

Open quantum systems, exotic decays and collective phenomena in nuclei

Yassid Ayyad

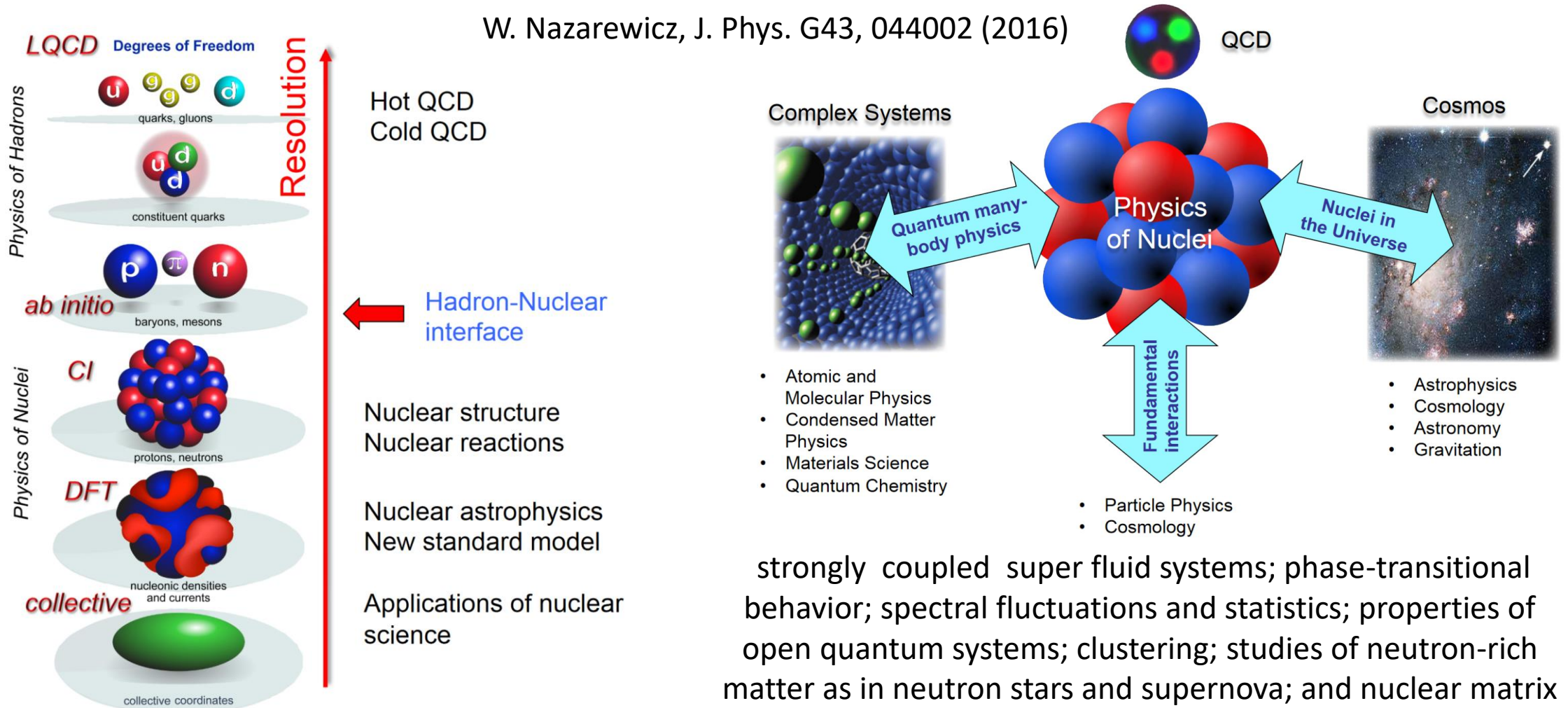
IGFAE - FRIB



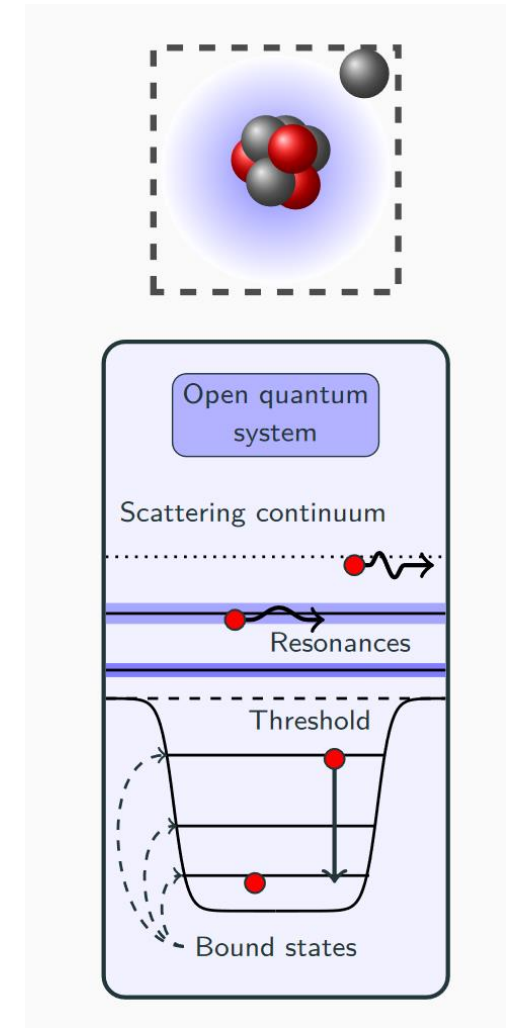
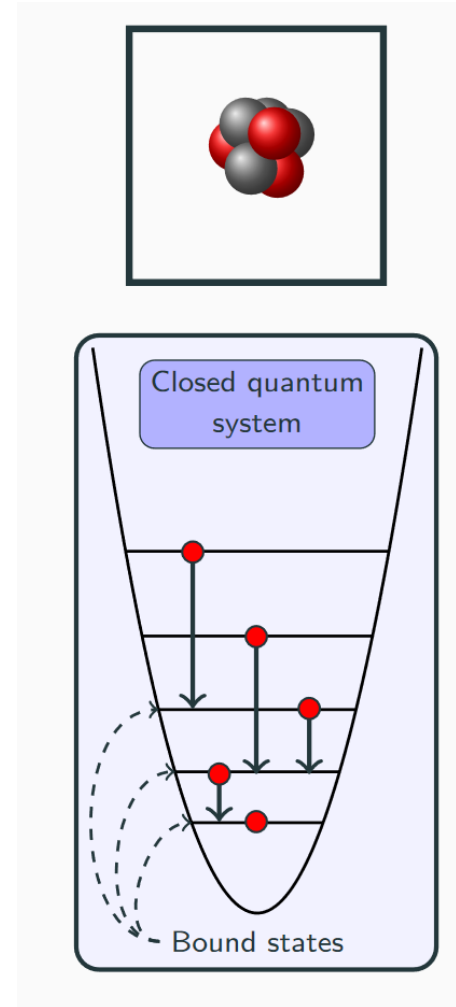
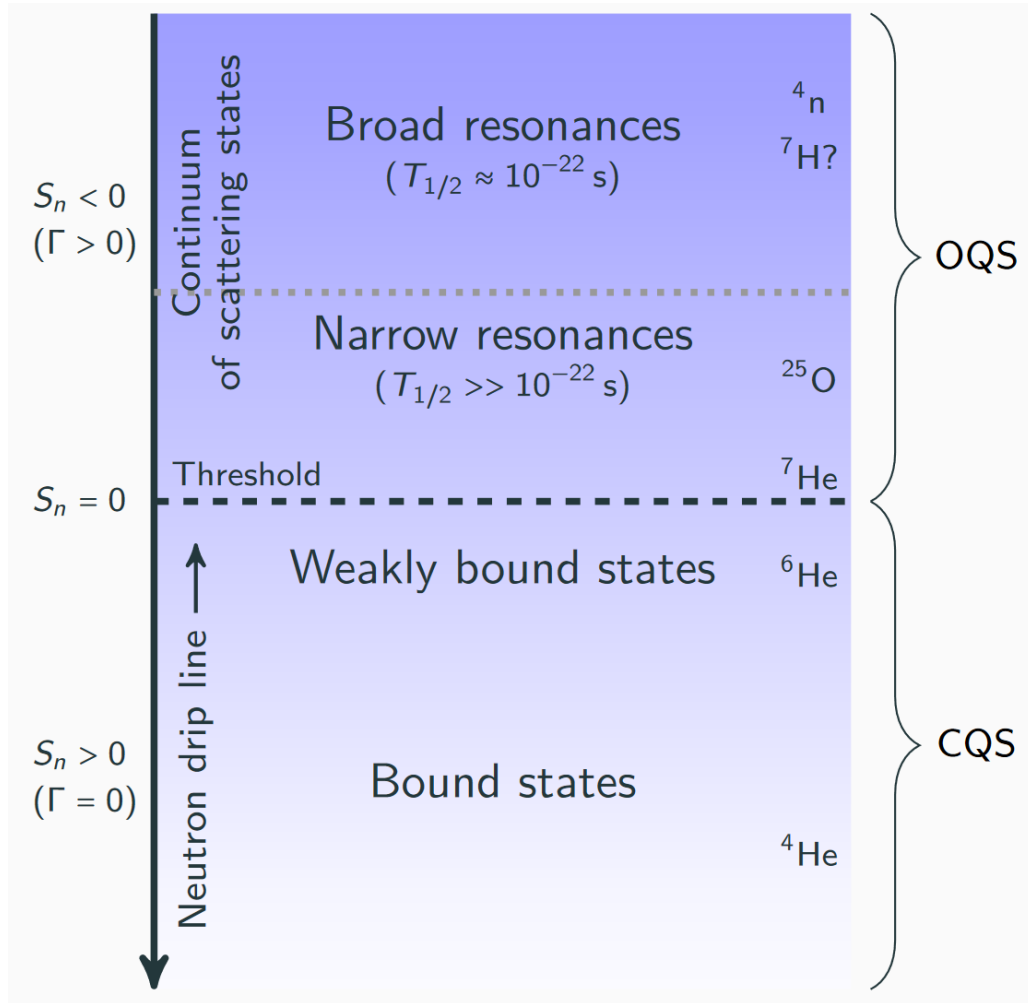
- PhD Nuclear physics GENP USC (Spain). 2008-2012.
- Specially appointed researcher at Research Center for Nuclear Physics (RCNP), Osaka, (Japan). 2012-2015.
- Research associate National Superconducting Cyclotron Laboratory (NSCL), East Lansing, MI (USA). 2015-2017.
- Scientific engineering associate, Lawrence Berkeley National Laboratory (LBNL), Berkeley (USA). 2017 -2018.
- Detector system physicist, Facility for Rare Isotope Beams (FRIB), East Lansing, MI (USA). 2018-present
- Ramon y Cajal fellow at IGFAE, USC (Spain). 2021.

Nuclei as open quantum systems

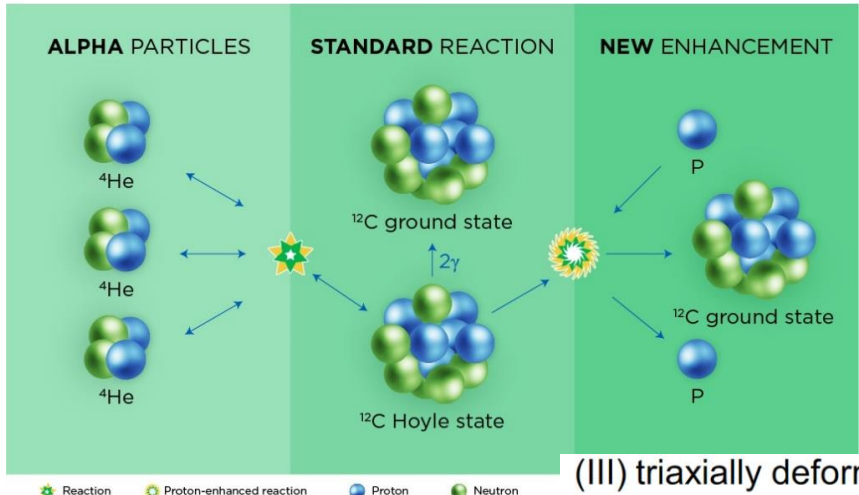
W. Nazarewicz, J. Phys. G43, 044002 (2016)



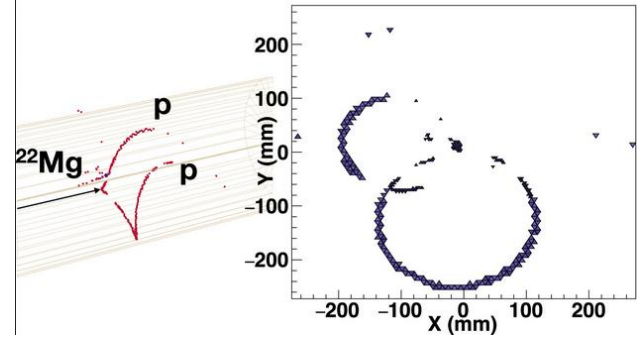
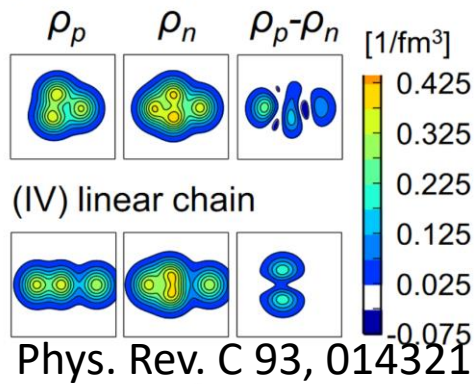
Nuclei as open quantum systems



Alpha clustering and proton radioactivity in nuclei



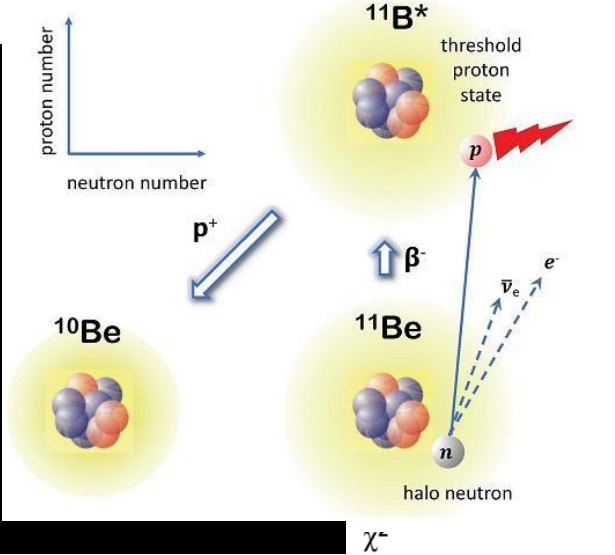
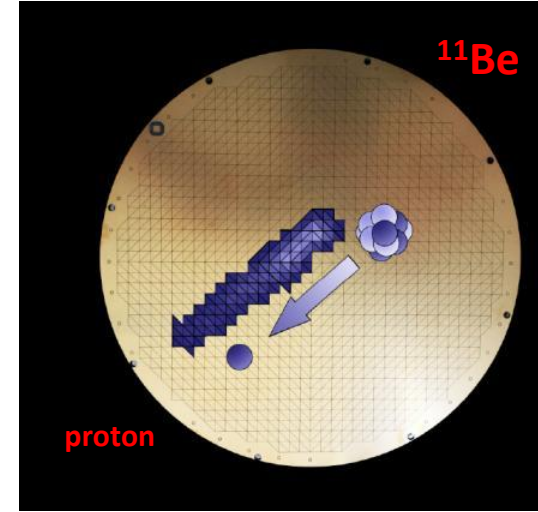
(III) triaxially deformed



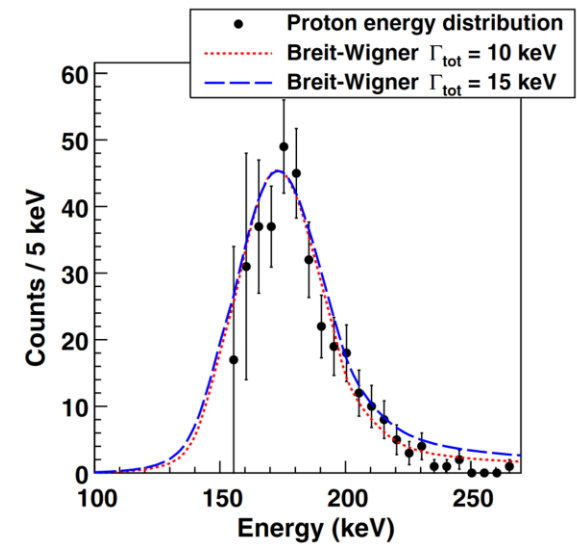
$^{22}\text{Mg} + ^4\text{He} \rightarrow ^{24}\text{Mg} + 2p$
(D. Regueira PhD work)

- Alpha clustering and near-threshold particle emission are ubiquitous phenomena along the landscape.
- Near the driplines, these phenomena change the properties of nuclei dramatically.
- Directly linked to astrophysical studies relevant for nucleosynthesis of heavy elements

Near-threshold resonances in ^{11}Be : An exotic open system



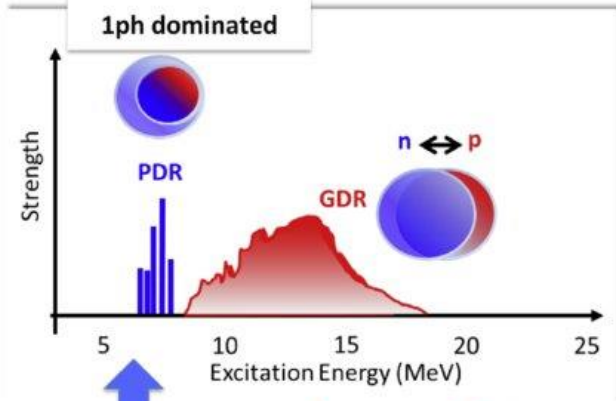
- First observation of β -delayed **proton** emission in a **neutron**-rich halo nucleus.
- Hypothetical scenario to explain the neutron lifetime anomaly through dark matter decay.
- “Inverse” Experiment at NSCL in July 2021: $^{10}\text{Be} + p$ at 300 keV/u



Y. Ayyad et al. Phys. Rev. Lett. 123, 082501 (2019)

Electric dipole (E1) response in halo nuclei

How nuclei react to external perturbations? Which collective modes arise depending on the structure?

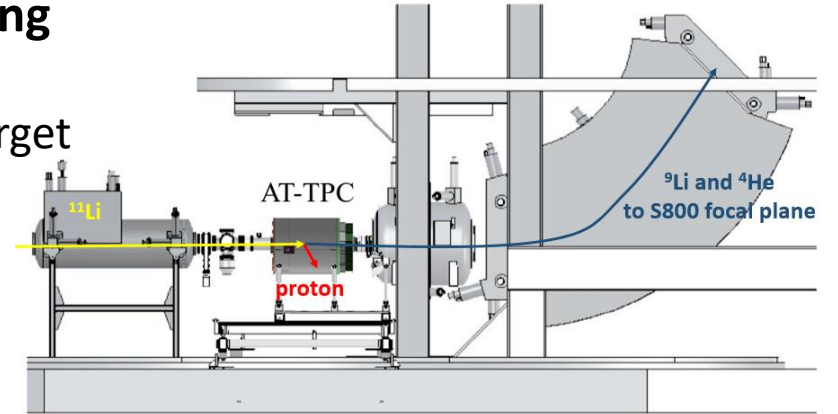


Inelastic proton scattering

$^{11}\text{Li}+p$ at 80A MeV

Unique setup with Active target and spectrometer

AT-TPC at FRIB (USA)



State Nature

Isospin character

skin properties

Level density

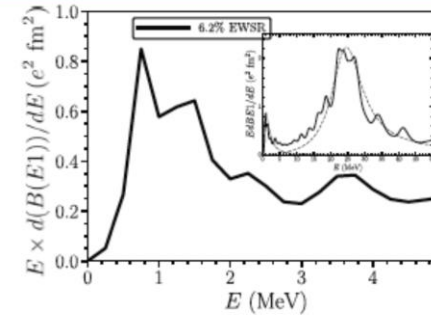
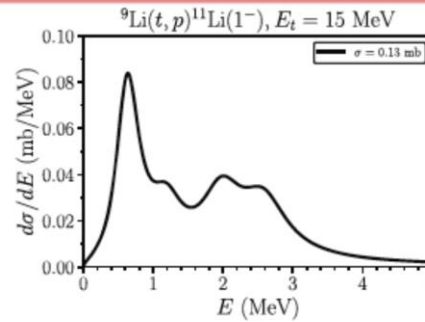
Isospin mixing

Polarisability

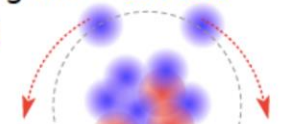
Electric Dipole Polarization
 $P = cE$

Halo nuclei exhibit a low-energy dipole resonant response. What is its nature?

Different probes are needed to understand the full electric response.



populating the ^{11}Li PDR with (t,p)



Broglia et al. Eur. Phys. J. A (2019) 55: 243

Two-neutron transfer

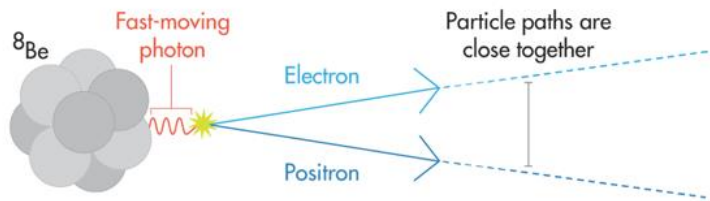
$^9\text{Li}(t,p)^{11}\text{Li}$ at 9A MeV

High-resolution solenoidal spectrometer

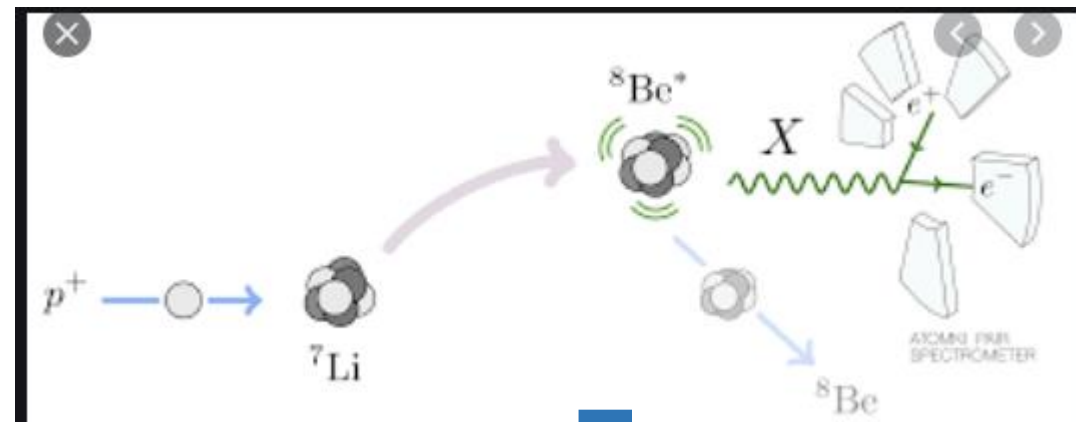
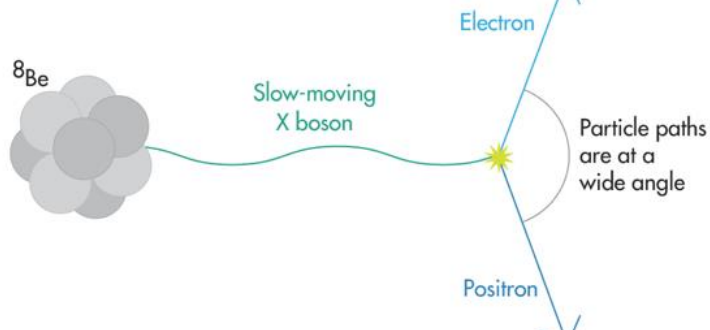
Isolde Solenoidal Spectrometer (ISS) at CERN

Search for the X17 boson with improved detection setups

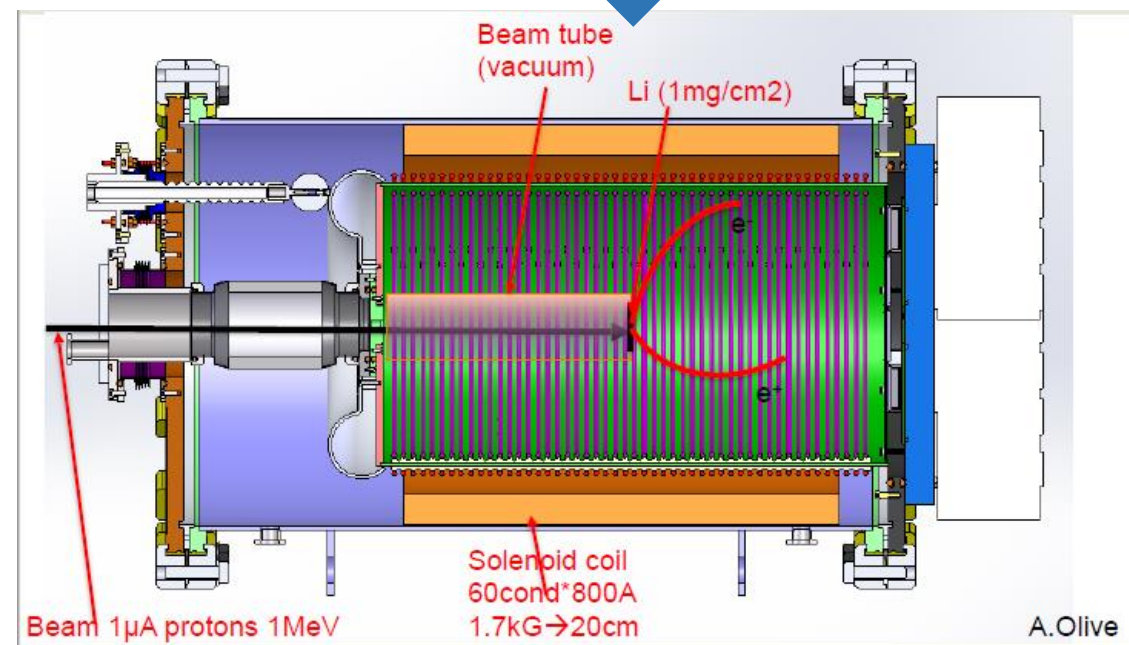
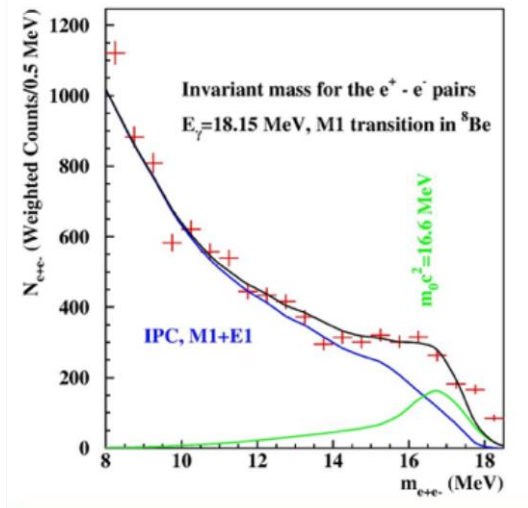
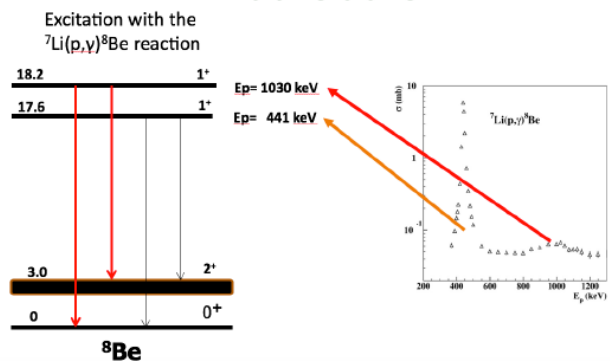
EXPECTED ^8Be TRANSITION



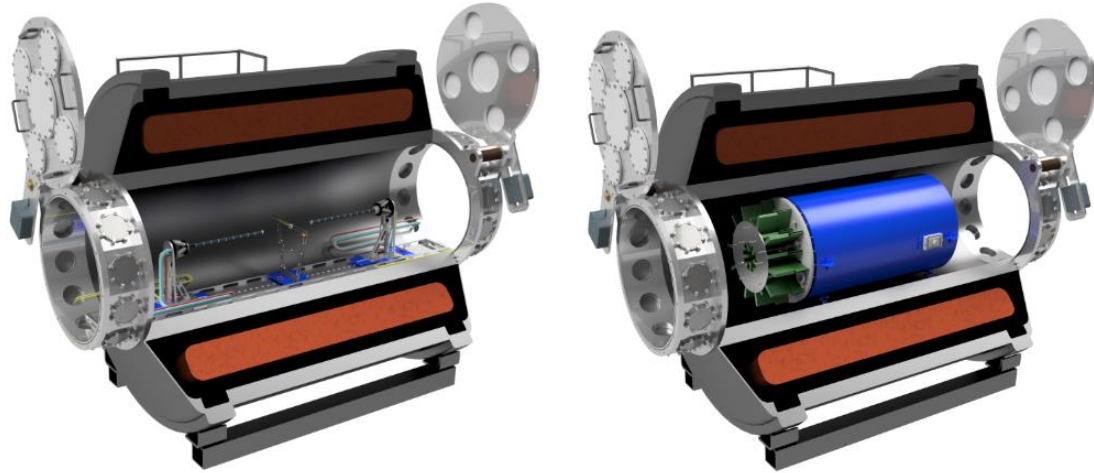
HYPOTHETICAL



Study the ^8Be M1 transitions



Tools of the trade



- **SOLARIS @ FRIB (A. Muñoz PhD work) (4 experiments)**
- **ISOLDE Solenoidal Spectrometer @ CERN (1 experiment)**
- **SpecMAT @ CERN (1 Lol)**
- **ATTPC @ ATLAS (1 experiment, 1 Lol)**
- **HELIOS @ ATLAS**
- **GADGETII @ FRIB**
- **HYDRA @ GSI**
- **Beam line instrumentation for FRIB.**

Thank you!