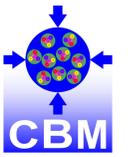


Hypernuclei studies in heavy-ion collisions with the CBM experiment



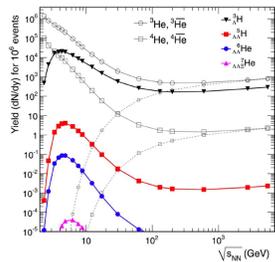
Susanne Glaessel for the CBM collaboration, Goethe University Frankfurt, Germany

New physics opportunities

Precise measurements of hypernuclei with high statistics at CBM:

- * Properties & production mechanism of hypernuclei
- * Hyperon-Nucleon(YN)- /Hyperon-Hyperon(Y) interactions
- * EoS of hadronic matter at high density & low temperature → neutron stars
- * Sufficient statistics for double hypernuclei, e.g. ${}_{\Lambda\Lambda}^6\text{He}$

Particle yields from thermal model calculations¹



Neutron star merger

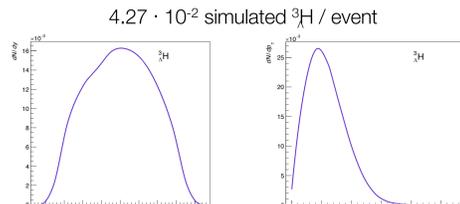
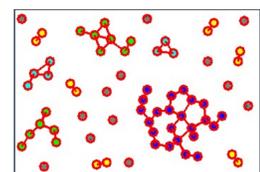


Simulation input

PHQMD^{2,3} events (10⁶): Au+Au at 4.9 GeV 10% most central events

- n-body microscopic transport approach to describe HICs
- cluster formation: due to potential interactions between baryons (QMD⁴)
- cluster recognition: search baryon accumulations in phase-space (MST)

cluster recognition with MST $|r_i - r_j| < 4.0$ fm



→ see talk by E. Bratkovskaya, session Light Flavor 2, Wed., 9:30 am

Reconstruction of ${}_{\Lambda}^3\text{H}$ 3-body-decay

${}_{\Lambda}^3\text{H}$ 3-body-decay as case study for ${}_{\Lambda}^6\text{He}$

${}_{\Lambda}^3\text{H} \rightarrow d + p + \pi^-$ (branching ratio = 40.1 %)

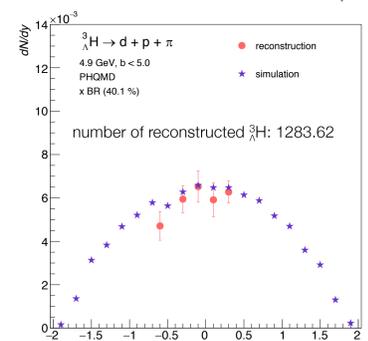
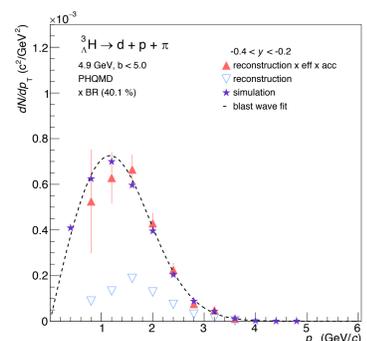
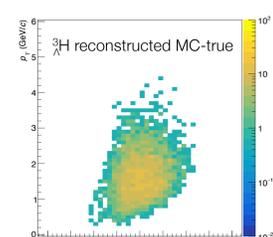
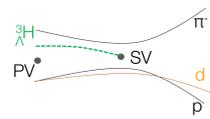
Full detector simulation and reconstruction chain

→ $1.59 \cdot 10^{-2}$ accepted ${}_{\Lambda}^3\text{H}$ / event

Reconstruction with PFSimple⁵ software based on KFParticleFinder⁶ using Kalman filter algorithm.

Particle identification with TOF-PID⁷.

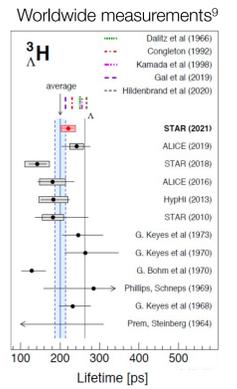
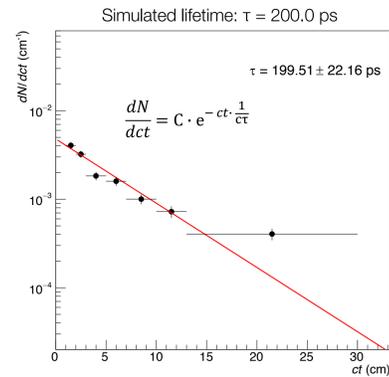
Extrapolation to unmeasured p_T -regions with Blast-Wave model fits⁸.



Description of y -spectrum within error bars for $-0.5 < y < 0.5$.

At rapidities $|y| > 0.5$: large systematic effects of extrapolation with given statistics.

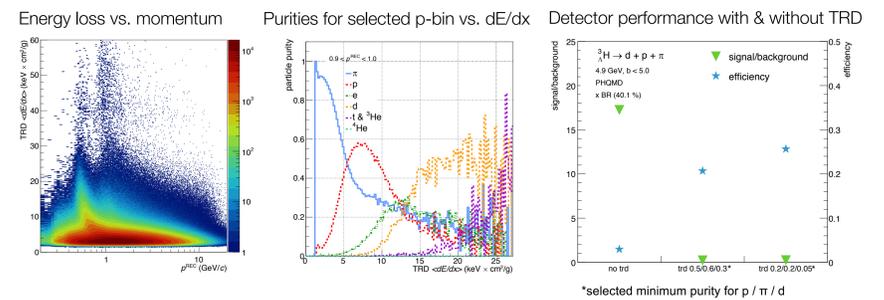
Lifetime measurement for ${}_{\Lambda}^3\text{H}$



Estimated lifetime $\tau = 199.5 \pm 22.2$ ps reproduces simulated lifetime well within error. Statistical error for only 10^6 events is already at the same range as latest STAR error.

Improving reconstruction performance with TRD-dE/dx

Particle identification based on specific energy loss for particle species depending on momentum.

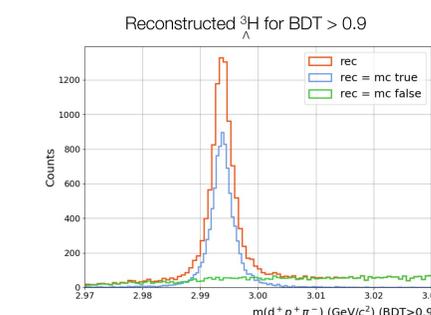
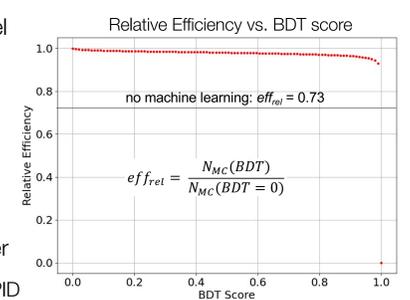


With TRD efficiencies can be increased from 3 % (without TRD) to up to 26 %.

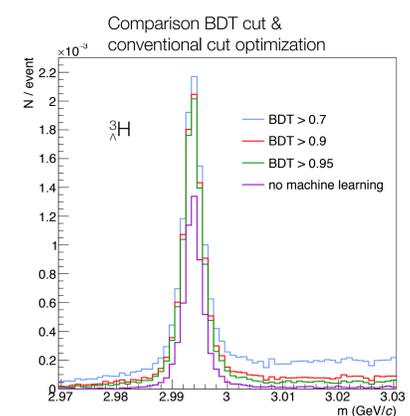
Improving reconstruction efficiency with Machine Learning approach

XBoost model¹⁰: Boosted decision tree model maps cut value vector of a candidate* to the probability of being a signal candidate → BDT score.

Training with Hipe4ML python package, Optuna¹¹ package used is for hyperparameter optimization. *candidate selection based on MC-PID



BDT	no ML	0.7	0.9	0.95
efficiency	0.427	0.540	0.533	0.529



Improvement of absolute efficiency in acceptance from 43 % (no ML) to 54 %.

References: ¹A. Andronic et al., Phys. Lett. B697 (2011) 203-207 | ²W. Cassing, E. Bratkovskaya, PRC 78 (2008) 034919; NPA831 (2009) 215 | ³W. Cassing, EPJ ST 168(2009) | ⁴J. Aichelin et al., PRC 101 (2020) 044905 | ⁵O. Lubynets et al., 36th CBM collaboration meeting (2019) | ⁶I. Kisel et al., IEEE T Nucl. Sci. 60, No. 5 (2013) 3703 | ⁷V. Klochov et al., 32nd CBM collaboration meeting (2018) | ⁸E. Schnedermann, J. Sollfrank, and U. Heinz, Phys. Rev. C 48, 2462 (1993) | ⁹Y-H Leung QM22 (STAR) | ¹⁰T.Chen, C. Guestrin, 22nd ACM SIGKD (2016). | ¹¹T. Akiba et al, 25th ACM SIGKDD (2019).