

Scientific method

... by means of intuition we isolate in a specific phenomenon certain elements which we then translate into a quantitative form. We next endeavor to discover some mathematical law or formula to which will correlate these elements in a systematic manner. Deduction made from this law must always be true of similar instances of the phenomenon and this can be verified by experiment.

... the mind itself be from the outset not left to take its own course, but guided at every step, and the business be done as if by machinery.

Francis Bacon (1561-1626)

Galileo Galilei

(1564 - 1642)



Wilhelm Röntgen (1845-1923)

The first human X-ray image: Berta Röntgen's hand

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> Photographic plate of Becquerel impressed by the radioactivity of uranium.



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Photographic plate of Becquerel impressed by the radioactivity of uranium.

Henri Becquerel (1852-1908)

Wilhelm Röntgen (1845-1923)

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Wilhelm Röntgen (1845 - 1923)

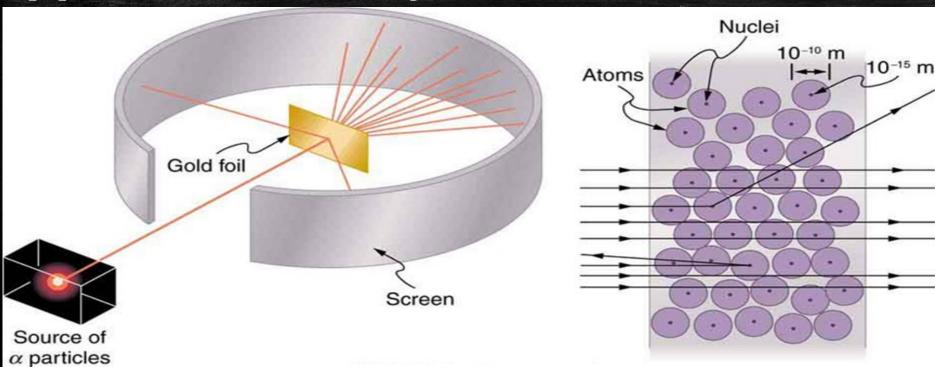
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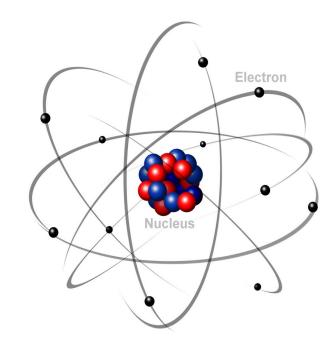
Henri Becquerel (1852 - 1908)

ite of sed by the uranium.

I remember ... later Geiger coming to me in great excitement and saying "We have been able to get some of the α -particles coming backwards... It was almost incredible as if you fired 15-inch at a piece of tissue paper and it come back and hit you.

Ernest Rutherford (1871-1937)





The modern era of nuclear physics Deep inelastic scattering

W 1.0 Gev ($\frac{d^2\sigma}{d\alpha dE} (W,q^2)$ W 3.0 Cev 0 10 MOTT 4E2 CON 2 T 1.0 de) enstic N ARBITRARY UNITS 10-1 10-3 0.5 1.0 1.5 2.5 2.0 q^2 IN $(BeV/c)^2$

One of the earliest examples of the relatively large cross sections and weak q^2 dependence that were found to characterize the deep inelastic scattering and which suggested point-like nucleon constituents.

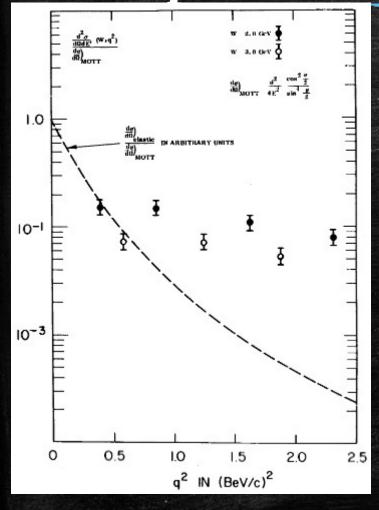


Richard E. Taylor J (1929-2018) Henry W. Kendall (1926-1999)

Jerome I. Friedman (1930)

The modern era of nuclear physics Deep inelastic scattering

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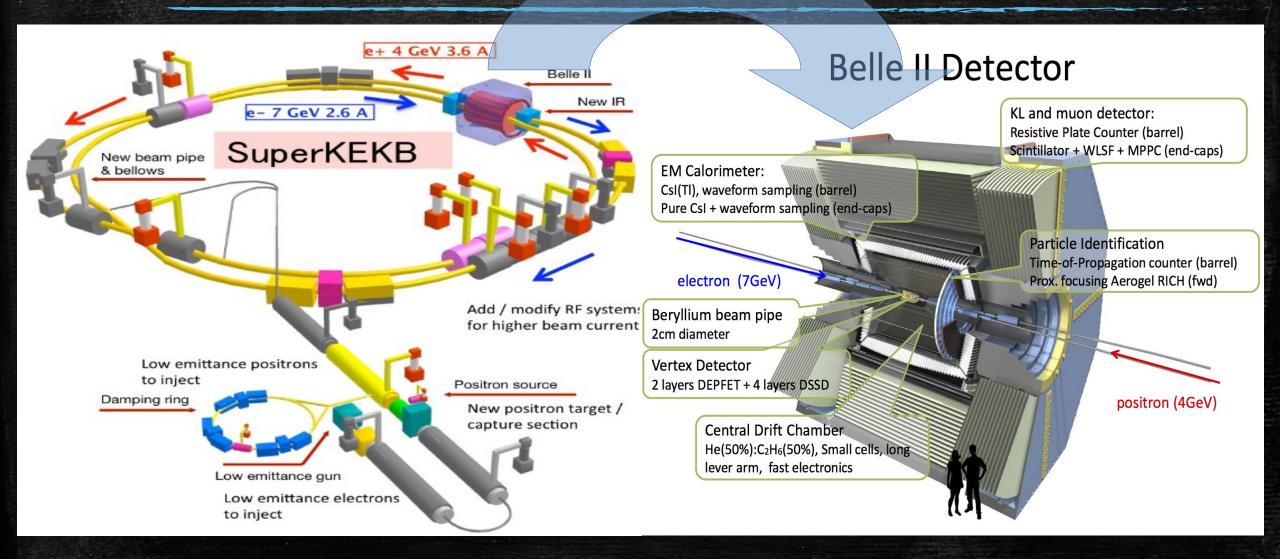
high energy particle beam

fixed target

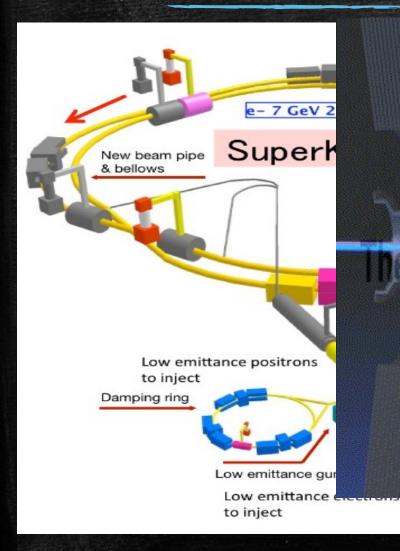
high energy particle beam

high energy particle beam

The modern experimental setup



The modern experimental setup



Belle II Detector

er: n sampling (barre') iorm sampling (eno caps)

GeV)

pipe

4 layers DSSD

Drift Chumber :C2H6(7.0%), Small cells, long n, most electronics KL and muon detector: Resistive Plate Counter (barrel) Scintillator + WLSF + MPPC (end-caps)

Particle Identification Time-of-Propagation counter (barrel) Prox. focusing Aerogel RICH (fwd)

positron (4GeV)

Let's consider a particle (e. g. π^0) which decays into two final state particles (i. e. y): $\tau \simeq 8.5 \times 10^{-17} \, [s]$ $c\tau \simeq 2.5 \times 10^{-6}$ [cm]

Question. How can we reconstruct a decaying particle ?

In high energy particle physics we use a "special tool" that is the theory of Special Relativity. In π^0 this theory the energy-momentum relation is given by :

 $E^2 = p^2 c^2 + m_0^2 c^4$

Typically, energy and three-momentum are unified into the energy-momentum vector i.e. four-momentum vector \mathbf{p}_{μ} : π^{0}

 $p_{\mu} = (E, p)$ with a square of four-momentum vector defined as : $p_{\mu}p^{\mu} = E^{2} - |p|^{2} (in a frame where c = 1) \Rightarrow p_{\mu}p^{\mu} = m_{0}^{2}$

Finally, we use conservation of four-momentum p_{μ} :

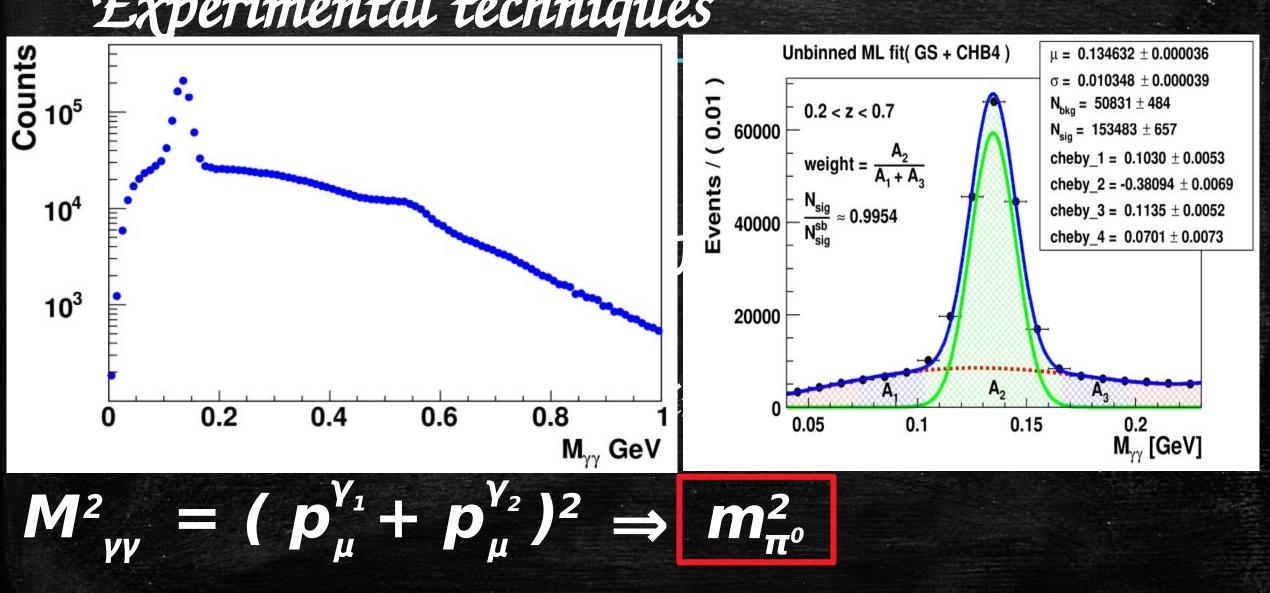
 $\boldsymbol{p}_{\mu}^{\boldsymbol{\pi}^{o}} = \boldsymbol{p}_{\mu}^{\boldsymbol{\gamma}_{1}} + \boldsymbol{p}_{\mu}^{\boldsymbol{\gamma}_{2}}$

to reconstruct the mass of a decaying particle

 $\pi^{\rm U}$

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 $M_{\gamma\gamma}^{2} = (p_{\mu}^{\gamma_{1}} + p_{\mu}^{\gamma_{2}})^{2} \Rightarrow m_{\pi^{0}}^{2}$



It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong.

R. P. Feynman