Produzione di quarkonio in collisioni tra ioni pesanti a LHC

Roberta Arnaldi
INFN Torino

Outlook

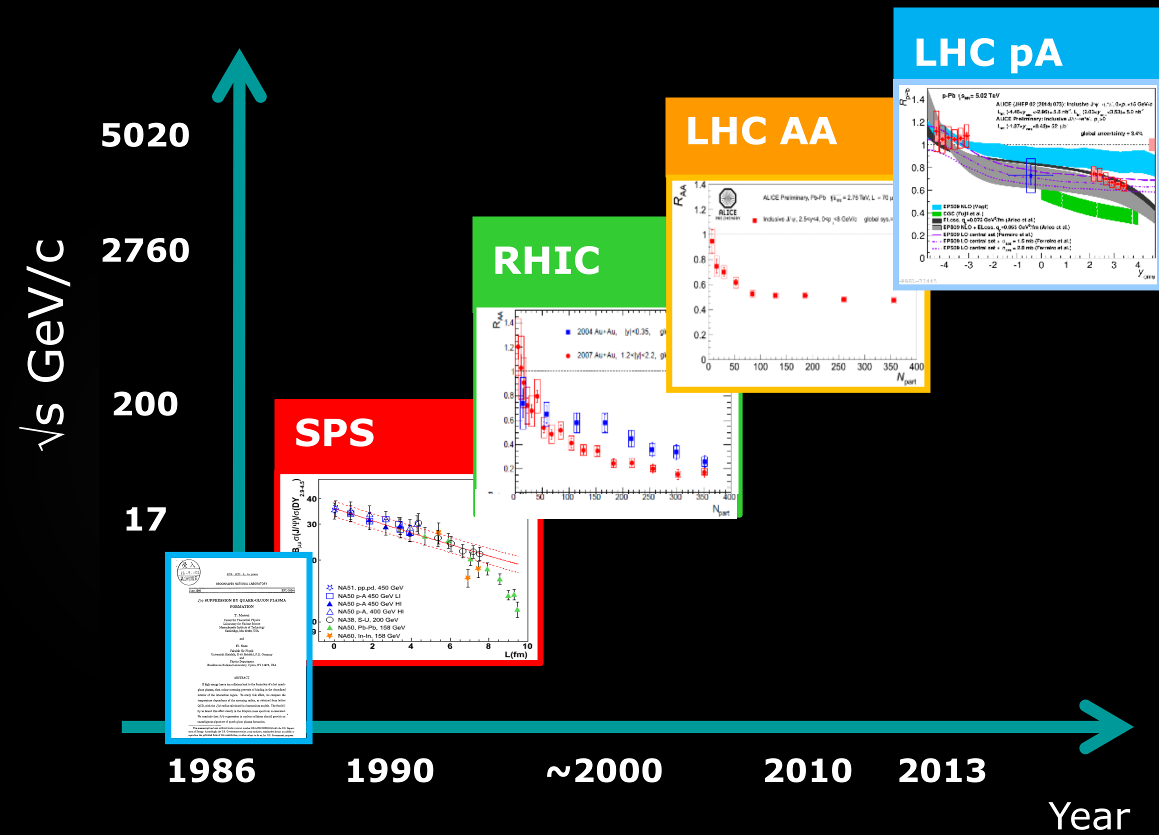
Quarkonium

(J/ψ, ψ(2S), ϒ) production

in pA and AA collisions

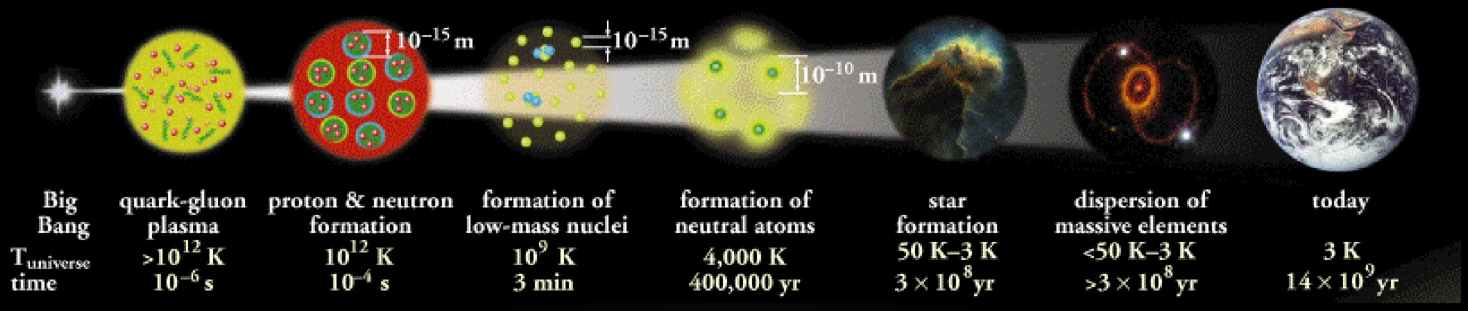
from

SPS → RHIC → LHC



Heavy-ions and Quark-Gluon Plasma

- Quark Gluon Plasma is a state of strongly interacting matter in which quarks and gluons are no more confined into hadrons
- QGP is formed at high temperatures and/or density

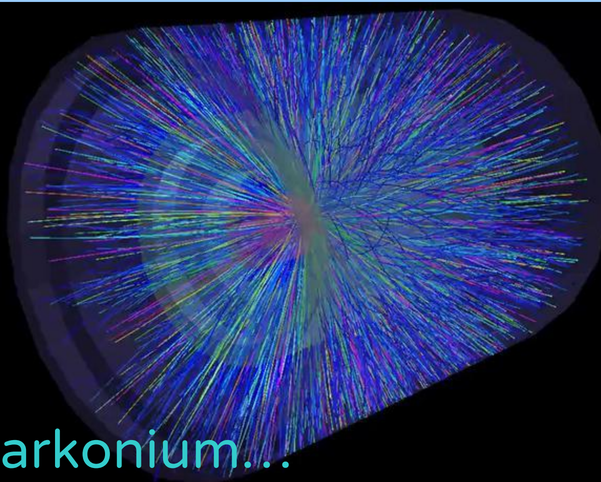


- How can QGP be produced in laboratory?

  ↓ heavy-ion collisions

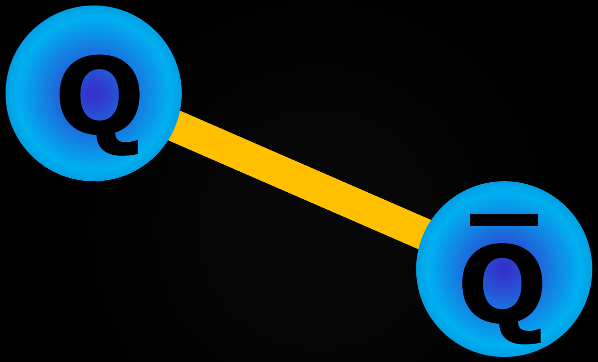
- How to understand the properties of the created hot medium?

  ↓ studying probes as jets, open heavy flavors, quarkonium…



Quarkonium in a hot medium

- At T=0, the binding of the Q and $\bar{Q}$ quarks can be expressed using the Cornell potential:



$$V(r) = -\frac{\alpha}{r} + kr$$

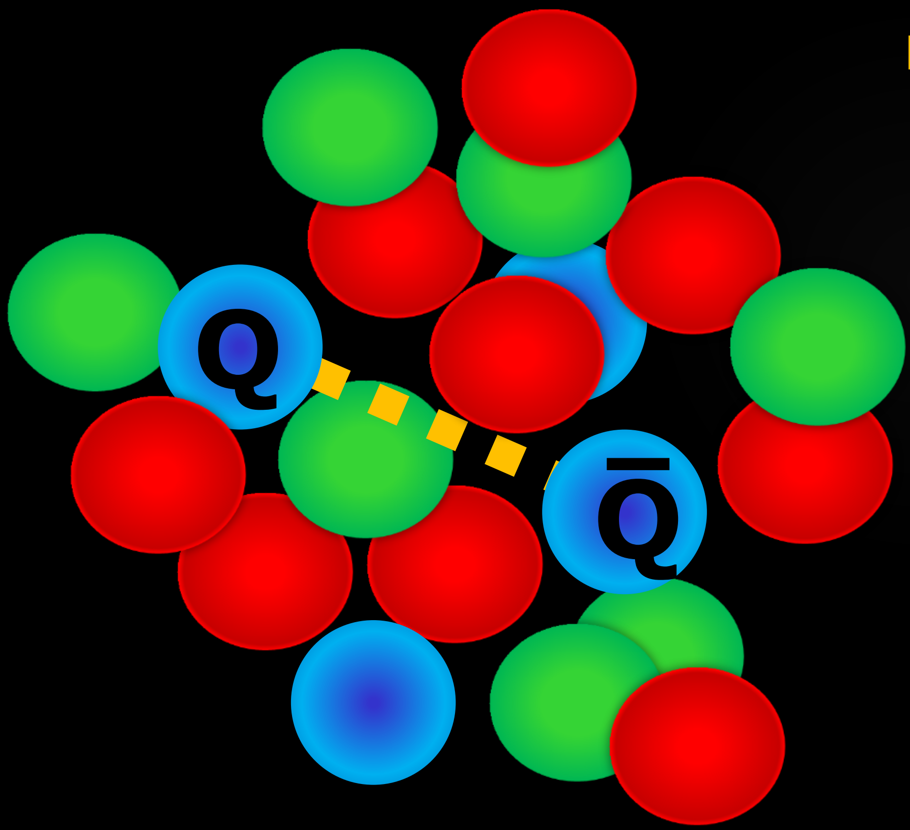
coulombian contribution, induced by a g exchange between Q and $\bar{Q}$

confinement term

Quarkonium in a hot medium

What happens to a $q\bar{q}$ pair placed in the QGP?

QGP consists of deconfined colour charges



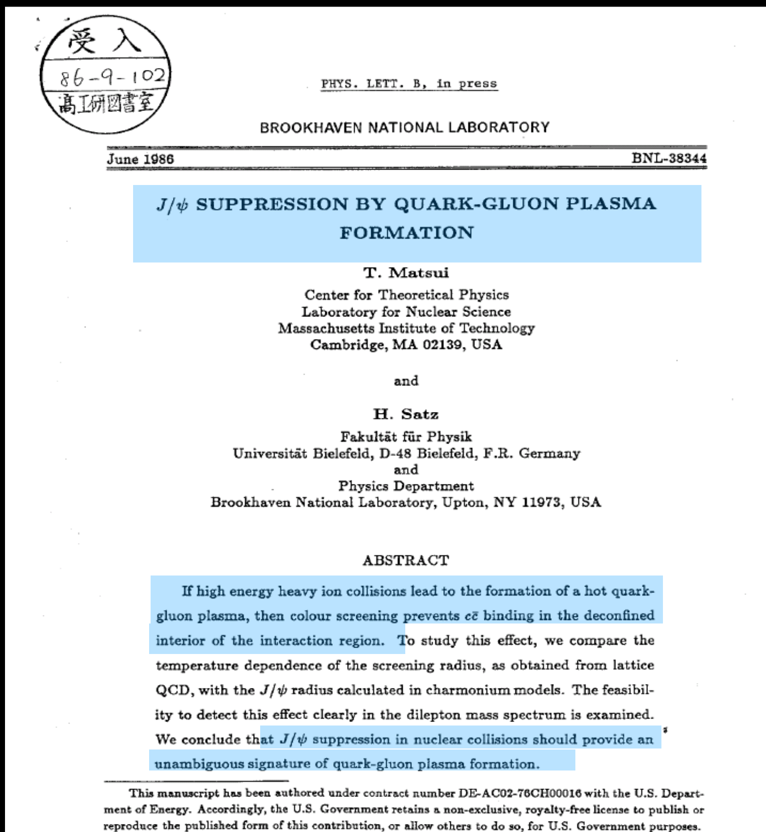
the binding of a $q\bar{q}$ pair is subject to colour screening:

$$V(r) = -\frac{\alpha}{r} + kr$$

$$\downarrow$$

$$V(r) = -\frac{\alpha}{r} e^{-r/\lambda_D}$$

- "confinement" contribution disappears
- coulombian term of the potential is screened by the high color density



PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui

Center for Theoretical Physics
Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

and

H. Satz

Fakultät für Physik
Universität Bielefeld, D-48 Bielefeld, F.R. Germany
and
Physics Department
Brookhaven National Laboratory, Upton, NY 11973, USA

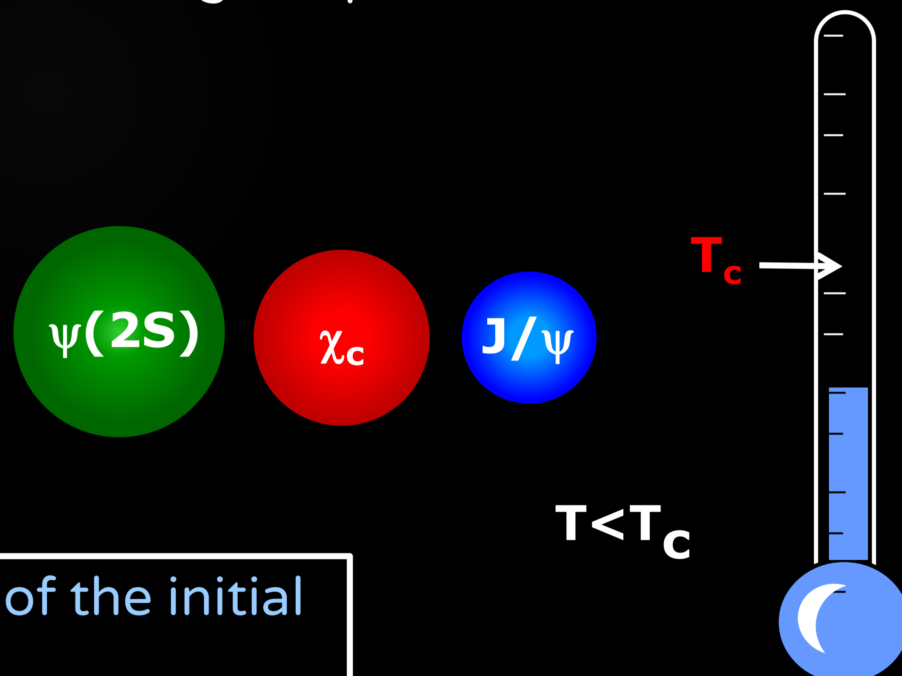
ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

This manuscript has been authored under contract number DE-AC02-76CH00016 with the U.S. Department of Energy. Accordingly, the U.S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

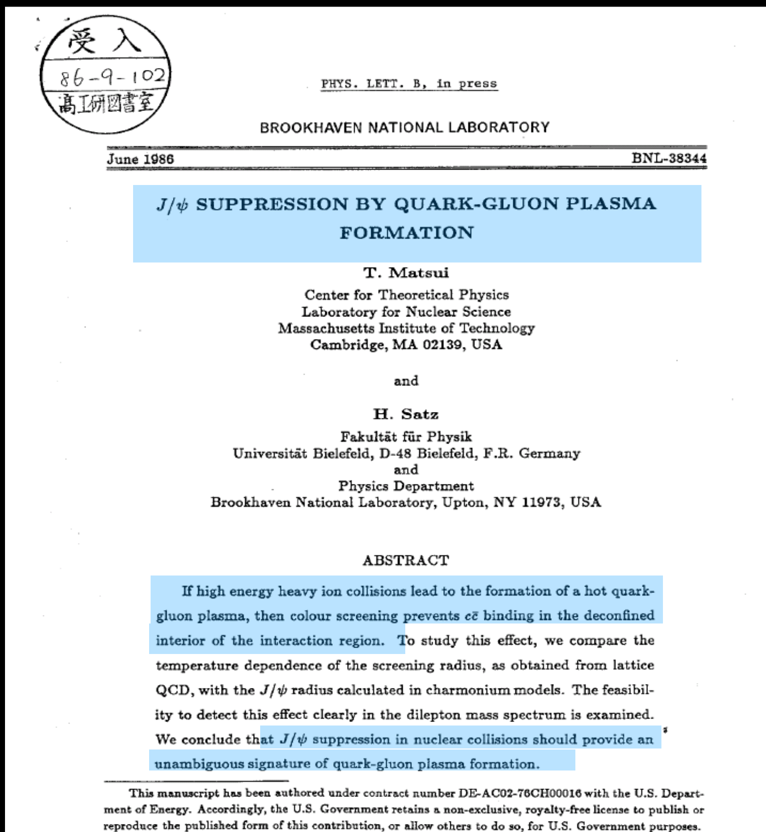
Sequential melting

Differences in the binding energies of the quarkonium states lead to a sequential melting of the states with increasing temperature



Quarkonium is a thermometer of the initial QGP temperature

Quarkonium in a hot medium



PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui
Center for Theoretical Physics
Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

and

H. Satz
Fakultät für Physik
Universität Bielefeld, D-48 Bielefeld, F.R. Germany
and
Physics Department
Brookhaven National Laboratory, Upton, NY 11973, USA

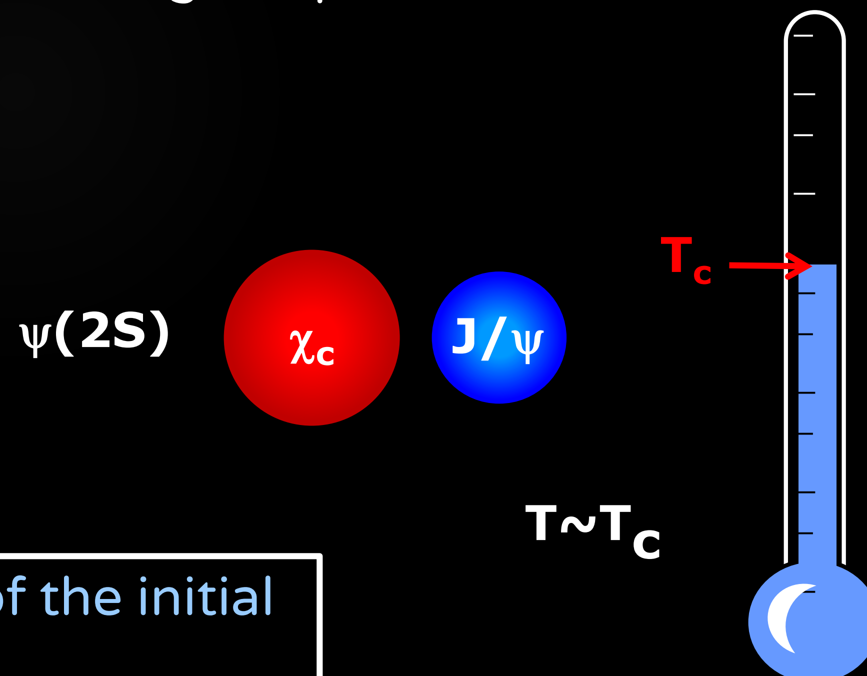
ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

This manuscript has been authored under contract number DE-AC02-76CH00016 with the U.S. Department of Energy. Accordingly, the U.S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

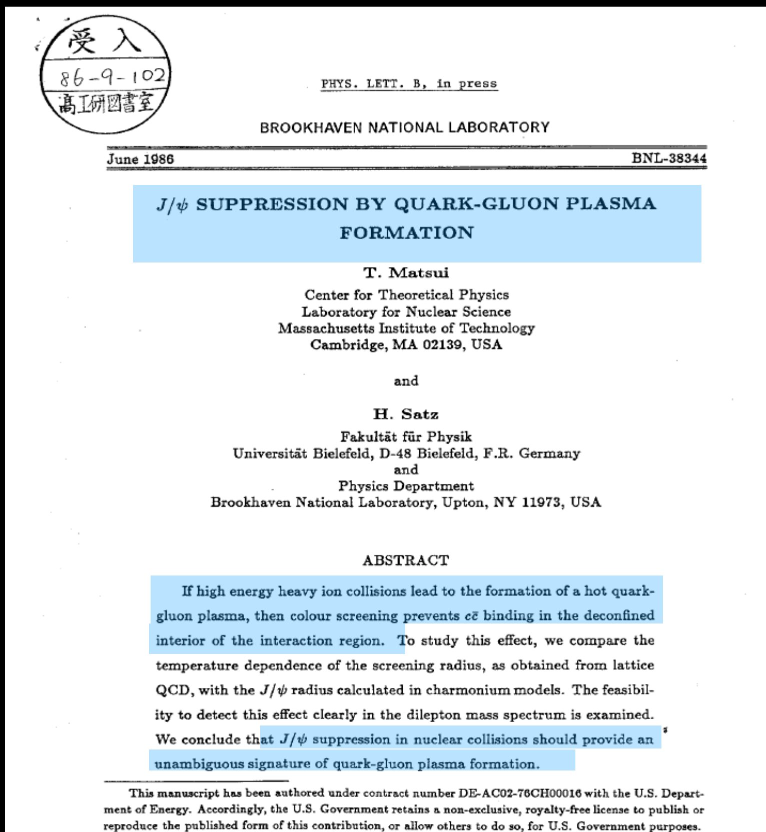
Sequential melting

Differences in the binding energies of the quarkonium states lead to a sequential melting of the states with increasing temperature



Quarkonium is a thermometer of the initial QGP temperature

Quarkonium in a hot medium



PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui
Center for Theoretical Physics
Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

and

H. Satz
Fakultät für Physik
Universität Bielefeld, D-48 Bielefeld, F.R. Germany
and
Physics Department
Brookhaven National Laboratory, Upton, NY 11973, USA

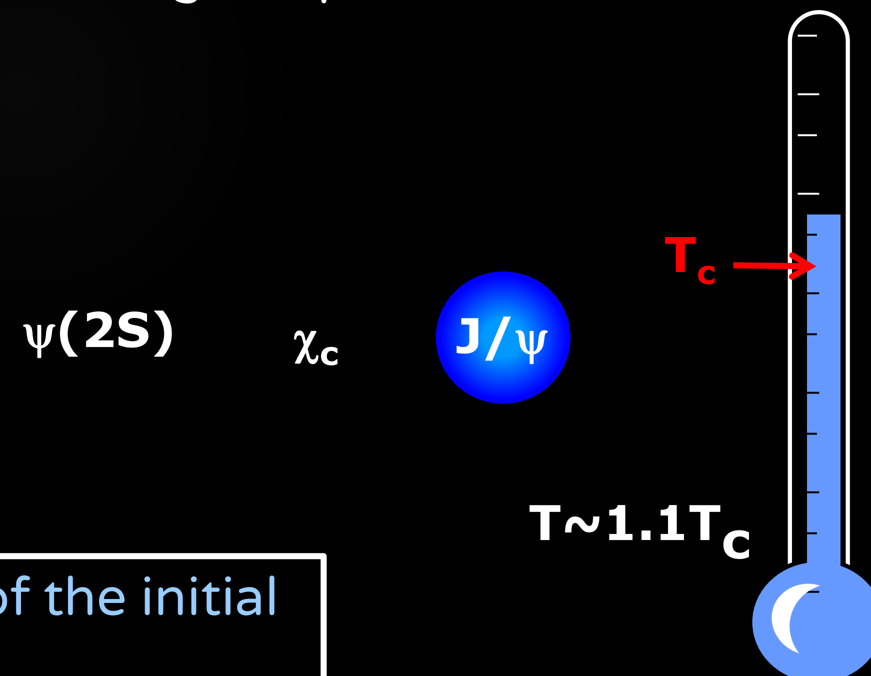
ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

This manuscript has been authored under contract number DE-AC02-76CH00016 with the U.S. Department of Energy. Accordingly, the U.S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

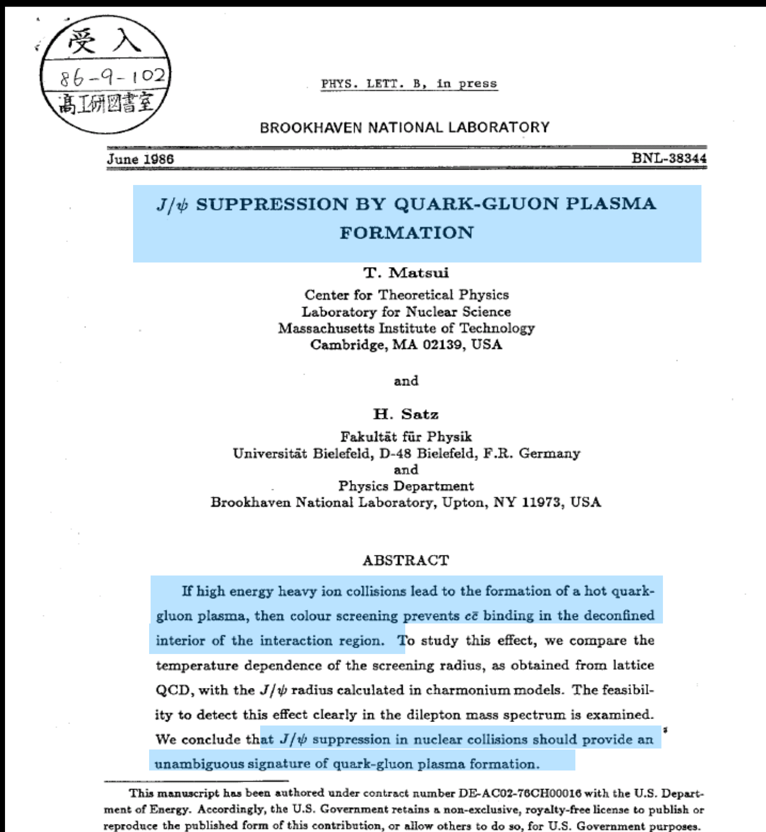
Sequential melting

Differences in the binding energies of the quarkonium states lead to a sequential melting of the states with increasing temperature



Quarkonium is a thermometer of the initial QGP temperature

Quarkonium in a hot medium



PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui
Center for Theoretical Physics
Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

and

H. Satz
Fakultät für Physik
Universität Bielefeld, D-48 Bielefeld, F.R. Germany
and
Physics Department
Brookhaven National Laboratory, Upton, NY 11973, USA

ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

This manuscript has been authored under contract number DE-AC02-76CH00016 with the U.S. Department of Energy. Accordingly, the U.S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

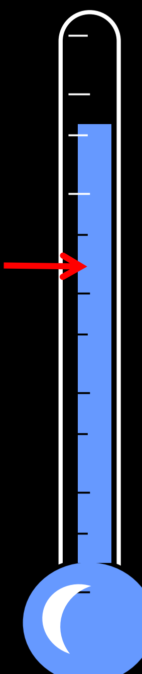
Sequential melting

Differences in the binding energies of the quarkonium states lead to a sequential melting of the states with increasing temperature

$\psi(2S)$ χ_c J/ψ

T_c

$T>>T_c$



Quarkonium is a thermometer of the initial QGP temperature

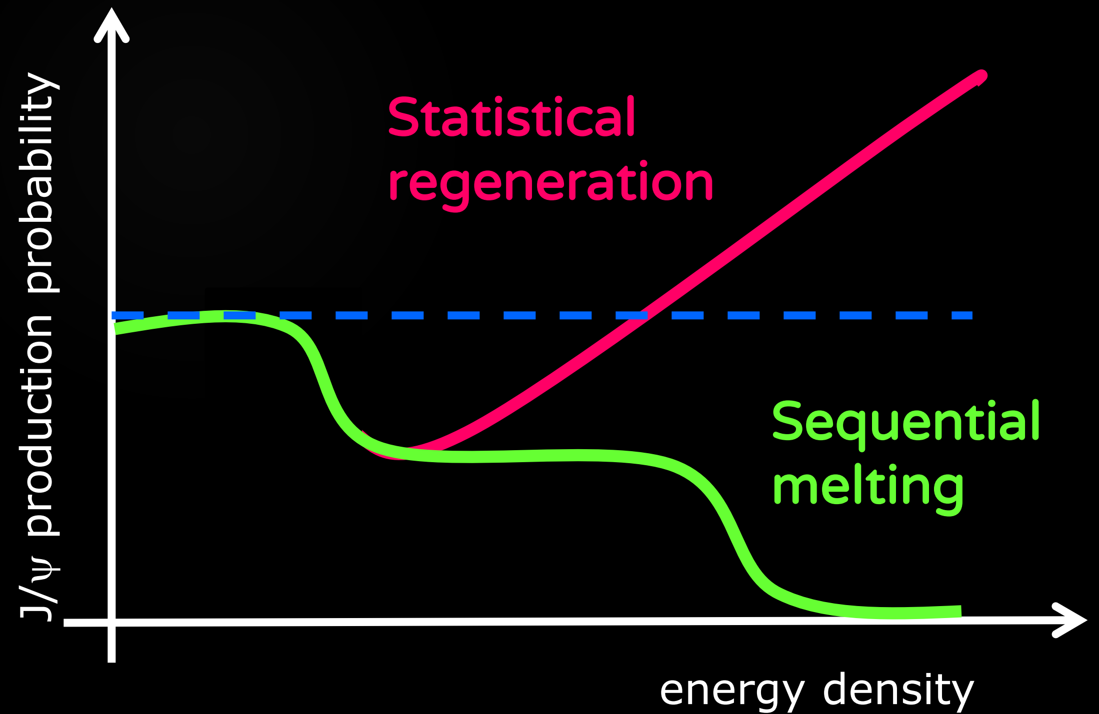
From suppression to recombination

(Re)combination

Increasing the collision energy the cc pair multiplicity increases

enhanced quarkonia production via (re)combination at hadronization or during QGP stage

Central AA collisions	SPS 20 GeV	RHIC 200 GeV	LHC 2.76TeV
N_{ccbar}/event	~0.2	~10	~75



P. Braun-Muzinger,J. Stachel, PLB 490(2000) 196
R. Thews et al, Phys.Rev.C63:054905(2001)

Cold matter effects

Cold Nuclear Matter Effects (CNM)

on top of mechanisms related to hot matter, other cold matter effects have to be taken into account to interpret quarkonium A-A results:

- nuclear parton shadowing
- energy loss
- $c\bar{c}$ in medium break-up

investigated through p-A collisions

Nuclear modification factor

Medium effects are quantified comparing the quarkonium yield in AA with the pp one, scaled by a geometrical factor (from Glauber model)

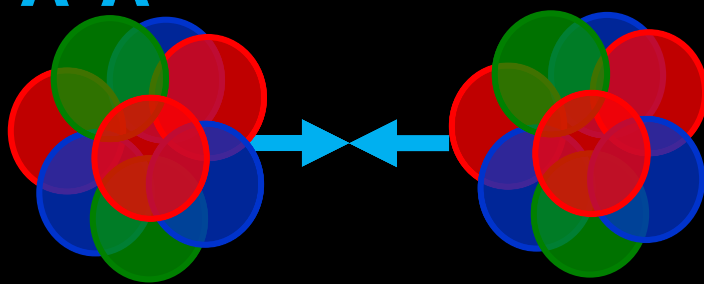
$$R_{AA}^{J/\psi} = \frac{Y_{AA}^{J/\psi}}{\langle T_{AA}\rangle \sigma_{pp}^{J/\psi}}$$

- $R_{AA} = 1$ → no medium effects
- $R_{AA} \neq 1$ → hot/cold matter effects

Heavy-ion program

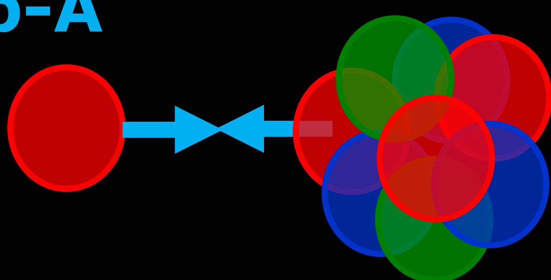
Different types of collisions……to investigate….

A-A



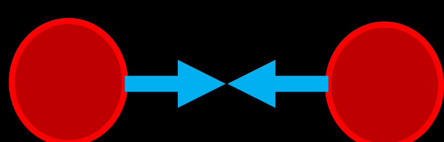
→ "Hot and dense" QCD matter

p-A



→ "cold nuclear matter", but not only…

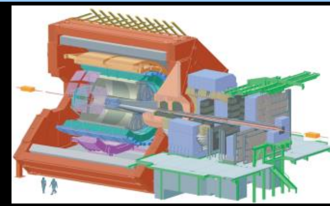
p-p



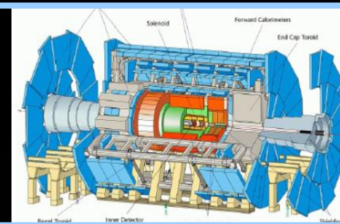
→
- "vacuum" reference for Pb-Pb and p-Pb
- genuine pp physics program

Quarkonium at LHC

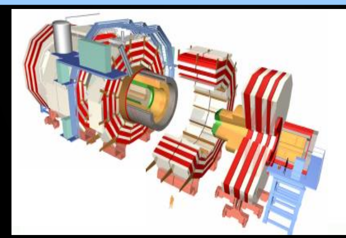
ALICE J/ψ, $\psi(2S) \rightarrow \mu^+\mu^-$
$\Upsilon \rightarrow \mu^+\mu^-$
$J/\psi \rightarrow e^+e^-$



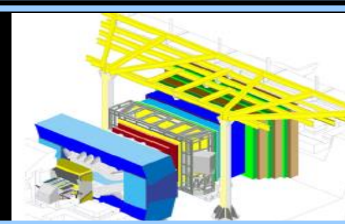
ATLAS J/ψ, $\psi(2S) \rightarrow \mu^+\mu^-$



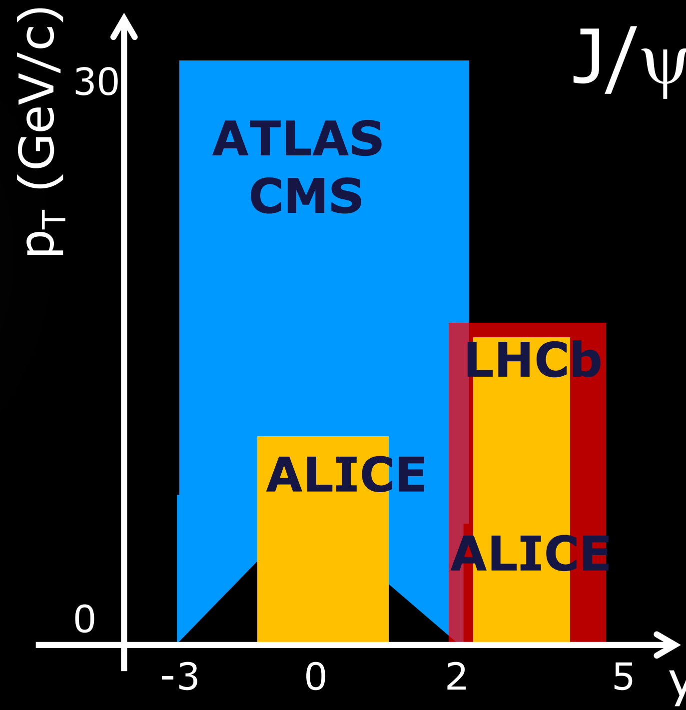
CMS J/ψ, $\psi(2S) \rightarrow \mu^+\mu^-$
$\Upsilon \rightarrow \mu^+\mu^-$



LHCb J/ψ, $\Upsilon \rightarrow \mu^+\mu^-$
(no heavy ion physics program in Run-1)

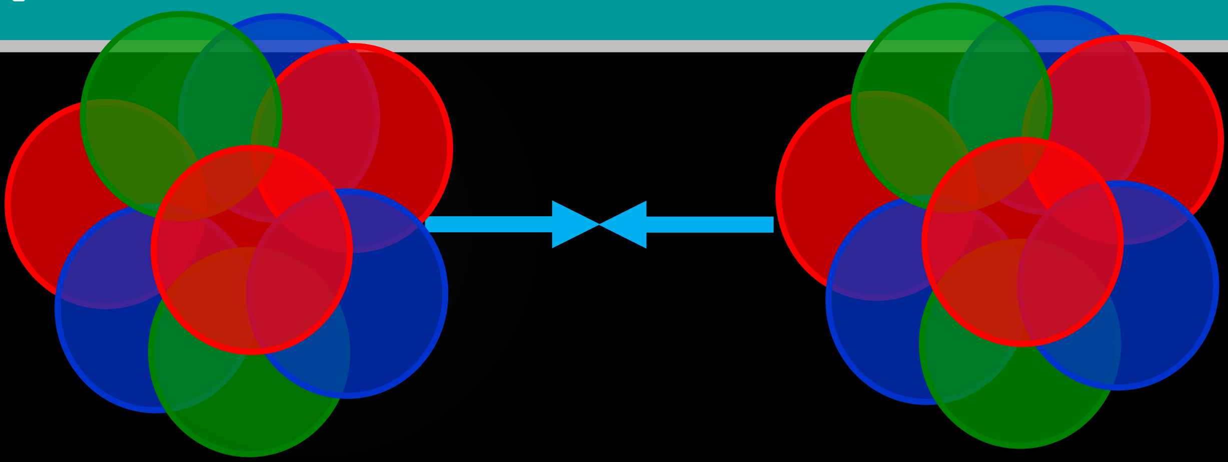


➡ Kinematic pp coverage of quarkonium measurements:



➡ Complementary quarkonium results from LHC experiments!

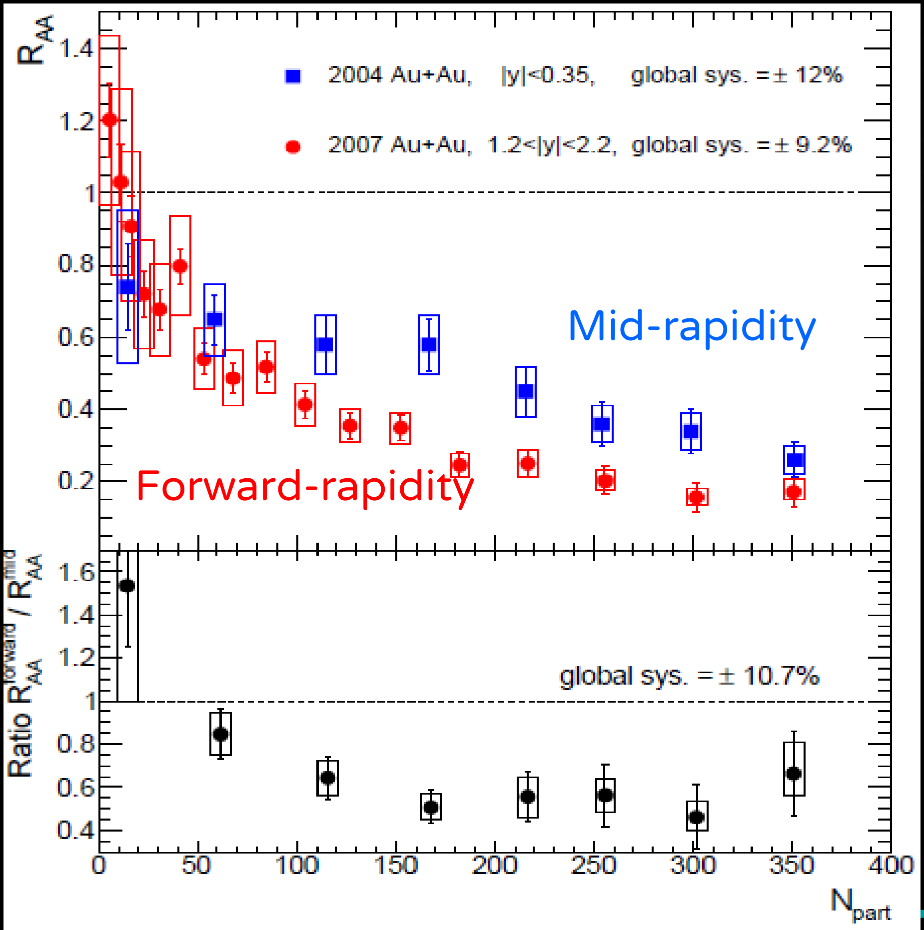
J/ψ in AA collisions



From SPS to LHC...

SPS ($\sqrt{s_{NN}}$ = 17 GeV)

first observation of J/ψ suppression beyond CNM effects



RHIC ($\sqrt{s_{NN}}$ = 39-200 GeV)

stronger suppression at forward rapidities (not expected if suppression increases with energy density, larger at mid-y)

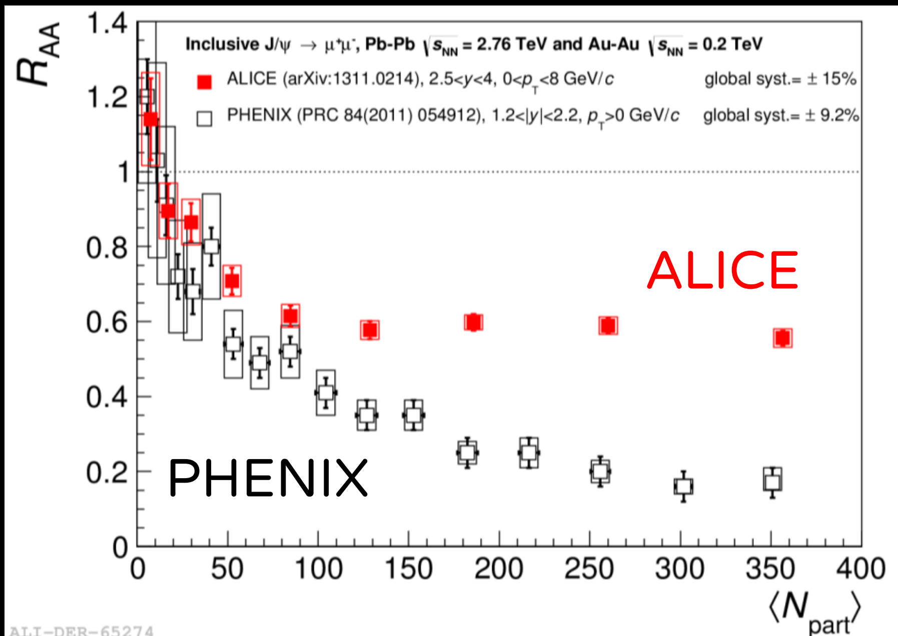
Hint for (re)combination at RHIC?

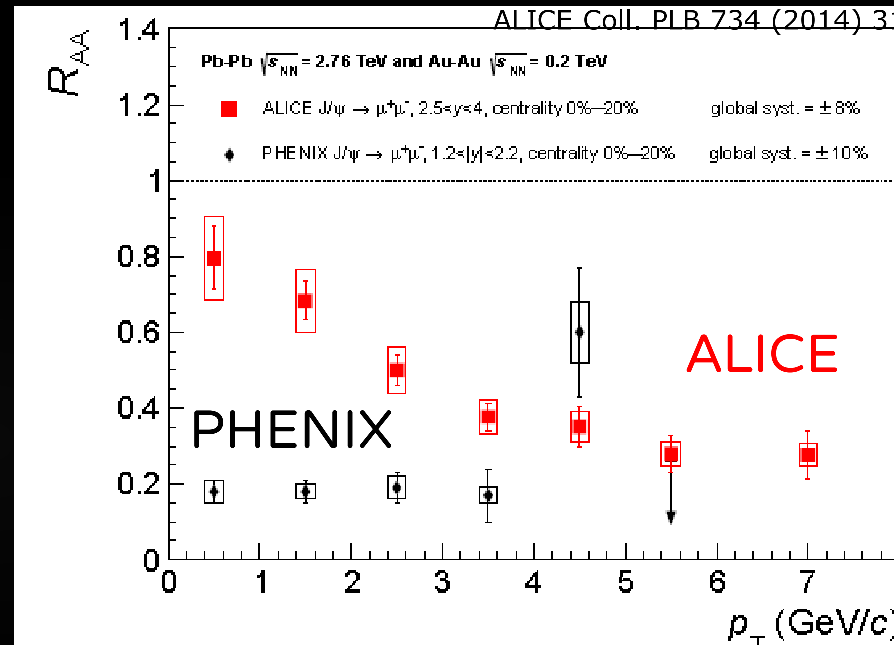
Decisive inputs from LHC:

higher energies
→ stronger suppression?
more charm
→ larger (re)combination?
more bottom
→ ϒ can be investigated

Low p_T J/ψ R_{AA} in ALICE

➡ J/ψ R_{AA} studied by ALICE in both central and forward y down to zero p_T





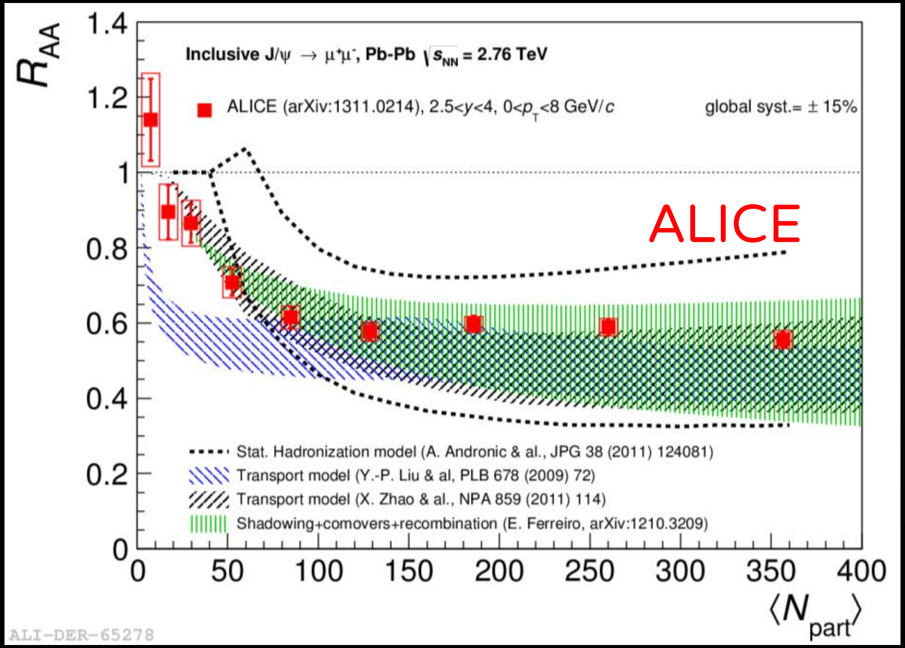
➡ **PHENIX (RHIC) vs. ALICE (LHC)** → investigate low p_T J/ψ

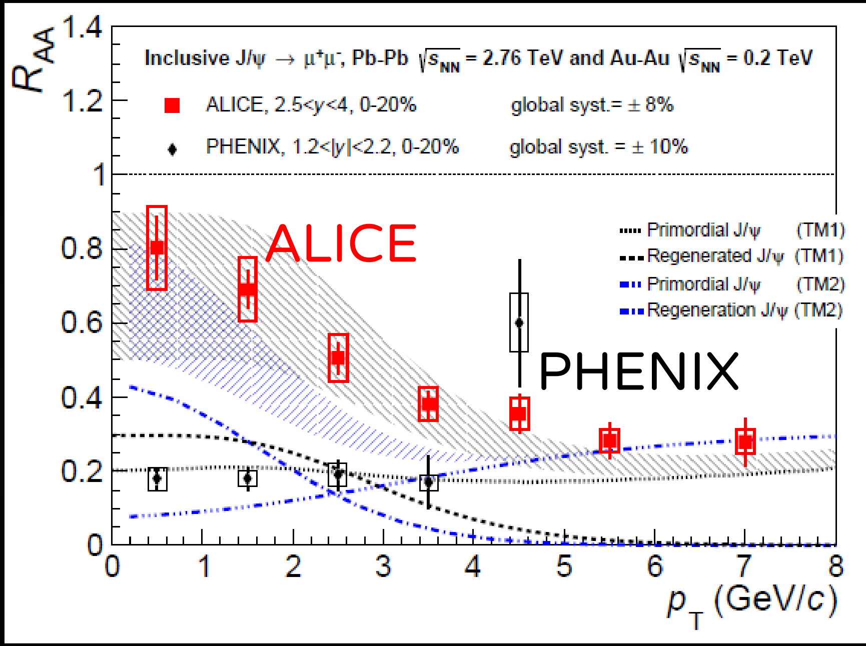
- **PHENIX:** stronger J/ψ suppression versus centrality with respect to ALICE, in spite of LHC larger energy densities
- **ALICE:** weaker suppression at low p_T

➡ recombination needed, at low p_T, to explain J/ψ R_{AA} @ LHC

Low p_T J/ψ R_{AA} in ALICE

- J/ψ R_{AA} studied by ALICE in both central and forward y down to zero p_T





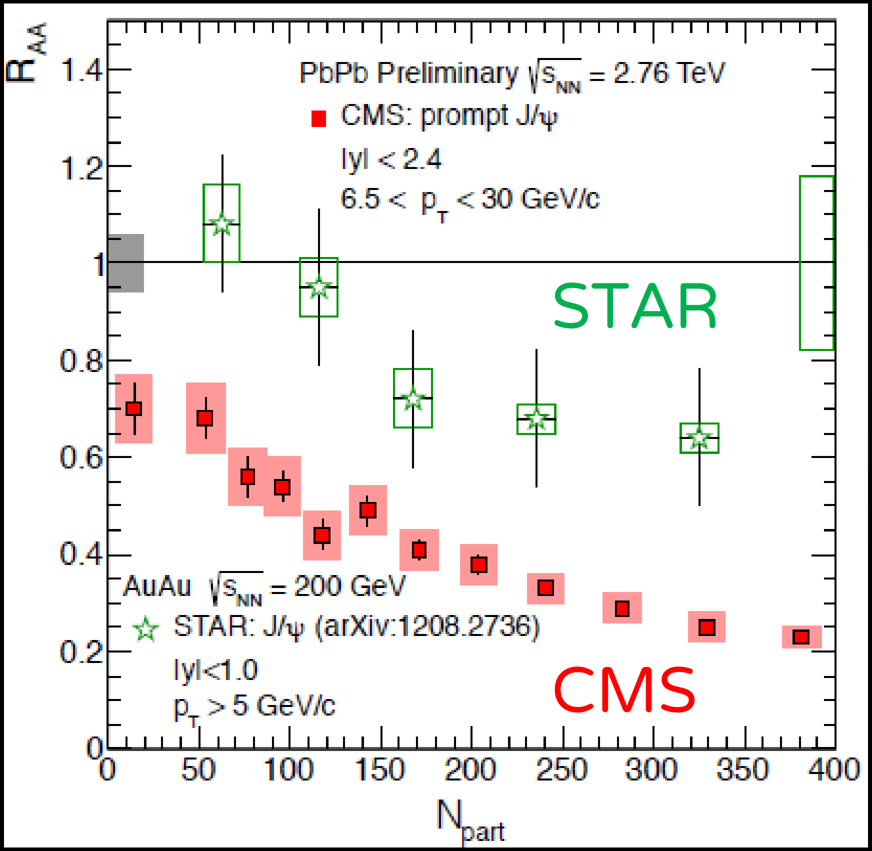
- **Comparison with theory**

  Models including J/ψ (re)combination in QGP or in the hadronic phase provide a reasonable description of ALICE results

  Still rather large theory uncertainties: models will benefit from a precise measurement of σ_{cc} and cold nuclear matter effects

High p_T J/ψ R_{AA} in CMS

STAR (RHIC) vs. CMS (LHC) → investigate high p_T J/ψ



Limits in CMS low-p_T J/ψ acceptance: muons need to overcome magnetic field and energy loss in the absorber

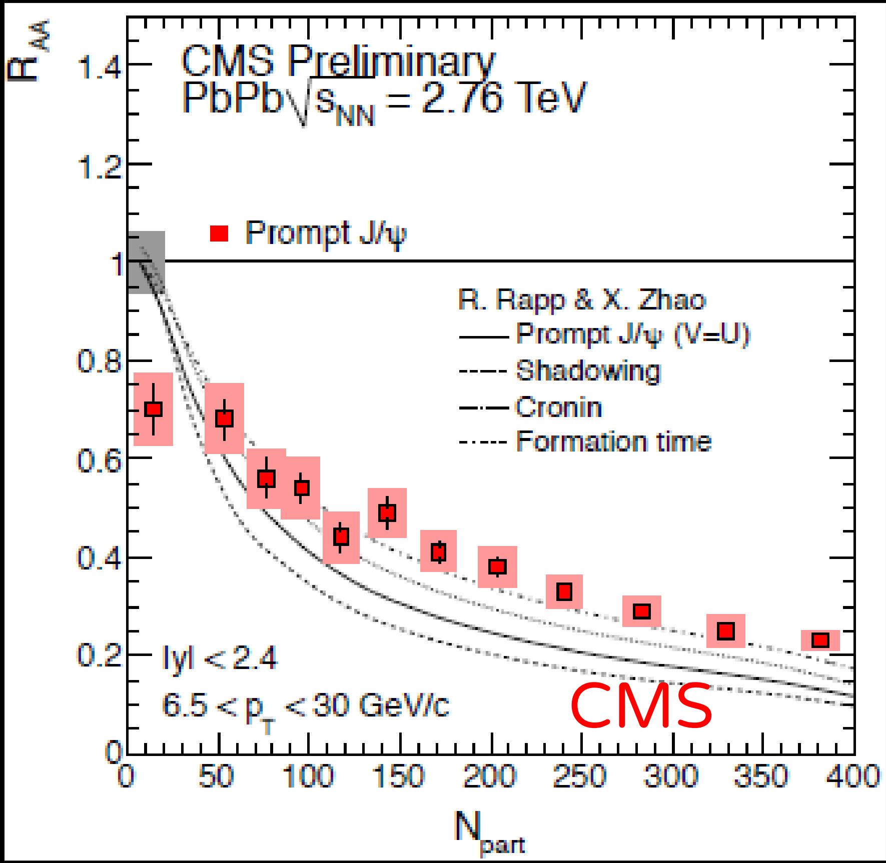
- mid-*y*: p_T>6.5 GeV/c
- forward *y*: p_T>3 GeV/c

High p_T: opposite J/ψ behavior compared to low-p_T results

Suppression stronger at higher √s (LHC), as expected from Debye screening

High p_T J/ψ R_{AA} in CMS

STAR (RHIC) vs. CMS (LHC) → investigate high p_T J/ψ



Limits in CMS low-p_T J/ψ acceptance: muons need to overcome magnetic field and energy loss in the absorber

- mid-*y*: p_T>6.5 GeV/c
- forward *y*: p_T>3 GeV/c

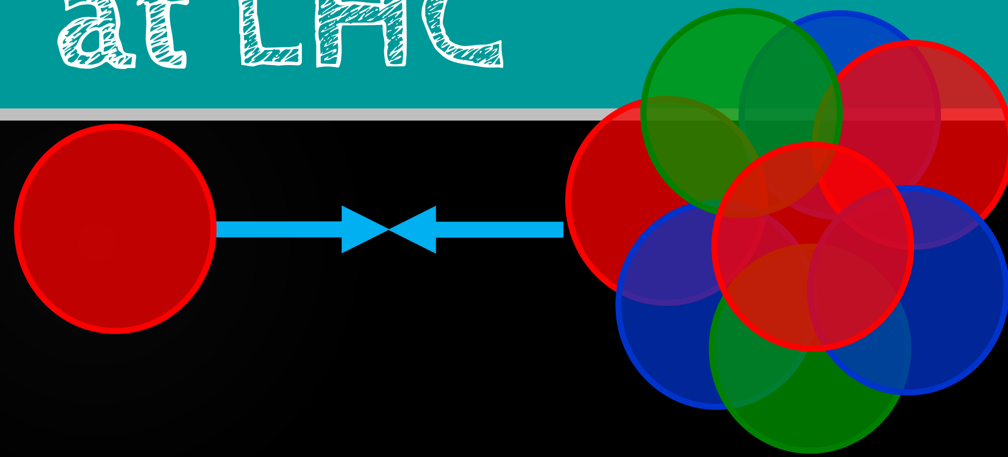
High p_T: opposite J/ψ behavior compared to low-p_T results

⬇

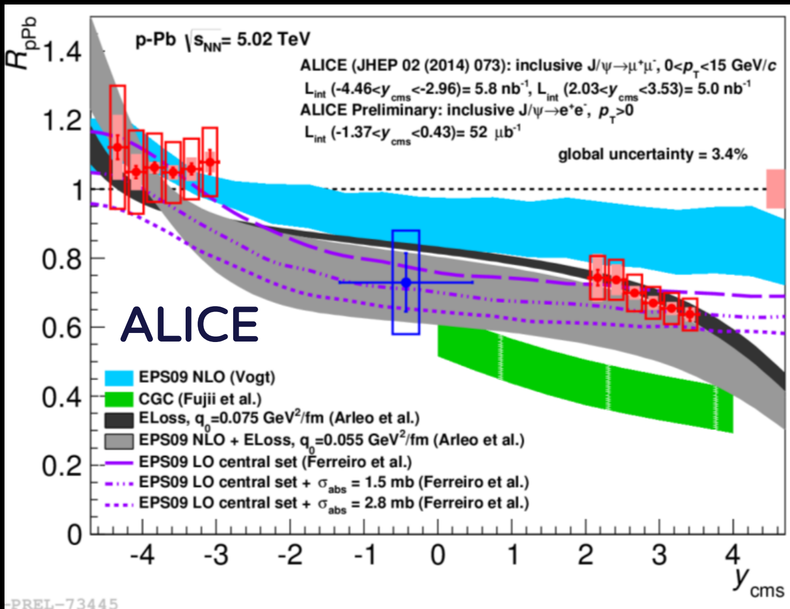
Suppression stronger at higher √s (LHC), as expected from Debye screening

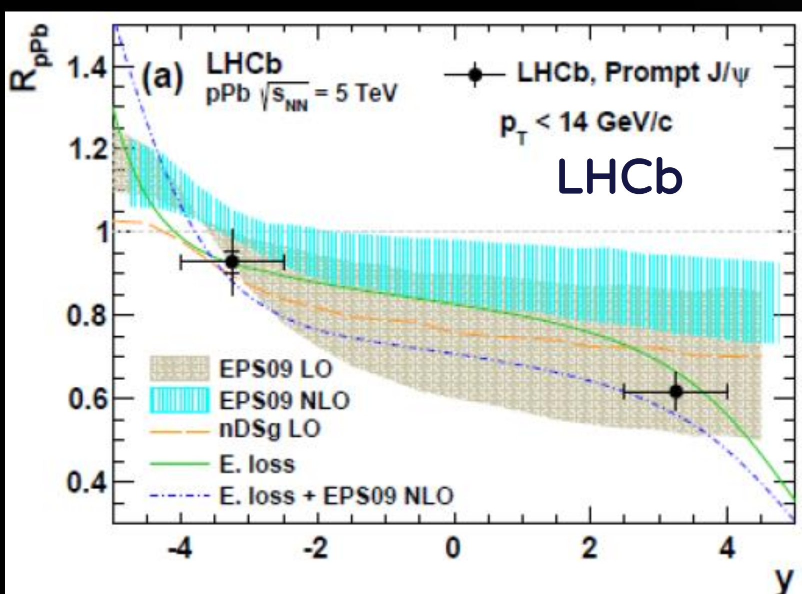
negligible (re)generation effects expected at high p_T

J/ψ in pA collisions at LHC

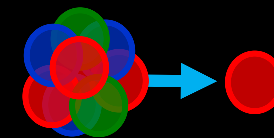


J/ψ in pA collisions

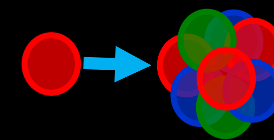




backward-y:
Pb-going direction



forward-y:
p-going direction



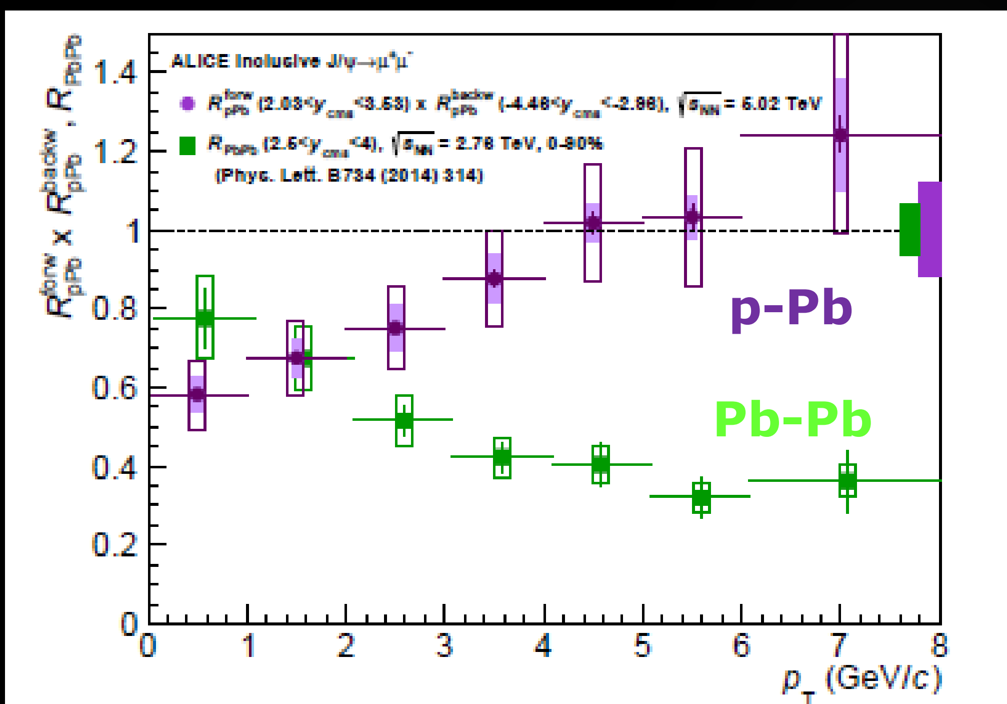
J/ψ production modified in pA because of CNM effects:
→ R_{pA} decreases towards forward y

Theoretical predictions: reasonable agreement with shadowing calculations and models including coherent parton energy loss

From pA to AA…

Once CNM effects are measured in pA, what can we learn on J/ψ production in PbPb?

Hypothesis:
- 2→1 kinematics for J/ψ production
- CNM effects (dominated by shadowing) factorize in p-A
- CNM obtained as R_{pA} x R_{Ap} (R_{pA}^2), similar x-coverage as PbPb



- Sizeable p_T dependent suppression still visible → CNM effects not enough to explain AA data at high p_T
- we get rid of CNM effects, by doing the ratio

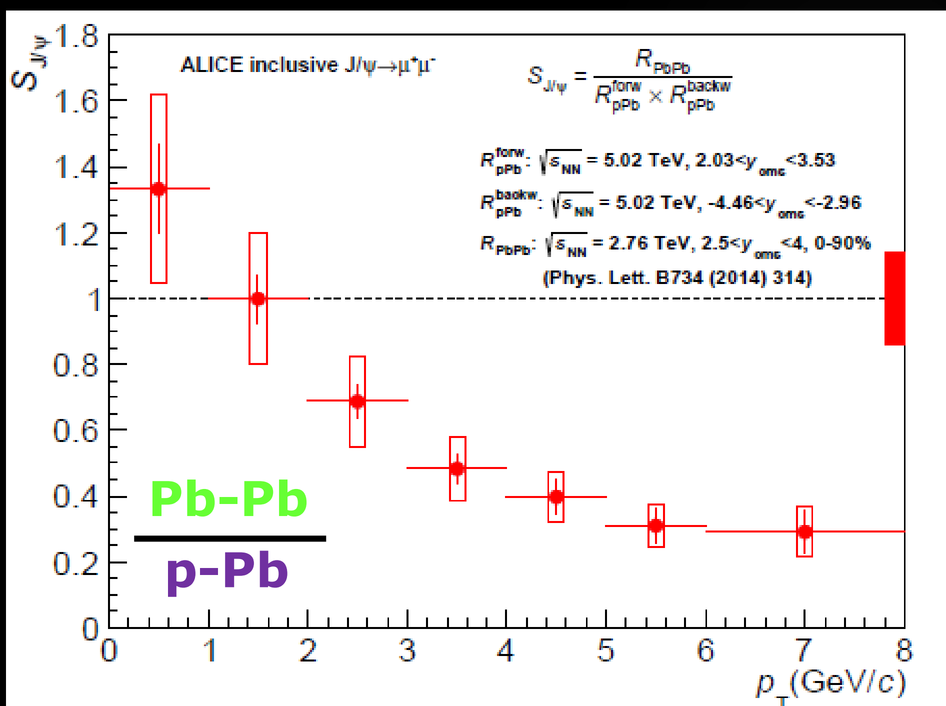
AA / pA

From pA to AA...

Once CNM effects are measured in pA, what can we learn on J/ψ production in PbPb?

Hypothesis:

- 2→1 kinematics for J/ψ production
- CNM effects (dominated by shadowing) factorize in p-A
- CNM obtained as R_{pA} x R_{Ap} ($R_{pA}{}^2$), similar x-coverage as PbPb



Sizeable p_T dependent suppression still visible → CNM effects not enough to explain AA data at high p_T

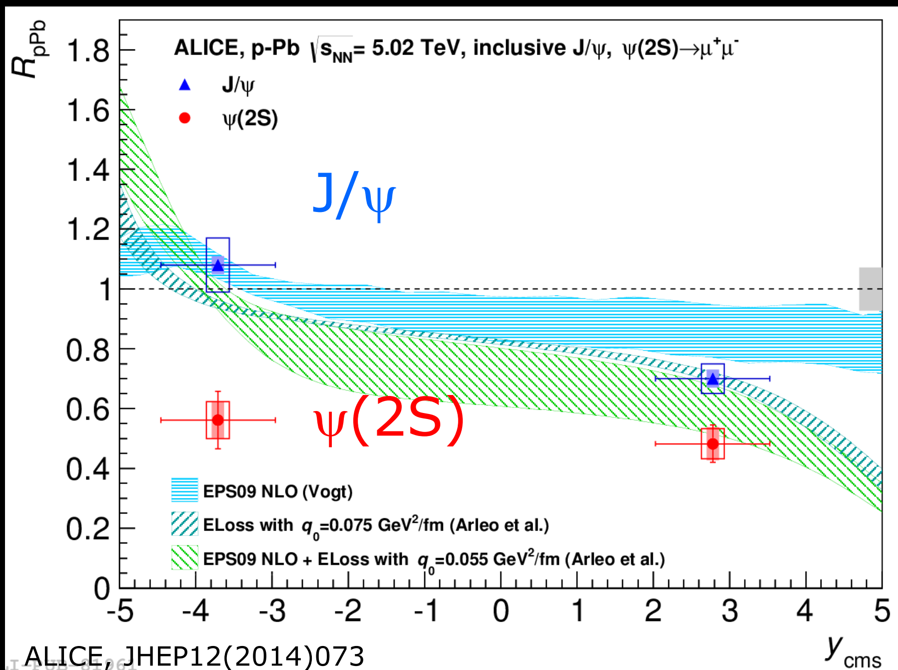
we get rid of CNM effects, by doing the ratio

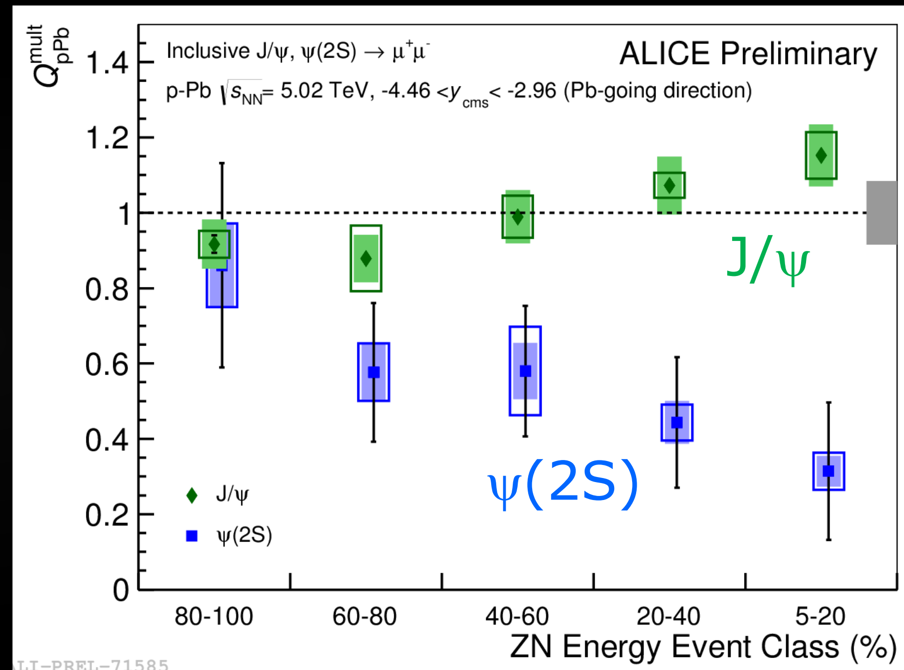
AA / pA

Evidence for hot matter effects in Pb-Pb!

ψ(2S) production in pA

- ψ(2S) is more suppressed than the J/ψ, in particular at backward-y → unexpected if only initial state effects are at play!



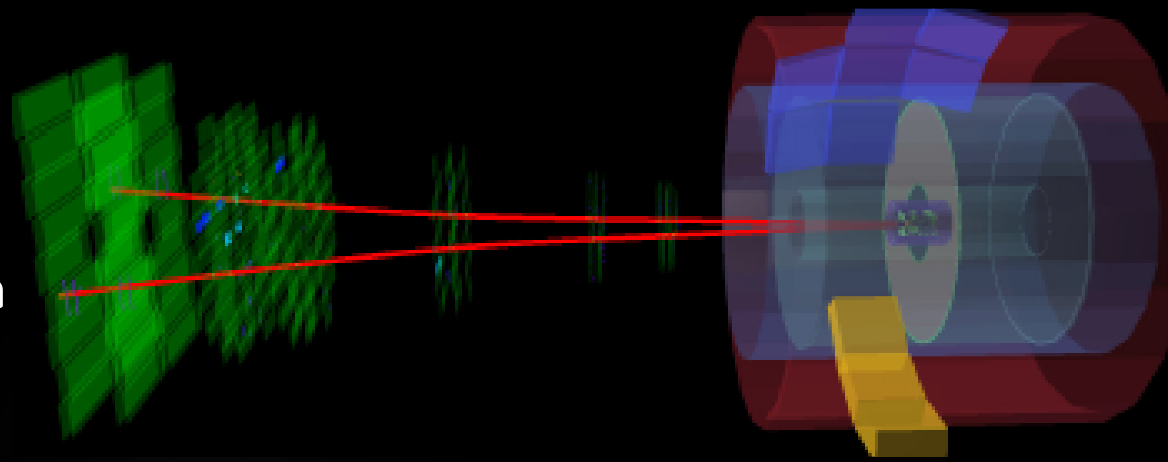


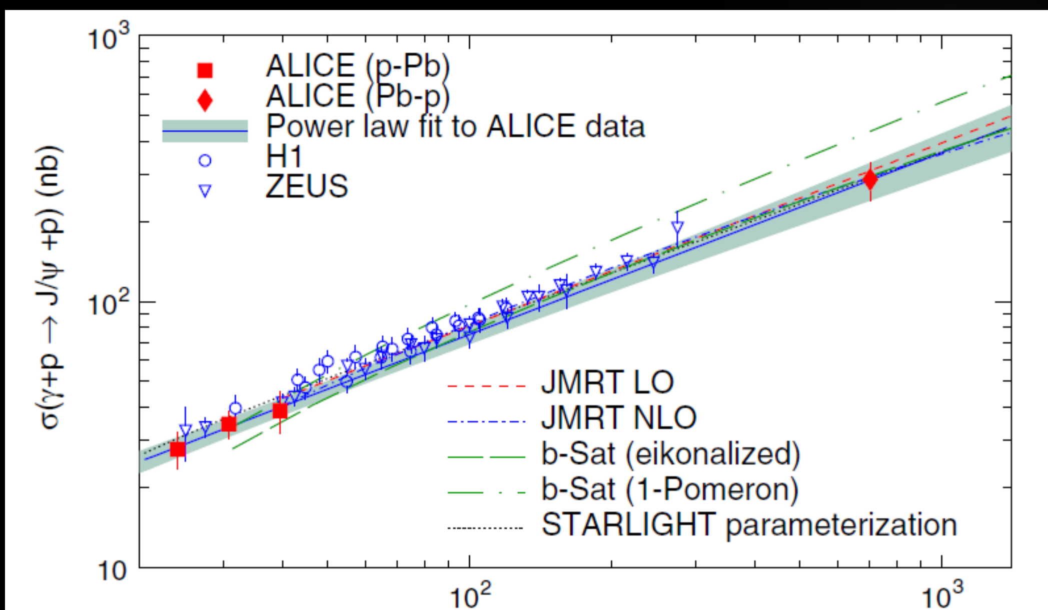
- Final state effects, affecting the loosely bound ψ(2S), related to the (hadronic) medium created in the p-Pb collisions?

J/ψ photo-production in pA

$p + \gamma \rightarrow J/\psi + p$

➡ tool to investigate the gluon PDF in the proton

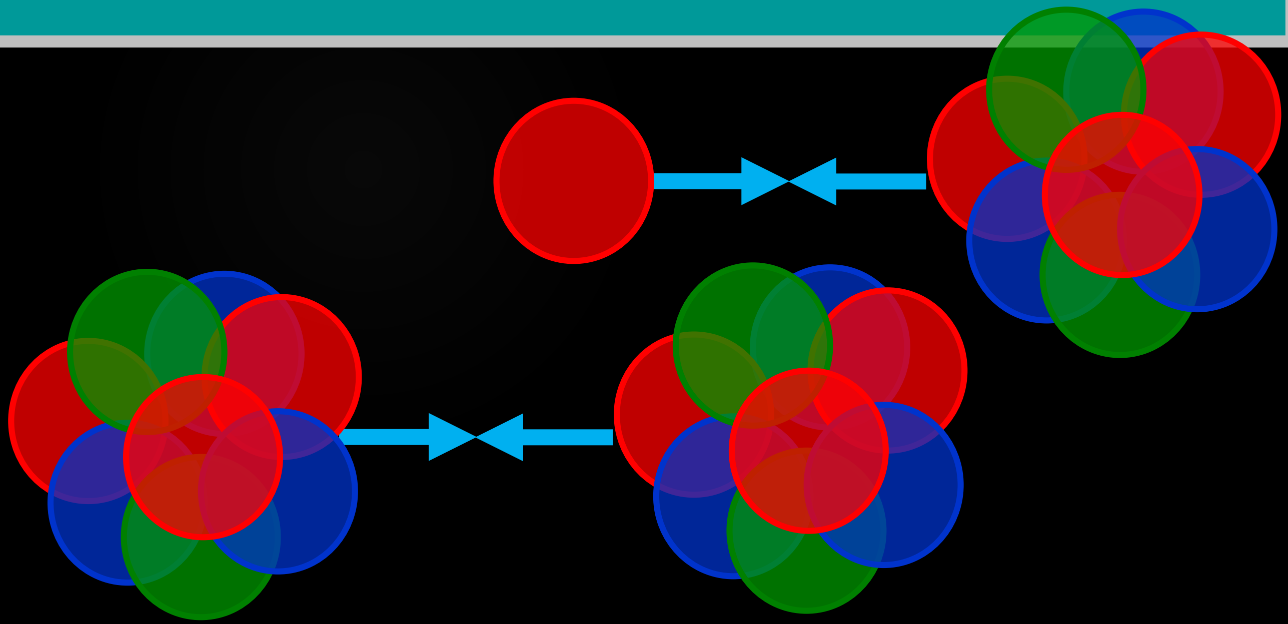




ALICE, PRL 113, 232504 (2014)

➡ ALICE results compatible with HERA, in spite of the larger energy
→ no significant change in the evolution of the gluon PDF

Υ in pA and AA collisions at LHC



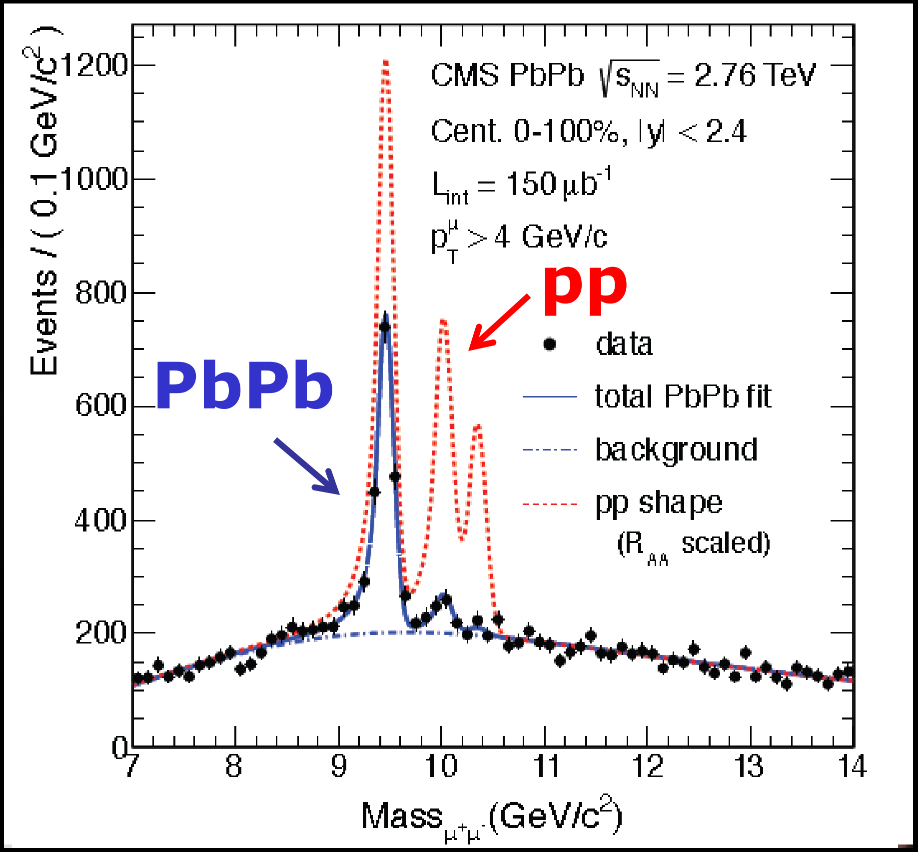
Bottomonium in AA

Main features of bottomonium production wrt charmonium:

- no B hadron feed-down
- smaller gluon shadowing effects
- (re)combination expected to be negligible
- theoretical predictions more robust due to the higher mass of b quark

with a drawback…smaller production cross-section

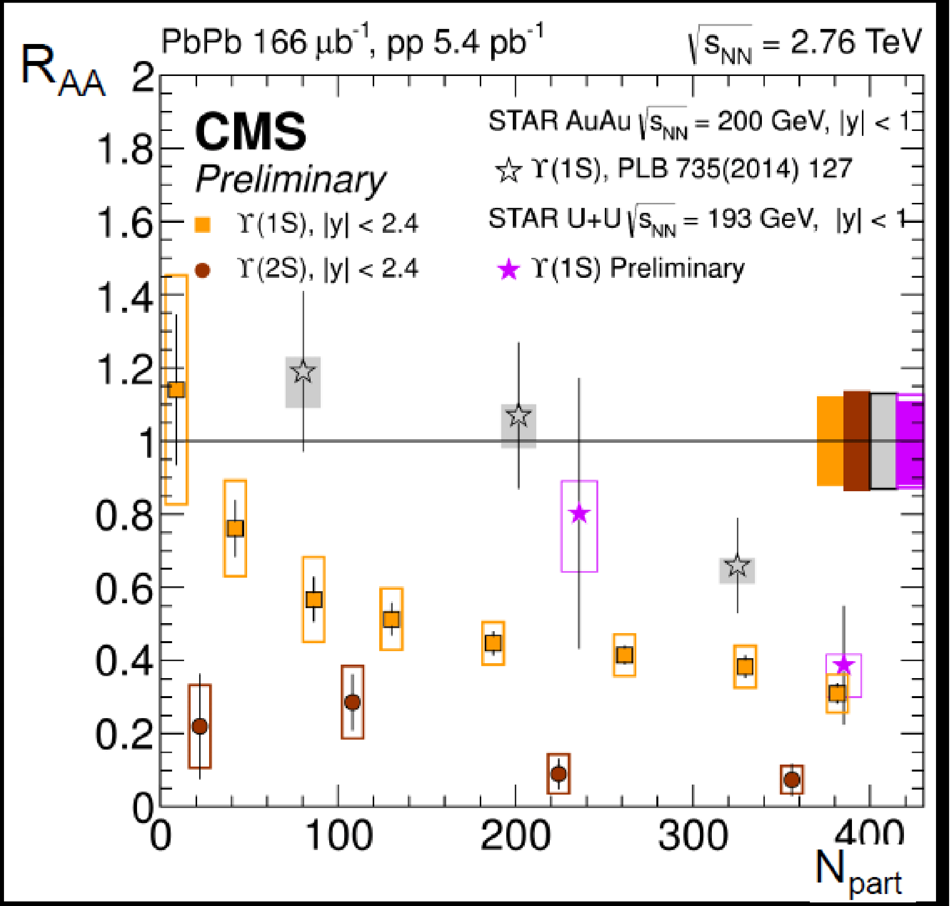
PRL 109, 222301 (2012)



Clear suppression of ϒ states in PbPb with respect to pp collisions

ϒ R_{AA} vs. centrality

- New high-statistics CMS results confirm the centrality dependent suppression for ϒ(1S) and ϒ(2S)



CMS, PRL109 (2012) 222301 and HIN-15-001
STAR, PLB735 (2014) 127 and preliminary U+U

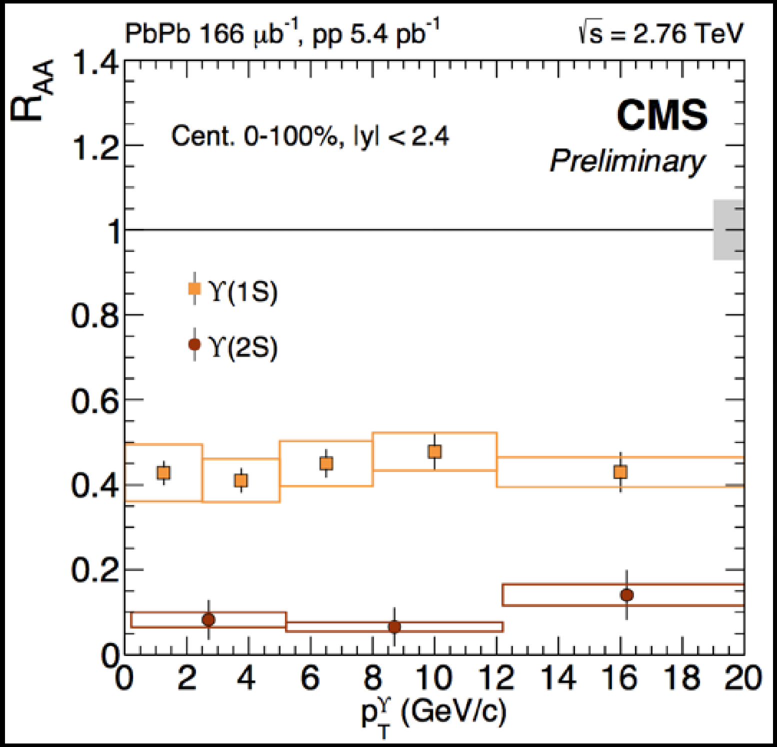
- Sequential suppression observed at LHC:

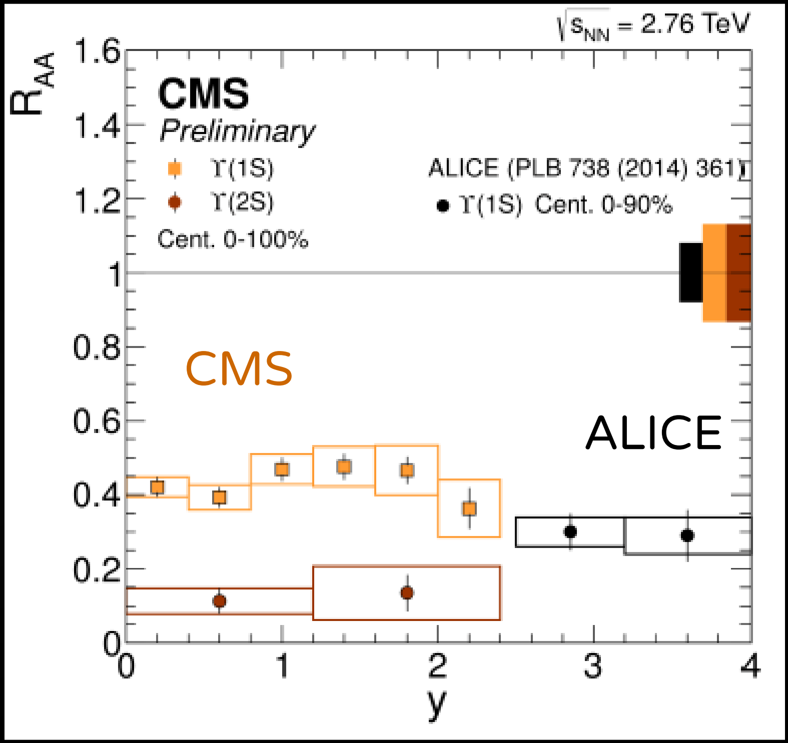
$$R_{AA}^{\Upsilon(3S)} < R_{AA}^{\Upsilon(2S)} < R_{AA}^{\Upsilon(1S)}$$

$R_{AA}(\Upsilon(1S))= 0.425\pm0.029\pm0.070$
$R_{AA}(\Upsilon(2S))= 0.116\pm0.028\pm0.022$
$R_{AA}(\Upsilon(3S))< 0.14$ at 95% CL

- ϒ(1S) suppressed also in central Au-Au and U-U collisions at RHIC

ϒ R_{AA} vs. p_T and rapidity



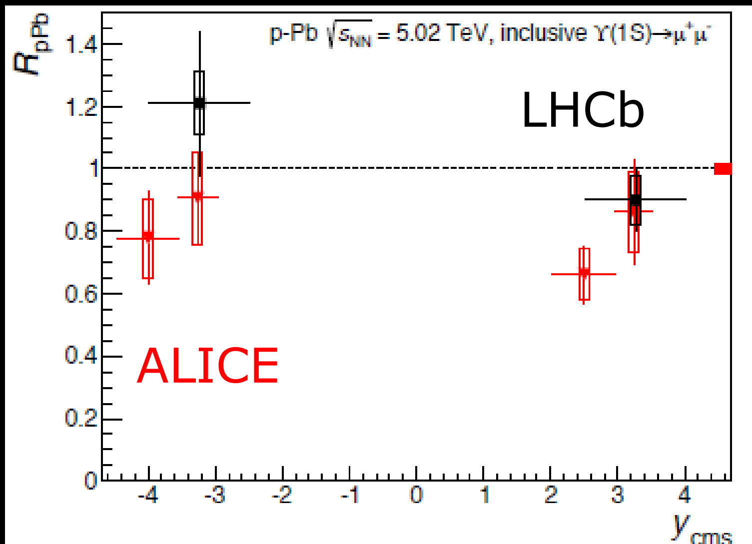


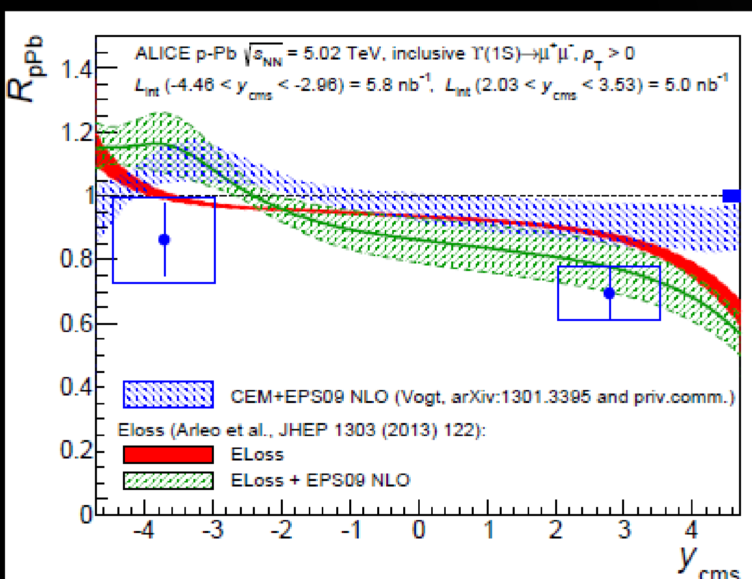
CMS, HIN-15-001
ALICE, PLB 738 (2014) 361

- ϒ(1S) suppressed by a factor ~2
- ϒ(2S) suppressed by a factor ~10

➡ No p_T or rapidity dependence of the suppression
→ Constraint for theoretical models!

Υ production in pA collisions





Υ(1S) measured at mid-*y* by CMS and at forward-*y* by both ALICE and LHCb

→ Compatible R_{pA} results within uncertainties (but LHCb systematically higher)

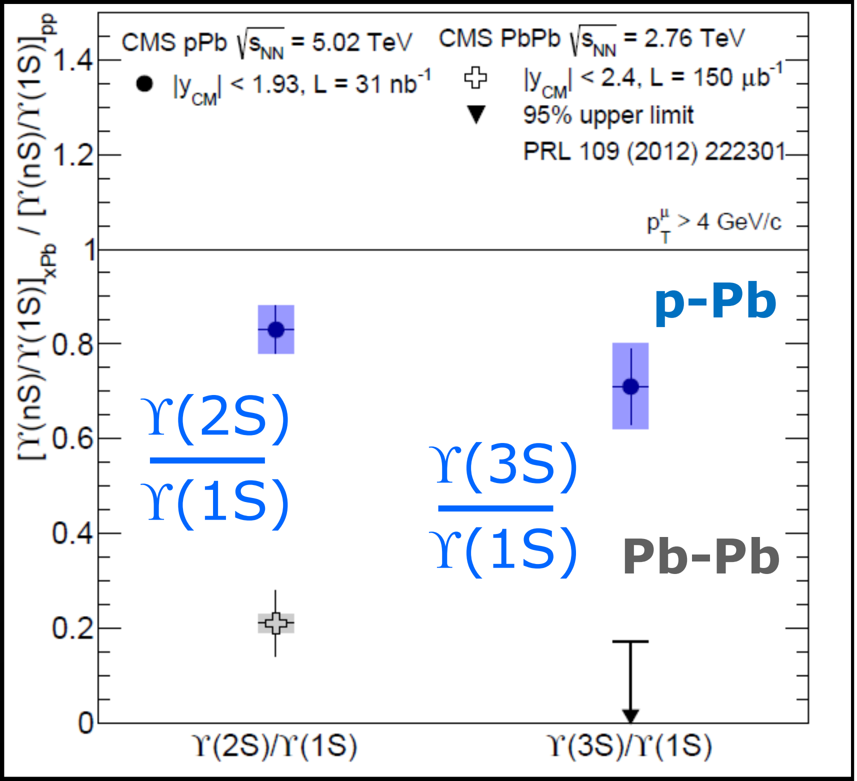
- Hint for stronger Υ(1S) suppression at forward-*y* (as for the J/ψ)
- Theoretical models based on initial state effects meet difficulties describing simultaneously forward and backward *y*

ALICE: arXiv:1410.2234, accepted by PLB
LHCb: JHEP 07(2014)094

Υ excited states in pA

p-Pb vs pp @mid-y:
Stronger excited states suppression with respect to Υ(1S)
Initial state effects similar for the three Υ states
→ Final states effects in p-Pb?

p-Pb vs PbPb @mid-y :
even stronger suppression of excited states in PbPb



CMS,JHEP04(2014)103

➡ ALICE (and LHCb) observes:

Υ(2S)/Υ(1S) (ALICE)
2.03<y<3.53: 0.27±0.08±0.04
-4.46<y<-2.96: 0.26±0.09±0.04

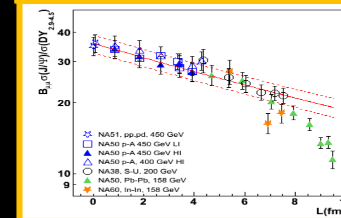
compatible with pp results
0.26 ± 0.08 (ALICE, pp@7TeV)

➡ Rapidity dependent final state effects at play?

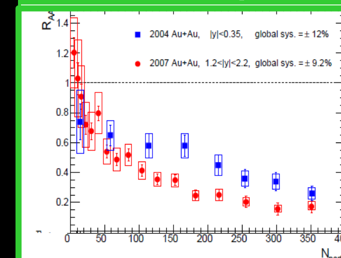
Quarkonium in Heavy-Ions

- Large wealth of results at LHC complementing SPS and RHIC measurements!
  - two main mechanisms at play in AA collisions
    1. suppression in a deconfined medium
    2. (charmonium) re-combination at high $\sqrt{s}$ and low p_T
  - in p-A collisions:
    - interplay of shadowing and coherent energy loss can satisfactorily describe quarkonium results
    - loosely bound $\psi(2S)$ is likely influenced by the hadronic final state
- Results from LHC Run2 eagerly awaited!
  - Energy increase ($\sqrt{s_{NN}}$=5TeV) will allow for confirmation of the (re) combination role at low p_T
  - Statistics increase will allow to sharpen Run-I results

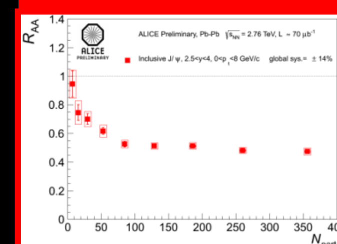
SPS



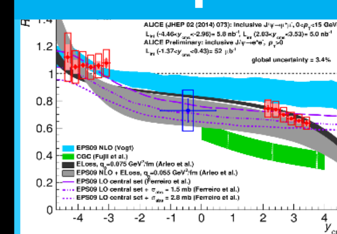
RHIC dA, AA



LHC AA

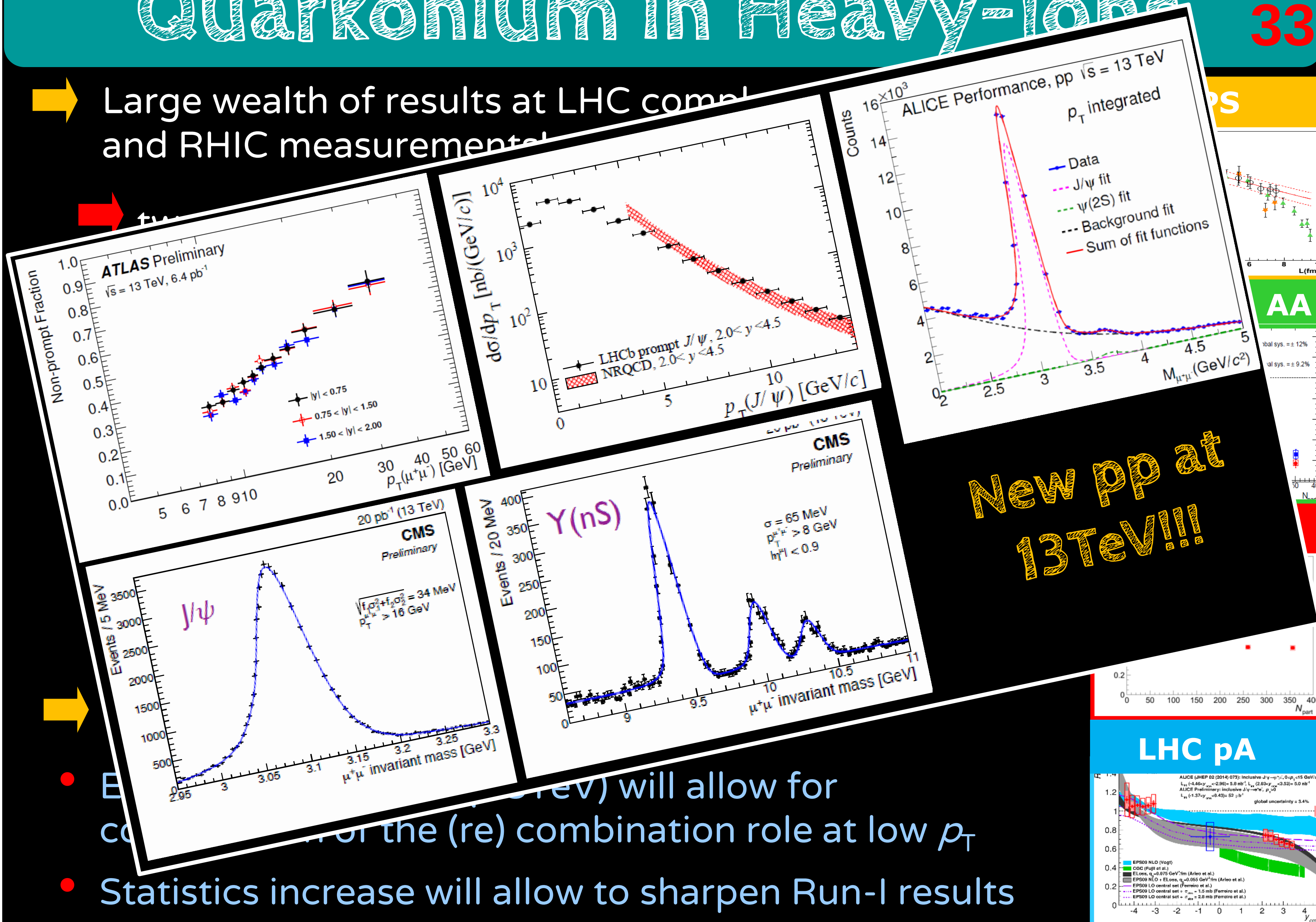


LHC pA



Quarkonium in Heavy-Ion

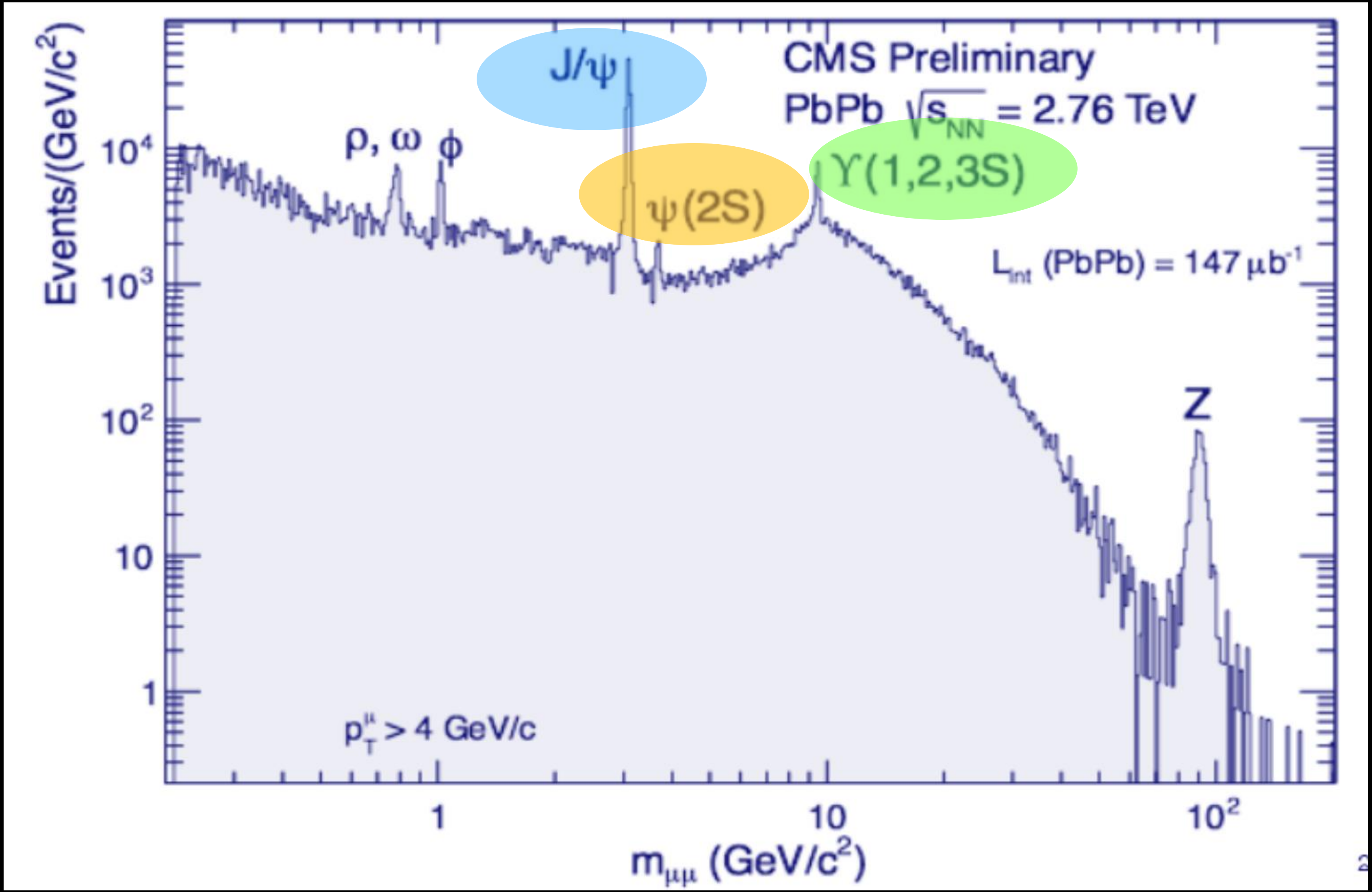
- Large wealth of results at LHC compl... and RHIC measurements!



- E... ...TeV) will allow for co... of the (re) combination role at low p_T
- Statistics increase will allow to sharpen Run-I results

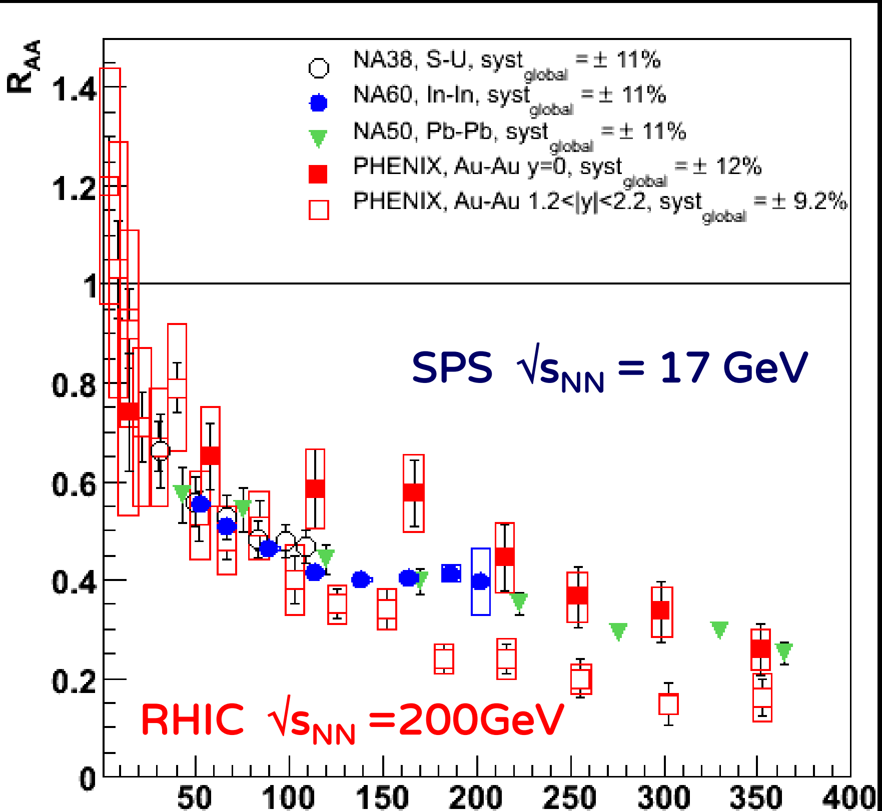
Backup slides

Quarkonium spectrum



From SPS to LHC...

- J/ψ studies at lower energies
  - SPS $\sqrt{s_{NN}}$ = 17 GeV
  - RHIC $\sqrt{s_{NN}}$ = 39-200 GeV



N.Brambilla et al. (QWG) EPJC71 (2011) 1534

- Puzzles from SPS and RHIC
  - RHIC: stronger suppression at forward rapidities
    (not expected if suppression increases with energy density, larger at mid-y)
  - SPS vs. RHIC: similar R_{AA} pattern versus centrality

  Hint for (re)combination at RHIC?

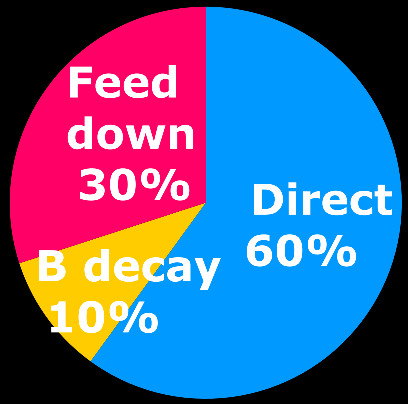
- Decisive inputs from LHC:
  - higher energies
    → stronger suppression?
  - more charm
    → larger (re)combination?
  - more bottom
    → ϒ can be investigated

Quarkonium production and decay

J/ψ production

Quarkonium production can proceed:

- directly in the interaction of the initial partons
- via the decay of heavier hadrons (feed-down)

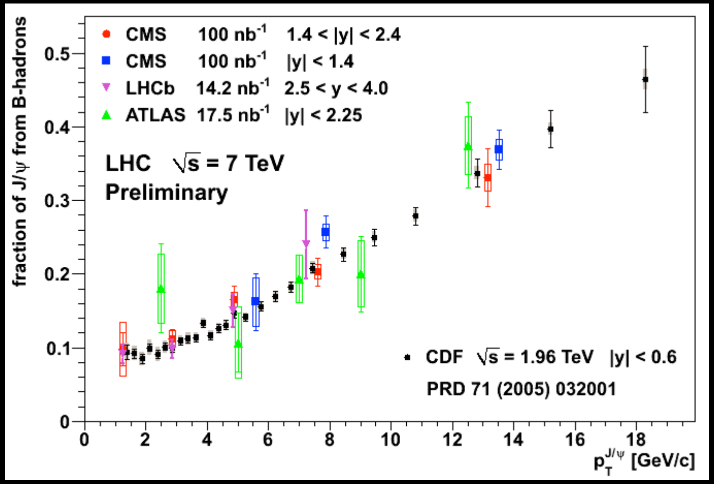


Prompt

- Direct production
- Feed-down from higher charmonium states:

Displaced

- B decay
  contribution is p_T dependent
  ~10% at p_T~1.5GeV/c

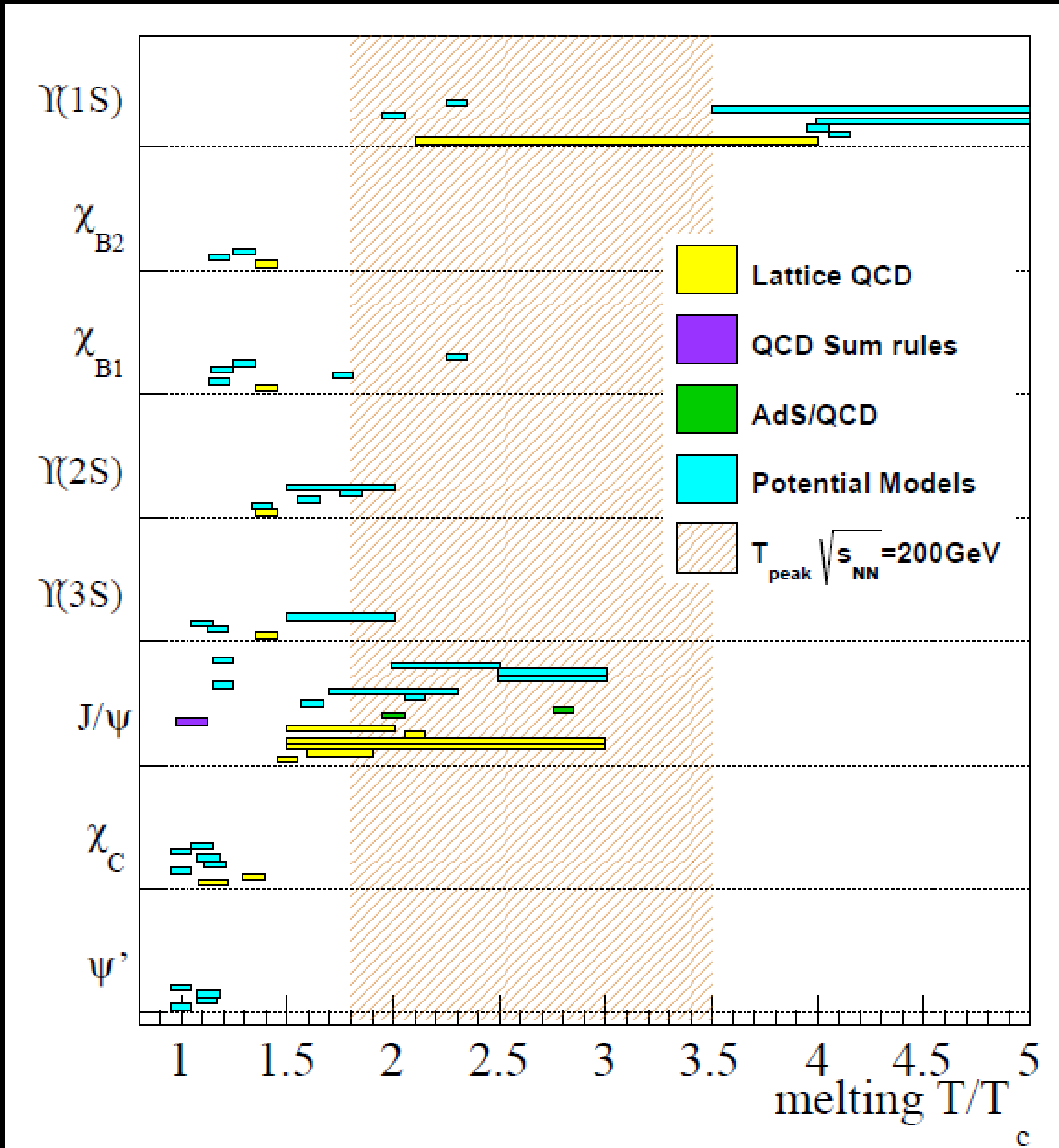


J/ψ decay

J/ψ can be studied through its decays:

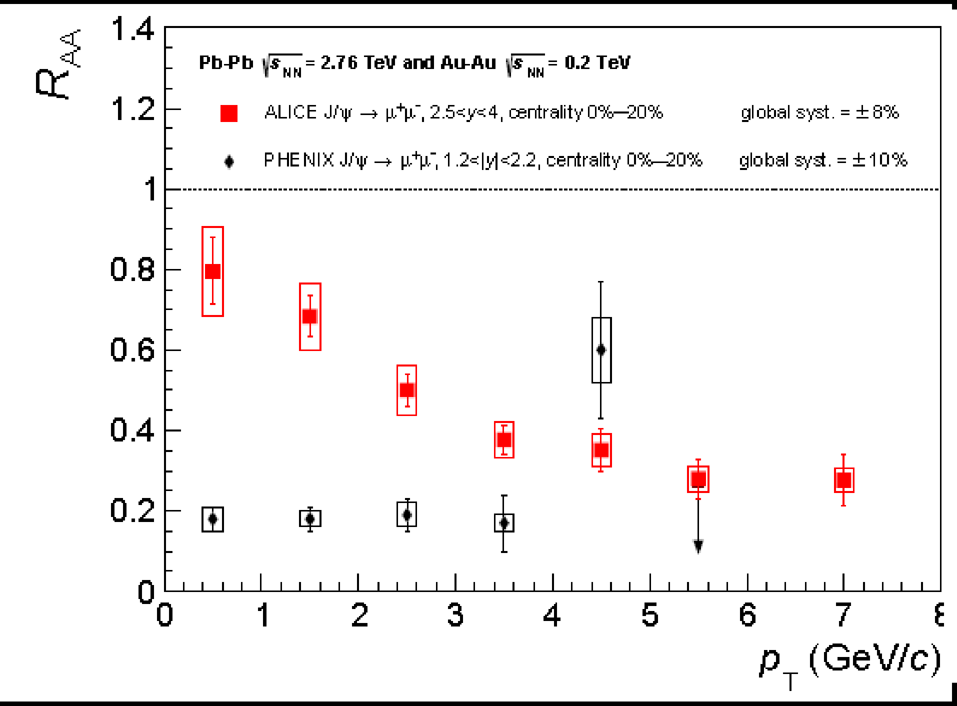
$J/\psi \rightarrow \mu^+\mu^-$ **$J/\psi \rightarrow e^+e^-$** (~6% branching ratio)

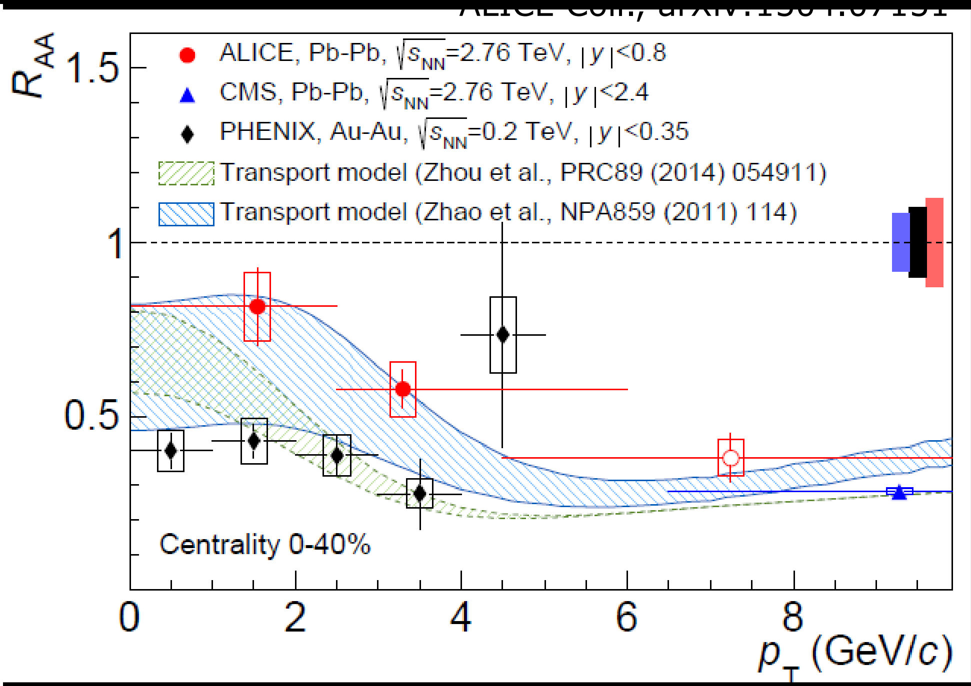
DISSOCIATION TEMPERATURES



Low p_T J/ψ: ALICE & PHENIX

- J/ψ production via (re)combination should be more important at low transverse momentum (p_T region accessible by ALICE)

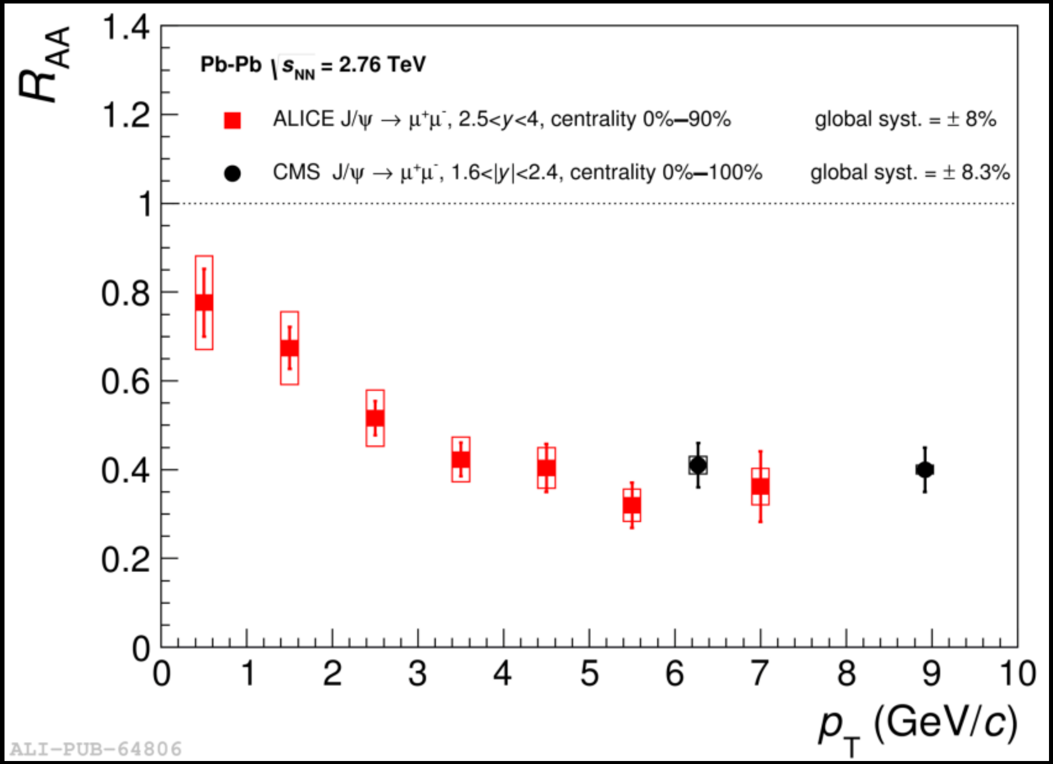




- Different suppression for low and high p_T J/ψ
  - → Smaller R_{AA} for high p_T J/ψ
- Striking difference, at low p_T, between PHENIX and ALICE patterns

CMS: high p_T J/ψ

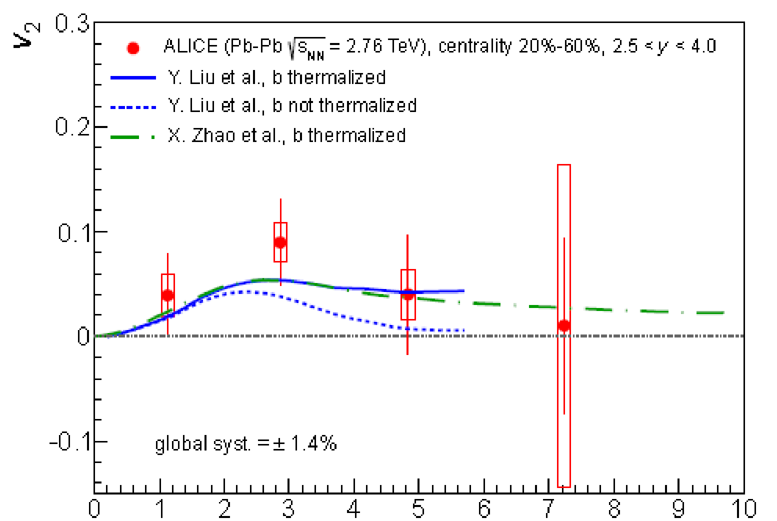
The high p_T region can be investigated by CMS!



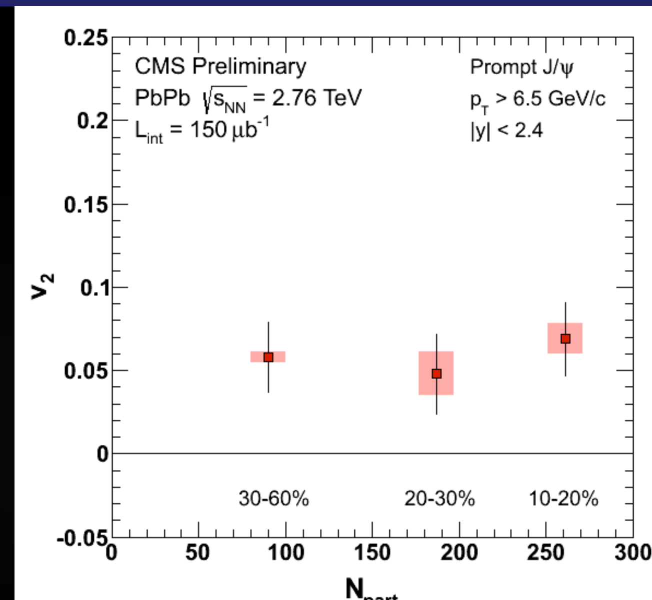
Good agreement with ALICE (at high p_T) in spite of the different rapidity range

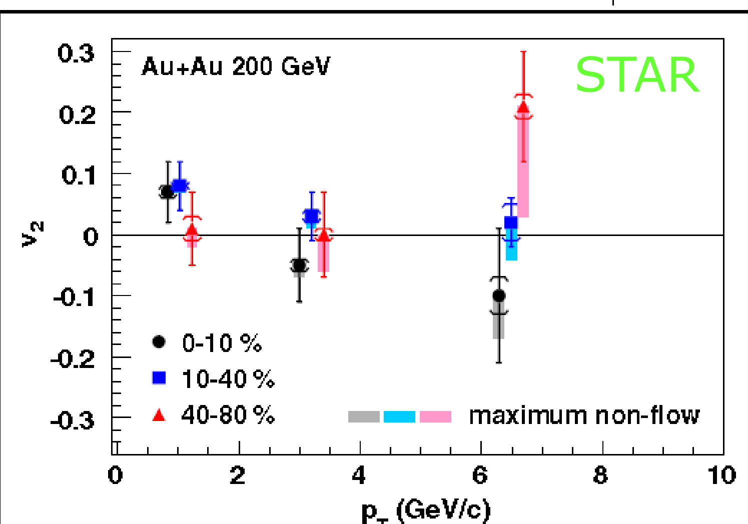
J/ψ flow

- The contribution of J/ψ from (re)combination should lead to a significant elliptic flow signal at LHC energy



ALICE PRL111, 162301 (2013)



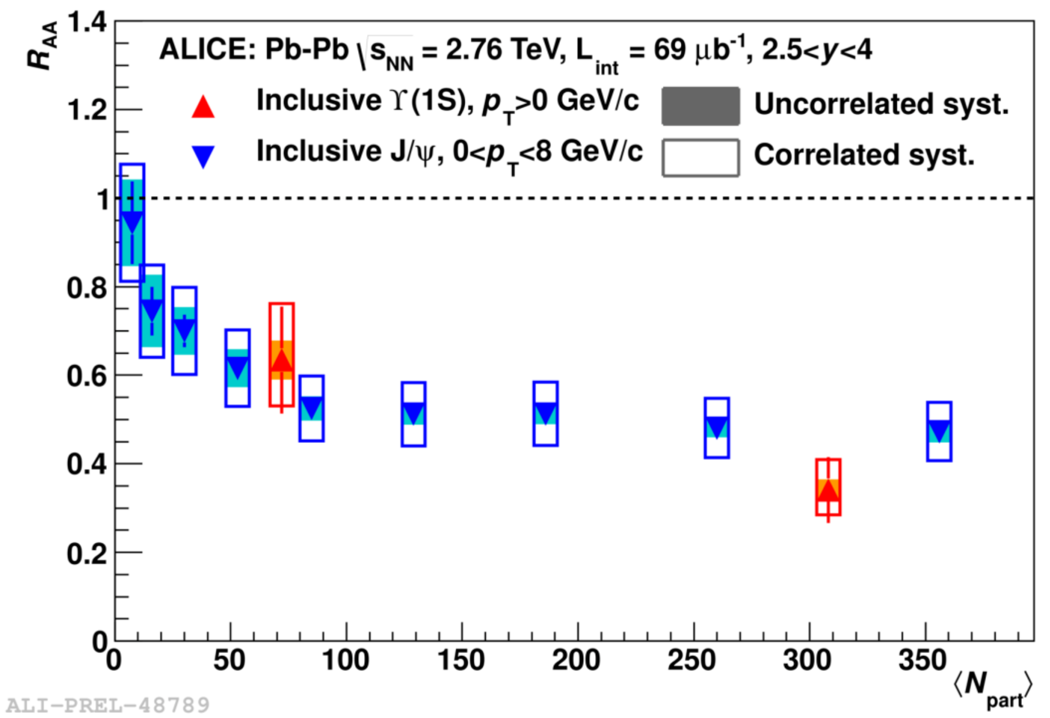


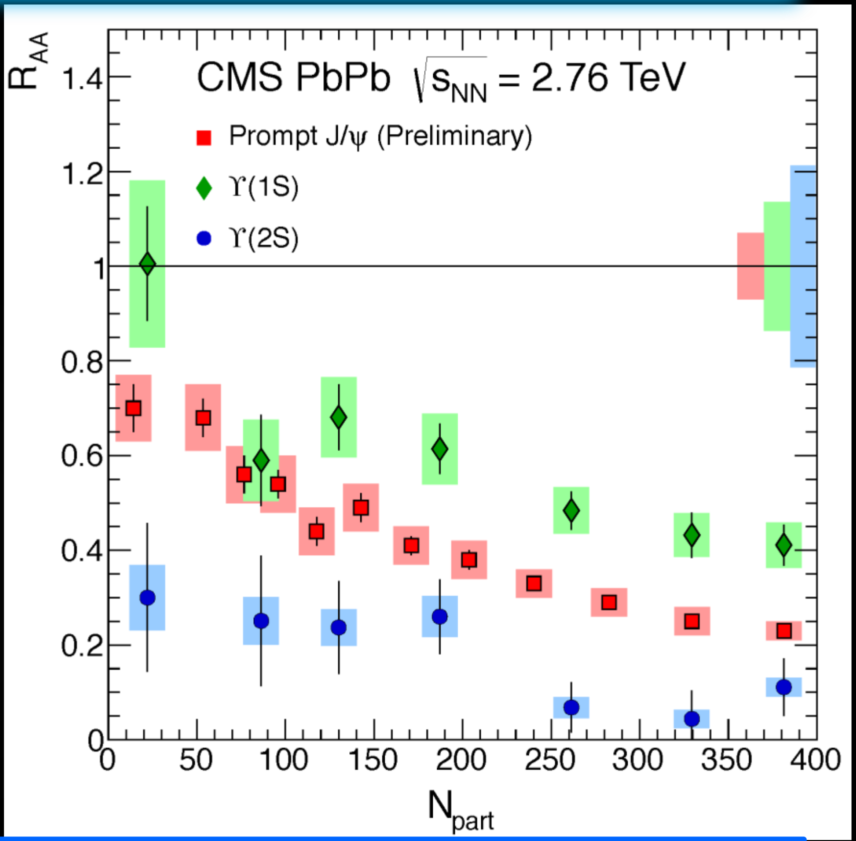
- Hint for J/ψ flow at LHC, contrary to v_2~0 observed at RHIC!

- ALICE: qualitative agreement with transport models including regeneration

- CMS: path-length dependence of energy loss?

Comparison ϒ and J/ψ



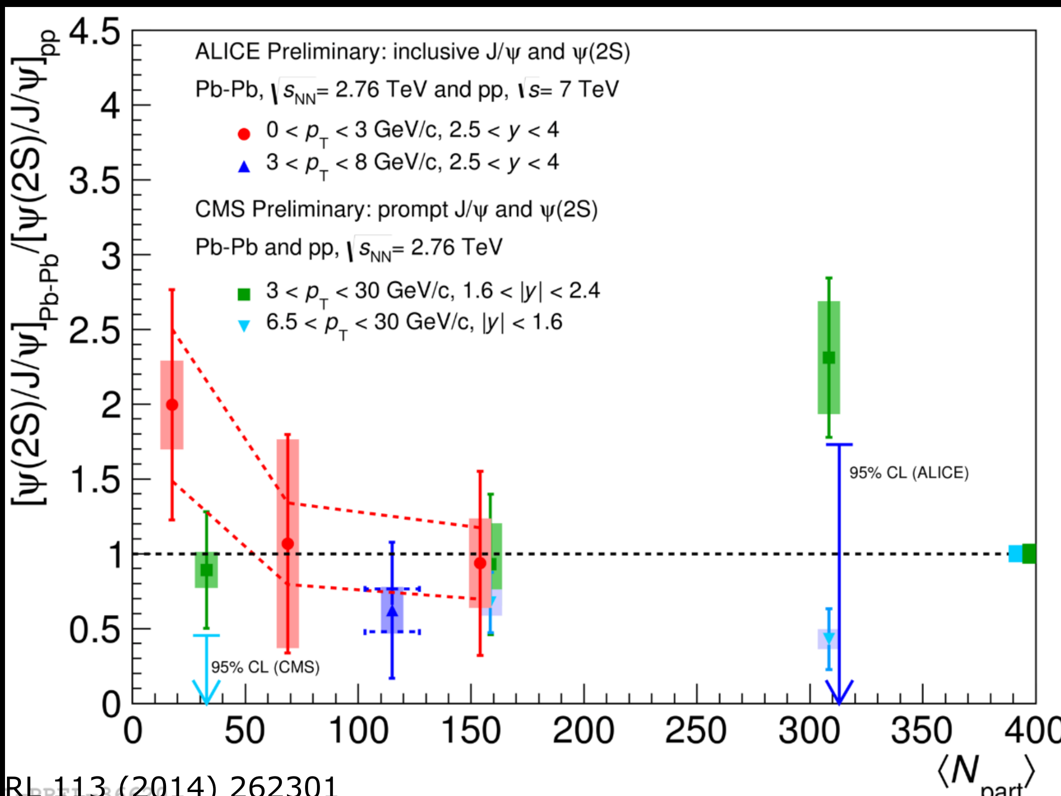


- Similar R_{AA} for low p_T inclusive J/ψ and ϒ(1S)
- Sequential suppression observed for prompt J/ψ and ϒ(nS) at high p_T

- interplay of the competing mechanisms for J/ψ and ϒ can be different and dependent on kinematics!

ψ(2S)/J/ψ IN PB-PB @LHC

- Being a more weakly bound state than the J/ψ, the ψ(2S) is another interesting probe to investigate charmonium behaviour in the medium
- The ψ(2S) yield is compared to the J/ψ one in Pb-Pb and in pp



RL 113 (2014) 262301

ALICE:

low p_T ($0<p_T<3$GeV/c) → ψ(2S) more suppressed than J/ψ

CMS:

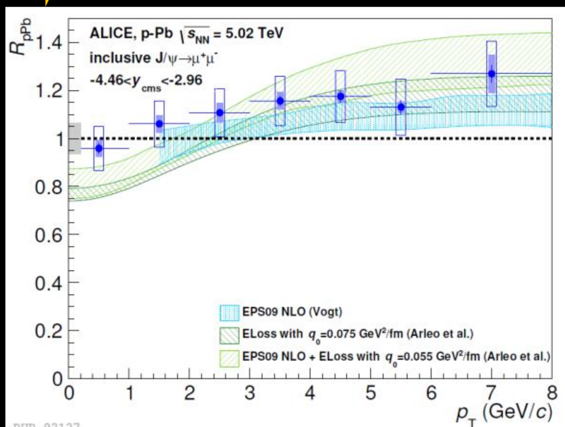
$p_T>3$ GeV/c & $1.6<|y|<2.4$ → ψ(2S) less suppressed than J/ψ

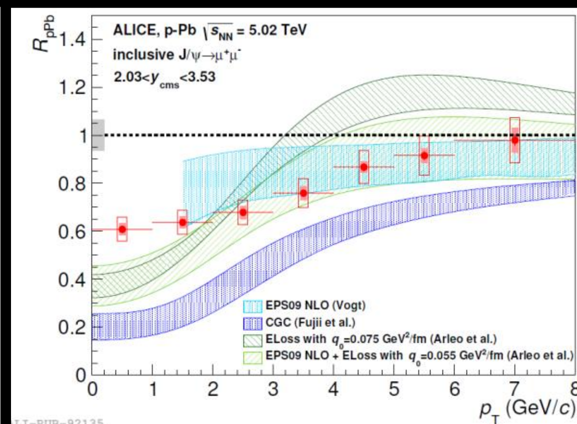
$p_T>6.5$ GeV/c & $|y|<1.6$ → ψ(2S) more suppressed than J/ψ

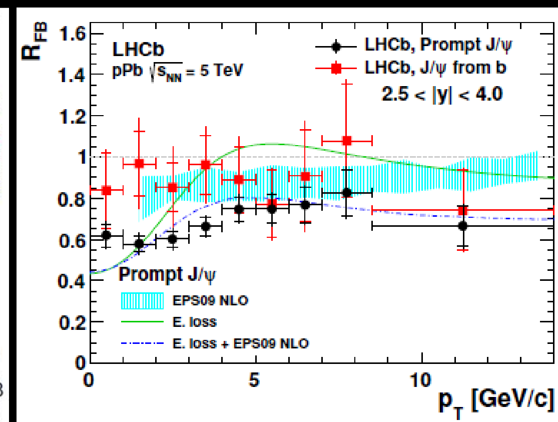
- Improved agreement between ALICE and CMS data (new pp CMS reference)
- Large statistics and systematic uncertainties prevent a firm conclusion on the ψ(2S) trend vs centrality

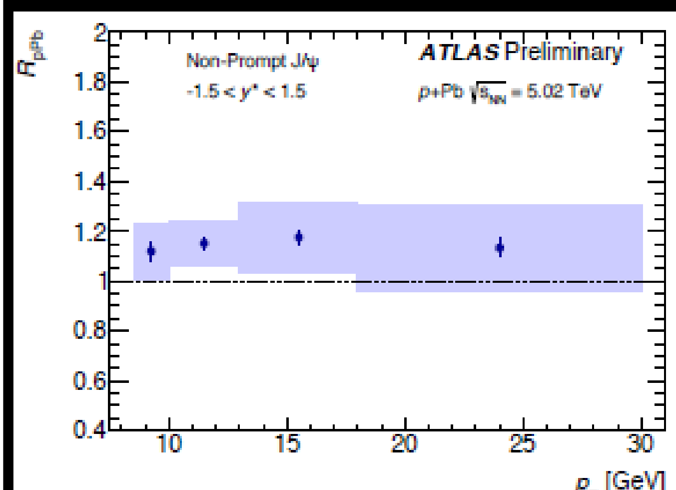
J/ψ in pA collisions

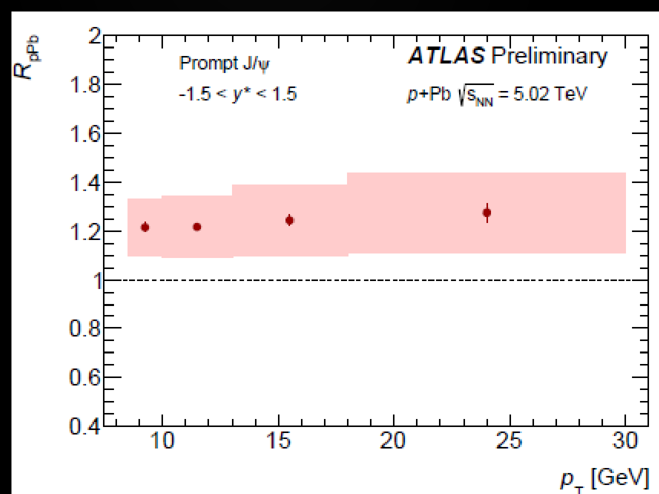
- Lots of new results now available on J/ψ production in p-Pb!
  - versus transverse momentum

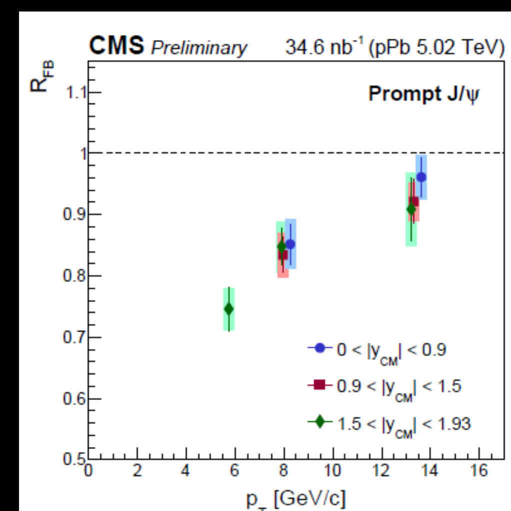








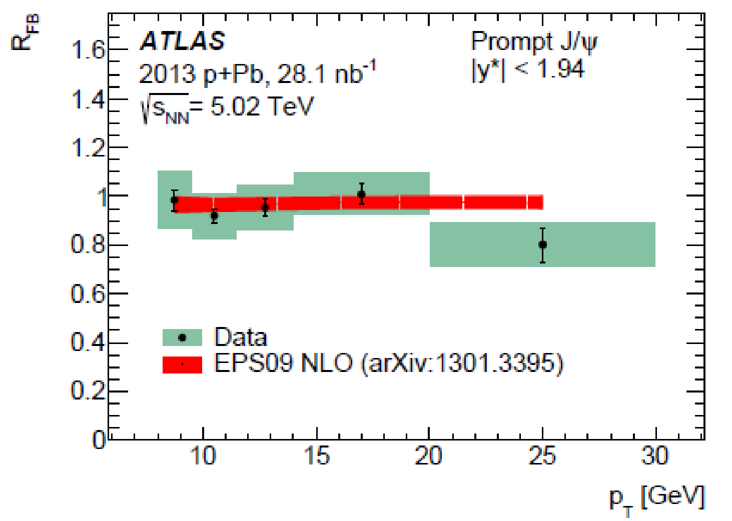


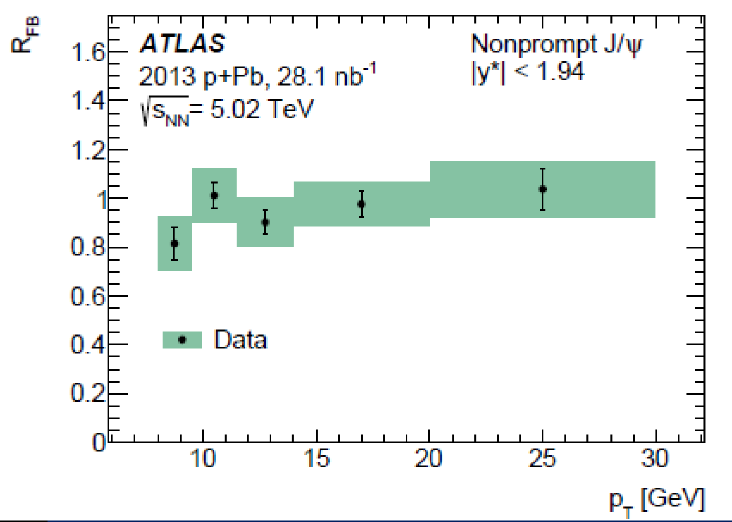


ALICE JHEP 06 (2015) 55, ATLAS-CONF-2015-023, CMS PAS HIN-14-009, LHCb JHEP 02 (2014) 072

p-Pb: role of CNM effects on J/ψ

ATLAS: |y|<1.94, 8<p_T<30GeV/c



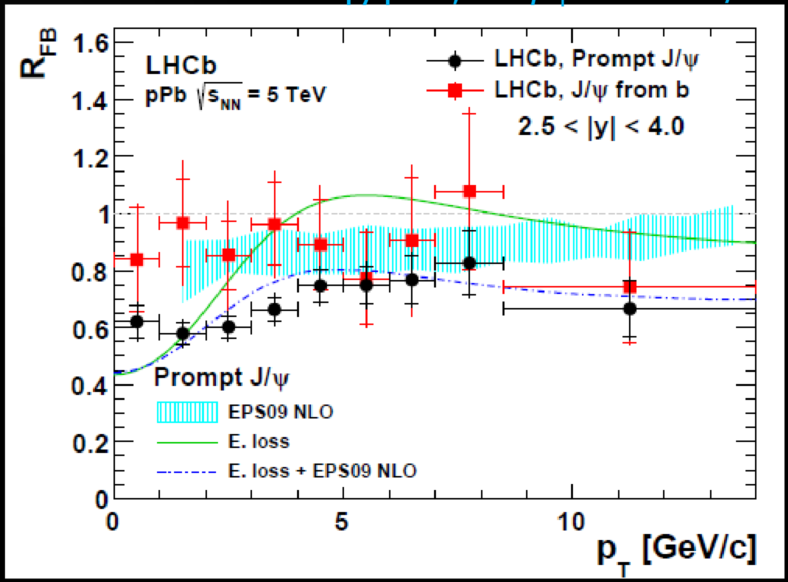


ATLAS and LHCb measure the forward to backward cross section ratio, R_{FB}, for

- Prompt J/ψ
- Non prompt J/ψ from B decay

Similar shadowing/saturation expected for quarkonia and b quarks

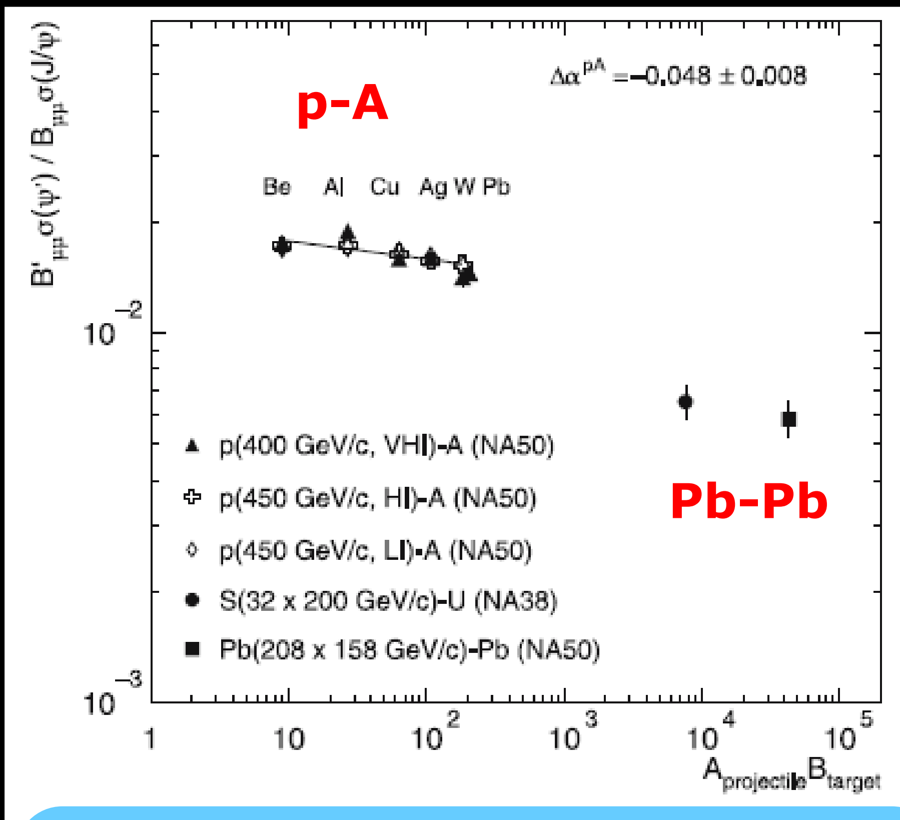
LHCb: 2.5<|y|<4, 0<p_T<14GeV/c



ATLAS/LHCb results indicate a strong kinematic dependence of CNM for both charmonium and b quark production

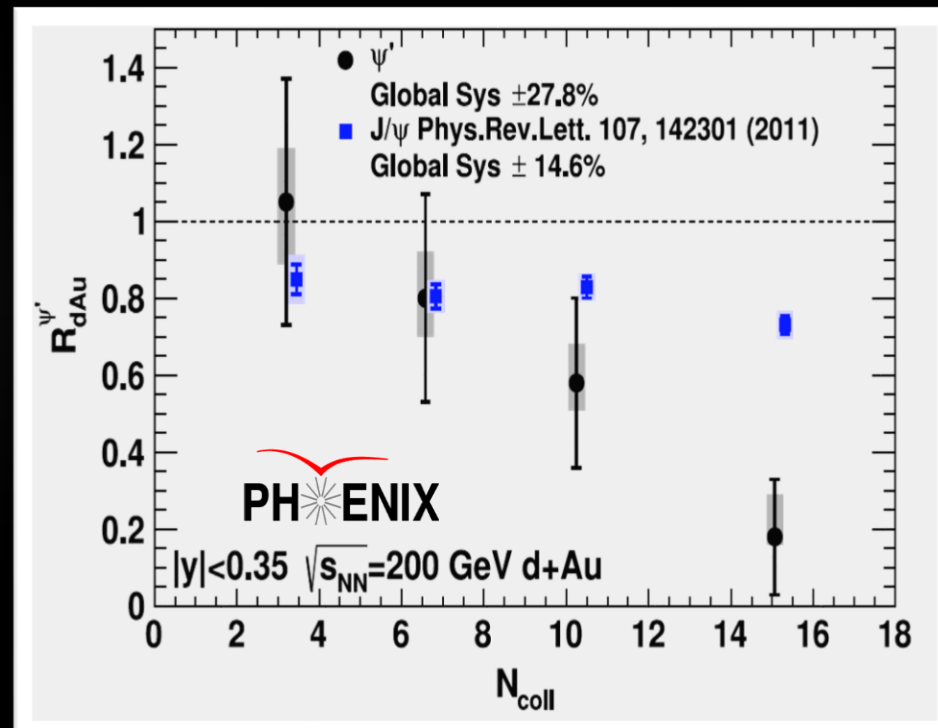
LOW ENERGY RESULTS: ψ(2S) FROM SPS & RHIC

SPS (NA50) pA, AA @ $\sqrt{s_{NN}}$ = 17 GeV



- ψ(2S) is more suppressed than J/ψ already in pA collisions and the suppression increases in Pb-Pb

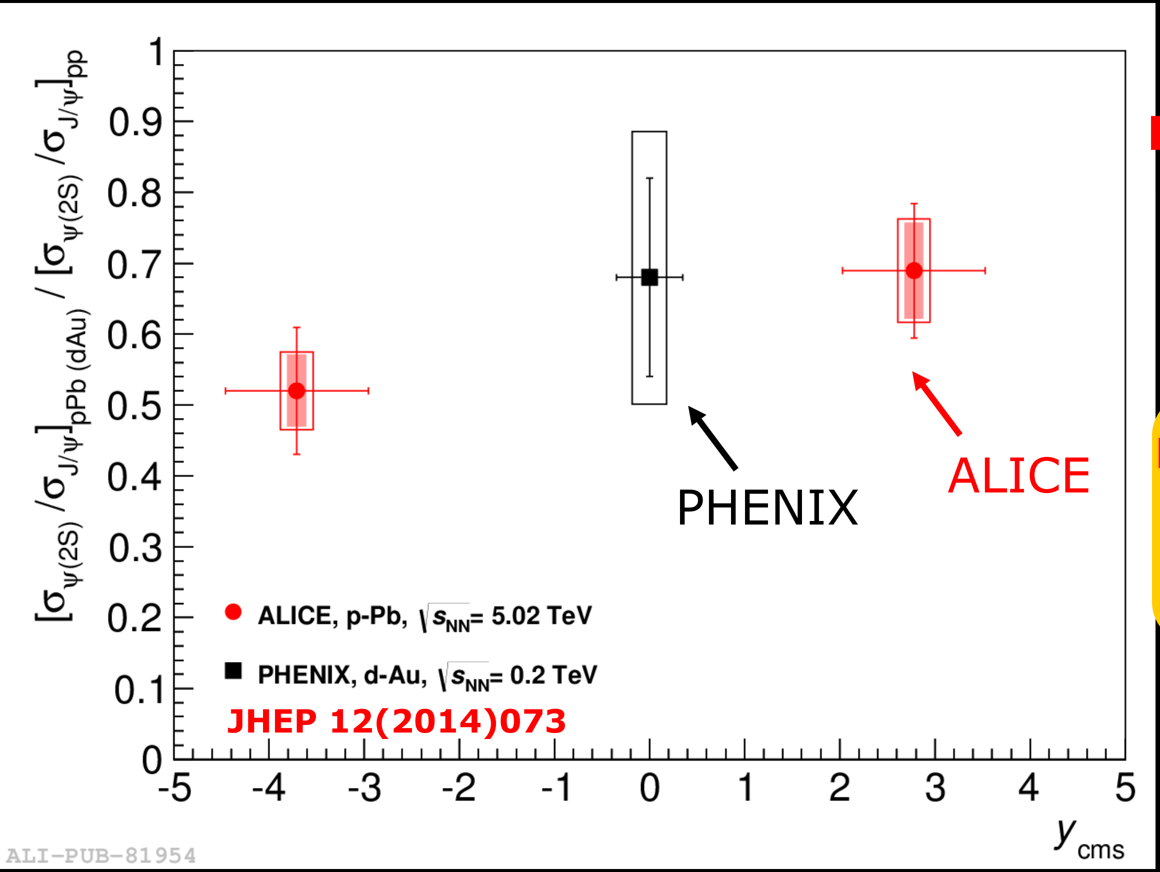
RHIC (PHENIX) d-Au @ $\sqrt{s_{NN}}$ = 200 GeV



- unexpected ψ(2S) suppression, stronger than the J/ψ one in d-Au

$\psi(2S)/J/\psi$ IN p-Pb

A strong decrease of the $\psi(2S)$ production in p-Pb, relative to J/ψ, is observed with respect to the pp measurement ($2.5<y_{cms}<4$, $\sqrt{s}$=7TeV)

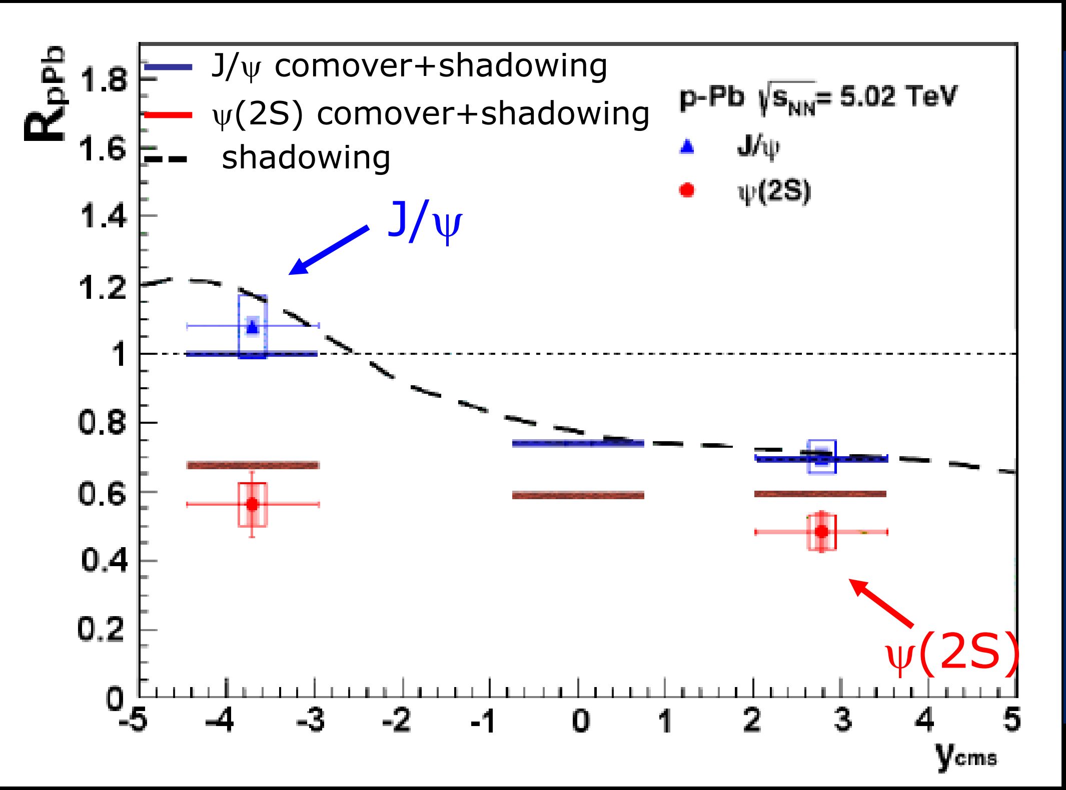


- Double ratio allows a direct comparison of the J/ψ and $\psi(2S)$ production yields between experiments
- Similar effect seen by PHENIX in d-Au collisions, at mid-y, at $\sqrt{s_{NN}}$=200 GeV

$[\psi(2S)/J/\psi]_{pp}$ variation between ($\sqrt{s}$=7TeV, 2.5<y<4) and ($\sqrt{s}$=5.02TeV, 2.03<y<3.53 or -4.46<y<-2.96) based on CDF and LHCb data (~8% included in the systematic uncertainty)

ψ(2S) vs J/ψ in p-A collisions

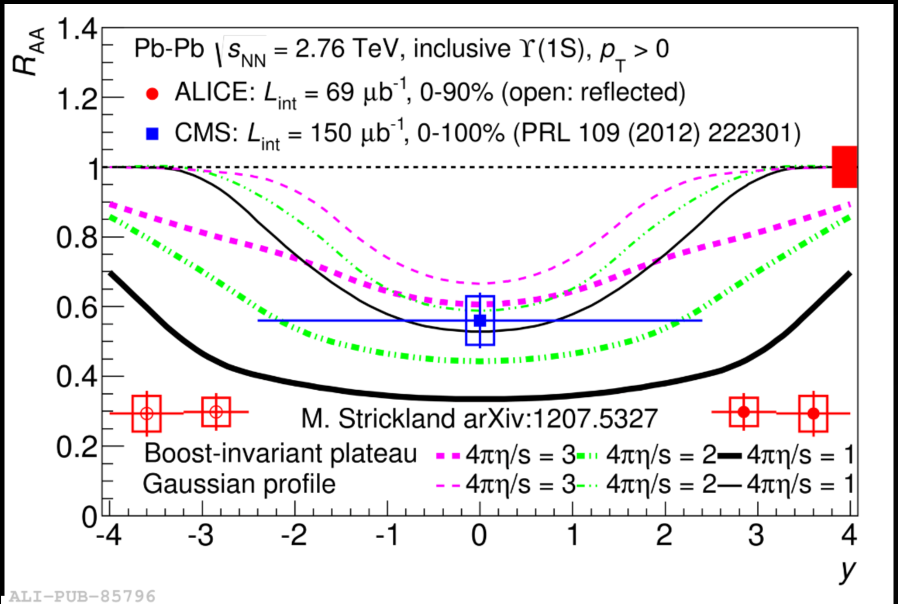
- Final state effects related to the (hadronic) medium created in the p-Pb collisions?

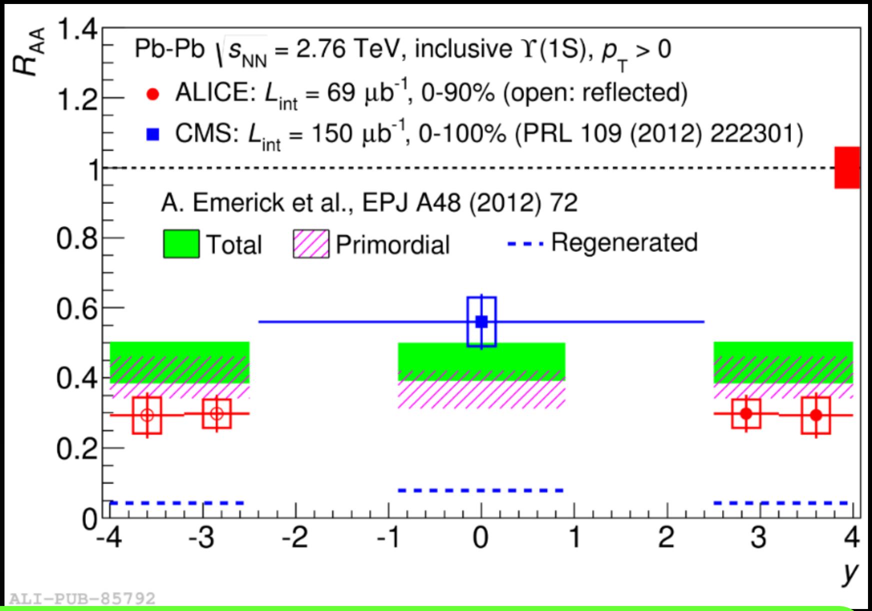


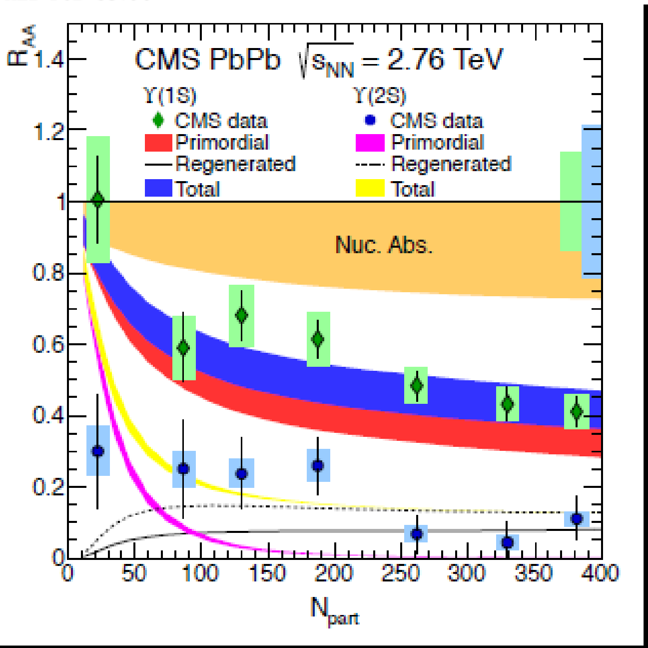
- Charmonium interaction with comoving particles:
  - Comovers dissociation affects more strongly the loosely bound ψ(2S) than the J/ψ
  - Comovers density larger at backward rapidity

E. Ferreiro arXiv:1411.0549

COMPARISON WITH THEORY





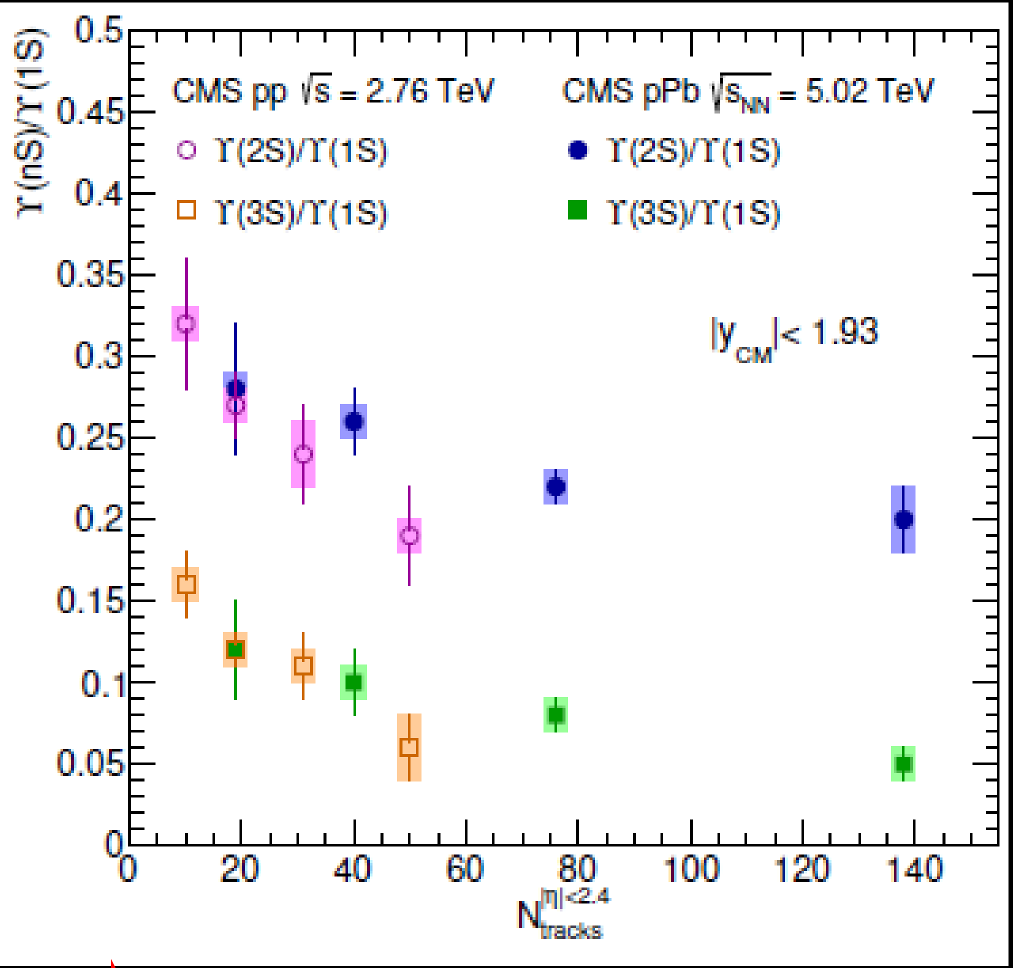


- Stronger suppression at forward rapidity (ALICE) than at mid-rapidity (CMS)

- Theory still meets difficulties in describing simultaneously the R_{AA} centrality and rapidity dependence (suppression slightly overestimated at forward-y, while better reproduced at mid-y)

ϒ(nS)/ϒ(1S) VS EVENT ACTIVITY

ϒ(nS)/ϒ(1S) studied as a function of event activity



Strong decrease with increasing charged particle multiplicity both in pp and p-Pb

ϒ production affects multiplicity?

ϒ(1S) produced with more particles than excited states

or multiplicity affects the ϒ?

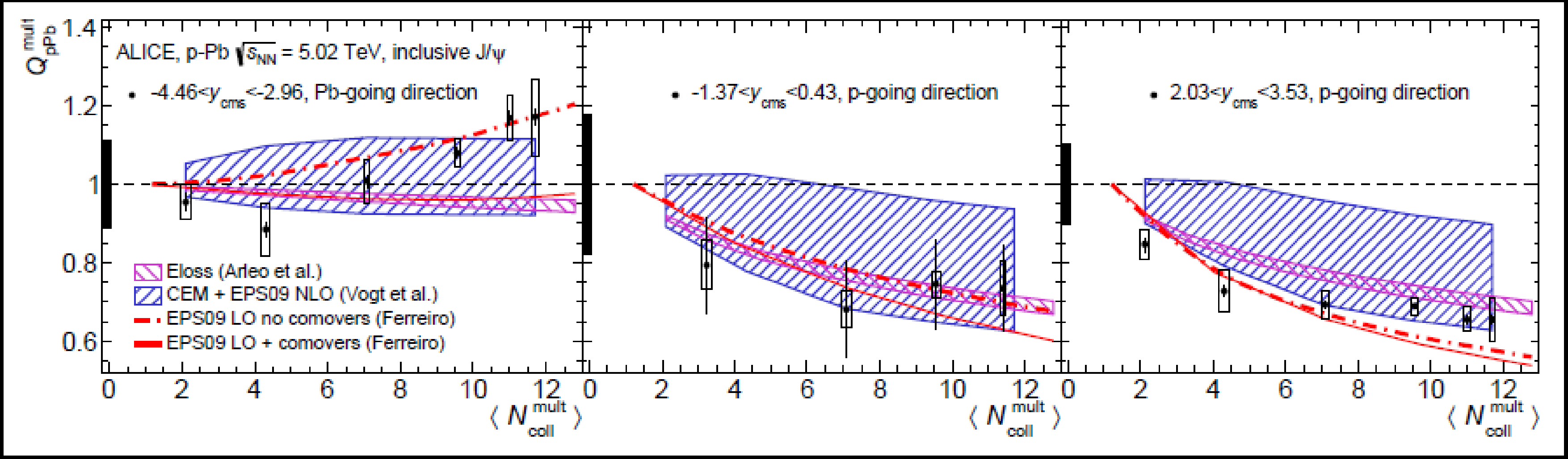
activity around the ϒ breaks the state

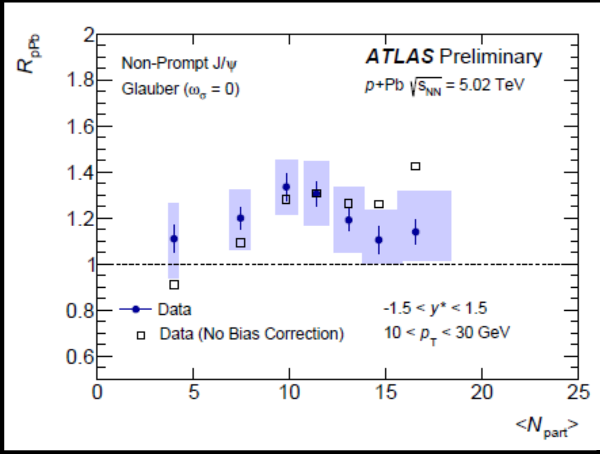
Weaker dependence when the activity estimator is in a different kinematic region with respect to the ϒ

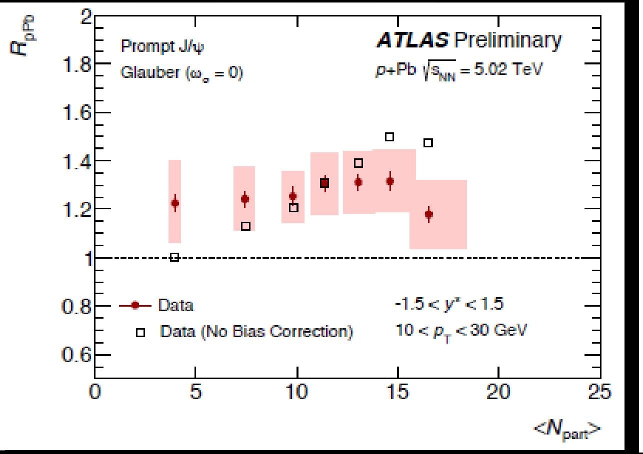
J/ψ in pA collisions

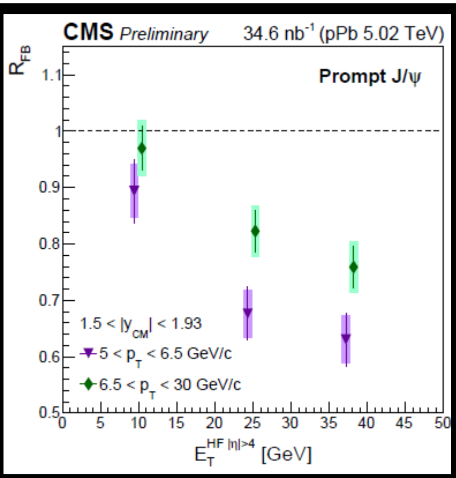
- Lots of new results now available on J/ψ production in p-Pb!
  - versus collision centrality or event activity...

ALICE arXiv:1506.08808
ATLAS-CONF-2015-023
CMS PAS HIN-14-009







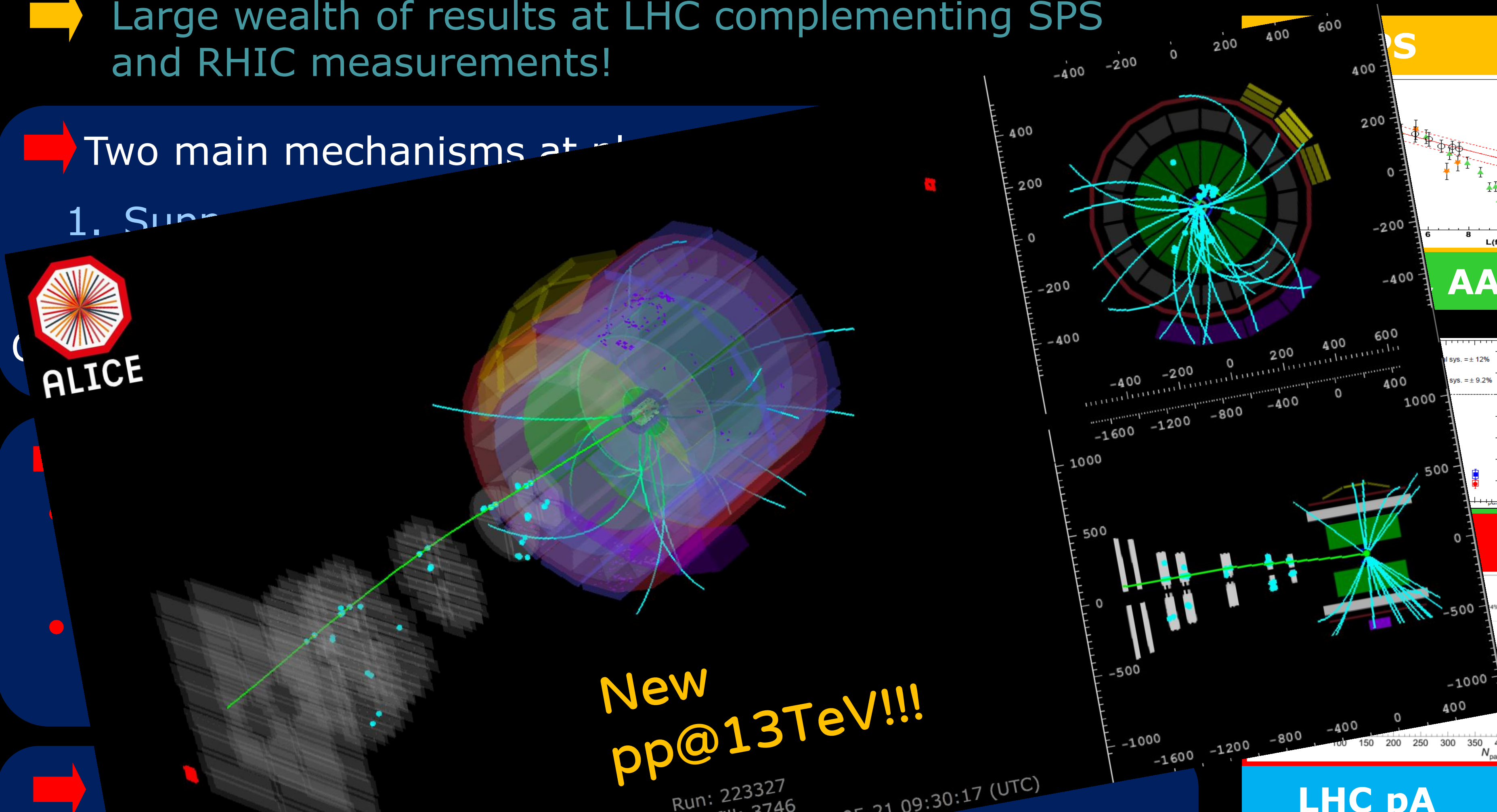


J/ψ in heavy ion collisions: where are we?

Large wealth of results at LHC complementing SPS and RHIC measurements!

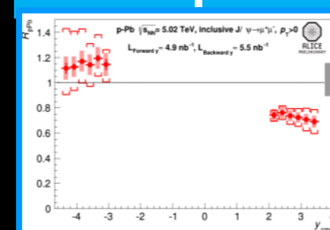
Two main mechanisms at pl

1. Supp



AA

LHC pA



E ... allow for confirmation

o ... ation role at low p_T

- Statistics increase will allow to sharpen Run-I results