Intensity-Upgrade Plans of RIKEN RI-Beam Factory

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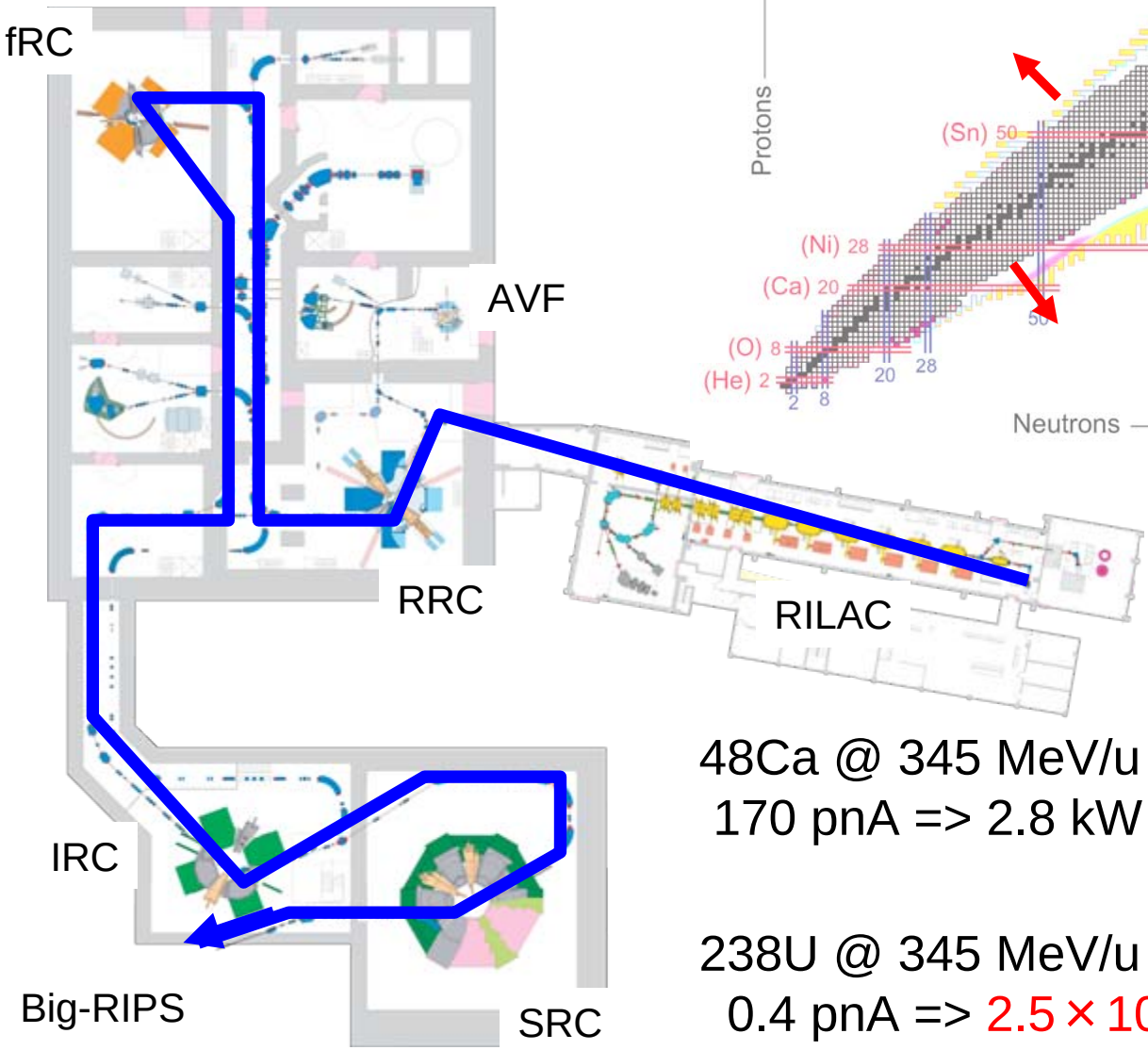
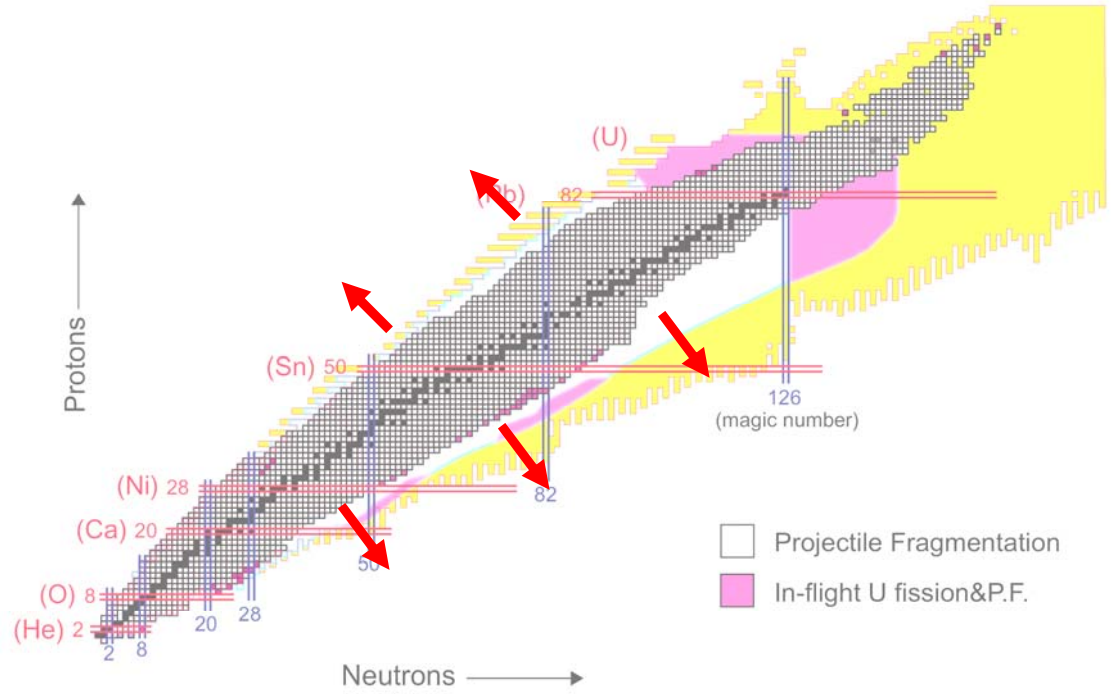
H. Fujisawa, N. Fukunishi, A. Goto, Y. Higurashi,
E. Ikezawa, M. Kase, T. Kageyama, M. Komiyama,
H. Kuboki, K. Kumagai, T. Maie, M. Nagase,
T. Nakagawa, J. Ohnishi, H. Okuno, N. Sakamoto,
Y. Sato, K. Suda, H. Watanabe, T. Watanabe,
Y. Watanabe, K. Yamada, H. Yamasawa, S. Yokouchi,
Y. Yano

Accelerator Group
RIKEN Nishina Center

Achievements in 2008





48Ca @ 345 MeV/u
170 pnA => 2.8 kW (CW) 1.1×10^{12}pps

238U @ 345 MeV/u
0.4 pnA => 2.5×10^{9}pps

0) Superconducting ECR ion source
   => Construction completed

Two-step plan to increase uranium (& xenon) beams

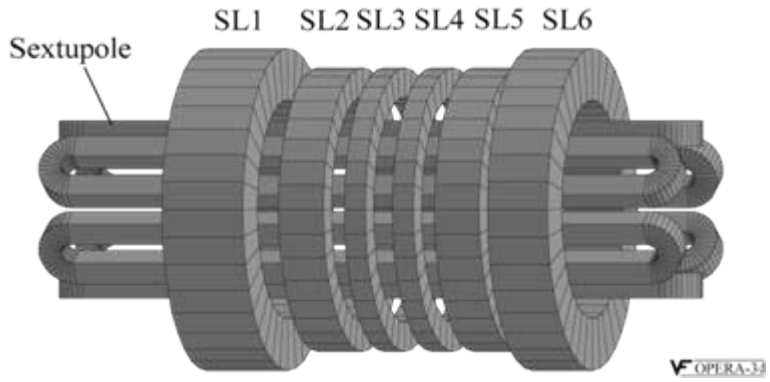
1) Build a new pre-injector for RILAC
   => SC-ECR on Cockcroft-Walton H. V. Terminal
   => will be operational in Oct. 2009

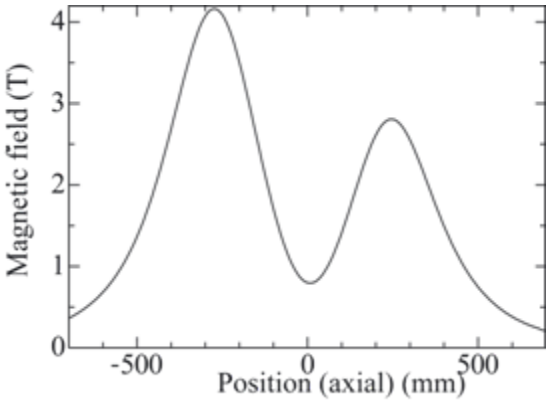
2) Build a new injector for RRC
   => SC-ECR + RFQ + DTL
   => independent operation of RILAC & RIBF
   => will be operational in FY2010

Superconducting ECR ion source

- Large plasma volume: 1100 cm^3
- Flat B_{min} configuration

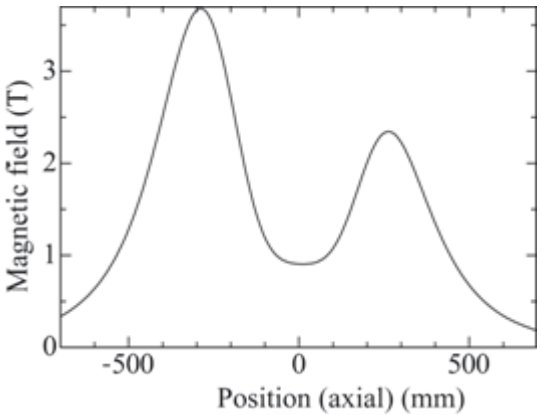
Construction started in Oct. 2007



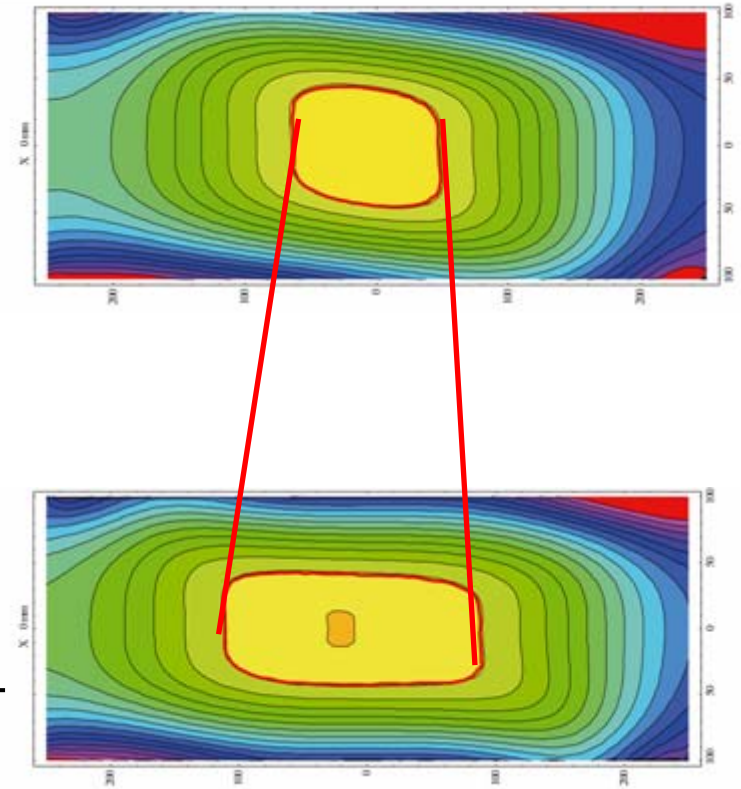


Classical B_{min}

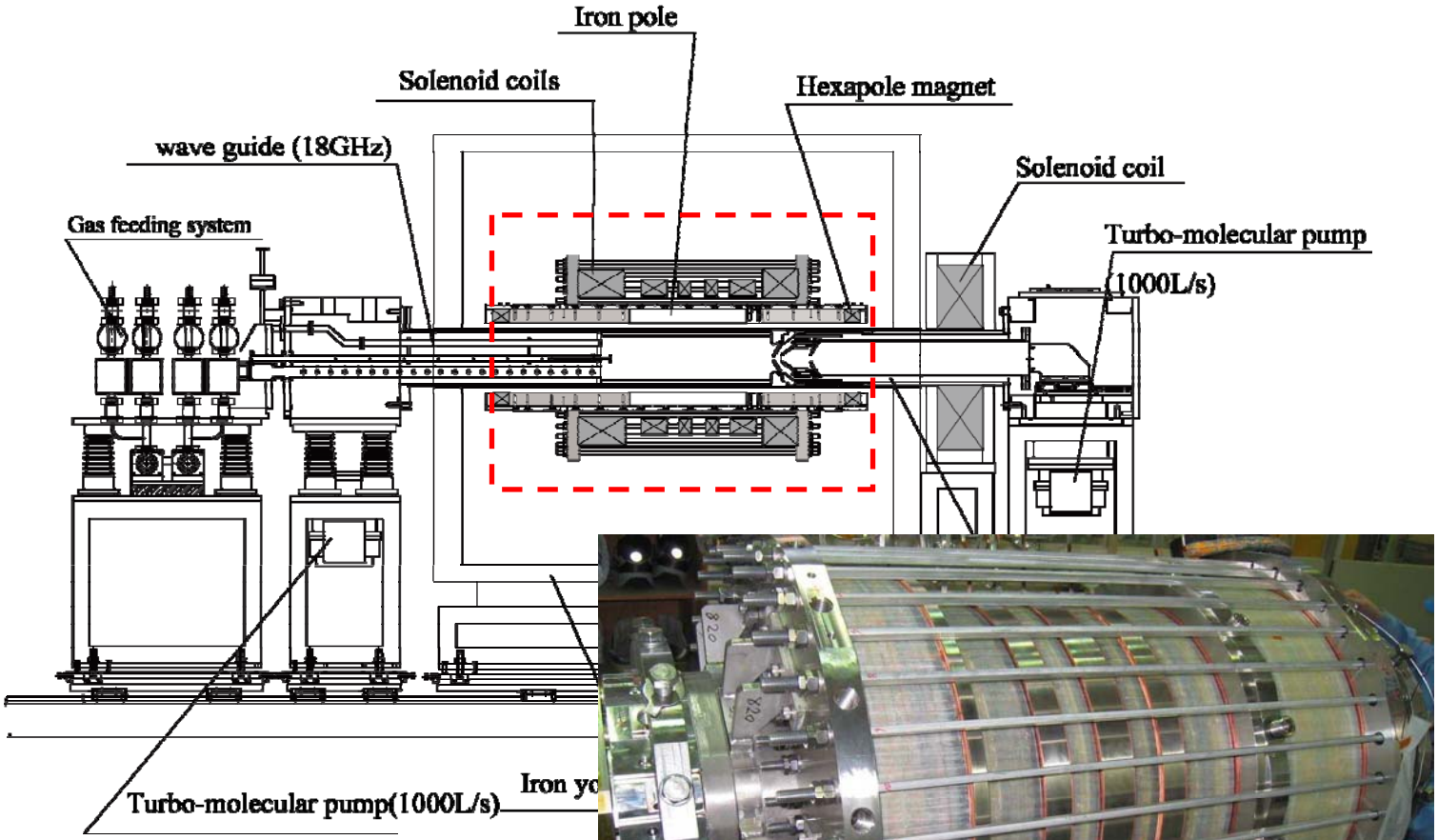
Flat B_{min}



Mirror Filed：3.8T/2.2T

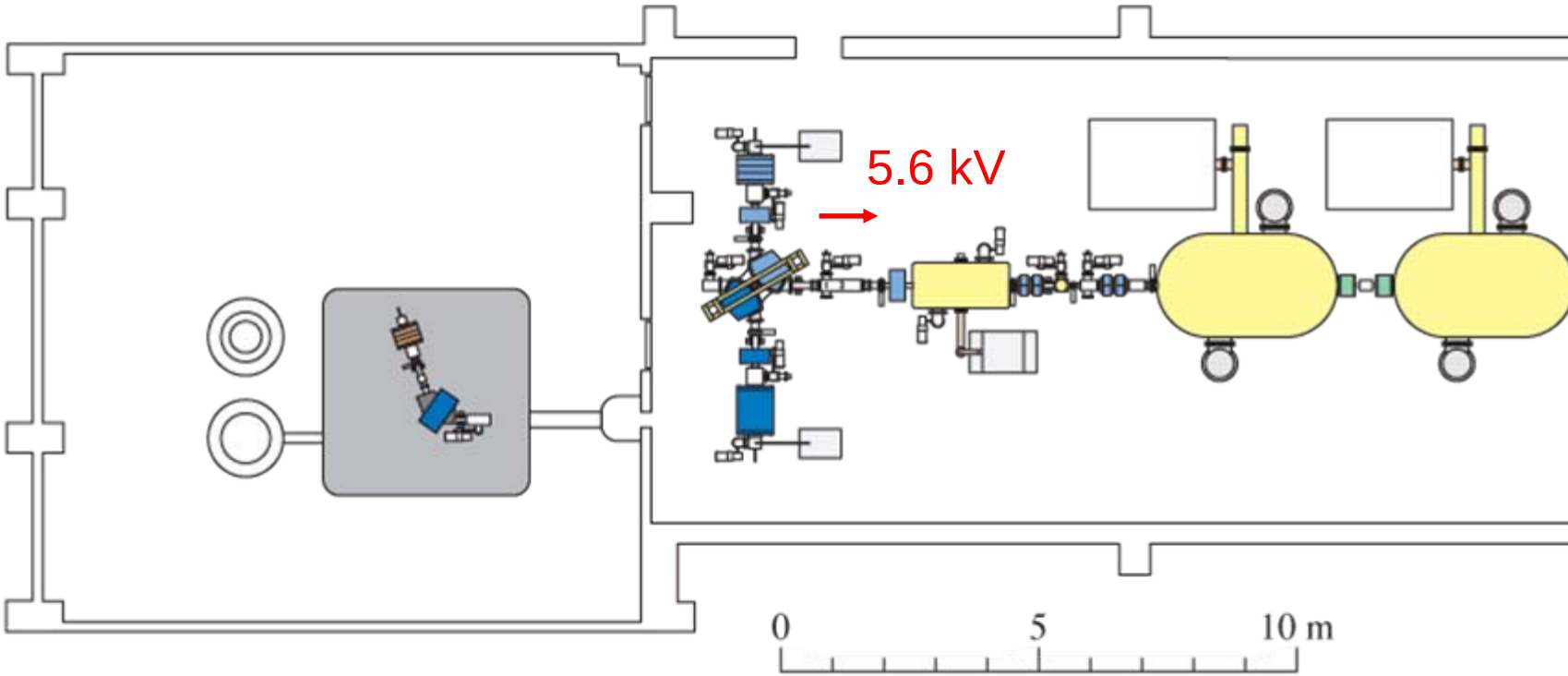


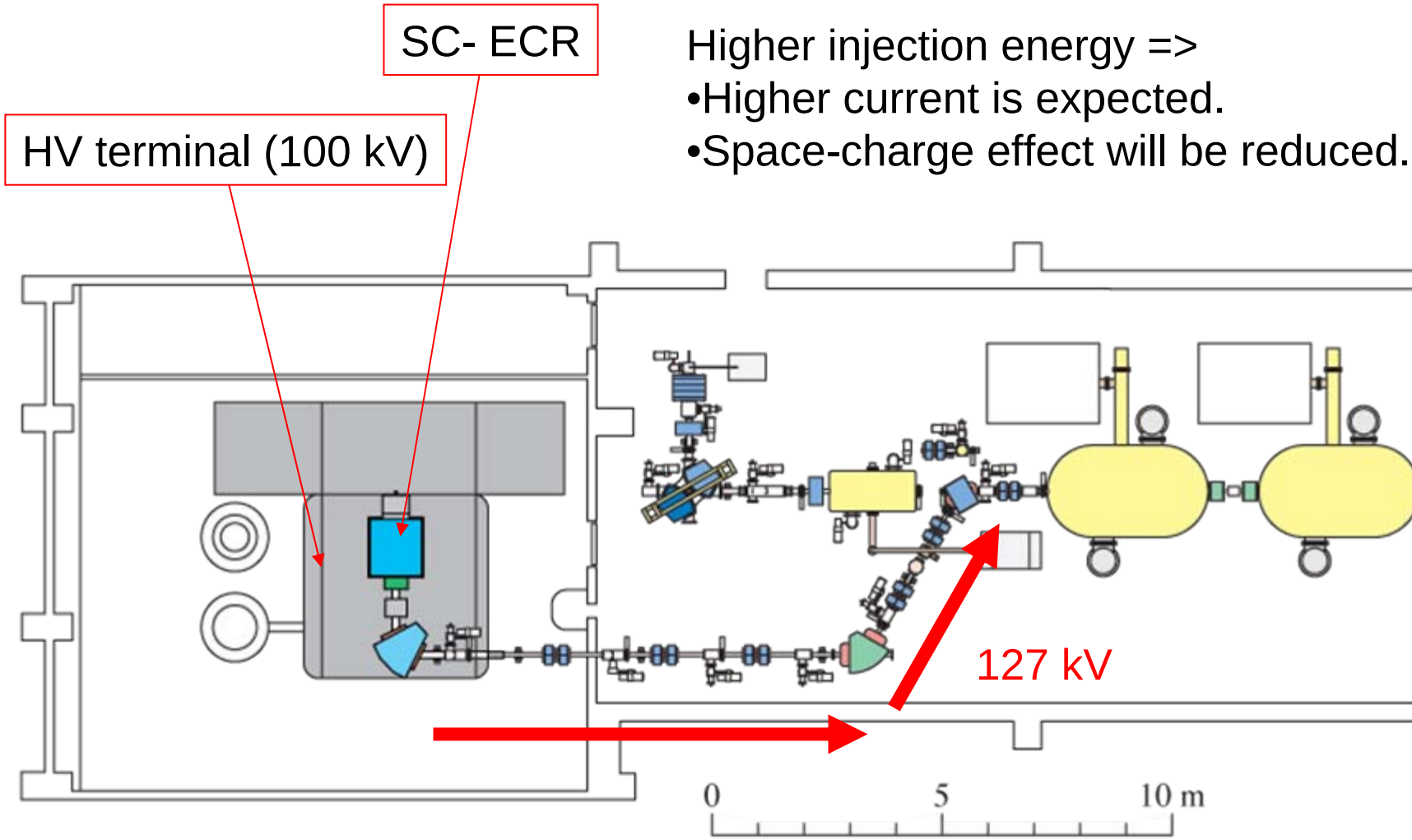
T. Nakagawa, ECRIS'08



- Stored Energy : 0.8MJ
- NbTi-copper conductor
- Bath-cooled in liquid helium

Successfully excited to the designed field in October 2008.


5.6 kV
0
5
10 m



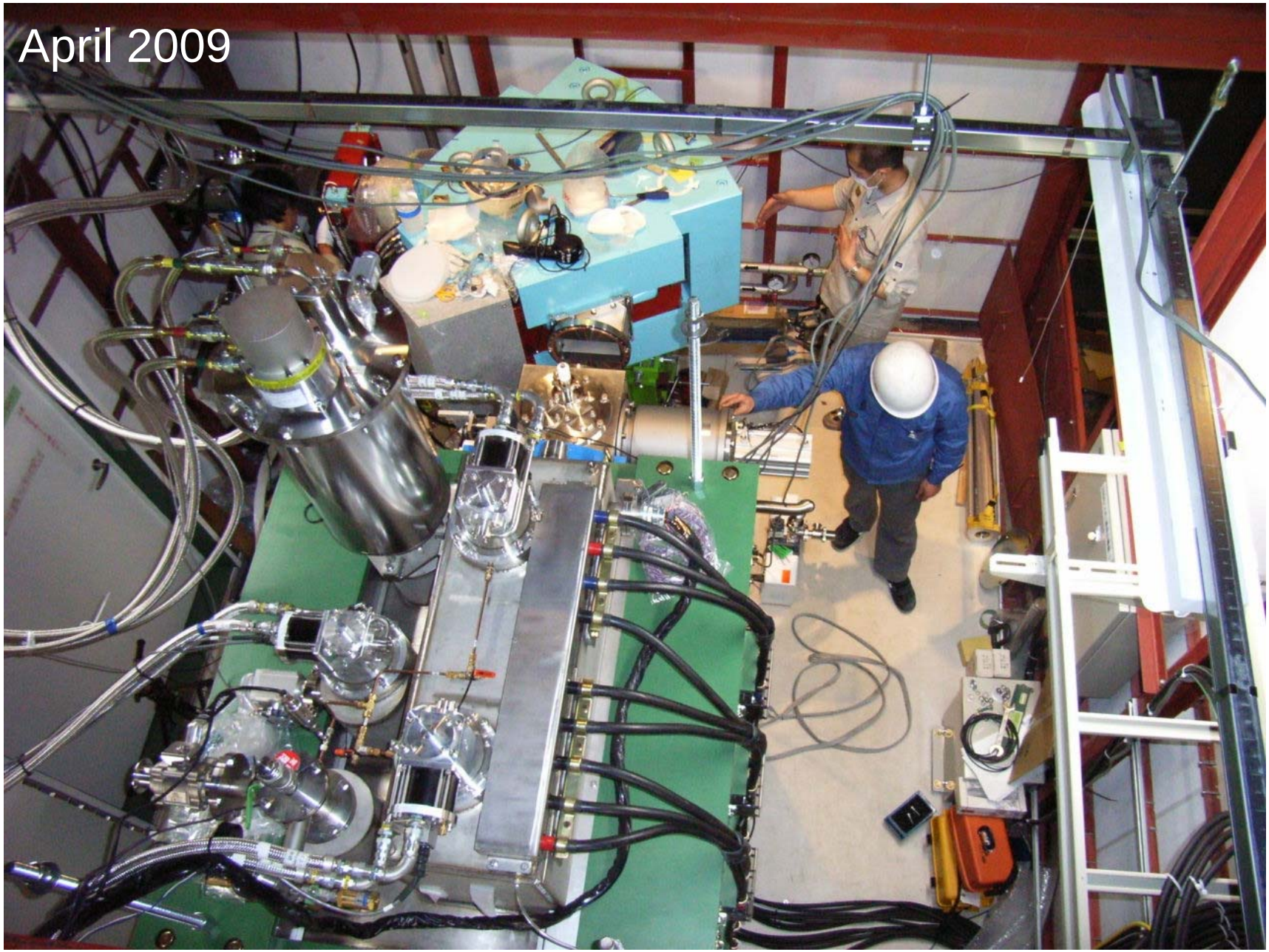
•Started with 18-GHz microwave source
=> 10 times U-beam expected

December 2008

J. Ohnishi

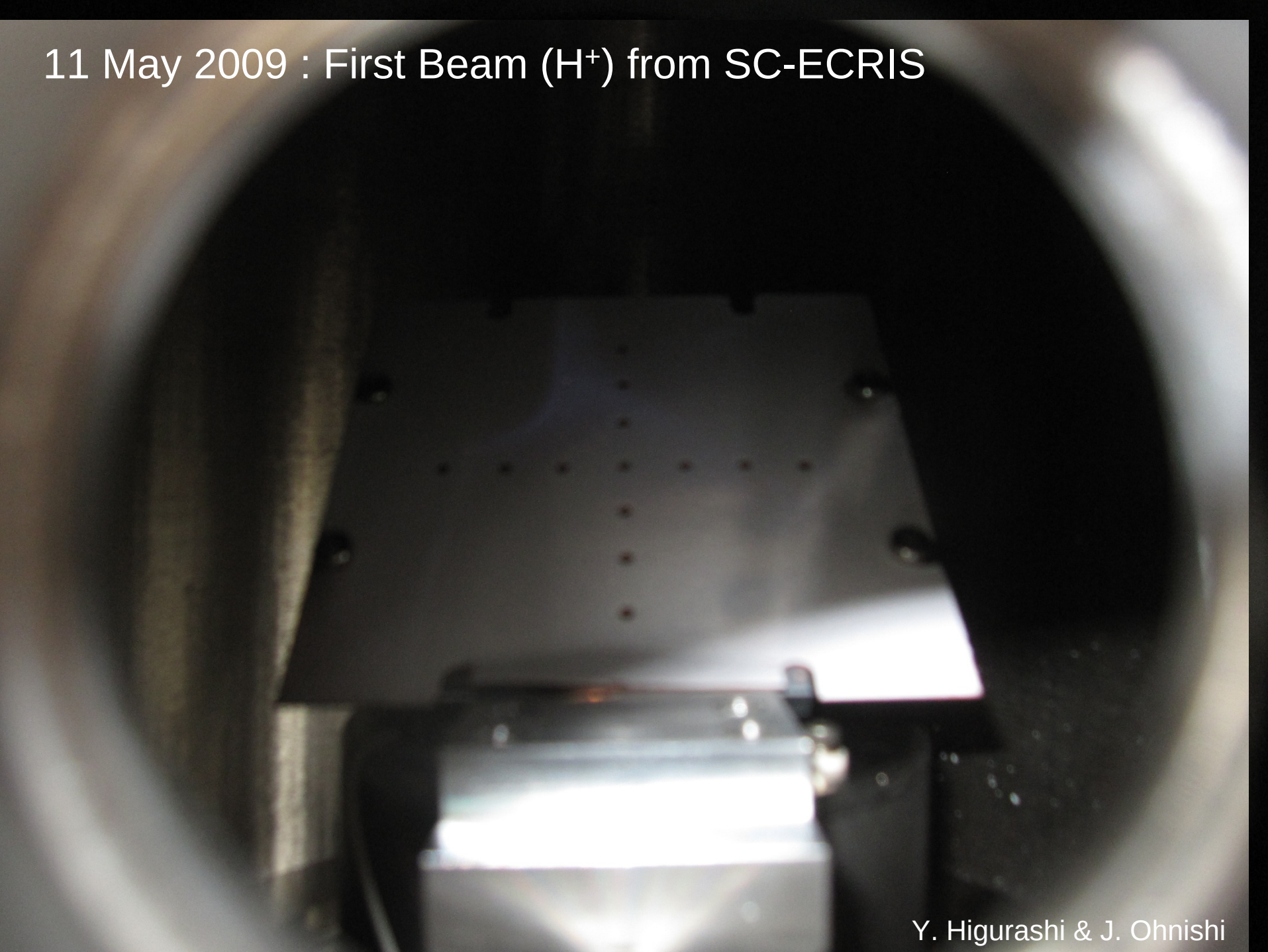
December 2008

J. Ohnishi



J. Ohnishi

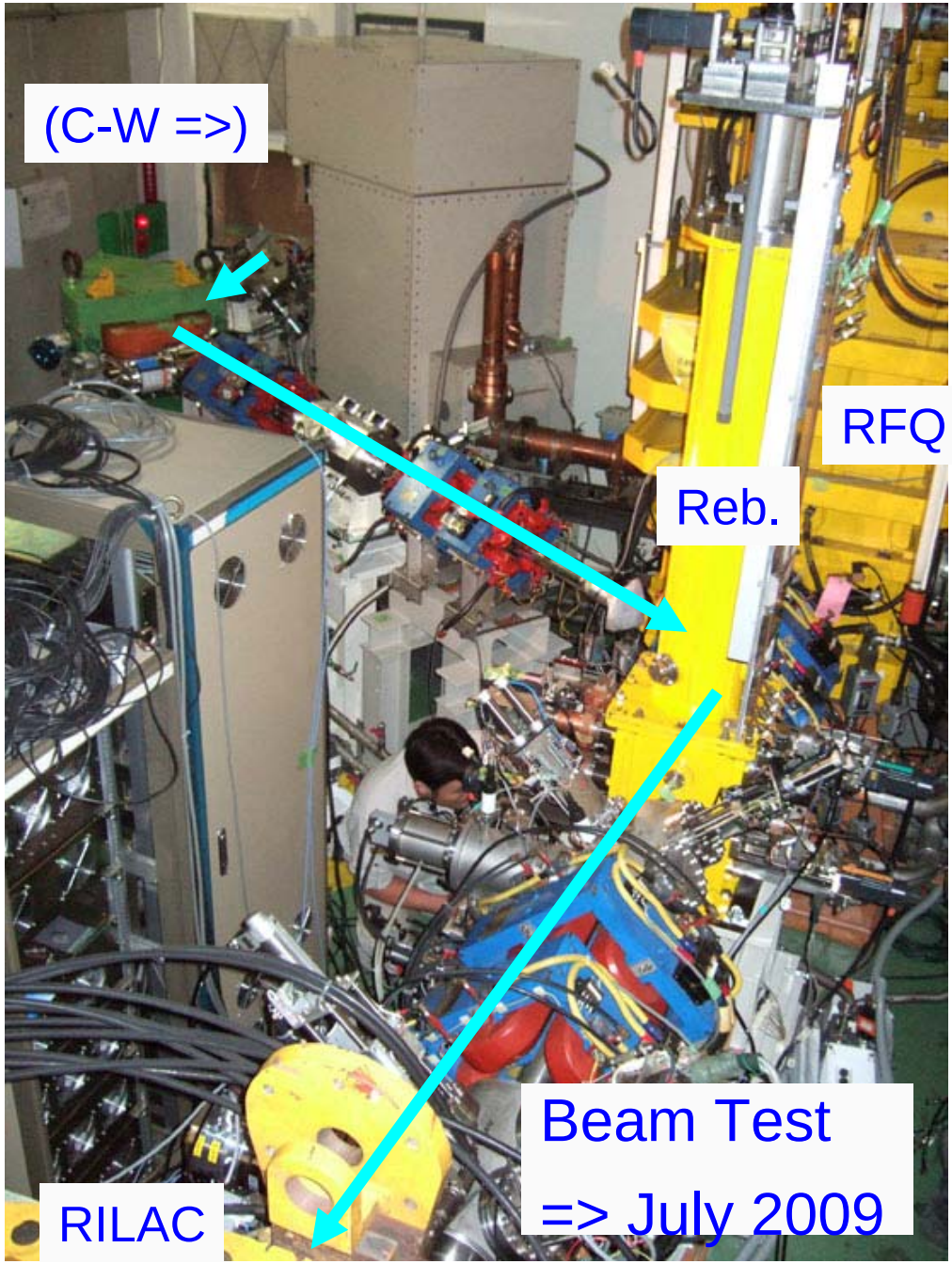
11 May 2009 : First Beam (H^+) from SC-ECRIS



Y. Higurashi & J. Ohnishi

Last Friday

MEBT line



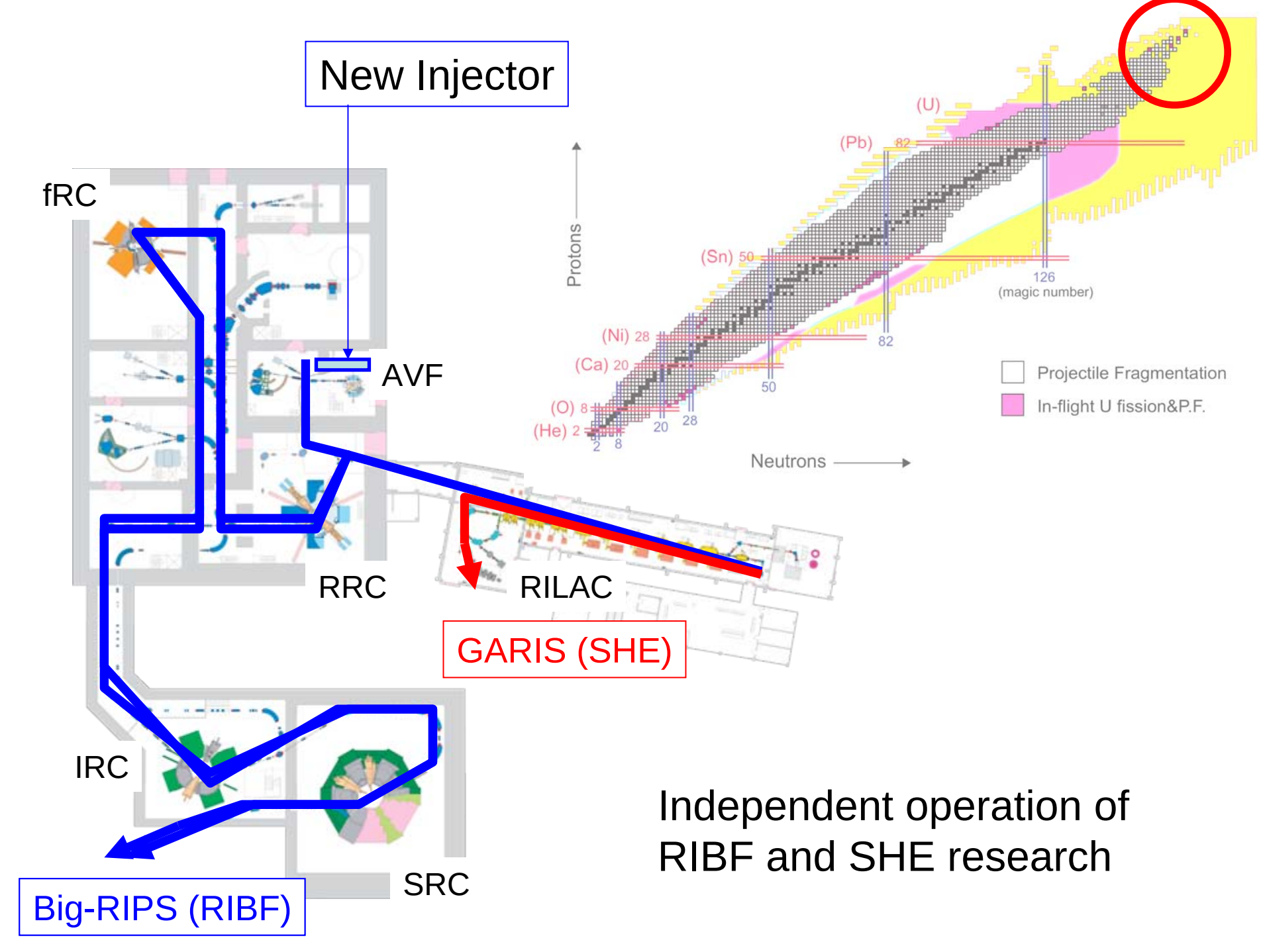
Y. Watanabe

Beam intensities of 345 MeV/nucleon beams at RIBF

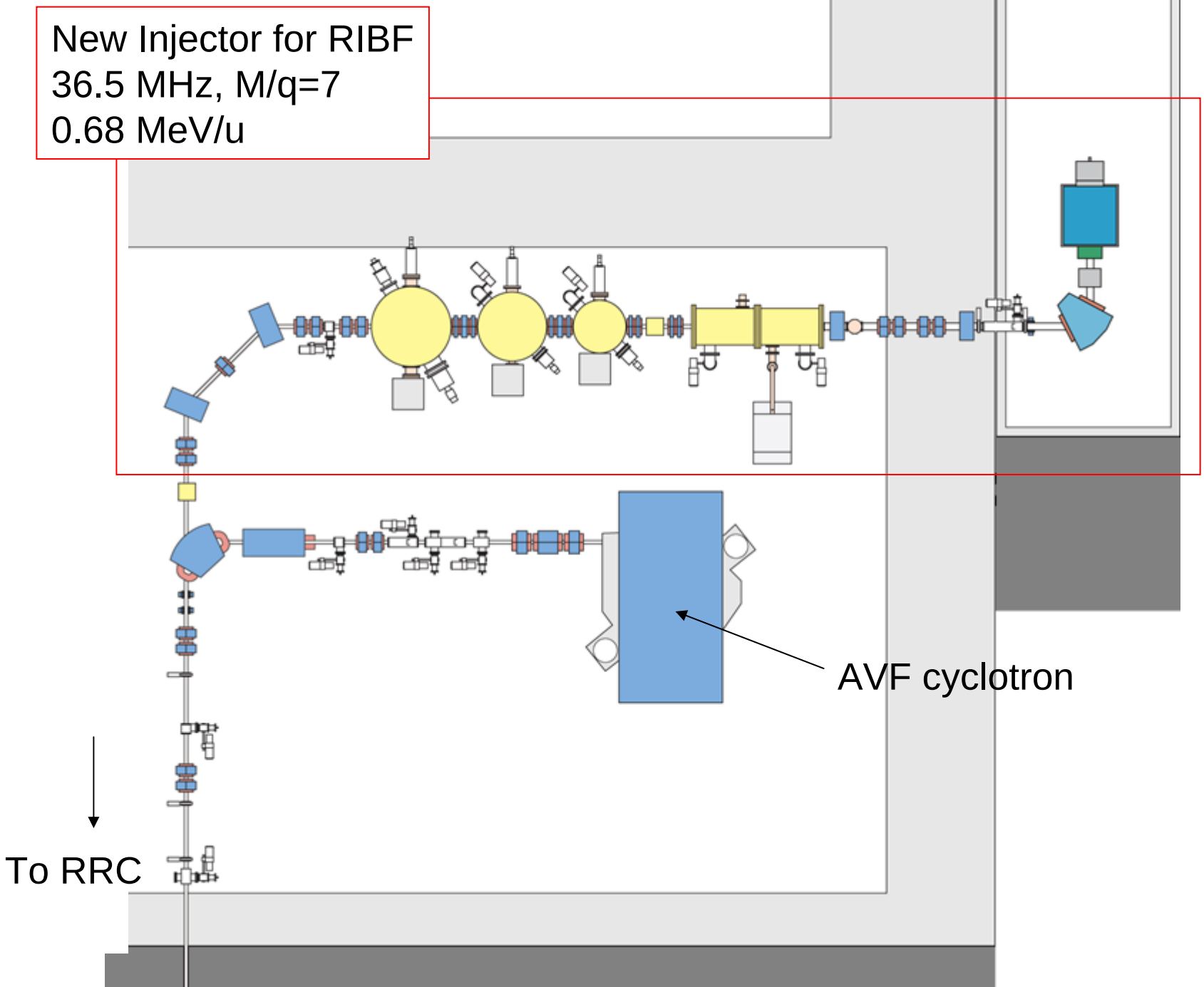
pnA

	^{48}Ca	Kr	Xe	^{238}U
Achieved FY2008	170	30 *1	-	0.4
Expected FY2009	200	30 *2	10	5 *3

*1: 1min *2: Limited by e04 CS *3: SC-ECR

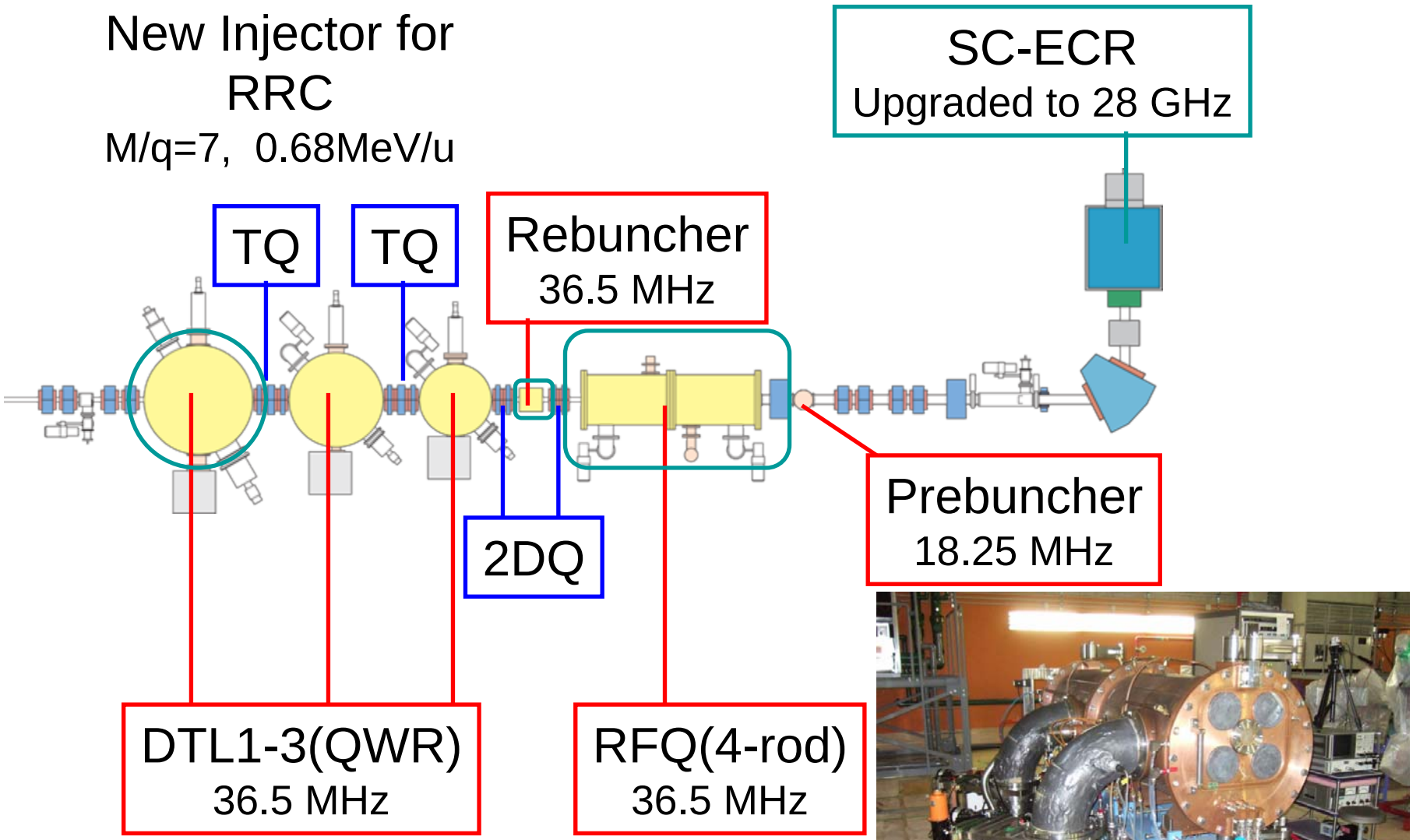


Independent operation of
RIBF and SHE research


New Injector for RIBF
36.5 MHz, M/q=7
0.68 MeV/u
AVF cyclotron
To RRC

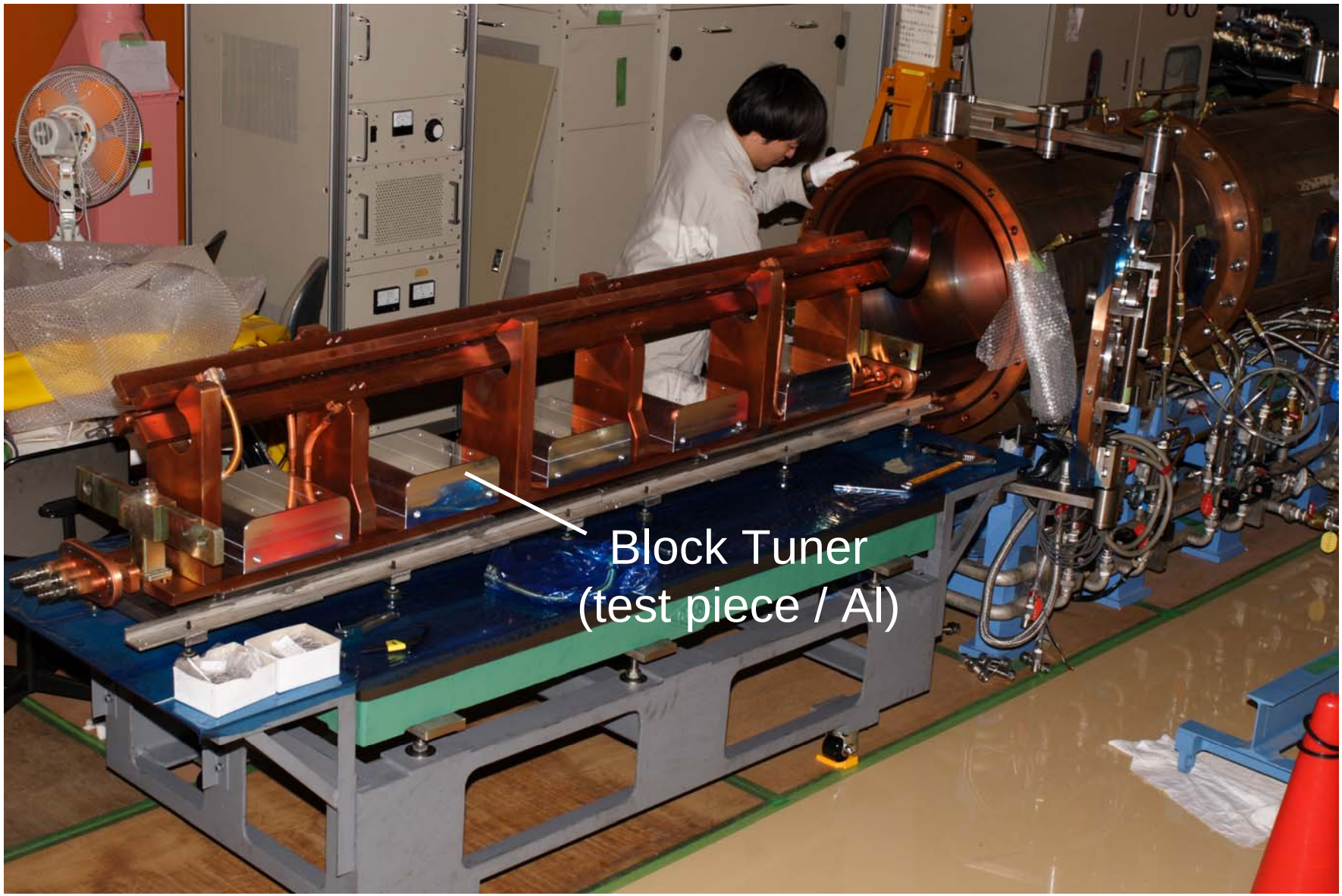
New Injector for RRC

M/q=7, 0.68MeV/u



H. Fujisawa, NIM A345 (1994) 23

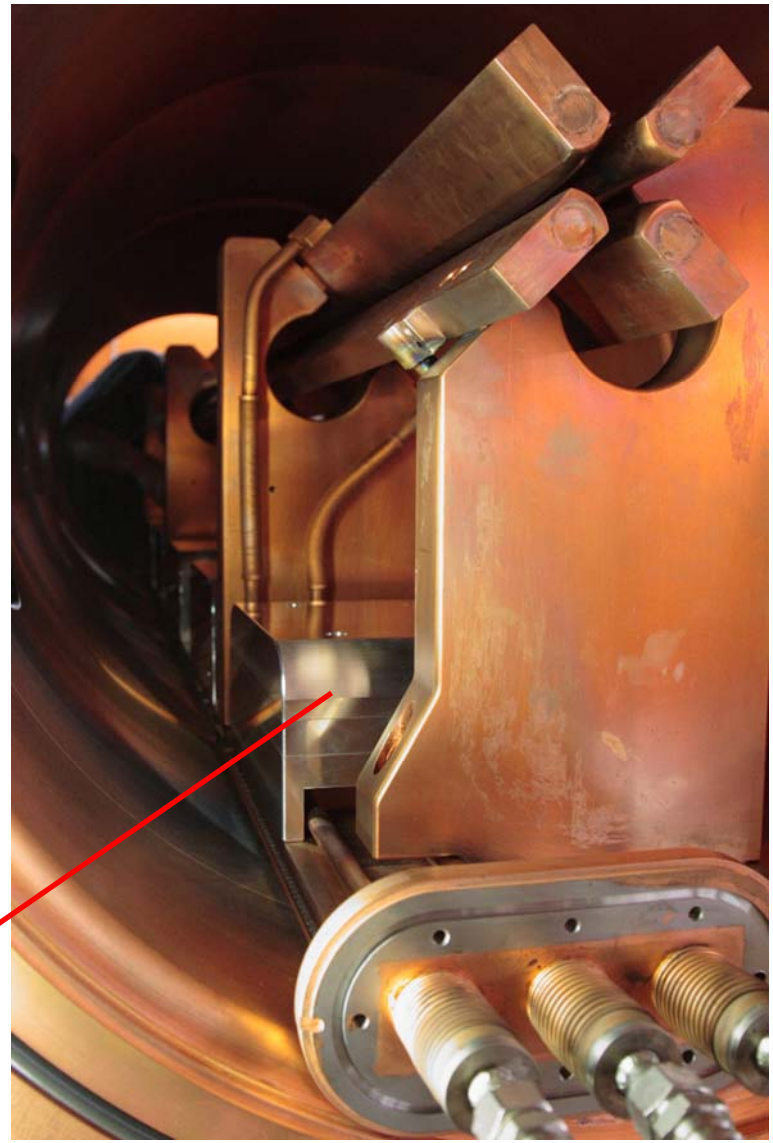
Fabrication will be completed in FY2009.
Operational in FY2010.


Block Tuner
(test piece / Al)

4-rod RFQ

36.5 MHz, M/q=7, Duty=100%

Ein (keV/u)	3.28
Eout (keV/u)	100
ε_{in} (mm•mrad)	200 π
Vane length (cm)	222
Vane voltage (kV)	42.0
Mean aperture: r_0 (mm)	8.0
Max. modulation: m	2.35
Focusing strength: B	6.785
ϕ_s (deg.)	-29.6

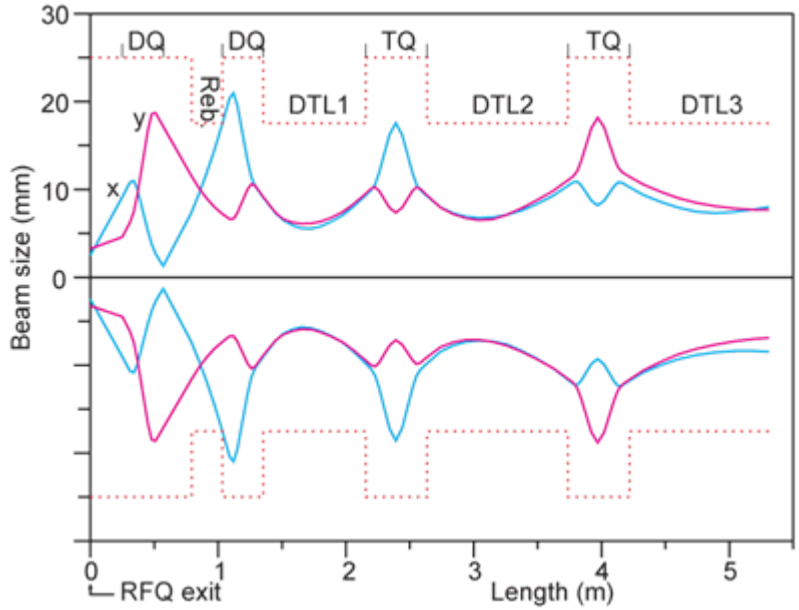


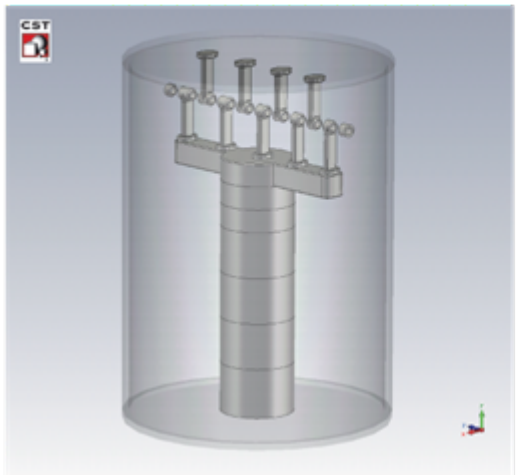
Block Tuner
(test piece / Al)

Drift Tube Linacs

36.5 MHz, M/q=7, Duty=100%

	DTL1	DTL2	DTL3
Ein (keV/u)	100	220	450
Eout (keV/u)	220	450	680
Ltank (m)	0.8	1.1	1.3
Height (m)	1.3	1.4	1.9
No. of gaps	10	10	8
Vgap (kV)	110	210	260
Lgap (mm)	20	50	65
a (mm)	17.5	17.5	17.5
Es (MV/m)	8.2	9.4	9.7
ϕs (deg.)	-25	-25	-25
Pcalc (kW)	5	13	15



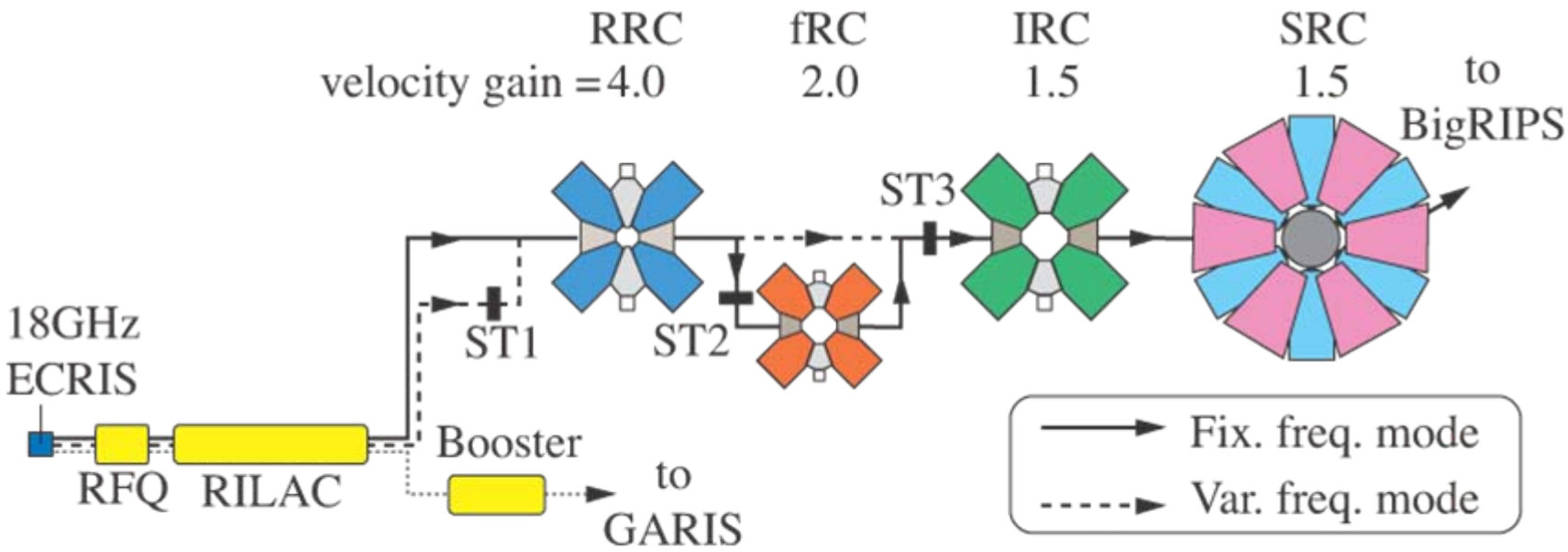


Quarter-Wavelength Resonator (QWR)

Mechanical design under progress

Summary

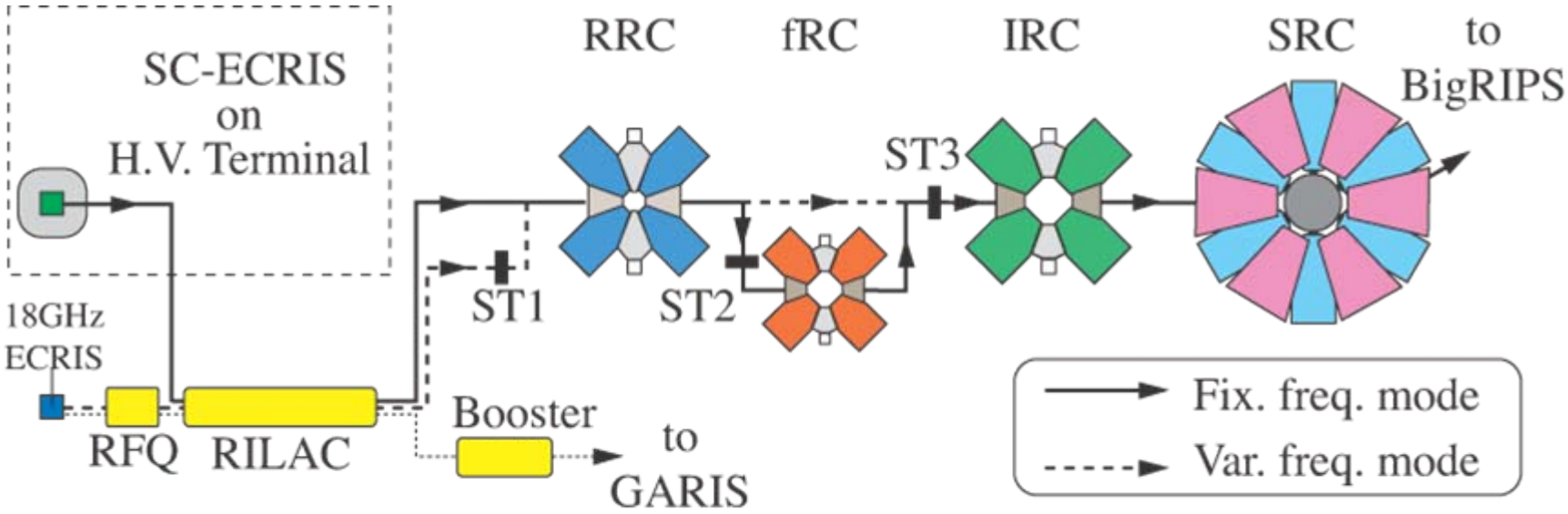
Present



U: 0.4 pnA

Summary

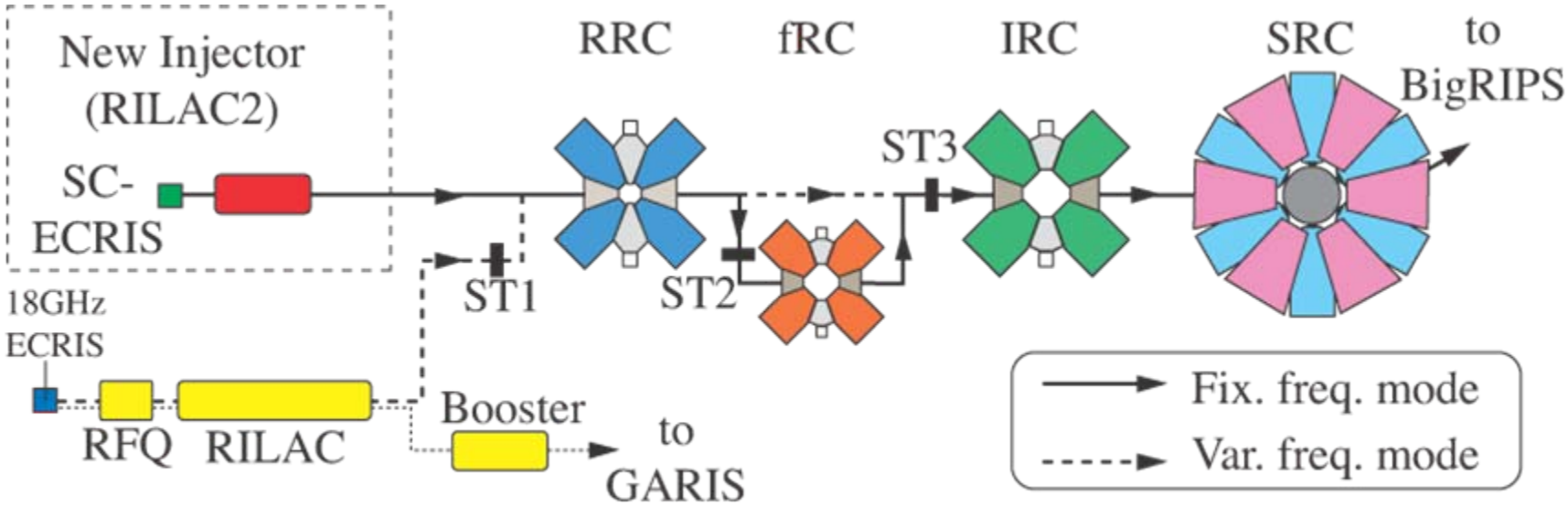
Oct. 2008



U: 5 pnA

Summary

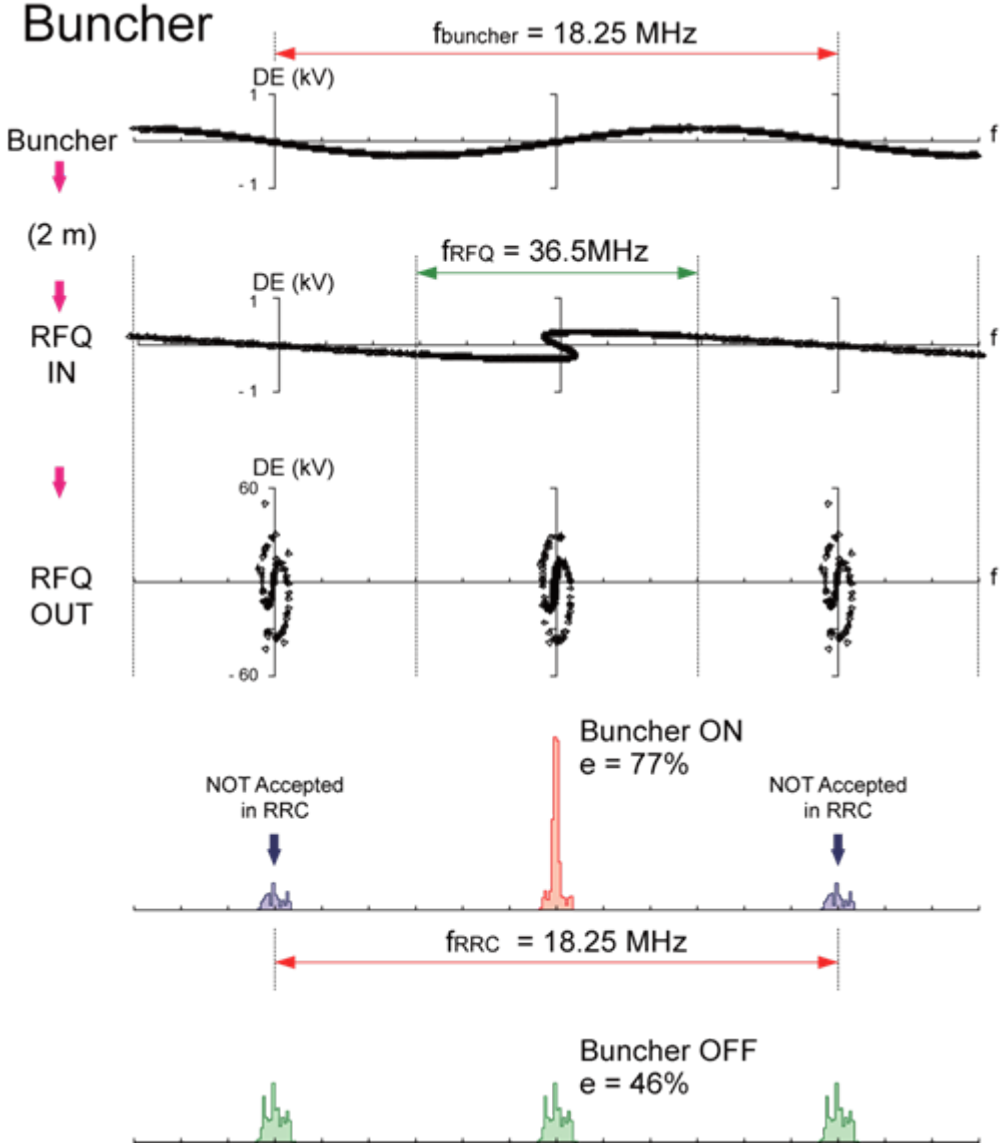
Mar. 2011

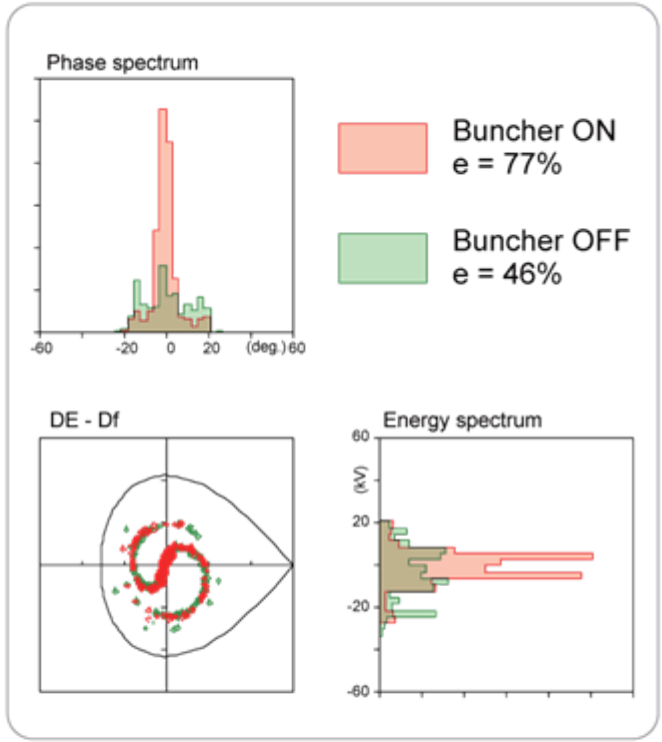


U: 50 - 100 pnA

Thank you for your attention!

Buncher





- Indispensable to the higher rf-mode operation of RFQ/DTLs.
- Phase- and energy width improved.

Quadrupole Magnets

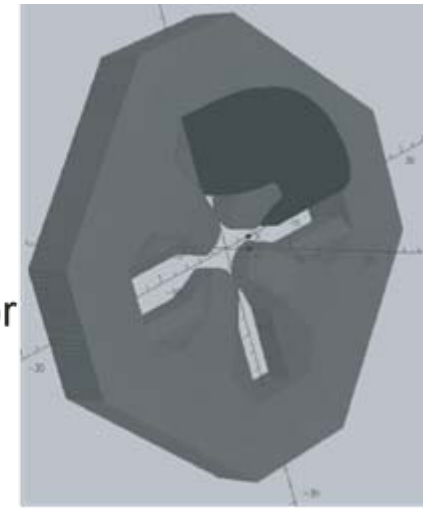
- High gradient ~ 40 T/m

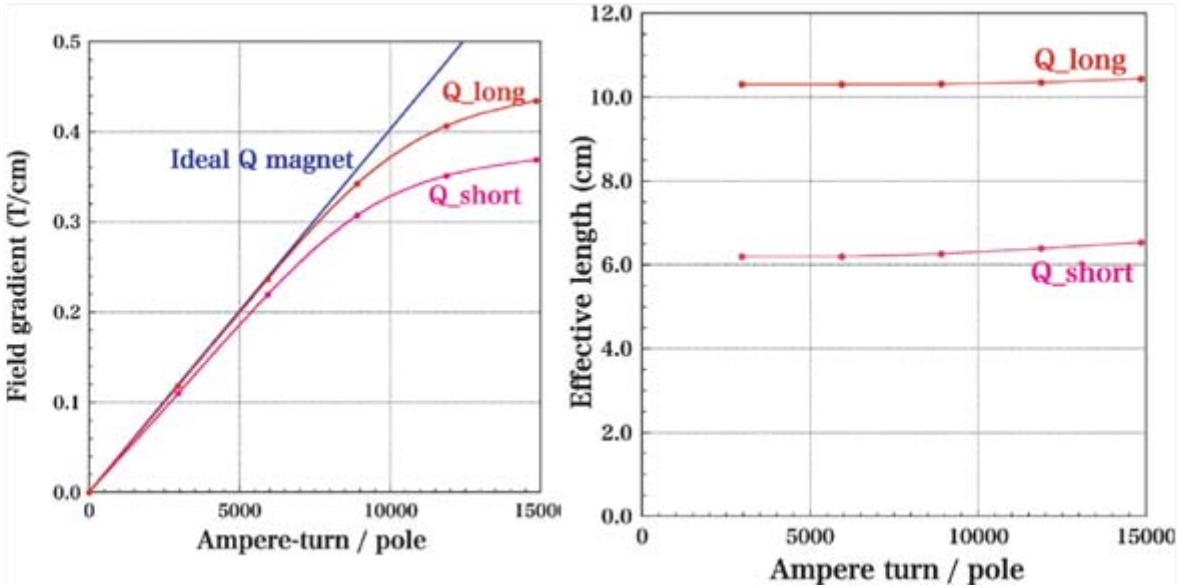
- Bore diameter = 50 mm

- 3D calculation (TOSCA)
  15000 AT/pole

- Cooling estimation
  (23 + 27) T - 300 A
  4×6 - 2×4 Hollow Conductor
  Dp = 5 kg/cm^2

⇒ DT < 26 °C

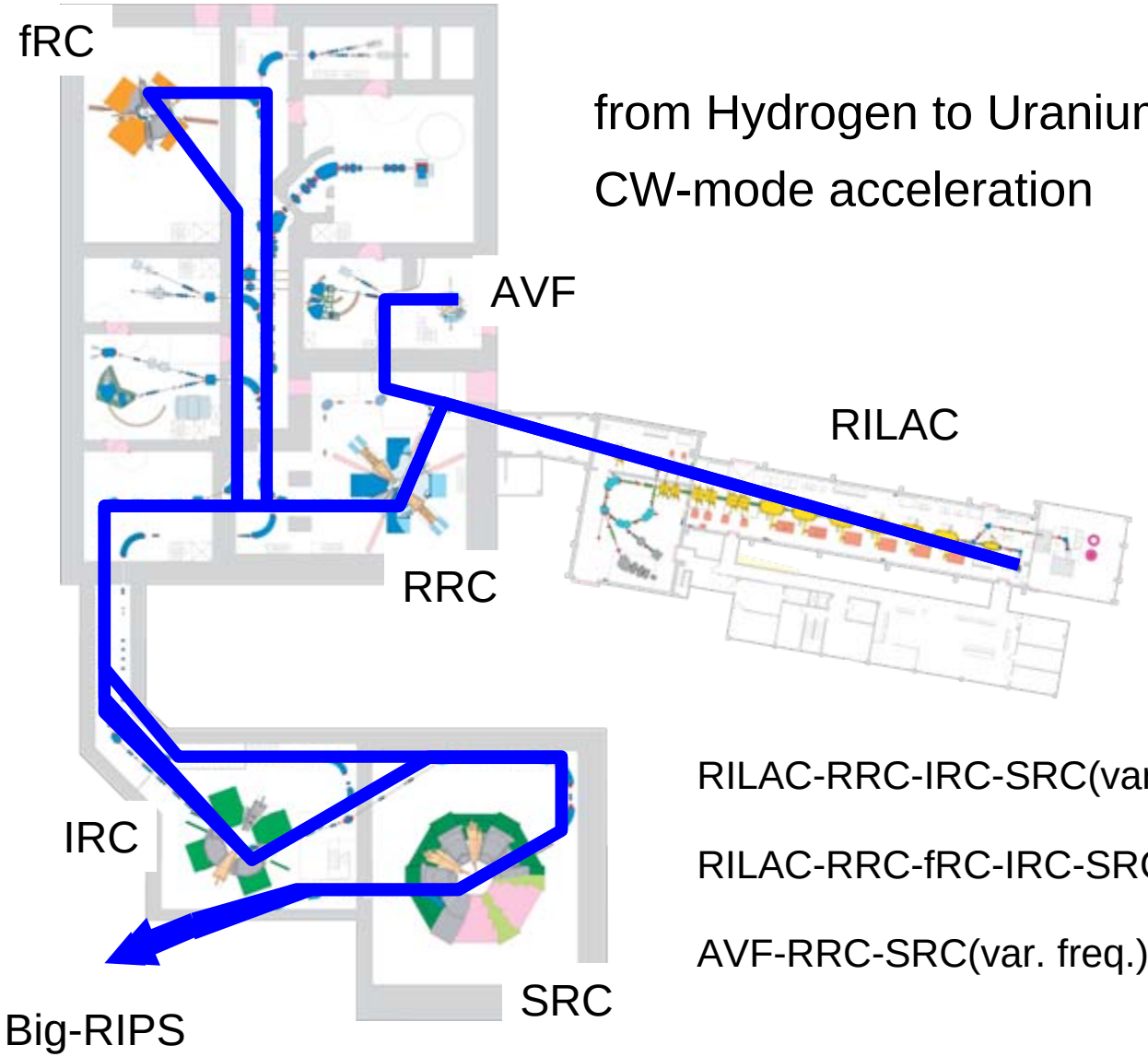




RIBF Accelerators

2 Injectors: RILAC & AVF

4 Booster Cyclotrons: RRC, fRC, IRC, SRC



from Hydrogen to Uranium => 345MeV/u

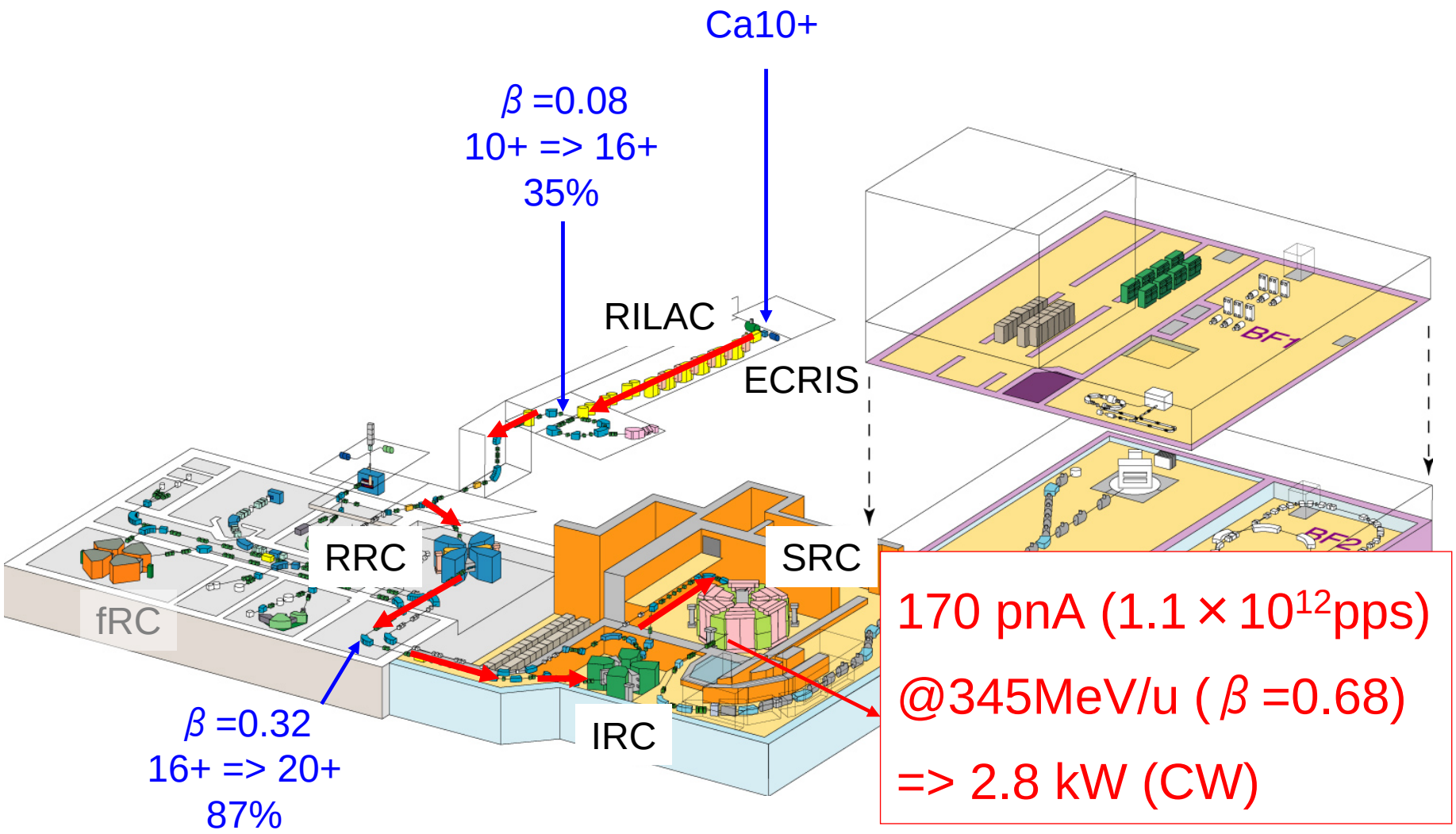
CW-mode acceleration

RILAC-RRC-IRC-SRC(var. freq.) : Max 400 MeV/u

RILAC-RRC-fRC-IRC-SRC(fixed freq.) : 345 MeV/u

AVF-RRC-SRC(var. freq.) : Max 440 MeV/u

Acceleration of ^{48}Ca (Dec. 2008)

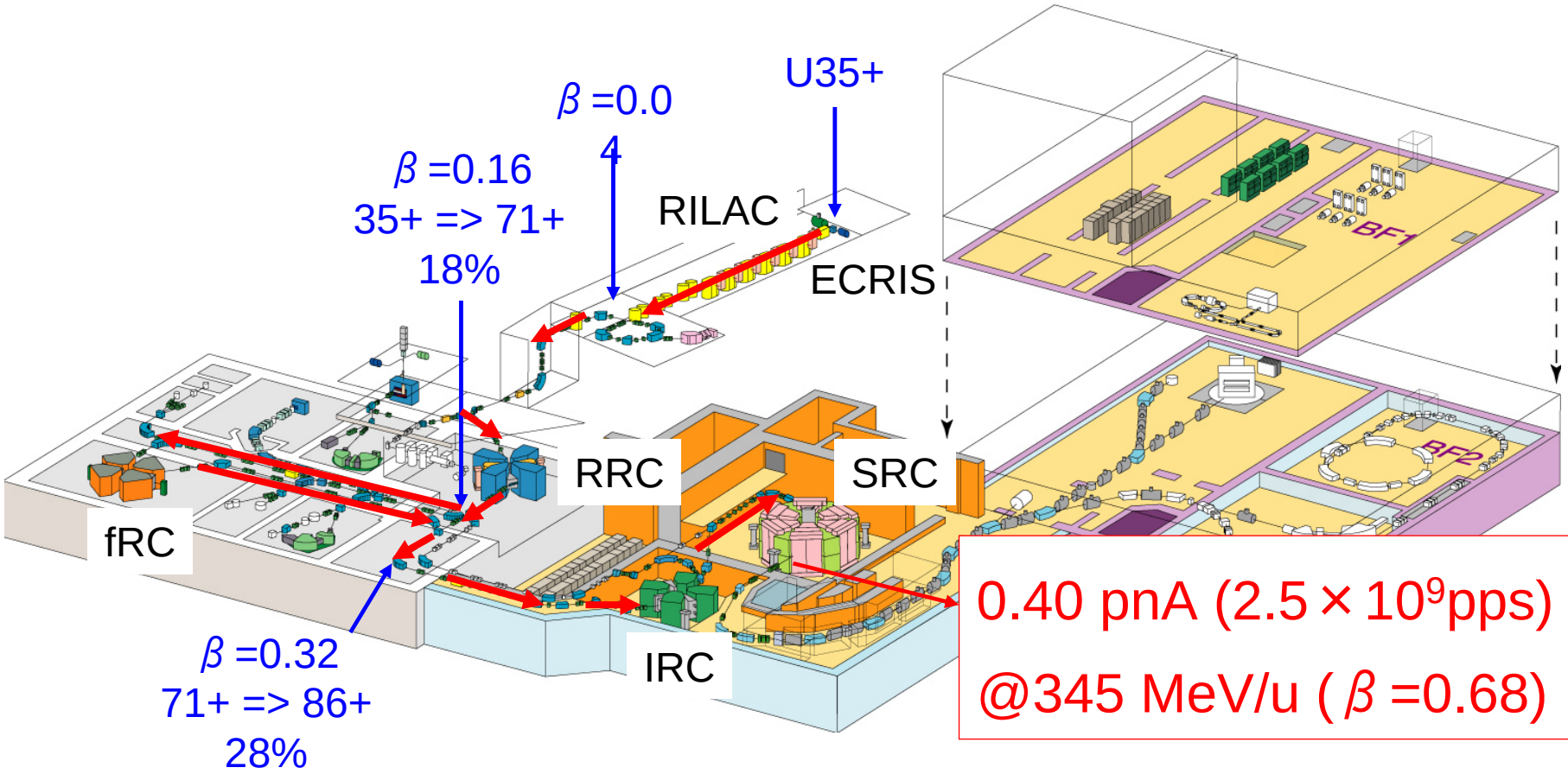


170 pnA (1.1×10^{12}pps)

@345MeV/u (β =0.68)

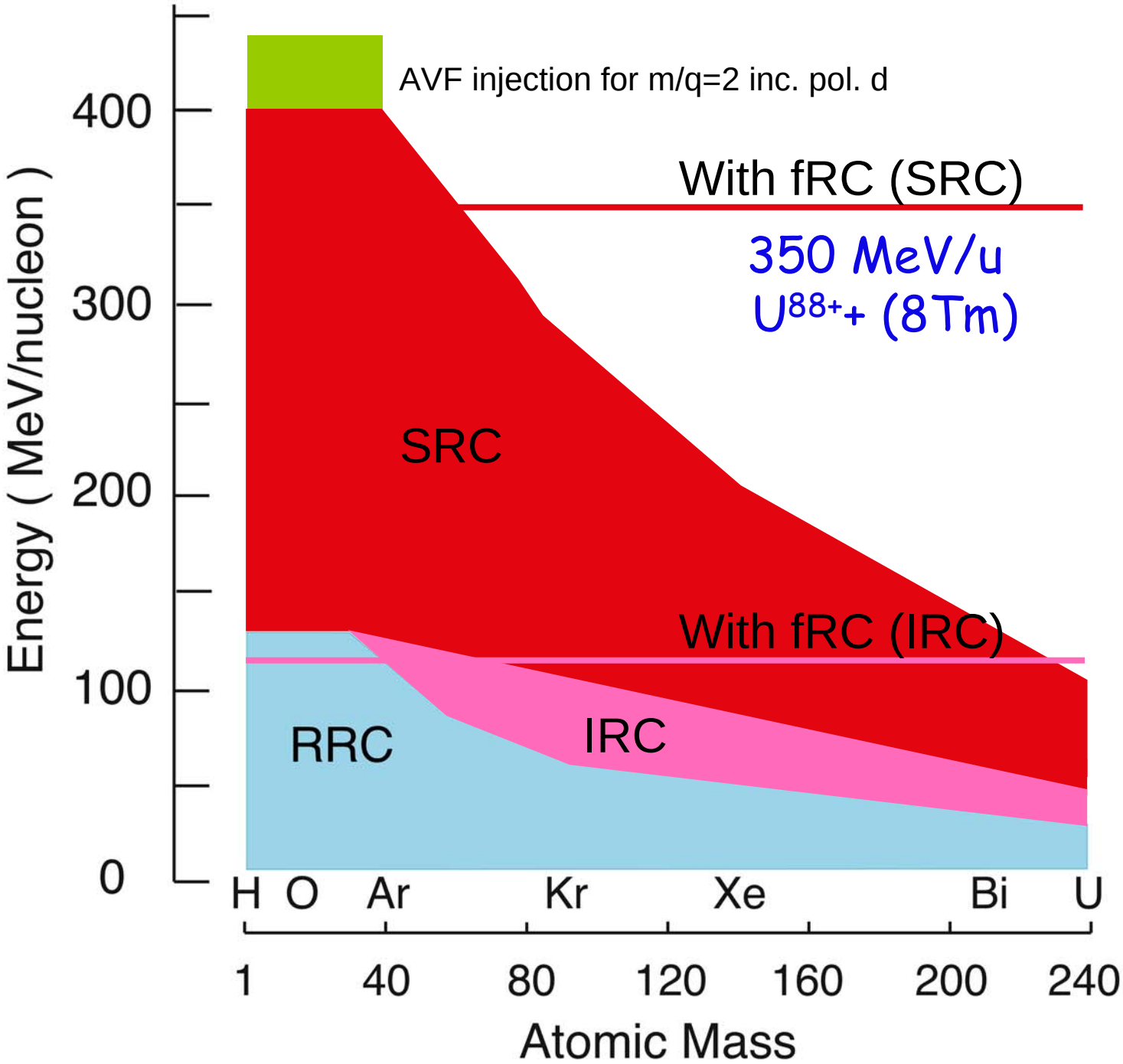
=> 2.8 kW (CW)

Acceleration of ^{238}U (Nov. 2008)

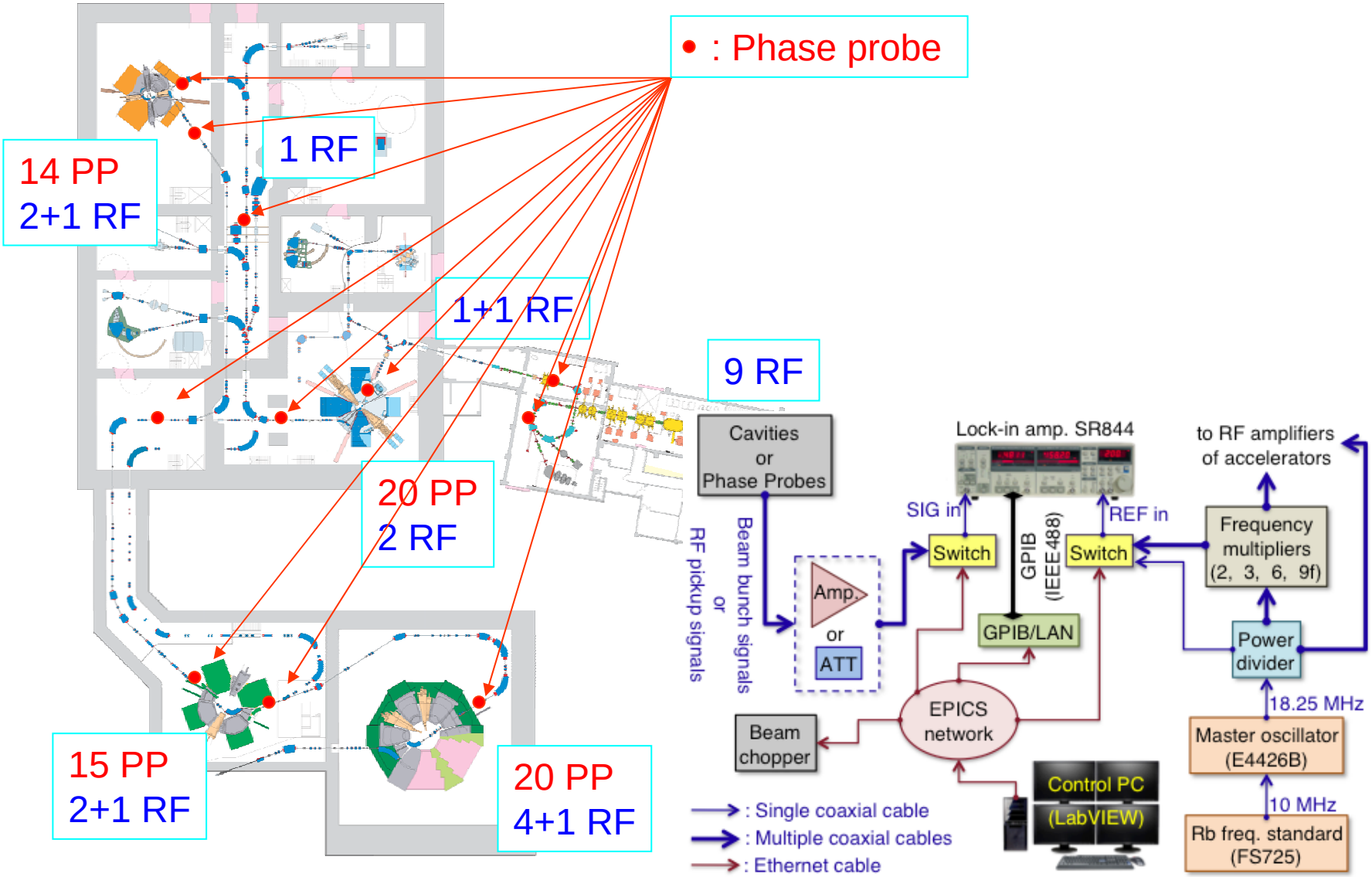


0.40 pnA (2.5×10^9pps)

@345 MeV/u (β =0.68)

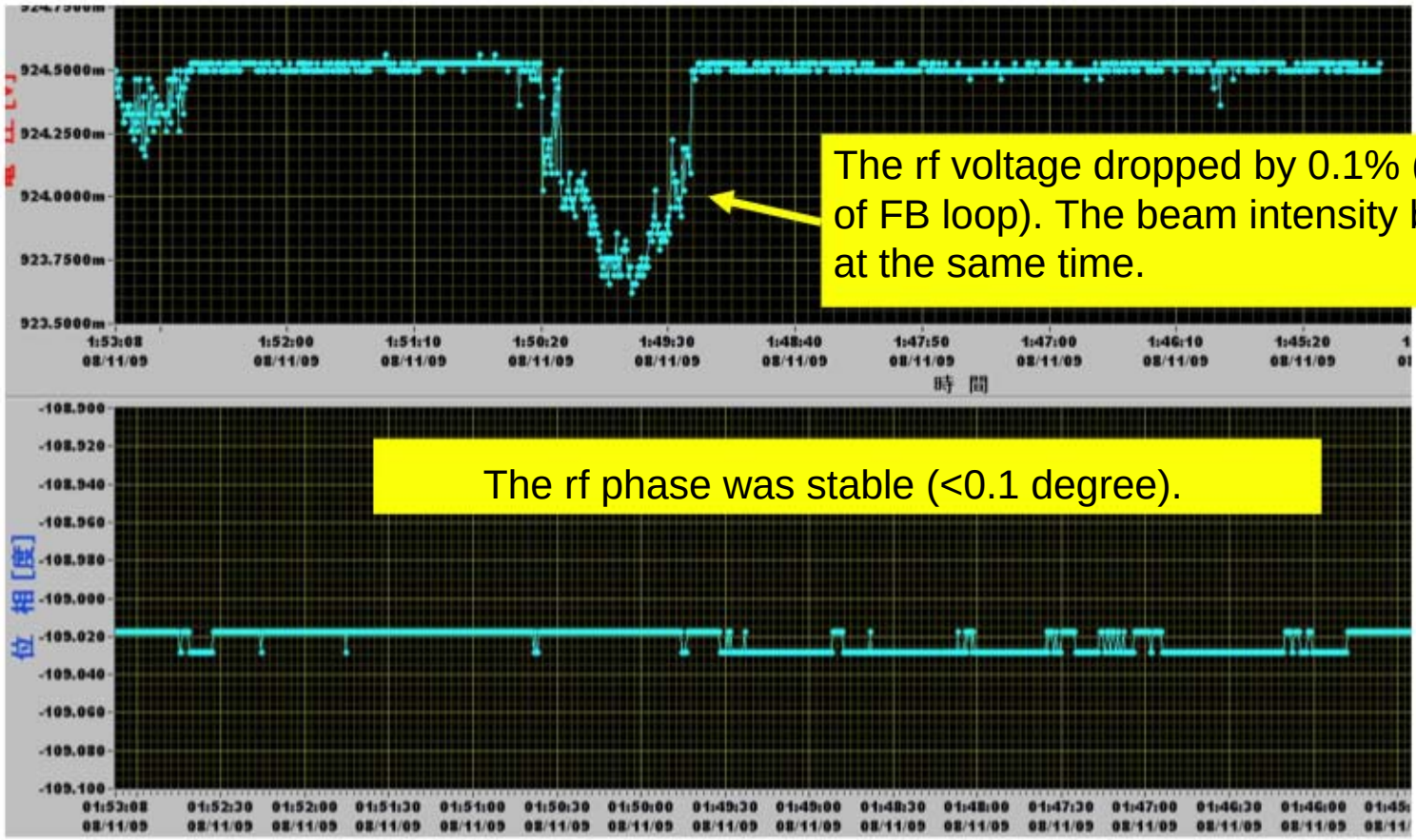

AVF injection for m/q=2 inc. pol. d
With fRC (SRC)
350 MeV/u
U88+ (8Tm)
SRC
With fRC (IRC)
RRC
IRC
Energy (MeV/nucleon)
400
300
200
100
0
H
O
Ar
Kr
Xe
Bi
U
1
40
80
120
160
200
240
Atomic Mass

Monitoring system of rf and beam stability based on Lock-in Amp.



Monitoring system of rf and beam stability

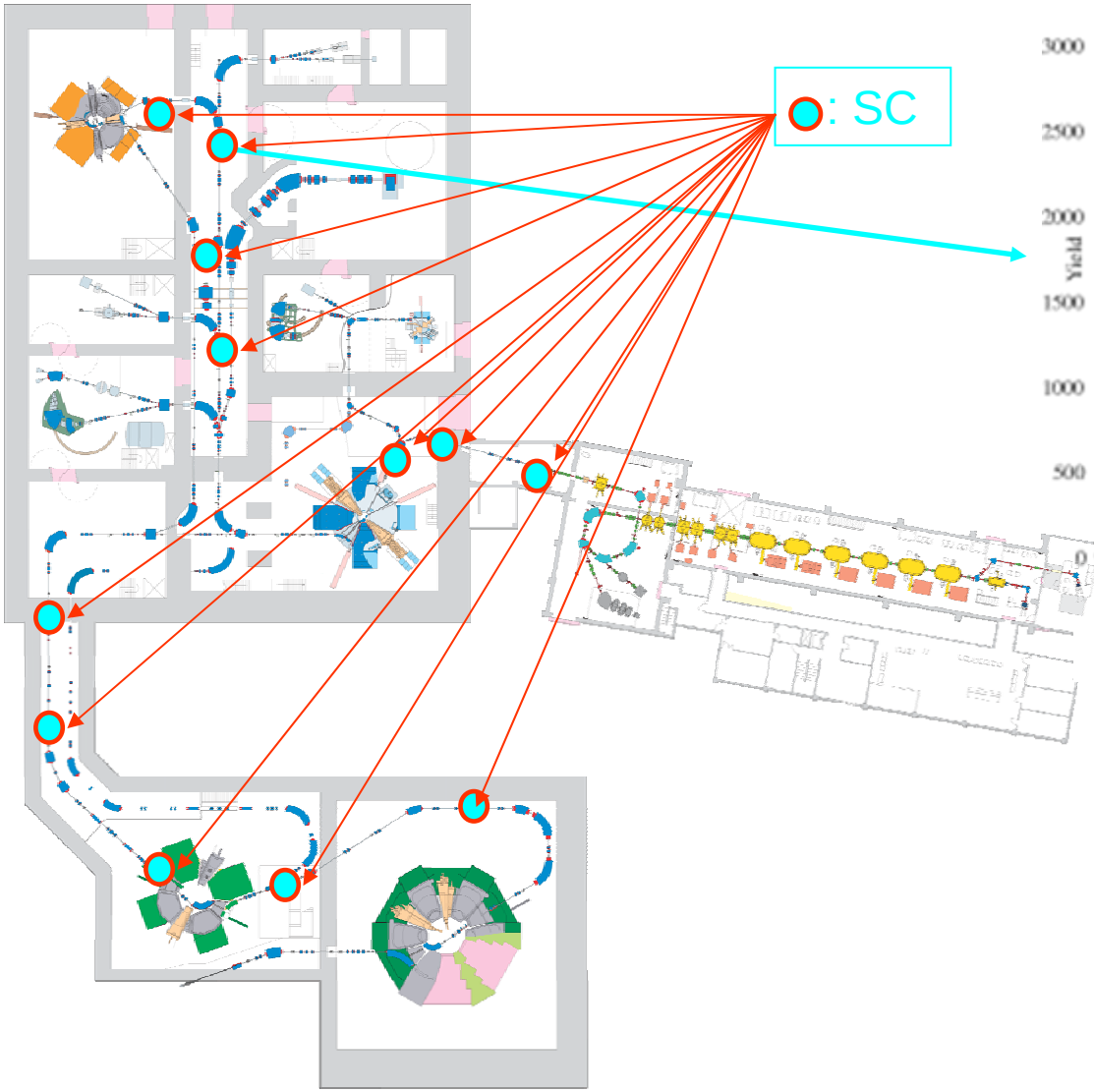
Example: Rf voltage and phase of SRC-Resonator #2

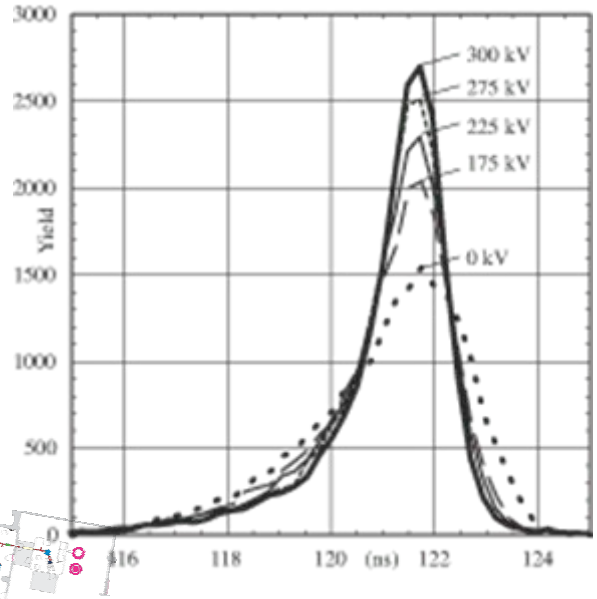


The rf voltage dropped by 0.1% (oscillation of FB loop). The beam intensity became half at the same time.

The rf phase was stable (<0.1 degree).

Plastic scintilator for monitoring beam phase width and beam energy (TOF)

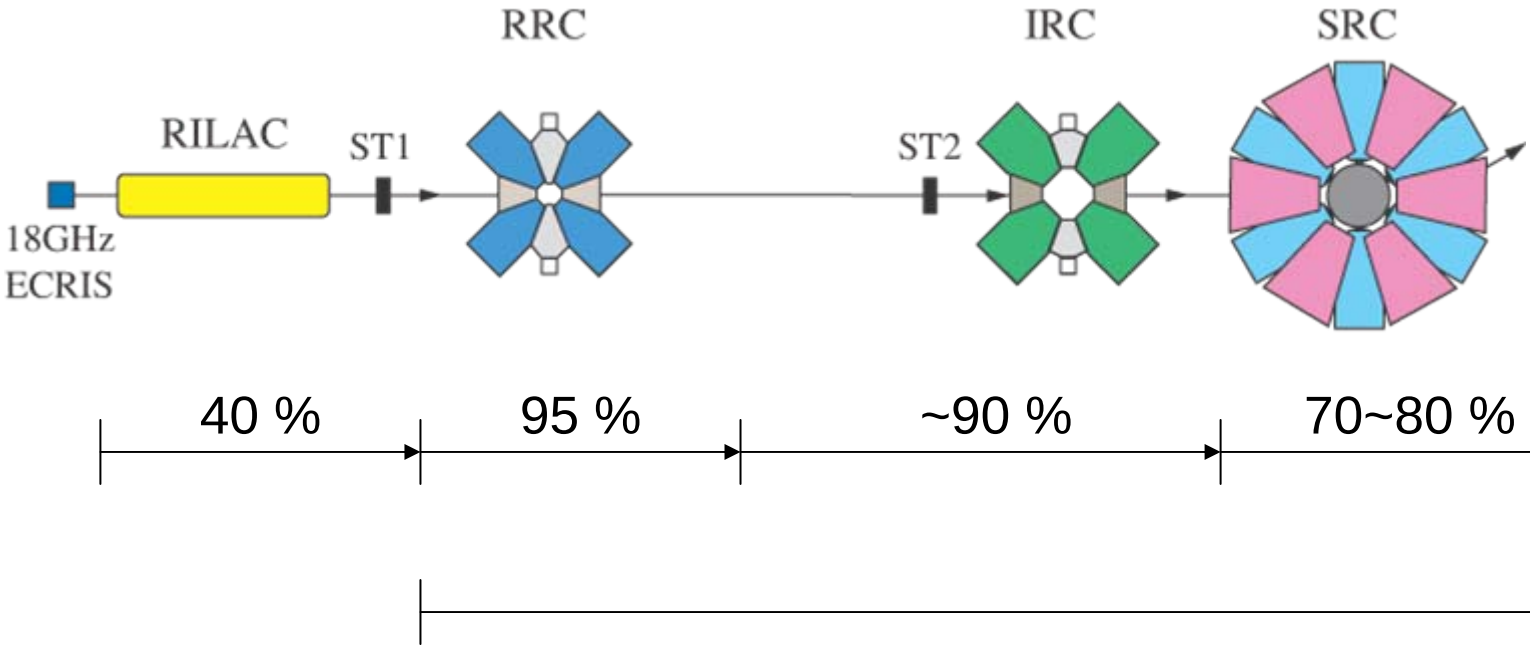




Beam phase v.s. Rebuncher voltage

Transmission through the accelerators for Ca beam

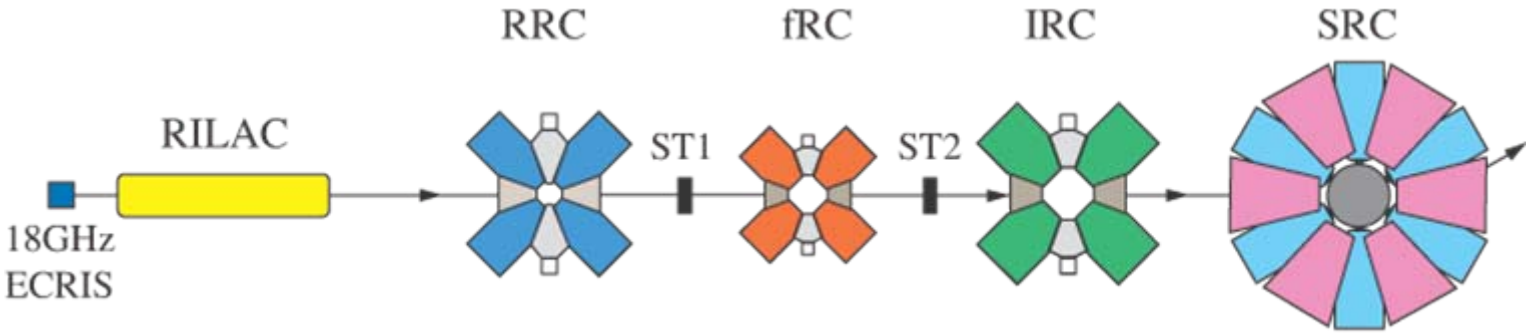
(stripping efficiency exculded)



- Transmission through RILAC
- Recovery time of SRC-RF
- Temperature control of RF-signal divider

Transmission through the accelerators for U beam

(stripping efficiency exculded)

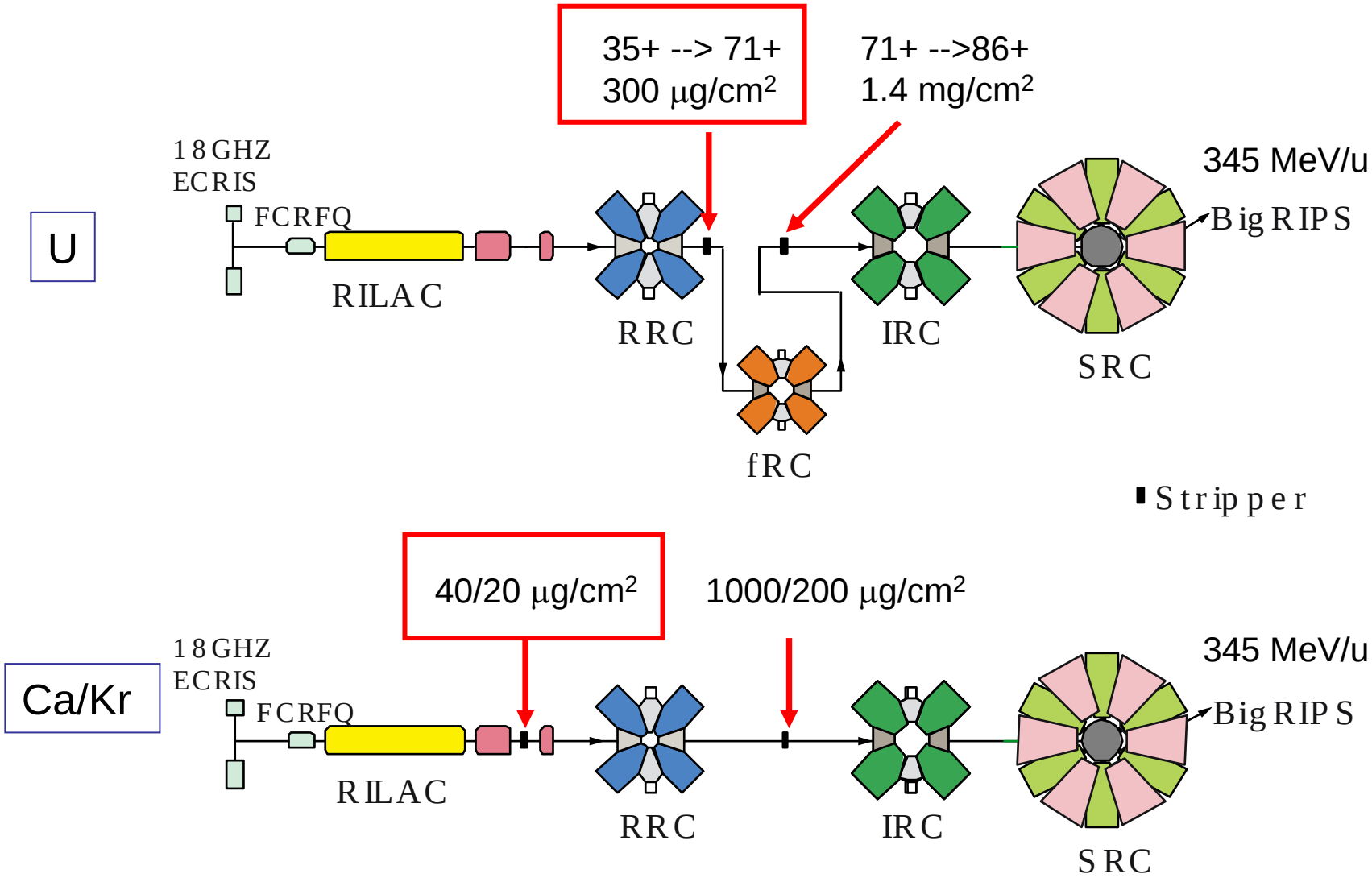


40 % ~75 % ~90 % ~90 % ~65 %

57 %

39 %

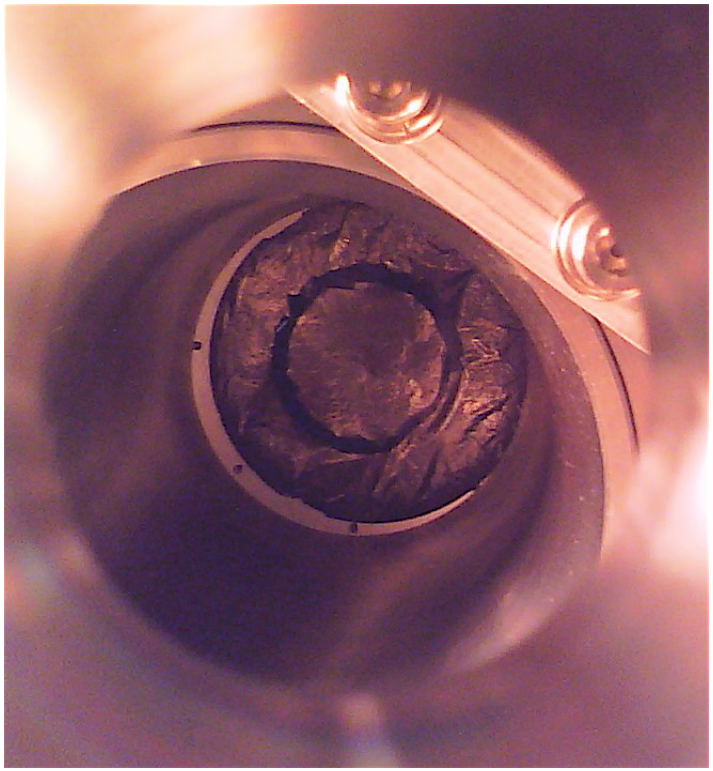
Charge strippers in RIBF

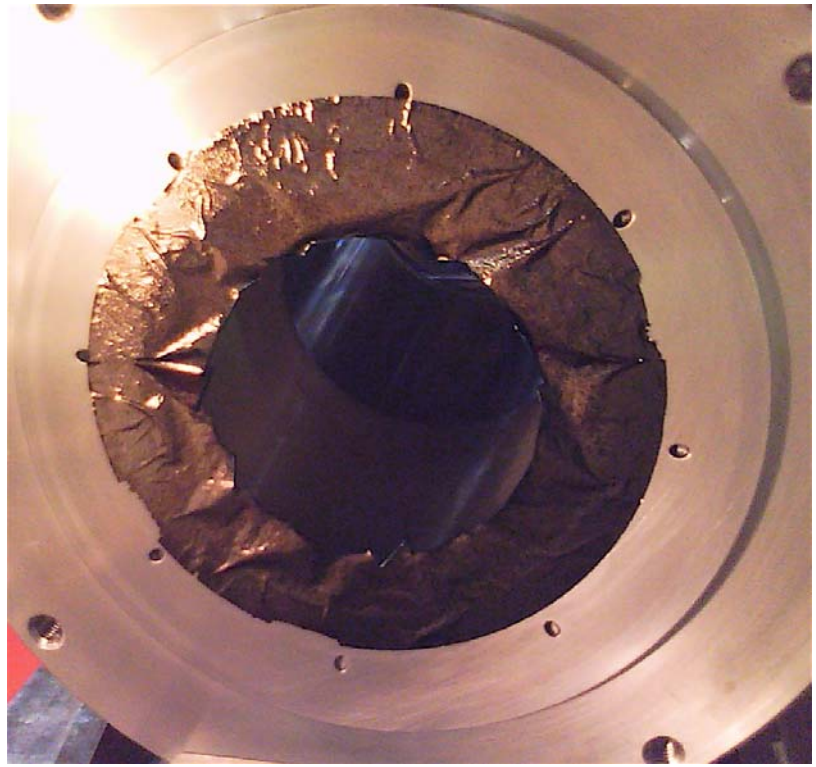


1st stripper for U acceleration (cont'd)

- Rotating stripper developments

Large area type (100 mmϕ) tested in May
=> Broken shortly

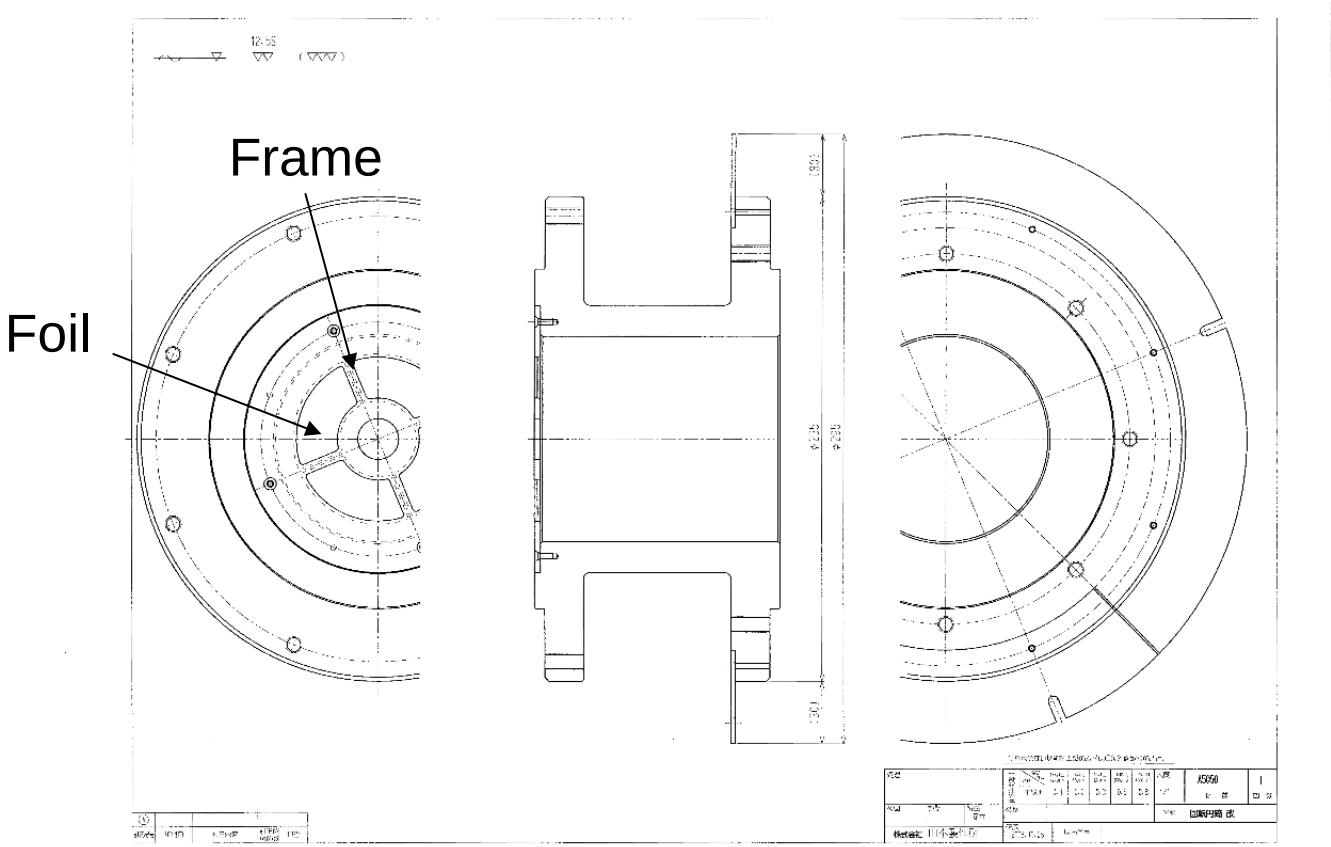


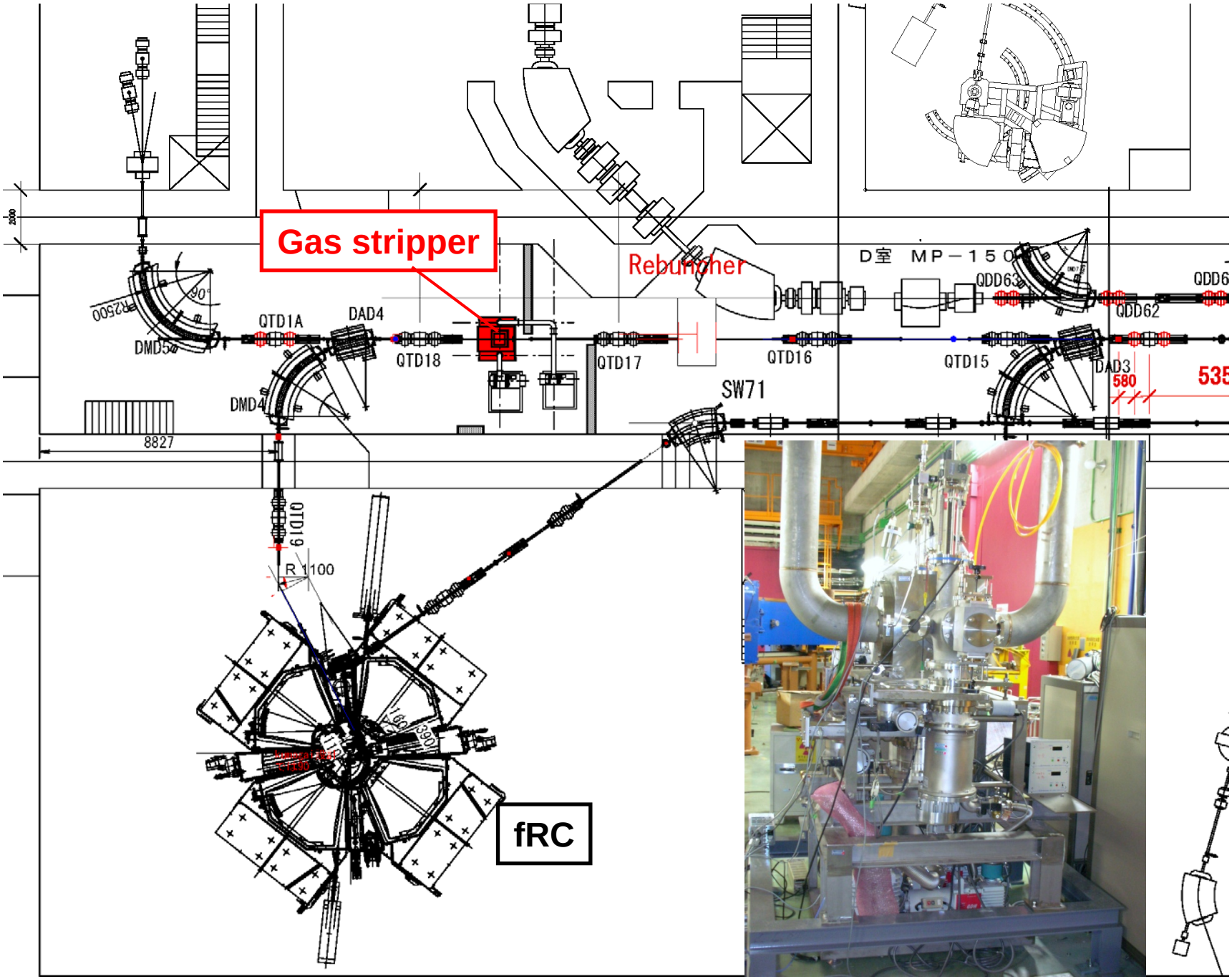


1st stripper for U acceleration (cont'd)

- Rotating stripper developments

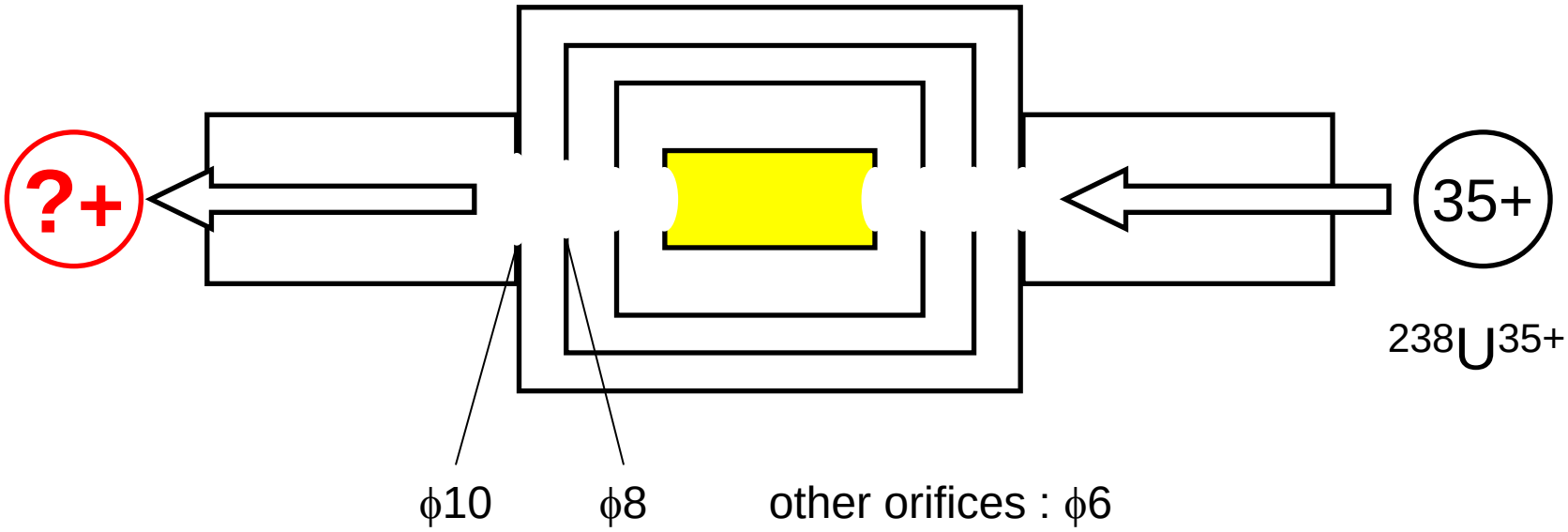
Small area type (GARIS type) will be tested in FY2009.




Gas stripper
Rebuncher
D室 MP－１５０
QDD63
QDD62
QDD6
QTD1A
DAD4
DMD5
QTD18
QTD17
QTD16
QTD15
DAD3
580
535
SW71
DMD4
8827
QTD19
R 1100
fRC

Schematic view of the chamber

N_2 : 180 ～1000 μg/cm^2
(depending on pump speed)



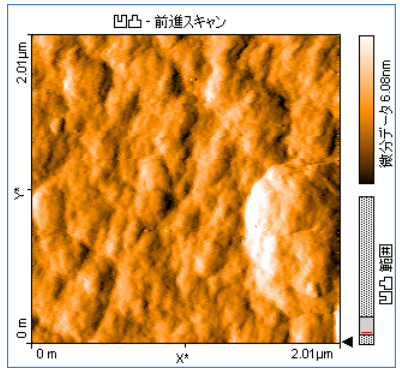
1st stripper after RRC (@11 MeV/u) for U acceleration

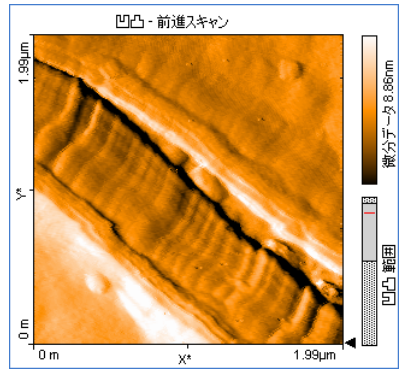
- Arizona Carbon 300 μg/cm2 (standard use) => Lifetime: 12 hours

- Heat treated PCC-foil developed in RIKEN

  => Almost the same quality (uniformity, lifetime) as that of Arizona Carbon

AFM image of PCC foil





Before irradiation

After irradiation

1st stripper after RILAC (@~2.7 MeV/u) for Ca, Kr, etc.

Carbon, 40 μg/cm^2

	MeV/u	pnA	Loss(W)	W/cm^2	Made by	Lifetime
^{48}Ca 345 MeV/u	2.7	1700	1.7	~13	RIKEN	>21h
^{86}Kr	2.3	1100	2.4	~24	RIKEN	4h
^{86}Kr	2.3	1100	2.4	~24	Arizona	0.16h
^{136}Xe 200 MeV/u	1.9	100	0.3	~10	RIKEN	4h
^{136}Xe 200 MeV/u	1.9	100	0.3	~10	Arizona	1.2h

Test for Zn will be carried out soon.