Measurements and theories, experimental methods.

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WORKSHOP

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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.

Galileo Galilei (1564-1642)

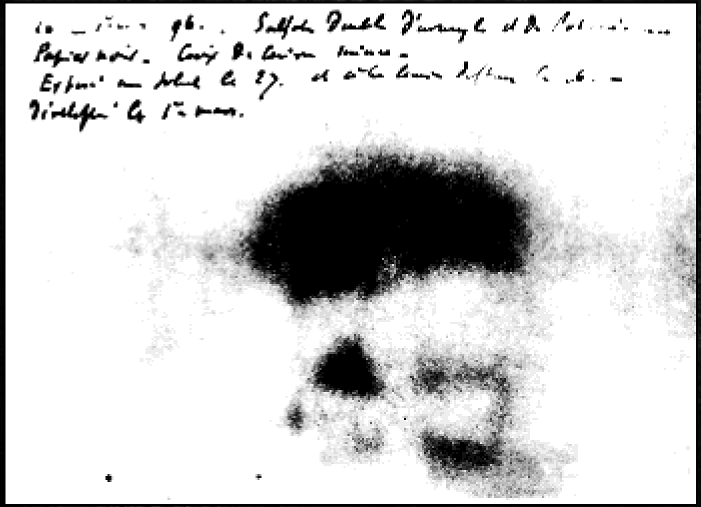
… the mind itself be from the outset not left to take its own course, but guided at every step, and the business be done as if by machinery.

Francis Bacon (1561-1626)

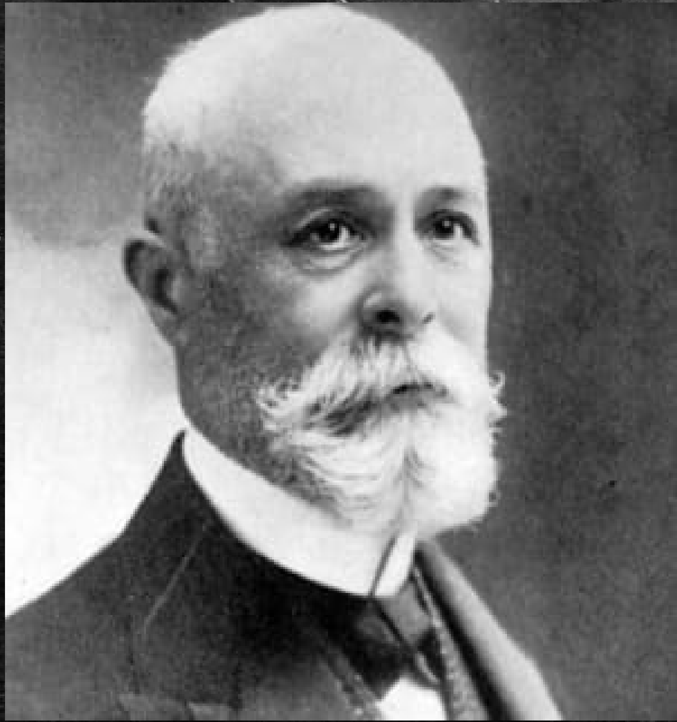
The era of nuclear physics

Wilhelm Röntgen
(1845-1923)

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



Henri Becquerel
(1852-1908)



Photographic plate of Becquerel impressed by the radioactivity of uranium.

The era of nuclear physics

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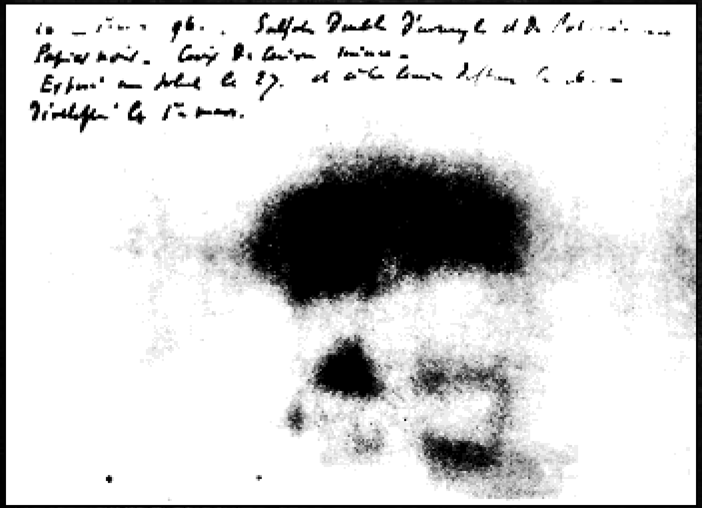

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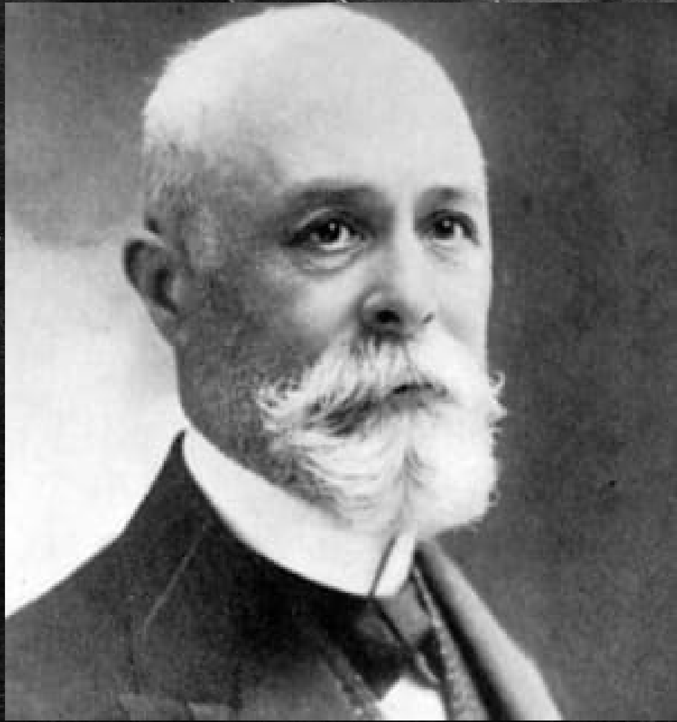

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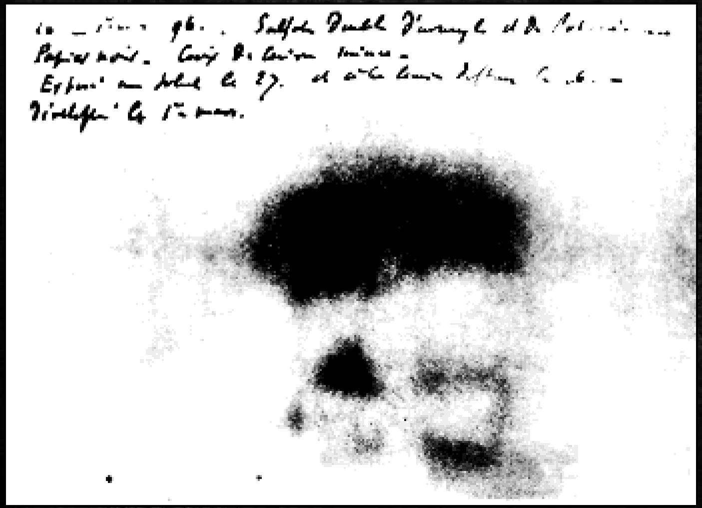

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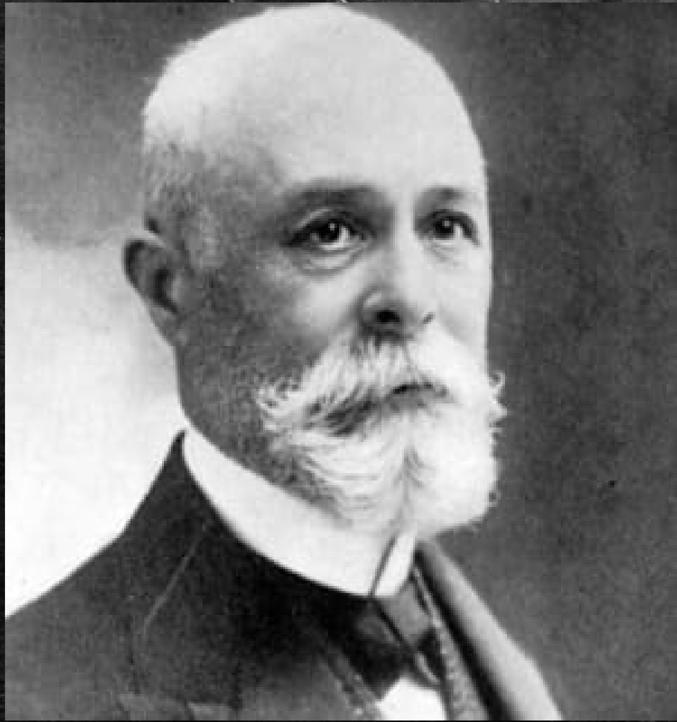
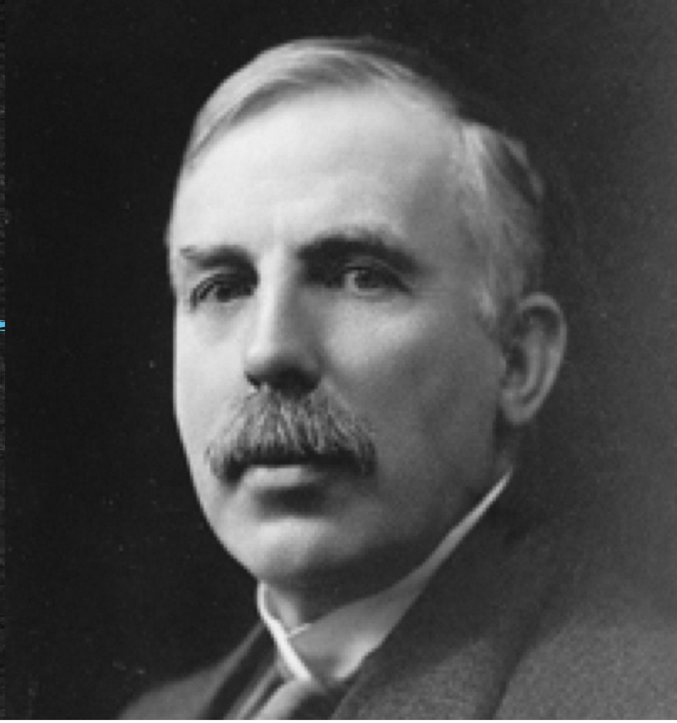
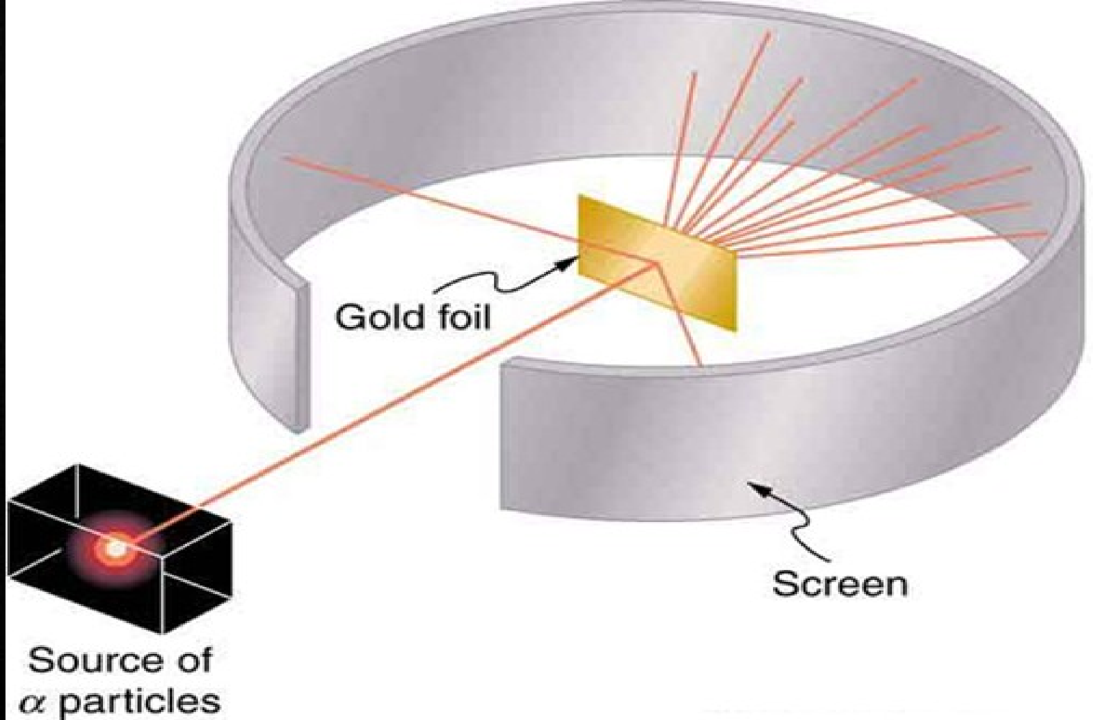


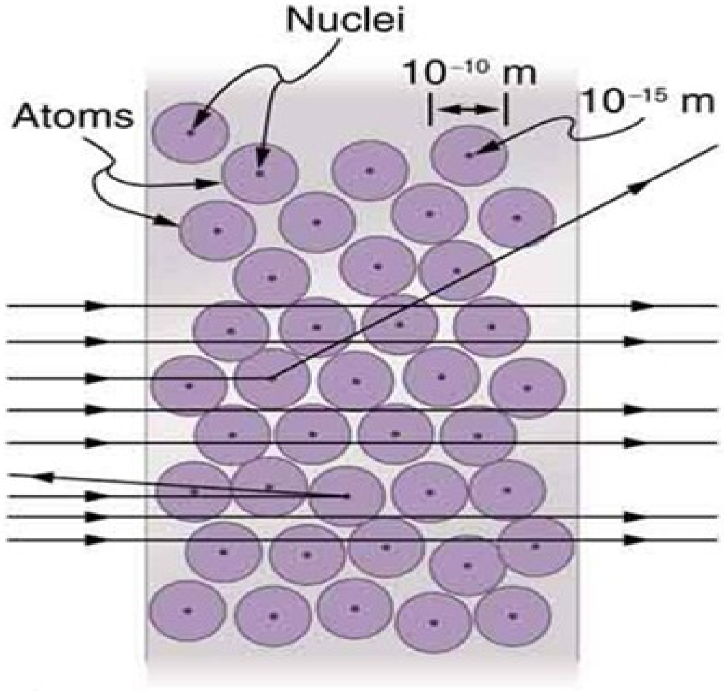
The era of nuclear physics

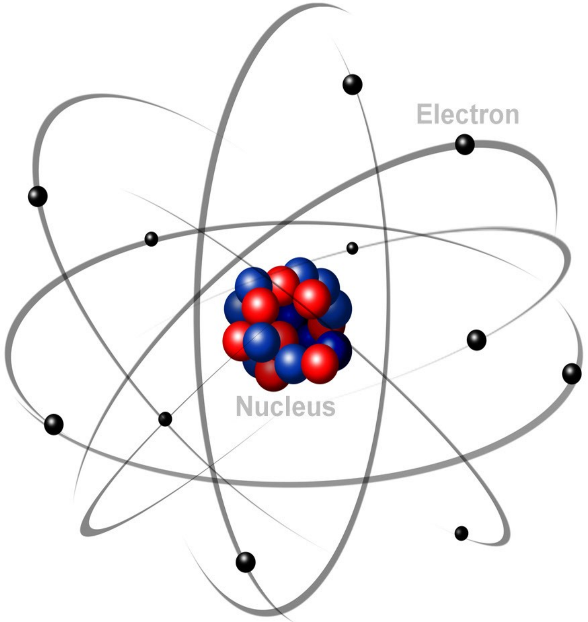
I remember …later Geiger coming to me in great excitement and saying ''We have been able to get some of the α-particles coming backwards… It was almost incredible as if you fired 15-inch at a piece of tissue paper and it come back and hit you.

Ernest Rutherford (1871-1937)

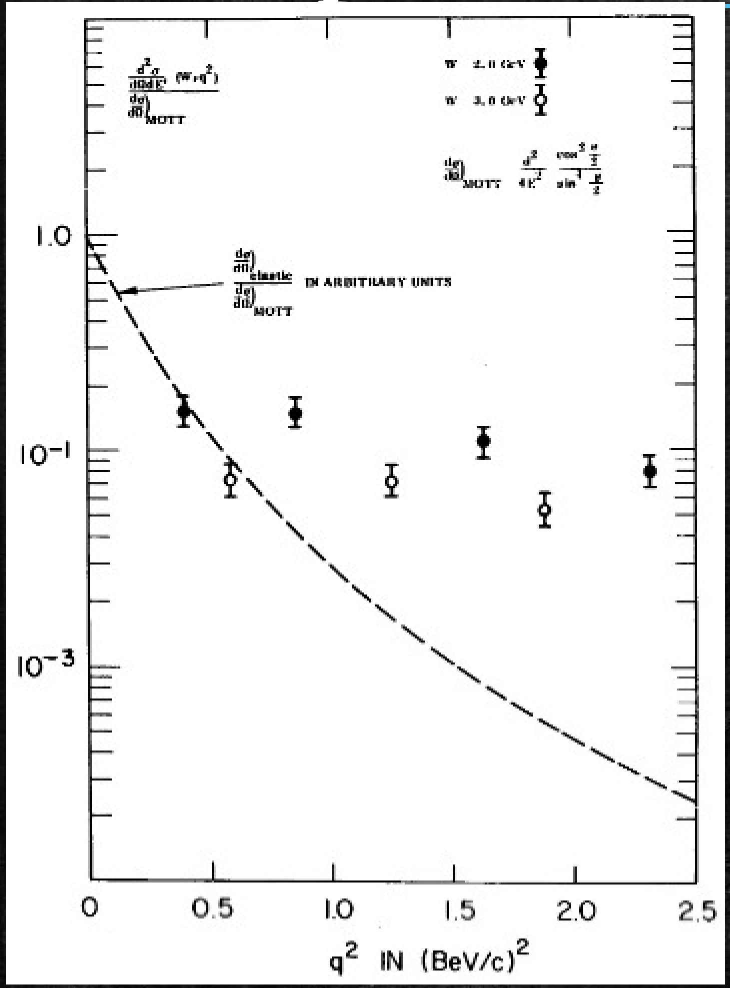








The modern era of nuclear physics
Deep inelastic scattering



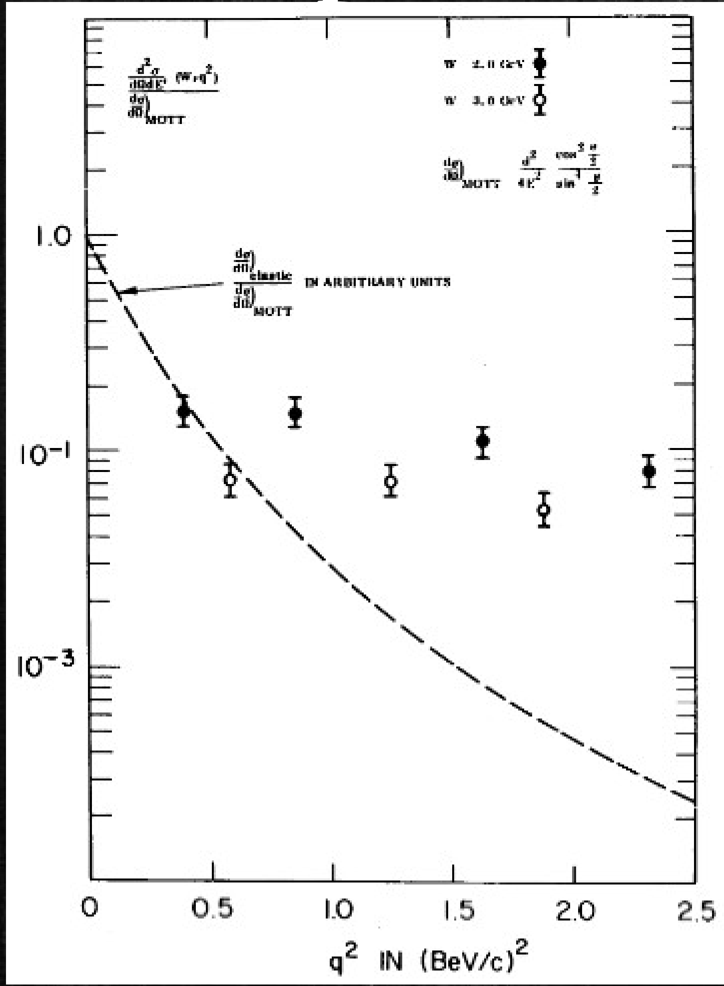
One of the earliest examples of the relatively large cross sections and weak q^2 dependence that were found to characterize the deep inelastic scattering and which suggested point-like nucleon constituents.

Richard E. Taylor
(1929-2018)

Henry W. Kendall
(1926-1999)

Jerome I. Friedman
(1930)

The modern era of nuclear physics
Deep inelastic scattering



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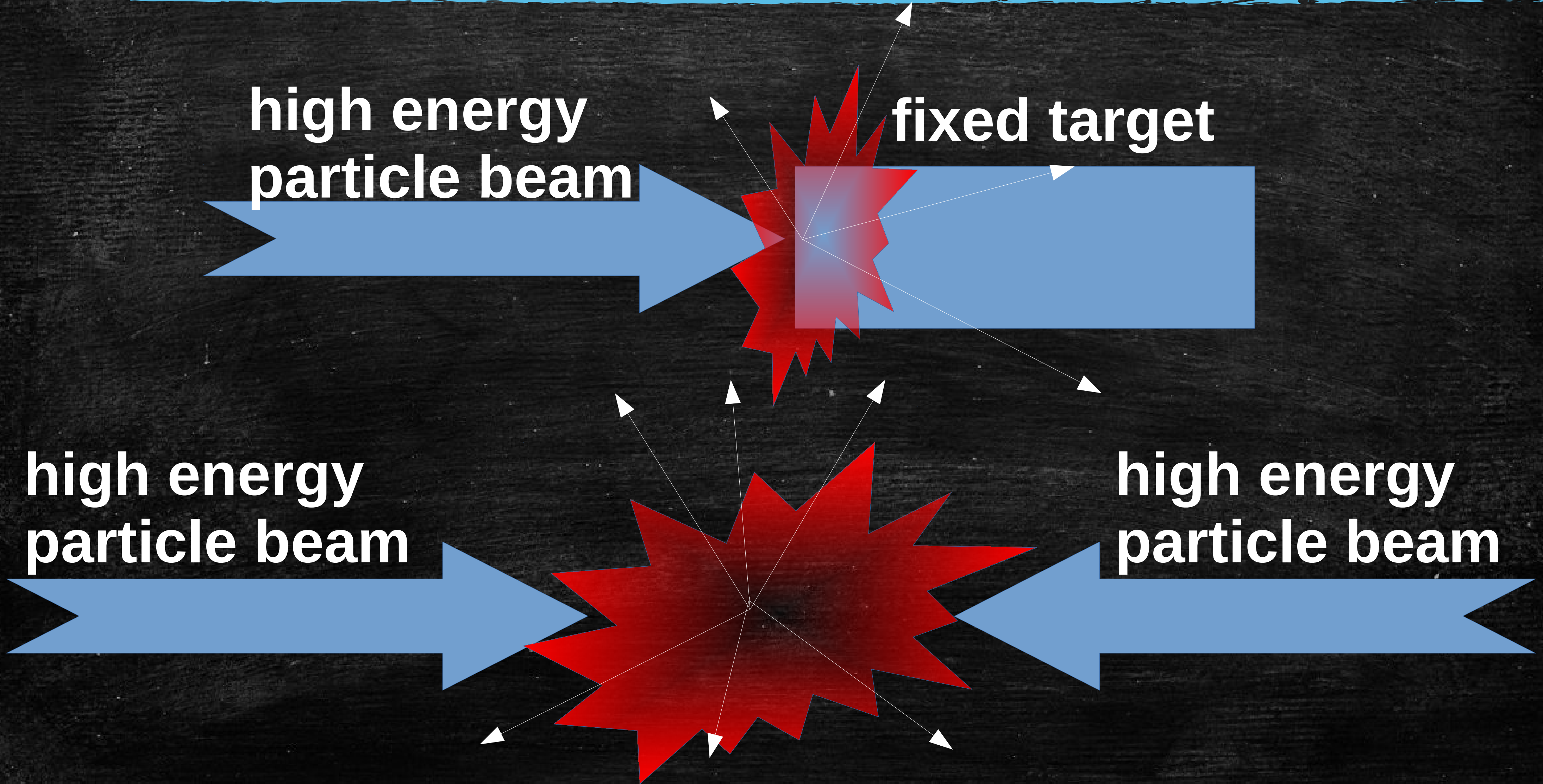
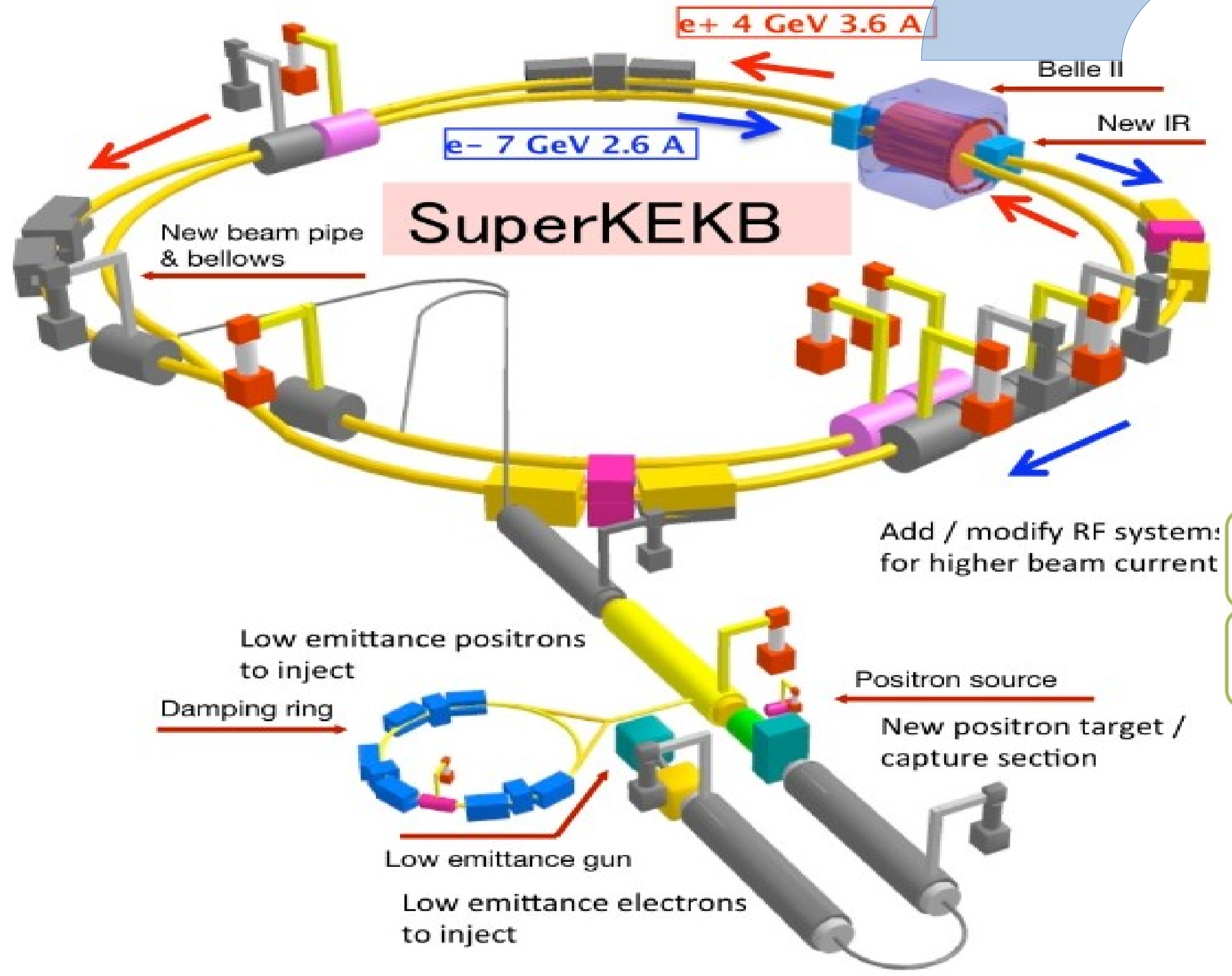
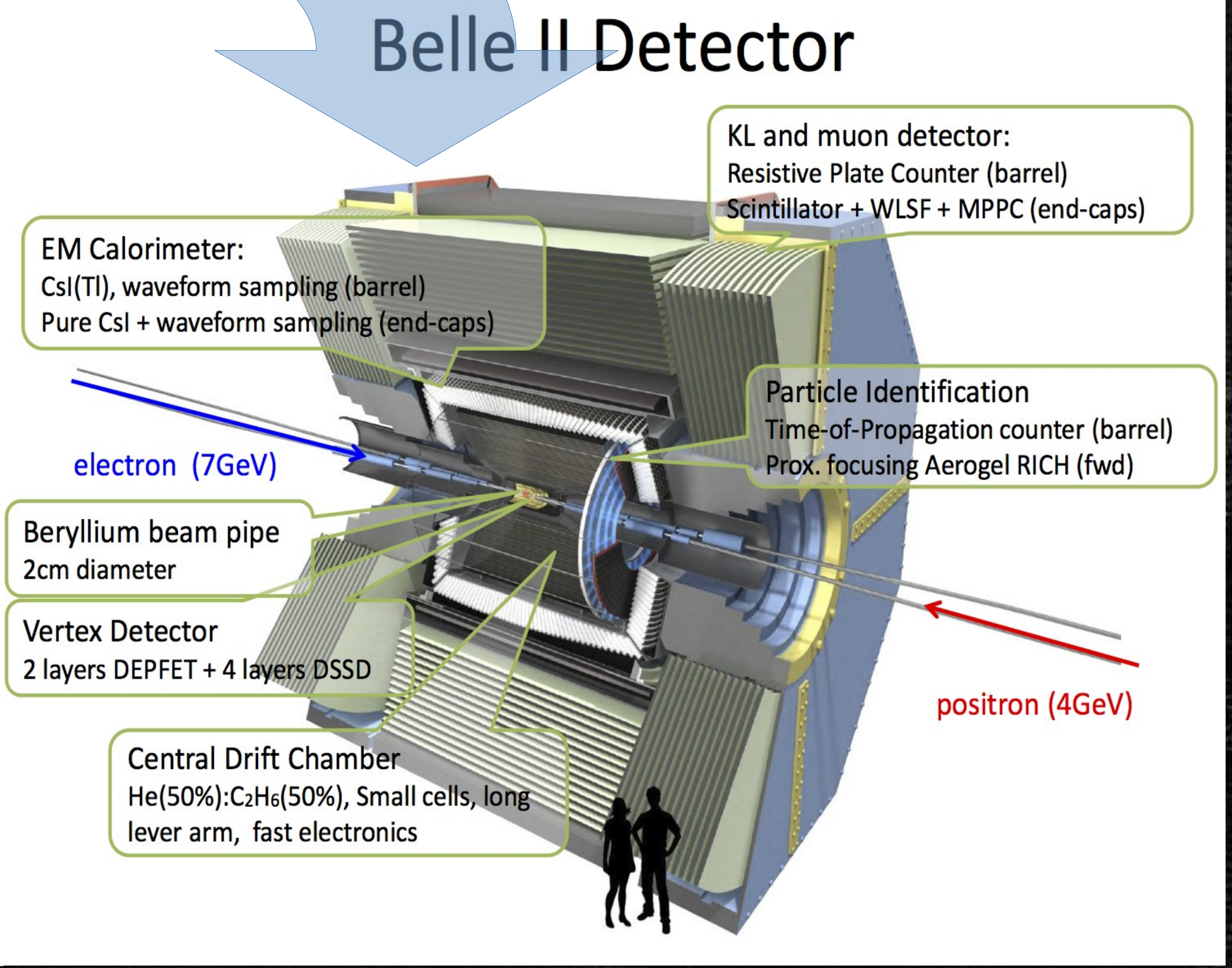
Deep inelastic scattering



The modern experimental setup





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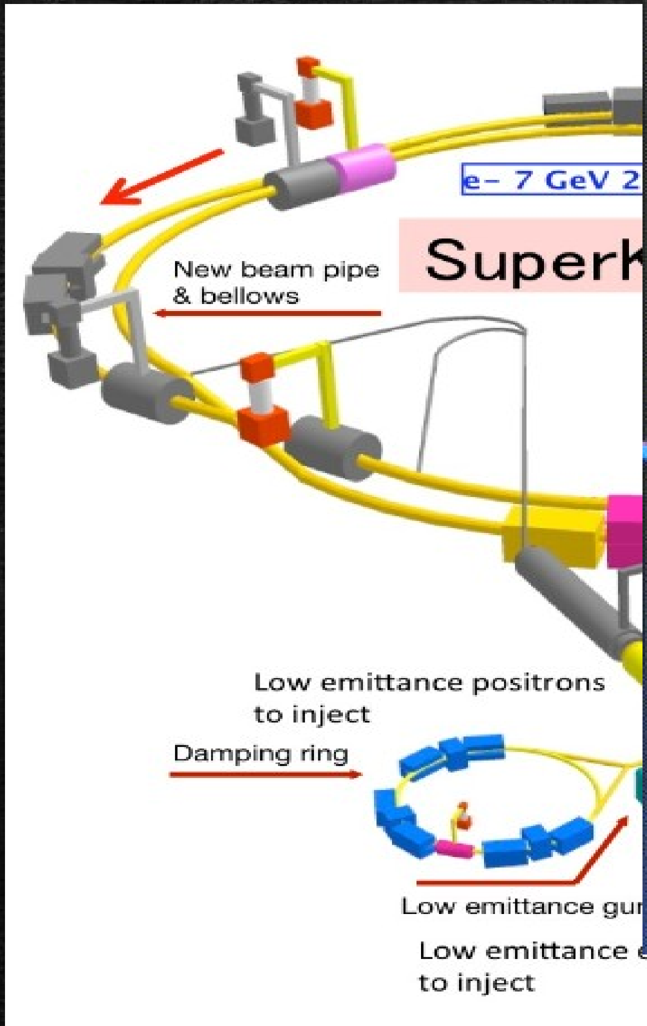
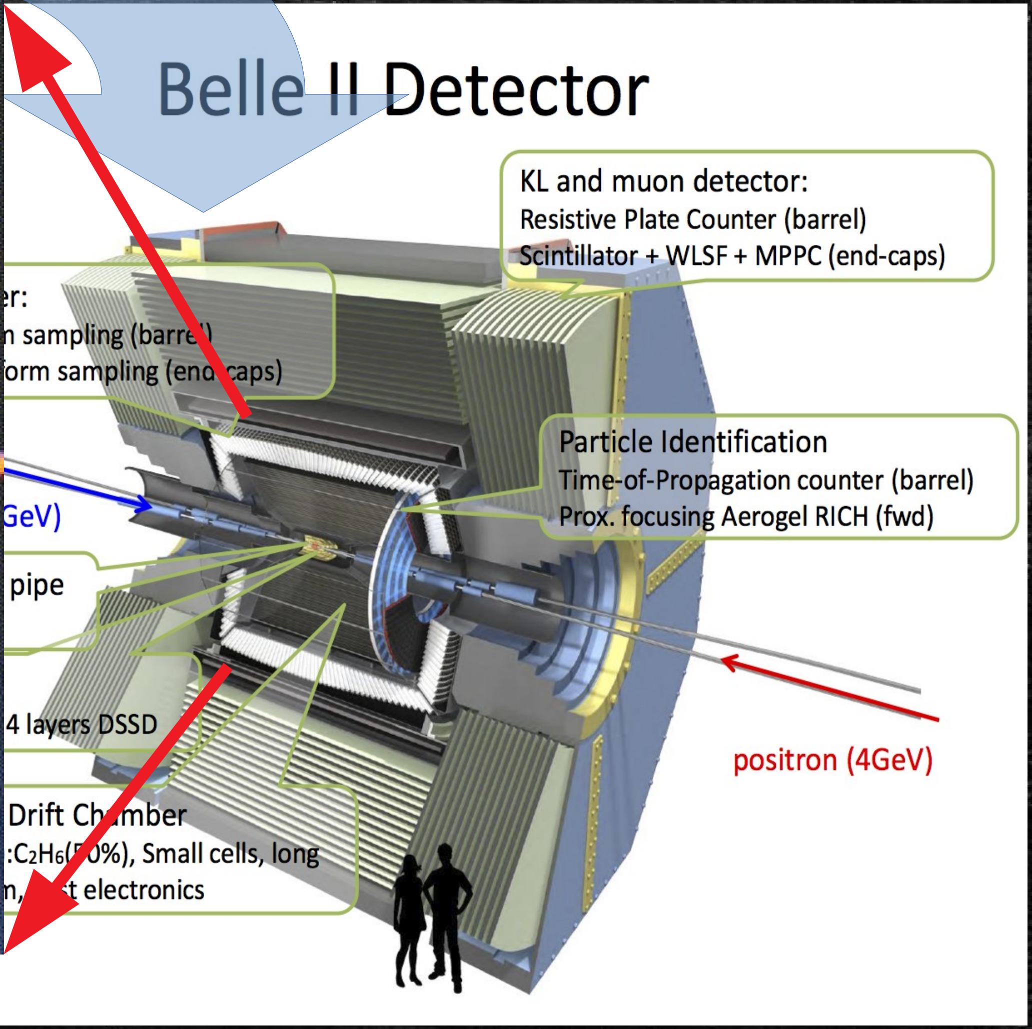
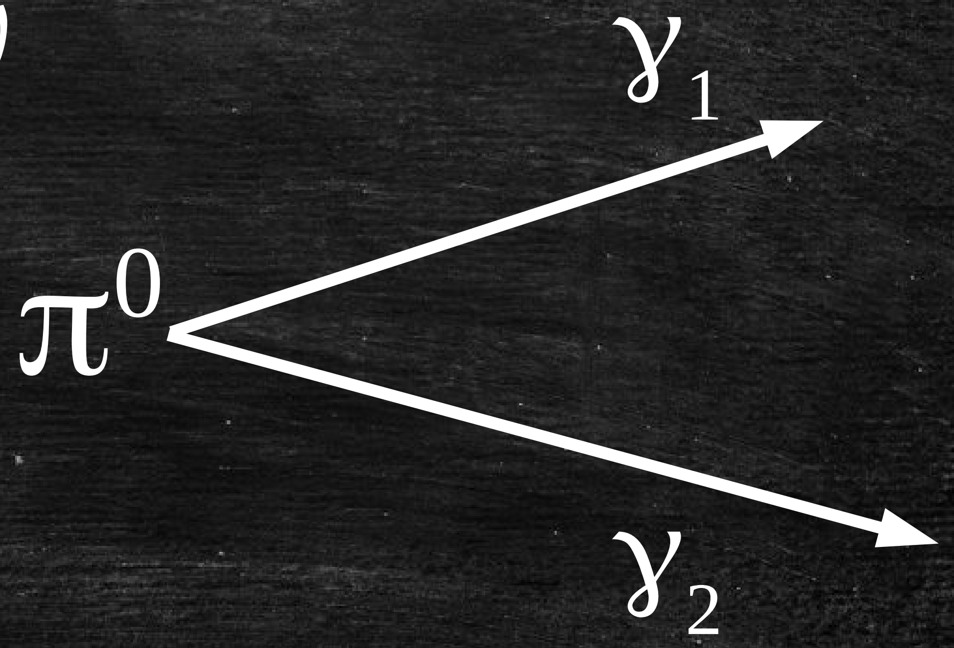




Experimental techniques

Let's consider a particle (e. g. π^0) which decays into two final state particles (i. e. γ) :



$\tau \simeq 8.5 \times 10^{-17}$ [s]

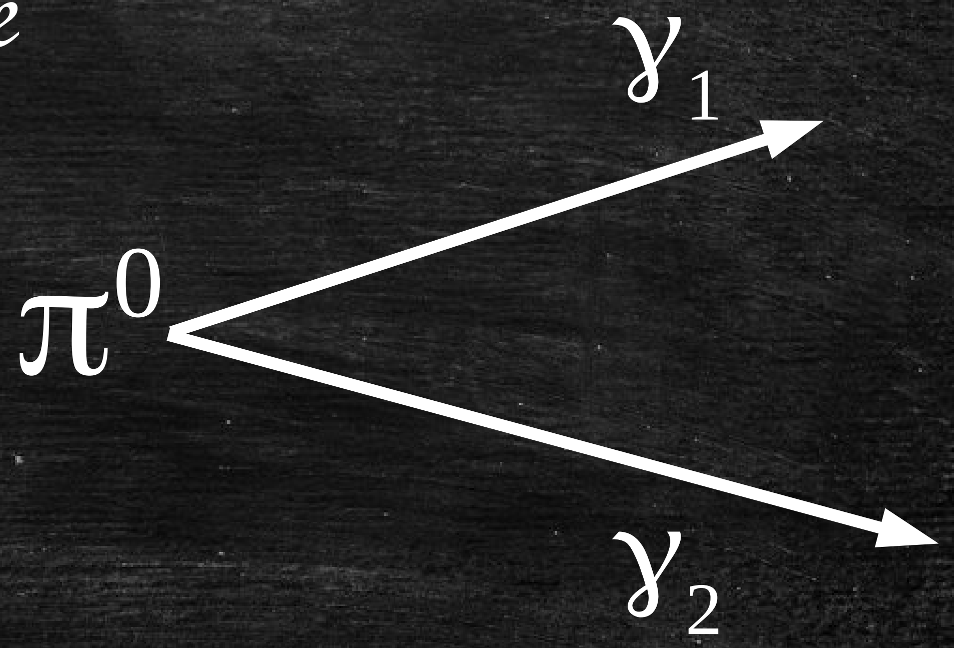
$c\tau \simeq 2.5 \times 10^{-6}$ [cm]

Question. How can we reconstruct a decaying particle ?

Experimental techniques

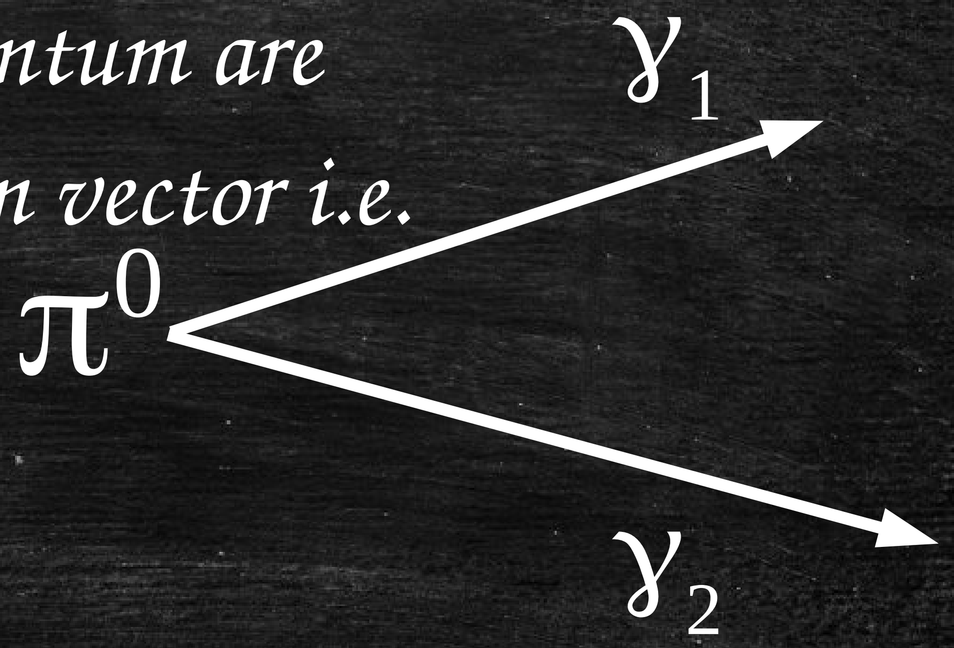
In high energy particle physics we use a "special tool" that is the theory of Special Relativity. In this theory the energy-momentum relation is given by :

$$\boldsymbol{E^2 = p^2c^2 + m_0^{\,2}c^4}$$



Experimental techniques

Typically, energy and three-momentum are unified into the energy-momentum vector i.e. four-momentum vector $\mathbf{p_\mu}$:



$$p_\mu = (E, \vec{p})$$

with a square of four-momentum vector defined as :

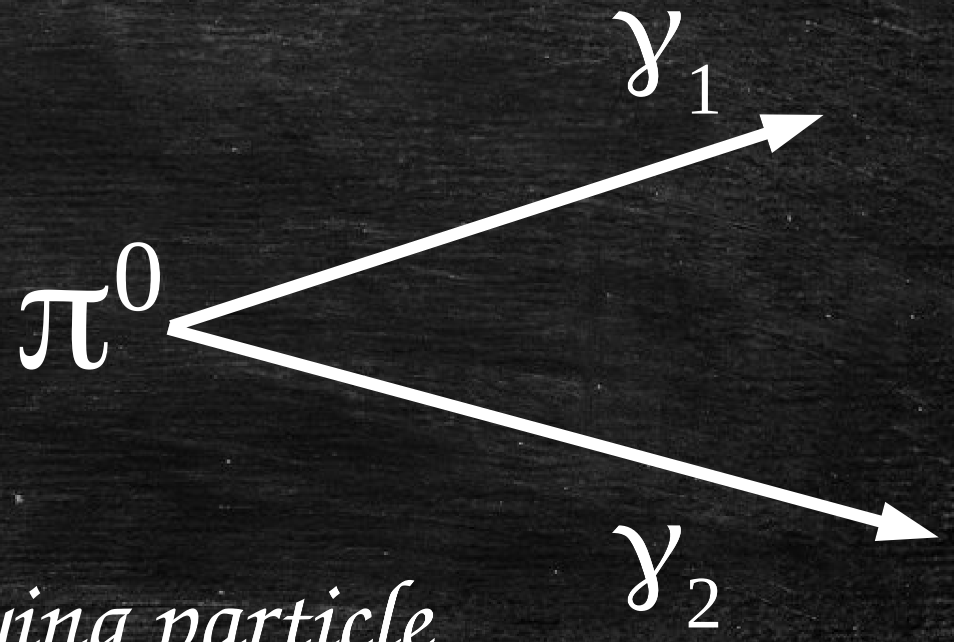
$$p_\mu p^\mu = E^2 - |\vec{p}|^2 \text{ (in a frame where } c = 1) \Rightarrow p_\mu p^\mu = m_0^2$$

Experimental techniques

Finally, we use conservation of four-momentum $\boldsymbol{p_\mu}$:

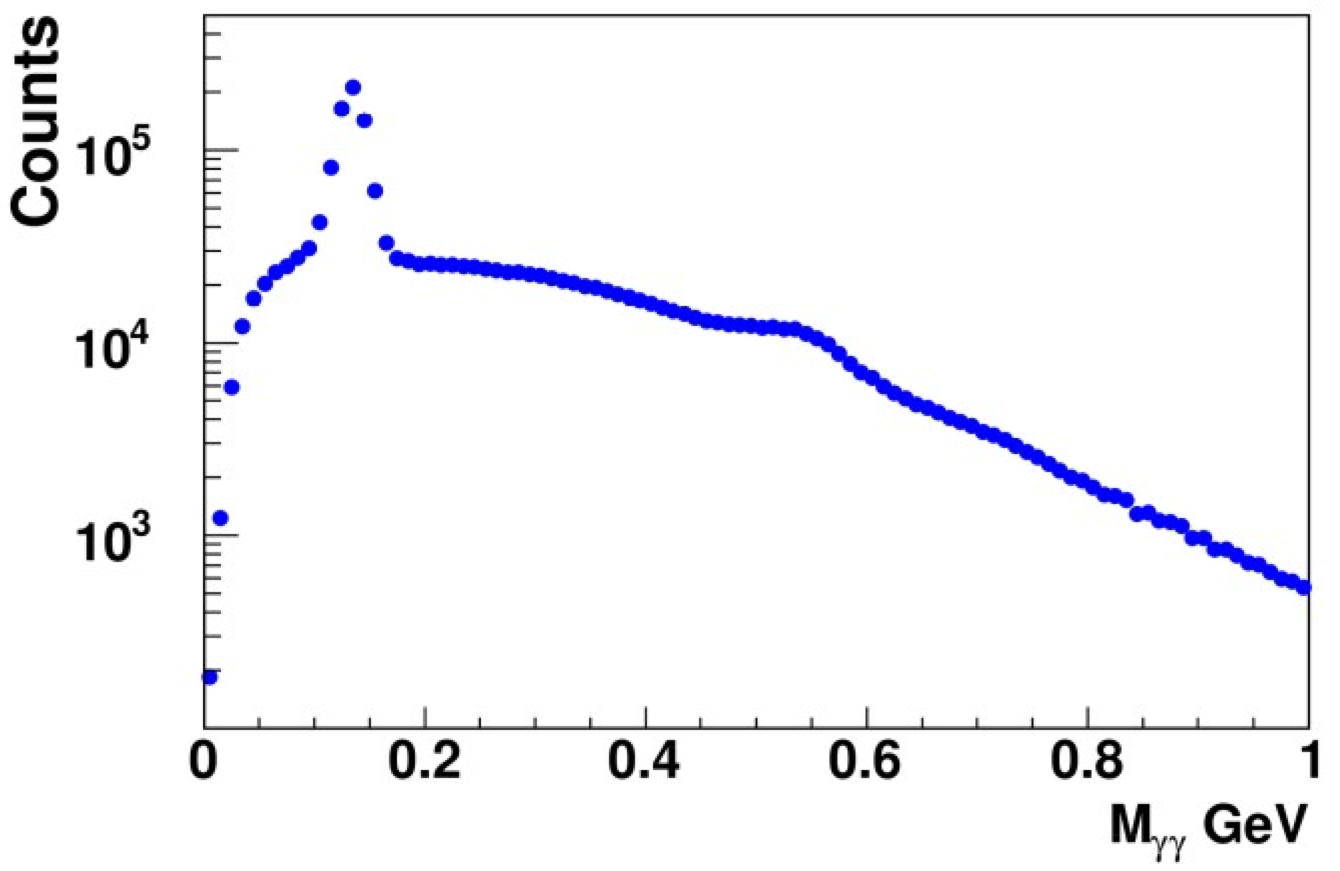
$$p_\mu^{\pi^0} = p_\mu^{\gamma_1} + p_\mu^{\gamma_2}$$

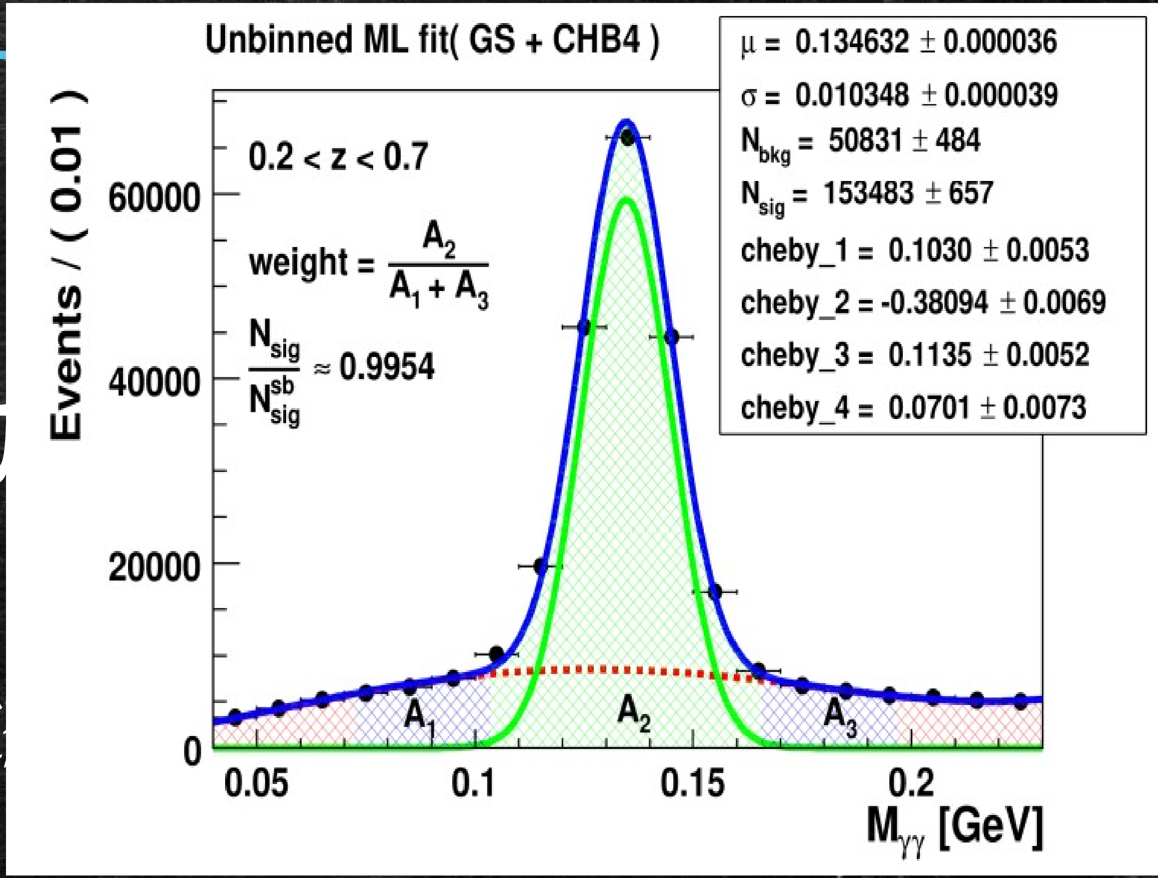
to reconstruct the mass of a decaying particle



$$M^2_{\gamma\gamma} = (\, p_\mu^{\gamma_1} + p_\mu^{\gamma_2}\,)^2 \Rightarrow \boxed{m^2_{\pi^0}}$$

Experimental techniques





$$M^2_{\gamma\gamma} = (p^{\gamma_1}_{\mu} + p^{\gamma_2}_{\mu})^2 \Rightarrow \boxed{m^2_{\pi^0}}$$

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