# Production of Short-Lived $^{37}$K

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## Aim of the Present Work

- The purpose of our work during the summer months of 2010 was to produce a radioactive beam of $^{37}$K with ≥ 99% purity.
- Once produced, the next step of the experiment is to measure the half-life of $^{37}$K with great precision.
- Goal is to reduce the error in $\tau(^{37}\text{K})$ to 0.03 %.

## Radioactive Isotope Production

Inverse kinematics:
- Heavy projectiles (heavy ion beams)
- Light targets (p, d, He)
- Forward-directed products

Useful nuclear reactions:
- Charge-exchange
- Fusion-evaporation
- Projectile fragmentation

Factors contributing to isotopic rates:
- Beam intensity ($\Phi$)
- Target thickness ($D$)
- Reaction cross section ($\sigma$)
- Transmission efficiency ($\varepsilon$)

Production rate:

$$R = \Phi \cdot D \cdot \sigma \cdot \varepsilon$$

## Theory and Planning

Theoretical calculations were performed using the NSCL program LISE++.
This program helps to select the best reaction combination and possible beam energy. It generates information such as, production rates, identities of possible contaminants and plots of what to expect in true data.

## Experimental Details

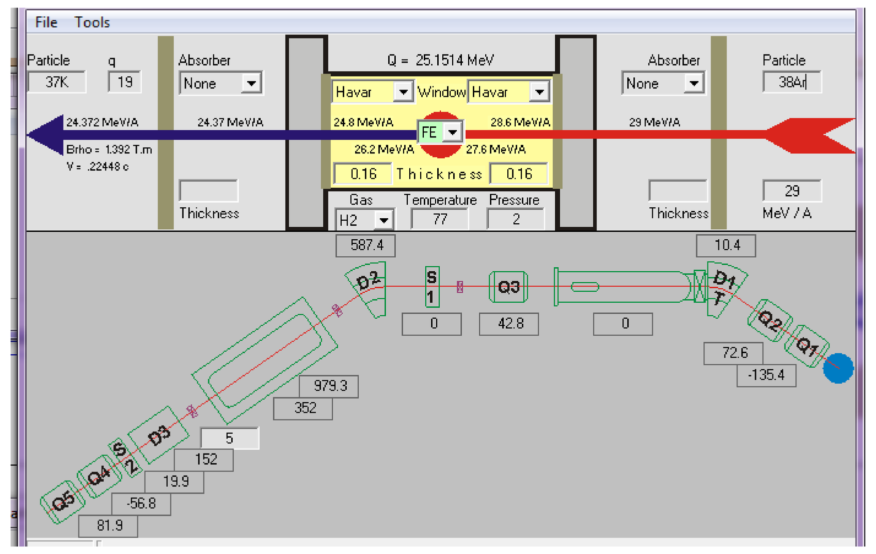
**Reaction**:
$^{38}$Ar (p,2n) $^{37}$K @ 25 MeV/u
$^{38}$Ar (p,2n) $^{37}$K @ 29 MeV/u
$^{38}$Ar (p,2n) $^{37}$K @ 29 MeV/u with Al degrader

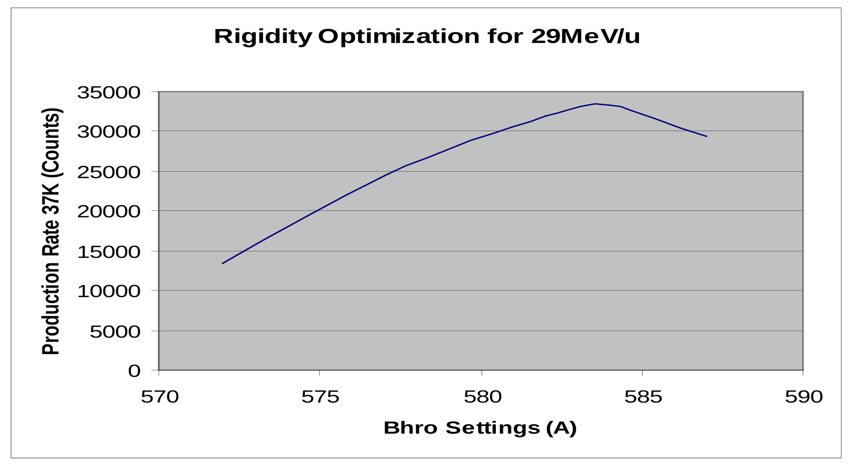
**Apparatus**:
MARS spectrometer.

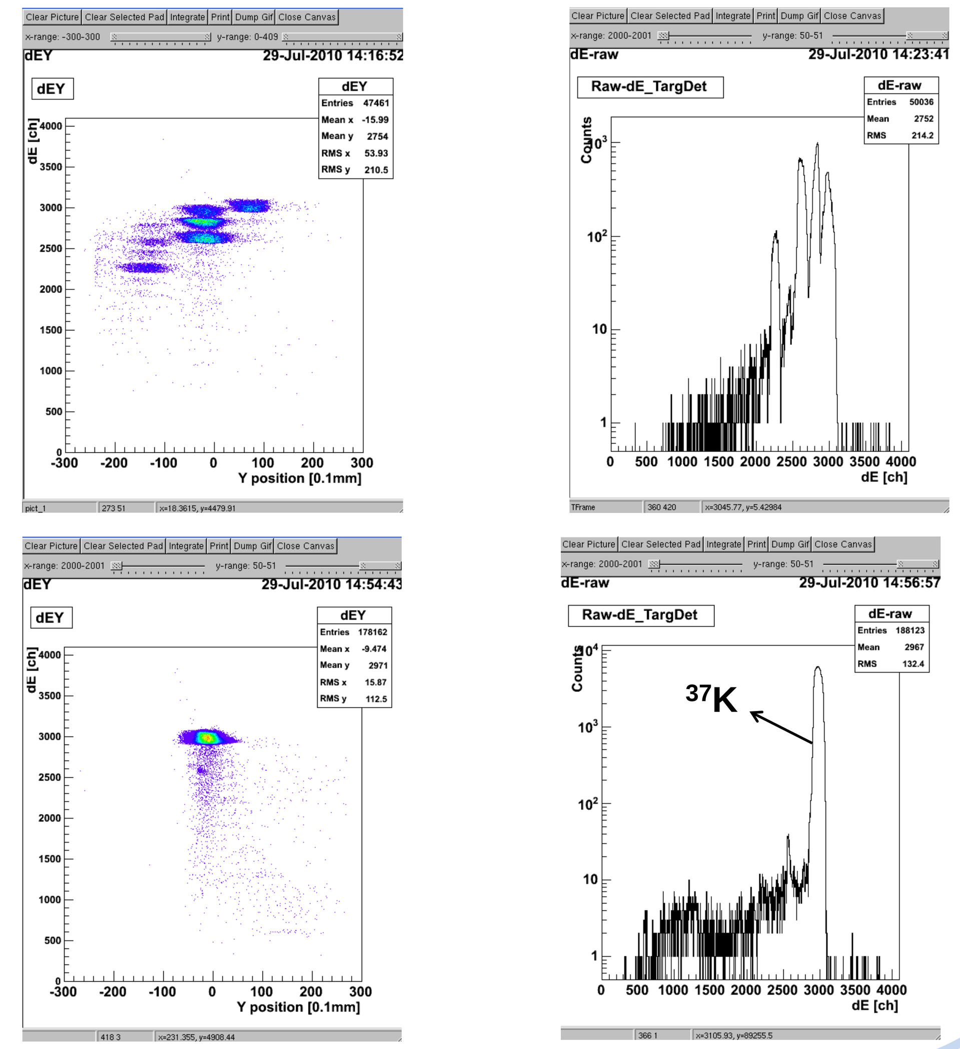
**Focal plane Detector**:
Silicon Strip detector.

## Data Collection

(1) For $^{37}$K production, a $^{38}$Ar beam of 25 MeV/u from K500 cyclotron was bombarded on a proton gas target (2 atmospheres pressure).
(2) MARS spectrometer was used to separate $^{37}$K from the primary beam.
(3) Settings of the MARS spectrometer were calculated using the MARSinator program.
(4) Separated products were detected at the focal plane using the strip detector.
(5) MARS settings were optimized for maximum production rate of $^{37}$K.
(6)Last slit of the MARS was optimized for purity of $^{37}$K.
(7) Step 1 to 6 was repeated for 29 MeV/u with and without the initial degrader.






## Data Analysis

Determining which isotopes we had produced and the amounts of each were our first goals. Identification was performed by multiplying the relative channel numbers by the energy calibration for the detector electronics of 0.295MeV/channel.
Additionally, it was important to record the production rate of each isotope to calculate the purity of the $^{37}$K in beam.

**25MeV/u Results**

| Channel | Data (MeV) | LISE++ (MeV) | Identity |
|---|---|---|---|
| 2535.45 | 747.96 | 755.04 | $^{37}$K |
| 2318.22 | 683.88 | 689.32 | $^{35}$Ar |
| 2183.84 | 644.23 | 652.09 | $^{33}$Cl |
| 2072.75 | 611.46 | 614.85 | $^{31}$S |
| 1948.47 | 574.80 | 577.62 | $^{29}$P |
| 1819.99 | 536.90 | 540.35 | $^{27}$Si |
| 1683.20 | 496.55 | 503.10 | $^{25}$Al |
| 1565.79 | 461.91 | 465.86 | $^{23}$Mg |
| 1447.73 | 427.08 | 428.64 | $^{21}$Na |
| 1328.40 | 391.88 | 391.41 | $^{19}$Ne |
| 1172.52 | 345.89 | 354.29 | $^{17}$F |
| 1055.64 | 311.41 | 317.18 | $^{15}$O |
| 958.72 | 282.82 | 280.08 | $^{13}$N |
| 834.93 | 246.31 | 242.97 | $^{11}$C |

**29MeV/u Results**

| Channel | Data (MeV) | LISE++ (MeV) | Identity |
|---|---|---|---|
| 3017.55 | 890.18 | 888.18 | $^{37}$K |
| 2811.73 | 829.46 | 833.65 | $^{35}$Ar |
| 2676.00 | 789.42 | 788.61 | $^{33}$Cl |
| 2548.08 | 751.68 | 743.58 | $^{31}$S |
| 2402.59 | 708.76 | 698.55 | $^{29}$P |
| 2236.59 | 659.79 | 653.46 | $^{27}$Si |
| 2080.35 | 613.70 | 608.41 | $^{25}$Al |
| 1936.81 | 571.36 | 563.37 | $^{23}$Mg |
| 1810.85 | 534.20 | 518.35 | $^{21}$Na |
| 1564.78 | 461.61 | 473.32 | $^{19}$Ne |
| 1303.26 | 384.46 | 428.42 | $^{17}$F |

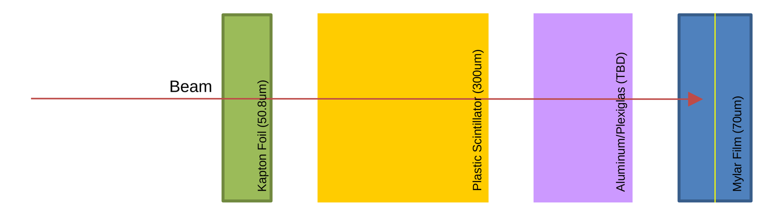
**29MeV/u with Degrader Results**

| Channel | Data (MeV) | LISE++ (MeV) | Identity |
|---|---|---|---|
| 2406.64 | 710.84 | 702.90 | $^{37}$K |
| 2365.44 | 697.81 | 704.372 | $^{35}$Ar |
| 2231.31 | 658.24 | 666.321 | $^{33}$Cl |
| 2130.55 | 628.51 | 628.276 | $^{31}$S |
| 2009.01 | 592.66 | 590.233 | $^{29}$P |
| 1892.38 | 558.25 | 552.142 | $^{27}$Si |
| 1748.66 | 515.86 | 514.855 | $^{25}$Al |
| 1618.08 | 477.33 | 476.030 | $^{23}$Mg |
| 1498.99 | 442.20 | 437.933 | $^{21}$Na |
| 1363.48 | 402.23 | 399.956 | $^{19}$Ne |
| 1226.33 | 361.77 | 362.022 | $^{17}$F |
| 1099.85 | 324.46 | 324.101 | $^{15}$O |
| 981.59 | 289.57 | 286.187 | $^{13}$N |
| 857.39 | 252.93 | 248.269 | $^{11}$C |

| Energy | 37K | Other Nucleons | Contamination (%) | Uncertainty (%) |
|---|---|---|---|---|
| 25MeV/u | 161550 | 1315 | 0.814 | 0.022 |
| 29MeV/u | 175644 | 1880 | 1.07 | 0.025 |
| 29MeV/u Degrader | 195613 | 3120 | 1.595 | 0.029 |

## Stopping Energies

Placement in the Mylar tape can be used as another source of filtering contaminants. SRIM, a program used to calculate the stopping energies of istopes was a great resource in planning. Knowing the beam must travel through approximately 50.8um Kapton foil, 0.3mm plastic scintillator, and stop somewhere in 70.3um Mylar tape all worked in these calculations.




**29MeV/u: Placement in Mylar (um)**

| Aluminum Thickness | $^{37}$K | $^{35}$Ar | 33Cl | 31S | 29P | 27Si |
|---|---|---|---|---|---|---|
| 172.11 | 5 | 2.14 | 16.17 | 28.68 | 43.66 | 59.16 |
| 163.12 | 10 | 8.69 | 21.37 | 34.49 | 50.56 | 66.67 |
| 153.45 | 15 | 13.79 | 27.31 | 41.33 | 58.4 | 75.47 |
| 146.42 | 20 | 18.13 | 32.24 | 47.05 | 64.43 | |
| 136.56 | 25 | 24.63 | 39.77 | 55.20 | 73.66 | |
| 131.54 | 30 | 28.39 | 43.75 | 59.83 | | |
| 123.35 | 35 | 34.38 | 50.39 | 67.70 | | |
| 117.37 | 40 | 39.30 | 56.04 | 73.79 | | |
| 111.52 | 45 | 44.82 | 61.92 | | | |
| 105.79 | 50 | 50.20 | 68.02 | | | |
| 100.94 | 55 | 54.97 | 73.35 | | | |
| 98.37 | 60 | 57.83 | | | | |
| 90.13 | 65 | 67.15 | | | | |

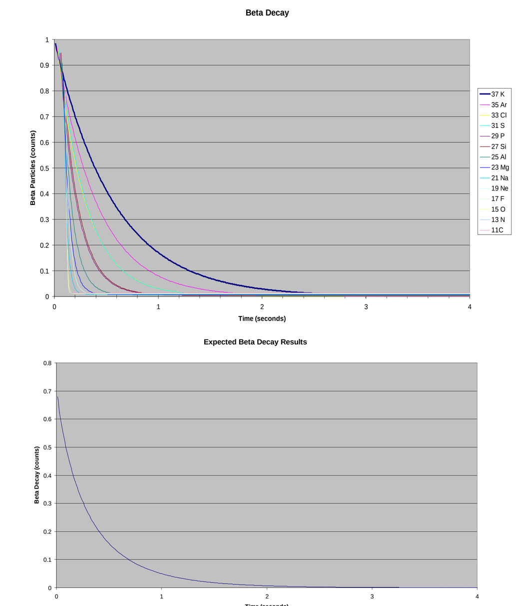
**29MeV/u: Placement in Mylar (um)**

| Plexiglas Thickness | $^{37}$K | $^{35}$Ar | $^{33}$Cl | $^{31}$S | $^{29}$P | $^{27}$Si |
|---|---|---|---|---|---|---|
| 294.71 | 5 | 1.18 | 41.43 | 81.10 | | |
| 278.88 | 10 | 15.41 | 55.28 | | | |
| 261.89 | 15 | 30.57 | 70.09 | | | |
| 249.56 | 20 | 41.56 | 81.04 | | | |
| 232.31 | 25 | 56.52 | | | | |
| 223.53 | 30 | 64.27 | | | | |
| 209.23 | 35 | 76.90 | | | | |
| 198.79 | 40 | | | | | |
| 188.59 | 45 | | | | | |
| 178.62 | 50 | | | | | |
| 170.18 | 55 | | | | | |
| 165.71 | 60 | | | | | |
| 151.38 | 65 | | | | | |

## Future Steps

Once the isotopes were identified it became critical to look ahead to the next step in the team's project. To measure the half-life of $^{37}$K our plan is to implant the isotope in a Mylar tape and count the amount of beta decay that occurs over a given period of time.
Knowing how much and exactly what contamination we have will affect the precision of this measurement.

| Nucleon | Half-Life (sec)* | Uncertainty (sec)* |
|---|---|---|
| 37K | 1.2248 | 0.0073 |
| 35Ar | 1.7752 | 0.001 |
| 33Cl | 2.5111 | 0.004 |
| 31S | 2.5740 | 0.017 |
| 29P | 4.1400 | 0.016 |
| 27Si | 4.1350 | 0.019 |
| 25Al | 7.1820 | 0.012 |
| 23Mg | 11.3243 | 0.0098 |
| 21Na | 22.4870 | 0.054 |
| 19Ne | 17.2480 | 0.029 |
| 17F | 64.6100 | 0.17 |
| 15O | 122.2400 | 0.27 |
| 13N | 597.8820 | 0.234 |
| 11C | 1221.6000 | 1.56 |




*N. Severijns, et al., Phys. Rev. C **78**, 055501 (2008).

## Conclusion

The team concluded for the highest production rate with the least contamination, an initial projectile beam energy of 29MeV/u with no degrader yields the best results.

With 29MeV/u we were able to obtain a production rate of 1756 counts/nC and purity of 98.93 ± 0.025 %.

Continuing into the next step this energy appears to maintain the best production rate and is easier to filter to higher purity during the half-life measurement.

## Acknowledgements

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