Enhancing and improving nuclear decay data

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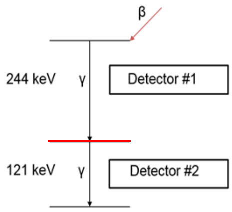
Measuring Lifetimes

- Two detectors gated on gamma rays above and below state of interest (marked red).
- Both detectors fire, time difference is plotted on a histogram.
- The spectrum after many events can be deconvoluted to extract the lifetime of the state of interest.



Motivation for the project

- Precise nuclear decay data is required in industry, for the modelling of future reactors.
- For waste assaying, intimate knowledge of the signature gamma rays related to particular radionuclides is important.
- The knowledge of these data is known to be needing improvement [1].
- This project aims to increase the depth of nuclear decay data by:
  1. Precise and accurate measurements of short-lived excitations within nuclei, NANA.
  2. Fission yield distributions from the recent experiment at IPN Orsay, using LICORNE.

NANA – The NAtional Nuclear Array

12 element, $LaBr_3$(Ce) scintillation, gamma-ray detector array, based at NPL to provide precise and accurate measurements of short lived ($> 10\ ps$ & $< 10\ ns$) states within nuclei.

Will be used at in-beam and decay experimental campaigns to serve as a standardised well-calibrated, well-understood fast-timing system.

A Geant4 and nptool Monte Carlo simulation has been created to provide efficiency and P/T parameters for different designs. The final design (fig 1) has been constructed at STFC Daresbury.

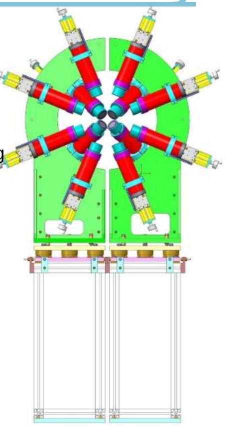


Fig 1: CAD design of the NANA array to be based at NPL, designed by STFC Daresbury

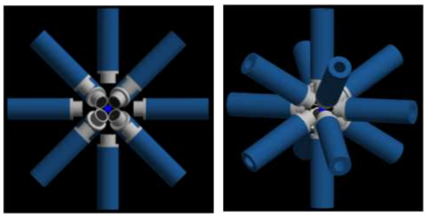


Fig 2: Geant4 simulations of NANA array.. Left Final design, of one hemisphere. Right; proposed design of solid sphere

Pulse Shape Analysis

- CAEN digitizer V1751C samples every 1 ns (1 MHz).
- A code has been created in C++ and ROOT that implements a digital CFD (constant fraction discriminator) to the pulse.
- Pulse from end of PMT is split, and one side delayed inverted an attenuated.
- Crossing point is energy independent!
- Interpolation between sampling points at crossing point returns sub ns timing!

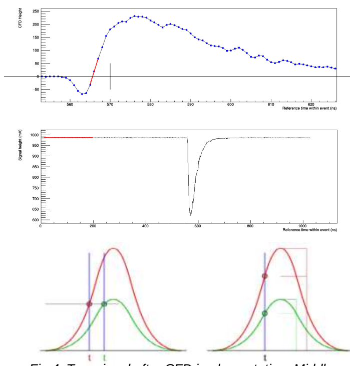


Fig 4: Top: signal after CFD implementation. Middle: untreated waveform from PMT anode signal. Bottom; Comparison of CFD vs Pulse height time triggering.

Preliminary Lifetime Measurements

Analysis code creates time difference spectrum, energy histograms and matrices.

Using the equation below [5]:

$$D(t) = \int_{-\infty}^{t} P(t' - t_0) e^{-\lambda(t-t')} dt'$$

For a ^{133}Ba source the $\frac{5}{2}^+$ lifetime has been resolved.

This agrees with literature value of 6.28(1) ns [6].

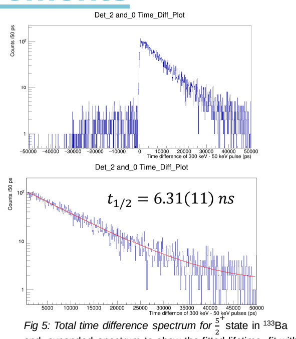


Fig 5: Total time difference spectrum for $\frac{5}{2}^+$ state in ^{133}Ba and expanded spectrum to show the fitted lifetime, fit with a n exponential with a constant background

Fast-neutron induced fission of ^{238}U at IPN Orsay

Fast-neutron induced fission yields of ^{238}U is an important dataset:

- Many new reactors will be fast reactors, therefore, ^{238}U will be an important component of their fuel cycle. In addition, about 10% of fissions in LEU thermal reactors are from ^{238}U induced by fast neutrons.
- Better understanding of the fission yields of the binary partners produced in the reaction is very important to the accuracy of models of these reactors.
- Will be a valuable resource for the sector as new reactors and novel (non-UOX) fuels come online.

....What was done at IPN Orsay

- LICORNE [2] source at IPN Orsay creates a focussed beam of neutrons.
- The fast neutrons (~1.4 MeV) irradiated a thick natural uranium target, producing fission of ^{238}U.
- The characteristic gamma rays of daughter nuclei were detected by the MINIBALL HPGE detectors.
- The RF-pulsing of the beam produced periodic "gamma-flashes", this was used as a reference time.
- In ROOT [3] matrices of time difference and gamma-ray energy were created.
- Gating on isomers, longer lived states in the daughter nuclei, that persist through the gamma flash of fission allows for the clean selection of binary partners.
- From this fission yields curves can be calculated in RADWARE's escl8r [4].

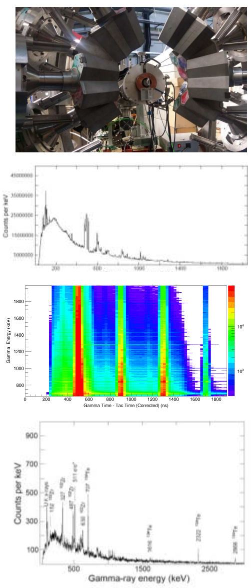


Fig 3: Top: experimental set-up of Orsay experiment, 2nd Top: Total gamma-ray spectrum, 3rd Top: Time profile of gamma-rays compared to beam pulse, Bottom: Isomer gated spectrum

REFERENCES

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[5] H. Mach, "A Method For Picosecond Lifetime Measurements For Neutron-rich Nuclei", *Nucl. Instruments Methods Phys. Res. A*, **280**(1989)407
[6] *National Nuclear Data Center, www.NNDC.bnl.gov*

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