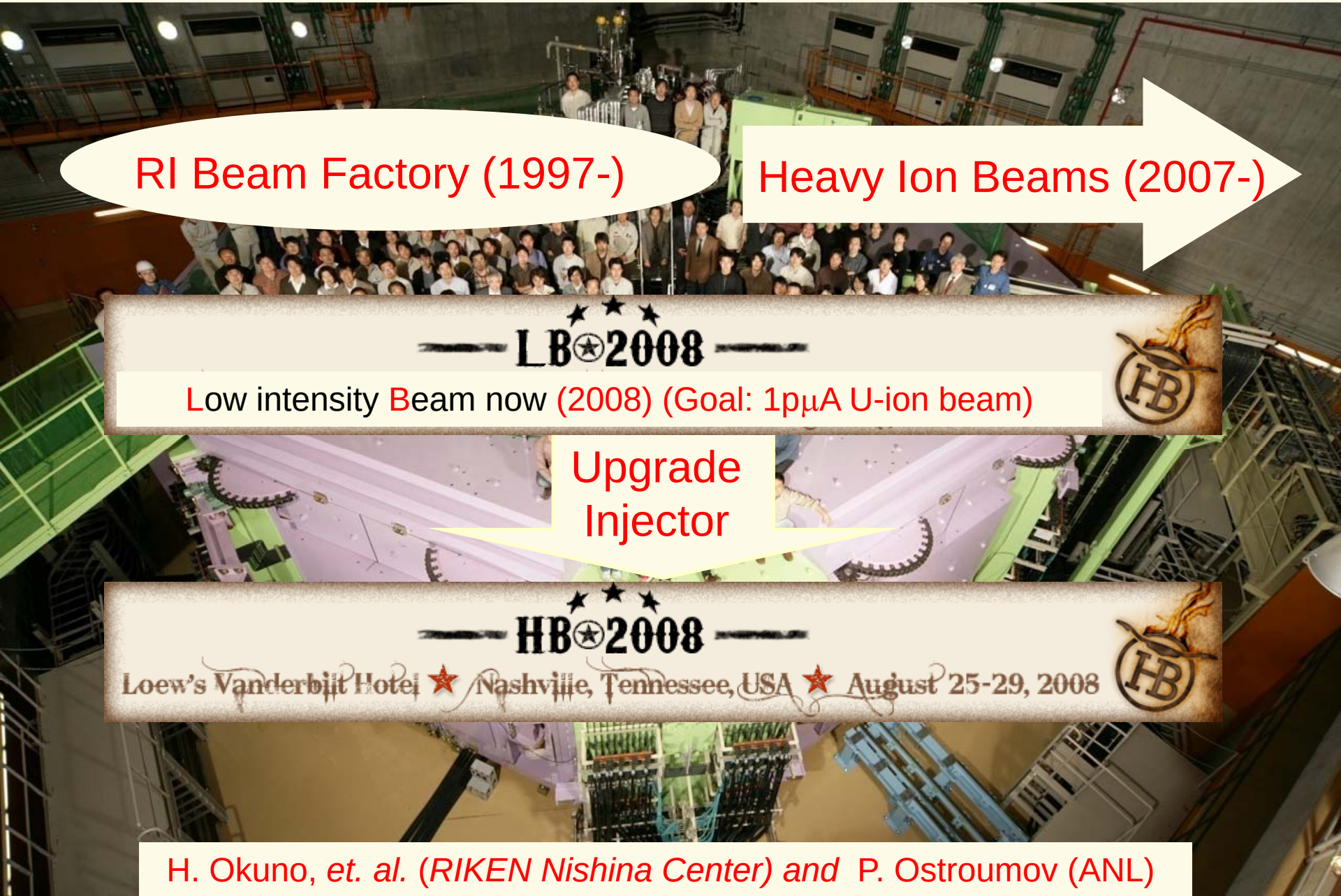
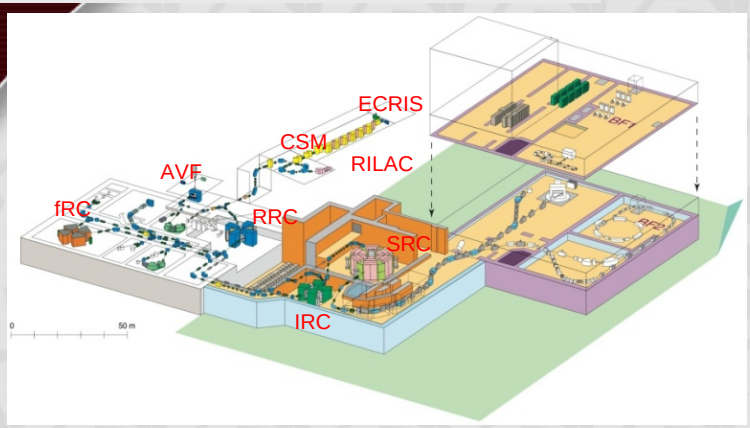
Heavy Ion Accelerators for RIKEN RI Beam Factory and Upgrade Plans



H. Okuno, *et. al.* (*RIKEN Nishina Center) and* P. Ostroumov (ANL)

Preview of the Talk

Introduction of RIBF

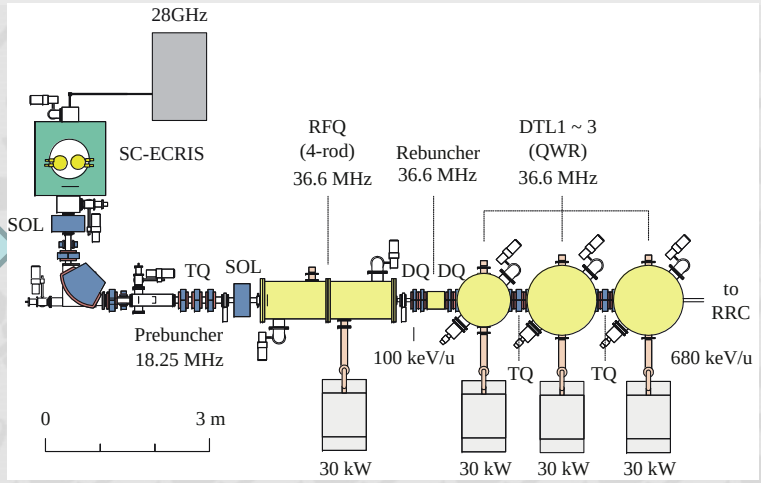


Status of the beam intensity

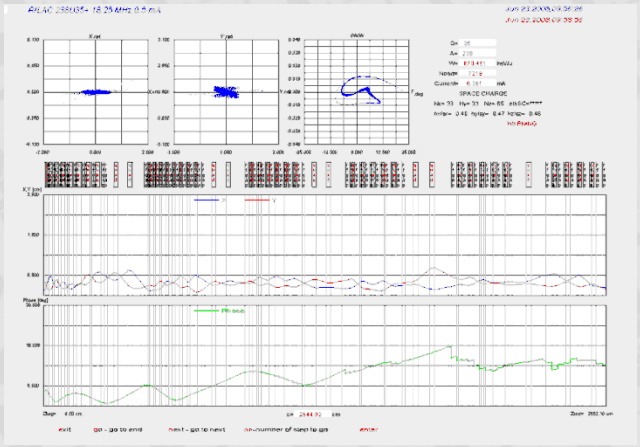
Fixed Frequency Mode

	Ion	ECRIS out	RFQ out	RILAC out	RRC out	1st Str. out	FRC out	2nd Str. out	IRC out	SRC out
June 2007	U	50.3	40	19.7	25.1	1.76	1.55	0.31	0.21	0.093
July 2008	U	---	44	16.3	15.1	1.85	2.00	0.53	0.35	-

Upgrade plans of the Injector



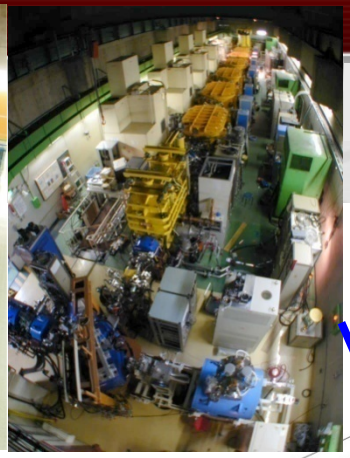
Simulation results using TRACK



Space Charge Forces

Introduction RIKEN RI Beam Factory





The Old Facility (1975~1990)

RRC

RILAC

ECRIS

RIBF

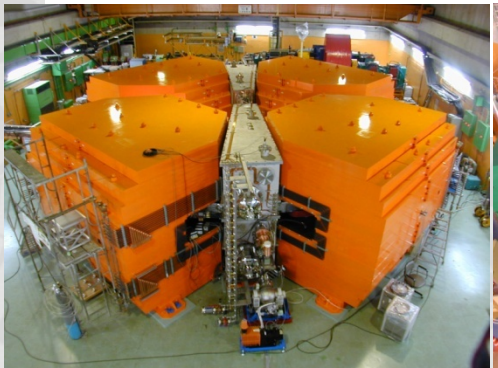
(1997~(2012))

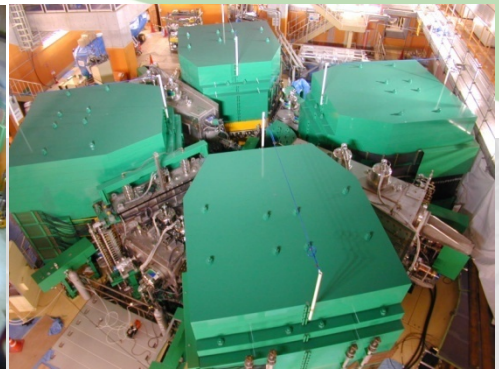
fRC

IRC

BigRIPS
(Fragment Seperator)

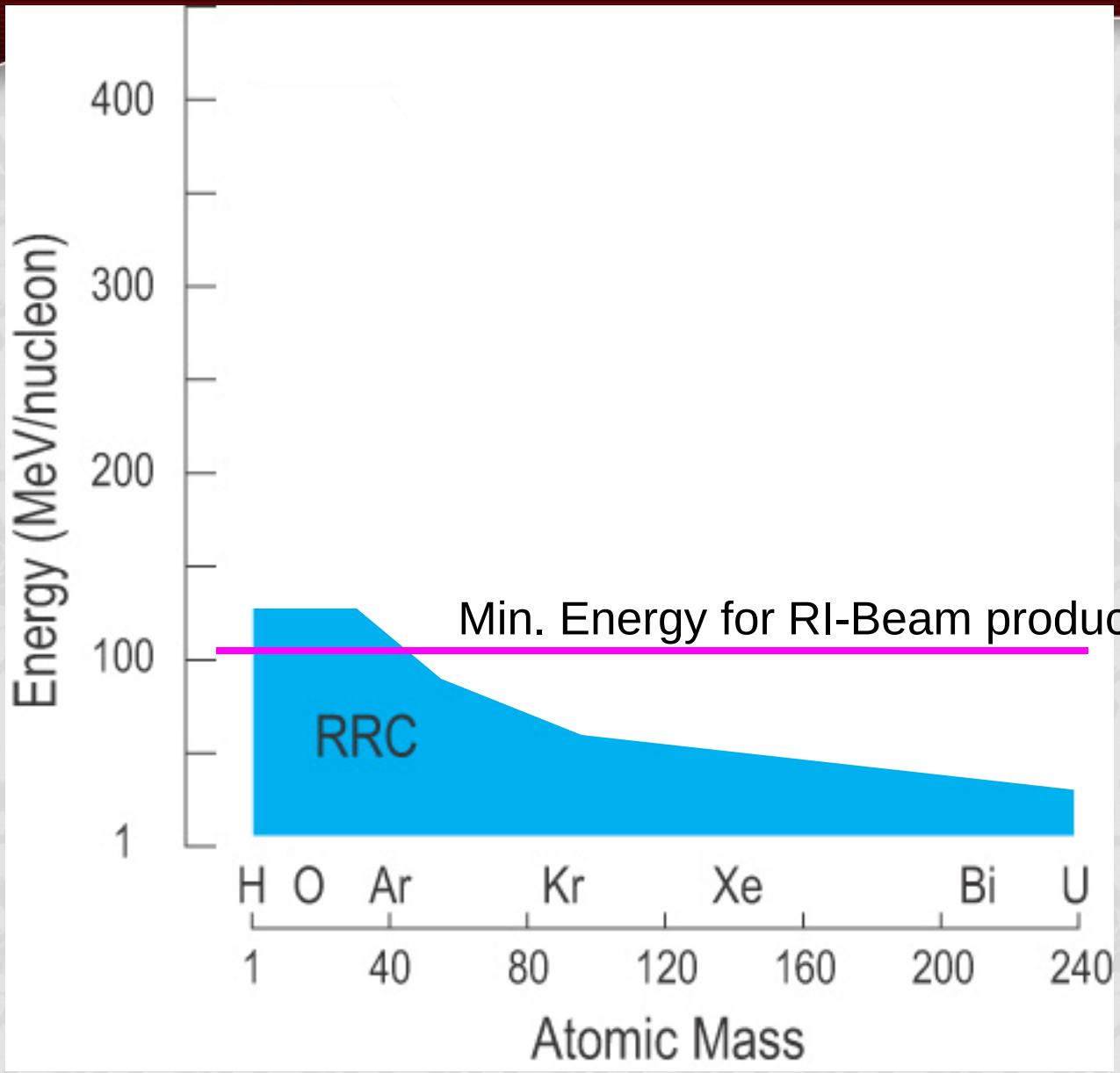
SRC -- World's First!



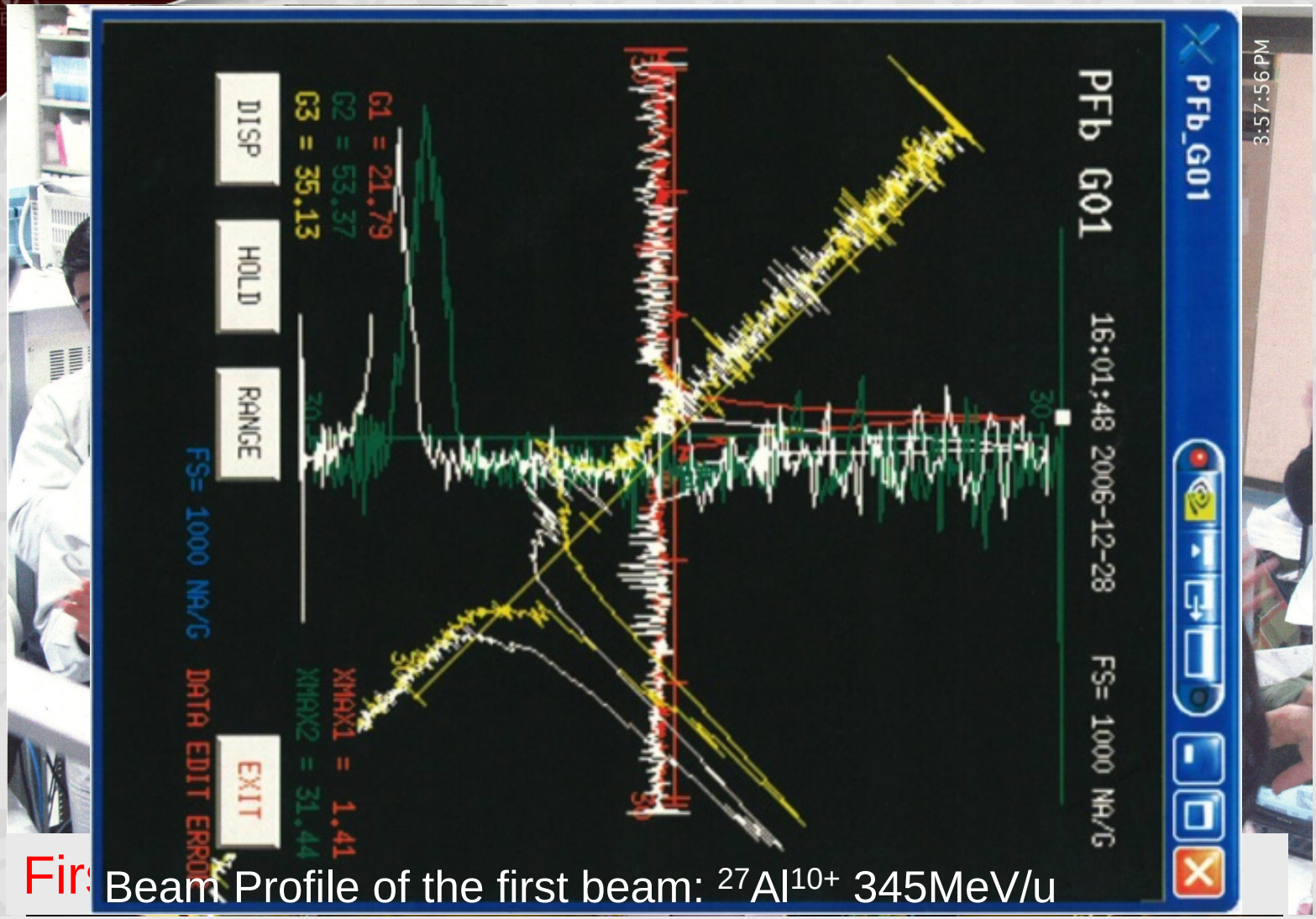




Performance of the RIBF Cyclotrons



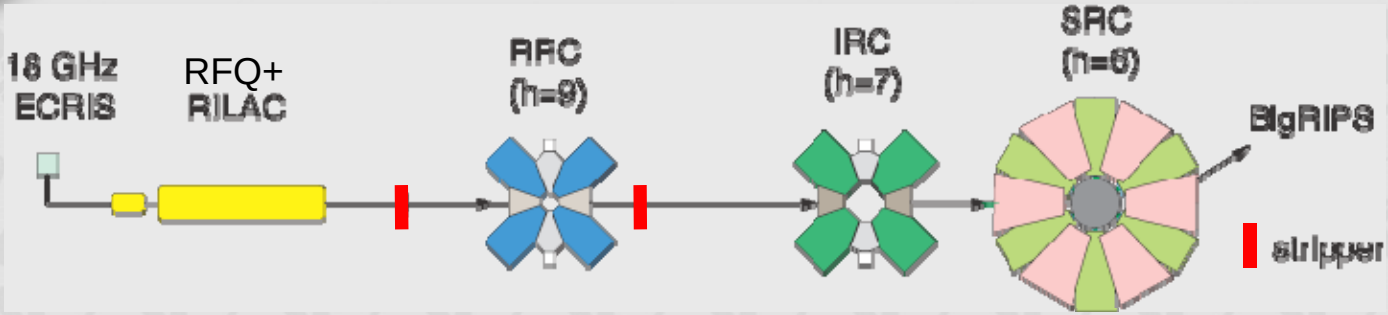
Symbolic photos and movie for RIBF construction and comissioning



Beam Profile of the first beam: $^{27}Al^{10+}$ 345MeV/u

H. Okuno, *et. al.*, "Commissioning of the Superconducting Ring Cyclotron for the RIKEN RI Beam Factory", *IEEE Trans. Appl. Superconduct.*, vol. 18, no.2, pp226-pp231, June 2008.

Variable Frequency mode

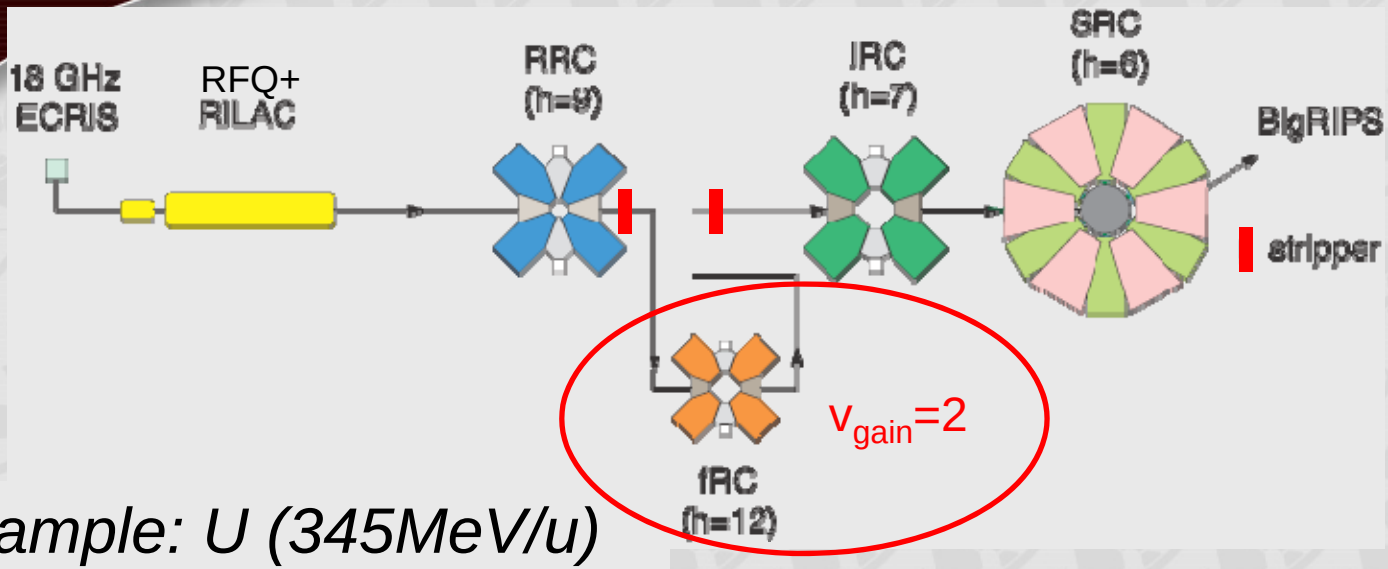


Example: The main parameters for Kr (345MeV/u)

	RFQ+ RILAC	1st Str.	RRC	2nd Str.	IRC	SRC
Freq. (MHz)	36.5		36.5		36.5	36.5
Q	18	→	26	→	34	34
E (MeV/u)	2.3		46		114	345

~~U (345 MeV/u) (Q@RRC > 70+)~~

Fixed Frequency Mode for U 345MeV/u acceleration



Example: U (345MeV/u)

	RFQ+ RILAC	RRC	1st Str.	FRC	2nd Str.	IRC	SRC
Freq. (MHz)	18.25	18.25		54.75		36.5	36.5
Q	35	35	→	73	→	86	86
E (MeV/u)	0.67	11		51		114	345

Accelerated Beams so far

T. Kubo, et. al., “Identification of New Isotopes **^{125}Pd** and **^{126}Pd** Produced by In-Flight Fission of 345 MeV/nucleon ^{238}U: First Results from the RIKEN RI Beam Factory” , Journal of the Physical Society of Japan Vol. 77, No8, August, 2008

	Ion	ECRIS out	RFQ out	RILAC out	RRC out	1st Str. out	FRC out	2nd Str. out	IRC out	SRC out
June 2007	U	50.3	40	19.7	25.1	1.76	1.55	0.31	0.21	0.093
	The F.C.s were not well calibrated (tend to show larger current than real)									
July 2008	U	---	44	16.3	15.1	1.85	2.00	0.53	0.35	-

8 times?

Variable Frequency Mode

	Ion	ECRIS out	RFQ out	RILAC out	1st Str. out	RRC out	2nd Str. out	IRC out	SRC out
Nov. 2007	Kr	---	---	---	---	---	---	---	30
June 2008	Ca	---	---	---	688	363	310	270	---

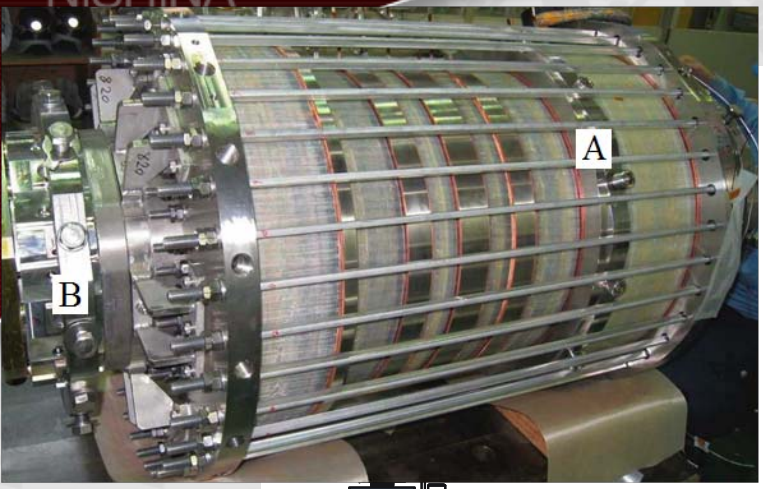
Good long term stability

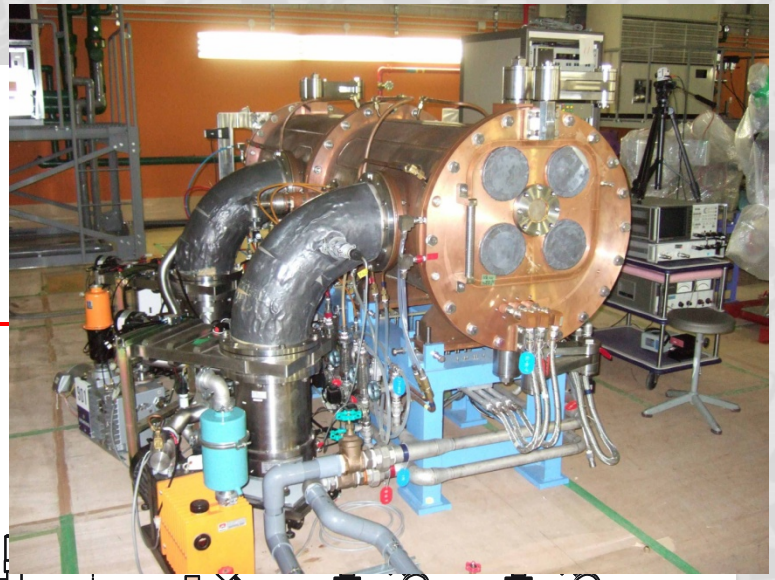
Goal intensity : 1000pnA

Key issues to increase the intensity of U beam

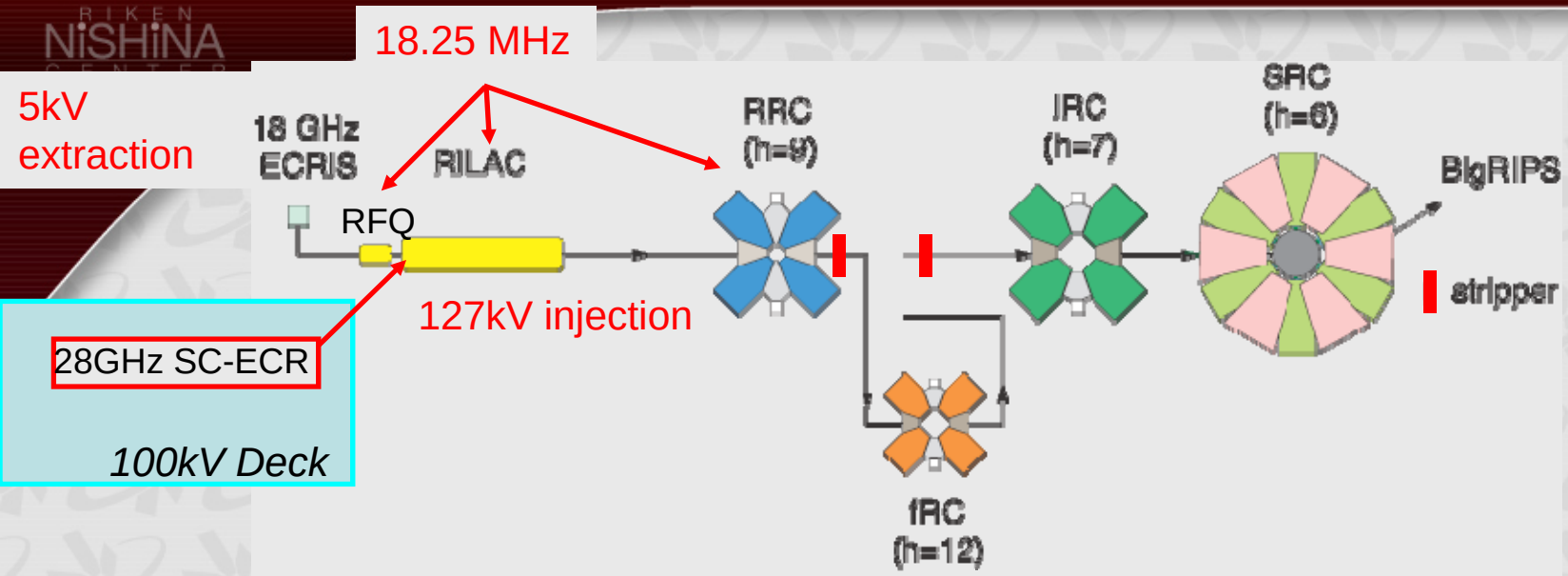
- Increase the beam intensity from the ion source
  - New 28GHz Superconducting ECR ion source
  - Goal intensity of U^{35+} >15 pμ A (1pμA @ SRC)
  - Operation test will be started in January 2009
- Improve transmission efficiency
  - Flattop acceleration in the cyclotrons
  - Careful tuning in each accelerator
  - New injector (Efficient acceleration in the low energy region)
  - Avoid the emittance growth due to the space charge.
- Make charge strippers with long lifetimes
  - The 1st stripper is critical.
  - Max. lifetime ~24hrs @500enA after RRC
  - Searching another candidate: Rotating, Gas, Liquid Li…
    - *Hasebe, Kuboki: INTDS2008 @Caen, France*

Plan A: New injector to RRC





Plan B:
Put the 28GHz ECR ion source before the existing RILAC



- *In the mode for U (345 MeV/u) acceleration*

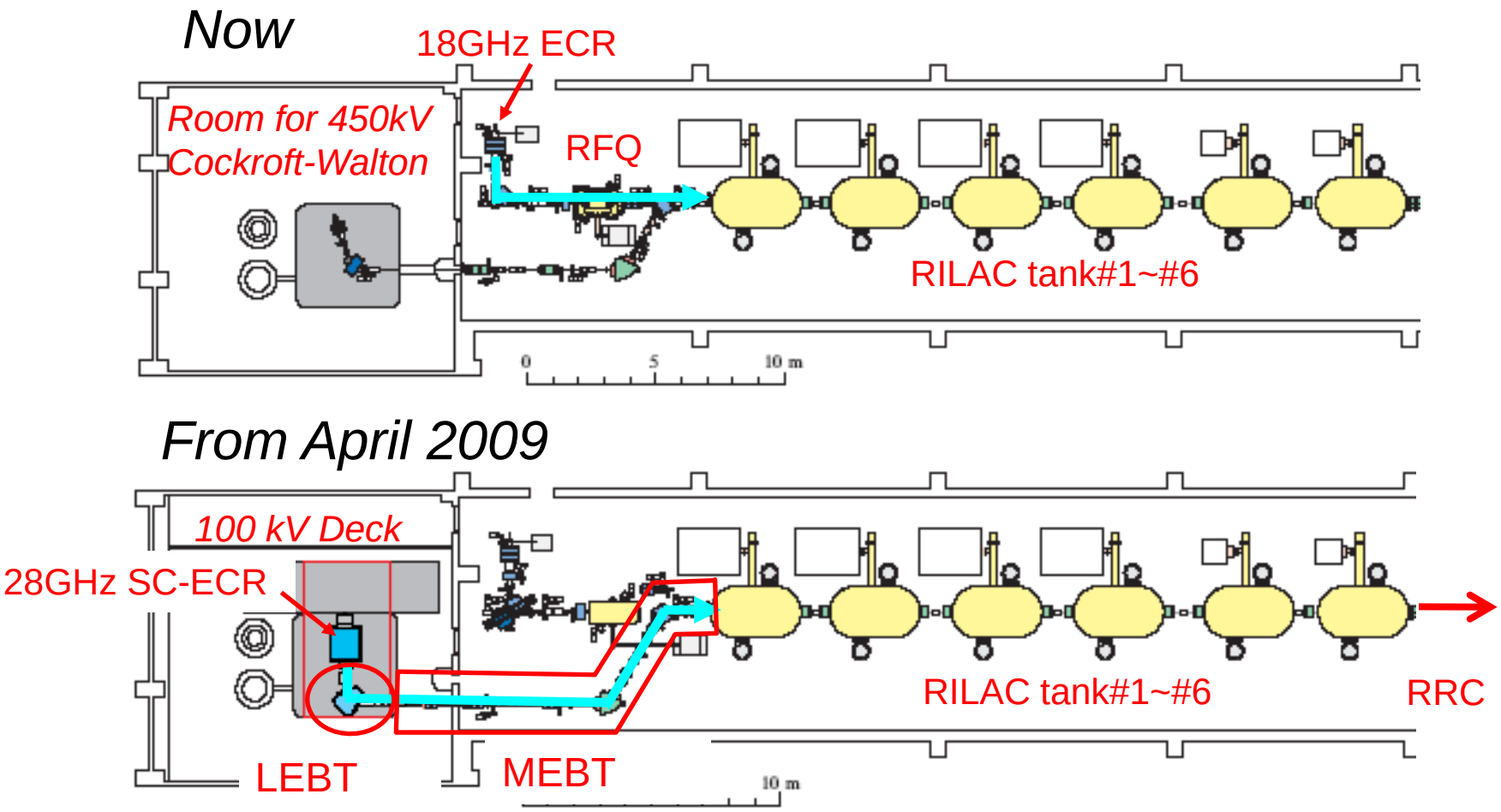
  Frequency of the injectors :18.25 MHz (Low)

  Extraction voltage : 5kV (Low)

  Acc. voltage after the RFQ :127kV (Low)

→put 28GHz ECR on the HV deck (127kV)
to directly inject to RILAC, skipping RFQ

Plan B is easy for us.



Beam Dynamics Study using the TRACK code

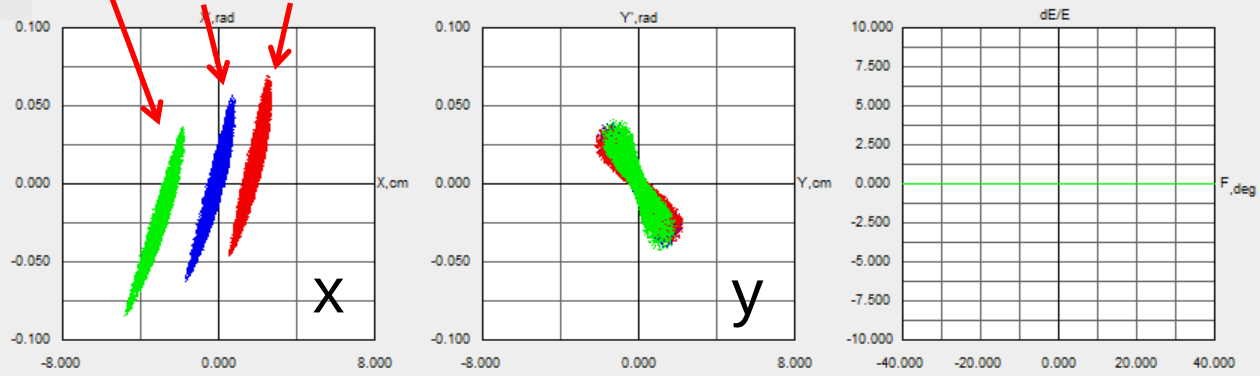
LEBT (Outline)

RIKEN 28GHz SC-ECR

Aug 15,2008,12:32:47
Aug 15,2008,12:37:27

0 mA

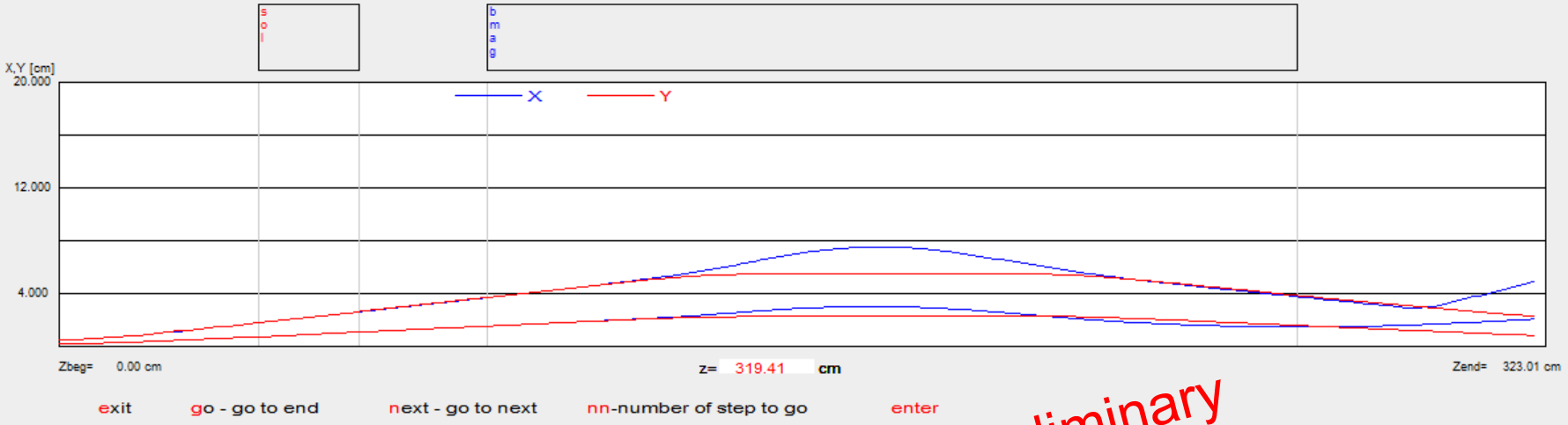
36+,35+,34+ of ^{238}U



Q= 35 34 36
W= 3.982 keV/u
current= 0.000 mA
SPACE CHARGE
Nx= 65 Ny= 65 Nz= 65 zlhSC=*****
hx/sx= NaN hy/sy= NaN hz/sz= NaN

Solenoid

90deg. Bending Magnet with fringing fields



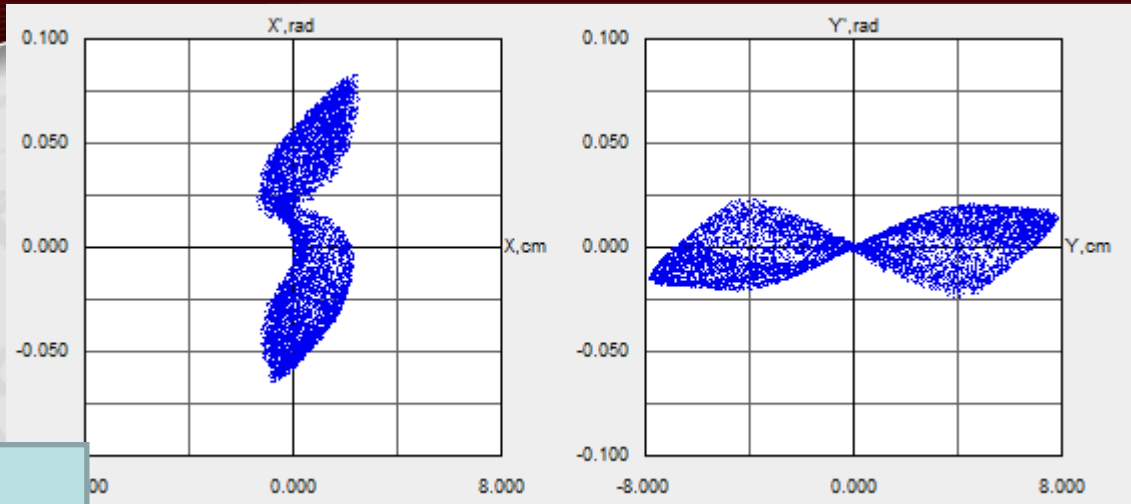
preliminary

from Ion Source (27kV)

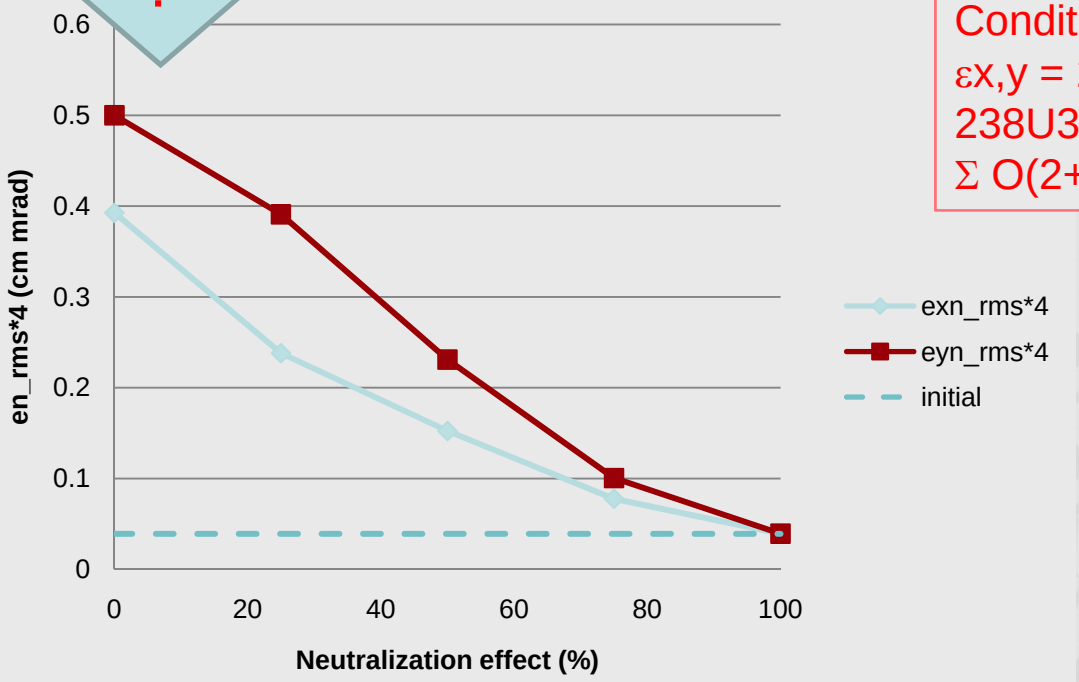
to selection slit

LEBT (Neutralization of Space Charge Effect)

0 %



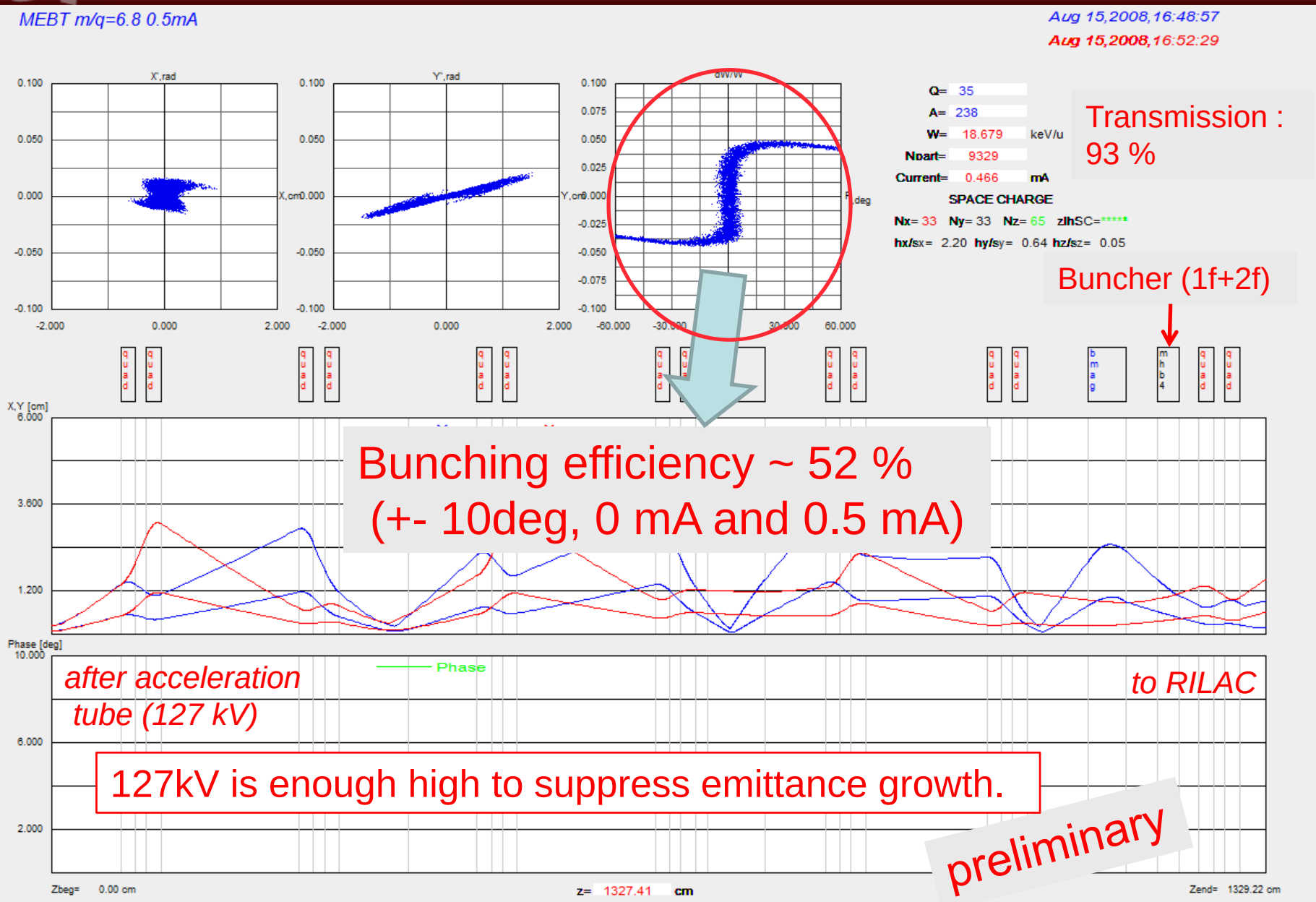
?



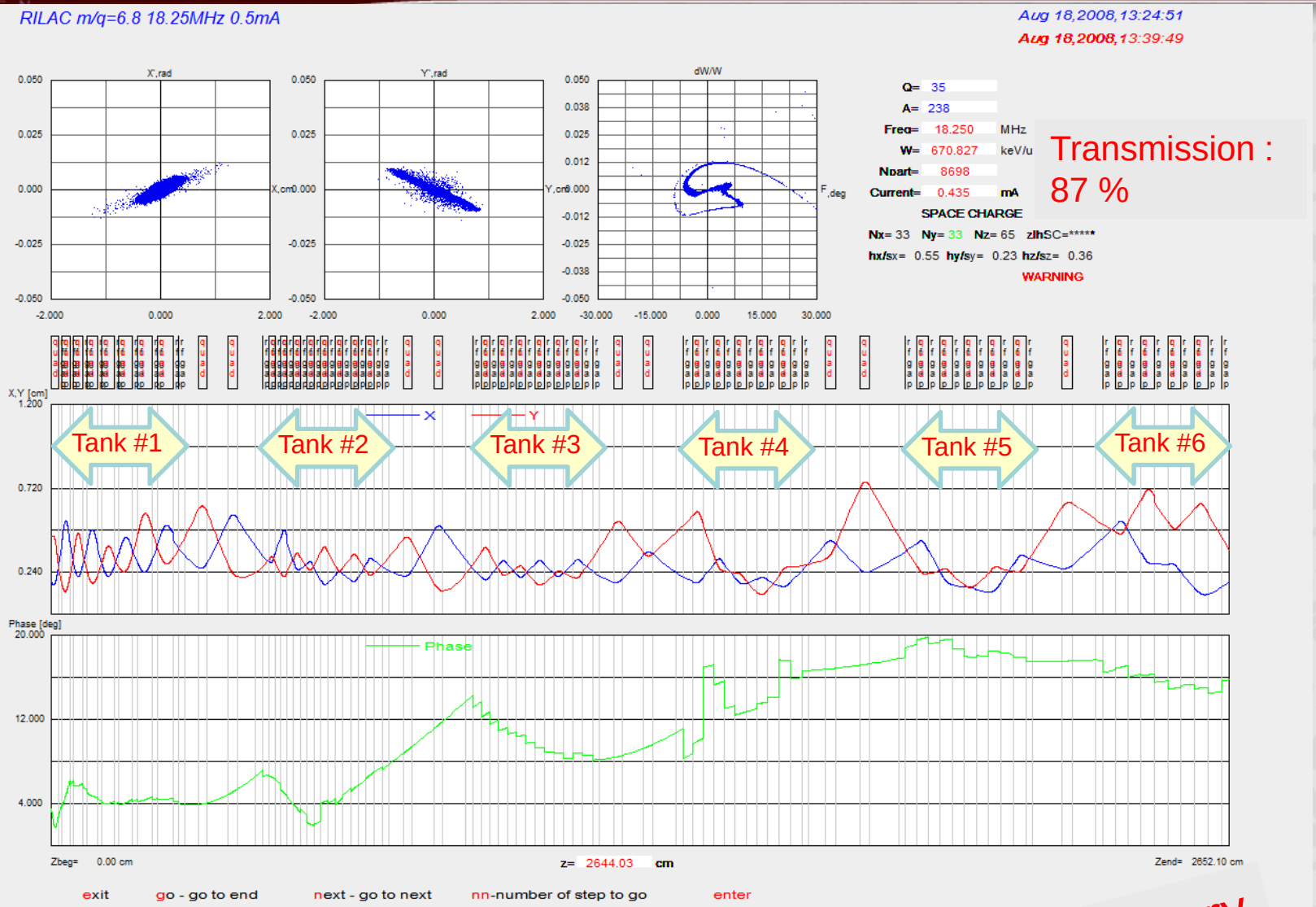
Conditions
εx,y = 200 π mm mrad
238U35+ = 0.5 mA
Σ O(2+,3+,4+,5+,6+) = 10 mA

preliminary

MEBT (127kV, 0 mA and 0.5 mA)

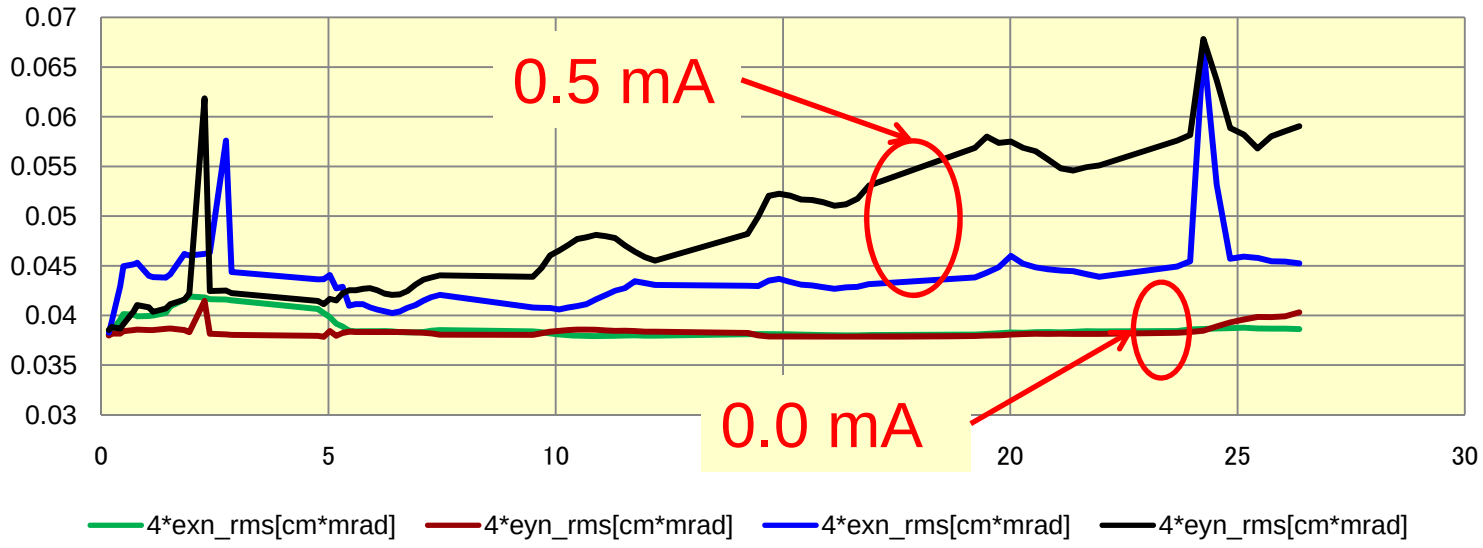


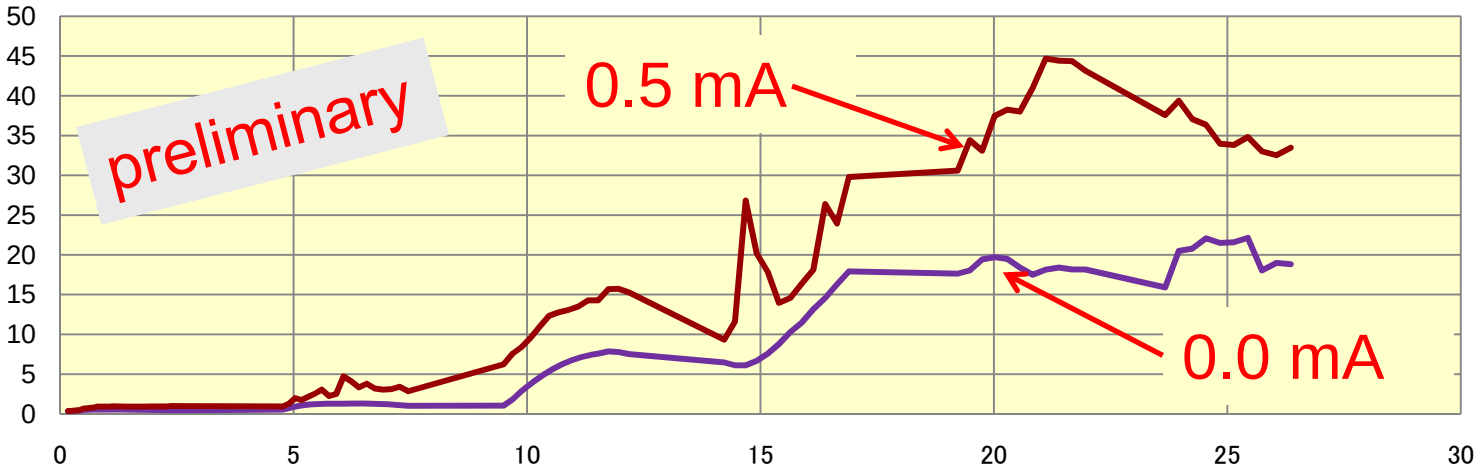
RILAC (Wideroe Type, 0 mA and 0.5 mA)



preliminary

Emittance (r.m.s.) growth in the RILAC

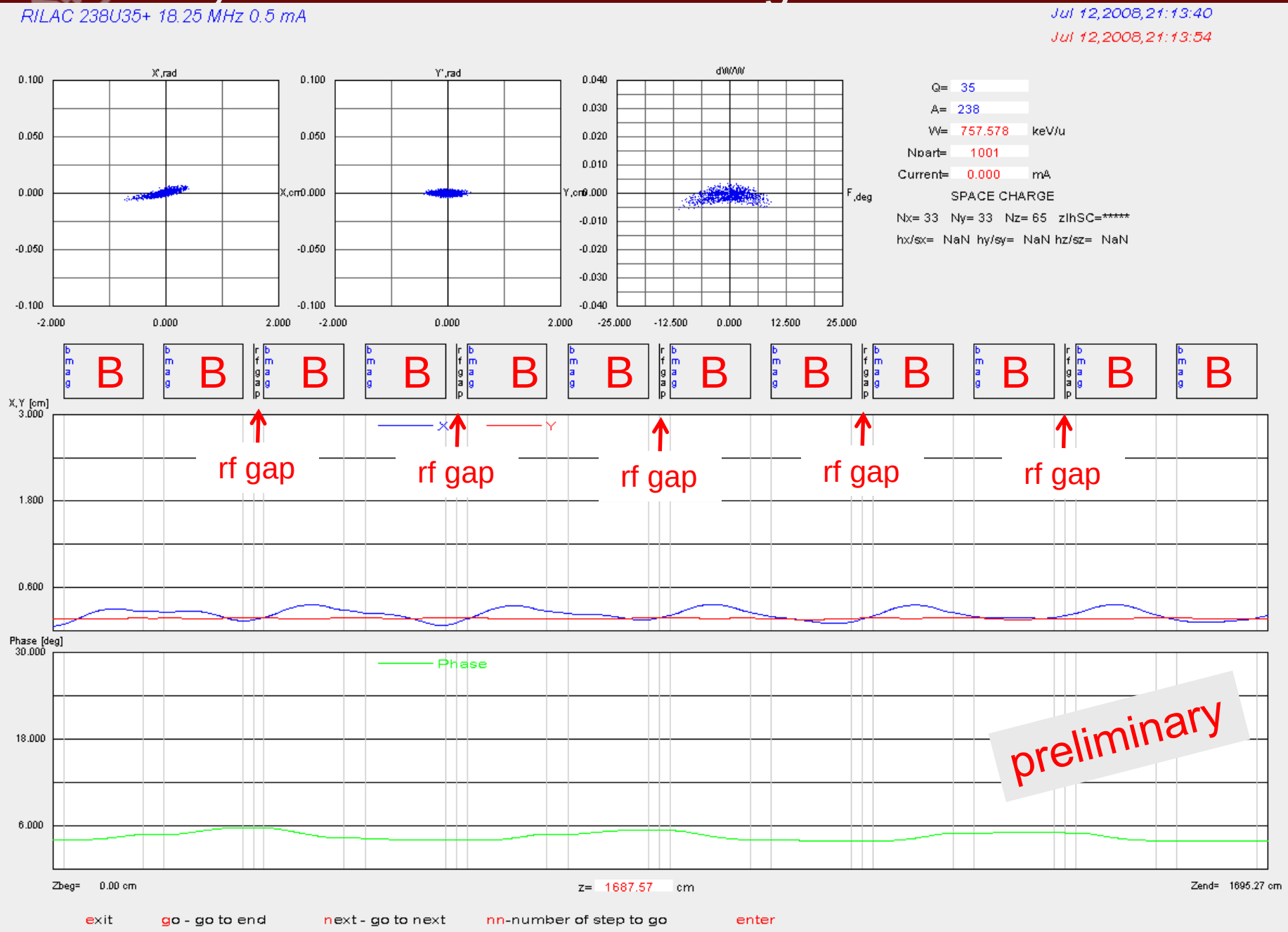




Efficiency in the succeeding cyclotrons will decrease.

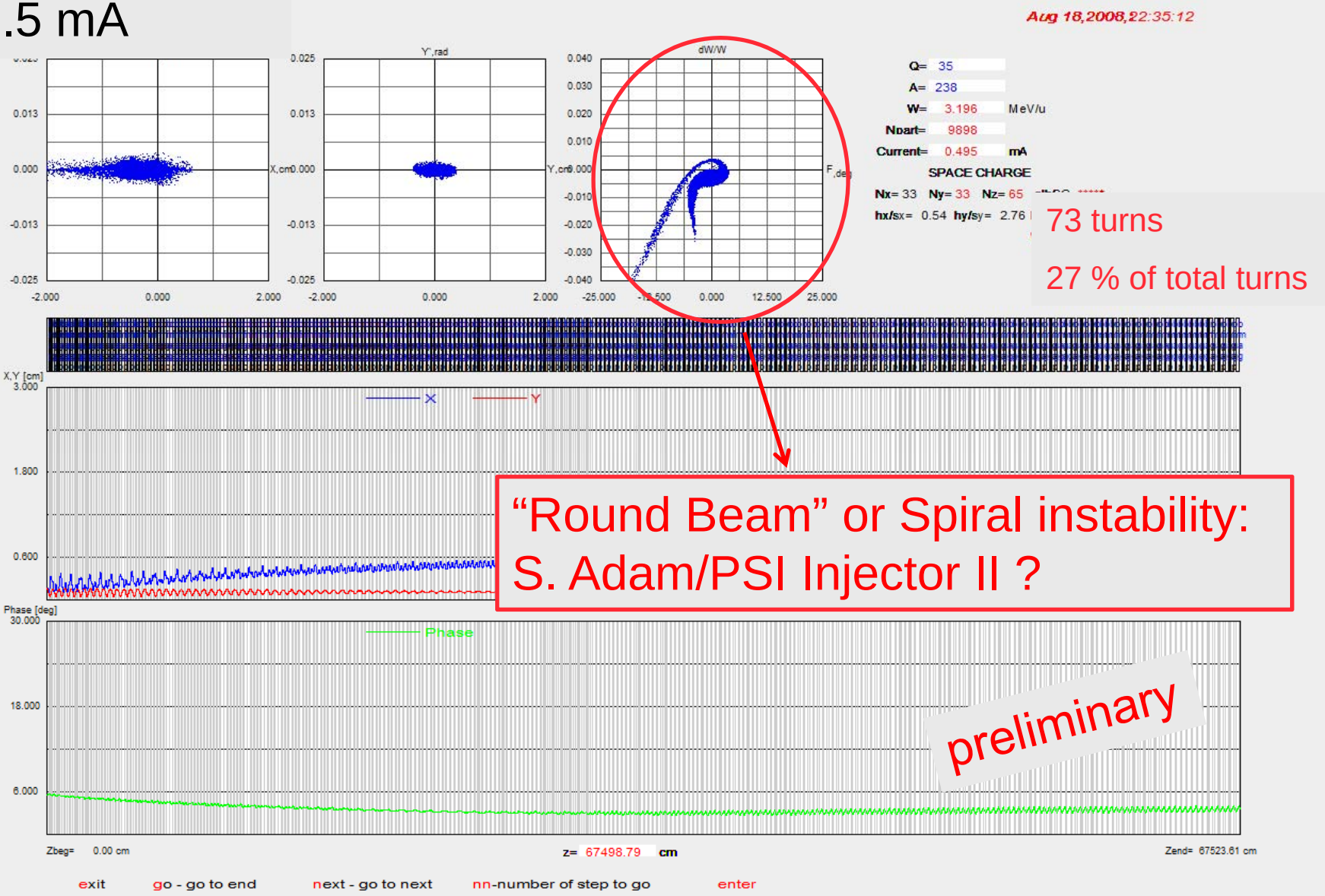
→ We need the new Injector (Plan A)!

Cyclotron Simulation using TRACK code



RRC (0 mA and 0.5 mA)

0.5 mA



73 turns

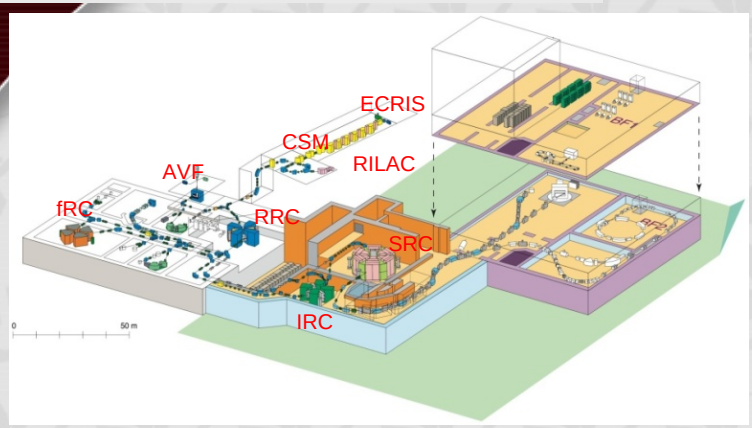
27 % of total turns

"Round Beam" or Spiral instability:
S. Adam/PSI Injector II ?

preliminary

Review of the Talk

Introduction of RIBF

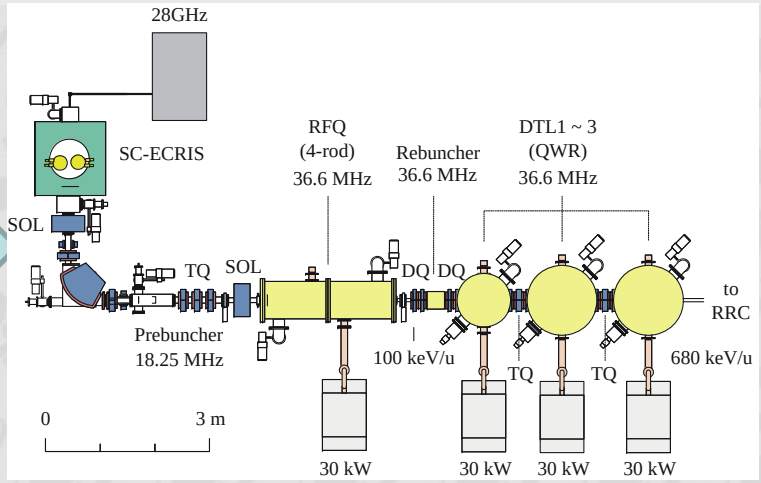


Status of the beam intensity

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	Ion	ECRIS out	RFQ out	RILAC out	RRC out	1st Str. out	FRC out	2nd Str. out	IRC out	SRC out
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July 2008	U	---	44	16.3	15.1	1.85	2.00	0.53	0.35	-

Upgrade plans of the Injector



Beam dynamics using TRACK

LEBT	MEBT	RILAC	RRC
Neut. Factor ?????	○	△	???? spiral ????

Space Charge Forces