M1 width of the 2^+_1 state in ^{22}Na and searches for tensor contributions to beta decay

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Introduction

The β - γ angular correlation in ^{22}Na β^+ decay has been measured with the GAMMASPHERE array at LBNL [1]. The result leads to an unexpectedly high breaking of the Conservation of the Vector Current hypothesis (CVC), a fundamental assumption of the Standard Model. CVC states that vector currents in fundamental interactions should be conserved. This is analogous to the conservation of the electric current (electric charge) in electromagnetism.

The breaking of CVC needs to be checked and there are two problems with the analysis that should be resolved. First, the GAMMASPHERE measurement was made to high precision but it conflicts with previous publications [1]. Second, the M1 width of the analog isovector magnetic dipole ($2^+ \rightarrow 3^+$) transition in ^{22}Na is used in the analysis but the current experimental value is based on unpublished ^{25}Mg(p,α) data which are limited by low statistcs [2].

Testing the CVC hypothesis

This experiment will determine two quantities that are used in the CVC analysis:

1. The M1 width of the E_x = 1952 keV excited state in ^{22}Na. We are interested in the $2^+ \rightarrow 3^+$ decay from E_x = 1952 keV to the ground state, however this decay is allowed via M1 or E2. The 1369 keV transition to E_x = 583 keV is purely M1 [3].

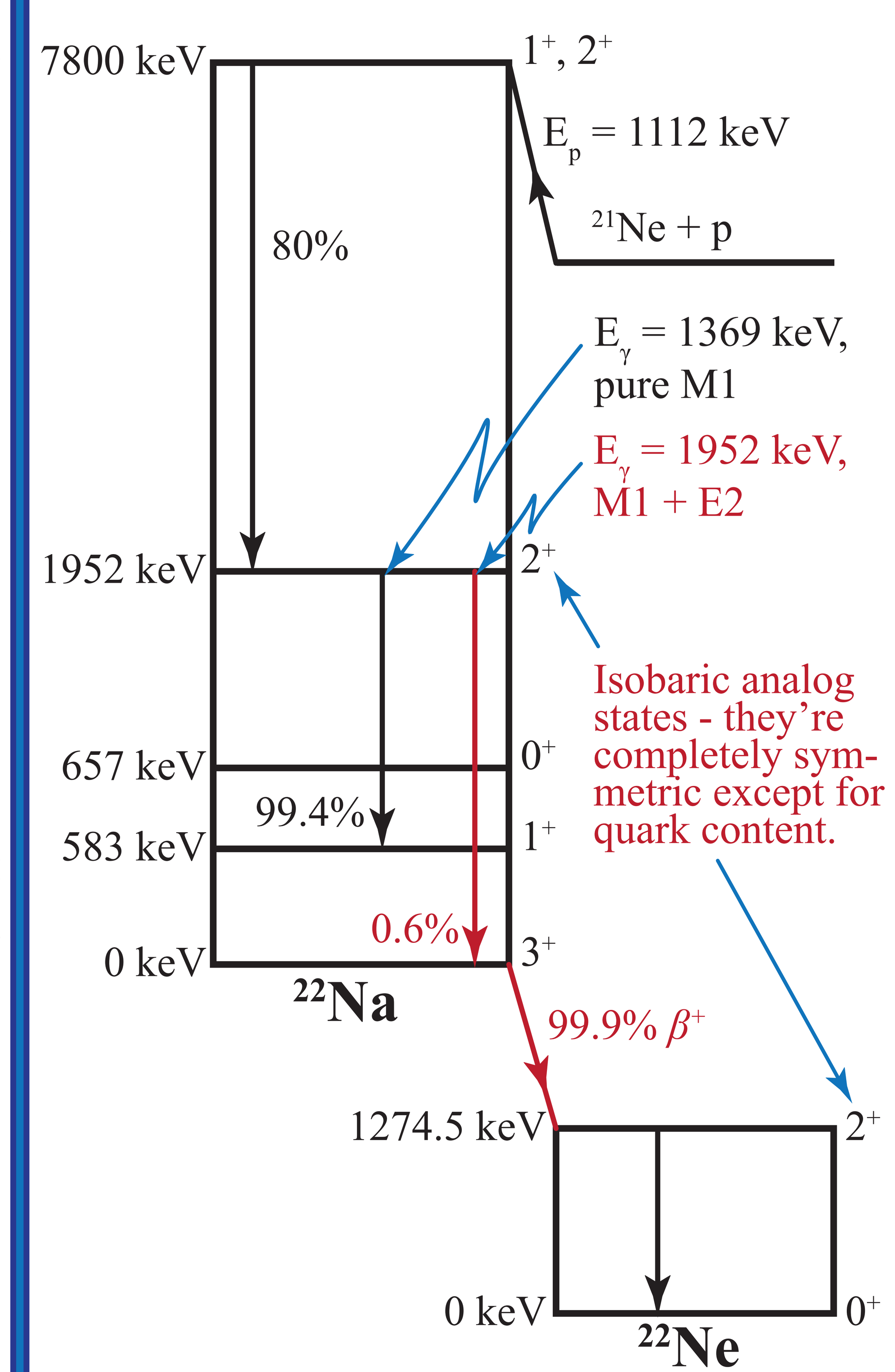
2. The β - γ angular correlation from ^{22}Na beta decay. The angular correlation will allow us to determine the M1-E2 mixing ratio because M1 and E2 transitions result in distinct angular distributions.

Procedure

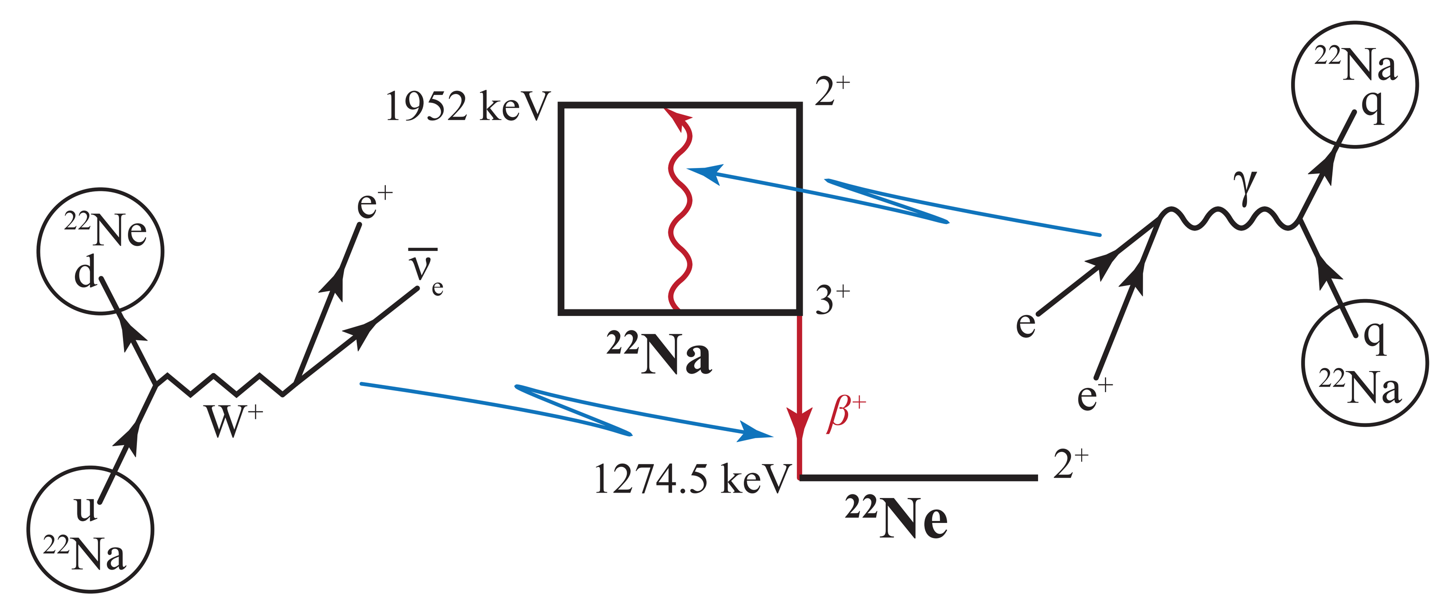
The state of interest in ^{22}Na was generated using a well known ^{21}Ne(p,γ) resonance at E_p = 1112 keV. A proton beam was prepared using a Van de Graaff model FN tandem electrostatic accelerator which has been modified to produce copious protons at low energies. Protons were run on a ^{21}Ne implanted tantalum target.

Two high purity germanium (HPGe) detectors and one sodium iodide (NaI) detector were used to collect γ-ray energy spectra resulting from interactions in the target. Spectra were collected using the NaI signal as a gate for the HPGe detectors. One HPGe detector was fixed at 90 degrees to the beam while the other was rotated about the target to collect angular correlation data.

Isobaric analog states in ^{22}Na and ^{22}Ne



Feynman diagrams representing the γ-ray and β^+ transitions between the ^{22}Ne and ^{22}Na 2^+ analog states



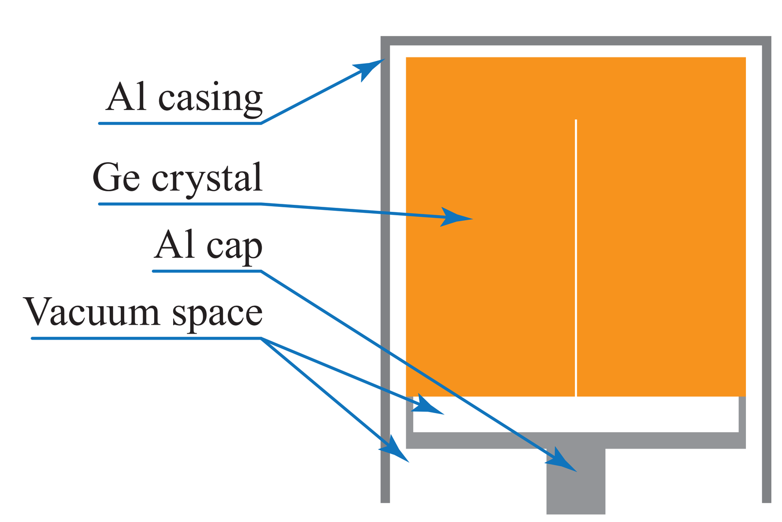
The γ-ray transition is allowed to proceed via M1 or E2, however CVC requires that the M1 part of the γ-ray transition must be equal to the vector part of the β-decay matrix element.

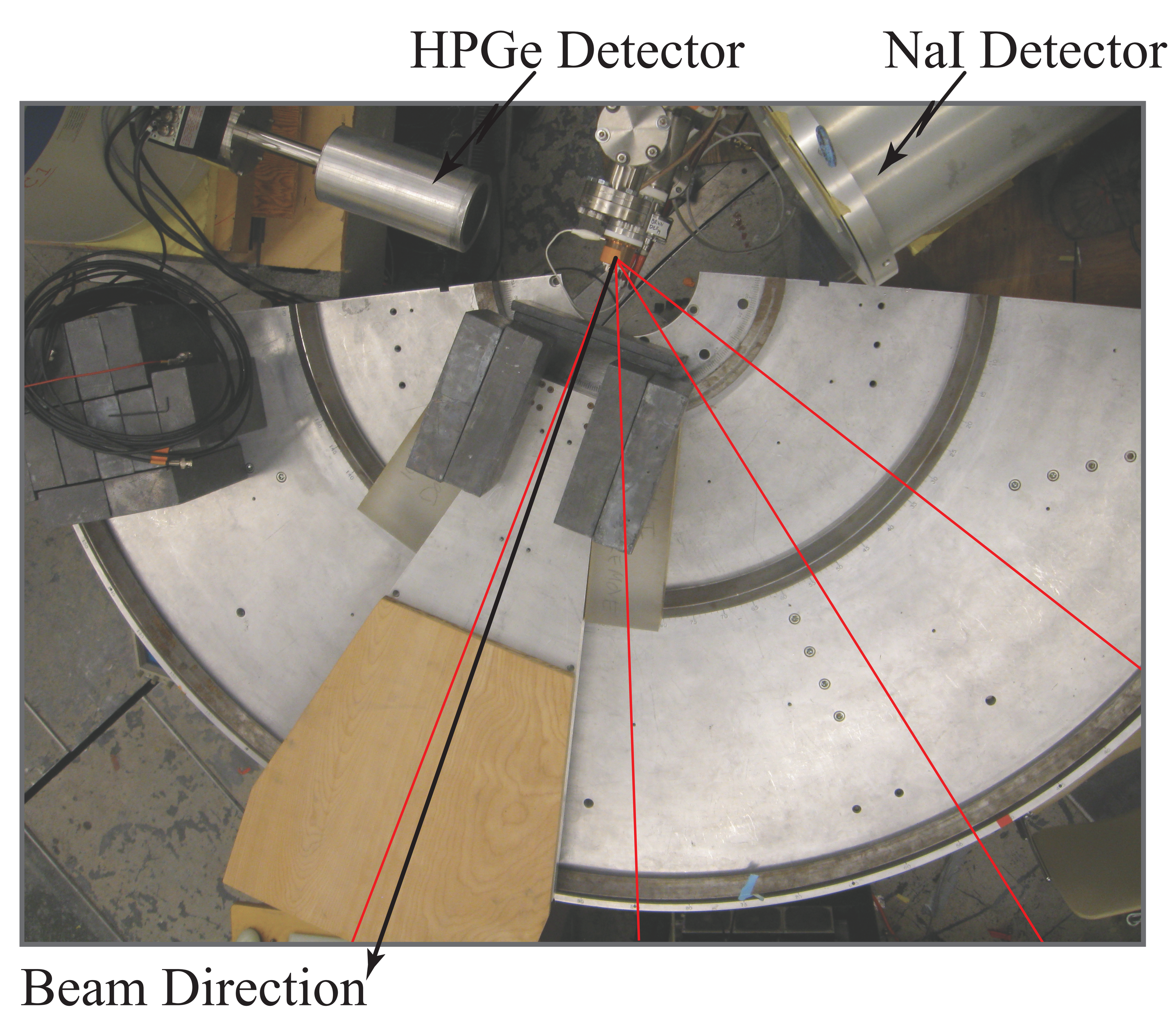
We expect that a more precise determination of the M1 width, combined with other available data, will preserve CVC.

Apparatus

The NaI detector, the static HPGe detector, and the rotating table for the movable HPGe detector are pictured at right. γ-ray spectra were collected with the moveable HPGe detector at the positions marked in the photo.

The HPGe detectors are essentially identical and a sketch of one of the crystals is provided below. The NaI detector is 10” in diameter by 10” long and was positioned so as to subtend the largest solid angle relative to the target without interfering with the movable detector.





^{21}Ne implanted Ta targets. The target used during the majority of the data collection is on the right hand side. It was implanted with 30 keV ^{21}Ne ions to a density of roughly 13 μg/cm^2.

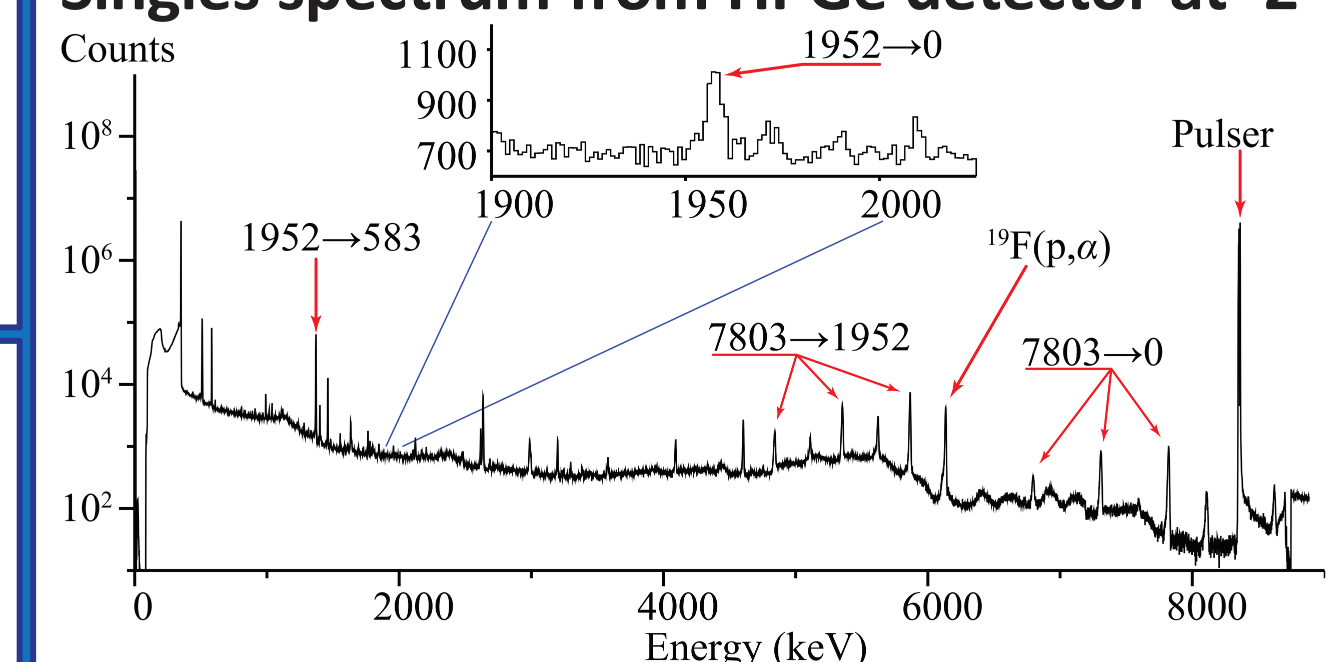
Current work: calibration

All relevant data have been collected. γ-ray spectra from the ^{21}Ne resonance were collected with the movable detector in four positions. Reference spectra were then collected from an uncalibrated ^{56}Co γ-ray source and a calibrated ^{60}Co source at each detector position. Reference spectra are being analysed in order to determine the absolute efficiency of the apparatus.

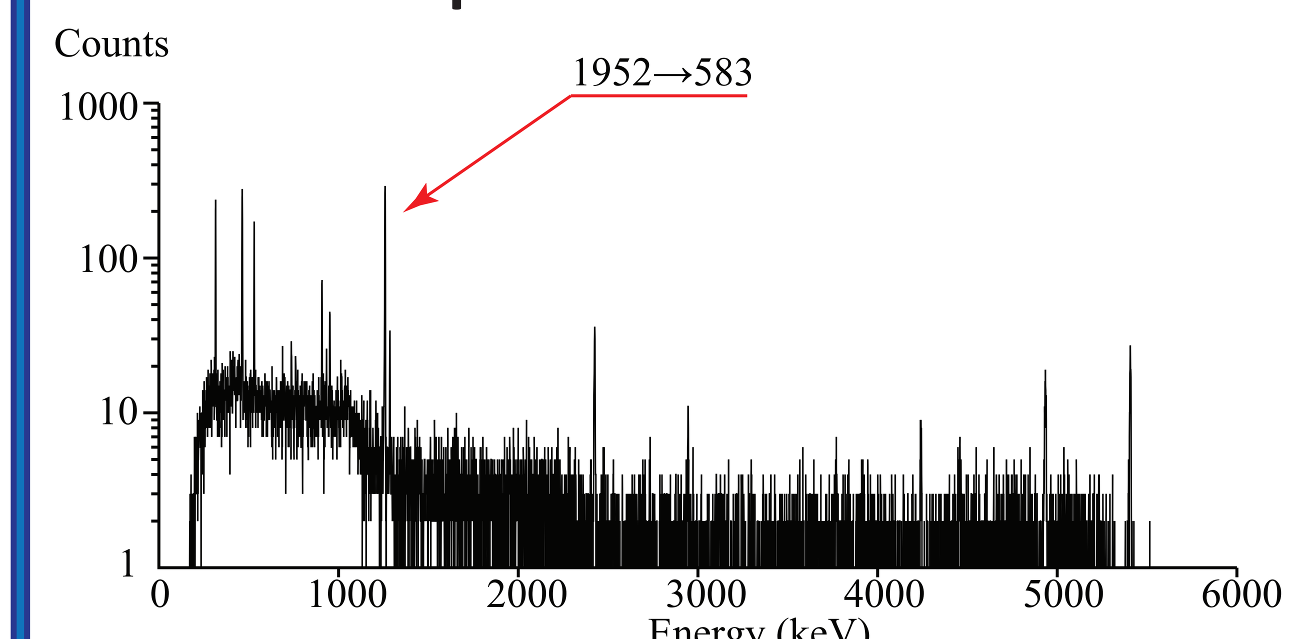
Monte-Carlo simulations of photon transport through the detectors are being run. The goal of these simulations is to produce an efficiency curve for each geometry that agrees with the observed ^{60}Co efficiencies and has the same shape as the ^{56}Co efficiency curve.

Once a reliable set of simulation parameters has been established, γ-rays in the ^{21}Ne spectra may be simulated in order to analyse the experimental data and generate theoretical γ-ray spectra at intermediate detector positions.

Singles spectrum from HPGe detector at -2°



Coincidence spectrum with NaI detector



References

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