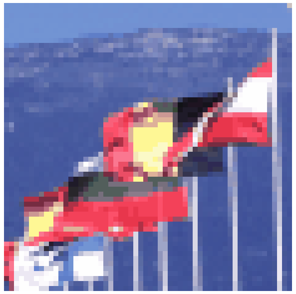
Heavy Ion Physics Program of CERN: Alice Setup at LHC.



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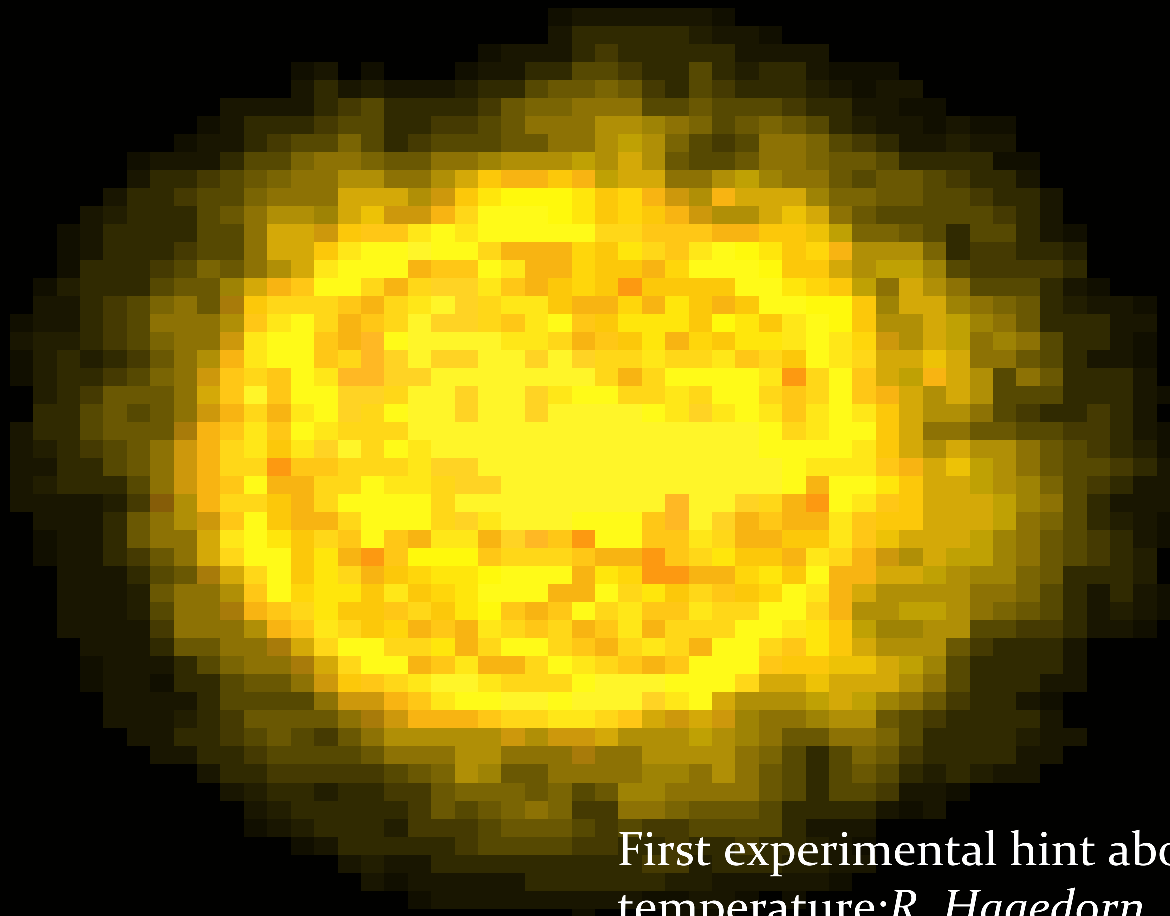
First School on LHC Physics: ALICE week
NCP Islamabad, 12-30 October,2009

$\rho_c \geq 7\text{-}10\ \rho$

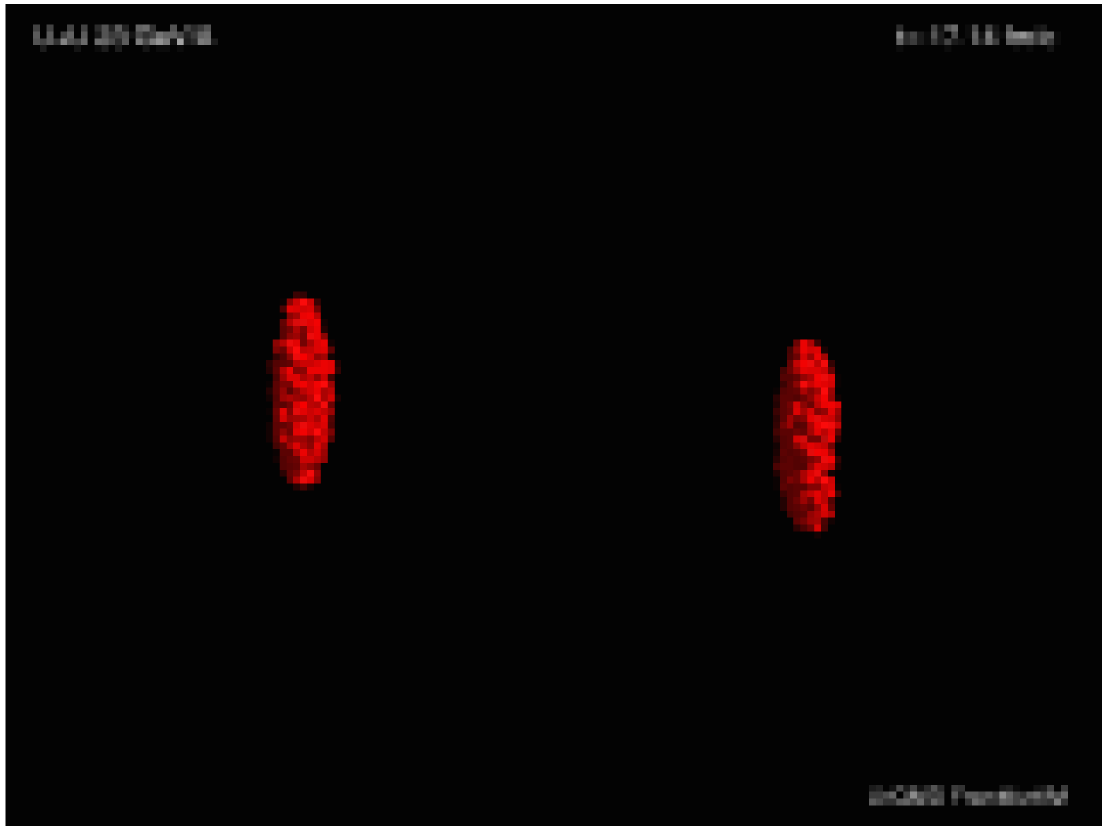


First experimental hint about critical temperature:*R. Hagedorn*, Suppl. Nuovo. Cimento **3** 1965, 3, p. 147.

$T_c \geq 5\ T$

Where could be QGP formed ?

Central collisions of ultrarelativistic heavy ions



$$b \to 0$$

How could we identify experimentally QGP?

Some of the traditional QGP signatures

- **Dilepton production**: A quark and an anti-quark can interact via a virtual photon γ^* to produce a lepton and an anti-lepton l^+l^- (often called dilepton). Since the leptons interact only via electromagnetic means, they usually reach the detectors with no interactions, after production. As a result dilepton momentum distribution contains information about the thermodynamical state of the medium.
- **Thermal Radiation**: Similar to dilepton production, a photon and a gluon can be produced via $q + \bar{q} \to \gamma + g$. Since the electromagnetic interaction isn't very strong, the produced photon usually passes to the detectors without any interactions after production. And just like dilepton, the momentum distribution of photons can yield valuable information about the momentum distributions of the quarks and gluons that make up the plasma, giving us a window into its thermodynamical properties.
- **Strangeness Enhancement**: Production of strange quarks requires a larger amount of energy compared to ordinary u and d quarks. The high energy densities in QGP are conducive for sś production, leading to an enhancement in the number of strange particles as compared to the strangeness production in p+p collisions.

Some of the traditional QGP signatures

- ***J/Ψ* suppression**: In a Quark-Gluon-Plasma (QGP), color screening due the presence of free quarks and gluons (similar to Debye screening seen in QED), the *J/ Ψ* particle — a bound state of charm and anti-charm quarks $\bar{c}c$ — can dissociate. This leads to a suppression of *J/ Ψ* production, a classic signature.
- **HBT:** The Hanbury-Brown-Twiss effect — first used to measure the diameter of a star is also used in high energy nuclear experiments, by measuring the space-time (or energy-momentum) correlation of identical particles emitted from an extended source. In ultrarelativistic heavy ion collisions, an HBT measurement can yield information about size and the matter distribution of the sources
- **Jet suppression**: In nucleon collisions, energetic partons (jets) can be produced via hard scatterings. In presence of deconfined matter, they interact strongly, leading to energy loss GeV/fm, mostly due to gluon bremsstrahlung processes. This results in a decrease in the yield of high energy particles or jet suppression.
- **Flow (radial and elliptic)** .

Obtained result cannot give possible to say surely that we have any experimental signal on Quark Gluon Plasma formation.

Why?

1.These results are model dependence;

2.These results could be explained by other ways.

What is a Problem ?

Before never physicists have had so difficult object as QGP which can't interact with our World and with our detectors due to Confinement .

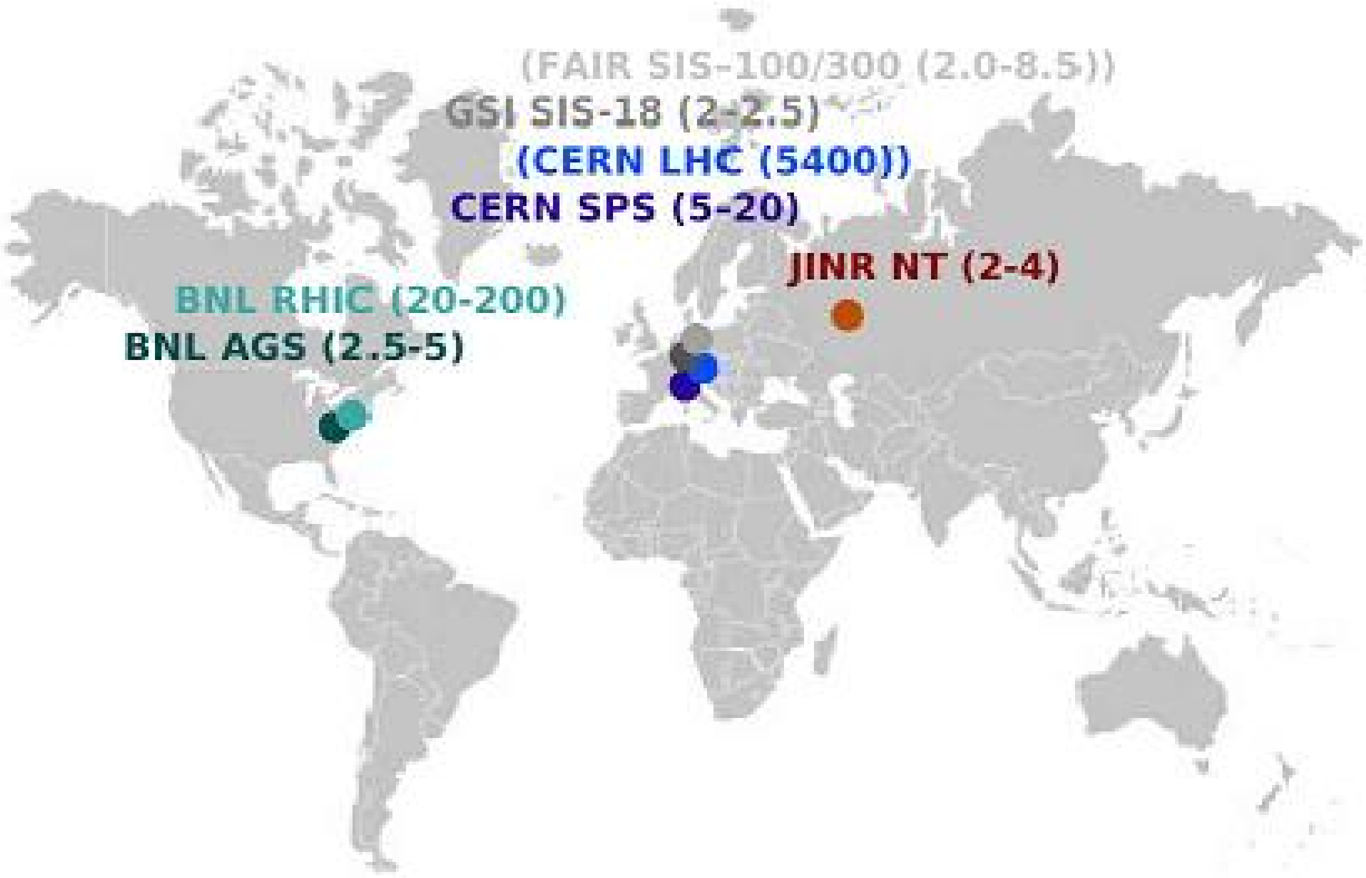
It is absent complete theory of strong interactions --- quantitative QCD.

In any case QGP could be formed in central collisions , in events with huge multiplicity of secondary particles – enormous background .

Traditional applied methods to process the data (single and multiparticle correlation methods, methods of effective mass , missing mass methods , HBT and others) are very sensitive to background information .

It is impossible to use 4π geometry detectors (because the volume of information is huge) which could give as some prompts to go forward surely.

Heavy Ion Accelerators



Accelerators and Colliders of Relativistic and Ultrarelativistic particles and nuclei

Name	Location	Beam	Energy
Synchrophasotron	JINR Russia	Light nuclei	4.2 A GeV
BEVALAC	BERCLY USA	Au	2 A GeV
SIS	GSI Germany	Au	1-2 A GeV
AGS	BNL USA	Au	11 A GeV
SPS	CERN Geneva	Pb-Pb	17.3 AGeV
NUCLOTRON	JINR, Russia	Au	5 -9 AGeV
SIS	GSI Germany	Au	10– 30 AGeV
RHIC	BNL USA	Au-Au	200 AGeV
LHC	CERN Geneva	Pb-Pb	5200 AGeV


Time Projection Chamber
Particle Identification Detector
High-Momentum Particle Identification Detector
Absorber
Dipole Magnet
L3 Magnet
Muon Chambers
Photon Spectrometer
Inner Tracking System
Alice

What will be new at LHC

	SPS	RHIC	LHC	
$\sqrt{s_{NN}}$ (GeV)	17	200	5500	
dN_{ch}/dy	500	850	1000-4000	
T/T_c	1.1	1.9	3.0-4.2	hotter
ε (GeV/fm^3)	3	5	15-60	denser

"The biggest step in energy in the history of heavy-ion collisions"

The ALICE experiment is the only LHC experiment designed specifically for the study of central nucleus–nucleus collisions, where thousands of charged particles per unit rapidity are expected.

The typical expected yearly running times are of the order of :

-- 10^7 s for proton-proton collisions ;
-- 10^6 s for the heavier systems.

Collision system	$\sqrt{s_{NN}}$(TeV) c.m.s. energy	L0 ($cm^{-2}s^{-1}$) expected luminosity	σ_{geom} (b) geometrical cross sections
pp	14.0	10^{34} *	0.07
PbPb	5.5	10^{27}	7.7
pPb	8.8	10^{29}	1.9
ArAr	6.3	10^{29}	2.7

* due to the limited rate capability of the ALICE detector, it is planed to limit the luminosity in the interaction region to a maximum of 10^{31} $cm^{-2}s^{-1}$

2000 CERN announced

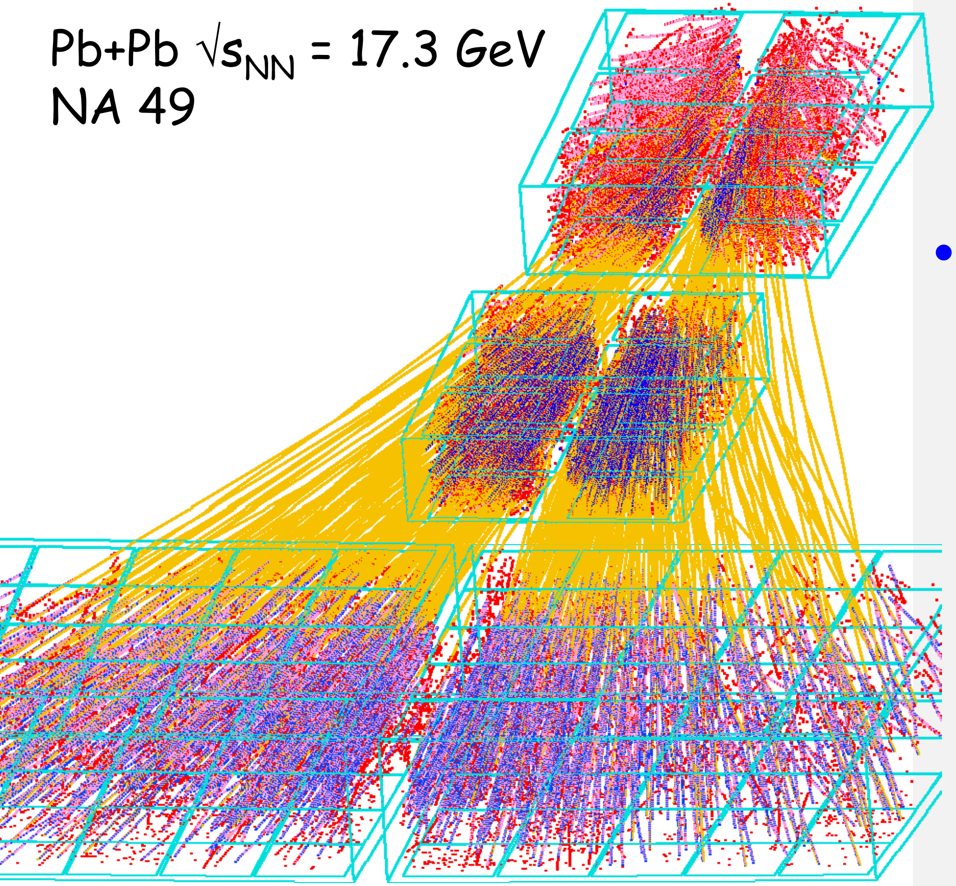
[http://webcast.cern.ch/Archive/Seminars /
Special/New_state_of_Matter_10022000.html]

evidence for the existence of a new state of matter :

- 20 times denser than normal nuclear matter, i.e. with a density of about 5 x10^{15} grams per cubic centimeter

- at temperatures over 100,000 times as hot as the centre of the sun, i.e. at about 2 trillion degrees Kelvin.

SPS: *"New State of Matter created at CERN"*



- 7 dedicated experiments:

  NA44, NA45/CERES, NA49, NA50, NA52/NEWMASS, WA97/NA57, and WA98

- *Compelling evidence for the existence of a new state of matter* (ε [3.2 GeV/fm^3]$>\varepsilon_c$, strangeness enhancement, J/ψ suppression, direct thermal photon radiation,…)

- Interpretation in terms of QGP formation not unique

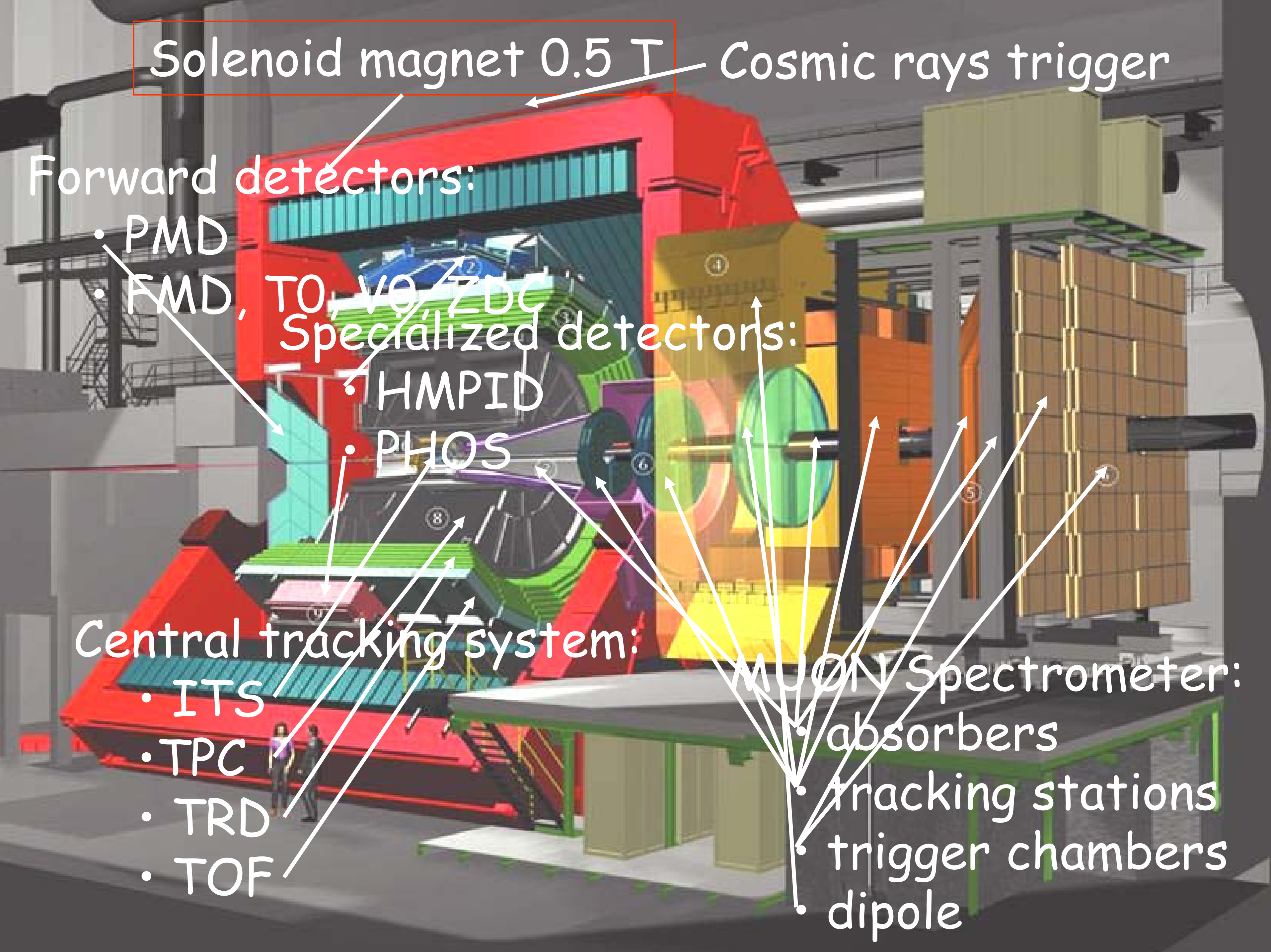
The ALICE experimental apparatus consists of following main components:

-- **The central detector,** $|\eta| < 0.9$ over full φ, is contained inside a large solenoidal magnet providing a magnetic field $|B| < 0.5$ T. It includes, from the interaction region outwards, a vertex detector – the Inner Tracking System (ITS) – made of six layers of silicon microdetectors (Si pixels, Si drifts and Si strips), a large Time Projection Chamber (TPC) , a Transition Radiation Detector (TRD) for electron identification and a Time Of Flight detector (TOF) for the identification of π, K , p. The central detector is completed by two detectors with reduced azimuthal acceptance: the High Momentum Particle Identification Detector (HMPID) – an array of ring imaging Cherenkov detectors for particle identification at high momentum – and the PHOton Spectrometer (PHOS) – a high resolution electromagnetic calorimeter made of high density scintillator crystals.

-- **The muon arm,** $-4.0 < \eta < -2.4$, consists of a hadron absorber positioned very close to the interaction region, a spectrometer made of a dipole magnet with a field integral of 3 Tm and five tracking stations, a second iron filter and two trigger stations.

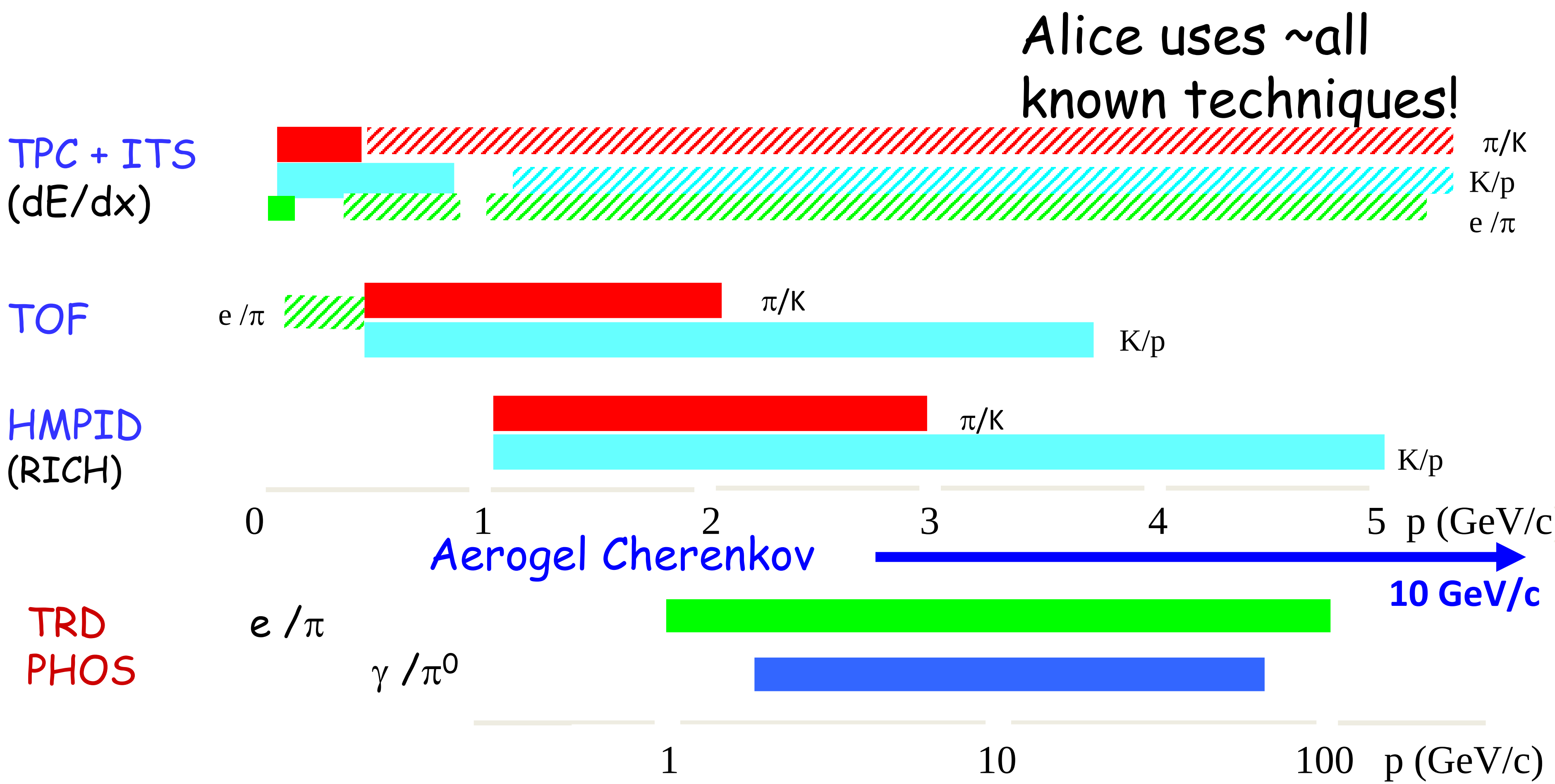
-- **The forward detectors:** the Photon Multiplicity Detector (PMD), the Forward Multiplicity Detector (FMD) – charged particle multiplicity – $-3.4 < \eta < 5.1$ – the Zero Degree Calorimeters (ZDC) and a system of trigger scintillators and quartz counters (T0 and V0).

-- **The array of scintillators for triggering on cosmic rays** (ACORDE).



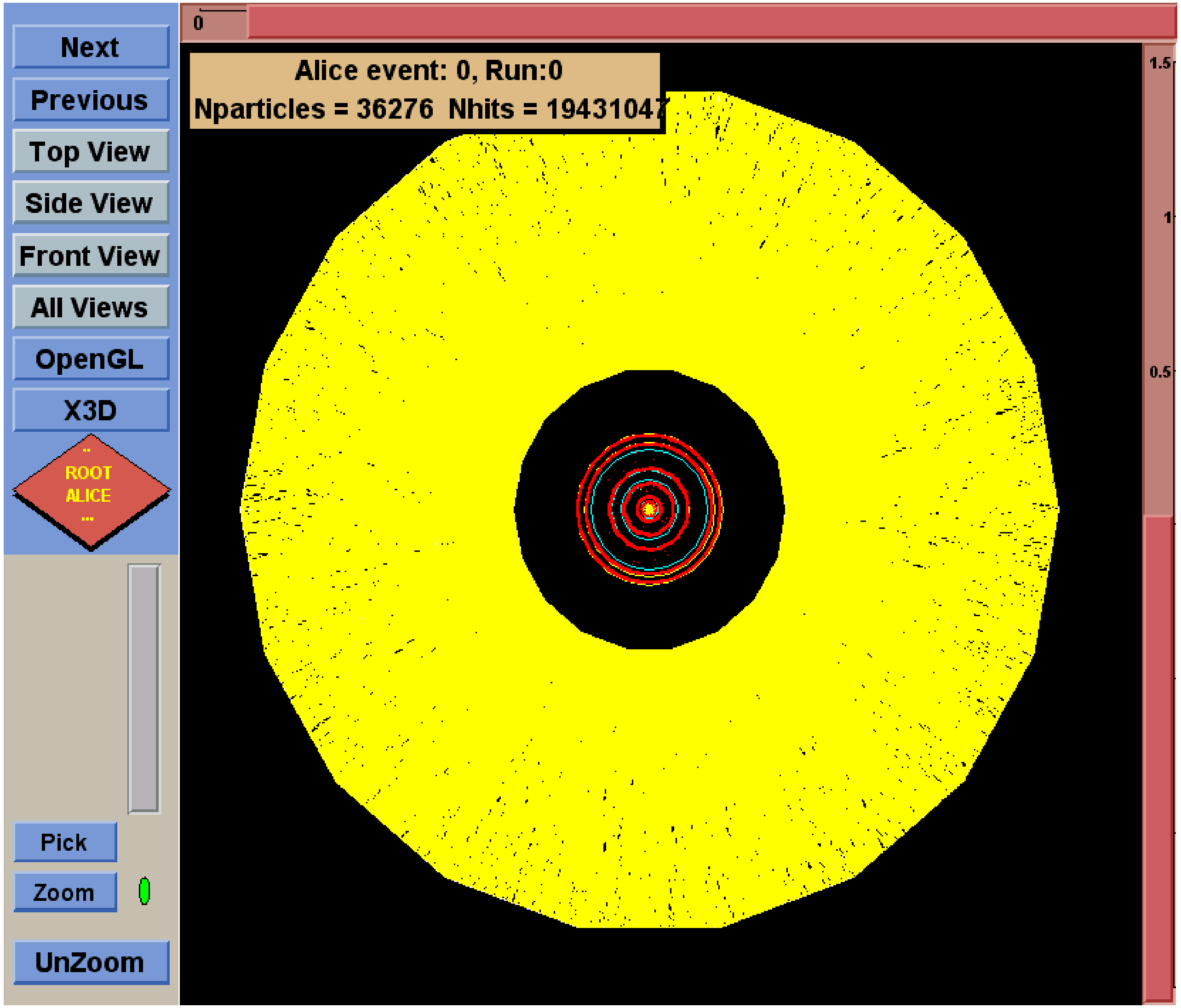
Solenoid magnet 0.5 T
Cosmic rays trigger
Forward detectors:
• PMD
• FMD, T0, V0, ZDC
Specialized detectors:
• HMPID
• PHOS
Central tracking system:
• ITS
• TPC
• TRD
• TOF
MUON Spectrometer:
• absorbers
• tracking stations
• trigger chambers
• dipole

ALICE PID



Alice uses ~all known techniques!
TPC + ITS
(dE/dx)
π/K
K/p
e /π
TOF
e /π
π/K
K/p
HMPID
(RICH)
π/K
K/p
0
1
2
3
4
5 p (GeV/c)
Aerogel Cherenkov
10 GeV/c
TRD
PHOS
e /π
γ /π0
1
10
100 p (GeV/c)

LHC: "The closest approximation of the Big Bang"



ALICE Physics Program

- Deconfinement:
  - charmonium and bottomonium spectroscopy
- Energy loss of partons in quark gluon plasma:
  - jet quenching high p_t spectra
  - open charm and open beauty
- Chiral symmetry restoration:
  - neutral to charged ratios
  - resonance decays
- Fluctuation phenomena - critical behavior:
  - event-by-event particle composition and spectra
- pp collisions in a new energy domain

Physics performance: examples

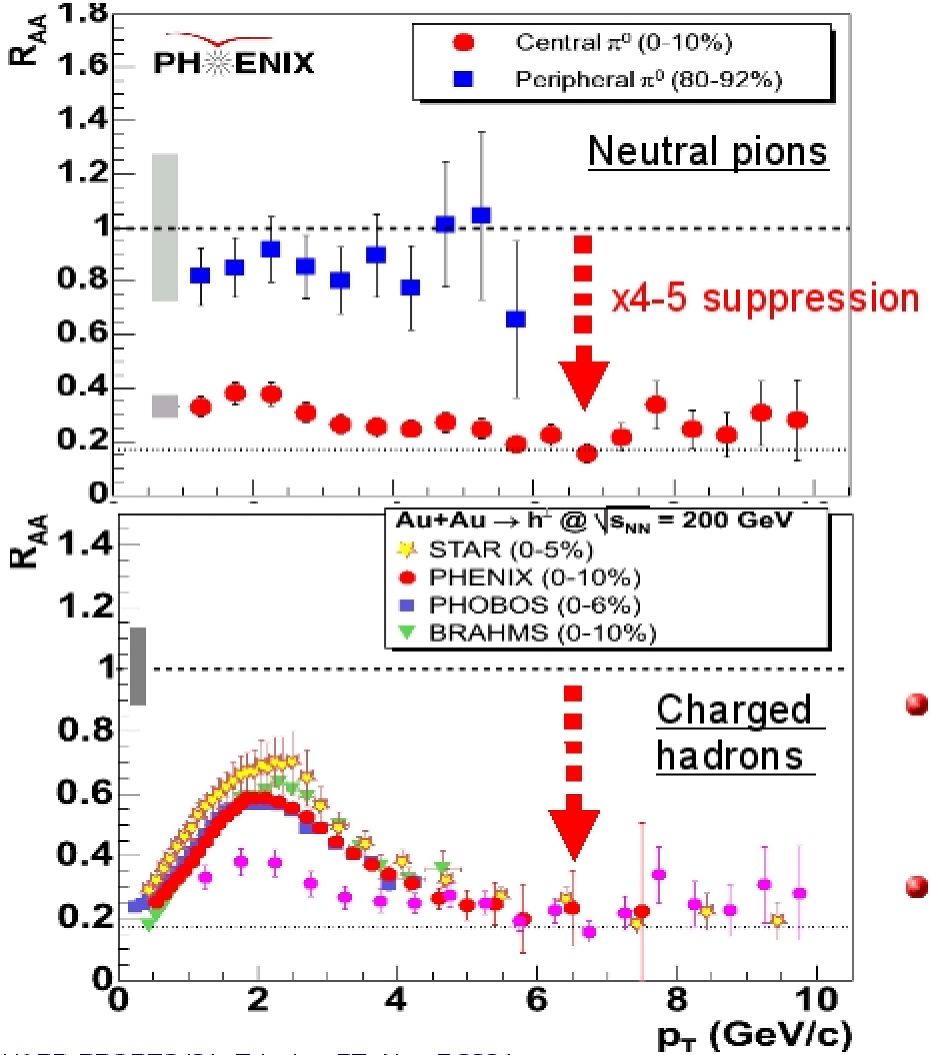
Heavy flavours in the central detector

Suppression of the production of high transverse momentum (p_T) particles ("quenching") was observed at the Relativistic Heavy-Ion Collider (RHIC) and interpreted as due to energy loss at the partonic level .

Theoretically , the energy loss effect is expected to be parton-specific (stronger for gluons than for quarks) and flavour-specific (weaker for heavy than for light quarks). One would therefore expect less high p_T quenching for heavy flavour particles, that originate from heavy quark jets, than for light flavour particles, that are created in both gluon and (mostly light) quark jets.

At the LHC, where much higher heavy flavour yields are expected (over 100 cc pairs and about 5bb pairs per central Pb-Pb collision) one should be able to study the production of heavy flavour hadrons in heavy-ion collisions at an unprecedented level of detail. In addition, unlike the RHIC detectors, ALICE is equipped with a vertex detector (the ITS) which allows to measure the separation from the primary vertex of the heavy flavour decay tracks. Therefore, it is anticipated being able to fully reconstruct heavy flavour decays and to measure separately the production of charm and beauty hadrons.

(1) High p_T suppression in central Au+Au @ 200 GeV

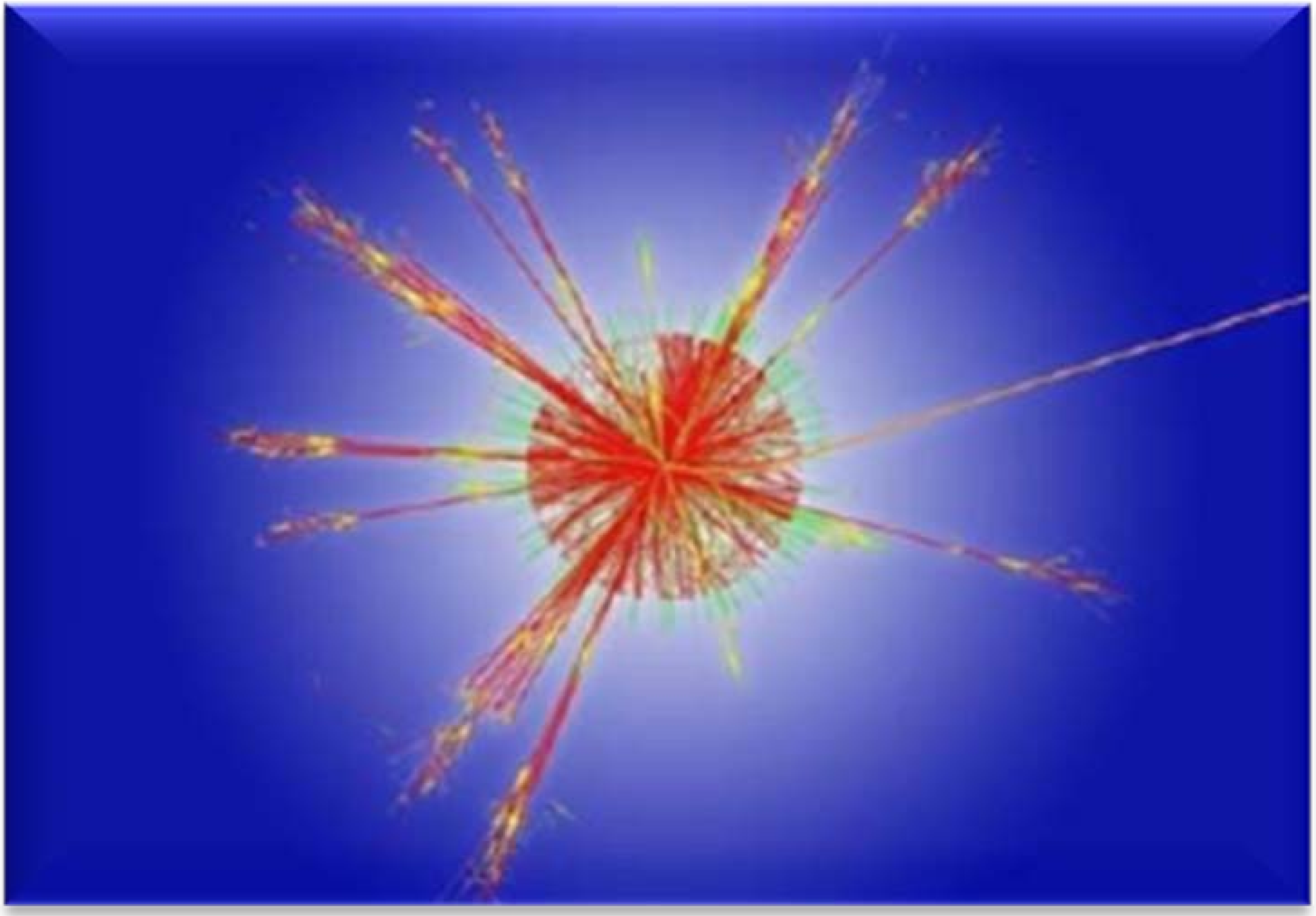


- $R_{AA} << 1$: well below pQCD (collinear factoriz.) expectations for hard cross-sections
- Consistent with "jet quenching" expectations for leading hadrons

Jets

At the LHC, jets will be abundantly produced. It is expected around one jet with energy above 20 GeV per central Pb-Pb event and about 10^5 jets with energy above 200 GeV in 10^6 s of Pb-Pb running. Such high energy jets will be easily visible and reconstruct able even in the very high multiplicity environment of central Pb-Pb collisions at the LHC.

The reconstruction of jets in heavy-ion collisions presents some difficulties due to the very high background. The introduction of a p_T cut should help reduce the soft background.



The art picture of jets in pp-collisions.

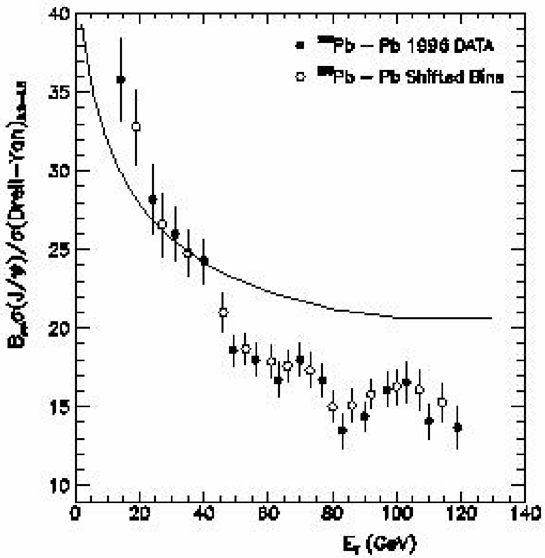
Quarkonia in the muon arm.

Quarkonia production is one of the prime observables in ultrarelativistic heavy ion physics, following an early prediction that the production of quarkonia would be suppressed in the Quark-Gluon Plasma (QGP). Anomalous suppression of the production of J/ψ was indeed observed in central Pb-Pb collisions at the CERN Super Proton Synchrotron (SPS), on top of the expected "nuclear" suppression systematics observed with lighter systems.

As an alternative to the QGP explanation, it was also proposed that the anomalous suppression could be due to an effect of dissociation of the produced J/ψ by interaction with commoving hadrons. In both cases, it was expected that the effect would be stronger at RHIC.

An important experimental issue: at the LHC energy one expects a significant (20 – 30 %) contribution to the J/ψ yield from B decays. This contribution will be controlled by measuring open B production both in the central detector and directly in the muon arm.

J/ψ-suppression



The ratio of the J/ψ to Drell-Yan cross-sections has been measured by NA38 and NA50 SPS CERN as a function of the centrality of the reaction estimated, for each event, from the measured neutral transverse energy Et [M.C. Abreu et al., Phys.Let. B 1999, 450, p. 456; M.C. Abreu et al., Phys.Let. B, 1997, 410, p. 337; M.C. Abreu et al. Phys.Let. B, 1997, 410, p. 327; M. C. Abreu et al. By NA50 Collaboration, Phys.Lett.B, 2001, 499, pp. 85-96].

Thank you