

# Moshe Friedman

SENIOR LECTURER · RACAH INSTITUTE OF PHYSICS

*The Hebrew University of Jerusalem*

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## Education

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### The Hebrew University of Jerusalem

PHD NUCLEAR PHYSICS

• Advisor: Prof. Guy Ron

*Jerusalem*

*2012 - 2017*

### The Hebrew University of Jerusalem

MSc NUCLEAR PHYSICS

• Advisor: Prof. Michael Paul

*Jerusalem*

*2009-2011*

### The Hebrew University of Jerusalem

BSc PHYSICS

*Jerusalem*

*2006 - 2009*

## Professional Experience

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- 2020- **Senior Lecturer**, Racach Institute of Physics, Hebrew University of Jerusalem
- 2019-2020 **Postdoctoral Fellow**, Racach Institute of Physics, Hebrew University of Jerusalem
- 2016-2019 **Research Associate**, NSCL, Michigan State University
- 2013-2015 **Teacher**, Preparatory School, Hebrew University of Jerusalem
- 2013 **Lecturer**, Shenkar College for Engineering and Design
- 2010-2011 **Teaching Assistant**, Preparatory School, Hebrew University of Jerusalem

## Awards and Fellowships

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- 2016 **Pazy postdoctoral fellowship - declined**, Pazy foundation *70 KUSD*
- 2013 **Marinov prize, for excellence in experimental nuclear physics**, Racah Institute of Physics

## Grants

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- 2022-2026 **A novel experimental technique to study neutron-induced charged-particle reactions at explosive stellar temperatures**, Israel Science Foundation, *750 KNIS*  
*Moshe Friedman*
- 2022-2025 **Basic equipment for the establishment of nuclear-physics detector lab at the Hebrew University**, Israel Science Foundation, *1030 KNIS*  
*Moshe Friedman*
- 2022-2024 **Construction of a Cryogenic Stopping Cell for the Collection and Extraction of Fission Products for the SARAF II Fission Research Facility**, Israeli Ministry of Energy, *498 KNIS*  
*Moshe Friedman and Guy Ron*
- 2021-2025 **Chemical Elements as Tracers for the Evolution of the Cosmos**, European Commission (H2020), *52/5000 KEUR*  
*ChETEC consortium*
- 2013-2015 **Calculations and Simulations for Prompt Fission**, Israeli Atomic Energy Commission, *150 KNIS*  
*Moshe Friedman and Guy Ron*

## Teaching Experience

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## Publications

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**Total citations: 321 h-index: 10 i10-index: 10**

25. M. Pauli, M. Tessler, M. Friedman, S. Halfon and L. Weissman, "The Liquid-Lithium Target at the Soreq Applied Research Accelerator Facility", *Eur. Phys. J. A*, in press (2022).
24. D. Ruth, R. Zielinski, C. Gu, T. Badman, M. Huang, J. Liu, P. Zhu, K. Allada, J. Zhang, A. Camsonne, J-P Chen, K. Slifer, K. Aniol, J. Annand, J. Arrington, T. Averett, H. Baghadasaryan, V. Bellini, W. Boeglin, J. Brock, C. Carlin, C. Chen, E. Cisbani, D. Crabb, A. Daniel, D. Day, R. Duve, L. El Fassi, M. Friedman, E. Fuchey, H. Gao, R. Gilman, S. Glamazdin, P. Gueye, M. Hafez, Y. Han, O. Hansen, M. Hashemi Shabestari, O. Hen, D. Higinbotham, T. Horn, S. Iqbal, E. Jensen, H. Kang, C.D. Keith, A. Kelleher, D. Keller, H. Khanal, I. Korover, G. Kumbartzki, W. Li, J. Lichtenstadt, R. Lindgren, E. Long, S. Malace, P. Markowitz, J. Maxwell, D.M. Meekins, Z.E. Meziani, C. McLean, R. Michaels, M. Mihovilovič, N. Muangma, C. Munoz Camacho, J. Musson, K. Myers, Y. Oh, M. Pannunzio Carmignotto, C. Perdrisat, S. Phillips, E. Piasetzky, J. Pierce, V. Punjabi, Y. Qiang, P.E. Reimer, Y. Roblin, G. Ron, O. Rondon, G. Russo, K. Saenboonruang, B. Sawatzky, A. Shahinyan, R. Shneur, S. Širca, J. Sjoegren, P. Solvignon-Slifer, N. Sparveris, V. Sulkosky, F. Wesselmann, W. Yan, H. Yang, H. Yao, Z. Ye, M. Yurov, Y. Zhang, Y.X. Zhao, X. Zheng, "Proton spin structure and generalized polarizabilities in the strong quantum chromodynamics regime", *Nat. Phys.*, 1-6 (2022).
23. T. Budner, M. Friedman, C. Wrede, B. A. Brown, J. José D. Pérez-Loureiro, L. J. Sun, J. Surbrook, Y. Ayyad, D. W. Bardayan, K. Chae, A. A. Chen, K. A. Chipps, M. Cortesi, B. Glassman, M. R. Hall, M. Janasik, J. Liang, P. O'Malley, E. Pollacco, A. Psaltis, J. Stomps and T. Wheeler, "Constraining the  $^{30}\text{P}(p, \gamma)^{31}\text{S}$  reaction rate in ONe novae via the weak, low-energy  $\beta$ -delayed proton decay of  $^{31}\text{Cl}$ ", *Phys. Rev. Lett.* **128**, 182701 (2022).
22. C. Yadav and M. Friedman, Novel Experimental Techniques for Neutron Induced Charge Particle Reaction Studies in Nuclear Astrophysics, 11048 (2022)., "Novel Experimental Techniques for Neutron Induced Charge Particle Reaction Studies in Nuclear Astrophysics", *EPJ Web Conf.* **260**, 11048 (2022).
21. T. Wheeler, A. Adams, J. Allmond, H. A. Pol, E. Argo, Y. Ayyad, D. Bardayan, D. Bazin, T. Budner, A. Chen, K. Chipps, B. Davids, J. Dopfer, M. Friedman, H. Fynbo, R. Grzywacz, J. Jose, J. Liang, R. Mahajan, S. Pain, D. Pérez-Loureiro, E. Pollacco, A. Psaltis, S. Ravishankar, A. Rogers, L. Schaedig, L. J. Sun, J. Surbrook, L. Weghorn, and C. Wrede, "Measuring the  $^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}$  Reaction in Type I X-Ray Bursts Using the GADGET II TPC: Hardware", *EPJ Web Conf.* **260**, 11046 (2022).
20. R. Mahajan, A. Adams, J. Allmond, H. A. Pol, E. Argo, Y. Ayyad, D. Bardayan, D. Bazin, T. Budner, A. Chen, K. Chipps, B. Davids, J. Dopfer, M. Friedman, H. Fynbo, R. Grzywacz, J. Jose, J. Liang, S. Pain, D. Perez-Loureiro, E. Pollacco, A. Psaltis, S. Ravishankar, A. Rogers, L. Schaedig, L. J. Sun, J. Surbrook, T. Wheeler, L. Weghorn, and C. Wrede, "Measuring the  $^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}$  Reaction in Type I X-Ray Bursts Using the GADGET II TPC: Software", *EPJ Web Conf.* **260**, 11034 (2022).
19. J. Ash, H. Wasaki, T. Mijatović, T. Budner, R. Elder, B. Elman, M. Friedman, A. Gade, M. Grinder, J. Henderson, B. Longfellow, A. Revel, D. Rhodes, M. Spieker, Y. Utsuno, D. Weisshaar and C. Y. Wu., "Cross-shell Excitations in  $^{46}\text{Ca}$  studied with Fusion Reactions induced by Reaccelerated Rare Isotope Beams", *Phys. Rev. C Lett.* **103**, L051302 (2021).
18. L. J. Sun, M. Friedman, T. Budner, D. Pérez-Loureiro, E. Pollacco, C. Wrede, B. A. Brown, M. Cortesi, C. Fry, B. E. Glassman, J. Heideman, M. Janasik, A. Magilligan, M. Roosa, J. Stomps, J. Surbrook and P. Tiwari, " $^{25}\text{Si}$   $\beta^+$ -decay spectroscopy", *Phys. Rev. C* **103**, 014322 (2021).
17. M. Friedman, "Production of Quasi-Stellar Neutron Field at Explosive Stellar Temperatures", *Eur. Phys. J. A* **56**, 155 (2020).
16. M. Friedman, T. Budner, D. Pérez-Loureiro, E. Pollacco, C. Wrede, J. José, B. A. Brown, M. Cortesi, C. Fry, B. Glassman, J. Heideman, M. Janasik, M. Roosa, J. Stomps, J. Surbrook and P. Tiwari, "Low-energy  $^{23}\text{Al}$   $\beta$ -delayed proton decay and  $^{22}\text{Na}$  destruction in novae", *Phys. Rev. C* **101**, 052802(R) (2020).
15. M. Friedman, J. Campbell, D. Day, D.W. Higinbotham, A. Sarty and G. Ron, "The double spin asymmetry of nitrogen in elastic and quasielastic kinematics from a solid ammonia dynamically polarized target", *Nucl. Instrum. Meth. A* **946**, 162701 (2019).
14. M. Friedman D. Pérez-Loureiro, T. Budner, E. Pollacco, C. Wrede, M. Cortesi, C. Fry, B. Glassman, M. Harris, J. Heideman, M. Janasik, B.T. Roeder, M. Roosa, A. Saastamoinen, J. Stomps, J. Surbrook, P. Tiwari and J. Yurkon, "GADGET: A Gaseous Detector with Germanium Tagging", *Nucl. Instrum. Meth. A* **940**, 93-102 (2019).
13. B.E. Glassman, D. Pérez-Loureiro, C. Wrede, J. Allen, D.W. Bardayan, M.B. Bennett, B.A. Brown, K.A. Chipps, M. Febraro, M. Friedman, C. Fry, M.R. Hall, O. Hall, S.N. Liddick, P. O'Malley, W.J. Ong, S.D. Pain, C. Prokop, S.B. Schwartz, P. Shidling, H. Sims, P. Thompson and H. Zhang, "Doppler Broadening in  $^{20}\text{Mg}(\beta p \gamma)^{19}\text{Ne}$  Decay", *Phys. Rev. C* **99**, 065801 (2019).
12. P. Abel *et al.*, "Isotope Harvesting at FRIB: Additional opportunities for scientific discovery", *J. Phys. G: Nucl. Part. Phys.* **46**, 33 (2019).

11. M. Paul, M. Tessler, M. Friedman, S. Halfon, T. Palchan, L. Weissman, A. Arenshtam, D. Berkovits, Y. Eisen, I. Eliahu, G. Feinberg, D. Kijel, A. Kreisel, I. Mardor, G. Shimel, A. Shor and I. Silverman, "Reactions along the Astrophysical s-Process Path and Prospects for Neutron Radiotherapy with the Liquid-Lithium Target (LiLiT) at the Soreq Applied Research Accelerator Facility (SARAF)", *Eur. Phys. J. A.* **55**, 44 (2019).
10. E. Aboud, M. B. Bennett, C. Wrede, M. Friedman, S. N. Liddick, D. Pérez-Loureiro, D. W. Bardayan, B. A. Brown, A. A. Chen, K. A. Chipps, C. Fry, B. E. Glassman, C. Langer, E. I. McNeice, Z. Meisel, W.-J. Ong, P. D. O'Malley, S. D. Pain, C. J. Prokop, H. Schatz, S. B. Schwartz, S. Suchyta, P. Thompson, M. Walters and X. Xu, "Toward complete spectroscopy using  $\beta$  decay: the example of  $^{32}\text{Cl}(\beta\gamma)^{32}\text{S}$ ", *Phys. Rev. C.* **98**, 024309:024309-13 (2018).
9. B.E. Glassman, D. Pérez-Loureiro, C. Wrede, J. Allen, D.W. Bardayan, M.B. Bennett, B.A. Brown, K.A. Chipps, M. Febraro, M. Friedman, C. Fry, M.R. Hall, O. Hall, S.N. Liddick, P. O'Malley, W.J. Ong, S.D. Pain, C. Prokop, S.B. Schwartz, P. Shidling, H. Sims, P. Thompson and H. Zhang, " $\beta$ -delayed  $\gamma$  decay of  $^{20}\text{Mg}$  and the  $^{19}\text{Ne}(p, \gamma)^{20}\text{Na}$  breakout reaction in Type I X-ray bursts", *Phys. Lett. B* **778**, 397-402 (2018).
8. A. Shor, M. Tessler, A. Plompen, A. Arenshtam, O. Aviv, D. Berkovits, M. Brandis, Y. Eisen, I. Eliyahu, G. Feinberg, M. Friedman, S. Halfon, M. Hult, B. Kaizer, D. Kijel, A. Krása, A. Kreisel, T. Palchan, M. Paul, A. Perry, I. Silverman, S. Vaintraub, L. Weissman, "Bismuth activation with quasi-Maxwellian neutrons at  $kT \sim 30$  keV", *Phys. Rev. C* **96**, 055805: 055805-12 (2016).
7. M. Tessler, M. Friedman, S. Schmidt, A. Shor, D. Berkovits, D. Cohen, G. Feinberg, S. Fiebiger, A. Krása, M. Paul, R. Plag, A. Plompen and R. Reifarh, "Neutron Energy Spectra and Yields from the  $^7\text{Li}(p, n)$  Reaction for Nuclear Astrophysics", *J. Phys. Conf. Ser.* **665**, 012027:012027-4 (2016).
6. M. Tessler, M. Paul, A. Arenshtam, G. Feinberg, M. Friedman, S. Halfon, D. Kijel, L. Weissman, O. Aviv, D. Berkovits, Y. Eisen, I. Eliyahu, G. Haquin, A. Kreisel, I. Mardor, G. Shimel, A. Shor, I. Silverman and Z. Yungrais, "Stellar 30-keV neutron capture in  $^{94,96}\text{Zr}$  and the  $^{90}\text{Zr}(\gamma, n)^{89}\text{Zr}$  photonuclear reaction with a high-power liquid-lithium target", *Phys. Lett. B* **751**, 418-422 (2015).
5. M. Paul, A. Arenshtam, S. Halfon, D. Kijel, M. Tessler, L. Weissman, D. Berkovits, Y. Eisen, I. Eliyahu, M. Friedman, G. Feinberg, A. Kreisel, I. Mardor, G. Shimel, A. Shor and I. Silverman, "A high-power liquid-lithium target (LiLiT) for neutron production", *J. Radioanal Nucl. Chem.*, 305: 783 (2015).
4. S. Halfon, A. Arenshtam, D. Kijel, M. Paul, D. Berkovits, I. Eliyahu, G. Feinberg, M. Friedman, N. Hazensprung, I. Mardor, A. Nagler, G. Shimel, M. Tessler and I. Silverman, "High-power liquid-lithium jet target for neutron production", *Rev. Sci. Instrum.* **84**, 123507:123507-11 (2013).
3. M. Friedman, D. Cohen, M. Paul, D. Berkovits, Y. Eisen, G. Feinberg, G. Giorginis, S. Halfon, A. Krása, A.J.M. Plompen and A. Shor, "Simulation of the neutron spectrum from the  $^7\text{Li}(p, n)$  reaction with a liquid-lithium target at Soreq Applied Research Accelerator Facility", *Nucl. Instrum. Meth. A* **698**, 117-126 (2013).
2. G. Feinberg, M. Friedman, A. Krása, A. Shor, Y. Eisen, D. Berkovits, D. Cohen, G. Giorginis, T. Hirsh, M. Paul, A. J. M. Plompen and E. Tsuk, "Quasi-stellar neutrons from the  $^7\text{Li}(p, n)^7\text{Be}$  reaction with an energy-broadened proton beam", *Phys. Rev. C* **85**, 055810:055810-12 (2012).
1. G. Feinberg, A. Shor, D. Berkovits, Y. Eisen, M. Friedman, G. Giorginis, T. Hirsh, A. Krása, M. Paul, A. Plompen and E. Tsuk, "Energy-broadened proton beam for production of quasi-stellar neutrons from the  $^7\text{Li}(p, n)^7\text{Be}$  reaction", *J. Phys. Conf. Ser.* **337**, 012044:012044-4 (2012).

## Presentations

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### INVITED TALKS

7. Neutron-induced cross section measurements using the Liquid Lithium Target at SARAF, September 2022, Nuclear Physics in Astrophysics X, Geneva, Switzerland.
6.  $\beta$ -Delayed Charged Particle Measurements for Studies of Novae and X-ray Bursts, December 2019, Physics Department Seminar, Ariel University, Ariel, Israel.
5. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, April 2019, CENPA Seminar, University of Washington, Seattle, WA, USA.
4. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, April 2019, Physics Colloquium, TRIUMF, Vancouver, BC, Canada.
3. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, April 2019, Argonne Heavy-Ion Group Discussion, Argonne National Lab, IL, USA.

2. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, March 2019, Nuclear Physics Seminar, Notre Dame University, Notre Dame, IN, USA.
1. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, October 2018, International Workshop on Generic Electronics for Physics Research, Bordeaux, France.

## SEMINARS, PROCEEDINGS AND CONFERENCES

21. Low-Background Measurement of Low-Energy  $^{23}\text{Al}$   $\beta$ -delayed Protons as a Probe for  $^{22}\text{Na}$  Destruction Rates in Novae, September 2021, The 16<sup>th</sup> International Symposium on Nuclei in the Cosmos, Chengdu, China (virtual).
20. Measurements of  $(n, p)$  and  $(n, \alpha)$  reactions at explosive stellar temperatures, August 2020, Low-Energy Community Meeting, virtual meeting organized by Argonne National Lab, IL, USA.
19. Low-Background Measurement of Low-Energy  $^{23}\text{Al}$   $\beta$ -delayed Protons as a Probe for  $^{22}\text{Na}$  Destruction Rates in Novae, February 2020, IPS 2020, Rehovot, Israel.
18. Low-Background Measurement of Low-Energy  $^{23}\text{Al}$   $\beta$ -delayed Protons as a Probe for  $^{22}\text{Na}$  Destruction Rates in Novae, June 2019, International Conference on Proton-Emitting Nuclei 2019, East Lansing, MI, USA.
17.  $\beta$ -Delayed Charged Particle Measurements for Studies of Novae and X-ray Bursts, May 2019, JINA-CEE Frontiers in Nuclear Astrophysics, Junior Researcher's Workshop, East Lansing, MI, USA.
16. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, April 2019, Research Discussion, National Superconducting Cyclotron Facility, East Lansing, MI, USA.
15. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, June 2018, 15th International Symposium on Nuclei in the Cosmos, Gran Sasso, Italy.
14. A  $\beta$ -Delayed Charged Particle Detector for Studies of Novae and X-ray Bursts, June 2018, Joint Nuclear Seminar, Jerusalem, Israel.
13. Development of a  $\beta$ -delayed charged particle detector for studying novae and X-ray bursts, October 2017, APS-DNP Fall Meeting, Pittsburgh, PA.
12. s-process Measurements with a Liquid-Lithium Quasi-Stellar Neutron Source at SARAF, Seminar, September 2016, NSCL/FRIB, MI, USA.
11. Measurement of the Proton Form Factor Ratio at Low Momentum Transfer, Seminar, May 2016, Joint Nuclear Seminar, Rehovot, Israel.
10. Measurement of the Proton Form Factor Ratio at Low Momentum Transfer, December 2015, IPS 2015, Ramat Gan, Israel.
9. N. Jovancevic, M. Friedman, L. Daraban, F.-J. Hamsch, S. Oberstedt, M. Hult, G. Lutter, G. Marissens and H. Stroh, "Modeling of Neutron Spectra Based on Activation Analysis", *Phys. Proc.* **64**, 204 (2015).
8. Measurement of the Proton Form Factor Ratio at Low Momentum Transfer, Seminar, February 2015, ANL, IL, USA.
7. Measurement of the Proton Form Factor Ratio at Low Momentum Transfer, Seminar, October 2014, LBNL, CA, USA.
6.  $^{235}\text{U}$  Prompt Fission Neutron Spectrum Measurement via Activation Technique with the DONA Detector at SARAF, April 2014, JDA 44, Ein Gedi, Israel.
5. G. Feinberg, M. Paul, A. Arenshtam, O. Aviv, D. Berkovits, D. Cohen, O. Dudovitch, Y. Eisen, I. Eliyahu, M. Friedman, Y. Ganon, S. Halfon, D. Kijel, A. Kreisel, G. Shimel, A. Shor, I. Silverman, M. Tessler, L. Weissman and Z. Yungrais, "Nuclear Astrophysics at SARAF with LiLiT", *In: The 27th conference of the nuclear societies in Israel*, (2014).
4. Measurement of the Proton Form Factor Ratio at Low Momentum Transfer, Seminar, December 2012, IPS 2012, Jerusalem, Israel.
3. A. Shor, G. Feinberg, Y. Eisen, M. Friedman, A. Krása, D. Berkovits, G. Giorginis, T. Hirsh, M. Paul and A. Plompen, "Effects of an energy broadened proton beam on the neutron distribution for the  $^7\text{Li}(p, n)^7\text{Be}$  reaction near threshold", *IN: NEMEA-6 Workshop Proceedings*, (2011).
2. G. Feinberg, A. Arenshtam, D. Berkovits, Y. Eisen, S. Halfon, D. Kijel, A. Nagler, A. Shor, I. Silverman, M. Paul and M. Friedman, "A Liquid-Lithium Target project for production of high-intensity quasi-stellar neutrons", *Proc. Sci. NIC XI*, (2010).
1. Targets as Neutron Sources for Nuclear Astrophysics at the Soreq Applied Research Accelerator Facility, December 2009, IPS 2009, Ramat Gan, Israel.