# Understanding $^{40}$K: the KDK (potassium decay) experiment

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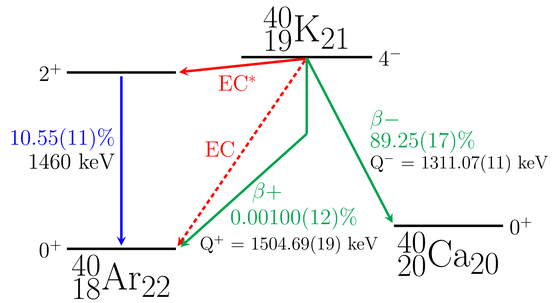
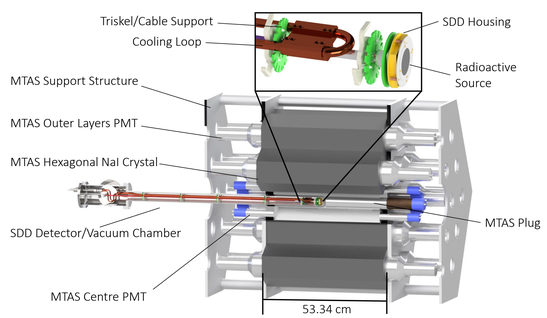
## $^{40}$K and electron capture




- Electron capture (EC, EC*) emits $\lesssim 3$ keV Auger electrons and X-rays from Ar
- EC* can be tagged by 1.4 MeV $\gamma$, EC can't
- Causes background in signal region of dark matter searches, in particular those using NaI. May constrain DAMA/LIBRA dark mater claim [1]
- **EC never observed! Predicted ratio of branching ratios $\rho = \frac{I_{EC}}{I_{EC*}}$: 0.005–0.03**
- Rare decay, of interest to nuclear theory
- Existence of EC debated in geochronology [2]. Has implication for K-Ar and Ar-Ar dating [3]

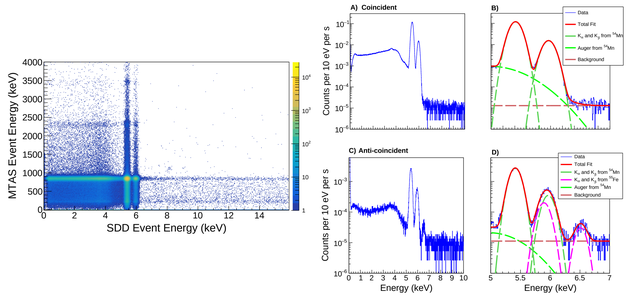
## Measuring EC with the Modular Total Absorption Spectrometer (MTAS)

- KCl source enriched in $^{40}$K, activity ~ 🍌
- Small, keV-threshold SDD detector to trigger on X/Augers from EC/EC*
- Large, efficient NaI veto to tag 1.4 MeV $\gamma$ from EC*: MTAS at Oak Ridge




## Determining MTAS tagging efficiency $\varepsilon$

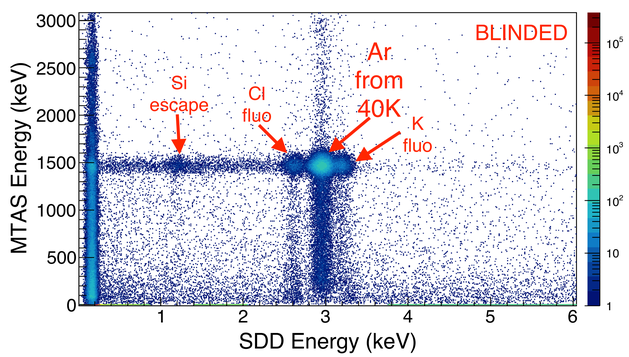
- Need to know $\varepsilon$, efficiency with which MTAS tags 1.4 MeV $\gamma$ when SDD triggers on an EC* X/Auger
- Use $^{54}$Mn, which decays overwhelmingly by EC* ($E_\gamma = 835$ keV) to $^{54}$Cr, and compare coincident to uncoincident Cr counts
- Source has same geometry as $^{40}$K




- SDD allows clear resolution of $K_\alpha$, $K_\beta$ lines, identification of $^{55}$Fe BG
- Accounting for difference in $E_\gamma$ and other factors, **tagging efficiency $\varepsilon = 0.9789(6)$ [4] — precision is important!**

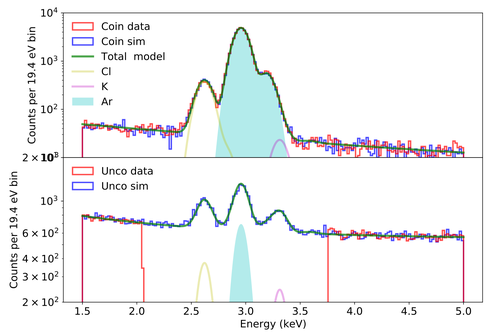
## 44-day $^{40}$K run

After minor stability cuts, and with signal region blinded:



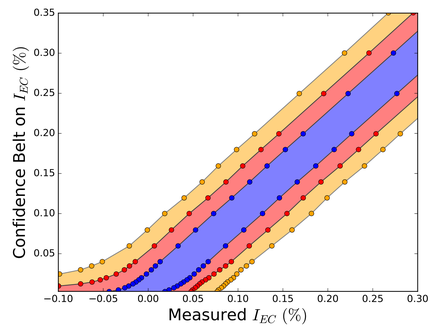

## Modelling blind region, and analysis

Simultaneous fit of coincident (open) and uncoincident (simulation of blind) spectra:




- Shape of Ar signal, and of Cl and K fluorescent backgrounds, common to both spectra
- Intensities, and flat and exponential backgrounds, independent
- Likelihood function to determine $\rho$ includes
  - Coincident and uncoincident Ar counts
  - Difference in X-ray emission probabilities for EC and EC*
  - MTAS tagging efficiency $\varepsilon$ (EC* looks like EC)
  - Spurious background coincidences (EC looks like EC*)

## Sensitivity of experiment




- Given measured $\varepsilon$ and known backgrounds, $\pm 15\%$ relative on $\rho = 0.02$ attainable
- Will also perform likelihood ratio test with null hypothesis ($\rho = 0$)
- **Unblinding expected this fall!**

## References

[1] J. Pradler, et al., Phys. Lett. B 720 (2013) 399.
[2] K. Min, et al., Geochimica et Cosmochimica Acta 64 (2000) 73.
[3] J. Carter, et al., Geochronology 2 (2020) 355.
[4] M. Stukel, et al., Nucl. Instr. Meth. Phys. Res. A 1021 (2021) 165593.



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