Towards an improved measurement of the 4^+-to-2^+ γ-decay in ^{8}Be: a new gas target chamber and detector simulation

V.M. Datar* and Suresh Kumar
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
** email: datar@barc.gov.in*

Introduction

The first direct observation of the γ-ray transition between the 4^+ and 2^+ resonances in ^{8}Be was found to be consistent with both ab-initio as well as cluster model calculations [1]. The precision in the measurement of the radiative capture cross section in the ^{4}He(^{4}He,γ)^{8}Be channel was rather poor, about ±30%, and not enough to discriminate between the two models.

The earlier measurement was made in a gas target chamber not optimised for the experiment. Six square Si(PIN) diodes were used for detecting the two α-particles following γ-decay in coincidence and a 14-BGO detector array (treated as 2 large detectors to simplify the electronics) for measuring the 4^+ to 2^+ γ-ray with an energy ~8 MeV. The main source of error was the large γ-ray background arising from the inelastic excitation of the 4.44 MeV state in ^{12}C which is a constituent of the Kapton window which isolates the ^{4}He gas target from the beam line vacuum. An improved measurement would require better shielding of these γ-rays and more segmentation of the γ-ray and α-detectors. A dedicated new gas target chamber has been designed which will allow better shielding of the 4.4 MeV γ-rays from Kapton. The results of a simulation of the α-α detection, following radiative capture in an extended gas target, are also reported.

Design of gas target chamber

The features required of the gas target chamber are: (a) chamber diameter appropriate for 19 hexagonal close packed BGO detectors, of size 6 cm face to face, above and below the active target area (b) entrance and exit windows with mildly stretched 7.6 μm Kapton foil isolating the gas in the target chamber from upstream and downstream beam line vacuum (c) heavy-met surrounding the Kapton foil to shield the BGO detectors from the 4.44 MeV γ-rays. Fig. 1 shows two views of the gas target chamber. The heavy met is shown as the shaded portion while the aperture placed near the centre stops scattered or reaction products from beam-entrance window interactions from reaching, and swamping, the annular Si strip detector (SiSD). The chamber also has ports for viewing the target zone through a glass window, gas inlet and outlet and a port through which a target ladder with foil targets can be mounted.

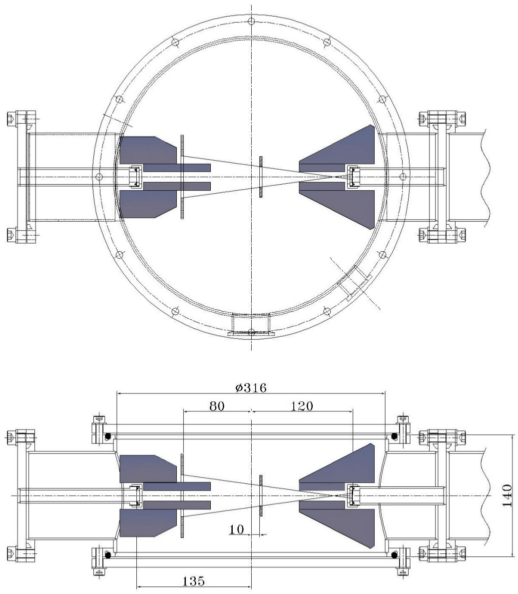

Fig. 1 Top and side views of gas target chamber showing only the essential features.

Simulation of α-α detection

The Monte Carlo simulation program written for the earlier experiment with 6 square detectors for detecting the α-particles following the decay of the 2^+ resonance was modified for the annular SiSD geometry. The annular detector was assumed to have an active area between inner and outer diameters of 48 mm and 96 mm, respectively [2]. A suitably placed aperture prevents the elastically scattered beam particles from the Kapton foil reaching the Si detector. This aperture also defines a certain longitudinal zone from where the ^{8}Be 2^+ decay α-particles are detected efficiently. The radiative capture was assumed to occur in a specified longitudinal span in the gas at a certain input pressure. The energy losses of (i) the beam as it travels in the (extended) gas target and (ii) the two α-particles emitted following the γ-decay in traversing the gas up to the Si detector, are calculated using SRIM-2008. Included in the simulation are the γ-ray energy corrected for the Doppler shift and, its angular distribution and the recoil effect on the momentum of the ^{8}Be in 2^+ resonance. The angular distribution of the α-particles following E2 gamma decay from the 4^+ resonance is also included. The various observables such as energy of the γ-ray and the two α-particles are written into a list file event- by-event for later analysis.

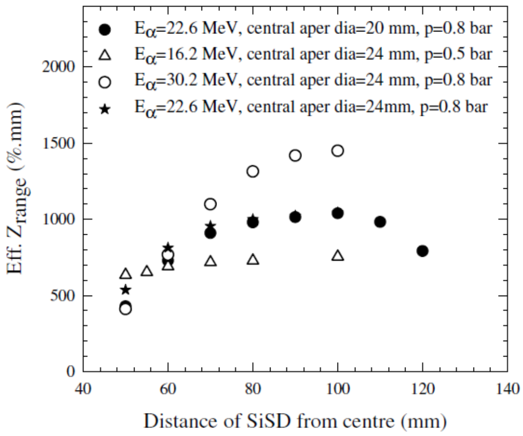

Fig. 2 Efficiency plots as a function of distance of the SiSD from the centre of the target chamber for 3 beam energies. The pressure of the He gas and central aperture diameter are indicated.

The product of efficiency and effective target length for α-α detection by the annular Si strip detector is shown for three ^{4}He beam energies as a function of distance of the SiSD from the centre of the chamber. In these simulations the aperture is placed at the centre of the gas target chamber. This efficiency is 3-4 times higher than that of the earlier set up. With increased granularity of the gamma ray detectors and the heavy met shielding an overall increase in statistics by about a factor of 10 is expected for similar beam time. In addition, a reduction in the contribution of systematic error is also expected. A conservative estimate of the improvement in precision expected is ~3 leading to an error in the radiative capture cross section of less than 10%. It would also be possible to scan the resonance by measurements at 5 beam energies with about 10 days of beam on target.

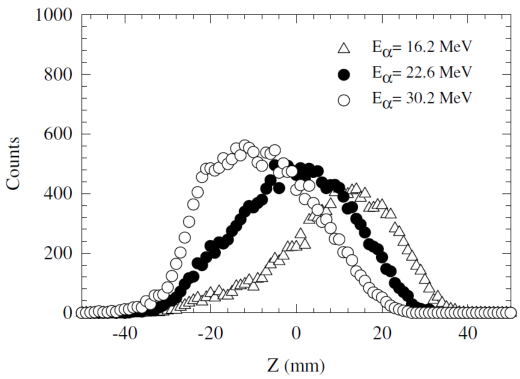

Fig. 3 Simulation results at three alpha energies for SiSD at 70 mm from the centre showing z-region contributing to α-α coincidences. Here a 24 mm aperture is placed at z=0.

Acknowledgements

We would like to thank L.S. Choughule and Sunil Kumar, MDPDS, BARC for quickly translating our ideas into digital drawings.

References

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[2] P. Sugathan, priv. comm.