Update on the KDK (Potassium Decay) Experiment

Presented by: Matthew Stukel, Queen's University on behalf of the KDK collaboration
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KDK Collaboration

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Technical and Electronic Support from M. Constable, F. Retiere (TRIUMF), K. Dering (Queen's University), Paul Davis, University of Alberta

Overview

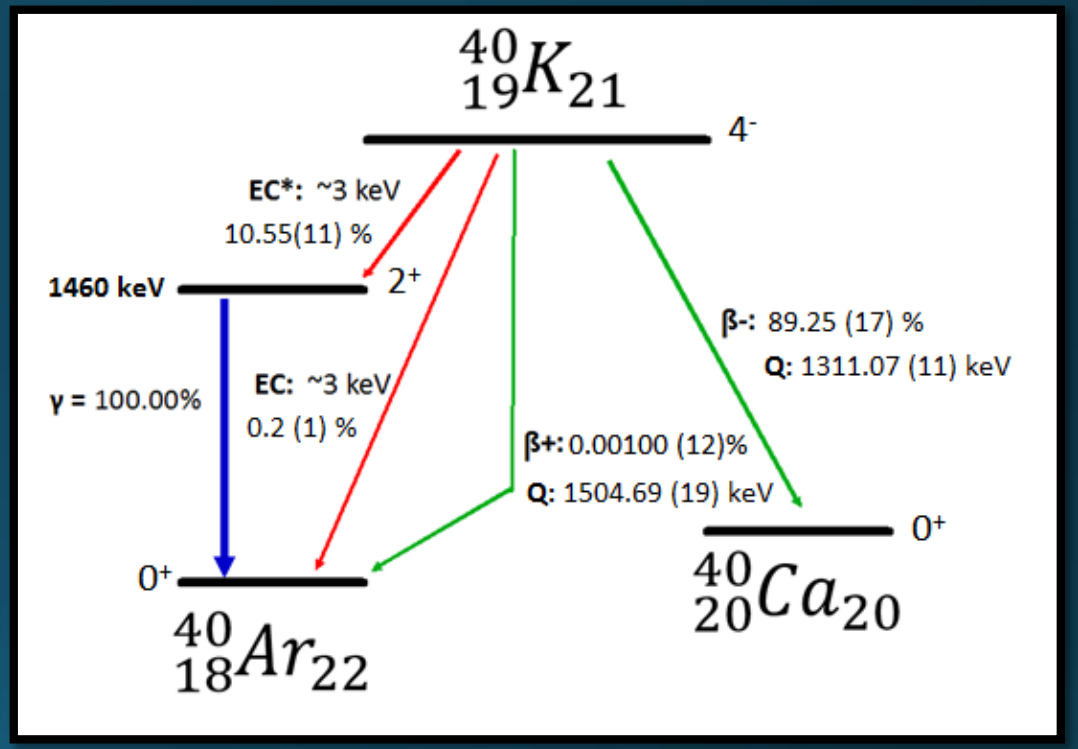
1. What is KDK?
2. KDK Experiment
3. KDK Results (Prelim.)

What is KDK?

- Pun for “Potassium Decay”
- KDK is an international collaboration dedicated to the measurement of the **unique-third forbidden** electron capture decay of ^{40}K

Why ^{40}K?

- Rare example of a unique-third forbidden electron capture decay
- Never been experimentally measured
- ^{40}K (0.0117%) can be found in natural potassium which is a contaminant in NaI
- ^{40}K is a background in many dark matter experiments (DAMA, SABRE, COSINE-100,etc..)
- Increase accuracy in K-Ar (Ar-Ar) dating
- Important Decay Channels:
  - 10.55 % to Ar-40* through electron capture, EC*
  - 0.2 % to Ar-40 through electron capture, EC
  - β- is the dominant decay channel



The different branching ratios of ^{40}K (EC)

Accepted LOGFT Value

$$BR_{EC} = 0.2(1)\%$$

Indirect Experimental Half-Life Value

$$BR_{EC} = 0.8(8)\%$$

Recent NNDC Value (2017)

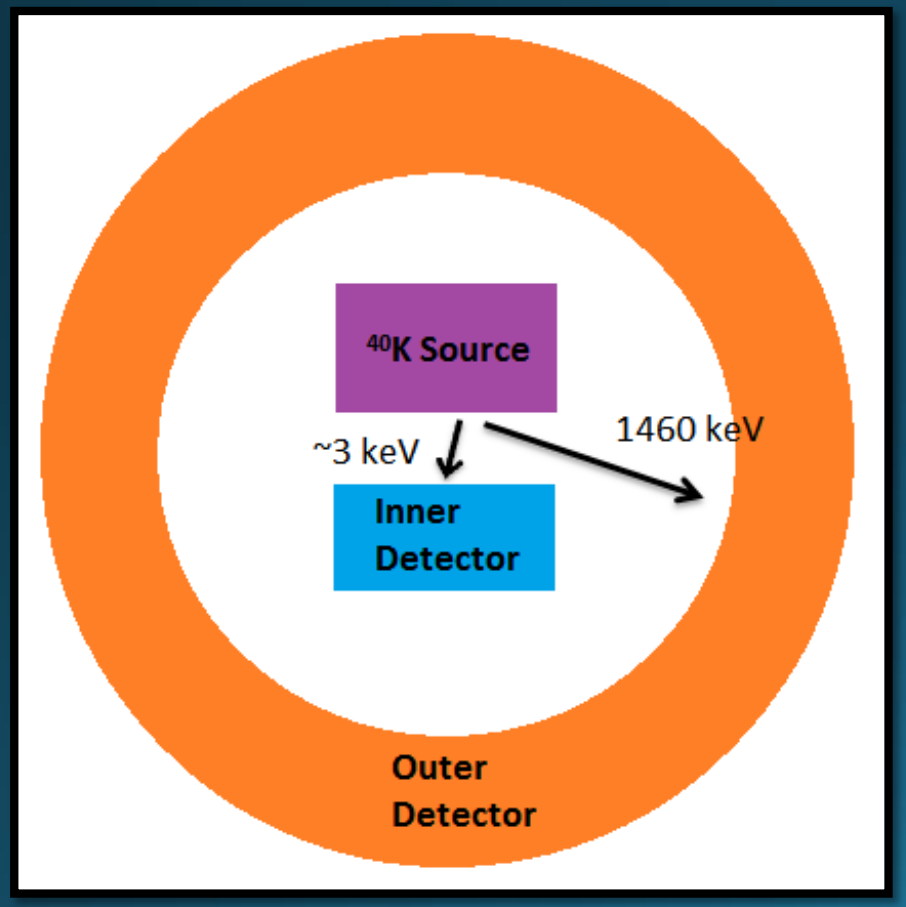
$$BR_{EC} = 0.046(6)\%$$

KDK Collaborator Value

$$BR_{EC} = 0.064(19)\%$$

KDK Experiment

- Perform a dedicated measurement of the BR of K-40 EC decay into ground state
- A small, inner detector will trigger on the X-rays from ^{40}K

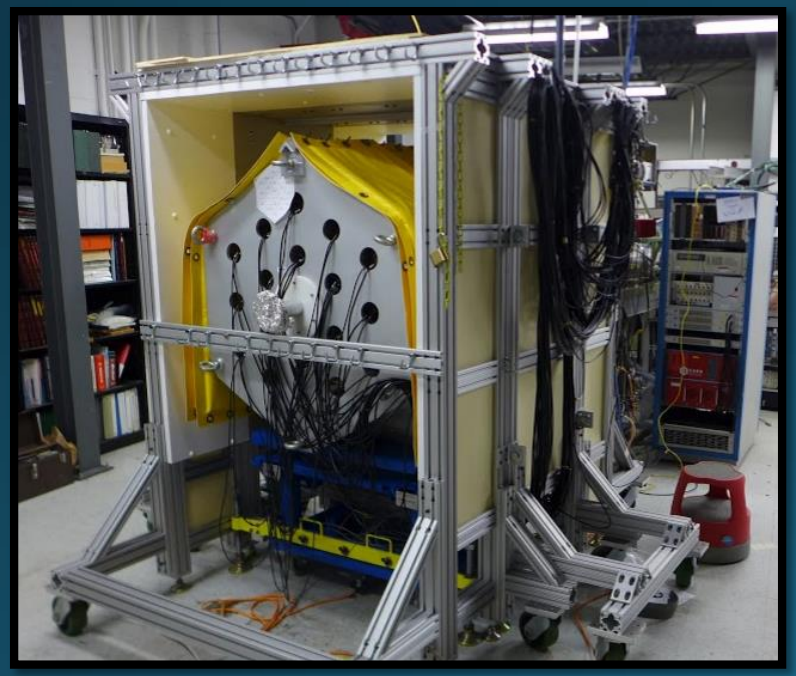


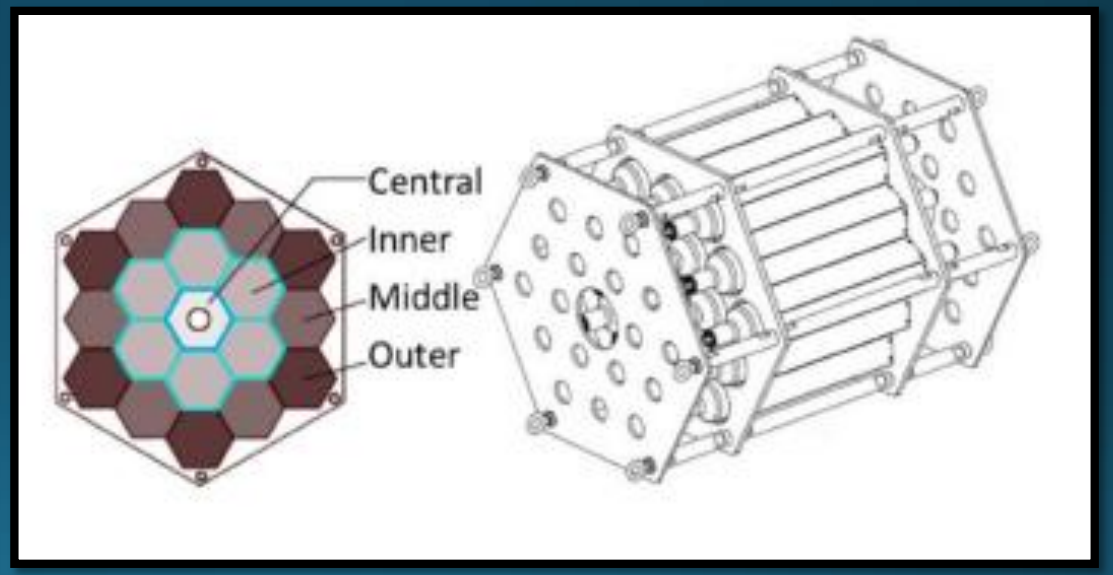
- Use an enriched (10%) ^{40}K source
- The internal detector will be surrounded by an larger detector in order to tag the 1460 keV gammas
- This will allow us to separate the events caused by the EC* decay from the direct EC

$$\frac{BR_{EC*}}{BR_{EC}} = \kappa$$

MTAS - External Detector

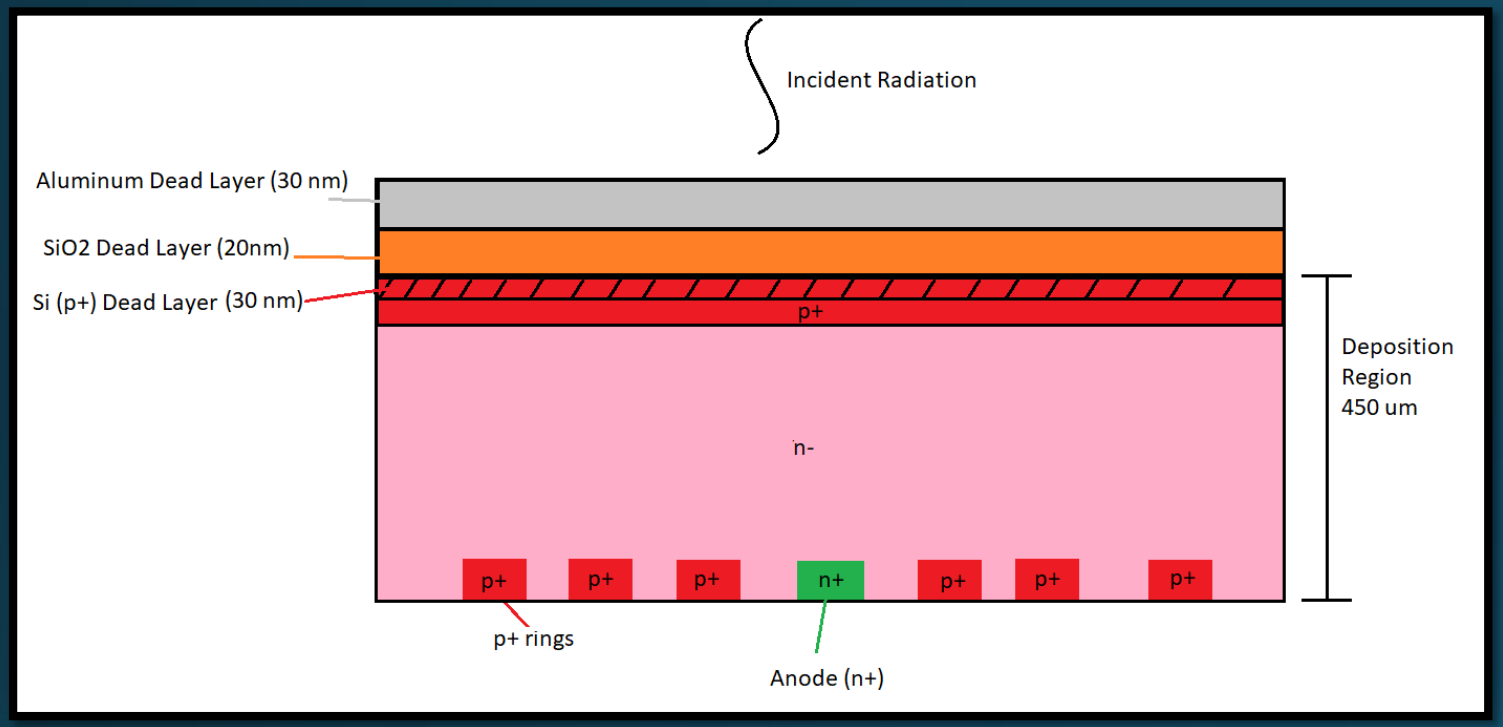
- The proposed external detector is the Modular Total Absorption Spectrometer (MTAS) from Oak Ridge National Lab (ORNL)
- The MTAS detector consists of 19 NaI(Tl) hexagonal shaped detectors (53cm x 20cm) weighing in at ~54 kg each
- MTAS can provide a ~98-99% (SNR=1) efficiency on tagging the 1460 keV gammas and ~4π coverage
- A high efficiency is needed to avoid false positives from the EC* channel and other background sources

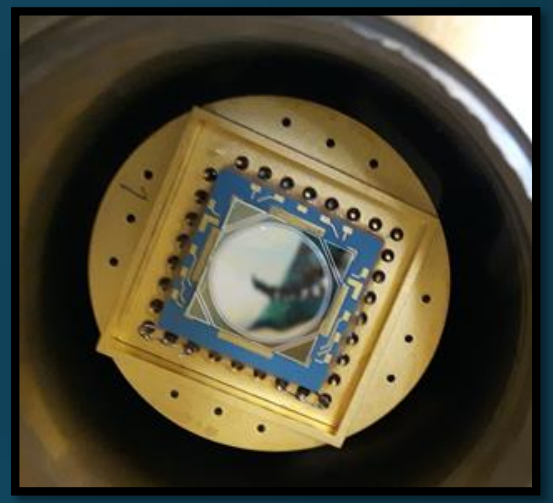


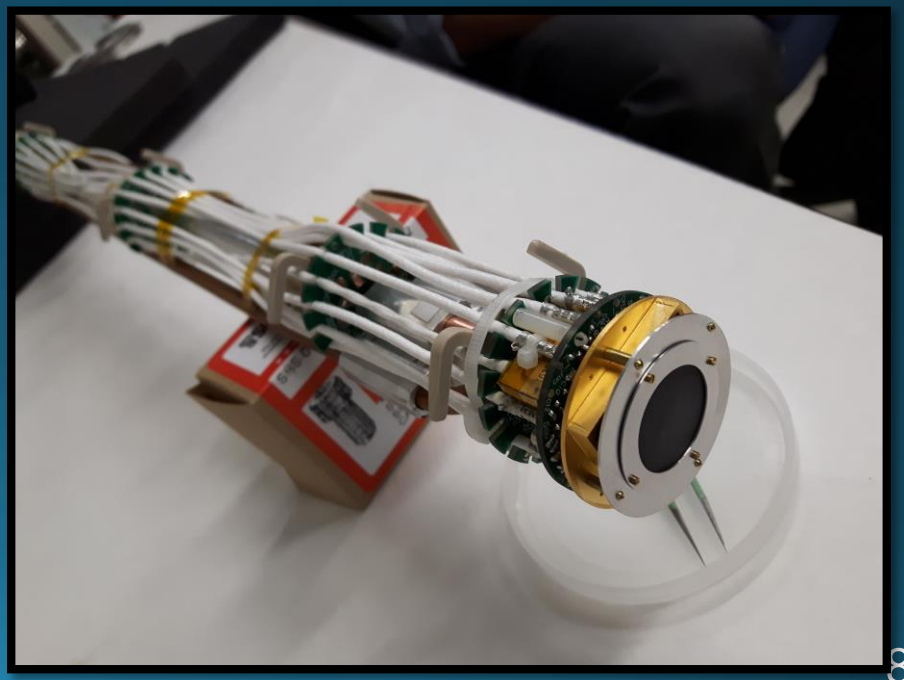


[2] Wolińska-Cichocka, M., et al. "Modular Total Absorption Spectrometer at the HRIBF (ORNL, Oak Ridge)." *Nuclear Data Sheets* 120 (2014): 22-25.

SDD - Internal Detector

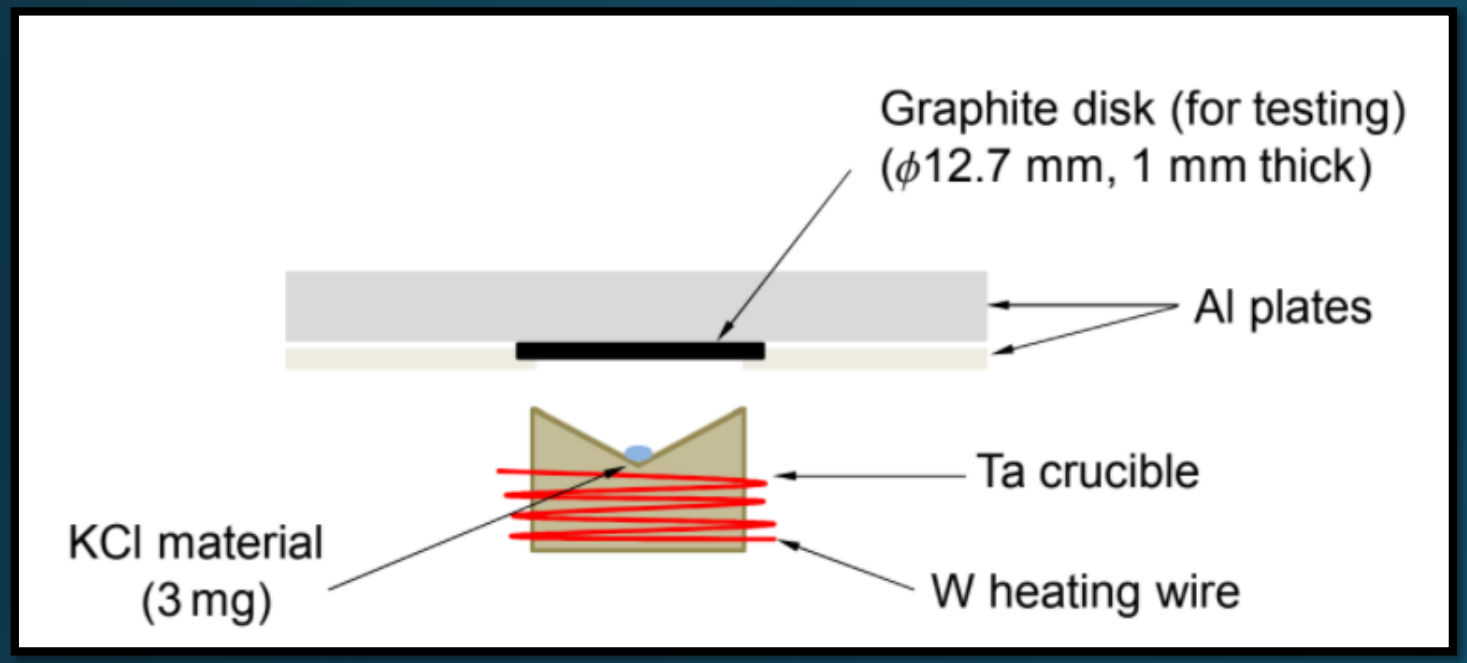


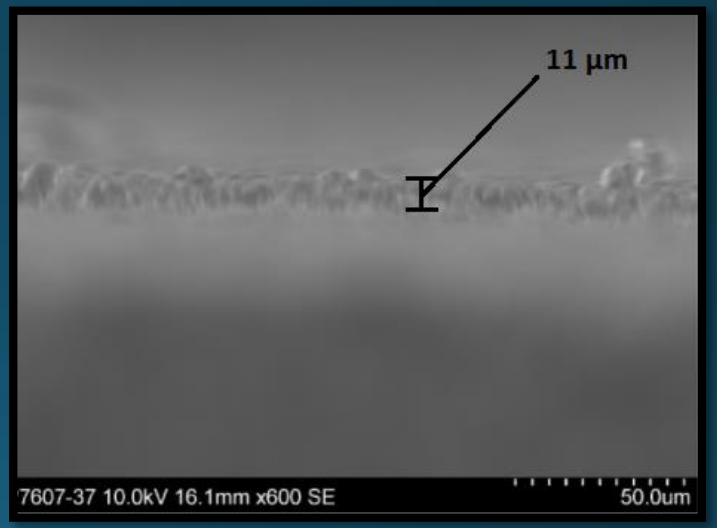




- SDD: Silicon Drift Detector
- Large n-type silicon wafer, small n^+ anode and planar p^+ cathode
- Rings (p^+) surround the anode, creating a potential that guides the electron clouds to the anode
- SDD is cooled to -30°C
- Advantage is the lower electrical noise than the planar anode counterpart
- ~100 mm^2 active area

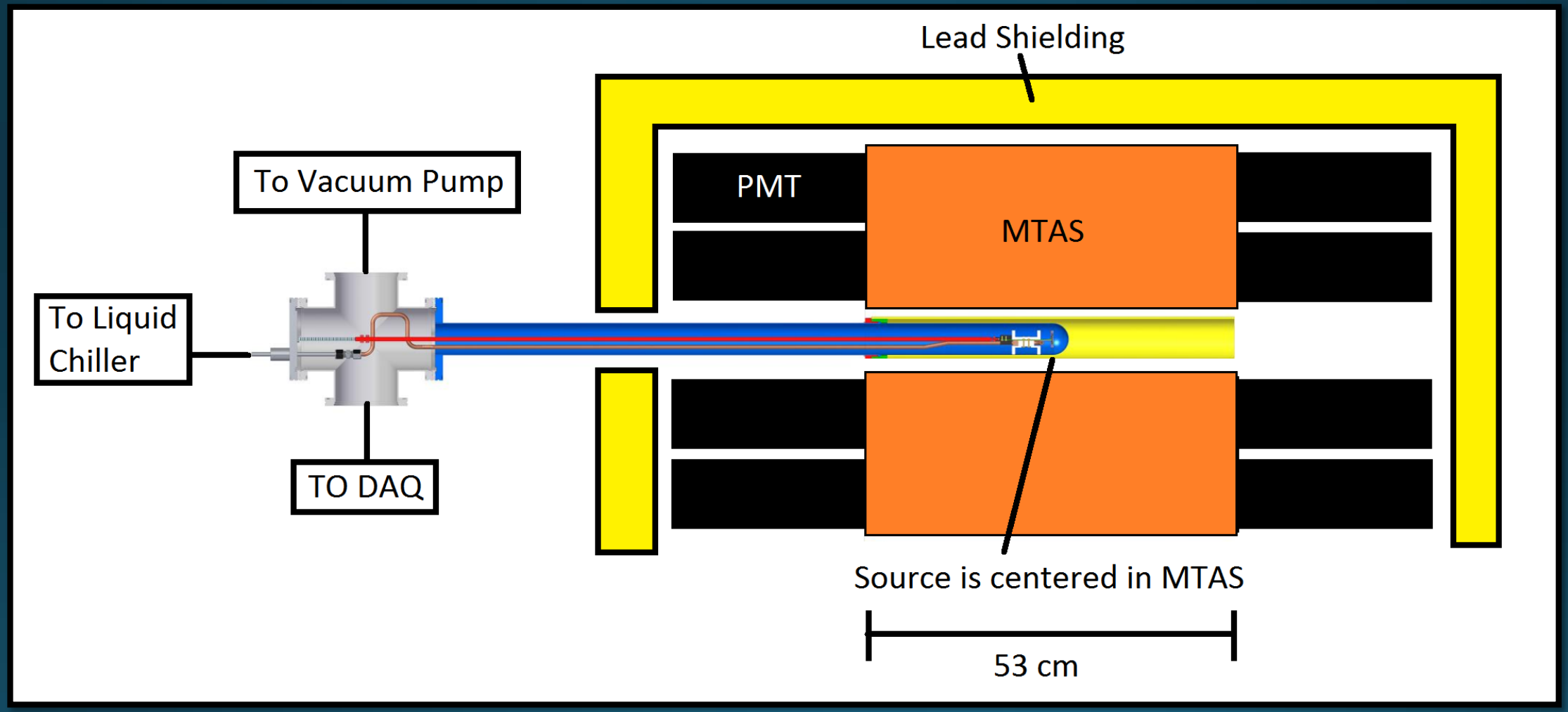
^{40}K Source Development



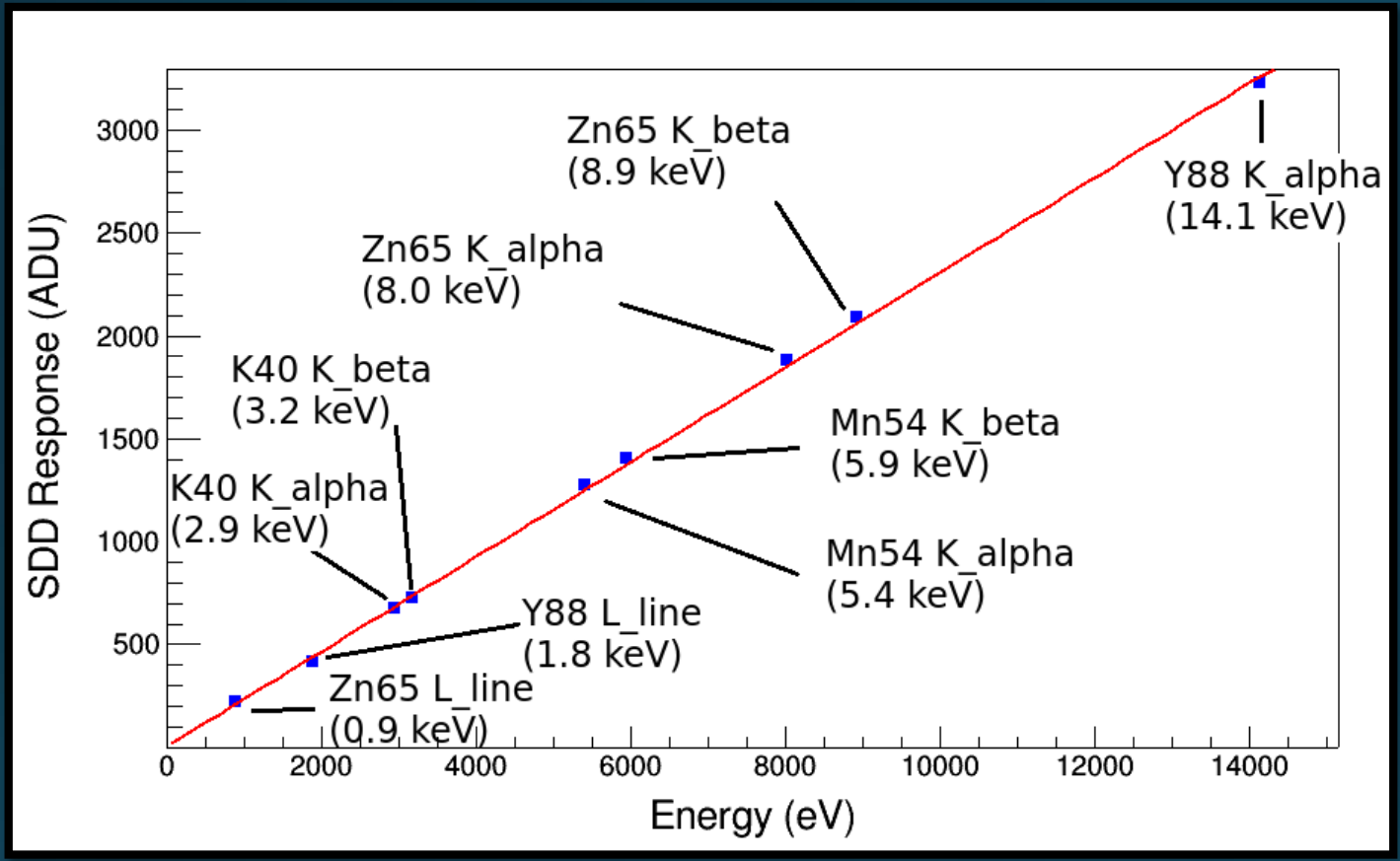


- ELECTRON BEAM DEPOSITION
- The electron beam is created by heating up a tungsten filament
- The released electrons are focused towards the tantalum crucible where 3.0 mg of enriched (16% ^{40}K) KCl is placed
- The heat causes the KCl to evaporate and deposit in the graphite disk placed above

KDK Experimental Setup

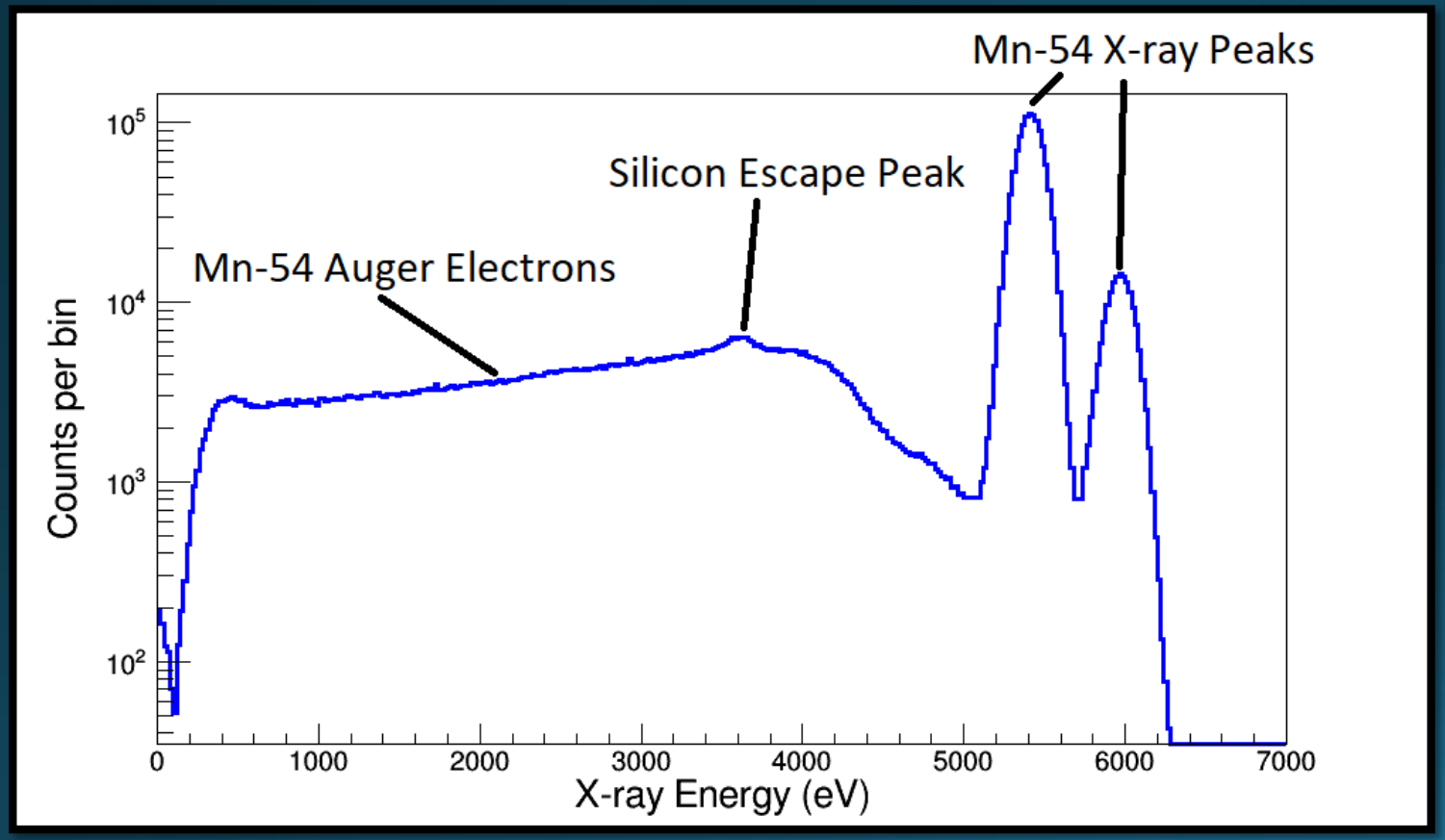


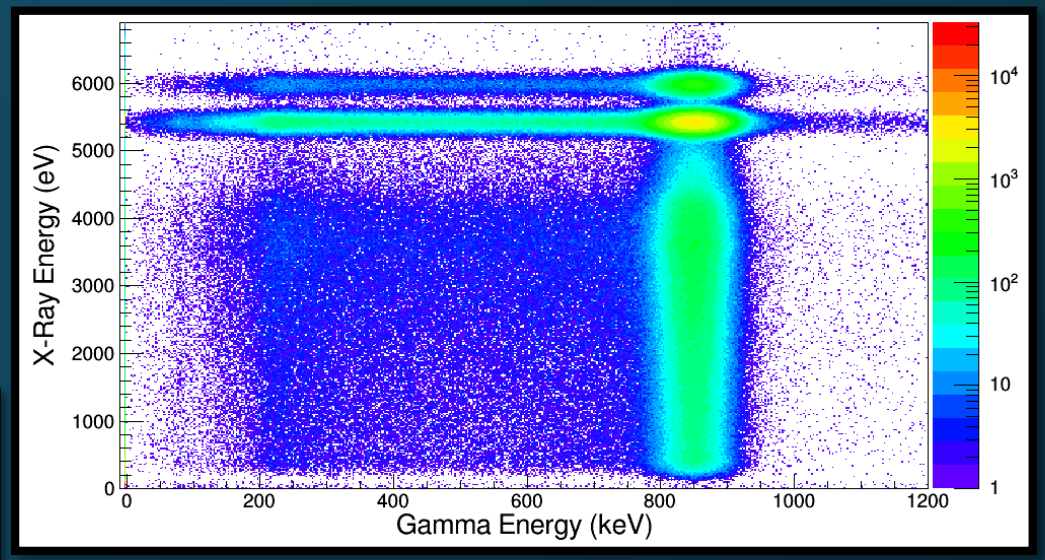
SDD Energy Calibration



- SDD was calibrated using 4 different sources
  - ^{65}Zn (0.9, 8.0 and 8.9 keV)
  - ^{88}Y (1.8, 14.1 keV)
  - ^{54}Mn (5.4, 5.9 keV)
  - ^{40}K (2.9, 3.2 keV)
- Calibration was very linear
- Energy Threshold: ~250 eV
- Energy Limit: ~15 keV
- FWHM: ~170 eV @ 6keV

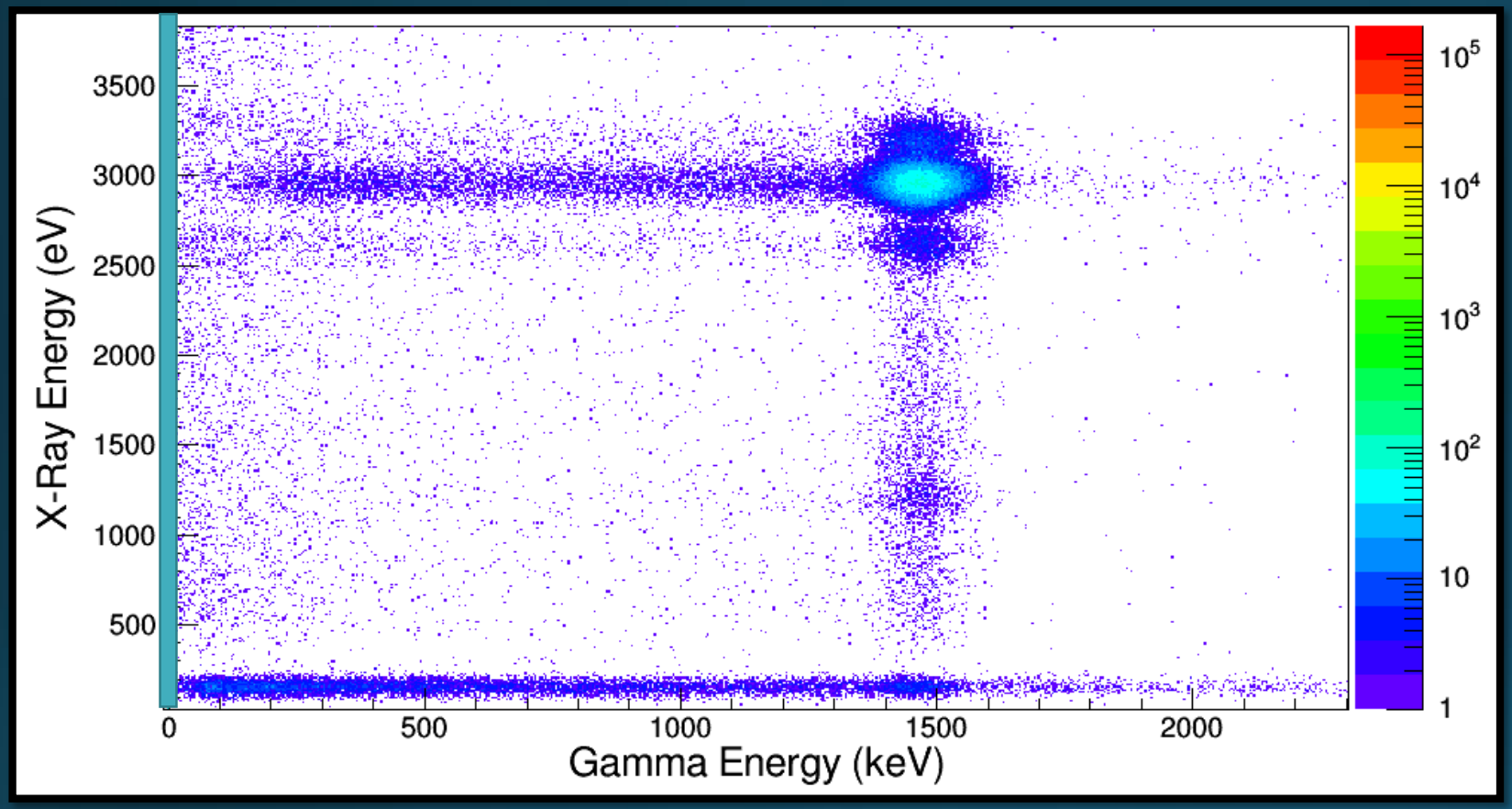
Data Analysis: ^{54}Mn

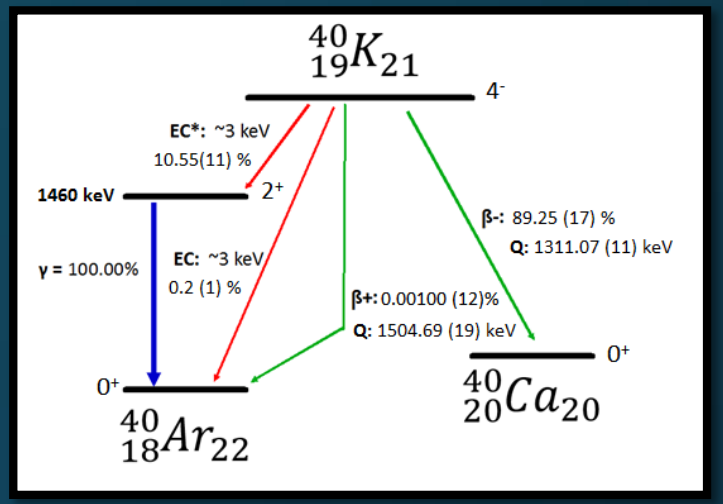




- ^{54}Mn source used to find our gamma tagging efficiency at 845 keV
- ^{55}Fe contamination due to source construction
- Efficiency: ~0.98 (For 1 us, coincidence window)

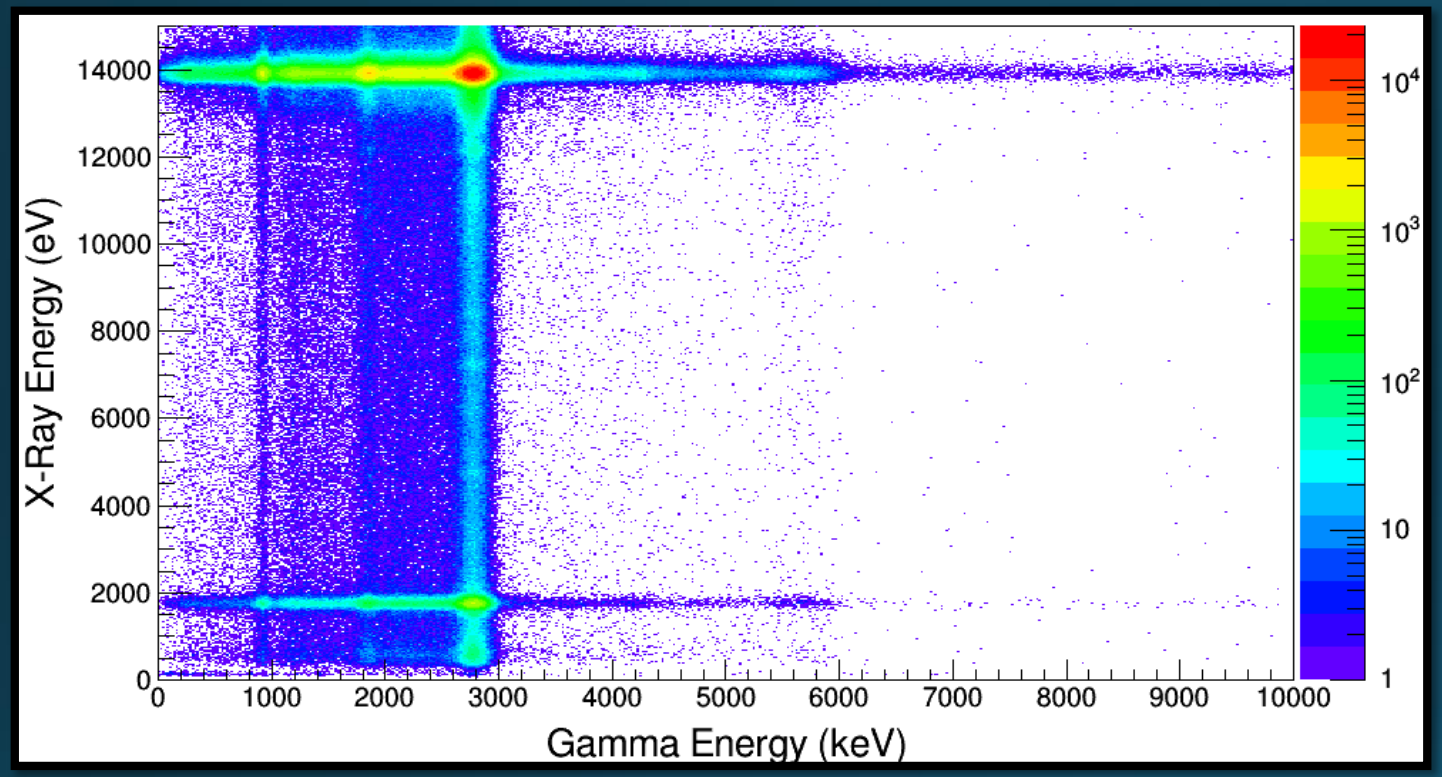
^{40}K Measurement

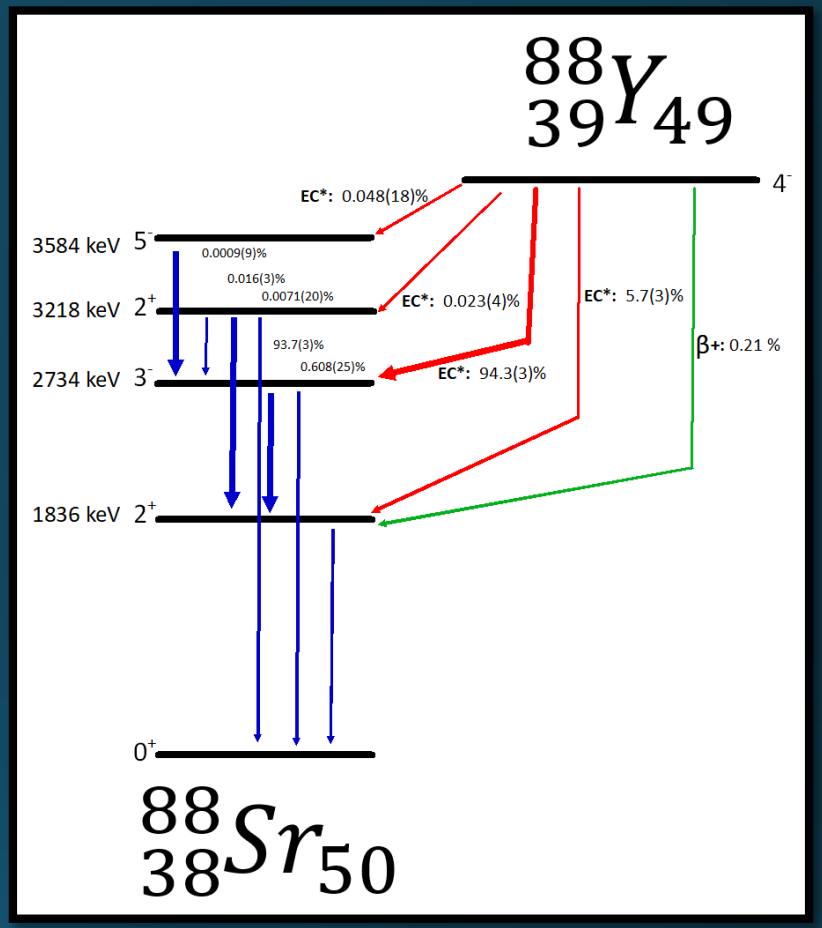




- All ^{40}K data was taken during the December 2017 campaign, ^{40}K visible in MTAS/SDD setup!
- Total Run Time: 43 days, Total Useable Time: 33 days, (due to power failure), Data is blinded
- Silicon Escape Peak (~1.2 keV), Cl fluorescence (~2.9 keV)

Extra Physics





- ^{88}Y has a unique third forbidden decay as well. Has never been experimentally measured (barely even theoretically predicted)
- Use of the KSr_2I_5 scintillator
- ^{110m}Ag: For reactor neutron flux measurements

Summary

- KDK is an experiment dedicated to the measurement of a rare decay of ^{40}K
- Uses a large outer detector MTAS and a small inner detector, SDD
- 33 days of data has been taken with a custom ^{40}K source
- Data analysis is ongoing with results expected to be published soon!!!

Acknowledgment

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References

1) Pradler, Josef, Balraj Singh, and Itay Yavin. "On an unverified nuclear decay and its role in the DAMA experiment." *Physics Letters B* 720.4-5 (2013): 399-404.
2) Wolińska-Cichocka, M., et al. "Modular Total Absorption Spectrometer at the HRIBF (ORNL, Oak Ridge)." *Nuclear Data Sheets* 120 (2014): 22-25.
3) Bernabei, R. et. al. “First model independent results from DAMA/LIBRA-phase2”. *arXiv preprint arXiv:1805.10486*. (2018)