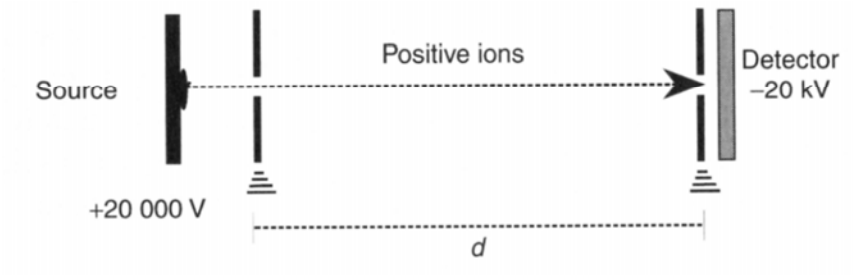
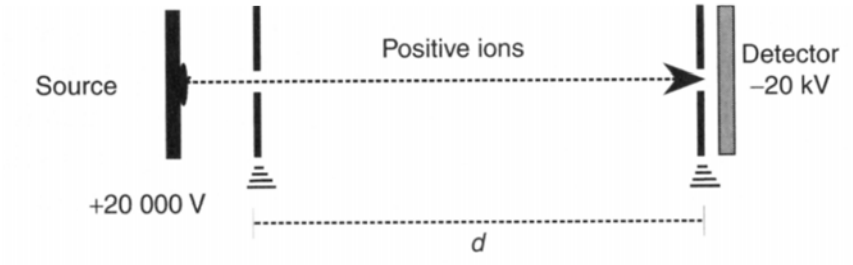
# Mass Resolution Based On Time of Flight (TOF)

- Based on simple principle of ions flying through space, accelerating under the influence of an applied electrostatic force.
- Force is the same on all ions, so heavier ions fly slower than light ones.




# Mass Resolution Based On Time of Flight (TOF)

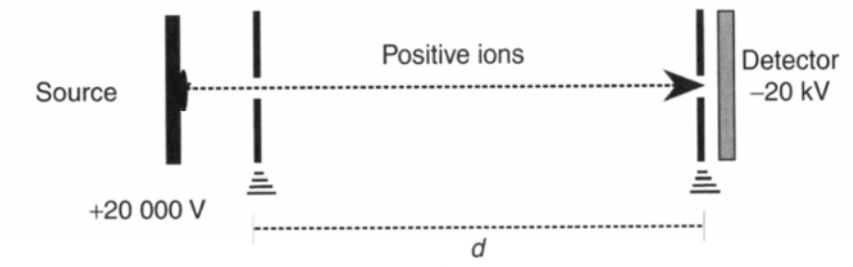



$$E_e\,(\text{ion}) = qV_S = zeV_S \qquad E_k\,(\text{ion}) = \frac{mv^2}{2}$$

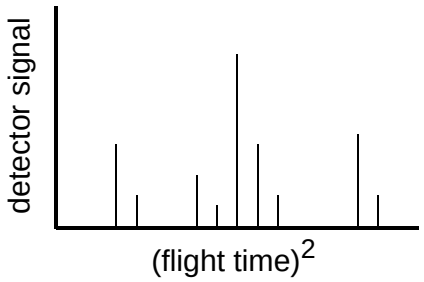
$E_e$ (ion) = $E_k$ (ion), so

$$v^2 = \frac{2zeV_S}{m} \qquad t^2 = \frac{d^2}{v^2} = \frac{m}{z}\left(\frac{d^2}{2eV_S}\right)$$

# Mass Resolution Based On Time of Flight (TOF)



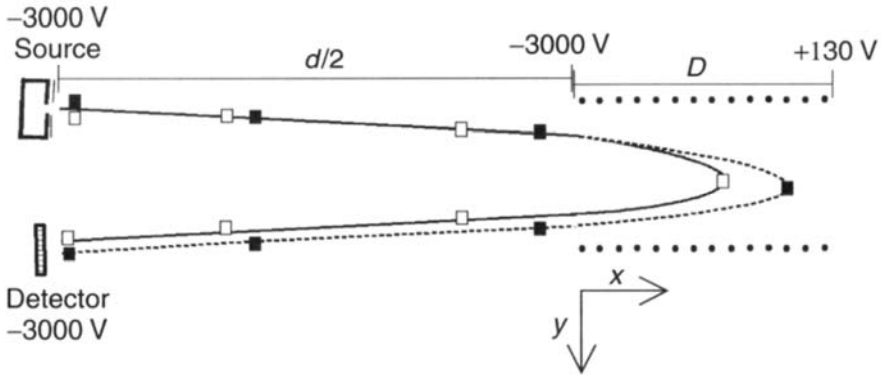

$$t^2 = \frac{m}{z}\left(\frac{d^2}{2eV_S}\right)$$




= mass spectrum.

# TOF Focusing by Reflectron

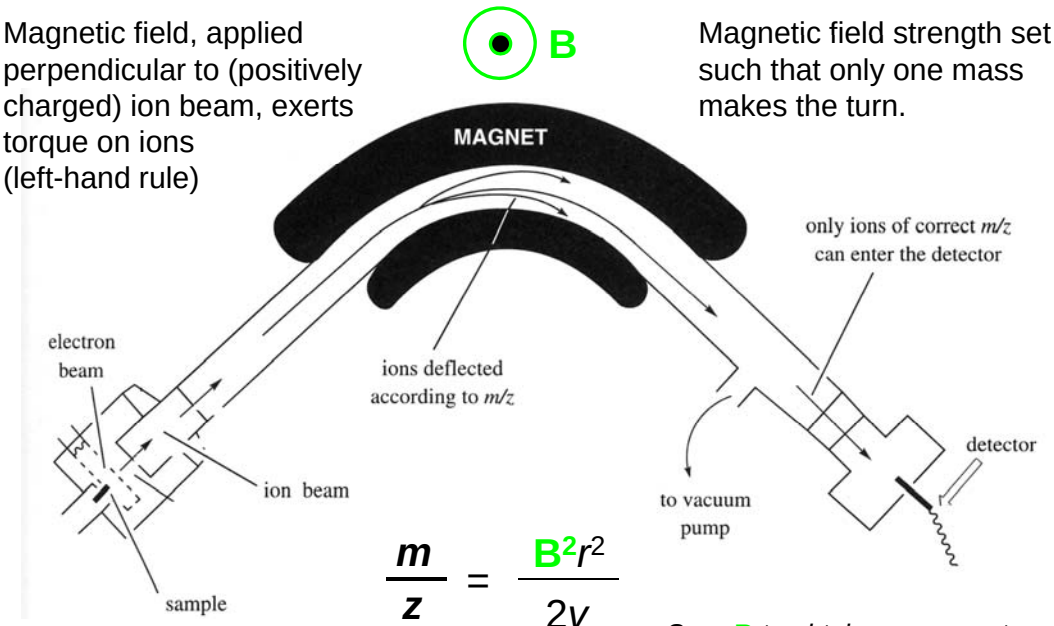
*Corrects for kinetic energy dispersion at source.*




□ & ■ : Same mass, different initial velocity

# Mass Resolution: Magnetic Sector Analyzers

Magnetic field, applied perpendicular to (positively charged) ion beam, exerts torque on ions (left-hand rule)



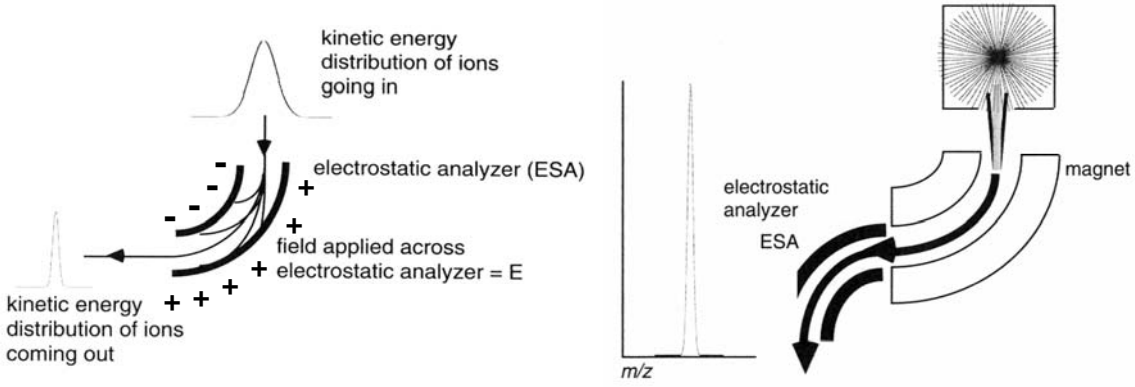

Magnetic field strength set such that only one mass makes the turn.

$$\frac{m}{z} = \frac{B^2 r^2}{2v}$$

*Scan **B** to obtain mass spectrum.*

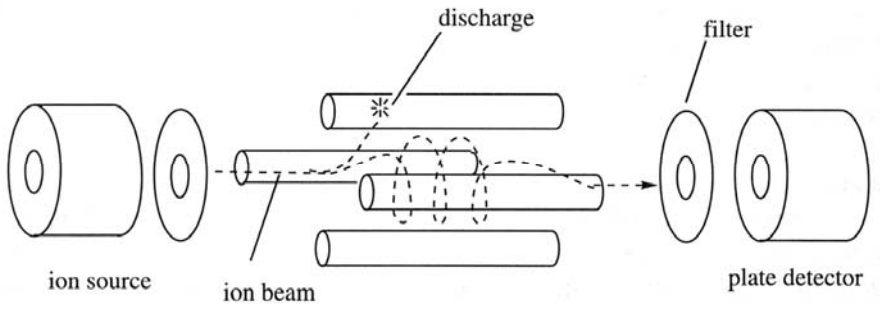
# Mass Resolution: Double-Focusing Analyzers

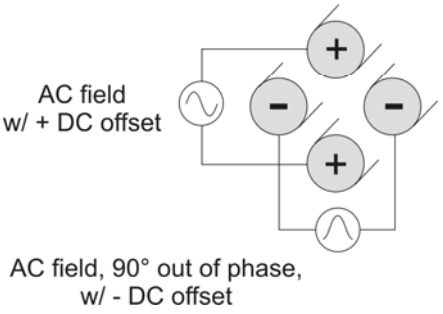
*Resolution improved by adding* Electrostatic Analyzer




*Double-Focusing Magnetic Sector-Electrostatic Analyzer*

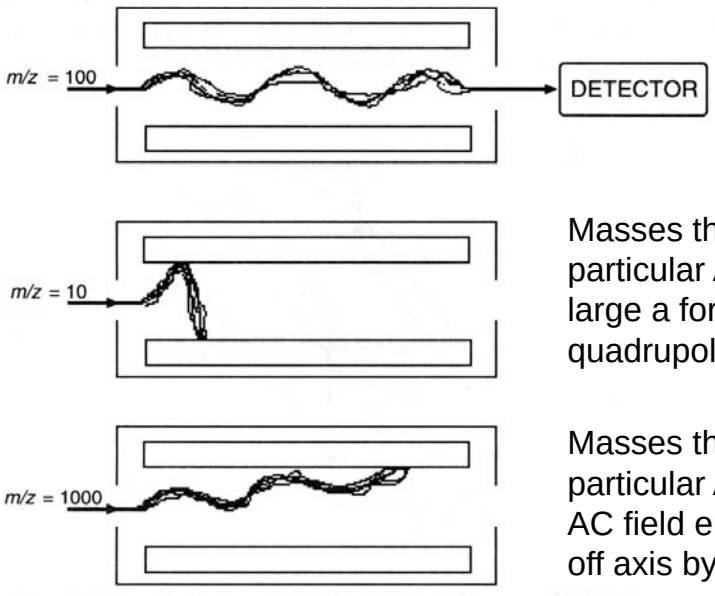
# Mass Resolution: Quadropole Mass Analyzers




- Potential of alternating field set such that ions travel a helical path.
- As with electrostatic analyzer, only ions of a particular mass can make the turn along that path.

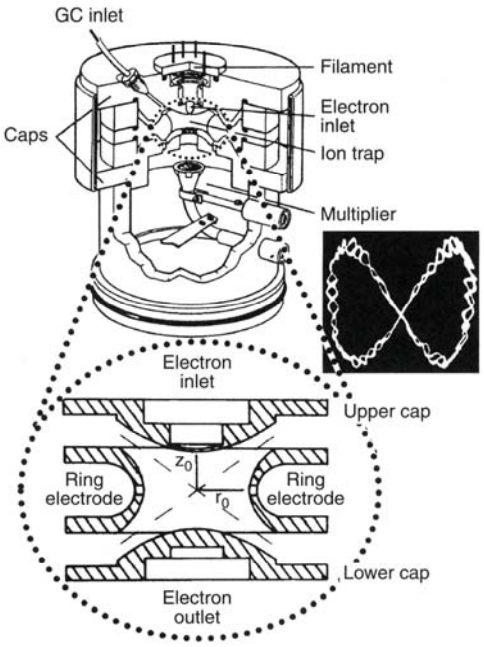
# Mass Resolution: Quadropole Mass Analyzers




Masses that are too small (for a particular AC voltage) feel too large a force, strike the quadrupole.

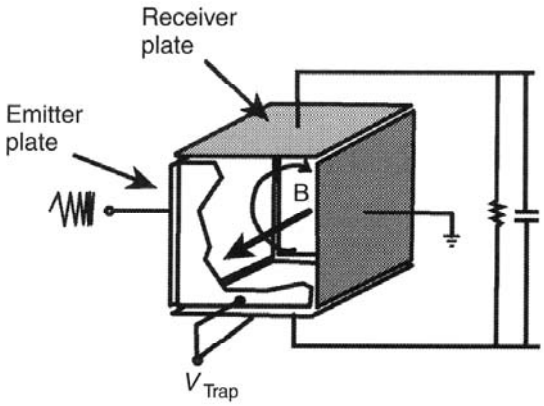
Masses that are too large (for a particular AC voltage) don't feel AC field enough, are attracted off axis by DC offset.

# Mass Resolution: Quadropole Ion Trap




- Designed to collect ions for periodic expulsion
- Interfaces continuous sources (e.g. GC-quadrupole) with pulsed detectors (e.g. TOF)
- Works like quadrupole-in-a-box.
- Can be set to collect a range of ion masses rather than just one.

# Fourier-Transform Ion Cyclotron Resonance (FT-ICR)




- Ions in applied magnetic field travel circular path, circle with frequency that depends on mass:

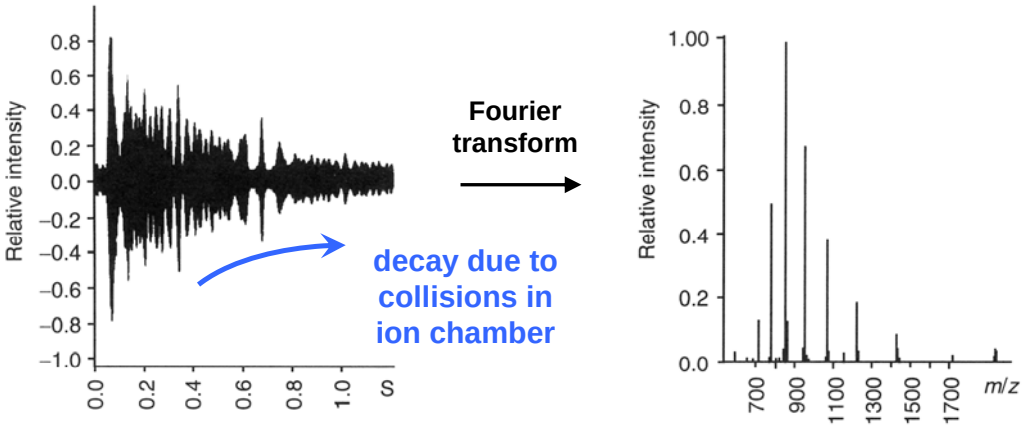
$$\nu = \frac{q\mathrm{B}}{m}$$

- Excitation RF (electrical) pulse at emitter creates packet of coherent ions.
- As these circulate past receiver, oscillating signal is detected.

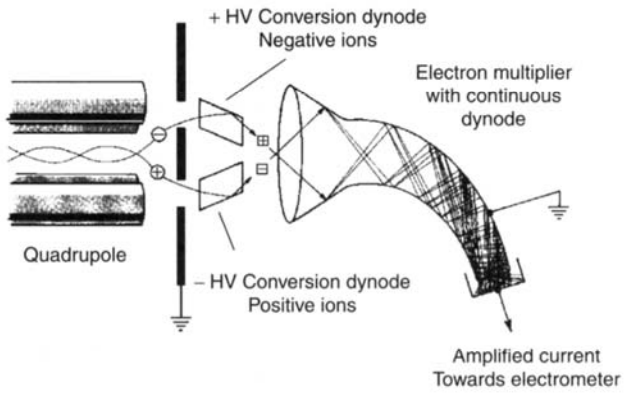
# Fourier-Transform Ion Cyclotron Resonance (FT-ICR)

Time-based signal
*(excited ions passing near receiver)*

Frequency-based signal
*(which depends on m/z)*




# Electron/Ion Multiplier Detection




- Impact of ions with semiconductor surface, held at very high potential, results in ejection of more ions.
- So, single ion impact creates cascade of ion ejections; single ion events can be detected.

Microchannel plate/array detectors:

Same principle.