ϒ measurement with ALICE

- Motivations
- ALICE muon spectrometer
- Nuclear modification factor
- pp collisions at $\sqrt{s}$ = 7 TeV (2011)
  - ϒ(1S) and ϒ(2S) differential cross section
- Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV (2011)
  - ϒ(1S) nuclear modification factor
- p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV (2013)
  - ϒ(1S) nuclear modification factor
  - ϒ(1S) forward-backward ratio

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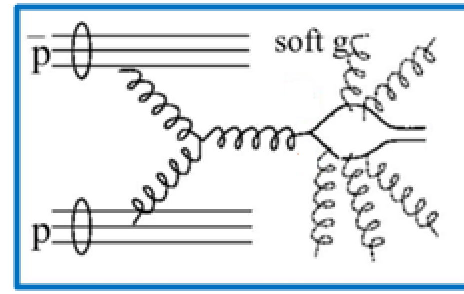
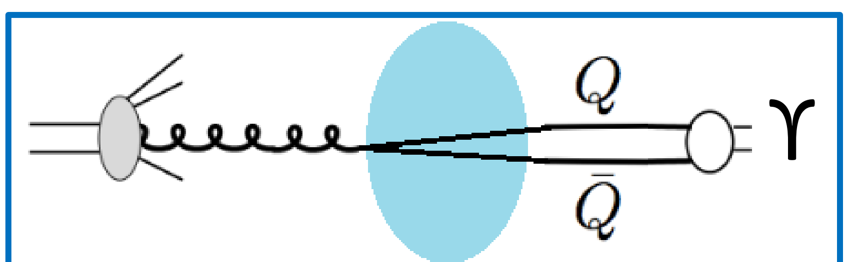
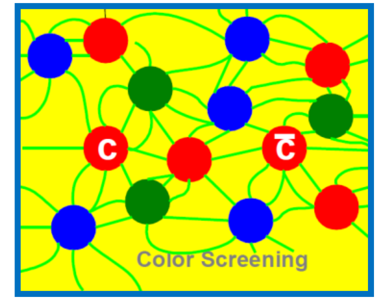
Motivations: pp and pA



- Proton-proton collisions
  - Testing the hadroproduction models (CEM, NRQCD: CSM, COM)
  - Baseline for pA and AA collisions measurements
- Proton-Nucleus collisions
  - Studying shadowing, saturation and energy loss at $x_{bjorken}$ and transfer momentum different than for J/ψ
  - Break-up should be small for the ϒ (long formation time, strong binding of beauty quark pairs)
  - Cold Nuclear Matter effects measurements are necessary for the study of hot nuclear matter effects in AA collisions



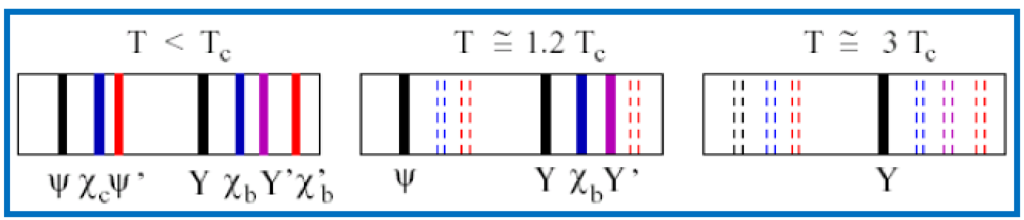
Motivations AA



- ➢Signature of the deconfinement
  - Quarkonium suppression by color screening

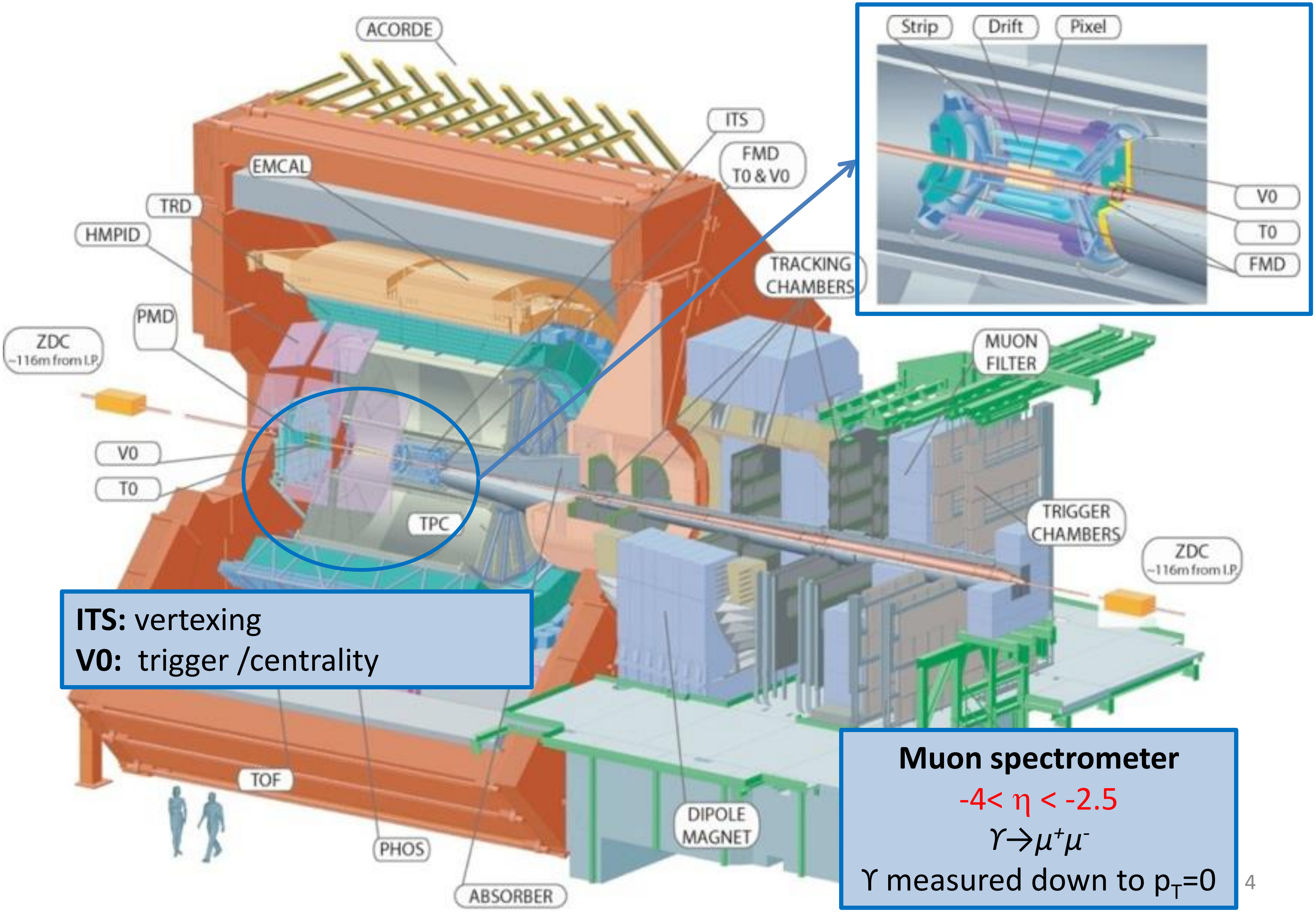
    (*Matsui and Satz, PLB 178 (1986) 416)*
- ➢ Temperature probe
  - Sequential suppression of quarkonia *(Digal et al. PRD 64 (2001) 0940150)*

    The ϒ(1S) should be suppressed at temperature much more important than other bottomonia (or charmonia). The ϒ family could serve as a very efficient thermometer



- ➢ Possible (re-)generation if beauty quark multiplicity is important
- ➢ Upsilon measurement:
  - ☺ Open heavy flavors doesn't decay into ϒ
  - ☺ ϒ (re-)generation shouldn't be very important
  - ☹ Important contribution from feed-down by higher mass bottomonia

The ALICE muon spectrometer

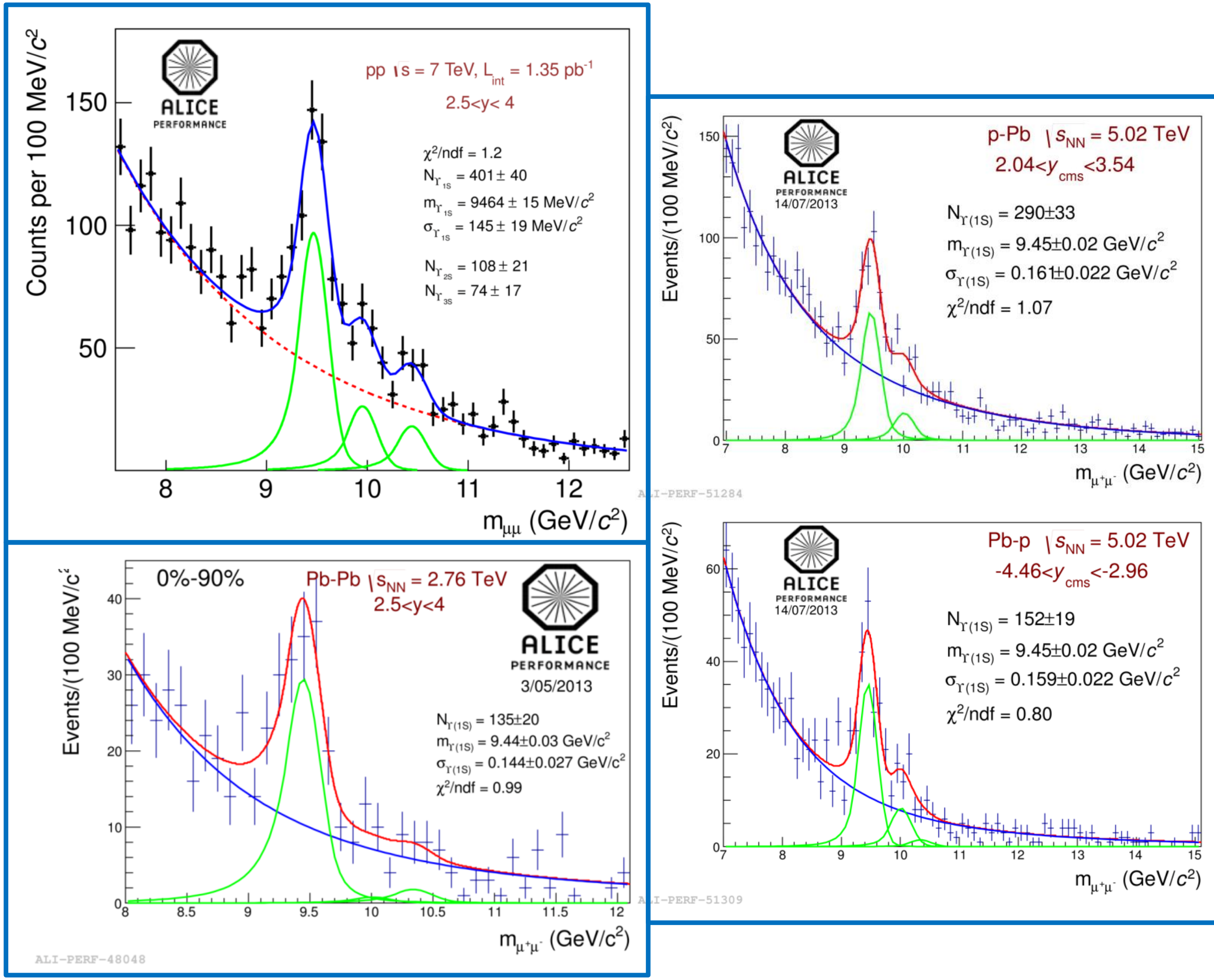


ITS: vertexing
V0: trigger /centrality

Muon spectrometer
$-4 < \eta < -2.5$
$\Upsilon \rightarrow \mu^+\mu^-$
Υ measured down to $p_T=0$

Invariant mass distributions

- ➢ The signal is extracted with a fit
- ➢ Low statistics:
- • Measurement of ϒ(1S) and ϒ(2S) in pp collisions
- • Measurement of ϒ(1S) in Pb-Pb, p-Pb and Pb-p



p-Pb and Pb-Pb collisions: R_{AA}

$$R_{PbPb(pPb)} = \frac{Y^{PbPb(pPb)}}{\langle T_{PbPb(pPb)} \rangle \times BR \times \frac{d\sigma_{pp}}{dy} \times \Delta y}$$

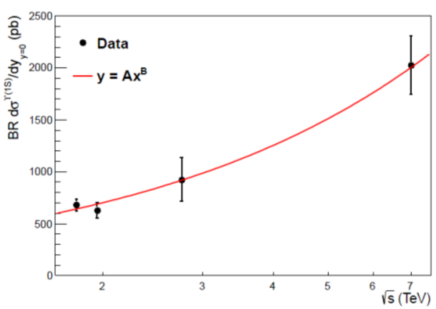
$$Y = \frac{N_{1S}}{N_{MB} \times A\varepsilon}$$

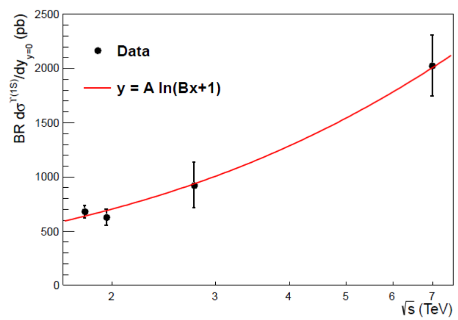
- Nuclear modification factor (R_{AA}):
  - Relative production of ϒ in Pb-Pb collisions with respect to pp collisions production at the same energy and scaled to the number of binary nucleon-nucleon collisions
  - $R_{AA} \neq 1 \rightarrow$ Nuclear effects

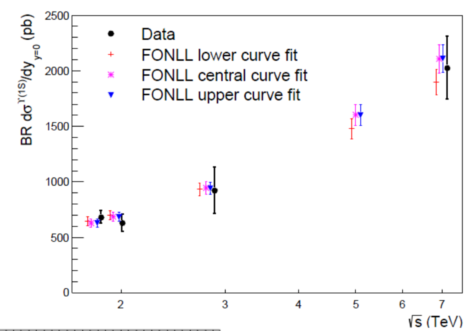
pp reference cross section for R_{AA}

- Υ was not measured in pp collisions at $\sqrt{s}$ = 5.02 TeV or $\sqrt{s}$ = 2.76 TeV in ALICE
- Estimate of $d\sigma_{pp}/dy$ at forward rapidity and $\sqrt{s}$ = 5.02 TeV or $\sqrt{s}$ = 2.76 TeV :
  1. Interpolation of $d\sigma/dy$ at y=0 from available mid-rapidity data (Tevatron+LHC)
  2. Extrapolation of $d\sigma/dy|_{y=0}$ at forward rapidity (2.5<y<4)

1.







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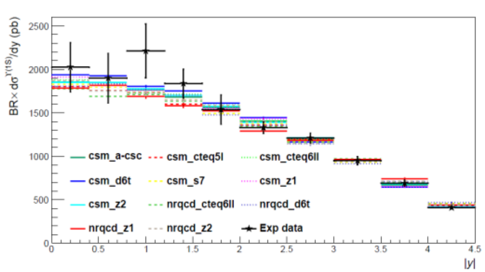
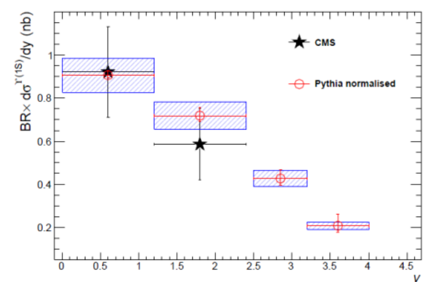




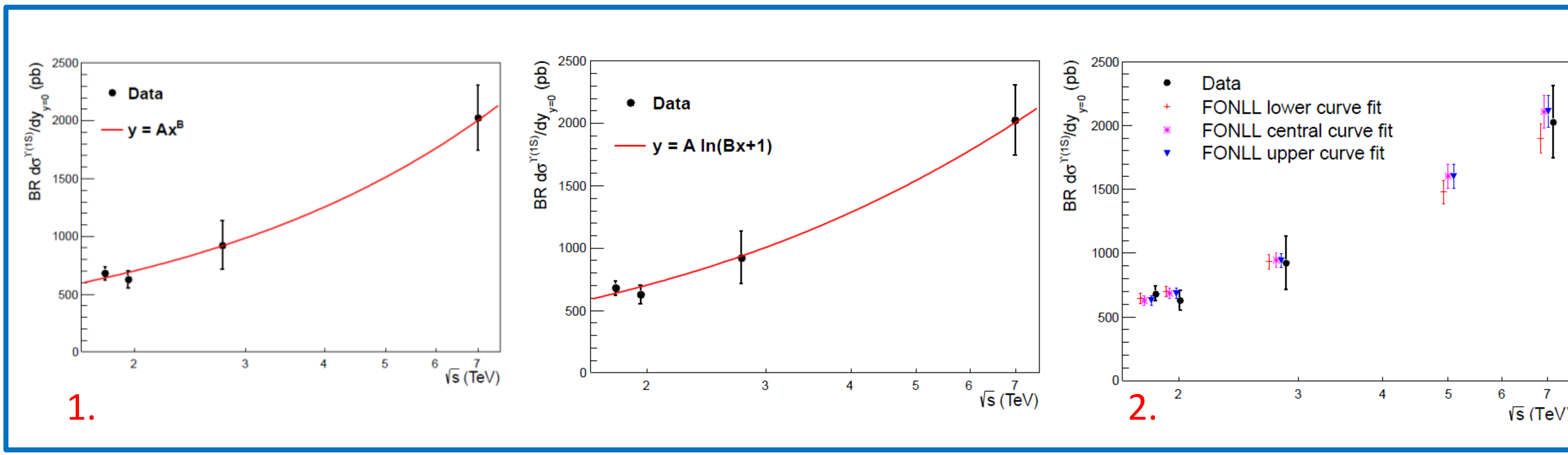
CDF(1.8 TeV) → D. Acosta et al. [CDF Collaboration], Phys. Rev. Lett. 88 (2002) 161802.
D0 (1.96 TeV) → V. M. Abazov et al. [D0 Collaboration], Phys. Rev. Lett. 94 (2005) 232001 [Erratum-ibid. 100 (2008) 049902] [hep-ex/0502030].
CMS(2.76 TeV) → S. Chatrchyan et al. [CMS Collaboration], JHEP 1205, 063 (2012) [arXiv:1201.5069 [nucl-ex]].
CMS(7 TeV) → V. Khachatryan et al. [CMS Collaboration], Phys. Rev. D 83, 112004 (2011) [arXiv:1012.5545 [hep-ex]].
LHCb(7 TeV) → R. Aaij et al. [LHCb Collaboration], Eur. Phys. J. C 72, 2025 (2012) [arXiv:1202.6579 [hep-ex]].

pp reference cross section for R_{AA}

- Interpolation of dσ/dy at y=0:
  1. Phenomenological approach
  2. Approach relying on pQCD and based on a CEM-like hypothesis

$$\left.\frac{d\sigma^{\Upsilon}}{dy}\right|_{y=0}\left(\sqrt{s}\right)=\alpha\cdot\left.\frac{d\sigma^{b\bar{b}}}{dy}\right|_{y=0}\left(\sqrt{s}\right)$$

- Production of beauty quark at various √s: pQCD FONLL
- α obtained by a fit of the ratio Data/pQCD FONLL



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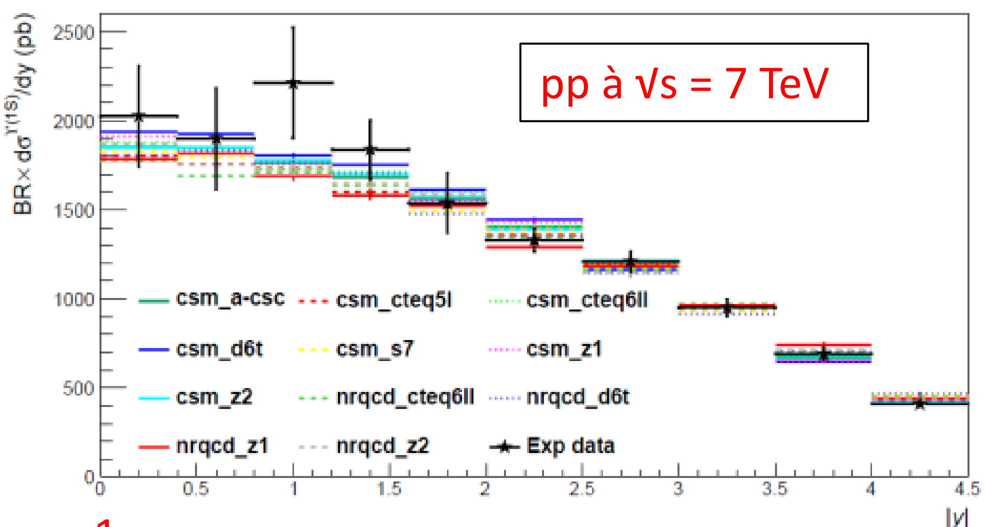
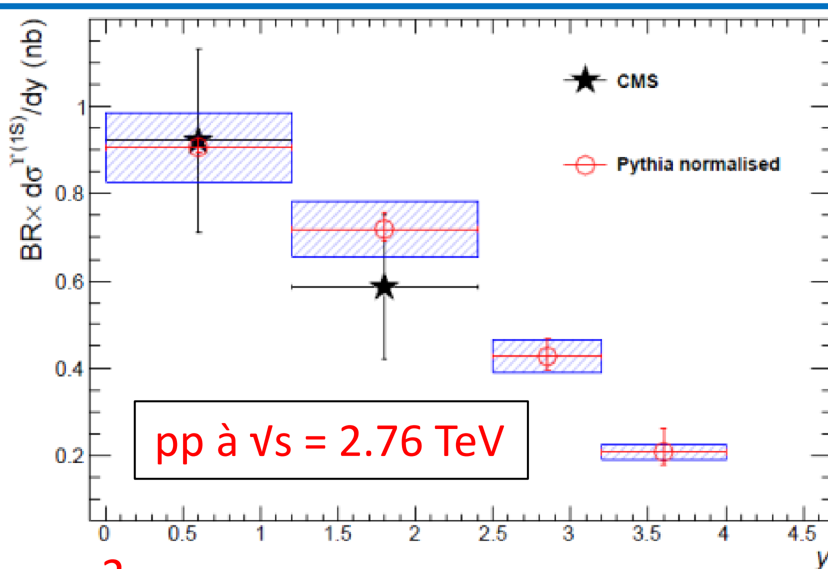
pp reference cross section for R_{AA}

- Extrapolation of $d\sigma/dy|_{y=0}$ at forward rapidity:
  1. Simulation of rapidity shapes on a large range with different tunings of Pythia 6.4 and shape selection according to their ability in reproducing pp at √s = 7 TeV data from LHCb (forward rapidity) and CMS (mid-rapidity)
  2. The shapes simulated at √s = 5.02 TeV or √s = 2.76 TeV with tunings which successfully passed the test are normalized to the interpolated $d\sigma/dy|_{y=0}$



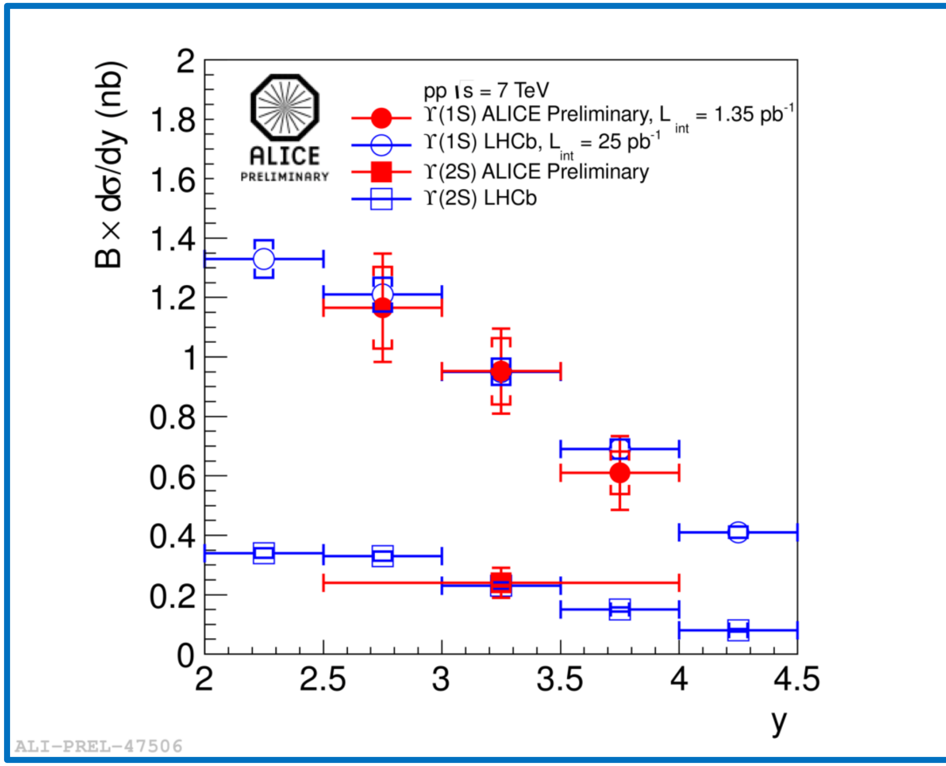
1.

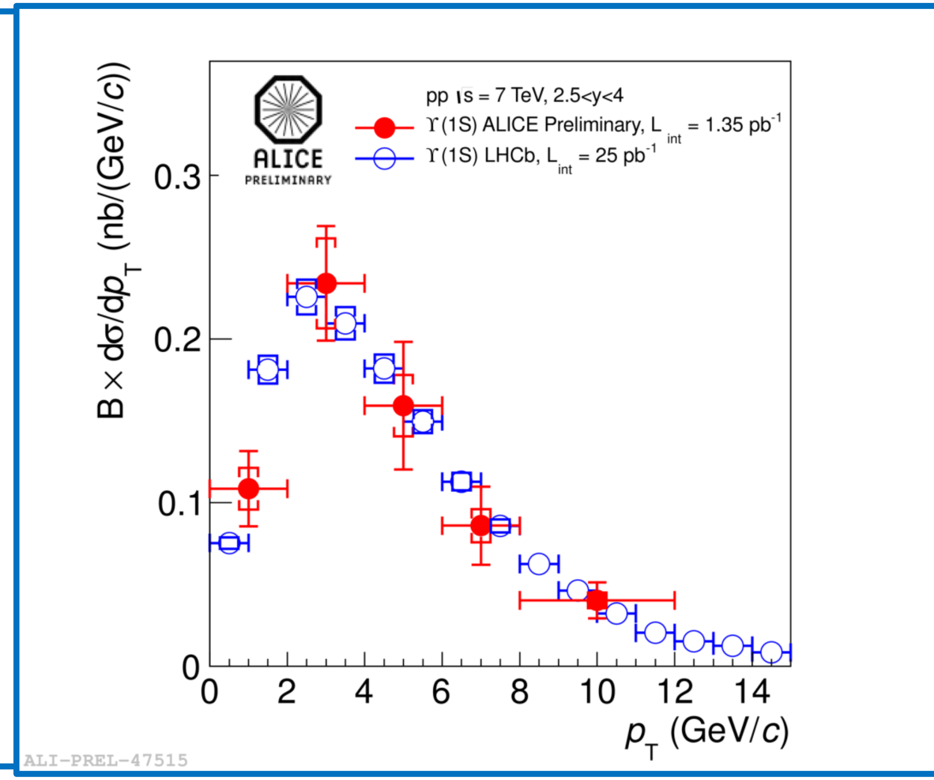


2.

CMS(7 TeV) → V. Khachatryan et al. [CMS Collaboration], Phys. Rev. D 83, 112004 (2011) [arXiv:1012.5545 [hep-ex]].
LHCb(7 TeV) → R. Aaij et al. [LHCb Collaboration], Eur. Phys. J. C 72, 2025 (2012) [arXiv:1202.6579 [hep-ex]].

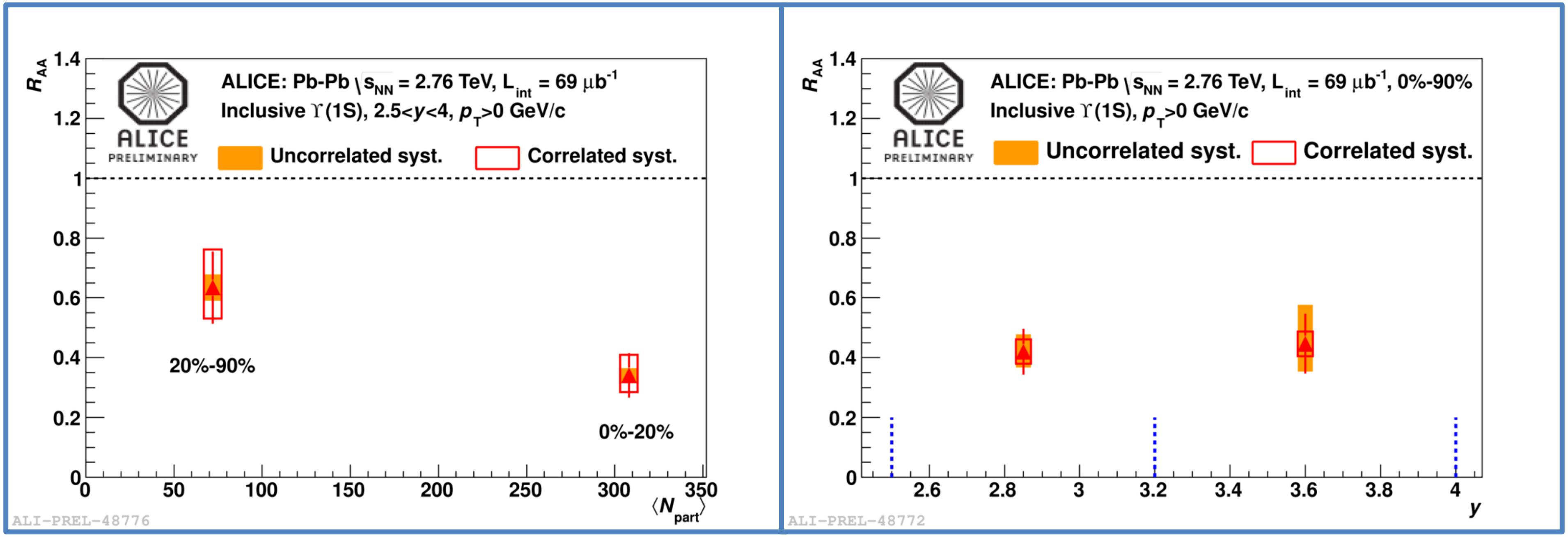
Cross section in pp collisions at √s = 7 TeV





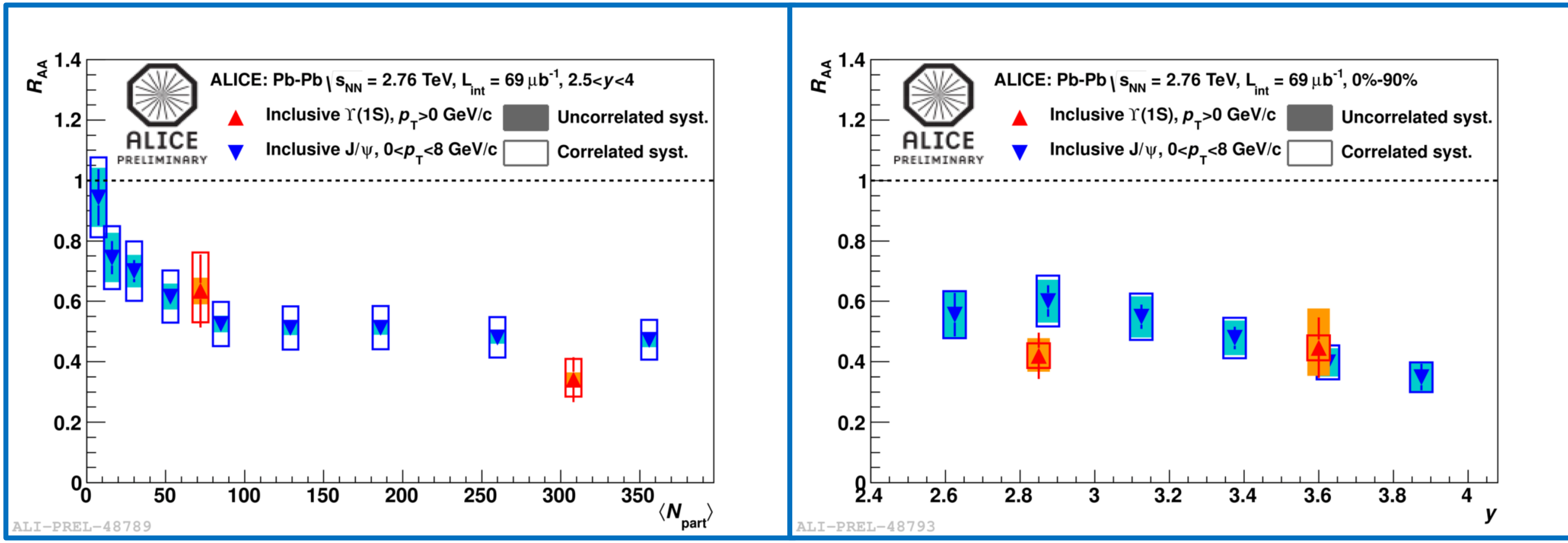
- ALICE and LHCb results are compatible *(EPJC 72 (2012) 2025)*
- Ability of ALICE in measuring ϒ

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



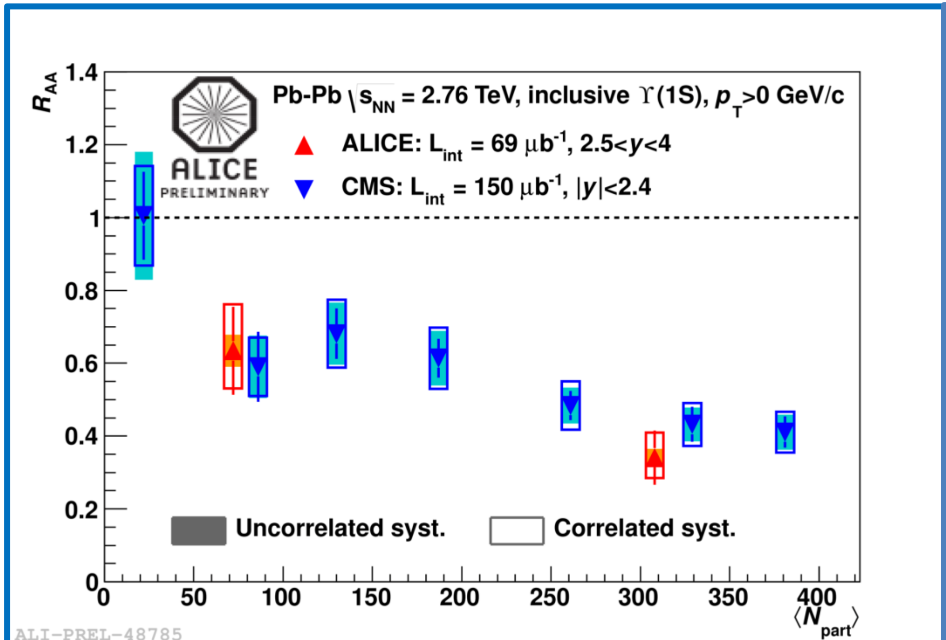
- Inclusive Υ(1S) is suppressed at forward rapidity
- The suppression is more important in central collisions
- The suppression is rather rapidity independent

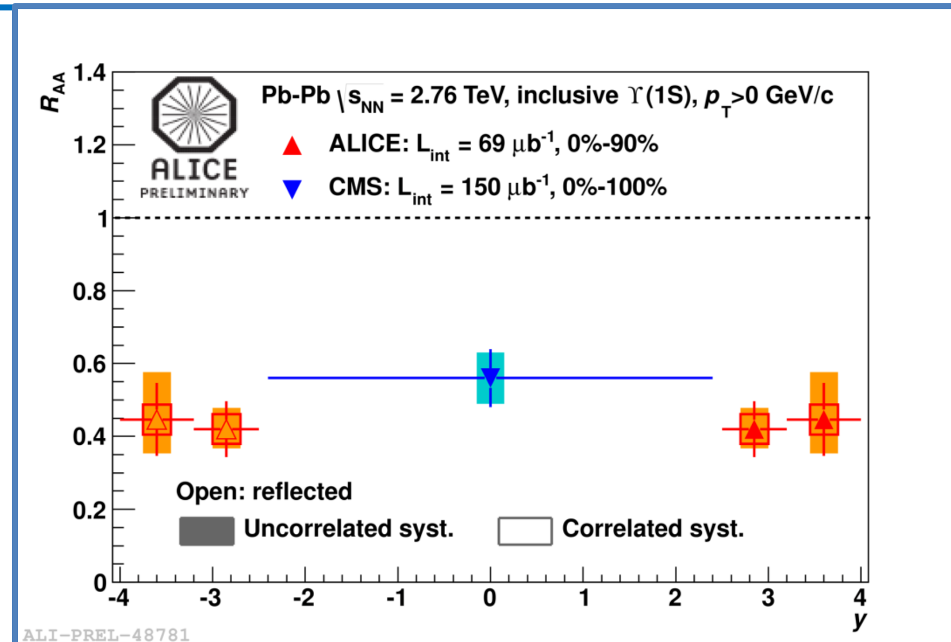
Inclusive Υ(1S) R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
Comparison with J/ψ data at forward rapidity



- The suppression of Υ(1S) and J/ψ is compatible at forward rapidity
- No straightforward interpretation can be given due to the unknown contributions of the suppression, the (re-)generation and the feed-down for J/ψ and Υ (Υ(1S) ~50% feed-down *(CDF: PRL 84, 2094 (2000))*)

Inclusive Υ(1S) R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV ALICE (2.5<y<4) and CMS (|y|<2.4) data

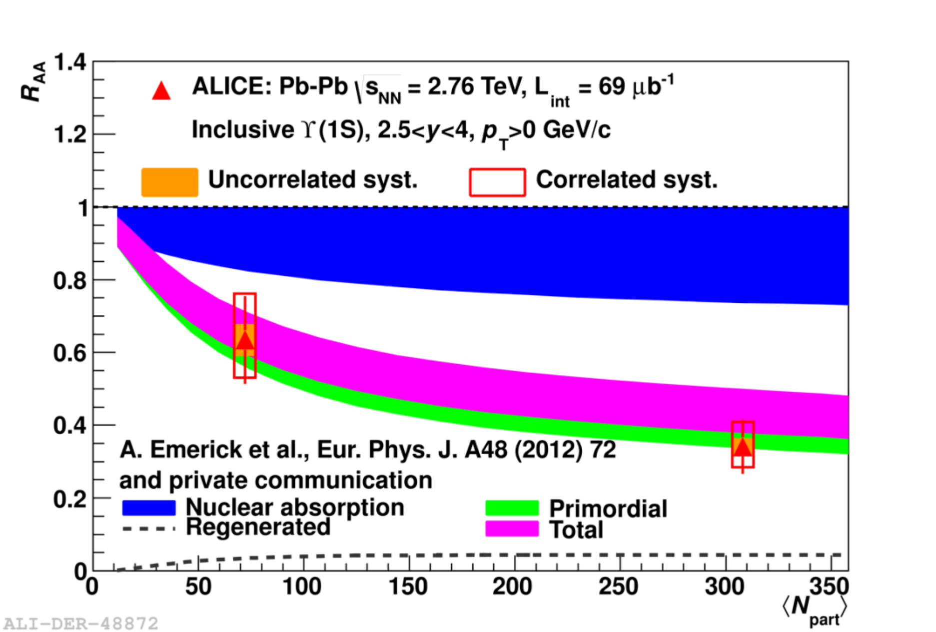


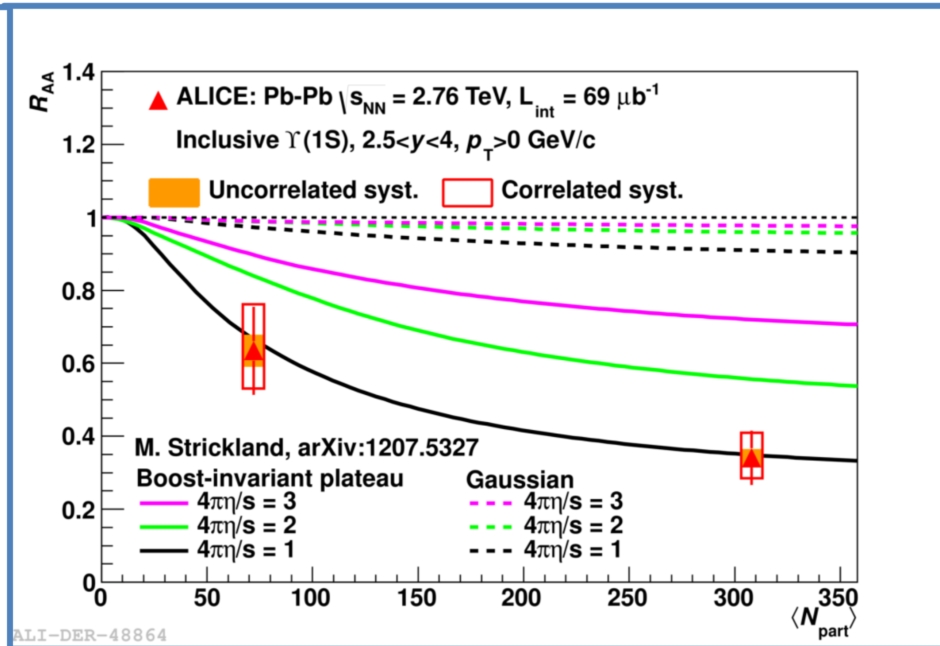


CMS data: PRL 109, 222301 (2012)

- The suppressions observed by ALICE and CMS are compatible
- The Υ(1S) suppression is rather weakly dependent on rapidity on the large interval covered by ALICE and CMS

Inclusive ϒ(1S) R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
Comparison with models



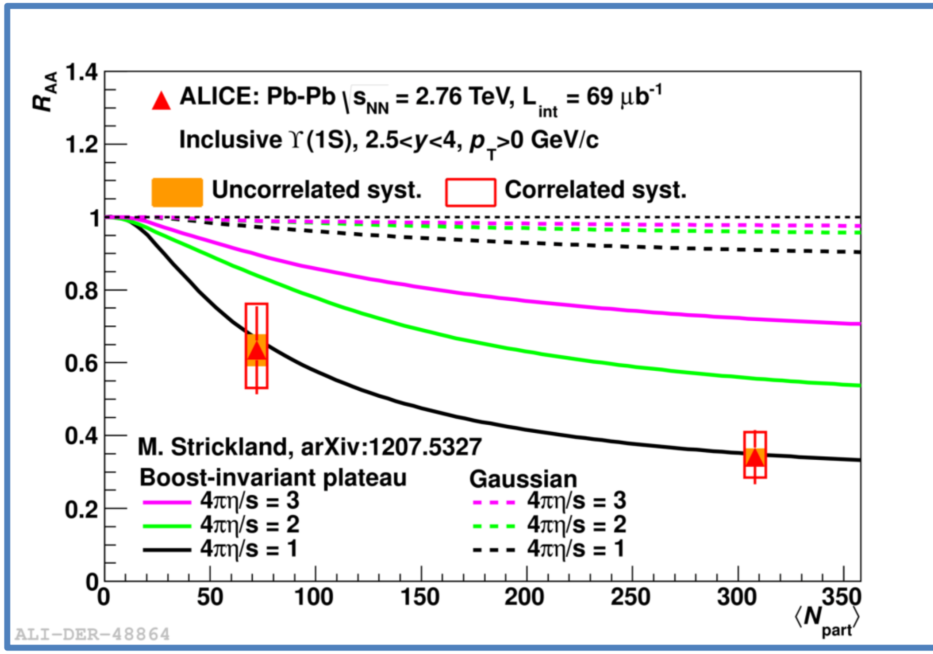


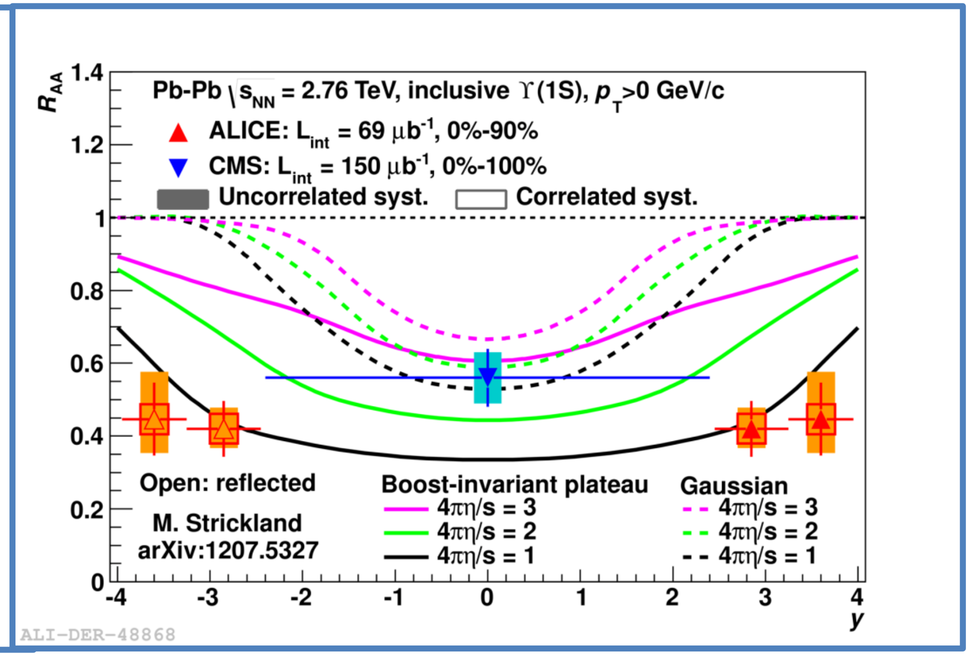
- Transport model with direct suppression
- Hypothesis: « strong binding scenario »
  → very small suppression of direct ϒ(1S)
  (due almost exclusively to CNM effects)
  → small regeneration component
- Isentropically expanding isotropic fire cylinder
- Feed-down taken into account
- CNM effects implemented with a phenomenological absorption cross section

- Screened potential model
  → small suppression of direct ϒ(1S)
  → No regeneration
- Anisotropic hydrodynamic formalism (HYDRO)
  → connection of the early stage of the QGP evolution with final stage (shear viscosity)
- Feed-down taken into account
- CNM effects not implemented

➢ Data are reasonably described by the transport model

Inclusive ϒ(1S) R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
Comparison with models

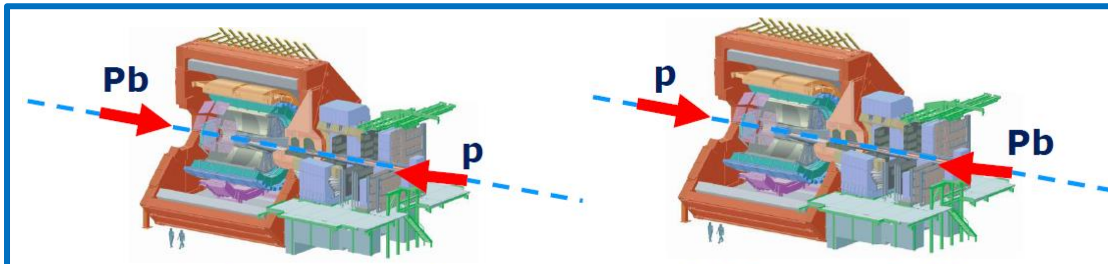




- The hydrodynamic model describes reasonably well the data with a boost invariant initial temperature profile and a minimal shear viscosity for the QGP

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

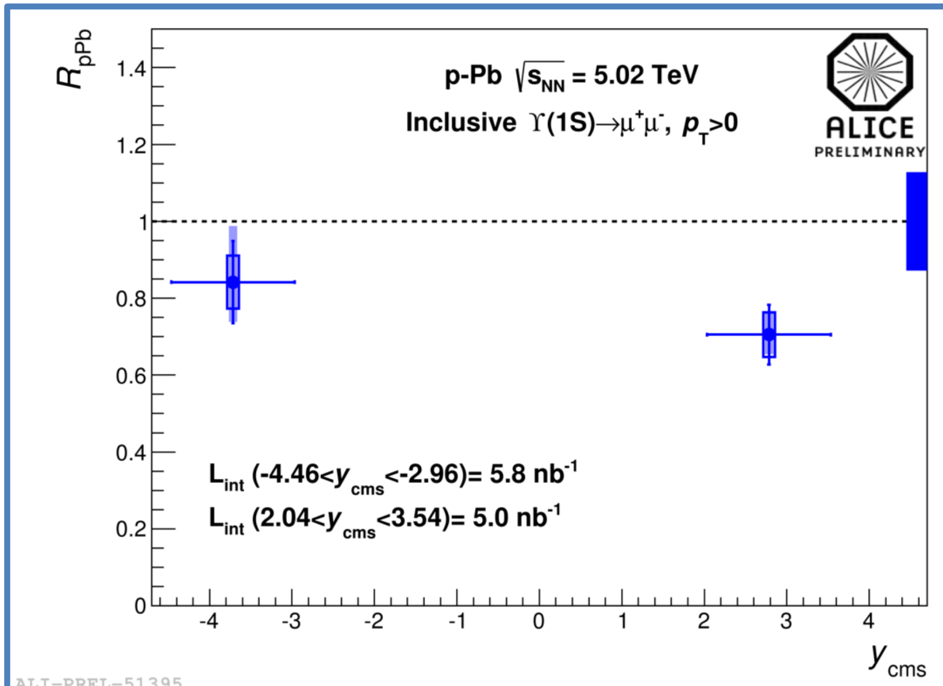
- The two LHC beam configurations allow to measure the Υ(1S) production at forward and backward rapidity



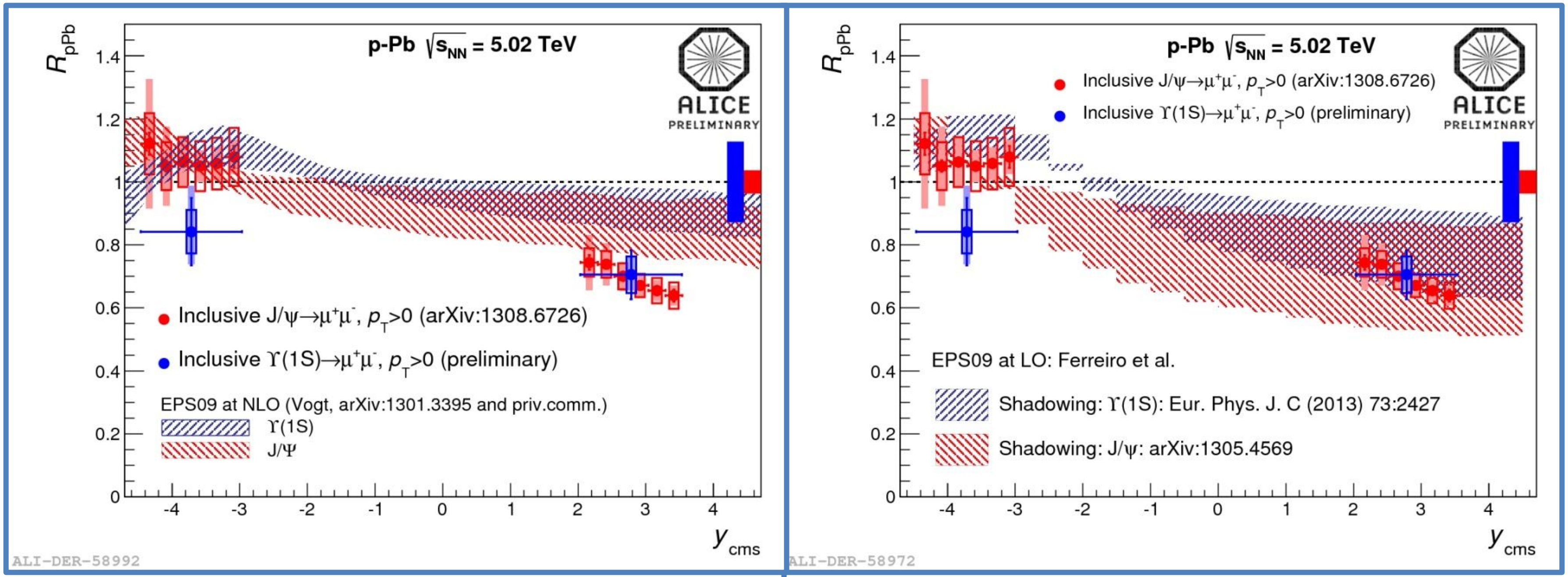
$-4.46<y_{CMS}<-2.96$ | $2.03<y_{CMS}<3.53$

$3.6\times10^{-2}<x_{bjorken}<0.16$ | $5\times10^{-5}<x_{bjorken}<3\times10^{-4}$

- Backward: data compatible with almost no suppression
- Forward: more suppression



$\Upsilon(1S)$ R_{pA} in p-Pb and Pb-p collisions at $\sqrt{s_{NN}}$ =5.02 TeV
EPS09 LO and EPS09 NLO

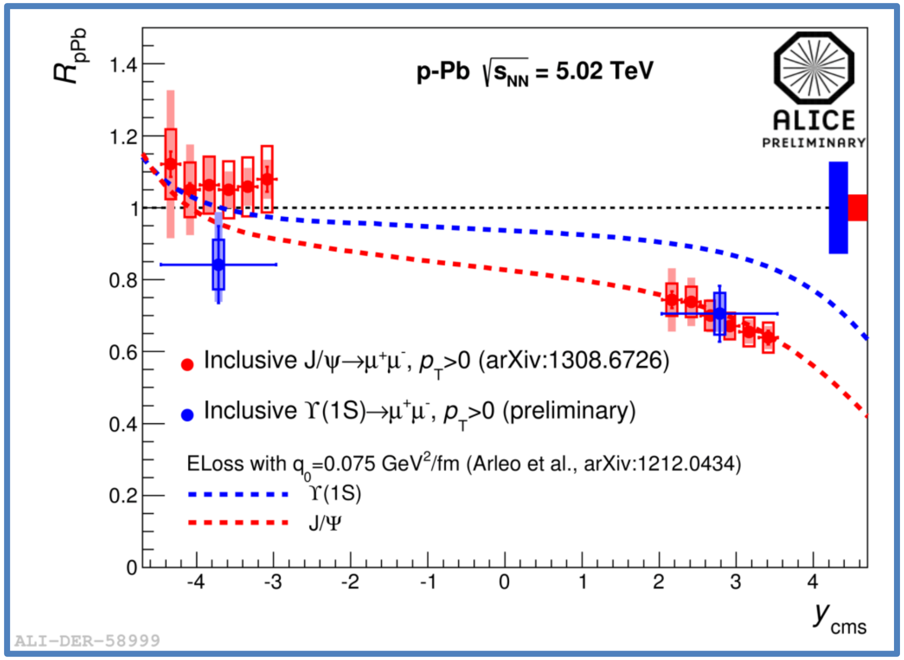


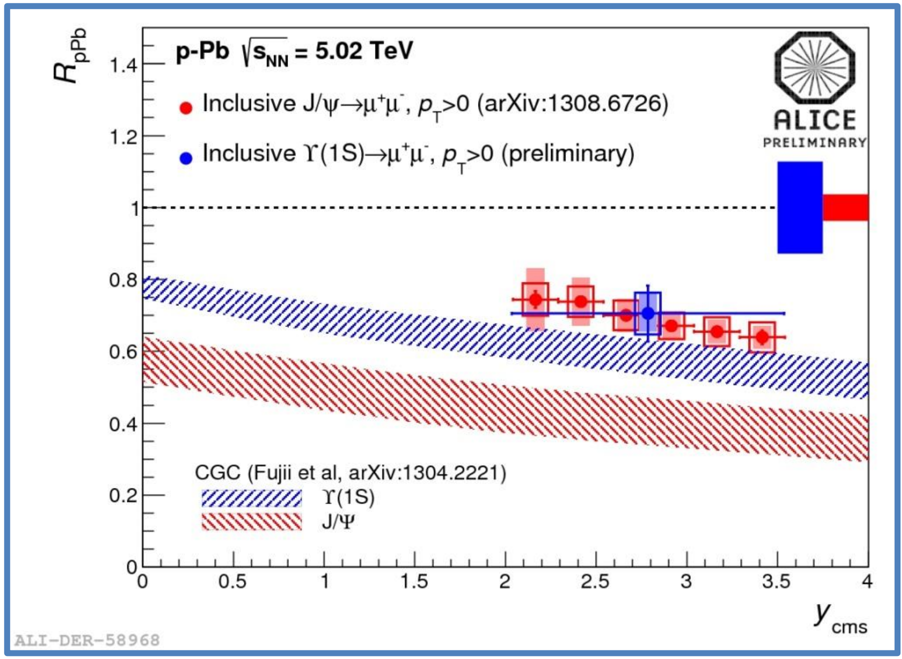
- NLO calculations
- Production model: CEM , 2→1 mechanism
- Error band: 30 EPS09 sets considered

- LO calculations
- Production model: CSM, 2→2 mechanism
- Error bands: Two identified EPS09 sets with maximum and minimum shadowing

- ϒ(1S) and J/ψ suppressions are compatible
- EPS09 NLO and LO predictions reproduce the data
- EPS09 NLO tends to underestimate the ϒ(1S) suppression at forward rapidity
- Better agreement with J/ψ data

Υ(1S) R_{pA} in p-Pb and Pb-p collisions at $\sqrt{s_{NN}}$ =5.02 TeV
Energy Loss and CGC models



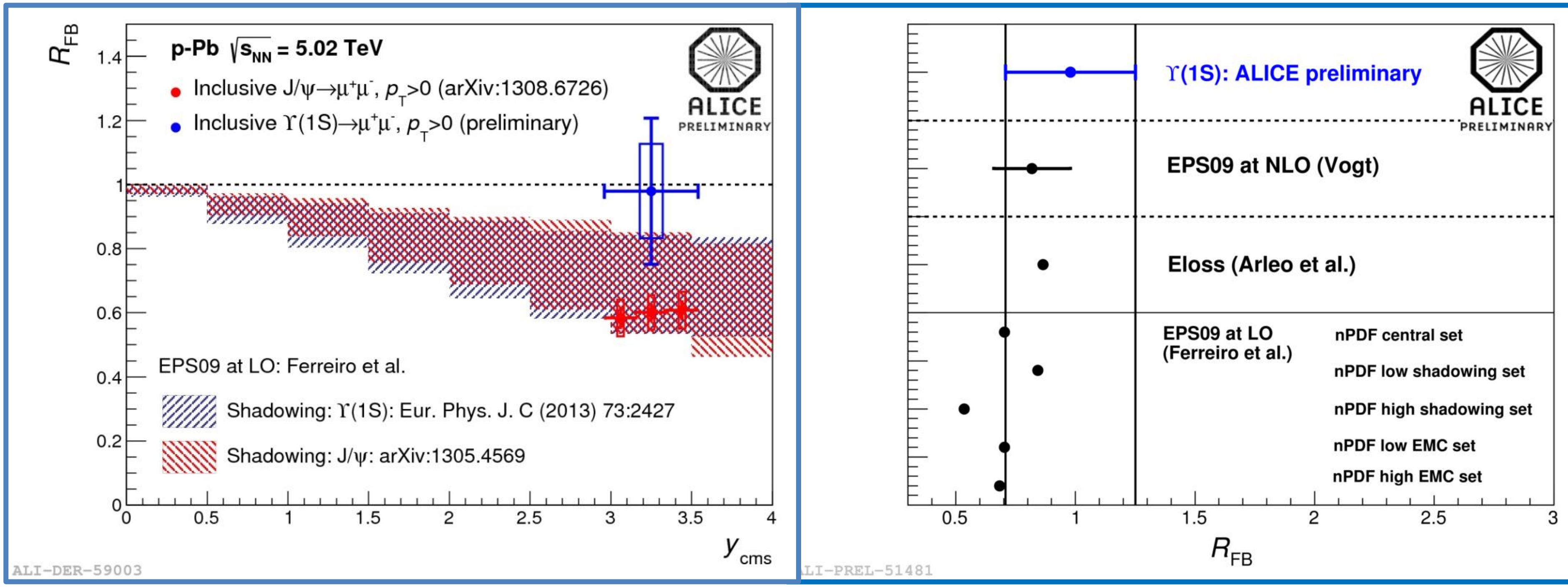


- Coherent parton energy loss:
  - Medium induced energy loss
  - Longed-lived, color octet heavy quark pairs
  - Single free parameter q_0
- See next talk by François Arleo

- Heavy quark pairs produced by a dense medium made of gluons of small $x_{bjorken}$ (saturation)
- Quarkonia production: CEM

- The energy loss model reproduces the data but tends to underestimate the Υ(1S) suppression at forward rapidity
- The CGC model is disfavored by J/ ψ data, results are better with Υ(1S) data

Forward-Backward ratio of inclusive Υ(1S): R_{FB}



- In the R_{pPb}/R_{Pbp} ratio the reference pp cross section and associated uncertainties are washed out but less statistics is available in the common y_{cms} range
- The Υ(1S) R_{FB} is compatible with the unity
- The J/ψ R_{FB} is significantly smaller than for Υ(1S)
- On the contrary to J/ψ , Υ data tends to favor a small shadowing effect
- Models describe Υ(1S) R_{FB}

Conclusion

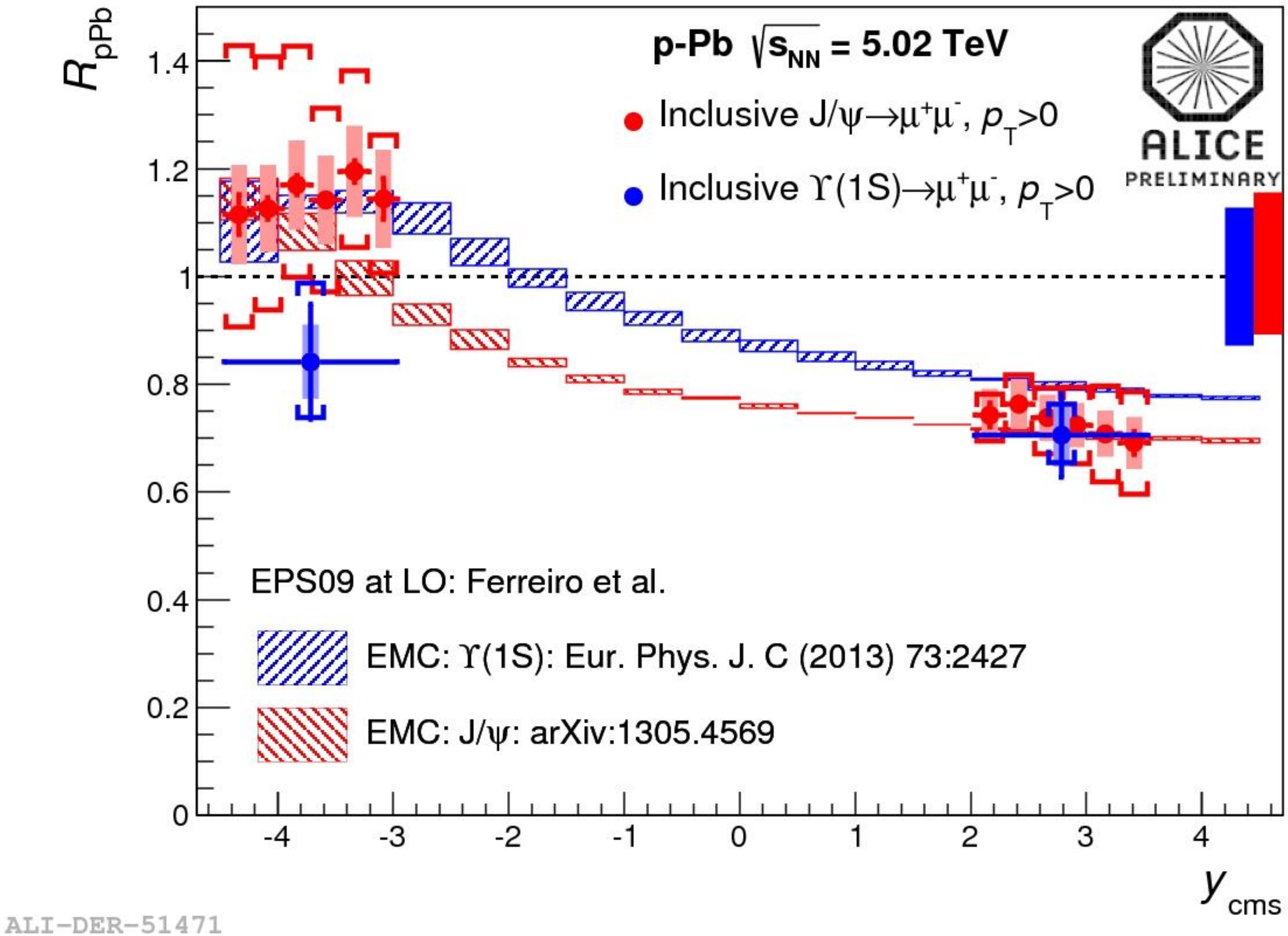
- pp collisions at $\sqrt{s}$ = 7 TeV
  - The inclusive Υ(1S) differential cross section has been measured as a function of y and p_T
- PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
  - The nuclear modification factor of inclusive Υ(1S) has been measured as a function of the centrality and of the rapidity
  - A suppression is observed and is more important in central collisions
  - The suppression is rather weakly dependent on rapidity in the large range covered by ALICE (2.5<y<4) and CMS (|y|<2.4)
  - Two models with different ingredients for the quarkonia/QGP interactions and the space-time evolution of the QGP describe reasonably well the data
- p-Pb and Pb-p collsions at $\sqrt{s_{NN}}$ = 5.02 TeV
  - R_{pPb}, R_{Pbp} and their ratio has been measured for the inclusive Υ(1S) as a function of y_{cms}
  - At backward rapidity data are compatible with an almost inexistent suppression
  - At forward rapidity data are more suppressed
  - Data are reasonably well reproduced by EPS09 NLO, LO, Coherent parton energy loss and a CGC model predictions within large experimental uncertainties

ALICE

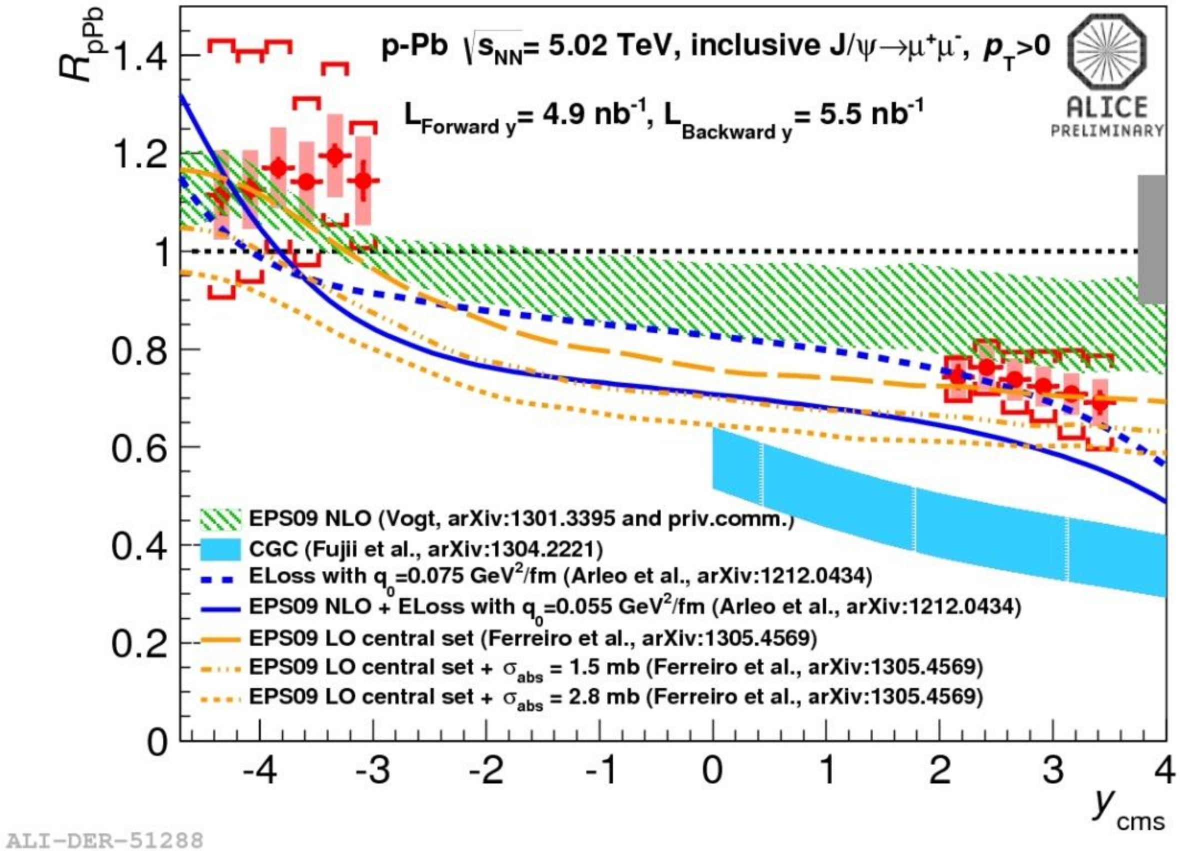
INFN

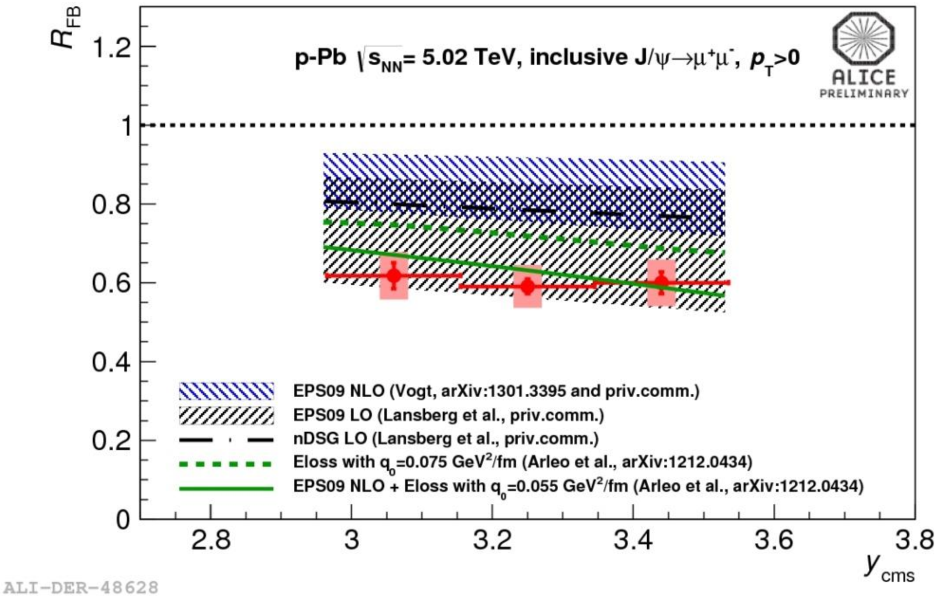
Back up

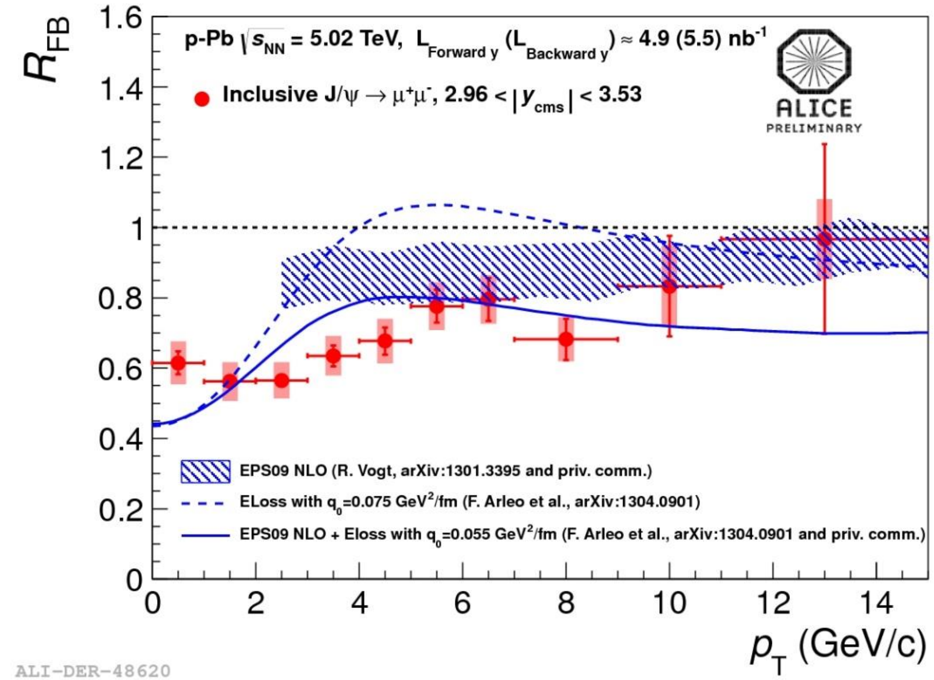
ϒ(1S) dans les collisions p-Pb Pb-p

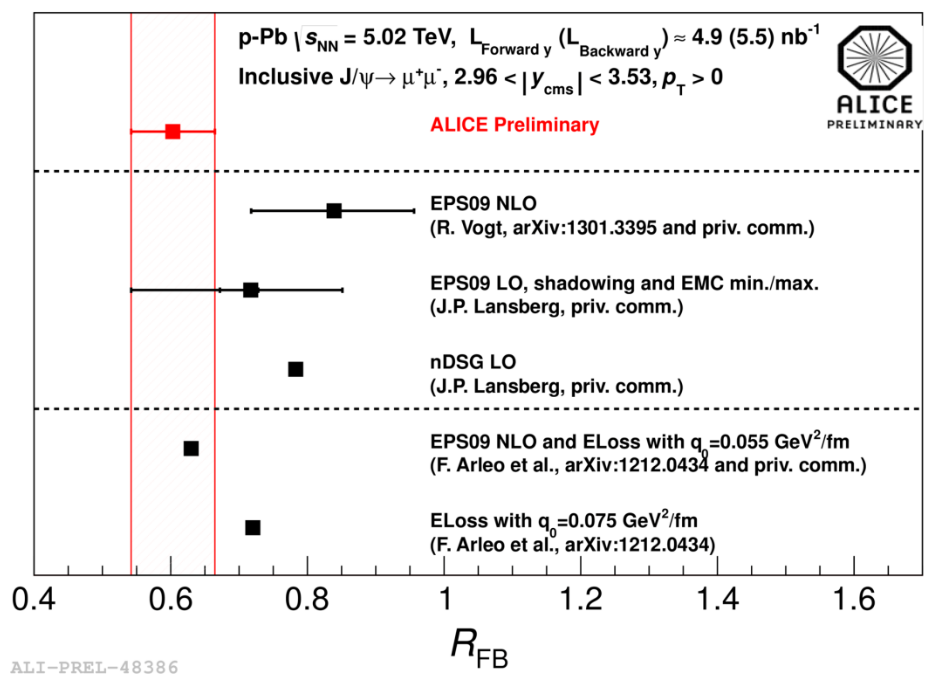


J/ψ dans les collisions p-Pb et Pb-p

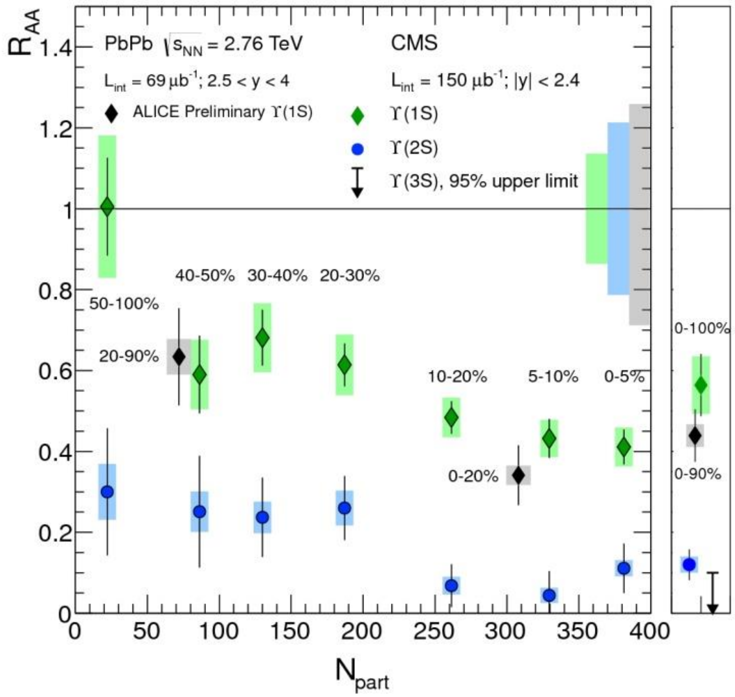


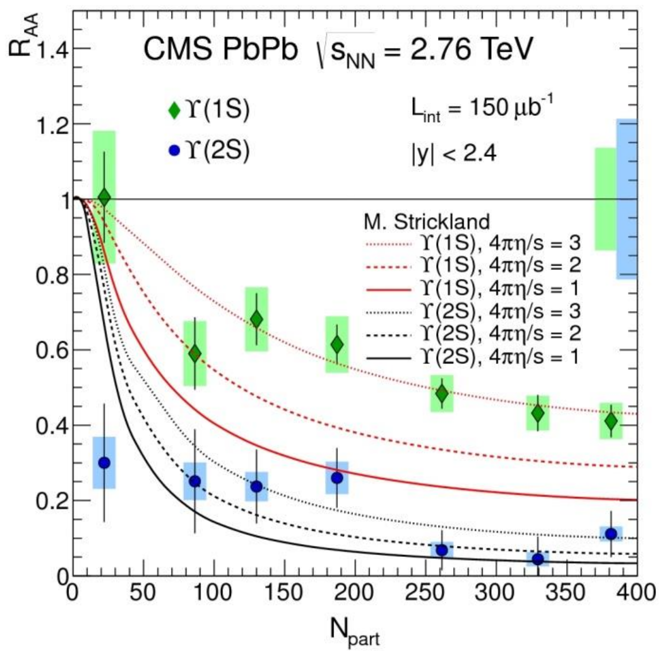

p-Pb √sNN = 5.02 TeV, inclusive J/ψ→μ+μ-, pT>0
ALICE PRELIMINARY
RFB
ycms
EPS09 NLO (Vogt, arXiv:1301.3395 and priv.comm.)
EPS09 LO (Lansberg et al., priv.comm.)
nDSG LO (Lansberg et al., priv.comm.)
Eloss with q0=0.075 GeV2/fm (Arleo et al., arXiv:1212.0434)
EPS09 NLO + Eloss with q0=0.055 GeV2/fm (Arleo et al., arXiv:1212.0434)
ALI-DER-48628

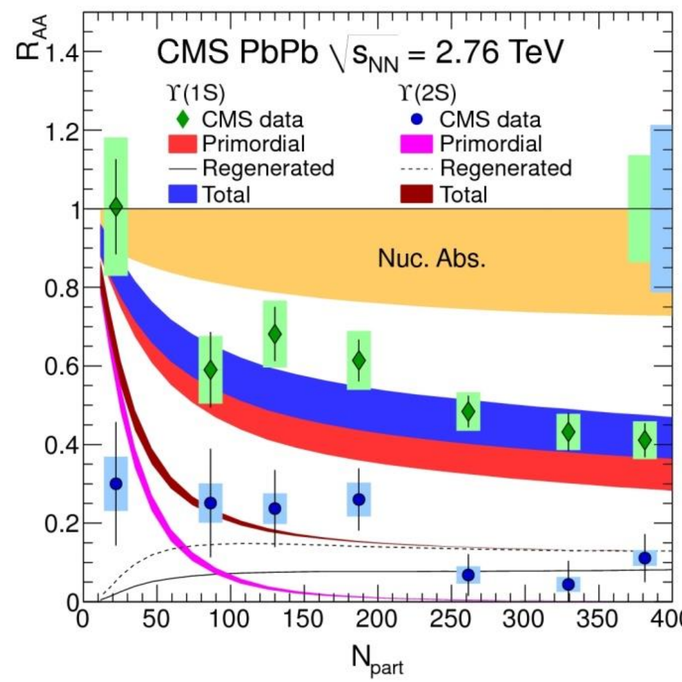

p-Pb √sNN = 5.02 TeV, LForward y (LBackward y) ≈ 4.9 (5.5) nb-1
Inclusive J/ψ → μ+μ-, 2.96 < |ycms| < 3.53
ALICE PRELIMINARY
RFB
pT (GeV/c)
EPS09 NLO (R. Vogt, arXiv:1301.3395 and priv. comm.)
ELoss with q0=0.075 GeV2/fm (F. Arleo et al., arXiv:1304.0901)
EPS09 NLO + Eloss with q0=0.055 GeV2/fm (F. Arleo et al., arXiv:1304.0901 and priv. comm.)
ALI-DER-48620


p-Pb √sNN = 5.02 TeV, LForward y (LBackward y) ≈ 4.9 (5.5) nb-1
Inclusive J/ψ→ μ+μ-, 2.96 < |ycms| < 3.53, pT > 0
ALICE PRELIMINARY
ALICE Preliminary
EPS09 NLO
(R. Vogt, arXiv:1301.3395 and priv. comm.)
EPS09 LO, shadowing and EMC min./max.
(J.P. Lansberg, priv. comm.)
nDSG LO
(J.P. Lansberg, priv. comm.)
EPS09 NLO and ELoss with q0=0.055 GeV2/fm
(F. Arleo et al., arXiv:1212.0434 and priv. comm.)
ELoss with q0=0.075 GeV2/fm
(F. Arleo et al., arXiv:1212.0434)
RFB
ALI-PREL-48386

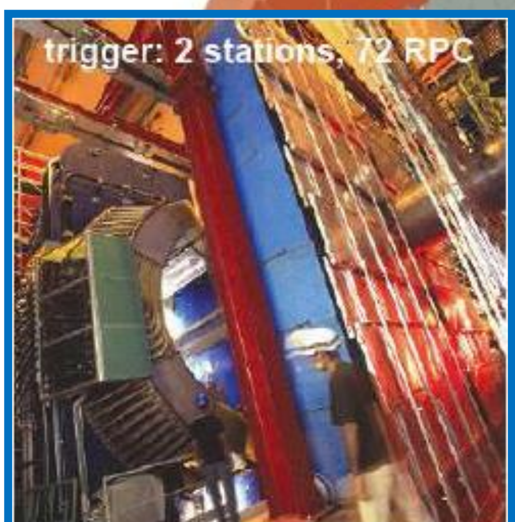
CMS

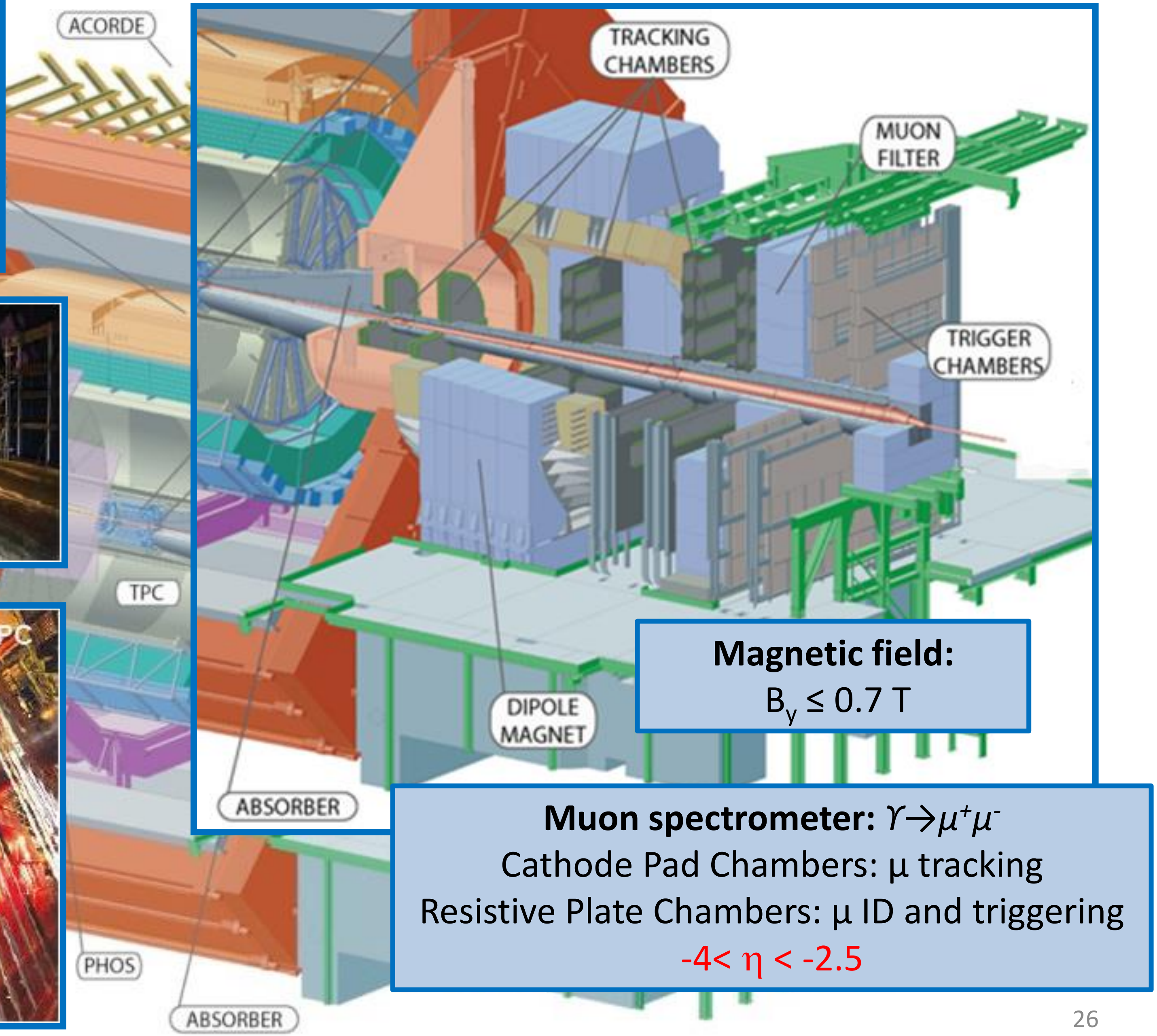

PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
L_{int} = 69 μb^{-1}; 2.5 < y < 4
ALICE Preliminary ϒ(1S)
CMS
L_{int} = 150 μb^{-1}; |y| < 2.4
ϒ(1S)
ϒ(2S)
ϒ(3S), 95% upper limit
50-100%
40-50%
30-40%
20-30%
20-90%
10-20%
5-10%
0-5%
0-20%
0-100%
0-90%
R_{AA}
N_{part}


CMS PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
ϒ(1S)
ϒ(2S)
L_{int} = 150 μb^{-1}
|y| < 2.4
M. Strickland
ϒ(1S), 4πη/s = 3
ϒ(1S), 4πη/s = 2
ϒ(1S), 4πη/s = 1
ϒ(2S), 4πη/s = 3
ϒ(2S), 4πη/s = 2
ϒ(2S), 4πη/s = 1
R_{AA}
N_{part}


CMS PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
ϒ(1S)
CMS data
Primordial
Regenerated
Total
ϒ(2S)
CMS data
Primordial
Regenerated
Total
Nuc. Abs.
R_{AA}
N_{part}

The muon spectrometer





Magnetic field:
$B_y \leq 0.7$ T

Muon spectrometer: $\Upsilon \rightarrow \mu^+\mu^-$
Cathode Pad Chambers: μ tracking
Resistive Plate Chambers: μ ID and triggering
$-4 < \eta < -2.5$