NEPTUNE *Plus*
Multicollector ICPMS

Another step ahead in MC-ICP-MS

Earth and Planetary Sciences • Nuclear Sciences

Thermo
SCIENTIFIC

Based on more than 35 years of experience in variable multicollector instrumentation, we have developed the advanced Thermo Scientific NEPTUNE *Plus*, our latest generation Multicollector ICP Mass Spectrometer.

It combines new, innovative features, like dual RPQ, compact discrete dynode multi ion counting multipliers and unmatched sensitivity using the Jet Interface, with the field-proven technology of the NEPTUNE instrument.

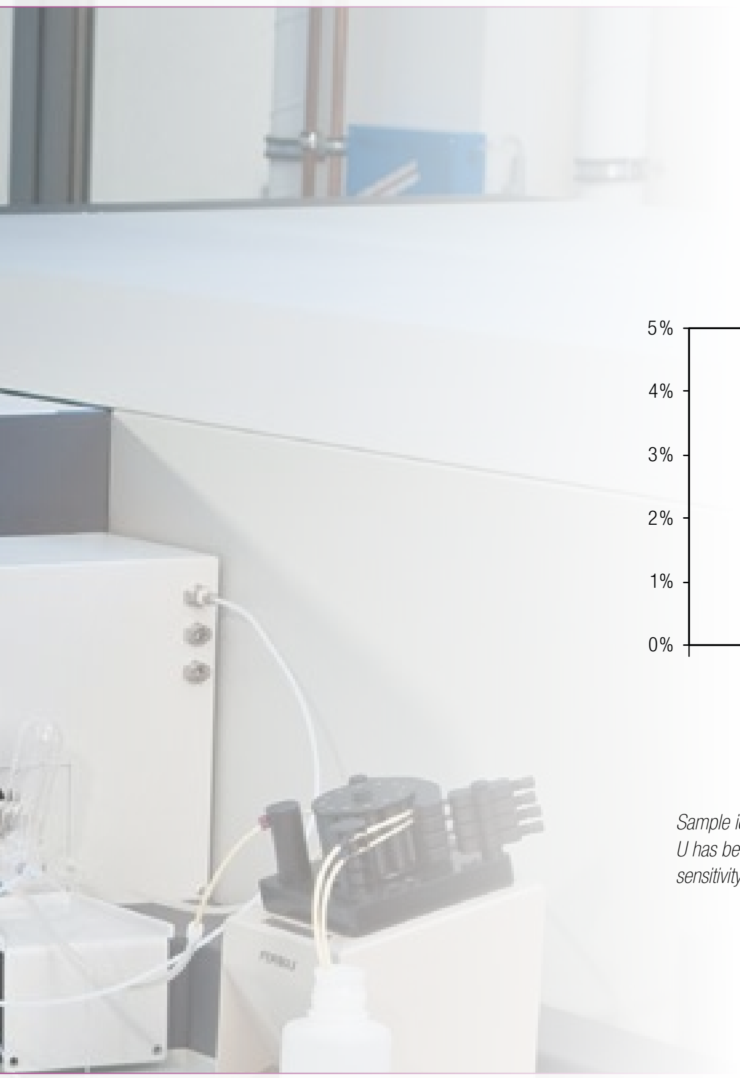
The NEPTUNE *Plus* represents a major step forward in multicollector ICP technology and opens the door to ever-expanding applications within Earth and Nuclear Sciences, as well as other disciplines.

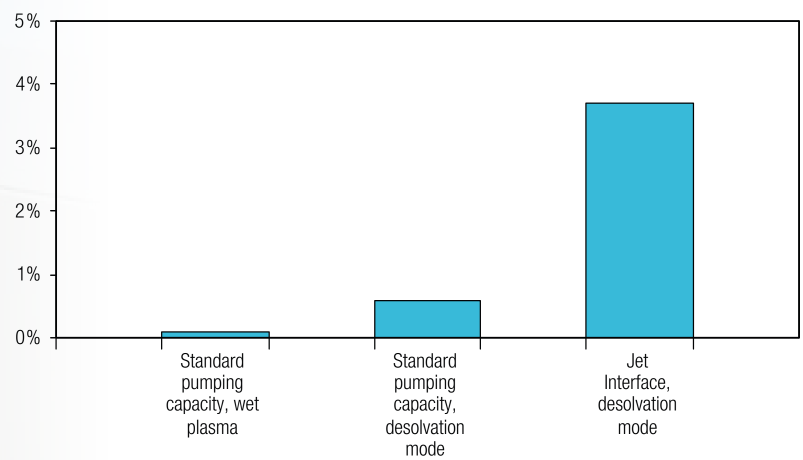
NEPTUNE *Plus*
Multicollector ICPMS

The NEPTUNE *Plus* is a double-focusing multicollector ICPMS, based upon field-proven technologies from the NEPTUNE: high mass resolution, variable multicollectors and multi ion counting. New features of the Neptune *Plus* include the Jet Interface for ground-breaking sensitivity, a dual RPQ option and multiple discrete dynode electron multipliers for high-dynamic ranges, unsurpassed linearity and stability.

Jet Interface
for ultimate sensitivity

The Jet Interface gives between 10 and 20 times higher sensitivity in desolvation mode, across the entire mass range. Sample ion yields of greater than 3% for uranium can be achieved with the Jet Interface. This is a major improvement in ICP technology, where uranium ion transmissions of < 0.1% are typical. The outstanding performance of the new Jet Interface is achieved by a significantly increased interface pumping capacity combined with a new designed high performance sample cone.





Sample ion yield for uranium using different pumping and plasma modes. Almost 4% ion transmission for U has been achieved with the Jet Interface using desolvation. The Jet Interface also significantly enhances sensitivity for laser ablation.

High Resolution Double Focusing
Multicollector ICPMS

How do we reduce the energy spread?

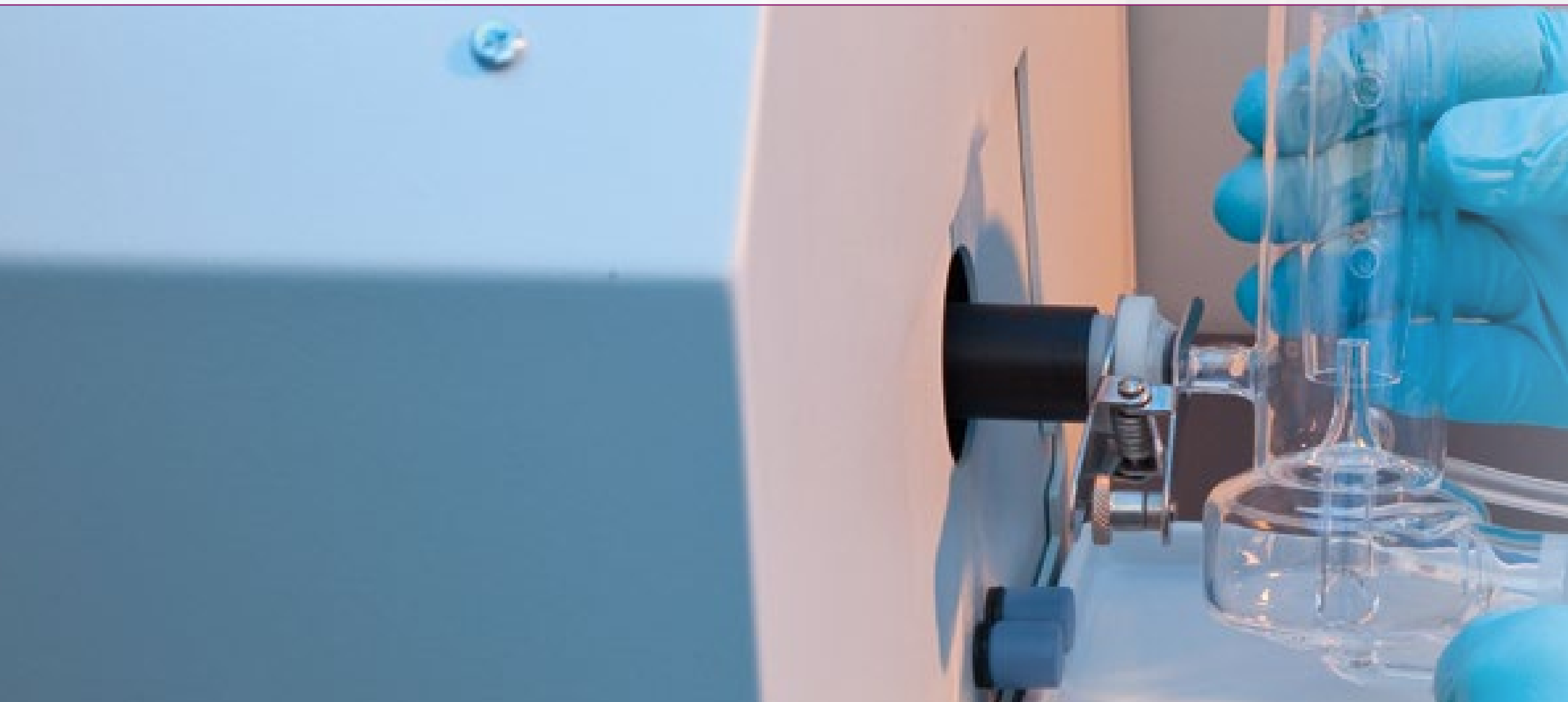
The kinetic energy distribution of ions generated in an ICP source is wider (~20 eV) than that from a thermal ionization source. A double-focusing analyzer, focusing both ion energy and angular divergence is the best technical solution for this challenge.

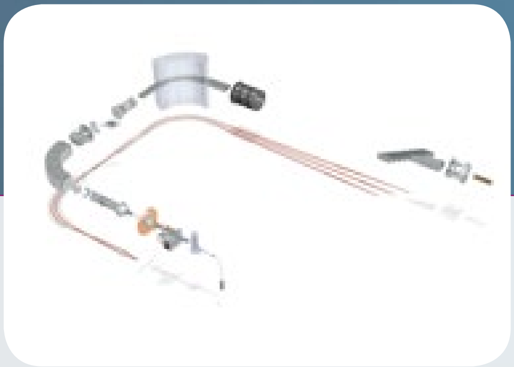
The ICP interface of the NEPTUNE *Plus* mass spectrometer reduces the initial kinetic energy spread from ~20 to ~5 eV by capacitively decoupling (CD) the plasma from the load coil using a grounded platinum guard electrode. This low-kinetic energy distribution, together with a wide energy acceptance of the mass analyzer and 10 kV acceleration voltage, minimizes all effects of ion energy spread on isotope ratios and mass bias.

The ion-transfer optics focus ions from the plasma onto the entrance slit of the double-focusing analyzer. Mass bias is mainly generated in the plasma interface and the ion-transfer optics. The excellent mass bias stability of the NEPTUNE *Plus* instrument, sensitivity and low background result from our unique ion-transfer optics and energy distribution reduction technology.

Why do we hold the plasma interface at ground potential?

The plasma interface is held at ground potential, allowing easy access to the nebulizer, spray chamber and torch. Changing from solution mode to any coupled device, for example laser ablation, gas chromatography or HPLC, is as straight forward as connecting an autosampler.





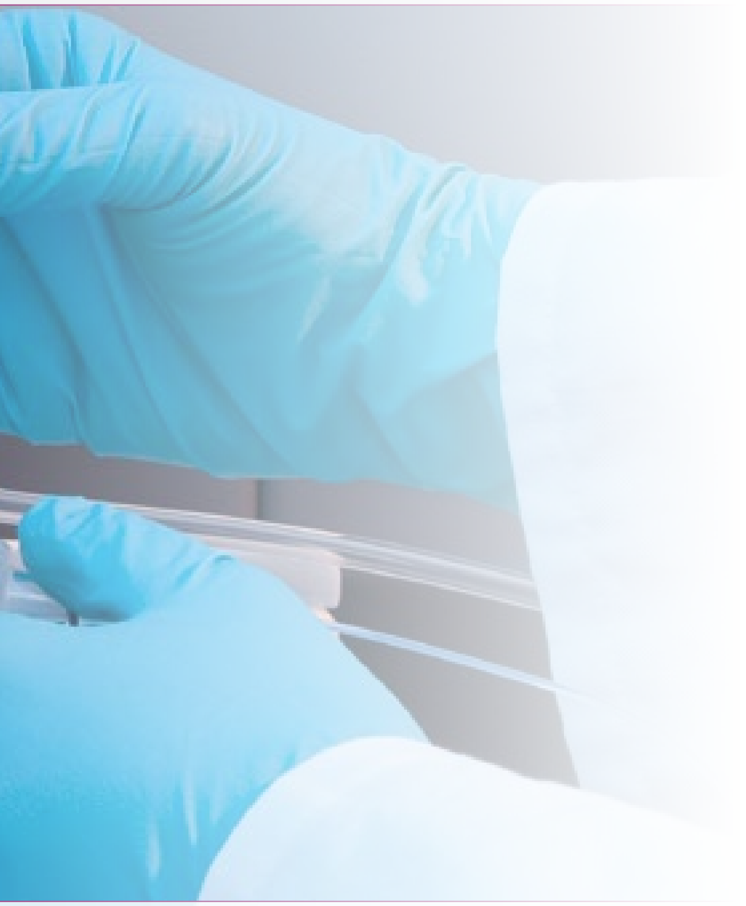
Why do you need high mass resolution
and how to achieve it?

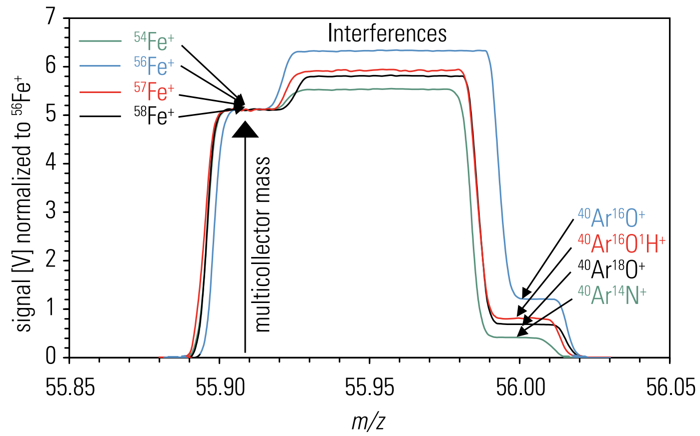
The ion optics of the NEPTUNE *Plus* MC-ICPMS provide high mass resolving power on all detectors along the image plane. The instrument can be operated at three different resolution settings: low, medium and high resolution can be selected with a mouse-click. In high resolution, resolving powers of up to $m/\Delta m = 8{,}000$ at >10% transmission can be achieved. The $m/\Delta m$ is derived from the peak slope of the rising edge measured at 5% and 95% relative peak height.

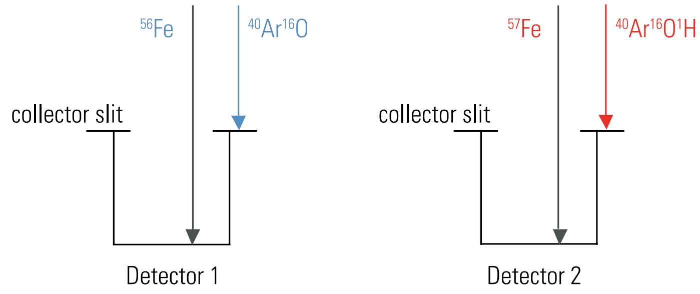
For high-precision isotope ratio measurements, a wide, flat, stable peak is mandatory. In order to achieve the high mass resolution necessary to separate molecular interferences from elemental peaks in a multicollector instrument, a small source slit has to be selected.

The detector slit, however, is kept in the low-resolution setting. Through this combination of source and detector slits, individual detectors of the variable multicollector can be positioned such that only analyte ions enter the detector, and any interfering ions are not allowed to pass to the detector. Elements, where high mass resolution is required for accurate, interference free analysis, are mainly in the low to medium mass range, e.g. Mg, Si, S, Ca, Cr and Fe.

According to the systematics of the nuclear mass defect, the majority of molecular interferences in the low and medium mass range are heavier than the elemental species. A wide detector slit in all resolutions is the best choice, since it guarantees the widest peak flatness at high resolving powers, which is a prerequisite for highly precise and accurate isotope ratio analyses.







Fully flexible
detection system

High-performance Faraday cups

The Faraday cups used in the NEPTUNE *Plus* are the largest ever produced for a commercial multicollector. They are laser machined from solid carbon to guarantee uniform response, high linearity, low noise and long lifetimes. The Faraday cups are designed to completely eliminate the need for cup factors.

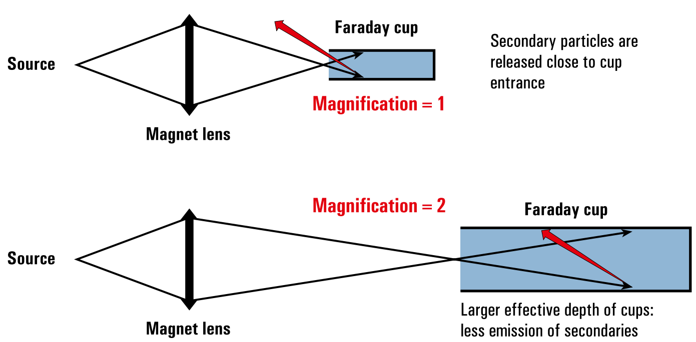
The effect of ion optical magnification on cup performance is depicted in the figure below. At increasing ion optical magnifications, the divergent angles of the ion beams are reduced and dispersion is increased. As a result, cups can be wider and deeper. Scattered particles released from the cup side walls by the incoming ion beams are less likely to escape and do not alter the “true” ion current measured.

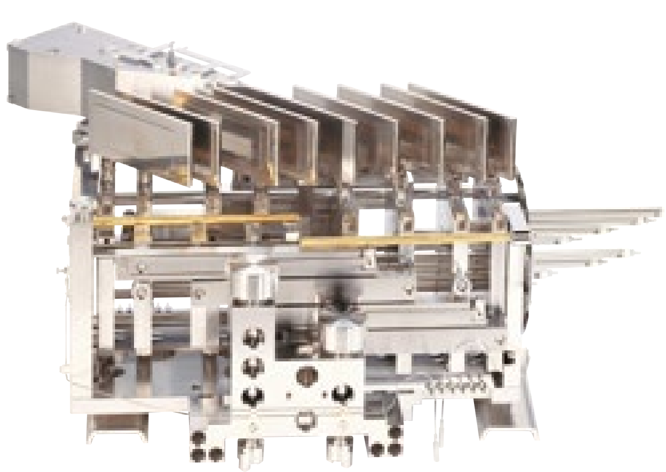
The Virtual Amplifier

Measurement system

Each Faraday cup is connected to a current amplifier. The amplifier signal is digitized by a high-linearity voltage to frequency converter with an equivalent digital resolution of 22 bit. This ensures sub-ppm digital resolution of all measured signals independent of the actual signal intensity. The amplifiers are mounted in a doubly shielded, evacuated and thermostated housing with a temperature stability of ± 0.01°C / hour.

To narrow the effective measurement range gap between ion counting and Faraday cup measurements, we offer a set of current amplifiers with Tera-Ohm feedback resistors ($10^{12}\,\Omega$), instead of the standard $10^{11}\,\Omega$ feedback resistors. While the use of larger resistors result in a 10 fold increase in amplifiers gain, the Johnson noise from the resistor increases by $\sqrt{10}$.





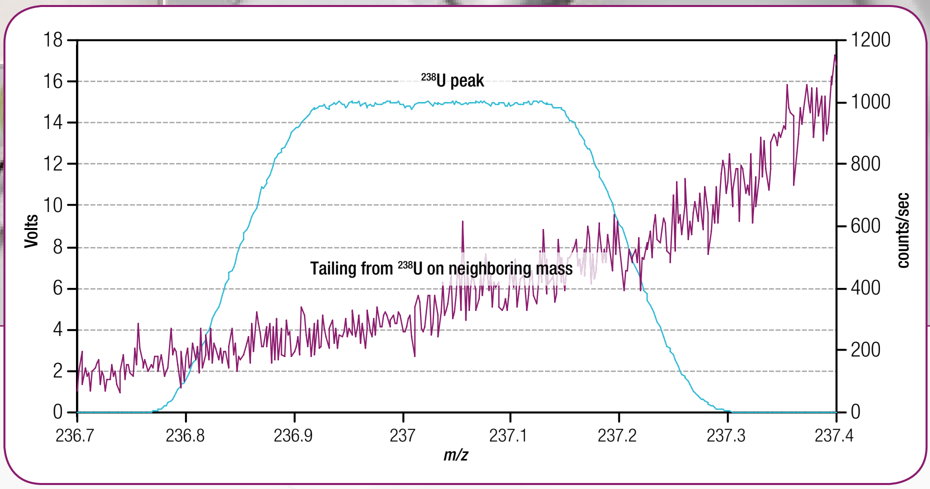
In practice, this offers a two to three-fold improvement in signal/noise. In addition, we offer $10^{10}\,\Omega$ amplifiers to increase the dynamic range up to 500 V.

Up to 10 current amplifiers with different gains can be installed simultaneously. Unique to the design of the NEPTUNE *Plus* system is a relay matrix that connects the amplifiers to the Faraday cups. The connection scheme between the amplifiers and the Faraday cups is software controlled. This enables the user to tailor the amplifier configuration to the needs of the current analytical task and its required precision. There is no need to open the amplifier housing and physically exchange the amplifiers, a procedure that is time-consuming and potentially harmful to the amplifiers.

Abundance sensitivity

The measurement of large isotope ratios is affected by scattered ions generated at slits and apertures, the flight tube walls and most importantly, the interaction of ions with residual gas particles. Ions which suffered one of these interactions have lost kinetic energy and/or have changed their direction of motion. As a result, these ions appear at incorrect mass positions along the focal plane, typically increasing background at neighboring masses.

The NEPTUNE *Plus* MC-ICPMS can employ 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 NEPTUNE *Plus* system by one order of magnitude to < 500 ppb.



Peak tailing from ^{238}U (purple curve, related to the counts/sec scale on the right-hand side) onto neighbouring mass. The ^{238}U beam is shown for reference (blue curve, relating to the Volts scale on the left-hand side).

Towards smaller samples
flexible and complete collector packages

Multi Ion Counting
using a new technology

Small sample amounts require the use of ion counting detectors, where individual ions are detected and counted. In a Multi Ion Counting (MIC) setup, an array of ion counters is placed in the focal plane of the mass analyzer to allow parallel detection of all required ion beams. The MIC approach offers the ultimate detection efficiency, because of the simultaneous detection of the isotopes. The ion counting detectors in the NEPTUNE *Plus* MC-ICPMS are all discrete dynode electron multipliers with high stability and linearity over a large dynamic range. Up to eight discrete dynode electron multipliers can be installed at one time.

MC-ICPMS, in combination with Laser Ablation, is a very powerful technique to obtain in-situ age information of a variety of minerals, especially zircons.

Often, it is mandatory to analyse Lu-Hf isotopes in conjunction with U-Pb in those minerals. The amount of Lu-Hf in zircons is sufficient for producing ion beam intensities to be measured in Faraday cup detectors, whereas Pb and U isotopes usually require ion counting detectors. The NEPTUNE *Plus* offers dedicated collector packages for the analysis of Pb-U and Lu-Hf isotopes in zircons.

It also offers the most flexible and complete collector package for the analysis of U isotopes in nuclear sciences. This package consists of five discrete dynode multiplier at 1 amu spacing for actinides and independent RPQ filters for the analysis of ^{234}U and ^{236}U on high abundance sensitivity channels. Packages are made up of an application dependent combination of multiple electron multipliers, dual detectors (Faraday/electron multiplier) and RPQs.

U and Pb collector packages
The nuclear package

	***Plus* Platform**					
	IC	**IC/RPQ**	**IC/ Faraday**	**IC/RPQ**	**Faraday**	**IC**
Config. 1	^{233}U	^{234}U	^{235}U	^{236}U	^{238}U	
Config. 2	^{233}U	^{234}U	^{235}U	^{236}U		^{238}U

The zircon package

	***Plus* Platform**															
	IC	**IC**	**IC**	**IC**	**IC**	**Faraday**	**Faraday**	**Faraday**	**Faraday**	**Faraday**	**Faraday**	**Faraday**	**Faraday**	**IC**	**Faraday**	**IC**
Config. 1	^{202}Hg	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb									^{232}Th		^{238}U
Config. 2	^{202}Hg	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb								^{232}Th		^{238}U	
Peak Jump						^{171}Yb	^{173}Yb	^{175}Lu	^{176}Hf	^{177}Hf	^{178}Hf	^{179}Hf				

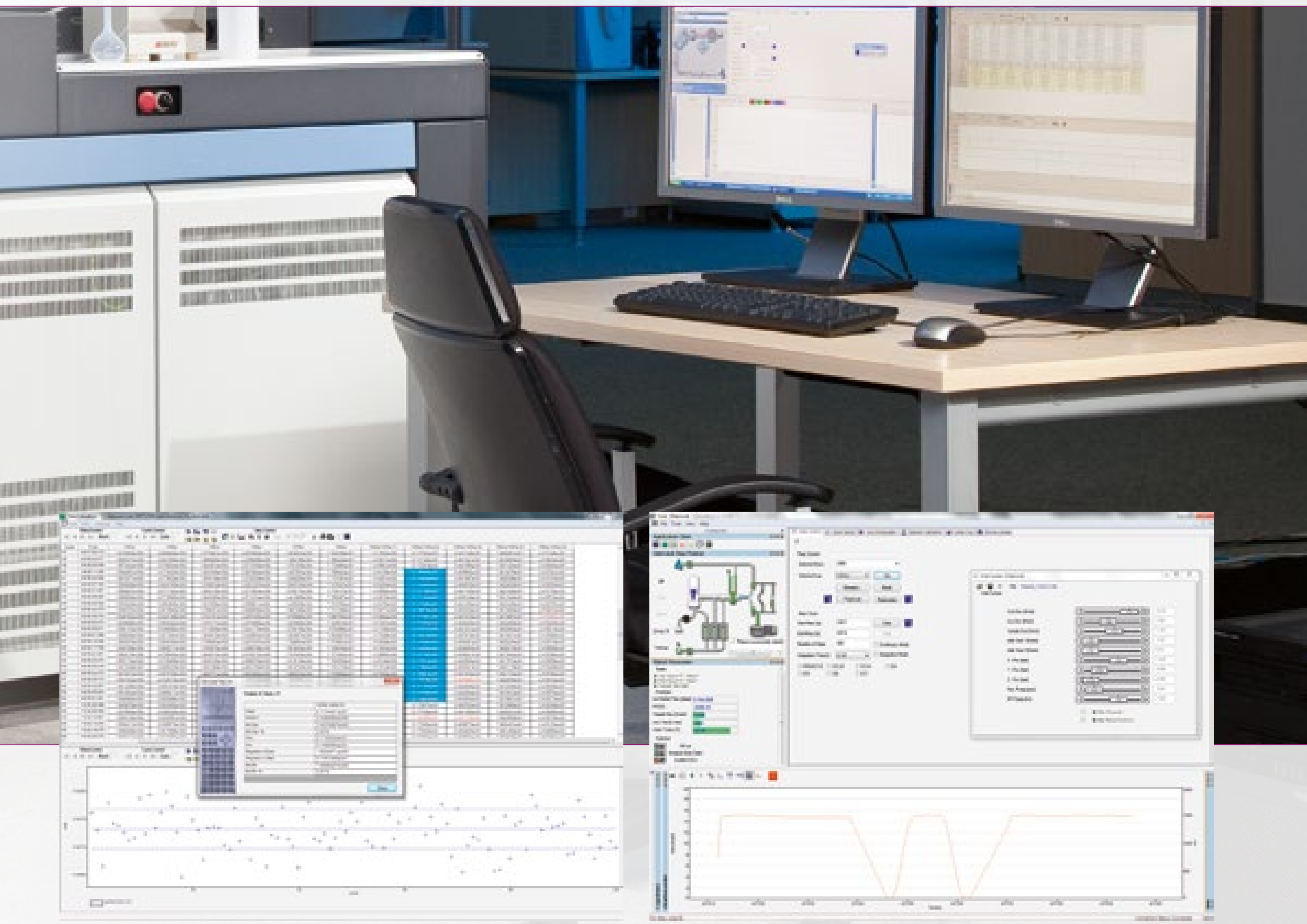
- Full dynamic range discrete dynode electron multipliers on all IC channels.
- High abundance sensitivity dual RPQ option for ^{234}U and ^{236}U detection.
- For other possible configurations, please contact your local sales specialist. Please also refer to the TRITON *Plus* brochure.

NEPTUNE *Plus*
software package

The software allows a fully automated plasma-ignition sequence. The cup configuration editor is used to define cup configurations. The method editor enables the user to set up measurement procedures, including static, multidynamic and fast single collector peak jumping strategies. On-line and off-line data evaluation packages are available, including statistical capabilities and display of the results in spreadsheet or graphical form. The user has access to all raw data and can monitor the results online during the analysis. The software allows data to be evaluated and flexibly exported; ideal for laser ablation applications.

The sequence editor provides automatic, unattended acquisition and evaluation of samples including sample/standard bracketing and blank subtraction. Triggering of, or triggering from coupled devices, e.g., from a laser system, is fully supported. Automated report generation of analytical results is included. Scripting based on the C programming language allows modification of supplied procedures.

For GC and HPLC applications, we offer an additional software package dedicated to the evaluation of transient signals.



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