Production of Solid High Desnsity Solid Ammonia Targets

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There is a national program at Jlab, Fermilab, the Higs facility that requires targets that are polarized via Dynamic Nuclear Polarization(DNP). The DNP process that we use involves freezing ammonia and forming 2mm beads that then get irradiated to introduce free electrons. The irradiated ammonia is then placed in a large magnetic field, and using microwaves, the spin of the electron flips and forces the spin of one of the protons in the ammonia to do the same. This process is repeated until the polarization of the ammonia approaches 90%.

The solid ammonia is made by flowing ammonia gas through a gas panel which I helped construct and into a cryostat that is submerged in a methanol ice bath at 97K which is lower than the melting point of ammonia which is 197K. The solid ammonia is harvested from the cryostat, crushed, and sorted into 2mm beads. These beads are stored and await irradiation. The method for making the methanol ice bath which I designed and constructed involves cooling a 1L dewar of methanol by pumping liquid nitrogen through a cooling helix submerged in the bath. When methanol begins to solidify on the cooling helix, the pump is shut off and the cooling helix is removed. Methanol ice cubes that were stored in liquid nitrogen are then added to the bath to cool it down further and ensure a stable temperature in the cold bath. When the bath contains equal parts solid and liquid methanol, the temperature is around the freezing point of methanol. Historically, the freezing of ammonia was accomplished rapidly with a liquid nitrogen bath at 77K. My goal is to create a slower cooling process to obtain solid ammonia crystals that have a higher density and a crystalline structure. We want these high density crystals in order to study whether the density can affect how the beads hold up under intense radiation.

I propose to modify the existing cooling apparatus to make accurate and reproducible beads. I will be constructing a new cooling apparatus that can maintain a steady temperature of 97K and has thermometry to monitor the temperature at the top, middle and bottom of the cryostat. By flowing both liquid nitrogen and cold nitrogen gas through a dual helix, the temperature can be controlled by flowing cold nitrogen gas though one line or cooled by flowing liquid nitrogen through the other. My goal is to get beads of ammonia that were made via the liquid nitrogen cooling bath and beads that were made with this new cooling apparatus and compare their densities using Archimedes principle in liquid nitrogen in a rough vacuum. I will also test whether the maximum polarization in the ammonia beads is changed by the density of the beads. The EGS4 software package simulates the passage of radiation through various materials. The ammonia is typically irradiated at the National Institute of Standards and Technology(NIST) Medical-Industrial Radiation facility(MIRF) facilities using a 10 MeV electron beam. This introduces paramagnetic radicals needed for the DNP process. I will use EGS4 to model the beam from the NIST MIRF facility to predict the expected dose rate of a radioactive source embedded in ammonia. My goal is to optimize the delivered dose of radiation in order to obtain maximum polarization in the sample and to test my prediction against actual polarization measurements made in Slifer lab.

I have completed some samples of ammonia using both liquid nitrogen cooling bath and the new methanol cooling bath. I will spend the month of january working on the construction of the cooling helix and measuring the density of ammonia crystals. The month of Febuary will be spent working on determining the maximum polarizations dependance on the dose rate. March will be focused on running the simulation EGS4, leaving a April to do analysis and write the paper. throughout the semester I will spend 20 hours per week on this project.