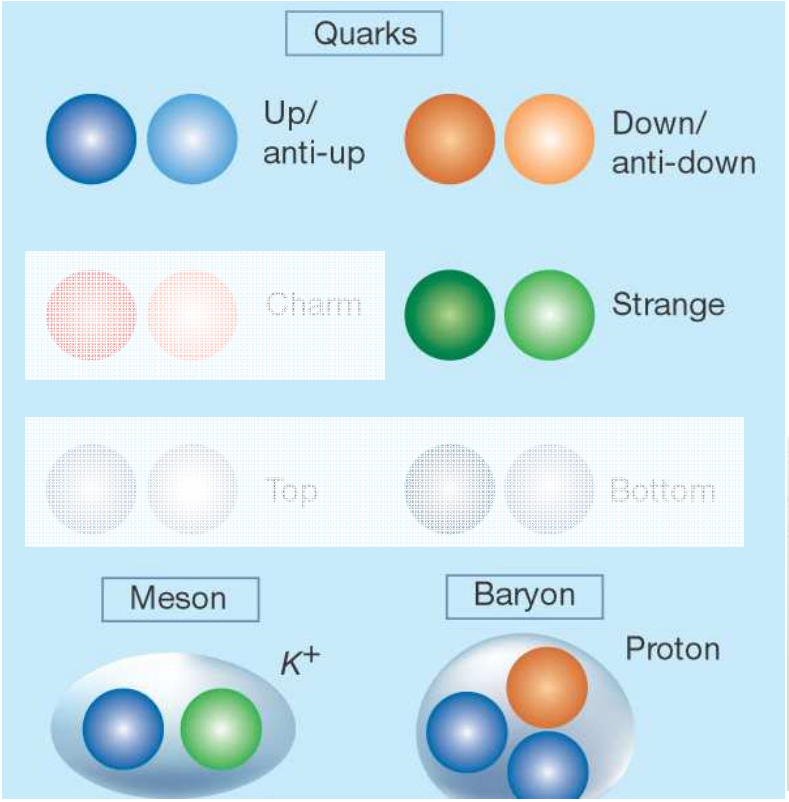
Introduction – History

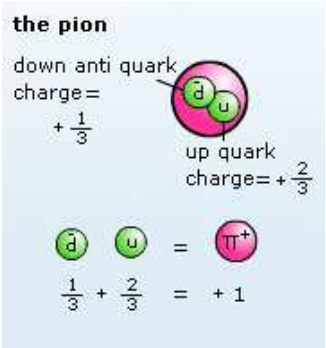


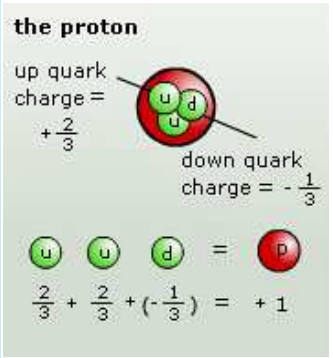
The up´s and down´s in the number of matter constituents

Introduction – History



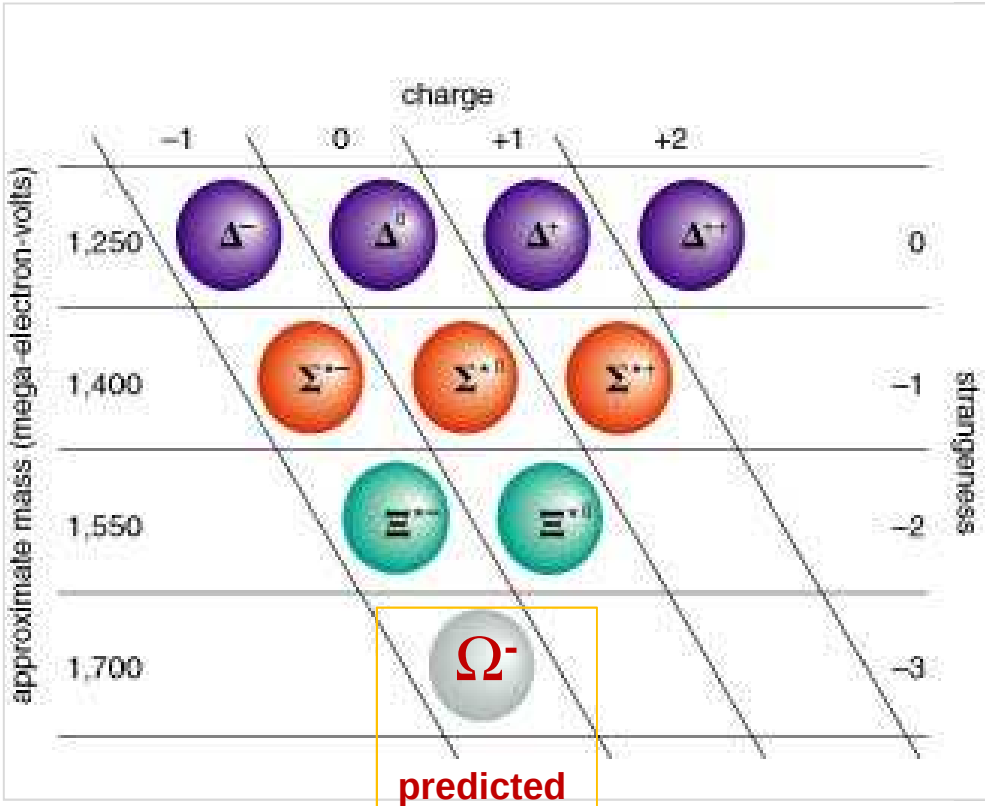


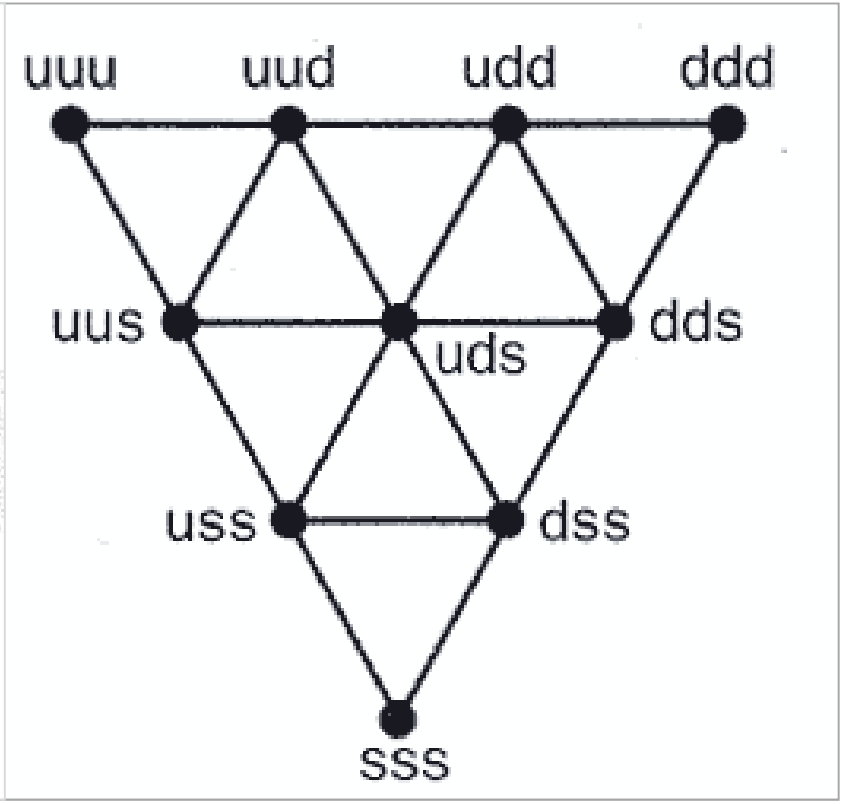




M. Gell-Mann and G. Zweig (1964): **Quarks** („Aces“)

Introduction – History





Hadrons (baryons & mesons) appear in „multiplets“: all members found

გმადლობთ