Implications of LHC heavy ion data for multi-strange baryon production

LHC Safety Assessment Group
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Prior to the start of LHC operations, the good agreement of measurements of particle production at RHIC and other accelerators with simple thermodynamic models allowed one to constrain severely any production of hypothetical strangelets in heavy ion collisions at the LHC. In particular, LSAG estimated that the thermal production of a single *normal* $A = 10$ nucleus in heavy ion collisions would require running the equivalent of 1000 LHCs for the entire lifetime of the Universe. This estimate of the production of normal nuclear matter provided an extremely conservative upper bound on the production of hypothetical exotic forms of strange quark matter. This argument has now been sharpened by LHC data, as we discuss below.

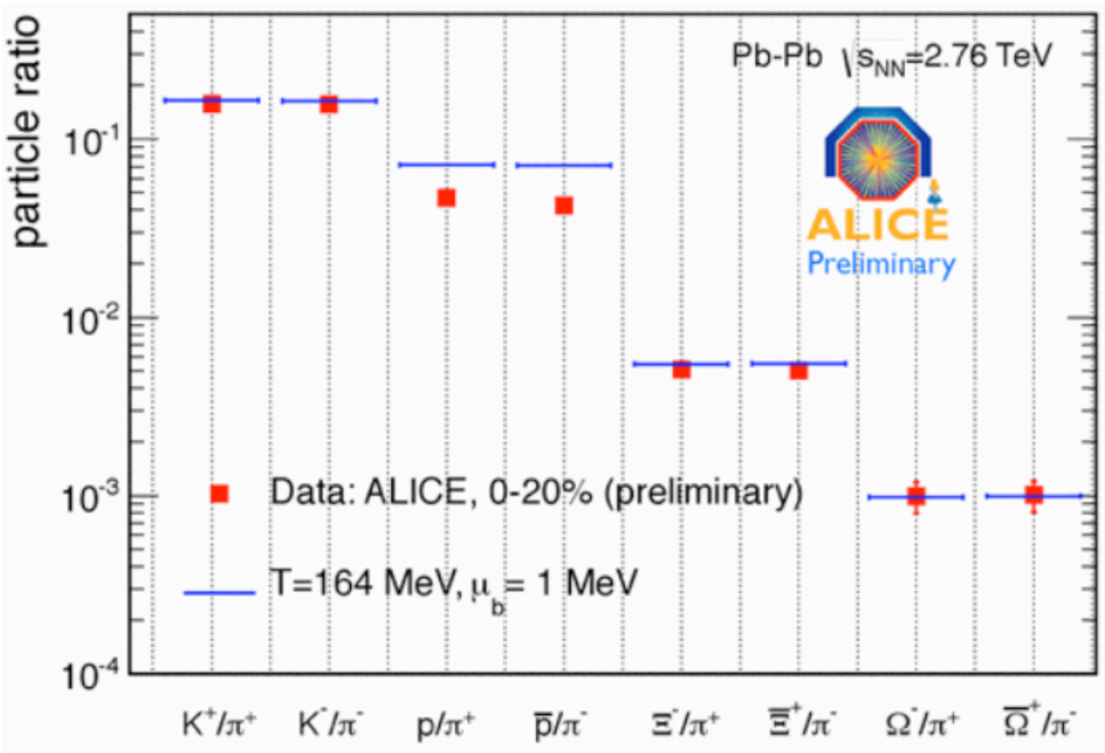
Aside from abundant production of strange quarks, the production of strange quark matter would require the availability of a significant net baryon number density in the collision, as well as a high probability that baryons coalesce. However, the baryon density was expected to decrease from RHIC to LHC energies, since the same number of baryons would be distributed over a larger volume. Also, just as ice cubes are not produced in furnaces, the high temperatures expected in heavy-ion collisions at the LHC would not allow the production of heavy nuclear matter, whether normal nuclei or hypothetical strangelets.

First data from the LHC heavy-ion program give strong support for these arguments given in the LSAG report. In particular, the production of strange particles agrees [1] with predictions of a thermal model according to which particles decouple from the heavy-ion 'furnace' at the expected temperature of 164 MeV, as seen in the Figure. Moreover, direct observations of protons, anti-protons, excited baryonic states and their corresponding anti-particles confirm that the produced matter has an extremely low net baryon density ($\mu \sim 1$ MeV), in agreement with expectations in the LSAG report, as also seen in the Figure. In addition, the ALICE experiment has presented first LHC measurements of the lightest nuclei and anti-nuclei, namely (anti-)deuterons, (anti-)tritons, (anti-)^{3}He and (anti)-^{4}He in heavy-ion collisions [2], following similar observations in heavy-ion collisions at RHIC. The observed yields correspond well to thermal expectations. Thus the three key ingredients in the LSAG analysis have already been validated by initial LHC data, and the conservative LSAG upper limit on the production of hypothetical strangelets is robustly confirmed.

Having confirmed the essential validity of the thermal picture of particle production, scientific interest focuses now on a detailed quantitative analysis of the microscopic dynamics underlying particle production in heavy-ion collisions.

[1] M. Floris, for the ALICE Collaboration, presented at the open session of the 107th LHCC meeting, CERN, Sept 22 2011,
https://indico.cern.ch/conferenceDisplay.py?confId=153317

[2] N. Sharma for the ALICE Collaboration, *"Production of nuclei and antinuclei in pp and Pb-Pb collisions with ALICE at the LHC"*, proceedings of the XXIInd Quark Matter Conference, J. Phys. G (to appear).



Measurements by the ALICE Collaboration [1] of the ratios of particle and antiparticle production in heavy-ion collisions at the LHC, which are generally in good agreement with a simple thermal model. The data confirm the expected rate of production of strange particles, as well as showing a low density of baryons.