Search for a Λnn bound state in Pb-Pb collisions with ALICE at the LHC

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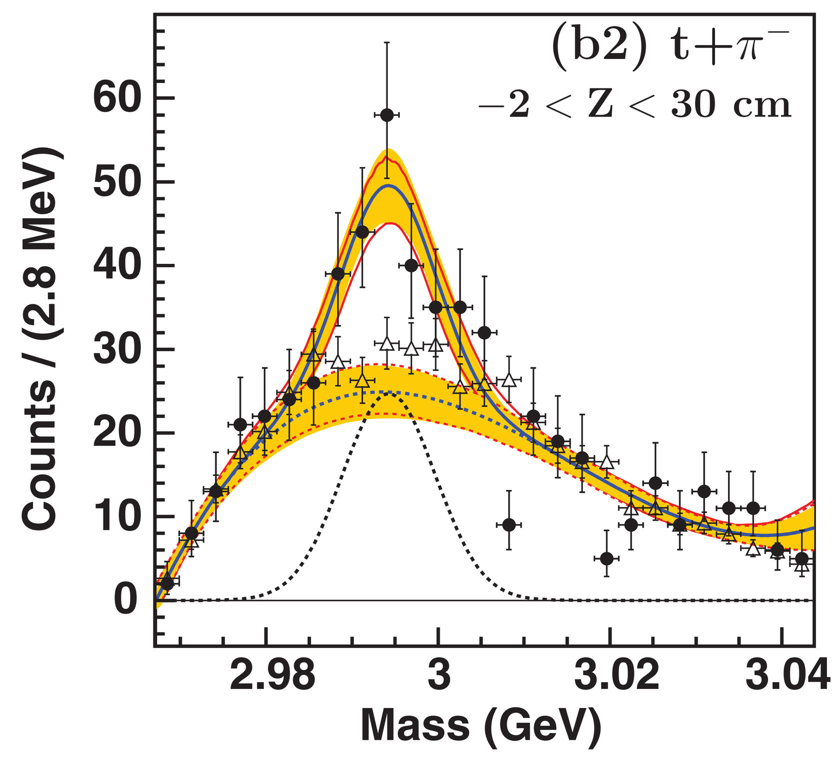
Physics motivation

The nuclear state composed by the Λ hyperon and two neutrons, the Λnn state, should be unbound [1][2], nevertheless new recent measurements indicate its formation at a mass of **2.993 GeV/c^2** as shown in the plot on the right. The production of a significant amount of baryons and strangeness at LHC energies allows for an increased production of potentially existing exotic QCD bound states. The Λnn state can be detected with ALICE via the decay channel Λnn->tπ and its observation would crucially contribute to the understanding of exotic nuclear bound states.



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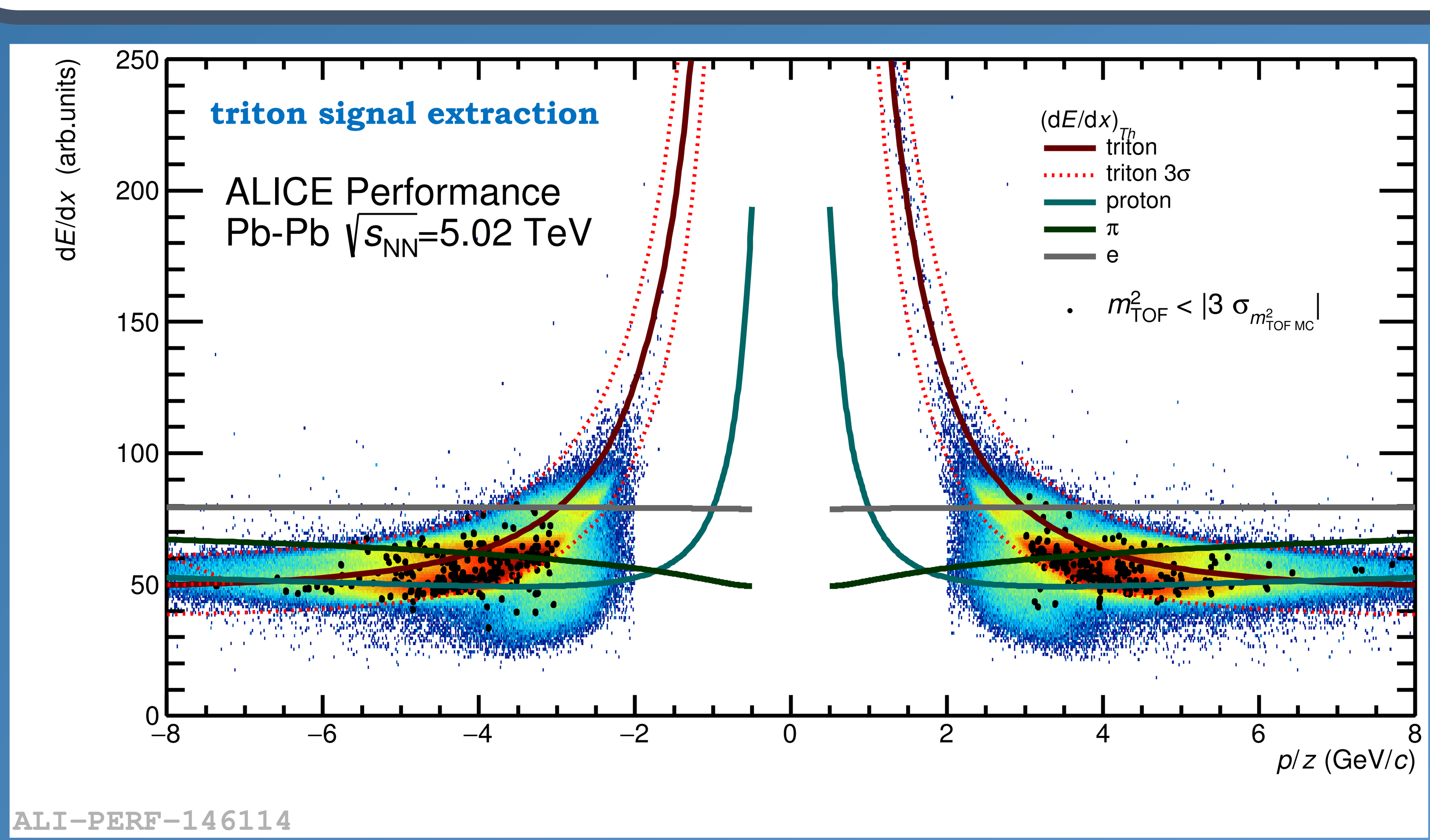
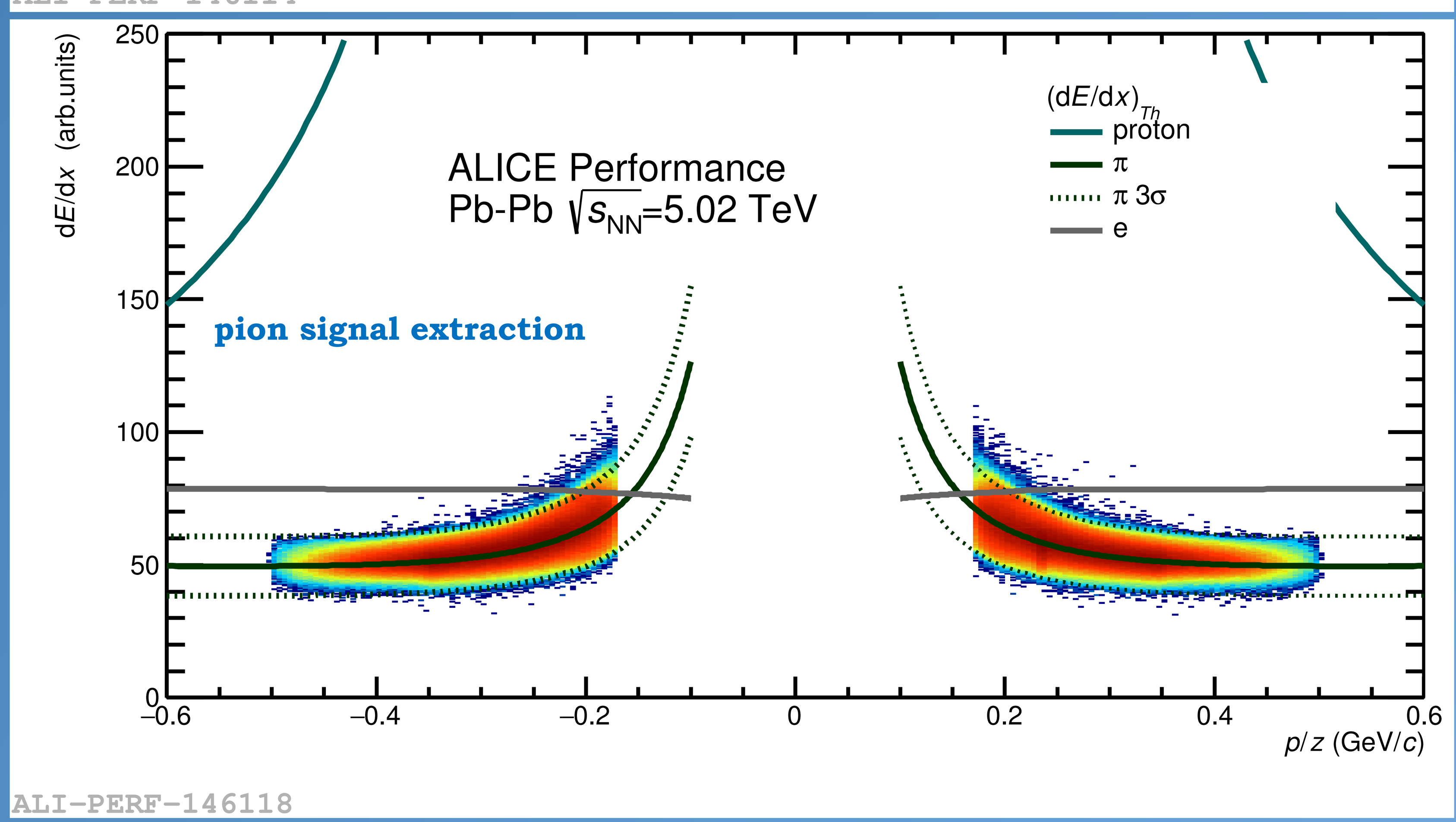




Analysis strategy

The main challenge of this analysis is that the signal is not only rare, but it may not even exist. A **machine learning** (ML) approach has been used to consider all the features of the signal. In particular the **Boost Decision Tree** (BDT) algorithm within the TMVA package [3] was used. The same analysis procedure was applied at both Pb-Pb collision energies $\sqrt{s_{NN}}$=2.76 TeV and $\sqrt{s_{NN}}$=5.02 TeV.

The particle identification (PID) for tritons was done via TPC **d*E*/d*x*** and Time Of Flight (TOF) measurements. The TOF signal was used in parallel to reject protons and pions below 4 GeV/*c* and the squared mass determined using the TOF detector was used above 3 GeV/*c* to have the necessary statistics for the BDT training stage. Only candidates containing antitritons were considered.

Λnn-> tπ extraction with ML

Training phase

Signal: dedicated MC simulations (the mass resolution was $\sigma_{\Lambda nn-MC}$≈2 MeV/c^2)

Background : V^0s from data and selected from the **sidebands** of the invariant mass distribution

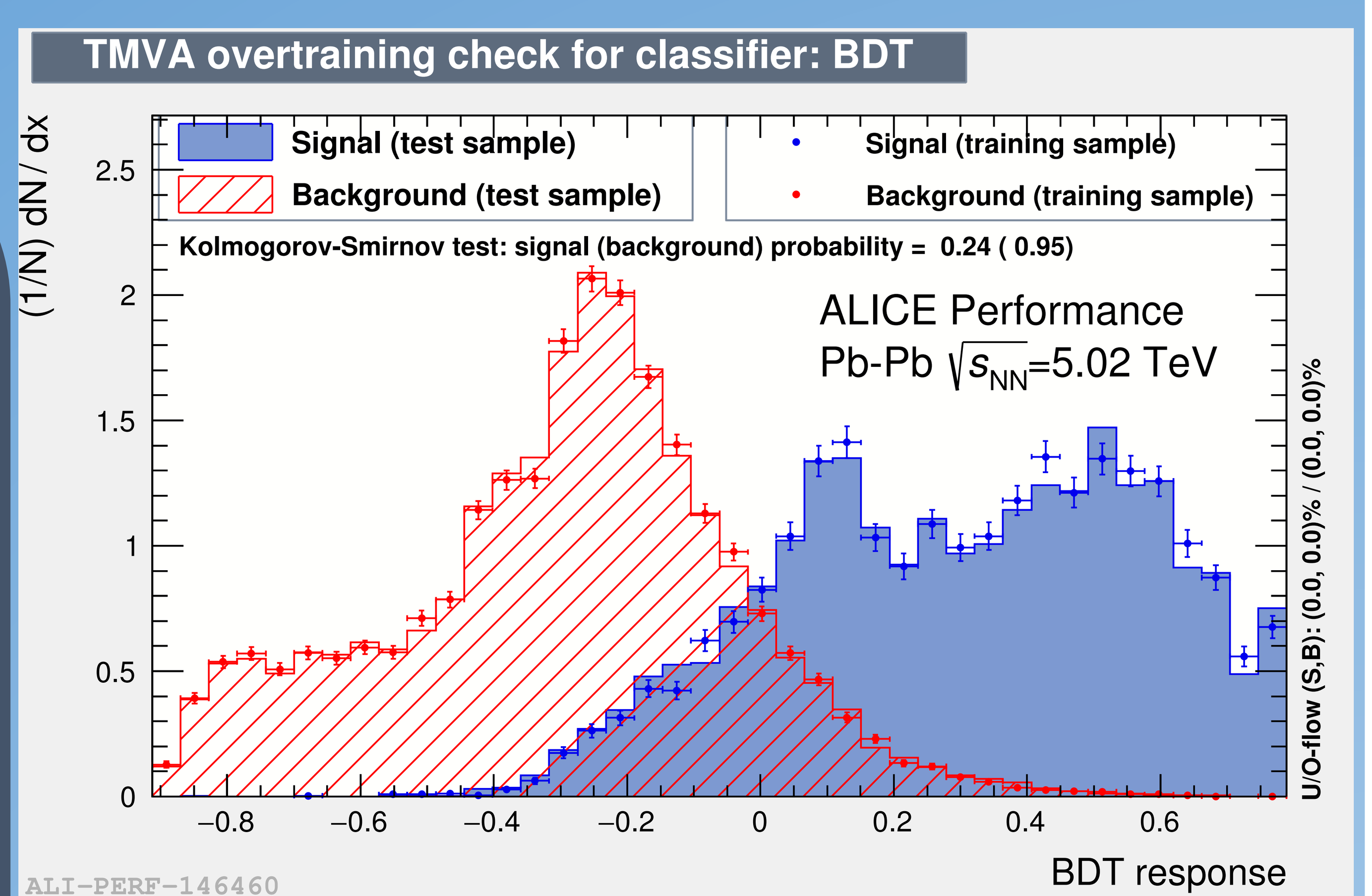
- M(tπ) < 2.982 GeV/c^2 - 3 $\sigma_{\Lambda nn-MC}$
- M(tπ) > 2.993 GeV/c^2 + 3 $\sigma_{\Lambda nn-MC}$.

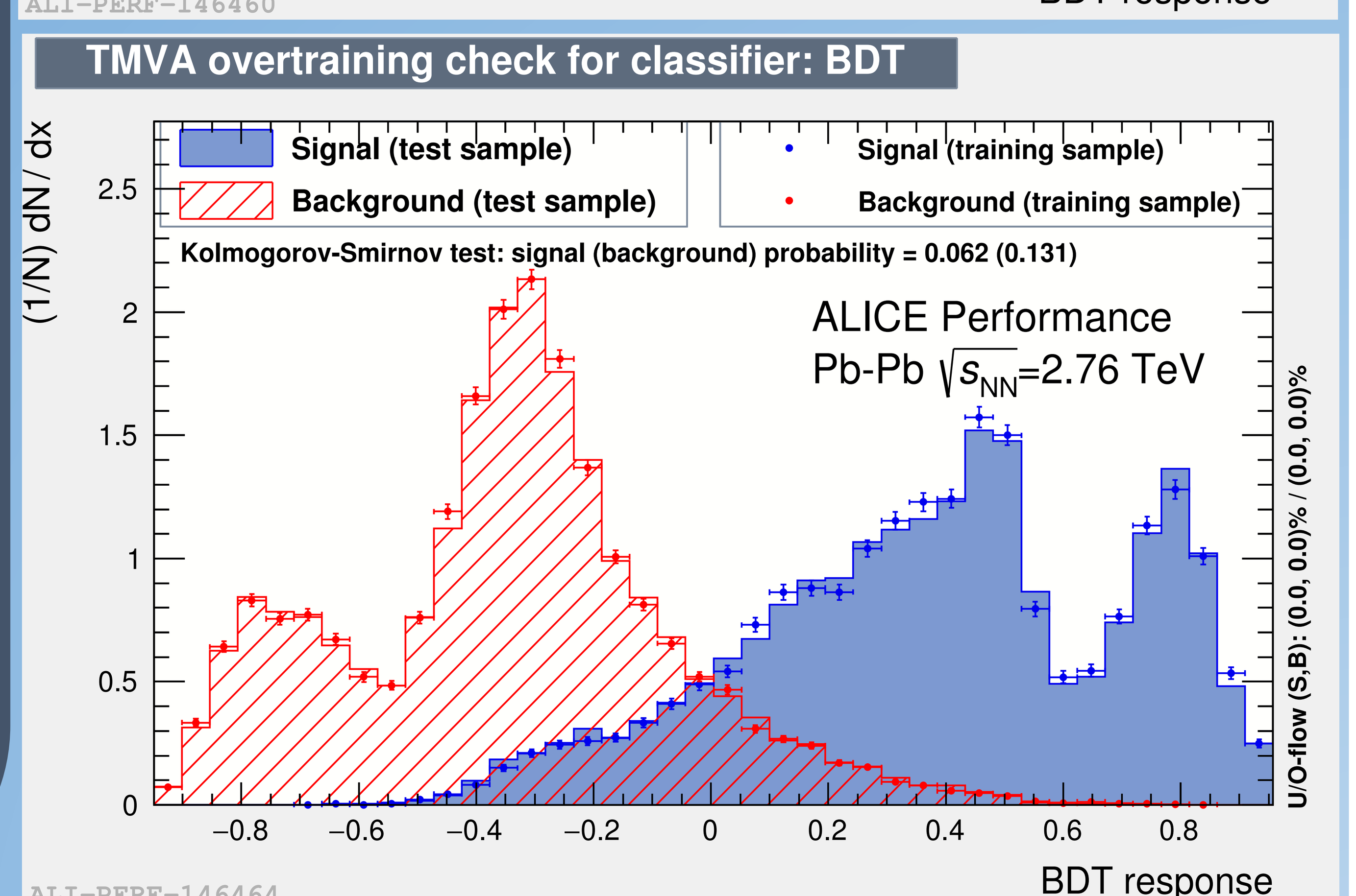
where 2.982 GeV/c^2 is the expected mass value at the *p** of the free Λ, 2.993 GeV/c^2 is the available measured value.

The PID selection was applied to tritons to have 10^4 candidates in both the signal sample and the background sample. Four variables were used and they were selected to avoid their correlations with the invariant mass in the background data sample. The plots on the right correspond to the results of the training stage and they show the BDT classifiers for both signal and background at both energies.

Application phase

The number of selected Λnn is compatible with the number of expected false positive candidates. Further studies are ongoing to include positive tritons.





[1] R. H. Dalitz and B. W. Downs in Phys. Rev. **110**, 958 (1958); **111**, 967(1958); **114**,593(1959).
[2] H. Garcilazo and A. Valcarce , Phys. Rev. C 89, 057001 (2014).
[3] https://root.cern.ch/tmva