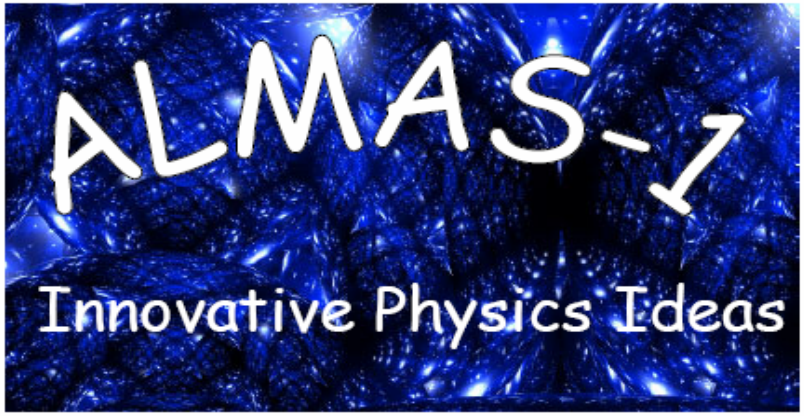
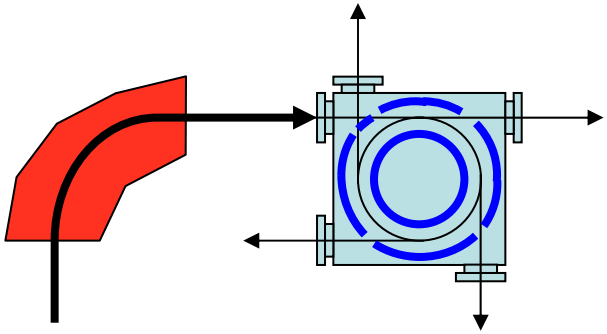



Workshop on Advanced
Laser and Mass Spectroscopy

October 19th to 20th 2006
GSI, Darmstadt, Germany

# *The Ion Circus – a circular Paul trap for cooling, separation and transport*

*Dave Lunney, CSNSM/IN2P3, Université Paris Sud (Orsay)*




Partnership:
GSI-LMU-JYFL-LPCC

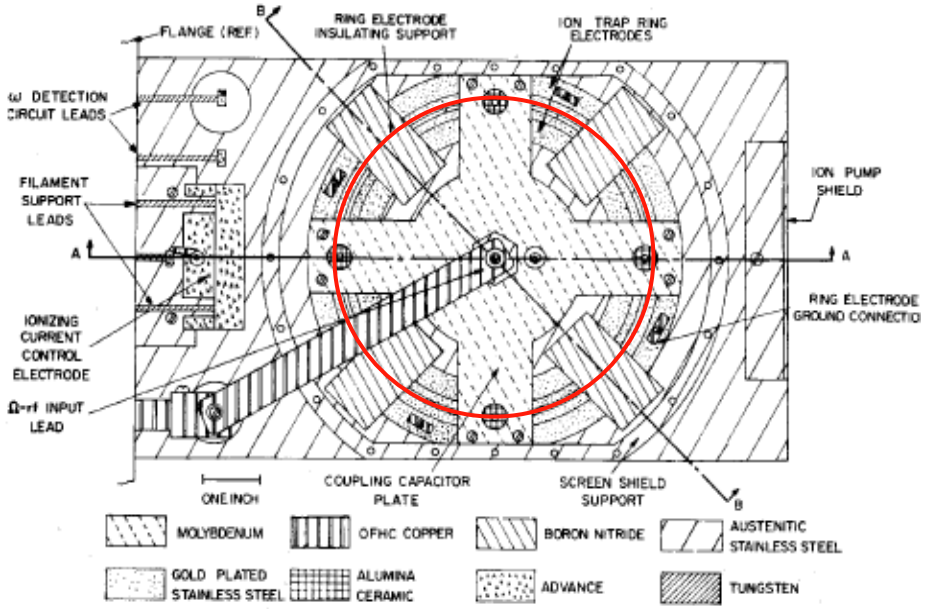

Total Length : 500 mm
linear Paul traps: a story of success!
0 1 2 3cm
NSCL

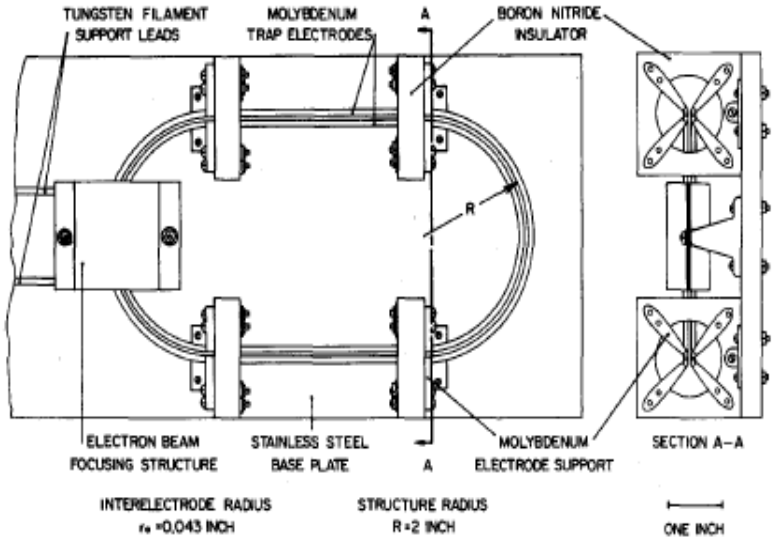
JOURNAL OF APPLIED PHYSICS VOLUME 40, NUMBER 8 JULY 1969

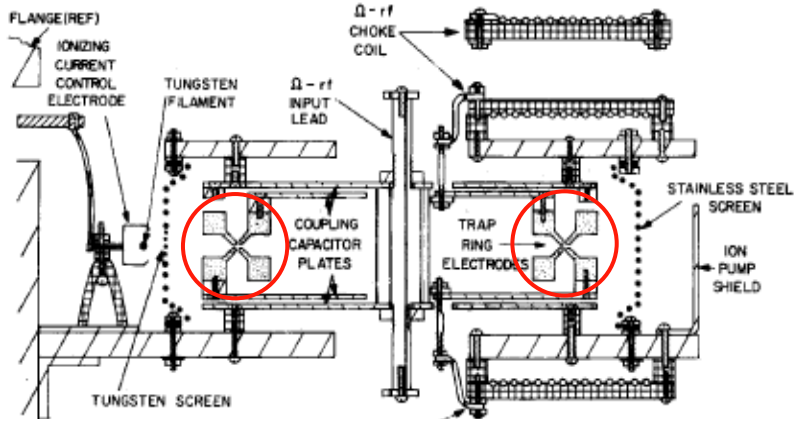
# Storage-Ring Ion Trap Derived from the Linear Quadrupole Radio-Frequency Mass Filter*

D. A. CHURCH†
*University of Washington, Seattle, Washington 98105*






## ACKNOWLEDGMENTS

This research was suggested by Dr. H. G. Dehmelt

# Observation of Ordered Structures of Laser-Cooled Ions in a Quadrupole Storage Ring

I. Waki,[a] S. Kassner, G. Birkl, and H. Walther
*Max-Planck-Institut für Quantenoptik, D-8046 Garching bei München, Federal Republic of Germany*

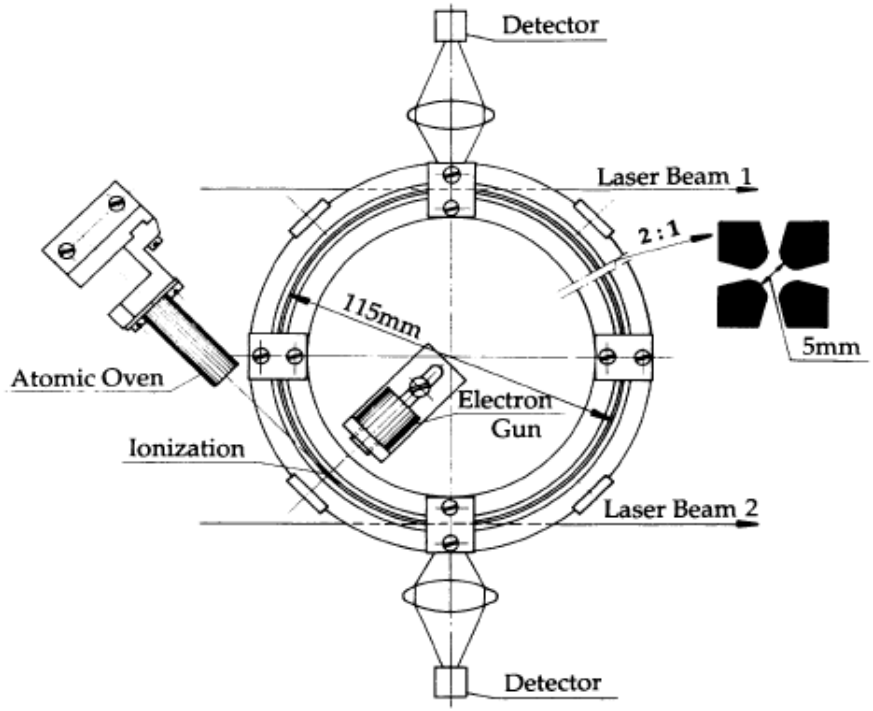



FIG. 1. Experimental setup of the quadrupole storage ring.

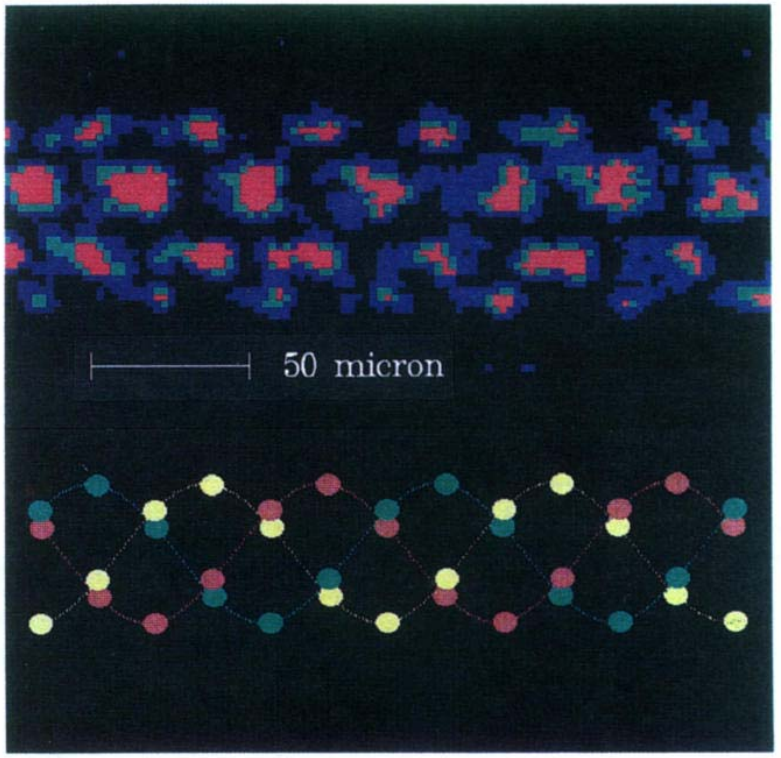
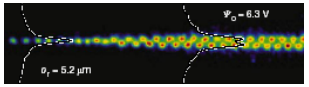
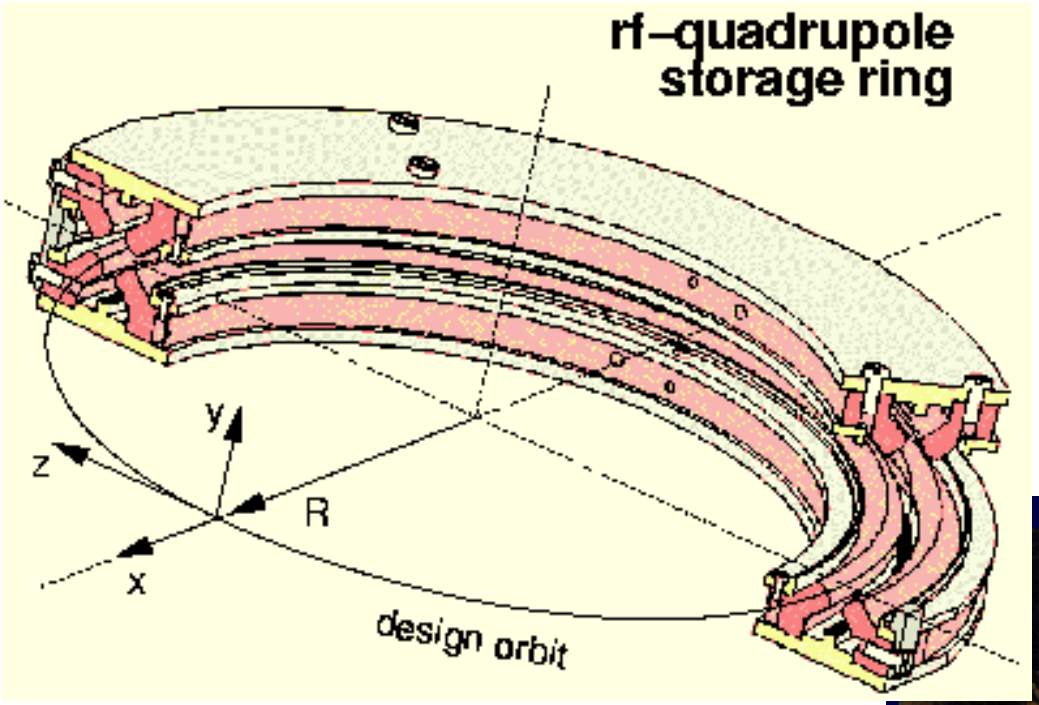



FIG. 6. Helical structure of $^{24}Mg^{+}$ ions with a diameter of $63 \pm 2$ $\mu$m. The experimental image (top) corresponds to three interwoven helices (shown in different colors, bottom). The closely appearing pairs of ions are sitting on opposite sites, resulting in twice the intensity at those positions ($\psi_0 = 1.1$ eV).

*Nature* **357**, 310 - 313 (28 May 1992)
G. Birkl, S. Kassner & H. Walther
**Multiple-shell structures of laser-cooled $^{24}Mg^{+}$ ions in a quadrupole storage ring**

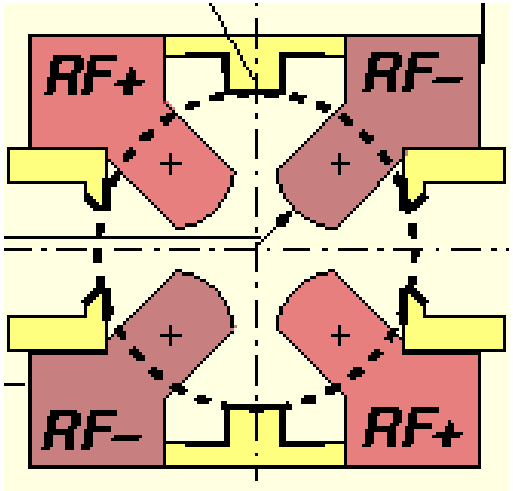
**letters to nature** T. Schätz, U. Schramm & D. Habs, NATURE, 412 (16 August 2001) 717

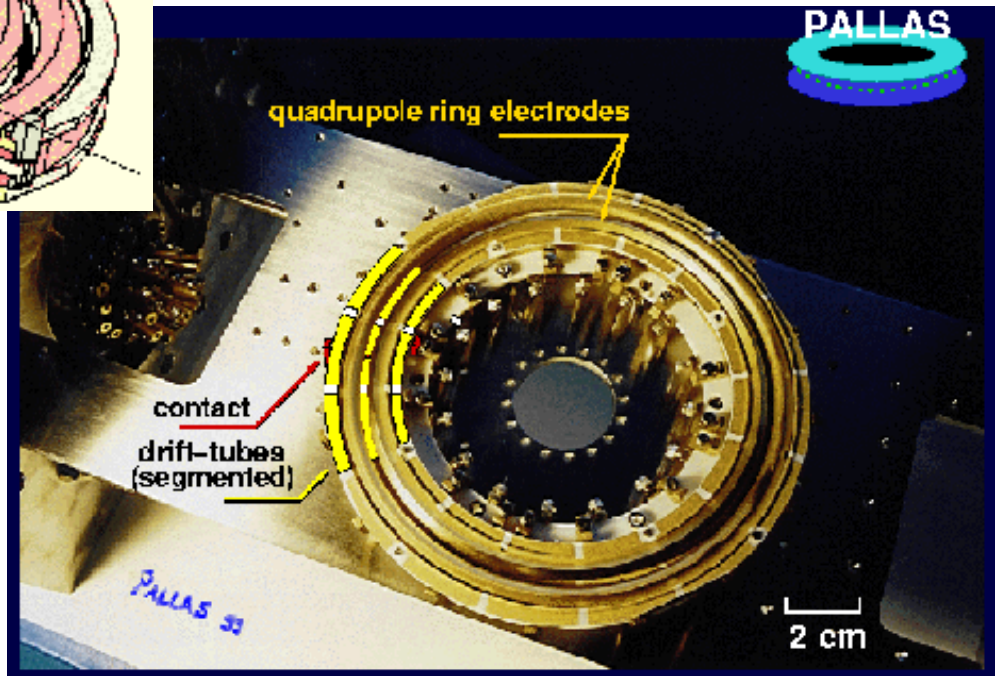


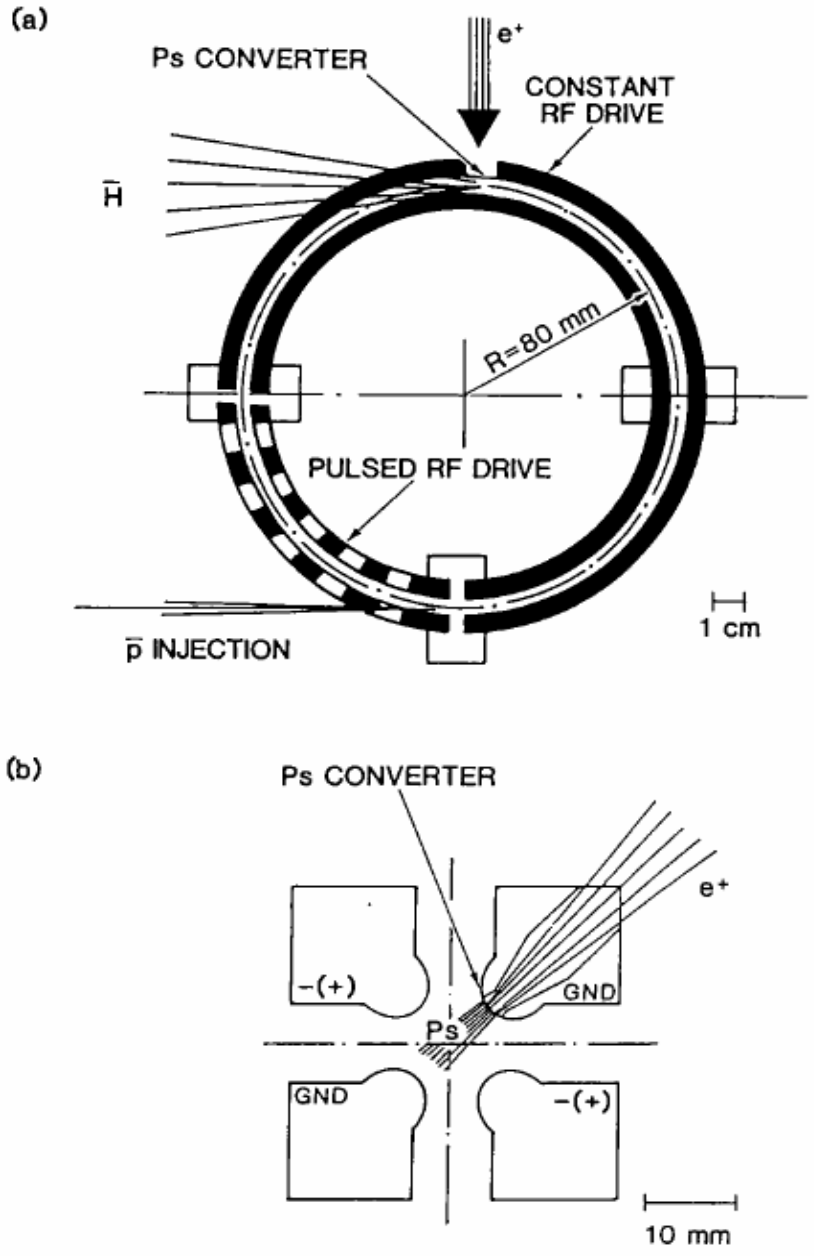



PALLAS storage ring
(circular Paul trap)

U. Schramm et al., LMU-Munich






Schematic layout of the RFQ race-track trap. Shown are the pulsed section



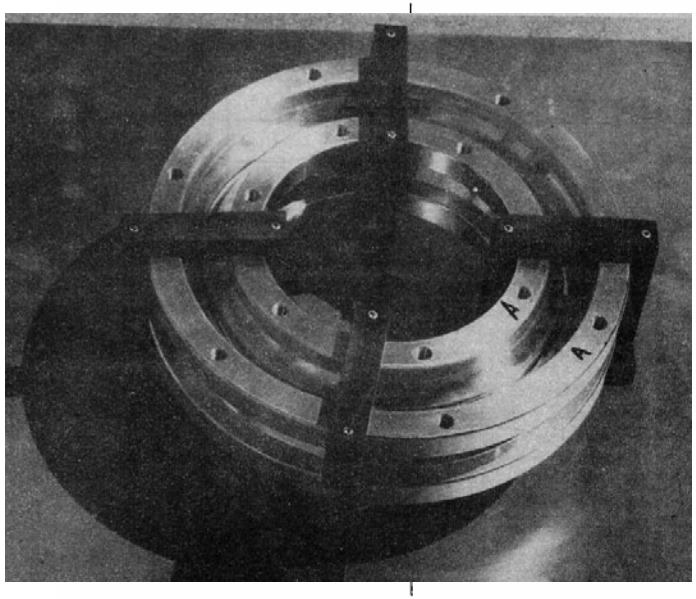


Fig. 2. Electrode structure of the RFQ ring trap for antihydrogen formation seen from the top. The RF drive to the lower left quadrant can be switched on and off rapidly for injecting antiprotons.

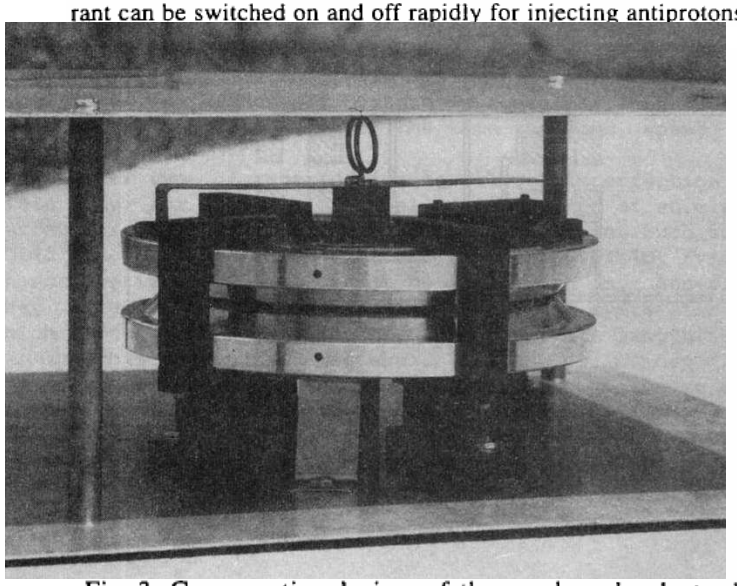


Fig. 3. Cross-sectional view of the quadrupole electrodes showing the beam profile displaced by the centripetal force.

Hyperfine Interactions 81(1993)263–273

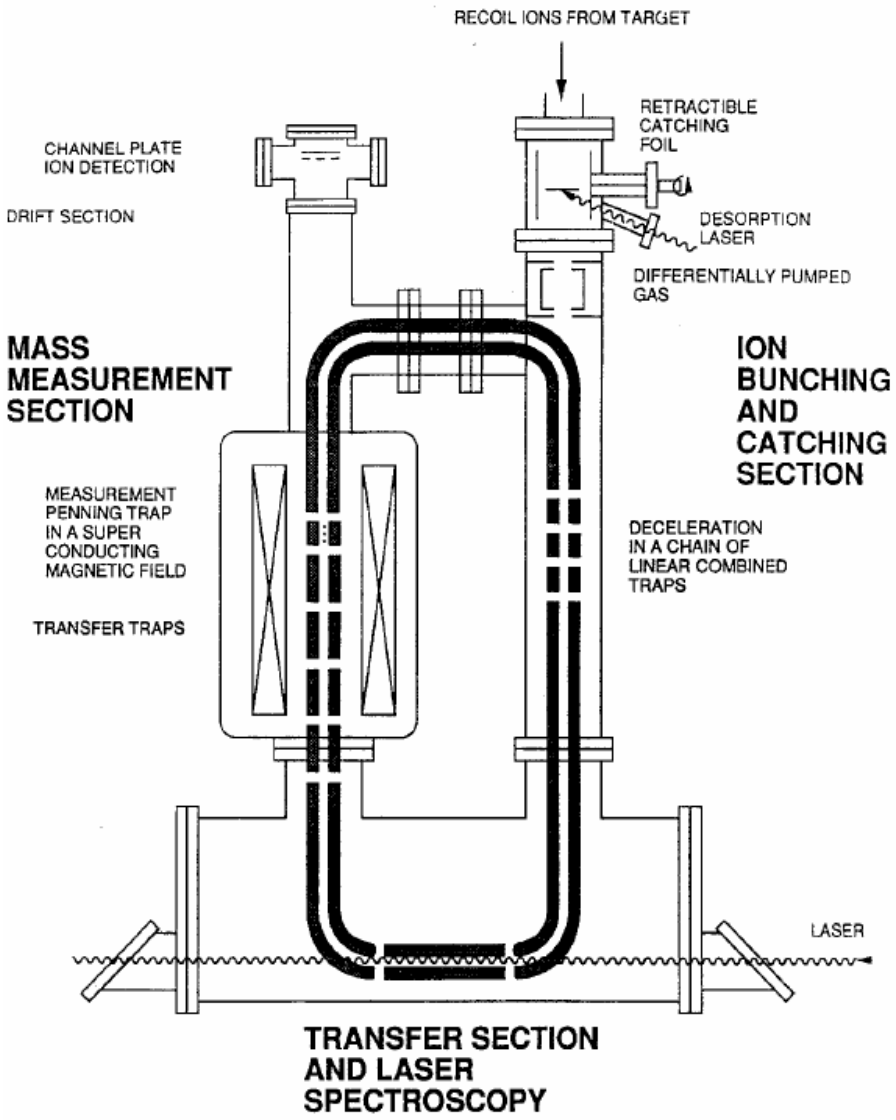



Fig. 3. Proposed linear combined trap for the RIB facility at ORNL. Three

Hyperfine Interactions 99 (1996) 193–200

# Ion storage at eV energies in an octopole ring

F.W. Bliek, R. Hoekstra and R. Morgenstern

*K.V.I., Atomic Physics, Zernikelaan 25, 9747 AA Groningen, The Netherlands*

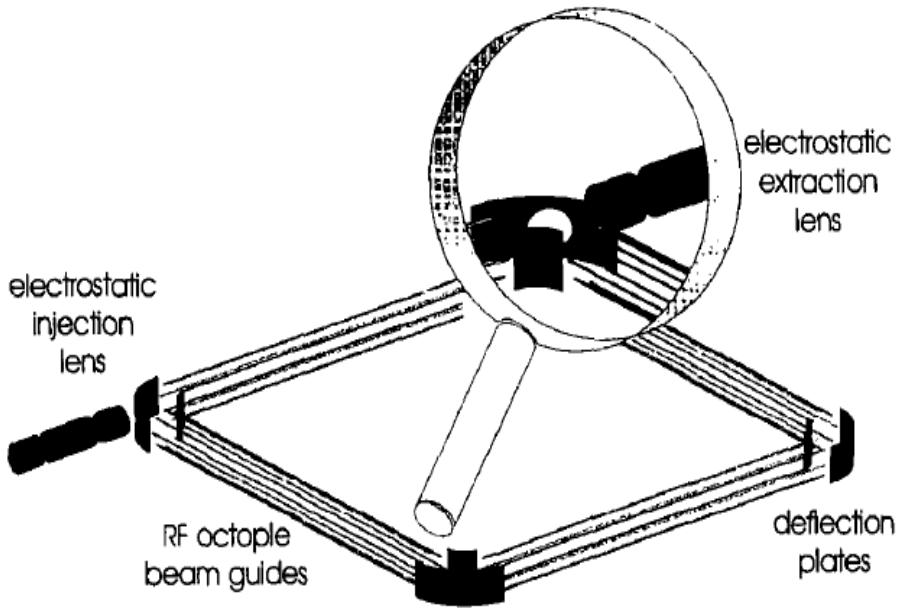



Fig. 4. Artistic impression of the table top ion storage ring.

ELSEVIER

International Journal of Mass Spectrometry 212 (2001) 25–40

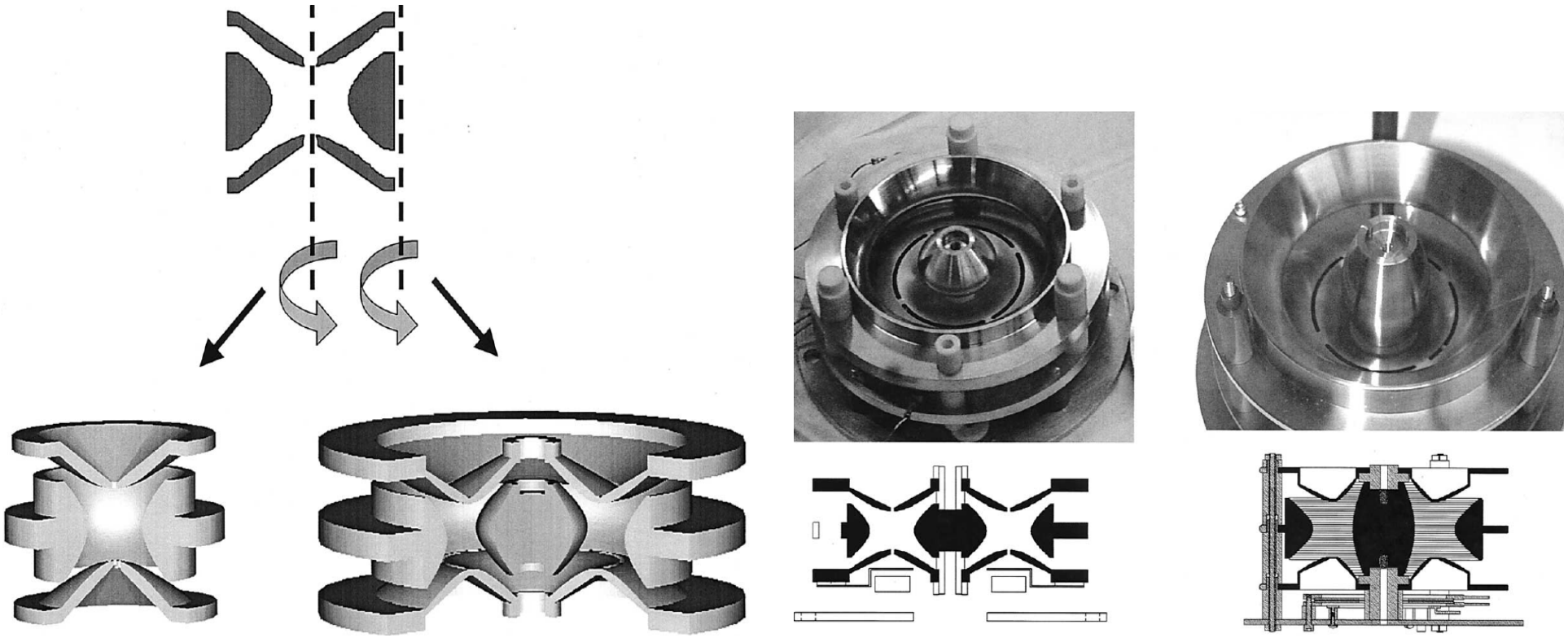
International Journal of Mass Spectrometry

www.elsevier.com/locate/ijms

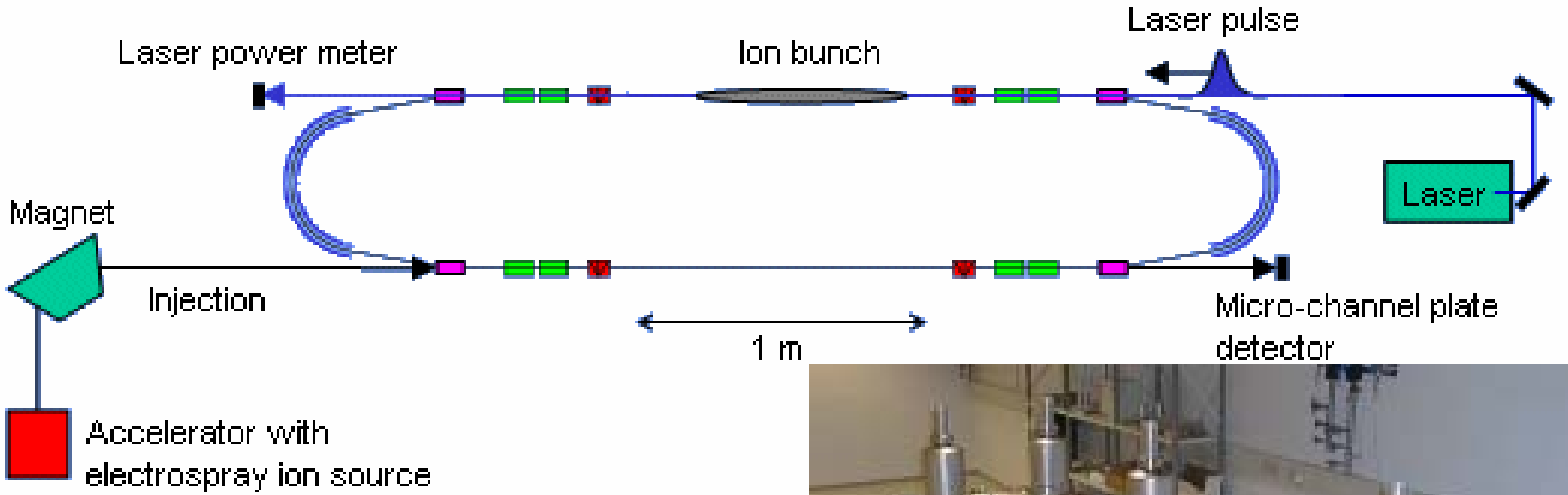
# Design, optimization and initial performance of a toroidal rf ion trap mass spectrometer

Stephen A. Lammert[a,*], Wolfgang R. Plass[b,1], Cyril V. Thompson[a], Marcus B. Wise[a]

[a]*Chemical and Analytical Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6365*
[b]*Department of Chemistry, Purdue University, W. Lafayette, IN 47907-1393*



# Institute for storage ring facilities
# Aarhus University (Denmark)

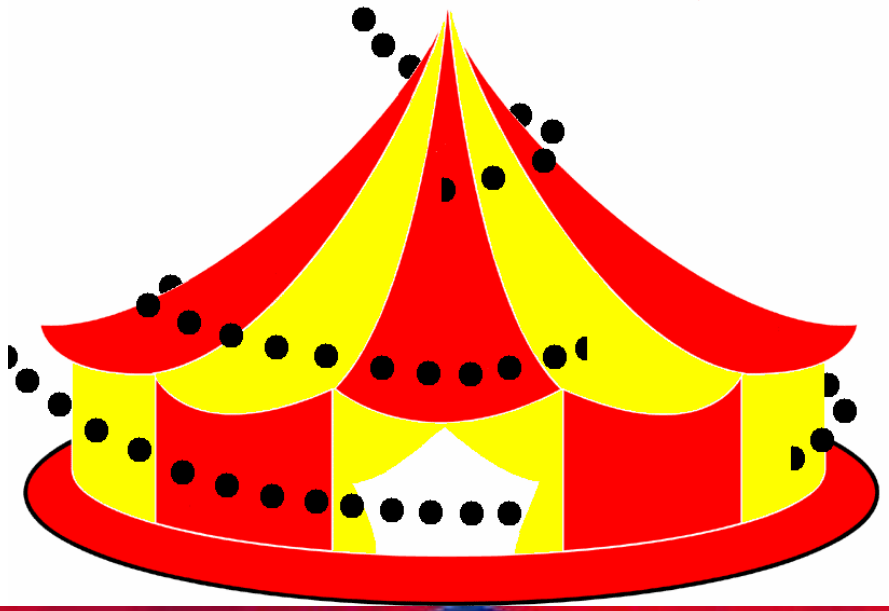



ELISA:
an electrostatic
storage ring
(for molecular physics)

# beam-handling: *terminology*

| transport | purification | preparation |
|---|---|---|
| focusing | ionization | accumulation |
| steering | separation | bunching (cooling) |
| | (cooling) | charge breeding |
| **facility** | **production** | **experiments** |

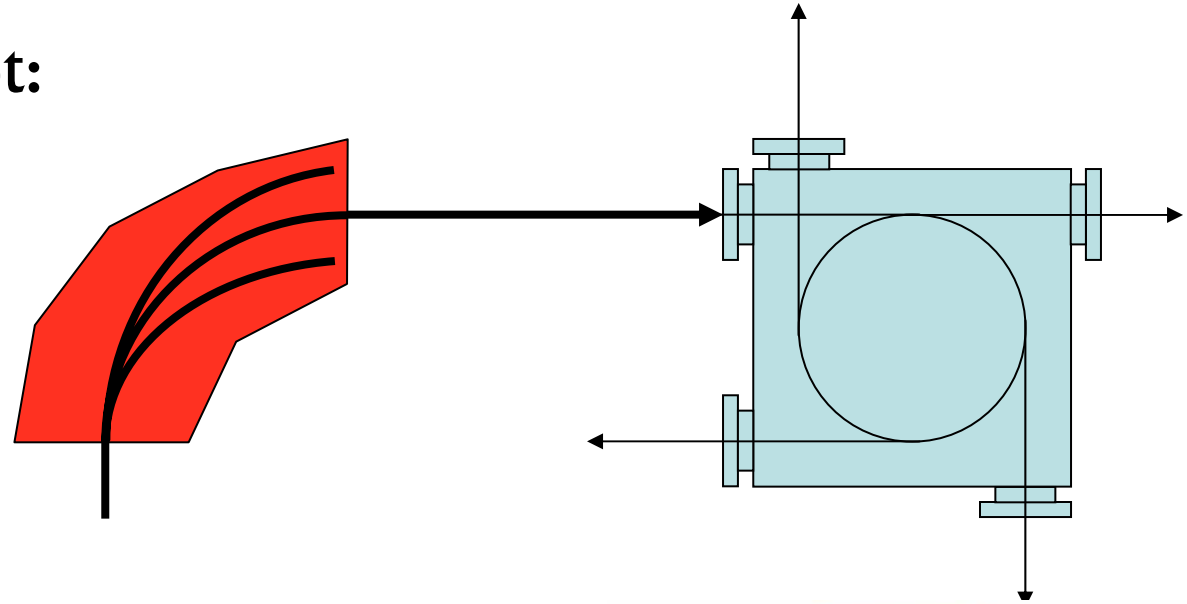
# Circus:  definition (1)

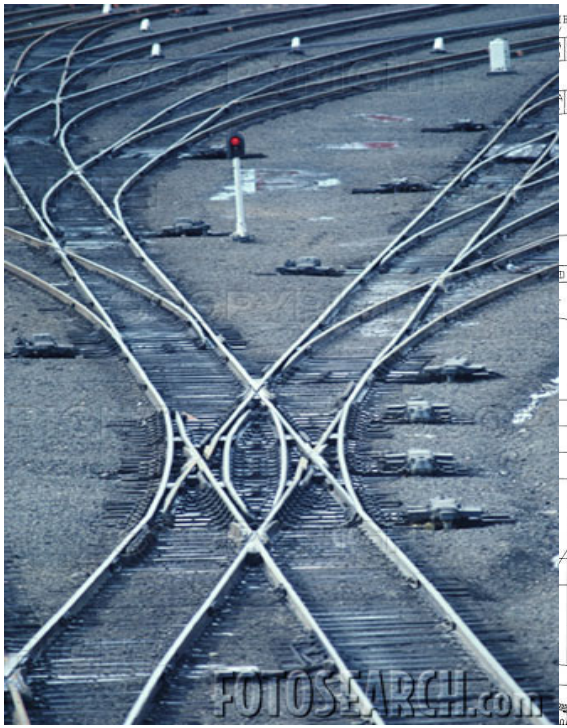


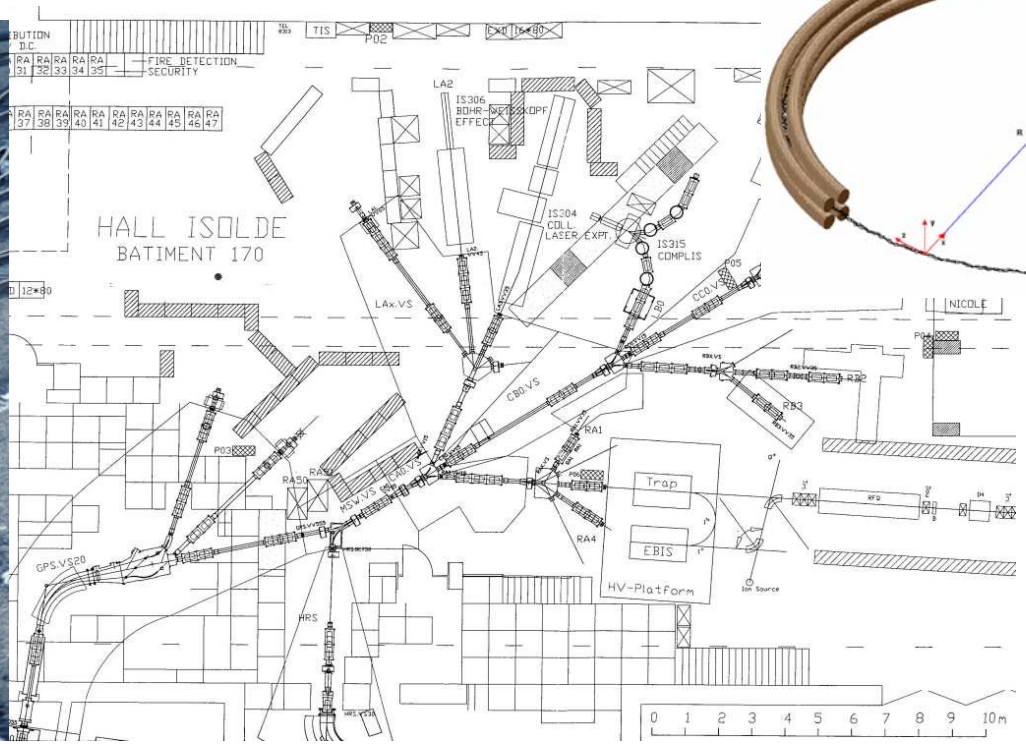
# Circus:  definition (2)

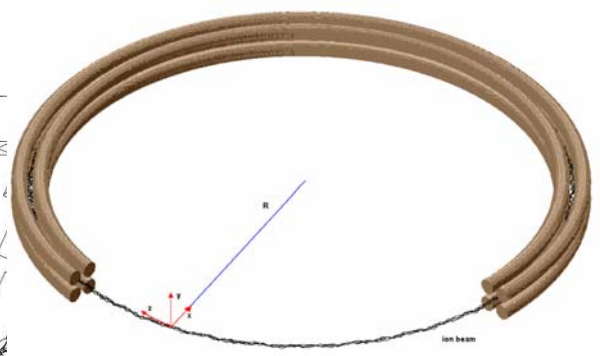
# The Ion Circus concept:

*transport*
*bunching*
*separation*
*cooling*



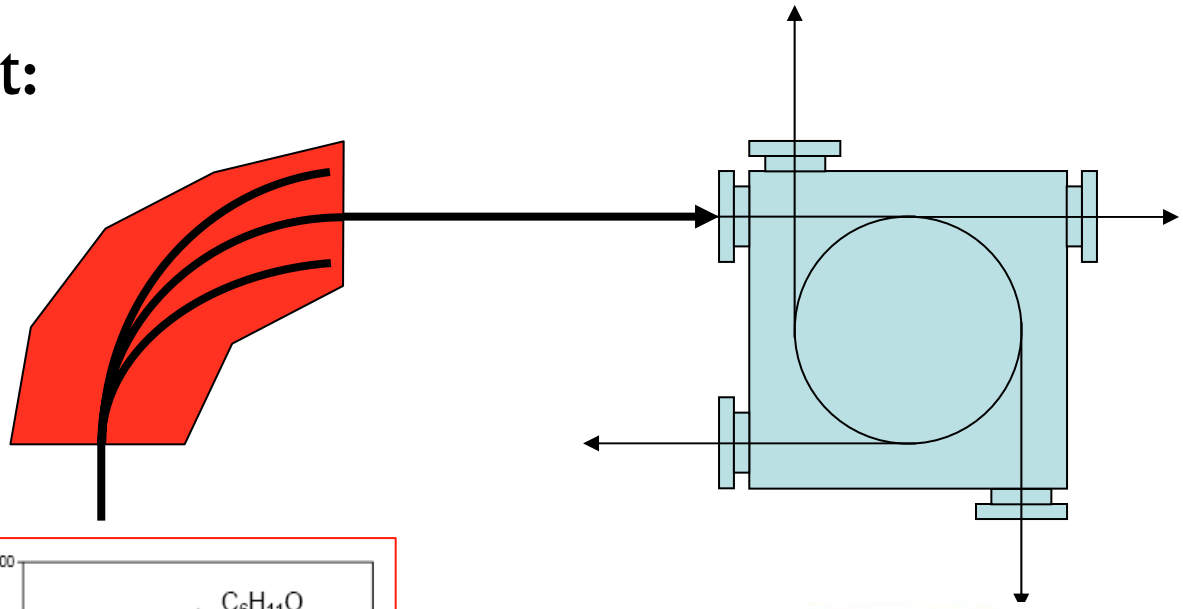


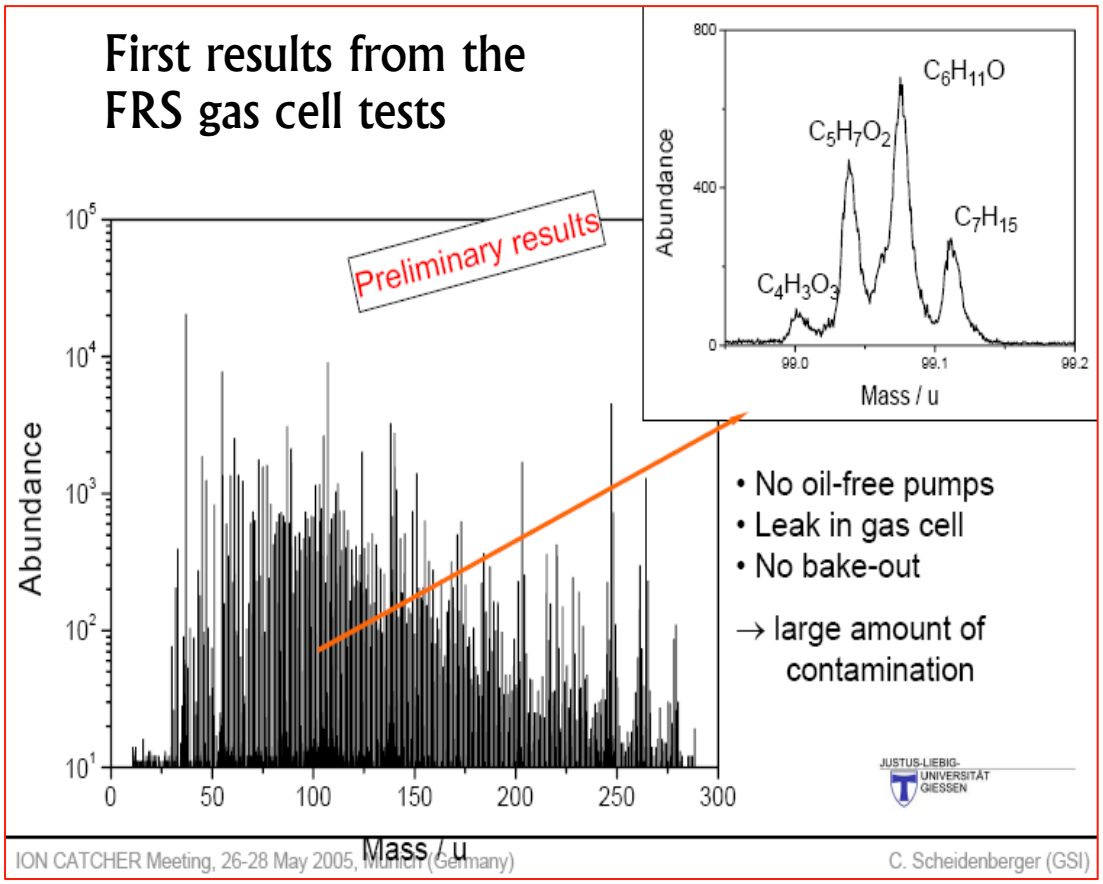



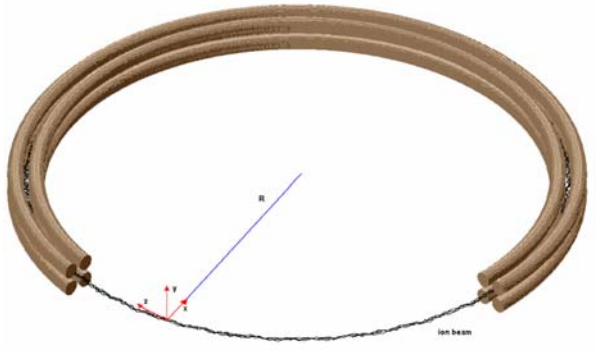



# The Ion Circus concept:

*transport*
*bunching*
*separation*
*cooling*





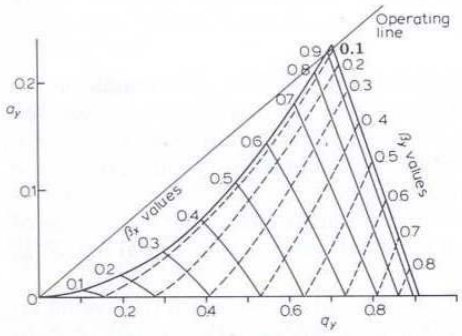



Fig. 2.10. The lower stability region normally used in mass filter lines for the $x$ and $y$ directions and a typical operating line.

# From the Book of Dawson; Chapter 2; Part B
## (Quadrupole Mass Spectrometry, Elsevier, 1976)

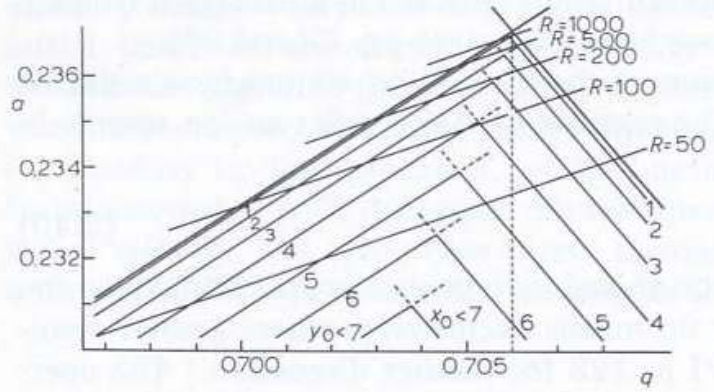



Fig. 2.12. The tip of the stability diagram showing operating lines nominally giving resolutions of 50, 100, 200, 500, and 1000. The lines parallel to the stability boundaries represent the maximum allowable initial $x$ or $y$ displacements, expressed as percentages of $r_0$, if there is to be 100% ion transmission for all initial rf phases. The calculations [3] were for ion entry parallel to the instrument axis and in the absence of fringing fields.

$$R = \frac{0.178}{(0.23699 - a_{0.706})} \qquad (2.35)$$

where $R$ is calculated from the width of the stable region for a particular scan line, and the $a_{0.706}$ is the $a$ value corresponding to $q = 0.706$.

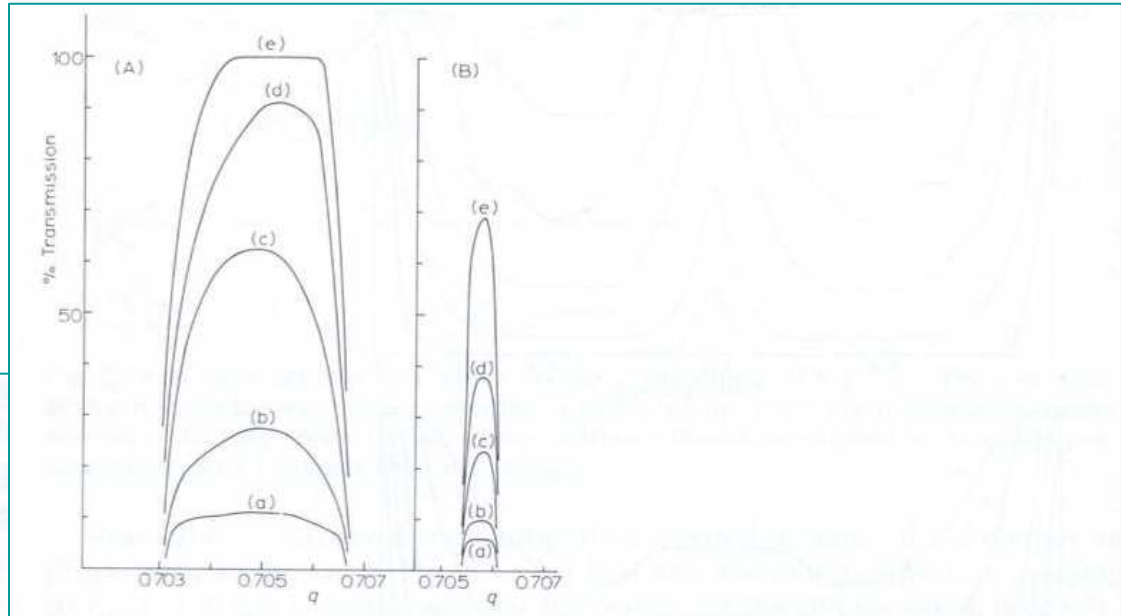
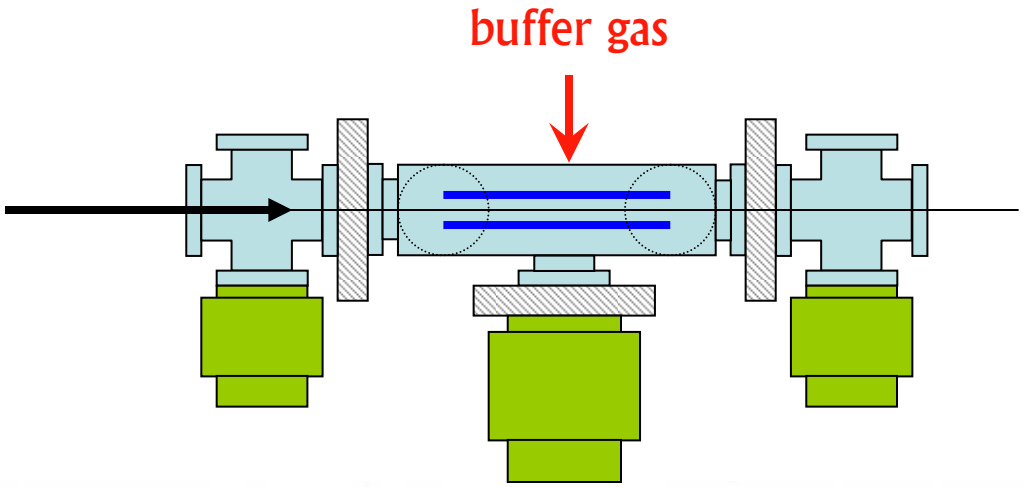
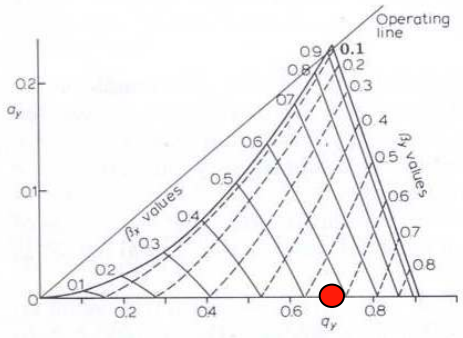
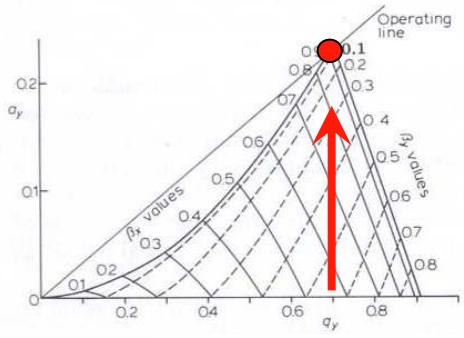
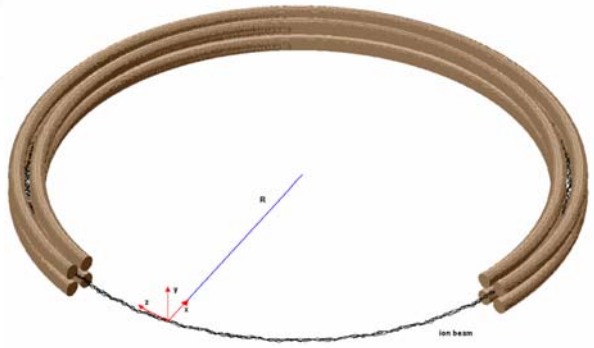



Fig. 2.21. Computed peak shapes obtained by summing ion transmission over all phases. The entrance apertures illustrated are (a) 4%, (b) 1%, (c) 0.25%, (d) 0.11%, and (e) 0.04%. The curves in (A) are for an operating line giving a resolution of 225 and those in (B) have $R = 1100$.



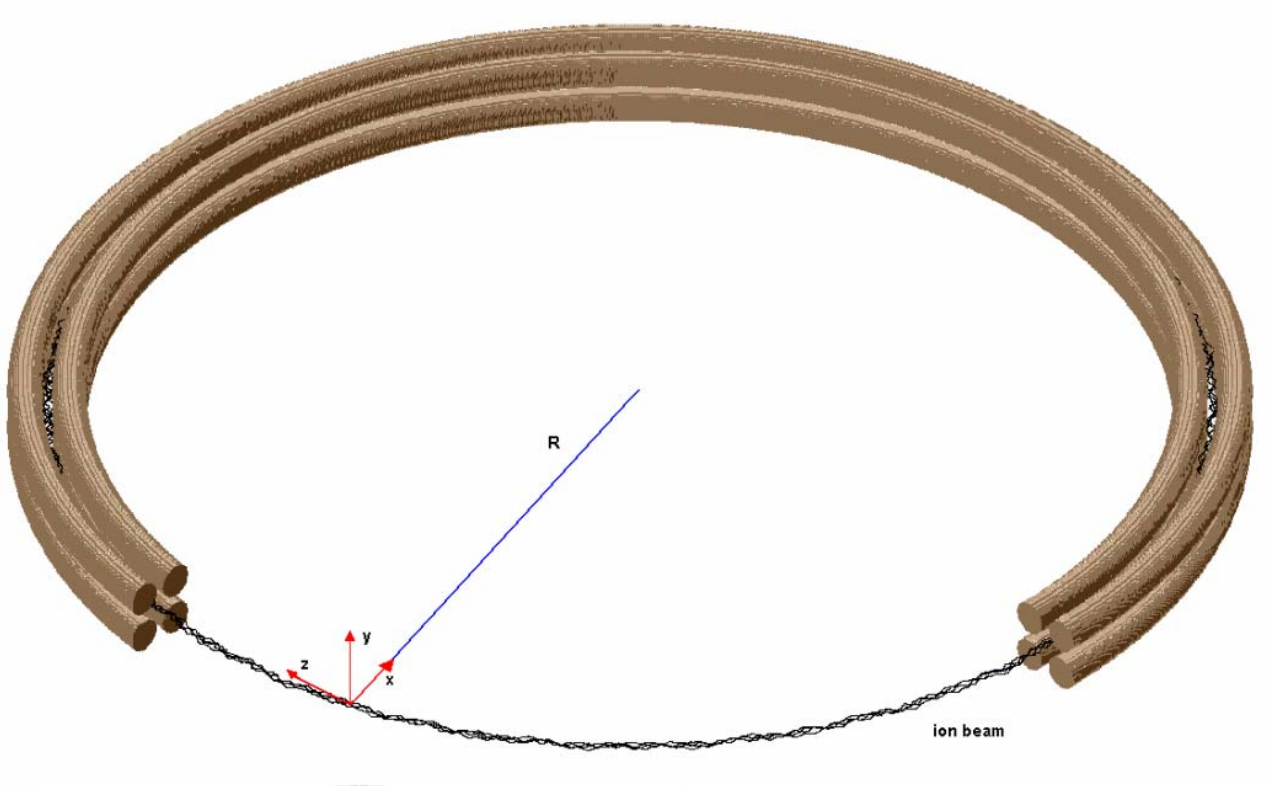



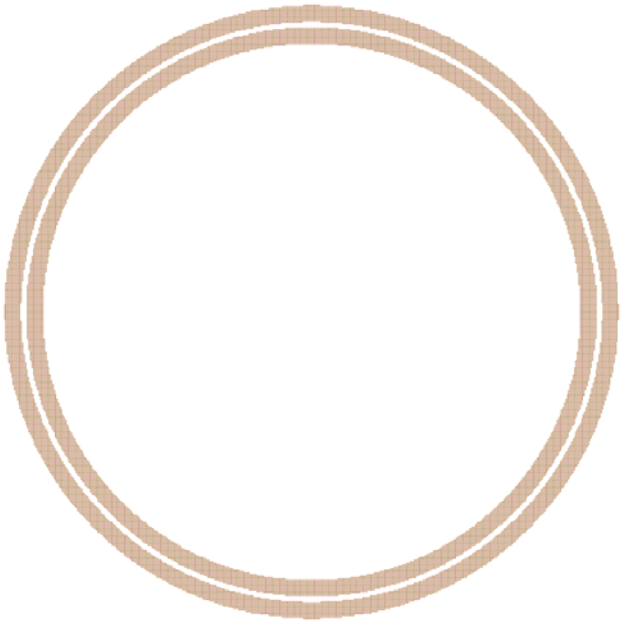



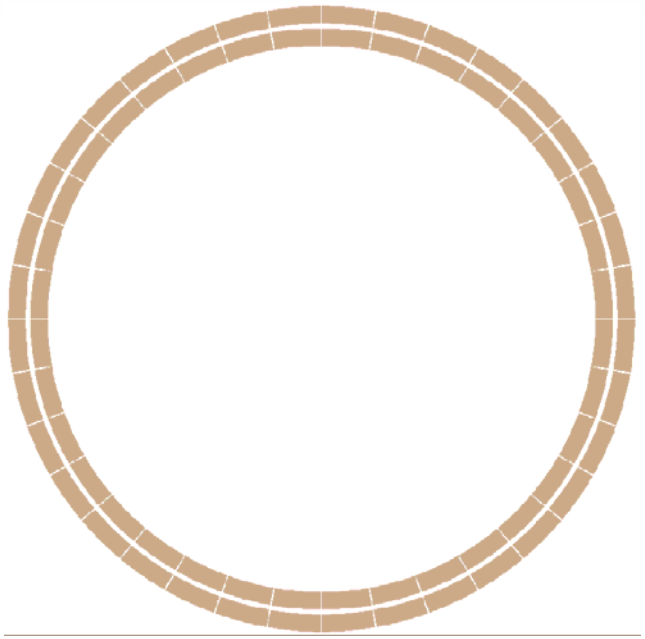
ring diameter: 40 mm
pole separation: 10 mm

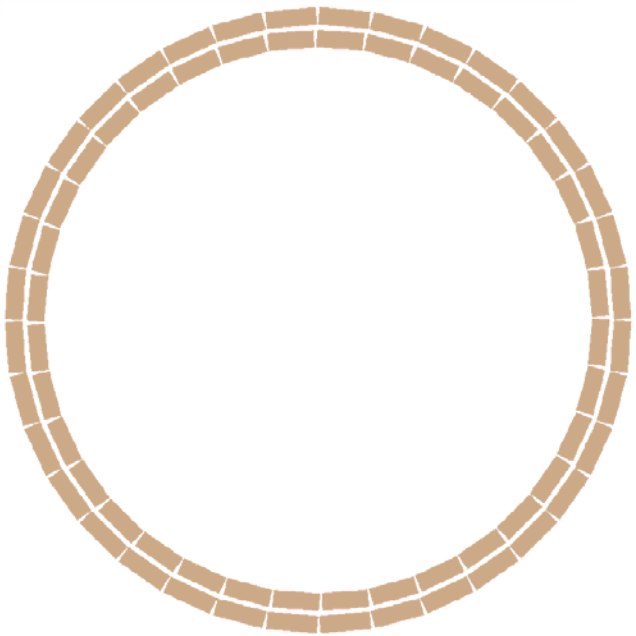
1 keV $^{85}$Rb ion
laptime: 26 μs

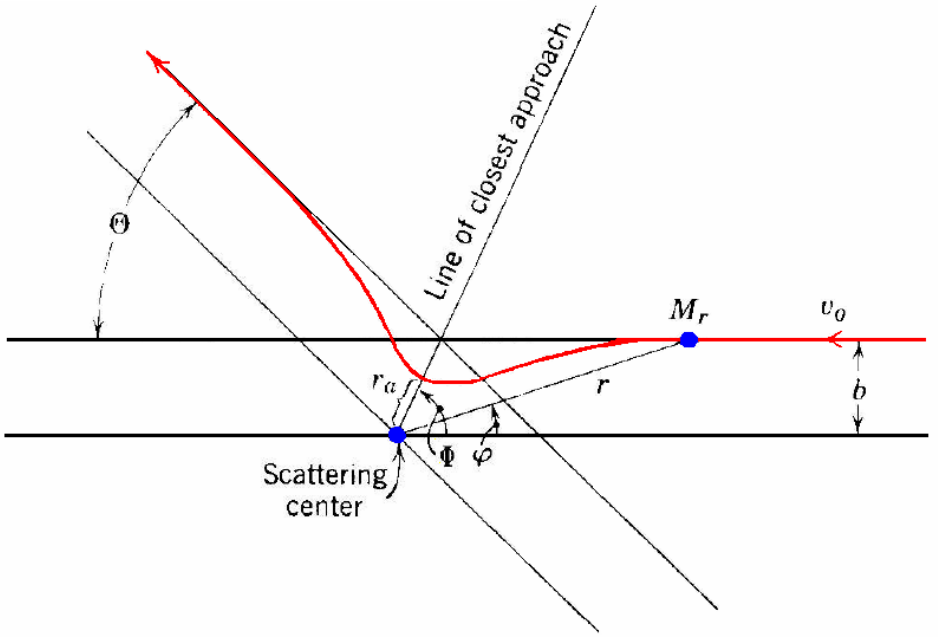
Enrique Minaya-Ramirez



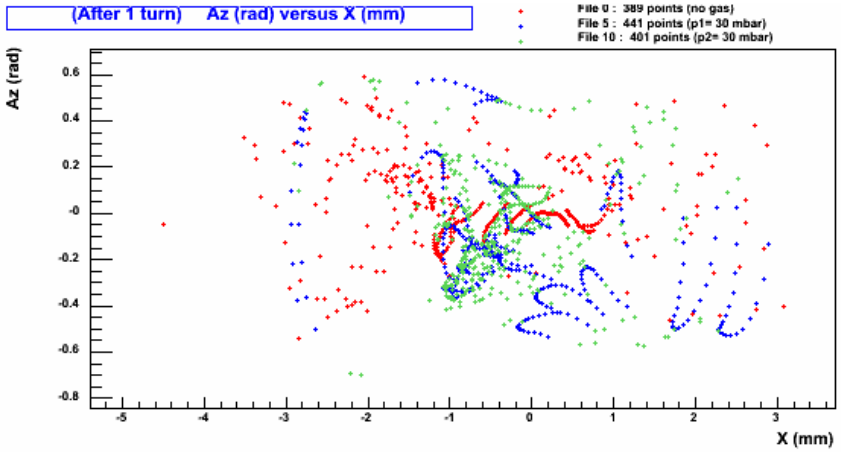


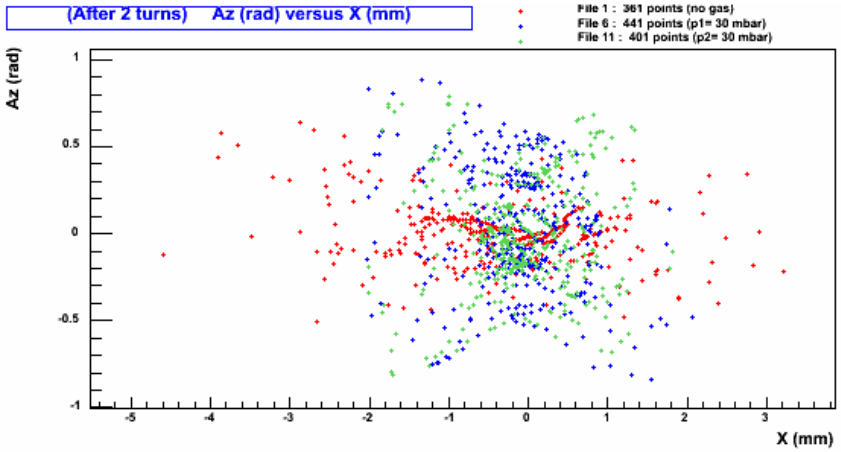


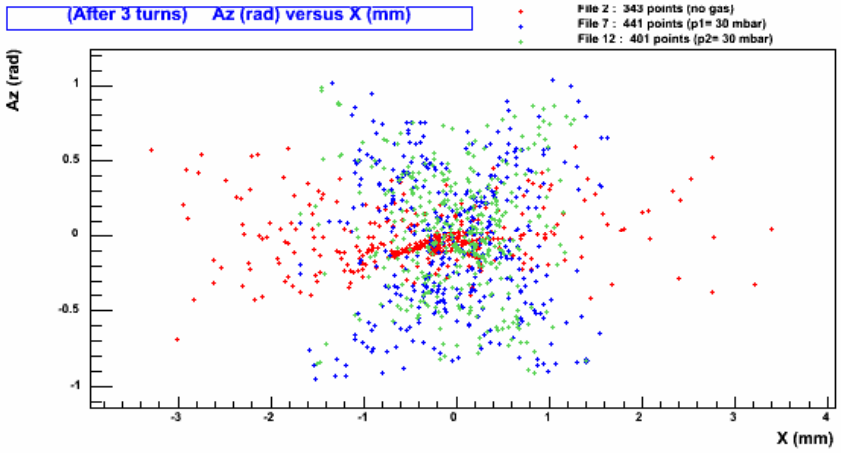


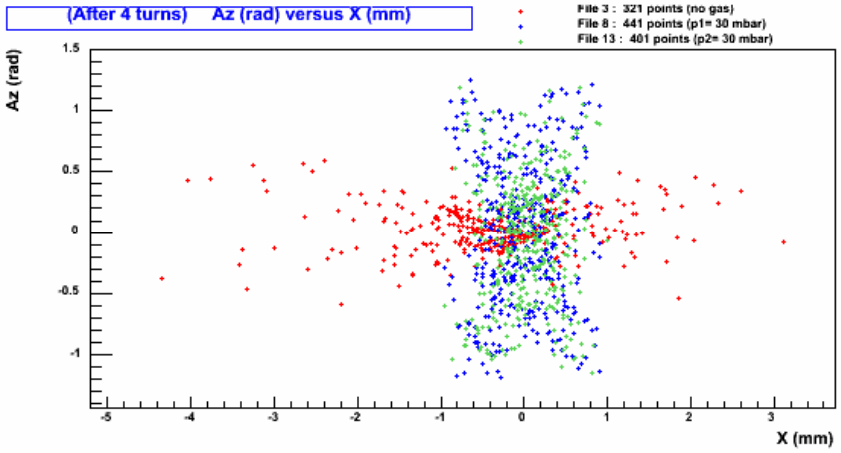

$$V(r) = \frac{B}{r^n} - \frac{C_6}{r^6} - \frac{C_4}{r^4}$$

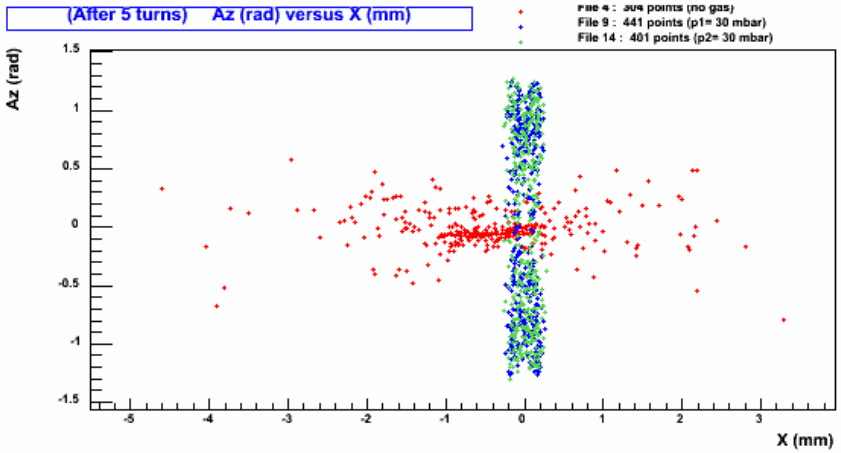
e.g., S. Schwarz, Ph.D. thesis (1998)

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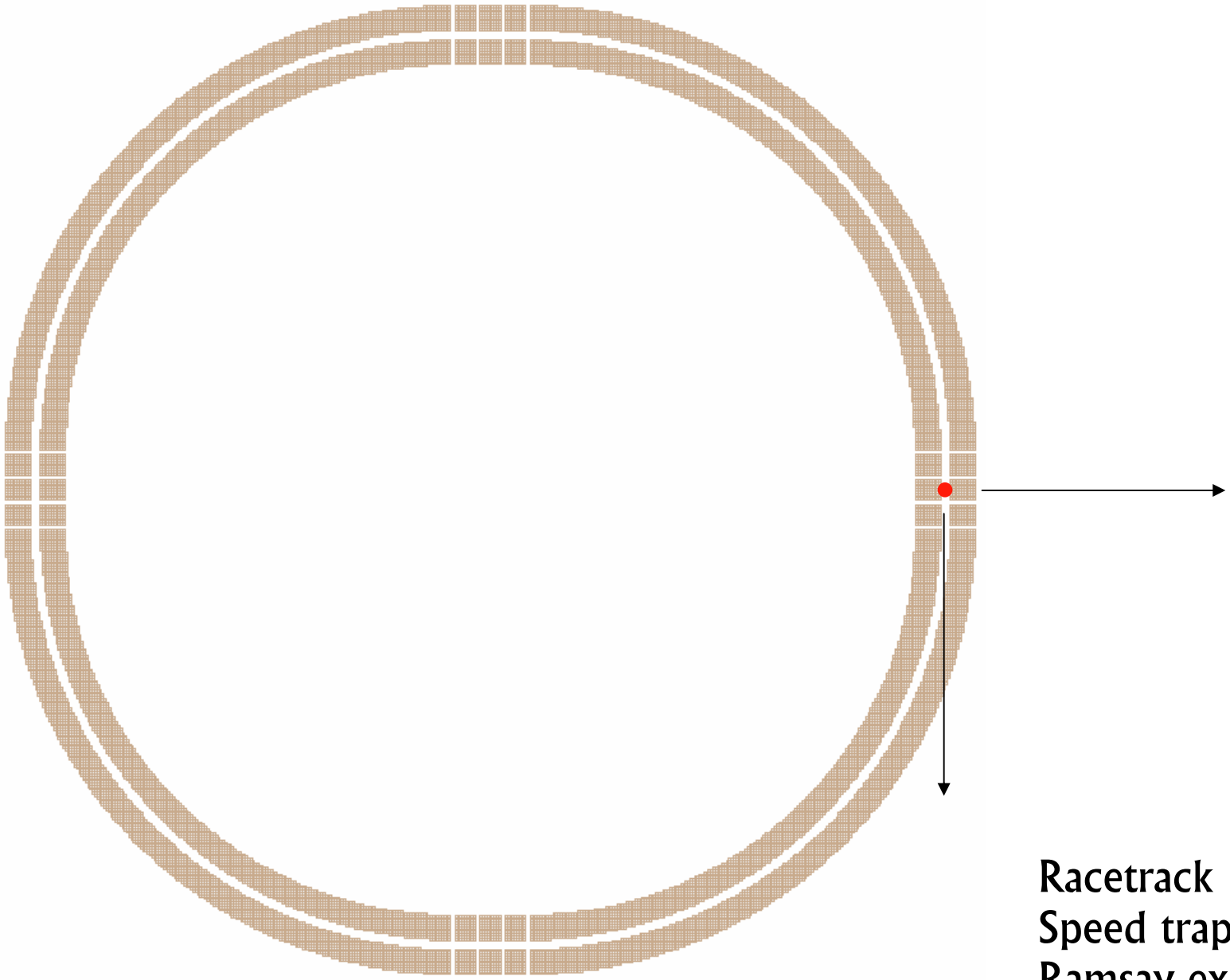
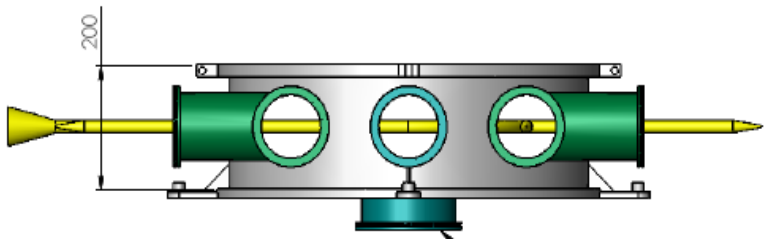
Vrf=1000Vpp,Vdc=0V,F=2.145e+006Hz
Theta=0rad
a=0
q=0.500101
D=62.5127V
T=4.662e-007s,Tr=5.90043e-005s,Tr/T=126.564
P=30mbar,T=300K Vtherm=231.085m/s
Turns_max=5turns_max
-->4rods-->Carre
q_over_m=1.13395e+006C/Kg Fact_v=0.319027 Fact_PT=37.1154
TOF=0.00479962 Tstep=0.00479962

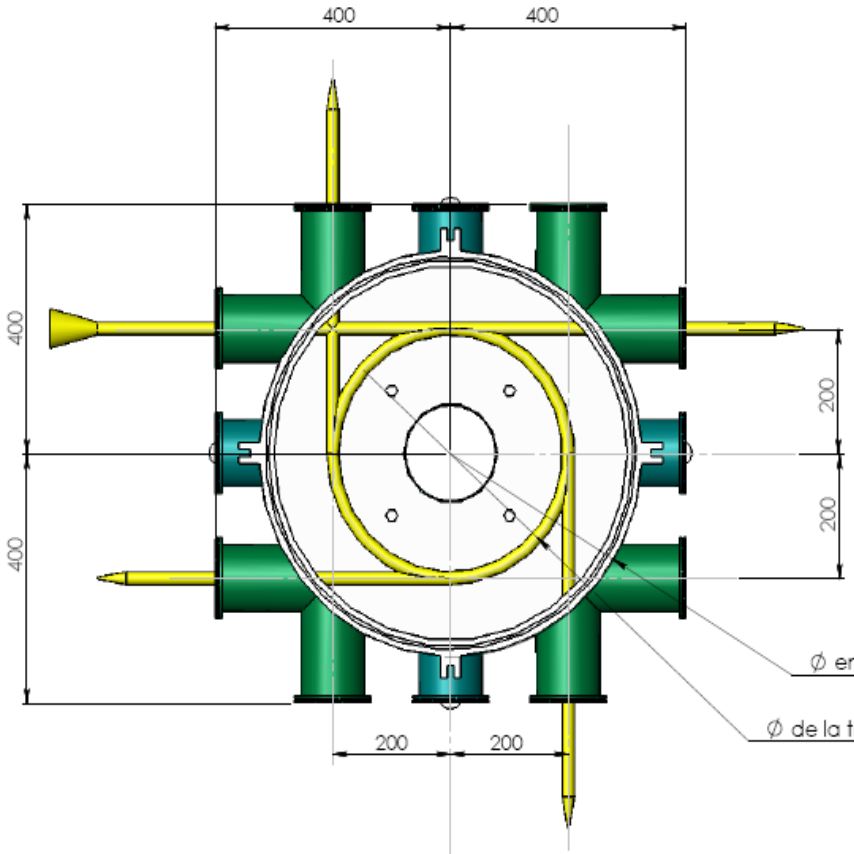
- Sans collisions
- Avec collisions ==> Electrodes en losange
- Avec collisions ==> Electrodes en Carré



Racetrack
Speed traps
Ramsay excitations




1 bride DN160 ISO-K




∅ enceinte : environ 600

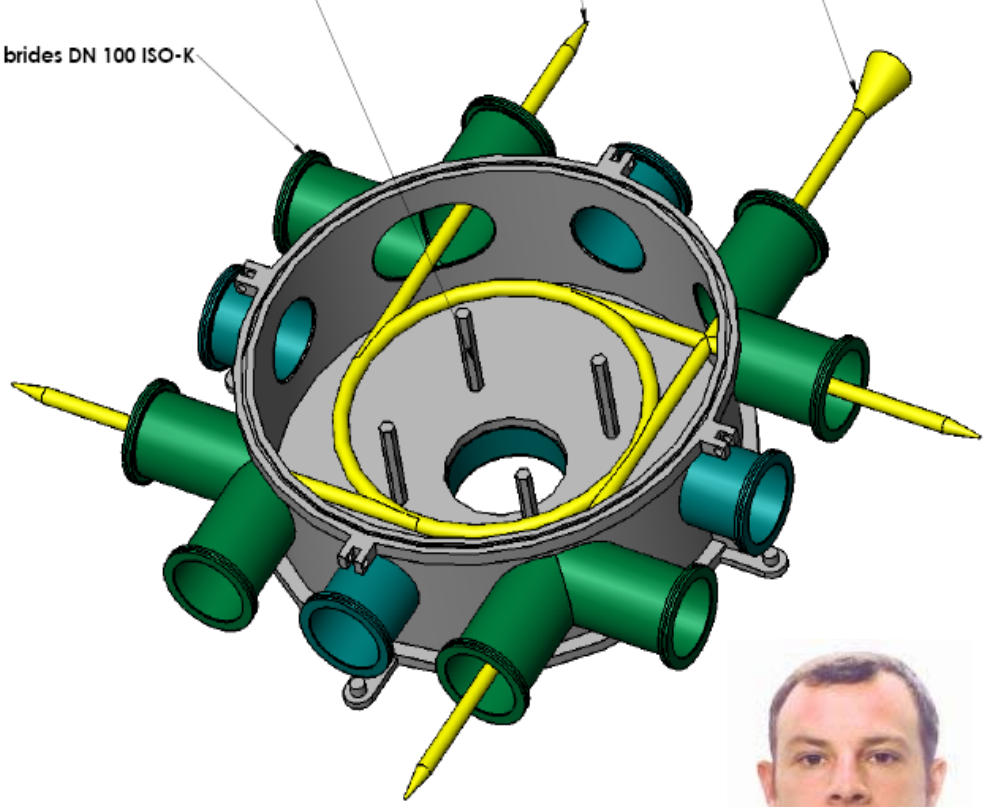
∅ de la trajectoire du faiseau 400

4 écrous M10 à souder sur le fond de l'enceinte pour permettre la fixation d'un montage

1 entrée du faisceau

4 sorties du faisceau

12 brides DN 100 ISO-K





100 (Dimensions en mm)

| | |
|---|---|
| Désignation : schéma de principe du cirque d'ions | |
| Ensemble : titre | Ref. : m102a005z |
| Tolérances générales : JS13 sauf spécif. | |
| Echelle : 1:8 | Matière : *** |
| Date de créat. : lundi 11 septembre 2006 16:20:33 | |
| Date d'enreg. : vendredi 15 septembre 2006 14:37:20 | |

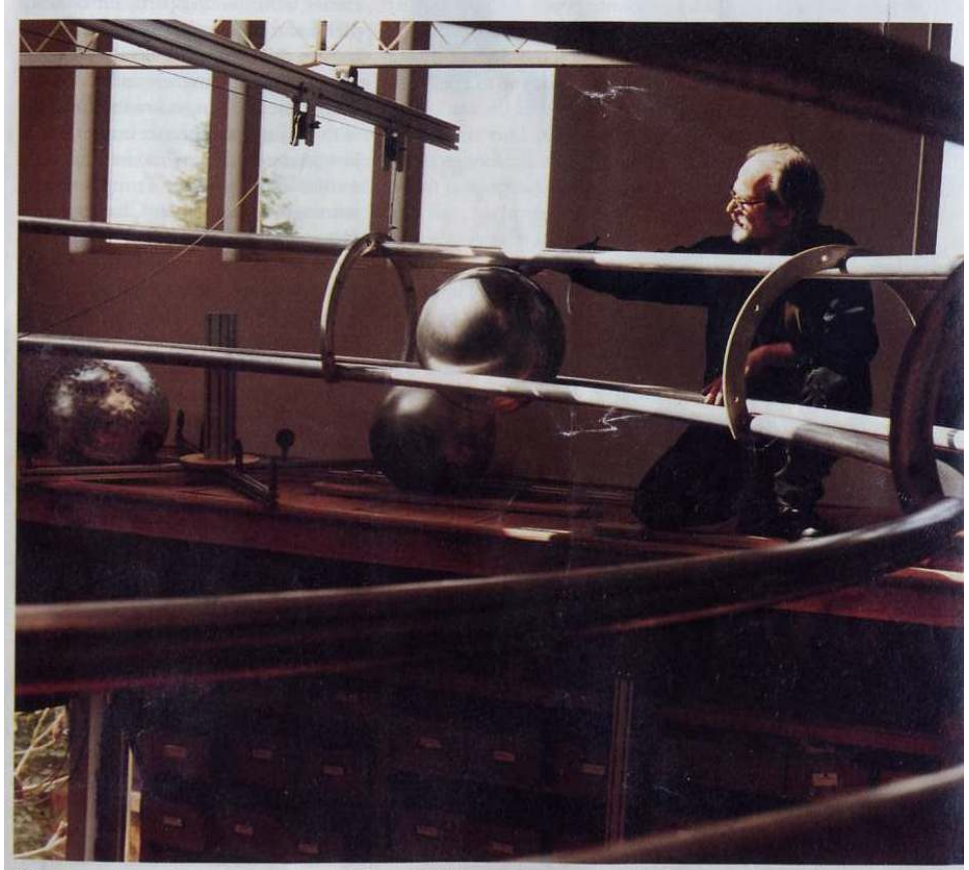
Dessiné par :
Stéphane CABARET
CSNSM
tél. : 01 69 15 52 21
fax : 01 69 15 52 68
cabaret@csnsm.in2p3.fr


ONWARD AND UPWARD WITH THE ARTS

# PERPETUAL MOTION

*Trimpin's sound sculpture.*

BY JEAN STROUSE



*Trimpin in his studio with a prototype of "Der Ring³," a physical metaphor for the way sound works. Photograph by*

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DIE EXPERIMENTIERLANDSCHAFT


(Gerhard)
TRIMPIN
Der Ring
Hoch Drei