# Fourier Transform Ion Cyclotron resonance mass spectrometry. The fundamentals

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Miniaturization for Synthesis, Analysis & Protéomics USR 3290

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***Université de Lille, CNRS***

# Bibliography

Marshall, A. G., & Verdun, F. R. (1989). *Fourier transforms in NMR, optical, and mass spectrometry: a user's handbook*. Elsevier (ebook 2016).

Marshall, A. G., Hendrickson, C. L., & Jackson, G. S. (1998). Fourier transform ion cyclotron resonance mass spectrometry: a primer. *Mass spectrometry reviews*, *17*, 1-35.

Nikolaev, E. N., Kostyukevich, Y. I., & Vladimirov, G. N. (2016). Fourier transform ion cyclotron resonance (FT ICR) mass spectrometry: Theory and simulations. *Mass spectrometry reviews*, *35*, 219-258.

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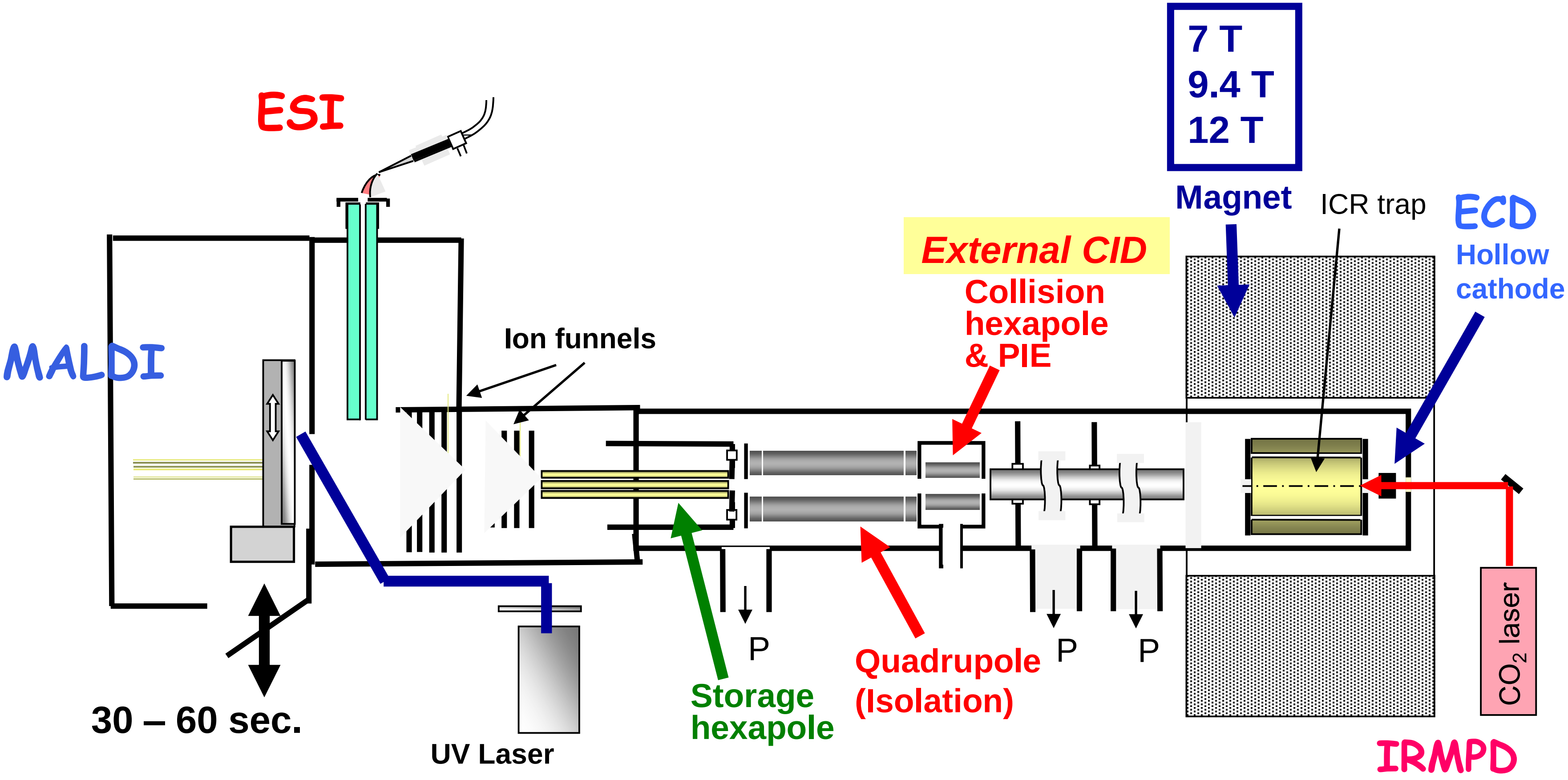
# Bibliography

Guillaume Van der Rest, Spectrométrie de masse à transformée de Fourier : notions de base et quelques applications. École de Printemps - CJSM, La Bresse, mars 2003, http://www.sfsm.fr/fr/actions-sfsm/enseignements-cours

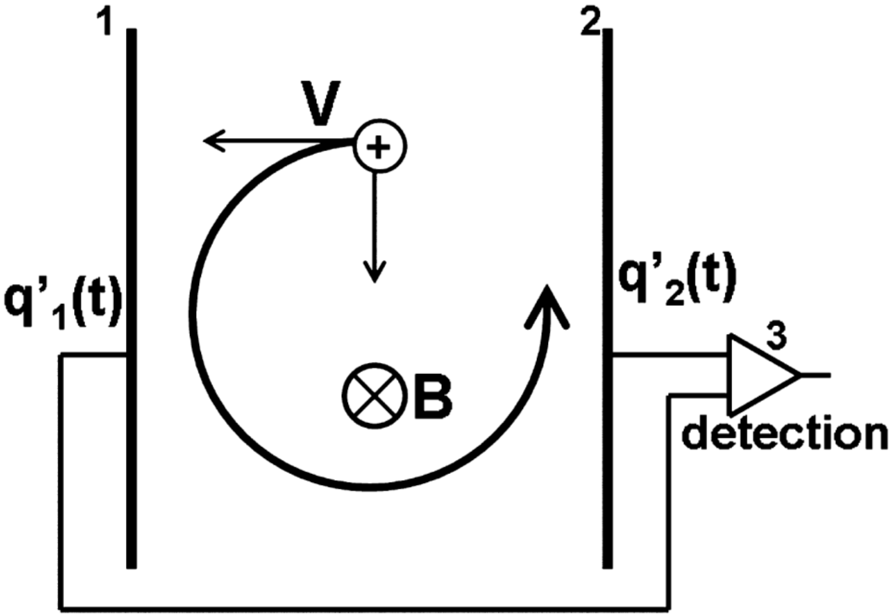
Carlos Afonso, Spectrométrie de masse FT-ICR : Aspects instrumentaux. Guillaume Van der Rest, Manipulation des ions dans une cellule FT-ICR & Méthodes d’activation électronique , Ecole thématique FT-MS (FT-ICR et Orbitrap): Fondements, mise en œuvre et applications à l’analyse de mélanges complexes, Avril 2014, Dammarie Les Lys, http://www.fticr.org/article168.html

# A schematic drawing of an high field FTICR MS

## Schematic drawing of a Bruker Apex FTICR MS



# Single charged particle in a homogeneous magnetic field



The principle of the ICR signal measurement. 1, 2: detection electrodes; $q_{01}(t)$ $q_{02}(t)$: induced image charges; and 3: preamplifier.

$$m\frac{dv}{dt} = qE + qv \wedge B$$

$$\frac{mv_{xy}^{2}}{r} = qv_{xy}B_0$$

$$v_{xy} = \sqrt{v_x^2 + v_y^2}$$

$$\omega = \frac{v_{xy}}{r}$$

# The fundamental equation

$$\omega = \frac{qB_0}{m}$$

$$\nu = \frac{1.53\times10^7 B_0}{m/z}$$

$$\nu = \frac{qB_0}{2\pi m}$$

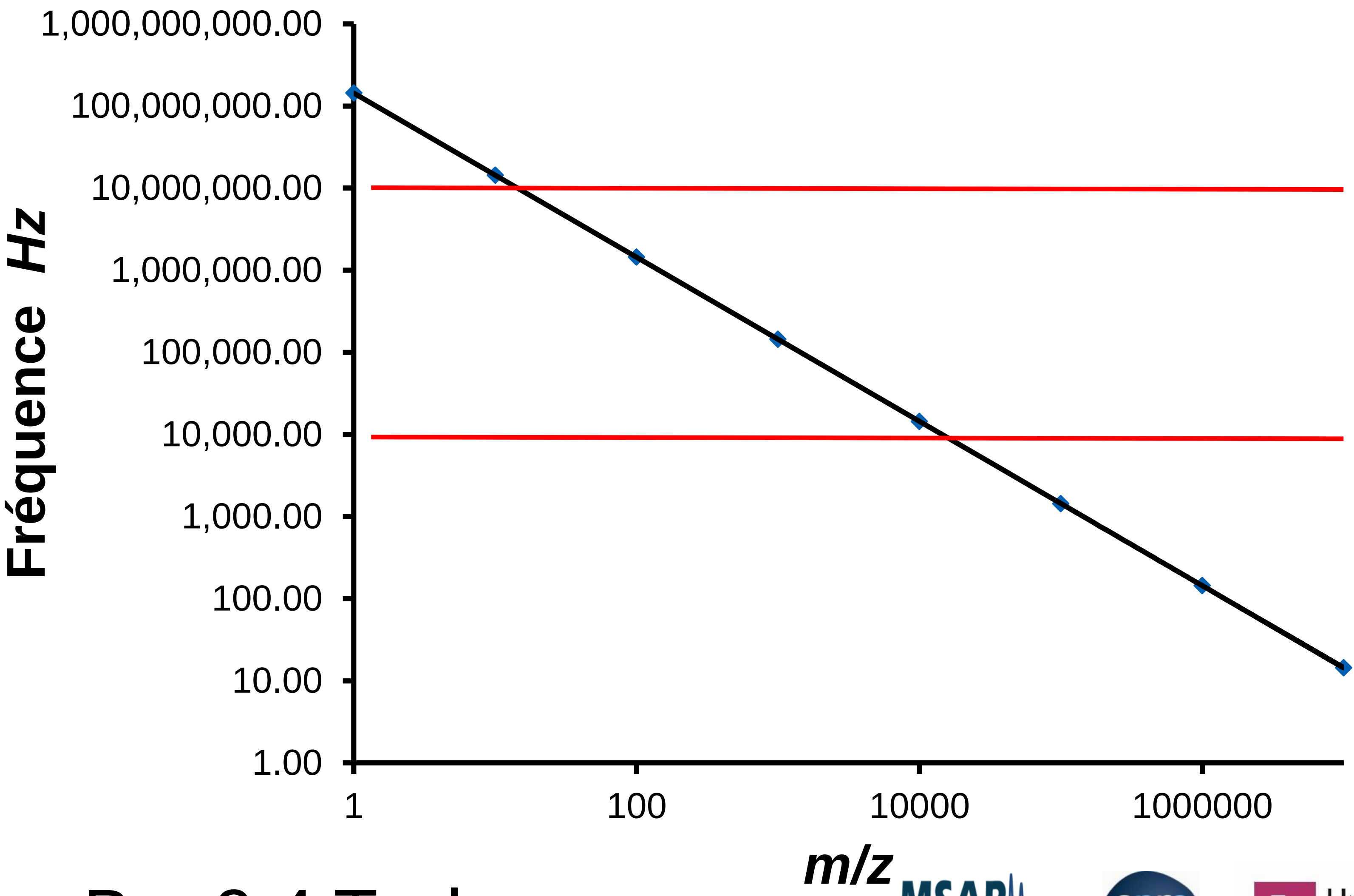
# Resolution (low pressure limit)

$$\frac{m}{\Delta m} = -\frac{qB_0}{m} \cdot \frac{1}{\Delta\omega}$$

$$\Delta\omega \cong {}^{1}\!/\!{}_{T_{Observation}}$$

$$\frac{m}{\Delta m} \cong \frac{qB_0 T_{Observation}}{m}$$

# The fundamental equation



B = 9.4 Tesla

# Radius of an ion at thermic equilibrium

$$\frac{m{v_{xy}}^2}{r} = qv_{xy}B_0$$

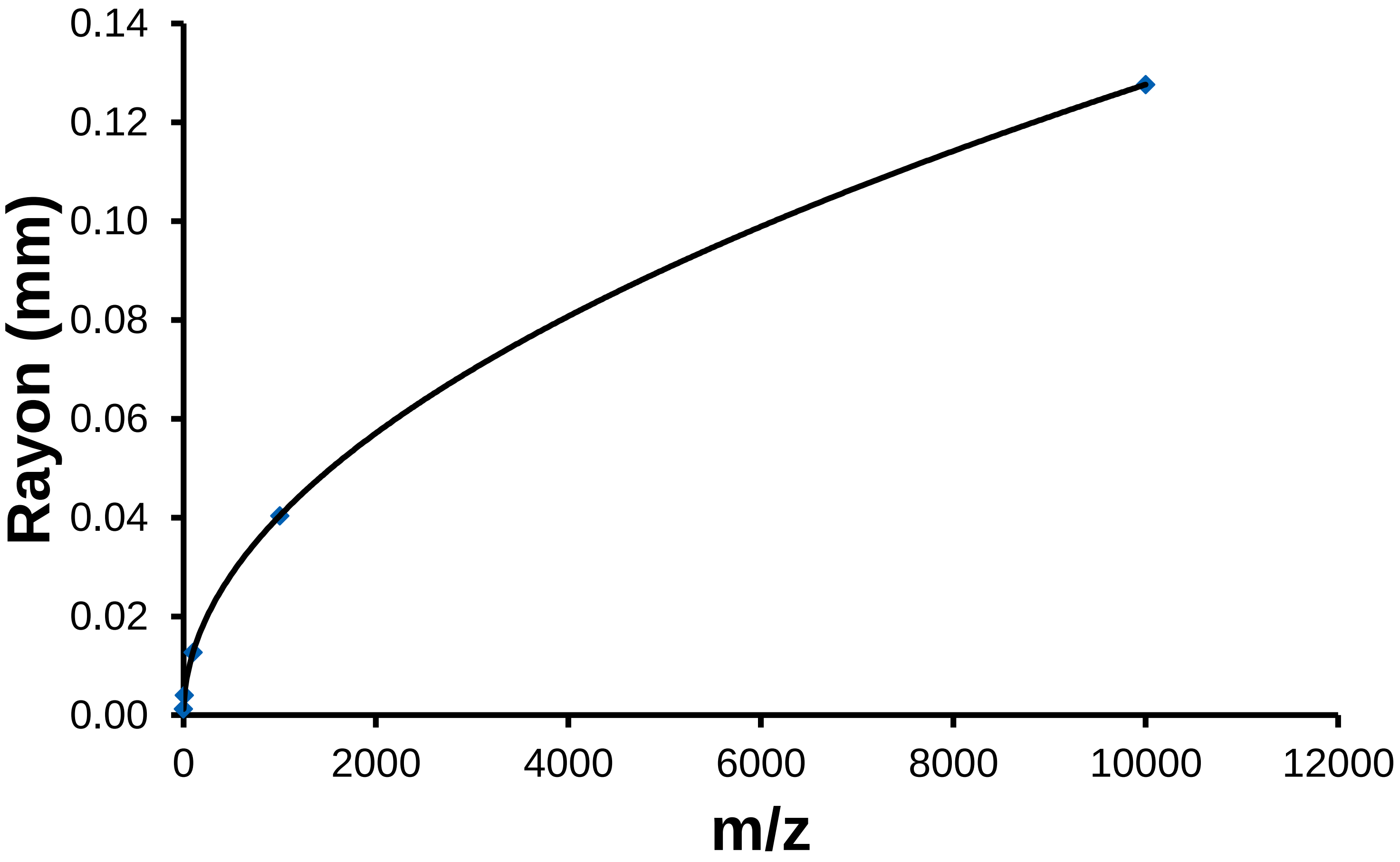
$$r = \frac{mv_{xy}}{qB_0}$$

$$\frac{m\langle v_{xy}^2\rangle}{2} \cong kT$$

$$r = \frac{1}{qB_0}\sqrt{\frac{mkT}{2}}$$

$$r = \frac{1.336\times10^{-6}}{zB_0}\sqrt{mT}$$

# Radius of an ion at thermic equilibrium



B = 9.4 Tesla

# Distance traveled by an ion as a function of time

$$\nu = \frac{qB_0}{2\pi m}$$

$$d = 2\pi \times r \times \nu \times T$$

$$m / z = 1000$$

$$B = 9.4\,T$$

$$r = 10\,mm$$

$$T = 1\,s$$

Distance traveled = 10 km

# Mean free path of an ion in a buffer gas

Mean free path inside the FT-ICR cell. Buffer gas $N_2$

| Name | Cytochrome c | Ubiquitin | Angiotensin I | Met-Arg-Phe-Ala |
|---|---|---|---|---|
| **Mass (amu)** | 12 369 | 8 570 | 1 296 | 523 |
| **Charge** | 15 | 10 | 3 | 1 |
| **CCS (Å$^2$)** | 2579 | 1732 | 474 | 160 |
| **Mean free path at $10^{-10}$ Torr (km)** | 12 | 18 | 66 | 194 |

$$Mean\ \ free\ \ path \cong \frac{kT}{\sqrt{2}\pi \times p \times d_m \times d_M}$$

# Kinetic energy of an ion in function of its diameter

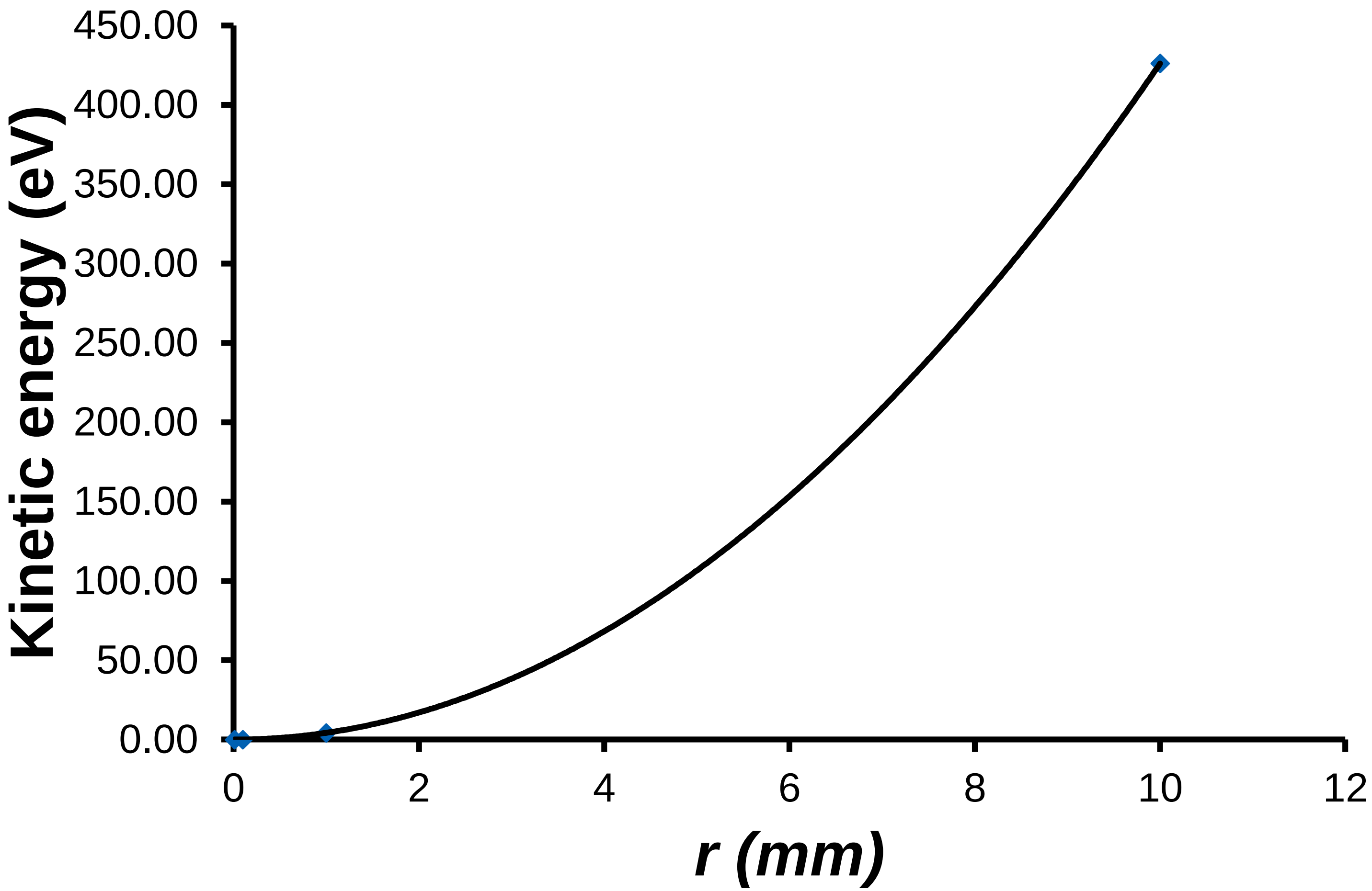
$$\frac{mv_{xy}^{2}}{r} = qv_{xy}B_0$$

$$v_{xy} = \frac{qB_0r}{m}$$

Kinetic energy

$$\frac{mv_{xy}^{2}}{2} = \frac{q^2 \times B_0^2 \times r^2}{2m}$$

# Kinetic energy versus orbit radius

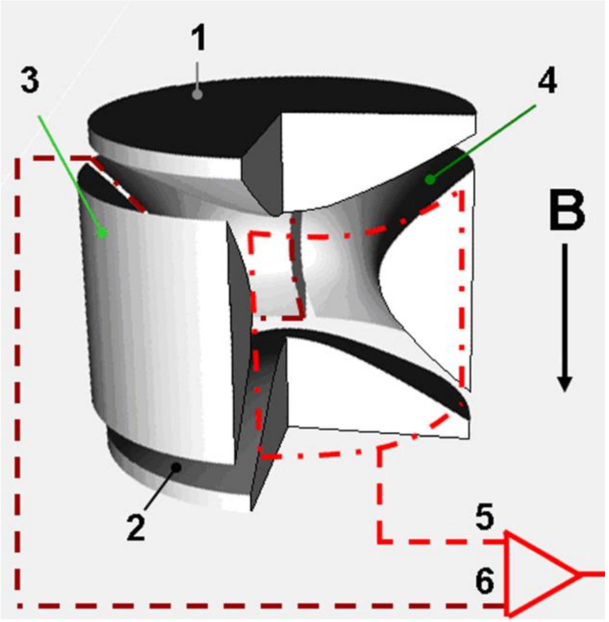


B = 9.4 Tesla, *m/z* = 100

# Single ion in a Penning trap: the ideal case (1/6)

$$\Phi(x,y,z) = -\frac{V_{Trap}}{2}\times\left[1+\frac{4}{a^2}(x^2+y^2-2z^2)\right]$$

a characteristic dimension of the trap



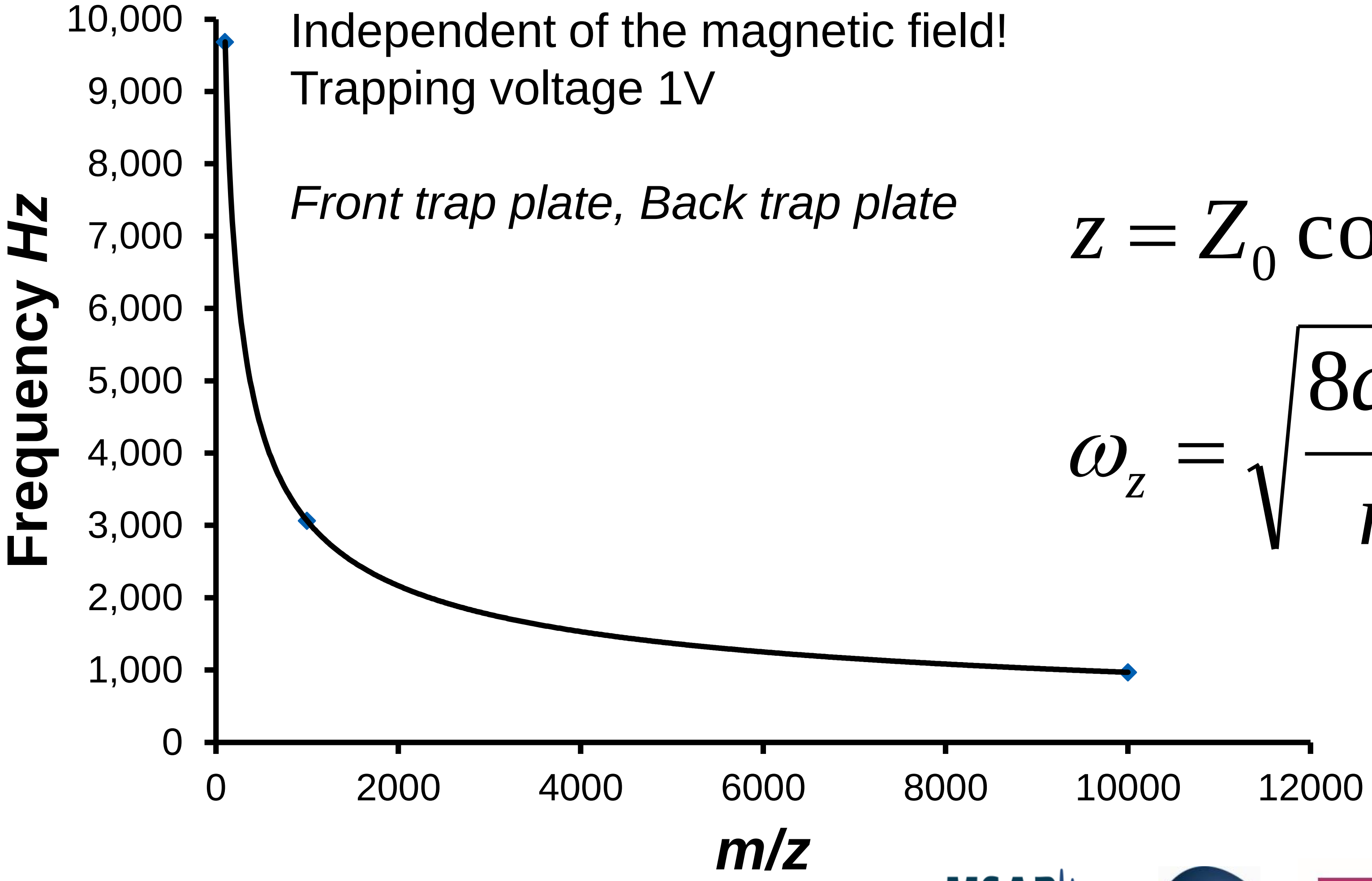
$$m\frac{d^2x}{dt} = qB\frac{dy}{dt} - 4\frac{qV_{Trap}}{a^2}x$$

$$m\frac{d^2y}{dt} = -qB\frac{dx}{dt} + 4\frac{qV_{Trap}}{a^2}y$$

$$m\frac{d^2z}{dt} = 8\frac{qV_{Trap}}{a^2}x$$

Hyperbolic ICR cell.
1, 2: trapping electrodes;
3, 4: excitation electrodes;
5, 6: detection electrodes

# Single ion in a Penning trap: the ideal case (2/6)



Independent of the magnetic field!
Trapping voltage 1V

*Front trap plate, Back trap plate*

$$z = Z_0 \cos \omega_z t$$

$$\omega_z = \sqrt{\frac{8qV_{Trap}}{ma^2}}$$

# Single ion in a Penning trap: the ideal case (3/6)

$$m\left(\frac{d^2x}{dt}+i\frac{d^2y}{dt}\right)=-iqB\left(\frac{dx}{dt}+i\right)\frac{dy}{dt}-4\frac{qV_{Trap}}{a^2}x$$

$$x+iy=A_+e^{i\varpi_+t}+A_-e^{i\varpi_-t}$$

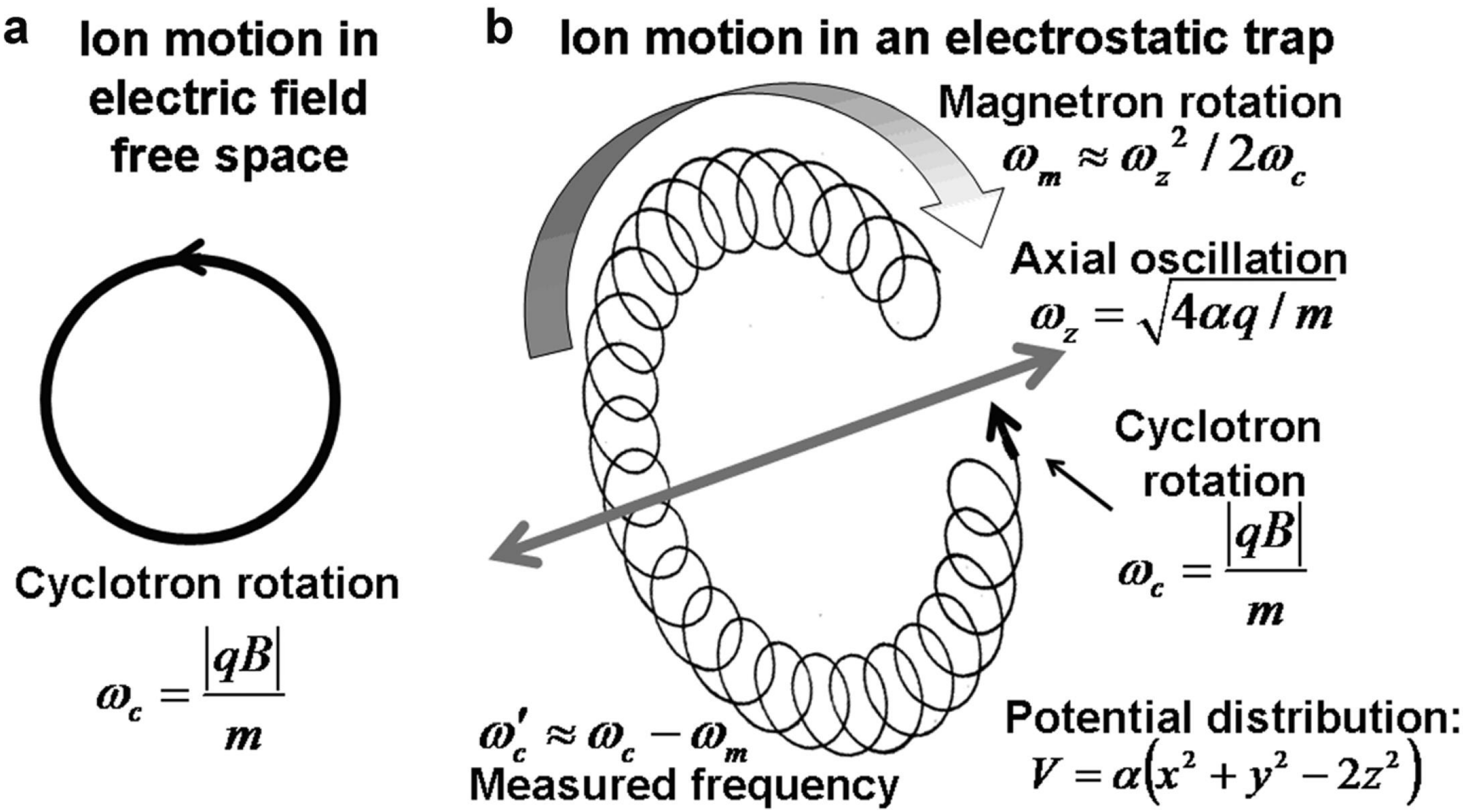
$$\varpi_\pm=\frac{qB\pm\sqrt{q^2B^2-\frac{16qV_{Trap}m}{a^2}}}{2m}$$

$$\varpi_\pm=\frac{\varpi_{Cyclotron}}{2}\pm\sqrt{\left(\frac{\varpi_{Cyclotron}}{2}\right)^2-\frac{\varpi_Z^2}{2}}\quad note\,that\,\varpi_++\varpi_-=\varpi_{Cyclotron}$$

$$if\,\varpi_{cyclotron}>>\varpi_Z$$

$$\varpi_+=\varpi_{Cyclotron}\left(1-\left(\frac{\varpi_Z}{\sqrt{2}\varpi_{Cyclotron}}\right)^2\right)\quad and\ \varpi_-=\varpi_{Magnetron}=\varpi_{Cyclotron}\left(\frac{\varpi_Z}{\sqrt{2}\varpi_{Cyclotron}}\right)^2$$

# Single ion in a Penning trap: the ideal case (4/6)



# Single ion in a Penning trap: the ideal case (5/6)

$$\varpi_{\pm} = \frac{qB \pm \sqrt{q^2B^2 - \frac{16qV_{Trap}m}{a^2}}}{2m}$$

$$q^2B^2 - \frac{16qV_{Trap}m}{a^2} > 0 \Rightarrow \frac{m}{q} < \frac{B^2a^2}{16V_{Trap}}$$

Upper mass limit: *B* = 9.4 T, Trapping voltage 1 V, *a* = 2.5 cm => $10^5$ *Da*

# Single ion in a Penning trap: the ideal case (6/6)

$$x + iy = A_+ e^{i\varpi_+ t} + A_- e^{i\varpi_- t}$$

$$x = A_+ \cos\varpi_+ t + A_- \cos\varpi_- t$$

$$y = A_+ \sin\varpi_+ t + A_- \sin\varpi_- t$$

$$x_0 = A_+ + A_-$$

$$\frac{dy_0}{dt} = A_+ \varpi_+ + A_- \varpi_-$$

$$A_+ = \frac{\frac{dy_0}{dt} - x_0 \varpi_-}{\varpi_+ - \varpi_-}$$

$$A_- = \frac{x_0 \varpi_+ - \frac{dy_0}{dt}}{\varpi_+ - \varpi_-}$$

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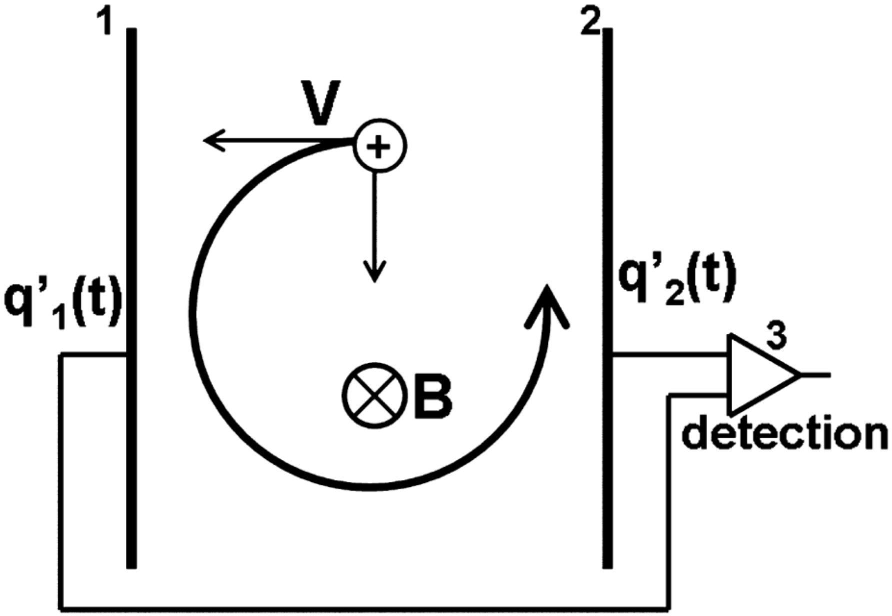
# Signal induced in a planar capacitor



$$\Delta Q = -2\frac{qy}{d}$$

$$i = \frac{d}{dt}\Delta Q$$

$$i = -\frac{2q}{d} \times \frac{dy}{dt}$$

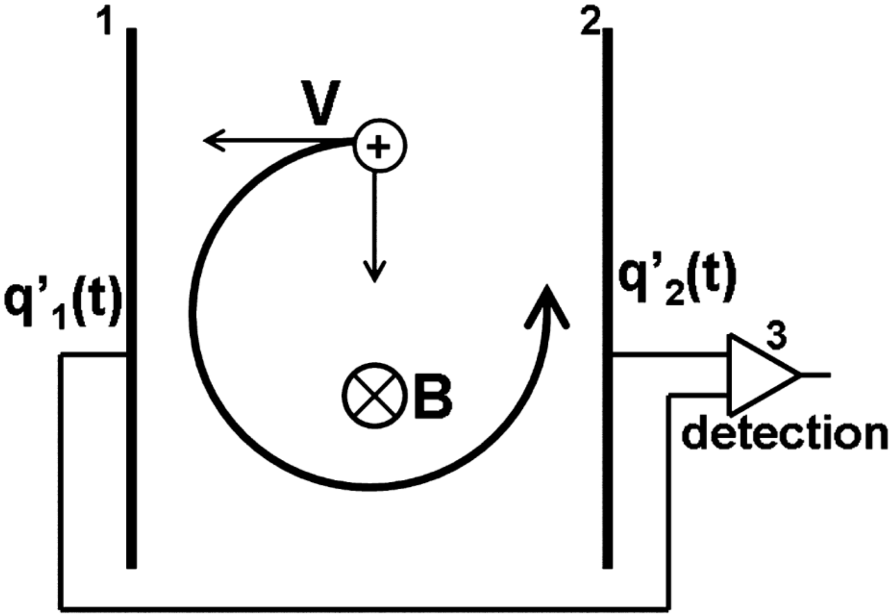
$$i = -\frac{2qR\varpi_{Cyclotron}}{d}\cos\varpi_{Cyclotron}t$$

The principle of the ICR signal measurement. 1, 2: detection electrodes; $q_{01}(t)$ $q_{02}(t)$: induced image charges; and 3: preamplifier.

*i* proportional to B via $\omega$

*i* proportional to *R/d*

# Ion excitation



$$\Delta Q = -2\frac{qy}{d}$$

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$$i = -\frac{2qR\varpi_{Cyclotron}}{d}\cos\varpi_{Cyclotron}t$$

The principle of the ICR signal measurement. 1, 2: detection electrodes; $q_{01}$(t) $q_{02}$(t): induced image charges; and 3: preamplifier.

*i* proportional to B via ω

*i is independent of m*

*i* proportional to *R/d*

# Coherent excitation of an ion

$$E = \frac{2V(\omega)}{d}$$

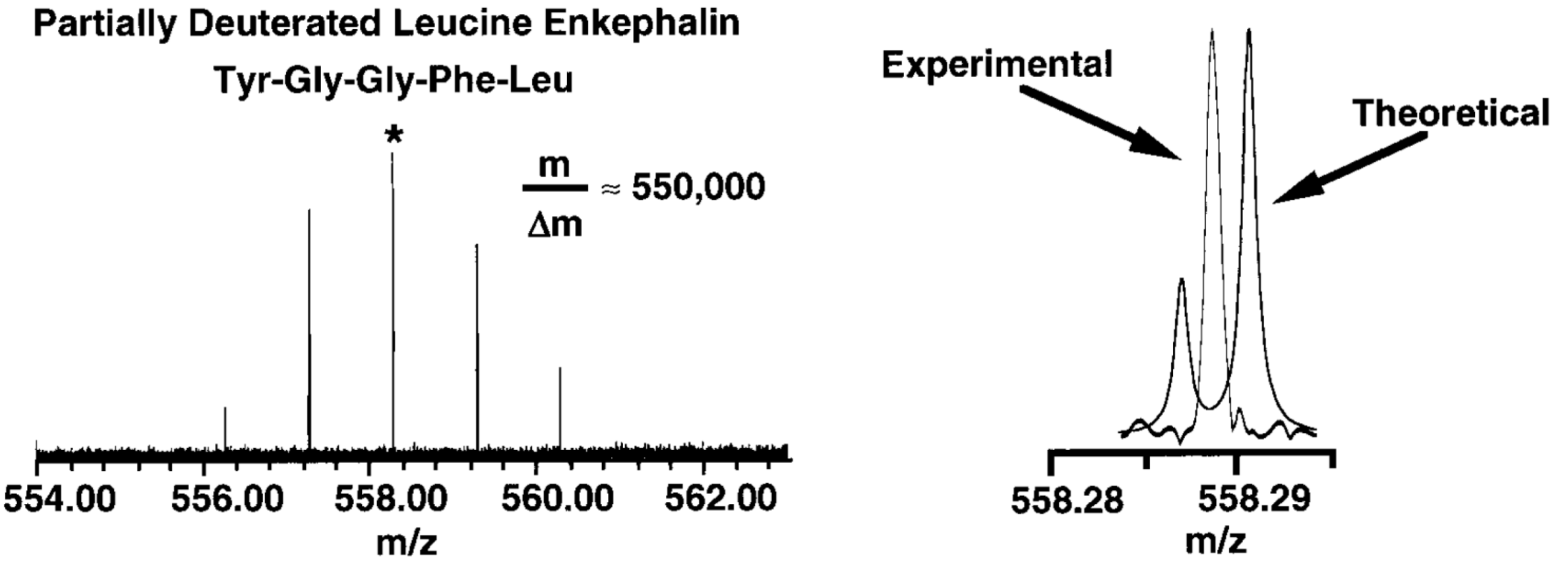
$$A(t) = qE \cdot v_{xy}$$

$$\frac{mv_{xy}^2}{2} = \int_0^{T_{excitation}} A(t)dt$$

The radius is independent of the mass
But not the energy, nor the distance traveled,
nor the phase ...

$$r = \frac{ET_{excitation}}{2B_0}$$

# Peak coalescence

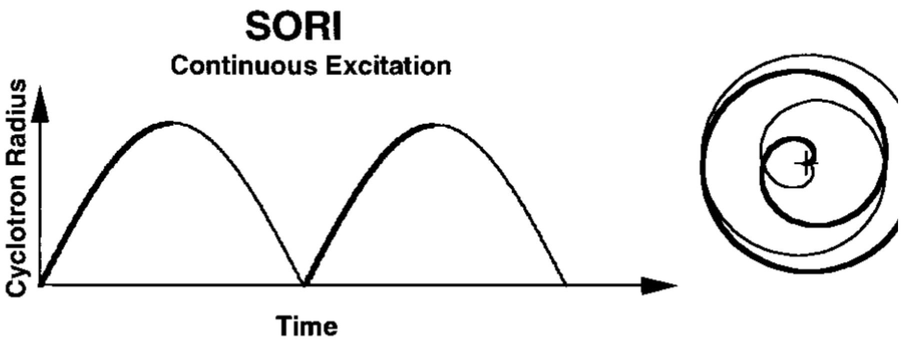


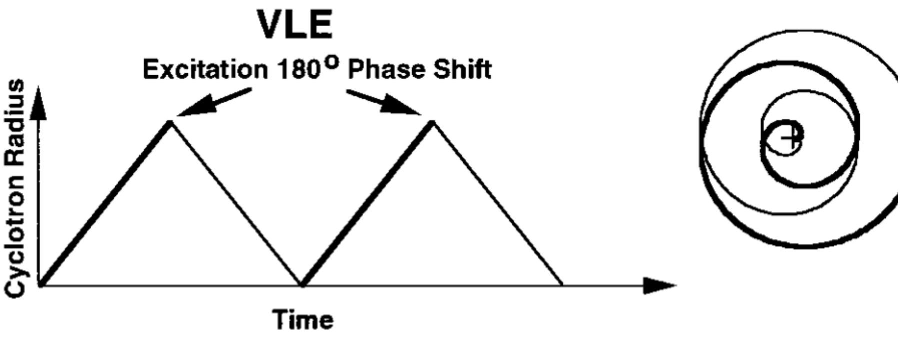
Partially Deuterated Leucine Enkephalin

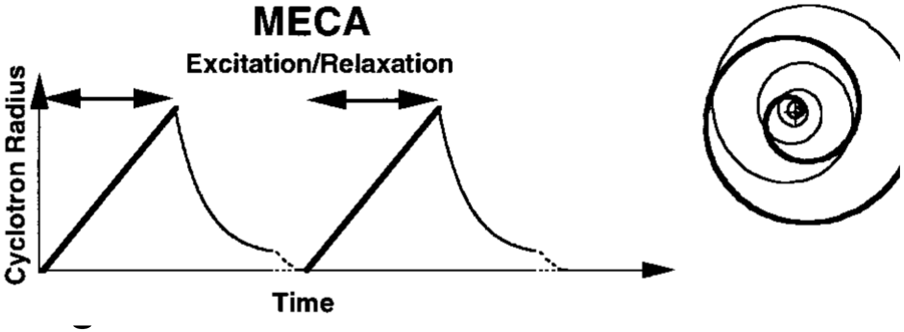
Tyr-Gly-Gly-Phe-Leu

$$\frac{m}{\Delta m} < \cong \frac{B^2 R}{m(n_1 q_1 + n_2 q_2)}$$

# Ion excitation for in-cell CAD







Time evolution of ion cyclotron radius (left) and ion *mo*tion based on repeated single-frequency dipolar excitation for collision induced dissociation (CID).

In sustained off-resonance irradiation (**SORI**) ions of a selected *m*/*z* ratio are alternately excited and de-excited due to the difference between the excitation frequency and the ion cyclotron frequency.

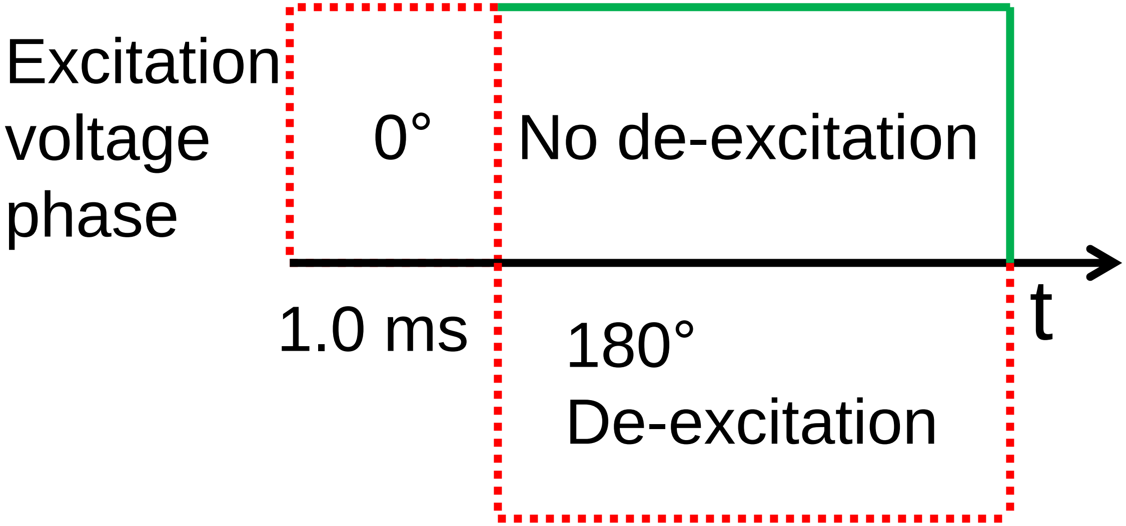
In **very low energy (VLE) CID** ions are alternately excited and de-excited by resonant excitation whose phase alternates bimodally between 0 and $\pi$.

In multiple excitation for collisional activation (MECA) ions are resonantly excited and then allowed to relax by collisions.

# Original ICR excitation reversibility proof

Coherently excited ions:

- Excitation voltage ***in phase with*** ion motion: ions excited to higher radius
- Excitation voltage ***in phase opposition with*** ion motion: ions de-excited to center of ICR cell.



Excitation voltage phase

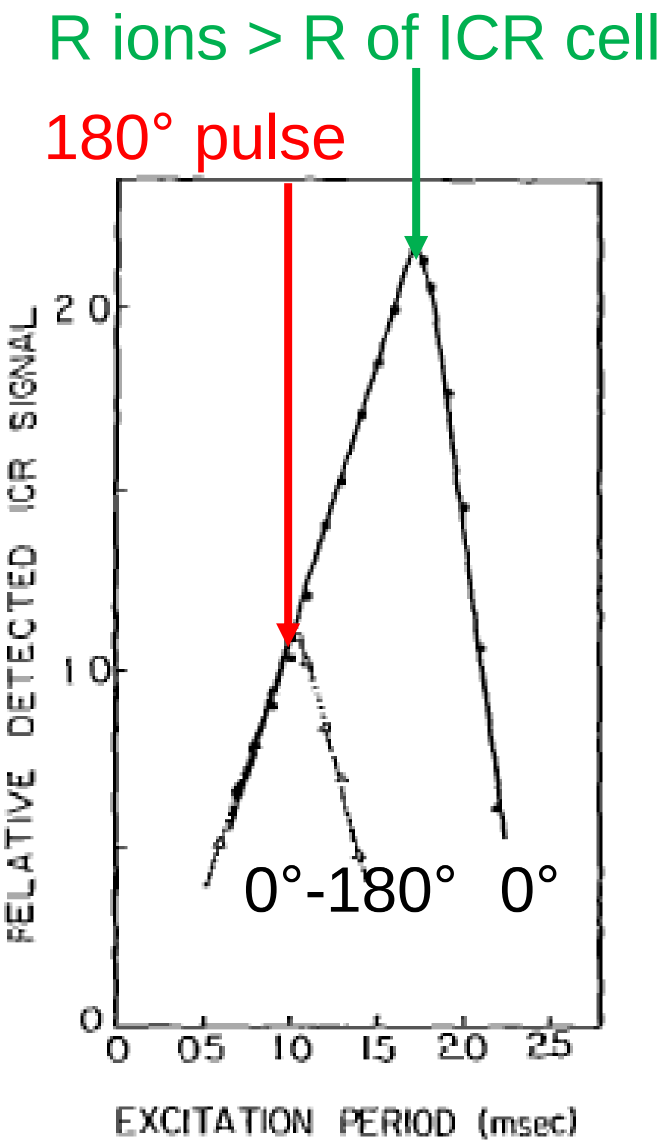
0°

No de-excitation

t

1.0 ms

180° De-excitation



R ions > R of ICR cell

180° pulse

0°-180°

0°

A.G. Marshall, T.C. Lin Wang, T. Lebatuan Ricca, *Chem. Phys. Letts.* 105 (1984) 233-236.

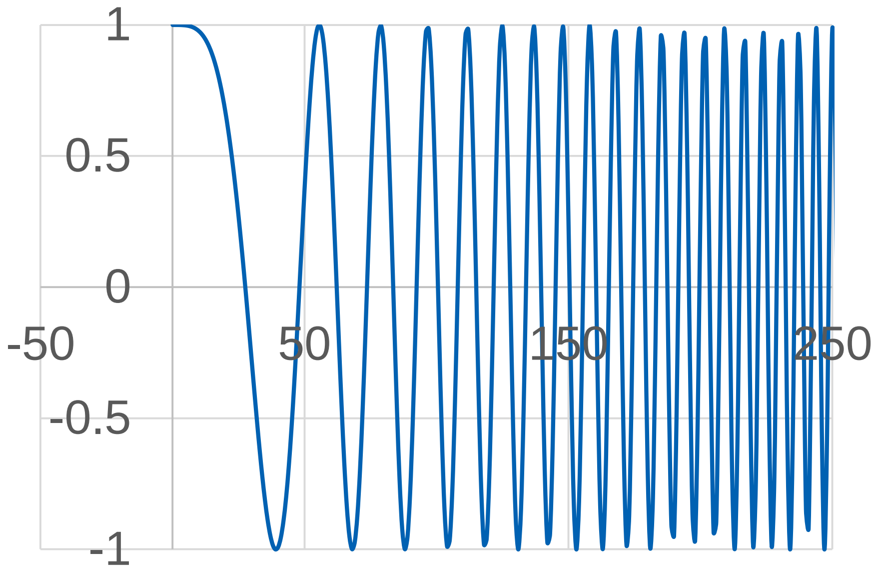
# Unoherent excitation of an ion

$$E = \frac{2V(\omega_{Excitation})}{d}$$

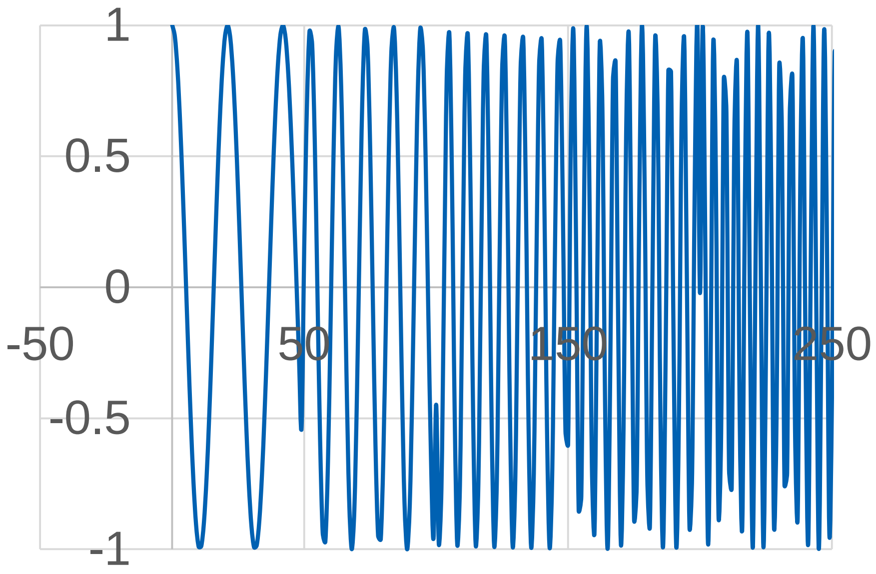
$$A(t) = qE \cdot v_{xy}(\varpi_{Cyclotron})$$

$$\frac{mv_{xy}^{2}}{2} \cong \int_{0}^{T_{excitation}} \sin(\varpi_{Exitation} t + \varphi) \sin(\varpi_{Cyclotron} t) dt$$

# Chirp excitation



Continuous chirp



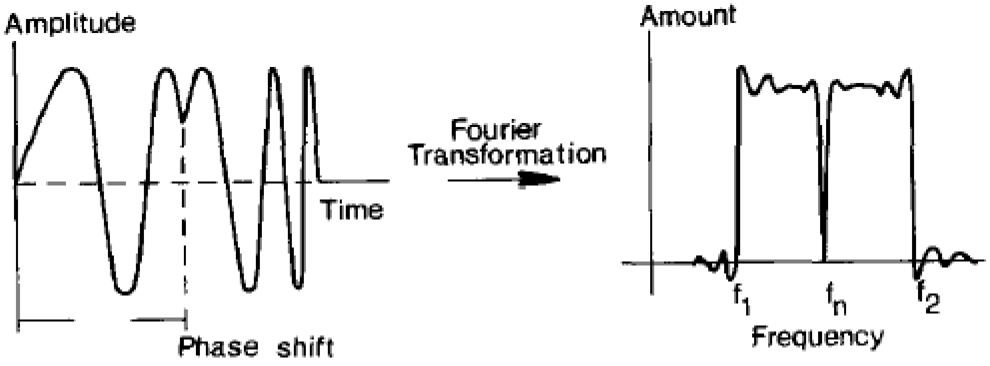
Chirp by block
Bruker

This scheme is weird see the next slide for explanation.

The phase must be continuous

# Isolation by Notch Ejection Method

In this method,



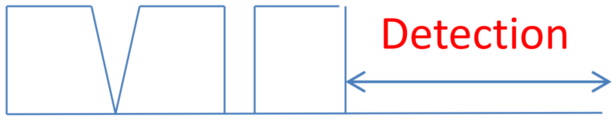
a) Phase inverted, introducing a notch centered on the frequency of interest, $f_n$.

b) Ion to be selected remains in the centre, all others are ejected.

T. Vulpius and R. Houriet, *Int. J. Mass Spectrom.* (1989) 88,283-290.
A.J. Noest and C.W.F. Kort, *Comput. Chem.,* (1983) 7, 81-86

# Experimental Technique

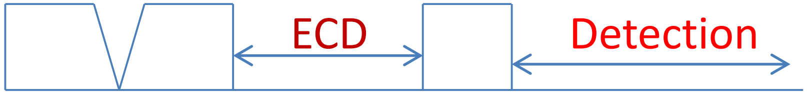
- Experiments performed on Bruker Daltonics 9.4 T ApexQE FT-ICR mass spectrometer.
- Sample: 1pm/µl of substance P (MW 1347.63) in 50:50 $H_2O$:MeOH + 0.1% formic acid



Ejection and isolation pulse

Detection pulse

Pulse Sequence for isolation



Ejection and isolation pulse

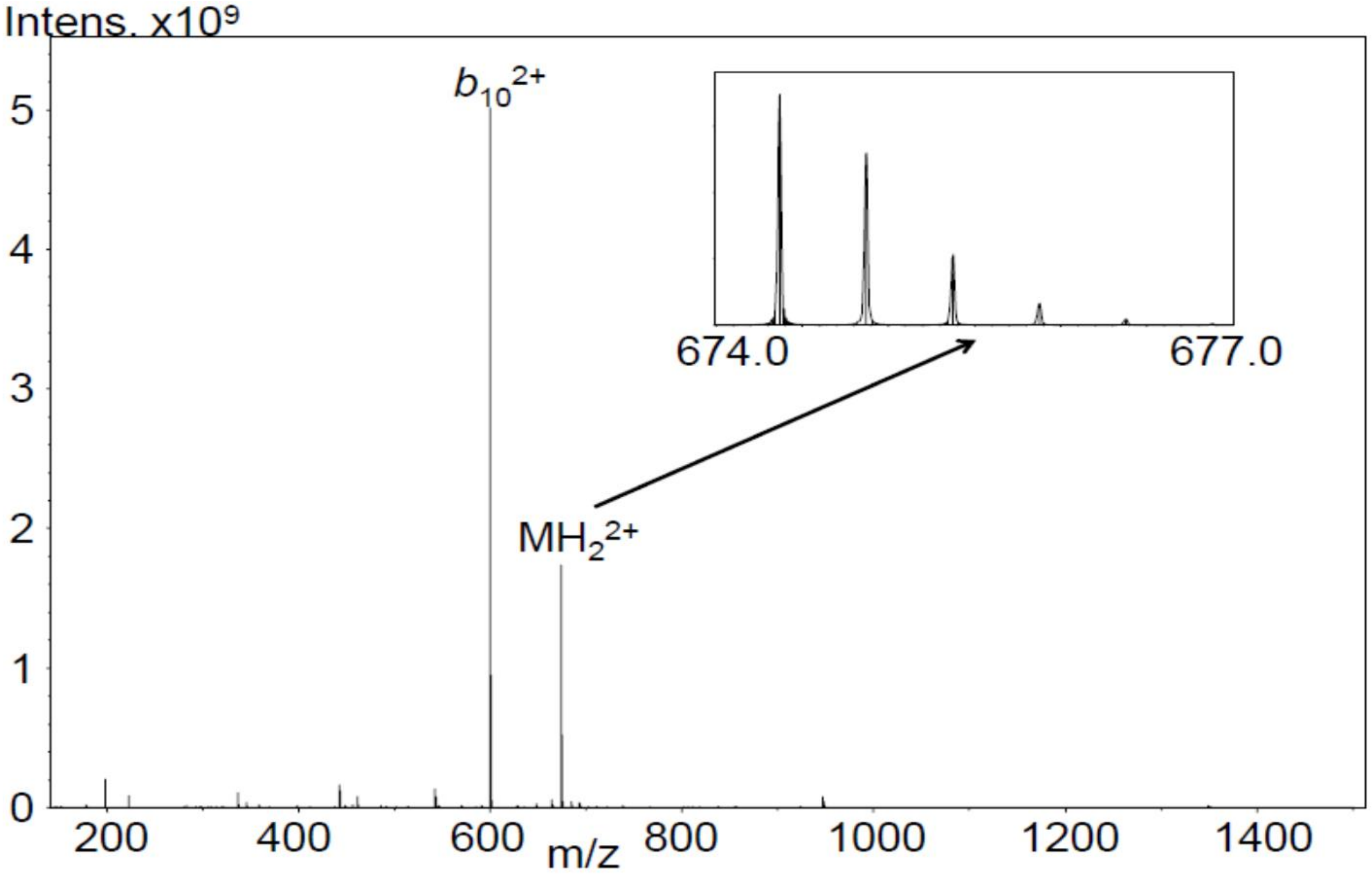
Detection pulse

Pulse Sequence for fragmentation after isolation

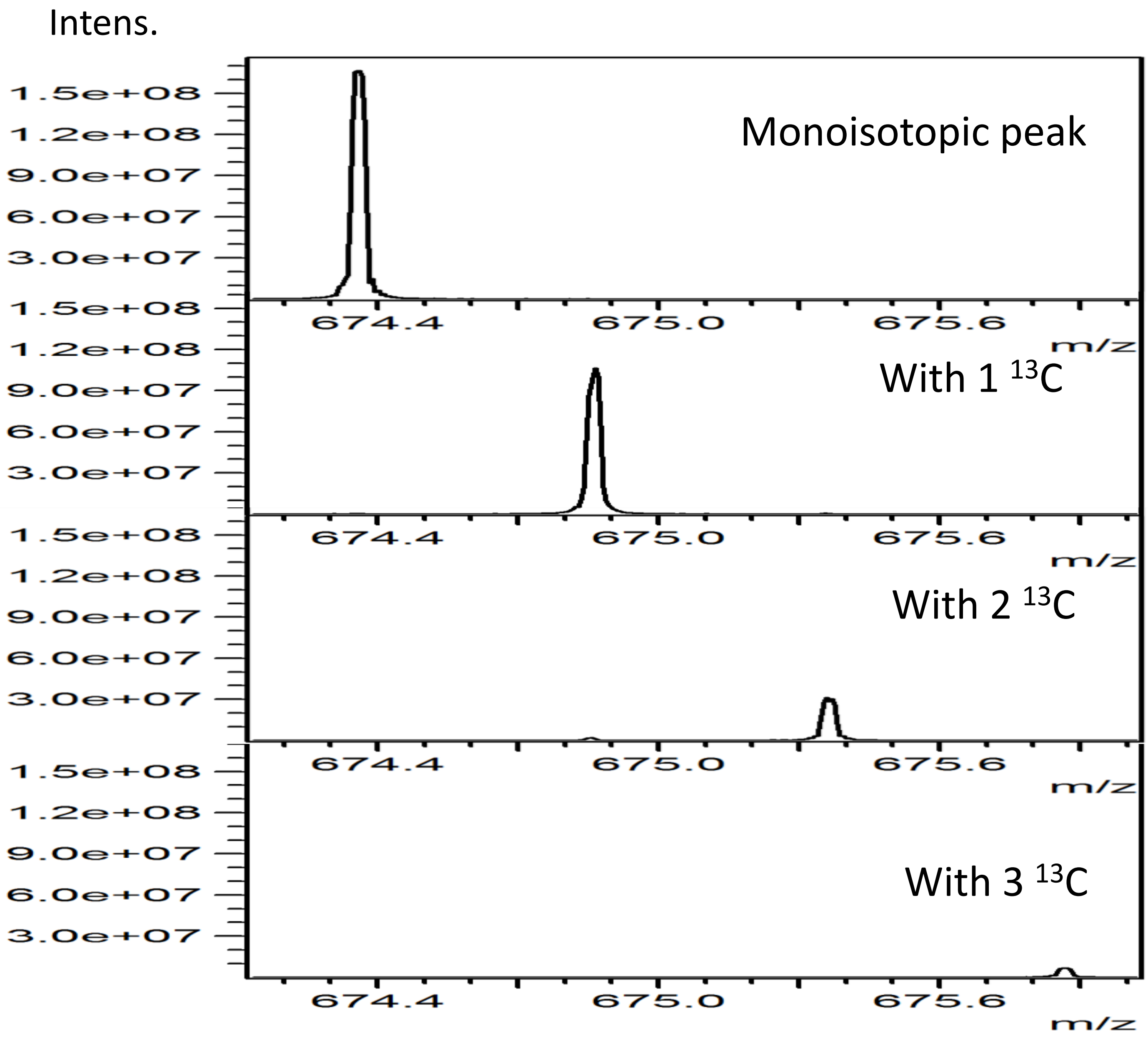
- Power level is an attenuation in dB
  Power of all pulses = 25 dB
- Pulse lengths are in µs per frequency increment of 62.5 Hz
  Ejection Pulse=300µs, Detection Pulse= 100µs
- Excitation pulse → ion radius increased → ion detectable
  Longer pulse length → ion ejected
  Shorter pulse length → ion detected
- For fragmentation by Electron Capture Dissociation
  ECD heater at 1.7A , Electron beam pulse duration 0.03 s

# Results with this Method

Mass spectrum of **substance P**



# Isolation of isotopes of $MH_2^{2+}$ up to three $^{13}C$ isotope



# Calibration laws

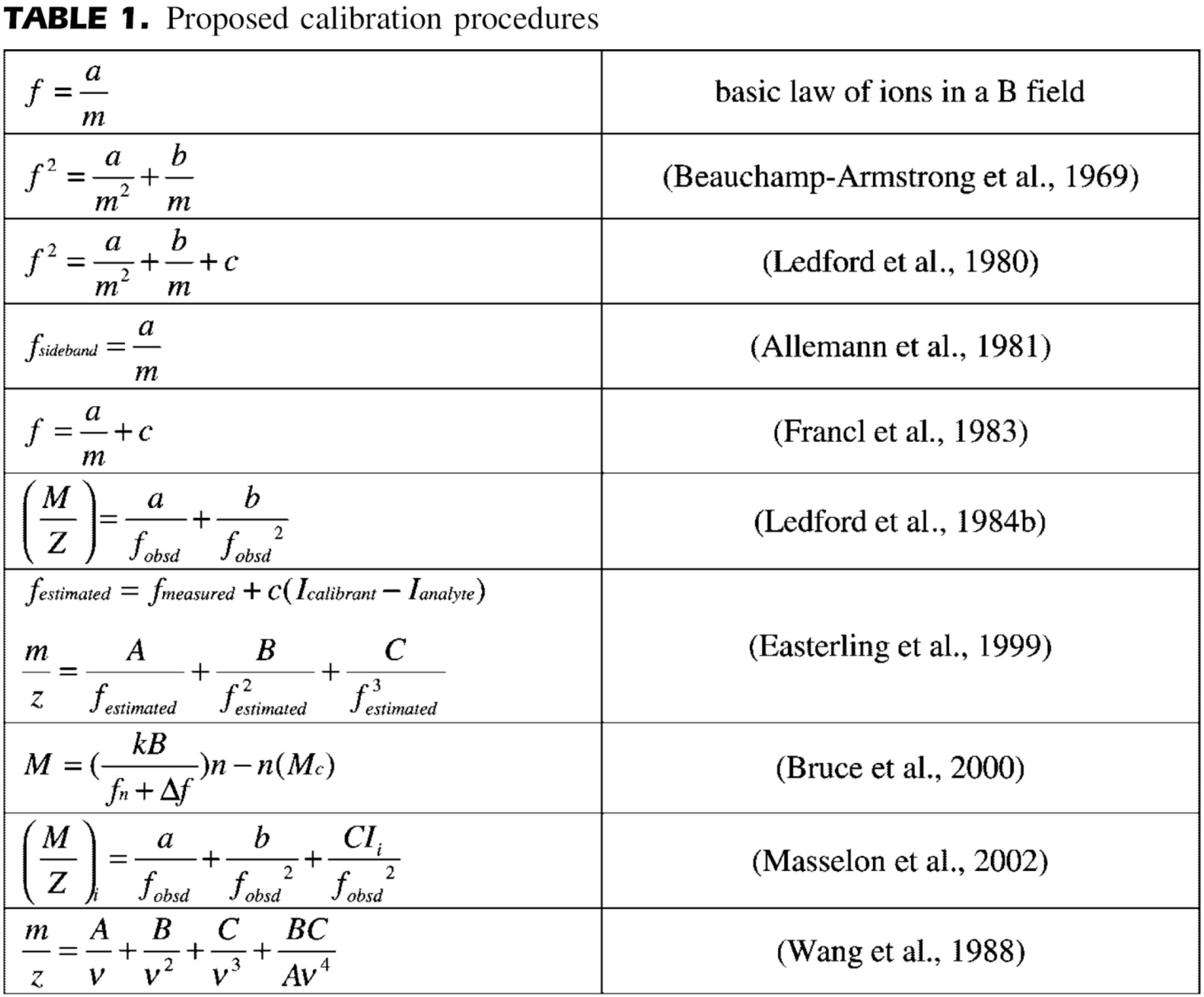


**TABLE 1.** Proposed calibration procedures

| | |
|---|---|
| $f = \frac{a}{m}$ | basic law of ions in a B field |
| $f^2 = \frac{a}{m^2} + \frac{b}{m}$ | (Beauchamp-Armstrong et al., 1969) |
| $f^2 = \frac{a}{m^2} + \frac{b}{m} + c$ | (Ledford et al., 1980) |
| $f_{sideband} = \frac{a}{m}$ | (Allemann et al., 1981) |
| $f = \frac{a}{m} + c$ | (Francl et al., 1983) |
| $\left(\frac{M}{Z}\right) = \frac{a}{f_{obsd}} + \frac{b}{f_{obsd}^2}$ | (Ledford et al., 1984b) |
| $f_{estimated} = f_{measured} + c(I_{calibrant} - I_{analyte})$<br>$\frac{m}{z} = \frac{A}{f_{estimated}} + \frac{B}{f_{estimated}^2} + \frac{C}{f_{estimated}^3}$ | (Easterling et al., 1999) |
| $M = (\frac{kB}{f_n + \Delta f})n - n(M_c)$ | (Bruce et al., 2000) |
| $\left(\frac{M}{Z}\right)_i = \frac{a}{f_{obsd}} + \frac{b}{f_{obsd}^2} + \frac{CI_i}{f_{obsd}^2}$ | (Masselon et al., 2002) |
| $\frac{m}{z} = \frac{A}{v} + \frac{B}{v^2} + \frac{C}{v^3} + \frac{BC}{Av^4}$ | (Wang et al., 1988) |

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# Calibration (Bruker)

2 parameters

$$f = \frac{ML1}{m} - ML2$$

$$m = \frac{ML1}{f + ML2}$$

3 parameters

$$f = \frac{ML1}{m} + \frac{ML3}{m^2} - ML2$$

$$m^2 f = mML1 + ML3 - m^2 ML2$$

$$m^2 (f + ML2) - mML1 - ML3 = 0$$

$$\delta = ML1^2 + 4(f + ML2)ML3$$

$$m = \frac{ML1 + \sqrt{\delta}}{2(f + ML2)}$$

# Broad band digital acquisition

The **Nyquist-Shannon** theorem states that the **sampling frequency** of a signal must be equal to or greater than **twice the maximum frequency** contained in this signal, in order to convert this signal from an analog form to a digital form without loss or aliasing

$$\nu_{\text{Nyquist-Shannon}} = \frac{qB_0}{2\pi m_{Start}}$$

$$\nu_{Sampling} \cong \frac{1}{m_{Start}}$$

$$\Delta t_{Sampling} \cong m_{Start}$$

Acquisition from 8 k ($2^{13}$ = 8 192) words to 8 M ($2^{23}$ = 8 386 608) words or above

# From ions to spectrum

Broad band acquisition

$$acquistiontime = v_{sampling} \times memory\_size$$

$$acquisition\ time \cong m_{Start} \times memory\_size$$

$$\frac{m}{\Delta m} \cong \frac{qB_0 T_{Acquisition}}{m}$$

$$\frac{m}{\Delta m} \cong \frac{1}{m} \times m_{Start} \times memory\_size$$

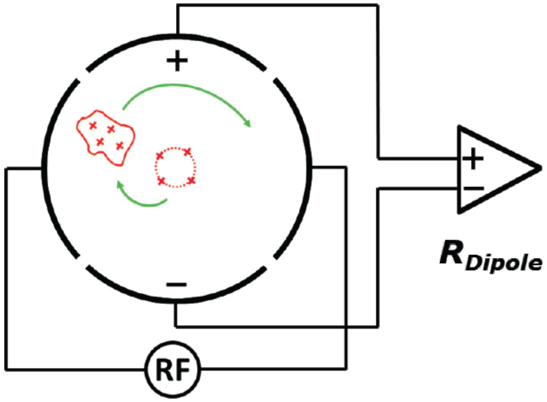
# Dependence of parameters according to the magnetic field

| | | |
|---|---|---|
| 1 | Frequency at a given mass | $B^{-1}$ |
| 2 | Resolution | $B$ |
| 3 | Acquisition time at a given resolution | $B^{-1}$ |

| | | |
|---|---|---|
| 4 | Kinetic energy for a given radius | $B^2$ |
| 5 | Highest mass | $B^2$ |
| 6 | Number of trapped ions | $B^2$ |

# Quadrupolar detection

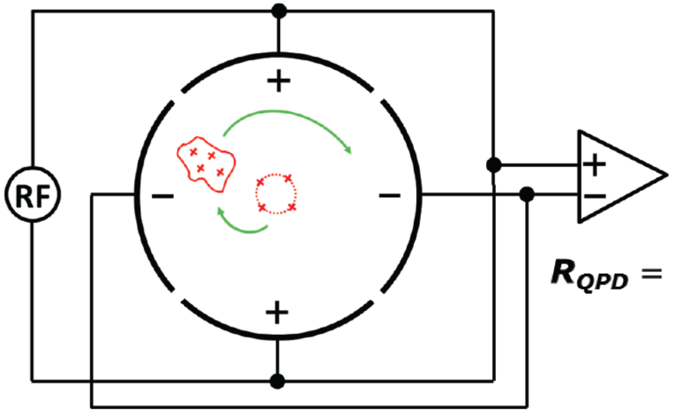
## Standard 1ω Dipole Detection



$R_{Dipole} = \nu \cdot T$

Direct detection of the cyclotron frequency $\omega_+$

## 2ω Quadrupolar Detection (QPD)



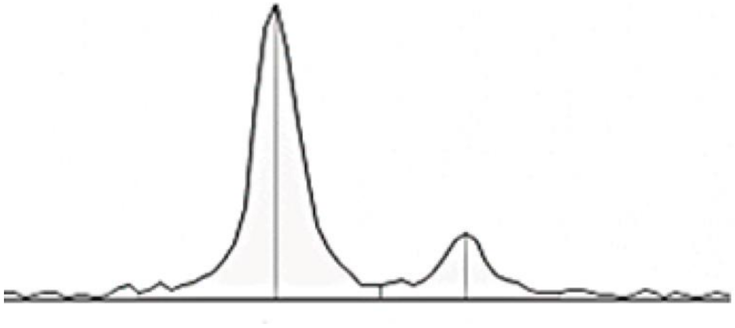
$R_{QPD} = 2 \cdot \nu \cdot T = 2 \cdot R_{Dipole}$

QUADRUPOLE-DETECTION FT-ICR MASS SPECTROMETRY*
L. SCHWEIKHARD, M. LINDINGER and H.-J. KLUGE published 1990

Direct detection of the **double** cyclotron frequency $2\omega_+$

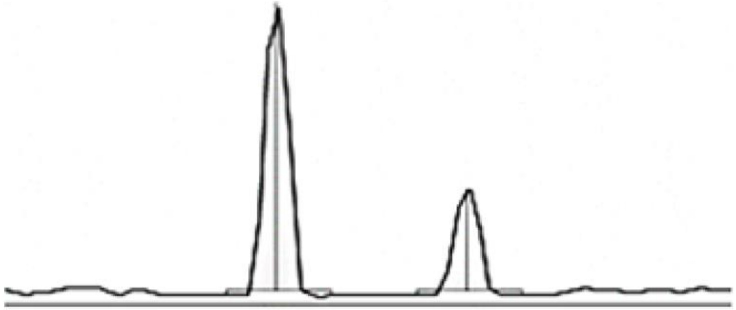
Direct detection of the cyclotron frequency

$$R_{DD} = \nu \cdot T$$

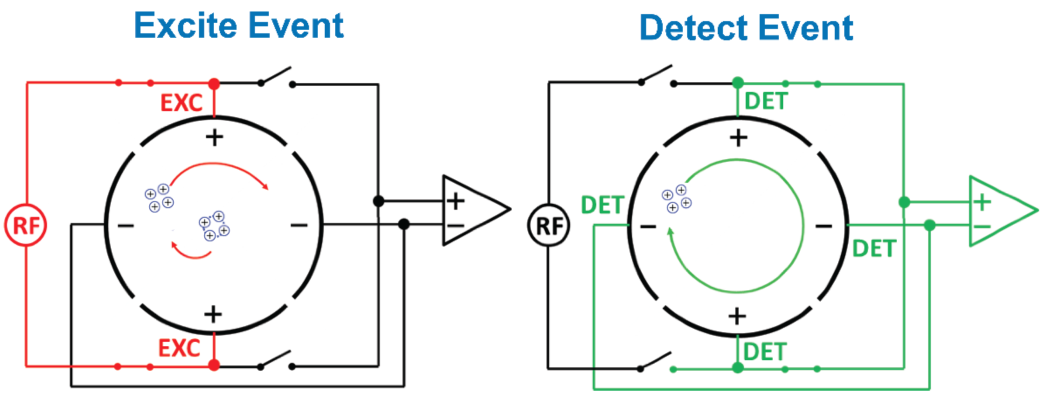


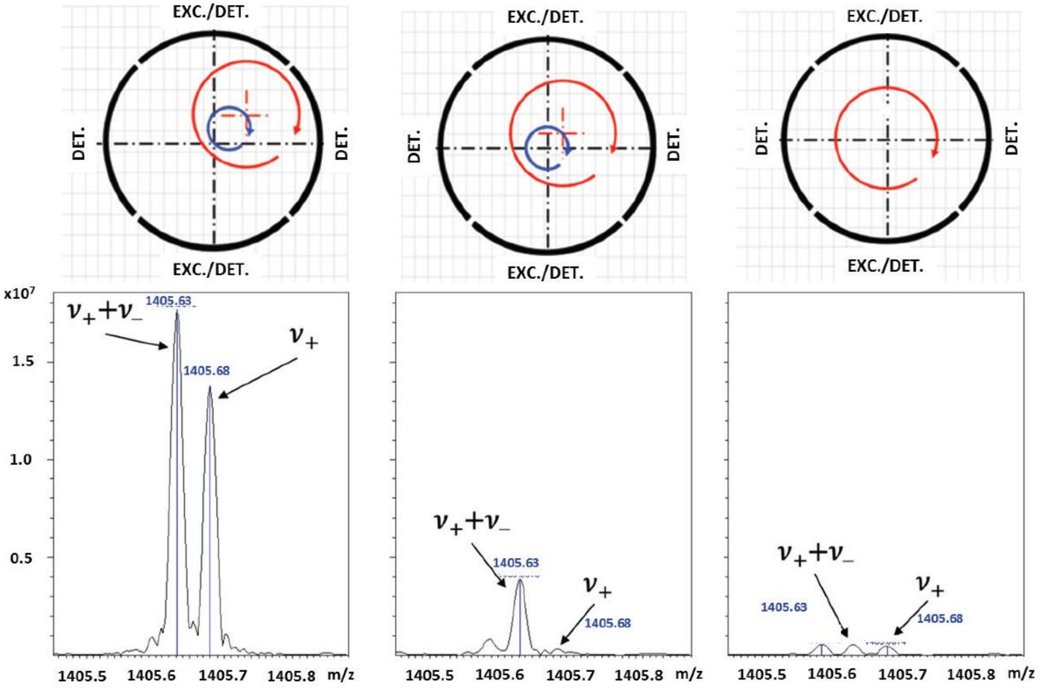
Direct detection of the double cyclotron frequency

$$R_{QPD} = 2 \cdot \nu \cdot T = 2 \cdot R_{DD}$$



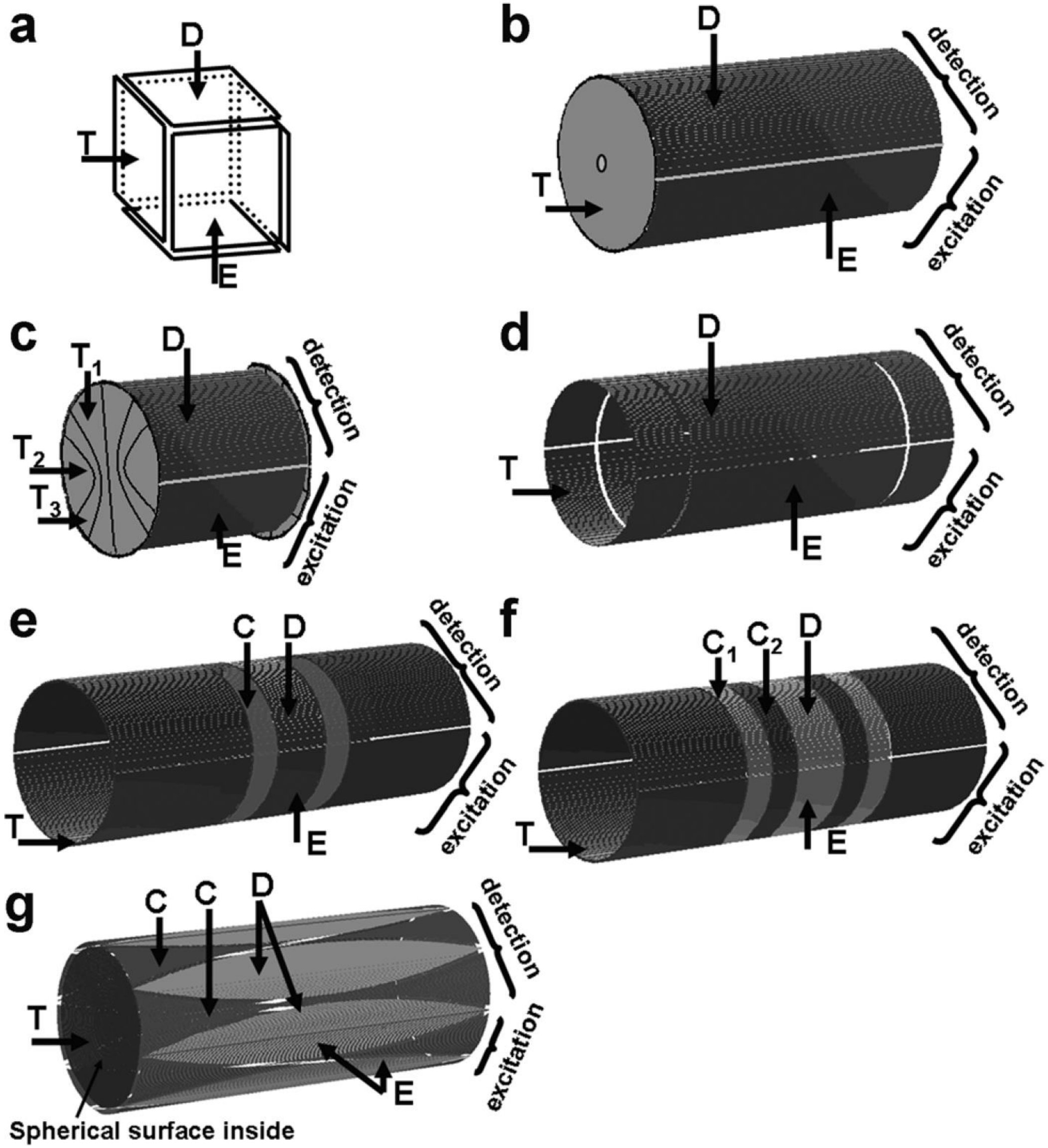
# Quadrupolar detection





**Uncorrected** → **dc Shimming** → **Gated Deflection**

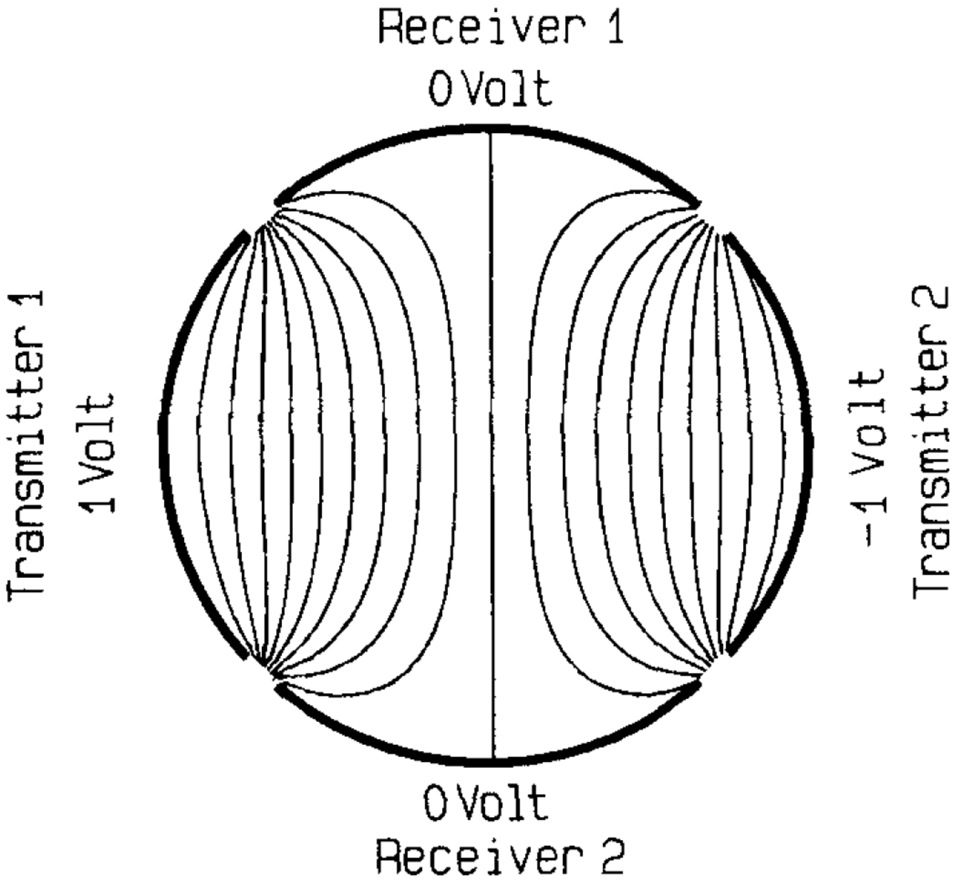
# The cell zoology



# Infinity cell

The 'Infinity Cell': a New Trapped-ion Cell With Radiofrequency Covered Trapping Electrodes for Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

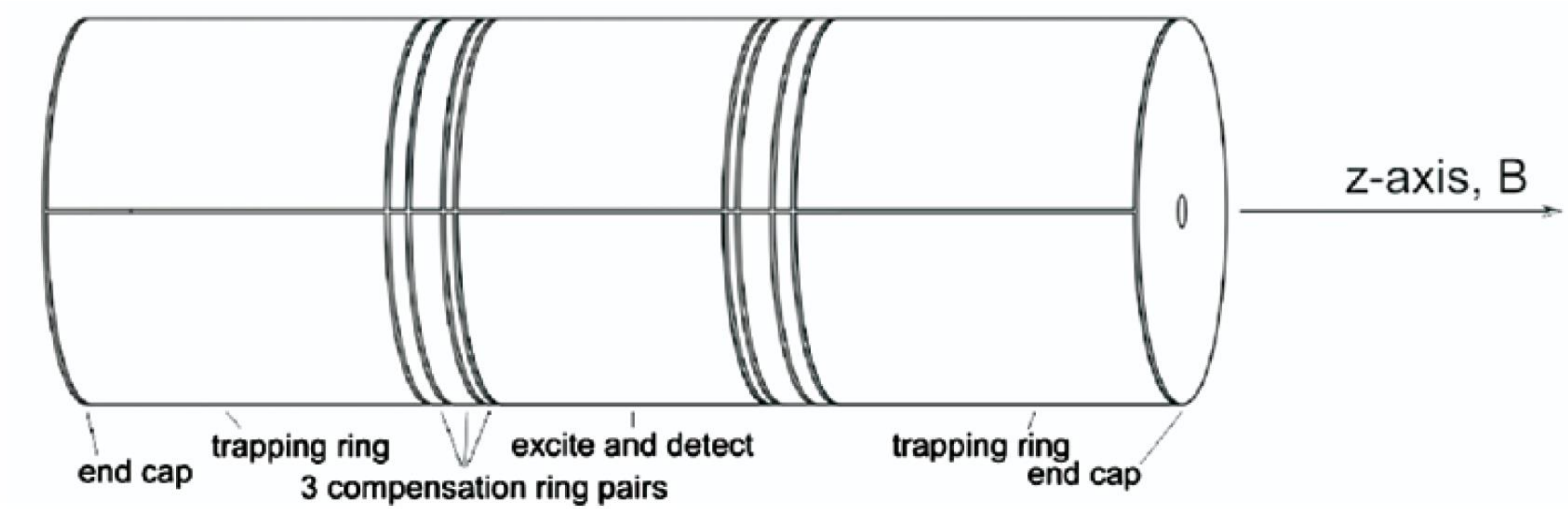
Detection



Excitation

# Compensated cells

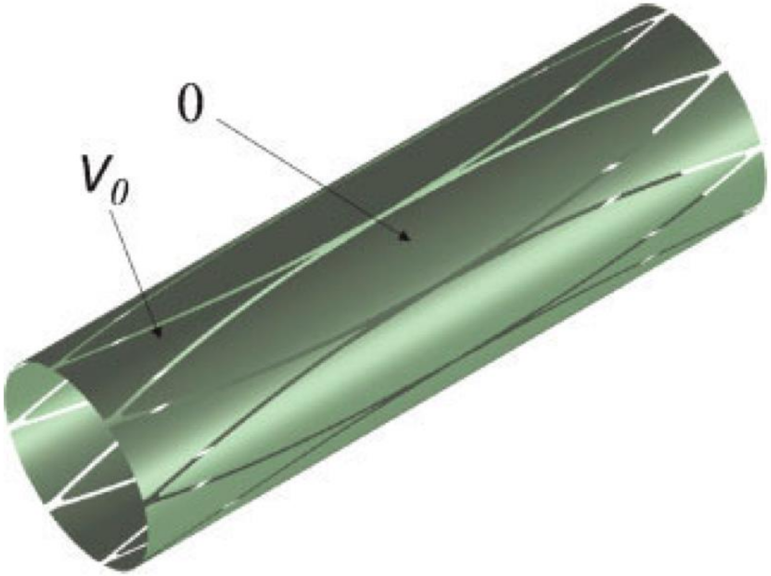
An Electrically Compensated Trap Designed to Eighth Order for FT-ICR Mass Spectrometry

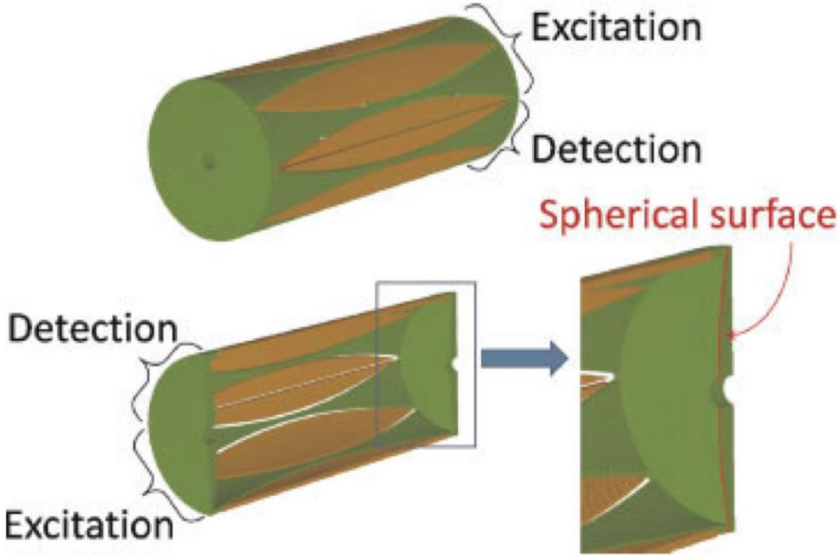


# Harmonized cell (Paracell®)

The method extends the region of harmonicity potentially to the entire cell volume. It is based on subdividing cell cylindrical surface into segments with shapes producing quadratic dependence on axial coordinate of an **averaged (along cyclotron orbit) electric potential** at any radius of cyclotron motion.

$$\Phi(x, y, z) = -\frac{V_{Trap}}{2} \times \left[1 + \frac{4}{a^2}(x^2 + y^2 - 2z^2)\right]$$

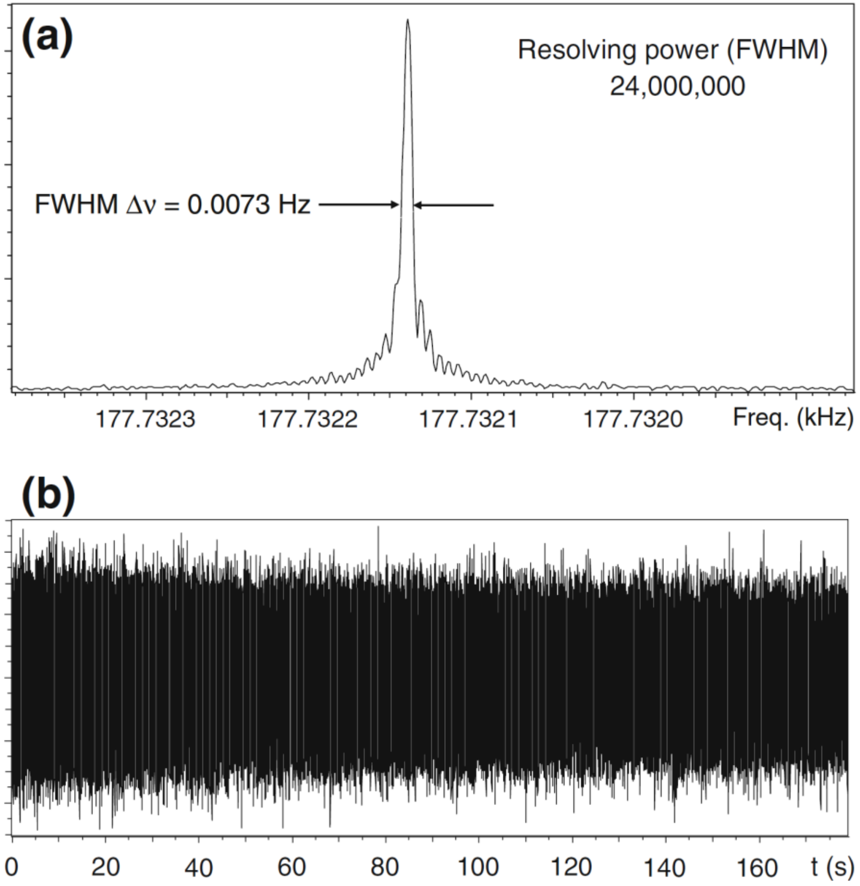




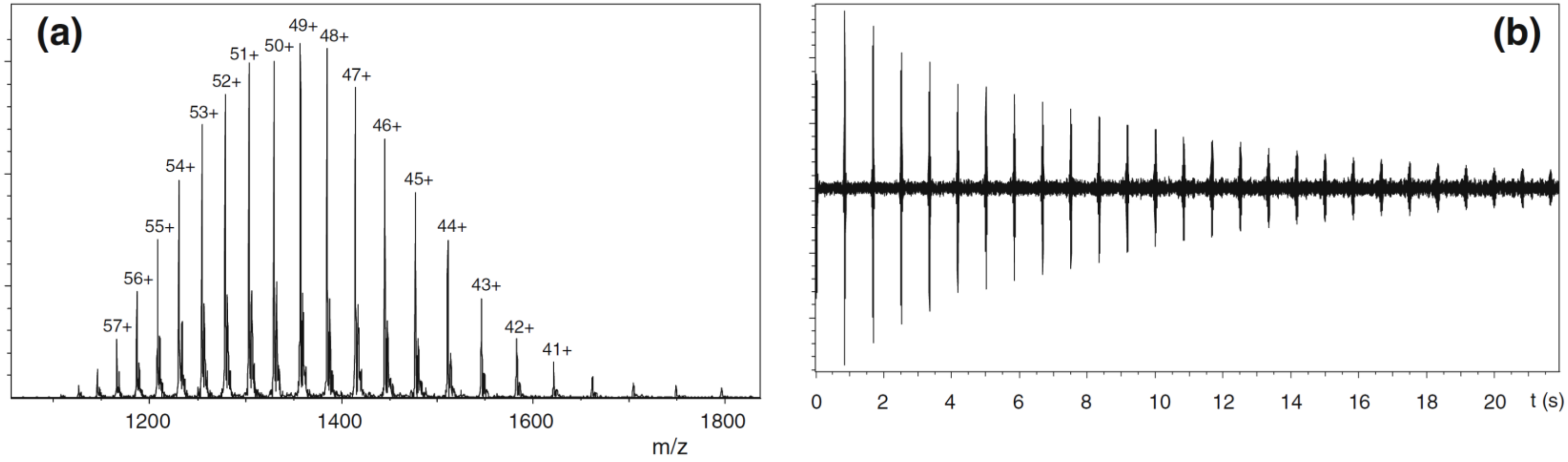
# Harmonized cell (Paracell®)

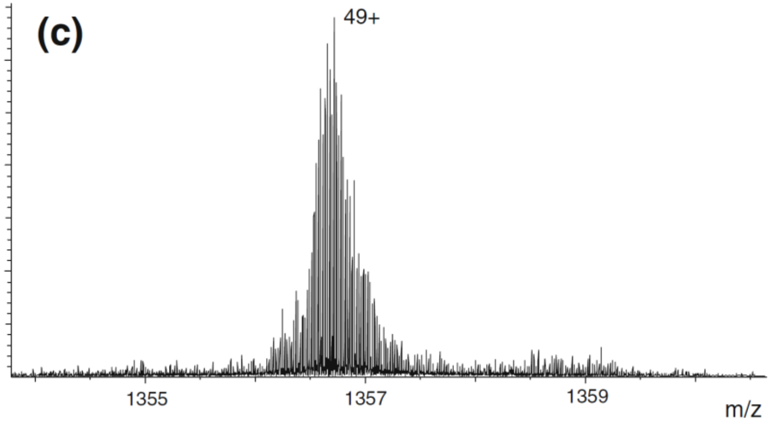
(a) Frequency spectrum (not calibrated) of the mono isotopic peak of singly charged, protonated reserpine (*m/z* 609.28066) with a resolving power of 24,000,000, resulting from magnitude FFT calculation without apodization.

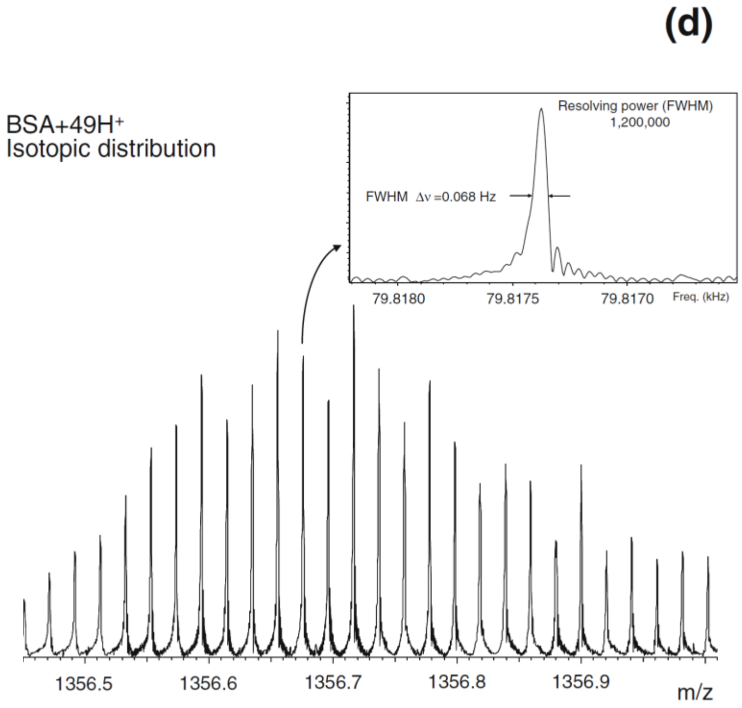
(b) Time domain spectrum of reserpine, detected over 3 min



# Harmonized cell (Paracell®)







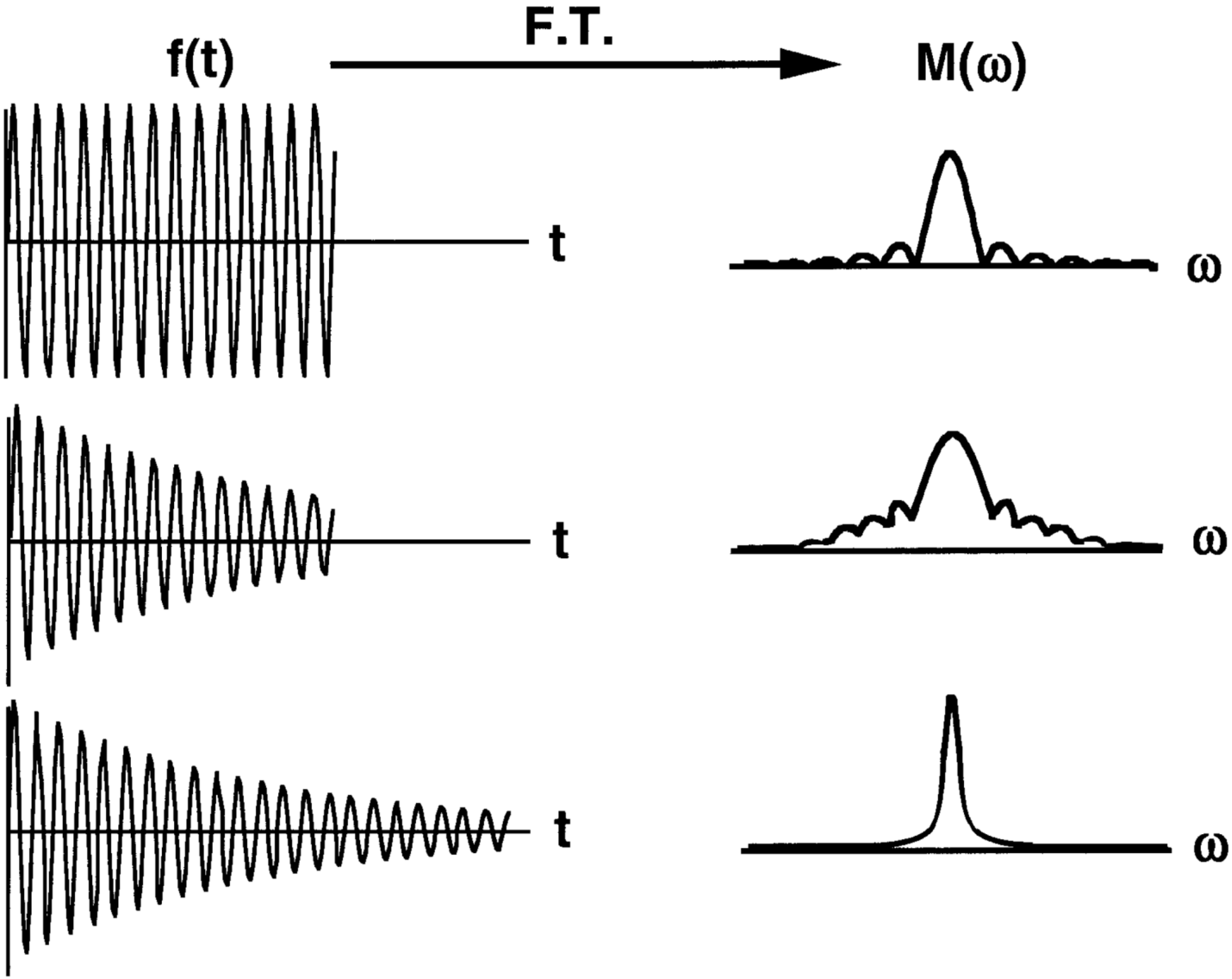
(a) Broadband mass spectrum of bovine serum albumin (BSA) showing the distribution of charge states ranging from 37+ up to 60+.

(b) Time domain spectrum of the isolated charge state 49+ (BSA with 49 protons) detected over 22 s.

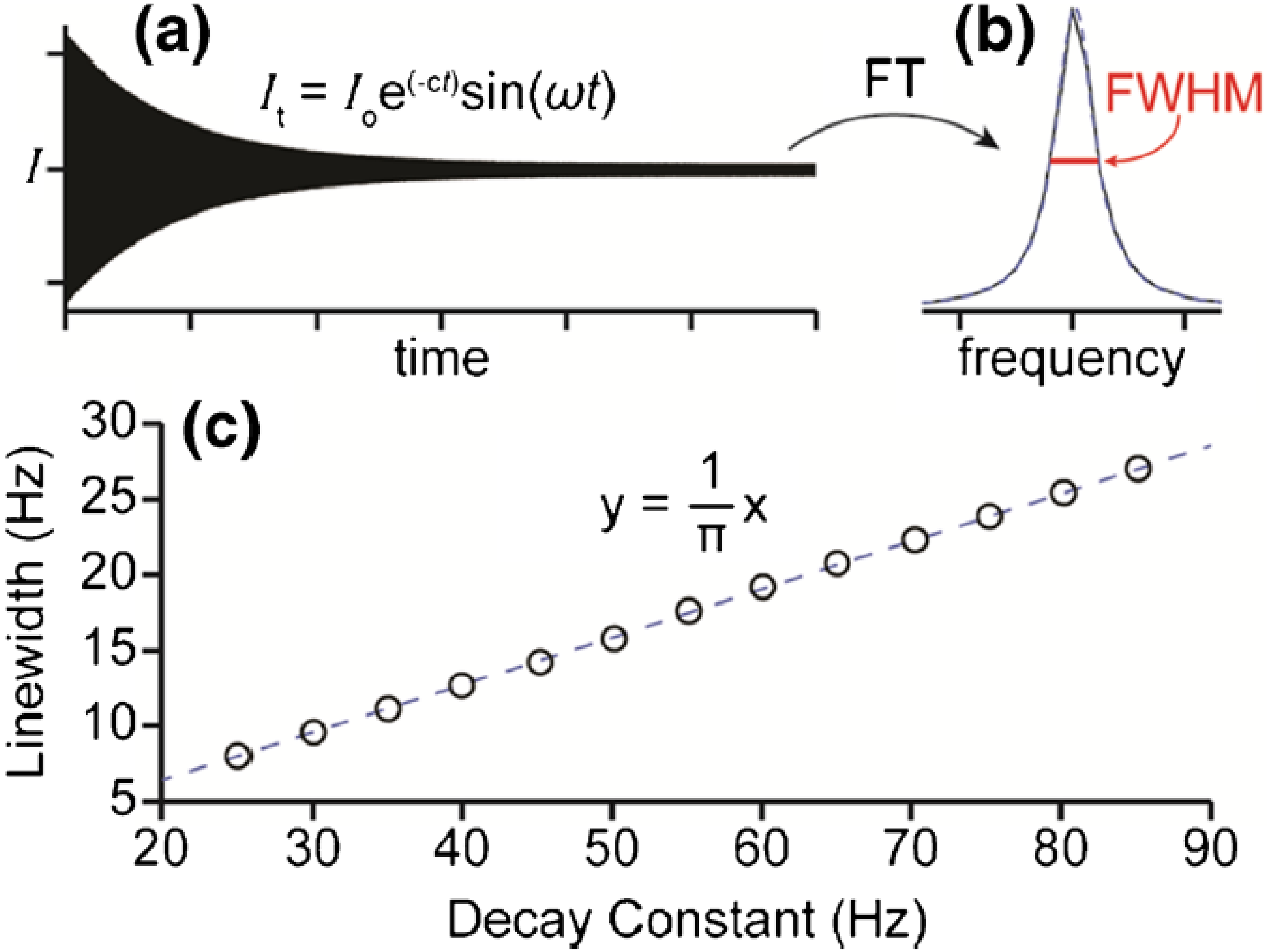
(c) Mass spectrum of the isolated charge state isotopic distribution of 49+ of BSA achieved by magnitude FFT calculation from the transient (b).

(d) Zoom in of the mass spectrum (c), demonstrating a resolving power of 1,200,000

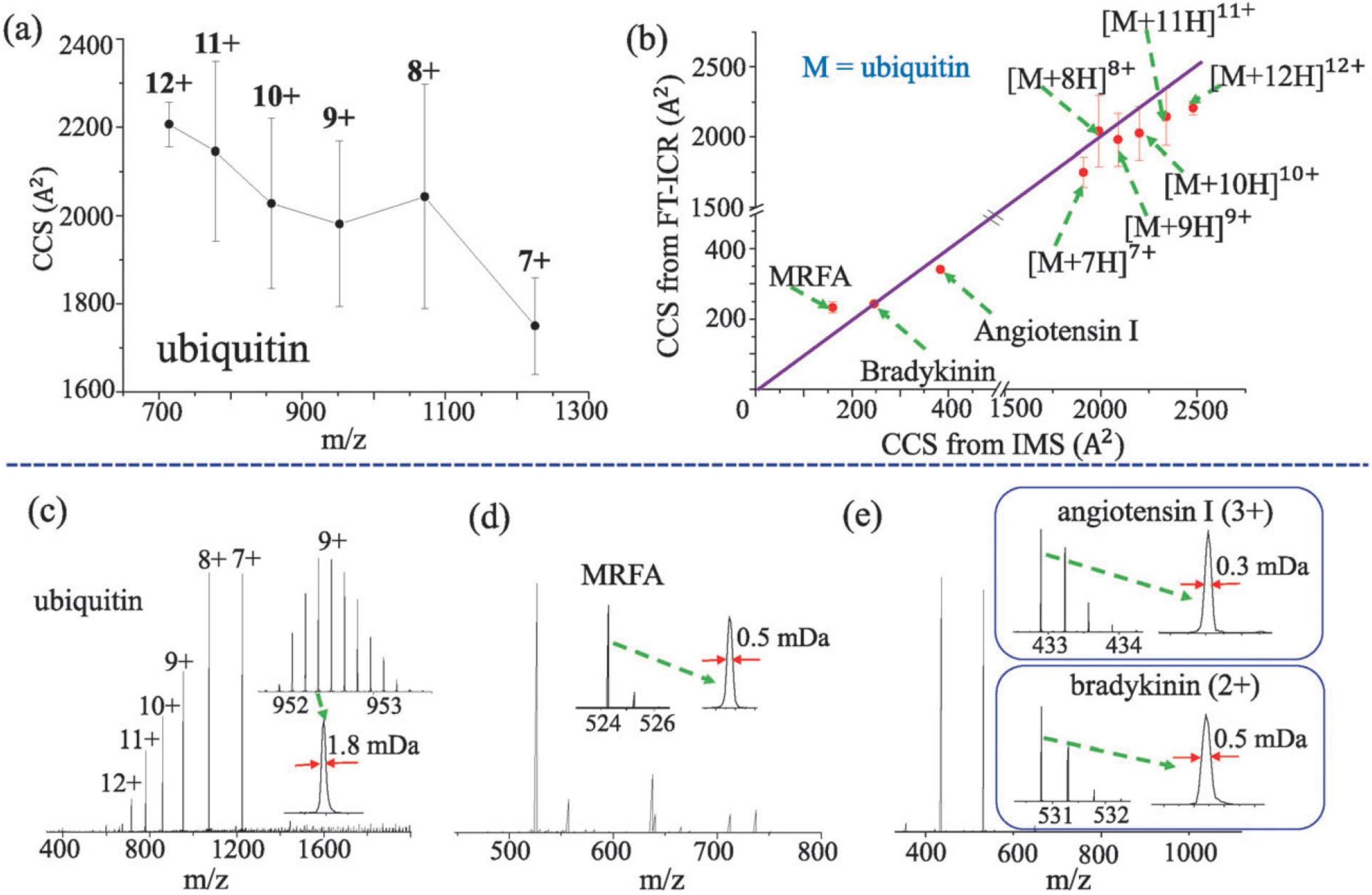
# Different pressure regime



# Radius of an ion at thermic equilibrium



# Ion mobility in the ICR cell



# The Bruker pulse programming language

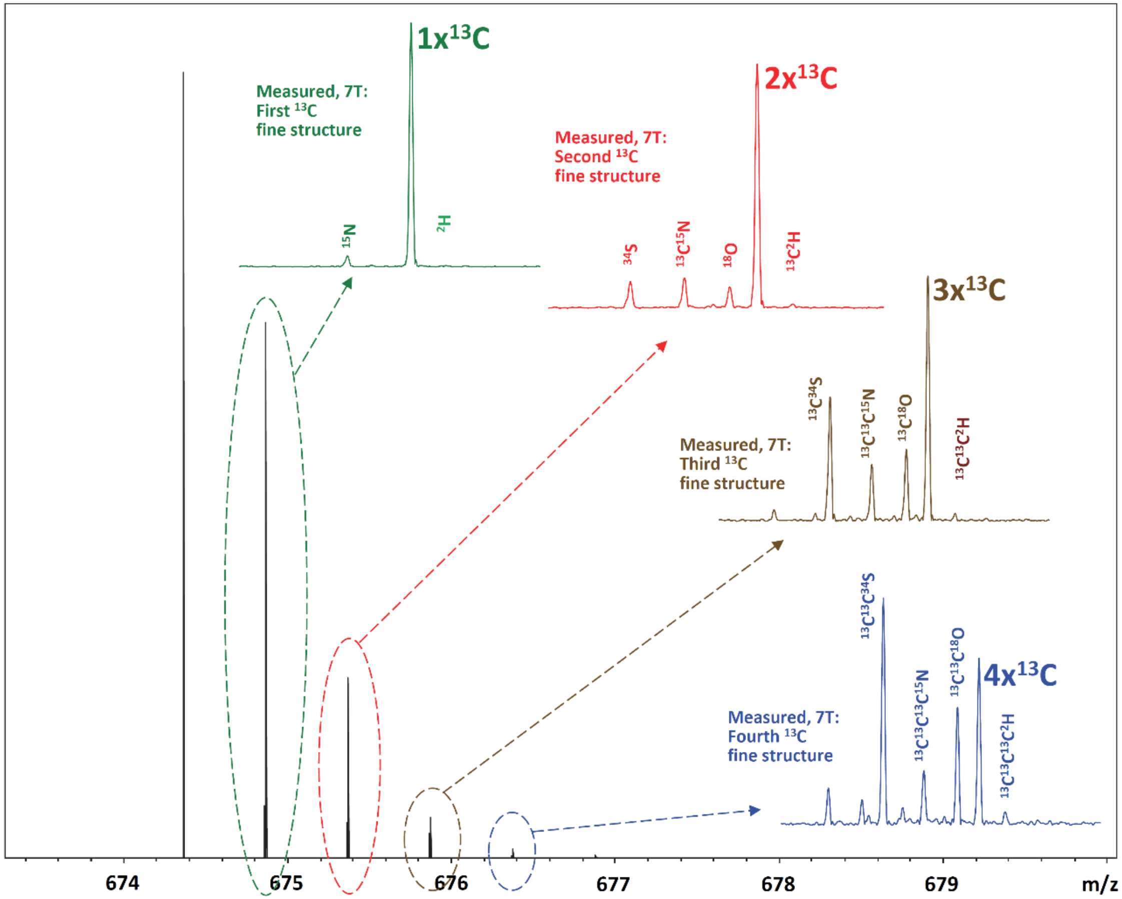
```
#===========================================================
You may create your own program. Here a 2D sequence
#===========================================================


# EXCITATION_KEY:
EXCITATION.lines = 12
#Not all the p_x and pl_y values are working; do not change the names
EXCITATION.1 = "   10u pl1:f1                              ; set attenuation for encoding sequence (FCU-1)"
EXCITATION.2 = "EXC_SWEC1, (p10 ph3 fq1):f1                ; Excitation pulse P1 sweep"
EXCITATION.3 = "   lo to EXC_SWEC1 times l31               ; L[31] steps in sweep"
#EXCITATION.4 = "d26                                                 ; Encoding period 2D delay with increment delay"
EXCITATION.4 = "vd                                                  ; Encoding period 2D delay with vd list"
EXCITATION.5 = "EXC_SWEC2, (p10 ph3 fq1):f1                         ; Encoding pulse P2 sweep"
EXCITATION.6 = "   lo to EXC_SWEC2 times l31                        ; L[31] steps in sweep"
EXCITATION.7 = "   d13 setnmr3|12                          ; trigger IRMPD laser pulse (XGPP_OUT[2])"
EXCITATION.8 = "   10u setnmr3^12"
EXCITATION.9 = "   10u pl3:f1                              ; set attenuation for observe pulse (FCU-1)"
EXCITATION.10 = "EXC_SWO, (p3 ph3 fq1):f1                  ; Observe pulse P3 sweep"
EXCITATION.11 = "   lo to EXC_SWO times l31                 ; L[31] steps in sweep"
#EXCITATION.12 = "  0.1u id26                     ; fixed increment to next encoding delay t1 of value id26"
EXCITATION.12 = "  0.1u ivd             ; increment to next encoding delay t1 in VD_2D list"

# PHASE_PROGRAM_DEFS_KEY:
#phase value angle degree 0 0; 1 90; 2 180
PHASE_PROGRAM_DEFS.lines = 4
PHASE_PROGRAM_DEFS.1 = "   ph1= 0 0 2 2              ; normal phase program for compensanting physical differential entries inverion"
PHASE_PROGRAM_DEFS.2 = "   ph2= 0 1 2 3              ; phase program: 0 1 2 3 (all other RF)"
PHASE_PROGRAM_DEFS.3 = "   ph3= 0 0 2 2              ; phase program: 0 0 2 2 (all other RF)"
PHASE_PROGRAM_DEFS.4 = "   ph4= 2 2 2 2              ; phase program: 2 2 2 2 (all other RF)“
```

# European network EU_FT-ICR_MS

*An Horizon 2020 INFRA for Starting Communities network*

www.eu-fticr.eu

# Why a FT-ICR MS centers network?



15 Tesla FT-ICR MS at the Czech Academy of Science, Institute of Microbiology (Prague) funded in part with EU ERDF funds (highest commercial magnetic field).

- **The most resolving mass spectrometer (× 10 versus the best other MS)**
- **Ubiquitous use in different scientific fields**
- Cost between 1.5 and 3 million euros
- But requires a skilled team

# The EU_FT-ICR_MS network

**11 academic FT-ICR MS center (3 in France) from 9 countries**

**2 companies (2 in France)**

**Bruker Daltonik**

**CAS4CADE (SME)**

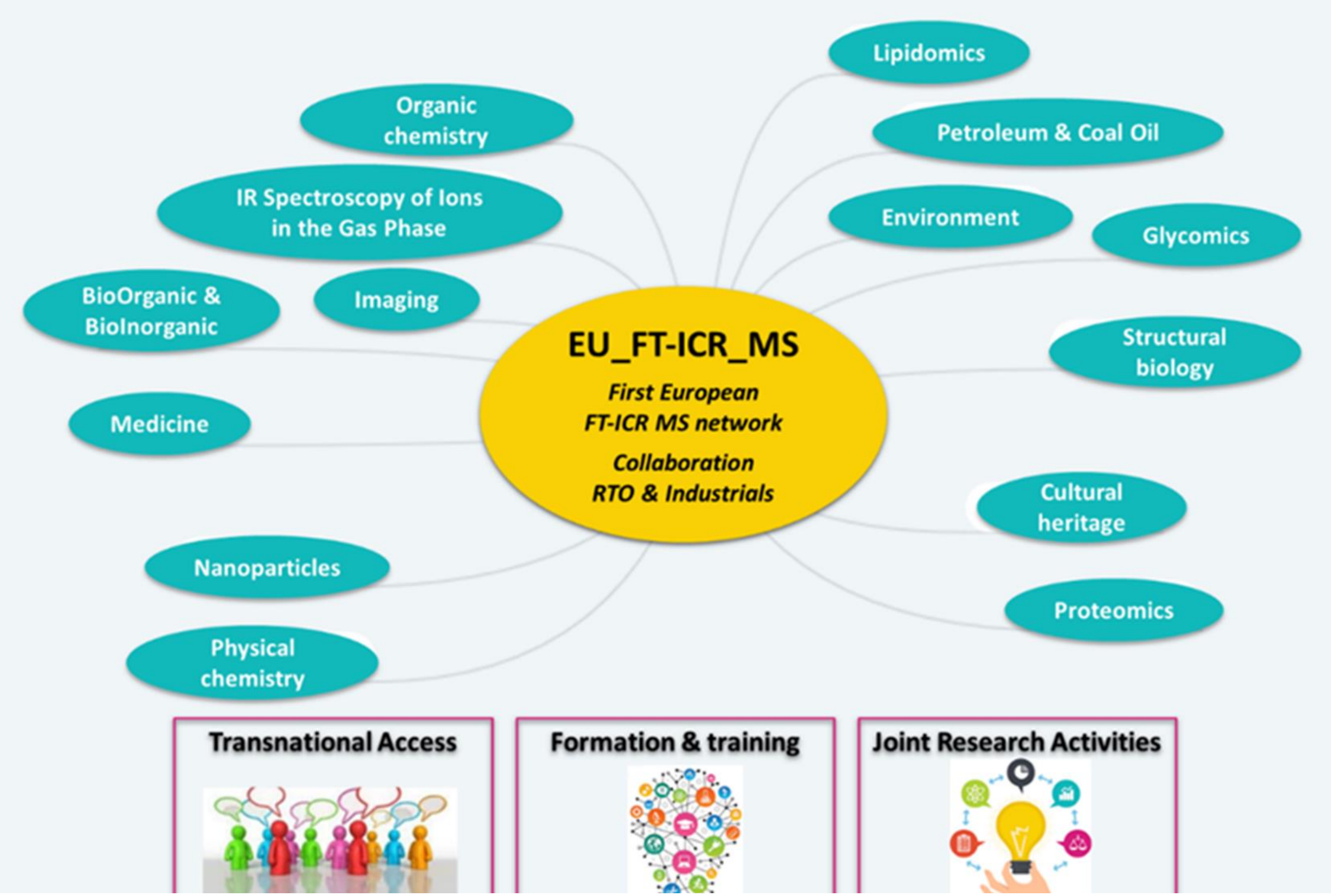
**Absiskey**

**5 millions euros (4 years)**

**A funding equal between partners (not a two circles model)**

**Started January 1<sup>st</sup> 2018, 0 hour**

# The site specificities and the different workpackages



And the very important WP **Open Data and *e*-Infrastructure**

# EU_FT-ICR_MS first actions

**Transnational access**
Apply on the web site.
**Experiments, travels and accommodation paid by EU.** One restriction: you should applied in a center from a different country than your own country of origin

**First Short course**
Atmospheric pressure ionization techniques for high resolution mass spectrometry of complex samples
5-7 March 2018, University of Rostock

**First summer school**
19-24 August 2018, University of East Finland (Joensuu)

**Booth or sessions** at **EFTMS 2018 meeting**, 23-27 Avril, Munich and **IMSC conference** (International Mass Spectrometry Conference), 26-31 August, Florence

# First Short Course of the EU_FT-ICR_MS network

## atmospheric pressure ionization techniques for high resolution mass spectrometry of complex samples

## When?

5-7 March 2018

## Where?

University of Rostock
Research building LL&M
Albert-Einstein-Strasse 25
18059 Rostock

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

Universität Rostock
Traditio et Innovatio

## Overview of the program

**Tutorial Lectures**
Basics of FT-ICR MS using atmospheric pressure ionization

**Instrument demos**

**Hands-On Exercises**
Electrospray ionization (ESI) and Atmospheric pressure chemical ionization (APCI)

**Data analysis**
Comparison of ionization features of ESI, APCI and GC- APCI/ Atmospheric pressure photo ionization (APPI) samples;
In parallel: running GC – APCI/APPI measurements

### You want to learn more about high resolution mass spectrometry and atmospheric pressure ionisation techniques?

## Registration:

please send an E-Mail using the application form to

**martin.sklorz@uni-rostock.de**

We will response as fast as possible and inform you about acceptance.
The application form is available as a download on our website.

www.zimmermann.chemie.uni-rostock.de/forschung/advanced-mass-spectrometry/hochaufloesende-massenspektrometrie/eu-ft-icr-ms/

**NO CONFERENCE FEES !**

Each participant (limited seats) will receive support for travelling and accommodation.

**REGISTER SOON!**

# Acknowledgements

cnrs dépasser les frontières

Université de Lille

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

l'Europe s'engage en Nord-Pas-de-Calais avec le FEDER

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DE L'ENSEIGNEMENT SUPÉRIEUR
ET DE LA RECHERCHE

Nord-Pas de Calais

BRUKER

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FR FT-ICR

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