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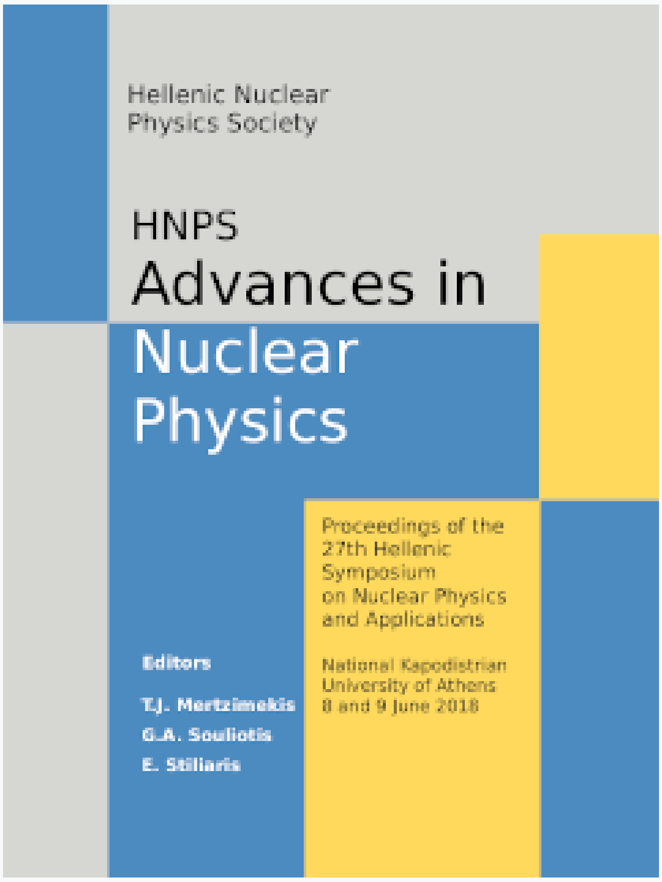

Branching Ratio Measurement in 23Ne Beta Decay

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Branching Ratio measurement in ^{23}Ne Beta decay

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Abstract We describe the branching ratio measurement experiment performed at Soreq Applied Research Accelerator Facility (SARAF) using the deuteron beam. We successfully produced 10^7/s ^{23}Ne atoms in the run and used them to measure the branching ratio in ^{23}Ne beta decay to the first excited state of ^{23}Na. We provide some preliminary results of the experiment whose data analysis currently ongoing.

Keywords beta decay, beyond standard model, branching ratio

INTRODUCTION

The Standard Model (SM) of particle physics is the remarkably successful theory in explaining various phenomena in universe and has been extensively tested by many experiments throughout the years. Along with testing SM at high energy/intensity frontier at high energy particle collider, it can also be tested at precision frontier. By conducting precise measurements on the beta decay of trapped and cooled radioisotopes one can study the weak interaction part of SM and thereby search for the new physics beyond standard model [1, 2].

One major area of active investigation in beta decay is to look for beta-neutrino angular correlation coefficient ($a_{\beta\nu}$), which is sensitive to the scalar or tensor currents [3, 4]. The *β-ν*

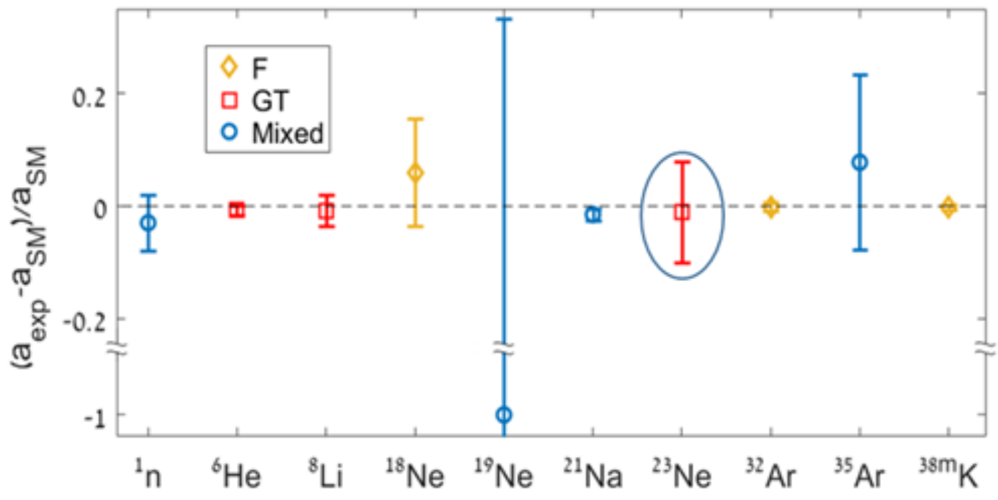

Fig. 1 beta-neutrino correlation co-efficient

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angular distribution for the allowed beta decay in an unpolarized nucleus is given as [5],

$$dW \propto E_e P_e (E - E_0)^2 \left(1 + a_{\beta\nu} \frac{\overrightarrow{P_e} \cdot \overrightarrow{P_\nu}}{E_e E_\nu}\right)$$

Where, E_0 is energy released, and Ee, Pe, Ev, Pv are respective energy and momenta of electron and neutrino, and $a_{\beta\nu}$ is the $\beta - \nu$ correlation coefficient.

Figure 1 shows the $a_{\beta\nu}$ values measured for various light and medium mass isotopes [6] and it can be seen there exists greater uncertainties in the previously measured $a_{\beta\nu}$ values in neon isotopes. This makes neon isotopes a good "hunting ground" to look for some beyond

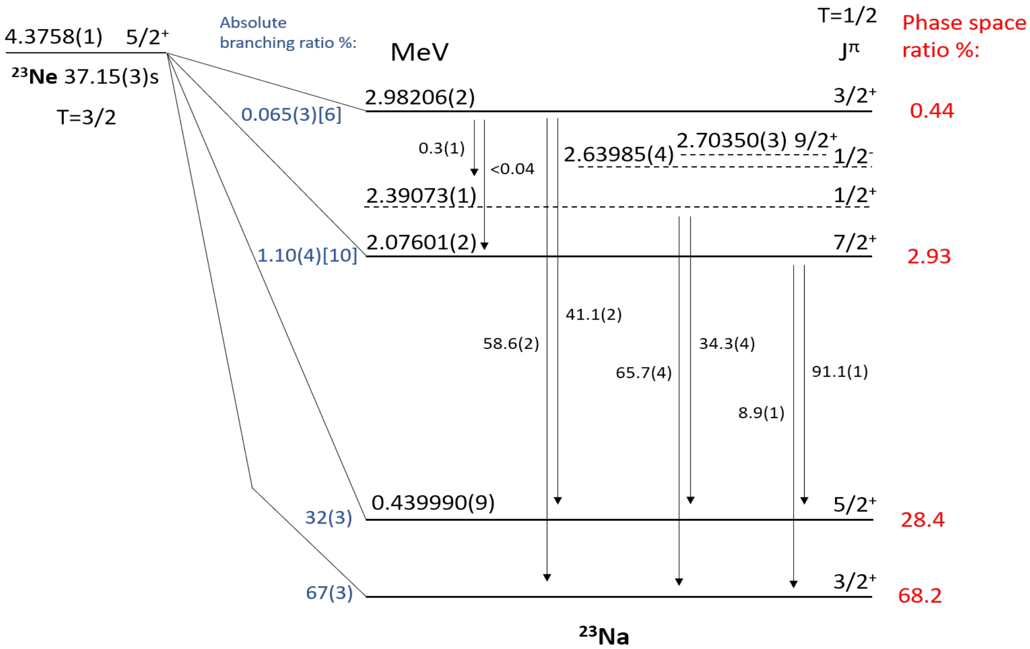

Fig. 2 Decay scheme of ^{23}Ne

standard model physics[7]. In our lab at SARAF, we are moving towards the trapping of ^{23}Ne isotope (along with other isotopes of Ne) and precise measurement (sub-percent) of $a_{\beta\nu}$ [6]. The experimental measurement of correlation coefficient $a_{\beta\nu}$ is done by studying the recoil ion spectrum of the radioisotope, in which principal contribution to the recoil energy spectrum of ion comes from the transition of the radioisotope to the ground state [8]. Now ^{23}Ne decays to ^{23}Na by beta emission with Q-value of 4.376 MeV. As shown in the decay scheme in Figure 2 the transition to the ground, second and third excited states are pure Gamow Teller (GT), while to the first excited state it is almost GT (Fermi fraction is <0.1%). Due to these various decay channels of ^{23}Ne, an accurate measurement of branching ratio is very crucial for more precise determination of $a_{\beta\nu}$. For ^{23}Ne only one measurement of branching ratio to the first excited state exists which was done by Penning as Schmidt and has an uncertainty of ~9% [9], which is not enough for better determination of $a_{\beta\nu}$ and needs to be measured again.

EXPERIMENTAL DETAILS

The ^{23}Ne isotopes were produced by (n-p) reaction on ^{23}Na. The experimental setup for the production of Neon and measurement of Branching ratio is as shown in Figure 3. In the first stage deuteron beam of 2.5 μA intensity accelerated to 4 MeV from the SARAF-I accelerator was hit on Lithium Fluoride (LiF) target. The LiF target is in the form of 400 μm thick crystals. In this collision process energetic neutrons, up to 20 MeV were produced by Li(d,n) process. The neutrons produced in this process were made to hit the 1.4 kg of table salt target. The neutrons collide with ^{23}Na nucleus produce ^{23}Ne in the NaCl crystal. For the efficient diffusion of ^{23}Ne atoms out of NaCl crystal, the salt was grounded finely and sieved through 40 μm mesh and also heated to 620 K. The ^{23}Ne atoms diffused out of NaCl crystals, effuse out of the target and travel to a measurement cell through a 10 m long 3" diameter hose. The measurement cell is located in the separate shielded room so as to reduce the background in the detectors. The measurement cell has 6.0 cm diameter and 3.8cm height and is made of SS as shown in Figure. 3.

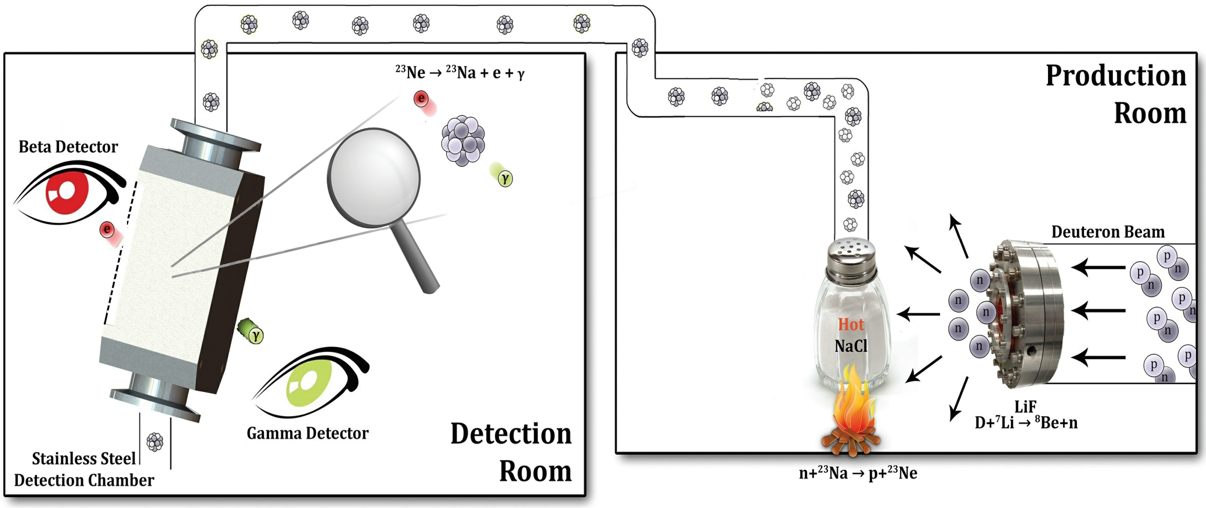

Fig. 3 Experimental Setup

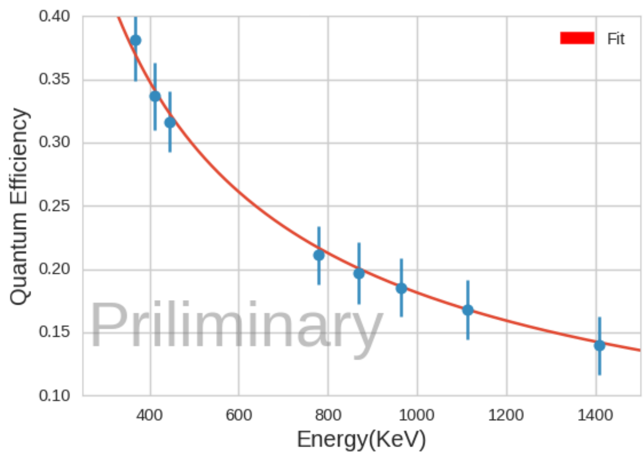

Fig. 4 Efficiency of HPGe detector

The input for the ^{23}Ne cell has KF-25 coupling and at another end, it has the same for pumping. Towards the side of gamma detector the wall thickness of the cell is 2 mm, while on the opposite side where the beta detector is placed, the cell wall is made by 25µm aluminized Mylar mounted on 38mm hole. This hole size fixes the effective volume of the experimental cell which is decided by the geant4 simulation. The vacuum inside the neon cells pulls the Mylar inwards making the curved shape. This curvature slightly reduces the neon cell volume.

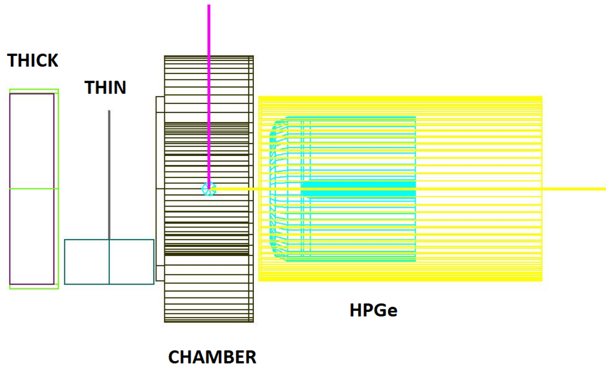

Fig. 5 Geant 4 Simulation

The decay products of the23 Ne atoms that decayed in the measurement cell are measured in co-incidence by a single HPGe and two plastic scintillator detectors. To discriminate the electron events from the gamma event, two plastic scintillators, thin and thick are used in coincidence making a $\Delta E/E$ telescope. The electrons events are then used to look for the triple co-incidence with HPGe detector to choose the only gammas emitted after the beta decay. The efficiency of the HPGe detector is obtained using the calibrated point ^{192}Eu source of known activity kept at 45 cm away from the detector. The quantum efficiency curve for the detector is shown in Figure 4.

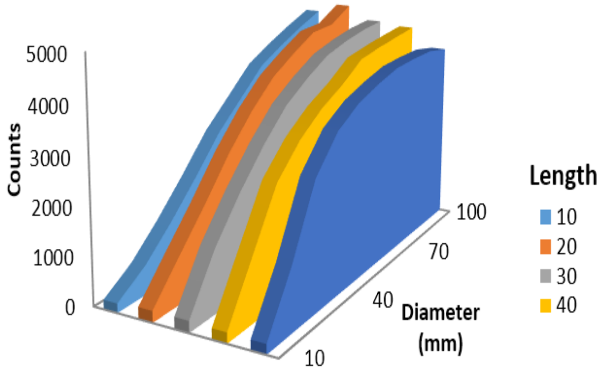

Fig. 6 Triple Coincidence Events

SIMULATION

To estimate the smallest size of the experimental chamber with maximum yields, we have performed the geant4 simulation. Figure 5 shows the geometry used in the simulation which depicts the actual experimental condition. In the simulation, the width and the diameter of the experimental chamber were varied while maximizing the number of triple coincidence events in thin, thick and HPGe detector. The results of the simulations are shown in Figure 6. Using these results we have chosen the shape of the experimental chamber. Although the simulation shows that with increasing the diameter of the chamber the number of triple co-incidences increased we have settled for diameter slightly smaller than the HPGe crystal diameter.

RESULTS AND DISCUSSION

The experimental run with the above mentioned experimental setup was performed in March 2018. The data analysis is currently ongoing and here we present only the preliminary results. Figure 7 shows the spectrum obtained from all the three detectors without any co-incidence condition applied.

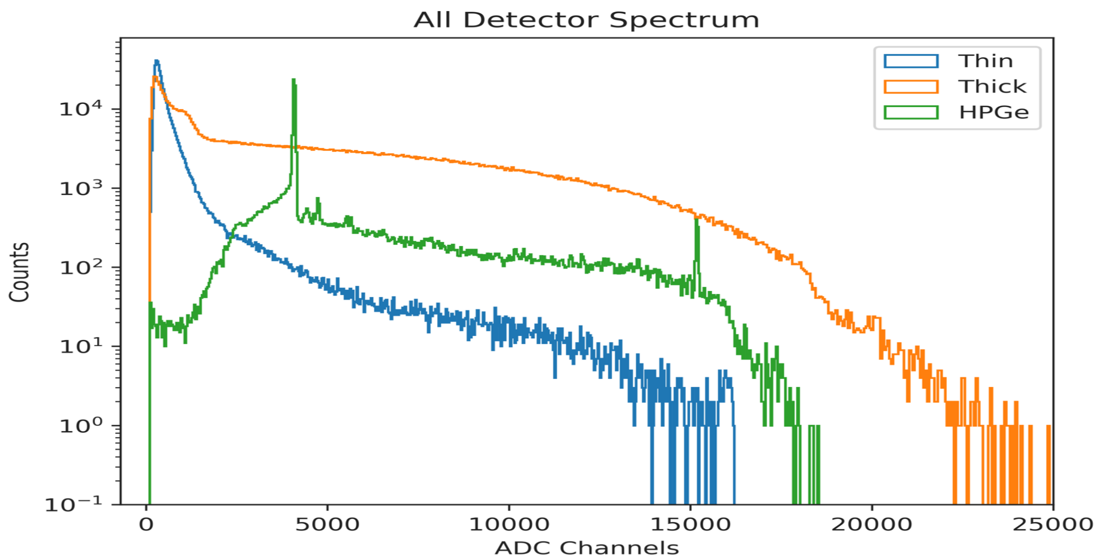

Fig. 7 Data from all the three detectors

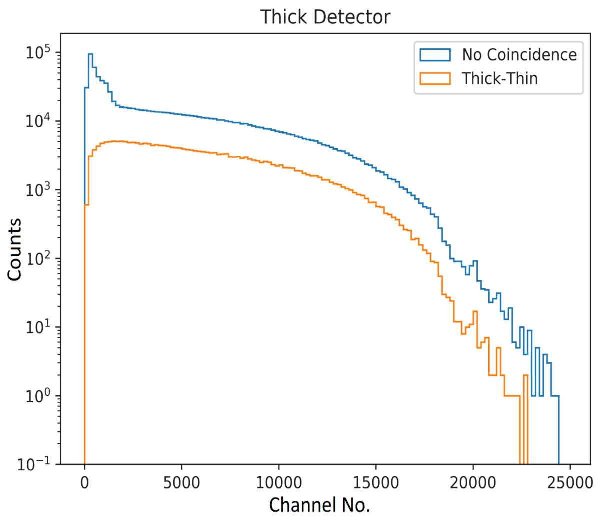

Fig. 8 Spectrum of thick scintillator detector used to detect electrons.

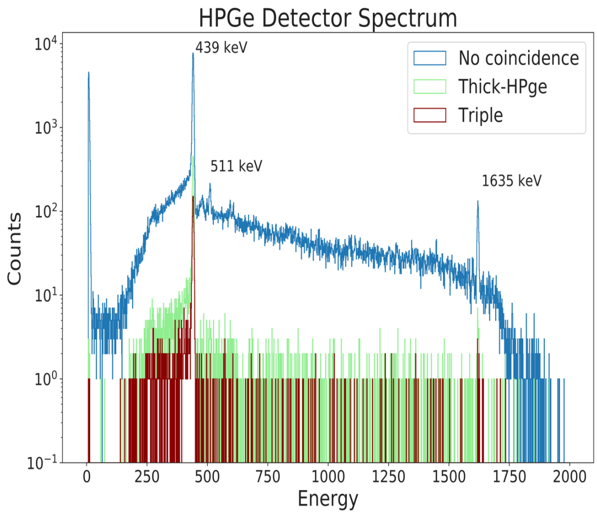

Fig. 9 HPGe detector spectrum from a single run

When we apply the co-incidence condition (with thin detector) to the thick detector spectrum we see gamma peak removed from the thick spectrum, as shown in Figure 8. This selects only electron events in the thin-thick beta telescope. On average we obtained about 1k thin-thick co-incidence events per sec.

Figure 9 shows the HPGe detector spectrum with different co-incidence condition. As it can be seen that under the triple co-incidence condition we remove most of the background along with 511 keV peak and select only the gammas coming out of beta decay. We estimate that in the experiment we have successfully produced 2 x 10^6 ^{23}Ne atoms /s, part of which got transported to the measurement cell and their beta decay product were measured. Currently, we are in the process of further data analysis and estimating systematics such as detector efficiency with better accuracy with which we will obtain the branching ratio.

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