Aobo Li

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EDUCATION BACKGROUND

Boston University **Boston, MA, US**
P.h.D., Physics *Sept. 2015 - Sept. 2020*
"The Tao and Zen of Neutrinos: Neutrinoless Double Beta Decay in KamLAND-Zen 800",
Advisor: Christopher P. Grant

University of Washington, Seattle **Seattle, WA, US**
B.S., Comprehensive Physics *Sept. 2011 - Jun. 2015*

APPOINTMENT

UNC Chapel Hill **Chapel Hill, NC, US**
COSMS Fellow,
Department of Physics and Astronomy *Sept. 2020 - Now*

Boston University **Boston, MA, US**
Graduate Research Assistants,
Department of Physics *Jan. 2017 - Sept. 2020*

University of Washington **Seattle, WA, US**
Undergraduate Research Assistant,
Center of Elemertary Nuclear Physics and Astroparticle *Sept. 2014 - Sept. 2015*

AWARDS

Dissertation Award in Nuclear Physics **American Physics Society**
https://www.aps.org/programs/honors/prizes/nuclear.cfm

Postdoctoral Award of Research Excellence **UNC Chapel Hill**
https://research.unc.edu/2022/09/14/2022-pare-award-recipients/

MLST Paper Award **NeurIPS 2022 ML4PS Workshop**
https://ml4physicalsciences.github.io/2022/

JOURNAL REFEREE

European Physical Journal C **Springer**
ISSN: 1434-6052

Nuclear Science and Techniques **Springer**
ISSN: 2210-3147

MACHINE LEARNING RESEARCH EXPERIENCE

KamLAND-Zen **Kamioka, Japan**
Leader of KamLAND-Zen Machine Learning group *Jan. 2019 - Present*

- Working with Professor Chris Grant (Boston U.) and Professor Lindley Winslow (MIT).
- Invented **KamNet**, a neural network classifier achieving state-of-the-art performance on spherical liquid scintillator detector. In the newest KamLAND-Zen result [1], KamNet succeeded in rejecting a critical high-background period where all other veto strategies failed. **With KamNet, KamLAND-Zen searches for $0\nu\beta\beta$ in the inverted mass ordering region for the first time in history**. Directly applying KamNet to the entire dataset will further enhance the search sensitivity by 85%. Leading author on [2].
- Leveraged conventioanl CNN model to reject cosmic muon backgrounds on current and next generation liquid scintillator detectors. Leading author on [3].

- Developed semi-supervised learning neural network model for KamLAND-Zen [4]. This algorithm independently extract a Bayesian prior for every KamLAND-Zen event.
- Mentored Hasung Song (Boston U.) to design KamNet systematic study and photon energy reconstruction algorithm.
- Mentored Zhenghao Fu (MIT) to develop directionality reconstruction algorithm for KamLAND-Zen events.
- Mentored Zhenghao Fu (MIT) to develop PonitNet-based generative models for data simulation. Manuscript under internal review.

LEGEND **Gran Sasso, Italy**
Organizer and leader of GeM group *Sept.2020 - Present*

- Working with Professor Julieta Gruszko (UNC Chapel Hill) and Professor John Wilkerson (UNC Chapel Hill).
- Initiated and lead the **Germanium Machine Learning (GeM)** group, providing artificial intelligence solutions to Ge detector experiments.
- Developed a self-supervised learning algorithm for active event exploration. This algorithm can actively identify events beyond our current understanding of detector microphysics. Investigating these events significantly boosts our knowledge about germanium detectors.
- Developed Cyclic Positional U-Net (CPU-Net). This model translates simulated pulses so that it is indistinguishable from detector pulses. CPU-Net can be used to generate like-real pulse shape simulations. This work is accepted by NeurIPS 2022 ML4PS workshop and was selected as outstanding submission to receive the MLST paper award.
- Mentored Ann-Kathrin Shuetz (LBNL) to optimize LEGEND neutron moderator design by collaborating with the MODE collaboration.
- Mentored Henry Nachman (UNC Chapel Hill) to apply the interpretable boosted decision tree models [5] to LEGEND. This project has been accepted by the Conference Experiences for Undergraduate (CEU) program at DNP 2022.
- Mentored Esteban Leon (UNC Chapel Hill) for the development of machine-learning-based autonomous data-cleaning.
- Mentored Nikita Zareskii (Kurchatov Institute) to perform waveform generation with GAN.
- Mentored Katharina Kilgus (U. Tubingen) to apply the attention-coupled RNN model to GERDA BEGe detector and LEGEND ICPC detector.
- Mentored Nikita Levashko (Kurchatov Institute) and Abigail Alexander (University College London) to perform machine-learning-based dead layer extraction with the attention-coupled RNN model.

Majorana Demonstrator **South Dakota, U.S.**
L3 task leader for machine learning group *Sept.2020 - Present*

- Developed the first machine learning analysis for Majorana Demonstrator as well as the first comprehensive machine learning analysis for any germanium detector experiment. This analysis leverage boosted decision tree (BDT) to jointly analyze all pulse shape parameters. A game-theory-based interpretability study is then adopted to understand the decision-making process of BDT. The interpretability study independently discovered new background signatures by learning from the machine. Manuscript [5] accepted by *Phys. Rev. C*.
- Designed attention coupled RNN model to separate single-site events from multi-site events. Mentored Tupendra Oil (U. of South Dakota), Laxman Paduel (U. of South Dakota), and Ravi Pitelka (UNC Chapel Hill) to apply this model to background rejection, ^{77}Ge gamma energy regression and waveform position reconstruction, respectively.

OTHER RESEARCH AND TEACHING EXPERIENCE

Analysis **KamLAND-Zen, SNO+ and THEIA**
Collaborator of KamLAND-Zen and SNO+ *Jan. 2017 - Present*

- Designed and conducted Bayesian analysis on KamLAND-Zen 800 [6][4], providing the official Bayesian limit for the most recent result [1].
- Investigated physics sensitivities for SNO+ and THEIA using MC simulations.
- Developed the official livetime calculation algorithm for SNO+, providing the detector livetime for use in all SNO+ publications[7][8][9].
- Participated in SNO+ data cleaning, processing/data flow, nearline and double beta decay analysis.

Hardware **SNO+, NuDot, and Majorana Demonstrator**
Collaborator of SNO+, NuDot, and Majorana Demonstrator *Jan. 2012 - Present*

- Participated in high voltage cable testing for MAJORANA demonstrator[10].
- Led the PMT high voltage test of NuDot.
- Participated in DAQ system test of NuDot.
- Participated in construction of the Long Term Testing Tank (LT3) for SNO+ Tellurium-loaded scintillator stability testing.
- Participated in SNO+ Tellerium-Diol Plant construction underground in SNOLAB.

Teaching **PIRE-GEMADARC**
Collaborator of PIRE-GEMADARC *July 2021 - August 2021*

- Designed and led *The Practical Machine Learning*[1], a machine learning summer school course as part of the Germanium Materials and Detectors Advancement Research Consortium (GEMADARC) through the NSF-PIRE (Partnerships for International Research and Education) program.
- Two years of teaching experience at Boston University.

Planning **Snowmass**
Snowmass participant *July, 2020 - Present*

- Invited to talk on behalf of the KamLAND-Zen collaboration on the Neutrino Physics and Machine Learning workshop, a Snowmass satelite workshop.
- Invited as a Snowmass/ACFI workshop panelist to talk about machine learning algorithms in tonne-scale neutrinoless double beta decay experiments.
- Contribute to *Future Advances in Photon-Based Neutrino Detectors: A SNOWMASS White Paper* [11].

SEMINARS

- Massachusetts Institute of Technology CSAIL, `ALFA Group Seminar`, Nov. 2018
- Stanford Linear Accelerator Center, `Seminar`, July 2019
- CAS IHEP JUNO group, `Seminar`, Oct. 2019
- Tsinghua University, `Department of Engineering Physics Seminar`, Oct. 2019
- Columbia University, `Department of Physics Seminar`, Feb. 2020
- Triangle Universities Research Laboratory, `TUNL Seminar`, March 2020

[1] Course website: `https://pire.gemadarc.org/education/school21/#ai`

- PIRE-GEMADARC collaboration, `PIRE Research Seminar`, Oct. 2020
- Triangle Universities Nuclear Laboratory, `TUNL Seminar`, April 2022
- Shanghai Jiaotong University, `Dark Matter and Neutrino Forum`, June 2022
- Indiana University Bloomington, `Seminar`, July 2022
- University of California San Diego, `HEP Seminar`, Sept. 2022
- University of California Irvine, `Physics Astro/Particle-ML seminar`, Nov. 2022
- University of New Mexico, `NuPAC Seminar`, Nov. 2022
- Los Alamos National Laboratory, `Seminar`, Nov. 2022

CONTRIBUTED ACADEMIC TALKS

- Suppression of Cosmic Muon Spallation Backgrounds in LS Detector Using Convolutional Neural Networks, APS DNP, Oct. 2019
- Deep Learning for KamLAND-Zen, APS DPF 2019, July 2019
- A Bayesian Approach to Neutrinoless Double Decay in KamLAND-Zen, TAUP 2019, Sept. 2019
- The Interpretable Machine Learning Algorithm for Majorana Demonstrator, APS April Meeting, April. 2021
- The Status and Prospect of KamLAND-Zen 800 with Artificial Intelligence Powered Analysis, TAUP 2021, Aug. 2021
- The Search for Neutrinoless Double Beta Decay in KamLAND-Zen 800, DNP 2021, Oct. 2021

INVITED ACADEMIC TALKS

- The Deep Learning Frontiers of KamLAND-Zen, Neutrino Physics and Machine Learning workshop, July 2020
- The Machine Learning Outlooks on Tonne-scale Neutrinoless Double Beta Decay Experiments, ACFI/Snowmass workshop, Dec. 2020
- The Interpretable Machine Learning Algorithm for Majorana Demonstrator, APS April Meeting, April. 2021
- Looking for Invisible Particles Through the Eyes of Artificial Intelligence, USD AI Symposium, March 2022
- First Search for the Majorana Nature of Neutrinos in the Inverted Mass Ordering Region with KamLAND-Zen. CoSSURF 2022, May 2022
- The Machine Learning Epochs of Neutrinoless Double Beta Decay. CoSSURF 2022, May 2022
- LEGEND - The Large Enriched Germanium Detector for Neutrinoless Double Beta Decay Search, NDM 2022, May 2022
- Building Efficient and Interpretable AI for Neutrinoless Double-beta Decay Searches, DNP 2022 Award Session, Oct. 2022
- The LEGEND Data Analysis System: Data processing, Storage, and Artificial Intelligence, IEEE NSS MIC RTSD 2022, Nov. 2022

INVITED PUBLIC TALKS

- Neutrino: Hunting Ghost Particles using Artificial Intelligence,UNC PDA TruTalk Series, Nov. 2022

POSTERS

- Deep Learning for liquid scintillator-Based Double-Beta Decay Searches, Neutrino 2018, June 2018
- The Philosophy of Neutrino: Neutrinoless Double Beta Decay and Deep Learning, Deep Learning for Science Summer School, Lawrence Berkeley National Laboratory, Berkeley, CA, July 2019
- A Bayesian Approach to Neutrinoless Double Beta Decay in KamLAND-Zen 800, Neutrino 2020, June 2020
- The First Machine Learning Analysis of Majorana Demonstrator, NDM 2022, May 2022
- Ad-hoc Pulse Shape Simulation Using Cyclic Positional U-Net, NeurIPS 2022 ML4PS Workshop, Dec. 2022

PUBLICATION

[1] S. Abe et al. Search for the Majorana Nature of Neutrinos in the Inverted Mass Ordering Region with KamLAND-Zen, 3 2022, 2203.02139. Accepted by PRL.

[2] A. Li, Z. Fu, L. Winslow, C. Grant, H. Song, H. Ozaki, I. Shimizu, and A. Takeuchi. KamNet: An Integrated Spatiotemporal Deep Neural Network for Rare Event Search in KamLAND-Zen. 3 2022, 2203.01870. Accepted by PRC.

[3] A. Li, A. Elagin, S. Fraker, C. Grant, and L. Winslow. Suppression of Cosmic Muon Spallation Backgrounds in Liquid Scintillator Detectors Using Convolutional Neural Networks. *Nucl. Instrum. Meth. A*, 947:162604, 2019, 1812.02906.

[4] A. Li. The tao and zen of neutrinos: Neutrinoless double beta decay in kamland-zen 800, 2020.

[5] I. J. Arnquist et al. Interpretable Boosted Decision Tree Analysis for the Majorana Demonstrator. 7 2022, 2207.10710. Accepted by PRC.

[6] Aobo Li. A bayesian approach to neutrinoless double beta decay analysis in KamLAND-zen. *Journal of Physics: Conference Series*, 1468:012201, feb 2020.

[7] M. Anderson et al. Measurement of the ^{8}B solar neutrino flux in SNO+ with very low backgrounds. *Phys. Rev. D*, 99:012012, Jan 2019.

[8] M. Anderson et al. Search for invisible modes of nucleon decay in water with the SNO+ detector. *Phys. Rev.*, D99(3):032008, 2019, 1812.05552.

[9] M.R. Anderson et al. Measurement of neutron-proton capture in the SNO+ water phase. *Phys. Rev. C*, 102(1):014002, 2020, 2002.10351.

[10] N. Abgrall et al. High voltage testing for the MAJORANA Demonstrator. *Nucl. Instrum. Meth.*, A823:83–90, 2016, 1603.08483.

[11] Joshua R. Klein et al. Future Advances in Photon-Based Neutrino Detectors: A SNOWMASS White Paper. 3 2022, 2203.07479.

[12] S. Abe et al. Search for supernova neutrinos and constraint on the galactic star formation rate with the KamLAND data. 4 2022, 2204.12065.

[13] S. Abe et al. Abundances of uranium and thorium elements in earth estimated by geoneutrino spectroscopy. *Geophysical Research Letters*, 49(16):e2022GL099566, 2022.

[14] N. Abgrall et al. The Majorana Demonstrator readout electronics system. *JINST*, 17(05):T05003, 2022, 2111.09351.

[15] I. J. Arnquist et al. Exotic dark matter search with the Majorana Demonstrator. 6 2022, 2206.10638.

[16] I. J. Arnquist et al. Search for Solar Axions via Axion-Photon Coupling with the Majorana Demonstrator. *Phys. Rev. Lett.*, 129(8):081803, 2022, 2206.05789.

[17] I. J. Arnquist et al. Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double-β Decay in ^{76}Ge. 7 2022, 2207.07638.

[18] A. Li, J. Gruszko, B. Bos, T. Caldwell, E. León, and J. Wilkerson. Ad-hoc pulse shape simulation using cyclic positional u-net. *Proceedings of NeurIPS 2022 Machine Learning for Physical Science Workshop*, December 2022. `https://ml4physicalsciences.github.io/2022/files/NeurIPS_ML4PS_2022_12.pdf`.

[19] I. J. Arnquist et al. Charge Trapping and Energy Performance of the MAJORANA DEMONSTRATOR. 8 2022, 2208.03424.

[20] S. Abe et al. Search for Low-energy Electron Antineutrinos in KamLAND Associated with Gravitational Wave Events. *Astrophys. J.*, 909(2):116, 2021, 2012.12053.

[21] V. Albanese et al. The SNO+ experiment. *JINST*, 16(08):P08059, 2021, 2104.11687.

[22] Y. Gando et al. The nylon balloon for xenon loaded liquid scintillator in KamLAND-Zen 800 neutrinoless double-beta decay search experiment. *JINST*, 16(08):P08023, 2021, 2104.10452.

[23] S. Abe et al. Search for Solar Flare Neutrinos with the KamLAND Detector. *Astrophys. J.*, 924(2):103, 2022, 2105.02458.

[24] Keishi Hosokawa. Search for charged excitations of dark matter by KamLAND-zen experiment. *Journal of Physics: Conference Series*, 1468(1):012065, feb 2020.

[25] M. R. Anderson et al. Development, characterisation, and deployment of the SNO+ liquid scintillator. *JINST*, 16:P05009, 2021, 2011.12924.

[26] M. R. Anderson et al. Optical calibration of the SNO+ detector in the water phase with deployed sources. *JINST*, 16(10):P10021, 2021, 2106.03951.

[27] N. Abgrall et al. The Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay: LEGEND-1000 Preconceptual Design Report. 7 2021, 2107.11462.

[28] Aobo Li. KamLAND-Zen 800 Status and Prospect with the Artificial Intelligence Powered Analysis. *J. Phys. Conf. Ser.*, 2156(1):012114, 2021.

[29] S. Abe et al. Search for Correlated Low-energy Electron Antineutrinos in KamLAND with Gamma-Ray Bursts. *Astrophys. J.*, 927(1):69, 2022, 2112.04918.

[30] I. J. Arnquist et al. Search for Pauli Exclusion Principle Violation by Pair Production in the Majorana Demonstrator Calibration Data. 3 2022, 2203.02033.

[31] I. J. Arnquist et al. The study of ^{13}C(α,n)^{16}O reactions in the Majorana Demonstrator calibration data. *Phys. Rev. C*, 105(1):064610, 2022, 2203.14228.

[32] I. J. Arnquist et al. Search for Spontaneous Radiation from Wavefunction Collapse in the Majorana Demonstrator. *Phys. Rev. Lett.*, 129(8):080401, 2022, 2202.01343.