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Title

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Quantifying Nuclear Reactions in Metal Hydrides at Low Energies

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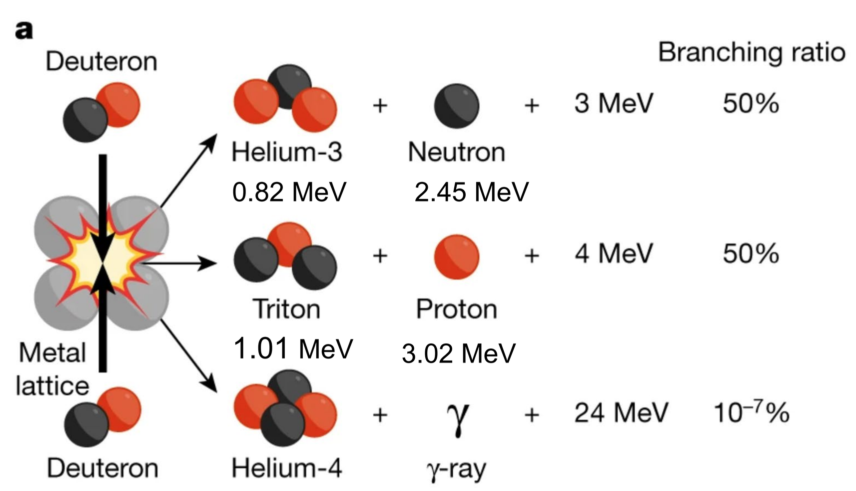
Why Metal Hydrides Are Used in Fusion

Metal hydrides can act as a dense, stable environment that facilitates the close interaction of hydrogen atoms. This property proves to be advantageous for initiating and assisting the fusion of Deuterium[1].

Metal hydrides have the following characteristics:

1. **High Hydrogen Density:** Store large quantities of hydrogen ions in a small space.
2. **Stable Hydrogen Release:** Their stability changes with temperature and pressure, allowing controlled hydrogen release under different conditions.



Motivation

Our goal is to advance nuclear fusion research by establishing new methods of controlling and harnessing these reactions at low energies.

We aim to discover how we can affect the rate of deuterium fusion at different energies within different metals.

We are probing the energy range between 5 and 15 keV, with plans to run at energies as low as 500 V. This includes energies within the screening regime, where the Coulomb barrier is decreased by electron screening effects (See the equation below). Here we expect a decrease in the amount of electrostatic repulsion and have seen this increase the rate of fusion reactions at low enough energies in previous experiments[2].

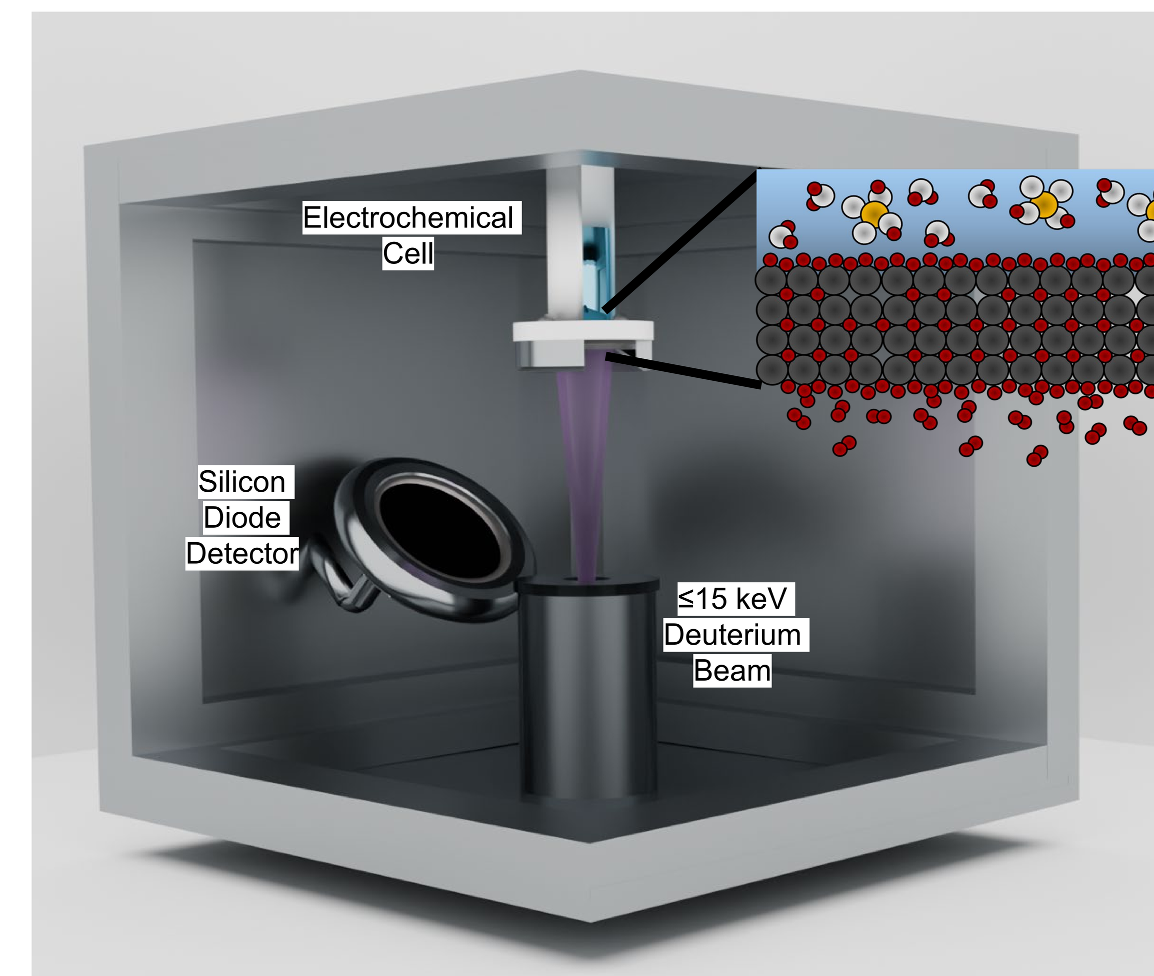
We are investigating if electrochemically loaded metal hydrides increase the yield of fusion products when compared to metal hydrides loaded with a beam only.

$$\sigma_{th}(E_{cm}) = \frac{S(E_{cm})}{E_{cm}+U_e}\exp\left[-\pi\sqrt{\frac{E_G}{E_{cm}+U_e}}\right]$$

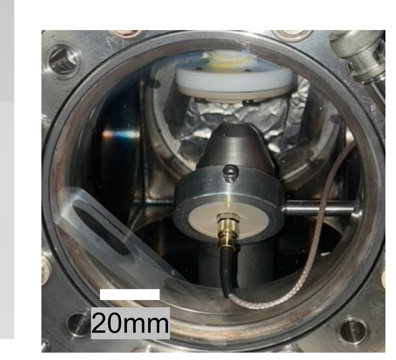
The equation for reaction cross section. Here E represents the ion kinetic energy, S(E) is the astrophysical S factor, U_e is the electron screening potential and the exponential is a screening term with E_G being the Gamow Energy ($2\mu Z_1^2 Z_2^2 e^4/\hbar$).

Our Experimental Setup

- An ion gun under vacuum accelerates a deuterium beam into a 0.25 mm thick Palladium or Titanium foil.
- This loads the foil with deuterium and induces DD fusion.
- The other side is exposed to deuterated sulphuric acid. We use this to induce electrolysis loading the foil electrochemically.
- This increases the hydrogen density in the foil which should allow for higher fusion rates.
- We then detect 3 MeV protons using a Silicon diode detector and (2.45) MeV neutrons using an EJ309 Detector.

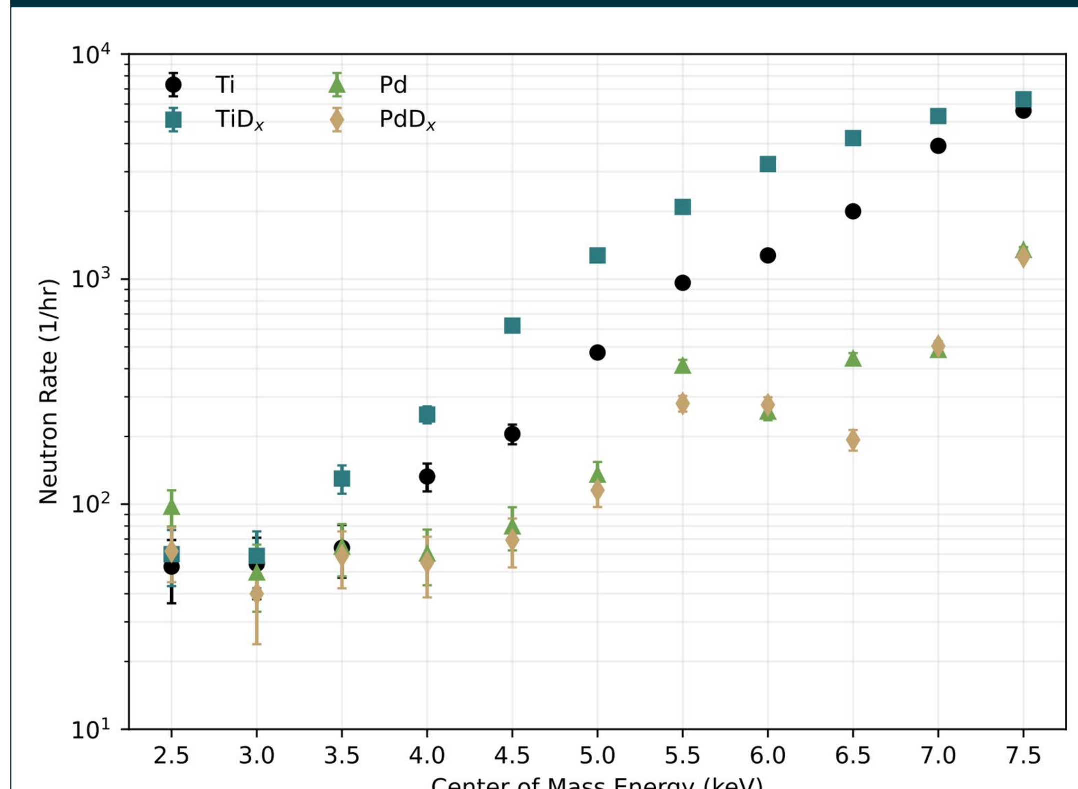


A Simplified model of our experimental setup, with a cut out diagram of electrolysis being used to electrochemically load the metal foil with hydrogen.



A Photo of our Chamber Interior.

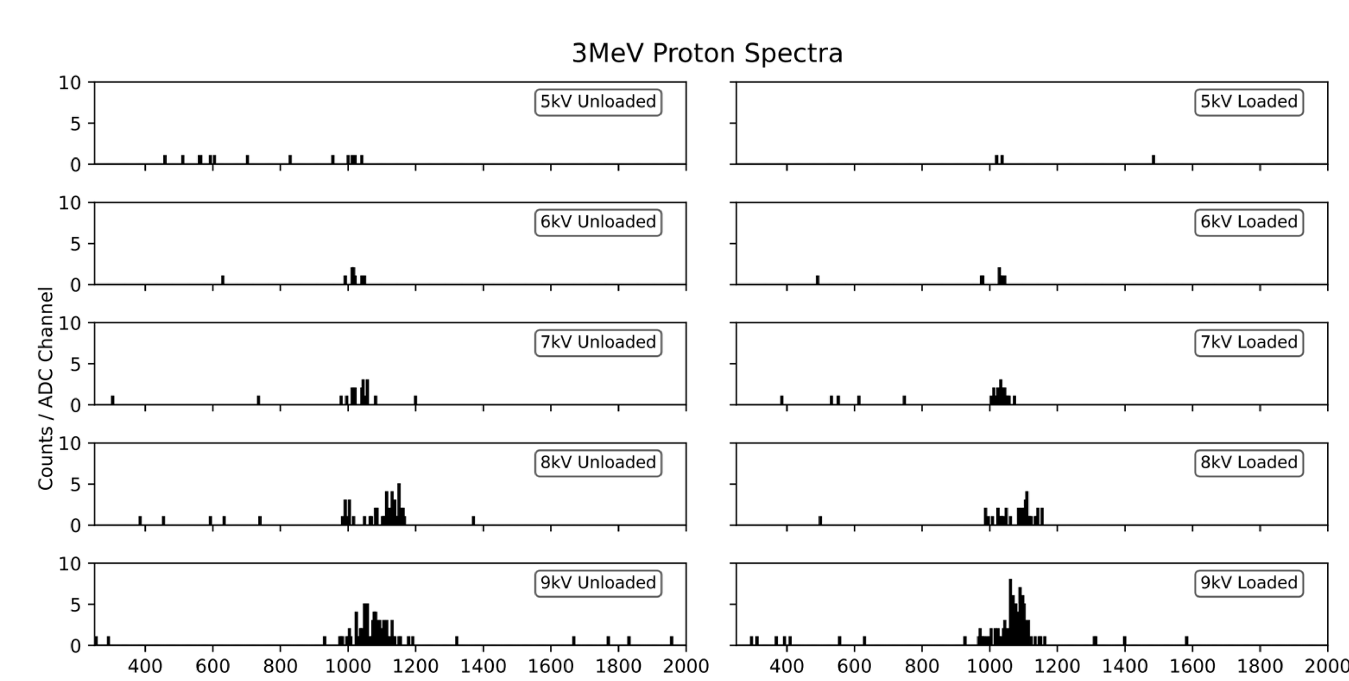
Initial Results



- We see a much higher rate of fusion in Titanium foil compared to Palladium foil as we would expect due to Titanium having a higher loading ratio than Palladium (2 : 0.9)
- Our initial results show a clear increase in fusion rate in Titanium loaded electrochemically compared to Titanium loaded with only a deuterium beam.
- Differing from Titanium, we see no increase in fusion rate when we electrochemically load Palladium foil compared to beam loading only.

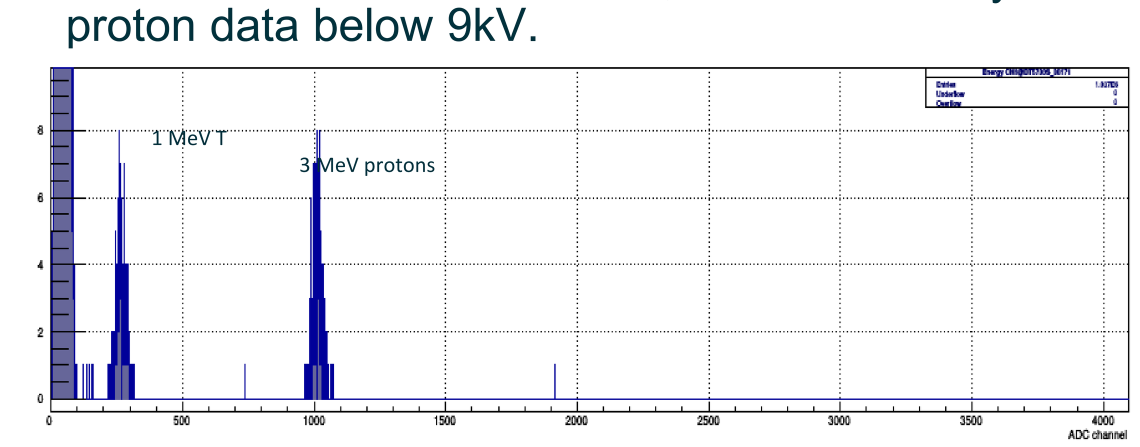
(Above) Plot of detected neutron rates per hour with center of mass energy of our beam. We show an overall increase in rate in Titanium with energy and show no increase in rate for Palladium.

(Right) Plots of proton count rate in our silicon diode detector with a Titanium foil. These plots show that our proton rate increases with beam energy, and also that overall rates generally increase when the foil is electrochemically loaded.



Challenges

- **Low Event Rates:** Due to the low expected cross sections at low energies, long measurement times are needed. We routinely run experiments for 8 hours and plan even longer runs in the future.
- **High Background rates:** We average a background rate of ~100 neutrons/hr in our EJ detector. As our neutron rate is on the order of 10-20 counts/hr at low energies our signal to background ratio is small and we have large uncertainties. Our diode sees background rates of 0.5 counts/hr, making the detection of protons much more reliable at low energies.
- **Noise Issues:** We must aim to operate with an optimal signal to noise ratio due to low rates. This has led to certain tradeoffs. In our system we receive noise from two sources. We see low energy noise from electron emission, which we have managed to remove using an Al foil, however, this also removes our Tritium counts. We also see too much noise at high energies, from x-ray emission, to make our silicon diode detector reliable, and so can only record proton data below 9kV.



An example spectra from our silicon diode detector w/o Al foil showing 2 peaks, representing 1 MeV Tritium (left) and 3 MeV Protons (right). The section furthest left is where our noise appears in the detector. Our Helium 3 peak likely falls within this noise.

Upcoming Plans

- **Run at energies below 5kV:** Currently we have lots of data between 5 and 15 keV, We are planning to take data at lower energies, down to 500 V.
- **Testing Different Metal Hydrides:** So far we have only tested Palladium, Titanium or a combination. Other metals would be interesting to look at, for example Nickel.
- **Running Beam and Electrochemistry in Parallel:** Currently we can only run our beam up to 5kV while loading electrochemically. We have planned changes which will allow us to run electrochemistry at up to 15kV beam energy.

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https://atap.lbl.gov/research/scientific-programs-and-centers/fusion-science-ion-beam-technology-program/