Implementation of Machine Learning techniques in ion optics

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Introduction & Motivation

✶ How to determine interaction between nucleons and hyperons?

→ **Hypernuclei spectroscopy**

✶ Crucial for Equation-of-State of Neutron Stars

✶ Short lifetime (~200 ps) → we detect decay products

✶ **Invariant mass** depends on its momentum:

→ **Reconstruction of momentum from products**

✶ **ML** for reconstruction of momentum of fragments

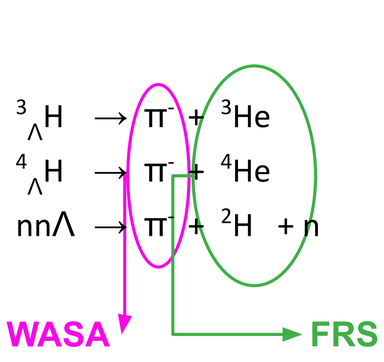
✶ Calibration of ion-optics from the experimental data

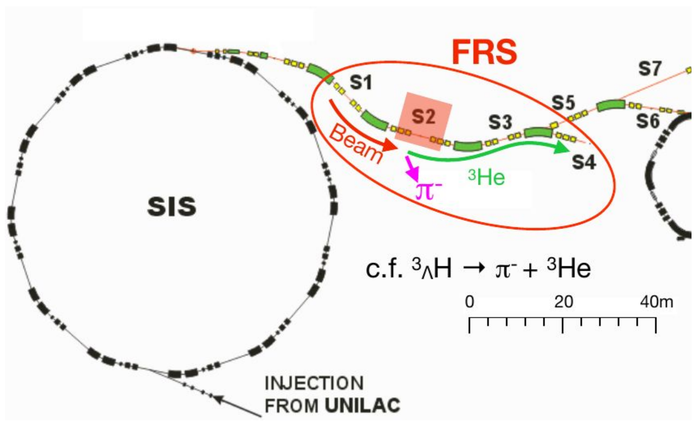
✶ Expected improvements from previous estimators

Experimental setup

Experimental observation of hypernuclei: S447 experiment[1]

►We detect products of mesonics weak decay: π^- & **fragment**





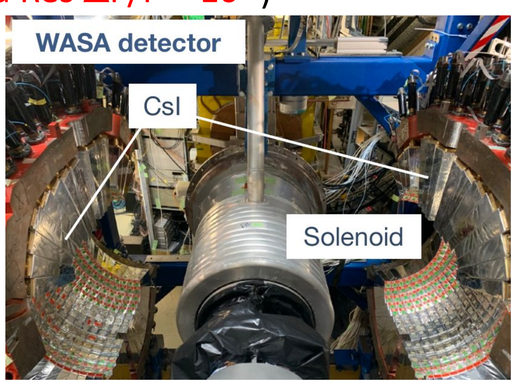
FRS

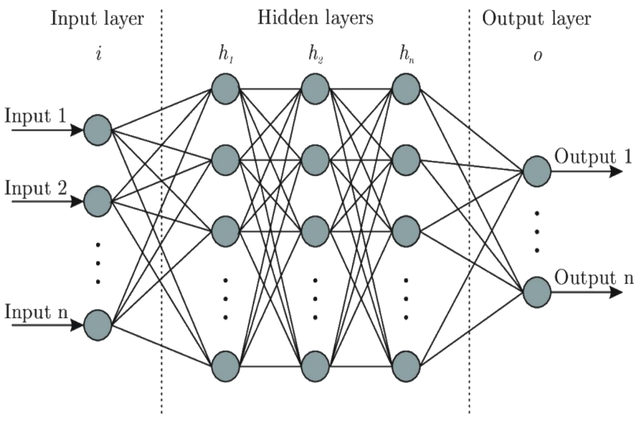
►The second half of the FRagment Separator FRS [2] serves as a high-resolution spectrometer (Momenta Res $\Delta P/P \sim 10^{-4}$)

WASA

►Wide Angle Shower Apparatus (WASA) [3] placed in the focal plane S2 of the FRS

►Includes: Mini Drift Chamber, plastic scintillators, CsI crystals, fiber trackers and solenoid of 1T





Machine Learning

►Training of models in order to calibrate ion optics of FRS

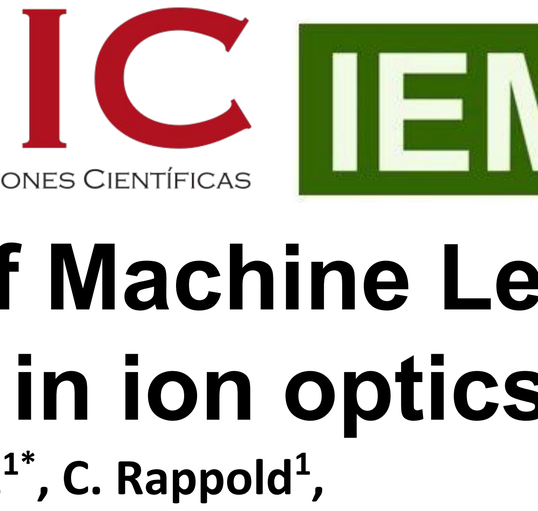
►Implementation of Neural Network models from sklearn[4]

►Implementation of automated Machine Learning methods from autosklearn[5] and TPOT[6]

Preliminary Results

Implementation of NN in 2017

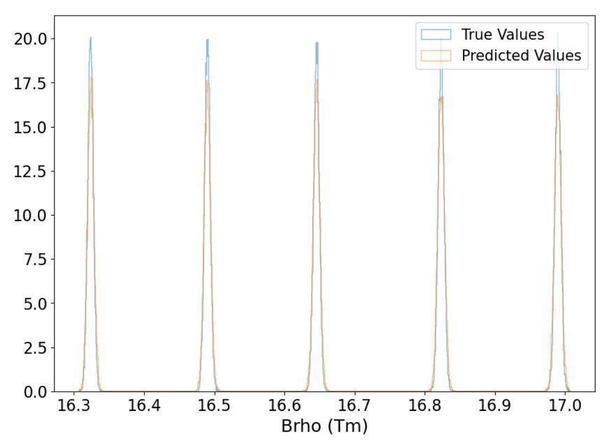
▻ Training manually tuned NN with mocadi data we get:

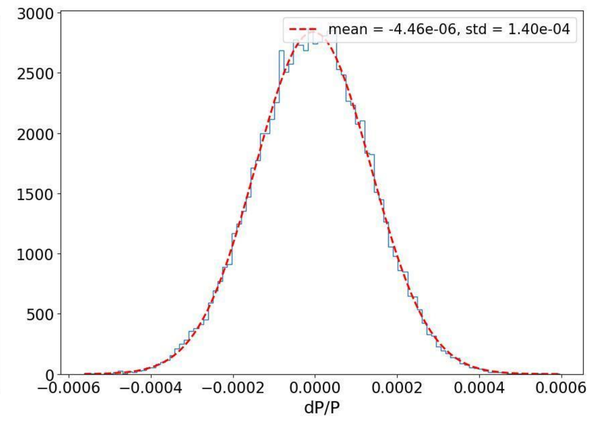


AutoML in 2024

▻ Automated data preprocessing, model selection and fitting of hyperparameters

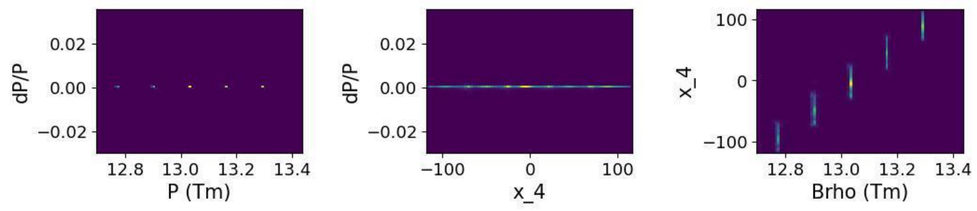
▻ Mocadi with WASA-FRS HypHI setting taking angles and momentum segments

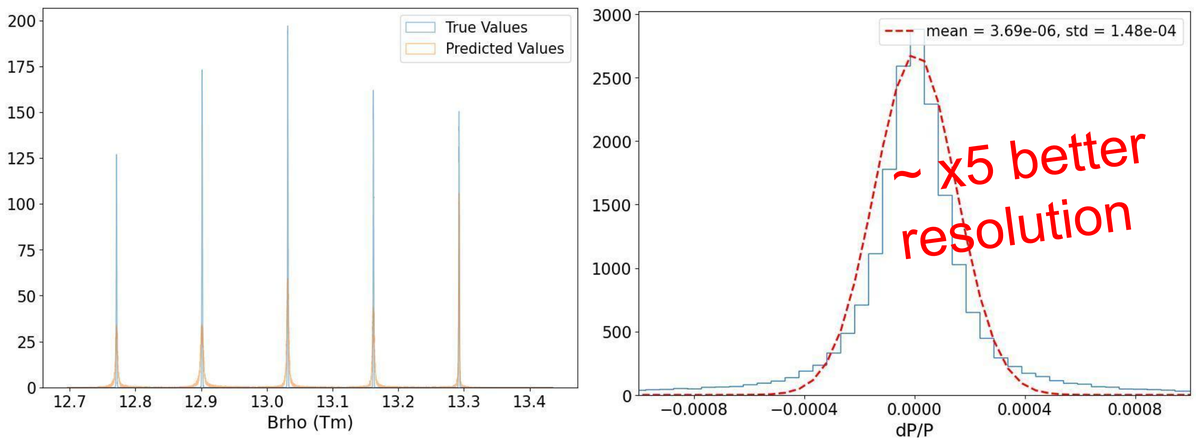




Experimental online data

▻ Using experimental online data from WASA-FRS HypHI we see a clear improvement of the results compared to the previous results





Conclusions

✔ Hypernuclei have short lifetime → they can be studied through their decay products

✔ From the momentum of the decay products we can reconstruct the invariant mass of the hypernuclei

✔ The implementation of ML techniques allows us to calibrate more accurately the ion optics of the FRS with a x5 improvement

References

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