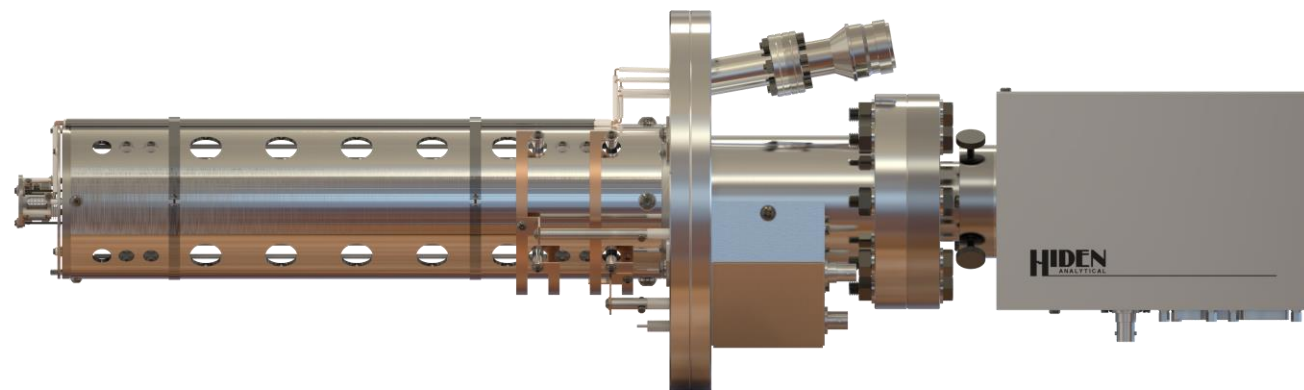
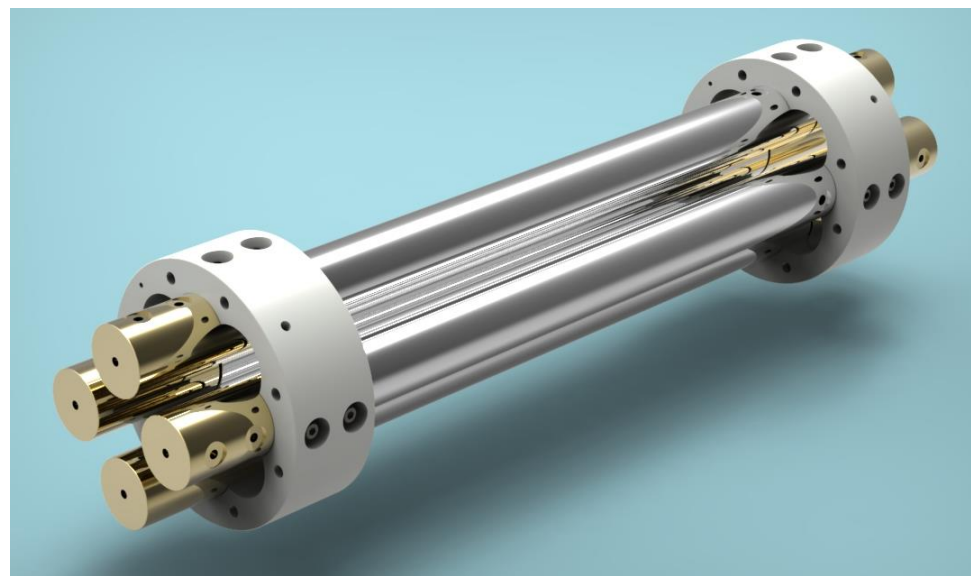


**RGA13, 12/10/17**

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

## Hiden's 20mm Triple Filter Quadrupole

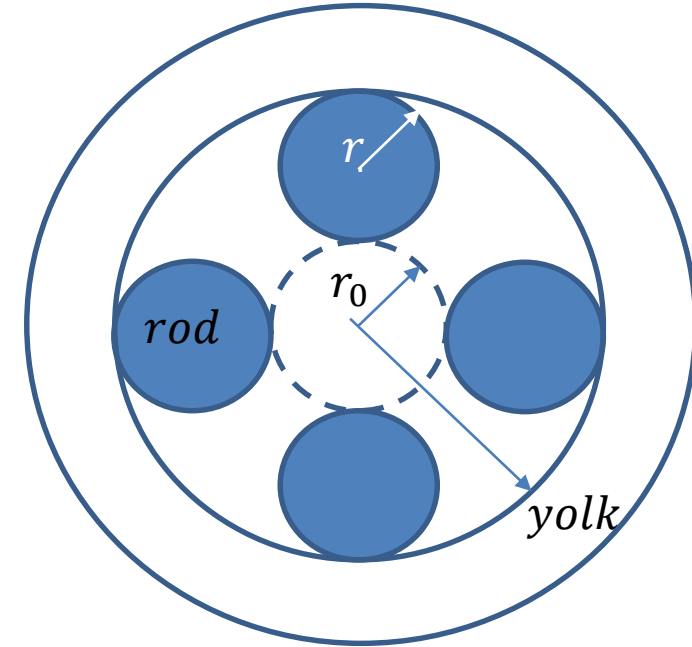


By comparison,  
6mm Triple Filter  
Quadrupole

- Quadrupoles are challenged by species with similar  $m/z$
- For example, He and  $D_2$  are separated by just 0.026u
- Separation requires a quadrupole with high resolving power

- 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

- 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



- High resolving power requires high mechanical precision to reduce scatter
- Hiden's investment - air gauge metrology
- Metrology data feedback to both yolk and rod suppliers is part of our ongoing performance management procedure
- Air gauge measurement as part of the quality control system enables precision in manufacture. Deviation of less than 1  $\mu\text{m}$  (< 50 PPB) is confirmed along the entire quadrupole assembly length

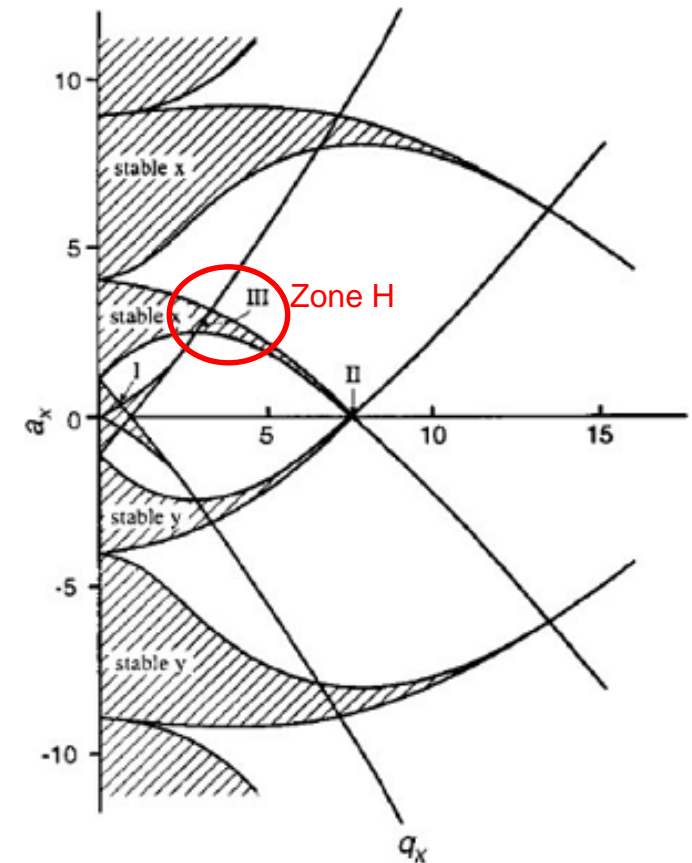


Hiden's Quadrupole air gauging tool

- Frequency is a determinant of number of RF cycles
- But increase frequency raises [RF Power]^5
- Hiden's High Power RF Generator provides >150W of electrical power to create High Frequency.
- Result – DLS-20 Electronics maximises RF frequency - and RF Cycles

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

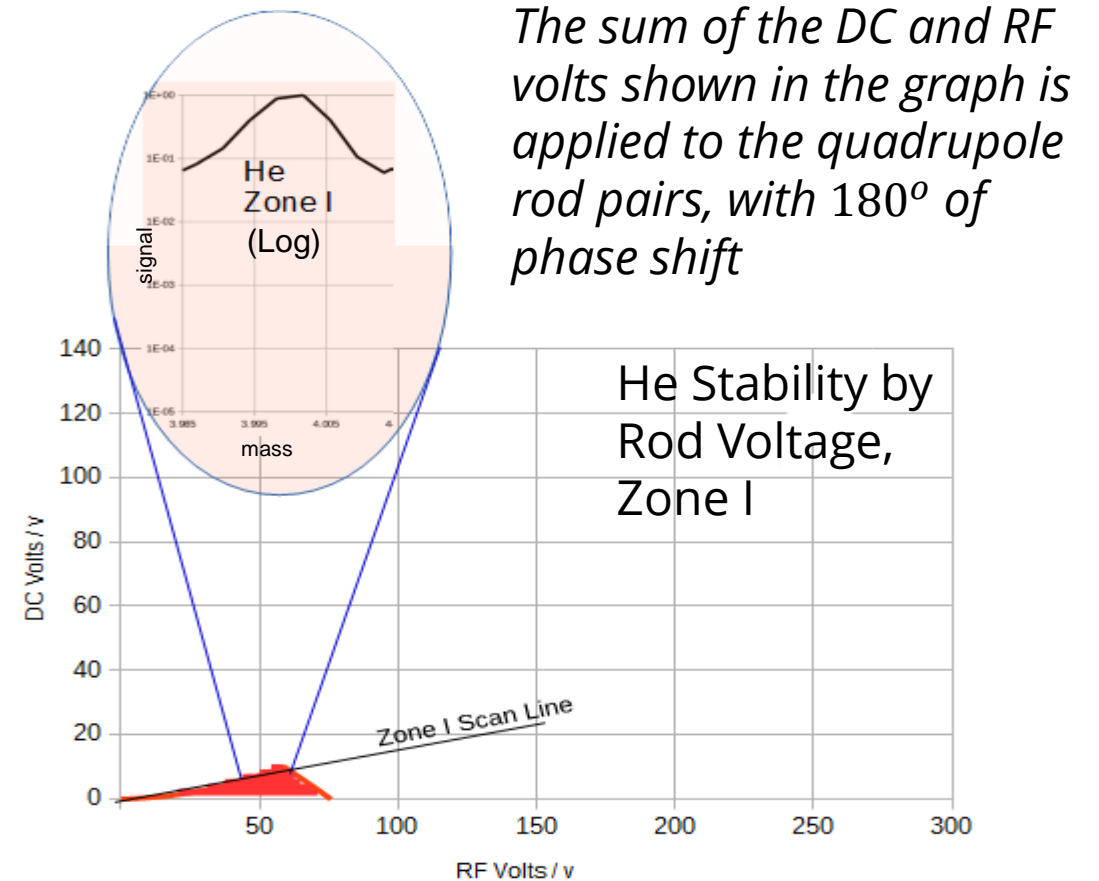
Regions of stability for x and y motions in a quadrupole, defined by Mathieu equation parameters a and q. Transmission of an ion occurs when a and q values are within both ‘stable x’ and ‘stable y’ boundaries



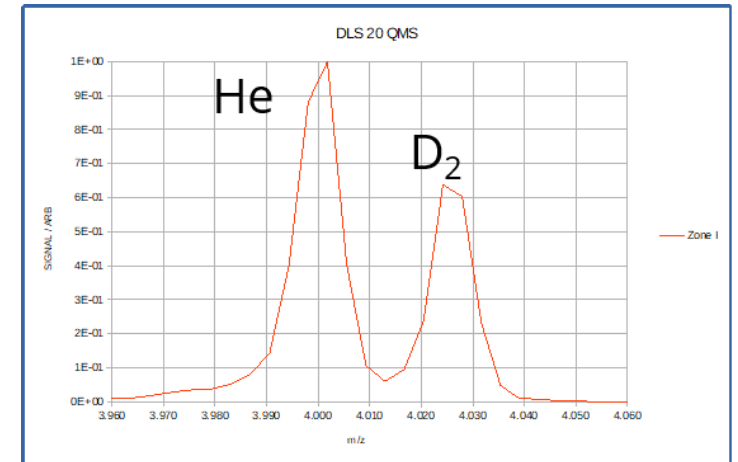


- In electrical terms the stability regions can be defined by their RF:DC ratio and their Volts per amu, for any rod diameter and frequency.
- For the DLS-20,
  - Zone I needs 14.6v of RF per u and a ratio 5.96
  - Zone H needs 66.7v of RF per u and a ratio 2.04
- Quadrupoles are normally operated in 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*

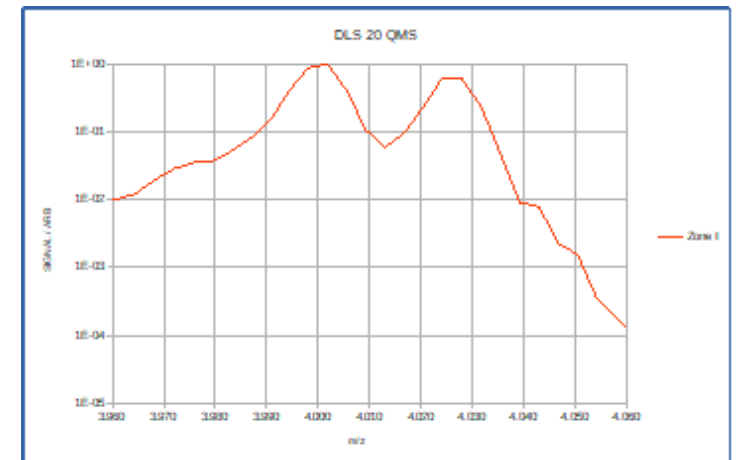
- Arrange volts within red boundary to create stable paths through quadrupole – yields He transmission
- Raise the scan line to increase resolution and achieve separation from  $D_2$  – gives  $D_2$  rejection



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

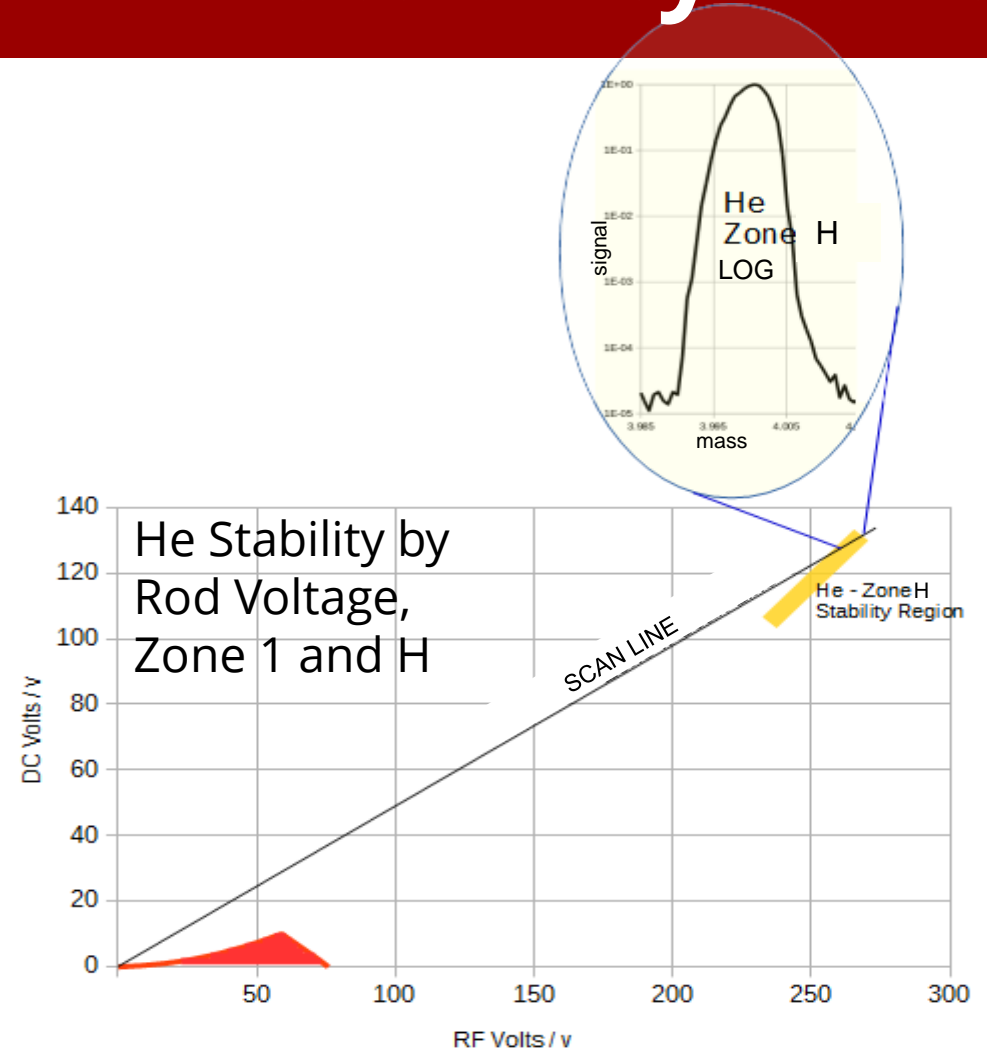


Lin

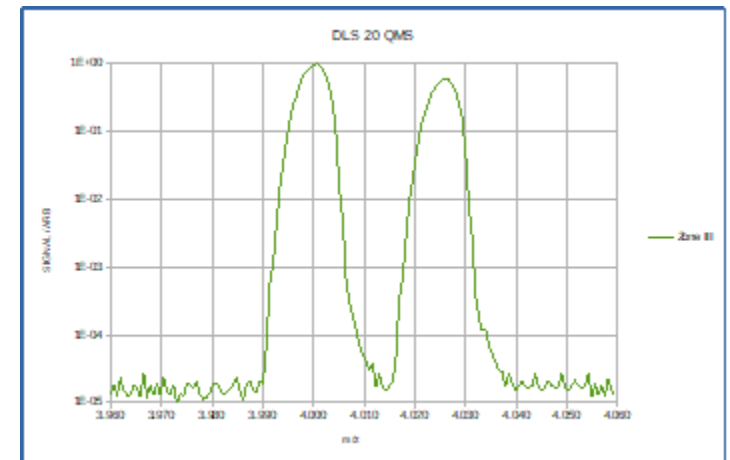
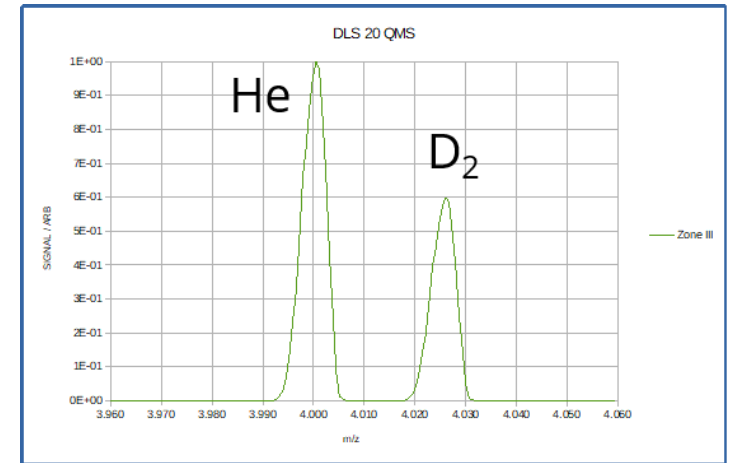


Log

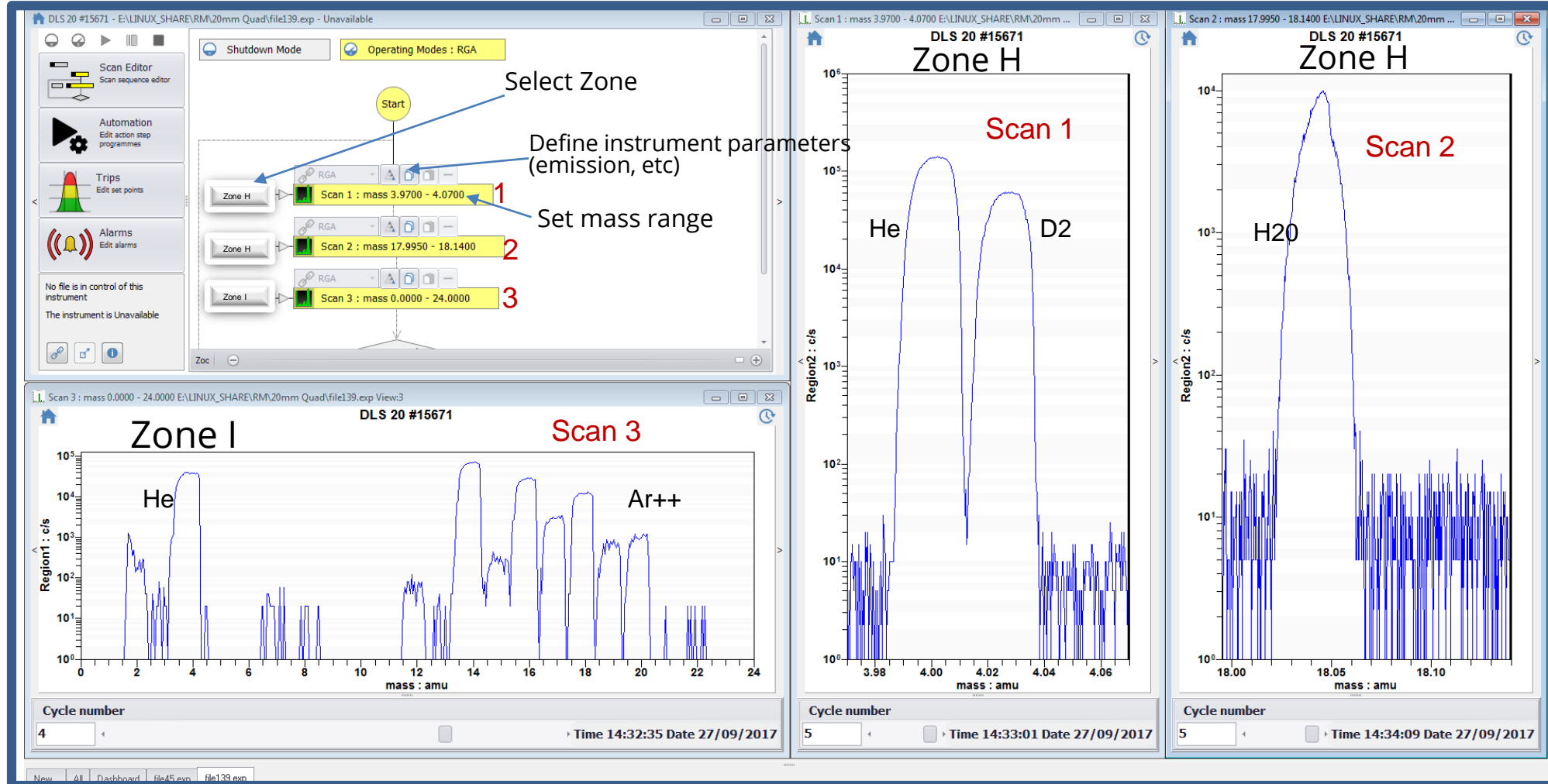
- Arrange volts within yellow boundary for He transmission
- Raise scan line to Upper Tip of boundary for least peak tailing
- Reduced Tailing yields improved rejection of D<sub>2</sub>

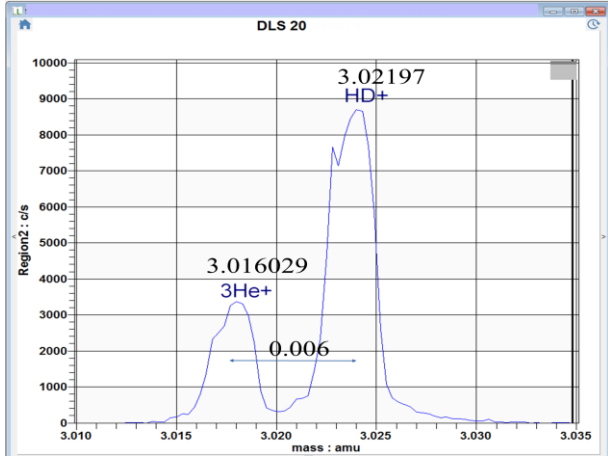


- Linear plot shows separation achieved
- Log plot reveals minimal peak tailing – high  $D_2$  rejection
- The contribution of  $D_2$  (abundance sensitivity) to He is  $<1$  ppm
- Detection limit of He in  $D_2$  increased by four orders of magnitude
- Sensitivity of  $>1 e-6A/Torr$

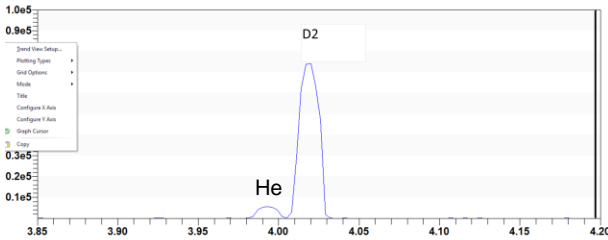


Hidden's software enables Zone I and H scans in the same event sequence.

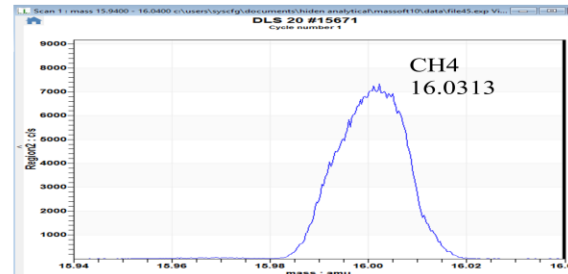
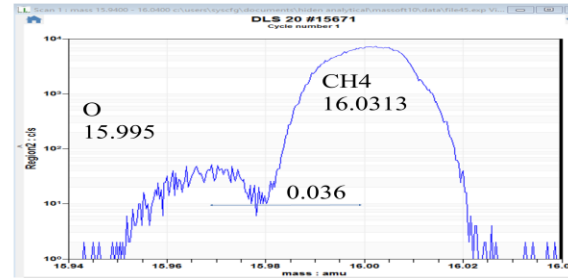
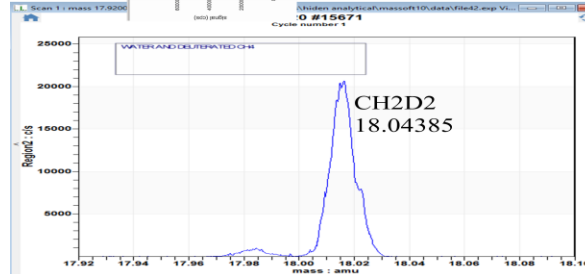
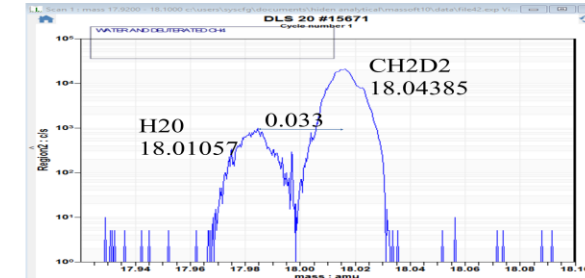




$3\text{He}$  and  $\text{HD}$  separated by  $0.006\text{u}$



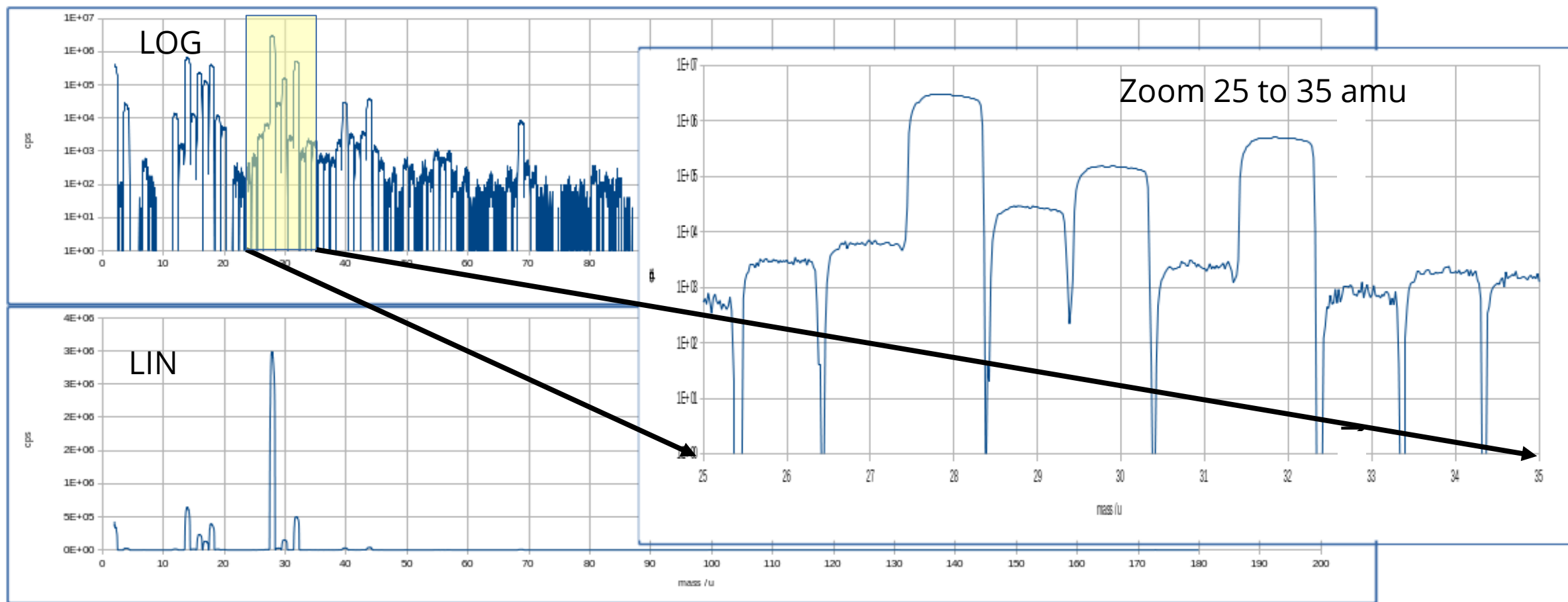
$4\text{He}$  and  $\text{D}_2$  separated by  $0.026\text{u}$



Deuterated species, 16, 17, 18 amu with  $0.033$  to  $0.036\text{u}$  separations

Data collected at  
Fusion  
Research centre







- 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 DLS-20 *dual zone* offers the choice of Zone I or Zone H
- The DLS-20 *dual zone* offers significant performance advantages for Fusion Research