Production of Short-Lived ^{37}K

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Purpose of Research

To produce, at the Cyclotron Institute at Texas A&M University, a beam of ^{37}K and filter unwanted contaminants using the MARS Spectrometer and then reduce the uncertainty of it's half-life to < 0.03%.

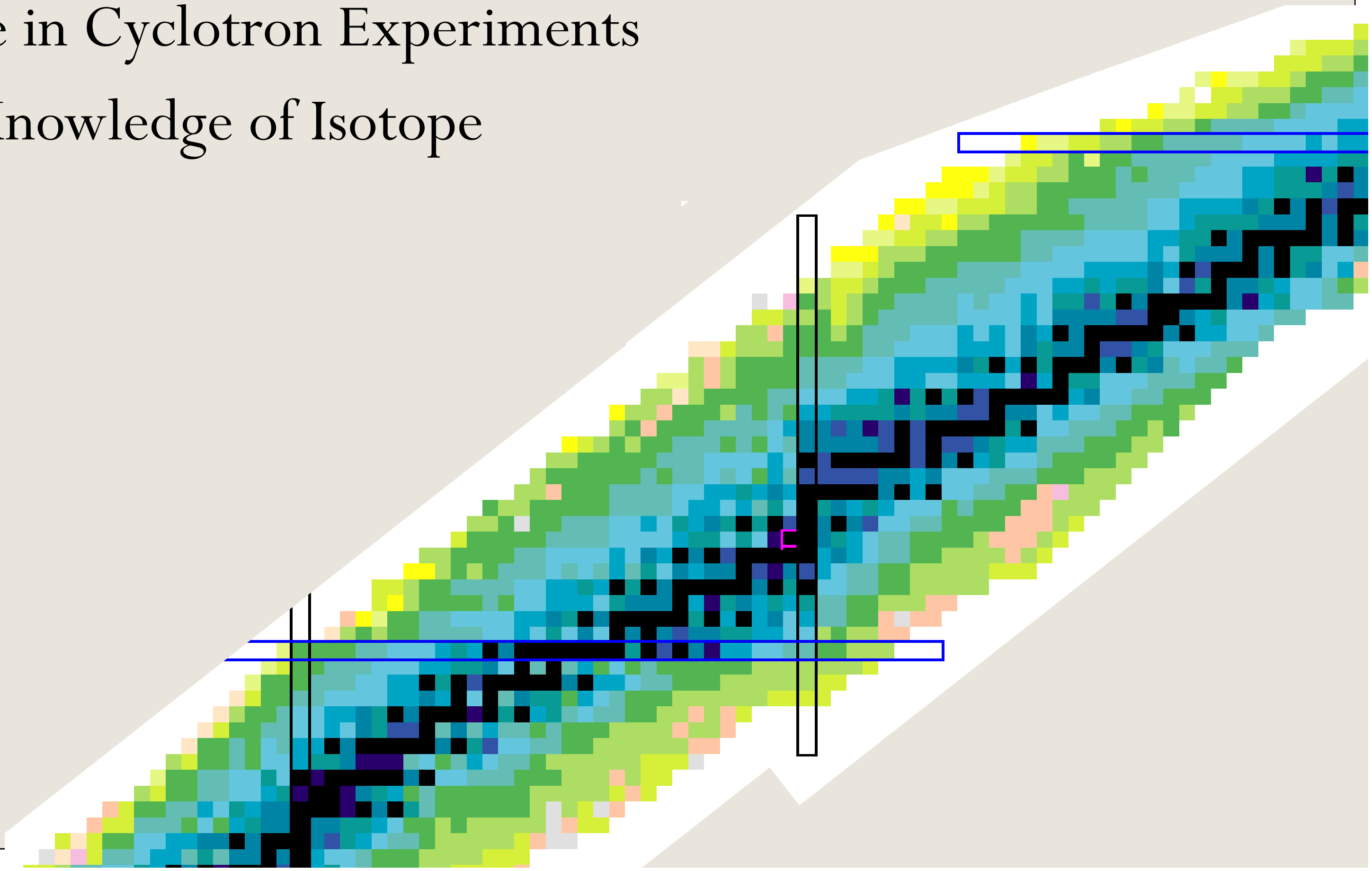
Current Half-Life ^{37}K: ***1.2248 ± 0.0073****

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

Beginnings

Why 37K?

* Isobaric Analog Decay
* Future use in Cyclotron Experiments
* Increase Knowledge of Isotope

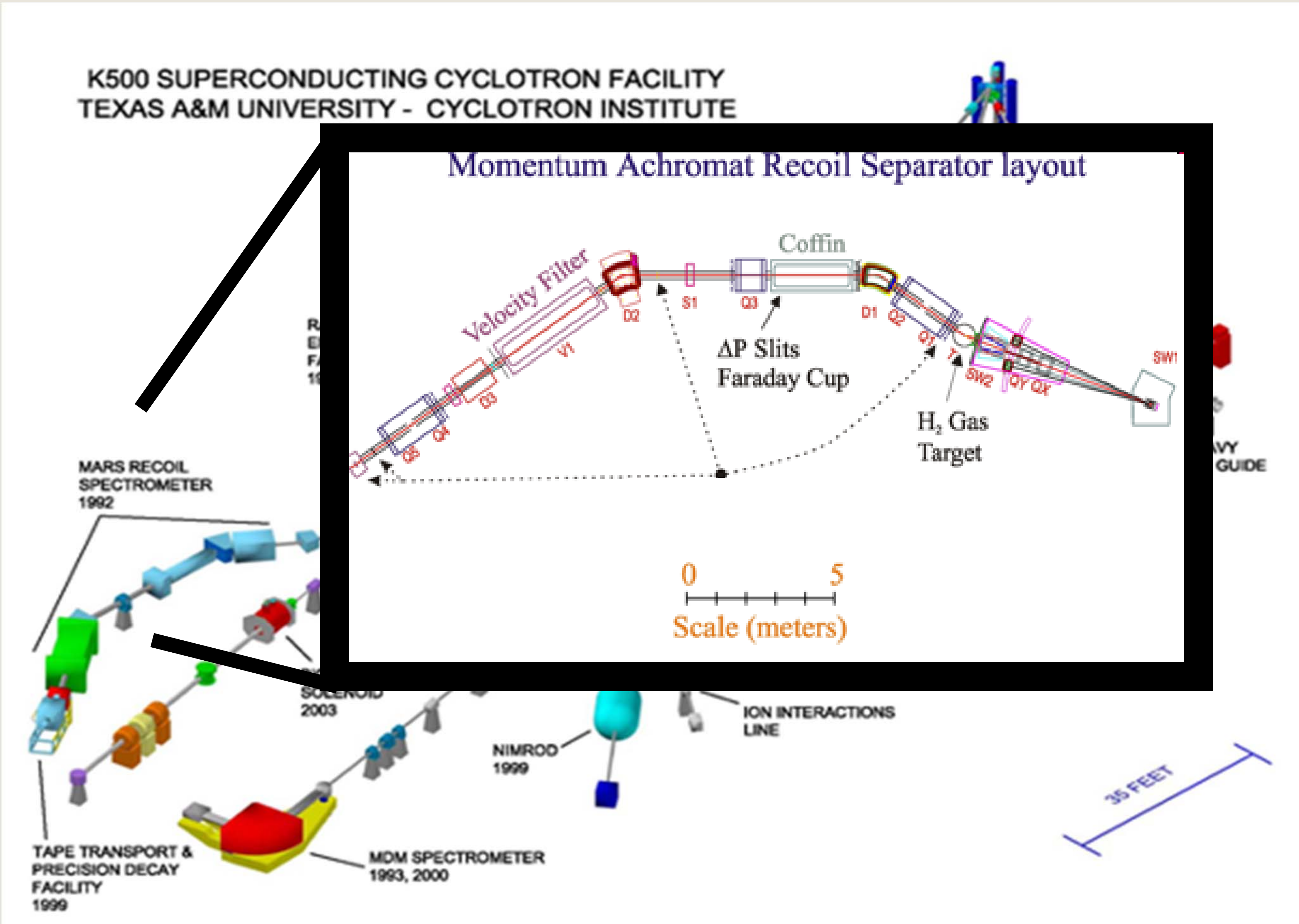


Method of Production

Using the K500 Cyclotron to produce a beam of ^{38}Ar at 25-30MeV/u and then bombarded a Hydrogen Gas target to trigger a series of nuclear reactions.

The products of these reactions then passed through the MARS Spectrometer to separate ^{37}K from the other fragments of the nuclear reaction.

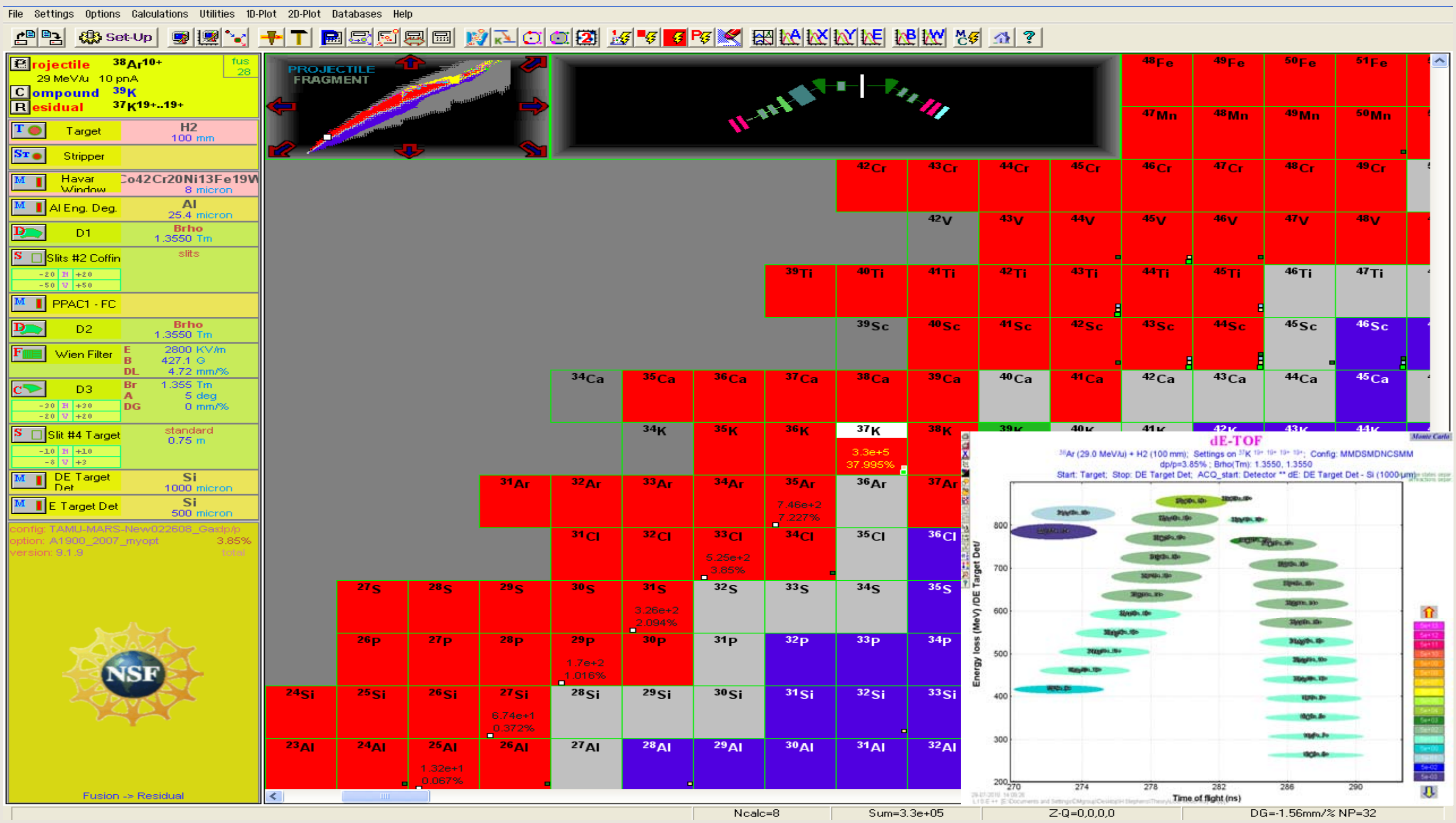
A detector was placed at the end of the spectrometer to analyze the resultant beam.



K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE
Momentum Achromat Recoil Separator layout
Coffin
Velocity Filter
D2
S1
Q3
D1
Q2
Q1
V1
D3
Q4
Q5
SW1
SW2
QY QX
ΔP Slits
Faraday Cup
H_2 Gas
Target
0
5
Scale (meters)
MARS RECOIL
SPECTROMETER
1992
NIMROD
1999
ION INTERACTIONS
LINE
TAPE TRANSPORT &
PRECISION DECAY
FACILITY
1999
MDM SPECTROMETER
1993, 2000
35 FEET

LISE++

- An essential program!
  - Helped determine optimal energy for desired results
  - Calculates Production Rates, Purity, and Plots of Resultant Beam



LISE++

The group determined the best energies for the experiment were 25MeV/u and 29MeV/u.

Two-Body Reaction (38Ar → 37K) Open Slit

Energy (MeV/u)	Upper Slit	Lower Slit	Result (MeV/u)	# Cont.	Production Rate
25	25	-25	19.082	24	6.45E+03

Fusion Reaction (38Ar → 37K) Open Slit

Energy (MeV/u)	Upper Slit	Lower Slit	Result (MeV/u)	# Cont.	Production Rate
29	25	-25	23.103	30	3.82E+05

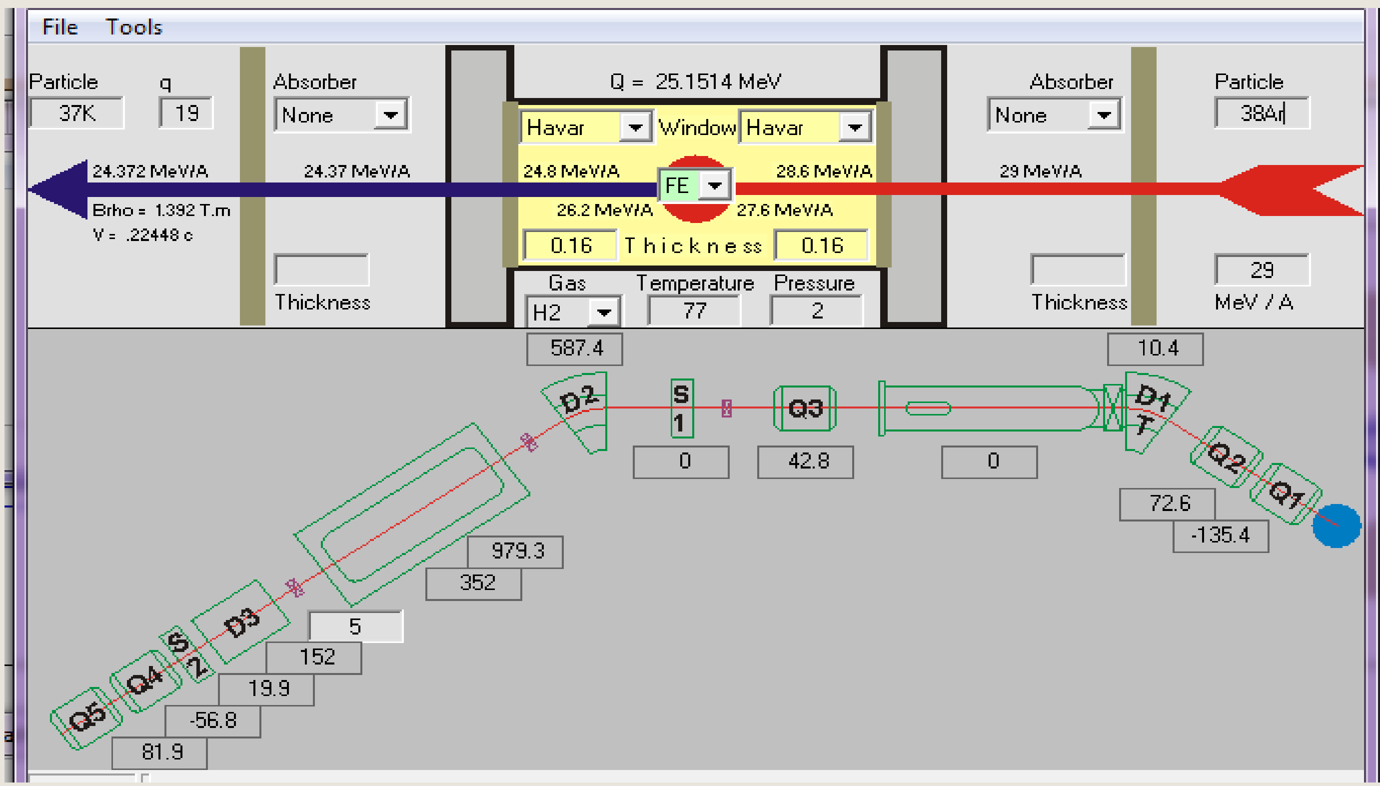
Note: Two-Body and Fusion Reactions both occur simultaneously in the actual experiment. However, LISE++ allows for analysis of individual types of reactions.

We also were able to determine approximate dipole settings for the MARS spectrometer as a starting point for the experiment.

MARSinator

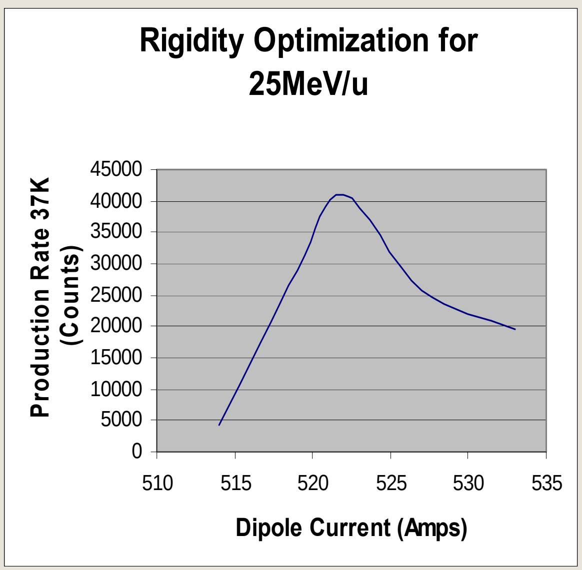
The MARSinator program inputs experimental settings and determines optimum dipole settings for the MARS Spectrometer.

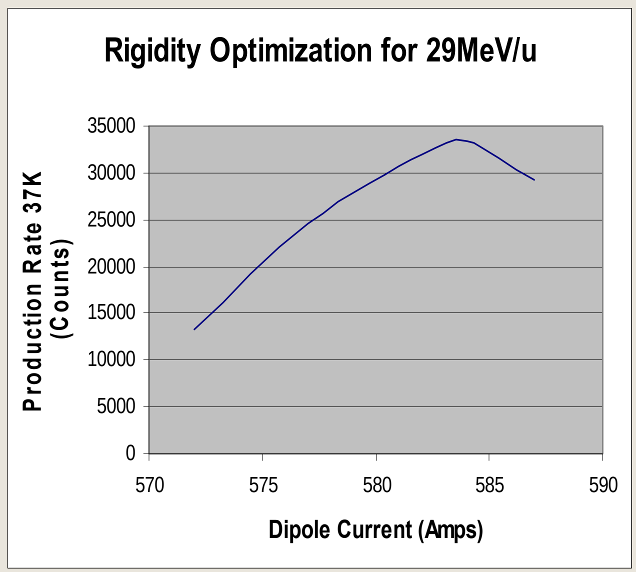
Dipole settings are adjusted to select out of the beam specific magnetic rigidity.

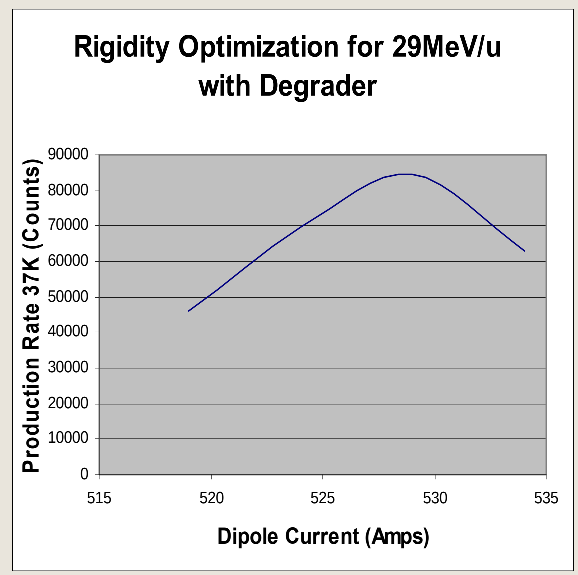


Conducting the Experiment

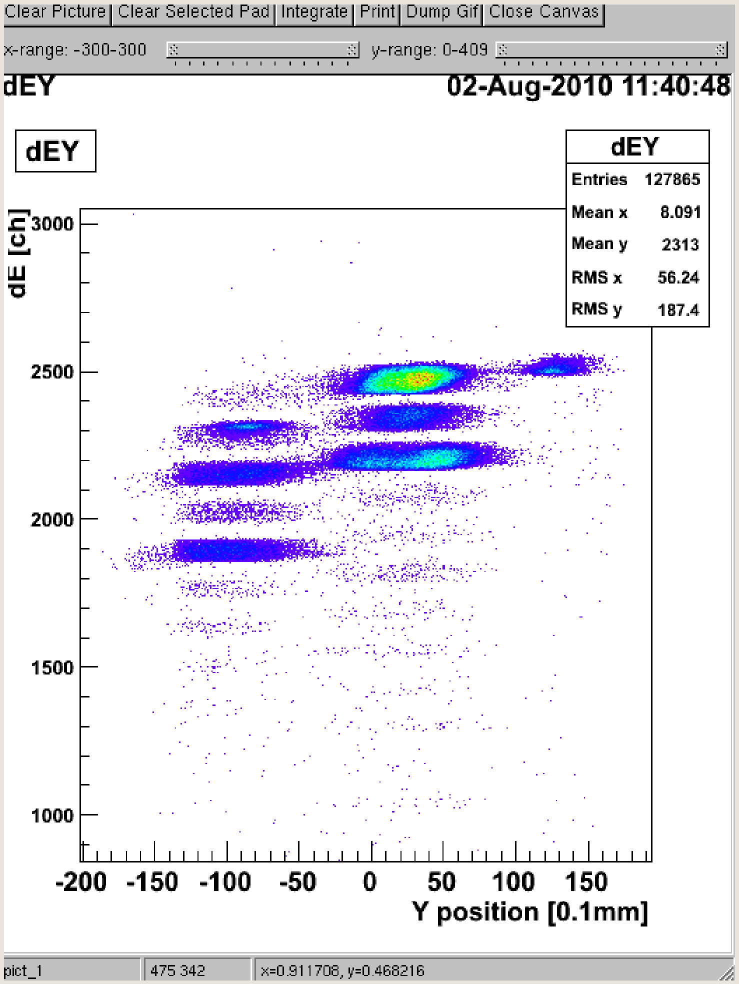
- Multiple Energy Settings: 25MeV/u, 29MeV/u, 29MeV/u with Degrader
- MARSinator Simulation for Rigidity Settings
- Short Collection, Extended 5 Minute Tests, Final Long Exposure (500,000 count)



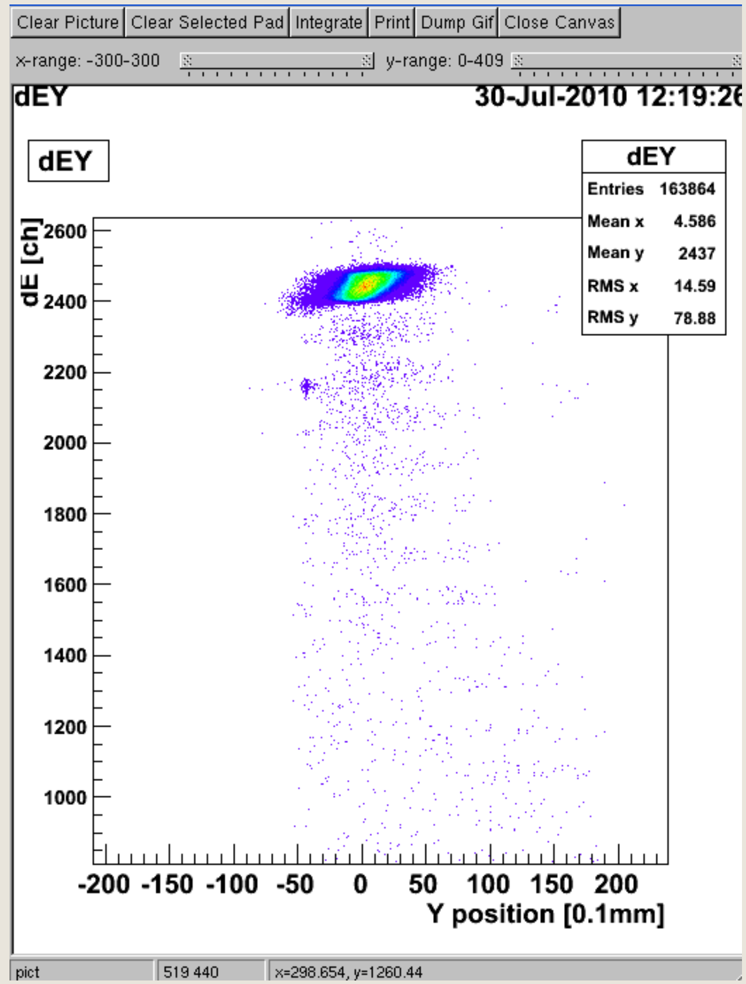




25 MeV/u

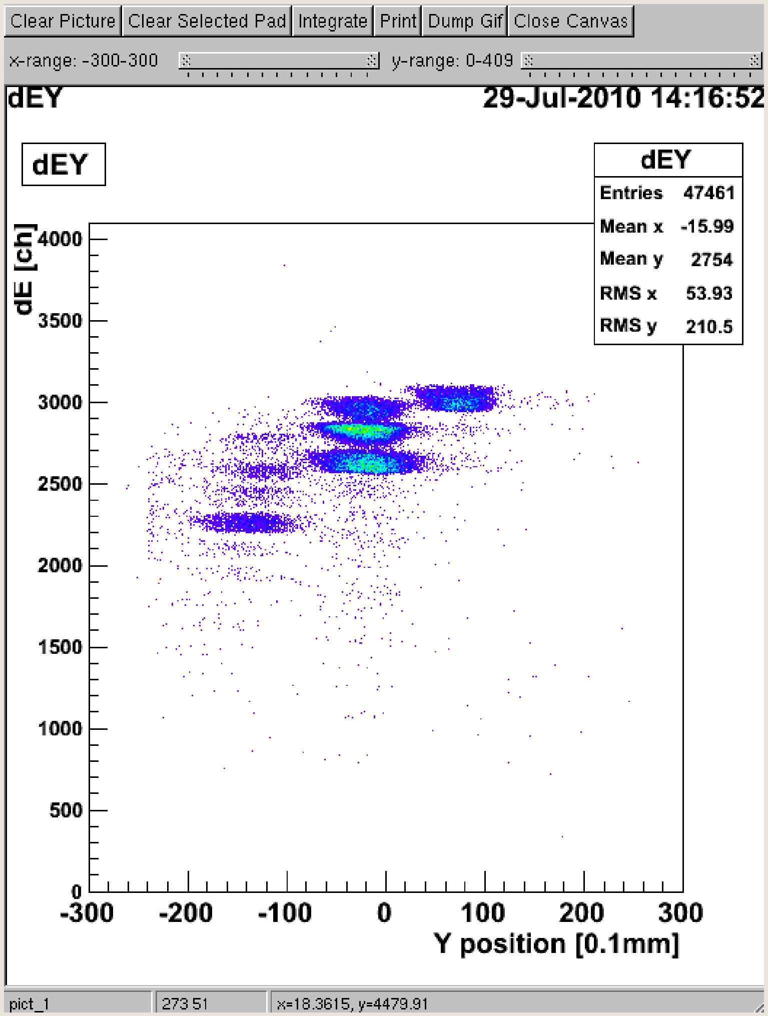


Rigidity: 537.6 A

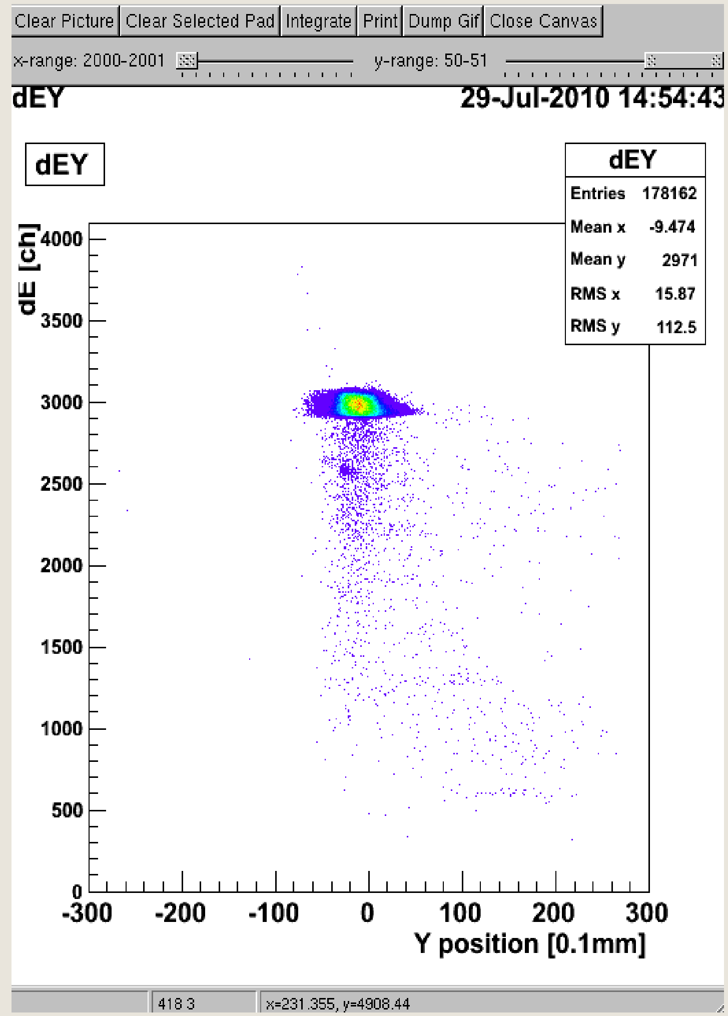


Rigidity: 528 A

29MeV/u

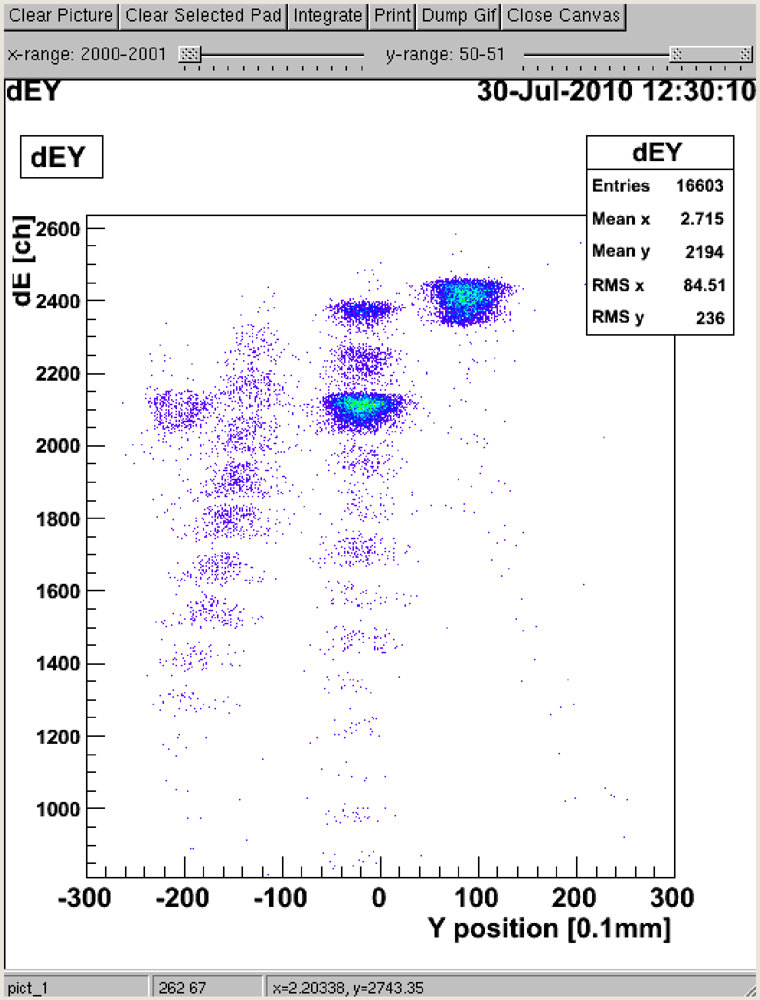


Rigidity: 587.4 A

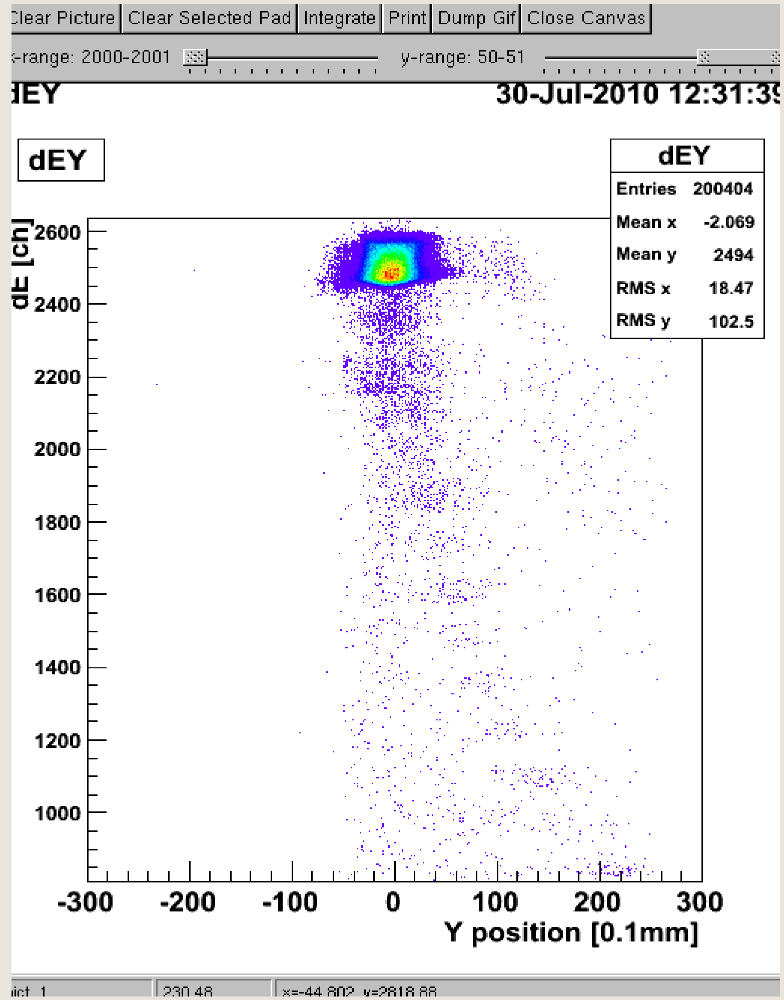


Rigidity: 584 A

29MeV/u with Degrader



Rigidity: 519 A



Rigidity: 534 A

Data Analysis

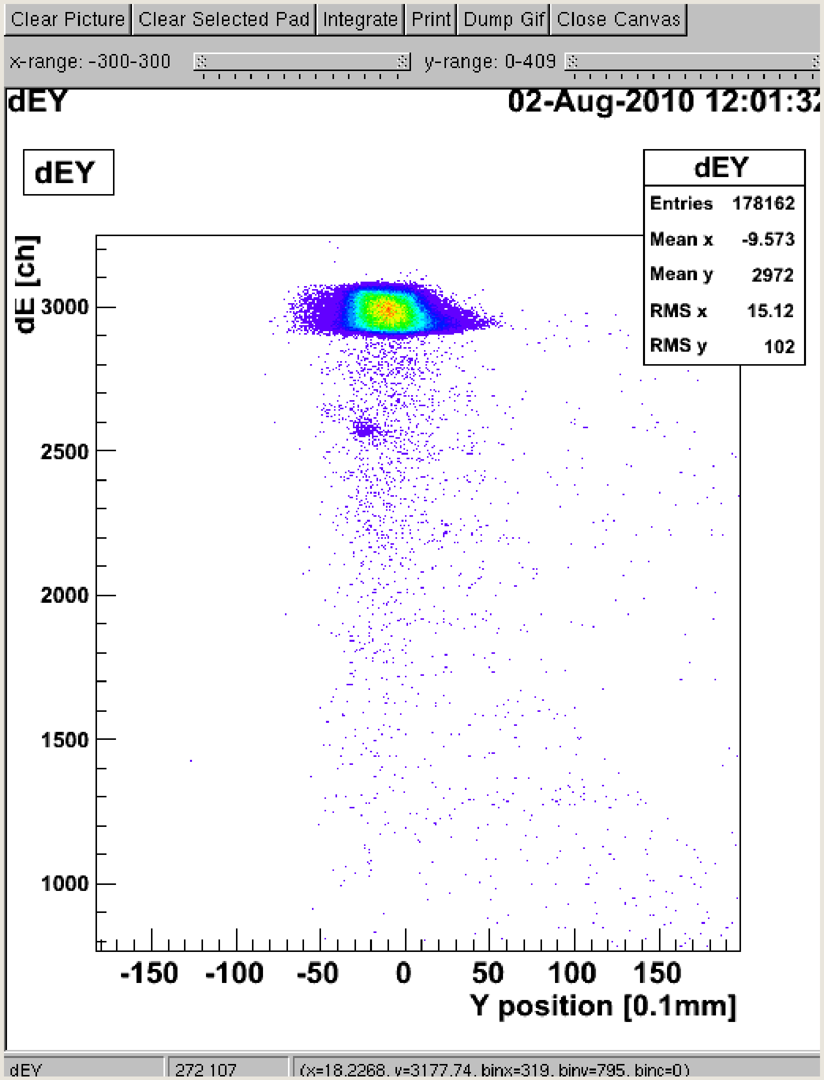
The bulk of the analysis from the team's experiment was based on identifying each isotope which was detected.

Our energy calibration value of 0.295MeV/channel was determined from prior experiments.

*Energy (MeV) = Channel Number * Energy Calibration*

*Energy (MeV) = 3017.55 * 0.295 = 890.18 MeV* $\longrightarrow$ *37K*

Data Analysis: Identification of Nucleons



Slits Closed - 101001 (Brho - 584A)			
Avg. Channel	*Data (MeV)*	*Identity*	*LISE++ (MeV)*
3017.55	890.18	37K	888.18
2811.73	829.460	35Ar	833.650
2676.00	789.419	33Cl	788.610
2548.08	751.684	31S	743.577
2402.59	708.763	29P	698.547
2236.59	659.793	27Si	653.460
2080.35	613.704	25Al	608.409
1936.81	571.360	23Mg	563.368
1810.85	534.200	21Na	518.345
1564.78	461.610	19Ne	473.321
1303.26	384.462	17F	428.419

Data Analysis: Production Rate

After identifying each isotope, the focus turned to understanding the amount we were able to produce.

These production rates help determine the purity of ^{37}K made.

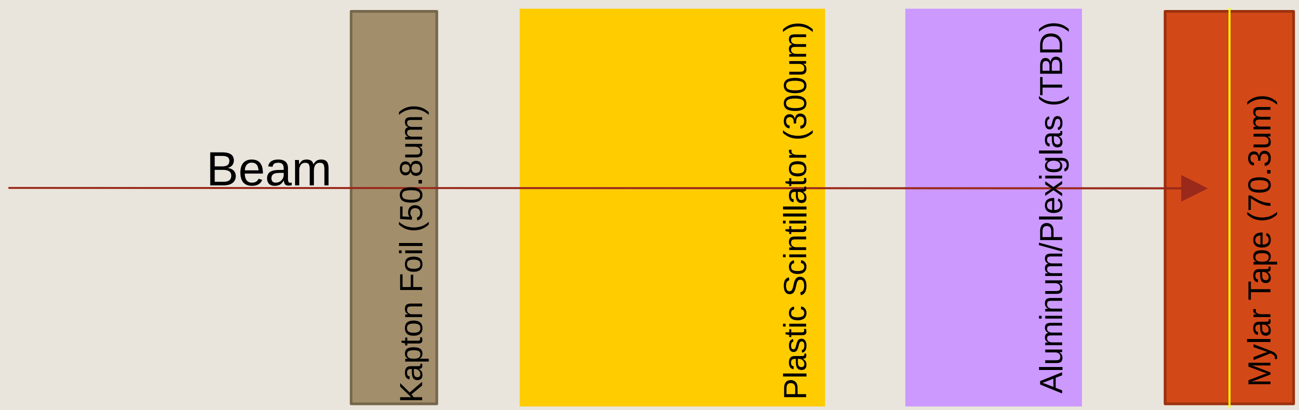
Production Rates and Contamination		
Identity	*Production Rate*	*% Contamination*
37K	1756.44	99.282 ± 0.942
35Ar	3.5	0.199 ± 0.011
33Cl	2.29	0.130 ± 0.009
31S	2.46	0.140 ± 0.009
29P	1.12	0.064 ± 0.006
27Si	1.63	0.093 ± 0.007
25Al	0.42	0.024 ± 0.004
23Mg	0.33	0.019 ± 0.003
21Na	0.25	0.014 ± 0.003
19Ne	0.22	0.013 ± 0.003
17F	0.28	0.016 ± 0.003

Energy (MeV/u)	Production Rate (counts/nC)	% Contamination	% Purity
25	807.75	0.814 ± 0.022	99.816 ± 0.022
29	1756.44	1.070 ± 0.025	98.93 ± 0.025
29 with Degrader	1956.13	1.595 ± 0.029	98.405 ± 0.029

What Comes Next?

Application of our results comes in the next experiment to be held August 20, 2010.

By implanting ^{37}K into Mylar tape, we will be able to measure the beta decay isotopes in our generated beam and determine the half-life of ^{37}K.



SRIM Calculations

We want to determine the optimum placement for ^{37}K.

25MeV/u: Placement in Mylar (um)

Aluminum Thickness	^{37}K	^{35}Ar	^{33}Cl	^{31}S	^{29}P	^{27}Si
85.74	5	0.00	7.25	16.81	28.24	41.28
79.04	10	0.00	11.91	21.73	34.09	47.79
72.69	15	7.64	16.76	27.02	40.37	57.99
66.74	20	12.75	21.69	32.70	46.57	65.54
60.14	25	17.85	27.65	39.63	54.16	70.83
56.38	30	21.01	31.88	43.94	58.93	
51.07	35	26.49	37.83	50.71	66.69	
46.52	40	32.00	43.34	56.89	73.07	
43.16	45	35.76	47.86	61.82		
39.41	50	40.38	52.94	67.44		
36.27	55	44.82	58.28	72.72		
33.47	60	49.41	62.84			
28.55	65	57.42	71.39			

29MeV/u: Placement in Mylar (um)

Aluminum Thickness	^{37}K	^{35}Ar	^{33}Cl	^{31}S	^{29}P	^{27}Si
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 Degrader: Placement in Mylar (um)

Aluminum Thickness	^{37}K	^{35}Ar	^{33}Cl	^{31}S	^{29}P	^{27}Si
64.61	5	20.72	30.80	46.60	63.32	
58.82	10	26.17	36.69	53.53	70.72	
53.28	15	32.00	43.34	60.82		
48.10	20	38.22	49.97	68.49		
43.16	25	44.44	56.93	76.50		
38.92	30	50.59	63.31			
34.63	35	57.01	70.42			
31.20	40	62.85				
27.90	45	68.46				
24.73	50	73.34				
22.07	55					
19.70	60					
15.51	65					

25MeV/u: Placement in Mylar (um)

Plexiglas Thickness	^{37}K	^{35}Ar	^{33}Cl	^{31}S	^{29}P	^{27}Si
143.53	5	0.00	9.76	34.16	60.42	
132.10	10	0.00	20.00	44.25	70.58	
121.08	15	8.71	29.80	53.88		
110.74	20	18.17	38.88	62.97		
99.25	25	28.13	49.01	73.14		
92.71	30	34.11	54.84			
83.49	35	42.30	62.75			
75.57	40	49.13	69.61			
69.73	45	54.28	74.74			
63.23	50	64.70				
57.80	55	68.60				
52.95	60	76.44				
44.50	65					

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					

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

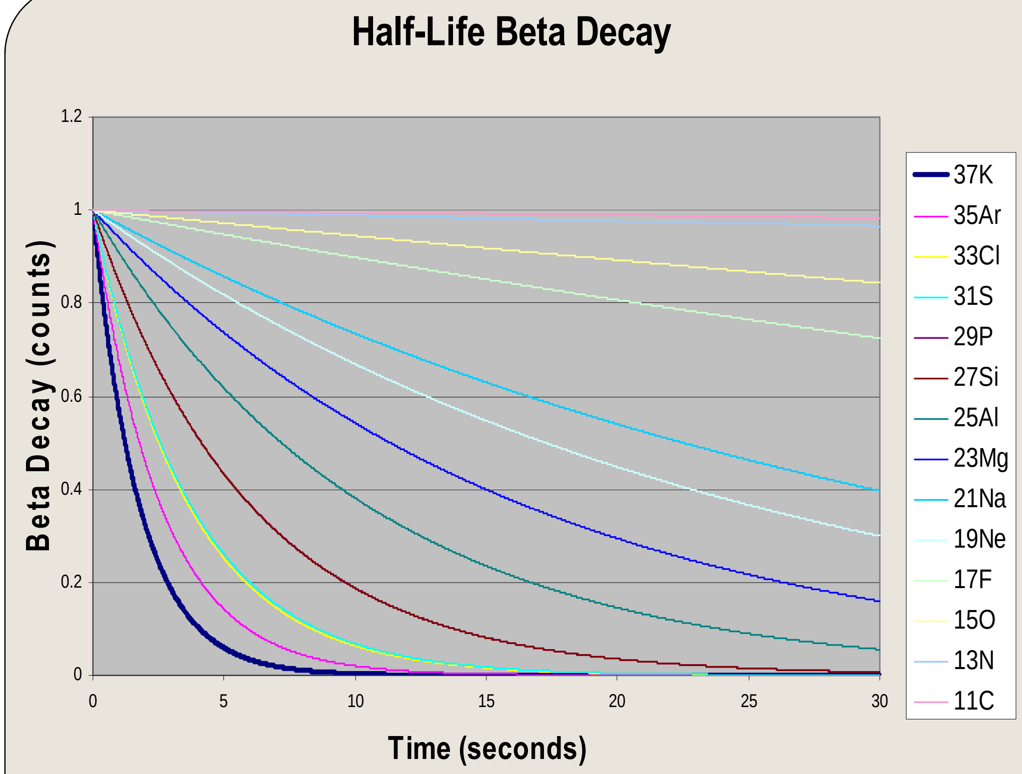
Plexiglas Thickness (um)	^{37}K	^{35}Ar	^{33}Cl	^{31}S	^{29}P	^{27}Si
107.02	5	34.45	56.16	87.93		
96.96	10	43.41	65.08			
87.32	15	51.88	73.75			
78.32	20	59.83	81.55			
69.73	25	67.29				
62.38	30	73.72				
54.95	35	80.36				
49.04	40					
43.39	45					
38.01	50					
33.56	55					
29.63	60					
22.81	65					

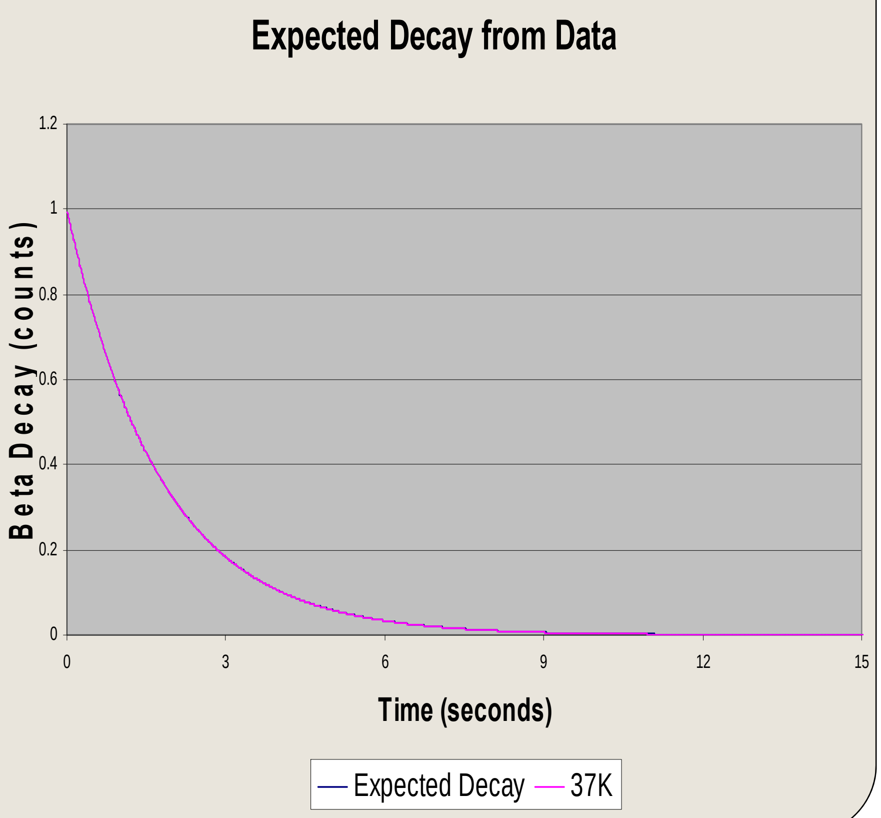
Measuring Half-Life

We can measure the half-life of what has been implanted onto the Mylar tape by counting the amount of beta decay per time. This is why purity is essential!

Nucleon	***Half-Life (sec)****	***Uncertainty (sec)****
^{37}K	1.2248	0.0073
^{35}Ar	1.7752	0.0010
^{33}Cl	2.5111	0.0040
^{31}S	2.5740	0.017
^{29}P	4.140	0.016
^{27}Si	4.135	0.019
^{25}Al	7.182	0.012
^{23}Mg	11.3243	0.0098
^{21}Na	22.487	0.054
^{19}Ne	17.248	0.029
^{17}F	64.61	0.17
^{15}O	122.24	0.27
^{13}N	597.882	0.234
^{11}C	1221.60	1.56

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


Half-Life Beta Decay
Beta Decay (counts)
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
Time (seconds)
37K
35Ar
33Cl
31S
29P
27Si
25Al
23Mg
21Na
19Ne
17F
15O
13N
11C


Expected Decay from Data
Beta Decay (counts)
1.2
1
0.8
0.6
0.4
0.2
0
0
3
6
9
12
15
Time (seconds)
Expected Decay
37K

Conclusion

It was concluded the best settings for optimal production and purity of ^{37}K is tuning the initial ^{38}Ar beam to 29MeV/u and possibly adding the Aluminum degrader.

Improvements can be made on the rigidity settings to increase production by setting the dipoles to 584Amps.

Additionally, when half-life is measured, we can expect to see small traces of other isotopes but maintain purity of 98.93 ± 0.025 % and rate of 1756 counts/nC.

A Special Thanks

I am very thankful for the patience and encouragement offered by the team which included Spencer Behling, Michael Mehlman, and especially Dr. Dan Melconian and Dr. Praveen Shidling. I could not have done it without them.

Also, I would like to thank the National Science Foundation and Department of Energy, as well as the Cyclotron Institute of Texas A&M for the funding and opportunity of this experience.