WHAT MATTERS FOR ALICE:
PRIMORDIAL MATTER
-13.819 BILLION YEARS

THE FIRST HOMINIDS ON EARTH (TOUMAI) - 7 MILLION YEARS
MORE THAN 1’000 BILLION DEGREES

TEMPERATURE OF THE SUN: 15 MILLION DEGREES
200 MILLION TONS PER cm$^3$

THE PYRAMID OF KHEOPSIN A PIN’S
UNDERSTANDING WHAT EVERYTHING THAT HAS A TANGIBLE REALITY IS COMPOSED OF
13.819 BILLION YEARS
$\sim 10^{21}$ m

GALAXY
NEURONS
MOLECULE

$10^{-9} m$
PROTON

$10^{-15}\text{m}$
The atom is 100,000 times larger than the nucleus, 99.999999999999999% is vacuum, and 99.995% of the atom mass.
MATTER IS MADE OF VACUUM
The elementary particles which constitute the proton only contribute 1% of its mass.
WHAT DO WE KNOW ABOUT MATTER?

MATTER IS IMMATERIAL

MATTER IS MADE OF VACUUM
THE FORCES STRUCTURE MATTER
THE GRAVITATIONAL FORCE

\[ R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8 \pi G T_{\mu\nu} \]
WHAT DO WE KNOW ABOUT MATTER?

MATTER IS STRUCTURED BY 4 FORCES

MATTER IS MADE OF VACUUM
MATTER IS IMMATERIAL

MATTER IS STRUCTURED
THE PARTICLES INTERACT BY EXCHANGING PARTICLE-MESSENGERS
REPULSIVE INTERACTION
ATTRACTIVE INTERACTION
<table>
<thead>
<tr>
<th>Quarks</th>
<th>Leptons</th>
<th>Messengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>u, c, t</td>
<td>e, μ, τ</td>
<td>g, Z, W, γ</td>
</tr>
<tr>
<td>d, s, b</td>
<td>νe, νμ, ντ</td>
<td>graviton</td>
</tr>
</tbody>
</table>
WHAT DO WE KNOW ABOUT MATTER?

4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

MATTER IS MADE OF VACUUM
MATTER IS IMMATERIAL
MATTER IS STRUCTURED PAR 4 FORCES
MOST ANCIENT PHOTO OF THE UNIVERSE:
380’000 YEARS AFTER THE BIG BANG, LUKEWARM ...
2700°C, FORMATION OF THE FIRST ATOMS

- 69.4% DARK ENERGY
- 25.8% DARK MATTER
- 4.8% VISIBLE MATTER
WHAT DO WE KNOW ABOUT MATTER?

ORDINARY MATTER REPRESENTS 4.8% OF THE UNIVERSE

MATTER IS MADE OF VACUUM
MATTER IS IMMATERIAL
MATTER IS STRUCTURED BY 4 FORCES
4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...
COSMOLOGY PLACES THE BIG BANG AT -13.819 BILLION YEARS
3 minutes later 99% of current matter is created out of elementary particles (Primordial Nucleosynthesis)
100 million YEARS LATER HEAVY ELEMENTS (C, O, Fe,...) ARE SYNTHETIZED IN THE HEART OF THE FIRST STARS
WHAT DO WE KNOW ABOUT MATTER?

99% OF CURRENT MATTER HAS BEEN CREATED IN 3 MINUTES

MATTER IS MADE OF VACUUM
MATTER IS IMMATERIAL
MATTER IS STRUCTURED BY 4 FORCES
4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...
ORDINARY MATTER REPRESENTS 4.8% OF THE UNIVERSE
MATTER IN ALL ITS STATES

SOLID

LIQUID

VAPOUR

PLASMA

MATTER CAN TRANSFORM
WHAT DO WE KNOW ABOUT MATTER?

MATTER HAS ACQUIRED STRUCTURE STARTING FROM A PLASMA OF QUARKS AND GLUONS.
HOW CAN WE RECREATE PRIMITIVE MATTER?
A RING WITH 27km CIRCONFERENCE IN A TUNNEL 100m BELOW GROUND ACCELERATES LEAD NUCLEI AT 99.9999997% OF THE SPEED OF LIGHT
WHEN TWO LEAD NUCLEI COLLIDE
BIG BANG

hadron gas:
$t_0 + 10^{-23}$ seconds

QGP:
$t_0 + 10^{-6}$ seconds

CMB:
$t_0 + 3.8 \times 10^5$ years

$LITTLE$ $BIG$ $BANG$

QGP:
$t_0 + 10^{-24}$ seconds

$t_0$ + $13.8 \times 10^9$ years

$t_0$
WHAT HAVE WE LEARNED UP TO NOW?
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

TEMPERATURE HIGHER THAN 5'500 BILLION DEGREES
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT EXTENDS IN A MICROSCOPIC VOLUME $10^{35}$ TIMES SMALLER THAN THE SIZE OF THE PRIMORDIAL UNIVERSE
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT LASTS AN INFINITELY SHORT TIME, $10^{17}$ TIMES SHORTER THAN THE PRIMITIVE MATTER OF THE BIG BANG
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT HAS THE PROPERTIES OF A PERFECT LIQUID (ZERO VISCOSITY)
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT IS OPAQUE TO MATTER BUT TRANSPARENT TO LIGHT
WHAT DO WE KNOW ABOUT MATTER?

99% of current matter has been made in 3 minutes.

4 elementary particles constitute ordinary matter...

Ordinary matter represents 4.8% of the universe.

Matter is made of vacuum.

Matter is immaterial.

Matter is structured by 4 forces.

4 elementary particles constitute ordinary matter...

Matter has acquired structure starting from a plasma of quarks and gluons.