Search for Di-Proton Radioactivity in Exotic Nuclei

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So far all experimental attempts to identify a potential di-proton radioactivity at or near the proton dripline have failed (e.g. [1]). A promising candidate that has not yet been studied is ^{17}Ne, where the first excited state ($J^\pi = 3/2^-, E^* =$1.288 MeV) is bound with respect to one-proton emission but unbound with respect to two-proton emission by 344 keV (for details see [2,3]). Therefore this state can only decay via two-proton decay to ^{15}O or γ-emission to the ground state of ^{17}Ne. In a recent intermediate energy Coulomb excitation experiment the γ-decay from the first excited state to the ground state ($J^\pi = 1/2^-$) has been measured for the first time and the experimental yield has been compared to the theoretically expected cross section. The measured γ-ray yield accounts only for 43% of the predicted yield from an excitation cross section of 18.7 mb, thus encouraging the investigation of a potential two-proton decay branch. However, if the missing cross section would decay via two-proton emission, the lifetime of this branch would be a factor 1700 smaller than predicted by standard barrier penetration calculations. The protons can either be emitted simultaneously but uncorrelated or via the emission of a di-proton (^{2}He configuration). This can only proceed to the ground state of ^{15}O, since the first excited state is at 5.18 MeV, well above the energy of ^{17}Ne. Moreover, the probability for a sequential decay through the ground state of ^{16}F is strongly hindered because this one is located 192 keV above the decay energy with a small width of ≈20 keV. Uncorrelated proton emission would lead to an isotropic angular distribution, while a significant angular correlation can be expected in case of the di-proton emission.

The experiment to search for this decay branch was performed at the National Superconducting Cyclotron Laboratory at the Michigan State University using the technique of projectile fragmentation to produce the radioactive ^{17}Ne beam. A primary beam of ^{20}Ne at 100 MeV/u was used to bombard a 790 mg/cm^2 ^{9}Be production target. The fragmentation products were mass separated in the A1200 fragment separator, where an achromatic degrader wedge provided a first purification of the secondary beam, leading to a composition of 15% ^{17}Ne and 85% ^{15}O. Since the dominant beam contaminant is identical to the final nucleus of the two-proton decay of ^{17}Ne, a further purification was required. This was achieved with a Wien filter able to completely remove all unwanted ion species. As a result, 3000 ^{17}Ne particles per second were scattered off a 250 mg/cm^2 ^{197}Au target with an energy of 60 MeV/u.

A compact detector stack was positioned inside a beam tube with a diameter of 15 cm (fig.1).

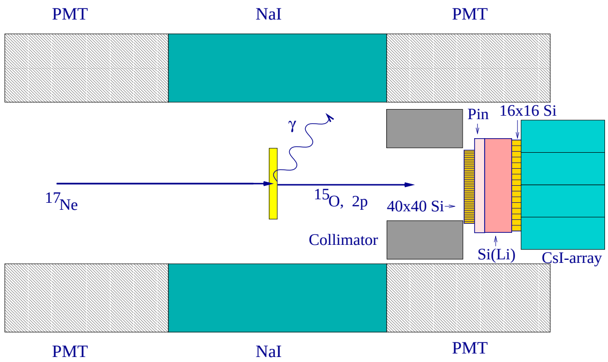

Fig. 1: Setup for the simultaneous detection of the two-proton decay and the γ-decay of the first excited state in ^{17}Ne

A 40x40 double-sided silicon strip detector, a pin diode, a 5mm thick Si(Li) detector, a 16x16 double-sided silicon strip detector and a 4x4 CsI array were positioned in a close geometry at a distance of 16.3 cm behind the target. Thus 80% of the proton angular distribution could be observed from 0^o to 7^o (as obtained from Monte Carlo simulations of the two-proton decay) with an angular resolution of 0.35^o per strip in the first detector. This 40x40 strip detector served to reconstruct the trajectories of the reaction products, while the subsequent pin diode (thickness 500μm, active area 5x5cm^2) provided the start signal for the trigger system. From both detectors an energy loss signal was derived and used for particle identification. The thickness of 5 mm of the following Si(Li) detector (diameter 5 cm) was chosen in a way to stop the heavy ^{15}O fragments completely, while protons would lose only about 20% of their initial energy. The 16x16 strip detector placed behind the Si(Li) allows to reconstruct the trajectories of the protons which then are stopped in the CsI array, consisting of 16 crystals, 1.7x1.7x5 cm^3 each, read out by pin diodes. In order to allow a simultaneous measurement of the proton decay and the γ-branch, a 38-element position sensitive NaI detector array was placed around the beam tube housing the target and the particle detector stack. A 6.5 cm thick lead collimator (with a central opening adapted to the size of the 40x40 strip detector) placed between target and detector stack shielded the NaI detectors from background γ-rays originating from the particle detectors.

Data were collected during 96 hours of beamtime and the offline analysis has just begun. Finally it should be noted that besides the possibility to investigate the potential two-proton decay from the first excited state in ^{17}Ne the data set obtained in the present experiment also allows to search for the ground state di-proton radioactivity in ^{16}Ne, though with reduced statistics.

References

[1] R. A. Kryger *et al.*, Phys. Rev. Lett. **74** (1995) 860
[2] M. J. Chromik *et al.*, submitted to Phys. Rev. **C**
[3] M. J. Chromik *et al.*, this report, p. 16