# FLSR - Frankfurt Low-Energy Storage Ring

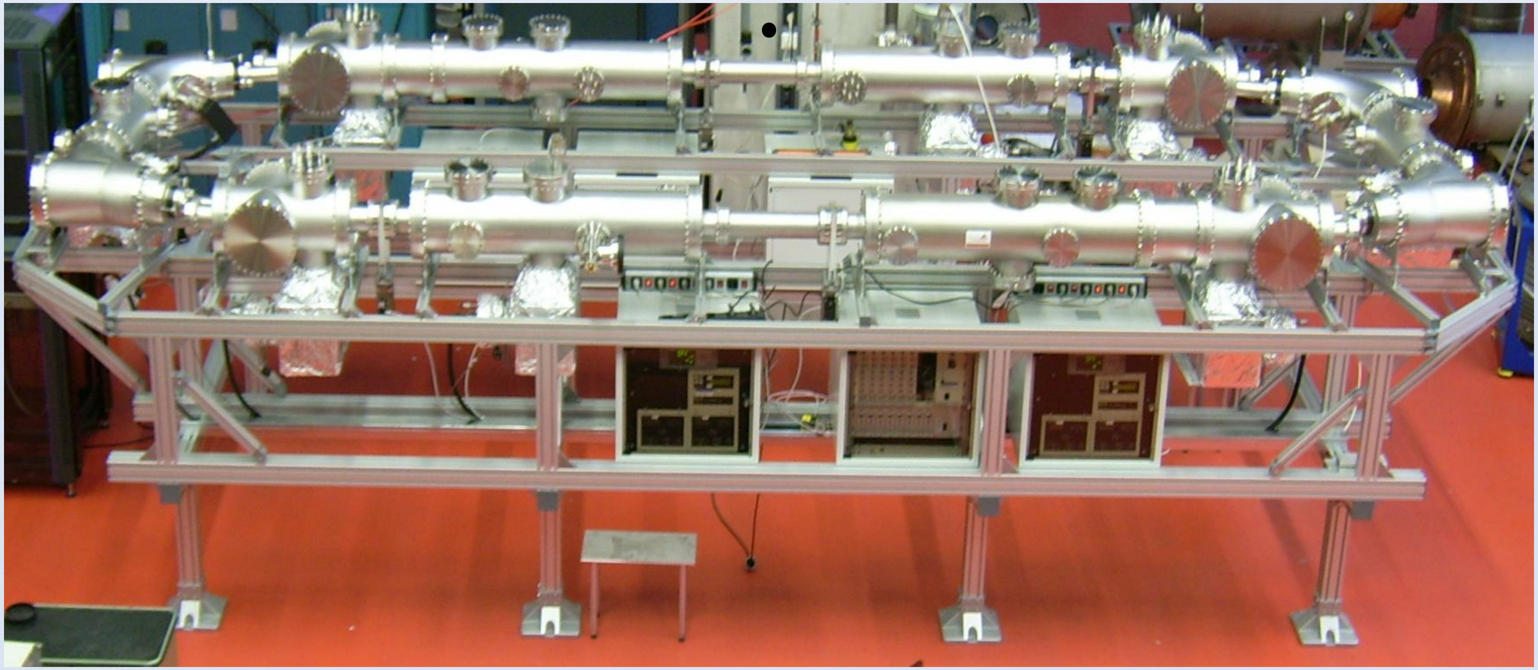
A fully electrostatic storage ring for ions of energies up to 50keV

"trap" for dynamic ions (atoms/molecules):

*K.E. Stiebing, V. Alexandrov, R. Dörner, S. Enz, N. Yu. Kazarinov, T. Kruppi, A. Schempp, H. Schmidt-Böcking, M. Völp, P. Ziel, M. Dworak, W. Dilfer*

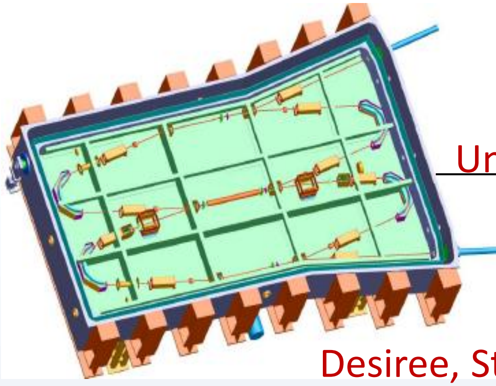
Nuclear Instruments and Methods in Physics Research A 614 (2010) 10–16

- not a "classical" storage ring (accumulator)
- enhancement of luminescence for rare products
- allows for detection of neutral reaction products
- complete experiments of the reaction dynamics in "state selected/prepared" atomic and molecular systems
- observation of "slow" processes ( τ ≤ ≈ sec)

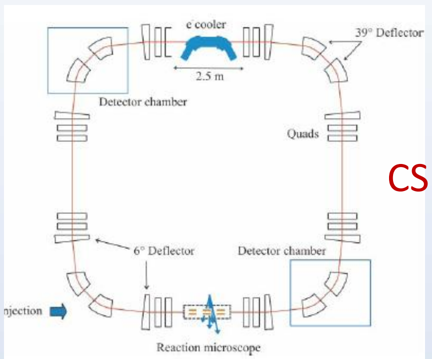


# Electrostatic Storage Rings

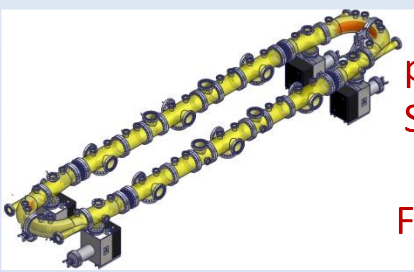
Under construction:



Desiree, Stockholm




CSR, MPI Heidelberg



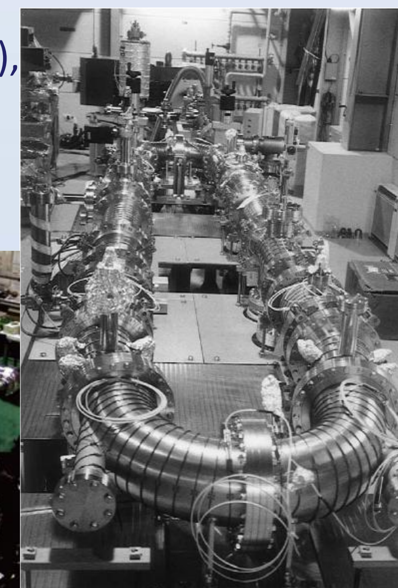
pro-ESR(KACST)
Saudi Arabia

FLSR Frankfurt
(2011)

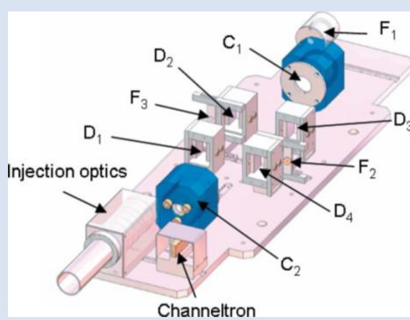
Existing rings:

ELISA (Aarhus),
Dänemark 1997

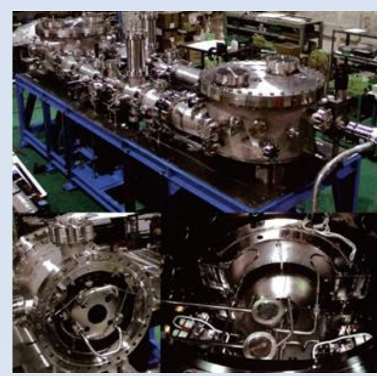
KEK (Tsukuba),
Japan (2000)



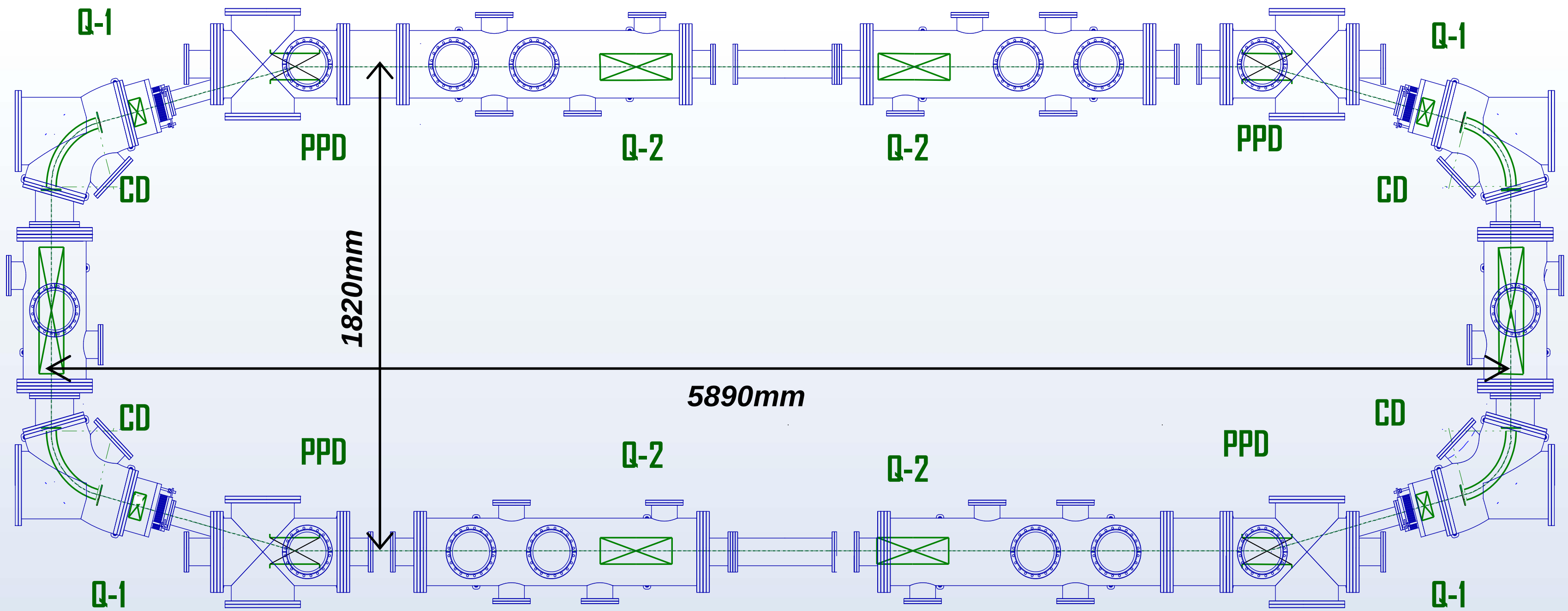
Mini-Ring Lyon (2008)
30cm trajectory length




TMU Tokyo (2004)



# The mechanical design




<u>General parameters :</u>

- Maximum energy - 50.0 keV
- Circumference - 14.7 m
- Time per revolution for protons of 50keV - 4.5 µs
- Focus in exp. Region - 3 x 4 mm²
- Tune values (Qx / Qy) - 3.574 / 2.125

<u>Quadrupoles :</u>

- Electrode lengths
  - singulet - 50 mm
  - triplet/doublet - 100 mm
- Dist. betw. electrodes - 90 mm
- Inner radius - 30 mm
- Voltage - ± 3.4 kV

<u>75° deflectors :</u>

- Height - 120 mm
- Radii - 230 mm /270 mm
- Voltage - ± 10.1 kV

<u>15° deflectors :</u>

- Plate area - 200 x 200 mm²
- Plate distance - 100 mm
- Voltage - ± 6.7 kV

<u>horizontal deflectors (correction):</u>

- Plate area - 200 x 200 mm²
- Plate distance - 100 mm
- built between electrodes doublets

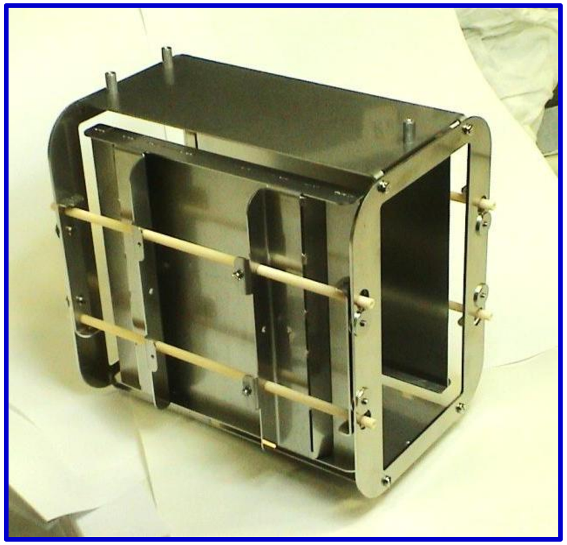
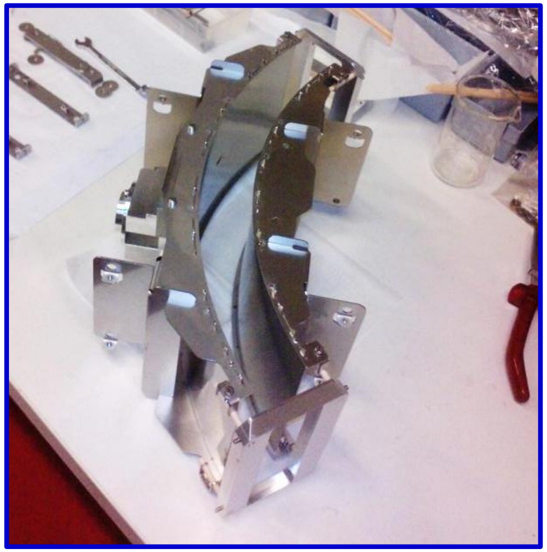
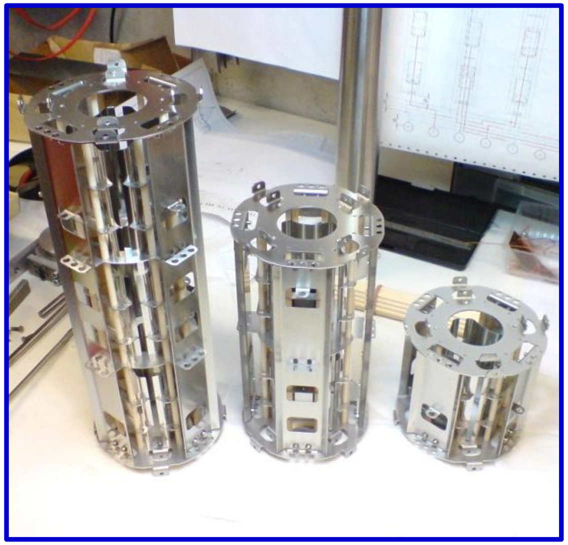
<u>Pumping systems:</u>

- 8 IGP/TSP Combinations - 750 l/s N2 - 1580 l/s H2
- Bake out box - Vermiculite® 250°C
- Best vacuum so far - ≤1 x $10^{-11}$ mbar

<u>Vacuum systems:</u>

- CF-250 - all flanges 316 LN (ESR)
- 4 basic chamber-types different set ups:
  - "racetrack" --- 15°-75°
  - "quadratic ring" --- 15°-60°-15°
- exeprimental sections separated by UHV valves

# The mechanical design

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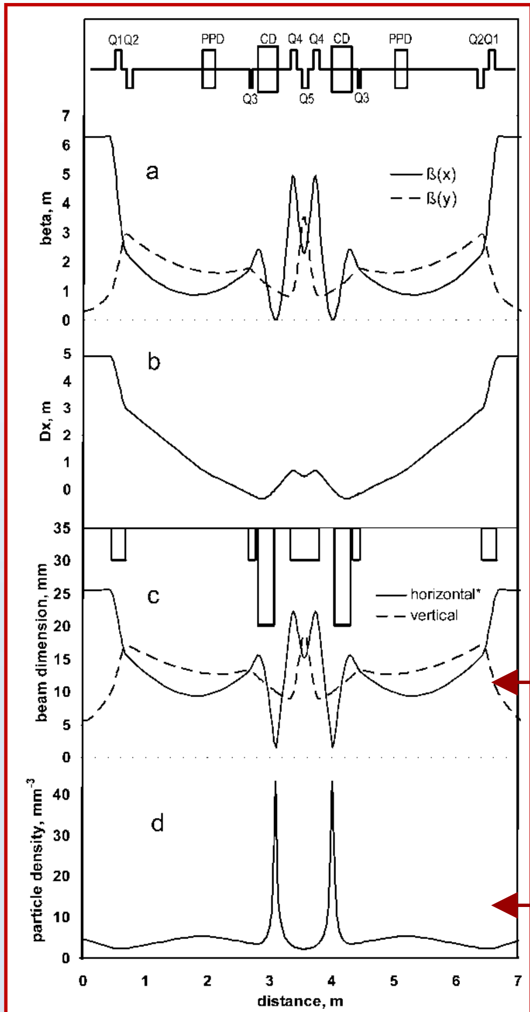
# Design of the FLSR:  Lattice: (using MAD-code)




*Lattice (top) and lattice functions in one half of ring.*

*Dispersion in one half of ring.*

*Beam sizes in one half of ring.*

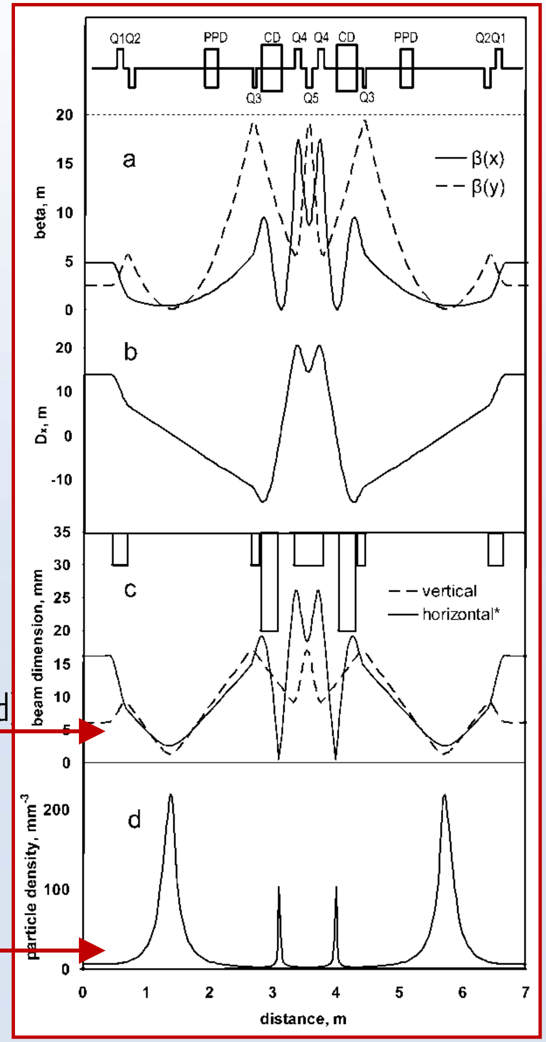
($\varepsilon = 100\ \pi$ mm mrad)

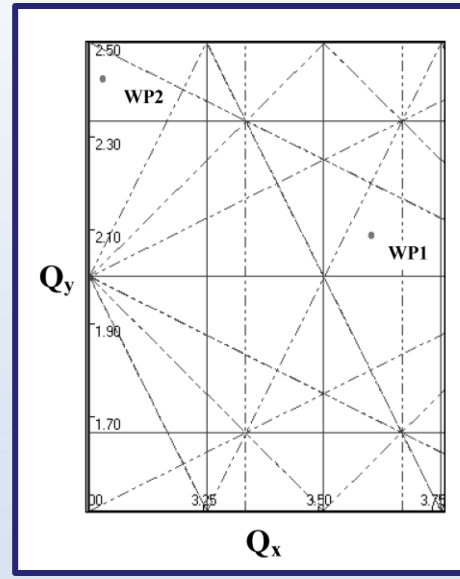
( $\varepsilon = 15\ \pi$ mm mrad)

*Particle density.*

$\varepsilon = 100\ \pi$ mm mrad,

$\varepsilon = 15\ \pi$ mm mrad.



# Activities 2008-2010 and present status of FLSR:

## 1. Ring:

- Manufacturing of all optical elements
- Alignment of the vacuum chambers
- Develop a procedure for bake-out
- Control systems for FLSR:
  - ✓ Voltage adjustment and control (Diploma thesis Marco Völp)
  - ✓ Vacuum control (Bachelor thesis Thomas Felix)
- Beam diagnostics:
  - ✓ 0°-neutral particle detector (Bachelor thesis Annika Jung)
  - ✓ Schottky diagnostics
    - Design of pick up (PHD thesis Mohammed Almalki)
    - Pulsing unit (Dirk Tiedemann)
- Alignment of the ion-optical elements :
  - ✓ alignment on optical test bench
  - ✓ Alignment in the ring

## 2. Transfer beam line:

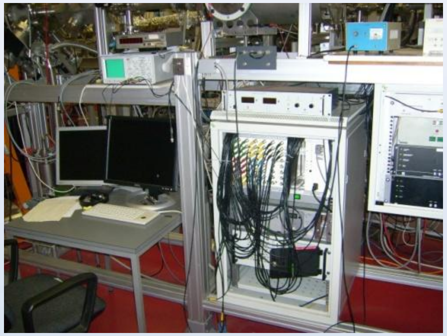
- two ion sources (14GHz ECRIS / Penning )
- two beam profile/emittance monitors
  - ✓ FPROM: Profile monitor (Diploma thesis Thomas Kruppi)
  - ✓ FIBAS: Data analysis system (Diploma thesis Steffen Enz)

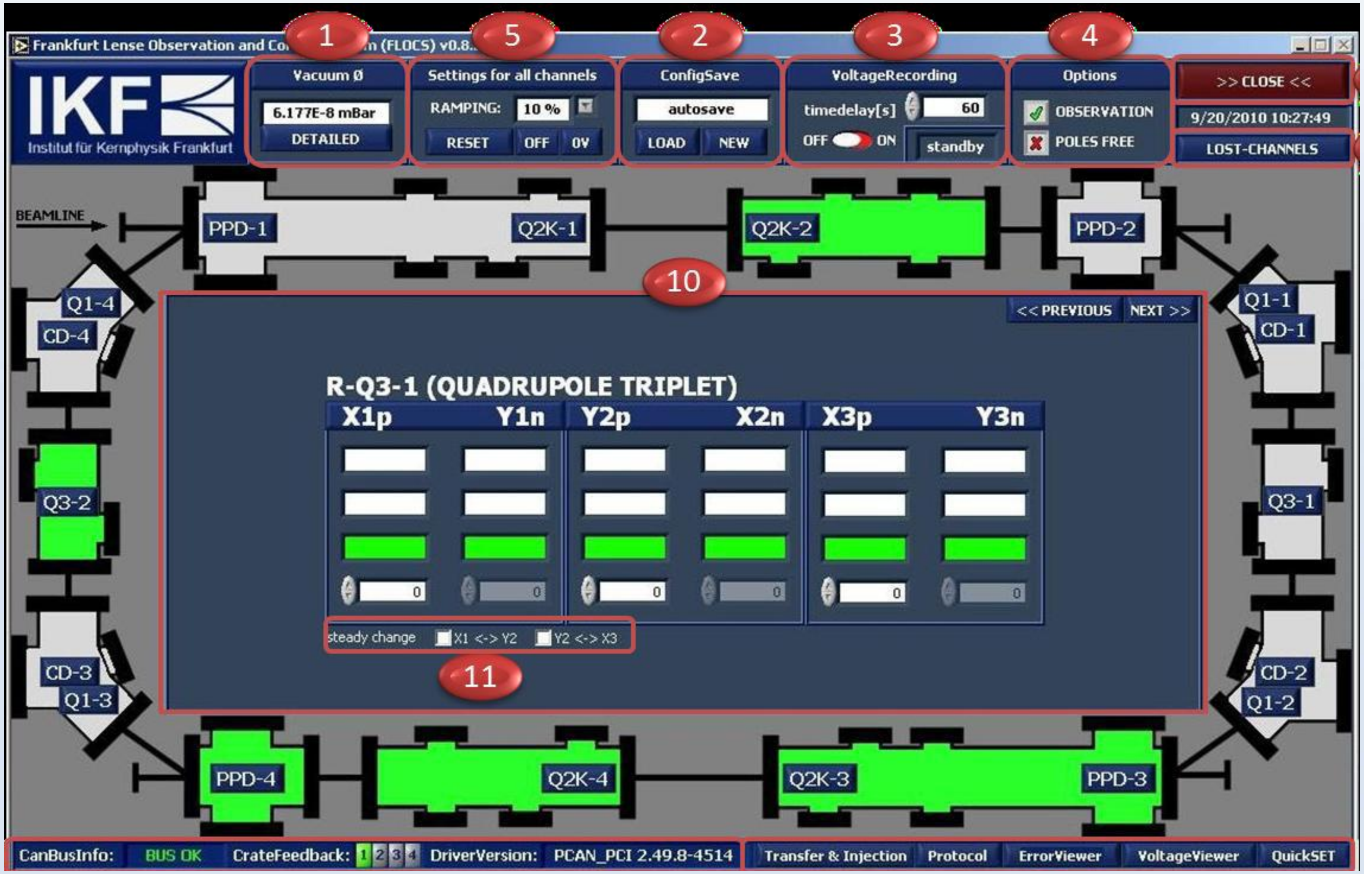
## 3. Injection beam line:

- Magnetic spectrometer (R=2m; allows analysis of ion of 50keV with Mass 6000)
- 1 FPROM system at the entrance into the injection optics to FLSR
- Injection optics: 3 electrostatic Doublets and 2 parallel plate deflectors

# *F.L.O.C.S. Frankfurt Lense Observation and Control System* *(verified in LabView®)*

- Set up and control of all voltages in the ring
  - display basic status of vacuum
  - perform protocol of all values automatically and on demand





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- Set up and control of all voltages in the ring
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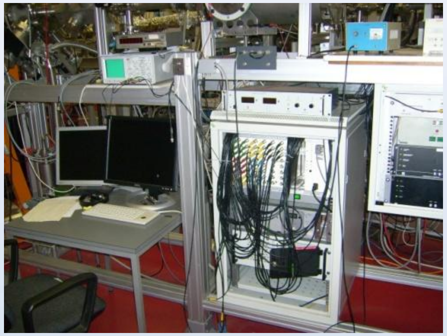
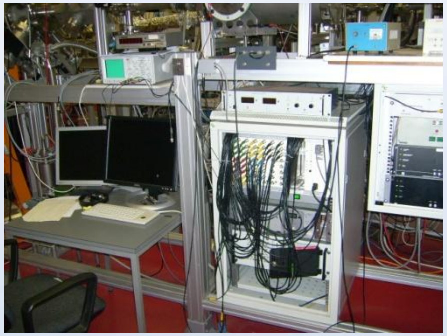
- Set up of all voltages in the transfer- and injection-line



# ***F.L.O.C.S. Frankfurt Lense Observation and Control System*** *(verified in LabView®)*

- Set up and control of all voltages in the ring
  - display basic status of vacuum
  - perform protocol of all values automatically and on demand
- Set up of all voltages in the transfer- and injection-line
- display and protocol of the vacuum measured in:
  - 8 Ion pumps,
  - 6 Bayart Apert ion gauges ,
  - 4 extractor ion guages



# Beam diagnostics:

## 0°- particle detector (neutrals):

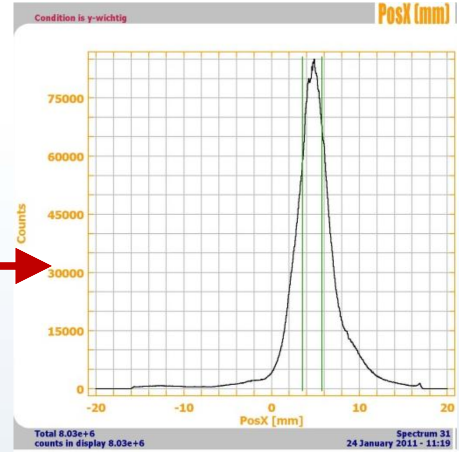
position sensitive MCP Detector of Ø 45 mm

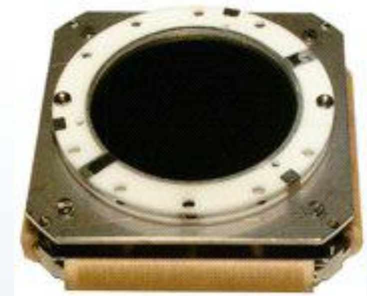
*49.6 keV, $Ar^{3+}$-beam ,*

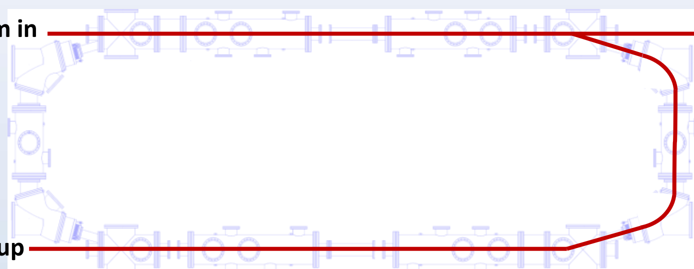
*3.2 μA, vacuum ~$10^{-8}$ mbar*

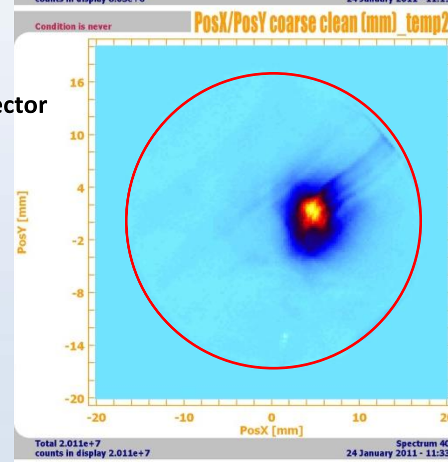
*transported without signifcant losses throught the first180°-bend , to a Faraday cup at the end of the second straight section*

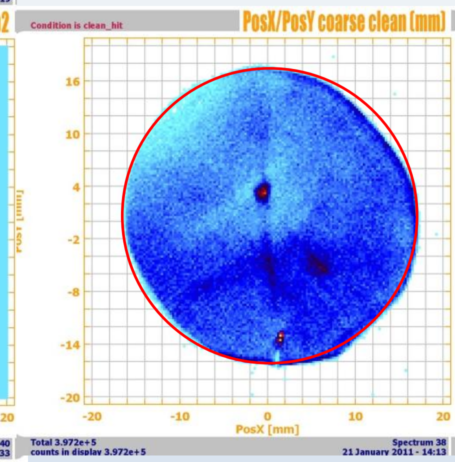
*! Using MAD design voltages !*



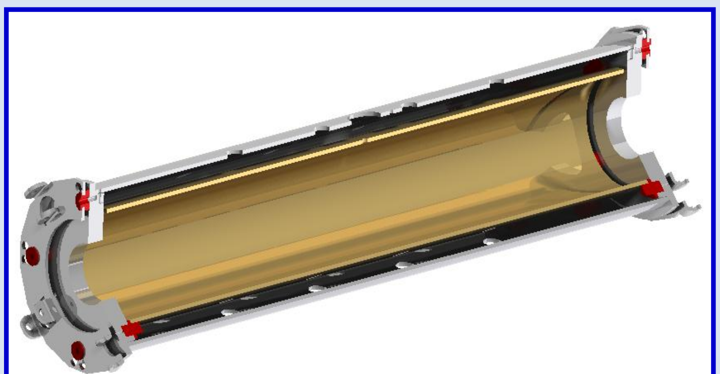



## Schottky diagnosis :

using a Tektronix RTSA (real time spectrum analyzer)

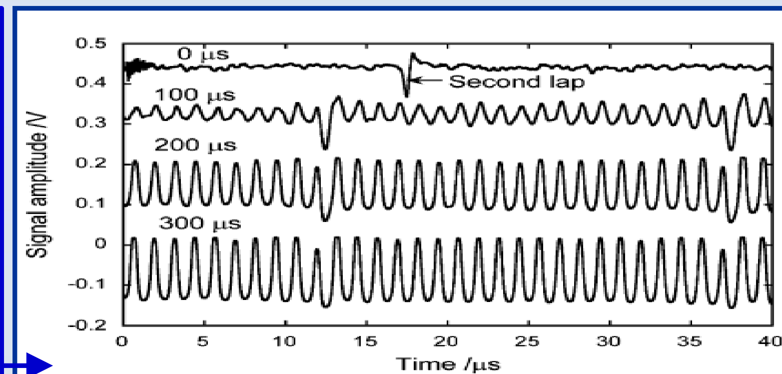


***BUNCHING CAVITY:***

(Using 20th harmonic)

| | |
|---|---|
| cavity length: | 35,6 cm |
| V($Ar^{3+}$ @45keV) | 760 kHz |
| Amplitude: | ~10 $V_{pp}$ |

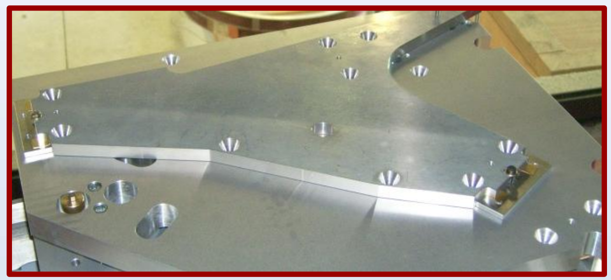
**S. Jinno, NIM A572 (2007) 568-579**



# *Alignment of the ion-optical elements on the test bench :*

- Straight sections: use telescopes aligned to the beam axis
- Challenge: adjust the 75°-Cylinder Deflectors (CD) in their 60°-Sector chambers of only Ø = 250 mm
  1. use a 175°-test bench for laser alignment and base plates with cones for attaching a tripod with conical posts
  2. align the base plate on the test bench by means of a “dummy CD” (tripod with laser mirror)
  3. align the CD on its own tripod plate on the base plate on the test bench
  4. align the base plate in the sector chambers by laser alignment (laser on the telescope position)
  5. “simply” insert the CD into the chamber (without further necessity of aligning)

optical 175°- bench

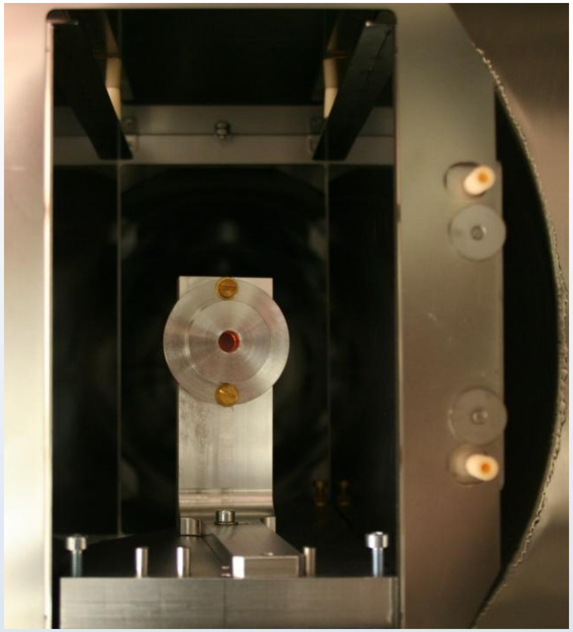


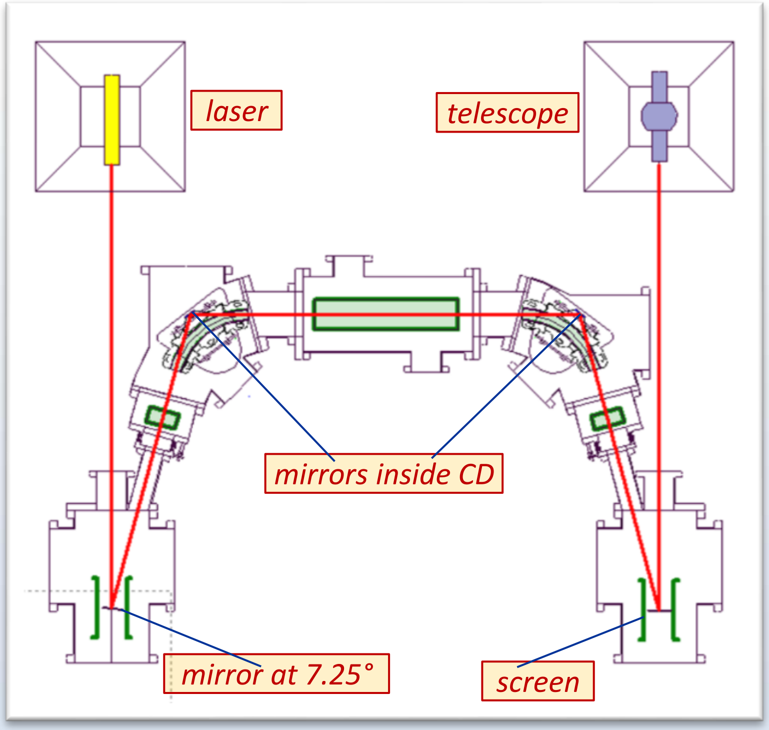
CD- base plate with cones for tripod

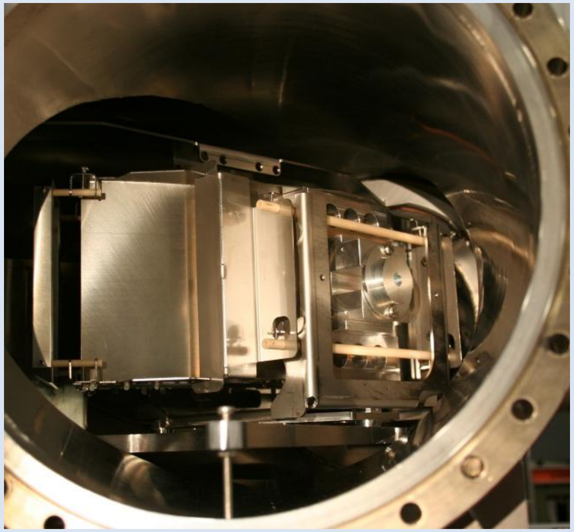
Adjusting the base plate by means of a laser mirror on tripod

Adjusting the CD on its tripod (to fit in the base plate in the chamber)

# Alignment of the ion-optical elements in the ring :





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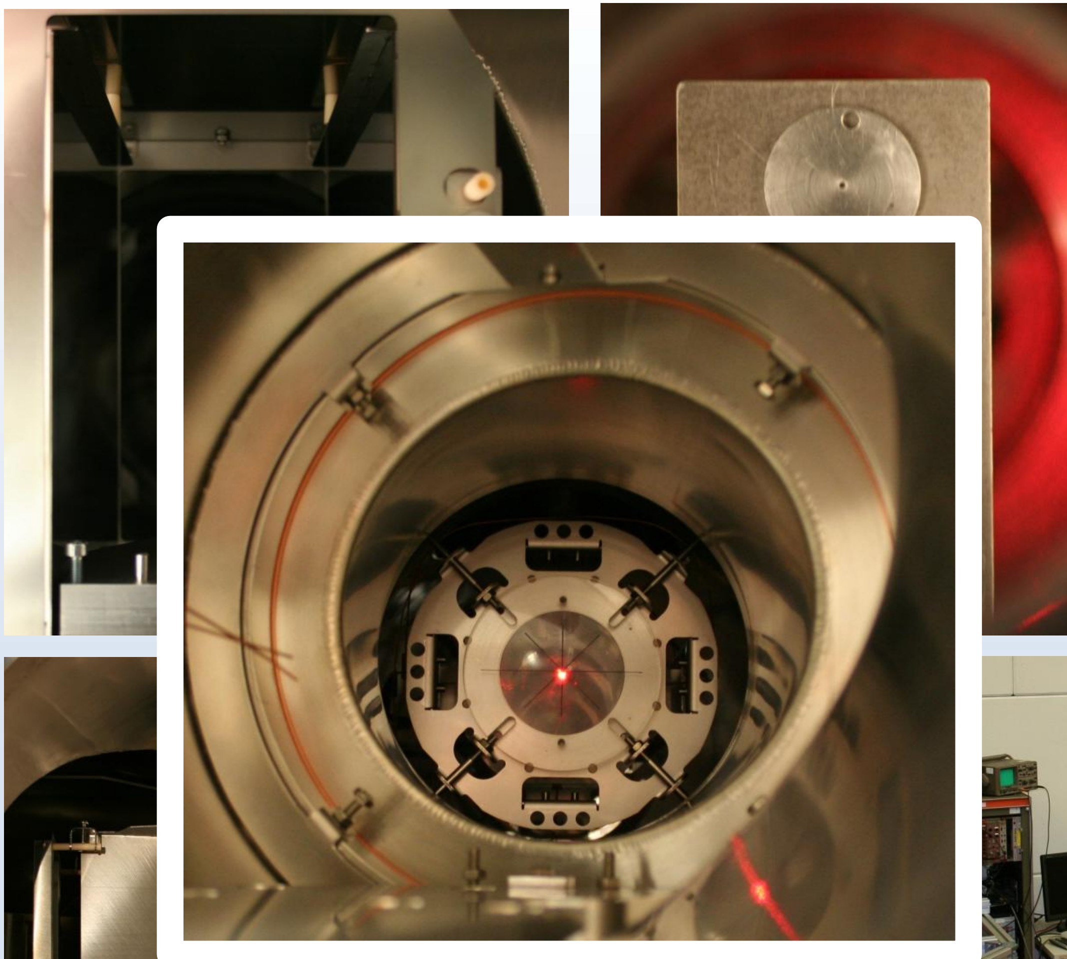
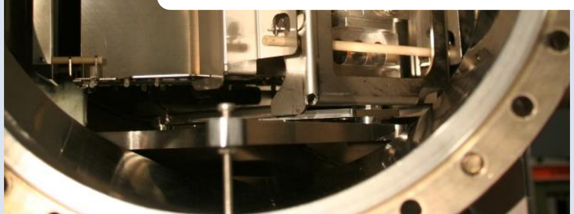
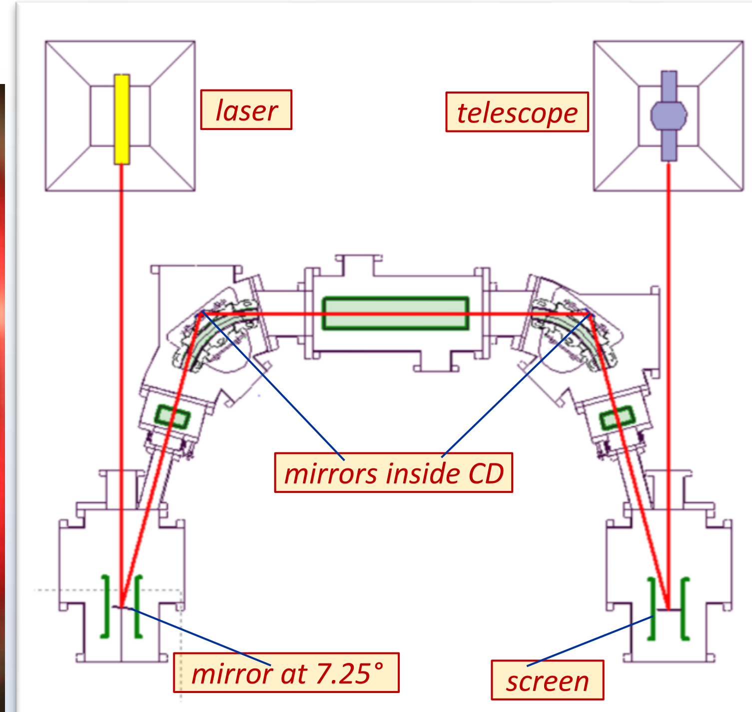
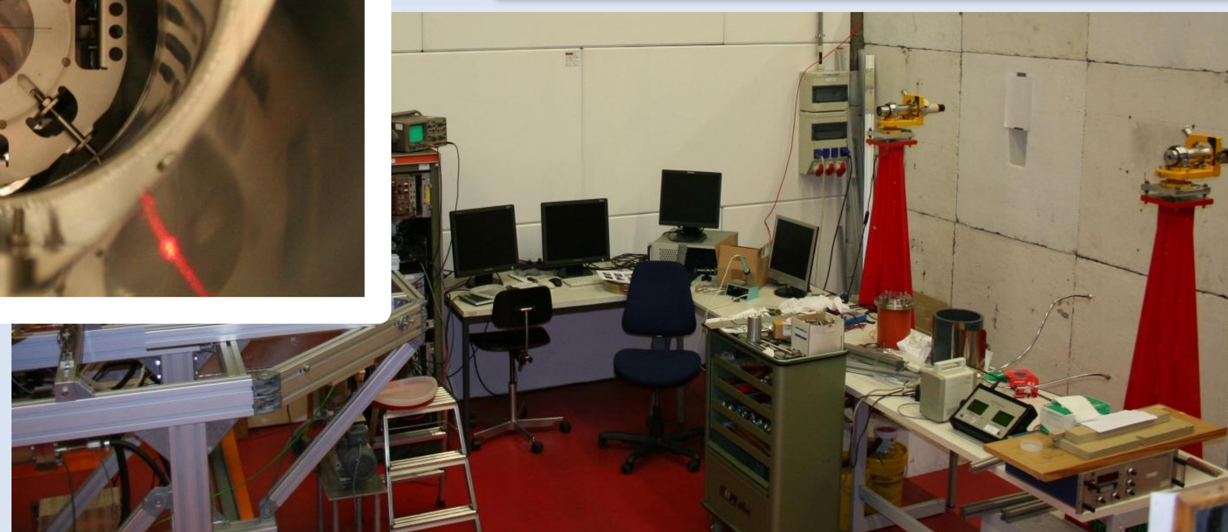
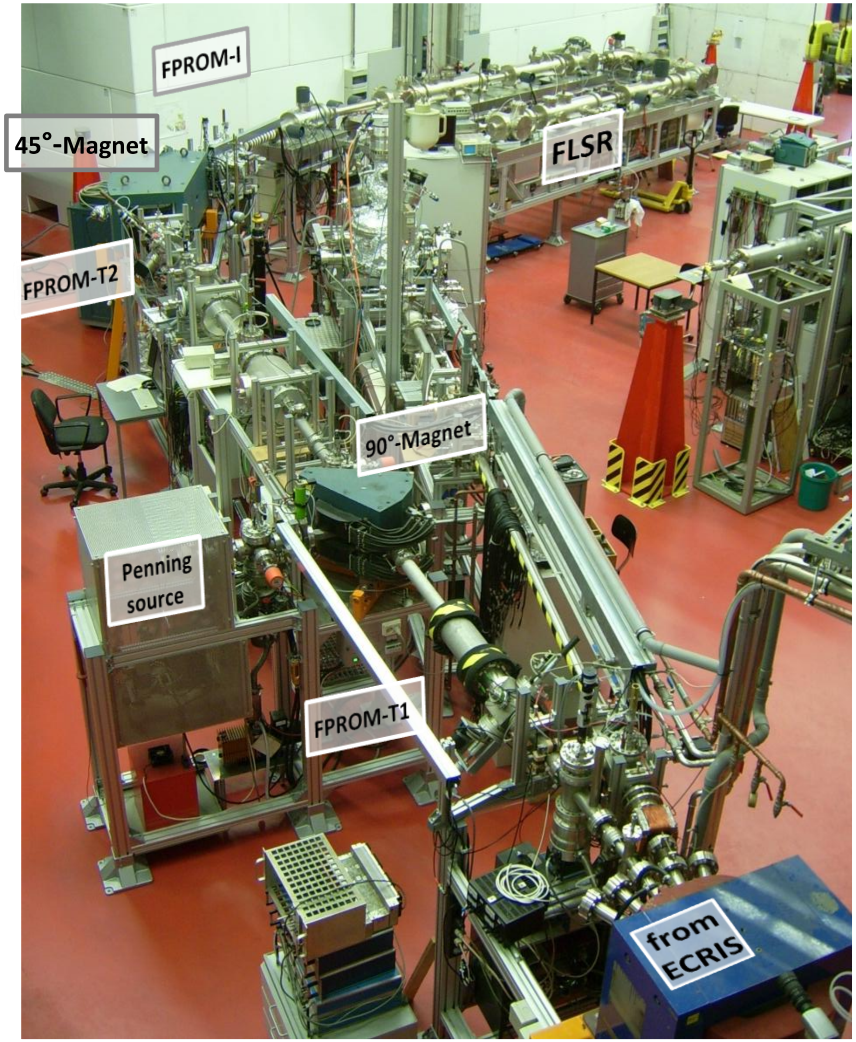






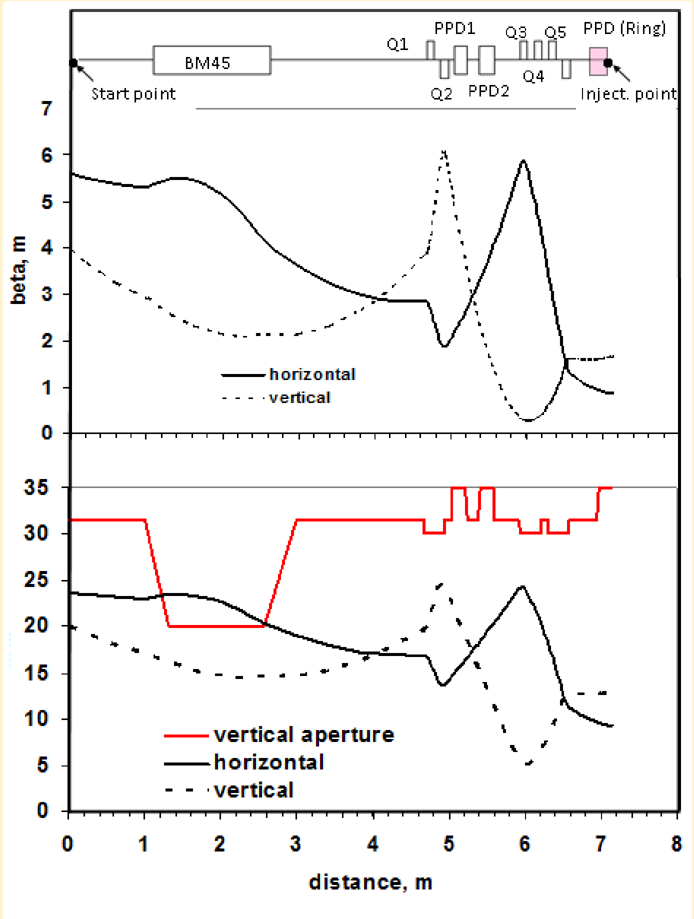



1. Transfer beam line/ Injection
    - two ion sources (14GHz ECRIS / Penning )
    - two FPROM profile/emittance monitors
2. Injection beam line:
    - Magnetic spectrometer
    - 1 FPROM system
    - injection optics




**MAD-calculation for the injection beam line**

- to meet the conditions at the injection points



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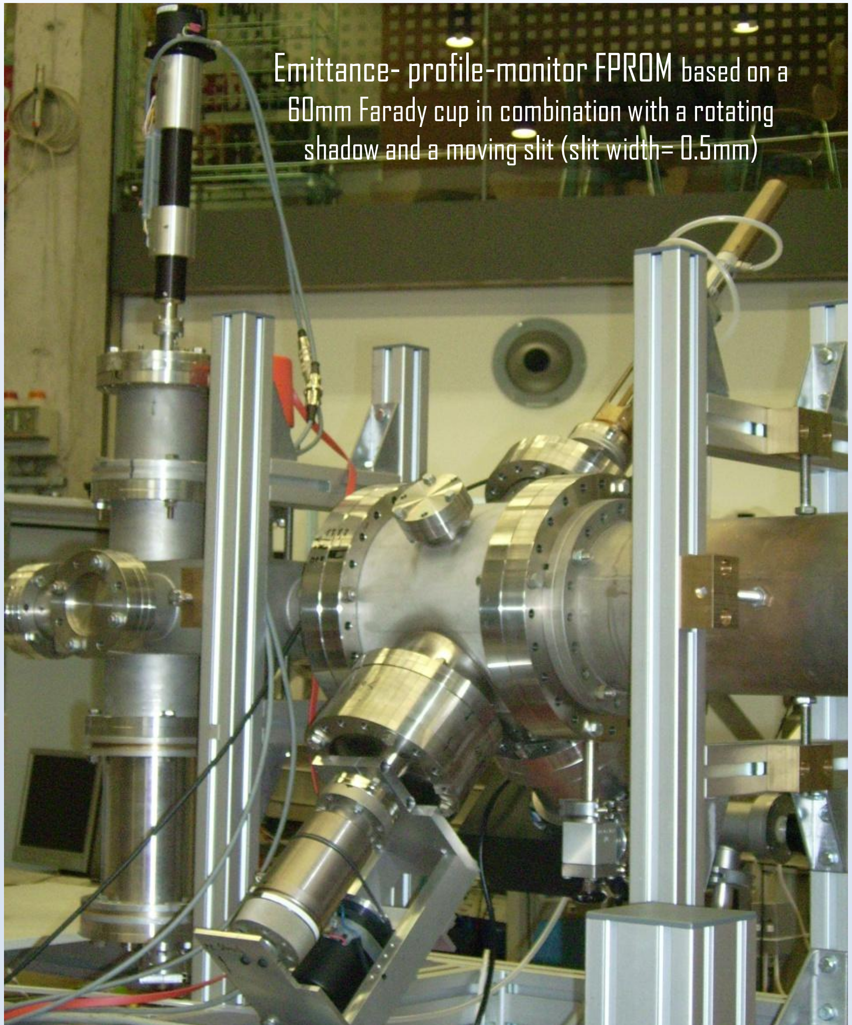



## PROFILE/EMITTANCE MEASUREMENTS:

**$Ar^{3+}$ 49.6 keV from ECRIS** — Profile(left) / Emittance (right)

FPROM -Transfer 1

$\varepsilon_{y,y'}(80\%) = 44\ \pi$ mm mrad

FPROM Tranfer 2

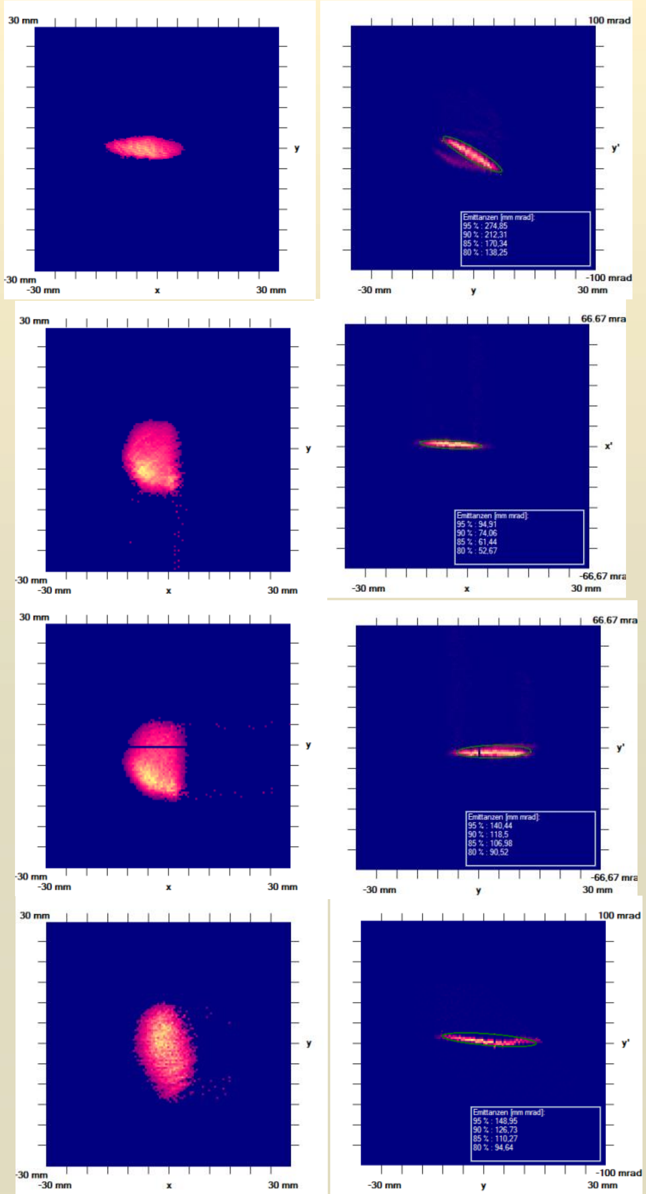
$\varepsilon_{x,x'}(80\%) = 16.8\ \pi$ mm mrad

FPROM Tranfer 2

$\varepsilon_{y,y'}(80\%) = 28\ \pi$ mm mrad

FPROM Injection

$\varepsilon_{y,y'}(80\%) = 30\ \pi$ mm mrad



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   - Magnetic spectrometer
   - 1 FPROM system
   - injection optics


## PROFILE/EMITTANCE MEASUREMENTS:

**p 25.0 keV from PENNING** Profile(left) / Emittance (right)

FPROM -Transfer 1 not available

$\varepsilon_{y,y'}(80\%) = 44\ \pi$ mm mrad

FPROM Tranfer 2

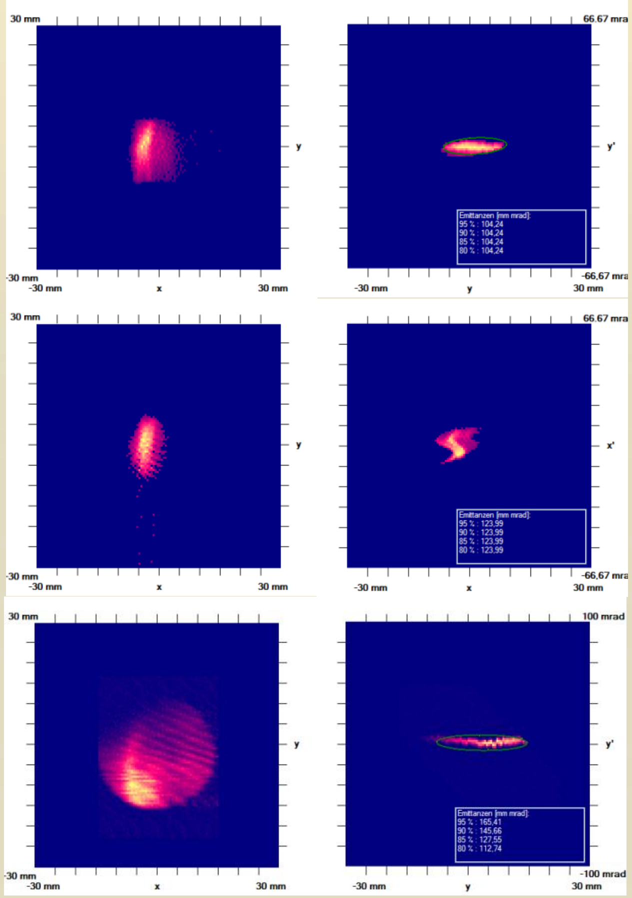
$\varepsilon_{x,x'}(80\%) = 33\ \pi$ mm mrad

FPROM Tranfer 2

$\varepsilon_{y,y'}(80\%) = 35\ \pi$ mm mrad

FPROM Injection

$\varepsilon_{y,y'}(80\%) = 30\ \pi$ mm mrad



# 1. What needs to be done:

- Finish the mechanics of the ring (probably within next two months)
- Bake out procedure
- Preparation of beams (tailoring the emittance of the injected beams)
- More diagnostics in the ring (scrapers, FPROM at the 0°-ports , Faraday cups)
- Improve vacuum is the injection region
  (better pumping of dumped beam, avoid beam losses by scattering at the components)
- can the injection scheme be improved?
  ( for the sake of simplicity, presently only single turn injection)
- In beam ion diagnostics (Schottky Noise, 0°-spectroscopy)
- Beam pulsing ?
- Cooling of beams?

*many thanks to:* *H. Schmidt-Böcking, A. Schempp, R. Dörner*

*P. Ziel, M. Dworak, W. Dilfer, D. Tiedemann , M. Almalki*

*V. Alexandrov, N. Yu. Kazarinov, ( from JINR, Dubna, Moscow-Region, Russia)*

*S. Enz, T. Kruppi, M. Völp, A. Jung, T. Felix*

*This work became possible by a grant from „Innovationsfonds der Hessischen Landesregierung“*

*The cooperation with V. Alexandrov was supported by BMBF (WTZ- Programm Grant No: RUS 05/A21)*