Current Status of KURRI FFAGs

FFAG13, Vancouver
Sep. 21 2013

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Outline

1. Summary of the machine time in FY 2012

2. Users of KURRI FFAG

3. User requirements

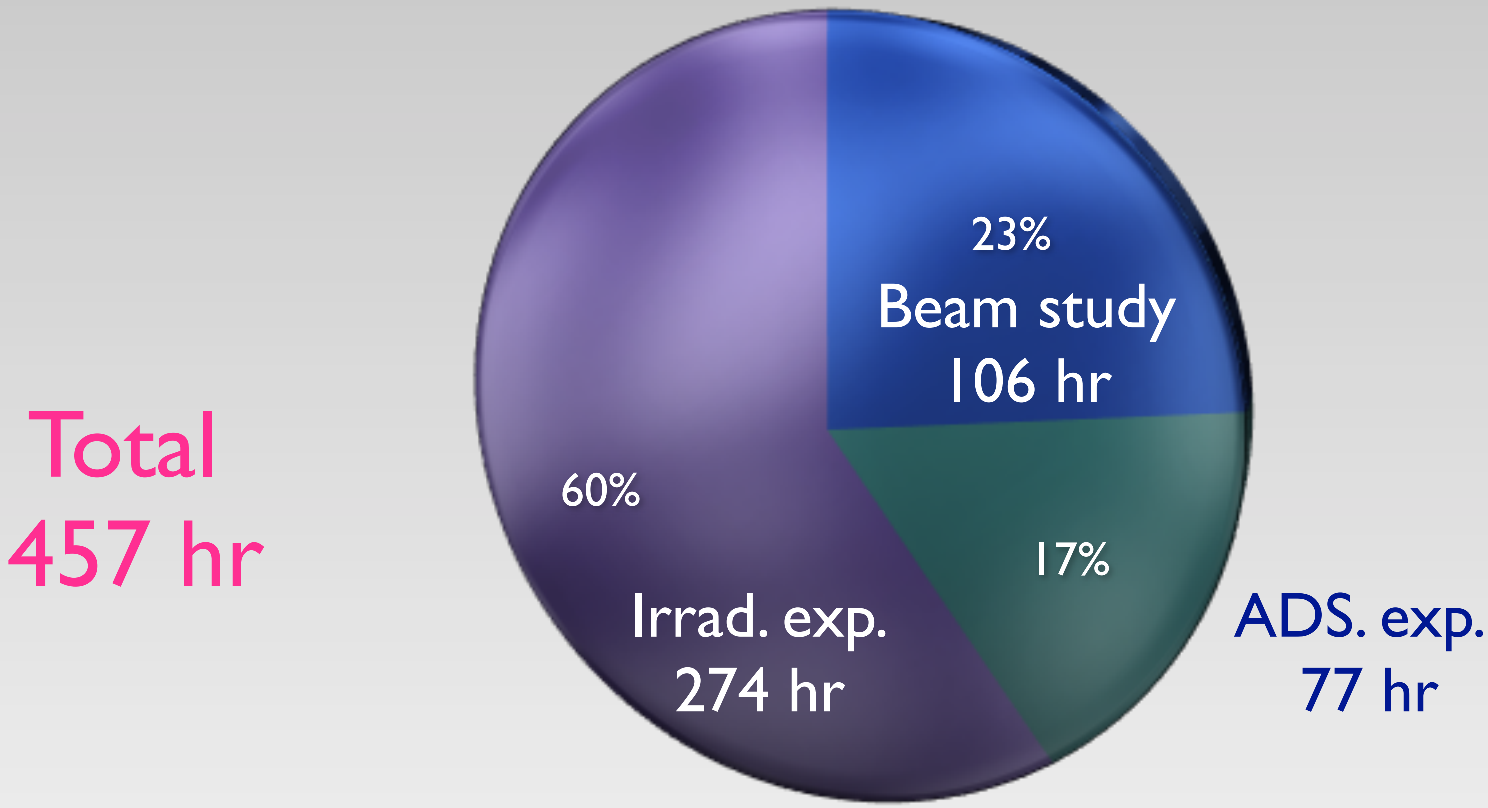
4. Control system upgrade

5. Beam diagnostics system upgrade

6. Results from beam studies in this summer

7. Summary

Summary of Machine Time (FY 2012)

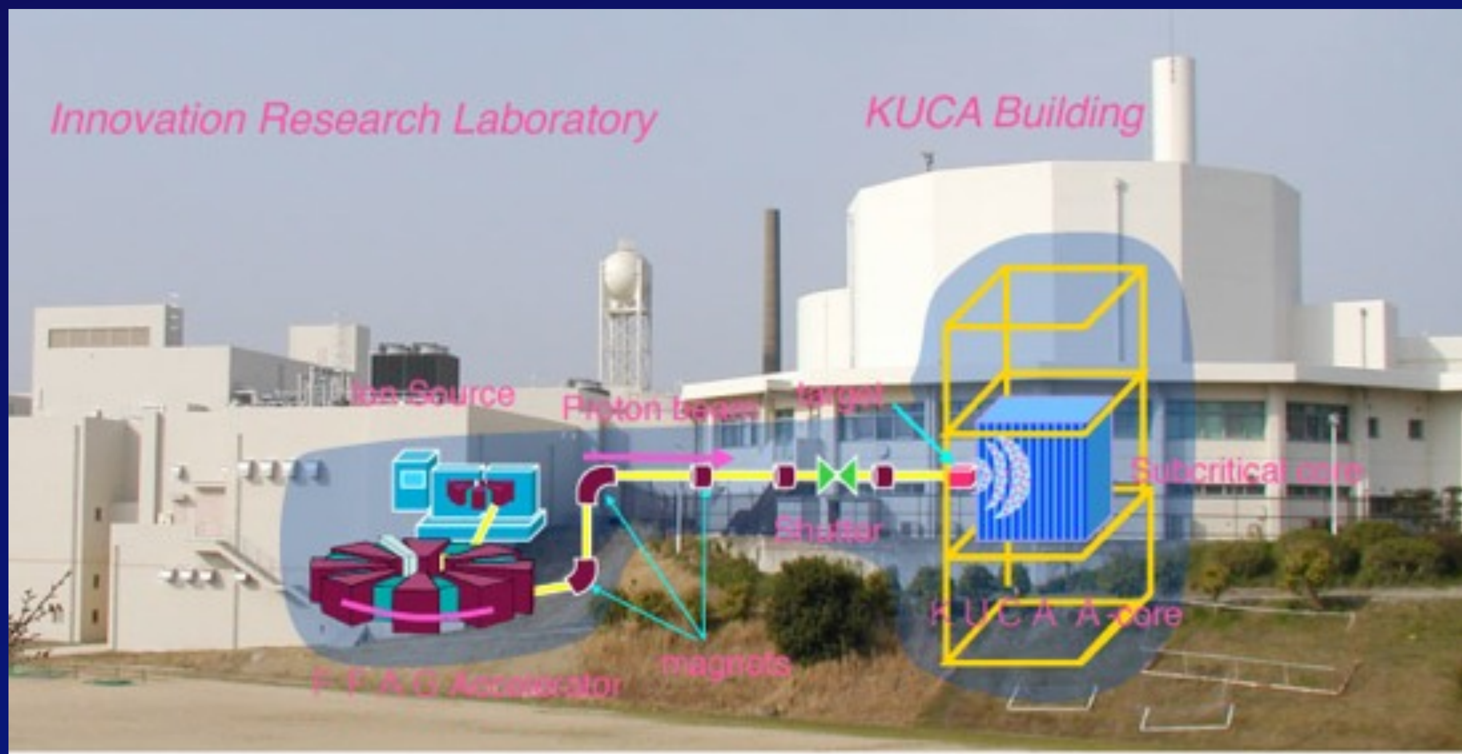


	unit	May. - Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Beam Study	hr	77	21	5	3	0	0	0
ADS Exp.	hr	0	0	28	0	49	0	0
Irrad. Exp.	hr	0	9	0	14	24	73	153
Ext. Energy	MeV	100/150	150	100	150	100	150	150

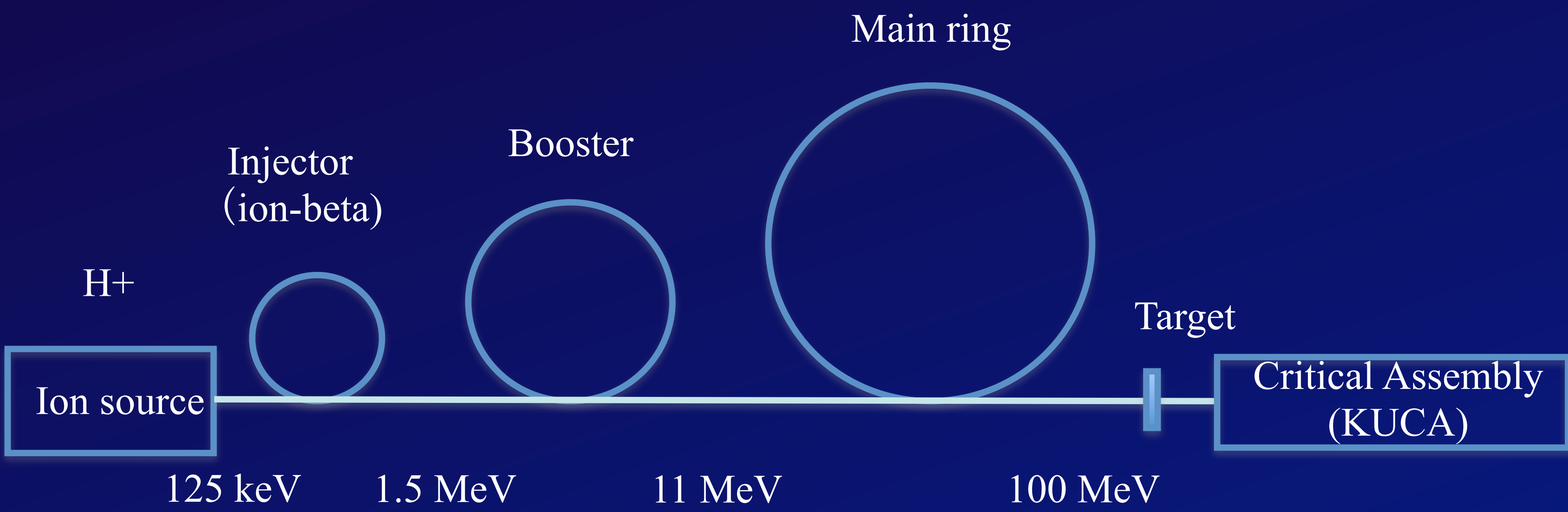
FFAG users of KURRI FFAG

- 2012
  - ADSR experiment (100MeV / 1nA)
  - Irradiation experiment for material engineering (higher the better : 150MeV / 10nA)
- 2013
  - Hybrid irradiation of proton and neutron (BNCT) to mice with tumor

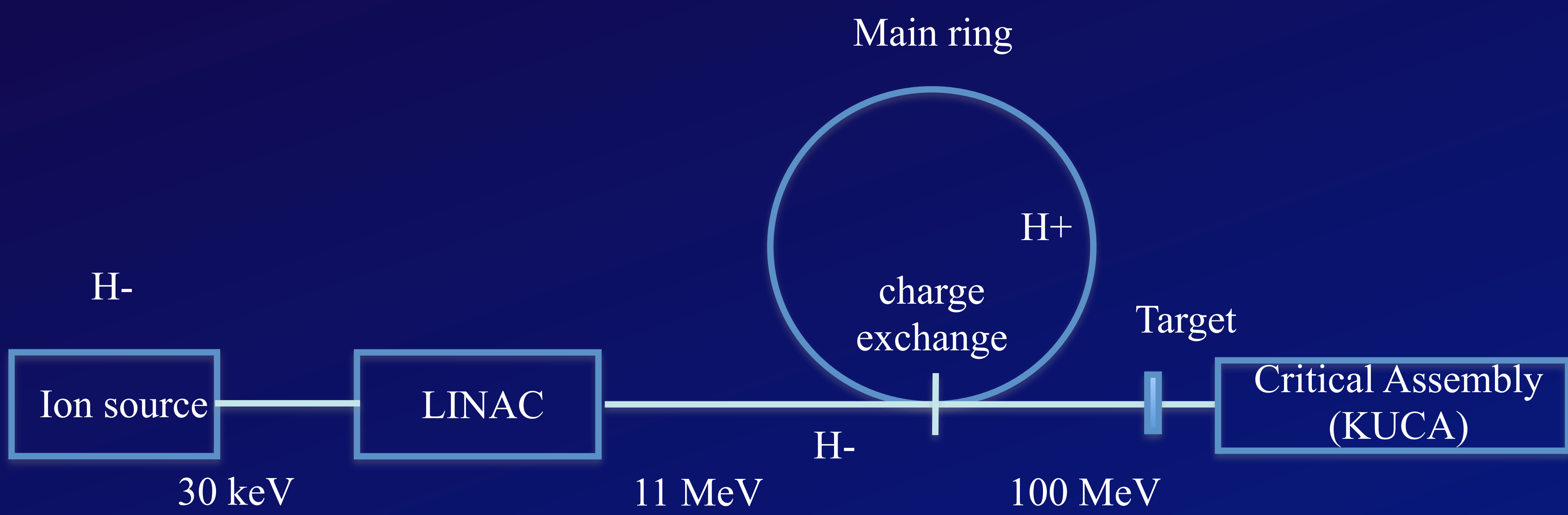
The KURRI-FFAG accelerator complex has been constructed in the innovation research lab. ; connected to KUCA to deliver the high energy proton beam.



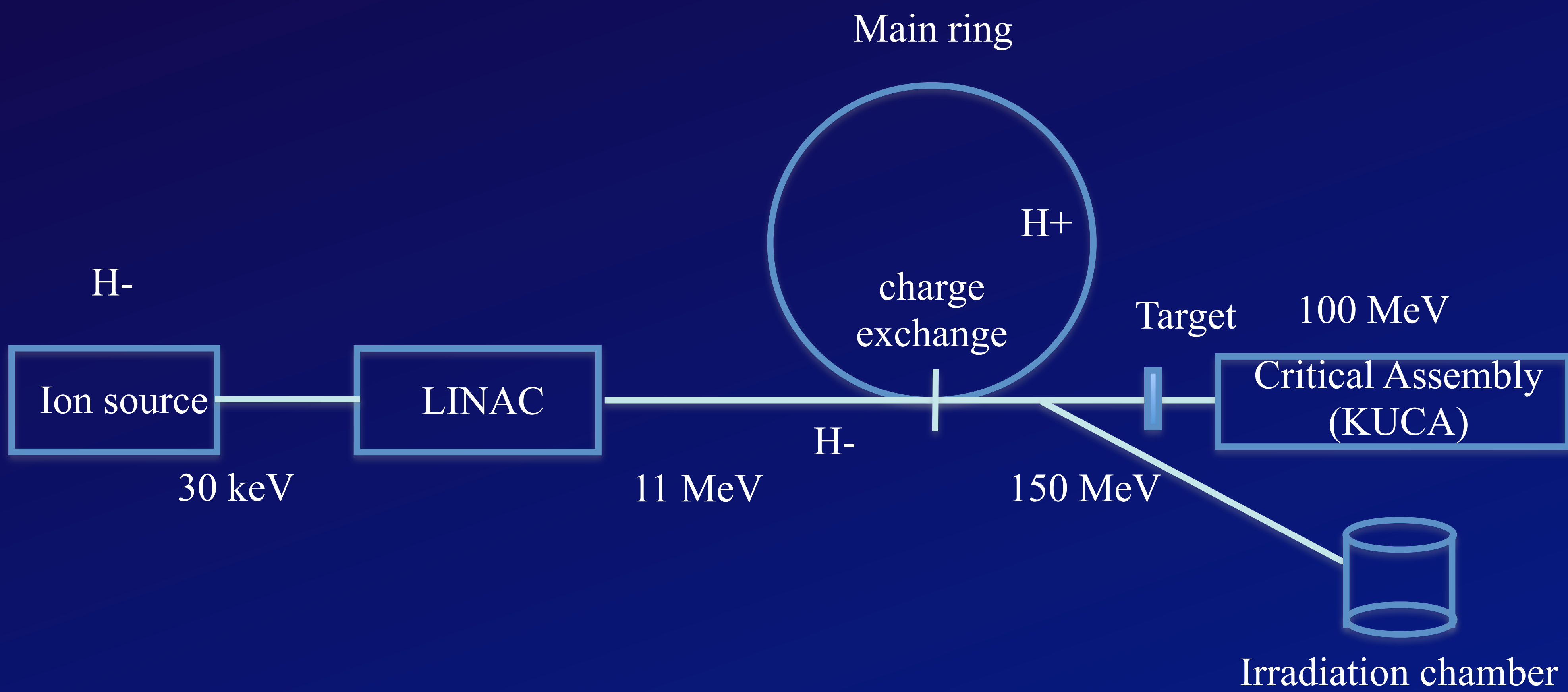
FFAG – KUCA ADS system schematic diagram (original) 2008 - 2010



FFAG – KUCA ADS system schematic diagram (upgraded) from 2011



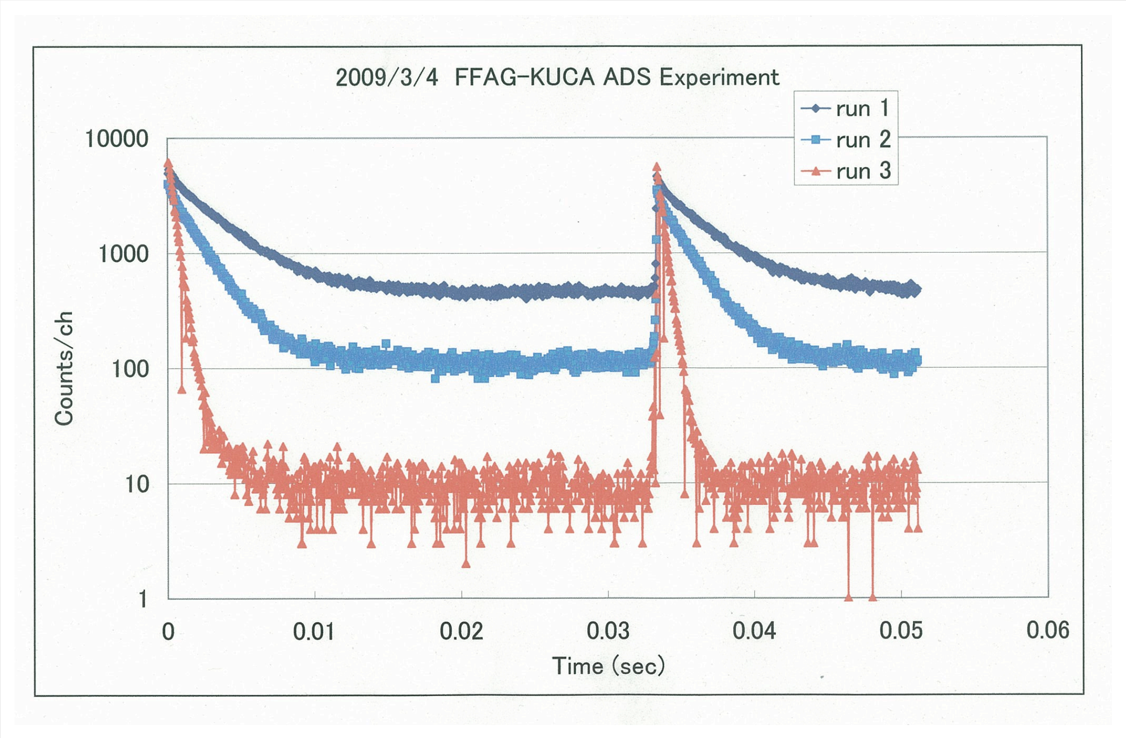
FFAG – KUCA ADS system schematic diagram (upgraded) from 2012



ADS experiments in KUCA

- There are two kinds of measurements in KUCA
  - Dynamic characteristics measurement detecting prompt and delayed neutrons

    Require ultra low intensity (but quite stable) beams to avoid piling up of neutron counting. e.g. 5pA - 10pA 1/1000 ordinary intensity



  - Neutron energy spectrum measurement using radio activation

Two-layer target study (^{235}U-core) - 2013

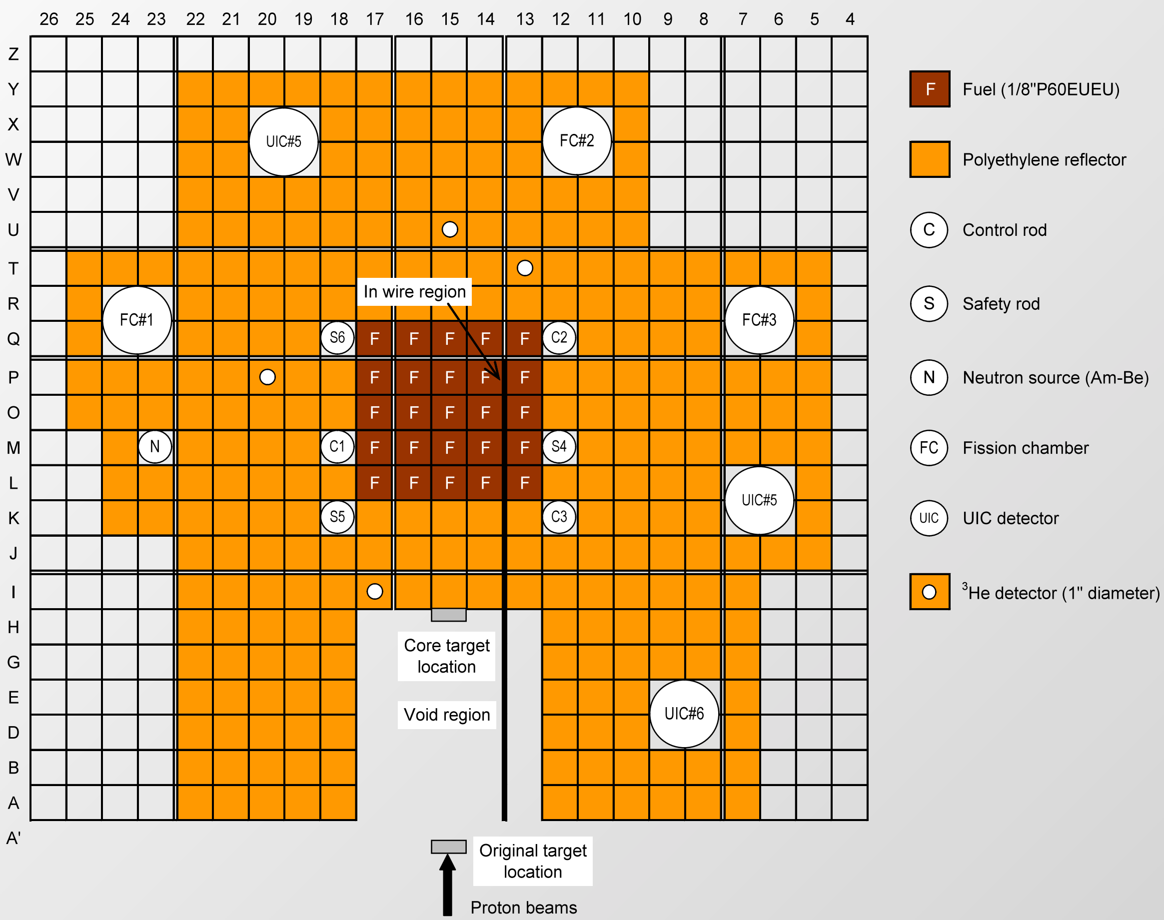


Fig. Core configuration of ^{235}U-loaded cores (100 MeV protons)

(Protons: 100 MeV, 0.5 nA, 100 ns, 20 Hz)

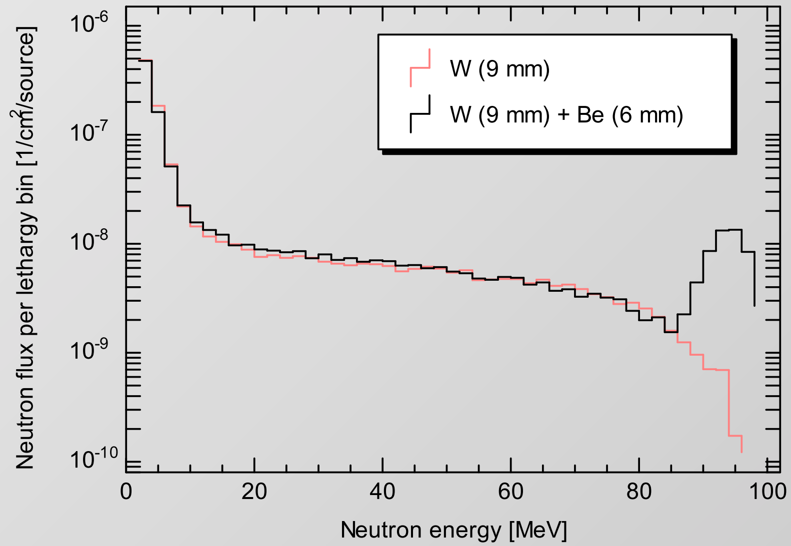


Fig. Neutron spectra (W vs. W+Be)

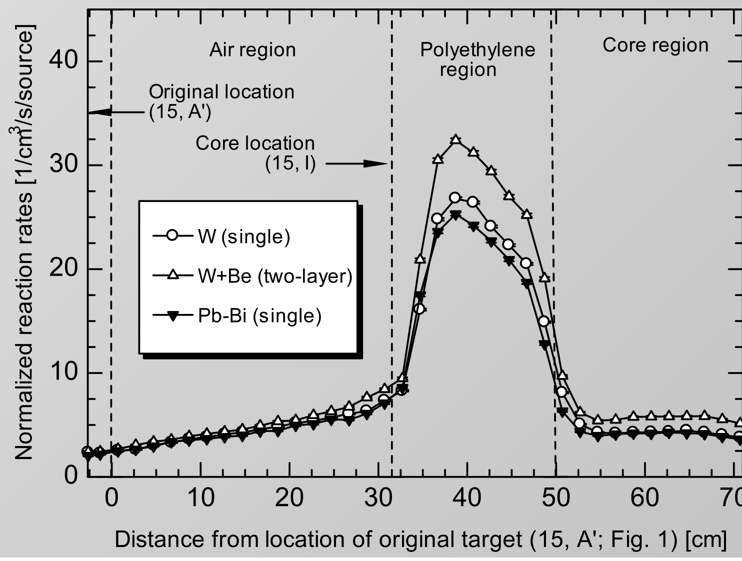
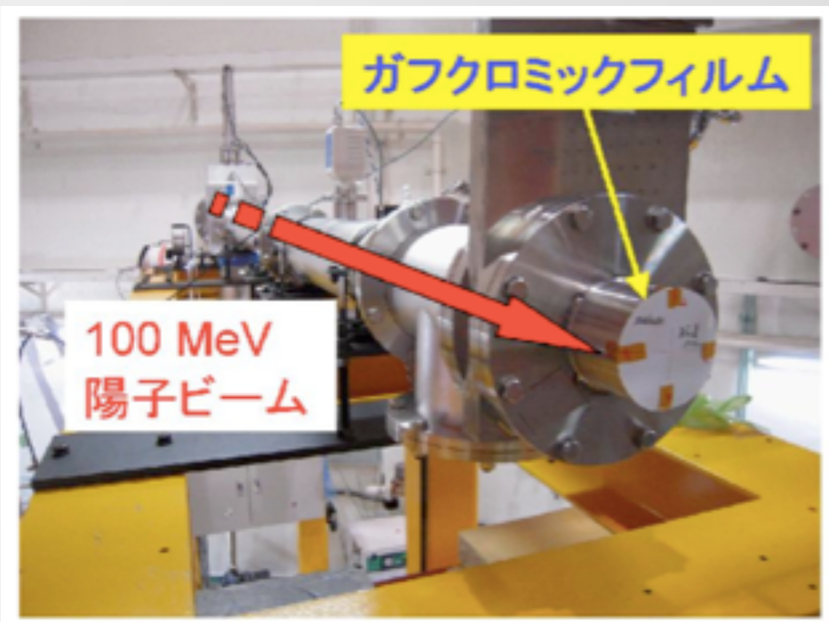


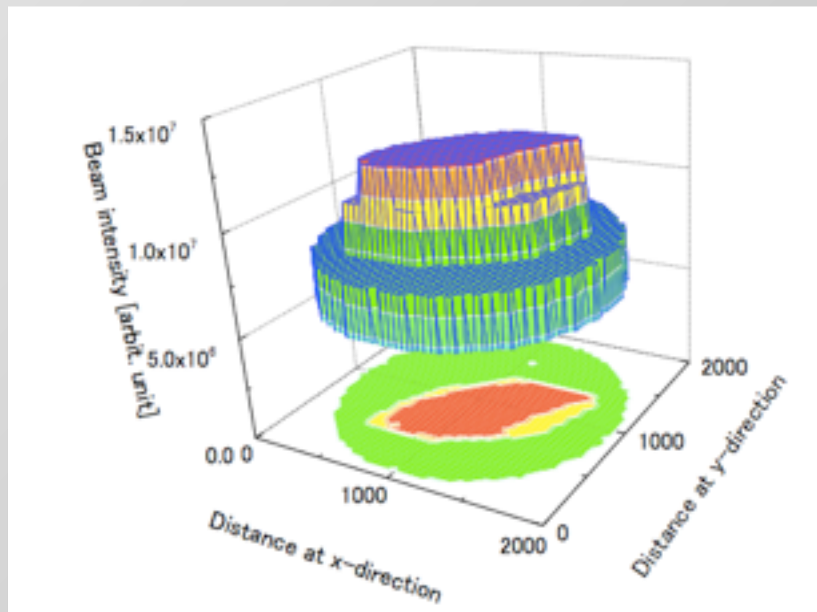
Fig. In reaction rates (W, W+Be and Pb-Bi)

Usually, a static measurement takes 1 - 2 hr. During this period, if the beam is down due to some hardware trouble .e.g. LINAC tube fault, the beam down time should be less than 1 minute, otherwise accumulated activity decays and data will be meaningless.

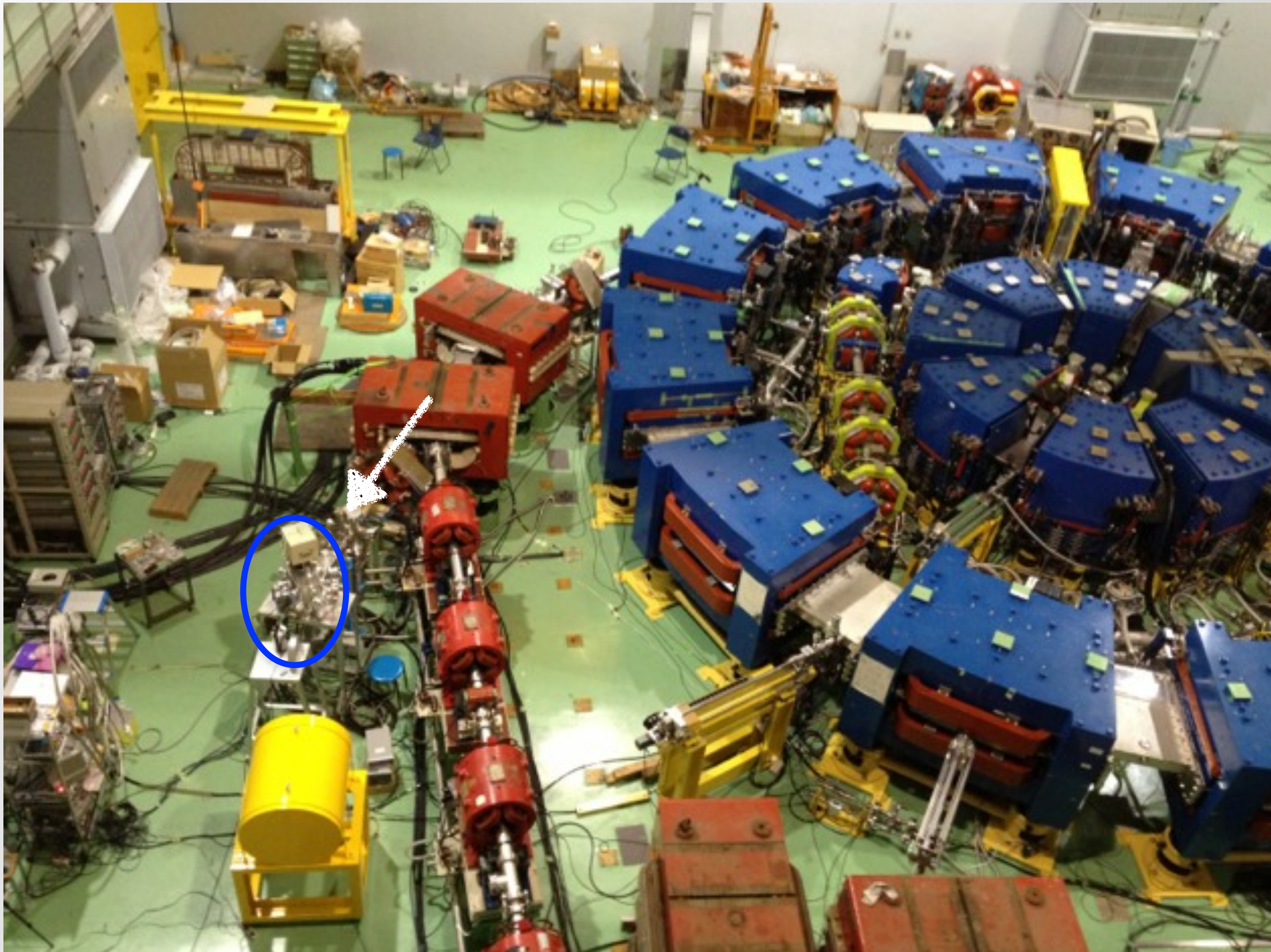
They also require stabilities concerned with:

1. Beam energy (B field of main F/D, RF pattern, kicker timing)
2. Pulse interval (OK, actually hard to change)
3. Beam profile (beam emittance, stability of extraction devices, BT system)
4. Beam intensity (ion source condition, LINAC rf, main ring rf)



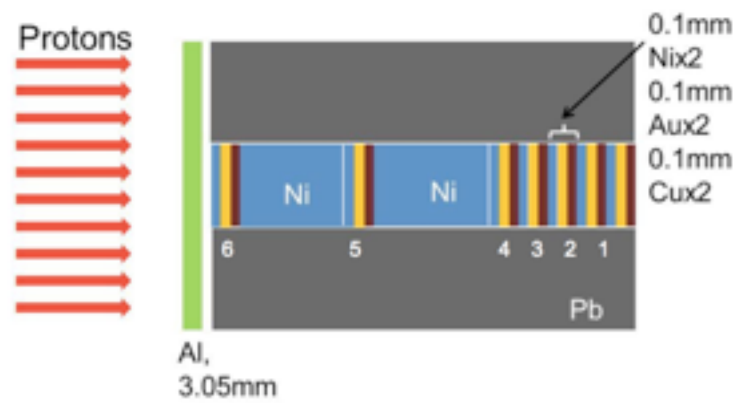


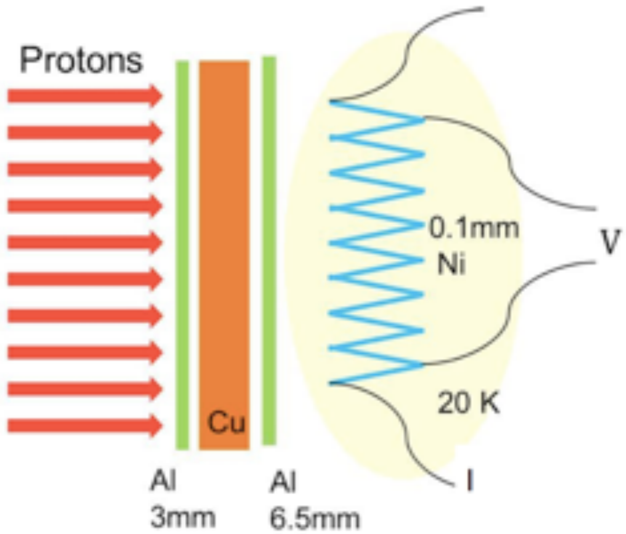
Beam Line and Chamber for Irradiation Experiments

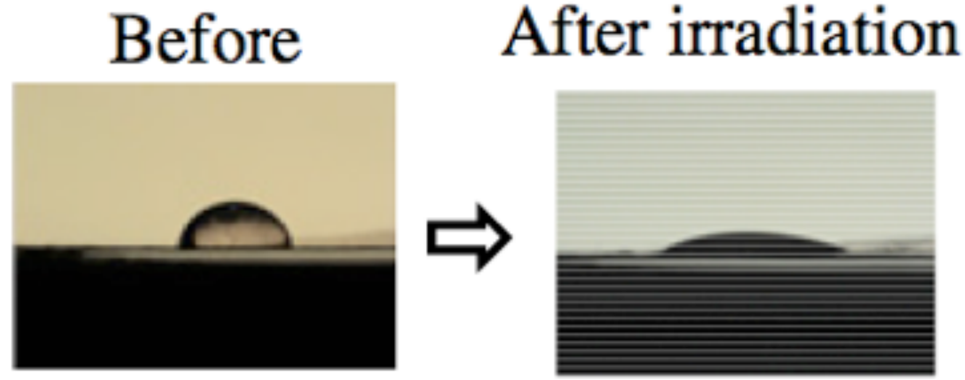


The irradiation port connected to the 150 MeV proton beam line.
It has cryogenics and traction control machine inside which realize measurements under irradiation of the proton beam.

This study was a result of “Clarification of material behaviors in ADS by an FFAG accelerator” carried out under the Strategic Promotion Program for Basic Nuclear Research by the Ministry of Education, Culture, Sports, Science and Technology of Japan.





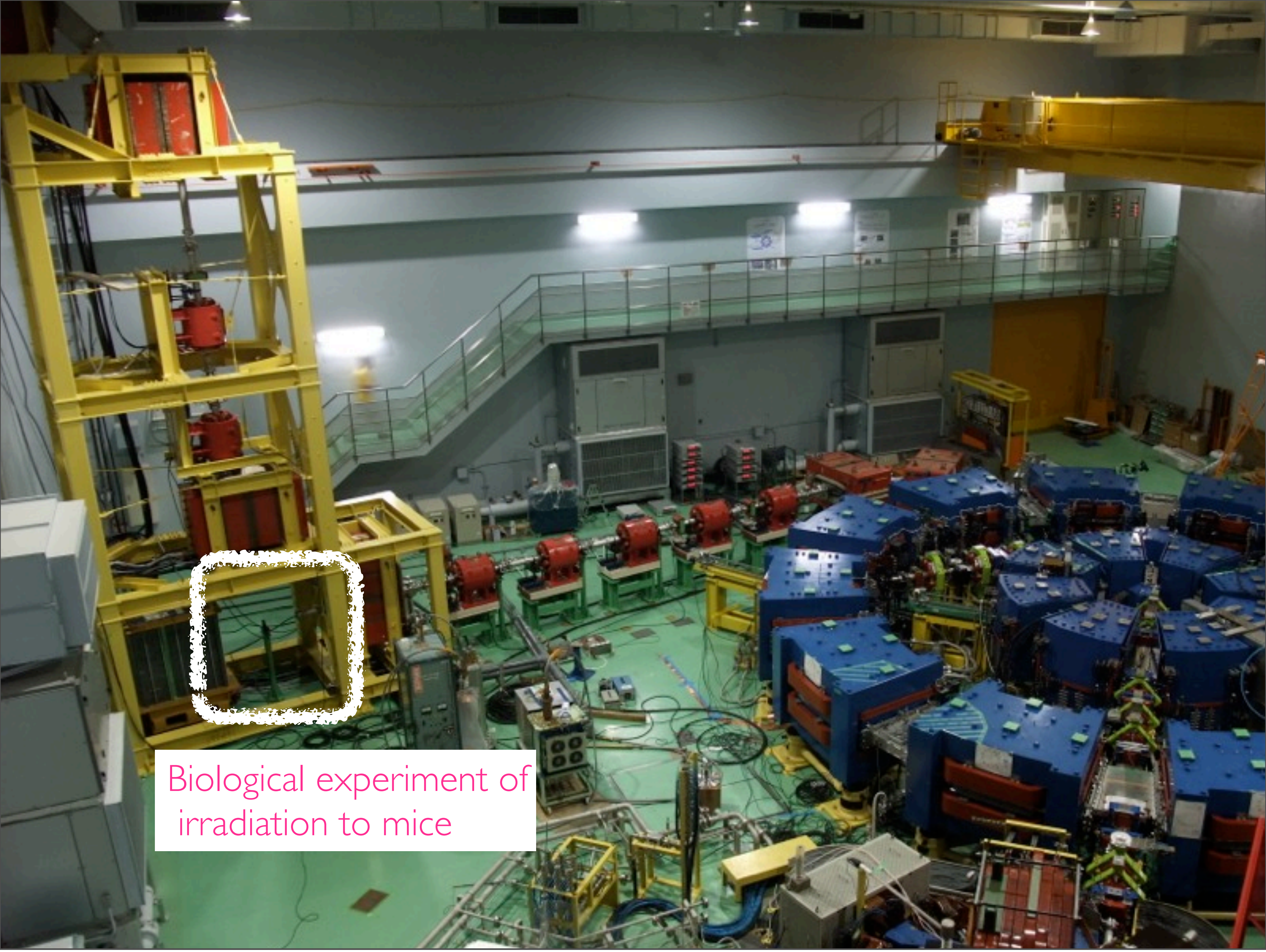


(a) Copper without oxide layer

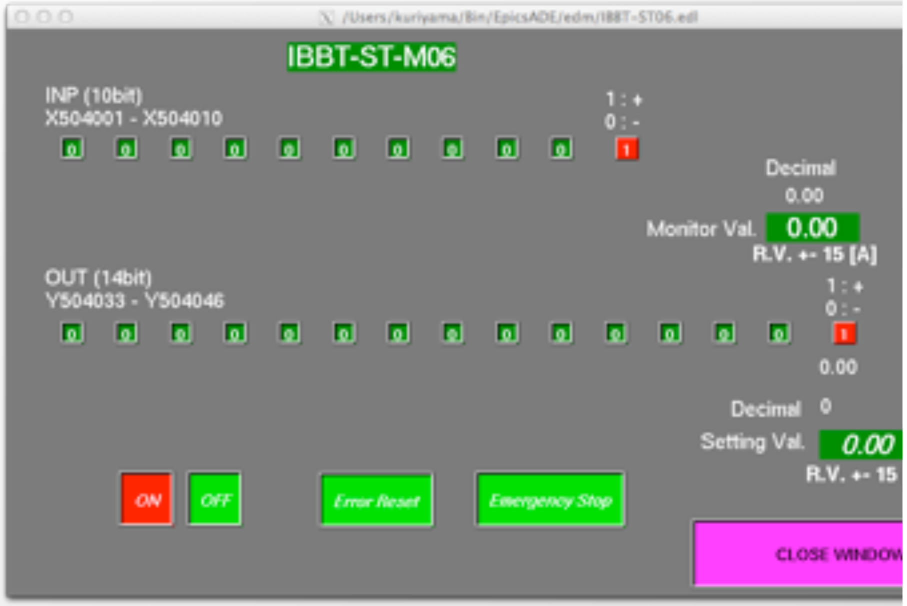
(b) Copper with oxide layer

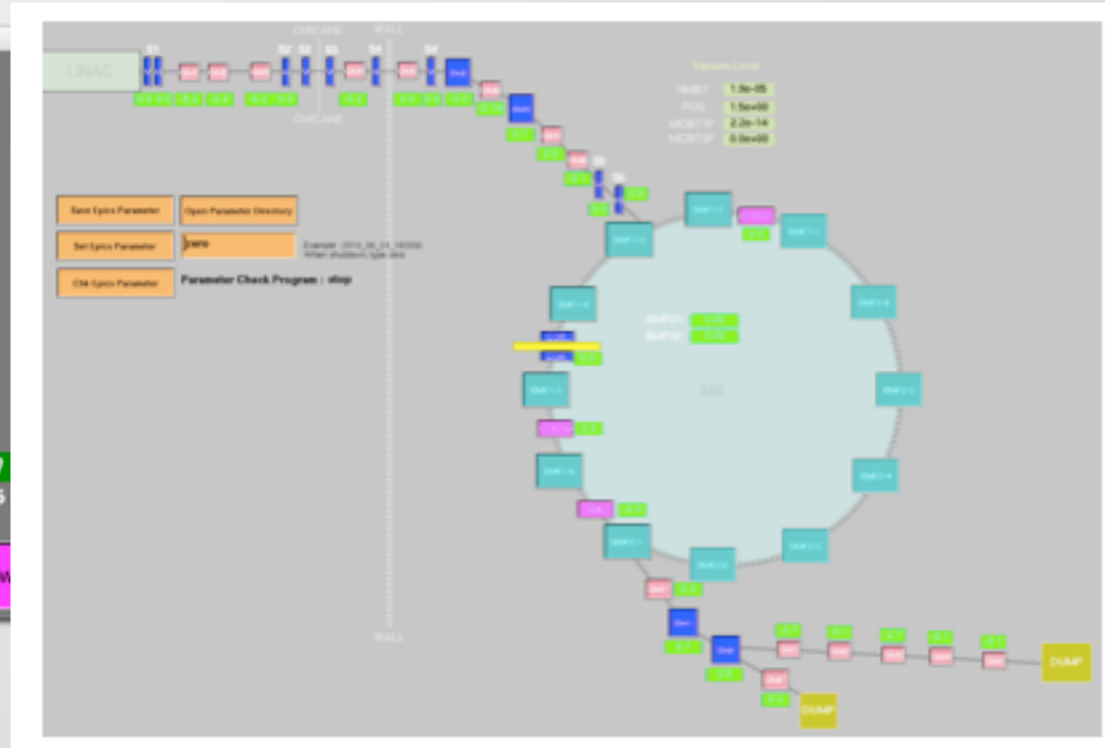
Discrepancies between measurements and theoretical calculations have been found in distributions of lattice defect in beam direction. They have used two different method i.e. positron life time measurement and electrical resistance measurements. They are planning to further measurement to confirm them in Dec.

Using the FFAG accelerator, irradiation effects on wall wettability were investigated in this study. Pictures show the wettability change before and after 100 MeV proton irradiation with 4.7 nA for 50 h. The wettability on copper surfaces was enhanced by the proton irradiation regardless of the surface conditions.

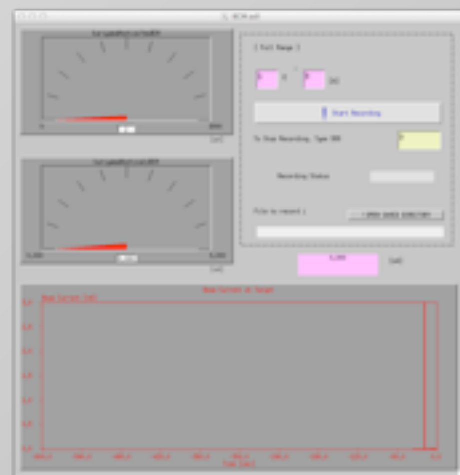

Biological experiment of
irradiation to mice

Upgrade of control system

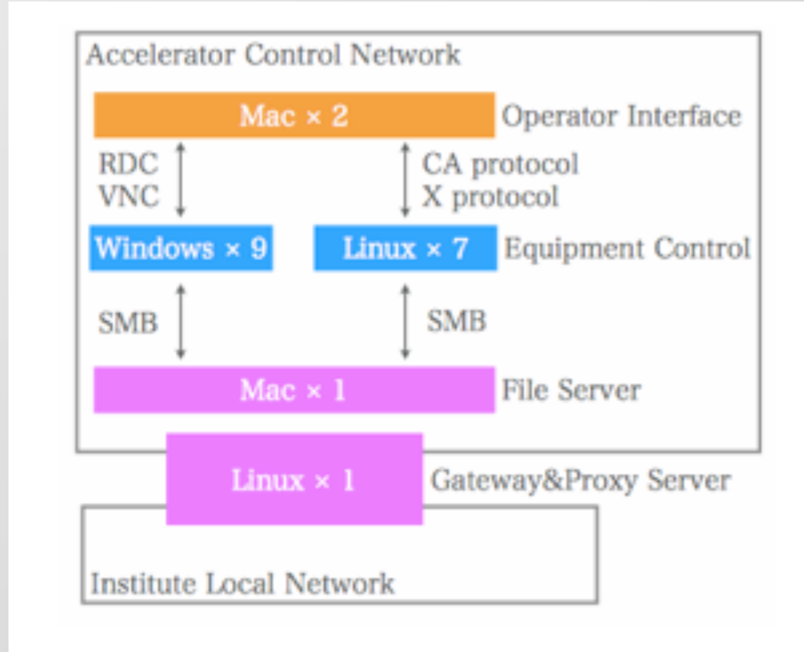


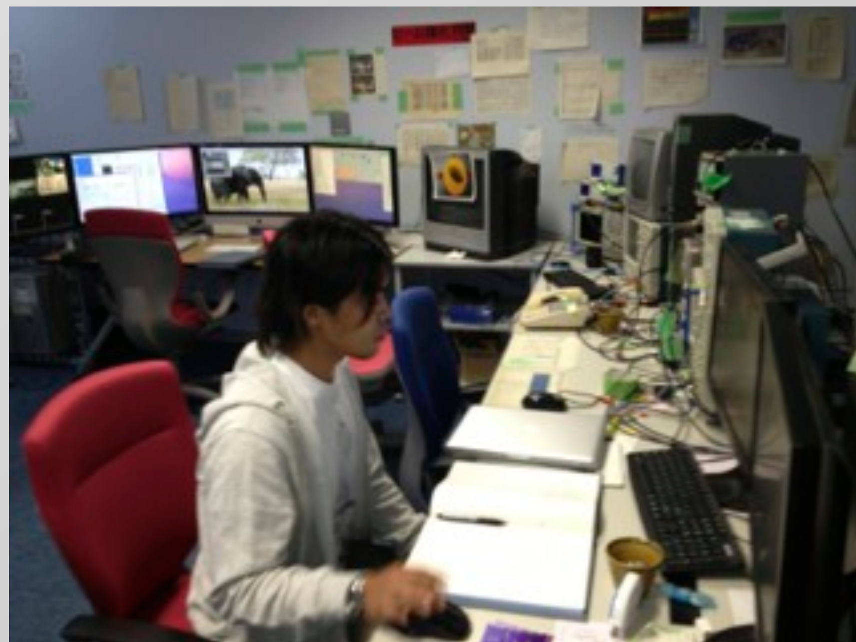


The control system of FFAG accelerator at KURRI has been upgraded with EPICS under collaboration with the KEK accelerator control group. Some parts of the system are using LabView on Windows XP, but they are going to be replaced by EPICS based program for more reliable and secure system.



View of Control Room

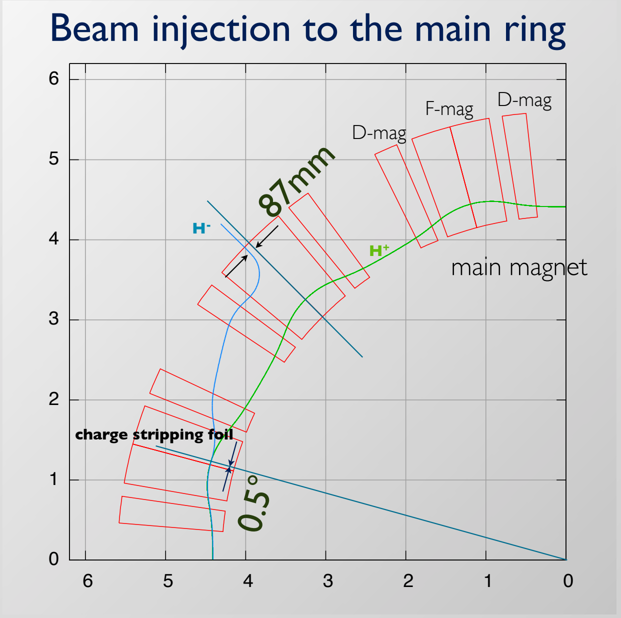




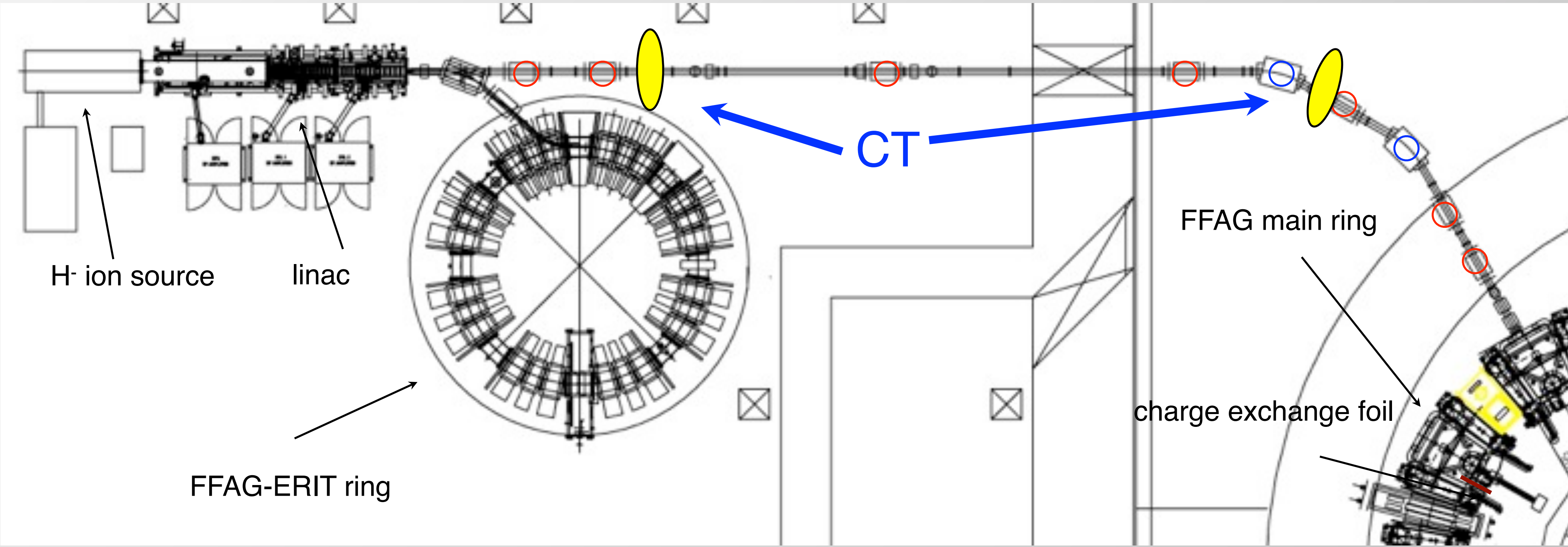
The FFAG accelerator control room. Only one person can operate whole system. There are two Macs link to Windows and LINUX PCs which command PLCs to control accelerator devices.

Beam diagnostics system upgrade

H- injection

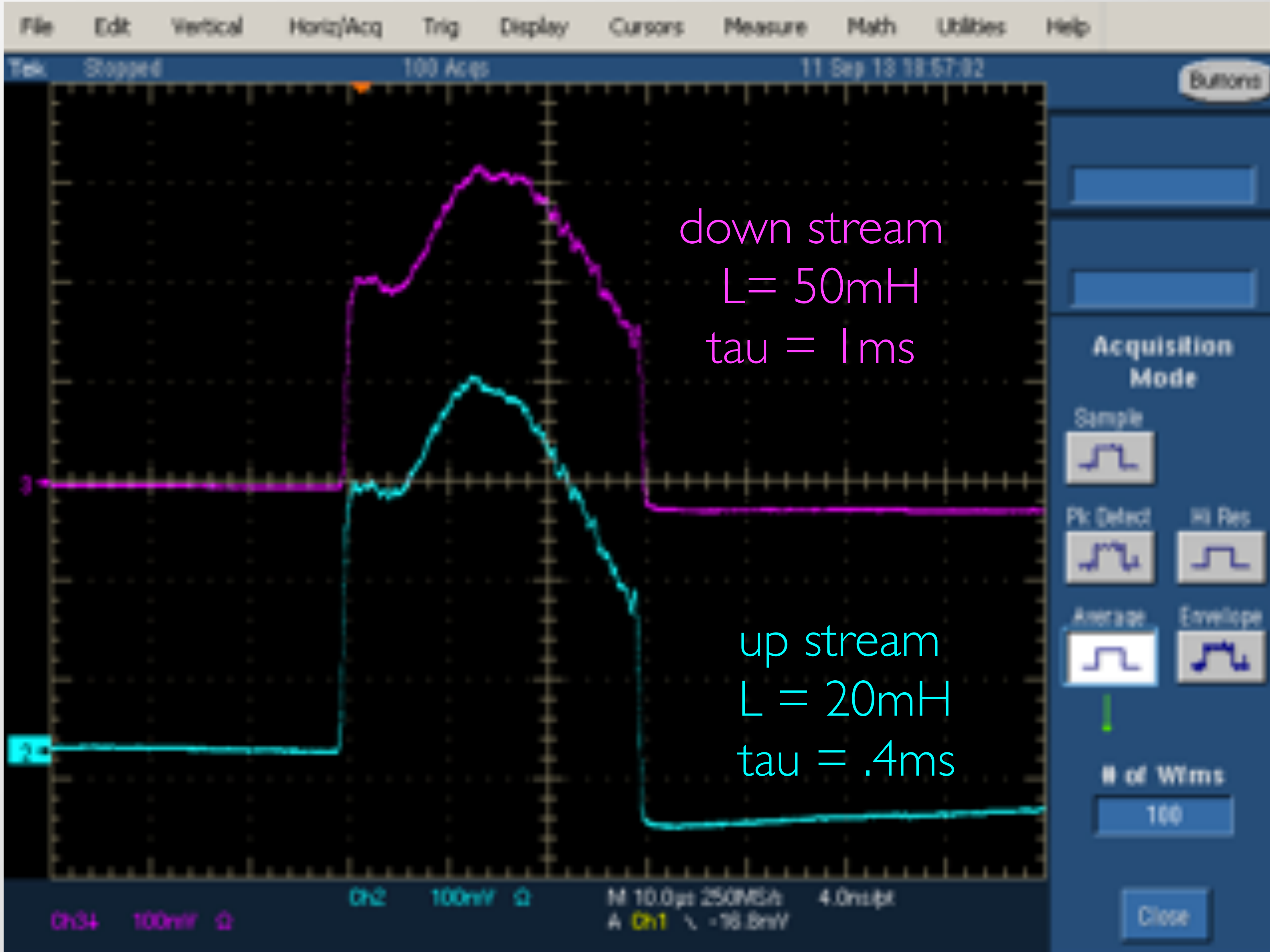


Beam injection to the main ring
D-mag
F-mag
D-mag
87mm
H-
H+
main magnet
charge stripping foil
0.5°

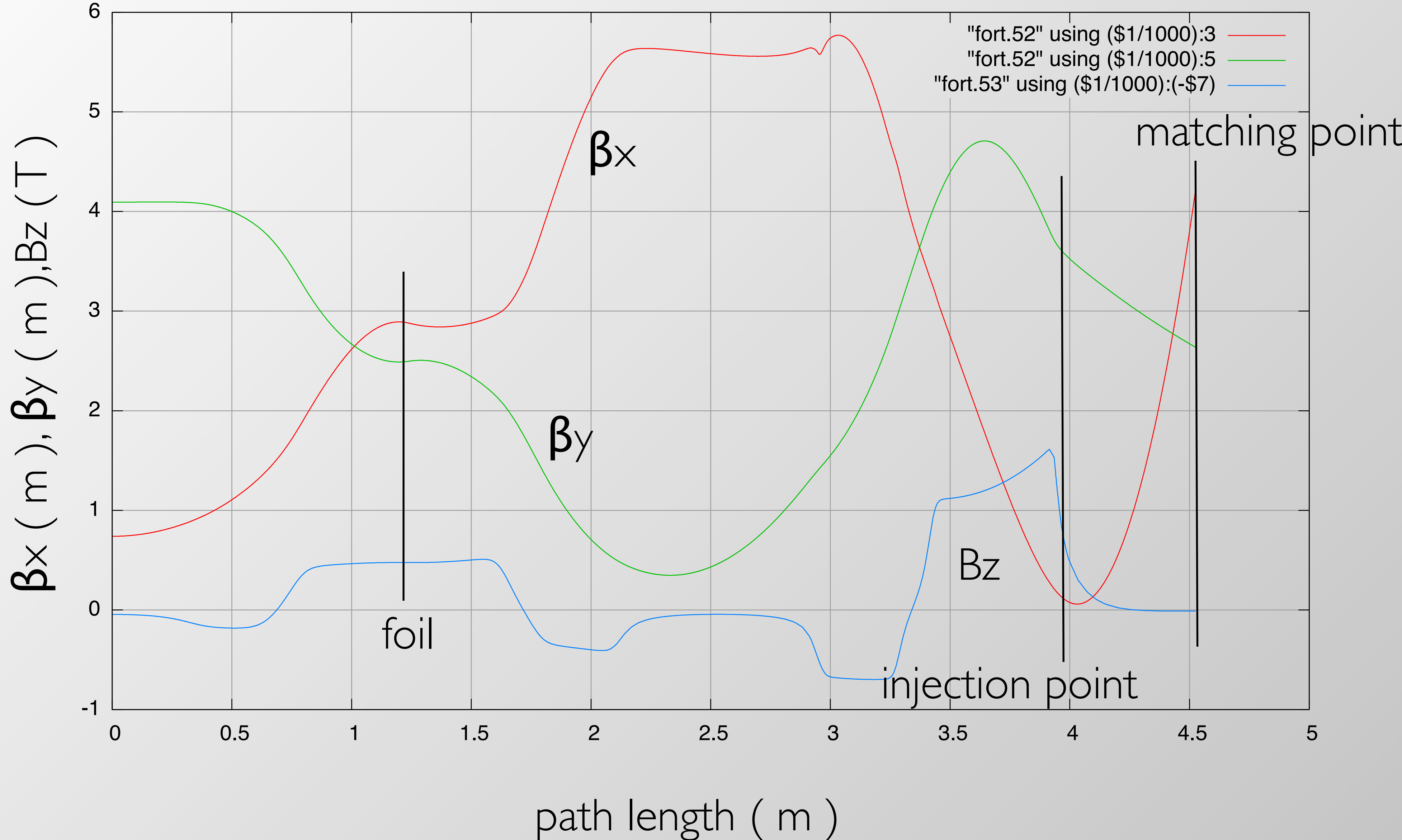


CT
H- ion source
linac
FFAG main ring
charge exchange foil
FFAG-ERIT ring

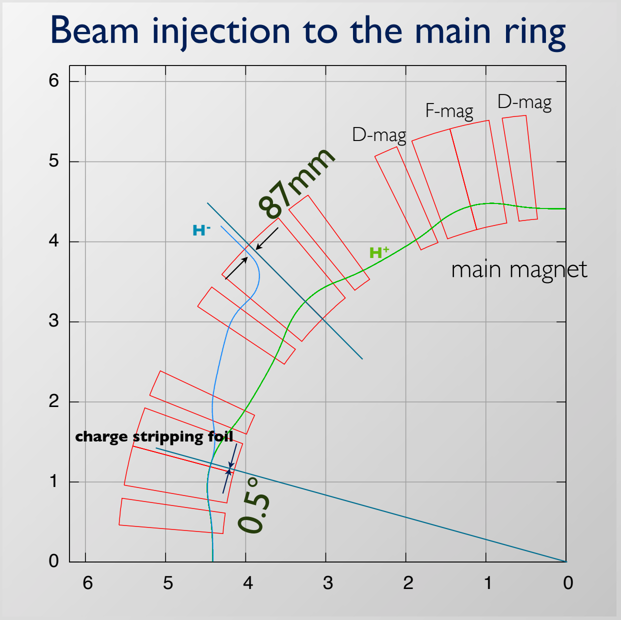
CTs installed in vacuum

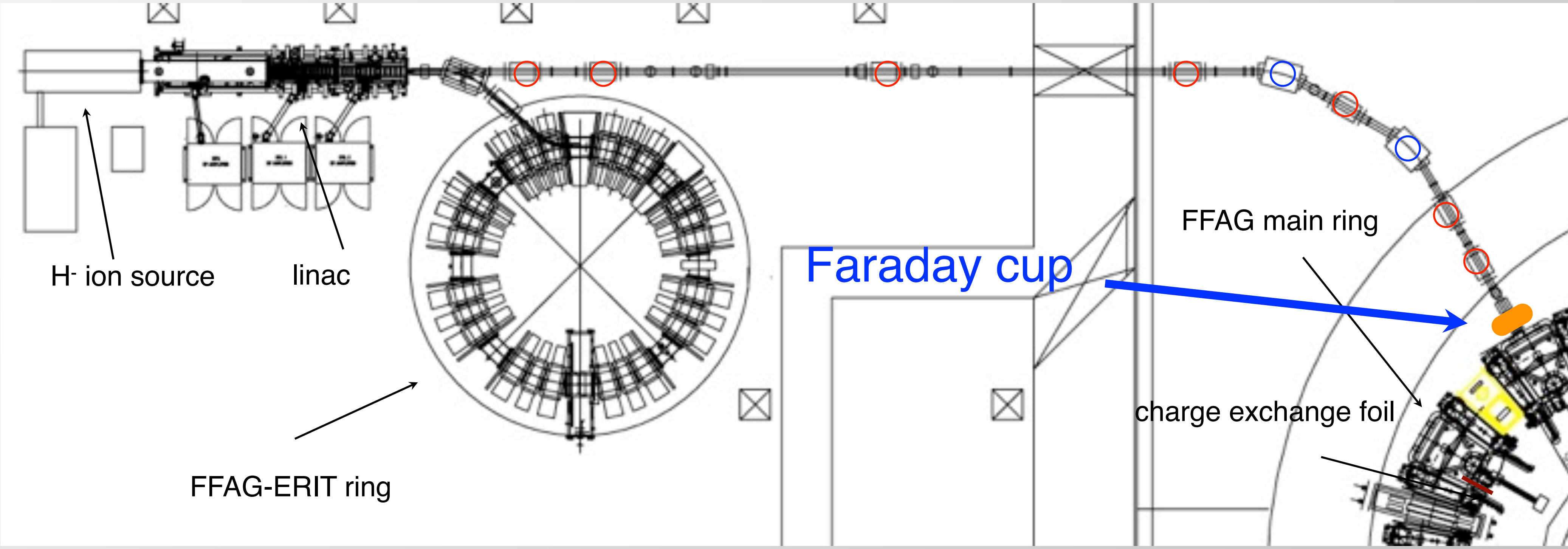


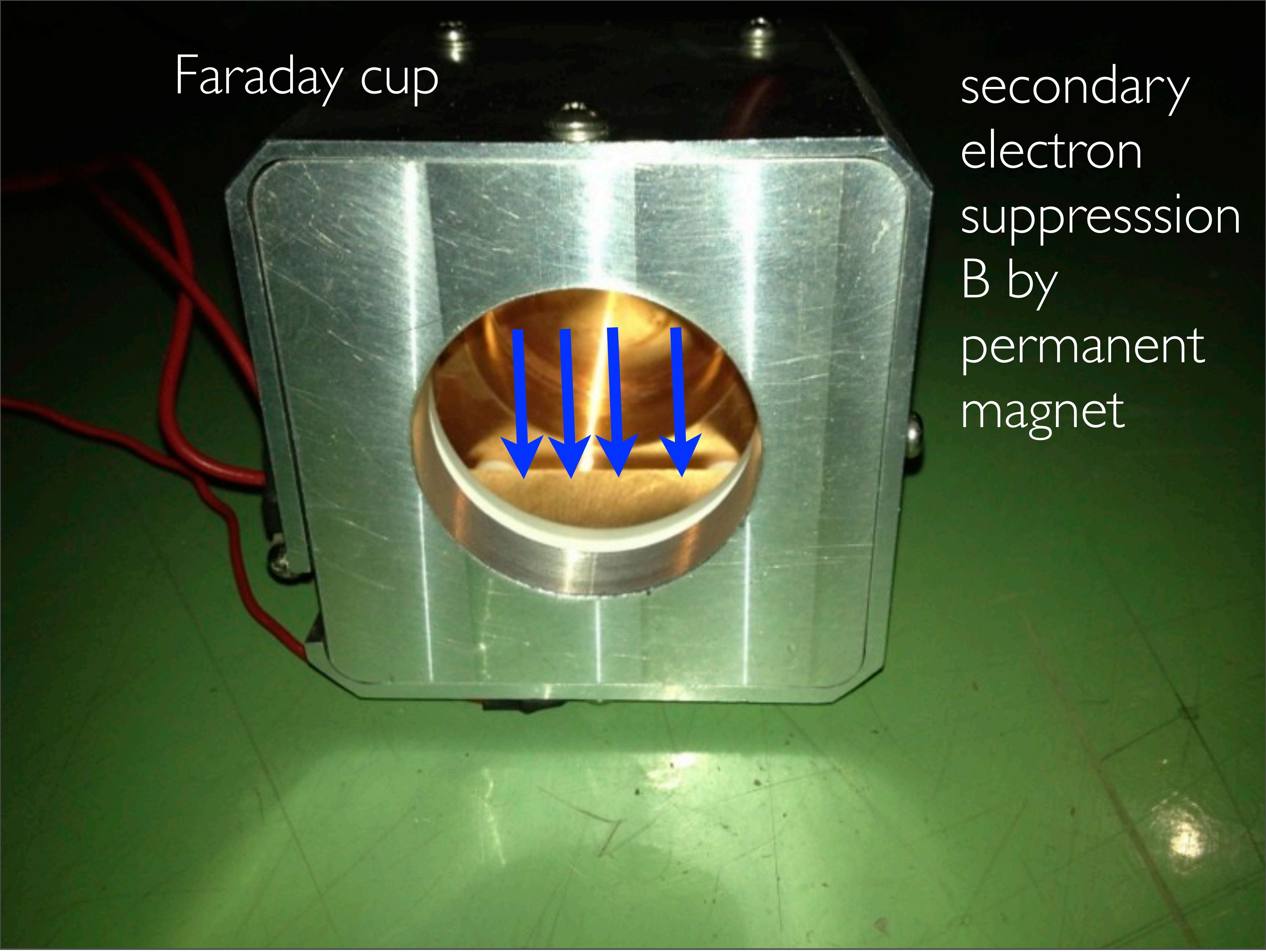
Beta functions calculated from backward tracking in the main ring



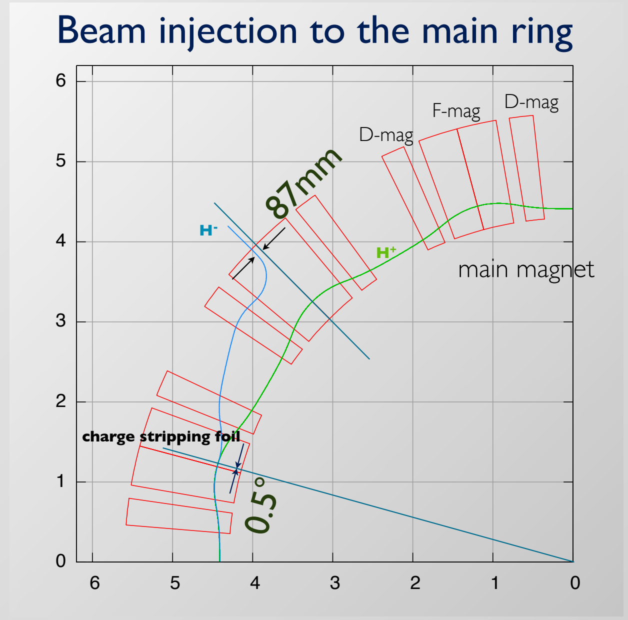
H- injection

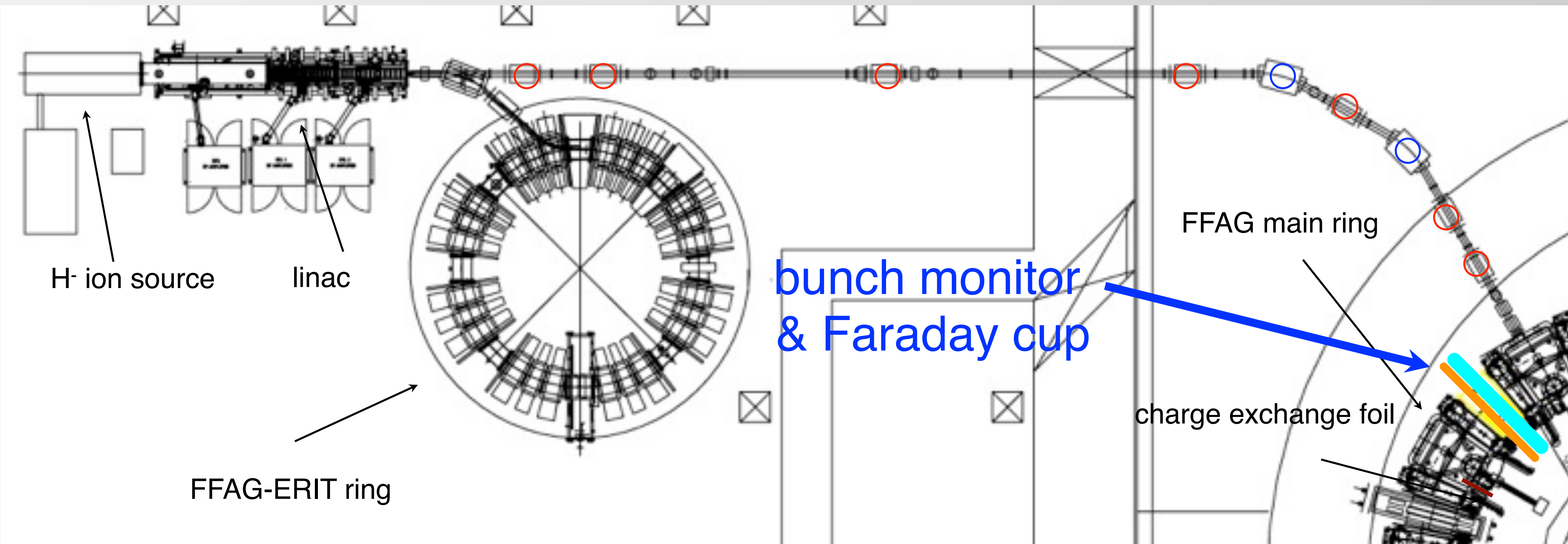

Beam injection to the main ring
D-mag
F-mag
D-mag
87mm
H-
H+
main magnet
charge stripping foil
0.5°
6
5
4
3
2
1
0

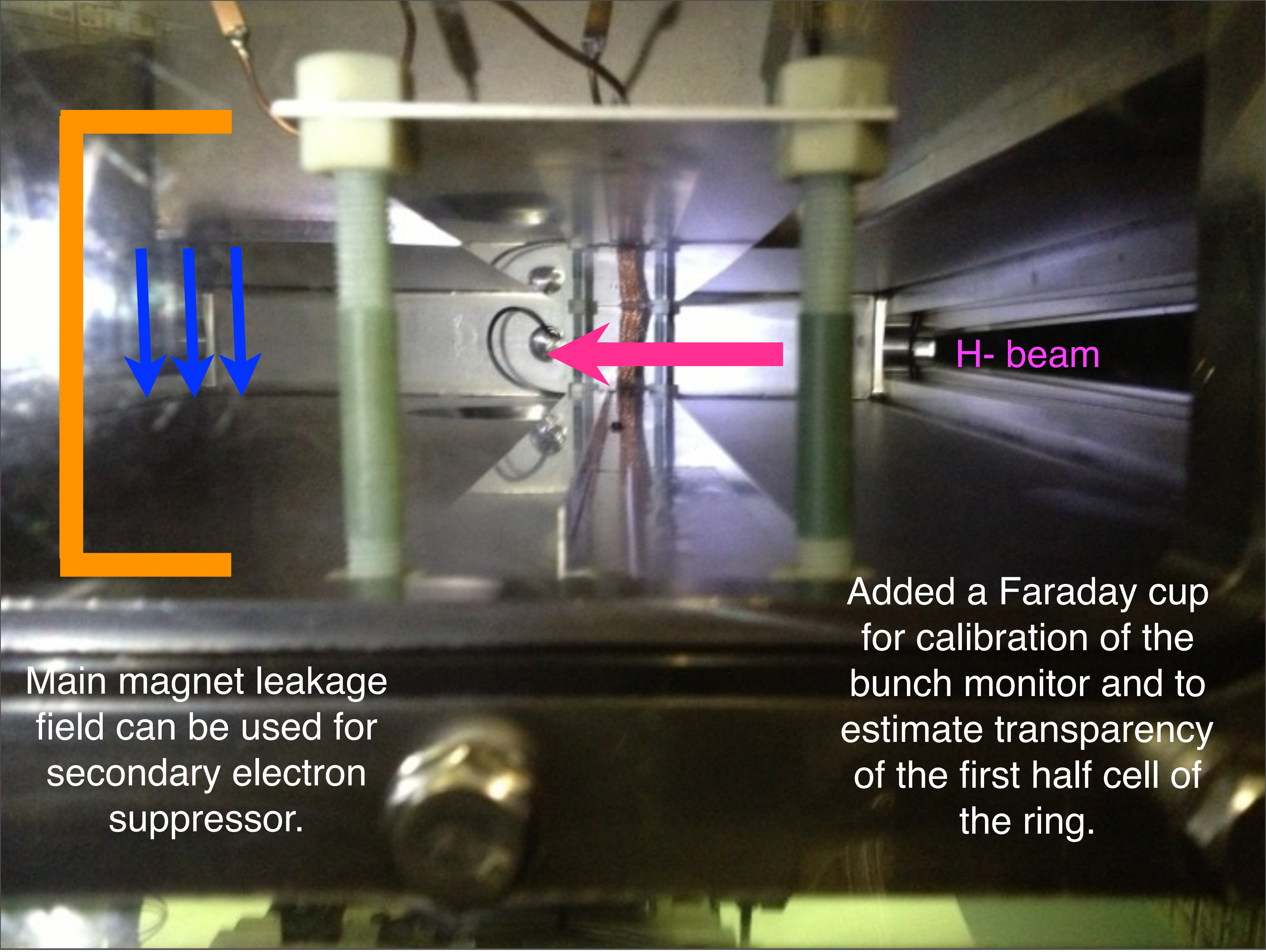

H- ion source
linac
FFAG-ERIT ring
Faraday cup
FFAG main ring
charge exchange foil


Faraday cup
secondary
electron
suppresssion
B by
permanent
magnet

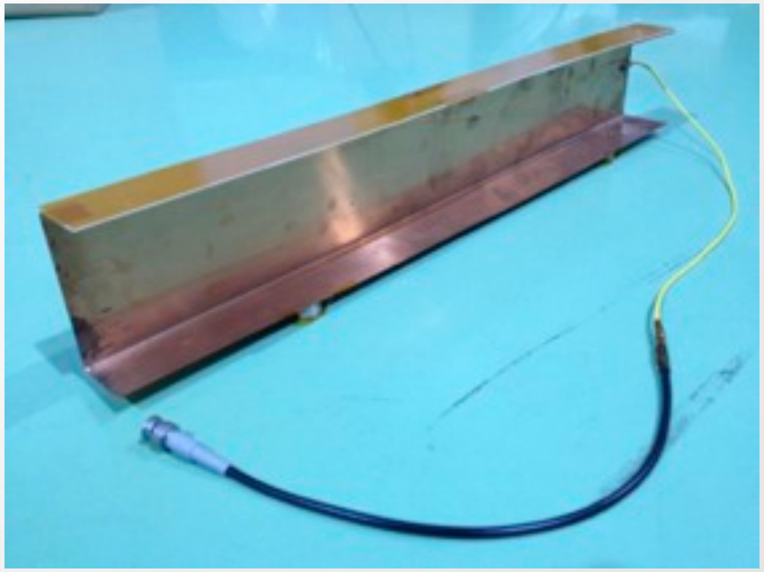
H- injection


Beam injection to the main ring
D-mag
F-mag
D-mag
87mm
H-
H+
main magnet
charge stripping foil
0.5°
6
5
4
3
2
1
0


H- ion source
linac
FFAG-ERIT ring
bunch monitor
& Faraday cup
FFAG main ring
charge exchange foil


H- beam
Main magnet leakage field can be used for secondary electron suppressor.
Added a Faraday cup for calibration of the bunch monitor and to estimate transparency of the first half cell of the ring.

Faraday cup



faraday cup signal is read thru 50Ω at 20Hz rep. rate

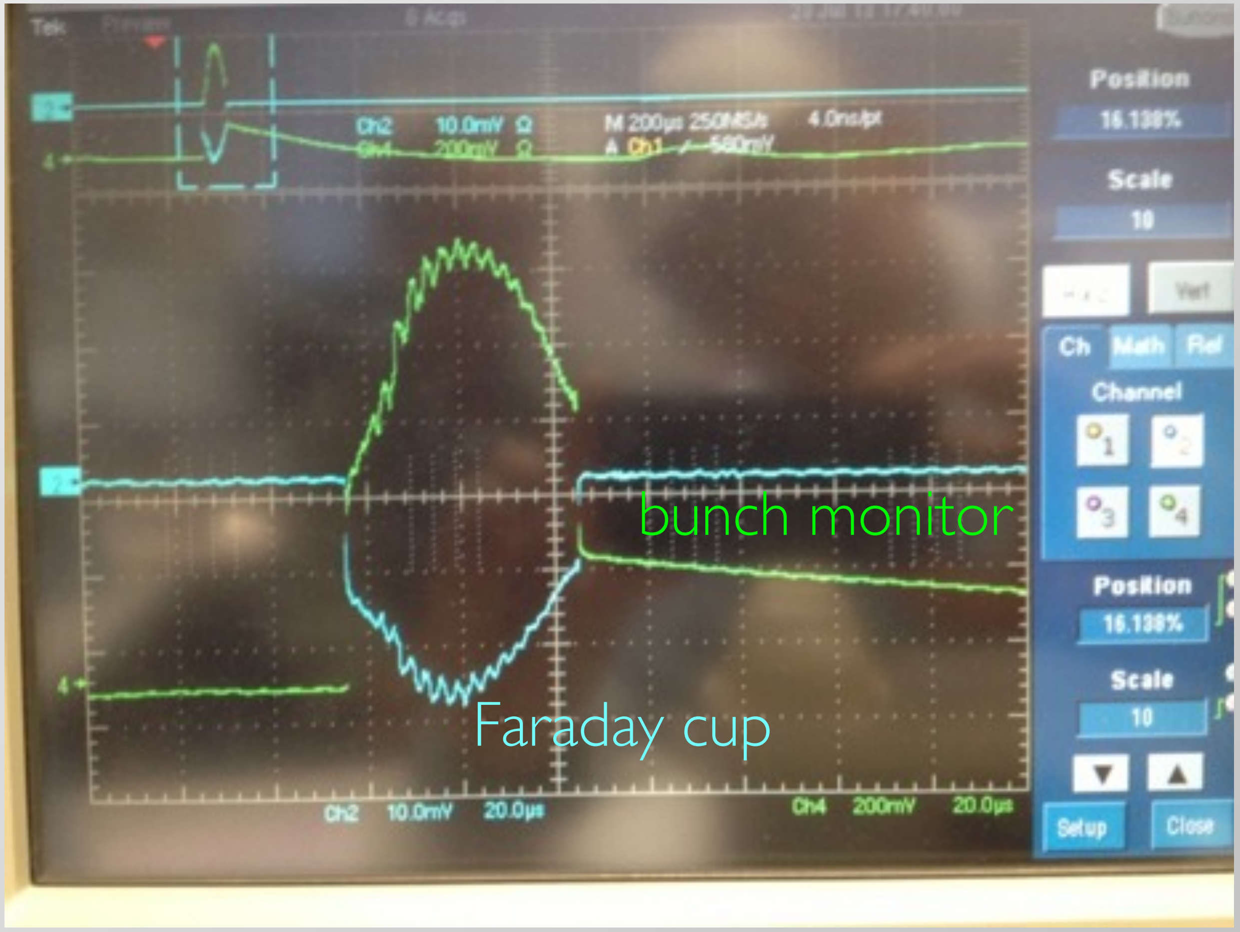
$$I_{\rm av} = \frac{\int V_{\rm FC} dt}{50} \times 20$$

Long tailed decay in bunch monitor signal seems to be back scatter of the secondary electron (suppression is not perfect)

→ RC constant

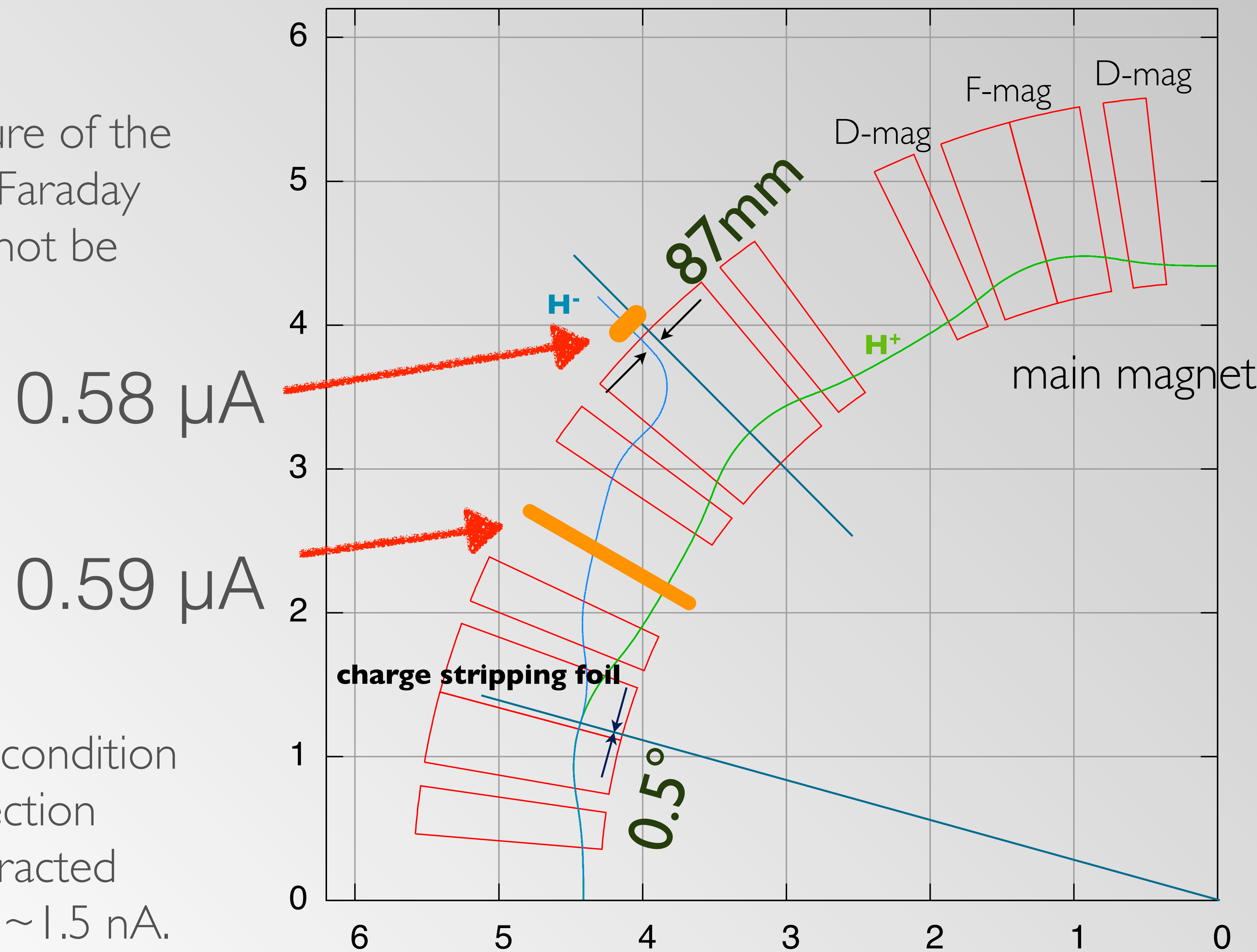
R = 1MΩ (input impedance of the amp)

C = 171pF



Beam injection to the main ring

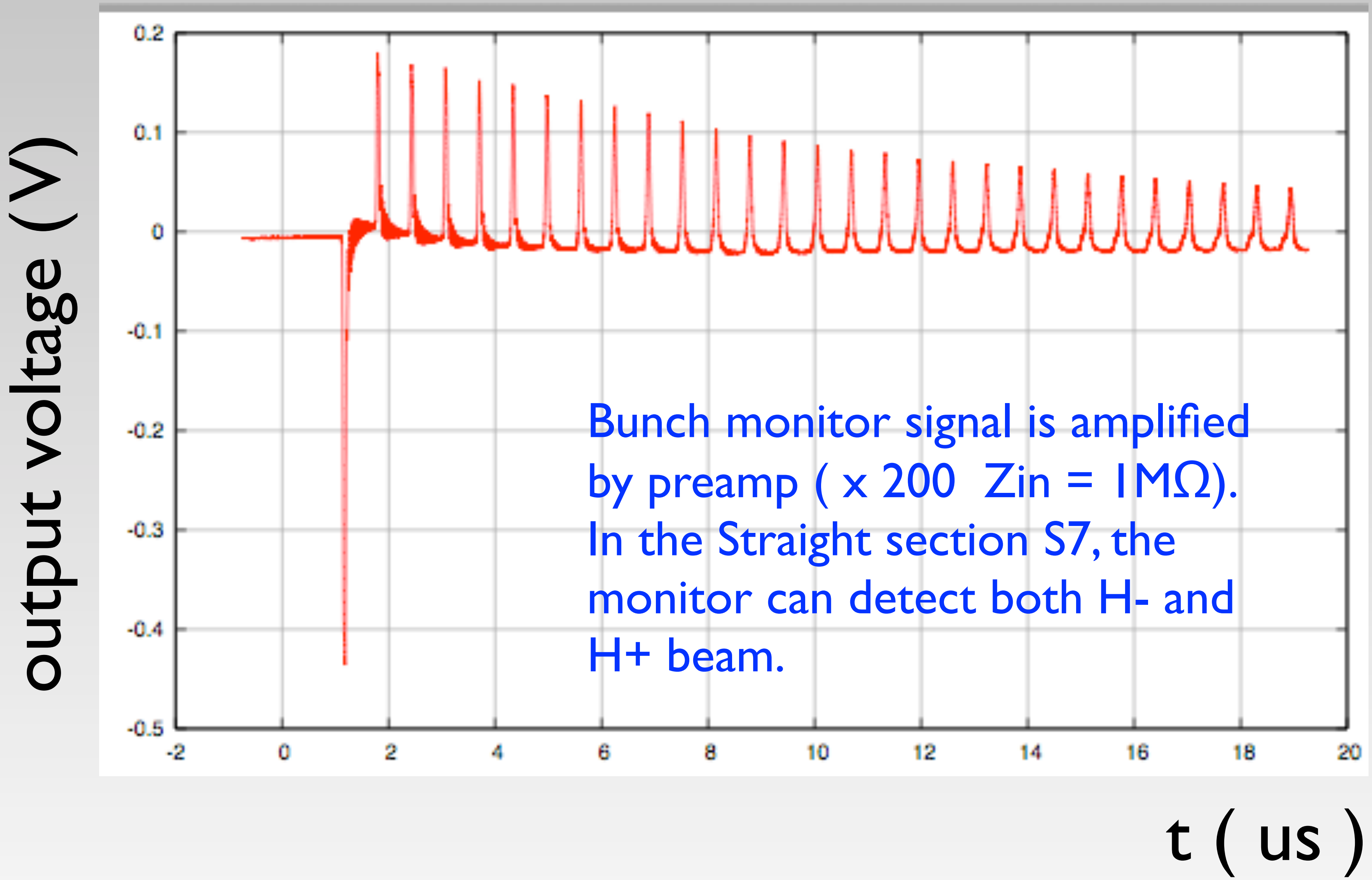
The aperture of the up stream Faraday cup might not be sufficient.



With this condition of the injection beam, extracted current is ~1.5 nA.

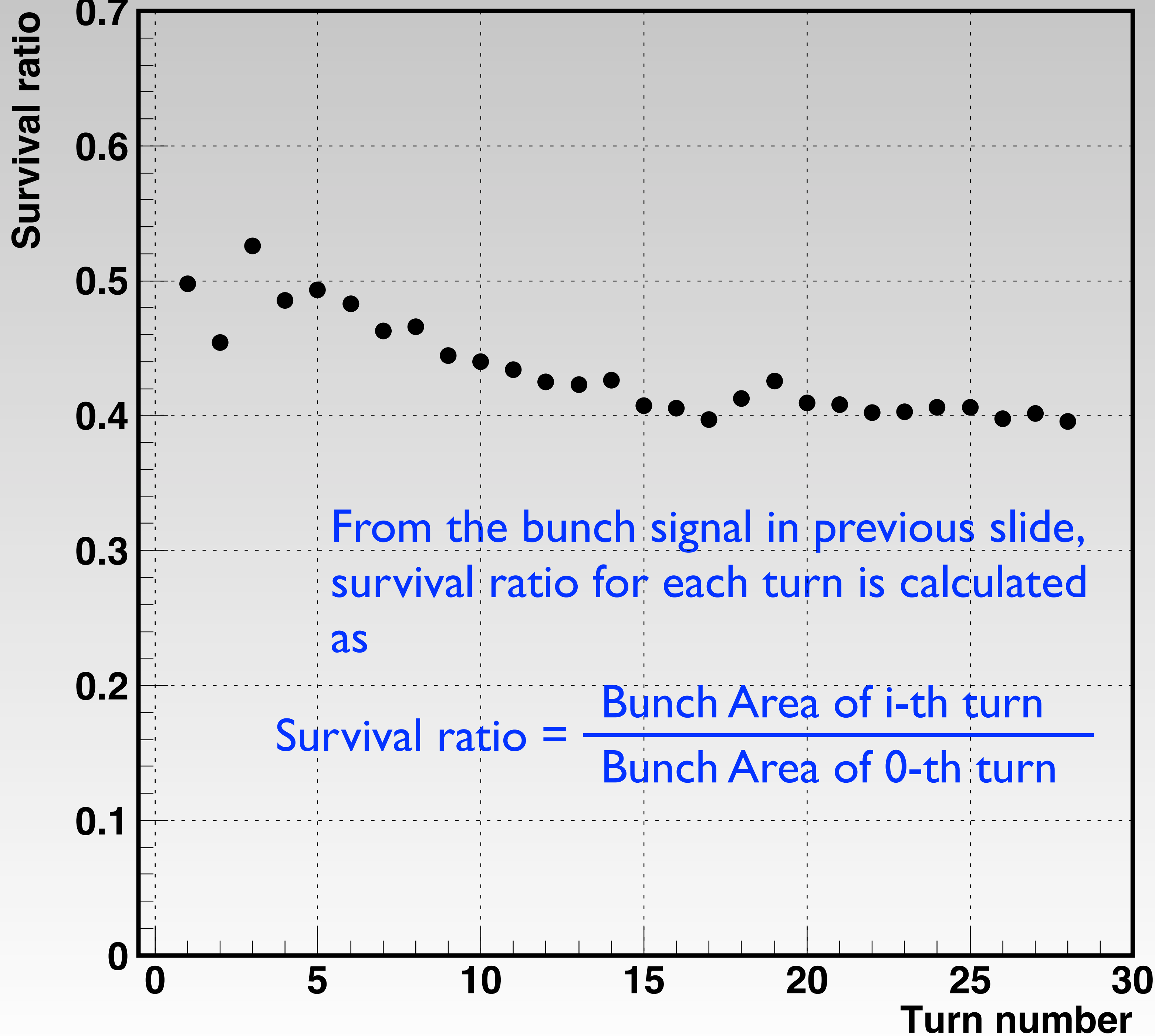
Results from beam studies in this summer

Injection Studies in ADSR-FFAG Ring



Beam signal from the bunch monitor

Survival ratio vs turn number



From the bunch signal in previous slide, survival ratio for each turn is calculated as

$$\text{Survival ratio} = \frac{\text{Bunch Area of i-th turn}}{\text{Bunch Area of 0-th turn}}$$

Results from beam studies in this summer

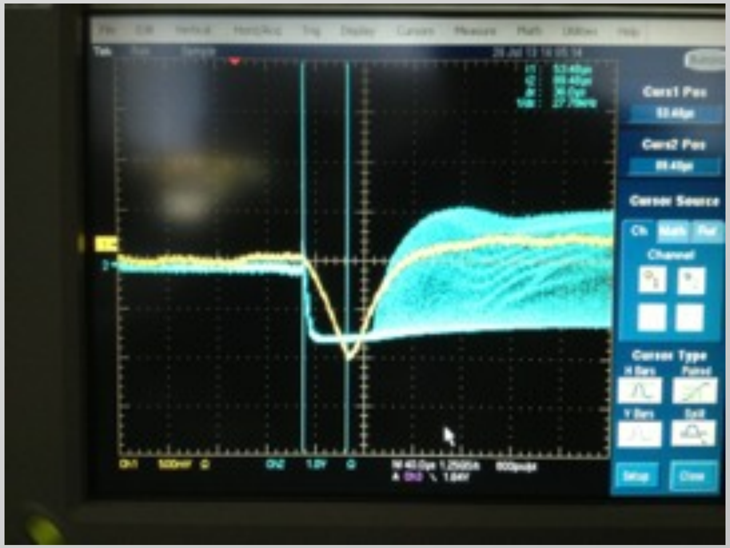
1. With short pulse, shorter than one turn, survival ratio after ~30 turns is ~40 %. That means injection efficiency at certain timing is high enough, still remaining some room for improvement thou.

2. Using intermediate pulse, say 4 turn equivalent, survival ratio after 1ms is

1 / 30.

3. With long pulse, e.g. 50us, after 1ms survival ratio is only

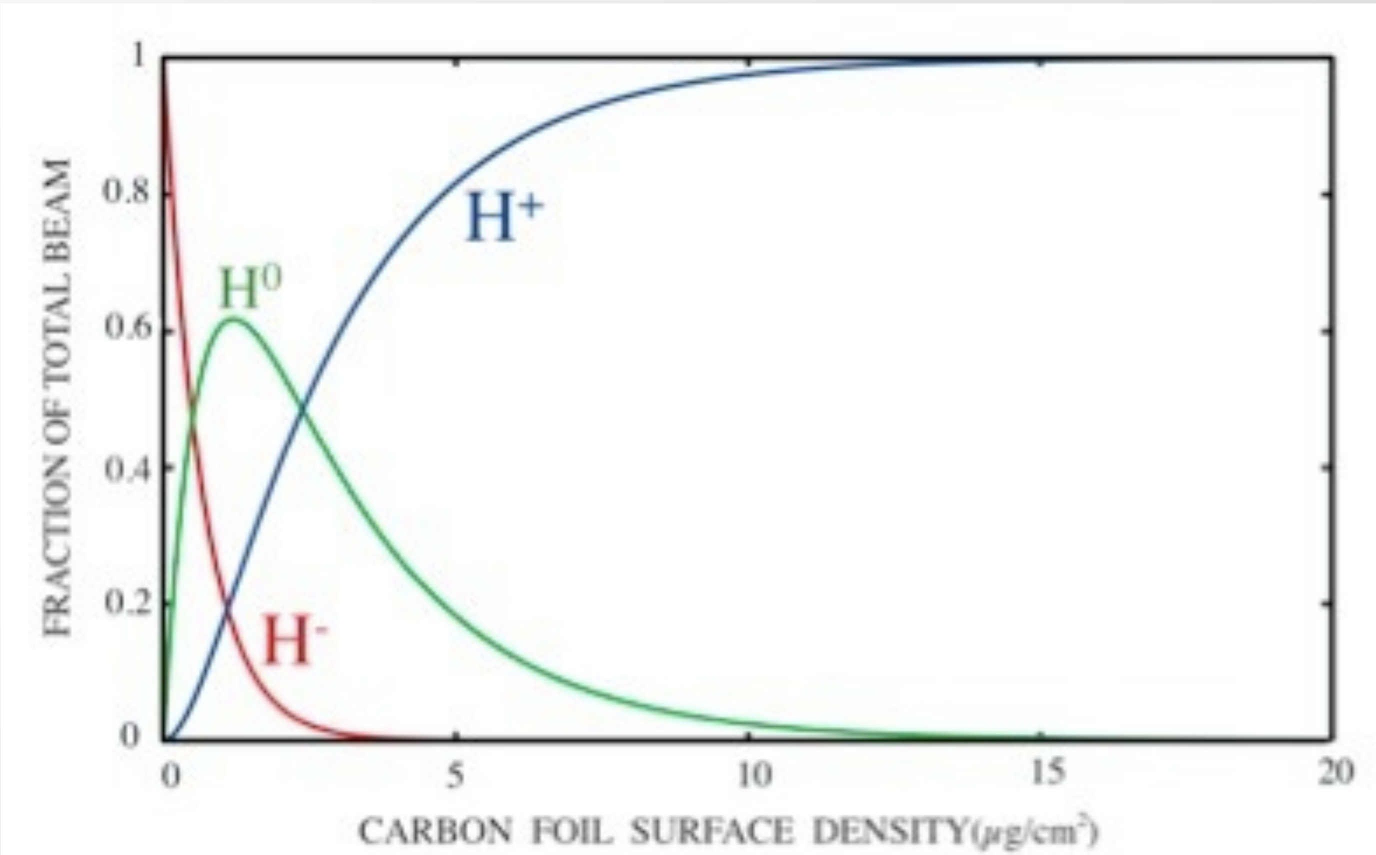
1 / 400.

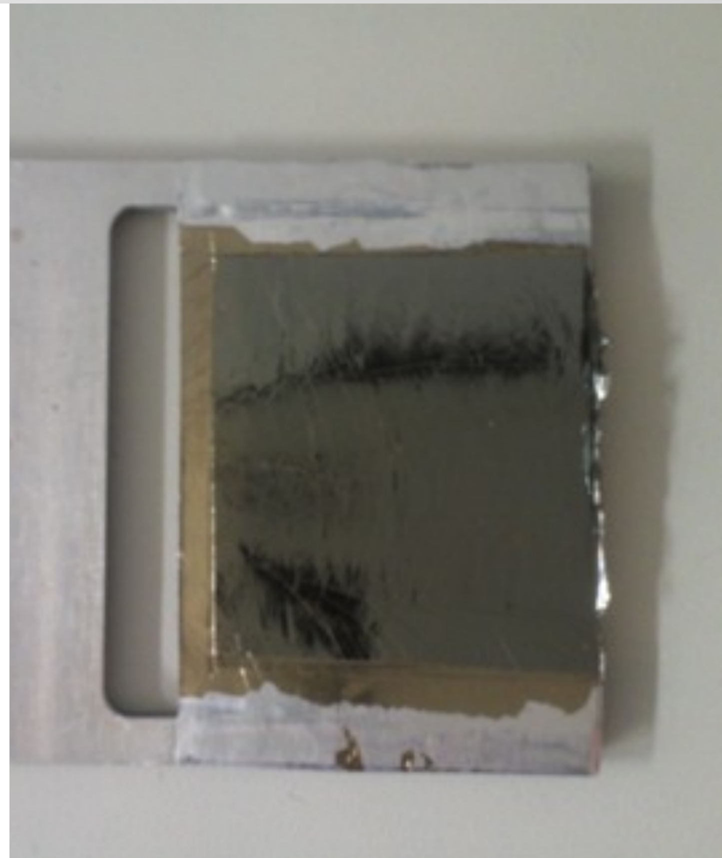


(Tom Uesugi talking detail)

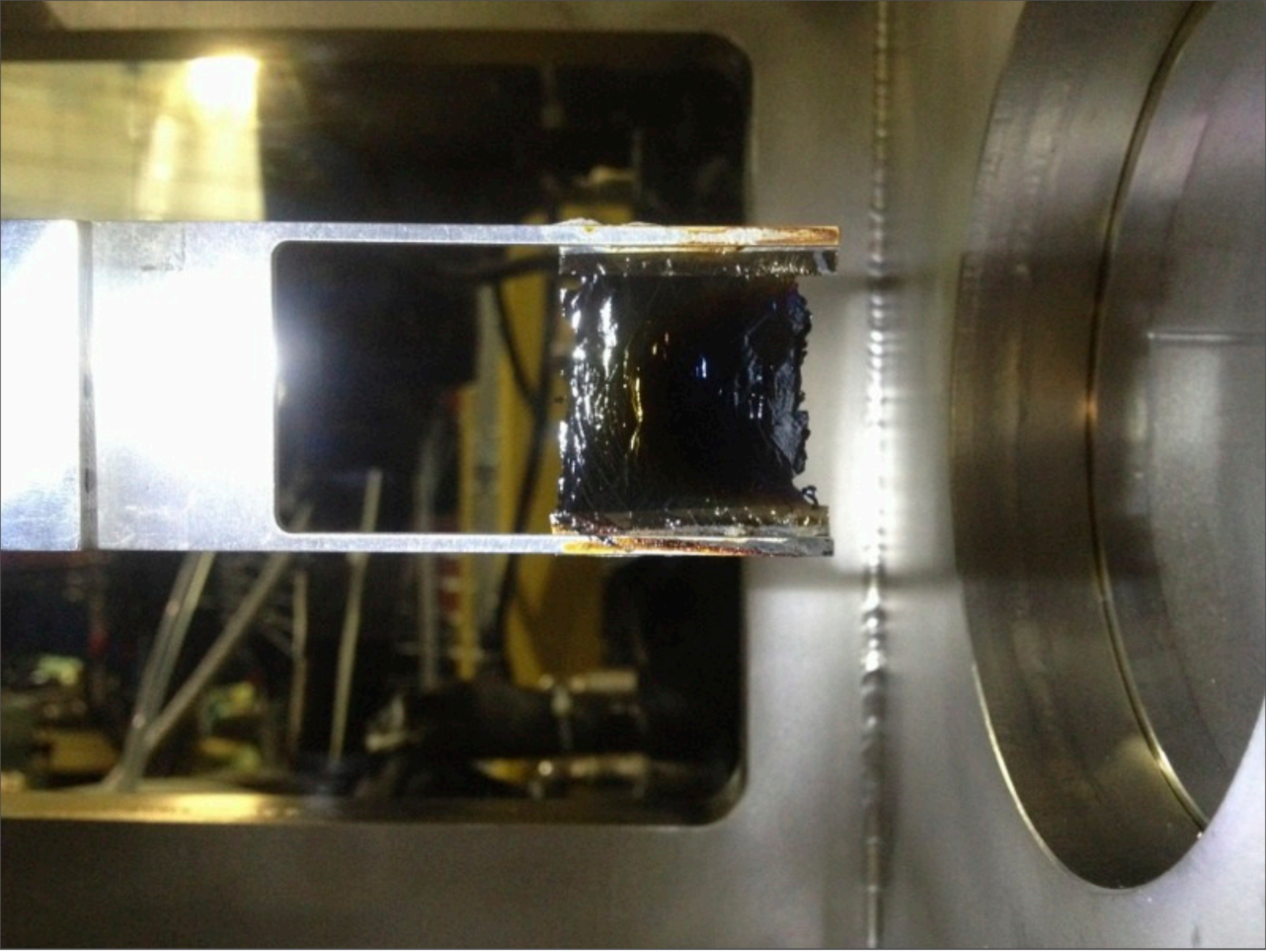
Emittance growth due to the multiple scattering by charge stripping foil

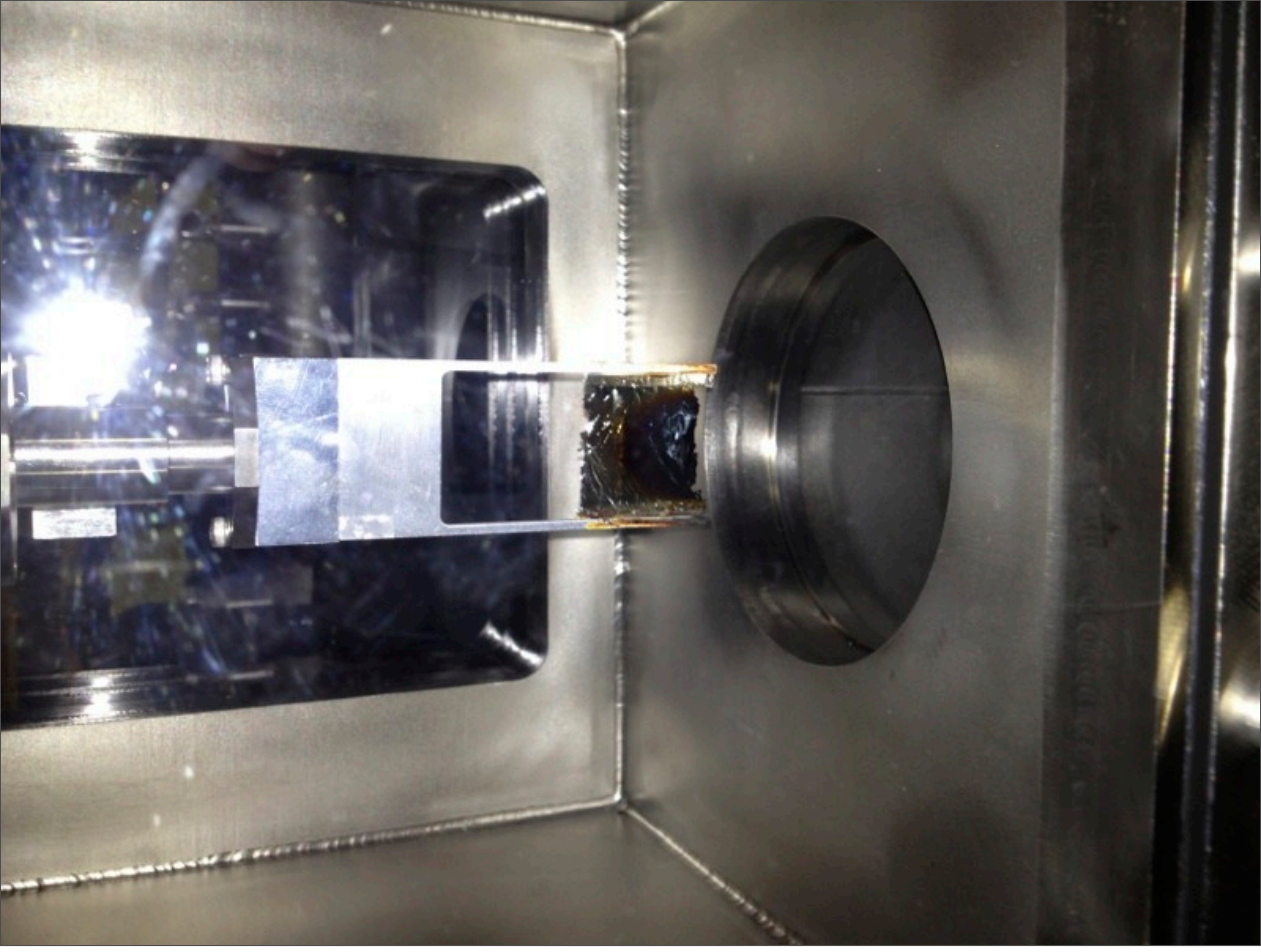
brand-new foil
20 ug/cm2





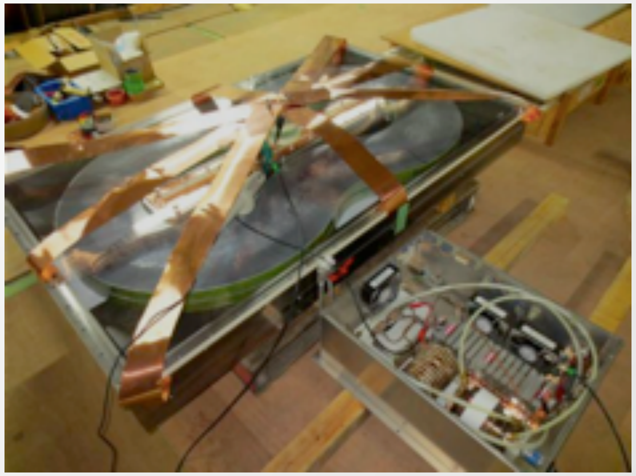
after 1.5 years...

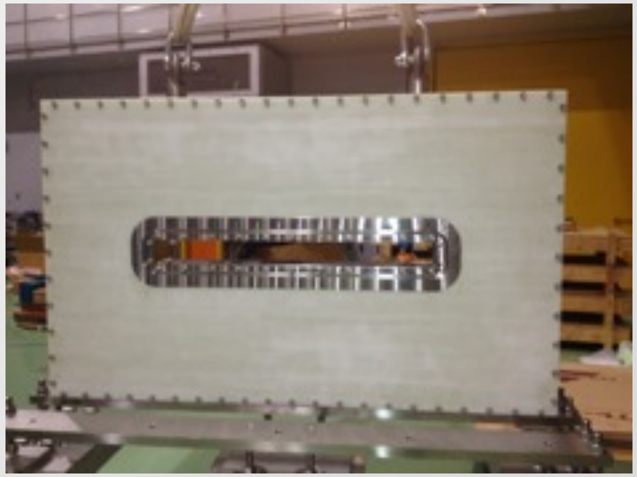




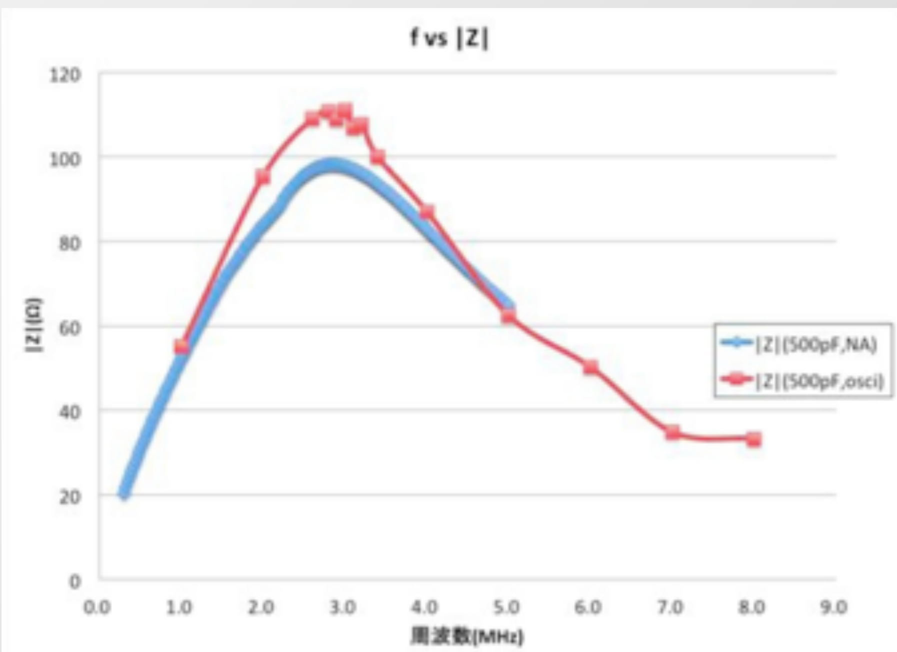
Filament in the ion source was broken in June 2013.

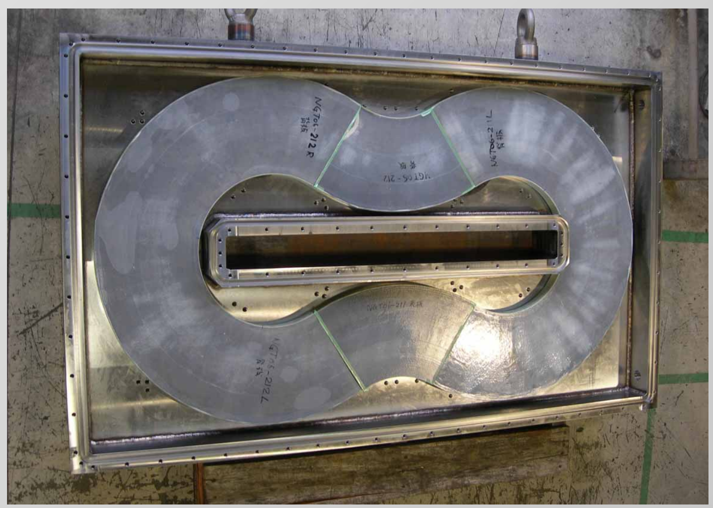
PETAL CORE CAVITY





1. New installation of another rf cavity to obtain higher accelerating voltage. (4kV → 2 x 4 kV)
2. Reuse of damaged circular core for wide aperture cavities.
3. A low-power measurements has been done.
4. With this new cavity, rep. rate 100 Hz can be accomplished.



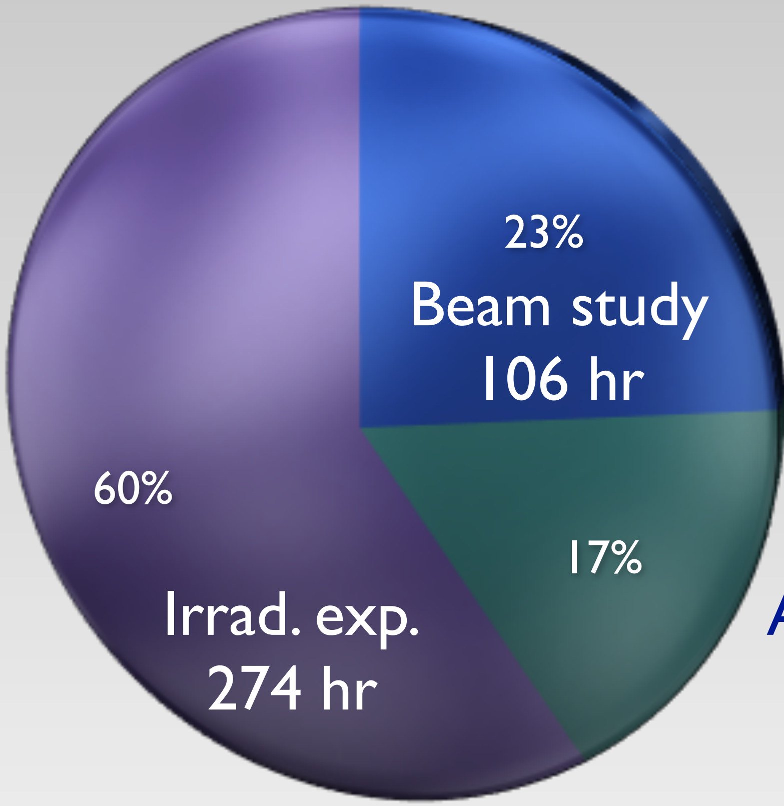


Summary

- In FY 2012, we delivered the beam for 3/4 of machine time. It corresponds more than half a year.
- Users got fruitful results with the beams from FFAG.
- We are required to deliver stable and constant beam by users.
- Beam diagnostics system and machine control system are now under upgrade.
- From beam injection and capture studies, survival ratio at 1ms for long pulse is only 1/400, even though injection efficiency for short and intermediate pulse is quite high.
- New cavity is under construction for high capture efficiency.

Summary of Machine Time (FY 2012)

Total
457 hr



ADS. exp.
77 hr

	unit	May. - Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Beam Study	hr	77	21	5	3	0	0	0
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Irrad. Exp.	hr	0	9	0	14	24	73	153
Ext. Energy	MeV	100/150	150	100	150	100	150	150


Thank you for your attention!