Experimental study of low-lying negative parity T=5 states in ^{48}Ca

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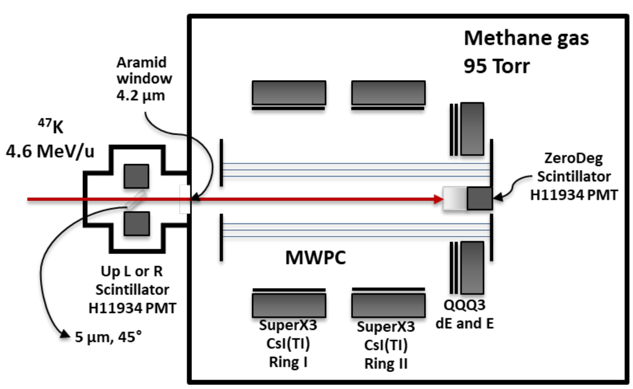
A study of particle-hole excitation levels near closed shells provides important information on single-particle properties and on two-body interactions. Experimental information on these relatively simple excitations in neutron-rich nuclei provide good indications for models that describe structure of exotic nuclei [1]. Although the changes in nuclear structure near the doubly magic ^{4}He, ^{16}O, ^{40}Ca nuclei were extensively studied and are well known, information on charge-changing particle-hole excitations (T=5 negative parity states) in ^{48}Ca is not yet available. A recent study identified four low-lying negative parity states and suggested model-dependent tentative spin-parity assignments [2]. In order to establish the level scheme of the low-lying negative parity T=5 states in ^{48}Ca, which are isobaric analog states of the neutron-proton particle-hole excitations in ^{48}K, we performed an ANASEN (active target detector) [3] experiment of ^{47}K(*p,p*)^{47}K in inverse kinematics at NSCL using ReA3 reaccelerated beam of ^{47}K at energy of 4.6 MeV/u. By measuring the excitation function of the elastic scattering in the center of mass energy range from 1 MeV to 4.5 MeV, we expect to determine excitation energies, spin-parities and proton partial widths of T=5 states in ^{47}K using R-matrix analysis. The T=5 states are expected to show up in the excitation function as narrow resonances.

A schematic layout of the experimental setup is shown in Fig. 1. A 5 μm thick scintillator foil was installed on the upstream of the beamline to produce the first tag of the beam which is used for the Time-



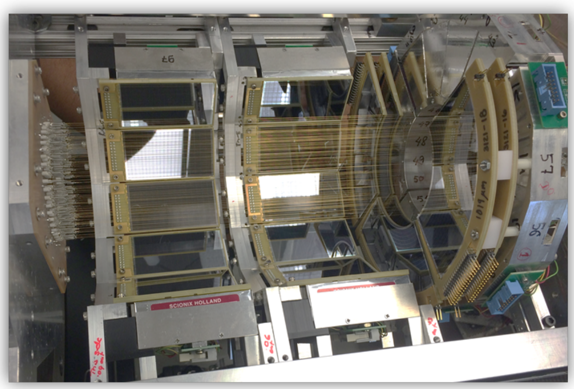


Fig. 1. Schematic drawing of ANASEN setup (left) and picture of detectors (right).

of-flight signal with either Silicon detector trigger signal or Zero-degree scintillator signal. A multi-wire proportional counter (MWPC) was installed around the beam axis to detect protons produced from elastic/inelastic scattering along the beam axis. SuperX3 and CsI(Tl) detectors were installed around the MWPC to measure final proton energies. Furthermore, QQQ3 dE and E detectors were set up at the downstream of the beam axis to cover forward focused protons. Finally, another thick scintillator was installed at zero degree of the downstream to produce the second tag of the beam.

The energy calibration of the QQQ3 dE and E detector was performed using ^{288}Th fission source under vacuum, which showed 5 strong alpha particle peaks with known energies from 5.18 MeV to 8.78 MeV. Fig. 2 shows an example of a calibrated energy spectrum on one QQQ3 dE detector and all strips of

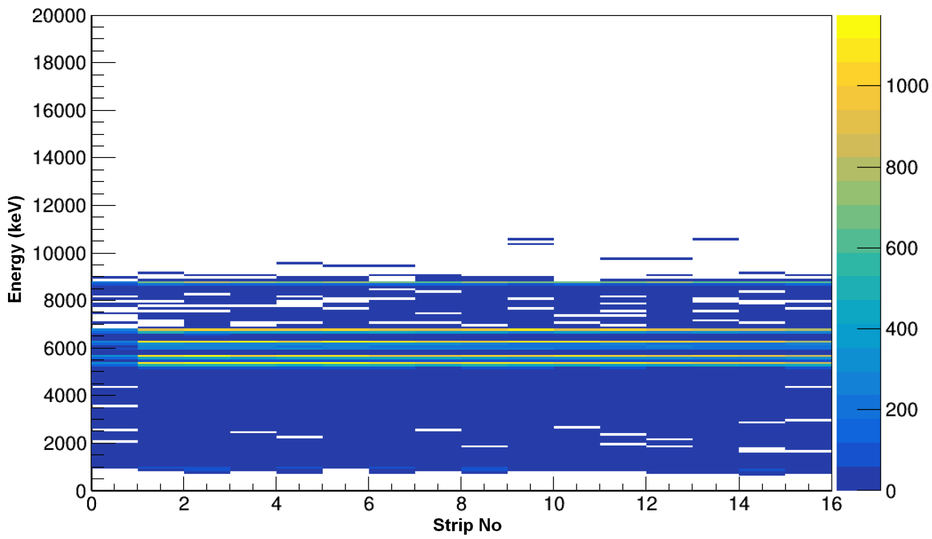


Fig. 2. QQQ3 Energy (keV) vs Front-side Strip No after the energy calibration.

the QQQ3 were validated after the calibration. Another ^{288}Th fission source data was taken with the Methane gas of 60 Torr pressure. The source was located at 164 mm upstream from the QQQ3 dE

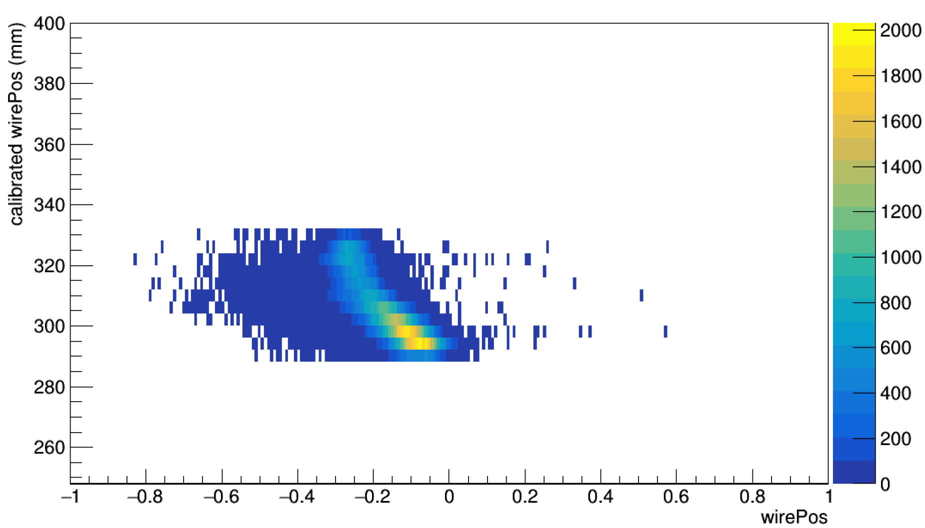


Fig. 3. Absolute wire hit position (mm) vs the ratio between wire-up and wire-down from the alpha source data.

detector (or 199 mm from the window). With the measured QQQ3 dE detector position of 363 mm from the window, each event in the source data provides an absolute hit position of wire from the source position and the Silicon detector hit position. Then, the wire hit position and the relative ratio between the upstream wire signal amplitude and the downstream wire signal amplitude could be calibrated as shown in Fig. 3. The data then fitted to the linear function to be used to find the wire hit position in the beam data.

After the position and energy calibration of the MWPC and QQQ3 dE and E detectors, we could plot the energy spectrum of the detectors from the beam data. The coincidence in time between the upstream scintillator and the QQQ3 detector was used to clean random background events. The particle identification (PID) plot was also very helpful to select high energy protons (using QQQ3 dE vs E) and all low energy protons (using QQQ3 dE vs wire E) as shown in Fig. 4. The energy of the high energy protons are used for further steps of data analysis.

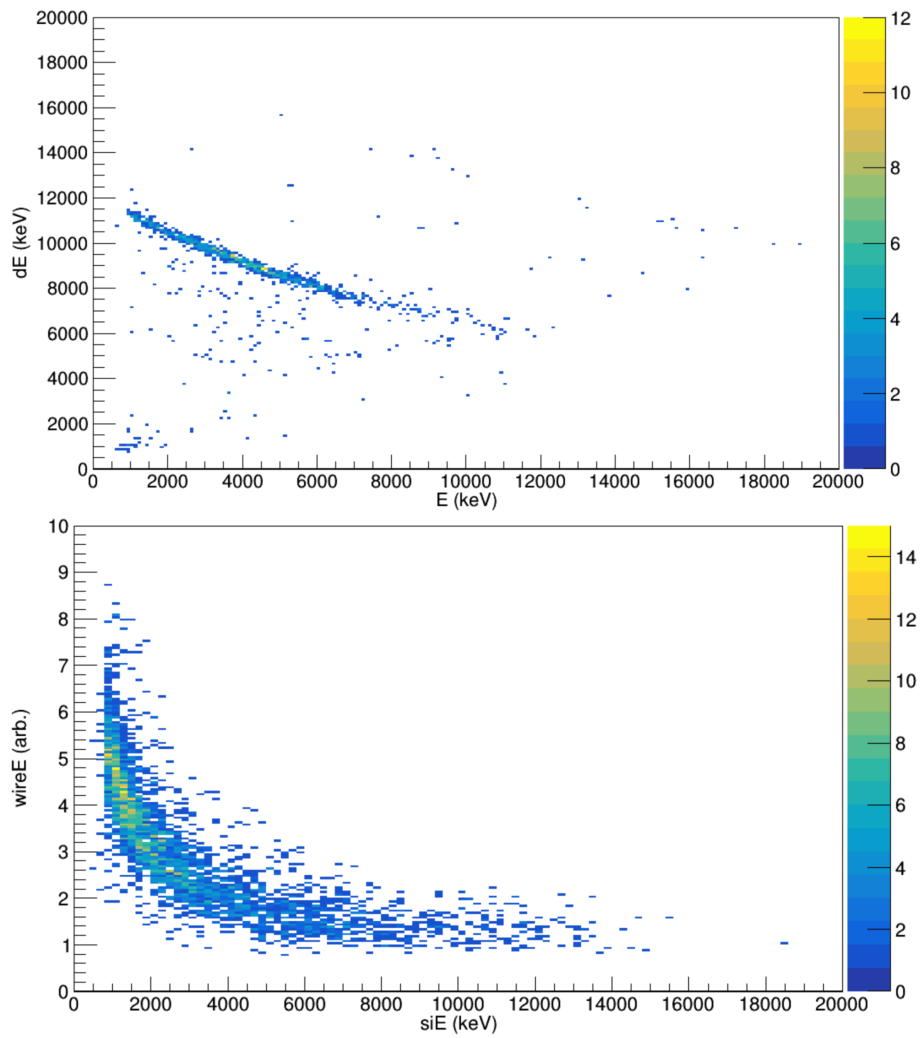


Fig. 4. QQQ3 PID plot for high energy protons gated on a QQQ3 Front Strip No. 6 (top) and PID from wire and QQQ3 to identify proton events gated on a QQQ3 Front Strip No. 6 (bottom).

With the clean proton events, the vertex of the reaction as well as angle of proton was calculated from the QQQ3 dE position and the wire hit position as shown in Fig. 5. Then, the center of mass (CoM)

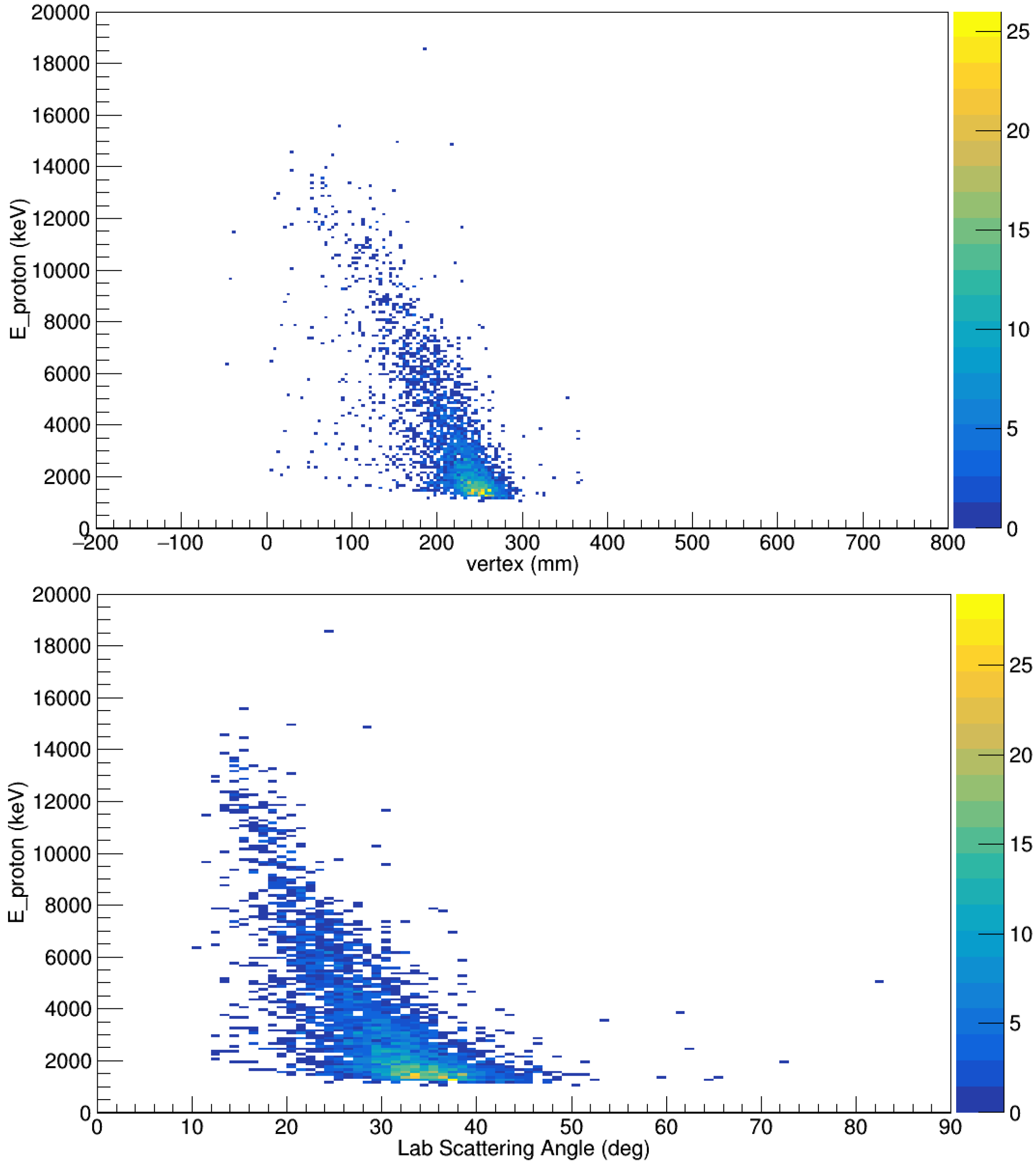


Fig. 5. Proton energy vs vertex position gated on a QQQ3 Front Strip No. 6 (top) and proton energy vs laboratory angle gated on a QQQ3 Front Strip No. 6 (bottom).

energy was calculated from the proton energy and angle shown in Fig. 6. Taking into account the beam energy loss in the gas after the window, target thickness at the vertex position, the effective solid angle of the QQQ3 detector as well as the total beam counts from the upstream scintillator scaler data, the excitation function will be calculated as a next step.

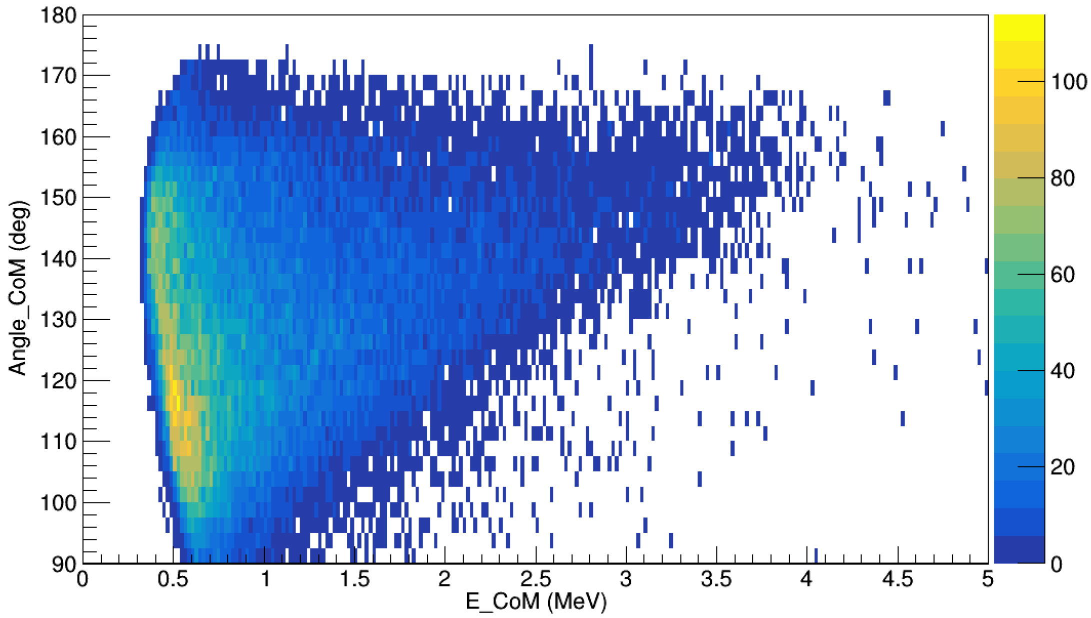


Fig. 6. Angle vs CoM energy from the angle and energy of protons.

In summary, in order to address excited states of the low-lying negative parity T=5 states in ^{48}Ca, we performed a ^{47}K(*p,p*)^{47}K reaction in inverse kinematics at NSCL using ReA3 reaccelerated beam of ^{47}K at energy of 4.6 MeV/u and the ANASEN detector system. By measuring the excitation function of the elastic, we expect to extract excitation energies, spin-parities and proton decay widths of ^{47}K. All of the calibration works are completed and examples of spectrums are shown. With additional steps, we will get a measured excitation function.

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