KURNS experiment in September 2018
- overview -

22 November 2018

Shinji Machida

Experiment plan

- Separate longitudinal and transverse effects by looking at only the beginning of acceleration.
    - 3.5% efficiency is the figure when the beam is accelerated to 19.5 MeV, which may have already suffered from resonances.

- Looking at the longitudinal phase space when the beams are outside the foil (tomography). Compare it with simulation.

- Optimise the capture process not only by scanning constant phi_s, but also introducing adiabatic capture with linear increase of phi_s.

- See the difference between two RF programme based on constant k (constk) and variable k (TOSCAk).

Uesugi's summary

Qualitative discussion

Transverse degree of freedom has been neglected.
Energy loss by foil-hit is fixed at 0.76 keV.

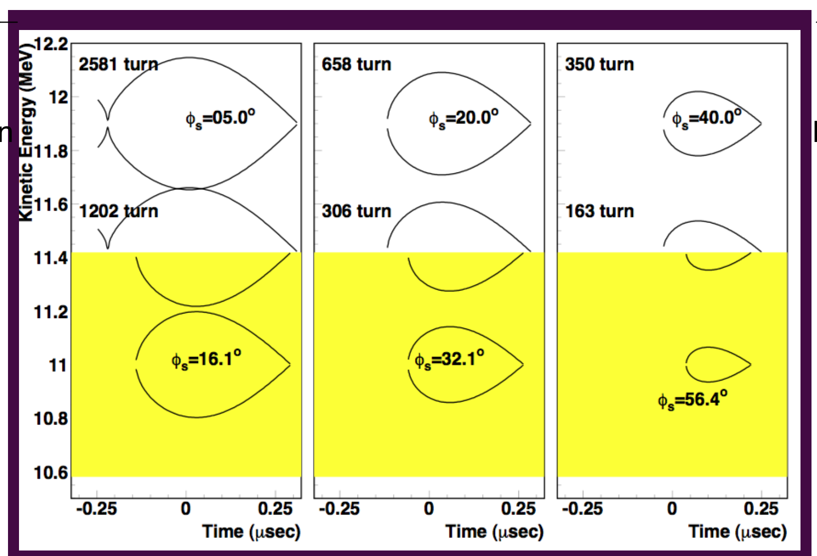
$$V \sin \phi_a = V \sin \phi_s - \Delta E_{loss}$$

Lower ϕ_a ← → Higher ϕ_a

Larger bucket
Slow acceleration

Higher capture efficiency

Many foil-hits



T. Uesugi, FFAG11, Oxford

Smaller bucket
Fast acceleration

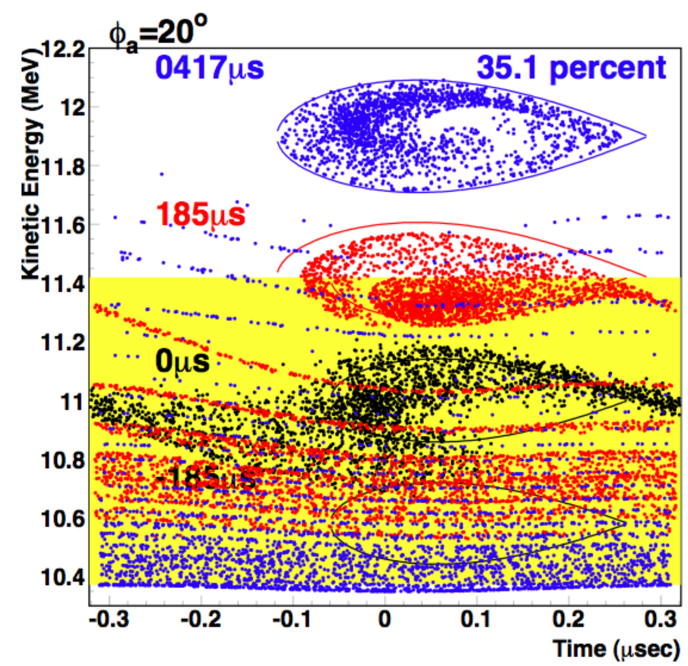
Lower capture efficiency

less foil-hits

Tom UESUGI, FFA'18, Kyoto, Sep, 2018

Effect of p drift and spread

SIMULATION
2015.12



Deviation of p by +-1%
is equal to the 20 deg bucket height.

δp of $\pm 1\%$

1% Drifting of p does reduce the capture efficiency.

Tom UESUGI, FFA'18, Kyoto, Sep, 2018

- Energy loss at the foil effectively reduces the bucket area and shifts phi_s.
- If the beams stays inside the foil, continuous energy loss leads to continuous beam loss.
- Trade off between capture (lower phi_s) and escape from the foil (higher phi_s).

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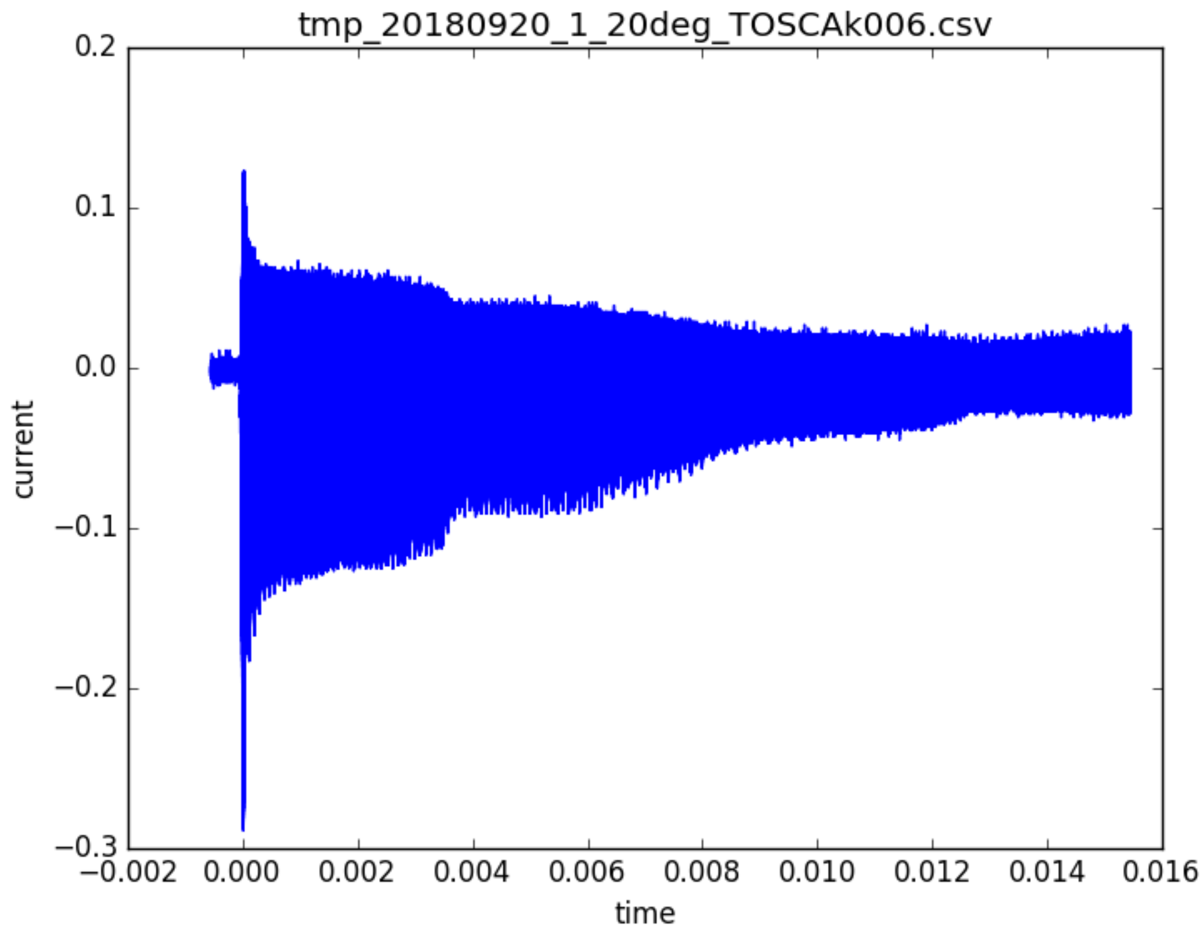
Data taking

- 18 September (Tue): setup diagnostic line for ToF and dp/p measurement.
- 19 September (Wed): ToF and dp/p measurement (timing was not reliable).
- 20 September (Thu):
  - sample data for tomography code
  - script test, **comparison between TOSCAk and constk, phis scan, different pattern.**
- 21 September (Fri):
  - **capture with different flattop energy.**
  - COD measurement.
- 25 September (Tue):
  - **capture with different flattop energy.**
  - **different foil position.**
  - **Attempt tp measure p/H- ratio.**
- 26 September (Wed):
  - no beam
- 27 September (Thu):
  - **continued from Tuesday**, but beam behave differently.

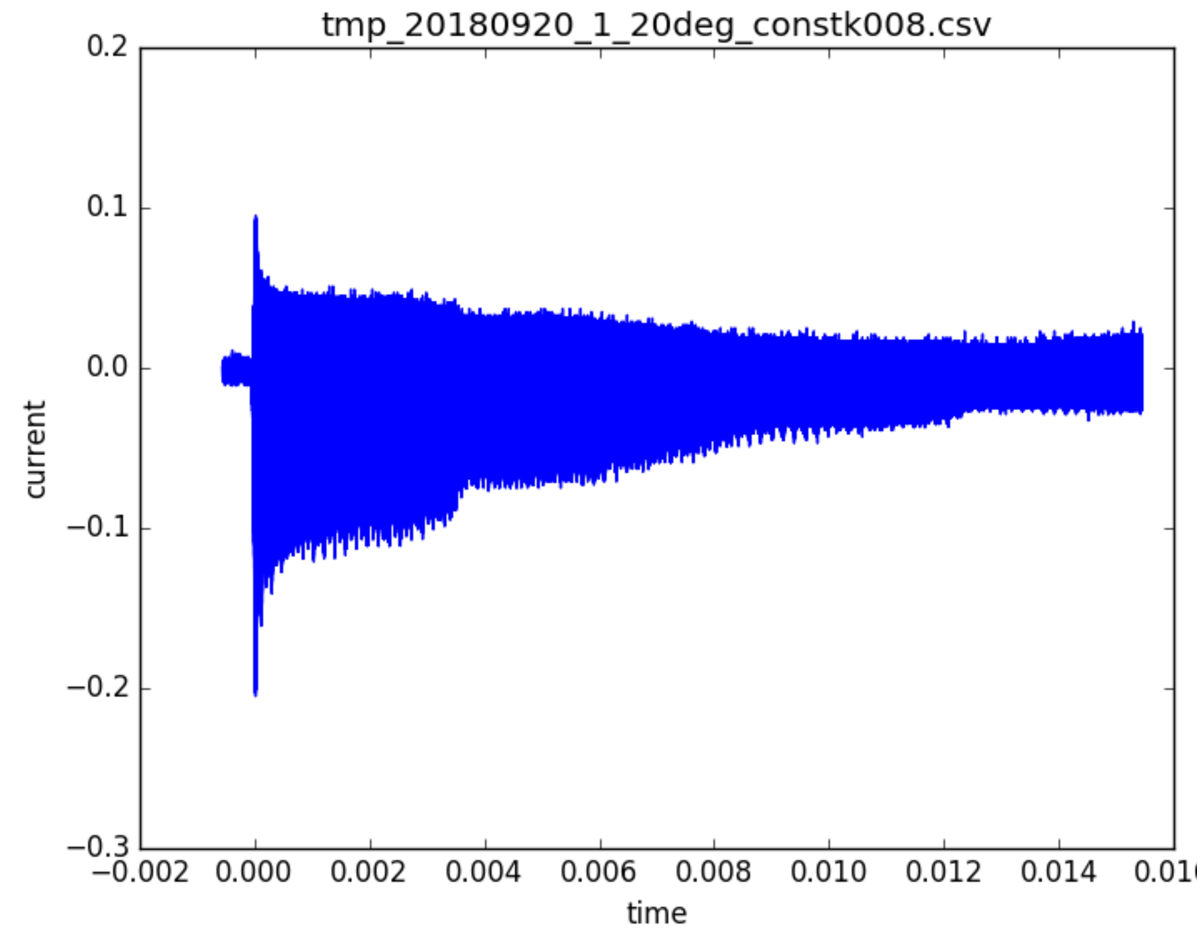
TOSCA k vs. const k

20 September

TOSCA k



constant k



We concluded there is no difference, **but**

we should have taken more shots to see shot to shot fluctuation.

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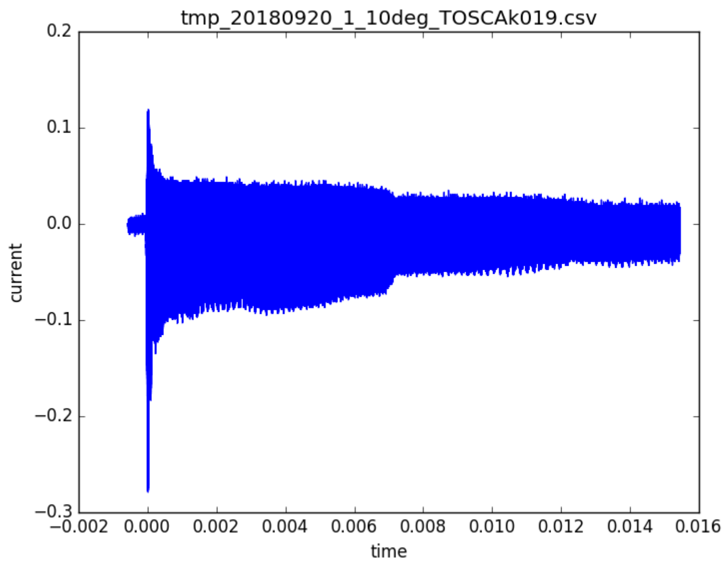
Different phis without flattop

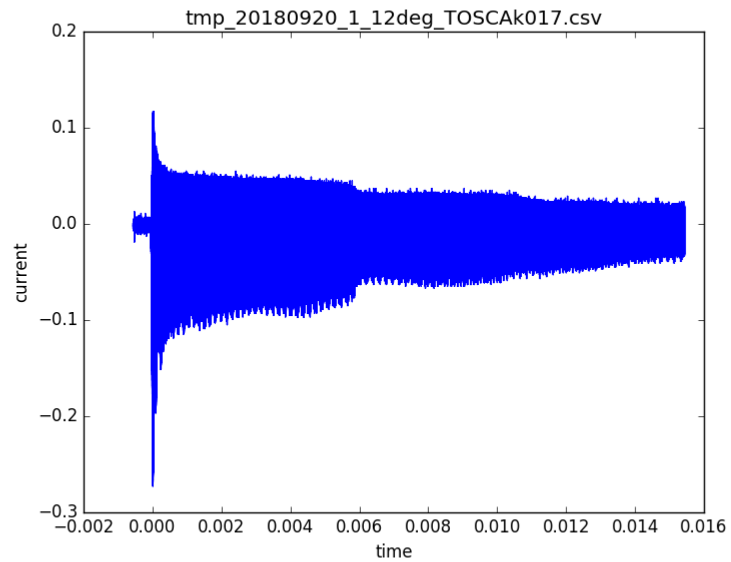
20 September

This confirms the previous finding by Uesugi

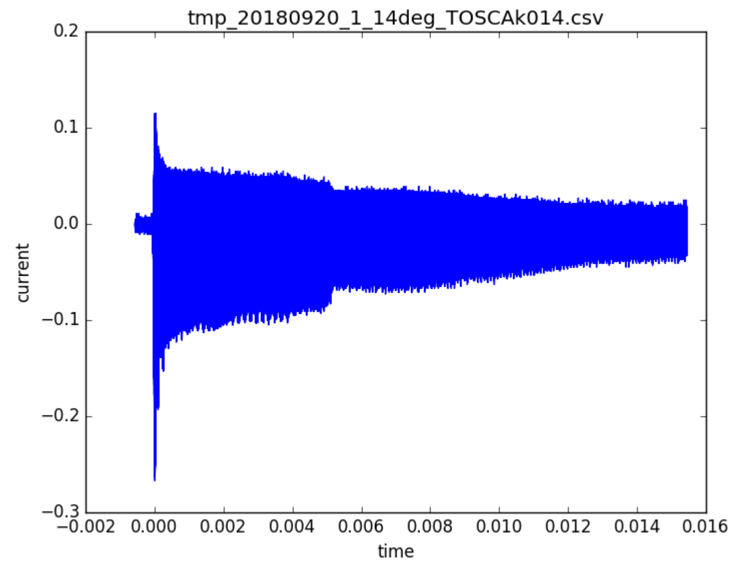
10deg



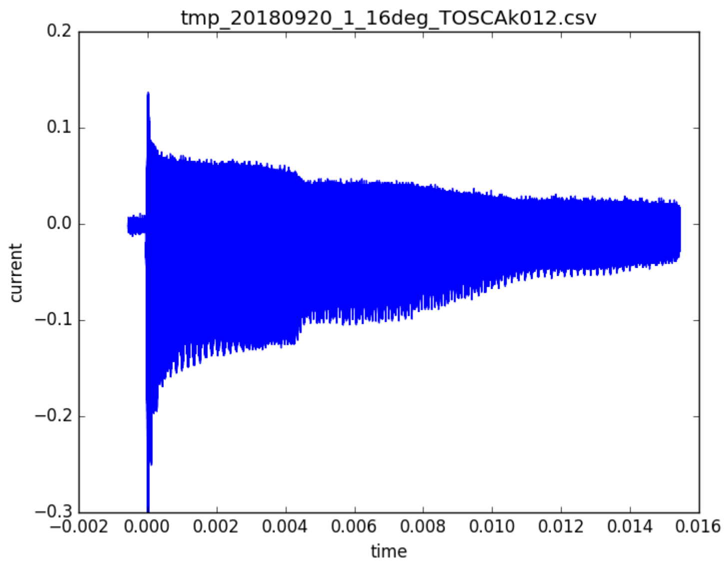
12deg



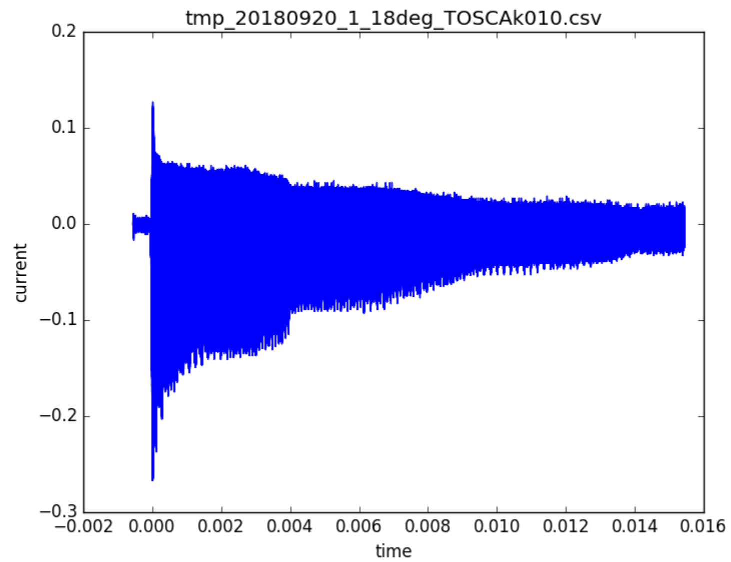
14deg



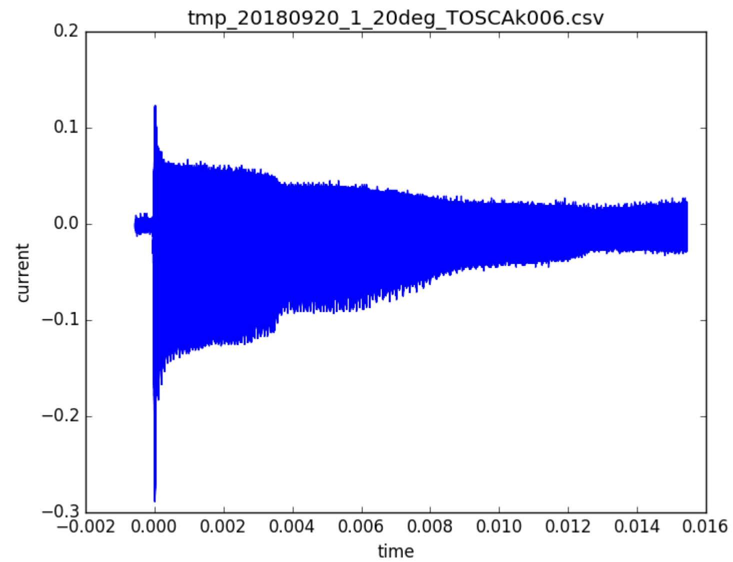
16deg



18deg



20deg

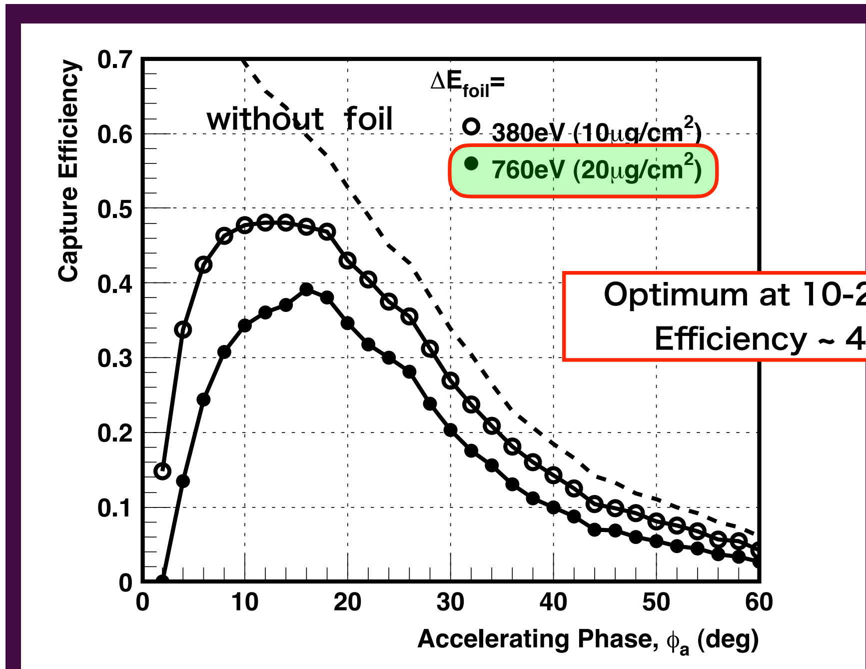


From summary by Uesugi at FFA18

1D SIMULATION

Dependence on accelerate speed

Transverse degree of freedom has been neglected.



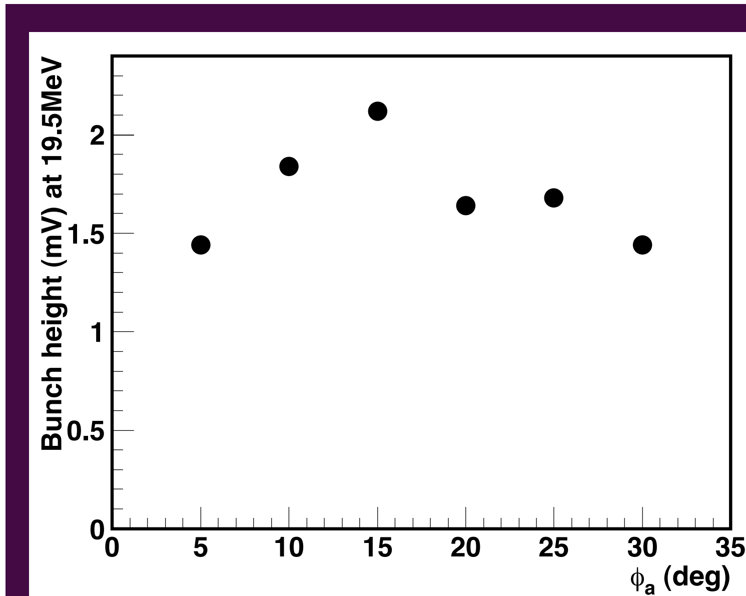
T. Uesugi, FFAG11, Oxford

EXPERIMENTS
2013.06.12

Dependence on acc speed (1)

constant k=7.645

Accelerating with constant V and ϕ_a are examined for different values of ϕ_a.



T. Uesugi, FFAG13, Vancouver

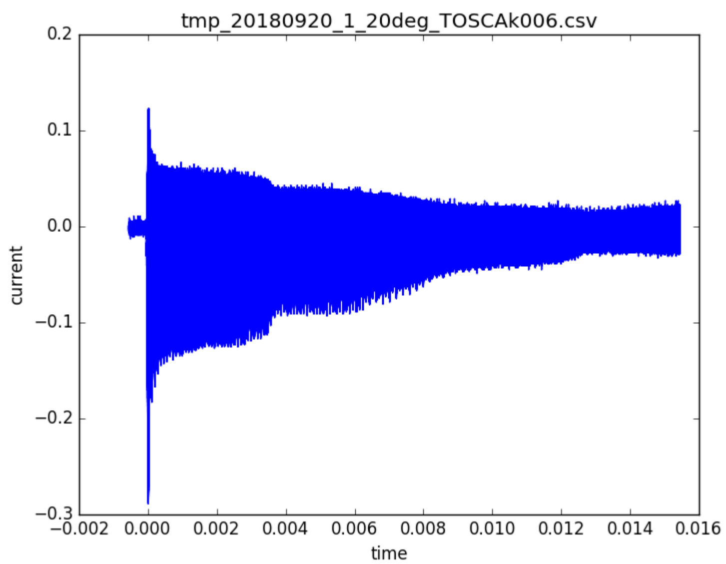
PHIa at 10 - 20 seems optimum

Different pattern with slow change of params

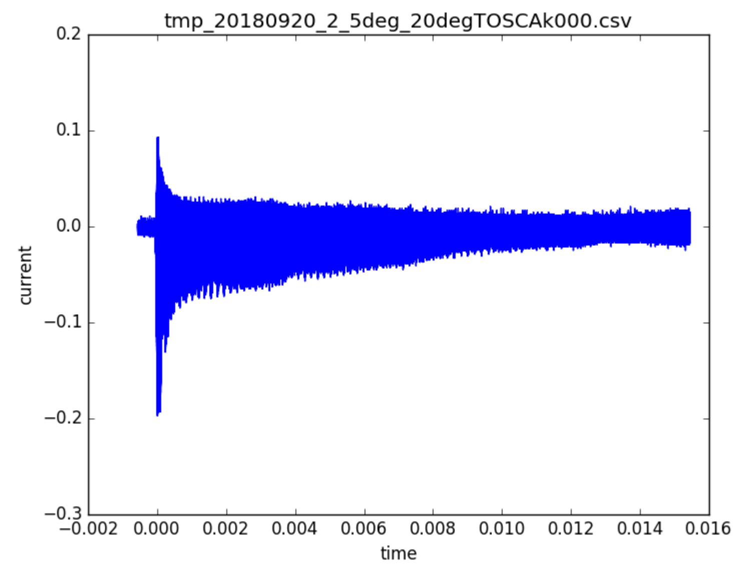
20 September

Constant phis of 20 deg seems the best.

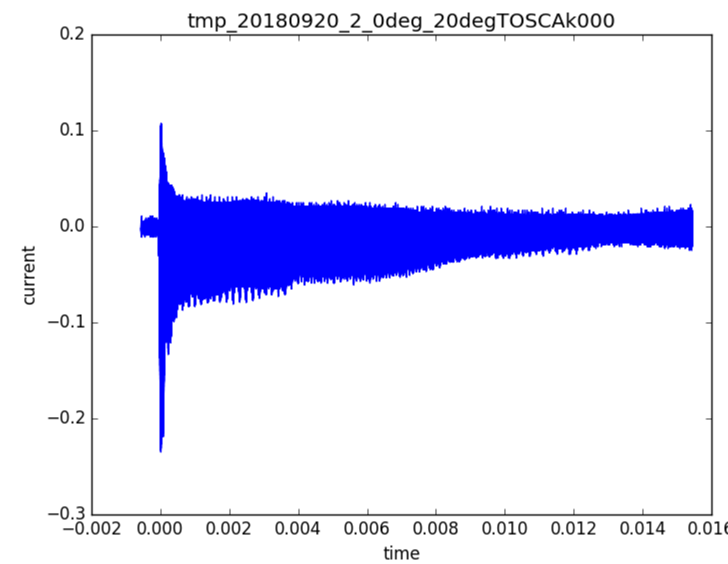
20deg



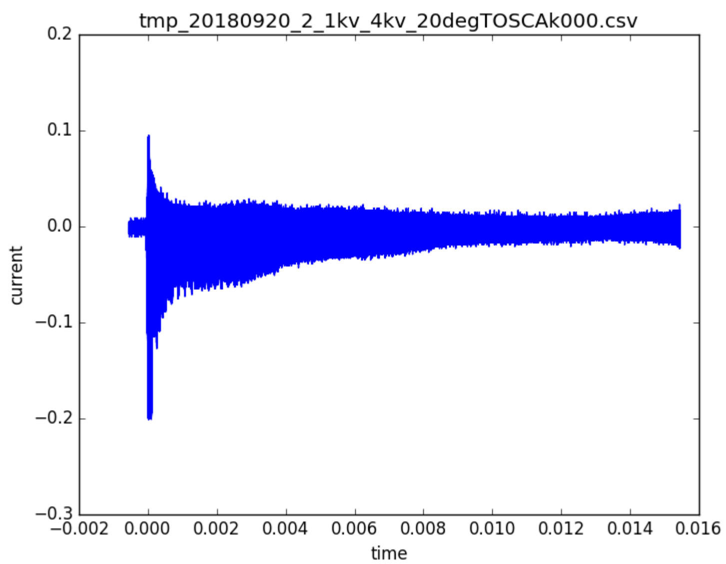
5-20deg



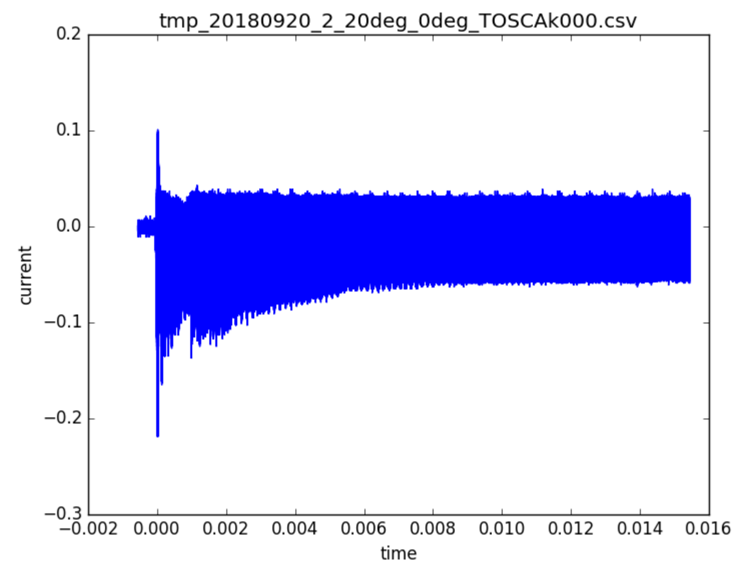
0-20deg



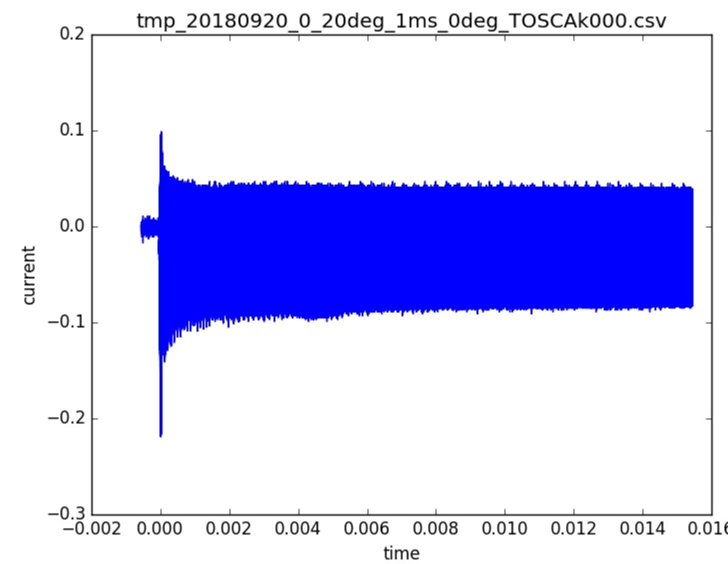
1-4 kV



20-0deg



20_1ms_0deg



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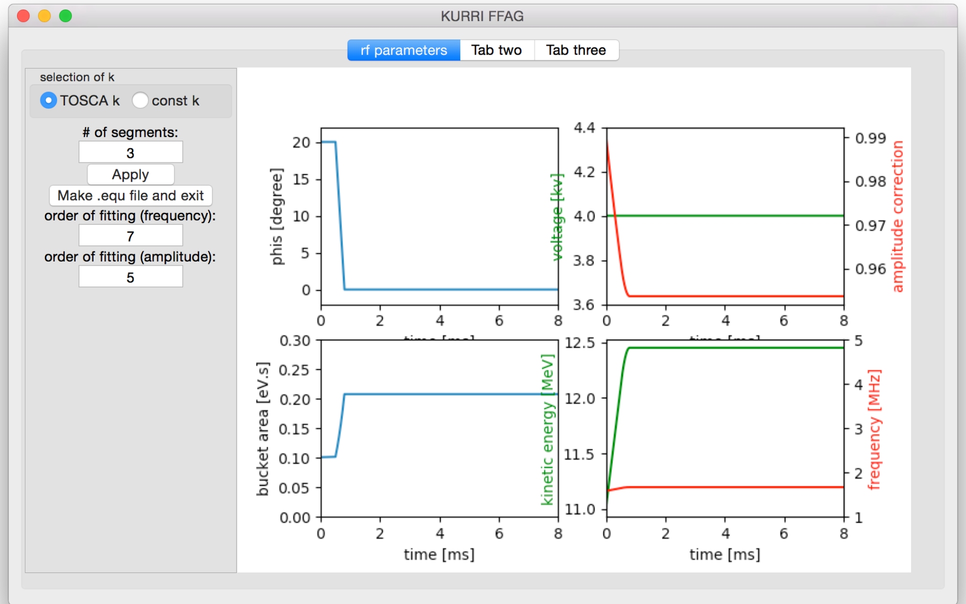
Foil and beam loss

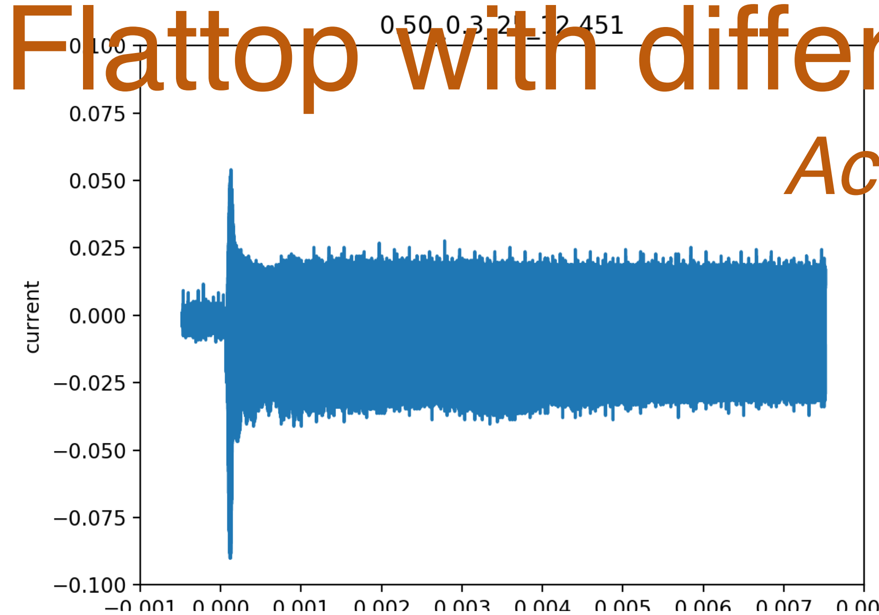
- Is the foil main source of beam loss?
- Can we see more beam loss when the beam stays inside of the foil (below 11.4 MeV).

21 September

Flattop with different energy

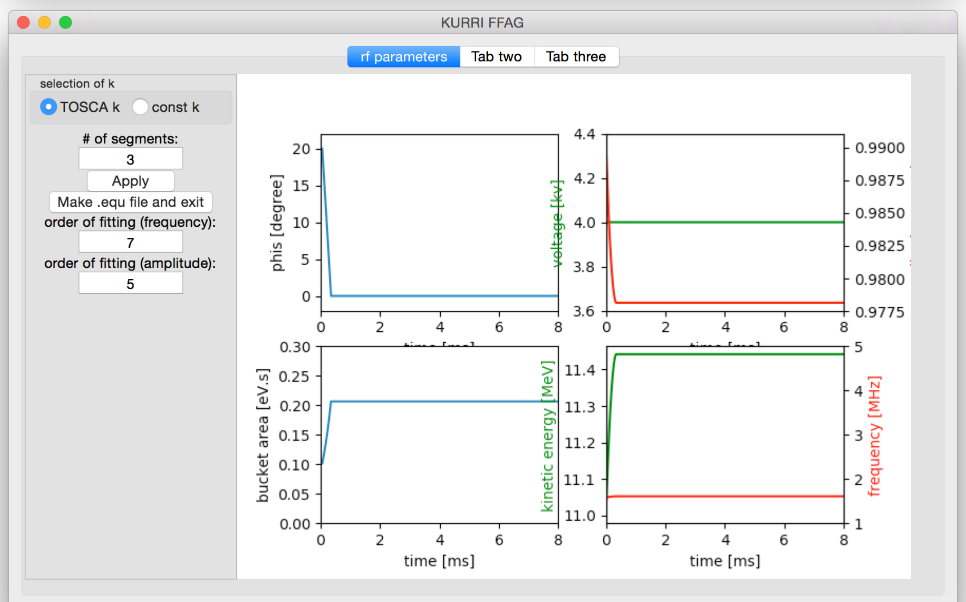
Acc for 50, 5, 0 ms

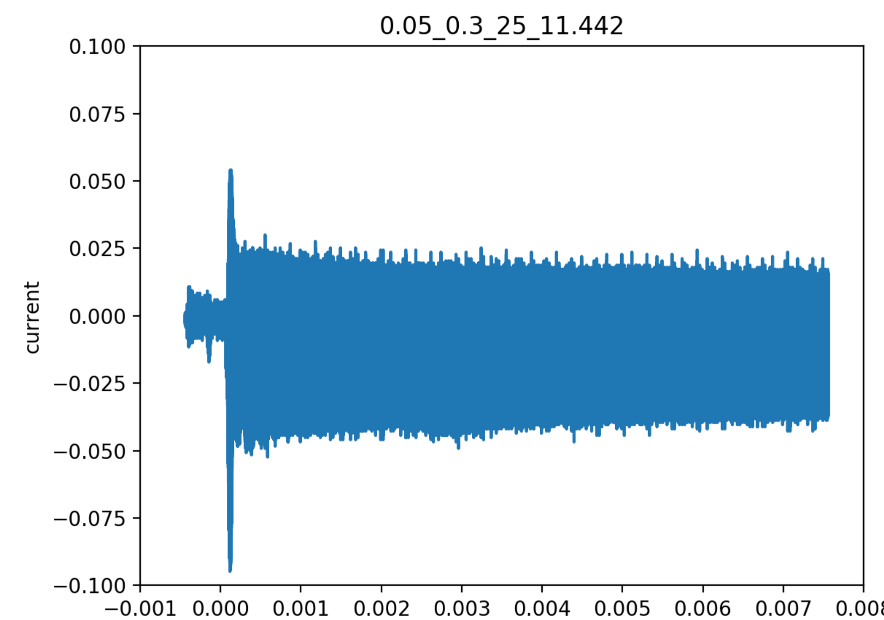




Flattop energy is

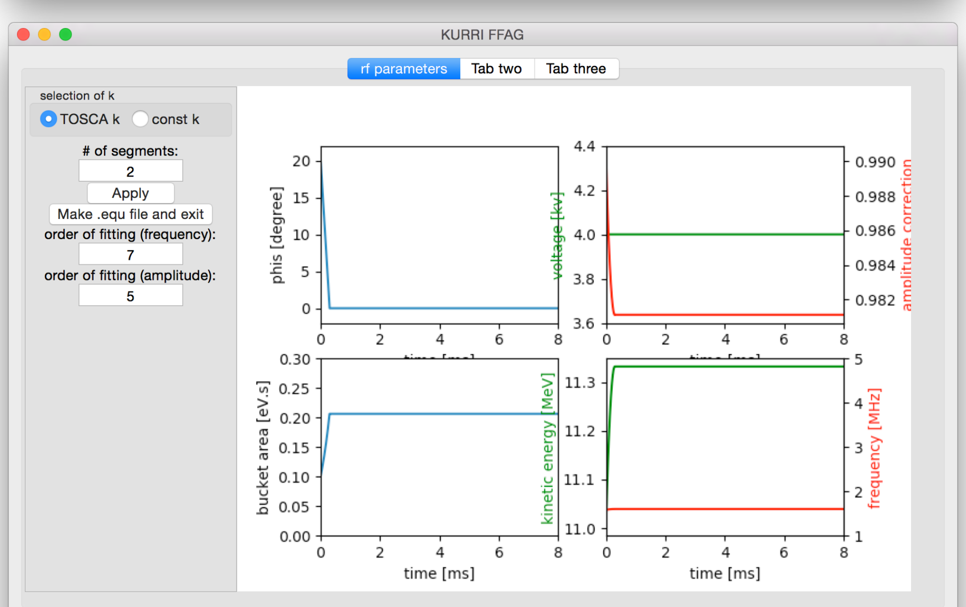
12.451 MeV

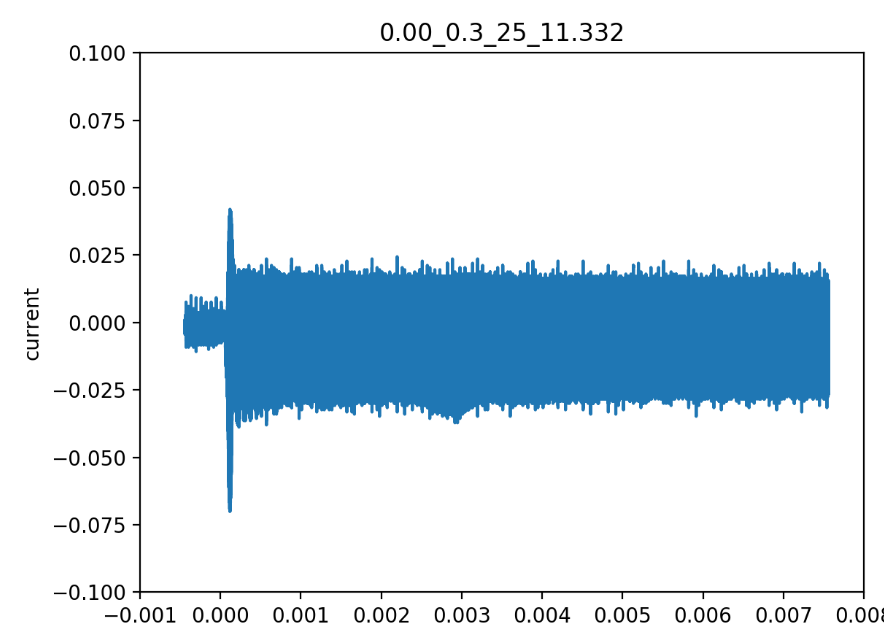




Parts of the beam is supposed to be within the foil.

11.442 MeV





11.332 MeV

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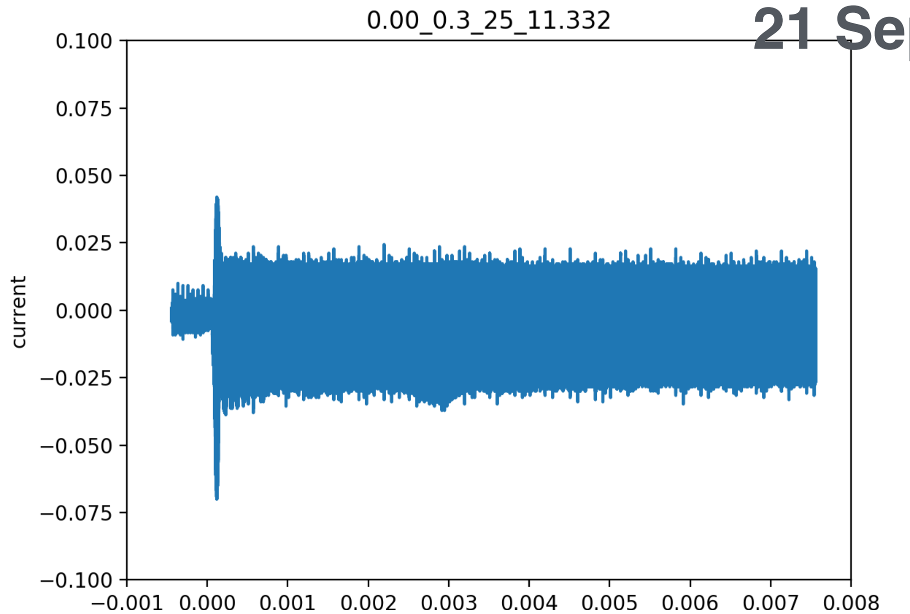
Flattop with different energy

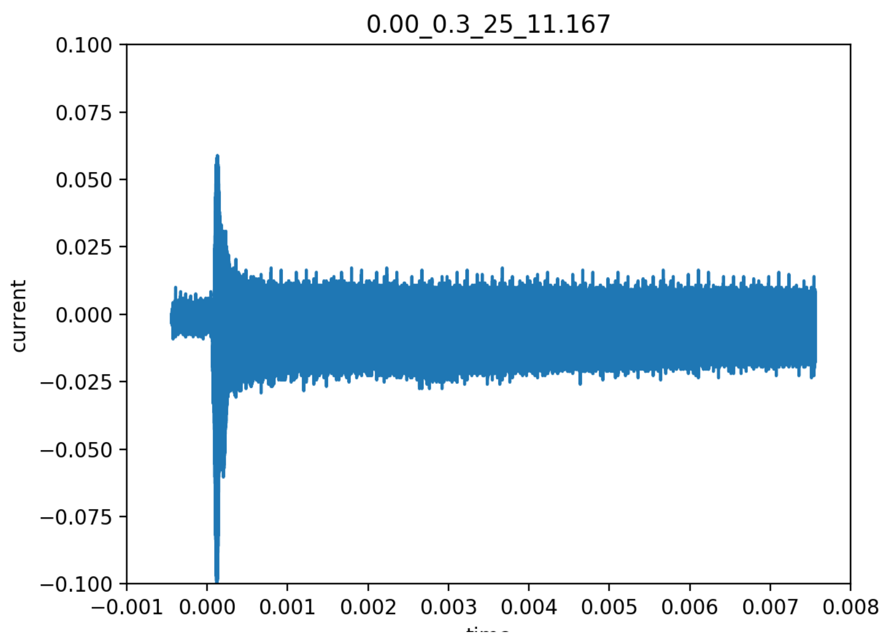
phis=5, 10, 20 deg.



Flattop energy is

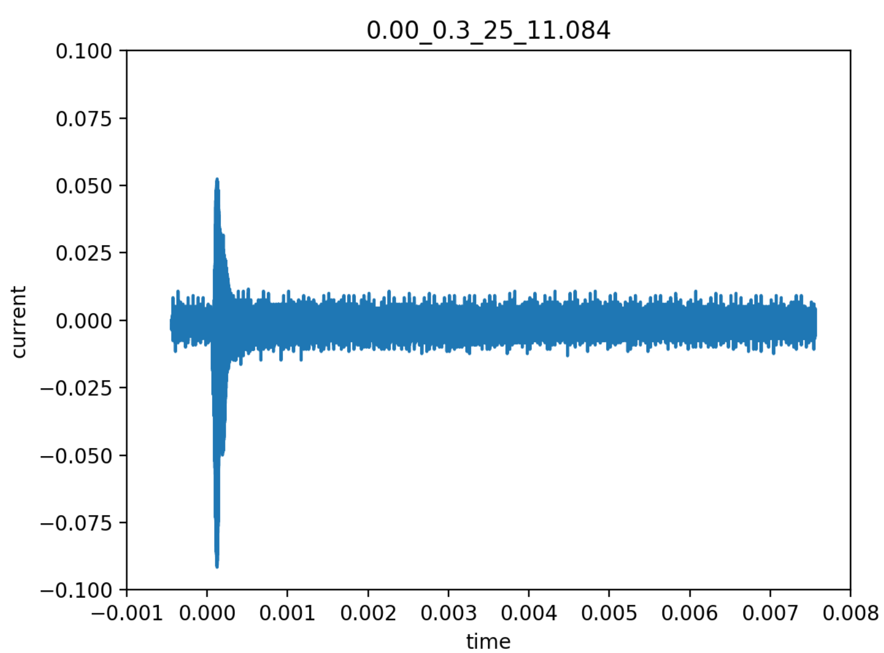
11.332 MeV

phi_s: from 20 to 0 deg in 0.3 ms



11.167 MeV

phi_s: from 10 to 0 deg in 0.3 ms



11.084 MeV

phi_s: from 5 to 0 deg in 0.3 ms

Possible explanation

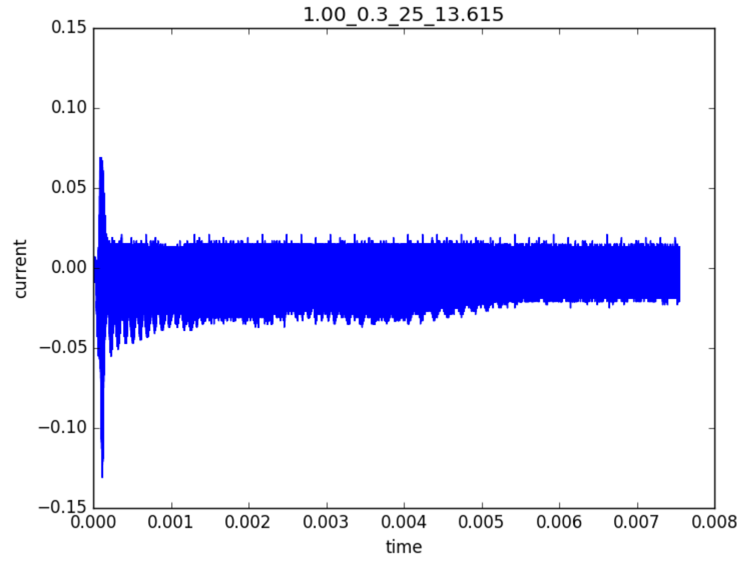
- We expect more (or continuous) beam loss when the beam stays inside of the foil.
- When almost no acceleration, capture is less. But not much beam loss when the energy is above ~11.3 MeV.
- (speculation) Foil position shifts so that the beam can escape the foil with lower (than 11.4 MeV) energy?

25 September

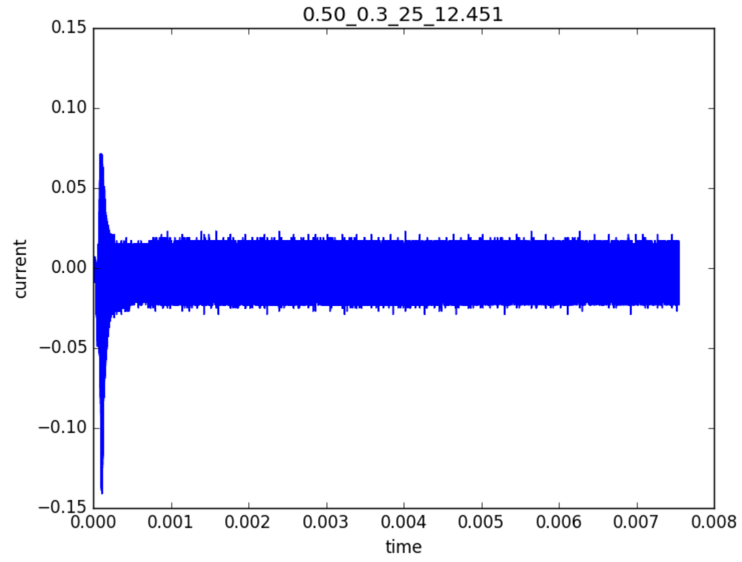
Repeat the same experiment first

Flattop energy is

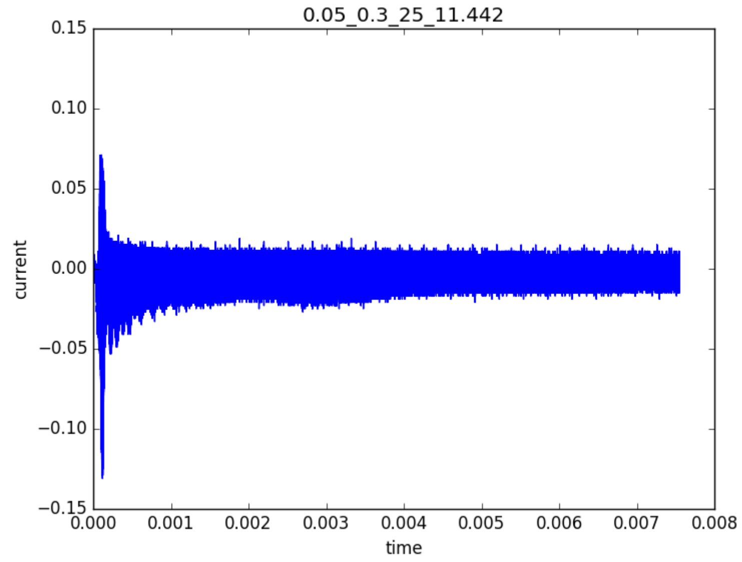
13.615 MeV



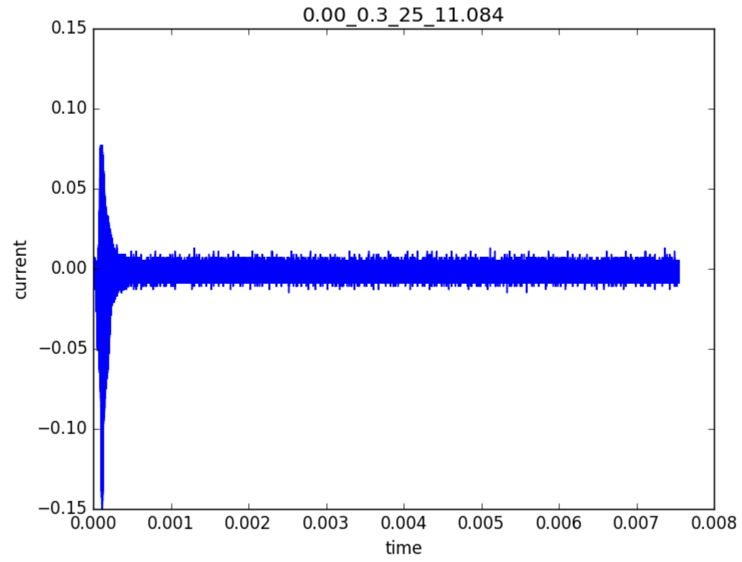
12.451 MeV



11.442 MeV



11.084 MeV



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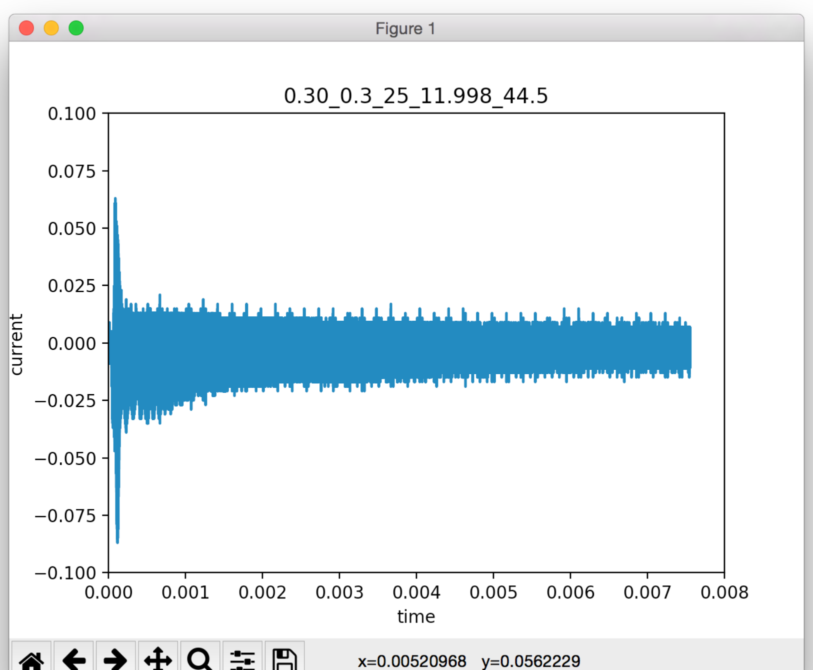
Change foil position at 11.998 MeV

Yes, the foil position change the capture efficiency.

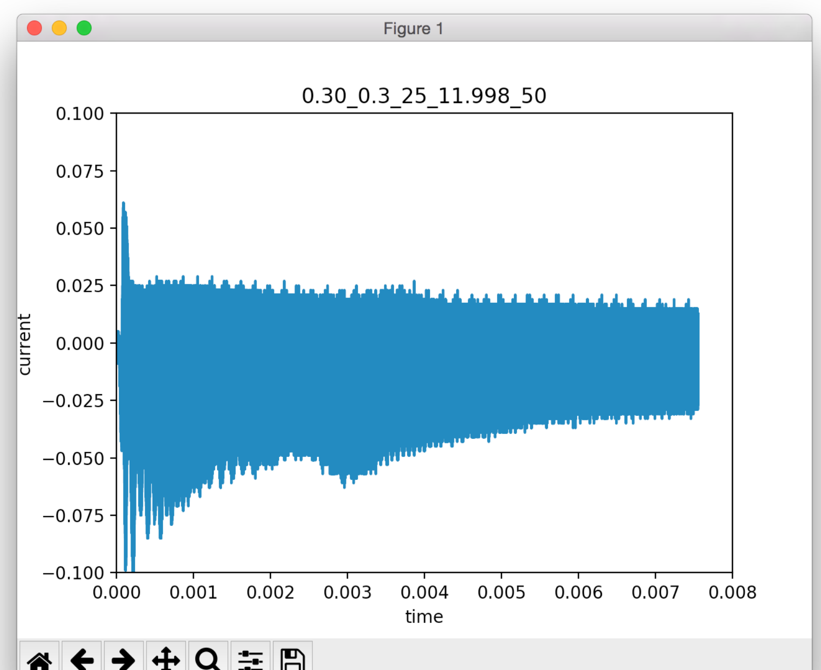
However there are two competing processes.

- Conversion rate of H- to proton if beam size is comparable to foil size.
- Time spent inside the foil.

11.998 MeV, 44.5 mm



11.998 MeV, 50 mm



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Measurement of p/H- ratio

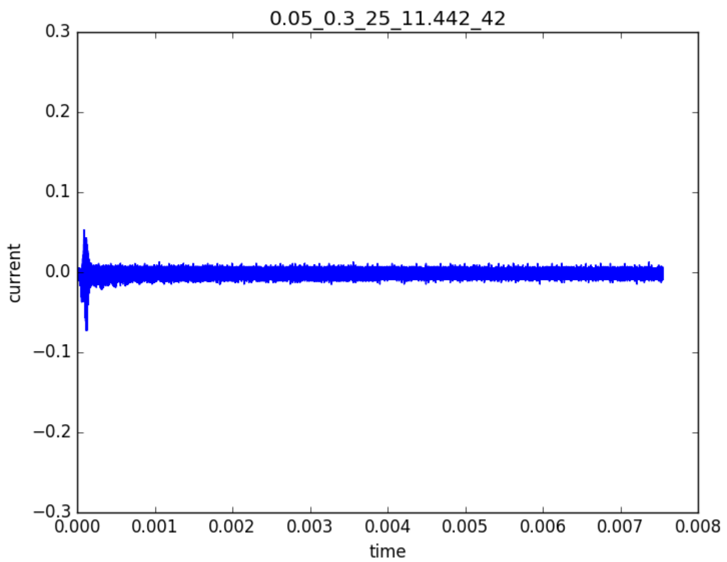
- JB tried to measure p/H- ratio.
- Short pulse (<1 micro second) could not be made.
- Beam intensity measurement after a whole turn with the main magnets turned on and off.

- JB may have comments/results.

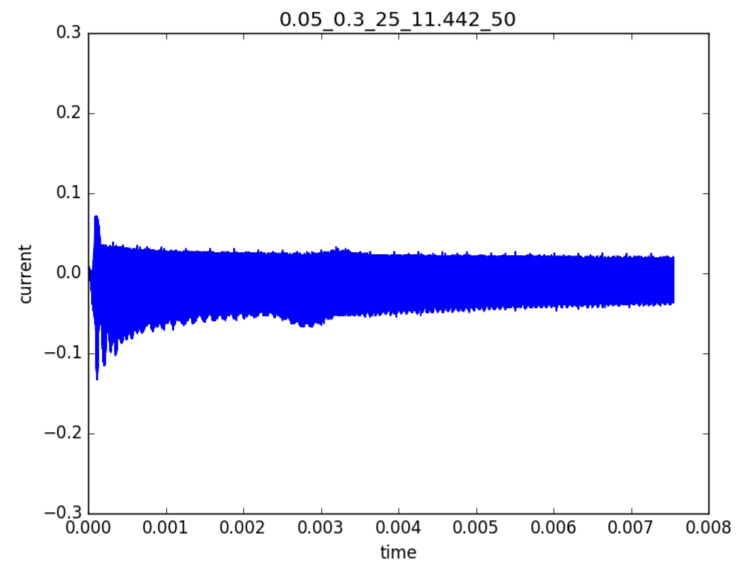
At 11.442 MeV

25 September

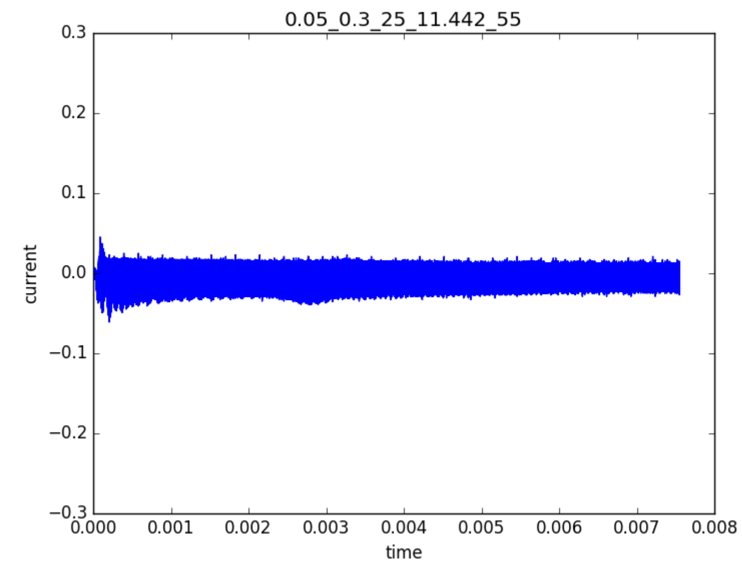
42 mm



50 mm

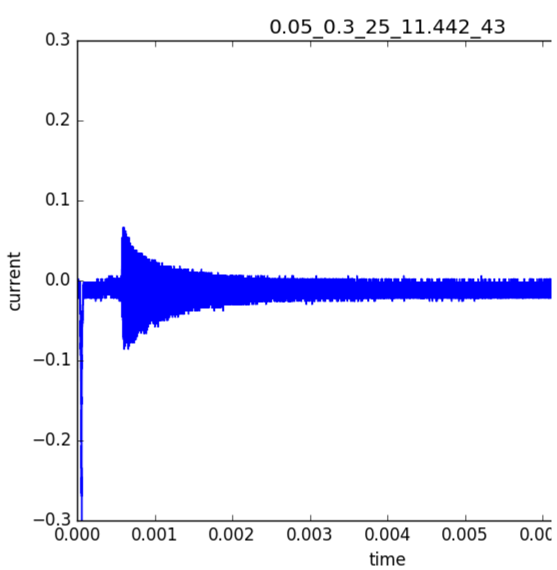


55 mm

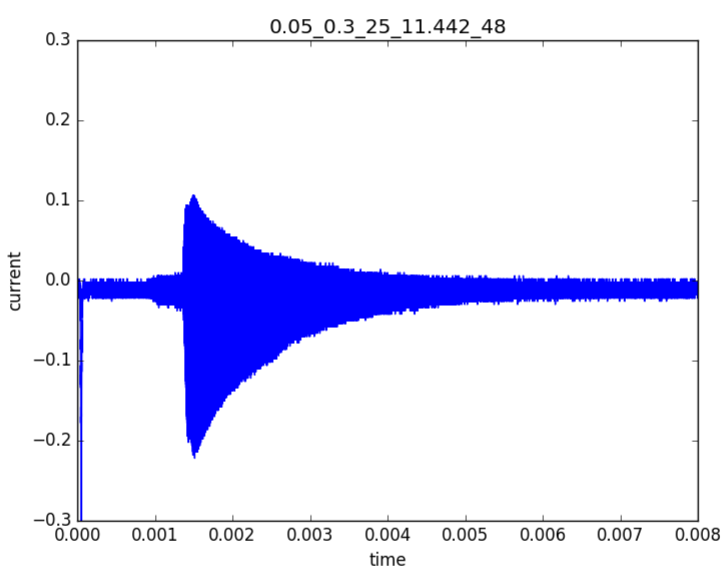


27 September

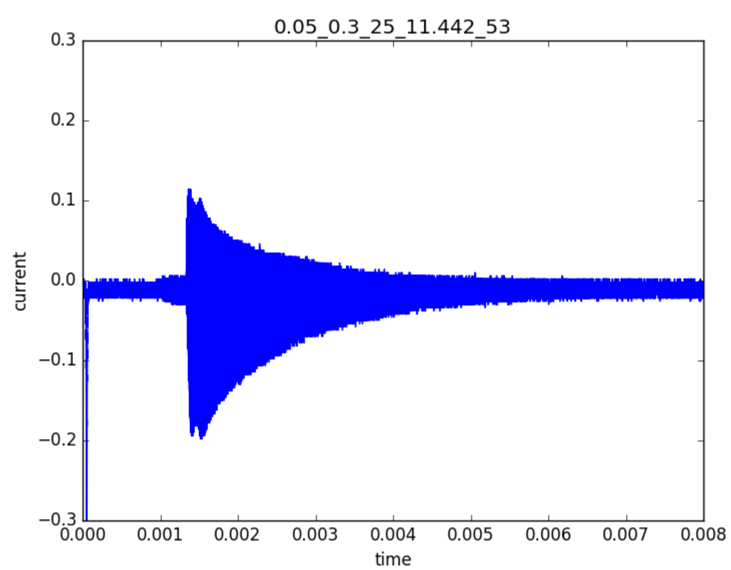
43 mm



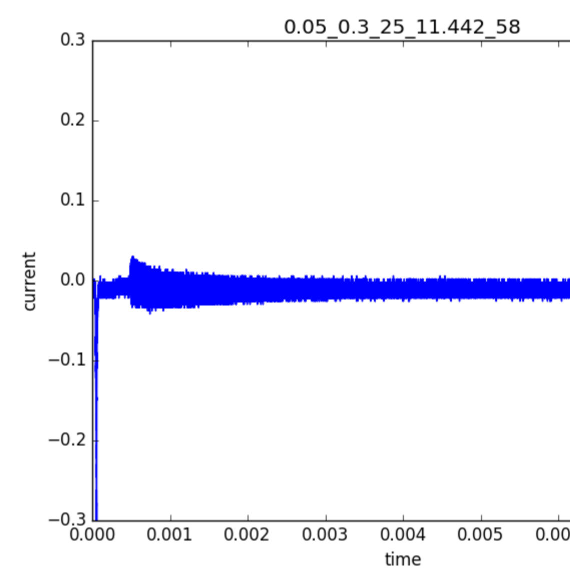
48 mm



53 mm



58 mm



Beam on the last day

- Beam behaves qualitatively different on the last day on 27 September.
- Something is not the same at the injection.

Conclusion (1)

- See the difference between two RF programme based on constant k (constk) and variable k (TOSCAk).
    - *Although we should have repeated the measurement several times, the data indicated there is no difference between TOSCAk and constk.*

- Optimise the capture process not only by scanning constant phi_s, but also introducing adiabatic capture with linear increase of phi_s.
    - *Several different RF patterns introducing more adiabatic capture process at injection. However, there is no clear indication that helps.*

Conclusion (2)

- Separate longitudinal and transverse effects by looking at only the beginning of acceleration.
  - 3.5% efficiency is the figure when the beam is accelerated to 19.5 MeV, which may have already suffered from resonances.

- *Several measurement with different flattop energy with almost no acceleration was performed. Beam loss due to foil scattering is not obvious.*
- *Foil position in terms of beam energy is crucial information for this measurement. This has not been completed.*
- *It seems (according to JB), the beam size at the foil is comparable to the foil size. p/H- conversion rate should be measured when the foil moves. This could be easily done with short pulse (< 1 micro sec).*

Conclusion (3)

- Looking at the longitudinal phase space when the beams are outside the foil (tomography). Compare it with simulation.
    - *Tomography code developed by David is a powerful tool to see the details. In particular, it may give the immediate answer to the following questions.*
    - *What makes so much different beam behaviour on 25 and 27 Sep? Can we see any difference in phase space.*
    - *Do Tosca k and cost k look identical in phase space?*
    - *Does smaller phis give more uniform distribution?*

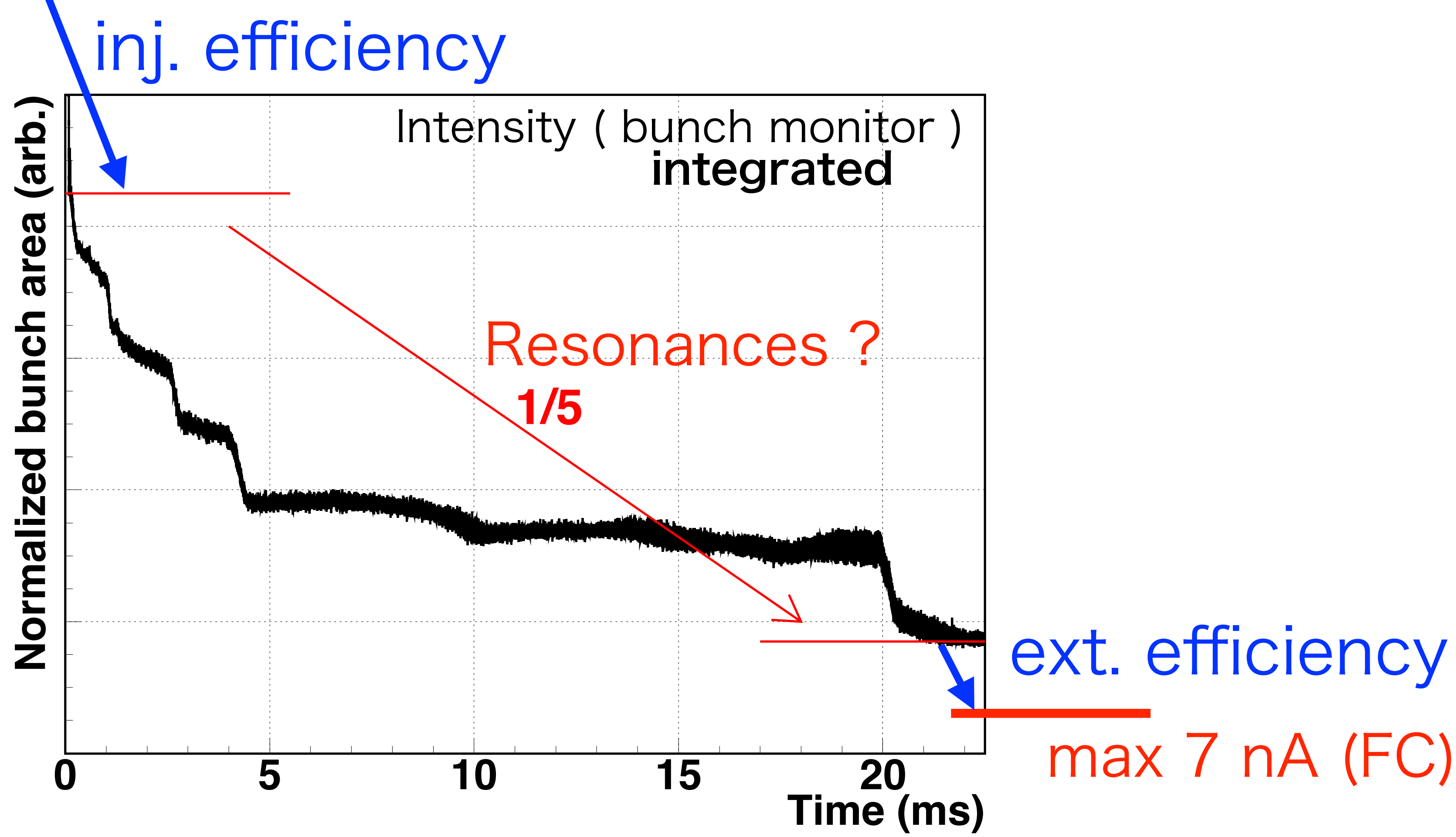
Backup

Beam loss at injection

EXPERIMENTS
2014.02.27

max. 1000 nA (FC)

Unknown factor : 3.5 %
at injection ?



max 7 nA (FC)

Tom UESUGI, FFA'18, Kyoto, Sep, 2018

Summary

Survival ratio;

Simulation ~ 35%

Experiment ~ 3.5% ??

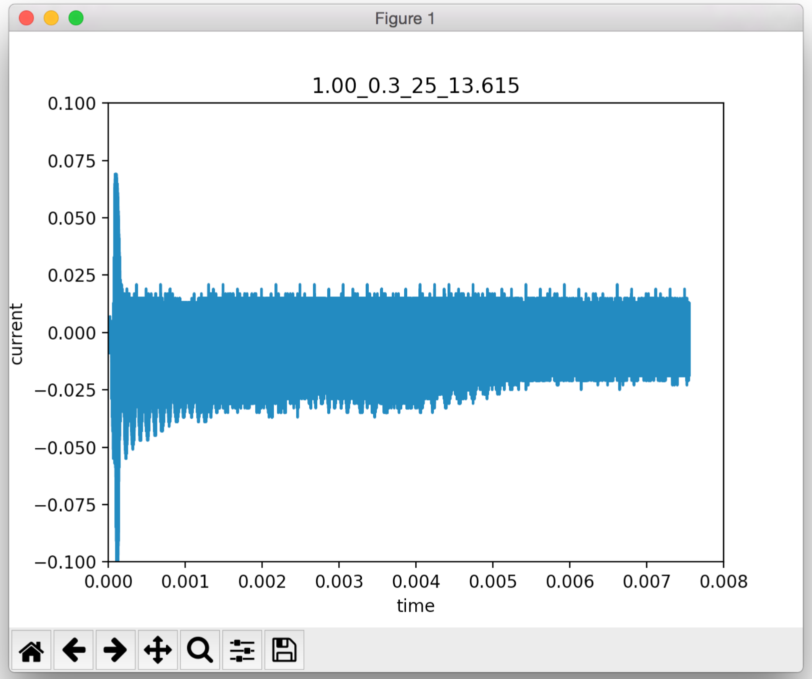
Most probable source of capture loss is
momentum spread (1% rms) and momentum drifting (-1%)
of injected beam.

but still survival ratio is 9%

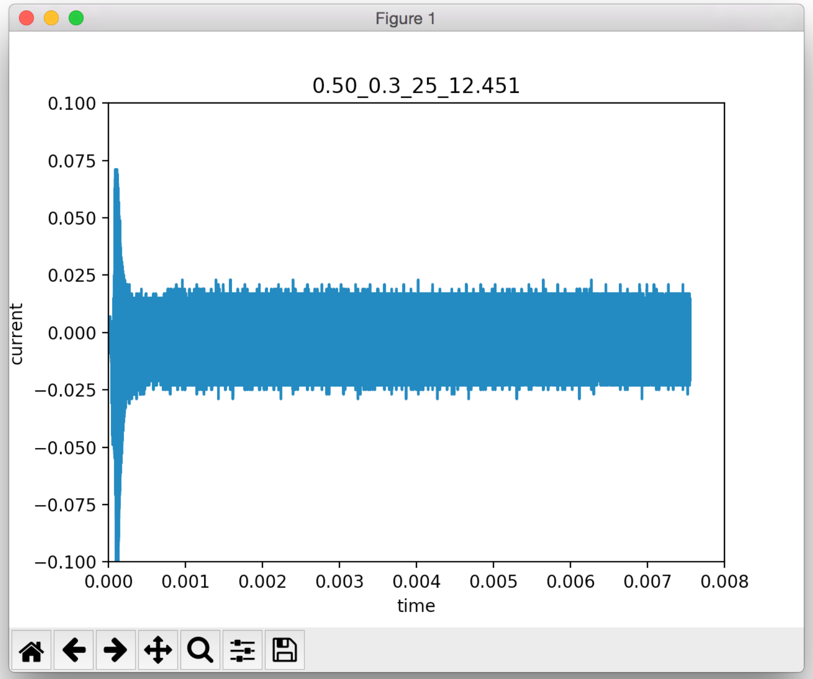
Flattop energy

Flattop energy is

13.615 MeV



12.451 MeV

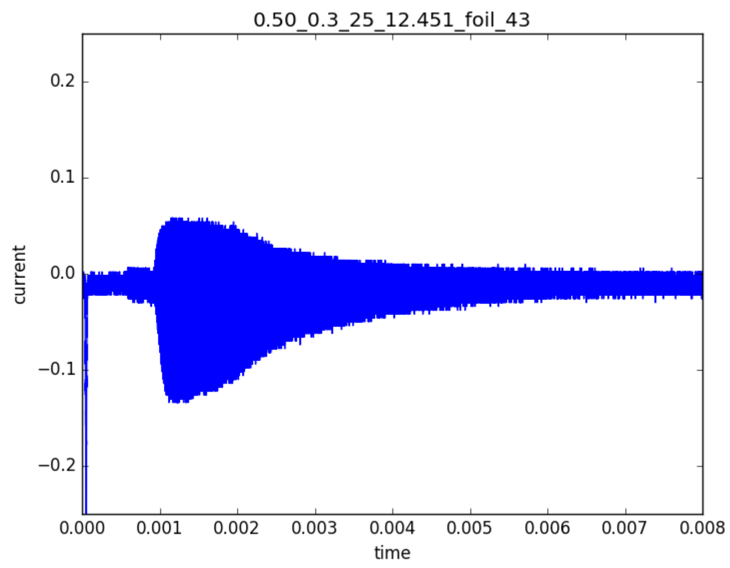


11.998 MeV 11.442 MeV 11.084 MeV

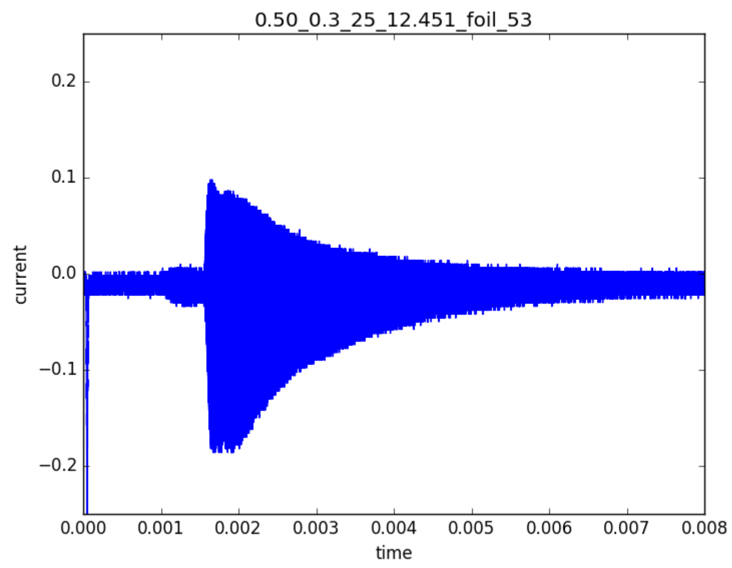
12.451 MeV

27 September

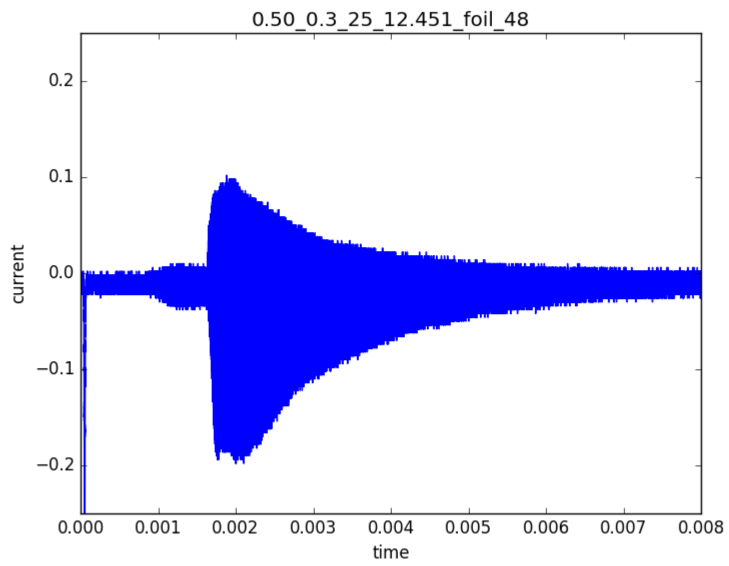
43 mm



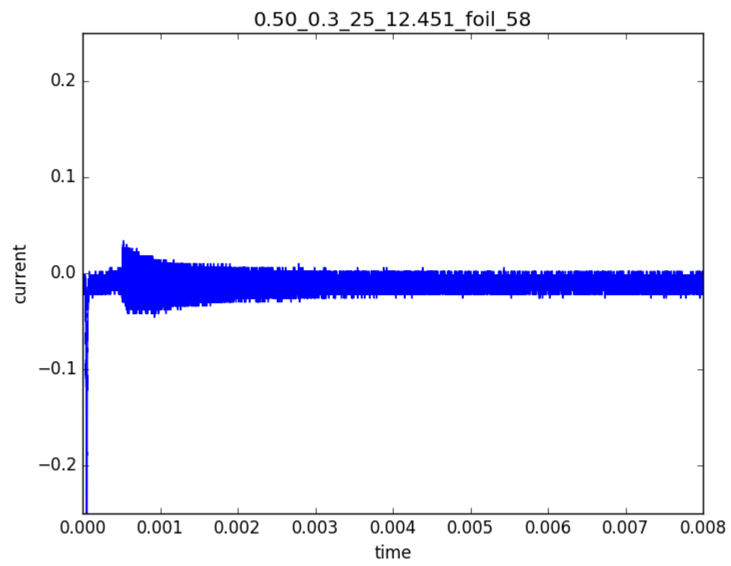
53 mm



48 mm



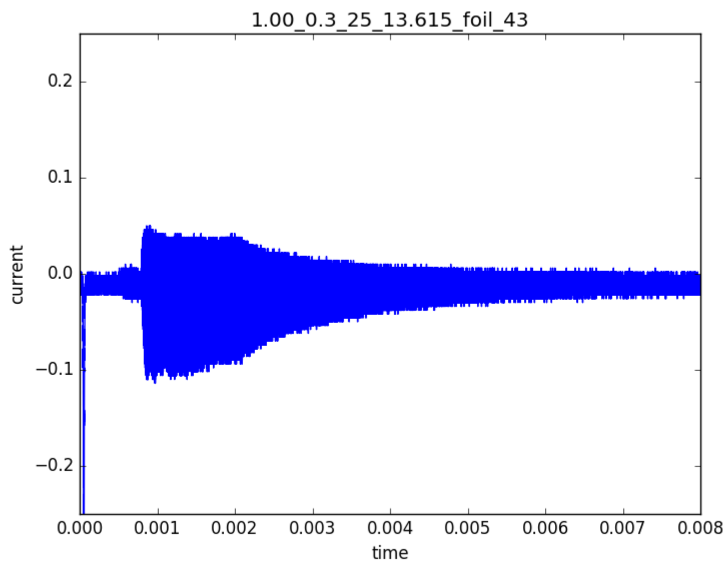
58 mm



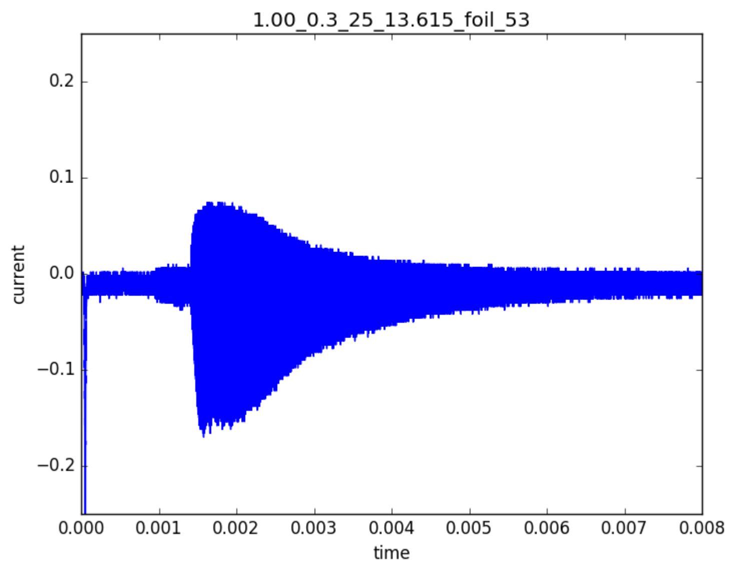
13.615 MeV

27 September

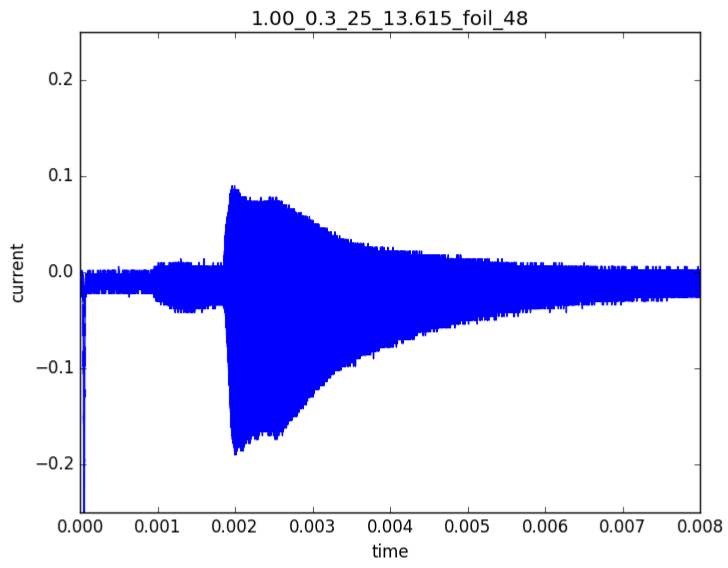
43 mm



53 mm



48 mm



58 mm