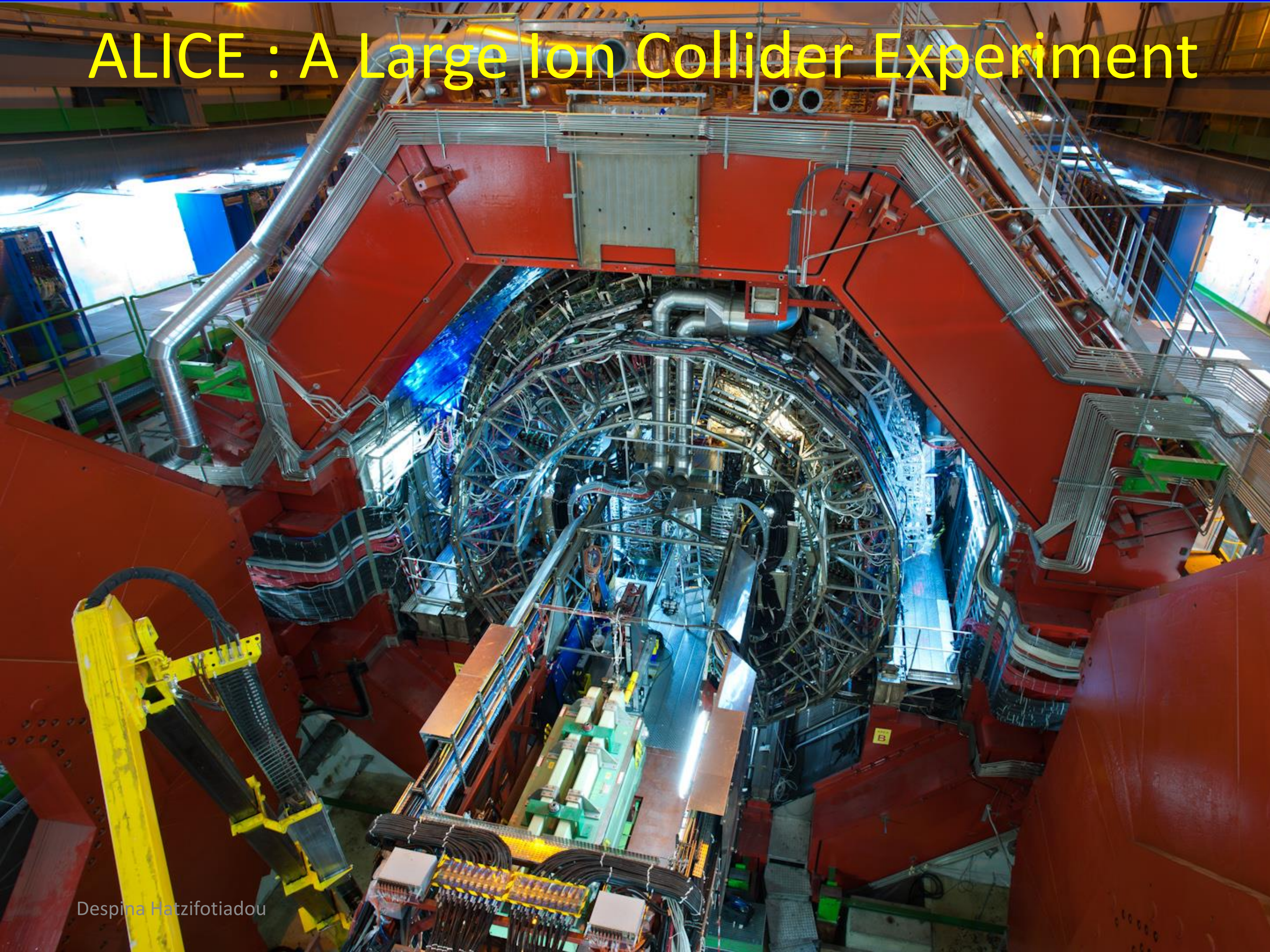
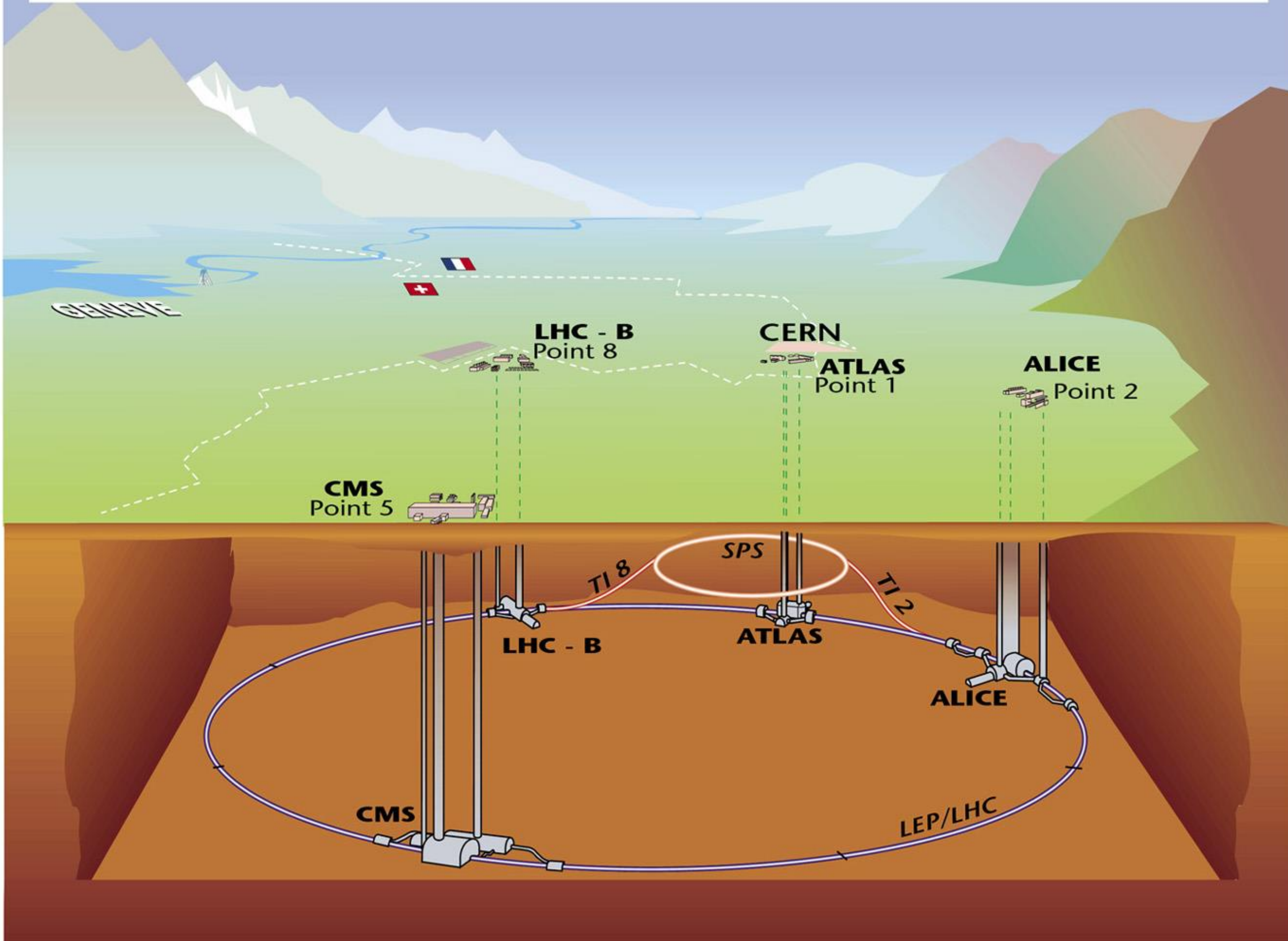
ALICE : A Large Ion Collider Experiment



Despina Hatzifotiadou

Overall view of the LHC experiments.



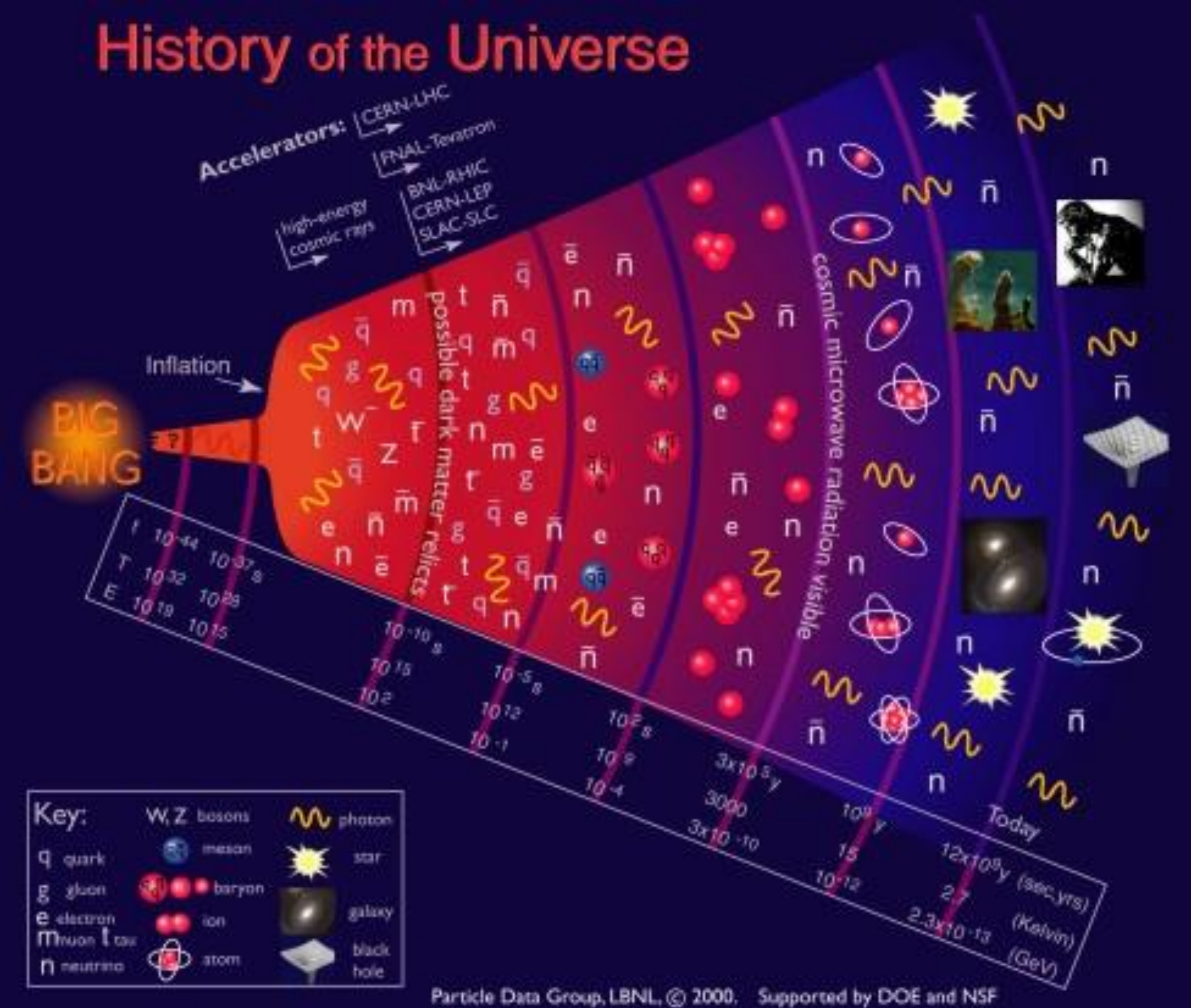
Heavy ions at LHC

In addition to protons, LHC accelerates and collides lead ions

isotope Pb ^{208} with 82 protons and 126 neutrons in the nucleus
Pb atom -> Pb^{29+} -> Pb^{54+} -> Pb^{82+} (bare lead nucleus)

Run 1 : Energy 3.5 TeV x 82 = 287 TeV (574 TeV at point of collision)
Run 2 : Energy 6.5 TeV x 82 = 533 TeV (1066TeV at point of collision)

Why are lead ion collisions at high energies of particular interest?



Millionths of a second after the big bang, all matter is made of free quarks and gluons,

THE QUARK GLUON PLASMA

As the universe cools and expands, the quarks and gluons are "imprisoned" for ever inside hadrons: from these, only protons and neutrons remain today

13.7 billion years ago the universe was born from a Big Bang

Little Bang

By colliding lead nuclei at very high energies we recreate the conditions of density and temperature which existed fractions of a second after the Big Bang

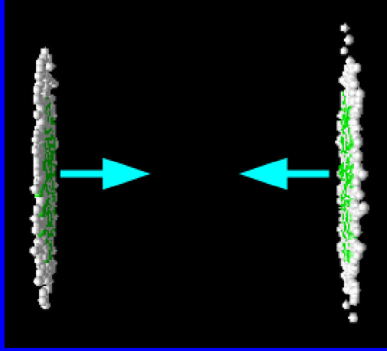
The protons and neutrons which constitute the lead nuclei melt liberating the quarks and gluons which are bound inside them

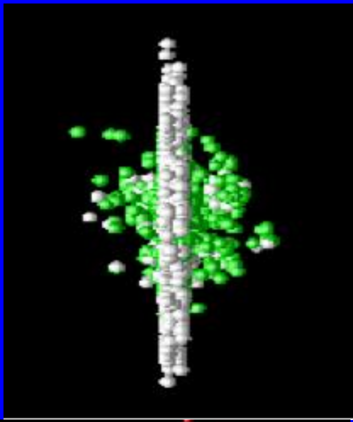
A new state of matter is created : the QUARK GLUON PLASMA

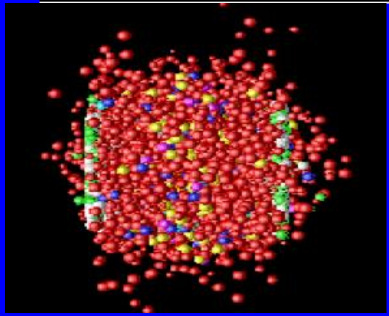
By studying its properties

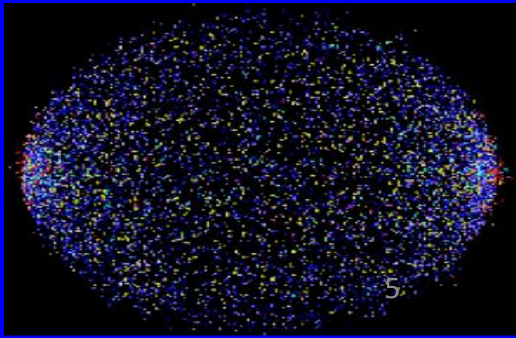
- We will understand better the processes which took place during the first fractions of a second in the life of the universe

- We will understand better the strong interaction and how the protons and neutrons acquire their mass

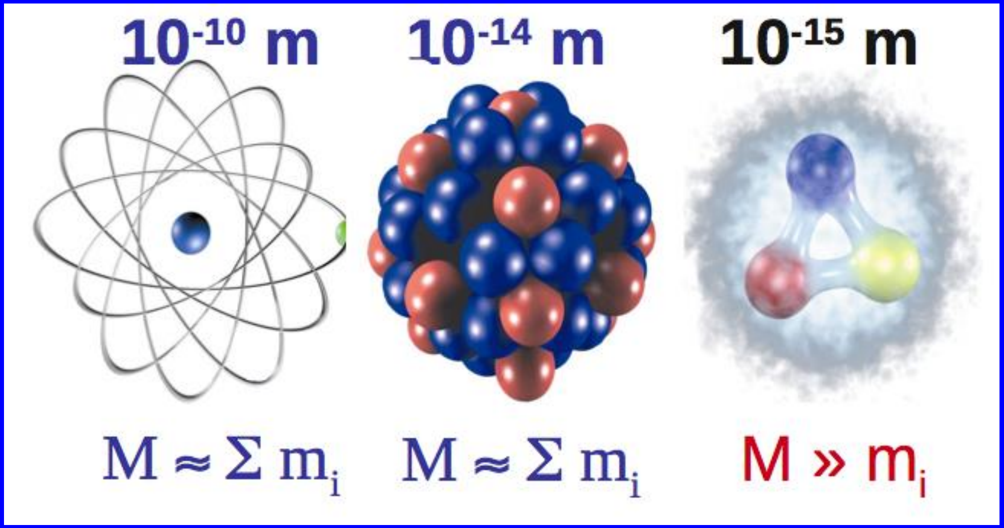








atom nucleus nucleon

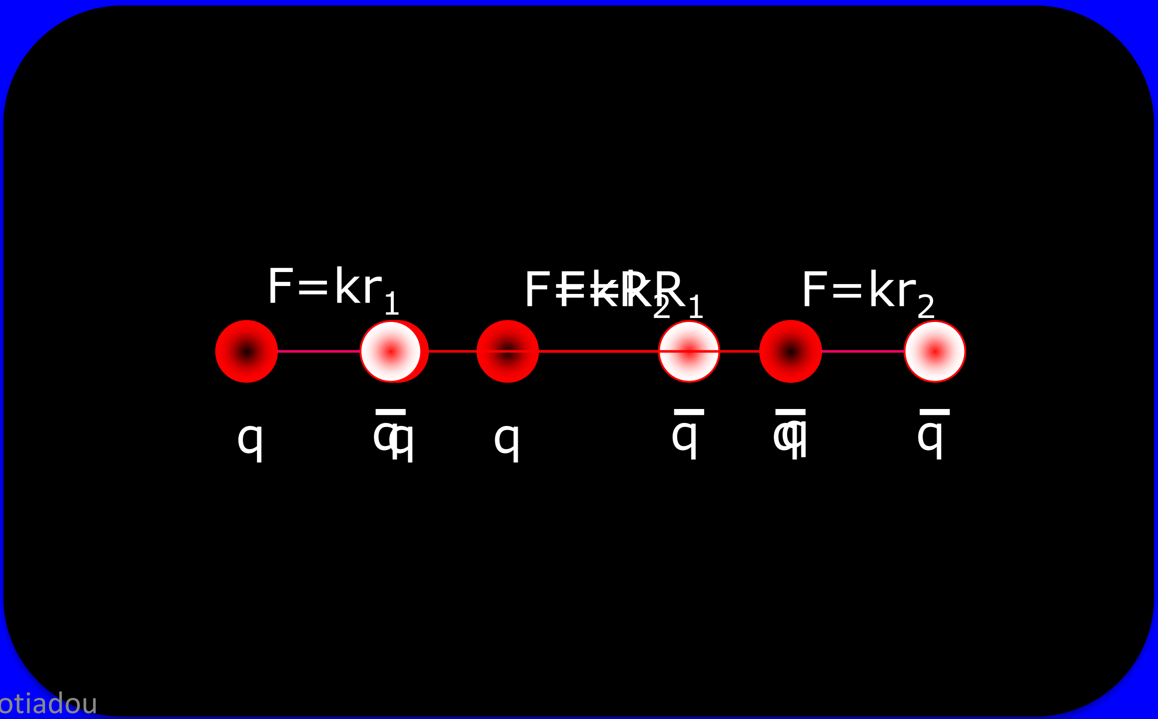


In nucleons (protons and neutrons) the mass is not defined by the sum of masses of their constituents but mainly from the energy due to the movement of quarks and the energy of the gluons

Example
the proton (uud) mass : 938 MeV/c^2
up quark mass : 1.7 – 3.3 Mev/c^2
down quark mass : 4.1 – 5.8 MeV/c^2
Sum : 7.5 -12.4 MeV/c^2

ALICE studies stong interactions..

Why are quarks permanently confined inside hadrons?



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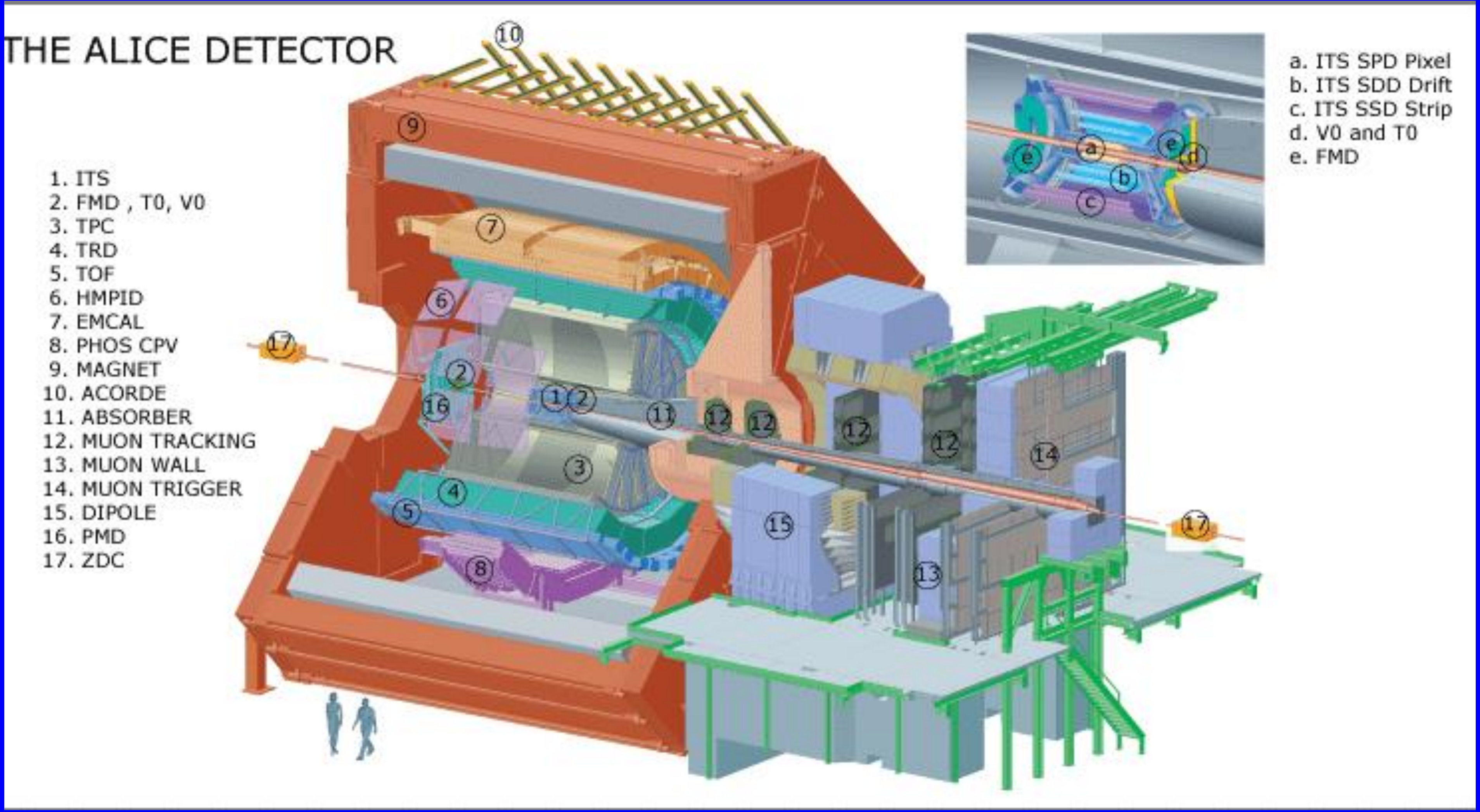
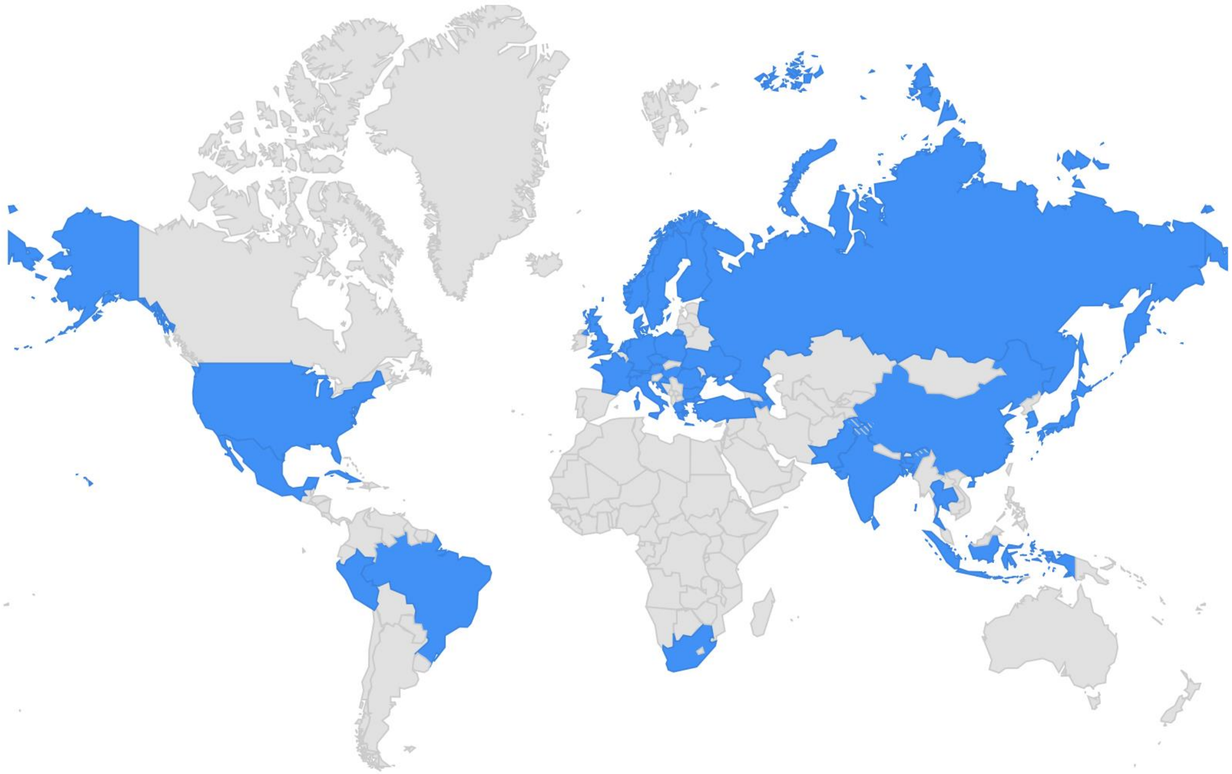
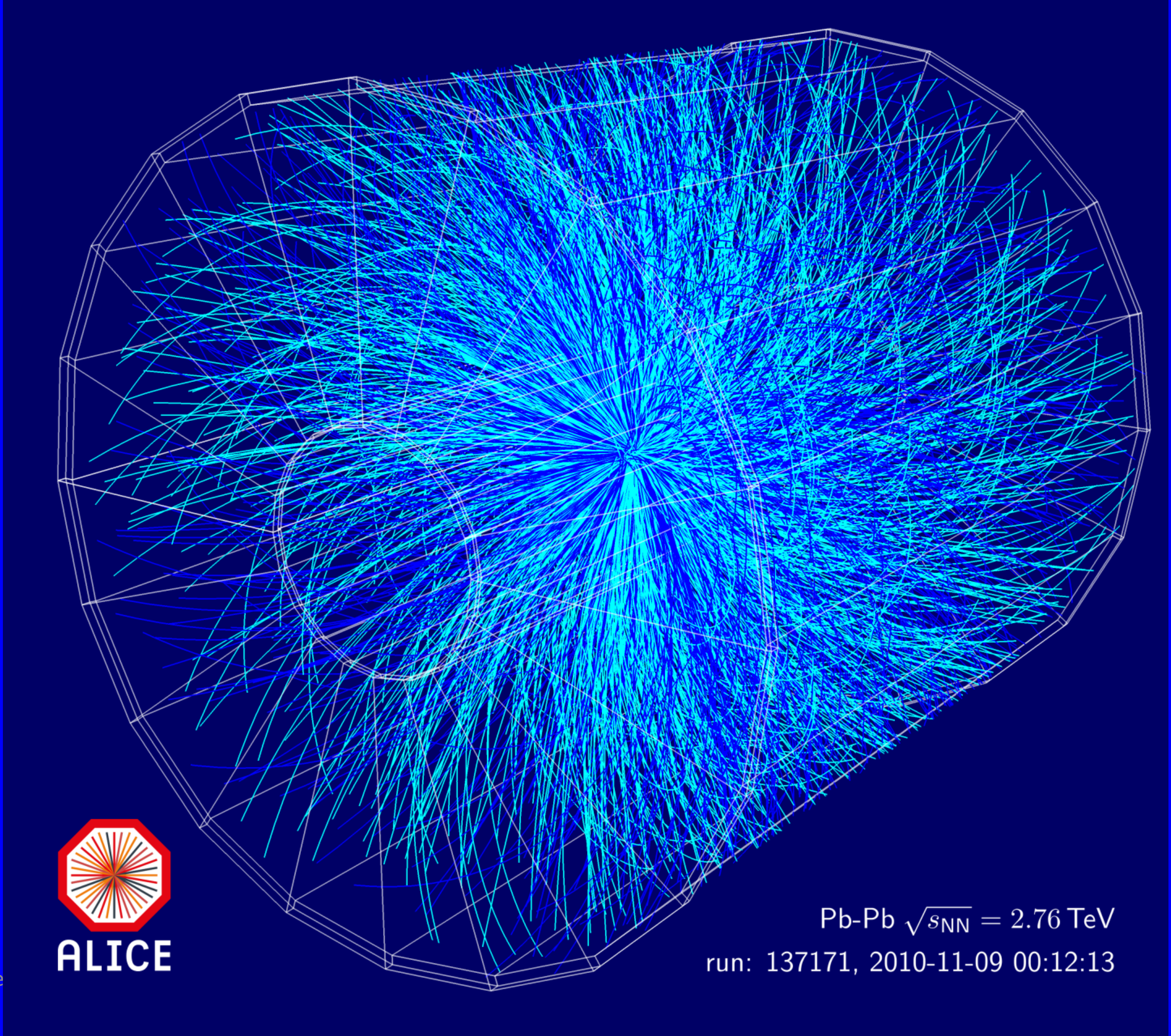


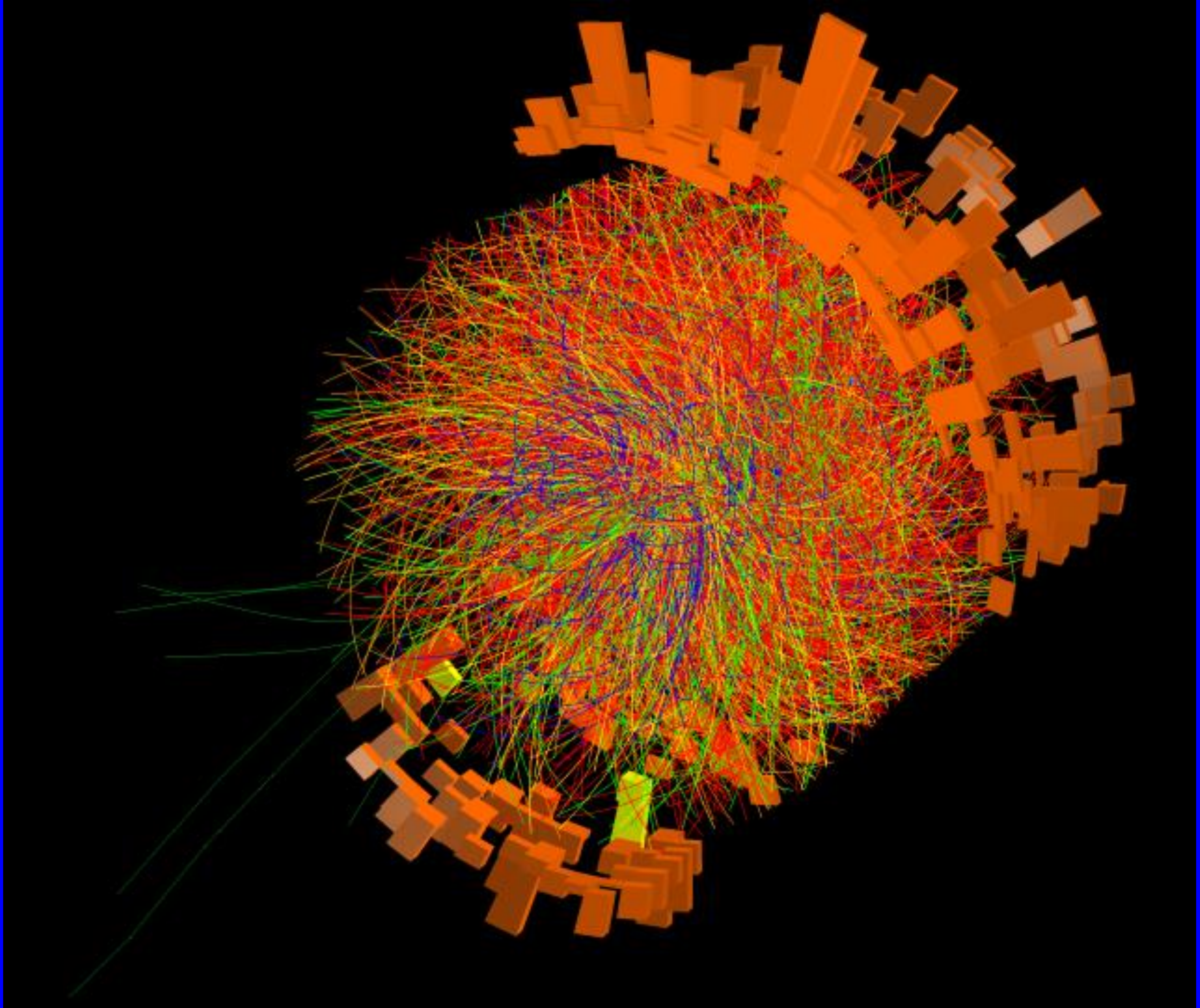
16 m x 16 m x 26 m 10 0000 tons installed at point 2 of LHC, 56 m underground

The Collaboration

40 countries, 172 institutes, 1988 members




Pb-Pb $\sqrt{s_{NN}} = 2.76$ TeV
run: 137171, 2010-11-09 00:12:13

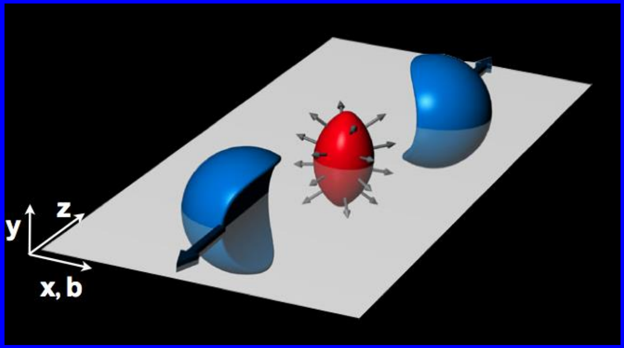


A perfect liquid at LHC

The primordial matter recreated by high energy lead ion collisons at the LHC was initially expected to behave like a gaseous plasma; instead, it appears to behave like a perfect liquid, with coordinated collective motion ("flow") among the constituent particles.

This had already been announced by experiments at RHIC

The dense matter created by lead collisions flows almost with no friction (like water, which has low viscosity) and not like honey (which has high viscosity)



Almond shape

More hadrons are observed parallel to the interaction plane than in the plane perpendicular to it

One of the most spectacular results of heavy-ion experiments

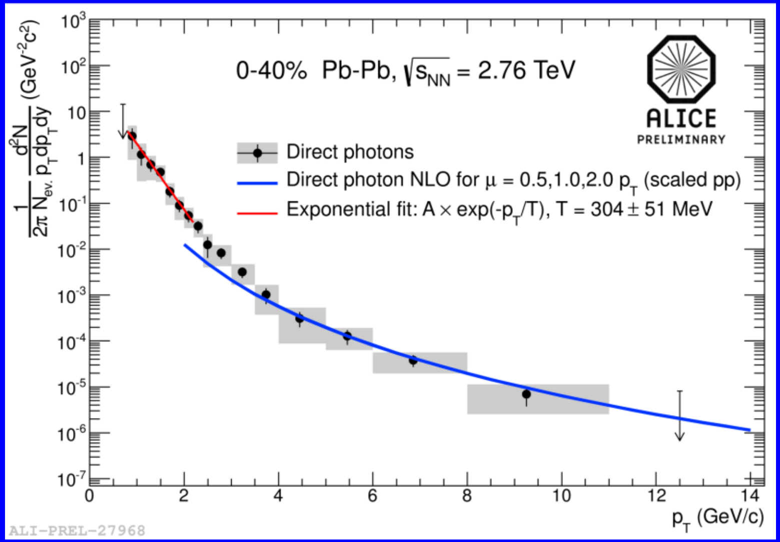
Highest man-made temperature

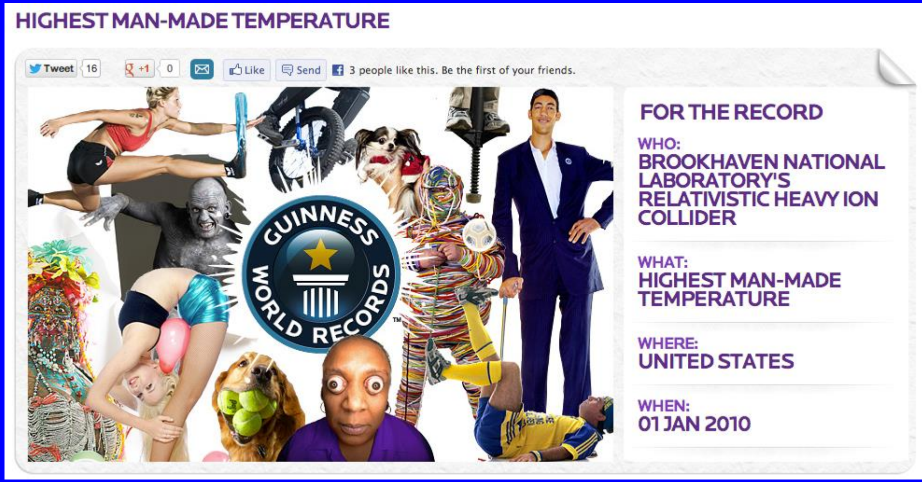
Thermal photons, radiated by the quark gluon plasma ("direct" photons, not coming from decays of hadrons) reflect the temperature of the system.

The inverse slope of the distribution of these photons suggests that the initial temperature of the system created by lead collisions is some trillion of degrees Kelvin.

This temperature is 250 000 times higher than the temperature in the core of the sun

The hottest piece of matter ever formed



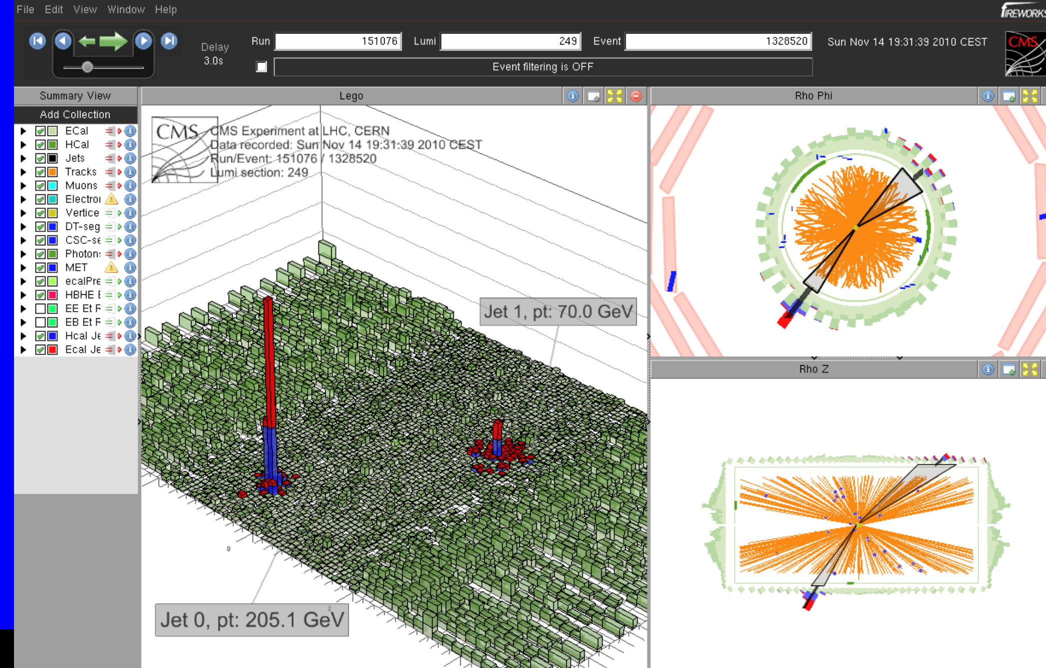


Before heavy ion collisions at LHC

Energy loss

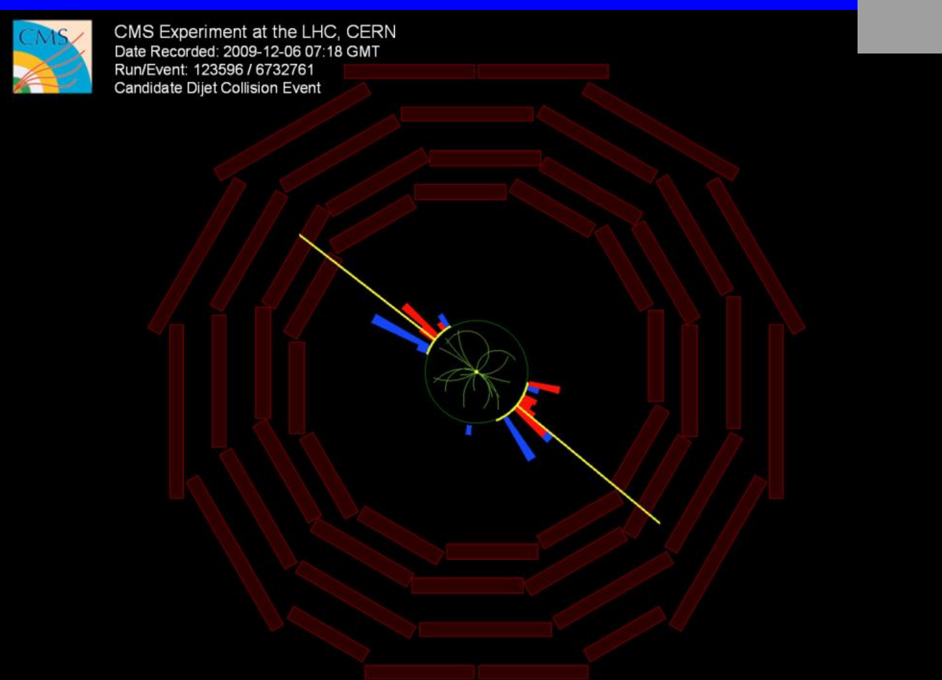
One of the first announcements from the first lead ion run at LHC, December 2010)

Jets going in opposite directions have ~ equal energies



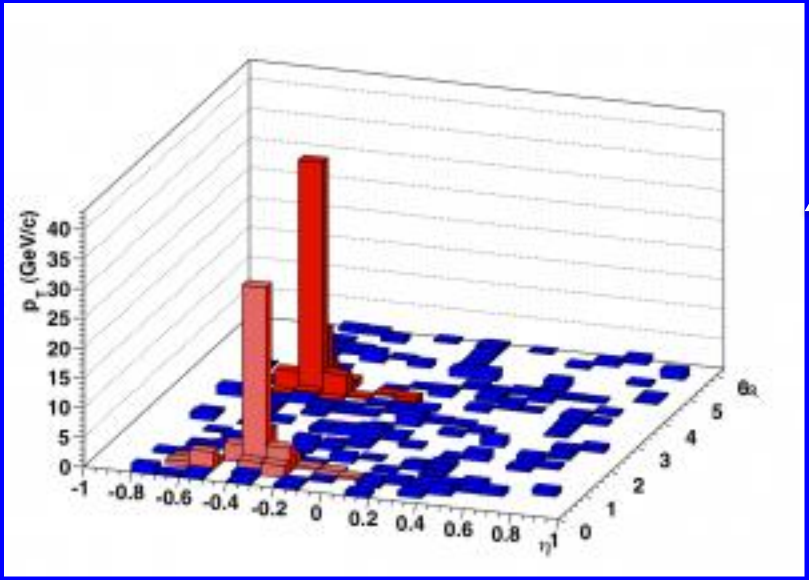
Lead ion collision event

One jet has much less energy than the other.
The jet produced near the QGP surface has high energy whereas the one that traverses the QGP is absorbed and scattered by the dense medium losing big part of its energy



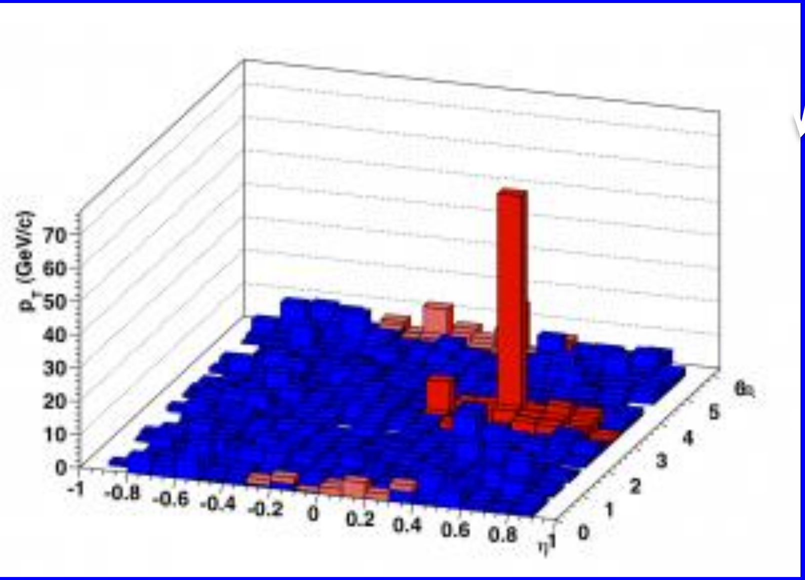
Proton collision event – two jets with energy of ~20 GeV

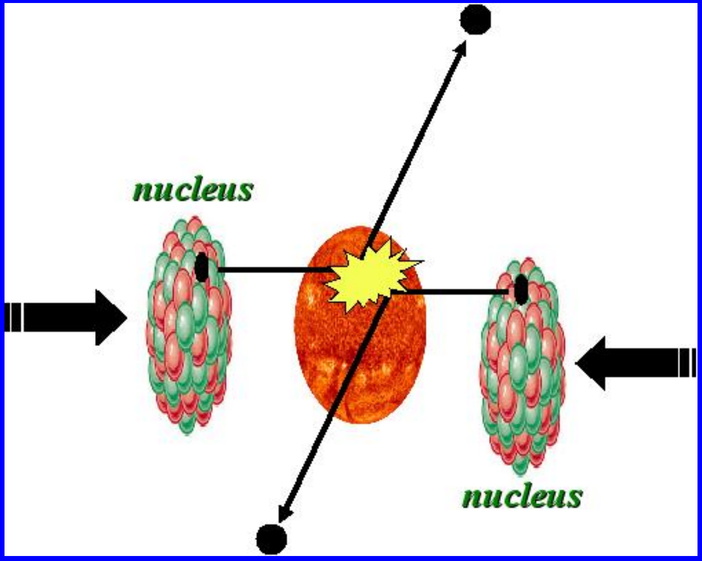
Jet Quenching



ALICE – peripheral lead ion collisions- two jets

ALICE – central lead ion collisions
1 jet is visible, the other has been absorbed while travelling through the QGP and does not come out





The J/Ψ mystery

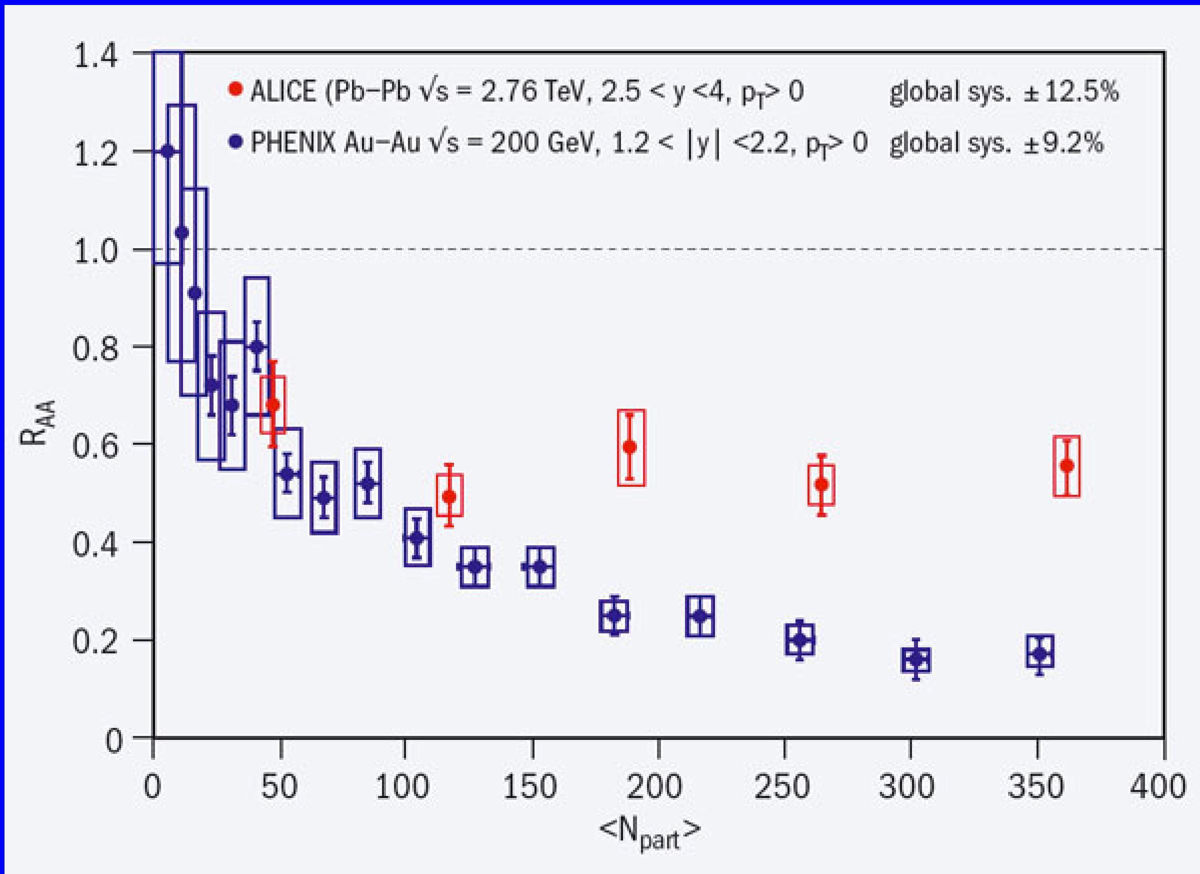
- J/Ψ Discovered in 1974, almost simultaneously, at Brookhaven (proton-nuclei collisions) and at SLAC (collisions e^+e^-)
- Bound state of a c quark and a c anti-quark (mass 3 GeV)
- The two “object” that make the J/Ψ are bound due to strong interaction

- Inside the quark gluon plasma, due to the high number of free colour charges, the binding between c-quark and c-antiquark becomes weaker, the pair disintegrates and the J/Ψ disappears
- Suppression of the observed J/Ψ signal

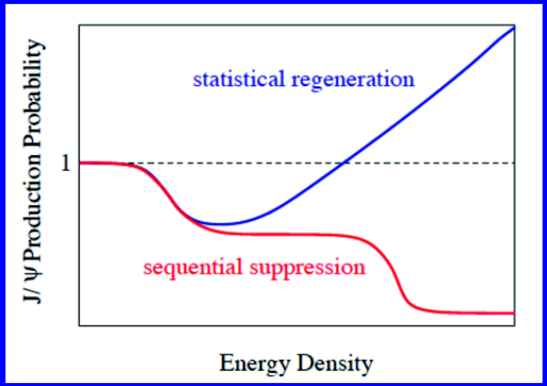
  (J/Ψ -> μμ and J/Ψ -> e^+e^-)

- Suppression depends on QGP temperature

The J/Ψ mystery



- Regeneration of J/Ψ at very central collisions
- Two competing phenomena
- Suppression of J/Ψ due to interaction with the quark gluon plasma
- Creation of many J/Ψ due to the high number of c – anti-c pairs created from the huge collision energy



Nuclear modification factor R_{AA}

$$R_{AA} = \frac{\text{number of J/Ψ observed in lead ion collisions}}{\text{number of J/Ψ observed in proton collisions}}$$