European Organization for Nuclear Research

$\bar{\mathrm{t}}$, $^{3}\overline{\mathrm{He}}$ and $^{4}\overline{\mathrm{He}}$ production in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

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ABSTRACT

This paper reports the results obtained during the 2019 CERN Summer Student Program. It focuses on production of anti-triton, $^{3}\overline{\mathrm{He}}$ and $^{4}\overline{\mathrm{He}}$ in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The study of the nuclei and anti-nuclei production at the LHC represents a fundamental step in understanding the nucleosynthesis mechanisms in heavy-ion collisions.

1 Introduction

Ultra-relativistic heavy-ion collisions at the LHC create suitable conditions for producing light (anti-)nuclei. The study of their production rates is attracting a continuously growing interest. Indeed the (anti-)nucleosynthesis mechanisms remain one of the outstanding issues in heavy-ion physics. ALICE (A Large Ion Collider Experiment) is the LHC experiment optimized to study collisions between heavy ions at the energies typical of the accelerator. Thanks to its excellent tracking and PID capabilities, the ALICE experiment allows one to clearly identify light nuclei and anti-nuclei.
This project focuses on the production of $\bar{\mathrm{t}}$, $^3\overline{\mathrm{He}}$ and $^4\overline{\mathrm{He}}$ (the latter being the heaviest anti-nucleus observed so far) in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.
The signal of nuclei is strongly contaminated from secondary particles, in particular from those originated in the interaction of primary particles with the detector material. For this reason, in this preliminary study I only considered anti-matter nuclei.
The detectors mainly involved in the study presented here are the Time Projection Chamber (TPC) and the Time Of Flight (TOF) detector.

2 Data Set

The analysis has been performed using the Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, collected by ALICE in 2018 (LHC Run2). The selected period is LHC18q, with a magnetic field of 0.5 T. The analysis is done using the ESDs. The following runs are those used in the analysis: 296244, 296273, 296377, 296433, 296510, 296304, 296378, 296191, 296414, 296549.

3 Event and Track Selection

Events were selected via the class AliEventCuts with standard settings for Pb-Pb in Run 2. The number of selected events is 29 millions. Among these, about 10 millions are in the highest-centrality class (0-10%). The centrality distribution of all selected events is shown in Figure 1.
The tracks are selected using the standard method GetStandardITSTPC-TrackCuts2011.

4 Particle Identification

Charged particles are identified in this analysis mainly by two detector systems: (i) The Time Projection Chamber (TPC) measures the energy loss per traveled distance of swift charged particles. (ii) The Time Of Flight (TOF) detector measures the time of flight of particles.

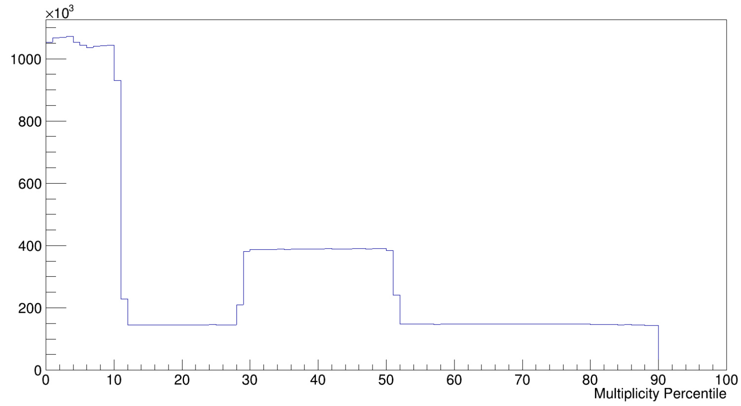

Figure 1: The centrality distribution of all the events that passed the selection made via the class AliEventCuts with standard settings for Pb-Pb in Run 2.

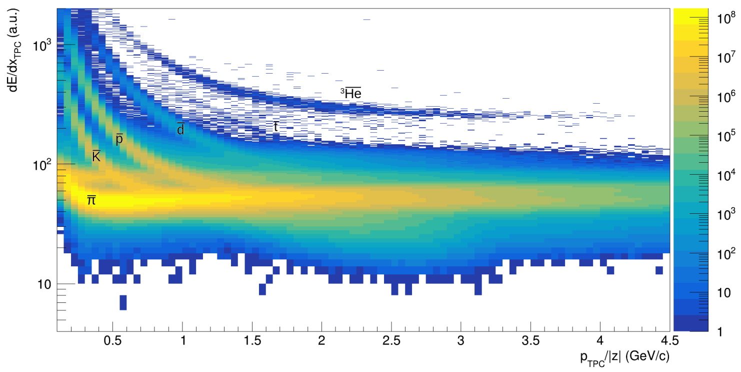

Figure 2: Energy loss per traveled distance of negative-charged particles measured by the TPC as a function of momentum.

For this project the PID is performed combining both TPC and TOF information: only tracks detected by the TPC with at least one hit on the TOF have been considered.
The first step in the PID analysis consists in checking the goodness of the detector response by comparing the expected signal to the observed one. This has been done both for the TPC and for the TOF as can be seen in Figure 2 and in Figure 3.

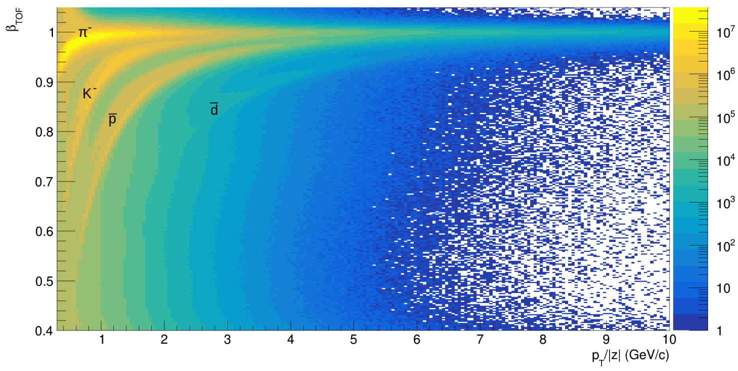

Figure 3: Velocity of negative-charged particle measured by the TOF as a function of transverse momentum.

4.1 $^3\overline{He}$ Identification

Figure 4 shows the distribution of the variable $n\sigma_{TPC}$ defined as follows:

$$n\sigma_{TPC} = \frac{dE/dx - dE/dx_{exp}}{\sigma_{dE/dx}} \tag{1}$$

of $^3\overline{He}$ as a function of p_T. For transverse momenta up to $p_T = 5\,\mathrm{GeV/c}$, $^3\overline{He}$ is identified by requiring a maximum deviation of the energy loss of 3σ with respect to the expected signal.

Once tracks are selected, the time measurement with the TOF can be used to obtain the mass squared. Another cut has been done on this latter variable, taking into account the values within 1.5 and 2.5 GeV^2/c^4. In Figure 5 the $^3\overline{He}$ TOF mass squared distribution is shown for the tracks which survived all the cuts.

Finally, to count the $^3\overline{He}$ tracks, the area under the peak in Figure 5 has been computed, resulting in about 3100 tracks of $^3\overline{He}$.

4.2 $^4\overline{He}$ Identification

Starting from the plot shown in Figure 4, the identification of $^4\overline{He}$ tracks can also be done. For this purpose the region with low p_T has been chosen, and $^4\overline{He}$ are identified in this region selecting $n\sigma_{TPC} > 3$ and m^2 between 2 and 6 GeV^2/c^4. The plot obtained with this procedure is shown in Figure 6 and it reports the squared mass of the selected tracks. The analysis gave as result 7 tracks of $^4\overline{He}$.

4.3 Anti-Triton Identification

Concerning the identification of anti-triton tracks, taking into account the $n\sigma_{TPC}$ distribution, it is required a maximum deviation of the energy loss of

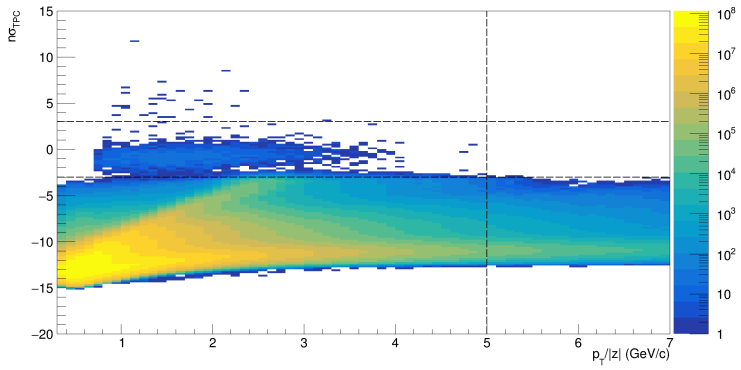

Figure 4: $n\sigma_{TPC}$ distribution of $^3\overline{\text{He}}$ as a function of p_T. The black dashed lines show where the cuts have been done. The region with $p_T < 5\,\text{GeV/c}$ has been chosen for both $^3\overline{\text{He}}$ and $^4\overline{\text{He}}$. The $^3\overline{\text{He}}$ has been selected between -3σ and 3σ from the expected value, while the $^4\overline{\text{He}}$ over 3σ.

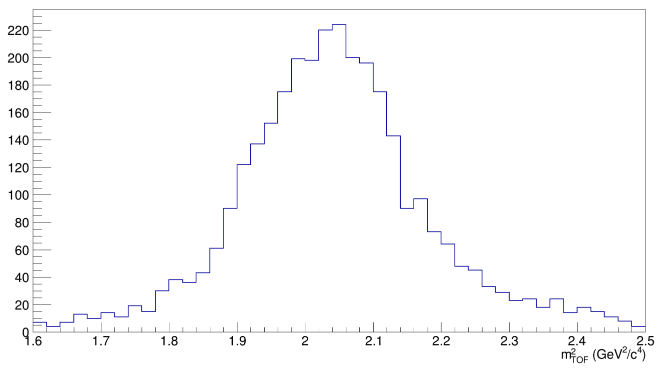

Figure 5: $^3\overline{\text{He}}$ TOF squared-mass distribution.

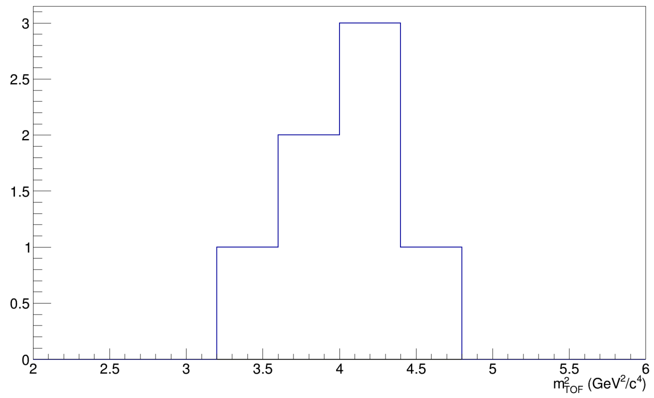

Figure 6: $^{4}\overline{\mathrm{He}}$ TOF squared-mass distribution.

3σ with respect to the expected signal. To identify the number of anti-triton, a cut has been done for $p_T < 2\,\mathrm{GeV/c}$ and for squared masses within 7 and 10 GeV^2/c^4. With such procedure, 3000 tracks of anti-triton are counted.

5 Conclusions

The raw counts of $\bar{\mathrm{t}}$ and $^{3}\overline{\mathrm{He}}$ in the latest LHC Pb-Pb run at $\sqrt{s_{NN}} =$ 5.02 TeV have been reported. Within this project the rarest anti-nucleus observed so far ($^{4}\overline{\mathrm{He}}$) have been also identified.

The obtained results are still preliminary results. Raw yields need to be corrected for detector acceptance and efficiency for extracting the production rates.