Hunting hypertritons in heavy ion-collisions with the ALICE experiment using a machine learning approach

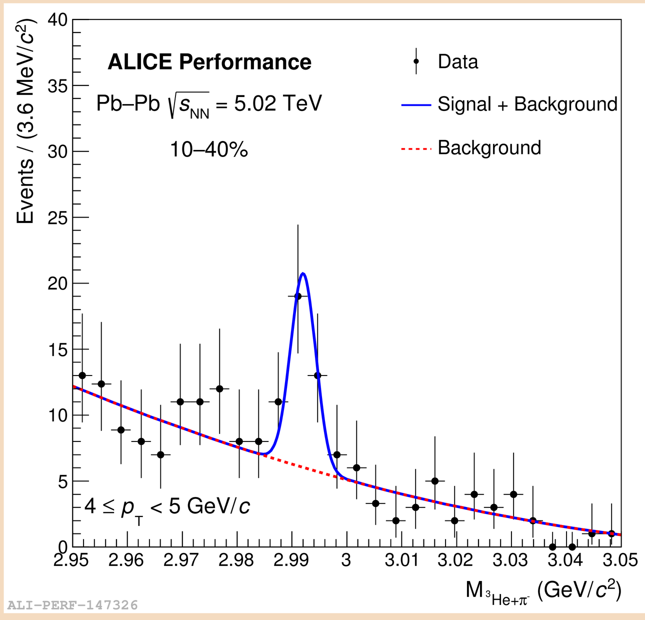
Pietro Fecchio for the ALICE Collaboration

DISAT Politecnico di Torino - INFN Torino
pietro.fecchio@cern.ch

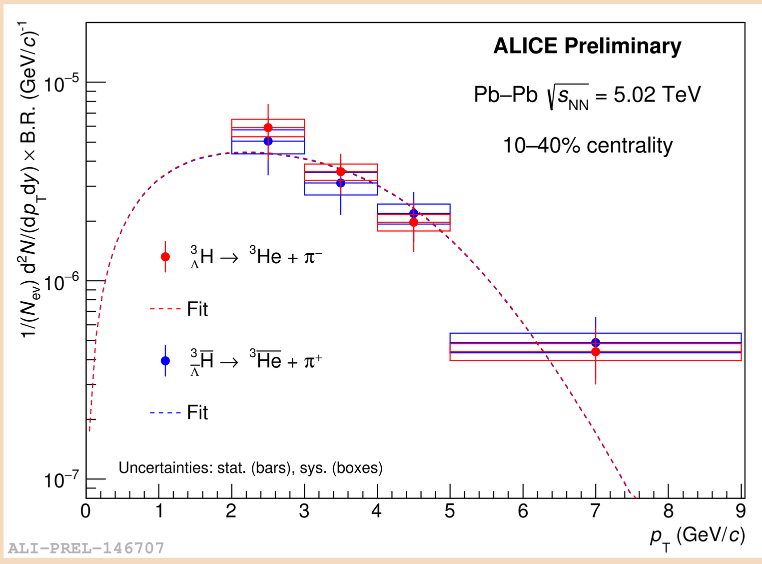
MOTIVATIONS

Hypertriton ($^{3}_{\Lambda}H$)

- Bound state of **p**, **n**, and **Λ**
  - **mass** = 2.99131 ± 0.00005 GeV/c² [1]
  - **Lifetime** (world average) = 216^{+16}_{-19} ps [2]
  - **Λ separation energy** B_Λ = 0.13 ± 0.05 MeV [1]
- Lightest known hypernucleus
- 2 mesonic decay channels accessible by ALICE
  - **^{3}He+π** decay (B.R. ≈ 25 %) [3]
  - **d+p+π** decay (B.R. ≈ 41 %) [3]



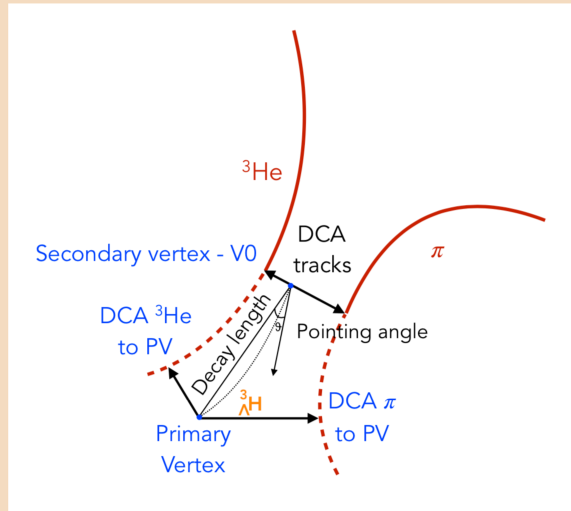
The study of hypertriton production can shed light on the formation mechanism of loosely-bound states in the extreme conditions of heavy-ion collisions



- Production yield and lifetime measured by ALICE in the 2-body decay channel with invariant-mass analysis
- Signal extraction is difficult due to the high combinatorial background
- The goal of this work is to show that **it is possible to improve the signal extraction** in the 2-body channel training a **Machine Learning model** to discriminate Signal and Background candidates

DATA PREPARATION

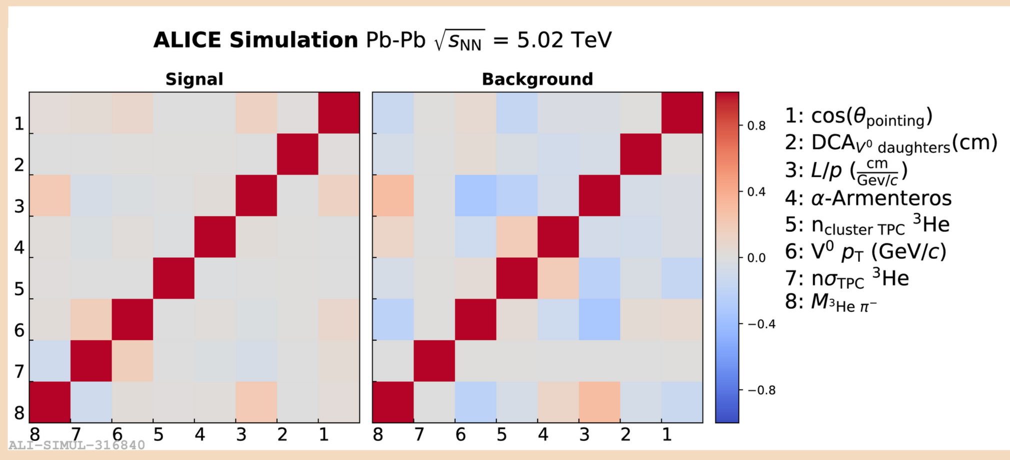
Training Set obtained combining Signal from Monte Carlo data and Background from real data ➞ Pb-Pb collisions at 5.02 TeV

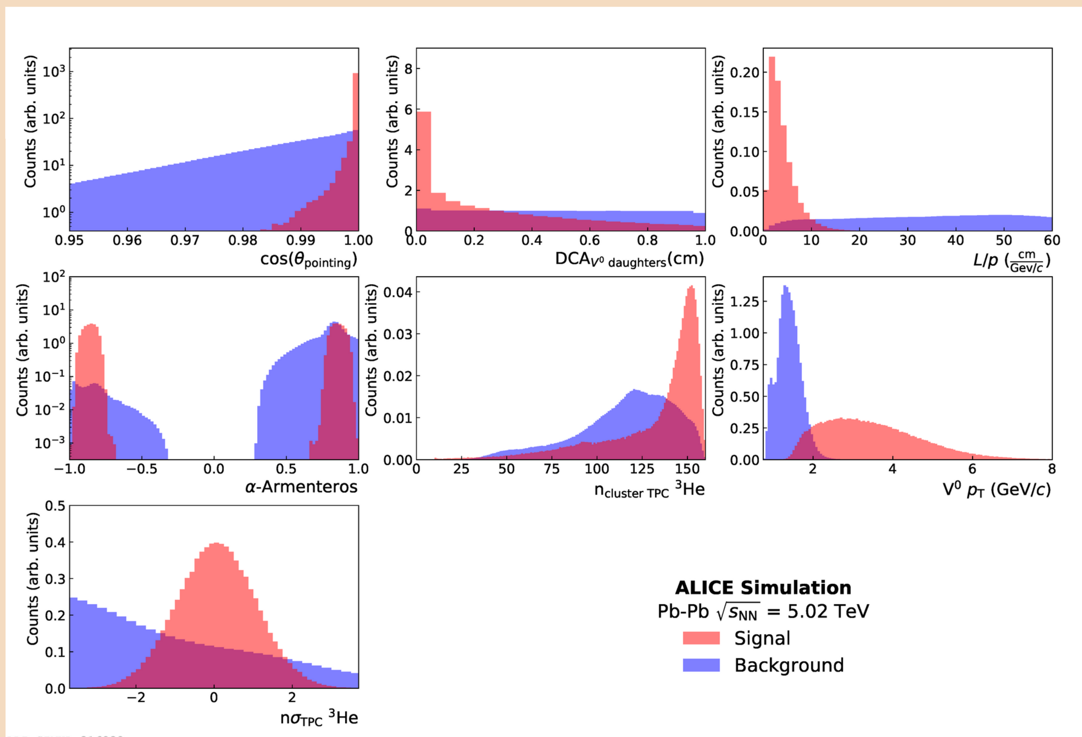


- **Signal**
  - 2.1 x 10⁵ Monte Carlo simulated hypertritons
  - expected p_T spectrum obtained assuming the ^{3}He spectrum for the hypertriton
- **Background**
  - 3.6 x 10⁶ background candidates
  - selected **excluding** the $2.980 < M_{^3He\ \pi} < 3.005$ GeV/c² invariant-mass interval (±5σ from the peak) to ensure that they are background candidates

In the Training Set only events in the same centrality class (10-40%) and p_T range (2-9 Gev/c) used in the standard analysis have been selected to have a meaningful performances comparison

Binary Classification: the BDT can learn how to discriminate between signal and background exploiting the topology of the 2-body decay and the correlations between the training features



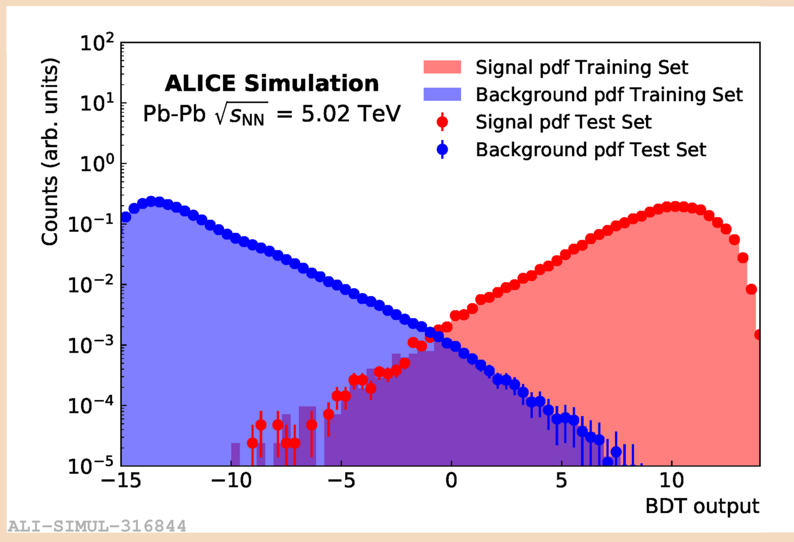


Features used for Training

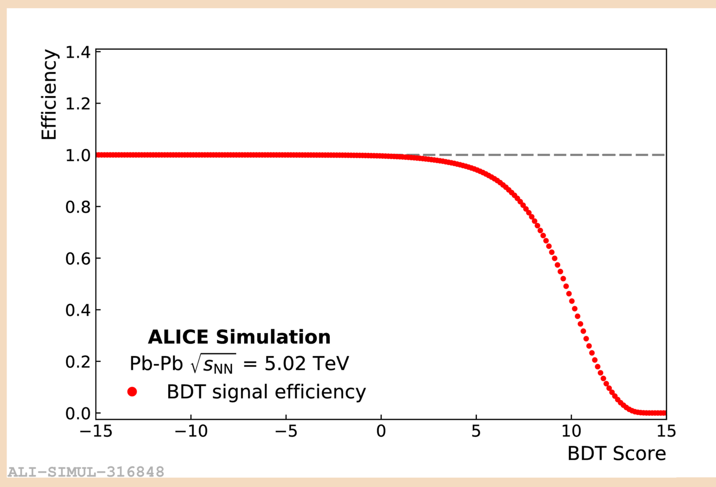
- cos($\theta_{pointing}$)
- $DCA_{V0\ daughters}$
- L/p
- α-Armenteros
- $n_{cluster\ TPC}$ ^{3}He
- V^0 p_T
- $n\sigma_{TPC}$ ^{3}He

TRAINING AND TESTING

- **The Model:** Boosted Decision Tree implemented in the ***XGBoost***[4] library:
  - Simple
  - Very suitable for binary classifications
- **Loss function:** logistic
- **Hyperparameters Optimization:**
  - 5-fold grid search



BDT output ➞ value related to the probability that a candidate is Signal or Background



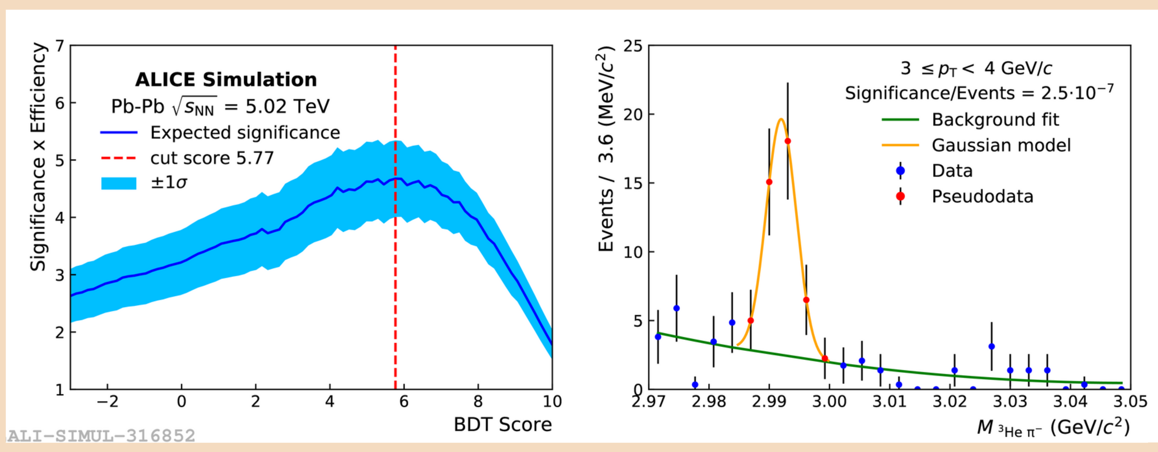
- **Excellent agreement** of the BDT score distributions between Training and Test Set
- **High efficiency** in the signal selection over a wide BDT score range
- **High background rejection** with BDT scores around 5

The BDT score has **excellent discriminating power** and the optimal selection on the BDT score must be found

PERFORMANCE

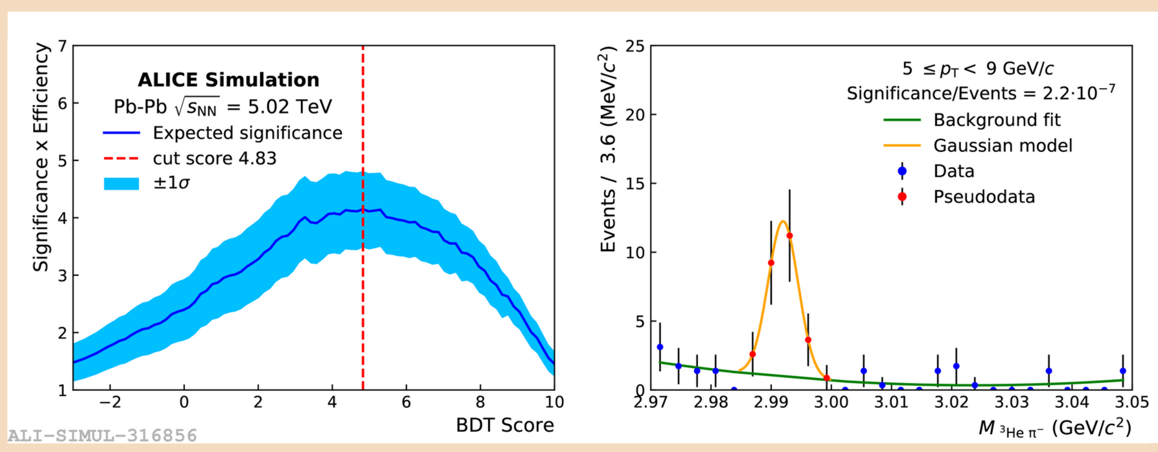
Significance estimation:

- measured hypertriton yield used to produce pseudodata for simulating the expected signal
- background shape obtained from real data



Selection on the BDT score:

- BDT score that maximize **Significance x BDT efficiency**
- Optimization for each p_T bin



Significance/Events used to compare the performance of this method with the standard analysis in the signal extraction

p_T (GeV/c) \ Sign./Events	Standard analysis	BDT analysis	Percentage increase
2-3	1.3	2.2	69%
3-4	1.6	2.5	56%
4-5	1.3	2.1	61%
5-9	1.2	2.2	83%

- **Increase** of the Significance/Events **in each considered p_T bin**
- **Very good improvement** at high p_T

RESULTS AND OUTLOOK

- This work shows that it **is possible to increase the performance** of the hypertriton signal extraction training a machine learning model (BDT) to discriminate between Signal and Background candidates
- The **significance/events increase by a factor up to 1.8** using this new approach

ONGOING

- The possibility to increase the performance of this method using different centrality classes or p_T ranges will be investigated.
- We are working to adapt this method to the **3-body decay** in order to extract the signal and obtain the measurement of the hypertriton lifetime with improved precision!

References
[1] D.H. Davis, Nucl. Phys. A 754 (2005) 3-13
[2] C. Rappold et al., Phys. Lett. B 728, 543 (2014)
[3] H. Kamada et al., Phys. Rev. C 57 (1998) 1595-1603
[4] Chen, T. and Guestrin, C. (2016) arXiv:1603.02754v1