A Large Ion Collider Experiment (ALICE)

Quark Gluon Plasma (QGP)

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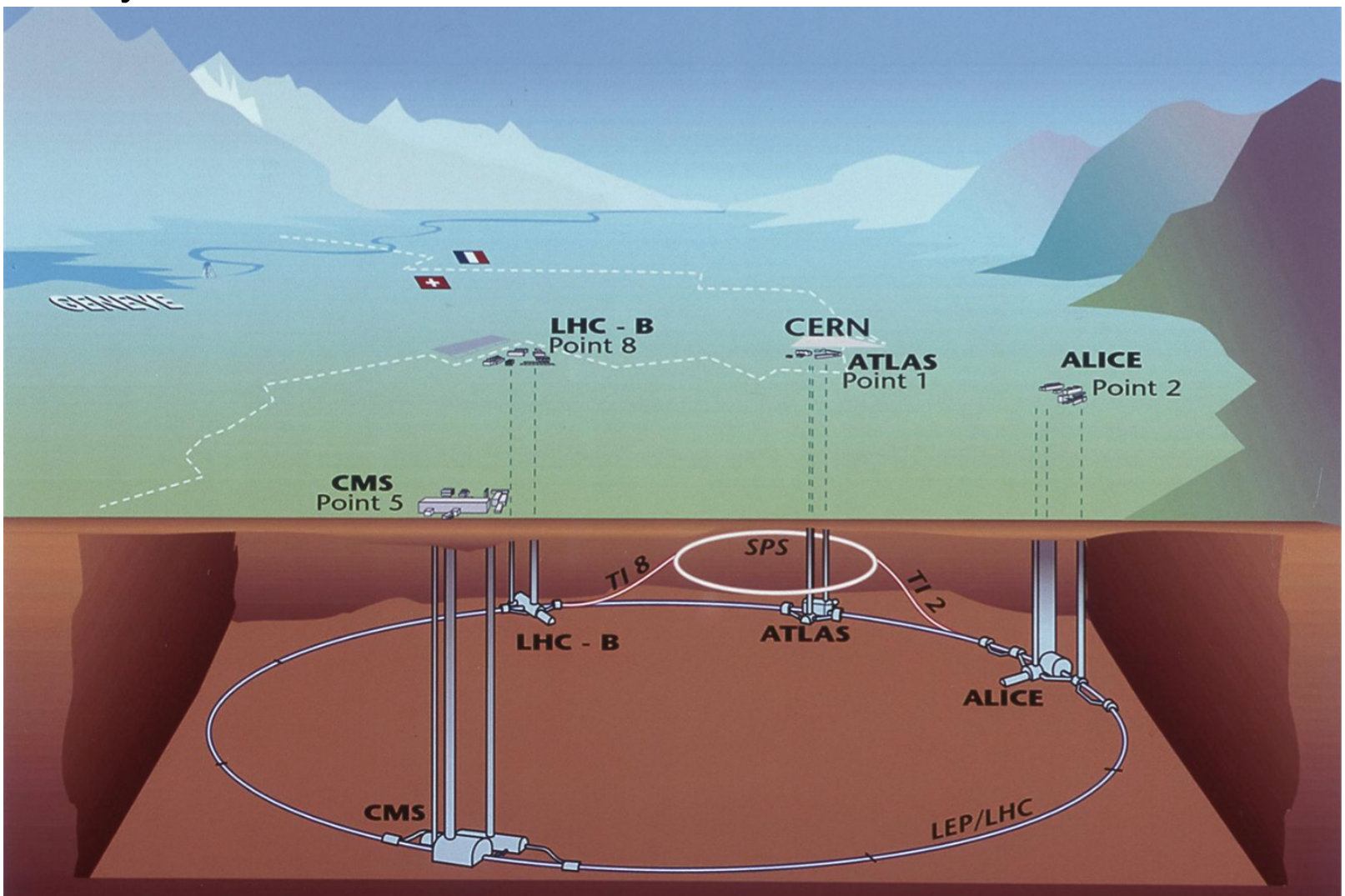
[1] On behalf of CIIT-ALICE Physics group

ALICE Detector on LHC ring

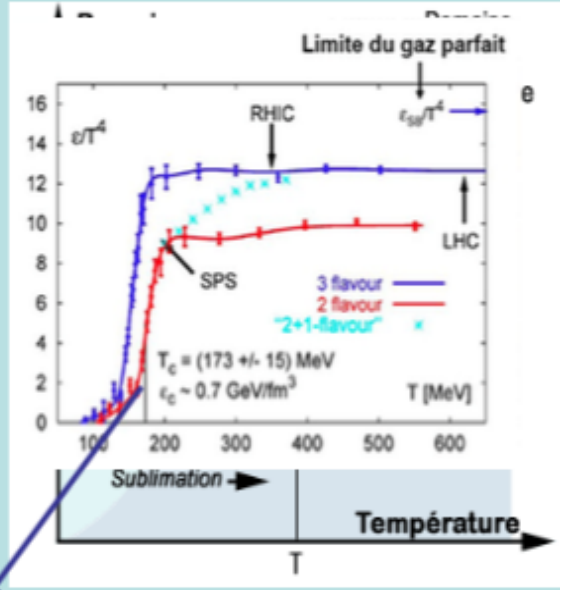
Located at P2 on LHC ring in a French town called St. Genis Pouilly.



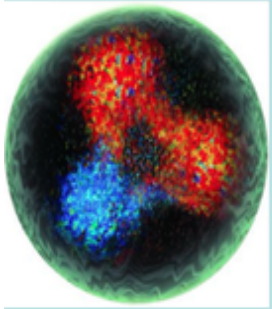
History and Motivation

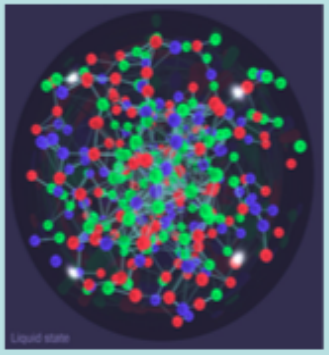
- **It is designed to study the physics of strongly interacting matter at extreme energy densities, where a phase of matter called quark-gluon plasma (QGP) forms.**
- First Idea of ALICE came in1992
- Proposed as central detector. Forward system was added later on one side
- Ten year spent in R&D
- First Lead-Lead collision data recorded in 2010.
  Lead-lead luminosity in 2011: 143.62/ub (sNN=2.76 TeV/nucleon)
- First proton-lead collisions recorded in 2013.
  Proton-lead luminosity in 2013: 31.94/nb (sNN=5.02 TeV/nucleon)

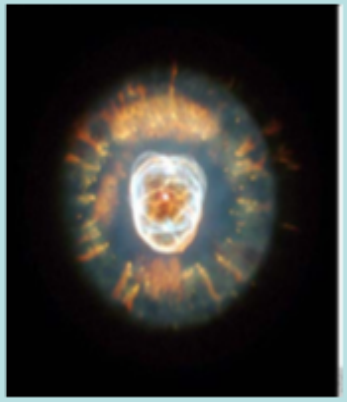
Phase Transitions and QGP

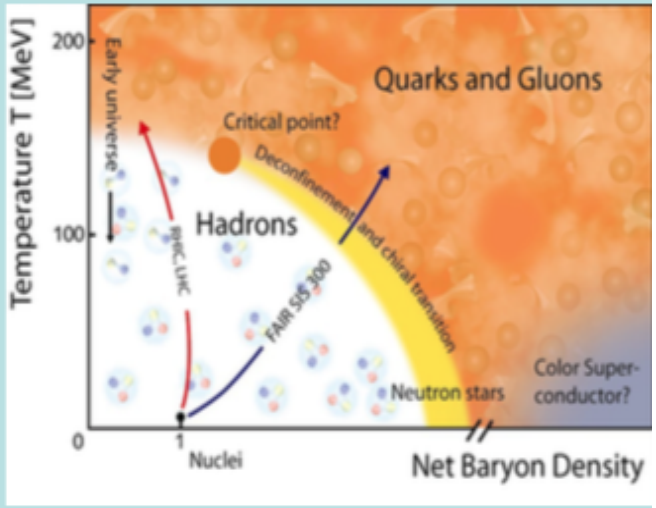


Temperature

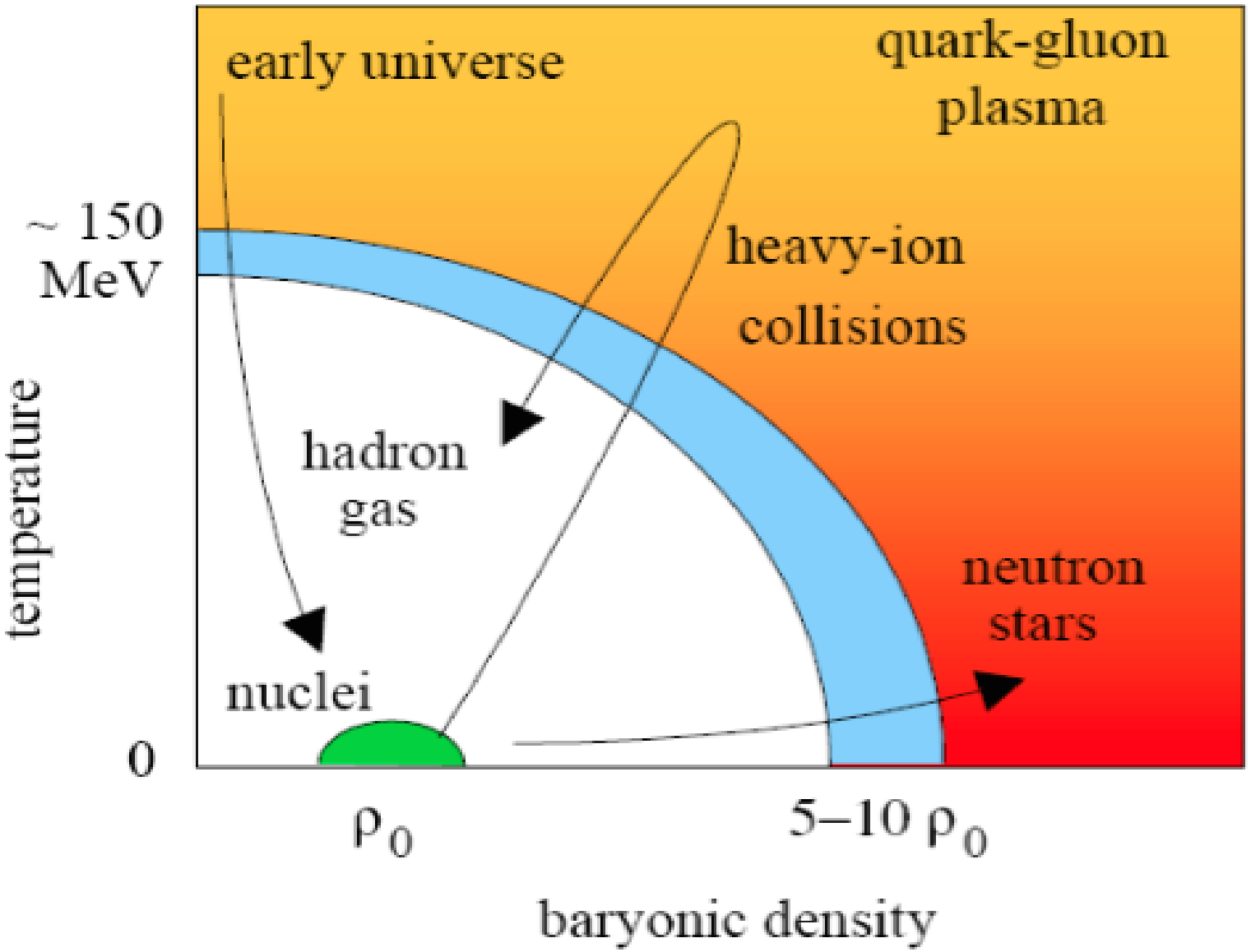




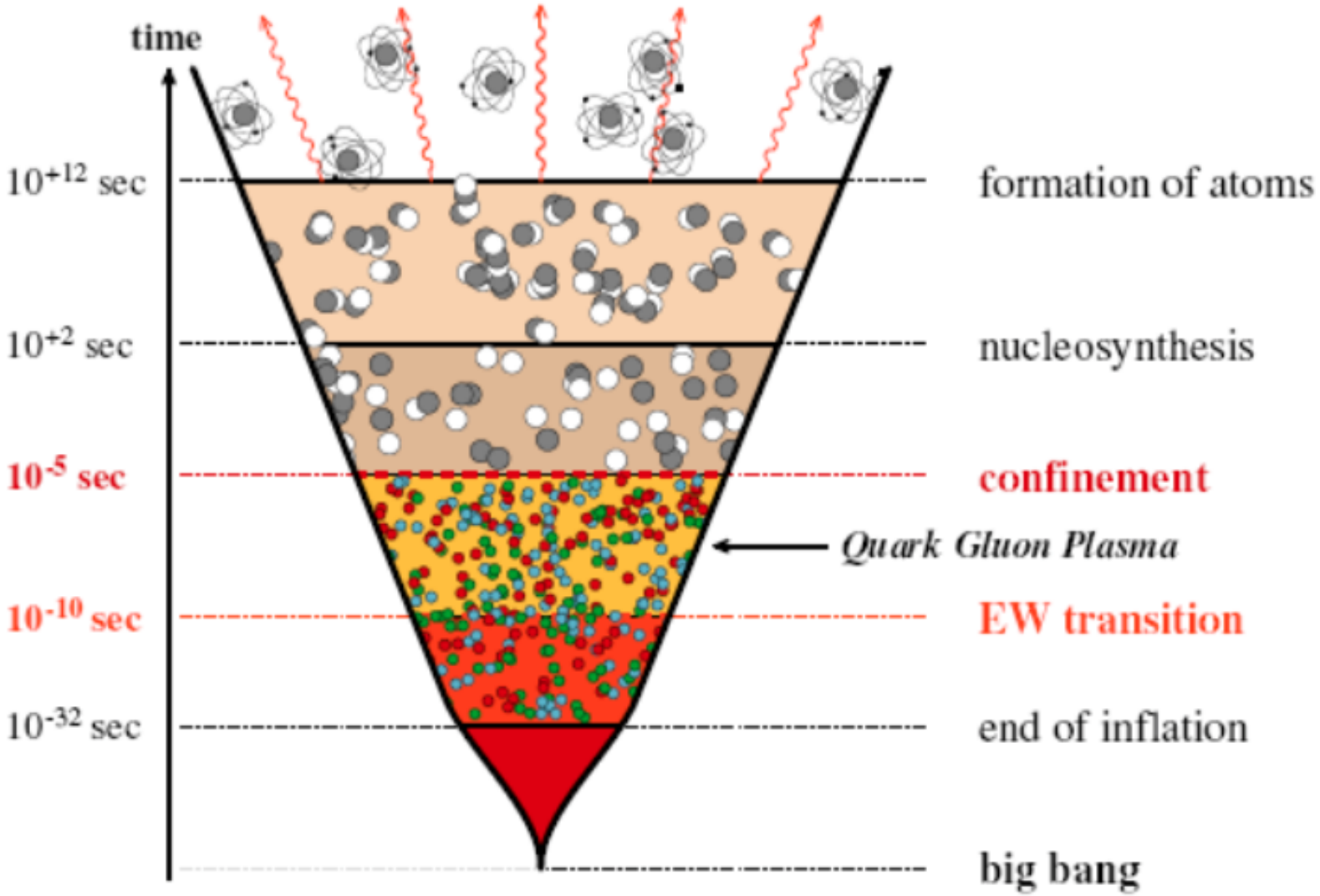




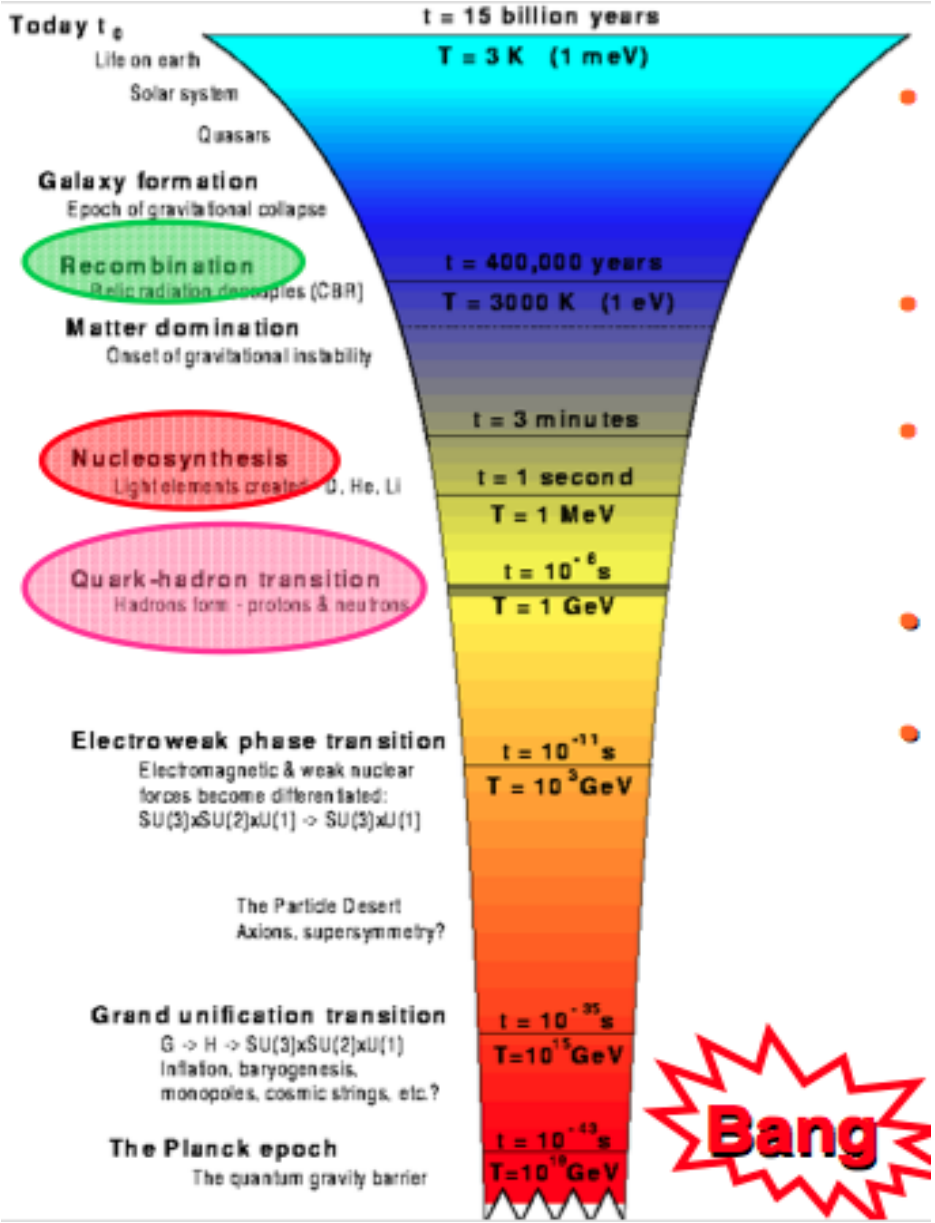
Phase Transitions



Evolution of Primordial Universe



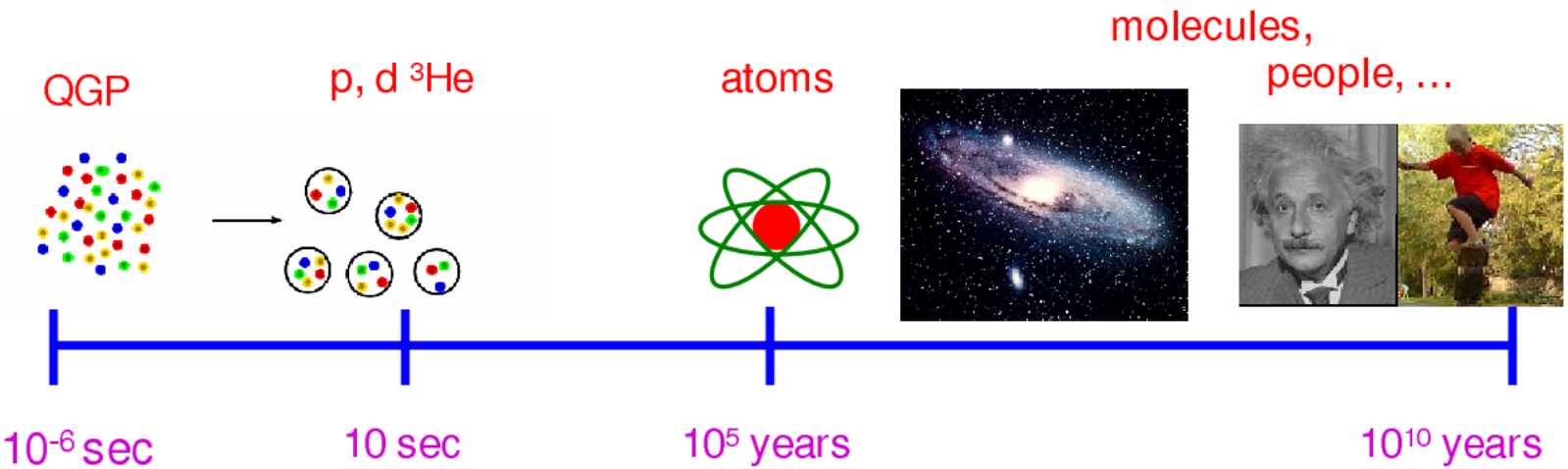
Evolution of Universe

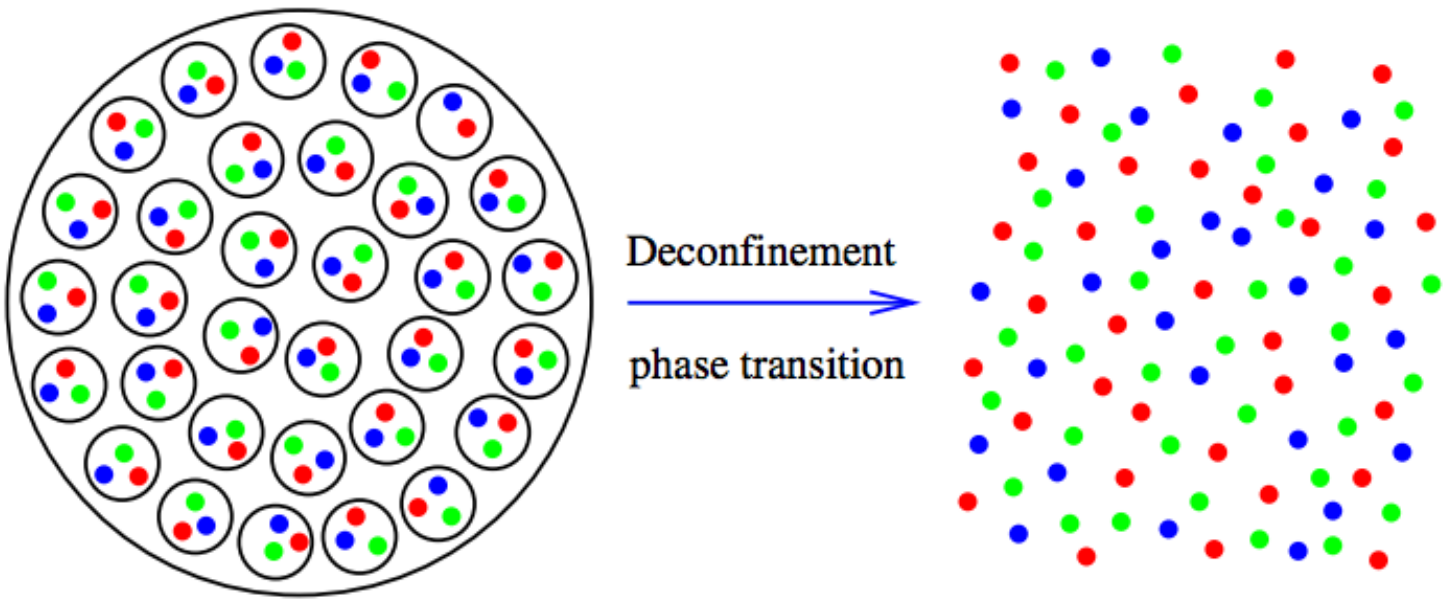


- Electromagnetic decoupling (T $\sim$1 eV, t$\sim$3-10^5 years), Thermal Freezeout.
- Matter still opaque to e.m radiation
- Atomic Nuclei (T$\sim$100 keV, t$\sim$200 s), Chemical Freezeout.
- Hadronization (T$\sim$ 0.2 GeV, t$\sim$ 10^{-5} s)
- Quarks and gluons

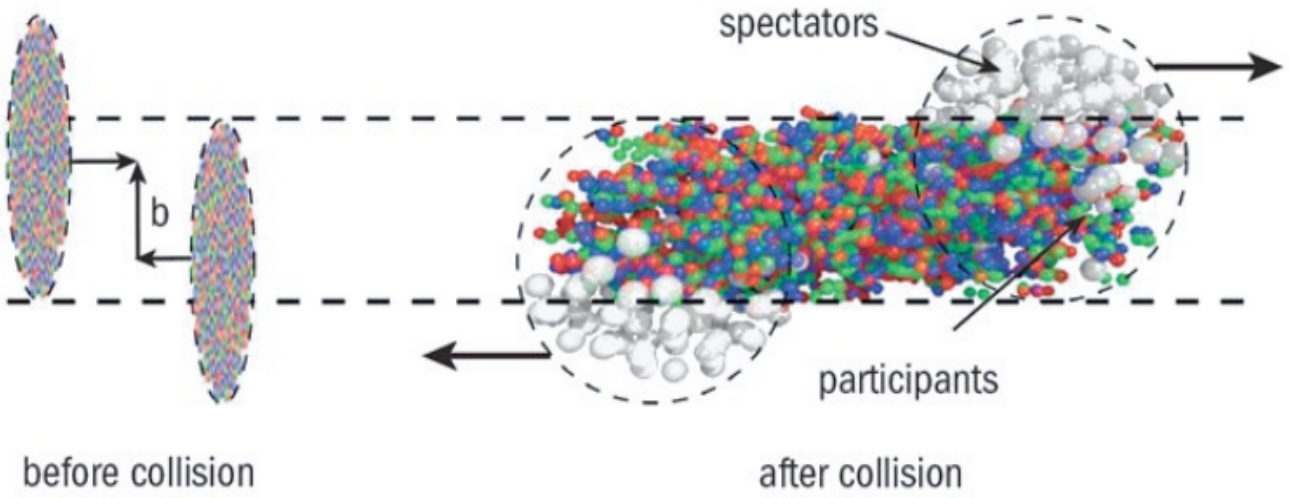
QGP to today

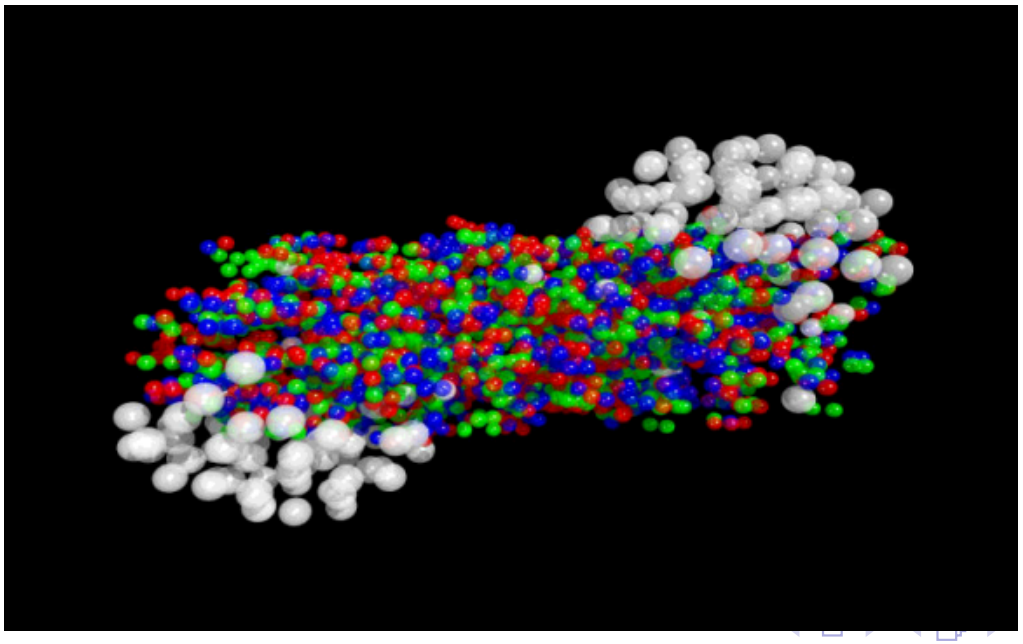
Evolution of Universe $\longrightarrow$





Heavy Ion Collisions





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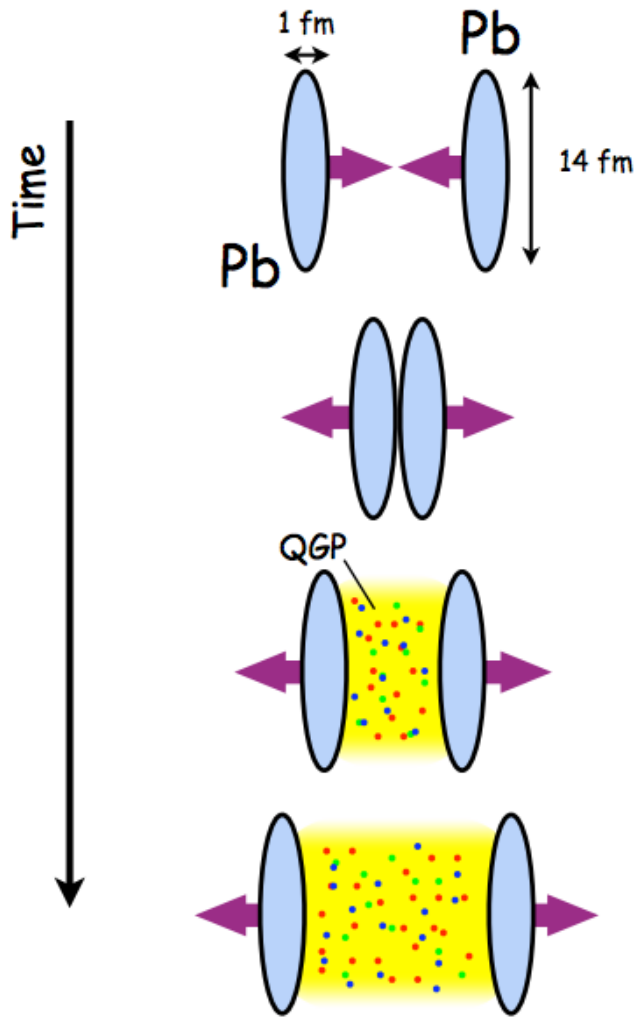


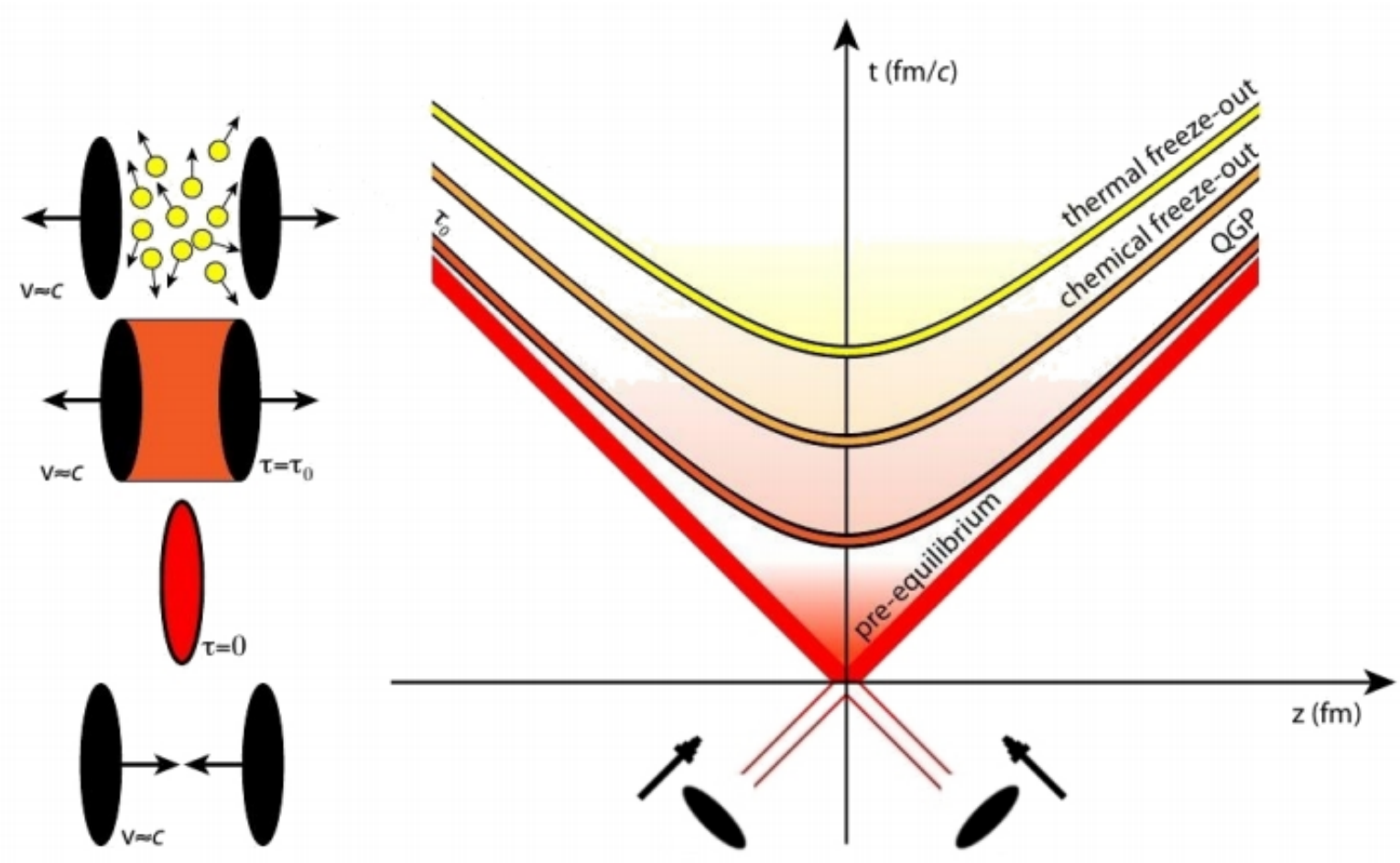
Heavy Ion Collision:
Ideal to get conditions at high T and ρ

Formation time $\tau_0 = 1$ fm/c
[1 fm/c = 3.3×10^{-24} s]

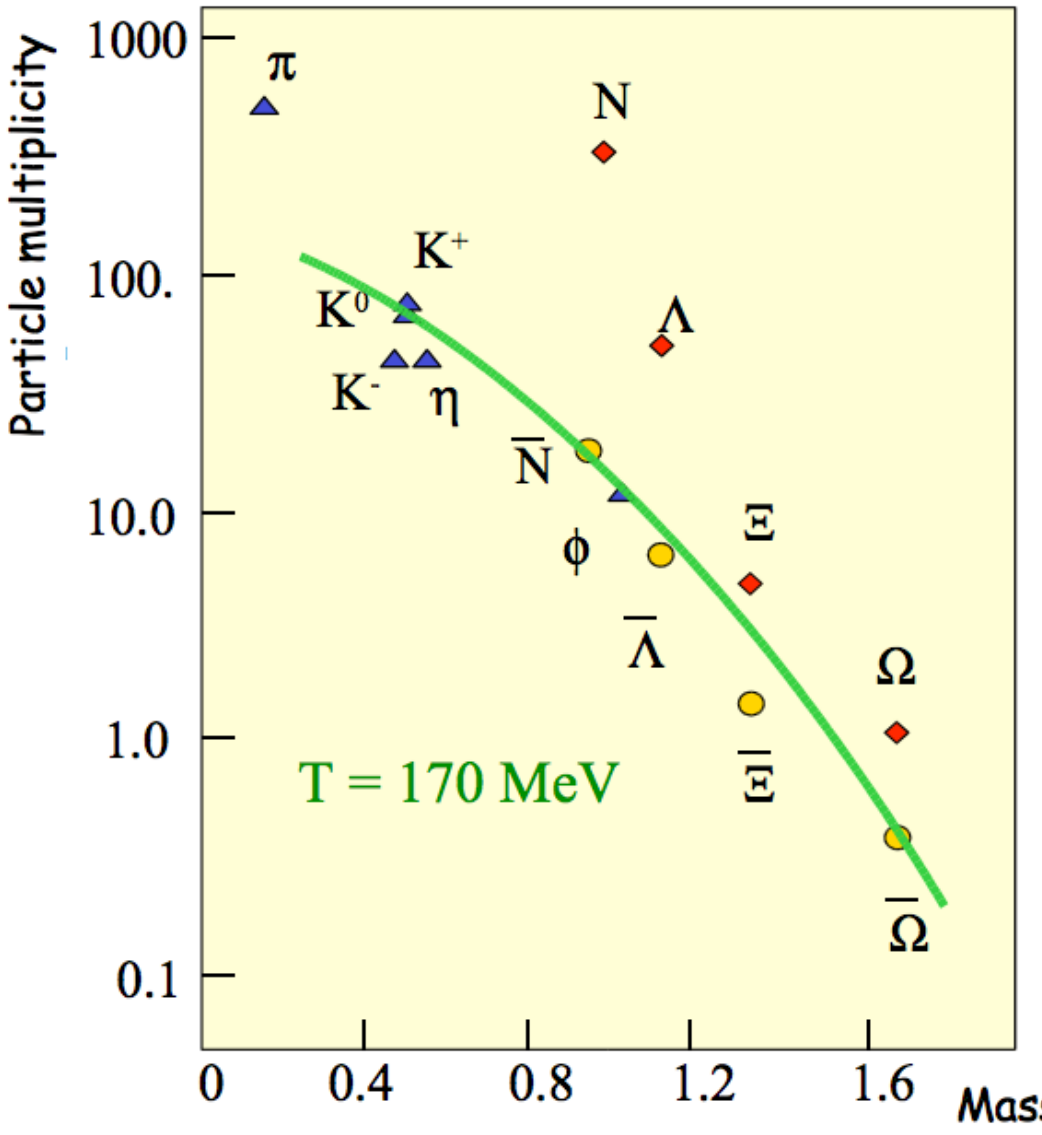
Temperature of $O(10^{12})$
Lifetime: 10 fm/c

QGP in equilibrium (!?)
Cool down: hadronization

Collision→(QGP)→Hadrons



Hadrons coming out of the QGP



Measured Particle Multiplicity

Consistent with particles being produced at:

$T \approx 170$ MeV

Signatures of the QGP

• Electromagnetic signatures: Photons, electrons, muons emitted from hot fireball (thermal radiation)

+: Mean free path much larger than fireball

→no final state interactions →direct probe of QGP phase

−: Small production rate, huge background from decay of π_0 and η

• Hadronic signatures: J/ψ-suppression, strangeness enhancement, jet quenching, ...

+: Large production rates

−: Final state interactions →modification of signal by hadronic phase

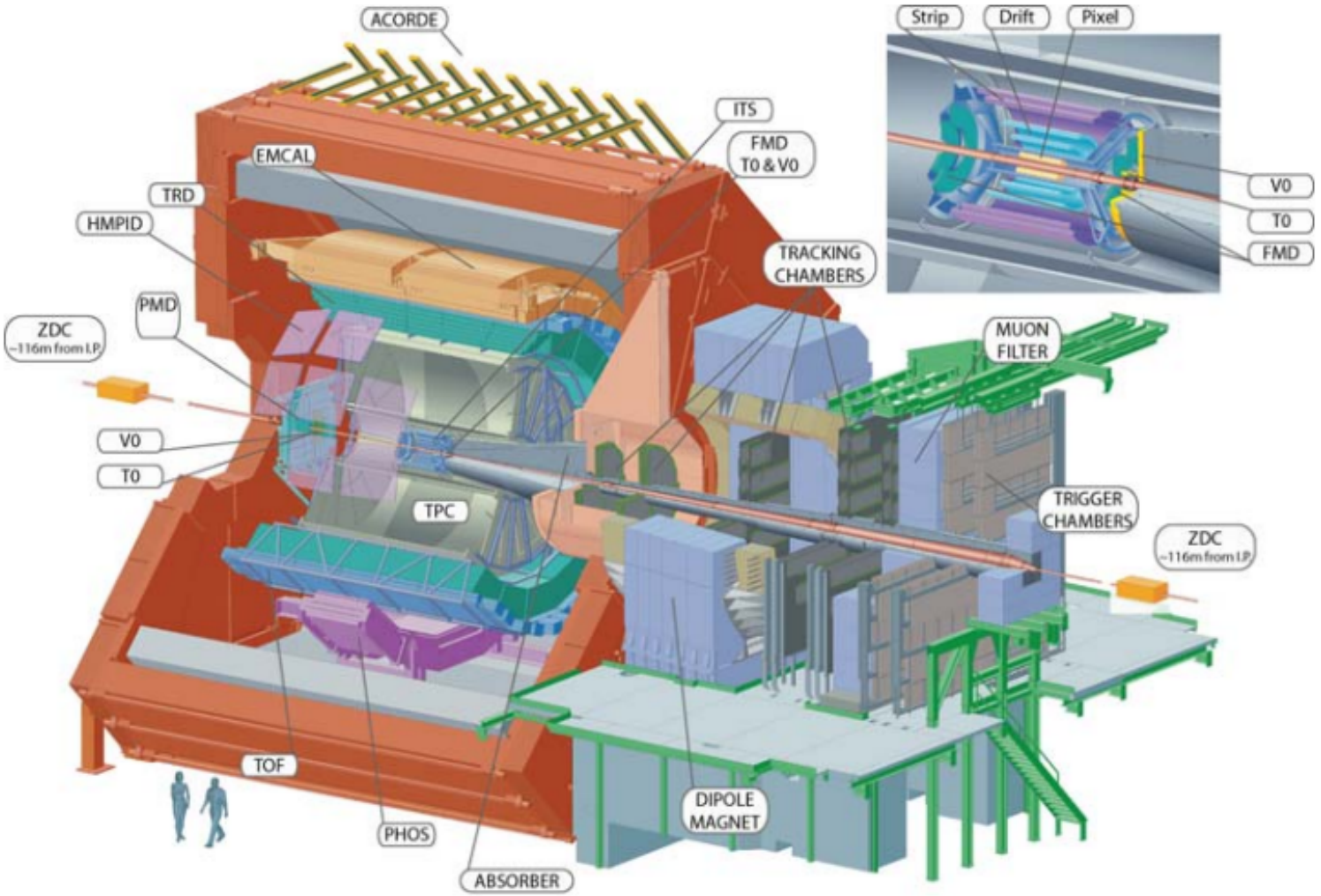
Signatures of the QGP

- Direct Photon Production
- Strangeness Enhancement
- J/Ψ suppression
- Jet Quenching
- Charged Particle Multiplicity

Physics Working Groups (PWGs)

- PWG-CF: Correlations and flow
- PWG-HF: Heavy Flavours
- PWG-LF: Light Flavour Spectra
- PWG-GA: Photons and Neutral Mesons
- PWG-JE: Jet Analysis
- PWG-DQ: Di-Leptons and Quarkonia
  - Low mass electron pairs (LMee)
  - Low mass muon pairs
  - J/Ψ electron decay ($J/\Psi \longrightarrow ee$)
  - J/Ψ muon decays ($J/\Psi \longrightarrow \mu\mu$)
  - Upsilon muon decays ($\Upsilon \longrightarrow \mu\mu$)

ALICE detector overview



- Height: 26m
- Width: 16m
- Weight:10k tons

ALICE subdetectors1

- ZDC and FMD: Located about 110 meters on both sides of ALICE (the ZDC: Zero Degree Calorimeter) and by measuring with the FMD:Forward Multiplicity Detector, T0, and V0 the number of particles produced in the collision and their spatial distribution. T0 also measures with high precision the time when the event takes place
- An ensemble of cylindrical detectors (from inside out: ITS Pixels, ITS, ITS Drift, ITS Strips, TPC, TRD)
  - Measures the passage of each particle carrying an electric charge at many points
  - Embedded in a magnetic field (produced by the huge red magnet)

ALICE subdetectors2

- TOF:measures, with a precision better than a tenth of a billionth of a second, the time that each particle takes to travel from the vertex to reach it, so that one can measure its speed.
- HMPID: measures the faint light patterns generatedby fast particles and the TRD measures the special radiation very fast particles emit when crossing different materials, thus allowing to identify electrons.
- Muons are measured by exploiting the fact that they penetrate matter more easily than most other particles: in the forward region a very thick and complex absorber stops all other particles and muons are measured by a dedicated set of detectors: the muon spectrometer.

Analysis Softwares and Tools

- Data generation/Acquisition $\rightarrow$ Simulation $\rightarrow$ Reconstruction $\rightarrow$ Analysis $\rightarrow$ Results
- Data either via generated files (simulated and reconstructed), or real data processed after triggering and standard reconstruction
- Analysis package mainly based on ROOT (but AliROOT).
- Object Oriented C++ programming codes (a few exceptions)
- Results redundancy internally

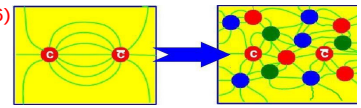
COMSATS in ALICE Collaboration

- R & D
  - Inner Tracking System (ITS) Upgrade.
  - Working on Improvement of Geometry of the depletion region of silicon sensors.
- Computing and Grid
  - Grid Node hosted at the CIIT.
  - Providing storage and computing facilities for the online submitted jobs
- Physics Analysis
  - 2 Groups working on different channels.
  - Jet Energy measurements and charged particle multiplicity.
  - J/*Psi* to muons decay in dilepton and quarkonia channel.

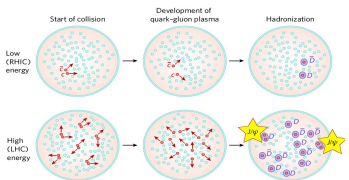
Some results from ALICE presented at ICHEP 2016

Quarkonia

- Color screening (Matsui and Satz 1986)
  - Sequential suppression (Digal, Petreczcy, Satz 2001)

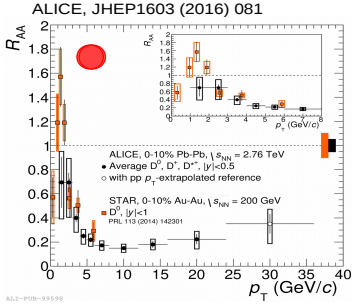


- Copious heavy-quark production at LHC
  - ~100 $c\bar{c}$ and 5-6 $b\bar{b}$ in central Pb-Pb collisions
- Charmonium creation at the phase boundary (Braun-Munzinger, Stachel 2000)
- Continuous melting and regeneration (Thews et al. 2001)



D meson suppression in AA collisions

ALICE, JHEP1603 (2016) 081

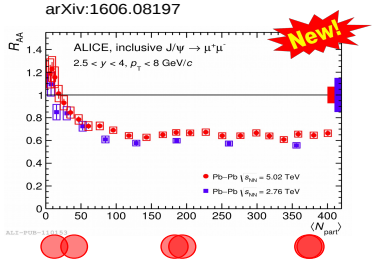


- Strong suppression of D-meson yields in the most central Pb-Pb collisions at mid-rapidity
- Results by STAR at $\sqrt{s_{NN}}$=200 GeV indicate that R_{AA}>1 at low p_T
  - Expected from charm conservation

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \times \frac{Y_{AA}}{Y_{pp}} = \frac{medium}{vacuum}$$

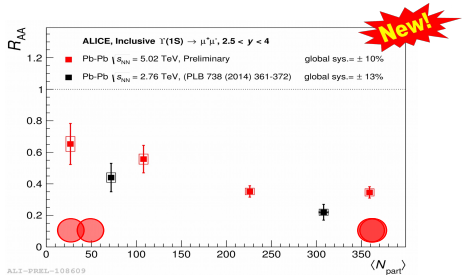
Inclusive J/ψ suppression in Pb-Pb collisions at 5.02 TeV

arXiv:1606.08197



- Similar suppression levels at both 5.02 and 2.76 TeV with nearly no centrality dependence for N_{part}>100

Υ(1S) suppression in Pb-Pb collisions at 5.02 TeV



- Bottomonium is much less affected by regeneration effects → cleaner probe for the medium properties
- A strong Υ(1S) suppression is observed in central collisions at both 2.76 and 5.02 TeV

- Hint of an increase of RAA with energy in central collisions. Good agreement between data and models which include J/ψ regeneration
- Bottomonium is much less affected by regeneration effects $\rightarrow$ cleaner probe for the medium properties. A strong $\Upsilon(1S)$ suppression is observed in central collisions at both 2.76 and 5.02 TeV

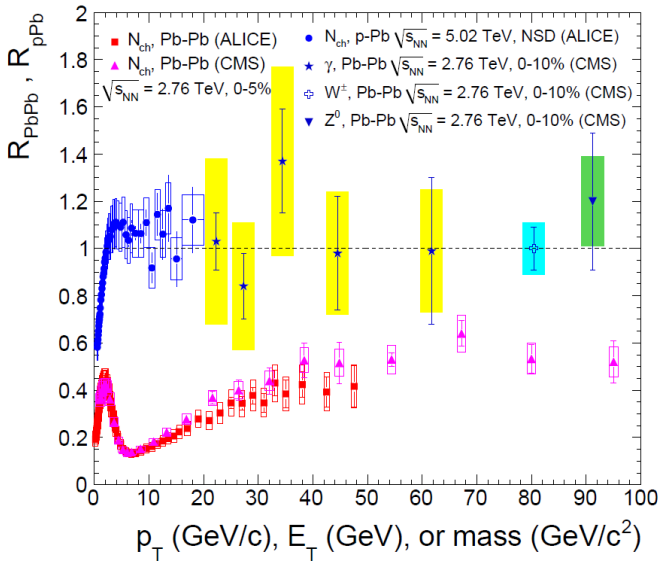
Conclusions

- Open heavy flavors
  - Strong modification of the charm and beauty kinematics in Pb-Pb collisions w.r.t. pp collisions, with a significant centrality dependence
  - Indication of stronger charm suppression w.r.t. beauty → quark-mass dependent energy loss
  - Positive D-meson elliptic flow
  - No large CNM effects supported by the p-Pb data → the strong suppression in central Pb-Pb collisions is largely a hot medium effect
- Quarkonia
  - New results on J/ψ suppression in Pb-Pb collisions at 5.02 TeV indicate similar suppression level as the 2.76 TeV data
  - The p_{T} dependence of the J/ψ suppression suggests an important contribution from regeneration
  - The new Y(1S) results at 5.02 TeV confirm the strong suppression observed in central Pb-Pb collisions at 2.76 TeV
- Next steps and questions:
  - Measure open heavy-flavor suppression down to p_{T}=0
  - Understand and disentangle CNM effects
  - Is the observed open heavy-flavor v_2 of hydro origin ?
  - Does J/ψ flow ?
  - Is the direct Y(1S) suppressed ?
- More Run-2 results coming soon !

Thanks

Back Up1

Medium effects (the nuclear modification factor)



p-Pb, ALICE PRL110(2013)082302
Pb-Pb, ALICE, Phys.Lett.B720 (2013)52
Pb-Pb, CMS, EPJC (2012) 72

γ, CMS, PLB 710 (2012) 256
$W^{\pm}$, CMS, PLB715 (2012) 66
Z^0, CMS, PRL106 (2011) 212301

$$R_{AA} = \frac{1}{N_{coll}} \times \frac{Y_{AA}}{Y_{pp}}$$

- N_{coll}: the number of binary nucleon-nucleon collisions
- Superposition of NN collisions → $R_{AA}=1$
  Suppression → $R_{AA}<1$
  Enhancement → $R_{AA}>1$
- Weakly interacting particles are not affected by the QGP
  - Photons, $W^{\pm}$ and Z^0 bosons R_{AA} are compatible with 1