The Jyväskylä Accelerator Laboratory

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JYFL

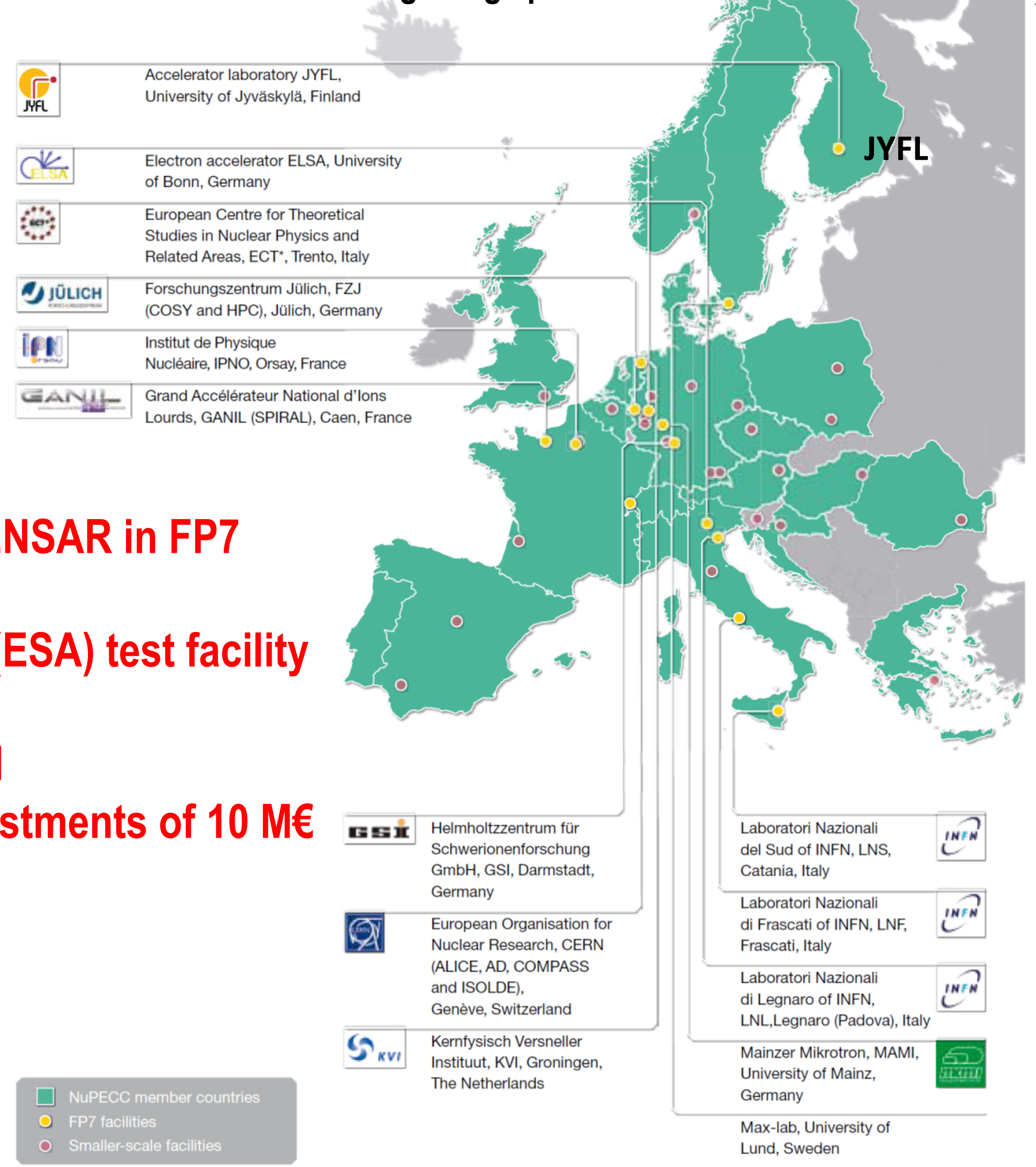
ECOS, Orsay, May 16, 2013

Status

JYFL Accelerator Laboratory

- Part of the Department of Physics
- Over 6000 beam time hours a year
- EU- Access Laboratory since FP4 - ENSAR in FP7
- Accredited European Space Agency (ESA) test facility
- International infrastructure in Finland
  - over 200 users a year, foreign investments of 10 M€

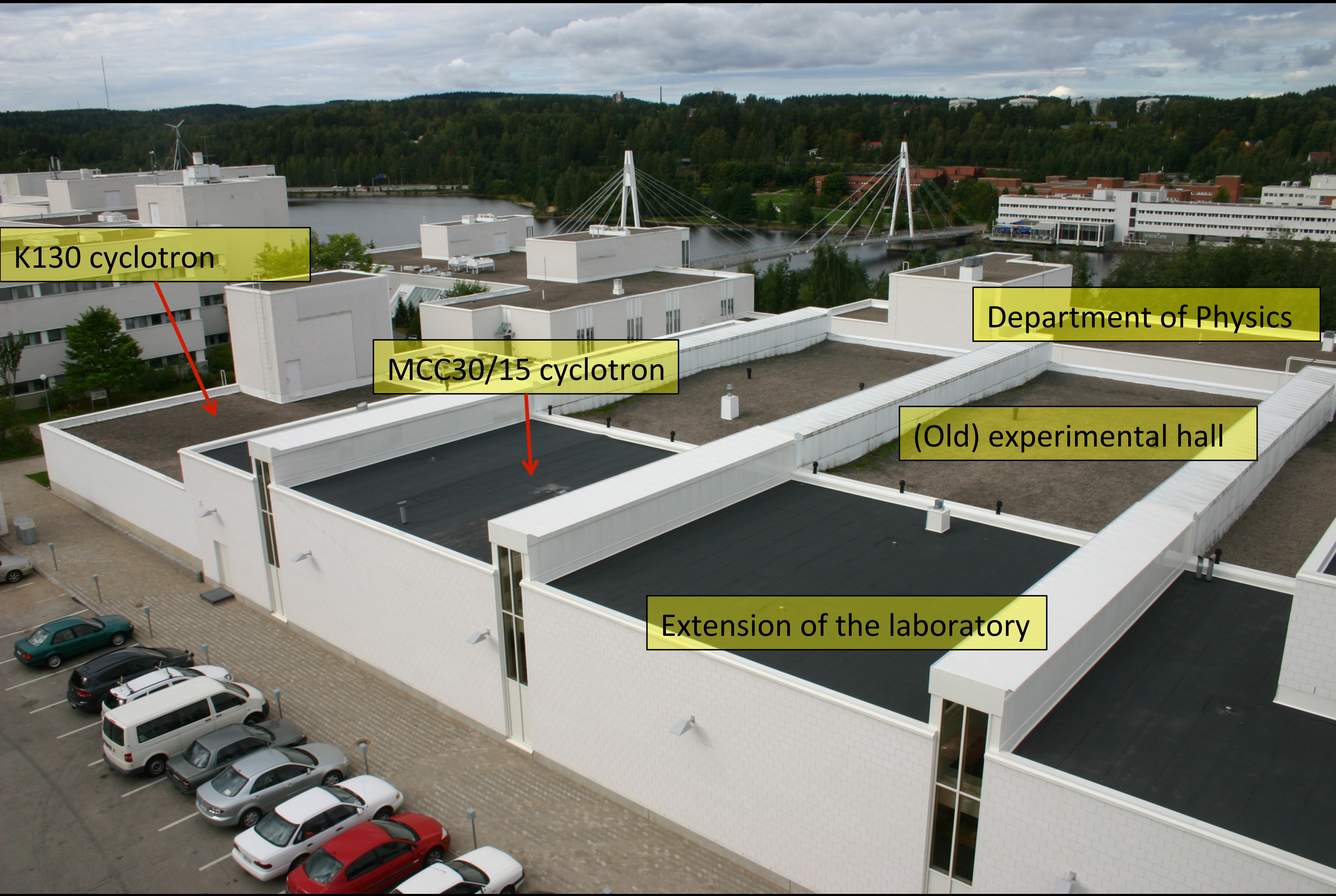
NuPECC Long Range plan 2010



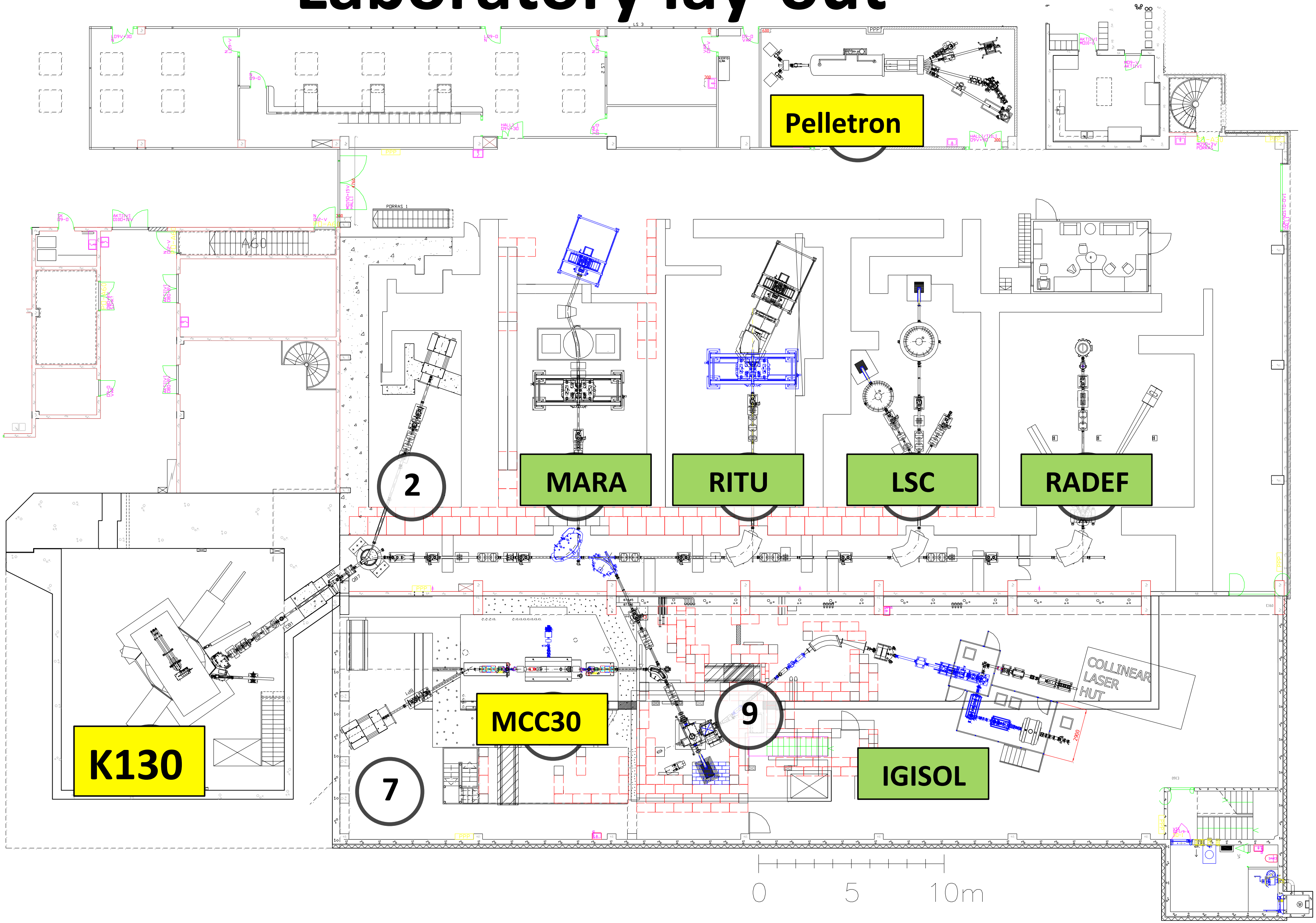
Current Nuclear Research Facilities in Europe.

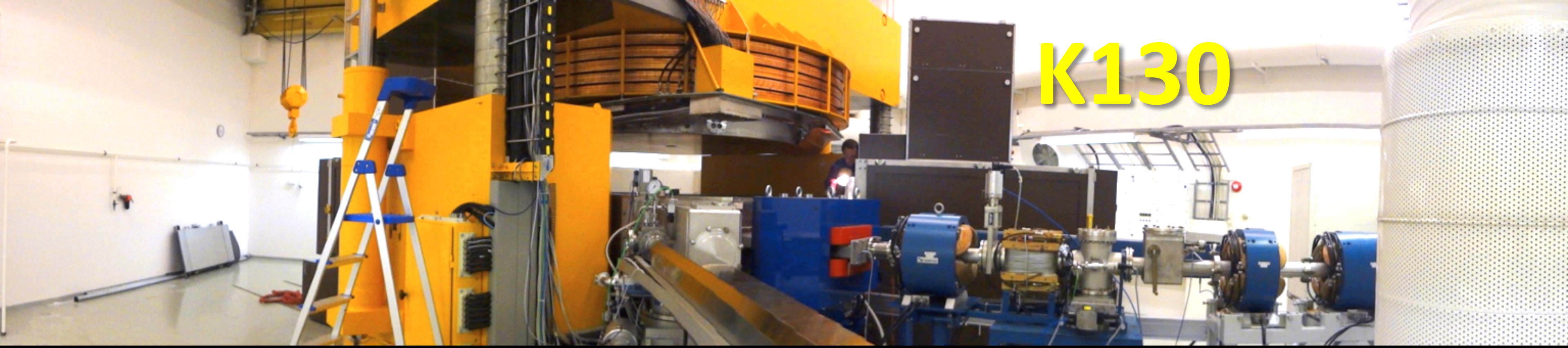

JYFL
Jyväskylä
Kortesuo
Kortepohja
Nisula
Tourula
Aittorinne
Kivistö
Halssila
Mäki-Matti
Savela
Kypärämäki
Jyväskylän Sokos
Jyväskylän Yliopisto
Lutakko
Rautpohja
Alvar Aalto Säätiö
Mattilanniemi
Mattilanpelto
Ainolanranta
Survo
Kekkola
Kuokkala
Sulkula
Kuokkalanpelto
Kukkumäki
Tarhamäki
Ristonmaa
Tikka
Jyväsjärvi
Vasikkalampi
Pohjanlampi
Kyllön sairaala
Keski-Suomen keskussairaala
Keskussairaala
Yrttisuon Perhepuisto
Map
Traffic
1000 ft
500 m
Imagery ©2012 Cnes/Spot Image, DigitalGlobe, GeoEye, Map data ©2012 Google - Report a problem

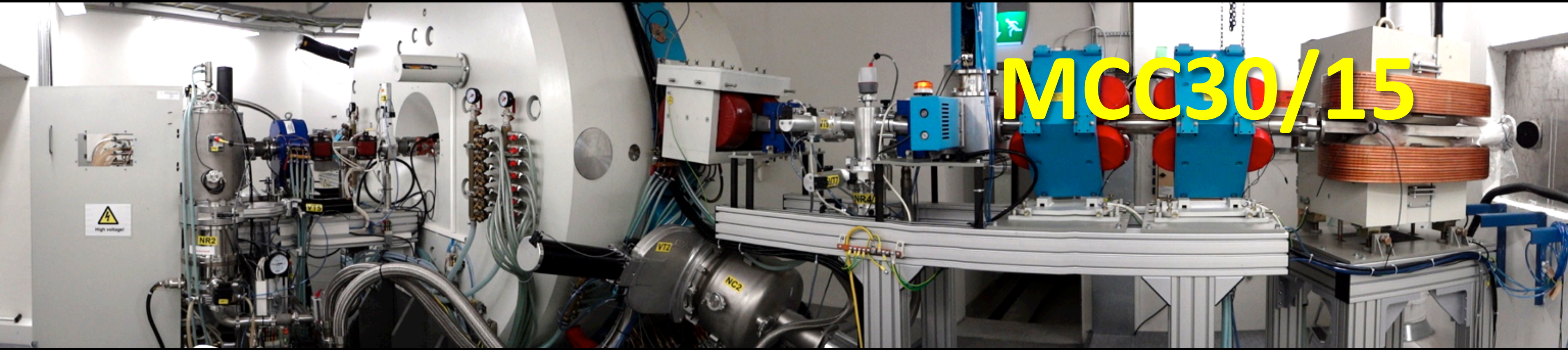
TIKKANOSTOT
Nanoscience Center
© 2012 Google
Report a problem
Image Date: August 2009


K130 cyclotron
MCC30/15 cyclotron
Department of Physics
(Old) experimental hall
Extension of the laboratory

Laboratory lay-out



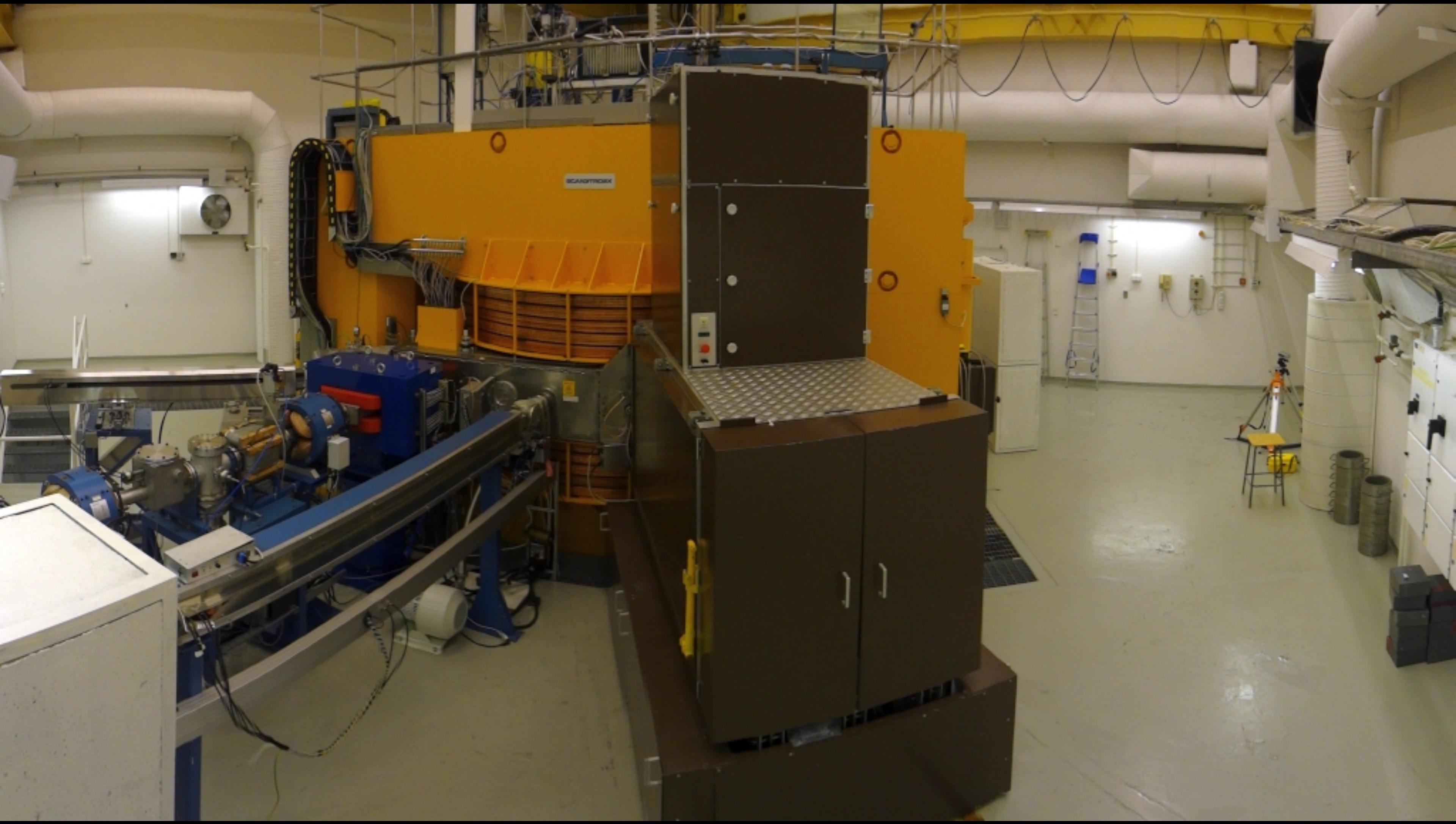

K130


MCC30/15

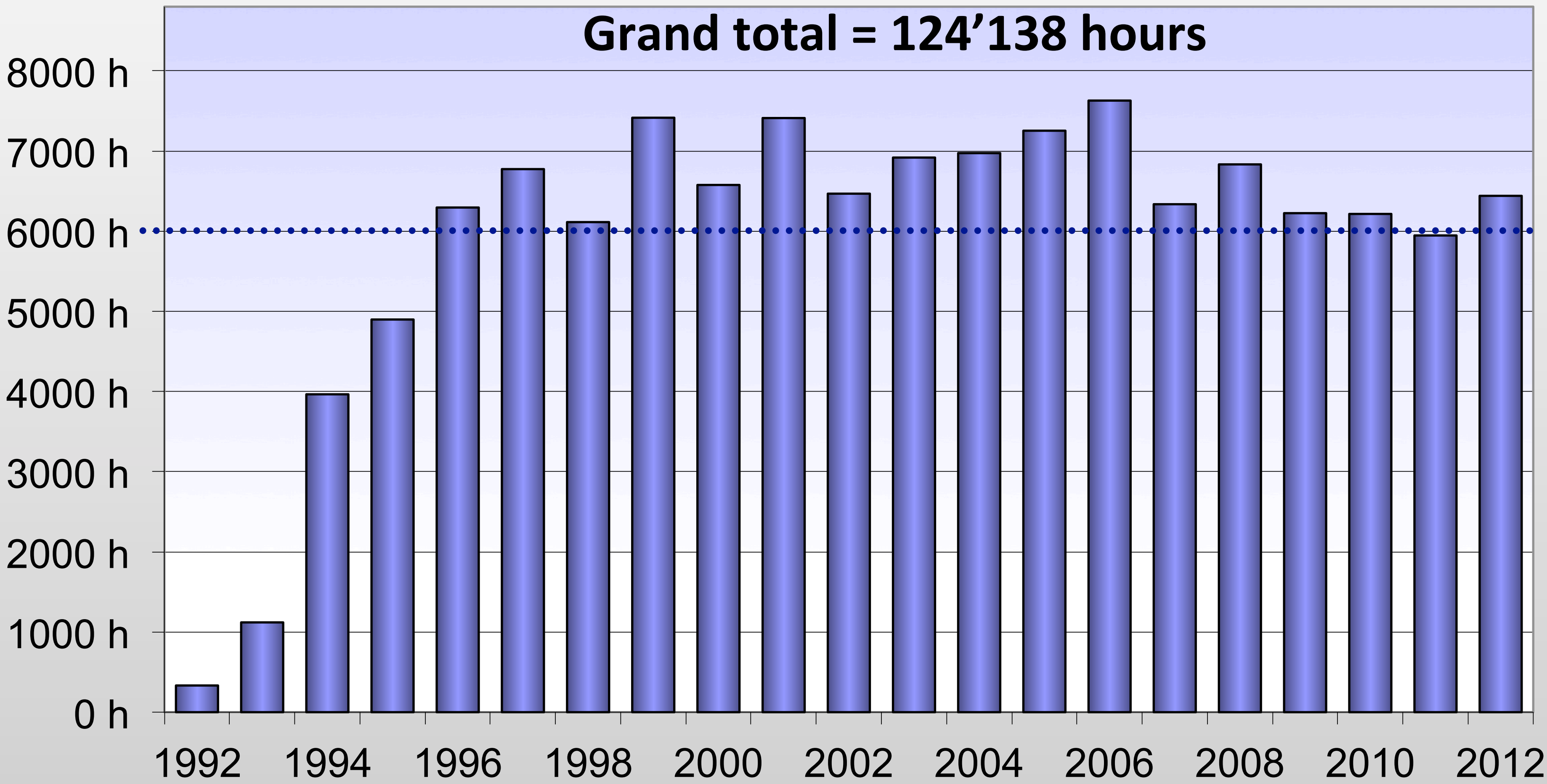

Pelletron
(1.7 MV)

Electron Linac for radiation damage tests

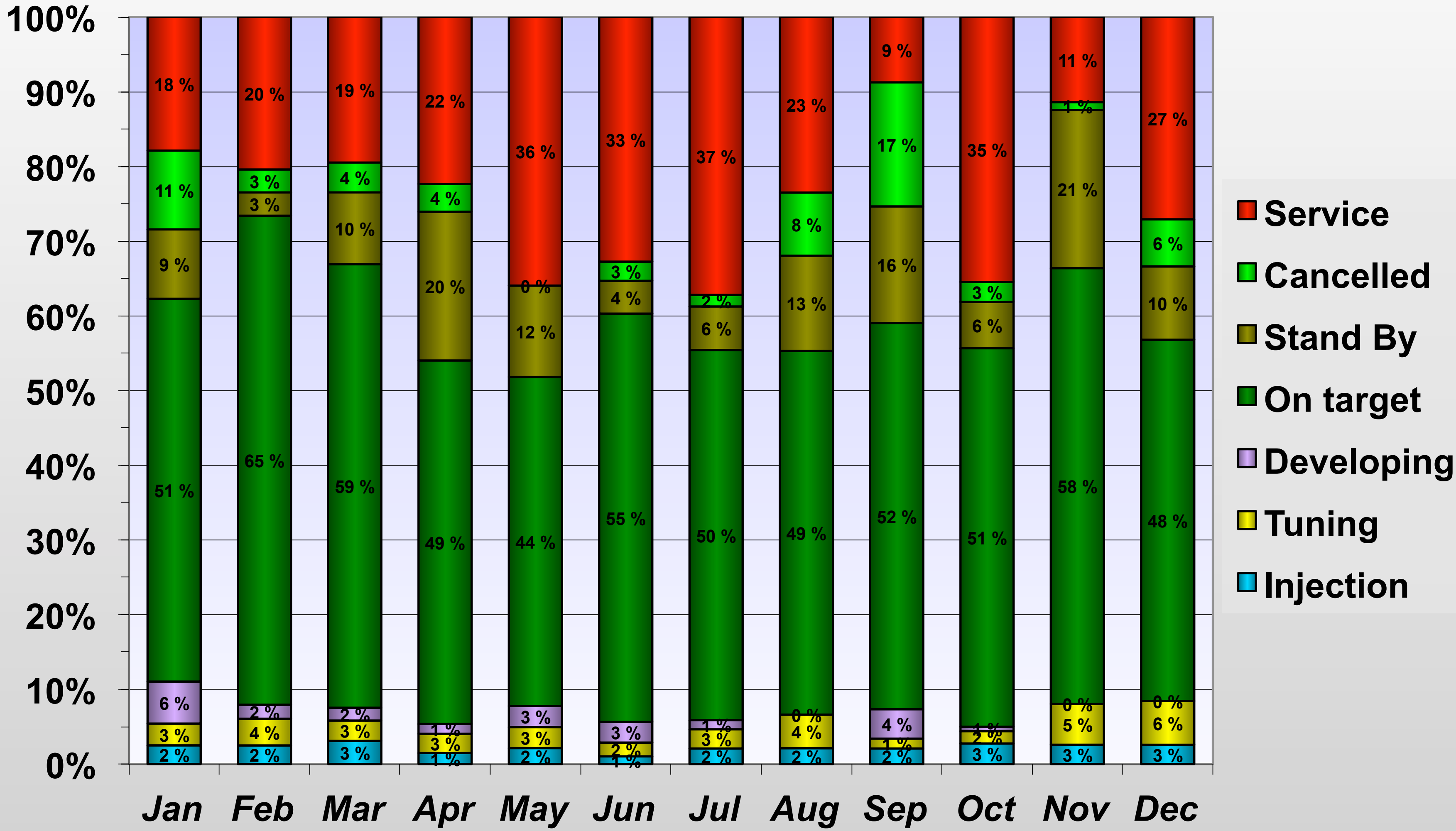
K130 Cyclotron



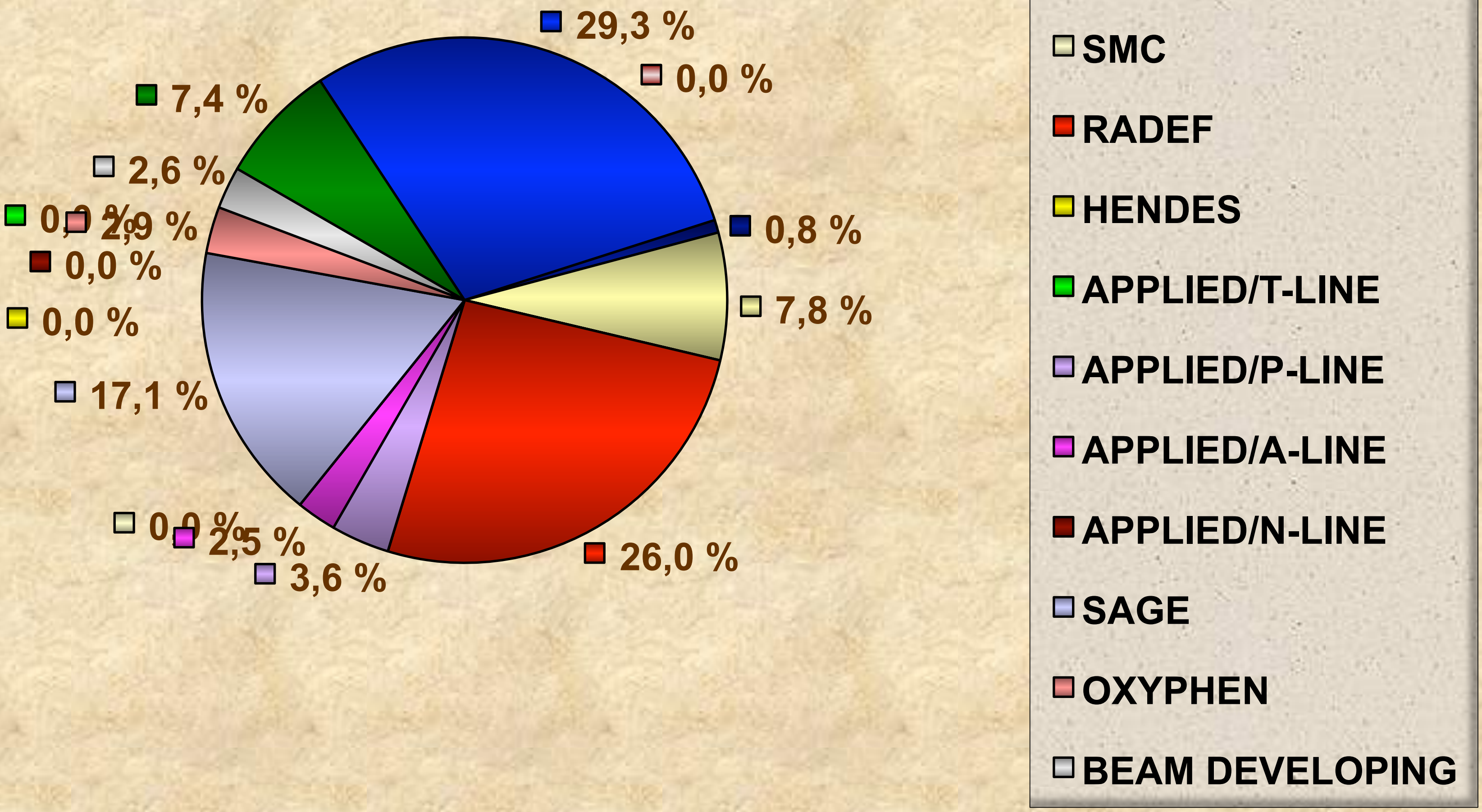
Operation of the Jyväskylä Cyclotron



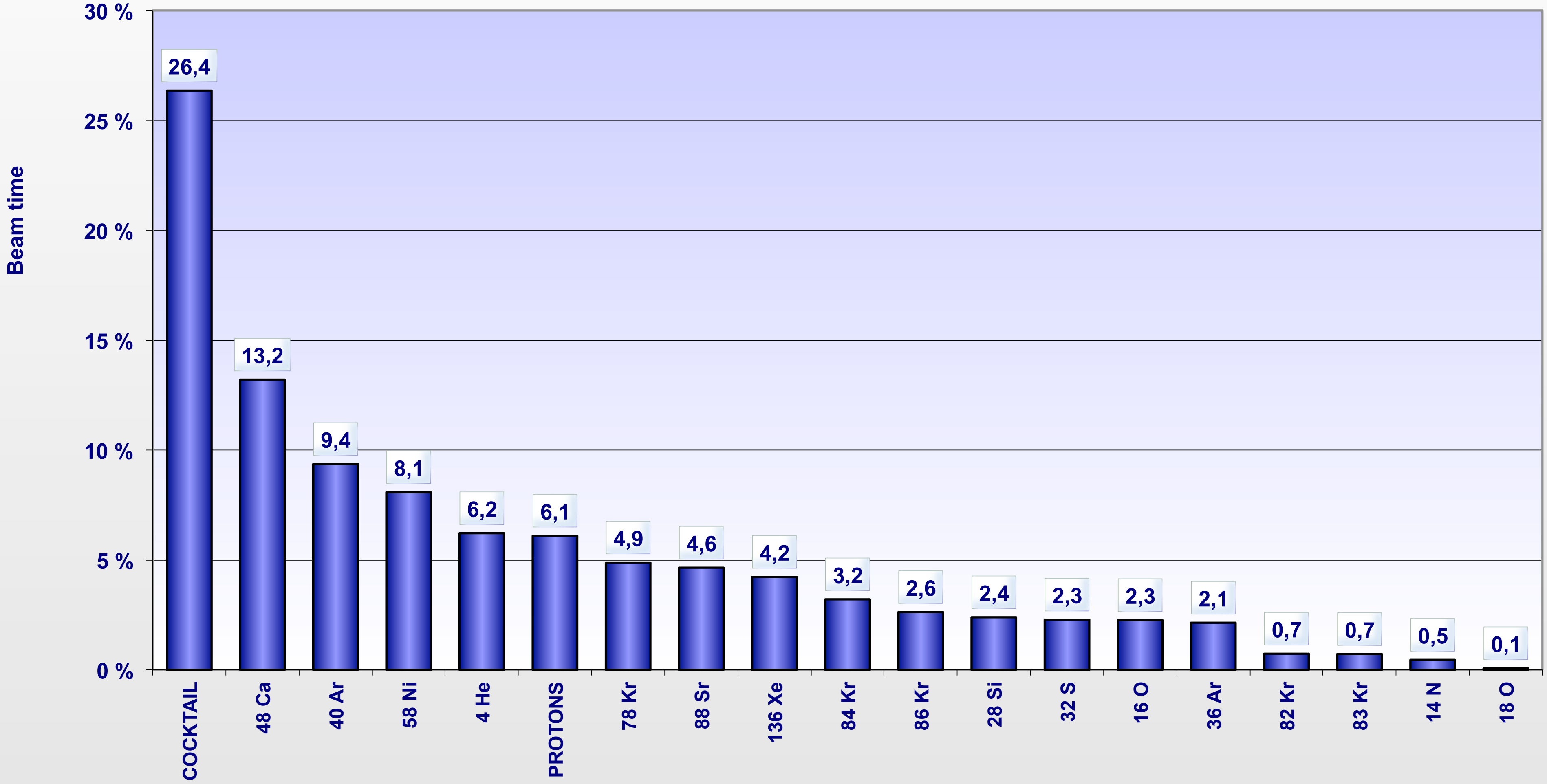
Monthly Use in 2012



Beam Users in 2012 (Total Hours)



Accelerated Ions in 2012 (All)



K130 - Accelerated ions 1992 – 2013 (highest energy shown)

32 elements

$_1$H			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
H -	62	62.1	
H+	80	80.0	Last used in 1995.
d -	55	27.5	
d +	65	32.5	

$_2$He			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
3 He 2+	100	33.0	
4 He 2+	120	29.9	

$_6$C			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
12 C 5+	240	19.9	
13 C 5+	250	19.2	

$_7$N			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
14 N 6+	310	22.1	
15 N 4+	300	19.9	

$_8$O			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
16 O 7+	330	20.6	
18 O 5+		10.3	

$_9$F			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
19 F 4+	105	5.5	

$_{10}$Ne			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
20 Ne 8+	400	19.9	
22 Ne 6+	223	10.1	

$_{12}$Mg			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
26 Mg 6+	140	5.4	

$_{13}$Al			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
27 Al 6+	133	4.9	

$_{14}$Si			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
28 Si 9+	353	12.6	
30 Si 7+	148	4.9	

$_{16}$S			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
32 S 9+	280	8.7	
33 S 5+	89	2.7	
34 S 7+	160	4.7	
36 S 8+	243	6.7	

$_{18}$Ar			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
36 Ar 9+	230	6.4	
40 Ar 12+	451	11.2	

$_{20}$Ca			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
40 Ca 9+	260	6.5	
42 Ca 9+	213	5.1	
44 Ca 9+	227	5.1	
48 Ca 10+	240	5.0	

$_{22}$Ti			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
46 Ti 9+	207	4.5	
47 Ti 9+	226	4.8	
48 Ti 11+	251	5.2	
49 Ti 10+	227	4.6	
50 Ti 11+	245	4.9	

$_{23}$V			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
51 V 10+	232	4.5	

$_{24}$Cr			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
52 Cr 10+	257	4.9	

$_{25}$Mn			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
55 Mn 12+	255	54.9	

$_{26}$Fe			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
54 Fe 12+	315	5.8	
56 Fe 11+	278	5.0	
56 Fe 15+		*9.3*	*Low intensity.*

$_{28}$Ni			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
58 Ni 12+	340	5.9	
60 Ni 13+	315	5.2	
61 Ni 13+	340	5.6	
64 Ni 14+	420	6.6	

$_{29}$Cu			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
63 Cu 13+	338	5.4	
65 Cu 15+	463	7.1	

$_{30}$Zn			
Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
64 Zn 14+	378	5.9	
66 Zn 13+	295	4.5	

$_{32}$Ge

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
72 Ge 12+	260	3.6	
74 Ge 13+	305	4.1	

$_{36}$Kr

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
78 Kr 17+	450	5.8	
82 Kr 16+	362	4.4	
82 Kr 22+		*9.3*	*Low intensity.*
83 Kr 16+	375	4.5	
84 Kr 20+	600	7.1	
84 Kr 22+	*781*	*9.3*	*Low intensity.*
86 Kr 20+	600	7.0	

$_{38}$Sr

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
84 Sr 16+	400	4.8	
86 Sr 17+	403	85.9	
88 Sr 16+	475	5.4	

$_{39}$Y

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
89 Y 23+	790	8.8	

$_{40}$Zr

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
90 Zr 17+	410	4.5	

$_{42}$Mo

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
98 Mo 19+	490	5.0	

$_{44}$Ru

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
102 Ru 19+	448	4.4	

$_{47}$Ag

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
107 Ag 21+	487	4.5	

$_{53}$I

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
127 I 23+	530	4.2	

$_{54}$Xe

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
128 Xe 23+	525	4.1	
129 Xe 25+	600	4.6	
129 Xe 37+		*7.4*	*Low intensity.*
130 Xe 23+	525	4.0	
131 Xe 27+	762	5.8	
131 Xe 35+		*9.3*	*Low intensity.*
132 Xe 22+	804	6.1	
136 Xe 30+	850	6.2	

$_{79}$Au

Ion	*E (MeV)*	*E (MeV/u)*	*Comments*
197 Au 38+	974	4.9	

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

Ion	Energy [MeV]	LET^{MEAS} @surface [MeV/mg/cm²]	LET^{MEAS} @Bragg peak [MeV/mg/cm²]	*LET^{SRIM} @surface [MeV/mg/cm²]*	*$Range^{SRIM}$ [microns]*	*LET^{SRIM} @Bragg peak [MeV/mg/cm²]*
$^{15}N^{+4}$	139	1.87	5.92 (@191 um)	*1.83*	*202*	*5.9 (@198 um)*
$^{20}Ne^{+6‡}$	186	3.68	9.41 (@138 um)	*3.63*	*146*	*9.0 (@139 um)*
$^{30}Si^{+8}$	278	6.74	13.7 (@114 um)	*6.40*	*130*	*14.0 (@120 um)*
$^{40}Ar^{+12‡}$	372	10.08	18.9 (@100 um)	*10.2*	*118*	*19.6 (@105 um)*
$^{56}Fe^{+15}$	523	18.84	29.7 (@75 um)	*18.5*	*97*	*29.3 (@77 um)*
$^{82}Kr^{+22}$	768	30.44	41.7 (@68 um)	*32.2*	*94*	*41.0 (@69 um)*
$^{131}Xe^{+35}$	1217	54.95	67.9 (@57 um)	*60.0**	*89**	*69.2 (@48 um)*

*Estimated values for 1.22GeV Xenon in Silicon

Towards(/back to) high intensities

1. Improve transmission from the ion source to the cyclotron
2. Improve the extraction efficiency from the cyclotron
    - Reason to decreased extraction efficiency was mainly ripple in RF voltage due to faulty electronics in phase control
        - Mainly solved
3. New 18 GHz RT/SC-ECRIS (plan)
    - New design based on MSU SUSI field configuration

Solutions to improve the transmission

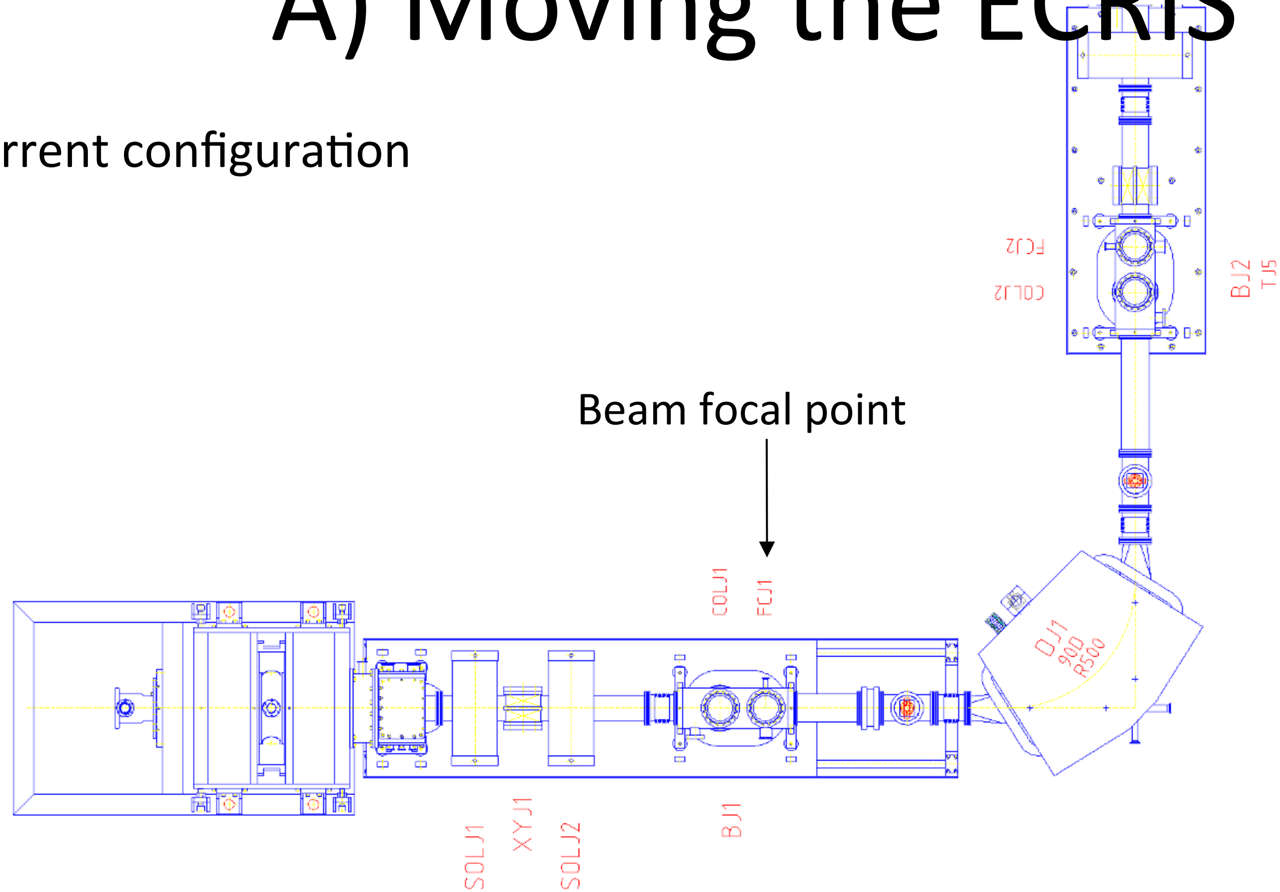
- Two different upgrades are proposed:

A) Minimization of the high space charge section by moving the ECRIS close to the dipole

B) Increasing the beam energy in the high space charge section by HV biasing this part of the beam line (increasing the ECRIS extraction voltage)

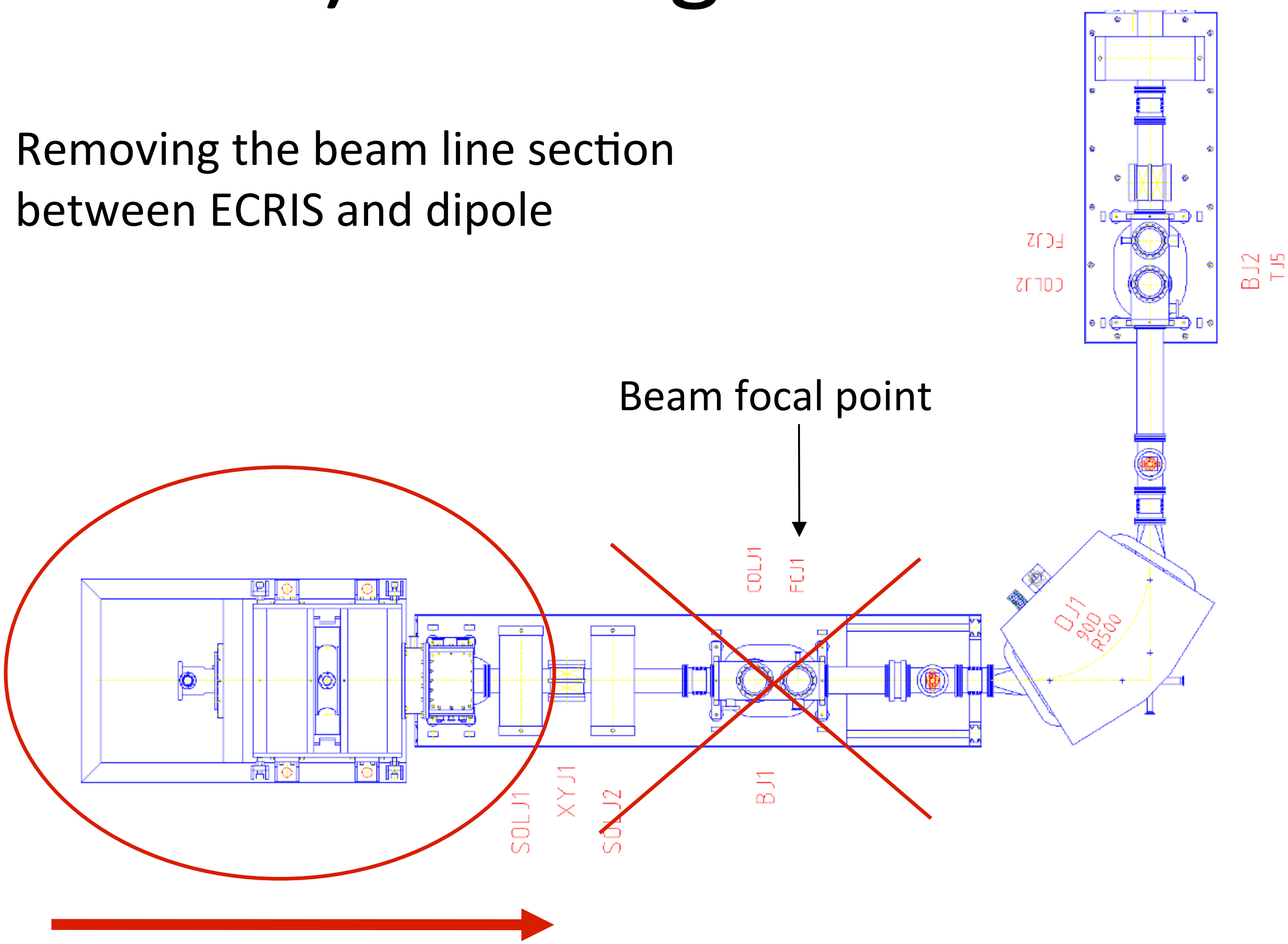
A) Moving the ECRIS

Current configuration

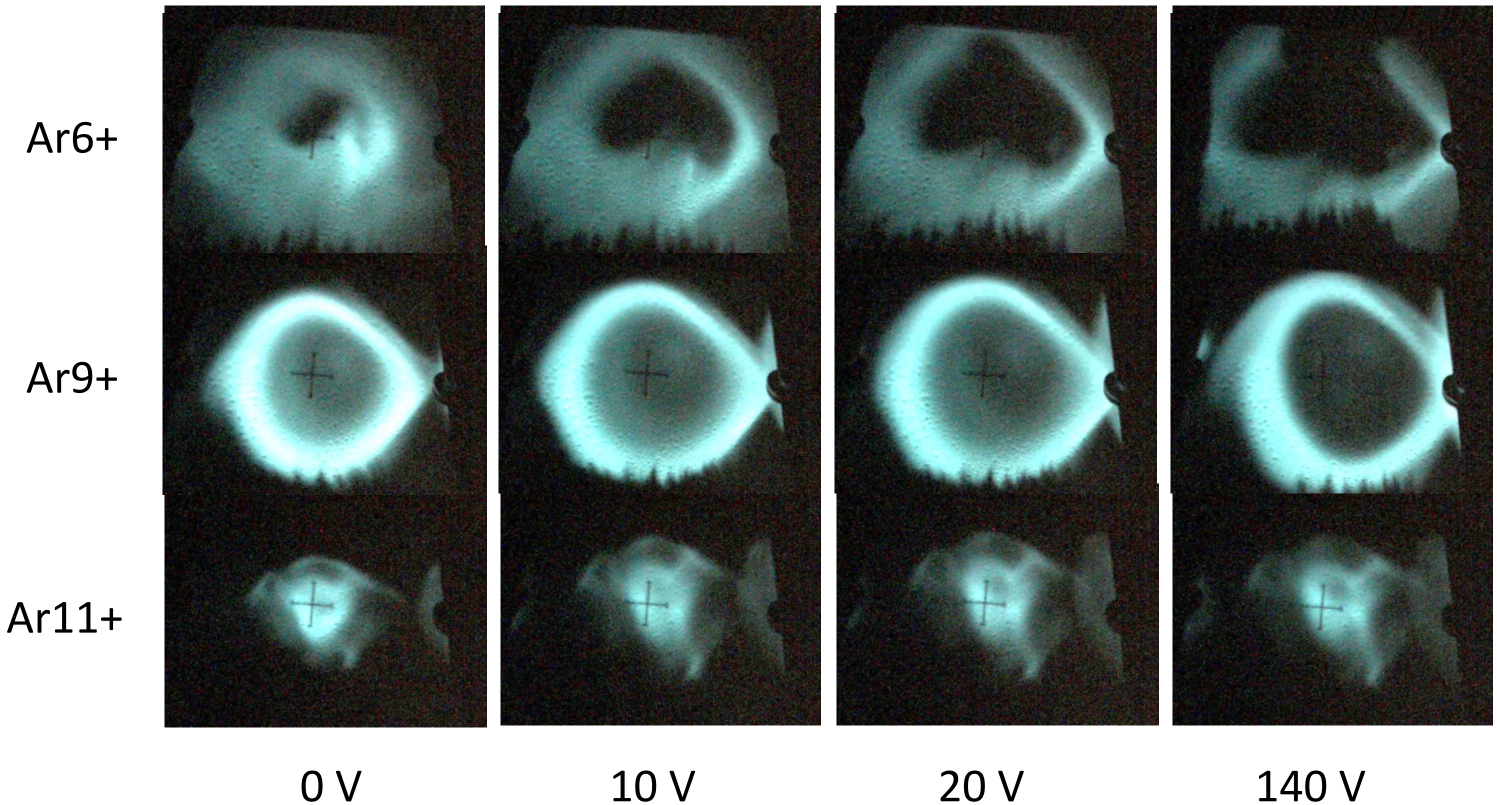


A) Moving the ECRIS

Removing the beam line section between ECRIS and dipole



Effect of removing electrons – beam profile



Hollowness caused by magnetic focusing induced ion species interactions (multiple focal points, “beam-inside-beam”)

Space charge affects also non-hollow beams (e.g. Ar11+)

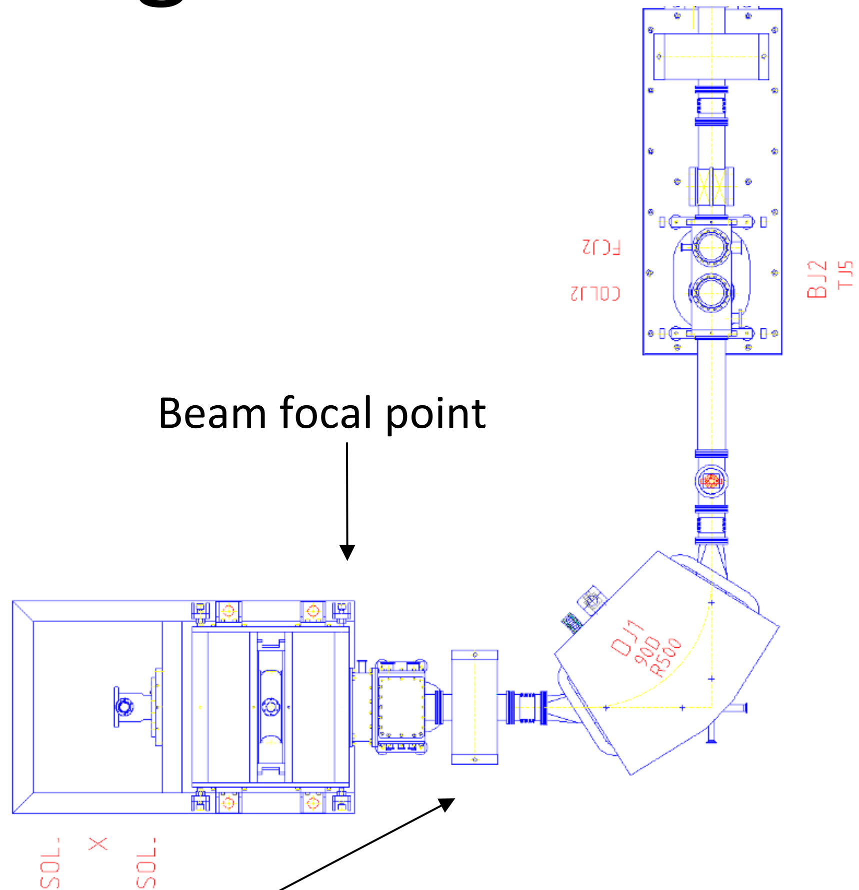
A) Moving the ECRIS

New position

High space charge section minimized

Beam focal point

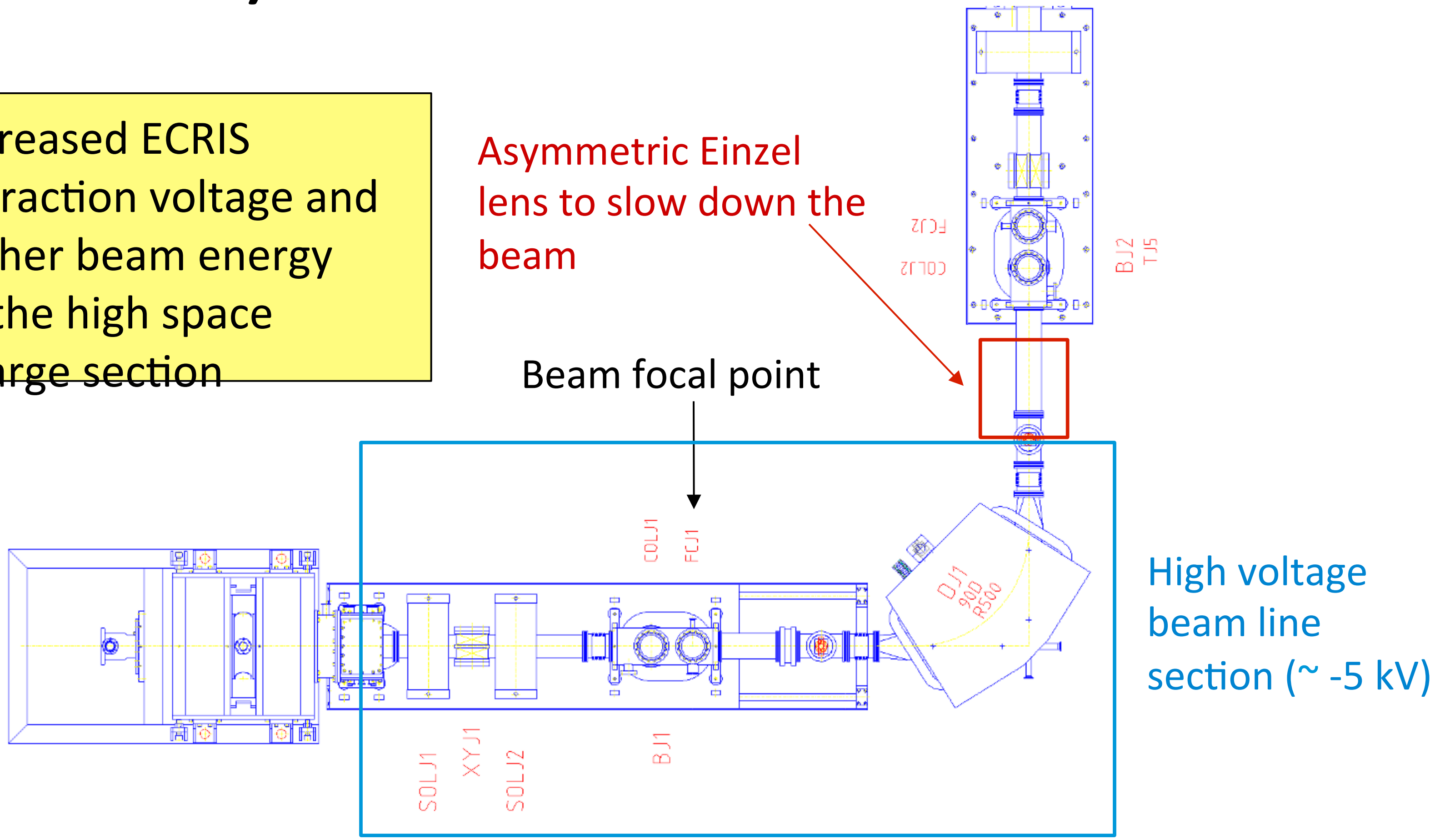
ECRIS on rails in order to be able to open the extraction



Glazer solenoid for ion optical fine tuning (match the focal point(s)). No beam waists between ECRIS and dipole

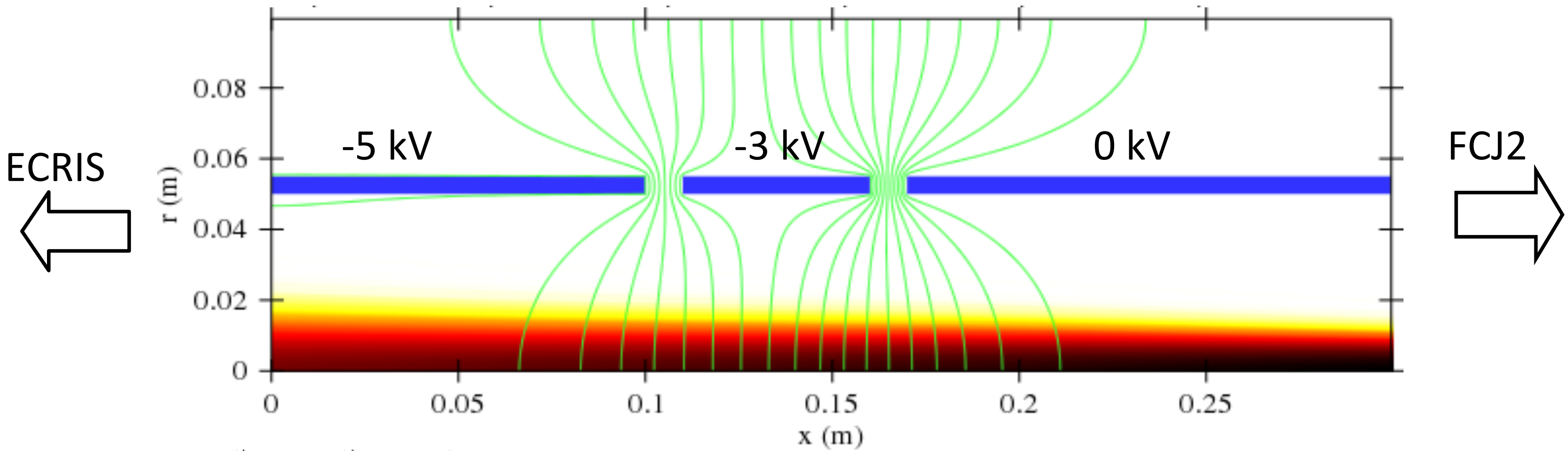
B) HV biased beam line

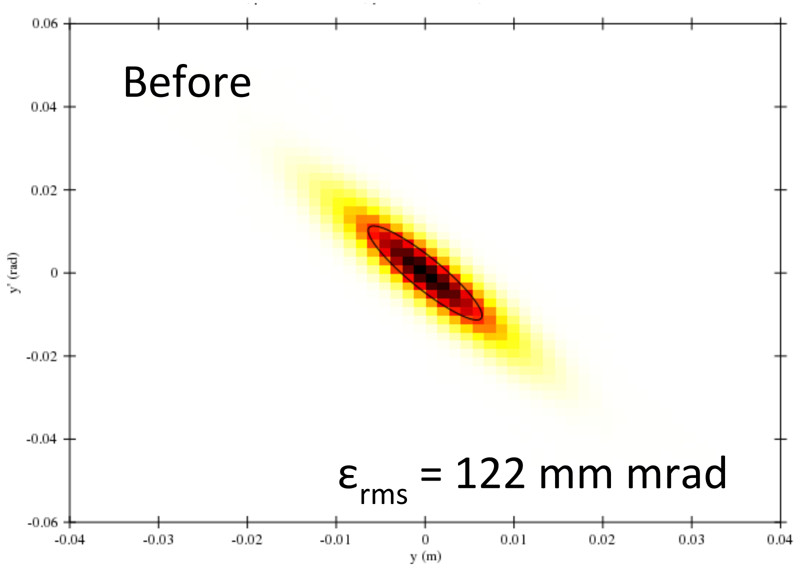
Increased ECRIS extraction voltage and higher beam energy at the high space charge section

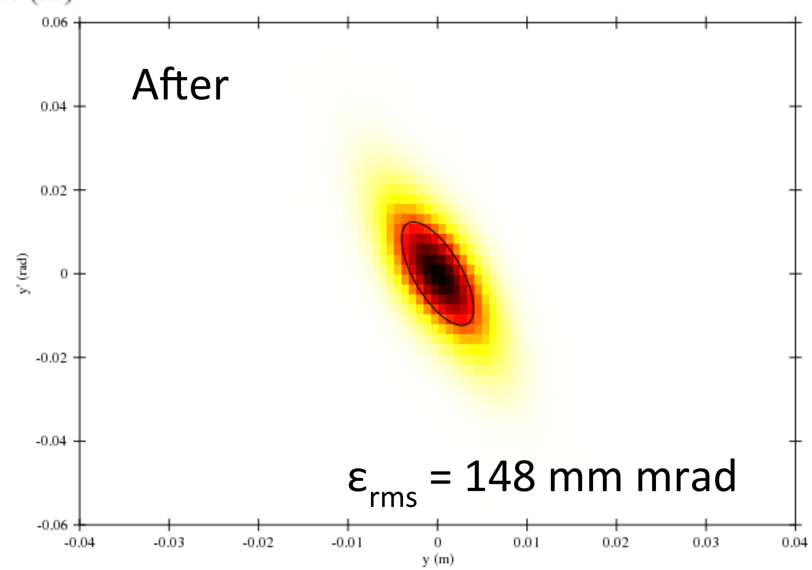


Slowing down the beam

Simple Einzel lens simulation







Both upgrades

- Upgrades are cumulative
  - Both offer improvement to current situation
- Can be done in phases
  - Flexible realization
  - Downtime in shorter periods
- Proposed: first ECRIS moved, later HV biasing applied to the beam line (biasing easier to do after moving the ECRIS)

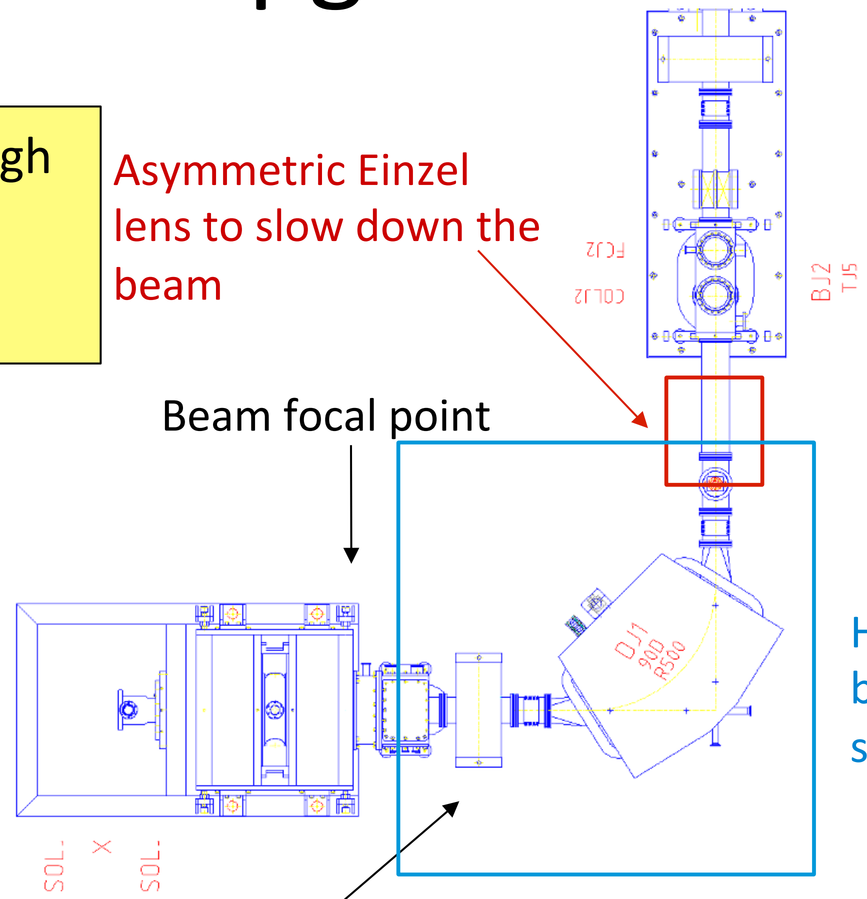
Both upgrades

Minimization of the high space charge section and HV biased beam line

Asymmetric Einzel lens to slow down the beam

Beam focal point

ECRIS on rails in order to be able to open the extraction

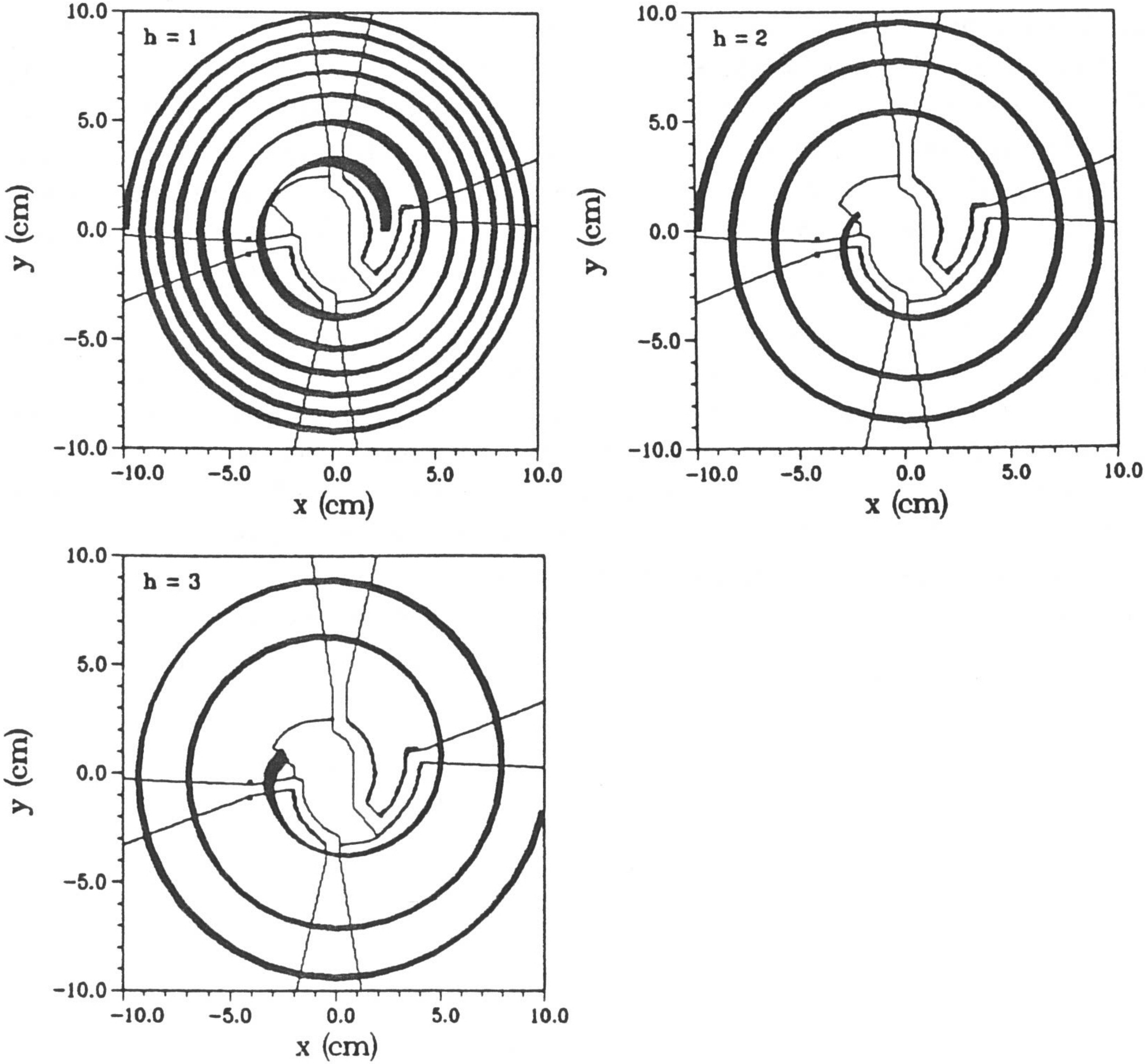


High voltage beam line section (~ -5 kV)

Glazer solenoid for ion optical fine tuning (match the focal point(s))

One more step?

- Slowing down the beam after q/m selection does not remove the possible space charge problem in the rest of the beam line
  - However, only one q/m left and the beam current very seldom exceeds the **space charge limit** (e.g. **1.3 mA for 6 keV proton** beam)
- If the space charge is a problem, increase the injection energy
  - **New central region and inflector** in the cyclotron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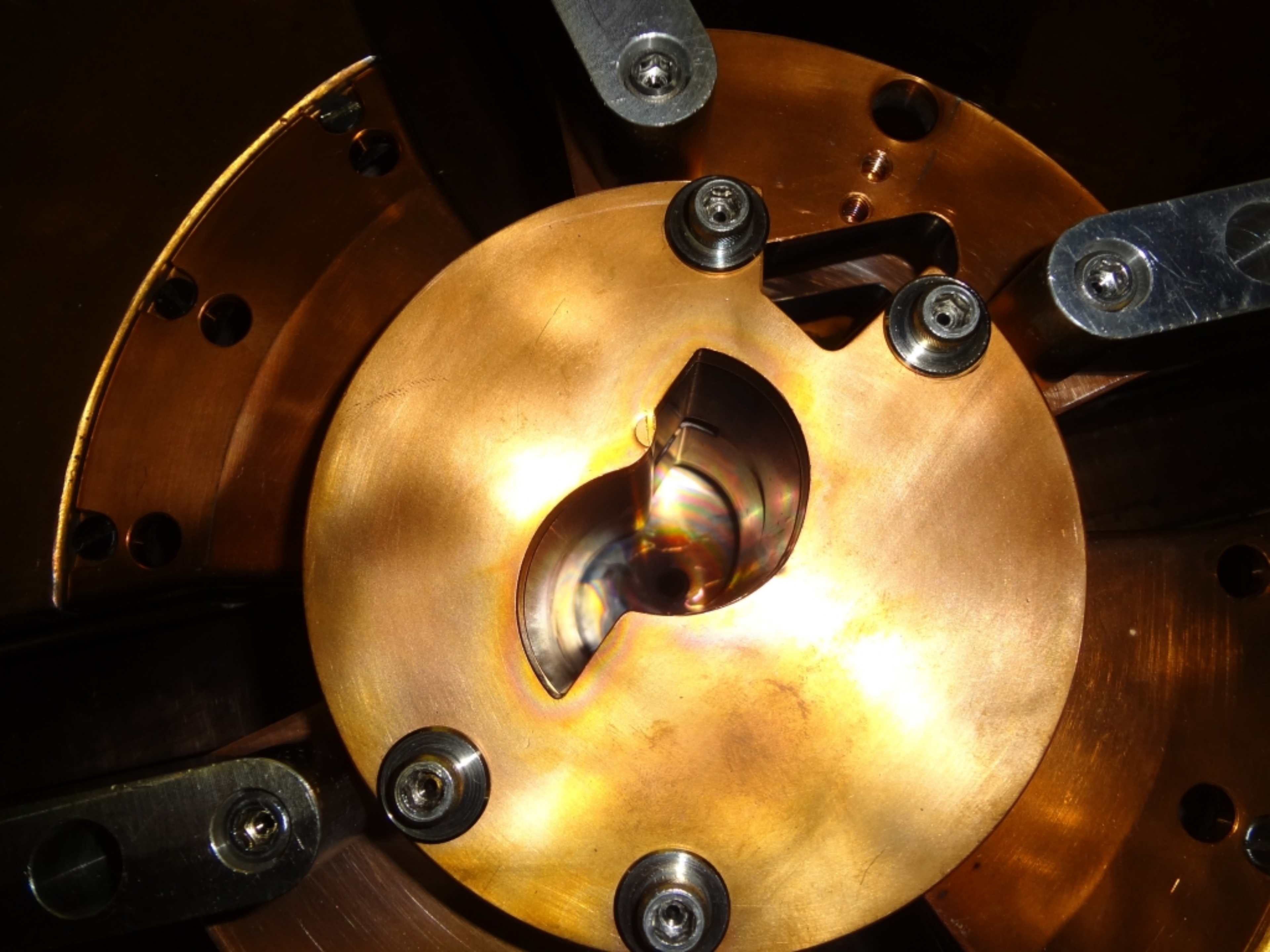
h = 2
h = 3
10.0
5.0
0.0
−5.0
−10.0
−10.0
−5.0
0.0
5.0
10.0
y (cm)
x (cm)



Future projects (International collaboration)

MIDAS: MInimization of Destructive plASma processes in ECRIS (ENSAR JRA)

- Coordinator: JYFL
- The focus is to increase the extracted current density of ions with mass over charge (M/q) ratio of 3-6, e.g. charge states 21-43 in the case of xenon
  - *the intensity of highly charged ion beams can be increased substantially by **minimizing the rate of charge exchange reactions***
  - *the intensities of the extracted beams can be increased by **influencing the ion losses towards the extraction***

Solid state RF amplifiers to replace RF-tubes

- The availability of conventional RF-tubes is foreseen to reduce in the future
- High power solid state amplifiers already in use for fixed frequency
- Development needed for a wide frequency range (e.g. 10 – 21 MHz)
  - *One commercial manufacturer at the moment*
  - *High development costs*
    - *Divide costs by several customers*
    - *R&D as international collaboration*