Production of an Energetic Beam of Tritium Particles at the NSCL

The A1900 mass separator at the NSCL used in the production of a beam of tritium particles.

Researchers at the National Superconducting Cyclotron Laboratory have produced a beam of tritium particles (Hydrogen-3) at an intensity of about 10 million particles per second that travel at about 45% of the speed of light. This unique capability provides a tool for determining weak interaction rates of importance for understanding stellar evolution.

To understand the evolution and in particular the explosion of stars (supernovae) it is important to model the nuclear reactions that take place in the interior of stars with a high degree of accuracy. Transitions governed by the nuclear weak interaction (electron capture and beta-decay) are of particular interest, since they influence the explosion process and modify the composition of the star. A large fraction of the star is ejected into space during the explosion and becomes part of the material that forms stars and planetary systems.

To study these rates experimentally, an ionized Hydrogen-3 beam will be shot at a thin foil containing particles of interest for astrophysics, for example an isotope of Nickel. A so-called charge-exchange reaction can take place, in which the Hydrogen-3 particle gives a neutron to the Nickel and receives a proton, becoming a Helium-3 particle, while leaving behind an isotope of Cobalt. By studying the probability that such a reaction takes place, the weak interaction rate can be deduced.

At the NSCL, the tritium beam is made as a secondary beam since Hydrogen-3 is not a stable particle. Oxygen-16 isotopes are injected into the Coupled Cyclotron Facility and accelerated to a velocity of about 51% of the speed of light. They then hit a thick Beryllium target producing a variety of nuclei at different speeds. The A1900 mass separator is then used to select the tritium at the velocity required for doing the charge-exchange experiments, about 45% of the speed of light. Finally, the tritons are guided through a beam line towards targets of interest. The Helium-3 particles produced in the reaction are detected in the S800 magnetic spectrometer.

The capability to produce tritons at this velocity and intensity and use them in charge-exchange experiments is unique in the world. The method has significant advantages over the use of other charge-exchange reactions, because high resolutions can be achieved and the details of the reaction can be studied and combined with data taken via the inverse reaction (i.e. using a Helium-3 beam and measuring Hydrogen-3) taken at other facilities.

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