TIMS

NuTIMS

Switchable Amplifiers

High Precision and Low Noise

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NuTIMS Switchable Amplifier System

Nu Instruments newly developed Peltier cooled switchable amplifier system allows two high impedance resistors (including 10^{13} ohms) to be fitted on any of the Faraday channels (optional for each Faraday channel).

Very low noise can then be achieved whilst maintaining and improving the ultrahigh precision associated with a TIMS instrument using the unique online resistor switching capability.

Incorporating the new Dual Source Calibration (DSC) board and Active Tau Correction (ATC) as standard, and optional mixed resistor amplifier boards, these latest advancements further enhance the flexibility and performance of the Nu TIMS.

Key Features

- Fully automated gain correction
- Active tau correction implemented within software
- Amplifier recovery time of less than 45 seconds after switching resistors
- Less than 30cps 2SD baseline long term uncertainty (using 480 second integration)
- Improved precision on small samples when using a 10^{12} ohm or 10^{13} ohm resistors
- Improved precision on minor isotopes when using 10^{13} ohm resistors

Noise Comparisons

Excellent short and long term noise reproducibility using switchable amplifiers

All 16 Faraday detectors fitted on the Nu TIMS system can be fitted with a switchable amplifier.

Each amplifier can switch between two resistors of selected sizes (10^{10} ohm, 10^{11} ohm, 10^{12} ohm, or 10^{13} ohm) to adjust the signal amplification gain associated to a Faraday detector and reducing noise for smaller signals when using 10^{12} ohm or 10^{13} ohm resistors.

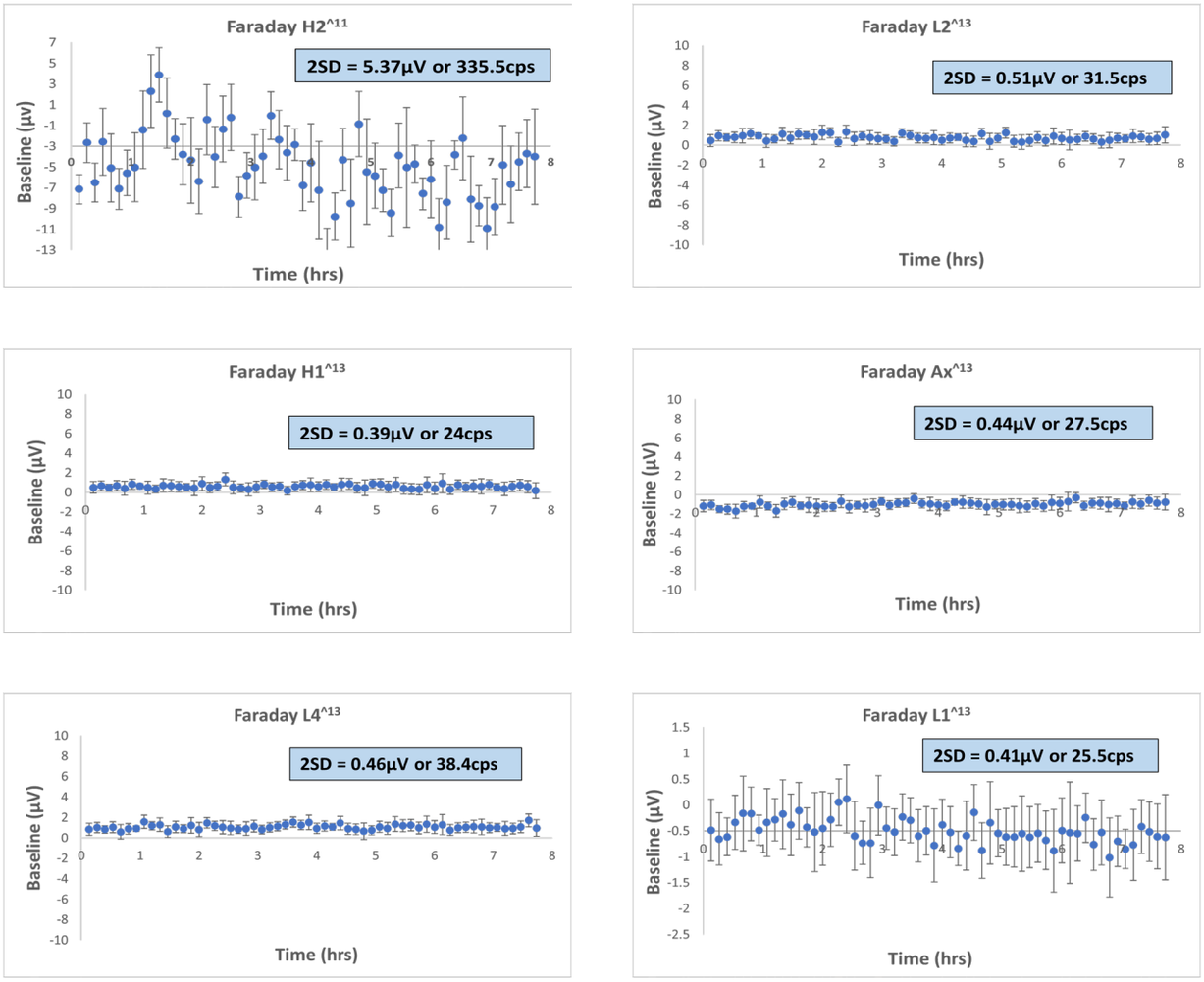


Figure 1. Example of long-term baseline noise on Faraday collectors using 10^{11} and 10^{13} ohm resistors, measured over a time period of > 7 hours (each measurement being 480 second integration).

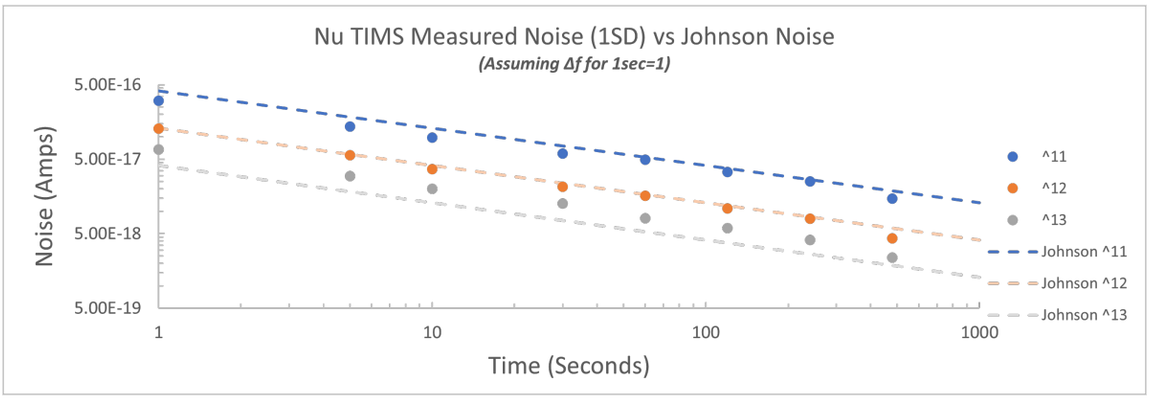


Figure 2. Nu TIMS measured noise vs Johnson noise over a range of integration times.

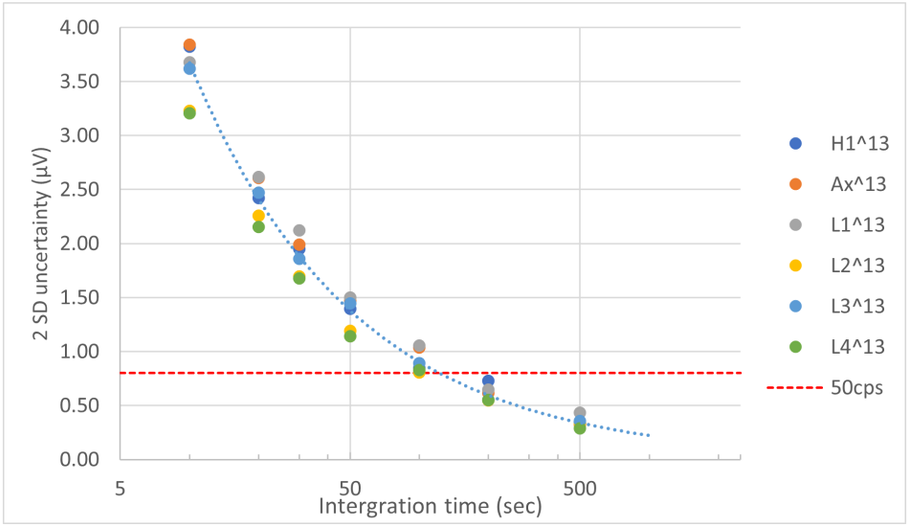


Figure 3. 2SD uncertainty variation of $10^{13}\Omega$ resistor amplifiers at different integration times for multiple Faraday collectors.

$10^{13}\Omega$ resistor amplifier summary

- Tenfold improvement in noise when compared to a standard $10^{11}\Omega$ resistor
- Less than 30cps 2SD uncertainty using a 480 second integration over several hours
- Typically 3µV 1SD uncertainty using 5 second integration

Measurement Precision

Improved precisions using $10^{13}\Omega$ amplifiers when compared to a $10^{11}\Omega$ on signals below 100mV or $10^{12}\Omega$ when below 40mV

Run Method
Static measurements consisting of 150 data points using 10 second integrations were run using three types of amplifier resistors. Zero measurements were performed 15 minutes prior to running.

Table 1. Resistor comparison of the $^{143}Nd/^{144}Nd$ isotope ratio when running at 500µV signal size on ^{143}Nd for 1500 seconds.

Comparison of Resistors						
	^{143}Nd intensity 500µV		^{143}Nd intensity 5mV		^{143}Nd intensity 17mV	
Resistor	Internal	External	Internal	External	Internal	External
Type (ohms)	2RSE (ppm)	2RSD (ppm)	2RSE (ppm)	2RSD (ppm)	2RSE (ppm)	2RSD (ppm)
$143^{(\hat{}11)}/144^{(\hat{}11)}$	3539	9254	357	1041	241	126
$143^{(\hat{}12)}/144^{(\hat{}12)}$	1208	2026	174	277	68	108
$143^{(\hat{}13)}/144^{(\hat{}13)}$	636	728	141	165	76	87

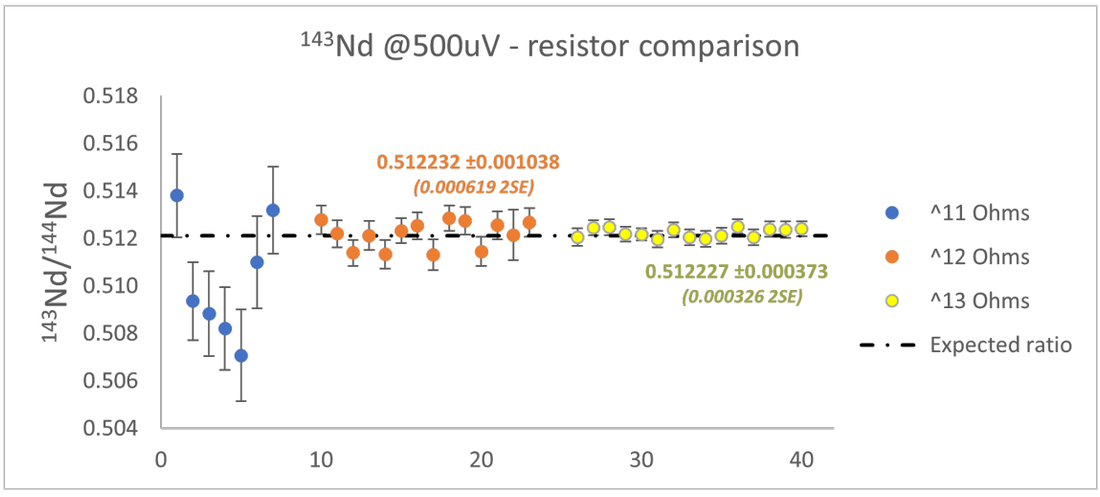


Figure 4. Resistor comparison of the $^{143}Nd/^{144}Nd$ isotope ratio when running at 500µV ^{143}Nd signal intensity for 1500 seconds.

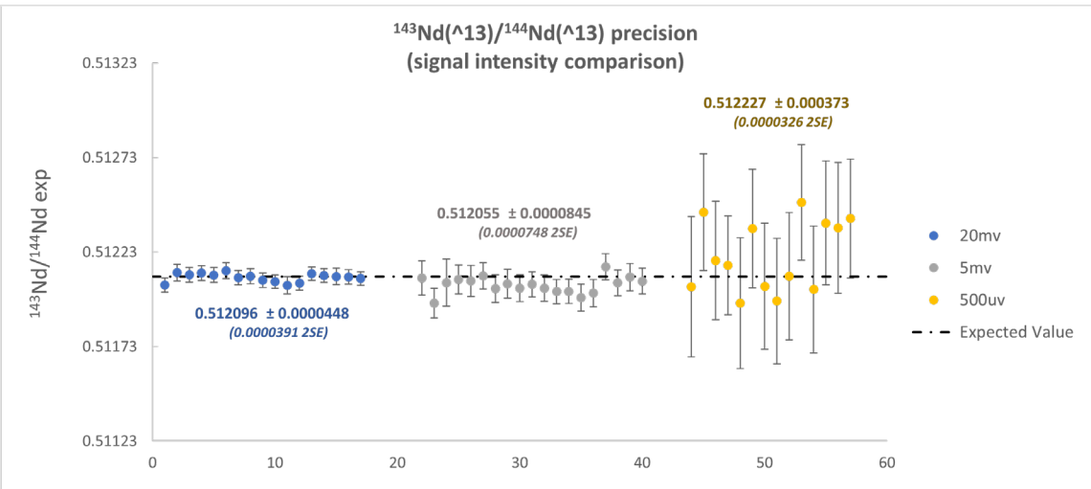


Figure 5. Precisions of $^{143}Nd/^{144}Nd$ (using $10^{13}\Omega$ amplifiers) with various ^{143}Nd signal intensities ran at 1500 seconds.*

Improvements in precision can be seen for both $10^{13}\Omega$ and $10^{12}\Omega$ resistors of a switchable amplifier at signals below 100mV when compared to a $10^{11}\Omega$ resistor

- Tenfold improvement in external precision when comparing $10^{11}\Omega$ and $10^{13}\Omega$ at 500μV ^{143}Nd signal intensity
- Twofold improvement in external precision when comparing $10^{12}\Omega$ and $10^{13}\Omega$ at 500μV ^{143}Nd signal intensity
- When using $10^{13}\Omega$ resistors, 728 ppm 2RSD for $^{143}Nd/^{144}Nd$ was achieved using a 500μv ^{143}Nd signal intensity

*Data comparable to: J.M.Koorneef, et al. (J. Anal. At. Spectro, 2013, 28, 749)

Active Tau Correction

Improved signal response when using Active Tau Correction (ATC)

When compared with $10^{11}\Omega$ resistors, $10^{13}\Omega$ resistors exhibit a slower decay response rate affecting transient signal measurement when using both resistors simultaneously. The affect on the ratio is demonstrated in Figures 7, 8, 9 and 10. This effect may be observed when measuring a ratio with a varying signal intensities.

The Active Tau Correction monitors the change in signal and adjusts within run for the tau effect ($\Delta v * Tau^{corr}$ = Actual).

Due to the slower decay rate of $10^{13}\Omega$ amplifiers, when using peak jumping mode, settling times will need to be set to a longer duration when using $10^{13}\Omega$ compared to $10^{12}\Omega$. Therefore, using $10^{12}\Omega$ resistors may still be beneficial depending on the application.

It has been observed that the Tau correction can induce a 0.5µV increase in noise (SD at 5 second integration). Therefore, this correction can be disabled in the software if preferred by the operator.

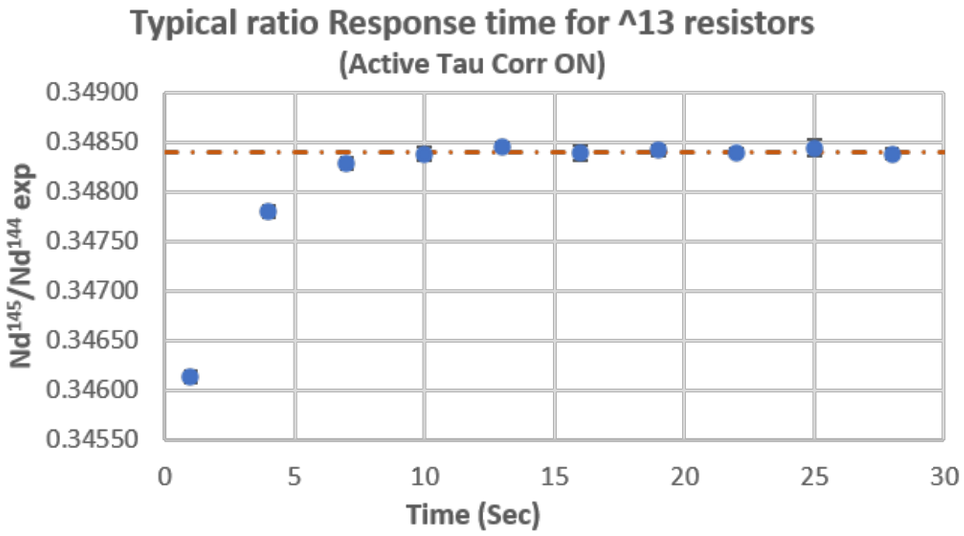
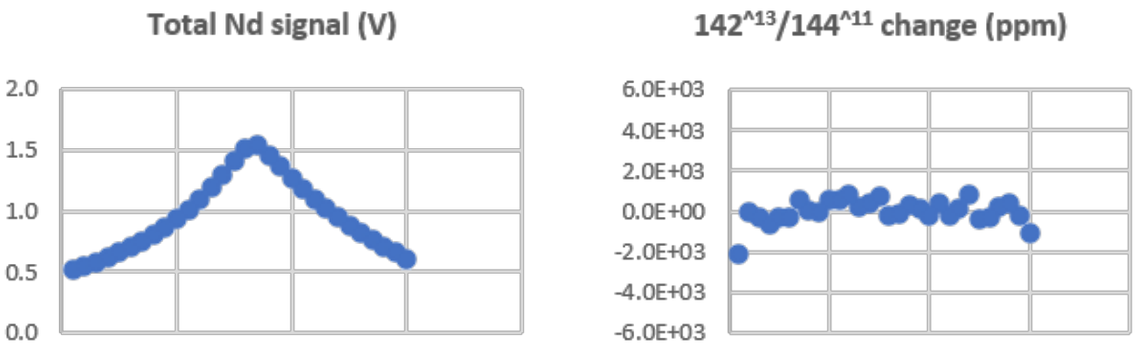
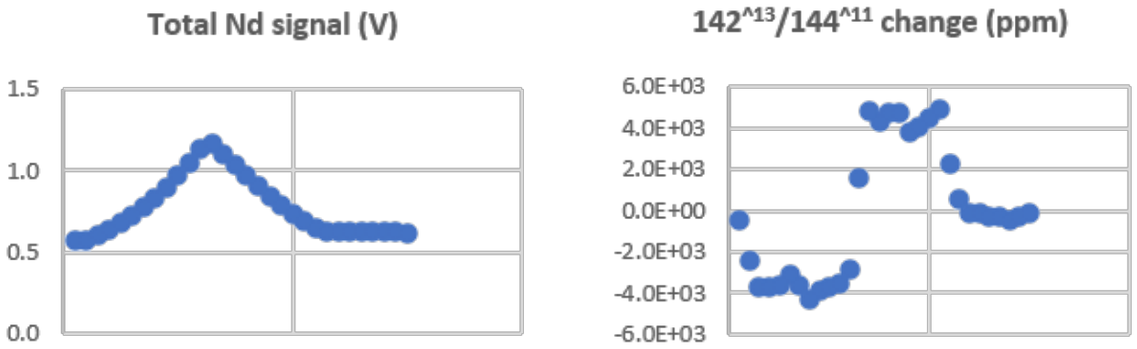


Figure 6. Peak jumping measurements monitoring $^{145}Nd^{(^13)}/^{144}Nd^{(^13)}$ after jumping from a zero measurement - Active Tau Correction enabled/on.

Corrected Signal = Measured Signal + (Change in signal*Tau factor)



Figures 7 and 8. ppm change in $^{142}Nd^{(^13)}/^{144}Nd^{(^11)}$ when varying the signal intensity - Active Tau Correction enabled/on.



Figures 9 and 10. ppm change in $^{142}Nd^{(^13)}/^{144}Nd^{(^11)}$ when varying the signal intensity - Active Tau Correction disabled/off.

Active Tau Correction allows for mixed resistor amplifier runs experiencing transient signal intensities by minimizing the effects from different amplifier response rates, when running static measurements

Switching Resistor Recovery Time

Rapid recovery times when selecting between different amplifier resistors, whilst maintaining previous gain calibrations

A switchable resistor amplifier can be fitted on any Faraday channel and switching performed by software control.

The recovery time of the amplifiers after switching resistors is less than 45 seconds and maintaining previous gain calibration*.

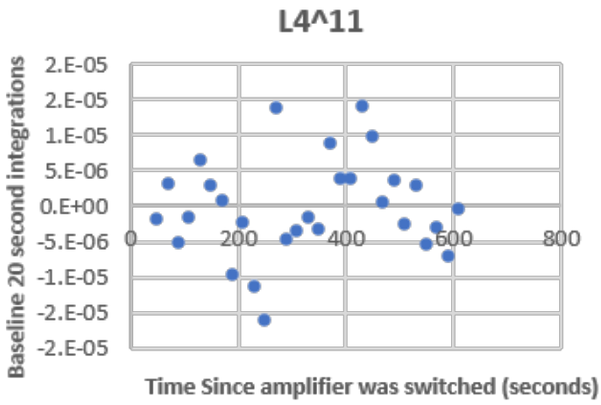


Figure 11. Baseline of a $10^{11}\Omega$ resistor after switching from a $10^{13}\Omega$ resistor vs time (20 second integration).

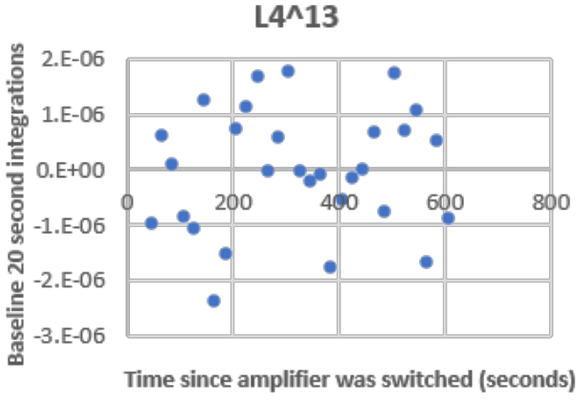


Figure 12. Baseline of a $10^{13}\Omega$ resistor after switching from a $10^{11}\Omega$ resistor vs time (20 second integration).

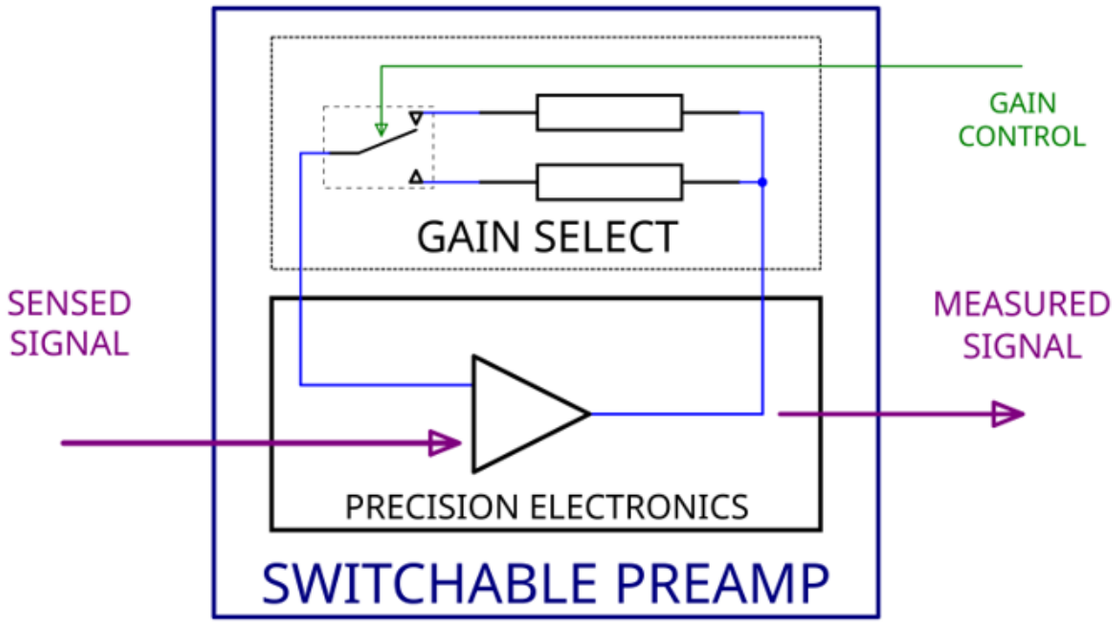


Figure 13. Switchable amplifier concept.

Maximum number of possible amplification states are now equivalent to 32 of the previous generation of amplifiers

The extended range of the latest switchable amplifiers allow for maximum flexibility, from low noise to ultra-high precision analysis

Switching recovery times are minimal and stable in under 45 seconds with the previous gain holding*

*Gain stability is isolated from the switching of resistors but still recommended to be re-calibrated every 2 weeks.

NdO Measurements

Improved precisions using $10^{13}\Omega$ resistor amplifiers for NdO measurements with sample sizes between 100pg - 10pg

Increased ionisation efficiencies (up to 35%) can be achieved when measuring the oxide form of neodymium. Coupled with the low noise associated with $10^{13}\Omega$ resistors, 32.9ppm 2RSD for the $^{143}Nd/^{144}Nd$ on sample sizes of 100pg have been achieved (Table 2).
Better than 140ppm 2RSD has been achieved for sample sizes as low as 10pg for $^{143}Nd/^{144}Nd$.

When running as an oxide form, loading in a correct manner can be crucial for the ion yield and control of interferences. The unique design of the Nu TIMS has 16 Faraday detectors fitted as standard, maximizing the number of interferences that can be monitored.

Running as the metal form may still be beneficial for sample sizes of 50pg as the loading manner is less critical.

Table 2. $^{142}Nd/^{144}Nd$ and $^{143}Nd/^{144}Nd$ isotope ratio measured for 100pg sample size - NdO Static measurements using the $10^{13}\Omega$ resistors, including Ion Yield (%).

^{143}Nd signal (V)	$^{142}Nd/^{144}Nd$	2RSE (ppm)	$^{143}Nd/^{144}Nd$	2RSE (ppm)	Ion Yield (%)
0.067	1.141805	38	0.51209	33	15
0.066	1.141819	33	0.51210	30	25
0.066	1.141841	33	0.51210	26	23
0.066	1.141816	31	0.51210	26	27
0.067	1.141804	31	0.51210	28	27
0.067	1.14186	38	0.51209	28	25
0.067	1.141798	66	0.51209	60	18
0.066	1.141788	39	0.51208	34	22
0.065	1.141778	44	0.51211	38	16
0.065	1.141801	49	0.51210	42	14
0.066	1.141812	34	0.51211	27	20
0.066	1.141816	35	0.51209	31	20
0.067	1.141803	36	0.51209	31	24
MEAN	**1.141805**	**39**	**0.51210**	**33.4**	**21.2**
2RSD (ppm)	**29**		**33**		

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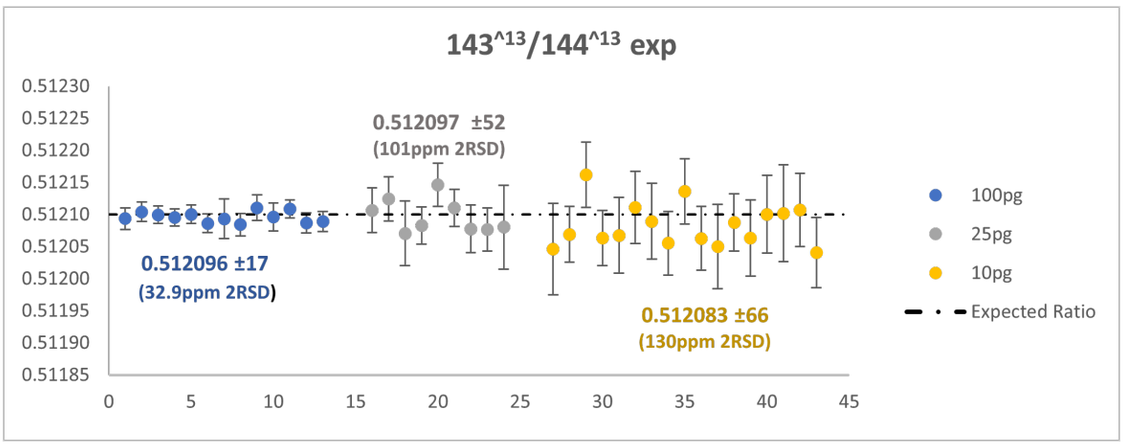

Figure 14. $^{143}Nd/^{144}Nd$ static analysis of small sample sizes using $10^{13}\Omega$ resistors.

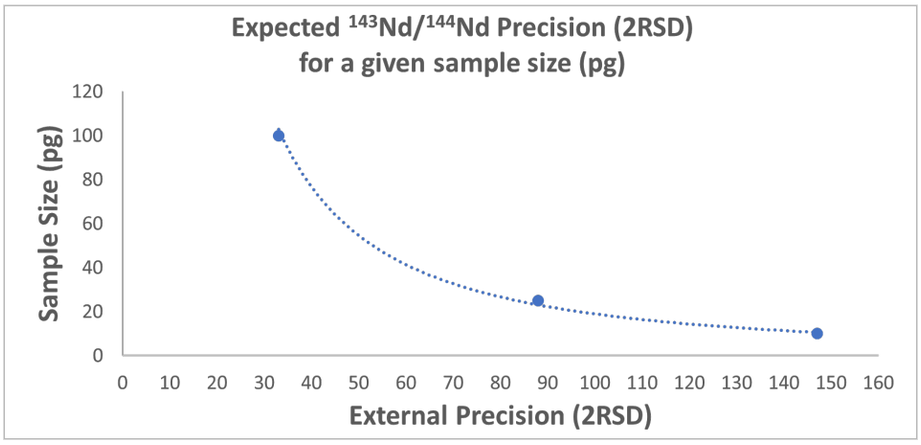

Figure 15. Indicative precision for given sample size when analysing as the oxide form.

Sample loading and interferences are the main sources affecting precision when measuring Nd in oxide form

A large range of interferences can be monitored on the Nu TIMS as 16 Faraday detectors are fitted as standard, which is advantageous when running NdO

External precision below 150 pm (2RSD) is achievable on NuTIMS for 10 pg NdO

Uranium Total Evaporation

Improved precisions using a combination of $10^{11}\Omega$ and $10^{13}\Omega$ amplifiers for 77ng sample size uranium (CRM U010) runs in TE mode

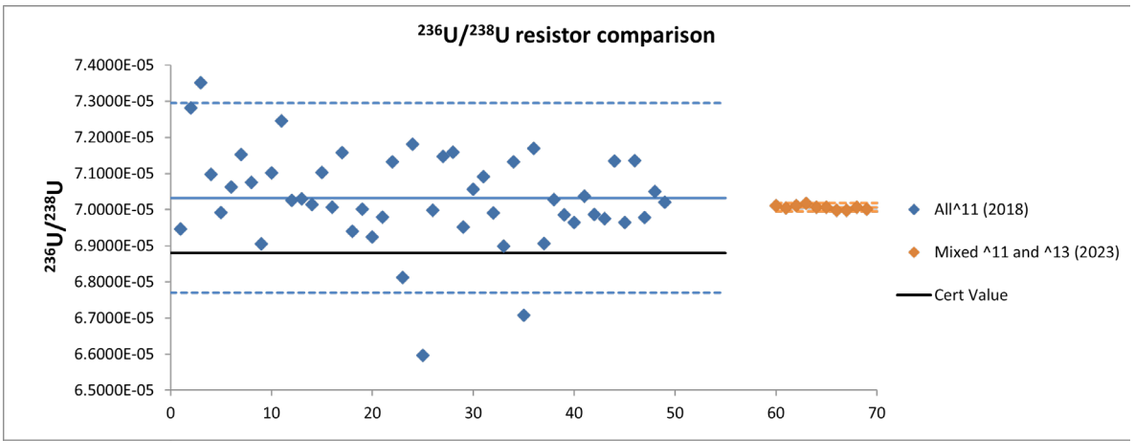

Figure 16. Total Evaporation (TE) runs of 77ng U010, comparing $^{236}U/^{238}U$ using $10^{11}\Omega$ (^{236}U and ^{238}U) vs using $10^{11}\Omega$ (^{238}U) and $10^{13}\Omega$ (^{236}U) resistors.

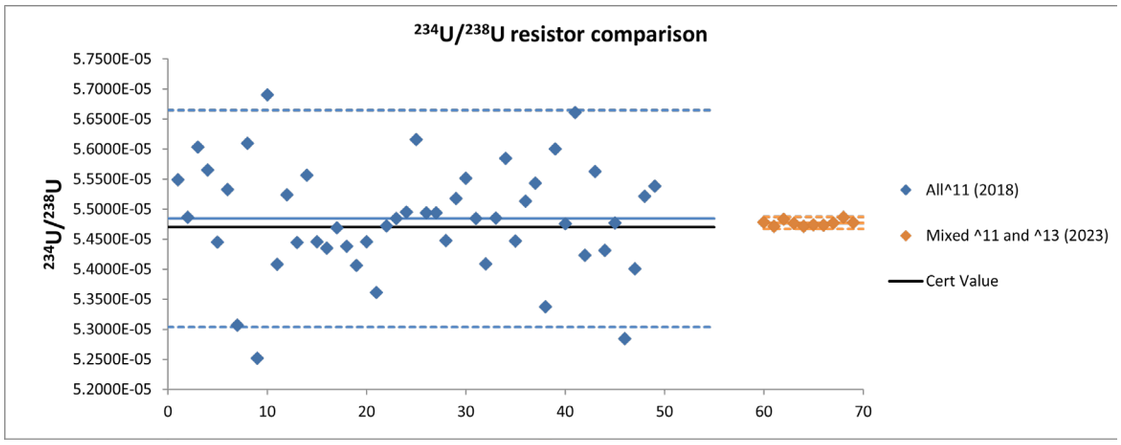

Figure 17. Total Evaporation (TE) runs of 77ng U010, comparing $^{234}U/^{238}U$ using $10^{11}\Omega$ (^{234}U and ^{238}U) vs using $10^{11}\Omega$ (^{238}U) and $10^{13}\Omega$ (^{234}U) resistors.

Improvements are shown for small sample size 77ng U010 using a Total Evaporation (TE) mode

External reproducibility improves more than tenfold for 300 - 400µV signal sizes when using the $10^{13}\Omega$ resistors for the minor isotopes

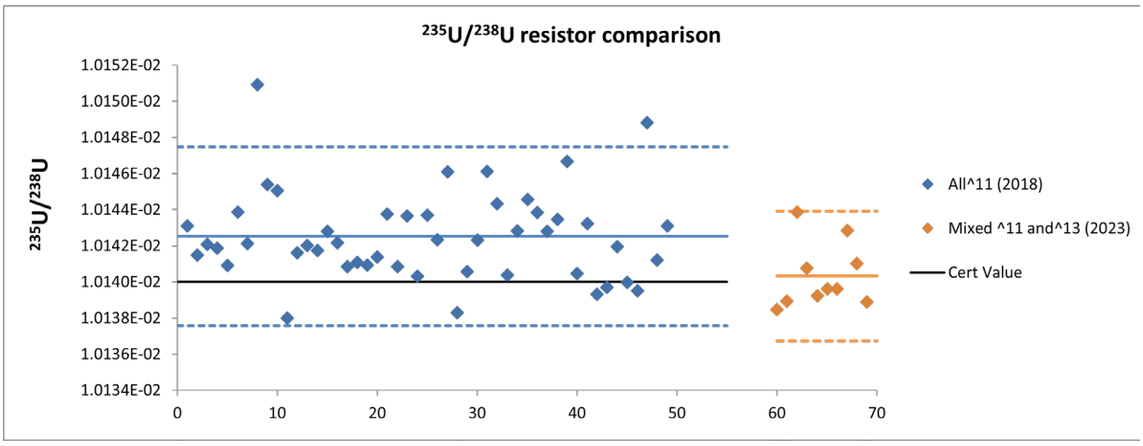

Figure 18. TE runs of 77ng U010, comparing U^{235}/U^{238} using $10^{11}\Omega$ vs using both $10^{11}\Omega$ and $10^{13}\Omega$ resistors

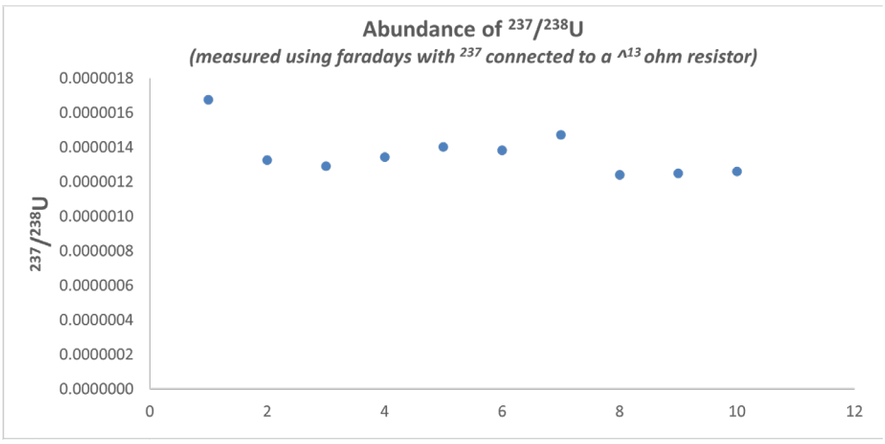

Figure 19. Abundance at mass ^{237} with respect to 238U using a $10^{13}\Omega$ amplifier, allowing the possibility to back correct the $^{236}U/^{238}U$ ratio for any tailing effects on the ^{236}U associated with the larger ^{238}U signal.

Better than 0.1% 1RSD achieved for sample size of 77ng for $^{234}U/^{238}U$ and $^{236}U/^{238}U$ when using the $10^{13}\Omega$ resistors for the minor isotopes

$^{237}U/^{238}U$ monitored with only 8.2μV signal using a $10^{13}\Omega$ resistor of a switchable amplifier

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