Production of nuclei and antinuclei in pp and Pb-Pb collisions with ALICE at the LHC

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Abstract.
We present first results on the production of nuclei and antinuclei such as (anti)deuterons, (anti)tritons, (anti)^{3}He and (anti)^{4}He in pp collisions at $\sqrt{s} = 7$ TeV and Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. These particles are identified using their energy loss (dE/dx) information in the Time Projection Chamber of the ALICE experiment. The Inner Tracking System gives a precise determination of the event vertex, by which primary and secondary particles are separated. The high statistics of over 360 million events for pp and 16 million events for Pb-Pb collisions give a significant number of light nuclei and antinuclei (Pb-Pb collisions: $\sim 30,000$ anti-deuterons($\bar{\rm d}$) and ~ 4 anti-alpha($^4\overline{\rm He}$)). The predictions of various particle ratios from the THERMUS model is also discussed.

1. Introduction

In the recent years, a lot of progress has been made by the heavy-ion collision experiments to search for the heavier (anti)nuclei and (anti)hypernuclei. It is important to study these nuclei and antinuclei in details in terms of their yields, spectra, flow etc., to understand their production mechanism in a collision. A Large Ion Collider Experiment (ALICE) at LHC has excellent particle identification capabilities using its various subsystems [1], to study these nuclei and antinuclei with large statistics data. The first results are presented for identified nuclei and antinuclei in mid-rapidity region for pp collisions at $\sqrt{s} = 7$ TeV and Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ =2.76 TeV at the LHC. These particles are identified using their specific energy loss (dE/dx) measurements in the Time Projection Chamber (TPC) of the ALICE experiment.

2. Experiment

For the present study, over 360 million triggered events for pp collisions ($\sqrt{s} = 7$ TeV) and nearly 16 million triggered events for Pb-Pb collisions ($\sqrt{s_{\rm NN}} = 2.76$ TeV) are analyzed. The various nuclei and antinuclei covered in this analysis are d($\bar{\rm d}$), t($\bar{\rm t}$), ^{3}He($^3\overline{\rm He}$), and ^{4}He($^4\overline{\rm He}$). We have used the Time Projection Chamber (TPC) which has full azimuthal acceptance for tracks in the pseudo-rapidity region $|\eta| < 0.9$. The specific

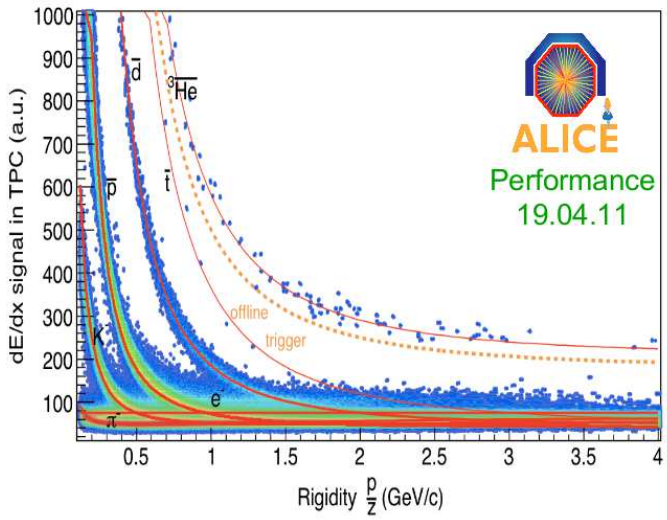

Figure 1. (Color online) Specific energy loss dE/dx vs. rigidity (momentum/charge) of negatively charged TPC tracks for Pb-Pb collisions ($\sqrt{s_{\rm NN}}$ = 2.76 TeV). The solid lines are parametrization of the Bethe-Bloch curve.

energy loss (dE/dx) versus rigidity (momentum/charge) of the negatively charged TPC tracks is shown in Fig. 1. Antinuclei are clearly identified over the wide range of momenta. The Inner Tracking System (ITS) containing six silicon layers, is used for precise determination of the event vertex, by which primary and secondary particles are separated. Primary tracks are selected with the condition that, at least one cluster in the ITS is associated to the track.

Secondary tracks are further rejected using the distance-of-closest approach (DCA) to the reconstructed primary vertex position. The $\rm DCA_Z$ distribution (Z-axis is along beam line) of identified antinuclei shows a very small number of tracks with $\rm DCA_Z$ value greater than 1.0 cm. A $\rm DCA_Z$ cut of 1.0 cm is applied in addition to standard track selection cuts, which reduces the fraction of secondary and back-scattered nuclei.

The probability of antinucleus production by interaction of particles with the detector material is very small. However, nuclei can be produced by interactions with the material. The final counts of primary $\rm d(\bar{d})$, $\rm t(\bar{t})$, and $\rm ^3He(^3\overline{He})$ are obtained by comparing the $\rm DCA_{XY}$ distribution of nuclei and antinuclei in various transverse momentum ($p_{\rm t}$) slices. Figure 2 shows an example for d and $\rm \bar{d}$ in the transverse momentum range 0.55 GeV/c < $p_{\rm t}$ < 0.65 GeV/c for Pb-Pb collisions. The top panel (for $\rm \bar{d}$) shows no significant number of tracks in $|\rm DCA_{XY}| > 1.0$ cm region, whereas bottom panel (for d) shows an almost flat background. The raw yield is obtained from the area under the peak minus background. A similar procedure is used to get the raw yields of $\rm d(\bar{d})$, $\rm t(\bar{t})$, and $\rm ^3He(^3\overline{He})$ for pp collisions at $\sqrt{s}$ = 7 TeV.

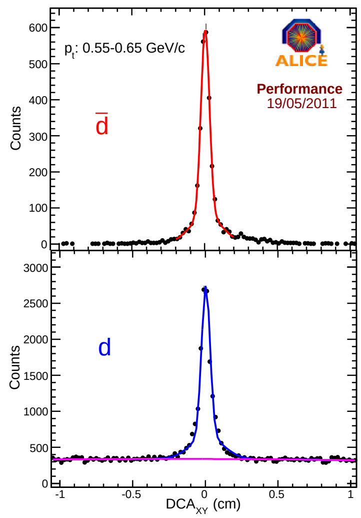

Figure 2. $\mathrm{DCA_{XY}}$ distribution of identified antideuterons (top panel) and deuterons (bottom panel) in the transverse momentum range 0.55 GeV/c < p_t < 0.65 GeV/c for Pb-Pb collisions ($\sqrt{s_\mathrm{NN}} = 2.76$ TeV).

3. Results

The raw spectra of $\mathrm{d}(\bar{\mathrm{d}})$, $\mathrm{t}(\bar{\mathrm{t}})$, and $^3\mathrm{He}(^3\overline{\mathrm{He}})$ are obtained for pp collisions at $\sqrt{s} = 7$ TeV and for Pb-Pb collisions at $\sqrt{s_\mathrm{NN}} = 2.76$ TeV. We observed about 20k antideuterons, 20 antitritons, and 20 $^3\overline{\mathrm{He}}$ candidates for the pp collisions collected in 2010. For Pb-Pb data, we observed nearly 35k antideuterons, 120 antitritons, and 700 $^3\overline{\mathrm{He}}$ candidates during the same year. As an example the left panel of Fig. 3 shows the raw spectra of $\bar{\mathrm{d}}$ for pp collisions at $\sqrt{s} = 7$ TeV. Antideuterons are identified in the transverse momentum range 0.5 GeV/c < p_t < 1.4 GeV/c. The right panel of Fig. 3 shows the raw yield of $^3\overline{\mathrm{He}}$ for Pb-Pb collisions at $\sqrt{s_\mathrm{NN}} = 2.76$ TeV. $^3\overline{\mathrm{He}}$ are identified in the transverse momentum range 1.2 GeV/c < p_t < 8.0 GeV/c. To get the final yields of nuclei and antinuclei the efficiency correction and annihilation correction have to be taken into account, this work is ongoing. We have also observed four candidates of $^4\overline{\mathrm{He}}$ in 17.8 million Pb-Pb collisions [1]. This is the full statistics of data ALICE has taken during heavy-ion run in the year 2010.

It will be interesting to compare the final yields of these nuclei and antinuclei in pp collisions at $\sqrt{s} = 7$ TeV and Pb-Pb collisions at $\sqrt{s_\mathrm{NN}} = 2.76$ TeV and also with the RHIC results for Au-Au collisions at $\sqrt{s_\mathrm{NN}} = 200$ GeV [2].

Furthermore, we will compare these ratios with statistical thermal model predictions and coalescence approaches. Figure 4 shows the ratio of particles with different masses, assuming chemical freeze-out temperature (T) between 110 MeV and 170 MeV. This shows that the particle ratios are very sensitive to the freeze-

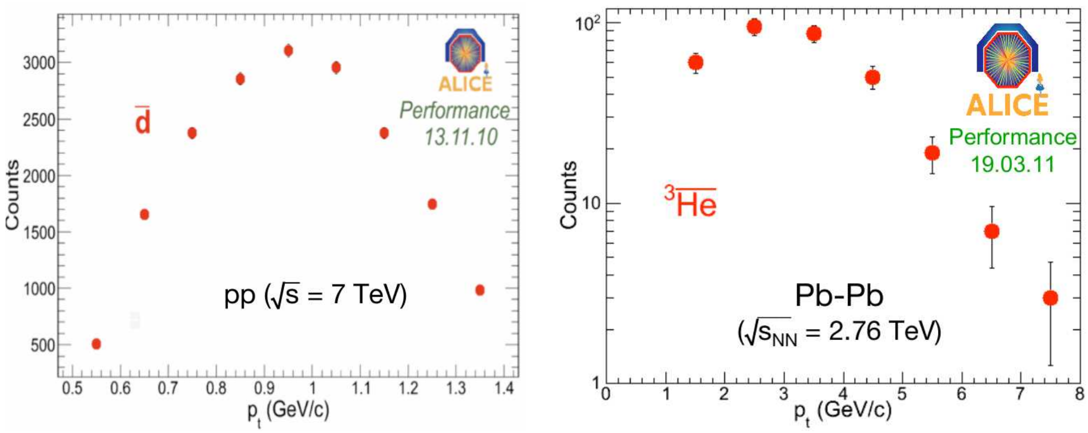

Figure 3. Left Panel: Raw yield of antideuterons as a function of transverse momentum (p_{t}) for pp collisions ($\sqrt{s}$ = 7 TeV), only statistical errors are included. Right Panel: Raw yield of $^{3}\overline{\mathrm{He}}$ as a function of transverse momentum (p_{t}) for Pb-Pb collisions ($\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV), only statistical errors are included.

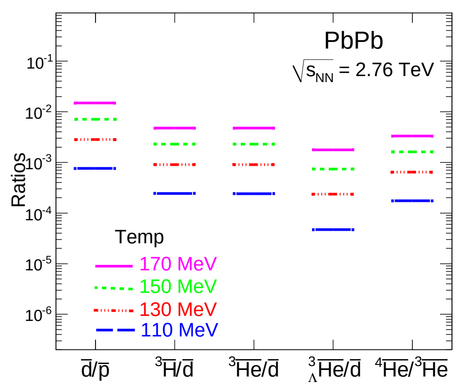

Figure 4. Ratios of particles with different masses predicted using the statistical thermal model (THERMUS [4]) for Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV.

out temperature [3]. These calculations are performed for Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV using the grand canonical approach of the THERMUS code [4].

References

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