Introduction to Nuclear Physics

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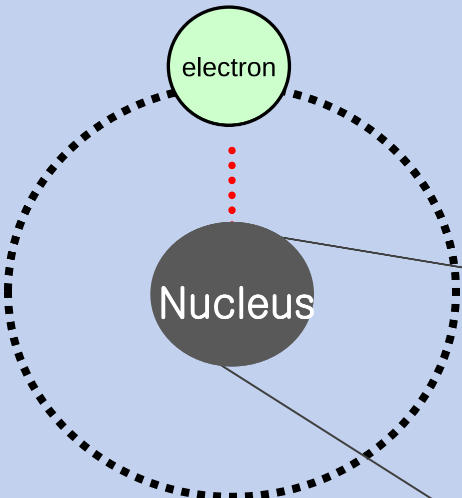
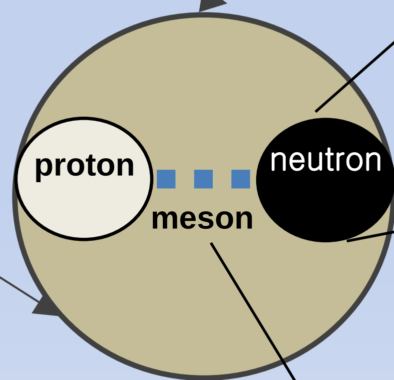
1. Some Histroy
2. Important developments
3. Current research

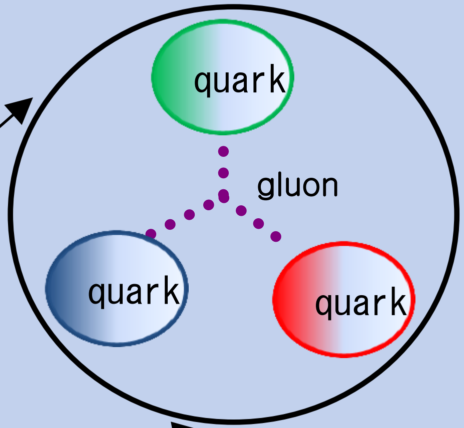


Nucleus A=Z+N

Proton number : Z

Neutron number: N





Mass of an Atom

Nucleon: 99.95 %

electron: 0.05 %

EM binding< 0.00001 %

Baryon

Proton, neutron,

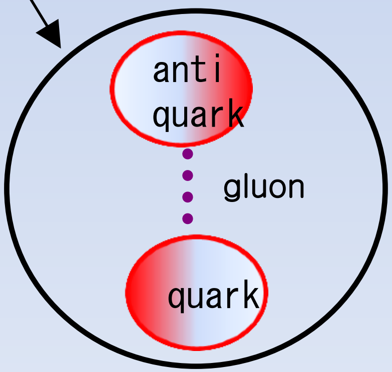
hyperons +

excited states

↓

Meson

Pion, rho, Kaon +



→ **Hadron**

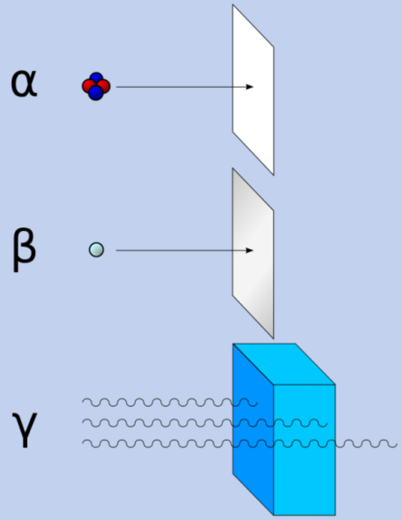
Baryon, Meson

I: Some History

☞1899-1990: E.Rutherford(1871-1937):

looked at radiation and found

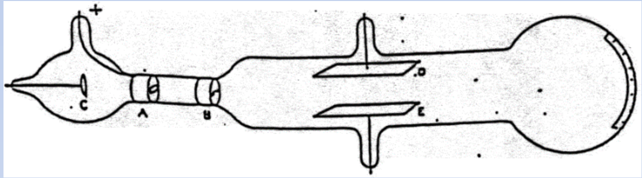
named according to their penetration length



α was identified as He ion

☞ 1897: J.J. Thomson (1856-1940, English):

looked at cathode rays and discovered electron



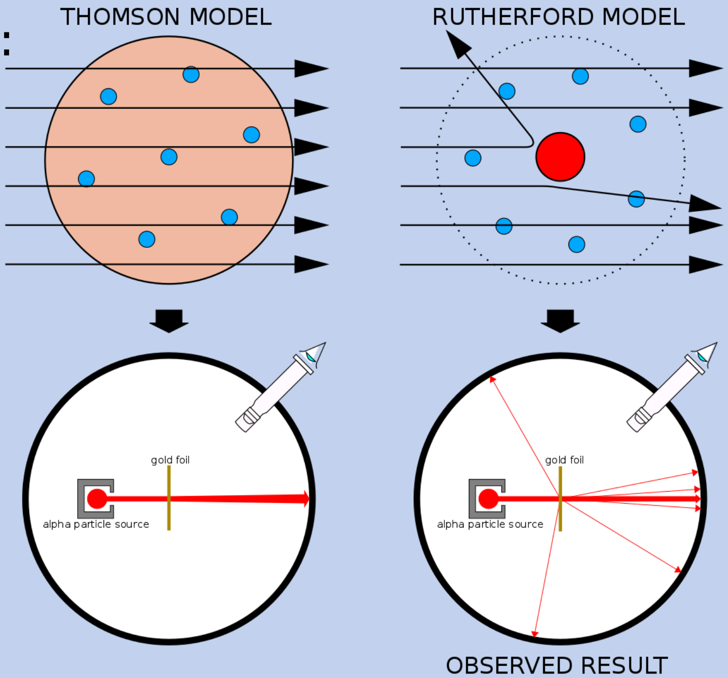
☞ 1904: Thomson proposed plum pudding model of Atom

electrons and cloud of positive charge

☞ 1911: Rutherford(McGill later Manchester):

α particle scattering on thin gold foil

→ established hard point like nucleus



☞ 1886, E. Goldstein(1850-1930) discovered hydrogen ion

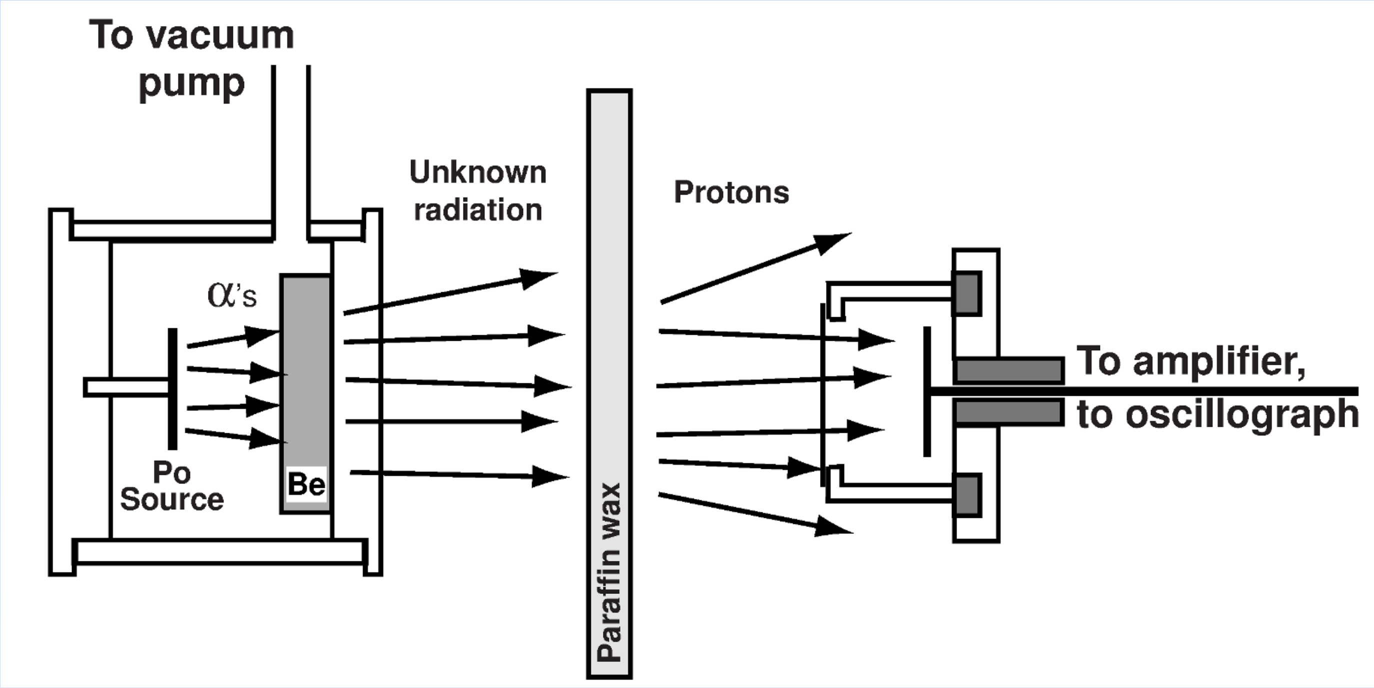
→ 1898, Wilhelm Wien(1864-1928) hydrogen ion has highest charge/mass

→ 1917 Rutherford discovered hydrogen ion in all nucleus

→ Also identified the first nuclear reaction $^{14}N + \alpha \rightarrow {}^{17}O + p$.

☞ 1920’s: physicists assumed that the atomic nucleus was composed of protons and "nuclear electrons"

☞ 1932, J. Chadwick (1891-1974 English) discovered neutron



A schematic diagram of the experiment used to discover the neutron in 1932. At left, a polonium source was used to irradiate beryllium with alpha particles, which induced an uncharged radiation. When this radiation struck paraffin wax, protons were ejected. The protons were observed using a small ionization chamber. Adapted from Chadwick (1932)

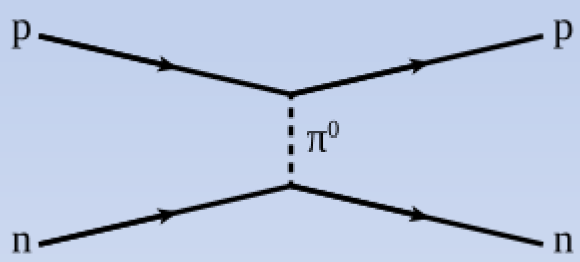
II: Important developements

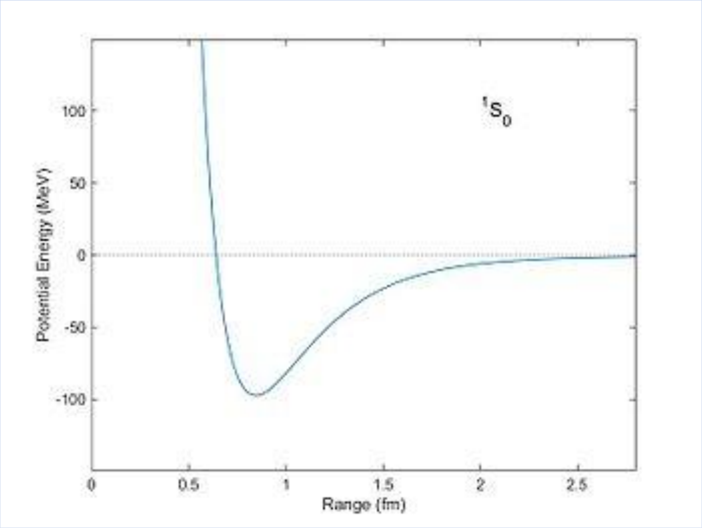
☞ 1930: Liquid drop model (George Gamow (Russia 1904-1968))

→ Explains spherical shape of nucleus and similar binding energy for all nucleons

☞ 1934: Pion exchange potential: H. Yukawa (1907-81)

→ Explains spherical shape of nucleus and similar binding energy for all nucleons





☞ 1947: Discovery of Pion: C.F. Powell (1903-1969 English)

→ Nuclear emulsion exposed on high mountains found tracks of pions

☞ Magic number and shell model

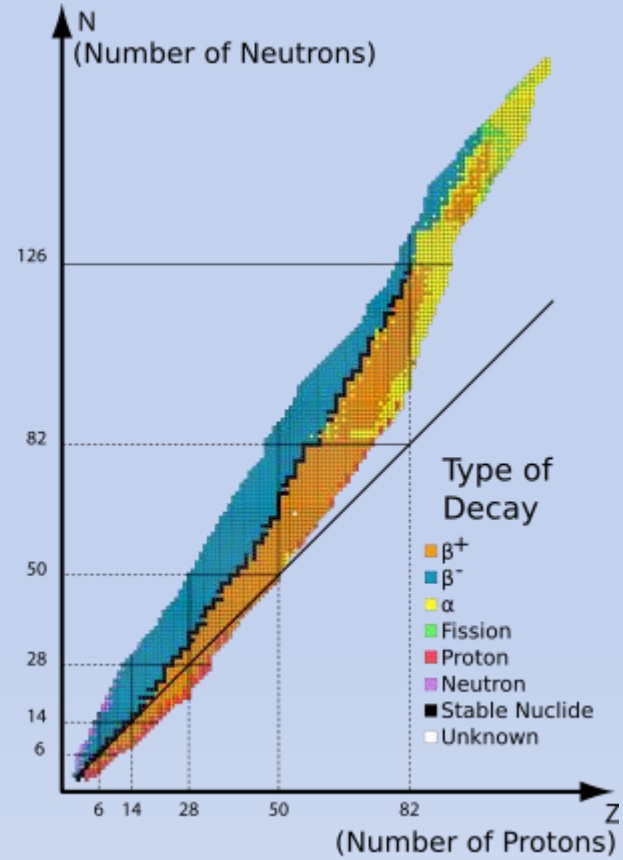
proton and/or neutron numbers are

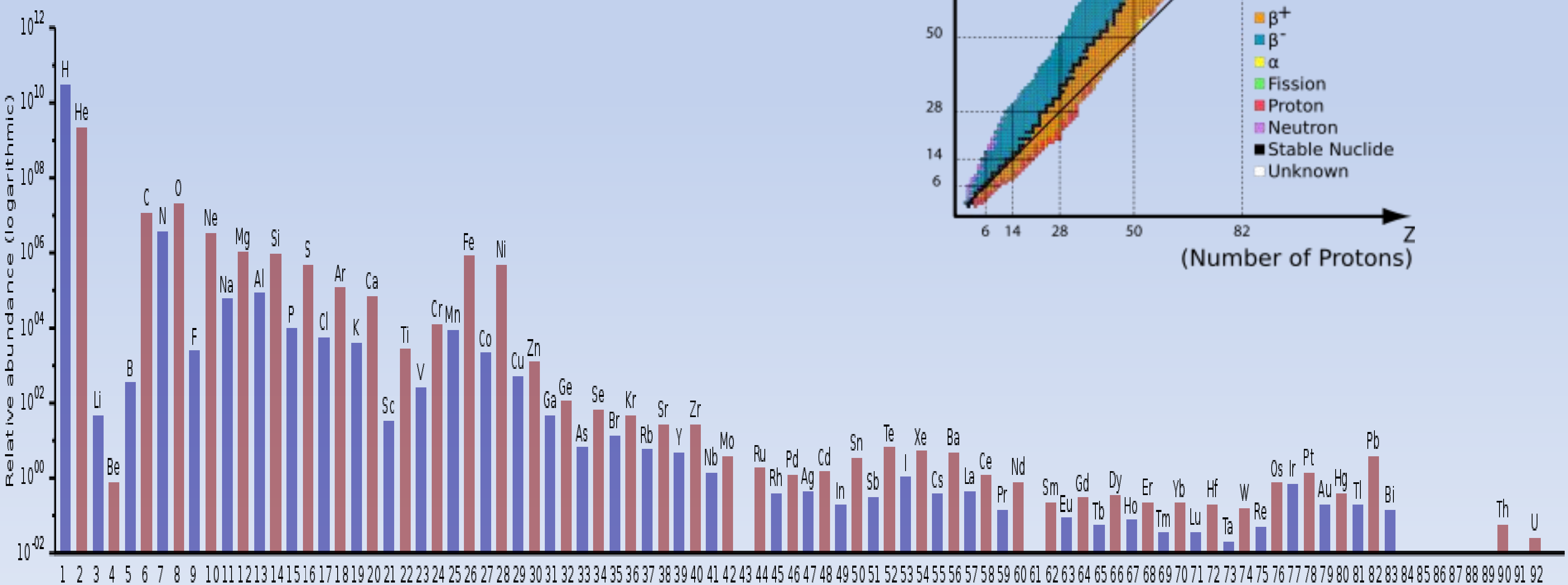
2,8,20,28,50,82,126

→ Shell model 1949

Nobel prize 1963

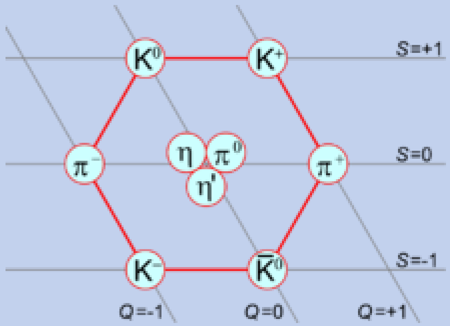
E. Wigner, M. Goeppert Mayer and H. Jensen

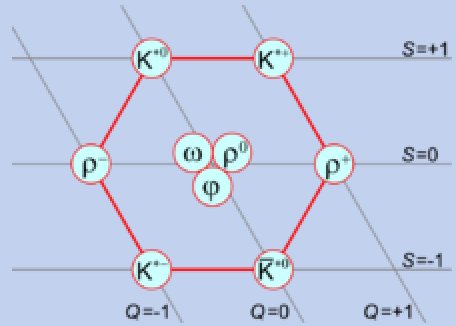


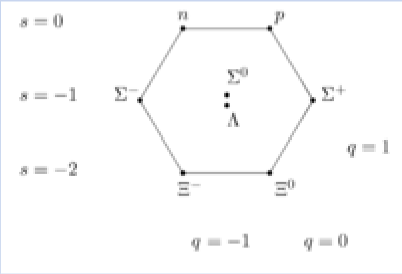


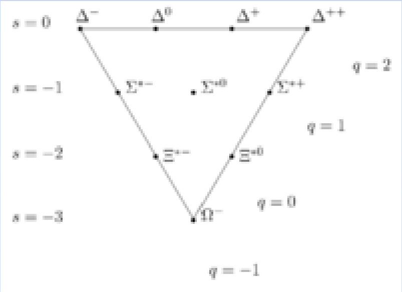
☞ Quark Model: M. Gell-Mann (1929-) G. Zweig (1937-)

→ Classification scheme for observed hadrons based on flavor SU(3)









☞ Color of quarks: Moo-Young Han (1934-2016, Korean), Y. Nambu (1921-2015)

→ Understand the Δ^{++}(spin 3 uuu quark state)

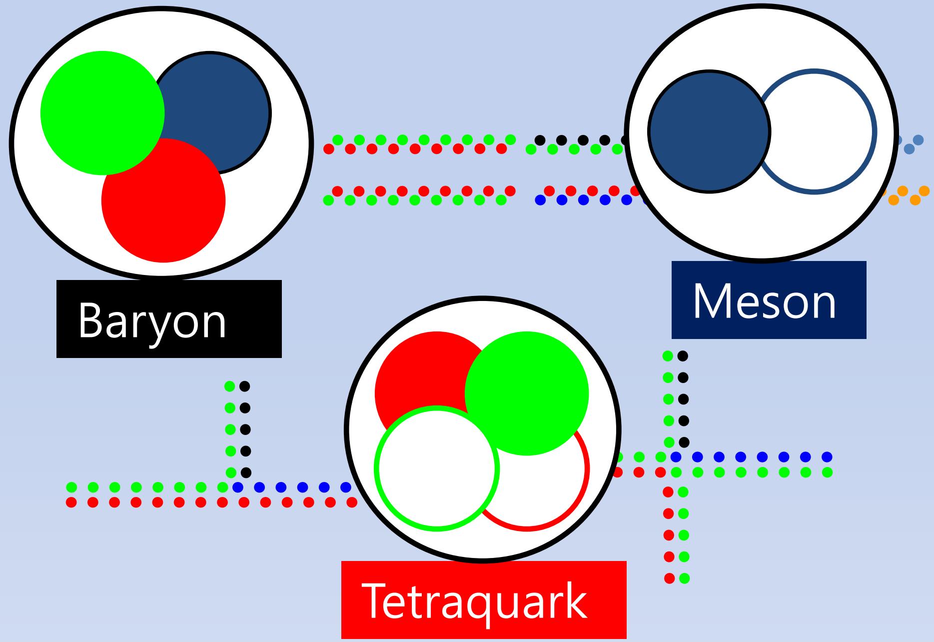
☞ Gauge theory: C.N. Yang (1922-), R. L. Mills (1927-1999)

→ Understand the Δ^{++} (spin 3 uuu quark state)

QED	vs	QCD

Charge

Boson



Boson interaction

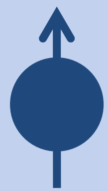
β function

$$\beta(e) = \frac{e^3}{12\pi^2}$$

$$\beta(g) = -\left(11 - \frac{2n_f}{3}\right)\frac{g^3}{16\pi^2}$$

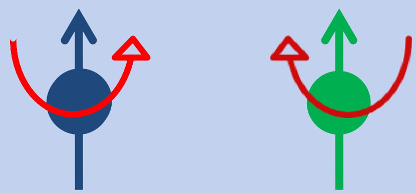
Chiral symmetry breaking for quarks

Broken phase



Vector symmetry , Massive quark

Symmetric phase

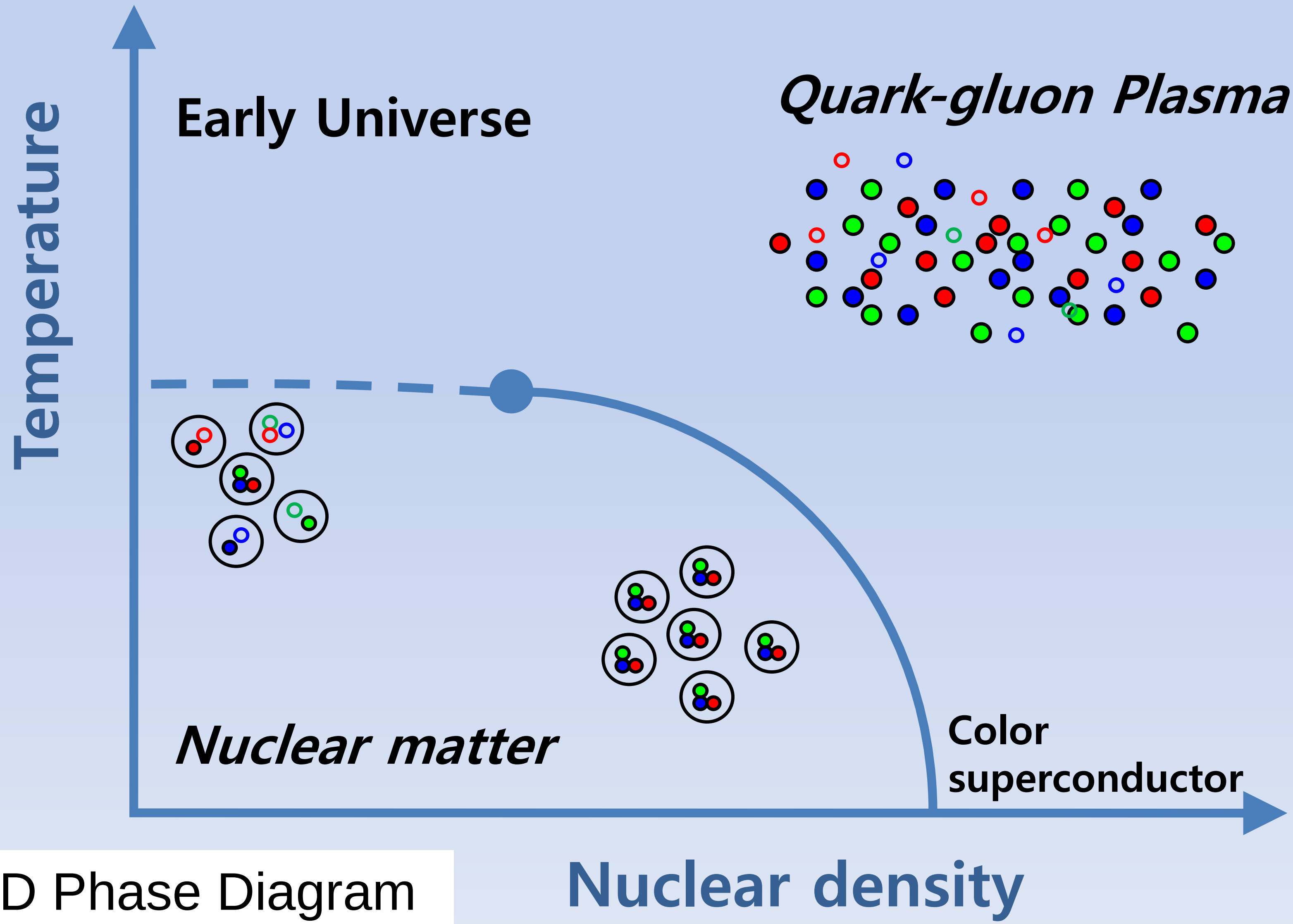


L, R symmetry, Massless quark

Spontaneous symmetry breaking: Y. Nambu (2008 NP)

NJL model → gap equation → quark mass + $\langle \bar{q} q \rangle$

Deconfinement and chiral symmetry restoration at high temperature and density

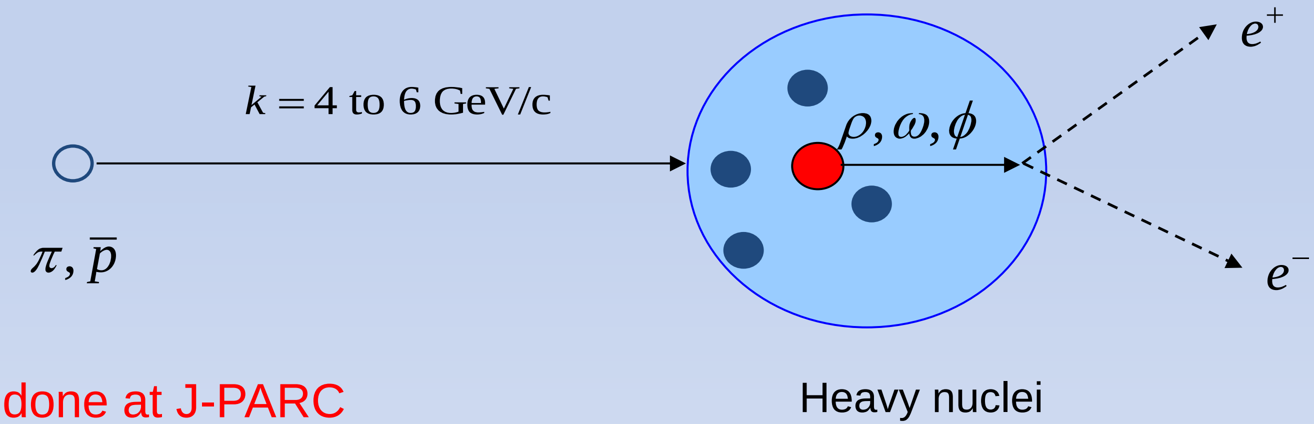


QCD Phase Diagram

Nuclear matter:

Chiral symmetry is partially restored but confinement persists

Hatsuda, Lee PRC (92)



Can be done at J-PARC

Particle production and freezeout in Heavy Ion Collision

- May be from Beam Energy Scan