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NSF

SOLVING THE MN PUZZLE

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PHYSICS AND APPLIED PHYSICS

UMASS LOWELL

Nuclear Applications and Nuclear Data Group at UML

Feb 13, 2025 - Workshop for Applied Nuclear Data Activities (WANDA) 2025

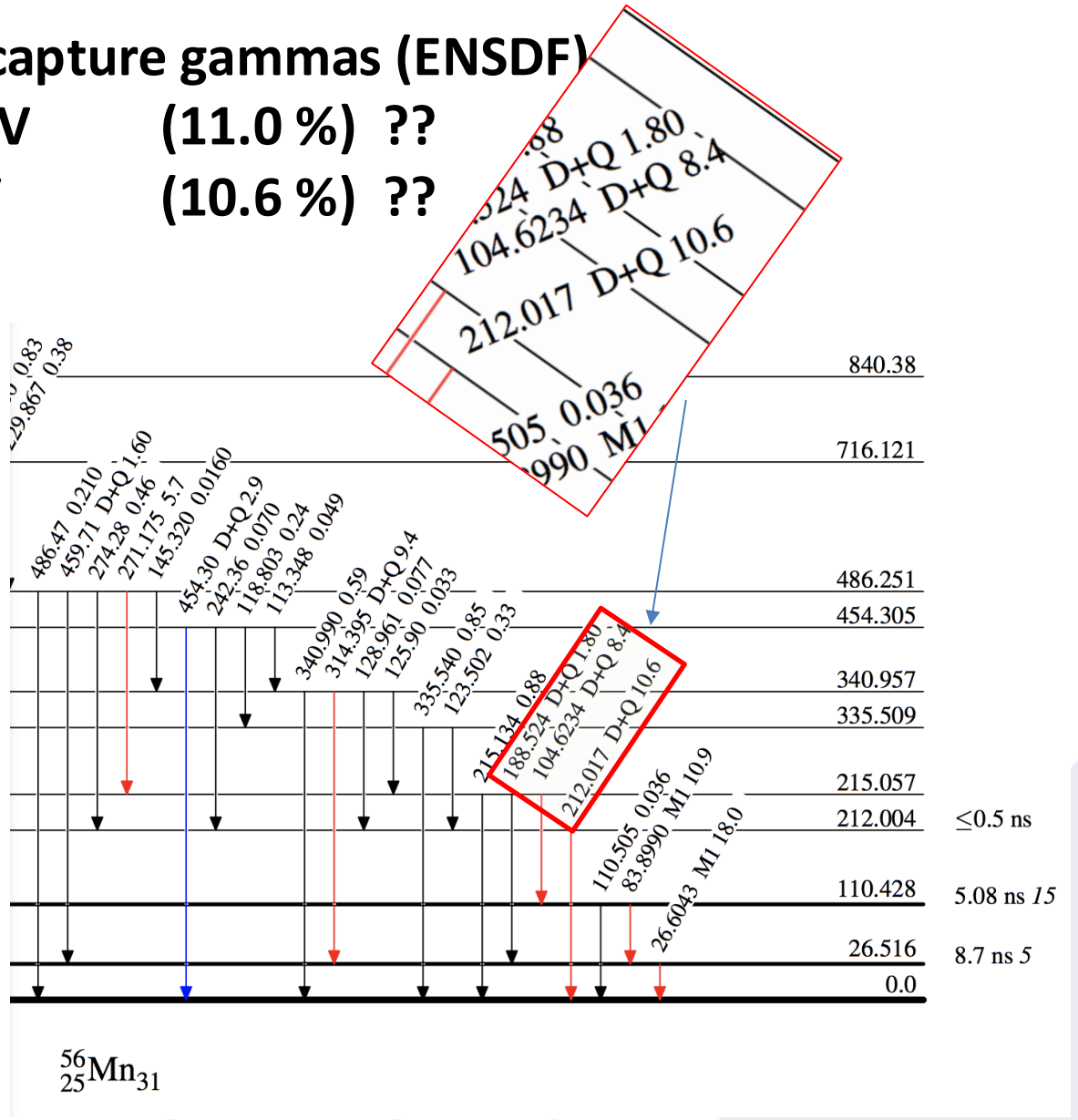
MOTIVATIONS: ^{55}MN(N,G) DISCREPANCIES

In collaboration with Brookhaven National Laboratory

Mn-56 capture gammas (ENSDF)

7058 keV (11.0 %) ??

212 keV (10.6 %) ??



- Data is typically older obtained with single HPGe shielded detector
- Pileup/deadtime correction and normalization procedures can be complicated
- Gaps and discrepancies found in data
- Improve ENDF to ENSDF correspondence

Learning with Purpose

- Supported by U.S. Department of Energy, Office of Science/Nuclear Data under Award No. DE-SC0022907.

MOTIVATIONS: CR, NI AND CU DISCREPANCIES

The work is carried out in collaboration with Brookhaven National Laboratory and supported by the US DOE, Office of Science, under Award No. DE-SC0024373

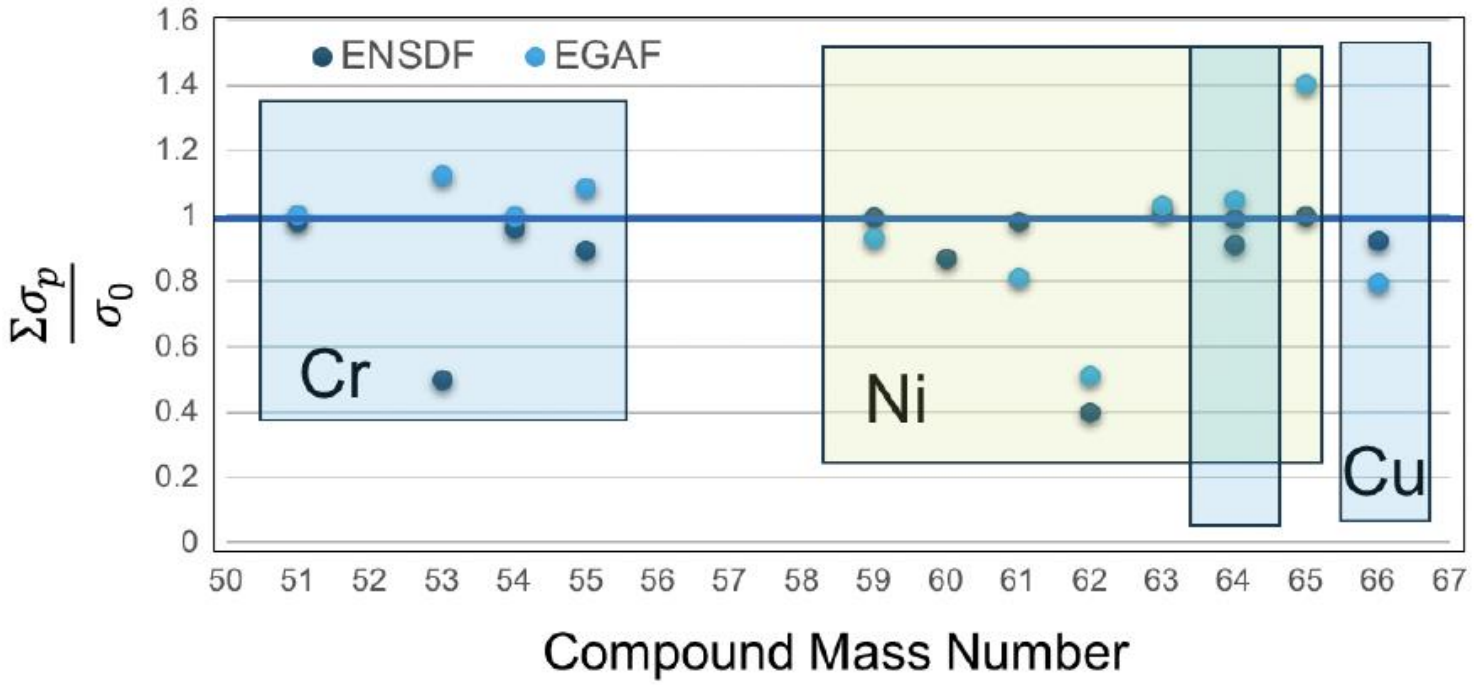
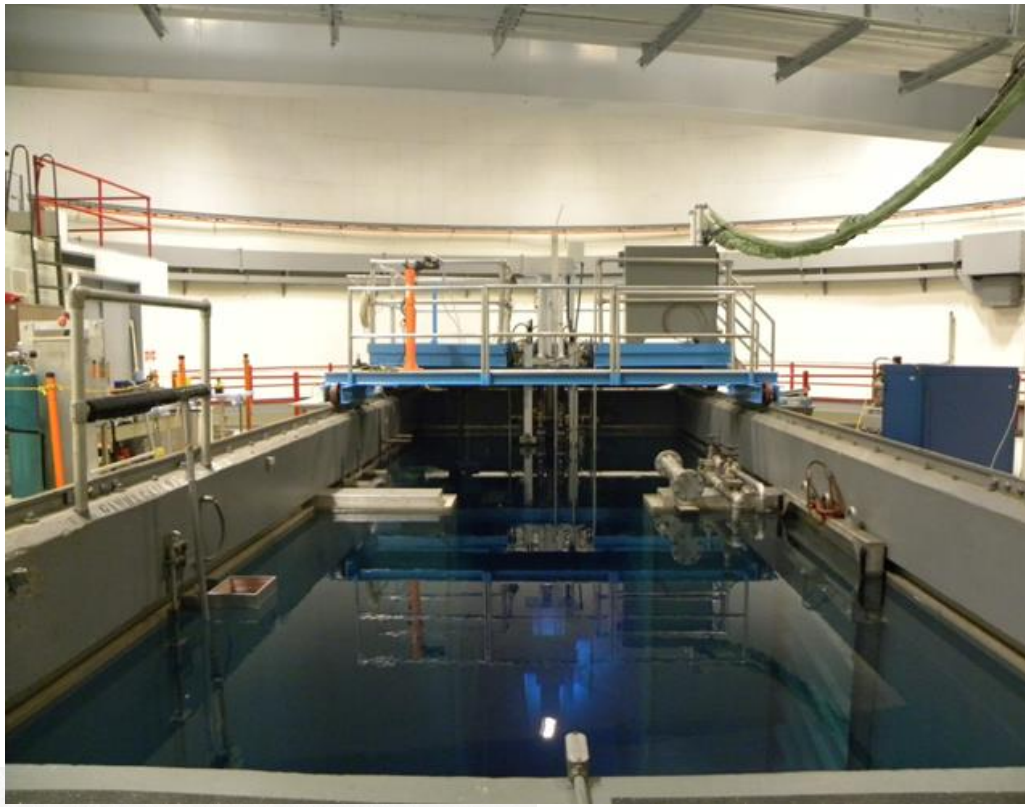
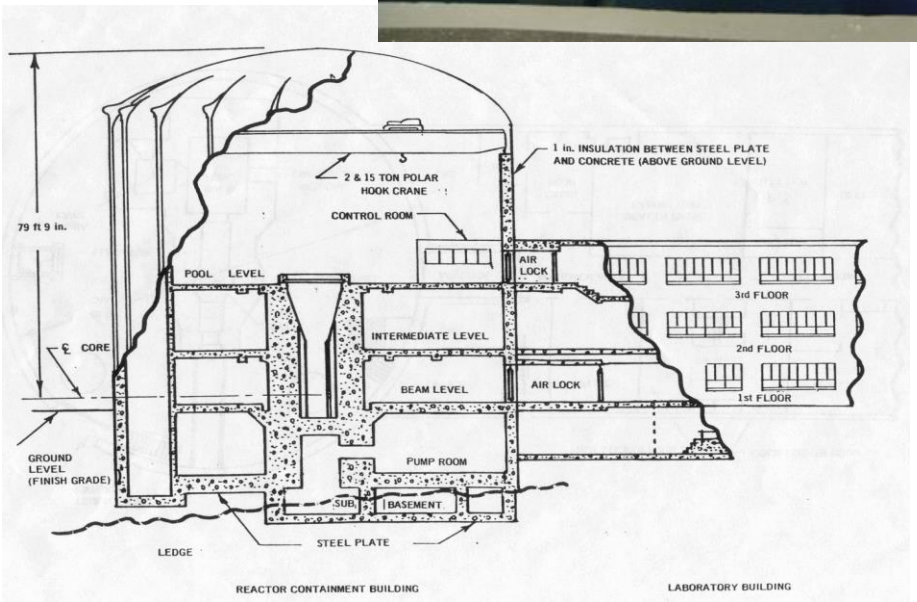


Figure 2 Ratio of the summed primary gamma-ray transition strength to the capture cross section for the Cr, Ni, and Cu isotopes. Data are plotted versus compound mass number (target +n). Data are compared for the ENSDF and EGAF libraries.

UML RESEARCH REACTOR

- 1 MW – in core flux $2x10^{13}$ n/cm^2/s
- Pool of 75,000 gallons of demineralized water
- Various irradiation capabilities available
- **https://www.uml.edu/research/radlab/**

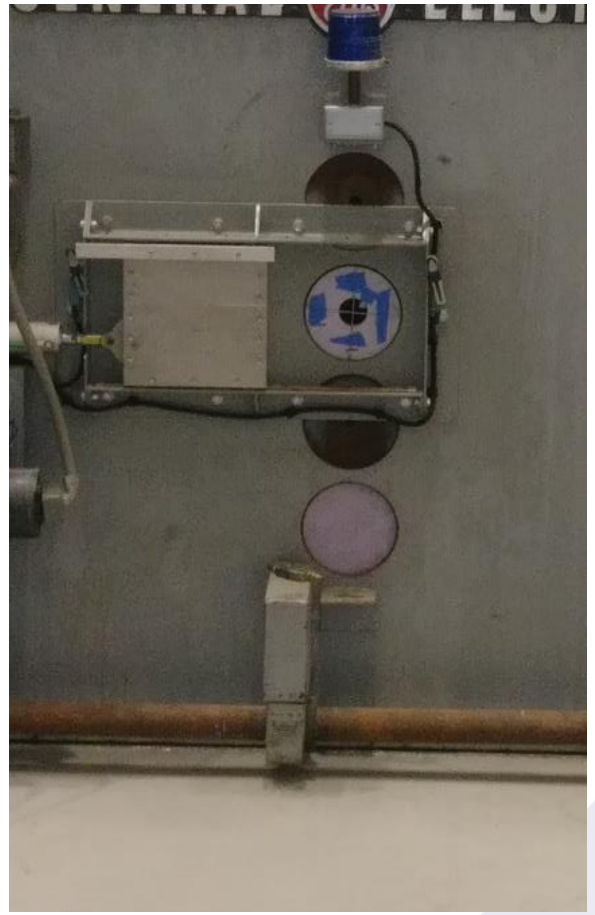




UMLRR FACILITIES – THERMAL COLUMN

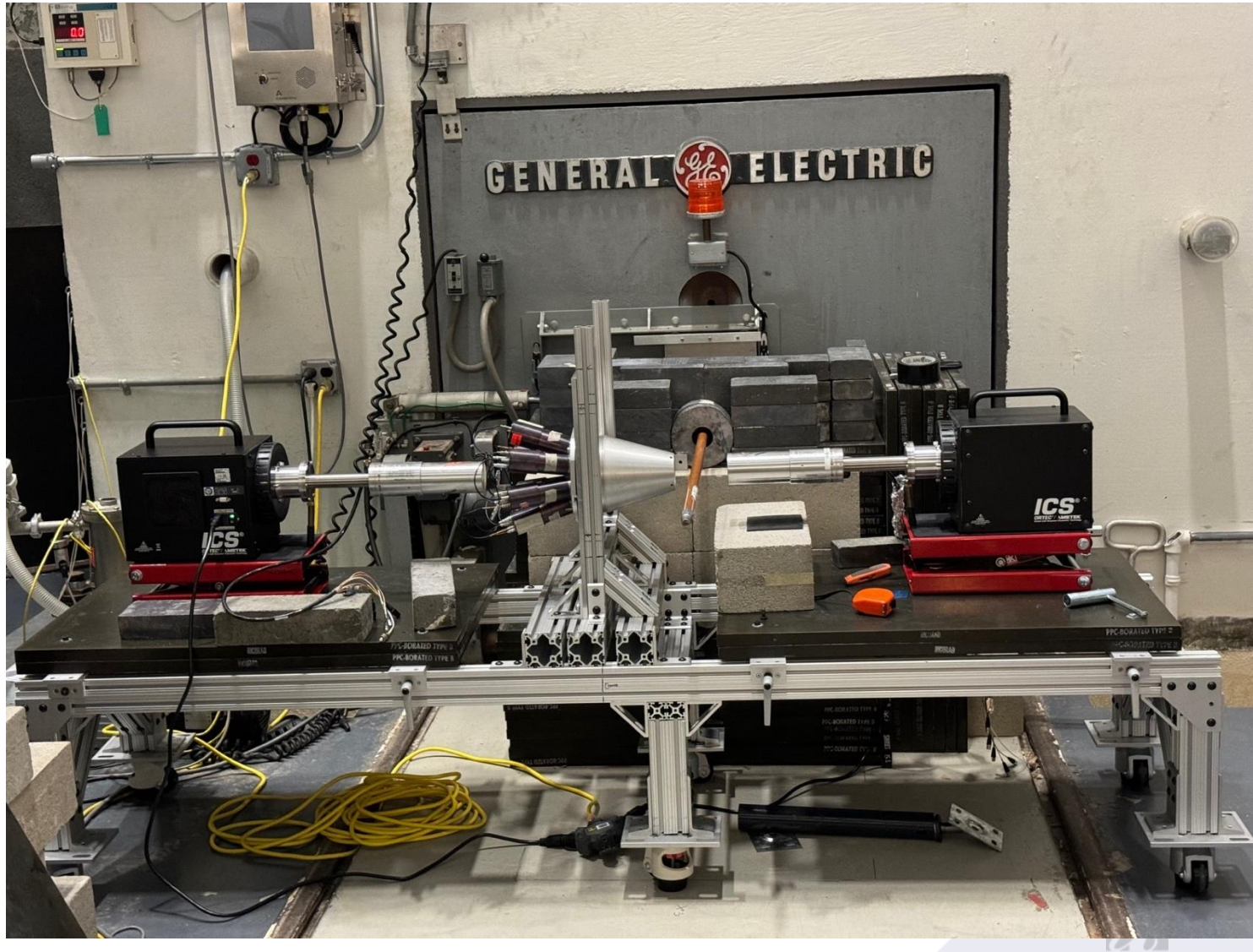
- Graphite column adjacent to the reactor core
- Pneumatic shutter
- 6-inch diameter beam – can be collimated
- Total thermal flux: ~6-7 x 10^6 n/cm^2/s
- Easy access, low gamma contamination, parallel beam

- https://www.uml.edu/research/radlab/



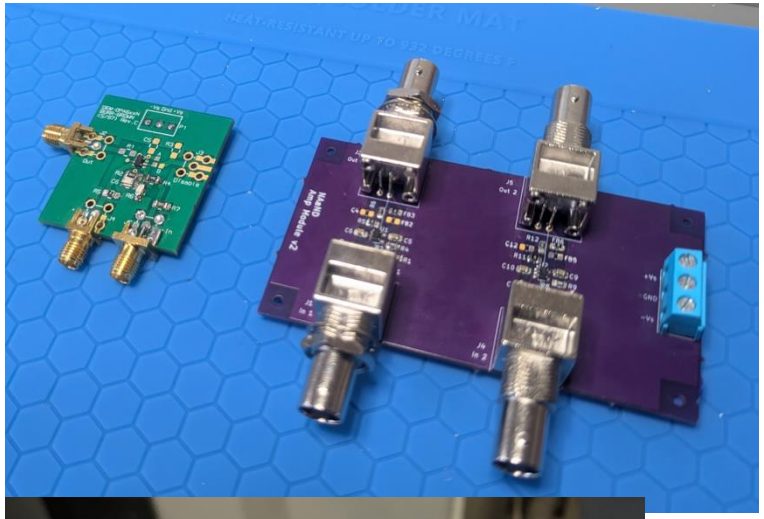
EXPERIMENTAL SETUP 2024

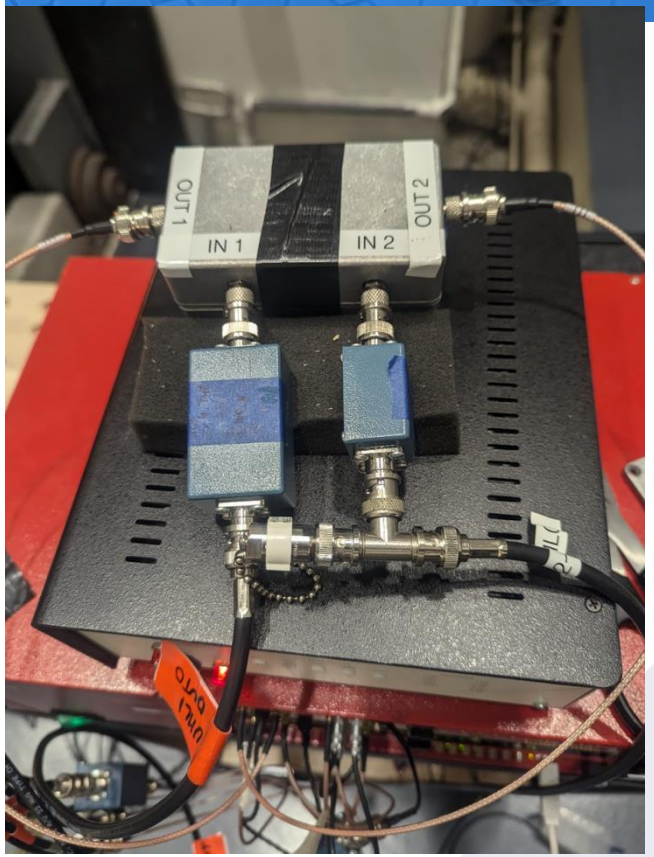
- **Dedicated detectors Ecooled acquired June 2024**
- **Transistor Reset Preamp – capable of high rates**
- **1 Compton Active Shielding**
- **In future, dedicated 100% HPGe will be added to the array**
- **Added Borated Silica wrapping around both HPGe**



CUSTOM ELECTRONICS FOR FAIRRAY

- Work by Graduate student – Daniel Fernandez
- Transistor Reset Preamp signals are the staircase voltage signal from -0.5V to -7.5V followed by a 5us long reset
- We developed a custom amplifier, based on Texas Instruments OPA657 low noise amp in non-inverting configuration. AC coupling forms 5us high pass filter on input.
- Good performance – no loss in resolution up to 50 kHz – recovers quickly after reset pulse (total ~10us)

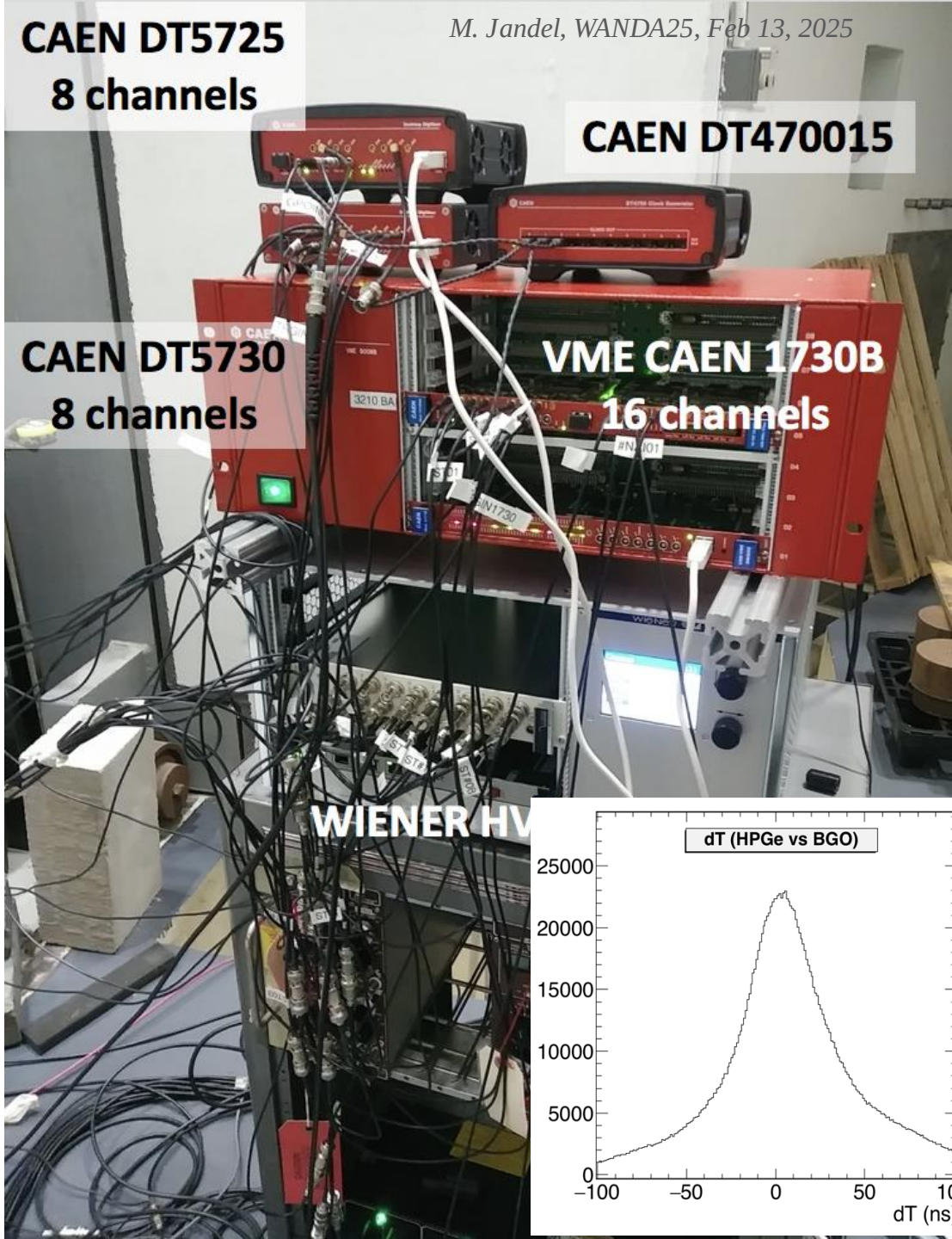




UMLDAQ – DATA ACQUISITION

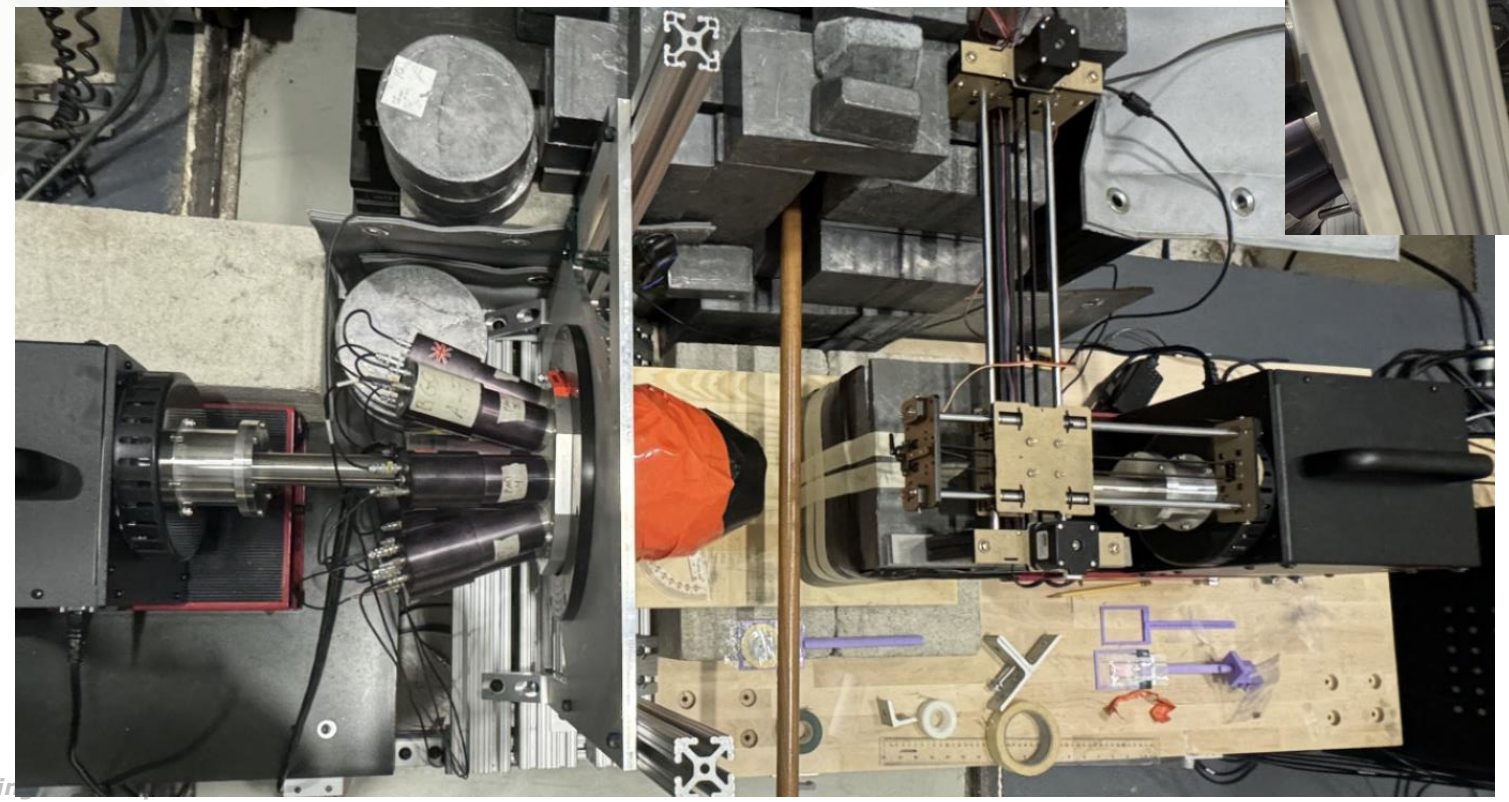
- UMLDAQ – based on CAEN hardware, software drivers and C++ libraries
- Asynchronous data acquisition using FPGA digital pulse processing
- VME based:
- 16 channel 14-bit 500-MHz CAEN V1730
- Two 8 channel x 14-bit 500-MHz CAEN V1730
- In house DAQ frontend and backend codes

- HPGe are using PHA firmware with trapezoid filter (4 channels)
- BGO/NaI are using PSD firmware using pulse integration (8 channels)
- BF3 is also on PHA firmware (1 channel)



ADDED SHIELDING – SAMPLE POSITIONING

- Lead around UML0 detector
- Anticompton shield around UML1
- Both wrapped in ¼ inch borated silica (Shieldwerx)



- Students designed sample holders
- 3D-printed
- Sample on X-Y stage (plotter)

MNCL2 MEASUREMENTS 2024/25

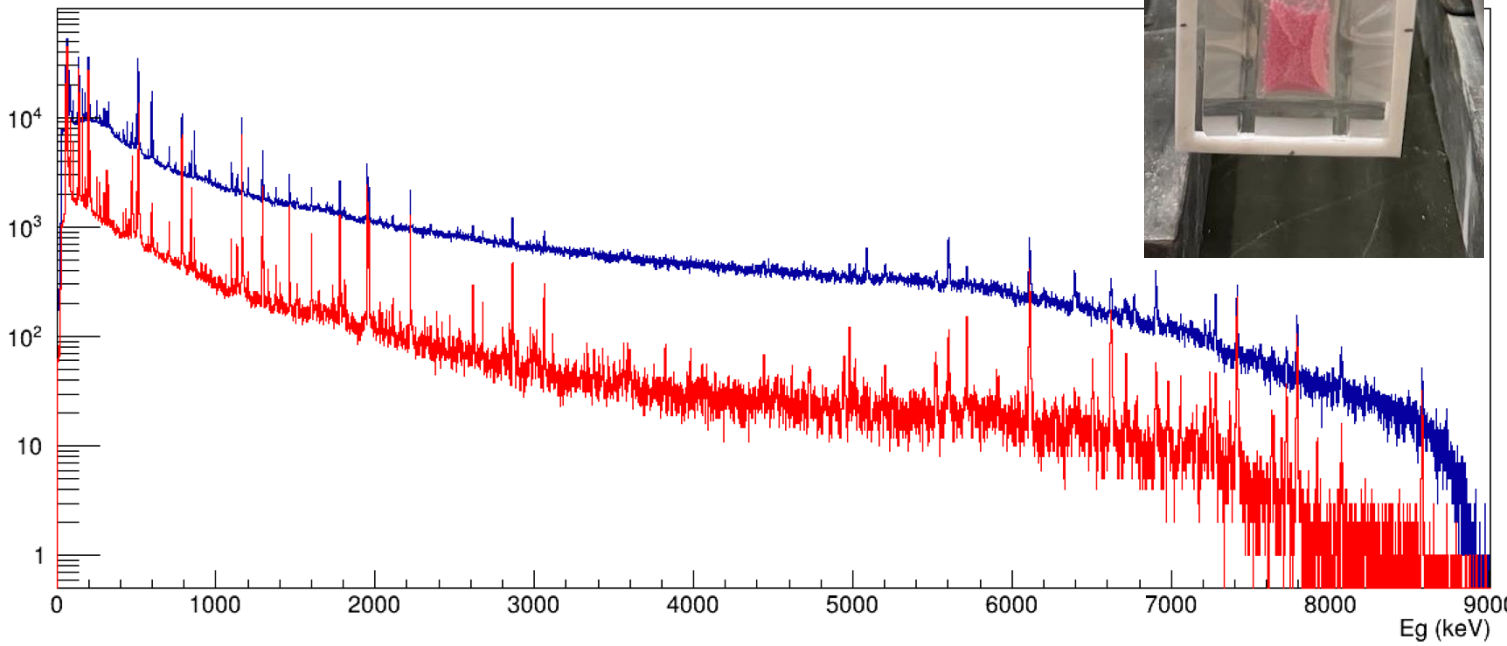
- Sample of 1.16 g of $MnCl_2$ (Sigma Aldrich)

$$N_\gamma^{Cl} = \Phi_\nu A_{beam} t \sigma_\gamma^Z(\varepsilon_\gamma^{Cl}) N_{target}^{Cl} \epsilon_{geo} \epsilon_{PE}(\varepsilon_\gamma^{Cl})$$

$$N_\gamma^{Mn} = \Phi_\nu A_{beam} t N_{target}^{Mn} \sigma_c I_\gamma(\varepsilon_\gamma^{Mn}) \epsilon_{geo} \epsilon_{PE}(\varepsilon_\gamma^{Mn})$$

$$I_\gamma(\varepsilon_\gamma^{Mn}) = 2 \frac{N_\gamma^{Mn}}{N_\gamma^{Cl}} \frac{\sigma_\gamma^Z(\varepsilon_\gamma^{Cl})}{\sigma_c} \frac{\epsilon_{PE}(\varepsilon_\gamma^{Cl})}{\epsilon_{PE}(\varepsilon_\gamma^{Mn})}$$

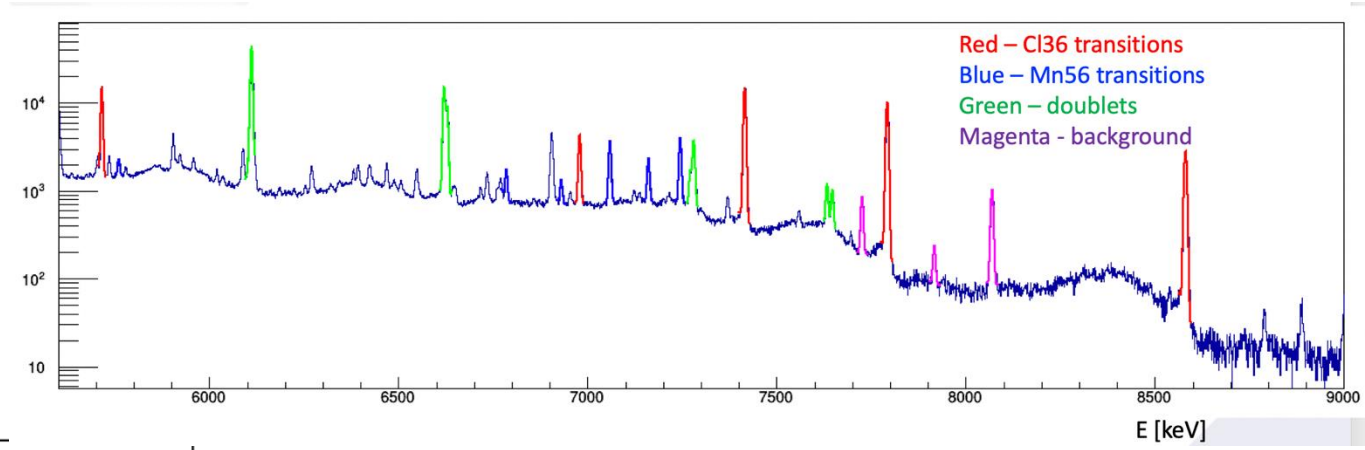
- N_γ: photopeak area
- ϵ_{PE}: photoelectric efficiency
- σ_γ^Z: γ-ray production cross section of ^{35}Cl
- σ_c: thermal capture cross section of ^{55}Mn

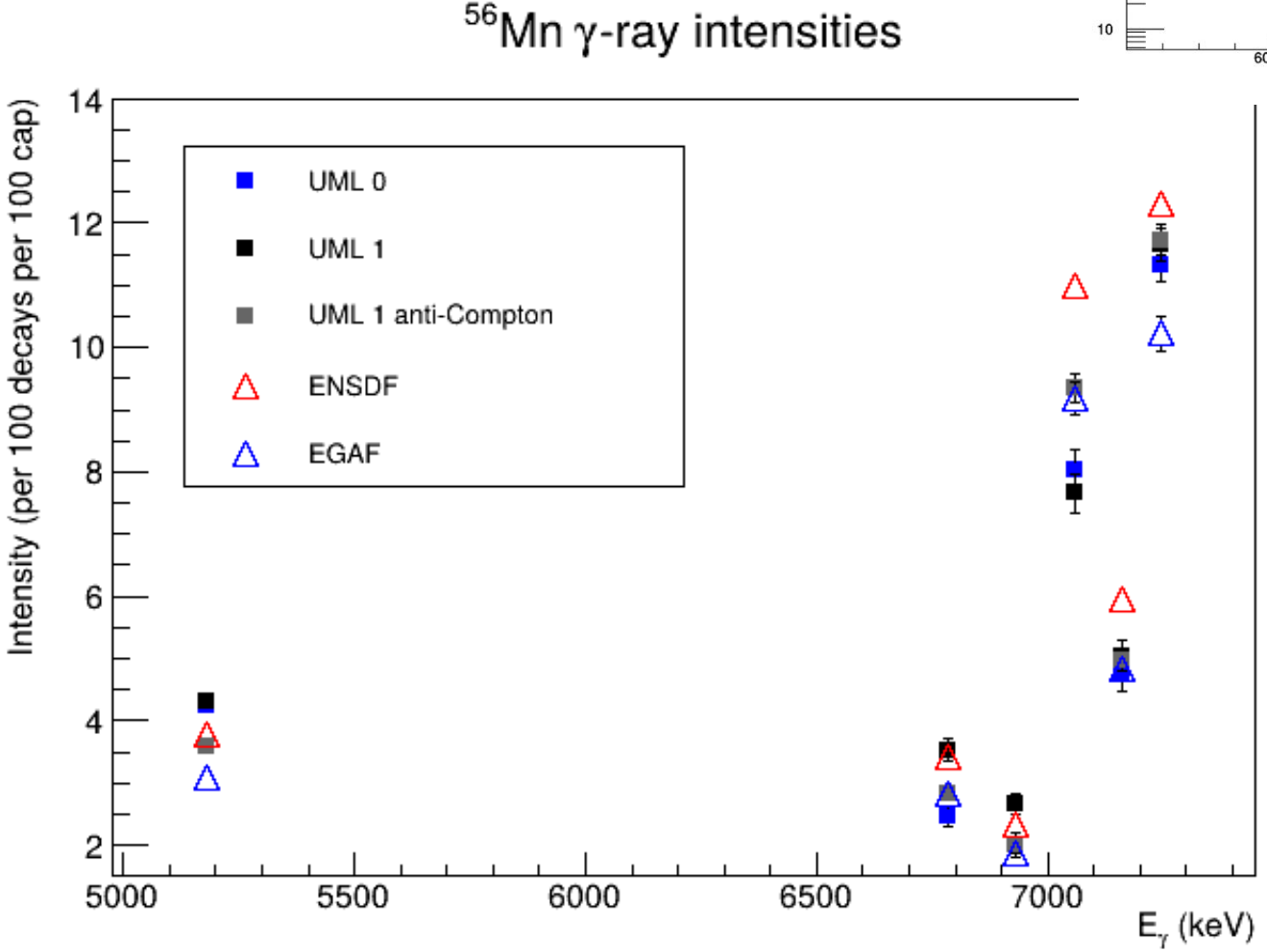


PhD thesis of Alex Howe (in progress)

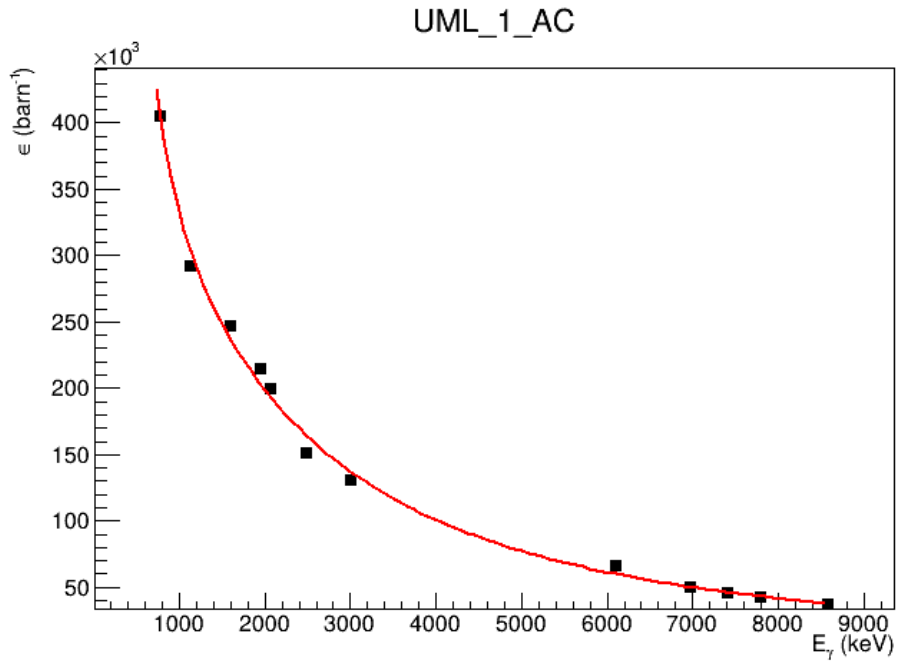
MNCL2

- Sample of 1.16 g of $MnCl_2$
- Runtime at 1 MW (~21 hours shown)
- Analysis by Alex Howe (UML)



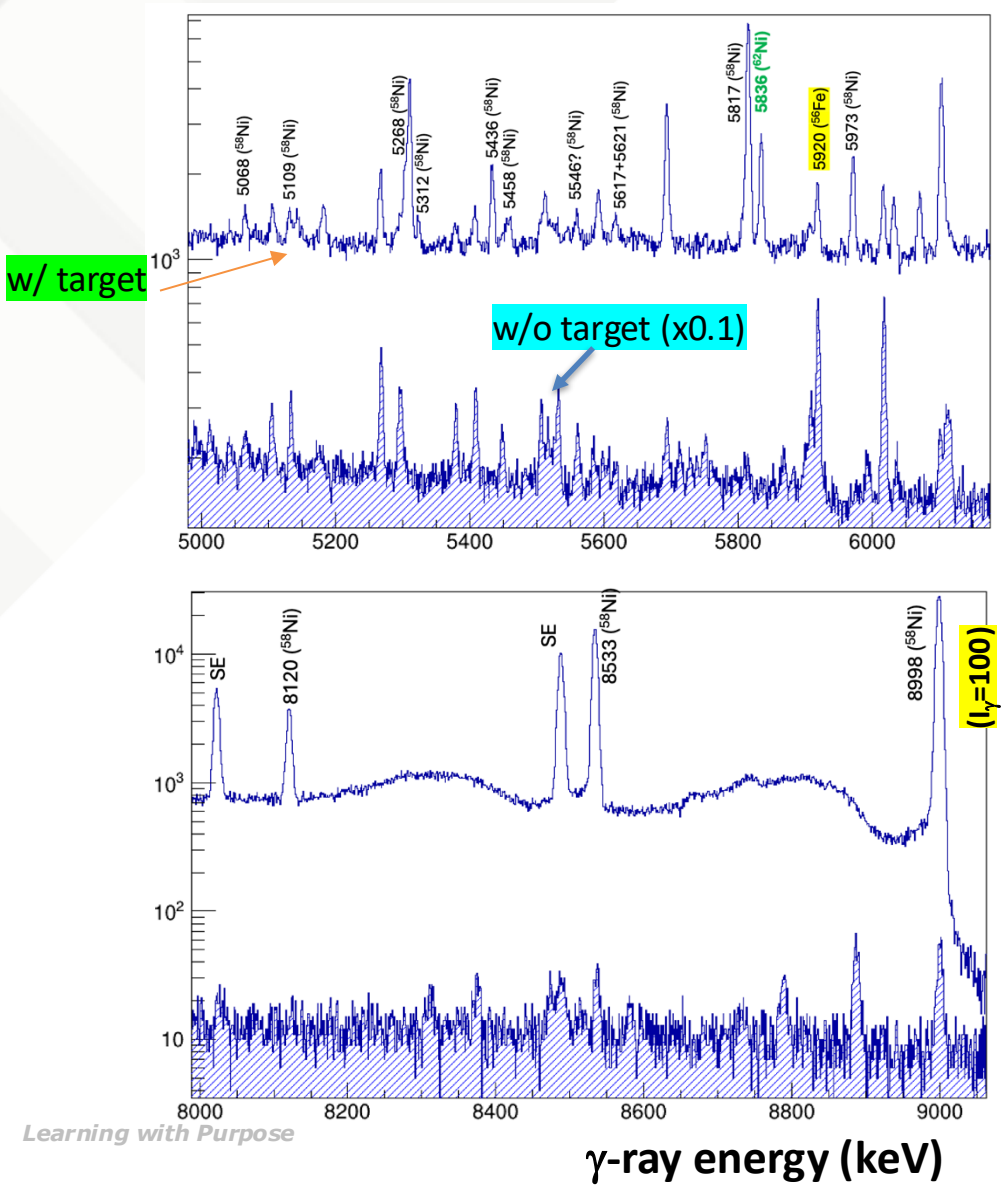


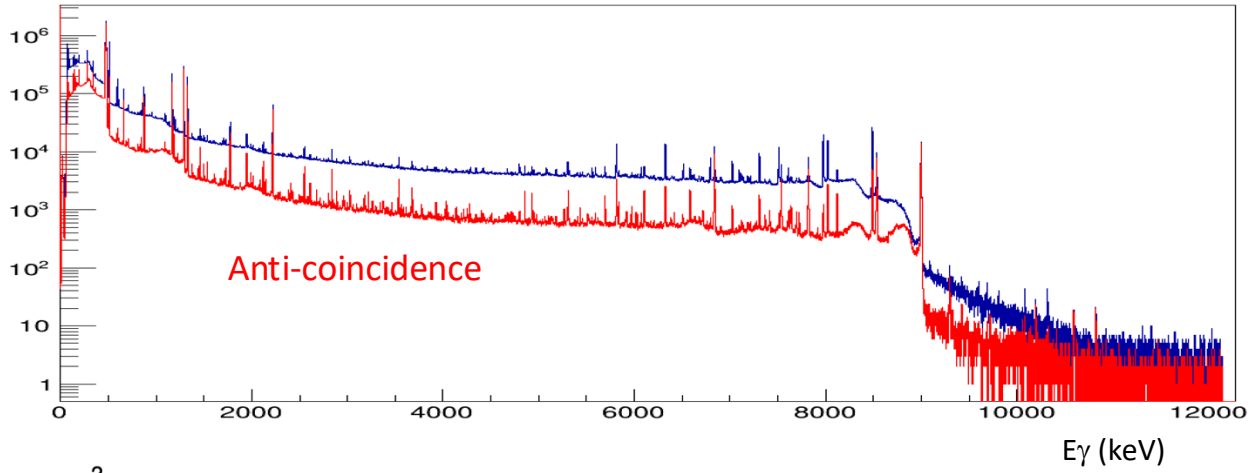
Relative photo-peak efficiency based on 36Cl data

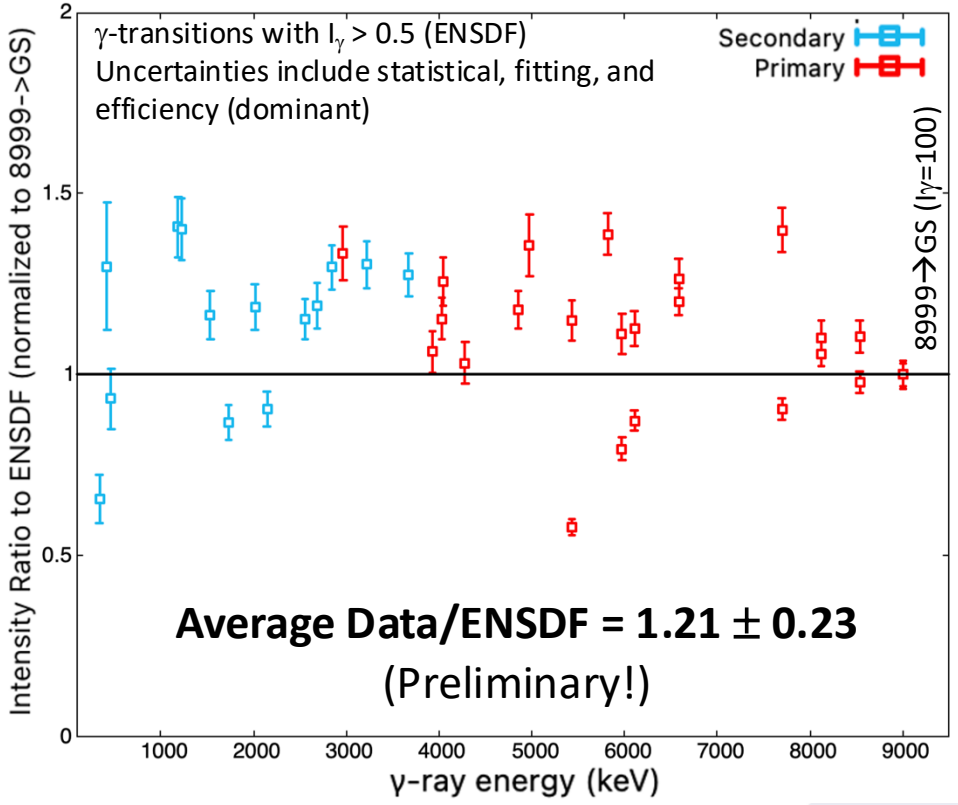


^{nat}Ni TARGET (20HRS @ 1 MW W/ AND W/O TARGET) – S. OTA (BNL)

- Analysis by Shuya Ota (BNL)

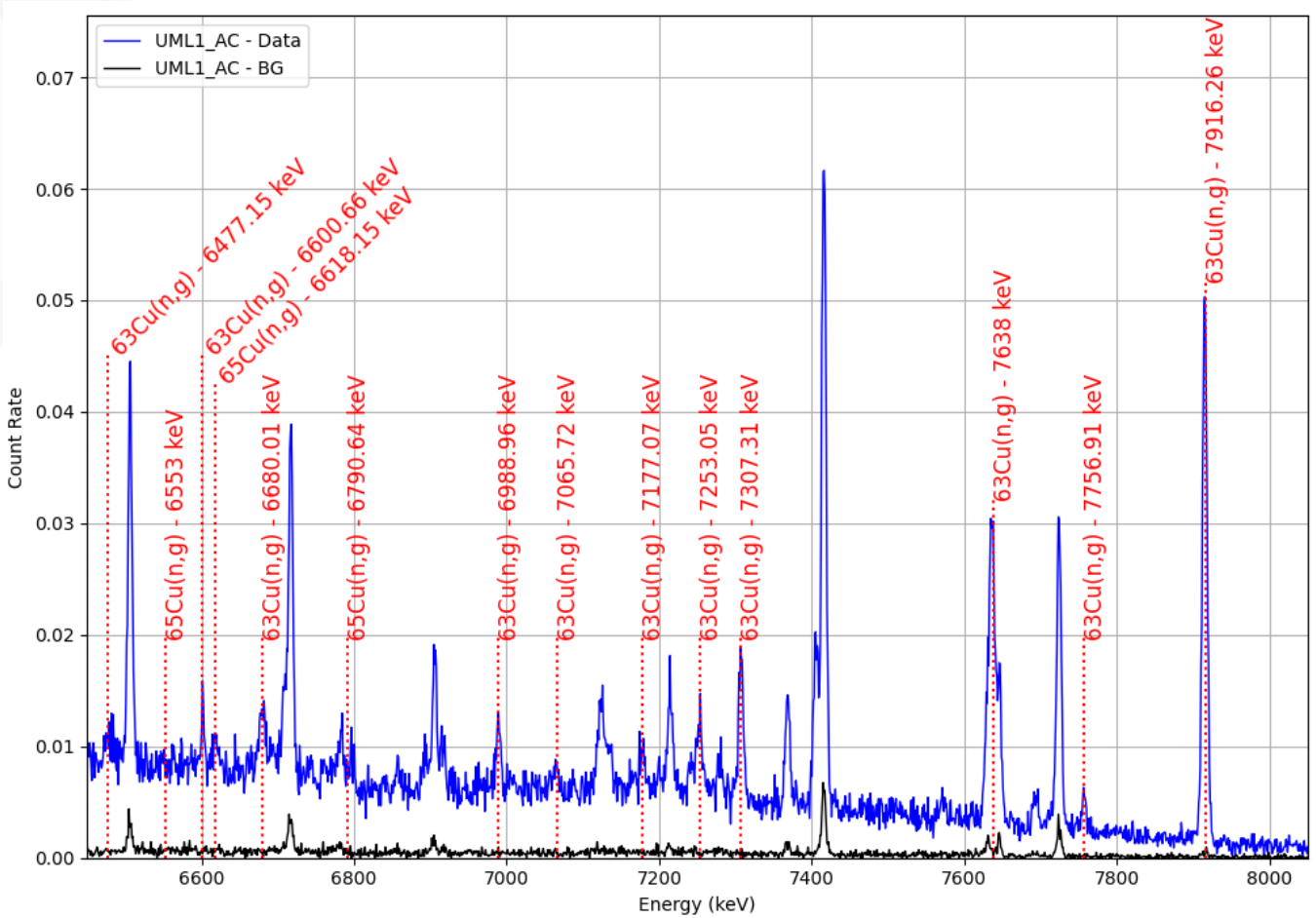






CU(N,G)

- Sample of 1g of natural Copper - ~20 hours
- 0-12 MeV spectrum – Cs137 + Co60 taped to the detectors
- Analysis by Daniel Fernandez – grad student of UML



Capture Gamma-ray spectra:

- Blank background data

- Copper

CURRENT PROJECTS AT UML THERMAL NEUTRON BEAM

- Measurements of capture gamma rays
  - DOE Office of Science: Mn-56 (2023-2025)
  - DOE Office of Science: Cu, Ni, Cr (2023-2026)
    - **New HPGe e-cooled detectors arrived in June 2024**
    - **New Collaboration with BNL (co-PI Shuya Ota)**
  - NSF Career: Gd (2022-2027)
- NNSA: CENTAUR2.0 Texas A&M led SSAA consortium
  - Future fission reaction studies and Fe(n,g) (2024-2029)

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- Stan Valenta, Milan Krticka (Charles University, Czech Republic) – DICEBOX, data analysis
- UML Nuclear Structure Group: P. Bender, P. Chowdhury, K. Lister
- E. Ricard-McCutchan, A. Sonzogni, S. Ota, Brookhaven National Lab.

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