Title
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DEUTERIUM-BEAM SPECIES MEASURED BY FUSION REACTIONS
IN THE NEUTRALIZER

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Using a surface barrier detector and standard nuclear
instrumentation, the energetic charged products of fusion reactions
between deuterium neutralizer gas and accelerated deuterium ions are
sorted in energy to yield a measurement of the species from a neutral
beam source, i.e., the proportions of accelerated D\(^+\), D\(_2\)\(^+\), and
D\(_3\)\(^+\). Such sources have been designed at LBL for the TFTR project at
Princeton University to accelerate currents of 5 mamps to 120
kilovolts,\(^1\) and the species distribution affects the power deposition
within the target plasma. The species mixture has been measured by
various techniques which sample downstream from the source, but this is
complicated by the differing divergences of the ionic species.
Furthermore, to compare with source physics models, one must project the
measurements back through the neutralizer gas of uncertain density
distribution. An integral measurement over the entire area of the beam
can be performed with Doppler shift spectroscopy, but it involves a
large number of cross sections, of which not all are known, and it is
also dependent upon the neutralizer gas distribution. The present
species measurement complements other measurements because it is
integrated over the entire beam, is independent of the neutralizer gas
distribution, and only requires one well known cross section.

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The diagnostic is "on-line", small, and relatively cheap. The D-D reaction has two branches with almost equal probability and with products:

\[ T (1.01) + H (3.02); \quad {^3}\text{He} (0.820) + n (2.45); \]

where the C. M. energies in MeV are given in parentheses. The velocities per nucleon of the three accelerated species are in the ratio \( 1: \sqrt{2}: \sqrt{3} \), and this fact allows the separation of the reaction products from each species. We observe at 135° to the beam, a compromise between mounting ease and maximizing the projection of the incident particles' velocity along the detector's line of sight. Detecting T seems preferable, because the higher velocity of P masks the differences in incident D velocities, and \(^3\text{He}\) loses far more energy passing through the necessary light-blocking foil and the detector dead layer due to its charge of 2.

An important advantage of a gas target over the Sc D\(_2\) target used in Reference 2 is the absence of spectrum broadening due to deceleration of D before it reacts. We do have other sources of broadening: electronics noise of the amplifier, angular acceptance of the collimator, beam divergence, accelerator power supply ripple (which can be countered with synchronous gating of the PHA), straggling in the foil and dead layer, and stray light or electrons.

We estimate a target density of \( 5 \times 10^{13} \) cm\(^{-3}\) and a detected volume of 370 cm\(^3\). In order to maximize the count rate, we used a
collimator made of a stack of rectangular channels 1.27 cm wide, 5.08 cm long, and 0.0127 cm high in the plane defining the reaction. With a 1 cm² detector at 70 cm from the center of the viewed volume, we take the average solid angle to be 1.0 x 10⁻⁴ sr.

In Fig. 1, the x's show the triton spectrum accumulated for 11.2 seconds at 112 keV with an accelerated current of 6.9 amperes from a 7 x 10 cm² source. A straight line background has already been subtracted. The solid curves show a seven parameter fit (three Gaussians with a common width) and the individual peaks. The fitted areas are 1788, 889, and 250 counts. The relative areas imply a species mix of 47: 35: 18, which compares well with a measurement of 54: 36: 10 using Doppler shift spectroscopy. For this measurement, we fed 2.8 Torr liters sec⁻¹ into the source and 4.5 into the neutralizer. The additional gas feed was intended to raise the count rate and presumably caused an atypically low full energy species fraction. A fit to the less well resolved proton data gave a species mix of 49: 36: 15 and a total count rate of roughly 500 sec⁻¹. For the experimental conditions we would predict rates of 262, 128, and 30 for a total of 420 counts sec⁻¹.

A double set of 250µg cm⁻² Cu foils was used to block light from the neutralizer plasma. A multi-channel collimator consisting of a stack of stainless steel meshes separated by 1.27 mm resulted in an acceptance angle of ±1.40°. This collimator seems to produce a much smaller tail on the low energy side of the proton peak than was observed with a collimator made from smooth plates. The FWHM of a pulser signal collected along with the data was roughly 21 keV and the FWHM's of the
triton and proton peaks were 25 and 28 respectively. This implied that the broadening due to the effects mentioned above was roughly 13 to 19 keV.

In the future, we plan to use a light-tight detector and a thermoelectrically cooled preamplifier in order to improve the resolution. Higher resolution would allow useful spectra to be taken with less beam time and at lower beam voltages.

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REFERENCES

MEASURED NEUTRALIZER D-D T SPECTRUM