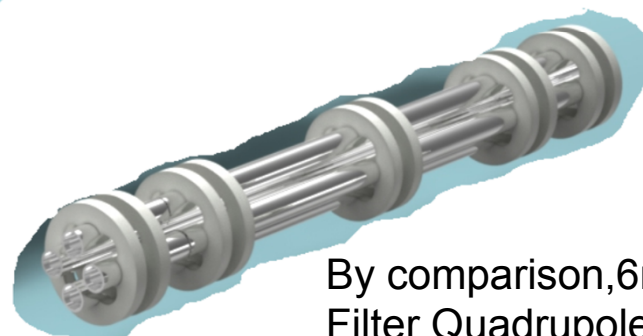
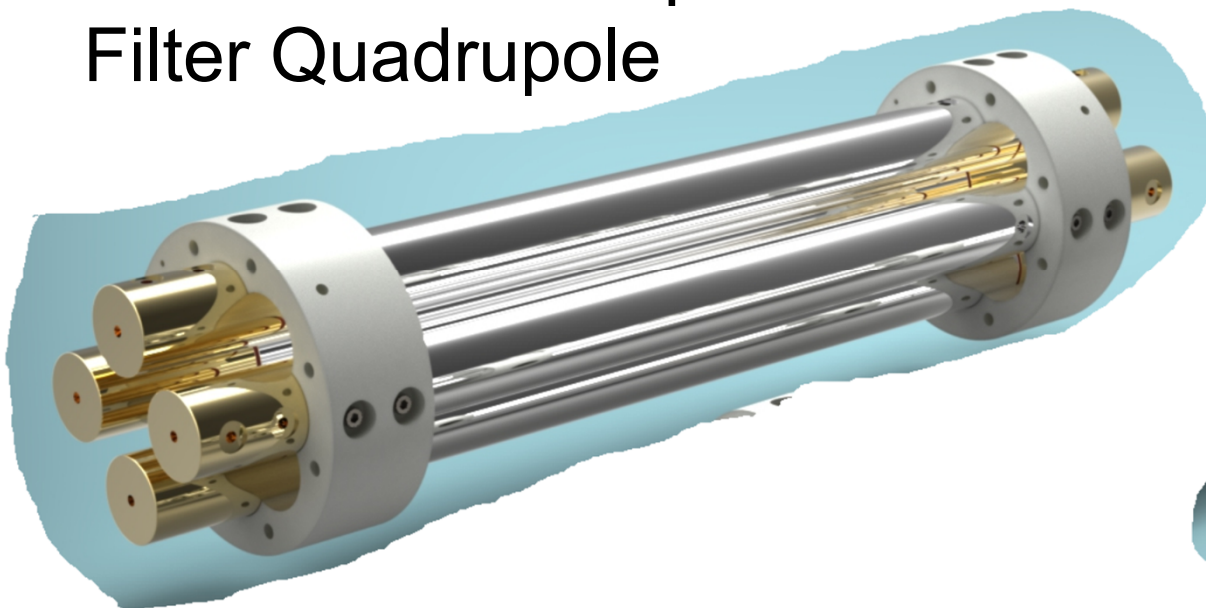
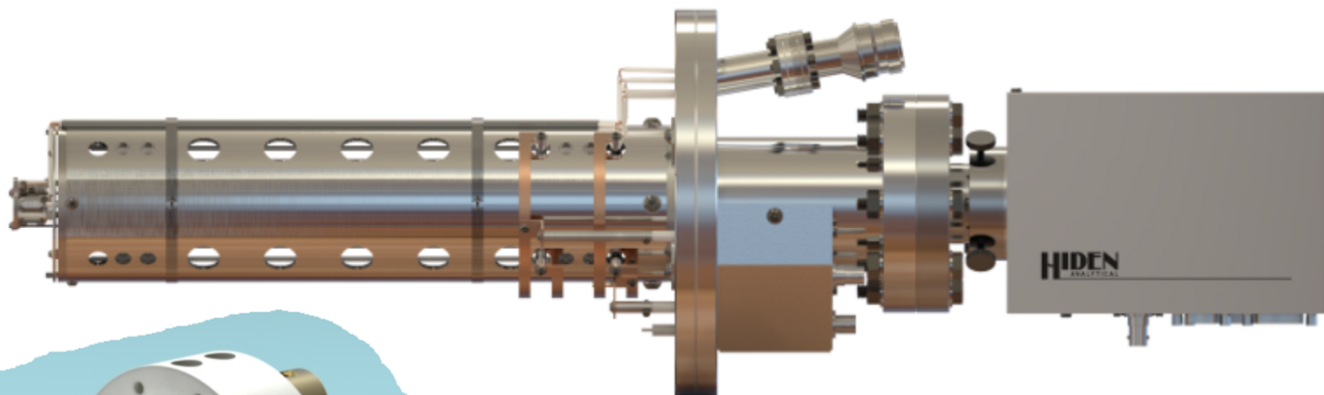


RGA13, 12/10/17

**Ultra High Resolution
20mm Quadrupole with Dual Zone operation.**

Hidden's 20mm Triple
Filter Quadrupole



By comparison, 6mm Triple
Filter Quadrupole

Quadrupole High resolution

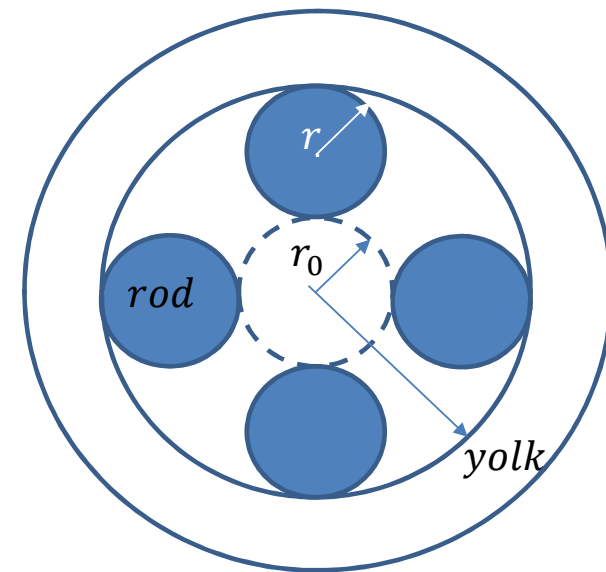
- Quadrupoles are challenged by species with similar m/z
- For example, He and D₂ are separated by just 0.026u
- Separation requires a quadrupole with high resolving power

Factors contributing to high resolution

- Residence time of ions in the quadrupole field - e.g. ion energy
 - Increased time yields greater rejection of unwanted m/z
- Field imperfections – e.g. variation in rod diameter
 - Reduce influence of mechanical tolerance by increasing rod diameter
- Number of RF cycles experienced by the ion – e.g. frequency
 - Resolution improves by square of number of cycles
- Pre and post filters – 3F analysers
- Stability zone – e.g. Zone I
 - Optimise choice of stability zone to reduce peak tailing

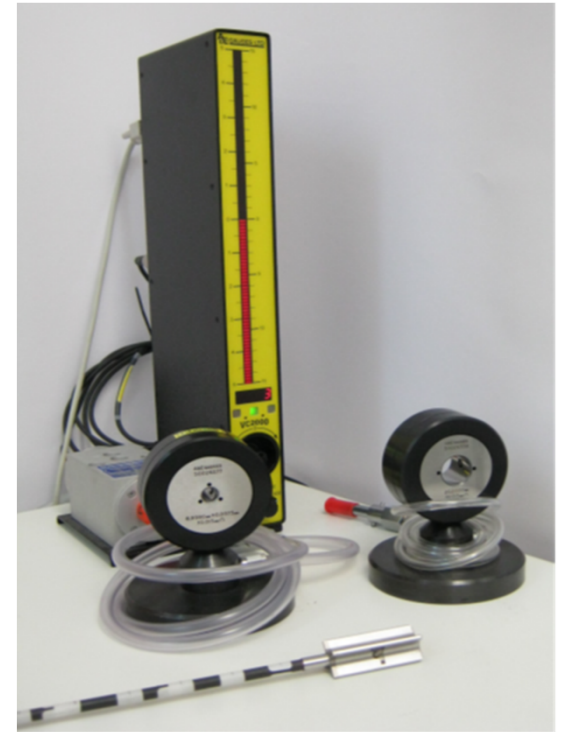
Field Radius

- filter 'scatter', degrades resolution
- scatter, $dM/M = 2 * dr_0 / r_0$
- Rod and yolk manufacturing tolerances contribute to dr_0 ,
- The larger the rod (& yolk) diameter, the lower the scatter.
- Conclusion - choose large, 20mm, rod size for high resolution



Minimising Field imperfections

- High resolving power requires high mechanical precision to reduce scatter
- Hiden's investment - air gauge metrology
- Both yolk and rod suppliers to improve tolerances, as part of on going performance management procedures.
- Hiden's 20mm rods now have diameter deviation less than 1 μ m along entire length – that's <50ppb



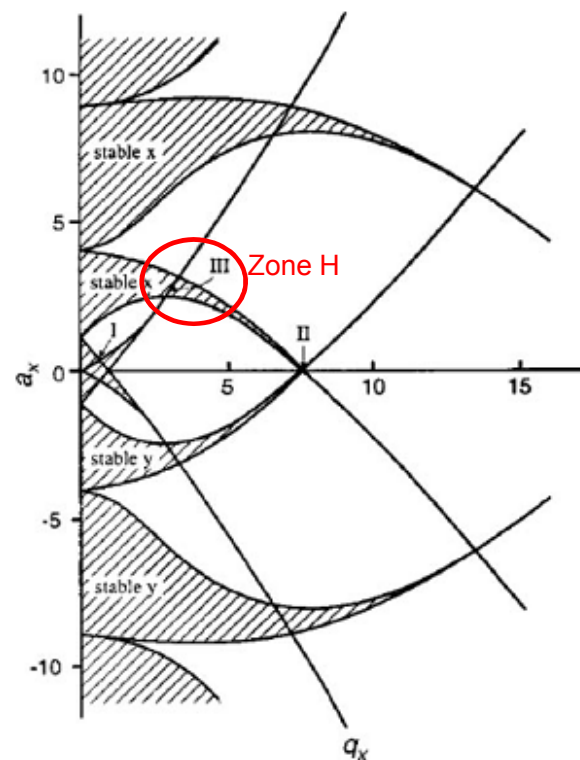
Hiden's Quadrupole air gauging tool

Maximise Frequency

- Frequency is a determinant of number of RF cycles
- But increase frequency raises $[\text{RF Power}]^5$
- Hiden's High Power RF Generator provides $>150\text{W}$ of electrical power to create High Frequency.
- Result - DLS20 Electronics maximises RF frequency - and RF Cycles

- Resolution and Stability Regions
- Quadrupoles are normally operated within Stability Zone I, but other zones exist
- Zone III gives opportunity to increase resolving power – **Hidden designation “Zone H”**

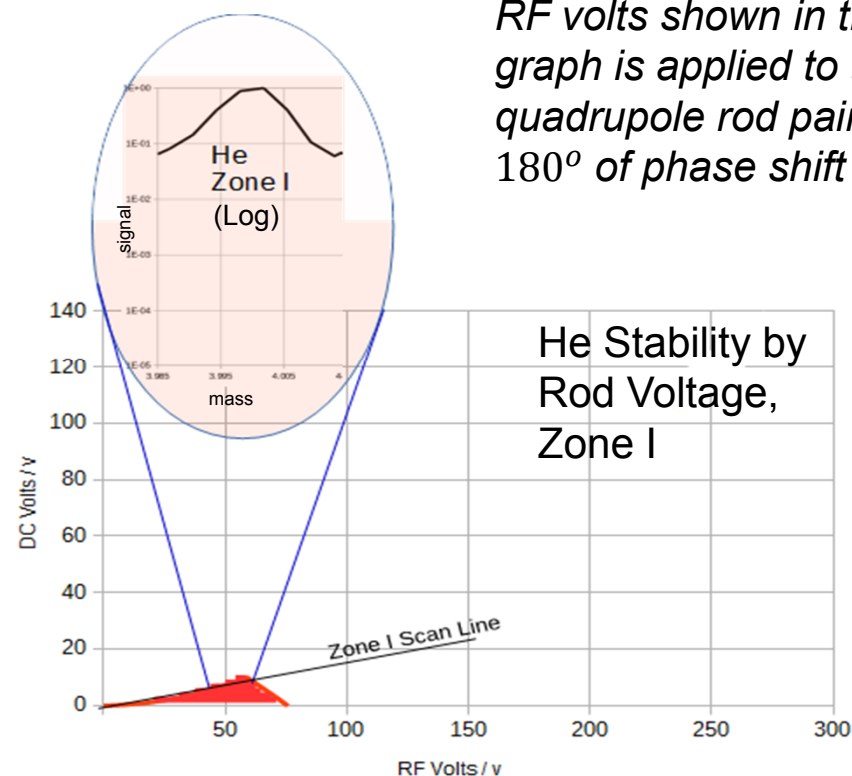
Regions of stability for x and y motions in a quadrupole, defined by Mathieu equation parameters a and q . Transmission of an ion occurs when a and q values are within both ‘stable x’ and ‘stable y’ boundaries



• Resolution and Stability Regions

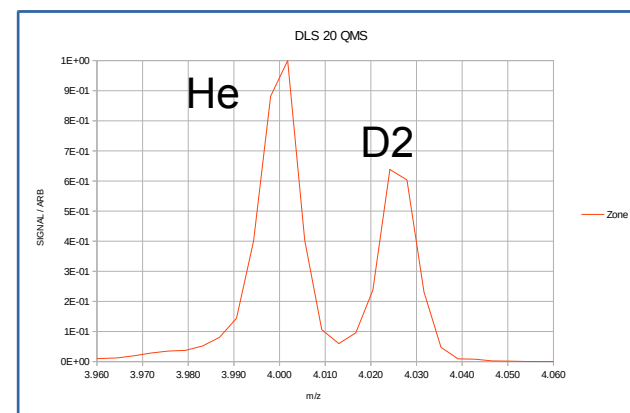
- In electrical terms the stability regions can be defined by their RF:DC ratio and their Volts per amu, for any rod diameter and frequency.
- For the DLS20,
 - Zone I needs 14.6v of RF per u and a ratio 5.96
 - Zone H needs 66.7v of RF per u and a ratio 2.04
- Quadrupoles are normally operated in Zone I
 - *Lowest volts per amu and good sensitivity make it suitable for all masses*
- Zone H offers higher resolving power
 - *High voltage requirements confine its use to lower masses*

- Stability Zone I.
- arrange volts within red boundary to create stable paths through quadrupole – yields He transmission
- raise the scan line to increase resolution and achieve separation from D2 – gives D2 rejection

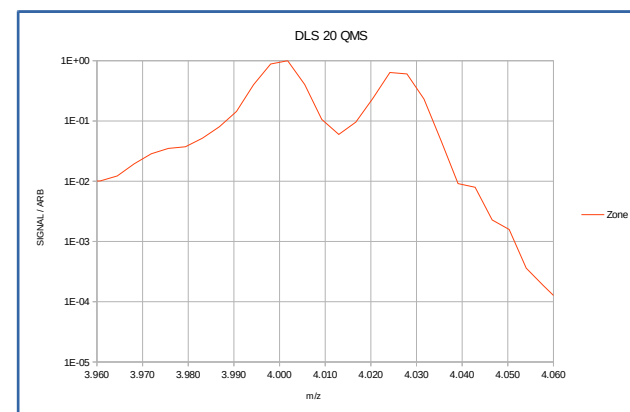


The sum of the DC and RF volts shown in the graph is applied to the quadrupole rod pairs, with 180° of phase shift

- Stability Zone I.
- Linear plot indicates separation
- Log plot reveals significant peak tailing, that is, incomplete rejection at adjacent mass
- The contribution of the D2 tail (abundance sensitivity) imposes a limitation on the level of He detection
- Sensitivity at this resolution of $> 2e-7A/Torr$

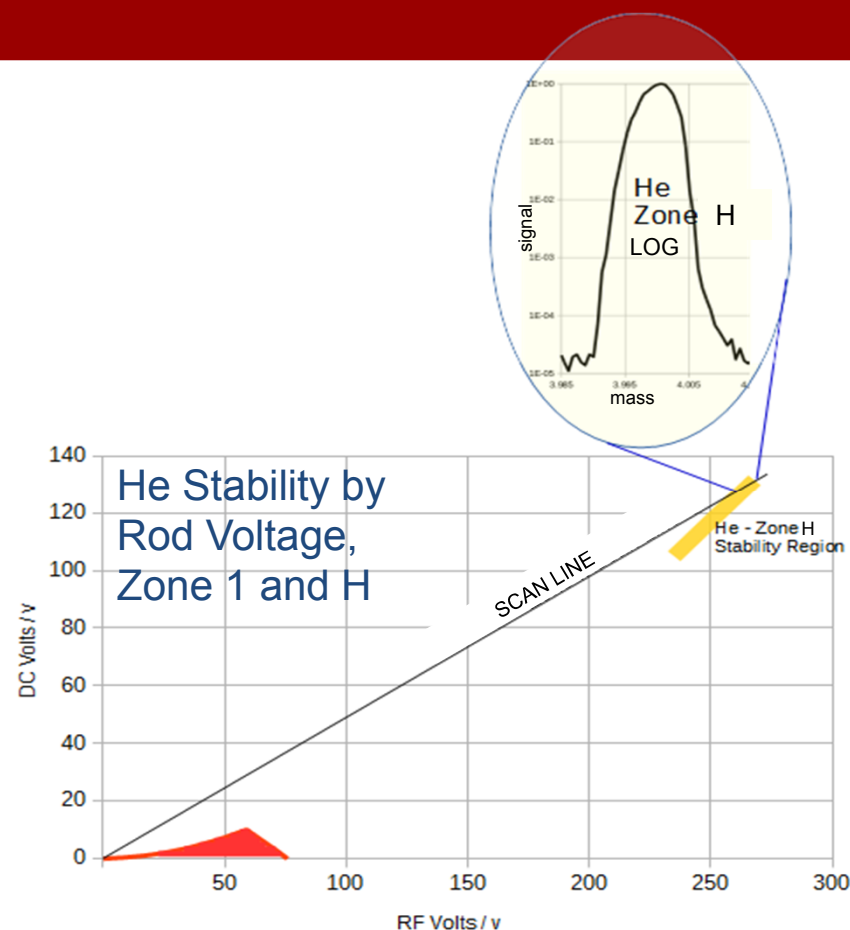


Lin

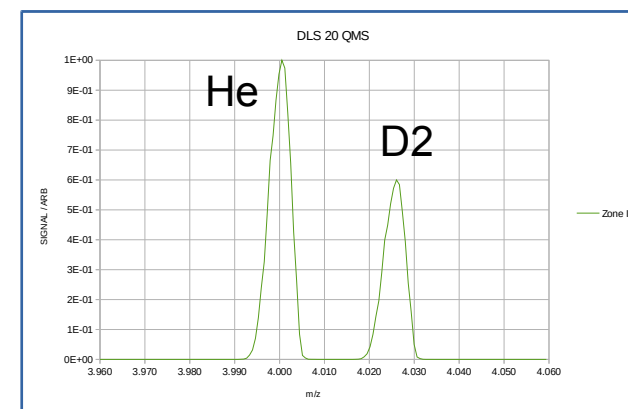


Log

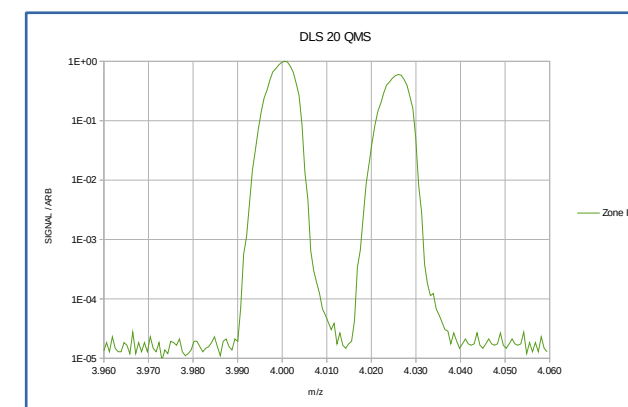
- Stability Zone H
- Arrange volts within yellow boundary for He transmission
- Raise scan line to Upper Tip of boundary for least peak tailing
- Reduced Tailing yields improved rejection of D2



- Stability Zone H
- Linear plot shows separation achieved
- Log plot reveals minimal peak tailing – high D2 rejection
- The contribution of D2 (abundance sensitivity) to He is <1ppm
- Detection limit of He in D2 increased by four orders of magnitude
- Sensitivity of $>1\text{e-}6\text{A/Torr}$



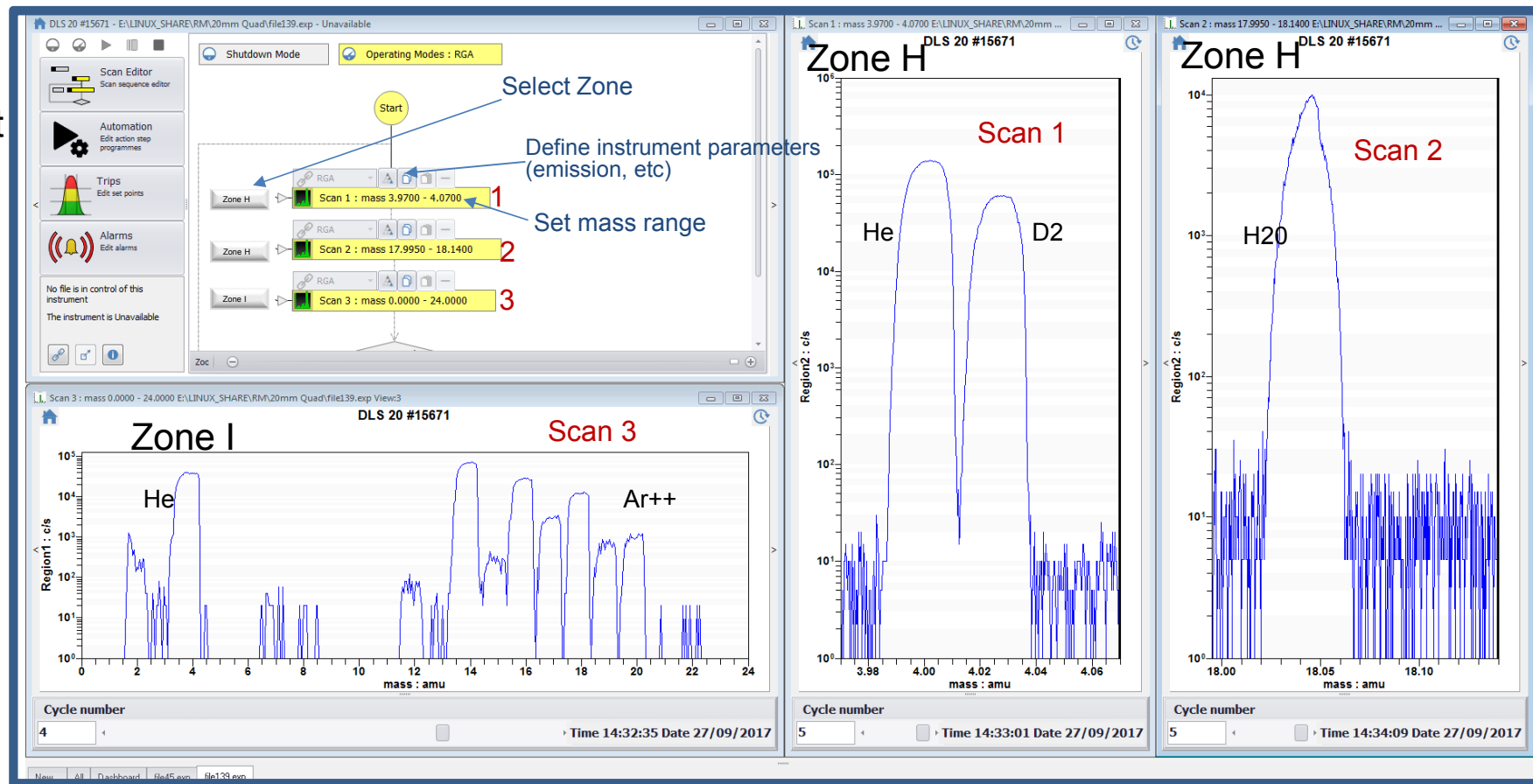
Lin



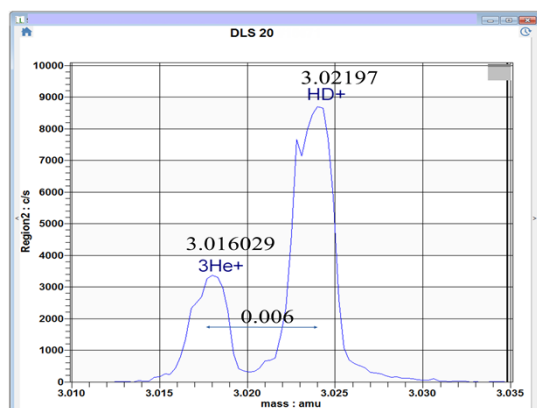
Log

Hidden software gives full control

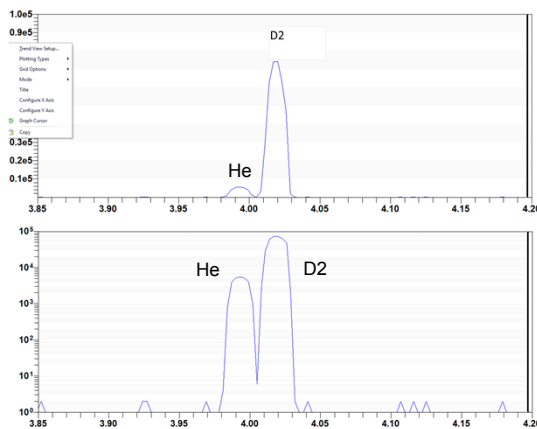
Hidden's software enables Zone I and H scans in the same event sequence.



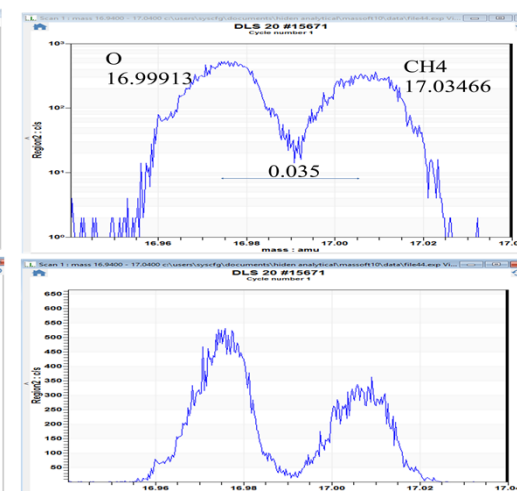
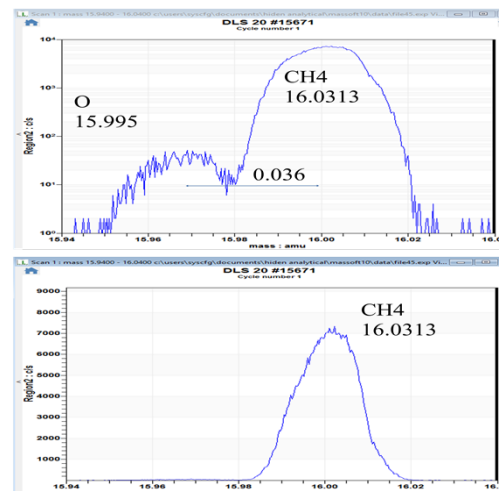
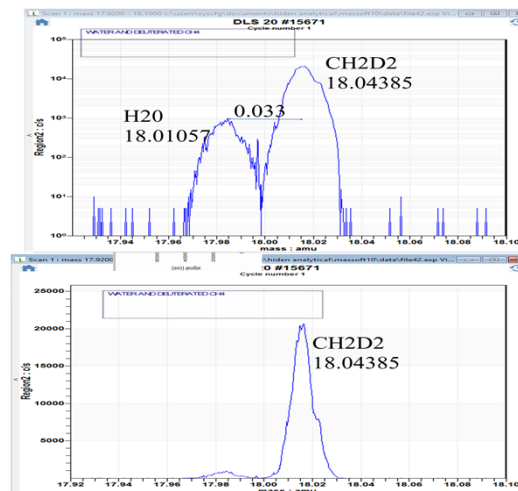
DLS20 in Fusion Research



3He and HD separated by 0.006u



4He and D_2 separated by 0.026u

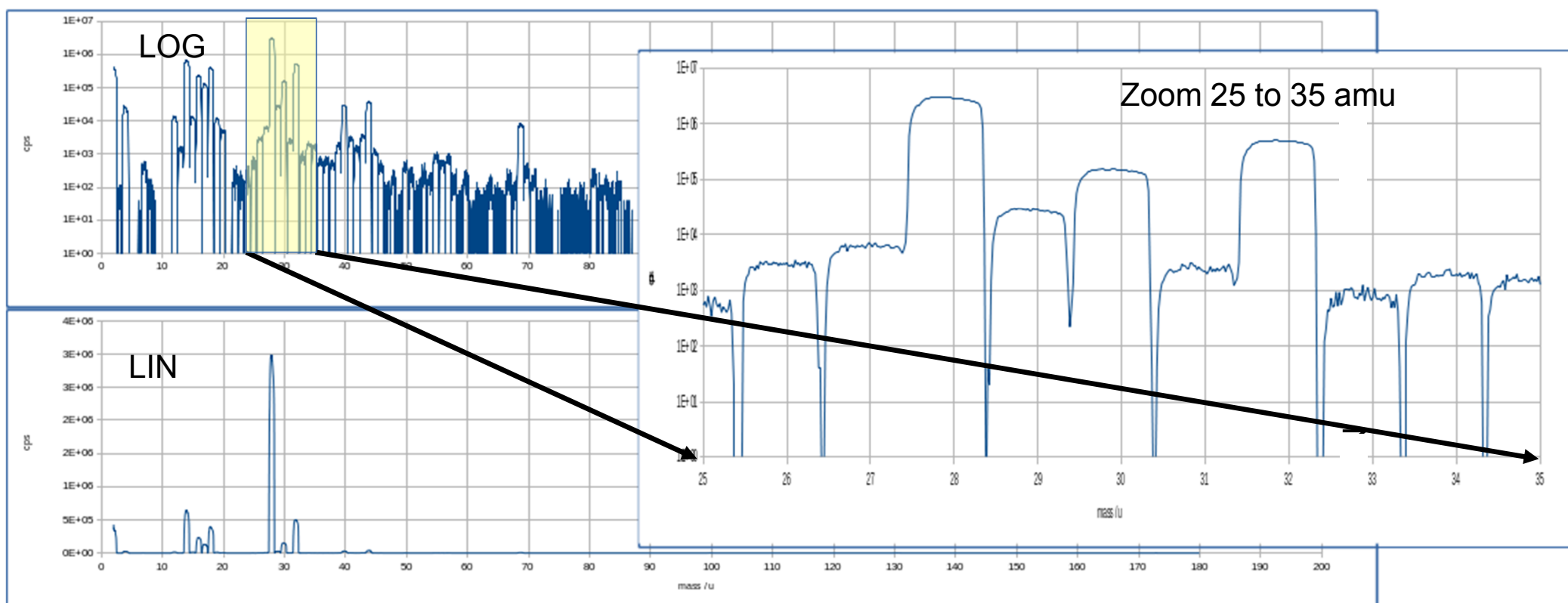


Deuterated species, 16, 17, 18 amu with 0.033 to 0.036u separations

Data collected at
Fusion
Research centre



DLS 20 - Zone I to 200amu



DLS20 - Summary

- Quadrupoles with high mechanical precision yield increased resolving power
- Quadrupoles operated in Zone H improve detection limits of species subject to interference from adjacent mass
- The *DLS20 dual zone* offers the choice of Zone I or Zone H
- The *DLS20 dual zone* offers significant performance advantages for Fusion Research