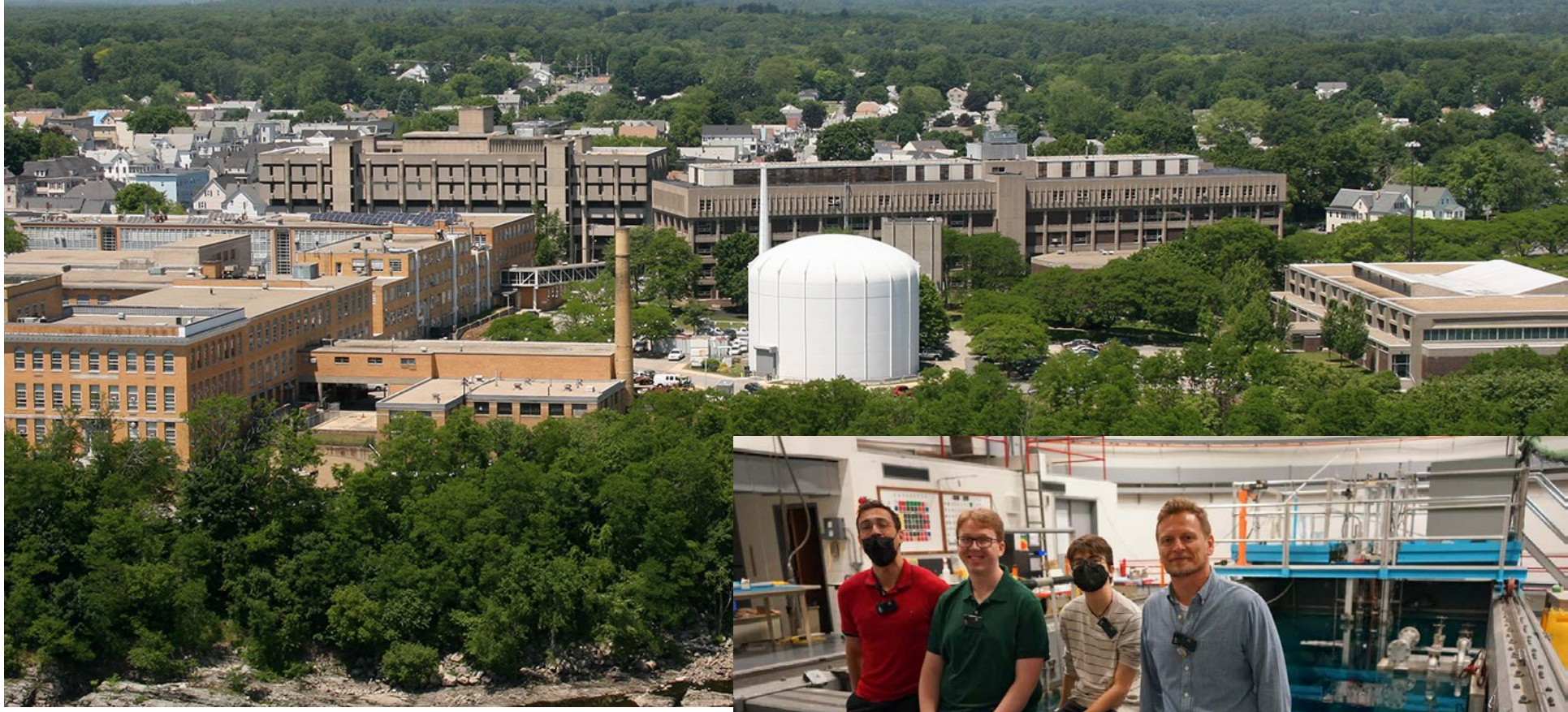
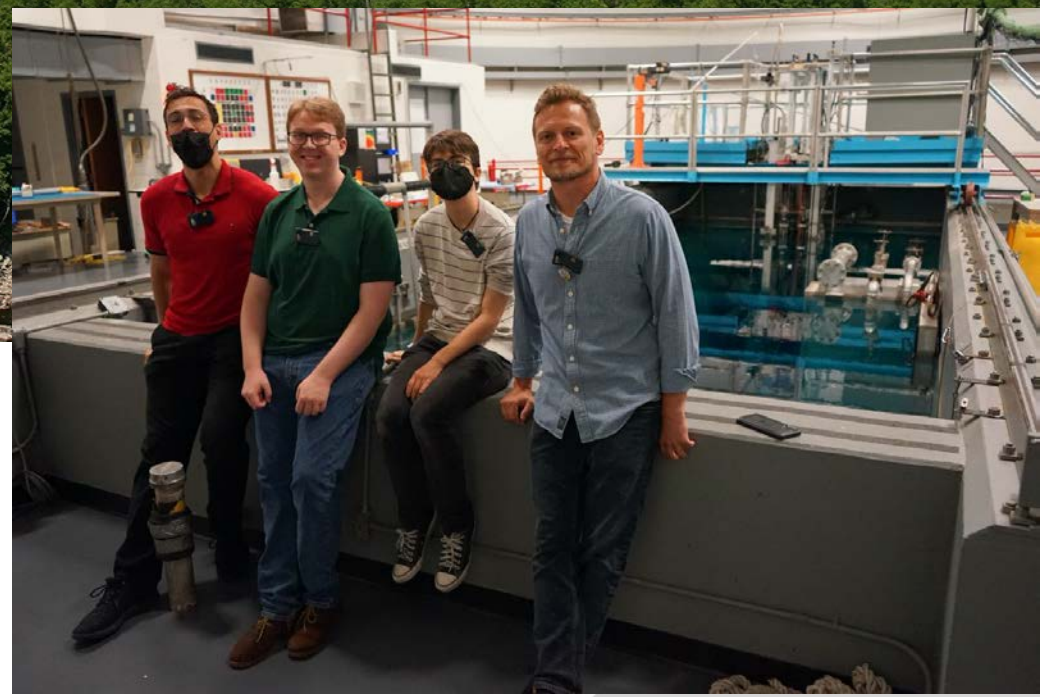


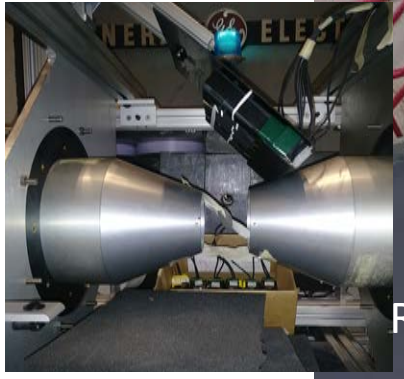


MARIAN JANDEL

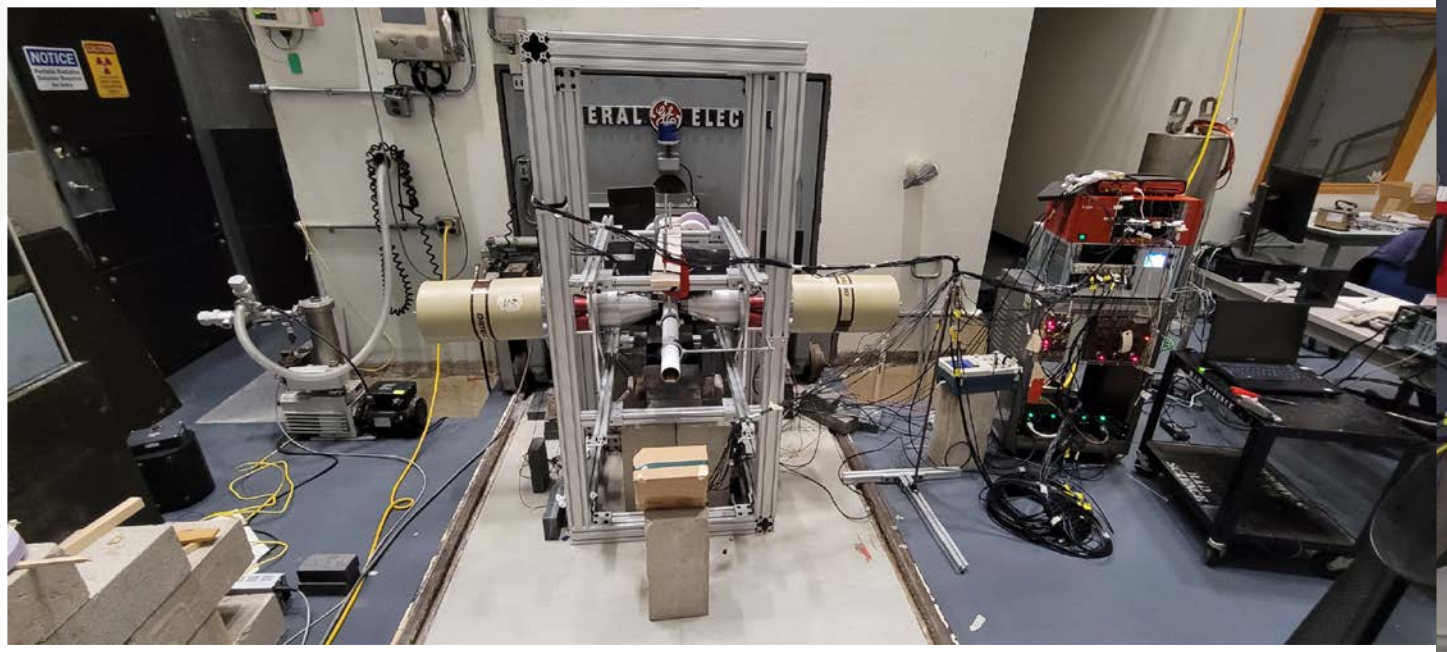
PHYSICS AND APPLIED PHYSICS
UMASS LOWELL

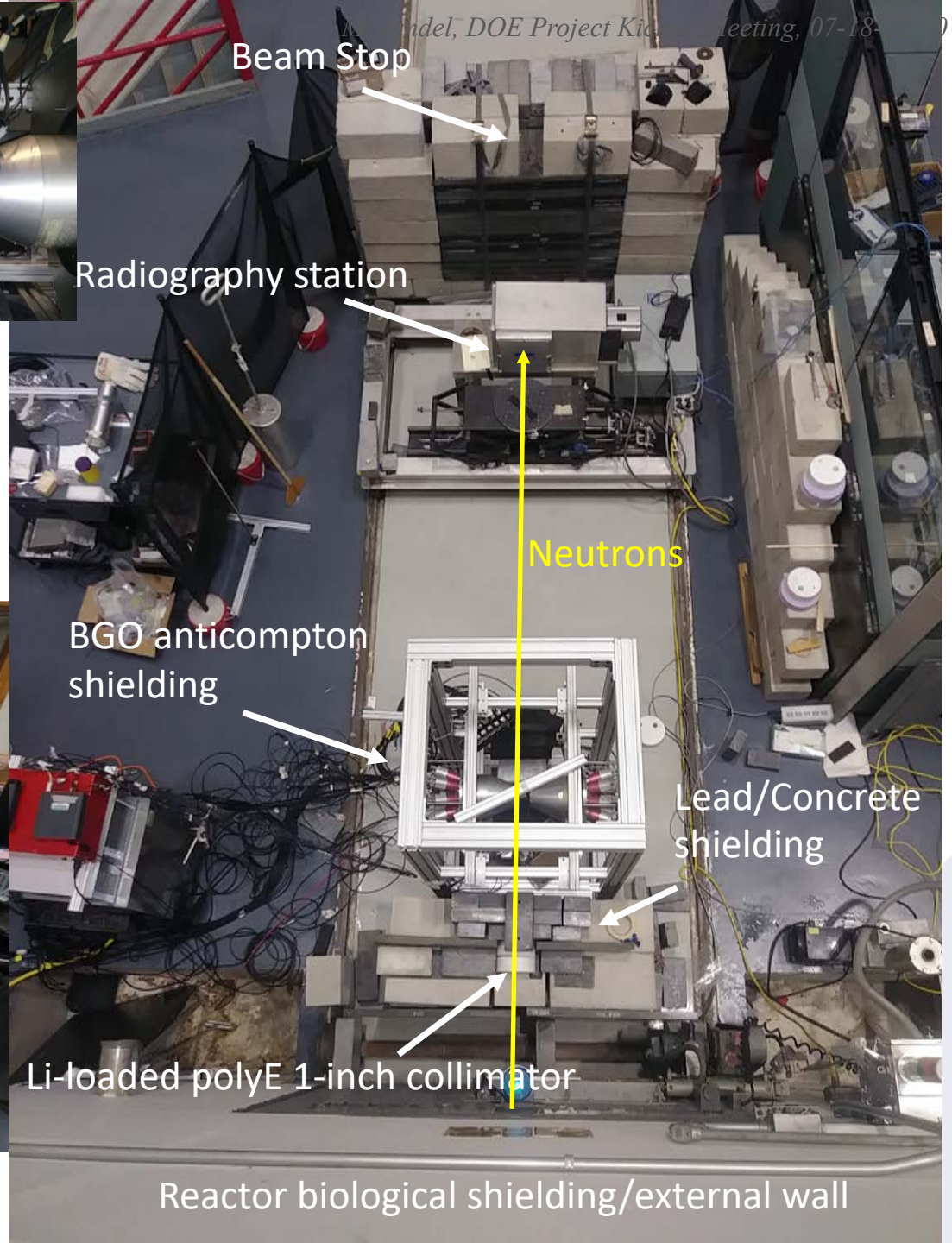
SOLVING THE ^{56}MN PUZZLE

MAD: MIXED ARRAY OF DETECTORS MEASUREMENTS



- First data obtained in 2021
- Using thermal neutrons from 1MW research reactor
- Flux ~ 5 x 10^5 n/cm^2/s

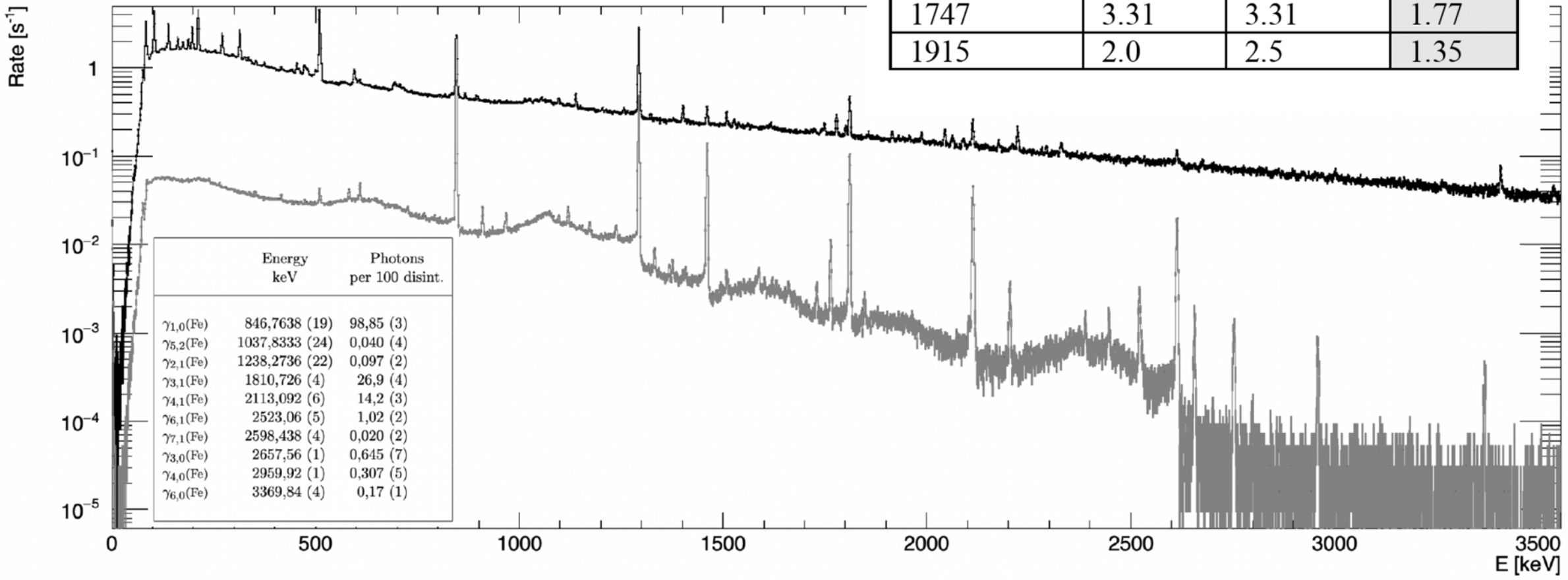




UML – DATA ON ^{55}MN(N,G)

PGNAA spectrum from ^{55}Mn(ng) (top) /
Beta-decay of ^{56}Mn (below)

Eg [keV]	Ig[%] EGAF	Ig[%] ENSDF	Ig[%] UML
212	15.9	10.6	11.9
271.2	7.04	5.7	5.9
314.4	10.9	9.4	8.5
1401	3.5*	0.88	3.4
1705	1.39	1.39	<0.5
1747	3.31	3.31	1.77
1915	2.0	2.5	1.35



	Energy keV	Photons per 100 disint.
$\gamma_{1,0}$(Fe)	846,7638 (19)	98,85 (3)
$\gamma_{5,2}$(Fe)	1037,8333 (24)	0,040 (4)
$\gamma_{2,1}$(Fe)	1238,2736 (22)	0,097 (2)
$\gamma_{3,1}$(Fe)	1810,726 (4)	26,9 (4)
$\gamma_{4,1}$(Fe)	2113,092 (6)	14,2 (3)
$\gamma_{6,1}$(Fe)	2523,06 (5)	1,02 (2)
$\gamma_{7,1}$(Fe)	2598,438 (4)	0,020 (2)
$\gamma_{3,0}$(Fe)	2657,56 (1)	0,645 (7)
$\gamma_{4,0}$(Fe)	2959,92 (1)	0,307 (5)
$\gamma_{6,0}$(Fe)	3369,84 (4)	0,17 (1)

UML – DATA ON ^{55}MN(N,G)

Activation/Decay of Mn-56

Eg [keV]	Ig[%] EGAF	Ig[%] ENSDF	Ig[%] UML
212	15.9	10.6	11.9
271.2	7.04	5.7	5.9
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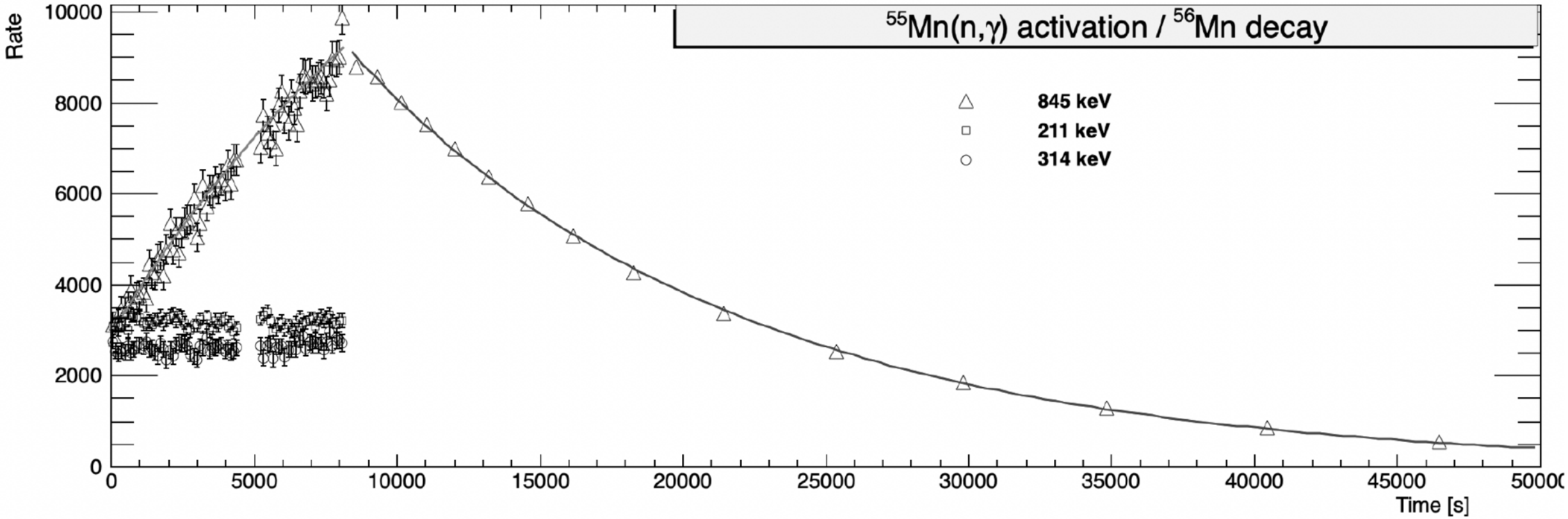
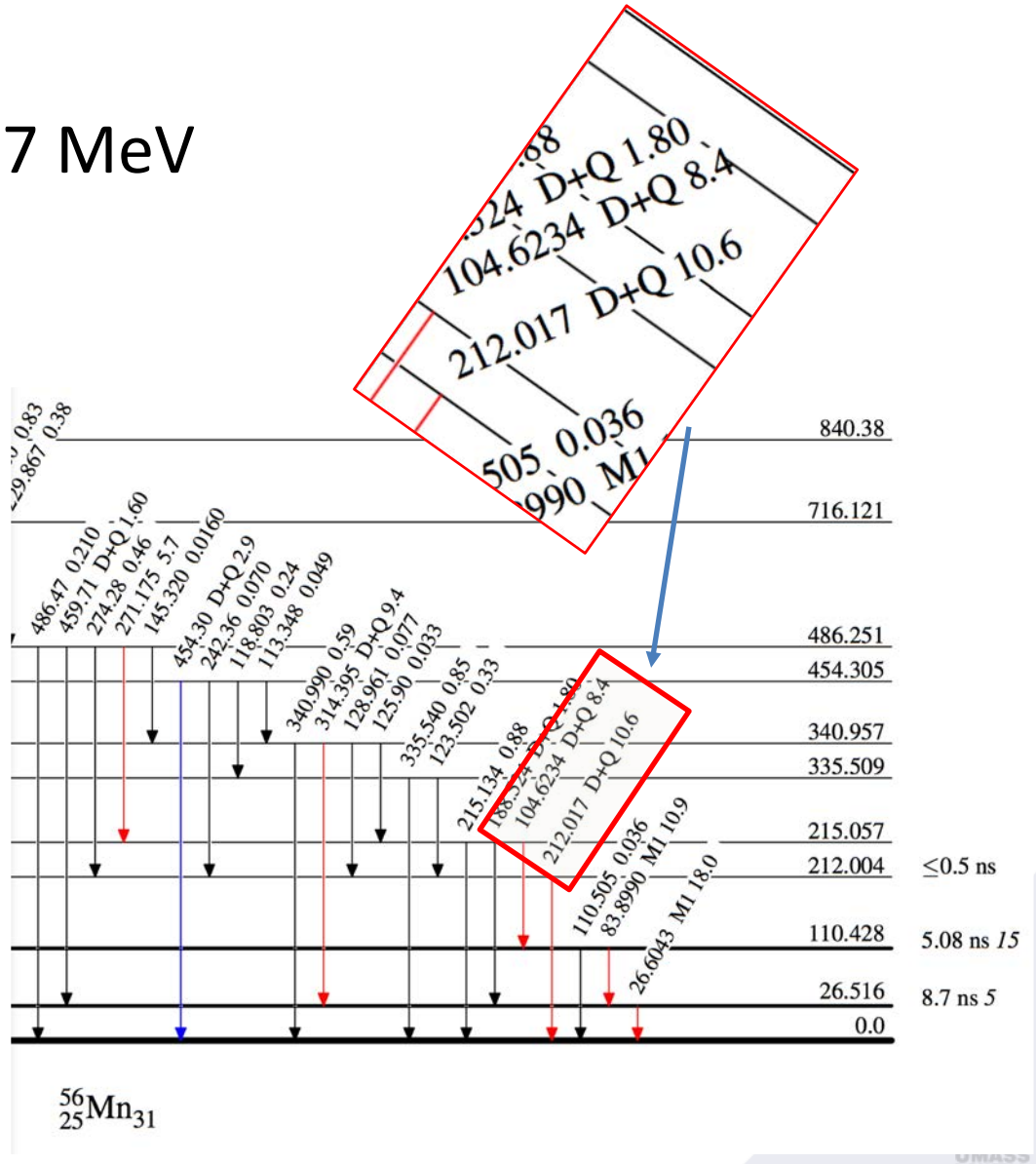


MOTIVATION FOR THE PROJECT: 56MN CAPTURE GAMMA

Mn-56 capture gammas (ENDSF):
Low lying 212 keV has smaller intensity as 7 MeV transition feeding it

7058 keV (11.0 %) ??
212 keV (10.6 %) ??

- Precise data needed also for discrete gamma rays – elemental/isotope identification
- PGNAA – prompt gamma neutron activation analysis – forensics, space exploration etc.
- Gaps and discrepancies found in data
- Improve ENDF to ENDSF correspondence

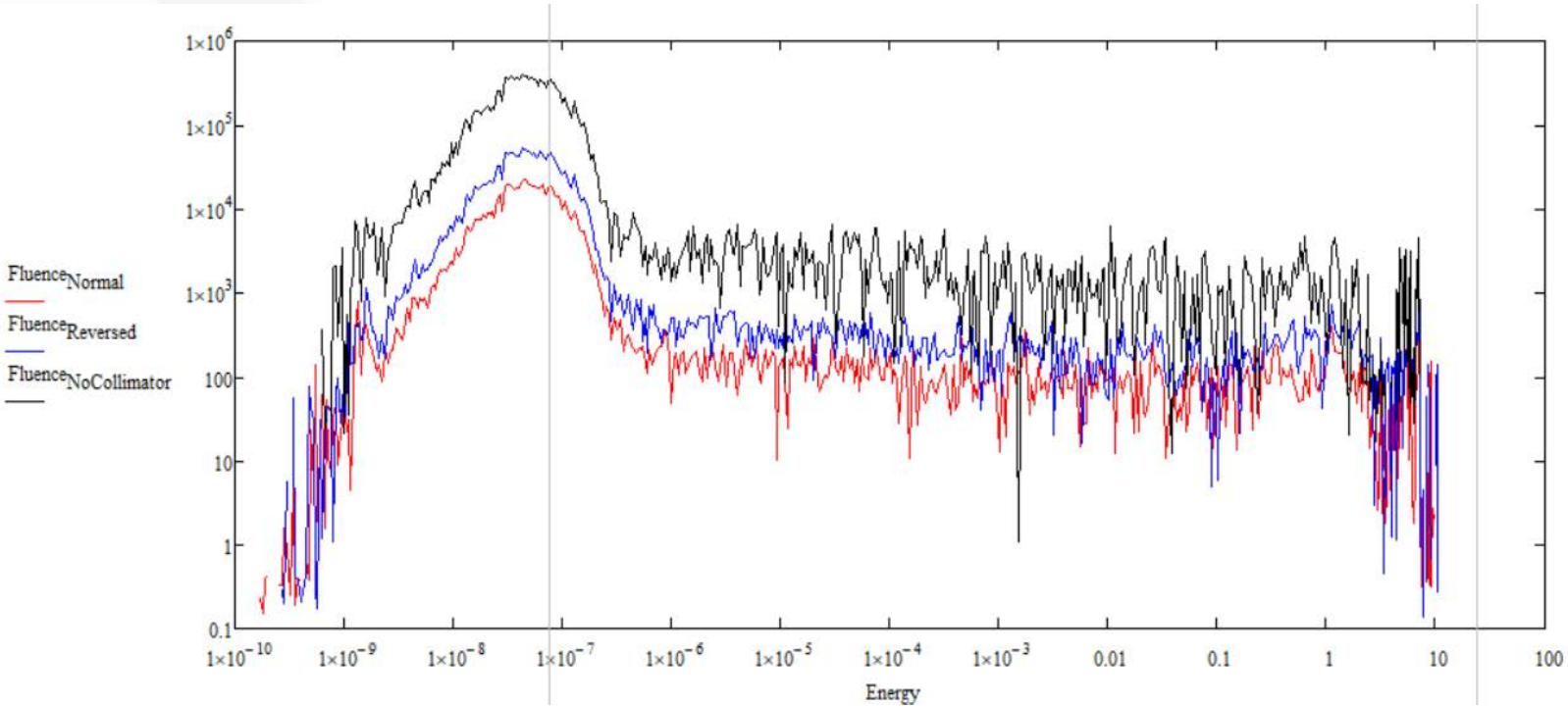


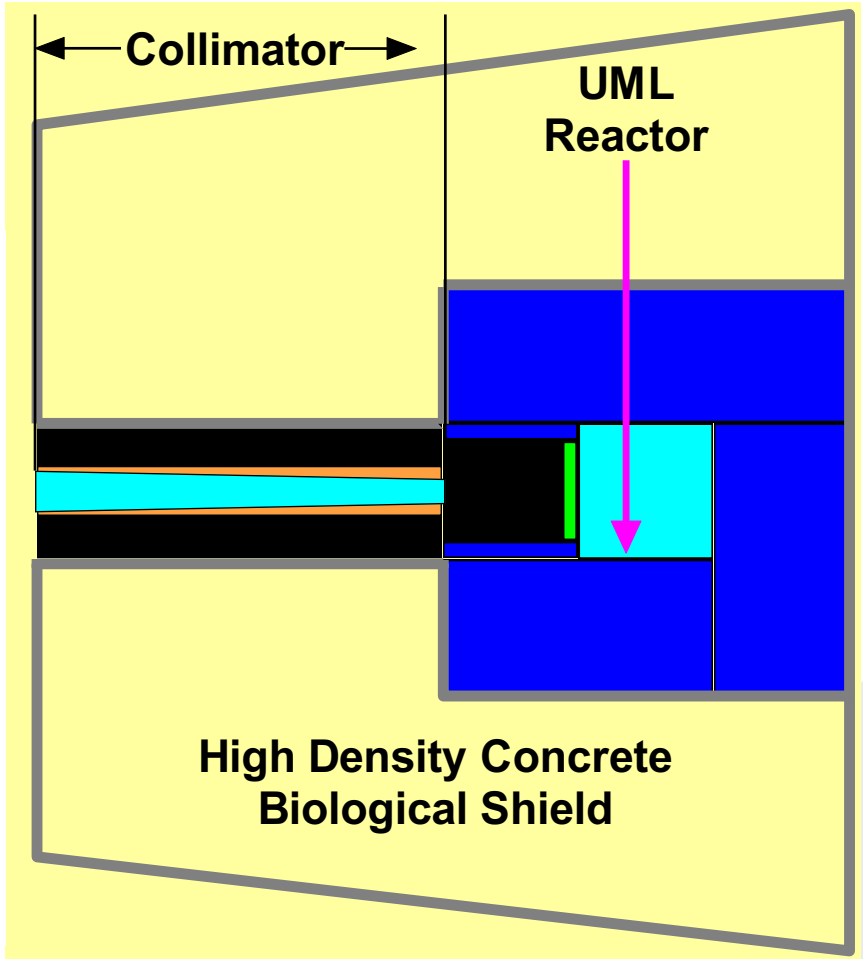
TASKS/MILESTONES

- **Task 1) Optimize the collimated beam of thermal neutrons and sample holder.**
  - **Milestone 1.1: Year 1, month 12 -** Well characterized low background well collimated beam of thermal neutrons.
- **Task 2) Design and install** the **M**ixed **A**rray of **D**etectors (**MAD**).
  - **Milestone 2.1: Year 1, month 6** - Finished and evaluated Geant4 models of MAD variants.
  - **Milestone 2.2: Year 2, month 6** - Benchmark the MAD configuration with Geant4 model.
- **Task 3) Optimize the data acquisition system (DAQ) for** the **M**ixed **A**rray of **D**etectors (**MAD**)
  - **Milestone 3.1: Year 1, month 12** - Production data ready DAQ
- **Task 4) Carry out coincident measurements of high-resolution capture gamma rays**
  - **Milestone 4.1: Year 2, month 6 -** Production data collected on ^{55}Mn(n,g) reaction.
- **Task 5) Perform calculations of Mn56 decay using DICEBOX and couple with Geant4.**
- **Task 6) Design algorithms that will optimize the model parameter space to match measured data.**
- **Task 7) Identify isotopes where nuclear structure data can be improved.**
-

TASK 1

- **Task 1) Optimize the collimated beam of thermal neutrons and sample holder.**
  - **Milestone 1.1: Year 1, month 12 -** Well characterized low background well collimated beam of thermal neutrons.
- The calculations in MCNP6
- Collimator can be flipped or removed to gain **18 x** more flux





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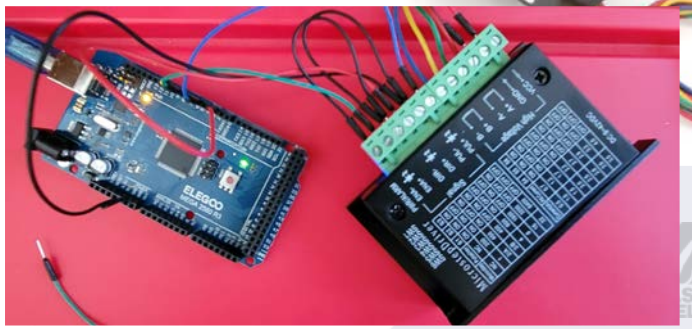
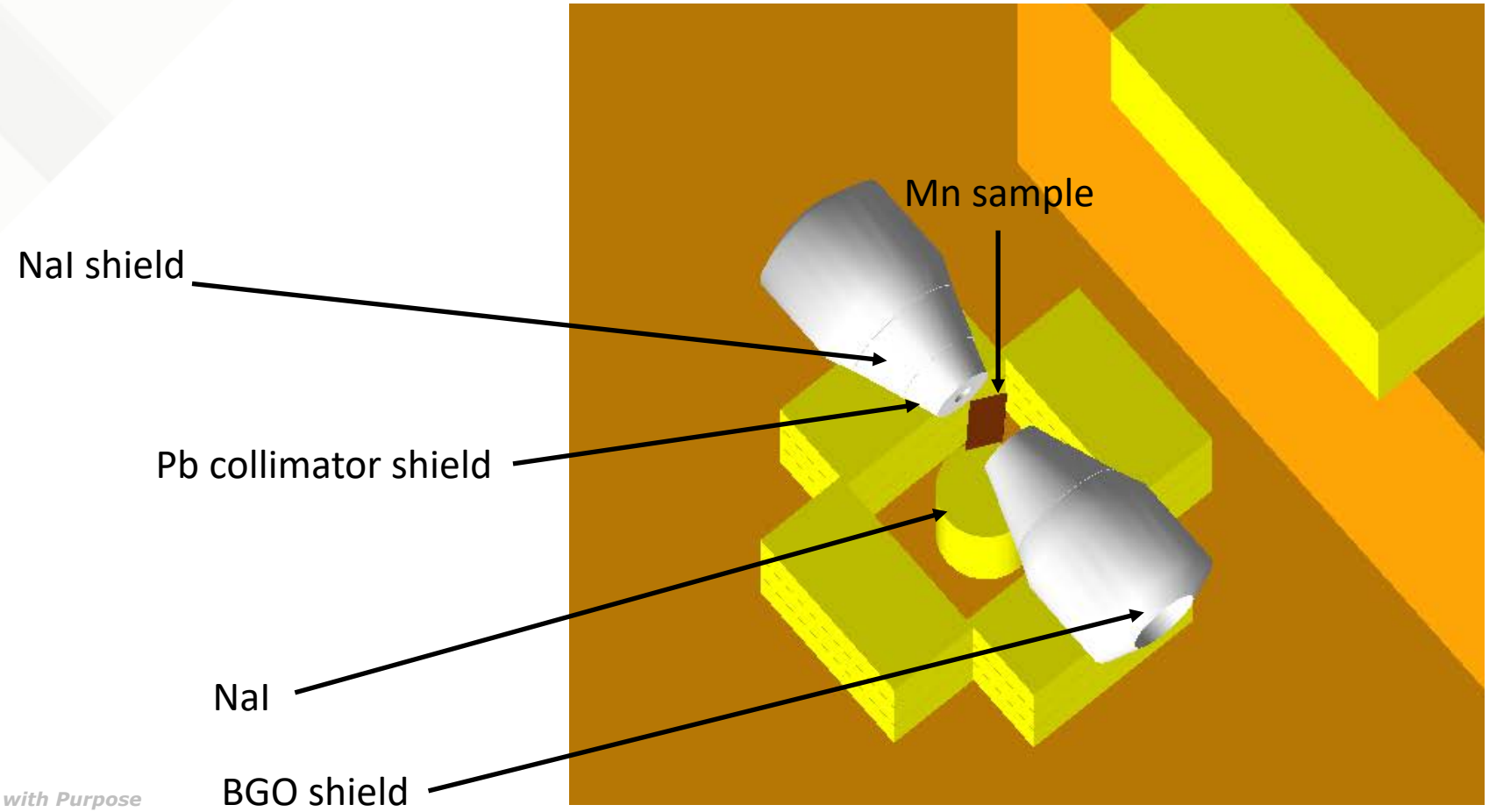
TASK 1: SAMPLE HOLDER

- Task 1) Actuator control designed by M. McGlynn
- Sample holder- 3D printed by Alex Howe



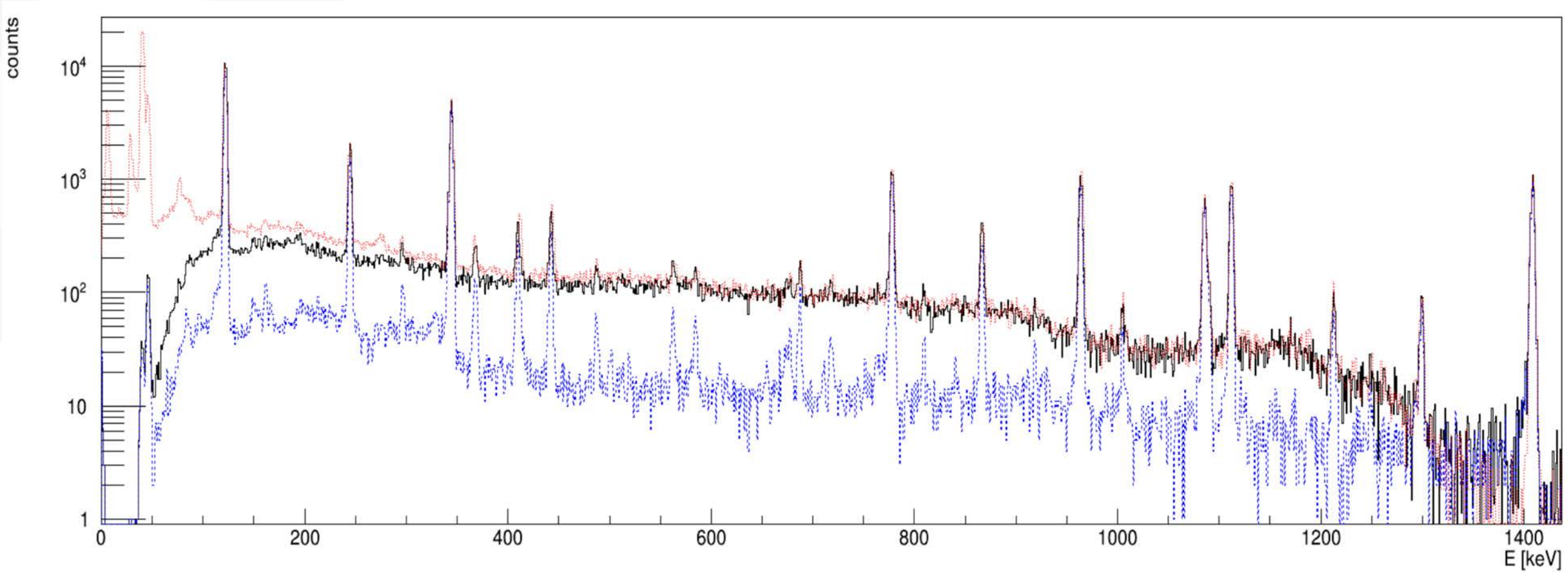
TASK 2 – ALEX HOWE MSC THESIS

- **Task 2) Design and install** the **M**ixed **A**rray of **D**etectors (**MAD**).
  - **Milestone 2.1: Year 1, month 6** - Finished and evaluated Geant4 models of MAD variants.
  - **Milestone 2.2: Year 2, month 6** - Benchmark the MAD configuration with Geant4 model.



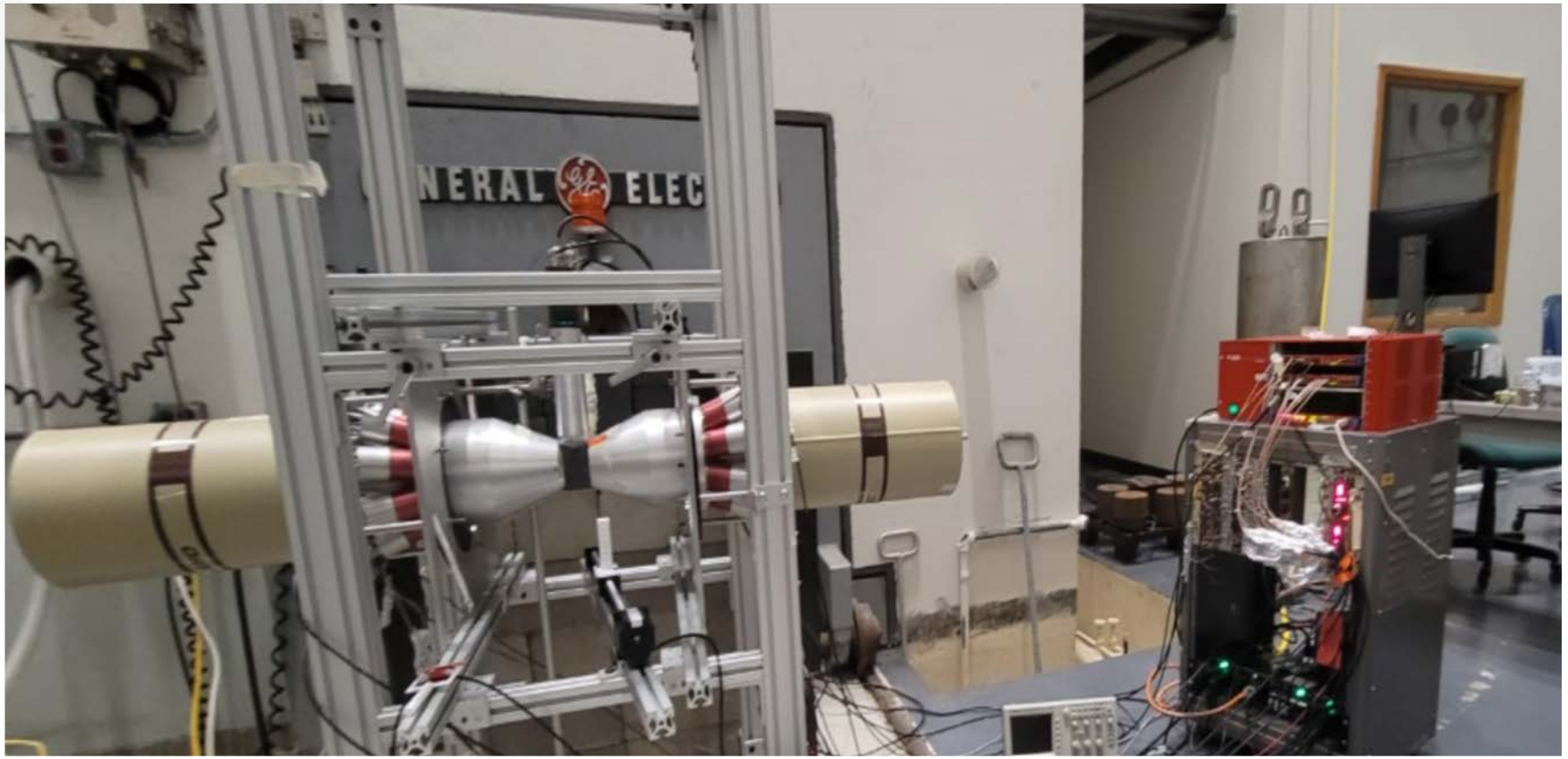
COMPARISON TO GEANT4 MODEL

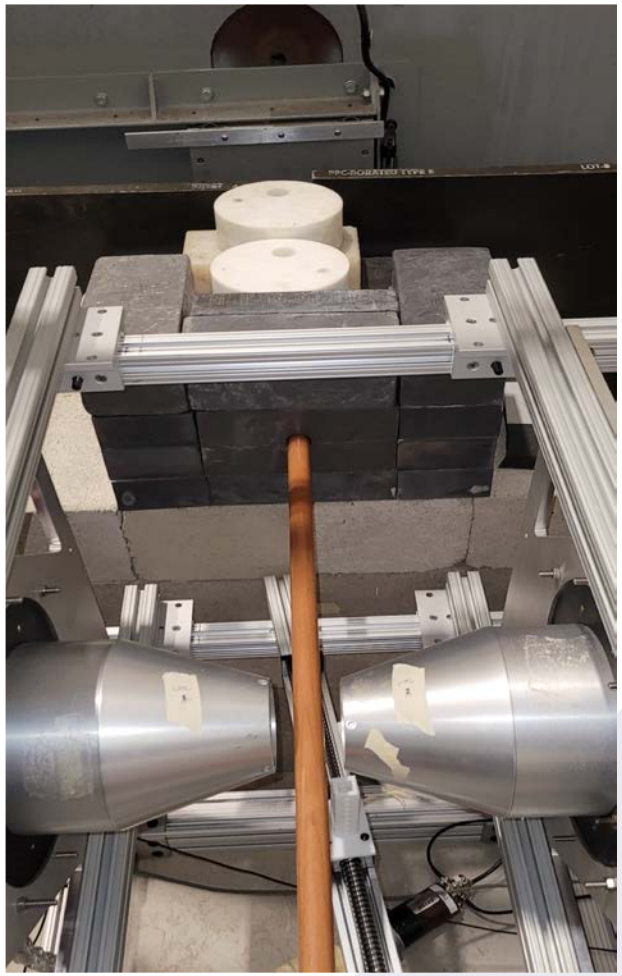
- Eu152 - red: Geant 4 black line: measurement blue: Compton suppressed data



TASK 2

- The **M**ixed **A**rray of **D**etectors (**MAD**) was installed in January 2023





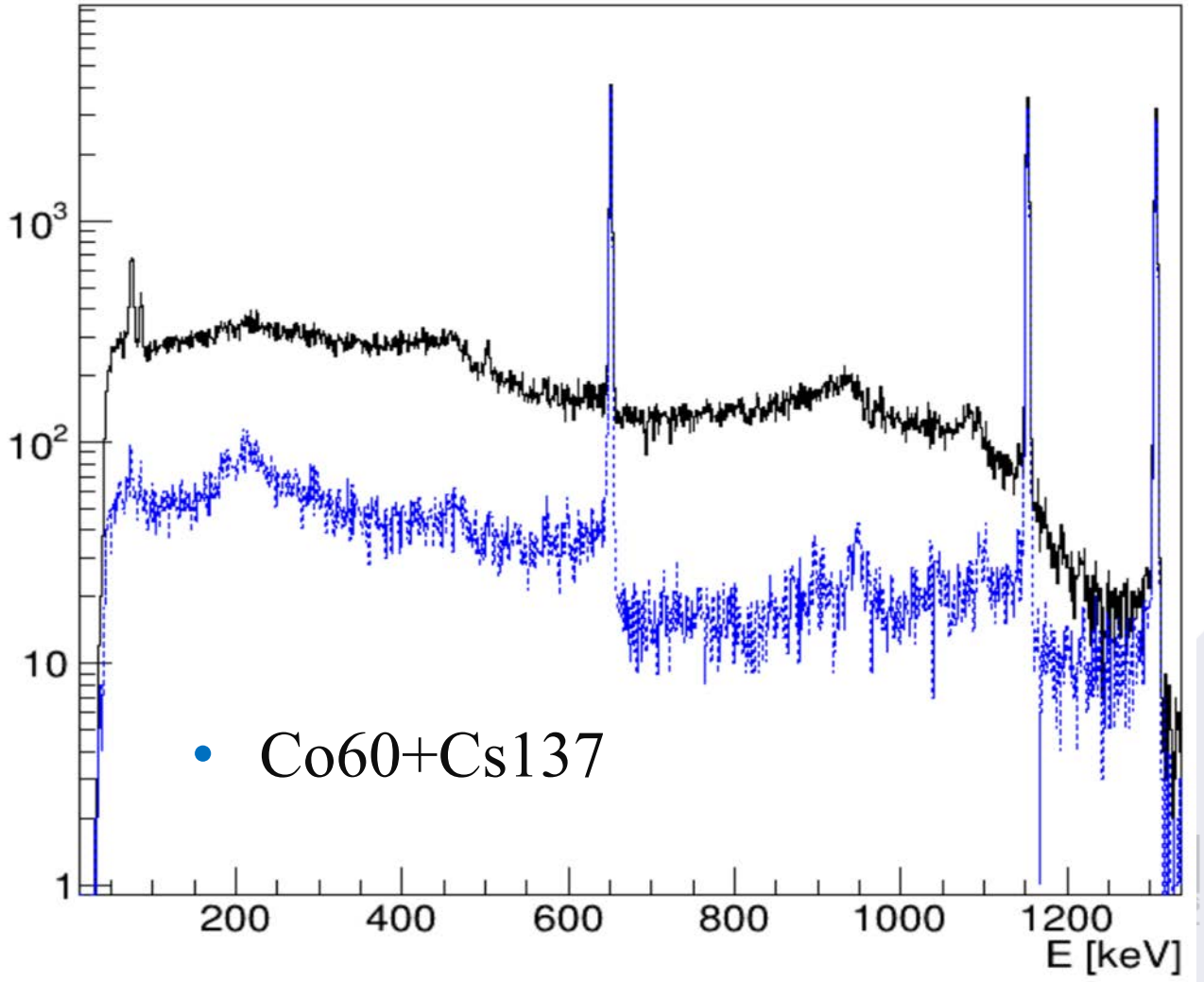
TASK 3 – PRODUCTION READY DAQ

- UMLDAQ – based on CAEN hardware, software drivers and C++ libraries
- Asynchronous data acquisition using FPGA digital pulse processing
- 16 channel 14-bit 500-MHz CAEN V1730S
- **2 x 8 channel 14-bit 250-MHz CAEN V1730SB (arrived in November 2022)**
- In house DAQ frontend and backend codes
- Off-line coincidence analysis down to ~10 ns

- DAQ is fully functional and operational
- Tested on a ~1 month long measurements in January – February 2023

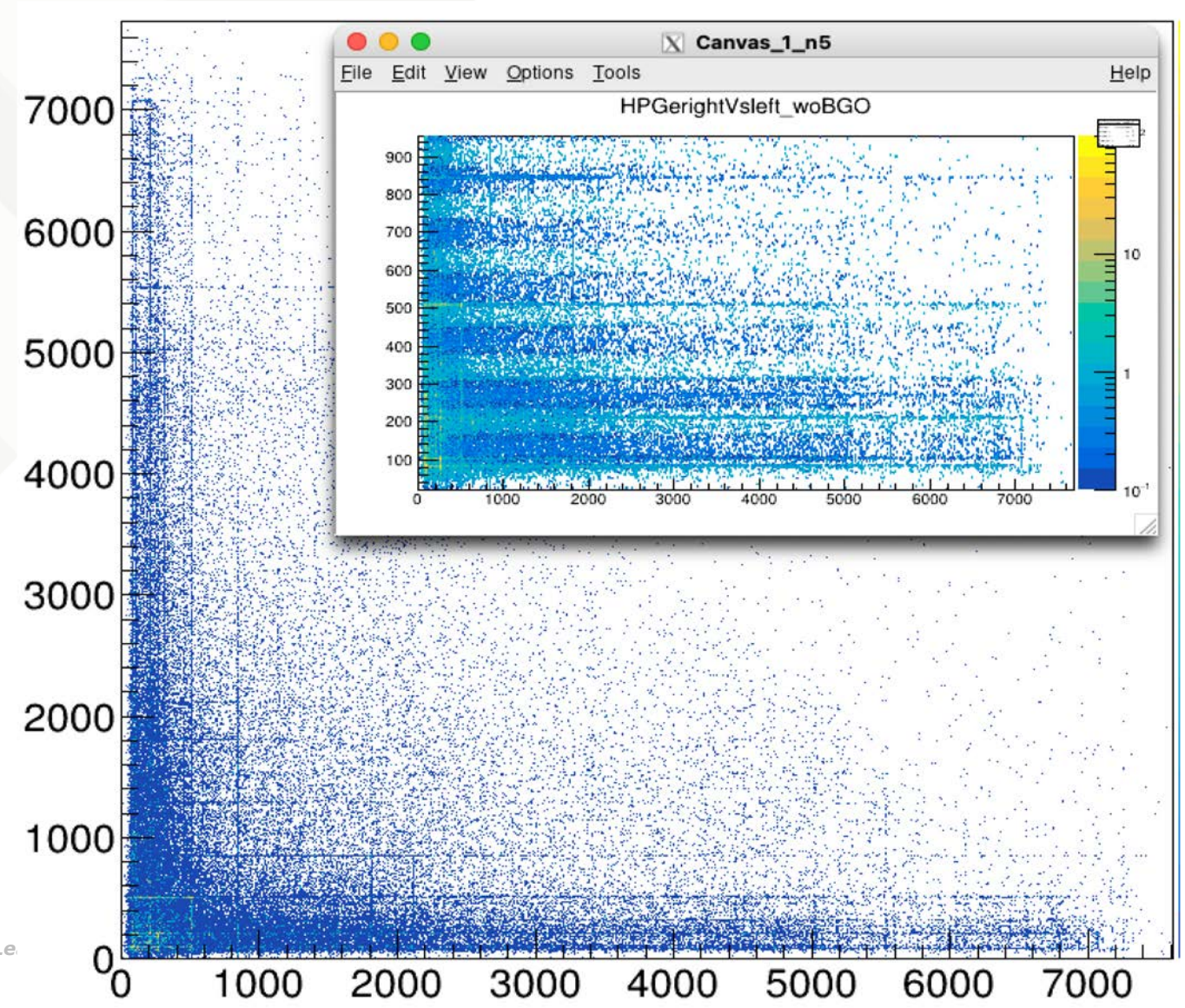
COMPTON SUPPRESSION

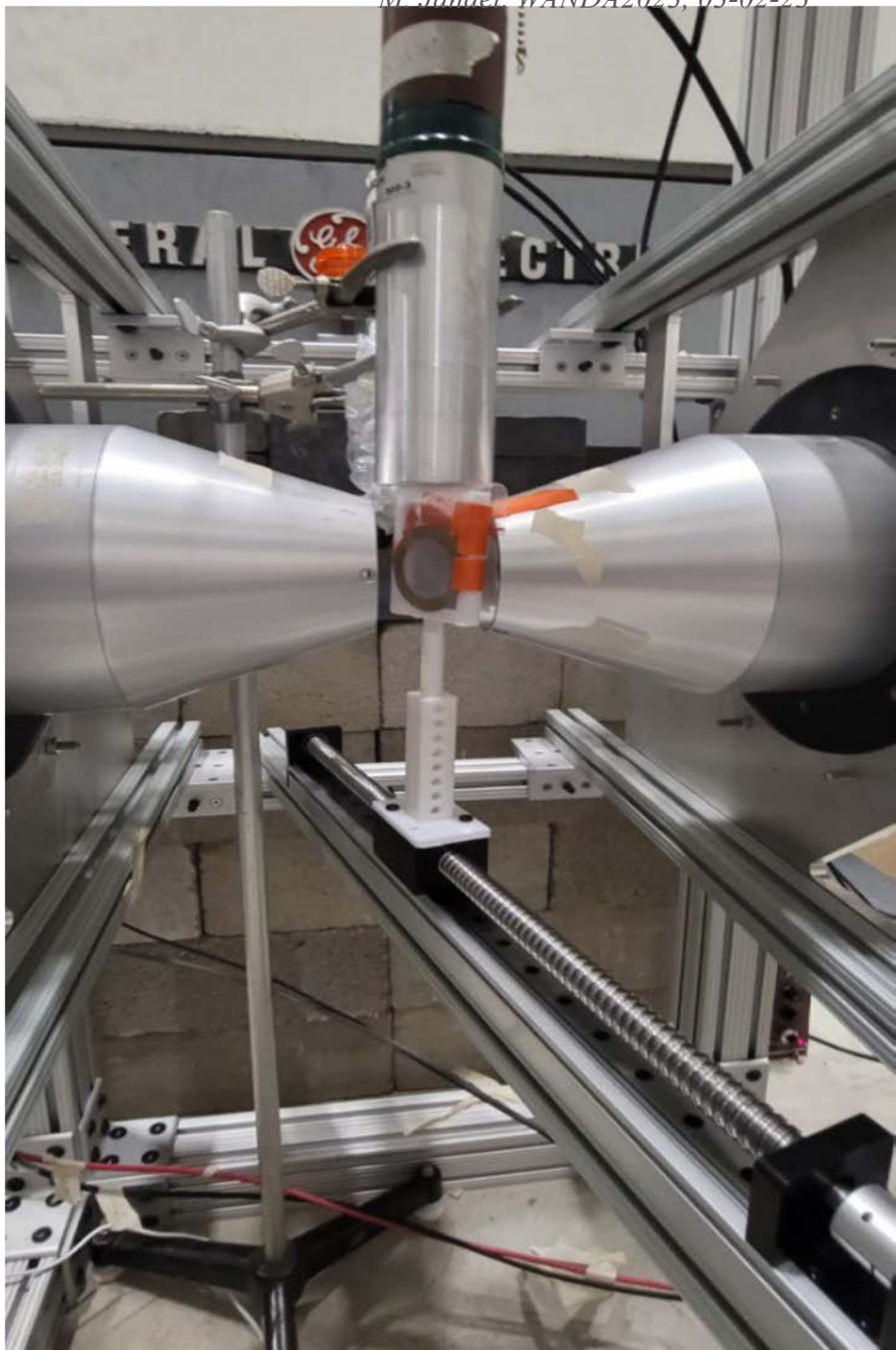
- Wee split daisy-chained signal into 4 signals from BGO



GAMMA-GAMMA COINCIDENCES

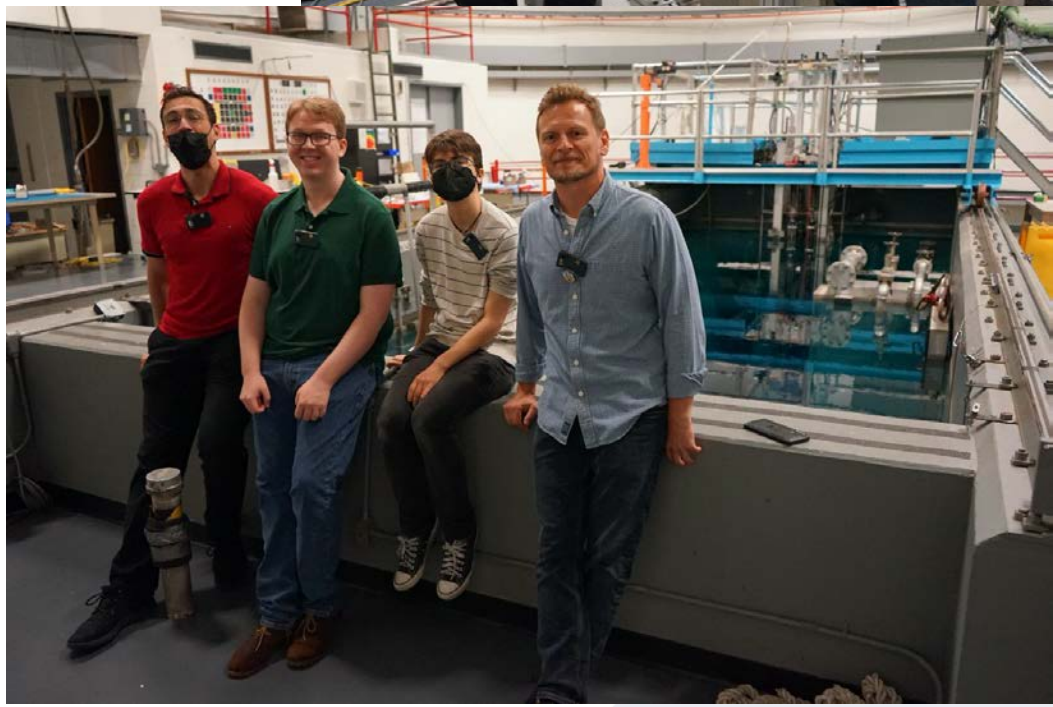
- Mn55(n,g) - ~ 50 gamma-gamma events





STUDENTS WORK

- MSc/PhD student Alex Howe (since June 2022)
- Undergrad: Michael McGlynn (since June 2022)
- Thermal Neutron Beamline was designed and build by grad students:
  - Razvan Stanescu, Hadrick Green, Toby Morris
- Capstone Project (undergrads) – Relevant to Mn56 project:
  - Paige Fink (2018) – Design of a proton-recoil neutron detector
  - Brad Vecchionne (2020) – Decomposition of NaI gamma-ray spectra
  - Oksana Solodovnyk (2021)– Activation analysis of Mn56
- Immersive scholars (undergrads):
  - Joshua Parker (2021) – Automated calibrations of HPGe detectors

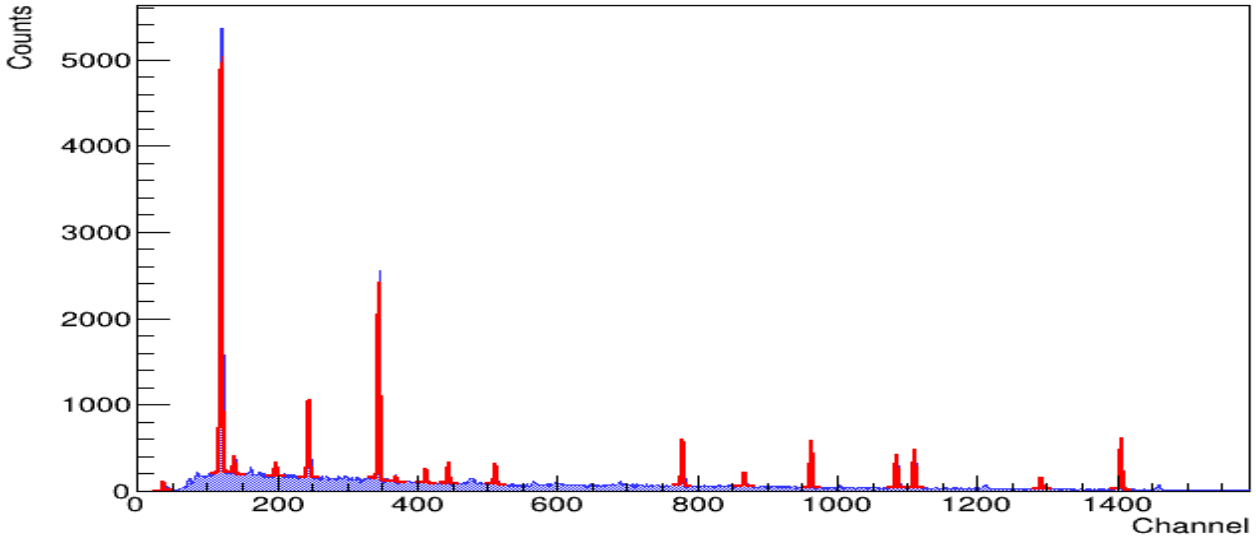


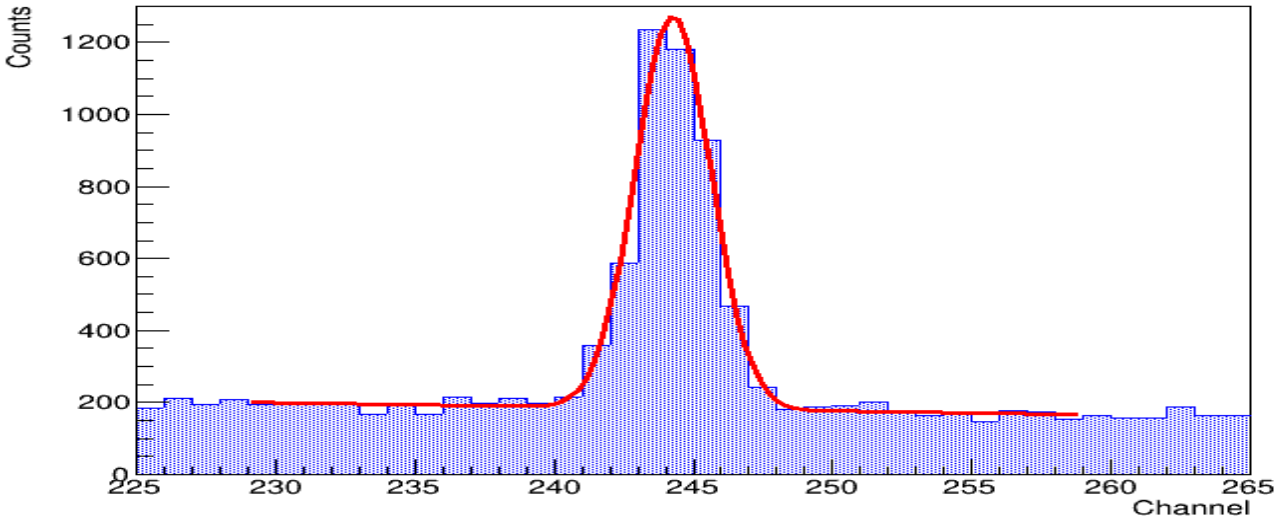
M. McGlynn: Finding Peaks in Eu-152 Calibration Source

- Created an algorithm to find the photopeaks from the background spectrum (first and second derivative)
- Fit them with Gaussians, using the metric
- And match them to ENDSF transitions in Eu-152 using the metric:

$$M(E_i') = \sum \exp\left(-(E_i' - e_j)^2\right)$$

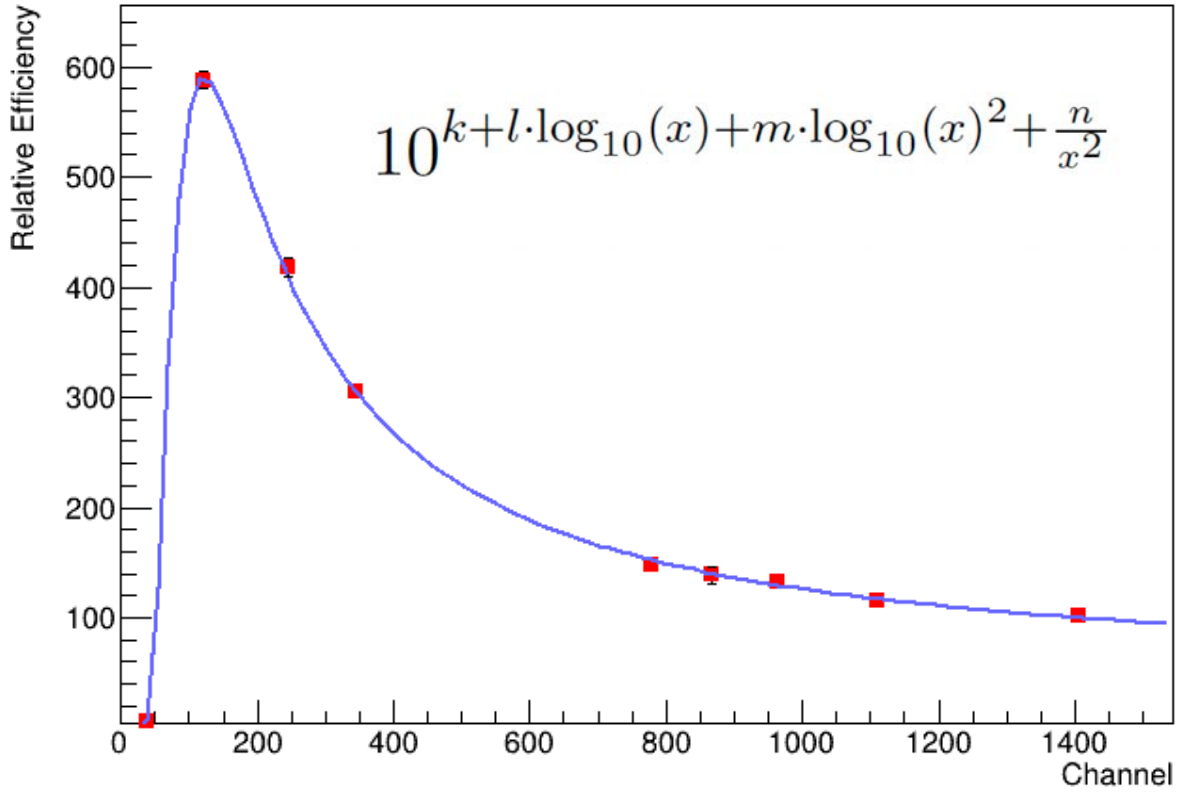
$$E_i' = \alpha E_i + \beta$$





M. McGlynn: Calibration of the Energy and Relative Efficiency

- Analyzed the data from the Gaussian fits and compared with data from ENSDF database to find the relative efficiency of the HPGe detector
- Wrote a fitting algorithm using gradient descent to calculate the energy per channel



PERSONNEL

- **UMass Lowell, Department of Physics and Applied Physics**

- **Principal Investigator: Marian Jandel**
- **MSc student: Alex Howe**
- **Undergraduate student: Michael McGlynn**
- **Co-I: Peter Bender and his students (HPGe maintenance and LN2 filling)**
- **Reactor Engineers: T. Regan, L. Bobek, K. Konomi**
- ***Post-doc*: *S. Valenta (~Summer 23)***

- **Collaborations:**
- **ENDSF group, Brookhaven National Lab: E. McCutchen**
- **Charles University, Prague: S. Valenta, M. Krticka, DICEBOX**

SUMMARY – MAD EXPERIMENTS 2023

- **Work is in progress, all tasks are on schedule**
- **In summer 2023 – series of experiments is planned**
- **2x HPGe mechanically cooled to measure low-E part of the spectrum will be added to MAD – from BNL**
- **Thanks to DOE for this opportunity !**