

Useful GC/MS Sensitivity for Improved Environmental Analyses



Definitions

- Sensitivity

- Analytical definition: slope of the plot of amount of analyte (x-axis) versus signal response (y-axis)
- Commonly used definition: minimum amount of analyte that gives an acceptable response (more correctly “limit of detection”)

- Sensitivity Specification (GC/MS)

- S/N achieved for a very small amount of analyte injected under a carefully defined set of the instrument conditions using a “matrix-free” sample

- Useable Sensitivity

- Instrument and method parameters and tools that enhance the signal response and reduced noise when **working with real sample matrices**



Seminar Overview:

Useful Sensitivity for Improved Environmental Analyses

Technology Curve – Where is GC/MS Today?

Hardware Evolution

GC – Capillary Flow Technologies (Backflush)

MS – Triple-Axis Detector, Gain Normalization and Fast Electronics for Synchronous SIM/Scan

Software Evolution

MS – Trace Ion Detection and Deconvolution

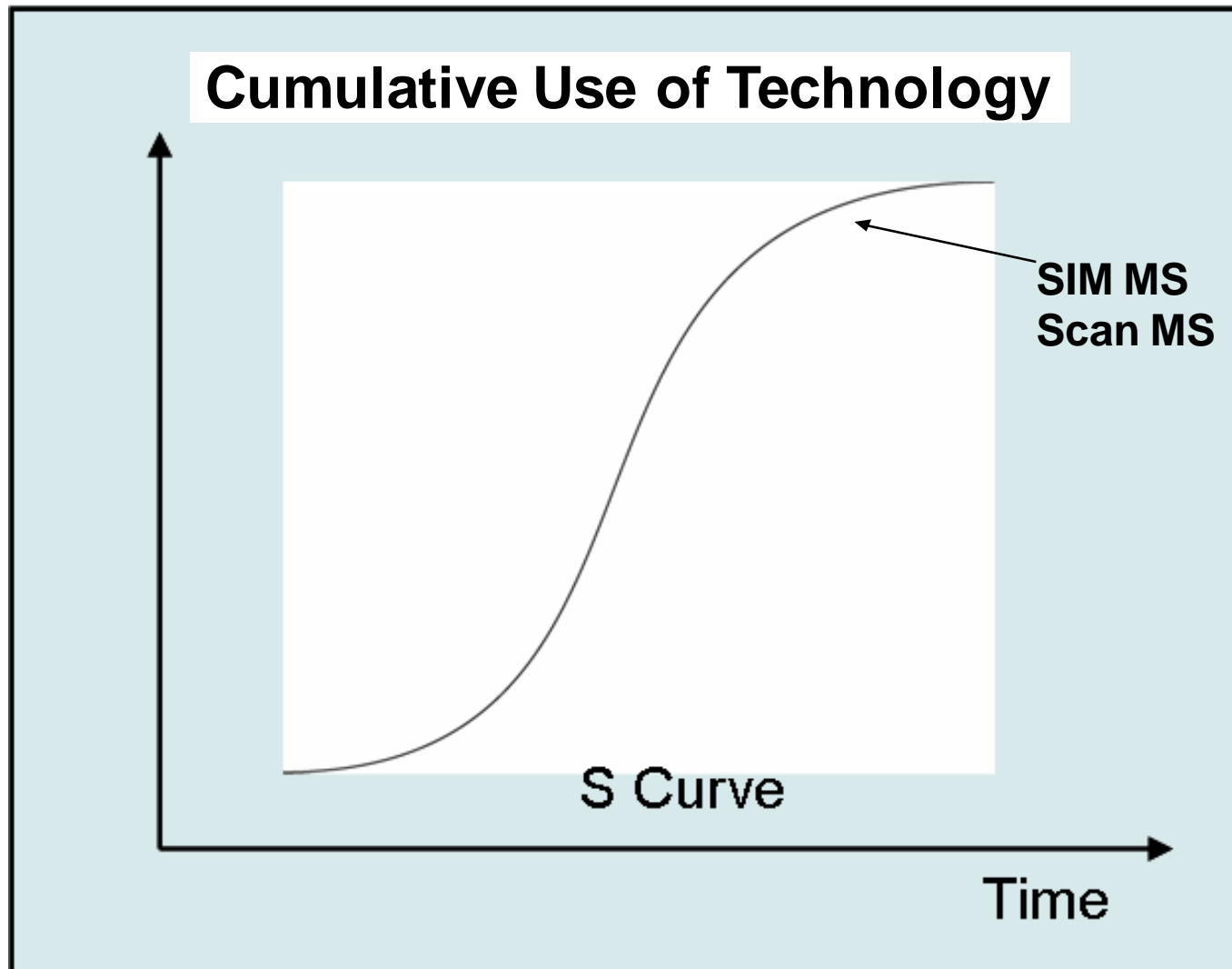
GC – Retention Time Locking and New Databases

Leap Promotion and Summary

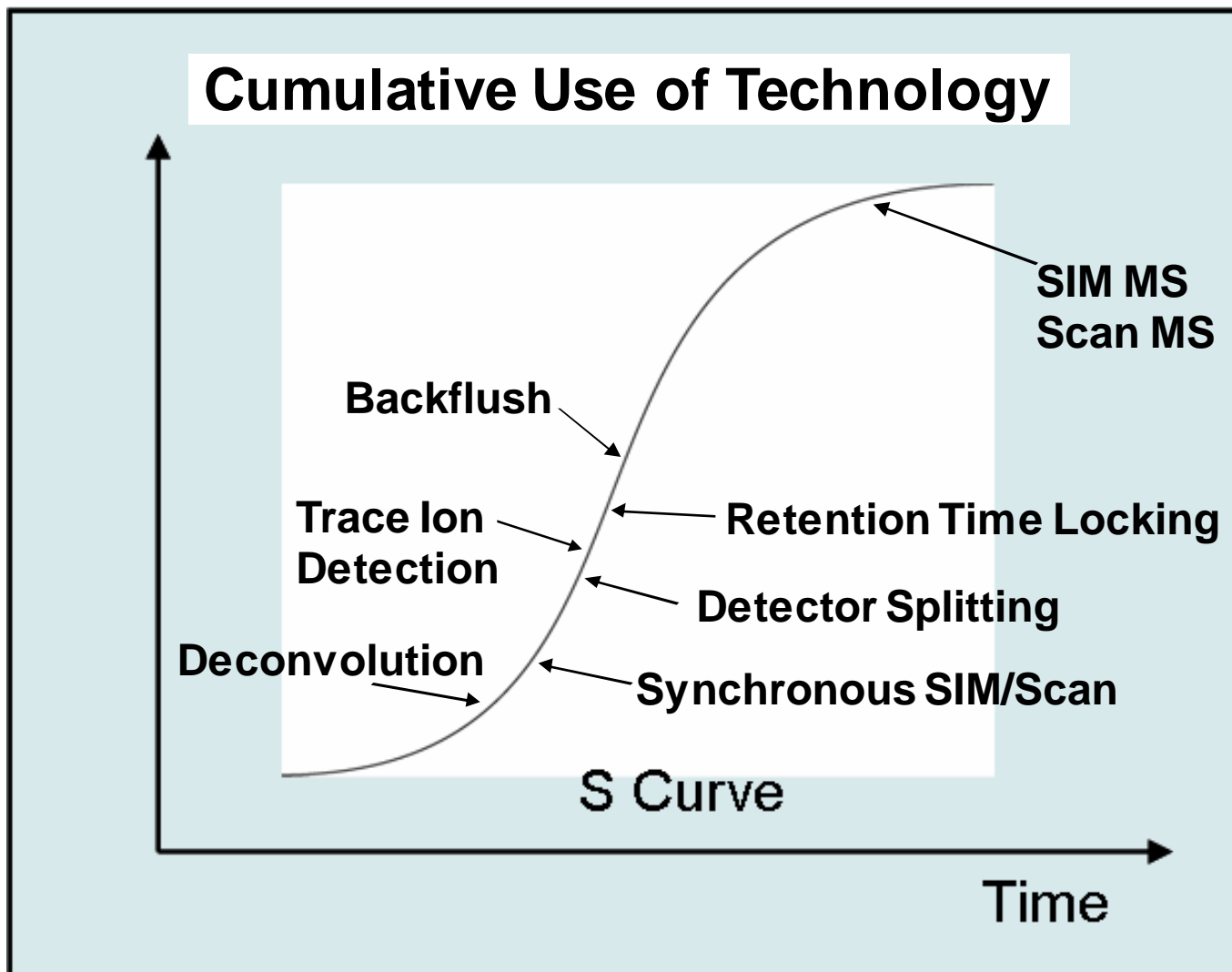
Literature References



Positioning of Basic GC/MS



Positioning of Newer GC/MS Technologies



Reasons for Slow Adoption of Technologies



- Unaware of the technical and/or practical benefits
- Too complicated; too much work to setup
- Not robust enough for routine use
- Technology 'imperfections' that impact performance

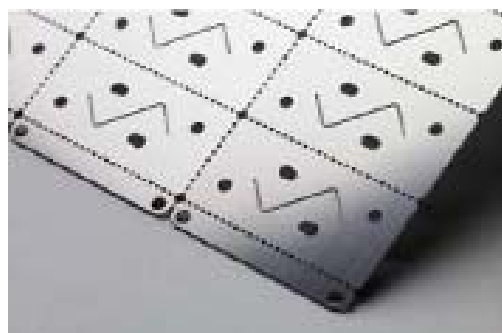
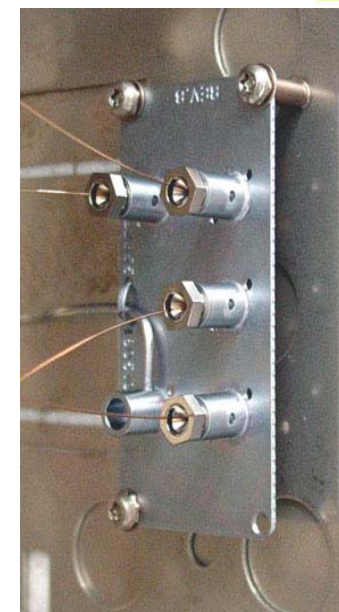
- Difficult to break long standing 'habits'
- Time/effort required to change established methods
- Constraint of government regulations



Capillary Flow Technology

... a proprietary Agilent Technology

- Photolithographic chemical milling for **low dead volume**
- Diffusion bond two halves to form a single flow plate
- Small, thin profile provides **fast thermal response**
- Projection welded connections for **leak tight fittings**
- Deactivation of all internal surfaces for **inertness**
- SilTite (**metal**) ferrules



5th Generation Electronic Pressure Control (EPC)



- 1st, 2nd Generation EPC
- 0.1 psi
 - cables
 - gas lines & connectors
 - large size

5890 GC

- 3rd, 4th Generation EPC
- 0.01 psi
 - Diffusion bonded plate (2D)
 - one cable
 - three gas connectors
 - "credit card" size

6890N GC



7890A GC

The only GC to regulate pressure to 0.001 psi



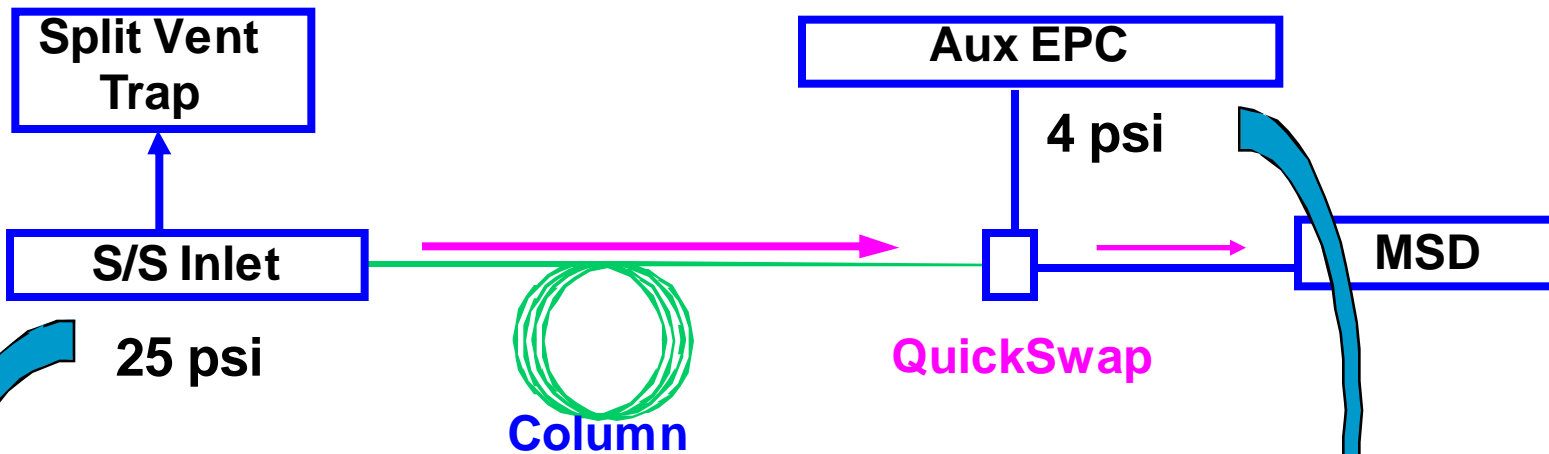
- 5th Generation EPC
- Metal injection molded (3D)
 - Digital signal pathways

... improved reliability and precision

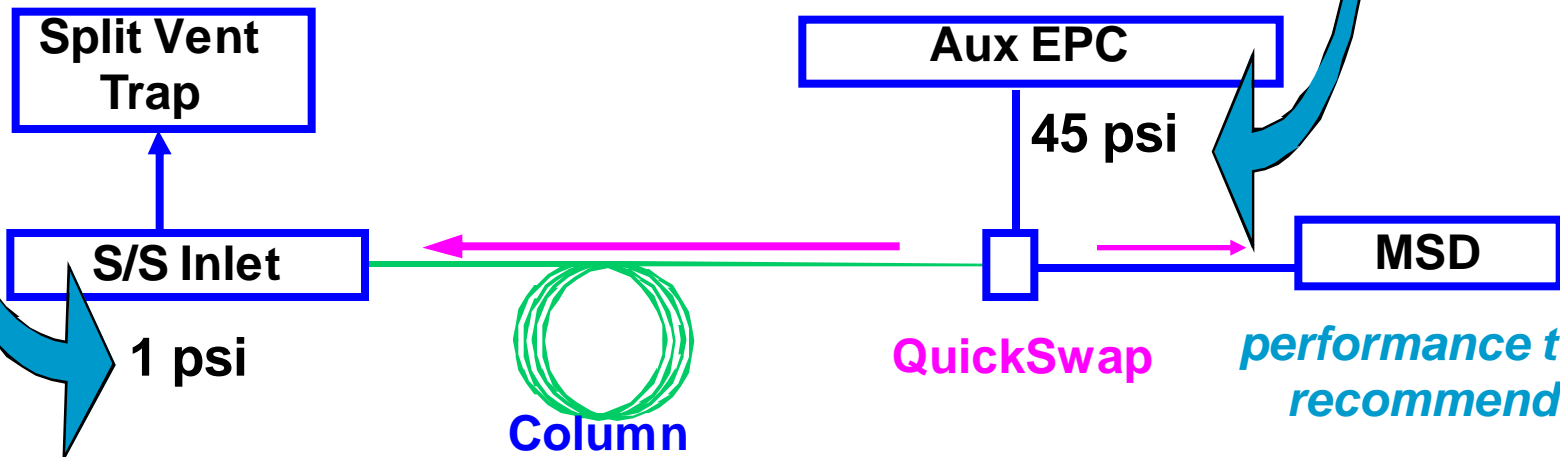


Backflush with QuickSwap

During GC Run



After GC Run



Benefits of Backflushing

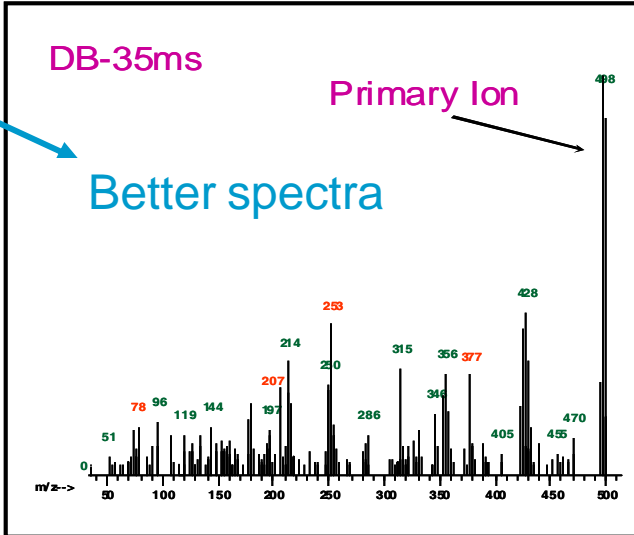
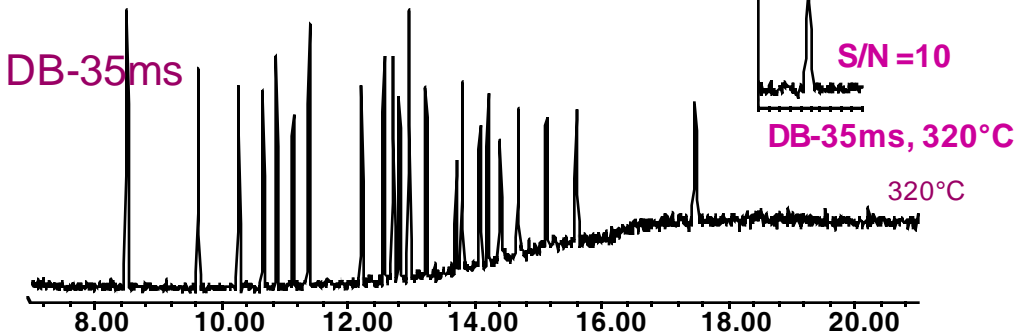
- **Shorter analysis times**
 - More samples per day per instrument
- **Lower operating costs**
 - Longer column life
 - Less frequent and faster GC & MSD maintenance
- **Less chemical background**



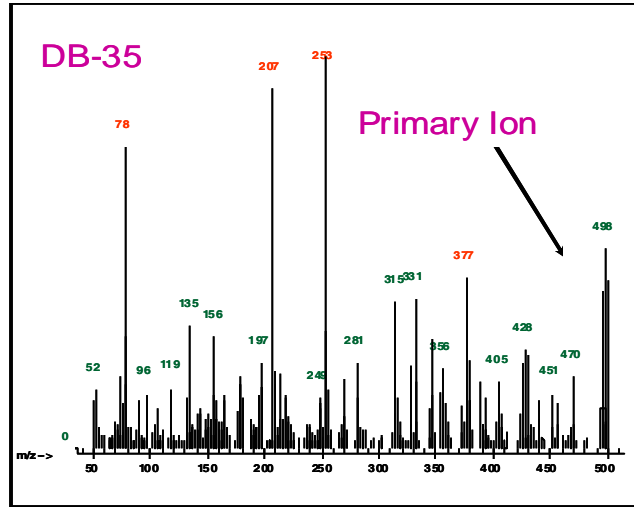
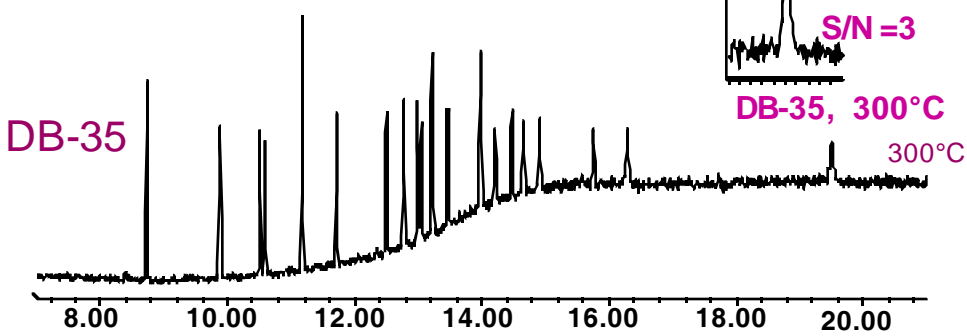
Industry Standard: Low Bleed Stationary Phases

Better signal to noise, higher upper temp limit, faster run time, improved spectral purity, and greater column inertness

Low bleed column \rightarrow Better detection limits \rightarrow Better spectra

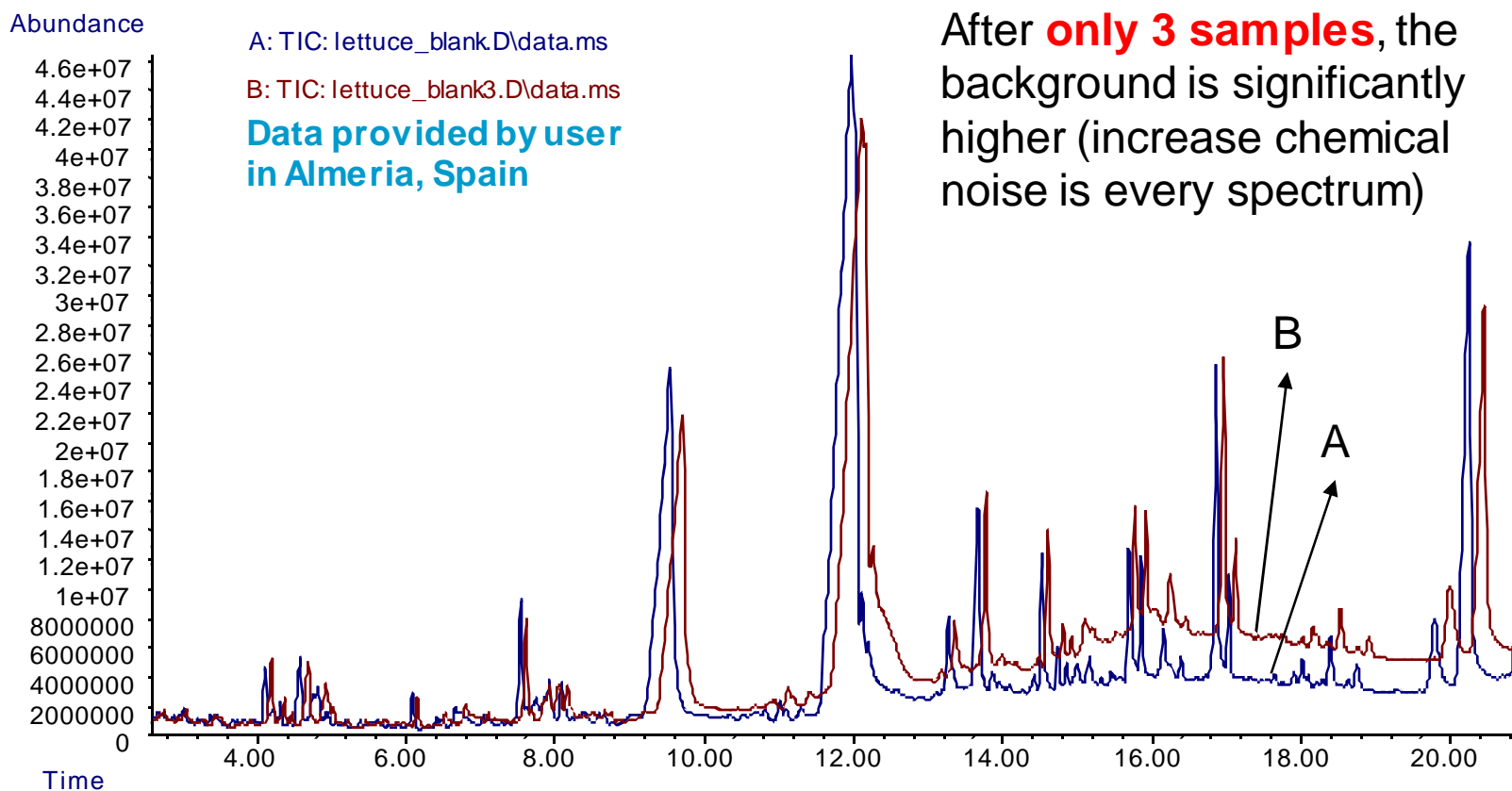


Standard column



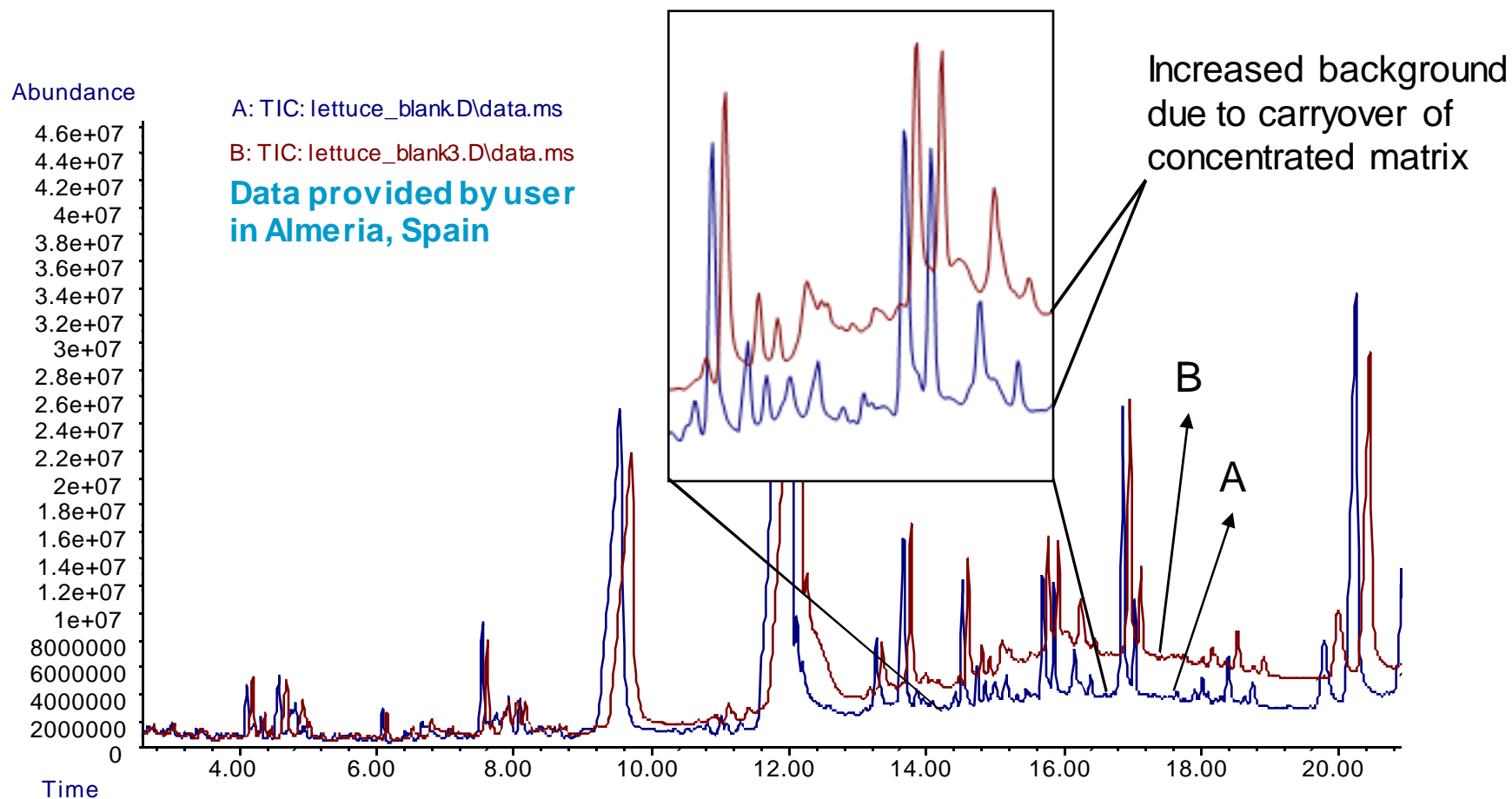
CLP Pesticides Analysis

Without Backflush: Increased Chemical Background (Spectral Noise) and Changes in Retention Time



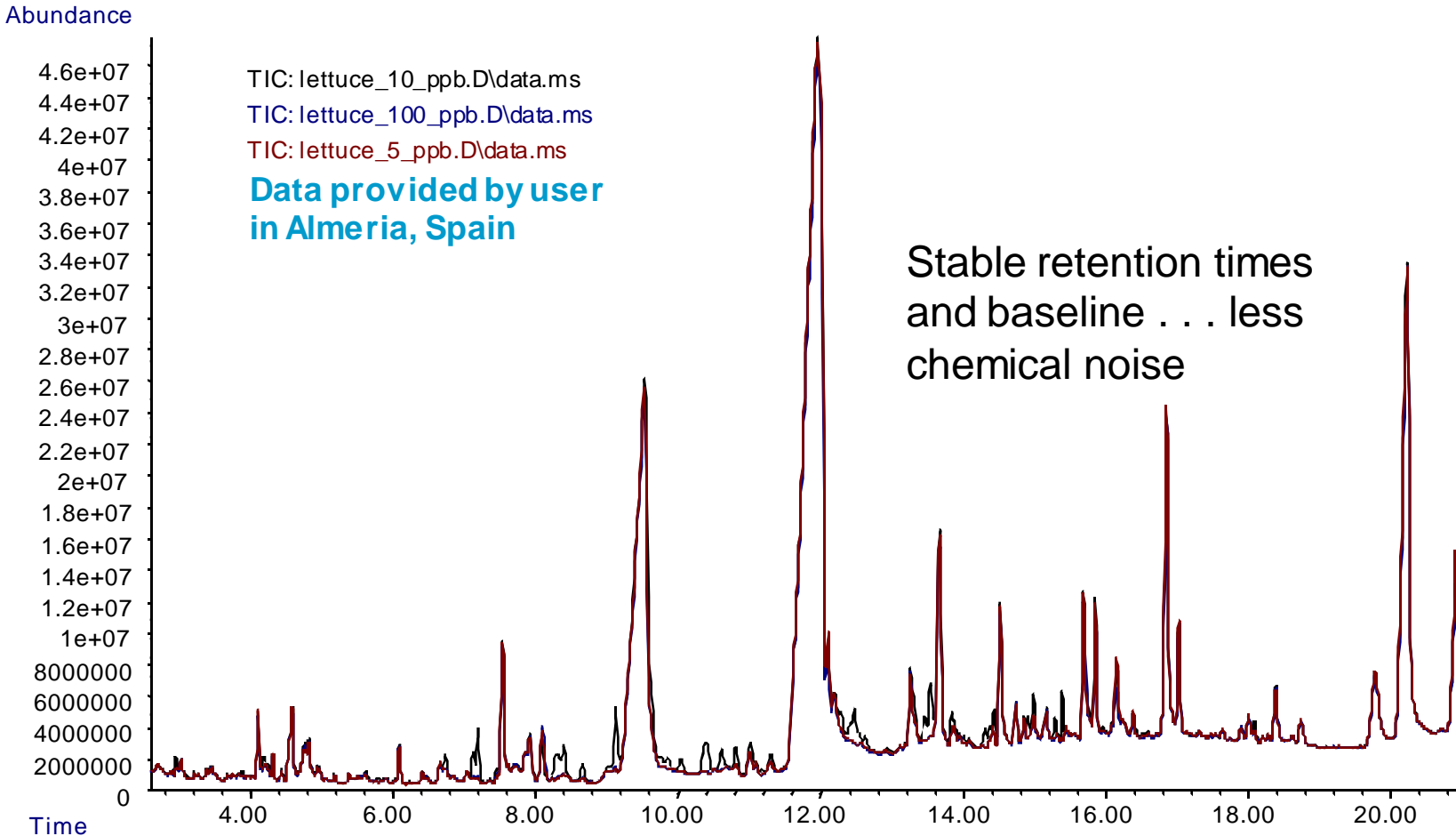
Overlay of two chromatograms of a blank extract injected BEFORE (A) and AFTER (B) three injections without backflush

Without Backflush: Increased Chemical Background (Spectral Noise) and Changes in Retention Time



Overlay of two chromatograms of a blank extract injected BEFORE (A) and AFTER (B) three injections without backflush

With Backflush: No Increased Chemical Background (Spectral Noise) and No Change in Retention Time



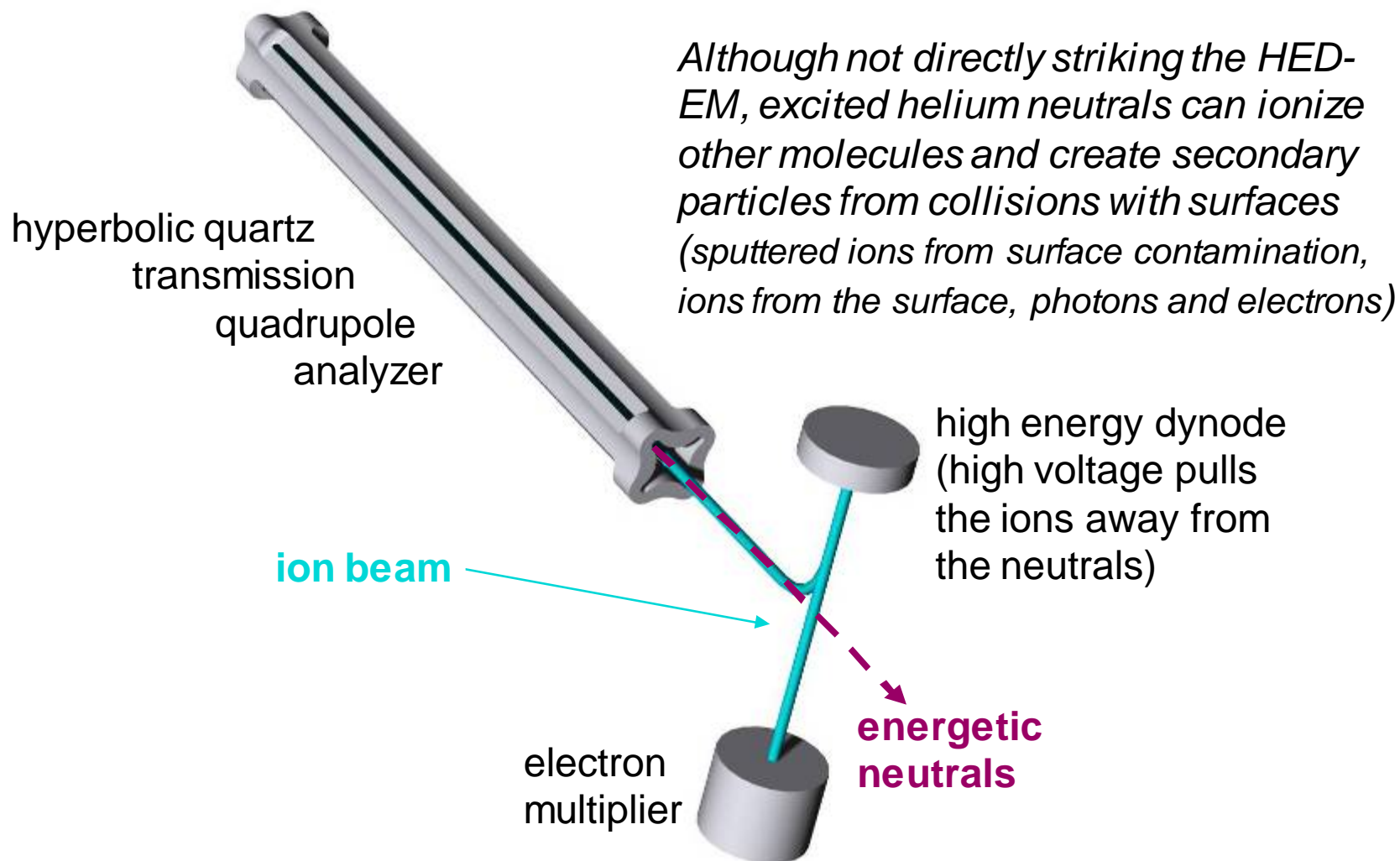
Overlay of three chromatograms of lettuce extract run with 2 min of back flush

Benefits of Backflushing

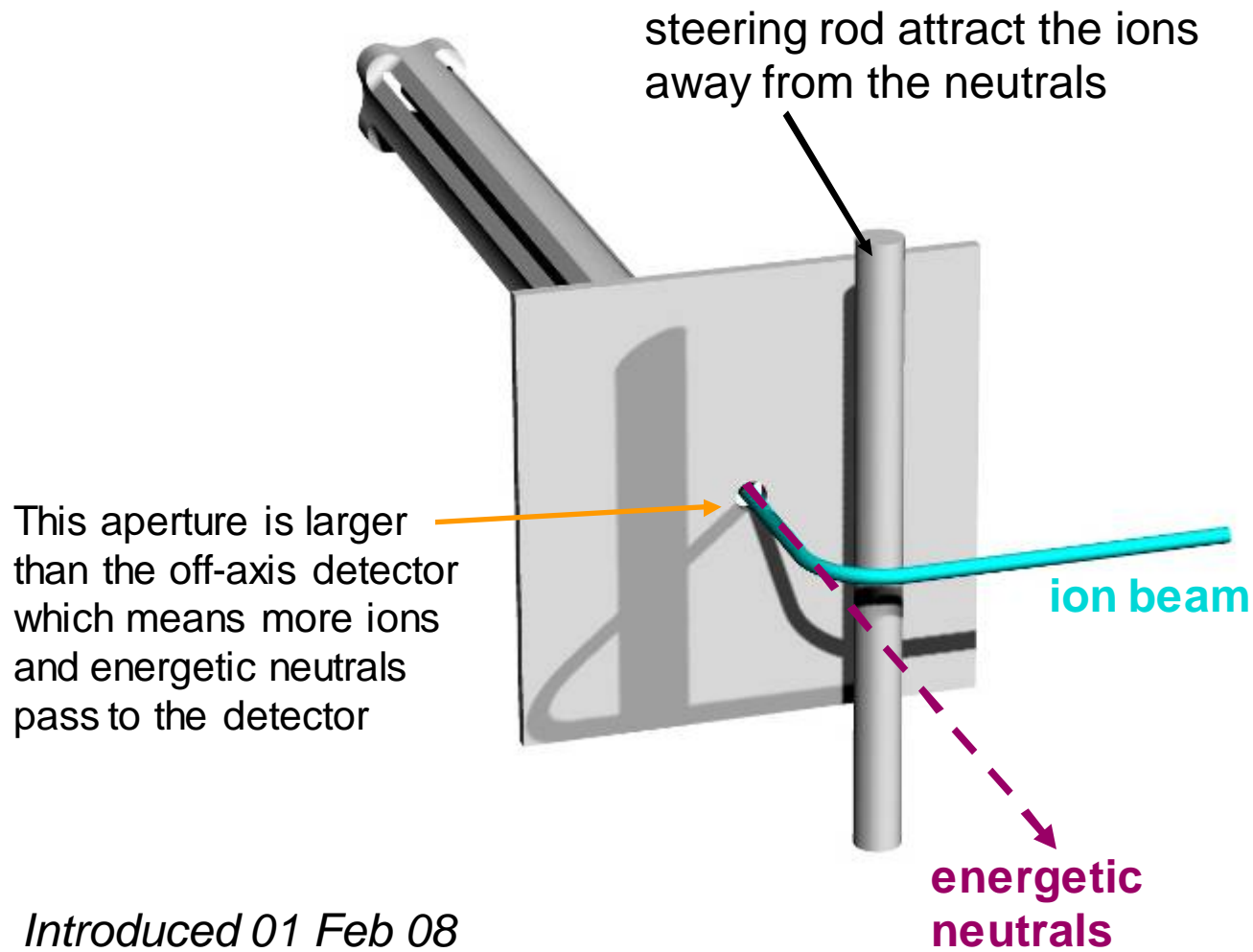
- More samples per day per instrument
- Longer column life
- Lower operating costs
- Less frequent and faster GC & MSD maintenance
- **Less chemical background**
 - More consistent retention times
 - More consistent baselines
 - Higher quality spectra (no increase in noise during analysis sequence)
 - Higher quality quantitation (no increase in interfering ions during analysis sequence)



Conventional Off-Axis Detector



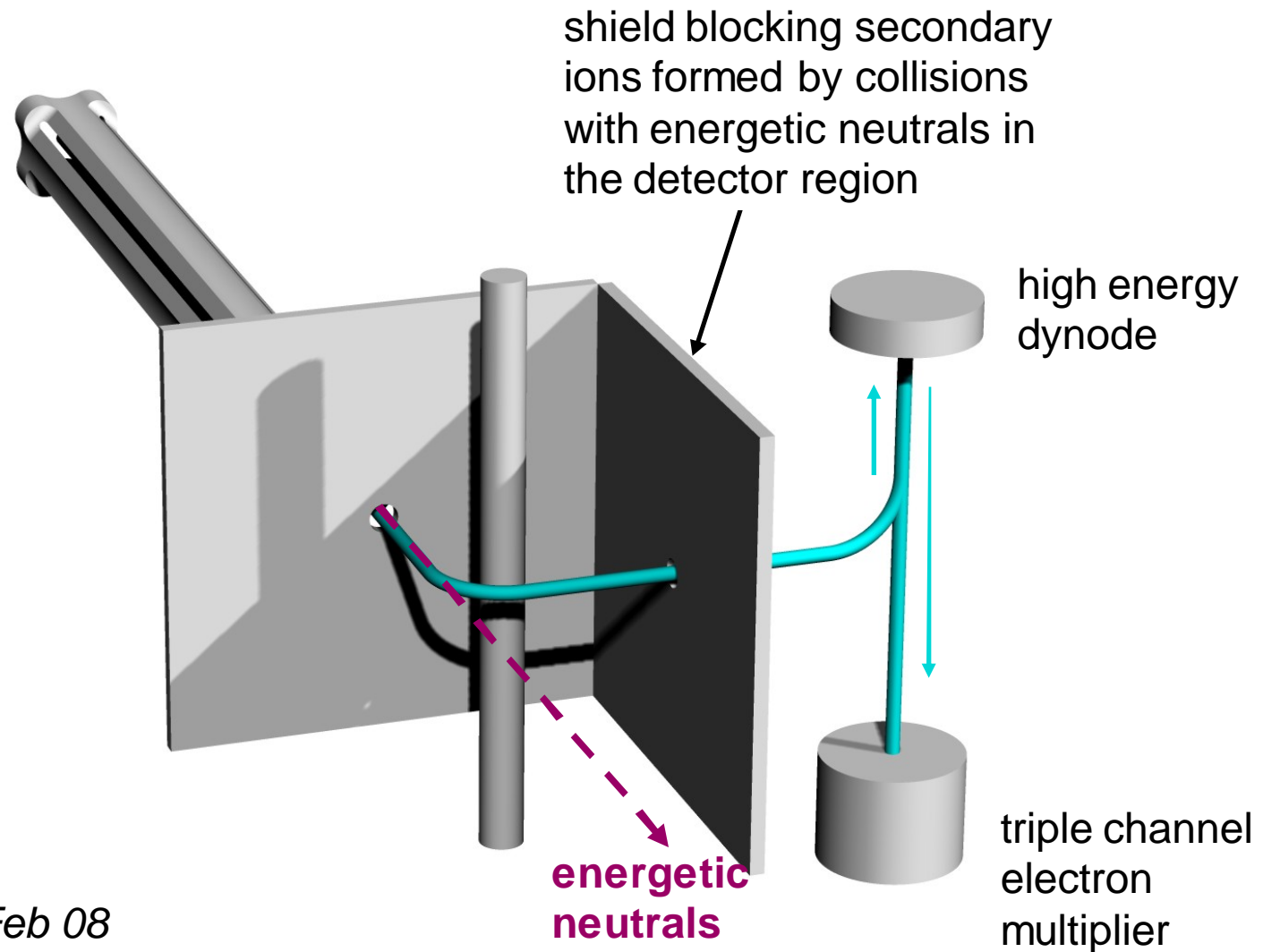
Triple-Axis Detector



Introduced 01 Feb 08



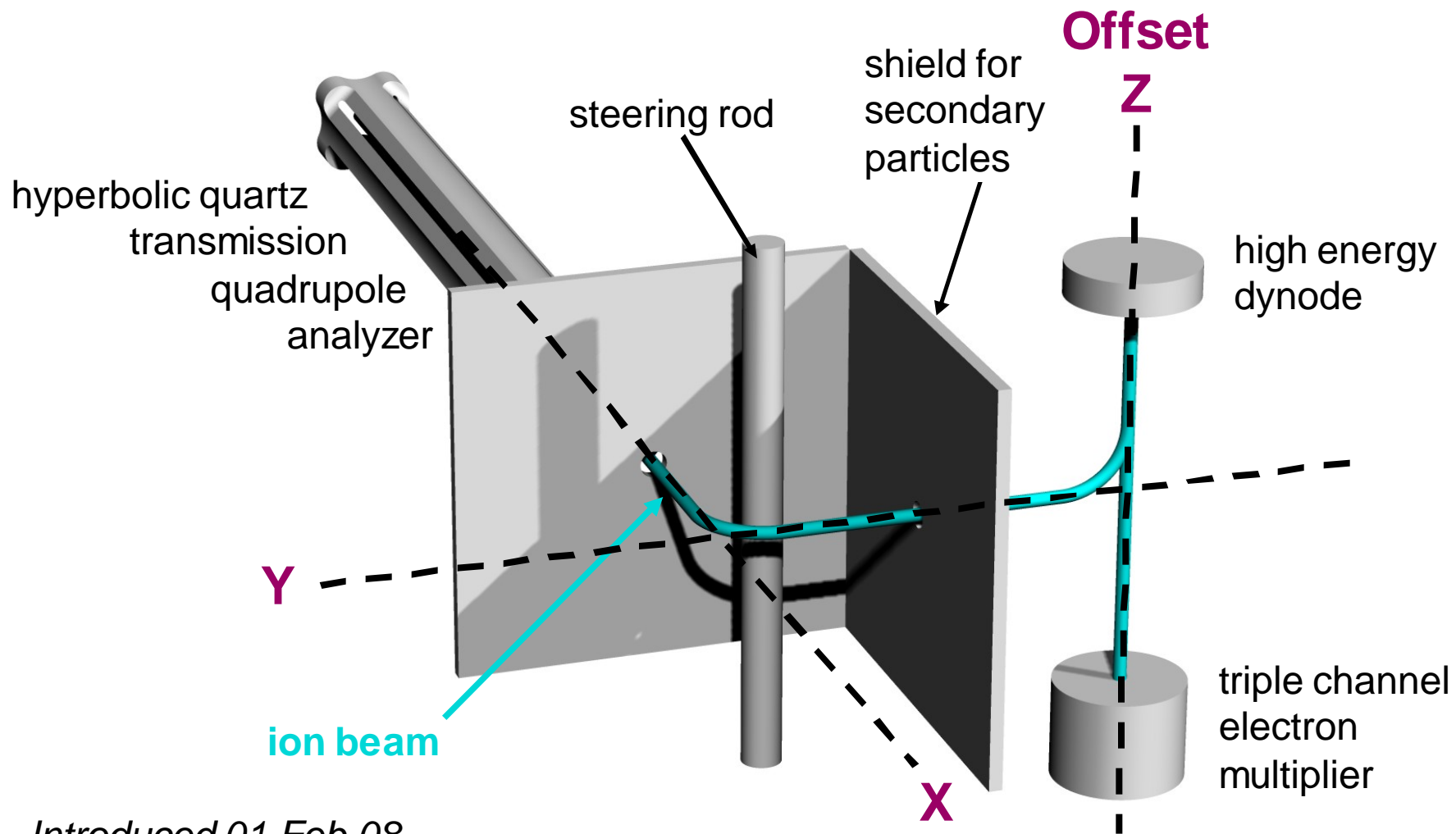
Triple-Axis Detector



Introduced 01 Feb 08



Triple-Axis Detector



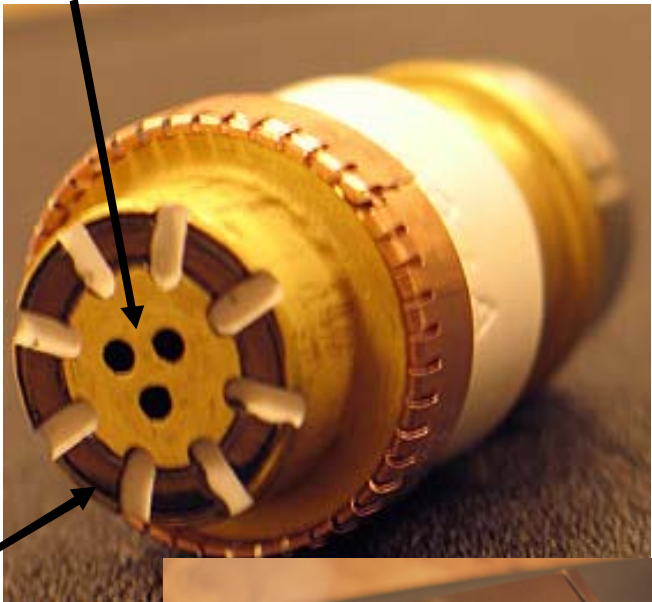
Introduced 01 Feb 08



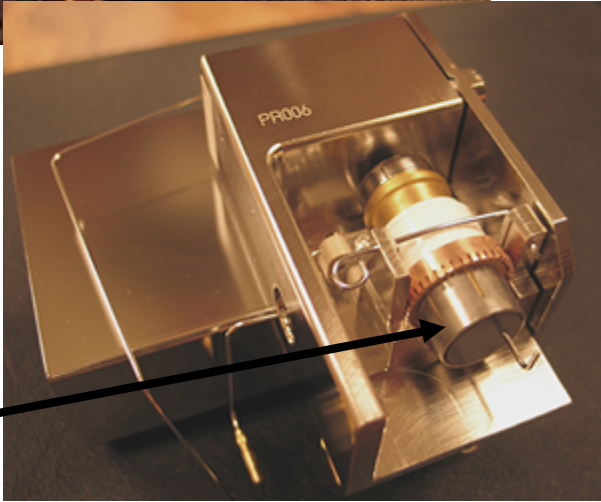
Triple Channel EM

Triple channels improve signal
Triple channels increase life

Exit of the triple channels



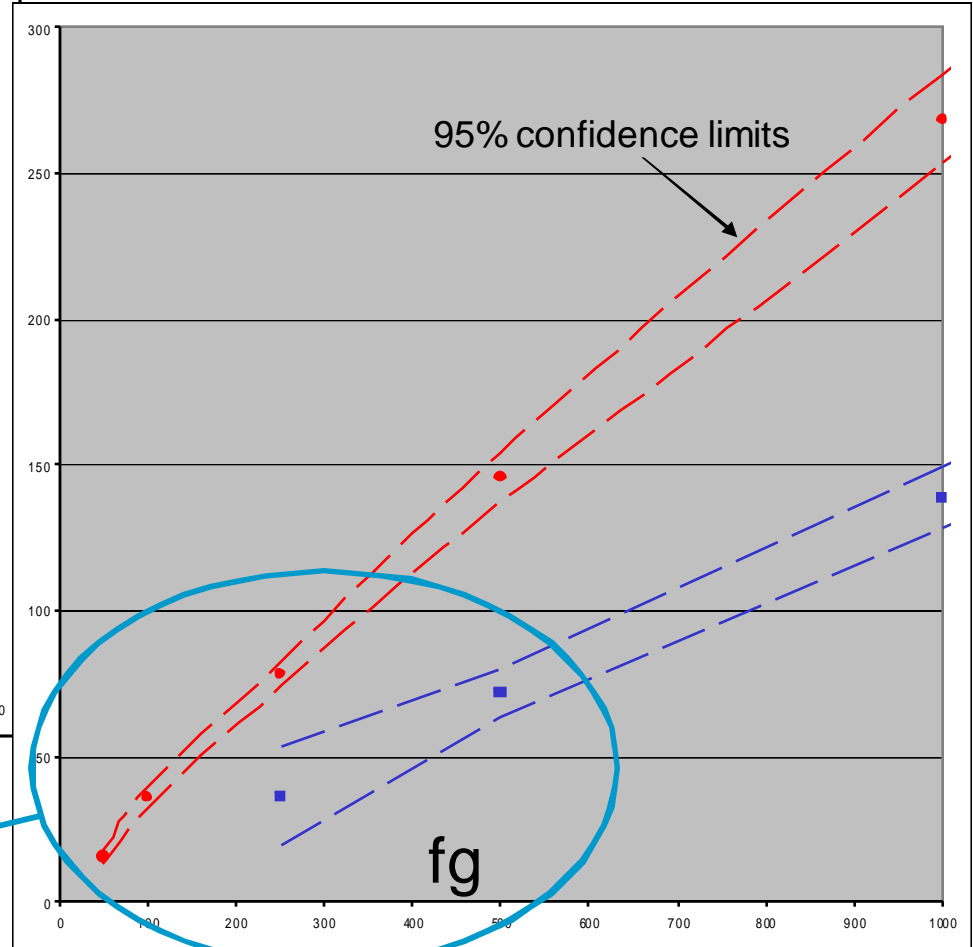
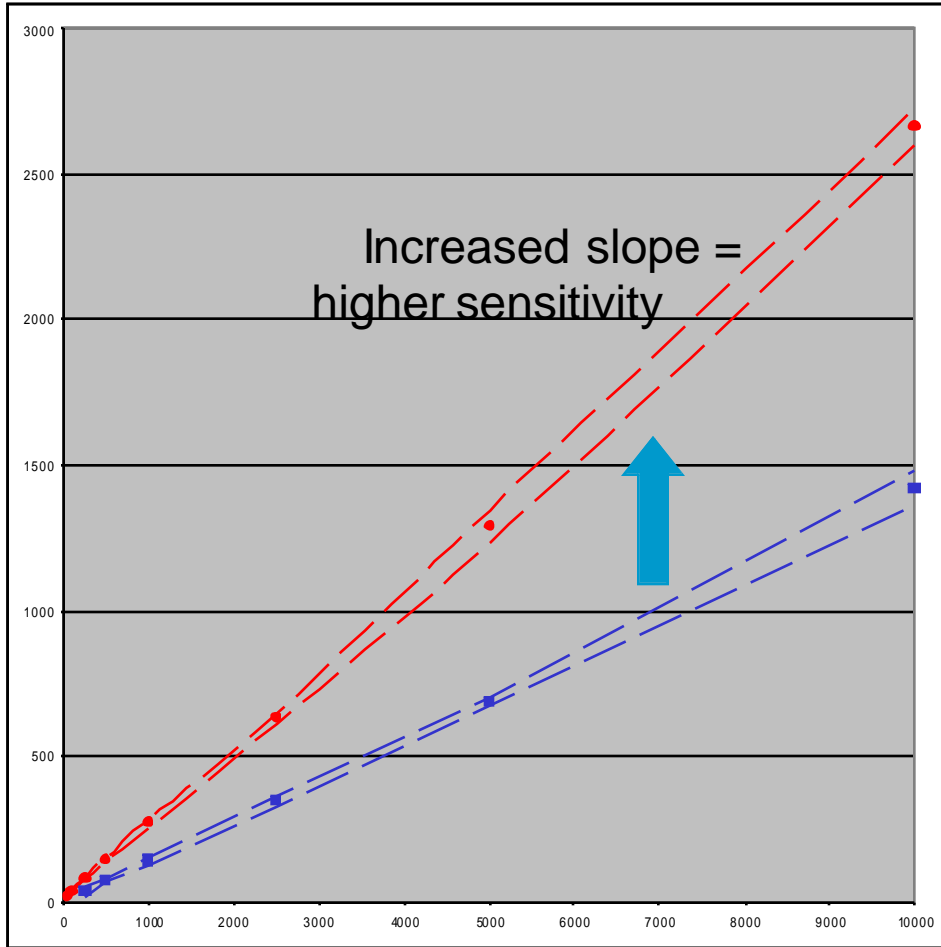
Collector removed to show exit passages



Collector

Introduced 01 Feb 08

Triple-Axis Detector: Higher Signal – Lower MDL



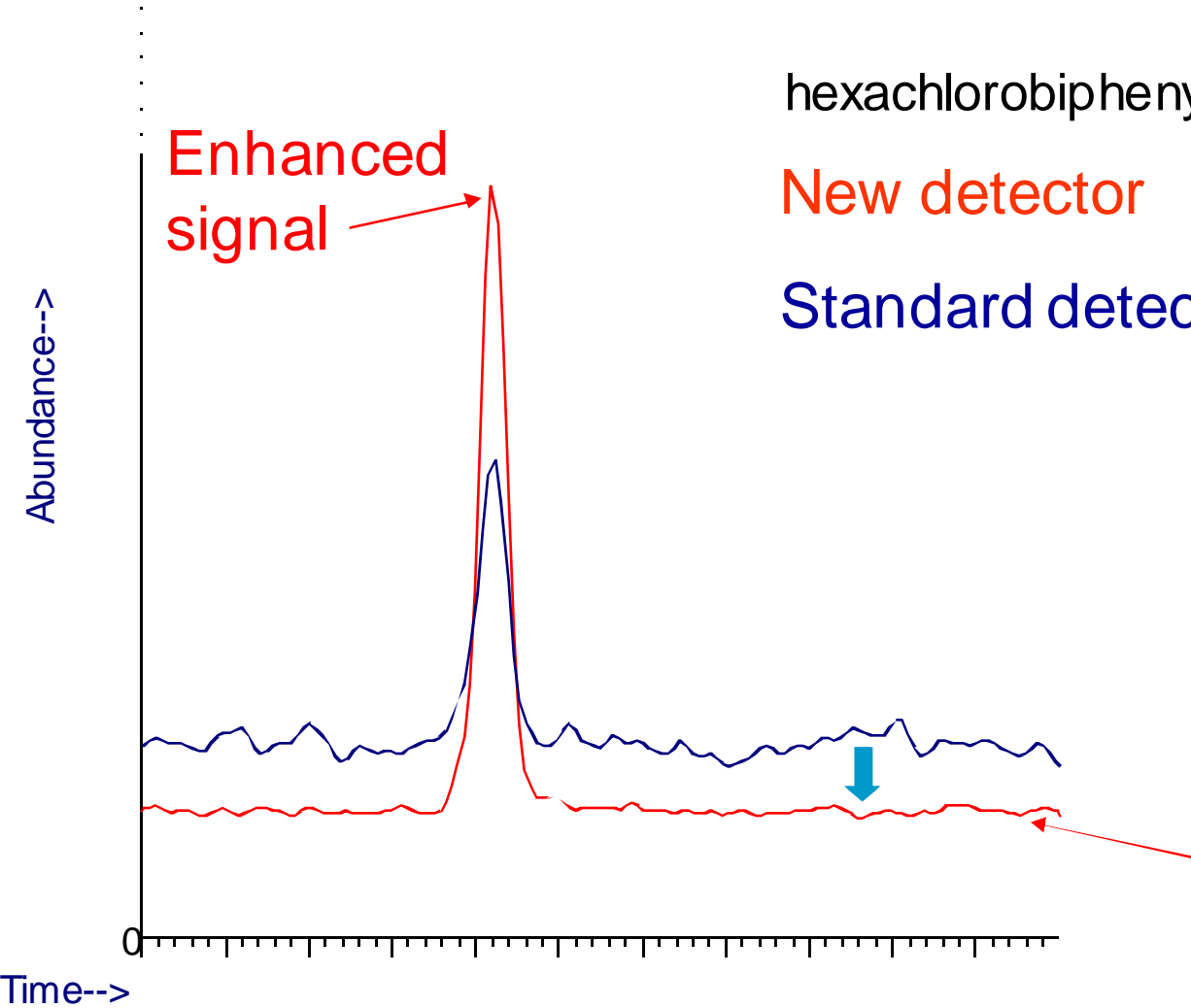
Improved detection limits!

New Detector for Enhanced EI Sensitivity!

hexachlorobiphenyl @ 250 fg

New detector S/N-rms: 250

Standard detector S/N-rms: 35

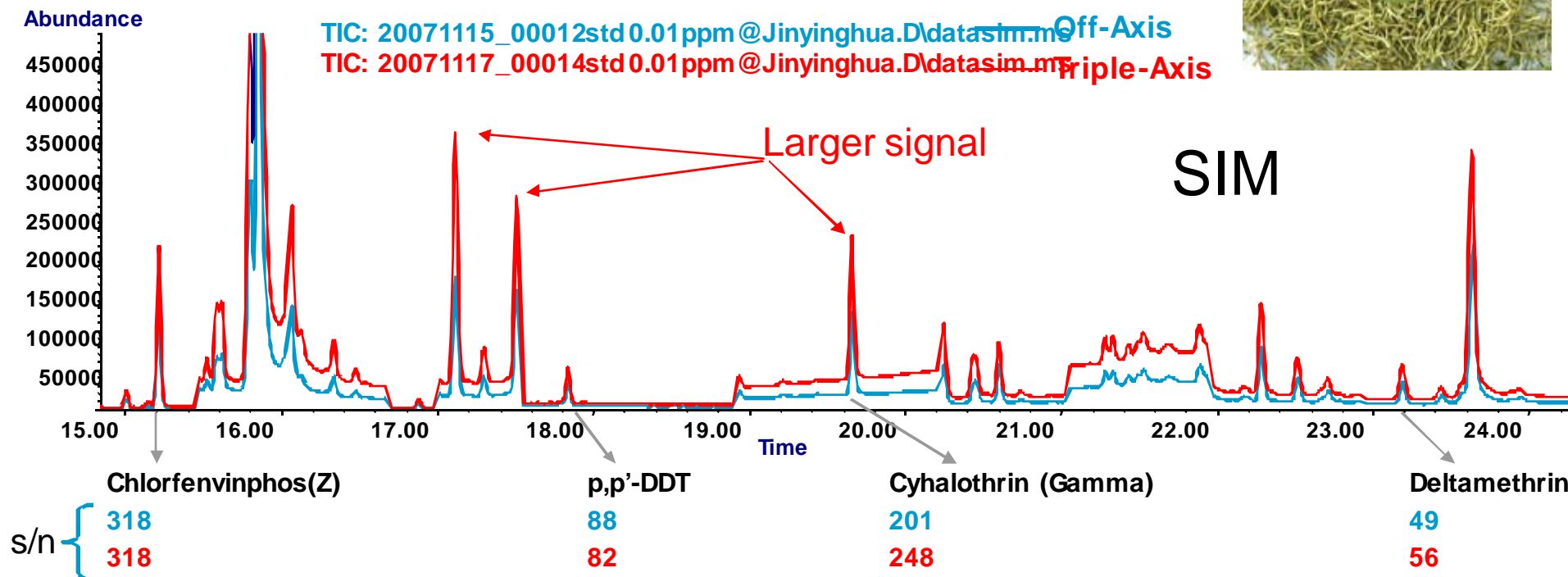


New 1 pg OFN specification:
400:1 for turbo pumps
200:1 for diffusion pump

Reduced
neutral noise

What about Chemical Noise Limited Baselines?

10-ppb standard in Jin Ying Hua extract



Comparable S/N in complex matrices..... Why?

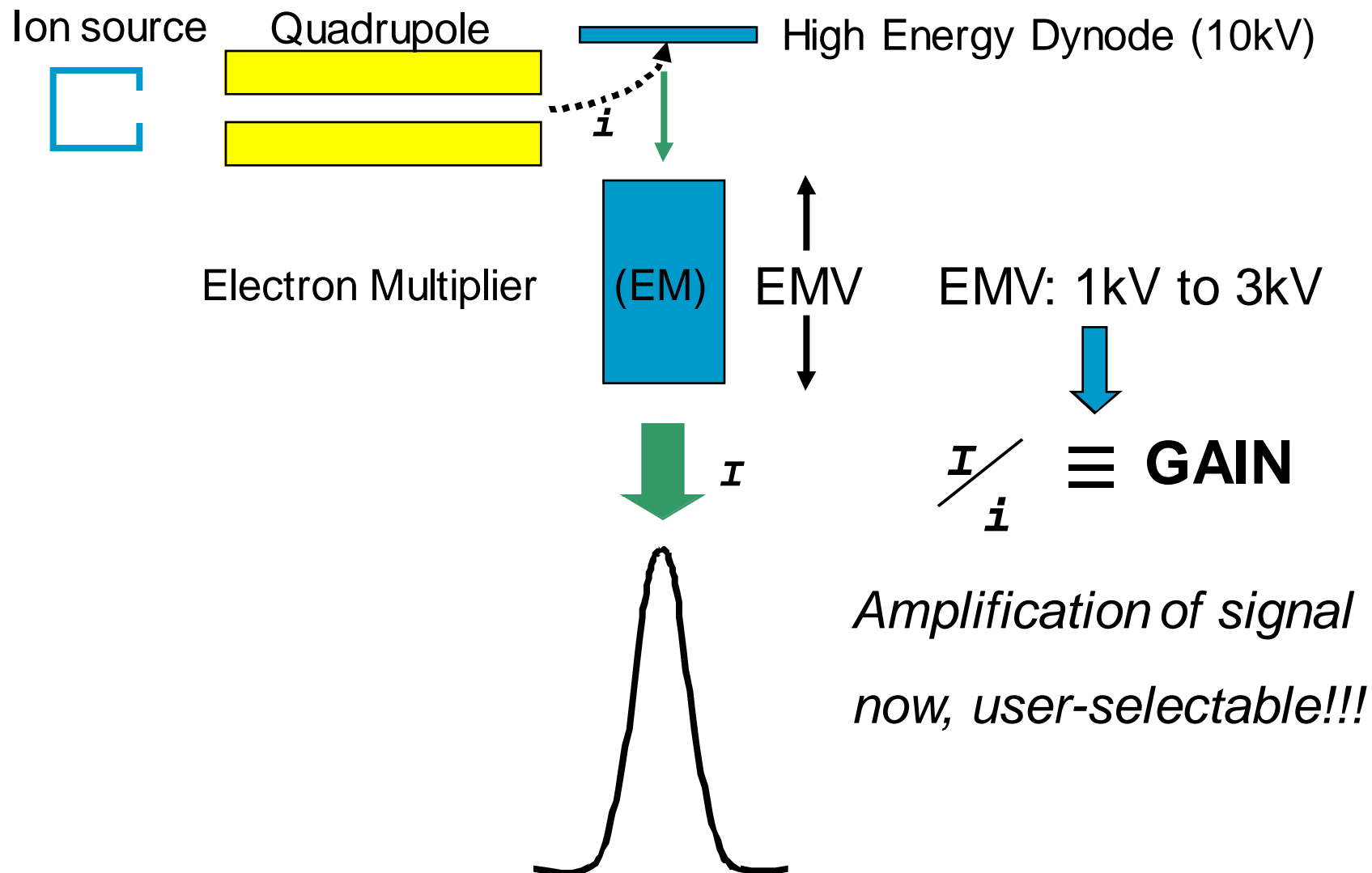
All ions (analytes and matrix peaks) will be amplified.

Triple-Axis Detector eliminates “neutral noise”, not matrix “chemical noise”

But increased signal will always improve ion statistics and integration



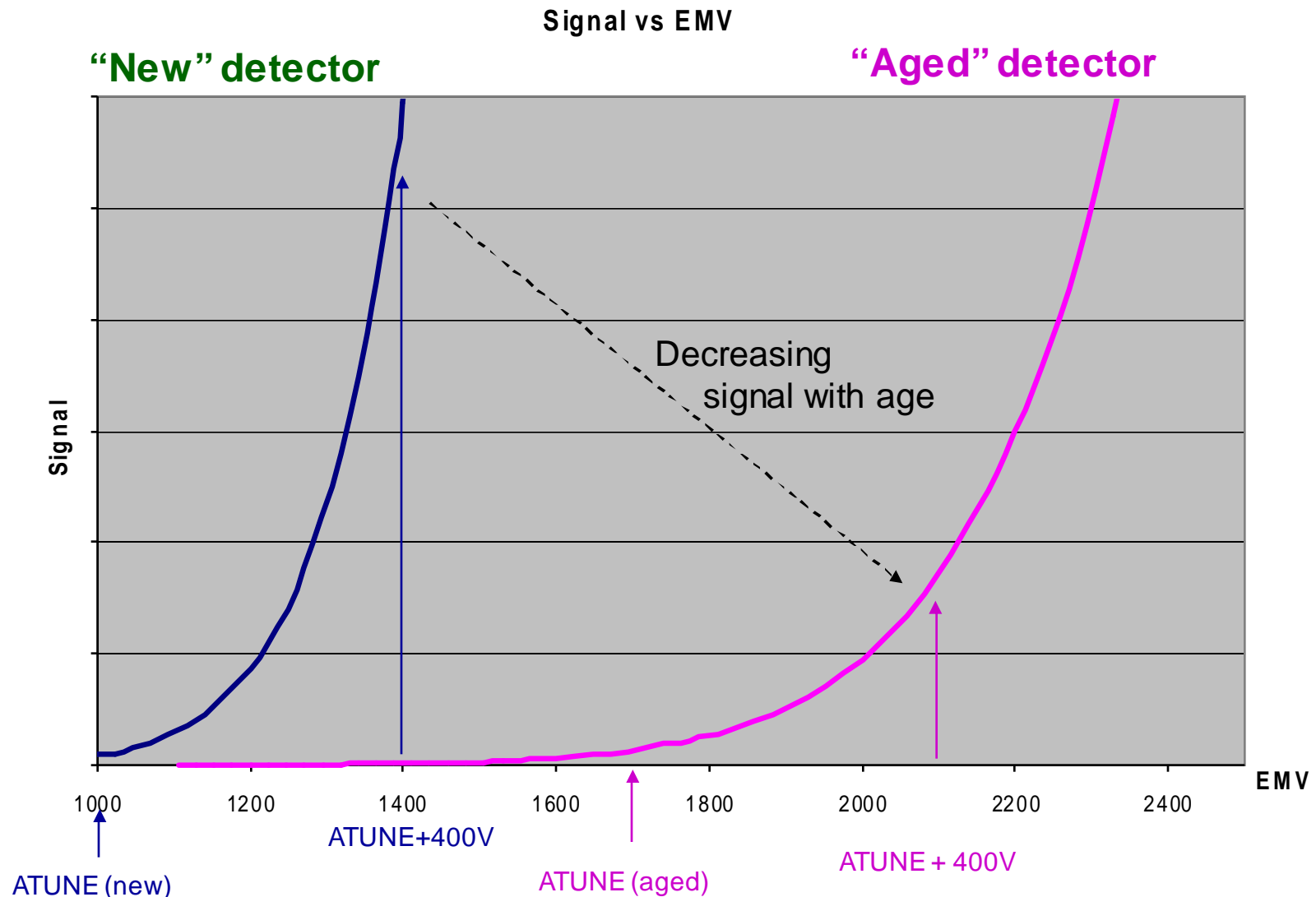
Gain Normalized Optimization of the EM



Disadvantage of *ATUNE + nV*

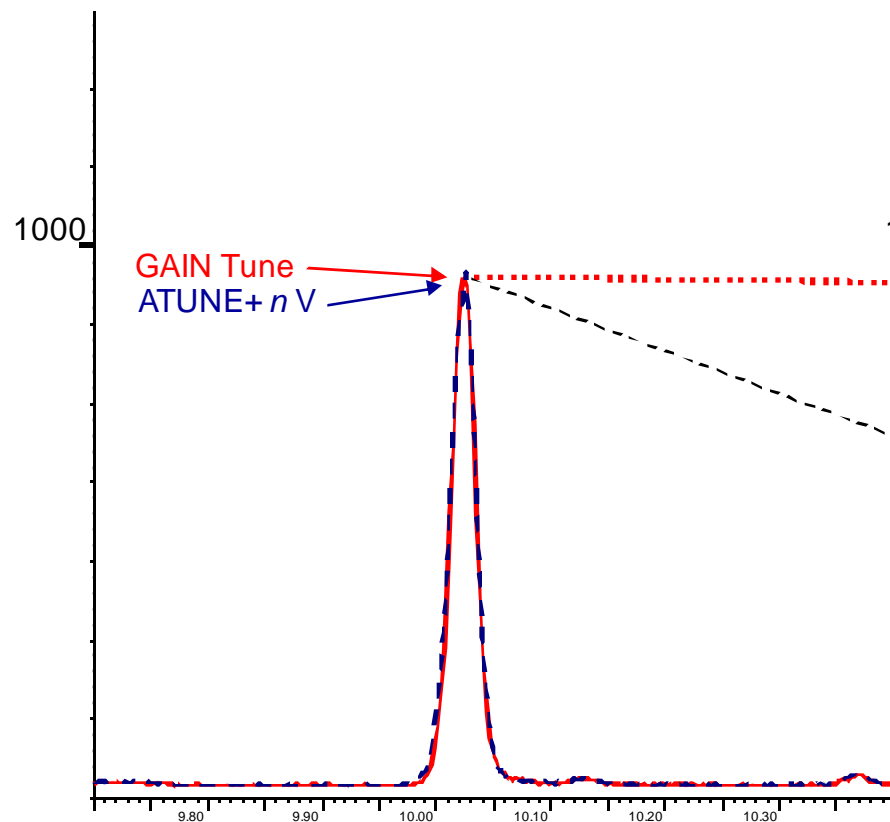


Detectors “age” over use: the same EMV setting will not give the same signal!

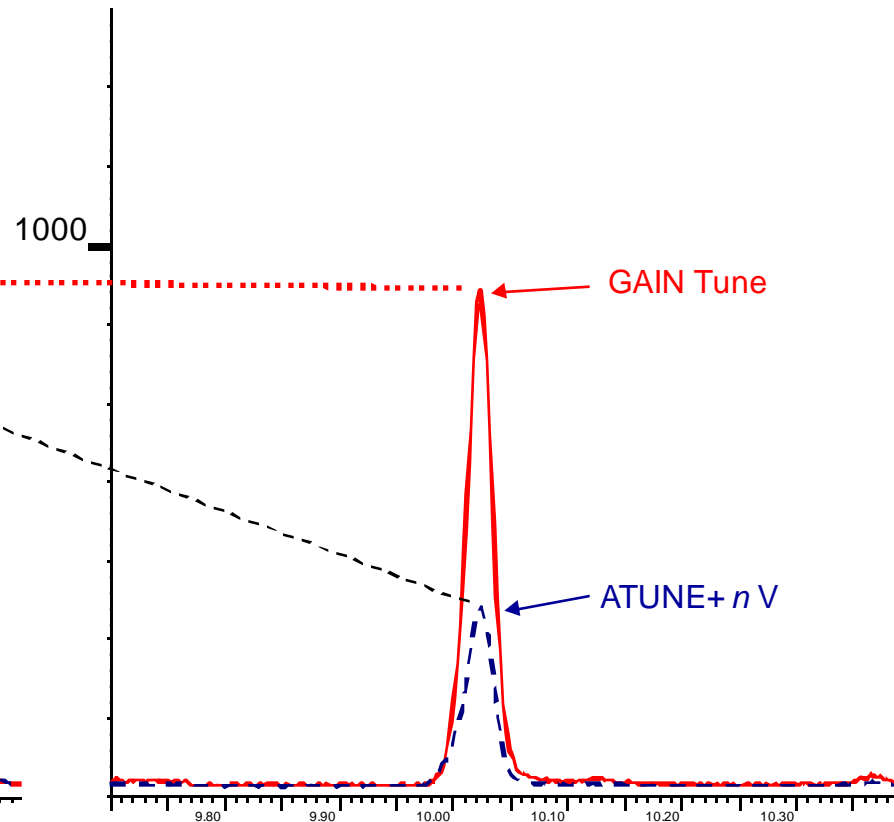


New Gain Normalized Methods

“New”



“Aged”

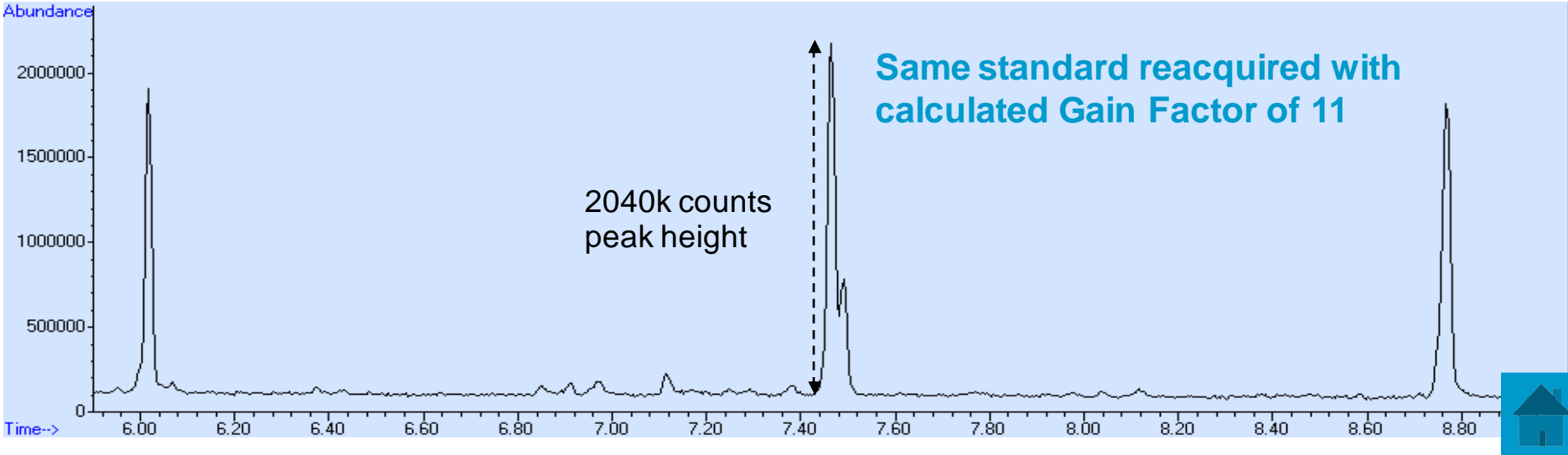
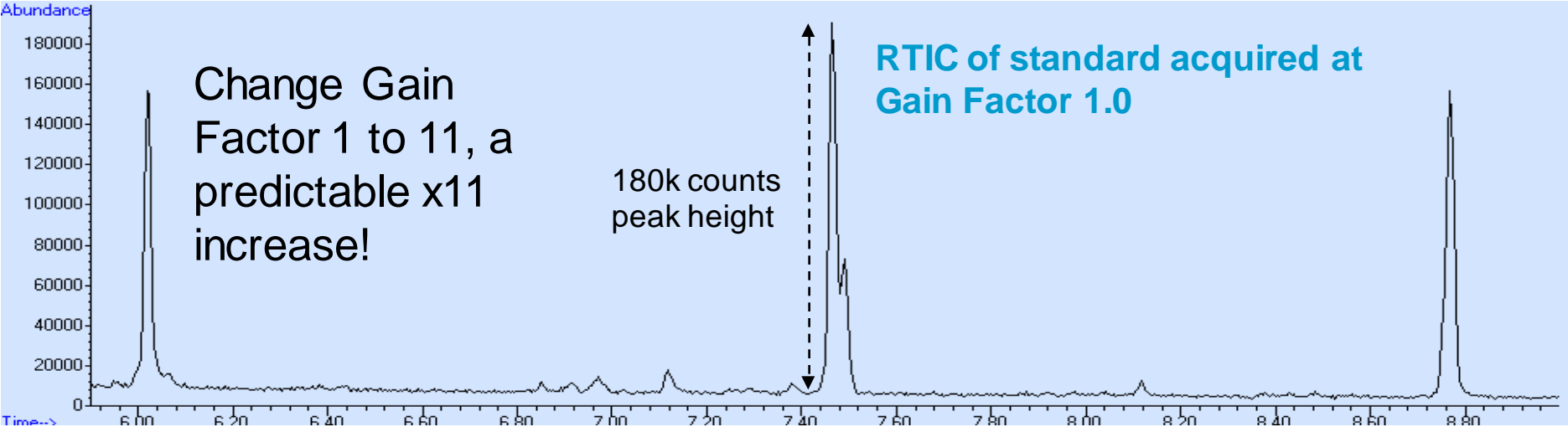


Consistent sensitivity over the life of the electron multiplier!
Consistent sensitivity from MSD to MSD and lab to lab!



Using Gain Factor for Method Optimization

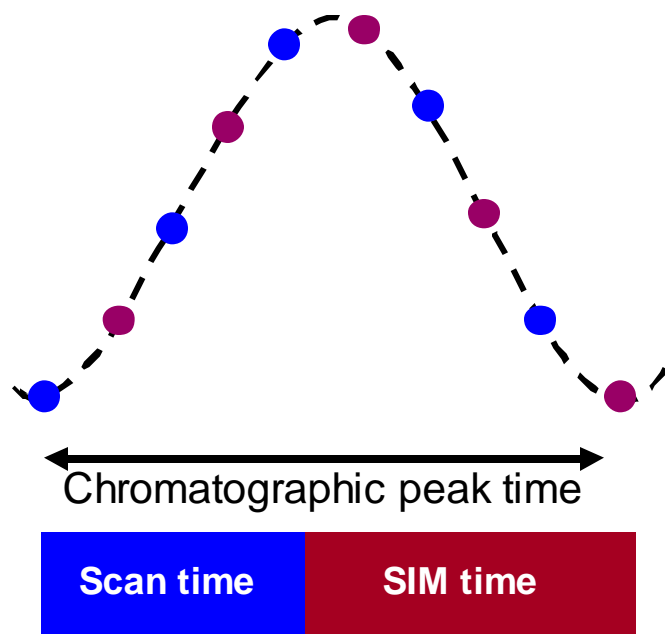
Change (Atune + 200V) to (Atune + 400 V) – How much increase?



Fast Electronics

Fast electronics allow SIM and Scan data in a single run

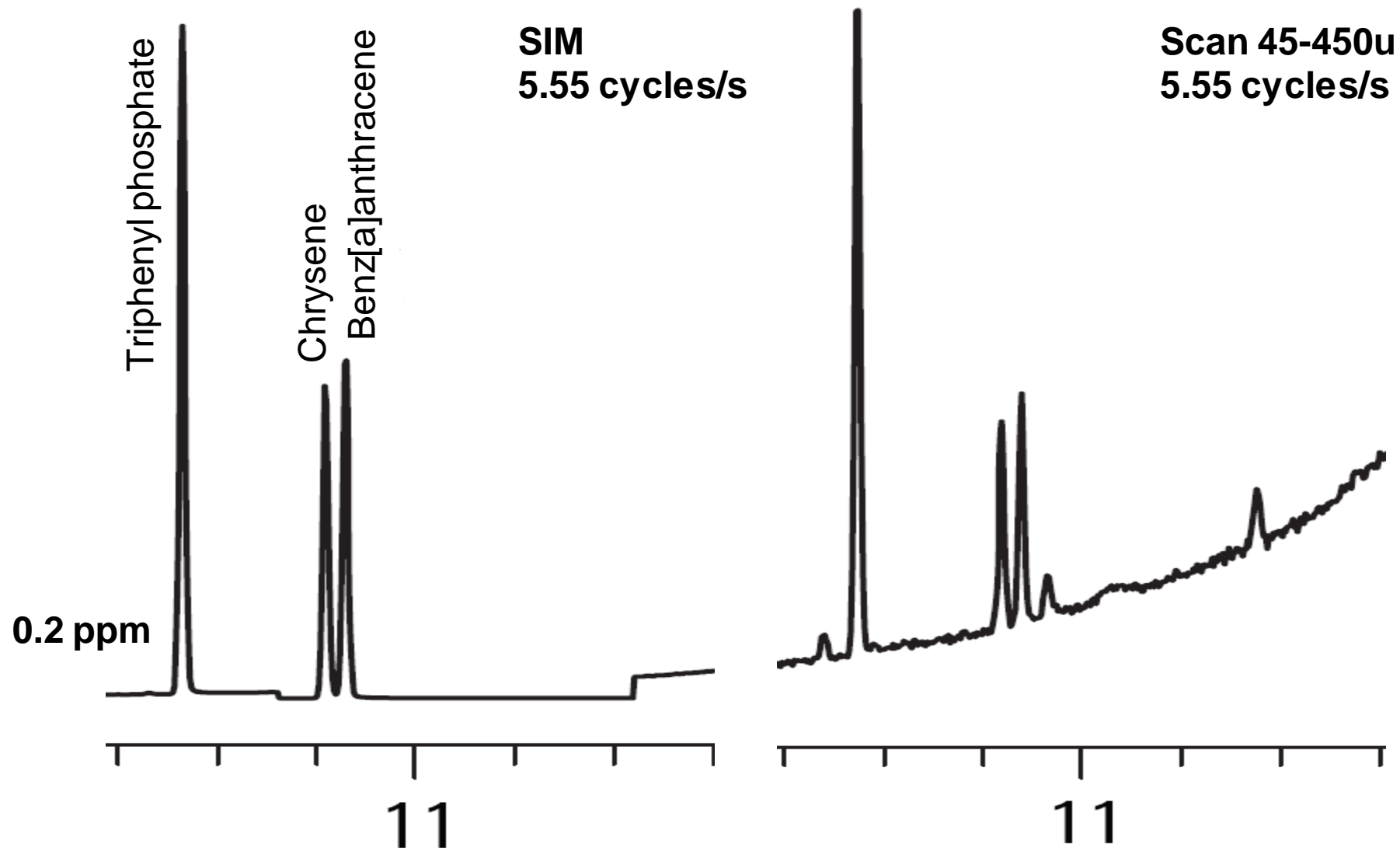
- **SIM** = maximum sensitivity for target compounds
- **Scan** = best identification of unknowns



- Scan data points
- SIM data points

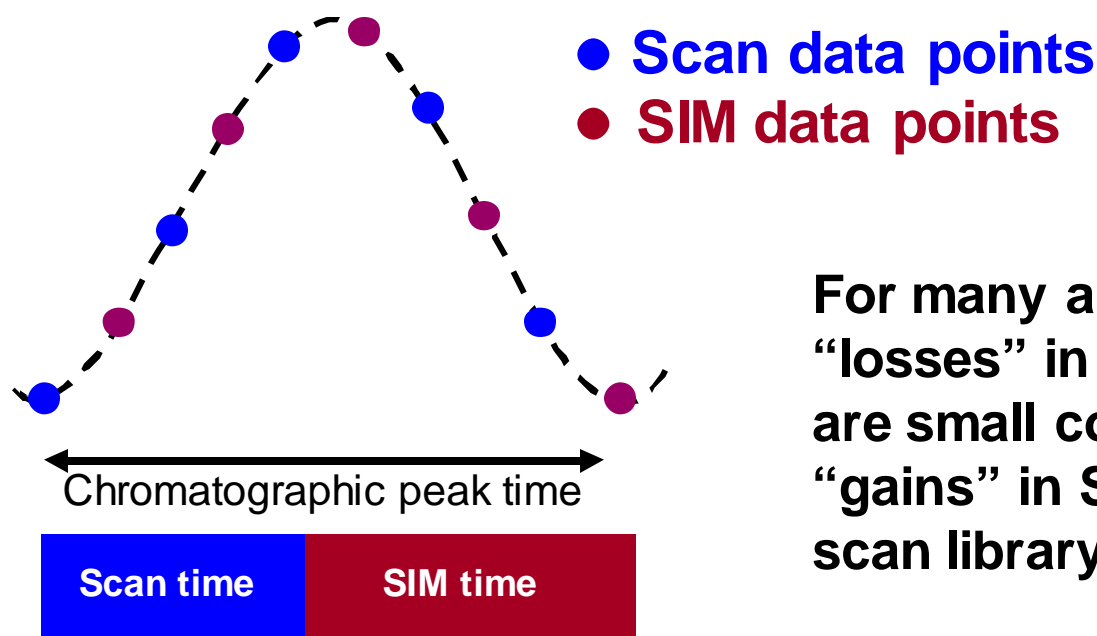
... more information from a single run

Synchronous SIM/Scan Comparison of PAHs



Synchronous SIM/Scan

- Under-sampling the peak (slow data rate) decreases area precision
 - 6 samples/peak width for area; 8 samples/peak width for height
- Shorter dwell time decrease SIM S/N slightly
- Faster scan rates decrease scan S/N slightly



For many applications . . . the “losses” in precision and S/N are small compared to the “gains” in SIM sensitivity and scan library searches

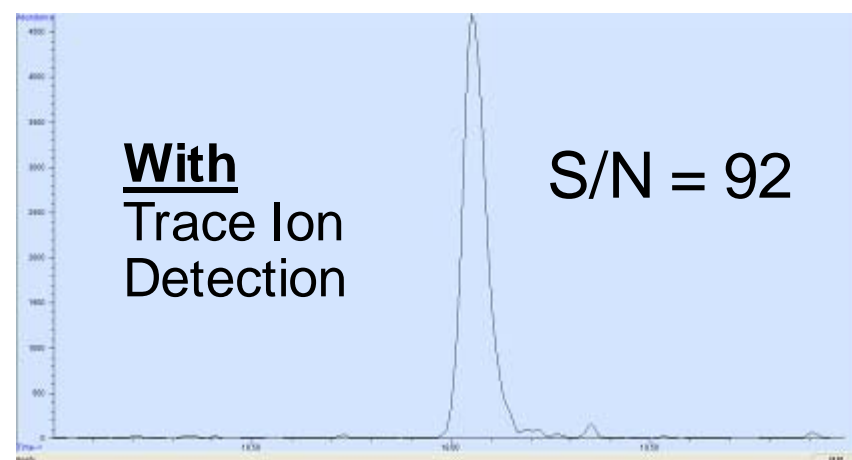
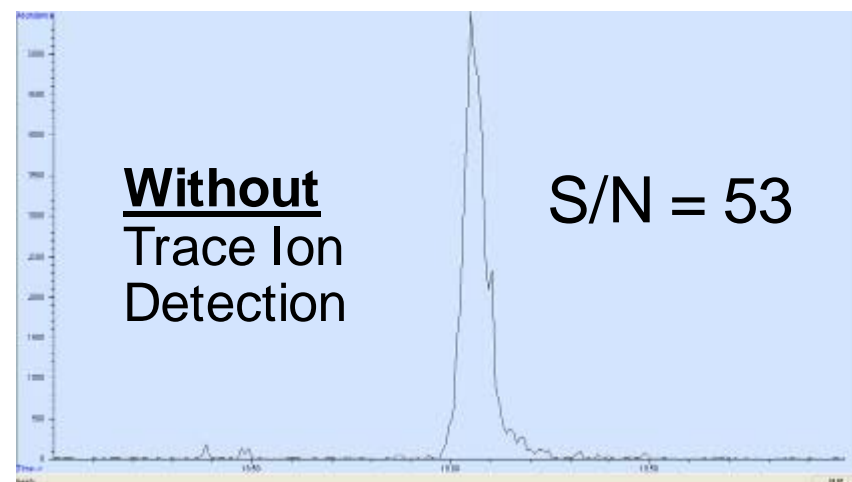


Trace Ion Detection Technology

Agilent proprietary algorithm

- Reduced noise level
- Improved peak shape
 - Especially under-sampled peaks
- Improved library match

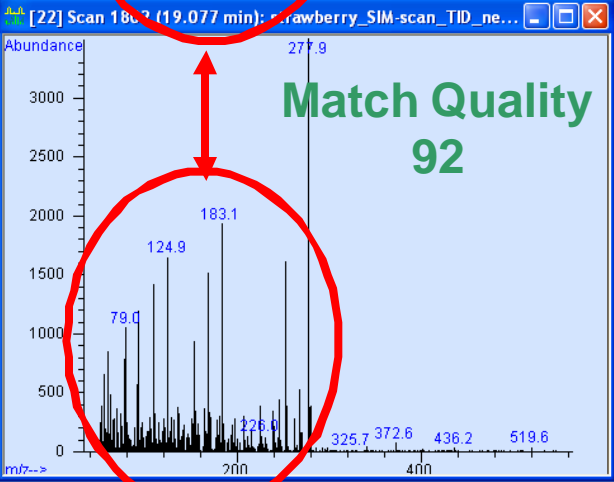
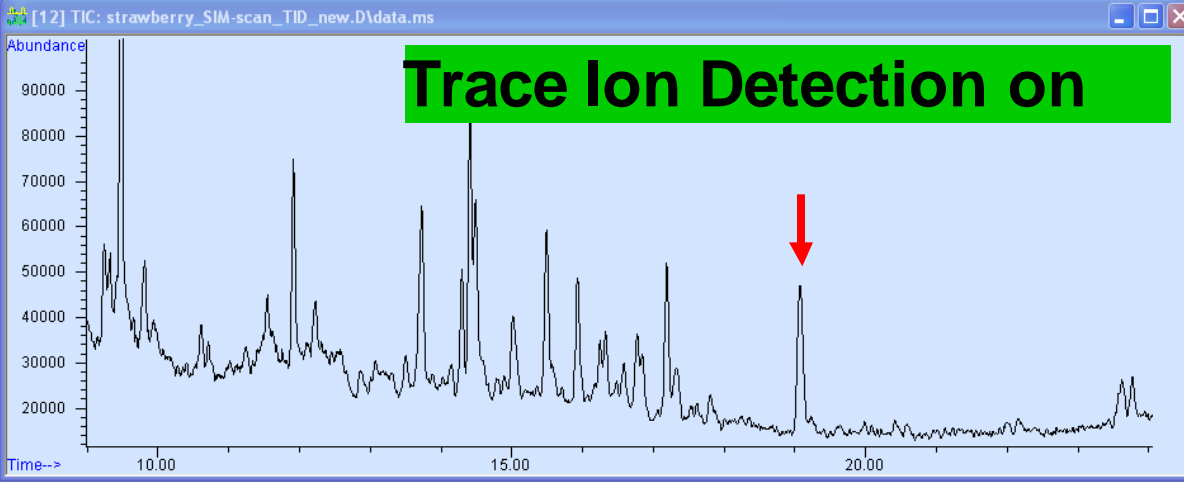
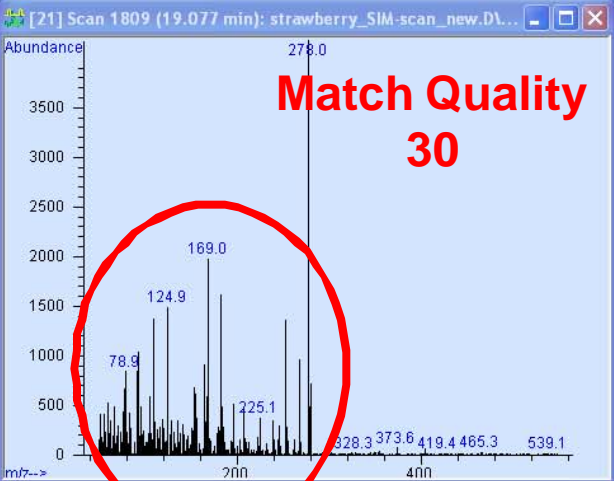
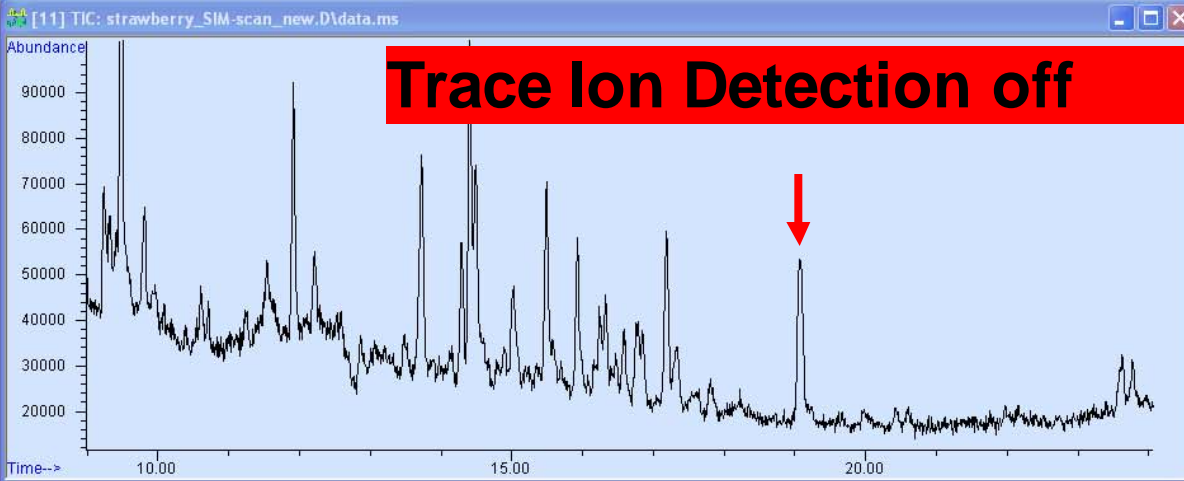
Default “OFF” in the ChemStation



... better detection at trace levels

Improve Library Match Quality

Fenthion in strawberry extract



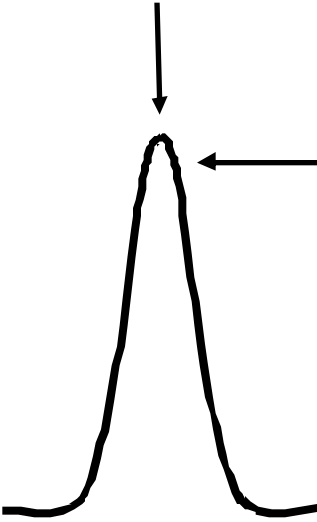
NIST AMDIS Background

- AMDIS: Automated Mass Spectral Deconvolution and Identification Software
 - G. Mallard, S. Stein, O. Toropov, NIST
- Originally developed for detection of chemical weapons in complex mixtures (environmental samples, process streams)
 - Designed to work without analyst input
- Agilent DRS Revision A.01, March 2004
- AMDIS 2.64 released December 2005 (noise reduction)
- **Agilent DRS Revision A.04, February 2008**
 - Integrated into QEdit for qual, quant, manual integration and reports
 - Truly a new, second generation product for deconvolution reporting

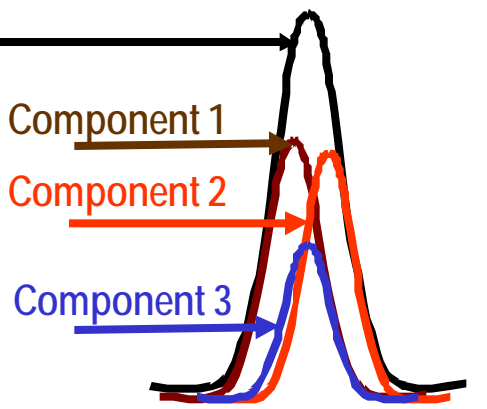


Deconvolution: Use Difference in Spectra, Retention Time and Peak Shape to Separate Coeluting Peaks

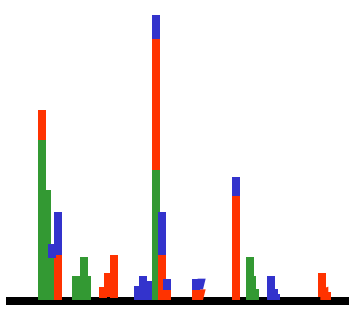
Peak detected with Trace Ion Detection



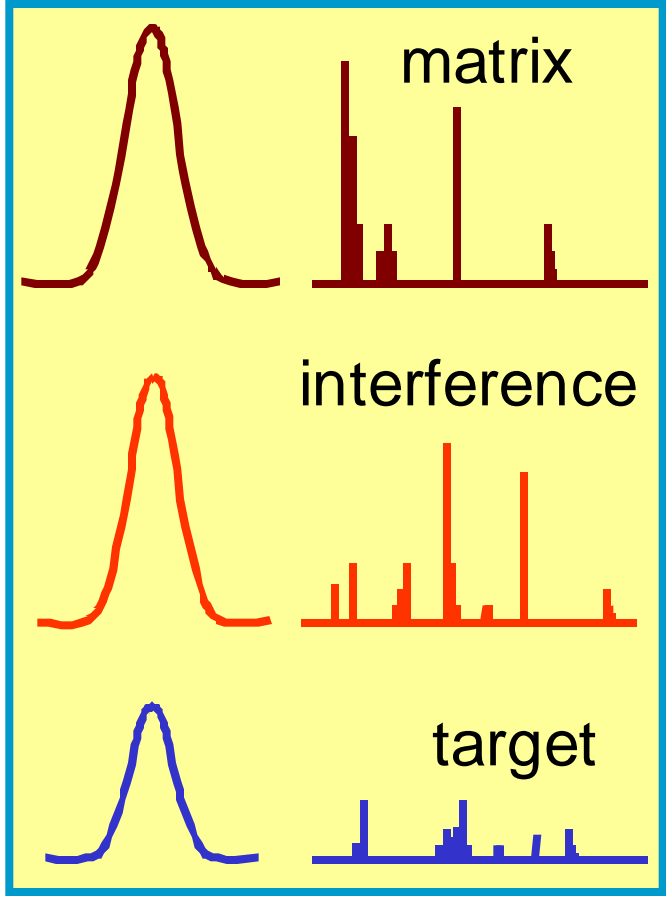
TIC & Spectrum



Deconvolution



Deconvoluted peaks and spectra



AMDIS Automatically Purifies Spectra by:



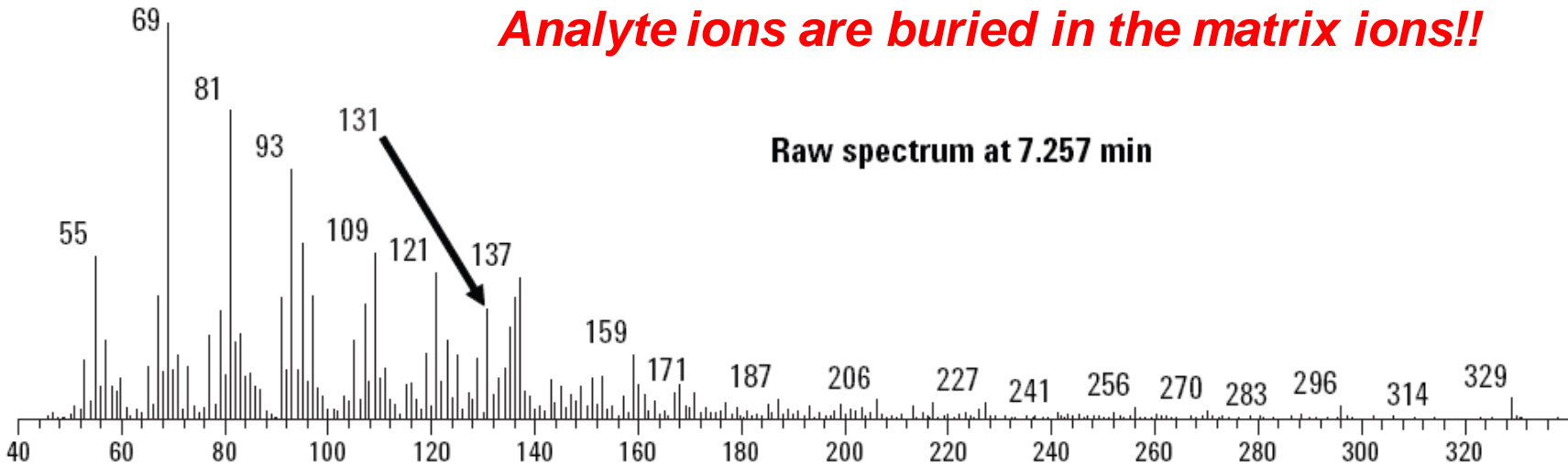
- True deconvolution
 - Even if no available background for subtraction
- Detailed treatment of noise
 - Complete noise analysis; used for component perception
- Correction for baseline drift
 - Flat baselines not required; determines baselines for each m/z
- Corrects for spectral skewing in spectra
 - Distortion generated by concentration change during scan period
- Extracts closely coeluting peaks
 - Separates components that have peak apexes with a single scan

*Power of
modern PCs
and matrix
mathematics*

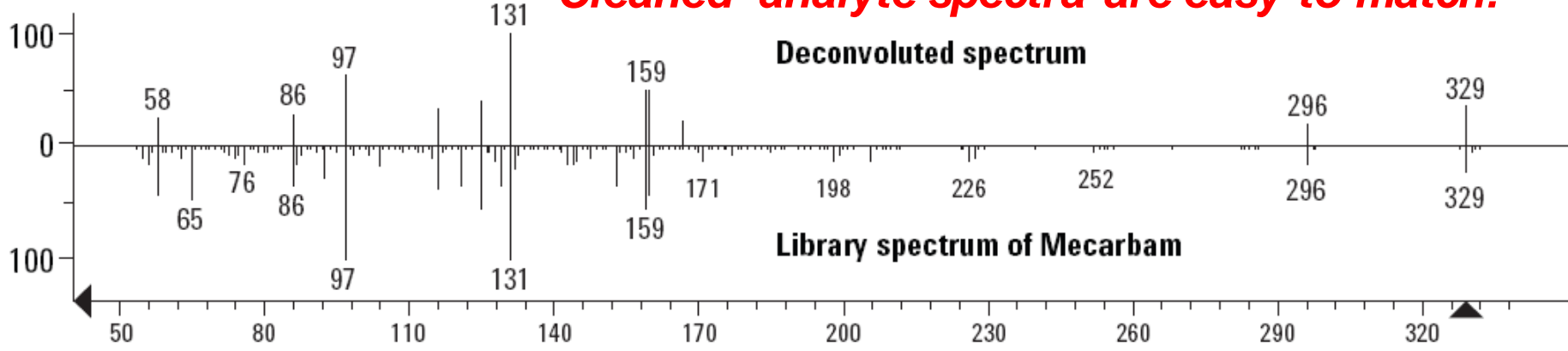


AMDIS: Pulling a Useable Spectrum Out of a Mess

Analyte ions are buried in the matrix ions!!



'Cleaned' analyte spectra are easy to match!



17 Surface Water Data Files: Pesticide Analysis

	*CDFA	Agilent DRS
Targets Found	37	Same 37 + 99 additional
False Positives	1	0
Processing Time	~ 8 hours	32 minutes

Save about 7.5 hours to do other jobs

*CDFA is the California Department of Food and Agriculture
Data files courtesy of Dr. Mark Lee and Steve Siegel



The Power of DRS: Detect the Undetected

MSD Deconvolution Report

Sample Name: + 400 ppb ISTDs, 25 µL PTV
Data File: C:\MSDCHEM\TDATA\SPINACH.D
Date/Time: 11:23:10 AM Monday, Apr 5 2004

The NIST library was searched for the components that were found in the AMDIS target library.

RT	Obs #	Compound Name	Ag len. ChemStation Amount (ng)	AMDIS		NIST	
				Match	RT Diff sec	Reverse Match	Hit Num.
13.145	84712	Di-n-butylphthalate	7.08	83	1.8	92	1
21.986	11117	Isoprene A		91	7.5	81	1
24.066	72529	p,p'-DDE		73	2.8	77	1
27.928	51336	Piperonyl butoxide	67.83	91	2.2	94	1
21.872	117817	Bis(2-ethylhexyl)phthalate		81	1.5	85	1
31.420	5234531	Fenmetrinol		87	3.7	74	1
31.616	5234531	Fenmetrinol		89	12.5	81	1
13.718		Phenanthrene d10	10				

All of these compounds were missed due to chemical noise, but AMDIS detected and confirmed all five by NIST05.

Hit number of the top 100 hits from 163,000+ compounds



New DRS V.04: Qual (Spectra) + Quant (Peak Area)



The screenshot displays the Quick Qedit software interface with several key components:

- Top Left:** A chromatogram showing an overlay of target ions (blue) and deconvoluted ion plots (green, red, black) for peaks at 27.010 and 27.013 minutes. The y-axis is Abundance (0-7000) and the x-axis is Time (26.86-27.06).
- Top Right:** Two zoomed-in chromatograms. The left one shows a target ion peak at 27.010 minutes, and the right one shows a deconvoluted ion peak at 27.013 minutes. Both have Abundance on the y-axis (0-400) and Time on the x-axis (26.86-27.02).
- Center:** A list of compounds with columns for #, Compound Name, and a status indicator. The list includes various pesticides and chemicals.
- Bottom Left:** A spectral review window showing the extracted spectrum (blue) and the library spectrum (red) for a peak at 27.014 minutes. The y-axis is Abundance (0-9999) and the x-axis is m/z (-13 to 345).
- Bottom Right:** A table of hits with columns for Ion, Exp%, and Act%. The table lists peaks at 149.00, 91.00, 206.00, and 104.00 minutes.

Yellow callout boxes highlight the following features:

- Overlay of target(s) and Deconvoluted ion plots** (Top Left)
- Target ion plot** (Top Right)
- Deconvoluted ion plot** (Top Right)
- Spectral review: Before AMDIS After AMDIS AMDIS Library** (Bottom Left)
- Hits X = MSD A = AMDIS** (Center)
- Areas & amounts from target ion and Deconvoluted ion** (Bottom Right)



New DRS A.04 Report with Quantitation from both MSD ChemStation and AMDIS results

MSD Deconvolution Report

Sample Name: + 400 ppb ISTDs, 25 µL PTV

Data File: C:\msdchem\1\DATA\Trifecta\SPINACH.D

Date/Time: 08:14 AM Thursday, Oct 25 2007

Adjacent Peak Subtraction = 1

Resolution = Medium

Sensitivity = High

Shape Requirements = Medium

GC retention time confirmation

The NIST library was searched for the components that were found in the AMDIS target library.

R.T.	Cas #	Compound Name	Amount (ppm)		AMDIS		NIST	
			Chem station	AMDIS	Match	R.T. Diff sec.	Reverse Match	Hit Num.
18.4431	84742	Di-n-butylphthalate	7.03	6.25	95	1.7	92	1
23.974	80057	Bisphenol A	16.8	7.96	97	8.7	91	1
24.0444	72559	p,p'-DDE	0.65		76	1.4	79	2
25.705	72548	p,p'-DDD	0.16	0.13	52	1.8	65	2
26.9932	50293	p,p'-DDT	0.15	0.09	53	0.7	43	6
27.009	85687	Butyl benzyl phthalate	0.31	0.16	54	0.2	57	25
27.9265	51036	Piperonyl butoxide	37.91	32.31	96	1.6	94	1
29.6685	117817	Bis(2-ethylhexyl)phthalate	3.39	2.69	93	1.2	85	3
31.6131	52645531	Permethrin II	223.78	201.65	90	3.8	91	3
13.718		Phenanthrene-d10	10					

p,p'-DDE target ion mismatch

Lower AMDIS amount due to elimination of interferences





Summary Quant Report with both MSD Chemstation and AMDIS results

Quant Time: Oct 25 07:32:46 2007
Quant Method : C:\msdchem\1\METHODS\Trifecta\DRS_DEMO.M
Quant Title :
QLast Update : Mon Mar 12 08:59:53 2007
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc	Units	Dev (Min)
Internal Standards						
1) Phenanthrene-d10	13.718	188	4953296	10.00	ppm	0.00
Target Compounds						
18) Di-n-butylphthalate	18.444	149	968921	7.03	ppm	95
22) Bisphenol A	23.974	213	2314813m	16.80	ppm	
24) p,p'-DDE	24.060	246	89448m	0.65	ppm	
25) p,p'-DDD	25.705	235	22062m	0.16	ppm	
26) p,p'-DDT	26.998	235	20015m	0.15	ppm	
27) Butyl benzyl phthalate	27.009	149	42742m	0.31	ppm	
30) Piperonyl butoxide	27.927	176	5222839	37.91	ppm	93
31) Bis(2-ethylhexyl)phtha...	29.669	149	466583m	3.39	ppm	
34) Permethrin II	31.614	183	30828861m	223.78	ppm	

AMDIS Imported Quantitation Results

18) Di-n-butylphthalate	18.443	149	860786	6.25	ppm
22) Bisphenol A	23.975	213	1095930	7.96	ppm
27) Butyl benzyl phthalate	27.010	149	21499	0.16	ppm
30) Piperonyl butoxide	27.927	176	4451580	32.31	ppm
31) Bis(2-ethylhexyl)phtha...	29.669	149	369915	2.69	ppm
34) Permethrin II	31.613	183	27779700	201.65	ppm

(#) = qualifier out of range (m) = manual integration (+) = signals summed

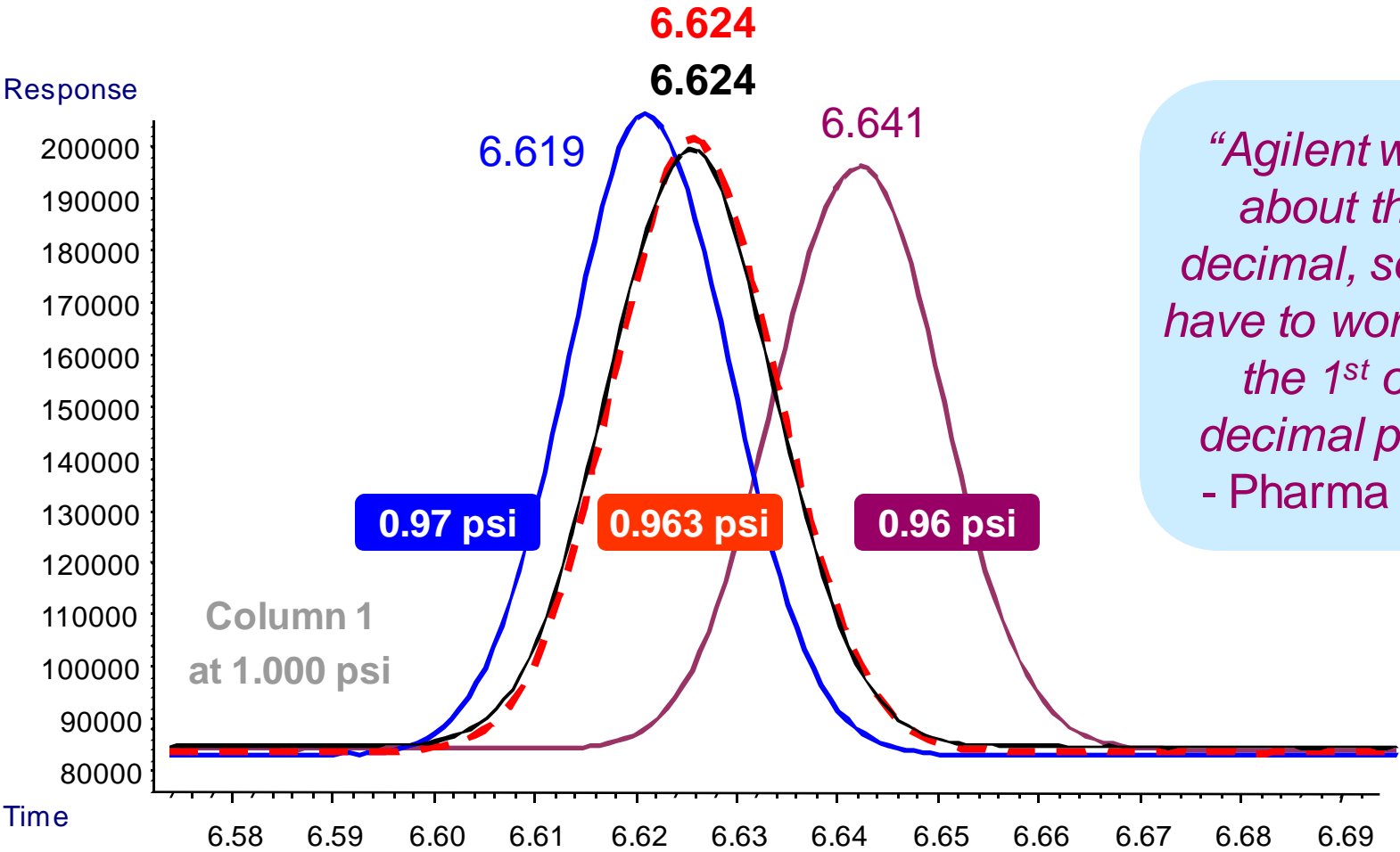
DRS_DEMO.M Thu Oct 25 07:50:12 2007

partial report



Why 1/1000 psi Matters!

-- Key to even better Retention Time Locking (RTL)

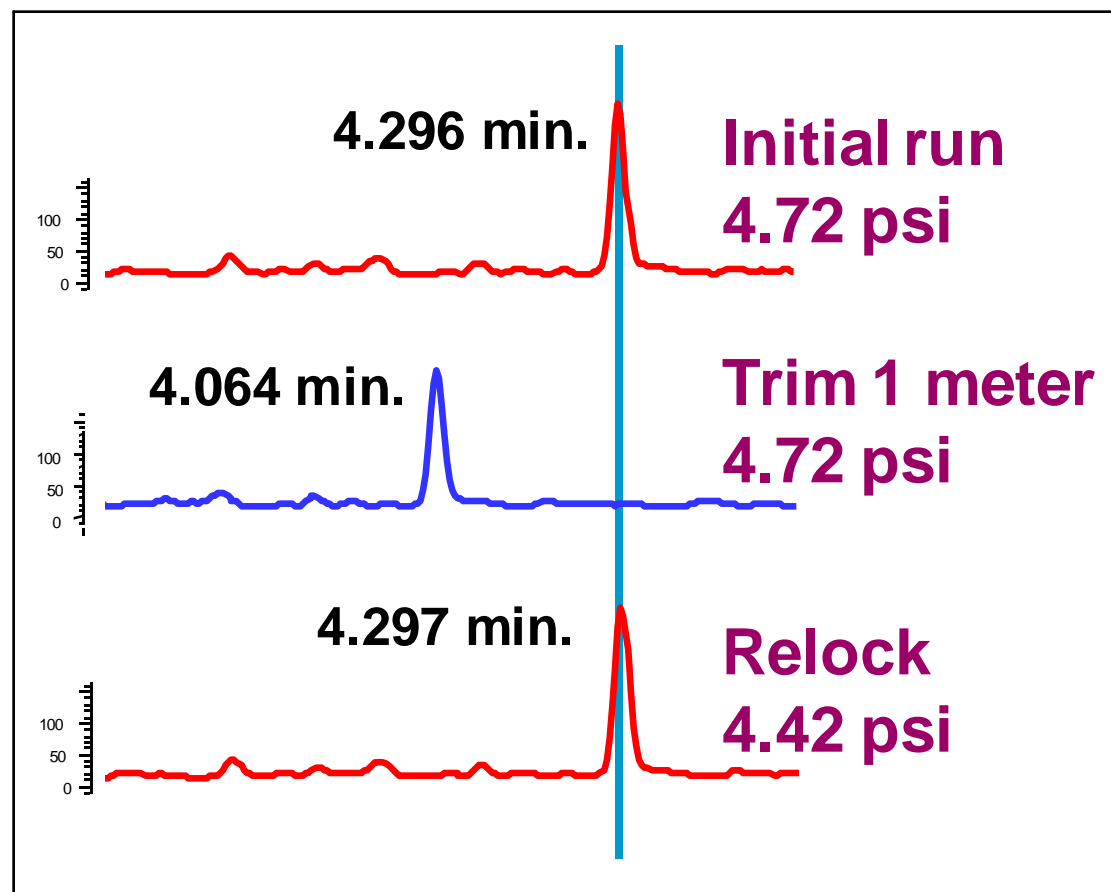


“Agilent worries about the 3rd decimal, so I don’t have to worry about the 1st or 2nd decimal point...”
- Pharma (USA)

Retention Time Locking

Improve Confidence with Retention Time Locking

- **Easy**
- **Quick**
- **Repeatable**
 - Run-to-run
 - Operator-to-operator
 - Instrument-to-instrument



Industry Specific Retention Time Locked Libraries

Part Number	RTL Database/Library	Number of Compounds
G1671AA	Hazardous Chemicals	730
G1672AA	Pesticide	926
G1673AA	Indoor Air Toxics	171
G1674AA	Forensic Toxicology	723
G1675AA	Japanese Positive List Pesticide	431
G1677AA	Environmental Semi-Volatile	one 8270 set of 273 ; two 525 sets of 120

Library include GC method details, Getting Started manual, application notes, and HELP files

Part Number	RTL Database/Library	Number of Compounds
Free	Volatile Organic Compounds	65
Free	PCB Congeners	209
Free	Forensic Toxicology	277
Free	Fatty Acid Methyl Ester	37
Free	Flavors	409
Free	Organotin Derivatives	Methyl, Ethyl, Pentyl

modify a library to your need... or create your own





Special Promotion for Capillary Flow Technologies and DRS-NIST-RTL Bundle

- Orders for the 5975C MSD with the Triple-Axis Detector
 - DRS-NIST05-RTL bundle priced with a 50% discount
 - Includes a choice of one RTL database
 - With the standard or performance turbo only (diff pump systems excluded)

- Orders for the 7890A GC
 - Selected Capillary Flow Technologies priced with a 50% discount
 - 2-way and 3-way purged splitter and Deans' switching

- Promotion active from February 1 until July 31, 2008



Improve Productivity and Useable Sensitivity in Food Analysis with Agilent's 7890A/5975C GC/MSD

**Trace Ion
Detection**

**Pesticide
Retention Time
Locked Databases**

**Deconvolution
Reporting
Software**



**Triple-Axis
Detector**

**Backflush and
other Capillary
Flow Technologies**

Upgrades Available for All 5975 MSDs



Thank you !!!



www.agilent.com/chem

... and browse our application warehouse for more related literatures



Appendix A: Literature References



References for Backflush

- [5989-6460EN](#) Analysis of Suspected Flavor and Fragrance Allergens in Cosmetics Using the 7890A GC and Capillary Column Backflush (March 2007)
- [5989-6066EN](#) Rapid Forensic Toxicology Screening Using an Agilent 7890A/NPD/5975C/DRS GC/MSD System (Jan 2007)
- [5989-6095EN](#) Direct Injection of Fish Oil for the GC-ECD Analysis of PCBs: Results Using a Dean Switch with Backflushing (Jan 2007)
- [5989-6018EN](#) Improving Productivity and Extending Column Life with Backflush (Dec 2006)
- [5989-5111EN](#) Simplified Backflush Using Agilent 6890 GC Post Run Command (June 2006)
- [5989-1716EN](#) New Tools for Rapid Pesticide Analysis in High Matrix Samples (October 2004)



References for Fast Electronics and Synchronous SIM/Scan

- [5988-4188EN](#) New Approaches to the Development of GC/MS Selected Ion Monitoring Acquisition and Quantitation Methods
- [5989-1574EN](#) 5973 Inert Performance Electronics: Considerations for GC/MS Methods in Scan and Selected Ion Monitoring Modes
- [5989-5669EN](#) Strategies for Developing Optimal Synchronous SIM-Scan Acquisition Methods—AutoSIM/Scan Setup and Rapid SIM
- [5898-3108EN](#) Improving Productivity with Synchronous SIM/Scan
- [5989-4184EN](#) Synchronous SIM/Scan Low-Level PAH Analysis Using the Agilent Technologies 6890/5975 inert GC/MSD



Supporting Literature for DRS

- **App Note 5989-7670EN**, Replacing Multiple 50-Minute FPD/ELCD/SIM Analyses with One 15-Minute Full-Scan Analysis for 10x Productivity Gain (*Meng/Szelewski, Nov07*)
 - Capillary flow technology for 3-way splitter
 - Simultaneously monitor multiple detector
 - Backflush to shorten analysis time and increase column lifetime
 - Trace Ion Detection to reduce noise before DRS
 - Next generation of DRS with AMDIS results in QEdit
 - Real results from US Food and Drug Administration/Center for Food Safety and Applied Nutrition (FDA/CFSAN)
 - Better, more accurate identification and quantification of trace compounds in complex matrices – with less operator experience and time



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Supporting Literature for DRS

- **App Note 5989-7436EN**, Screening for Pesticides in Food Using the Japanese Positive List Pesticide Method: Benefits of Using GC/MS with Deconvolution Reporting Software and a Retention Time Locked Mass Spectral Database (*Wylie, Sept07*)
- **App Note 5989-6677EN**, Reducing Analysis Time Using GC/MSD and Deconvolution Reporting Software (*May07*)
- **App Note 5989-6066EN**, Rapid Forensic Toxicology Screening Using an Agilent 7890A/NPD/5975/DRS GC/MSD System (*Quimby, Jan07*)
- **App Note 5989-5435EN**, Screening for 171 Volatile Organic Air Pollutants Using GC/MS with Deconvolution Reporting Software and a New Indoor Air Toxics Library (*Wylie, Aug06*)



Supporting Literature for DRS

- **App Note 5989-5076EN**, Screening for 926 Pesticides and Endocrine Disruptors by GC/MS with Deconvolution Reporting Software and a New Pesticide Library (*Wylie, Apr06*)
- **App Note 5989-4834EN**, Screening for Hazardous Chemicals in Homeland Security and Environmental Samples Using a GC/MS/ECD/FPD with a 731 Compound DRS Database (*Quimby, Szelewski, Feb06*)
- **App Note 5989-1716EN**, New Tools for Rapid Pesticide Analysis in High Matrix Samples, (*Szelewski, Quimby, Oct04*)
- **App Note 5989-1654EN**, A Blind Study of Pesticide Residues in Spiked and Unspiked Fruit Extracts Using Deconvolution Reporting Software
- **App Note 5989-1157EN**, Comprehensive Pesticide Screening by GC/MSD using Deconvolution Reporting Software (*Wylie/Szelewski/Meng, May04*)

