Gamma-ray spectroscopy of neutron-rich ^{148}Ce

M.-M.Satrazani[1], L.P.Gaffney[1], and the S1626 GRIFFIN Collaboration[2]

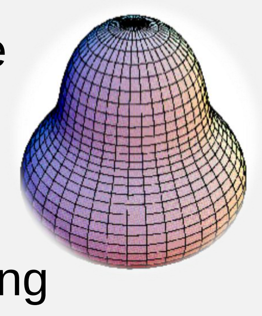
[1]Department of Physics, Oliver Lodge Laboratory, University of Liverpool, UK.

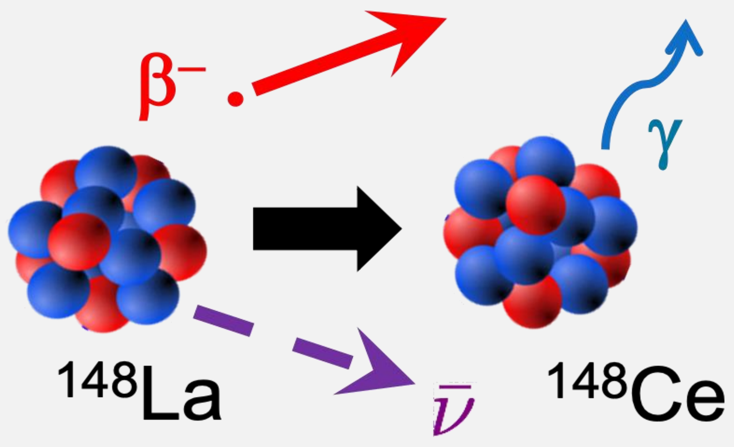
[2] Science Division, TRIUMF, Vancouver, Canada.

Magda Satrazani

Introduction & Motivation

- Beta decay occurs in unstable neutron-deficient and neutron-rich nuclei. When the daughter nucleus of a *β-decay* is left in an excited state, it can further de-excite by emitting *γ-rays* of a specific energy.
- Belonging to the mass region of the neutron-rich lanthanides of the nuclide chart, the Ce isotopes with 146 ≤ A ≤ 152 are transitional nuclei characterized by a few nucleons outside of the so-called closed shells. It is predicted that isotopes in this region possess octupole deformation. Octupole correlations are the result of the long range octupole-octupole interaction between nucleons occupying pairs of orbitals which differ by 3 units in both orbital and total angular momentum, which gives rise to an asymmetric pear-shaped form [1,2,3].





Experiment

- The production of the ^{148}Cs RIB took place at the radioactive beam facility ISAC at the TRIUMF particle accelerator center in Vancouver, Canada in June 2018, where the TRIUMF cyclotron sent a $500\ MeV$ proton beam onto a thick heated UC_x target. The reaction products passed through a heated tube onto an ion source and the resulting ion beam was separated and re-accelerated before it was implanted on a moving tape collector.
- The tape is a $25\ mm$ wide aluminized mylar tape that is moving in a continuous loop of $135\ m$. After a collection period, that depends on the lifetimes of the products of interest, the ISAC beam is interrupted, the tape is pulled through a pathway of rollers and the samples are moved out of the vacuum chamber. The used tape is stored in a tape box behind a lead shield and γ-rays from daughter nuclei don't interfere in the detection of γ-rays from the parent nuclei of interest.
- The spectroscopy of ^{148}Ce has been performed using the GRIFFIN spectrometer which consists of an array of 16 HPGe clover detectors for gamma detection, 8 LaBr3 detectors for fast-timing measurements of excited-state lifetimes, 5 scintillators for conversion electron spectroscopy, a Zero Degree Scintillator for fast-timing measurements of ultra-fast gamma decays from daughter nuclei, that occur in very short times and an aluminised mylar moving tape collector placed at the centre of the GRIFFIN array.

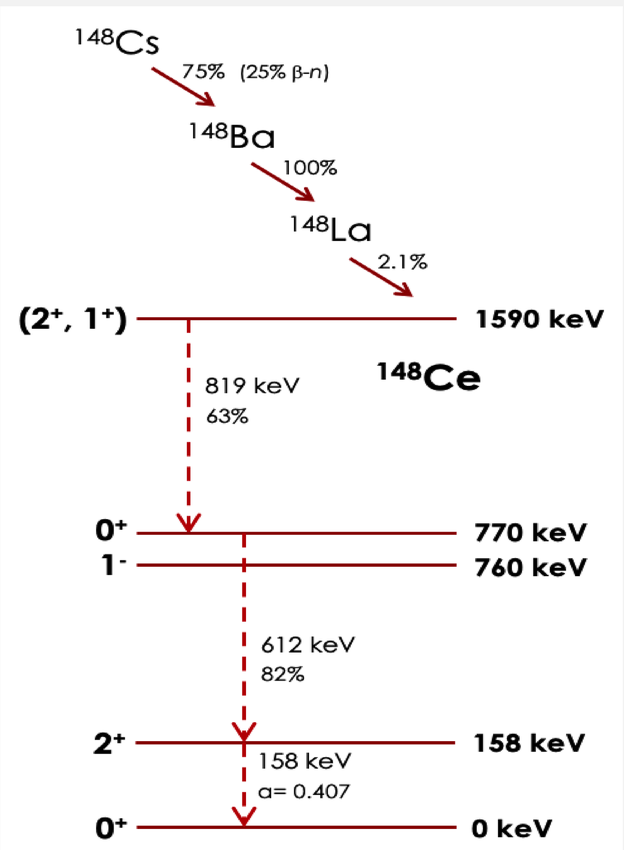


Figure 1. Beta-decay of ^{148}Cs

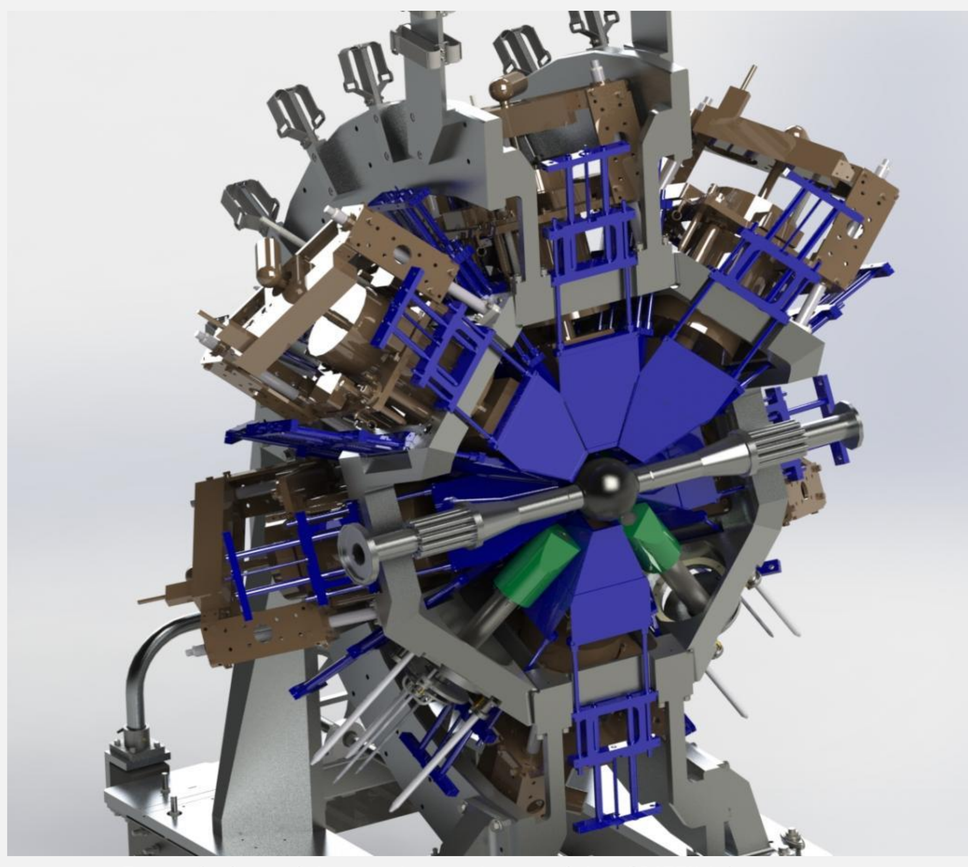


Figure 2. One of the two hemispheres of the GRIFFIN Spectrometer

Data Acquisition

$8TB$ of data

$32h$ running time for ^{148}Cs

$4 \cdot 10^4\ pps\ (beta)$ beam intensity for ^{148}Cs

Data Analysis

- Gamma-ray spectroscopy is a measuring technique based on the study of the electromagnetic properties of excited states such as energies, intensities, relative and absolute transition rates, angular distributions.
- With coincidence gamma-ray spectroscopy and by applying an addback and a suppressed addback correction, the background radiation can be significantly reduced helping to avoid non-interesting peaks and to make weaker peaks more visible in the spectrum.

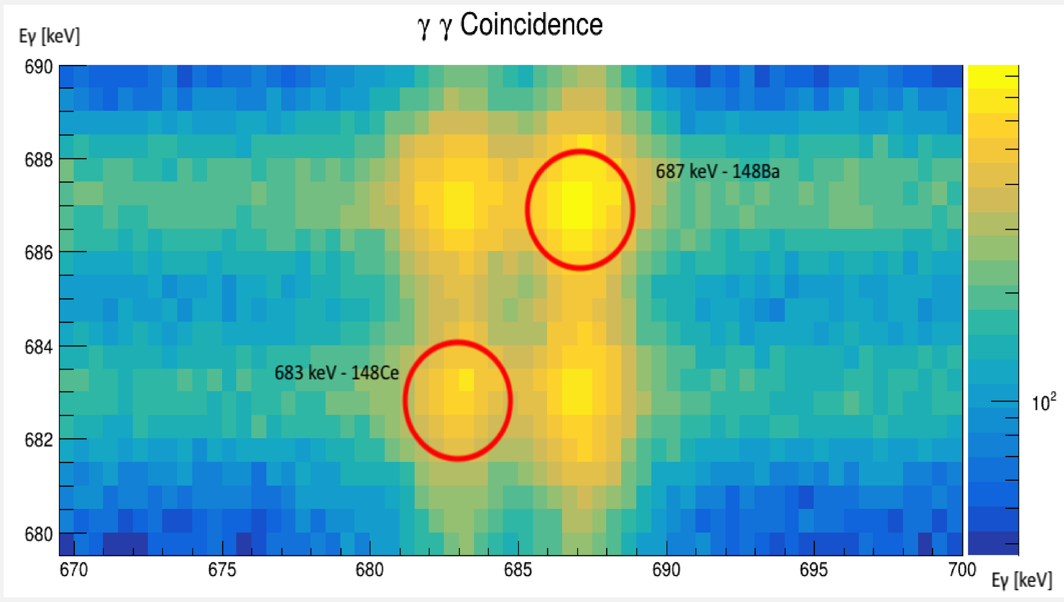


Figure 3. Gamma-gamma coincidence matrix of the ^{148}Cs data.

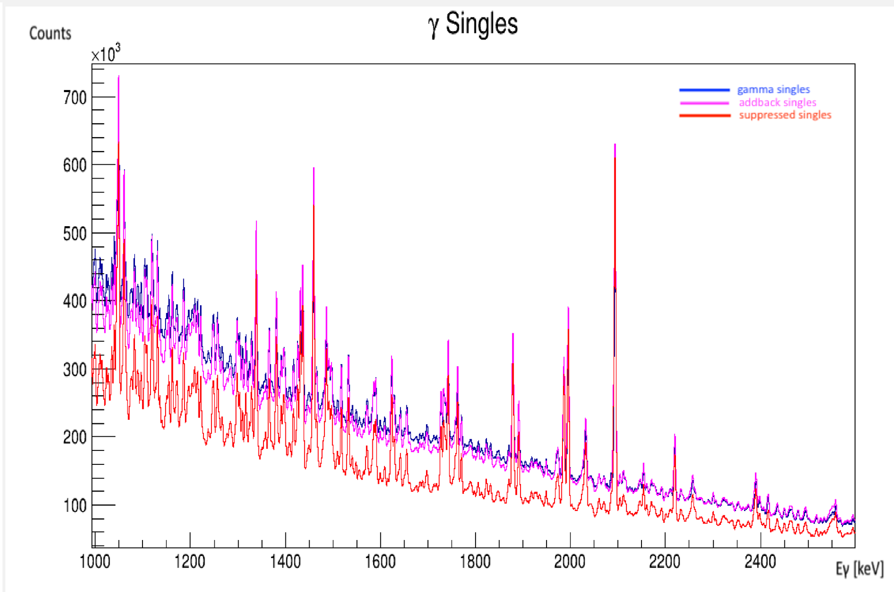


Figure 4. Gamma-ray energy spectrum of the singles, the addback singles and the suppressed addback singles combined

- A combination of these methods and information can contribute to the building or extension of the decay scheme and give us an insight on the nuclear structure of the nucleus of interest.

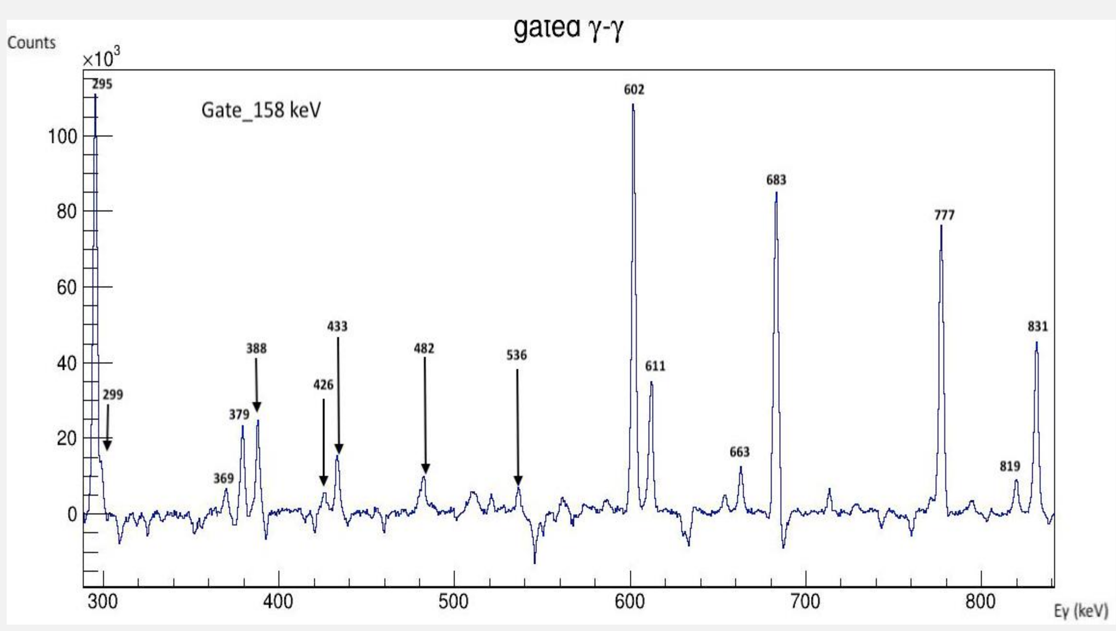


Figure 5. Gated spectrum of ^{148}Ce at 158 keV.

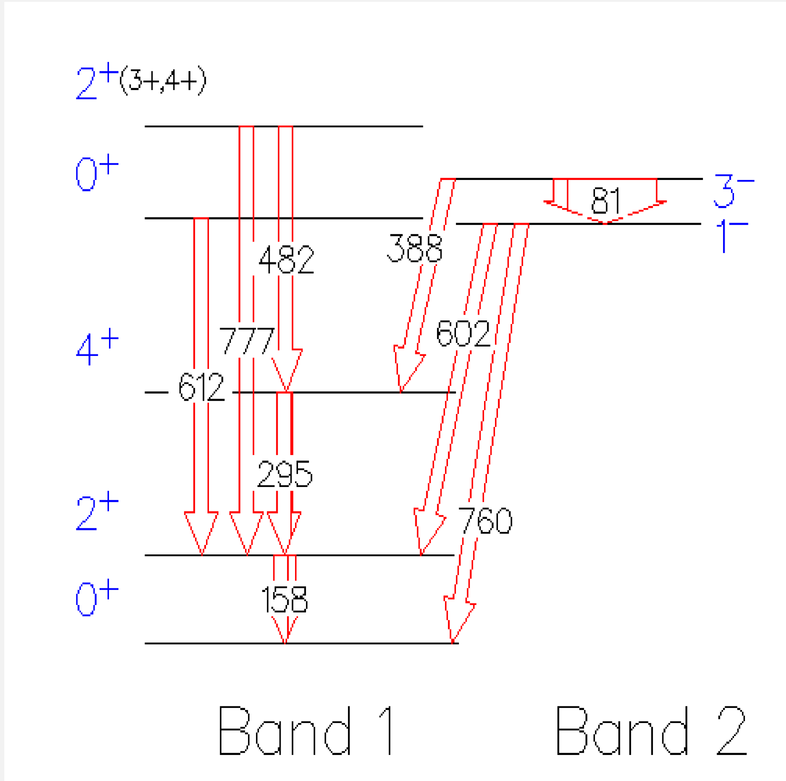


Figure 6. Decay scheme of ^{148}Ce.

Results

- Based on the longest tape cycle it was possible to identify the isotope of interest and to measure the lifetime of a particular γ-ray, by gating on the energies of the peaks of interest.

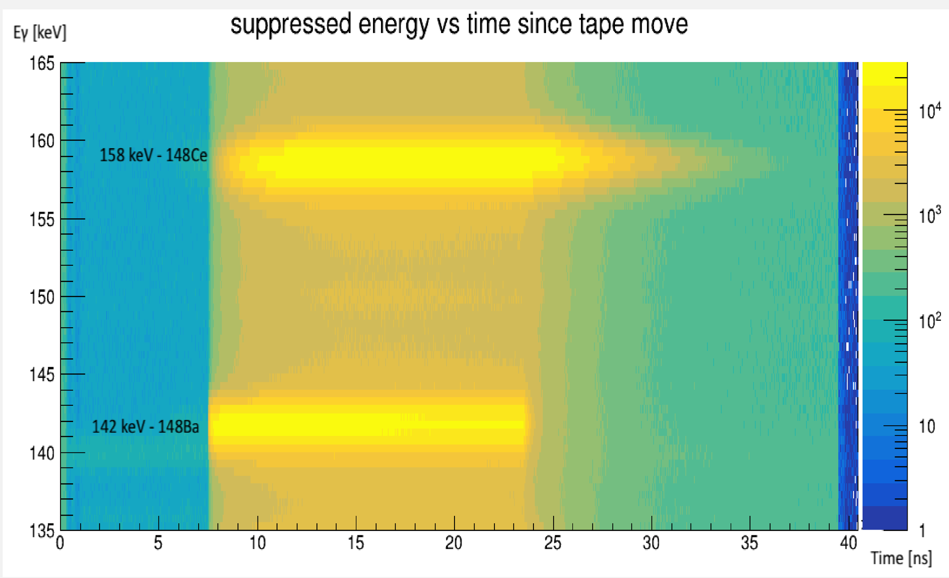


Figure 7. Energy vs time for the longest tape cycle for the ^{148}Cs data.

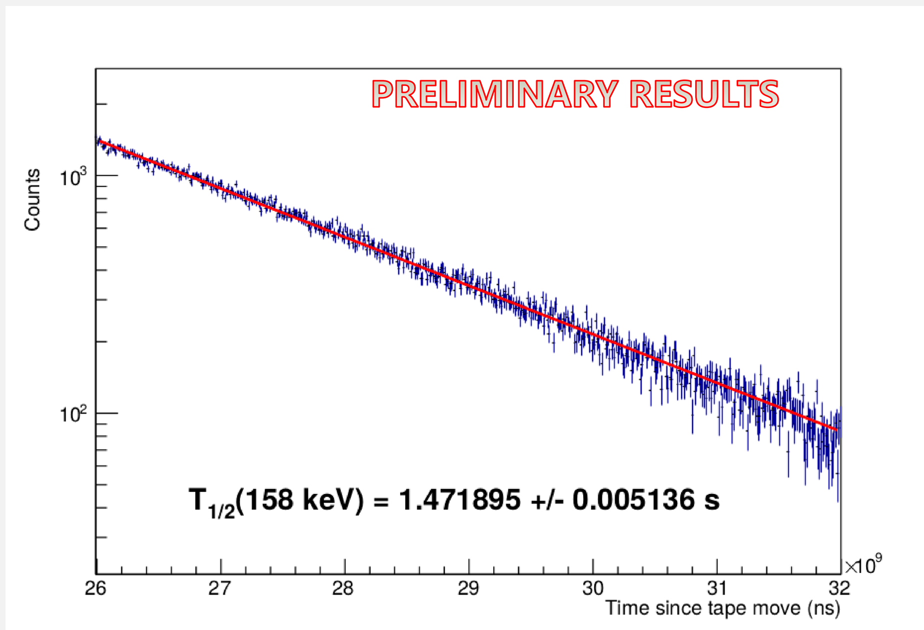


Figure 7. Measurement of the lifetime of the 158 keV γ-ray in ^{148}Ce.

Conclusion & Future Directions

- The lifetime of the 158 keV γ-ray was calculated. Spectroscopy studies for the verification and extension of the decay scheme of ^{148}Ce is on-going.
- The investigation and measurement of the lifetime of the excited 3^- state in ^{150}Ce and the measurement of the characteristic B(E1)/B(E2) ratios are in progress.
- Complementary studies of ^{146}Ce will take place at HIE ISOLDE in 2023.

References

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