Investigation of ^{26}Na via one-neutron transfer using the SHARC and TIGRESS Arrays

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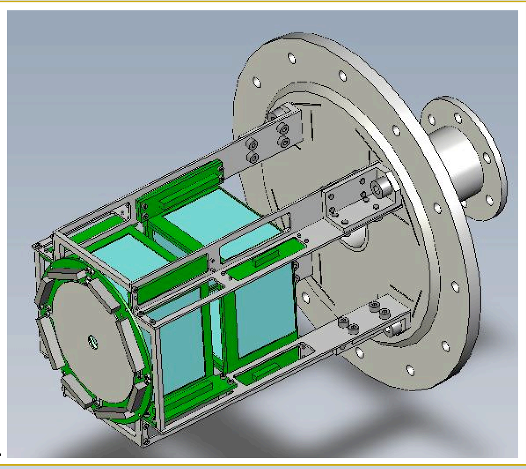
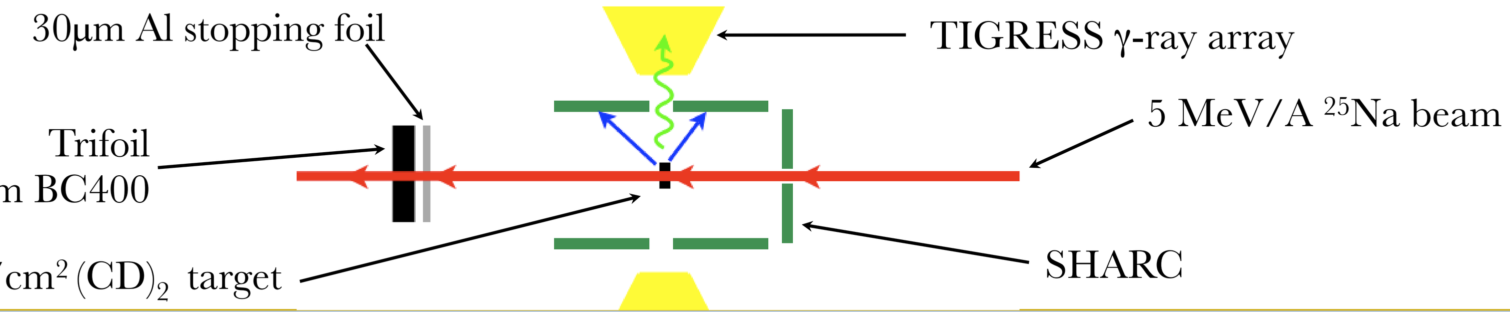
Experimental Details

The purpose of the experiment is to study the odd-odd nucleus ^{26}Na via one-neutron transfer, employing an intense beam of up to 3 $\times 10^7$ pps of ^{25}Na at 5.0 MeV/A from the ISAC-II facility at TRIUMF. The new silicon array, SHARC[1], was used for the first time and was coupled to the segmented γ-ray array TIGRESS. The γ rays were employed to distinguish between a high density of states in ^{26}Na. A novel scintillator detector, the trifoil, was mounted in-beam and downstream of the target. It was employed to identify and reject reactions occuring on the carbon component of the 0.5 mg/cm^2 $(CD)_2$ target.



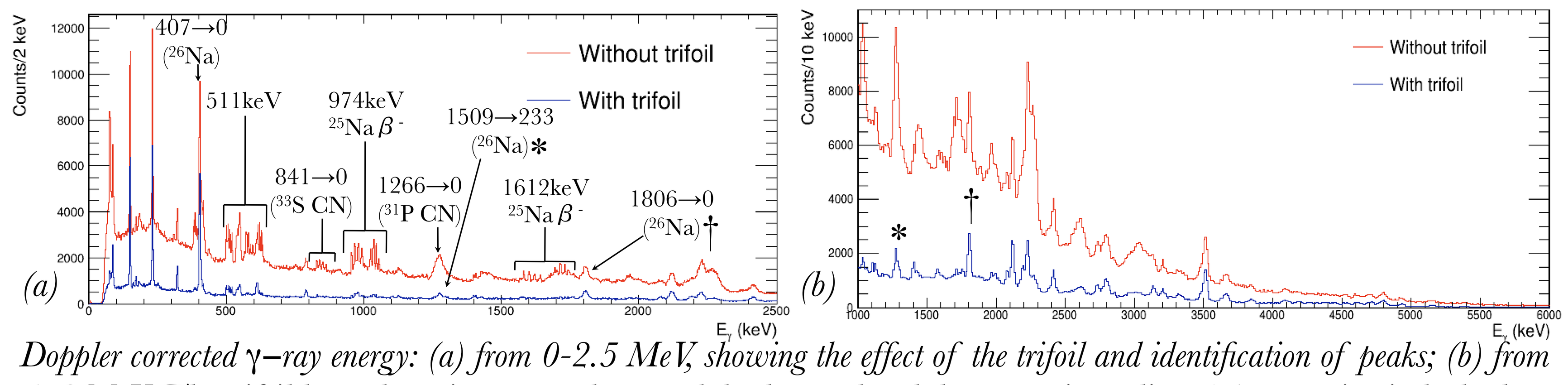
Technical drawing of SHARC[1], showing the CD detector and both upstream and downstream boxes.

Setup



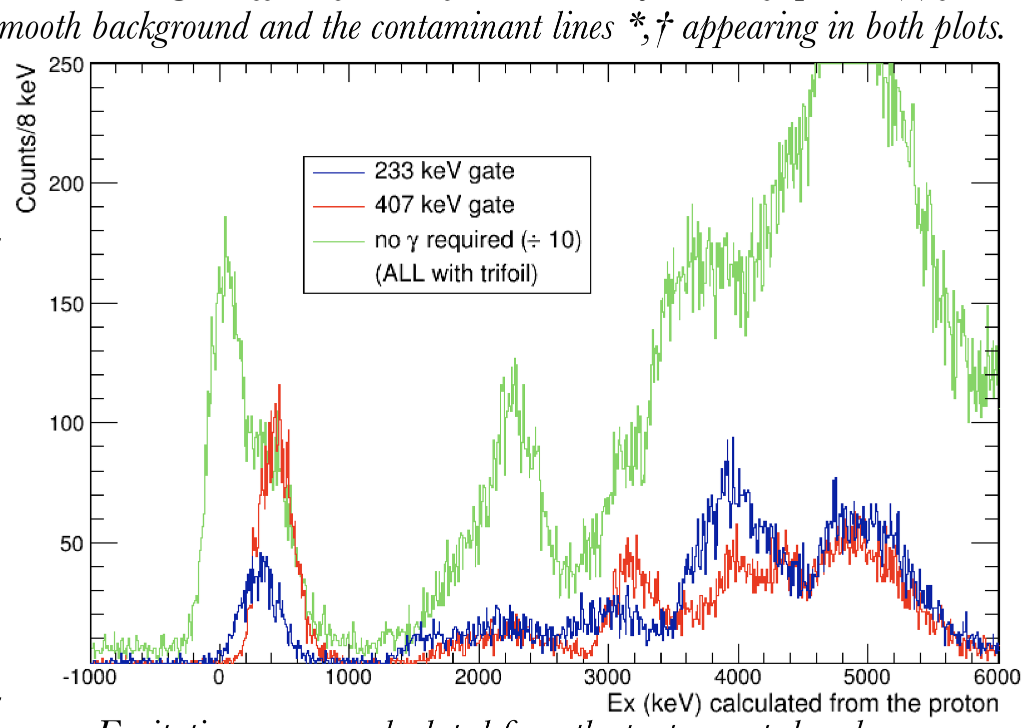
Data Analysis

TIGRESS was operated in fully escape-suppressed mode, with Compton suppression performed in the data analysis, along with Doppler corrections (β = 0.09). The data were collected using a single silicon trigger, and TIGRESS was only read out with a coincident hit in SHARC. A requirement on the downstream trifoil detector reduced unwanted background counts significantly, both for protons and γ rays. This enabled γ rays from ^{26}Na to be easily identified.



*Doppler corrected γ−ray energy: (a) from 0-2.5 MeV, showing the effect of the trifoil and identification of peaks; (b) from 1-6 MeV. The trifoil has a large impact on the smooth background and the contaminant lines *,† appearing in both plots.*

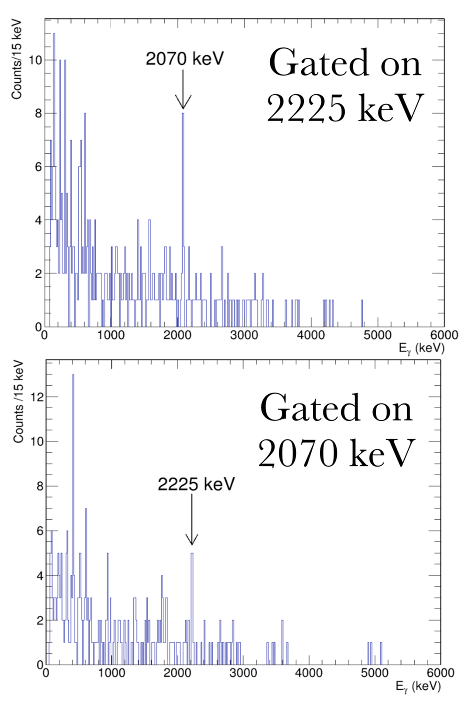
The excitation energy, calculated from the energy and angle of the proton, provided a useful basis for building up a level scheme of ^{26}Na. Entry points associated with γ rays can be determined. Plotting E_x with a gate on a strong γ ray, such as the 233 or 407 keV, indicates which states decay via that particular γ ray.



Excitation energy, calculated from the proton, gated on low-energy γ rays in ^{26}Na. All gates include a trifoil requirement.

γγ Coincidence Data

The data from γγ coincidences allows γ−ray cascades to be identified. For a small range, 400 keV say, of excitation energies, a diagonalised matrix of γγ coincidences can be plotted, and even weak transitions can then be seen. Knowing the coincident γ−ray energies means that E_γ can be plotted with a gate on each of those γ rays, as shown on the right. Here, a state in ^{26}Na at 4295 keV decays, apparently by via the state at 2225 keV.



γ-ray Efficiencies

The dead time of TIGRESS is not simple to measure due to the buffering system in the TIG10 digital electronics when the data are read out. A relative efficiency curve was produced using ^{152}Eu, ^{133}Ba and ^{56}Co sources. An absolute efficiency for the array will be calculated using the isolated 2 MeV peak in E_x. For singles protons, all of the main γ decays are known, and the intensities of these peaks can be corrected for efficiency with this relative efficiency curve. The singles and γ coincidence counts for this multiplet will then be used to get the efficiency normalisation.

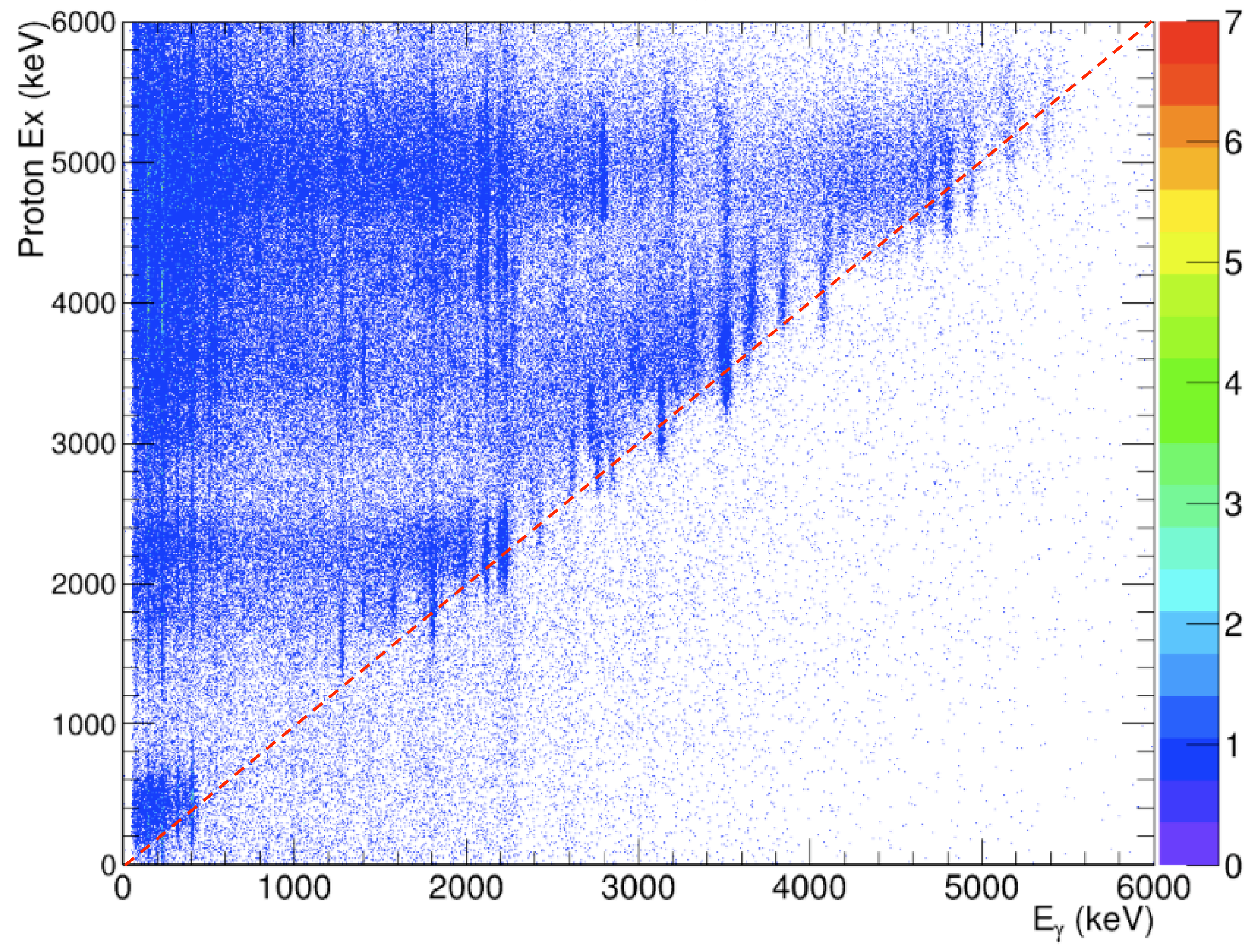
References

[1] CA Diget *et al.*, J. Inst. G **6**, P02005 (2011)
[2] Sangjin Lee *et al.*, Phys. Rev. C **73,** 044321 (2006)
[3] GL Wilson *et al.*, Rutherford Centennial Conference J Phys.: Conf. Ser. (2011), in press.

The funding from STFC is gratefully acknowledged.

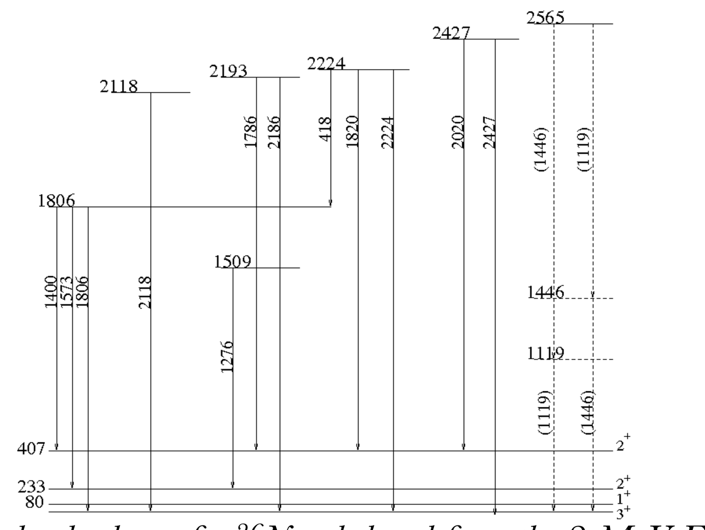
Results

The plot below, of excitation energy versus γ-ray energy, contains information regarding the population energy and the decays of γ rays which is key to building up a level scheme of ^{26}Na. It is possible to deduce which states decay straight to the ground state (the y=x line) or to low lying states. The utility of the better γ-ray energy resolution is evident.



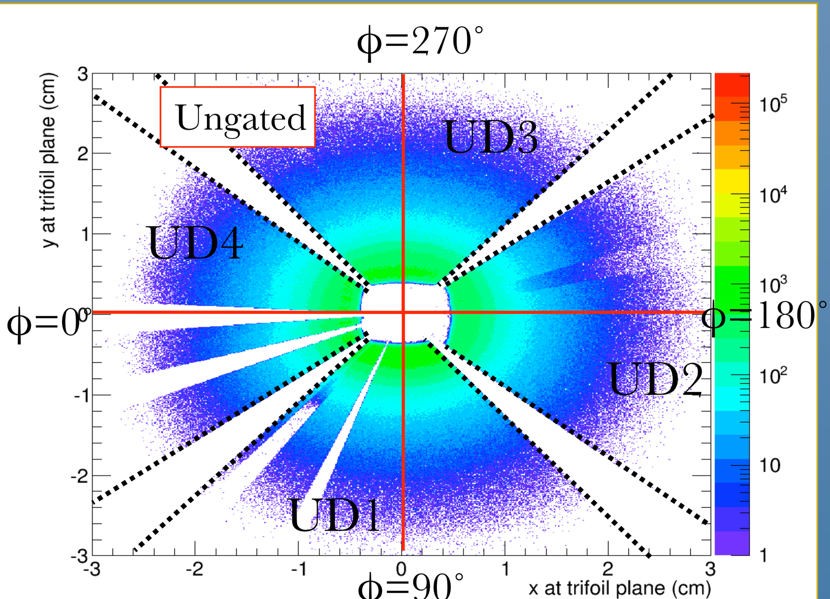
E_x (determined from proton E, θ) vs γ-ray energy, with a trifoil requirement. The y=x line indicates ground state decays.

The long vertical lines in the plot above indicate the population of high-lying states that decay via γ-ray cascades through the low-lying states that often are also populated directly. By gating on the E_x parameter, the direct population and the indirect feeding can largely be separated.



Energy level scheme for ^{26}Na, deduced from the 2 MeV E_x peak. Spin-parities for the lower levels from reference [2].

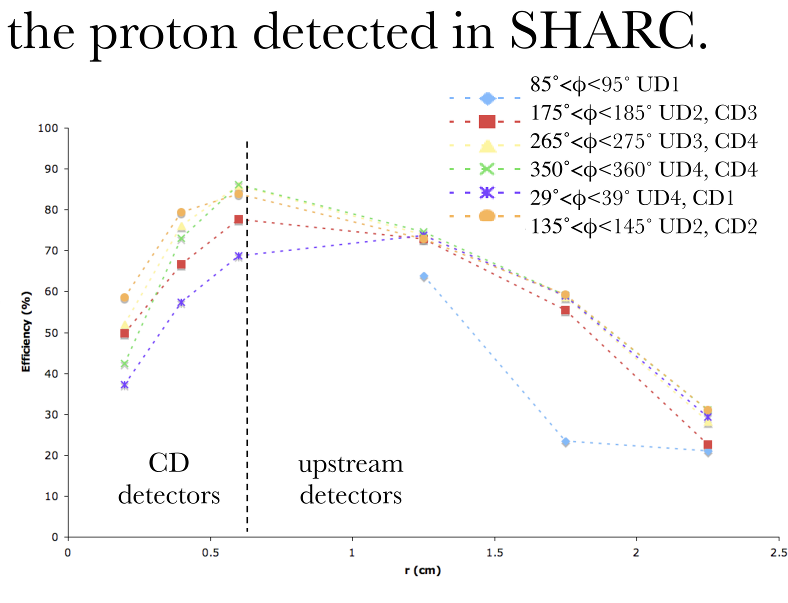
Trifoil Efficiency



Position on the trifoil for recoils, reconstructed using the proton energy and angle recorded upstream in SHARC.

Prior to this experiment, the specifics of the trifoil performance were relatively unknown. For this experiment, 90% of the γ rays from fusion-evaporation products were successfully vetoed as they were stopped in the aluminium stopping foil in front of the trifoil detector, and hence did not produce a trifoil trigger. However, this was at a cost of a reduction in ^{26}Na γ rays by 30%. For proton detection, the trifoil effected a ten-fold background reduction. Both results are discussed in reference [3]. Trifoil performance also depends on the position of the recoil at its plane, since its three PMTs are located at the top of the detector. To quantify this effect on efficiency, the position of the recoil at the trifoil plane was reconstructed from the kinematics of the proton detected in SHARC.

Radial cuts in the above plot of the trifoil plane were taken from the centre to the outer edge of the foil, for 10° slices in φ. The trifoil efficiency at various values of r was calculated. The dip in efficiency at low r is due to the degradation of the trifoil at the beam spot. At large r, there is low efficiency for the 85°< φ< 95° slice, which is furthest from the PMTs.



Efficiency vs radial distance from the centre of the trifoil, for 10° slices in φ.