Upsilon(ϒ) production in ALICE : status and future prospects

XXIV QUARK MATTER DARMSTADT 2014

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ABSTRACT

The production of bottomonium states and their suppression is a probe of the properties of the hot and dense medium created in high-energy heavy-ion collisions. In particular, some of the ϒ states have a smaller size and larger binding energy than the J/Ψ and their study provides valuable information complementary to those obtained from charmonium. The ϒ(1S) state is expected to dissociate at a higher temperature than all the other quarkonium states, thus proving to be an effective thermometer of the system. This poster will highlight details of the ϒ analysis in Pb-Pb collisions, along with future prospects of ϒ studies in the ALICE experiment for the upcoming Run-2 of the LHC.

INTRODUCTION

Charmonia: J/ψ, Ψ ', $\chi_{c,}$ **Bottomonia**: ϒ (1S), ϒ' (2S), ϒ''(3S)

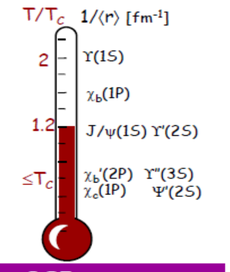
Lattice QCD: Evaluation of spectral functions ⇒ $T_{melting}$

Models based on potential with largest possible binding ⇒ most bound charmonium states melt by $1.3T_c$. Upsilon (1S) survives until $2T_c$. (PRL 99, 211602)

Lattice results : Consistent with quarkonium melting

Suppression pattern → thermometer of QCD matter

Upper limit melting temperatures



The QGP thermometer

(courtesy: A .Mocsy, 417th WE-Heraeus-Seminar,2008)

Charmonia :

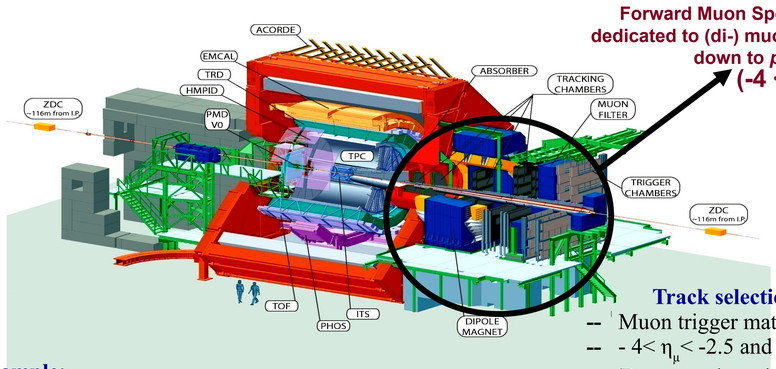
– Regeneration, from coalescence of charm and anti-charm quarks, is the dominant mechamism at LHC.
– This effect makes the quantitative analysis of suppression effects more difficult.

Bottomonia :

– Regeneration effects are much weaker.
– No feed-down from open heavy-flavors but only from higher-mass bottomonia.
– Suppression effects **should be more evident.**

ALICE ϒ ANALYSIS IN Pb+Pb 2.76 TeV

The ALICE experiment (LHC-CERN)
A Large Ion Collider Experiment



Forward Muon Spectrometer is dedicated to (di-) muon measurement down to $p_T = 0$ ($-4 < \eta_{lab} < -2.5$)

Track selection:

-- Muon trigger matching
-- $-4 < \eta_\mu < -2.5$ and $17.6 < R_{abs} < 89$ cm (R_{abs} = track position at the absorber end)
-- $-4 < y_{\mu\mu} < -2.5$ and track momentum > 2 GeV/c

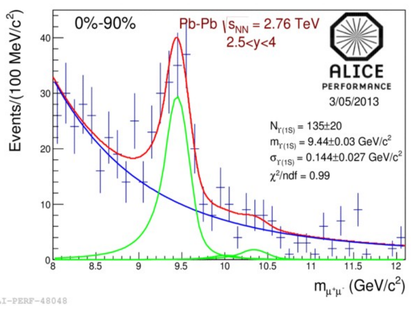
Data sample:

- Minimum bias trigger (V0A && V0C && SPD)
- Rejecting beam-gas interactions by selecting tracks pointing to the interaction vertex
- Run selection dependent on the stability of the muon spectrometer tracking and triggering performance

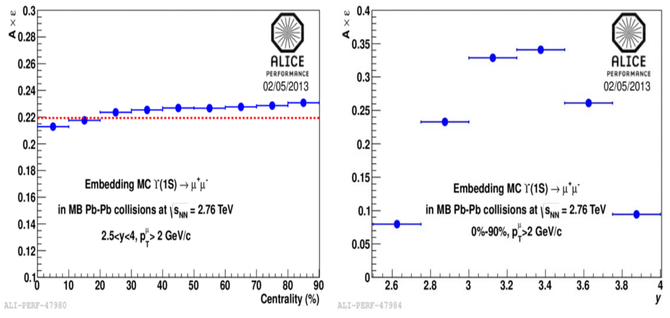
Centrality selection:

- Based on a geometrical-Glauber model fit of the V0 amplitude
- Centrality bins used in this analysis: [0% - 20%], [20% - 90%] & [0% - 90%] with rapidity bins [$y_{\mu\mu}$] (2.5 to 3.2) and (3.2 to 4.0)

◊ **Integrated luminosity after data selection: 69 μb^{-1}**



On the plot: total fit function (**red**), signal (**green**) and the background (**blue**)



- **The ϒ signal** is extracted by means of a fit to the opposite-sign dimuon invariant mass spectrum
- The ϒ line-shapes are described by extended crystal ball with the tail parameters fixed with Monte Carlo results
- The underlying background is fitted using a sum of two exponentials or a sum of two power-law functions
- The amplitude, position and width of ϒ(1S) are kept as free parameters
- Parameters of the double exponential and amplitude of ϒ(2S) and ϒ(3S) kept free
- Width of 2S and 3S constrained to those of 1S as per PDG ratio
- The mass differences between states were fixed from PDG values

- Acc × Eff correction plotted as a function of **centrality** and **rapidity**
- Small decreasing of the reconstruction efficiency with increasing centrality ~7% due to increasing detector occupancy
- Acc x eff peaked at mid-rapidity and decreasing towards the edge of the acceptance
- Systematic uncertainty on ϒ (1S) cross section includes conributions from tracking (~10%) and trigger (~2%) efficiencies, matching between tracking and trigger detectors (1%), signal extraction (~5-10 %) and Monte Carlo inputs to acceptance calculation (~4-7%)

ϒ(1S) R_{AA}

ϒ(1S) yield per unit rapidity

$$\frac{dY_{\Upsilon(1S)}}{dy} = \frac{N_{\Upsilon(1S)}}{BR \cdot N_{MB} \cdot A \times \varepsilon \cdot \Delta y}$$

0% - 90%	($R_{AA}^{\Upsilon(1S)}$ ± stat. ± uncorr. ± corr.)
2.5< y < 4.0 $p_T > 0$	0.304 ± 0.046 ± 0.019 ± 0.037

ϒ(1S) Nuclear Modification factor

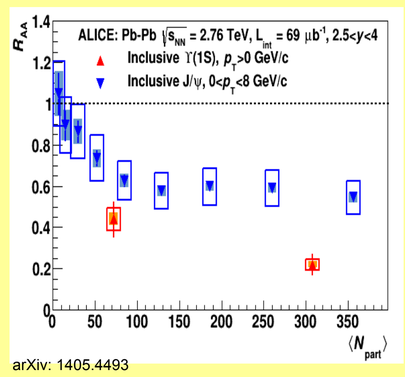
$$R_{AA} = \frac{\frac{dY_{\Upsilon(1S)}}{dy}}{\langle T_{AA} \rangle \cdot \frac{d\sigma^{pp}}{dy}}$$

$\langle T_{AA} \rangle$ = the average nuclear overlap function

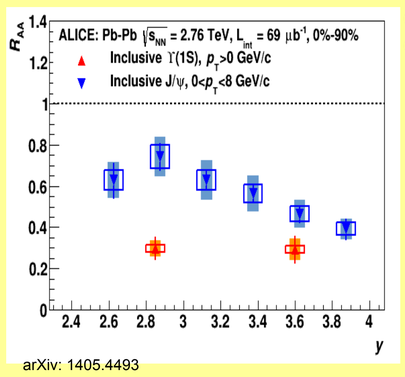
$\frac{d\sigma_{pp}}{dy}$ = the pp reference y-differential cross-section

The inclusive ϒ(1S) cross-section per unit of rapidity in pp collisions at 2.76 TeV is obtained from the rapidity interpolation of LHCb data [R Aaij et. al. , LHCb Collab. , arXiv:1402.2359]

RESULTS AND COMPARISONS



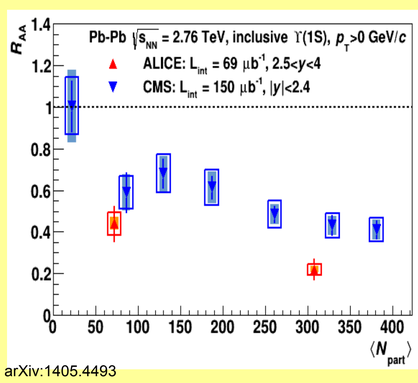
arXiv: 1405.4493



arXiv: 1405.4493

COMPARISONS WITH CHARMONIA

- Inclusive ϒ(1S) showing more suppression in rapidity and centrality than J/ψ
- Not a straight forward interpretation due to important contributions of regeneration of J/ψ and feed-down from higher mass states for ϒ



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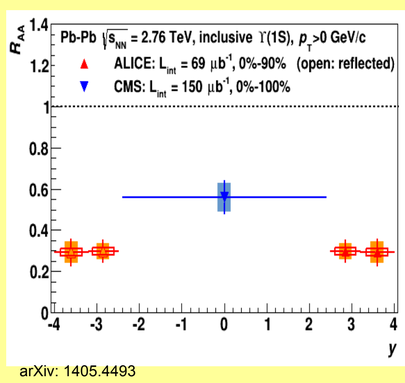
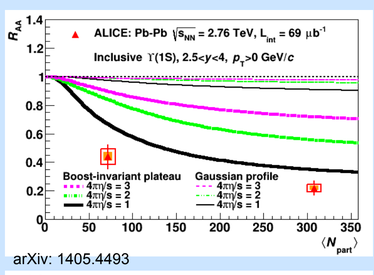


arXiv: 1405.4493

COMPARISONS WITH CMS ϒ(1S)

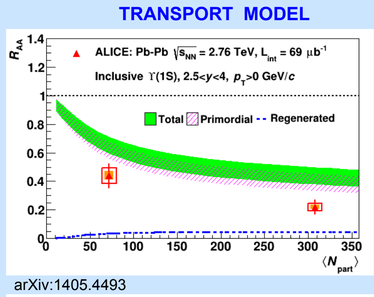
- ϒ(1S) more suppressed in forward rapidity (ALICE) than mid-rapidity (CMS :PRL 109 (2012) 222301) results in central collisions

DYNAMICAL MODEL



arXiv: 1405.4493

TRANSPORT MODEL



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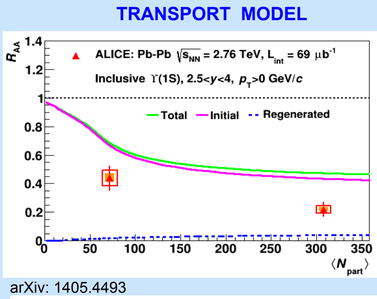

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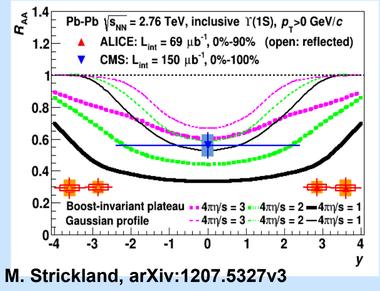
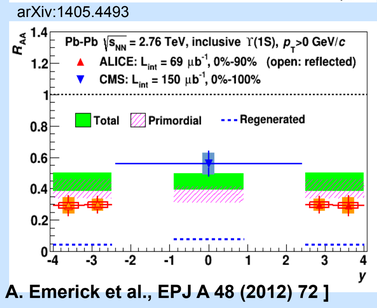
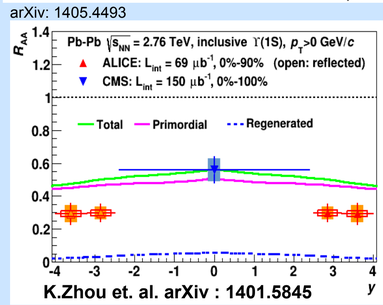


M. Strickland, arXiv:1207.5327v3



A. Emerick et al., EPJ A 48 (2012) 72]



K.Zhou et. al. arXiv : 1401.5845

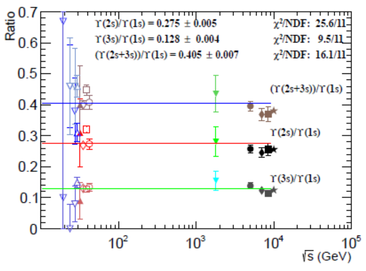
Dynamical and Transport Models overpredict ϒ(1S) R_{AA} at forward rapidity

Run-II PROSPECTS

Pb-Pb in RUN II (expected numbers)
– 1 nb^{-1} luminosity
– ~ 5 TeV Energy
-- with respect to 2011
• ~ 14 times the Integrated Luminosity
• ~ double cross section
– ~ 4k ϒ(1S) counts expected

– Reachable goals
• 4-5 centrality bins with stat uncertainty < 10%
• Nuclear Modification factor of ϒ(2S)

W. Zha et. al., arXiv : 1308.4720



What do we expect for 2S/1S and 3S/1S production ratios at forward rapidity in pp-collisons?

The pp and pA world data from W. Zha et. al. arXiv : 1308.4720
ϒ(2S)/ϒ(1S) = 0.275 ± 0.005 & ϒ(3S)/ϒ(1S) = 0.128 ± 0.004

In ALICE Muon rapidity (2.5 <y< 4.0) for pp collisions the ratio calculations match with this world data summary
L S. Kisslinger and D. Das, Mod. Phys. Lett. A 28, 1350067 (2013)
L. S. Kisslinger and D.Das, Mod. Phys. Lett. A 28, 1350120 (2013)

experiment	system	energy (GeV)	rapidity	ϒ(2S)/ϒ(1S)	ϒ(3S)/ϒ(1S)	ϒ(2S+3S)/ϒ(1S)	ref.
CFS ▽	p+p	19.4	$\langle y \rangle_{ac}$= 0.40	0.670 ± 0.940	0.100 ± 0.600	0.770 ± 1.115	[26]
CFS ▽	p+p	23.7	$\langle y \rangle_{ac}$= 0.21	0.460 ± 0.130	0.000 ± 0.080	0.460 ± 0.157	[26]
CFS ▽	p+p	27.4	$\langle y \rangle_{ac}$= 0.03	0.380 ± 0.110	0.080 ± 0.060	0.460 ± 0.122	[26]
CFS △	$p+P_t$	27.4	$y = 0$	0.310 ± 0.030	0.150 ± 0.020	0.460 ± 0.034	[27]
E605 ▲	$p+B_e$	38.8	$y = 0$	0.310 ± 0.110	0.090 ± 0.060	0.400 ± 0.125	[28]
E605 ◊	$p+C_u$	38.8	$-0.15 < x_F < 0.25$ ($-0.28 < y < 0.46$)	0.270 ± 0.011	0.131 ± 0.008	0.400 ± 0.014	[29]
E886 □	p+d	38.8	$0 < x_F < 0.6$ ($0.00 < y < 0.98$)	0.321 ± 0.012	0.127 ± 0.009	0.448 ± 0.016	[30]
E886 ○	p+p	38.8	$0 < x_F < 0.6$ ($0.00 < y < 0.98$)	0.274 ± 0.017	0.134 ± 0.013	0.408 ± 0.022	[30]
CDF ▼	$p+\bar{p}$	1800	$\lvert y \rvert < 0.4$	0.281 ± 0.048	0.155 ± 0.032	0.436 ± 0.058	[31]
CMS ●	p+p	7000	$\lvert y \rvert < 2.0$	0.258 ± 0.012	0.138 ± 0.010	0.396 ± 0.015	[32]
LHCb ◆	p+p	7000	$2.0 < y < 4.0$	0.245 ± 0.015	0.124 ± 0.008	0.369 ± 0.020	[33]
ATLAS ■	p+p	7000	$\lvert y \rvert < 2.25$	0.256 ± 0.019	0.115 ± 0.010	0.371 ± 0.024	[34]
LHCb ★	p+p	8000	$2.0 < y < 4.5$	0.256 ± 0.005	0.125 ± 0.003	0.381 ± 0.006	[35]