EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the zirconium-88 thermal neutron absorption cross section at EAR2

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Abstract:

This letter of intent proposes to measure the underlying resonance responsible for the ^{88}Zr thermal neutron capture cross section. The cross section of ^{88}Zr was measured to be 861,000 barns when a 10 barn cross section was expected. This 2019 breakthrough marks the only time such a large neutron cross section was discovered in the last 70 years and is second only to ^{135}Xe. Despite having a larger neutron cross section than any stable isotope (^{3}He, ^{6}Li, ^{10}B, ^{157}Gd, etc), ^{88}Zr has the drawback of being radioactive with an 83-day half-life. A preliminary study suggests that a 100mCi sample (3×10^{16} target atoms) with 5×10^{18} protons on target (3×10^{18} for the sample and 2×10^{18} for background measurements) can maintain a signal to background ratio above unity and statistical uncertainty under 1% up to an energy of 5eV. This study could allow for the first measurement of the responsible resonance and is complimentary to the ongoing transmission-based measurements at the DICER experiment at LANL.

Requested protons: 5×10^{18} protons on target
Experimental Area: EAR2

The majority of results in this letter of intent is from a study by Dr. Lerendegui-Marco wherein it is suggested that the ideal location for the ^{88}Zr target sample will be 5cm above the SiMon chamber. The signal and background rates are given in figure 1. The ^{88}Zr(n,γ) rates utilized TENDL-2021 libraries, which include a low-energy resonance to reproduce the large thermal cross section measured in 2019 [1]. In the case of a 100mCi sample, the signal to background ratio remains above unity from thermal energies up to an epithermal energy of 5eV. Figure 2 gives the expected background subtracted counts and statistical uncertainty as a function of energy, showing sub-percent statistical uncertainty through 10eV. The scenario shown here used 3×10^{18} protons on target for the sample and 2×10^{18} protons on target for background measurements.

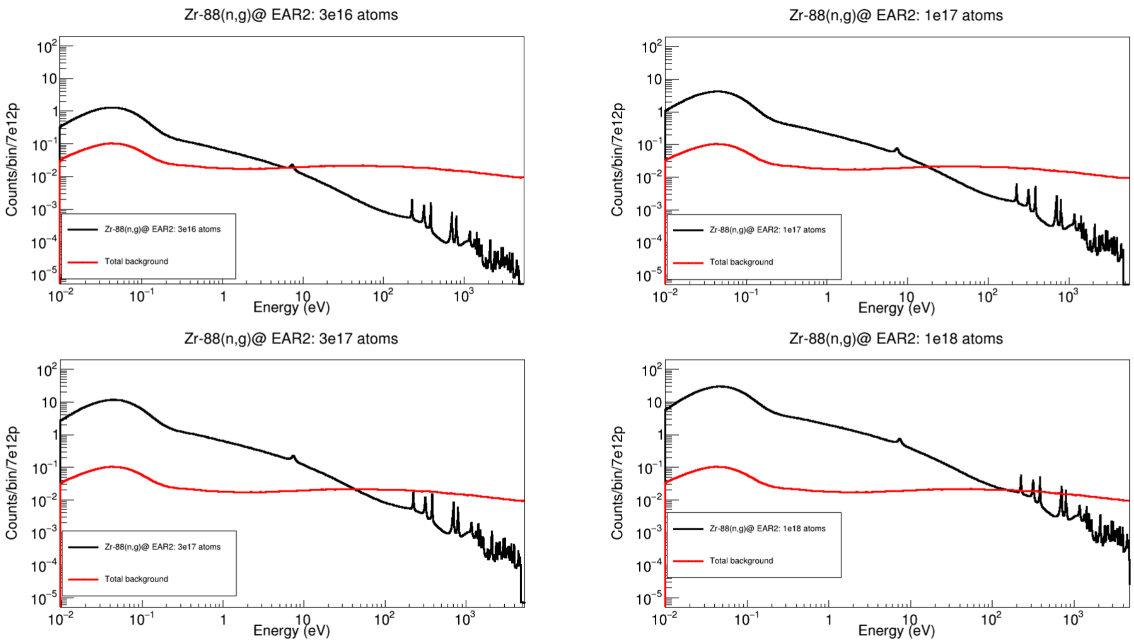

Figure 1: Signal and background rate estimates at EAR2. The 100mCi sample proposed here corresponds to 3×10^{16} atoms, top left.

Sample preparation is still being considered by the University of Dallas group. A yttrium target is bombarded by 25 MeV protons to maximize the cross section of the ^{89}Y(p,2n)^{88}Zr reaction, see figure 3. The UD exploration includes discussion with the University of Alabama at Birmingham group which made the initial samples for the 2019 Schusterman et. al. study, gathering of quotes from the UD DOE National Isotope Development Center, and discussions with the Nuclear Physics and Accelerator Technologies (NPAT) and Nuclear and Radiochemistry (NRC) groups at LLNL. The LLNL NRC group has extensive experience with ^{88}Zr chemistry. The facilities and safety protocols required to work with high amounts of ^{88}Zr activity are already in place in this group as well, allowing the work to be performed as soon as the sample is available. The NRC and NPAT groups collaborated for the initial discovery of the large neutron cross section of ^{88}Zr, which opened the door to this project, and therefore are well-positioned to continue this work with capabilities and experience that are in place at LLNL. The suggested source configuration is a powder within a ultra-high purity aluminum screw capped capsule.

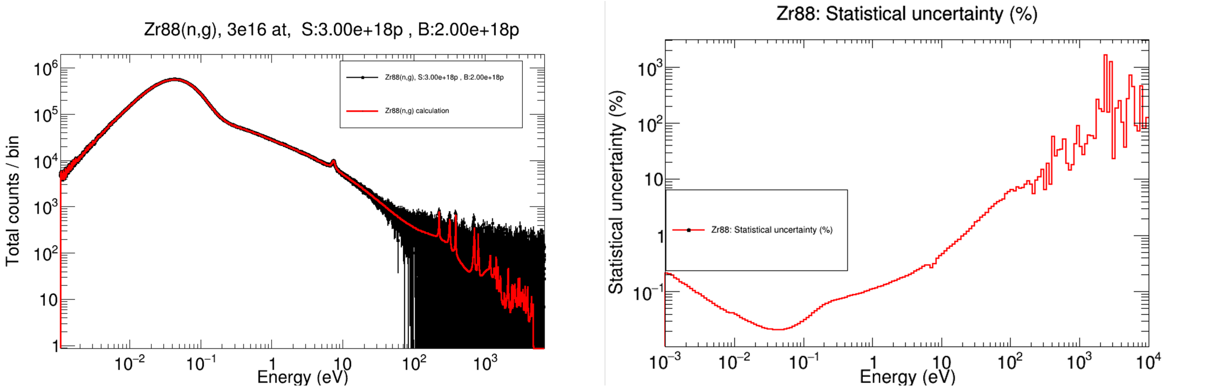

Figure 2: Background subtracted counts (left) and statistical uncertainty (right) for 100mCi ^{88}Zr(n,γ) with 3×10^{18} protons on target for the sample and 2×10^{18} protons on target for background measurements.

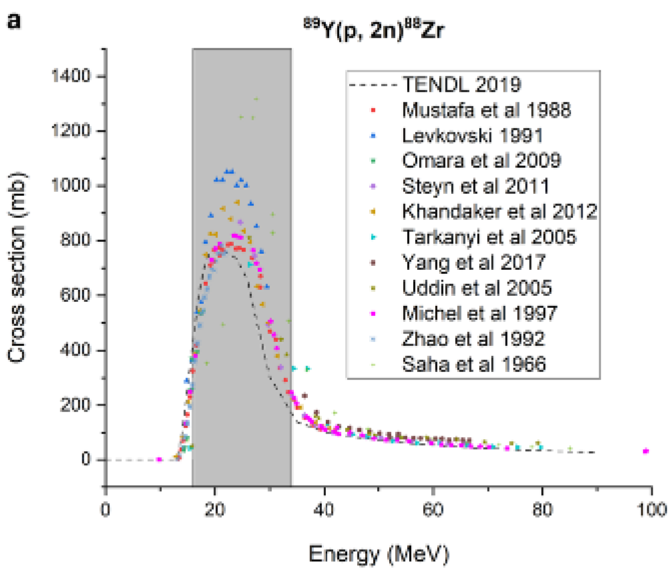

Figure 3: The ^{89}Y(p,2n)^{88}Zr cross section as a function of incident proton energy [2].

Summary

5×10^{18} protons on target are requested for measurement of the ^{88}Zr(n,γ) cross section. With a signal to background rate above unity and sub-percent statistical uncertainty in background subtracted counts through 5eV, there is a high likelihood that this campaign will reveil the resonance responsible for the anamolous ^{88}Zr neutron cross section.

Summary of requested protons: 5×10^{18} protons.

References

[1] J. A Schusterman et al., Nature 565 (2019), 328-330

[2] A. V. Matyskin et al., Scientific Reports 13 (2023), 1736

Appendix

DESCRIPTION OF THE PROPOSED EXPERIMENT

Please describe here below the main parts of your experimental set-up:

Part of the experiment	Design and manufacturing
If relevant, write here the name of the fixed installation you will be using [Name fixed/present n_TOF installation:	☒ To be used without any modification ☐ To be modified
If relevant, describe here the name of the flexible/transported equipment you will bring to CERN from your Institute **University of Dallas**: • 100mCi ^{88}Zr sample within an ultra-high purity Aluminum screw capped capsules. Since ^{88}Y daughters provide a roughly equal amount of radioactivity, the total radioactivity of the sample will be roughly 200mCi.	Standard equipment supplied by a manufacturer ☐ CERN/collaboration responsible for the design and/or manufacturing

HAZARDS GENERATED BY THE EXPERIMENT
Additional hazard from flexible or transported equipment to the CERN site:

Domain	Hazards/Hazardous Activities		Description
Mechanical Safety	Pressure	☐	[pressure] [bar], [volume][l]
	Vacuum	☐	
	Machine tools	☐	
	Mechanical energy (moving parts)	☐	
	Hot/Cold surfaces	☐	
Cryogenic Safety	Cryogenic fluid	☐	[fluid] [m3]
Electrical Safety	Electrical equipment and installations	☐	[voltage] [V], [current] [A]
	High Voltage equipment	☐	[voltage] [V]
Chemical Safety	CMR (carcinogens, mutagens and toxic to reproduction)	☐	[fluid], [quantity]
	Toxic/Irritant	☐	[fluid], [quantity]
	Corrosive	☐	[fluid], [quantity]
	Oxidizing	☐	[fluid], [quantity]
	Flammable/Potentially explosive atmospheres	☐	[fluid], [quantity]
	Dangerous for the environment	☐	[fluid], [quantity]
Non-ionizing radiation Safety	Laser	☐	[laser], [class]
	UV light	☐	
	Magnetic field	☐	[magnetic field] [T]
Workplace	Excessive noise	☐	
	Working outside normal working hours	☐	
	Working at height (climbing platforms, etc.)	☐	
	Outdoor activities	☐	
Fire Safety	Ignition sources	☐	
	Combustible Materials	☐	
	Hot Work (e.g. welding, grinding)	☐	
Other hazards			