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Beam experiments in January 2023

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KURNS beam stacking

January experiment

- (horizontal) tune measurement with different initial amplitude [1~2 days]
- Preparation of March experiment
    - First try of step 1 experiment [~3 days]
    - Test of step 2 and 3 experiments [~1 days]

- Total ~ a week if allowed

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Outline of the publication, my proposal

- Title?: Experimental verification of beam stacking in a FFA

- Introduction
  - FFA has wide momentum acceptance. Beam stacking of many acceleration cycle in momentum space is possible.
  - Only FFA can handle both acceleration and beam stacking in one ring.
  - Demonstration if it is feasible in practice, that is, **momentum spread is under control** (without beam loss).

- Momentum spread measurement
  - Schottky scan
  - Other methods
  - …

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Outline of the publication, my proposal

- Main part
  - Part 1: Optimisation of debunching and rebunching process for an accelerated beam.
    - Optimised rebunching is not necessarily the reverse process of debunching.
    - What is the key parameter we must control?
    - Why optimised process is the best, in what sense?

  - Part 2: Influence of an accelerating bucket to a coasting beam circulating at the top energy.
    - This is another source of deterioration of momentum spread.
    - When it becomes significant? Acceleration frequency become a harmonic of revolution frequency?

  - Part 3: How we combine a coasting beam and an accelerated beam together. How we can minimise the momentum spread of beams after stacking.
    - One sequence of optimised step1 and step2. See if it works.
    - Two beam stacking is enough for demonstration purpose.
    - Case of more than two is one of discussion items.

First try of step 1 measurement

- Basically, measurement of momentum spread after debunching (and rebunching) process with different RF patterns. If we can see the difference.

- Test several RF patterns for debunching after (or including) acceleration up to a certain energy (~50 MeV).
- Test dp/p measurement methods, one or some of below.
    - Schottky measurement
    - Tomography
    - Transverse beam size
    - Phase displacement
    - Perturbation by an empty bucket

- Roughly ~3 days (excluding offline analysis)?

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First try of step 1 measurement

Schottky scan

- Accelerate up to ~50 MeV and debunch **adiabatically** according to David's RF programme
  - Start taking FAB signal after (or slightly before) RF becomes zero.
  - Set windows 1 ms, 5 ms, 10 ms and analyse frequency spectrum.
  - Repeat the same analysis for data starting from 1 ms, 5 ms, 10 ms later since RF is off.
- Accelerate up to ~50 MeV (final energy should be the same above) and **switch off RF abruptly**.
  - Repeat the same process above.
  - Do we see the difference of dp/p as a result of adiabatic debunching and abrupt debunching?

- FAB signal comes an array of beam current sampled every X ns.
  - Prepare analysis code to see frequency spectrum.

What is X usually?

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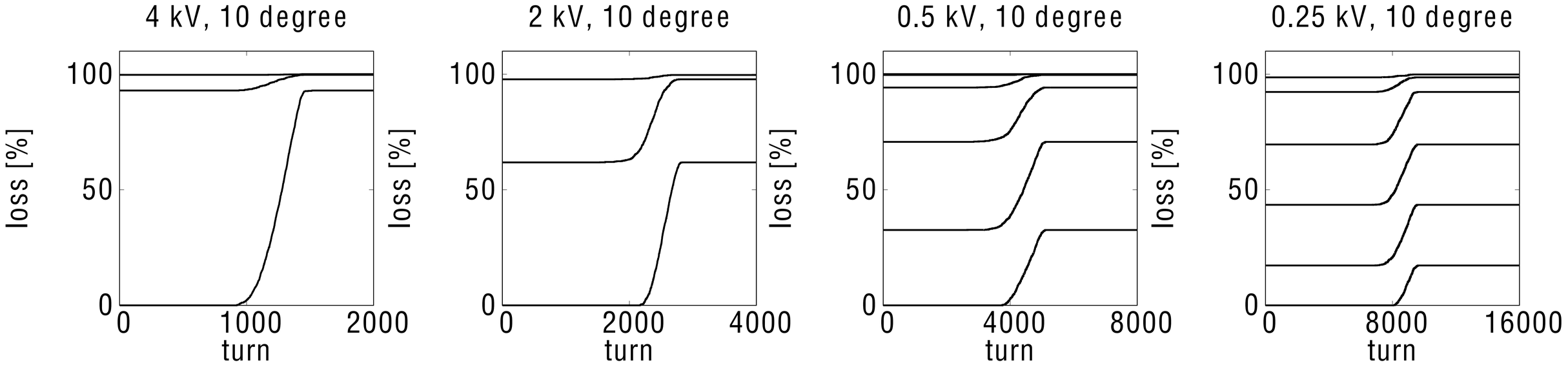
First try of step 1 measurement

phase displacement and CR's proposal

- Repeat phase displacement acceleration with as low voltage as reasonable (0.25 kV?).
- Measure beam loss at scraper.
  - With larger dp/p, the beam loss signal lasts longer.



- Record bunch monitor signal in the process of empty bucket crossing.
  - Set the scraper position so that the first crossing does not cause beam loss, only appearance of bunch monitor signal.
  - Whether timing of bunch monitor signal is different for small and large dp/p beams.

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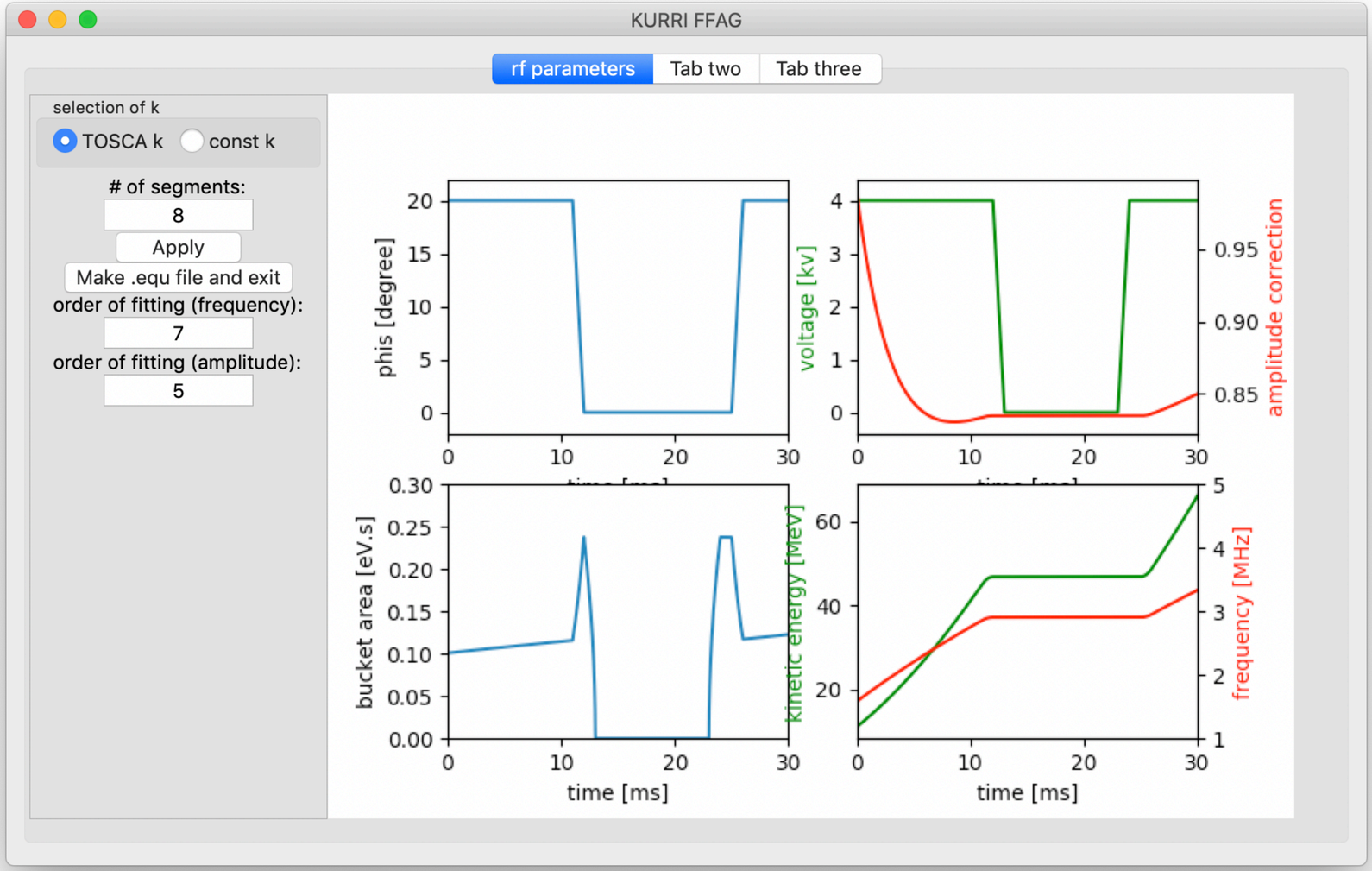
First try of step 1 measurement

AWG script

- AWG script based on David's RF programme. Not ready yet.
- Is script running at KURNS?



Example from 2019 experiment

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First try of step 1 measurement

tomography of debunching process

- Any progress so far?

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Step 1: One bunch only

Subject	Preparation	Measurements
Debunch adiabatically the 1st bunch	• Determine RF profile (frequency and voltage) to minimise dp/p after debunch • Fix energy for debunching (two or three).	• dp/p measurement • Feasibility and accuracy
Rebunch the coasting beam	• Determine RF profile (frequency and voltage) to minimise longitudinal emittance	• Beam intensity measurement • Longitudinal tomography measurement
Repeat debunch and rebunch process	• Same above	• **Beam intensity**, **dp/p** increase at debunch, **longitudinal emittance** increase at rebunch vs. the number of process

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What would be the AWG requirements?

Test of step 2 and 3 measurements

- Acceleration of h=2 RF frequency.
    - How high energy h=2 RF can be used for acceleration.

    - Accelerate the beams up to ~ 50 MeV and debunch to see if feasible.
    - Acceleration of h=2 empty buckets.

- Test trigger
    - If the second trigger can add another acceleration cycle without disturbing the first beam.

- Roughly ~1 days (excluding offline analysis)?

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Test of step 2 and 3 measurements

h=2 acceleration

- Acceleration with h=1 RF up to ~50 MeV.
  - By integrating bunch signal, measure beam current (AC component) as a function of time.

- Acceleration with h=2 RF up to ~50 MeV.
  - Do the same above.

- Compare beam current vs time for h=1 and 2. Acceleration with h=2 may have significant beam current reduction at some timing (momentum).

- Repeat with different phis.
  - Assume that ordinary operation uses phis=20 degree. Try 10, 30, … degree and compare h=1 and 2.

Test of step 2 and 3 measurements

trigger test

- Test trigger
  - If the second trigger can add another acceleration cycle without disturbing the first beam.
  - AWG script composed of acceleration of 1st beam, debunching of 1st beam and acceleration of 2nd beam.
  - Synchronise the injection of 1st beam and 2nd beam. How?

Step 2: One coasting beam and an empty bucket

Subject	Preparation	Measurements
After debunching at E1, increase RF voltage with frequency at several points between injection and E1.	• Simulation to see how the coasting beam is affected. • When E1 is increased and RF frequency ratio approach 2, how quickly interference grows?	• dp/p measurement vs time (time scale should be determined by simulation)
Increase the energy of an empty bucket and adiabatically decrease voltage as if the beam is accelerated and debunched.	• Simulation to see how the coasting beam is affected.	• dp/p measurement
(optionally) rebunch the coasting beam	• Same with one bunch	• Beam intensity measurement • Longitudinal tomography measurement

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Step 3: One coasting beam and another accelerating beam

Subject	Preparation	Measurements
Increase the energy of the 2nd beam and adiabatically decrease voltage.	• Simulation to see how the coasting beam is affected and the 2nd beam is added.	• dp/p measurement
Rebunch the coasting beam from two acceleration.	• Determine RF profile (frequency and voltage) to minimise longitudinal emittance	• Beam intensity measurement • Longitudinal tomography measurement
Repeat debunch and rebunch process (similar to measurement with one bunch but different dp/p)		• **Beam intensity**, **dp/p** increase at debunch, **longitudinal emittance** increase at rebunch vs. the number of process

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Backups

(horizontal) tune measurement

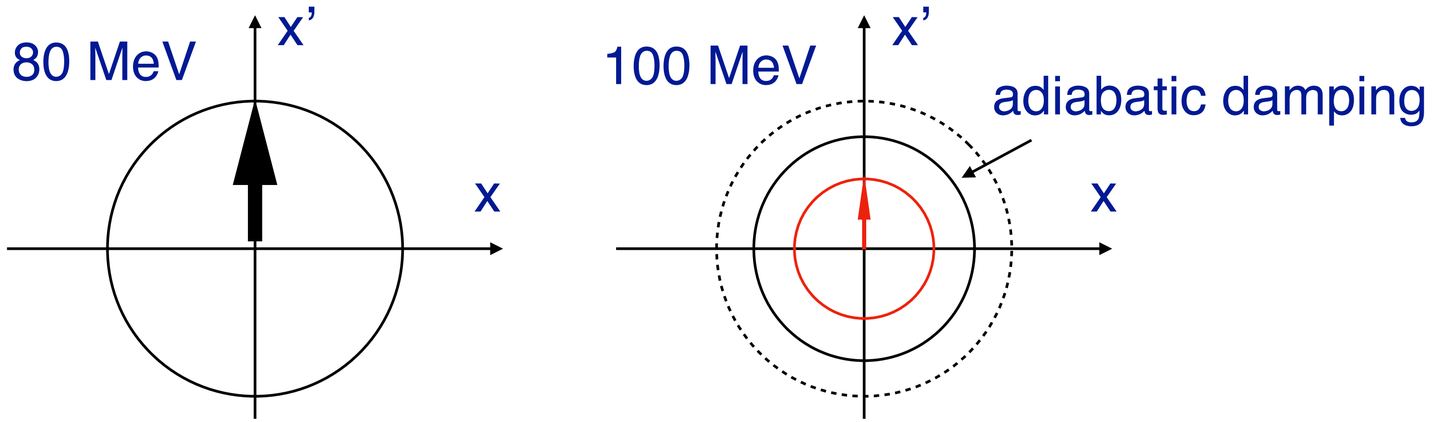
purpose and idea

- Measure amplitude dependent tune shift.
- Tune measurement by turn-by-turn BPM.
- Difficult part is to control initial betatron amplitude.
  - Small amplitude tune should be measured by small oscillations excited with a shaker.
  - Can the extraction kicker be excited with different strength?
  - Kick angle is inversely proportional to the beam momentum with the same kicker strength.
- Combined of two (at different beam momentum with different kicker strength) should give us results which can be scaled.

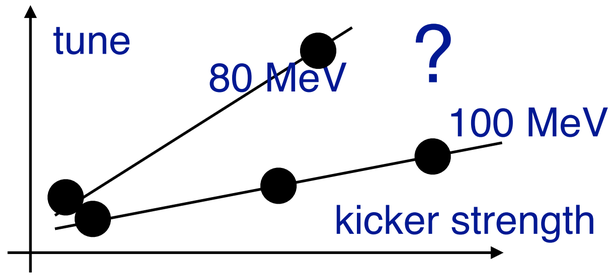
(horizontal) tune measurement

methods

- Accelerate the beams up to 2 different energy, e.g. 80 MeV and 100 MeV.
- Using the extraction kicker, excite a coherent oscillations.
  - Measure horizontal tune with several different kicker strength at 80 MeV and 100 MeV.
  - Obtain amplitude dependent tune shift results at 80 MeV and 100 MeV.
  - The same strength of the kicker magnet gives 90% of coherent oscillations at 100 MeV compared with 80 MeV (black and red arrows below).



- How the gradient of amplitude dependent tune shift scales at 80 MeV and 100 MeV with known kicker strength.
  - If the geometrical dynamic aperture is independent of momentum, …



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(horizontal) tune measurement

days necessary for data taking

- Is there any installation of equipment necessary?
  - BPM, extraction kicker, power supply, etc.
  - Vacuum breaking is involved?

- Measurement takes a day or two.
  - Do data taking in the early stage of two weeks period.
  - Offline analysis takes a few days.
  - If the results do not look convincing, do data taking again in the second week.

- Total 1~2 days (excluding offline analysis) depending on hardware preparation.