# Concepts for Elongated Spiral and Helical Ion Guides

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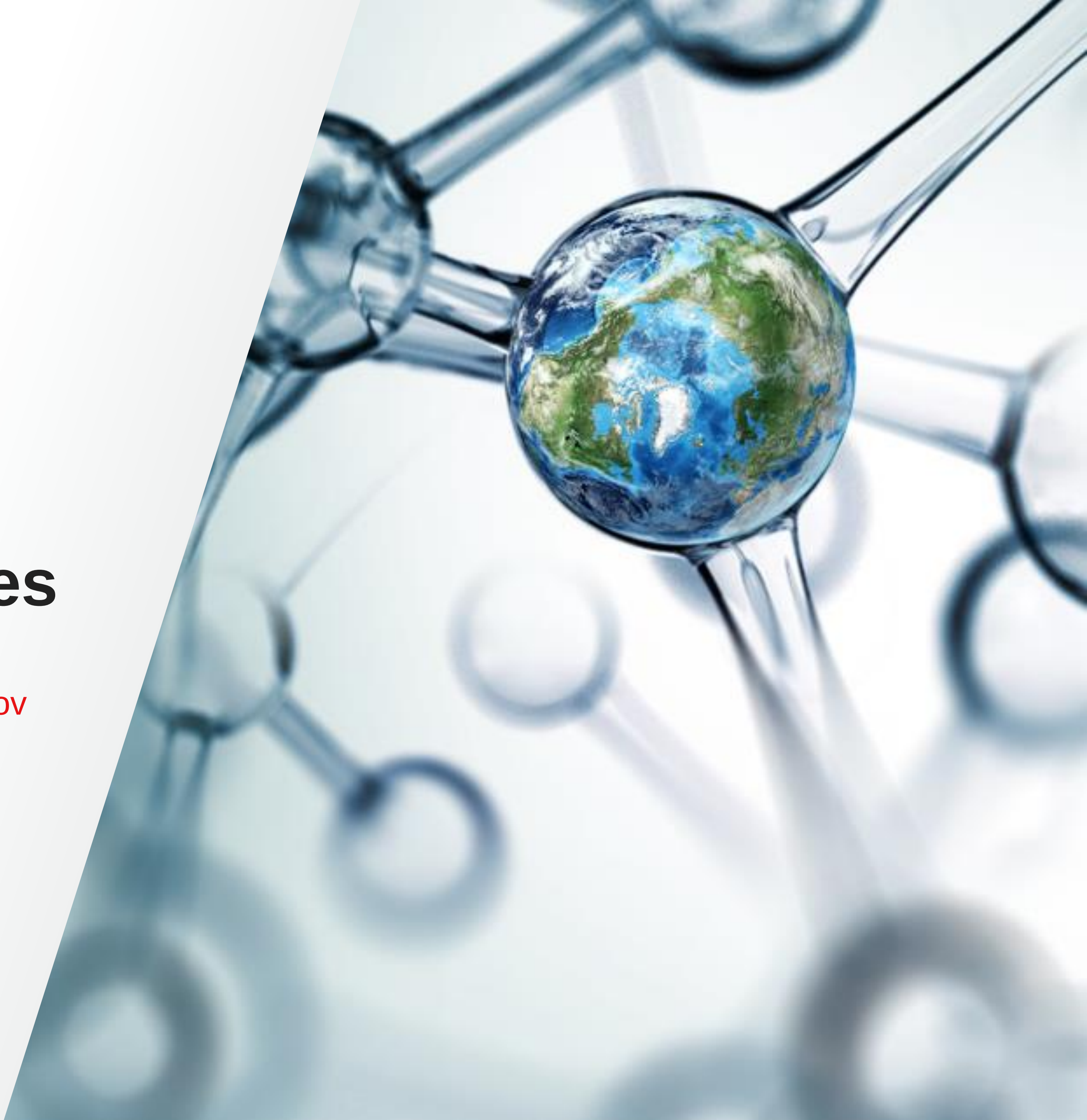


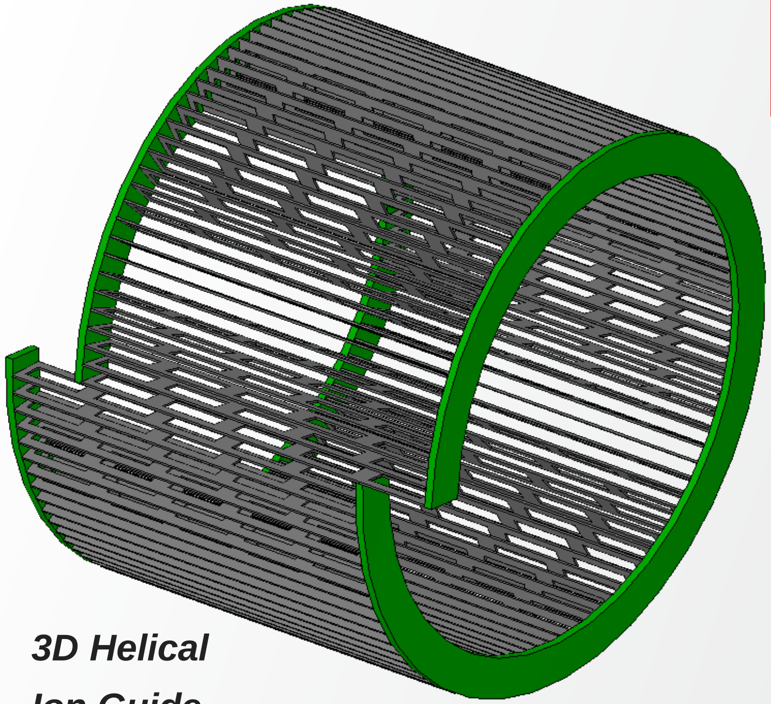
# Abstract


- Simple concepts have been proposed to construct helical and spiral ion guides from a series of plate electrodes, each containing multiple apertures, to allow for the very long 10+ meter ion drift paths suitable for high resolution ion mobility analyzers.
- Simulations of both types of ion guide are presented vs more conventional linear and circular equivalents and show high performance for the spiral.

# Introduction

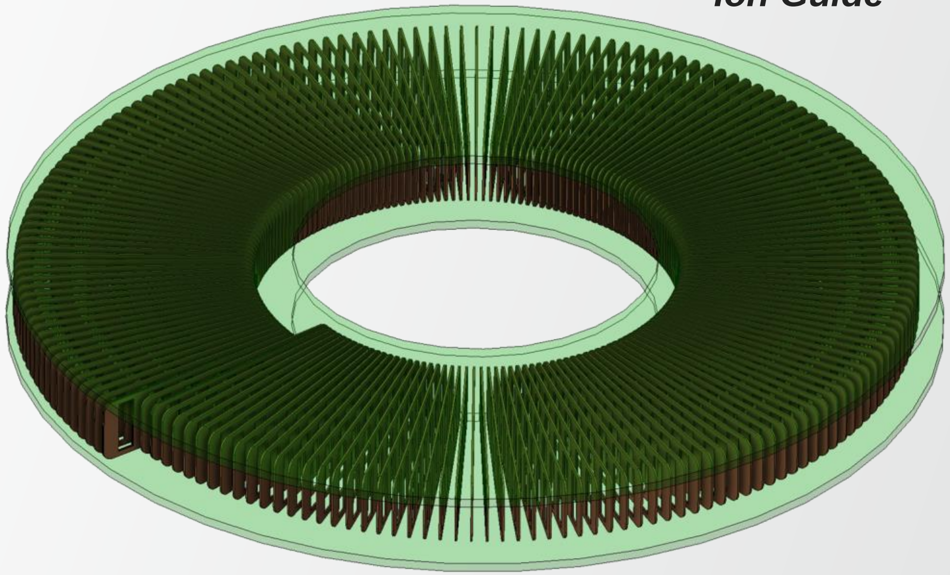
- High resolution ion mobility analyzers benefit from greatly elongated long flight paths. Stacked ring RF ion guides may form very long channels, and may even be folded into a compact volume, however the linear scaling of path length to number of ring electrodes and ensuing complexity limits them to around 1m, excepting PCB printed electrodes.

- An improvement is considered whereby each electrode is shared over multiple parts of the channel. Ion guide structures are proposed comprised of multi-aperture plate electrodes, stacked to form a series of circular channels. A continuous axial or radial shift down the electrode stack causes the channels to fuse, merging into a single elongated helical or radial ion path respectively.



***3D Helical Ion Guide***

***Flat Spiral Ion Guide***



# Introduction

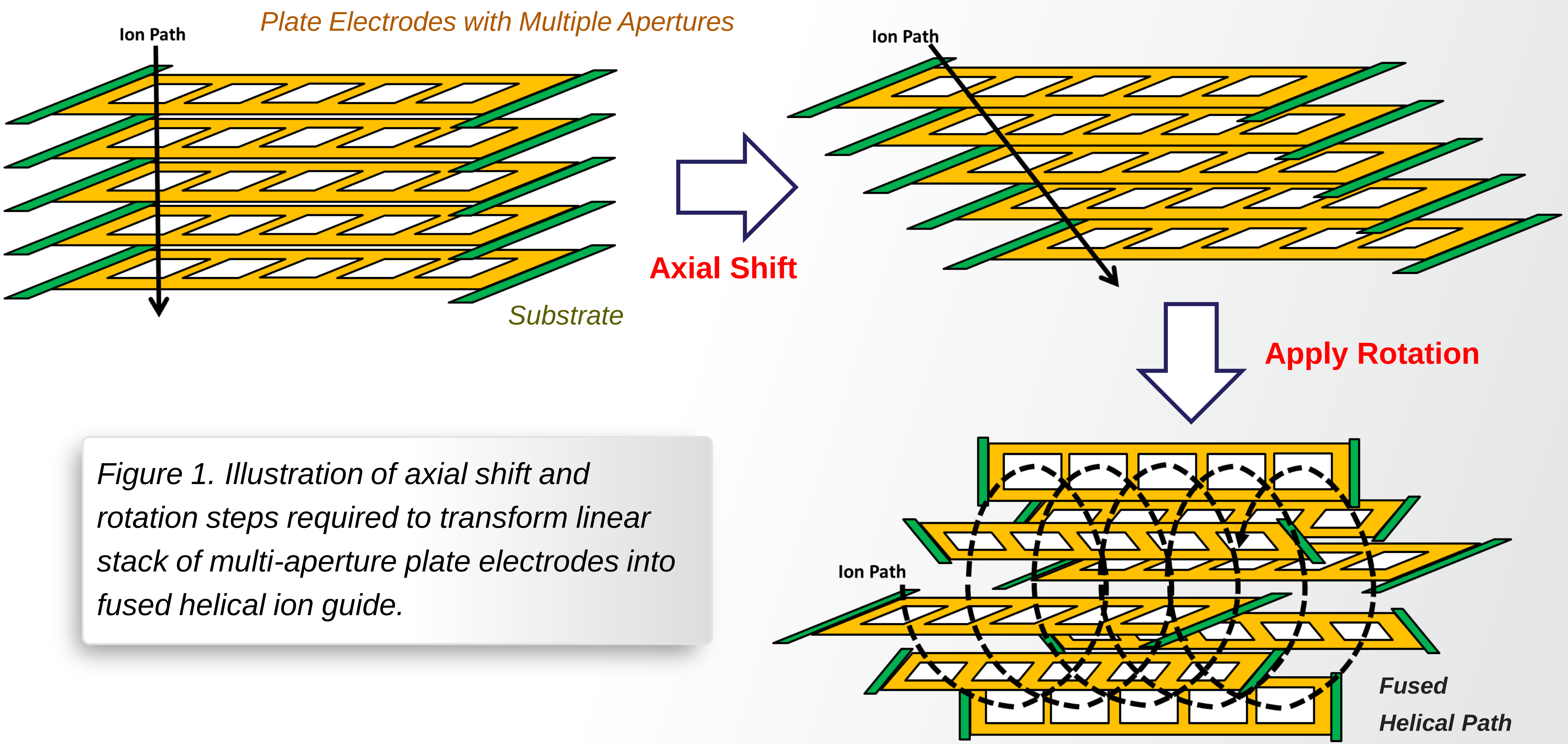
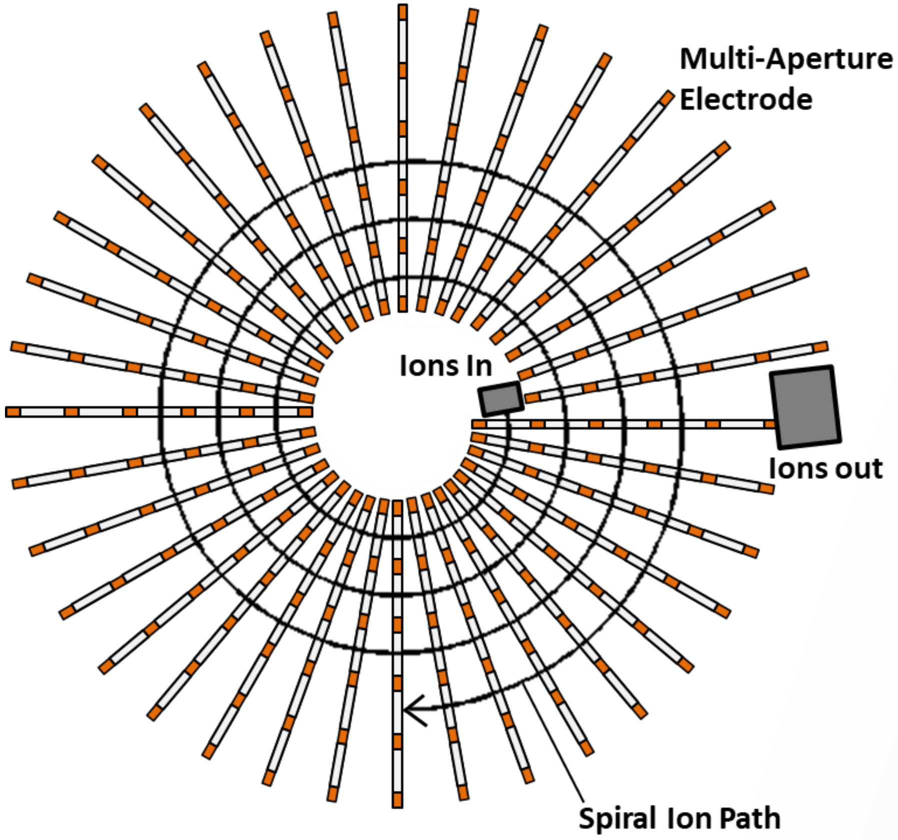



*Figure 1. Illustration of axial shift and rotation steps required to transform linear stack of multi-aperture plate electrodes into fused helical ion guide.*

# Introduction



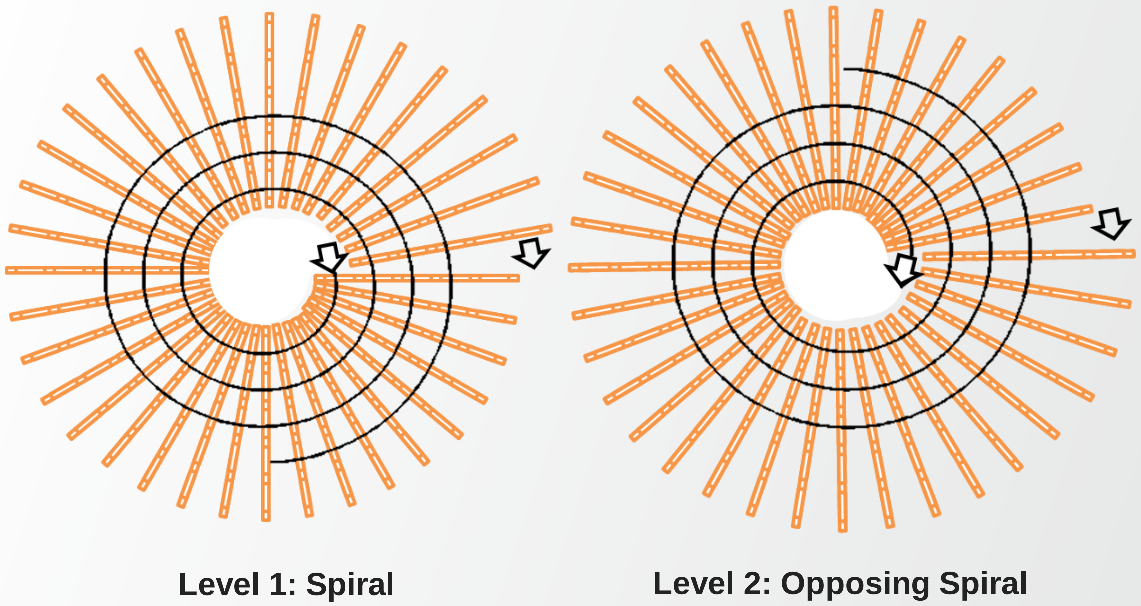
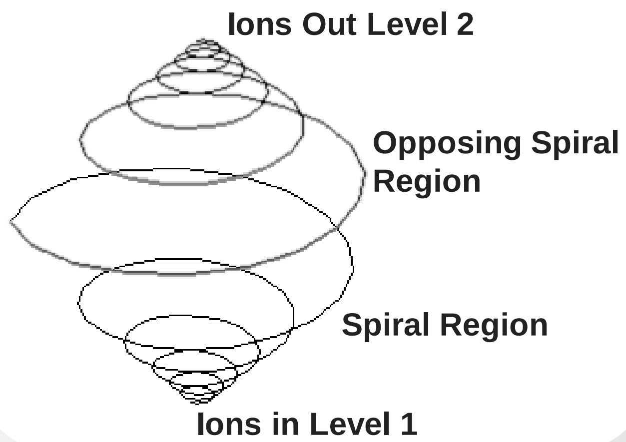




*Figure 2. Construction of an Archimedes Spiral-like ion guide. Successive plates shift to higher radius to form merged spiral path.*

*A helical shift may also be applied, resulting in a whirlpool shaped ion path that may be conjoined to additional layers to form extremely long, tightly folded ion paths*



# Simulation Details

- Models of the ion guides were constructed in MASIM3D software with 0.5mm thick electrodes, 1 and 1.5 mm spacing for the spiral and helix respectively.
- 250V 2MHz Trapping RF was applied with a 4-phase, 100 KHz RF travelling wave superimposed to propel ions along the guide. 4 mbar of stagnant $N_2$ was generally applied.
- The spiral was 2D, given a radius of 58.5mm, 5mm high apertures and spacing of 10mm, whilst the helix was 3D with a radius of 50.5mm and 15x5mm apertures.
- Equivalent circular and linear ion guides were also constructed to act as controls.

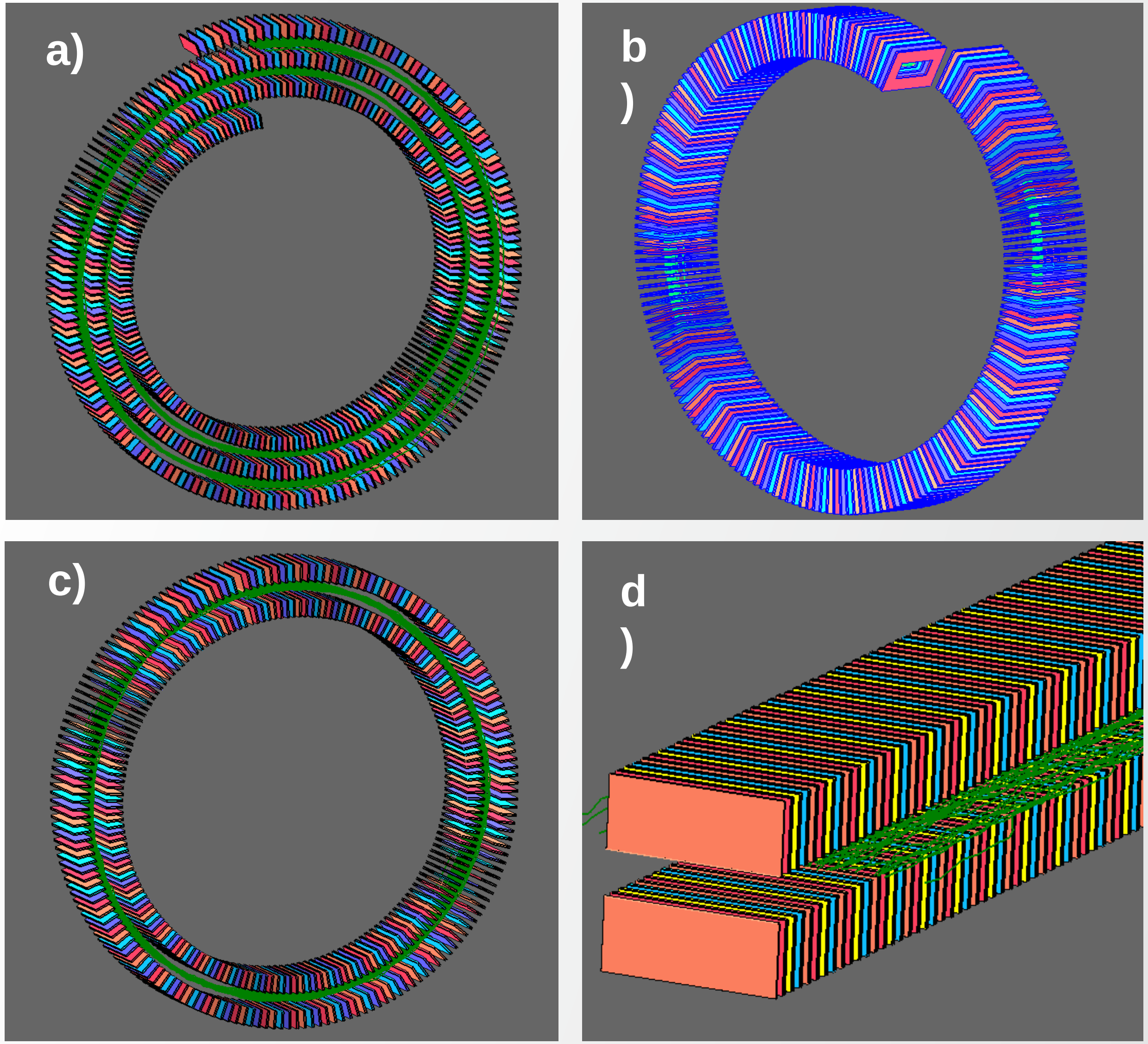



*Figure 3. Modelled ion guide structures: a) 2D Archimedes Spiral, b) 3D Helical Spiral, c) 2D Circle and d) 2D Linear.*

# Simulation Results

- Figure 4 shows general simulation performance obtained from the linear ion guide, for tuning of applied waveforms.
- The spiral ion guide showed no loss of performance compared to either the circle or linear guides.

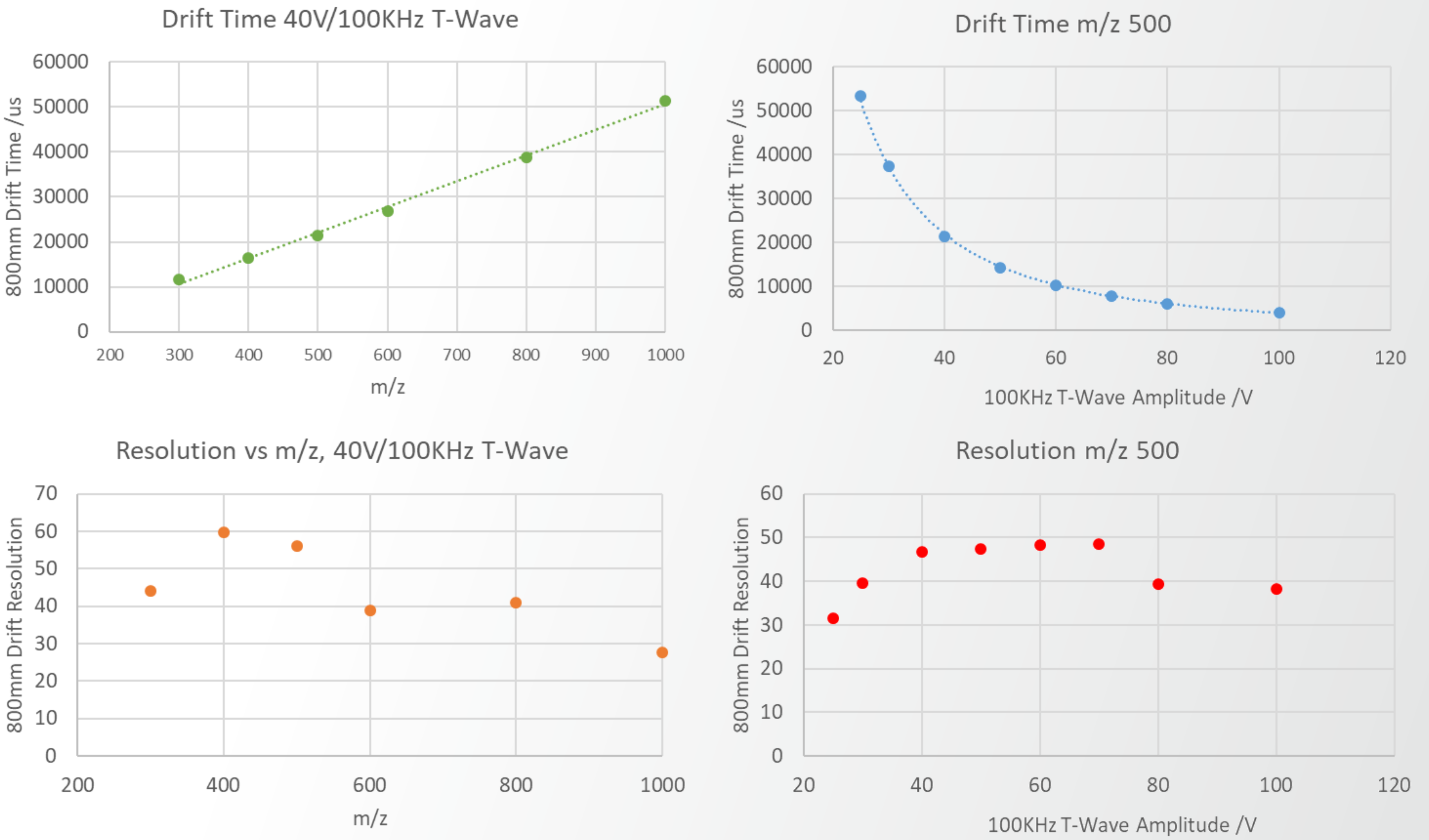



*Figure 4. Drift times and resolution of various m/z ions through linear ion guide at 4 mbar $N_2$ pressure, with various T-Wave amplitudes applied.*

# Simulation Results

- Figure 5 shows a comparison of resolution change as ions traverse two rotations of either the helix or the circle, with a roughly similar path to the 800mm length in Figure 4.
- Resolution of the spiral is equivalent, if not greater than the circle, and should be as the spiral path is slightly longer. Resolution values meet expectations and seem comparable to existing analysers of ~1m path length.
- More troublesome was the 3D spiral, which appeared to transmit ions well but produced approximately halved mobility resolution. There seems no good physical reason for the axial shift to cause this and is presently thought to be an inaccuracy in the 3D model.

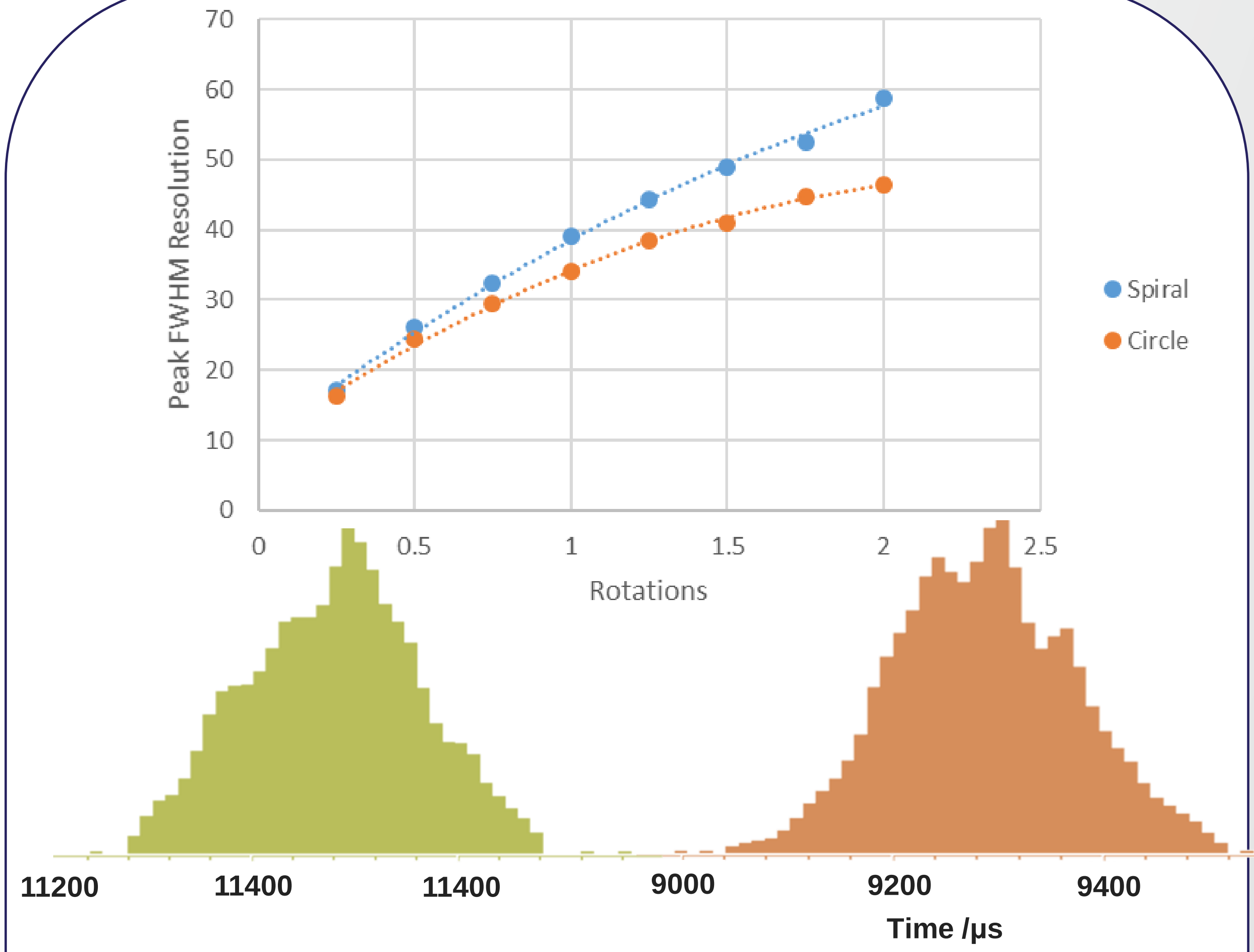



*Figure 5. Mobility resolution of ions travelling through the Archimedes spiral and circular systems, as well as time-of-flight histograms at the end of the second rotation.*

# Conclusions

- Concepts have been proposed for helical and spiral ion guides that allow very long, tightly folded ion paths.
- Simulations show that ions may be successfully passed through these structures. High resolution has been demonstrated for 2D models such as the spiral.
- 3D helixes suffered a reduction of performance, though this flaw is extremely unlikely to be representative of reality.

## TRADEMARKS/LICENSING



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