

# OASIS AI Workshop 2026

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J. Ljungvall

June 15, 2026

# This is workshop number four(six)

## OASIS WS on Machine Learning and AI in the AGATA community

A short meeting to make a snapshot of the work presently done and ideas for the future within the AGATA and OASIS communities. It will be held via webinar

 15 juin 2026 09:00

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## OASIS WS on Machine Learning and AI in the AGATA community

A short meeting to make a snapshot of the work presently done and ideas for the future within the AGATA and OASIS communities. It will be held via ZOOM

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## OASIS WS on Machine Learning and AI in the AGATA community

A short meeting to make a snapshot of the work presently done and ideas for the future within the AGATA and OASIS communities.


 17 janvier 2023 12:50

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## OASIS WS on Machine Learning and AI in the AGATA community


A short meeting to make a snapshot of the work presently done and ideas for the future within the AGATA and OASIS communities.

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## The 2nd OASIS Workshop


 27 avril 2020 - 28 avril 2020

 108 (J)CLab

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## OASIS WS

 23 mai 2019 - 24 mai 2019

 Orsay

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# OASIS AI 2026

An continuation of work started under the OASIS ANR

- A yearly reminder of what we are doing in the AGATA collaboration
- Not only for HPGe and  $\gamma$ -ray tracking

To inspire and exchange ideas.

- Who is doing what?
- Are we advancing AGATA with what we do?
- Is there a low-hanging fruit for AI not yet picked?

Define a policy for use of AI in AGATA (code base)

- Should we have one?
- We have happily adopted licences from open source community before, let us be inspired?

# Examples of AI and ML from nuclear physics

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Jason D. Holt 4

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**Muon Nuclear Data Development Project** #1

Yukinobu Watanabe, Megumi Nishura, Shirotsugu Ahe, Sayari Banas, Hiroki Inamoto et al. (May 15, 2026)

e-Print: 2605.15529 [nucl-ex]

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**Microscopic derivation of the interacting boson model parameters with machine learning** #2

Y. Otsu, K. Nomura (May 15, 2026)

Published in: Phys.Lett.B 878 (2026) 140532 + e-Print: 2605.15623 [nucl-th]

pdf DOI cite claim reference search 0 citations

**AI-assisted modeling and Bayesian inference of unpolarized quark transverse momentum distributions from Drell-Yan data** #3

ZhongBo Kang (UCLA and SUNY Stony Brook), Luke Sellers (UCLA), Congqun Zhang (UCLA), Curtis Zhou (UCLA) (Apr 15, 2026)

e-Print: 2604.14133 [hep-ph]

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**Linking Electromagnetic Moments to Nuclear Interactions with a Global Physics-Driven Machine-Learning Emulator** #4

Jose M. Muro, Andrei Bely, Andreas Ekström, Gaute Hagen, Jason D. Holt et al. (Mar 27, 2026)

e-Print: 2603.26905 [nucl-th]

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**VarP-GP: cost-efficient Bayesian emulation of quark-gluon plasma modeling with variable statistical precision** #5

R. Ehlers (LBNL, NSD and UC, Berkeley), Y. Ji (Duke U. and Unlimited, UT), P.M. Jacobs (LBNL, NSD and UC, Berkeley), S. Malik (Duke U. and Unlimited, UT) (Mar 4, 2026)

e-Print: 2603.05545 [nucl-th]

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**Trace Anomaly of Cold Dense Matter Constrained by Collective Flow** #6

Bao-An Li (Texas A-M, Commerce) (Jan 15, 2026)

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**Understanding charge radii with machine learning: Discovering physics expressions** #7

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# Examples of AI and ML from nuclear physics

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**AI-assisted modeling and Bayesian inference of unpolarized quark transverse momentum distributions from Drell-Yan data** #1  
 Zhong Bo Kang (UCLA and SUNY Stony Brook), Luke Seliger (UCLA), Congque Zhang (UCLA), Curtis Zhou (UCLA) (Apr 15, 2024)  
 e-Print: 2404.14133 [hep-ph]  
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**Single-particle strength toward  $N = 32$ : Spectroscopy of  $^{24}\text{Ca}$  via the  $^{20}\text{Ca}(d, p)$  reaction** #2  
 C. Ferreira, K. Wimmer, D. Suzuki, N. Inai, A. Jungblut et al. (Mar 15, 2024)  
 Published in: Phys.Rev.C 113 (2024) 4, 044311 - e-Print: 2403.18632 [nucl-ex]  
 pdf DOI cite oai reference search 0 citations

**Physics-Informed Global Extraction of the Universal Small- $x$  Dipole Amplitude** #3  
 Si Wei Qiu (CCNL, Wuhan, Inst. Part. Phys. and Huazhong Normal U., LGP and Huazhong Normal U.), Fu-Peng Li (Fudan U. and Fudan U., Shanghai), Long-Gang Pang (CCNL, Wuhan, Inst. Part. Phys. and Huazhong Normal U., LGP and Huazhong Normal U.), Guang-You Qiu (CCNL, Wuhan, Inst. Part. Phys. and Huazhong Normal U., LGP and Huazhong Normal U.), Shu-Yi Wei (SDU, Qingdao) et al. (Mar 9, 2024)  
 e-Print: 2403.09039 [hep-ph]  
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**Realizing the scientific program with polarized ion beams at the future BNL Electron Ion Collider** #4  
 EPOS Scientific Consortium - Grigor Alkhan (Brookhaven) et al. (Oct 12, 2023)  
 Published in: Phys.Rev.C 113 (2024) 6, 065501 - e-Print: 2510.10794 [nucl-ex]  
 pdf DOI cite oai reference search 4 citations

**The DNA of nuclear models: How AI predicts nuclear masses** #5  
 Kate A. Richardson (JAFI, Cambridge and MIT LNS), Sokratis Trifonopoulos (JAFI, Cambridge and MIT LNS and CERN and Zurich U.), Mike Williams (JAFI, Cambridge and MIT LNS) (Aug 11, 2023)  
 e-Print: 2308.08370 [nucl-th]  
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Number of authors:  10 authors or fewer 5

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Document Type:  article 11,  published 7,  conference paper 1,  review 1

Author:  Tarja Hovi 4,  Markus Dieckhoner 4,  Yoshitaka Hata 3,  Leticia FouadHiri 3,  Avinash Deshpande 3,  Ian C. Cloet 3

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# Examples of AI and ML from nuclear physics

## Understanding Charge Radii with Machine Learning: Discovering Physics Expressions

B. Maheshwari<sup>a</sup>, P. Van Isacker<sup>a</sup>

*<sup>a</sup>Grand Accélérateur National d'Ions Lourds, CEA/DSM-CNRS/IN2P3 Bvd Henri Becquerel F-14076 Caen, France*

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### Abstract

We introduce a robust, interpretable machine learning (ML) framework that combines numerical regression for high-accuracy predictions with symbolic regression to uncover the underlying physics. This hybrid approach efficiently derives analytical expressions by leveraging the smoothed predictions of optimized ML models, a significant acceleration over direct symbolic regression on raw experimental data.

We apply this framework, as an example, to nuclear charge radii across the nuclear chart, notably including light nuclei that are often excluded from such studies. We employ Light Gradient Boosting Machine (LGBM) and Gaussian Process Regression (GPR) models to map correlations between charge radii and key physical features: mass  $A^{1/3}$  and proton number  $Z^{1/3}$  dependencies, total binding energy, and for the first time, the pairing gap. Our models are rigorously trained using four-fold cross-validation with automated hyperparameter optimization, ensuring robustness and generalizability, which is critical for the typically small and skewed datasets in nuclear physics. Finally, we distill the knowledge from the initial LGBM and GPR models into simplified, interpretable mathematical expressions via symbolic regression, white-boxing these ML models. The derived formulas provide physical insights comparable to traditional many-body models and demonstrate a powerful pathway for physics expression discovery guided by ML.

**Keywords:** Charge Radii, Machine Learning, Light Gradient Boosting Machine, Gaussian Process Regression, Symbolic Regression

cl-th] 7 Dec 2025

# Examples of AI and ML from nuclear physics

## Linking Electromagnetic Moments to Nuclear Interactions with a Global Physics-Driven Machine-Learning Emulator

Jose M. Munoz,<sup>1</sup> Antoine Belley,<sup>1</sup> Andreas Ekström,<sup>2</sup> Gaute Hagen,<sup>3,4</sup> Jason D. Holt,<sup>5,6</sup> and Ronald F. Garcia Ruiz<sup>1</sup>

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(Dated: June 5, 2026)

Understanding how specific components of the nuclear interaction shape observable properties of atomic nuclei remains a central challenge in nuclear structure research. While previous studies have focused on bulk observables such as nuclear energies and charge radii, it is unclear how distinct operator components of nuclear interactions impact complementary observables such as nuclear electromagnetic moments. Here, we develop a global, physics-constrained emulator to establish a quantitative link between electromagnetic moments and components of chiral nuclear forces. Unlike traditional sensitivity analyses that vary low-energy constants independently, we quantify parameter contributions while accounting for correlations within the physically supported parameter manifold. We show that, unlike bulk observables, electromagnetic moments probe complementary spin and isospin sectors of the interaction and exhibit a pronounced isotope-dependent sensitivity. These developments enable a quantitative assessment of the importance of prospective measurements, providing predictions with quantified uncertainties for observables that may be beyond the current experimental reach.

# Examples of AI and ML from nuclear physics

Eur. Phys. J. C manuscript No.  
(will be inserted by the editor)

## Pulse shape discrimination for $\alpha$ event rejection in BEGe-type high-purity germanium detectors

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Received: date / Accepted: date

**Abstract** High-purity germanium detectors are widely used in rare-event searches due to their excellent energy resolution and extremely high intrinsic (radio)purity. In experiments searching for neutrinoless double beta decay in  $^{76}\text{Ge}$  such as LEGEND, pulse shape discrimination is required to suppress multi-site  $\gamma$  events. In this work, we investigate whether pulse shape discrimination classifiers trained exclusively on  $\gamma$  ray data can be used to identify and reject

### 1 Introduction

High-purity germanium (HPGe) detectors have been successfully applied in  $\gamma$ -spectrometry due to their excellent energy resolution and high detection efficiency. In addition, they are also deployed in searches for rare events, such as dark matter particles interactions or neutrinoless double beta ( $0\nu\beta\beta$ ) decay. The latter can theoretically occur in several

cs.ins-det] 13 May 2026

# Examples of AI and ML from nuclear physics

CERN-TH-2025-153

## The DNA of nuclear models: How AI predicts nuclear masses

Kate A. Richardson,<sup>1,2,\*</sup> Sokratis Trifinopoulos,<sup>1,2,3,4,†</sup> and Mike Williams<sup>1,2,‡</sup><sup>1</sup>*NSF AI Institute for Artificial Intelligence and Fundamental Interactions*<sup>2</sup>*Laboratory for Nuclear Science, MIT, Cambridge, MA 02139, USA*<sup>3</sup>*Theoretical Physics Department, CERN, Geneva, Switzerland*<sup>4</sup>*Physik-Institut, Universität Zürich, 8057 Zürich, Switzerland*

Obtaining high-precision predictions of nuclear masses, or equivalently nuclear binding energies,  $E_b$ , remains an important goal in nuclear-physics research. Recently, many AI-based tools have shown promising results on this task, some achieving precision that surpasses the best physics models. However, the utility of these AI models remains in question given that predictions are only useful where measurements do not exist, which inherently requires extrapolation away from the training (and testing) samples. Since AI models are largely *black boxes*, the reliability of such an extrapolation is difficult to assess. We present an AI model that not only achieves cutting-edge precision for  $E_b$ , but does so in an interpretable manner. For example, we find that (and explain why) the most important dimensions of its internal representation form a double helix, where the analog of the hydrogen bonds in DNA here link the number of protons and neutrons found in the most stable nucleus of each isotopic chain. Furthermore, we show that the AI prediction of  $E_b$  can be factorized and ordered hierarchically, with the most important terms corresponding to well-known symbolic models (such as the famous liquid drop). Remarkably, the improvement of the AI model over symbolic ones can almost entirely be attributed to an observation made by Jaffe in 1969 based on the structure of most known nuclear ground states. The end result is a fully interpretable data-driven model of nuclear masses based on physics deduced by AI.

30 Sep 2025

# Examples of AI and ML from nuclear physics

REVIEWS OF MODERN PHYSICS, VOLUME 94, JULY-SEPTEMBER 2022

## **Colloquium: Machine learning in nuclear physics**

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 (published 8 September 2022)

09:00 – 10:20	<b>AI and Machine Learning in the AGATA community</b>	
09:00	<b>Introduction to the workshop</b>	⌚ 20m
	Orateur: Joa Ljungvall (IPHC/IN2P3/CNRS)	
09:20	<b>Machine learning for basis generation</b>	⌚ 20m
	Orateur: Dr Luca Zago (ip2i Lyon)	
09:40	<b>Gamma-ray tracking using Machine Learning</b>	⌚ 20m
	Orateur: Amel KORICHI (CSNSM-IN2P3/CNRS)	
10:00	<b>AGATA PSA basis with AGATAGeFEM</b>	⌚ 20m
	Orateur: Joa Ljungvall (IPHC/IN2P3/CNRS)	
10:20 – 10:30	Coffe break	⌚ 10m
10:30 – 11:50	<b>Machine learning and AI outside of AGATA</b>	
10:30	<b>Machine learning to analyse data from VAMOS</b>	⌚ 20m
	Orateur: Dr Antoine Lemasson (GANIL / CNRS)	
10:50	<b>PhysiCal-PET: Physics based Calibration of PET scanners</b>	⌚ 20m
	Orateur: Mojahed Abushawish (Universidad de Madrid)	
11:10	<b>Bayesian Optimization Applied to Radioactive Beam Transport for the AGATA-EXOTIC Campaign at LNL</b>	⌚ 20m
	Orateur: Davide Genna (Università degli Studi di Milano & INFN Sezione di Milano)	
11:30	<b>Level-Scheme Construction as a Constrained Inverse Problem: Probabilistic Structure Recovery from <math>\gamma</math>-Ray Observables</b>	⌚ 20m
	Orateur: Mlle Samantha Buck (University of Guelph)	
11:50 – 12:50	<b>Round table discussions</b>	
11:50	<b>Machine learning and AI in AGATA - how to adapt IT infrastrucutre</b>	⌚ 20m
	Orateur: Olivier Stezowski (IP2i)	
12:10	<b>AI generated code in AGATA - how to mange it?</b>	⌚ 20m
	Orateur: Dr Emmanuel CLEMENT (GANIL)	