Research Based Development of Innovative and Indigenous Technologies for Nuclear Physics Laboratories

Thesis Pre-submission Seminar

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Outline

The importance of nuclear physics hands-on education in the Indian context

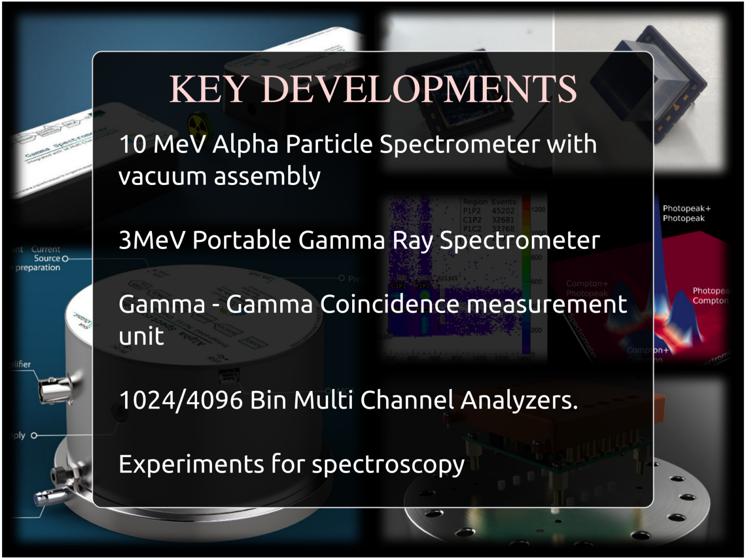
- PIB report[1] by DAE, Govt of India outlines the nation's goals for nuclear resources in in health, power generation, and defence.
- More than 35,000 crores [2] have been sanctioned for development of nuclear power plants.
- As of 2018, 6 nuclear power plants(4.4GWe total) are under construction. Expected completion by 2024-25[3].
- A trained workforce will be required for maintenance and operation needs for these and a large number of particle accelerators being deployed across the country for medical applications.

Challenges in the field

- Neglect of experimental nuclear physics teaching labs
  - Lack of indigenous equipment and technology.
  - High prices (Gamma spectrometer costs $>$ 4Lakhs, Coincidence setup $>$ 10L)
  - Difficulties in enriched source procurement.
  - Lack of modernisation in existing tools
- Only 6 universities[4] have been awarding degrees dedicated to nuclear engineering.
- Education in nuclear physics is greatly dependent on a handful of institutions such as BARC and IUAC under DAE.

Purpose

My purpose for this research is to develop affordable nuclear physics equipment using the latest advances in technology, and identify natural sources for experimentation, as well as carry out simulations that will provide a theoretical backing to the obtained results.



KEY DEVELOPMENTS

10 MeV Alpha Particle Spectrometer with vacuum assembly

3MeV Portable Gamma Ray Spectrometer

Gamma - Gamma Coincidence measurement unit

1024/4096 Bin Multi Channel Analyzers.

Experiments for spectroscopy

Overview of the planned research

Development of Instruments for nuclear physics from the ground up.
Key Instruments designed and tested with consumers:

- Alpha Spectrometer: A complete USB Powered instrument for acquiring Alpha Particle Spectra with a 10MeV range, 1K Multi Channel Analyzer(MCA), and associated software.
- Gamma Spectrometer: Portable Gamma Ray Spectrometer with 3 MeV full Scale range, and a built-in 1K MCA.
- 1K MCA, 4K MCA : Independent USB powered multi-channel analyzers with List mode and histogram mode data acquisition options, adjustable noise thresholds, and 0-4V input ranges.
- Dual Parameter MCA for Gamma-Gamma Coincidence measurements
- Multi-Pixel Alpha Detector: For recording beam profiles and deflection
- Data Acquisition, Visualization and Analysis software for Linux/Windows/Android.

Slightly detailed overview

- Electronics Development : Circuits for Preamplifiers, Shaping Amplifiers, Multi-Channel Analyzers, and power supplied were designed with KiCAD and manufactured.
- Hardware Development : Vacuum chambers and pumps, enclosures, shielding were prepared using SolidWorks and machined.
- Software : I authored CNSPEC, a Python based software for Data acquisition , analysis, & visualization for all the above instruments
  - Open Sourced, and tested with multiple platforms such as Windows/Linux/OSX .
  - Visualization: Histograms, surface plots. Analysis: Curve fitting, half life calculation etc.
  - Remote access and environment data consolidation on a unified platform [Beta testing].
  - Android App: A minimal android app has been developed for the gamma spectrometer, making it truly portable and a handheld mobile accessory for radiation surveying.
- Experiment Development: Develop and document a range of nuclear physics experiments which adequately explain concepts. Add those which may currently not be covered by the limited curriculum. Novel experiments which have been elaborated in their respective chapters
- Distribute to universities
  - further enhance product design with feedback.
  - Develop new experiments as per curriculum
  - Suggest alternatives to existing curriculum

I have the following major publications:

- Jithin B.P. and O.S.K.S. Sastri, "Novel coincidence setup using indigenously developed portable USB gamma spectrometer and associated analysis software," *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 964, p. 163 793, 2020, ISSN: 01689002. DOI: 10.1016/j.nima.2020.163793
- Jithin B.P., V. V. V. Satyanarayana, S. Gora, *et al.*, "Measurement Model of an Alpha Spectrometer for Advanced Undergraduate Laboratories," *Physics Education*, vol. 35, no. Jan-March 2019, 2019. [Online]. Available: http://www.physedu.in/pub/2019/PE18-08-518
- Jithin B.P., S. Gora, V. Satyanarayana, *et al.*, "Gamma Spectra of Non-Enriched Thorium Sources using PIN Photodiode and PMT based Detectors," *Physics Education*, 2020
- Jithin B.P., "SEELablet : A Technological Platform for Development of Innovative Experiments for Undergraduate Education," *APT Tunes*, vol. May 2018, 2018. [Online]. Available: https://aptkerala.org/images/stories/apttunes/APT{_}TUNES2018.pdf

Conference publications:

- Jithin B.P. and O.S.K.S Sastri, "Indigenously developed gamma spectrometer," in *Proceedings of the DAE Symp. on Nucl. Phys. 63 (2018) 1072*, 2018, pp. 1072–1073. [Online]. Available: http://sympnp.org/proceedings/63/G19.pdf
- Jithin B.P. and O.S.K.S. Sastri, "Gated MCA technique for demonstration of coincidence phenomena with a set of indigenously developed gamma spectrometers," in *Recent Issues in Nuclear and Particle Physics, Viswa Bharati*, 2019
- Jithin B.P. and O.S.K.S. Sastri, "Compact dual-parameter MCA for $\gamma\gamma$ Coincidence Measurements," in *Proceedings of the DAE Symp. on Nucl. Phys. 64 (2019) 920*, 2019. [Online]. Available: http://sympnp.org/proceedings/64/G37.pdf
- Jithin B.P. and O.S.K.S. Sastri, "Background Gamma Radiation Surveying in the IndianPeninsula with a Portable USB Spectrometer," in *Proceedings of the DAE Symp. on Nucl. Phys. 64 (2019)*, 2019. [Online]. Available: http://sympnp.org/proceedings/64/G28.pdf
- Jithin B.P., *Learning Microcontrollers with Python*, 2019. (visited on 05/11/2020)
- Jithin B.P., "Simulation of N-Well Kronig- Penney Potential using Matrix Approach.," in *NACISP-2018*, IAPT, 2018

I am also a contributor to the following publications:

- Swapna Gora, Jithin B.P., V. Satyanarayana, *et al.*, "Alpha Spectrum of ^{212}Bi Source Prepared using Electrolysis of Non-Enriched ThNO$_3$ Salt,", 2019
- A. Sharma, S. Gora, J. Bhagavathi, *et al.*, "Simulation study of nuclear shell model using sine basis Simulation study of nuclear shell model using sine basis,", vol. 576, 2020. DOI: 10.1119/10.0001041
- O. S.K. S. Sastri, S. Aditi, J. Bhardwaj, *et al.*, "Numerical Solution of Square Well Potential With Matrix Method Using Worksheets,", 2019

And was invited to speak at the following events:

- Entrepreneurship lecture at IISER, Mohali by the Technology Business Incubator
- One day teacher training workshop at Sir P T Sarvajanik College, Surat
- Computer Interfaced Instruments Workshop at Educode.be, Brussels, Belgium
- National Workshop on Nuclear Physics, Calicut University
- FOSS Young Professionals' Meet, ICFOSS
- Workshop on Nuclear Physics at Amity University, Noida.
- Science Hack Day, Belgaum
- Workshop and Demos at India Science Fest, IISER Pune

Prior Experience and Resources for Research

- Open source designs by IUAC, New Delhi[18][19] for preamplification and shaping of signals created by alpha particles incident on photodiodes are available free of cost.
- I have some prior experience with embedded systems design and communication, as well as software development[8].
- My thesis work at IISER involved working with vacuum systems and interfacing high end data acquisition equipment.
- Well equipped design lab courtesy CSpark Research - A scientific instruments company.
- Access to machine shops, laser cutters, and 3D printing facilities.

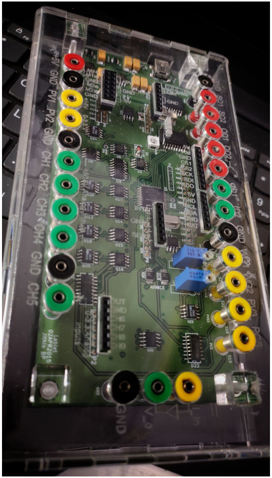
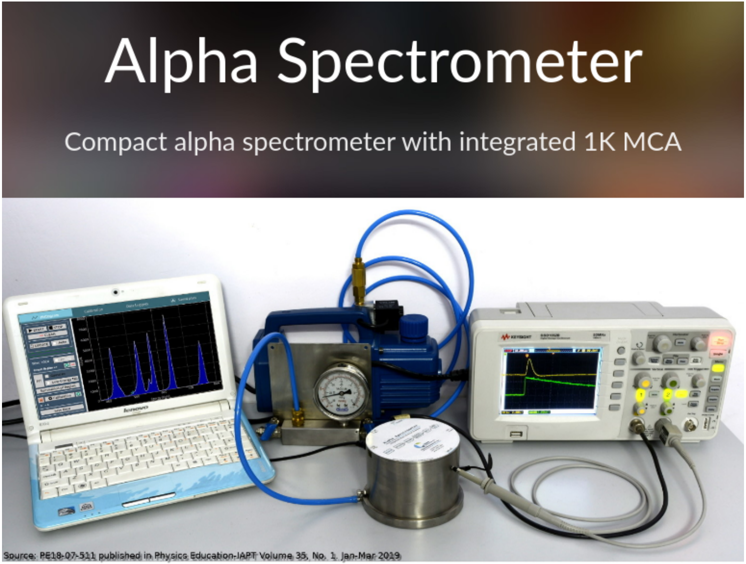


Figure: SEELablet: A data acquisition tool for which I was one of the major developers


Alpha Spectrometer
Compact alpha spectrometer with integrated 1K MCA
Source: PE18-07-511 published in Physics Education-IAPT Volume 35, No. 1. Jan-Mar 2019

Publications

Title	Journal	Author(s)
Measurement Model of an Alpha Spectrometer for Advanced Undergraduate Laboratories	Physics Education- IAPT Volume 35: No 1. Jan-Mar 2019	Jithin B.P. , V.V.V. Satyanarayana, Swapna Gora, O.S.K.S Sastri & Ajith B.P.
Alpha Spectrum of 212-Bi Source Prepared using Electrolysis of Non-Enriched ThNO3 Salt	Physics Education- IAPT Volume 35: No. 1. Jan-Mar 2019	Swapna Gora, B.P. Jithin, V.V.V. Satyanarayana, O.S.K.S Sastri and B.P Ajith

Cover feature

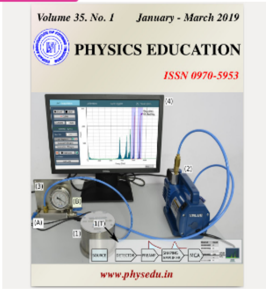


Figure: This instrument is currently being used in MSc and Research labs in over 20 universities across India.

Alpha Spectrometer: Detector Development work

High quality silicon photodiodes with 10mm*10mm area were procured from various sources and tested.
A PCB was designed to mount the detector, and also act as a collimator.

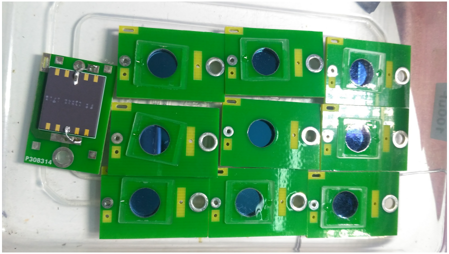


Figure: A set of detectors mounted on collimator PCBs. A silicone cover is placed to protect the active area from dust, and must be removed before usage.

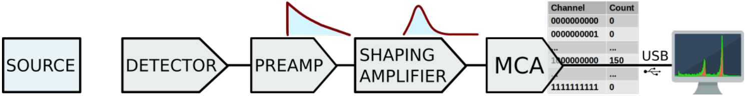


Figure: Entire schematic for the alpha spectrometer development

Alpha Spectrometer: Vacuum chamber CAD design

Alpha particles are easily attenuated in air, and this necessitates the use of a vacuum chamber.
The following CAD design was prepared using SolidWorks, and visual appeal was added using Keyshot.

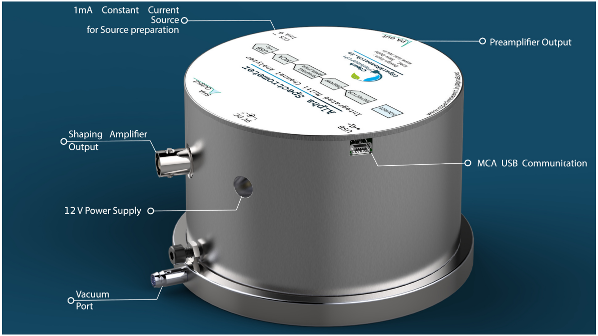


Figure: CAD render of the Alpha Spectrometer [Prepared by : Sharath BP]

CAD designing prior to actual fabrication is essential to ensure that all components align properly. The above design includes two circuit boards for signal processing, and a multi-channel analyzer.

Alpha Spectrometer: Instrument Schematic

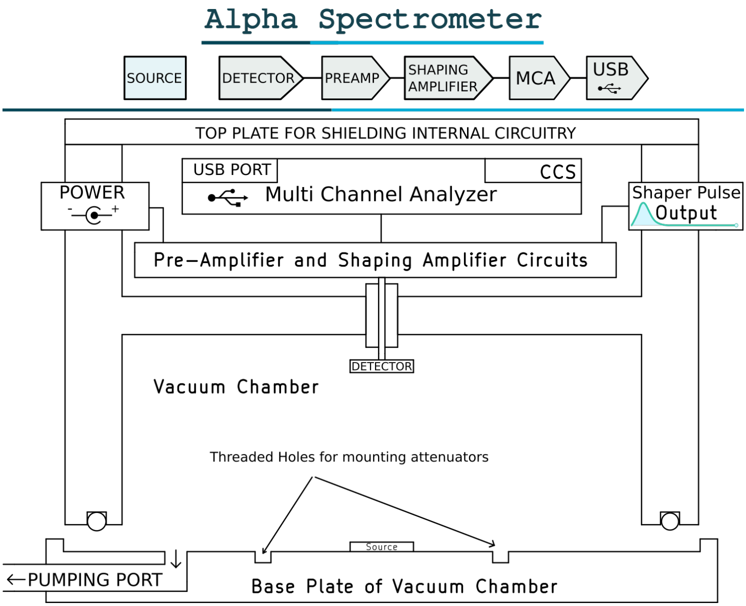


Figure: CAD render of the Alpha Spectrometer

Alpha Spectrometer: Vacuum chamber machining

Made from a 1" thick SS pipe, a partition with an electrical feedthrough is welded such that one side is vacuum tight, and houses the detector, and the other side contains the electronics. Distance from the detector to the electronics is kept minimal to ensure noise proofing.

Figure: Vacuum chamber showing the detector housing assembly and electrical feedthrough. The MCA is stacked on the analog electronics.

Alpha Spectrometer: Software

Software development targets for the instrument are two fold

- The firmware for the MCA written in Embedded C
- User facing application for visualizing and analyzing data on a pc/laptop. An android app was separately developed.

I have published the python software under open source terms[20].

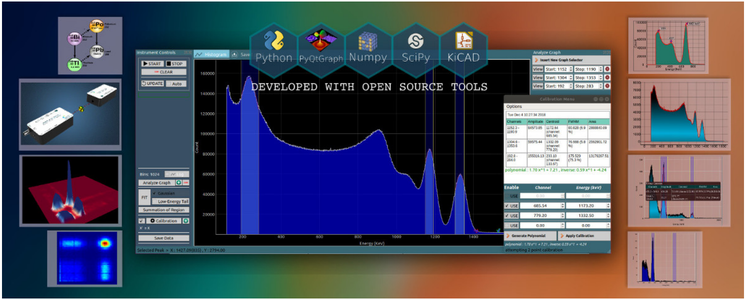


Figure: A fully featured Python app was written and packaged for Windows and Linux. I have made it modular in order to be compatible with the Alpha Spectrometer, the Gamma Spectrometer, and the independent Multi Channel Analyzers discussed in later sections

Alpha Spectrometer: Python Library

The Python library is used by the graphical interface for acquiring and analyzing data from the instruments connected to a USB port, but is also available for direct use.
This facilitates teaching of concepts through simple code examples.

```python
import time,sys
import numpy as np
from MCALib import connect

dev = connect()

fname = 'DATA/bi212_19mA_10min_31mar18/data_240mins.csv'
dev.loadFile(fname)

# Get the data. Supply an optional name argument in case of multiple files/connected hardware.
x = dev.getHistogram() #name = fname / name='/dev/ttyUSB0'

#Optional-Uncomment next two lines to print the whole array. No decimal Points. Suppress scientifi
#np.set_printoptions(threshold = np.inf,precision = 0,suppress=True) #
#print (x)

#plot the loaded spectrum
import matplotlib.pyplot as plt
plt.plot(x) #Plot RAW data

FIT = dev.gaussianTailFit([750,850]) #Apply a gaussian+Lorentzian FIT between 700 and 900  channel
if FIT:
        plt.plot(FIT['X'],FIT['Y']) #Plot fitted data
        print('Gaussian+low energy tail Fit : ',FIT['centroid'],FIT['fwhm'])

FIT = dev.gaussianFit([500,600]) #Apply a gaussian FIT between 500 and 600 channel.
if FIT:
        plt.plot(FIT['X'],FIT['Y']) #Plot fitted data
        print('Gaussian Fit : ',FIT['centroid'],FIT['fwhm'])

plt.show()
```

Alpha Spectrometer: Python Library

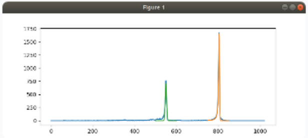
The results from the code shown previously are displayed below. The Python programming language makes it incredibly simple for beginners to achieve tangible results.

Results from offline data analysis

The results of the above code on offline analysis of 212-Bismuth spectrum are shown

Gaussian fitting was carried out on the first peak(Green) and overlaid.

Gaussian+Low energy tail(Lorentzian) was carried out on the second peak (Orange).



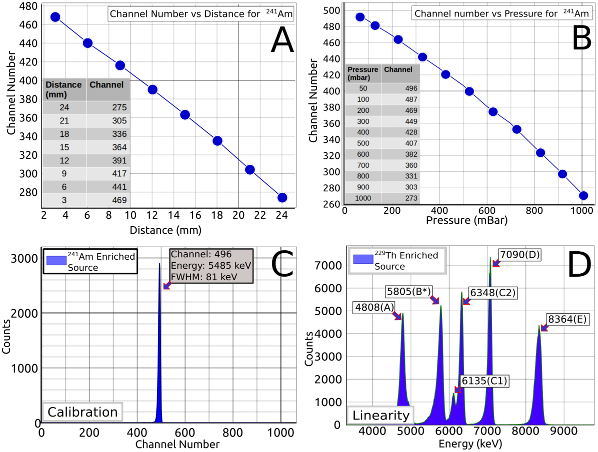
The Python library is used to encourage students to understand the acquired data, and interpret and analyze it manually instead of relying on the graphical interface. However, the GUI is far more efficient, and feature rich.

TERMINAL OUTPUT [CENTROID, FWHM]

```
Gaussian+low energy tail Fit :  804.5779218431603 5.52159634760166
Gaussian Fit :  550.0967122469116 7.927848067452287
```

Validation using Experiments

Characterisation and testing carried out using standard enriched sources ^{241}Am and ^{229}Th.



Distance (mm)	Channel
24	275
21	305
18	336
15	364
12	391
9	417
6	441
3	469

Pressure (mbar)	Channel
50	496
100	487
200	469
300	449
400	428
500	407
600	382
700	360
800	331
900	303
1000	273

Figure: a) Effect of source-detector distance on the centroid of the lone peak of ^{241}Am. b) Effect of air pressure is studied for the same centroid . c) Alpha spectrum for ^{241}Am under 50mBar vacuum with source-detector distance = 2cm . d) Alpha spectrum for ^{229}Th under similar conditions as in (c) **Jithin2019**

Experiments and Example Spectra

We have optimized a process to extract ^{212}Bi from Thorium Nitrate solution via electrolysis. This typically takes about 10 minutes, and has the following advantages over enriched sources when viewed from a pedagogical perspective.

- ^{212}Bi has the highest branching ratio which can be verified easily by students.
- It has a short half life of 60.5 minutes, and therefore the decay curve can be visualized within a few hours of data collection
- The short half-life, and low count rate allows for safe disposal.

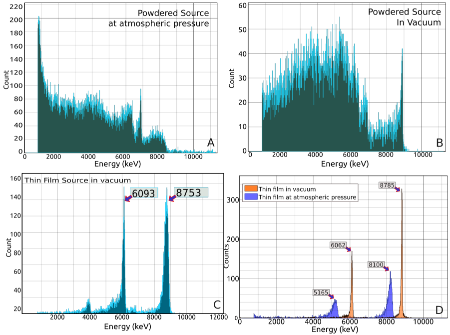
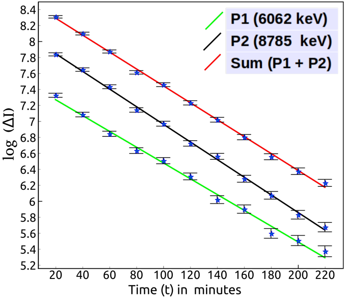


Figure: Radioactive sources under various attenuating factors; a) Alpha spectrum of Thorium nitrate salt; b) The same salt studied under vacuum; c) Thin film of ^{212}Bi under vacuum; d) Comparison of ^{212}Bi spectrum in 1 mbar vacuum and under attenuation due to 1 Bar atmospheric pressure. Data acquired by Swapna Gora [15]

Half-life estimation of ^{212}Bi



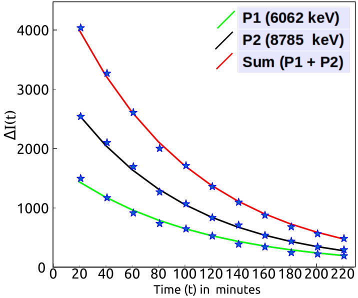


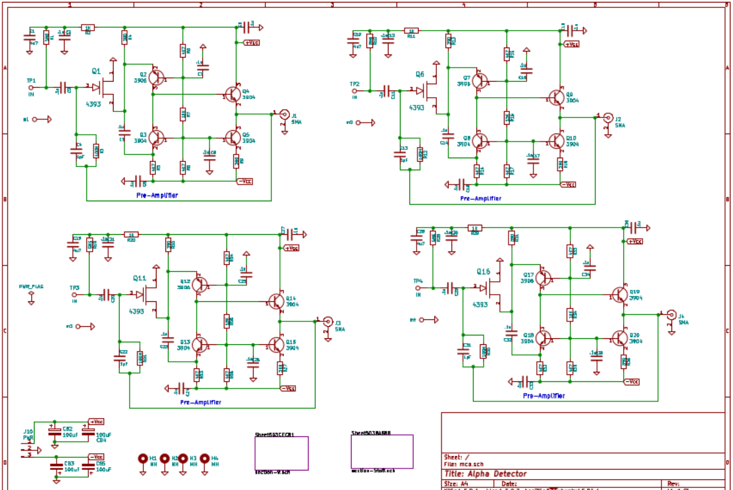
Figure: Activity of extracted ^{212}Bi recorded in 10 minute intervals. The exponentially decaying nature of the alpha energies at 6.05Mev and 8.75 MeV, and their sum total can be clearly seen. The log plot is a straight line as expected [15].

Half-life was estimated to be 62.5 Minutes for the 8754keV peak by applying a least square fit to the data.

Multi-Pixel alpha Detector

Since we have already developed the electronics for an alpha spectrometer, we used this knowledge to start work on developing a multi-pixel grid of 3x3 Alpha detectors

This setup can gather information about the spread of alpha particle beams, and also carry out spectroscopy.



Multi-Pixel alpha Detector: Layout

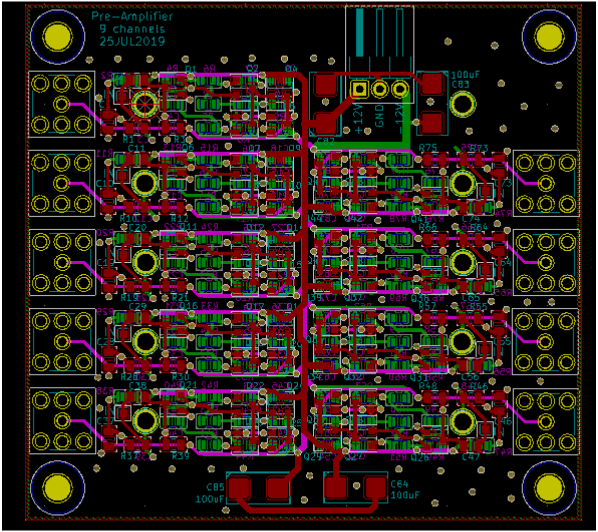
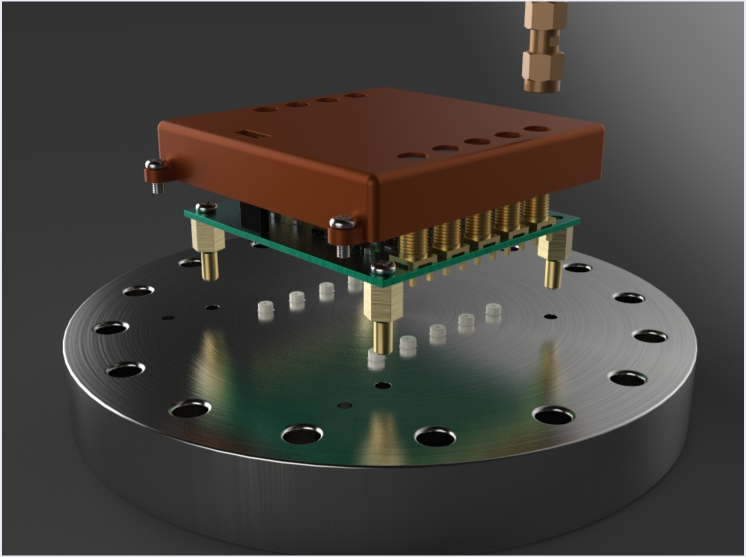


Figure: Layout for the 9 channel preamplifier which will be mounted on a CF-100 flange, the other side of which will hold the detector array.

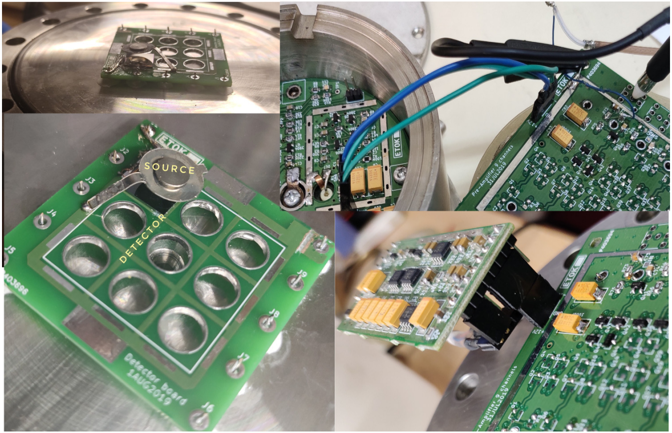
Multi-Pixel Preamplifier: Flange design

CAD design showing the preamplifier board mounted on a CF100 flange.

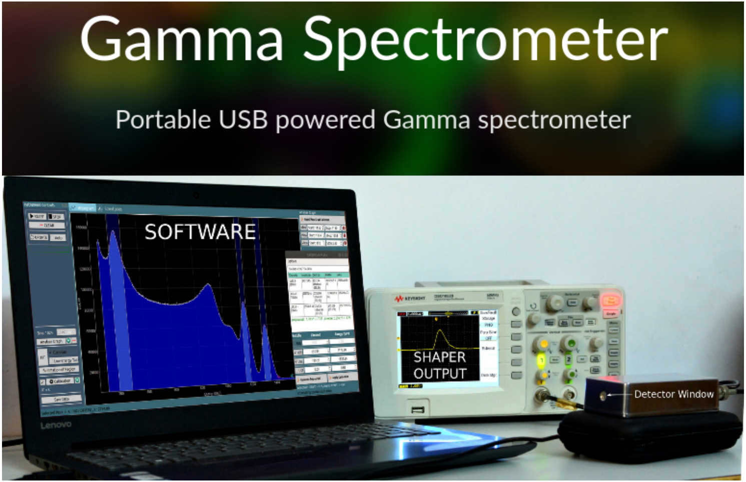


Progress made with multi-pixel detector array

- Different bandwidth op-amps were used to obtain fastest possible rise times from the preamplifier array.
- Feedthroughs Vacuum tested down to 10e-13 mBar.



Portable Gamma Spectrometer



Publications

Title	Journal	Author(s)
Indigenously developed gamma spectrometer	Proceedings of the DAE Symp. on Nucl. Phys. 63 (2018) 1072	Jithin B.P. and O.S.K.S. Sastri
Novel coincidence setup using indigenously developed portable USB gamma spectrometer and associated analysis software	Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment	Jithin B.P. and O.S.K.S. Sastri
Gated MCA technique for demonstration of coincidence phenomena with a set of indigenously developed gamma spectrometers	Recent Issues in Nuclear and Particle Physics (RINP2)	Jithin B.P. and O.S.K.S. Sastri
Compact dual-parameter MCA for γ-γ Coincidence Measurements	Proceedings of the DAE Symp. on Nucl. Phys. 64 (2019)	Jithin B.P. and O.S.K.S. Sastri
Background Gamma Radiation Surveying in the Indian Peninsula with a Portable USB Spectrometer	Proceedings of the DAE Symp. on Nucl. Phys. 64 (2019)	Jithin B.P. and O.S.K.S. Sastri
Gamma Spectra of Non-Enriched Thorium Sources using PIN Photodiode and PMT based Detectors	Physics Education-IAPT Volume 38: No 1. Jan-Mar 2020	Jithin B.P. , Swapna Gora V.V.V. Satyanarayana , O.S.K.S Sastri & Ajith B.P.

Electronics design and foundations

The following topics for electronics development were dealt with.

1. Preamplifier design. Transistor based, and Opamp based designs. Rise time comparisons were made, and parameters were optimised.
2. Shaping amplifier design. Sallen Key active filter based design.
3. Multi Channel Analyzer: 1K MCA with Peak sensing circuitry incorporated
4. Power supplies. Charge pumps used to generate bipolar signals from a single power source

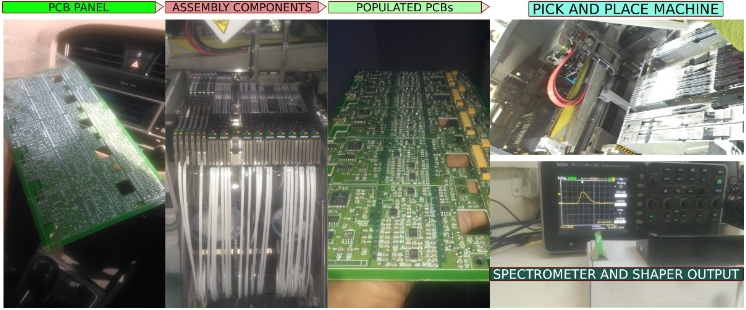


Figure: An overview of the electronics assembly process starting from PCB fabrication to automated assembly

The pre-amplifier output pulses, with typical rise time of around 1μs corresponding to the average decay time of the CsI scintillator, are shaped to a pseudo-gaussian signal with a shaping time of around 3μs. The shaping amplifier consists of a CR-RC-RC differentiator and integrator circuit[15] implemented using two active RC filters in the Sallen-Key configuration[21] as shown in Figure 15.

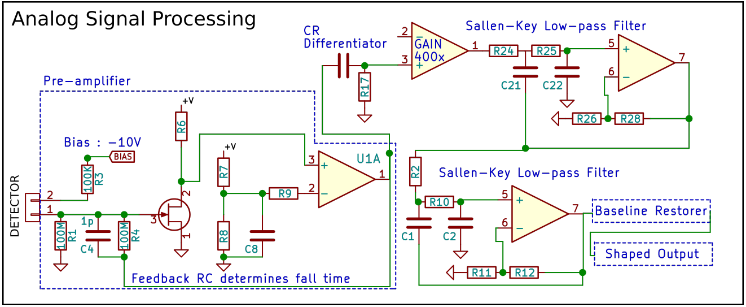


Figure: The analog signal processing circuits consisting of the pre-amplifier (inside the dotted box), and the two-stage shaping amplifier

Linearity Testing

linearity tests were carried out using a pulse generator.

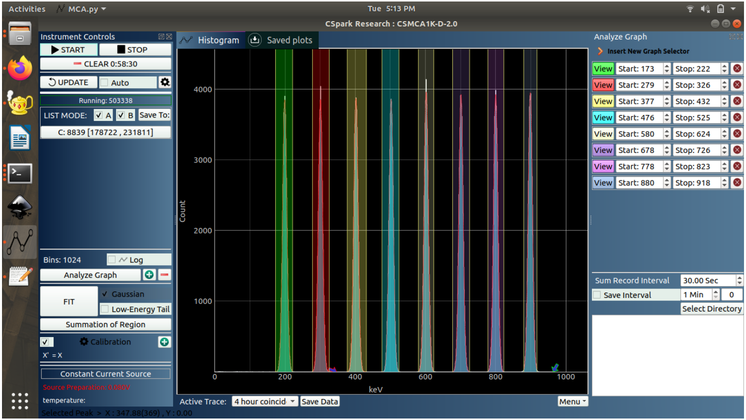
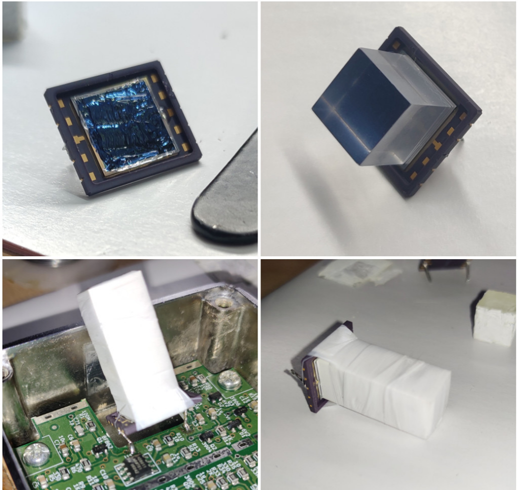


Figure: Results from Linearity testing. Pulses of varying heights were injected into the spectrometer using a charge terminator, and the instrument's linearity was tested in the full range.

Preparation of Gamma Detectors

Procured Cesium Iodide scintillators of various geometries, and prepared detectors by mating them with photodiodes. Obtained spectra of Cobalt-60, and compared efficiency as a function of detector size. Photopeak efficiency of 662 keV peak from cesium 137 improved from 30% to 36% when optical grease was used at the interface.



Custom Built gamma detectors: RESULTS

Windowed photodiodes need to be procured in order to get better results. The windowless photodiodes currently in use are easily damaged by optical grease.
This work is mentioned at the end of the NIMA paper as an extended goal. The aim is to develop the ability to create detectors of any geometry in order to maximize efficiency.

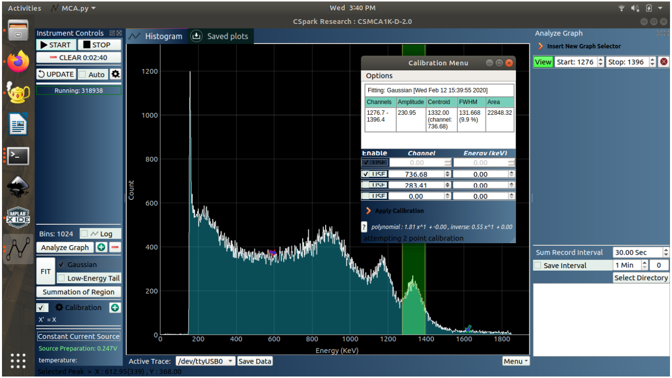
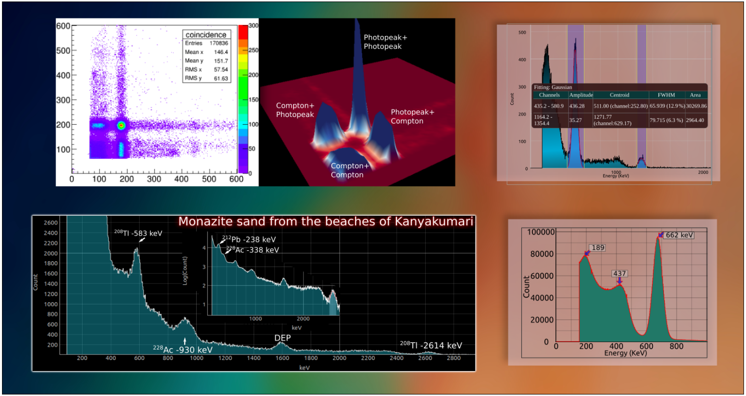


Figure: 60-Cobalt spectrum with a custom built scintillator with was 20mm long. optical grease at the interface of the scintillator and photodiode performs index matching, and increases light collection efficiency

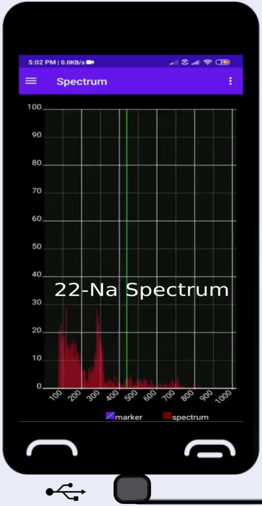
Example Spectra and Experiments

A summary of the various spectra obtained from the Gamma Spectrometer



Android App

An Android app was written to make this a truly portable system

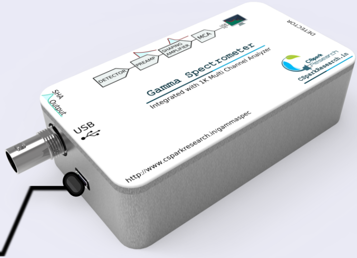


Written in Java using Android Studio

The spectrometer is connected to any android phone (SDK 18+) via USB OTG

Basic Capabilities implemented for START/STOP/VISUALIZE SPECTRUM.

Will be redesiged as a phone's back panel



Elementary Gamma-Gamma Coincidence demonstration

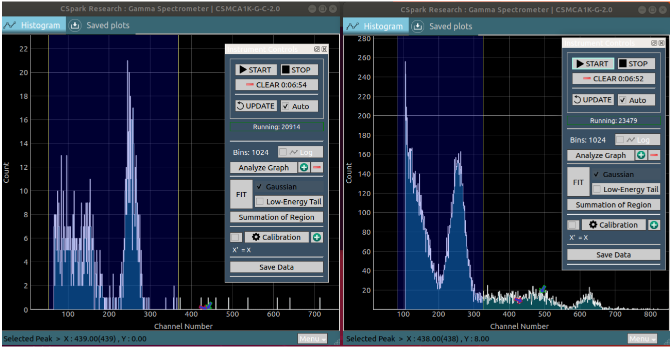
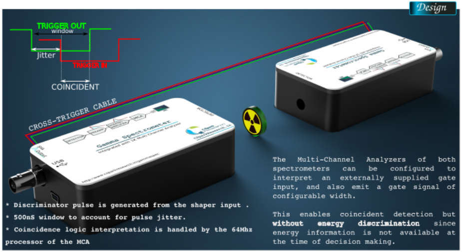
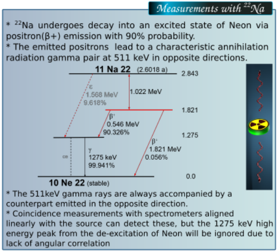


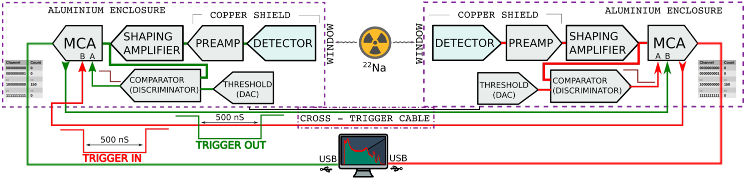
Figure: On the right is the full gamma spectrum from Na-22 which includes peaks at 1275keV, 511keV and their associated compton portion. On the left is the spectrum from a gated MCA configured for coincidence measurements

- Spectra shown is only preliminary, and the setup had several shortcomings.
- List mode data acquisition will be necessary, and has been implemented in the form of a dual parameter MCA.

Design of the simple coincidence demonstration setup







Radiation surveying. Paper Accepted in Physedu-IAPT

A paper comparing the spectrum from 1gm Monazite Sand (from Kerala. approximate activity of 330Bq from 232Th, and 30Bq from U_{nat}) with Thorium Nitrate salt in order to validate the usability of our gamma spectrometer for radiation safety applications was communicated to Physics Education. It has been accepted for Publication, and will appear in the next issue [7].
A poster for this work was also presented at the DAE symposium on Nuclear and Particle Physics 2019**BP2019**.

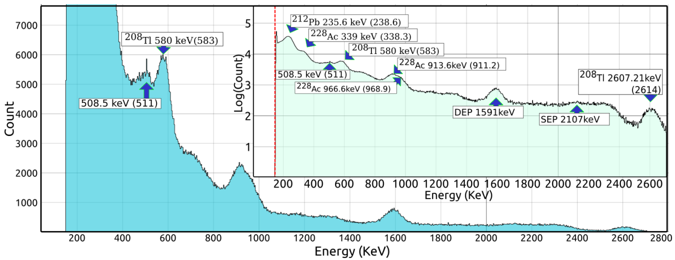


Figure: The Gamma spectrum of $ThNO_3$ powder obtained with GammaSpec1K spectrometer with CsI scintillator having volume $10mm * 10mm * 8mm$. Results accepted for publication

Performance Comparison with 3x3" NaI scintillator at IREL

Data acquired at IREL with 3" x 3" NaI scintillator based system

1g Monazite	Full	238 keV	583 keV	930 keV	2614 keV
Gross Counts	970787	287079	138376	103526	2761
Normalized	**1**	**0.295718**	**0.14254**	**0.106641**	**0.002844**

Data Acquired with our 1"x1" system. Satisfactory normalized ratio was measured.

Took overnight spectrum (14 Hours)

Total : 12,33,420

Fitting: Gaussian+Lorentzian tail [Sat Jan 12 10:36:03 2019]

Channels	Peak (Manual)	Centroid	FWHM	Total Counts (Normalized Ratio)
2480.0 - 2760.8	2623	2624.34 (channel:782.34)	130.653 (5.0 %)	**2097 (0.0017)**
1495.0 - 1718.0	1580	1587.35 (channel:473.20)	161.775 (10.2 %)	9895 (0.008)
873.9 - 1003.9	932	917.65 (channel:273.56)	3.055 (0.3 %)	**22685 (0.0183)**
193.4 - 294.4	234	228.25 (channel:68.04)	1.176 (0.5 %)	**347729 (0.282)**
505.6 - 660.2	583	580.61 (channel:173.09)	53.543 (9.2 %)	**72616 (0.06)**

Half a peak at 338 keV

POSTER: Radiation surveying. DAE SYMPNP 2019

Monazite : weakly radioactive sand found in the beaches of South India.
Composition : ^{232}Th and trace amounts of Natural Uranium. Has safe levels of radiation and is easily available
Activity : 1gm sample was measured as approx 300 Bq of ^{232}Th and 30Bq of nat/U in secular equilibrium with daughters. Table 1 shows Energy yield
*Its low activity required long acquisition times , and data in figure 1 was collected over 14 hours.

Nuclide	E(MeV)	Yield fraction	Emission Rate
^{228}Ac	0.129	0.024	7.8
^{228}Ac	0.209	0.0389	12.64
^{212}Pb	0.238	0.43	139.75
^{228}Ac	0.338	0.11	35.75
^{208}Tl	0.583	0.3	97.5
^{212}Bi	0.727	0.0658	21.39
^{228}Ac	0.911	0.258	83.85#
^{228}Ac	0.964	0.0499	16.22#
^{228}Ac	0.969	0.158	51.35#
^{208}Tl	2.614	0.35	113.75

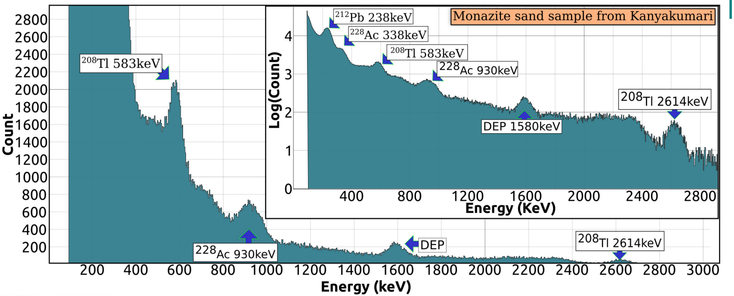
Table 1: Yield Fractions

Highlighted cells have relatively higher yield fractions.

These have been identified in our spectrum shown below.

Appears as a single broad peak at 930 keV.

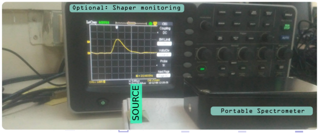
1gm Monazite Sand Gamma Spectrum



Efficiency Comparison

1gm Monazite with 3”x3” Scintillator				
Total	238 keV	583 keV	930 keV	2614 keV
970787	287079	138376	103526	2761
1	0.29571	0.1425	0.1066	0.00288
Monazite with 10mmx10mm scintillator				
Total	238 keV	583 keV	930 keV	2614 keV
12,33,420	347729	72616	22685	2097
1	0.282	0.06	0.0183	0.0017

Photograph

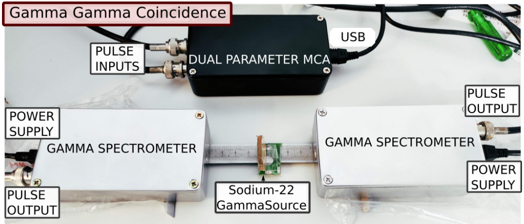


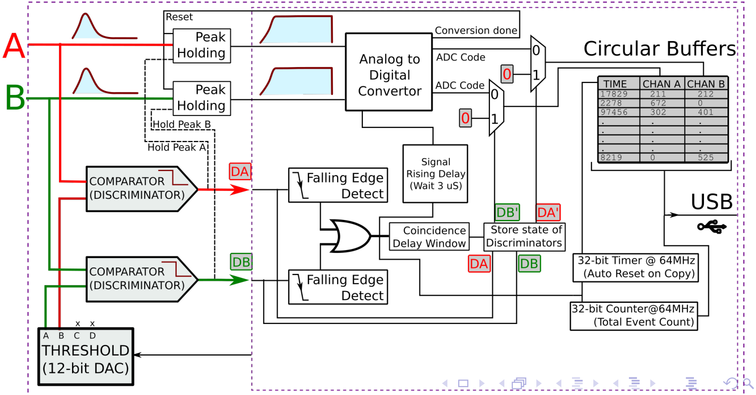
Overview of the Enhanced Gamma Coincidence setup

The following additional aspects were undertaken to create a $\gamma - \gamma$ coincidence setup which could overcome the limitations of the elementary design.

- Electronics Development : Dual Parameter Multi-Channel Analyzer.
  - Accepts two shaper inputs from two separate gamma spectrometers.
  - Separate discriminators with coincidence detection implemented in the firmware.
  - list mode acquisition with 1200 wide sample buffer for timestamp, peak1, and peak2.
- Hardware Development : Rotational stage for angular correlation measurement.
- Software : Data acquisition , analysis, & visualization for list mode data from the new MCA.
- Plotting of 2D histogram data.
- Experiments performed with 22-Na.

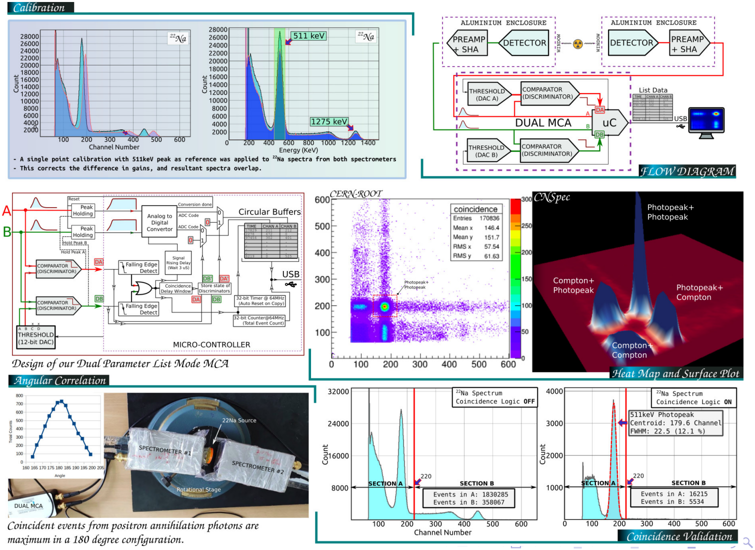
New arrangement with Dual Parameter MCA





POSTER: Coincidence Measurements. DAE SYMPNP 2019

This was presented at the DAE Conference in Mumbai, and later accepted for Publication in Nuclear Instruments and Methods in Physics Research - A .

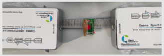


Development Process

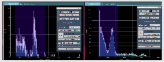
The design process for developing the instrument

Electronics Development
- Circuit development inclusive of all signal processing stages
- Designed Preamplifier, Shaping amplifier, MCA and power Supply
- Got PCB designs fabricated, assembled them by hand, and tested. Carried out robotic assembly

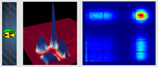
Mechanical Design
- Prepared CAD drawing using SolidWorks.
- die-cast aluminium boxes were electroplated for optimal appearance
- Exported 3D circuit model from KiCAD and adapted into the design



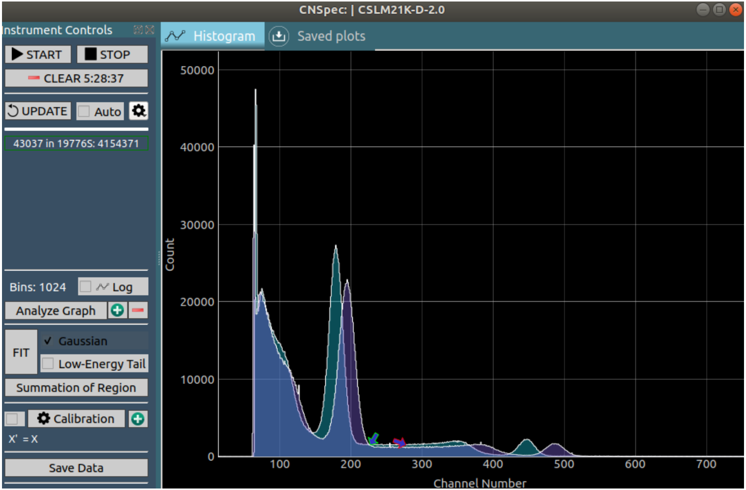
Acquisition Software
- Uses cross-platform open source libraries and languages
- Firmware written in C for MCA's microcontroller
- Software written in Python + Numpy, Scipy PyQtGraph, PyQt5.



Publications, Experiments
- Conferences: DAE - SYMPNP 2018 RINP2 - 2019
- Spectra from various gamma sources Co-60, Cs-137, Na-22
- Coincidence of 22-Na positron annihilation gamma via dual MCA.



Software development



The following features were implemented

- Capability to interpret list mode data
- Filtering data based on energy gates
- Plotting heat maps using CERN-Root
- Plotting 2D histograms using Pyqtgraph surfaces

2D Histogram(Heatmap) of 22-Na positron annihilation phenomena

Two spectrometers were placed facing each other, and a 22-Na source was placed in the center .

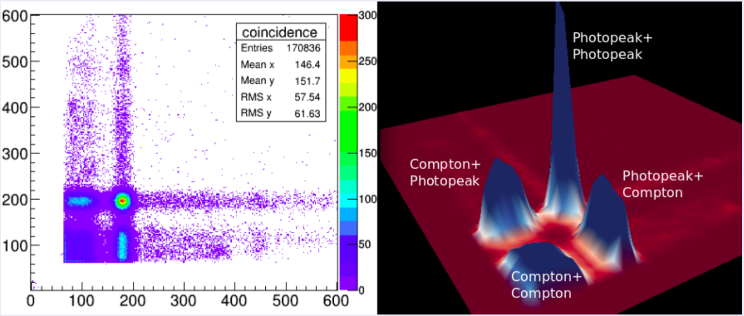


Figure: 2D histogram visualized as a heat map and a surface plot. This confirms the usability of the new design

Angular Correlation data from 22-Na positron annihilation

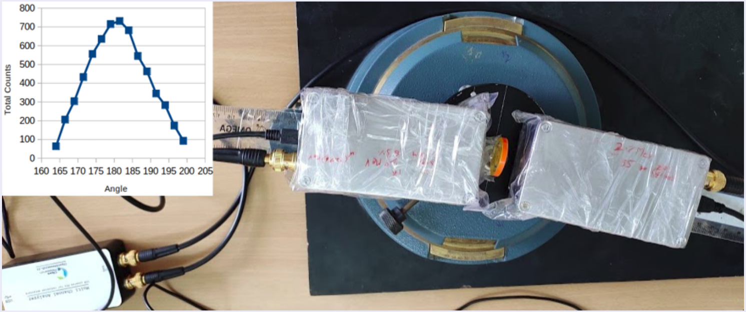


Figure: Angular correlation data further confirms the design's capabilities

I dismantled an optical spectrometer in order to use the rotary stage. Attached a gamma spectrometer on each of the telescopic forks, and acquired coincidence counts in 5 minute intervals for different angles subtended with a point source placed at the midpoint.

Science Hack Day, Belgaum

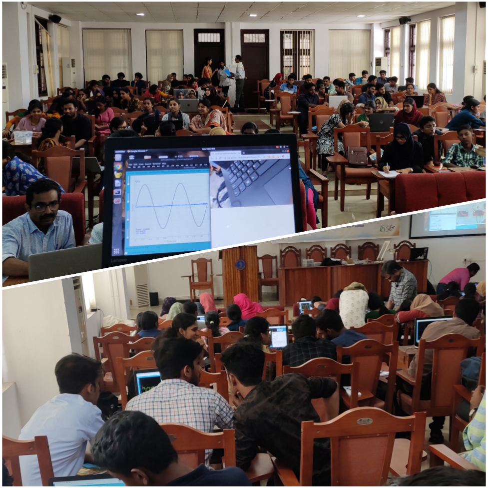
Co-Organiser at SHD 2019 . Conducted a workshop for 100 participants on developing timers and counter circuits. Delivered lightning talk on PhD research. Workshop on microcontroller based data acquisition systems development.

India Science Fest, IISER Pune

Ran a two day demo session at the India Science Fest organised at the Indian Institute of Science Education and Research. Over 10,000 people were estimated to have attended.

National Workshop on Nuclear Physics, Calicut University

Resource person at three day workshop on computer interfaced experiments, and two day workshop on nuclear physics experiments publicised by DAE, and hosted at Calicut University.



One Day Teacher Training Workshop, Surat

Organised a one day workshop on nuclear physics experiments at Sir P T Sarvajanik College of Science, Surat, as an invited speaker. Demonstrated various demos of generic science phenomena, half-life estimation, and gamma-gamma coincidence to teachers selected from various colleges across Surat.

Invited speaker for conducting a 2 hour session at scipy.in , IIT Bombay . Also delivered a lightning talk.

Future Course of Action

- Nuclear Instruments
  - In light of online migration, *learning by doing* is bound to suffer. This can be mitigated by developing virtual labs where data can be acquired remotely.
  - Especially for nuclear physics experiments, physical presence is not mandatory, and simple tasks such as source manipulation/switching can be done with actuators.
  - This also makes nuclear experiments safer since students do not need to handle sources physically, and can focus on data acquisition and analysis.
  - A framework built with Python Flask as the backend, and Ember.js as the frontend is in beta testing, and will be improved at a later date.
- CSpark Research
  - My company has developed a good network of clients in over 70 top institutions across India and abroad, and products deployed to over 2000 users. Efforts will be made to refine and add to the product line
  - Push open source platforms to assist schools and colleges in migrating to digital education.
  - Offer online courses on programming and develop a platform for catering to new and existing users.

Acknowledgements

I am indebted to my guide, Prof O.S.K.S. Sastri for enabling me to pursue this research and allowing tremendous creative liberties and decision making freedom. He has offered complete support in outreach programmes, and also popularized this research across domains.

This progress has been massively facilitated due to financial and material support via CSpark Research, a company whose foundation was actively encouraged by my father, Dr Ajith Kumar . His expertise as a particle physicist, has been instrumental in shaping this research. He has actively offered guidance, access to designs, and helped me define goals. My brother and mom have wholly supported me and contributed to design and manufacturing tasks.

Several professors from various institutes have offered their valuable time and resources to test and validate the designed equipment along with their students. *[IUAC,PU,CU,JU,PTSCE,CUK, DU,..]

Special thanks to the entire group - Jyoti Ma'am, Vandana Ma'am, Swapna, Aditi, and all my friends for making this a memorable experience.

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