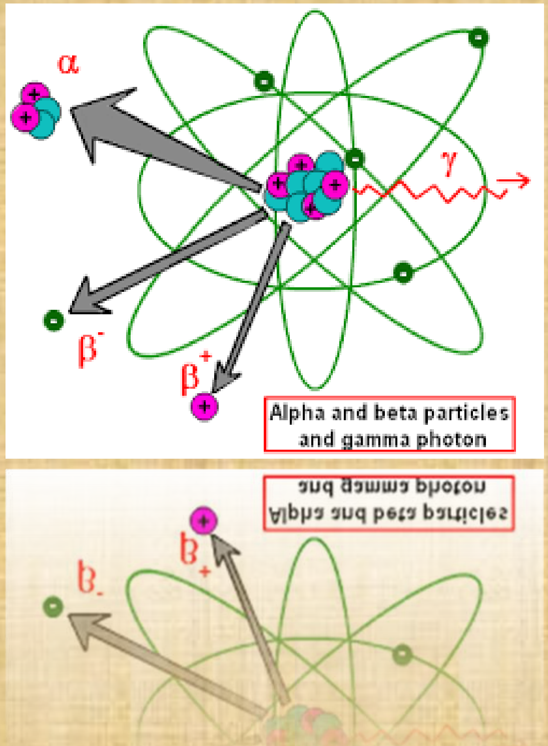
Precision Measurement of Lifetime of 5/2+ First Excited State of ^{133}Cs set in Nuclear Resonance Conditions



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Hanul Workshop, 08/03/2016

Introduction

- Lifetime of a nuclear state is an important parameter in studying EM Transitions.

- EM Transitions are observables used to study and understand the Nuclear Structure.

- In Exotic Nuclei, EM Transitions provides model independent information on the possible alteration of the shell structure

- An important and effective method of accurate measurement of EM Transitions is precision measurement of Lifetimes of excited states as long as this parameter is constant.
- However, some studies have shown the possibilities that the lifetime of a nuclear state can vary depending on several conditions.

Variation of Nuclear Lifetime

- Nuclear Lifetime can be varied by Altering the Chemical or Physical conditions of the nucleus.

Chemical	0.318%	H. Mazaki et al.(1980)
Pressure 10 GPa	0.046%	H. Mazaki et al.(1980)
Low Temp.	0.013%	D.Byers et el. (1958)

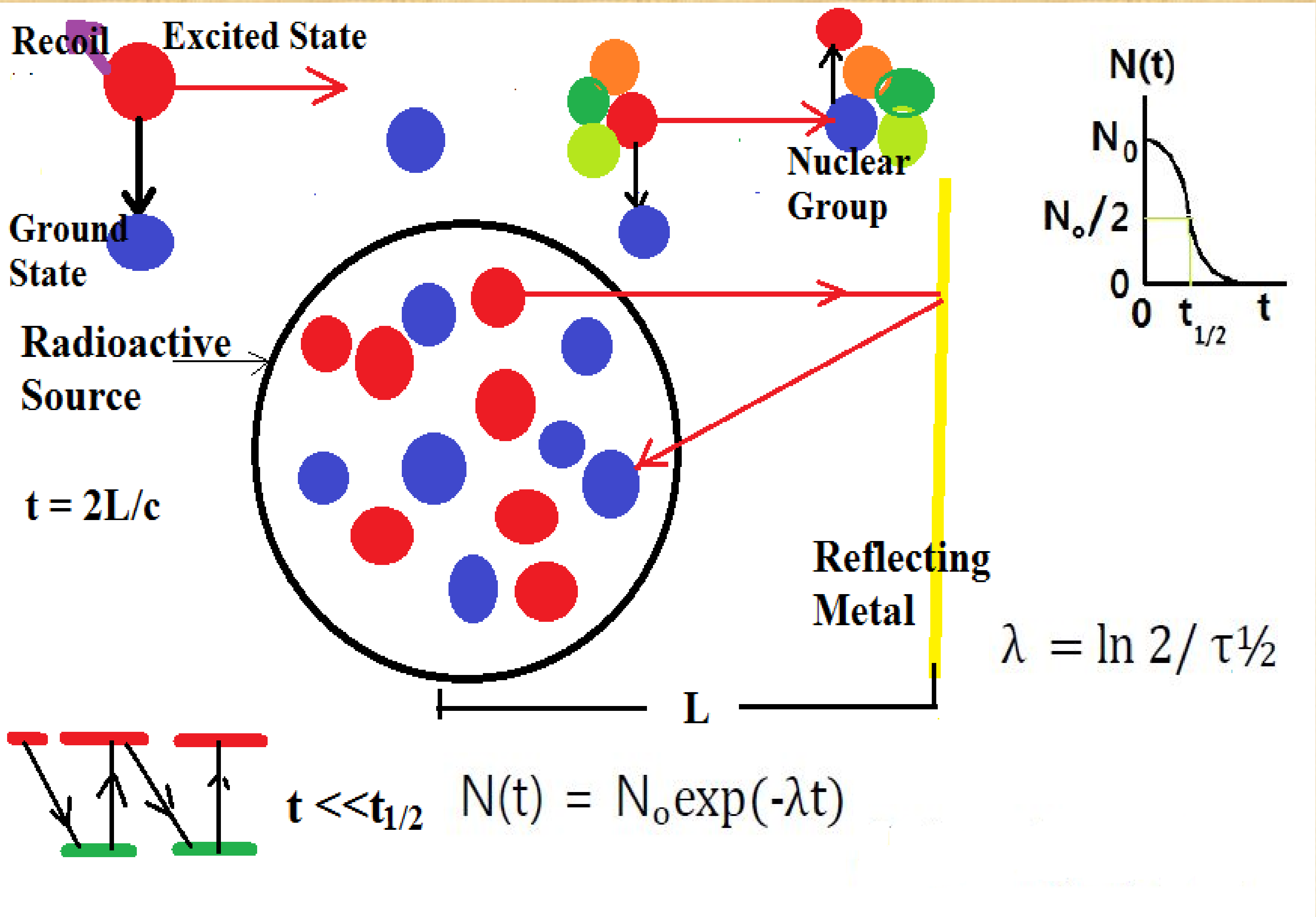
- Recently, a New method for varying Nuclear Lifetime by Populating the nuclei in excited state was proposed.
- Requires Recoilless emission and reabsorption of gamma rays by the nucleus.

- Il Tong Cheon used the method of metallic reflectors to calculated the possible change in nuclear lifetime (Il –Tong Cheon et al., JKPS (2005))

4.2K	15K	77K
5%	4.5%	0.4%

- The change also increased as the distance between the reflectors decreased.
- The experiment should be carried out in Low Temperatures and the Detectors should have Good Timing Performance and Energy Resolution.
- The predicted change is in order of 0.4%, thus
- **High precision Lifetime measurement system is required to observe any change in Lifetime.**

Mechanism of Variation of Nuclear Lifetime



Our objective is to study the Lifetime of ^{133m}Cs when the source is mixed with impurities of ^{133}Cs at ground state.

We need a system of Detectors that are Fast Enough to Detect short lifetimes, Good Time and Energy Resolution and Fairly Good Efficiency.

Requirements for this Experiment

- **In order to conduct this experiment successfully, a lifetime timing system with the following capabilities is required;**

  1.Fast enough to detect short lifetimes in ns range.

  2.High Timing Resolution.

  3. Very good Energy Resolution

  4. High Detection Efficiency

- **On the other hand, since we need to make measurement at lower temperatures, a cryostat system is needed to cool down the radioactive sources used in this experiment.**

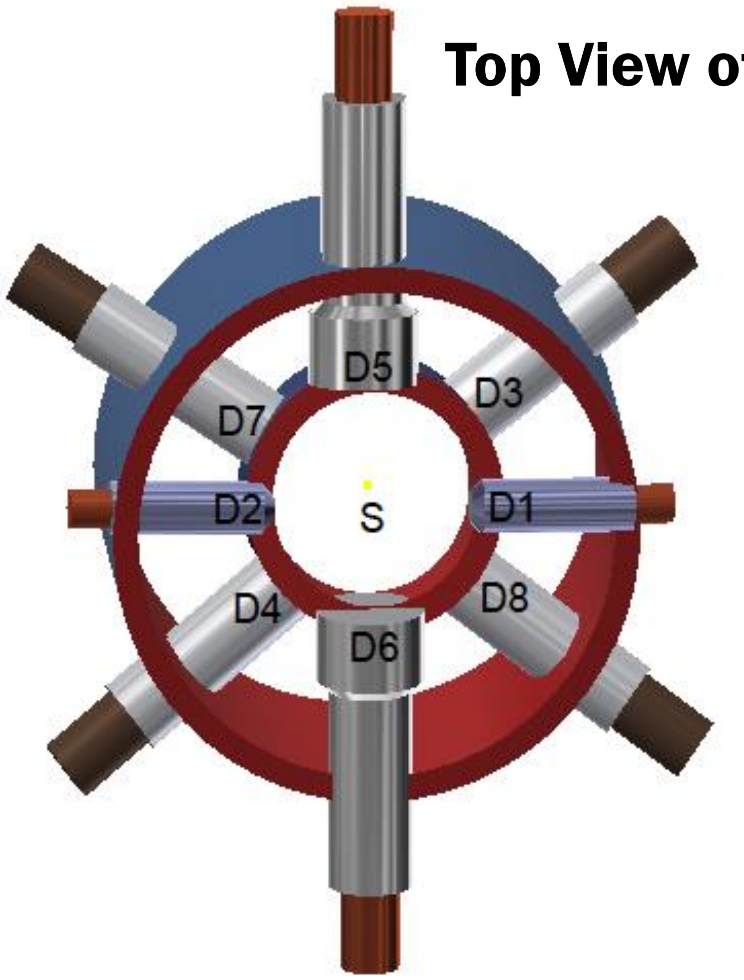
Important Properties of Scintillation Detectors

Parameter	NaI(Tl)	CsI(Pure)	$LaBr_3$	BaF_2	CsI(Tl)	$PbWo_4$
Resolution (%)	6 – 7	17 –185	3 – 4	12	4 – 5	
Decay Time (ns)	250	35 (s), 6 (f)	26	0.6 – 0.8 (f) 630 (s)	1000	6
Light Yield (Photons/Mev)	40,000	2000	63,000	1800 (f), 10000 (s)	54,000	200
Wavelength (nm)	410	315		180 – 240 (f) 310 (s)	565	420
Density (g/cm^3)	3.67	4.51	5.29	4.88	4.5	8.3

Proposed Detector System

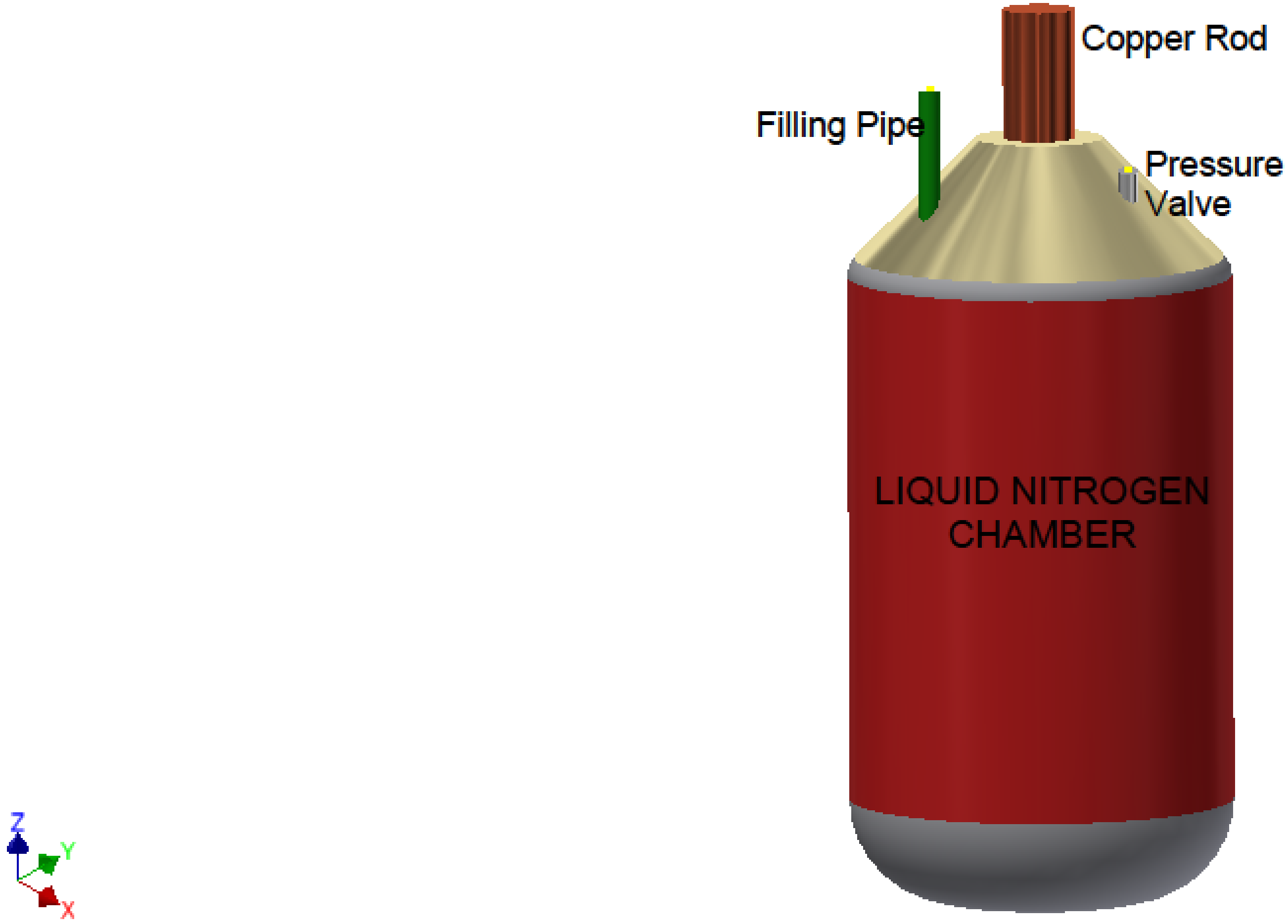
- A system of 8 different scintillation detectors is proposed for this study.
- These Detectors include two "1.5x1.5" LaBr3 Detectors, four "2x2" NaI(Tl) Detectors and "3x3" NaI(Tl) Detectors.
- These Detectors are named D1 to D8 for convenience.
- LaBr3 Detectors are faster and offer higher energy resolution than NaI(Tl) detectors will enhance high timing resolution as well as accurate selections of Energy gates.
- The use of 8 detectors will help to collect data in relatively short time thus reducing possible electronic noise due to heating of devices.
- NaI(Tl) Detectors ensure high efficiency of the system.
- NIM circuits and the CAMAC system will be use to process signals

Detector System



Top View of the Detector System

The Cryostat System



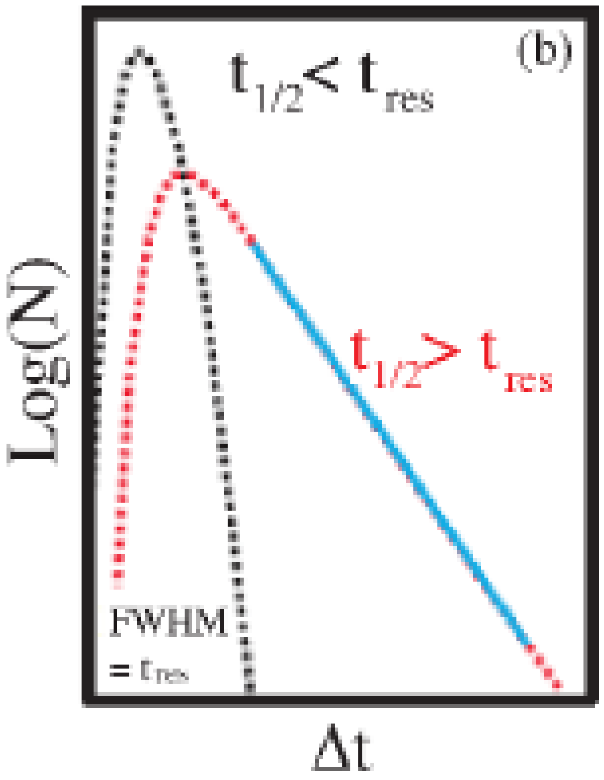
Timing Method

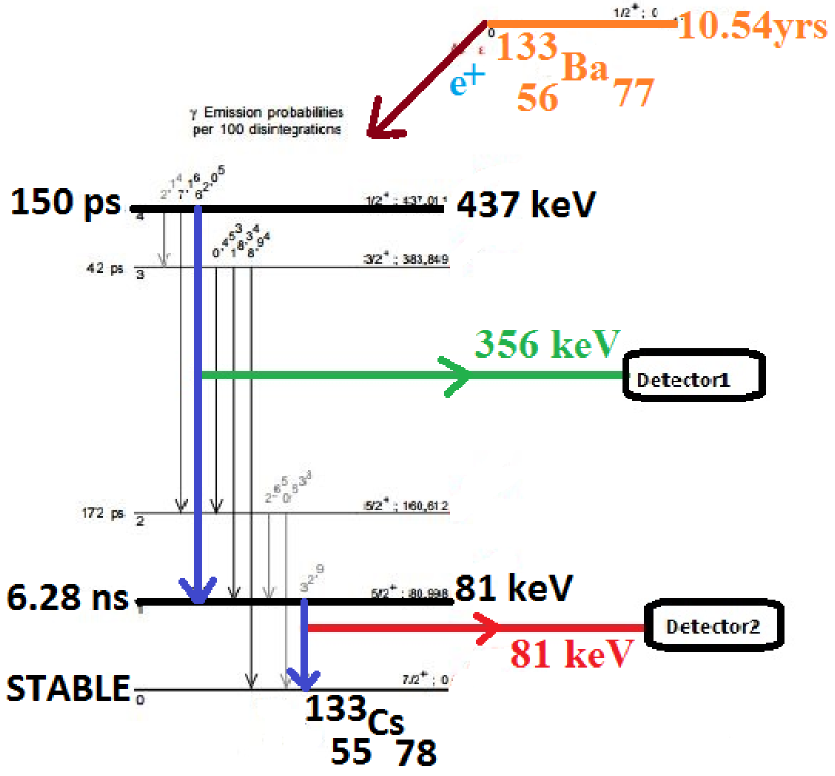
- Several lifetime measurement techniques exist but here the Fast Timing electronic technique is employed.
- This technique requires,

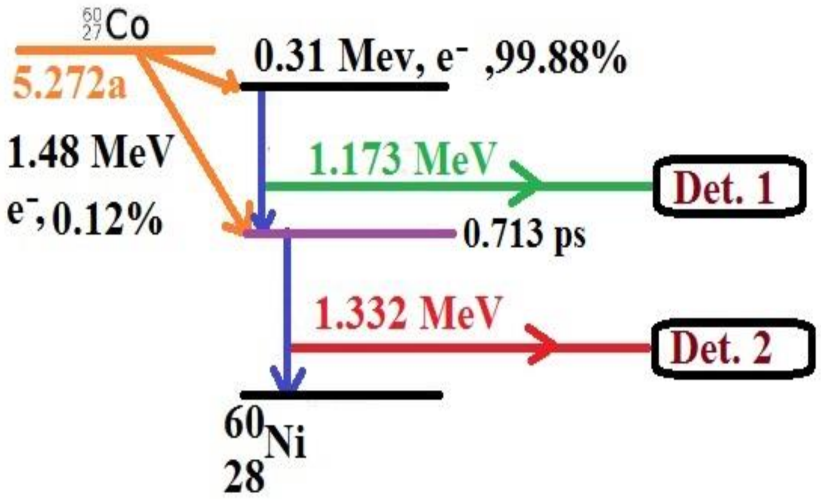
1. Placing energy gates such that one detector detects gamma photons from one transition and the other sees photons from the next transition.
2. Measure the time difference between the two signals from the detectors.

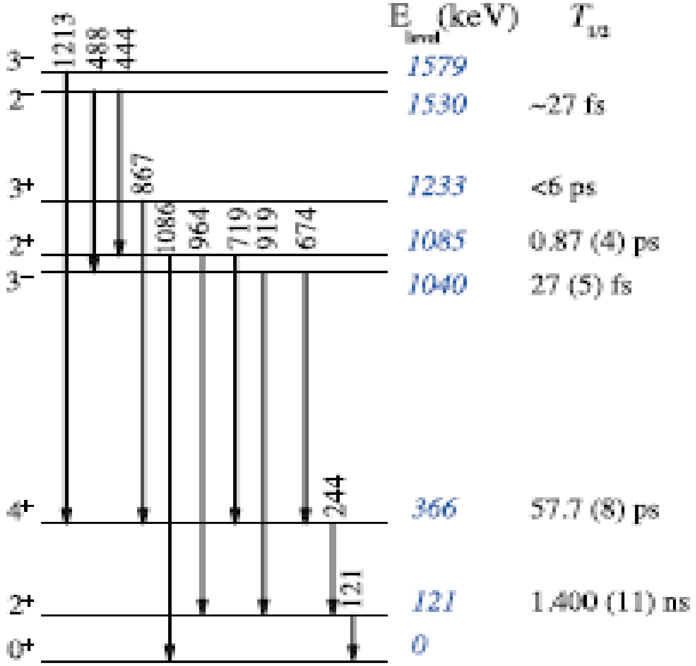
- If the lifetime of an intermediate state is shorter than the time resolution of the system, then a log plot of counts versus time difference is a Gaussian peak.
- Otherwise, the log plot will show a linear part that correspond to the lifetime of the intermediate state.

Fast Timing electronic Technique

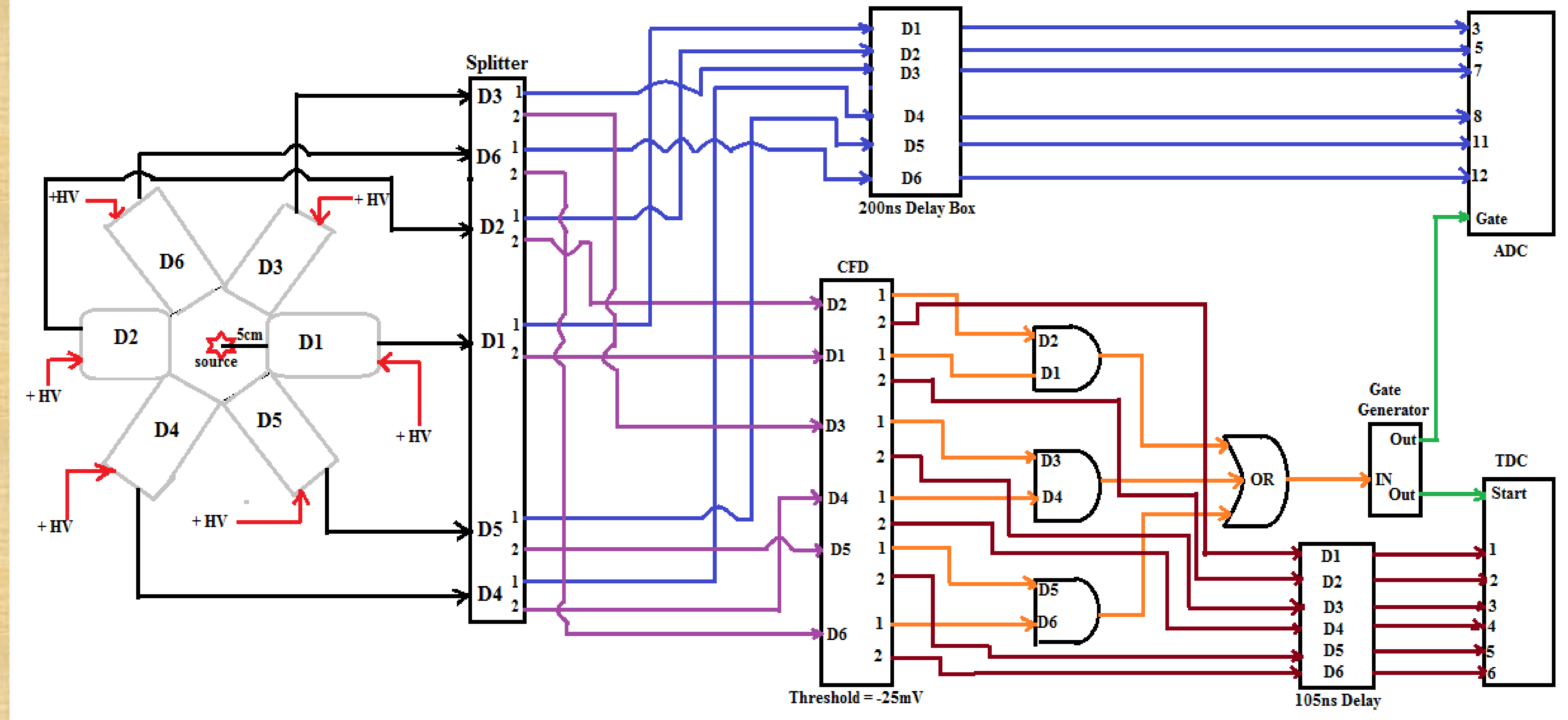






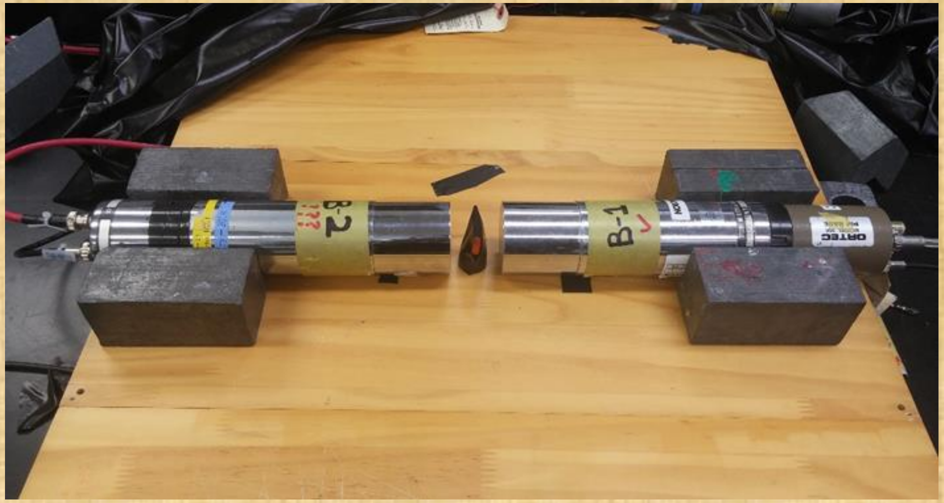


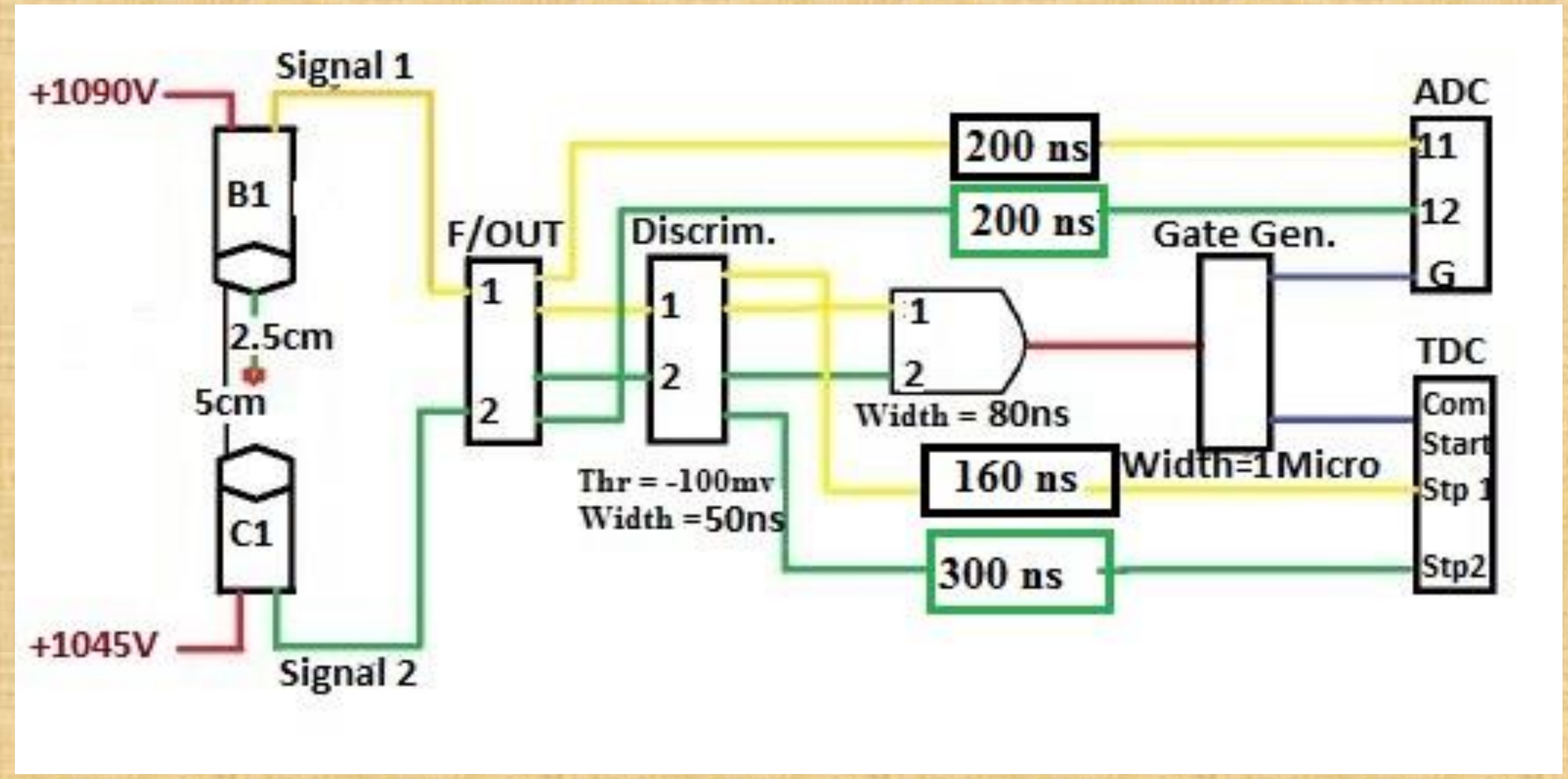
Electronic Circuit for this experiment

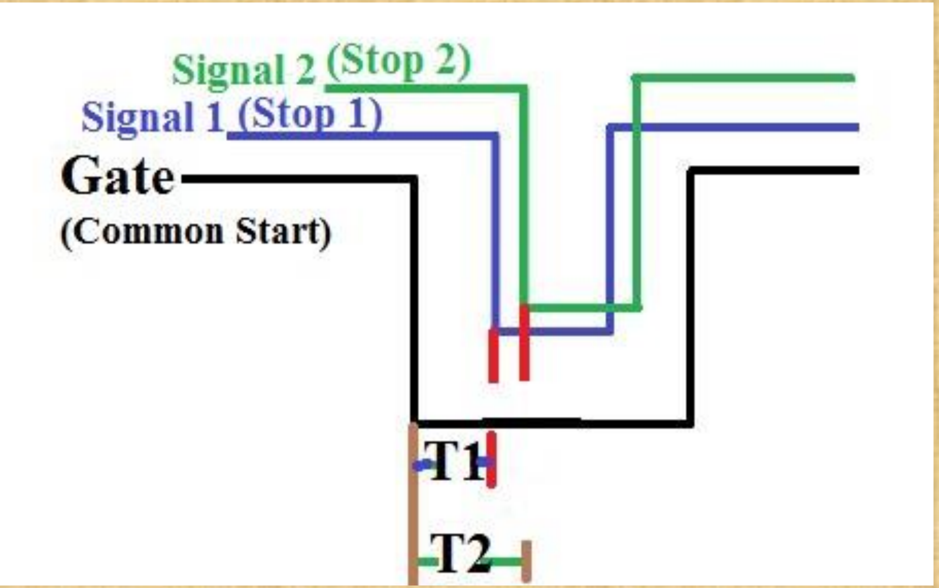


System Test using two NaI(Tl) Detectors

- Two NaI(Tl) Detectors were used to measure the Lifetime of 81 keV state using ^{133}Ba source.
- ^{60}Co source was used to determine Time Resolution of the system.



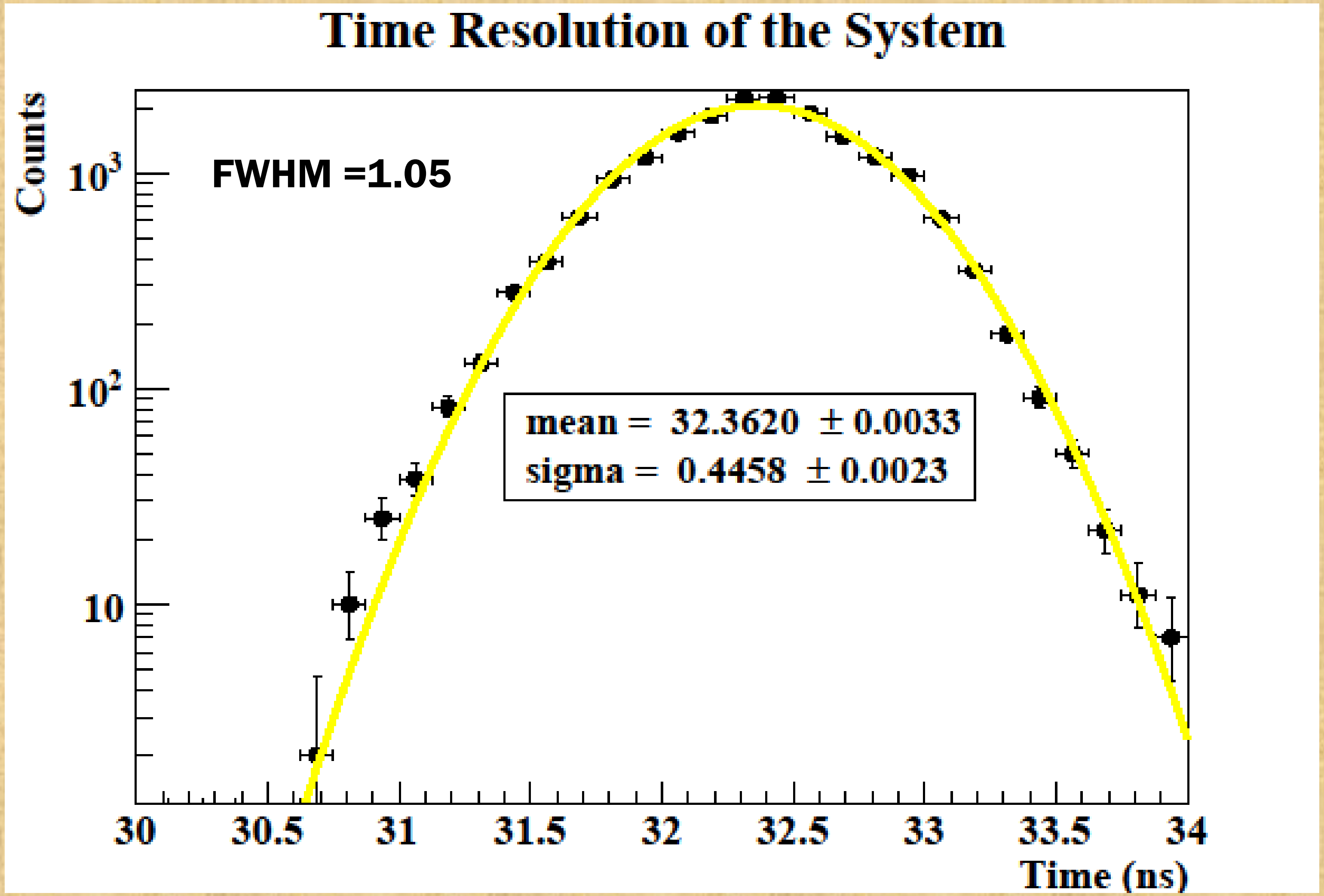




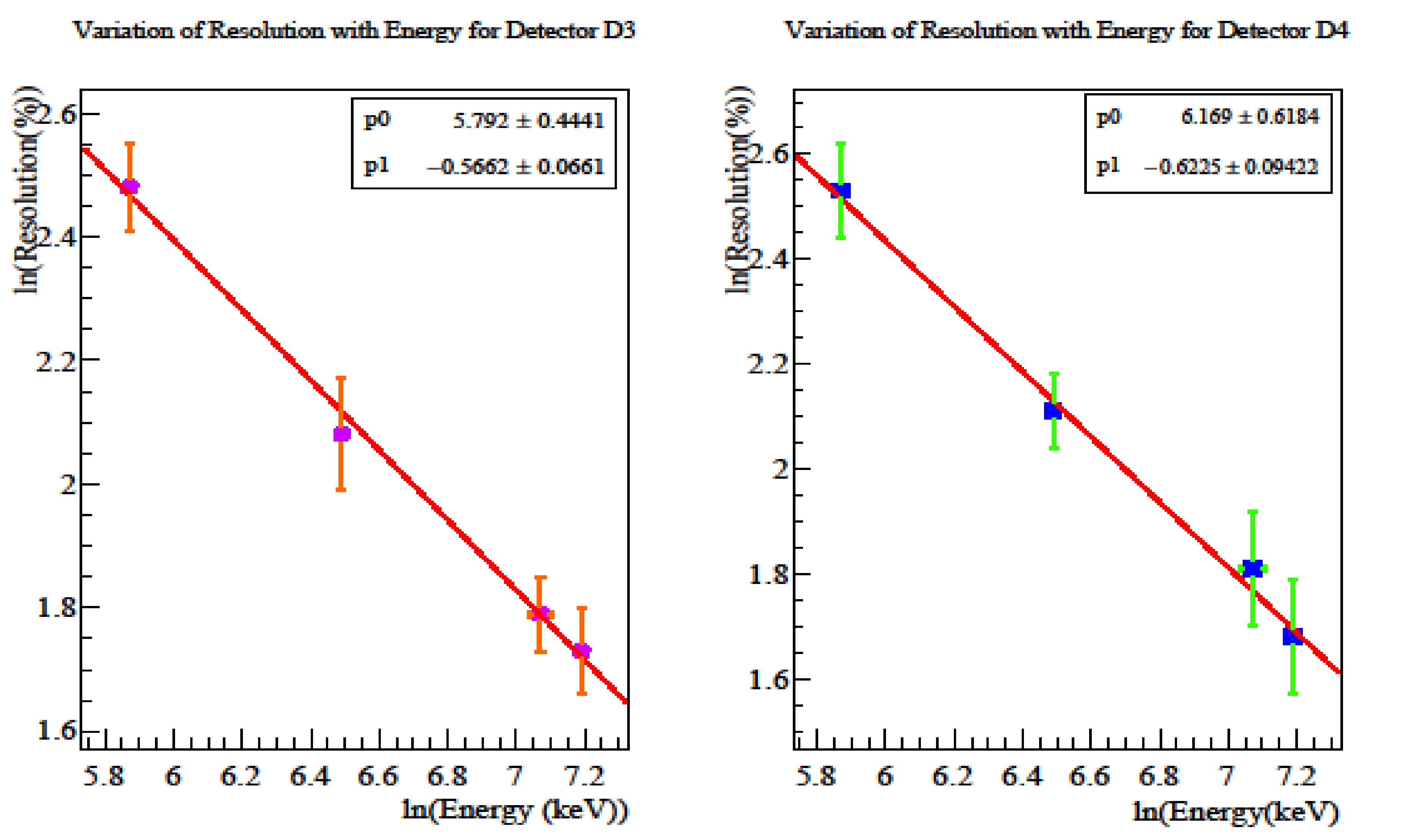
Time Resolution of the System

- An advantage is taken of the fact that the lifetime of the 1173 keV state of Co-60 is very short.

- With the results shown in the picture on the left, the resolution of our system is calculated to be 3.24%



Energy Resolution of the System

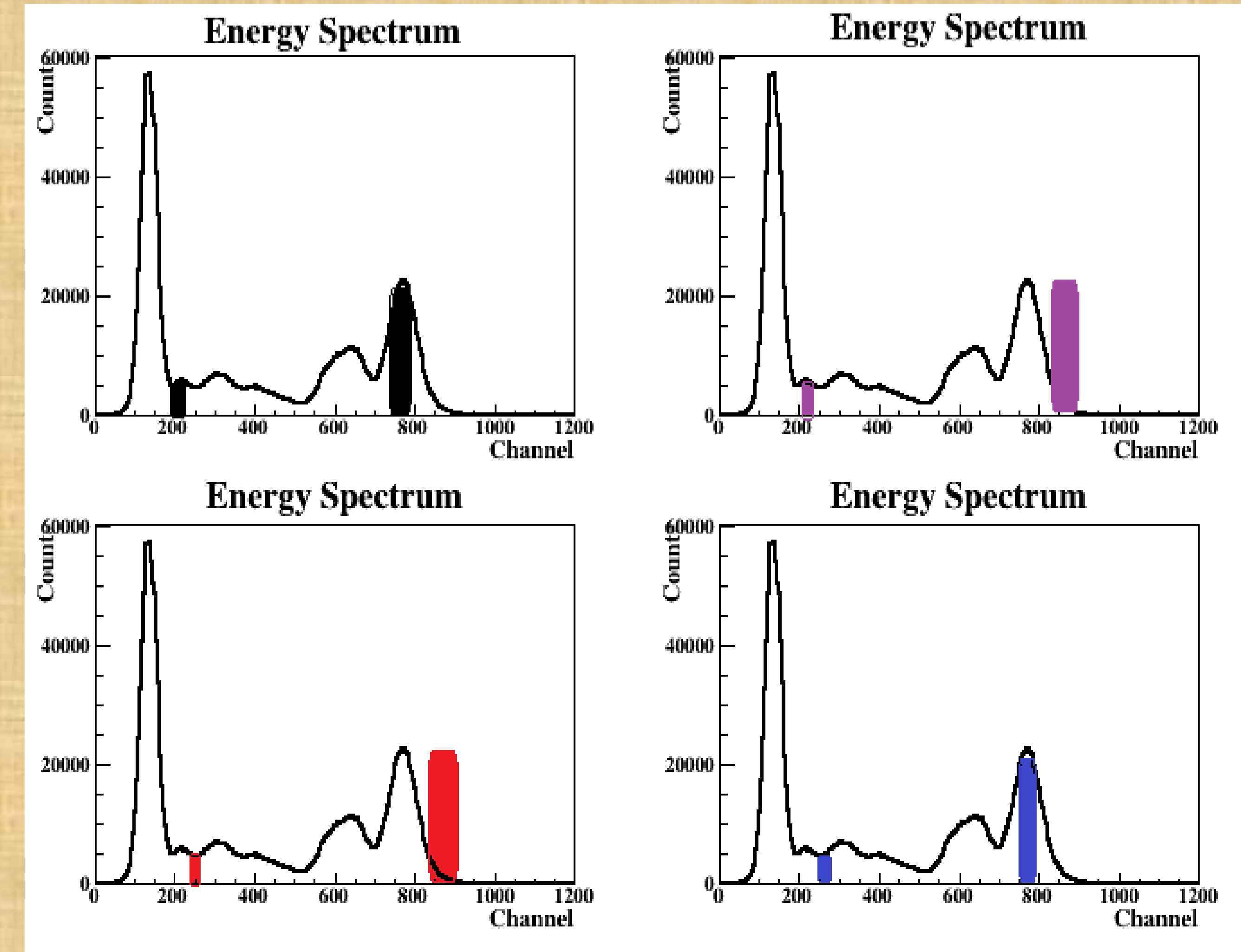


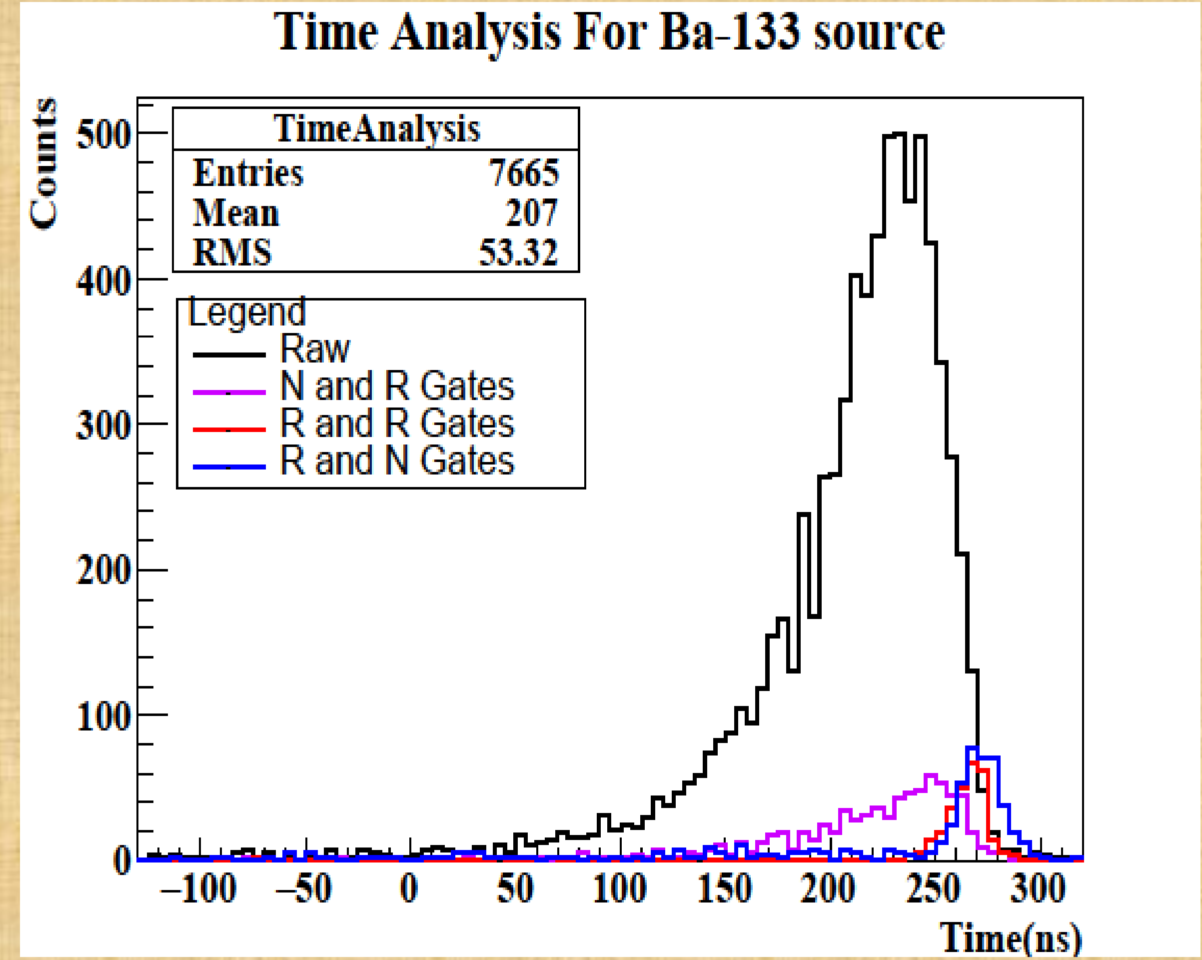
Determining Lifetime of 81 keV state of ^{133}Cs

- **Accurate measurement of Lifetime of a state requires careful and clean placing of energy gates on detectors.**
- **However, the background (mainly Compton) contribution in the lifetime projection plots can not be underestimated despite good energy and time resolutions.**
- **In this experiment, the background contribution is addressed by obtaining the time differences for following combinations of energy gates.**

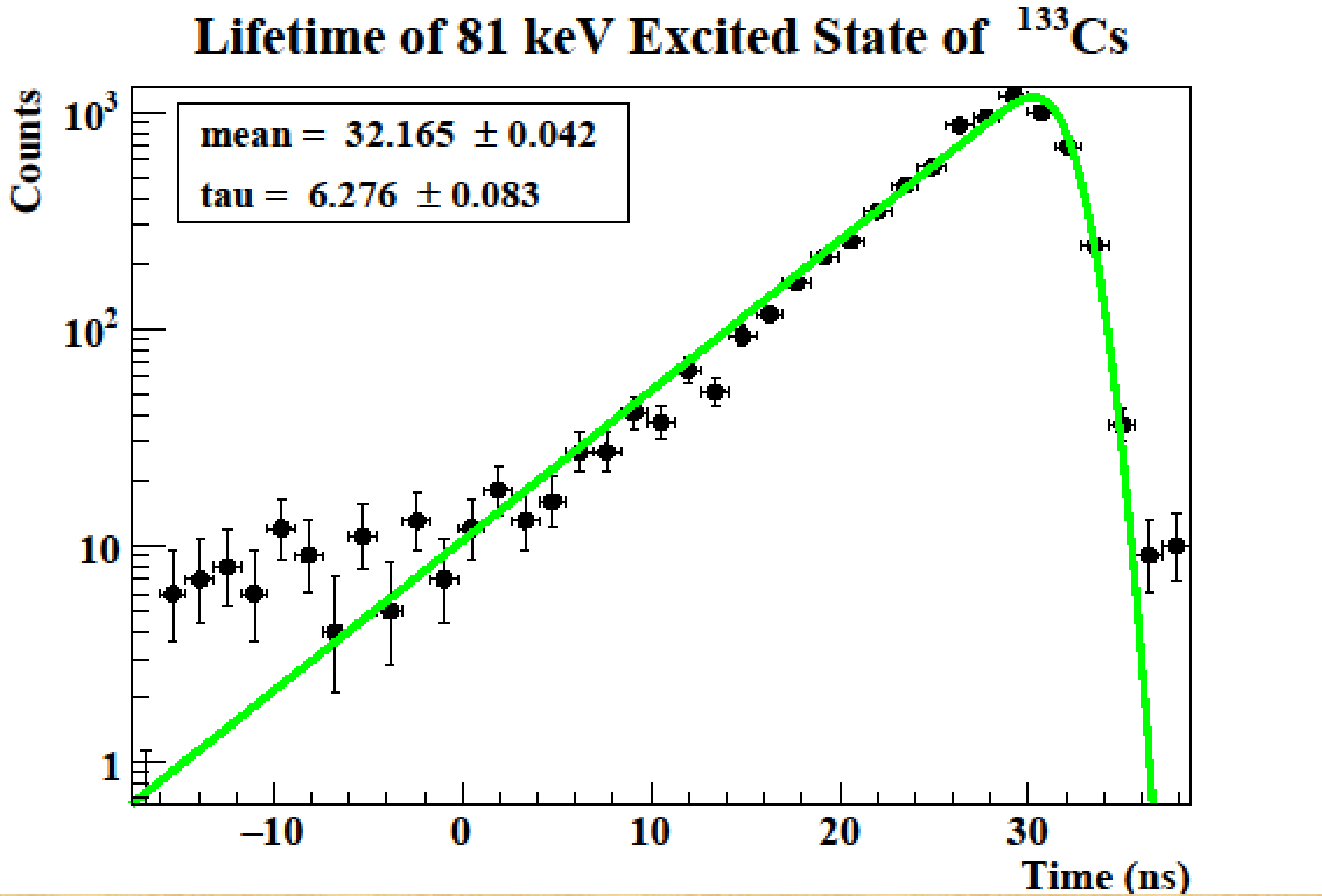
- **(Raw) referring to 81 keV and 356 keV peaks**
- **(BG1) referring to 81 keV peak and the region to the Right of 356 keV peak**
- **(BG2) referring to the region to the Right of both 81 keV peak and 356 keV peak**
- **(BG3) referring to the region to the Right of 81 keV peak and the 356 keV peak.**
- **The Final time spectrum used to extract Lifetime is obtained by (RAW) – (BG1) – (BG2) – (BG3).**
- **This way, the Compton contributions from higher energy transitions are eliminated.**

Energy gates and Time Spectra

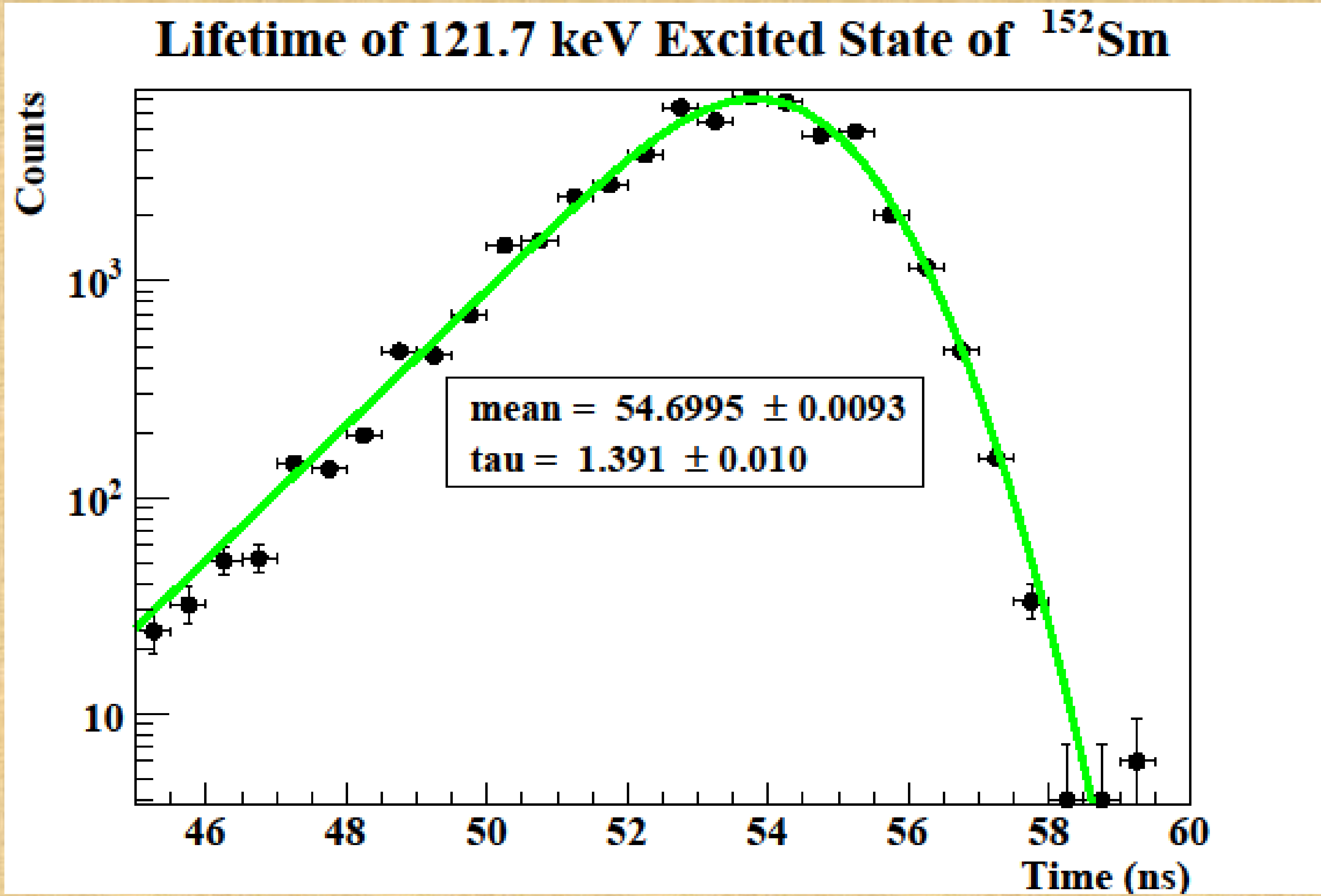




Lifetime of 81 keV state of ^{133}Cs



Lifetime of 121.7 keV in ^{152m}Sm



Summary and Remarks

- The system of two NaI(TI) Detectors has been used for measuring lifetimes of 81 keV and 121 keV excited states of 133Cs and 152Sm respectively.

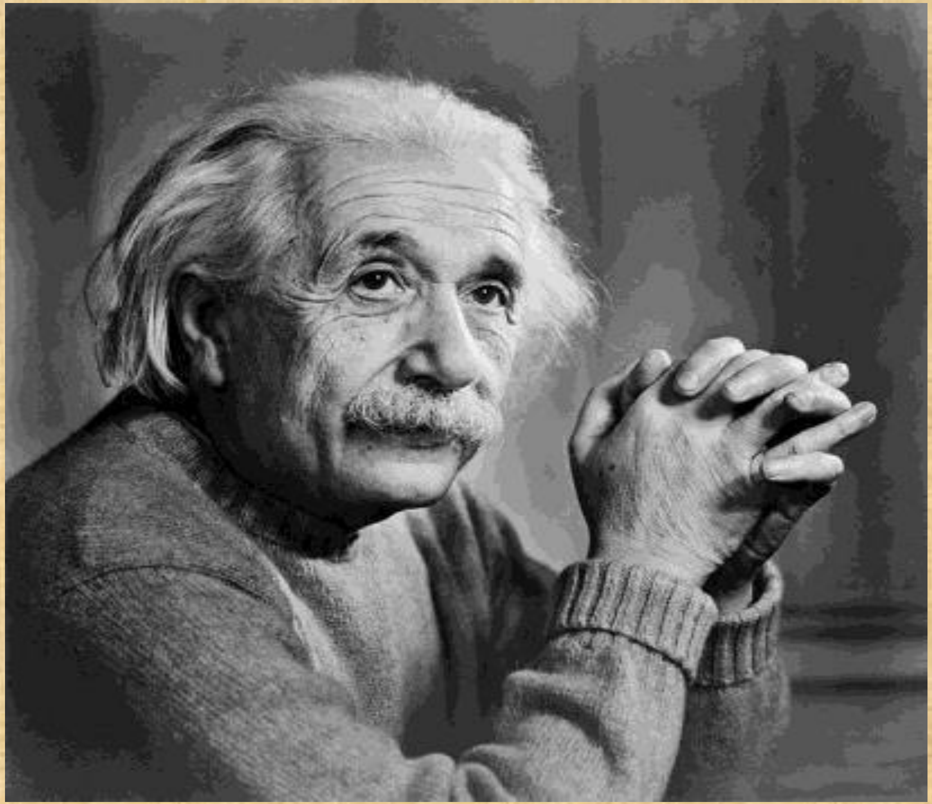
- The Lifetimes have been observed to be 6.276 ns and 1.391 ns for 81 keV and 121 keV states respectively.

- These results are well within the values given in several literature including the Nuclear data Book.

- This shows that, this time measurement system can be used to precisely measure the Lifetimes of excited states in range of ns

- In the next step, the system will be tested again with all 8 proposed detectors in position.

THANK YOU FOR LISTENING!!! JAH BLESS YOU ALWAYS!!



"God Does Not Throw Dice, Therefore one Should See Real Entity hidden Behind Any Phenomenon"

Backup

Accidental Coincidence and Selection of Peak Region

The ratio of True coincident events to Accidental coincident events is calculated as;

$$N_0 = 7955Bq$$
$$\tau = 107ns$$

$$\frac{N_C}{N_A} = \frac{1}{2N_0\tau} = 587$$

Offline selection of coincident peaks is done using the following range,

$$R = (\mu - 1.645\sigma, \mu + 1.645\sigma)$$