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Plan of experiments at KURRI

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04 February 2014

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)

Injection seems to be the biggest issue

- Injection of 2.56 us (= 0.640 x 4 turns)
  - survival after 1 ms is 1/30.
- Injection of 50 us (= 0.640 x 78 turns)
  - survival after 1 ms is 1/400.
  - only 1.5 times more than 4 turns injection.

- cf, short pulse within a bucket survives 40% after 1.92 us (= 0.640 x 30 turns). This is injection efficiency.

Check list

- Horizontal and vertical orbit matching.
- Horizontal and vertical optics matching.
- Dispersion matching in horizontal.
- Emittance growth by multiple scattering at foil.
- Energy loss at foil.
- Optimum rf frequency w.r.t beam momentum.
- Optimum phi_s.
- Measurement of linac beam quality (dp/p, emittance).

Measurement of linac beam quality

experiment 0

Make the rest of the experiment easy if we know dp/p at least.

Spectrometer type measurement is already planned?

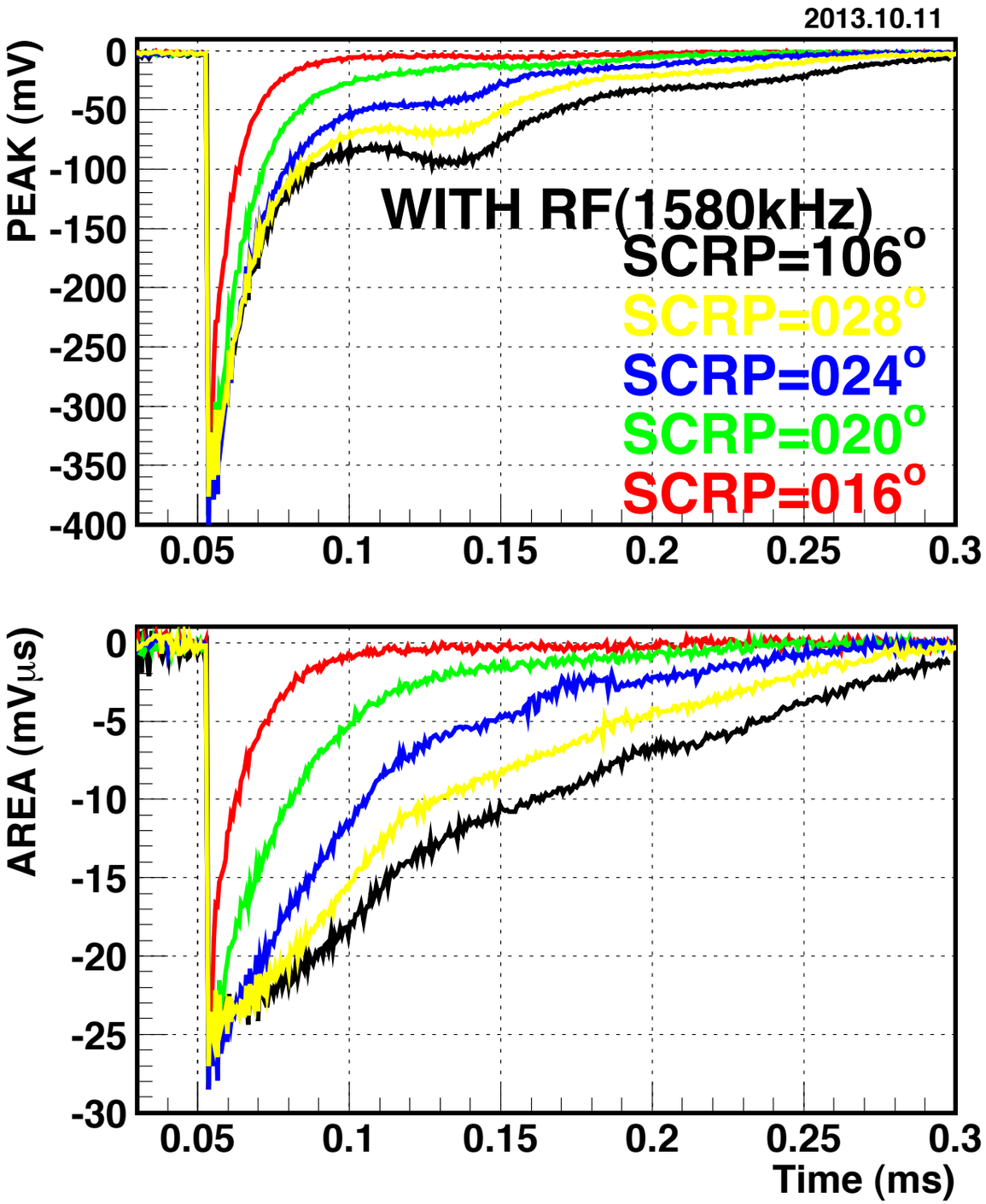
Relative rf phase among RFQ, DTL1 and DTL2 change dp/p.

How the injection efficiency change when phase is adjusted?

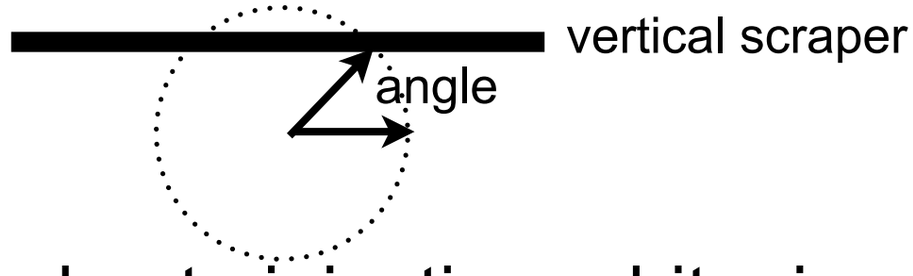
Stability, day to day, is also important factor.

F/D/COR	814/995/445
HMBT-ST	Normal values
RF	off
BMON	(INU), AMP
OSCILLO	AC-50 Ω, Obake-subtracted
CHOPPER	0.2% (0.316 revolutions)

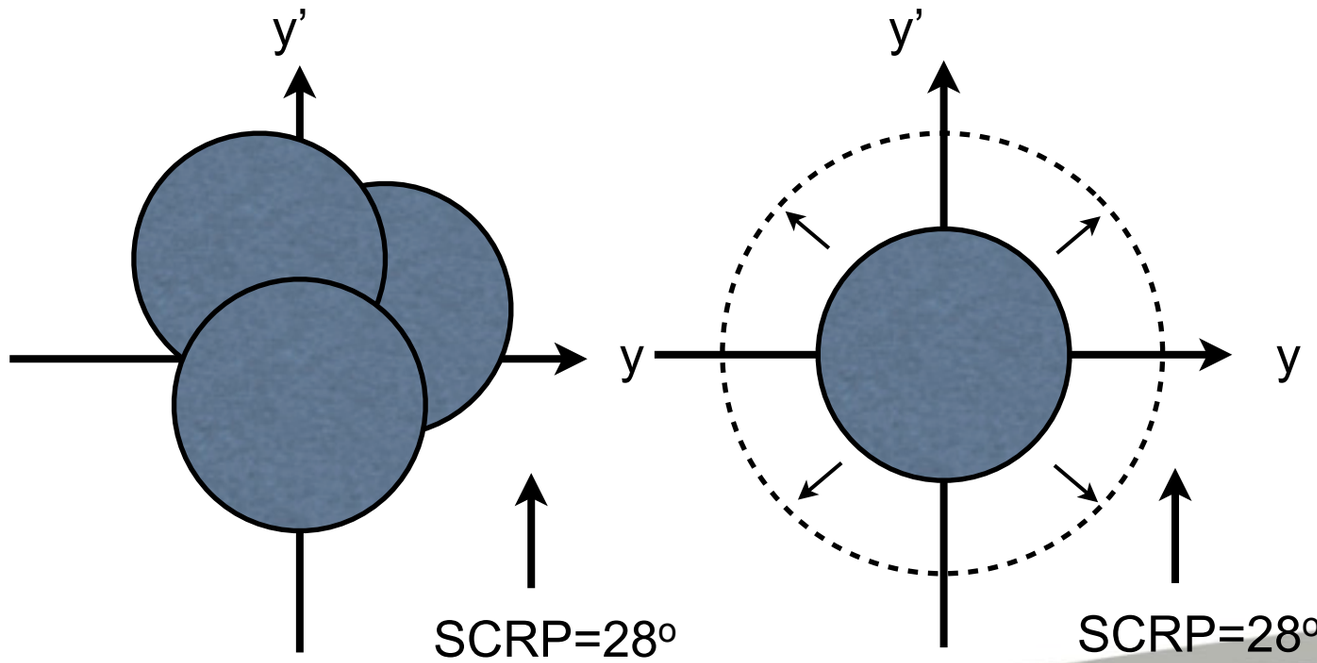
Vertical orbit matching (1)



Small aperture difference results in large difference in intensity.



Is this due to injection orbit mismatch instead of gradual emittance growth?



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Vertical orbit matching (2)

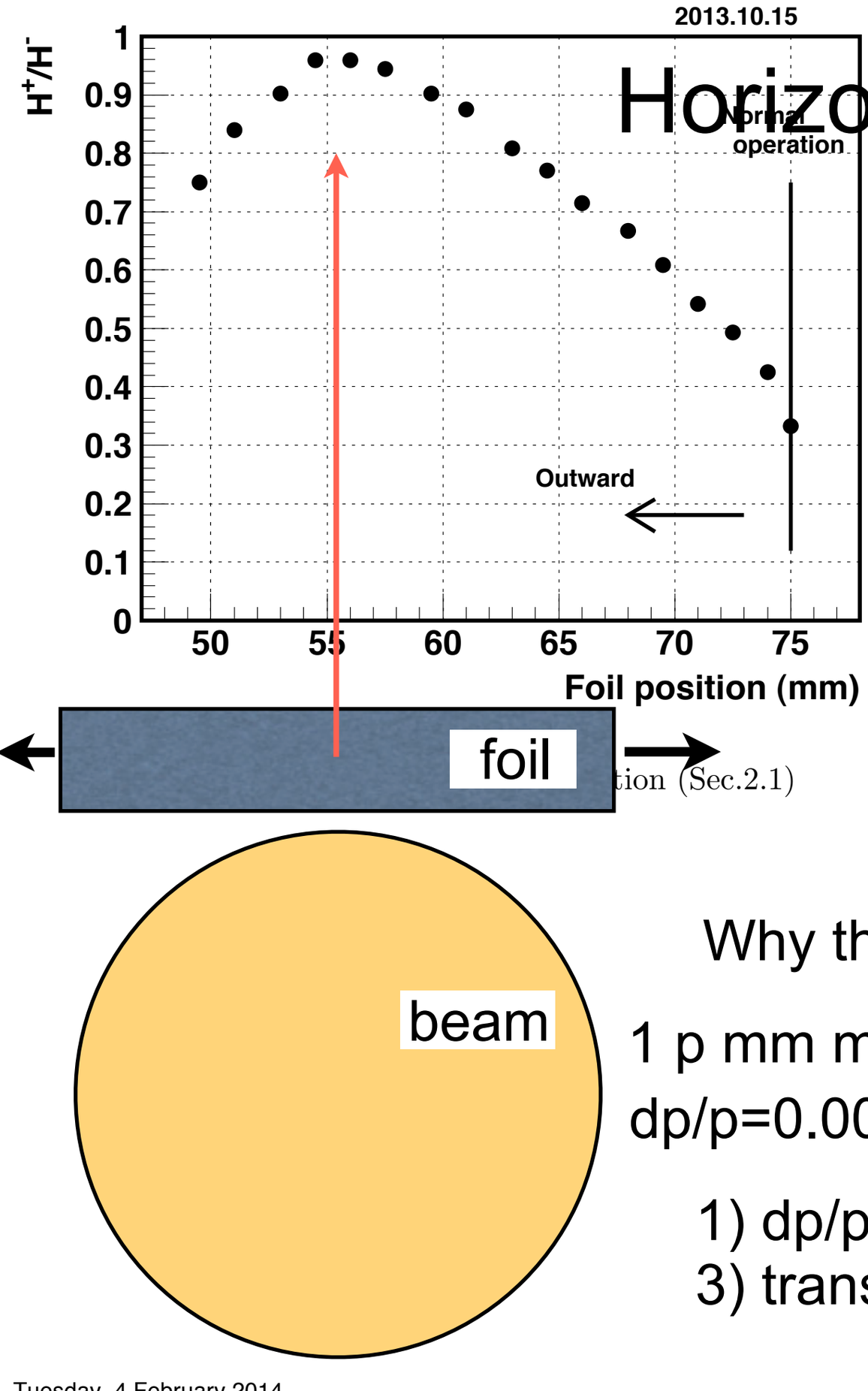
experiment 1

If the vertical coherent oscillation can be observed by the new system, tuning of orbit matching is easy.

If not, set the scraper around the beam edge and minimise beam loss.

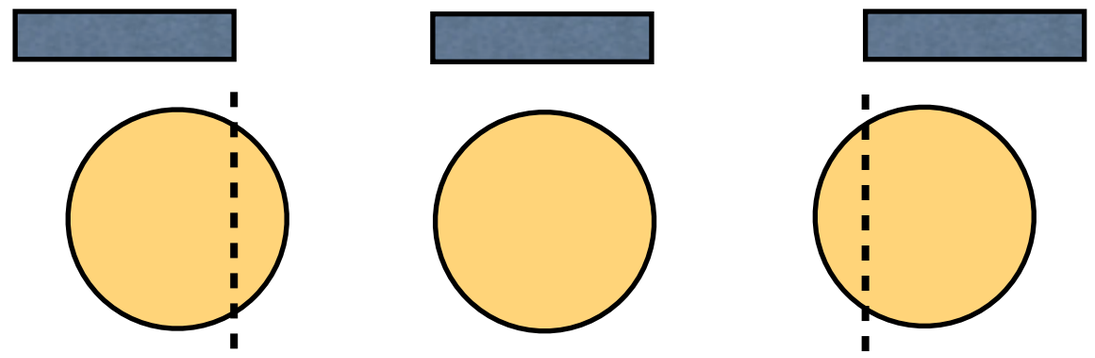
Q: Which knobs are available to change *y* and *y'* at injection point?

Horizontal beam size from linac



Assume foil size is 25 mm x 25 mm.

Beam size must be ~25 mm because no flat top in the graph of H+/H- ratio.



Why the beam is so wide?

1 p mm mrad (90%, nor.) -> 4.3 mm@beta=3 m

dp/p=0.0015 (90%) -> 1 mm@eta=0.54 m

1) dp/p is 10 times larger, 2) dispersion is larger.
3) trans. emittance is larger.

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Consistent with Suzie's measurement

Emittance estimate (RF OUT)

[Data: 20131113_2]

$$\varepsilon = \frac{x^2}{\beta}$$

Turn 1: Δr<5mm
Turn 6, 11, 16: Δr~25mm

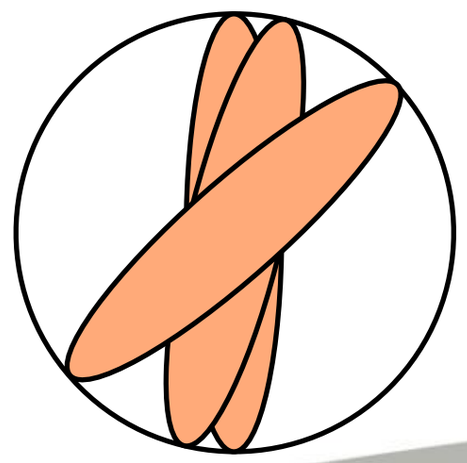
Turn 1: $\varepsilon \approx \frac{1}{\beta}\left(\frac{\Delta r}{2}\right)^2$

After 'smearing out' of n turns: $\varepsilon \approx \frac{1}{\beta}(\Delta r)^2$

Turn 1:
Assuming β=1.0m, Δr= 5mm = 0.005m
ε_x = 6.25 pi mm mrad

Turn 6, 11, 16:
Assuming β=1.0m, Δr= 25mm = 0.025m
ε_x = 625 pi.mm.mrad -> 100-fold increase in 5 turns!?
(NB. not accounting for dispersion, momentum spread)
If you assume this is $\varepsilon_{100\%}$ then $\varepsilon_{RMS} = (1/6)^*\varepsilon_{100\%}$

However, I suspect that optics is mismatched at injection.



TO DO: same analysis for other probes & with RF), also same analysis after attempt to fix injection angle/position.

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We may see tumbling by looking at the beam at several locations.

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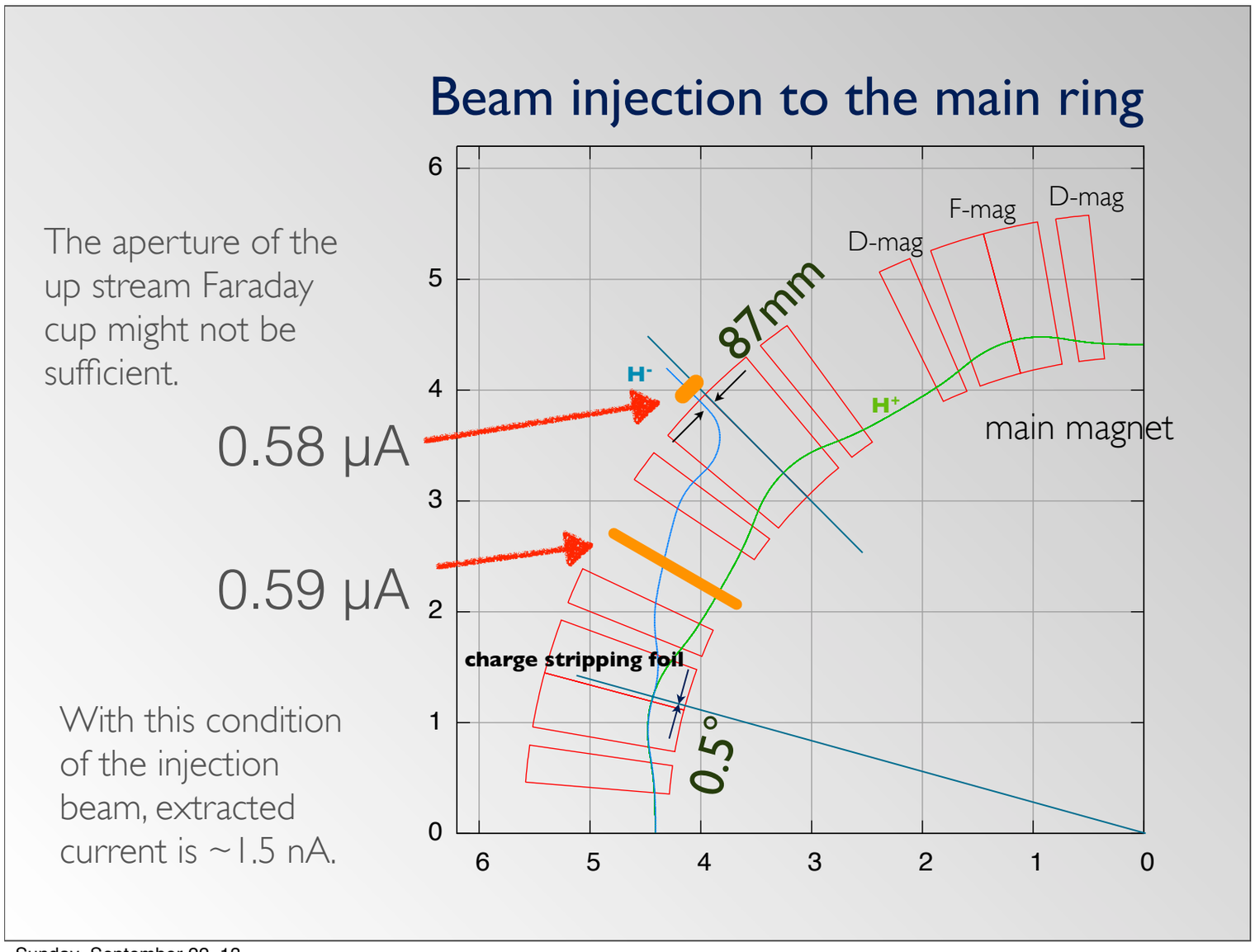
Measurement of dispersion function@foil

experiment 2



If the position at foil can be measured (foil position which gives maximum H+),

1) change main magnet strength to change "equivalent momentum".
2) measure how much the beam position moves.

Making a dispersion matching is tricky because higher momentum beam must bend more on average.

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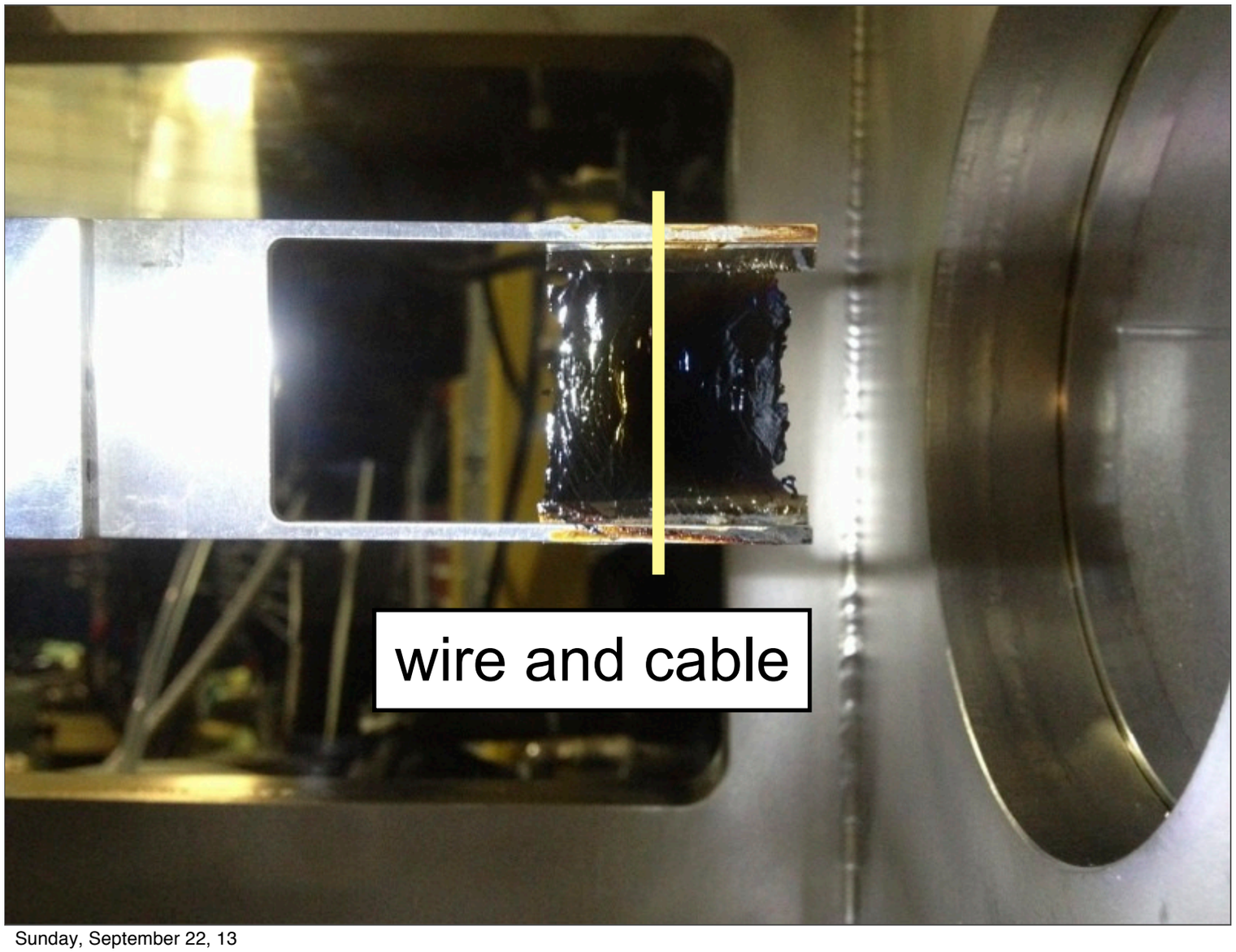
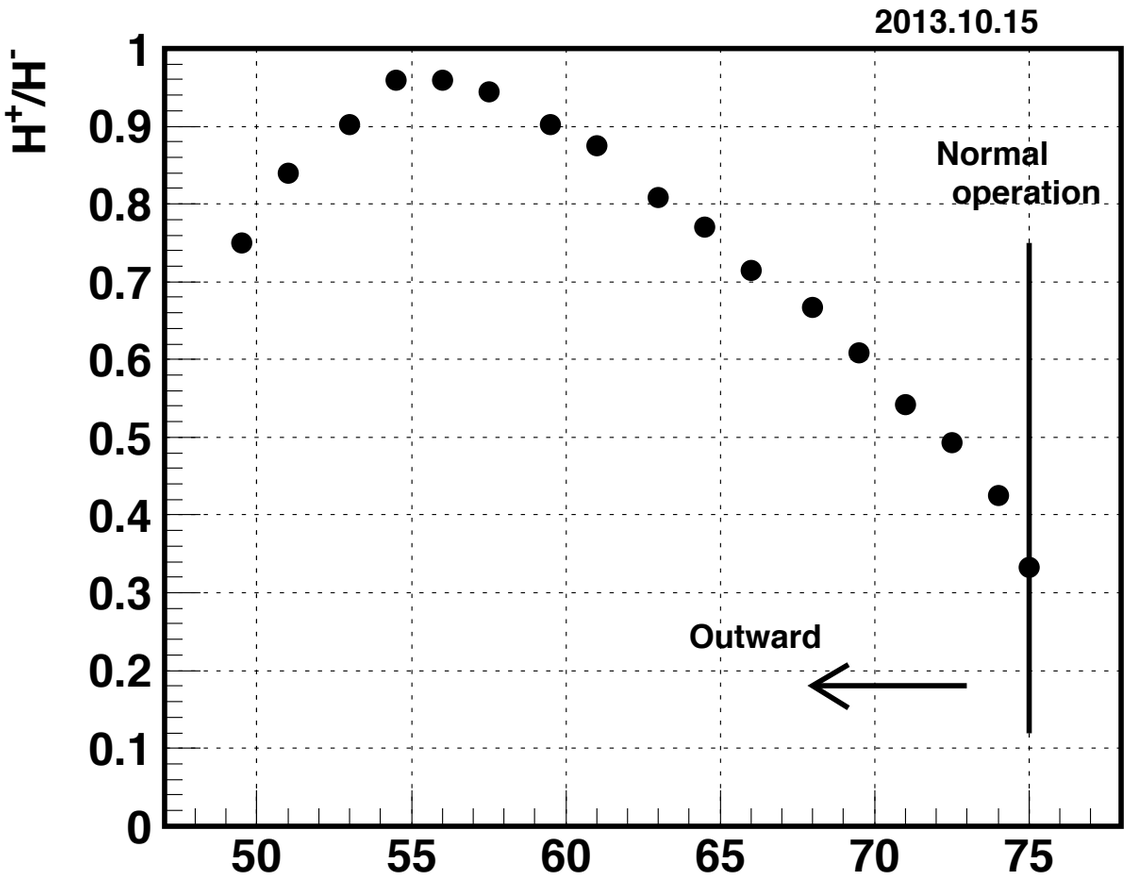
Position (profile) measurement at foil position

experiment 2'



Put a wire instead of foil to measure horizontal profile (or simply beam centre).

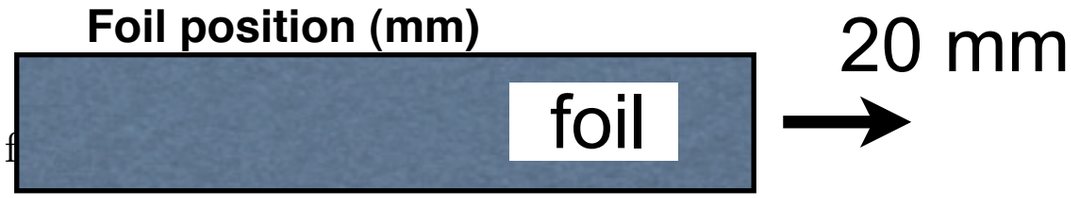


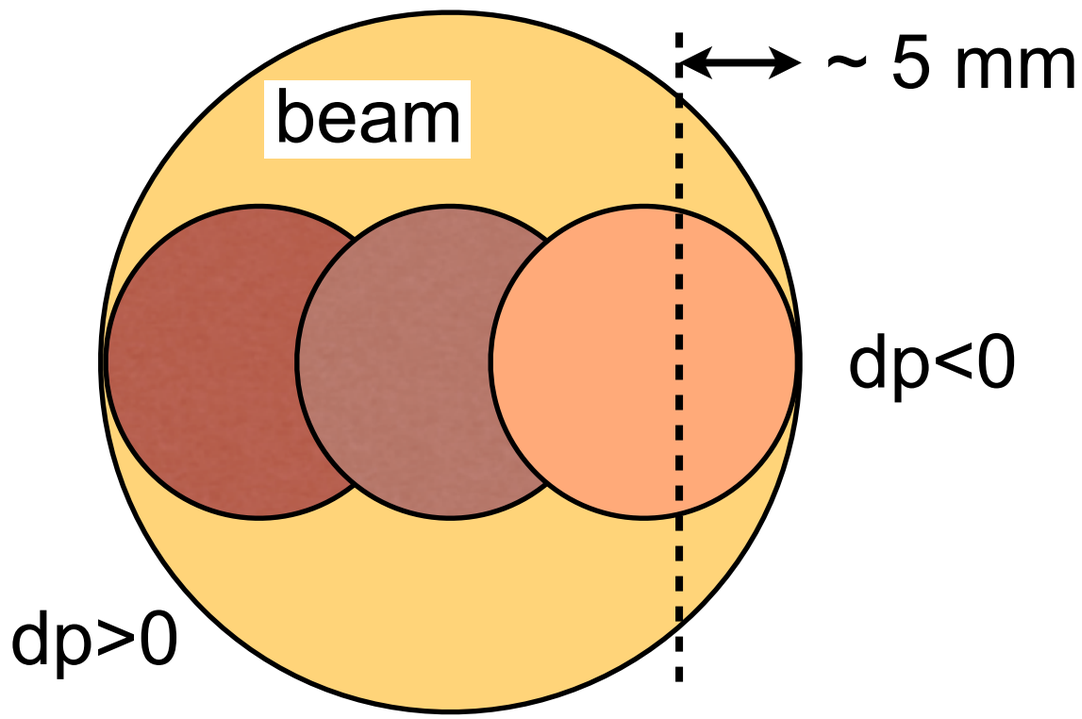
Momentum dependence

(experiment 3)

Move of 20 mm still give 30% beam can be another reason that beam is wide.

図 2: Injection efficiency vs f





Injecting one size of the beam may mean we do momentum selection (injecting relatively low momentum side).

Optimum rf frequency is different depend on foil position.

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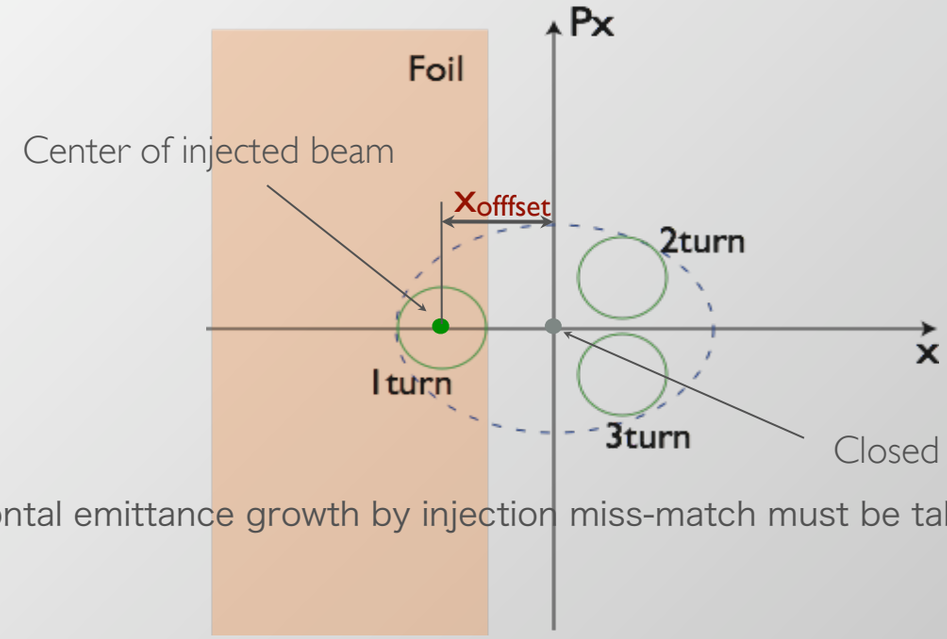
Horizontal orbit (mis-) matching

Off-center Injection

Low energy injection(11MeV), circulated beam hit foil many times. Energy loss and emittance growth are become problem. To decrease the hitting probability, H- beam is injected off-center by about 10 mm parallel shift of injection line.



Horizontal emittance growth by injection miss-match must be taken account.

It is not clear if we should inject a beam on the closed orbit.

Horizontal BPM tells us the amplitude of mismatch and position of closed orbit.

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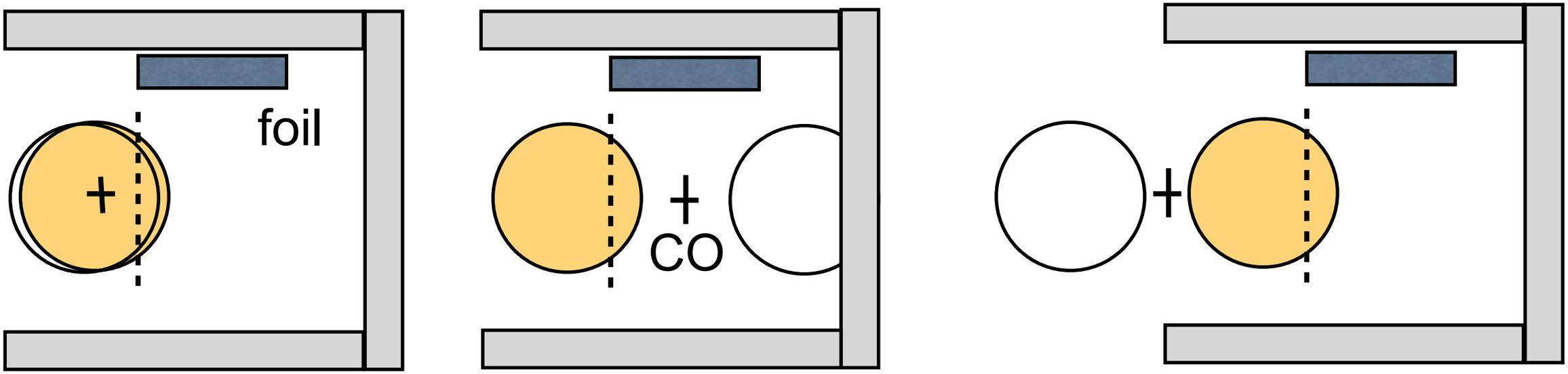
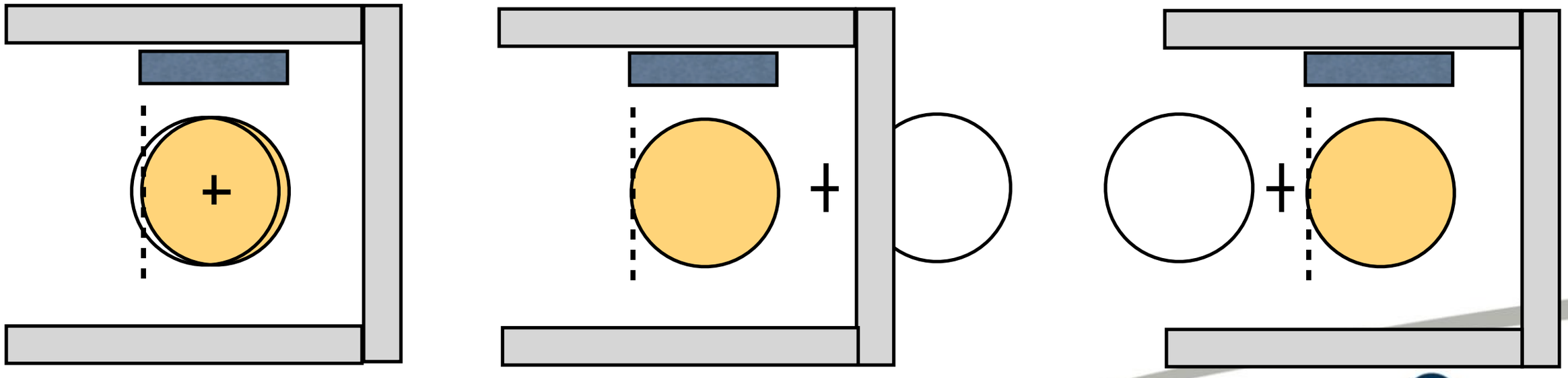
Measure the location of closed orbit

75 mm



foil frame

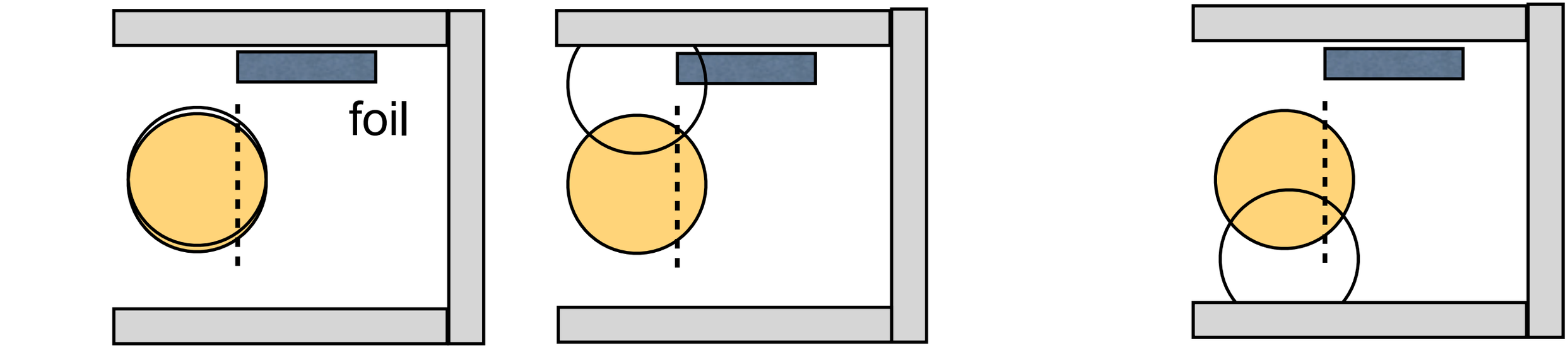
55 mm



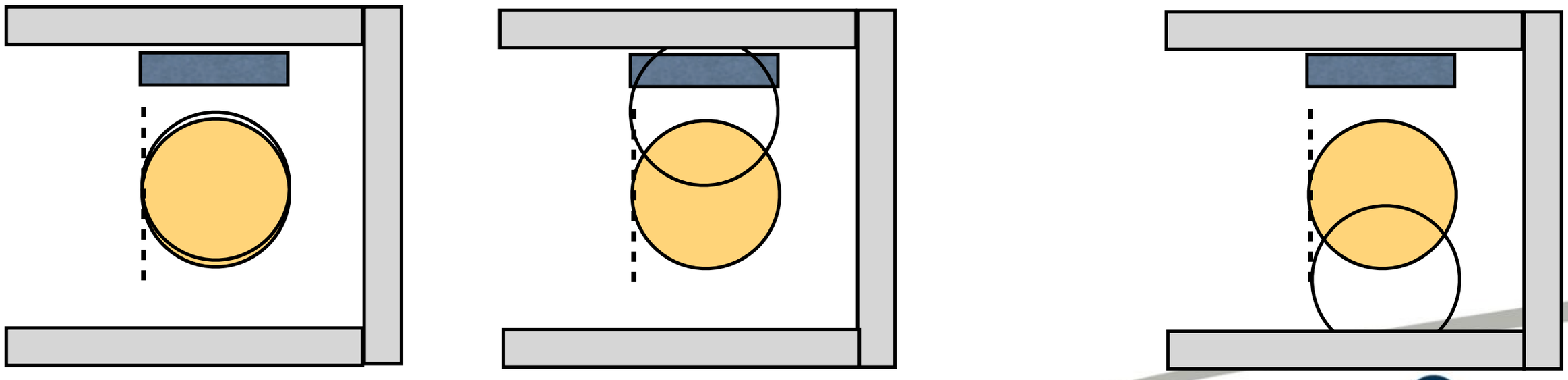
Measure CO at other places and translate.

Same for vertical

75 mm



55 mm



Measure CO at other places and translate.

ionary buckets

F/D/COR	814/995/445
RF	AWG,f1580, 0.950 Vpp (太田様 5 Vpp), 906.88 μs
BMON	(INU), AMP
OSCILLO	AC-50 Ω, 0.2 ms/div, 0.5MS
CHOPPER	0.334% (0.537 revolutions)

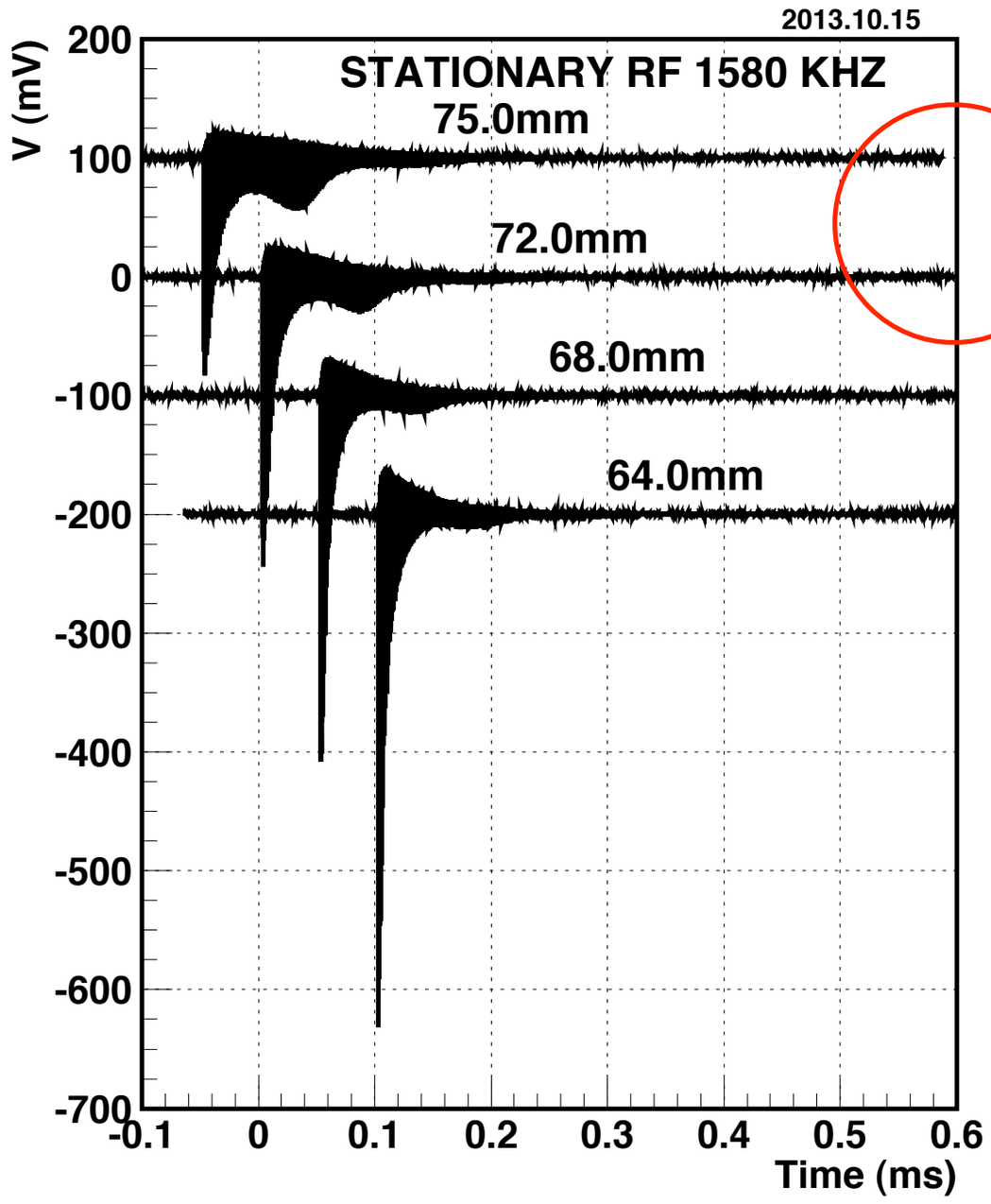
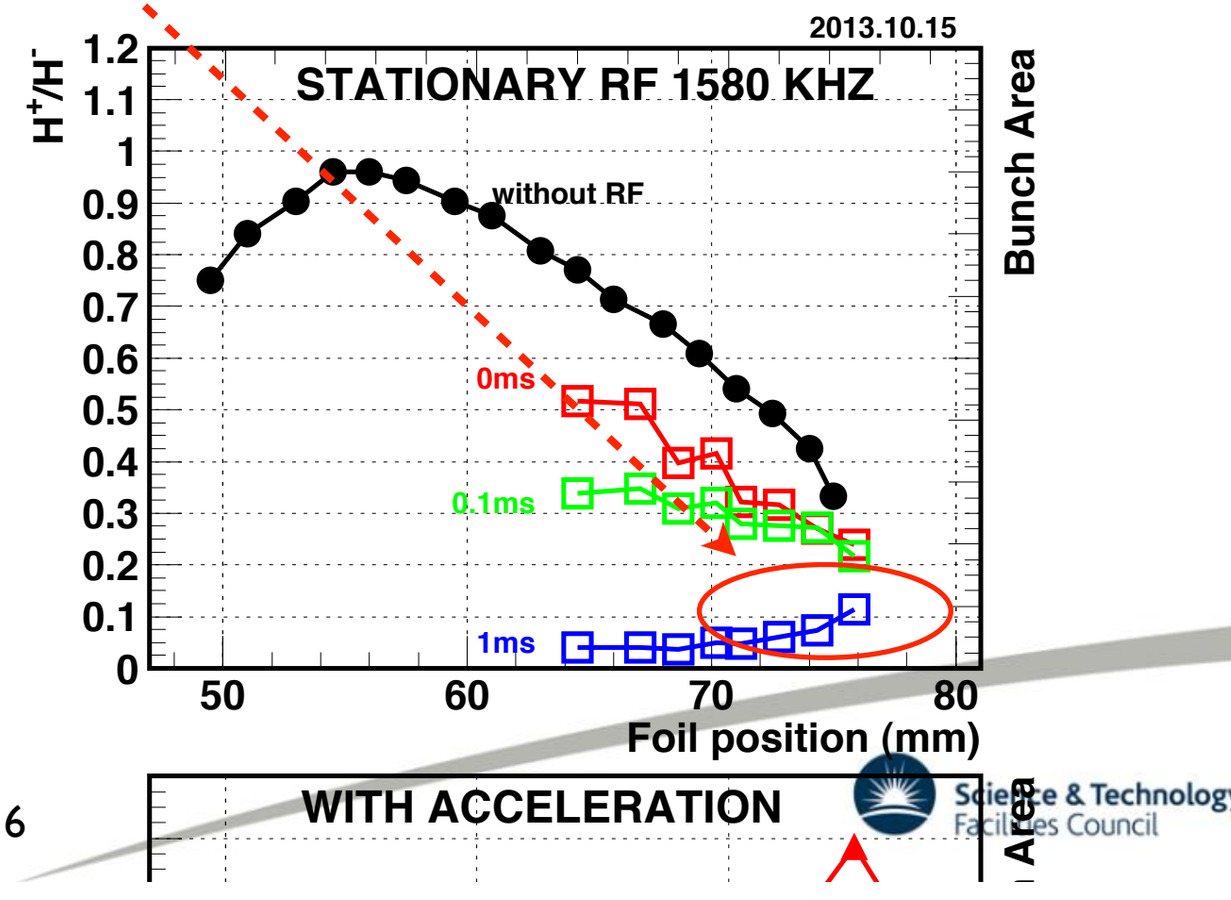


図 5:

In stationary rf bucket

Need to know
1) where is the closed orbit,
2) amplitude of initial mismatch.

Is there any particles survive at 1 ms when foil is 72 to 75 mm?



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ionary buckets

F/D/COR	814/995/445
RF	AWG,f1580, 0.950 Vpp (太田様5 Vpp) 204.88 μs
BMON	(INU), AMP
OSCILLO	AC-50 Ω, 0.2 ms/div, 0.5MS
CHOPPER	0.334% (0.537 revolutions)

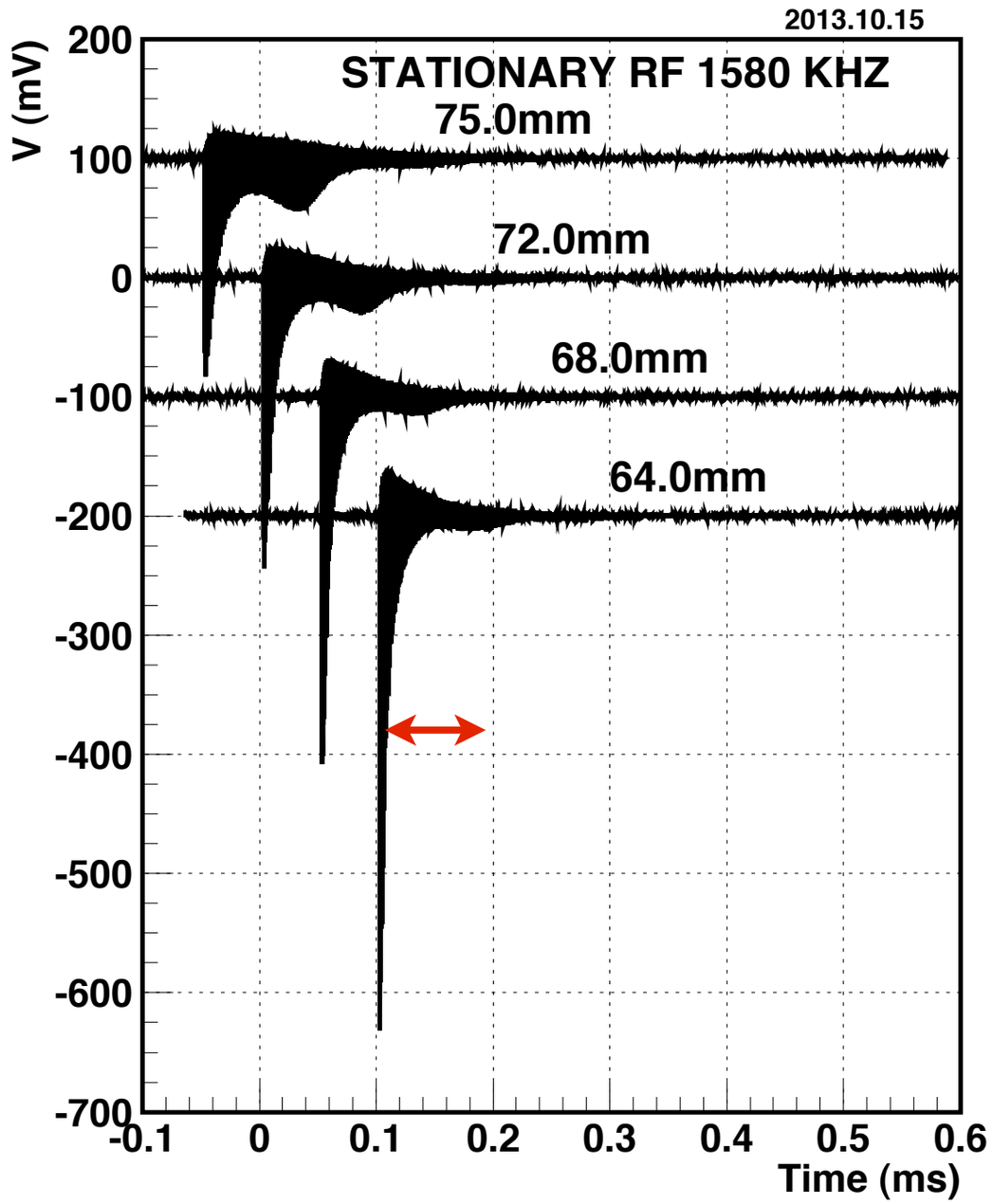


図 5:

Emittance growth from scattering

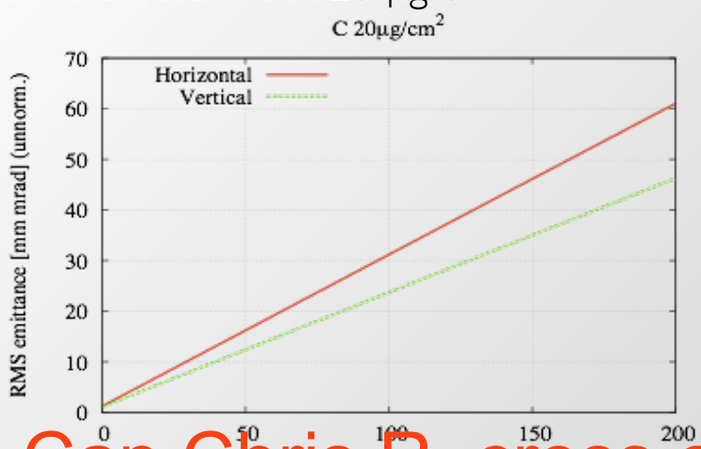
Figure shows considerable beam is lost in 0.05 to 0.1 ms. (78 to 156 turns)

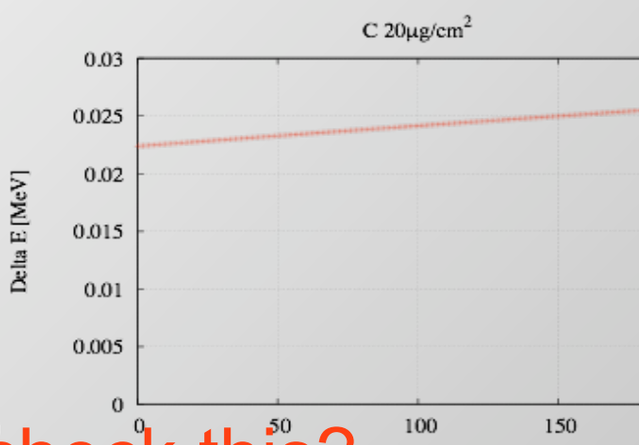
From Okabe's slide at FFAG11, rms emittance (unnor.) becomes ~45 p mm mrad.

rms beam size becomes ~12 mm.

Emittance Blow up(2)

Foil thickness : 20 μg/cm^2





Can Chris R. cross check this?

17

- disp. : 0.54[m]

ionary buckets

F/D/COR	814/995/445
RF	AWG,f1580, 0.950 Vpp (太田様 5 Vpp), 906.88 μs
BMON	(INU), AMP
OSCILLO	AC-50 Ω, 0.2 ms/div, 0.5MS
CHOPPER	0.334% (0.537 revolutions)

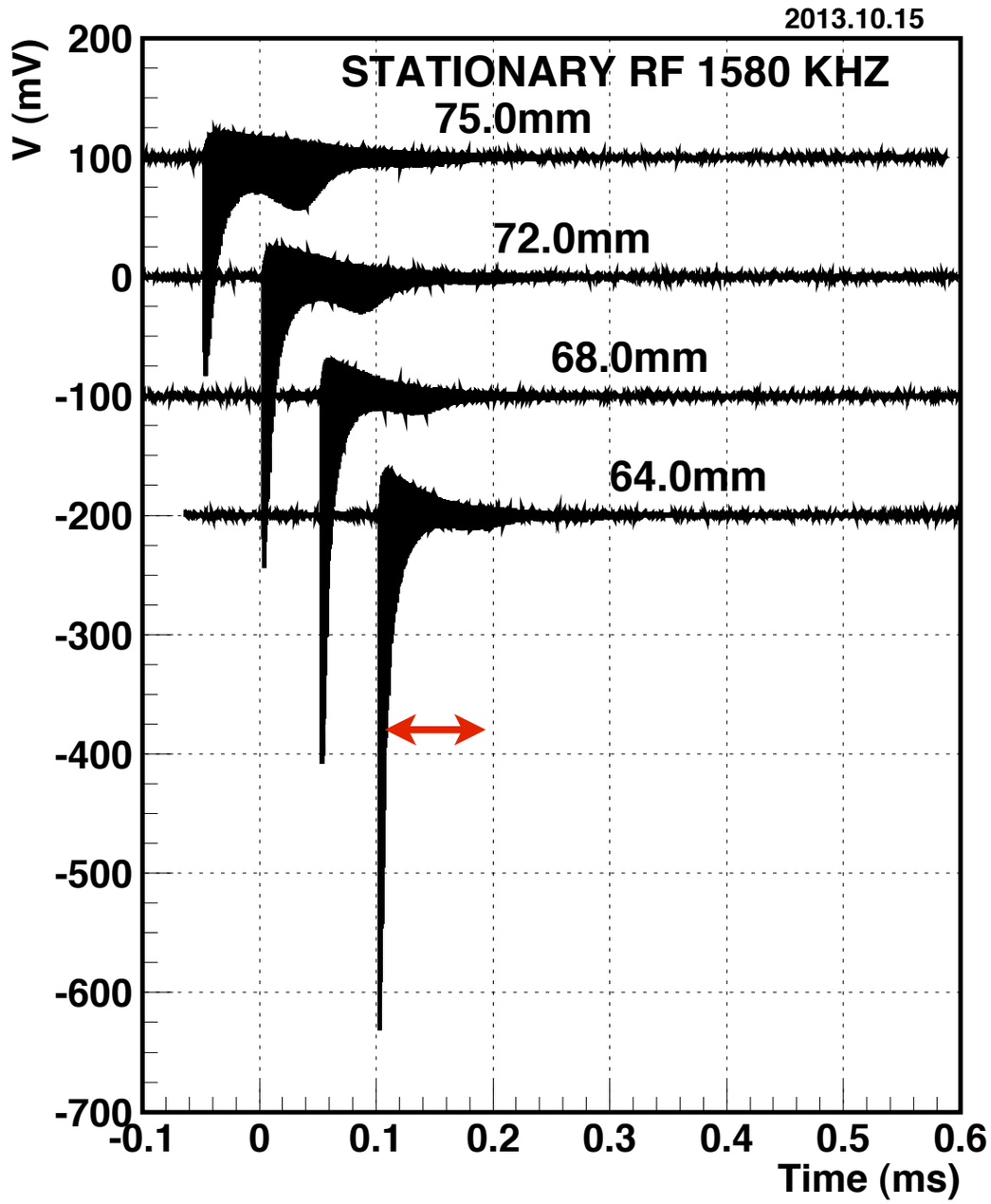


図 5:

Empirical rule

Difference between 75 mm and 64 mm comes from hitting probability (FP).

Assume FP~1 at 64 mm, then a condition which makes a beam survive is

FP x t < ~0.1 ms

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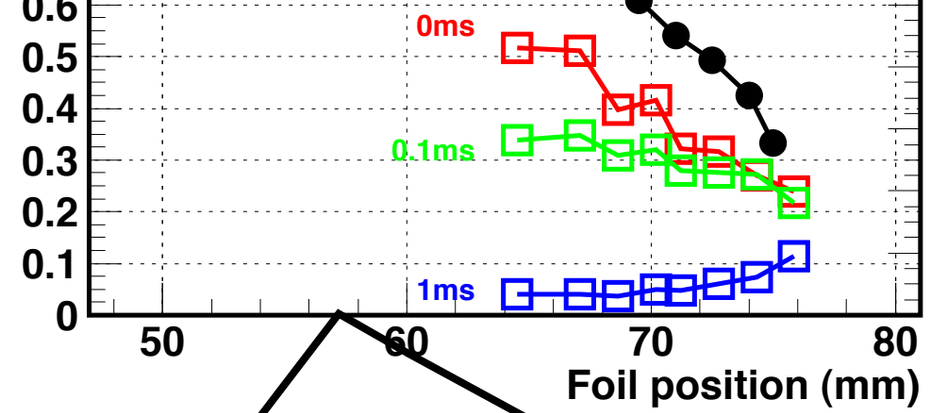
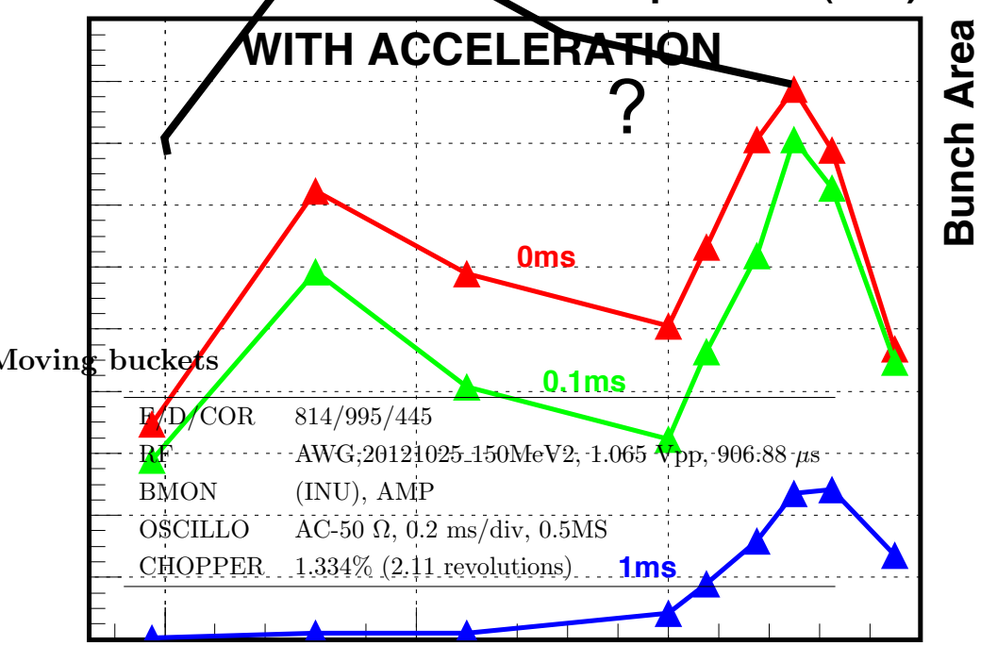
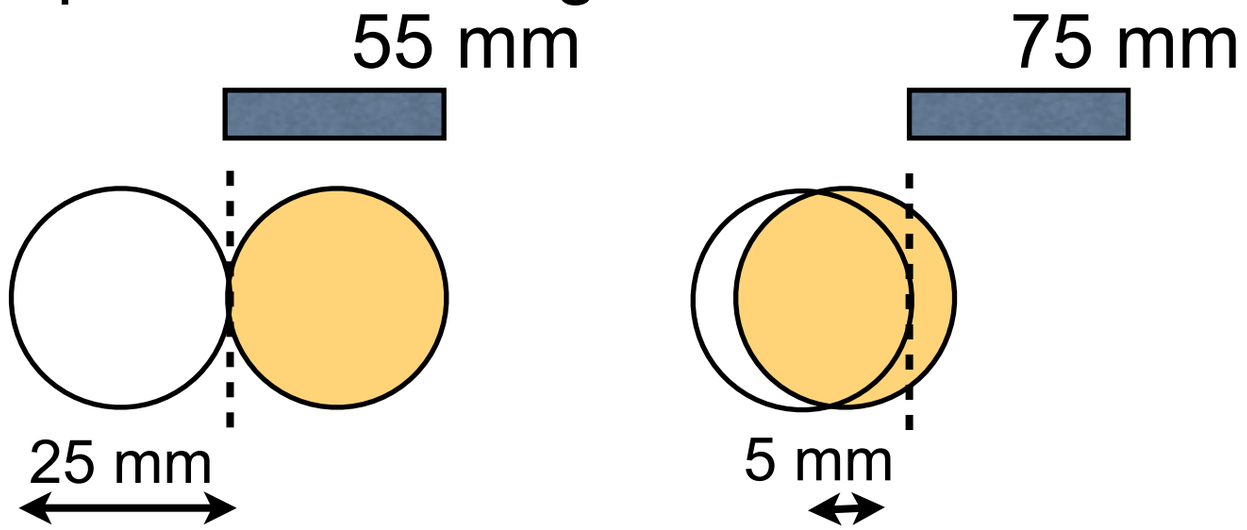
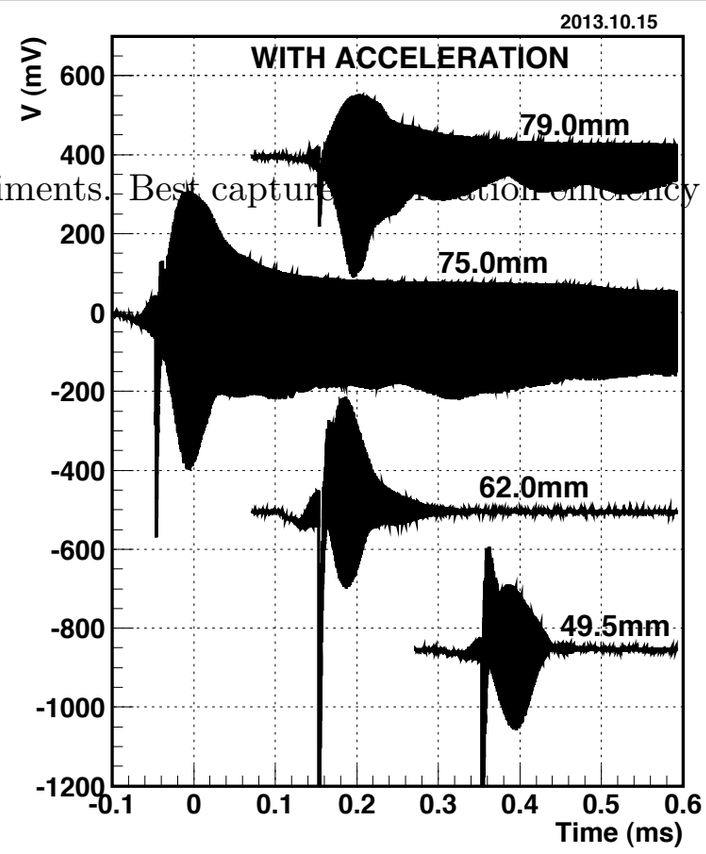




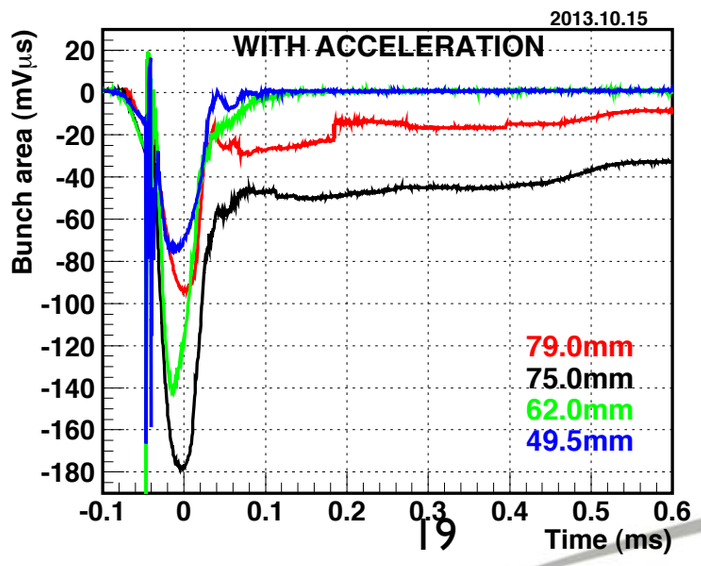
In moving rf bucket

Beam moves 6~7 mm in 0.1 ms when phis=20~30 deg.





1) takes ~0.4 ms to go out of foil.
2) FP ~ 1



1) takes <0.1 ms to go out of foil.
2) FP < 1

FP x t < ~0.1 ms

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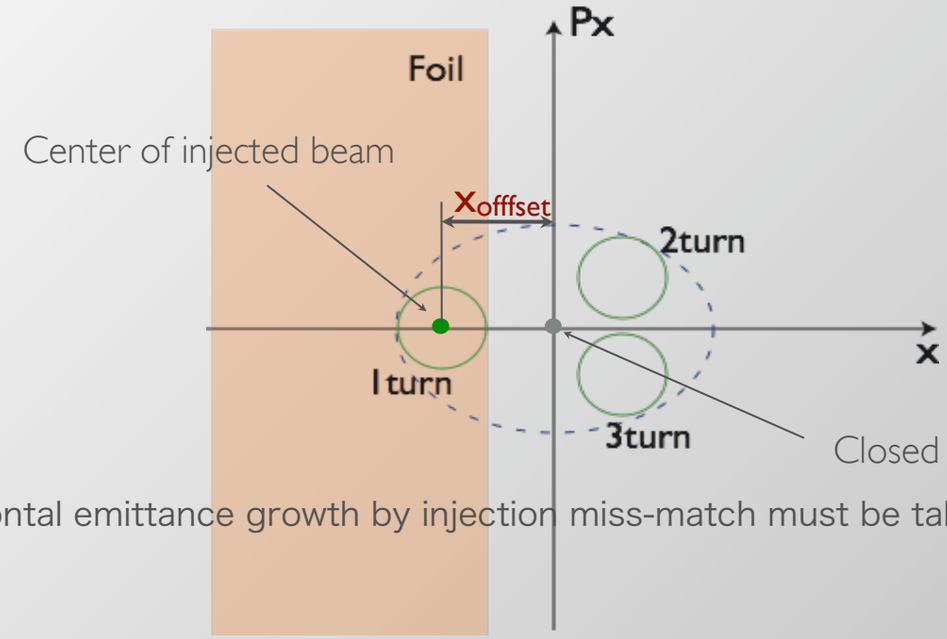
Horizontal orbit mis-matching

experiment 4

Off-center Injection

Low energy injection(11MeV), circulated beam hit foil many times. Energy loss and emittance growth are become problem. To decrease the hitting probability, H- beam is injected off-center by about 10 mm parallel shift of injection line.



Horizontal emittance growth by injection miss-match must be taken account.

Manipulate closed orbit@foil to decrease FP.

In practice, it may be difficult to shift the beam from closed orbit for more than a beam size. (beam size is too big.)

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Can we repeat this after knowing COD position?

F/D/COR	814/995/445
RF	AWG,f1580, 0.950 Vpp (太田様 5 Vpp), 906.88 μs
BMON	(INU), AMP
OSCILLO	AC-50 Ω, 0.2 ms/div, 0.5MS
CHOPPER	0.334% (0.537 revolutions)

F/D/COR	814/995/445
RF	AWG,20121025_150MeV2, 1.065 Vpp, 906.88 μs
BMON	(INU), AMP
OSCILLO	AC-50 Ω, 0.2 ms/div, 0.5MS
CHOPPER	1.334% (2.11 revolutions)

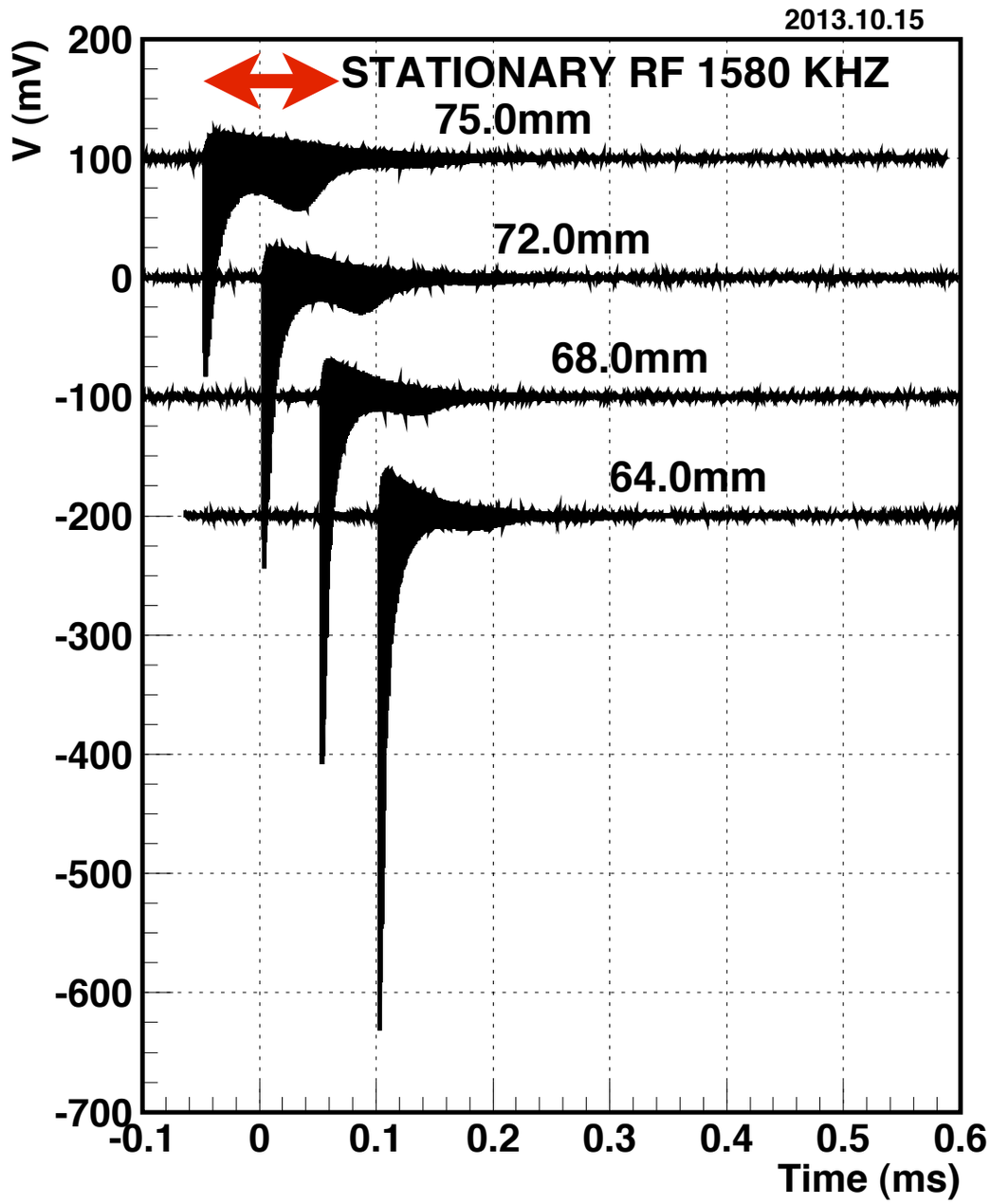

図 5:

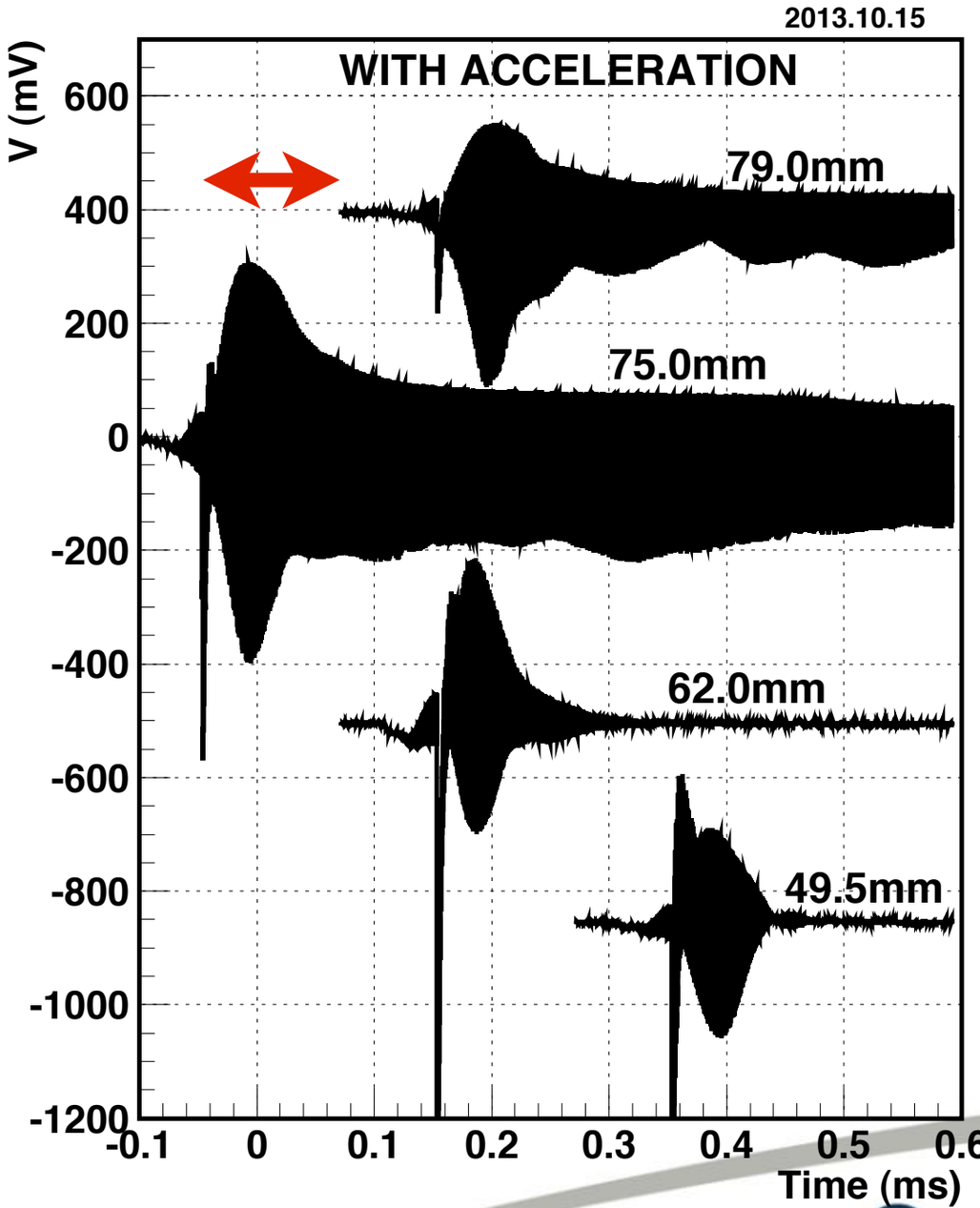

図 3: Dependence on foil position, with rf-acceleration.

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Injection seems to be the biggest issue

- Injection of 2.56 us (= 0.640 x 4 turns)
  - survival after 1 ms is 1/30.
- Injection of 50 us (= 0.640 x 78 turns)
  - survival after 1 ms is 1/400.
  - only 1.5 times more than 4 turns injection.

- Still 1/400 seems worse than expected. May need to consider longitudinal (accumulated momentum spread) as well.

Check list

- Horizontal and vertical orbit matching. *experiment 1*
- Horizontal and vertical optics matching.
- Dispersion matching in horizontal. *experiment 2*
- Emittance growth by multiple scattering at foil. *experiment 4*
- Energy loss at foil. *experiment 4*
- Optimum rf frequency w.r.t beam momentum. *experiment 3*
- Optimum phi_s.
- Measurement of linac beam quality (dp/p, emittance). *experiment 0*

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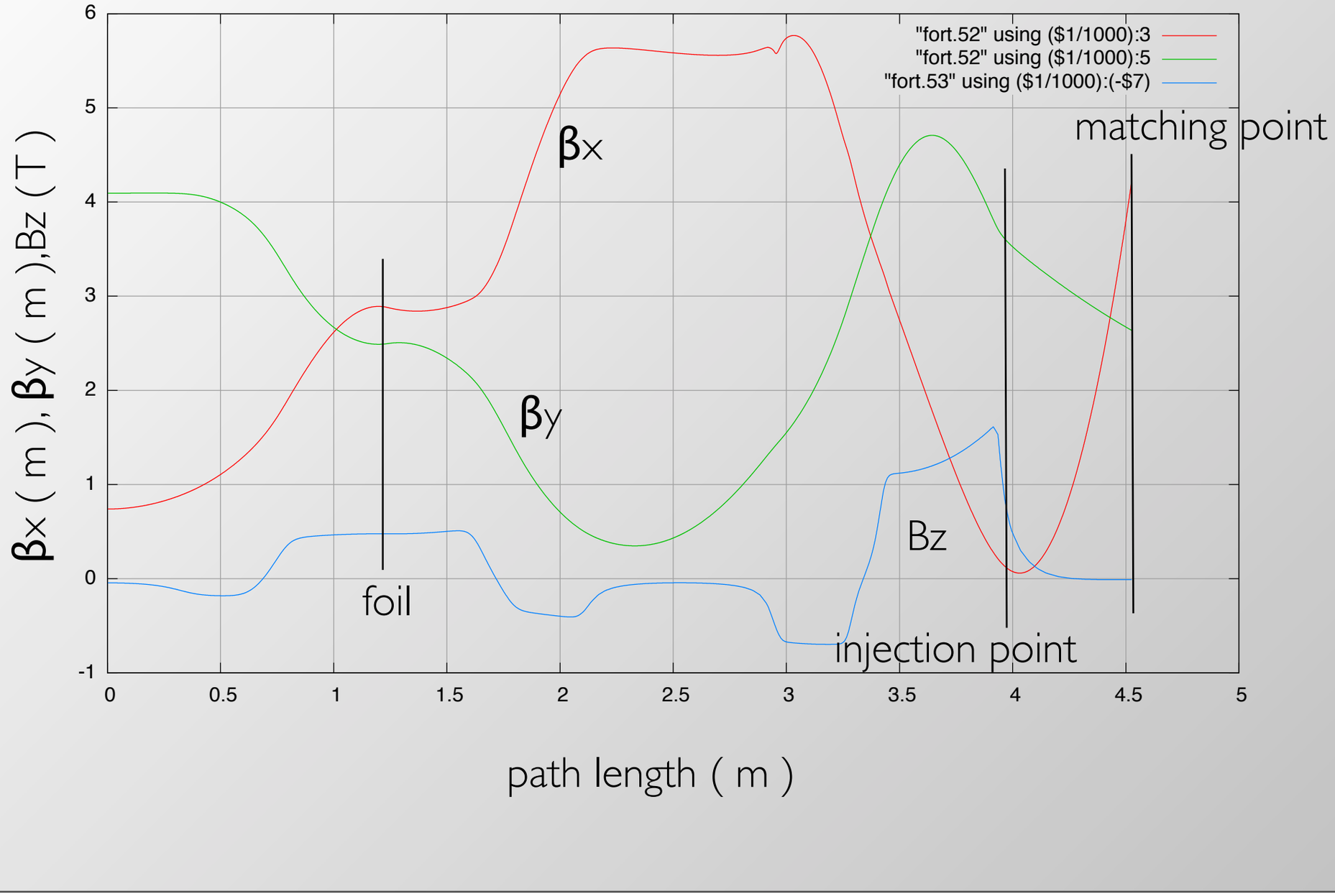
Other topics

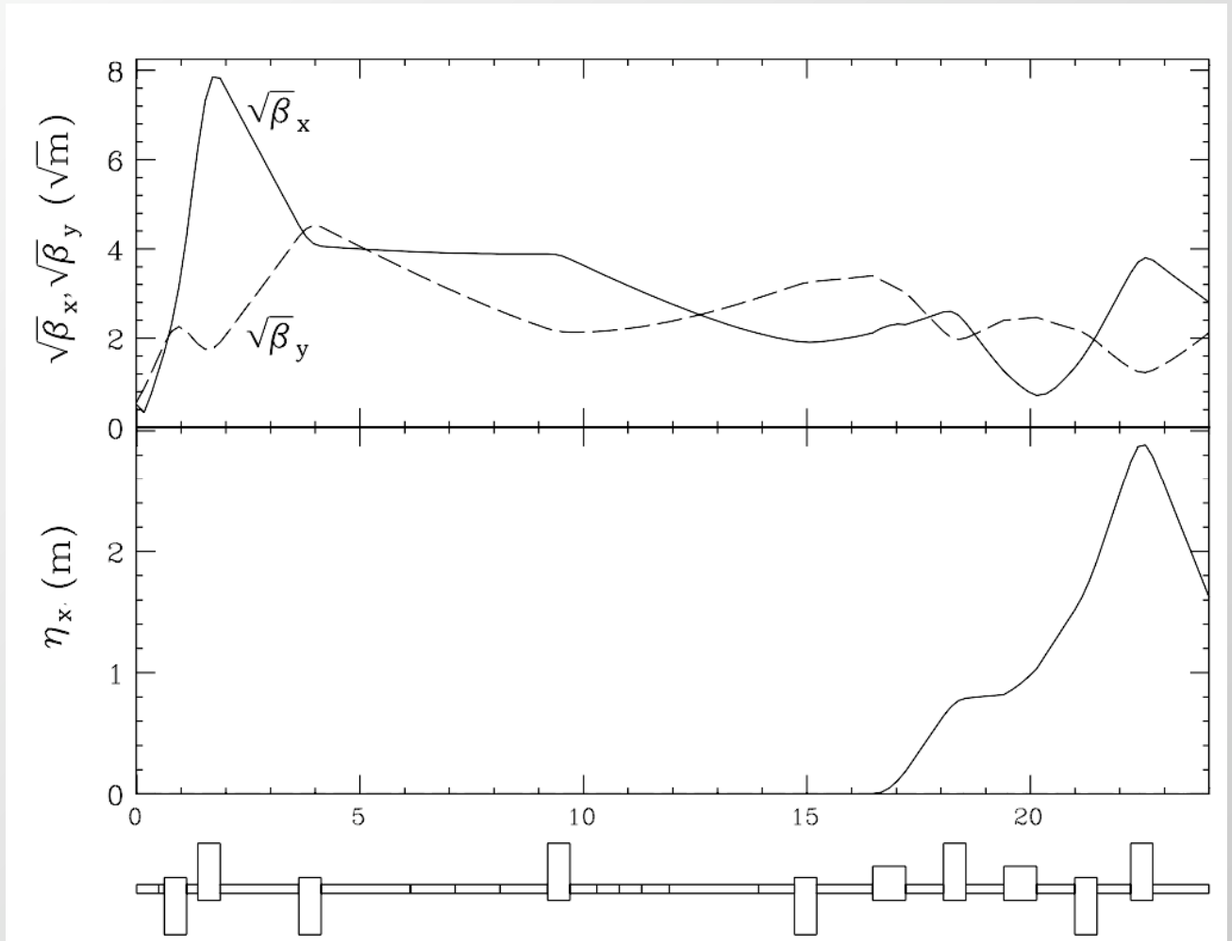
- COD correction by correction coils at rf cavities and its measurement.
- Tune optimisation and its measurement during a cycle.

Backup slides

Beta functions calculated from backward tracking in the main ring



New Beam optics



linac ST QD QF ~

Initial twiss para. -> Beam measurement

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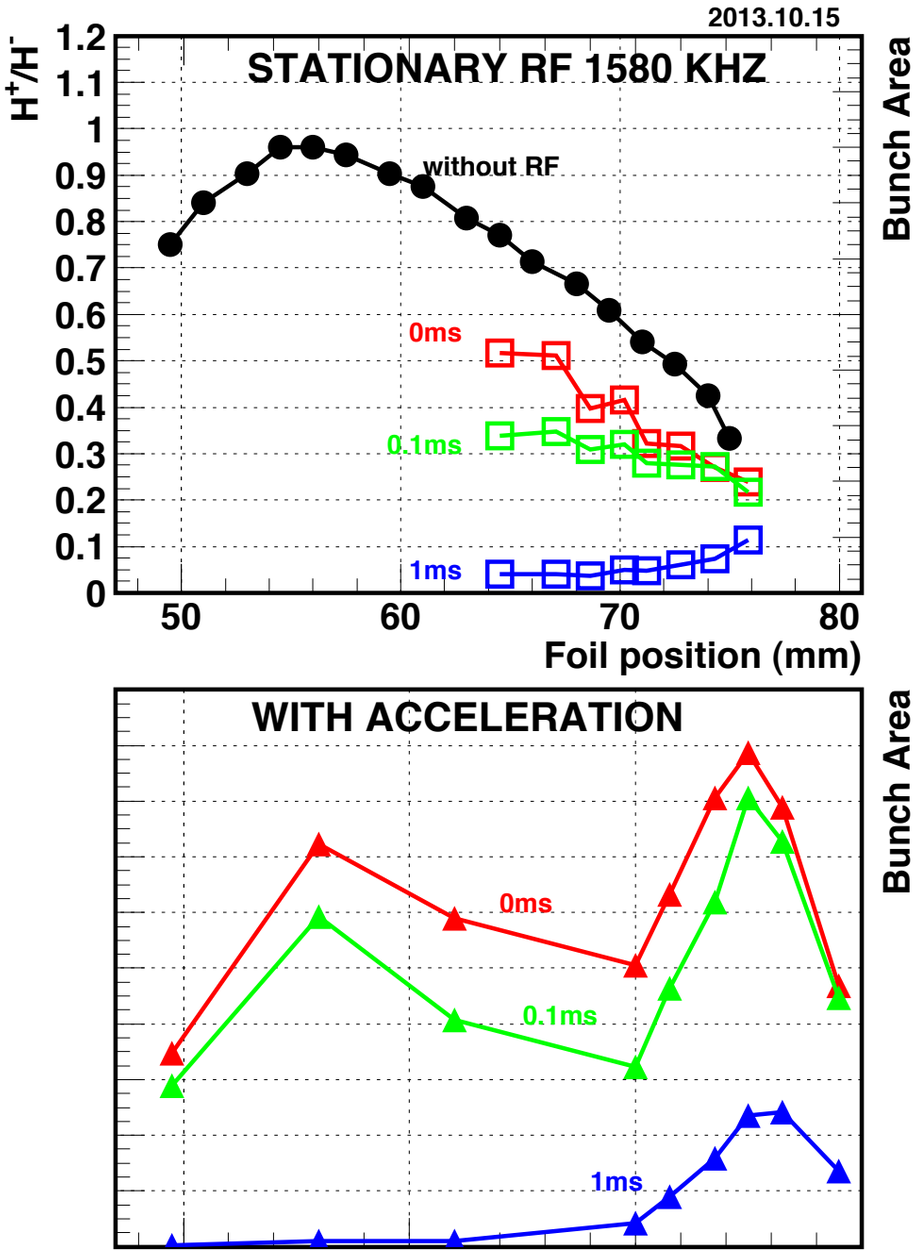

- Injection efficiency is maximum at 55 mm.

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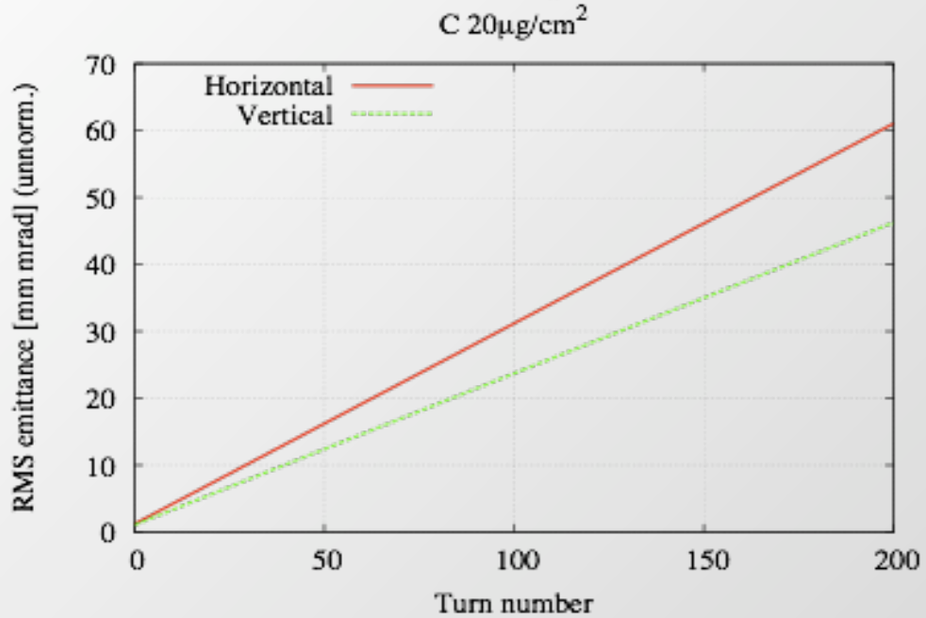
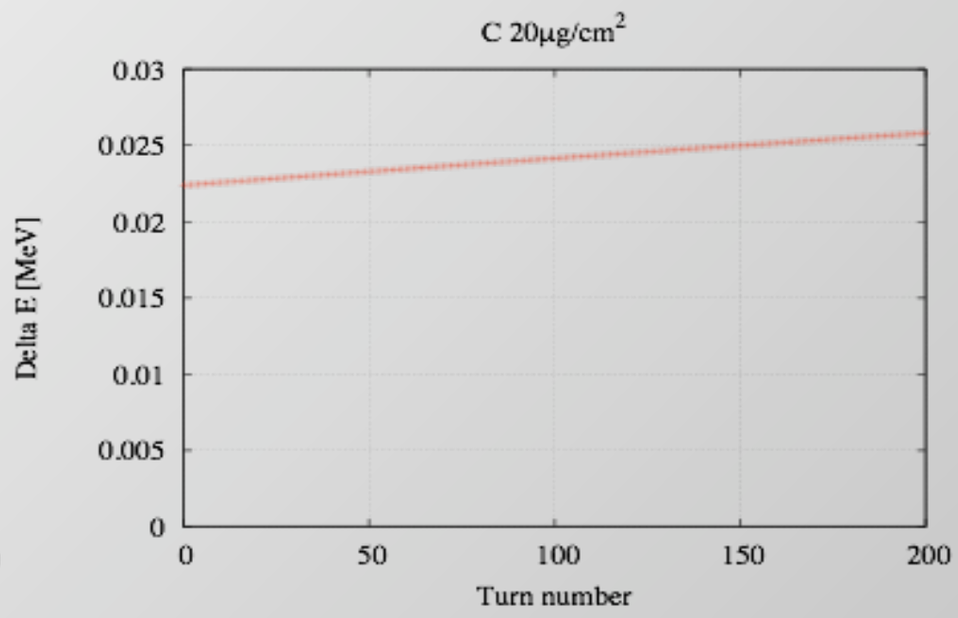
Emittance Blow up(2)

Foil thickness : 20 μg/cm^2





- disp. : 0.54[m]
- hori. beta : 3.31[m]@foil
- vert. beta : 2.50[m]@foil

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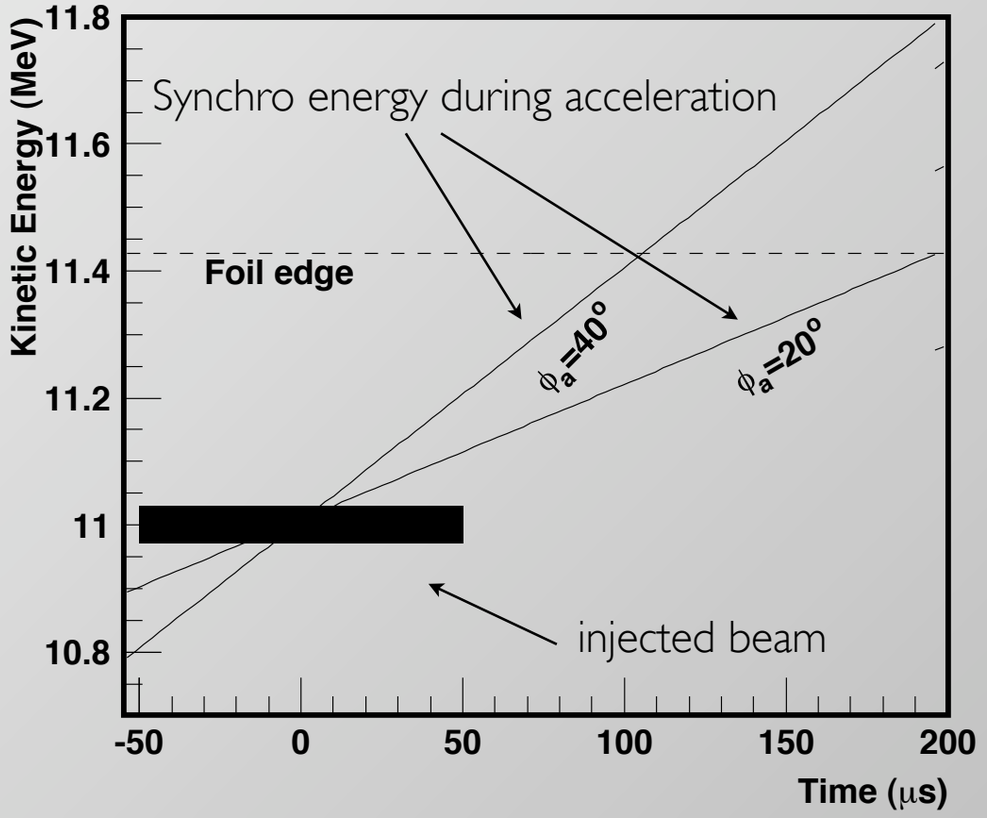
Simulation of accelerate after capture

- Linac beam : 100us(flat), (11.0+-0.03) MeV
- Foil : 20ug/cm^2(E loss 760eV), 10mm width
- RF voltage : 4kV

Flow of beam injection

- Injected beam is accelerated during injection(100us)
- Acceleration phase : 20, 40deg.

Detail of this simulation will be talked by Tom. Uesugi at tomorrow presentation.



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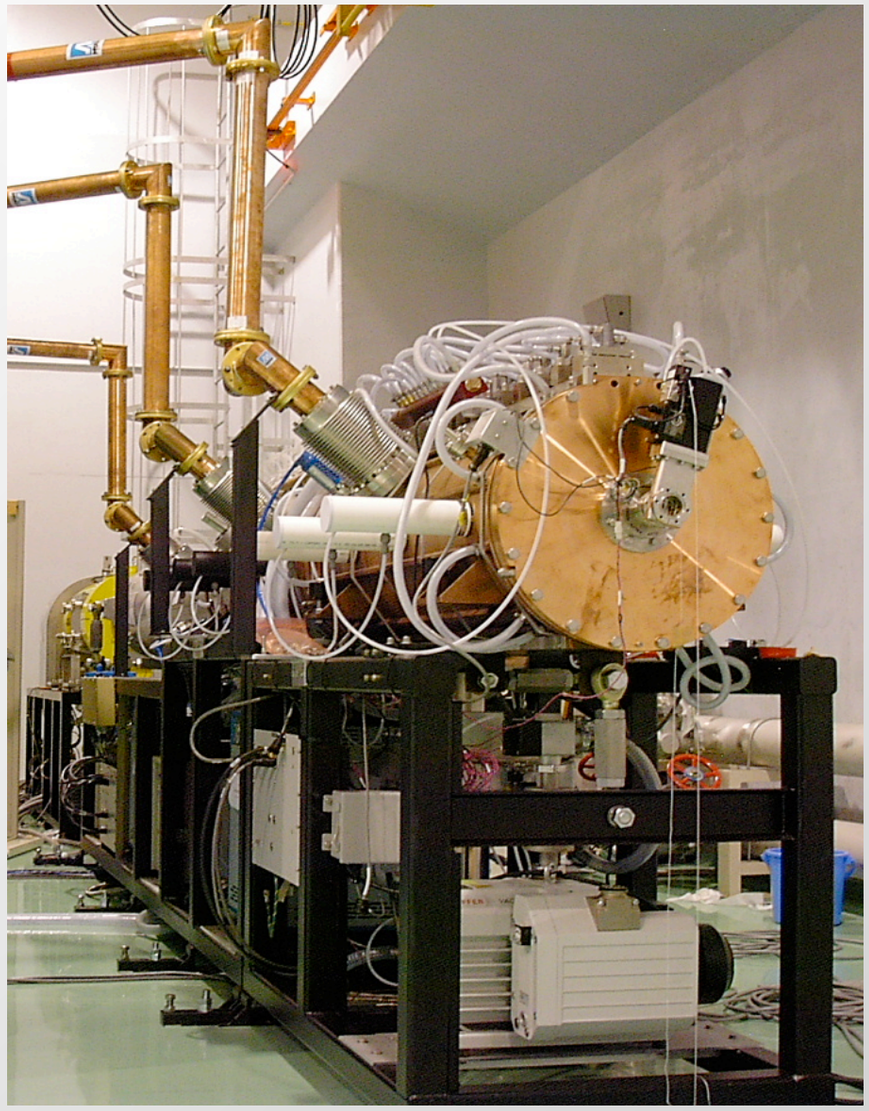
New injector
Linac and H^- Ion Source



Linac beam parameter

Ion ：H^-

E_{ext} ：11MeV

Beam Pulse width(MAX) ：100 μsec

Peak Curr.(MAX) ：~5 mA

：~$3.12*10^{12}$[ppp]

(Present injector) ：~$6.00*10^{8}$[ppp]

rep. rate :1Hz~200Hz

Horizontal

norm. emittance (90%)：0.680 mm•mrad

Vertical

norm. emittance (90%)：0.630 mm mrad

Ene. 90% : ΔE ~ 45KeV