CERN
Latvian Teacher Programme 2016

Particle accelerators

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A bit of history, Great things happen here

- Founded in 1954.
- In the 1960. Niels Bohr

SPEECH DELIVERED BY PROFESSOR NIELS BOHR

ON THE OCCASION OF THE INAUGURATION OF THE CERN PROTON SYNCHROTRON

ON 5 FEBRUARY, 1960

Press Release PR/56
12 February, 1960

It may perhaps seem odd that apparatus as big and as complex as our gigantic proton synchrotron is needed for the investigation of the smallest objects we know about. However, just as the wave features of light propagation make huge telescopes necessary for the measurement of small angles between rays from distant stars, so the very character of the laws governing the properties of the many new elementary particles which have been discovered in recent years, and especially their transmutations in violent collisions, can only be studied by using atomic particles accelerated to immense energies. Actually we are here confronted with most challenging problems at the border of physical knowledge, the exploration of which promises to give us a deeper understanding of the laws responsible for the very existence and stability of matter.

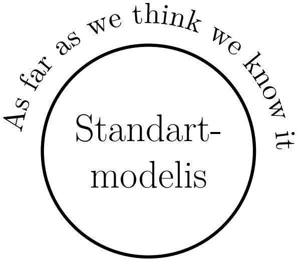
A bit of history, Great things happen here

- The name CERN comes from French :”Conseil Européen pour la Recherche Nucléaire”, or European Council for Nuclear Research”
- CERN is collaboration between 20 EU and 1 non-EU country(Israel).
- 1973 - The discovery of neutral currents in the Gargamelle bubble chamber;
- 1983 - The discovery of W and Z bosons in the UA1 and UA2 experiments;
- World Wide Web
- 1989 - The determination of the number of light neutrino families at the Large Electron–Positron Collider (LEP) operating on the Z boson peak;

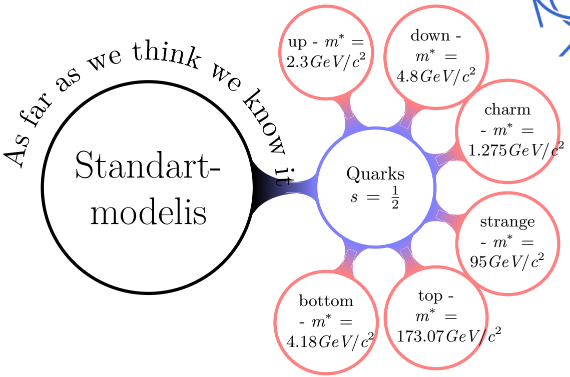
A bit of history, Great things happen here

- 1995 - The first creation of antihydrogen atoms in the PS210 experiment;
- 1999 - The discovery of direct CP violation in the NA48 experiment;
- 2010 - The isolation of 38 atoms of antihydrogen;
- 2011 - Maintaining antihydrogen for over 15 minutes;
- 2012 - A boson with mass around $125 GeV/c^2$ consistent with long-sought Higgs boson

Standartmodelis - kā būvējas lietas



Standartmodelis - kā būvējas lietas



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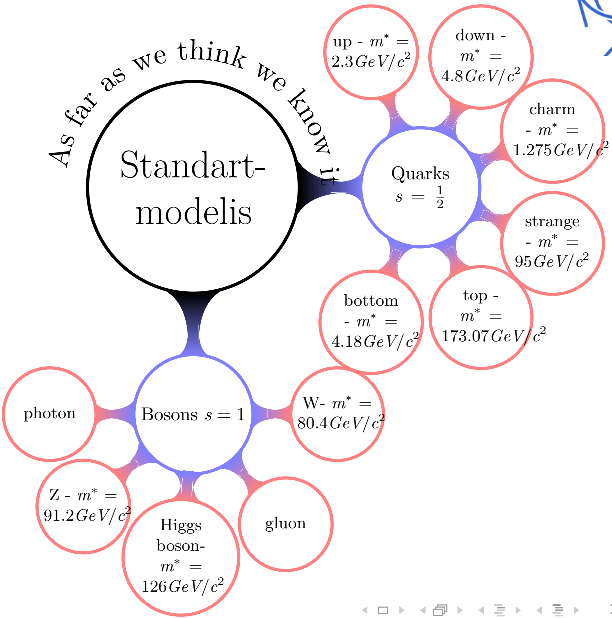
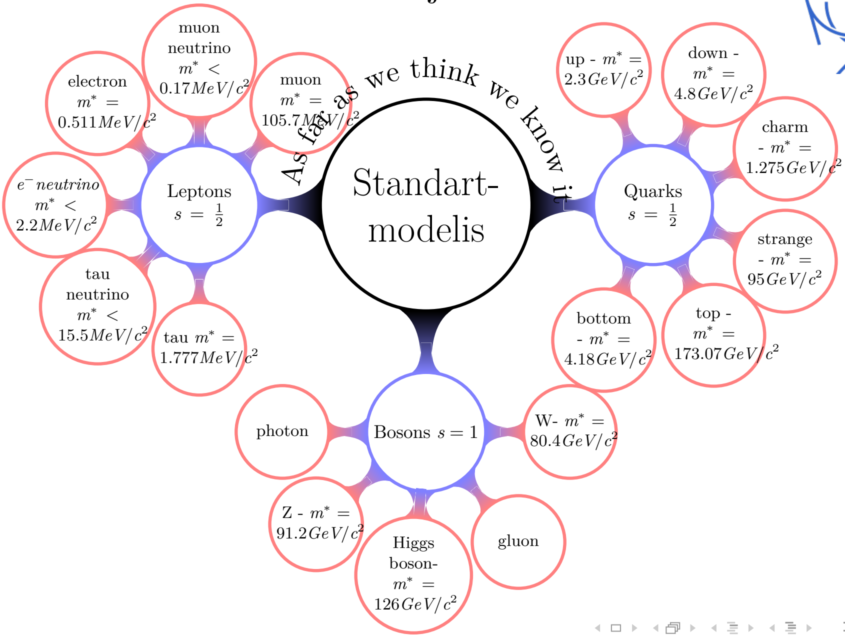
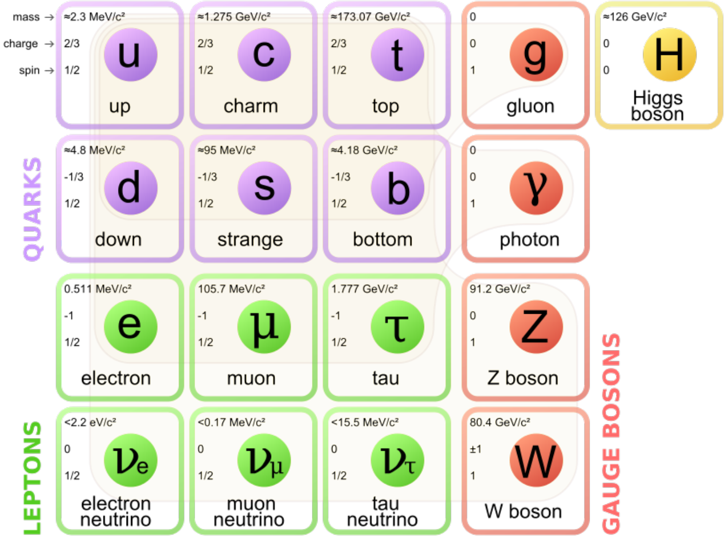


Standartmodelis - kā būvējas lietas



Standartmodel



Energy

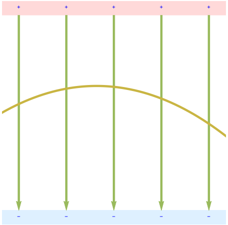
All particle masses are measured in eV

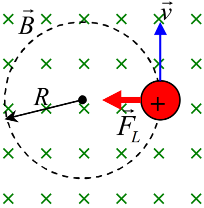
Where 1 electron is accelerated with 1 V, hence $E = qV$

$$1eV = (1.602 \cdot 10^{-19}) \cdot (1V) = 1.602 \cdot 10^{-19}J$$

Generally particles have speed of $0.999997828 \times c$ at injection (450GeV) and up to $0.999999991 \times c$ (7TeV) at the time of collisions. So generally we talk about energies and not speed.

Physics behind





$$\vec{F} = q \cdot \vec{E}$$

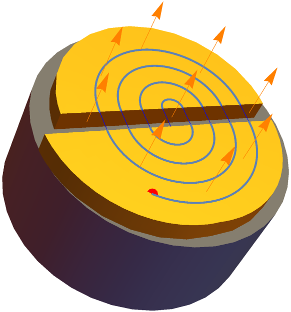
$$\vec{F} = q\vec{v} \times \vec{B}$$

Physics behind

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$\begin{cases} F_L = evB \\ F_{centr} = \frac{\gamma m_0 v^2}{\rho} \end{cases}$$

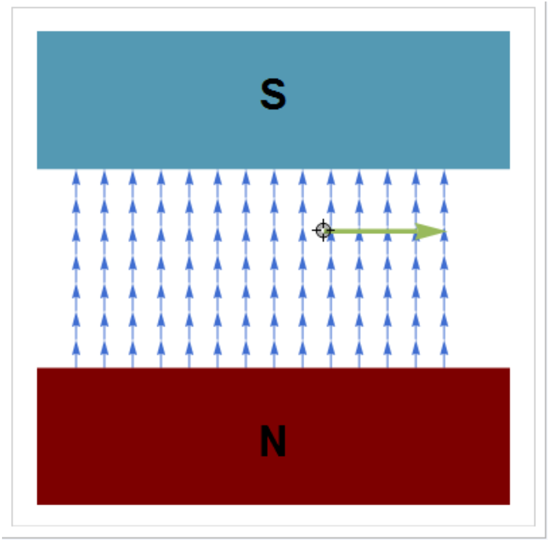
Physics behind



$$E_p = \frac{1}{2}\frac{e^2}{m_0}B^2R^2_{max}$$

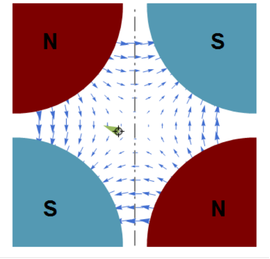
which was invented by Lawrence.

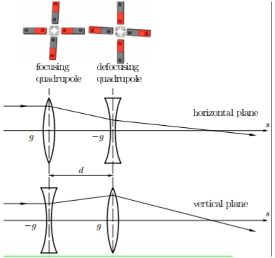
Physics behind

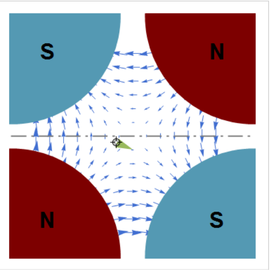


These magnets allows us to keep particles in their nearly circular orbits.
And these are superconducting magnets (NbTi) working at 1.9 K

Physics behind

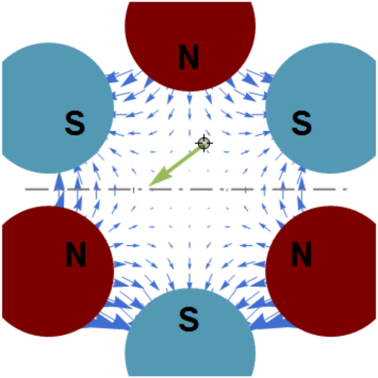




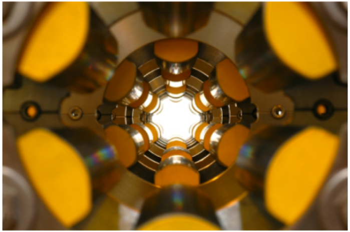


Magnetic dipoles are used to deflect the particle beam into a circular orbit. Magnetic quadrupole magnets, in addition, focus the beam in a transverse plane (vertically by focusing or horizontally by defocusing).

Physics behind

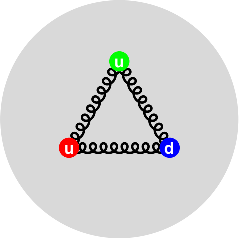


The beam point of view - Those are sextupoles - Six poles



Diamond light source - UK

Collisions



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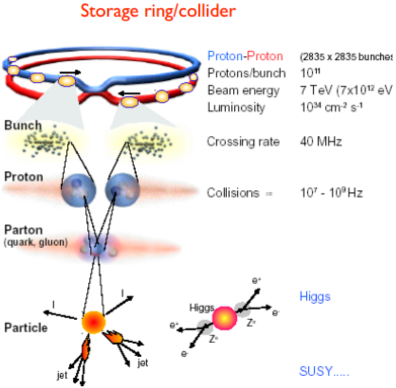


Storage ring/collider
Proton-Proton
(2835 x 2835 bunches
Protons/bunch
10^{11}
Beam energy
7 TeV ($7x10^{12}$ eV
Luminosity
10^{34} cm^{-2} s^{-1}
Bunch
Crossing rate
40 MHz
Proton
Collisions ≈
10^7 - 10^9 Hz
Parton
(quark, gluon)
Particle
l
l
jet
jet
Higgs
Z^o
Z^o
Higgs
SUSY.....

Collisions

The energy available (for example, to make new particles) is the centre-of-mass energy.

In the case of 2 beams it is simply the sum of the energies of the two colliding particles ($E = E_{b1} + E_{b2}$), whereas in case of colliding into stationary target, it is proportional to the square root of the energy of the particle hitting the target ($E \infty \sqrt{E_b}$).

Moreover, heavier particles lose less energy in the synchrotron than light particles.

Collision

Electrons (and positrons) are point like particles: no internal structure

The energy of the collider is totally transferred into the collision

$$E_{coll} = Eb_1 + Eb_2 = 2Eb\,(200\,GeV)$$

<u>Pros</u>: the energy can be precisely tuned to scan for example, a mass region.
Precision measurement (LEP)
Cons: above a certain energy is no more possible to use electrons because of too high synchrotron radiation

Protons (and antiprotons) are formed by quarks and gluons

The energy of each beam is carried by the proton constituents, and it is not the entire proton which collides, but one of his constituent

$$E_{coll} < 2Eb\,(8\,TeV)$$

<u>Pros</u>: with a single energy possible to scan different processes at different energies.
Discovery machine (LHC)
Cons: the energy available for the collision is lower than the accelerator energy

Collision

In addition to the studies of proton–proton collisions, heavy-ion collisions at the LHC will provide a window onto the state of matter that would have existed in the early Universe, called "**quark-gluon plasma**".

When heavy ions collide at high energies they form for an instant a 'fireball' of hot, dense matter that can be studied by the experiments.

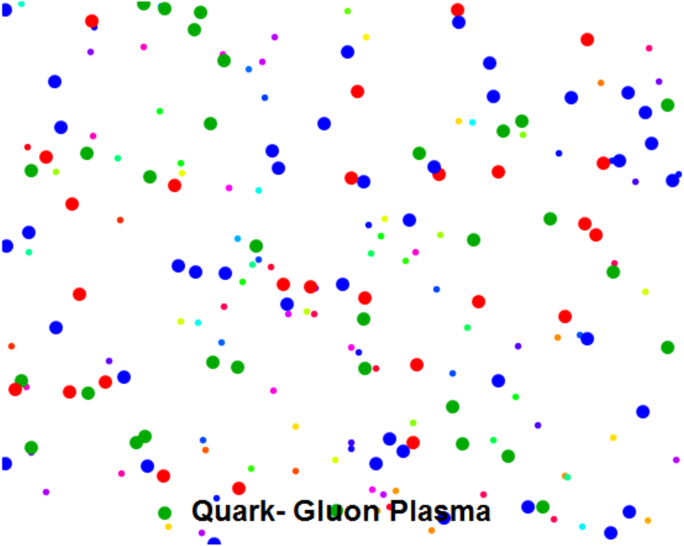
Collision

The Universe, born from the Big Bang, went through a stage during which matter existed as a sort of extremely hot, dense soup — called quark-gluon plasma (QGP).

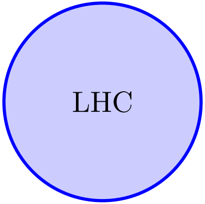
As the Universe cooled, the quarks became trapped into composite particles such as protons and neutrons. The LHC is able to reproduce the QGP.

In the collisions, the temperature will exceed 100000 times that of **the centre of the Sun**.
In these conditions, the quarks are freed again and the detectors can observe and study the primordial soup, thus probing the basic properties of the particles and how they aggregate to form ordinary matter.

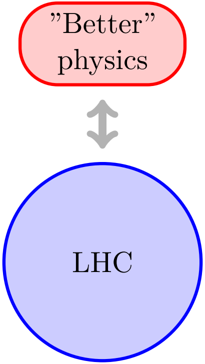
Collision



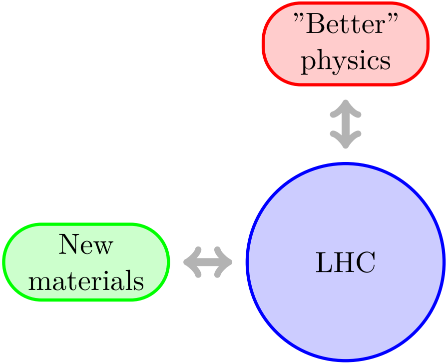
Conclusions



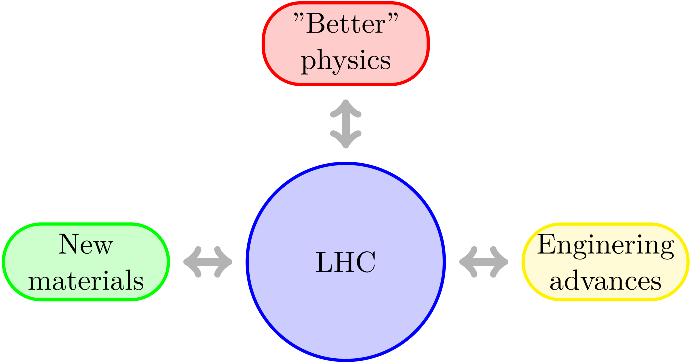
Conclusions



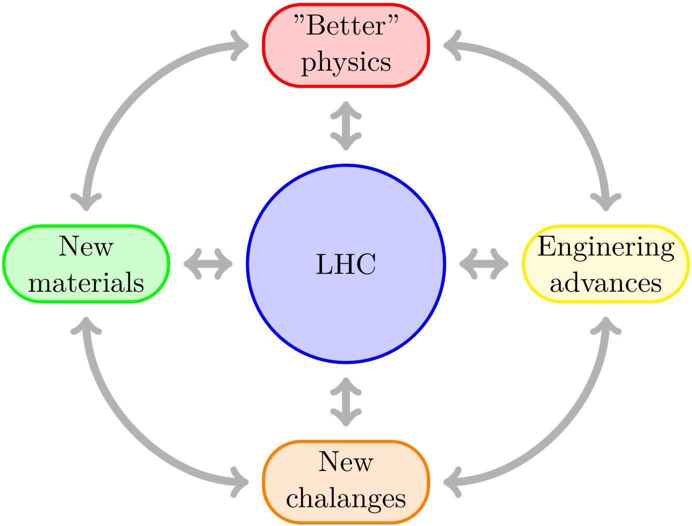
Conclusions



Conclusions



Conclusions



Conclusions

Paldies par uzmanību!