Research and Software Portfolio

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Main Repository: github.com/ayushpriyadarshi-18/geant4-detector-simulation-pipeline

1. Research Profile

I am an Integrated BS–MS Physics student at the Indian Institute of Technology Roorkee with research experience in computational detector physics, Geant4-based Monte Carlo simulations, ROOT-based analysis, gamma-ray spectroscopy, scientific software development, and detector instrumentation.

My current research develops angle-resolved annihilation-photon correlation factors for coincidence-summing corrections in high-efficiency NaI(Tl) detectors. I am first and corresponding author of an annular-detector conference paper submitted to the DAE Symposium on Nuclear Physics 2026 on 8 September 2026, and I developed its public Python reproducibility package. This work is the validated annular stage preceding our ongoing application to a near-4π soccer-ball array.

I am interested in PhD research involving detector simulations, radiation detection, nuclear and particle instrumentation, scientific software, computational physics, and high-performance simulation workflows.

2. Current Research

Angle-Resolved Annihilation-Photon Correlation Factors for an Annular NaI(Tl) Detector

Institution: Department of Physics, Indian Institute of Technology Roorkee
Supervisor: Prof. Anil Kumar Gourishetty
Role: First and corresponding author; lead derivation, simulation analysis, software, validation, figures, and manuscript writing
Status: Submitted to the DAE Symposium on Nuclear Physics 2026 on 8 September 2026

This study establishes the angular factors needed to apply the coincidence-summing correction formalism to an annular NaI(Tl) detector before extending it to the more complex soccer-ball geometry. I corrected and extended an earlier unpublished mathematical treatment into a full-interval, angle-resolved formulation; analysed a one-million-event Geant4 11.3.2 simulation in 0.25° bins; implemented attenuation and peak-response weighting; and created a public Python package that reproduces the analysis.

The calculation gives a solid-angle coverage of 10.456 sr (83.205% of 4π) and the full-precision factors $w_{L1} = 1.260741$, $w_{L2} = 1.253825$, and $w_G = 1.269388$. Independent numerical methods agree, coefficient handling is checked against reference attenuation data, and the simulation physics is supported by experimental validation from the collaboration.

Public reproducibility package: github.com/ayushpriyadarshi-18/angular-factors-calculator

Coincidence-Summing Correction for β^+ Emitters in a Near-4π NaI(Tl) Detector Array

Institution: Department of Physics, Indian Institute of Technology Roorkee
Supervisor: Prof. Anil Kumar Gourishetty
Period: July 2026–Present
Status: Ongoing research; peer-reviewed journal manuscript planned with confirmed second authorship

High-efficiency detector arrays can record two or more coincident photons within the same resolving interval. For beta-plus emitters, the back-to-back 511 keV annihilation photons and an accompanying characteristic gamma ray can redistribute counts from individual photopeaks into sum peaks. Correcting this effect requires detector-specific information about the angular relationship between the annihilation photons and the nonuniform response of the surrounding detector geometry.

Prof. Gourishetty is developing the coincidence-summing correction formalism. My contribution is the computational implementation needed to apply and validate it:

- Extended my Geant4–Python platform with the detector, source, campaign, and analysis capabilities required for the study.
- Reconstructed the eight-block near-4π NaI(Tl) reference detector published by Byun et al. and reproduced its angular factors within a maximum relative difference of 2.3%.
- Implemented custom Geant4 sources directly from nuclear decay schemes, including emission probabilities, characteristic gamma rays, and back-to-back 511 keV annihilation photons.
- Completed 10^8-event campaigns for Na-22, O-14, and Sc-44.
- Calculated the geometry-dependent angular factors required for the 32-element TIFR soccer-ball detector array.

- Benchmarked the detector model against published experimental measurements for the physical TIFR soccer-ball array, with simulated efficiencies consistent within 5%.
- Validated the correction procedure against separate coincidence-free monoenergetic simulations.

The detector-specific factor values, detailed correction results, calculation tables, plots, and research code remain private until approved for public release by the supervisor.

From Research Platform to Scientific Study

Master's thesis: built a reusable simulation and analysis platform → **annular study:** established and publicly reproduced the angular-factor method → **soccer-ball study:** applied the method to the physical near-4π array → **next output:** separate peer-reviewed journal paper.

3. Master's Thesis and Continuing Research Platform

A Python-Assisted Geant4 Workflow for Automated Scintillation Detector Response Simulations

This project developed a Python-assisted Geant4 workflow for automated scintillation detector response simulations. The work combines a configurable Geant4 C++ simulation backend with Python automation scripts for campaign-level simulation and analysis.

The pipeline supports:

- Geant4 macro generation
- Simulation campaign execution
- ROOT-file validation
- Deposited-energy extraction
- Spectrum generation
- Peak-count extraction
- Total non-zero count extraction
- CSV/table generation
- Geometry and material comparison
- Public reference output generation

The workflow was developed as part of my master's thesis, consolidated into a public research software repository, and continues to be maintained and extended for current research.

Repository: github.com/ayushpriyadarshi-18/geant4-detector-simulation-pipeline

Software page: ayushpriyadarshi-18.github.io/software

4. Simulation and Analysis Workflow

The project connects the normally separate steps of a Geant4 detector-response study into a single reproducible workflow.

1. Define detector geometry, material, source, and event statistics.
2. Generate Geant4 macro files using Python.
3. Execute Geant4 simulations using the configured C++ backend.
4. Validate ROOT outputs and check simulation completion.
5. Extract deposited-energy quantities from ROOT trees.
6. Generate gamma-ray spectra.
7. Extract counts in photopeak and sum-peak windows.
8. Merge outputs into final CSV tables.
9. Store spectra, logs, macros, ROOT files, and tables as traceable outputs.

This structure makes it easier to repeat large simulation campaigns, compare geometries and materials, and preserve analysis consistency across runs.

5. Detector Geometries

The workflow was tested on multiple scintillation detector geometries.

Solid Cylindrical Detector

A conventional cylindrical scintillation detector geometry was implemented for baseline detector-response studies. This geometry is useful for studying size dependence, material dependence, and comparison with standard gamma-ray detector configurations.

Hollow Annular Detector

A hollow cylindrical detector geometry was implemented to study higher solid-angle coverage around a central source region. This geometry is relevant for coincidence and sum-peak studies where geometric efficiency is important.

Near-4π Soccer-Ball Detector

A custom near-4π modular detector geometry was implemented using pentagonal and hexagonal detector elements arranged around a central cavity. This geometry was designed to explore high-coverage scintillation detection and sum-peak response in compact detector assemblies.

6. Detector Materials and Sources

The workflow supports detector-response comparison across multiple scintillator materials, including NaI, LaBr3, CsI, BGO, GGAG, and PbWO4.

The simulation campaigns included monoenergetic gamma-ray sources and radioactive-decay cases. Public reference demonstrations were prepared using Cs-137 simulations across multiple detector geometries.

The analysis extracts deposited-energy spectra and peak-window counts, including photopeak counts, sum-peak counts, and total non-zero energy-deposition counts.

7. ROOT-Based Analysis

The analysis stage uses ROOT output files produced by the Geant4 backend. Python scripts validate the ROOT files and extract deposited-energy quantities from the event tree.

The extracted quantities are used to generate:

- Deposited-energy spectra
- Log-scale spectrum plots
- Peak-window count tables
- Total non-zero count summaries
- Combined CSV result tables

This made the workflow useful not only for running simulations, but also for automatically producing analysis-ready outputs.

8. High-Performance Computing Validation

The workflow was tested on the PARAMGanga high-performance computing facility at IIT Roorkee. High-statistics simulations, including 10^8-event Cs-137 runs, were performed to test whether the same Geant4–Python workflow could scale beyond small local reference simulations.

The HPC validation demonstrated that the pipeline structure could support both lightweight local tests and larger simulation campaigns.

9. Research Software Output

Angular Factors Calculator

Role: Lead Developer and Maintainer
Repository: github.com/ayushpriyadarshi-18/angular-factors-calculator

This public Python package reproduces the annular-detector study from ROOT angular histograms and documented detector parameters. It provides ROOT-file inspection and analysis, coefficient-based factor calculation, dual numerical methods, machine-readable JSON and CSV outputs, automated regression tests, continuous integration, citation metadata, and a command-line interface. The package separates the reusable angular-factor calculation from the larger private detector-simulation workflow.

Geant4 Detector Simulation Pipeline

Role: Developer and Maintainer
Repository: github.com/ayushpriyadarshi-18/geant4-detector-simulation-pipeline

The public repository contains:

- Geant4 C++ source code
- Python automation scripts
- Example macro files
- ROOT output validation tools
- Spectrum-generation scripts
- Count-extraction scripts
- Reference spectra
- CSV result tables
- Logs and visualisation files

The repository serves as both a research output and a reproducibility package for the thesis work.

The current beta-plus-emitter study uses a privately extended working copy. Unpublished source models, detector-specific calculations, and research outputs are intentionally excluded from the public repository pending manuscript development and supervisor approval.

10. Manuscripts and Conference Presentations

A. Priyadarshi, R. Chauhan, A. Srivastava, and G. Anil Kumar, "Angle-resolved annihilation-photon correlation factors for an annular NaI(Tl) detector," submitted to the DAE Symposium on Nuclear Physics, 2026. Submission date: 8 September 2026.
Role: First and corresponding author.

A first-author conference paper based on this work has been accepted for poster presentation at IEEE Nuclear Science Symposium 2026.

A. Priyadarshi, G. A. Kumar, K. Madhan, and V. Ranga, "A Python-based Tool for Automated Geant4 Simulations of Scintillation Detectors," accepted for poster presentation at IEEE Nuclear Science Symposium, 2026.
Status: Accepted for poster presentation.

11. Related Instrumentation and Systems Projects

Radio Telescope Control and Embedded Linux Support

I contributed to Raspberry Pi-based embedded Linux and hardware-control support for a student-led radio telescope project under the Physics and Astronomy Club, IIT Roorkee. This work involved custom Raspberry Pi image preparation, boot configuration modifications, networking over a power/data port, support for an initially unsupported Wi-Fi module, and hardware-control integration.

Raspberry Pi Home Server and Network Gateway

I designed and maintain a Raspberry Pi-based home server for self-hosted services, home automation, file sharing, reverse proxy services, DNS filtering, and network gateway functionality. This project strengthened my practical Linux, networking, Docker, and systems-administration experience.

WiFi IP Mouse

I built a Raspberry Pi-based WiFi IP mouse system during the Syntax Error Hackathon organised by SDS Labs, IIT Roorkee. The project won First Prize and involved network-based device control under hackathon time constraints.

12. Technical Strengths

- Geant4 detector simulation
- Python automation
- ROOT-based analysis
- C++ simulation backend development
- Scientific software workflows
- Linux-based development
- Git-based version control

- HPC simulation execution
- Detector-response modelling
- Gamma spectroscopy analysis
- Coincidence-summing analysis
- Custom radioactive-source modelling
- Raspberry Pi and embedded Linux systems
- Scientific instrumentation and hardware-control support

13. Research Direction and Application Areas

For PhD research, I am interested in applying and extending my experience in computational detector physics, simulation automation, scientific software, and scientific instrumentation.

The skills developed through my Geant4–Python detector simulation work are broadly applicable to multiple areas of physics, including:

- Nuclear and particle detector simulation and instrumentation
- Radiation detection and gamma spectroscopy
- Astroparticle, cosmic-ray, and space-radiation studies
- Reactor, neutron, accelerator, and radiation-transport studies
- Scientific software and high-performance Monte Carlo workflows

My strongest current direction is toward groups working on detector-response modelling, Geant4 simulations, radiation detection, nuclear or particle instrumentation, and computational tools for experimental physics.