Υ production in p-Pb and Pb-Pb collisions with ALICE at the LHC

Javier Castillo
for the
ALICE Collaboration

Outline

- Introduction

- ϒ production in pp collisions
  - Testing production models

- ϒ suppression in Pb-Pb collisions
  - Probing the QGP

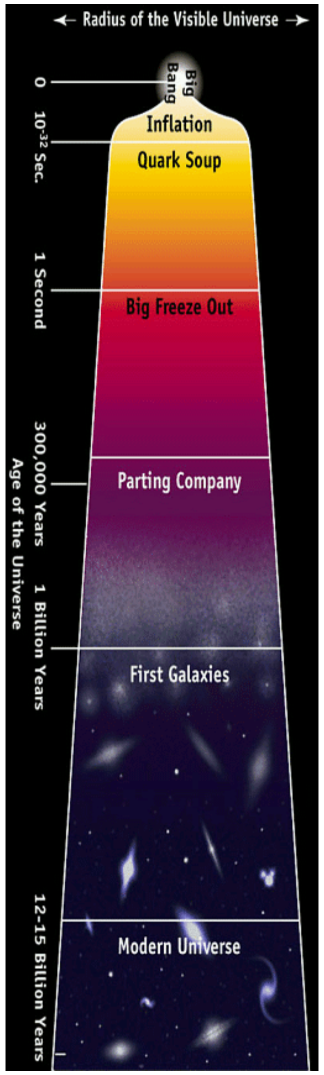
- ϒ production in p-Pb collisions
  - Addressing cold nuclear matter effects

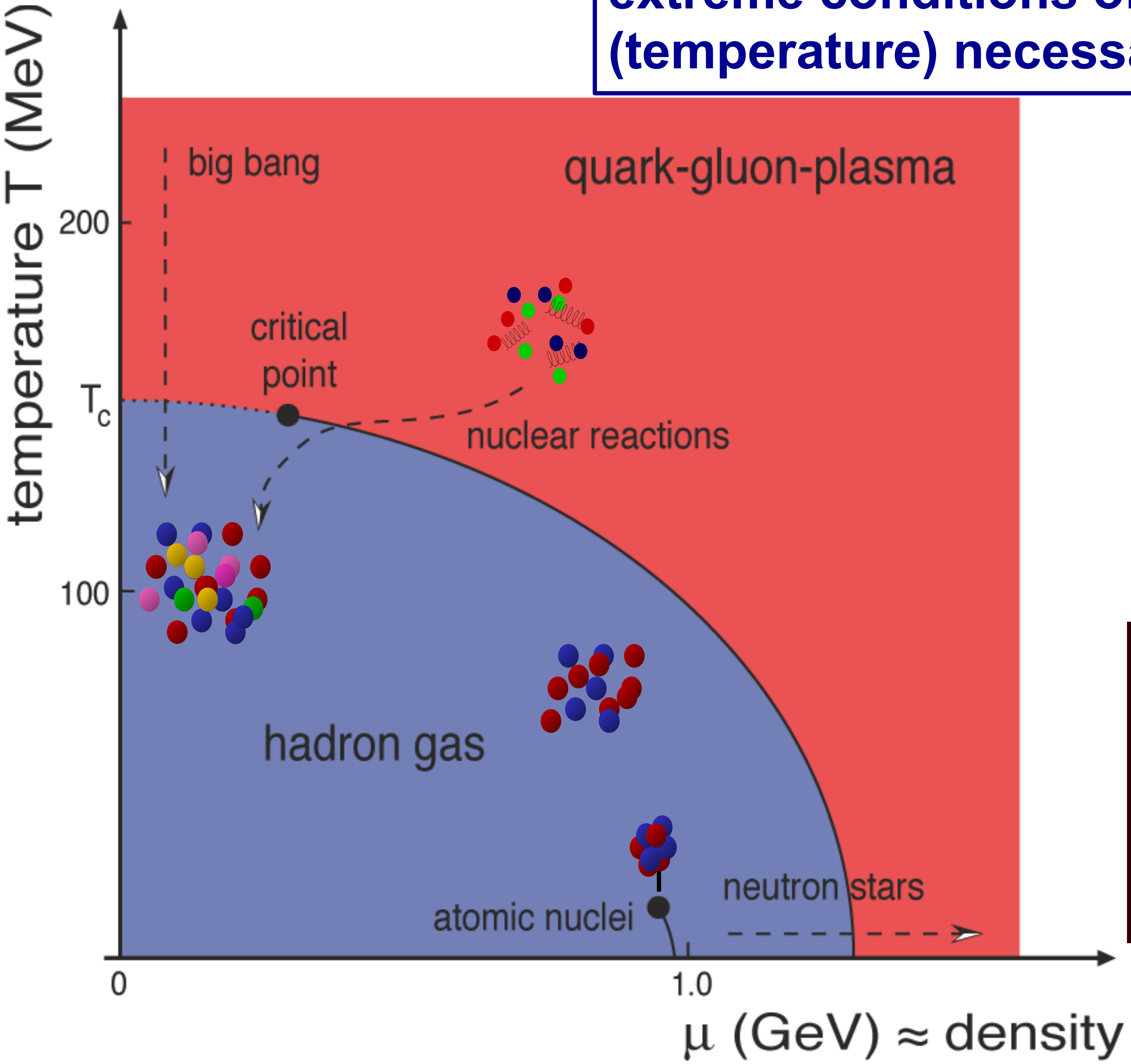
- Summary

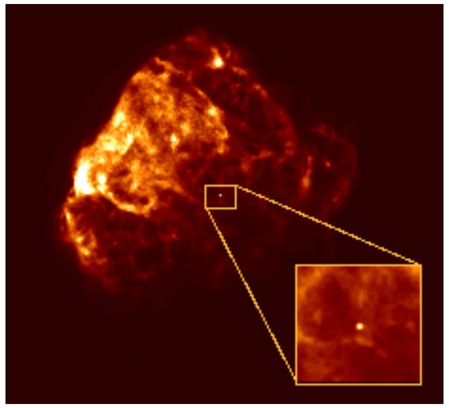
Quark Gluon Plasma

Main goal of ALICE:
Study the properties of the deconfined state of nuclear matter, the Quark Gluon Plasma (QGP)

Ultra relativistic heavy ion collisions, such as Pb-Pb at the LHC, provide the extreme conditions of energy density (temperature) necessary to form the QGP

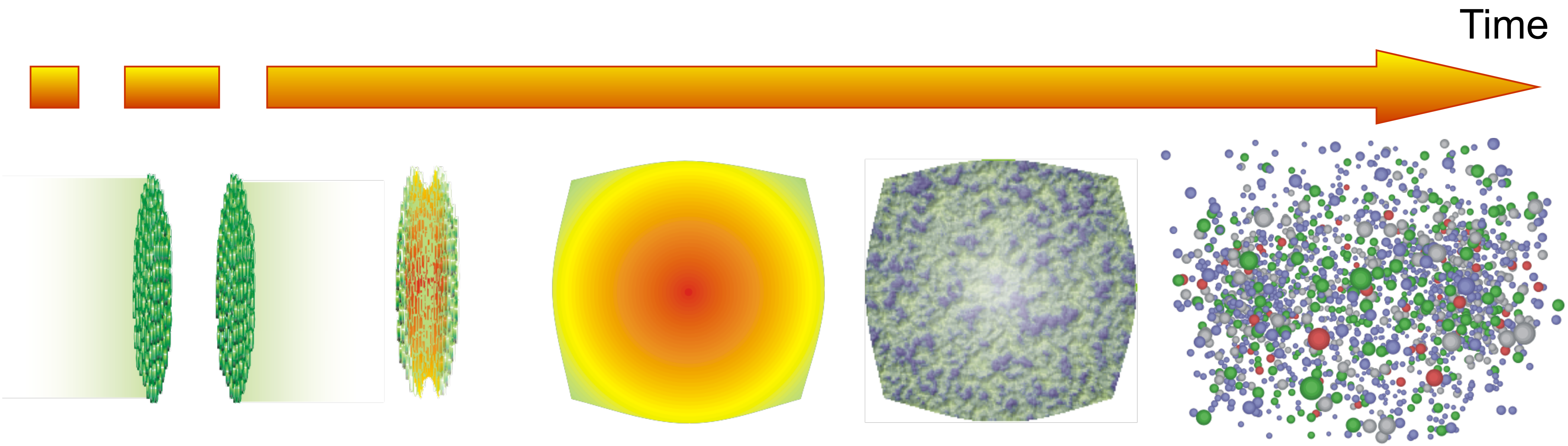






Heavy ion collisions

Heavy ion collisions



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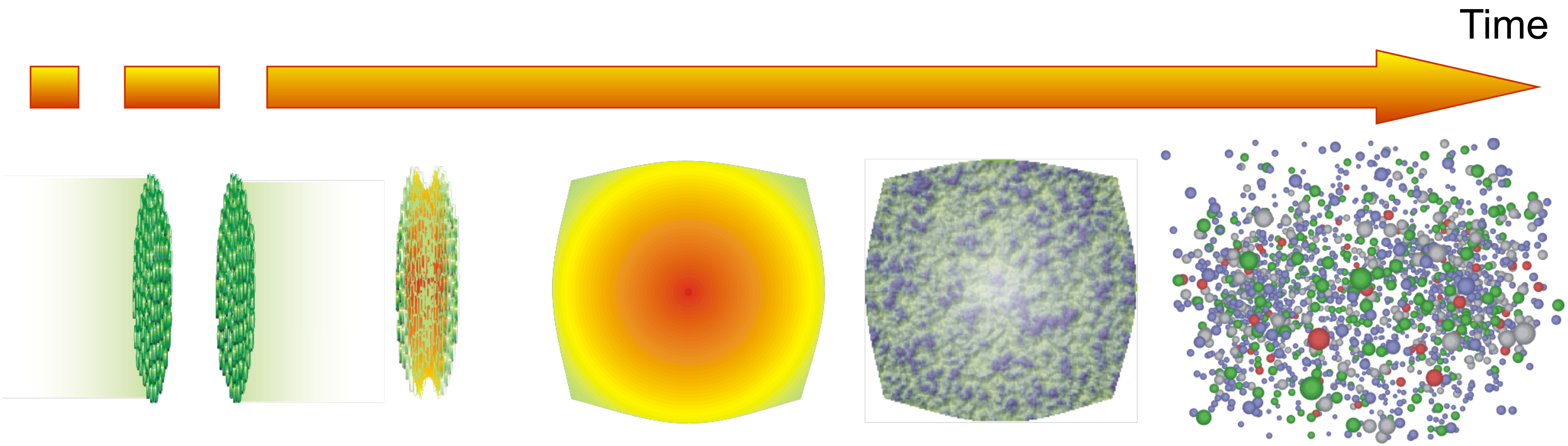
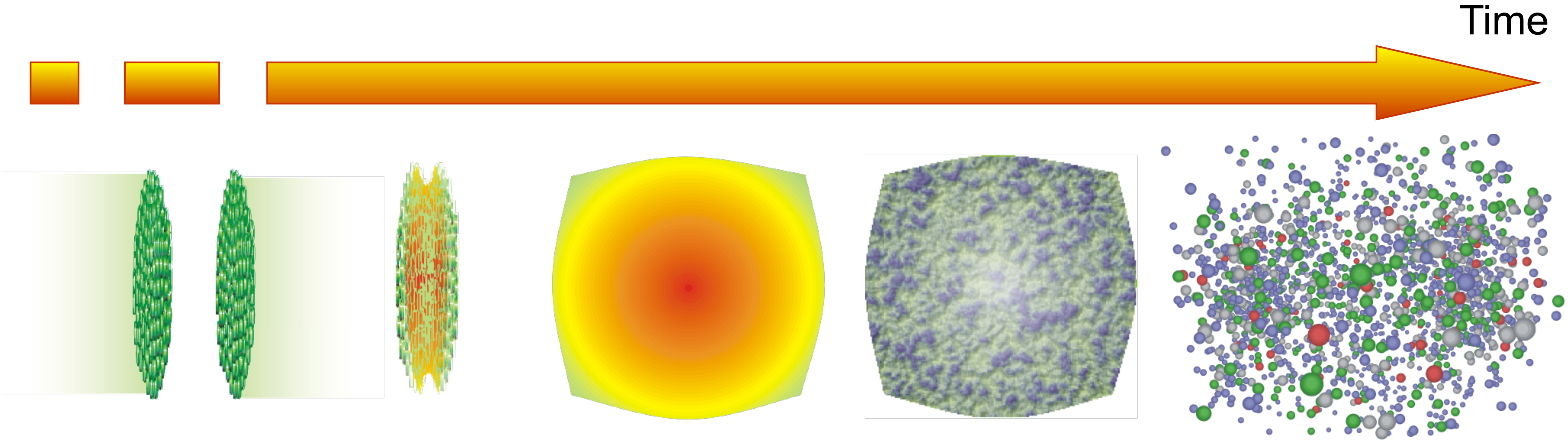


Time

Studies of the created medium

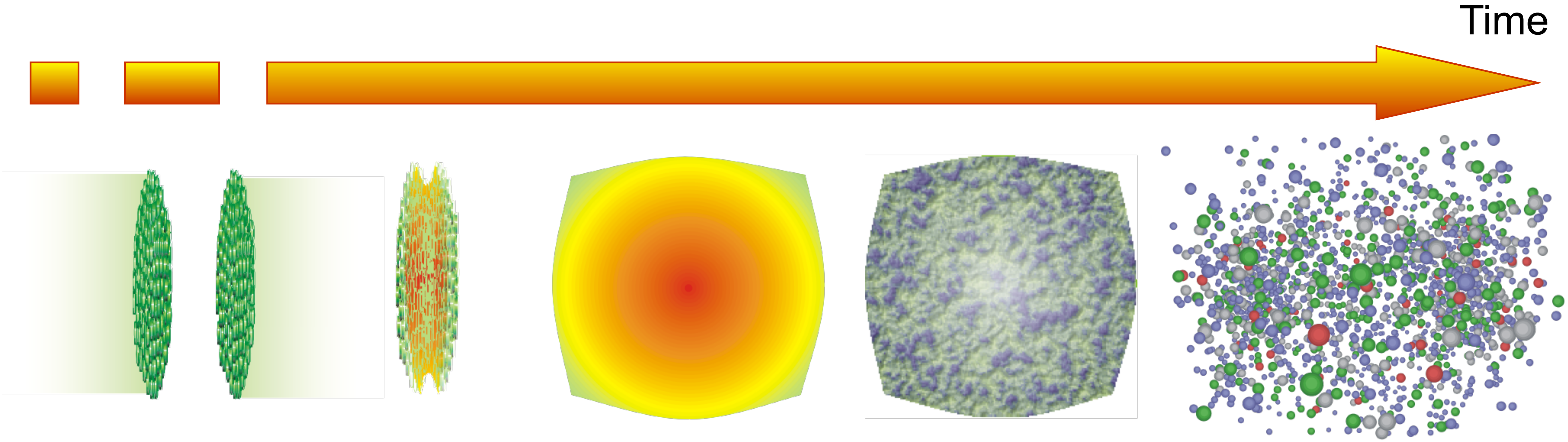
Heavy ion collisions



Studies of the created medium

- Bulk properties
  - How does the medium behave

Heavy ion collisions

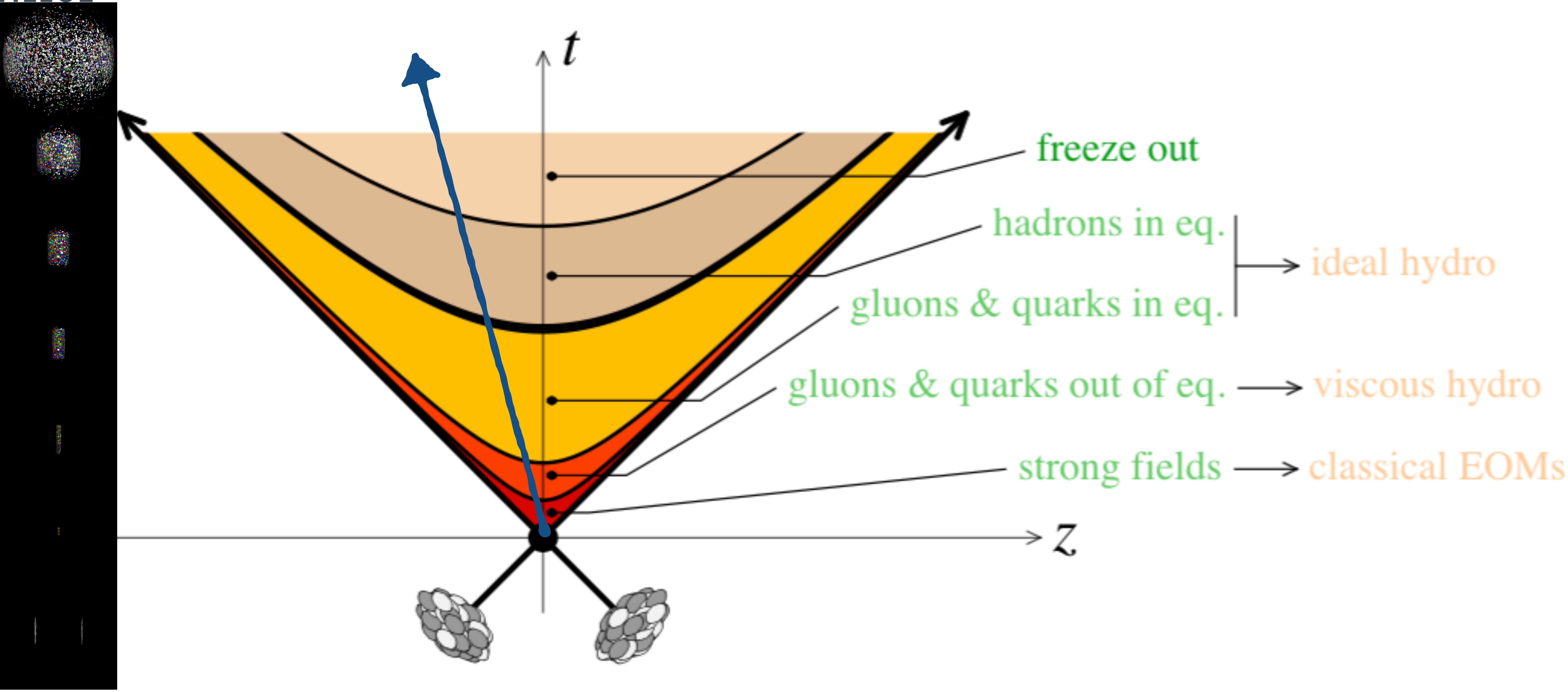


Studies of the created medium

- Bulk properties
  - How does the medium behave

- Probing the medium
  - How does a probe react to the medium

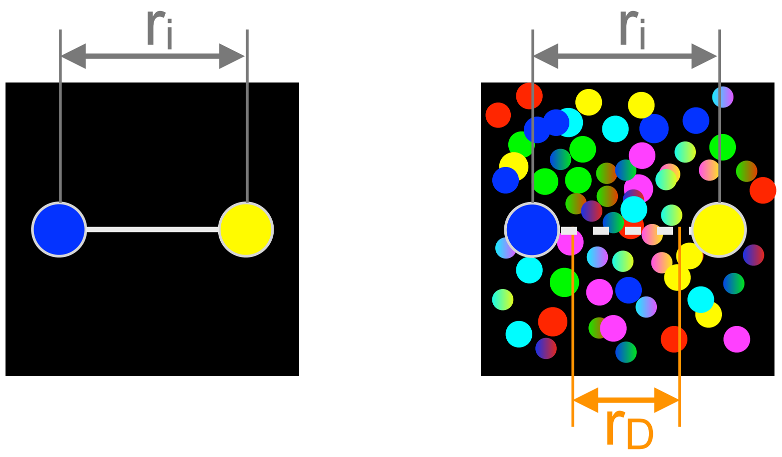
Quarkonia as probes of the QGP



- Quarkonia are important probes of QCD matter
  - Heavy-quark pair production is a perturbative process
  - Their binding is inherently non-perturbative
  - Produced early in the collision
    - Sensitive to the properties of the surrounding medium

Quarkonia and the QGP

- Quarkonium suppression
  - In a QGP, a Q-Qbar pair could be colour-screened by the surrounding coloured quarks and gluons [PLB 178 (1986) 416]
  - Quarkonia should be suppressed by the QGP
  - The suppression increases with the QGP temperature



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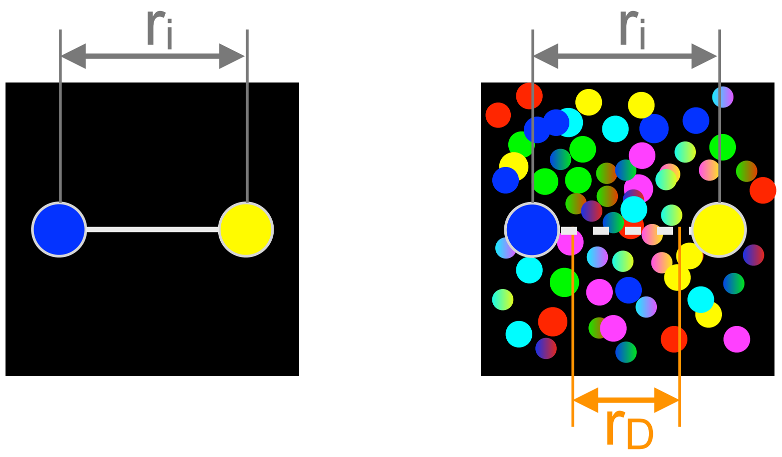
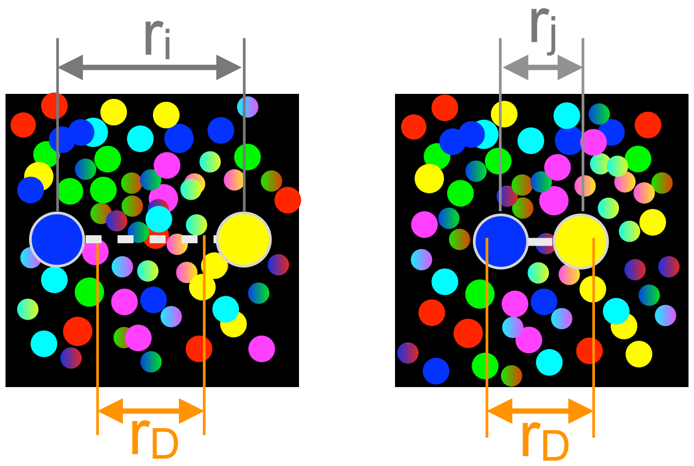
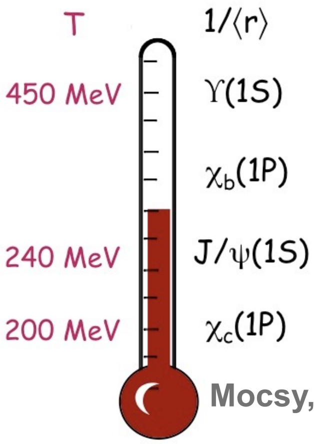


- Sequential suppression
  - The survival probability of the quarkonia depends on its binding energy (or radius) [ZPhysC 51 (1991) 209]
  - Different quarkonium states have different survival probabilities





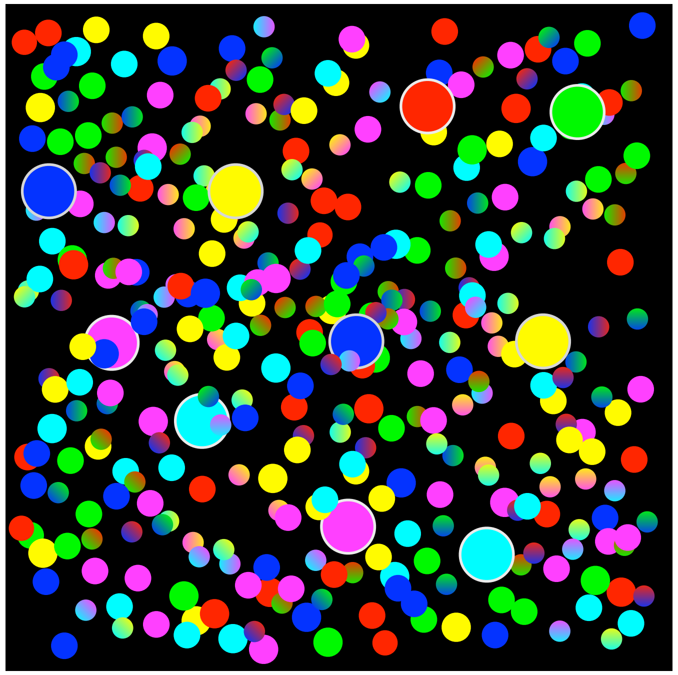
Matsui & Satz, PLB168 (1986) 415

Mocsy, EPJC61 (2009) 705

  - Could provide an estimate of the QGP temperature

Quarkonia and the QGP

- Quarkonium regeneration
  - If the initial number of Q-Qbar pairs is large
  - If heavy quarks thermalise in the QGP
  - Then quarkonia can form at the phase boundary by statistical hadronization [PLB 490 (2000) 196] or during the QGP evolution [PRC 63 (2001) 054905] by heavy quark recombination



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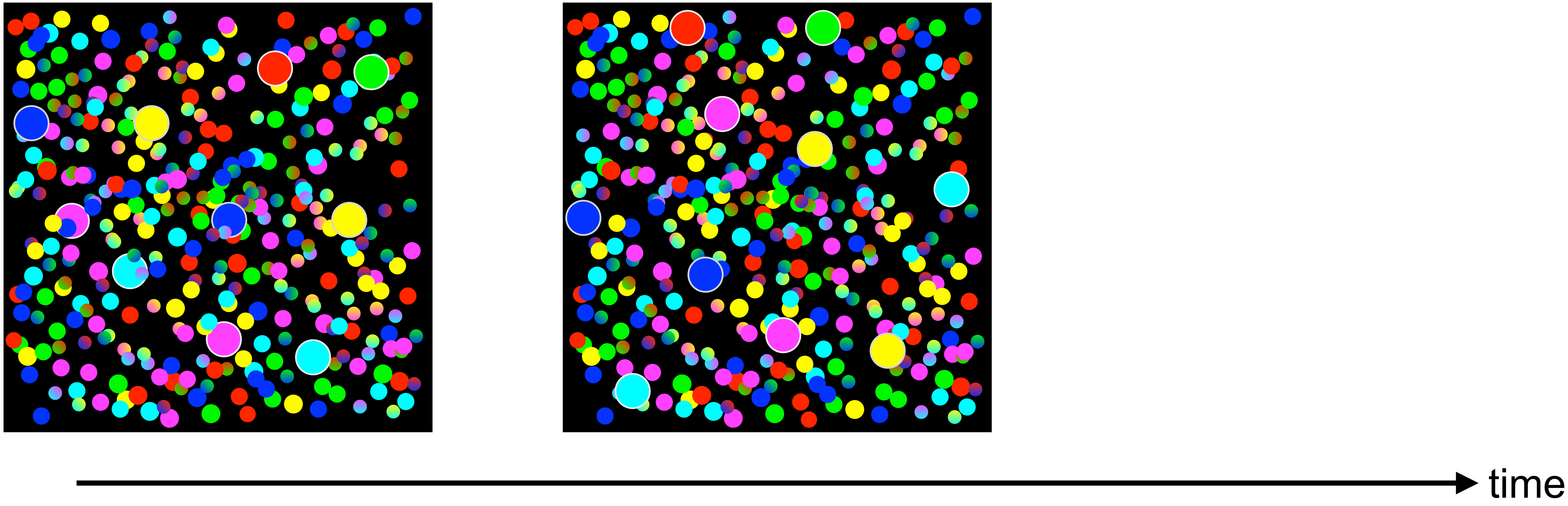

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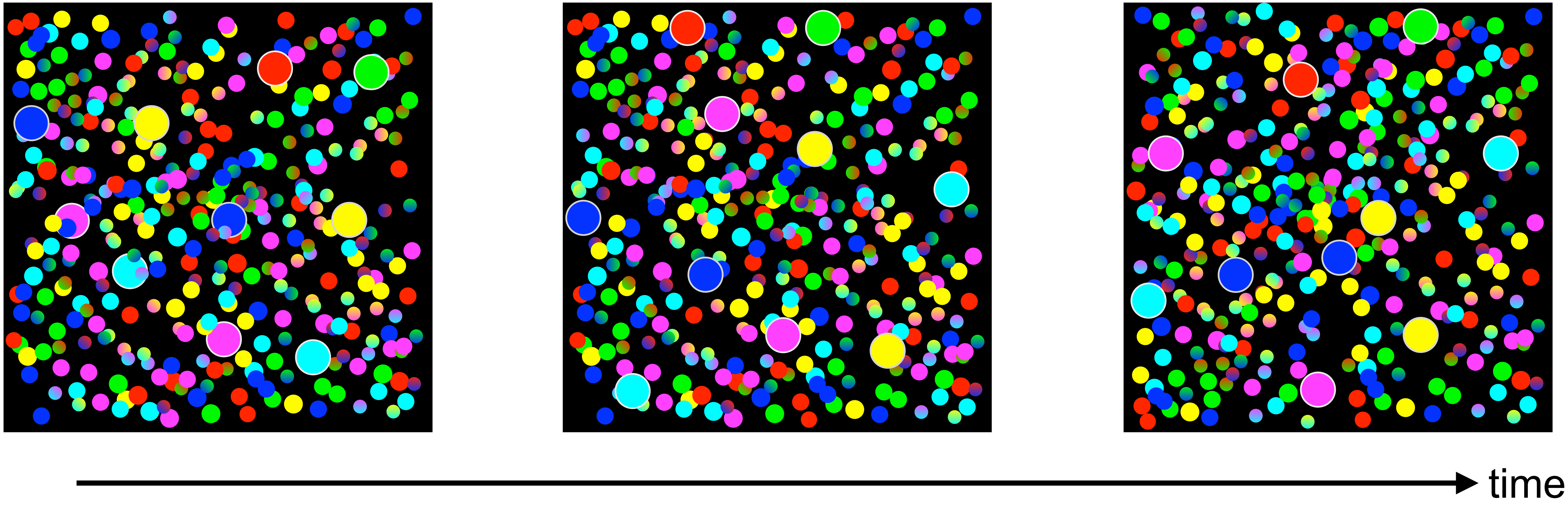

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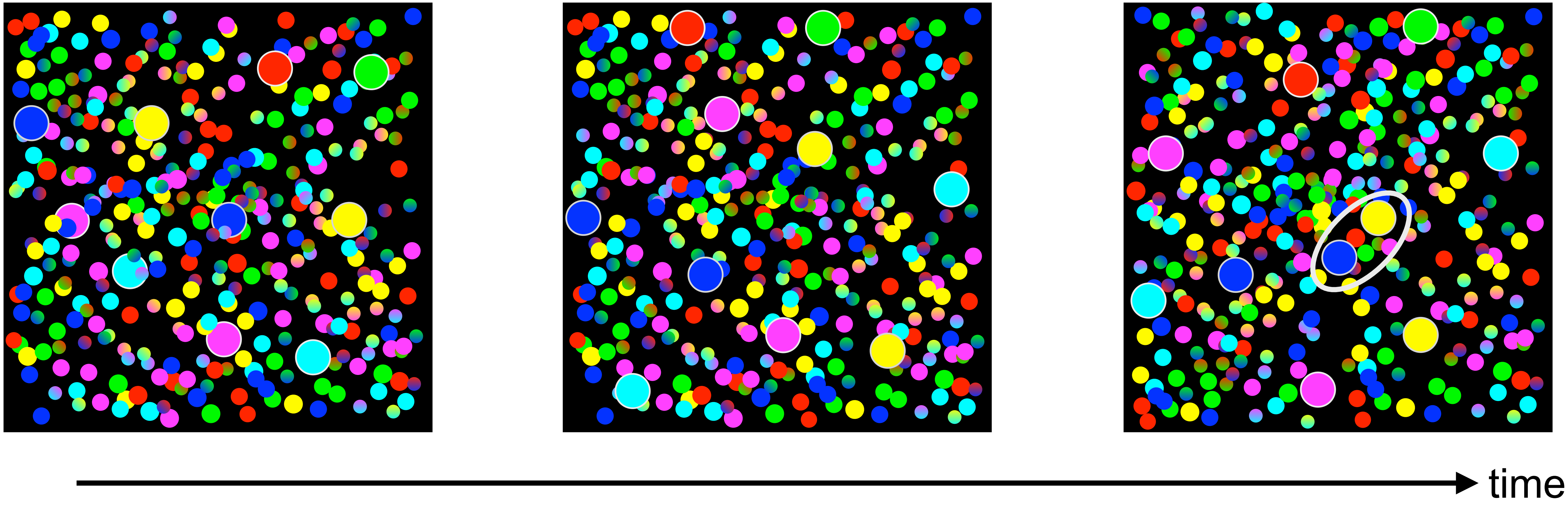
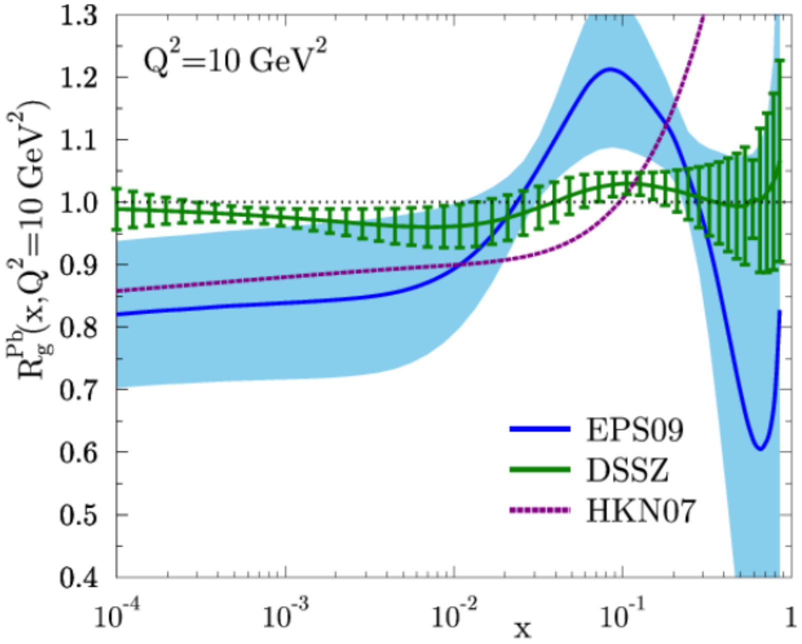


  - Will compete with quarkonium suppression, possibly compensate or even exceed it

Cold Nuclear Matter (CNM) effects

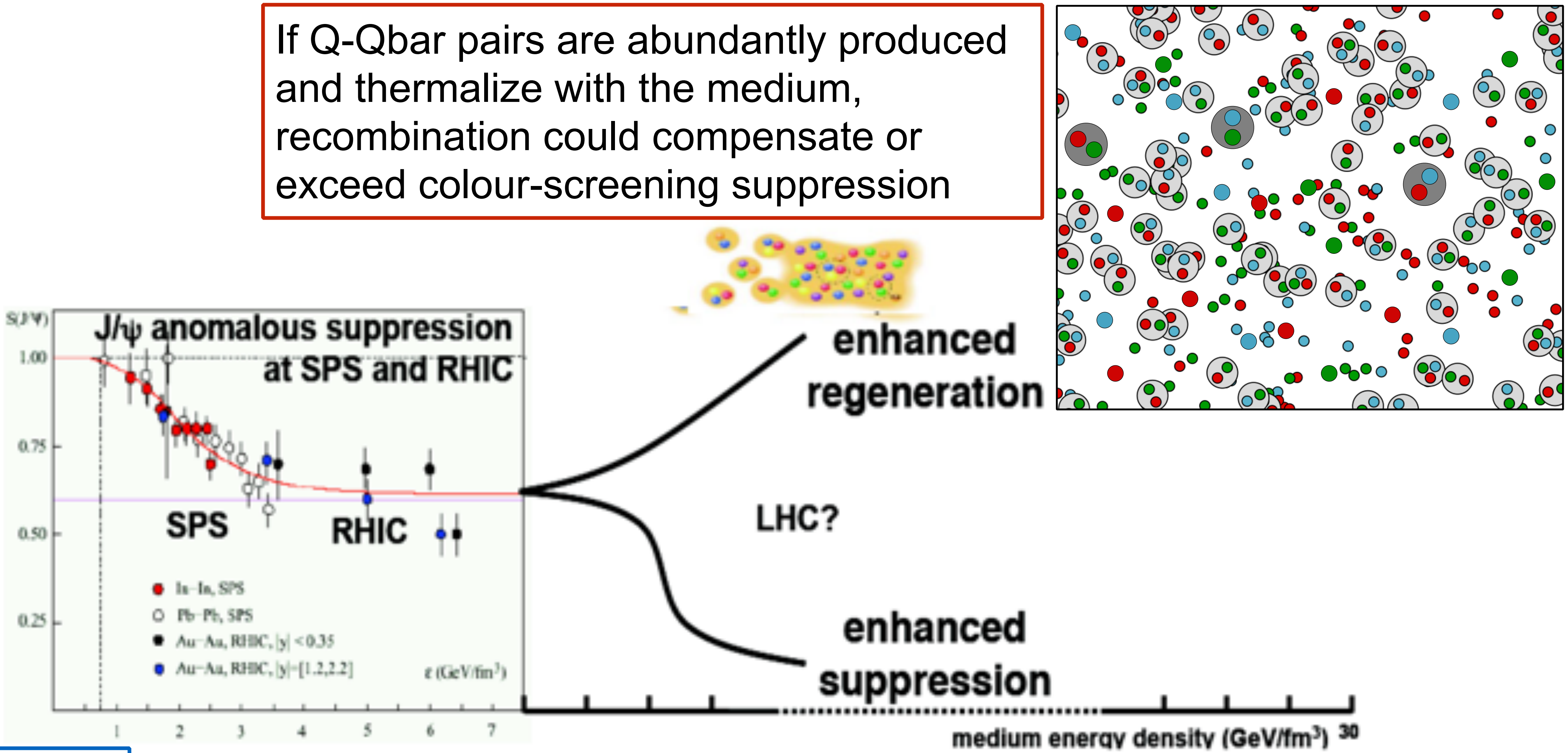
- In Pb-Pb collisions quarkonium production is also affected by Cold Nuclear Matter (CNM) effects
  - Modification of the Parton Distribution Functions in the nuclei with respect to free nucleons
    - Has been parametrised over the past years
    - Significant uncertainties and spread between different approaches



  - Saturation via Colour Glass Condensate (CGC)
  - Energy loss of partons producing the heavy quark pair
    - Latest developments consider coherent parton energy loss
  - Nuclear absorption (heavy-quark pair break-up)
    - Expected to be negligible at LHC energies
- p-A collisions used to study CNM effects in the absence of a hot medium

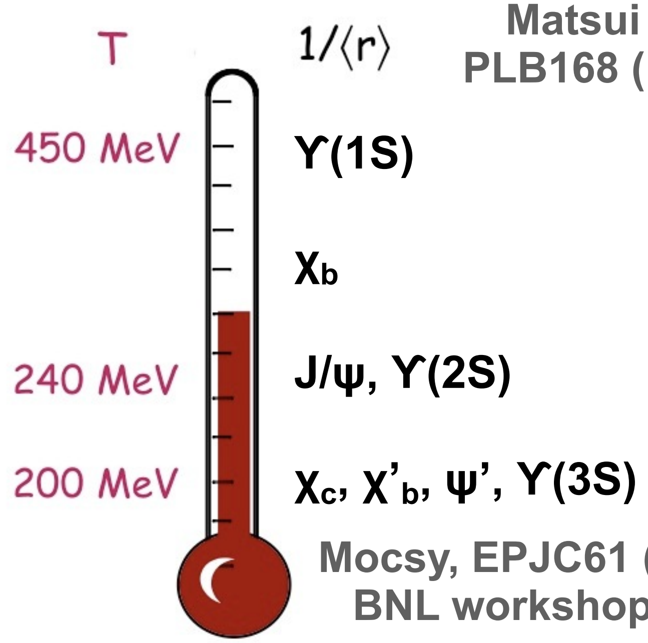
Quarkonia and the QGP – in short

If Q-Qbar pairs are abundantly produced and thermalize with the medium, recombination could compensate or exceed colour-screening suppression



“Cold Nuclear Matter” effects could alter the quarkonium yields: nuclear absorption, gluon shadowing, …

Sequential quarkonium suppression by colour-screening could provide a measurement of the QGP initial temperature



Matsui & Satz, PLB168 (1986) 415

Mocsy, EPJC61 (2009) 705
BNL workshop in June

Bottomonia

- Quarkonium production in heavy-ion collisions are at least affected by
  - Suppression in the QGP
  - Regeneration in the QGP or at phase boundary
  - CNM effects
  - Feed-down from heavy-flavour hadrons decay

- The study of both Bottomonium and Charmonium families in both p-Pb and Pb-Pb collisions help to disentangle the different mechanisms at play

- Bottomonia with respect to Charmonia
  - Less sensitive to regeneration
    - At LHC, about 100 c-cbar pairs and about 5 b-bbar pairs in central Pb-Pb collisions
  - Do not suffer from feed-down of heavy-flavour hadrons decays
  - Probe different kinematic (Bjorken-x) range

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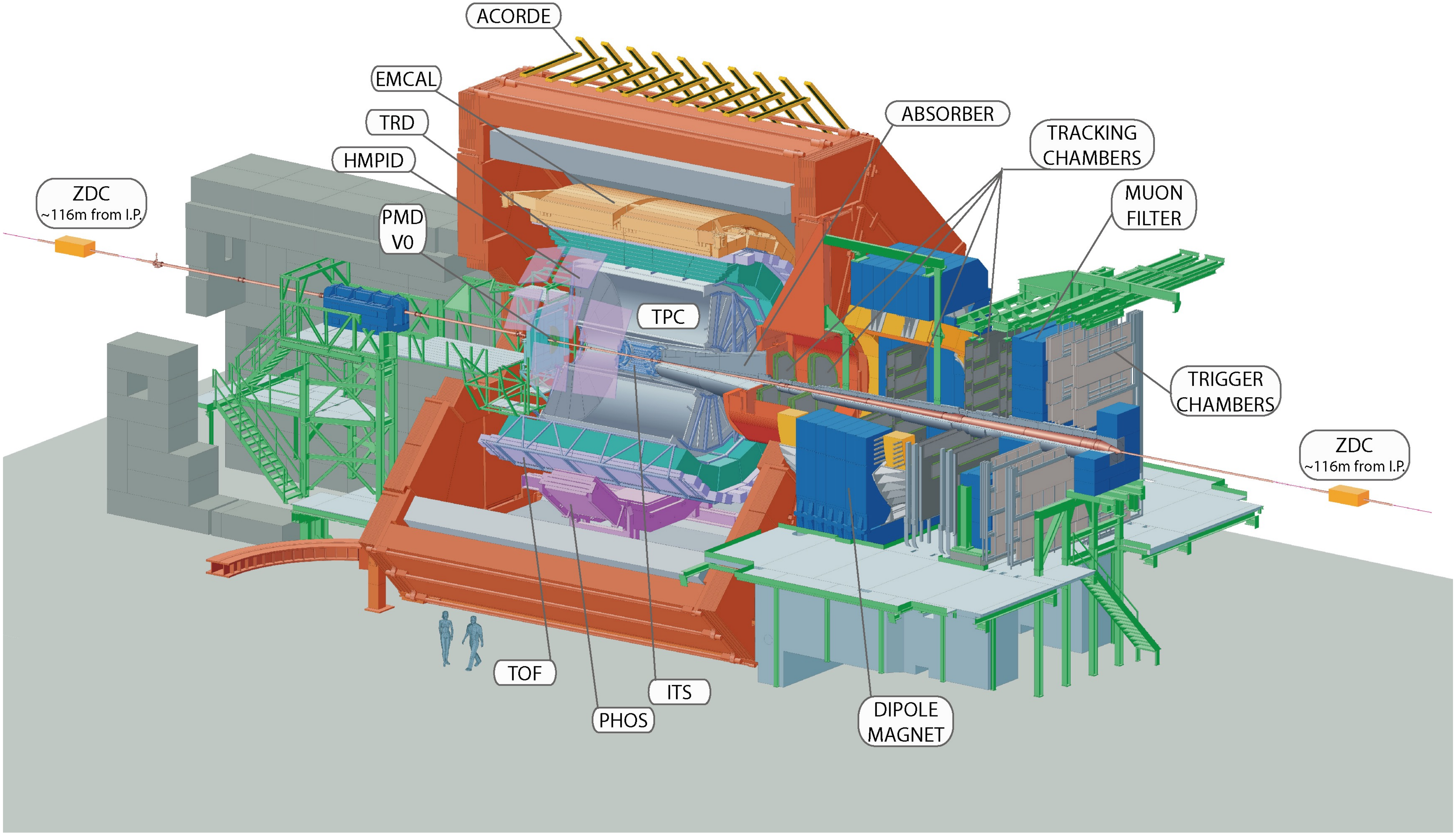
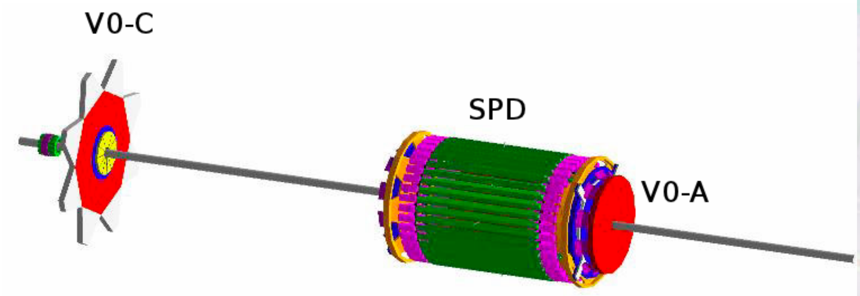
- Theoretically, it is unclear that the same suppression formalism developed for charmonia can be extended to bottomonia

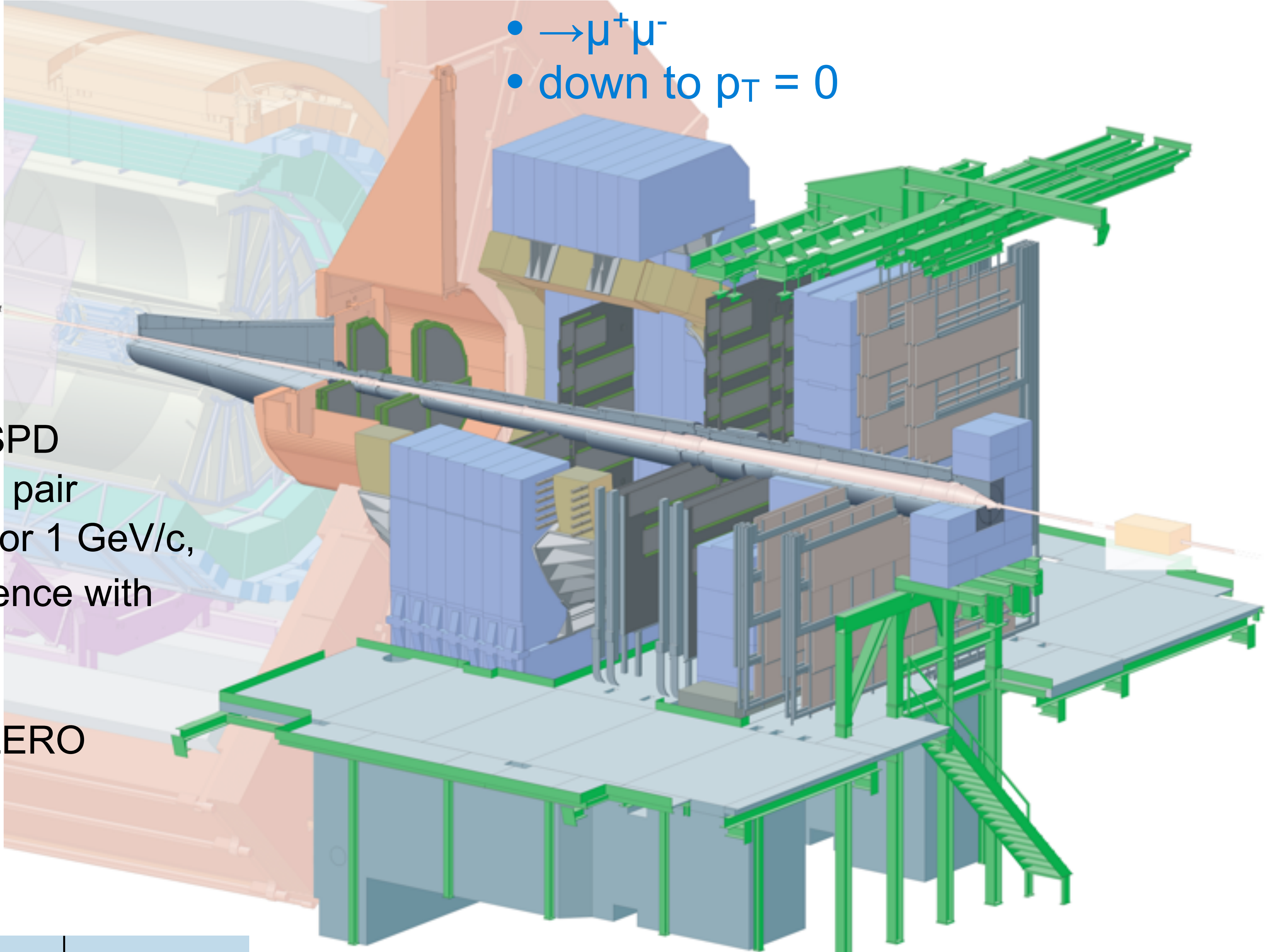
ALICE


ACORDE
EMCAL
TRD
HMPID
ZDC
~116m from I.P.
PMD
V0
TPC
ABSORBER
TRACKING
CHAMBERS
MUON
FILTER
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
ITS
PHOS
DIPOLE
MAGNET

Υ reconstruction in ALICE

Muon spectrometer ($-4.0 < \eta_{lab} < -2.5$)
- Quarkonia
  - $\rightarrow \mu^+\mu^-$
  - down to $p_T = 0$





- Minimum Bias trigger: VZERO and SPD
- Di-muon trigger: opposite-sign muon pair candidate (single muon track $p_T \gtrsim 0.5$ or 1 GeV/c, depending on data sample) in coincidence with MB trigger
- Vertex determination: SPD
- Centrality in Pb-Pb: Glauber fit to VZERO signal amplitude

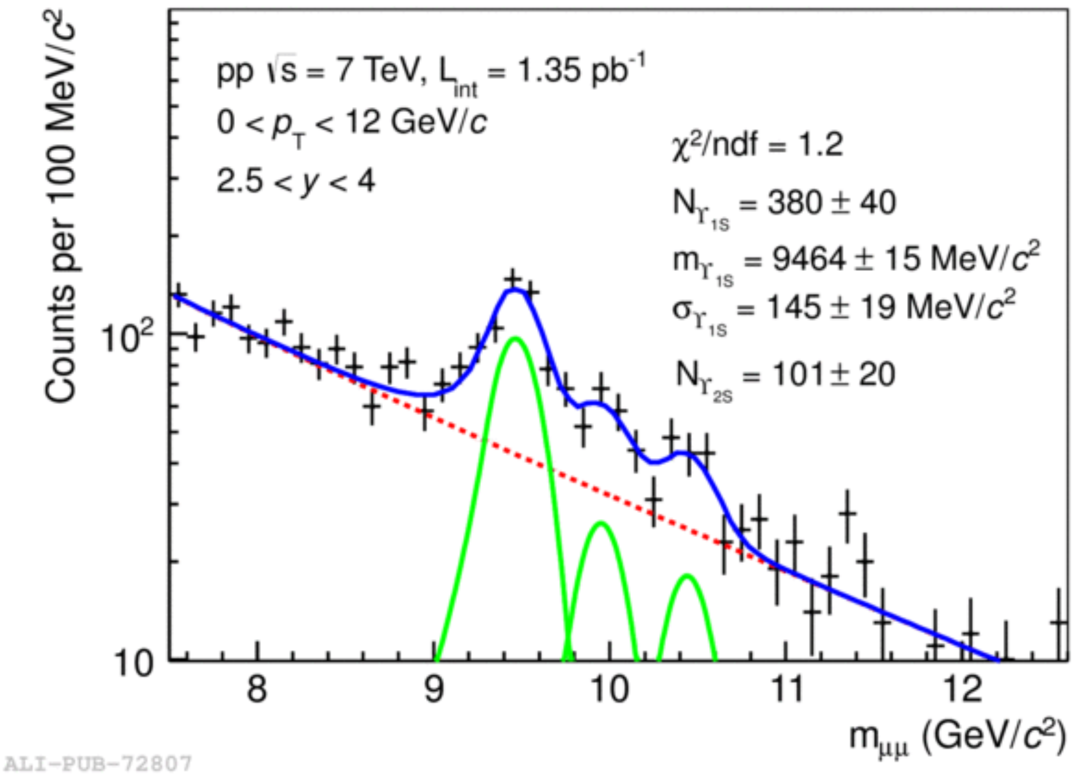
Data sets

System	pp	Pb-Pb	Pb-p	p-Pb
$\sqrt{s_{NN}}$	7 TeV	2.76 TeV	5.02 TeV	5.02 TeV
Int. Luminosity	1.35 pb^{-1}	69 μb^{-1}	5.8 nb^{-1}	5.0 nb^{-1}

- Absorbers (front, conical, filter)
- Dipole magnet
- Tracking chambers
- Trigger system

Υ analyses

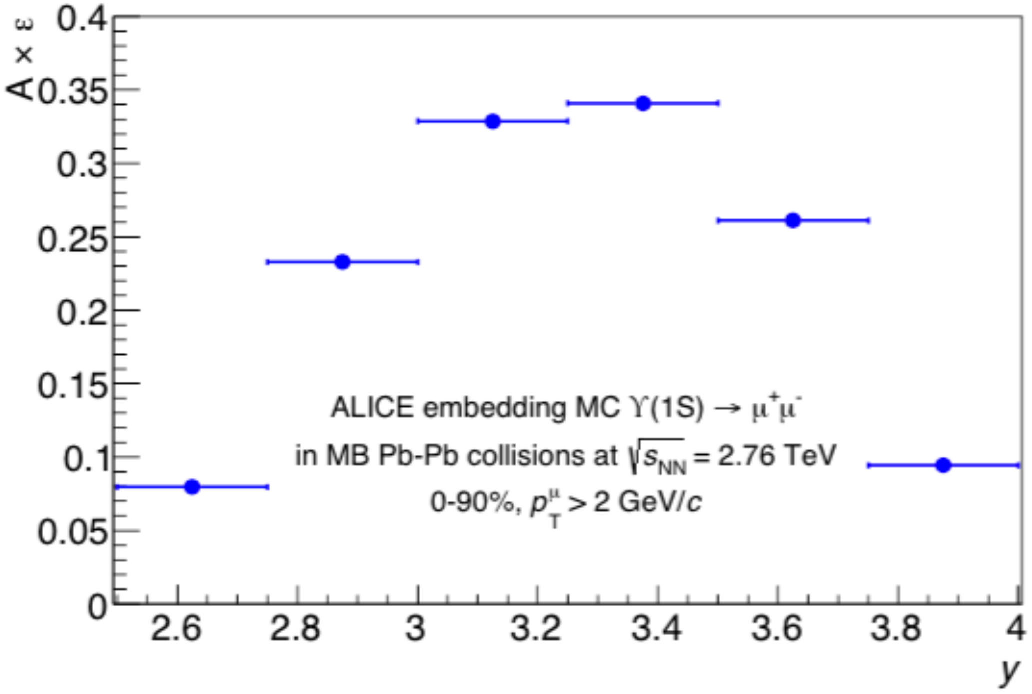
- Build the invariant mass distribution of opposite sign muon tracks
  - matching with tracklets in the muon trigger system
    - removes hadrons escaping the front absorber and low momentum muons (π & K decays)
  - $-4 < \eta_{\mu} < -2.5$
  - $17.6 < R_{abs} < 89$ cm (R_{abs} = track radial position at the absorber end)
  - $2.5 < y^{\mu\mu}_{lab} < 4$

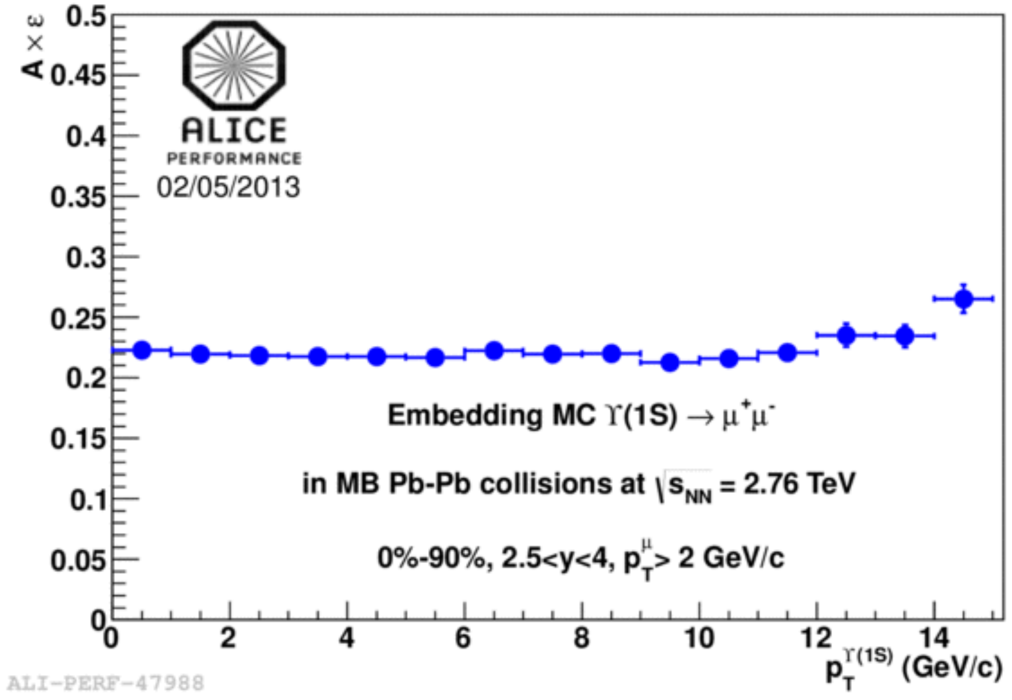


- Signal extraction
  - Fit to the invariant mass distribution with a combination of signal and background shapes
  - Signal: extended Crystal-Ball function
    - Gaussian core with two independent power-law tails at low and high mass
  - Background: double exponential, double power-law, variable width Gaussian

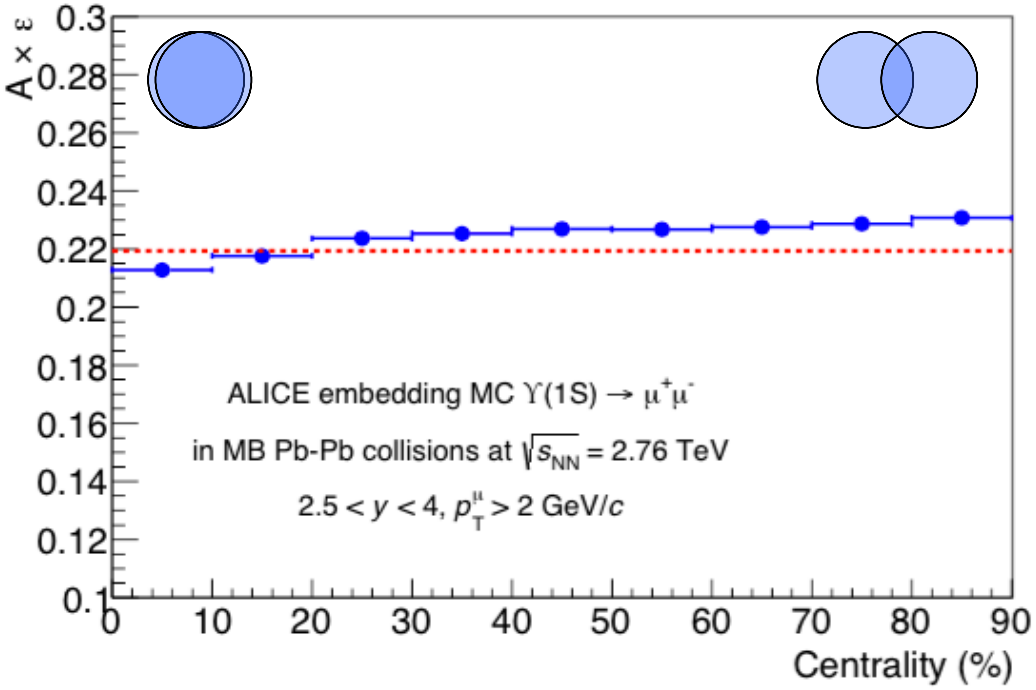
ϒ Acceptance x Efficiency

- Acceptance x Efficiency
  - Use either embedding (Pb-Pb) or pure simulations (pp and p-Pb) with time-dependent status of the spectrometer

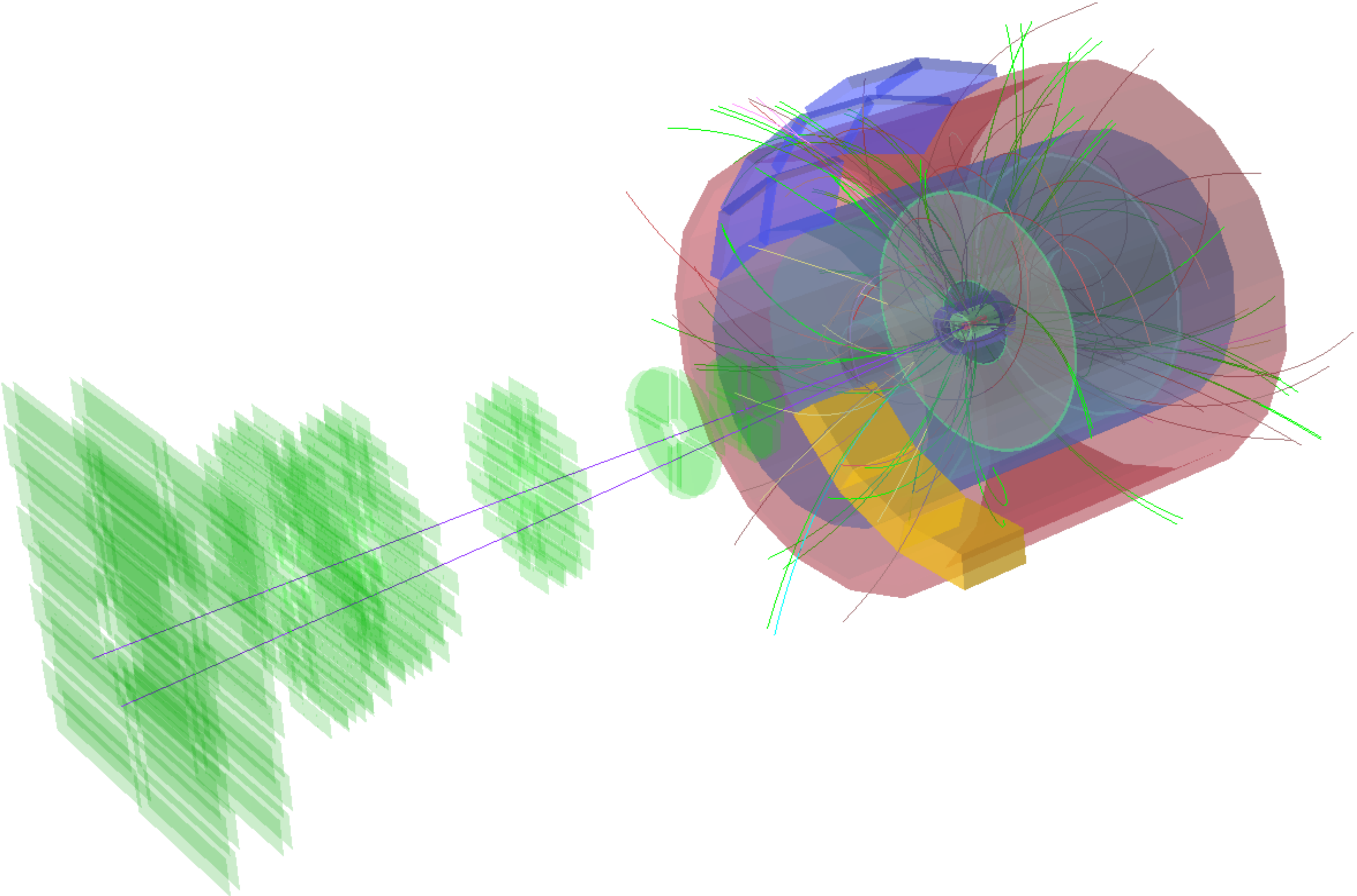




- Slight drop of efficiency from peripheral to central collisions due to increase of detector occupancy



pp collisions at √s = 7 TeV

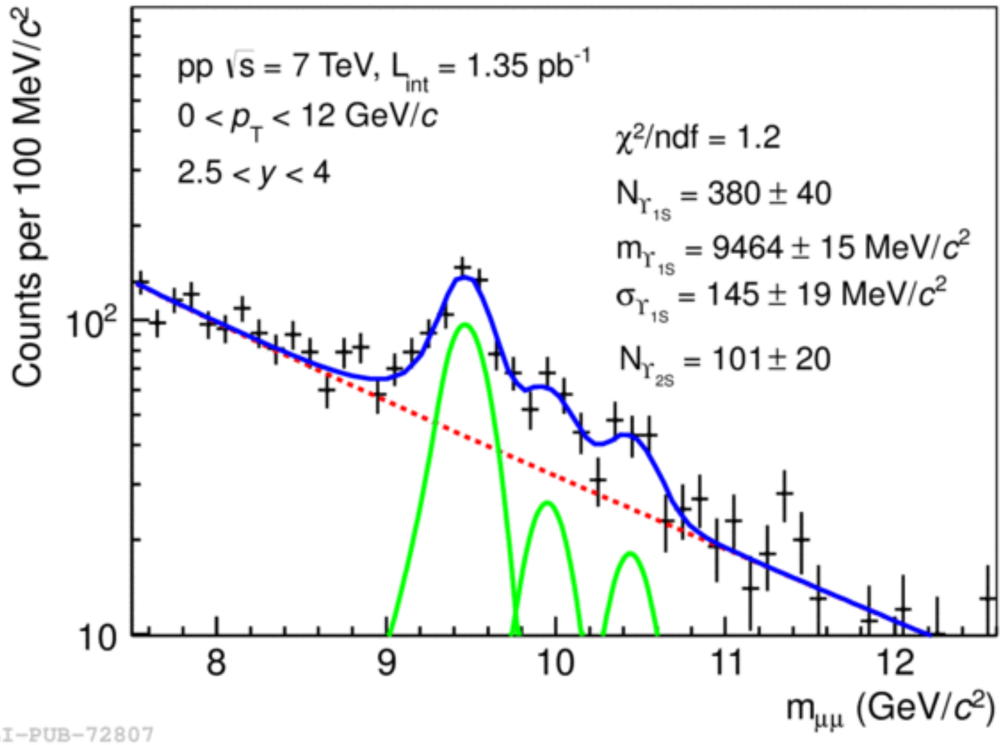


pp collisions at 7 TeV

pp @ 7 TeV

EPJC 74 (2014) 2974

- Υ(1S) and Υ(2S) cross section
- Υ(1S) cross section vs p_T and rapidity
- Good agreement ALICE - LHCb for both Υ(1S) and Υ(2S)
- Fraction of Υ(1S) from Υ(2S) decays is
  - $f^{\Upsilon(1S)} = 0.090 \pm 0.027 \pm 0.005$



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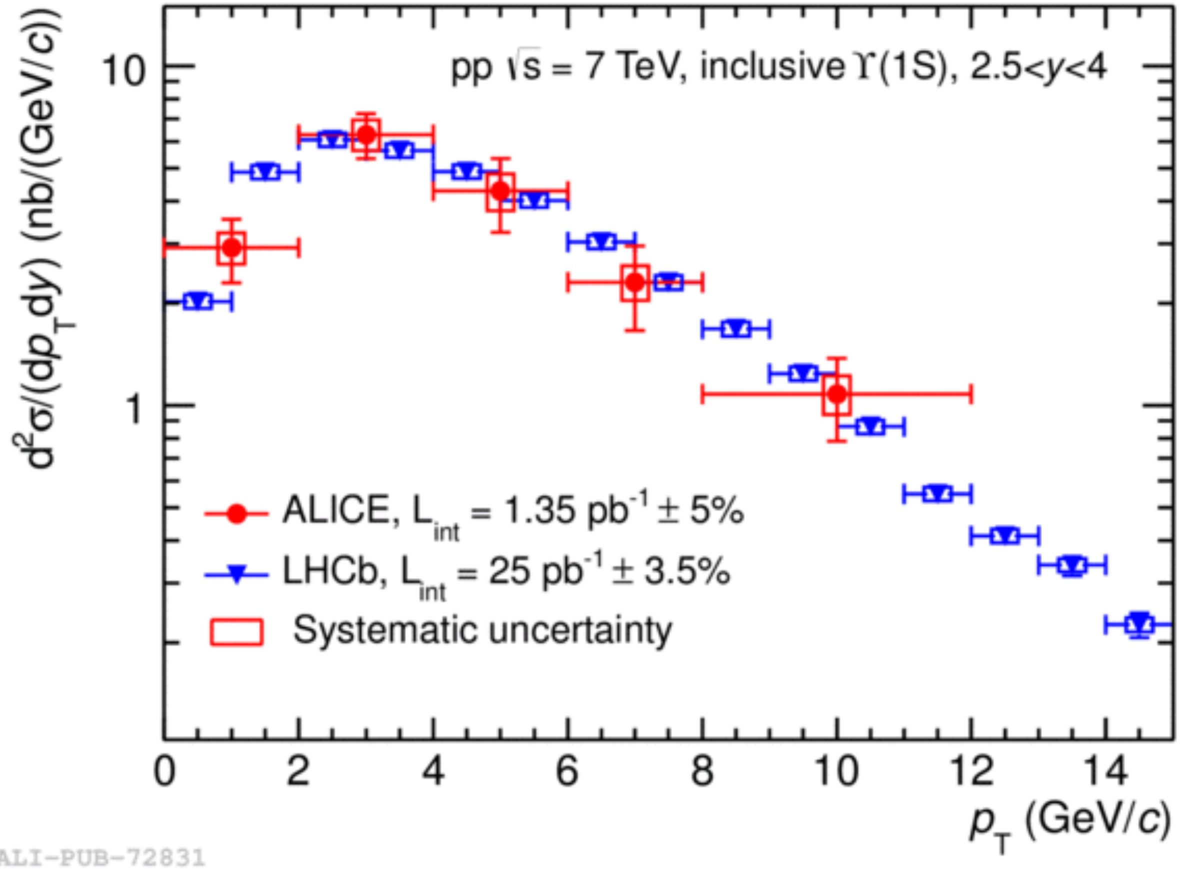

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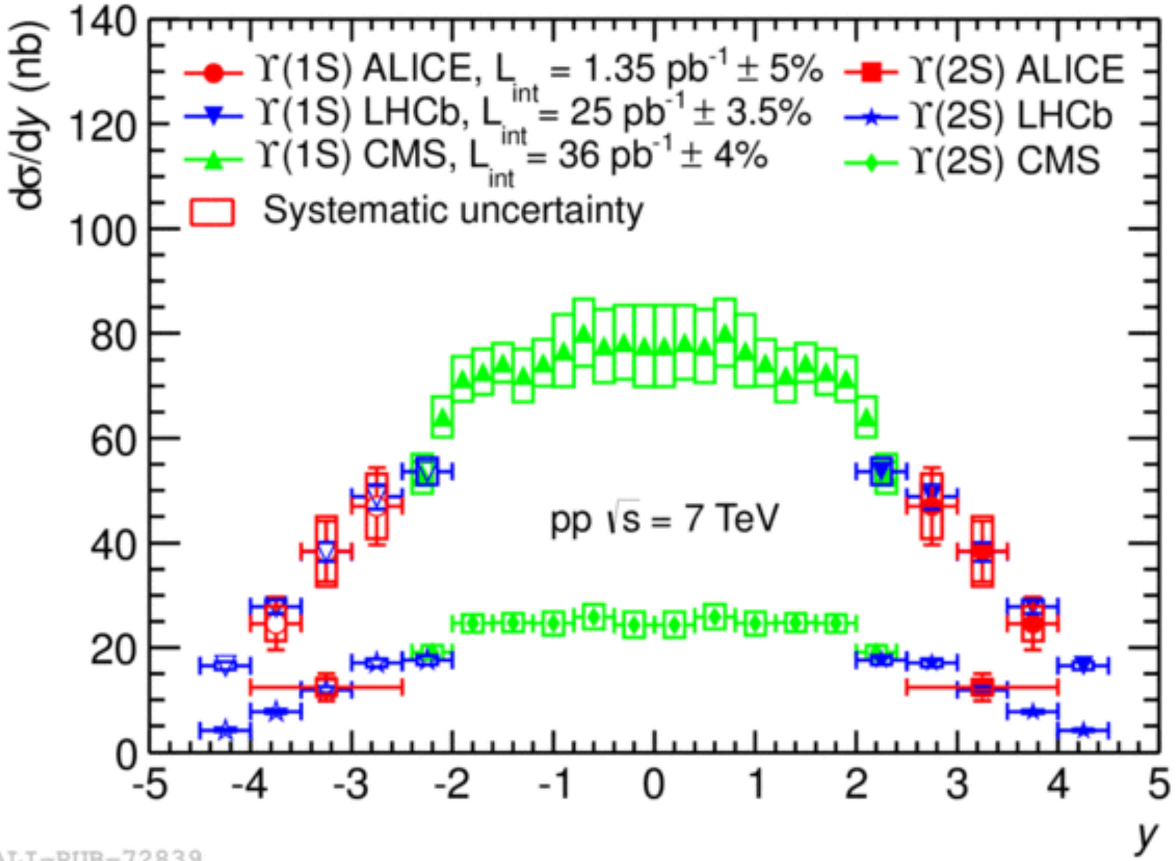

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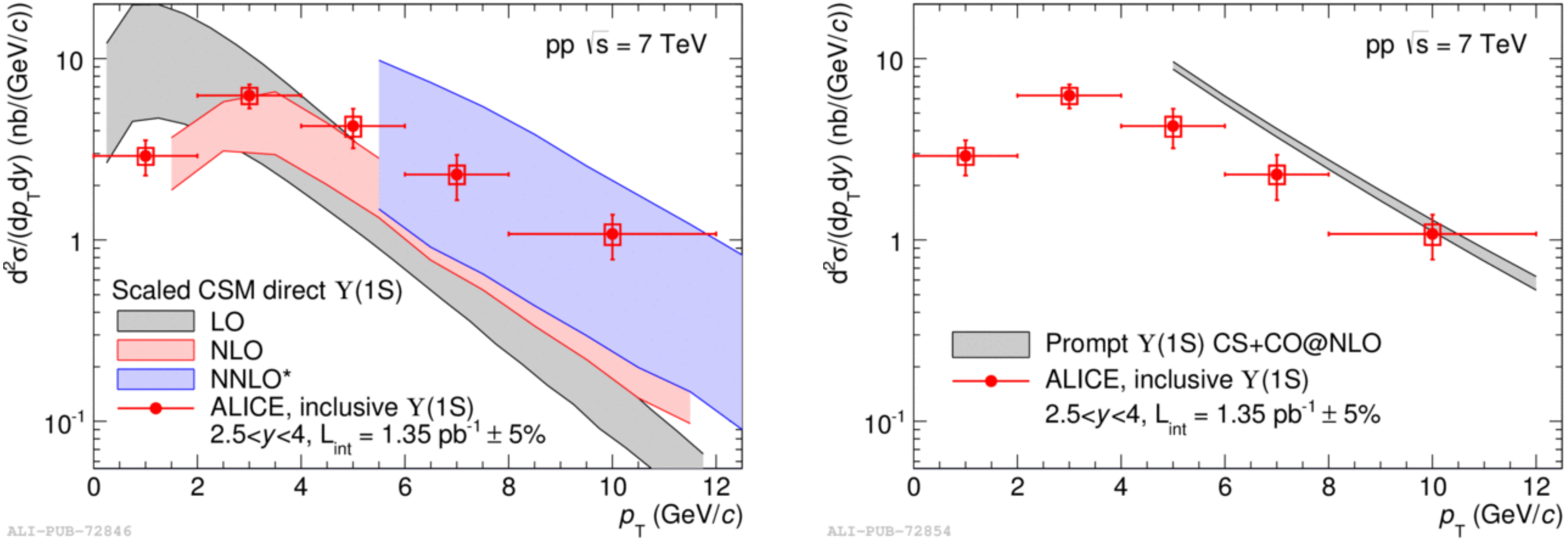
Model comparison

EPJC 74 (2014) 2974

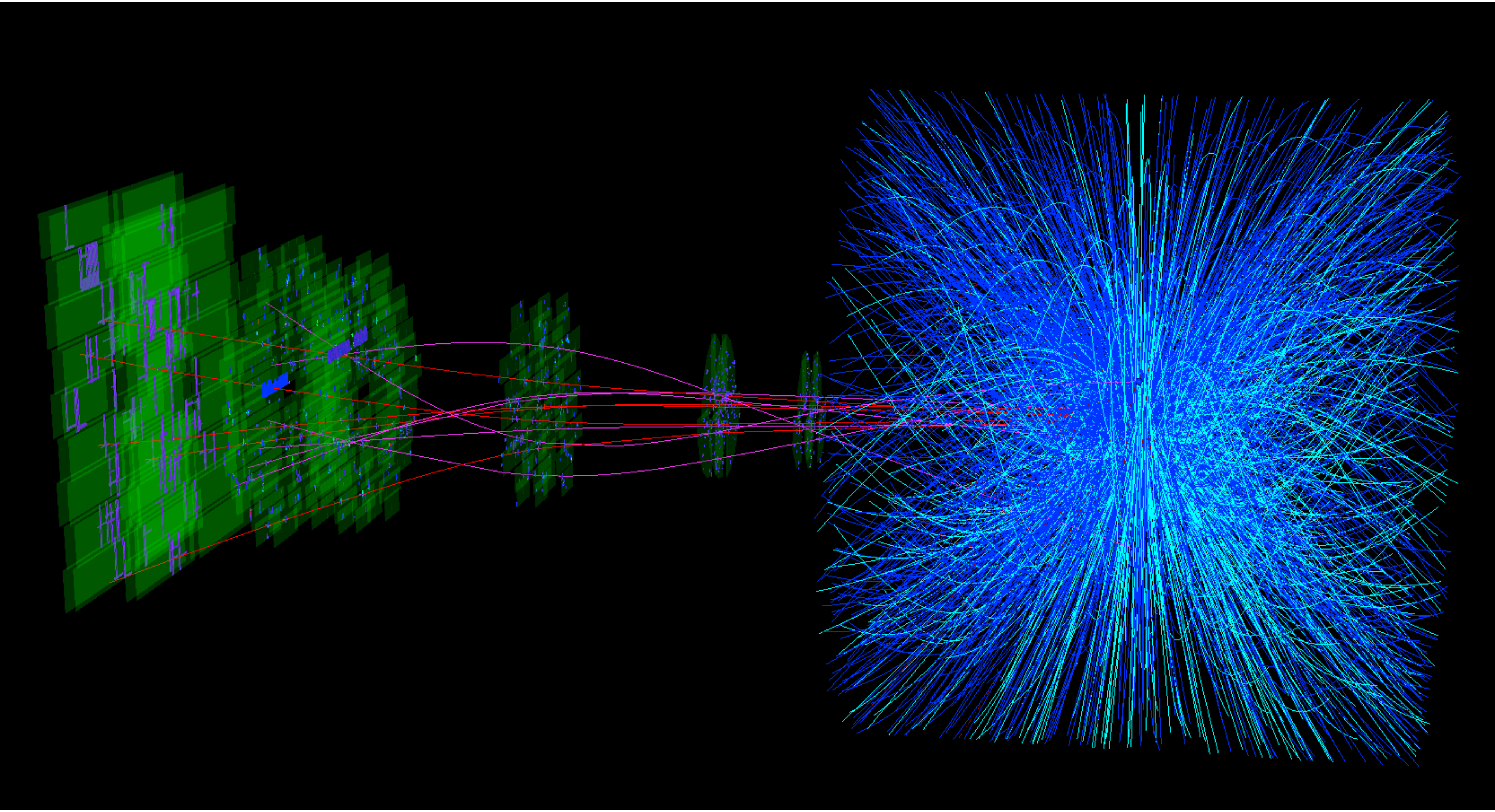


- Color Singlet Model [NPA470 (2013) 910]
  - At Leading Order (LO)
    - Qualitatively describes the data at low p_T and the rapidity dependence (not shown)
    - Underestimates the data at high p_T
  - Addition of the leading-p_T NNLO contributions
    - Helps to improve the situation at high p_T

- Non-Relativistic QCD [PRD84 (2011) 114001]
  - Matrix elements fixed to data sets from Tevatron, RHIC and LHC
    - Good agreement at high p_T

- Similar conclusions reached with other quarkonia (but η_c).
- No consensus yet on quarkonium production mechanism in pp collisions

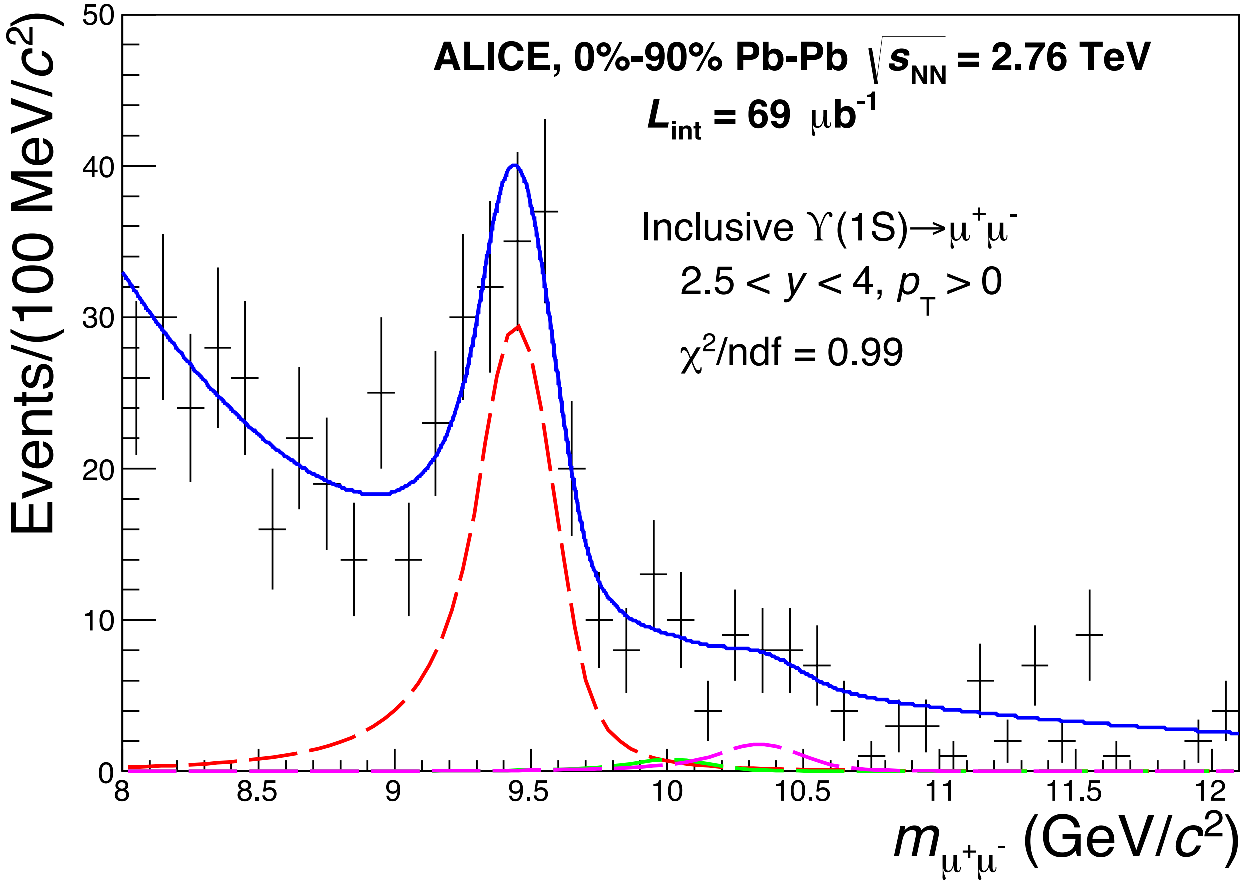
Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV



Pb-Pb collisions

PLB 738 (2014) 361

- Υ(1S) production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



- Suppression of Υ(1S) production in Pb-Pb collisions can be measured by the nuclear modification factor

$$R_{AA} = \frac{Y^{\Upsilon}}{\langle T_{AA}\rangle \times \sigma^{\Upsilon}_{pp}}$$

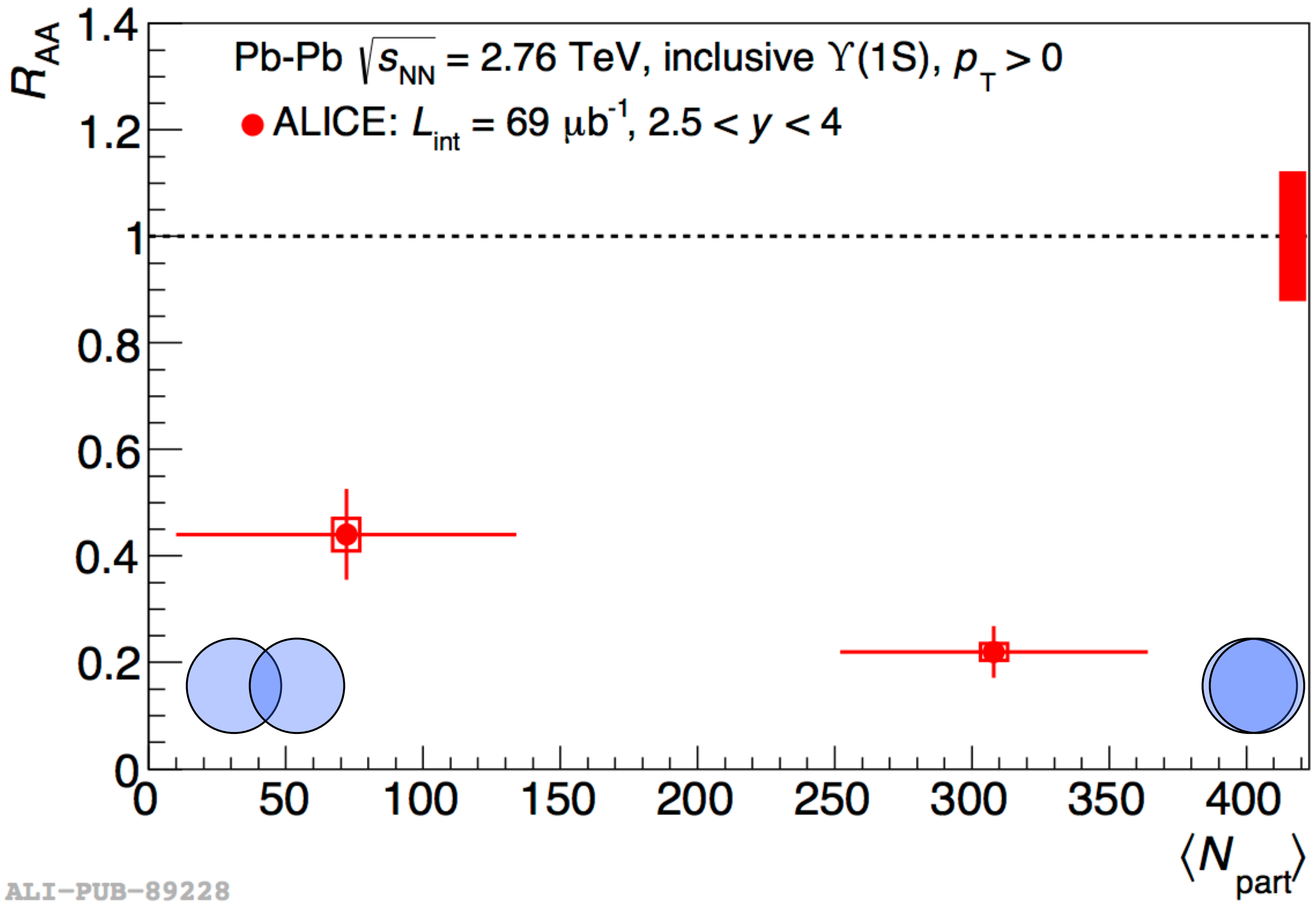
- To calculate the nuclear modification factor we now use the Υ(1S) cross section measured by LHCb in pp collisions at 2.76 TeV [EPJC74 2835 (2014)]

Inclusive Υ(1S) nuclear modification factor

PbPb @ 2.76 TeV

PLB 738 (2014) 361

- R_{AA} of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV



Uncertainties:

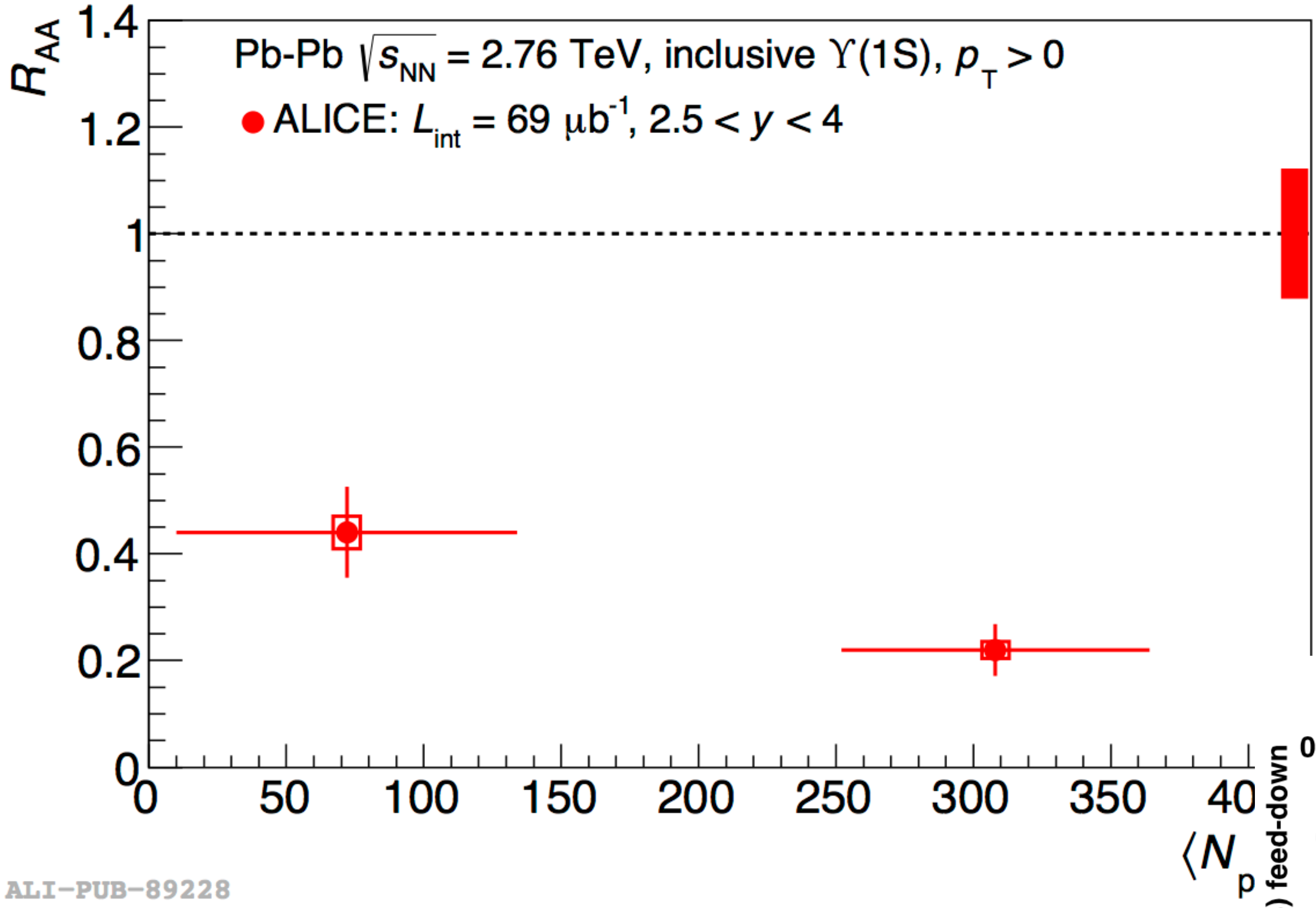
- Bars: Statistical
- Open boxes: Uncorrelated systematic
- Full box: Correlated systematic

- Strong suppression of inclusive Υ(1S)
  - Centrality 0% – 90%; $p_T > 0$; $2.5 < y < 4.0$:
    - $R_{AA} = 0.304 \pm 0.047(\text{stat}) \pm 0.042(\text{syst})$
  - Stronger suppression in more central collisions

Inclusive Υ(1S) nuclear modification factor

PLB 738 (2014) 361

- R_{AA} of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

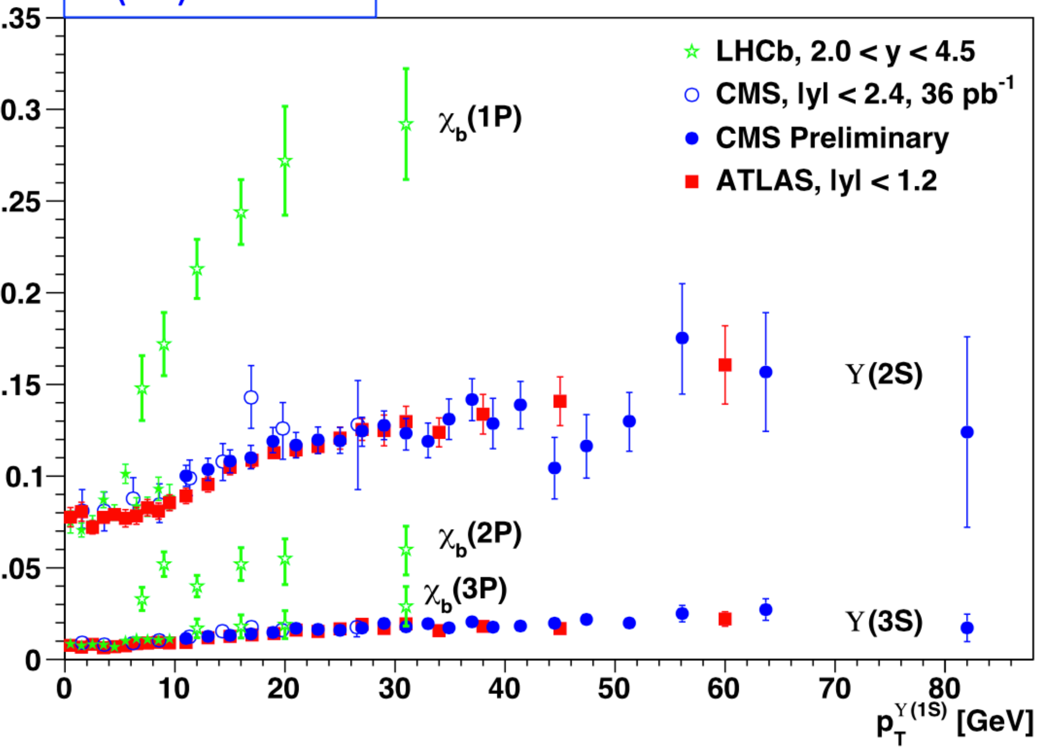


ALI-PUB-89228

Uncertainties:
- Bars: Statistical
- Open boxes: Uncorrelated systematic
- Full box: Correlated systematic

Υ(1S) from all

H. Wöhri @ Quarkonium 2014



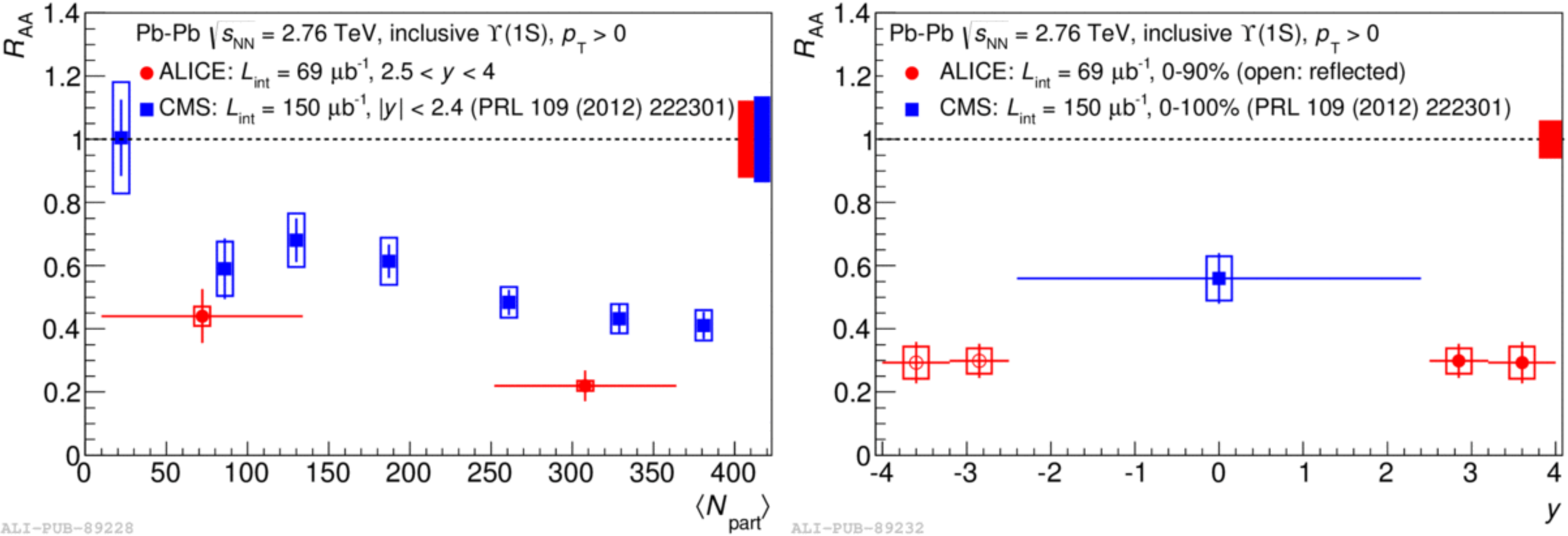
- Strong suppression of inclusive Υ(1S)
  - Centrality 0% – 90%; $p_T > 0$; 2.5 < y < 4.0:
    - R_{AA} = 0.304 ± 0.047(stat) ± 0.042(syst)
  - Stronger suppression in more central collisions
  - Contribution from feed-down?
    - At most 30% suppression. And the rest?

Comparison with mid-rapidity measurement

PbPb @ 2.76 TeV

PLB 738 (2014) 361

- Mid-rapidity measurement from CMS Collaboration [PRL 109 (2012) 222301]



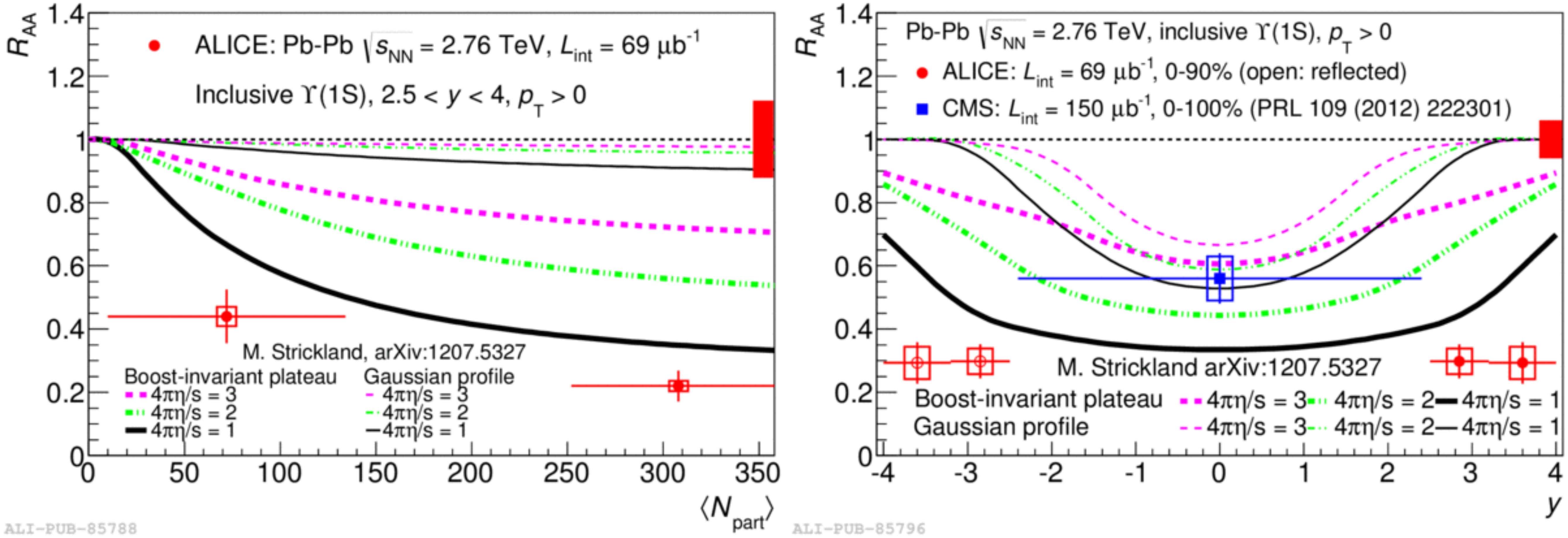
- Stronger suppression at forward rapidity than at mid rapidity
  - – Unexpected in a scenario with only suppression by the QGP since a smaller or similar energy density is expected at forward than at mid rapidity
  - – Role of regeneration?
  - – Role of CNM effetcs?

Comparison with models – Dynamical

PbPb @ 2.76 TeV

PLB 738 (2014) 361

- R_{AA} of inclusive ϒ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



- M. Strickland, [arXiv:1207.5327]
  - Thermal suppression of bottomonium states
  - Anisotropic hydro model
  - Two temperature rapidity profiles: Boost invariant or Gaussian
  - Three tested shear viscosities
  - Feed down from higher mass states included
  - No CNM effects included
  - No regeneration included

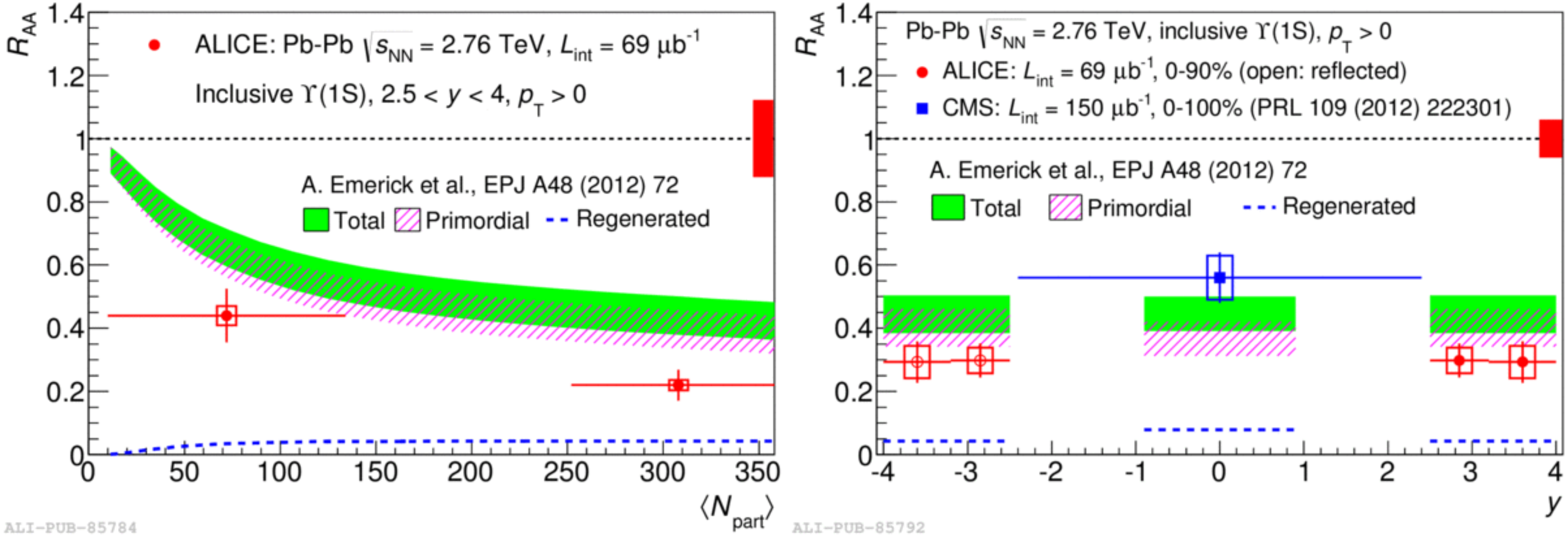
In all cases the model underestimates the measured ϒ(1S) suppression at forward rapidity

Comparison with models – Transport

PbPb @ 2.76 TeV

PLB 738 (2014) 361

- R_{AA} of inclusive ϒ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



- A. Emerick et al., [EPJ A48 (2012) 72]
  - – Transport model
  - – Suppression of ϒ resonances by the QGP
    - Mainly of the higher mass states
  - – Small regeneration component included
  - – Feed down from higher mass states included
  - – CNM included via an “effective” σ_{ABS} = 0–2 mb

Model does not reproduce the strong rapidity dependence of the R_{AA} and underestimates the ϒ(1S) suppression at forward rapidity

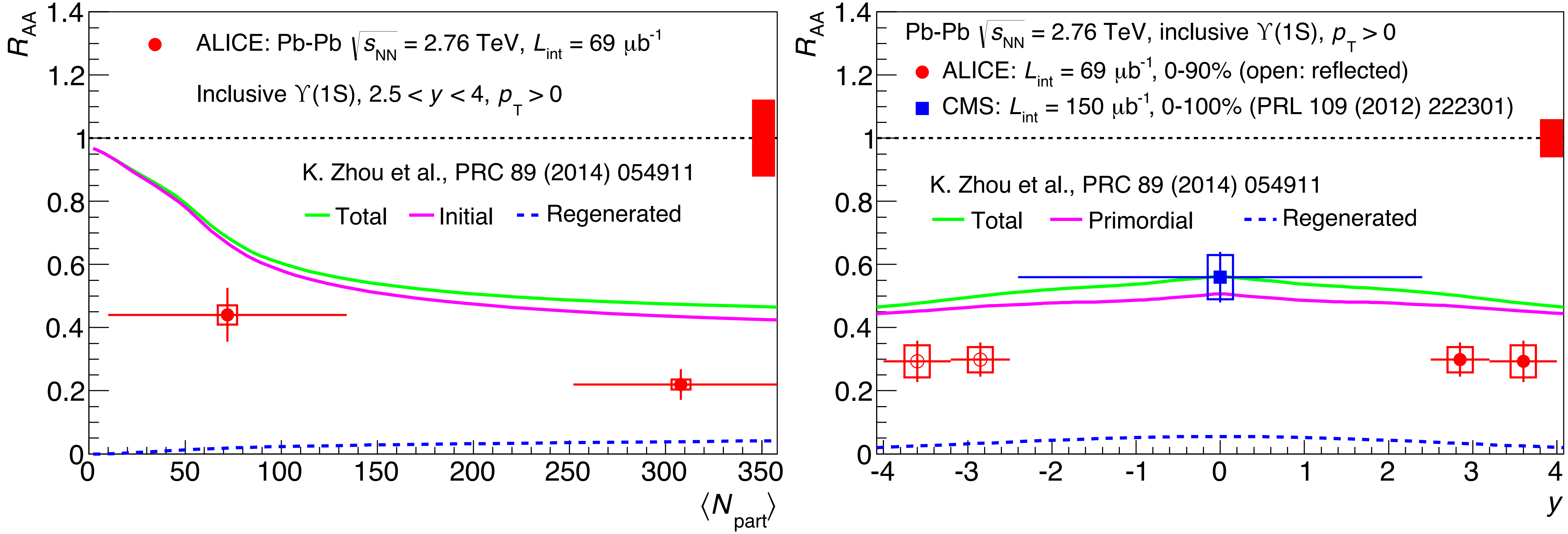
- Stronger suppression of direct ϒ(1S)?
- Role of regeneration?
- Role of CNM effects?

Comparison with models – Transport II

PbPb @ 2.76 TeV

ALICE-PUBLIC-2014-001

- R_{AA} of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



- K. Zhou et al., [PRC89 (2014) 054911 and private communication]
  - Transport model
  - Suppression of resonances by the QGP
    - Mainly the higher mass states
  - Small regeneration component included
  - Feed down from higher mass states included
  - CNM included: EKS98

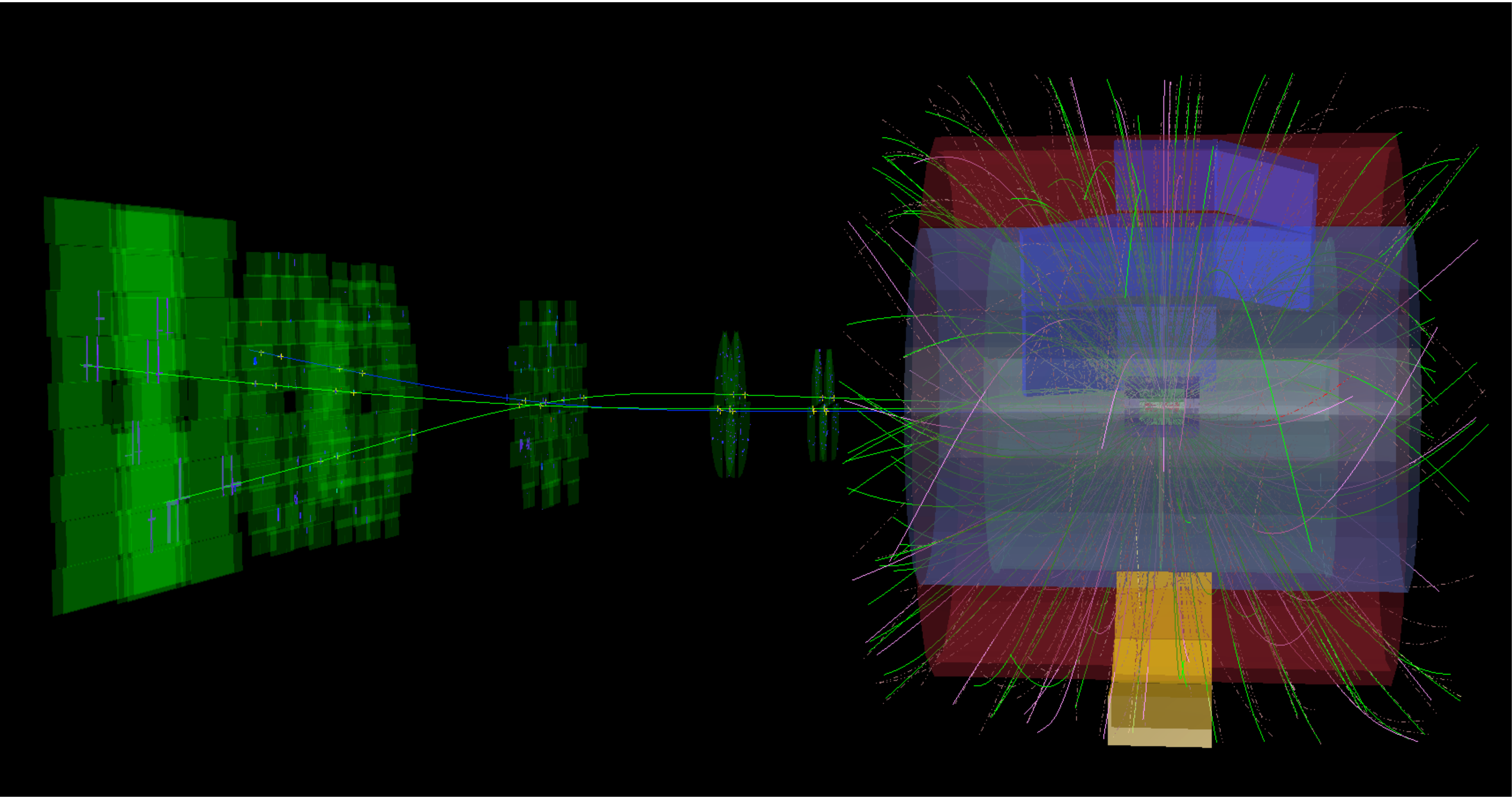
Model does not reproduce the strong rapidity dependence of the R_{AA} and underestimates the Υ(1S) suppression at forward rapidity

- Suppression of direct Υ(1S)?
- Role of regeneration?
- Role of CNM effects?

Summary Pb-Pb

- ϒ(1S) is strongly suppressed at forward rapidity in Pb-Pb collisions
  - Suppression increases with increasing centrality of the collision
  - Centrality 0% – 90%; $p_T > 0$; $2.5 < y < 4.0$:
    - $R_{AA} = 0.304 \pm 0.047(\text{stat}) \pm 0.042(\text{syst})$
- ϒ(1S) is more suppressed at forward rapidity than at mid-rapidity
  - Suppression by the QGP may not be the only mechanism at play?
- Available theoretical models
  - do not reproduce the strong rapidity dependence of the ϒ(1S) R_{AA}
  - and underestimate the measured suppression at forward rapidity
- Feed-down from higher mass states can only account for 30% of ϒ(1S) suppression

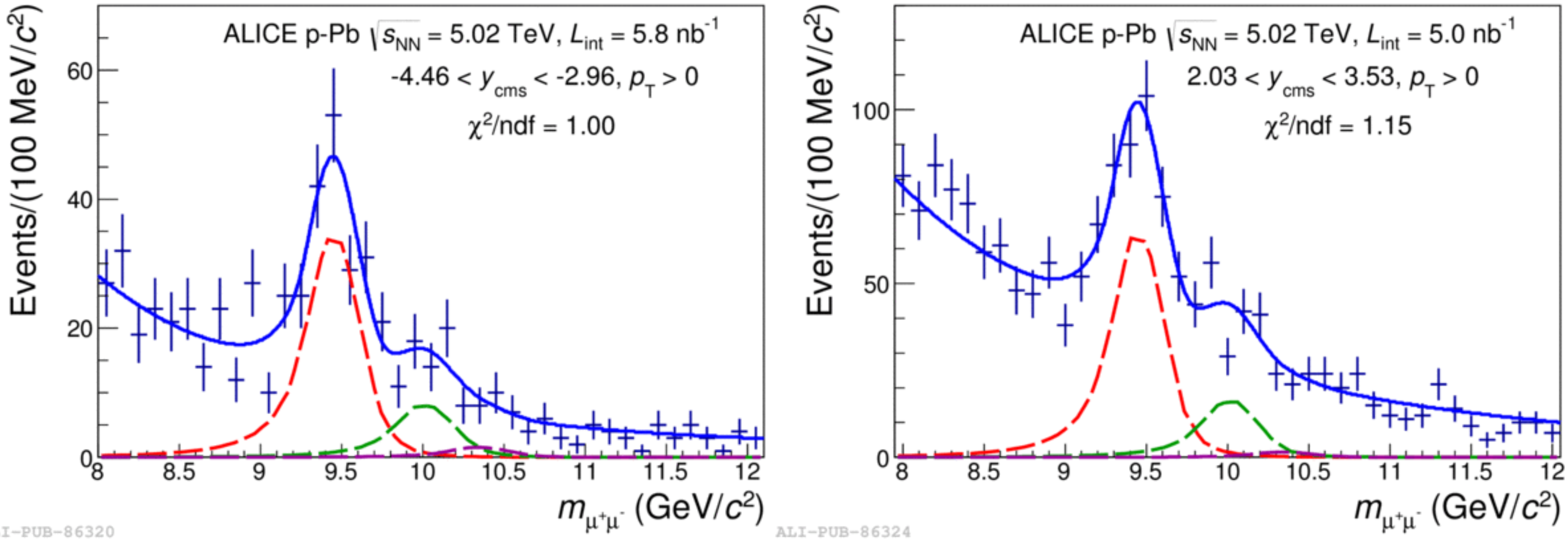
p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



p-Pb and Pb-p collisions

PLB 740 (2015) 105

- Inclusive Υ(1S) production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



- Two configurations

$-4.46 < y_{cms} < -2.96$ (backward)

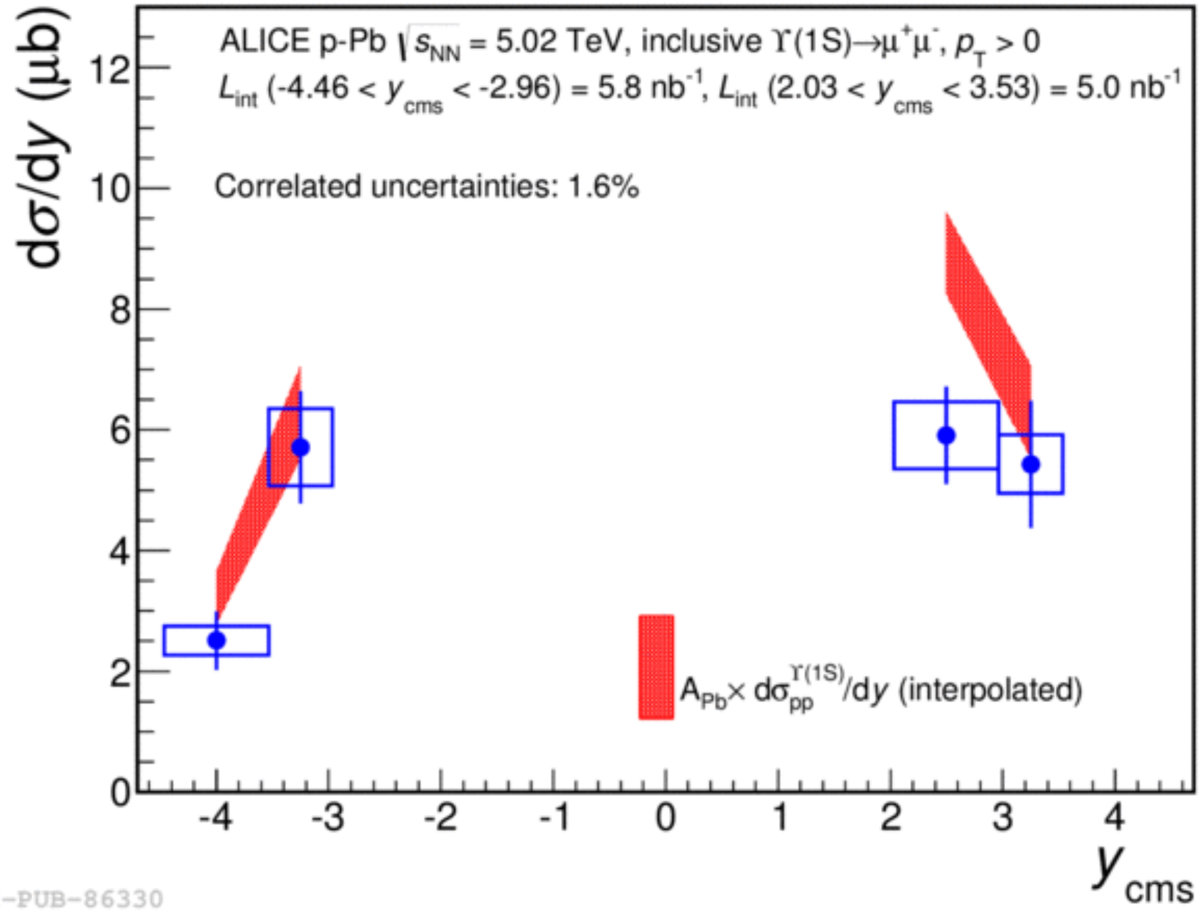
$2.03 < y_{cms} < 3.53$ (forward)

Production cross section

pPb @ 5.02 TeV

PLB 740 (2015) 105

- Rapidity integrated cross sections
  - $\sigma_{Y(1S)}(-4.46 < y_{cms} < -2.96) = 5.57\pm0.72(\mathrm{stat})\pm0.60(\mathrm{syst})$ µb;
  - $\sigma_{Y(1S)}(2.03 < y_{cms} < 3.53) = 8.45\pm0.94(\mathrm{stat})\pm0.77(\mathrm{syst})$ µb.
  - $\sigma_{Y(2S)}(-4.46 < y_{cms} < -2.96) = 1.85\pm0.61(\mathrm{stat})\pm0.32(\mathrm{syst})$ µb,
  - $\sigma_{Y(2S)}(2.03 < y_{cms} < 3.53) = 2.97\pm0.82(\mathrm{stat})\pm0.50(\mathrm{syst})$ µb.



ALI-PUB-86330

- Y(2S)-to-Y(1S) cross section ratio
  - $-4.46 < y_{cms} < -2.96$: 0.26 ± 0.09 ± 0.04
  - $2.03 < y_{cms} < 3.53$: 0.27 ± 0.08 ± 0.04

- Similar values measured in pp collisions by ALICE ($2.5 < y < 4.0$) and LHCb ($2.0 < y < 4.5$)
  - ALICE 7 TeV: 0.28 ± 0.08
  - LHCb 2.76 TeV: 0.24 ± 0.03
  - LHCb 7 TeV: 0.25 ± 0.02
  - LHCb 8 TeV: 0.23 ± 0.01

No evidence of different amount of CNM effects on Y(2S) with respect to Y(1S)

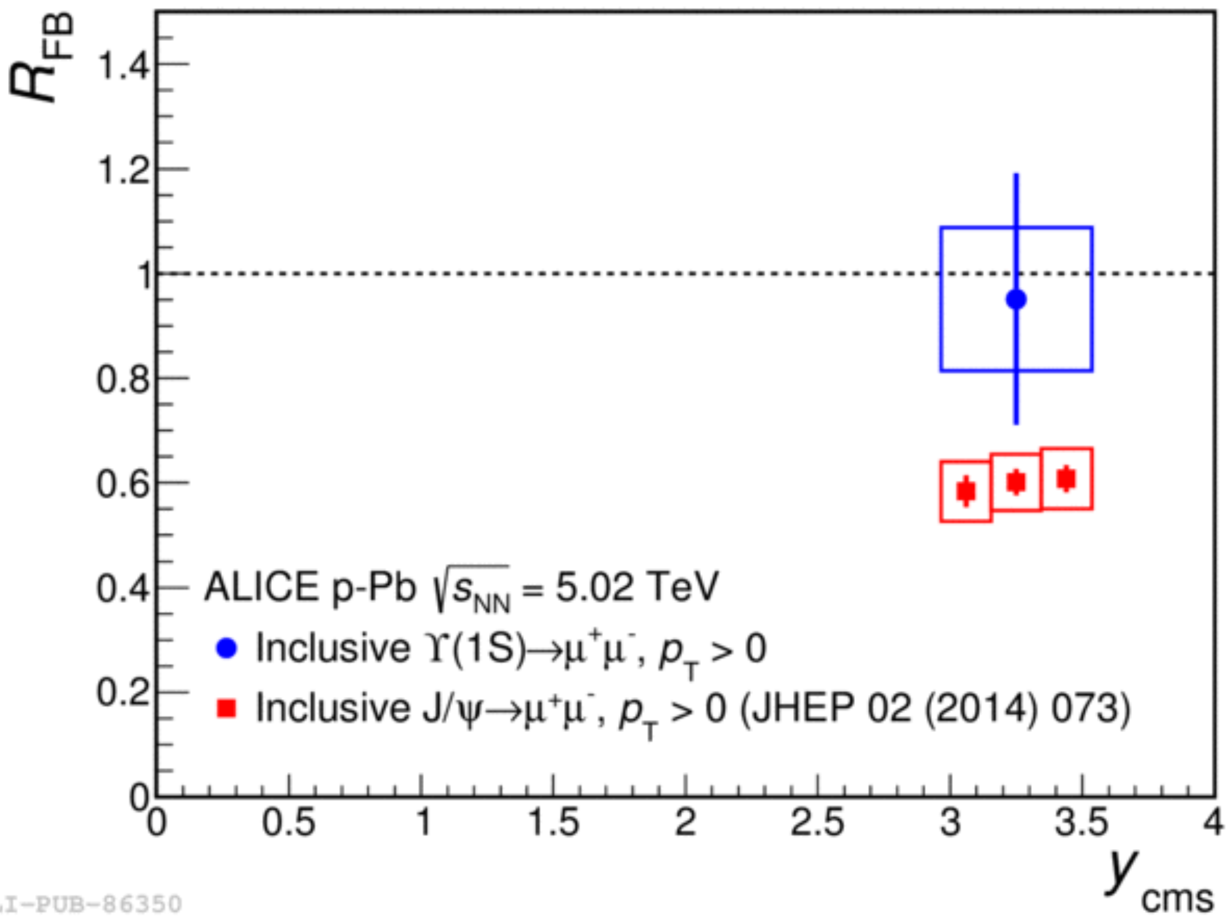
- At mid-y CMS measures $[Y(2S)/Y(1S)]_{pPb}/[Y(2S)/Y(1S)]_{pp} = 0.83 \pm 0.05(\mathrm{stat}) \pm 0.05(\mathrm{syst})$

Forward to Backward ratio

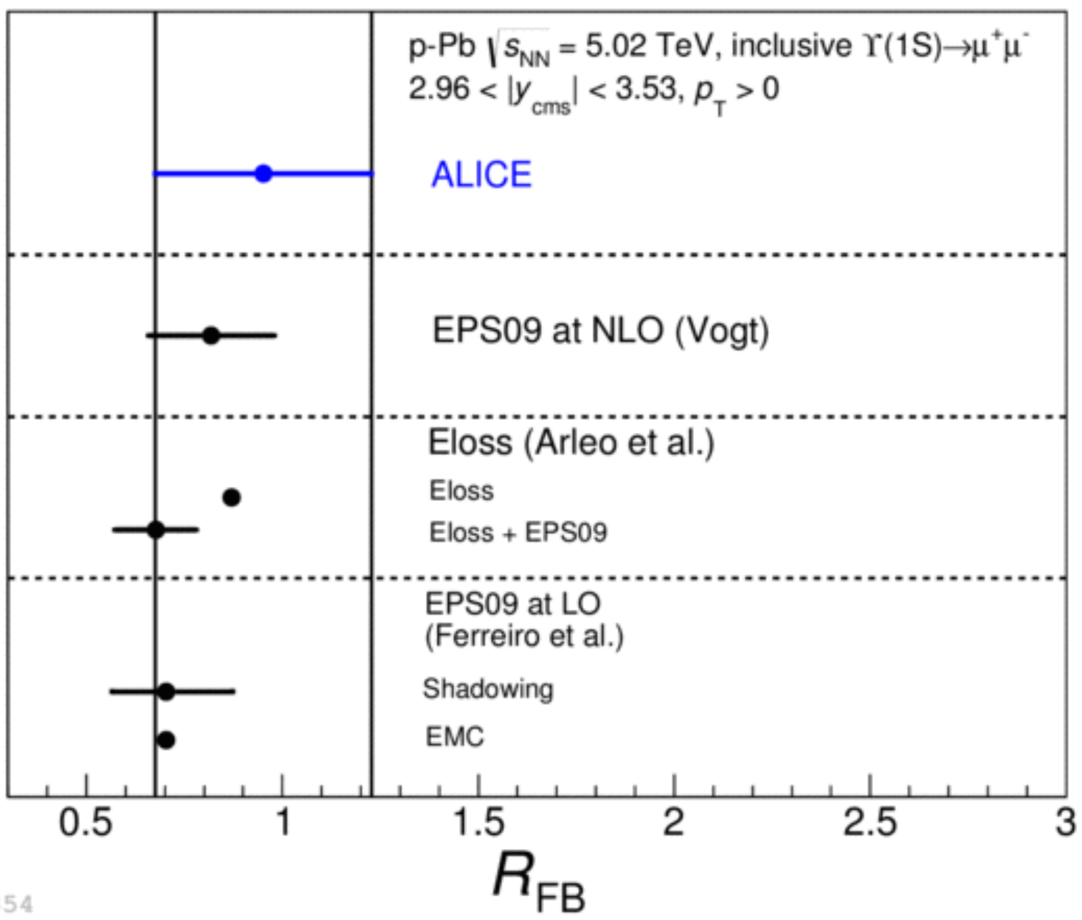
pPb @ 5.02 TeV

PLB 740 (2015) 105

- Ratio of the Forward to Backward yields
  - Pros: No need of pp reference
  - Cons: Rapidity acceptance restricted to common region 2.96 < $|y_{cms}|$ < 3.53



ALI-PUB-86350



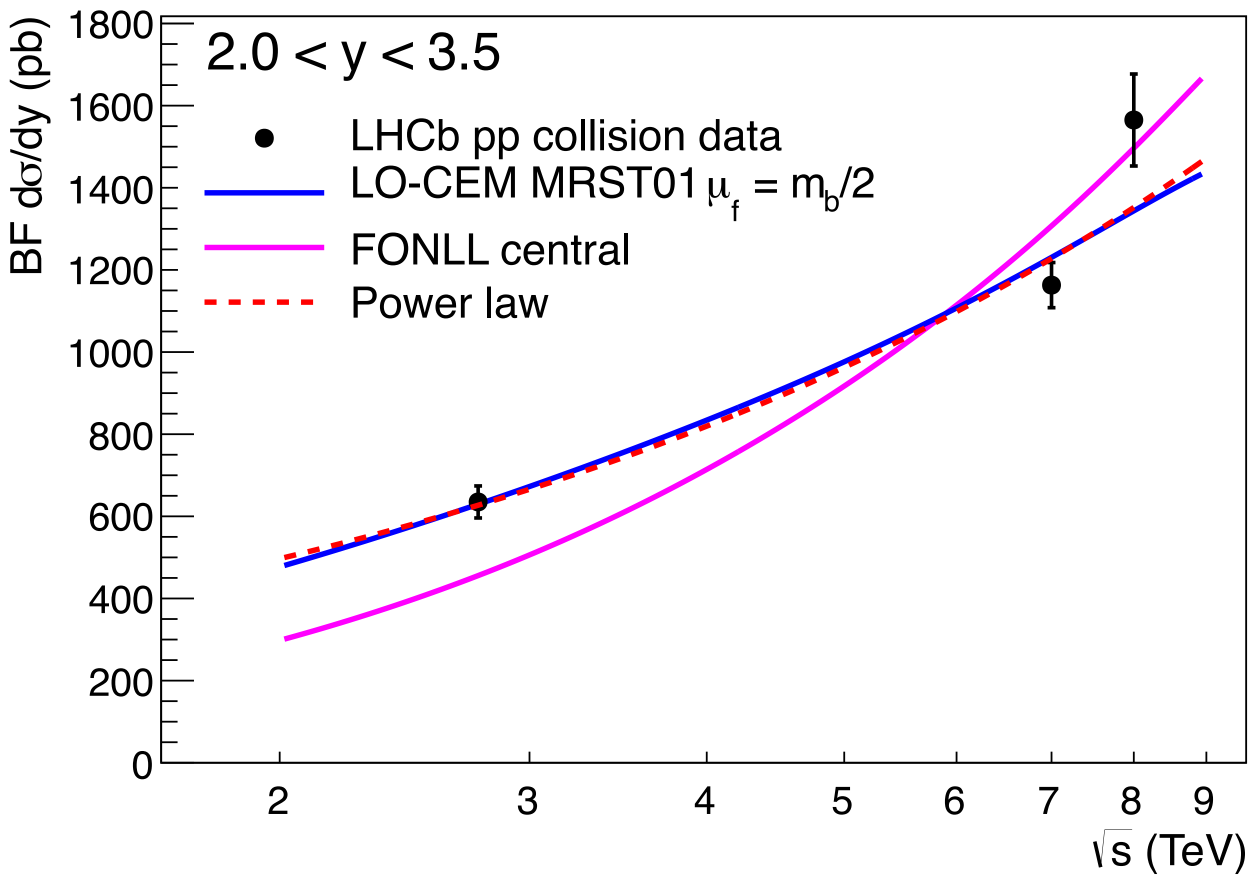
ALI-PUB-86354

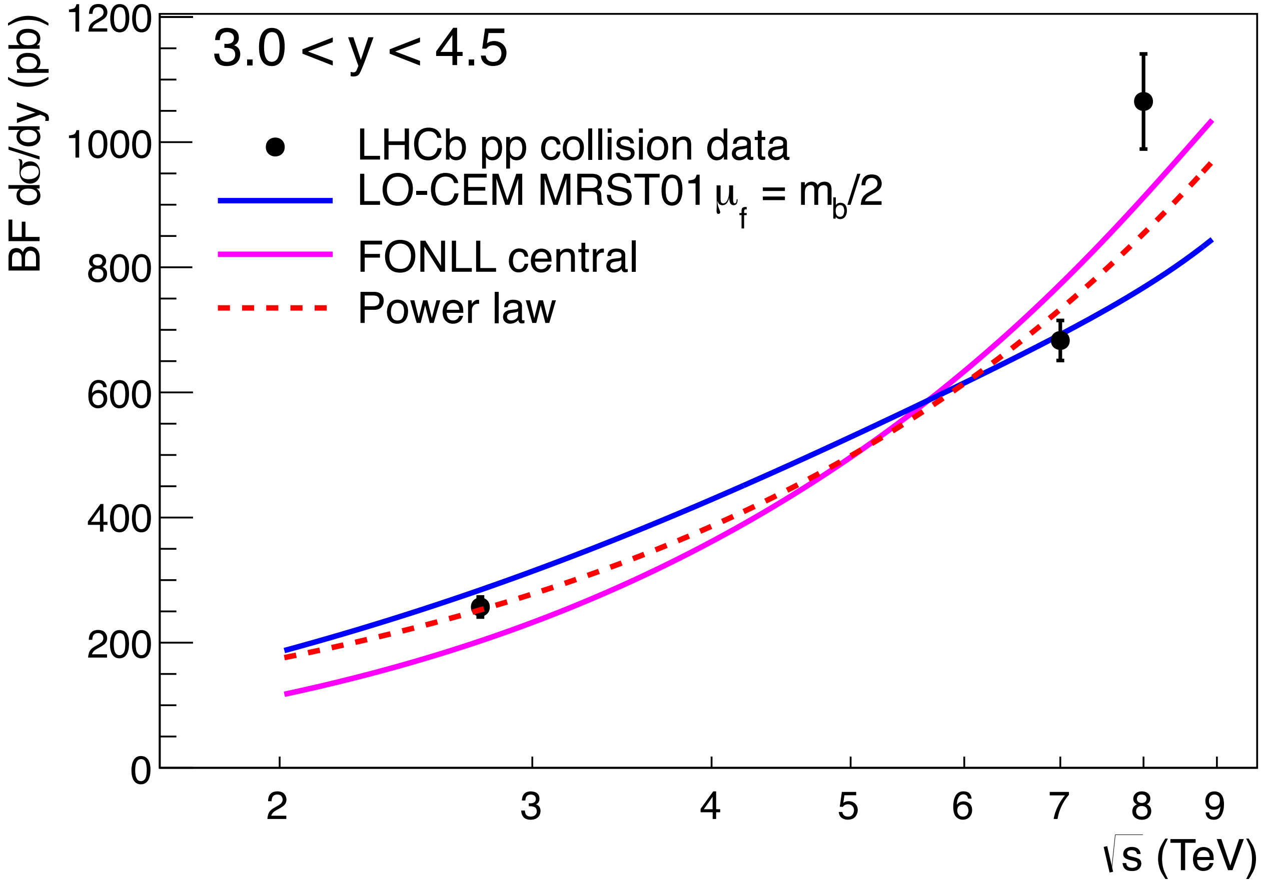
  - All models are in agreement with our measurement within uncertainties

pp reference @ 5.02 TeV

ALICE-PUBLIC-2014-002

- No pp data exist at $\sqrt{s}$ = 5.02 TeV!
- Energy interpolation at forward rapidity
  - using LHCb data at 2.76, 7 and 8 TeV
  - and several “reasonable” functional forms
  - but also pQCD FONLL calculation
- Obtained cross-sections
  - dσ/dy(5.02 TeV, Y(1S), $2.0 < y < 3.5$)×BF($\mu^+\mu^-$) = 967 ± 76 pb,
  - dσ/dy(5.02 TeV, Y(1S), $3.0 < y < 4.5$)×BF($\mu^+\mu^-$) = 513 ± 58 pb.





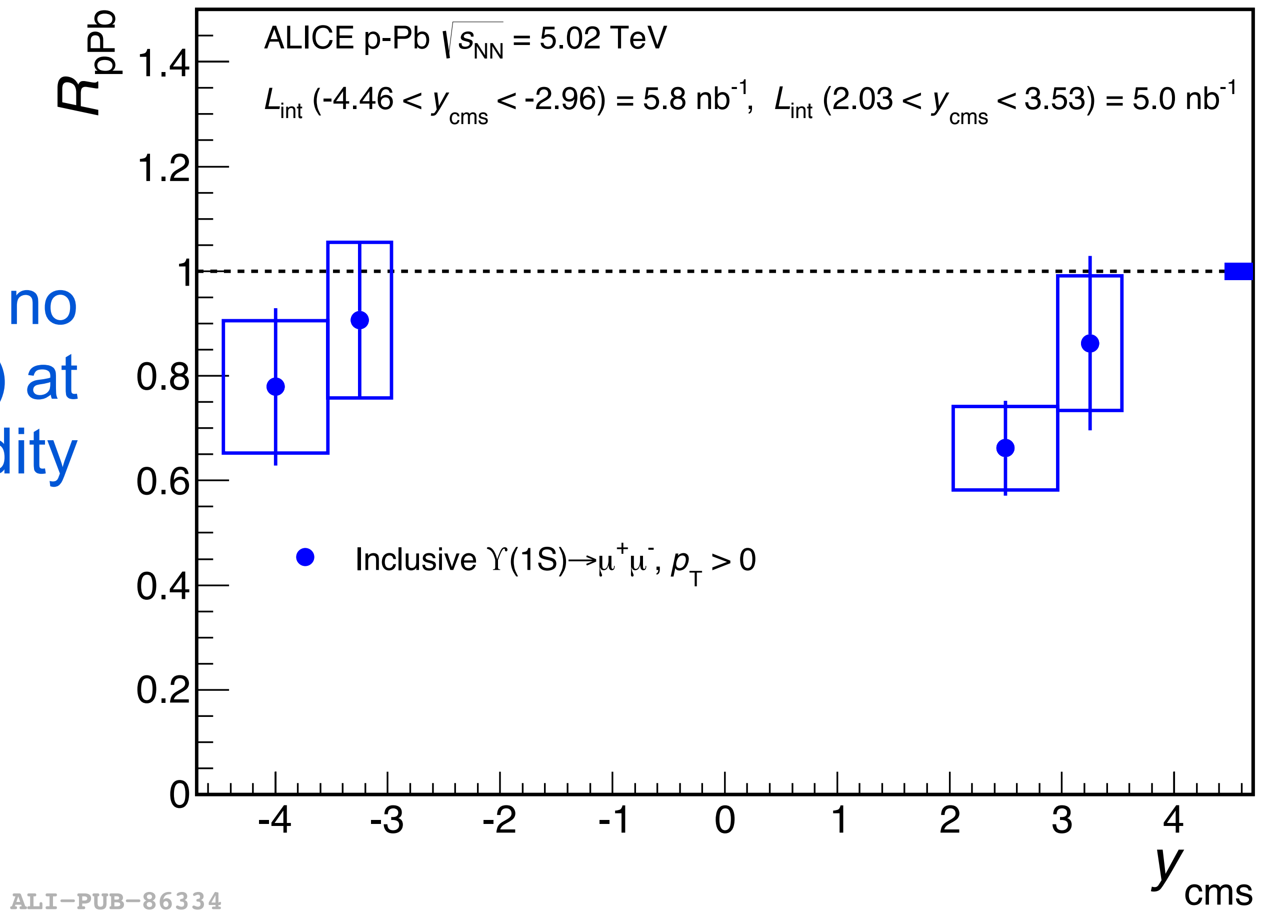
ϒ nuclear modification factor in p-Pb

PLB 740 (2015) 105

- Inclusive ϒ(1S) R_{pPb}

Uncertainties:
- Bars: Statistical
- Open boxes: Systematic
- Full box: Correlated systematic

Consistent with no suppression (0.8σ) at backward rapidity



Indication of suppression (2.7σ) at forward rapidity

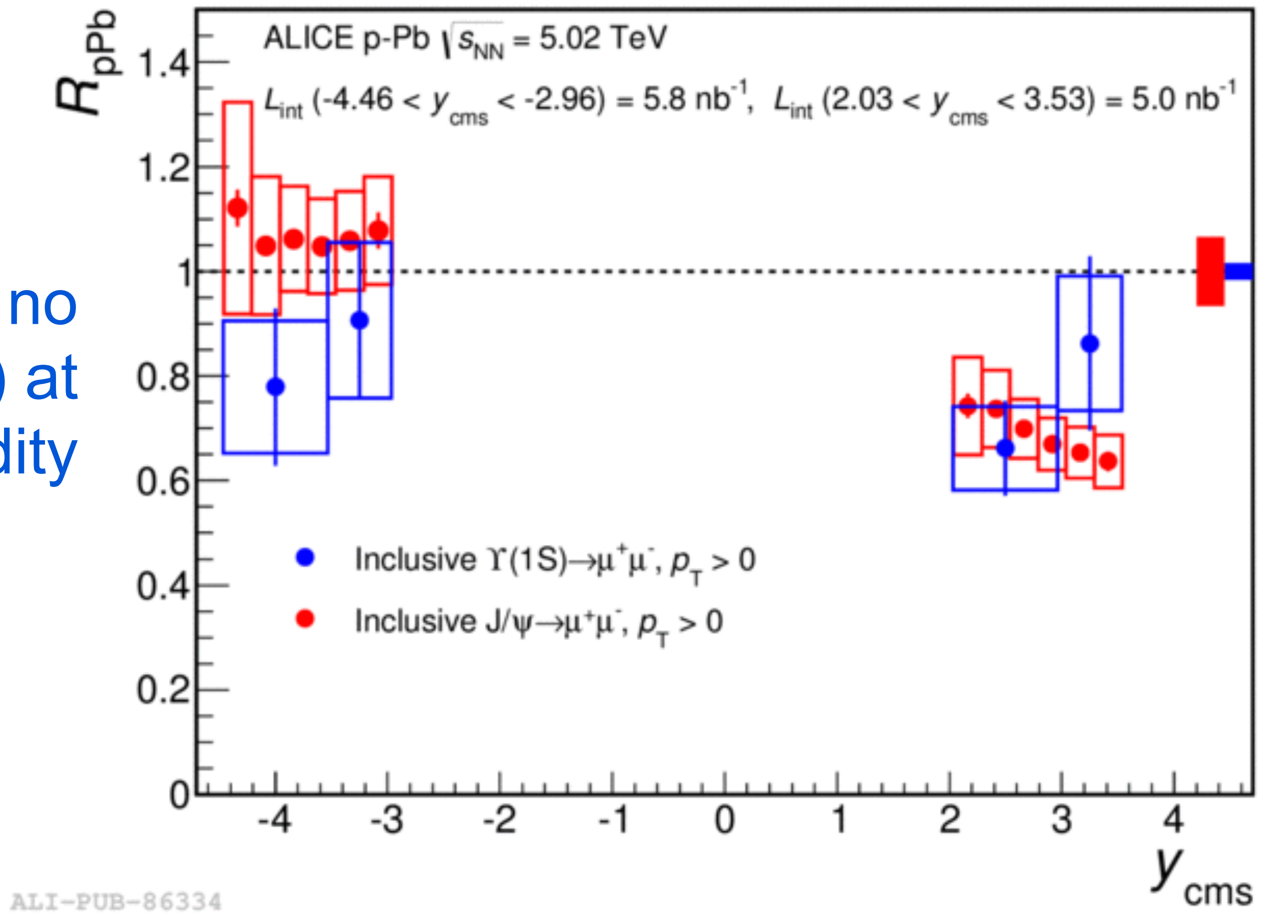
- Assuming a 2→1 production process the tested Bjorken-*x* ranges are
  - Backward: $3.6\cdot10^{-2} < x < 1.6\cdot10^{-1}$ (antishadowing region)
  - Forward: $5.5\cdot10^{-5} < x < 2.5\cdot10^{-4}$ (shadowing region)

Comparison with J/ψ

PLB 740 (2015) 105
JHEP 02 (2014) 073

- Comparison with ALICE J/ψ R_{pPb}
  - – Forward: similar suppression
  - – Backward: slightly lower ϒ R_{pPb}, but compatible within uncertainties

Consistent with no suppression (0.8σ) at backward rapidity



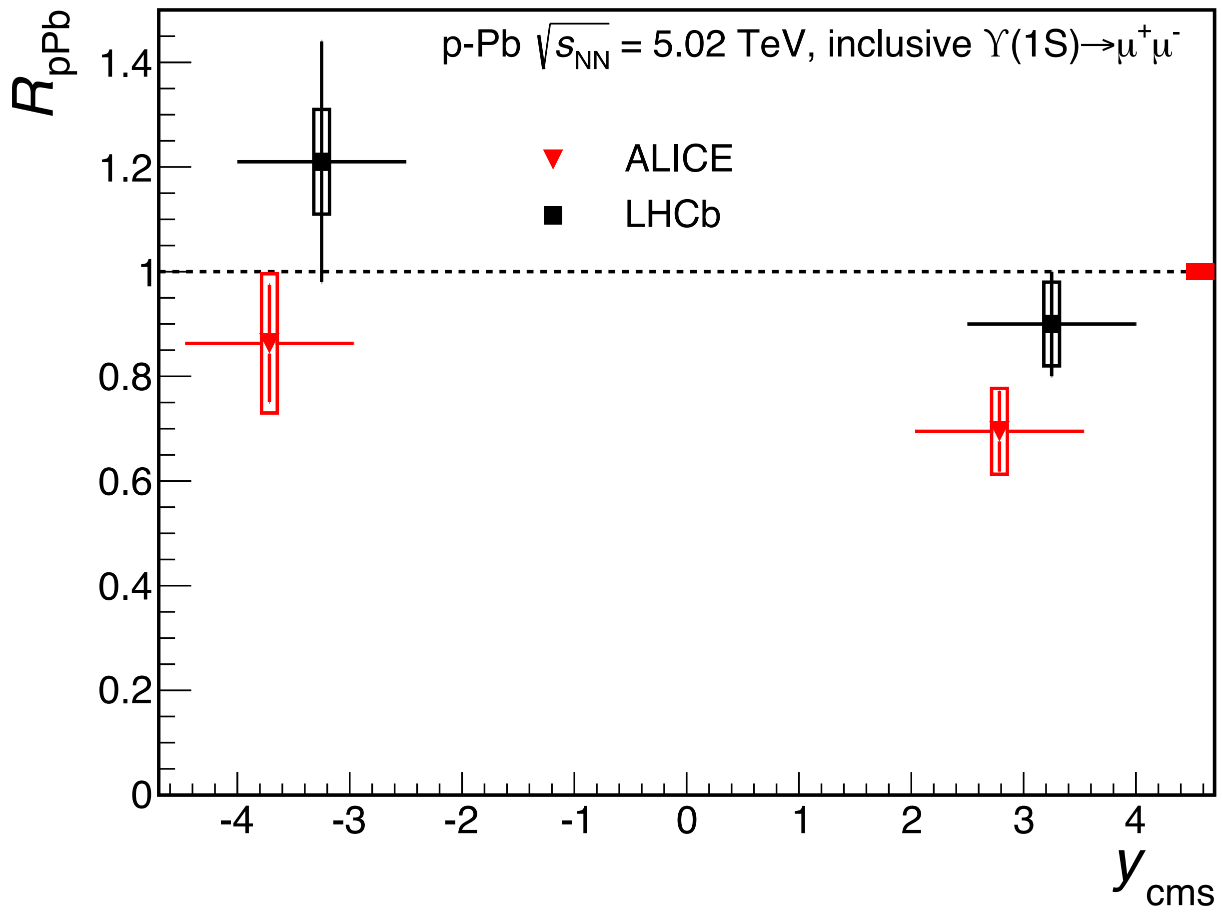
Indication of suppression (2.7σ) at forward rapidity

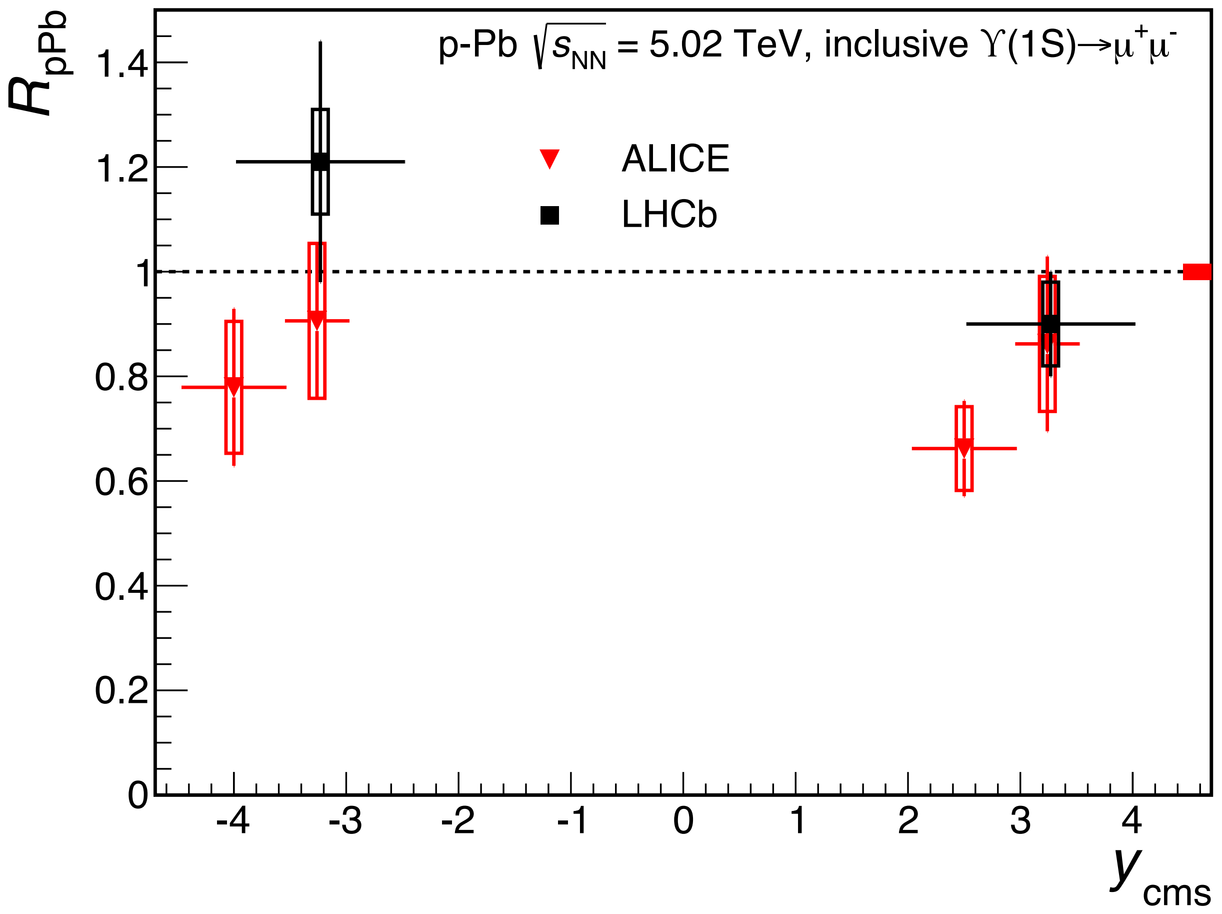
- Assuming a 2→1 production process the tested Bjorken-*x* ranges are
  - – Backward: $3.6\cdot10^{-2} < x < 1.6\cdot10^{-1}$ (ϒ) and $1.2\cdot10^{-2} < x < 5.3\cdot10^{-2}$ (J/ψ)
  - – Forward: $5.5\cdot10^{-5} < x < 2.5\cdot10^{-4}$ (ϒ) and $1.8\cdot10^{-5} < x < 8.1\cdot10^{-5}$ (J/ψ)

Comparison with LHCb

ALICE-PUBLIC-2014-002
LHCb-CONF-2014-003

- Comparison with LHCb Υ R_{pPb}
  - Both measurements are compatible
  - R_{pPb} systematically higher for LHCb than ALICE

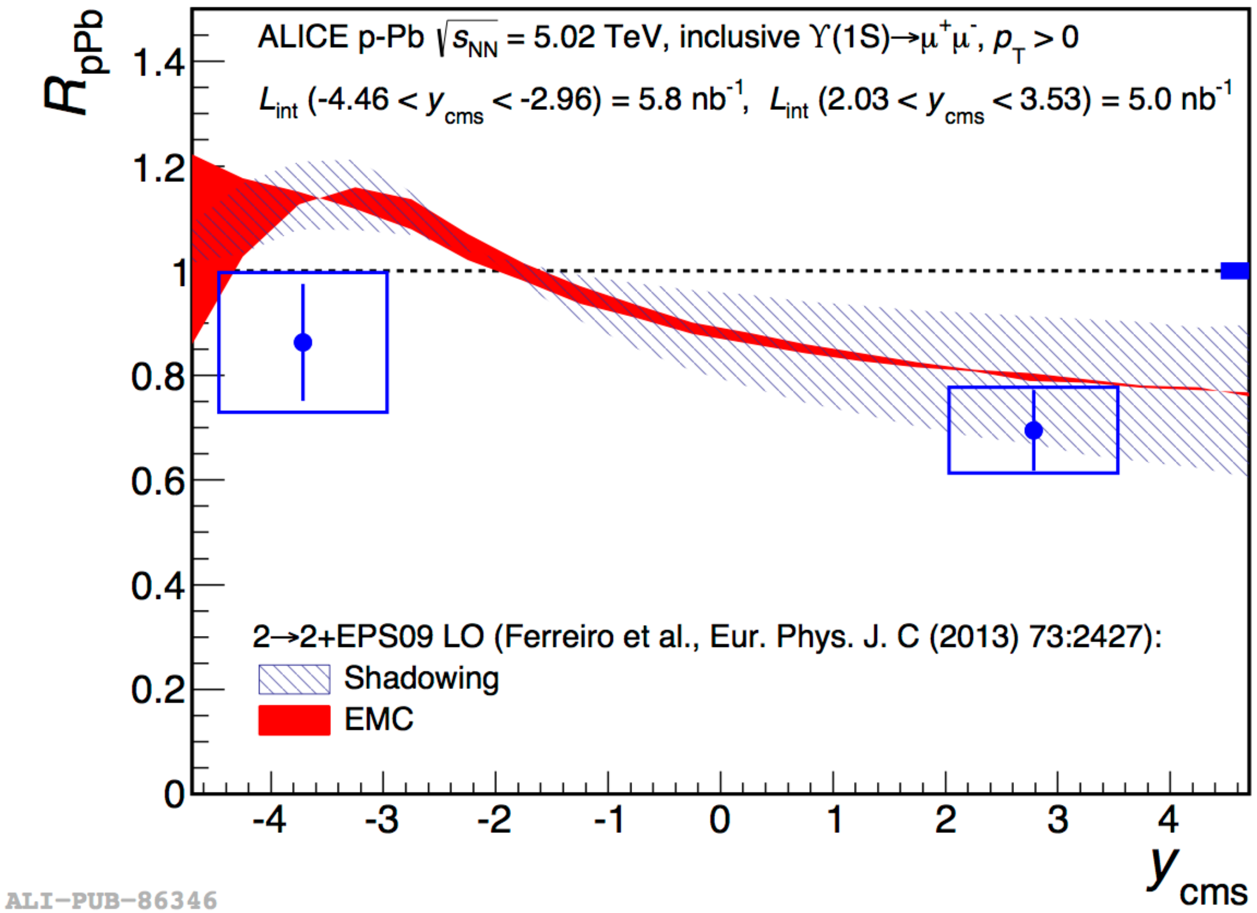




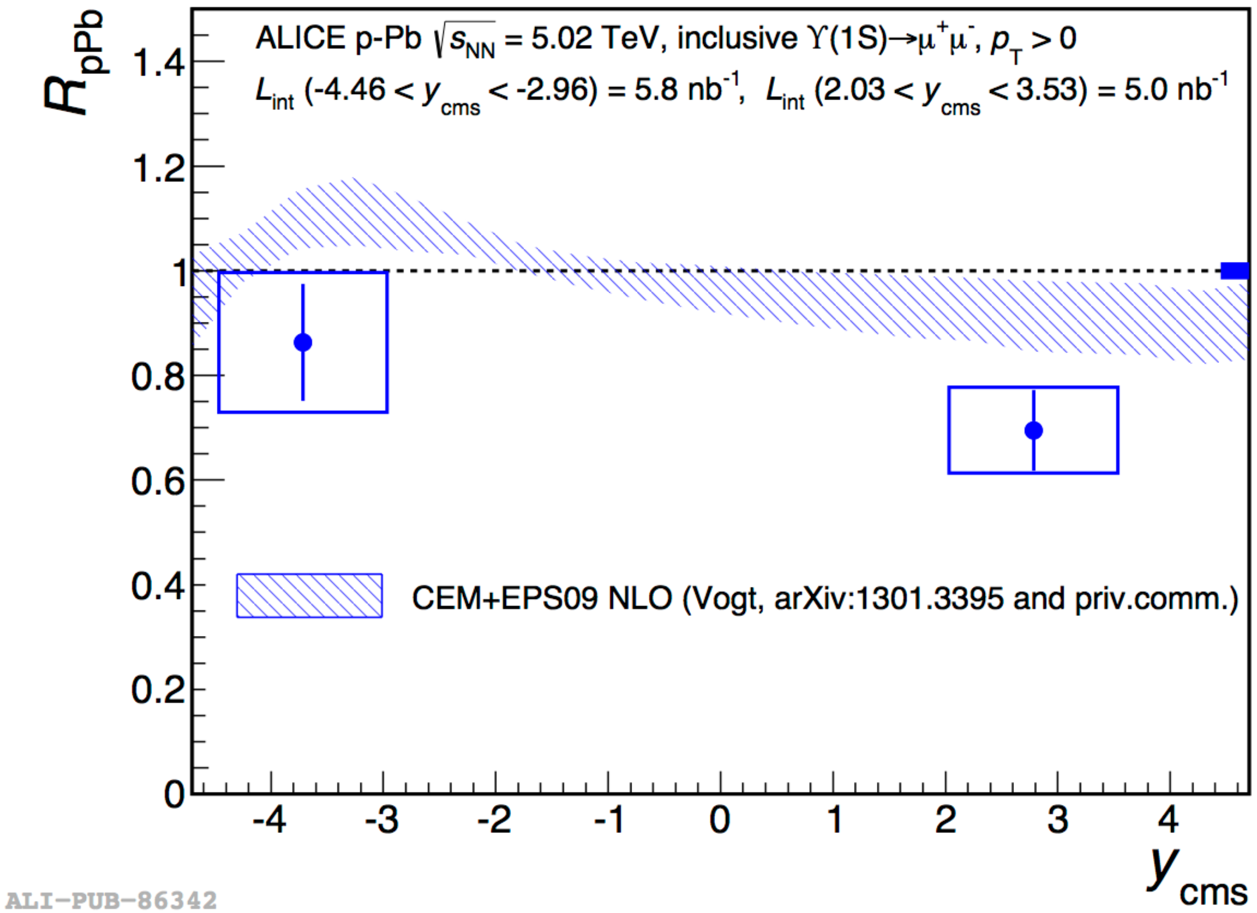
R_{pPb} – Model comparisons

pPb @ 5.02 TeV

PLB 740 (2015) 105



ALI-PUB-86346

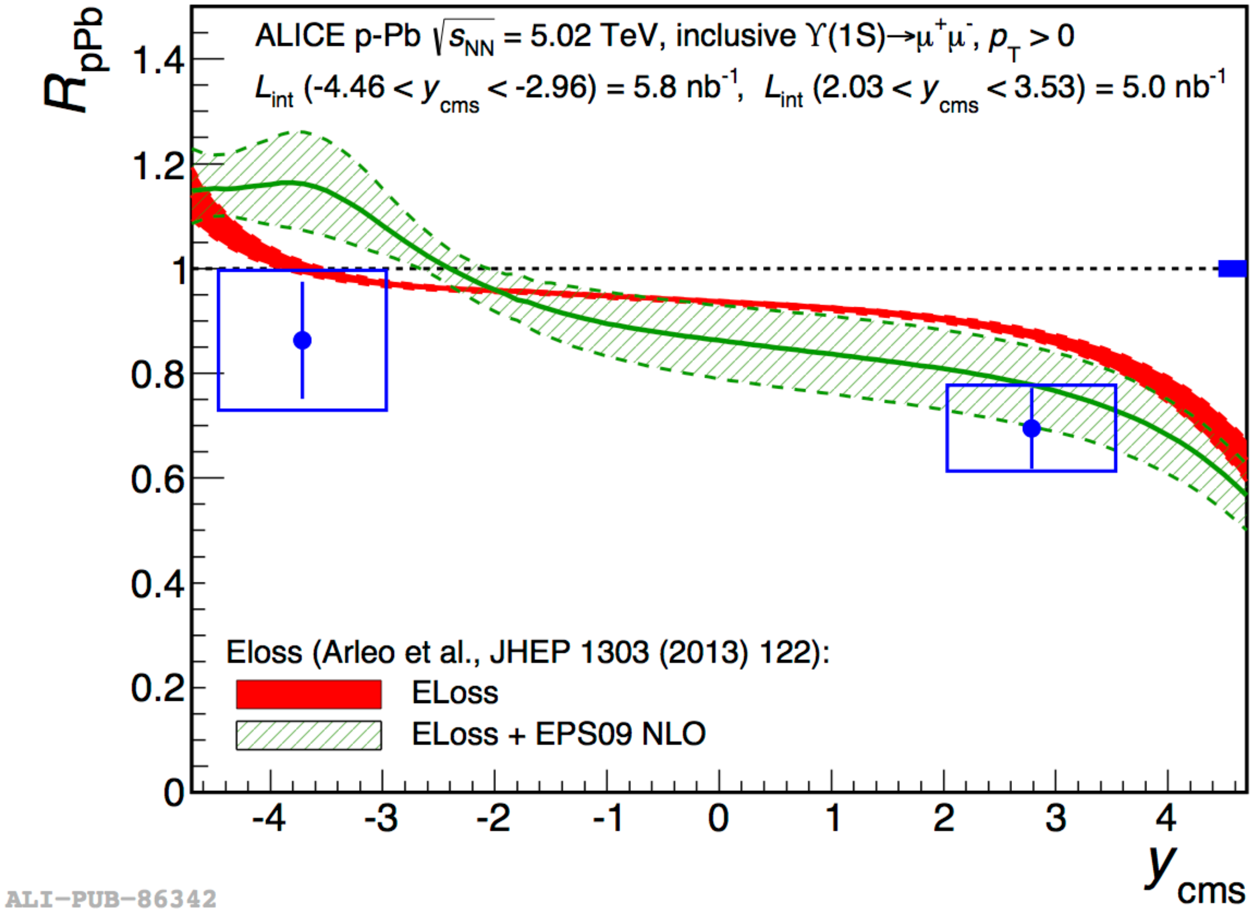


ALI-PUB-86342

- Ferreiro et al. [EPJC 73 (2013) 2427]
  - Generic 2→2 production model at LO
  - EPS09 shadowing parameterization at LO
  - Fair agreement with measured R_{pPb}
    - Although slightly overestimates it in the antishadowing region
- Vogt [arXiv:1301.3395]
  - CEM production model at NLO
  - EPS09 shadowing parameterization at NLO
  - Fair agreement with measured R_{pPb} within uncertainties
    - Although slightly overestimates it

R_{pPb} – Model comparisons

PLB 740 (2015) 105



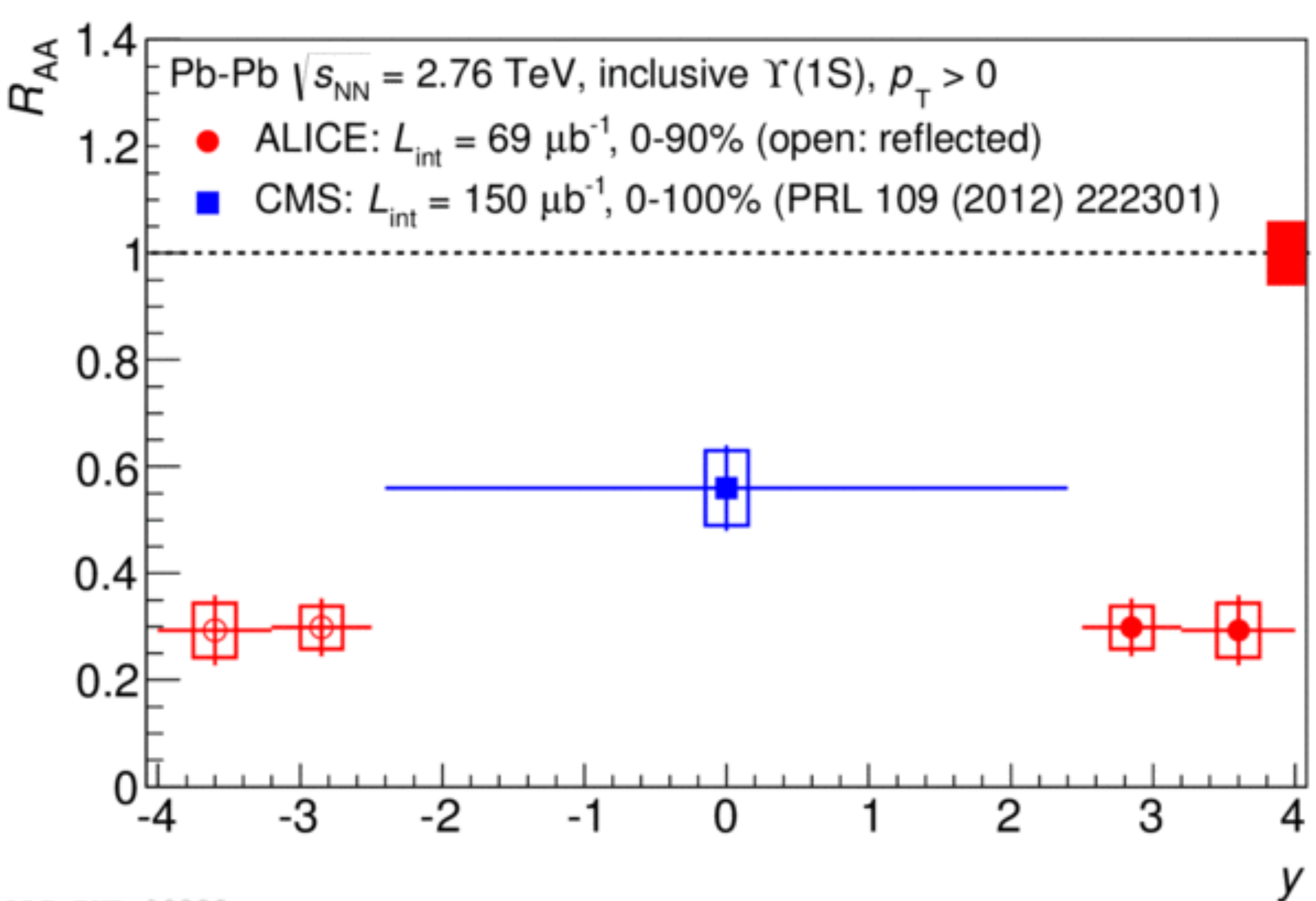
- Arleo et al. [JHEP 1303 (2013) 122]
  - – Model including a contribution from coherent parton energy loss
  - – With or without shadowing (EPS09)
  - – Forward: Better agreement with ELoss and shadowing
  - – Backward: Better agreement with ELoss only

Summary – p-Pb

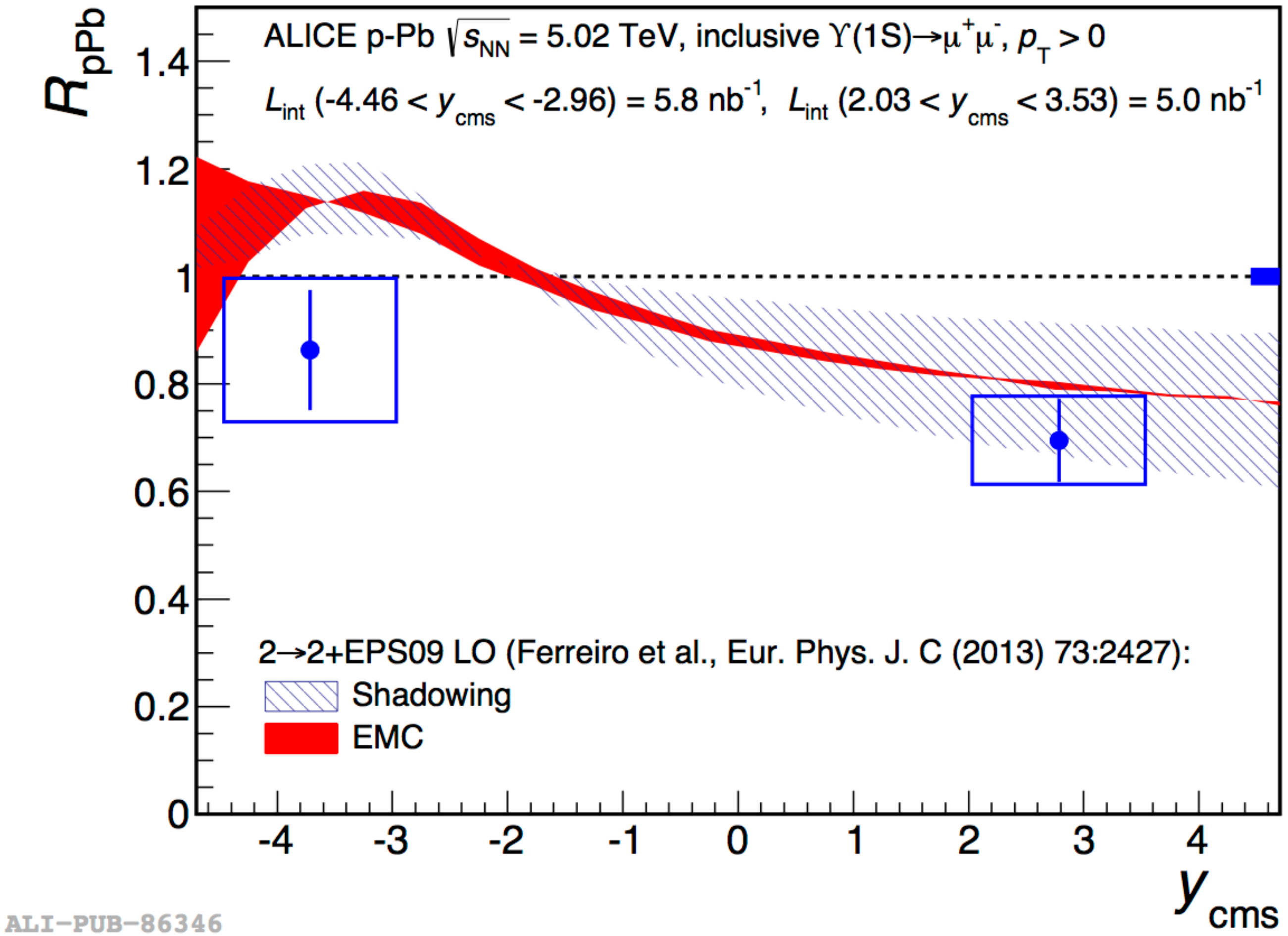
- A suppression of Υ(1S) at forward rapidity (small-*x* region)
  - Similar R_{pPb} as for J/ψ
- A R_{pPb} consistent with unity at backward rapidity (large-*x* region)
  - Model comparisons suggest smaller anti-shadowing than assumed
- No indication, within uncertainties, of different CNM effects on Υ(2S) with respect to Υ(1S)

Back to Pb-Pb

- In Pb-Pb collisions the suppression of the higher mass states will account for at most 30% suppression of $\Upsilon(1S)$ (from feed-down)
- CNM effects?
  - Cannot be easily extrapolated from p-Pb to Pb-Pb
    - Rely on model calculations
    - Assuming factorisation of CNM effects (validated in a CEM approach up to NLO), the expected suppression in Pb-Pb from CNM (R_{PbPb}^{CNM}) can be estimated from the measured R_{pPb} as $R_{PbPb}^{CNM}(y) = R_{pPb}(-y) \times R_{pPb}(y)$



ALI-PUB-89232



ALI-PUB-86346

Summary

- The production of inclusive Υ(1S) and Υ(2S) at forward rapidity has been measured in pp collisions at $\sqrt{s}$ = 7 TeV

- The production of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV shows
  - Strong suppression of Υ(1S) at forward rapidity
    - Suppression increases with increasing centrality of the collision
    - Suppression is larger at forward rapidity than at central rapidity
  - Available models do not reproduce the strong rapidity dependence of the R_{AA} and underestimate the measured suppression at forward rapidity
    - Stronger suppression of direct Υ(1S)?
    - Role of regeneration?
    - Role of CNM effects?

- The production of inclusive Υ(1S) and Υ(2S) in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV shows
  - A suppression of Υ(1S) at forward rapidity (small-*x* region)
    - Similar R_{pPb} as for J/ψ
  - A R_{pPb} consistent with unity at backward rapidity (large-*x* region)
    - Model comparisons suggest smaller anti-shadowing than assumed
  - No indication, within uncertainties, of different CNM effects on Υ(2S) with respect to Υ(1S)

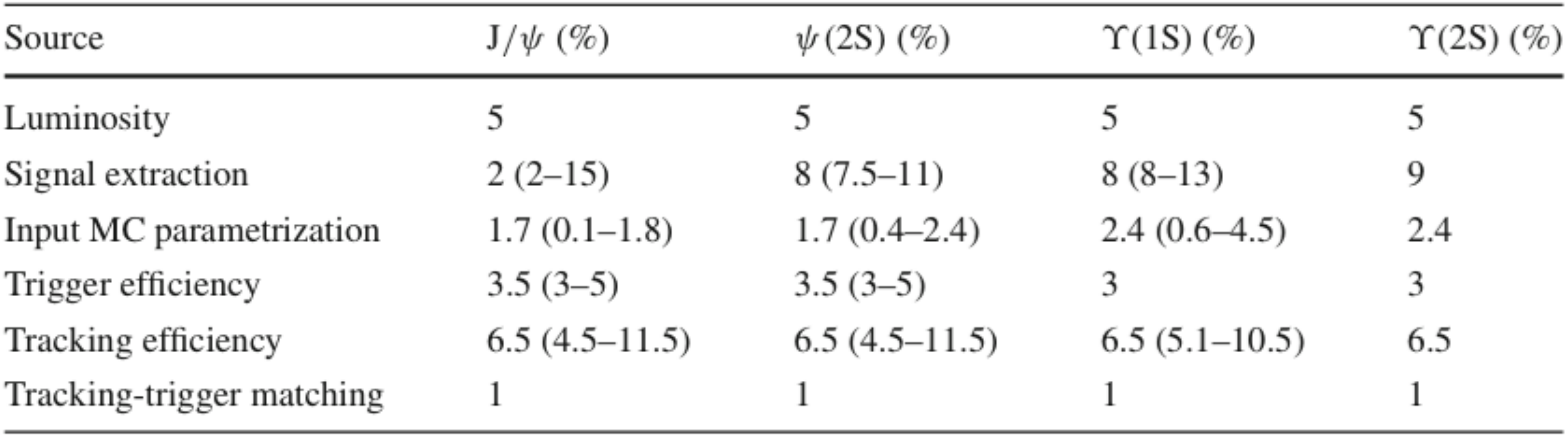
Outlook

- More to expect from LHC Run 2
- Pb-Pb at $\sqrt{s_{NN}}$ = 5 TeV
  - Confirm stronger suppression of ϒ(1S) at forward rapidity compared to mid-rapidity
  - Observe stronger suppression of the ϒ(2S) than of ϒ(1S) also at forward rapidity
  - Good pp reference is important
- p-Pb collisions
  - Provide stronger experimental constraints on CNM effects
  - Establish wether CNM effects on ϒ(2S) are stronger than on ϒ(1S) also at forward rapidity
  - Good pp reference is important

Back-up

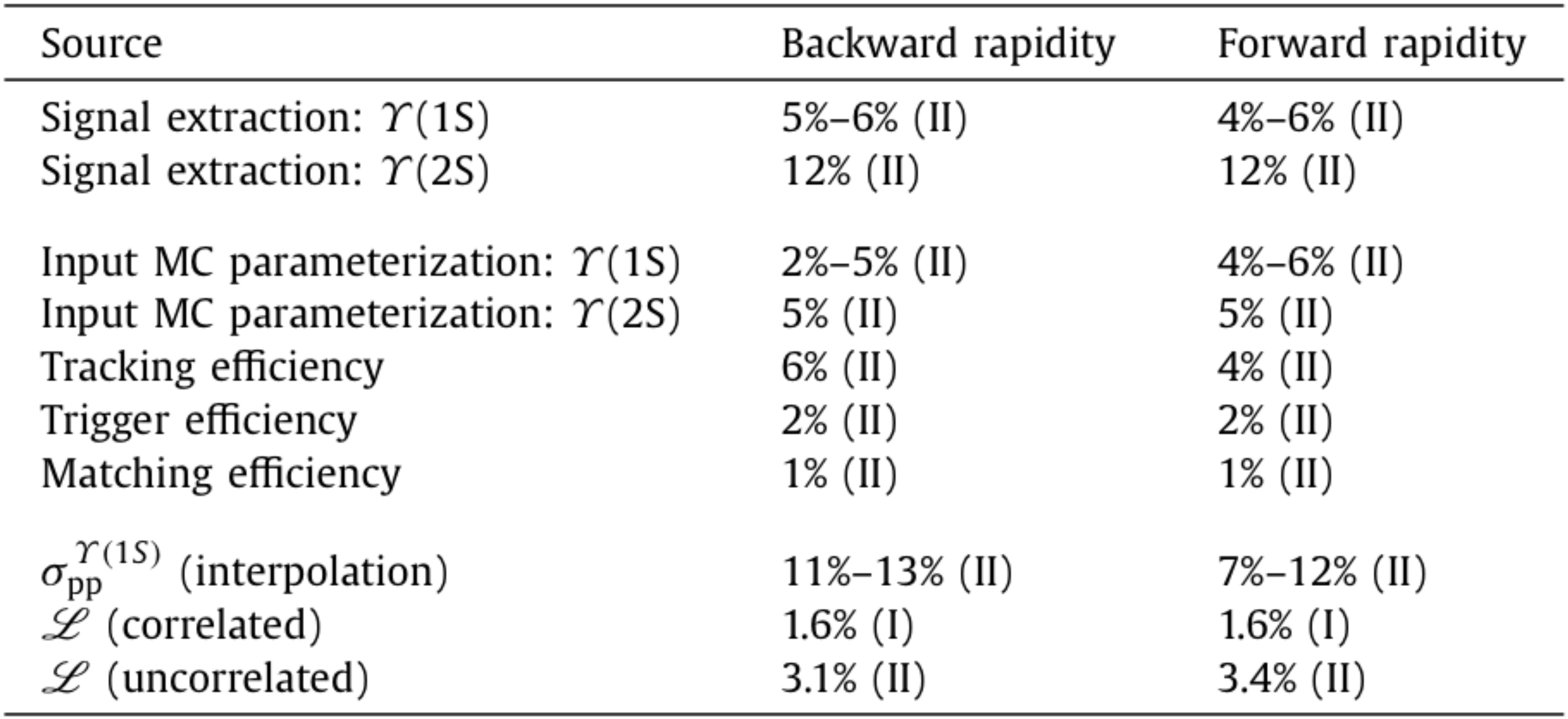
-

Systematic uncertainties – pp



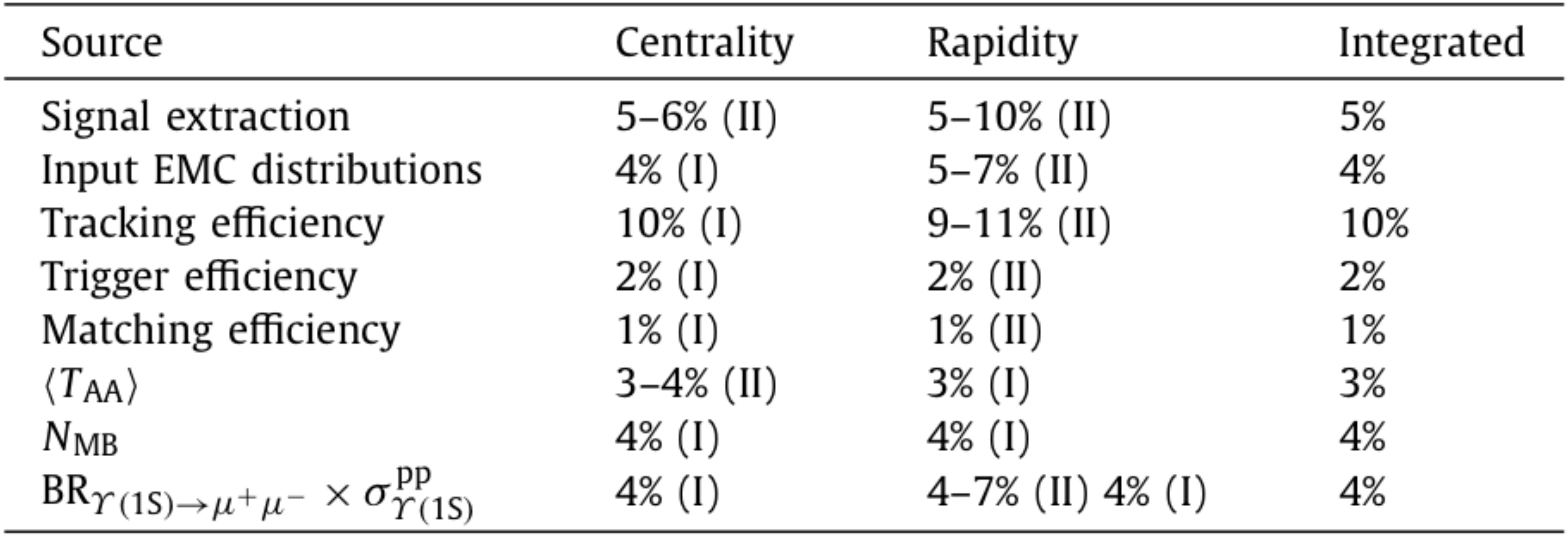
Source	J/ψ (%)	ψ(2S) (%)	Υ(1S) (%)	Υ(2S) (%)
Luminosity	5	5	5	5
Signal extraction	2 (2–15)	8 (7.5–11)	8 (8–13)	9
Input MC parametrization	1.7 (0.1–1.8)	1.7 (0.4–2.4)	2.4 (0.6–4.5)	2.4
Trigger efficiency	3.5 (3–5)	3.5 (3–5)	3	3
Tracking efficiency	6.5 (4.5–11.5)	6.5 (4.5–11.5)	6.5 (5.1–10.5)	6.5
Tracking-trigger matching	1	1	1	1

Systematic uncertainties – p-Pb



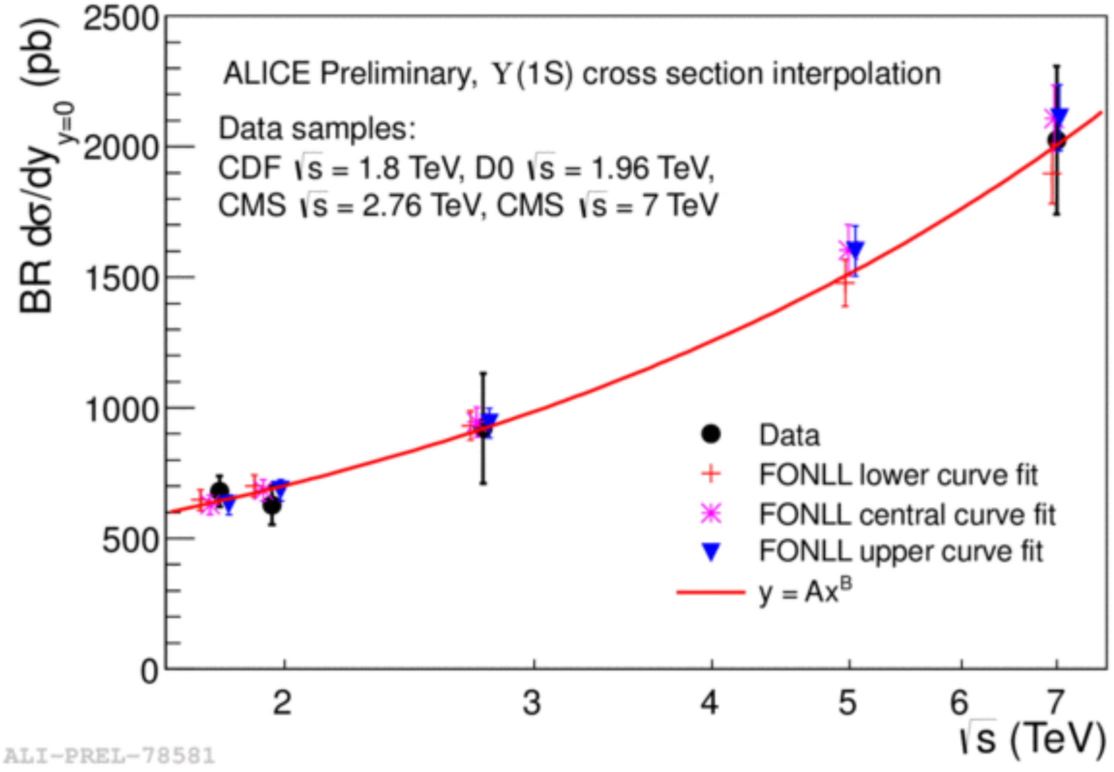
Source	Backward rapidity	Forward rapidity
Signal extraction: $\Upsilon(1S)$	5%–6% (II)	4%–6% (II)
Signal extraction: $\Upsilon(2S)$	12% (II)	12% (II)
Input MC parameterization: $\Upsilon(1S)$	2%–5% (II)	4%–6% (II)
Input MC parameterization: $\Upsilon(2S)$	5% (II)	5% (II)
Tracking efficiency	6% (II)	4% (II)
Trigger efficiency	2% (II)	2% (II)
Matching efficiency	1% (II)	1% (II)
$\sigma_{pp}^{\Upsilon(1S)}$ (interpolation)	11%–13% (II)	7%–12% (II)
$\mathscr{L}$ (correlated)	1.6% (I)	1.6% (I)
$\mathscr{L}$ (uncorrelated)	3.1% (II)	3.4% (II)

Systematic uncertainties – Pb-Pb



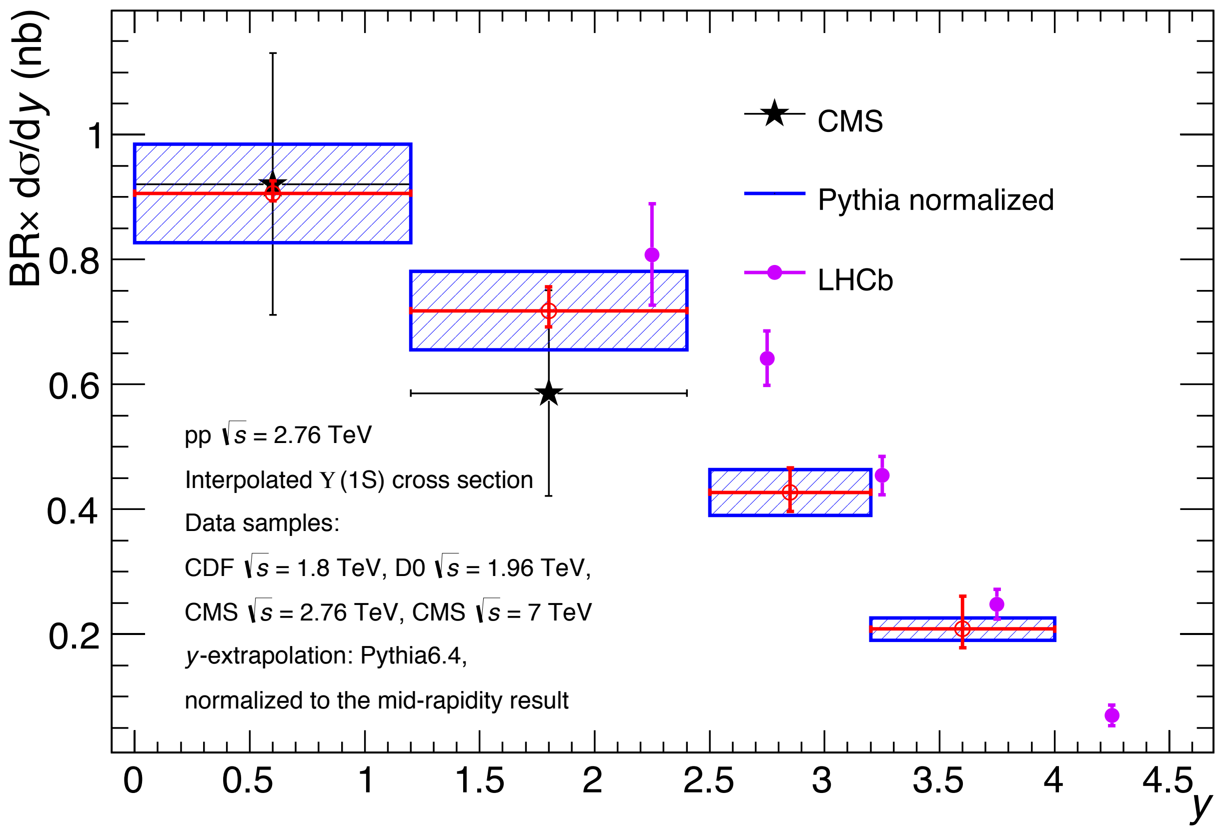
Source	Centrality	Rapidity	Integrated
Signal extraction	5–6% (II)	5–10% (II)	5%
Input EMC distributions	4% (I)	5–7% (II)	4%
Tracking efficiency	10% (I)	9–11% (II)	10%
Trigger efficiency	2% (I)	2% (II)	2%
Matching efficiency	1% (I)	1% (II)	1%
$\langle T_{\mathrm{AA}} \rangle$	3–4% (II)	3% (I)	3%
N_{MB}	4% (I)	4% (I)	4%
$\mathrm{BR}_{\Upsilon(1\mathrm{S})\to\mu^+\mu^-} \times \sigma^{\mathrm{pp}}_{\Upsilon(1\mathrm{S})}$	4% (I)	4–7% (II) 4% (I)	4%

pp reference @ 2.76 TeV



Approach used for preliminary results

- Energy interpolation at mid-rapidity
  - using CDF@1.8 TeV, D0@1.96 TeV, CMS@2.76 TeV, CMS@7 TeV data
  - and several “reasonable” functional forms
  - but also pQCD FONLL calculation
- Rapidity extrapolation
  - Test and select many Pythia tunes using CMS and LHCb data at 7 TeV
  - With selected tunes extrapolate the mid-rapidity point above to forward rapidity



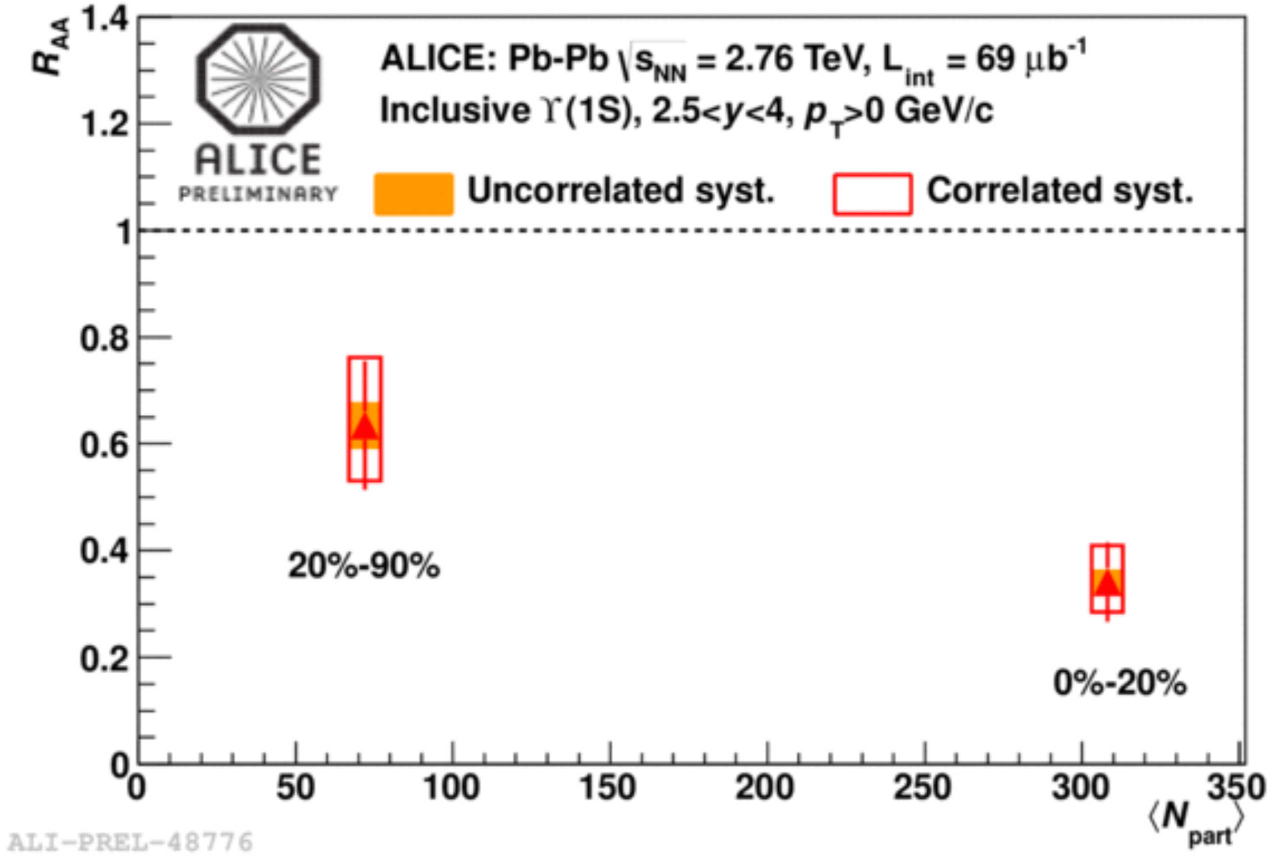
Approach used for the publication

- Use data from LHCb [EPJC74 2835 (2014)]
- pp cross section at 2.76 TeV (2.5<y<4)
  - LHCb measurement: $\sigma[\Upsilon(1S)\rightarrow\mu\mu]=0.670\pm0.025$ (stat.)±0.026 (syst.) nb
  - ALICE extrapolation: $\sigma[\Upsilon(1S)\rightarrow\mu\mu]=0.465^{+0.071}_{-0.045}$ (extrap.) ±0.041(norm.) nb

Preliminary inclusive Υ(1S) R_{AA}

PbPb @ 2.76 TeV

- R_{AA} of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV



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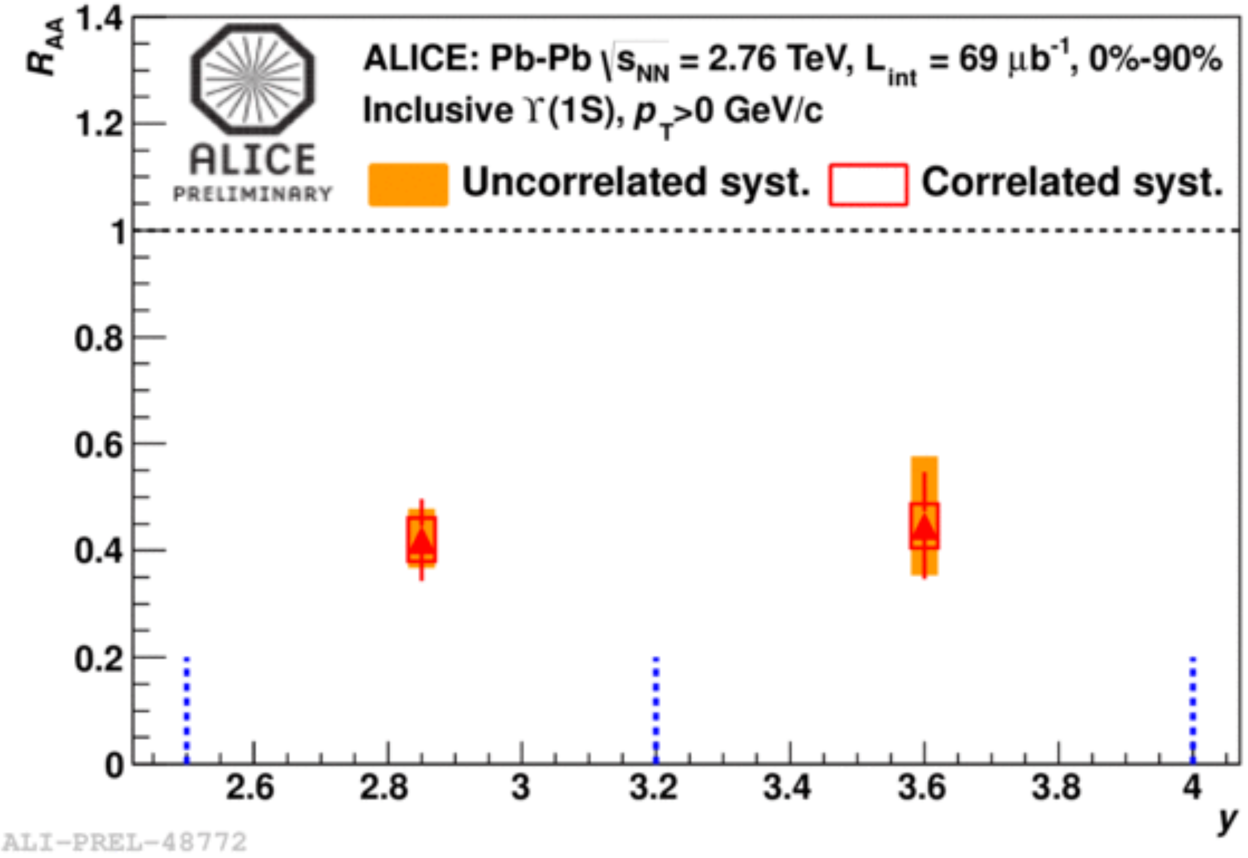


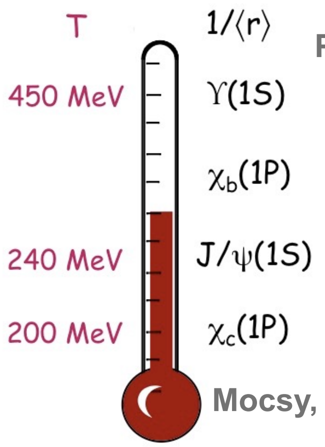
ALI-PREL-48772

- Depending on the rapidity interval, the pp reference obtained with the interpolation and extrapolation procedure and the LHCb data [EPJC74 (2014) 2835] differ by 30-35%, which implies a change on the modification factor by 1.3 to 2.2σ.

Motivations

- Quarkonia are important probes of QCD matter
  - – Heavy-quark pair production is a perturbative process
  - – Their binding is inherently non-perturbative
  - – Produced early in the collision
    - Sensitive to the properties of the surrounding medium

- ϒ in pp collisions
  - – Test of production models
  - – Reference for Pb-Pb studies
- ϒ in Pb-Pb collisions
  - – Quarkonia could be suppressed in the QGP by colour screening
    - Different binding energies mean that sequential suppression of different quarkonium states is expected
  - – Compared to charmonia
    - Regeneration is expected to be smaller
    - No feed-down from open heavy flavours
    - Smaller cold nuclear matter effects are expected
- ϒ in p-Pb collisions
  - – Study Cold Nuclear Matter effects
  - – Compared to charmonia
    - Different kinematics range (Bjorken-*x*) probed



Matsui & Satz, PLB168 (1986) 415

Mocsy, EPJC61 (2009) 705