Experiences with application of full scan high resolution MS for pesticide residue analysis

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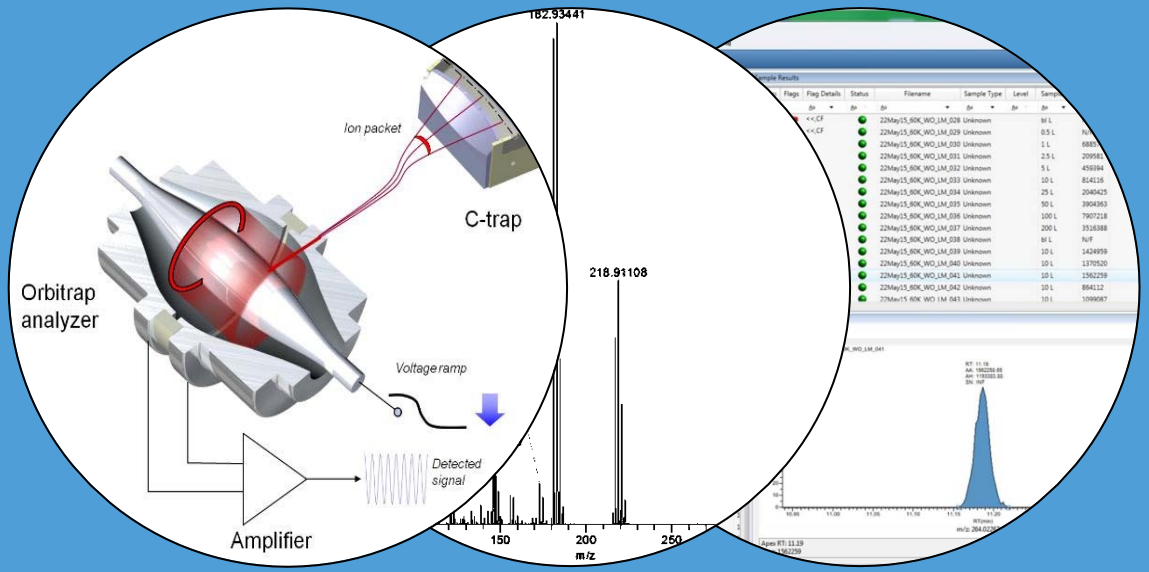

Current routine practice

Chromatography with mass spectrometric detection

Pesticide Residue analysis

Pesticide Manual:

1630 entries

Current golden standard:

Targeted quantitative measurement by LC-MS/MS and GC-MS/MS
Multi-residue methods, ~150-250 analytes/method

Emerging:

Non-targeted measurement by LC and GC + full scan MS
for better coverage of pesticide scope and easier measurement

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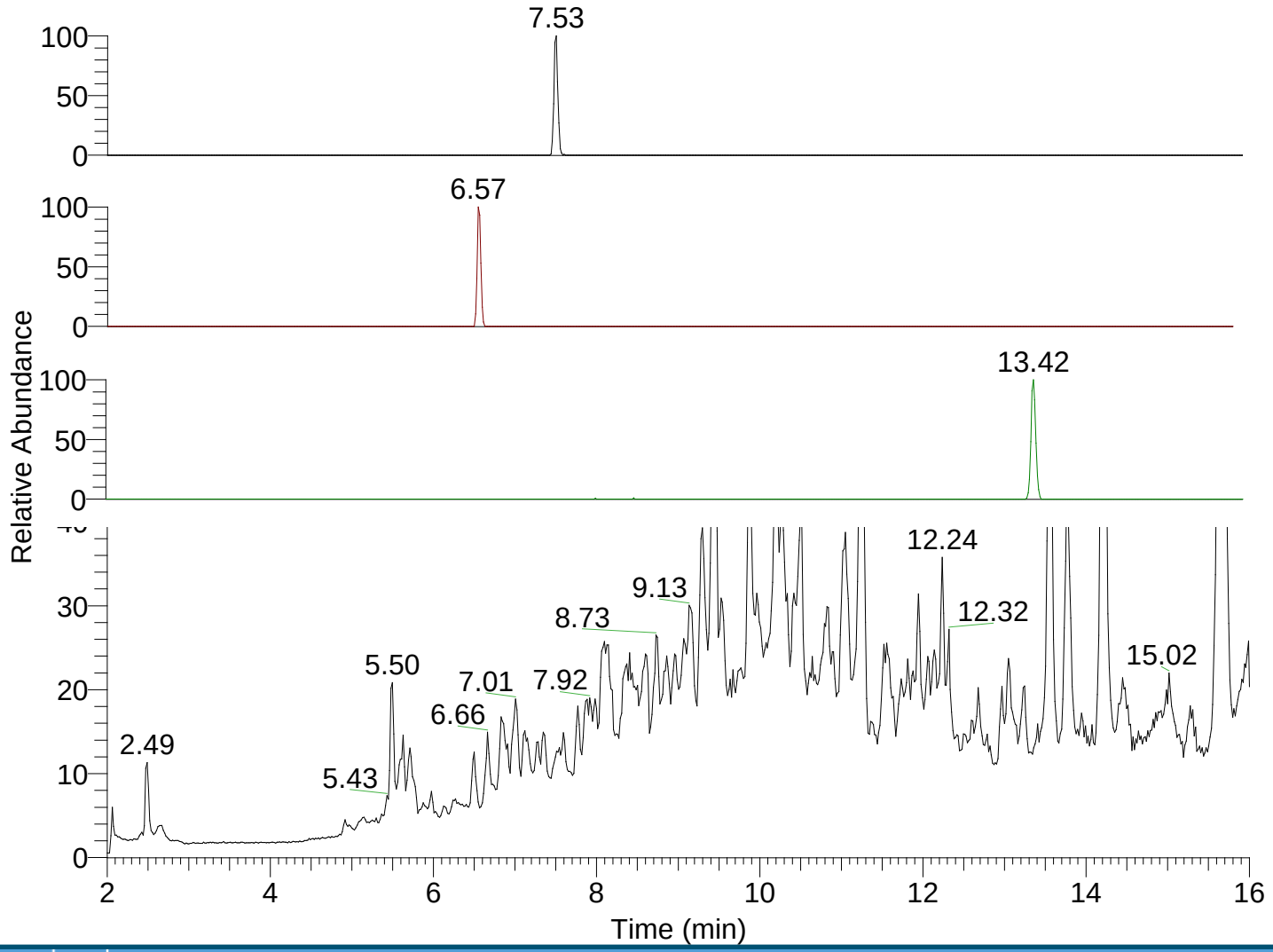
Selectivity using HR-MS

Extract signal of exact mass ± x Da (ppm), e.g. Dimethoate $[M+H]^+$ 230.0069 ± 5 ppm (±0.0012 Da)



m/z 230.0069
$C_5H_{12}NO_3PS_2$
dimethoate

m/z 230.0536
$C_9H_6F_3N_3O$
flonicamid

m/z 365.1449
$C_{19}H_{25}ClN_2OS$
pyridaben

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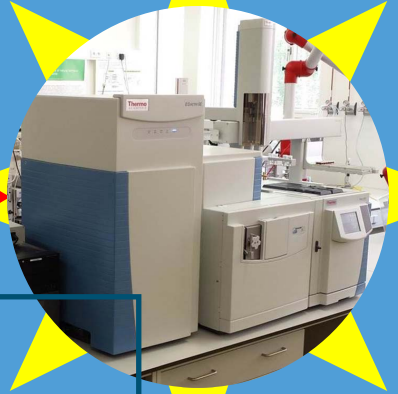
Leek spiked @ 10 ppb,
Full scan m/z 135-1000; Res = 70,000

Work flow

LC-ESI-Q-Orbitrap-MS

Sample — Extract

QuEChERS extraction



(2015)

GC-EI-Q-Orbitrap-MS

Raw data

Quan (usual suspects):

XICs, MEW ± 5 ppm, 2 ions
Manual verification of all targets in all samples
Extensive AQC:
Linearity, LOQ
recoveries/RSDs
Identification: peaks 2 ions fully overlap RT ±0.1 min from sequence, ion ratio ±30% (rel)

Qual (others):

XICs, MEW ± 5 ppm, 2 ions
Fully automated by software

Detection: RT ±0.5 min from database, peaks detected for both ions

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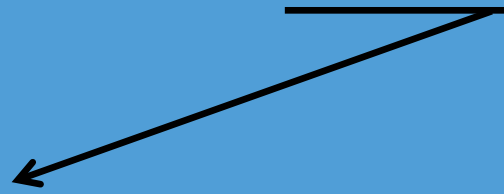
LC-HRMS: Identification

LC-ESI-MS: soft ionisation → no fragments

Generation of fragments:
1) needed for identification, 2) improve screening selectivity

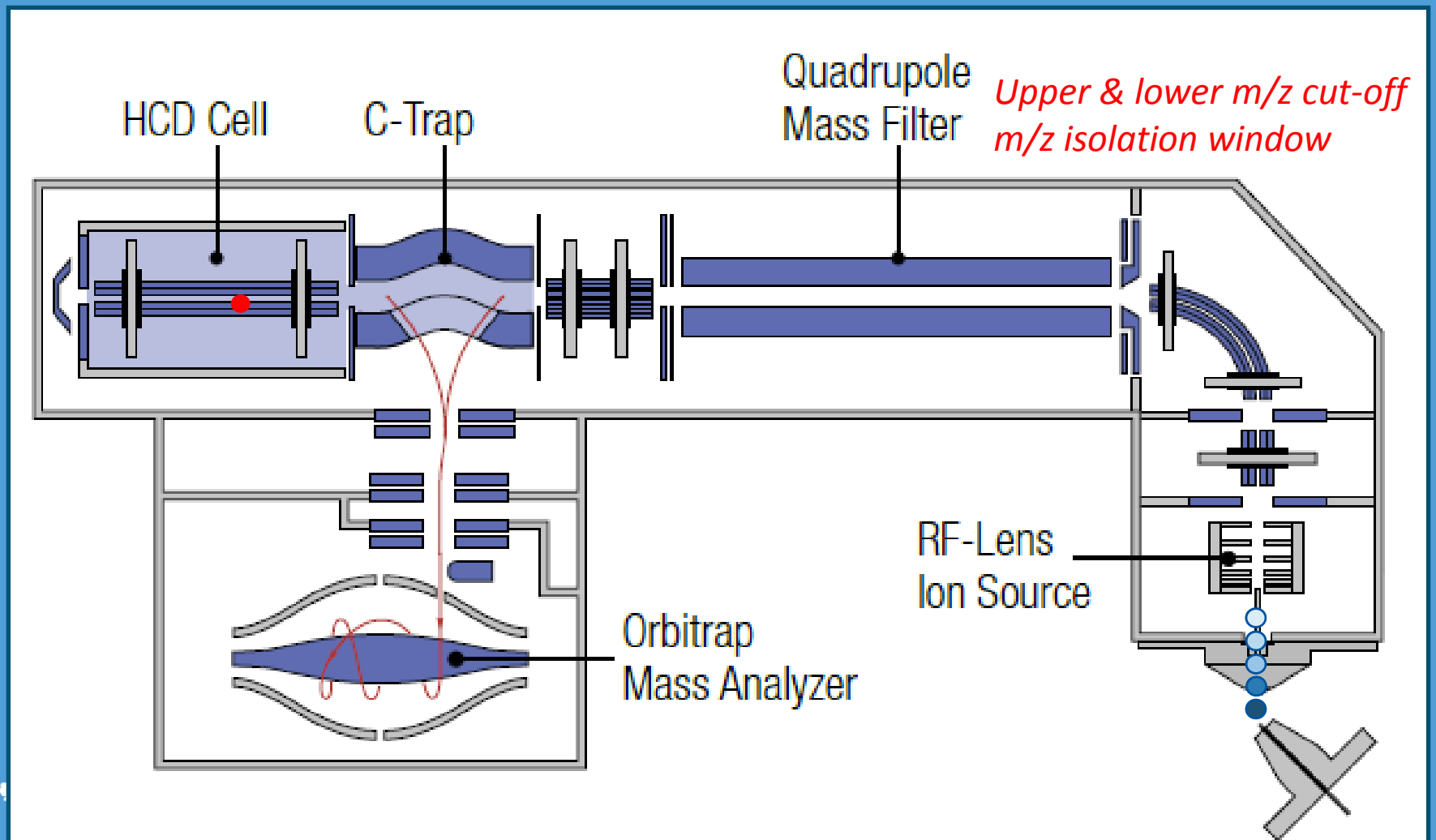
For optimum detection and identification:
full scan acquisition without and with fragmentation in 1 run



Non-targeted fragmentation:
two options: AIF and vDIA

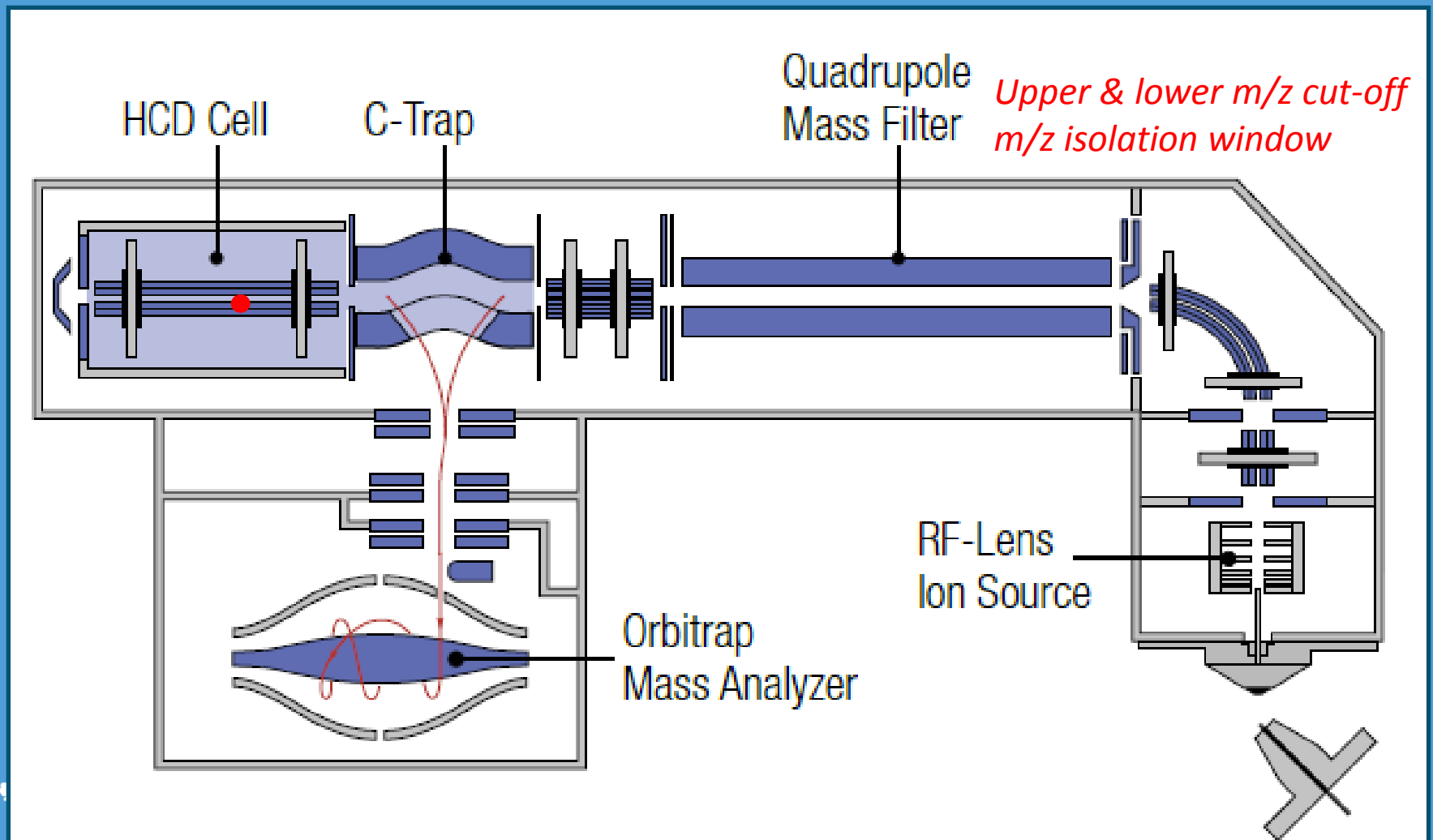
Combined Full scan + vDIA acquisition

FS: m/z 100-1000	ϟ: 100-200	ϟ: 200-300	ϟ: 300-400	ϟ: 300-400	ϟ: 500-1000	FS: m/z 100-1000



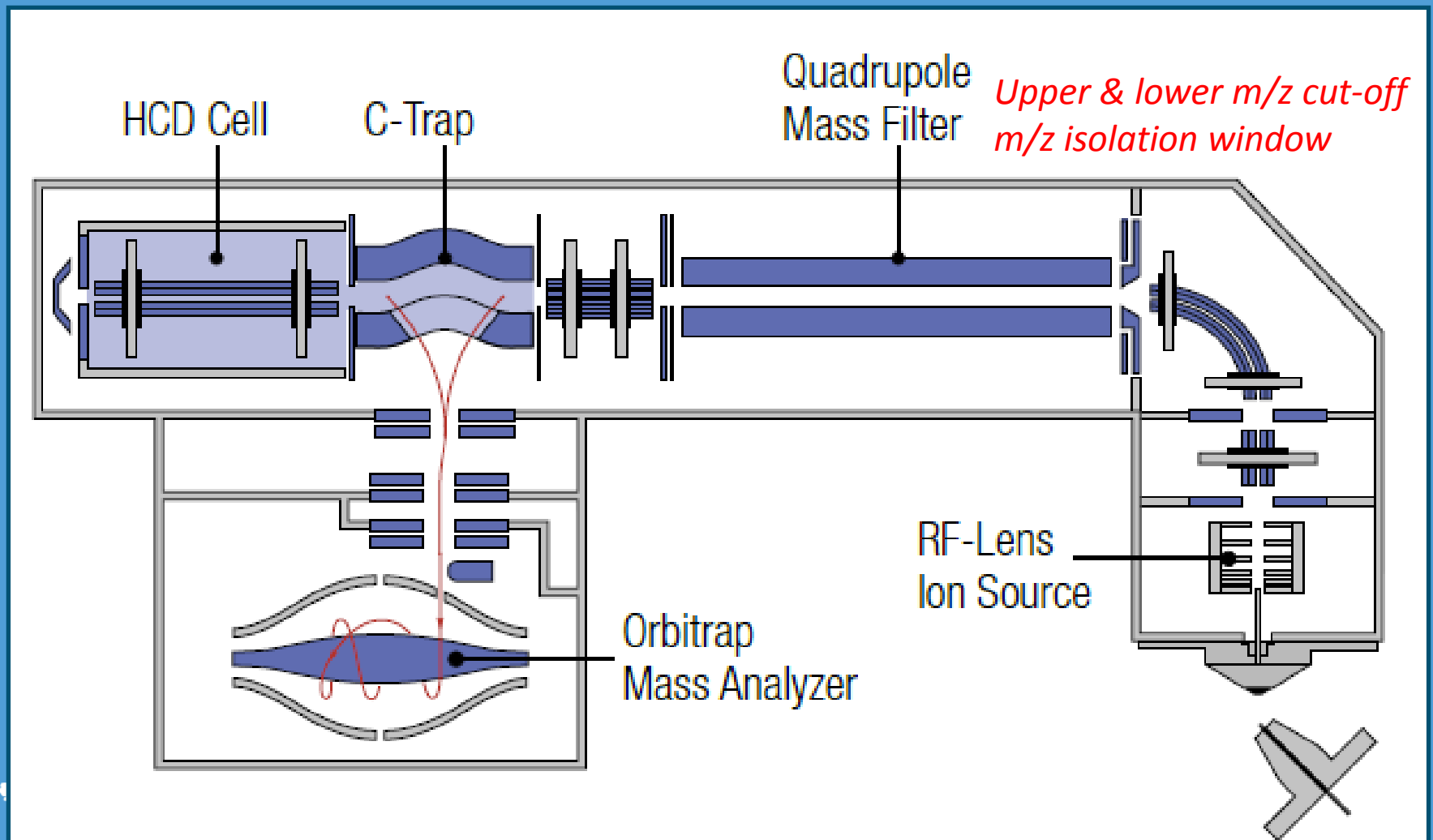
Combined Full scan + vDIA acquisition

FS: m/z 100-1000	ϟ: 100-200	ϟ: 200-300	ϟ: 300-400	ϟ: 300-400	ϟ: 500-1000	FS: m/z 100-1000



Combined Full scan + vDIA acquisition

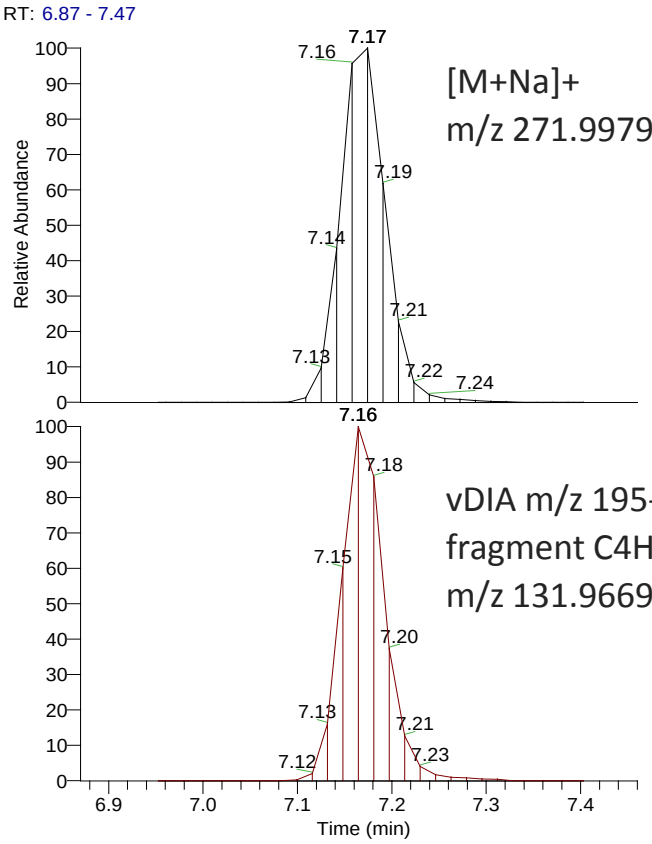
FS: m/z 100-1000	ϟ: 100-200	ϟ: 200-300	ϟ: 300-400	ϟ: 300-400	ϟ: 500-1000	FS: m/z 100-1000



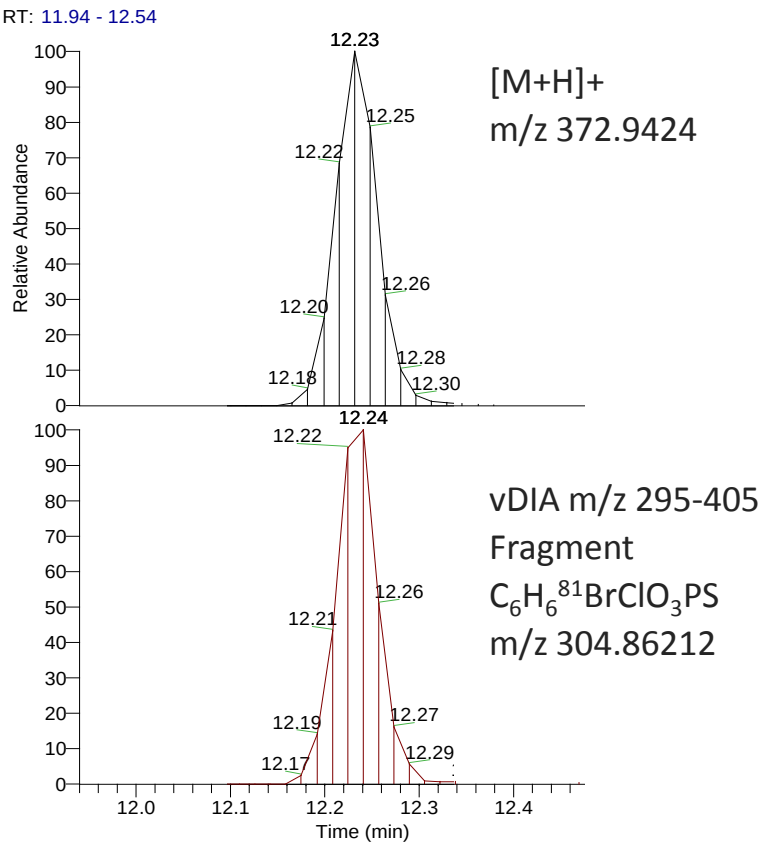
Scan speed sufficient (FS + vDIA)?

full scan: no fragmentation m/z 135-1000@70K	Fragments of 95-205@35K	Fragments of 195-305@35K	Fragments of 295-405@35K	Fragments of 395-505@35K	Fragments of 495-1005@35K	978 ms

50 ppb Clothiadinin ($C_6H_8ClN_5O_2S$) in lettuce



50 ppb Profenofos ($C_{11}H_{15}BrClO_3PS$)in lettuce



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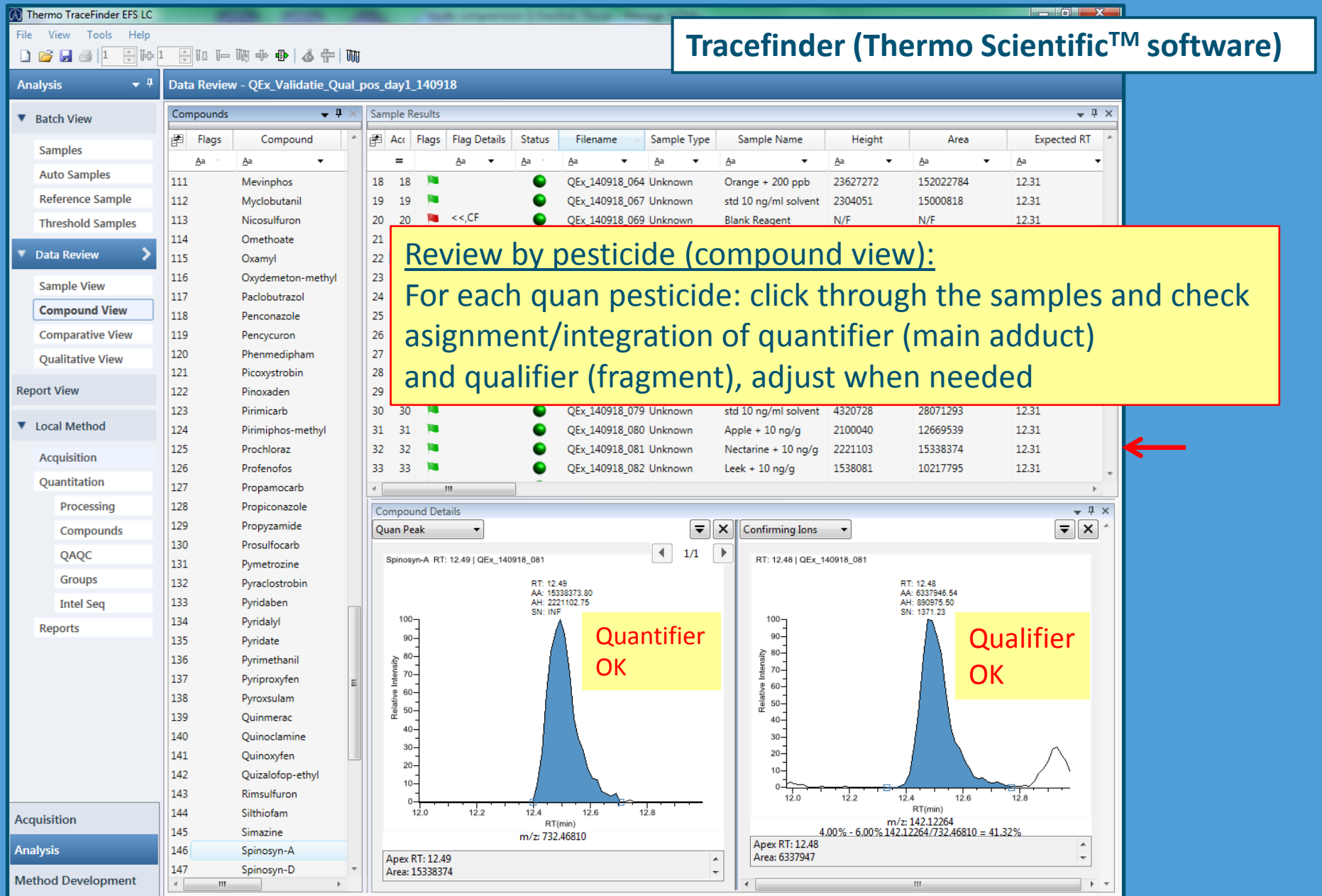
Quantitative data review

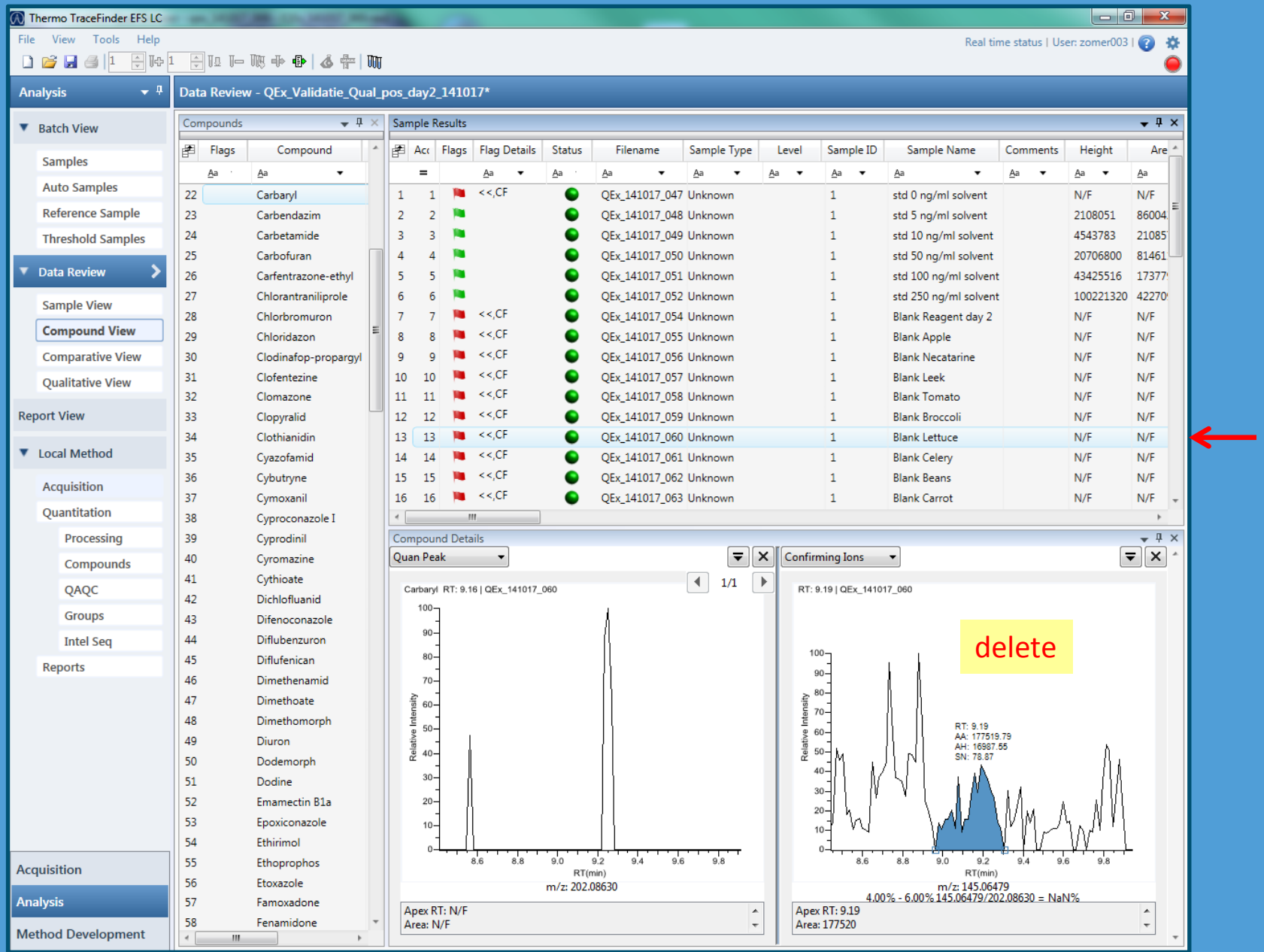


Tracefinder (Thermo Scientific™ software)

Review by pesticide (compound view):

For each quan pesticide: click through the samples and check asignment/integration of quantifier (main adduct) and qualifier (fragment), adjust when needed

Quantitative data review



Qualitative screening: method set up

Same raw data, different data review

High number of target pesticides, low probability of detection

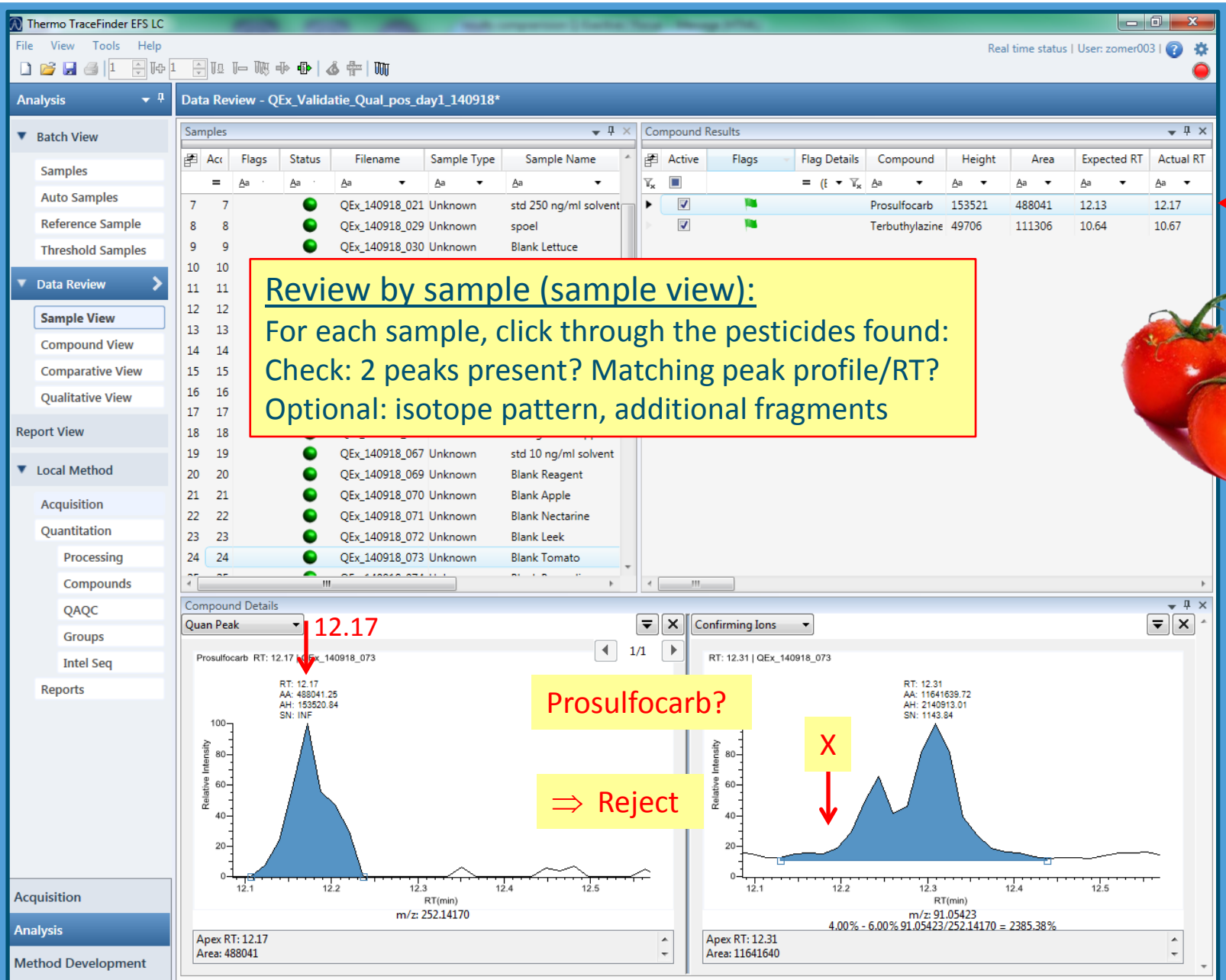
Manual verification of all XICs too time consuming

⇒ Automated pesticide detection by the software (Tracefinder; Thermo Scientific™)

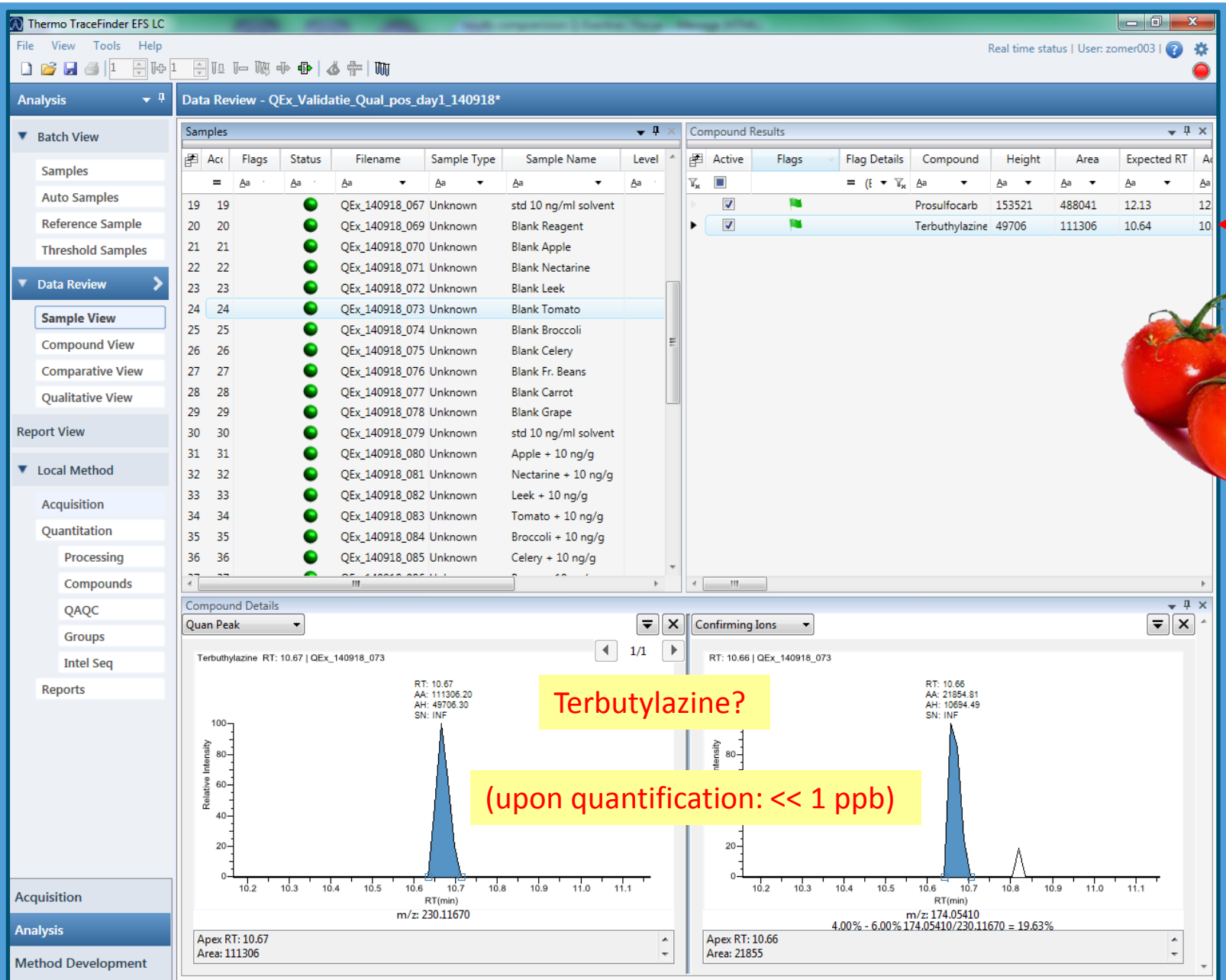
Default settings for pesticide detection (quan module used without quantification)

Mass extraction window:	exact m/z ±5 ppm
Time window:	database RT ± 0.5 min
Requirement:	signal found for pre-set adduct AND fragment ion
Output:	report of samples showing only pesticides found

Screening: data review



Screening: data review



GC-HRMS: introduction

Features/specifications:

Q Exactive GC

Resolution FWHM @ m/z 200 (scan speed)
15,000; 30,000; 60,000; 120,000
~ 18 Hz → 3 Hz
m/z 30-3000
Acquisition options: Non-targeted (full scan) /
Targeted (SIM, MS/MS, data-dependent MS/MS)
Mass accuracy: internal < 1 ppm RMS; external < 3 ppm RMS
Dissociation in source EI / PCI / NCI

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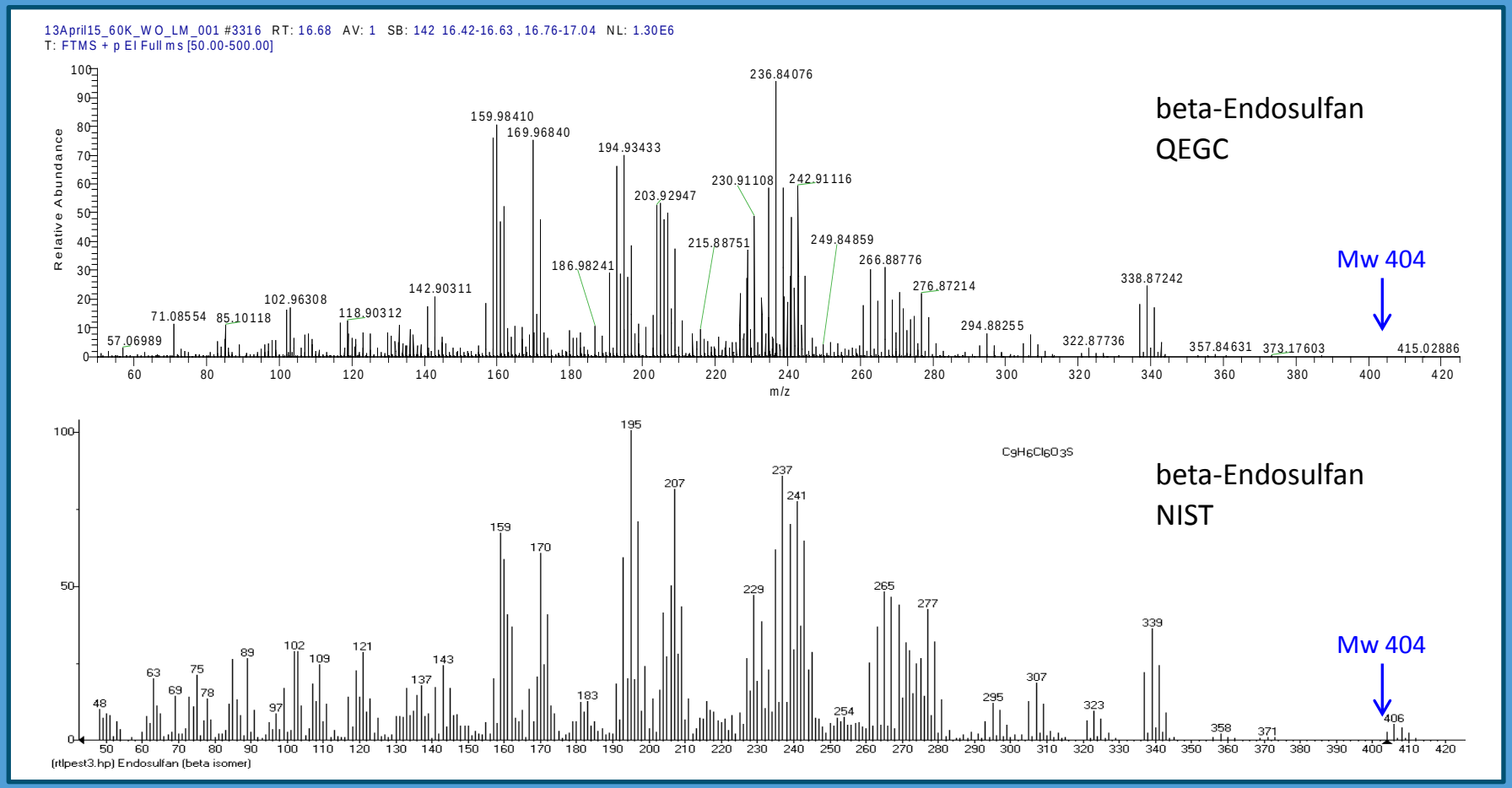
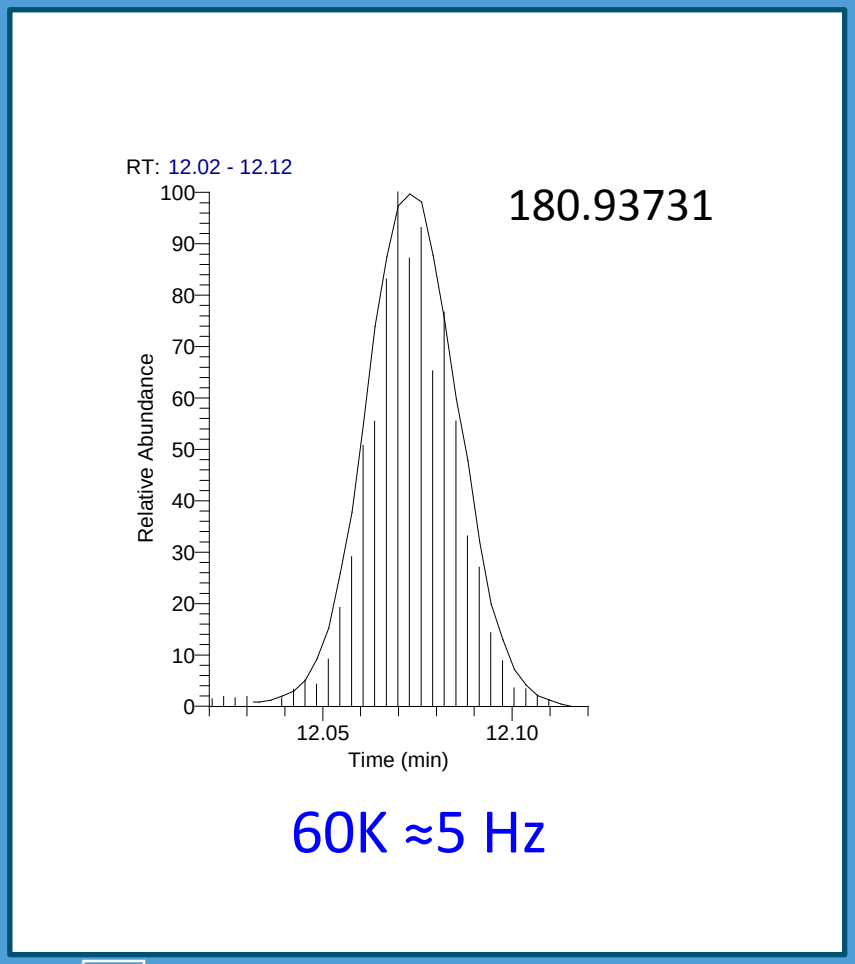
Identification

GC-EI-MS: hard ionisation techique, multiple fragments
=> one acquisition event suffices



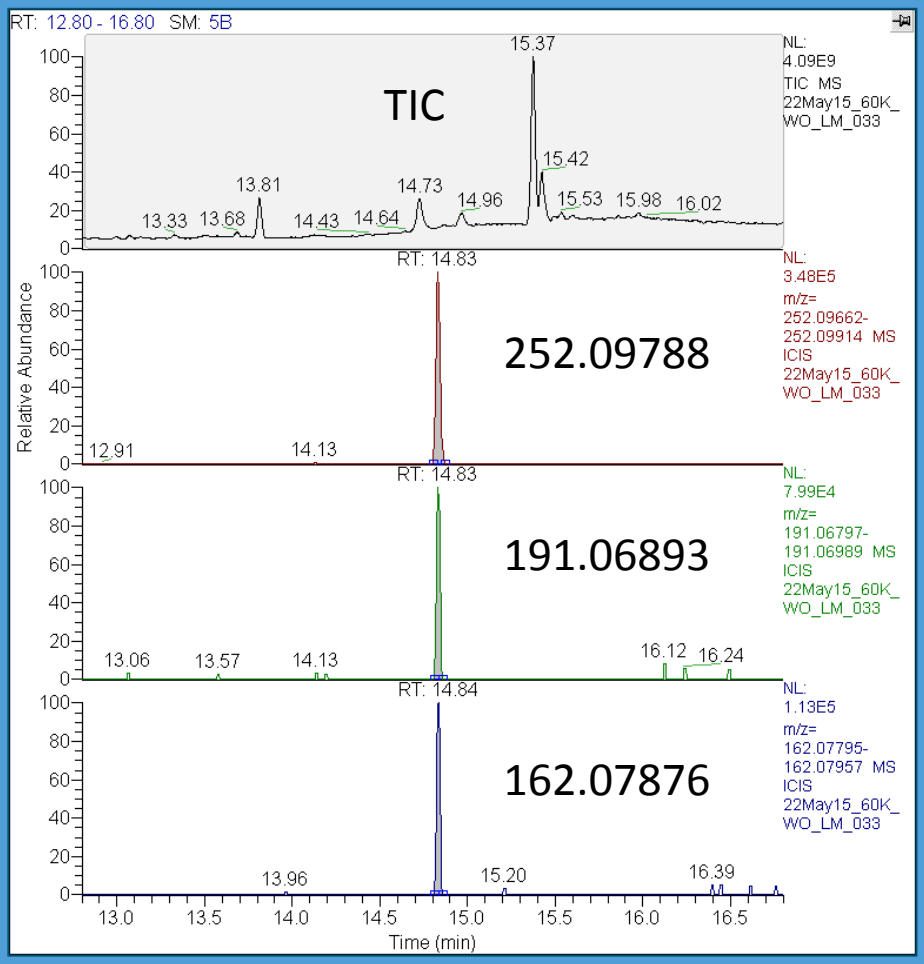
Scanspeed and XICs vs TIC

Lindane
C6Cl3H4
10 ppb in leek



60K ≈5 Hz

Pendimethalin
C11H14N3O4
10 ppb in leek

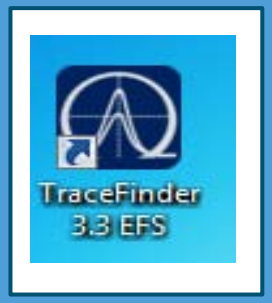


Method (datahandling)

Thermo Scientific™ Software:

XCalibur

TraceFinder 3.3 EFS



NIST library

Pesticide database with t_r and exact masses of (fragment) ions

On-going (currently 574 pesticides)

Method development:

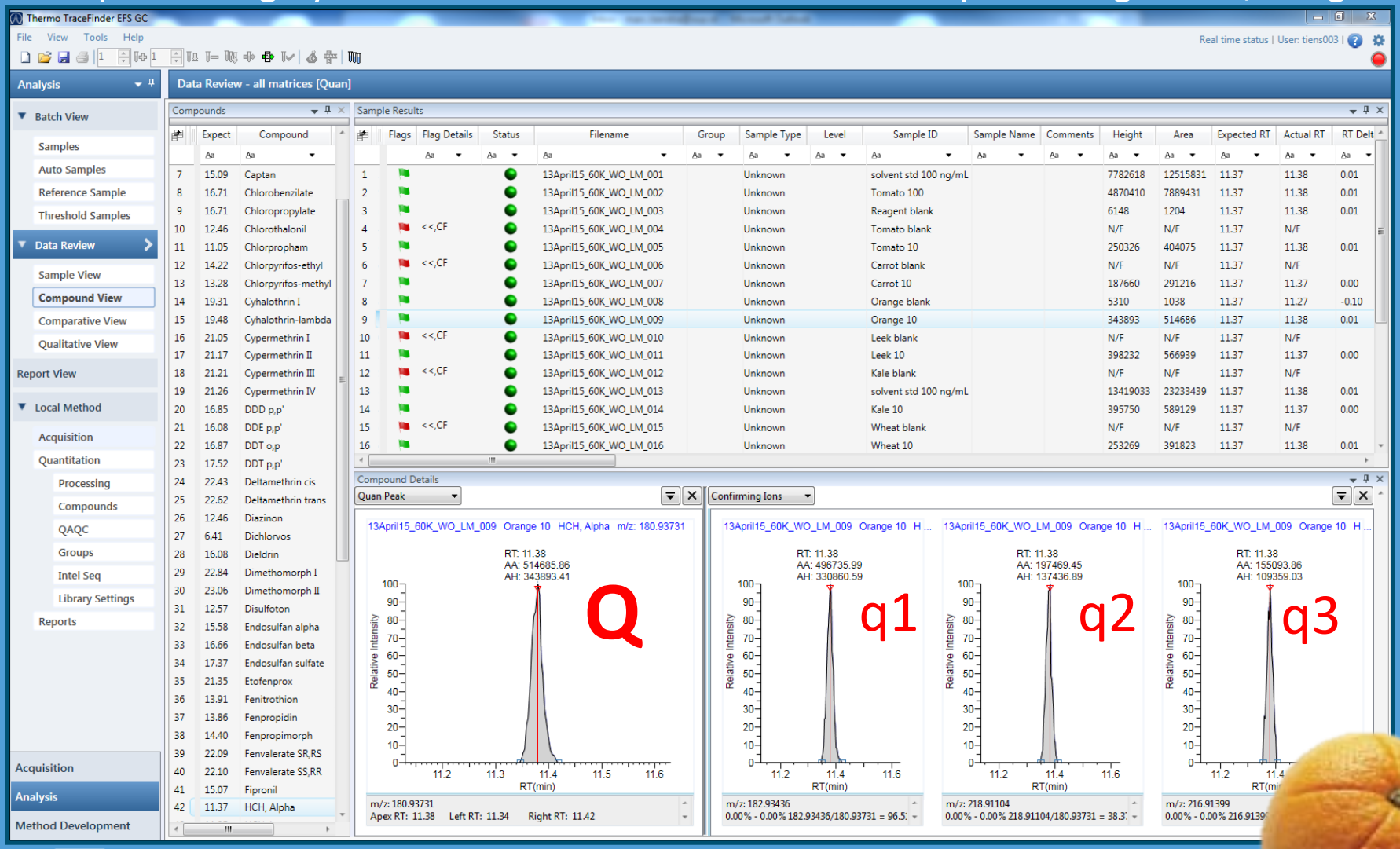
Default MEW: ± 5 ppm

Assess sensitivity/selectivity of the different ions available for each pesticide

CompoundNa	RT	Q;q1;q2;q3;q4;q5;q6	Q	Q	q1	q1	q2	q2	q3	q3	q4	q4	q5	q5
2-phenylphenol	9.47	170;141;115	C12H9O	169.06479	C12H10O	170.07262	C11H9	141.06988	C9H7	115.05423				
Azoxystrobin	22.76	344;388;329;172;360;403	C20H14N3O3	344.10297	C21H14N3O5	388.09280	C19H11O3N3	329.07949	C10H6O2N	172.03931	C20H14O4N3	360.09788	C22H17N3O5	403.11627
Bifenthrin	18.51	181;166;141;165;153	C14H13	181.10118	C13H10	166.07770	C13H9	165.06988	C12H9	153.06988				
Biphenyl	7.88	154;153;152;76	C12H10	154.07770	C12H9	153.06988	C12H8	152.06205						
Bitertanol	20.11	170;168;112;(141;152)	C12H10O	170.07262	C8H14ON3	168.11314	C4H6ON3	112.05054	C11H9	141.06988	C12H8	152.06205		
boscalid	21.03	140;142;342;344;112	C6H3ONCl	139.98977	C6H3ONCl(37)	141.98682	C18H12Cl2N2O	342.03212	C18H12ClCl(37)N2O	344.02917	C5H3NCl	111.99485		
Bupirimate	16.3	273;193;208;316;166	C10H17N4O3S	273.10159	C10H17N4	193.14477	C11H18N3O	208.14444	C13H24N4O3S	316.15636	C8H12ON3	166.09749		
Captan	15.09	79;149;107;80	C6H7	79.05423	C8H7NO2	149.04713	C7H7O	107.04919	C6H8	80.06205				
chlorfenvinphos	15.08	267;269;323;295;325	C8H6O4Cl2P	266.93753	C8H6O4ClCl(37)P	268.93458	C12H14O4Cl2P	323.00013	C10H10O4Cl2P	294.96883	C12H14O4ClCl(37)P	324.99718		
Chlorobenzilate	16.71	251;139;253;141;111	C13H9OCl2	251.00250	C7H4ClO	138.99452	C13H9OClCl(37)	252.99955	C7H4Cl(37)O	140.99157	C6H4Cl	110.99960		
Chloropropylate	16.71	251;139;253;141;111	C13H9OCl2	251.00250	C7H4ClO	138.99452	C13H9OClCl(37)	252.99955	C7H4Cl(37)O	140.99157	C6H4Cl	110.99960		
Chlorothalonil	12.46	266;264;268;124;229	C8Cl3Cl(37)N2	265.87806	C8Cl4N2	263.88101	C8Cl2Cl(37)2N2	267.87511	C8N2	124.0056	C8N2Cl3	228.91216		
Chlorpropham	11.05	127;171;213;154	C6ClH6N	127.01833	C7H6NO2Cl	171.00816	C10H12ClNO2	213.05511	C8H9NCl	154.04180				
Chlorpyrifos-ethyl	14.22	197;199;258;313;125	C5Cl3H2NO	196.91965	C5H2Cl2Cl(37)NO	198.91670	C5H3Cl2NO3PS	257.89428	C9H11Cl2NO3PS	313.95688	C2H6O2PS	124.98206		
Chlorpyrifos-methyl	13.28	286;288;125	C7H7Cl2NO3PS	285.92558	C7H7ClCl(37)NO3PS	287.92263	C2H6O2PS	124.98206						
coumaphos	20.28	226;362;210;109;182	C10H7O2ClS	225.98498	C14H16ClO5PS	362.01391	C10H7O3Cl	210.00782	C2H6O3P	109.00491	C9H7O2Cl	182.01291		
Cyhalothrin I	19.31	197;141;208;181	C8H9ClF3	197.03394	C8H7F2	141.05103	C14H10ON	208.07569	C13H9O	181.06479	C14H11NO	209.08352		
Cyhalothrin-lambda	19.48	197;141;208;181	C8H9ClF3	197.03394	C8H7F2	141.05103	C14H10ON	208.07569	C13H9O	181.06479	C14H11NO	209.08352		
Cypermethrin I	21.05	163;127;209;181	C7H9Cl2	163.00758	C7H8Cl	127.03090	C14H11NO	209.08352	C13H9O	181.06479	C12H8	152.06205		
Cypermethrin II	21.17	163;127;209;181	C7H9Cl2	163.00758	C7H8Cl	127.03090	C14H11NO	209.08352	C13H9O	181.06479	C12H8	152.06205		
Cypermethrin III	21.21	163;127;209;181	C7H9Cl2	163.00758	C7H8Cl	127.03090	C14H11NO	209.08352	C13H9O	181.06479	C12H8	152.06205		
Cypermethrin IV	21.26	163;127;209;181	C7H9Cl2	163.00758	C7H8Cl	127.03090	C14H11NO	209.08352	C13H9O	181.06479	C12H8	152.06205		
DDD p,p'	16.85	235;237;199;212;165	C13Cl2H9	235.00758	C13H9ClCl(37)	237.00463	C13H8Cl	199.03090	C14H9Cl	212.03873	C13H9	165.06988		
DDE p,p'	16.08	245;248;318;316;176;210	C14Cl2H8	245.99976	C14H8ClCl(37)	247.99681	C14H8Cl3Cl(37)	317.93451	C14H8Cl4	315.93746	C14H8	176.06205	C14H7Cl	210.02308
DDT o,p	16.87	235;237;199;212;165	C13Cl2H9	235.00758	C13H9ClCl(37)	237.00463	C13H8Cl	199.03090	C14H9Cl	212.03873	C14H8Cl2	245.99976	C13H9	165.06988
DDT p,p'	17.52	235;237;199;212;165	C13Cl2H9	235.00758	C13H9ClCl(37)	237.00463	C13H8Cl	199.03090	C14H9Cl	212.03873	C14H8Cl2	245.99976	C13H9	165.06988
Deltamethrin cis	22.43	253;174;172;251;255;181;209	C7H9BrBr(81)	252.90450	C7H9Br(81)	173.98616	C7H9Br	171.98821	C7H9Br2	250.90655	C7H9Br(81)2	254.90246	C13H9O	181.06479

Quantitative data processing method

Data processing by TraceFinder + manual verification of peak assignment/integration



alpha-HCH 10 µg/kg, XICs exact mass ±5ppm

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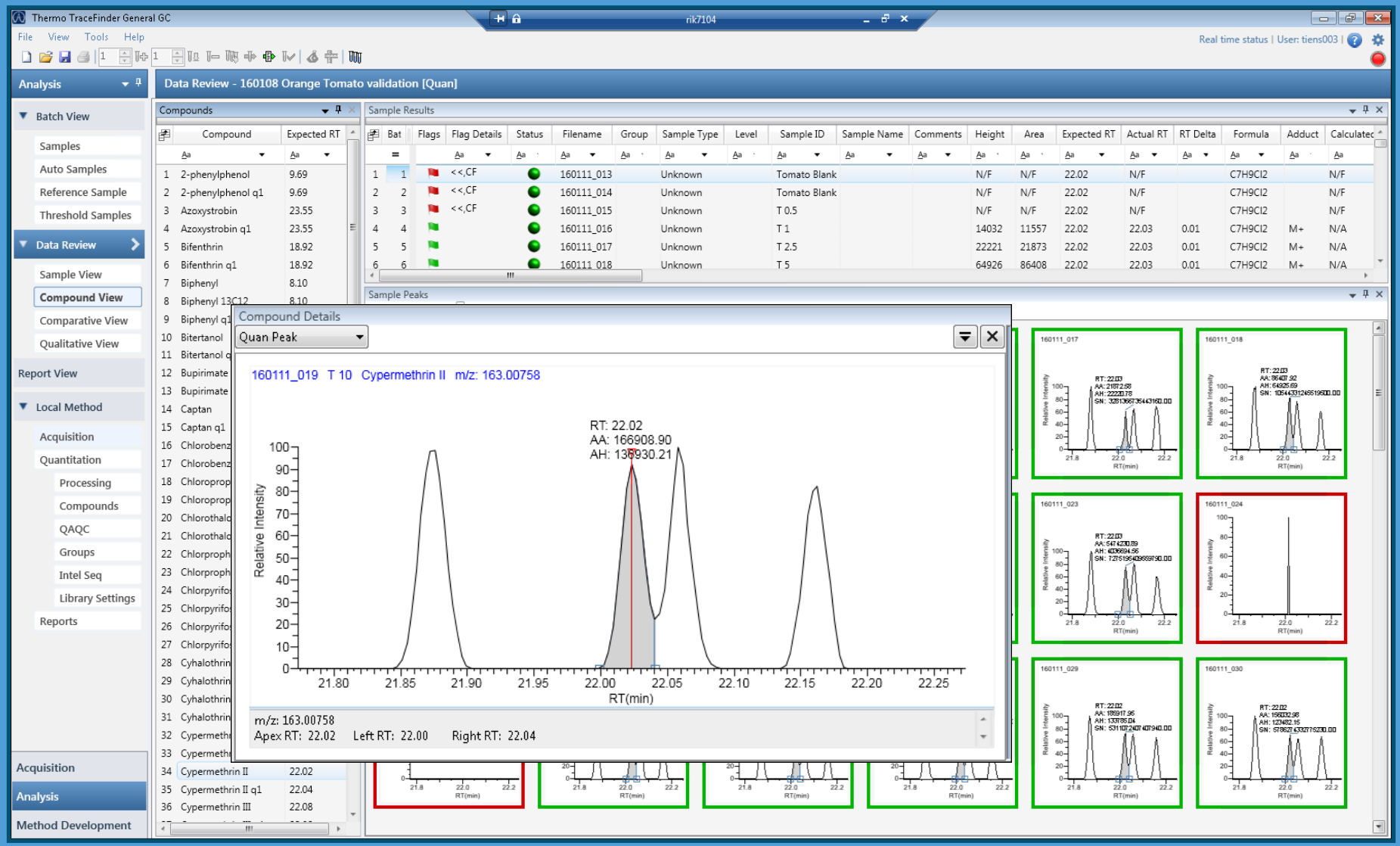
Quantitative data processing method



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Qualitative screening

Two approaches:

1. Library: match of EI-spectra

deconvolution of HR spectra

⇒ cleaned spectrum

Library search (NIST, PEST library)

Software:

Report if match (SI) > user threshold

Analyst: manual review hits

2. Database: RT + 2 exact masses

RT ± 0.5 min

XICs ± 5 ppm

2 ions (w/o ratio criterion)

Software:

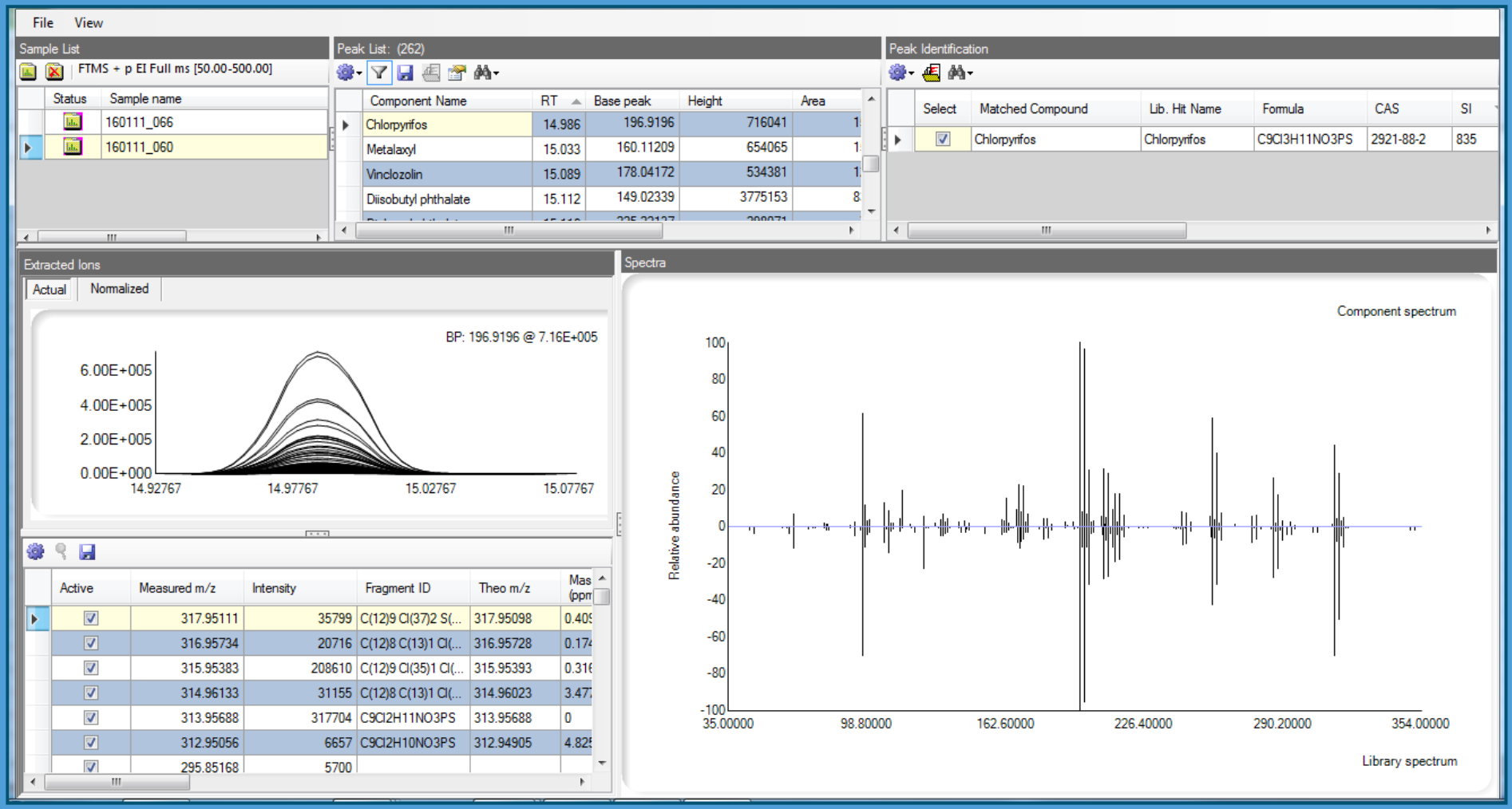
Report if signal is found for both ions

Analyst: manual review hits

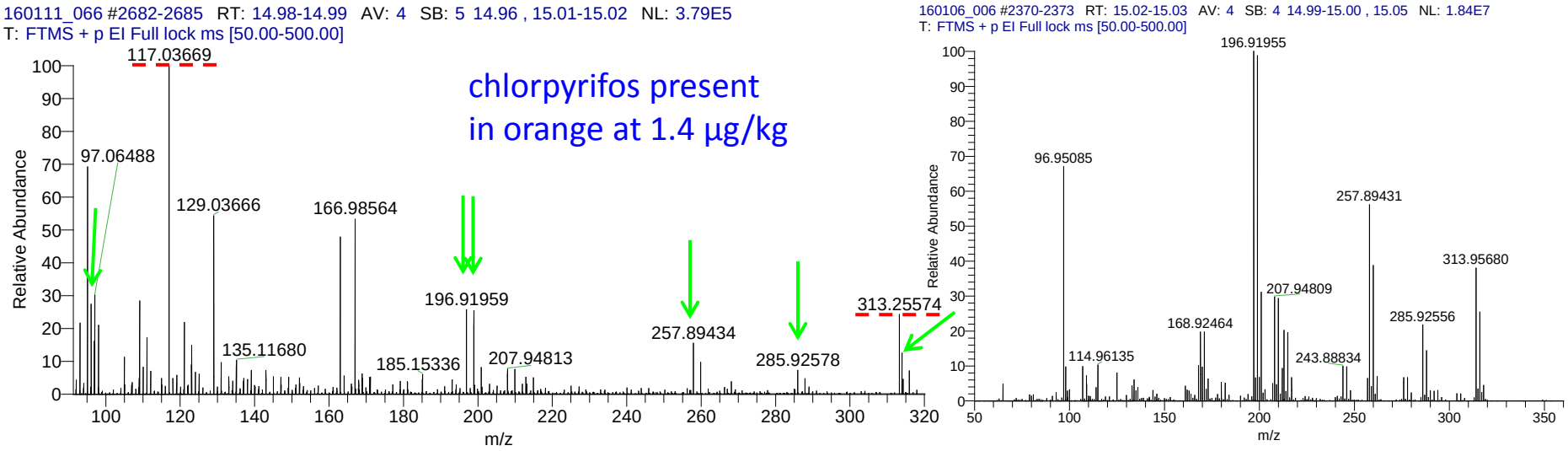
Only briefly assessed, preliminary results

Qualitative screening: approach-1

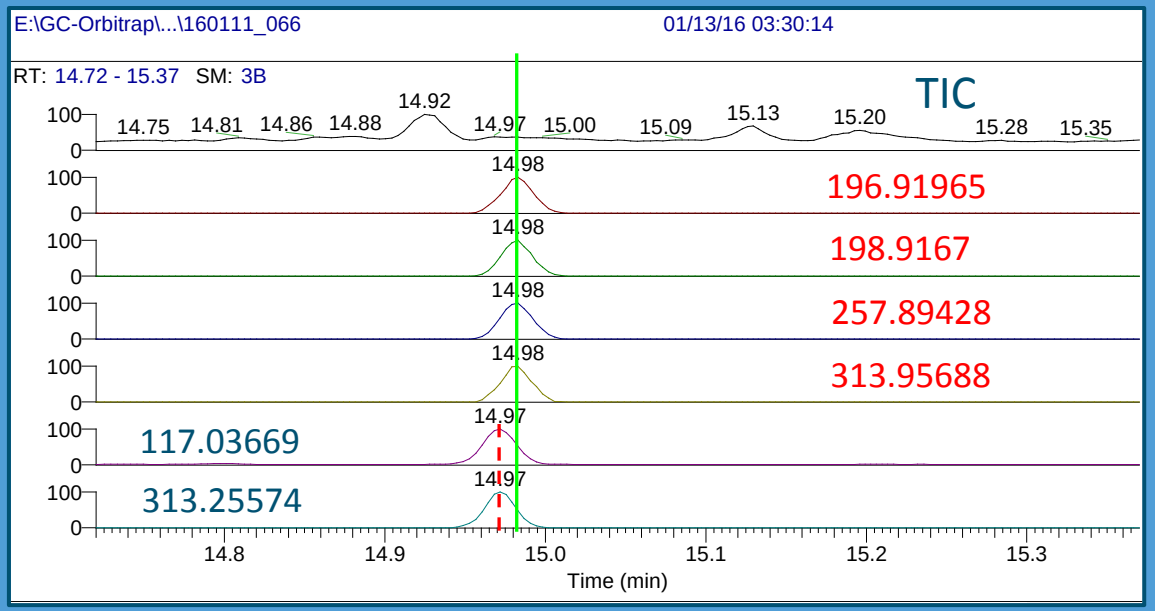
Orange spiked @ 10 µg/kg: 73% automatically found



Qualitative screening



Not automatically found by spectral match....



easily found through approach-2

Qualitative screening: prelim. conclusion

Two approaches:

1. Library: match of EI-spectra

deconvolution of HR spectra
⇒ cleaned spectrum
Library search (NIST, PEST library)

Software:
Report if match (SI) > user threshold

Analyst: manual review hits

+ allows screening for analytes not (yet) included in dedicated HR/AM database
- low µg/kg levels in complex matrices are challenging

2. Database: RT + 2 exact masses

RT ± 0.5 min
XICs ± 5 ppm
2 ions (w/o ratio criterion)

Software:
Report if signal is found for both ions

Analyst: manual review hits

+ better screening sensitivity
- needs database with t_r / exact masses

Conclusions

Food Additives & Contaminants: Part A, 2015
http://dx.doi.org/10.1080/19440049.2015.1085652

Taylor & Francis
Taylor & Francis Group

Simultaneous quantitative determination, identification and qualitative screening of pesticides in fruits and vegetables using LC-Q-Orbitrap™-MS

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***LC**-Q-Orbitrap-HRMS*
published 2015

Analytica Chimica Acta
Hans G.J. Mol, Marc Tienstra, Paul Zomer

Evaluation of gas chromatography - electron ionization - full scan high resolution Orbitrap mass spectrometry for pesticide residue analysis

***GC**-Q-Orbitrap-HRMS*
submitted 2016

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Thank you for your attention!

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