Strange Particle and Strangeness enhancement as a signature of QGP

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UNIVERSITY OF JAMMU

INTERNATIONAL MASTERCLASSES
hands on particle physics

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Outline of the talk

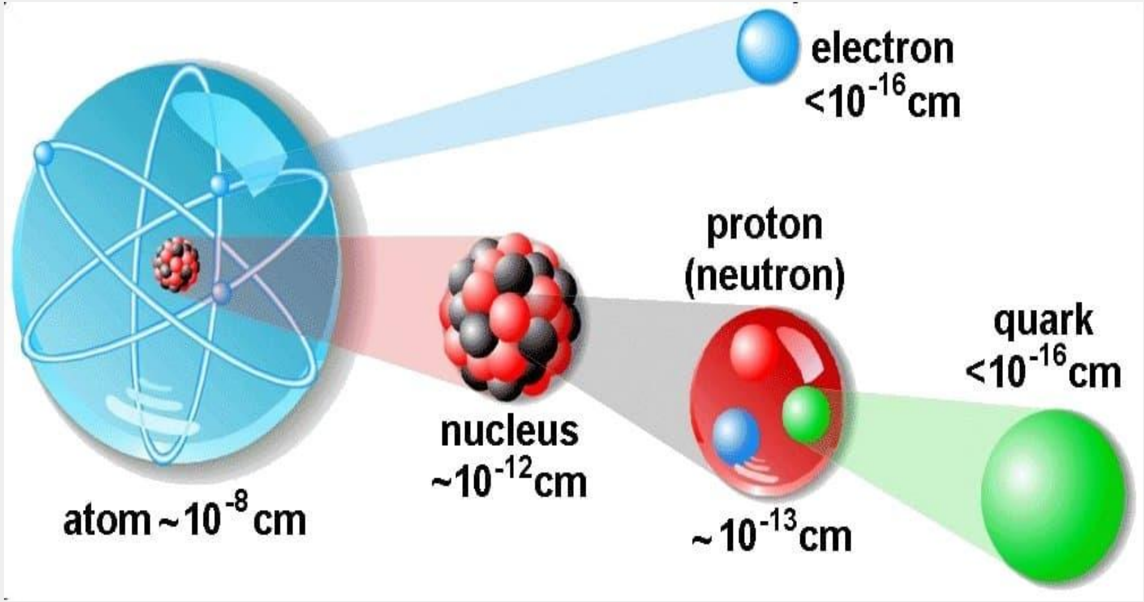
- ✔ Fundamental Particle
  - Is Atom a fundamental Particle ?
- ✔ What is a quark
  - Is Quark a free particle ?
  - QGP (Quark-Gluon Plasma)
- ✔ What is strange particle or strange quark
  - Why they are called STRANGE ?
  - V0 particle and their decay pattern
- ✔ What is Strangeness enhancement
  - Why the strange quarks get enhanced in QGP?

Fundamental Particle

Fundamental particle is a particle that is not composed of any other particle or we say which has no substructure.

Is Atom a fundamental Particle ?

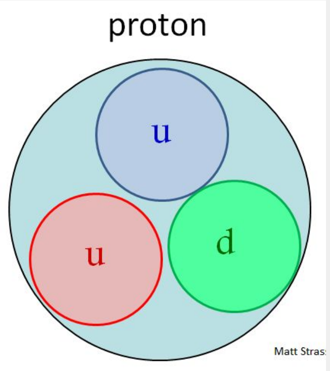
No, atom is not a fundamental particle

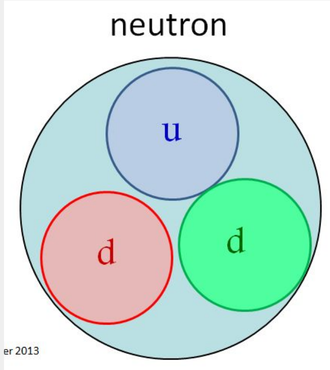


Quarks

A quark is a type of elementary particle and a fundamental constituent of matter.

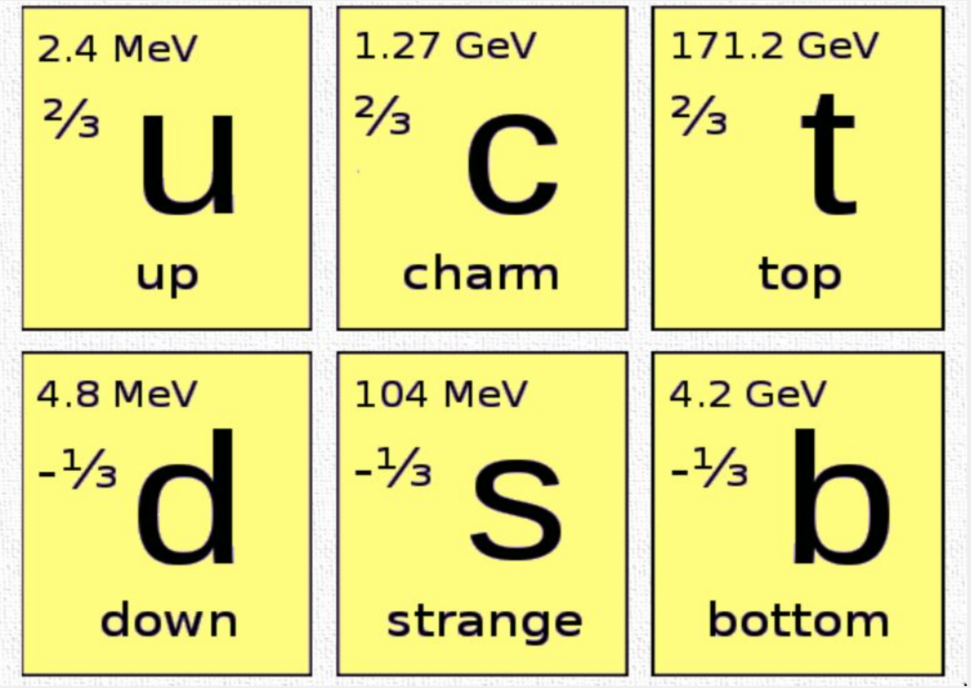
In composite particles, such as protons and neutrons Quarks seem to be bound together.





Types of Quarks

Quarks basically come in 6 Flavours.



Among all these quarks, the u and d are the most lightest quarks.
The 3rd lightest quark is the s quark.

Most of the matter we see around is made up of u & d quarks, because u & d are the most stable quarks.

Is Quark a free particle ?

No quarks can not exist free in nature. Quarks are always bound in groups to form ***hadrons***.

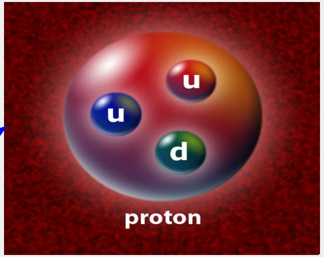
Baryons

consisting of 3 quarks or antiquarks

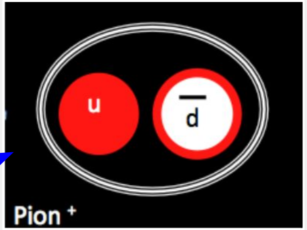
Mesons

consisting of 1 quark and 1 antiquark

Symbol	Name	Quark content
p	proton	uud
$\bar{p}$	antiproton	$\bar{u}\bar{u}\bar{d}$
n	neutron	udd
Λ	lambda	uds
Ω^-	omega	sss



Symbol	Name	Quark content
π^+	pion	$u\bar{d}$
K^-	kaon	$s\bar{u}$
ρ^+	rho	$u\bar{d}$
B^0	B-zero	$d\bar{b}$
η_c	eta-c	$c\bar{c}$

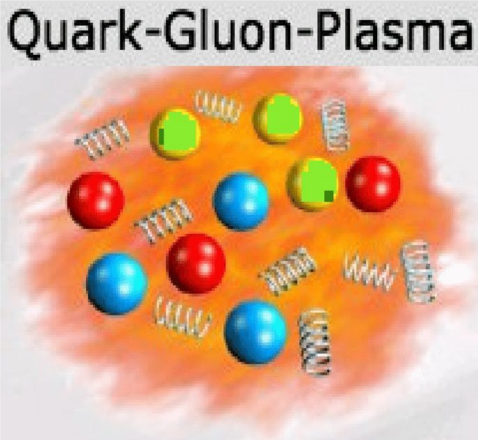


Why we are interested in QGP (Quark-Gluon Plasma) ?

➔ The QGP is a deconfined phase of matter, where all the quarks and Gluons exist freely.

➔ This is the phase which existed just a few micro-sec after the Bigbang.

Explains how the universe today we see is created ?



➔ We can create QGP experimentally in the laboratory by colliding heavy ions at very high energies.

➔ Critical Temperature ~ 200 MeV (~ 2×10^{12} k)

➔ Lifetime of QGP ~ 10^{-22} sec

Thus if we have information about this QGP phase, we can learn how the universe is created.

Strange Particle

Strange particles are hadrons containing at least one strange quark (s)

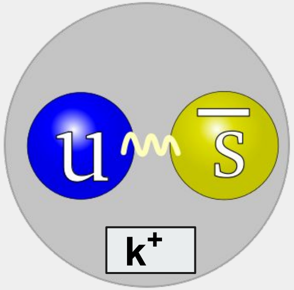
Particles containing strange quarks are :

Kaons (K^+, K^-, K^0)	Mass of K^+, K^- ~ 493 MeV
Lambda (Λ^0) ,	Mass of Λ ~ 1115 MeV
Sigma (Σ)	Mass of Σ ~ 1197 MeV
Cascade (Ξ)	Mass of Ξ ~ 1321 MeV
Omega (Ω)	Mass of Ω ~ 1672 MeV

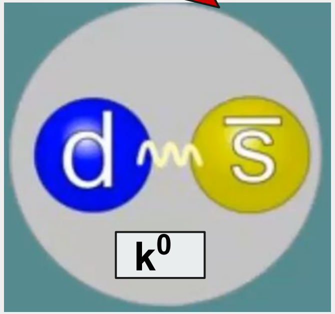
All the particles consist of one or more strange (s) quarks.

Pictorial view of the strange particles

Mesons Family

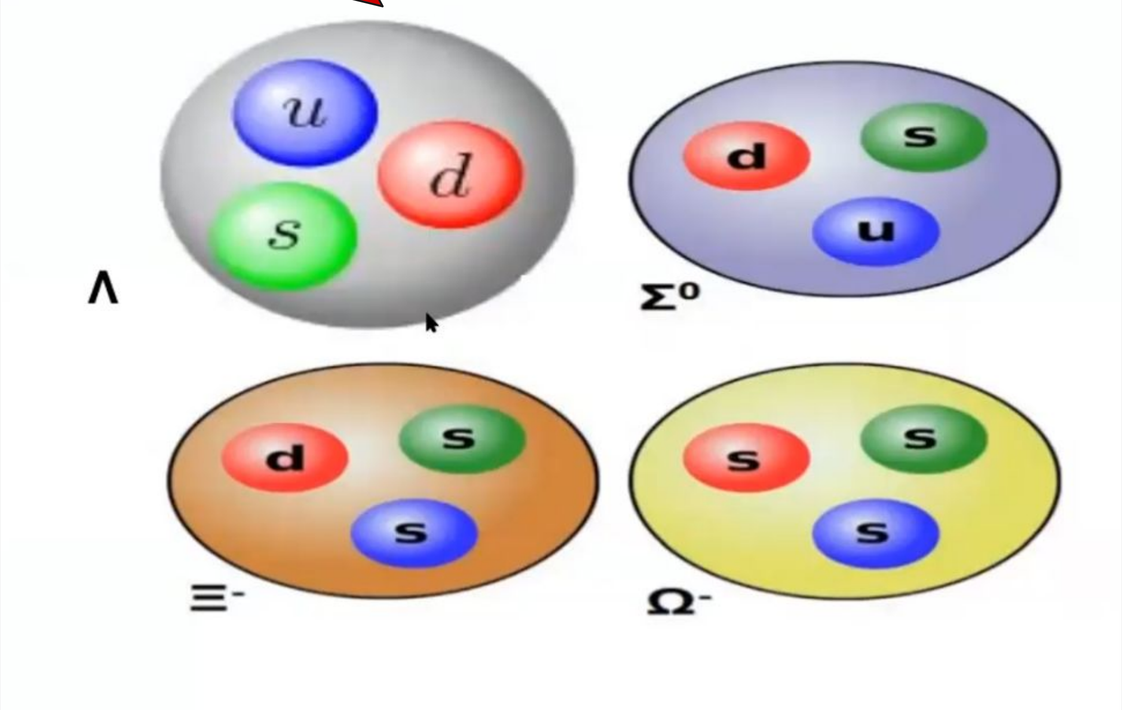


Lightest neutral strange Meson



Lightest neutral strange Baryon

Baryons Family



Why they are called STRANGE

➔ **Strange thing about the strange quark**

Strange quarks are produced via Strong Interaction (~ 10^{-24} sec) but decay via Weak Interaction (lifetime is around ~ 10^{-10} sec).

➔ Strange particles are always produced in pairs (strangeness conservation law).

➔ The Strange particles are <u>not stable</u> and thus quickly decay into lighter particles soon after their production.

➔ The search for the strange particles is thus based on the identification of their decay products, which must originate from a common secondary vertex

Neutral Strange Particles (V0 Particle)

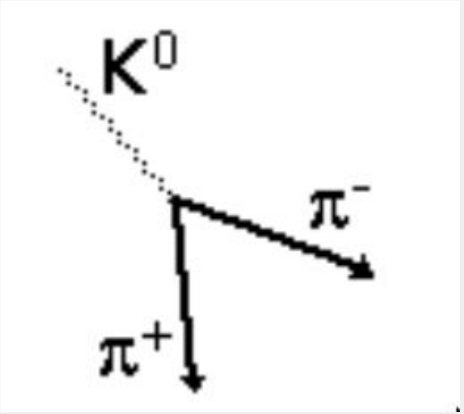
➔ **The neutral strange particles are the ones that gives a characteristic decay pattern (V shaped) and of charge 0, so they are called as V0 particles.**

Three different V0 strange particles

$K^0_s \rightarrow \pi^+\pi^-$

$\Lambda \rightarrow \pi^- p^+$

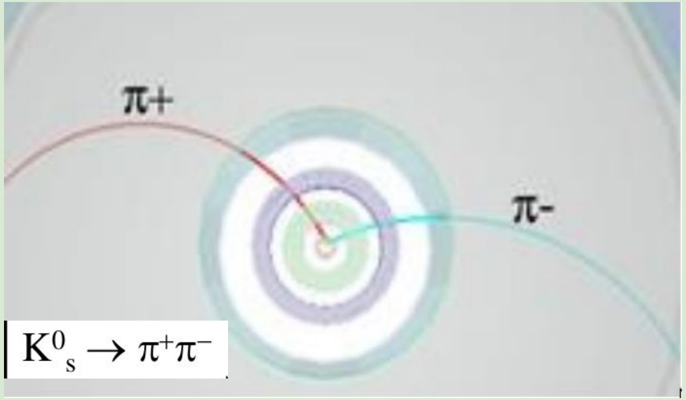
(anti) $\Lambda \longrightarrow \pi^+ P^-$

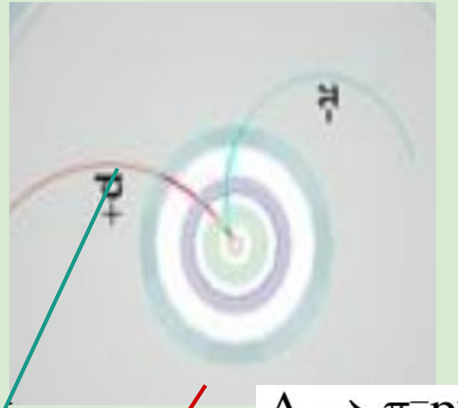


These V0 particles always decay into two oppositely charged particles. <u>(Charge conservation law)</u>

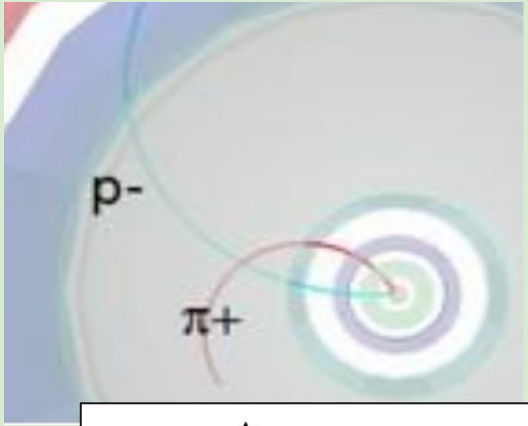
Neutral Strange Particles (V0 Particle)

The decays of V0 particles are shown in picture below:





$\Lambda \rightarrow \pi^- p^+$



(anti) $\Lambda \longrightarrow \pi^+ P^-$

P = Q.B.R

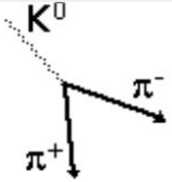
P =mv

P = momentum
Q = electric charge
B = magnetic field
R = radius of curvature

The red tracks indicated positive charge and the green tracks indicate negative charge.

How do we identify each V0?

$K^0 \rightarrow \pi^+ + \pi^-$



Calculate the (invariant) mass

Energy conservation $E = E_1 + E_2$

Momentum conservation $\mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2$

Total energy $E^2 = p^2c^2 + m^2c^4$

c=1 $E^2 = p^2 + m^2$

$E = E_1 + E_2$ $E_1^2 = p_1^2 + m_1^2$ $E_2^2 = p_2^2 + m_2^2$

$E^2 = p^2 + m^2$ $m^2 = E^2 - p^2 = (E_1+E_2)^2 - (p_1+p_2)^2 = m_1^2 + m_2^2 + 2E_1E_2 - 2\,\mathbf{p}_1 . \mathbf{p}_2$

Calculate the mass of the initial particle from the values of the mass and the momentum of the final particles

Particle Identification (done by a number of PID detectors) ⟹ m_1 m_2

Radius of curvature of the particle tracks due to magnetic field ⟹ p_1 p_2

Why strangeness is important in QGP ?

To find a direct evidence of QGP phase transition in heavy-ion collisions is quite difficult. But there are some indirect evidences which we call as the signatures of QGP formation.

The Strangeness production in heavy ion collisions is one of the signature of quark–gluon plasma (QGP) formation.

The production of strange quark in a QGP is believed to be enhanced (Increased) as compare to that of a normal hadronic matter.

Strangeness enhancement in QGP

Why strange quarks production gets enhanced (increased) in QGP

The Temp. (~200 M eV) for QGP is comparable to 2 mass of the strange quarks (~ 2 * 104 MeV).

After the u and the d quark, the next lightest quark is the s quarks

Also the gluon-gluon fusion channel dominates in strange quarks production inside QGP

Strangeness enhancement in QGP

Why strange quarks production gets enhanced in QGP

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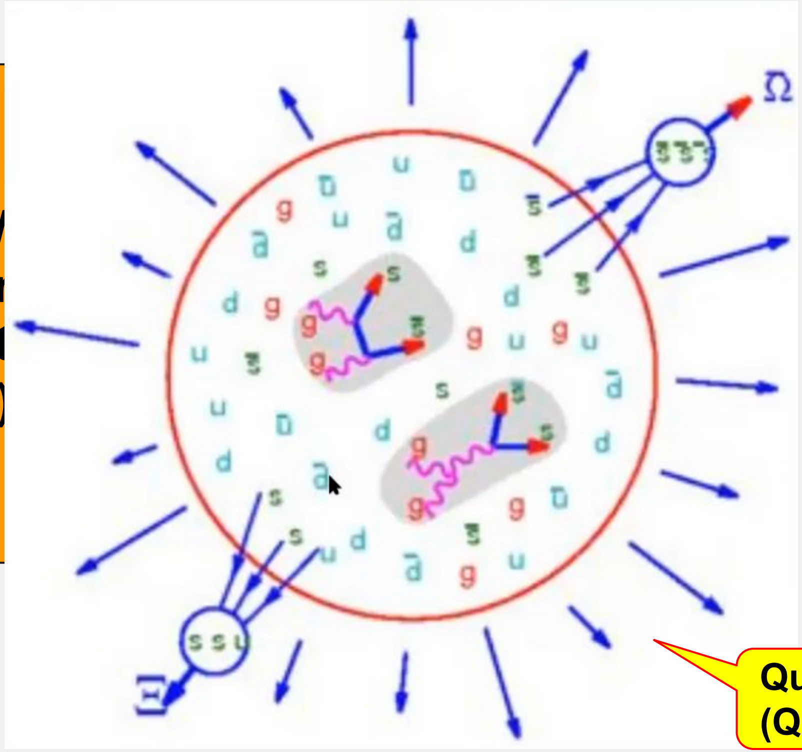

Also the gluon-gluon fusion channel dominates in strange quarks production inside QGP

Quark Gluon Plasma (QGP)

Thank You