K500 Single Event Effects Facility Calibration Procedures and Results

Issued 15 April 2026

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Revision History

Revision	Issued	Changes
R001	27 February 2026	Original Issue
R002	15 April 2026	Updated calibration procedures and results

1 Objective

This document serves as an overview of the calibration procedures and results for various beam measurement and diagnostics devices used at the k500 Single Event Effects Facility.

2 Calibration Status Overview

Calibration Type	Date Last Performed	Calibration Cycle	Date Next Due	Supported Measurements
TetrAMM Picoammeter	4/2/26	1 Year	4/2/27	Flux, Fluence
Silicon Detector – Alpha Source	3/31/26	1 Year	3/31/27	Ion Species, Kinetic Energy, Flux, Fluence
Silicon Detector – Electronics	4/6/26	1 Year	4/6/27	Ion Species, Kinetic Energy, Flux, Fluence
SiLi Detector – Alpha Source	12/10/24	1 Year	**12/10/25**	Ion Species, Kinetic Energy, Flux, Fluence
SiLi Detector – Electronics	4/6/26	1 Year	4/6/27	Ion Species, Kinetic Energy, Flux, Fluence
Photomultiplier Tube w/ Scintillator	3/31/26	1 Year	3/31/27	Flux, Fluence
Stage and Fiducial Alignment	4/7/26	6 Months	10/7/26	Stage position (X,Y,Z,Rotation), Airgap Measurement
Beam Uniformity Verification Procedure	8/28/25	1 year	8/28/26	Uniformity

3 TetrAMM Picoammeter Calibration

The *TetrAMM 4-Channel Fast Interface Bipolar Picoammeter with Integrated Voltage Bias Source* [1] *(*TetrAMM) is employed for various K500 current readback systems which support measurements of beam flux and fluence.

The TetrAMM has two dynamic ranges available, a high range of 1 µA and a low range of 1 nA. The analog to digital converter (ADC) of TetrAMM devices has a resolution of 24 bits, and excellent linearity over the full current range. To confirm the TetrAMM calibration, a calibrated Keithley Model 2635B SourceMeter (S/N 4531602) [2] is turned on and left to warm up for over 2 hours. For TetrAMM input protection, a voltage limit of 0.5V is set on the SourceMeter. A BNC to triaxial adaptor (high channel A - 2635B open guard) is used to connect the SourceMeter to the TetrAMM Picoammeter. The adaptor connects the HI and LO pins to the center conductor and shield of the BNC cable respectively, and the BNC shield is locally grounded at the current SourceMeter. A shorted guard adapter is also connected to the Lo-Lo pin for proper source grounding. The BNC output is connected to a TetrAMM input channel and the SourceMeter output is turned on. The setpoint current and source current are both recorded from the SourceMeter. The TetrAMM current is measured using a 1-second average by FRIB's EPICS control system software. This process is repeated for each channel on the TetrAMM, and for each dynamic range. TetrAMM devices are given a pass rating on calibration if the measured current is < 1% of the expected value in the high current range, and < 1% in the low current range.

TetrAMM calibration results are shown in **Appendix I.**

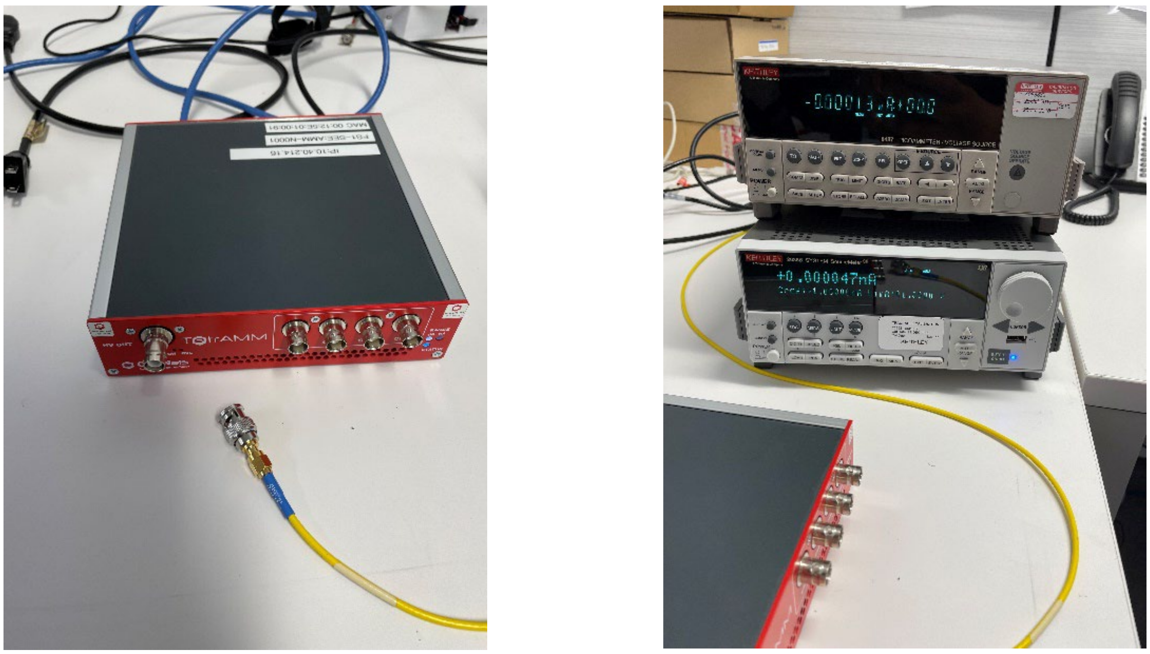

Figure 1: Example of TetrAMM picoammeter (left) and Keithley SourceMeter (right) used in calibration.

4 Silicon Based Detectors Calibration Procedure

Silicon based detectors are industry standard tools capable of measuring deposited beam energy and intensity. These measurements can be used to establish multiple reported beam parameters, including beam species purity, kinetic energy, flux, and fluence. The k500 facility supports two types of detectors; the Silicon PIN Diode Detector and the Lithium Drifted Silicon Detector. Each detector system is supported by the same ancillary electronics, primarily the Cremat preamplifier [3] and multi-channel analyzer (MCA) [4] systems. Calibration of each detector system is carried out in two parts. The first is validation of the supporting electronics by simulating detector pulses. The second is validation of the detector mechanism via a 228Th alpha check source

4.1 Silicon Based Detectors – Electronic Calibration Procedure

For a silicon-based detectors it is known that E = 3.62 eV per electron hole pair production [5]. From this, one derives that a detector will generate a known charge with a deposited energy demonstrated by Equation 1.

$$\frac{E\ [MeV]}{Q\ [pC]} = 22.60\ [\frac{MeV}{pC}] \qquad (1)$$

The differential form of the *Capacitance Equation* is given by Equation 2.

$$dQ = C * dV \qquad (2)$$

Using this relation, we arrive at Equation 3.

$$E\ [MeV] = (C * dV)\ [pC] * 22.60\ [\frac{MeV}{pC}] \qquad (3)$$

Knowing this, one can emulate a particle of any energy by injecting a known charge as a sharp edge through a capacitor into the Cremat preamplifier unit. A calibrated Keysight Model DSOX1204G Oscilloscope (S/N CN62197121) [6] is used to generate the voltage waveform with a known amplitude. The waveform generator and capacitor operate in place of the detector for purposes of energy calibration and verification. The figure below illustrates the calibration setup of the electronics system.

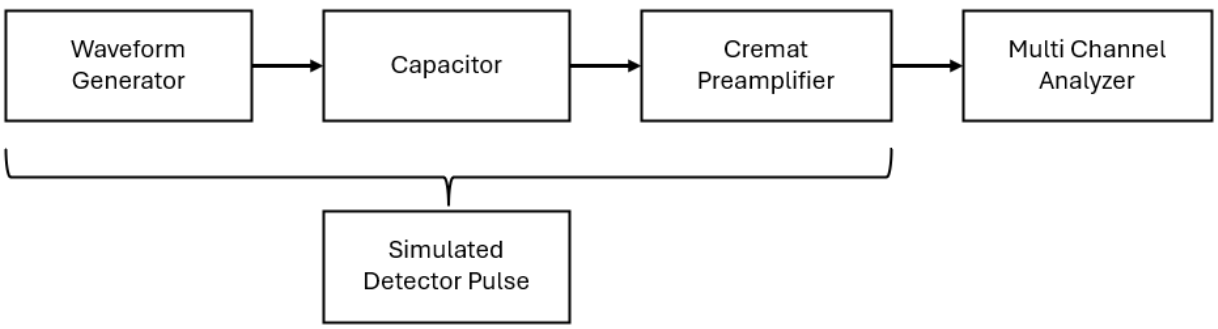

Figure 2: Electronic setup to simulate detector pulses in Si and SiLi detectors.

The output waveform is constructed with the following parameters to generate a triangle wave with a sharp edge -

- Waveform Type: Ramp
- Frequency: 1Khz
- Offset - 0
- Symmetry – (0% for Negative Pulse)/(100% for Positive Pulse)
- Output Load – High Z

Various types of Cremat preamplifiers are used, supporting energy domains of 0.05, 0.5, and 5.0 GeV. Each type of preamplifier is calibrated over their expected operational range. Each measurement is conducted over a ~10 second interval. This generates a reading on the MCA with an expected count total equal to the live time in seconds multiplied by 1000 (at 1kHz input). If the measured count total is within 1% of the expected value, a pass is given for counts detection. The MCA measures the peak of each pulse from the preamplifier output and assigns it to one of 16384 energy bins. A scale factor in [MeV/bin] is applied to the measurement such that the peak histogram of the energy measurements is within <1% of the expected energy as defined in Equation 3. For example, a 1.0V amplitude injected through a 104pF capacitor would have an expected energy peak centered around 2350 MeV. If the measurement is centered at bin 4000, a scale factor of 2350/4000 = 0.5875 [MeV/bin] is applied. The scale factor is assigned to the preamplifier unit, then subsequent validation measurements over the operational range are made by altering the input voltage. The calibration is successful if the peak histogram of the energy measurements is within <1% of the expected energy for all measurements.

Calibration results of electronic systems are shown in ***Appendix II***.

4.2 Silicon Based Detectors – Alpha Source Calibration Procedure

Each Si based detector is also validated by comparison to a 228Th alpha source spectrum. Table 1 lists expected alpha energies and abundances for the 228Th decay chain. Figure 3 demonstrates the main energy lines of 228Th decay chain.

Table 1: Expected alpha energies and abundances for 228Th decay chain.

Decay	Alpha Energy [MeV]	Relative Abundance [%]
228Th → 224Ra [7]	5.42315	73.4
224Ra → 220 Rn [8]	5.68537	94.92
212Bi → 208Ti [9]	6.05078	25.13
220Rn → 216Po [10]	6.22808	99.8
216Po → 212Pb [11]	6.7783	99.9
212Po → 208Pb [12]	8.78486	100

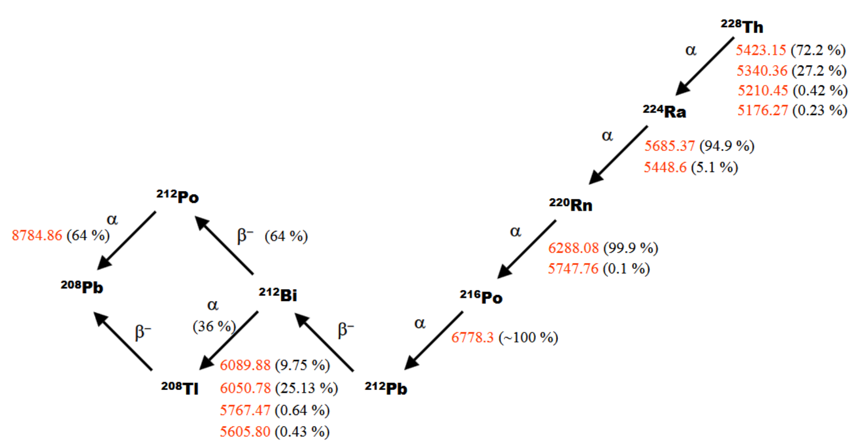

Figure 3: Pictorial representation of 228Th decay chain [13].

To begin calibration, each detector is placed in a small vacuum chamber with a verified 228Th source placed ~ 2.5 inches away. The chamber is pumped down until vacuum is under 1E-5 torr. The detector is biased using a Tennelec HV power supply, the signal is amplified using a Cremat preamplifier, and the output signal is shaped using an Ortec 671 shaper [14]. The spectrum is acquired using an Ortec 927 MCA [15] over a 30-minute period. The spectrum data is then exported and analyzed using python's SciPy library to detect peaks and fit using linear regression [16][17].

A detector is considered to pass validation if the following two conditions are met -

•All six energy peaks as described in Table 1 are resolved in the measured spectrum.
•The *Coefficient of Determination* of the expected energy versus bin fit is >0.99 to ensure linearity.

Calibration results of the detectors using an alpha source are shown in ***Appendix III***.

5 Photomultiper Tube (PMT) with Fast Scintillator Calibration Procedure

The Photomultiplier Tube with Fast Scintillator assembly is an intercepting beam device often utilized to establish beam flux (up to 1E6 pps/cm²) and fluence. To confirm the PMT assembly is functional, a coincidence measurement between a known source and PMT signal is made. The calibration procedure for the PMT assembly is as follows.

The assembly is first placed securely inside an opaque vacuum chamber. A LED is then positioned ~2cm above the scintillator surface. The LED is connected to a Tektronix AFG3102C Function Generator [18] with frequency of 5 Khz. The function generator output signal is also connected to a Tektronix MDO34 Oscilloscope [19]. The PMT assembly is connected to an NHS 62 60N HV Power Supply [20] and biased to -1800V. The output signal of the assembly is also connected to the same Tektronix MDO34 Oscilloscope to perform the coincidence measurement.

The function generator is powered on, producing light pulses at a frequency of 5 kHz. These pulses are recorded on the oscilloscope, where each LED pulse should correspond to an inverted output response signal from the PMT. The detector assembly passes calibration if a coincidence measurement between the LED signal and PMT is successfully demonstrated. A successful output measurement is shown below in Figure 4.

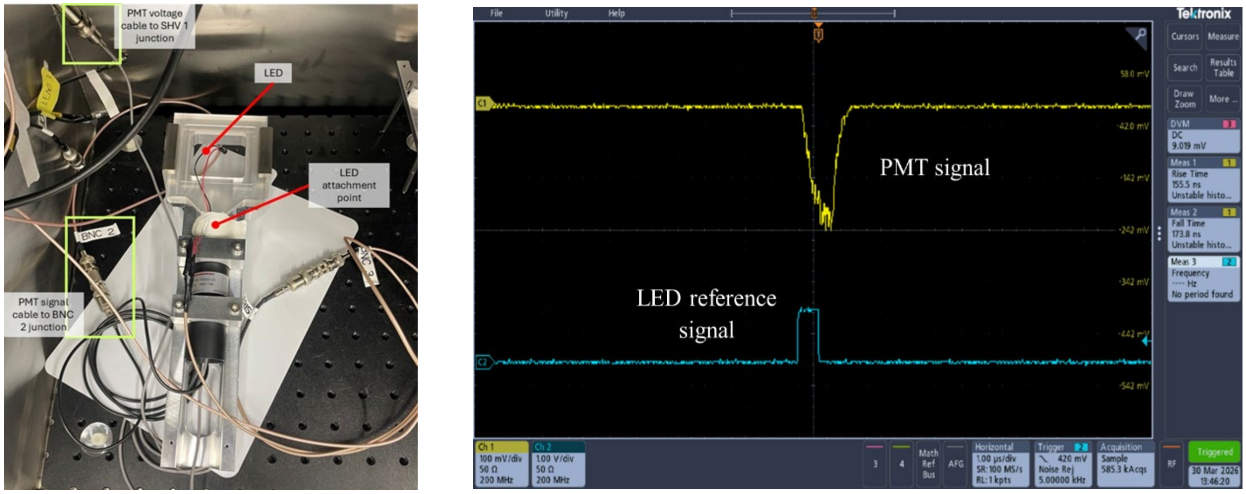

Figure 4: PMT assembly setup (left) and successful coincidence measurement (right).

Results of the PMT measurement are shown in ***Appendix IV***

6 Stage and Laser Fiducial Alignment

The K500 user end station includes a laser alignment system that supports positioning of devices under target. The alignment of the end station and laser system is necessary to provide accurate air gap distances and device positioning. A dedicated mounting plate is used to perform alignment of the laser system. Two sets of guidelines are inscribed on the plate's vertical and horizontal center, with each line having a width of 1.5 ± 0.5 mm.

Alignment of the system is carried out in two parts. First is alignment of the X/Y lasers which are perpendicular to the beam axis and are used for device positing. The second is calibration of the Z laser which is parallel to the beam path and is used for airgap calculations. The mounting stage is first set to its home position (X=0, Y=0, Z=455). An AT402 Laser Tracker (or similar FRIB approved instrument) is erected near the end station and referenced to the FRIB alignment network. Using a spherically mounted retroreflector (SMR) probe, the location of the plate center is measured relative to the vacuum window pipe. The plate position is then adjusted until the deviation in (X,Y) is <1mm from the beamline center. Once within the parameters, the new position is defined as the stage's home.

Next, the X/Y lasers are aligned to the plate's guidelines. A pass on the calibration is given if the lasers do not deviate from the guidelines over the stages Z range of motion (Z =30 to Z = 455). This provides an uncertainty in positioning bounded by the width of the guidelines (1.5 ± 0.5 mm).

Z laser calibration occurs after the X/Y calibration has been successfully completed. The vacuum window position is measured using an SMR probe and defined as Z=0. Using a SMR probe on the stage platter, a guideline from Z=0 to Z=100 is recorded with respect to the stage calibration position (X=0, Y=0, Z=264). To validate the stroke length and repeatability of the Z laser, three trials are performed. In each trial, the laser is moved to the 30 mm, 50 mm, 70 mm, and 100 mm positions. At each location the Z and X position are measured. The Z laser passes calibration if the measured δZ value is <1mm from expected value and the δX value is <1 mm from 0.

Finally, the Z laser is set to its midpoint (Z=50) and the stage is moved from Y=0 to its lower limit of Y=-65. Measurements of the spot sizes are made at each Y value to determine how much the pitch of the Z laser deviates over the stages Y range of motion. A pass is given if values all values of δX and δZ measurement do not deviate greater than 1mm from their expected value.

Stage alignment results are shown in ***Appendix V***.

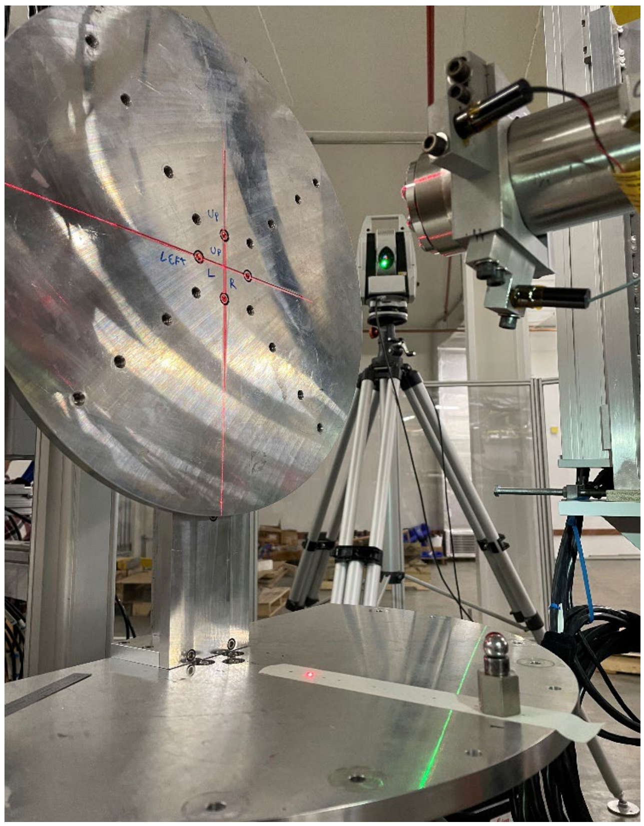

Figure 5: Example of stage alignment setup. Shown is the AT402 laser tracker (center), SMR probe on platter (bottom right), beamline (right), and mounting plate (left).

7 Beam Uniformity Verification Procedure

Beam uniformity is measured during user operations using an in-vacuum scintillator (referred to as a viewer) any time a new beam configuration is established. This is accomplished by measuring the RMS error of the viewer image using a dedicated camera system and image analysis software (VIOLA). While this method provides a quick and accurate measurement of beam uniformity, small imperfections in the viewer coating suggests that this measurement method is likely to overestimate the nonuniformity when compared to the true beam structure.

To validate true beam uniformity at the target, a Radiochromatic Film (RCF) is exposed to a subset of available facility ions (16O, 40Ar, 129Xe, and 197Au). Each exposure is conducted until the RCF target exposure becomes visible. Once all the film exposure trials are completed, an image of the film is recorded and processed for measurement. For each target, a measurement of the mean pixel value and standard deviation is recorded. The beam uniformity passes validation if the ratio of the standard deviation to mean value is $\leq 10\%$ for all measured trials.

Uniformity validation results are shown in ***Appendix VI***.

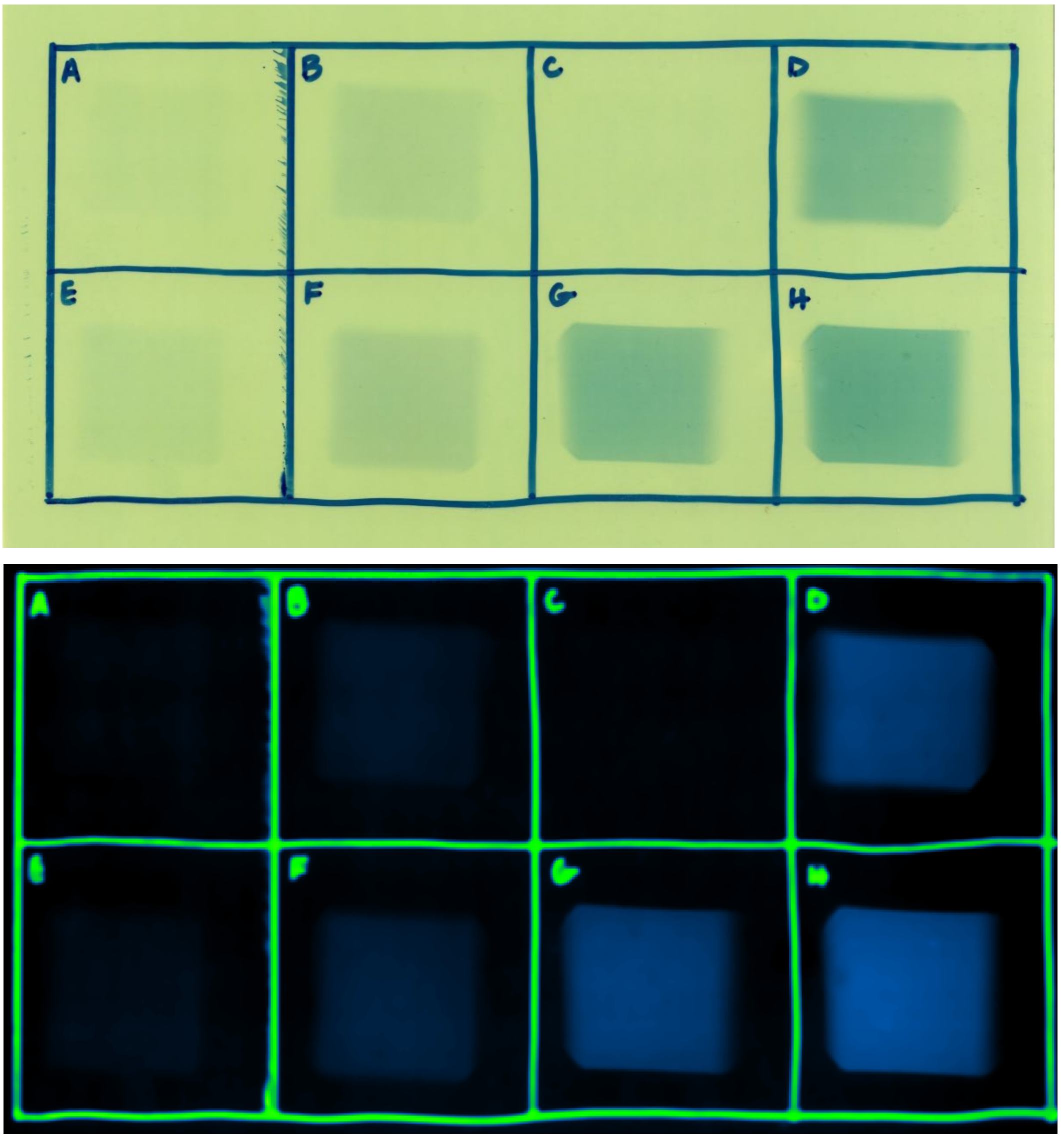

Figure 6: Example of RCF exposure over eight trials. Preprocessed image (Top) and postprocessed (Bottom) are used to measure the mean and standard deviation pixel count.

8 Notes on Reported Beam Size Values

An external viewer plate is established approximately 80mm from the beam exit window to measure the beam size at a user's target. The viewer plate includes known lines of thickness and separation and is coated in P22 phosphor scintillating material. When beam is exposed to the viewer plate the size is measured against the known markings using a dedicated camera system and image analysis software (VIOLA). The plate is recoated on a yearly basis, or at the discretion of FRIB staff upon inspection. The viewer plate's schematic is included in ***Appendix IX***.

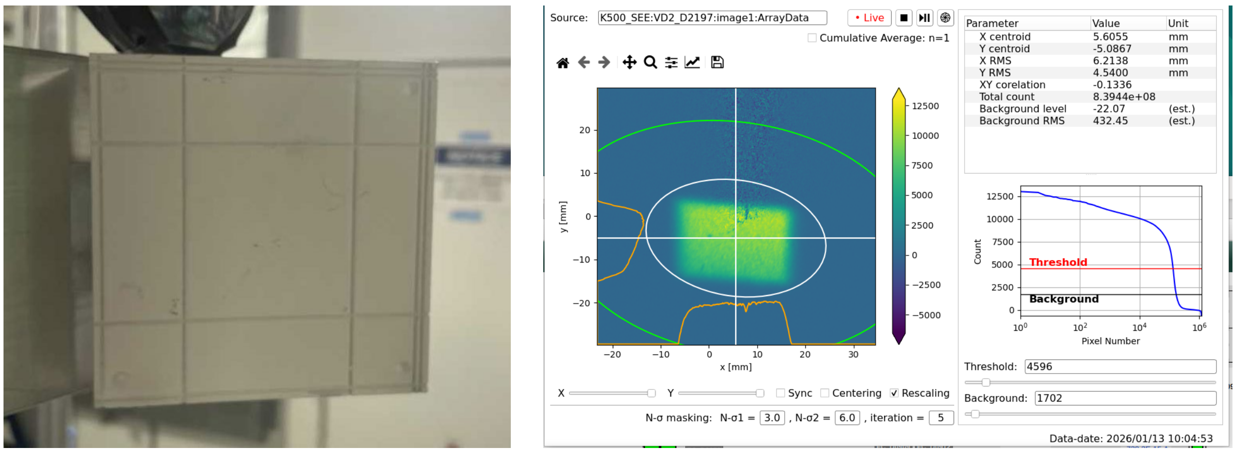

Figure 7: (Left) External viewer plate located ~80mm from beam exit. (Right) Image and size calculation software while viewer is under exposure from beam.

9 Notes on Reported Timing Values

Facility time is generated by a Rubidium atomic clock that is synchronized to a GPS Time reference. This provides a timing resolution of 12.4ns. Time is broadcast across the facility's local network utilizing NTP (network time protocol). All data streams are then time-stamped with the clock. Beam generated by the facility ion source is modulated by an electrostatic chopper to a 99.5% duty factor (50-µs gap at 100Hz repetition rate). An *Event Generator* produces the event signals per the facility clock. *Event Receivers* are used with data acquisition units to record signals per the facility clock and signal events. Due to continuous synchronization with the GPS timing reference no yearly calibration is required.

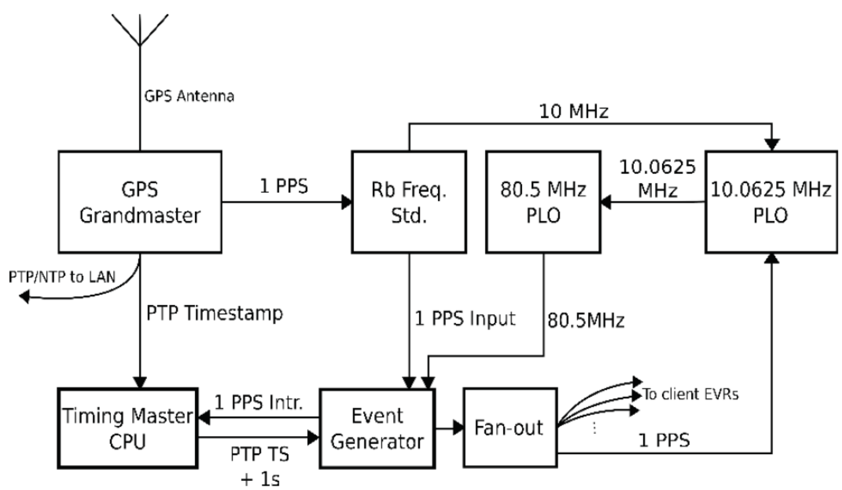

Figure 8: Schematic overview of the facility timing structure.

10 Notes on Reported LET, Range, and Dose Values

Reported values of the linear energy transfer (LET), projected ion range in a material, and dose are all derived quantities dependent on other facility measurements (primarily the ion species, kinetic energy, and fluence). FRIB performs simulations to calculate these values using SRIM's Transport of Ions in Matter (TRIM) program [21]. The LET and range values are provided directly from SRIM simulations, while the dose is calculated by Equation 4 shown below.

$$Dose\ [Rad] = Fluence\ \left[\frac{particles}{cm^2}\right] * LET\ \left[\frac{MeV cm^2}{mg}\right] * (1.602 * 10^{-5}\ [\frac{J}{Kg}]) \quad (4)$$

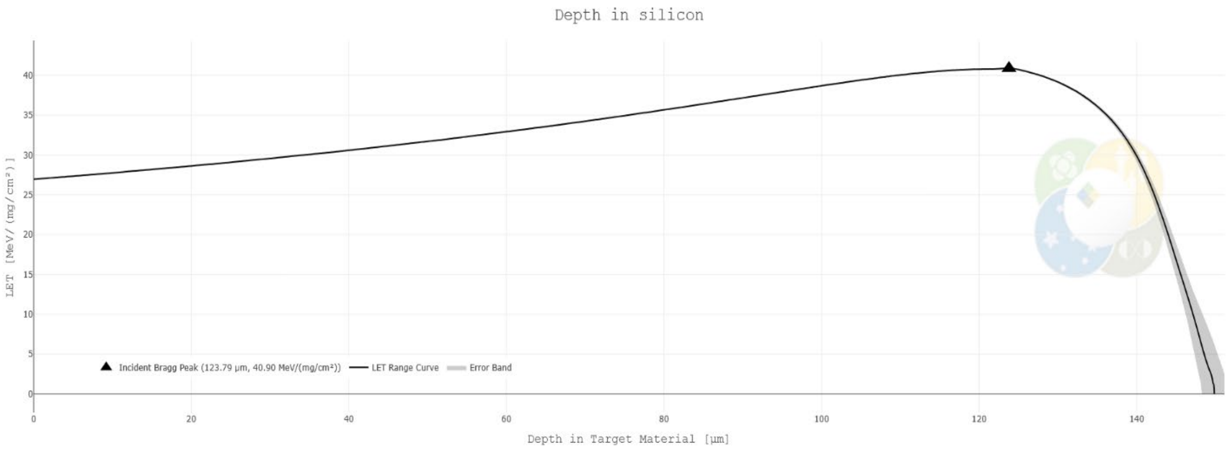

Figure 9: Calculated *Bragg Curve* for 84Kr ion at 13.7 MeV/u into Silicon target using in-house FRIB tool based on SRIM simulations.

11 Notes on Datasheets and Technical Drawings

The K500 facility uses various degrading foils and materials. The manufacture datasheets determining purity and thickness for these materials, and relevant technical drawings, are included in ***Appendix VI***.

12 References

[1] https://www.caenels.com/products/tetramm/
[2] https://www.tek.com/en/products/keithley/source-measure-units/2600b-series-sourcemeter
[3] CR-112-R2.1 Spec sheet
[4] N6725 / N6725S - 8 Channel 14-bit 250 MS/s Digitizer - CAEN - Tools for Discovery
[5] Knoll, 2010, 368. Table 11.1.
[6] https://www.keysight.com/us/en/product/DSOX1204G/oscilloscope-70-100-200-mhz-4-analog-channels-waveform-generator.html
[7] Sukhjeet Singh, Balraj Singh Citation: Nuclear Data Sheets 130, 127 (2015)
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Appendix I: Results of TetrAMM Picoammeter Calibration

TetrAMM 1 (24Y42W0766)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	1.000	1.000	1.000	1.000	1.000	0.998	1.000	1.000
Percent Difference	0.060	0.060	0.060	0.060	0.060	-0.090	0.060	0.060
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 2 (24Y42W0764)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	1.000	0.999	0.999	0.999
TetrAMM Readback	1.000	1.000	1.000	1.000	1.016	1.000	1.000	0.997
Percent Difference	0.060	0.070	0.060	0.060	1.575	0.100	0.060	-0.221
Pass/Fail	Pass	Pass	Pass	Pass	Fail	Pass	Pass	Pass

We note that Channel 1 (nA) failed our calibration metric. The use of this channel has been discontinued until a manufacturer calibration can occur.

TetrAMM 3 (24Y42W0765)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	1.000	0.999
TetrAMM Readback	1.000	1.000	1.000	1.000	0.999	1.000	0.999	1.001
Percent Difference	0.070	0.060	0.060	0.070	0.040	0.080	-0.150	0.200
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 4 (24Y42W0767)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	1.000	1.000	0.998	0.999	0.999	0.999
Percent Difference	0.000	0.000	0.060	0.070	-0.100	0.000	0.000	0.000
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 5 (24Y21W0398)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Percent Difference	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 6 (24Y21W0399)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	0.999	0.999	0.999	0.999	1.000	0.999
Percent Difference	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 7 (24Y21W0403)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Percent Difference	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 8 (24Y21W0402)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	1.003
Percent Difference	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.399
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 9 (24Y21W0401)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TetrAMM Readback	0.999	0.999	0.999	0.999	1.000	0.999	0.999	0.999
Percent Difference	0.000	0.000	0.000	0.000	0.089	0.010	0.040	0.020
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

TetrAMM 10 (24Y21W0400)	Channel 1 (1 µA)	Channel 2 (1 µA)	Channel 3 (1 µA)	Channel 4 (1 µA)	Channel 1 (1 nA)	Channel 2 (1 nA)	Channel 3 (1 nA)	Channel 4 (1 nA)
Setpoint	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Source Readback	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
TetrAMM Readback	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Percent Difference	-0.010	-0.010	-0.020	-0.010	-0.010	0.010	-0.020	0.010
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Appendix II: Results of Silicon Detector Electronic Calibration

Capacitor Measurement: 102.5 pF

Preamp: CR01-5GEV – 75 LSB

SF [MeV/bin]	Input [V]	Bin Measured	E Theory [MeV]	E Measured [MeV]	Percent Difference	Acquisition Time [s]	Counts Theory	Counts Measured	Percent Difference	Pass/Fail
0.3916	0.017	101	39.4	39.6	0.43	10.39	10390	10368	-0.21	Pass
0.3916	0.17	1007	393.8	394.3	0.14	10.42	10420	10402	-0.17	Pass
0.3916	0.425	2514	984.5	984.5	0.00	10.3	10300	10306	0.06	Pass
0.3916	0.85	5039	1969.0	1973.3	0.22	10.02	10020	10014	-0.06	Pass
0.3916	1.7	10025	3938.1	3925.8	-0.31	10.27	10270	10306	0.35	Pass

Preamp: CR05-0.6GEV – 120 LSB

SF [MeV/bin]	Input [V]	Bin Measured	E Theory [MeV]	E Measured [MeV]	Percent Difference	Acquisition Time [s]	Counts Theory	Counts Measured	Percent Difference	Pass/Fail
0.041	0.021	1180	48.6	48.4	-0.55	10.42	10420	10397	-0.22	Pass
0.041	0.042	2373	97.3	97.3	0.00	10.41	10410	10400	-0.10	Pass
0.041	0.106	5979	245.5	245.1	-0.17	10.28	10280	10252	-0.27	Pass
0.041	0.213	11988	493.4	491.5	-0.39	10.57	10570	10586	0.15	Pass

Preamp: CR03-0.5GEV - 120 LSB

SF [MeV/bin]	Input [V]	Bin Measured	E Theory [MeV]	E Measured [MeV]	Percent Difference	Acquisition Time [s]	Counts Theory	Counts Measured	Percent Difference	Pass/Fail
0.04075	0.0045	254	10.4	10.4	-0.71	10.43	10430	10398	-0.31	Pass
0.04075	0.021	1191	48.6	48.5	-0.23	10.34	10340	10351	0.11	Pass
0.04075	0.042	2388	97.3	97.3	0.02	10.22	10220	10239	0.19	Pass
0.04075	0.106	5987	245.5	244.0	-0.65	10.42	10420	10413	-0.07	Pass
0.04075	0.213	11999	493.4	489.0	-0.91	10.12	10120	10131	0.11	Pass

Preamp: CR04-5GEV - 75 LSB

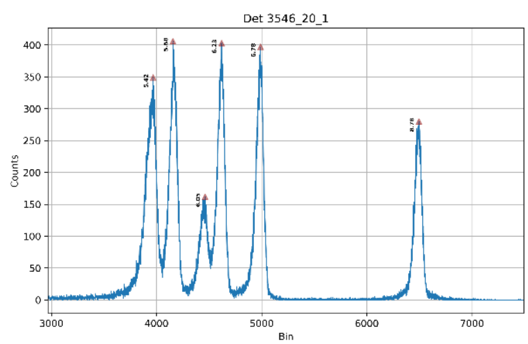
SF [MeV/bin]	Input [V]	Bin Measured	E Theory [MeV]	E Measured [MeV]	Percent Difference	Acquisition Time [s]	Counts Theory	Counts Measured	Percent Difference	Pass/Fail
0.39585	0.017	100	39.4	39.6	0.52	10.4	10400	10366	-0.33	Pass
0.39585	0.17	994	393.8	393.5	-0.08	10.22	10220	10218	-0.02	Pass
0.39585	0.425	2488	984.5	984.9	0.04	10.37	10370	10367	-0.03	Pass
0.39585	0.85	4995	1969.0	1977.3	0.42	10.26	10260	10252	-0.08	Pass
0.39585	1.7	9956	3938.1	3941.1	0.08	10.35	10350	10373	0.22	Pass

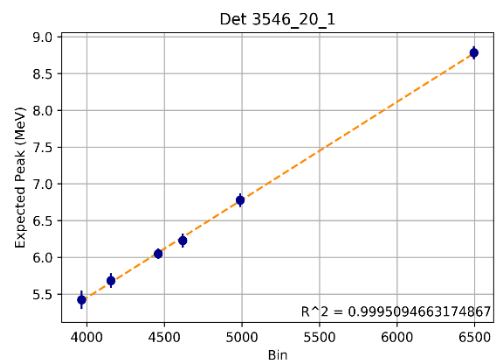
Preamp: CR06-0.05GEV – 250 LSB

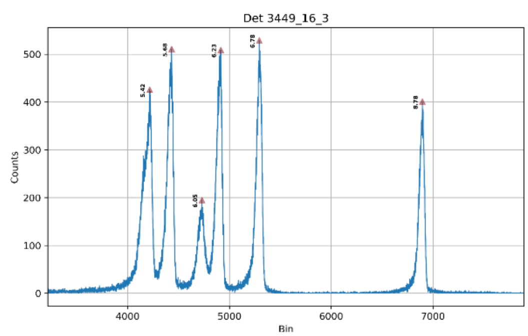
SF [MeV/bin]	Input [V]	Bin Measured	E Theory [MeV]	E Measured [MeV]	Percent Difference	Acquisition Time [s]	Counts Theory	Counts Measured	Percent Difference	Pass/Fail
0.00395	0.0021	1234	4.9	4.9	0.20	10.23	10230	10220	-0.10	Pass
0.00395	0.0042	2456	9.7	9.7	-0.29	10.32	10320	10321	0.01	Pass
0.00395	0.0106	6160	24.6	24.3	-0.92	10.43	10430	10419	-0.11	Pass
0.00395	0.0213	12420	49.3	49.1	-0.58	10.17	10170	10173	0.03	Pass

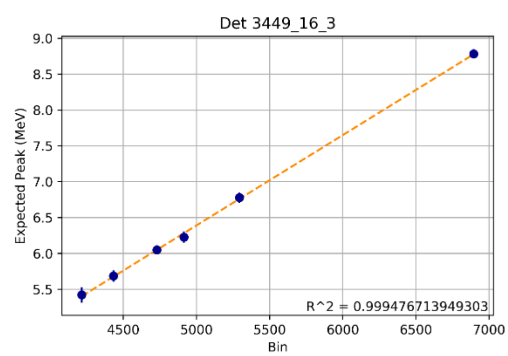
Appendix III: Results of Silicon Detector Calibration with Alpha Source

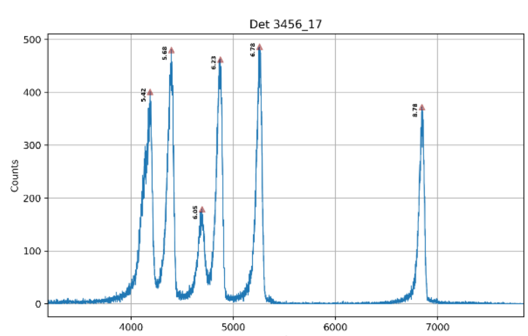
Detector Type	Detector S/N	Peak Detection Pass/Fail	Coefficient of Determination (r^2)	r^2 Pass/Fail
Si	3546-20-1	Pass	0.999509	Pass
Si	3449-16-3	Pass	0.999476	Pass
Si	3456_17	Pass	0.999557	Pass
SiLi	3228	Pass	0.998800	Pass

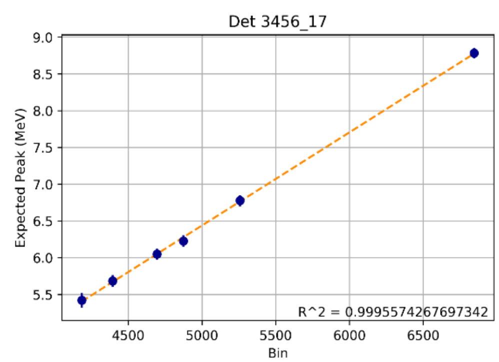


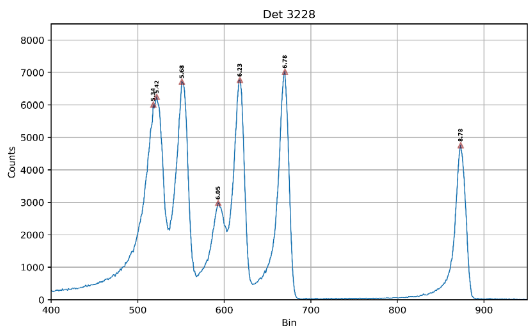


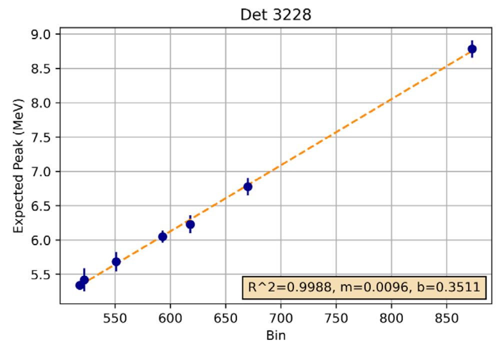






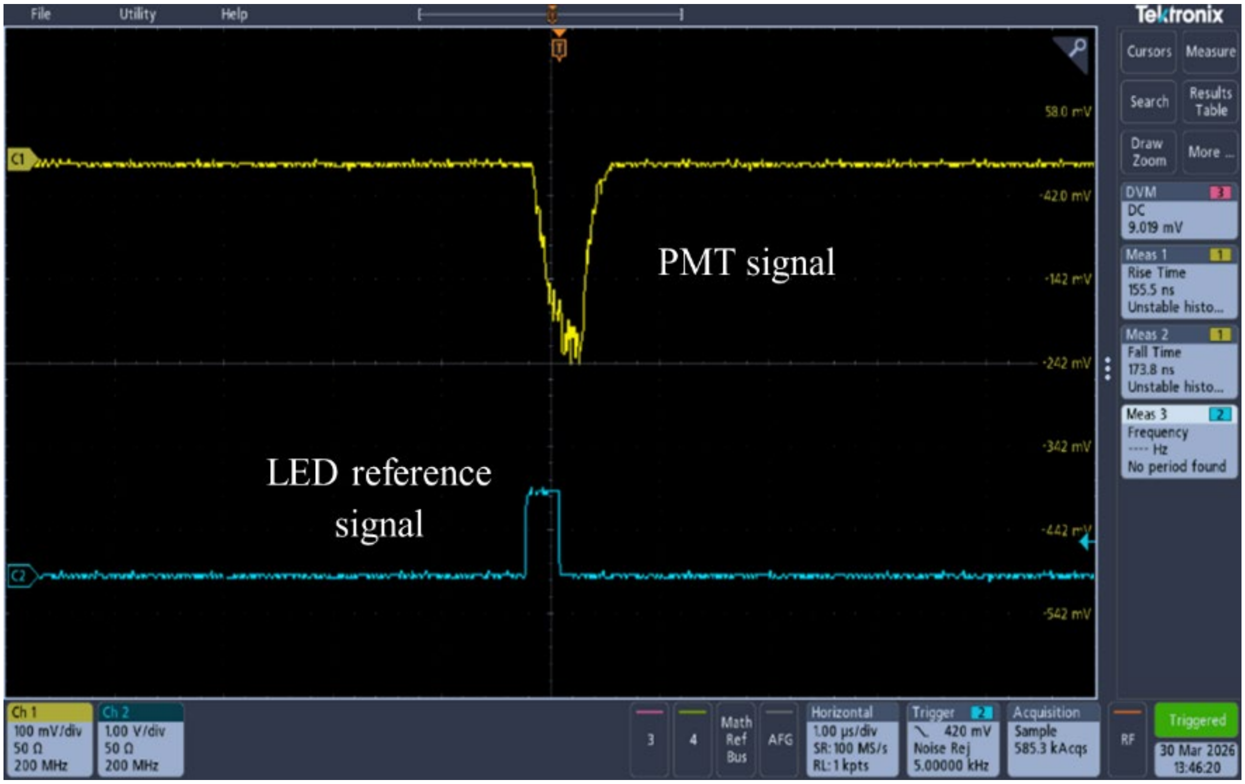



Det 3228
Counts
Bin
0
1000
2000
3000
4000
5000
6000
7000
8000
400
500
600
700
800
900


Det 3228
Expected Peak (MeV)
Bin
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
550
600
650
700
750
800
850
R^2=0.9988, m=0.0096, b=0.3511

Appendix IV: Results of PMT Coincidence Measurement

Coincidence Measurement Pass/Fail: Pass



Appendix V: Results of Stage and Laser Fiducial Alignment

X/Y Beam Center Measurement

Measurement	Expected Value [mm]	Measured Value [mm]	Pass/Fail
$\hat{X}$	0.000	-0.143	Pass
$\hat{Y}$	0.000	0.764	Pass

Z Laser Stroke Trial 1

Z Position Theory [mm]	Z Position Measured [mm]	δZ [mm]	δX [mm]	Pass/Fail
30.000	30.706	0.706	-0.076	Pass
50.000	50.115	0.115	-0.835	Pass
70.000	70.265	0.265	-0.646	Pass
100.000	100.298	0.298	-0.406	Pass

Z Laser Stroke Trial 2

Z Position Theory [mm]	Z Position Measured [mm]	δZ [mm]	δX [mm]	Pass/Fail
30.000	30.177	0.177	0.141	Pass
50.000	50.457	0.457	-0.189	Pass
70.000	70.415	0.415	-0.68	Pass
100.000	100.262	0.262	-0.336	Pass

Z Laser Stroke Trial 3

Z Position Theory [mm]	Z Position Measured [mm]	δZ [mm]	δX [mm]	Pass/Fail
30.000	30.543	0.543	-0.074	Pass
50.000	50.128	0.128	-0.207	Pass
70.000	70.332	0.332	-0.322	Pass
100.000	100.02	0.02	-0.811	Pass

Z Laser Pitch Trial 1

Y Position [mm]	δZ [mm]	δX [mm]	Pass/Fail
0	0.243	-0.537	Pass
-65	-0.082	-0.745	Pass

Z Laser Pitch Trial 2

Y Position [mm]	δZ [mm]	δX [mm]	Pass/Fail
0	0.243	-0.537	Pass
-65	-0.089	-0.745	Pass

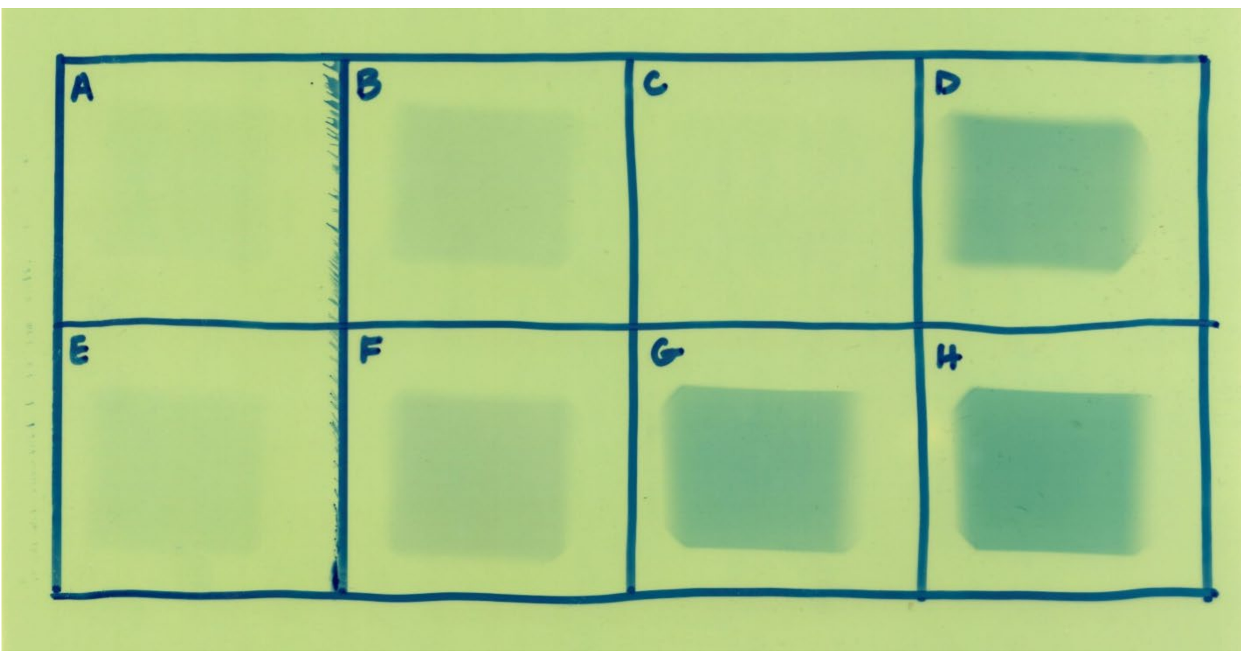
Z Laser Pitch Trial 3

Y Position [mm]	δZ [mm]	δX [mm]	Pass/Fail
0	0.242	-0.529	Pass
-65	-0.077	-0.737	Pass

Appendix V: Results of Beam Uniformity Verification Procedure

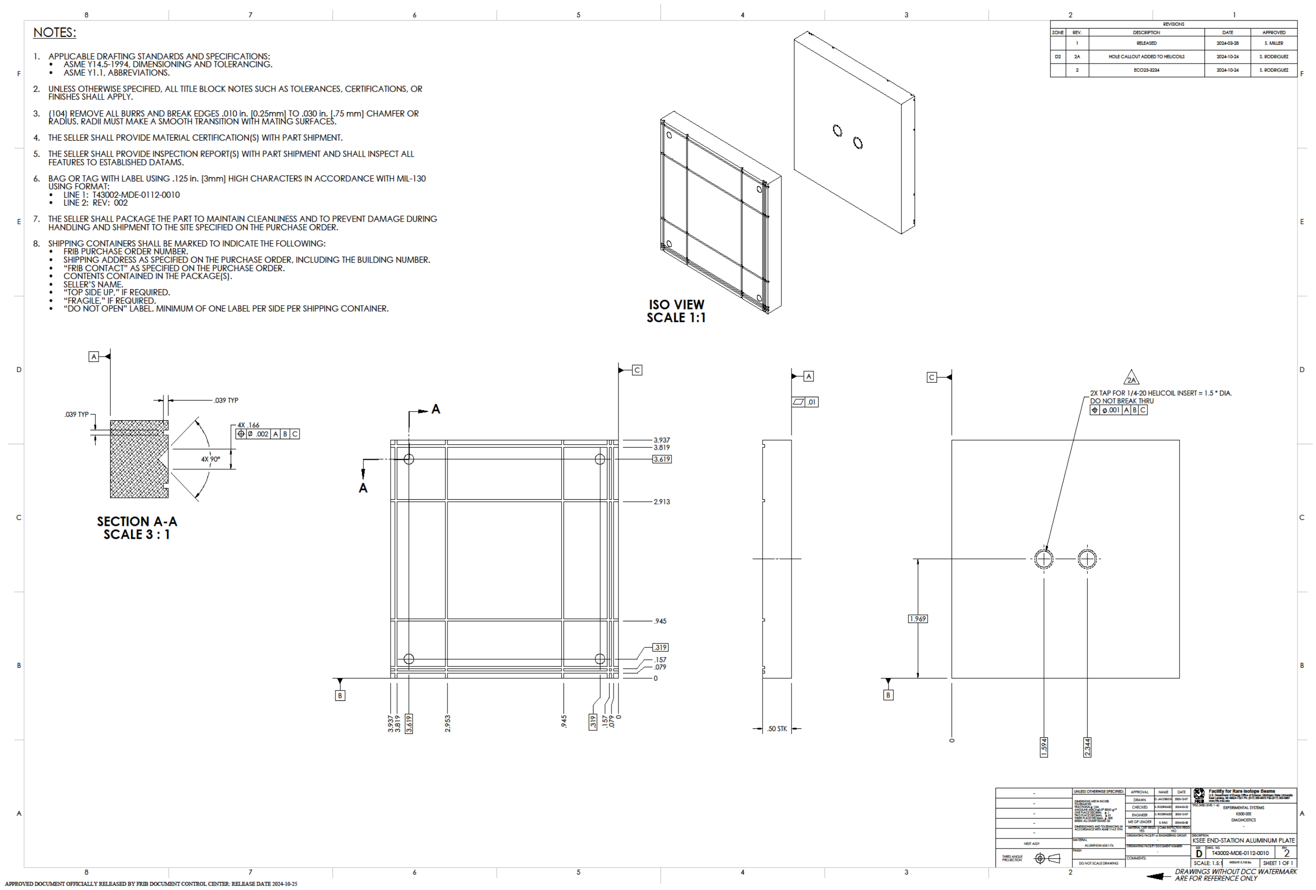
Target	Ion	LET - Si Equivalent [MeV/(mg/cm²)]	Run Duration [s]	Fluence [ions/cm²]	Dose -Si Equivalent [rad]	Area (cm2)	Mean Pixel Value	Std Dev. Pixel Value	StDev/Mean (%)	Pass/Fail
A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	129Xe	57.7	100	1.35E+06	1243.5	7.6	14.644	1.444	10%	Pass
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	40Ar	7.6	300	4.05E+07	4940.11	8.5	41.146	4.021	10%	Pass
E	197Au	85	30	5.10E+05	694	6.0	8.915	0.914	10%	Pass
F	197Au	85	90	1.35E+06	1832.75	7.1	22.095	2.08	9%	Pass
G	16O	0.9	300	1.89E+08	2611.03	9.9	42.635	3.038	7%	Pass
H	16O	0.9	600	3.38E+08	4674.67	9.6	53.901	4.786	9%	Pass

Trials A and C produced insufficient data to perform an accurate measurement and are excluded from this report.

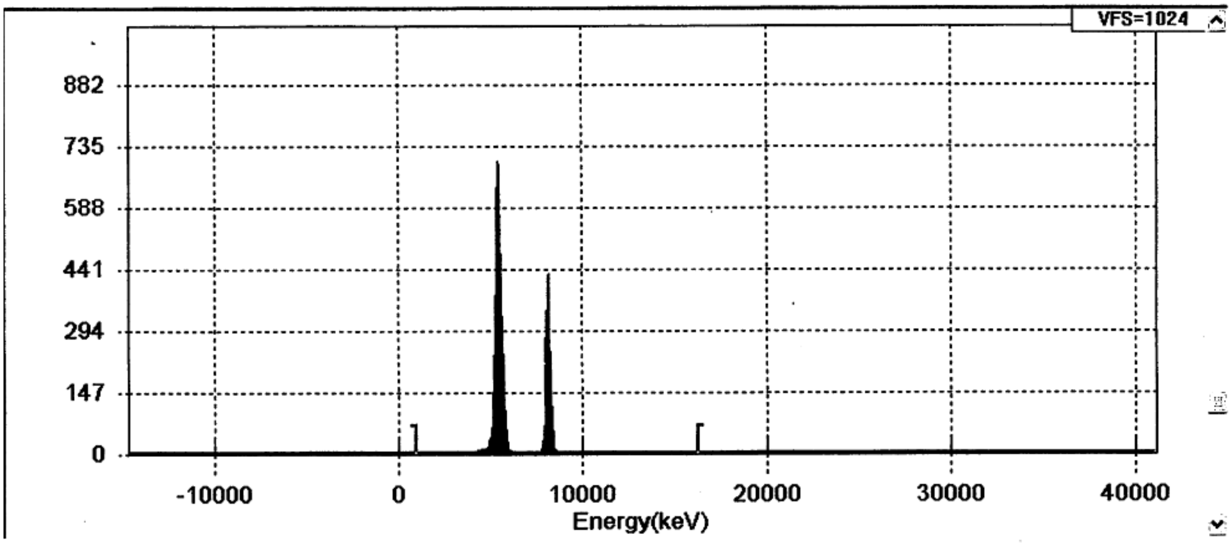


Appendix VI: Material Datasheets and Drawings

External Viwer Schematic



MSX25-500 Si Detector (S/N 3546-20-1)

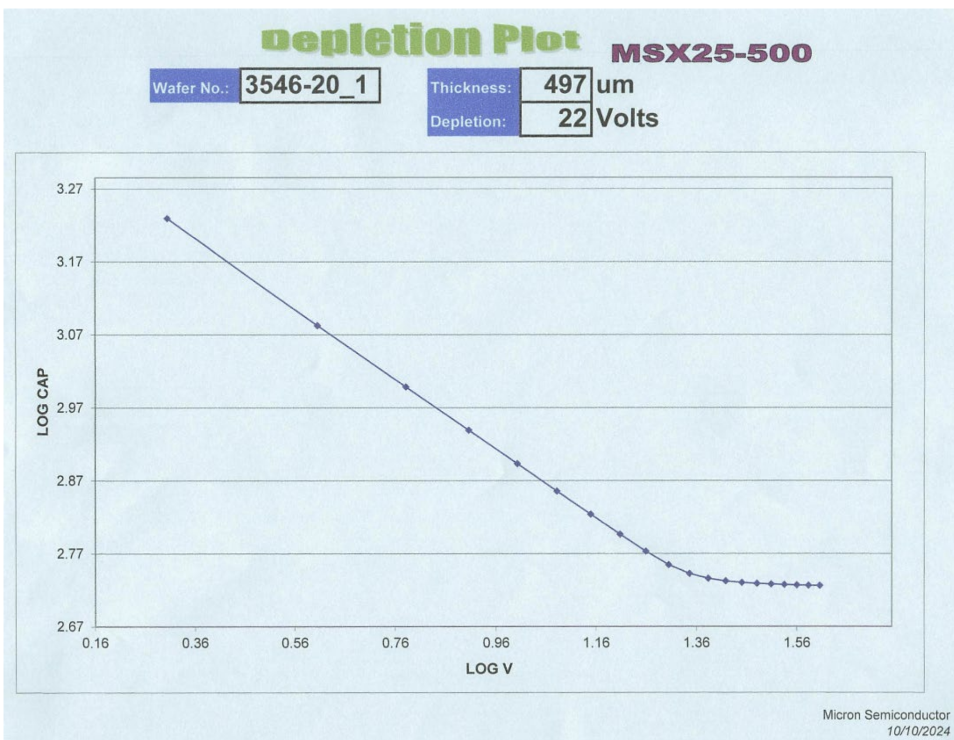


MSX25-500, 3546-20-1, T: 497uM, IR: 60nA, VBIAS: 60V, DATE: 15/10/2024, 18.7°C, 24%RH

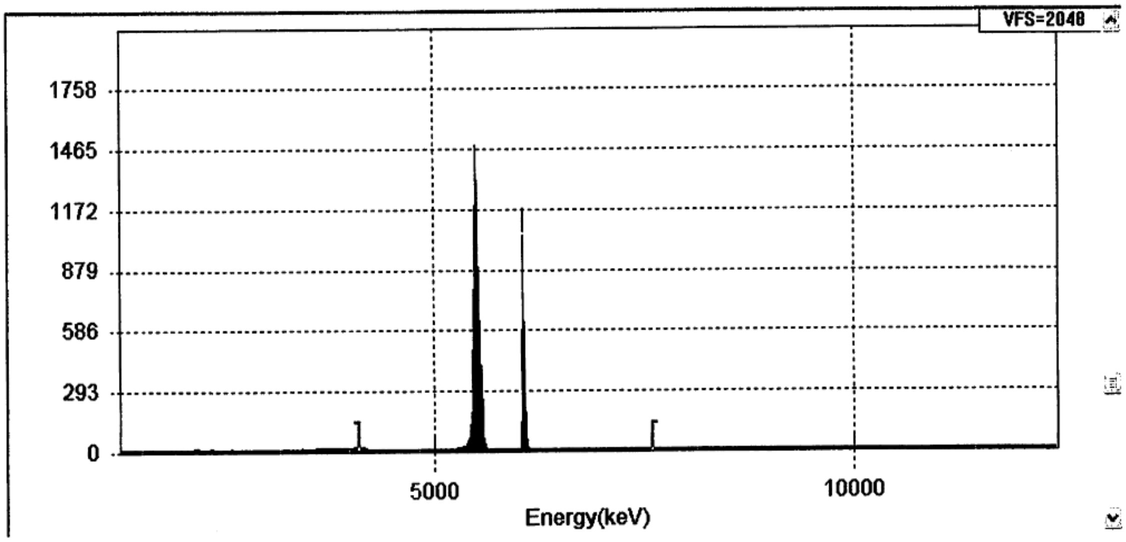
NN JUNCTION
DETECTOR LINE – 89.7 Kev
SYSTEM – 57.1 Kev
CALCULATED – 69.1 Kev

P+N JUNCTION
DETECTOR LINE – 79.9 Kev
SYSTEM – 58.5 Kev
CALCULATED – 54.4 Kev

AMPLIFIER R: 10MΩ



MSX25-1500 Si Detector (S/N 3449-16-3)

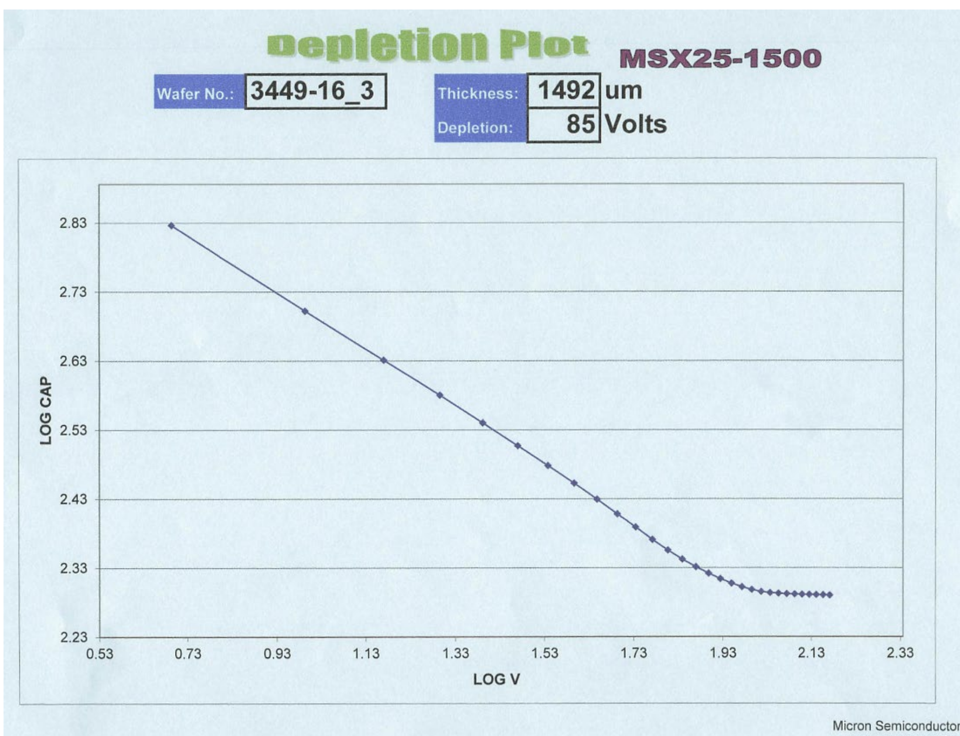


MSX25-1500, 3449-16-3, VBIAS: 300 V, IR: 535 nA, T: 1492 uM, 10/10/24, 16.6°C, 24%RH

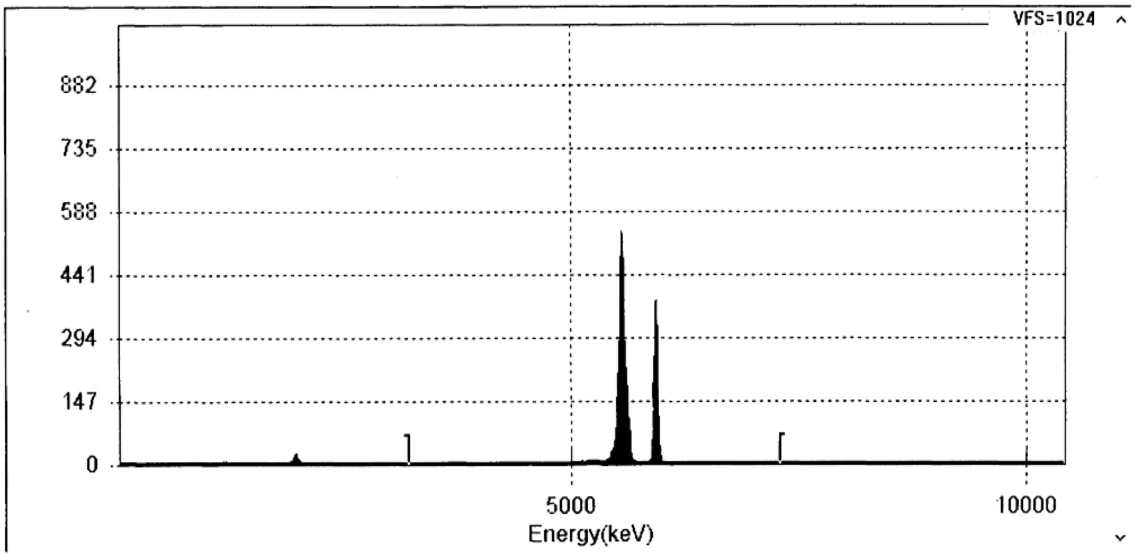
PN+
DETECTOR LINE – 60.5 Kev
SYSTEM – 29.6 Kev
CALCULATED – 52.8 Kev

NN+
DETECTOR LINE – 61.5 Kev
SYSTEM – 29.4 Kev
CALCULATED – 54.1 Kev

AMPLIFIER BIAS: 10MΩ



MSX25-1500 Si Detector (S/N 3456-17)

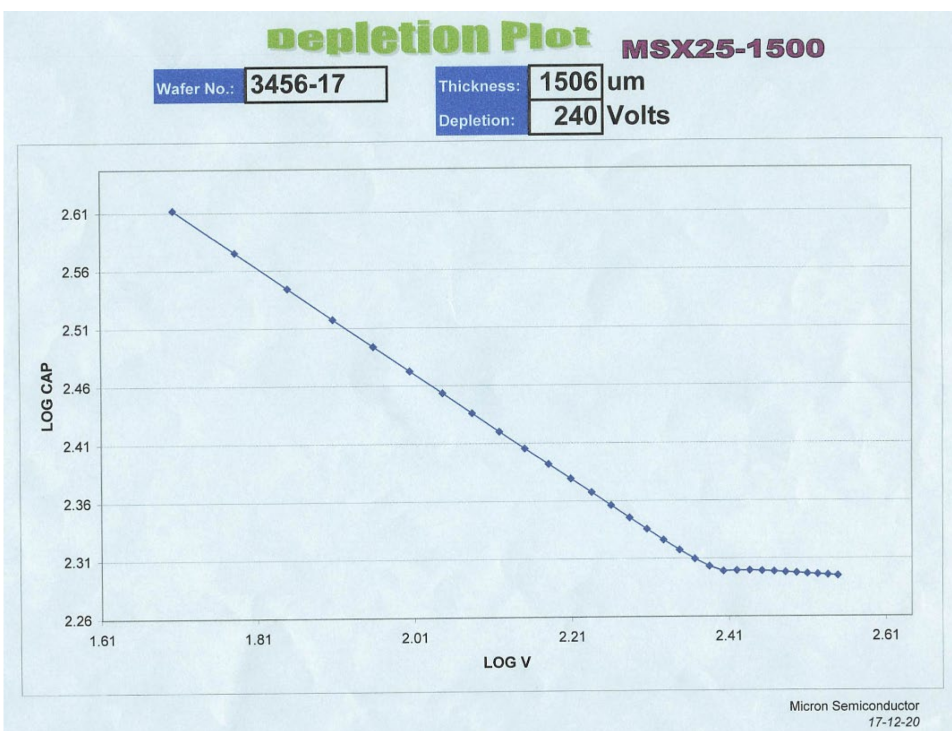


MSX25-1500, 3456-17 , T: 1506 uM, IR: 700 nA, VBIAS: 420 V, DATE: 30/06/22, 18.4DgrC, 24%RH

PN JUNCTION
DETECTOR LINE – 61.8 Kev
SYSTEM – 45.9 Kev
CALCULATED – 41.4 Kev

NN JUNCTION
DETECTOR LINE – 82.2 Kev
SYSTEM – 47.8 Kev
CALCULATED – 66.9 Kev

AMPLIFIER R: 10Mohms



10 Micrometer Thick Copper Foil (99.9% Purity)

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ADVANCED MATERIALS
INNOVATION DELIVERED

Copper Foil

Formula: Cu
Percentage Purity: 99.9%
Thickness: 0.01mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7440-50-8
UOM Code: 635-041-76
Legacy Code: CU000230
Distributor Code: GF63504176
SKU: 1000048266
Product Code: CU00-FL-000230

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	29
Crystal structure	Face centred cubic
Electronic structure	Ar 3d¹? 4s¹
Valences shown	1, 2
Atomic weight(amu)	63.546
Thermal neutron absorption cross-section(Barns)	3.8
Photo-electric work function(eV)	4.5
Natural isotope distribution(Mass No./%)	65/ 30.8
Natural isotope distribution(Mass No./%)	63/ 69.2
Atomic radius - Goldschmidt(nm)	0.128
Ionisation potential(No./eV)	4/ 55.2
Ionisation potential(No./eV)	6/ 103
Ionisation potential(No./eV)	1/ 7.73
Ionisation potential(No./eV)	5/ 79.9
Ionisation potential(No./eV)	3/ 36.8
Ionisation potential(No./eV)	2/ 20.29

Mechanical Properties

Element	Value
Material condition	Soft
Material condition	Hard
Poisson's ratio	0.343
Poisson's ratio	0.343
Bulk modulus(GPa)	137.8
Bulk modulus(GPa)	137.8
Tensile modulus(GPa)	129.8
Tensile modulus(GPa)	129.8
Izod toughness(J m?¹)	68
Izod toughness(J m?¹)	58
Hardness - Vickers(kgf mm?²)	87
Hardness - Vickers(kgf mm?²)	49
Tensile strength(MPa)	314
Tensile strength(MPa)	224
Yield strength(MPa)	270
Yield strength(MPa)	54

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	1.69@20@20°C
Temperature coefficient(K?¹)	0.0043@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.76

Physical Properties

Element	Value
Boiling point(C)	2567
Density(gcm?³)	8.96@20°C

Thermal Properties

Element	Value
Melting point(C)	1083
Latent heat of evaporation(J g?¹)	4796
Latent heat of fusion(J g?¹)	205
Specific heat(J K?¹ kg?¹)	385@25°C
Thermal conductivity(W m?¹ K?¹)	401@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	17@0-100°C

5 Micrometer Thick Copper Foil (99.97% Purity)

goodfellow ADVANCED MATERIALS INNOVATION DELIVERED

Copper Foil

Formula: Cu
Percentage Purity: 99.97%
Thickness: 0.005mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7440-50-8
UOM Code: 779-585-56
Legacy Code: CU000150
Distributor Code: GF77958556
SKU: 1000046523
Product Code: CU00-FL-000150

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	29
Crystal structure	Face centred cubic
Electronic structure	Ar 3d¹? 4s¹
Valences shown	1, 2
Atomic weight(amu)	63.546
Thermal neutron absorption cross-section(Barns)	3.8
Photo-electric work function(eV)	4.5
Natural isotope distribution(Mass No./%)	65/ 30.8
Natural isotope distribution(Mass No./%)	63/ 69.2
Atomic radius - Goldschmidt(nm)	0.128
Ionisation potential(No./eV)	4/ 55.2
Ionisation potential(No./eV)	6/ 103
Ionisation potential(No./eV)	1/ 7.73
Ionisation potential(No./eV)	5/ 79.9
Ionisation potential(No./eV)	3/ 36.8
Ionisation potential(No./eV)	2/ 20.29

Mechanical Properties

Element	Value
Material condition	Soft
Material condition	Hard
Poisson's ratio	0.343
Poisson's ratio	0.343
Bulk modulus(GPa)	137.8
Bulk modulus(GPa)	137.8
Tensile modulus(GPa)	129.8
Tensile modulus(GPa)	129.8
Izod toughness(J m?^{1})	68
Izod toughness(J m?^{1})	58
Hardness - Vickers(kgf mm?^{2})	87
Hardness - Vickers(kgf mm?^{2})	49
Tensile strength(MPa)	314
Tensile strength(MPa)	224
Yield strength(MPa)	270
Yield strength(MPa)	54

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	1.69@20@20°C
Temperature coefficient(K?^{1})	0.0043@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.76

Physical Properties

Element	Value
Boiling point(C)	2567
Density(gcm?^{3})	8.96@20°C

Thermal Properties

Element	Value
Melting point(C)	1083
Latent heat of evaporation(J g?^{1})	4796
Latent heat of fusion(J g?^{1})	205
Specific heat(J K?^{1} kg?^{1})	385@25°C
Thermal conductivity(W m?^{1} K?^{1})	401@0-100°C
Coefficient of thermal expansion(x10?? K?^{1})	17@0-100°C

300 Micrometer Thick Aluminum Foil (99.9999% Purity)

goodfellow
ADVANCED MATERIALS
INNOVATION DELIVERED

Aluminum Foil

Formula: Al
Percentage Purity: 99.9999%
Temper: As Rolled
Thickness: 0.3mm
Length 1: 50mm
Length 2: 50mm
UOM Code: 969-346-41
Legacy Code: AL0002CA
Distributor Code: GF96934641
SKU: 1000222012
Product Code: AL00-FL-000808

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value
Material condition	Soft

Element	Value
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?²)	21
Hardness - Vickers(kgf mm?²)	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?¹)	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?³)	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?¹)	10800
Latent heat of fusion(J g?¹)	388
Specific heat(J K?¹ kg?¹)	900@25°C
Thermal conductivity(W m?¹ K?¹)	237@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	23.5@0-100°C

150 Micrometer Thick Aluminum Foil (99.999% Purity)

Aluminum Foil

Formula: Al
Percentage Purity: 99.999%
Temper: As Rolled
Thickness: 0.15mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7429-90-5
UOM Code: 120-894-39
Legacy Code: AL000802
Distributor Code: GF12089439
SKU: 1000028825
Product Code: AL00-FL-000615

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value

Material condition	Soft
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?^{2})	21
Hardness - Vickers(kgf mm?^{2})	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?^{1})	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?^{3})	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?^{1})	10800
Latent heat of fusion(J g?^{1})	388
Specific heat(J K?^{1} kg?^{1})	900@25°C
Thermal conductivity(W m?^{1} K?^{1})	237@0-100°C
Coefficient of thermal expansion(x10?? K?^{1})	23.5@0-100°C

100 Micrometer Thick Aluminum Foil (99.999% Purity)

goodfellow
ADVANCED MATERIALS
INNOVATION DELIVERED

Aluminum Foil

Formula: Al
Percentage Purity: 99.999%
Temper: As Rolled
Thickness: 0.1mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7429-90-5
UOM Code: 782-259-50
Legacy Code: AL000565
Distributor Code: GF78225950
SKU: 1000012856
Product Code: AL00-FL-000165

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value

Material condition	Soft
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?²)	21
Hardness - Vickers(kgf mm?²)	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?¹)	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?³)	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?¹)	10800
Latent heat of fusion(J g?¹)	388
Specific heat(J K?¹ kg?¹)	900@25°C
Thermal conductivity(W m?¹ K?¹)	237@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	23.5@0-100°C

50 Micrometer Thick Aluminum Foil (99.999% Purity)

goodfellow
ADVANCED MATERIALS
INNOVATION DELIVERED

Aluminum Coil

Formula: Al
Percentage Purity: 99.999%
Temper: As Rolled
Thickness: 0.05mm
Coil Width: 150mm
Length: 50m
CAS Number: 7429-90-5
UOM Code: 556-268-73
Legacy Code: AL0002AA
Distributor Code: GF55626873
SKU: 1000015561
Product Code: AL00-FL-000755

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value

Material condition	Soft
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?²)	21
Hardness - Vickers(kgf mm?²)	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?¹)	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?³)	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?¹)	10800
Latent heat of fusion(J g?¹)	388
Specific heat(J K?¹ kg?¹)	900@25°C
Thermal conductivity(W m?¹ K?¹)	237@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	23.5@0-100°C

25 Micrometer Thick Aluminum Foil (99.999% Purity)

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ADVANCED MATERIALS
INNOVATION DELIVERED

Aluminum Foil

Formula: Al
Percentage Purity: 99.999%
Temper: As Rolled
Thickness: 0.025mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7429-90-5
UOM Code: 738-080-24
Legacy Code: AL000431
Distributor Code: GF73808024
SKU: 1000011585
Product Code: AL00-FL-000131

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value

Material condition	Soft
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?²)	21
Hardness - Vickers(kgf mm?²)	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?¹)	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?³)	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?¹)	10800
Latent heat of fusion(J g?¹)	388
Specific heat(J K?¹ kg?¹)	900@25°C
Thermal conductivity(W m?¹ K?¹)	237@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	23.5@0-100°C

12.5 Micrometer Thick Aluminum Foil (99.5% Purity)

goodfellow ADVANCED MATERIALS INNOVATION DELIVERED

Aluminum Foil

Formula: Al
Percentage Purity: 99.5%
Thickness: 0.0125mm
Length 1: 50mm
Length 2: 50mm
CAS Number: 7429-90-5
UOM Code: 126-748-00
Legacy Code: AL000287
Distributor Code: GF12674800
SKU: 1000015494
Product Code: AL00-FL-000735

Material Properties for Metals

Atomic Properties

Element	Value
Atomic number	13
Crystal structure	Face centred cubic
Electronic structure	Ne $3s^2$ $3p^1$
Valences shown	3
Atomic weight(amu)	26.98154
Thermal neutron absorption cross-section(Barns)	0.232
Photo-electric work function(eV)	4.2
Atomic radius - Goldschmidt(nm)	0.143
Ionisation potential(No./eV)	4/ 120
Ionisation potential(No./eV)	5/ 154
Ionisation potential(No./eV)	6/ 190
Ionisation potential(No./eV)	1/ 5.99
Ionisation potential(No./eV)	3/ 28.4
Ionisation potential(No./eV)	2/ 18.8

Mechanical Properties

Element	Value
Material condition	Soft

Element	Value
Material condition	Hard
Poisson's ratio	0.345
Poisson's ratio	0.345
Bulk modulus(GPa)	75.2
Bulk modulus(GPa)	75.2
Tensile modulus(GPa)	70.6
Tensile modulus(GPa)	70.6
Hardness - Vickers(kgf mm?²)	21
Hardness - Vickers(kgf mm?²)	35-48
Tensile strength(MPa)	130-195
Tensile strength(MPa)	50-90
Yield strength(MPa)	110-170
Yield strength(MPa)	Oct-35

Electrical Properties

Element	Value
Electrical resistivity(µOhmcm)	2.67@20@20°C
Superconductivity critical temperature(K)	1.175
Temperature coefficient(K?¹)	0.0045@0-100°C
Thermal emf against Pt (cold 0C - hot 100C)(mV)	0.42

Physical Properties

Element	Value
Boiling point(C)	2467
Density(gcm?³)	2.7@20°C

Thermal Properties

Element	Value
Melting point(C)	660.4
Latent heat of evaporation(J g?¹)	10800
Latent heat of fusion(J g?¹)	388
Specific heat(J K?¹ kg?¹)	900@25°C
Thermal conductivity(W m?¹ K?¹)	237@0-100°C
Coefficient of thermal expansion(x10?? K?¹)	23.5@0-100°C