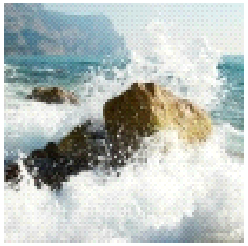


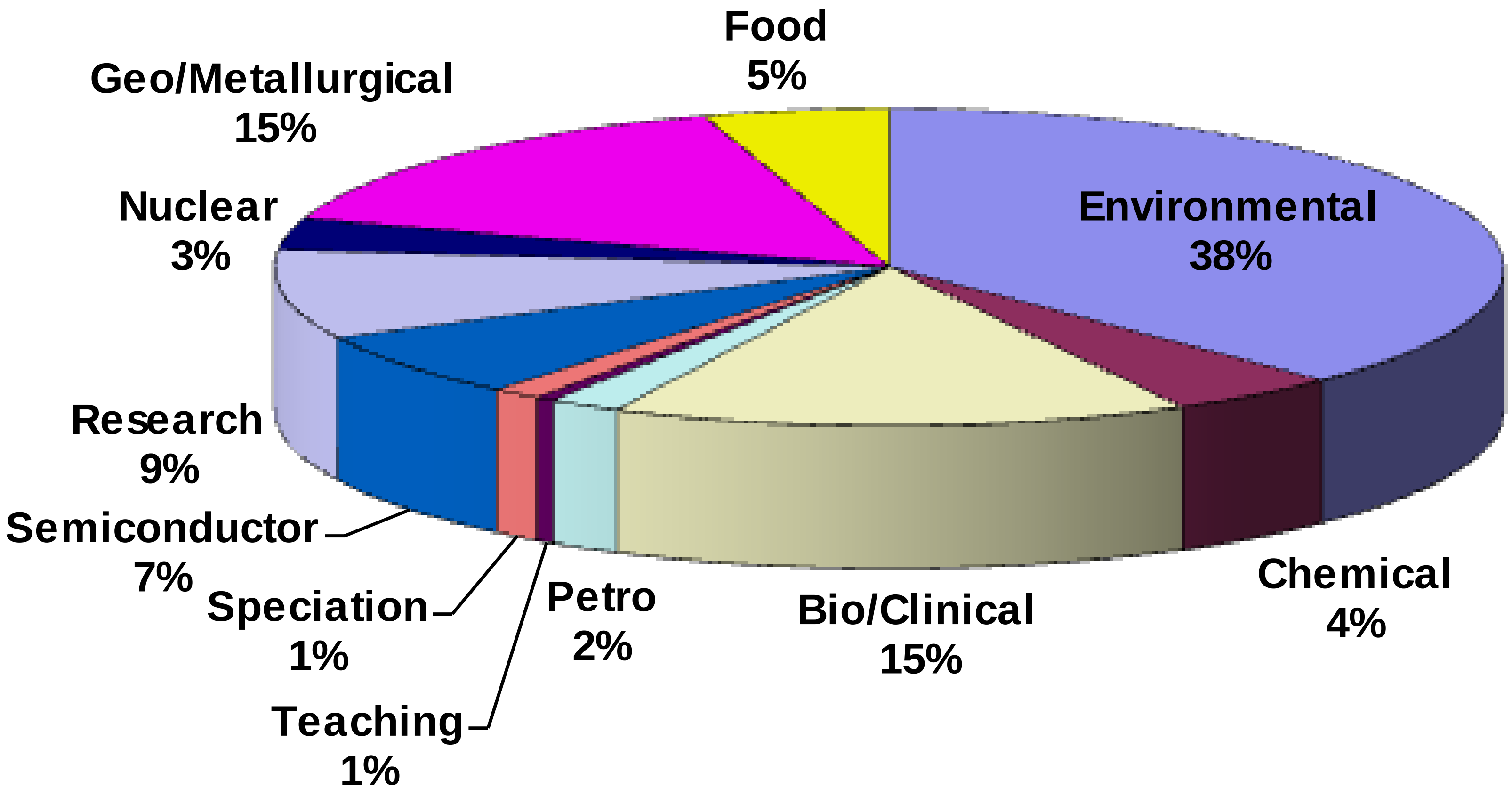



HUMAN HEALTH | ENVIRONMENTAL HEALTH

ICP-MS Technology, NexION 350

Fabio Mariconti
Inorganic Line Leader
Budapest, October 17th 2016

ICP-MS NexION 350...



Introducing the NexION:

- 1983 - ELAN 250
  - First commercially available ICP-MS
  - Dual Cone Interface
  - PlasmaLOK
  - Cryogenic pumping system
  - On-board computer
  - Manual operation

- 1987 - ELAN 500 Joint Venture between PerkinElmer + SCIEX formed

  50% SCIEX (R&D / Manufacturing) - 50% PerkinElmer (Sales and Service)
  - Improved sensitivity
  - Improved resolution - new quadrupole and power supply
  - OmniRange - extended dynamic range

- 1990 - ELAN 5000
  - First turbo pumped ICP-MS
  - First free-running ICP RF generator
  - Improved interface
  - TotalQuant - First automated spectral interpretation and semi-quantitative analysis package

  - 1994 - ELAN 6000
  - First simultaneous automatic extended dynamic range detection system – 9 orders of magnitude
  - First single lens system - AutoLens - simplicity with improved performance

  - 1999 - ELAN 6100DRC
  - Dynamic Reaction Cell (DRC)
  - First Cell ICP-MS capable of sub-ppt detection limits for all Period 4 elements (K-Se)
  - Wins PittCon Gold Award for best new product
  - Uses high temperature plasma conditions, minimal matrix effects, obsoletes cool plasma

  - 2002 – 2005 ELAN 9000, DRCe, DRC II
  - Improved low mass sensitivity
  - Dual Inlet Turbo pump
  - Cassette Torch
  - Chromera

  - 2008 - Celebrating 25 years of success in ICP-MS
  - Over 3300 ELAN ICP-MS systems worldwide
  - Over 1600 DRC systems worldwide

Introducing the NexION:

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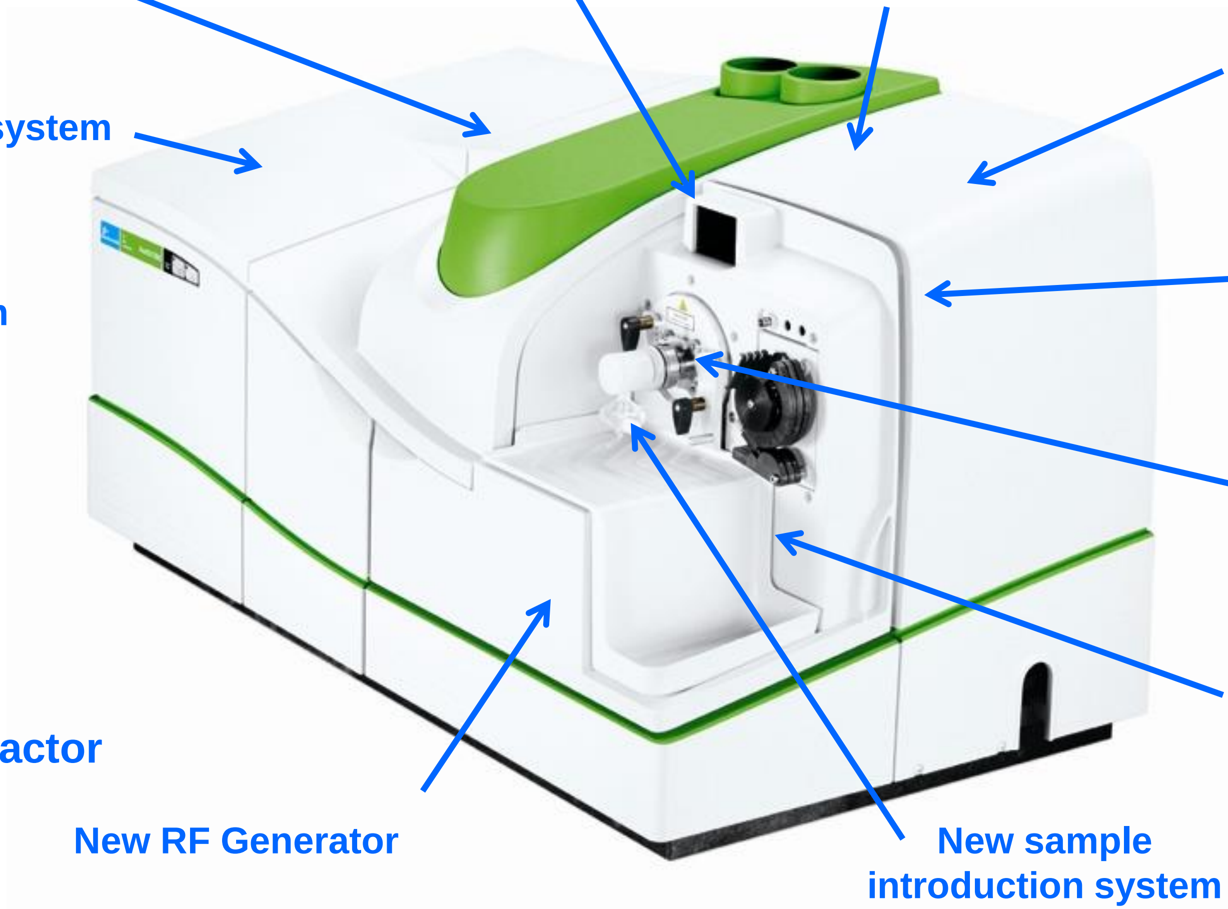
New mass analyzer

New plasma viewport
color screen

New methods of interference removal
Universal Cell Technology

New ion optics
Quadrupole Ion Deflector

New detection system



New interface
Triple cone design

New vacuum system

New torch mount
Improved cassette

Better lab facilities utilization

New torch positioning
motorized XYZ

New form factor

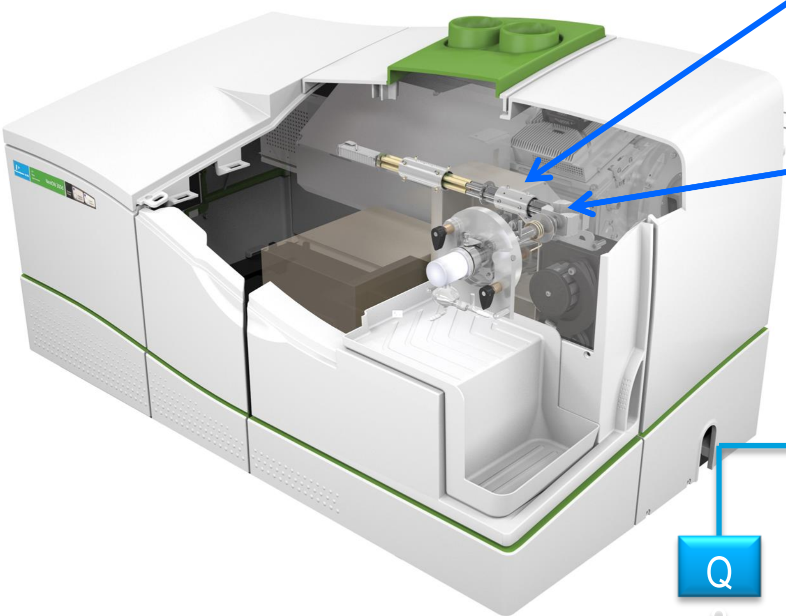
New RF Generator

New sample introduction system

…the 7th generation ICP-MS from PerkinElmer

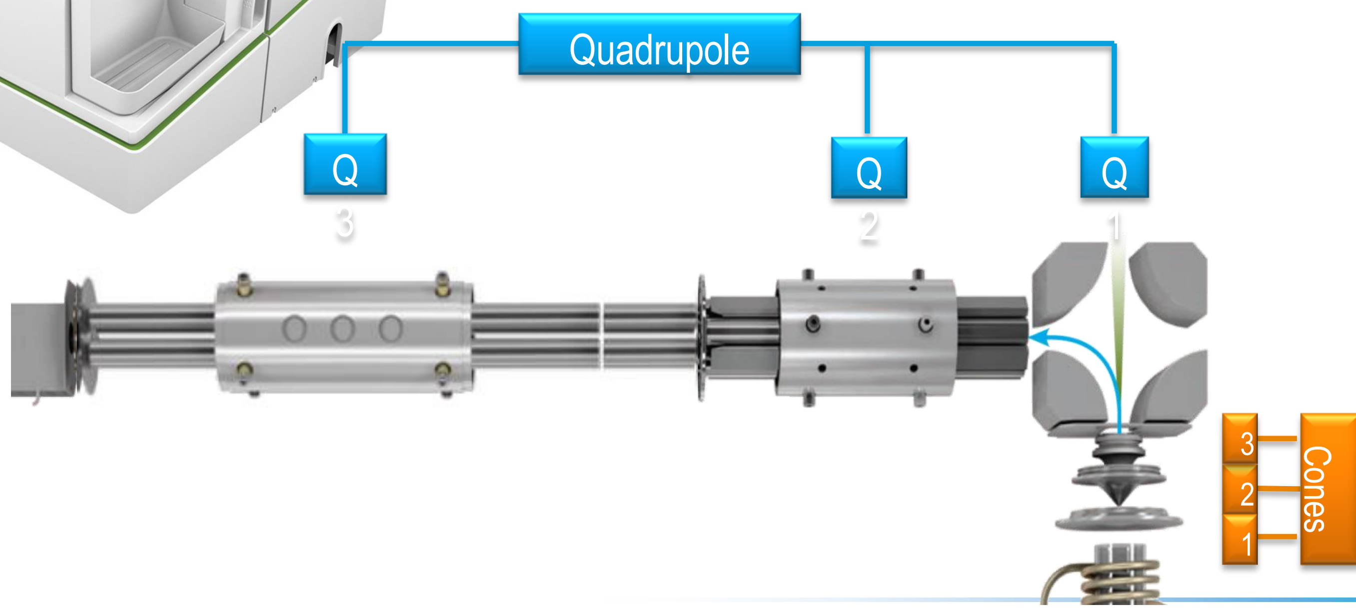
NexION Features

- **New Methods of Interference Reduction** (UCT™)



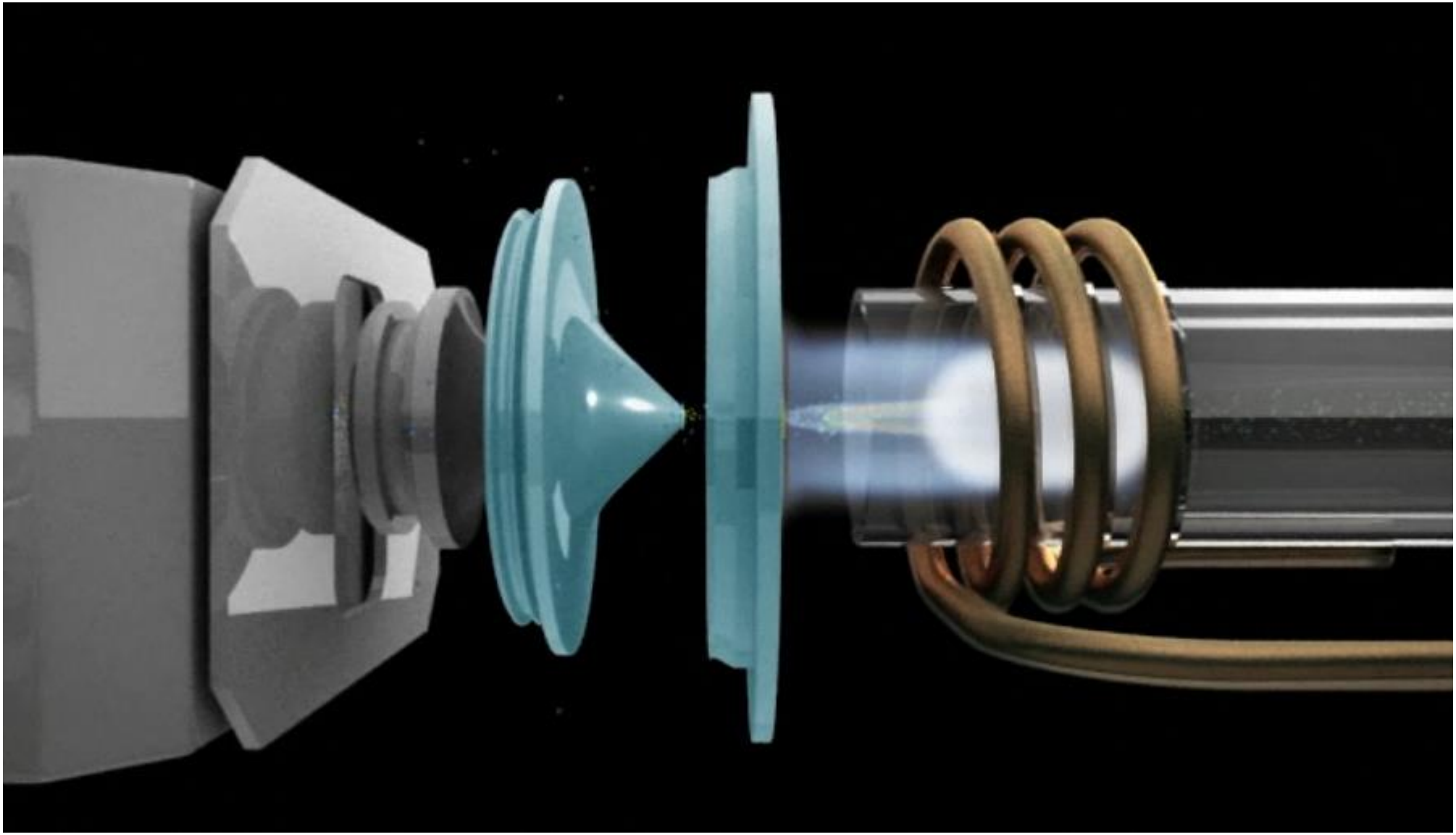
- **New interface**

Unique combination of Triple Cone Interface and Quadrupole Ion Deflector (QID)

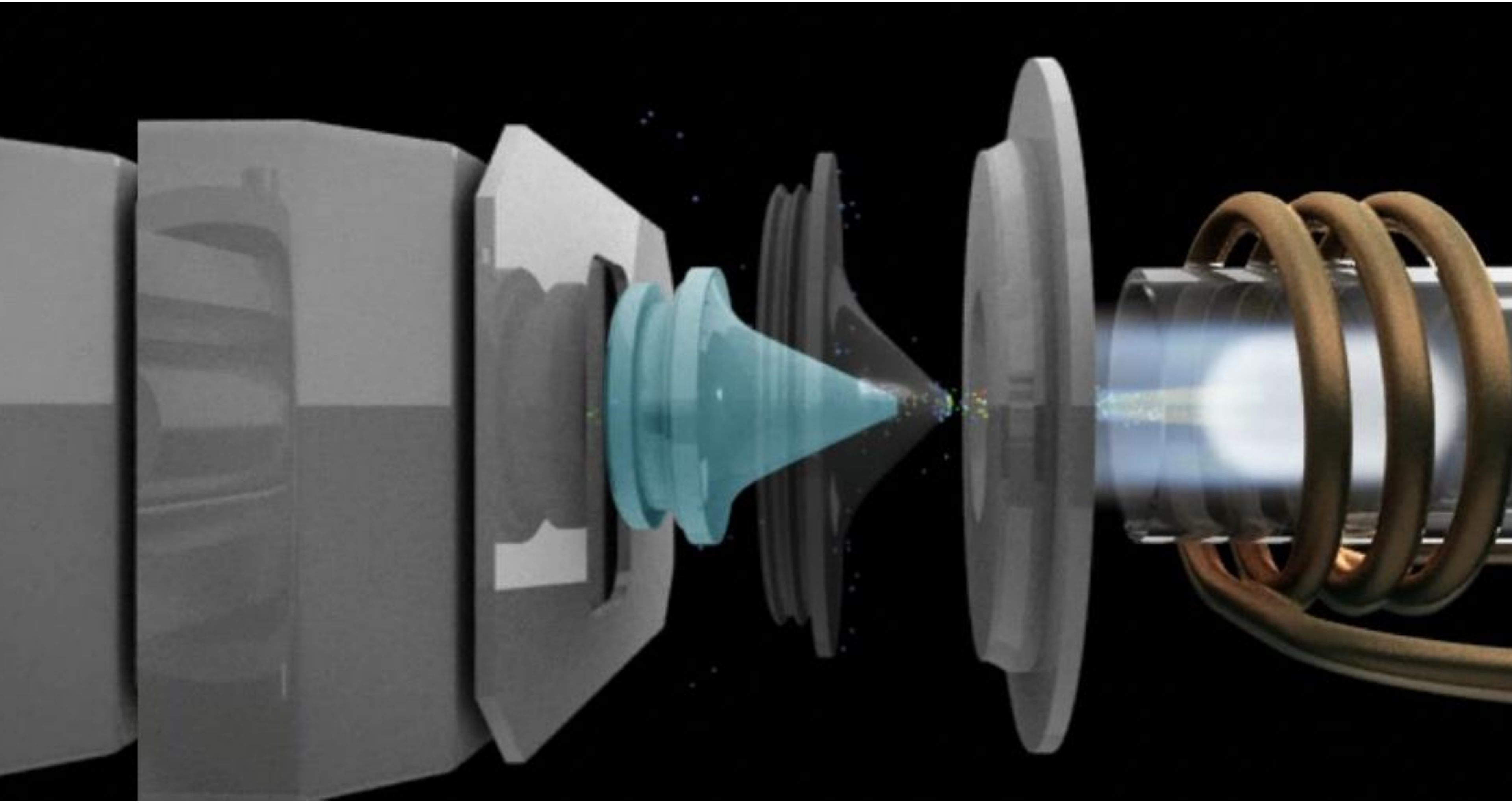


Why is this important?

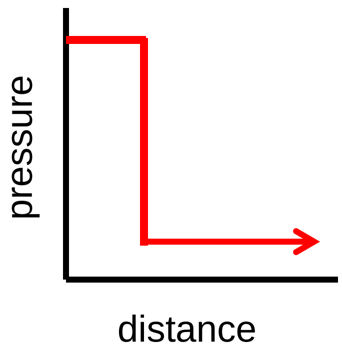
NexION Features



NexION Features



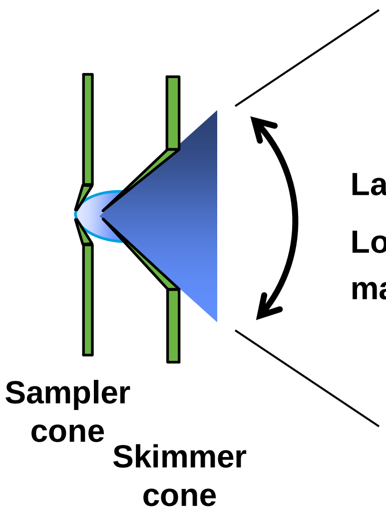
Benefits of a Triple Cone Interface



Older ICP-MS systems –

Pressure drops in one large step:

- **large beam divergence,**
- **more dirt into mass spectrometer – creates more drift and required maintenance**

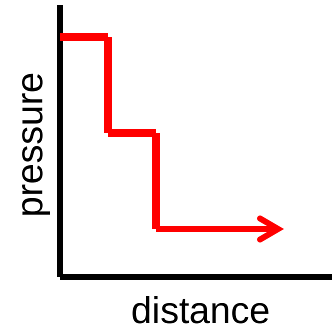


Large beam divergence

Lots of material deposits inside mass spectrometer

Legend: Blue = beam from plasma (ions + neutrals + dirt);

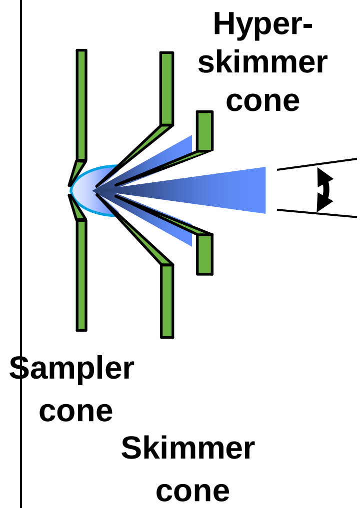
Red = pressure drop per cone



NexION

Pressure drops in two smaller steps:

- **less beam divergence,**
- **dirt prevented from entering mass spectrometer – very little drift, reduced maintenance**



Well confined beam (~2-3 mm)

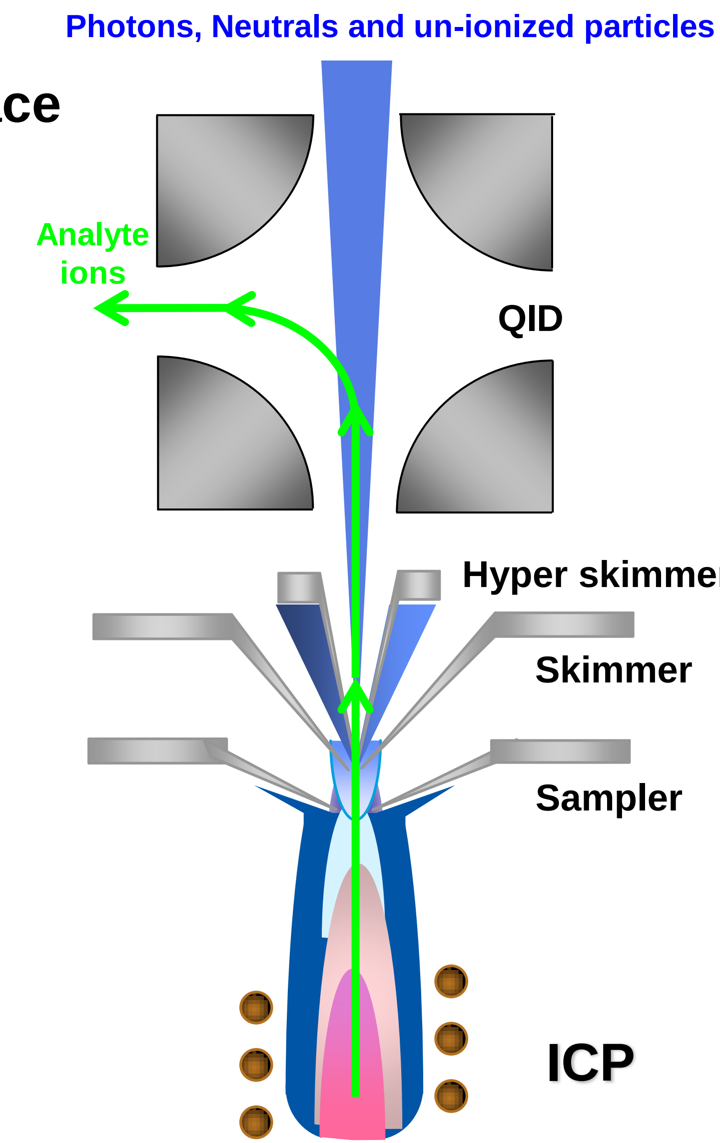
Almost no deposition inside mass spectrometer

Material that never enters mass spectrometer

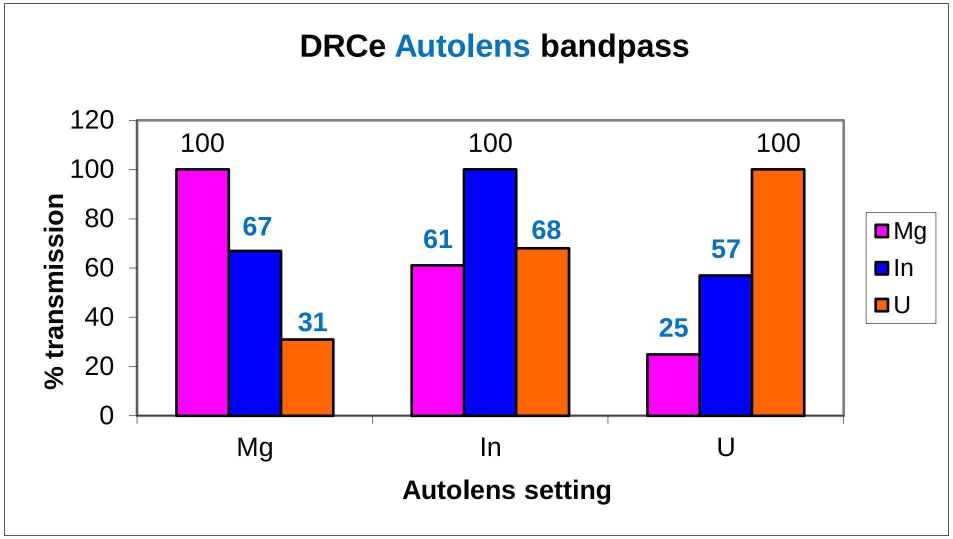
NexION Features

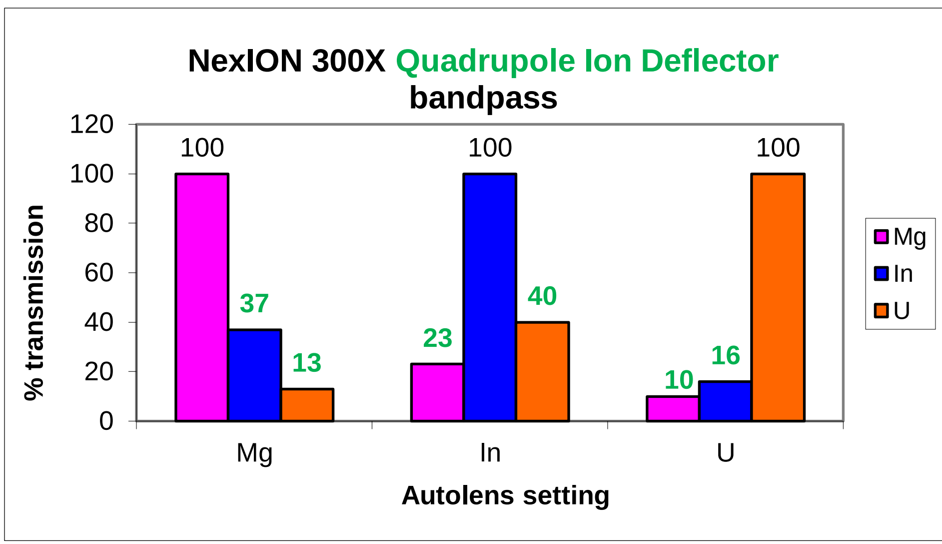
➢**Unique combination of Triple Cone Interface and Quadrupole Ion Deflector provide:**

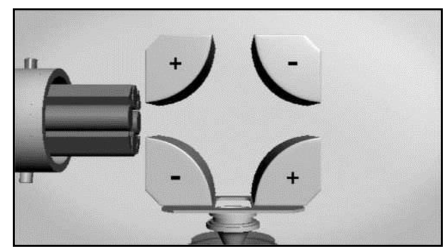
- Incredible stability
  - Mass spectrometer (including cell) remains clean when analyzing dirty samples
  - Ion Optics require very infrequent cleaning
  - More time running samples, less time cleaning or recalibrating
- Very low background noise
- 10x improvement in low mass sensitivity

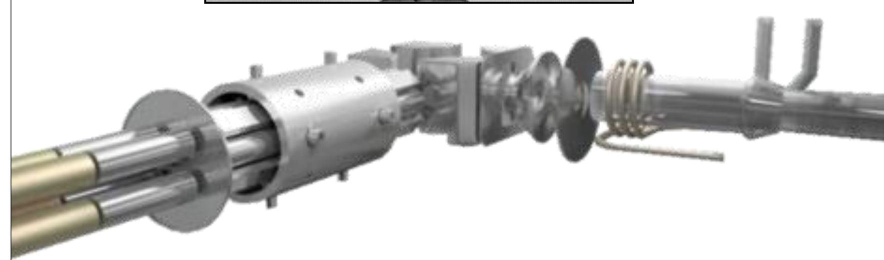


QID: Excellent Mass Selectivity

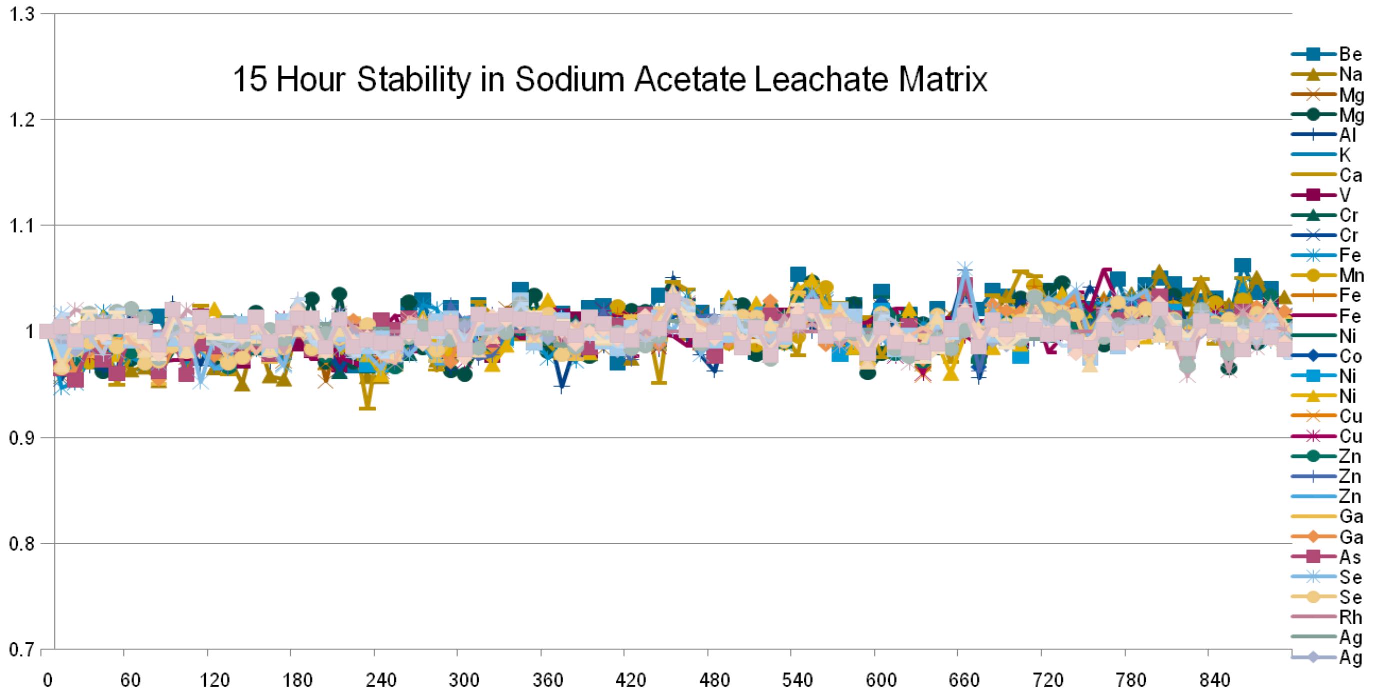








NexION Features



15-hour stability using Rh as the internal standard. All results have been normalized to the mean. Most analytes were +/- 3% over the 15 hour period. Sample matrix was TCLP extract solution at 0.1% Sodium Acetate. The analytes were spiked at 100 ppb.

The Spectral Interferences Problem in ICP-MS

Interferences on major isotopes inhibiting low-level determinations

- ^{27}Al from $^{12}C^{15}N^{+}$
- ^{51}V from $^{35}Cl^{16}O^{+}$
- ^{52}Cr from $^{40}Ar^{12}C^{+}$
- $^{56}Fe^{+}$ from $^{40}Ar^{16}O^{+}$, $^{40}Ca^{16}O^{+}$
- ^{58}Ni from $^{58}Fe^{+}$, $^{40}Ca^{18}O^{+}$ (use ^{60}Ni)
- ^{60}Ni from $^{44}Ca^{16}O^{+}$
- ^{63}Cu from $^{23}Na^{40}Ar^{+}$ (use ^{65}Cu)
- ^{75}As from $^{40}Ar^{35}Cl^{+}$
- ^{80}Se from $^{40}Ar^{40}Ar^{+}$

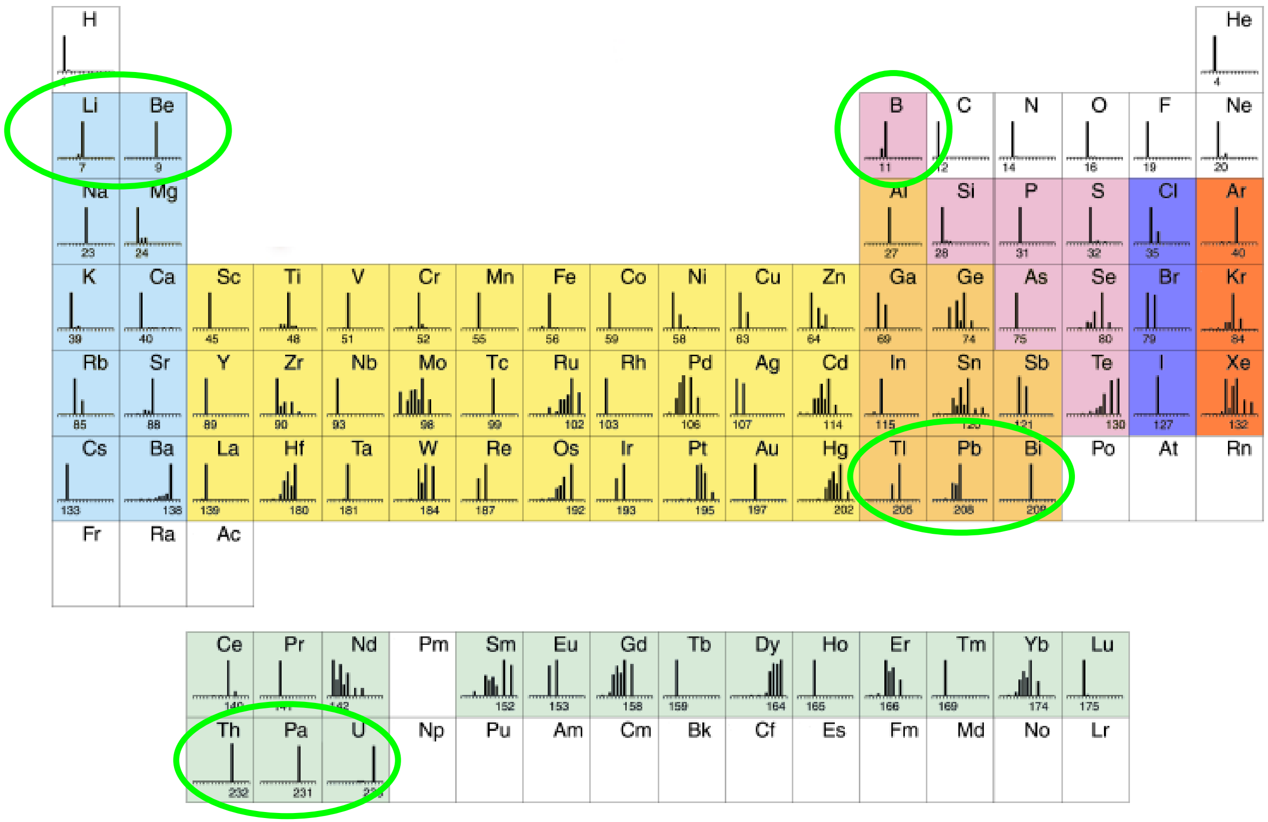
NexION Features

- Universal Cell Technology - Tri-Mode cell instrument
  - Standard (STD) mode (uses no cell gases)
    - Unique vented cell provides true classical ICP-MS spectra
  - Collision mode (uses an inert cell gas, collision gas)
    - Separates analyte ions from polyatomic isobaric interferences using Kinetic Energy Discrimination (KED)
  - Reaction mode (uses a reactive gas)
    - Separates analyte ions from interfering ions based on specific chemistry in the Dynamic Reaction Cell (DRC)

The right mode for the application

Universal Cell Technology (UCT™)

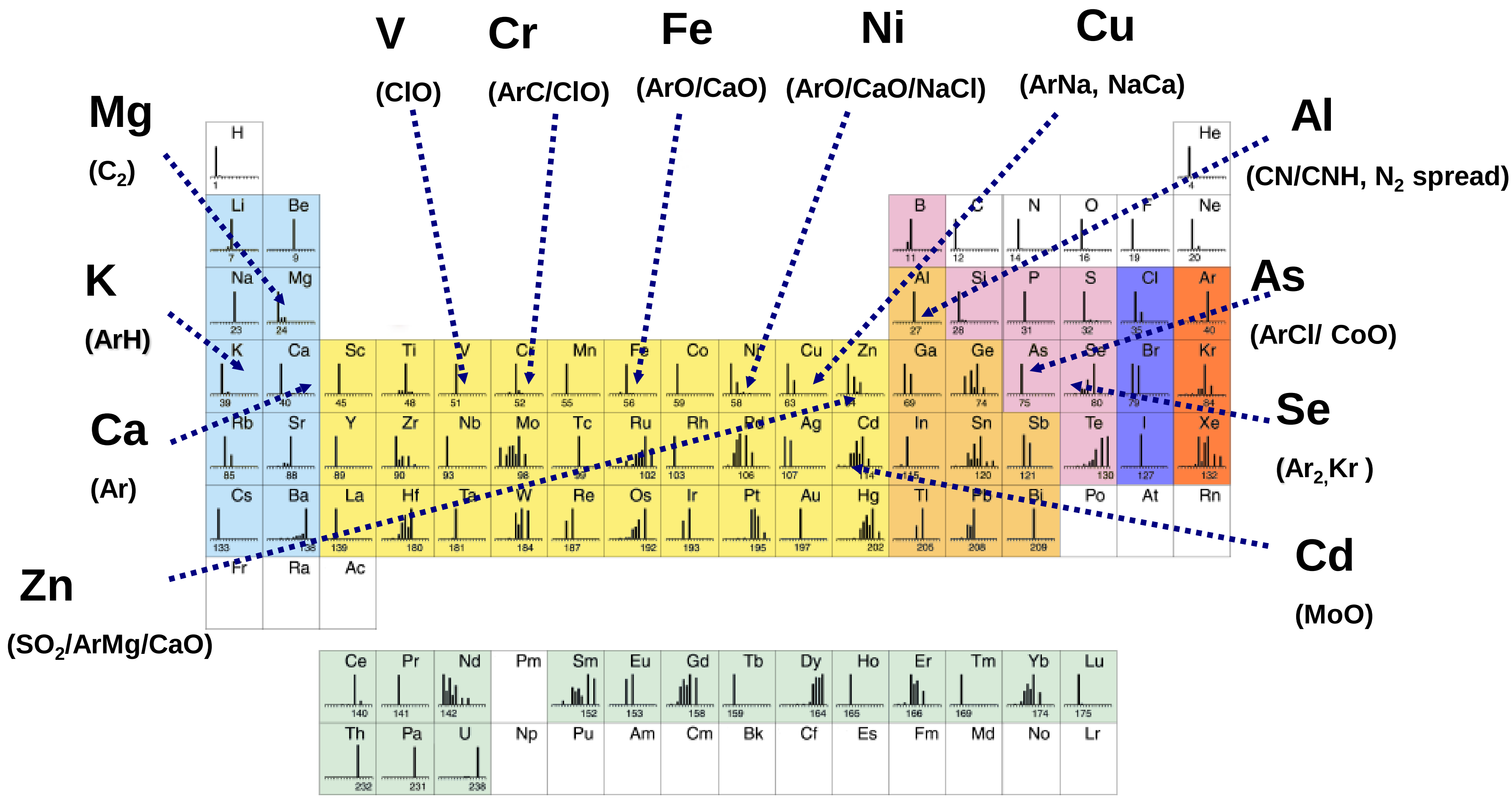
- The STD mode is most suitable for:
  - Applications with few interferences on analytes of interest
  - Low mass or high mass elements



… BECs for interfered elements can be in the ppb range

Limitations of STD mode

➢ Important mid-mass elements suffer from common interferences



ICP-MS : Interferences correction

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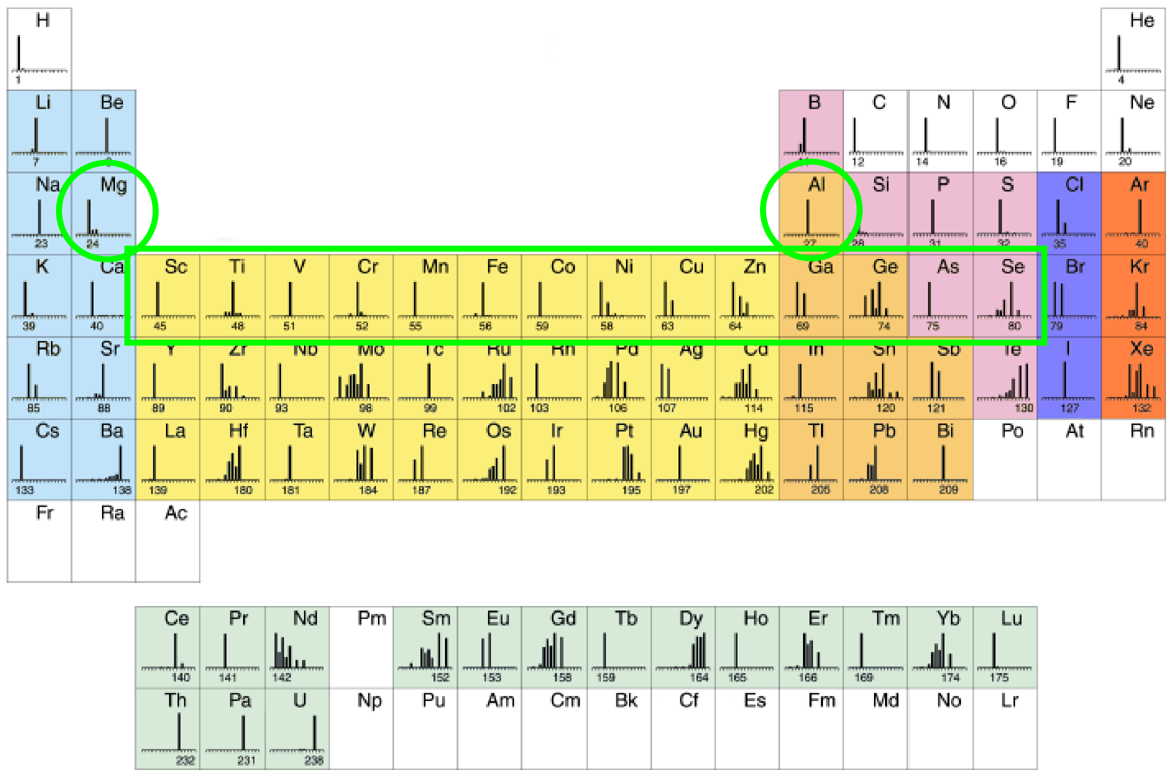
Int Std	Analyte (*)	Mass (amu)	Corrections
	As	74.9216	-0.0004*mass35
	As	74.9216	
	Ca	43.9555	
	Ca	42.9588	
	Cd	113.904	
	Cd	110.904	
	Co	58.9332	-0.0005*Ca43
	Cr	51.9405	-0.00055*Cl35
	Cu	64.9278	
	Cu	62.9298	
	Fe	56.9354	-0.08*Ca43
	Mg	23.985	
	Mn	54.9381	
	Mo	97.9055	
	Na	22.9898	

Int Std	Analyte (*)	Mass (amu)	Corrections
	Ni	59.9332	-0.002*Ca43
	Ni	61.9283	
	Pb	207.977	
	Rh	102.905	
	Se	76.9199	
	Se	77.9173	
	Se	81.9167	
	V	50.944	-3.127*(ClO 53 -(0.113*Cr 52))
	V	50.944	
	V	50.944	-0.0047*Cl 35
	Zn	67.9249	
	Zn	63.9291	- 0.035313 * (Ni 60-(0.007*Ca 43))
	Zn	65.926	
	Hg	201.971	
	Hg	199.968	

Universal Cell Technology (UCT™)

PerkinElmer
For the Better

- The Collision (KED) mode is most suitable for:
  - First row transition elements
  - Applications susceptible to common interferences at moderate levels



… BECs for interfered elements are in the ppt range

Properties of KED mode operation

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- KED – Physical and electronic filtering process
  - Dependent on collision cross sections, gas density, cell length and voltage barrier
  - Efficiency limited to 3-4 orders of magnitude interference reduction

KED – Kinetic Energy Discrimination

- Kinetic Energy Discrimination - The process of separating energy distributions by exploiting differences in collision cross sections
  - In ICP-MS, it's specifically the difference in collision cross section between elemental ions and their polyatomic interfering isobars.
    - e.g. ^{56}Fe & ^{56}ArO, ^{78}Se & $^{78}Ar_2$, ^{51}V & ^{51}ClO

Although polyatomic isobars share the same mass and energy characteristics as the elemental ions, they can have significantly larger collision cross sections (σ).

larger cross-section = more collisions = lower energy

- Compare:

V and ClO	- K and ArH
Se and Ar_2	- Cd and MoO
Fe and ArO	- Au and TaO
$\Delta\sigma >> 0$, good performance	$\Delta\sigma \sim 0$, poor performance

Energy distribution of ions inside the instrument

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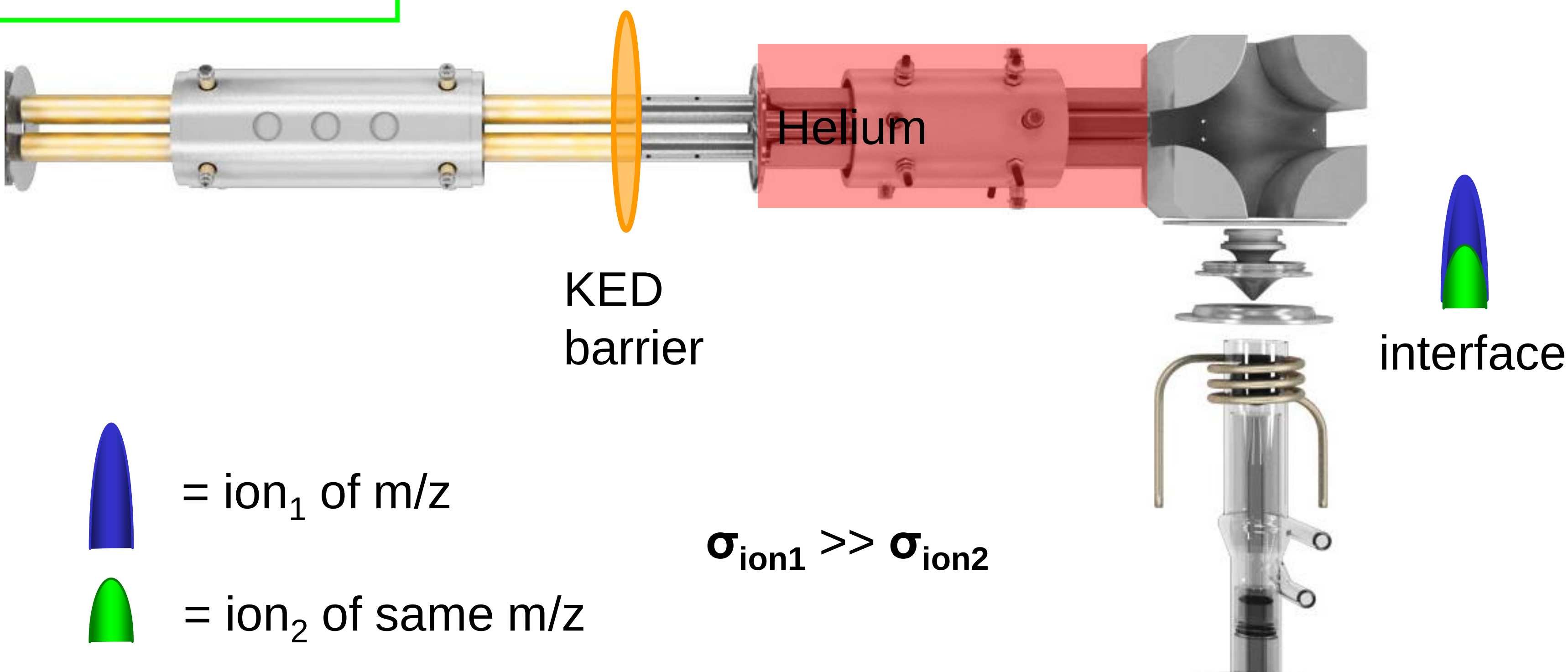
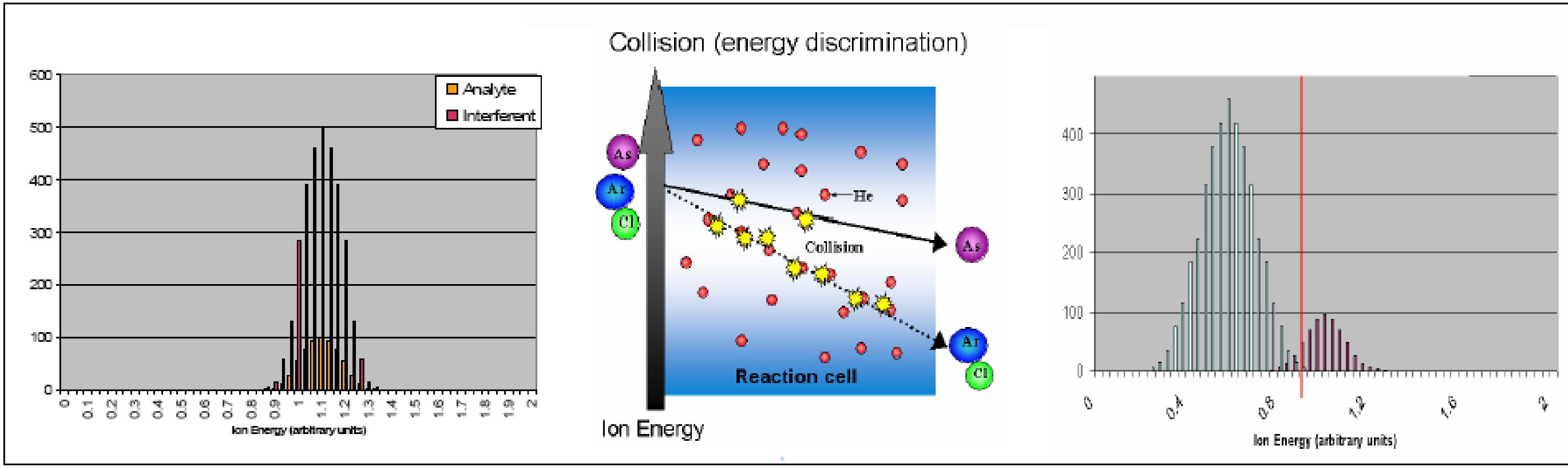
	Ar_2^+	Se^+
Initial energy:	5 V	5 V
# collisions:	5	2
Energy lost:	2.5 V	1 V
Exit energy:	2.5 V	4 V

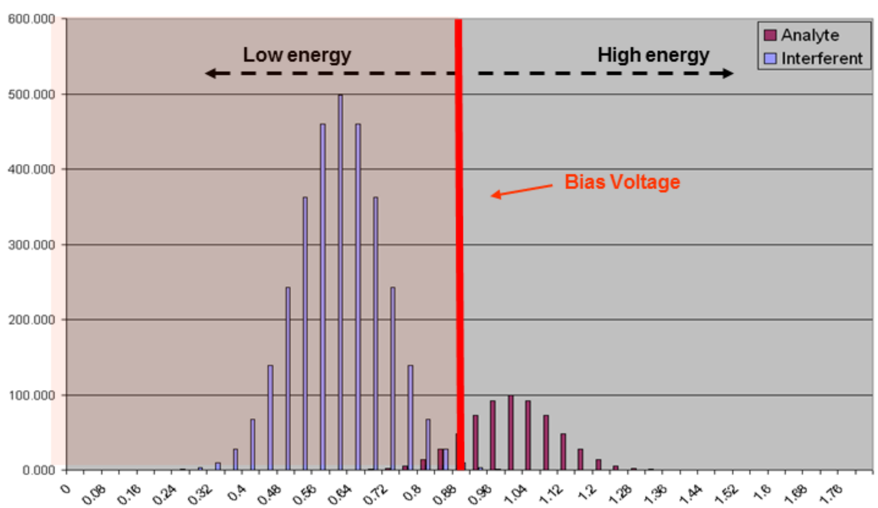
Separation is based on difference Kinetic Energy using appropriate HARDWARE (KED barrier, focusing multipole)

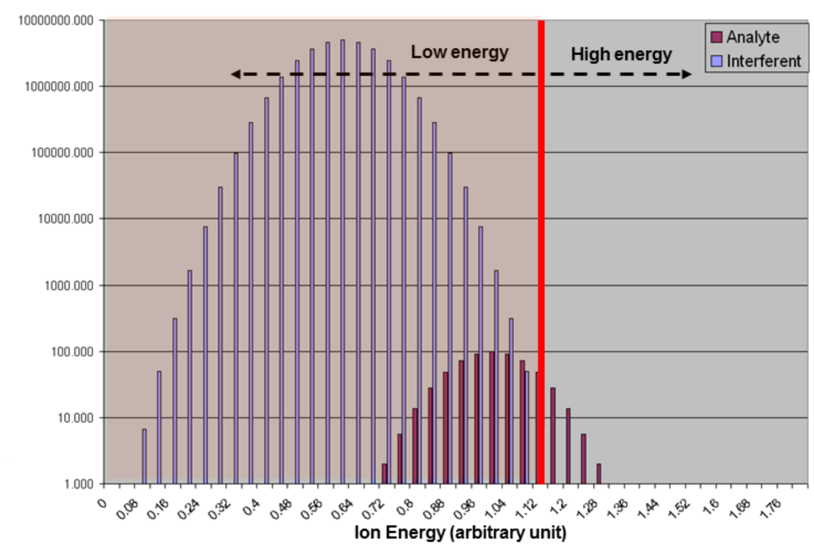


KED barrier repels ions that don't have enough energy to enter the quad

- Collision - reduction of energies of polyatomic ions







Collision Cell KED (Energy Discrimination)

Sensitivity

Interferences Elimination

Universal Cell Technology (UCT™)

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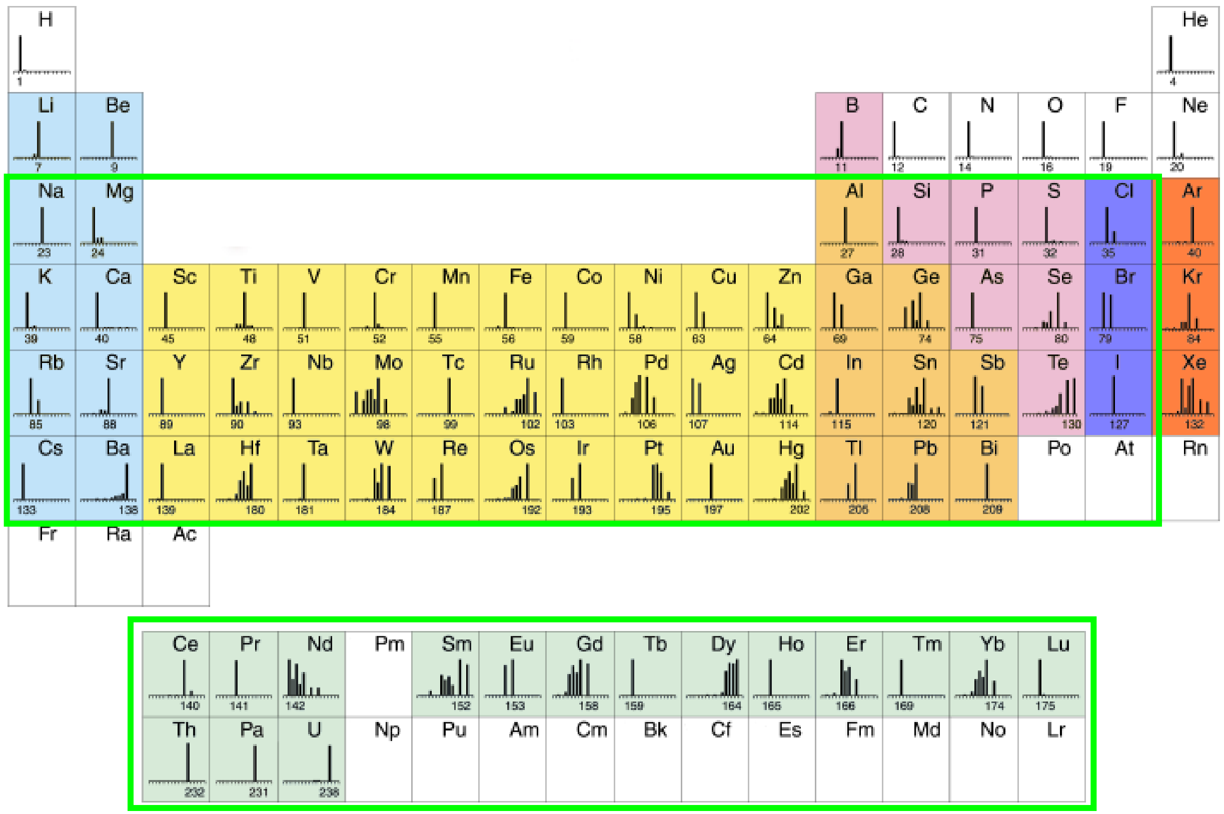
For the Better

- The Reaction (DRC) mode is most suitable for:
  - Applications with the highest level of interferences that require the lowest BECs



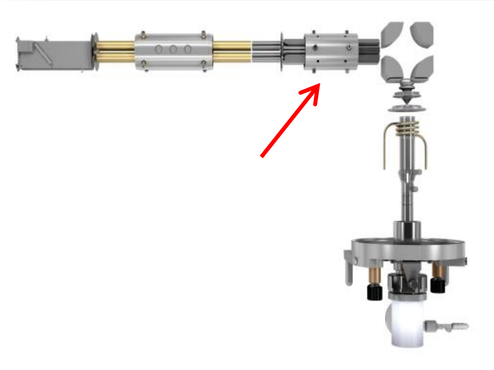
… BECs for interfered elements are in the sub-ppt range

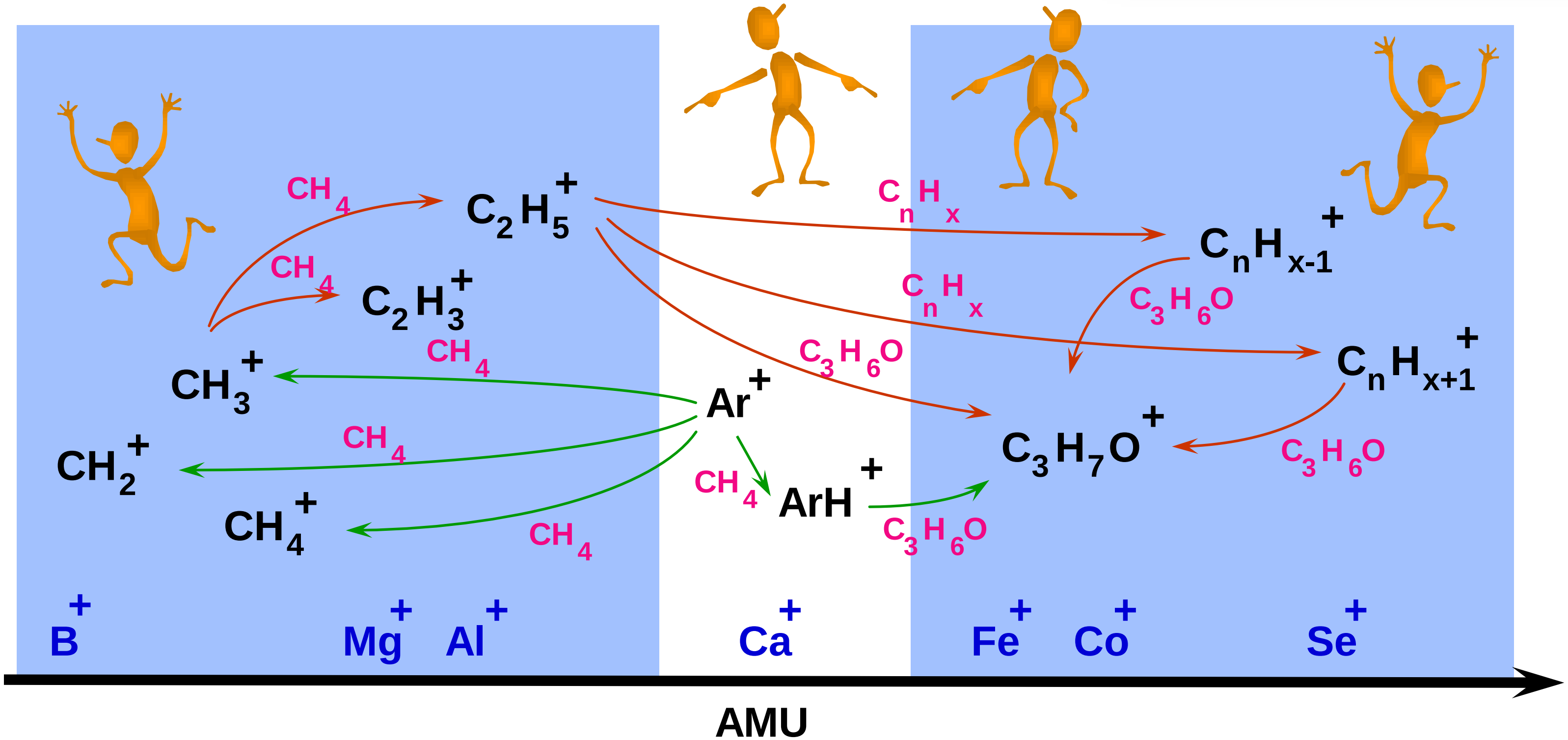
Properties of DRC mode operation

- DRC – Purely chemical filtering process between ions and molecules
  - Uses electronics to drive the reaction to the products side
    - A + B ► C + D (bandpass forces C + D to dominate)
  - Dependent only on the reaction rates of the ions in the beam and the reaction gas
    - Faster reaction rates dominate over slower ones
    - Independent of mass
  - Can be extremely efficient at reducing interferences
    - Up to 9 orders of magnitude reductions are possible

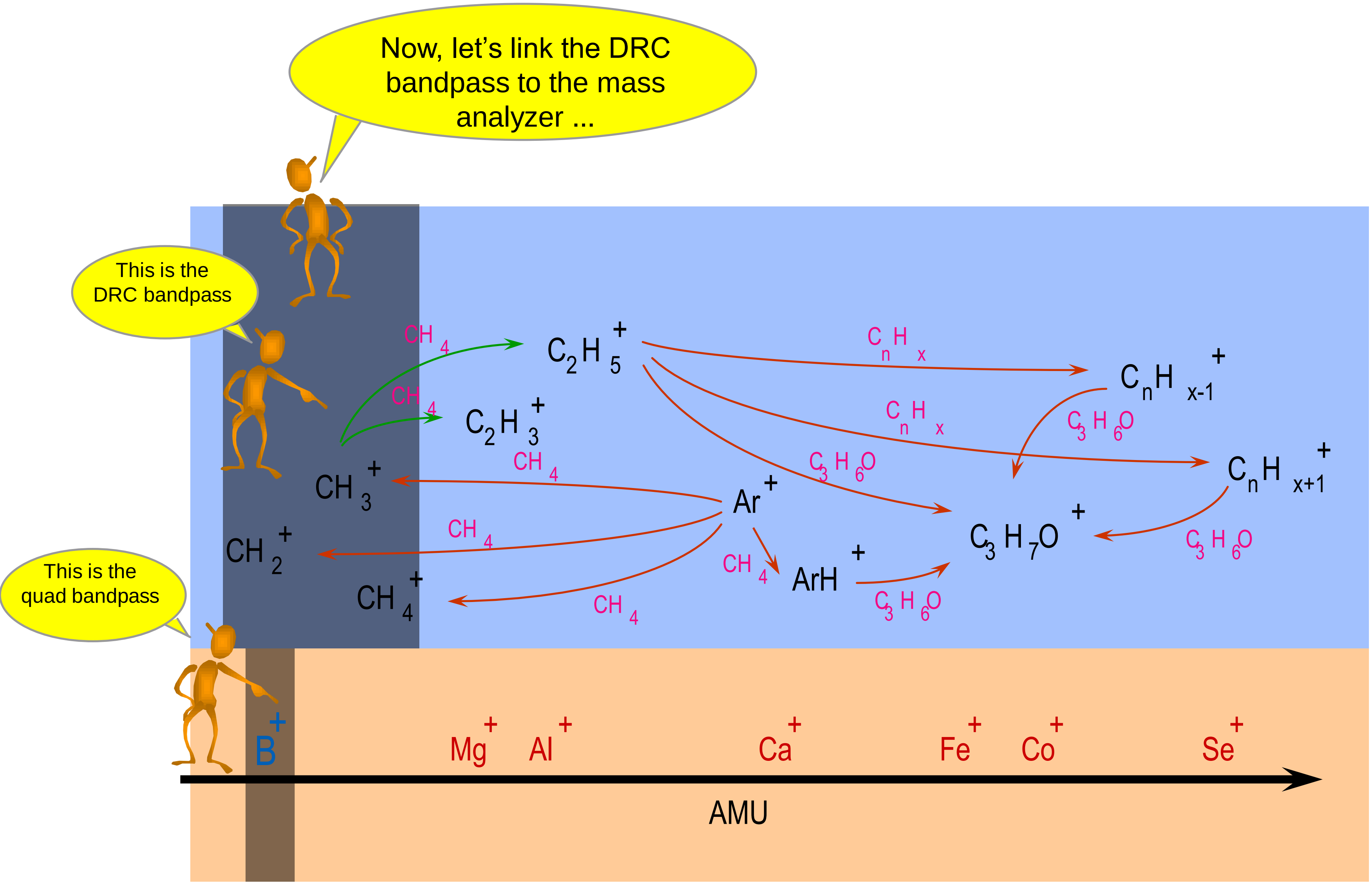
Low (RPq) and High (Rpa) mass cut-off applied

- "q" parameter sets low mass cut-off
- "a" parameter sets high mass cut-off





How DRC works…



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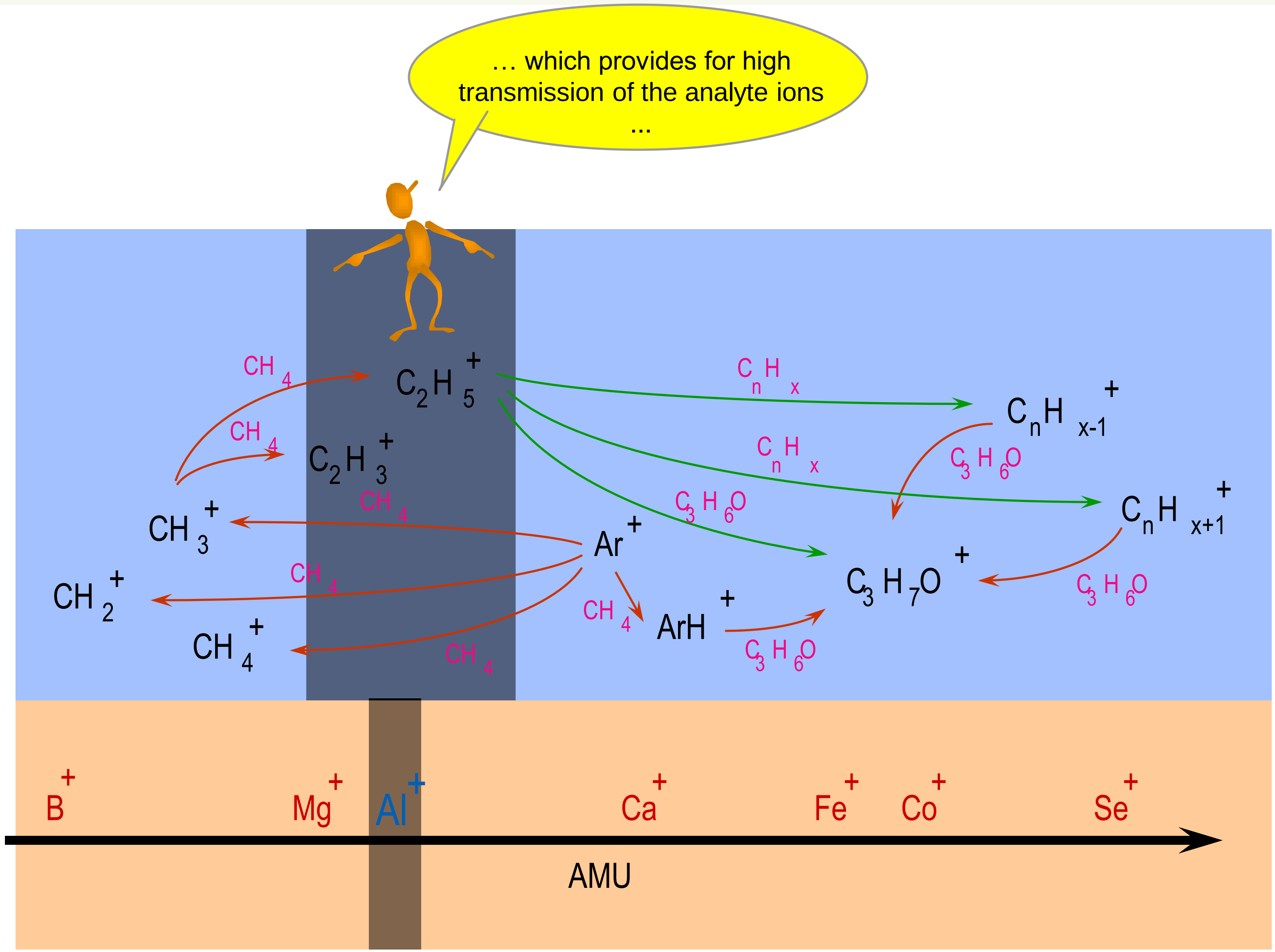

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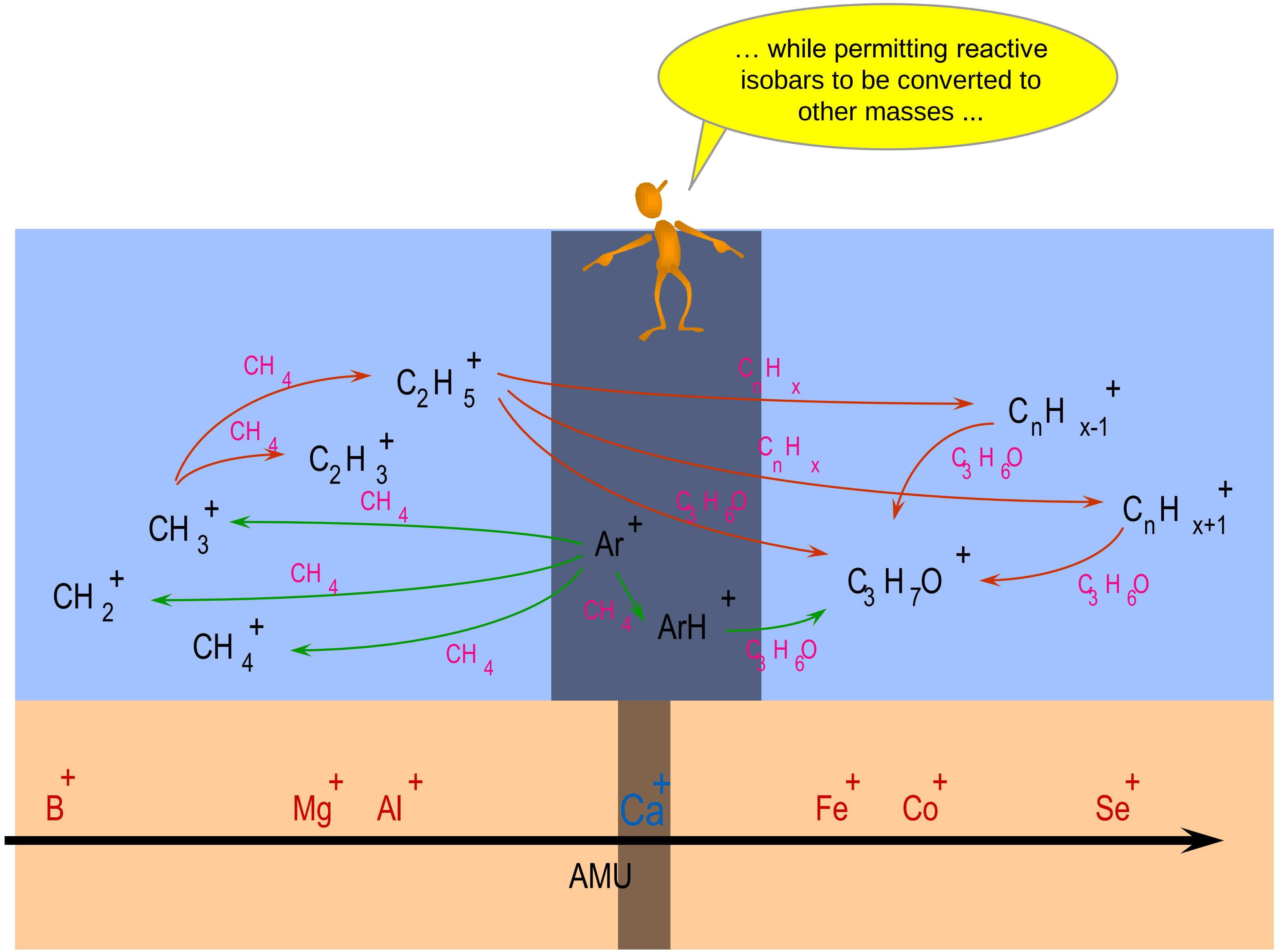
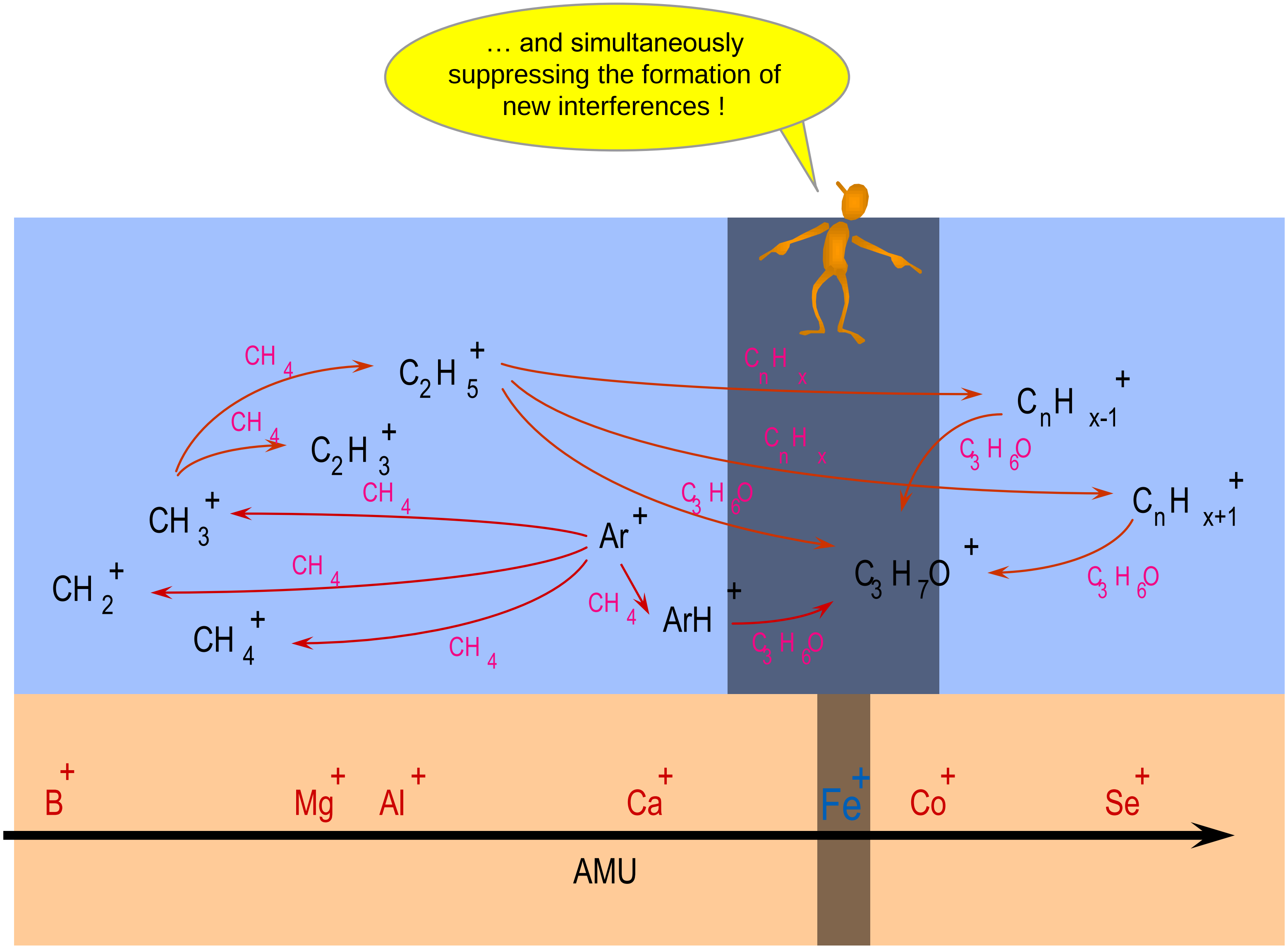
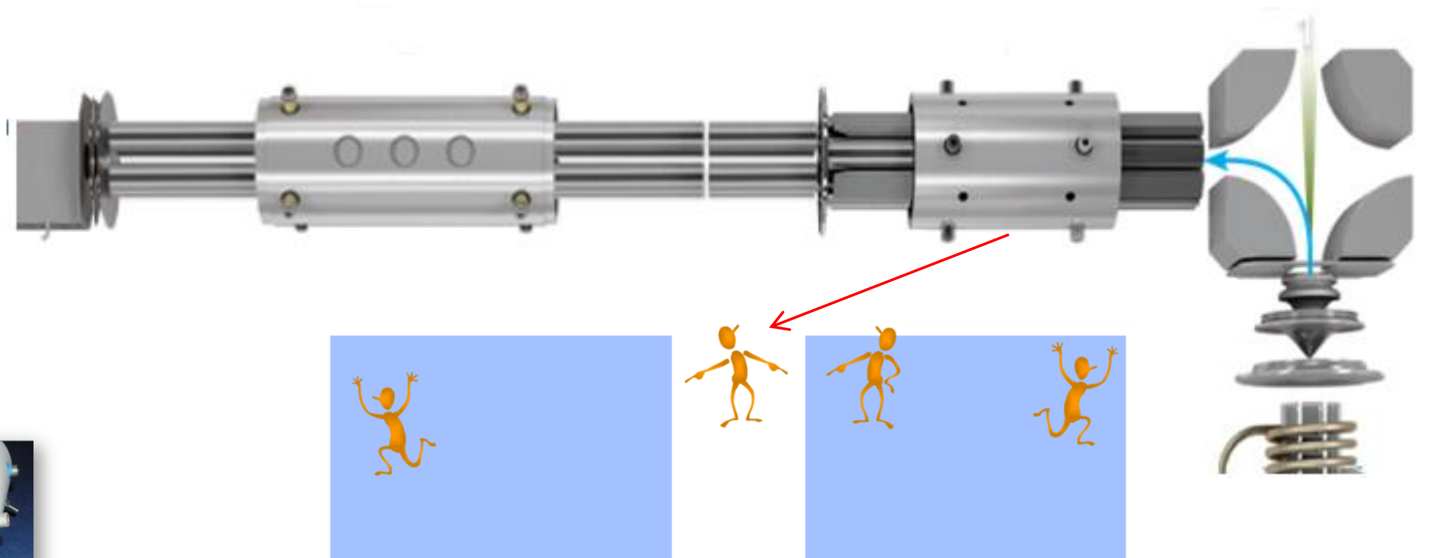


How DRC works…



DRC Technology

Separation is based on different mass – charge ratio
using appropriate HARDWARE (quadrupole to create a dynamic band pass)



- "q" parameter sets low mass cut-off
- "a" parameter sets high mass cut-off

Interference Reduction (UCT™)

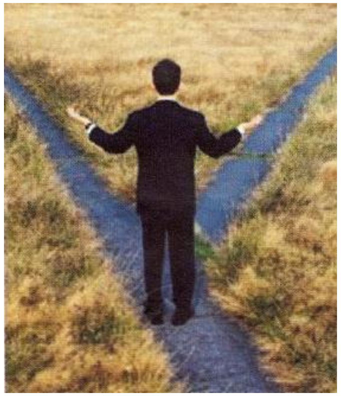
- In a cell **is the nature of the gas** that we use to reduce/eliminate the interferences that define if we have more reaction (CH4, NH3, O2, H2) or collision (He) events
- **Any supplier** can introduce the gas that he wants in the cell but how to manage what is happening in the cell depends from the **hardware** available in the different instruments
- **THIS IS THE IMPORTANT DIFFERENCE AMONG THE INSTRUMENTS AVAILABLE IN THE MARKET!**

Interference Reduction (UCT™)

- In the past the customer had to chose

between **KED** (passive cell) approach or **Band pass** approach (active) cell

- **Not from Collision or Reaction cell !**



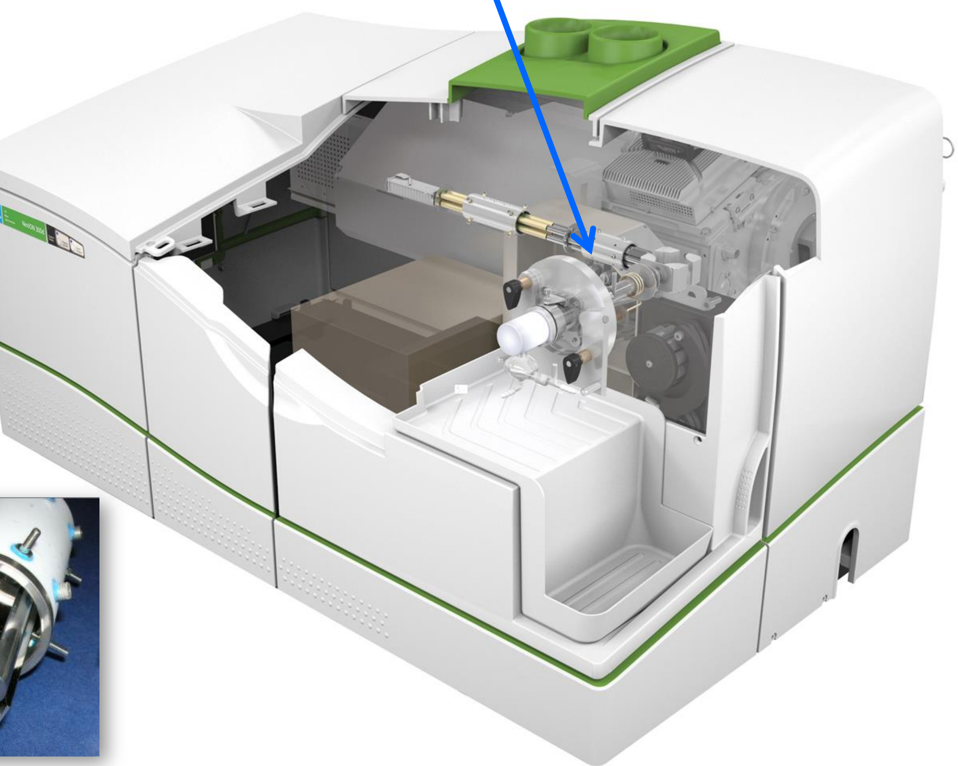
- Simply have everything ! All the technologies available nowadays to eliminate the interferences in a Quadrupole ICP-MS !

EASY and POWERFUL !

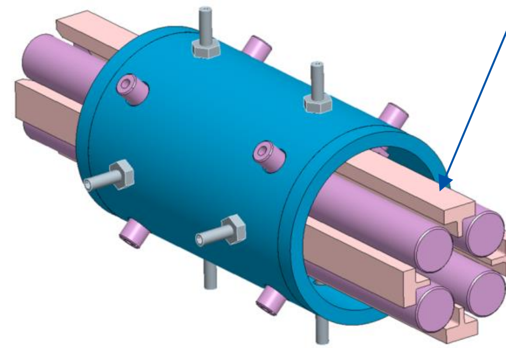
Not from Collision or Reaction cell !

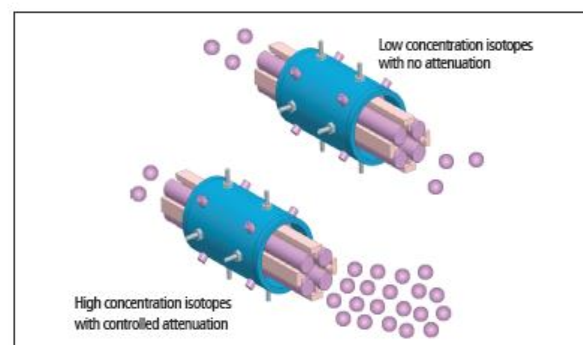
NexION Features

- **Improved Interference Reduction** (UCT™)



Axial Field Electrode





Physics

1. Quadrupole can create a band pass (DRC)
2. Quadrupole can become a passive ion guide (KED)
3. Multi-pole can only be a passive ion guide

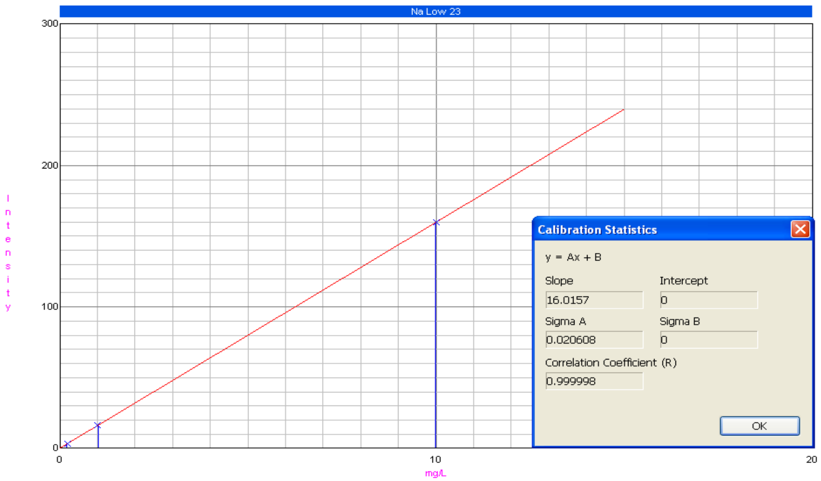
Why is this important?

Extending Standard Working Range with EDR - Why is this important ?

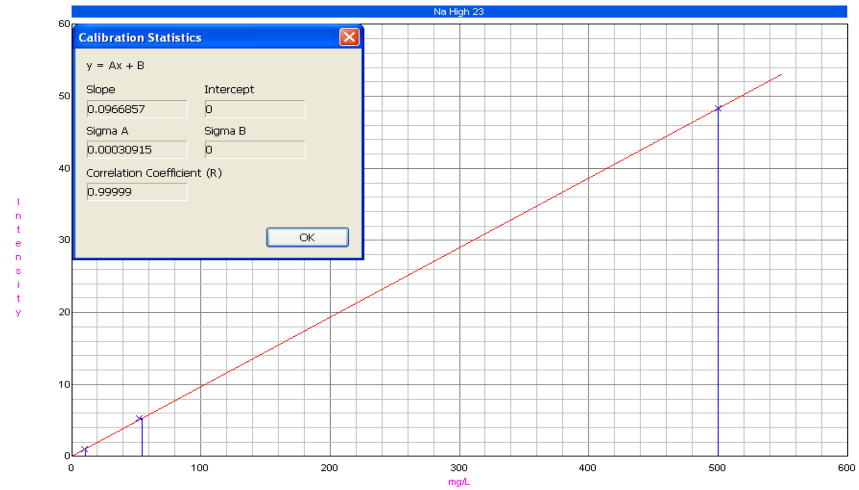
PerkinElmer
For the Better

- Selective attenuation of high signals through control of the bandpass parameters
- If needed both low and high calibration ranges can run in a single method

- Avoids dilutions
- Avoids rerunning samples
- All elements in the solution can be determined in a single analytical run



Standard Calibration of Sodium – from DL to 10 mg/L Range



Extended Calibration of Sodium – from DL to 500 mg/L Range

❖Linear Dynamic Ranges (LDR) were run for all major analytes: Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium > 500 ppm

❖These analytes in environmental samples are usually high and frequently require additional dilutions to bring them into range

❖Fewer dilutions for the user

❖Higher productivity for the lab

EDR extends (not shifts) the upper linear range by 4 orders of magnitude

ICP-MS NexION 350...