KTA1

Slides to introductory lecture on 14.10.2013

Meilensteine der Kern- und Teilchenphysik

1897	Discovery of electron
1900	α, β and γ radioactivity
1905	Photon identified as quantum of electromagnetic field
1911	Discovery of atomic nucleus
1912	Discovery of cosmic rays
	Invention of cloud chamber
1913	Bohr model of atom
1919	Discovery of proton
1923	de Broglie wave–particle duality
1925	Introduction of electron spin
1926	Wave mechanics
1927	Uncertainty Principle
1928	Dirac wave equation
1930	Neutrino hypothesis
1931	Operation of first cyclotron and of Van der Graaff accelerator
1932	Discovery of positron
	Discovery of neutron
1933	Discovery of electromagnetic showers
1934	Theory of beta decay
	Discovery of Čerenkov effect
1935	Yukawa theory of nuclear forces
1936	Breit–Wigner resonance formula
1937	First evidence for mesotron (= muon)
1939	Observation of mesotron (= muon) decay
1940	Spin-statistics theorem
1945	Phase stability in accelerators (synchrotron principle)
1946	First proposal of Big Bang model
	Two-meson hypothesis

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1947	Discovery of pion and $\pi \to \mu$ decay in cosmic rays
	Prediction of muon-induced nuclear fusion
	Two-meson hypothesis (again)
	Discovery of V particles
1948	Quantum electrodynamics
	Observation of $K \to 3\pi$ decay
	Pion production at accelerators
1950	Spark chamber invented
	Semiconductor detector invented
	Discovery of neutral pion and $\pi^0 \to 2\gamma$ decay
1951	Observation of Λ hyperon and neutral kaon, K_S^0
1952	Evidence for $\Delta(1232)\pi p$ resonance
	Strong focussing principle for synchrotron
	Invention of bubble chamber
1953	Evidence for Σ and Ξ hyperons
	First V events at accelerator: associated production
	First hypernucleus event
	τ–θ $(= K\pi 3/K\pi 2)$ paradox
1954	Prediction of long-lived K_L^0
	Invention of strangeness quantum number and classification
1956	Observation of antiproton
	Detection of (anti)neutrinos from reactor
	Experimental evidence for K_L^0
	Proposal for colliding-beam accelerators
1957	Observation of muon-induced nuclear fusion
	Two-component neutrino, $V - A$ theory
	Parity non-conservation in weak decays
	Resolution of τ–θ paradox
1958	$(\pi \to e)/(\pi \to \mu)$ branching ratio
	Neutrino helicity measurement
1959	Operation of CERN PS, Brookhaven AGS
1961	K_L–K_S regeneration
	Discovery of ρ, ω, η pion resonances
1962	Pion β-decay $\pi^+ \to \pi^0 e^+ \nu$
	First accelerator neutrino beams and interactions
	ν_μ and ν_e as separate neutrino flavours
1963	Cabibbo theory of hadronic weak decays
1964	Streamer chamber invented
	Introduction of quarks and quark model
	First evidence for Ω^- hyperon
	Discovery of CP violation in K^0 decay
	Higgs mechanism of spontaneous symmetry breaking
1965	Observation of cosmic microwave background radiation
	Introduction of colour quantum number and vector gluons
1967	Baryon asymmetry of universe (Sakharov criteria)
1968	Weinberg–Salam–Glashow electroweak model
	Deep inelastic ep scattering. Bjorken scaling and partons
1970	Invention of multiwire proportional chamber
	Proposal of fourth quark (charm)
1972	Solar neutrino deficit (^{37}Cl experiment)
	Fermilab Tevatron operates
	CKM matrix for weak quark decays
1973	QCD as field theory of interquark interactions
	Neutrino scattering experiments confirm that partons are quarks
	Discovery of neutral weak currents
1974	Discovery of J/ψ and ψ' $c\bar{c}$ resonances
1975	Charmed baryons and mesons
	Discovery of τ lepton
	$e^+e^- \to$ quark jets
1976	CERN SPS operates
1977	Discovery of $\Upsilon(= b\bar{b})$ states
	Emergence of Standard Model
1978	Parity violation in polarised electron–deuterium scattering
1979	$e^+e^- \to$ three jets (PETRA)
1980	Evidence for $\Upsilon(3S)$ and $\Upsilon(4S)$ (CESR)
1981	Observation of mesons and baryons containing b quarks
1983	Discovery of Z^0 and $W^\pm$ bosons
1987	Observation of B^0–$\bar{B}^0$ mixing
	SN 1987A Supernova neutrino burst
1990	Z^0 produced at e^+e^- colliders LEP and SLC
	Number of neutrino flavours $N_\nu = 3$ from Z^0 width
1993	Solar neutrino deficit confirmed in gallium experiments
	Atmospheric neutrino flavour anomaly
	Precise measurements of Z^0 decay parameters confirm Standard Model
1995	Discovery of t quark at Fermilab collider
1997	$e^+e^- \to W^+W^-$ pair production at LEP 200 collider

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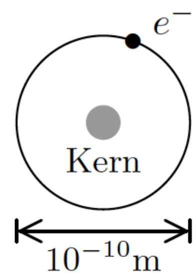
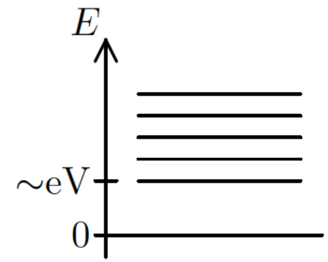
1998: Super-Kamiokande: Atmospheric neutrino oscillations
2000: tau-neutrino detection
2002: SNO: neutrino flavor conversion of solar neutrinos
2002: CP violation in B-mesons
2007: direct detection of solar Be-7 neutrinos
2011: non-zero mixing angle theta_13
2012: Discovery of Higgs particle

The Nobel Prize in Physics 2013
François Englert, Peter Higgs

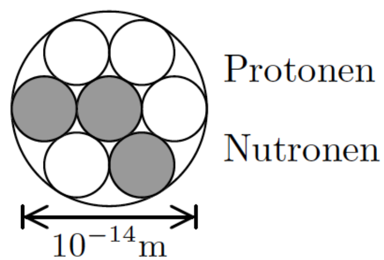
Längenskala und Hierarchie der Struktur der Materie

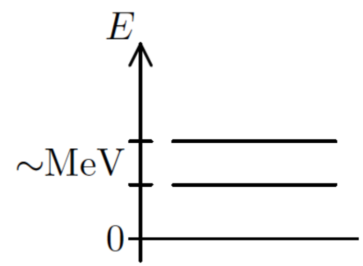
- **Atom**:



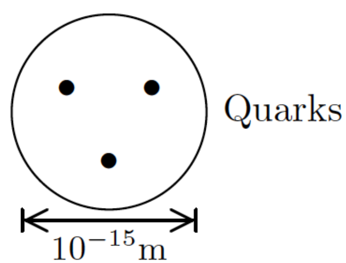


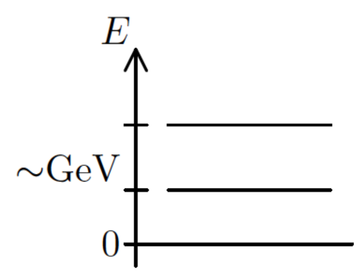
- **Kern**:

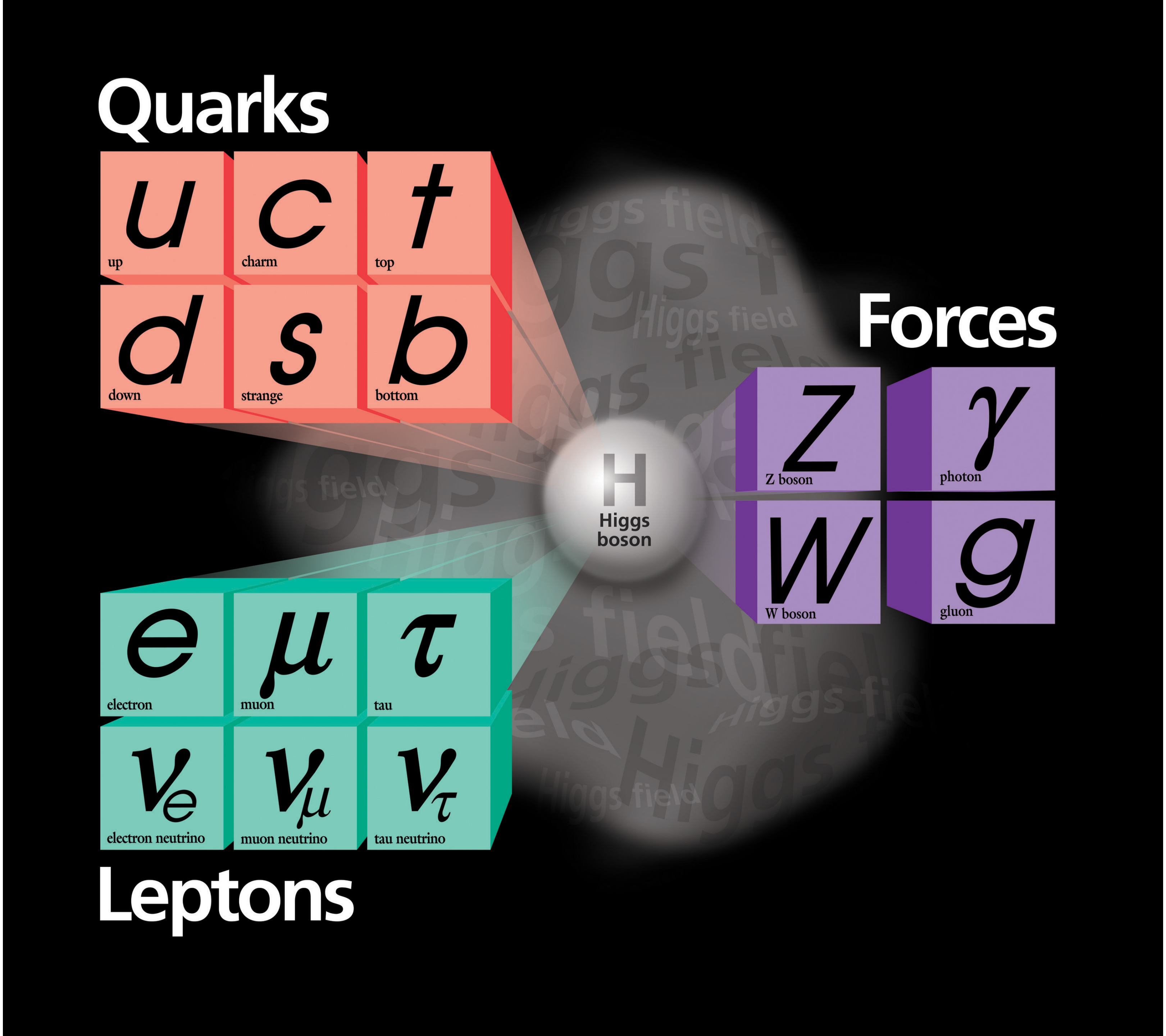




- **Nukleon**:

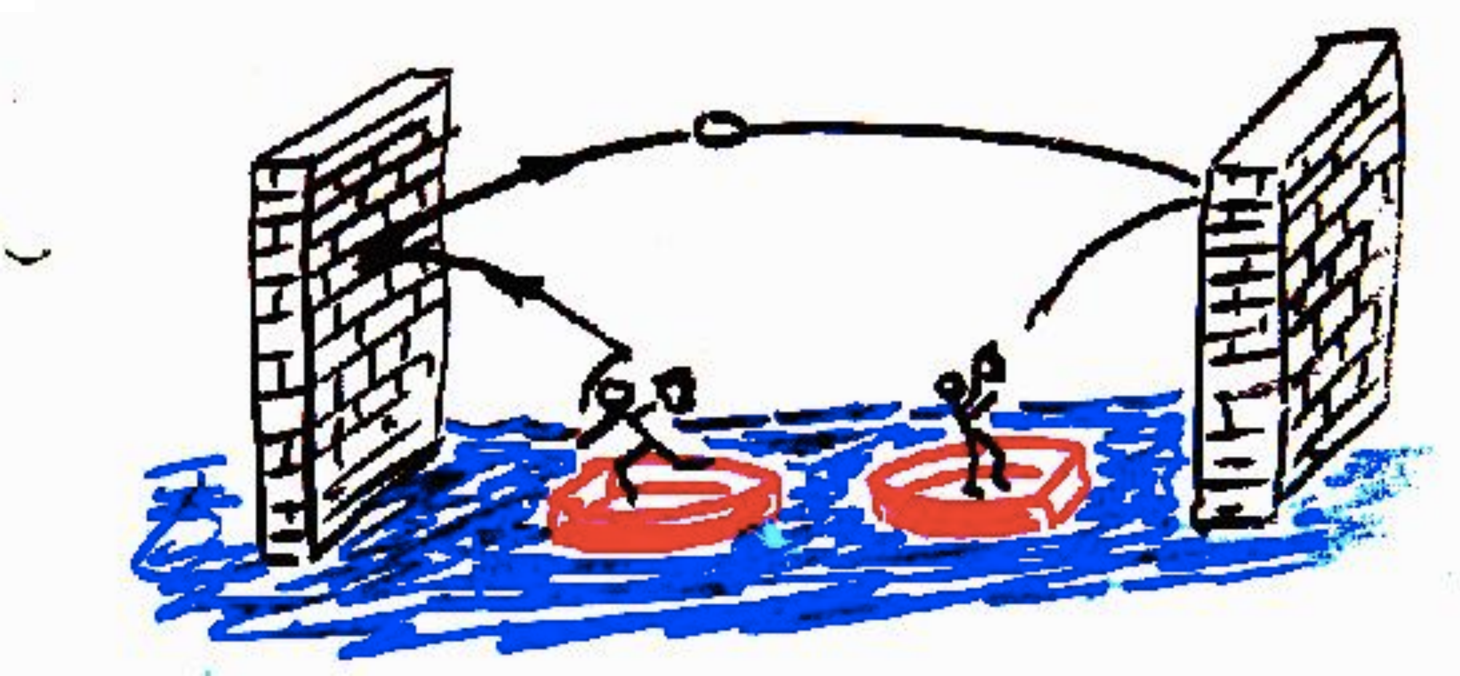




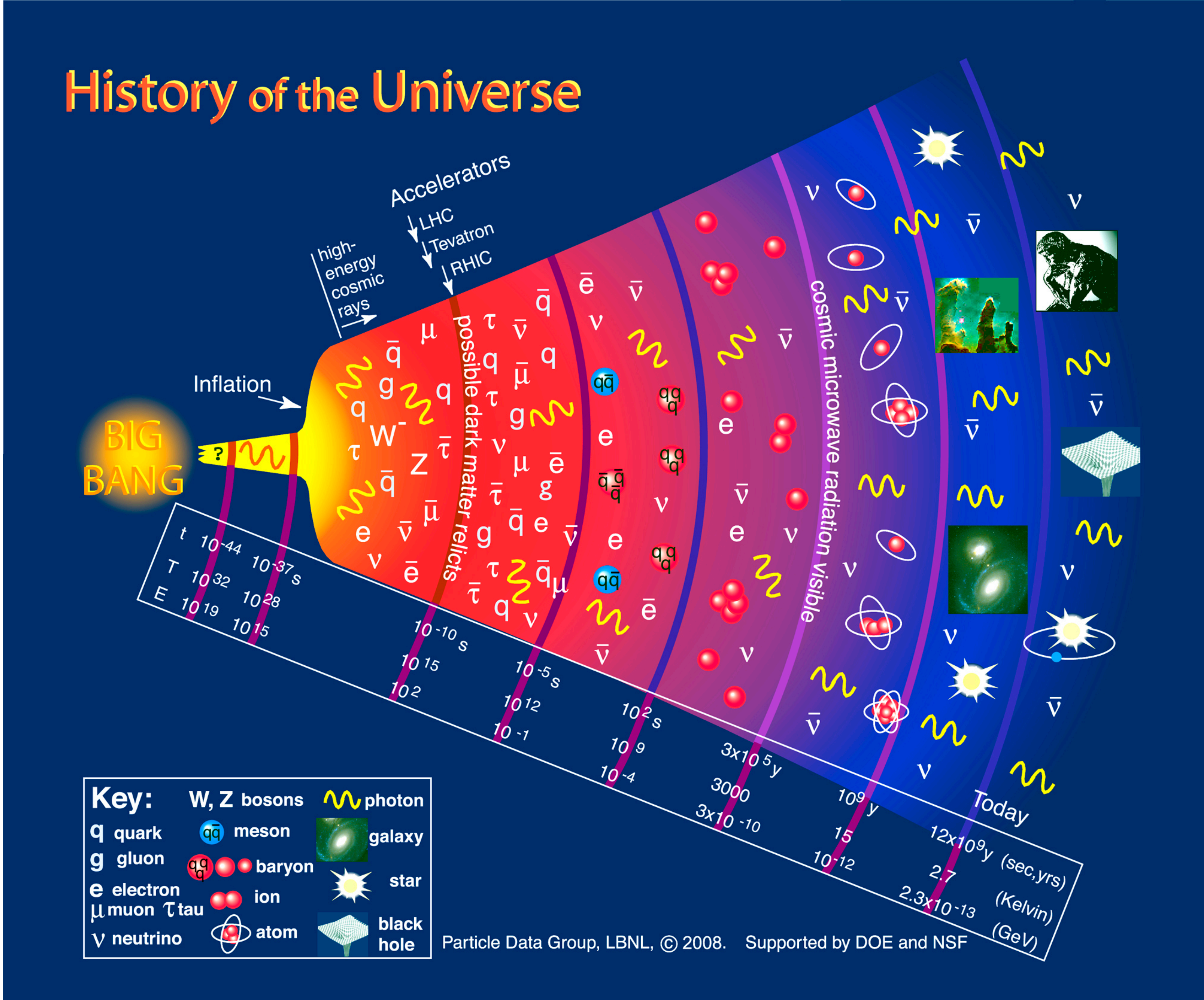

Quarks
u
up
c
charm
t
top
d
down
s
strange
b
bottom
Forces
Z
Z boson
γ
photon
W
W boson
g
gluon
H
Higgs
boson
Higgs field
e
electron
μ
muon
τ
tau
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
Leptons

Wechselwirkung vermittelt durch Austauschteilchen

Abstoßung



Anziehung


History of the Universe
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10-44 10-37 s
T 10 32 10 28
E 10 19 10 15
10 -10 s
10 15
10 2
10 -5 s
10 12
10 -1
10 2 s
10 9
10 -4
3x10 5 y
3000
3x10 -10
10 9 y
15
10 -12
Today
12x10 9 y (sec,yrs)
2.7 (Kelvin)
2.3x10 -13 (GeV)
Key:
W, Z bosons
photon
q quark
meson
galaxy
g gluon
baryon
e electron
ion
star
μ muon τ tau
ν neutrino
atom
black hole
Particle Data Group, LBNL, © 2008. Supported by DOE and NSF

Urknalltheorie der Entstehung des Universums.
Stützen: kosmische Hintergrundstrahlung, primordiale Nukleosynthese (Bild der leichten Kerne($A \leq 7$)).

Zeitskalen:

$t \simeq 10^{-44}$ s: Planck-Ära, 10^{19} GeV; $U_{pot} \approx -mc^2$

$t \simeq 10^{-36}$ s: GUT-Brechung, 10^{15} GeV

$t \simeq 10^{-10}$ s: Brechung elektromagnetischer und schwacher Wechselwirkung; 10^2 GeV ($\sim M_{W,Z_0}c^2$)

$t \simeq 10^{-6}$ s: Quark-Confinement; 1 GeV $\rightarrow$ Bildung der Nukleonen
$p + \bar{p} \longrightarrow 2\gamma$
$n + \bar{n} \longrightarrow 2\gamma$

$t \simeq 1$ s: ν-Entkopplung; 1 MeV
$e^- + e^+ \longrightarrow 2\gamma$

$t \simeq 5$ min: Bildung leichter ($A \leq 7$) Kerne; 10^2 keV
z.B. $p + n \longrightarrow {}^2\mathrm{H} + \gamma$ ($E_\gamma = 2,2$ MeV)

$t \simeq 10^5$ a: Photonen entkoppeln; $\simeq$ eV
$p + e^- \longrightarrow$ H-Atom

$t \gtrsim 10^6$ a: Strukturbildung