# LEARN:
# Learning Electromagnetic Structure in Light Nuclei with AI

**LOI submitted by Sonia Bacca (Mainz) and Nir Barnea (Jerusalem)**

**Presented by Randolf Pohl (Mainz)**

# Preamble

- EM structure of light nuclei is crucial to the nucleosynthesis of light elements, the structure of halo nuclei, and muonic atoms.
- Challenges encountered in the theory for the EM structure of light nuclei can be overcome exploiting the emerging AI technology.
- **Goal**: establish a **virtual network of nuclear theorists** to leverage on emerging AI and advance research on EM responses of light nuclei, while, at the same time, **supporting experiments performed at the transnational access facilities.**

# Team

Sonia Bacca (**PI**), Johannes Gutenberg University Mainz
Nir Barnea (**PI**), Hebrew University, Israel
Joanna E. Sobczyk, Chalmers University of Technology, Sweden
Laura Marcucci, Michele Viviani, Pisa University, Italy
Alessandro Lovato, Valencia University, Spain (and ANL, USA)
Noemi Rocco, Valencia University, Spain (and FNAL, USA)
Saori Pastore, Washington University St. Louis, USA

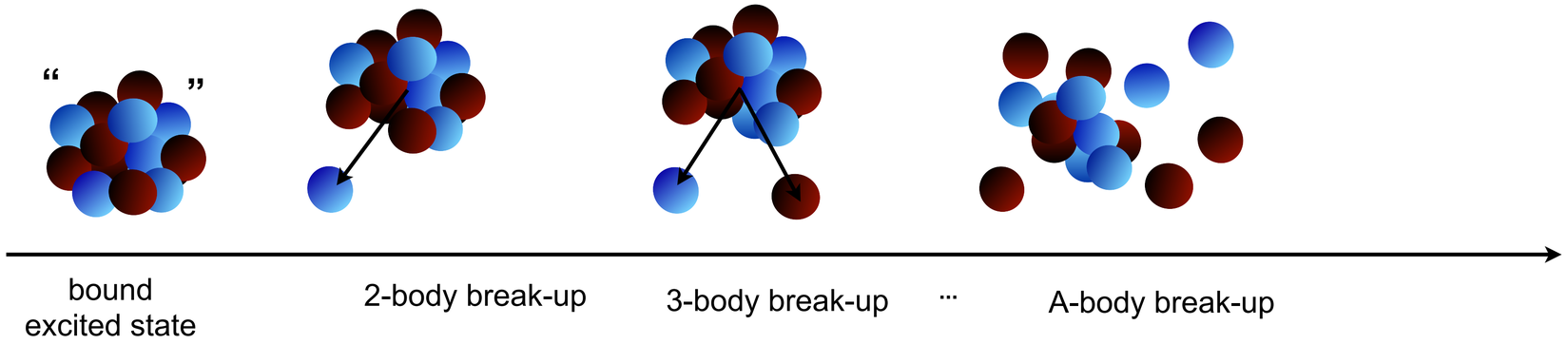
# Objectives

1) Invert integral transforms
2) Develop new many-body methods
3) Neural networks for muonic atoms

# 1) Invert integral transforms

$$R(\omega) = \sum\!\!\!\!\!\!\int_f \left| \left\langle \psi_f \left| J^\mu \right| \psi_0 \right\rangle \right|^2 \delta(E_f - E_0 - \omega)$$

Difficult to calculate $|\psi_f\rangle$




inversion

$$L(\sigma, \Gamma) = \frac{\Gamma}{\pi} \int d\omega \frac{R(\omega)}{(\omega - \sigma)^2 + \Gamma^2} = \langle \tilde{\psi} | \tilde{\psi} \rangle$$

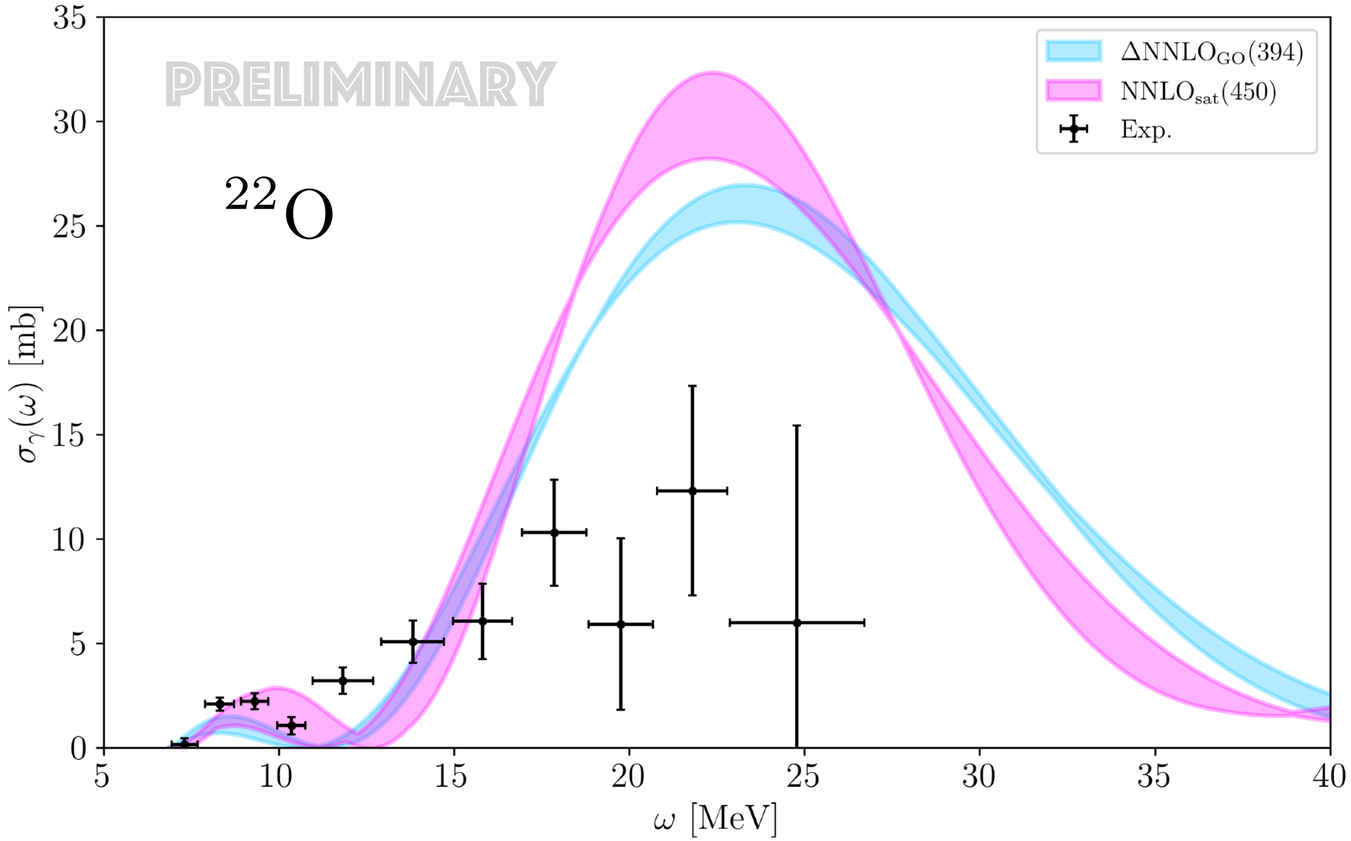
Easier to calculate $|\tilde{\psi}\rangle$

but need inversion

# 1) Invert integral transforms

Inversions are particularly delicate for **neutron-rich nuclei** when the response function has a multi-peak structure

El Batchy, Marino, **Bacca,** unpublished



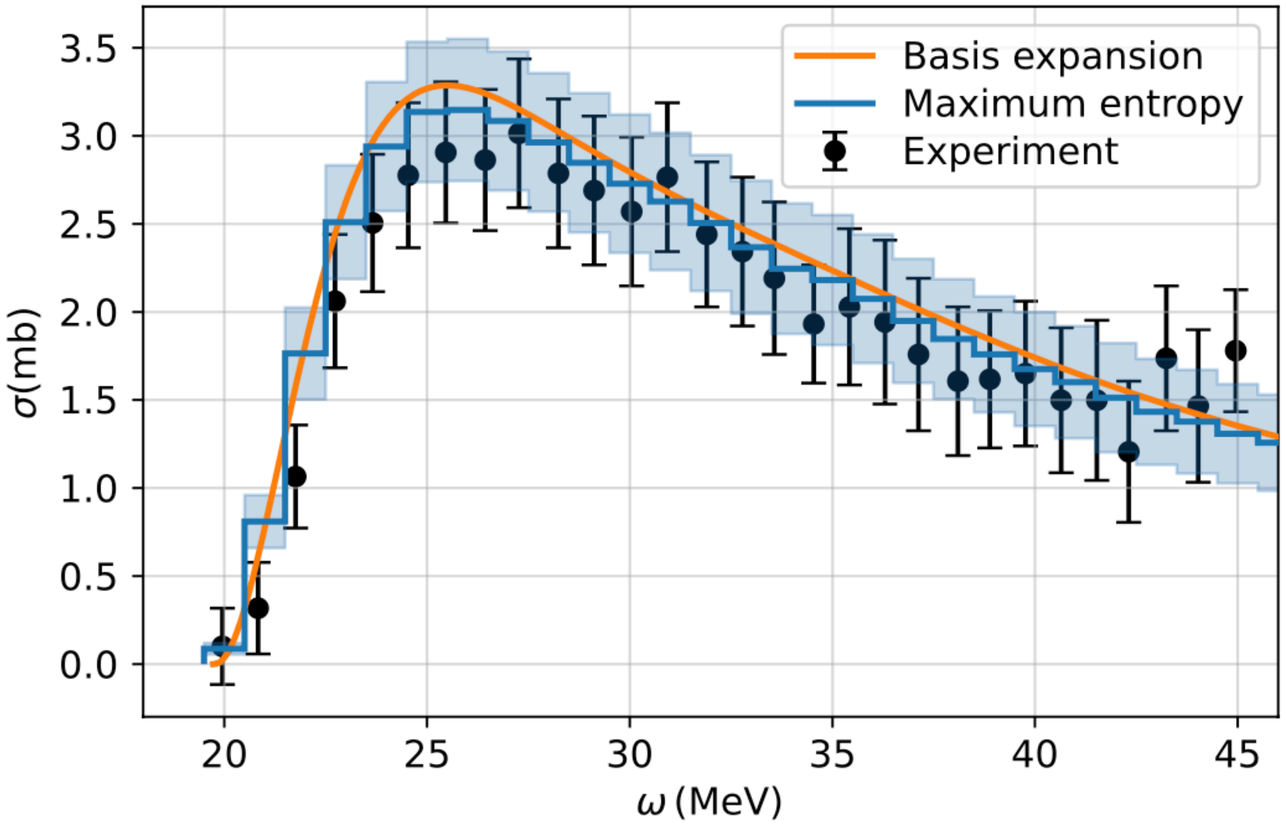

→ AI can be used to improve inversions

→ Support FAIR program at R3B

# 2) Develop new many-body methods

Neural network quantum states and integral transforms

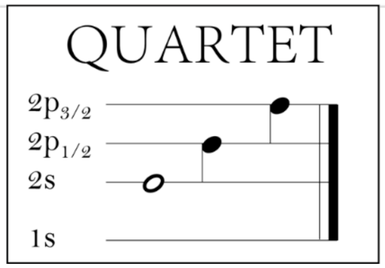
E.Parnes, **N.Barnea**, G.Carleo, A.Lovato, N.Rocco, X.Zhang, arXiv:2504.20195.




→ Extend it to the heavier and more exotic nuclei

→ Support MAMI/MESA and FAIR programs

# 3) Neural networks for muonic atoms



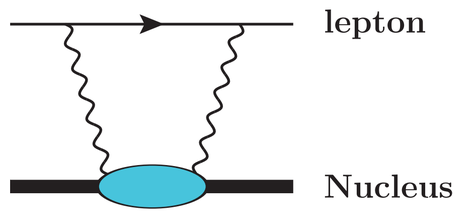




Extract $\langle r_c^2 \rangle = \dfrac{(E_{Expt} - E_{Theory})}{F}$

by measuring $E_{Expt}$, and
assuming $E_{theory}$ is provided

The most difficult part of $E_{theory}$ comes from a TPE correction

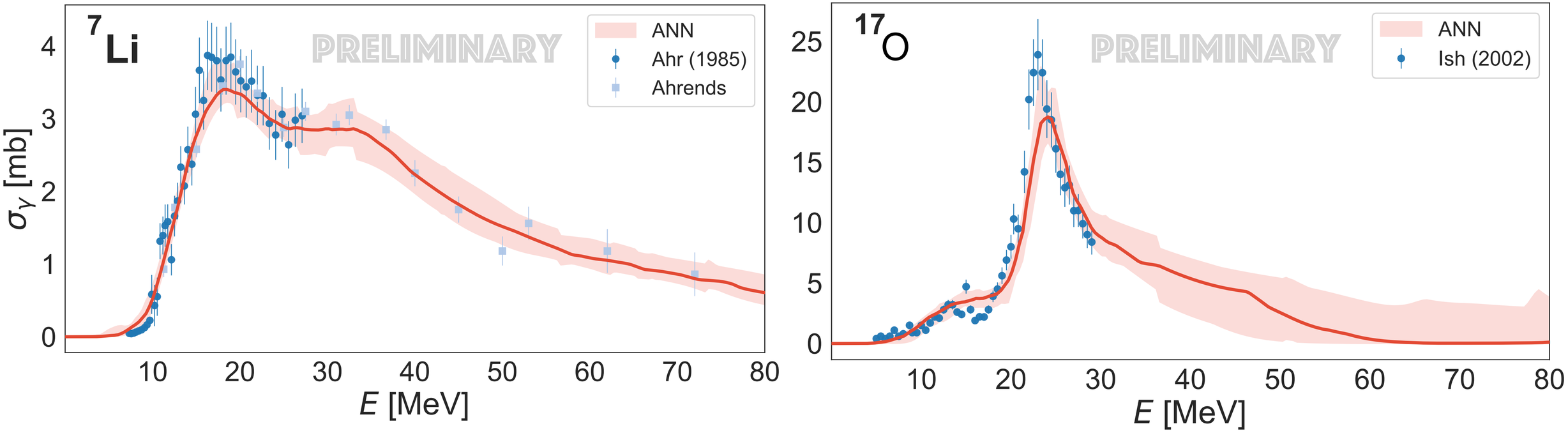



Ji, **Bacca**, **Barnea**, JPG (2018) →
TPE related to EM response functions

# 3) Neural networks for muonic atoms

Train artificial neural network to photo-absorption data for light nuclei

Jiang, Egert, **Bacca**, unpublished




→ Use this to extract TPE corrections and support experiments at PSI

# Estimated Budget Request

Travel budget 20K Euro/ year = 80K Euro
*to facilitate the collaboration among the theorists*

1 x Postdoc Position for 3 years = 230K Euro
*to carry out part of the research proposed here*

THANK YOU

# Question

- Can one include more collaborators from outside EU?
  E.g., from China?