Future Prospects for Heavy Ion Physics The ALICE Experiment

Presented by

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Outline of Talk

- What is a QGP ?
- Why Interesting ?
- QGP Signatures

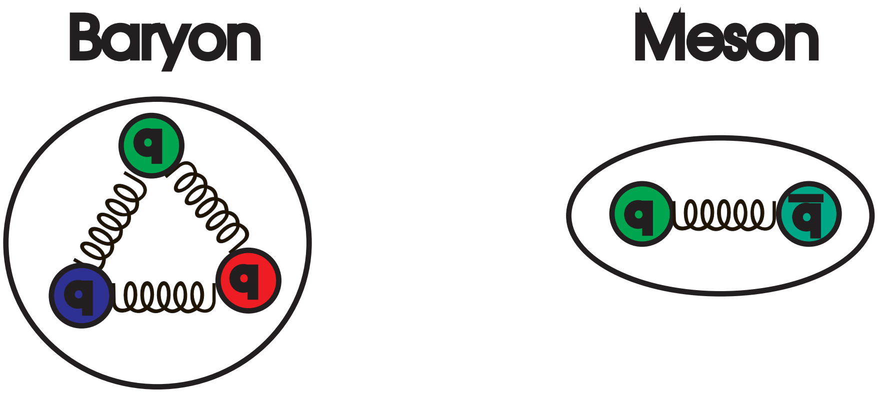
- Two most interesting results on J/Ψ and Strangeness production at the SPS.

- ALICE Physics:
  Global variables, Dileptons, J/ψ
  Strangeness, Charm, Beauty.
- The U.K. Contribution to ALICE

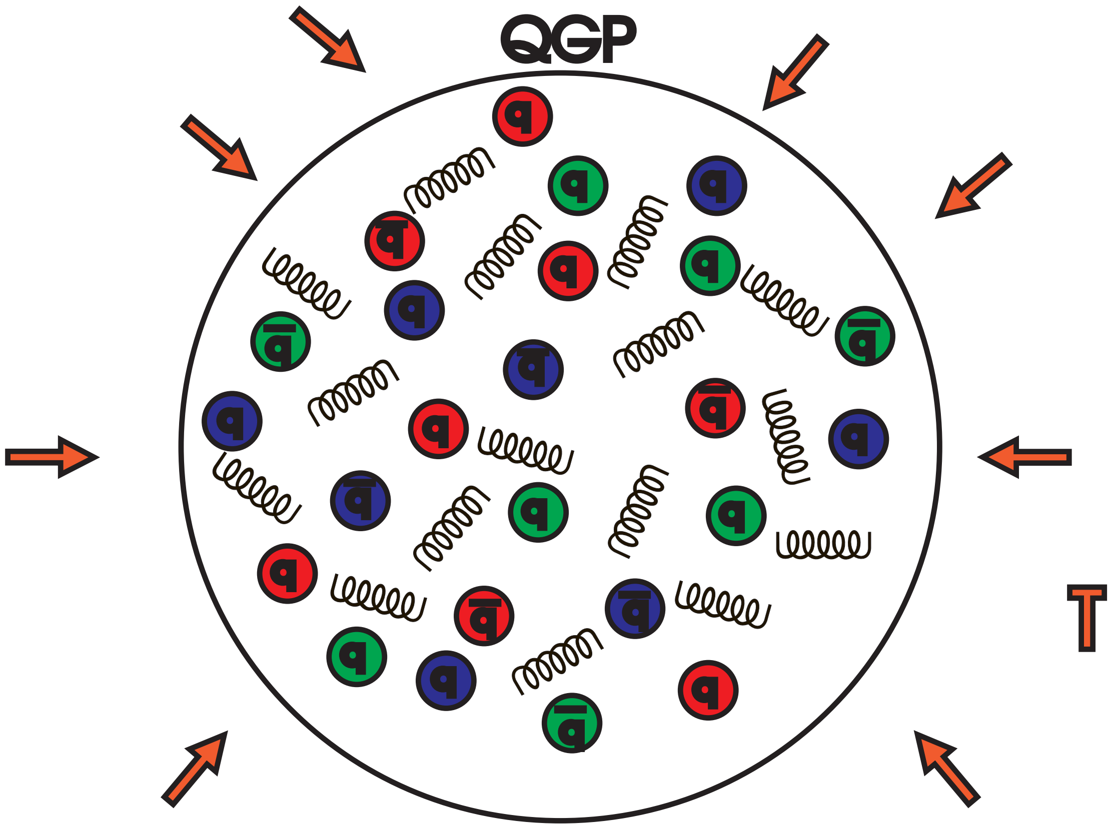
- Summary and Conclusions

What is a QGP ?

Normal hadronic matter.



QCD also predicts that under extreme conditions of temperature and/or density hadronic matter will 'melt' into an free gas of quarks and gluons.



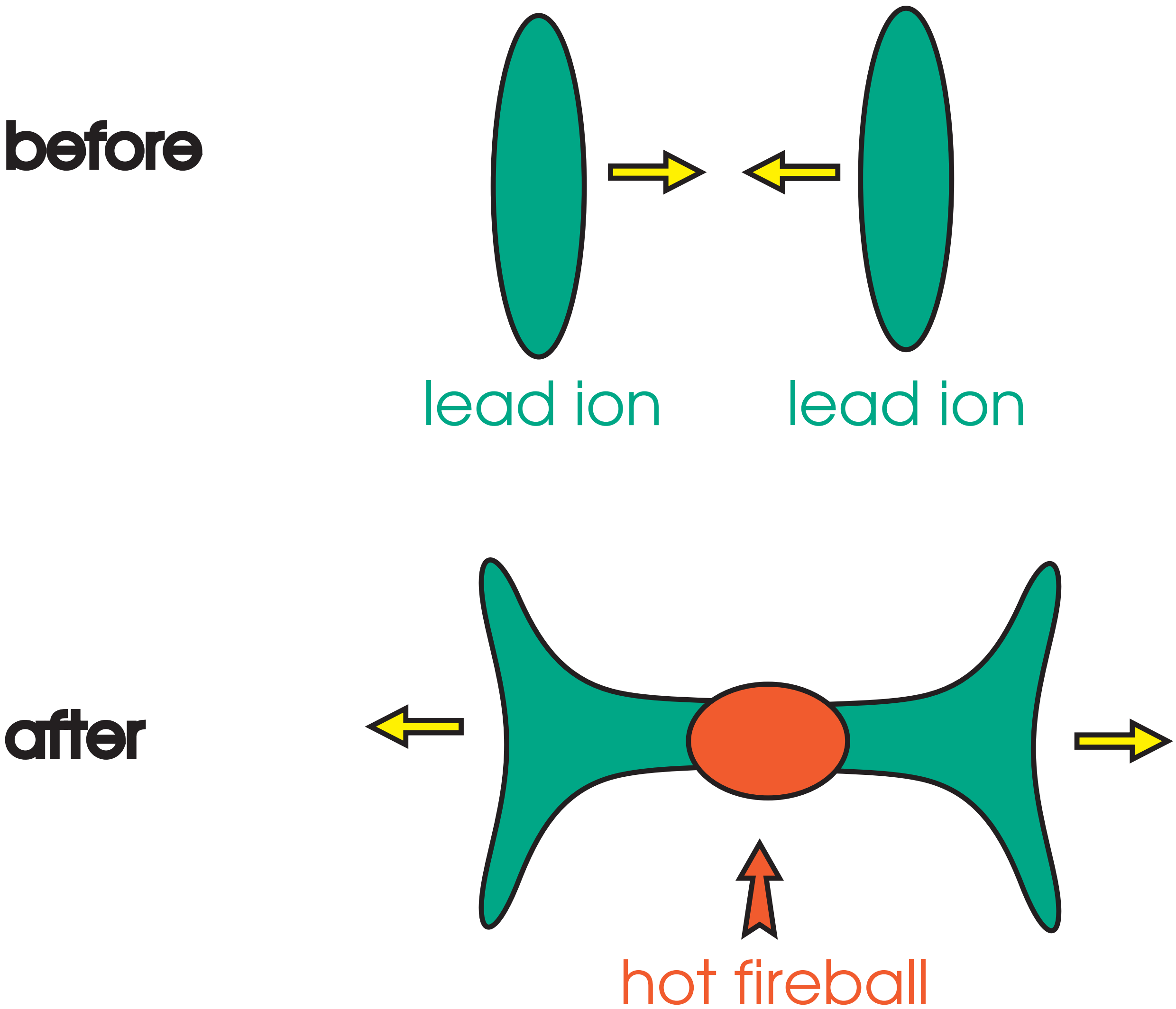
Why Interesting ?

- Study of QCD and confinement under extreme conditions
  Test of non-perturbative QCD.
- Test of field theory: only field theory phase transition that can be observed experimentally.
- Chiral Symmetry: chiral symmetry should be restored in a QGP.

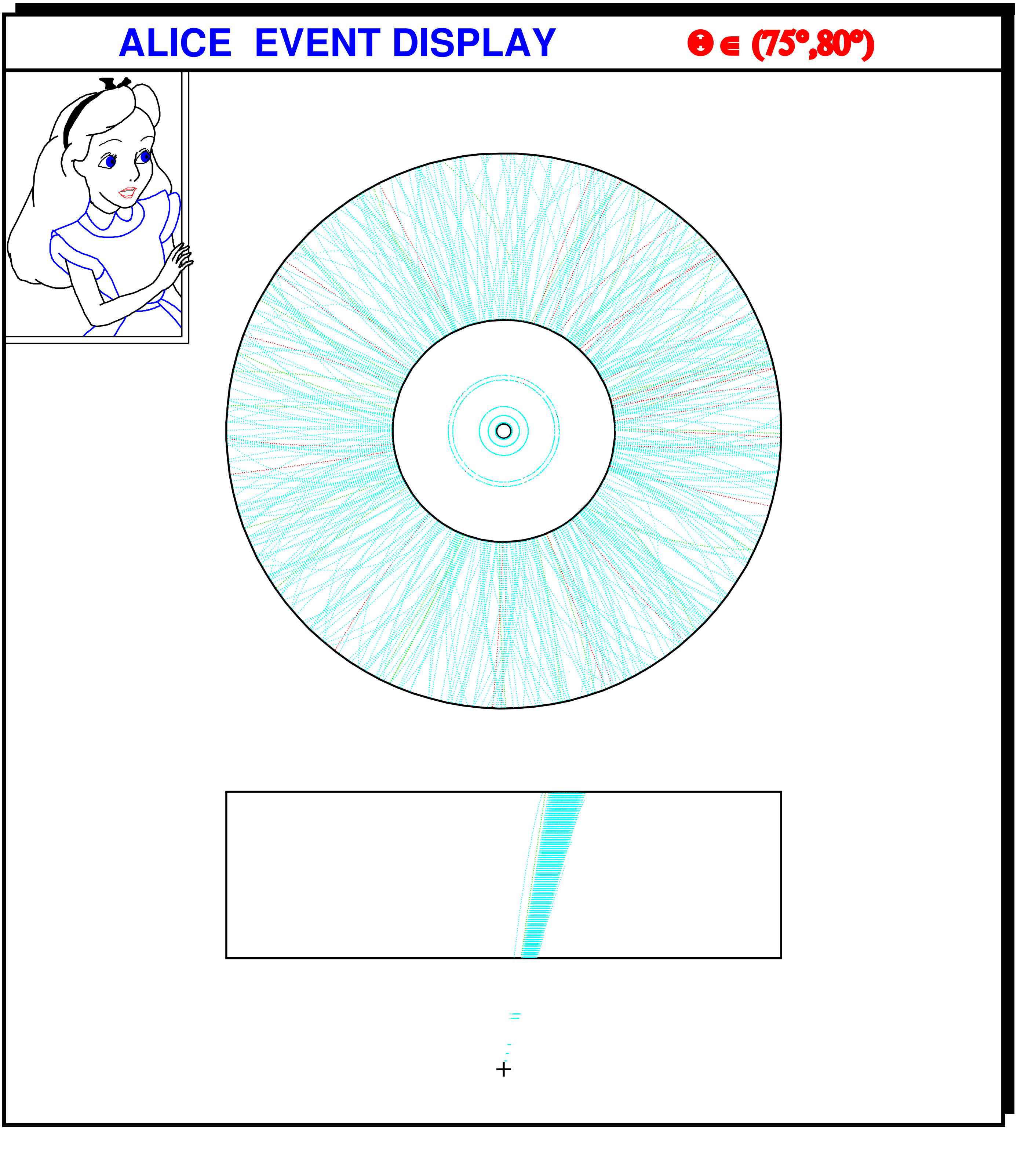
- Cosmology: Early Universe was a QGP until ~10^{-5} seconds after the Big Bang.

- Astrophysics: Core of neutron stars may be a QGP.

How to Produce a QGP



Hot fireball is produced in the centre-of-mass of the colliding system.
So look at particles coming from this fireball.


ALICE EVENT DISPLAY
Θ ∈ (75°,80°)

Signatures

Look for signatures in quantities that will not change during hadronisation.

- Particles that do not interact strongly.
- Quantum numbers which remain unchanged by strong interaction.

Direct Photons

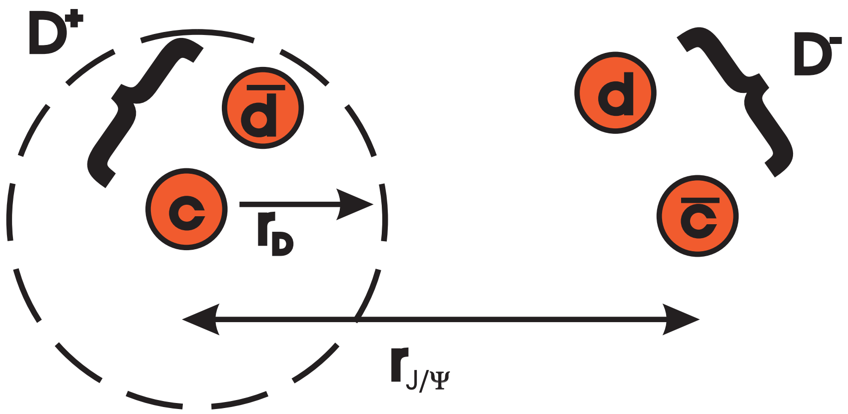
Thermal dilepton production

J/Ψ Suppression

Strangeness enhancement

J/Ψ Suppression

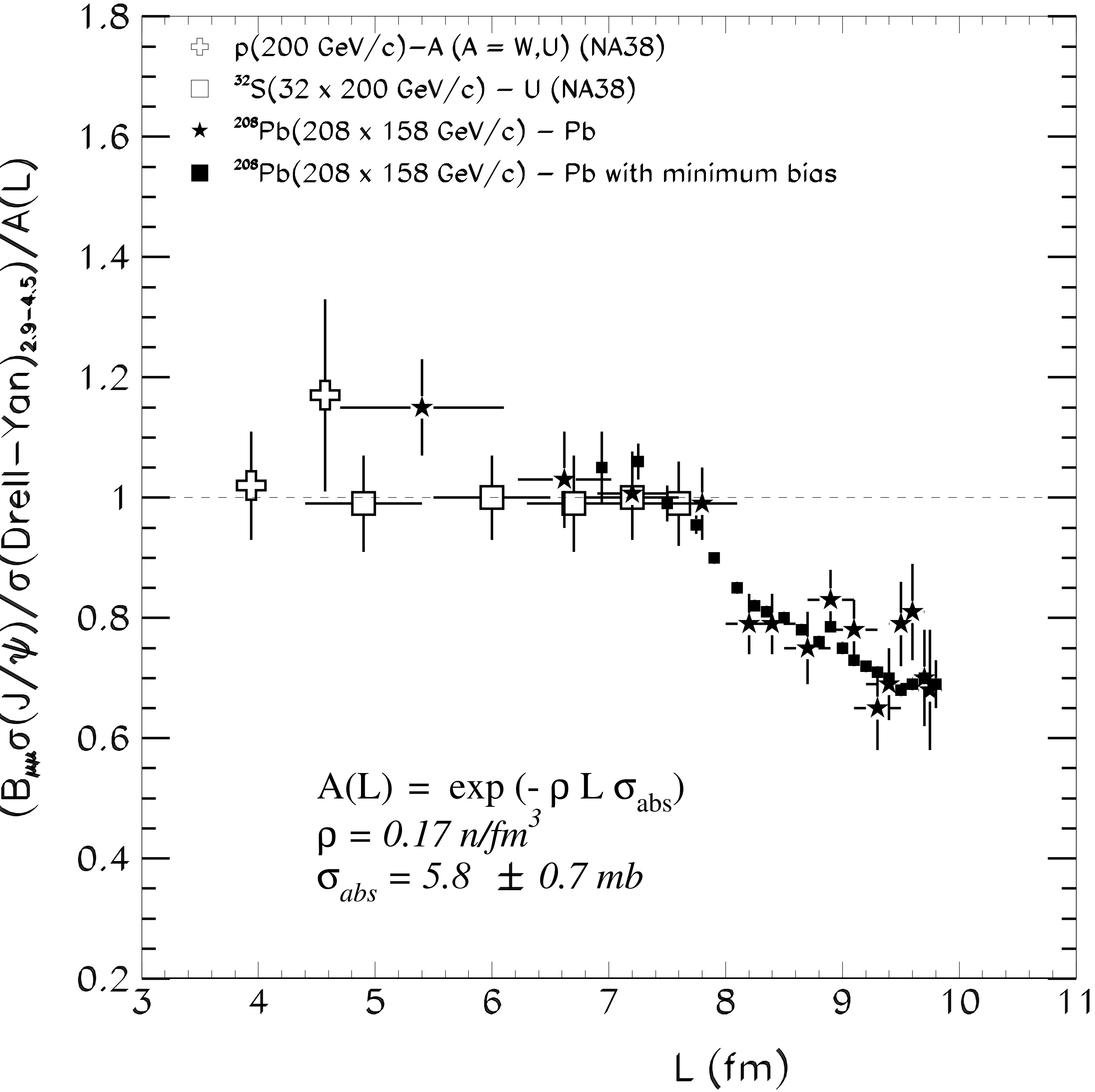
Colour screening in QGP:
screening radius < size of J/Ψ (~0.5 fm)
so $c\bar{c}$ bound state cannot form inside
QGP.



Charm quarks separate and appear
after hadronisation in the form of
D mesons.

But can also get J/Ψ suppression in
dense hadronic matter
($J/\Psi + \pi \rightarrow D\bar{D}X$)

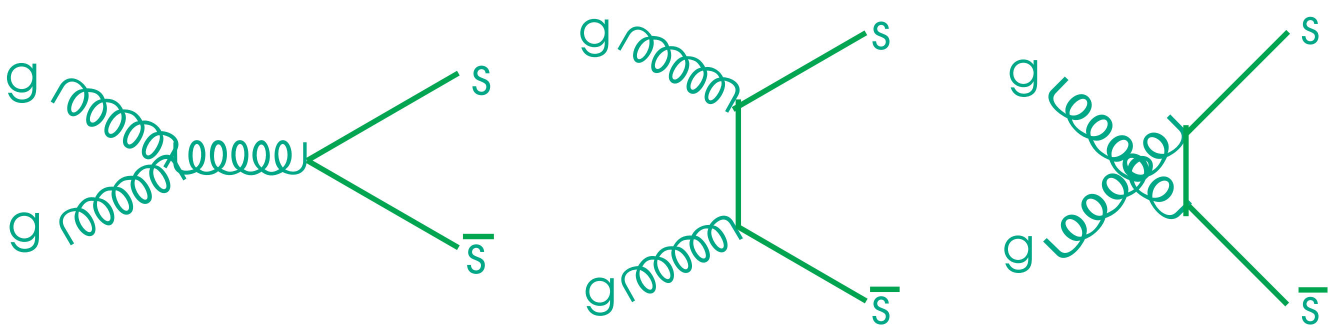
Look at ψ' as well
QGP predicts ψ' suppressed more

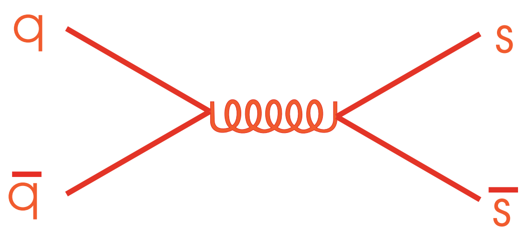


p(200 GeV/c)−A (A = W,U) (NA38)
^{32}S(32 x 200 GeV/c) − U (NA38)
^{208}Pb(208 x 158 GeV/c) − Pb
^{208}Pb(208 x 158 GeV/c) − Pb with minimum bias
A(L) = exp (- ρ L σ$_{abs}$)
ρ = 0.17 n/fm^3
σ$_{abs}$ = 5.8 ± 0.7 mb
$(B_{\mu\mu}\sigma(J/\psi)/\sigma(\text{Drell-Yan})_{2.9-4.5})/A(L)$
L (fm)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
3
4
5
6
7
8
9
10
11

Strangeness Enhancement

Gluon rich QGP:





Energy needed to produce $s\bar{s}$ pair
= $2m_s \sim 300$ MeV.
QGP temperature ~ 200 MeV
$\therefore$ easy to produce $s\bar{s}$ pairs.

Many u and d quarks from initial ions so $u\bar{u}$ and $d\bar{d}$ supressed by Pauli Blocking.

Strangeness Enhancement

Hadron Gas Case:

$\pi\, p \rightarrow \Lambda\, K$ (530 MeV)
more difficult to produce strangeness in HG.

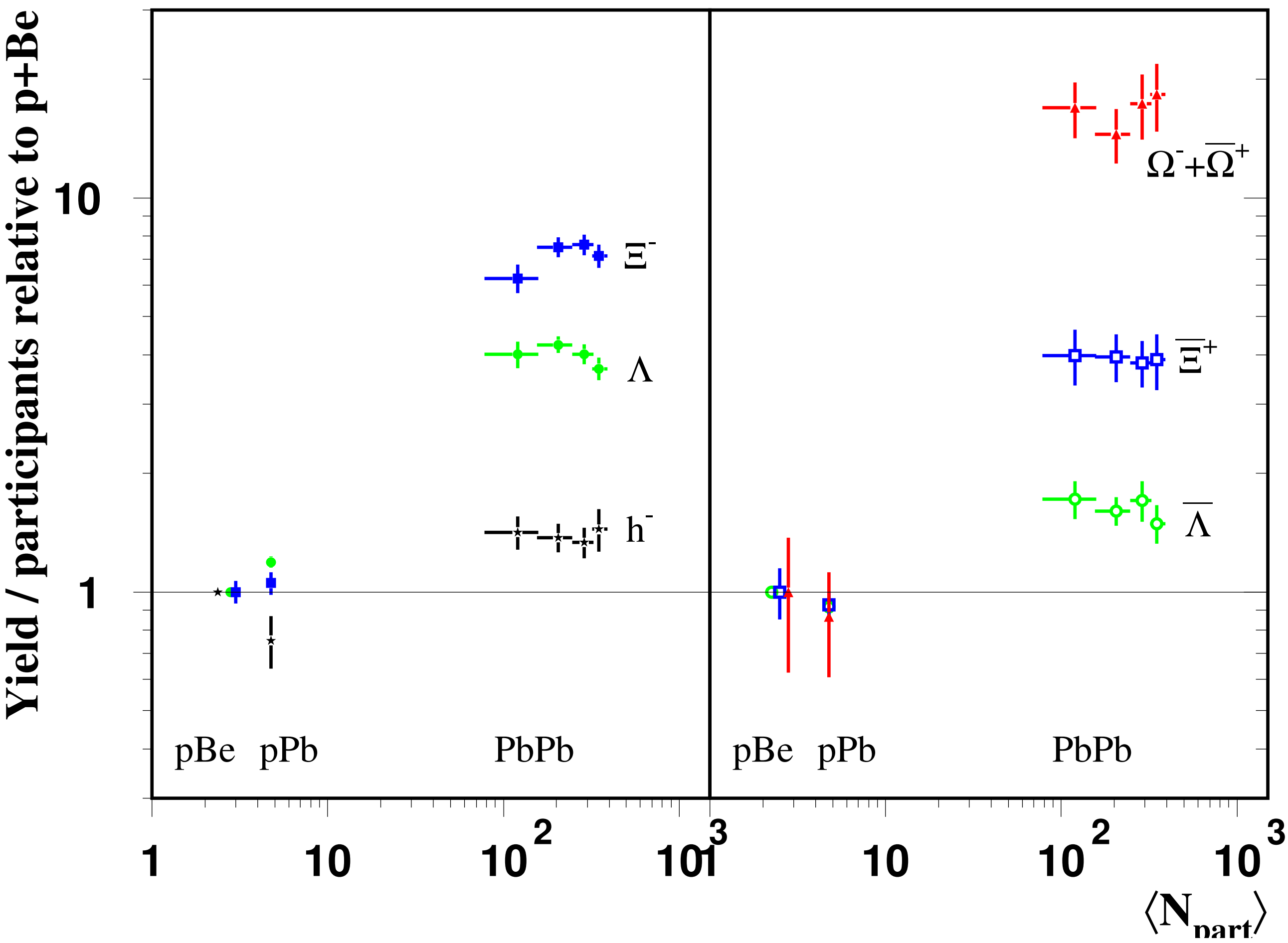
Strange antibaryons even more difficult to produce

$p\, p \rightarrow p\, p\, \Lambda\, \bar{\Lambda}$ (2.23 GeV)

Equilibrium HG may give similar yields to QGP but equilibrium take > 10 times longer than in QGP case; much longer than lifetime of fireball.

Heavy strange baryons and antibaryons are most difficult to produce in HG

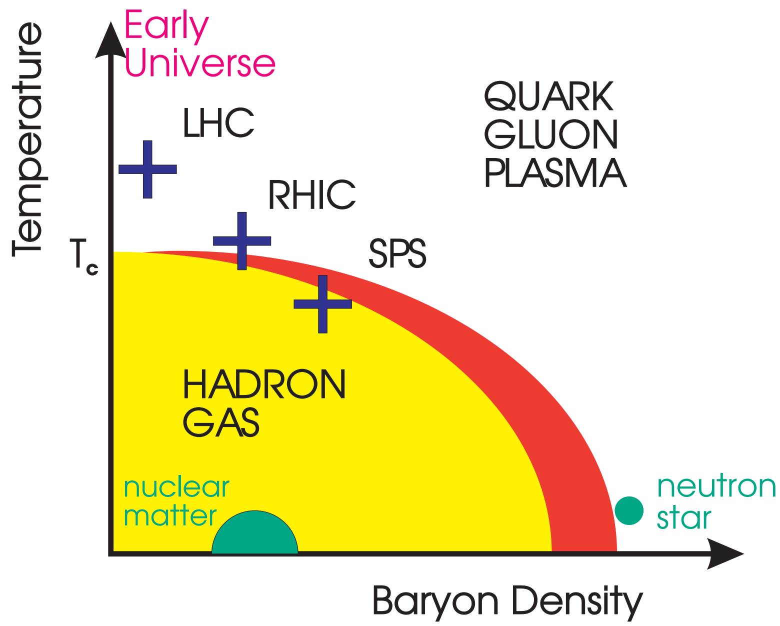
$\therefore$ Look at Λ, Ξ, Ω and their antiparticles



Yield / participants relative to p+Be
10
1
pBe
pPb
PbPb
Ξ^-
Λ
h^-
$\Omega^-+\overline{\Omega}^+$
$\overline{\Xi}^+$
$\overline{\Lambda}$
1
10
10^2
10^3
$\langle N_{part} \rangle$

ALICE PHYSICS

	SPS	RHIC	LHC
$\sqrt{s}$ (GeV/c)	20	200	5500
ε (GeV/fm^3)	2-3	2-7	8-30



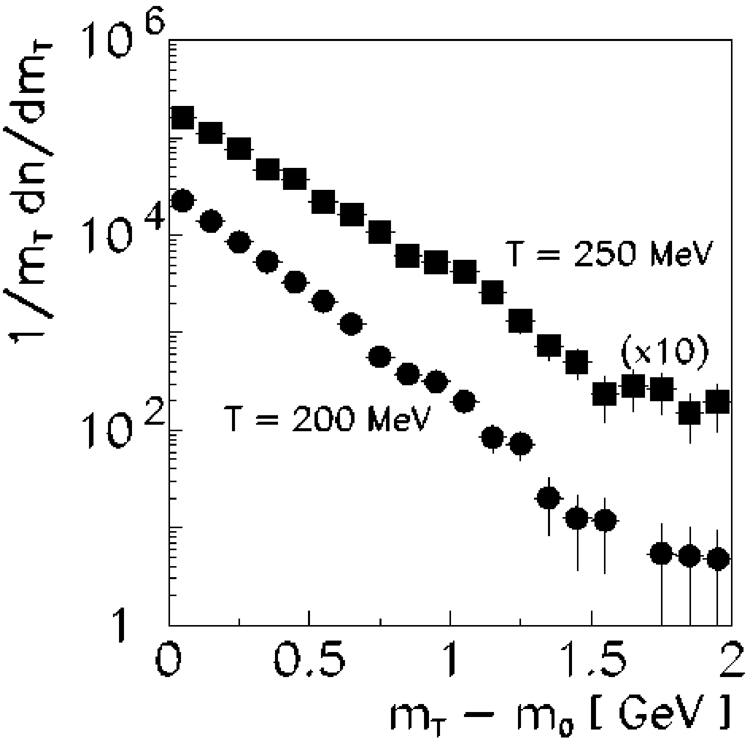
ALICE

- Run with p-p, light ions, and Pb-Pb
- Able to study in pure QGP region and near the phase boundary
- Study all observables in one detector
- many on an event-by-event basis

Global Variables

Need to measure volume, temperature, chemical potential, and energy density of system.

Transverse mass distributions give information on the temperature of the system.



Transverse mass plot for **one** ALICE event

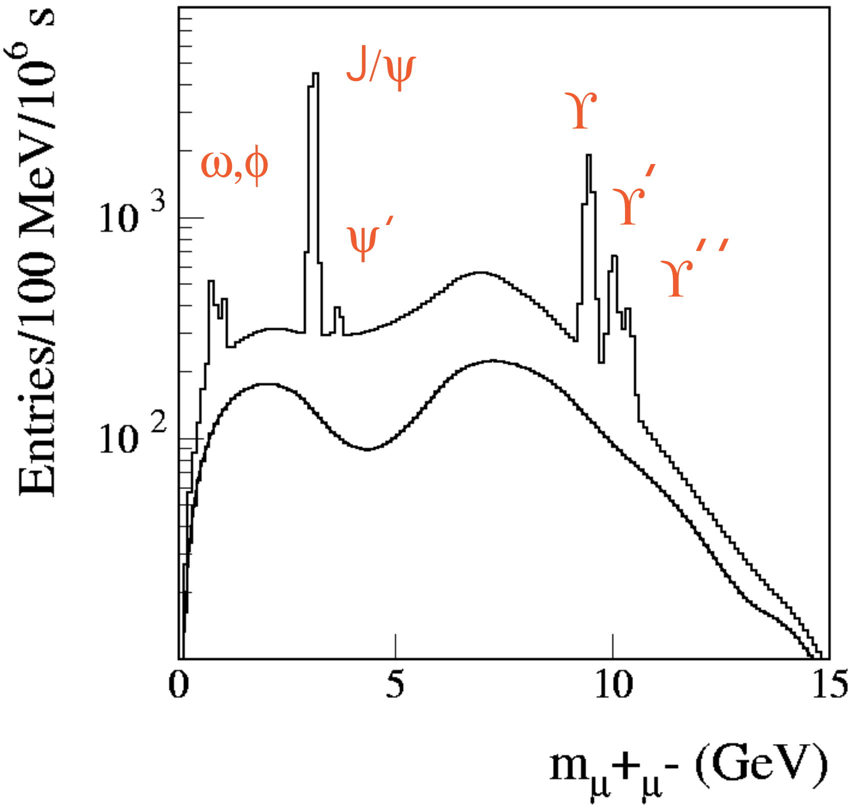
Pion interferometry measures the size of the system at freeze-out on an event-by-event basis.

Can also do K^0 interferometry

E_T distributions give information on what fraction of the projectile energy goes into the fireball.

e^+e^-, $\mu^+\mu^-$, J/ψ and all that

- Photon enhancement will be observed if signal > 5% above background.



Dimuon Arm

Low mass $\mu\mu$ enhancement

Study J/ψ & ψ' suppression

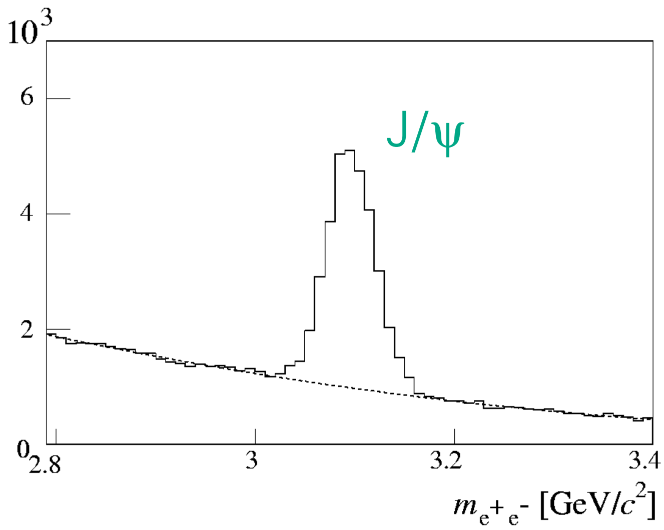
&

Υ, Υ', & Υ'' Suppression (test of the colour field strength).

Mass distribution with p_T>3 GeV/c and Υ selection cuts

e^+e^- Identification in ITS, TPC, & TOF

Also study J/ψ via its e^+e^- decay mode (cross-check for $\mu\mu$).



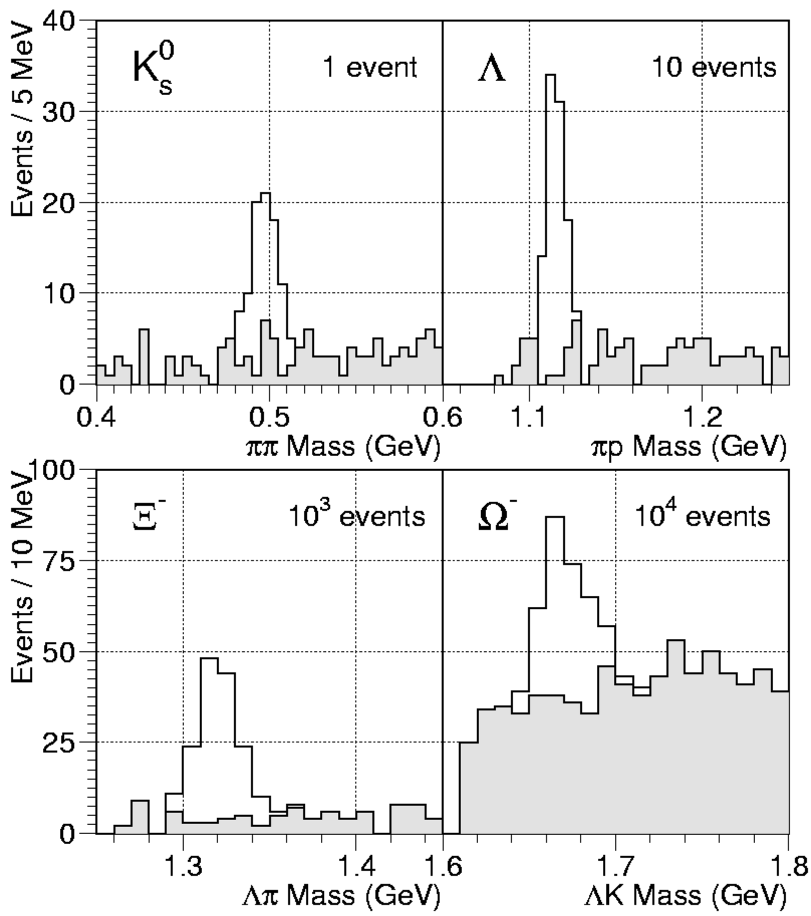
J/ψ for 5×10^7 events after cuts

Strange & Multistrange Hyperons

Hyperon enhancement is an excellent QGP signature.

Measures conditions at freeze-out.

Relative yields give info on temperature, chemical equilibrium, and strangeness saturation.



Hyperon mass plots from Pb-Pb events at ALICE

D mesons: early part of collision.

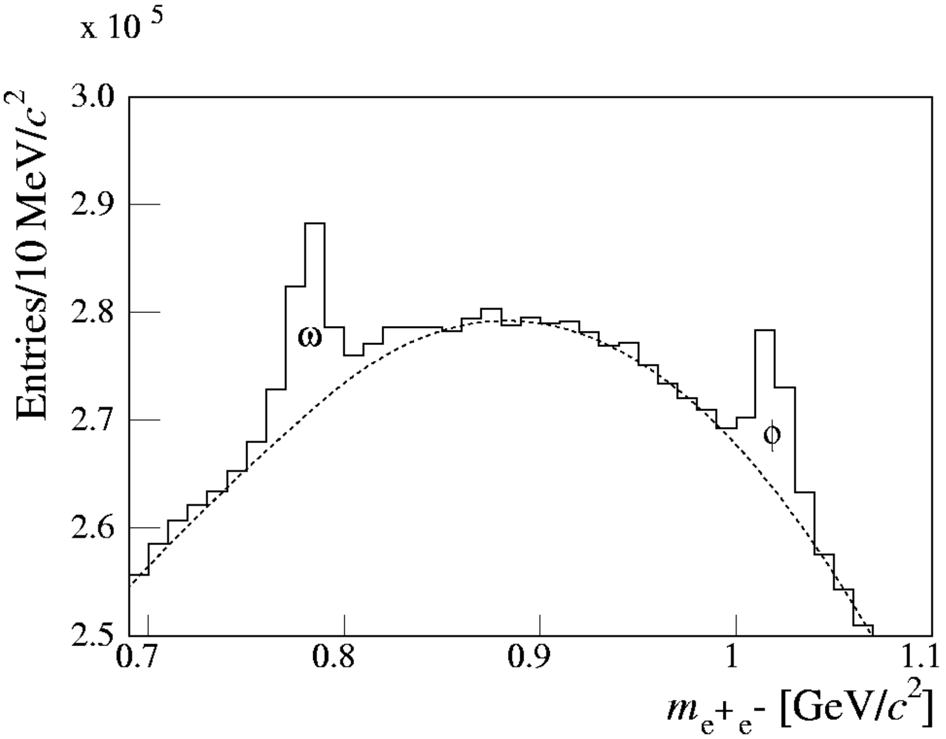
Normalise J/ψ supression to charm production.

New Physics

Partial chiral symmetry restoration near phase boundary:

Leptonic decays of vector mesons very interesting.

ρ, ω, & ϕ mass shift



Mass plot of 5 x 10^7 events after cuts.

Disoriented Chiral Condensate (DCC)

Chiral symmetry of QCD could lead to regions of vacuum with non-zero isospin.

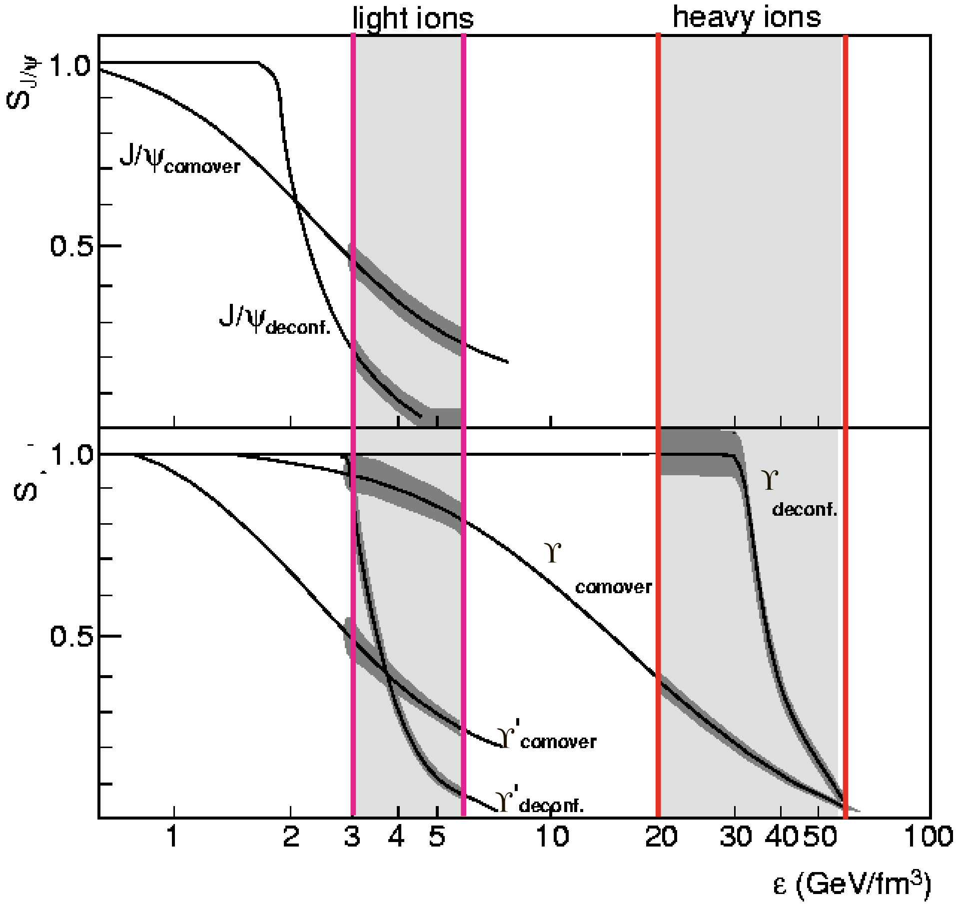
Should show up in events with too many neutral or too many charged particles.

↳ Measure $\pi^0/(\pi^+ + \pi^- + \pi^0)$.

Υ & Υ' Suppression

Strength of colour field can be determined by the amount of Υ & Υ' suppression.

Light and heavy ion running produces systems with different ε: near phase boundary and pure QGP.



Quenched Jets

Energy loss of fast quarks & gluons is $\propto$ Debye screening scale.

No jets if QGP produced

Affects shape of p_T spectra

ALICE U.K.

The Birmingham Group is responsible for the entire ALICE central trigger system.

- design
- construction
- implementation
- control software development
- trigger simulation software

Detector must operate under widely differing running conditions (Pb-Pb, p-p, Ca-Ca ints). Trigger in rare cross-section processes and central collisions. Must prevent pile-up in TPC (except for rare dimuon events).

Quite different conditions from pp experiments and require different solutions.

Birmingham is responsible for an essential part of the ALICE detector and hence has a large influence.

ALICE U.K.

Birmingham plays a vital role in this exciting new field of particle physics.

ALICE will explore a part of particle physics never before explored. Great opportunity to discover exciting, new physics.

There is even the possibility to do Pomeron-Pomeron physics at ALICE

Would need to install Roman Pots

Would need more manpower/collaborators

There are opportunities for experimentalists, theorists, and even phenomalogists from the UK to get involved. New comers are always welcome.

Summary

Study of the QGP is important to HEP:

Study of the Vacuum
Nature of confinement
Non-perturbative QCD
Accessible field theory phase transition
Chiral Symmetry

Interesting results from the SPS

New physics seen

Possible QGP formation

ALICE will be the only experiment to study pure QGP in conditions similar to those in the early Universe.

ALICE will also be able to study the QGP & chiral symmetry near the phase boundary using light ions.

ALICE will be able to study all current observables in one detector, many on an event-by-event basis.

New collaborators very welcome

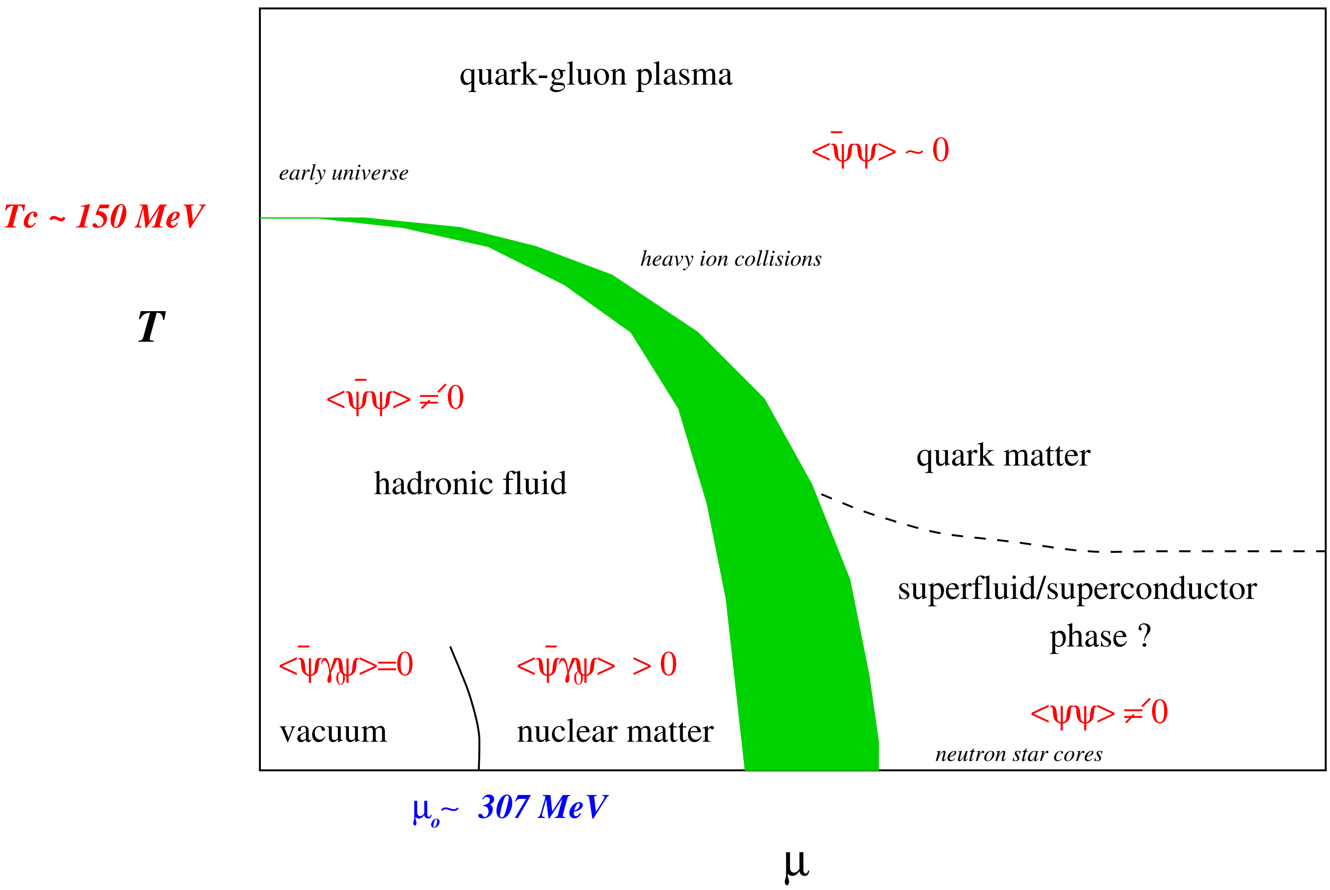


Figure 1: Qualitative phase diagram for QCD.

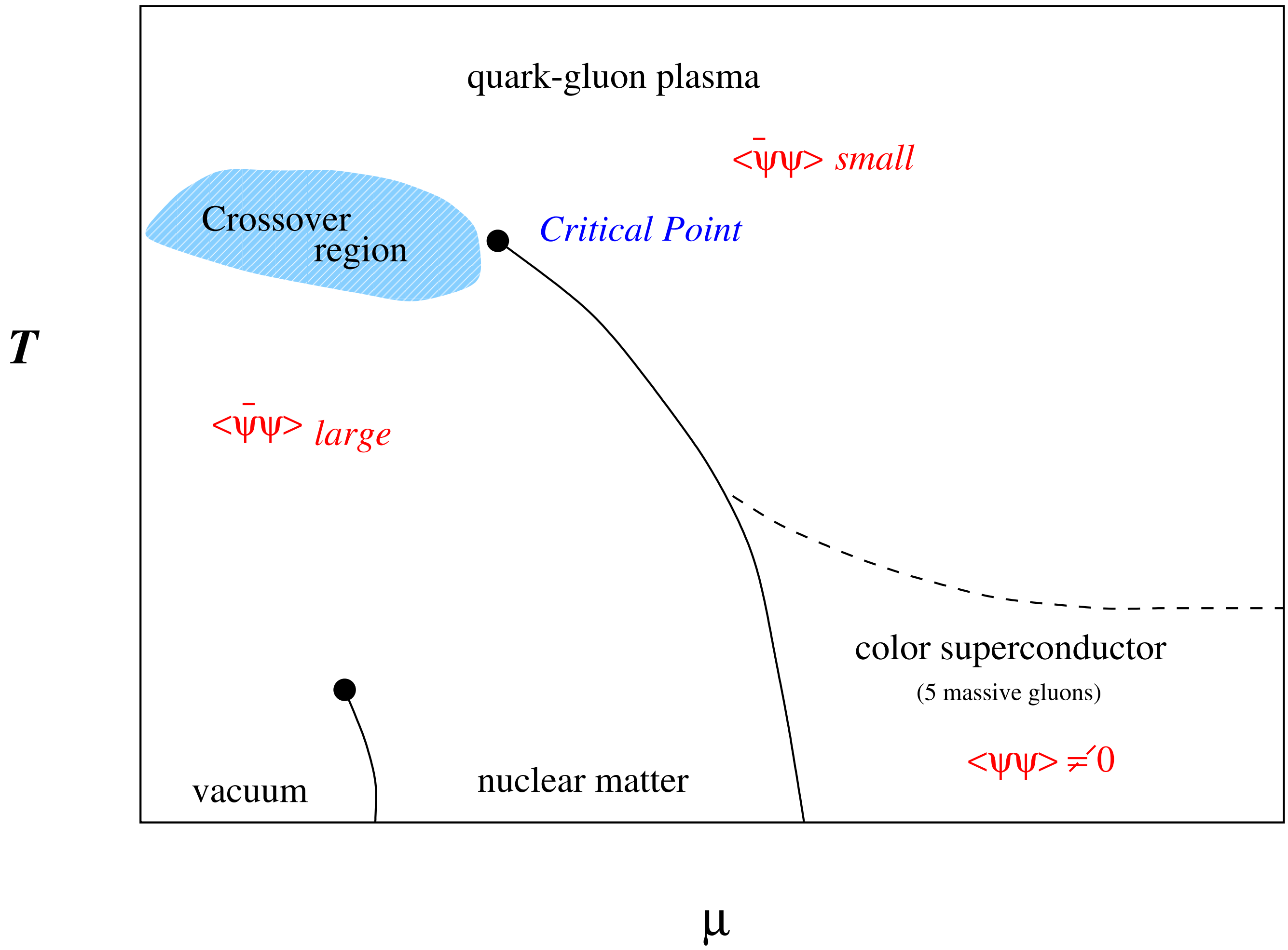


Figure 1: Tentative phase diagram for QCD with 2 light flavors.

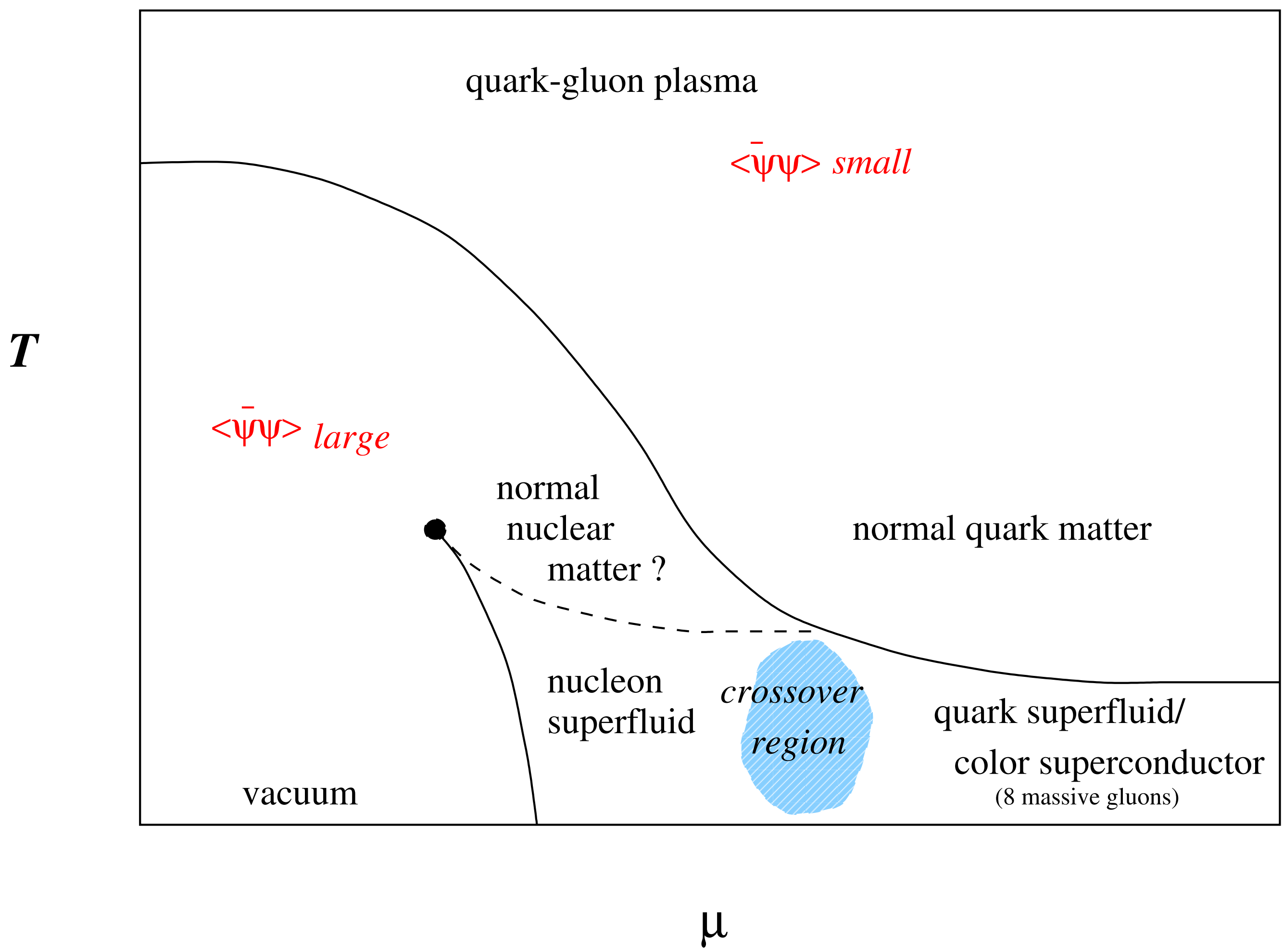


Figure 1: Tentative phase diagram for QCD with 3 light flavors.