Measurement of the nuclear modification factor for high-$p_T$ charged hadrons in pPb collisions with the ATLAS detector

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24 September 2016
introduction

- modification of charged particle production in p+Pb collisions is expressed by $R_{pPb}$:

$$R_{pPb} = \frac{1}{T_{pPb}} \frac{1/N_{\text{evt}} \ dN_{\text{ch}}/d\eta d\rho_T}{d\sigma/d\eta d\rho_T}$$

- in case of no nuclear effects $R_{pPb}$ shouldn’t differ from unity at high $p_T$

- nevertheless, CMS and later ATLAS brought results causing many discussions:
  - not seen by ALICE
  - all these results have only interpolated pp reference

- is this real or is there a problem with a reference?

![Graph showing $R_{pPb}$ vs $p_T$]
• modification of charged particle production in p+Pb collisions is expressed by $R_{pPb}$:

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• is this real or is there a problem with a reference?
- inner detector – 2 T magnetic field
- forward calorimeter – used for determination of centrality
• centrality based on energy deposited in Forward Calorimeter \((-4.9 < \eta < -3.1)\)
• this is only the Pb-going side
• nuclear thickness function: \(T_{pPb} = (N_{\text{part}} - 1)/\sigma_{NN}\)
collected luminosity & event selection

- **pPb 2013 (5.02 TeV): 25 nb\(^{-1}\)**
  - for this preliminary the same datapoints used as in ATLAS-CONF-2014-029
  - both p+Pb and Pb+p
  - remove pile-up, diffractive events
  - MB trigger: MBTS signal
  - jet triggers: anti-k\(_T\) algorithm (R=0.4); several jet \(E_T\) thresholds

- **pp 2015 (5.02 TeV): 25 pb\(^{-1}\)**
  - accept pile-up, as the yield is scaled by luminosity
  - MB trigger: a track in the inner detector
  - jet triggers: anti-k\(_T\) algorithm (R=0.4); several jet \(E_T\) thresholds
applied several corrections to get back to the particle level:
- rejecting fake and secondary tracks
- correct for finite momentum resolution (Bayesian unfolding)
- track reconstruction efficiency

measurement is done in rapidity:
- pp collisions are symmetric
- pPb collisions are asymmetric:
  \[
  E = 1.57 \text{ TeV (Pb)} \rightarrow \sqrt{s_{NN}} = 5.02 \text{ TeV} \quad \leftarrow \quad E = 4 \text{ TeV (p)}
  \]
- \( y \rightarrow y - y_{CM}; \quad y_{CM} = -0.465 \)
- rapidity in data as well as in MC calculated assuming all particles are pions; there is a minor correction to fix that
| source                                         | max. uncertainty |
|-----------------------------------------------|------------------|
| track selection                               | 5%               |
| track-particle association                    | 7%               |
| particle composition                          | 1%               |
| jet trigger efficiency                        | 1%               |
| fake and secondary tracks                     | 2%               |
| unfolding procedure                           | 7%               |
| momentum resolution                           | 1%               |
| detector material                              | 4%               |
| luminosity                                    | 5%               |

- the highest uncertainties are typically at the highest $p_T$ and $|y|$.
- large reduction of the systematics with respect to previous measurement due to missing 10% on the interpolation.
pp and pPb spectra

- pPb – same as in ATLAS-CONF-2014-029
- pp – new results from ATLAS-CONF-2016-108
pp and pPb spectra

with interpolated reference:

\[
\frac{1}{(2\pi p_T)^2} \frac{d^2\sigma}{dy dp_T} [\text{mb GeV}^2] = \text{(data)}
\]

\[
\text{ATLAS Preliminary}
\]

pp, \( \sqrt{s} = 5.02 \text{ TeV} \)

\[
L_{\text{int}}^{pp} = 25 \text{ pb}^{-1}
\]

pPb, \( \sqrt{s_{NN}} = 5.02 \text{ TeV} \)

\[
L_{\text{int}}^{p\text{Pb}} = 25 \text{ nb}^{-1}
\]

-2.0 < \( y^* < 1.5 \)

\[
\text{Preliminary ATLAS} = 5.02 \text{ TeV}
\]

\[
\text{spp, } -1 = 25 \text{ pb}^{pp}_{\text{int}}
\]

\[
\text{p+Pb } L = 5.02 \text{ TeV}
\]

\[
\text{NN} s_{\text{Pb}} = 25 \text{ nb}^{p\text{Pb}}_{\text{int}}
\]

-2 < \( y^* < 1.5 \)
pp interpolation and data at 5.02 TeV

- 2.76 TeV and 7 TeV pp data were used for logarithmic interpolation ($\ln(\sqrt{s})$)
- pp data at 5.02 TeV agrees with the interpolation pretty well at low $p_T$
- at high $p_T$ there is a difference of $\sim 30\%$

(additional 10% systematic uncertainty on the interpolation procedure not displayed)
$R_{pPb}$ has no $p_T$ dependence over whole $p_T$ range
there is no significant deviations from unity
$R_{\text{pPb}}$ in 0–90%

- used the same pPb data points as in previous analysis (ATLAS-CONF-2014-029)
- the "enhancement" in the previous results comes from interpolated reference
\( R_{\text{pPb}} \) in 0–90%

- good agreement at low \( p_T \) with arXiv:1605.06436 (submitted to PLB), it does not use pp data @ 5.02 TeV
$R_{pPb}$ in centrality intervals

- no centrality dependence at high $p_T$
- different dependence at low $p_T$ in different centrality intervals
$R_{ppb}$ in centrality intervals

- this is understood and compatible with previous results (using interpolated reference)
• measured charged particle spectra in pp collisions with $\sqrt{s} = 5.02$ TeV

• there is a difference between measured pp spectra @ 5.02 TeV and results with interpolation

• when using pp data, $R_{pPb}$ has no $p_T$ dependence in the whole $p_T$ range and it is consistent with unity

• centrality dependence at low $p_T$ is similar to the previous results

• no centrality dependence at high $p_T$