Charmonia and bottomonia in p-Pb: what is available from run-1?

Some “delicate” items: prompt vs inclusive, reference pp cross sections....

Results and discussion of the comparison with models (ALICE-centric)

From p-Pb to Pb-Pb; CNM extrapolations
LHC: p-Pb data taking

Carried out on January/February 2013

Beam energy: $\sqrt{s_{NN}} = 5.02$ TeV

Energy asymmetry of the LHC beams ($E_p = 4$ TeV, $E_{Pb} = 1.58$ A·TeV)

$\rightarrow$ rapidity shift $\Delta y = 0.465$ in the proton direction

Beam configurations:

Data collected with two beam configurations (swapping the beams)

- $2.03 < y_{CMS} < 3.53$
- $-4.46 < y_{CMS} < -2.96$
- $-1.37 < y_{CMS} < 0.43$

Integrated luminosities (ALICE)

- $5.01 \pm 0.17$ nb$^{-1}$ (p-Pb sample, forward rapidity)
- $51.4 \pm 1.6$ µb$^{-1}$ (p-Pb sample, mid-rapidity)
- $5.81 \pm 0.18$ nb$^{-1}$ (Pb-p sample, backward rapidity)
Summary of charmonium results

<table>
<thead>
<tr>
<th>J/ψ</th>
<th>ALICE</th>
<th>CMS</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{pA}$ vs $y$</td>
<td>♦</td>
<td></td>
<td>♦</td>
</tr>
<tr>
<td>$R_{pA}^{prompt}$ vs $y$</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{pA}$ vs $p_T$</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Q_{pA}$ vs centr.</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rel. yield vs $N_{ch}(E_T)$</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\psi(2S)$</th>
<th>ALICE</th>
<th>CMS</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{pA}$ vs $y$</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{pA}^{prompt}$ vs $y$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{pA}$ vs $p_T$</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Q_{pA}$ vs centr.</td>
<td>♦</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rel. yield vs $N_{ch}(E_T)$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additionally

- ALICE
- Double ratios $\psi(2S)/J/ψ$
  - vs $y$
  - vs $p_T$
  - vs centrality

- ALICE $\leftrightarrow$ LHCb: similar forw./backw. $y$-range (slightly larger for LHCb)
- Satisfactory for forw/backw $J/ψ$, fairly good for $\psi(2S)$, CMS results will be welcome
### Summary of bottomonium results

**Additionally**

- CMS
- Double ratios $\Upsilon(2S)/\Upsilon(1S)$
- $\Upsilon(3S)/\Upsilon(1S)$
  - Integrated
  - vs $N_{ch}(E_T)$

- Just scratching the surface
  - more data needed
Estimating the pp reference

- No pp data available for the moment at $\sqrt{s}=5.02$ TeV
- Negotiations with the machine for having a short pp run in fall 2015

**Problem**
- If a short run is chosen (few days)
  - Take those days from the “pp period”, get low $L_{\text{int}}$
- If a longer run is needed (few weeks)
  - Take those days from the “Pb-Pb period”, get large $L_{\text{int}}$
  - Delicate balance

- Look in some detail at the procedure for $J/\psi$ at forward/backward $y$
- **ALICE/LHCb joint task force** → converge on an **interpolation procedure** using pp data at $\sqrt{s} = 2.76$, 7 and 8 TeV

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>process</th>
<th>$\sigma(J/\psi)$ [µb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALICE</td>
<td>2.76</td>
<td>inclusive</td>
<td>$3.34 \pm 0.13 \pm 0.27$</td>
</tr>
<tr>
<td>ALICE</td>
<td>7</td>
<td>inclusive</td>
<td>$6.78 \pm 0.04 \pm 0.64$</td>
</tr>
<tr>
<td>LHCb</td>
<td>2.76</td>
<td>inclusive</td>
<td>$3.48 \pm 0.06 \pm 0.27$</td>
</tr>
<tr>
<td>LHCb</td>
<td>7</td>
<td>inclusive</td>
<td>$6.55 \pm 0.01 \pm 0.37$</td>
</tr>
<tr>
<td>LHCb</td>
<td>8</td>
<td>inclusive</td>
<td>$7.59 \pm 0.01 \pm 0.55$</td>
</tr>
</tbody>
</table>

Typical uncertainties on existing data: up to $\sim 10\%$, dominated by systematics

LHCb-CONF-2013-013; ALICE-PUBLIC-2013-002
Interpolation procedure

- Interpolation procedure makes use of
  - Empirical approach
  - Theoretical calculations (LO CEM and FONLL)

\[
\sigma(\sqrt{s}) = \begin{cases} 
p_0 + \sqrt{s} \ p_1 \\
(\sqrt{s}/p_0)^{p_1} \\
p_0(1 - \exp(-\sqrt{s}/p_1)) 
\end{cases} \quad \text{linear} \\
\text{power law} \\
\text{exponential}.
\]

<table>
<thead>
<tr>
<th>model</th>
<th>cross-section $[\mu b]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>linear</td>
<td>$5.17 \pm 0.41$</td>
</tr>
<tr>
<td>power law</td>
<td>$5.26 \pm 0.40$</td>
</tr>
<tr>
<td>exponential</td>
<td>$5.38 \pm 0.40$</td>
</tr>
<tr>
<td>average</td>
<td>$5.28 \pm 0.40 \pm 0.10$</td>
</tr>
</tbody>
</table>

Small relative spread
Max. deviation $\rightarrow$ syst unc.
Interpolation procedure

- Calculate cross sections at $\sqrt{s} = 2.76$, 5 and 7 TeV using CEM and FONLL
- **Fix the normalization** in order to fit existing 2.76 and 7 TeV data
- Re-normalize 5 TeV calculation using the fit results

- Use **maximum difference** between CEM/FONLL and empirical fit as a further uncertainty

\[
\sigma_{\text{incl}} = 5.28 \pm 0.40_{\text{exp}} \pm 0.10_{\text{inter}} \pm 0.05_{\text{theo}} \text{mb} = 5.28 \pm 0.42 \text{mb}.
\]
Rapidity dependence

- First interpolate bin-per-bin the measured cross sections, with the same procedure used for the integrated results.
- The pp and p-Pb y-coverage is not exactly the same (up to 0.5 units mismatch)
  → Extrapolate with various empirical functions.
**p_T dependence**

- **Forward rapidity analysis**
  - 3-step procedure
  1) √s-interpolation (between 2.76 and 7 TeV) of d²σ/dydp_T
  2) Account for rapidity “mismatch” via empirical shapes (as for y-dependence)
  3) (small) correction for ⟨p_T⟩ dependence on rapidity

- **Central rapidity analysis**
  1) Empirical √s-interpolation at y=0 (data by PHENIX, CDF, ALICE)
     1a) neglect small y-shift in p-Pb wrt pp (negligible wrt uncertainties)
  2) Use scaling properties of p_T distributions plotted vs p_T/⟨p_T⟩
     (get ⟨p_T⟩ at 5 TeV from an interpolation of mid-rapidity results at various √s)
**ψ(2S) interpolation**

- **R_{pPb}ψ(2S)** is obtained via the **double ratio** with respect to J/ψ

\[
R_{pA}^{ψ(2S)} = R_{pA}^{J/ψ} \times \frac{σ_{pA}^{ψ(2S)}}{σ_{pA}^{J/ψ}} \times \frac{σ_{pp}^{J/ψ}}{σ_{pp}^{ψ(2S)}}
\]

- **Problem:** no reference pp ratio at \(\sqrt{s} = 5\) TeV
- **Solution:** use ALICE \(\sqrt{s} = 7\) TeV results, estimating the \(\sqrt{s}\)-dependence of the ratio \(ψ(2S)/J/ψ \rightarrow \) small
- **Verified by**
  - Extrapolating the ALICE value of the ratio at \(\sqrt{s} = 7\) TeV from forward to central rapidity (use Gaussian y-shape from J/ψ data and \(y_{max}\) scaling for \(ψ(2S)\))
  - Interpolating linearly (or via exponential or polynomial) between CDF and ALICE to \(\sqrt{s} = 5\) TeV, \(y=0\)
  - Extrapolating to \(\sqrt{s} = 5\) TeV, forward-y
- Get a **4% difference** between \(\sqrt{s} = 7\) TeV and \(\sqrt{s} = 5\) TeV at forward-y
- Take conservatively an **8% systematic uncertainty**
Prompt vs inclusive $R_{pA}$

- LHCb and CMS can separate the $J/\psi$ component from $B$-decays thanks to their tracking capability in the vertex region (Si detectors).
- ALICE can do that at midrapidity but NOT at forward rapidity.
  - This limitation will be overcome after LS2 $\rightarrow$ Muon Forward Tracker.

- Can the presence of $J/\psi$ from $B$-decays create a sizeable difference between $R_{pA}^{\text{inclusive}}$ and $R_{pA}^{\text{prompt}}$?

$$R_{pA}^{\text{prompt}} = \frac{R_{pA}^{\text{inclusive}} - R_{pA}^{\text{non-prompt}}}{1 - f_b} \cdot f_b$$

- $f_B$ increases with $p_T$
- $f_B$ decreases with $y$
$R_{pA}$ for open beauty

- Results from
  - LHCb (forward $y$, low $p_T$)
  - ALICE (central $y$, low $p_T$)
  - CMS (central $y$, high $p_T$)

show no strong effects in pPb collisions
From $R_{pA}^{\text{incl}}$ to $R_{pA}^{\text{prompt}}$

- Assume $R_{pA}^{\text{non-prompt}} = 1$

The value of $R_{pA}^{\text{prompt}}$ can differ significantly from $R_{pA}^{\text{prompt}}$ at large $f_B$.
Is the difference significant for ALICE?

Exercise

1) Assume $R_{pPb}^{\text{non-prompt}} = 1$
2) Plot $R_{pPb}^{\text{prompt}}$ vs $f_B$ for the values of $R_{pPb}^{\text{inclusive}}$ measured by ALICE
3) Plot the ALICE point at the $f_B$ value corresponding to the $p_T$ where the measurement is performed

Result

For ALL the $p_T$ range accessible to ALICE, the difference between $R_{pPb}^{\text{inclusive}}$ and the calculated $R_{pPb}^{\text{prompt}}$ is smaller than the uncertainties
p-Pb results vs “centrality”

- **Fixed-target experiments**
  - Simply use different targets to “tune” the amount of nuclear matter crossed by the probe under study
  - No need to develop dedicated algorithms to slice results in centrality
- **Collider experiments**
  - Each change of nucleus implies several days of tuning
  - Impractical, need to define centrality classes

- Loose correlation between \( N_{\text{part}} \) and typical centrality-related observables
Biases on centrality determination

- Various centrality estimators can be used, e.g.
  - Number of tracklets at $|\eta_{\text{lab}}| < 1.4$ (CL1)
  - Signal amplitude on scintillator hodoscope $2 < \eta_{\text{lab}} < 5.1$ (V0A)
  - Signal from slow nucleons in ZeroDegree Calorimeters (ZDC)

- When $N_{\text{coll}}$ is obtained from CL1 and V0A estimators → significant bias
- Biases related to several effects
  - Large fluctuations on multiplicity at fixed $N_{\text{part}}$
  - Jet veto effect (from hard processes in peripheral collisions)
  - Geometric bias (related to increasing $b_{NN}$ in peripheral collisions)
Hybrid method

- It has been found that the bias is larger when the rapidity gap between the considered probe and the centrality estimator becomes small.

- Solution: use the ZDC (very large y) to slice in centrality → no bias on particle production at central rapidity.

- However, the connection between slow-nucleon signal and centrality is not so well established → take the $N_{\text{coll}}$ distribution from each ZDC-selected bin assuming $dN/d\eta$ at mid-rapidity is $\propto N_{\text{part}}$ (or that the target-going charged particle multiplicity is $\propto N_{\text{part}}$).
Now, to the results...

- Number of **signal** events
- Forward rapidity $\rightarrow$ **fit** of the invariant mass spectra (CB2 + background)

- Low $\psi(2S)$ statistics at high $p_T$, but better S/B

- $N_{J/\psi} \sim 67000, N_{\psi(2S)} \sim 1100$ (p-Pb)
- $N_{J/\psi} \sim 57000, N_{\psi(2S)} \sim 700$ (Pb-p)
Mid-rapidity $J/\psi$

- Background through mixed-events
- Normalized to same-event sample in the continuum region

- Less statistics than at forw/backw $\gamma$ (no trigger on electron pairs)
- $\Upsilon(1S)$: enough statistics for two rapidity bins \(\rightarrow\) to be published
- $\Upsilon(2S)$ peak has a $\sim 3\sigma$ significance
J/ψ results: $R_{pPb}$ vs $y$

- Strong suppression at forward and mid-$y$: no suppression at backward $y$
- Data are consistent with models including shadowing and/or energy loss
- Color Glass Condensates (CGC) inspired models underestimate data
- Dissociation cross section $\sigma_{\text{abs}} < 2$ mb cannot be excluded
The $p_T$ dependence of $J/\psi$ $R_{p\text{Pb}}$ has been studied in the three $y$ ranges

- **backward-**$y$: negligible $p_T$ dependence, $R_{pA}$ compatible with unity
- **mid-**$y$: small $p_T$ dependence, $R_{pA}$ compatible with unity for $p_T>3\text{GeV}/c$
- **forward-**$y$: strong $R_{pA}$ increase with $p_T$

**Comparison with theory:**

- Data consistent with pure shadowing calculations and with coherent energy loss models (overestimating $J/\psi$ suppression at low $p_T$, forward-$y$)
- CGC calculation overestimate suppression at forward-$y$
The ratio of the forward and backward yields in the common $y$-range $2.96 < |y_{\text{cms}}| < 3.53$ is free from the reference-related uncertainties.

- Less sensitive than $R_{\text{pPb}}$ to the comparison with theory models, as there can be agreement with models that systematically overestimate or underestimate $R_{\text{pPb}}$. 

For more details, please refer to the graphs and data provided.
Event activity dependence: $Q_{pPb}$

- At forward-$y$, strong $J/\psi$ $Q_{pA}$ decrease from low to high event activity.
- At backward-$y$, $Q_{pA}$ consistent with unity, event activity dependence not very significant.

\[ Q_{pA}^{J/\psi} = \frac{Y_{pA}^{J/\psi}}{\langle T_{pA} \rangle \sigma_{pp}^{J/\psi}} \]

Inclusive $J/\psi \rightarrow \mu^+ \mu^-$, p-Pb $\sqrt{s_{NN}} = 5.02$ TeV, $0 < p_T < 15$ GeV/c

- $2.03 < y_{cms} < 3.53$, p-going direction
- $-4.46 < y_{cms} < -2.96$, Pb-going direction
- $Q_{p\text{Pb}}$ shows a strong dependence on event activity, $y$, and $p_T$.
- **Low event activity classes:** similar backward and forward-$y$ behaviour, consistent with no modification, with a negligible $p_T$ dependence.
- **High event activity classes:** $p_T$-dependent $Q_{p\text{A}}$ behaviour. Difference between forward and backward-$y$ is larger for increasing event activity class.
$\psi(2S)/J/\psi$

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

- The double ratio allows a direct comparison of the $J/\psi$ and $\psi(2S)$ production yields between experiments

- Similar effect seen by PHENIX in d-Au collisions, at mid-$y$, at $\sqrt{s_{NN}}=200\text{ GeV}$

- $[\psi(2S)/J/\psi]_{\text{pp}}$ variation between ($\sqrt{s}=7\text{TeV}$, $2.5<y<4$) and ($\sqrt{s}=5.02\text{TeV}$, $2.03<y<3.53$ or -$4.46<y<-2.96$) evaluated using CDF and LHCb data (amounts to 8% depending on the assumptions → included in the systematic uncertainty)
The $\psi(2S)$ suppression with respect to binary scaled pp yield can be quantified with the nuclear modification factor

$$R_{pA}^{\psi(2S)} = R_{pA}^{J/\psi} \times \frac{\sigma_{pA}^{\psi(2S)}}{\sigma_{pA}^{J/\psi}} \times \frac{\sigma_{pp}^{J/\psi}}{\sigma_{pp}^{\psi(2S)}}$$

(again, used $\sqrt{s}=7$TeV pp ratio including an 8% systematic uncertainty related to the different kinematics)

- $\psi(2S)$ suppression is stronger than the $J/\psi$ one and reaches a factor $\sim 2$ wrt pp
- Same initial state CNM effects (shadowing and coherent energy loss) expected for both $J/\psi$ and $\psi(2S)$

Theoretical predictions in disagreement with $\psi(2S)$ result

Other mechanisms needed to explain $\psi(2S)$ behaviour?
$\psi(2S)$ $R_{pPb}$ vs $Y_{cms}$

- The $\psi(2S)$ suppression with respect to binary scaled pp yield can be quantified with the nuclear modification factor.
- Can the stronger suppression of the weakly bound $\psi(2S)$ be due to break-up of the fully formed resonance in CNM?

Possible if formation time $(\tau_f \sim 0.05-0.15 \text{ fm/c}) <$ crossing time $(\tau_c)$

- Forward-$y$: $\tau_c \sim 10^{-4} \text{ fm/c}$
- Backward-$y$: $\tau_c \sim 7 \cdot 10^{-2} \text{ fm/c}$

Break-up effects excluded at forward-$y$

At backward-$y$, since $\tau_f \sim \tau_c$, break-up in CNM can hardly explain the very strong difference between $J/\psi$ and $\psi(2S)$ suppressions.

Final state effects related to the (hadronic) medium created in the $p$-$Pb$ collisions?
$\psi(2S) \ R_{pPb} \ vs \ p_T$

- The $p_T$-dependence of the $R_{pPb}$ has also been investigated.

![Graphs showing $R_{pPb}$ vs $p_T$](image)

- As already observed for the $p_T$-integrated results, $\psi(2S)$ is more suppressed than the $J/\psi$.

- Theoretical models are in fair agreement with the $J/\psi$, but clearly overestimate the $\psi(2S)$ results.

*arXiv:1405.3796*
The sizeable $\psi(2S)$ statistics in p-Pb collisions allows the differential study of $\psi(2S)$ production vs $p_T$.

Different $p_T$ correspond to different crossing times, with $\tau_c$ decreasing with increasing $p_T$.

If $\psi(2S)$ breaks-up in CNM, the effect should be more important at backward-$y$ and low $p_T$.

No clear $p_T$ dependence is observed at $y<0$, within uncertainties.
The $\psi (2S)$ $Q_{pA}$ is evaluated as a function of the event activity. $Q_{pA}$ instead of $R_{pA}$ due to potential bias from the centrality estimator, which are not related to nuclear effects.

$$Q_{\psi (2S)}^{pA} = Q_{pA}^{J/\psi} \times \frac{\sigma_{\psi (2S)}^{pA}}{\sigma_{pA}^{J/\psi}} \times \frac{\sigma_{pp}^{J/\psi}}{\sigma_{pp}^{\psi (2S)}}$$

with

$$Q_{pA}^{J/\psi} = \frac{Y_{pA}^{J/\psi}}{T_{pA}^{mult} \cdot \sigma_{pp}^{J/\psi}}$$

- Clear $\psi (2S)$ suppression, increasing with event activity, both in p-Pb and Pb-p collisions.
- Rather similar $\psi (2S)$ suppression at both forward and backward rapidities.
$\psi(2S) \, Q_{pPb}$ vs event activity

The $\psi(2S) \, Q_{pA}$ is evaluated as a function of the event activity.

Rather similar $\psi(2S)$ suppression, increasing with $N_{\text{coll}}$, for both ALICE and PHENIX results.
J/ψ and ψ(2S) $Q_{ppb}$ vs event activity

- J/ψ and ψ(2S) $Q_{pA}$ are compared vs event activity

- **forward-γ:** J/ψ and ψ(2S) show a similar decreasing pattern vs event activity

- **backward-γ:** the J/ψ and ψ(2S) behaviour is different, with the ψ(2S) significantly more suppressed for largest event activity classes

→ Another hint for ψ(2S) suppression in the (hadronic) medium?
- The inclusion of an "effective" comover cross section $\sigma_{\text{co-J}/\psi}=0.65$ mb on top of nuclear shadowing gives qualitative agreement with data.

- Same comover cross section from SPS to LHC?

- Looks like a fortuitous accident, seen the differences in
  - Nature of the medium
  - Absence of modeling of time evolution

- Or there is some deeper meaning to that?
ψ(2S) looks good too

- **Factor 10 larger comover cross section** for ψ(2S)  
  → May be justified by geometrical considerations, but...  
  does the “medium” see any difference between a ccbar evolving to a J/ψ or to a ψ(2S) before the resonance is formed?

- Anyway **excellent qualitative agreement**!
- Comparison using the same x-axis variable **mandatory**
- **Interplay between modeling of expansion** (between $\tau_0$ and freeze-out), comover density and comover cross section values. Can the data give constraints here?
Energy loss approach (François)

- $y$-range covered at LHC: well inside the "applicability" region
- Good description in a pure $E_{\text{loss}}$ approach
- Interplay with shadowing/saturation?
- The model works well also where it should not!
  - By chance?
  - Or is there a deeper meaning?
γ(1S) results

- Reference pp cross sections obtained via energy interpolation at mid-rapidity, using CDF@1.8 TeV, D0@1.96 TeV, CMS@2.76 TeV, CMS@7 TeV data + forward-y extrapolation using various PYTHIA tunes
- Alternative approach using LHCb data for final release of the results

- Consistent with no suppression at backward rapidity
- Indications of suppression at forward rapidity
\( \gamma(1S) \): model comparisons

- Ferreiro et al. [EPJC 73 (2013) 2427]
  - Generic 2\( \rightarrow \)2 production model at LO
  - EPS09 shadowing parameterization at LO
  - Fair agreement with measured \( R_{pPb} \), although slightly overestimated 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 overestimated it
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 $E_{\text{loss}}$ and shadowing
- **Backward**: Better agreement with $E_{\text{loss}}$ only

LHCb results are **systematically above** the ALICE ones, although within uncertainties

Clear situation where more data are mandatory
CNM effects from p-Pb to Pb-Pb

- x-values in Pb-Pb $\sqrt{s_{NN}}=2.76$ TeV, $2.5 < y_{\text{cms}} < 4$
  \[ 2.10^{-5} < x < 9.10^{-5} \quad 1.10^{-2} < x < 6.10^{-2} \]

- x-values in p-Pb $\sqrt{s_{NN}}=5.02$ TeV, $2.03 < y_{\text{cms}} < 3.53$ \[ 2.10^{-5} < x < 8.10^{-5} \]
- x-values in p-Pb $\sqrt{s_{NN}}=5.02$ TeV, $-4.46 < y_{\text{cms}} < -2.96$ \[ 1.10^{-2} < x < 5.10^{-2} \]

→ Partial compensation between $\sqrt{s_{NN}}$ shift and y-shift

- If CNM effects are dominated by shadowing
  - $R_{\text{PbPb}}^{\text{CNM}} = R_{\text{pPb}} \times R_{\text{Pbp}} = 0.75 \pm 0.10 \pm 0.12$
  - $R_{\text{PbPb}}^{\text{meas}} = 0.57 \pm 0.01 \pm 0.09$

  “compatible” within 1-$\sigma$

- Same kind of “agreement” in the energy loss approach

...which does not exclude hot matter effects which partly compensate each other
**p_T-dependence**

- Perform the extrapolation as a function of $p_T$

No more “agreement” between Pb-Pb and CNM extrapolations

- High-$p_T$ suppression is not related to CNM effects

- At low $p_T$, CNM suppression is of the same size of the effects observed in Pb-Pb: recombination?
Conclusions

- Rather extensive set of results from LHC run-1 in p-Pb are available
  - For $J/\psi$, differential studies vs $p_T$, $y$ and centrality with good statistics
  - For $\psi(2S)$, statistics is smaller but interesting results anyway
  - CMS results at high-$p_T$ and mid-rapidity would be welcome

- For $\Upsilon$ states, a larger data set would be beneficial

- Question: better running again at $\sqrt{s_{NN}} = 5$ TeV or go to $\sqrt{s_{NN}} = 8$ TeV?
  Discussion with machine and experiments ongoing, inputs useful

- Comparisons with theory models
  - $J/\psi$: qualitative agreement with energy loss (+ shadowing?), no (or small) extra-absorption
  - $\psi(2S)$: evidence for extra-suppression at backward-$y$ (comovers?)
  - $\Upsilon$ states: more data needed for a meaningful comparison
Backup
Direct B in p-Pb (mid-y)

- Use FONLL for pp reference cross section
- $R_{pA}^{FONLL}$ is compatible with unity for all three B-mesons

$B^+ \rightarrow J/\psi K^+$
$B^0 \rightarrow J/\psi K^*$
$B_S \rightarrow J/\psi \phi$

$\langle p_T \rangle > 10$ GeV/c
$R_{pPb}$ & $R_{AA}$ for jets and $b$ jets

- Discriminating variable → Flight distance of the secondary vertex
- $b$-jet fraction → template fits to secondary vertex inv. mass distributions
- $b$-jet $R_{AA}$ is much smaller than $R_{pPb}$ → strong in-medium effects
- No jet modification in $p$-Pb collisions
- No flavour dependence of the effect

S. Chatrchyan et al. (CMS), arXiv:1312.4198
Do not forget CNM...

- In the $\gamma$ sector, the influence of CNM effects is small

Hints for suppression of $\gamma(1S)$ at forward rapidity?

- (Small) relative suppression of $\gamma(2S)$ and $\gamma(3S)$ wrt $\gamma(1S)$ at mid-rapidity
- Qualitative agreement with models within uncertainties
- CNM cannot account for all of the effect observed in Pb-Pb
Strong correlation of charmonia/bottomonia/open charm relative yields as a function of quantities related to the hadronic activity in the event.

Observation related to the role of MPI in pp also in the hard sector?