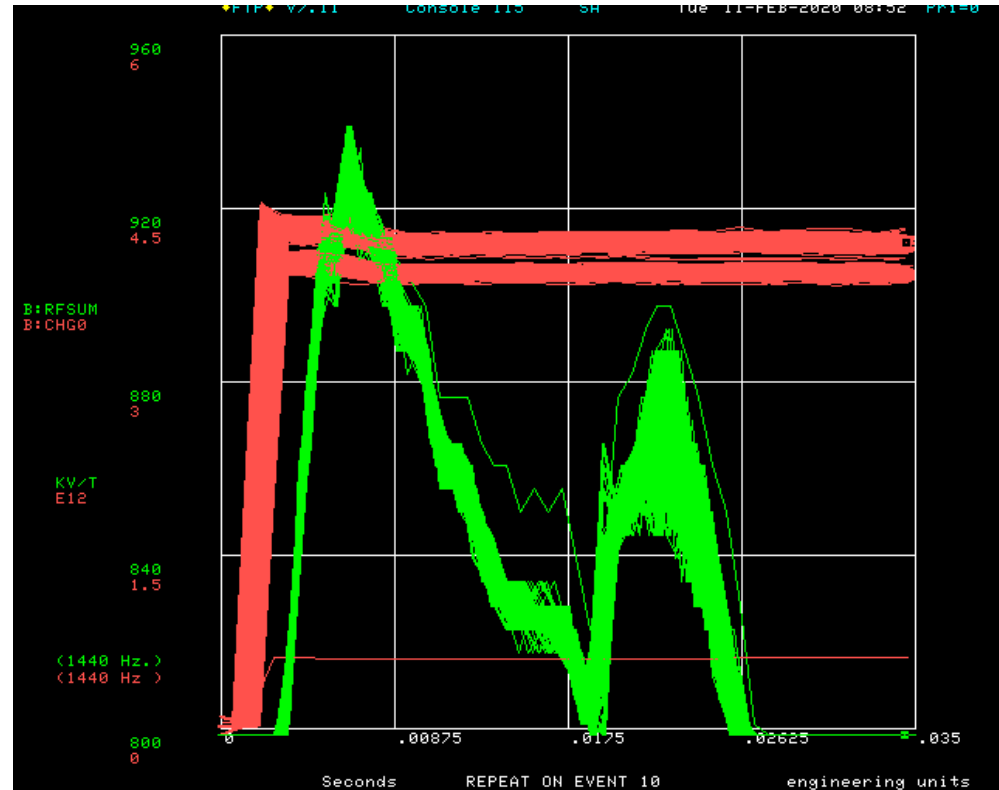# Low Intensity Cycles

Paul Derwent

27 February 2020

Started with an observation

- Plot of B:RFSUM up and running, saw an outlier trace

- Was on the SY cycle
  - Intensity down by factor of 6
  - Voltage up by 40 kV

Started with an observation

- Plot of B:RFSUM up and running, saw an outlier trace

- Was on the SY cycle
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- Thought about it for a bit
  - Probably beam loading

- RFSUM is measured gap voltage
  - up to phase and calibration between the cavities
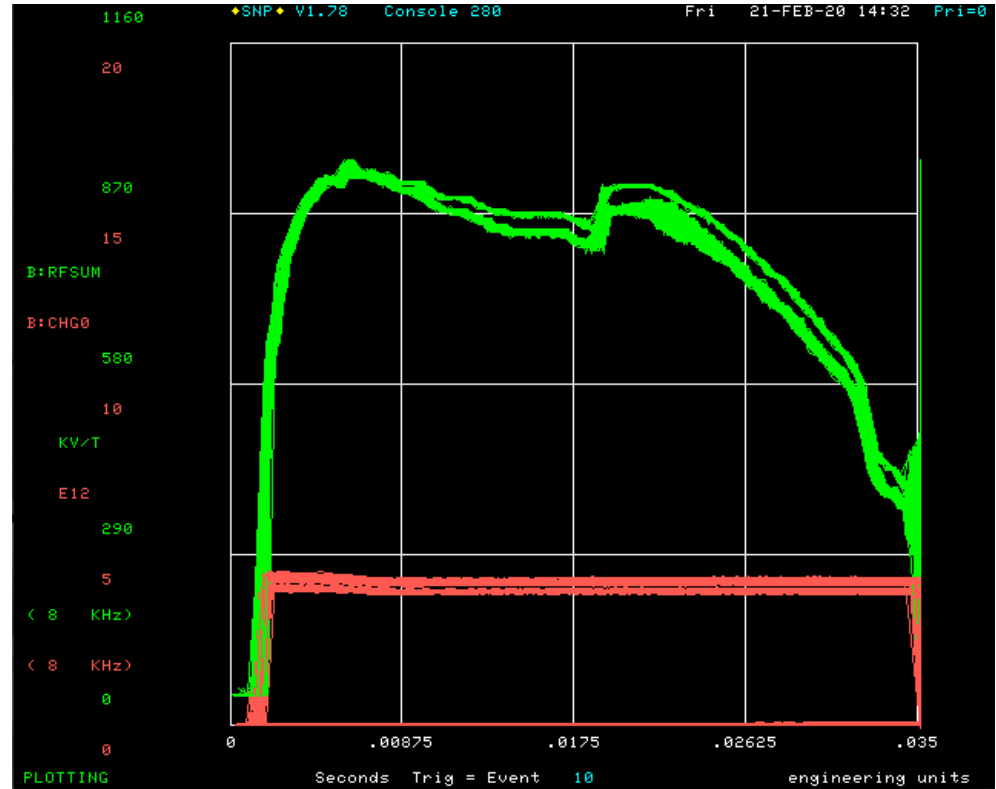
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Phasor Diagram

- Conventions from TM-1915 for the phasor diagram
  - Accelerating voltage is +x
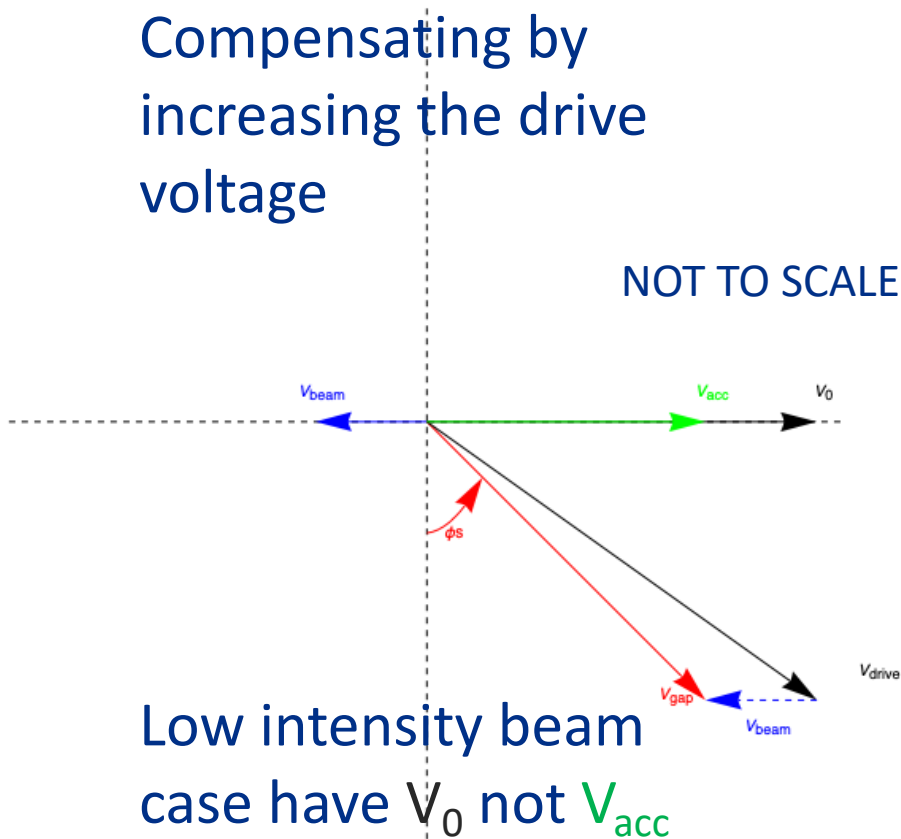 - $V_{acc} = V_{gap} \, Sin(\phi s)$

Necessary for acceleration
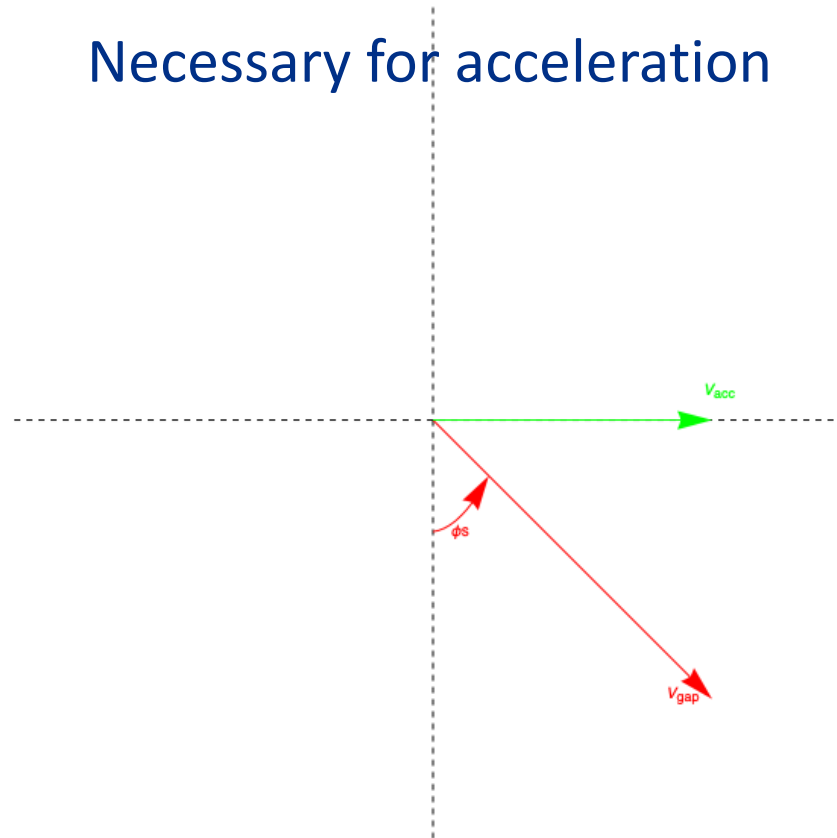
- Drawn below transition as $\phi s < 90$
- Max effect at transition ($\phi s = 90$)

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Phasor Diagram

- Conventions from TM-1915 for the phasor diagram
  - Accelerating voltage is +x
  - $V_{acc} = V_{gap} \sin(\phi s)$
  - Beam loading is –x

  - Beam loading
    - $V_{beam} = i_b R_{shunt}$
    - $i_b \sim 2x$ beam current (Fourier component)
    - $R_{shunt} = 60 \ k\Omega$

- Drawn below transition as $\phi s < 90$
- Max effect at transition ($\phi s = 90$)

Compensating by increasing the drive voltage

NOT TO SCALE

Low intensity beam case have V_0 not V_{acc}

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Phasor Diagram

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To scale
~2.8° change in ϕ_s

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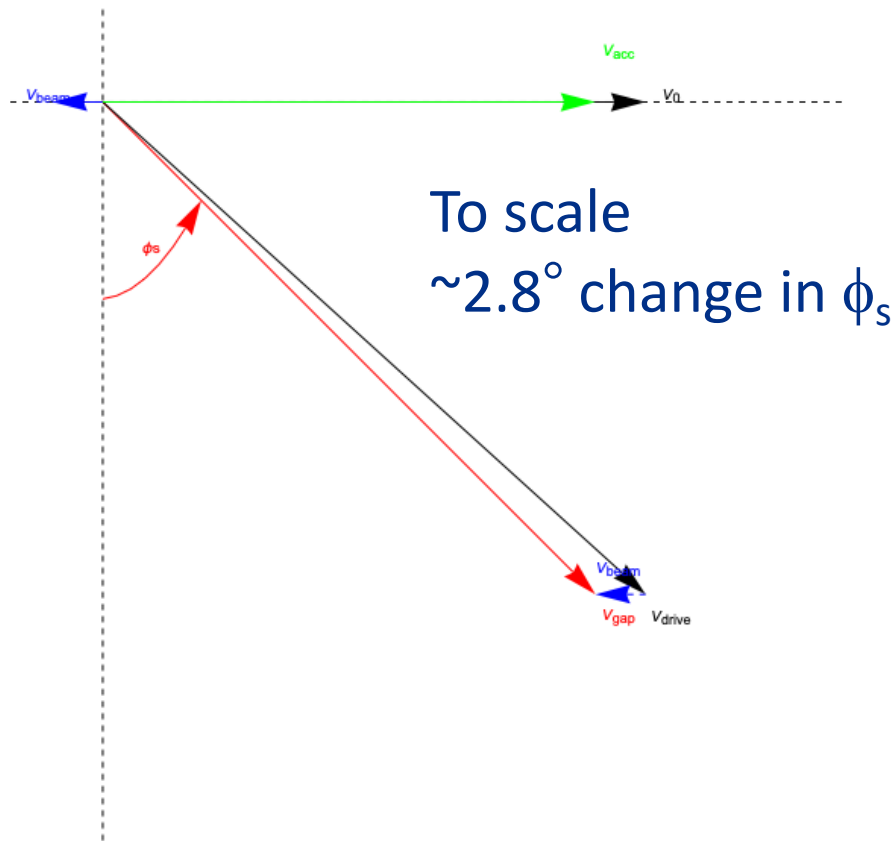
Calculate the effects

- Not doing active compensation
  - Have fixed voltage curve (up to feedback loops)

- Assume that have tuned RF curves for the NuMI and BNB cycles
  - So that energy gain (V_{acc}) matches the Bdot

- SY cycles have lower intensity
  - V_{beam} is smaller, so gap voltage is larger

- Calculated V_{gap} under these assumptions

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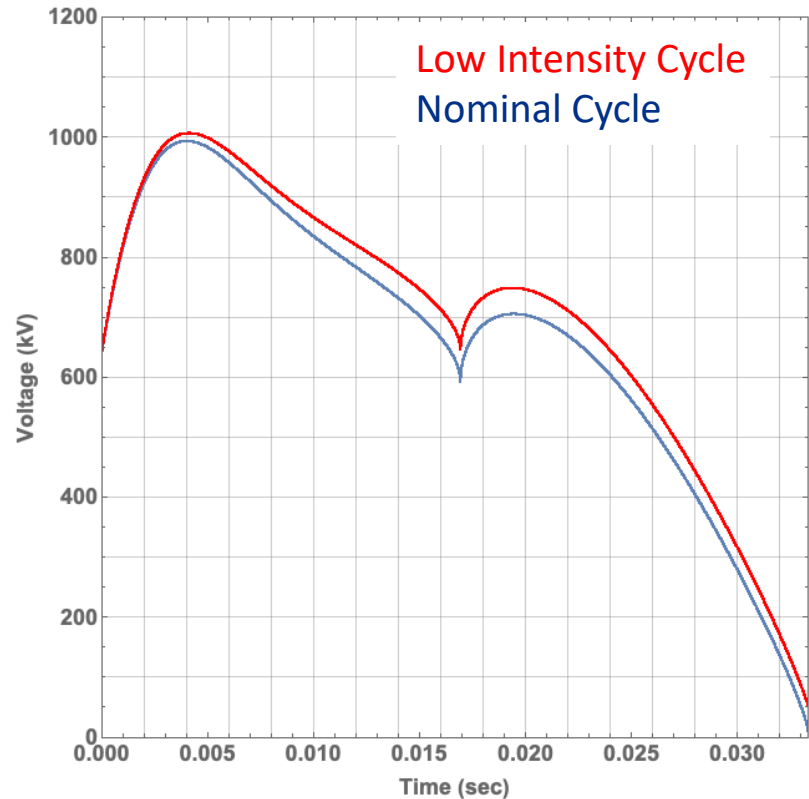
Observations

- Averaged over 20 pulses
  - Couple seconds on $15
  - 20 minutes on $13

- Change in shape looks like prediction!
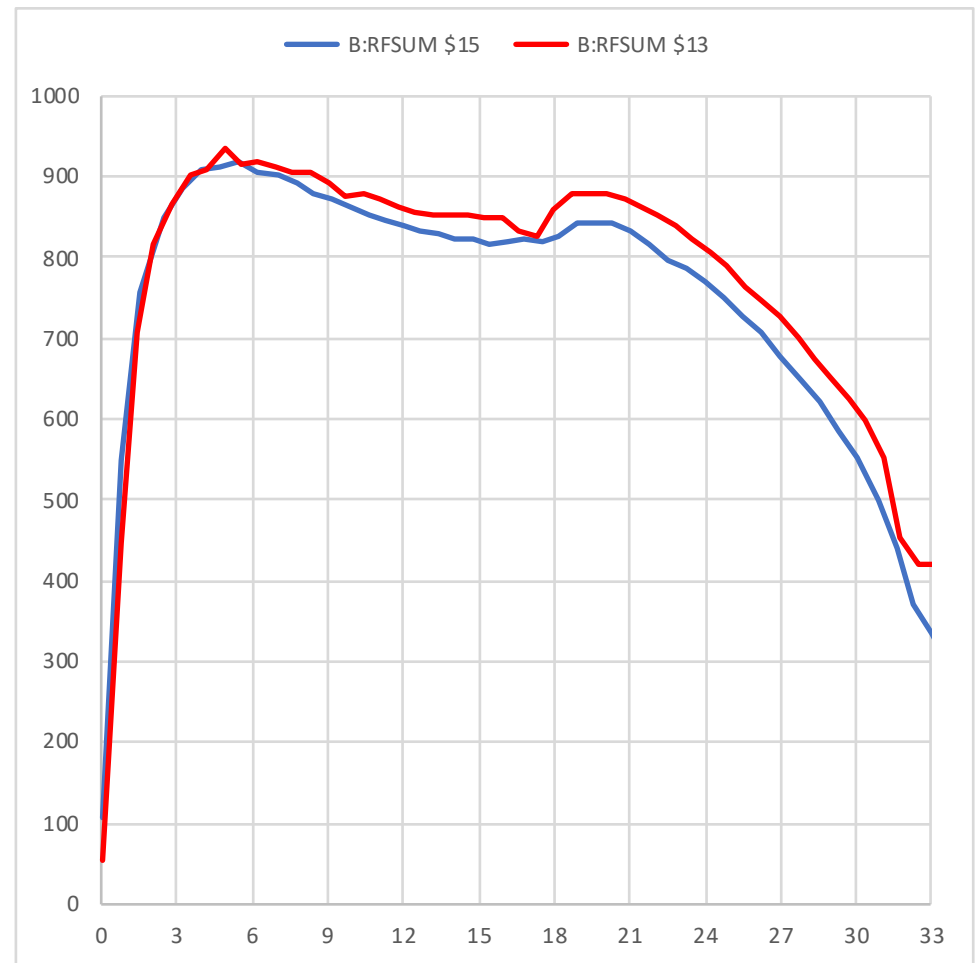
What impact does it have on beam?

- Guess it would have phase / energy oscillations as the energy gain is greater than required by Bdot.

- Feedback loops ?
  - Two Phase loops
    - STnnE: Phase of drive/gap and reference in sync
      - ±5 degree swing above transition for $15, not for $13?
      - Mode 1 / Mode 2 intensity dependent signals show up at 20 msec

    - PDnnE: Phase of cavity (bias supply) and drive in sync

  - Not sure what is going on
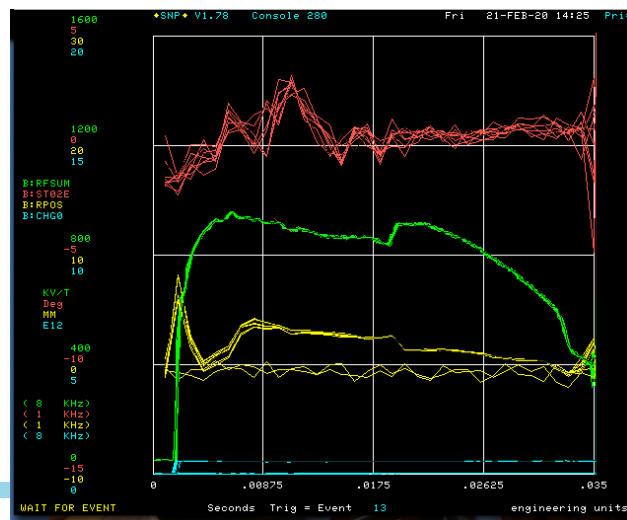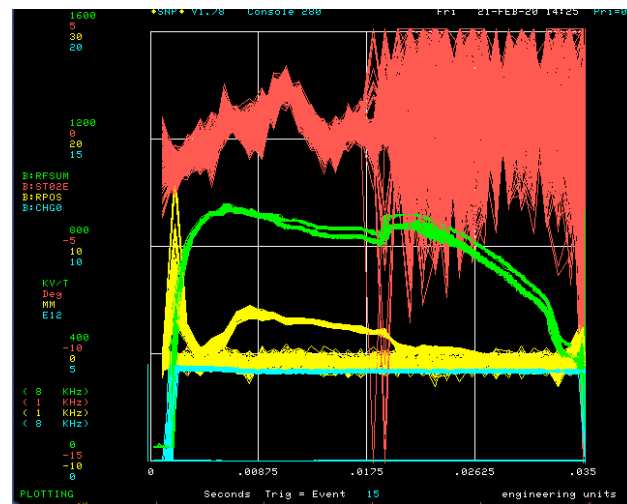
What impact does it have on beam?

- Guess it would have phase / energy oscillations as the energy gain is greater than required by Bdot.

- Feedback loops mitigate it?
  - RPOS is different?

  - Not sure what is going on

- Losses?
  - It is 1 cycle out of 856!
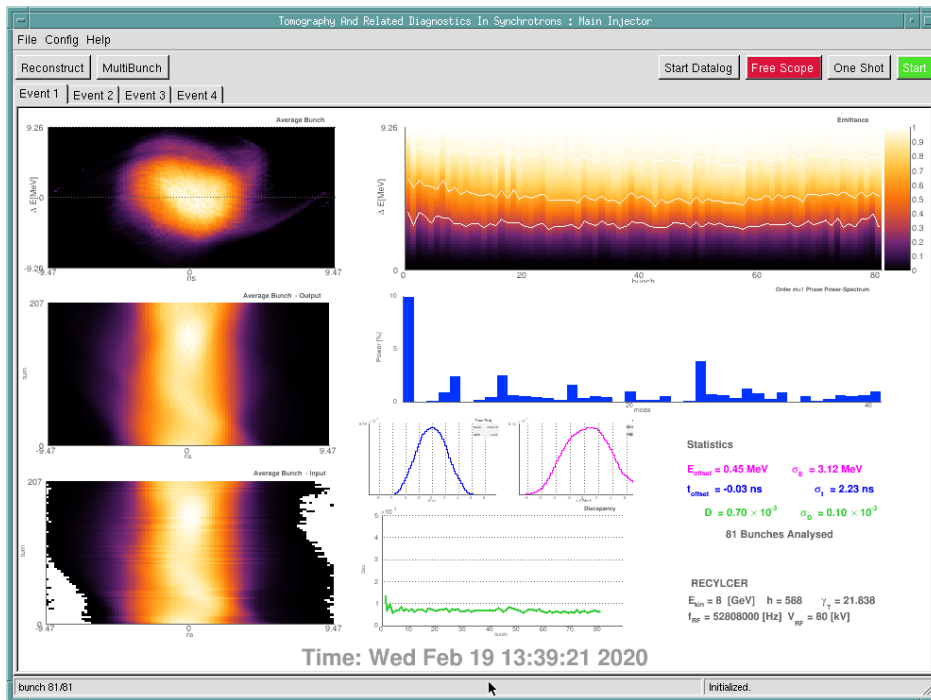 - With intensity down by factor of 7!

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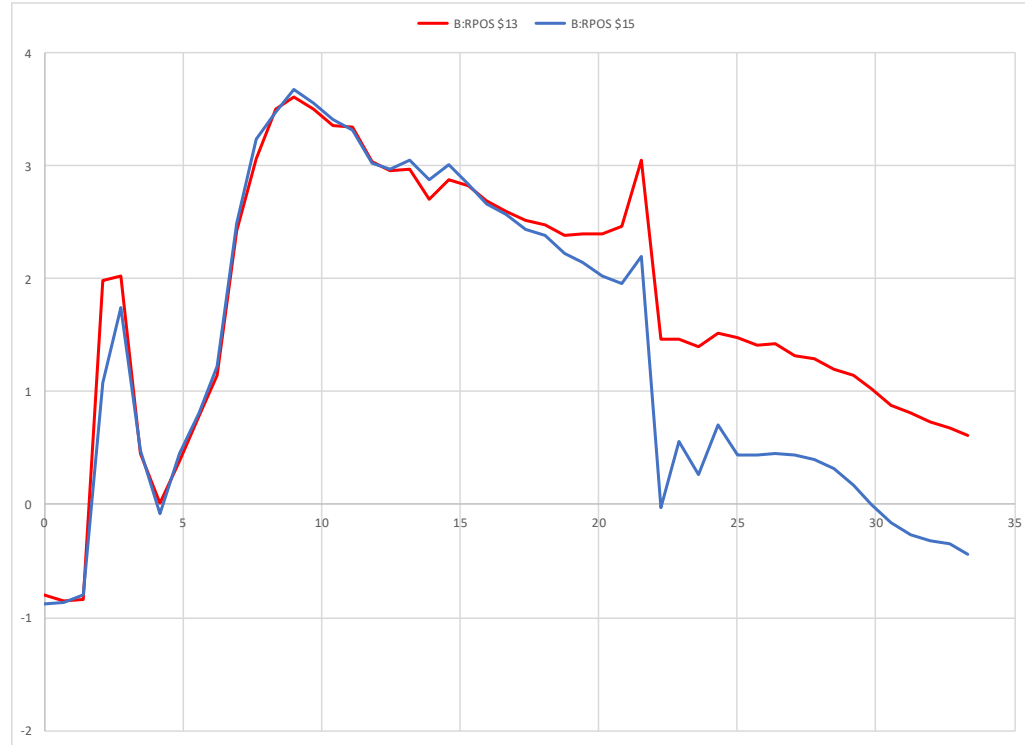
What impact does it have on beam?

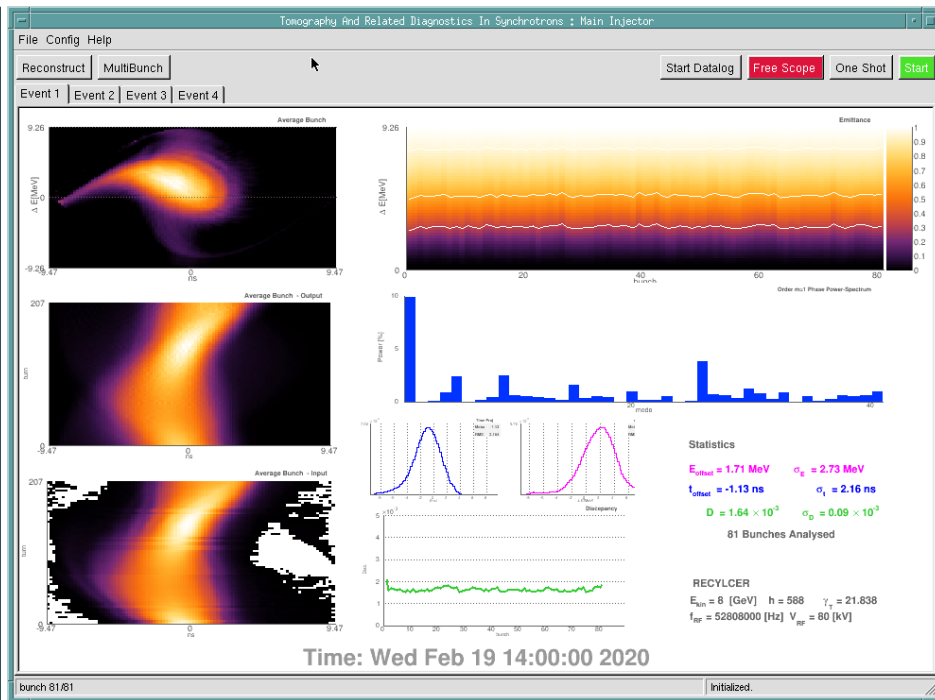- Longitudinal phase space would look different – voltage gain does not match Bdot
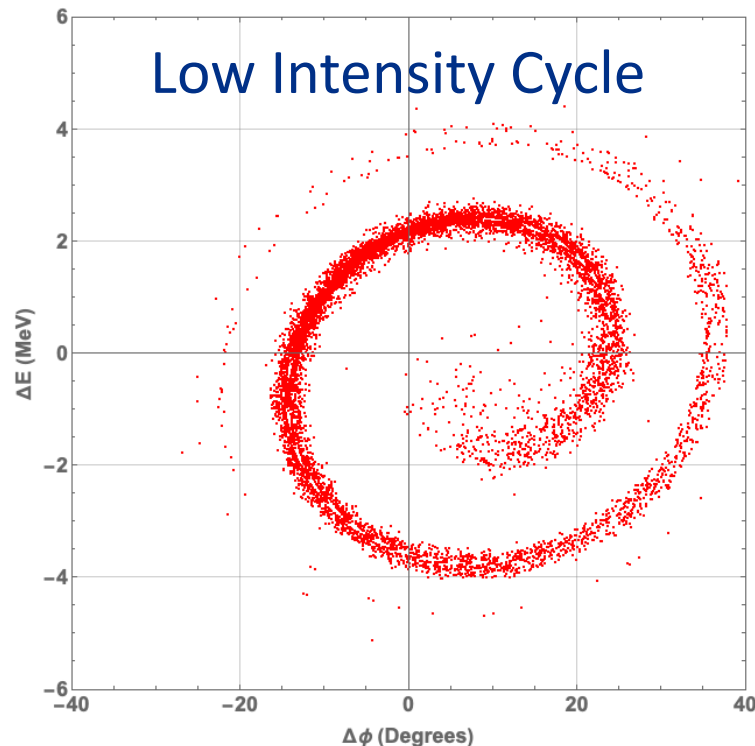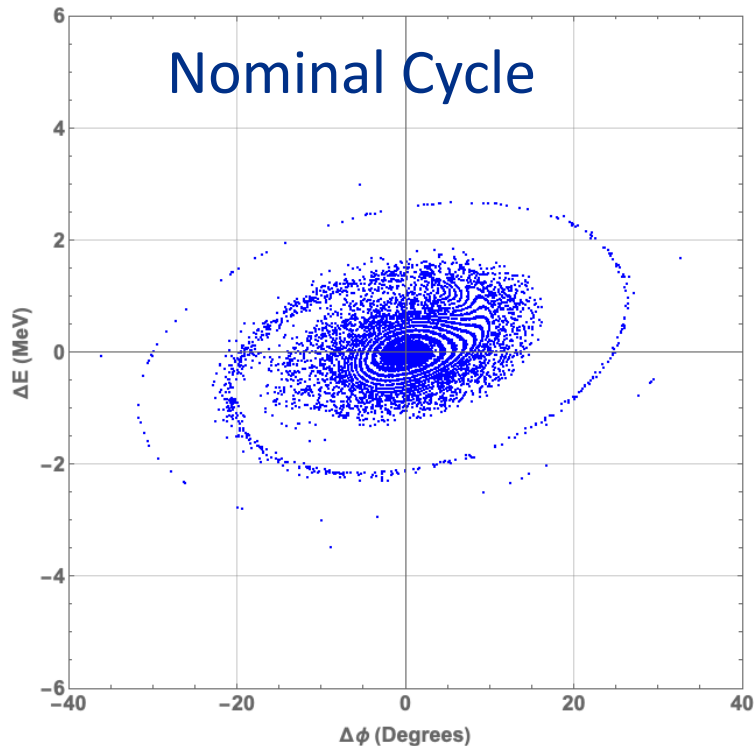
Nominal Cycle

Low Intensity Cycle

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Looked at them in the Recycler with TARDIS

Nominal Cycle
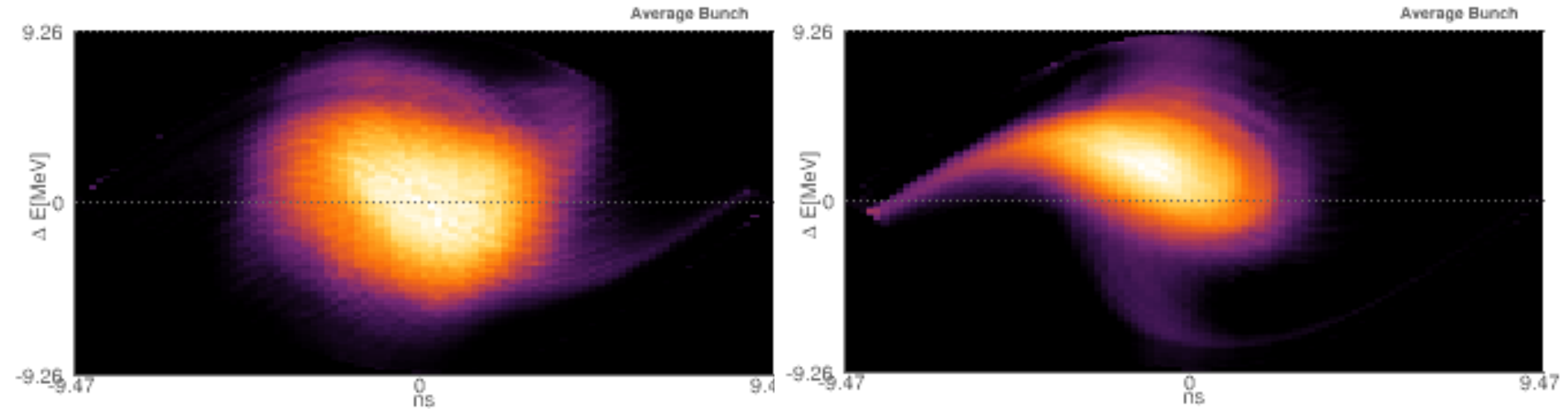
Low Intensity Cycle

🟦 Fermilab

Looked at them in the Recycler with TARDIS

Nominal Cycle

Low Intensity Cycle

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What impact does it have on beam?

- Longitudinal phase space would look different – with a BiNormal input distribution

Nominal Cycle

Low Intensity Cycle

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