Neutron Generator Operations

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LUX

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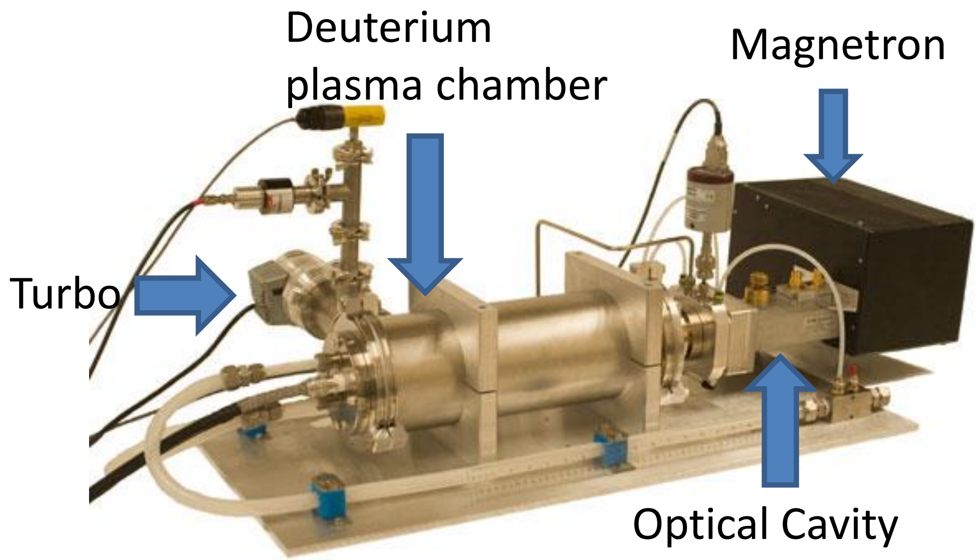
Overview

- LUX uses an Adelphi DD-108M neutron generator to produce mono-energetic neutrons.
- A hole in insulation allows the neutrons into the water tank.
- A tube filled with air positioned between the generator and the detector in the water tank allows neutrons through.

The Generator

- The Generator contains the following components:
  - Power Cart
  - Chiller
  - Magnetron
  - Optical waveguide and cavity
  - Deuterium plasma chamber
    - Titanium target
  - Deuterium supply + MFC
  - Turbo + roughing vacuum pumps



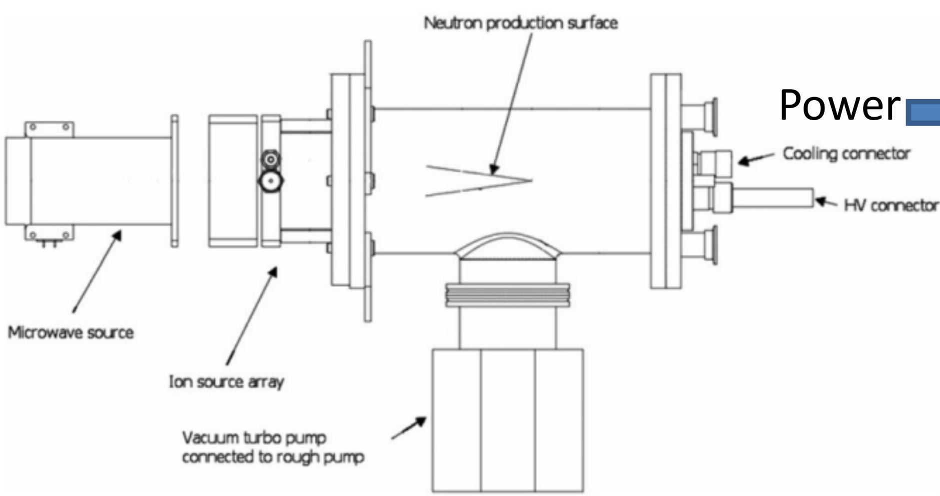


Diagram from “Development of a transportable neutron activation analysis system to quantify manganese in bone in vivo: feasibility and methodology” Liu et al.

Deuterium Management

- A small amount of Deuterium between 5 and 20 mTorr is maintained in the plasma chamber.
- This is accomplished by bleeding deuterium gas from a bottle via a mass flow controller while simultaneously pumping it out through the turbo.

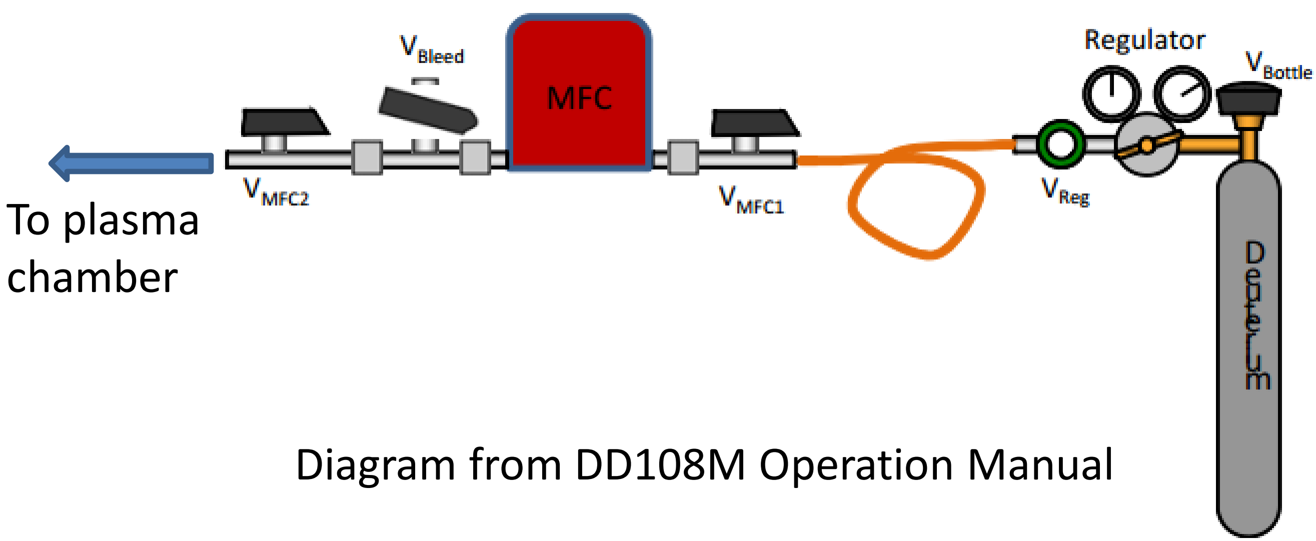


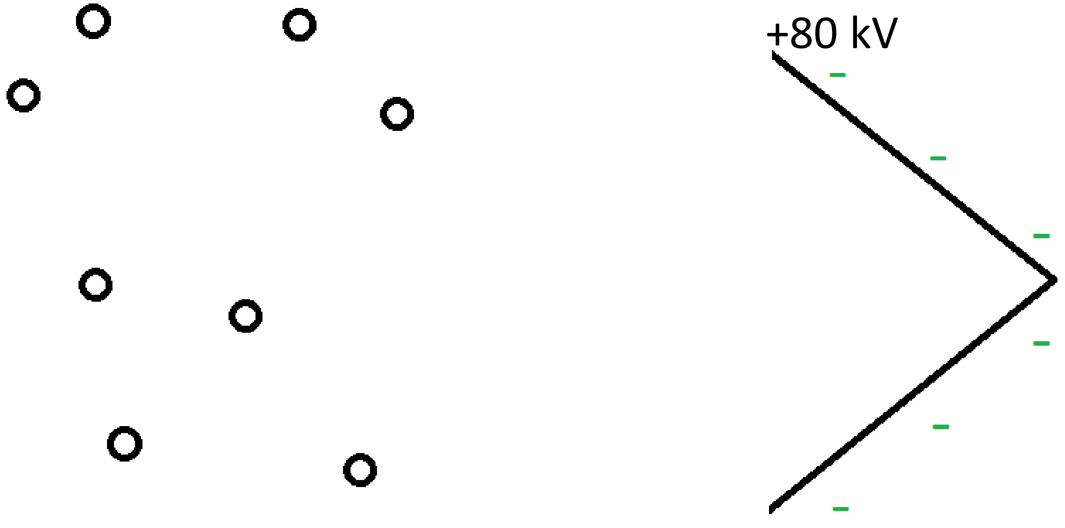
Diagram from DD108M Operation Manual

Plasma Ignition

- The Deuterium gas is ionized via “RF induction discharge.”
- The RF signal is provided by microwave radiation generated in the magnetron and amplified in the optical cavity.
  - The magnetron uses ~75 mA at ~100 kV
  - Pulsing of the magnetron allows for the creation of short (10s of μs) neutron bursts.

Fusion Process

- The titanium target wedge is biased to at least 80 kV.



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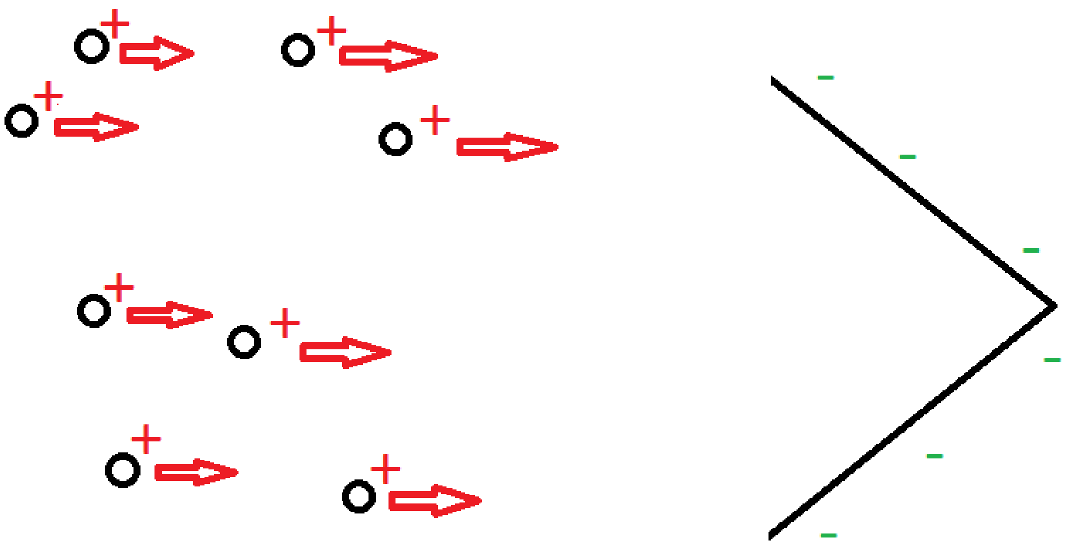

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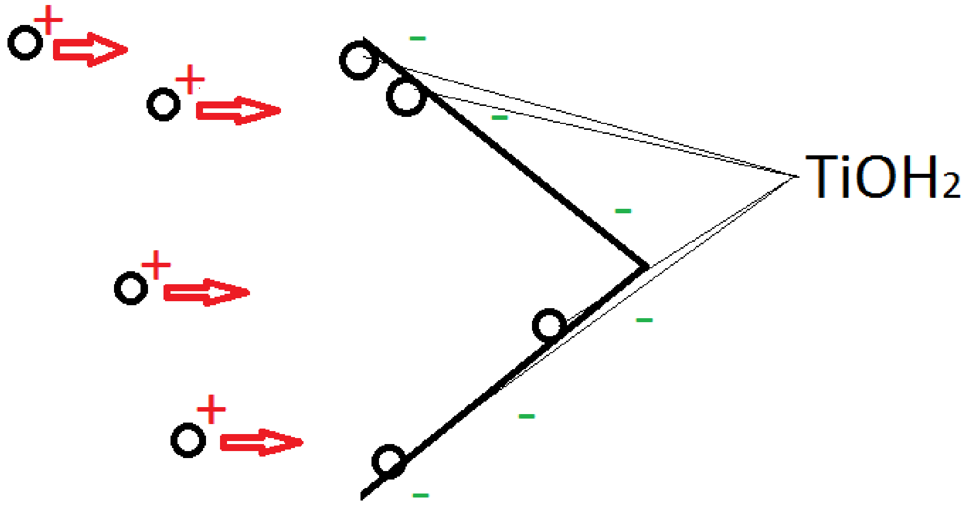

Fusion Process

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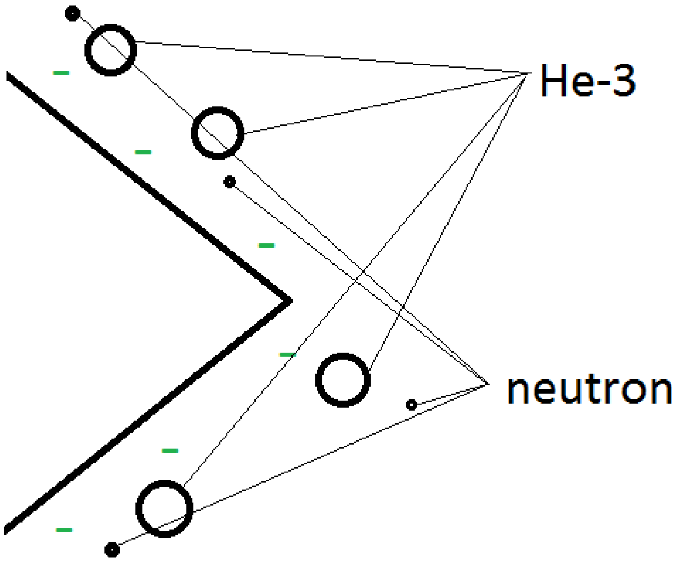
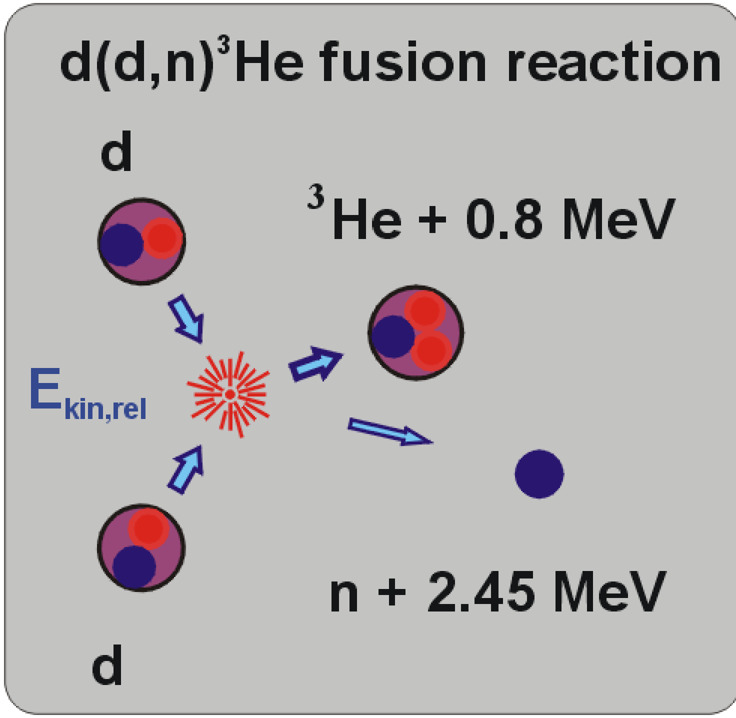
- When the magnetron pulses the Deuterium gas becomes ionized.
- The first bunch of Deuterium that strikes the target binds to the surface to form Titanium Hydrate.
- When another Deuterium strikes a bound one they can fuse to produce Helium 3 and a 2.5 MeV neutron.



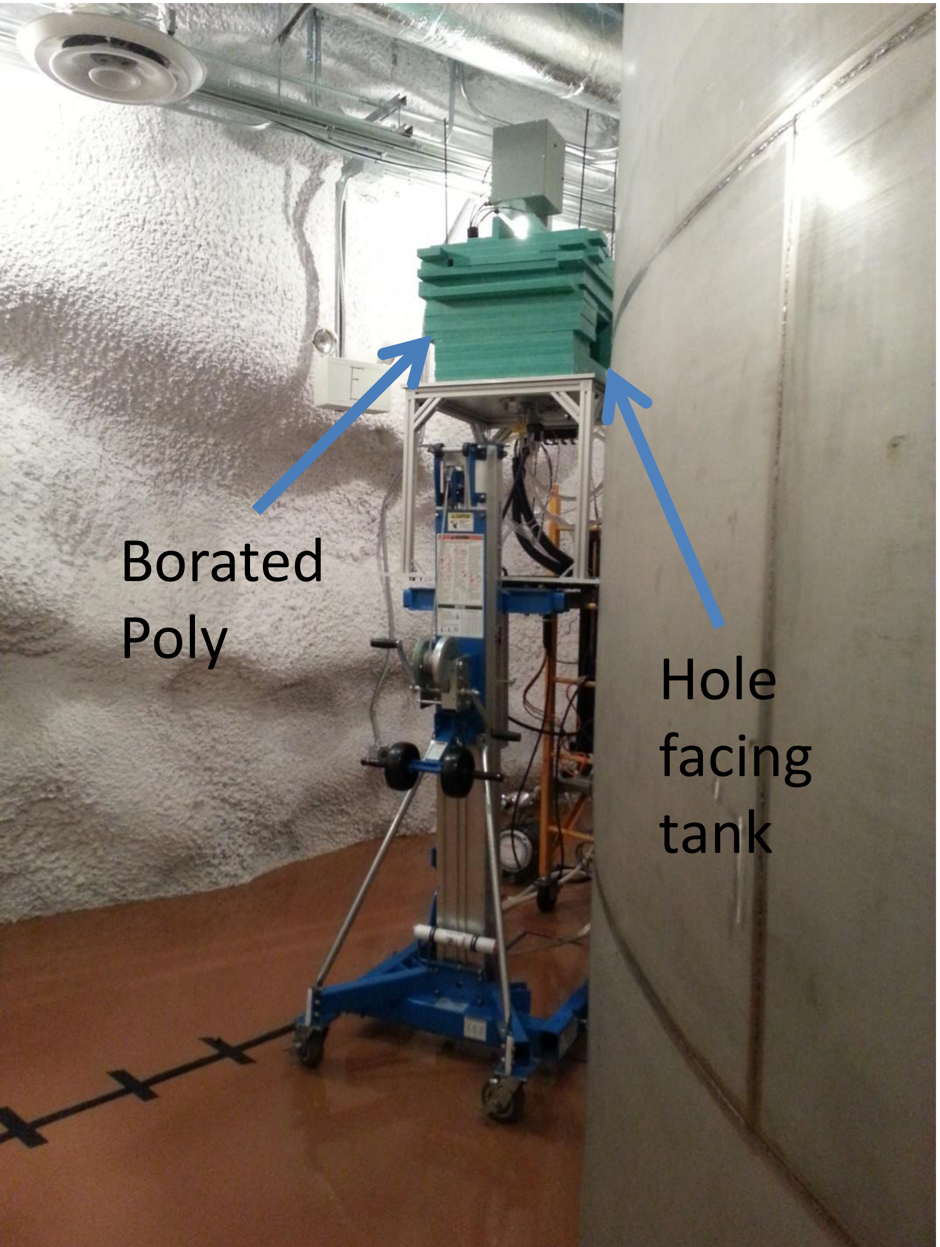
A (very) brief Foray into nuclear physics.

- There are actually 2 possible fusion processes for D-D.
  - D + D -> Tritium + Proton
  - D + D -> ^{3}He + n   (the one we care about)
- The masses of the relevant particles are
  - D: 1876.1MeV
  - ^{3}He: 2809.4 MeV
  - N: 939.6 MeV
- This gives a Q-value of 3.2 MeV (measured 3.268 MeV)
- Since the max 80 keV from acceleration is insignificant, the momentum is evenly split between the n and ^{3}He which, since this is non-relativistic (3.268 MeV << m_n or m_{He}) gives the neutron ¾ of the energy (m_{He} ~ 3 m_n) which is 2.45 MeV.



http://www2.mpq.mpg.de/lpg/research/neutrons/neutrons.html

Shielding



- A substantial amount of neutrons are emitted in all directions and so must be blocked.
- We use borated polyethelene blocks for shielding but leave a gap between the generator and the water tank.

The Tube

- An Air-Filled tube bridges the gap between the generator and the detector inside the water tank.
- The Tube has an ID of 4.9 cm and is 377 cm long.
- It comes ~3 cm from both the water tank wall and the cryostat wall.
- The tube is stored at the top of the tank and is lowered into position by a pair of winches.

Backup

Lingering Questions

- Why is the target a “v”?
- What is “RF induction discharge?”
  - If it’s just RF induction with a coil and thermal ionization, why do they say discharge? If not, what’s that about?
- My numbers for the Q-value don’t match exactly, even when adding more sig-figs, what’s up with that?
- What’s up with the oxygen in $TiOH_2$? The manual says “titanium hydrate.” And are both Hs in the $TiOH_2$ typically Deuterium or just one?
- Is the strong interaction such short scale that being bound doesn’t virtually affect it at all? If so, what happens to the molecule after one of the Hs is converted to a He and n?