Beam stacking experiment proposal at KURNS 23/06/22

J.B. Lagrange
On behalf of IBG, ISIS, RAL, STFC

FETS-FFA questions

Beam stacking questions for FETS-FFA:

- How many protons can we accumulate without beam loss by beam stacking at top energy?
- How many protons can we capture and extract without beam loss after beam stacking?

Note: “without beam loss” to be defined later (e.g. 5%, 1%, or 0.1%).

Demonstration of concept at KURNS

- Stack 2 beams
- Measure the effect of accelerating beam/RF bucket on stacked beam

Main Ring parameters

Radius	4.54 m
RF frequency	1.6 ~ 5.2 MHz
Revolution time	0.625 ~ 0.192 μs
Beta (11 MeV, 18 MeV)	0.1518, 0.1931 (ratio=1.27)
Beta (11 MeV, 47 MeV)	0.1518, 0.3052 (ratio=2.01)
Beta (0.4 GeV, 1.2 GeV)	0.7131, 0.8986 (ratio=1.26)

Experiment proposal

- 3 Steps:

    1. Coasting beam characterisation: 1 week
    2. Measurement of interference of empty bucket (accelerating RF without beam): 1 week
    3. Measurement of stacked beam: 1 week

One bunch only

Subject	Preparation	Measurements
Debunch adiabatically the 1st bunch	• Determine RF profile (frequency and voltage) to minimise $\Delta p/p$ after debunch	• $\Delta p/p$ measurement • Transverse beam profile measurement
Rebunch the coasting beam	• Determine RF profile (frequency and voltage) to minimise longitudinal emittance	• Beam intensity measurement • Longitudinal tomography measurement • Transverse beam profile measurement
Repeat debunch and rebunch process	• Same as above	• Beam intensity, $\Delta p/p$ increase at debunch, longitudinal emittance increase at rebunch and transverse beam profile increase vs. the number of process

Momentum spread measurement

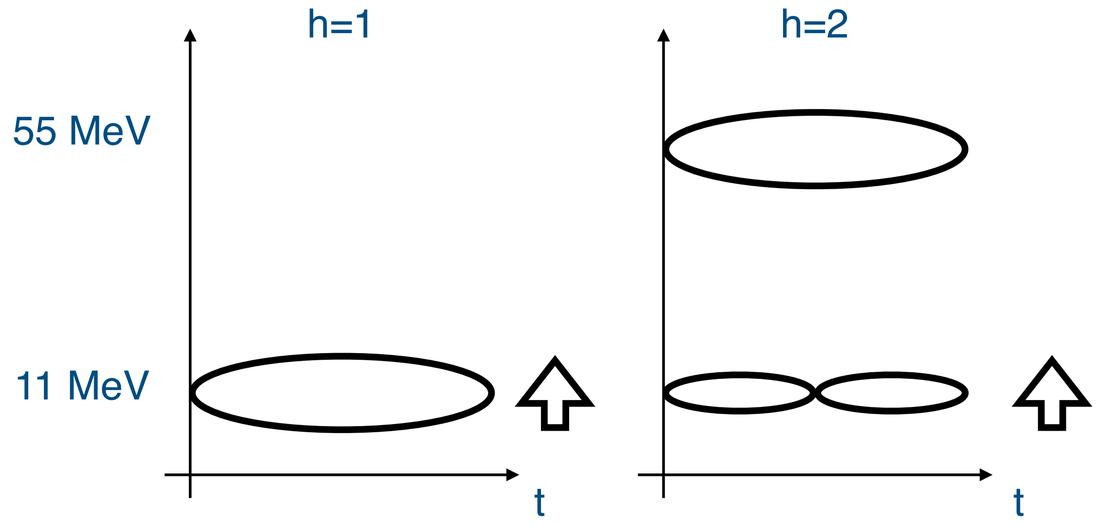
- Bunched beam: longitudinal tomography
- Coasting beam?
  - Measure of beam size, with known dispersion (D=0.53 m)
  - Possible if $\Delta p/p \cdot D$ (~1 cm) >> beam size
  - Emittance of the beam after injection (i.e. ~100 hits on foil)?

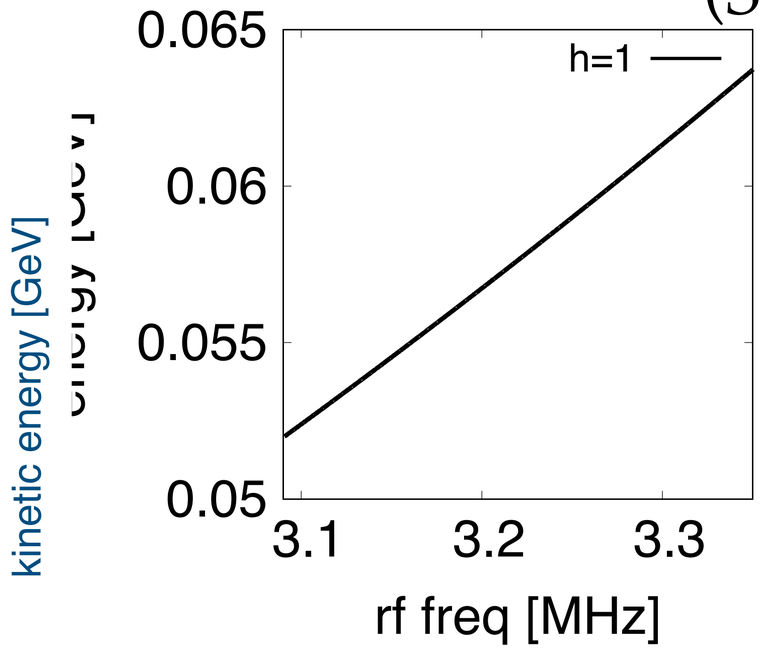
Coasting beam and empty bucket

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?	• Δp/p measurement vs time (time scale should be determined by simulation) • Transverse beam profile measurement
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.	• Δp/p measurement • Transverse beam profile measurement
(optionally) rebunch the coasting beam	• Same with one bunch	• Beam intensity measurement • Longitudinal tomography measurement • Transverse beam profile measurement

Setting up

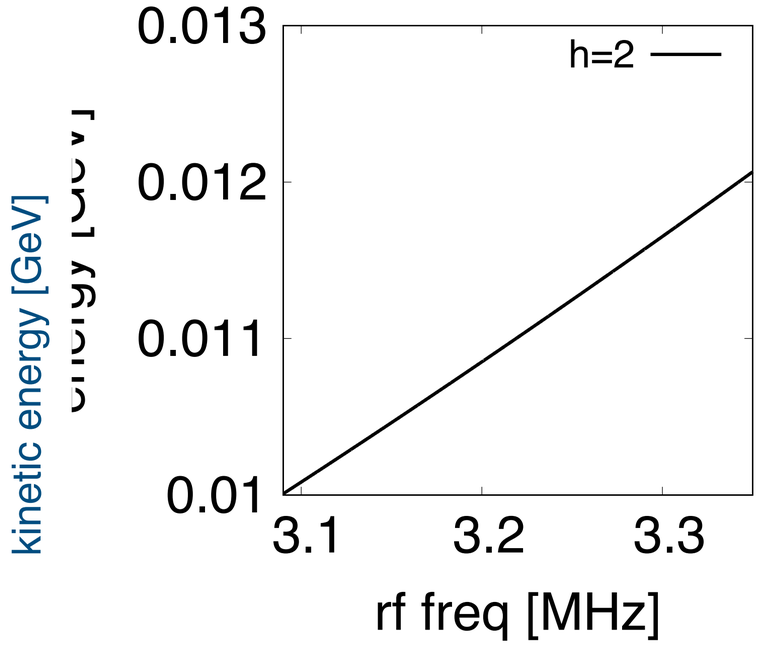
(S. Machida)





- "accelerate" an empty bucket either with h=1 or 2 RF frequency.
  - phis = **20 degree**, voltage = 4 kV.

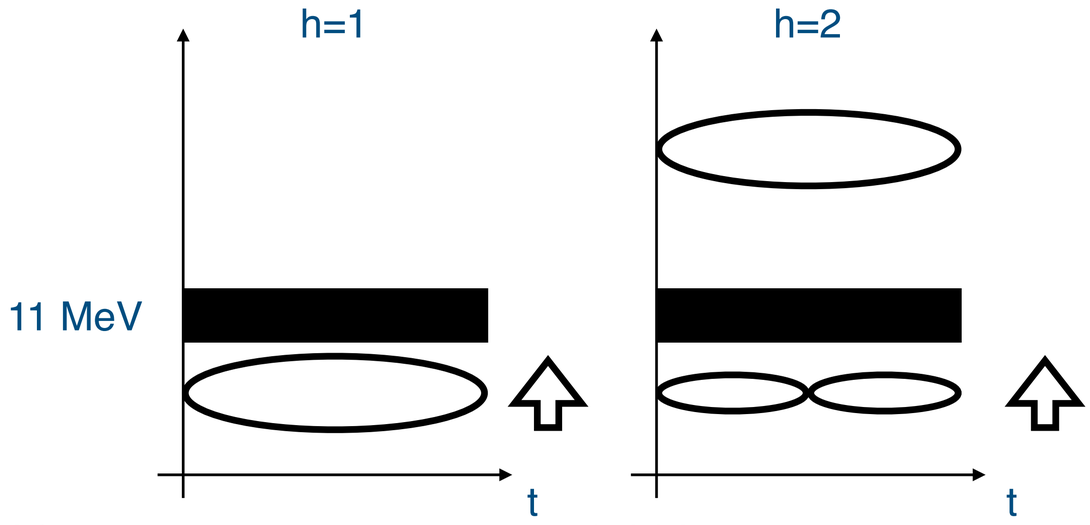
- RF frequency with h=2 at injection.
  - h=2 at ~11 MeV
  - h=1 at ~55 MeV (not at 44 MeV due to horizontal excursion.)

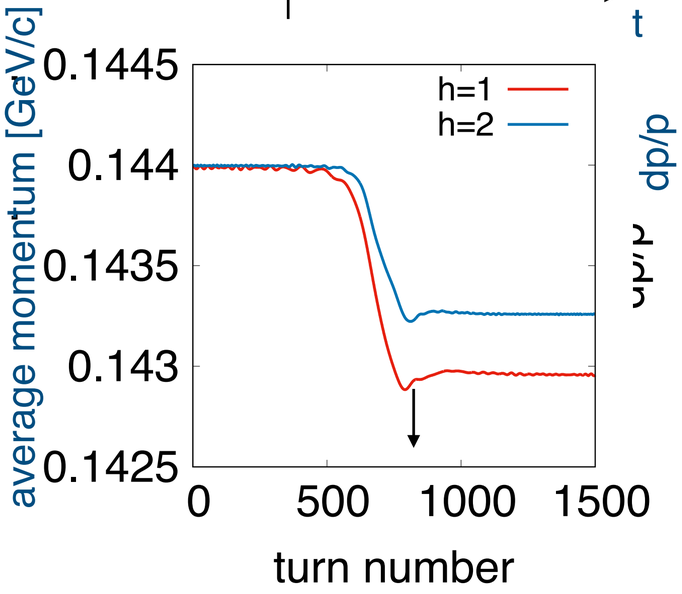


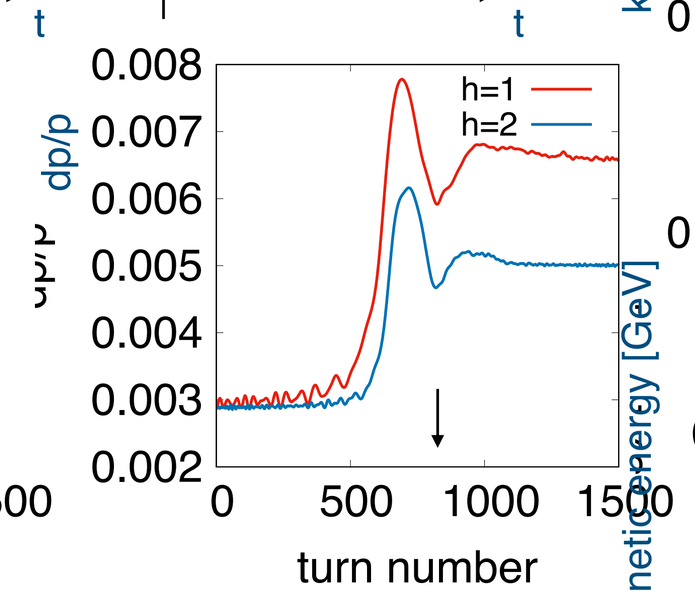
Science and Technology Facilities Council

Effects on coasting beam at injection energy (11 MeV)

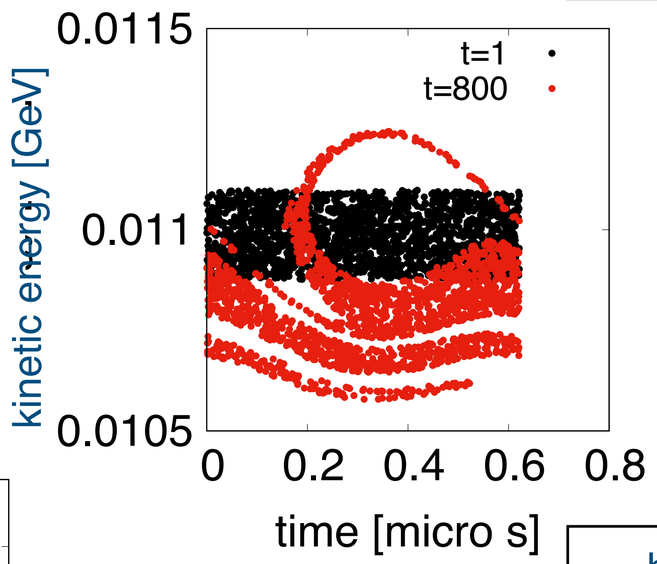
(S. Machida)

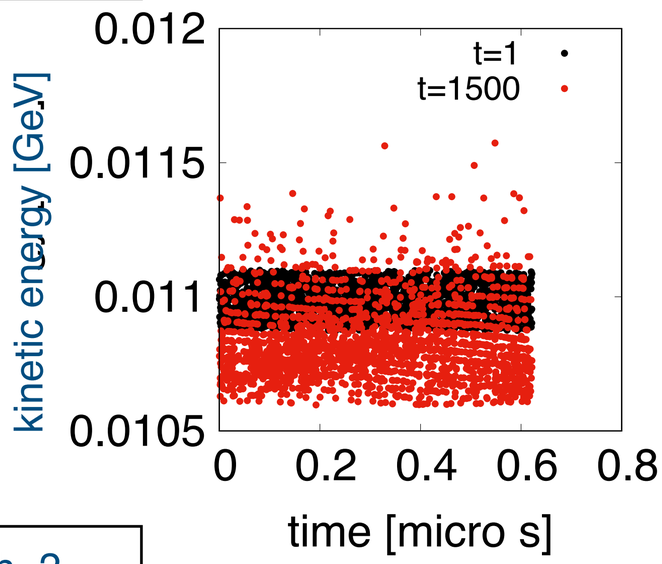




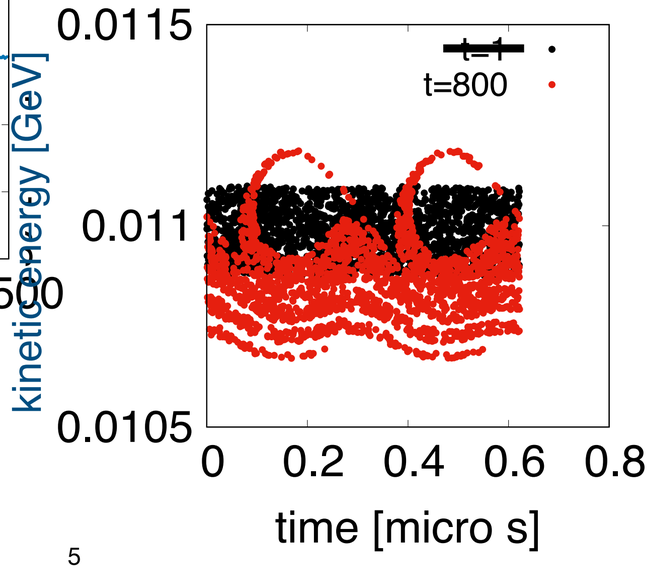


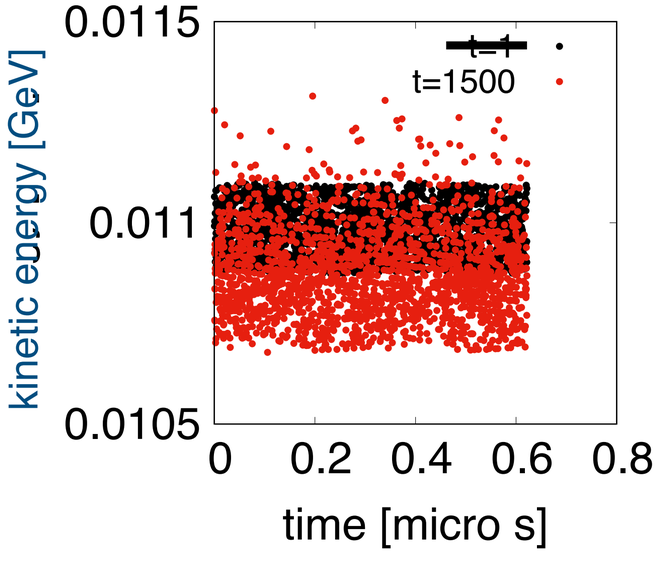
h=1





h=2

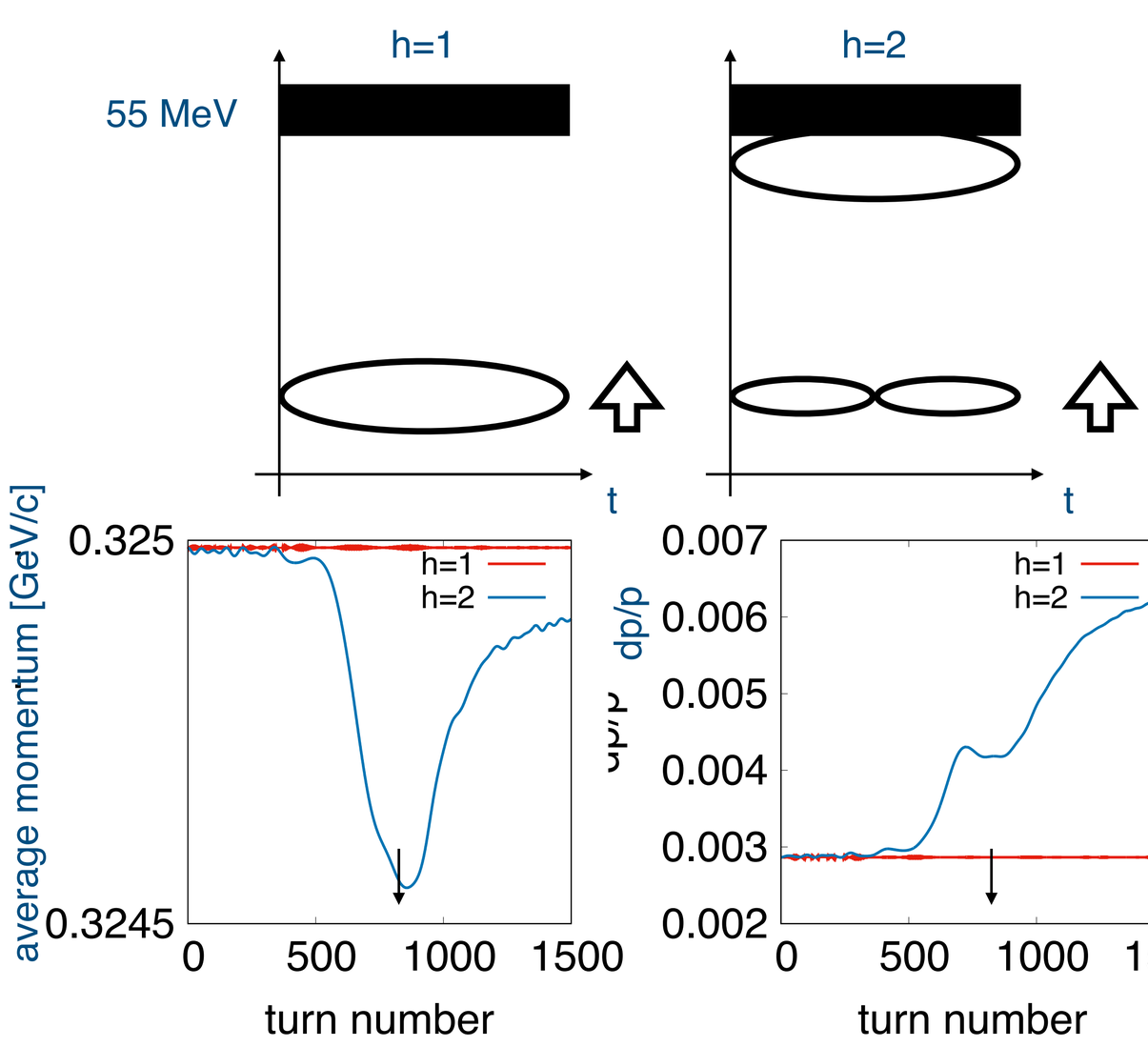


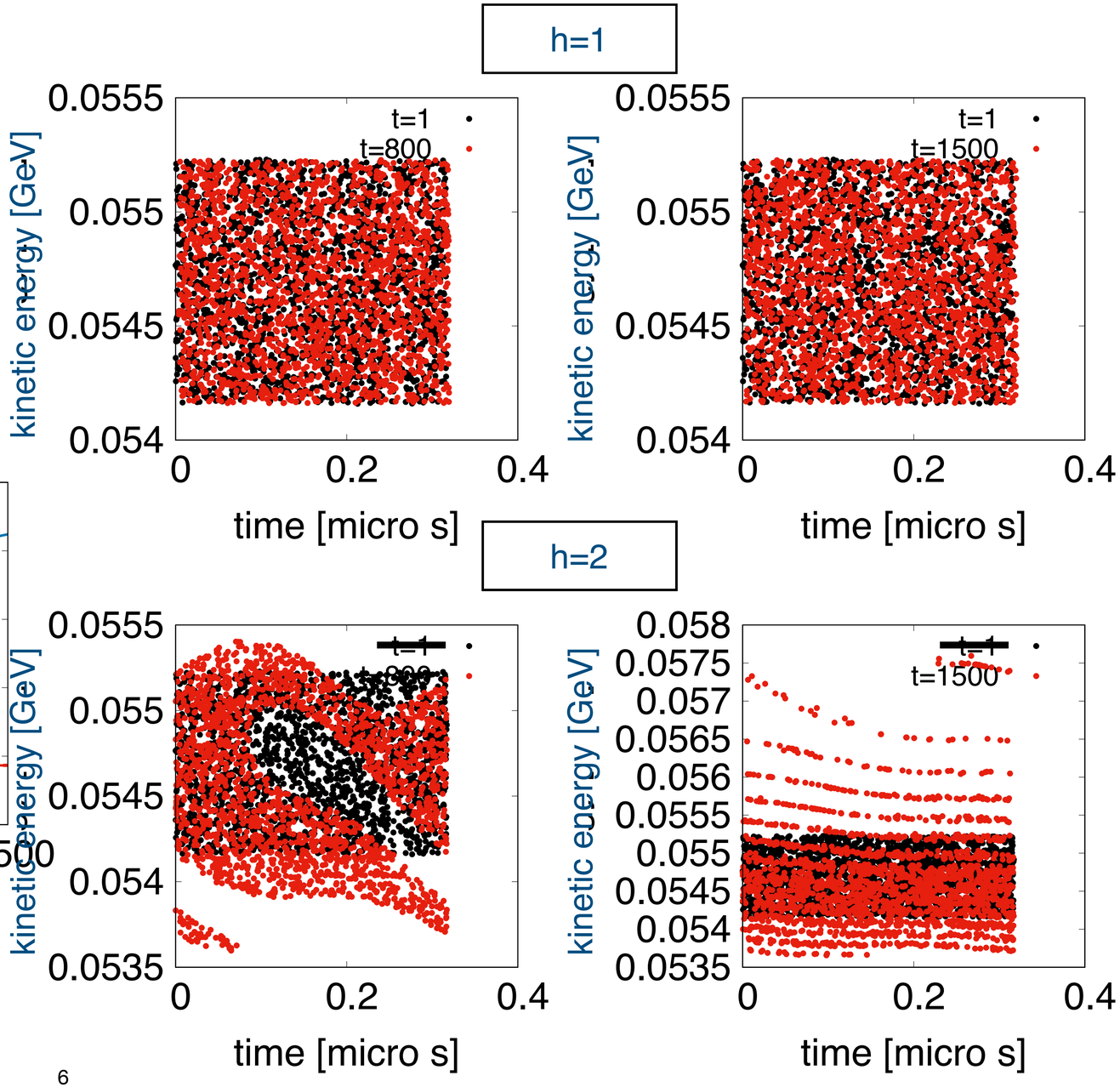


Science and Technology Facilities Council

Effects on coasting beam at higher energy (55 MeV)

(S. Machida)





Science and Technology Facilities Council

Revised plan

- h=1 RF does not affect stacked beam
- Normal operation of KURNS main ring does not show interference
- After accelerating the beam with h=1 bucket to E1 and debunching, accelerate an empty bucket of h=2 to E2<E1
- Hopefully enough shunt impedance of the cavity to 2x3.2 MHz (normal range of RF frequency 1.6 to 5.2 MHz)
- To demonstrate beam stacking of 2 beams, is it possible to capture and accelerate the beam with h=2 from injection?

Schedule

- Reasonable date for IBG members would be next winter (January, February 2023)
- Proposal from Ishi san: 10/01/23 to 27/01/23