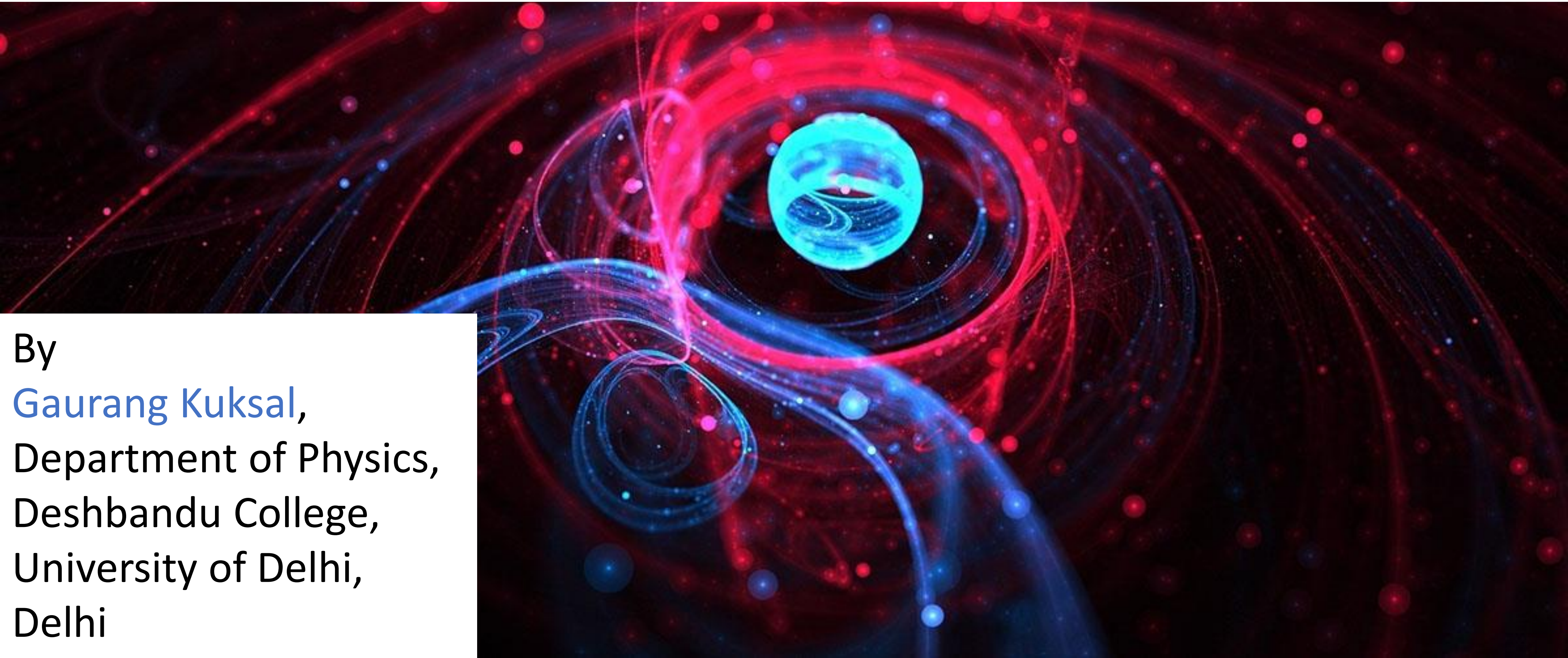
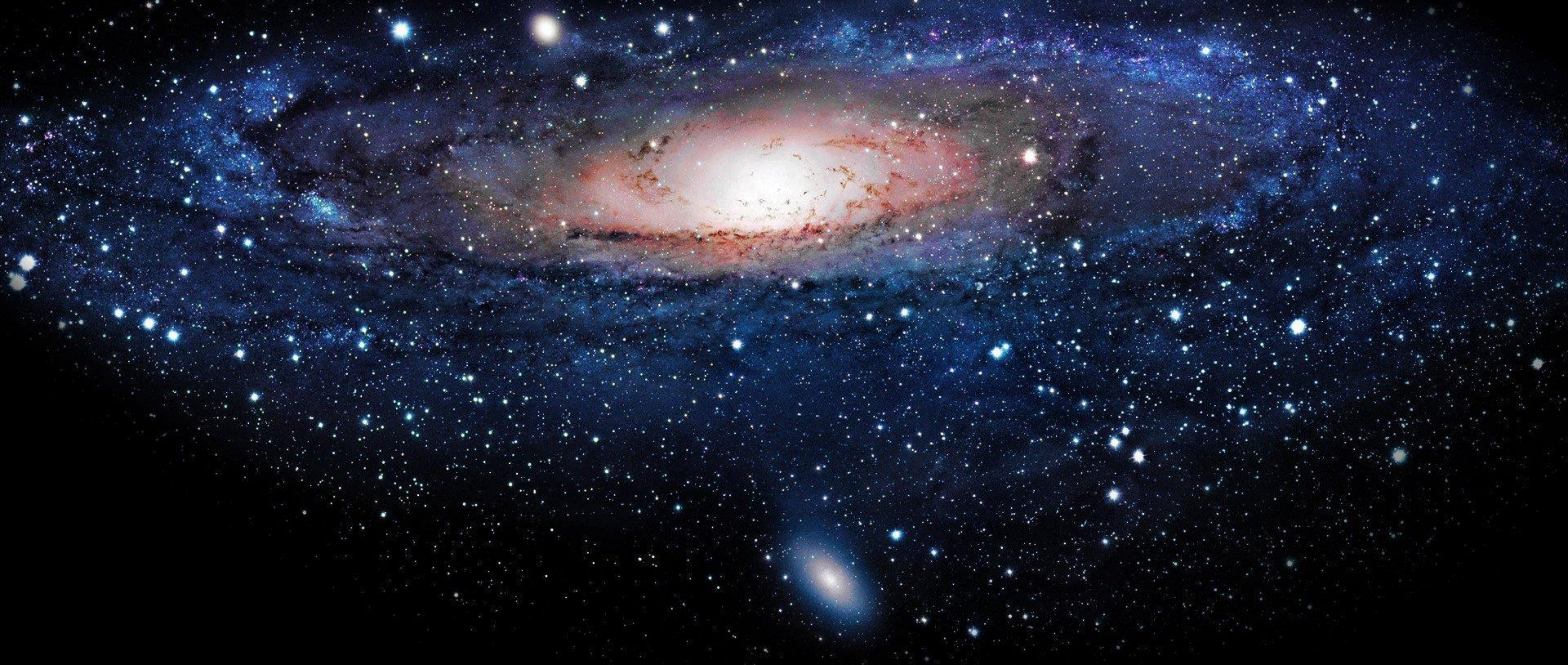
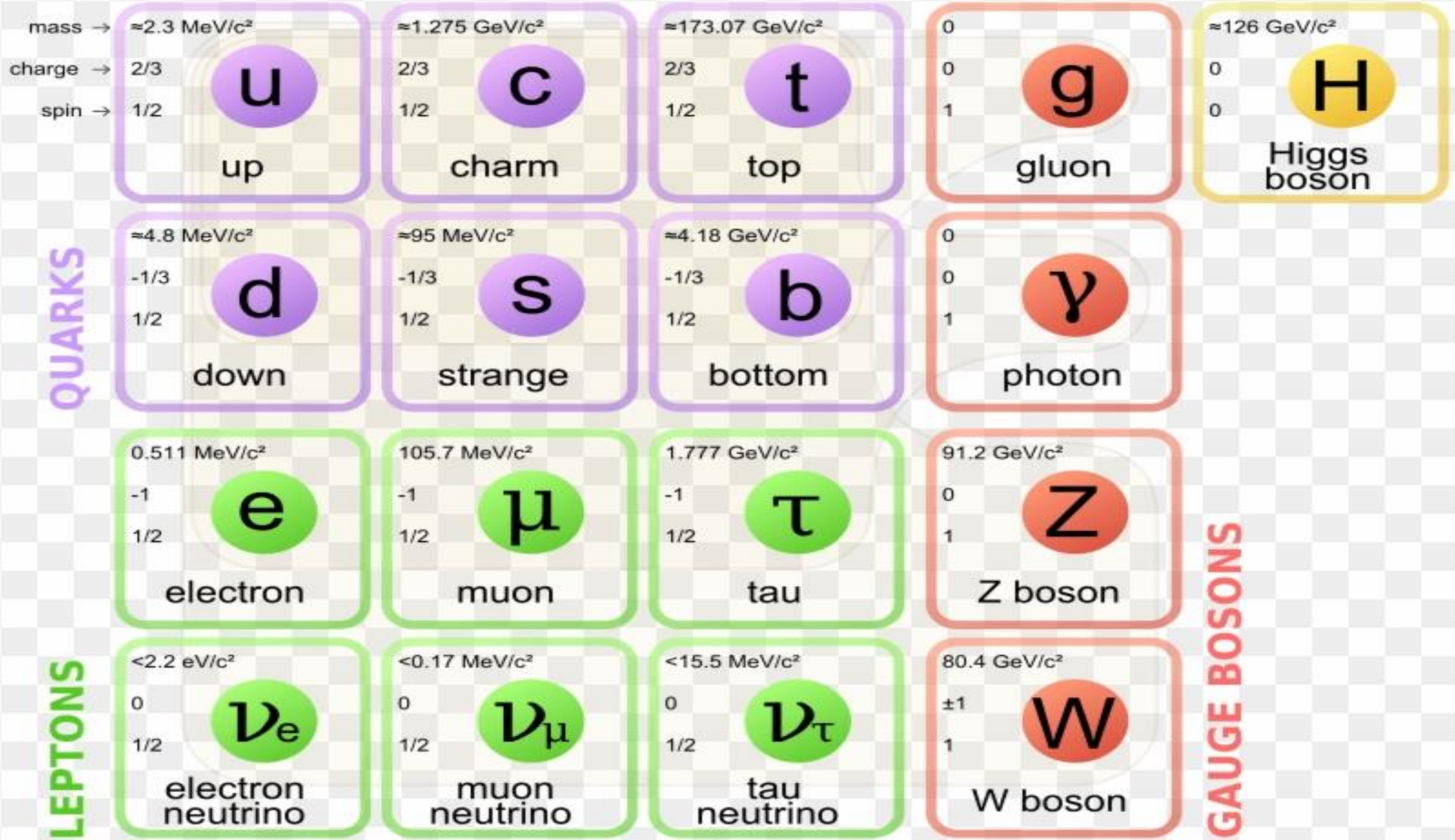
EMISSION OF TWO GAMMA RAY PHOTON FROM QUARK-GLUON PLASMA WITH CHEMICAL POTENTIAL

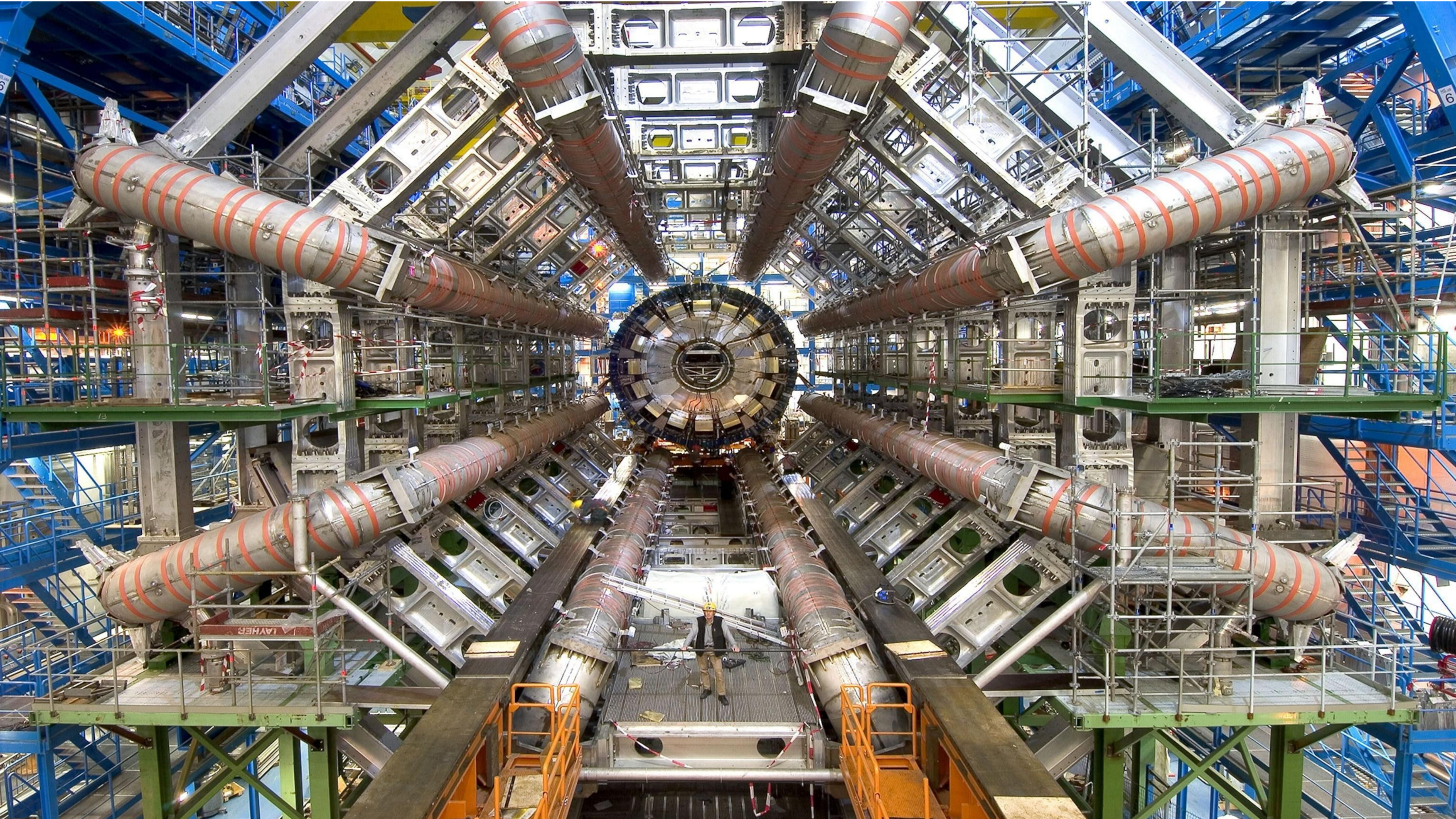


By
Gaurang Kuksal,
Department of Physics,
Deshbandu College,
University of Delhi,
Delhi

INRODUCTION



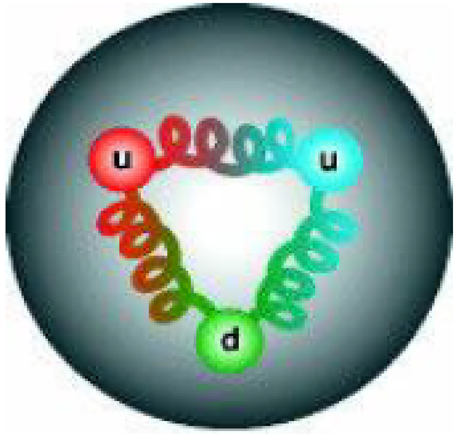

mass →
charge →
spin →
≈2.3 MeV/c²
2/3
1/2
u
up
≈1.275 GeV/c²
2/3
1/2
c
charm
≈173.07 GeV/c²
2/3
1/2
t
top
0
0
1
g
gluon
≈126 GeV/c²
0
0
H
Higgs boson
≈4.8 MeV/c²
-1/3
1/2
d
down
≈95 MeV/c²
-1/3
1/2
s
strange
≈4.18 GeV/c²
-1/3
1/2
b
bottom
0
0
1
γ
photon
0.511 MeV/c²
-1
1/2
e
electron
105.7 MeV/c²
-1
1/2
μ
muon
1.777 GeV/c²
-1
1/2
τ
tau
91.2 GeV/c²
0
1
Z
Z boson
<2.2 eV/c²
0
1/2
νe
electron neutrino
<0.17 MeV/c²
0
1/2
νμ
muon neutrino
<15.5 MeV/c²
0
1/2
ντ
tau neutrino
80.4 GeV/c²
±1
1
W
W boson
QUARKS
LEPTONS
GAUGE BOSONS

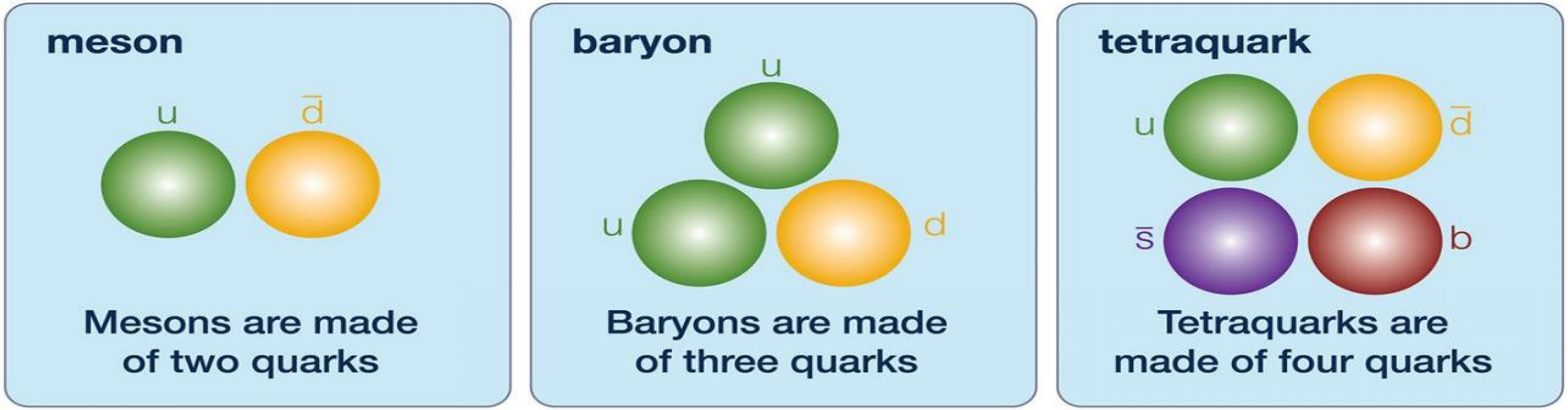


What is Quark-Gluon Plasma?

At room temperature, quarks and gluons are always confined inside colorless objects (hadrons):

protons, neutrons, pions, ...



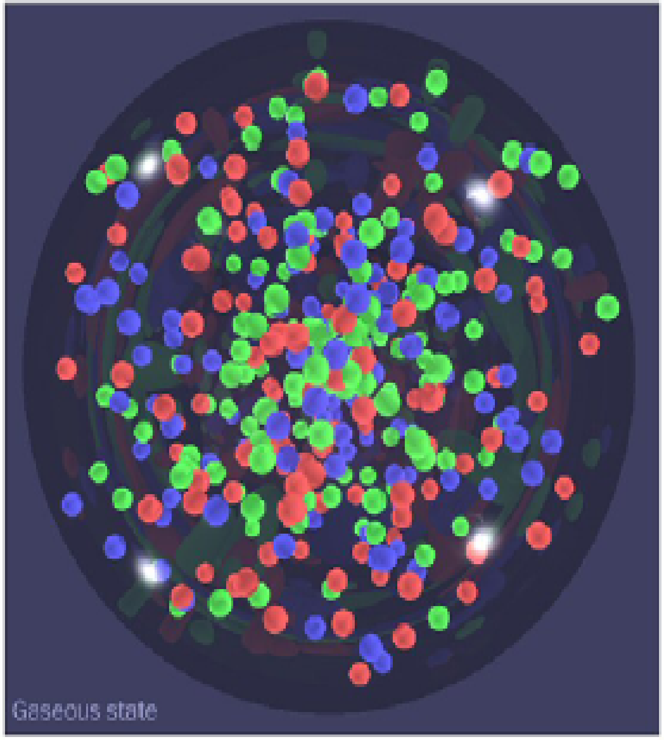


Very high temperature (asymptotic freedom):

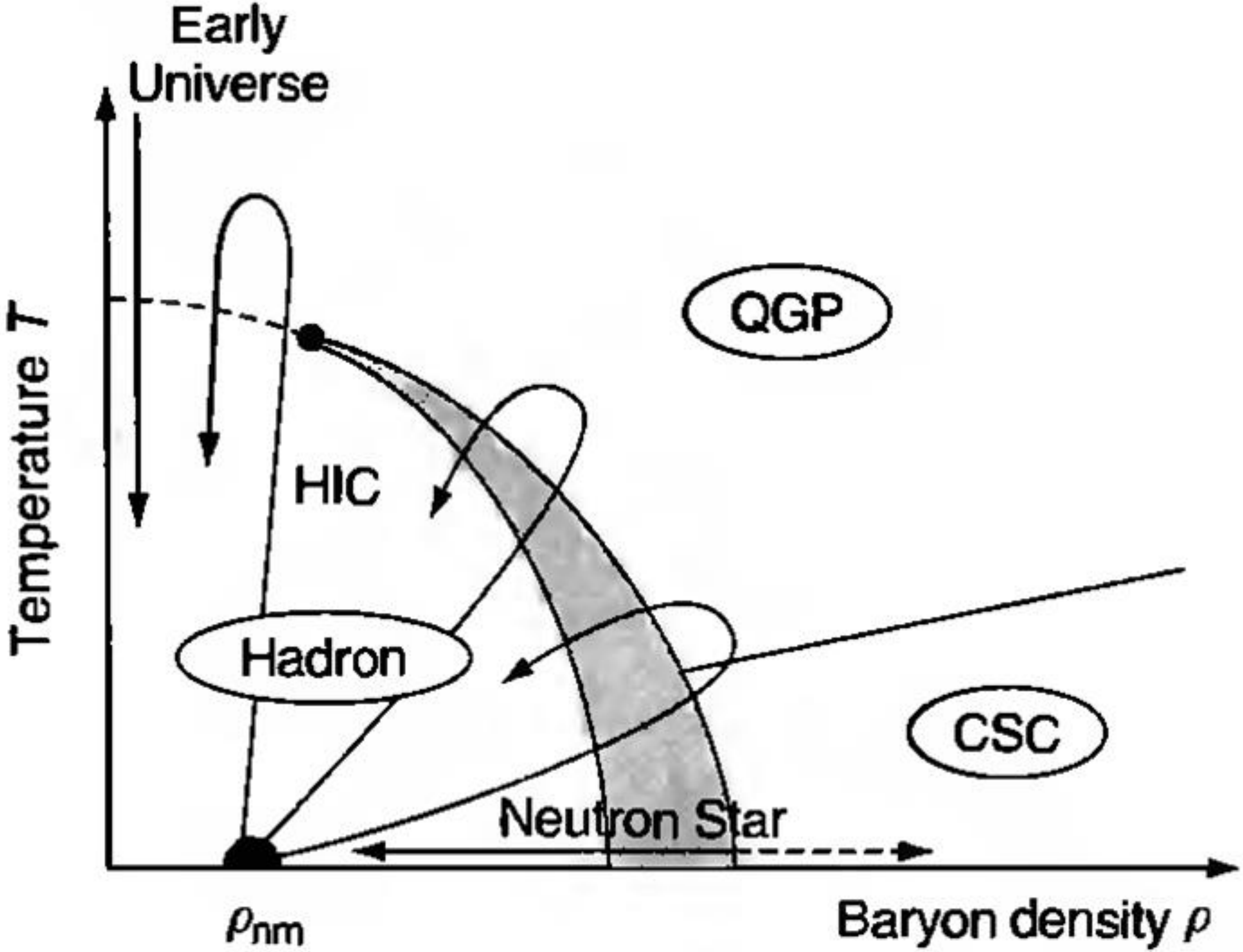
→ Interactions become weak

→ quarks and gluons deconfined

→ Quark-gluon plasma (QGP)

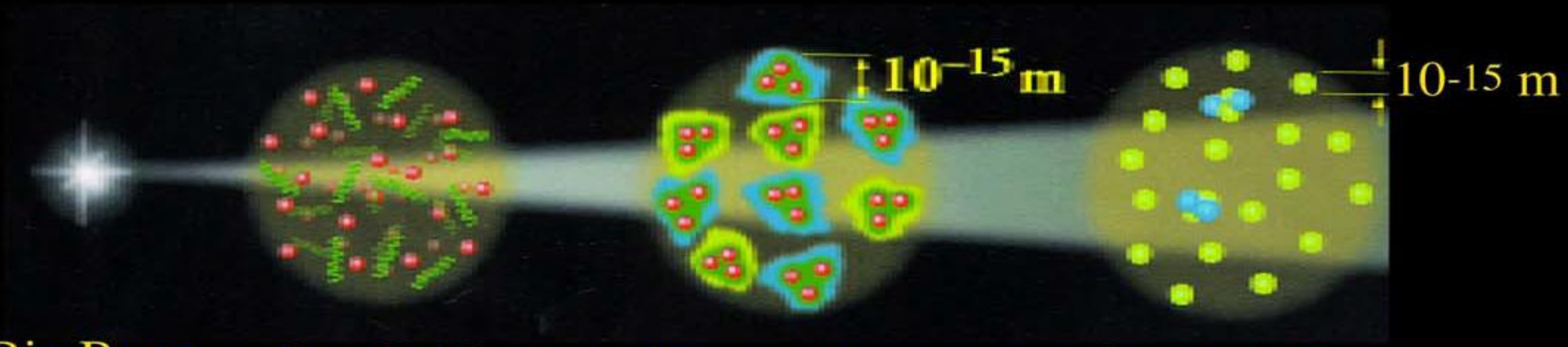


Infinitely high temperature:
QGP may behave like an ideal gas.


Early
Universe
Temperature T
QGP
HIC
Hadron
CSC
Neutron Star
ρ_{nm}
Baryon density ρ

QGP and the Universe

History of the Universe

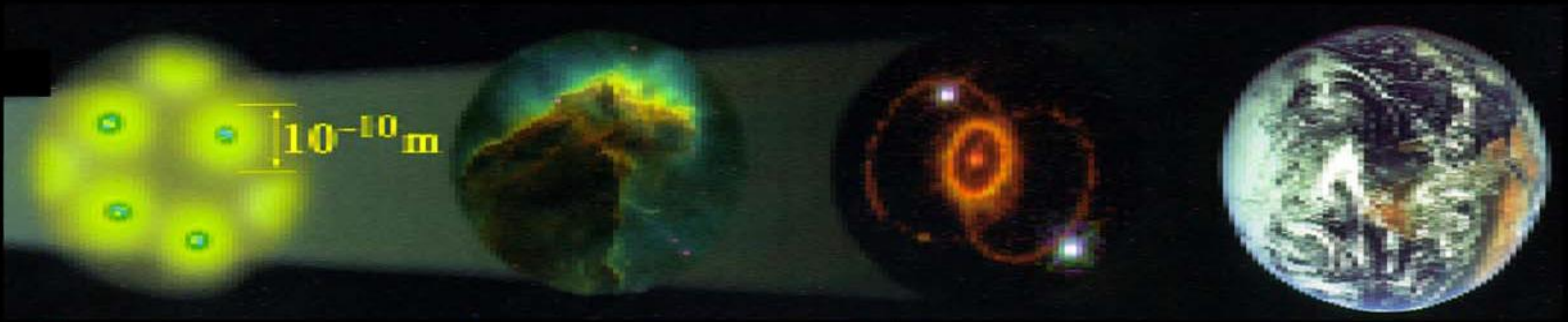


Big Bang

Quark-Gluon Plasma
10^{13}K, 10^{-6}s

Protons& Neutrons
10^{12}K, 10^{-4}s

Low-mass Nuclei
10^{9}K, 3 min



Neutral Atoms
4000K, 10^{5}y

Star Formation
10^{9}y

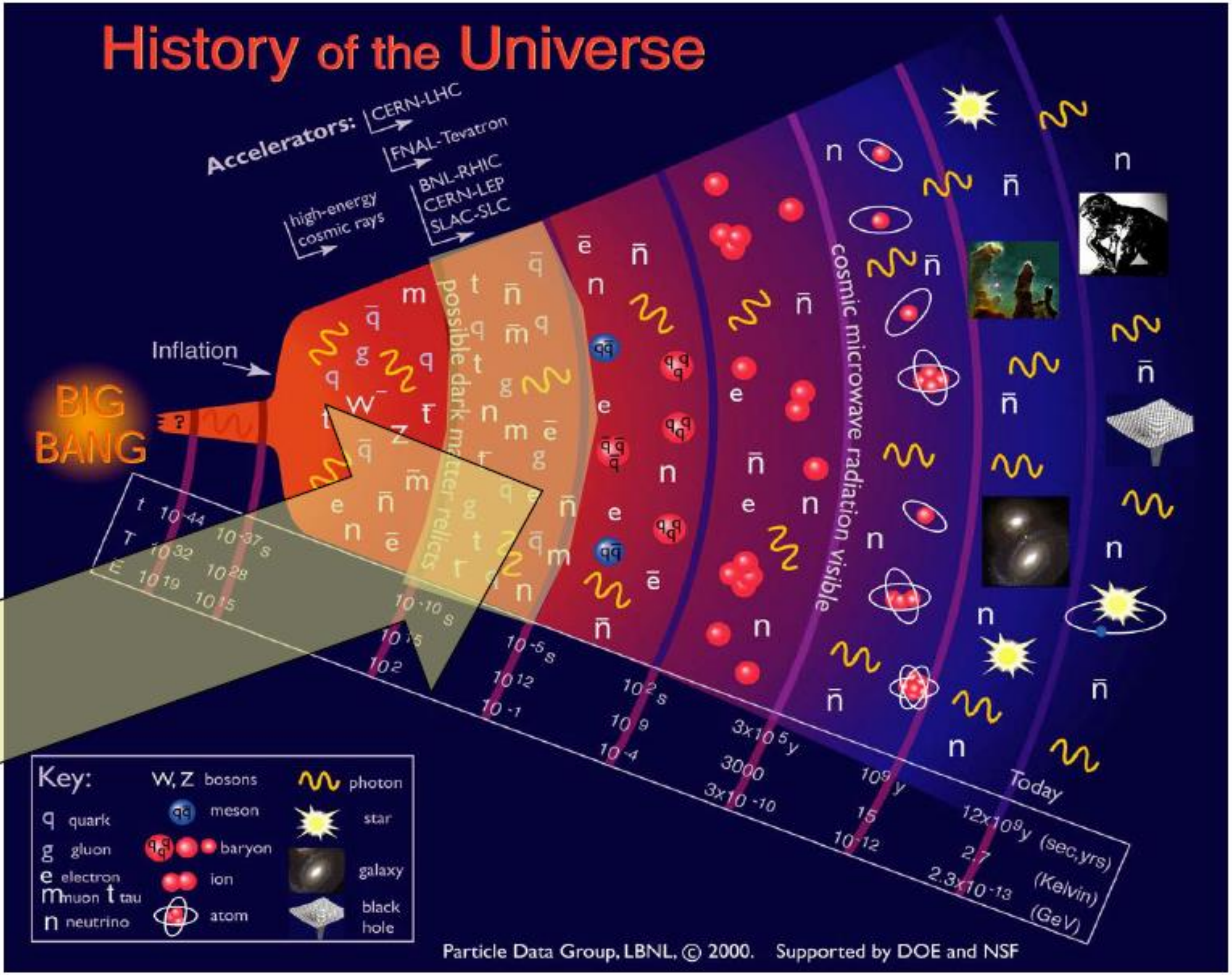
Heavy Elements
>10^{9}y

Today

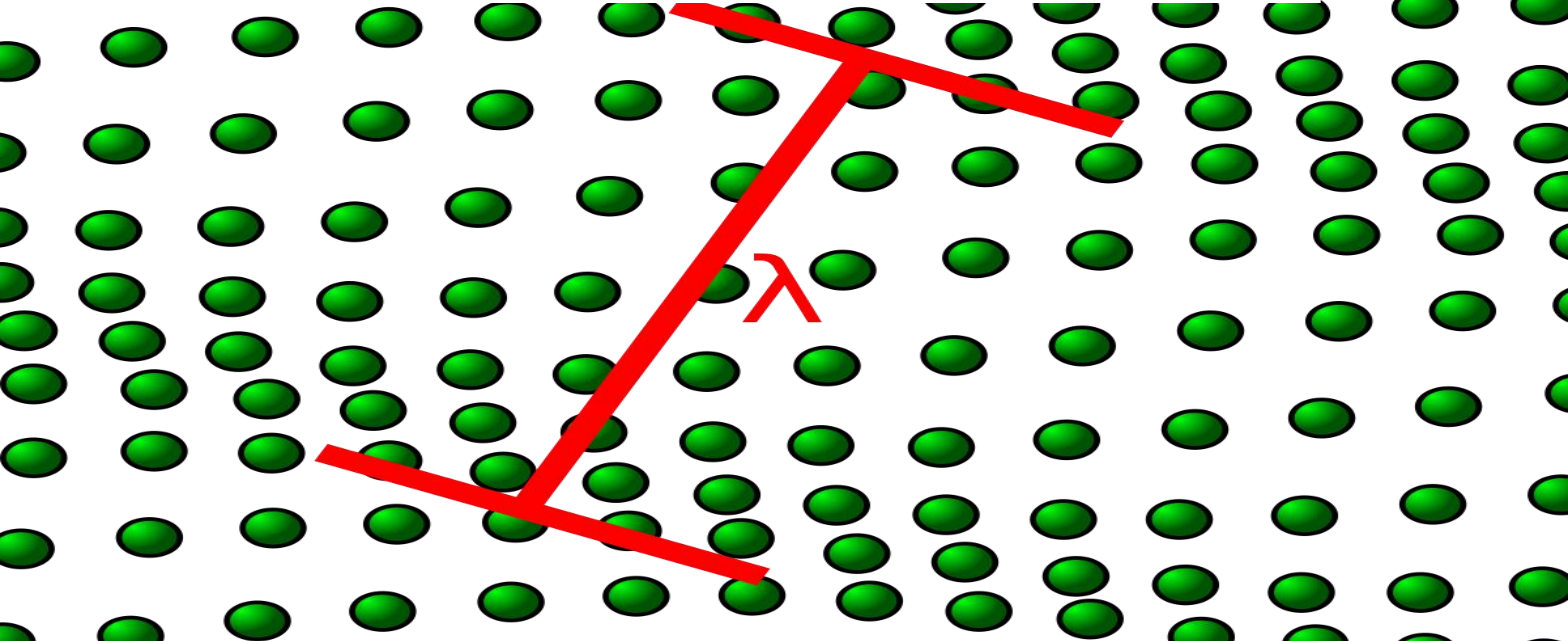
Source: Nuclear Science Wall Chart

- **Energy density**
  - **1 GeV/fm^3 →**
    - **1.8x10^{15}g/cm^3**
- **Temperature**
  - **170 MeV →**
    - **2.0x10^{12} K**

Conditions that prevailed ≈ 10 μs after the Big Bang



Quasi-particle model



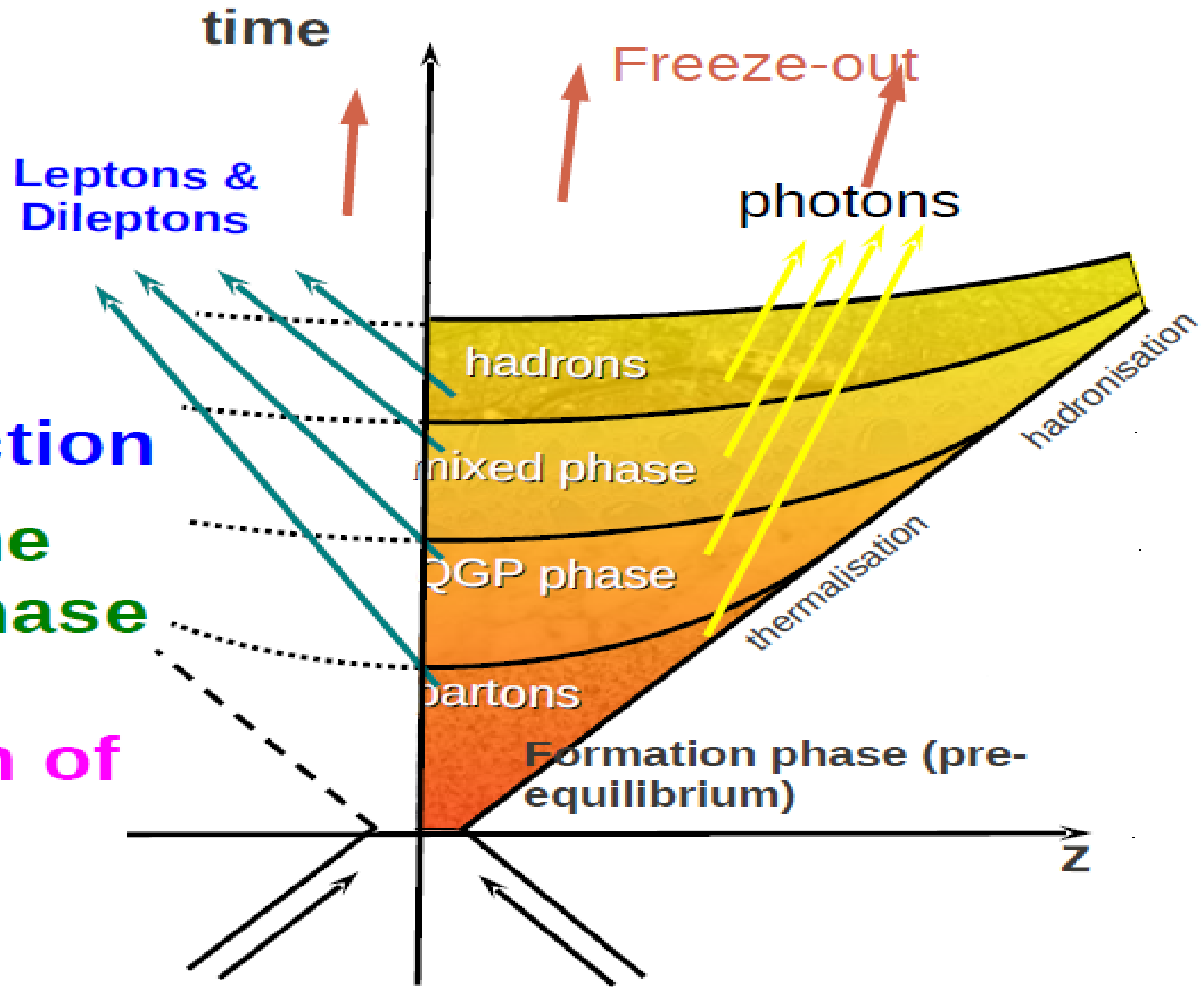
Proposed by Golviznin and Satz and then by Peshier et. al. , V.M.Bannur, Agotiya, Chandra to explain the EOS of QGP (Quasiparticles are ubiquitous in finite-temperature calculations H A Weldon).

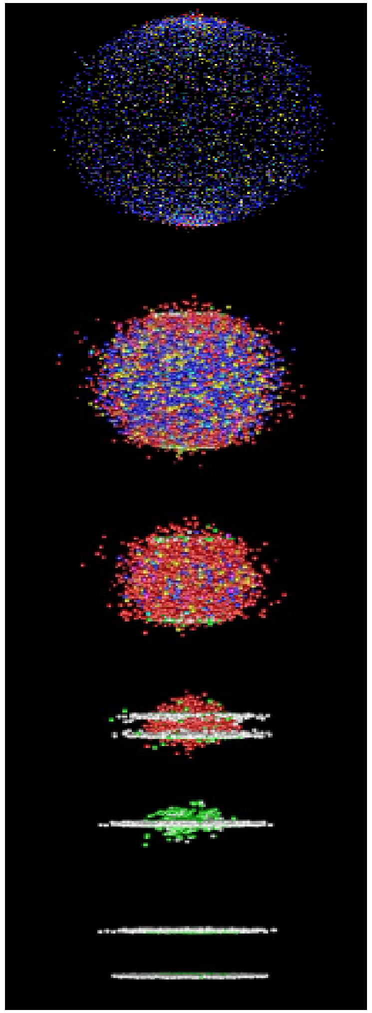
- Quarks and gluons in QGP are not bare quarks and gluons, but they are quasi-particles.
- Quasiparticles are the thermal excitations of the interacting quarks and gluons.
- Due to collective behaviour in QGP, massless partons acquire masses equal to their respective plasma frequencies and become quasi-partons.
- QGP is made up of non-interacting quasi-partons.

OUR WORK

Electromagnetic radiations

- Why studying electromagnetic radiations ?
- Electromagnetic probes do not interact strongly
- Suffer little or no final state interaction
- Give access to the hot and dense phase of the reaction
- Carry information of the system at the time of their production





Direct photons

Photons in the QGP-phase are mainly produced via the following processes:

$$q + \bar{q} \rightarrow \gamma + g$$

Annihilation + Compton effect

$$g + q \rightarrow \gamma + q$$

$$q + \bar{q} \rightarrow \gamma + \gamma$$

Mainly produced in QGP state

We have to deal with background problems because of hadronic decays into photons, especially by

$$\pi^0 \rightarrow \gamma + \gamma \;\; ; \quad \pi^+ + \pi^- \rightarrow \gamma + \gamma$$ **and** $$\eta \rightarrow \gamma + \gamma (or\ 3\pi^0)$$

In principle, these photons can be distinguished by invariant mass analysis. But this is very difficult, if 100 neutral pions or more are produced in the reaction.

The diphoton production rate is usually comes from the processes:

$q + q(\text{bar}) \longrightarrow 2\gamma$

The number of diphotons emitted per space-time volume per invariant mass in the quark gluon plasma phase is expressed as:

$$\frac{dN_{\gamma\gamma}}{d^4x dM} = \frac{1}{(2\pi)^4}(M^2 - 4m_q^2)^{1/2} M^2 \lambda_q^2 T^2 \sigma_{q\bar{q}\to\gamma\gamma}(M^2)\left(\frac{M}{T}\right) K_1\left(\frac{M}{T}\right)$$

where, $\lambda_q = e^{\frac{\mu}{T}}$

Diphoton mass spectrum can be written as:

λ_q^2

$$\frac{dN_{\gamma\gamma}}{dM^2 dy} = \frac{1}{2(2\pi)^4} \times \pi R^2 M^3 \int_{\tau_i}^{\tau_f} \sigma_{q\bar{q}\to\gamma\gamma}(M^2)\left(1 - 4m_q^2 / M^2\right)^{1/2} T(\tau) K_1\left(\frac{M}{T}\right) \tau d\tau$$

Electromagnetic radiations

I) Photons:

Testing pQCD

Thermal photons

II) Low Mass Region:

Vector mesons in medium

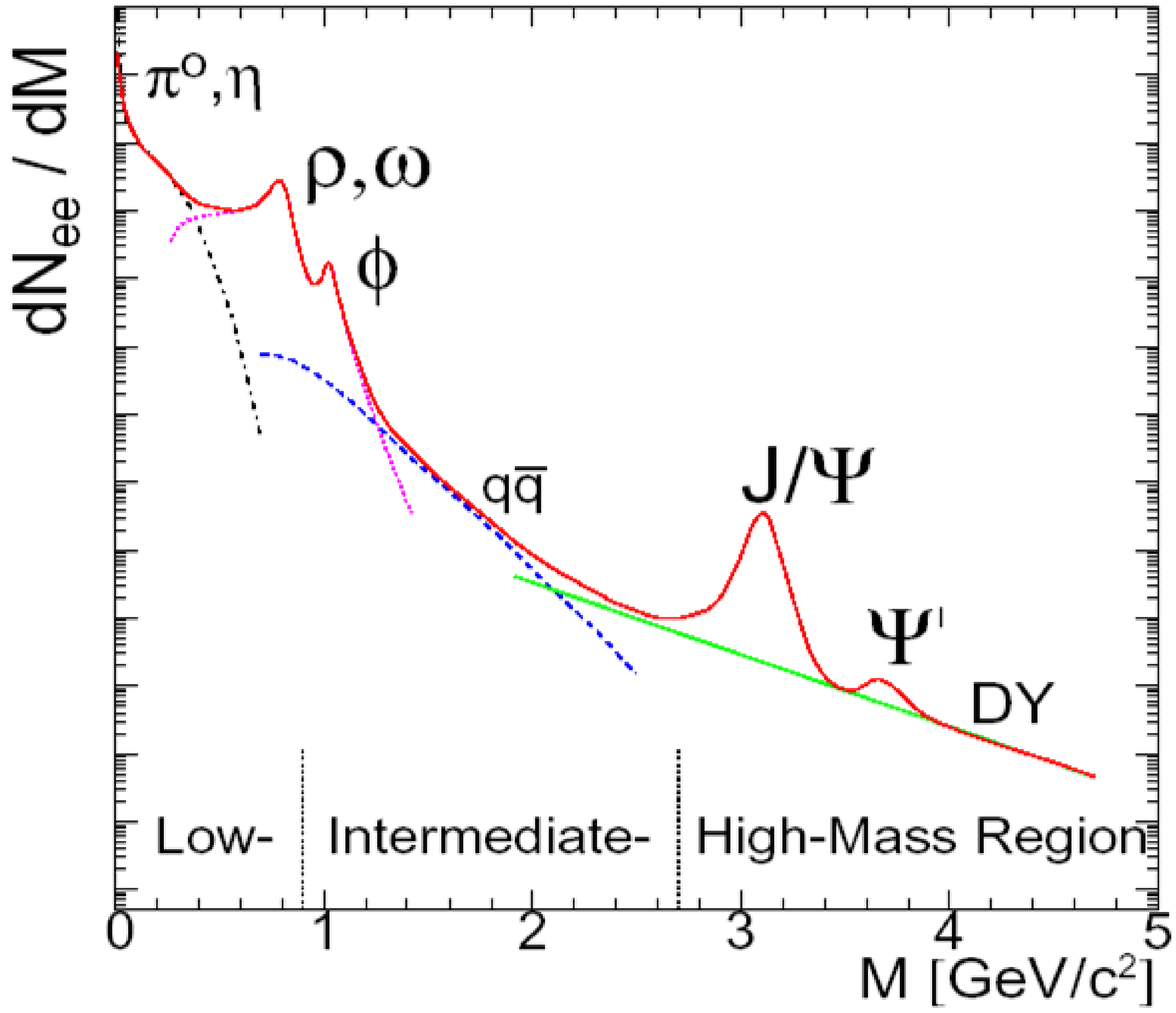
III) Intermediate Mass Region:

Thermal QGP

Open charm

IV) High Mass Region:

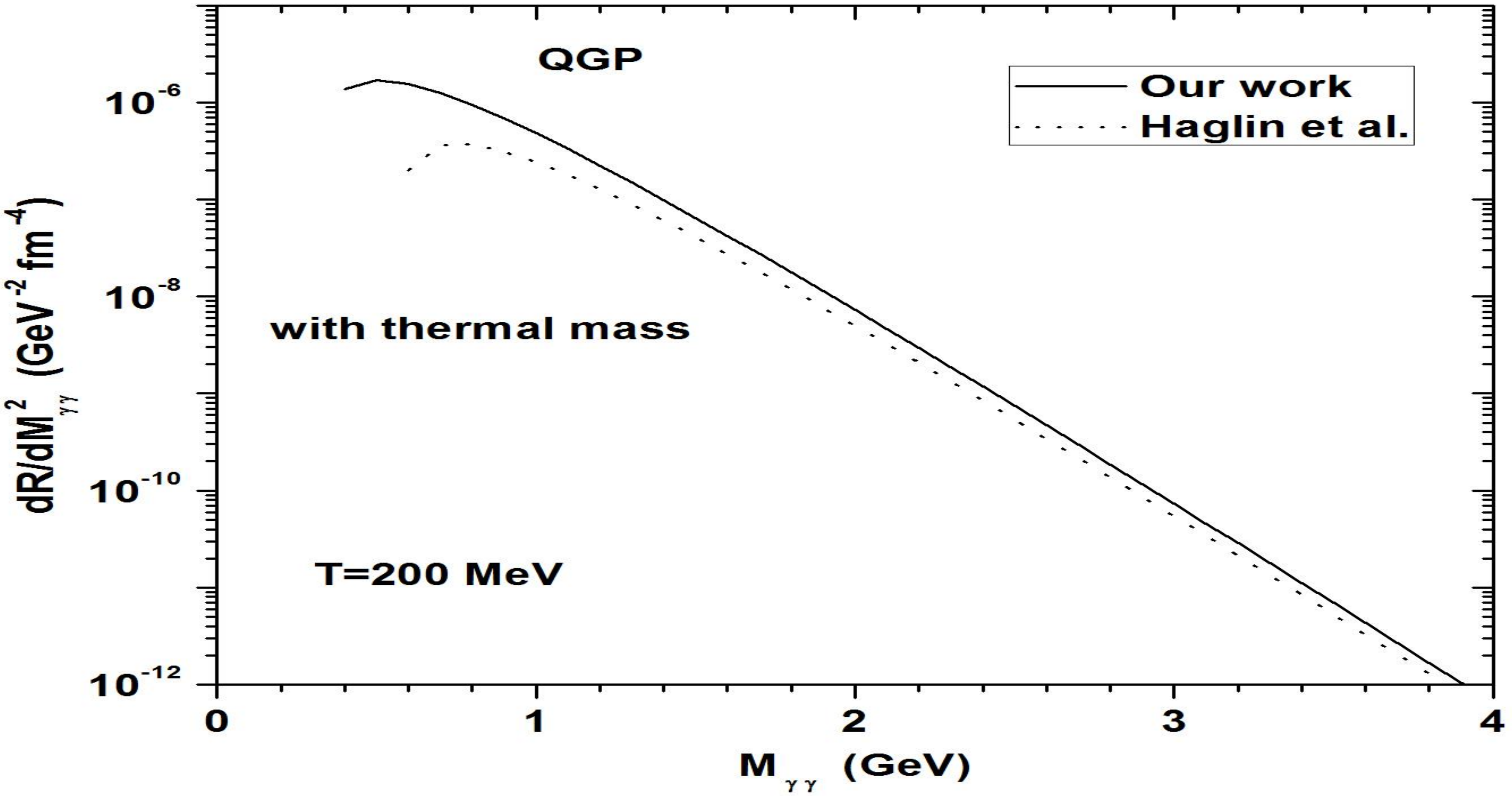
Heavy quarks resonances

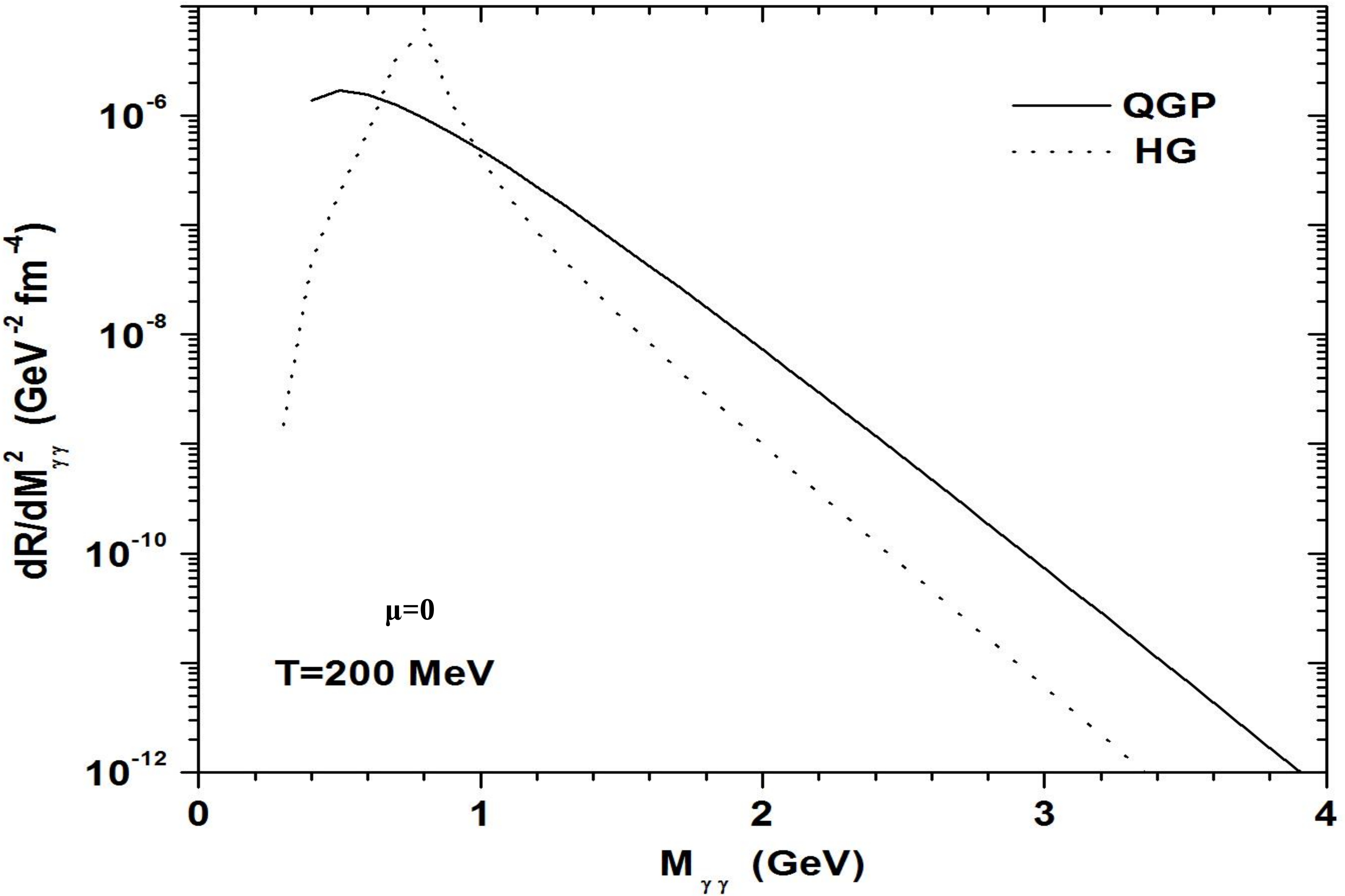


RESULTS

Diphoton mass spectrum :

$\mu=0$





QGP
HG
10^{-6}
10^{-8}
10^{-10}
10^{-12}
$dR/dM^2_{\gamma\gamma}$ (GeV^{-2} fm^{-4})
μ=0
T=200 MeV
0
1
2
3
4
$M_{\gamma\gamma}$ (GeV)

Effect of chemical potential

All our previous calculations were based on the assumption of vanishing chemical potential for the quarks.

The changes in result by introducing finite chemical potentials, by making following change

from $-\frac{E}{T}$ to $\frac{\mu - E}{T}$

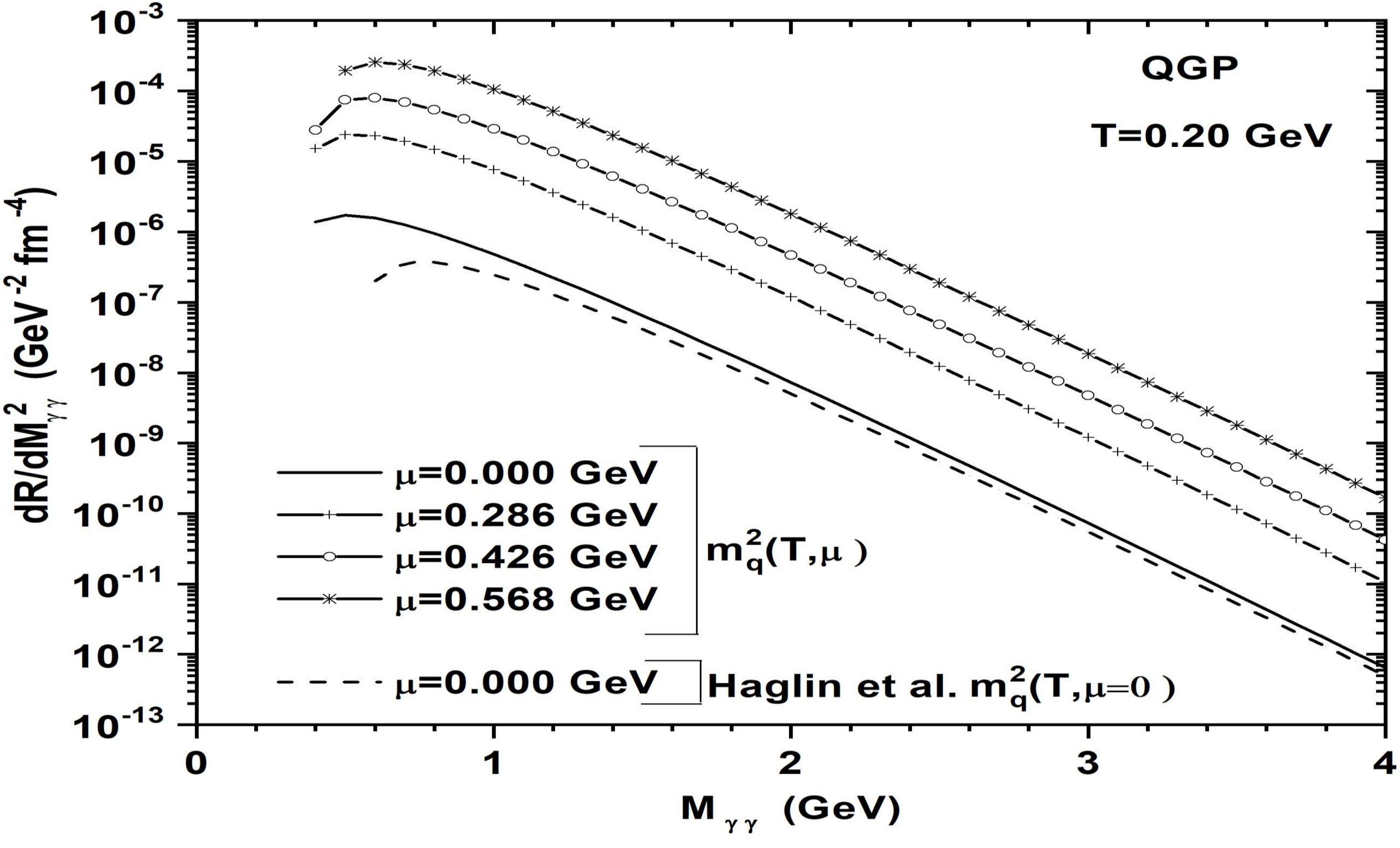
where 'μ' is the potential.

Finite value of quark mass depend on temperature and chemical potential (Quasi-Particle Model):

$$m_q^2(T,\mu) = \gamma_q g^2 T^2 \left[1 + \frac{\mu^2}{\pi^2 T^2} \right]$$

where, μ is the chemical potential.

Use: Peshier et al., Bannur et al., Kumar et al., Srivastava et al. and many more.



QGP
T=0.20 GeV
$dR/dM^2_{\gamma\gamma}$ $(GeV^{-2} fm^{-4})$
$M_{\gamma\gamma}$ (GeV)
μ=0.000 GeV
μ=0.286 GeV
μ=0.426 GeV
μ=0.568 GeV
$m_q^2(T,\mu)$
μ=0.000 GeV
Haglin et al. $m_q^2(T,\mu=0)$

Summary

- Two photon decays using a phenomenological model emitted from a quark-gluon plasma at high temperature and chemical potential is studied.

- We used a similar idea of our earlier calculations of photon production rate in QGP and hadronic state at RHIC and LHC. For the phenomenology of heavy-ion collisions, we present emission spectra by taking into account the parametrization factors in thermal dependent quark mass.

- The quasi-model of quark mass is used in such a way that the diphoton emission is reviewed and significant with quark mass dependent on temperature and chemical potential. This indicates that quark mass plays a pivoted role in the diphoton production rate.


THANK YOU