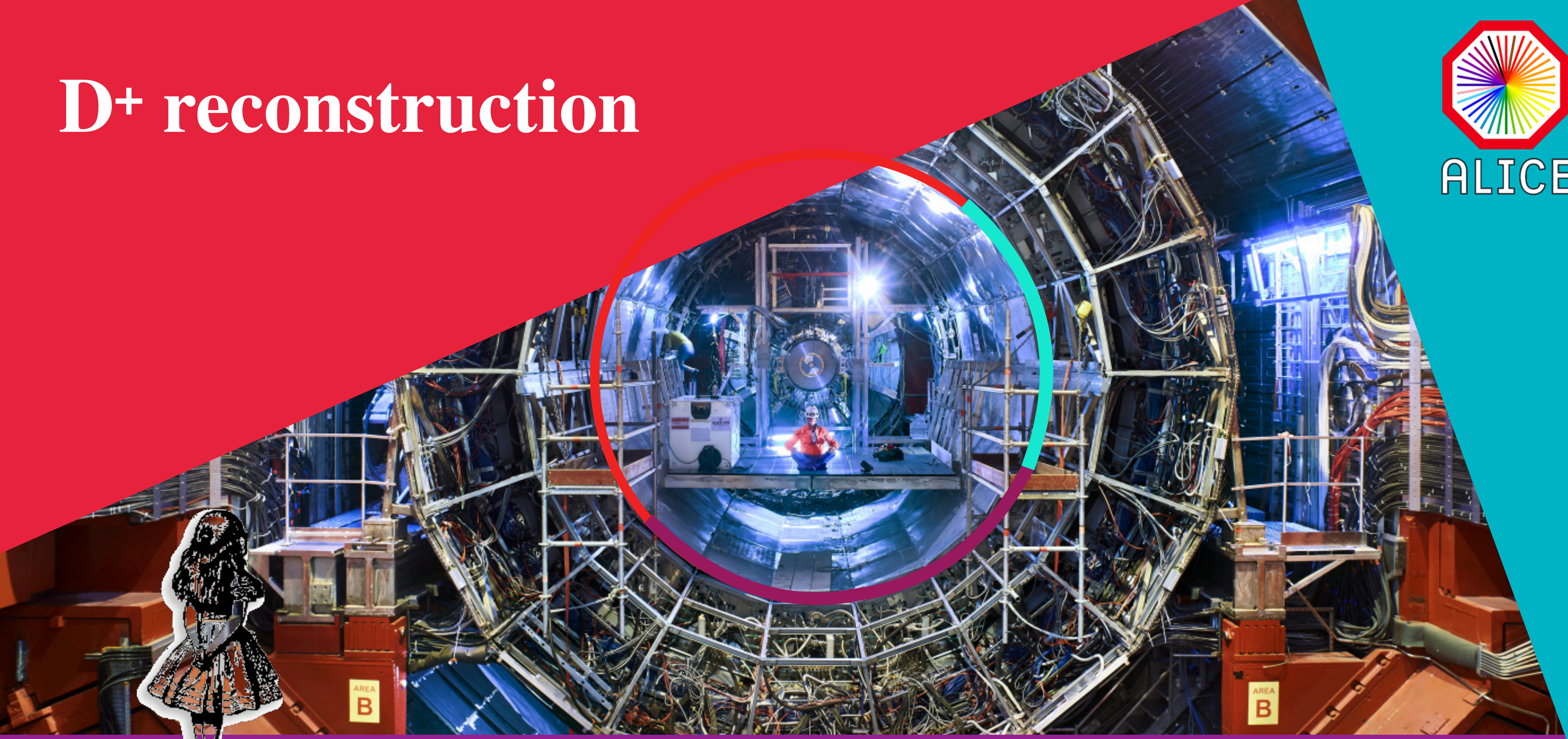
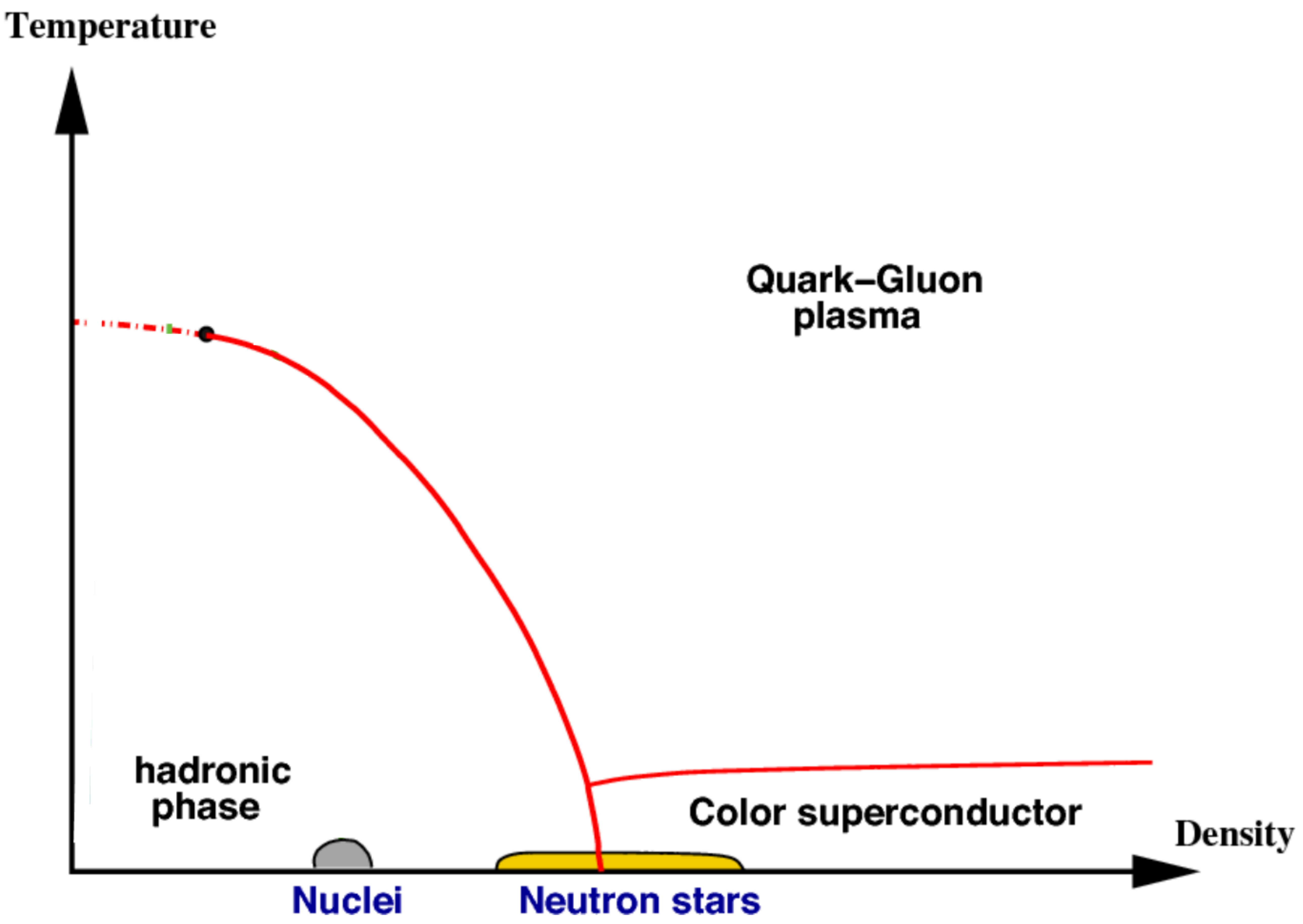
D^+ reconstruction



ALESSANDRO GRELLI

QCD Phase Diagram



arXiv:1205.0579 [hep-ph]

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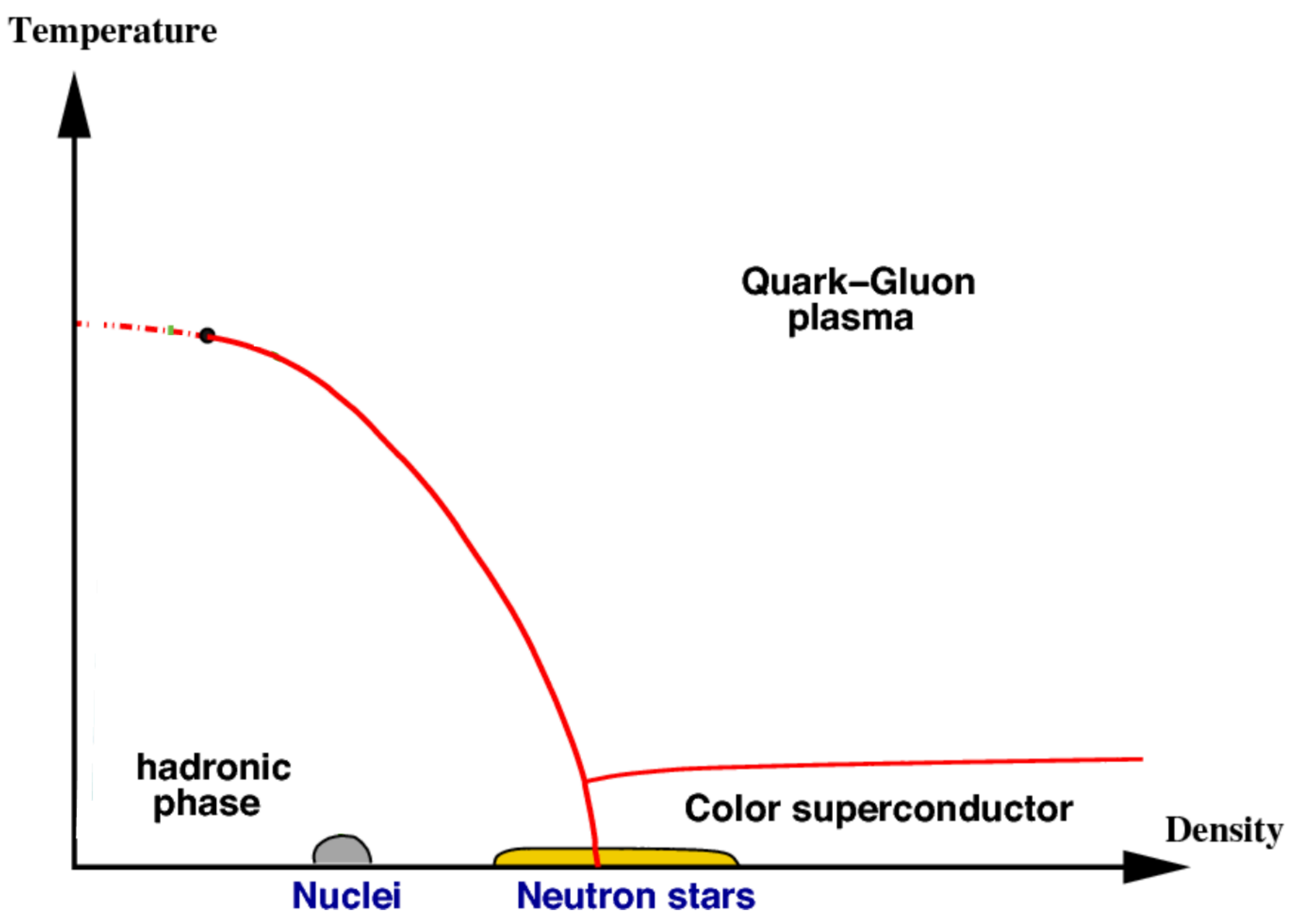
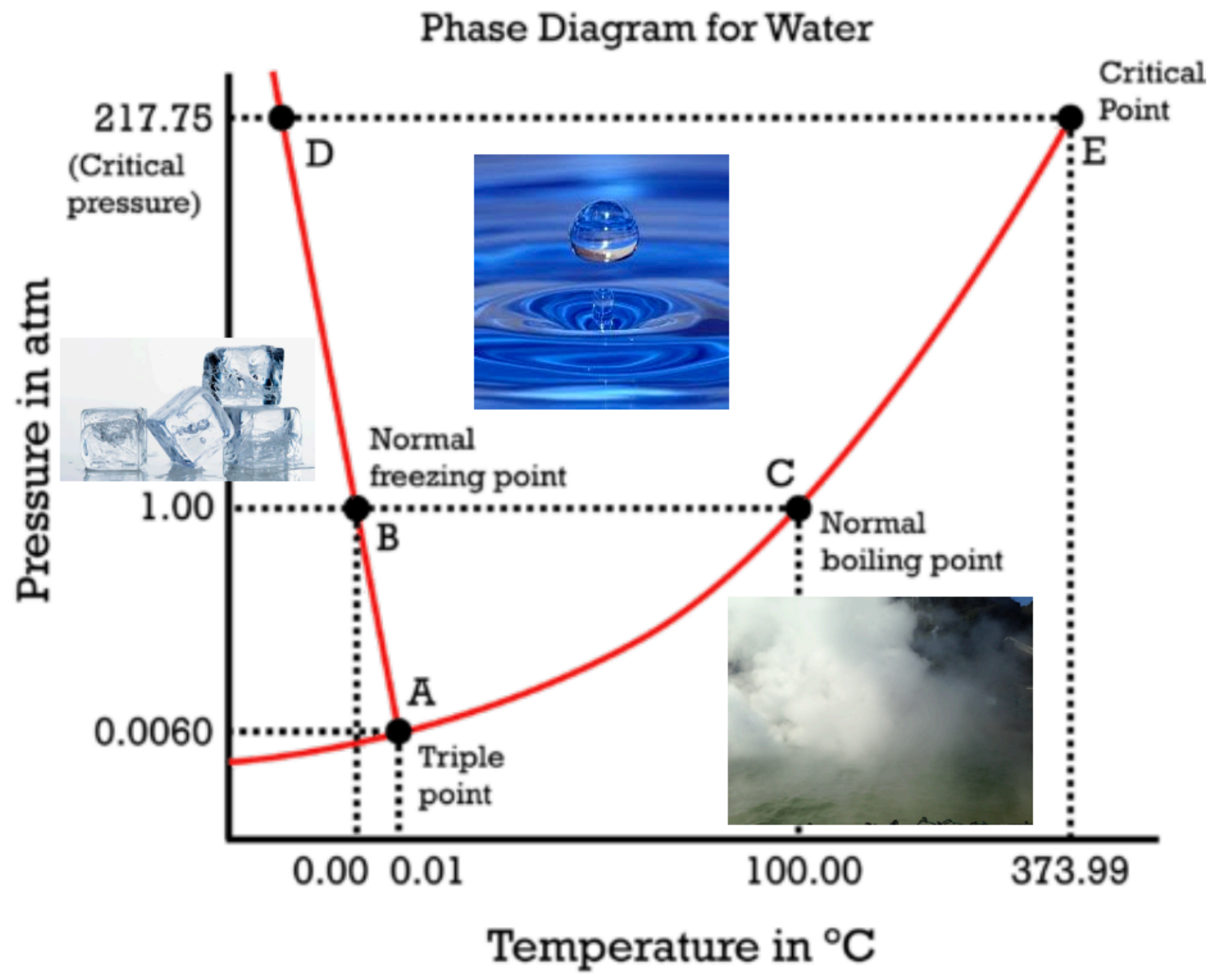
QCD Phase Diagram





arXiv:1205.0579 [hep-ph]

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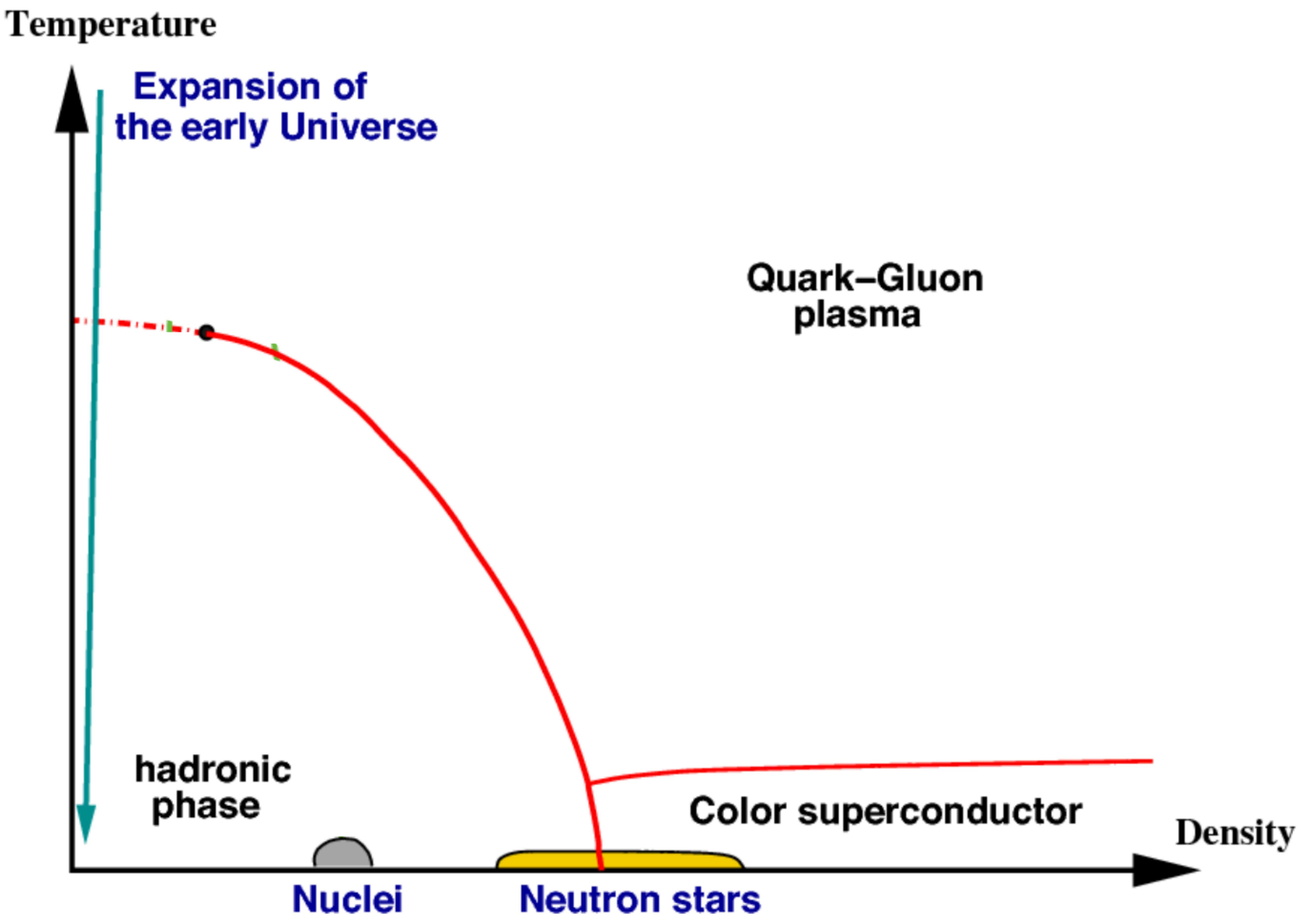

arXiv:1205.0579 [hep-ph]

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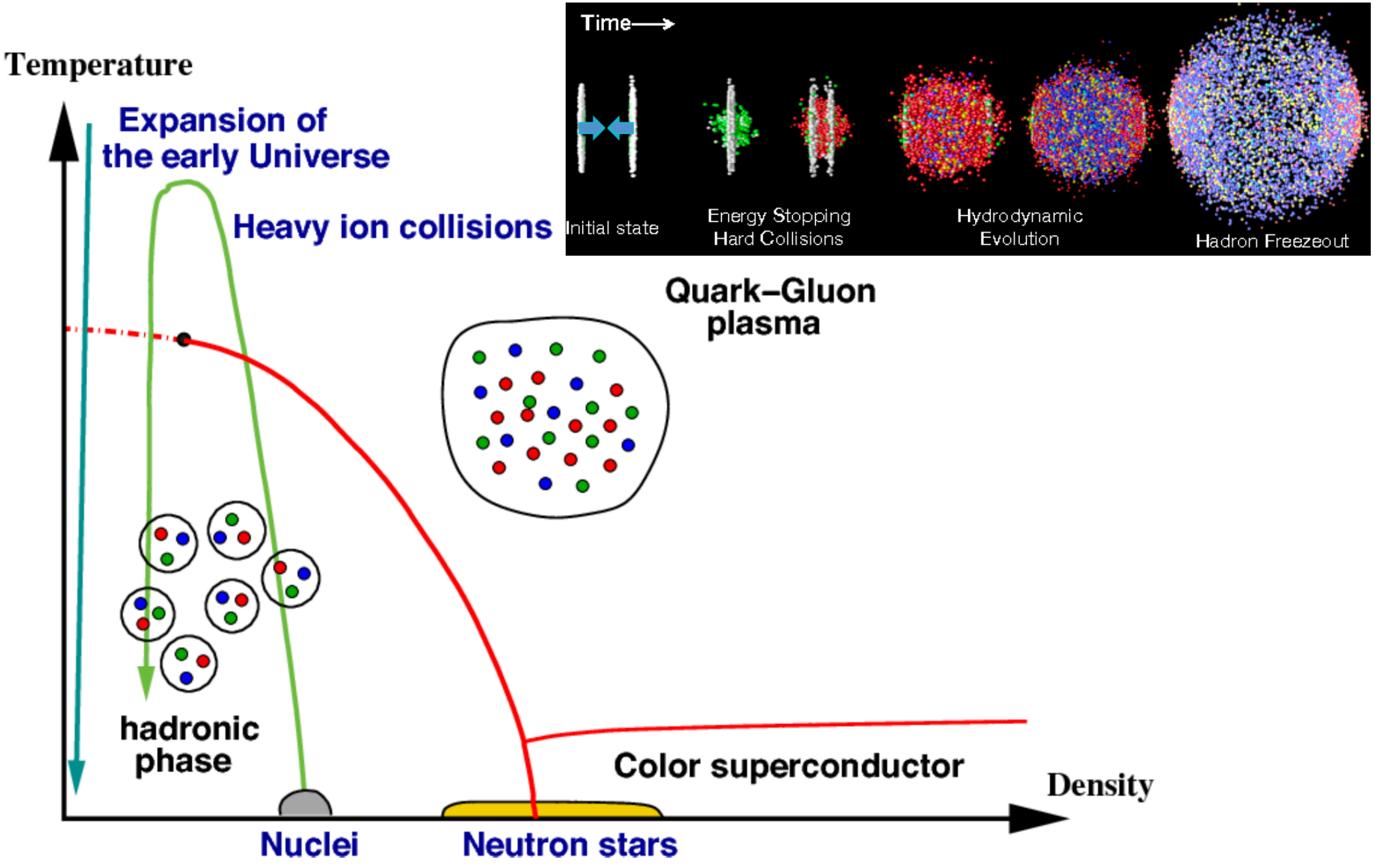
QCD Phase Diagram



arXiv:1205.0579 [hep-ph]

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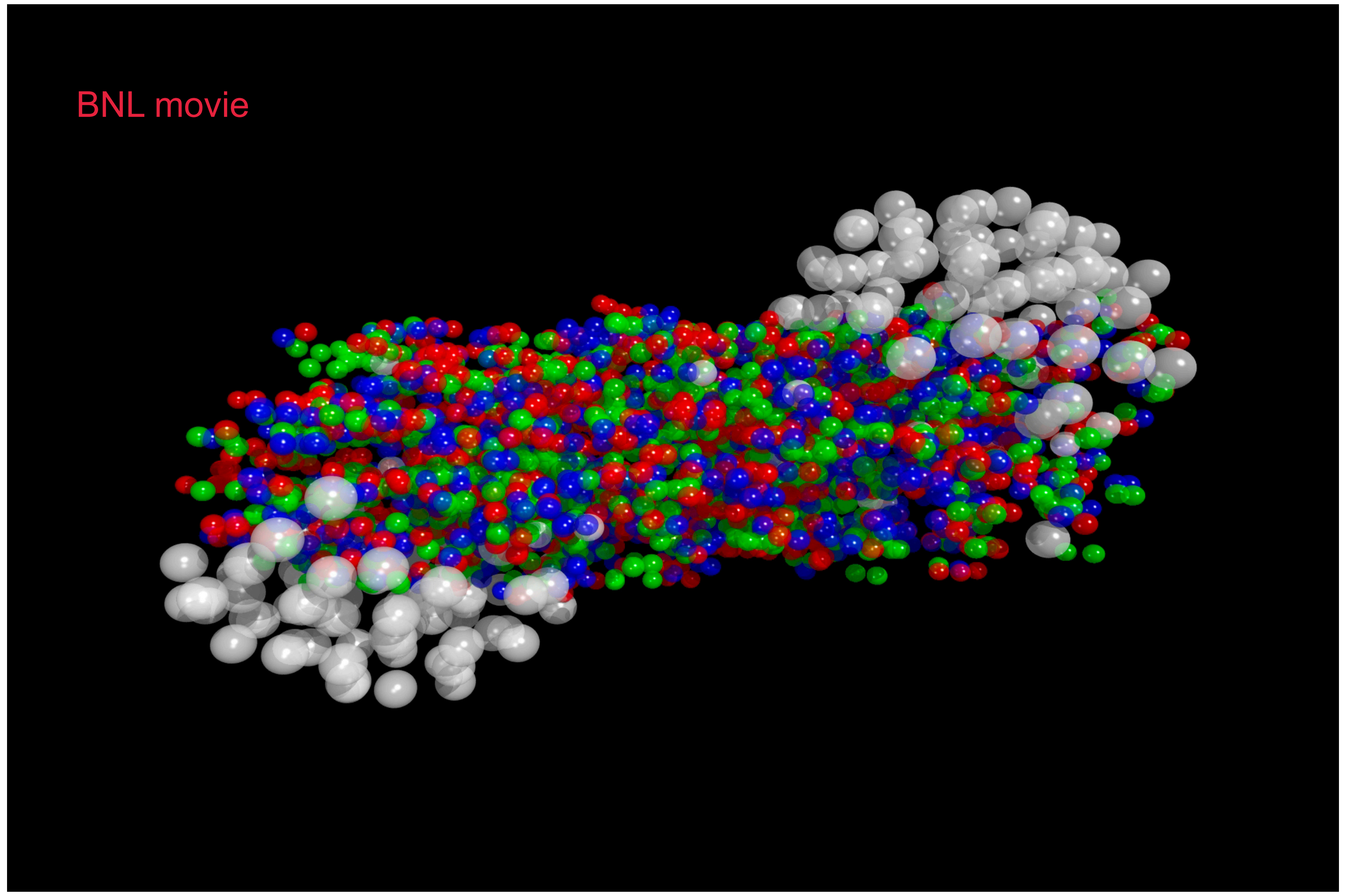
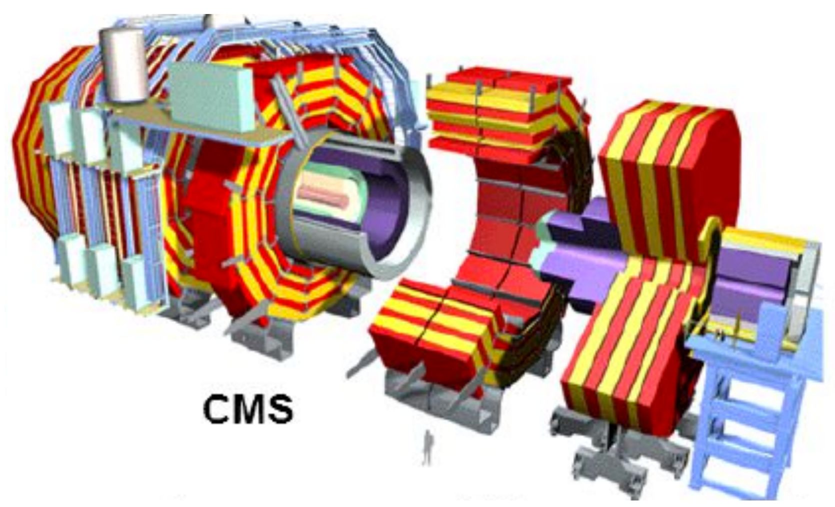
Heavy-ion collisions

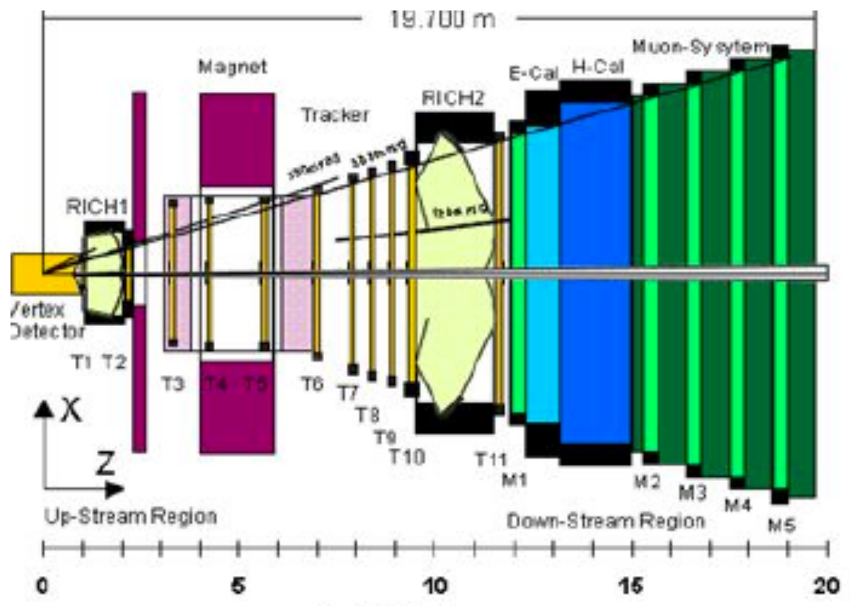
- ☑ The QGP formed is expected to be ~10^{-15} m in size and to live about 10^{-15} s

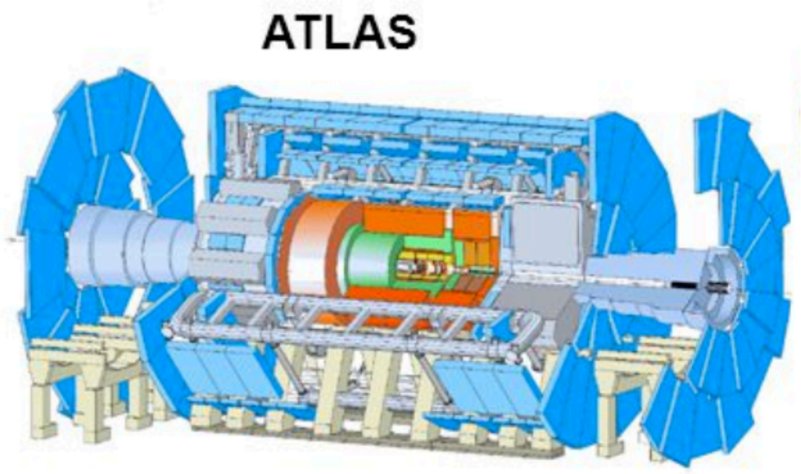


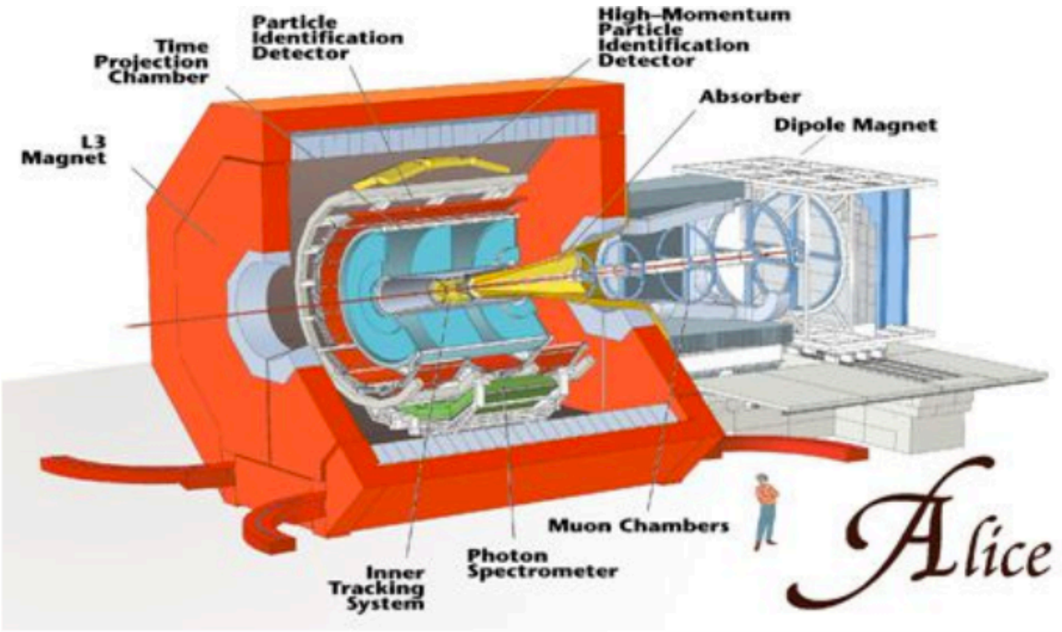
Our experimental setup

The Large Hadron Collider





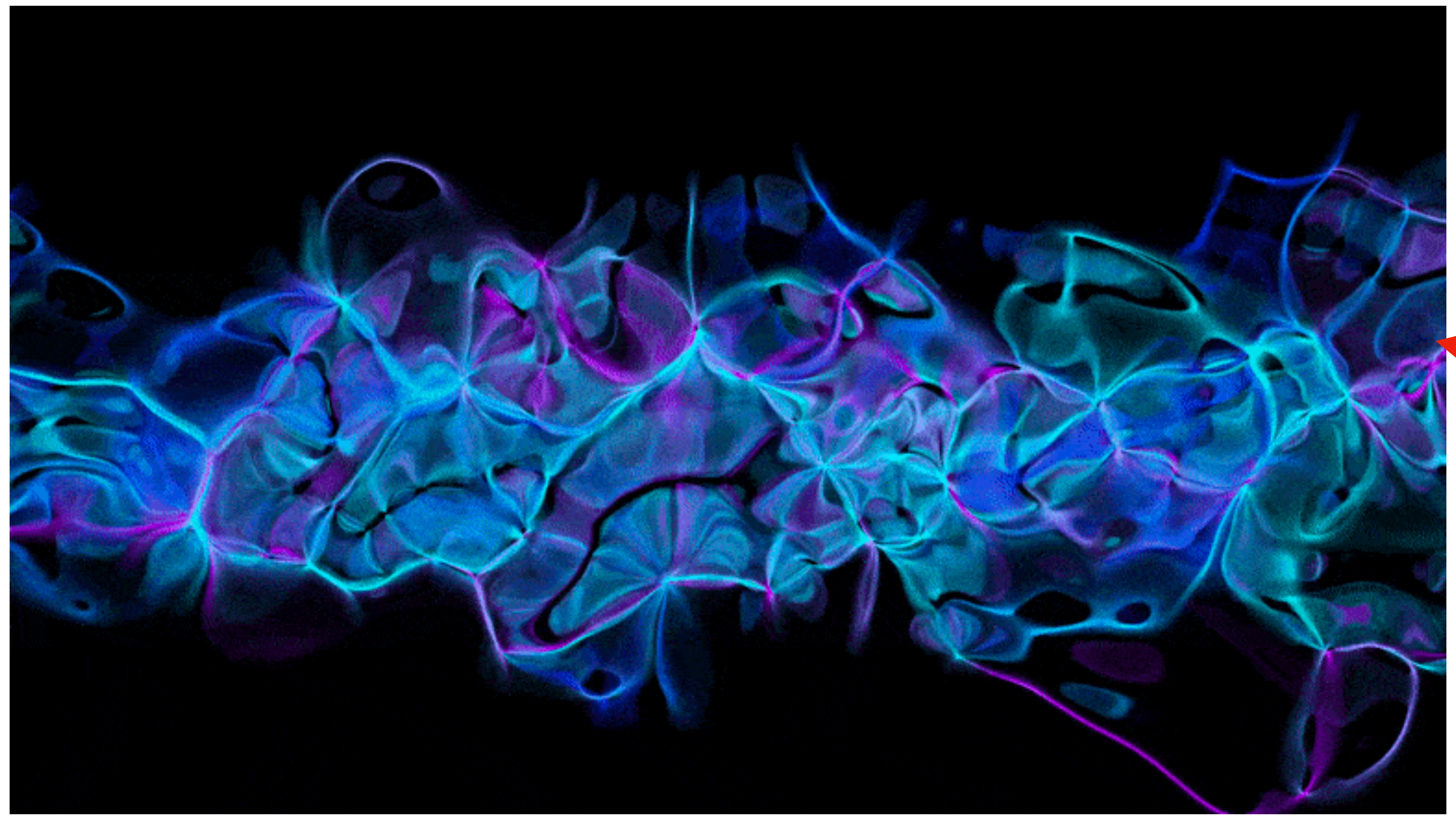


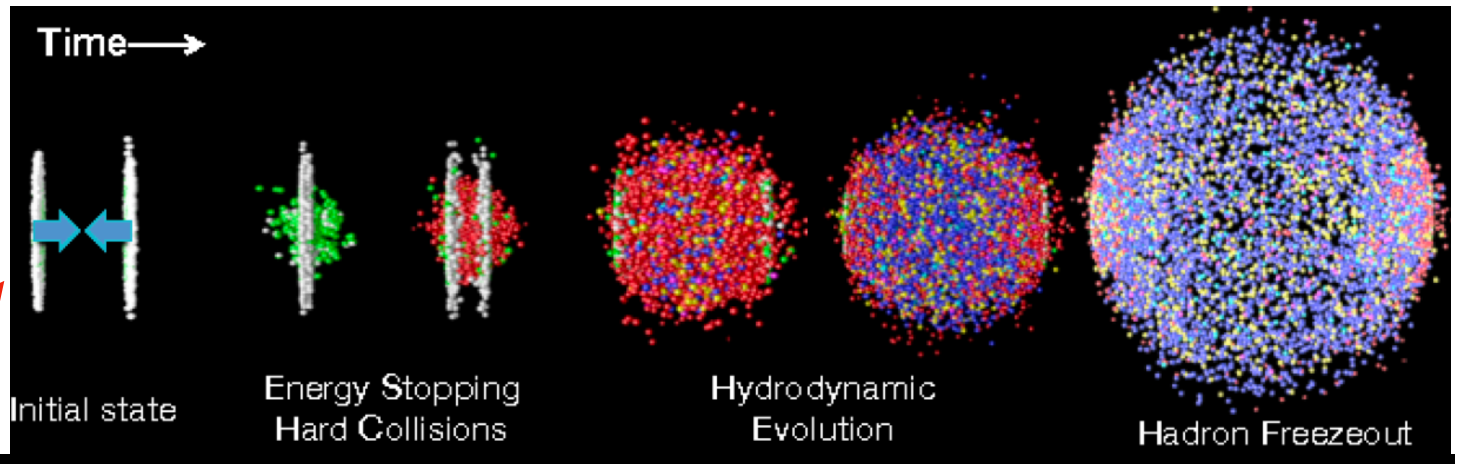


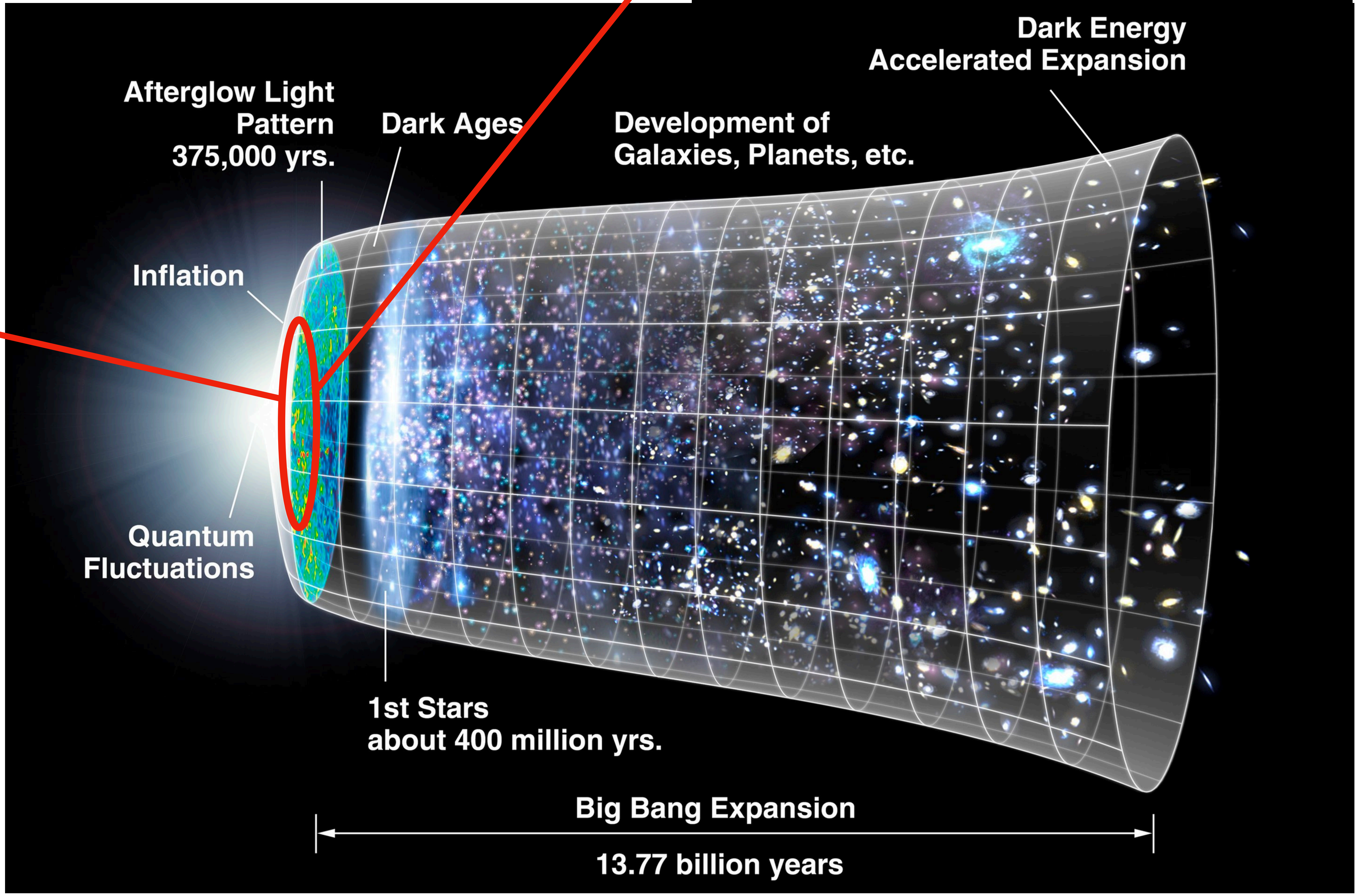
The largest machine ever built by mankind (27km circumference)

What about the Universe

About **10^{-6} s** after the Big Bang all the matter of our Universe was in a Quark-Gluon Plasma state (QGP)







Do you know that the ratio viscosity/density of QGP is almost the same as water?

- **Fun fact:** if you take a bottle of water and let the water come out from the tap, well the QGP would flow out in the exactly same way!

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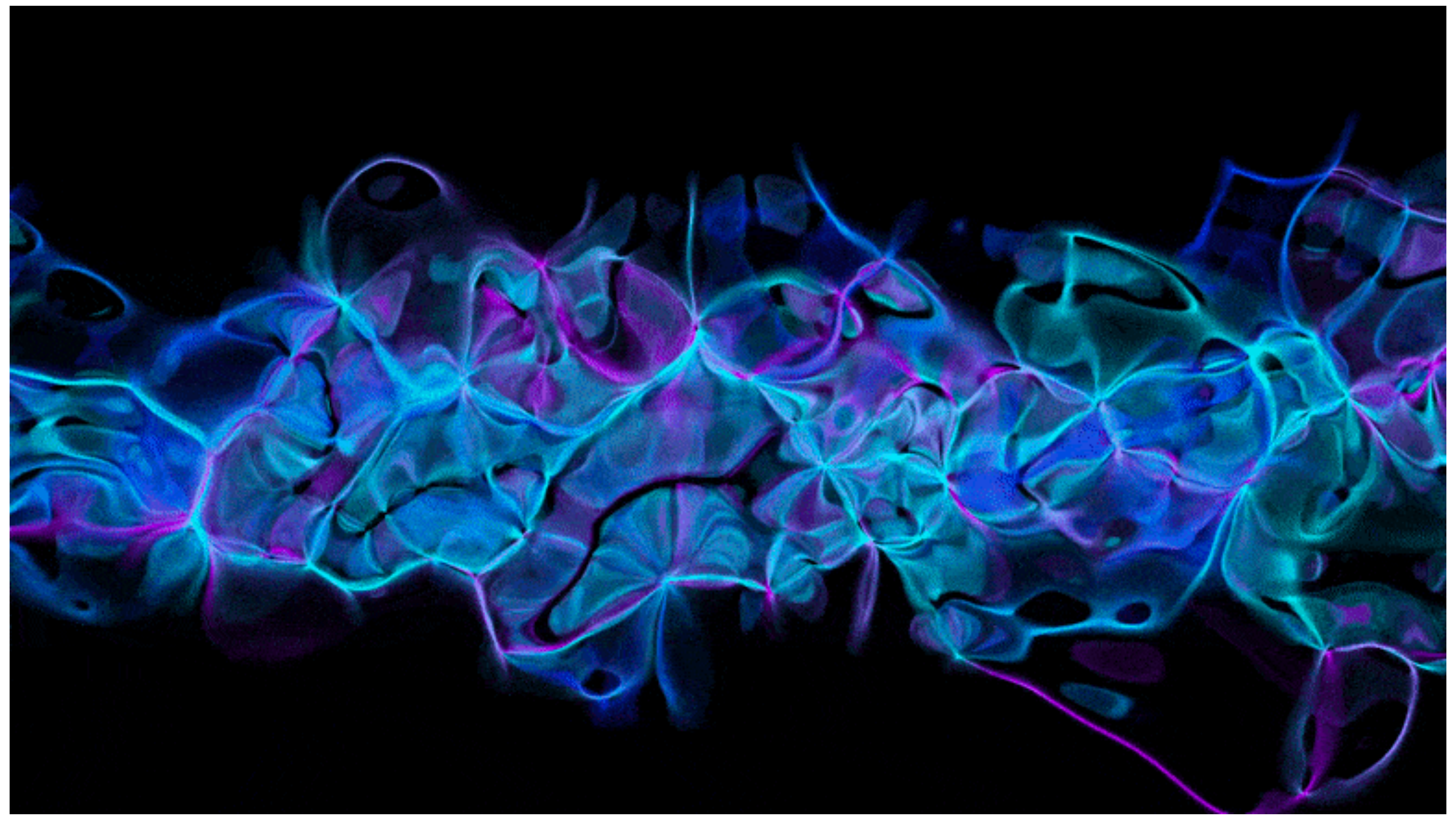

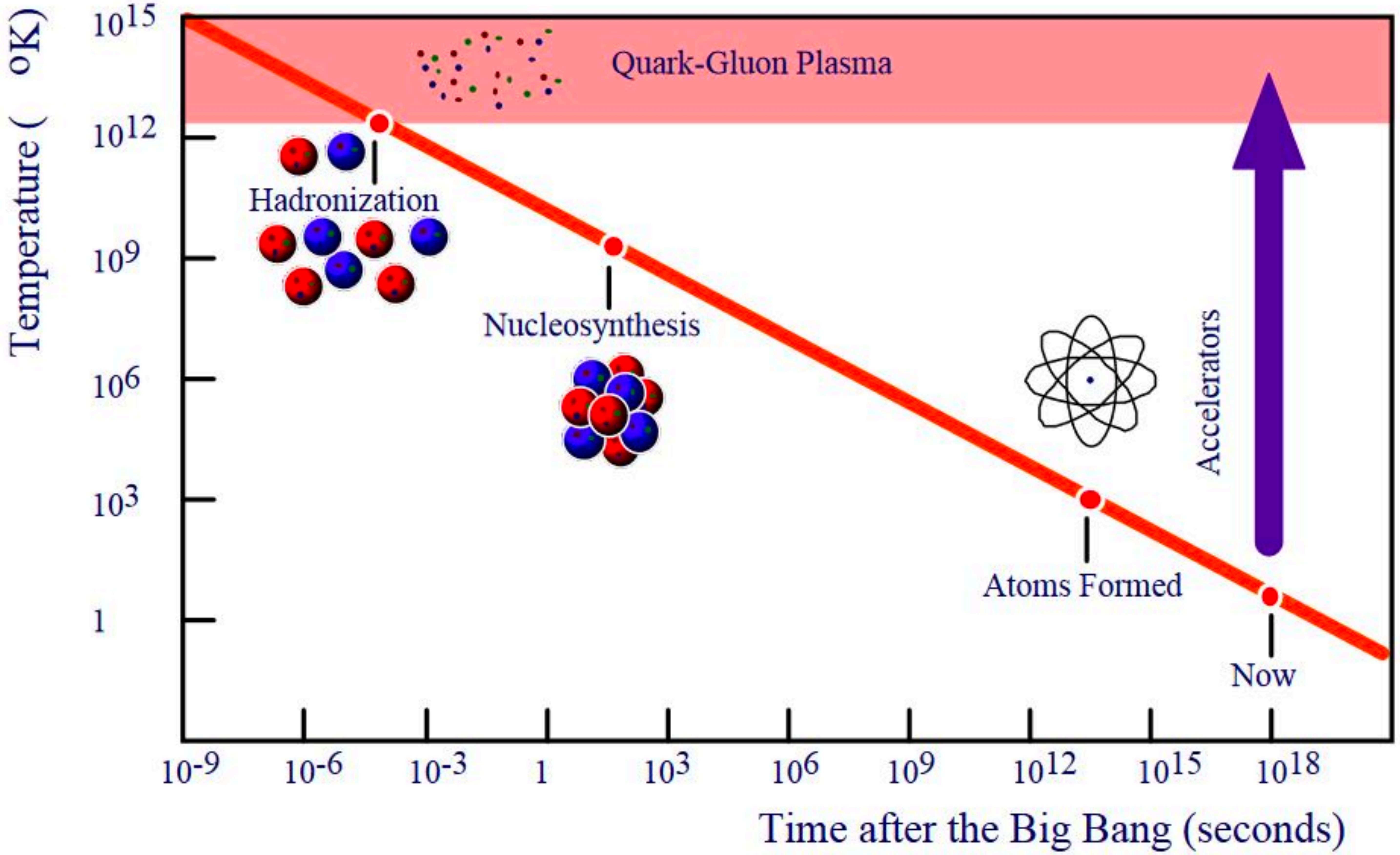

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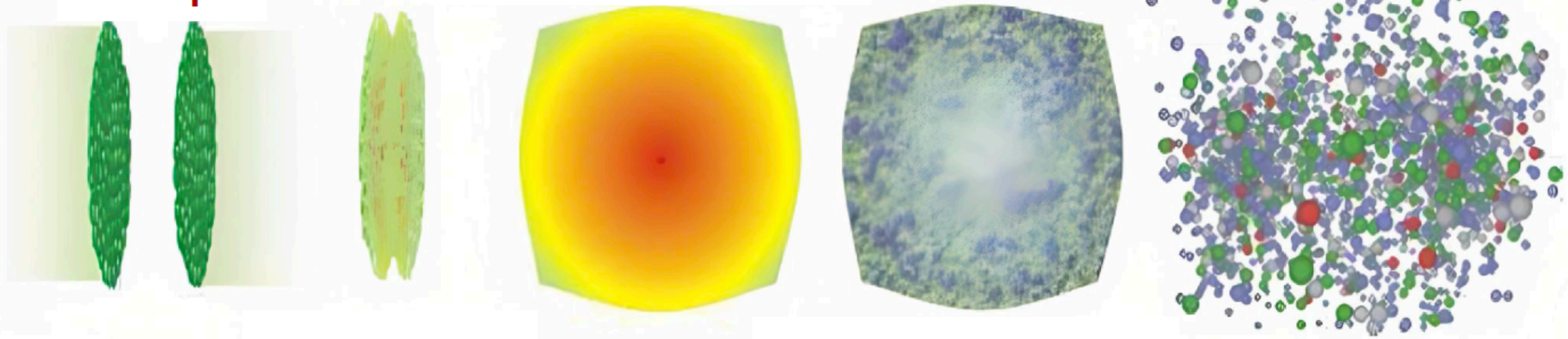
Heavy-ion collisions

$\tau \sim 0$ fm/c $\tau \sim 1$ fm/c $\tau \sim 10$ fm/c $\tau \sim 10^{15}$ fm/c

Initial and pre-equilibrium phase

Hadronisation



QGP phase

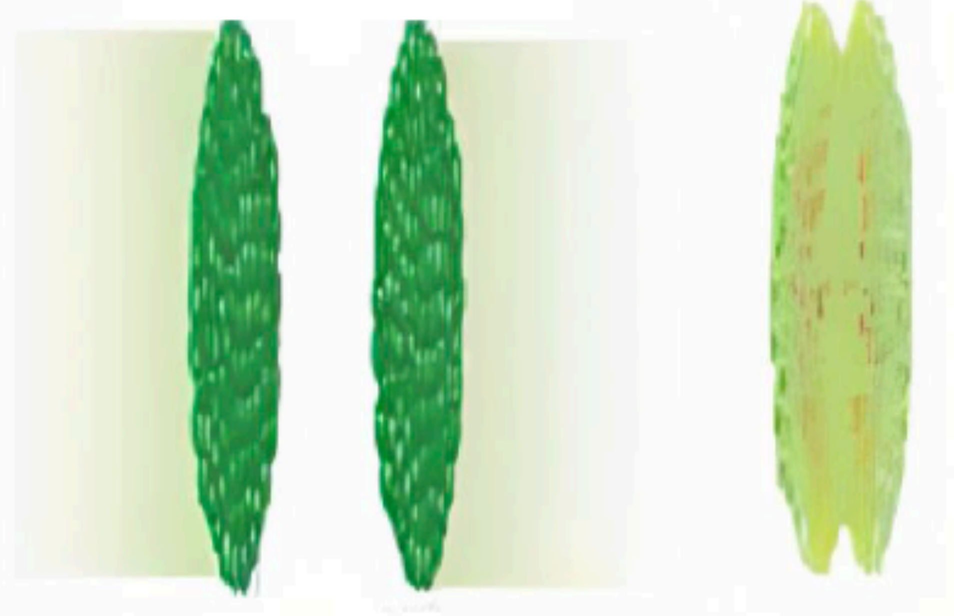
Hadronic phase and rescattering

- ☑ Just to give an idea temperatures generated exceed the **2×10^{12} K** (~500.000 times larger than the core of the Sun)

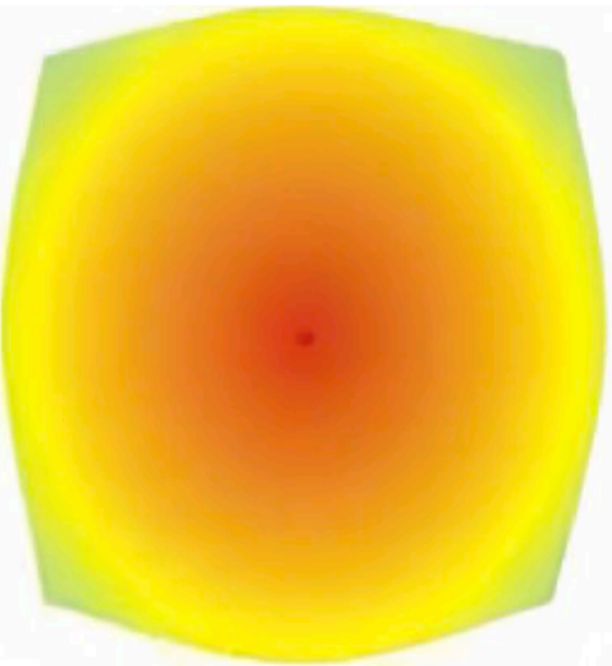
Heavy-ion collisions

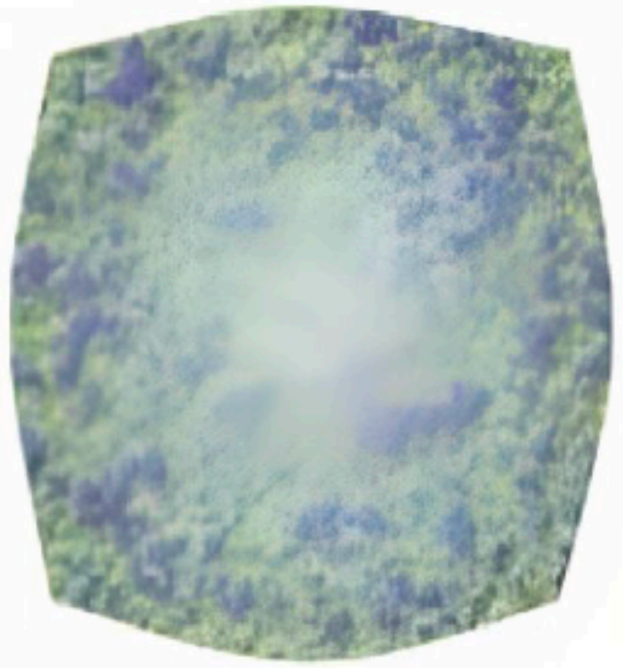
$\tau \sim 0$ fm/c | $\tau \sim 1$ fm/c | $\tau \sim 10$ fm/c | $\tau \sim 10^{15}$ fm/c

Initial and pre-equilibrium phase

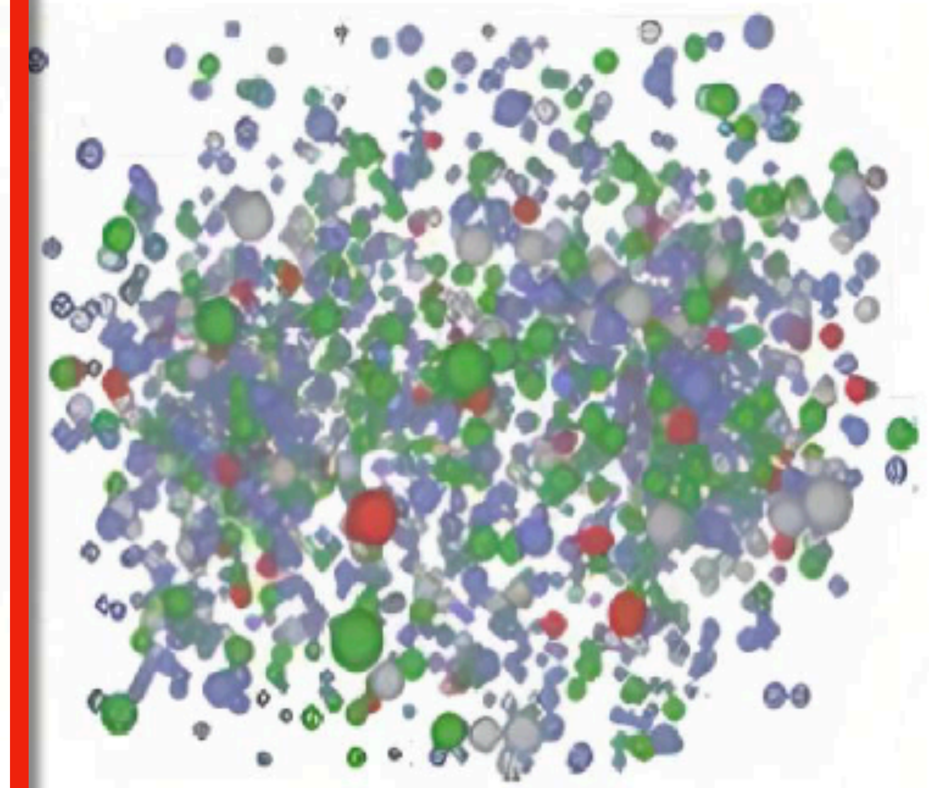


Hadronisation





QGP phase



Hadronic phase and rescattering

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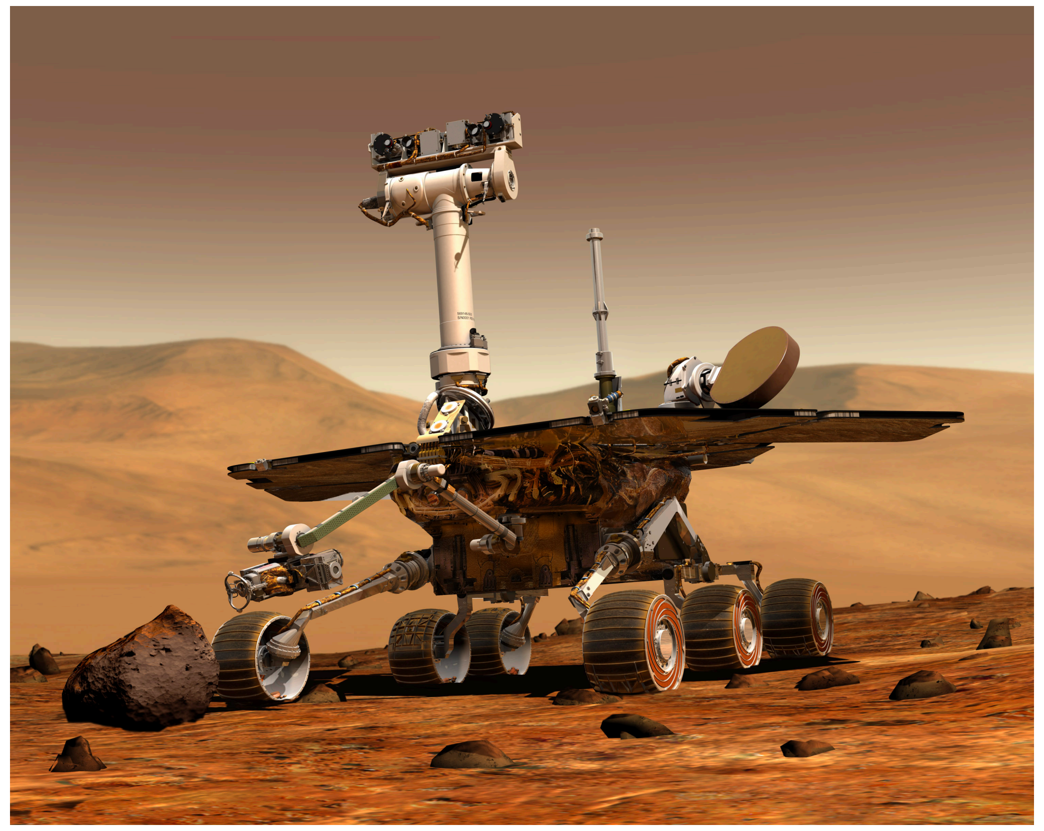
How to probe QGP



Hard probes (charm and beauty quarks):

- Produced at the early stage of the collision (*large mass requires high Q^2, $\Delta t \sim 0.01$-0.13 fm*)
- pQCD can be used to calculate initial cross sections

$\tau_{charm} \sim 1/2m_c \sim 0.1$ fm/c

- Traverse the hot and dense medium:
  - ✓ Thermal production in the medium from QGP expected to do not play a major role (depend from initial temperature)
  - ✓ Thermal production from hadronic matter (i.e $\pi N \rightarrow \Lambda_c D$) expected to play a minor effect

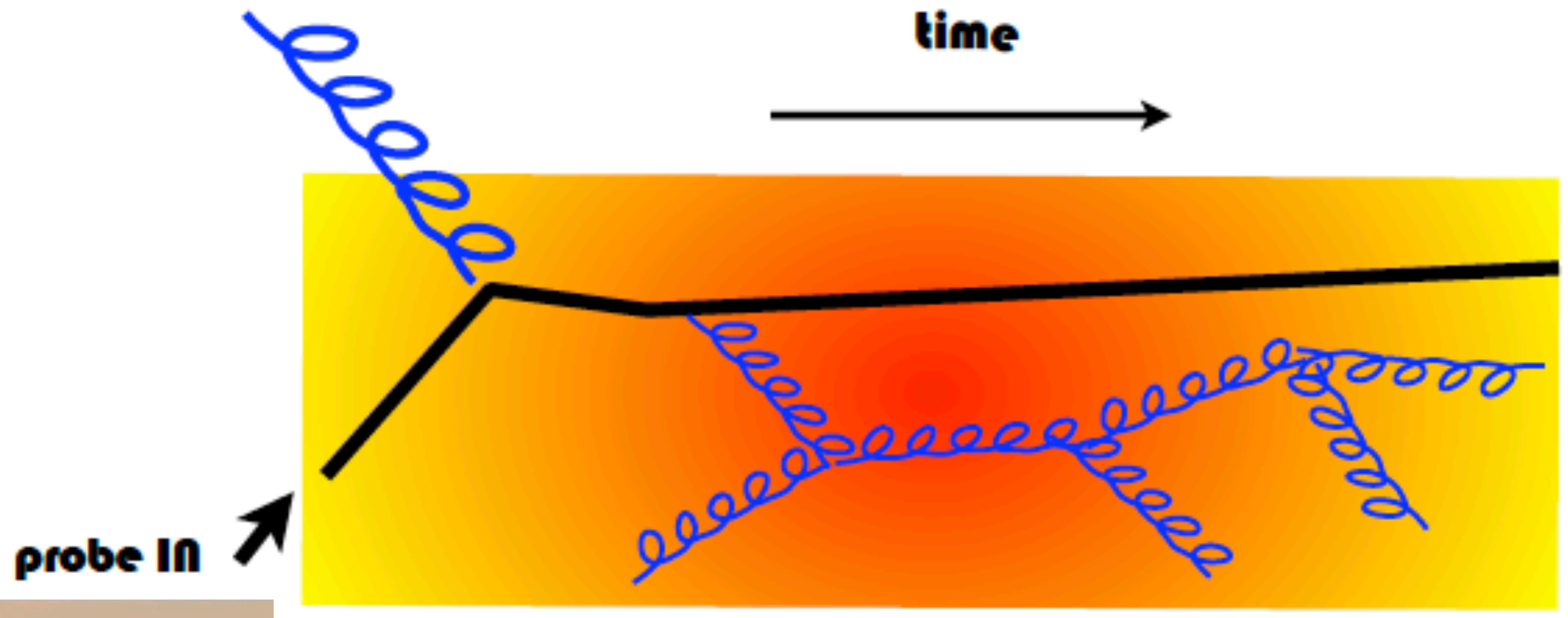
Phys. Rev. C56, 2707 (1997)

How to probe QGP

☑ Heavy quarks are expected to lose less energy than light quarks and gluons due to color-charge and dead cone effect → higher penetrating power into QCD medium.

Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B 519 199-206 (2001).
Armesto, Carlos A. Salgado and Urs A. Wiedemann. PRD 69 (2004) 114003

M. Djordjevic, M. Gyulassy, Nucl. Phys. A733 (2004) 265.



E_{loss}(light) > E_{loss}(charm) > E_{loss}(beauty)

➔ *Let's see it a bit more in detail*

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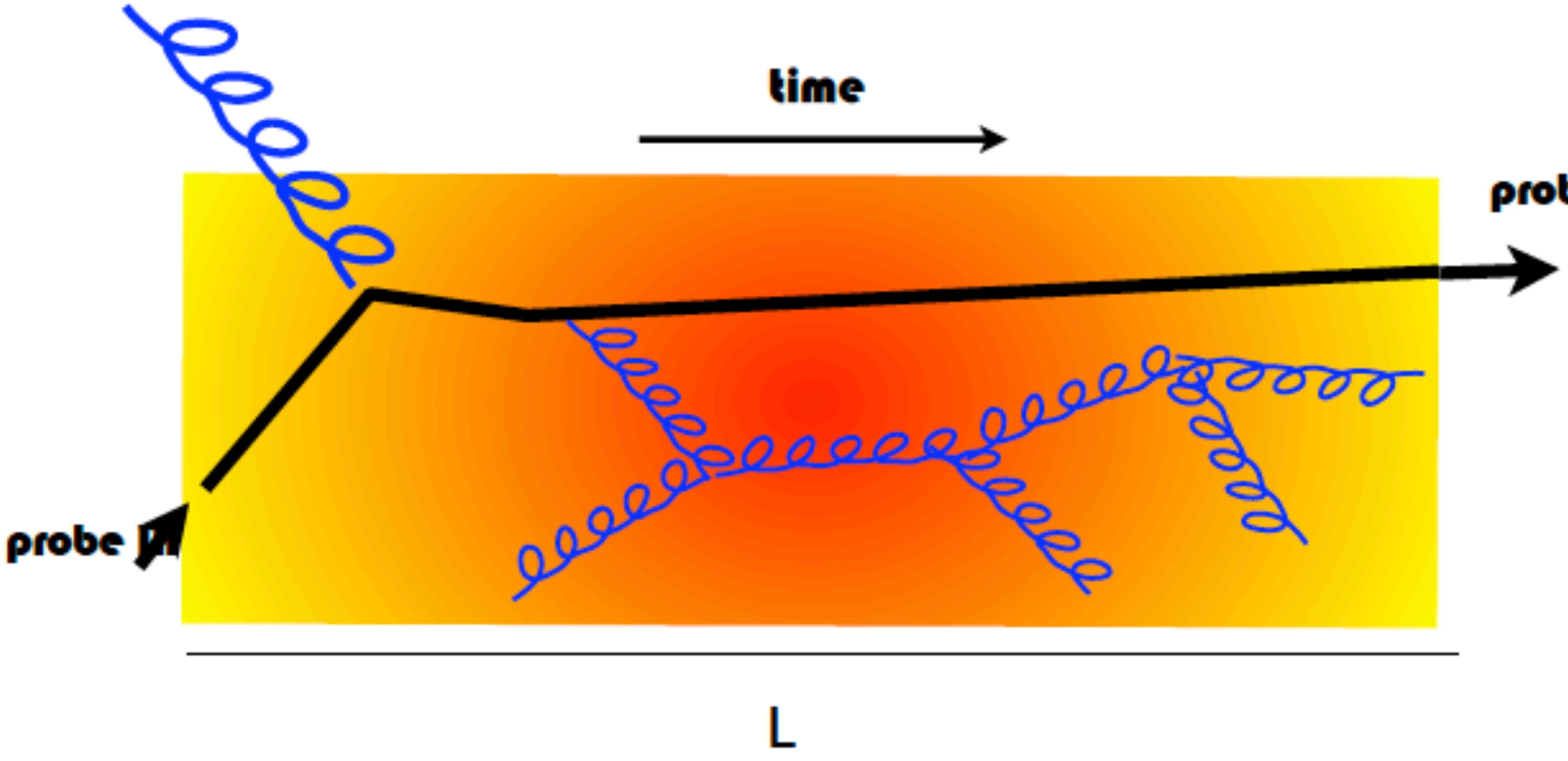
How to probe QGP



Radiated gluon energy:

$$\hat{q} = \frac{\langle k_T^2 \rangle}{\lambda}$$

transport coeff.

$$\omega \frac{dI}{d\omega} \propto \alpha_s C_R \sqrt{\frac{\hat{q}L^2}{\omega}}$$

Casimir coupling factor: 4/3 for quarks and 3 for gluons

arxiv-hep-ph0008241
Phys.Rev.D71:054027, 2005

⇨ Color charge dependence of radiative E_{loss}

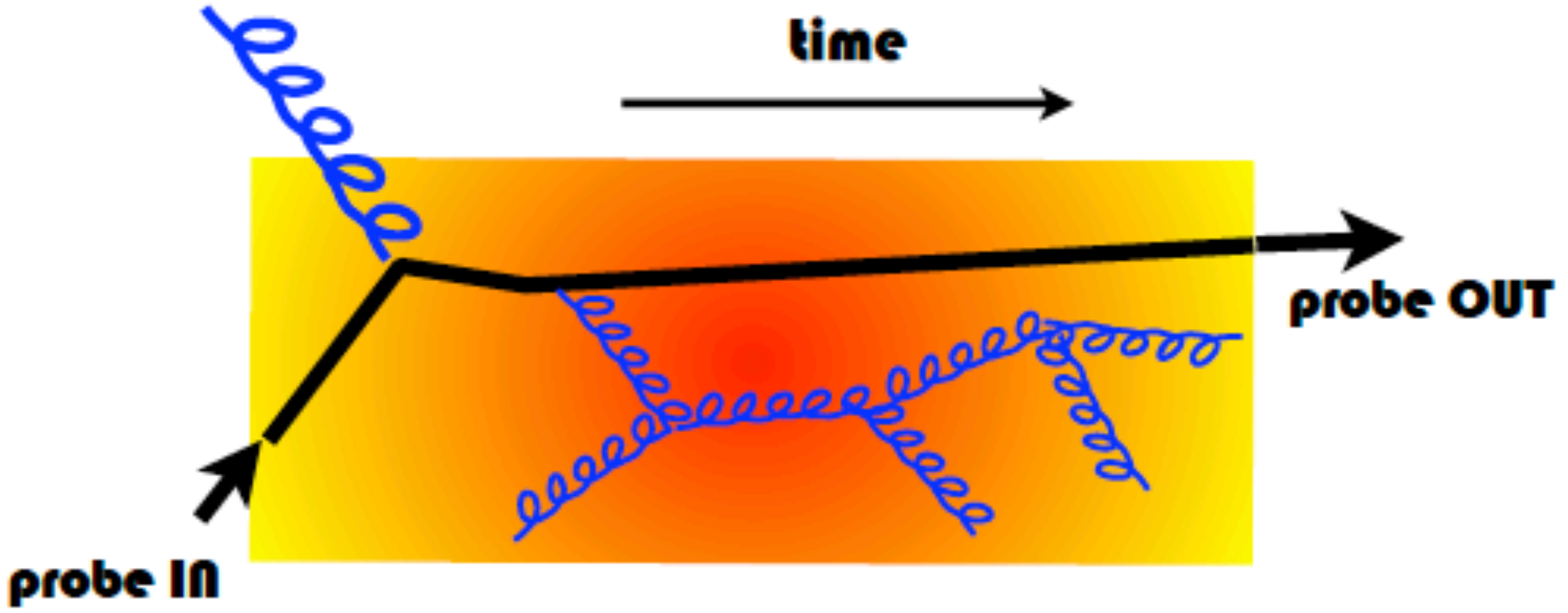
$$\Delta E_g > \Delta E_{c \approx q}$$

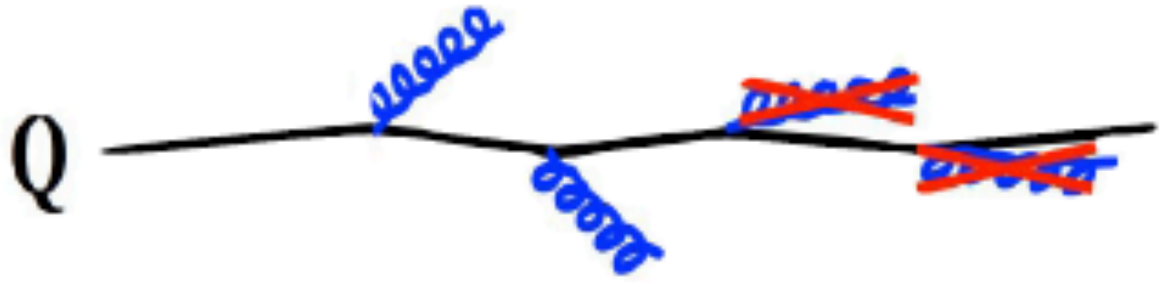
M. Djordjevic, M. Gyulassy, Nucl. Phys. A733 (2004) 265.

Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B 519 199–206 (2001). N. Armesto, C. A. Salgado and U. A. Wiedemann. PRD 69 (2004) 114003

How to probe QGP

- In vacuum gluon radiation suppressed for $\theta < m_Q/E_Q$ (dead cone effect)





Gluonsstrahlung probability

$$\propto \frac{1}{[\theta^2 + (m_Q / E_Q)^2]^2}$$

- With dead cone → lower energy loss due to "angle-dependent" factor

Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B 519 199–206 (2001).

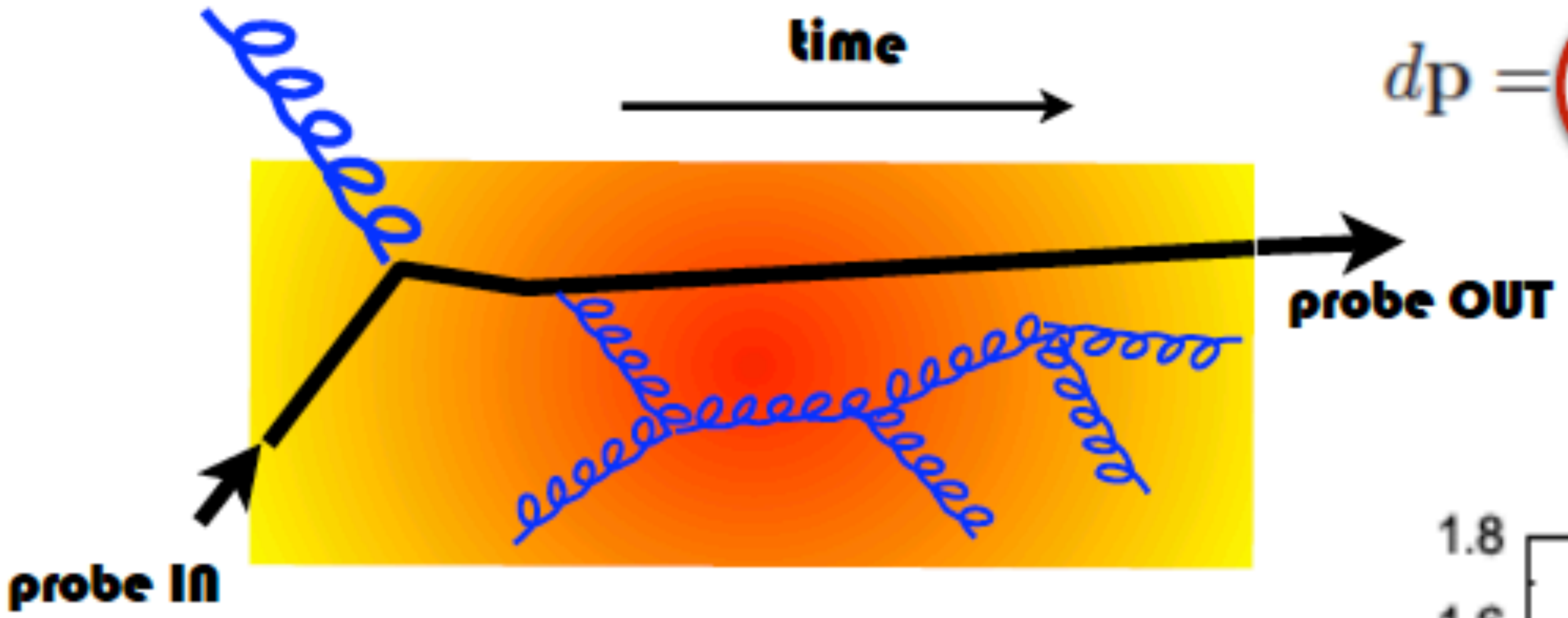
$$\omega \frac{dI}{d\omega}\Big|_{Heavy} = \omega \frac{dI}{d\omega}\Big|_{Light} \times \left(1 + \left(\frac{m_Q}{E_Q}\right)^2 \frac{1}{\theta^2}\right)^{-2}$$

⇨ $E_{loss}(c) > E_{loss}(b)$

M. Djordjevic, M. Gyulassy, Nucl. Phys. A733 (2004) 265. A. Salgado and U. A. Wiedemann. PRD 69 (2004) 114003

How to probe QGP

- If use **Langevin formalism:**



$$dx = \frac{p}{E} dt,$$

$$dp = -\Gamma(p)\, p\, dt + \sqrt{2D(p + dp)\, dt}\, \rho$$

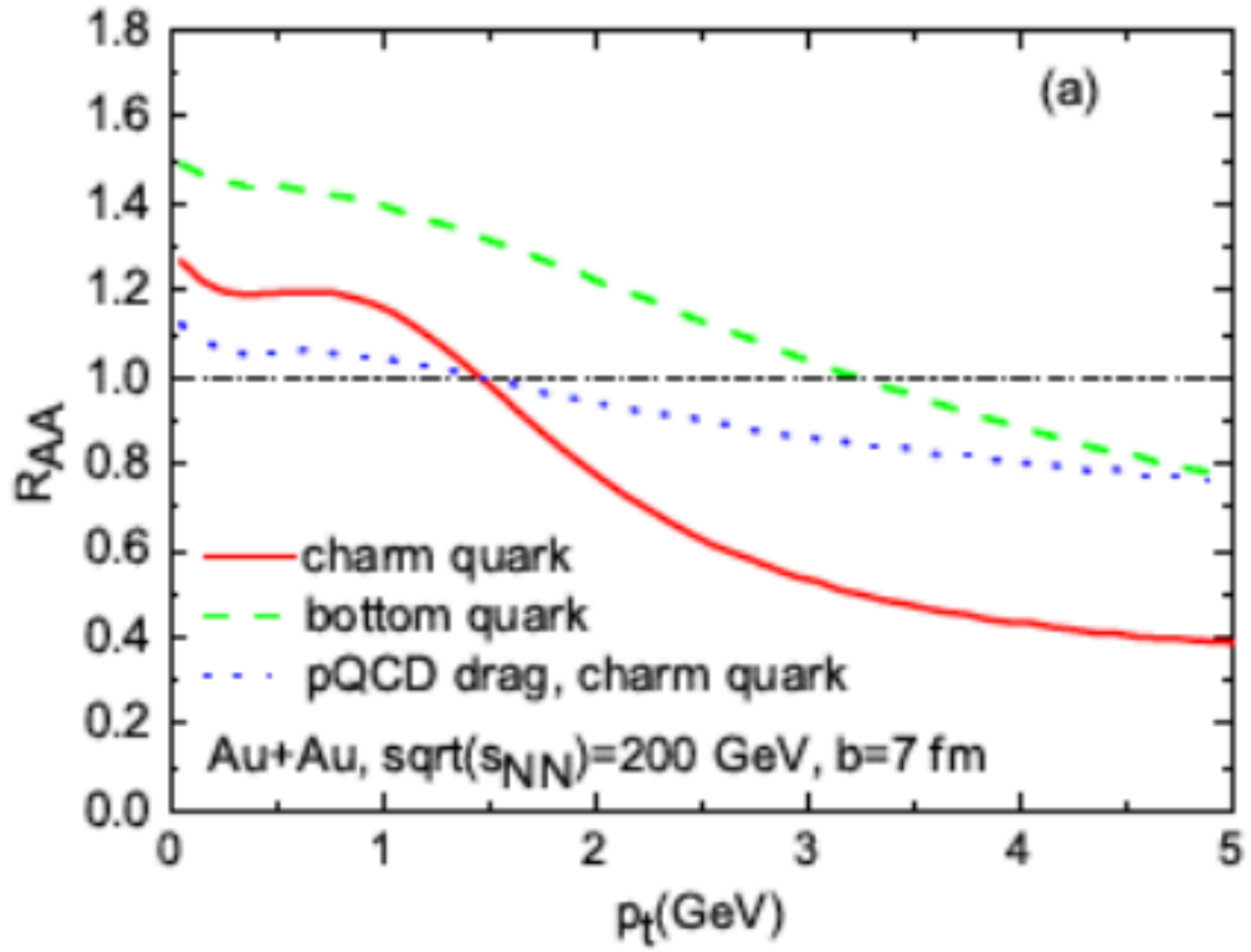
Drag coefficient: E_{loss} term

Diffusion term

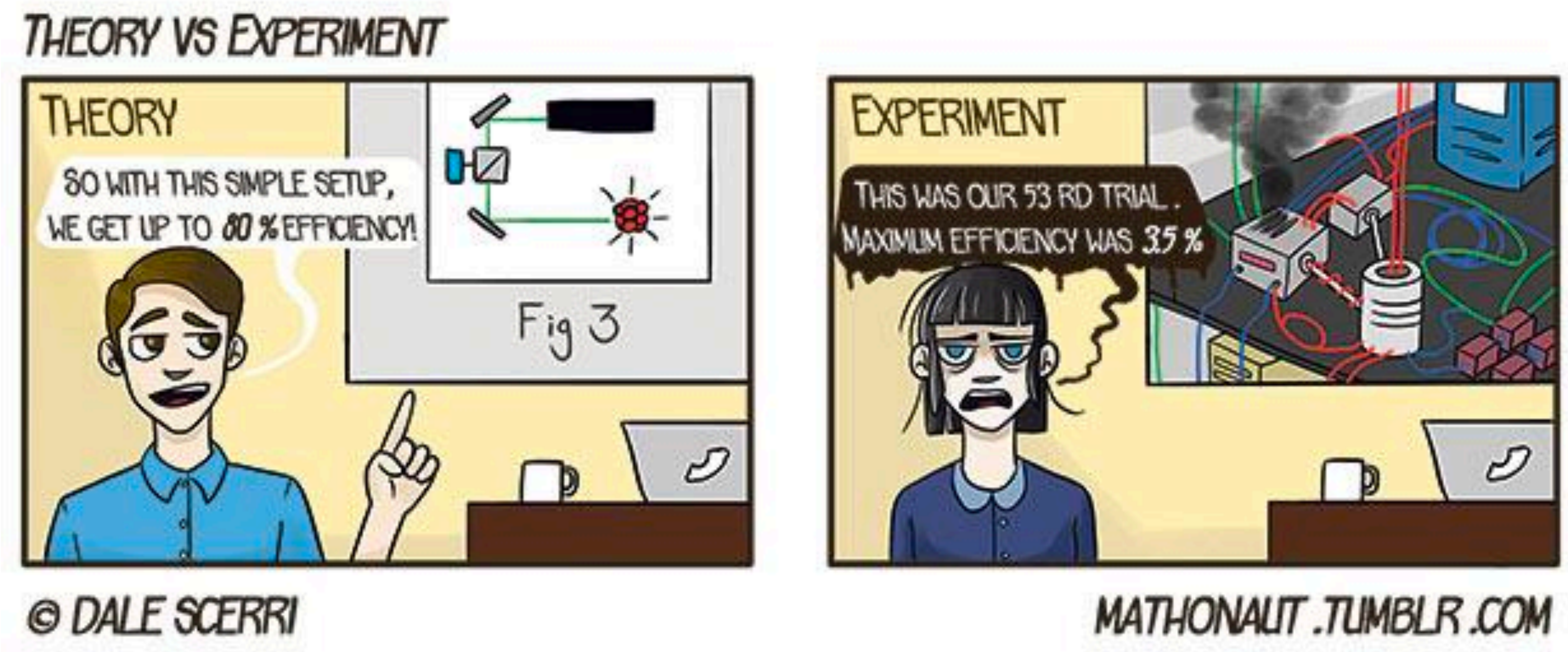
- Both the terms: $\Gamma(p)$ e D are proportional to $1/m_Q$

- Lower E_{loss} for b quark

He, Rapp, Fries, PRC86 (2012) 014903



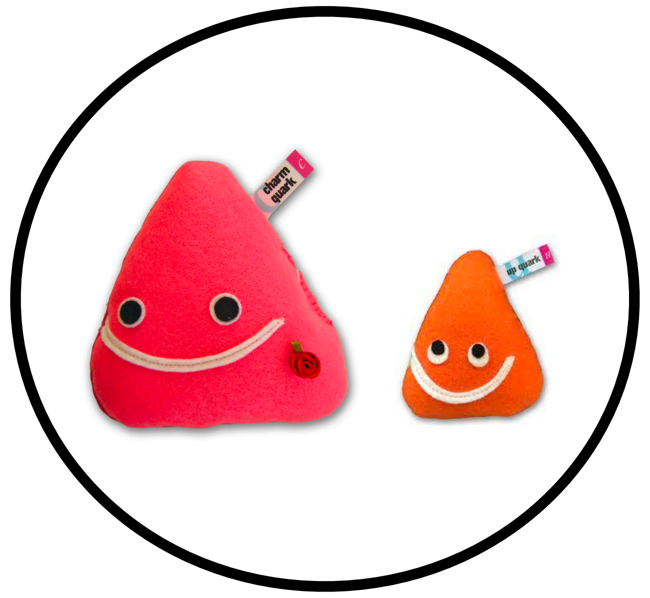
But in practical terms?



How do we "use" a quark?

Charm quarks is confined into hadrons (particles), we cannot directly access it

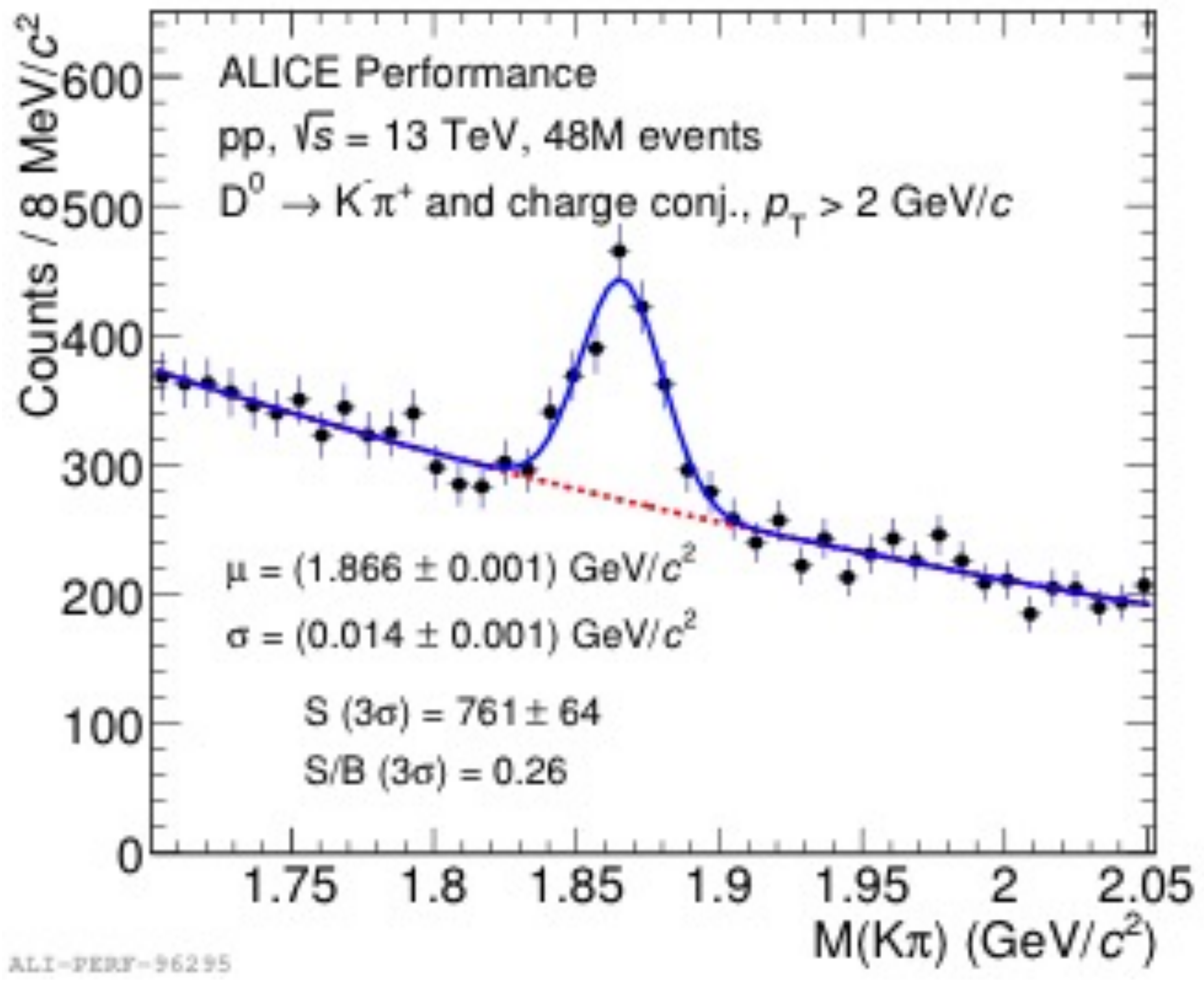
D^0 meson



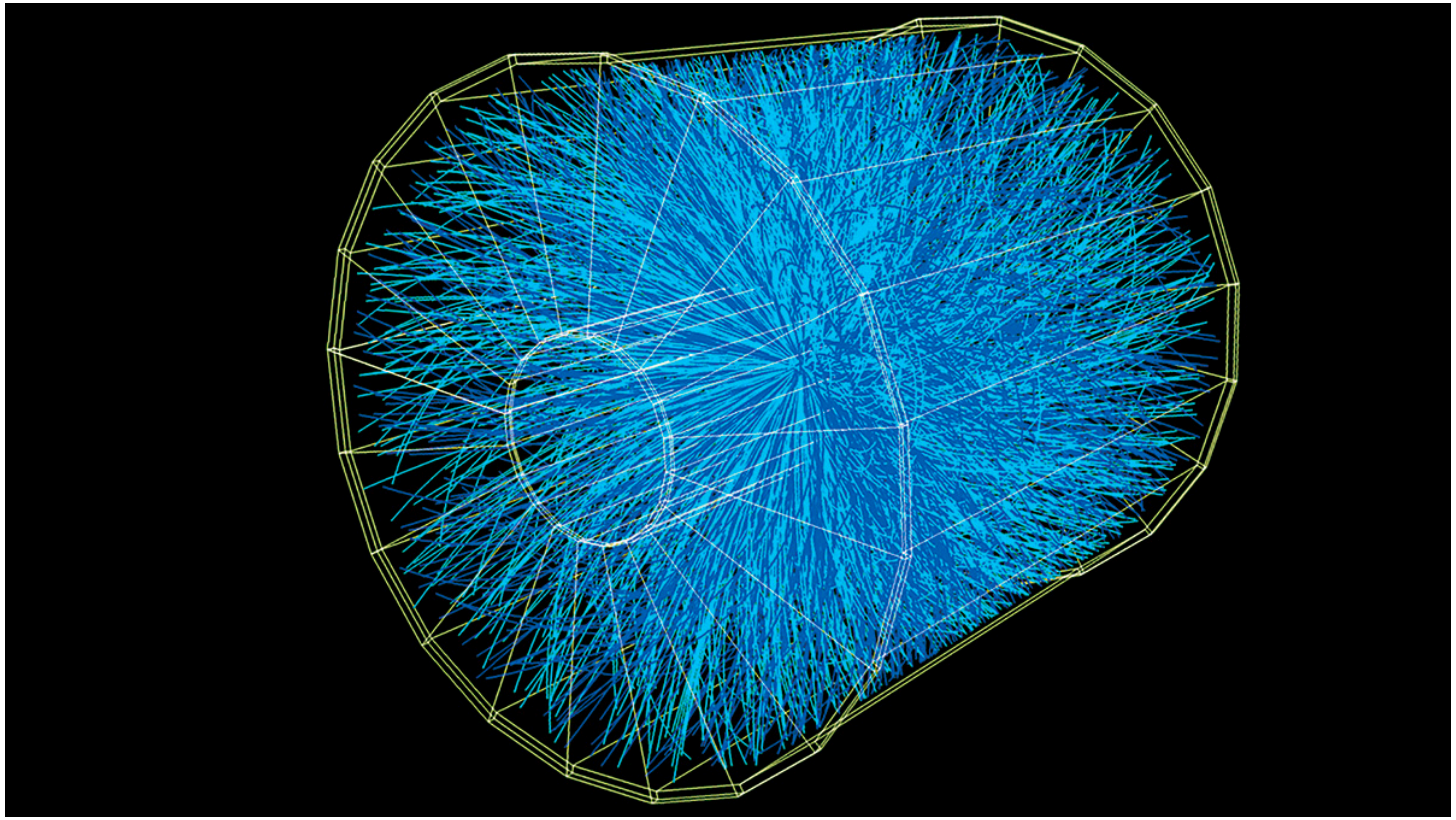
We can use particles that "contain" the charm quark, like the D^0 meson

$D^+ \rightarrow K\pi\pi$

Of all the D^0 we select only the one "easy" to see in our ALICE detector



Easy to see? Well ……

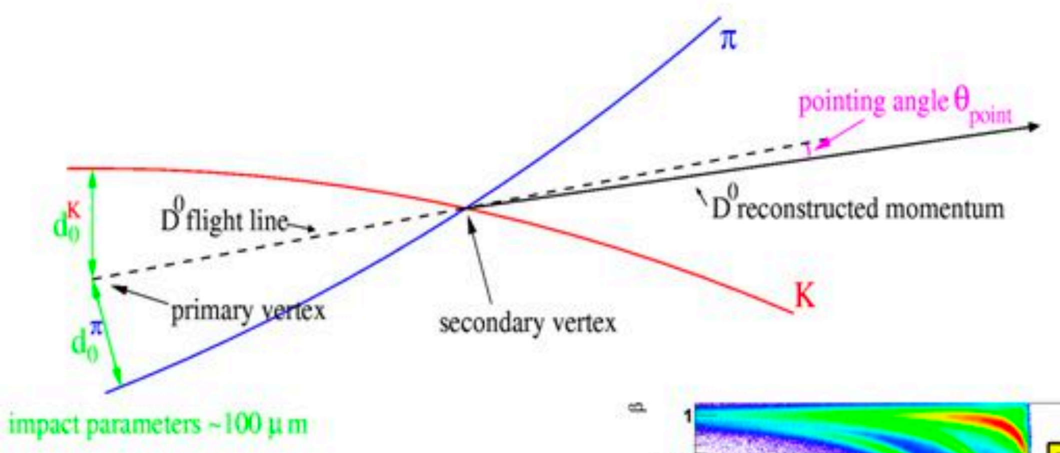


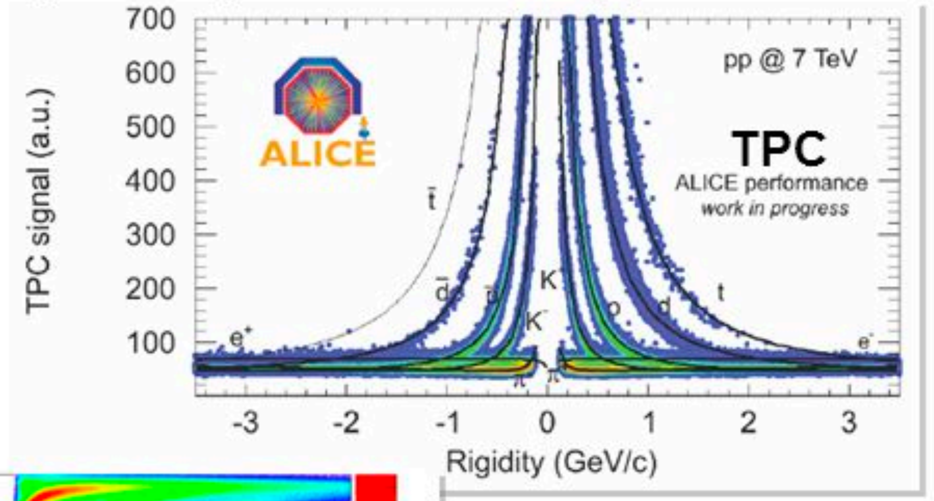
- Out of thousand of particles we need to find the correct kaon and pions

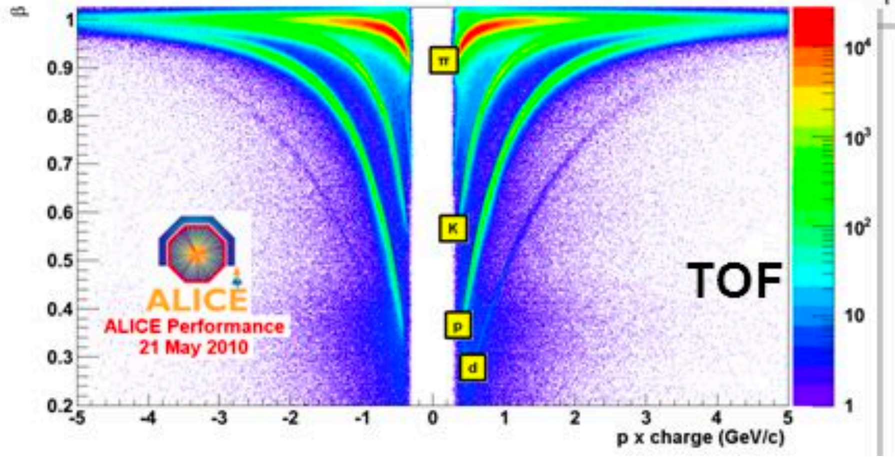
$$D^+ \to \boxed{K\pi\pi}$$

- The combinatorial is enormous, just taking combinations of 2 is not an option!

- We need to suppress combinatorial with particle identification and topology







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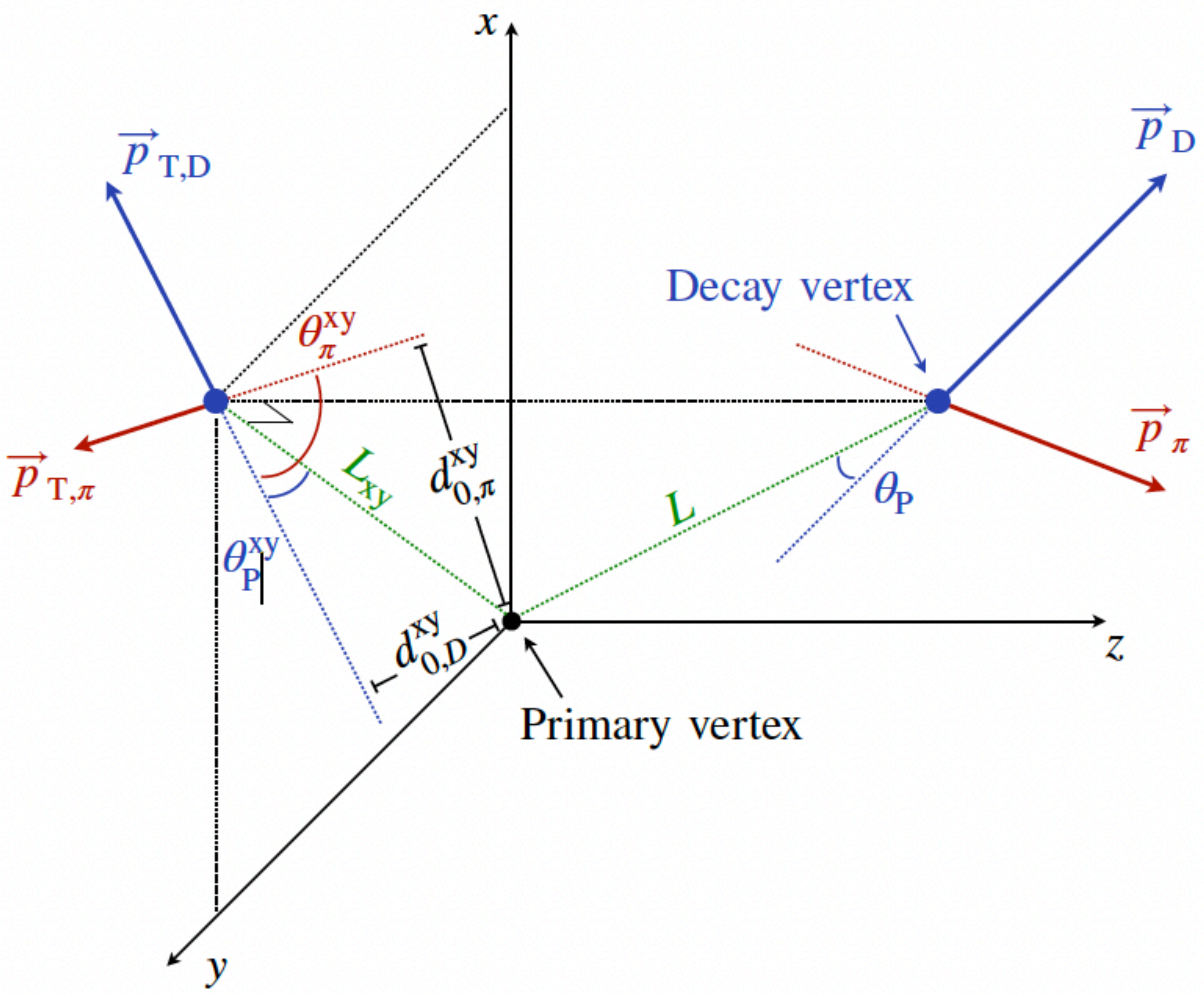
Topological selections

$D^+ \rightarrow K\pi\pi$



L = decay length: distance from collision point to decay vertex

NLxy = Normalised decay length: projection of L in xy plane divided by its uncertainty

DCA = Dispersion of the decay tracks around decay vertex (due to resolution effects we do not see the D+ daughters coming from the same point)

$d^{xy}{}_0$= Impact parameter of the track vs collision vertex

Cosθ_p= Cosinus of the angle between D flight line and its reconstructed momentum (sum of the daughters momenta)

https://cds.cern.ch/record/2713513/files/CERN-THESIS-2020-017.pdf

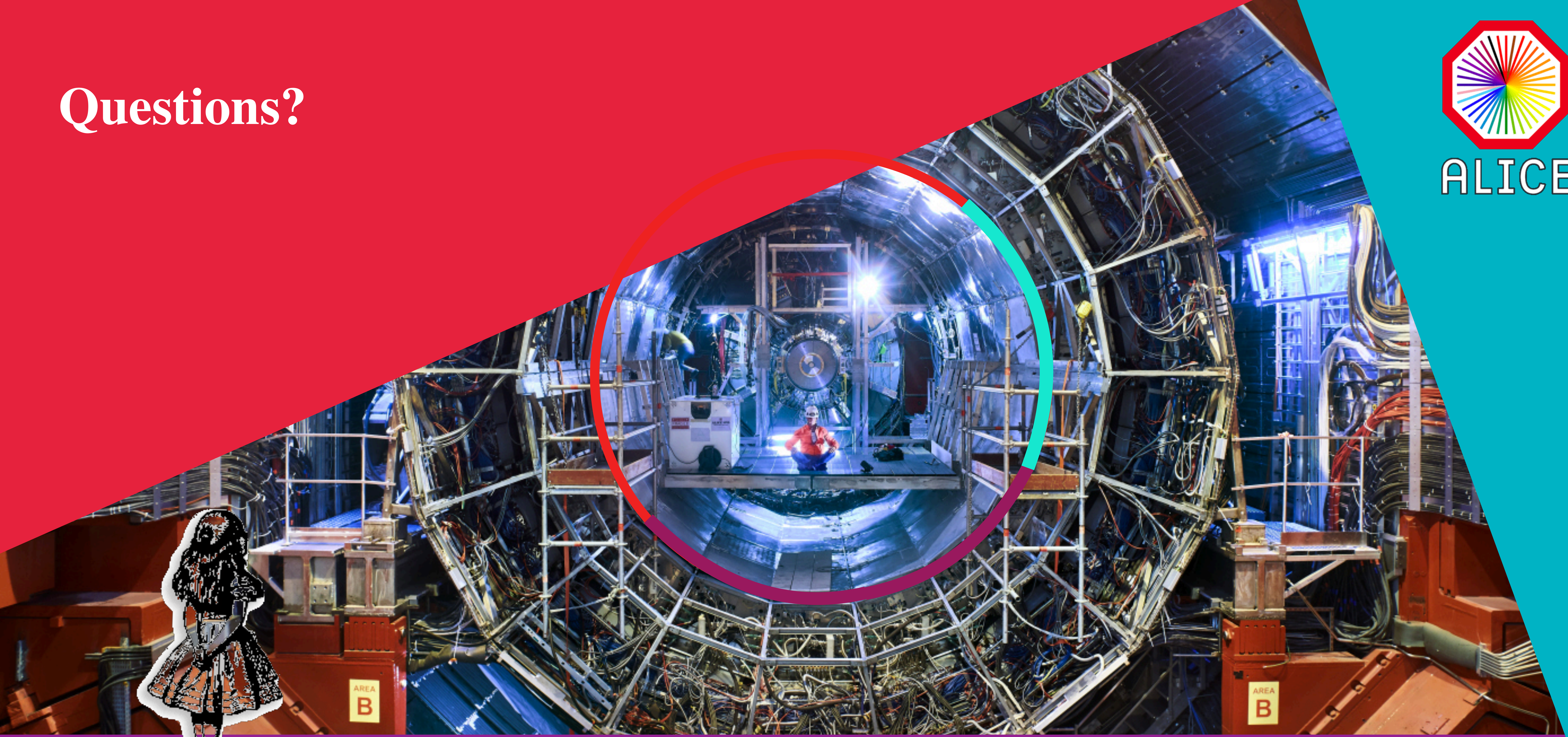
The project

- The data you have are synthetic data from the ALICE collaboration. Signal (D+ decays) and combinatorial background topological variables have been included as well as the invariant mass calculation

- Can you build a learning strategy to separate efficiently signal and background? (i.e can you see the D+ particle?)

- Can you compare different learning strategies and tell which one is the best suited for the job?

Questions?



ALICE

Nikhef

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