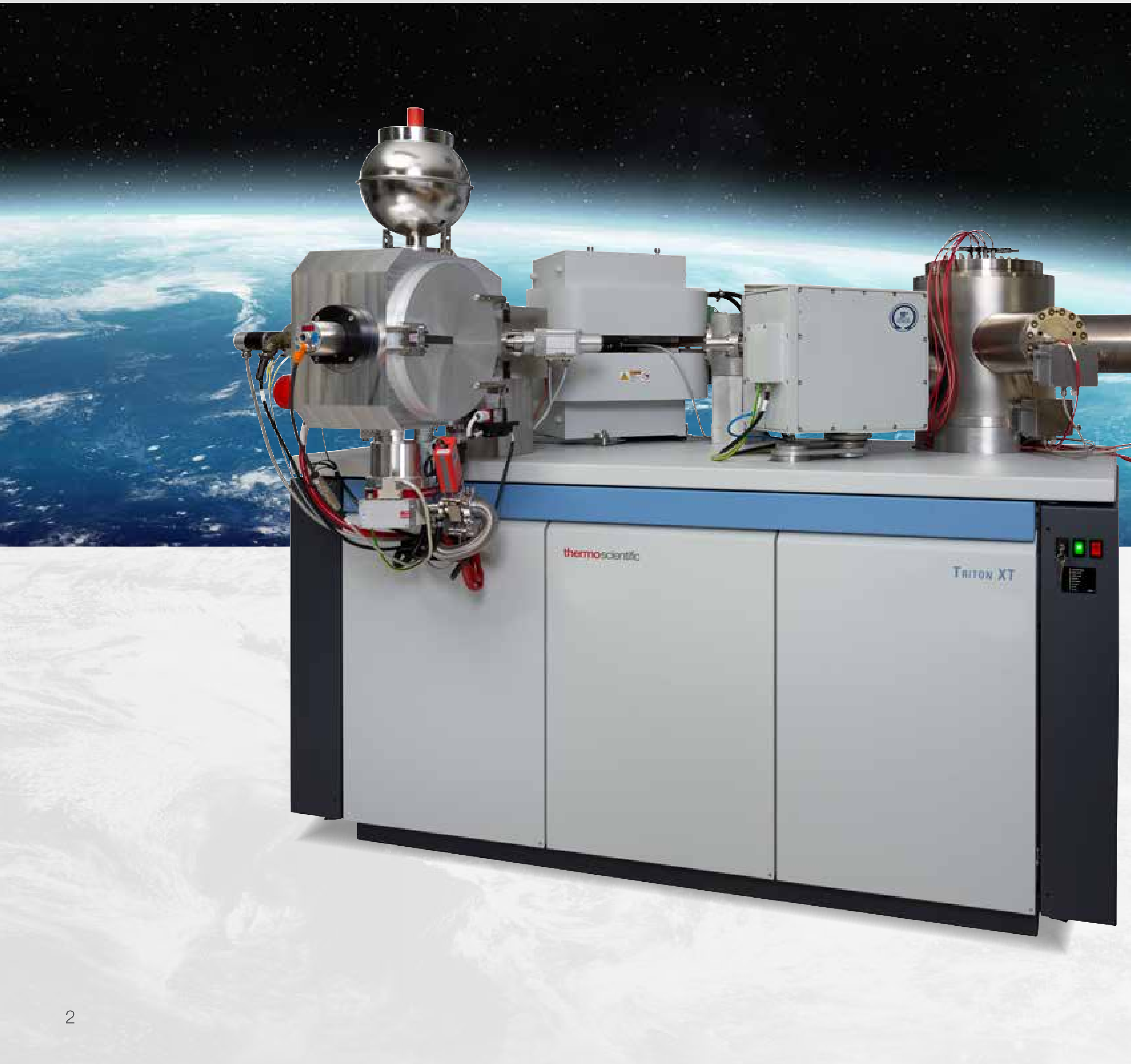
Thermo Scientific Triton XT TIMS

Triton XT TIMS

A new edition of the market leading Thermo Scientific™ Triton™ Series TIMS, capturing the best of technology for high-precision isotope ratio analysis.



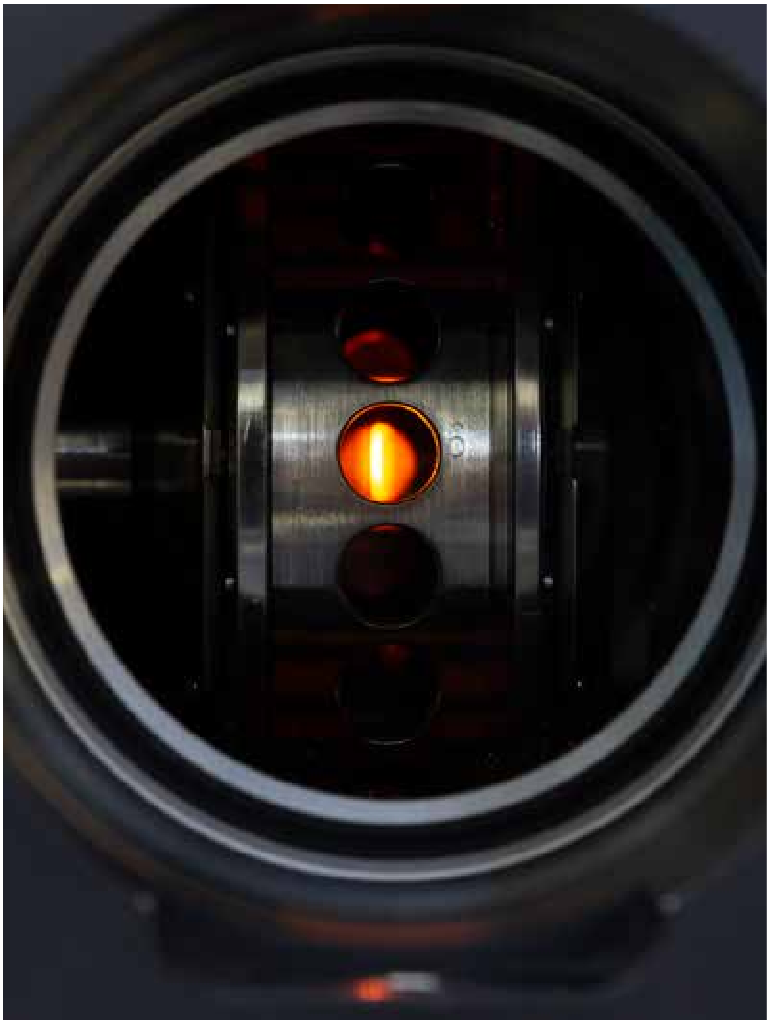
Thermo Fisher Scientific: pioneering multicollector technologies,

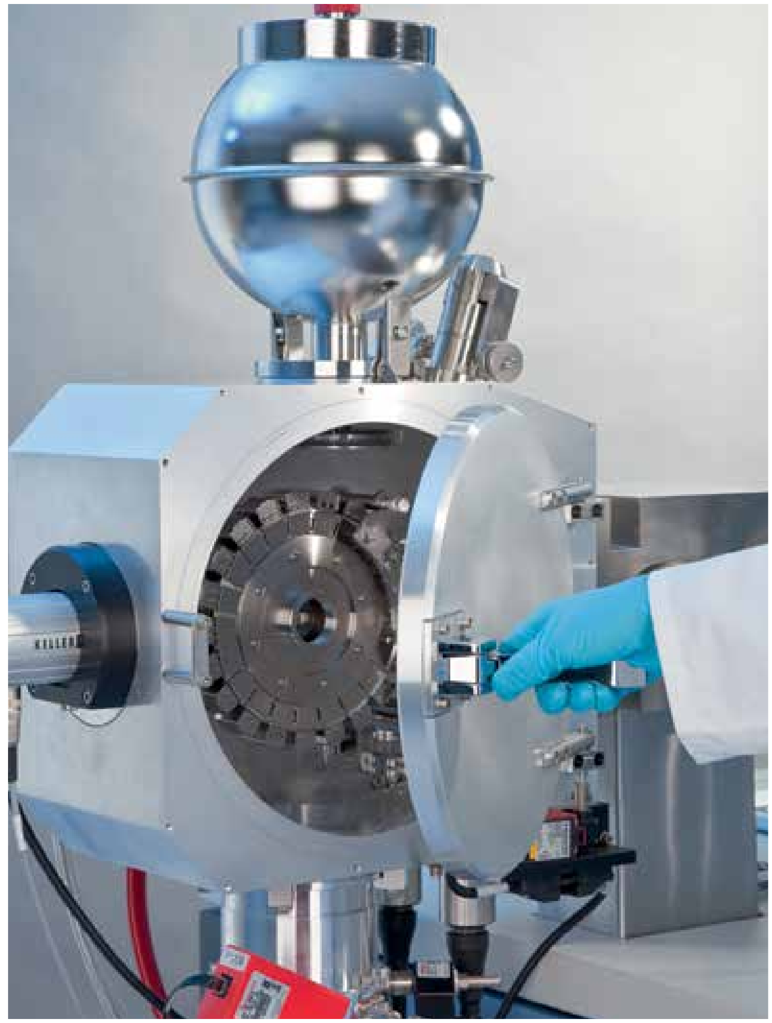
- First with RPQ for abundance sensitivity.
- First to introduce a reliable moveable collector array with over 500 in operation.
- First to report ultra-high-precision static isotope ratio measurements and first with virtual amplifier.
- First with mass range to cover static Li measurements, now extendable to static Ca.
- First with stable and linear SEM and then CDD ion counters.
- First with 10^{13} Ω Amplifier Technology, extending the lower limits of the ultimate detector. Now with electronic gain calibration and tau correction.

All these firsts have been supported by continuous improvement of our instrumentation, with software that facilitates access to the latest technologies. The Triton TIMS Series instruments are the established market leader for TIMS, with an enviable reputation for producing robust scientific datasets.

Every Triton TIMS instrument is supported by a professional global organization that ensures long term, ongoing support. The result is a user base that has achieved exceptional scientific productivity.

… perfecting multicollector technology for application.





Triton XT TIMS

Result of over two decades of development

The Thermo Scientific™ Triton XT™ TIMS is a multicollector thermal ionization mass spectrometer integrating the established field-proven technologies from the Triton Series instruments, combined with the latest developments in technology for isotope ratio analysis from Thermo Fisher Scientific™. The Triton XT TIMS incorporates Thermo Scientific™ 10^{13} Ω Amplifier Technology™ so that users can extract the highest precision information from limited sample amounts. For the toughest analytical challenges the Triton XT TIMS can be configured with options for enhancing abundance sensitivity (RPQ) and with ion counter arrays (SEM and CDD). Every user benefits from the stability of the Triton Series instrumentation. Tuning is aided by the stability of tune parameters and a high degree of automation; so that less time and effort is spent on tuning and more time is spent generating robust scientific datasets.

Thermal ionization source

The Triton XT TIMS has a thermal ionization source that is characterized by a very small kinetic energy spread of the ions (~0.5 eV). Ions are accelerated by a high stability potential field of 10 kV (positive or negative). The ion source optics of the Triton XT TIMS have been optimized for maximum ion transmission for both single and double filament techniques. The sample turret holds 21 single or double filaments , which can be easily exchanged without tools.

Special care has been taken by shaping the ion source lens elements so that build-up of contaminations and memory in the source are minimized. The lens stack is readily accessible by the user for inspection and maintenance. Halide lamps enable fast and convenient bake out of the ion source.

A range of options are available for the Triton XT TIMS. Options for increasing sample throughput include a preheat device for advanced heating of samples and a cryogenic pump for rapid pump down of the source. Options for improving performance for specific isotopic systems include a gas bleed valve for highest ion yields and a high precision pyrometer for filament temperature control.

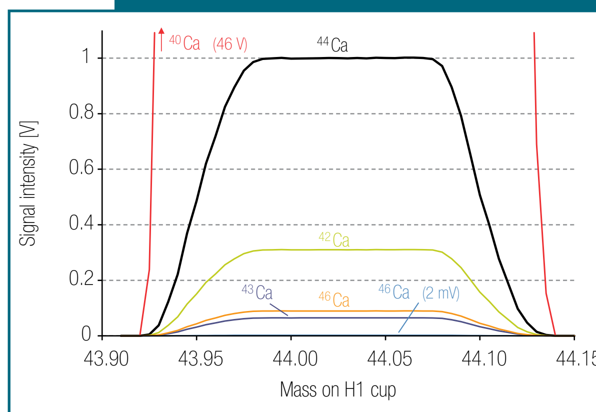
Magnetic sector

The magnetic sector focuses ions of different mass along an inclined focal plane. Due to the minimal ion energy spread of the ion source, a magnetic sector field achieves accurate separation of masses (single-focusing geometry). The magnet is water-cooled and laminated for high stability, high-speed peak jumping and low hysteresis. Switching between isotopic systems of different masses does not require long settling times and there is no need to adjust the positioning of the magnet. Baffles are installed along the flight tube in order to minimize scattering of ions from the side walls.

CASE STUDY

Ca isotope analysis using a set of amplifiers

The isotope system of calcium is applied in many different fields of geochemistry, environmental sciences and life sciences. Ca isotopes are characterized by a large range of natural abundances spanning a range of ca. $4x10^{-5}$, from ^{40}Ca with a natural abundance of 96.4% to 0.004% for ^{46}Ca. Accordingly, Ca isotope measurements are particularly challenging.



Cup	L4	L3	L2	L1	C	H1	H2	H3	H4
Amplifier	10^{11}	10^{13}	10^{13}	10^{13}		10^{11}	10^{13}		10^{13}
Isotope	^{40}Ca	^{41}K	^{42}Ca	^{43}Ca		^{44}Ca	^{46}Ca		^{48}Ca

Five 10^{13} Ω amplifiers are recommend for the static Ca measurement as well as a special H4 Faraday cup (requires additional optional items). Peak scan of all Ca isotopes with a cup configuration as shown above of a sample with natural Ca isotope composition.

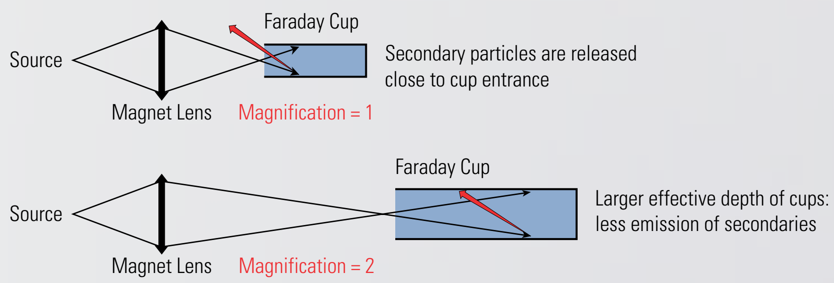
The static multicollection of all Ca isotopes using amplifiers of different resistances offers the best solution for precise and fast isotope analysis. It benefits from a 100% duty cycle (no loss of collection time due to mass jumping) and low noise 10^{13} Ω amplifiers to measure the minor isotopes ^{48}Ca, ^{46}Ca, ^{43}Ca, ^{42}Ca and interference element ^{41}K.

The detection system

High-performance Faraday cups

The Faraday cups used in the Triton XT TIMS are precision machined from solid carbon to guarantee uniform response and long lifetimes. The Faraday cup design completely eliminates the need for cup factors. The effect of ion optical magnification on cup performance is depicted in the figure below and ensures complete capture of each ion beam.

At increasing ion optical magnifications, the divergent angles of the ion beams are reduced and dispersion is increased. This allows for wider and deeper cups to be used, which capture each ion beam in entirety. Scattered charged particles released from the cup side walls are captured within the cup, so that the “true” ion current is measured.



Multicollector

At the heart of the Triton XT TIMS is the variable multi-collector detector array. A highly reliable mechanism brings up to 9 Faraday cups into precise alignment with ion beams of different dispersions. This ensures the flexibility to cover isotopic measurements from Li through to UO_2, with highly reliable and precise repositioning of collectors for the different isotopic systems. The positioning resolution of the Faraday cup detectors is better than 5 µm. The dispersion of the Faraday cup array allows for the static measurement of ^{6}Li and ^{7}Li, and can be extended to cover ^{40}Ca to ^{48}Ca.

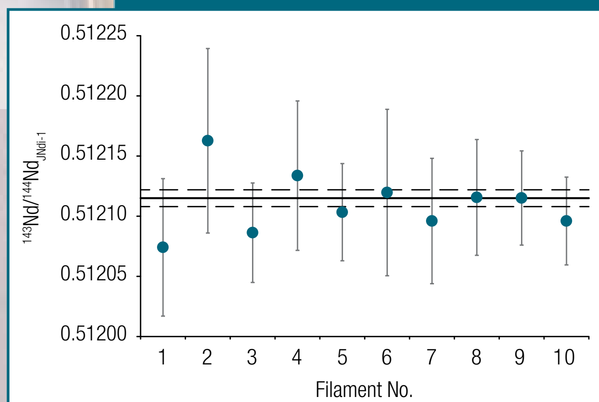
Versatility

The design of the mass analyzer of the Triton XT TIMS ensures that multiple applications can be covered by one instrument without compromise, and with minimal effort and time required when switching between isotopic systems.

CASE STUDY

100 pg Nd isotope measurements

$^{143}Nd/^{144}Nd$ is an important isotopic system for geochemistry applications, and is commonly measured at a high precision using standard 10^{11} Ω amplifiers. Sample amounts in the sub-µg and ng range are needed, which typically requires the aggregation of many mineral grains. Single mineral grain samples often result in signal intensities that would compromised by the electronic noise of 10^{11} Ω amplifiers. 10^{13} Ω Amplifier Technology allows sub-ng sample amounts to be analyzed at precisions that approach the theoretical limits of counting statistics. The Triton XT TIMS with 10^{13} Ω Amplifier Technology significantly expands the isotope geochemist's toolbox.



Results for Nd isotope measurements on 100 pg JNdi-1 aliquots (blue dots with 2 SE error bars). Solid and dashed black lines refer to the average and 2 SD uncertainty values for published JNdi-1 $^{143}Nd/^{144}Nd$ ratios on Nd loadings being 1,000 to 10,000 times higher. Note: the data presented are not warranted because they exceed product specifications.

10^{13} Ω Amplifier Technology

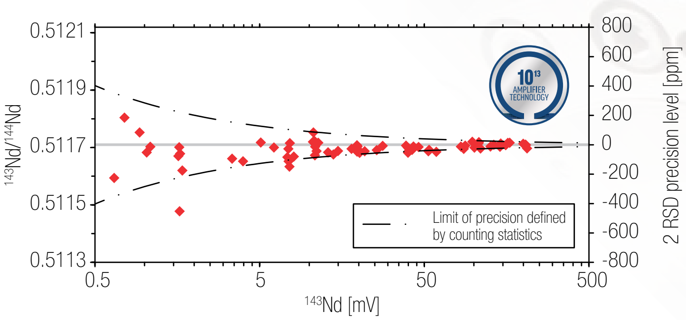
Extending the lower limits of the ultimate detector

Faraday cups are the detector of choice for high precision isotope ratio measurements. Ion currents can be measured to the highest degree and accuracy and precision, without the uncertainty of linearity and yield corrections. The ion current amplifiers of the Triton XT TIMS are mounted in a doubly shielded, evacuated housing, and temperature regulated to within 0.01 °C / hour, which guarantees stable baselines and stable gains.

The standard amplifier for TIMS incorporates a 10^{11} Ω feedback resistor, accommodating a wide dynamic range of ion currents, and facilitating ppm-level isotope ratio measurement precision from high intensity ion beams. However, electronic baseline noise limits their application for low intensity ion beam measurements (<500 fA / 3 Gcps).

The proprietary 10^{13} Ω Amplifier Technology in the Triton XT TIMS guarantees fast response times with extremely low noise characteristics. The benefits of Faraday cups can now be realized at low signal intensities (30 kcps – 3 Mcps), delivering external precisions that approach the ultimate limits of counting statistics. The dynamic range of 10^{13} Ω Amplifier Technology extends to 30 Mcps.

Exclusive to Neptune and Triton Series instruments is a software controlled relay matrix that connects any amplifier to any Faraday cup. This enables the user to tailor the amplifier-cup configuration to the needs of each measurement.



The isotope system of neodymium (Nd) demonstrates the precision and accuracy of 10^{13} Ω Amplifier Technology with gain calibration. Results for all signal intensities are accurate and at the limit of counting statistics uncertainty.

Note: the data presented are not warranted because they exceed the product specifications.

Thermo Scientific 10^{13} Ω Amplifier Technology has revolutionized the measurement of isotope ratios from low intensity ion beams, with a growing list of publications that prove the utility and performance of this technology for isotope geochemistry applications.

CASE STUDY

U/Pb geochronology using 10^{13} Ω Amplifier Technology

U/Pb geochronology by isotope dilution thermal ionization mass spectrometry (ID-TIMS) is the most precise and most accurately calibrated method for the age determination of rocks and minerals (e.g. zircon). The precise and accurate analysis of Pb/Pb and U/Pb isotope ratios are required to obtain a useful age information.

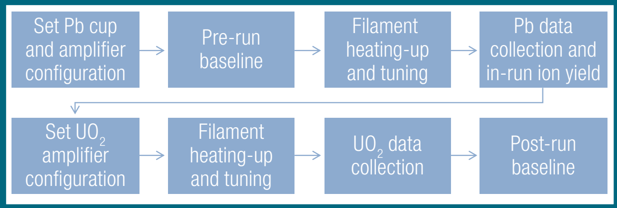
Traditionally, most studies employ ion counting systems to measure the Pb isotope composition, due to the small amounts of radiogenic Pb available. However, ion counters are limited in their dynamic range and require determination of their dead time and of ion yields for Pb and U. Given the uncertainty on these factors, precision is typically limited at the 0.05 ‰ level.

Faraday cups connected to 10^{13} Ω Amplifier Technology enable low-noise static multicollector measurements of low intensity ion beams. Measurement times can be reduced, and collection efficiency can be increased when compared to single collector ion counting measurements. More importantly the limitations to precision inherent to ion counter measurements can be overcome, with the proven linearity and long-term gain stability of Faraday cup amplifiers.

Cup	L4	L3	L2	L1	C	H1	H2	H3	H4
Pb configuration									
Amplifier				10^{13}	SEM	10^{13}	10^{13}	10^{13}	10^{13}
Isotope				^{202}Pb	^{204}Pb	^{205}Pb	^{206}Pb	^{207}Pb	^{208}Pb
U configuration									
Amplifier	10^{13}	10^{13}	10^{13}	10^{13}					
Isotope	$^{265}(UO_2)$	$^{267}(UO_2)$	$^{270}(UO_2)$	$^{272}(UO_2)$					

Five 10^{13} Ω amplifiers are recommend for the U/Pb measurement (requires optional items).

The isotope measurements of Pb and U are carried out with one Faraday cup configuration, allowing an immediate switch from the Pb, to the UO_2 measurements. The measurements take further advantage from the within-run determination of the $^{18}O/^{16}O$ ratio for the UO_2 molecular ion measurements. Uncertainties of <0.02% of single crystal U-Pb dates and <0.01% of relatively small populations of statistically equivalent dates are documented in the literature[1]. Note: these figures of merit are not warranted because they exceed product specifications.



Optimized workflow for the U/Pb measurement, with switchover between the Pb and UO_2 measurements

1. Wotzlaw et al., Journal of Analytical Atomic Spectrometry, 2017, DOI: 10.1039/c6ja00278a.

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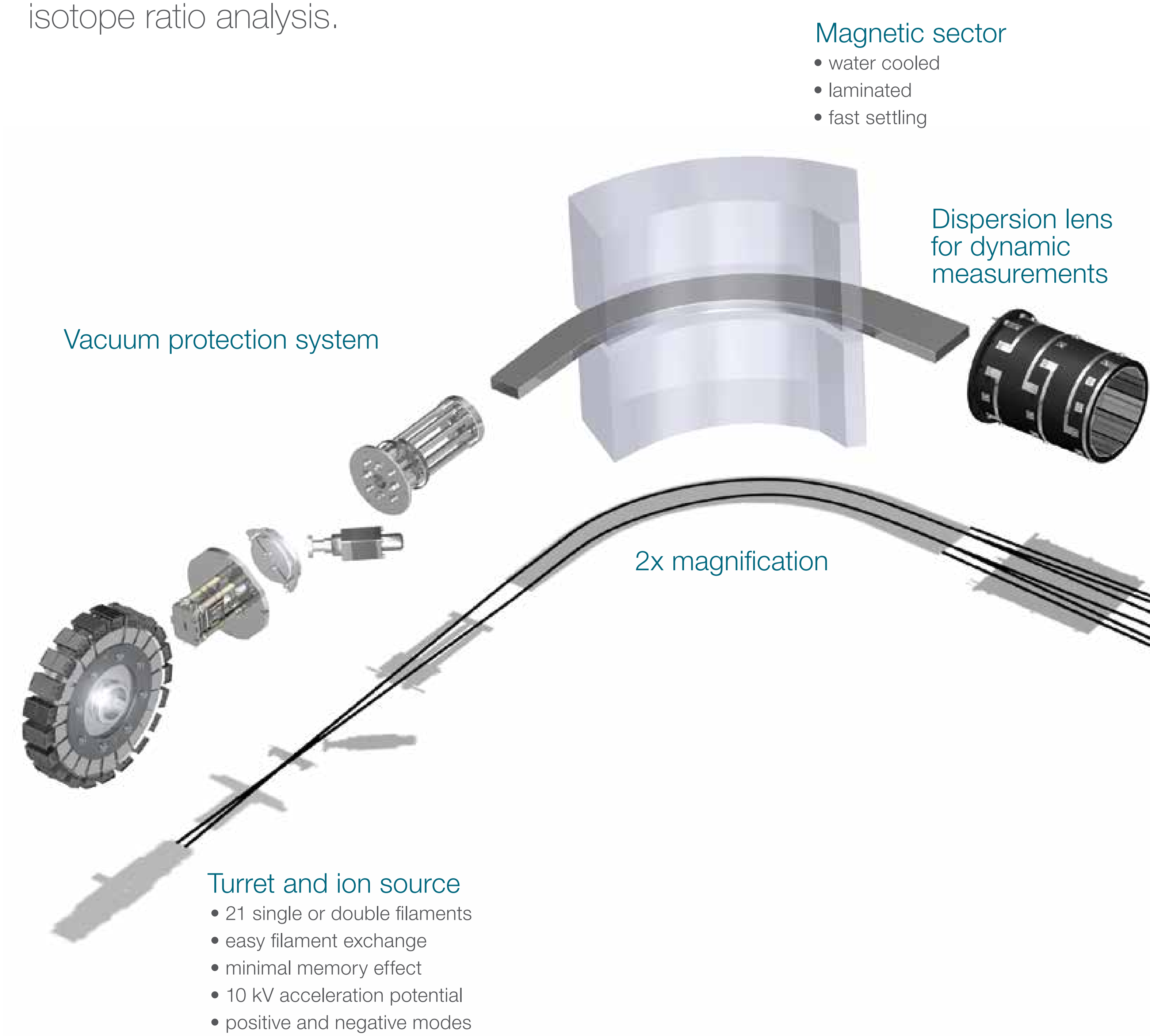
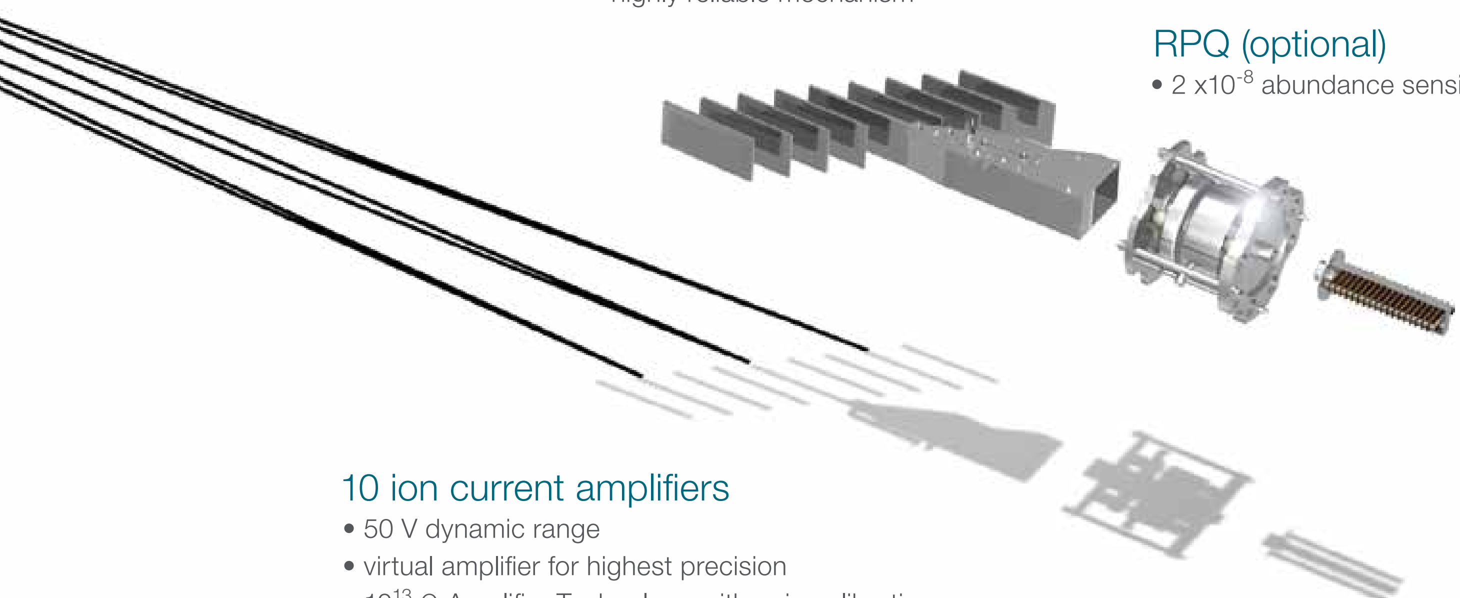


8 moveable Faraday cups
1 central dual-mode detector

- no cup factors
- precise positioning
- maximum flexibility
- highly reliable mechanism

RPQ (optional)

- 2 x10^{-8} abundance sensitivity



10 ion current amplifiers

- 50 V dynamic range
- virtual amplifier for highest precision
- 10^{13} Ω Amplifier Technology with gain calibration
- high stability

SEM

- high linearity
- high stability
- long lifetime

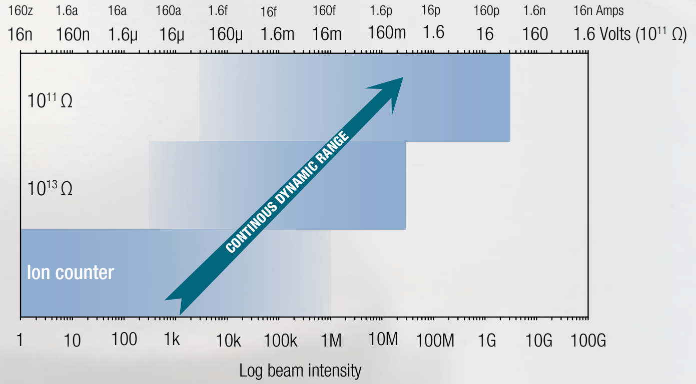
Flexibility of detector type

The Triton XT TIMS offers a highly flexible detector system, with 3 different detector types spanning more than 9 orders of magnitude in signal intensity range (from 1 cps to 3 Gcps / 50 V on 10^{11} Ω amplifier). The central channel of the Triton XT TIMS is equipped with a dual mode detector that can be switched from Faraday cup to SEM ion counter.

Amplifiers and the virtual amplifier

Each Faraday cup detector is connected to an ion current amplifier. The amplifier signal is digitized by a highly linear voltage to frequency converter, with an equivalent digital resolution of 22 bits. This ensures sub ppm digital resolution of all measured signals, independent of the actual signal intensity. The ion current amplifiers of the Triton XT TIMS are mounted in a doubly shielded, evacuated housing, and temperature regulated to within 0.01 °C / hour, which guarantees stable baselines and stable gains. The Triton XT TIMS includes standard 10^{11} Ω amplifiers with 50 V range, as well as 10^{13} Ω Amplifier Technology that extends the benefits of Faraday cups to lower ion beam intensities.

The propriety relay matrix allows any of the amplifiers to be connected to any of the Faraday cups. Amplifier selection is via software, allowing the appropriate amplifiers to be used for different isotopic measurements. The proprietary virtual amplifier concept allows cancelation of gain factor uncertainties by using amplifier rotation, so that low ppm external reproducibility can be achieved using efficient static measurements.



The Triton XT TIMS includes 10^{11} Ω amplifiers with a 50 V range, as well as 10^{13} Ω Amplifier Technology and an SEM ion counter, spanning the dynamic range from 1 cps to 30 Gcps.
With an optional 10^{10} Ω amplifier, the dynamic range of the detector system can be extended to over 10 orders of magnitude.

Secondary Electron Multipliers and Multi Ion Counting arrays

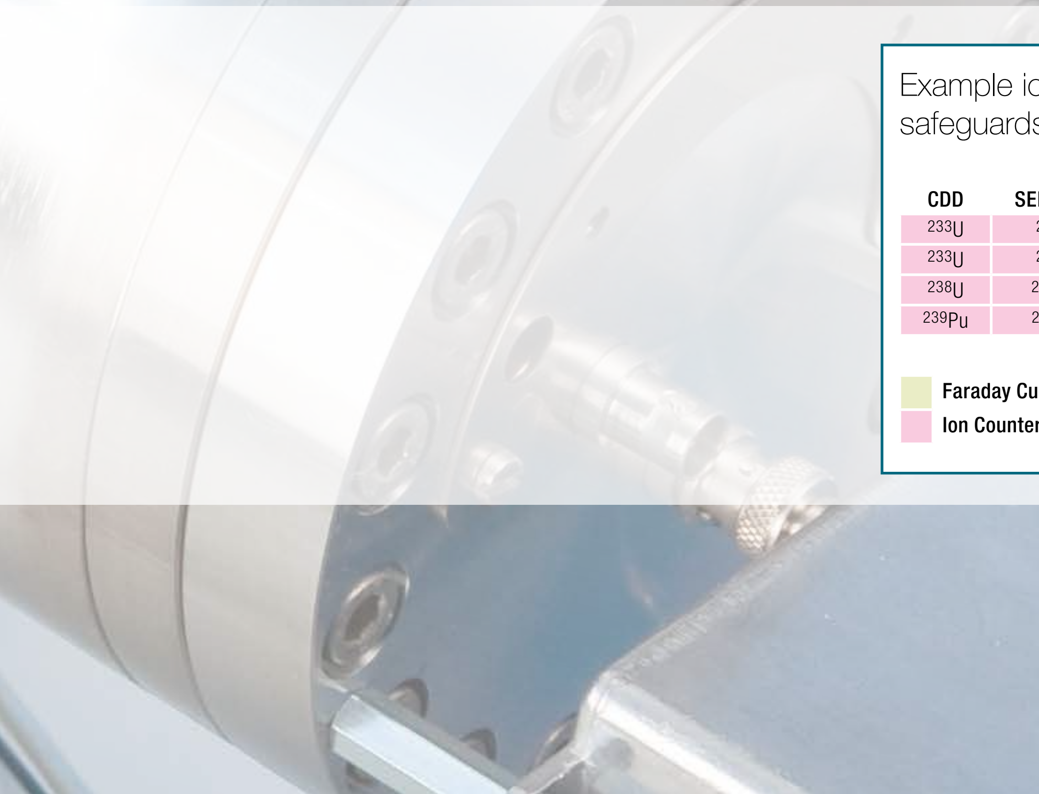
The smallest sample amounts and lowest abundance isotopes require the use of ion counting detectors. The Triton XT TIMS can be equipped with a Multi Ion Counting (MIC) array to allow simultaneous detection of the lowest intensity ion beams.

Efficiency is significantly increased compared with single collector measurements. Up to eight discrete dynode secondary electron multipliers can be installed on the Triton XT TIMS, with packages tailored for different applications. The SEM and CDD ion counters available for the Triton XT TIMS offer excellent stability, linearity and lifetime.

Abundance Sensitivity and the RPQ

Abundance sensitivity is a measure of the tailing of an intense ion beam onto neighboring masses. This can be caused by the scattering of ions, for example by their interaction with residual gas molecules. The results are elevated baselines for masses neighboring bright ion beams. The abundance sensitivity of the Triton XT TIMS is 2×10^{-6} measured at 1 mass unit either side of ^{238}U. The result is accuracy for most isotope ratio measurements.

The Triton XT TIMS can can be fitted with up to two Retarding Potential Quadrupole Lenses (RPQ) that act as high selectivity filters for ions with disturbed energy or angle. The use of an RPQ improves the abundance sensitivity of the Triton XT TIMS by two orders of magnitude to $<2 \times 10^{-8}$ measured at 1 mass unit either side of ^{238}U. The result is that extreme isotope ratios can be measured accurately without bias from mass tailing.



CASE STUDY

Analysis of ^{234}U and ^{236}U in nuclear materials

Reliable analysis of $^{234}U/^{238}U$ and $^{236}U/^{238}U$ provides key information for nuclear safeguarding, but measurements can be challenged by the very low abundance of ^{234}U and ^{236}U. Ion counters offer the lowest quantification limits for these isotopes. Scattered ions (tailing), from ^{238}U and ^{235}U, can bias the measured ratios. The Retarding Potential Quadrupole (RPQ) improves abundance sensitivity by an order of magnitude, for accurate quantification of minor isotopes. The Triton can be configured with two RPQ lenses for simultaneous ^{234}U and ^{236}U analysis. Nuclear MIC packages offer comprehensive coverage of U and Pu isotopic measurements, with flexibility to use combinations of ion counters and Faraday cups.

Example ion counter arrays for nuclear safeguards' measurments.

CDD	SEM RPQ	SEM/L5*	SEM RPQ	L4	CDD
^{233}U	^{234}U	^{235}U	^{236}U	^{238}U	
^{233}U	^{234}U	^{235}U	^{236}U		^{238}U
^{238}U	^{239}Pu	^{240}Pu	^{241}Pu		^{244}Pu
^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu		^{244}Pu

Faraday Cup (10^{11} / 10^{13} Ω)

Ion Counter (CDD / SEM)

*** Dual-mode detector, switchable between Faraday and SEM.**
Please contact your local sales specialist to discuss the range of configurations available.

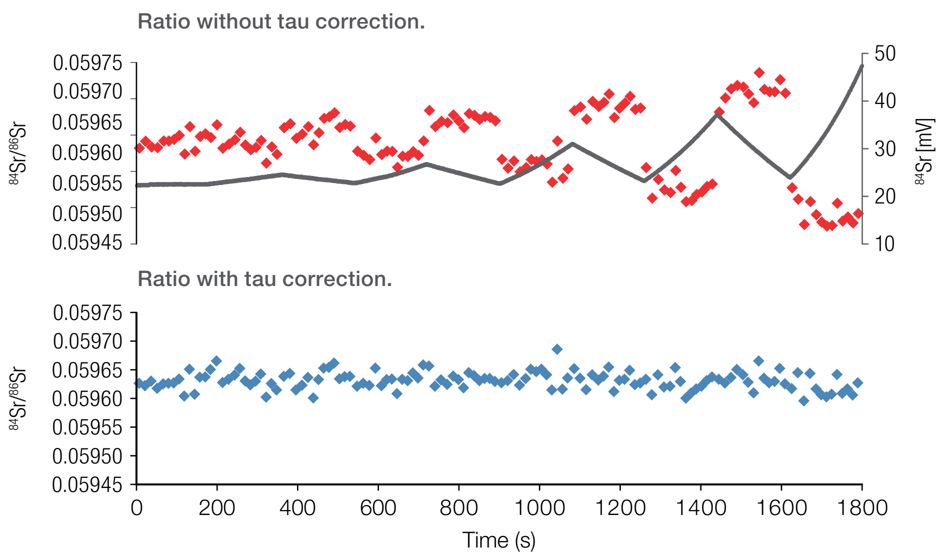
Multicollector Software Suite v3.30

10^{13} Ω Amplifier Technology made easy

The Triton XT TIMS is supported by a new Multicollector Software release. 10^{13} Ω Amplifier Technology is enhanced by online tau correction, which makes 10^{13} Ω Amplifier Technology as easy to use as standard Faraday cup amplifiers.

Until now, without additional offline corrections, the different detector response rates between 10^{13} Ω Amplifier Technology and 10^{11} Ω amplifiers, or ion counters, has limited the accuracy and precision that could be achieved for measurements with variable signal intensities. Online tau correction now corrects for the different detector response rates, delivering accuracy and precision.

Also supported is the new 3.3 pA gain calibration board, allowing easy and precise, software-controlled gain calibration of 10^{13} Ω Amplifier Technology. Cross-calibration precision of detectors no longer limits the precision of isotope ratios from low intensity ion beams.



Experiment showing the effect of signal intensity changes on the mass fractionation corrected isotope ratios measured by detectors with different response rates (^{84}Sr measured using 10^{13} Ω Amplifier Technology, ^{86}Sr using a standard 10^{11} Ω amplifier). Signal changes forced by ramping of the filament current (grey line) create bias in the measured isotope ratios (red dots), which can be effectively corrected for (blue dots). Tau correction is included in Multicollector Software Suite version 3.30 and effectively removes bias from signal intensity changes.

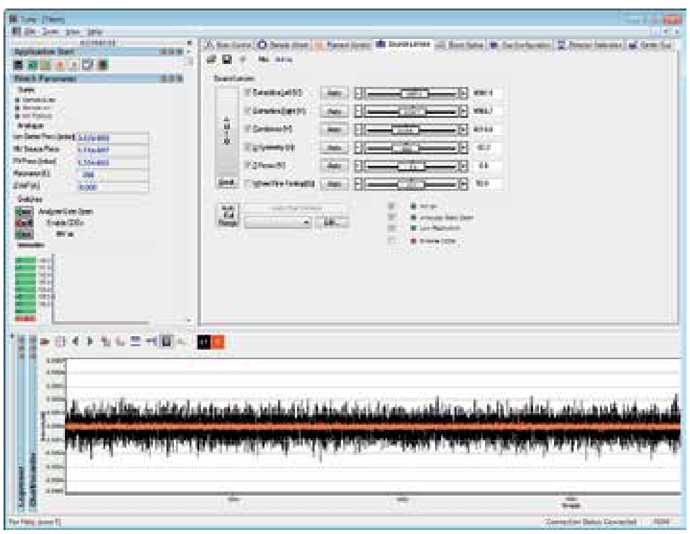

Triton XT
DELL

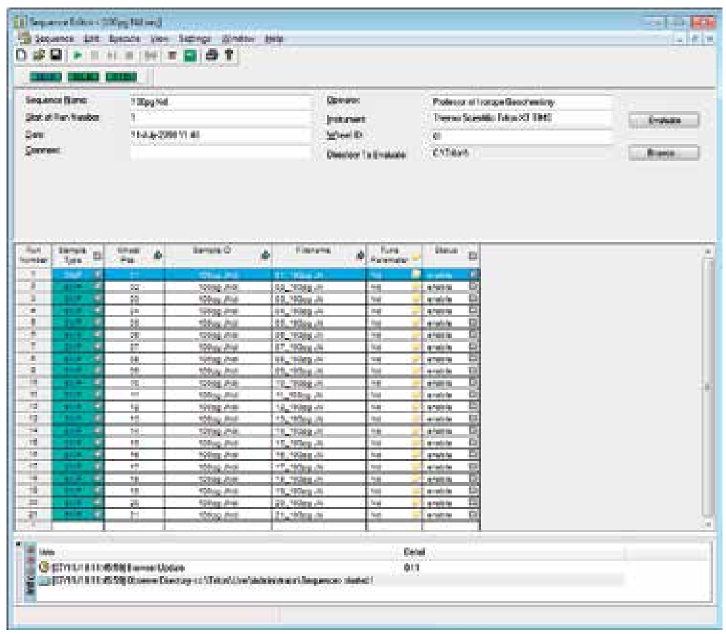
Multicollector Software Suite

Comprehensive software for MC-ICP-MS & TIMS

The Thermo Scientific Multicollector Software Suite supports scientific productivity by providing all the necessary tools for running the instrument, from setup through to results. The software is clearly laid out and easy to use, with automatic routines for total evaporation measurements for sample throughput with minimal effort. The results are directly evaluated within the software, so that no external data reduction is necessary.

- Tune – fully automated instrument startup; straight forward control of tuning parameters and collector positioning; clear display of signal traces.
- Method Editor – automated filament control and focusing; customizable data acquisition parameters; drag and drop isotope ratio builder with built-in mass bias and interference corrections; formula editor for custom corrections; full support of total evaporation and multidynamic measurements.
- Sequence Editor – complete automation of sample measurements for unattended operation of the instrument.
- Data Evaluation – raw data and calculated results are displayed in spreadsheet or graphical form; evaluation parameters such as tau correction can be toggled on or off, and the data re-evaluated; raw data and calculated results can be exported to a variety of data formats.





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