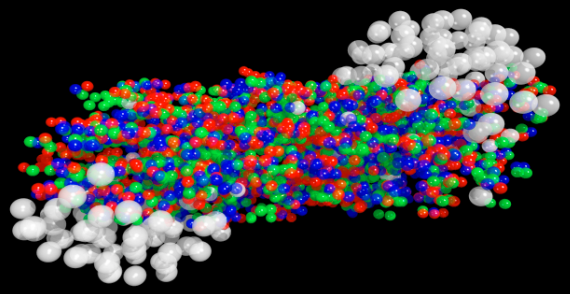
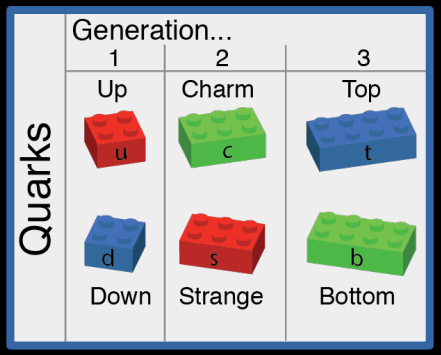
Charmonium production in Pb-Pb collisions at 5.02 TeV with CMS

Andre Stahl
Laboratoire Leprince-Ringuet

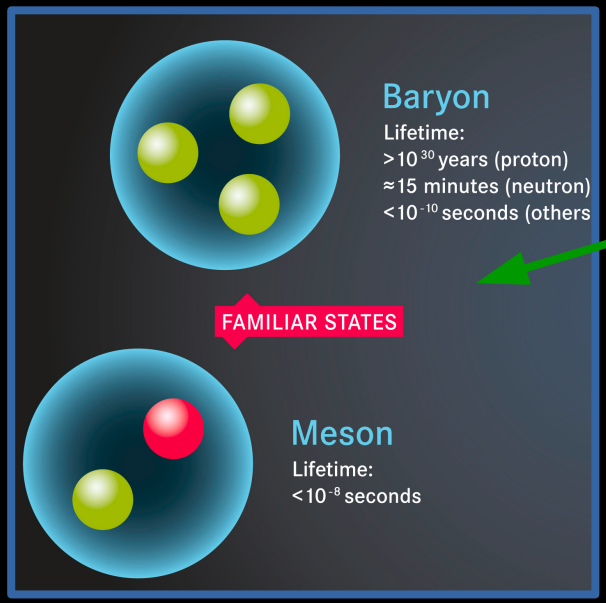


Quantum Chromo-Dynamics

QCD is the theory of strong nuclear force, which describes the interactions between quarks and gluons

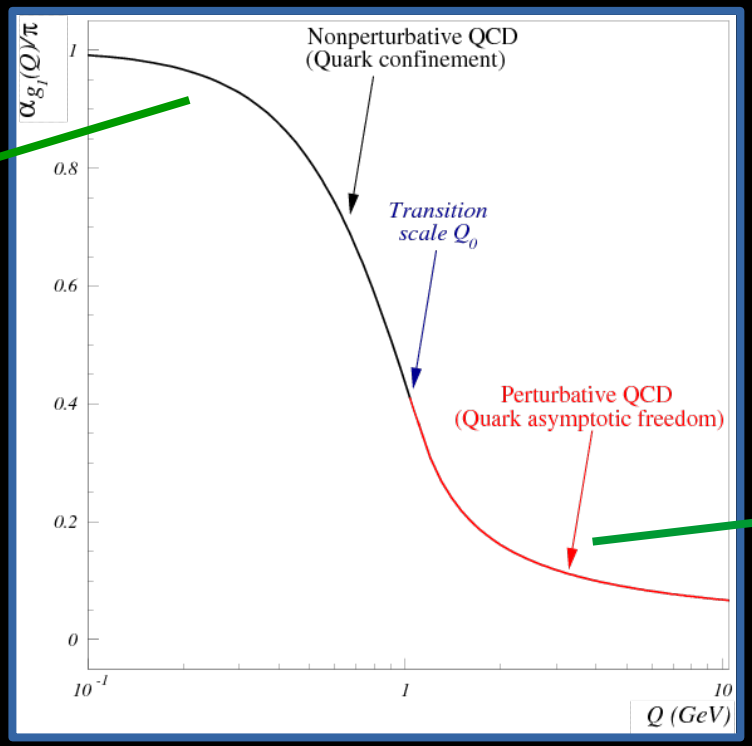


Hadrons

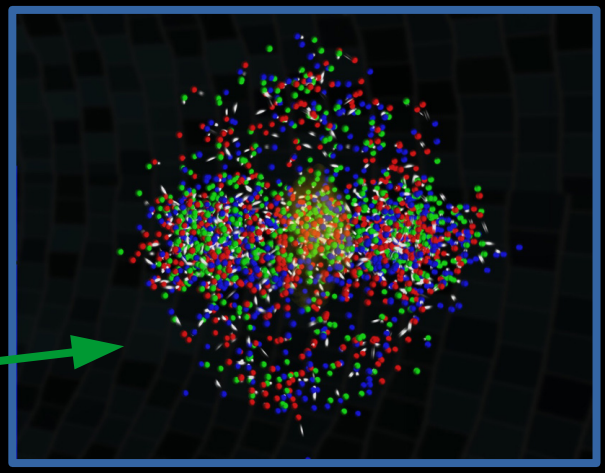


Confinement

Coupling Strength vs Energy



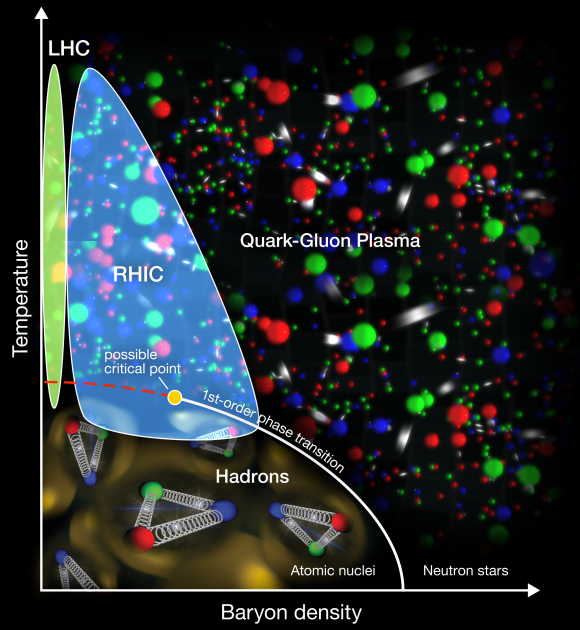
Quark-Gluon Plasma



Asymptotic Freedom

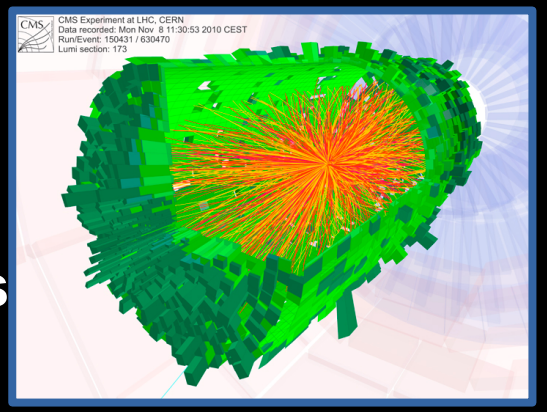
Quark-Gluon Plasma

State of matter where quarks and gluons are deconfined

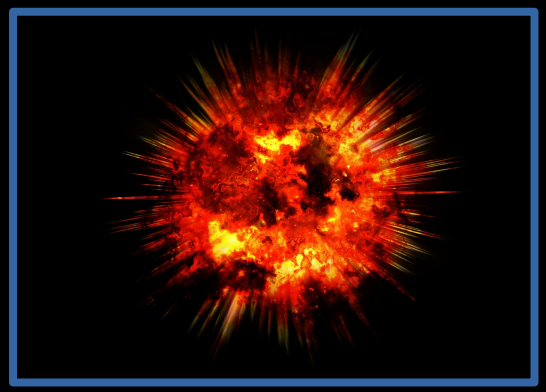


Formed at high temperature and low density

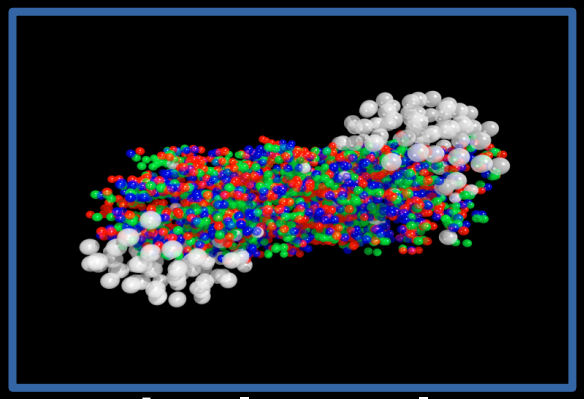
At LHC the QGP is formed in HI collisions



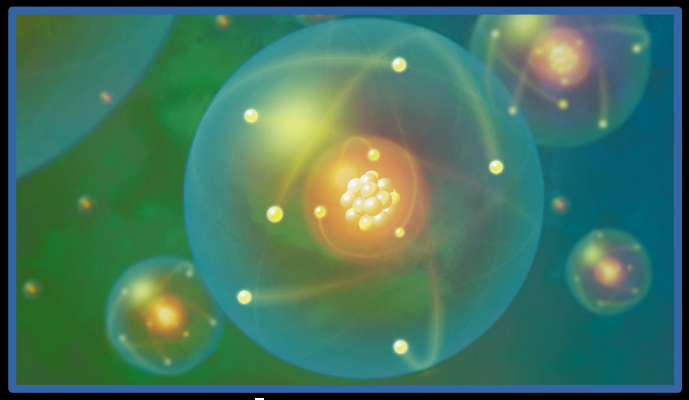
Experiment



Big Bang



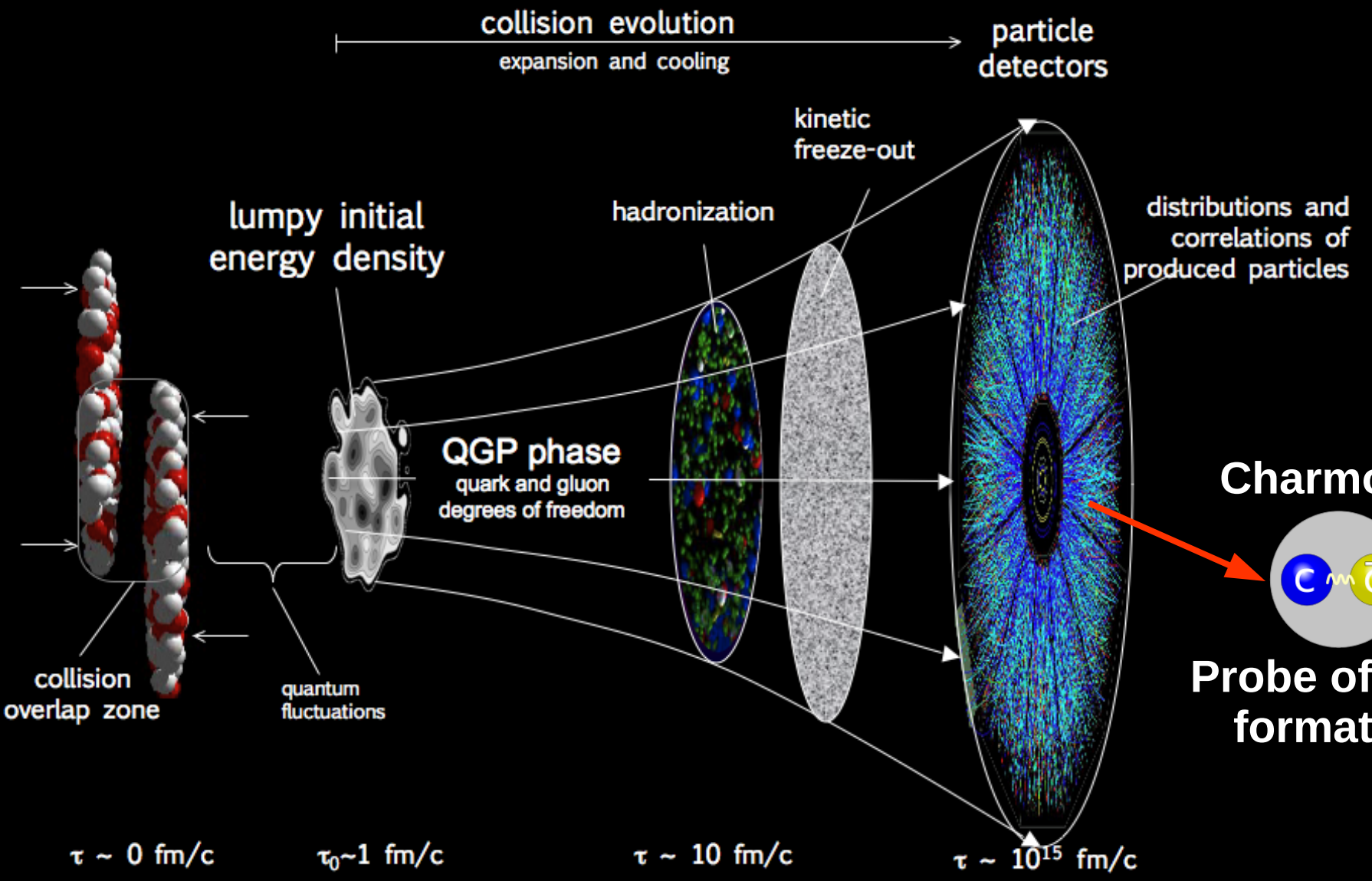
Quark-Gluon Plasma



Nuclear Matter

Quark-Gluon Plasma

Nuclear collisions and the QGP expansion



Charmonia

Probe of QGP formation

Charmonium in Heavy-Ion collisions

$\sqrt{s_{NN}}$ (TeV)

5.02

2.56

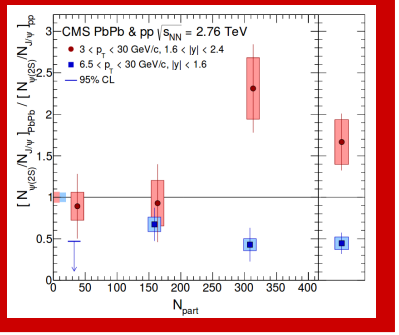
0.02

0.039

0.017

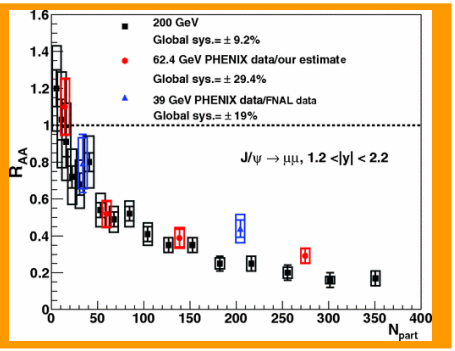
LHC

ALICE
ATLAS
CMS
LHCb



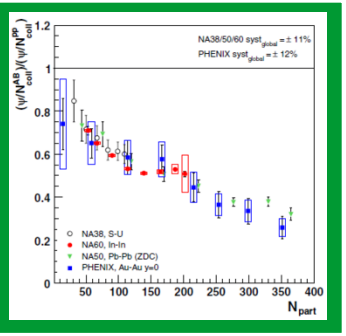
RHIC

PHENIX
STAR



SPS

NA38
NA50
NA60



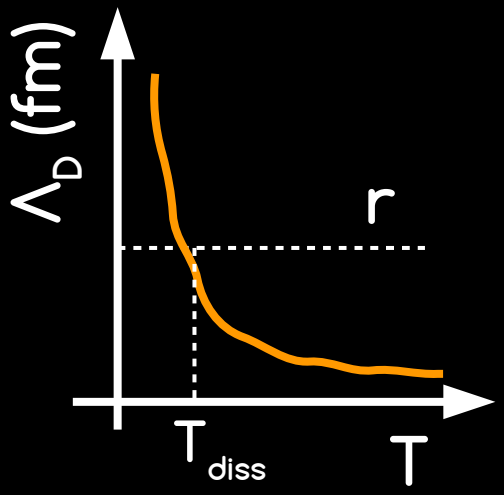
1986 2000 2009 2017

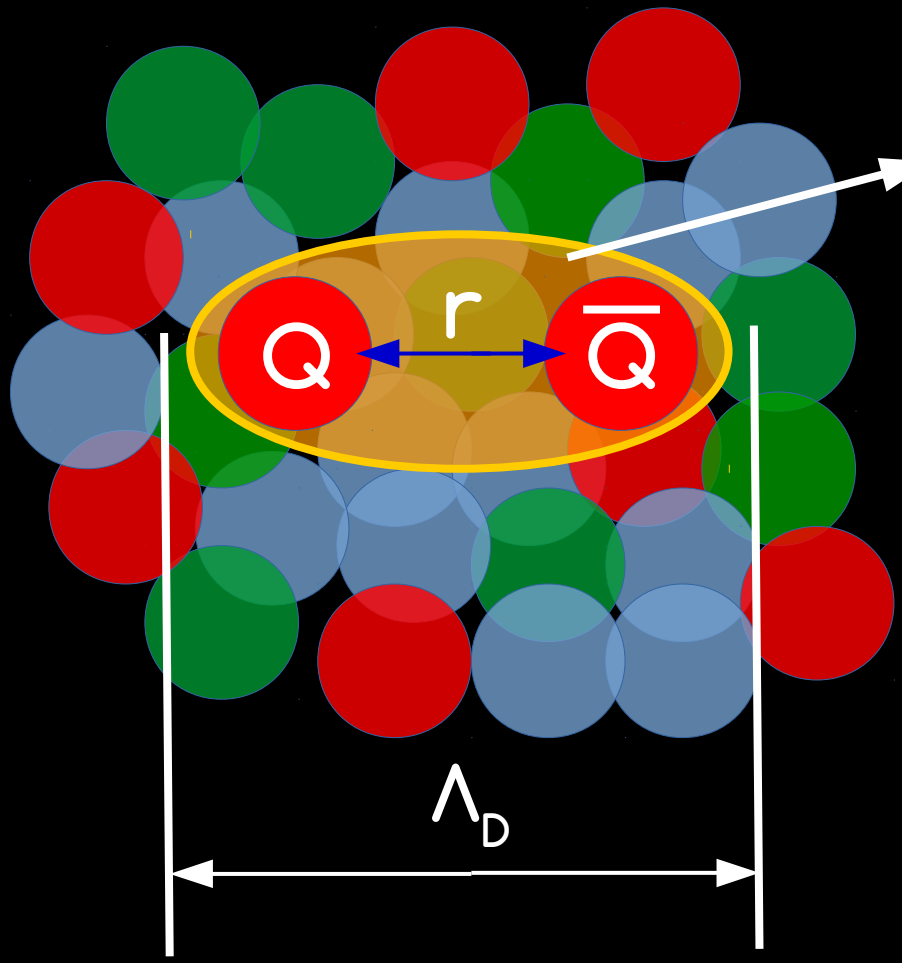
Year

Charmonium Suppression

→ **Suppression:** **Production suppressed via color screening in the QGP**

$T<T_{diss}$





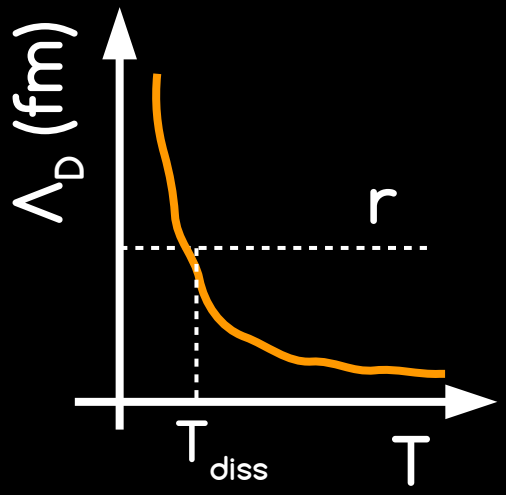
Quarks confined

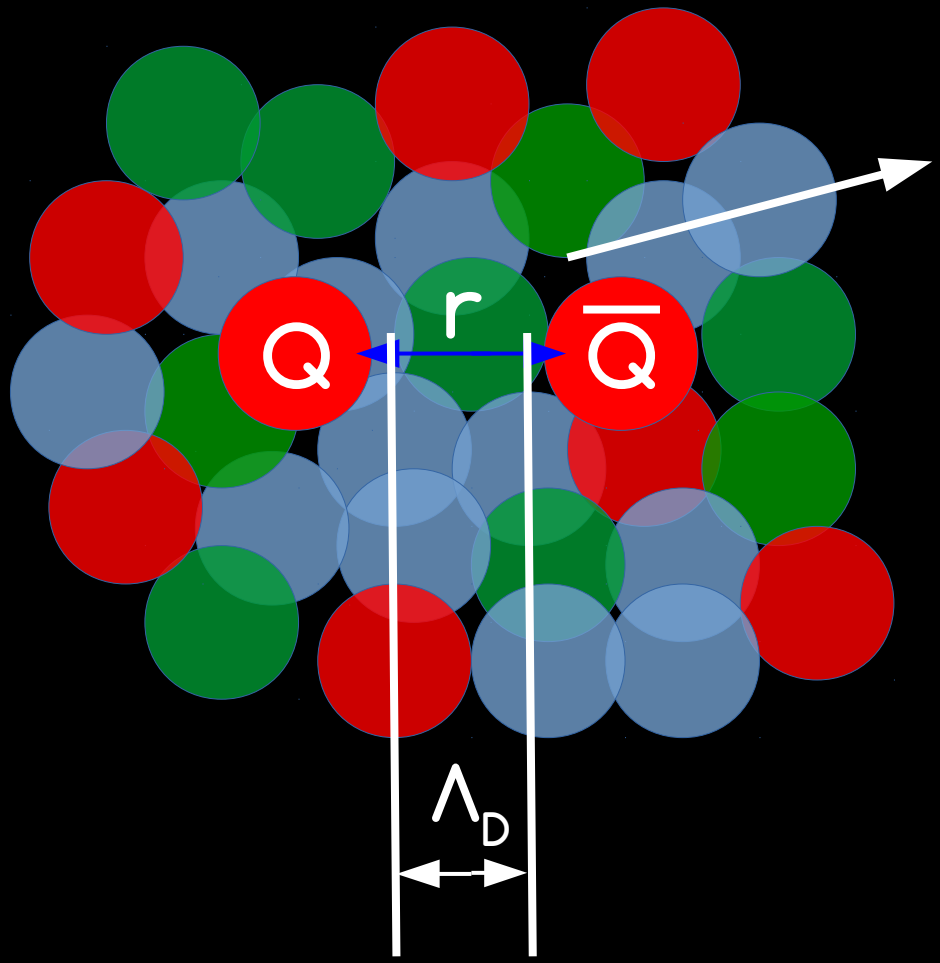
Proposed by T. Matsui and H. Satz in 1986

Charmonium Suppression

→ **Suppression:** **Production suppressed via color screening in the QGP**

$T > T_{diss}$





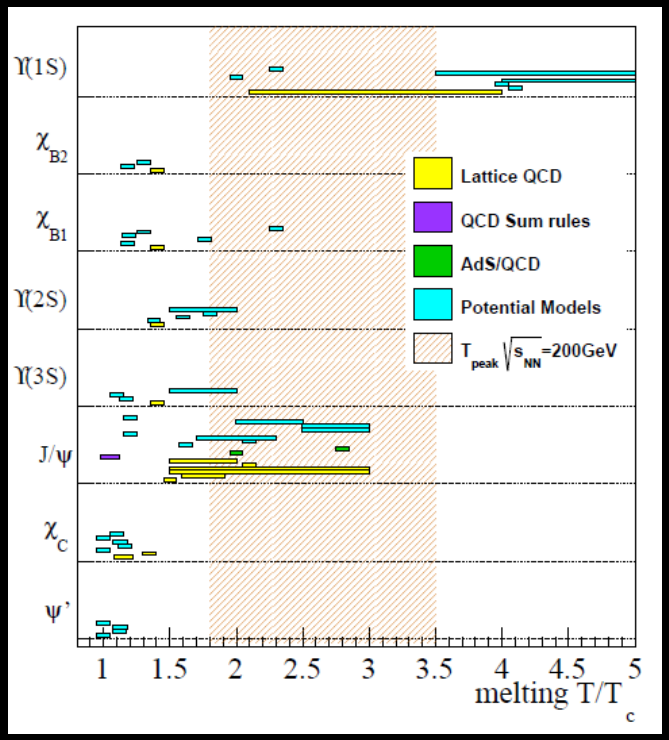
Quarks free

Proposed by T. Matsui and H. Satz in 1986

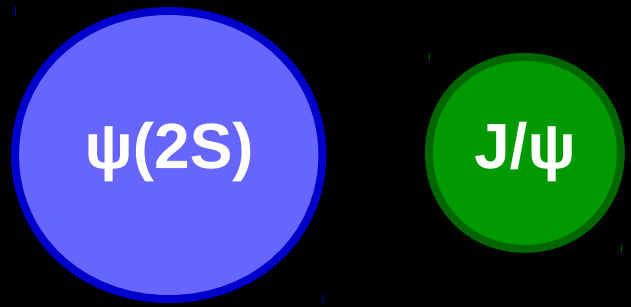
Charmonium Suppression

→ **Suppression:** Production suppressed via color screening in the QGP

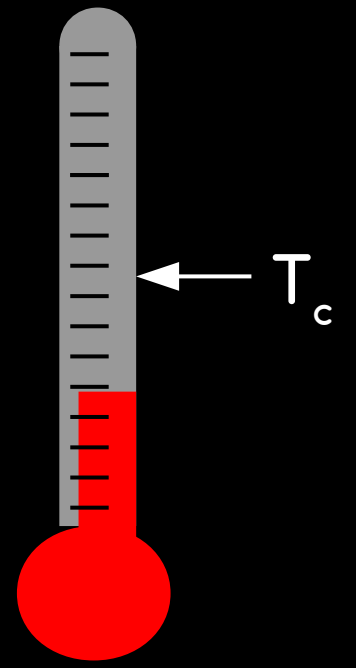
→ **Sequential Melting:** Differences in binding energies lead to sequential melting with temperature



PHENIX, Phys.Rev C91, 024913



$T<T_c$



Charmonium Suppression

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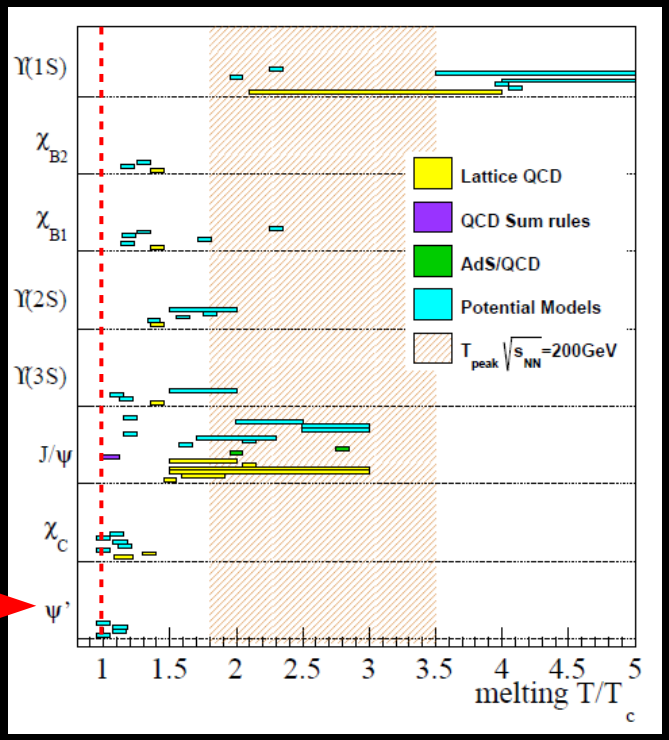
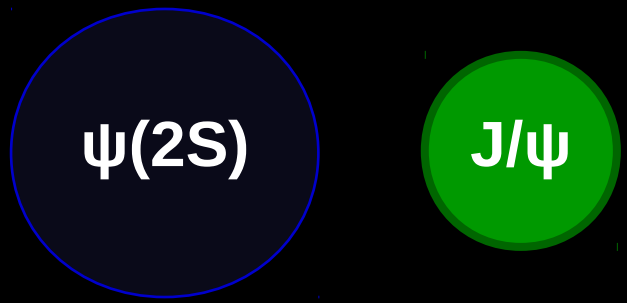
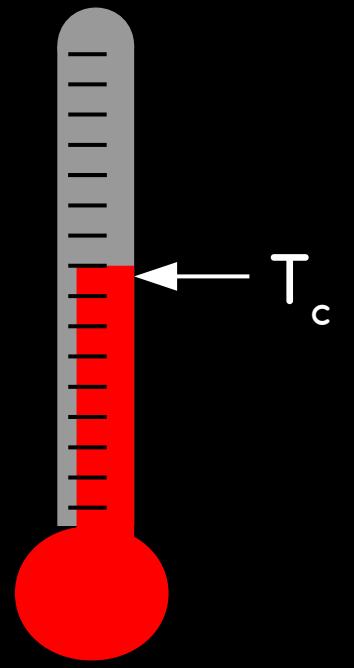
→ **Sequential Melting:** Differences in binding energies lead to sequential melting with temperature



PHENIX, Phys.Rev C91, 024913



$T \sim T_c$



Charmonium Suppression

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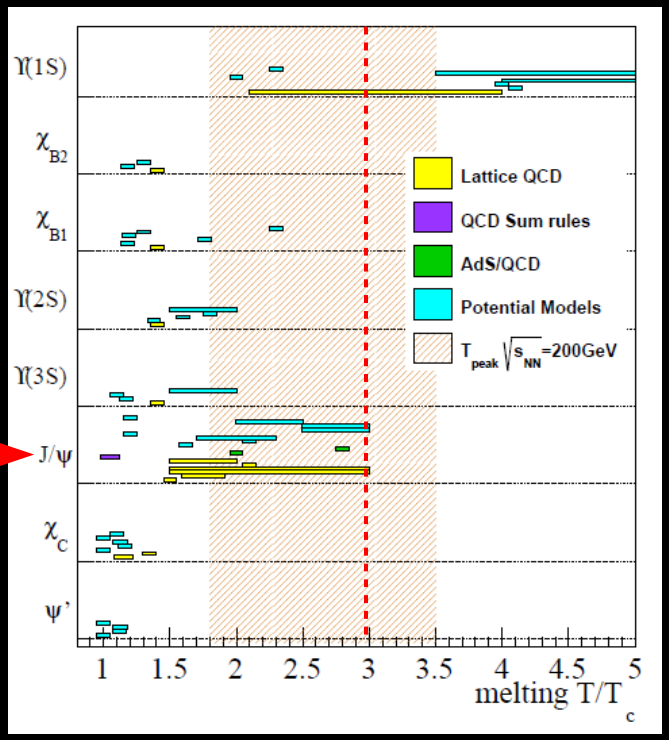
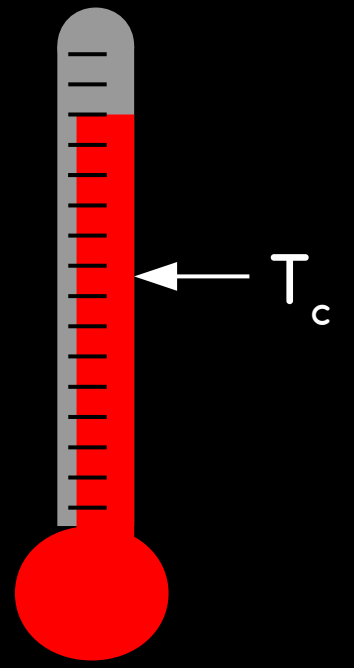


PHENIX, Phys.Rev C91, 024913

$T > T_c$

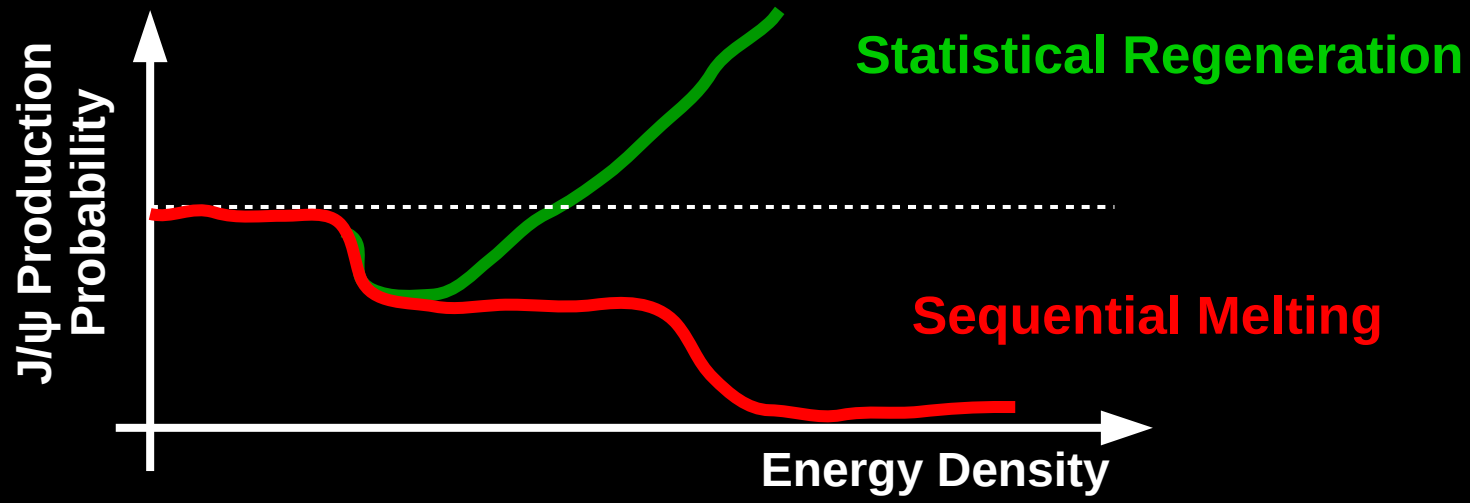


Charmonium Regeneration

→ **Recombination:** Number of $C\bar{C}$ pairs increase with collision energy

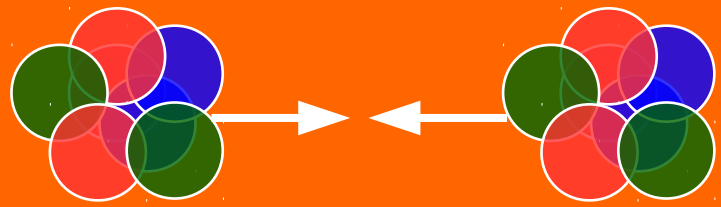
Central AA collisions	$\frac{N_{c\bar{c}}}{\text{event}}$
SPS, 20 GeV	~0.2
RHIC, 200GeV	~10
LHC, 2.76TeV	~85
LHC, 5.02 TeV	~115

→ **Regeneration:** Charmonium production enhanced via recombination at hadronization phase



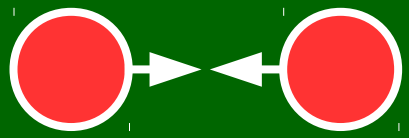
Charmonium in p-p and Pb-Pb

Pb-Pb



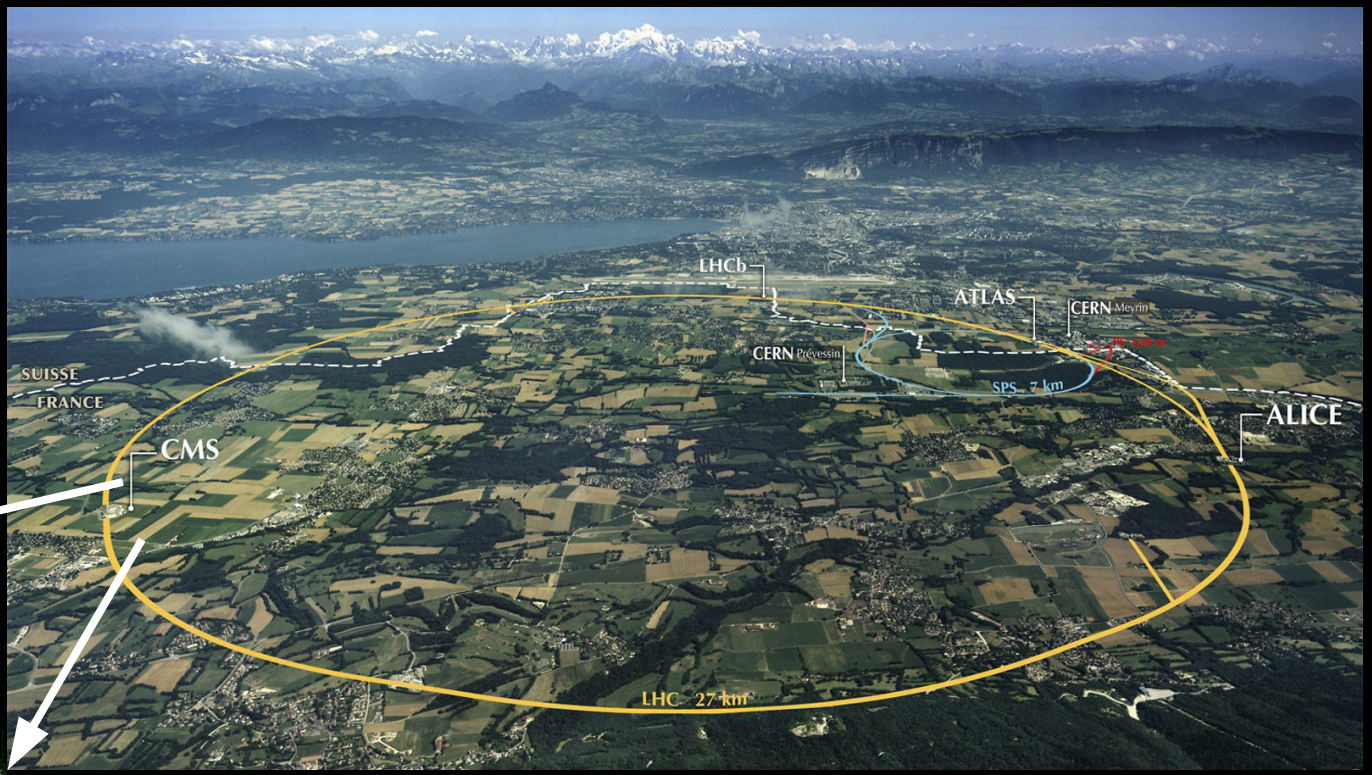
Hot Matter Effects:
Suppression vs Regeneration

p-p

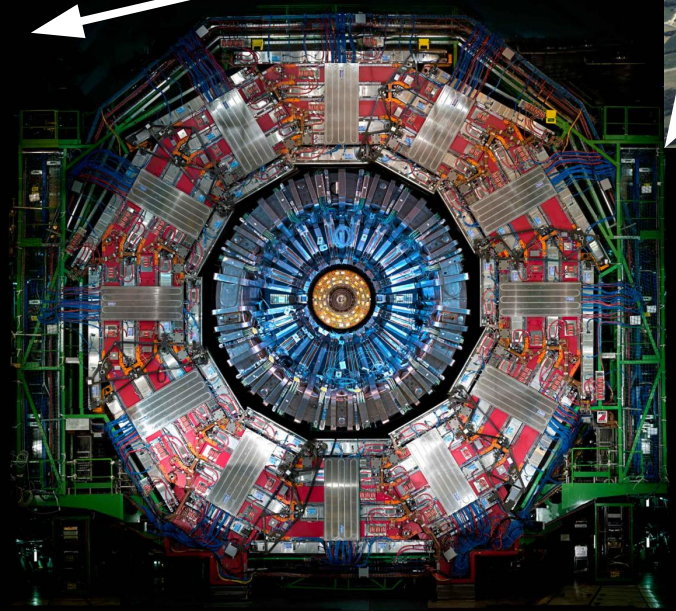


Reference:
No QGP expected

Large Hadron Collider



LHC Collider



CMS Detector

LHC Runs: Recorded by CMS

Run 1 (2011-2013)	
p-p $\sqrt{s_{NN}}$ = 2.76 TeV	L = 5 pb^{-1}
Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV	L = 150 μb^{-1}

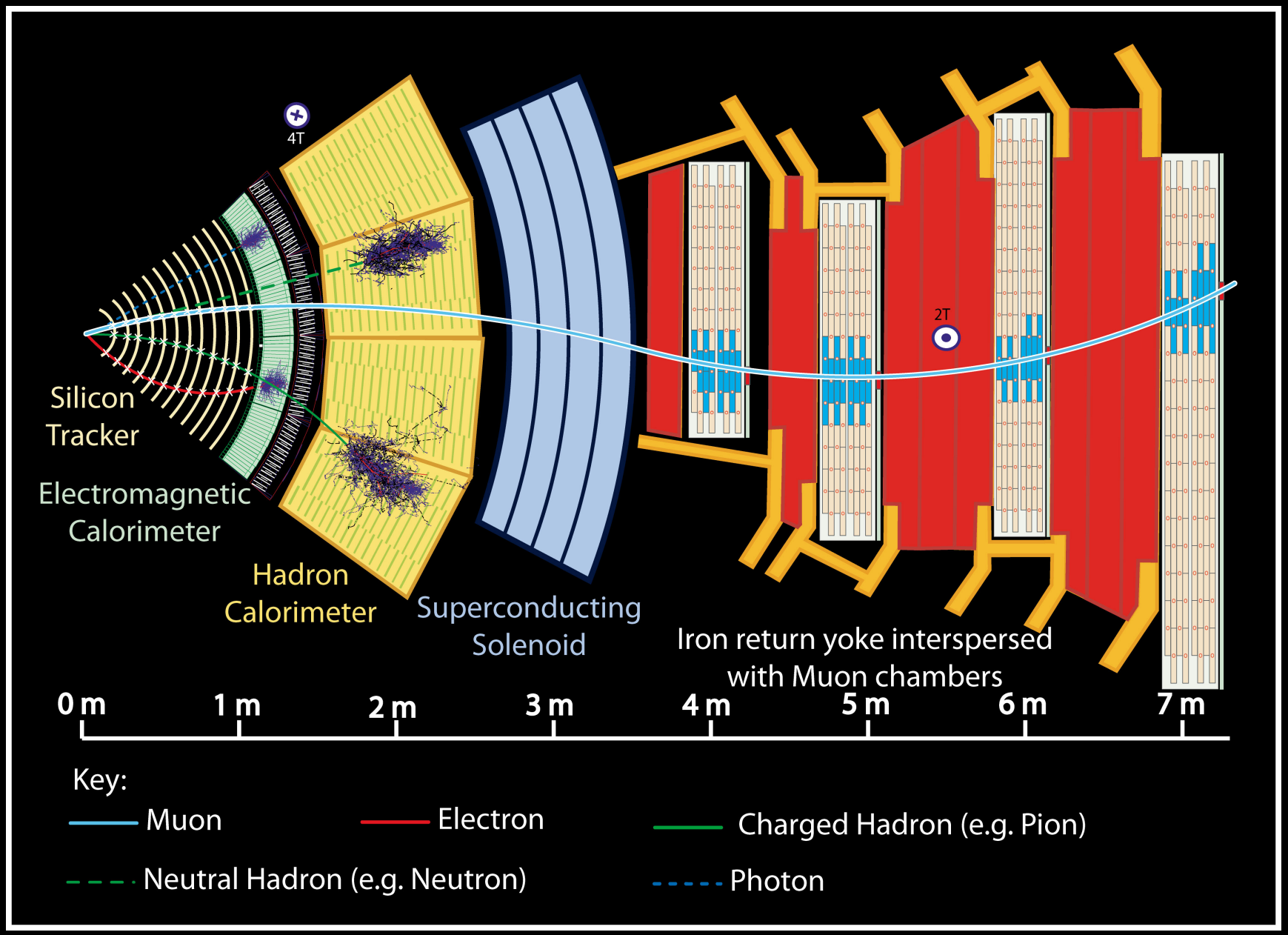
Run 1

Run 2

Run 2 (2015)	
p-p $\sqrt{s_{NN}}$ = 5.02 TeV	L = 28 pb^{-1}
Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV	L = 460 μb^{-1}

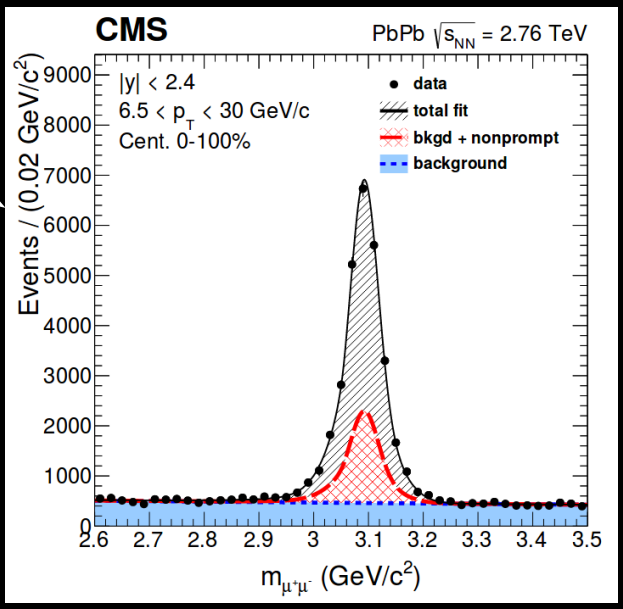
- ~2x increase in Energy
- ~3x increase in Pb-Pb Luminosity (~information stored)

Compact Muon Solenoid Detector



J/Ψ Reconstruction

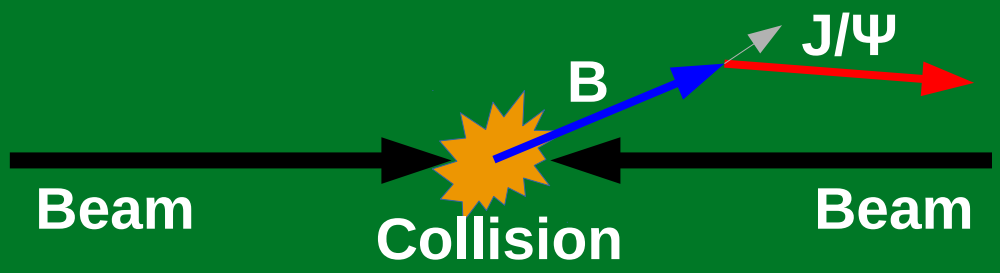
- Channel: J/Ψ → μ^+ μ^- → Inv Mass



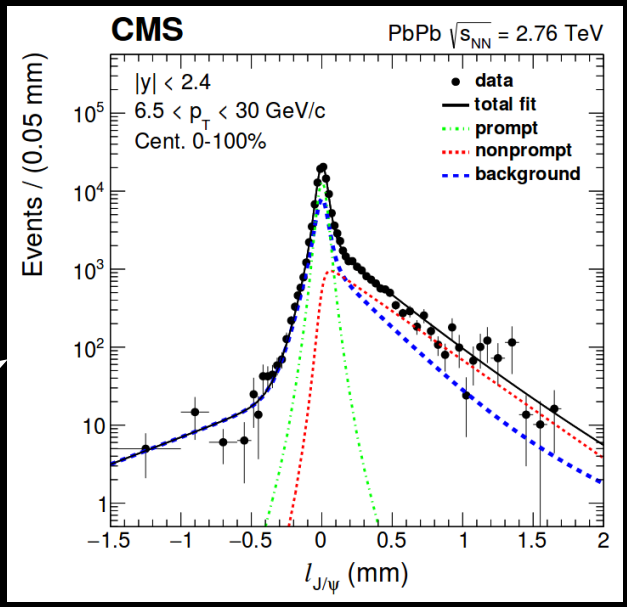
- J/Ψ production can be classified as:

Prompt: Direct or by feed-down

Non-Prompt: From B-meson decays



Decay Length: Distance between Primary and secundary vertex



arXiv:1610.00613v2

Main Observables

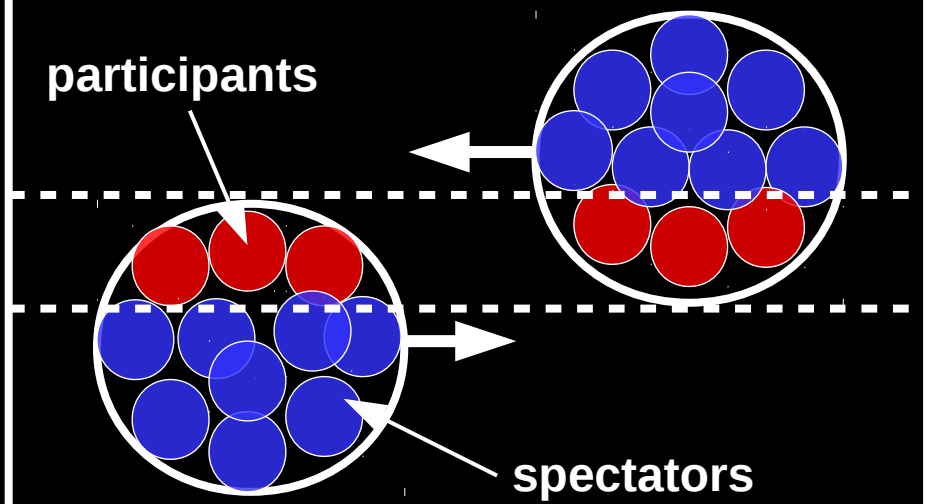
Nuclear Modification Factor R_{AA}

$$R_{AA}^{J/\psi} = \frac{Y_{AA}^{J/\psi}}{\langle T_{AA} \rangle \sigma_{pp}^{J/\psi}}$$

Medium effects quantified comparing the Pb-Pb charmonium yield with the p-p cross section, scaled by a geometrical factor (from Glauber model)

- **No medium effects** → $R_{AA} = 1$
- **Hot matter effects** → $R_{AA} \neq 1$

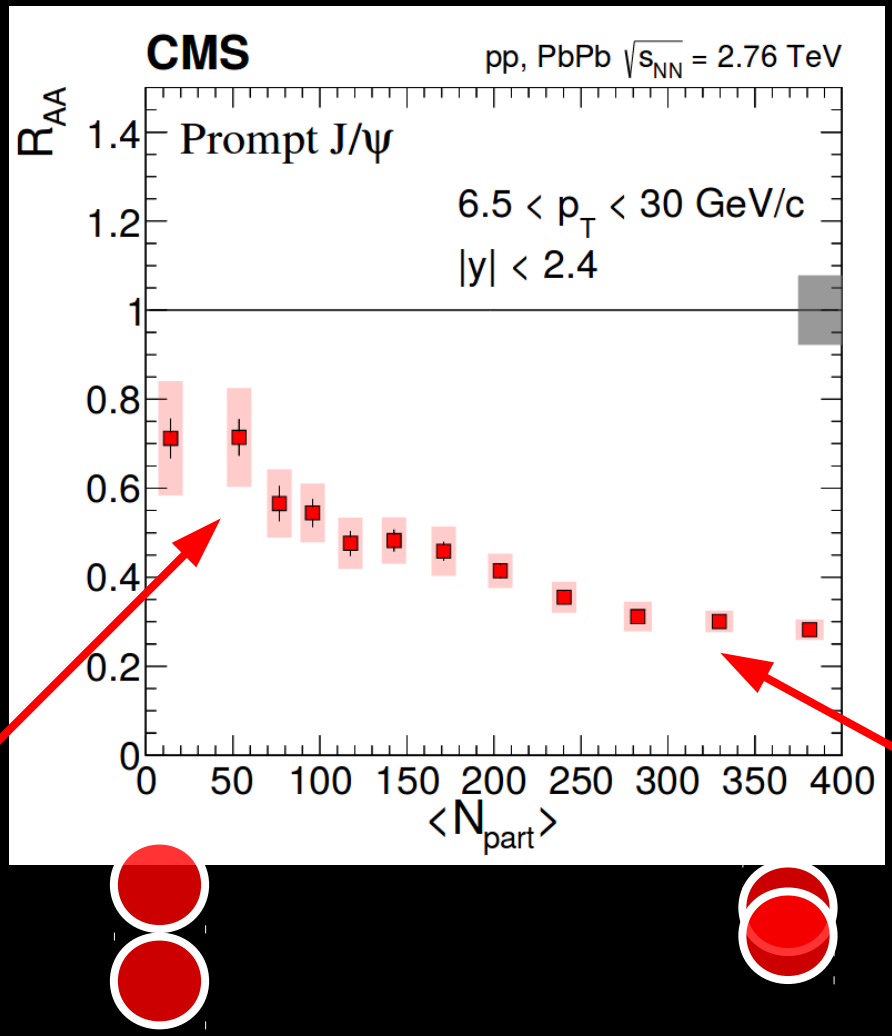
Centrality



→ Can be estimated experimentally by measuring the number of charge tracks produced or the energy deposited in the transverse plane.

→ Experimental access to different medium densities and geometries

J/Ψ R_{AA} in Run 1



arXiv:1610.00613v2

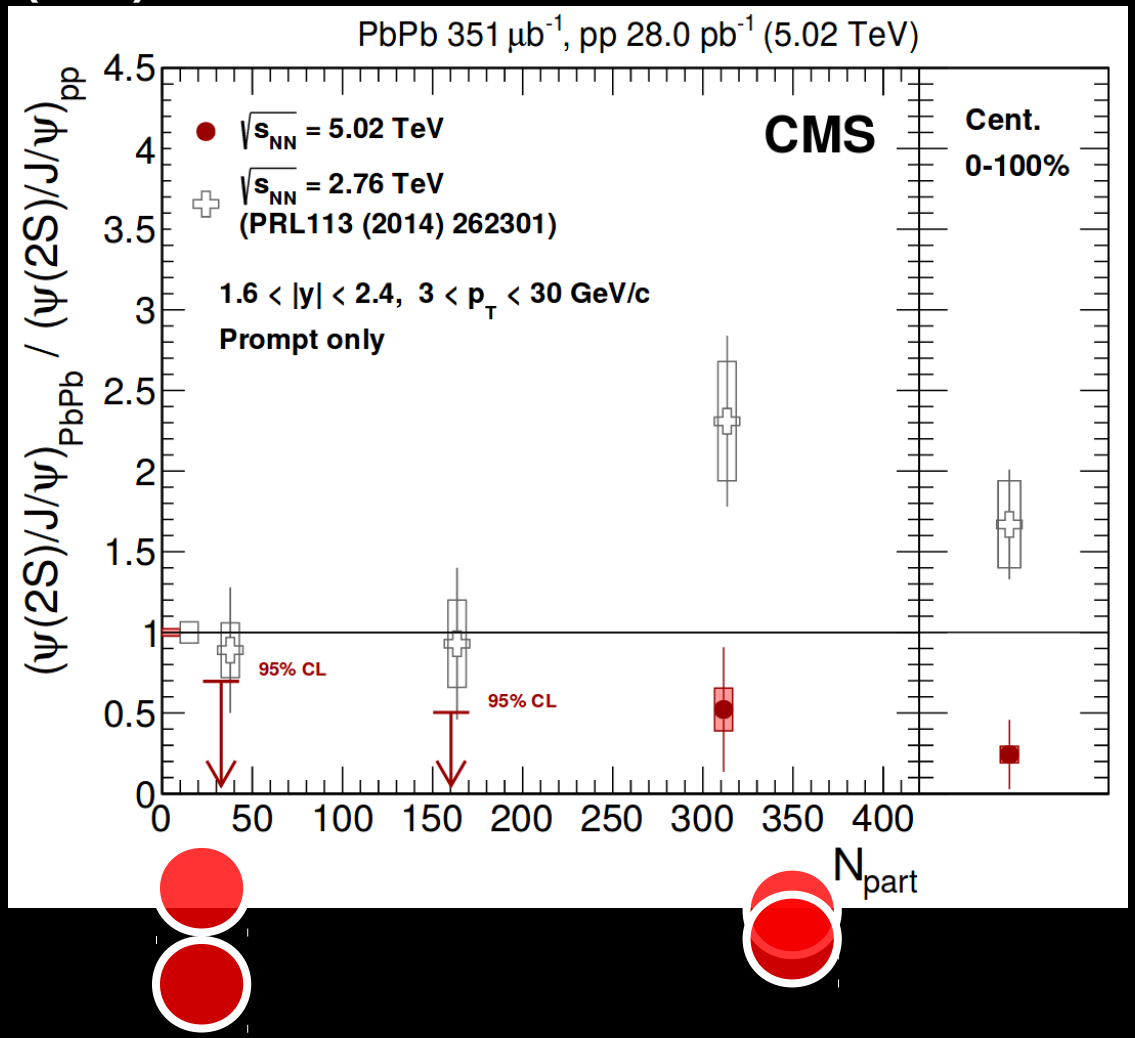
peripheral

central

→ Stronger suppression seen in central events

Charmonia in Run 2

Phys. Rev. Lett. 118 (2017) 162301



Sequential Melting: Ratio of R_{AA} Ψ(2S)/Jpsi < 1

→ **Ψ(2S) more suppressed than J/Ψ at 5.02 TeV**

→ **Ψ(2S) slightly less suppressed compared to J/Ψ at 2.76 TeV central events**

Summary

- Suppression of J/Ψ mesons observed in Pb-Pb collisions at 2.76 TeV

- Suppression of Ψ(2S) with respect to J/Ψ mesons observed in Pb-Pb collisions at 5.02 TeV

J/Ψ R_{AA} @ 5.02 TeV results coming soon!