ION BEAM RESEARCH AND DEVELOPMENT WORK AT JYFL

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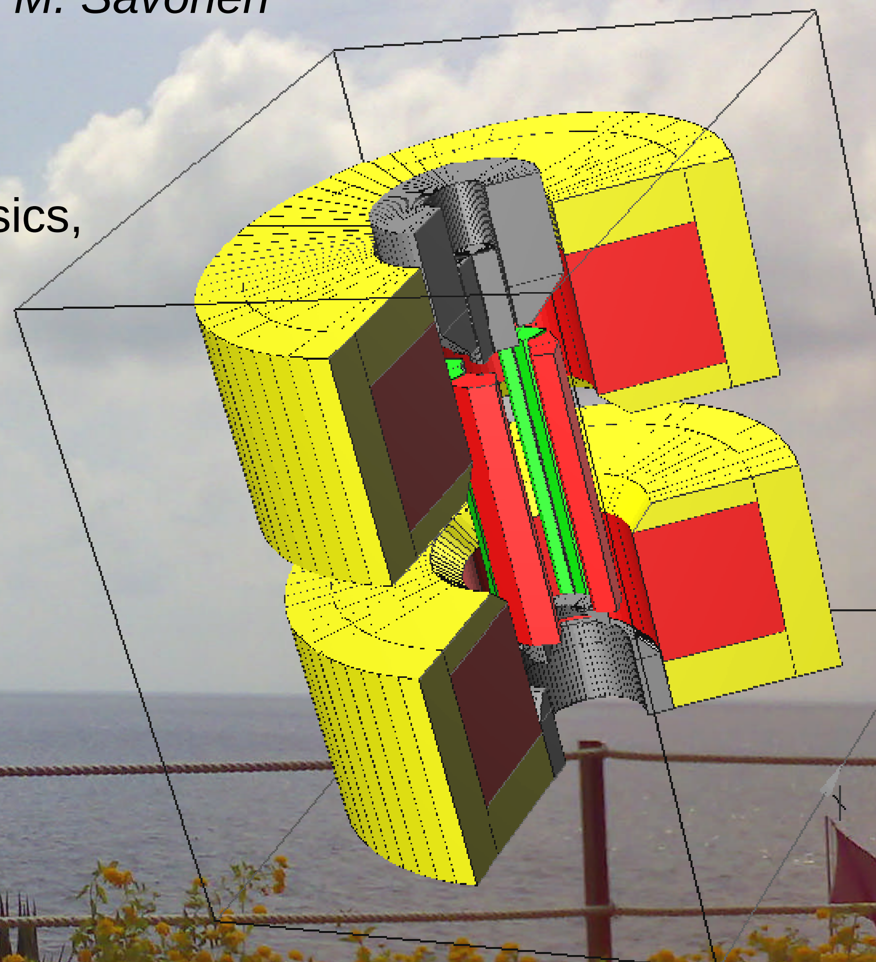


Contents

- research work to solve a serious beam transmission problem

    - measurements to define the bottle-neck concerning the beam transmission (ECRIS? Beam line? Cyclotron?)
    - injection voltage vs. transmission efficiency
    - tests with beam viewers
    - tests with quadrupoles to improve the beam profile

- new metal ion beams

- bremsstrahlung results will be presented by T. Ropponen

Injection line of K-130 cyclotron/ Beam intensity measurement points

Transmission efficiency for different sections were defined

After cyclotron

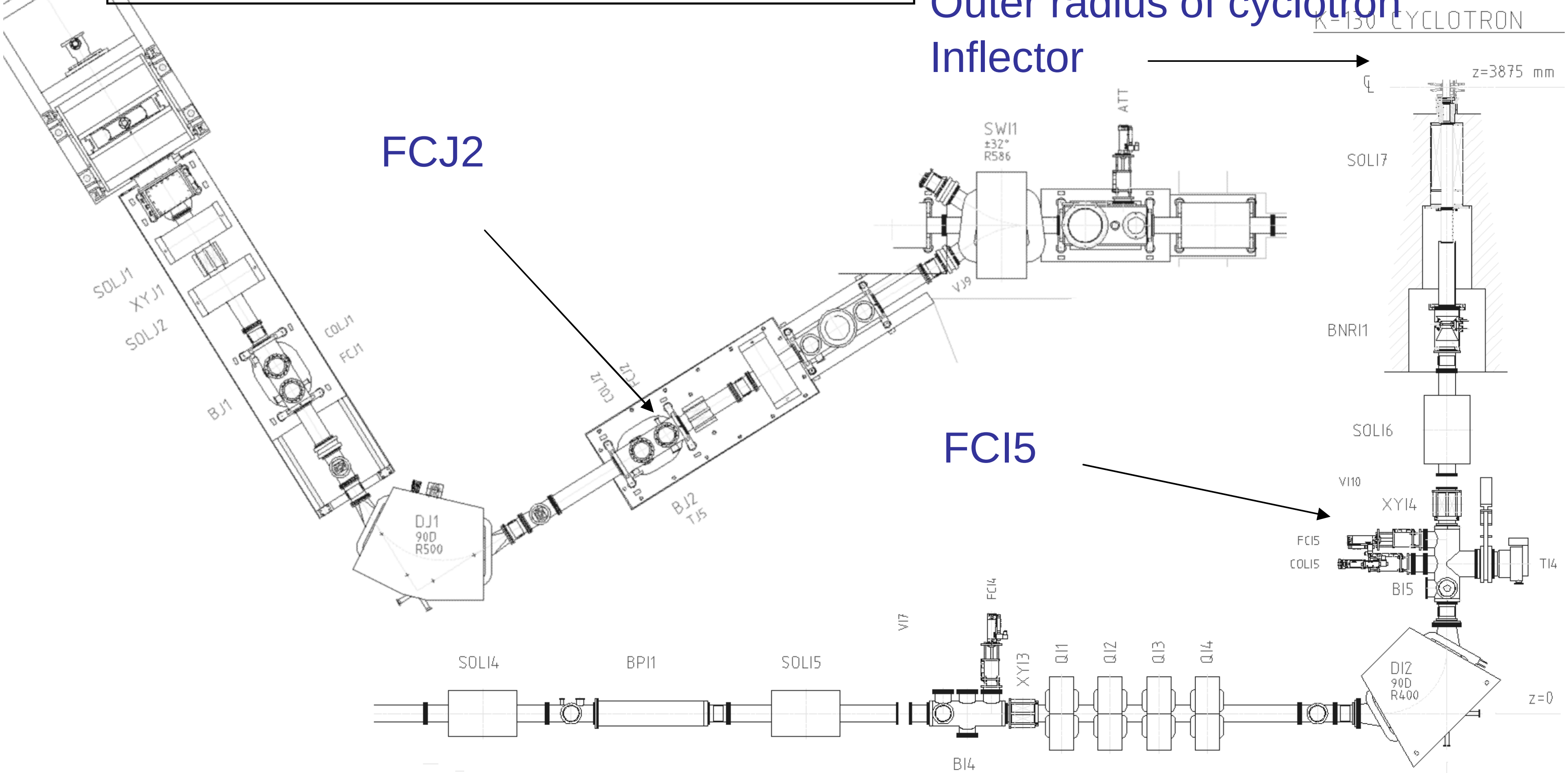
After deflector

Outer radius of cyclotron

Inflector

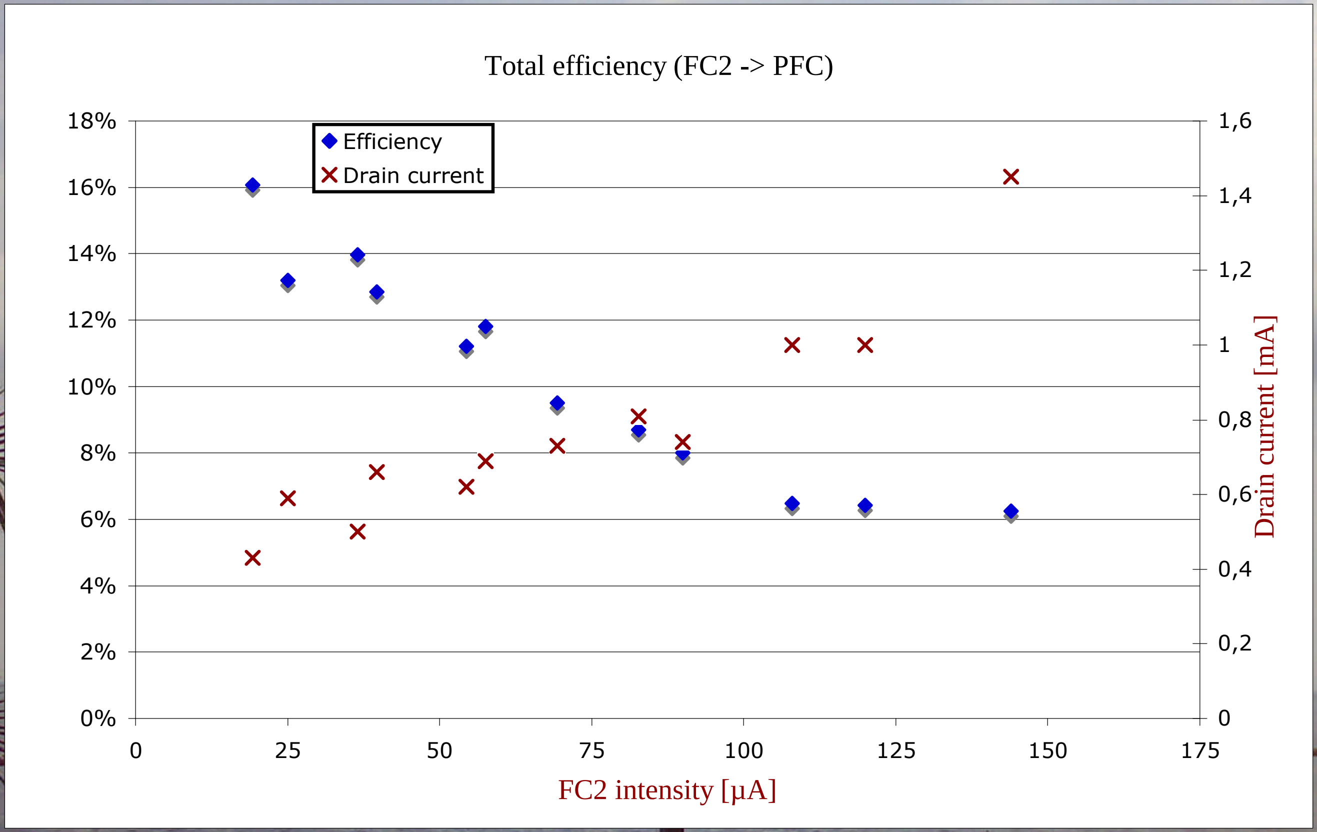
FCJ2

FCI5



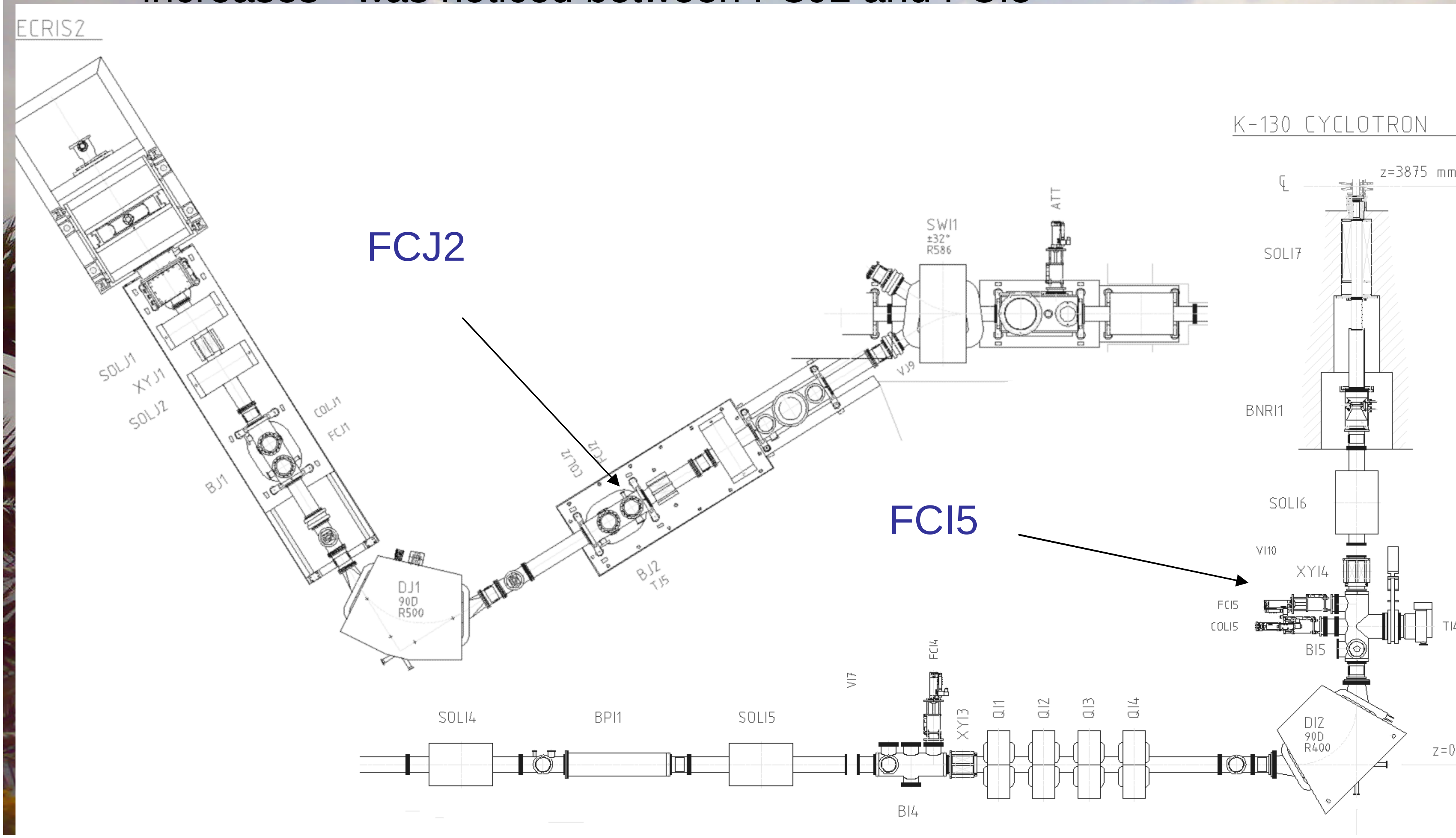
Total transmission efficiency

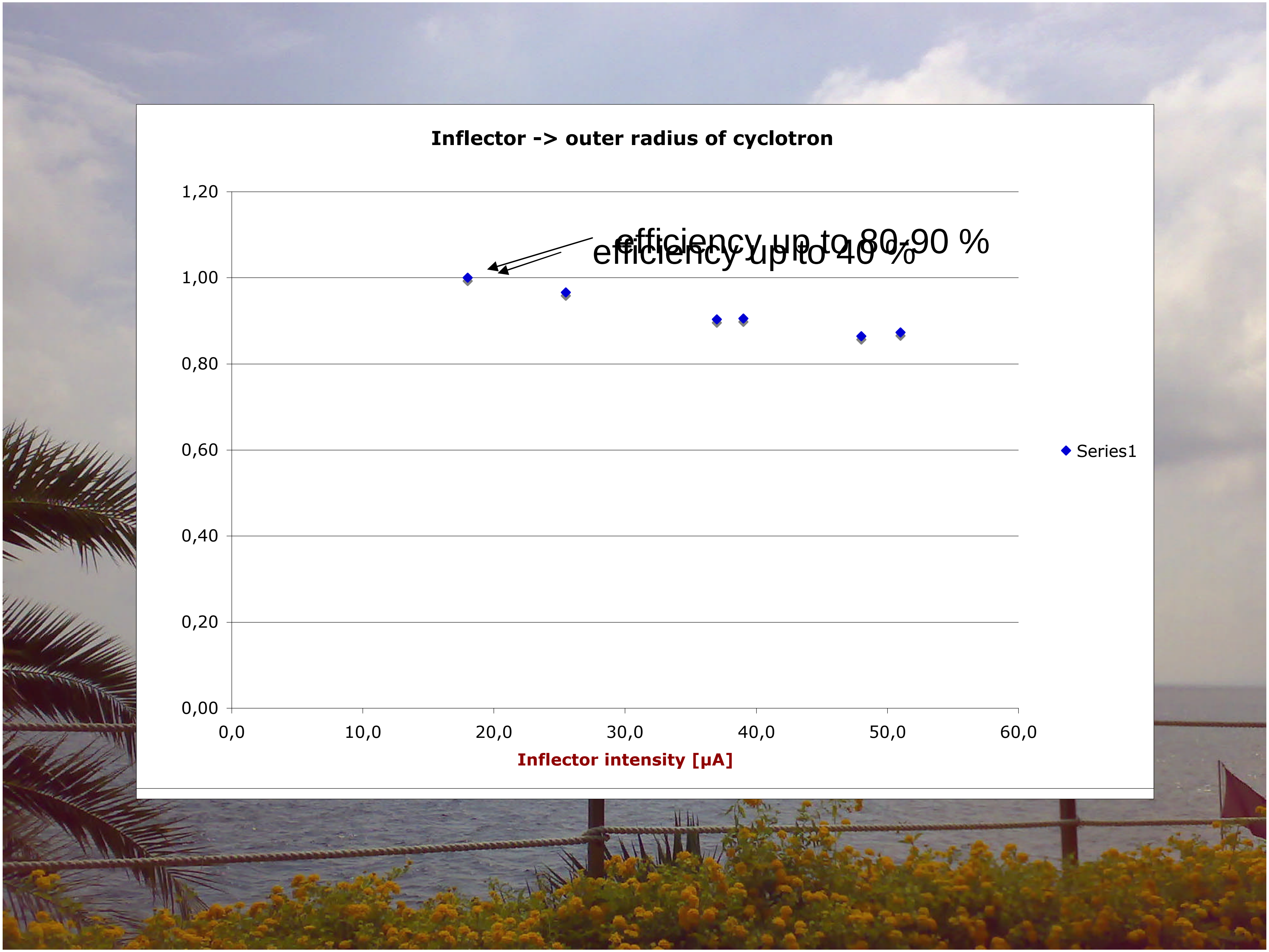
From FCJ2 to the first FC after cyclotron (PFC)

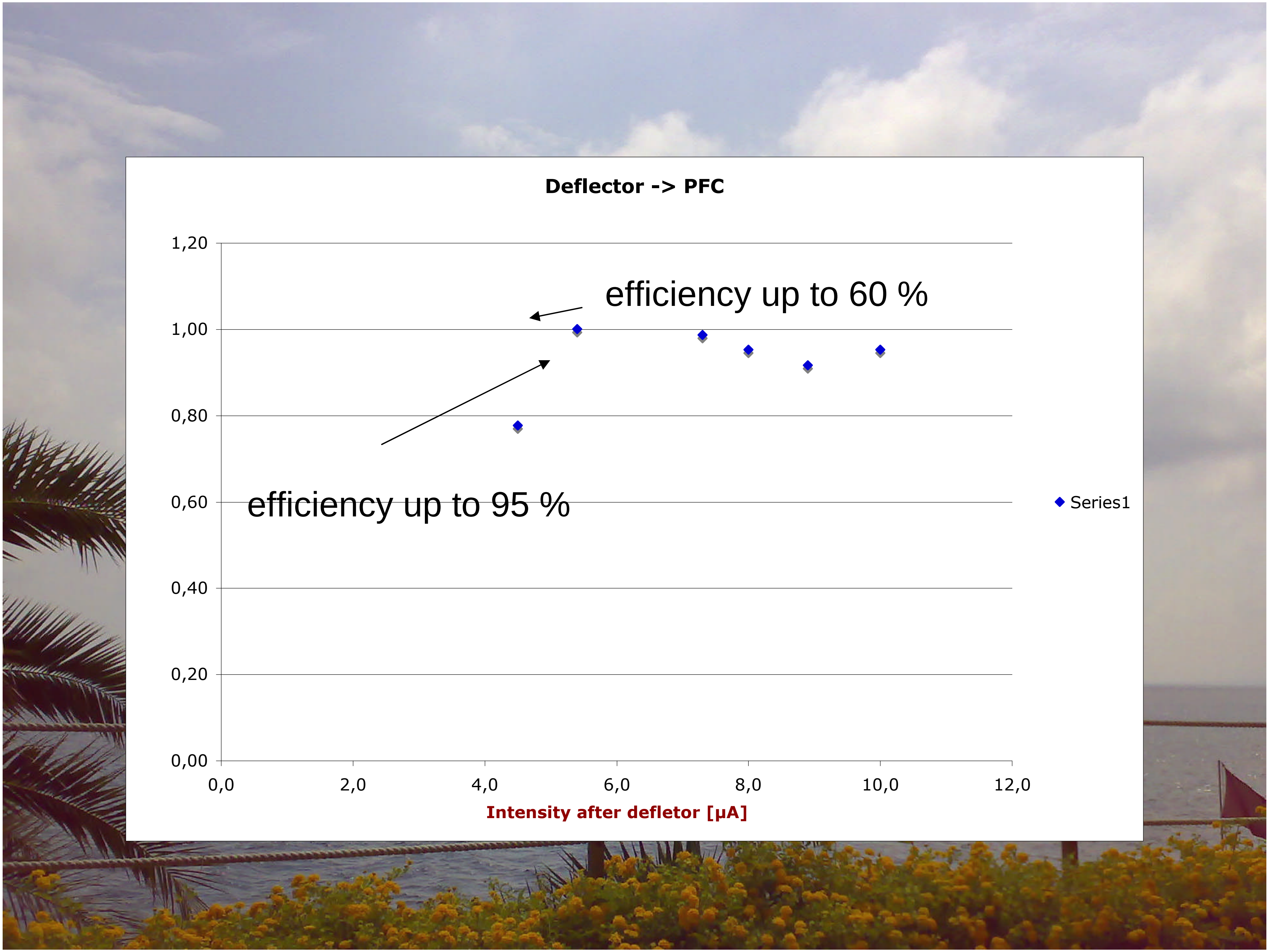


Different sections

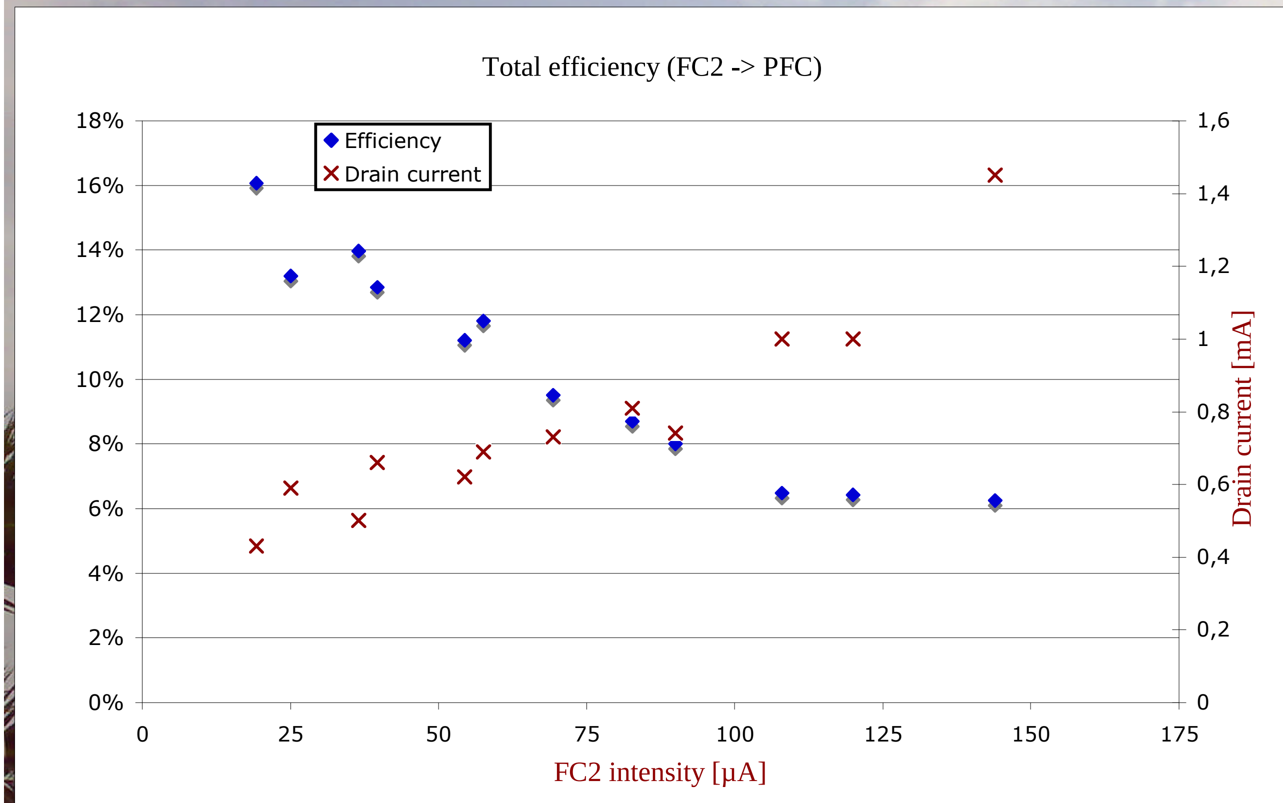
Same tendency - i.e. decrease of efficiency when the beam intensity increases - was noticed between FCJ2 and FCI5




Inflector -> outer radius of cyclotron
efficiency up to 80-90 %
efficiency up to 40 %
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0,0
10,0
20,0
30,0
40,0
50,0
60,0
Inflector intensity [μA]
Series1



Deflector -> PFC
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
Intensity after defletor [µA]
efficiency up to 60 %
efficiency up to 95 %
Series1



FCJ2-> FCI5 up to 90 %

FCI5-> infl. up to 90 %

cyclotron up to 40 %

deflector up to 60 %

defl.-> PFC up to 95 %

≈ 18 % OK

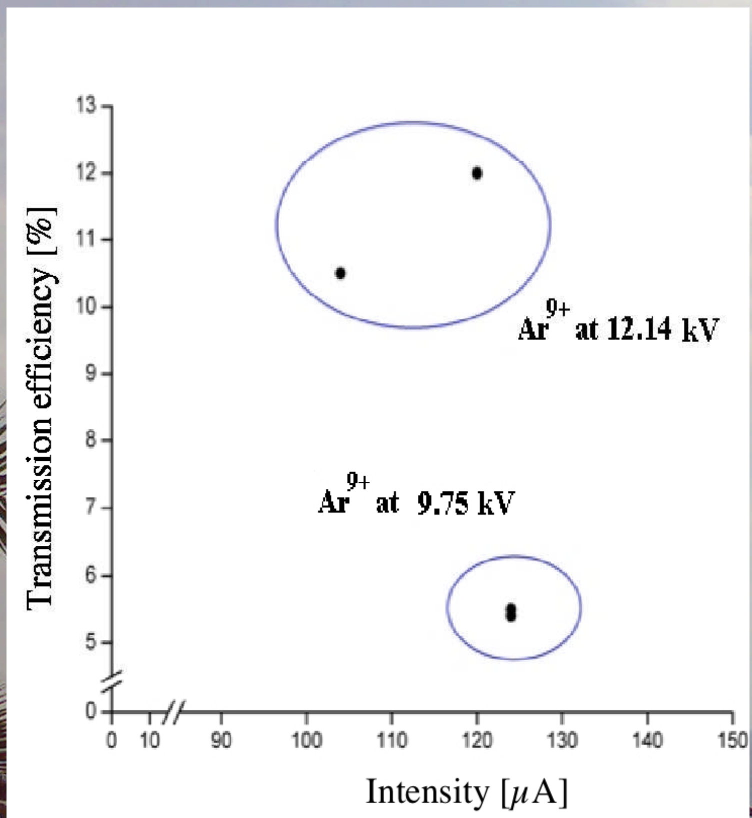
Conclusions concerning the transmission efficiency measurements

- the efficiency decreases as a function of intensity only in the section between FCJ2 - FC5

- after the afore-mentioned section the emittance of the beam approximately equals to the acceptance of the cyclotron

Consequently, the transmission problem exists before the cyclotron but what is wrong?

Efficiency vs. injection voltage



Effect was stronger than can be anticipated from Child-Langmuir law (40 % vs. 100 %).

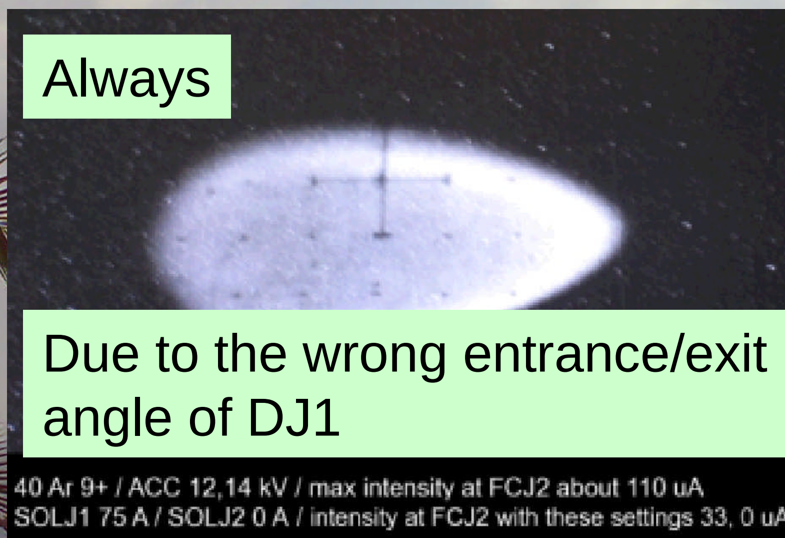
This indicates that the beam quality improves fast with the injection voltage

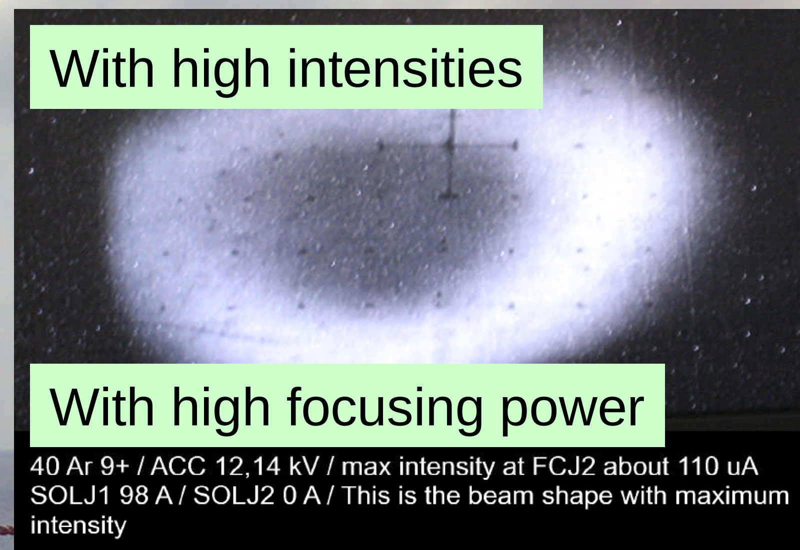
Fast degradation of beam quality with intensity due to higher space charge?

Beam profiles

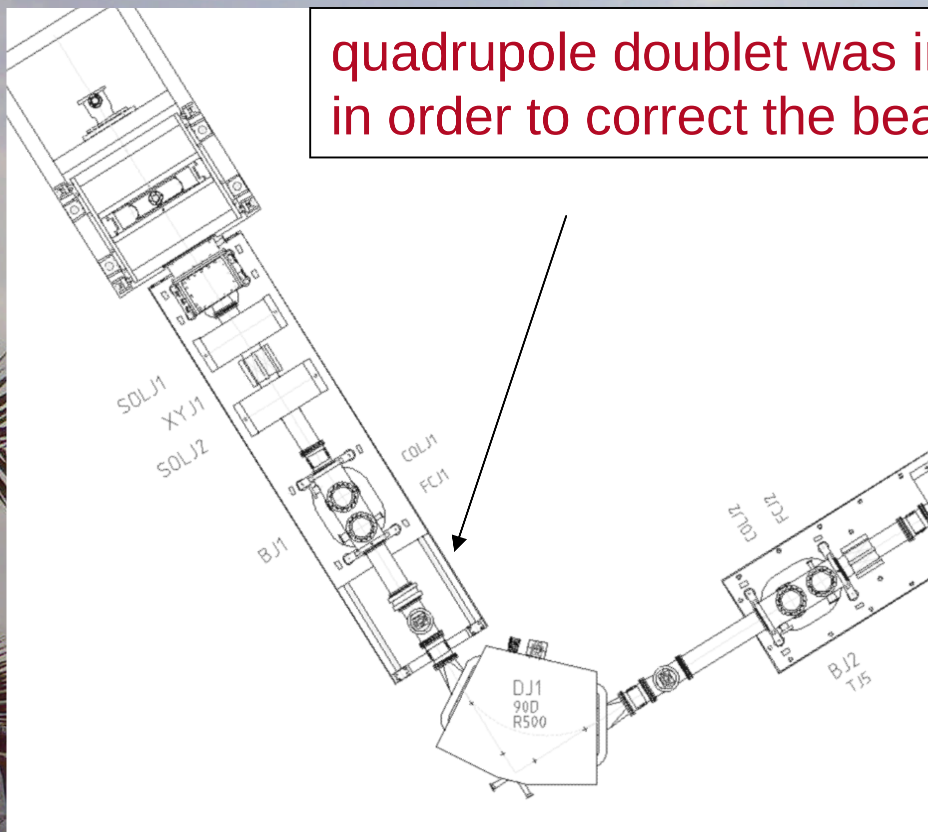
Beam profile has been studied by KBr-viewers

Two problems were found:



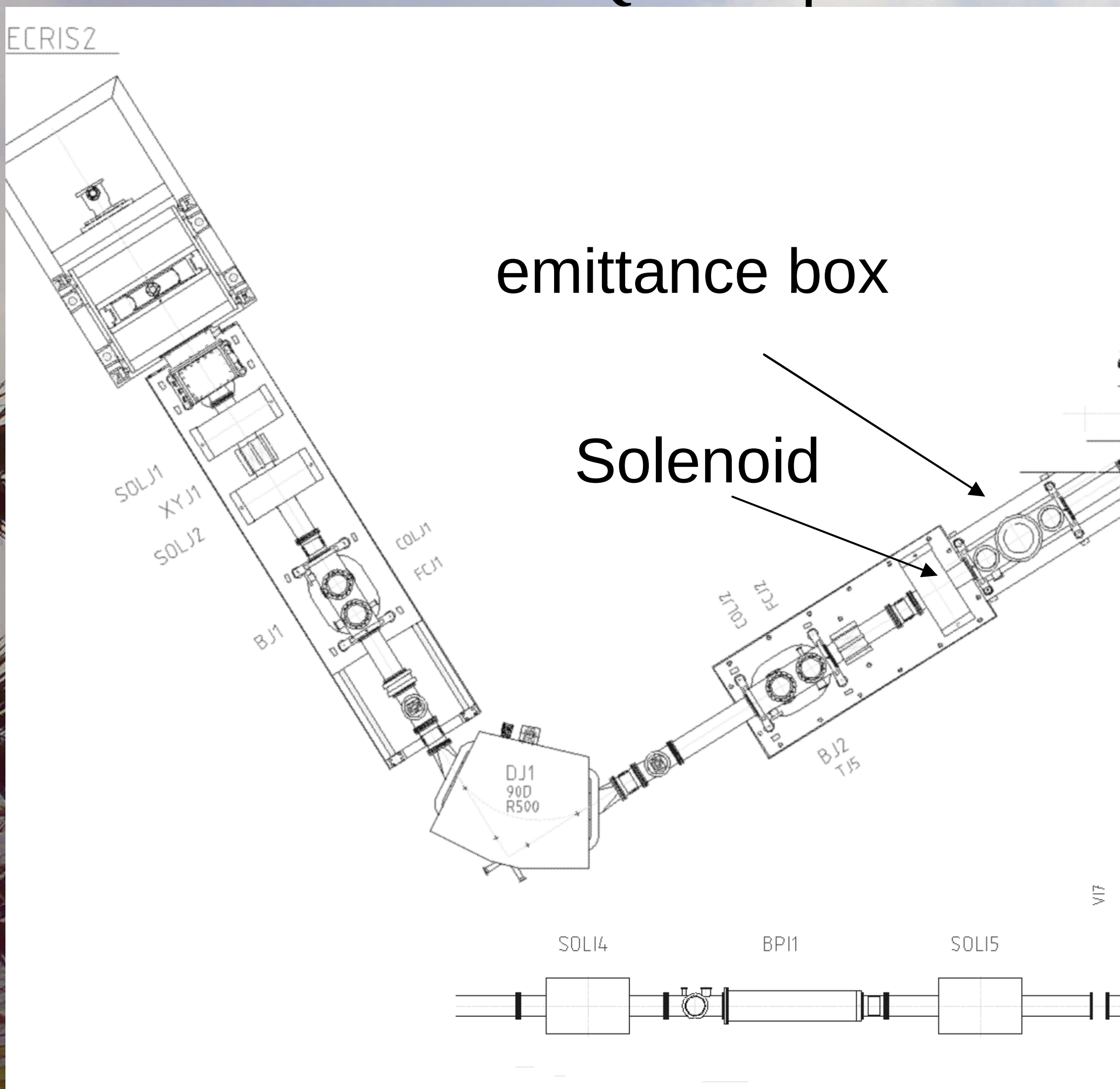


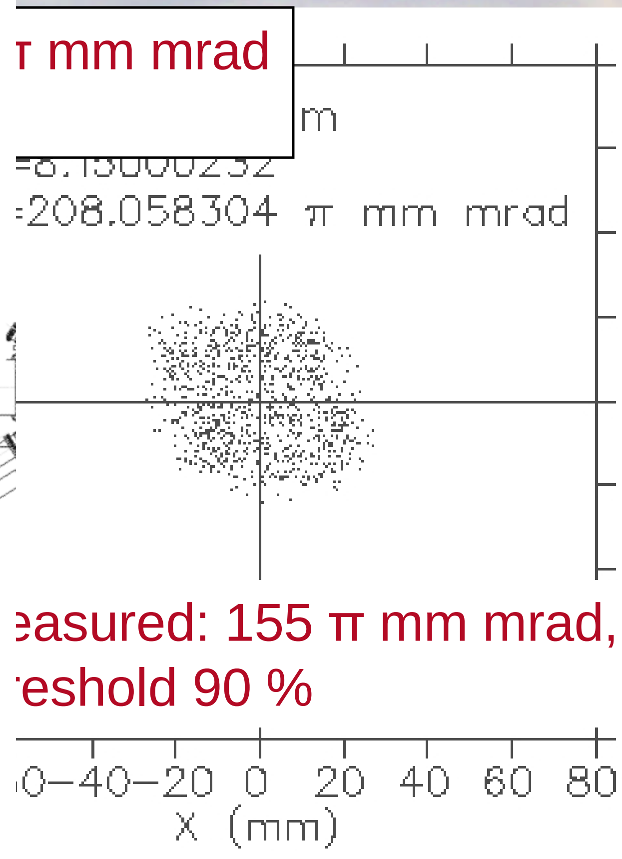
Test with quadrupoles



quadrupole doublet was installed before DJ1 in order to correct the beam profile

Quadrupole results

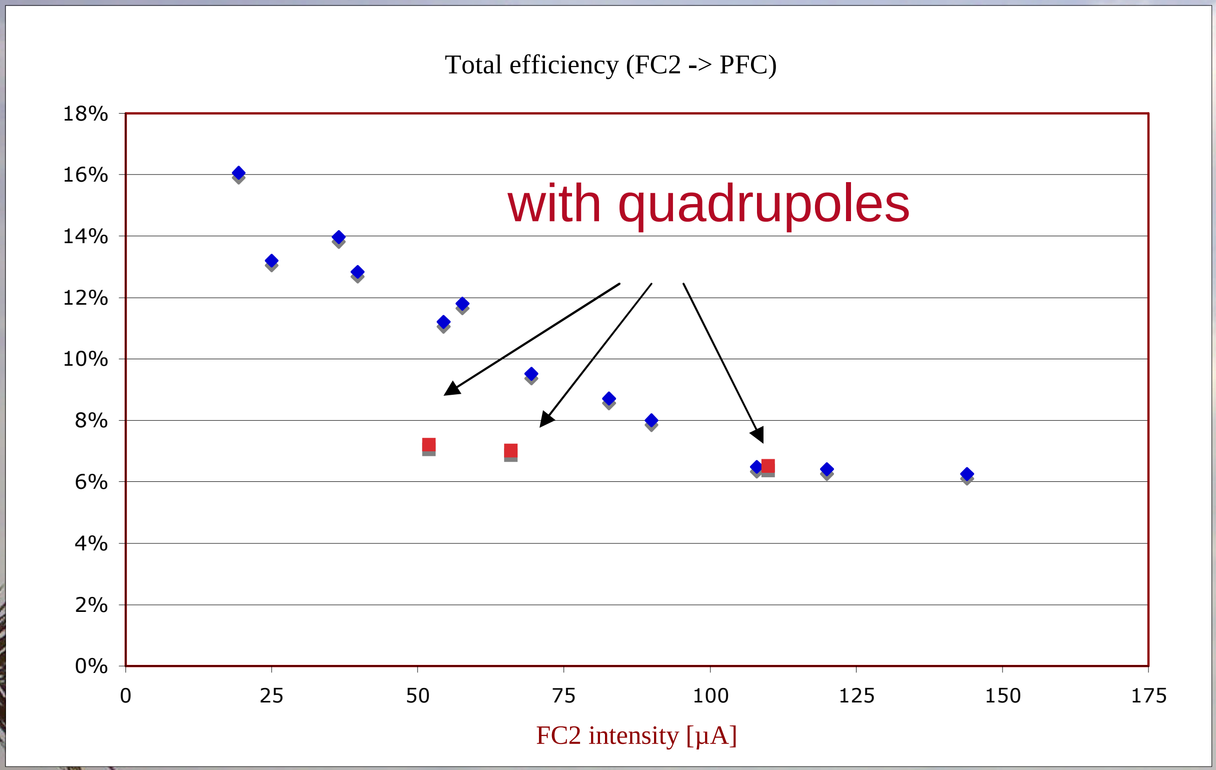




Tests with K130 cyclotron (with quadrupoles)

According to results with quarupoles a remarkable improvement
in transmission efficiency was expected (remarkable decrease in emittance).
But....

	I (FCJ2)	I (PFC)	Efficiency
without quadr.	52 µA	4,1 µA	7,2 %
with quadr.	66 µA	4,7 µA	7,0 %
+ ECR tuning	110 µA	7,2µA	6,5 %



- we succeeded in decreasing the efficiency of low intensity beams!

- however, the intensity dependence is not seen!

The reason for the disappointing result is still unknown

Future beam transmission R & D

- explanation for the quadrupole result has to be found

- explanation for the hollow beam structure has to be found

ECRIS/beam formation/space charge effect?

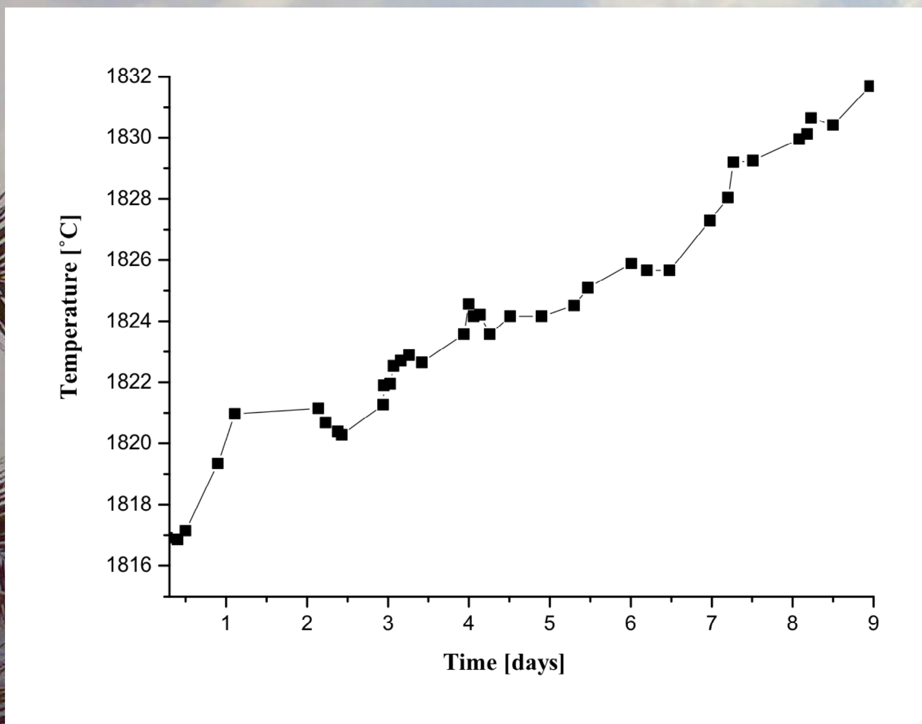
- electrostatic focusing (like NSCL/MSU)?

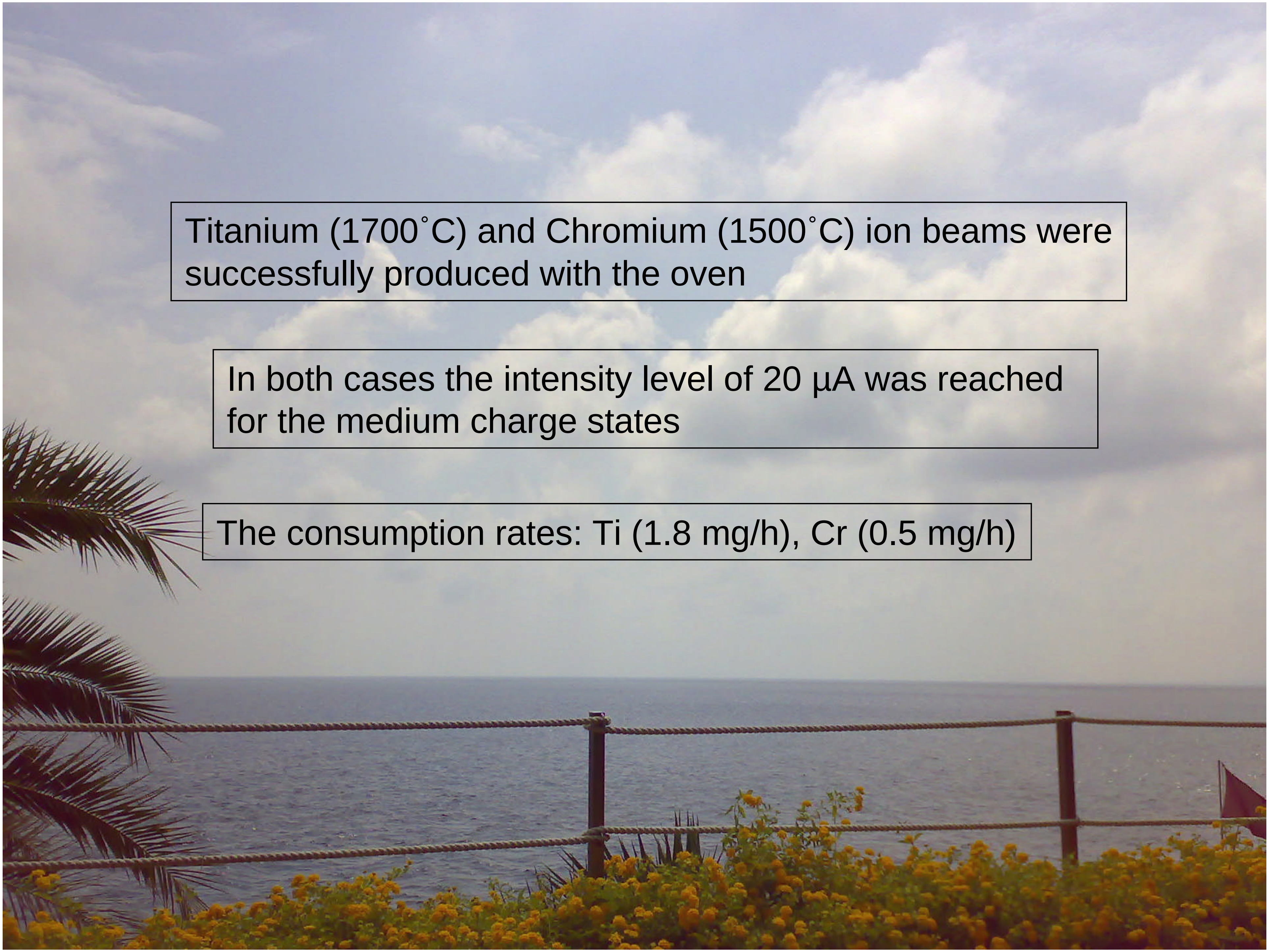
- ECRIS closer to dipole?

- higher injection voltage: requires new central area of cyclotron

Results with the inductively heated oven

The latest version of inductively heated oven seems to be reliable in operation





Titanium (1700˚C) and Chromium (1500˚C) ion beams were successfully produced with the oven

In both cases the intensity level of 20 µA was reached for the medium charge states

The consumption rates: Ti (1.8 mg/h), Cr (0.5 mg/h)

Summary

1) a lot of information about the beam transmission has been gotten

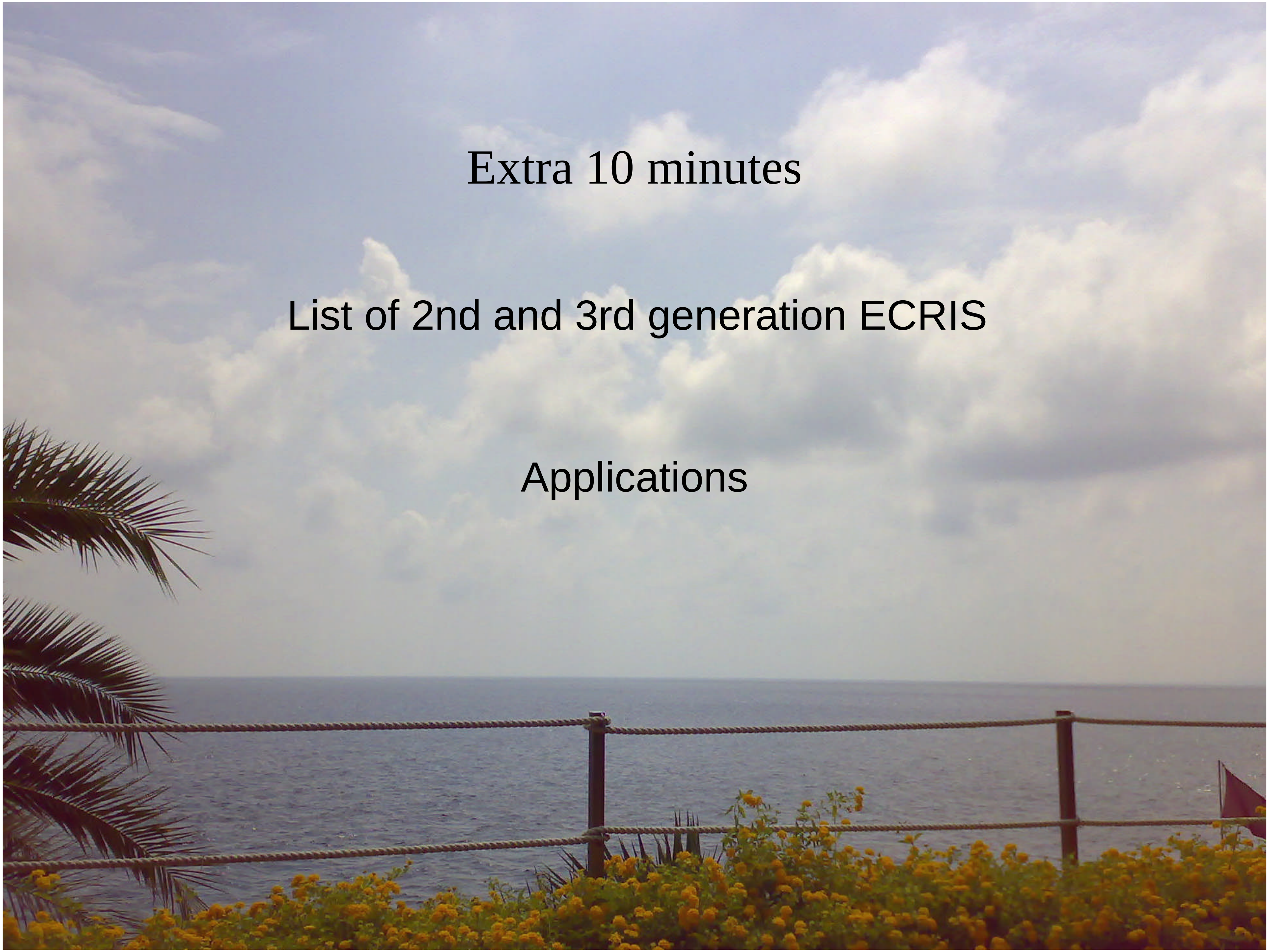
- different options to solve the transmission problem will be considered:

  electrostatic focusing, ECRIS closer to dipole, higher injection voltage?

2) studies to understand the hollow beam structure
(also beam formation)

3) Bremsstrahlung experiments

4) Metal ion beams



Extra 10 minutes

List of 2nd and 3rd generation ECRIS

Applications

List of 2nd and 3rd generation ECR ion sources

SECOND GENERATION ECR ION SOURCES		
Lab./country	**ECRIS**	**Purpose**
LBNL/USA	AECR-U 10 + 14 GHz	cyclotron injection for 1) and 2)
NSCL/MSU/USA	ARTEMIS-A 14 GHz	cyclotron injection for 1)
	ARTEMIS-B 14 GHz	test bench for ECRIS R&D
ANL/USA	ECR2 14 GHz (+TWTA)	linac injection for 1)
	ECR1, 10 GHz	charge breeder for linac
TAMU/USA	ECR2, 14 GHz	1)
	CBECRIS, 14 GHz	charge breeder
RIKEN/Japan	RIKEN 18 GHz ECRIS	inj. for heavy ion linac and RIBF
	Liq. He-free SC-ECRIS, 18 GHz	inj. for heavy ion linac and RIBF
CNS Tokyo/Japan	Liq. He-free SC-ECRIS, 14 GHz	AVF cyclotron injection
Vienna Univ./Austria	14 GHz ECIRS, all perm. Magn.	Experiments with low energy HC ions
IMP/China	LAPECR2 (all perm magn) 12-14 GHz	multi-purpose, HV platform
	LAPECR1 (all perm magn)12-14 GHz	4)
	LECR3, 14/18 GHz	for HIRFL cyclotrons
	LECR2M 14/18 GHz	material physics, ECRIS R&D
NIRS/Japan	NIRS-ECR 10 GHz	carbon ion therapy
	NIRS-HEC, 18 GHz	carbon ion therapy
	Kei 8/10 GHz	experimental
	Kei2 8-11 GHz, all perm magn	source development
Gunma Univ/Japan	KeGM 10 GHz	carbon ion therapy
GSI/Germany	14.5 GHz Caprice	multi-purpose
	14.5 GHz Caprice	test bench for ECRIS R&D
Heidelberg/Germ.	Supernanogan 14 GHz (2), all perm.mag	carbon ion therapy
LNS/INFN/Italy	CAESAR 14/18 GHz	inj. for K800 cyclotron
	SERSE 18/(28) GHz	inj. for K800 cyclotron
LNL/INFN/Legnaro	Supernanogan, 14 GHz, all perm.magn	1)
LPSC	PHOENIX, 14 GHz	charge breeder R&D

1) nuclear physics
2) space effects testing
3) radiobiological
4) material and atomic physics
5) hadron therapy

AB Dep./CERN	GTS-LHC, 14/18 GHz	for hadron injector at CERN
GANIL/France	ECR4, 14 GHz	1), 2), 3), 4)
	ECR4M, 14 GHz	1), 2), 3), 4)
	SUPERSHYPIE, 14 GHz	solid state physics
	GTS 18 GHz	1)
KVI/the Netherl.	KVI-AECR 14 GHz	cycl. (AGOR) inj. For 1) and 3)
JYFL/Finland	JYFL-14 GHz ECRIS (+ TWTA)	cycl. injection for 1), 2) and 4)
ATOMKI/Hungary	14 GHz ECRIS	?
Frankfurt/Ger.	IKF-ECRIS, 14 GHz	4), ECRIS R&D
JINR/Russia	DECRIS-2, 14 GHz	1)
	ECR4M, 14 GHz	1), applications
	DECRIS-SC, 18 GHz hybrid	inj. for CI-100 cyclotron (applied phys.)
	DECRIS-4, 14 GHz	at test bench, will be used for U400 cycl.
Vinca inst./Serbia and Montenegro	MVINIS, 14/18 GHz	material modifications
Biont/Slovak rep.	DECRIS-2M, 14 GHz	material modifications (nanotechn)
Astana/Kazakhstan	DECRIS-3 14 GHz	inj. for DC-60 cycl., applied physics
Triumf/Canada	Phoenix 14 GHz	charge breeding
Kochi Univ./Japan	10 GHz NANOGAN	ion beam lithography
New Delhi/India	PKDELIS, 14/18 GHz, hybrid	inj. for linear accelerator
MSL/Sweden	14 GHz Hypernanogan	inj. synchrotron (storage ring)
KEK-JAERI/Japan	ECRCB, 18 GHz	charge breeder for KEK-JAERI RNB
RCNP/Osaka/Japan	18 GHz SC-ECRIS	inj. for cyclotron
iThemba/South Afr	ECR4, 14 GHz	inj. for cyclotron
	GTS 14/18 GHz	under construction
Cancer Cent. Marburg	Supernanogan, 14 GHz (2),perm. magn	carbon ion therapy
TIFR/Mumbai/India	Supernanogan, 14 GHz, perm. magn	4)
VECC/Calcuta/India	Hypernanogan, 14/18 GHz	1), 4)
CLRC/Daresbury/UK	PHOENIX 14/18 GHz	charge breeder
CNAO/Pavia/Italy	Supernanogan, 14 GHz (2),perm. magn	carbon ion therapy
Oxford Instr./UK	NANOGAN 10 GHz	ion implantation
Xion/France	Supernanogan, 14 GHz, perm. magn	ion implantation
HMI/Berlin/Germ.	Supernanogan, 14 GHz, perm. magn	ion implantation, 1)

THIRD GENERATION ECR ION SOURCES		
LBNL/USA	VENUS 28 GHz	cyclotron injection and ECRIS R&D
IMP/China	SECRAL 28 GHz	HIRFL cyclotron injection
RIKEN/Japan	28 GHz ECRIS	inj. for RIBF, under construct.
NSCL/MSU/USA	SUSI 18/(24) GHz	cyclotron injection for 1)
GSI/Germany	MS-ECRIS 28 GHz	under construct., multipurpose
LPSC/France	A-Phoenix 18/28 GHz, hybrid	under commissioning

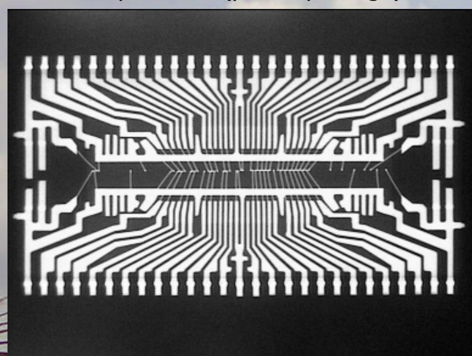
Total number of ion sources in the list: 70
(unknown number of 1st generation sources)

Main applications	
nuclear/high energy physics	≈ 34
material science	≈ 12
ECRIS R&D	≈ 7
hadron therapy	≈ 9
implantation/nanotech.	≈ 5
charge breeder	≈ 6
space effects testing	≈ 4

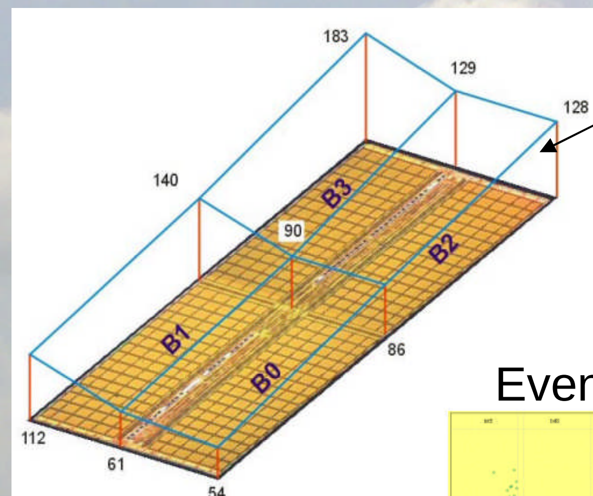
Japan	11
Germany	9
USA	9
France	6
China	5
Italy	5
Russia	4
India	3
South Africa	2
Switzerland	2
UK	2
Austria	1
Canada	1
Finland	1
Hungary	1
Kazakhstan	1
Netherland	1
Serbia Montenegro	1
Slovak rep.	1
Sweden	1

Electronic component testing

X-ray of Hitachi 256-Mbit SDRAM
in 54-pin TSOP (plastic package)

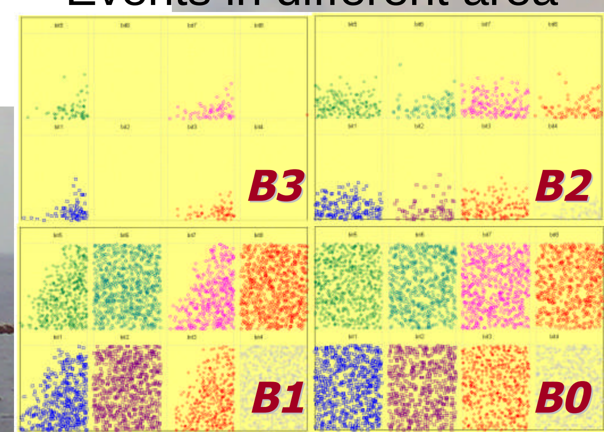


Today, nearly all memories are assembled with centre bond pads and a lead frame on top of the die



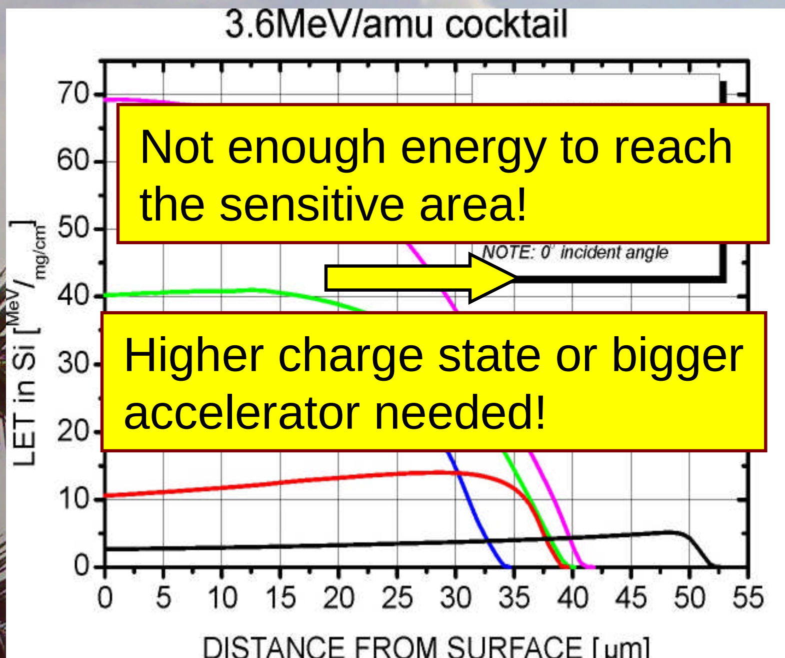
Si-layer

Events in different area



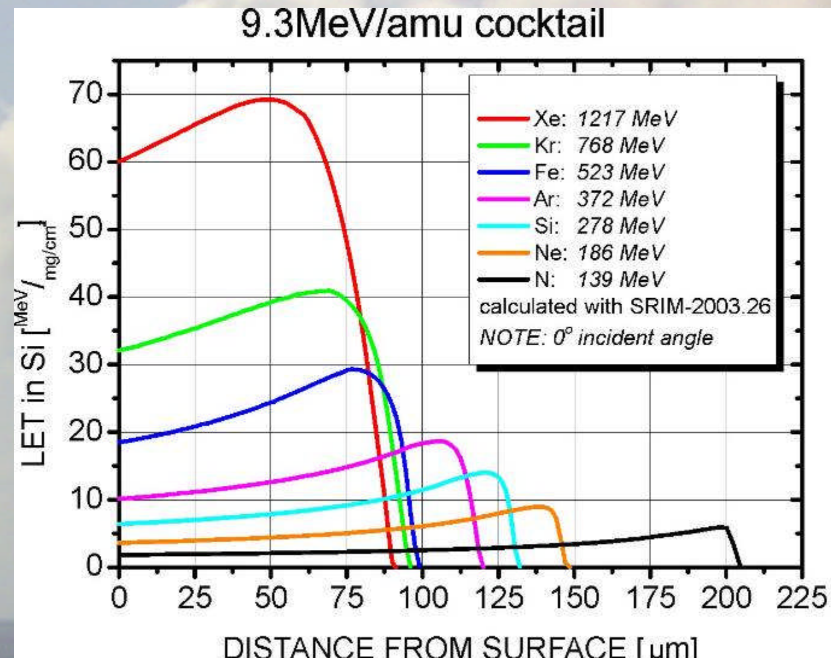
SEE tests

Higher charge state (Xe^{35+})



Not enough energy to reach the sensitive area!

Higher charge state or bigger accelerator needed!



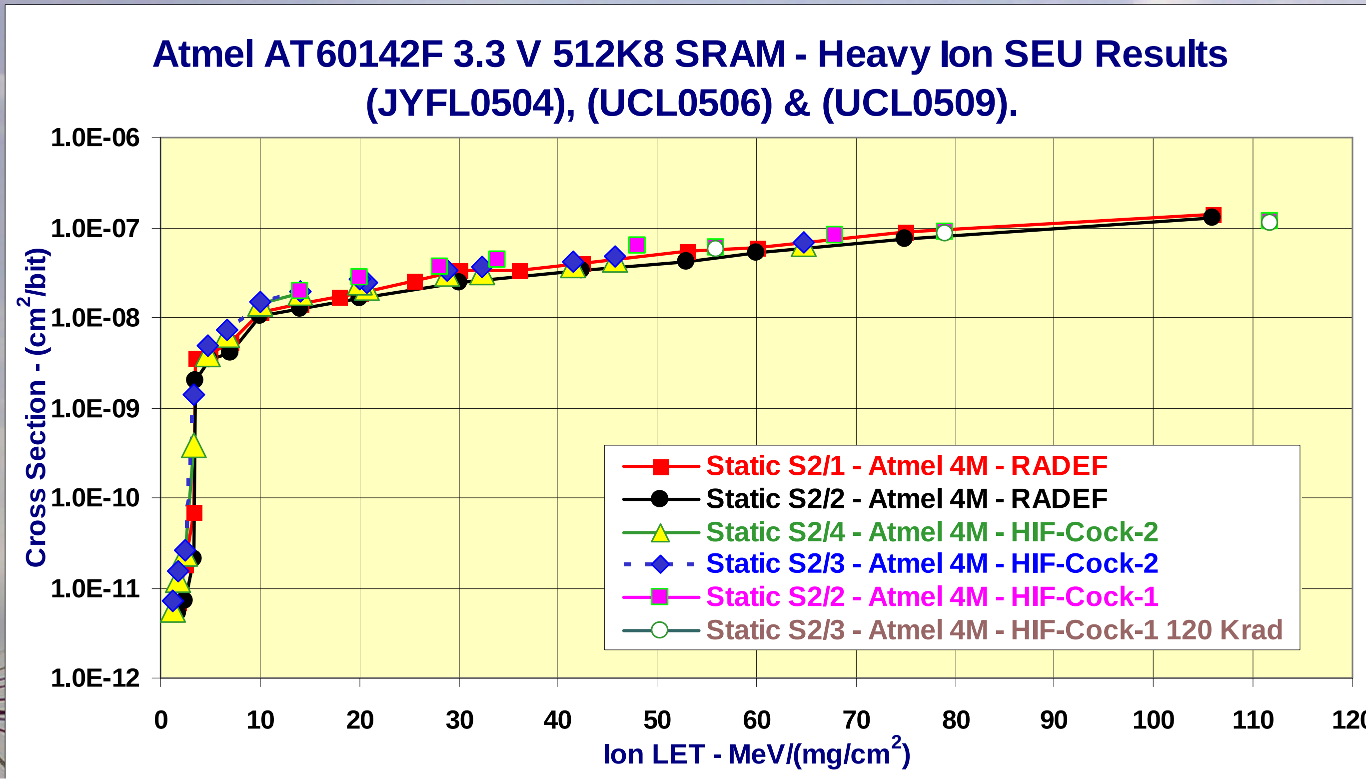
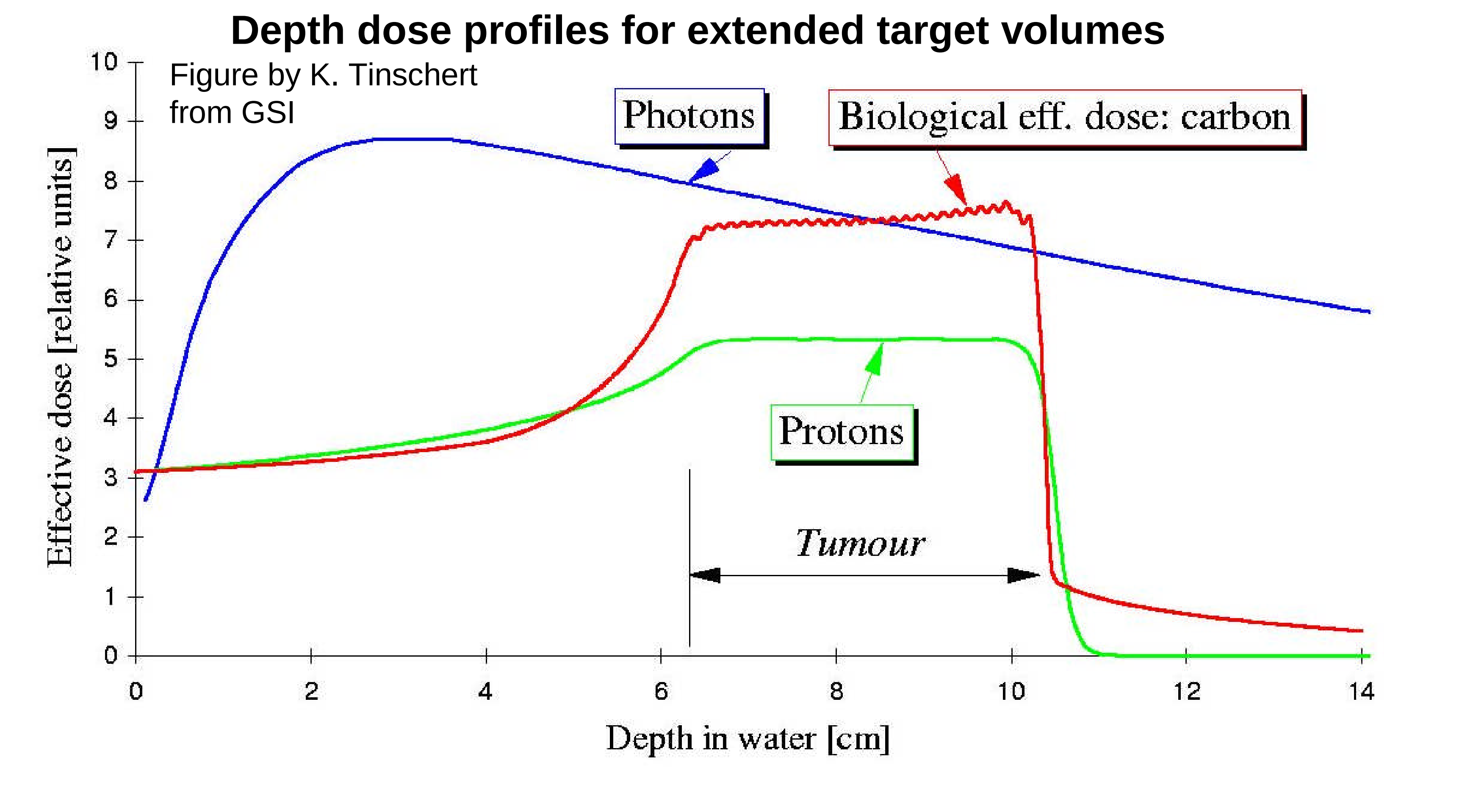


Table 1. 9.3 MeV/amu cocktails (M/Q≈3.7, ‡M/Q≈3.3).

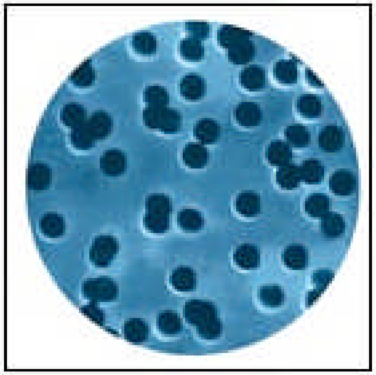
Ion	Energy [MeV]	LET^{SRIM} @surface [MeV/mg/cm^2]	$Range^{SRIM}$ [microns]	LET^{SRIM} @50µm [MeV/mg/cm^2]	LET^{SRIM} @ Bragg peak [MeV/mg/cm^2]	LET^{BNL} [MeV/mg/cm^2]	$Range^{BNL}$ [microns]
$^{15}N^{+4}$	139	1.8	202	2.1	5.9 (@198µm)	2	210
$^{20}Ne^{+6}$ ‡	186	3.6	146	4.4	9.0 (@139µm)	4	150
$^{30}Si^{+8}$	278	6.4	130	7.8	14.0 (@120µm)	7	129
$^{40}Ar^{+12}$ ‡	372	10.1	118	12.6	19.6 (@105µm)	10	118
$^{56}Fe^{+15}$	523	18.5	97	24.3	29.3 (@77µm)	18	99
$^{82}Kr^{+22}$	768	32.1	94	39.2	41.0 (@69µm)	30	97
$^{131}Xe^{+35}$	1217	60.0*	89*	69.2	69.2 (@48µm)	53	97

Hadron therapy (by carbon ions)



Porous membranes

Oxyphen



Our pores are more uniform than others.

RoTrac® Capillary Membranes are microporous membranes that open up countless new areas of application. These high-tech products made of polyester are characterized by:

- A defined pore diameter usually ranging from 0,1 µm to 10,0 µm
- A defined pore density ranging between 10^5 to 10^9 pores per cm^2

The distibution of the pores across the surface is so dense that there can be several billion pores on a surface of 1 square centimeter, depending upon the pore diameter.

Specialities

Based on a variety of different features, RoTrac® Capillary Pore Membranes have already provided ideal solutions in many applications such as:

- Liquid filtration
- Controlled release of substances
- Controlled release of fragrances
- Moisture barrier
- Venting for electronic devices
- Venting for boxes and closures

life science, etc...

http://www.quertech.com/crbst_29.html

Aluminium
Titanium
Polymers

Hard*ion*+ **Surface Metallurgy**

Quertech Ingénierie controls the technology of the particle accelerators which allow a treatment at low temperature (80 °C).

A NEW TECHNOLOGY
A Process : the insertion of nitrogen, helium, by a particle accelerator from 0 to 10 µm re-alloy, nano-structure or amorphise the surface.
A treatment machine : composed mainly of a micro-accelerator of particule and a vacuum chamber. Process and machine are under Quertech ingénierie patent.

No deposit, no coating : a real re-alloy. an amorphisation or a nano-restrucration

A RANGE OF MACHINES
The power of the ion source and the size of the vacuum chamber determine the treatment time and the size of the part to be treated.

GAINS
Hardness : up to 780 % of increase (15 GPa, Vickers extrapolation 1530 Hv)
Elasticity & rigidity
Corrosion : resistance strongly increased
Temperature : gain on study
Friction : reduction of the friction coefficient (0.14 - 0.17).

Treatment limited to the zones under constraints: processing time optimized
Minimal preparation of the substrate: reduction of use of polluting agents to ach
Delamination Impossible : strong connection of the layer within the substrate (mixing).
Cieve
ultra-cleanliness. Alumina pulverized during the treatment.

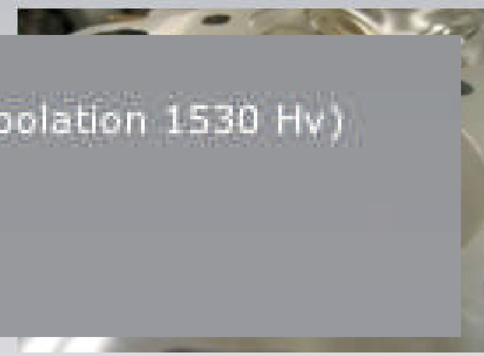
APPLICATIONS
Automotive area, motorization
Increased hardness and thermal resistance of the head of a piston.

Injection mouldings
Increased hardness of the mating planes of a mould (hammering) and anti-corrosion
treatment of the moulding surface (Chlorine corrosion).

F.A.Q.
Processing time ?
Depends on the ion source power, the surface area to treat and the size of the part
(vacuum). An average estimate of the time needed is 10 s per cm² treated.
Maximum size of the part to be treated ?
Depends on the capacity of the vacuum chamber.

"God created the Solids, the Devil their Surfaces "

Wolfgang Pauli
Nobel Prize in Physics



Bodycote
outsourcing for industry

BIOMÉDICAL

Problématique

- **Inflammations** articulaires causées par les débris résultants du frottement
- **Cytotoxicité** par relargage
- Difficulté de la nécessaire colonisation cellulaire
- Traitements de surface actuels supportant mal la stérilisation (température)

Proposition Hard*ion*+

- Dureté (X7)
- **Réduction du frottement** par amélioration de l'état de surface
- Barrière de diffusion
- **Adhésion cellulaire** favorisée par l'implantation d'Azote
- Tenue à la température du traitement (stérilisation)