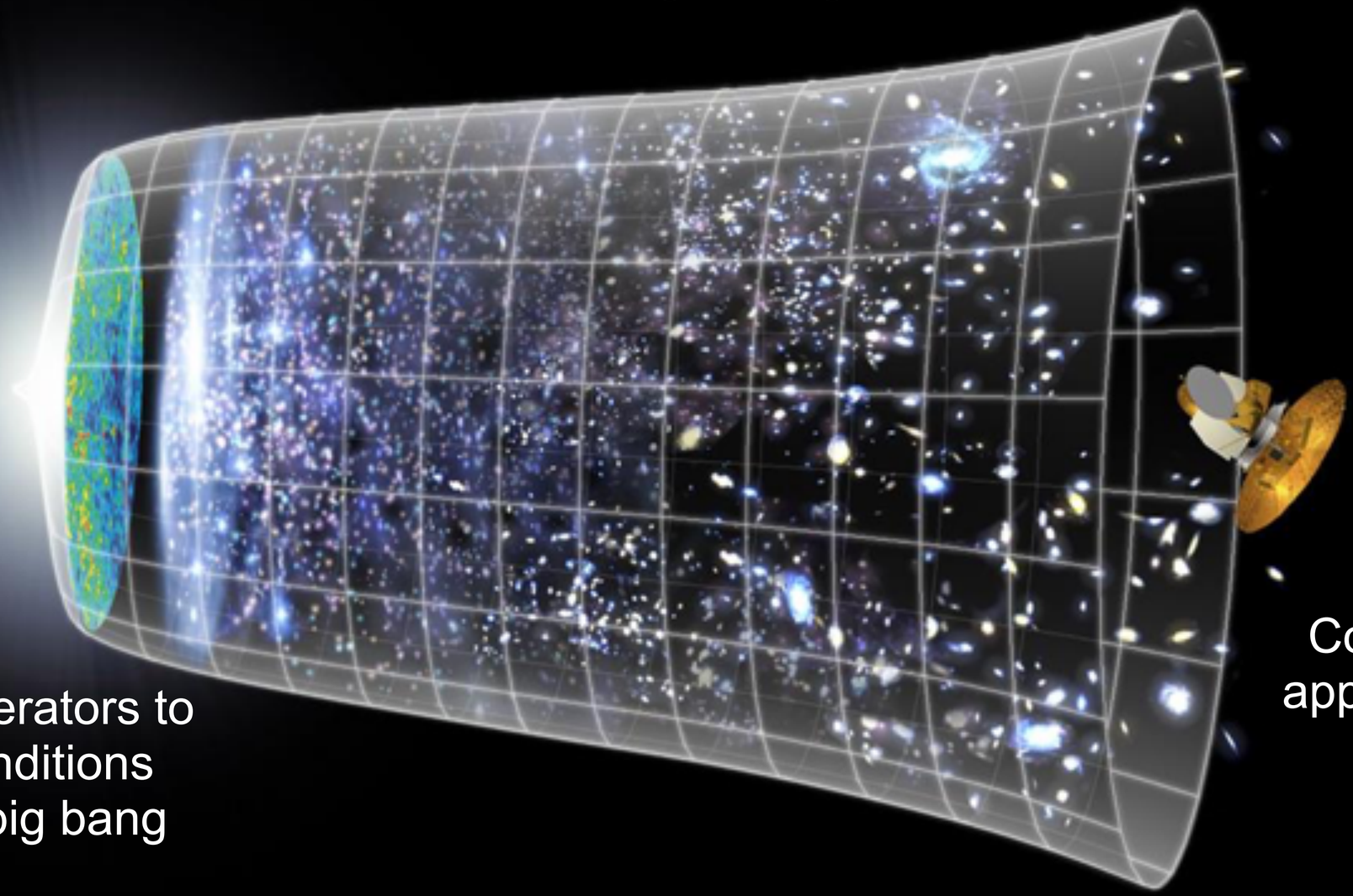
FZU Institute of Physics of the Czech Academy of Sciences

Top quark at ATLAS

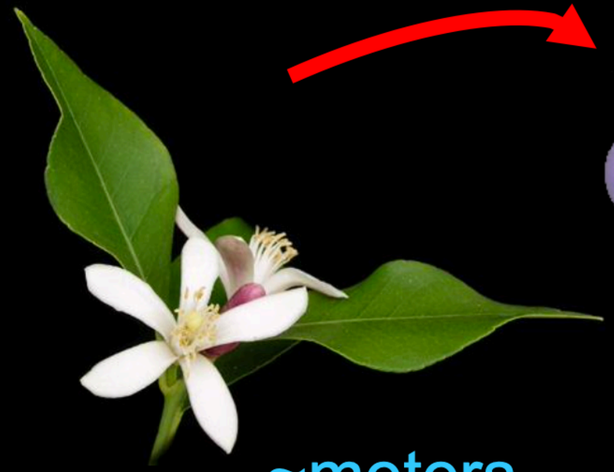
Try to understand the very first moments of our Universe after the Big Bang



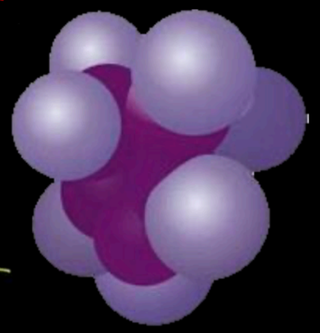
Big Bang

Use particle accelerators to re-create the conditions shortly after the big bang

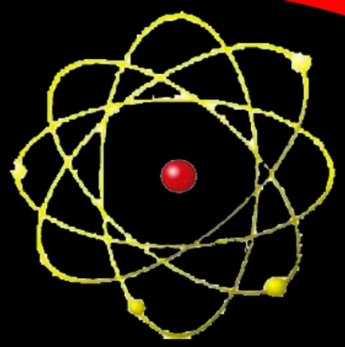
Complementary approach: ‘looking back’



~meters
matter



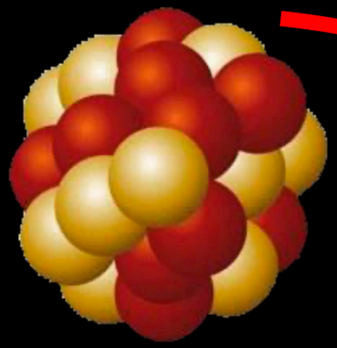
10^{-9} m
molecules



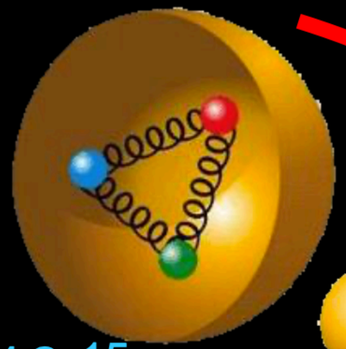
10^{-10} m
one atom

is made from electrons around a nucleus

the nucleus is made from
protons and neutrons



10^{-14} m



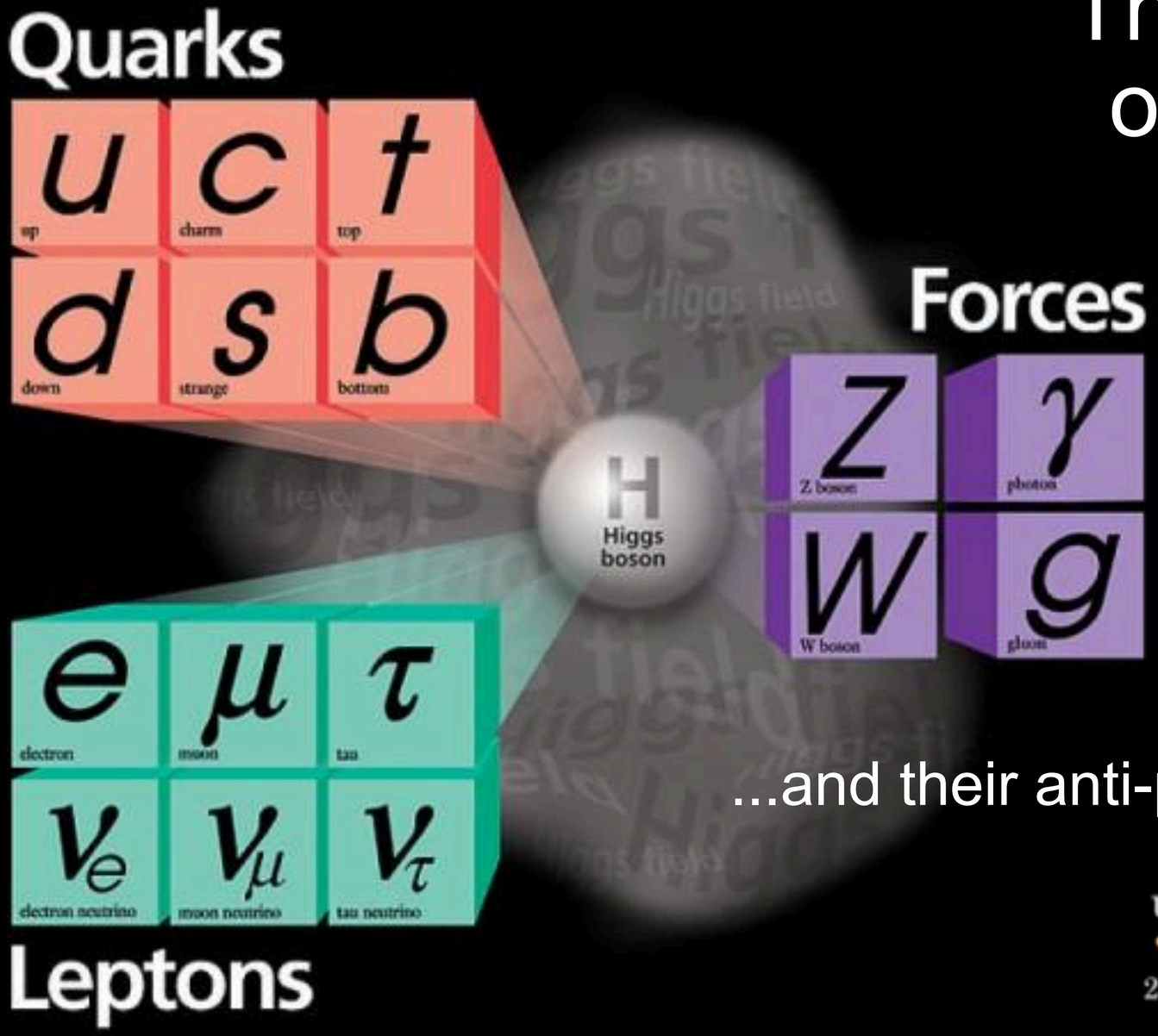
10^{-15} m

protons and neutrons
contain quarks

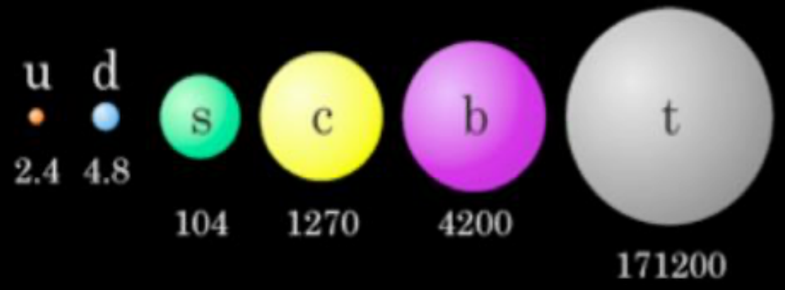
$<10^{-18}$ m
quarks, electrons
(= fermions)

electron, quark < 10^{-18} m = 0.000,000,000,000,000,001 m
→ fundamental constituents

The Standard Model of Particle Physics



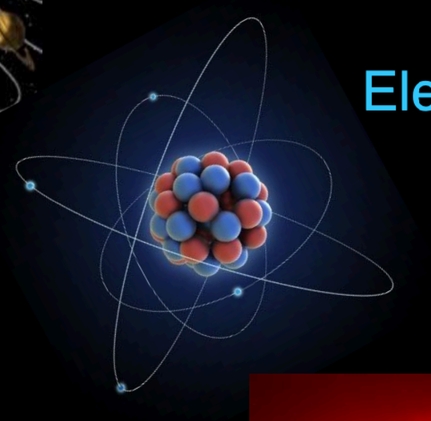
...and their anti-particles !



Fundamental forces

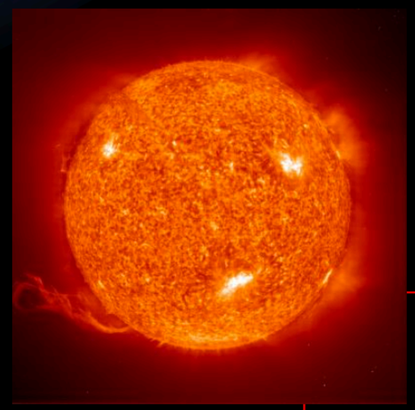
Gravity

Graviton ?



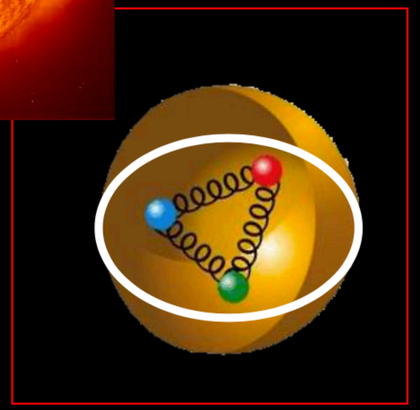
Electromagnetic Force

Photon



Weak Force

W, Z



Strong Force

Gluon

the forces act through their associated particles

LHC - basic facts

- 4 experiments
- 26.7 km in circumference
- 50-175 m underground
- Operating temperature 1.9 K
- Energy 14 TeV
- ~ 9600 magnets
- 7600 km of cables

LHC proton beam

- Each proton beam consist of 2808 bunches
- Each bunch contains 10^{11} protons
- Total beam energy is 360 MJ -> energy of moving TGV!

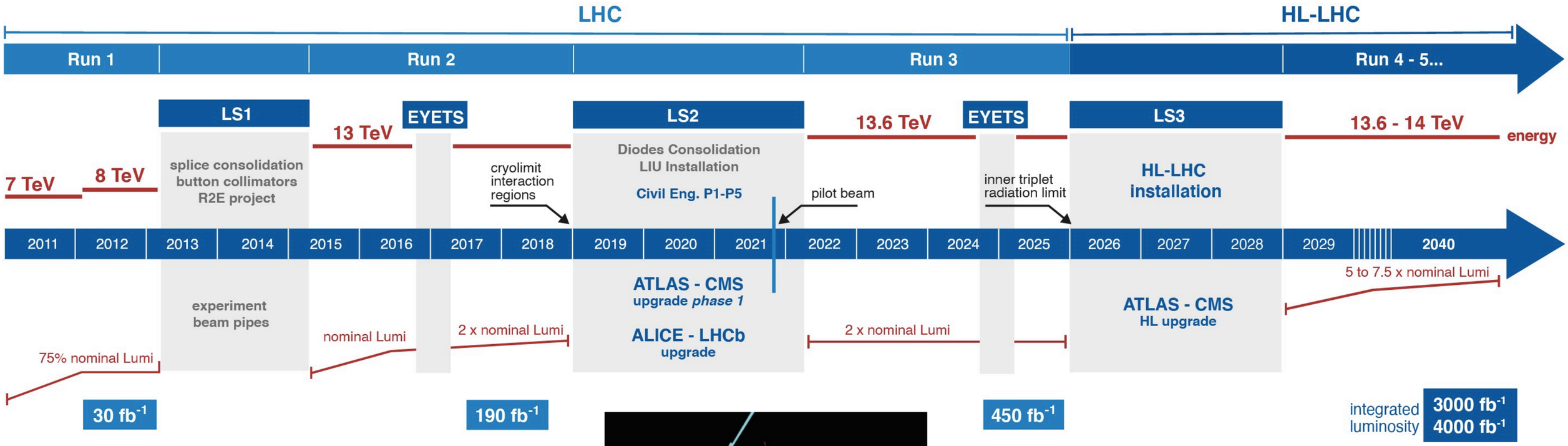
Cross section

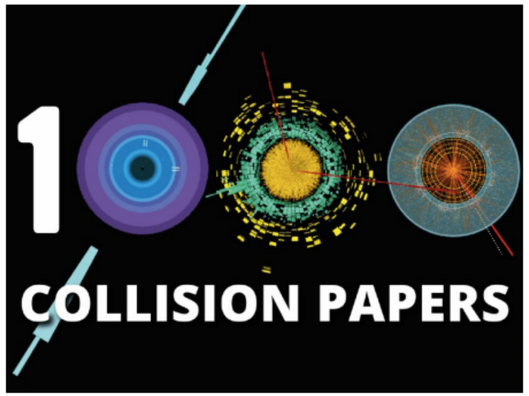
- Describe the probability that two particles will collide and interact in a certain way

Luminosity

- measures how many particles pass through a square centimetre per second

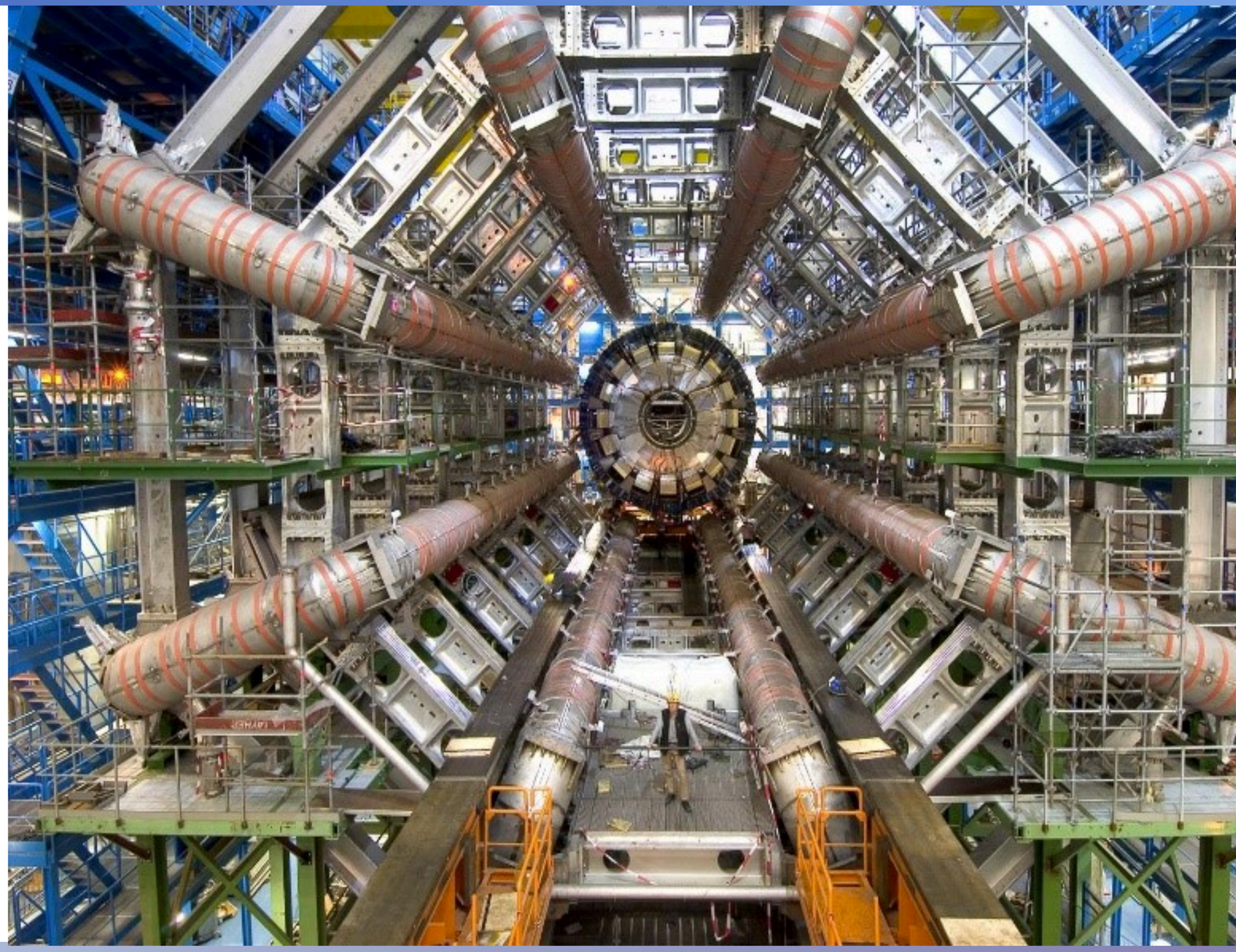
LHC / HL-LHC Plan



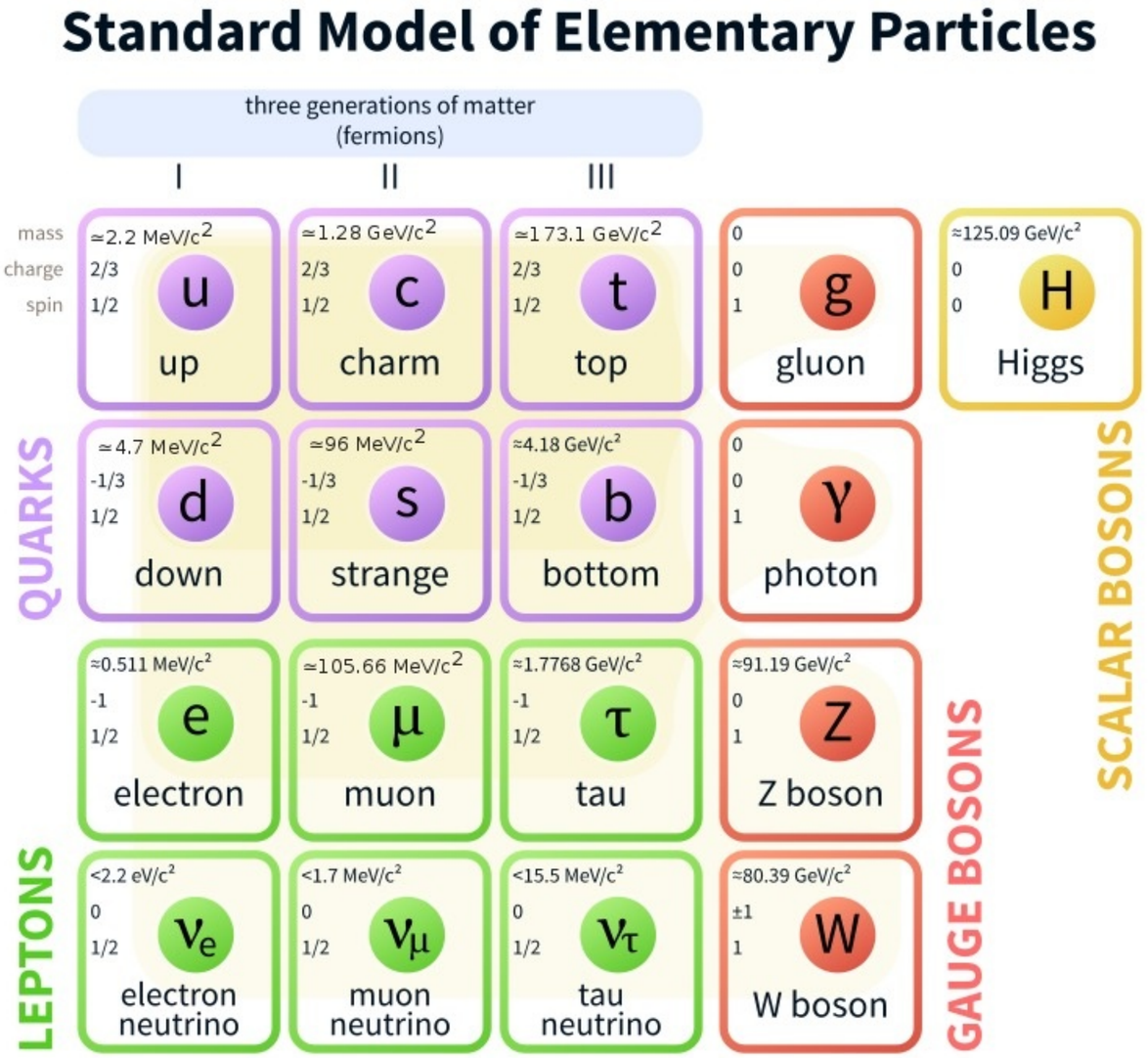


- The detector have four major systems:
  - Inner Detector
  - Calorimeters
  - Muon Spectrometer
  - Magnet system

- Weight ~ 100 B747 Jumbo-jet (empty)
- Size of 1/2 Notre Dame de Paris
- Precision: 1 micrometer



Top quark - introduction



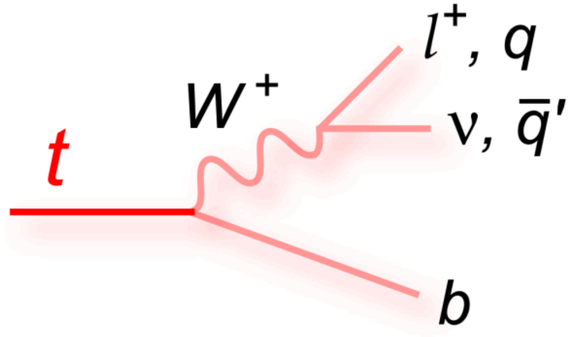
What makes top quark special:

a large mass, which is equivalent to the mass of a gold atom

Top quark - introduction

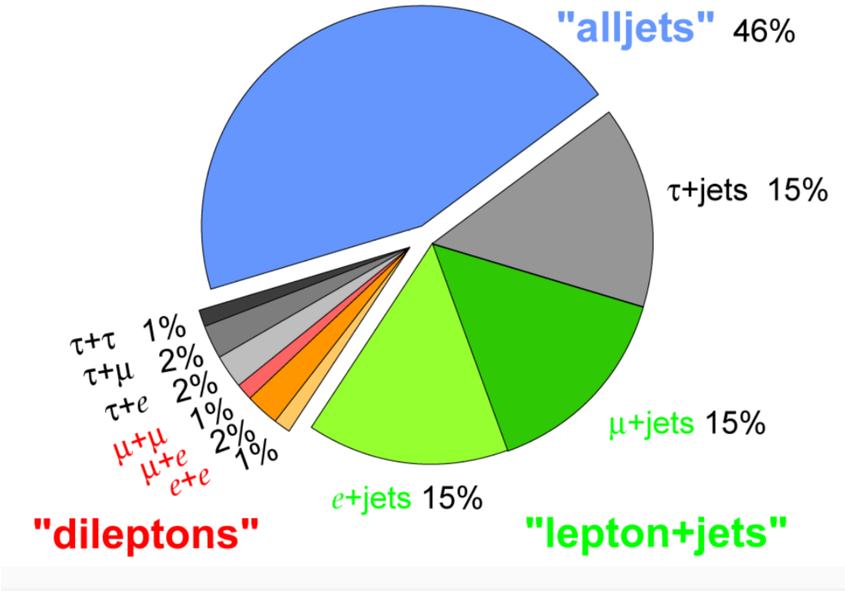
- **Objeven v roce 1995 ve Fermilabu**

- **Unikátní částice**
  - Nejtěžší elementární částice
  - Unikátní vlastnosti z hlediska teorie i experimentu

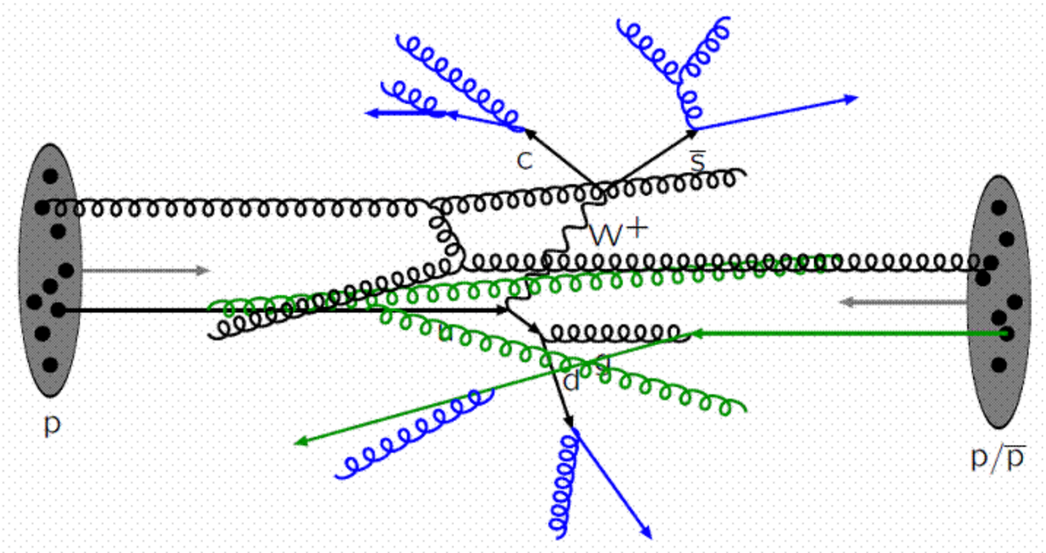


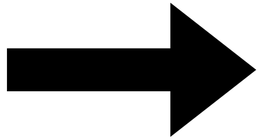
- **Velmi krátká doba života**
  - Jediný kvark , který nehadronizuje
  - Vlastnosti jsou studovány skrze rozpadová produkty

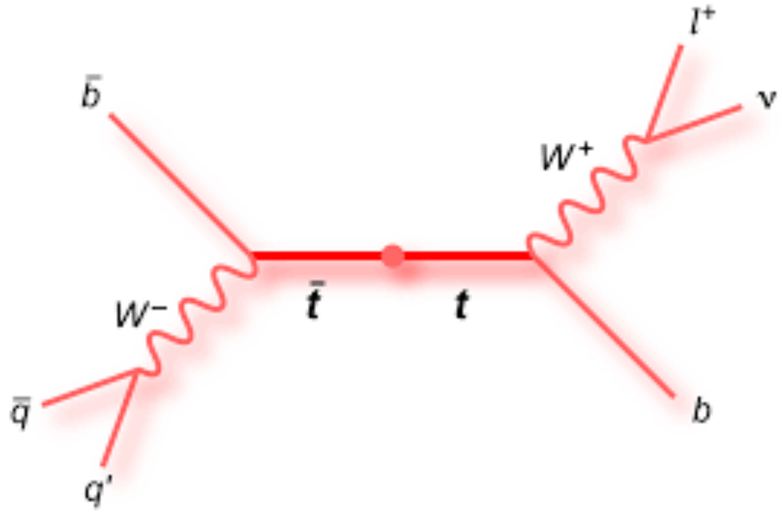
- **Vlastnosti**
  - Hmotnost: 172.76 ± 0.3 GeV / c2
  - Doba života: 5×10^{-25} s
  - Elektický náboj: +2/3 e



Analýza dat ~ hledání jehly v kupce sena



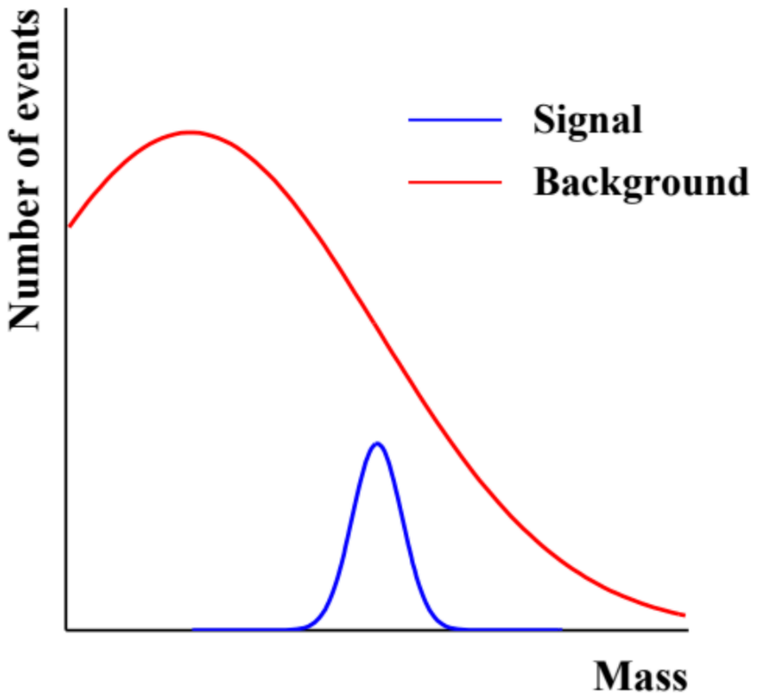


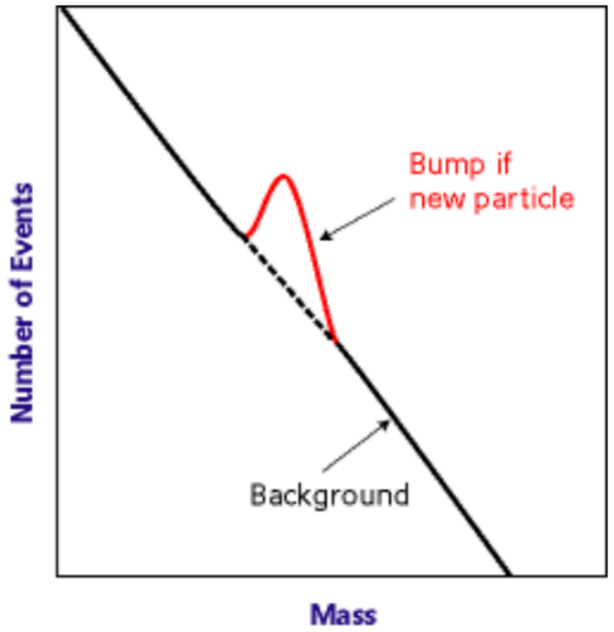


- Zkoumaná data obsahují hledaný signál (někdy) a pozadí (vždycky)
  - Signál = to, co nás zajímá
  - Pozadí = vše kromě toho, co nás zajímá

Klíčová je redukce pozadí!

Měření hmoty top kvarku





- Meříme "hrb" ~ vážíme hmotnost top kvarku
  - Pozie "hrbu" ~ hmotnost top kvarku
  - Šířka “hrbu” ~ přesnost měření

Měření hmoty top kvarku

- Jednotky : $e = \hbar = c = 1$

Theorem

$$E = \sqrt{m^2 + p^2} \qquad \Longrightarrow \qquad m = \sqrt{E^2 - p^2}$$

- ZZE : $E = E_1 + E_2 + E_3$
- ZZH : $\vec{P} = \vec{P}_1 + \vec{P}_2 + \vec{P}_3$

$$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$

- $$M = \sqrt{\left(\sum_{i=1}^{3} E_i\right)^2 - \left(\sum_{i=1}^{3} \vec{P}_i\right)^2}$$