Development of (p,p′γ) detection capabilities at iThemba LABS through the study of low-lying $E1$ strength in ^{58}Ni

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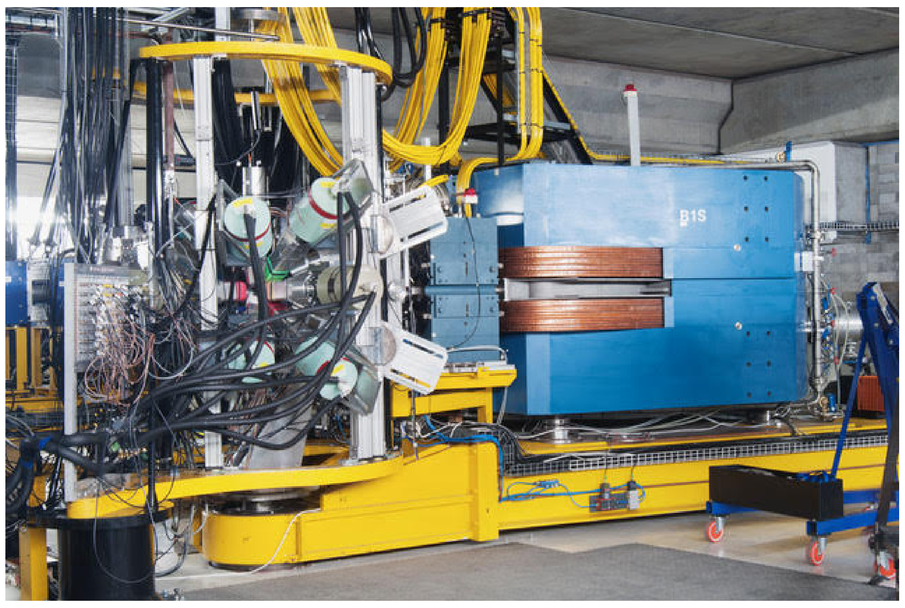
Introduction and Scientific Motivation

- The Pygmy Dipole Resonances (PDR) can be described as an oscillation of excess neutrons against an inert core with $Z \simeq N$.
- It is attributed to a concentration of $J^{\pi} = 1^{-}$ states around the particle threshold.
- Studies of the PDR are useful in understanding the formation of the neutron skin in nuclei, nucleosynthesis and supernova explosion processes.
- Different contributions of the coulomb component, mixtures of isovector and isoscalar nuclear interactions can be used to excite the PDR.
- α-particles are appropriate for probing the isoscalar component of the nucleus while protons with energies around 80 MeV will excite more isoscalar and isovector states with better sensitivity to the inner transition density.
- Coupling the measurements of hadronic probes with γ-decay measurements restores the selectivity to low spin excitations.
- This study seeks to test if sufficient information can be retrieved from the (p,p'γ) reaction regardless of the undesired background that is usually carried by light ion beams.

Experimental Setup (K600 Magnetic Spectrometer + BaGeL)



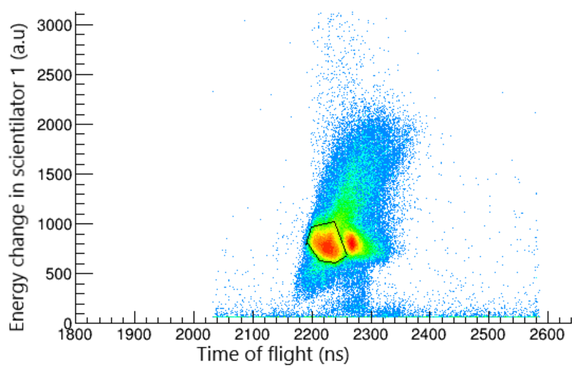
K600 Magnetic Spectrometer coupled with a Ball of HPGe and $LaBr_3$ (BaGeL).

An 80 MeV proton beam was used to excite the PDR of a 5 mg/cm^2 thick ^{58}Ni target through a $(p,p'\gamma)$ reaction at 0°. The scattered protons were analysed using the K600 magnetic spectrometer and the gamma decay was measured with BaGeL, a ball of HPGe and $LaBr_3$ detectors.

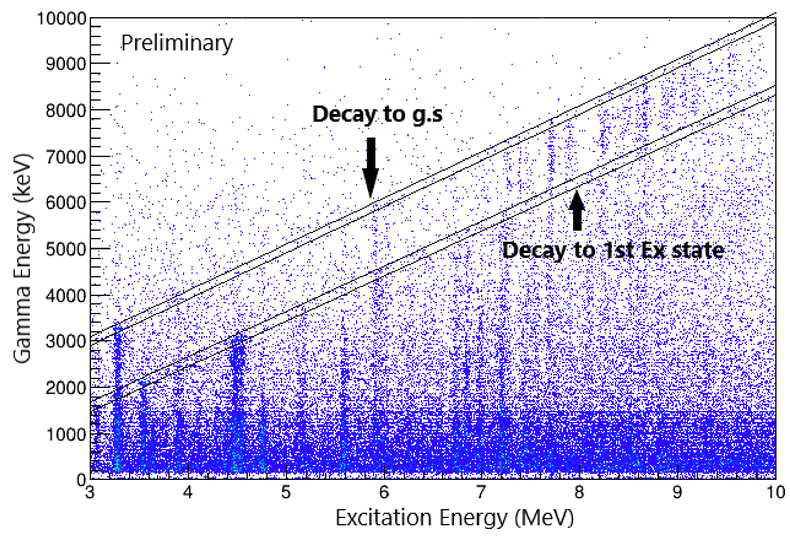
- **K600 magnets**: A quadruple, two dipoles and two trim coils.
- **Dispersion mode**: The high dispersion mode used in this study has access to a limited energy range but with a very high energy-resolution.
- **Focal plane detectors**: One Vertical Drift Chamber(VDC) and two scintillators for the detection of the inelastically scattered protons.
- **Gamma detectors**: 12 HPGe and 6 $LaBr_3$ detectors placed 17 cm from the target at backward scattering angles.

Results and Discussions

- Two techniques were used to identify the particles of interest:
  1. Particle identification (PID) through time-of-flight(TOF) of the inelastically scattered protons.
  2. Energy changes ($\Delta E - \Delta E$) of the inelastically scattered protons in the scintillator detectors.

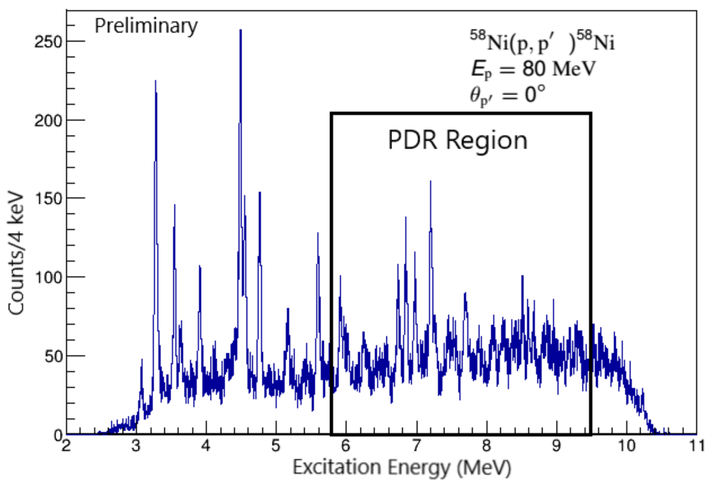


PID through TOFs of the protons.

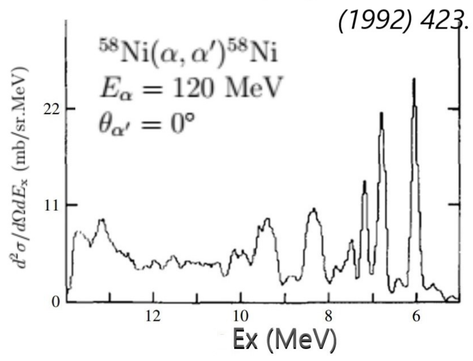


Preliminary coincidence matrix showing a correlation between the measured excitation energy and the detected gamma rays. Transitions between nuclear states appears on the diagonal bands.

- ^{58}Ni states around 3-9 MeV from the K600 (p,p'γ) reaction were excited.

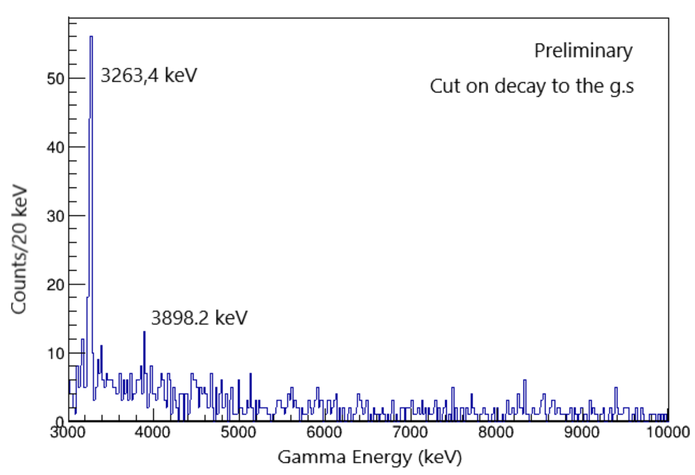


T.D. Poelhekken et al., Phys. Lett. B 278 (1992) 423.



Comparison of the K600 preliminary and the KVI (Groningen) spectra: Protons and alphas can excite many of the same states. Owing to its isoscalar internal structure, the alpha particles mostly excite the isoscalar component of the nucleus. Therefore some of the states that appear on the (p,p') spectrum and are not on the alpha spectrum can be associated with the isovector component of the nucleus.

- Further investigation into the 6-9 MeV excited states of ^{58}Ni in the K600 spectra will be carried out so that it can be determined which peaks should be assigned to the $J^{\pi} = 1^{-}$ states.
- The coincidence matrix shows that a relatively small number of higher energy γ-rays (around 6-9 MeV) were also detected and they decayed to the ground state. The faint lines at these higher excitation energies can be accounted for as a result of low statistics of the gamma events from this experiment.



Preliminary γ-ray spectrum gated on the ground state transition ($E_X \approx E_\gamma$).

Conclusions and Outlook

- Preliminary results show that coincidence conditions between the protons and γ-rays favour low-spin states by selecting mostly transitions to the first excited state and ground state.
- Analysis of the high-lying states is ongoing and the necessary suggestions on the development of the (p,p′γ) detection system at iThemba LABS will be provided.

For further reading

1. A. Bracco et al., Prog. Part. Nucl. Phys. 106 (2019) 360–433.
2. D. Savran et al., Prog. Part. Nucl. Phys. 70 (2013) 210-245.

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