Status of the Intra-bunch Feedback at J-PARC Main Ring

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Collaborators

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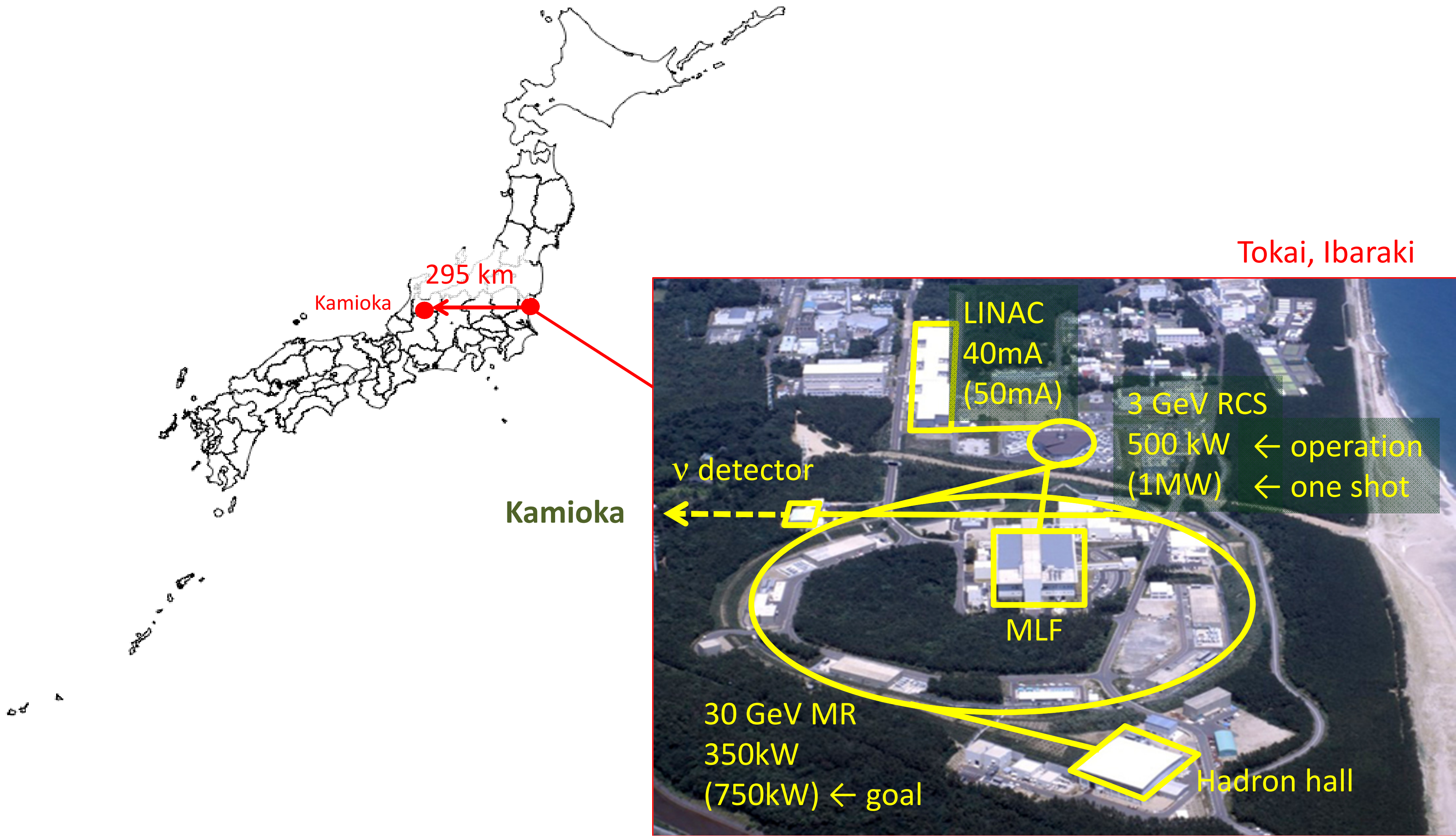
Japan Proton Accelerator Research Complex



Outline

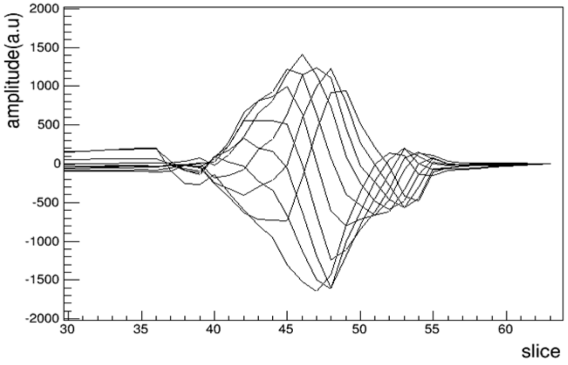
- **Introduction**
  - Upgrade history of the J-PARC MR transverse feedback
- **Feedback during acceleration**
  - Timing slip
  - Timing matching
  - Initial result
- **Summary and prospect**

J-PARC MR parameters

- Circumference 1567.5 m
- Injection Energy 3 GeV
- Extraction Energy 30 GeV
- Revolution at injection 5.384us(185.7kHz) RF 1.67MHz

  at extraction 5.231us(191.2kHz) RF 1.72MHz
- Harmonic number 9
- Repetition time for fast extraction 2.5 s

Transverse oscillation without FB



At high beam power

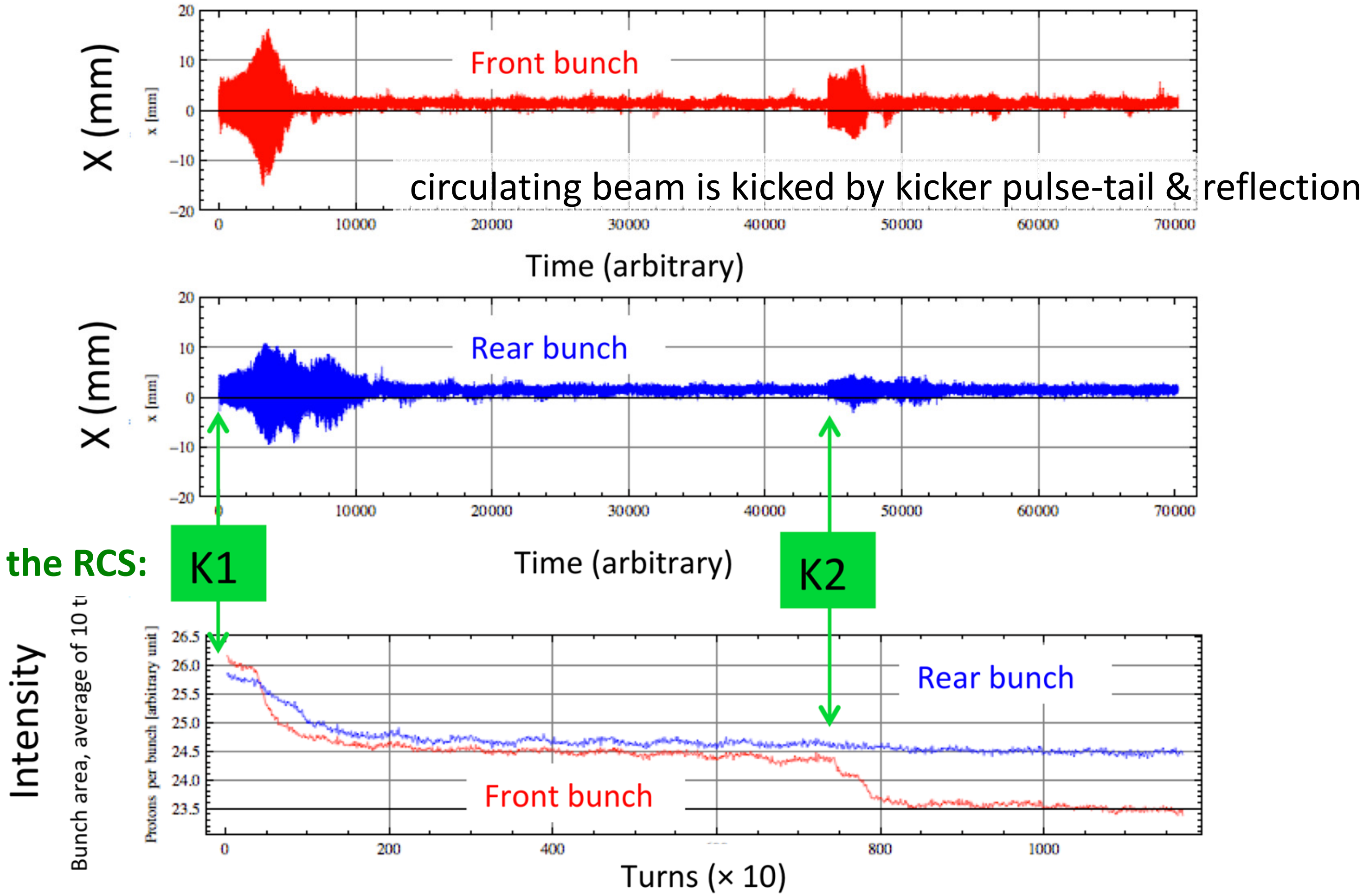
- Collective motion causes beam losses,

  other than non-linear resonances (due to space charge).

Two obstacles

(1) Injection error & succeeding collective motion

$N_B \sim 1.67 \times 10^{13}$ ppp
2 bunches
$\xi x \sim -7.5$
$\xi y \sim -7.0$

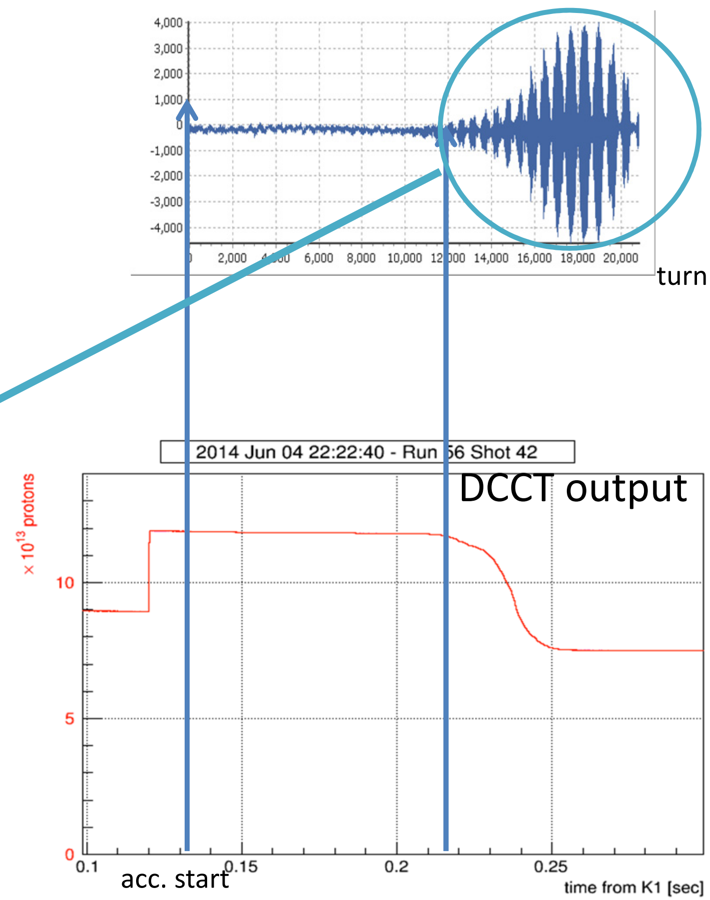


(2) Instability during acceleration

Instabilities has been observed at the beam power 230kW, with chromaticity *ξy=-0.3* .
We avoid this instabilities by tuning chromaticity *ξy=-3.2* .

Observed bunch motion

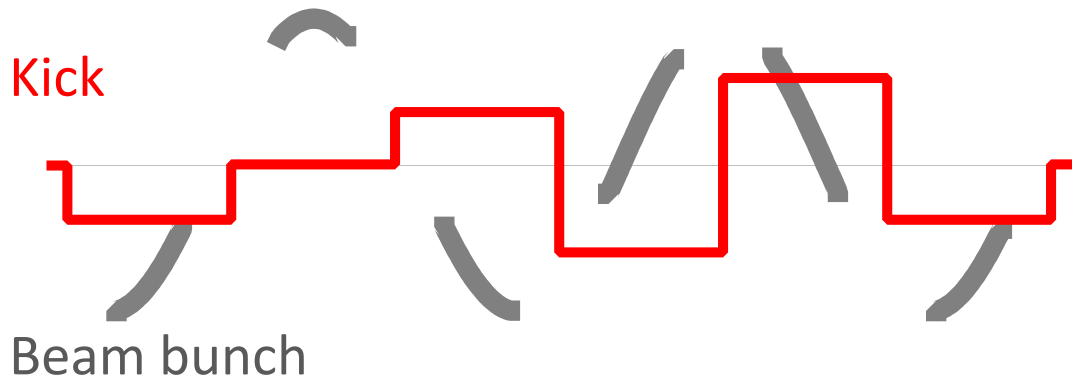
Vertical betatron oscillation amplitude



Keigo Nakamura, *et al.*, IPAC2014, Dresden, Germany

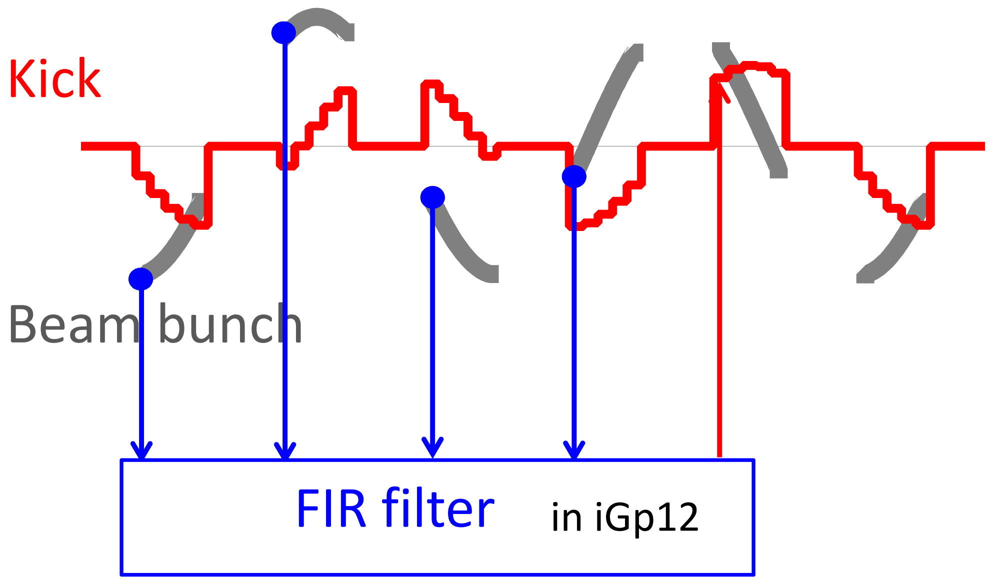
B x B feedback

Bunch-by-bunch (BxB) feedback
slice ~ 590 ns



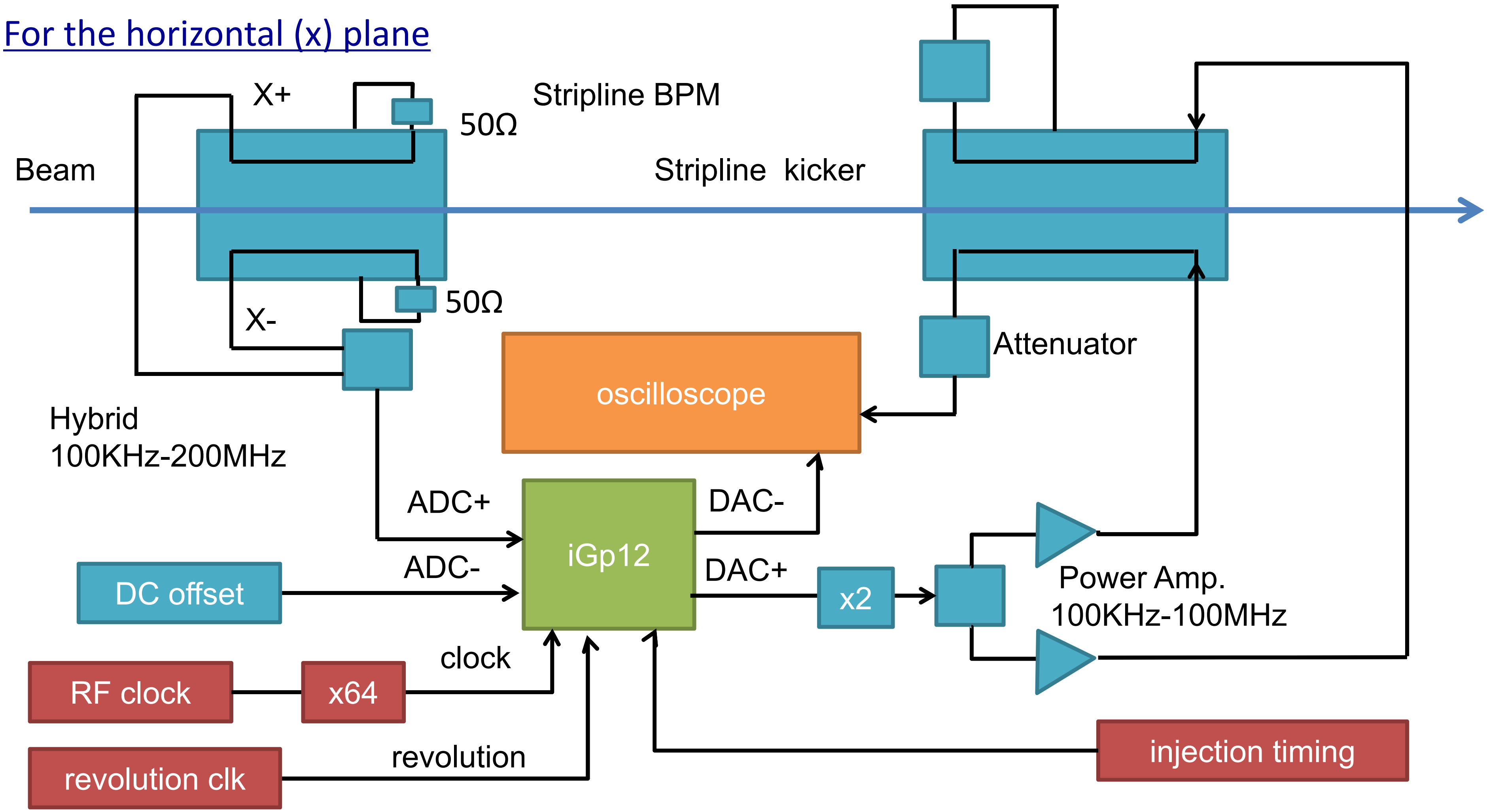
Intra-bunch feedback

Intra-bunch feedback
slice ~ 10 nsec



Schematic view

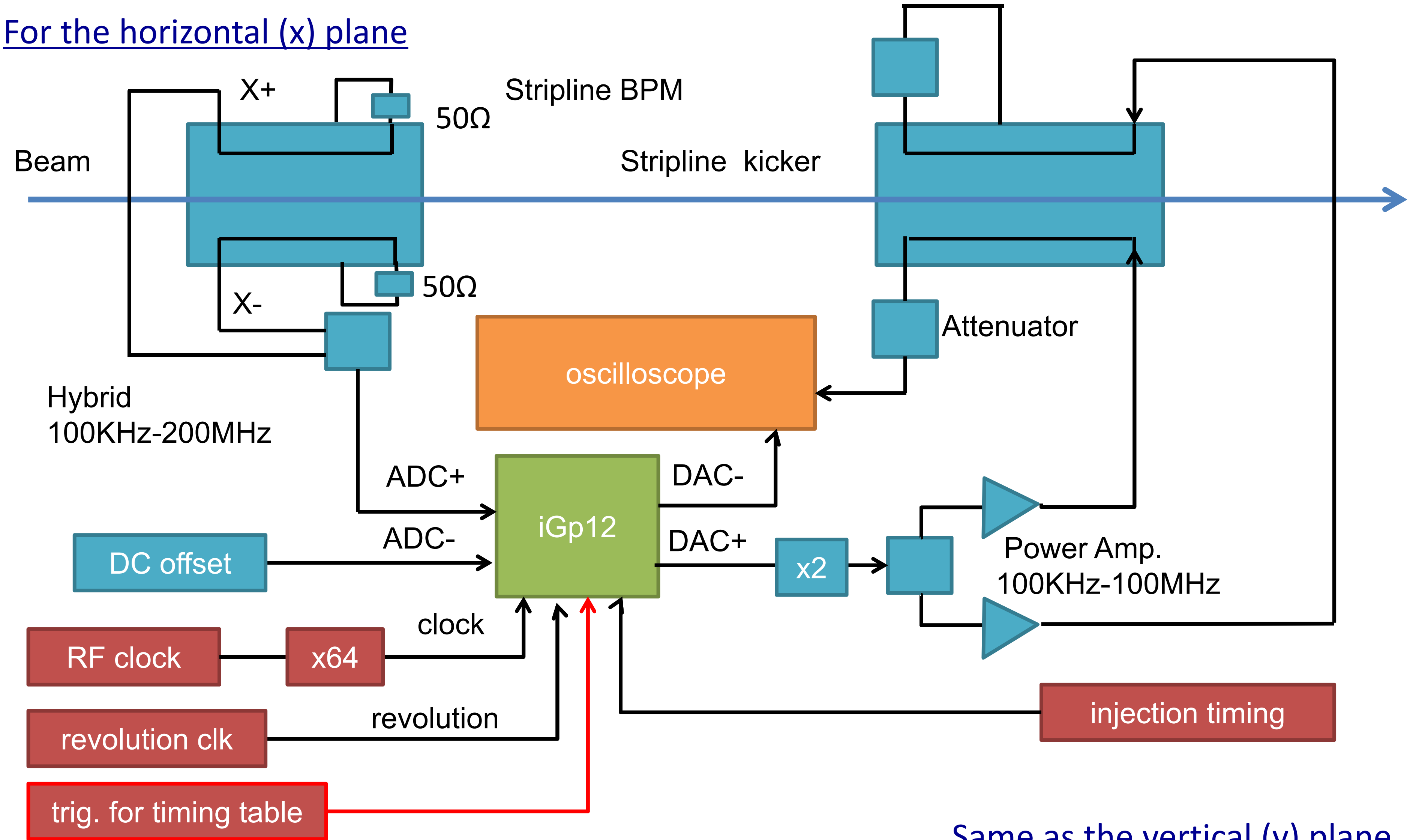
For the horizontal (x) plane



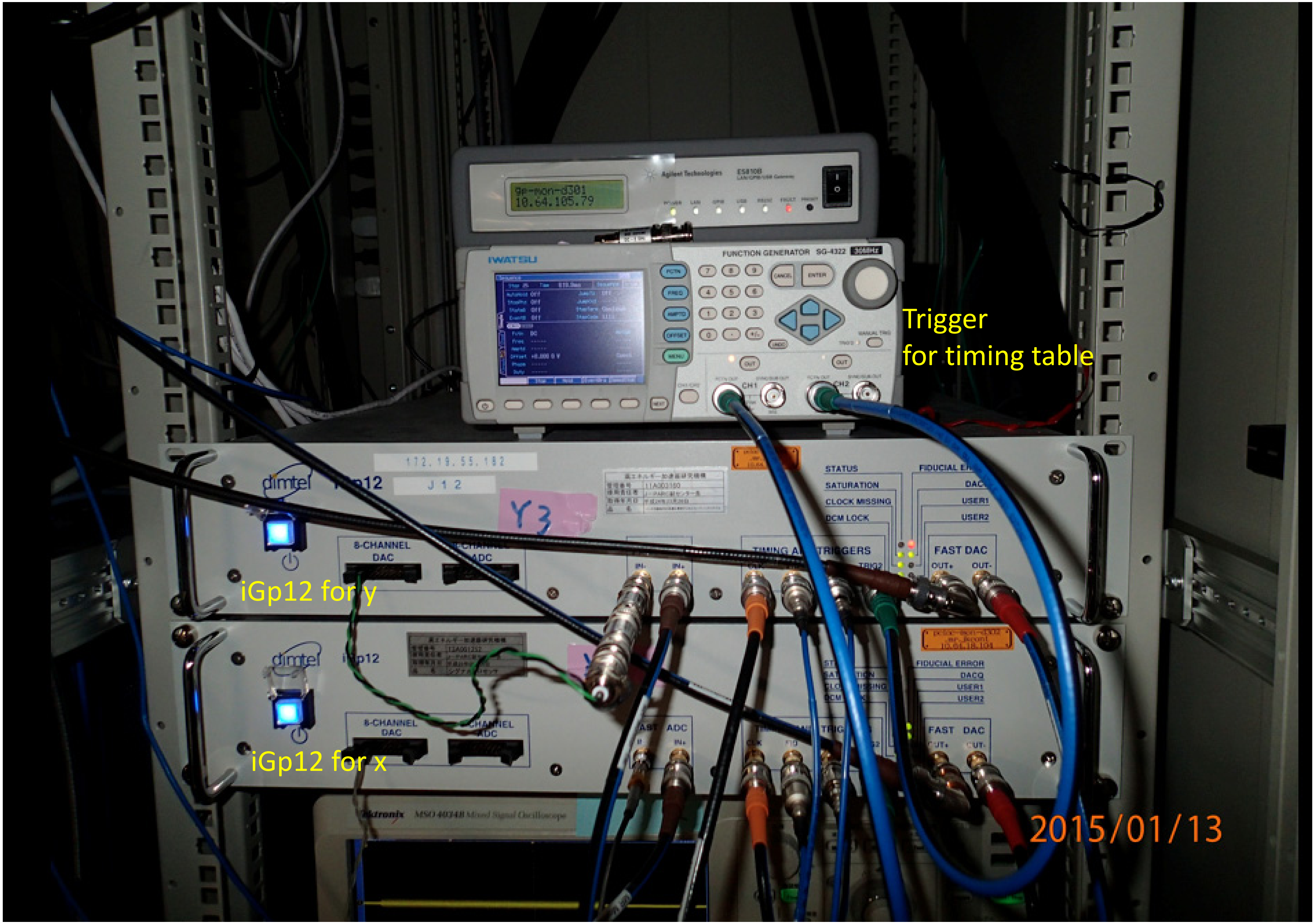
Same as the vertical (y) plane

Schematic view

For the horizontal (x) plane



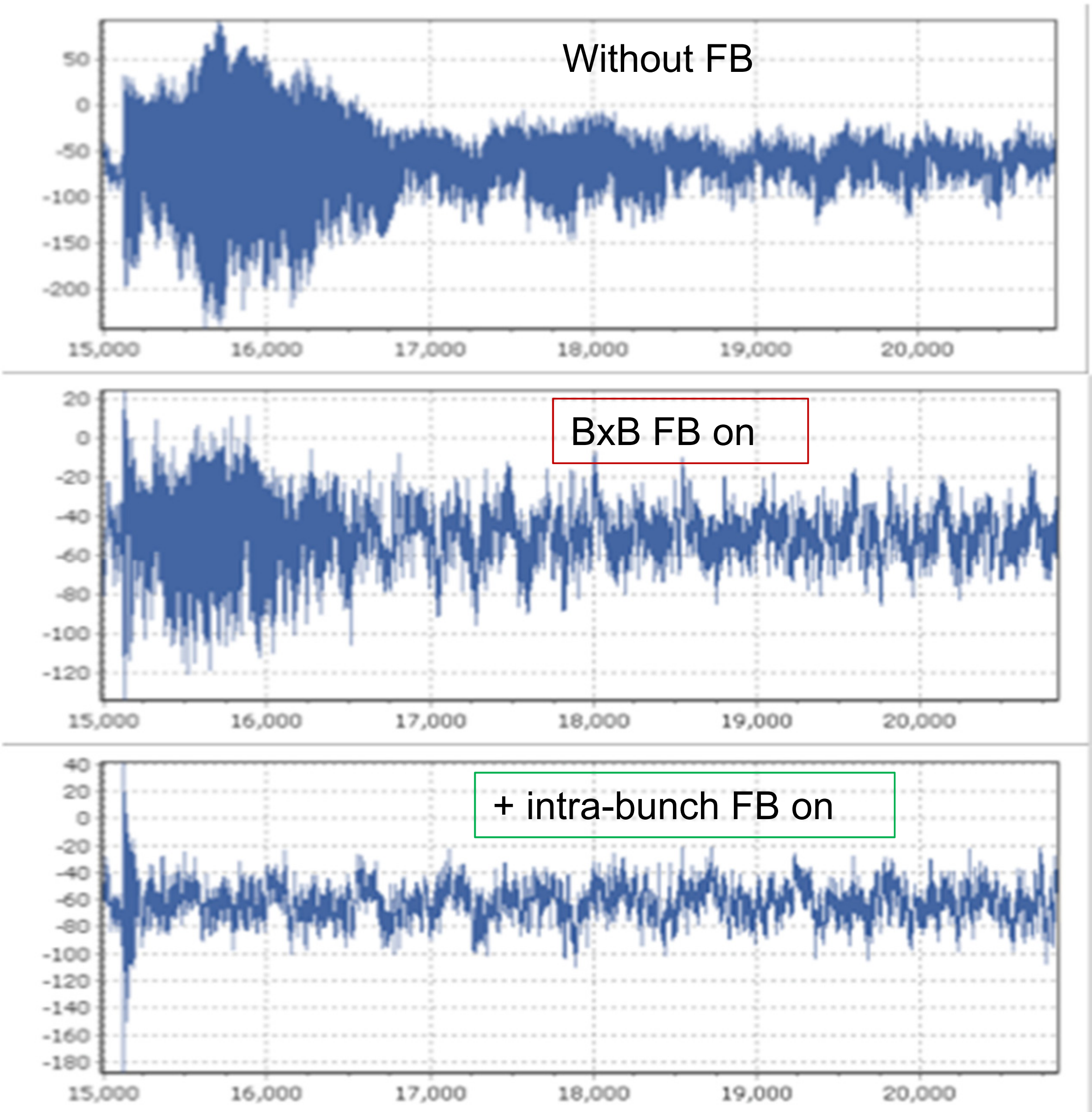
Same as the vertical (y) plane



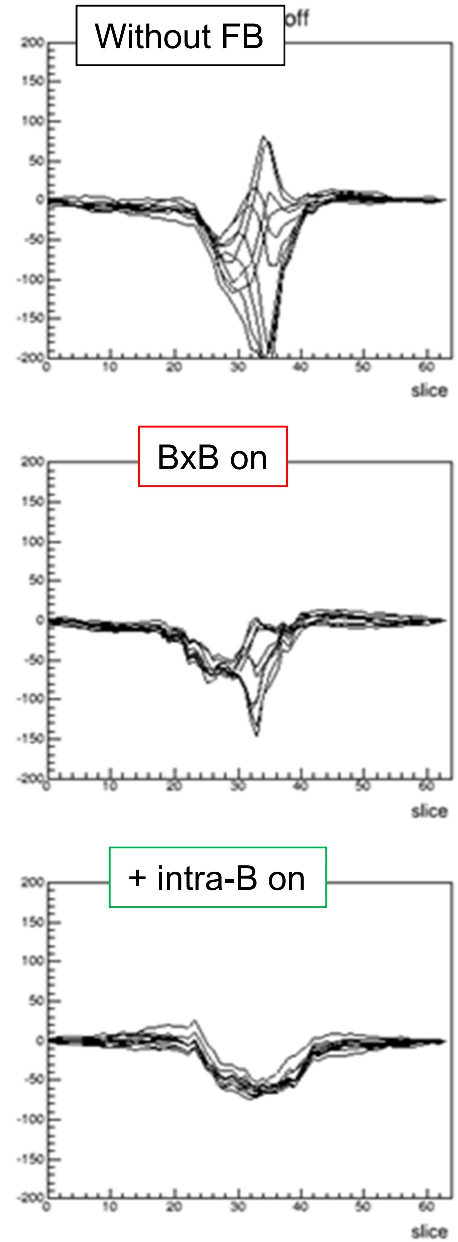
Trigger
for timing table
iGp12 for y
iGp12 for x
2015/01/13

3 GeV injection flat bottom

Oscillation of one bunch slice

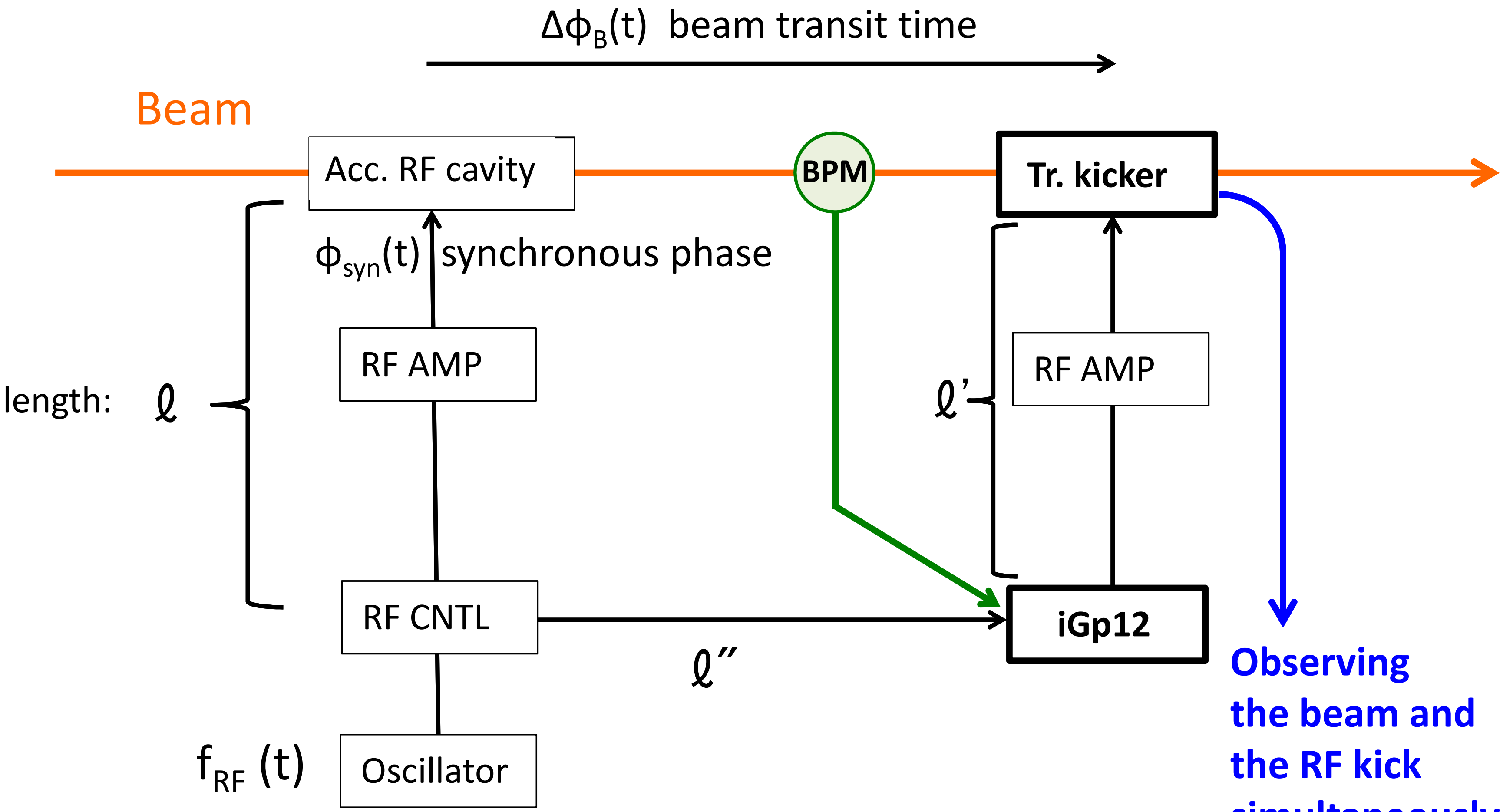


Bunch signal every 5 turns



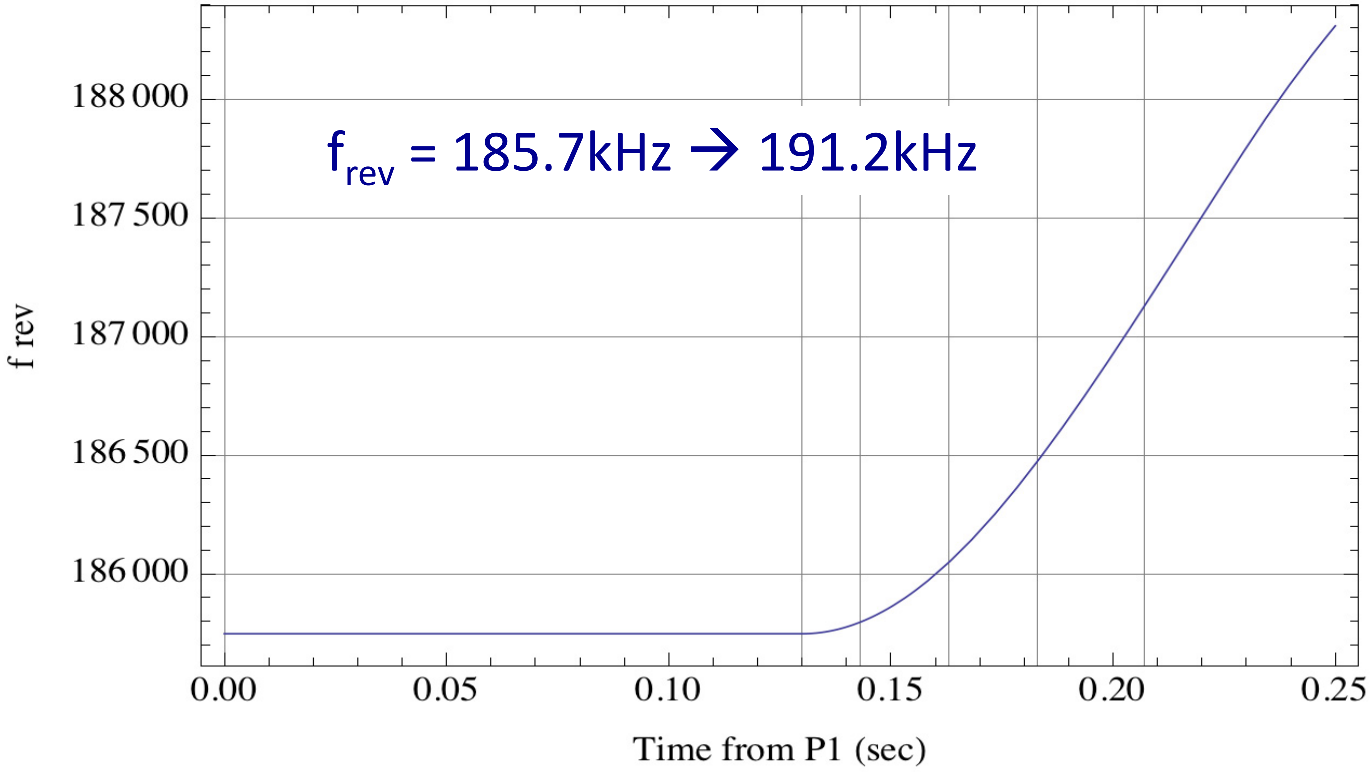
Timing slip

Parameters are changing during acceleration upto 30 GeV

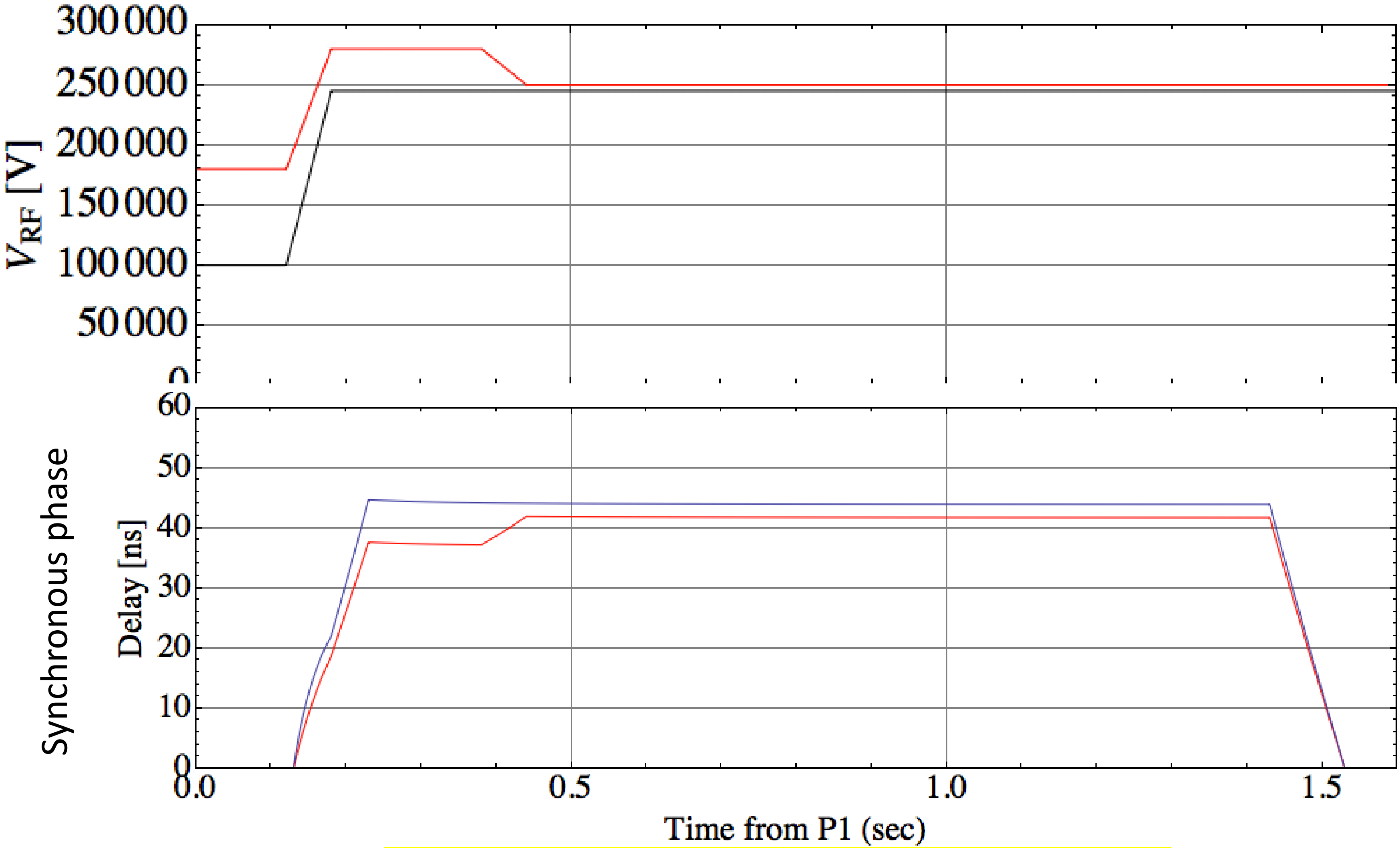


Observing the beam and the RF kick simultaneously

Example of revolution frequency

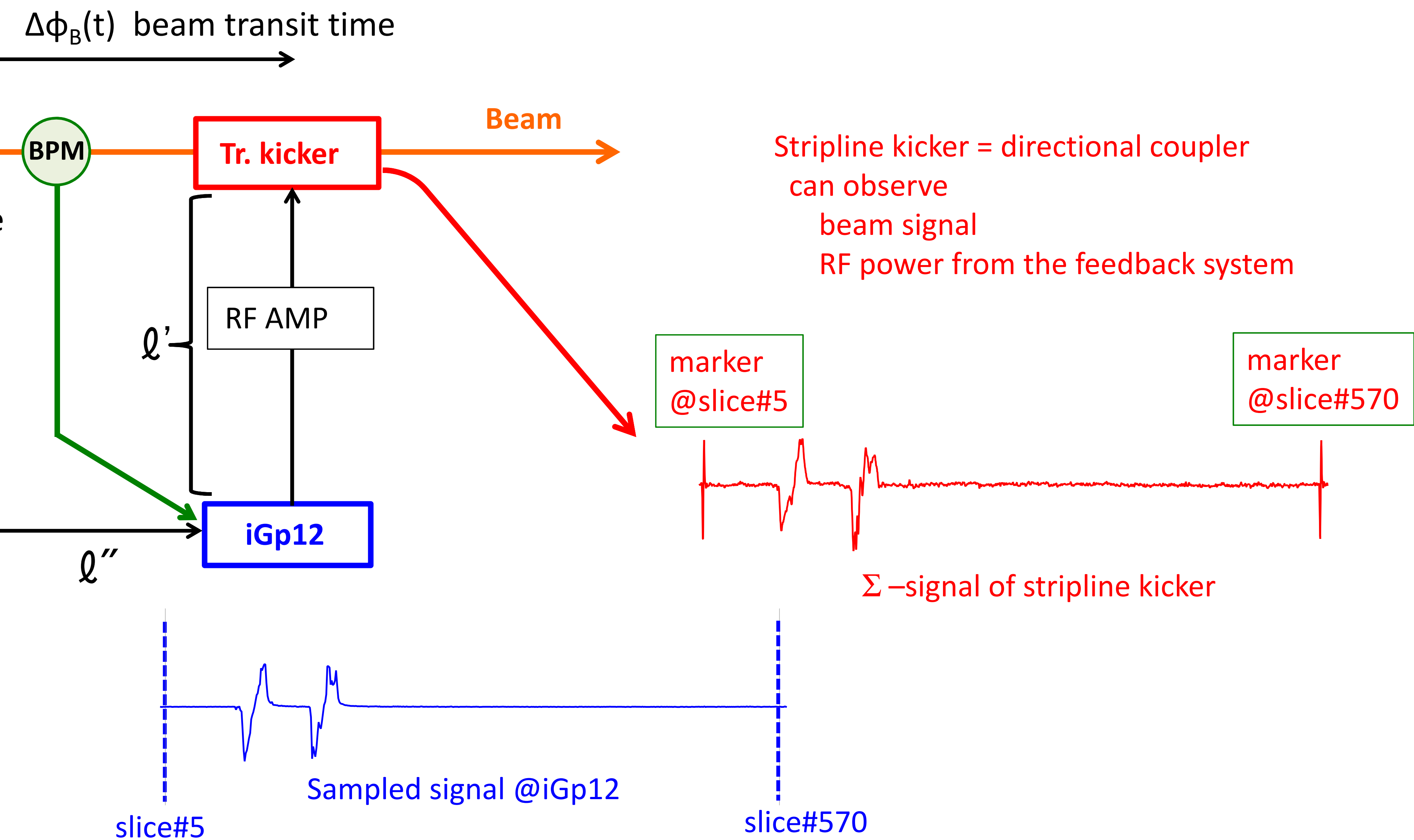


Example of synchronous phase



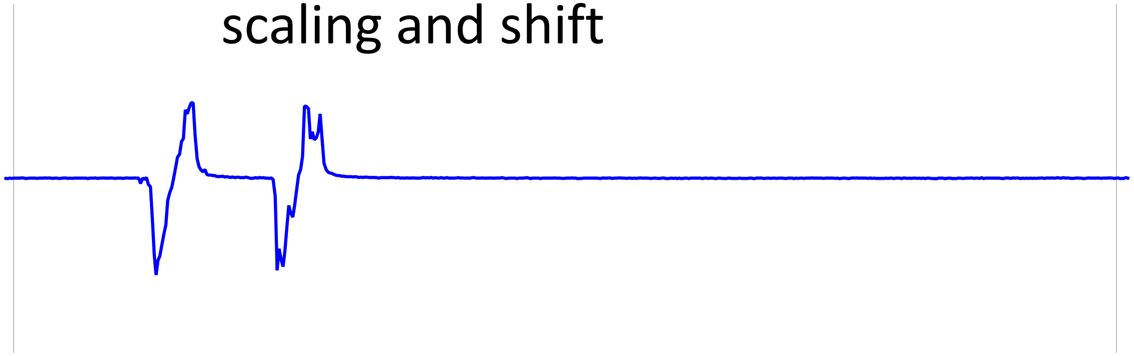
We need rapid parameter optimization

Sampled by iGp12 ← Compare → signals on the stripline kicker



Unit in oscilloscope (kicker) = **time (sec)**

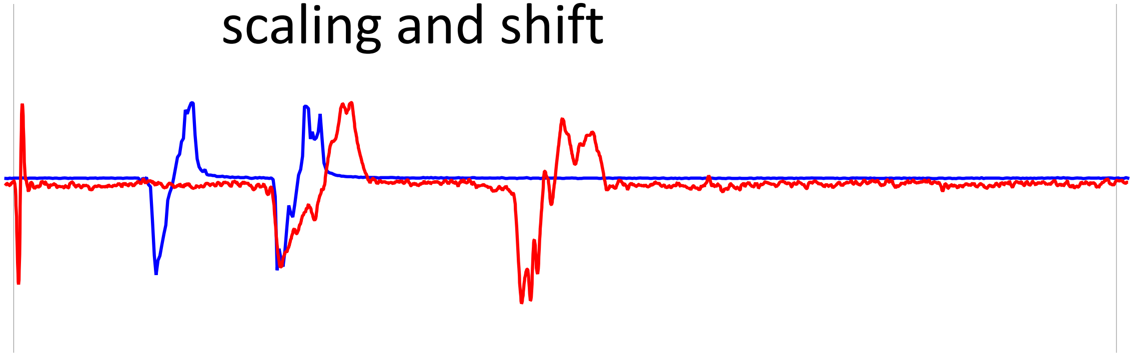
Referencing the marker #5, 570
scaling and shift



Unit in iGp12
RF CLK x 64

Unit in oscilloscope (kicker) = **time (sec)**

Referencing the marker #5, 570
scaling and shift



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Referencing the marker #5, 570
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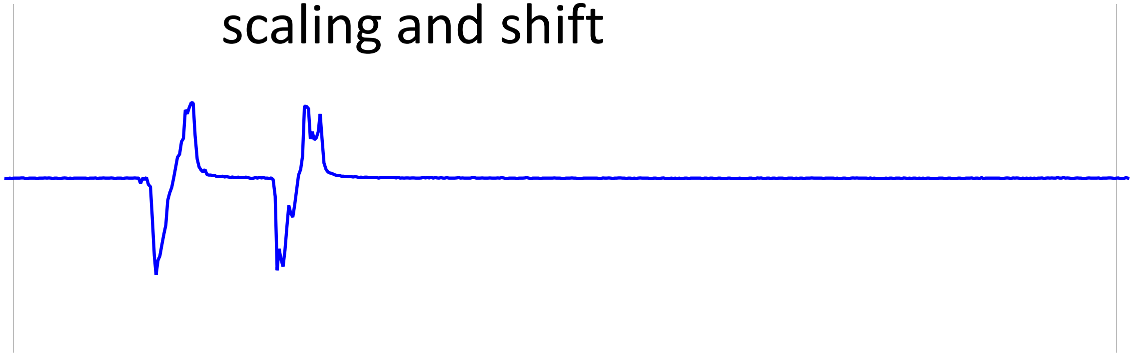

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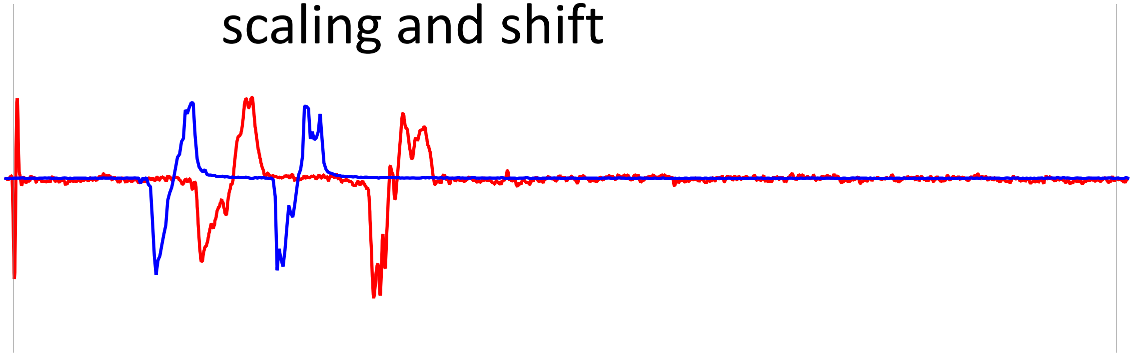

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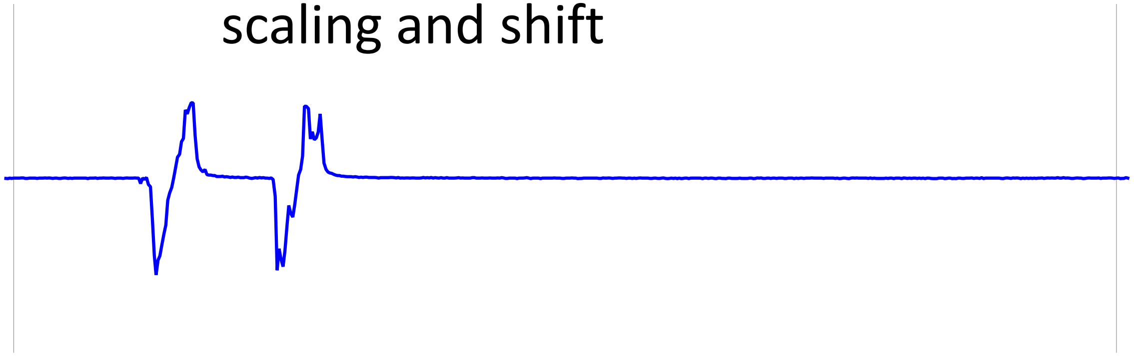

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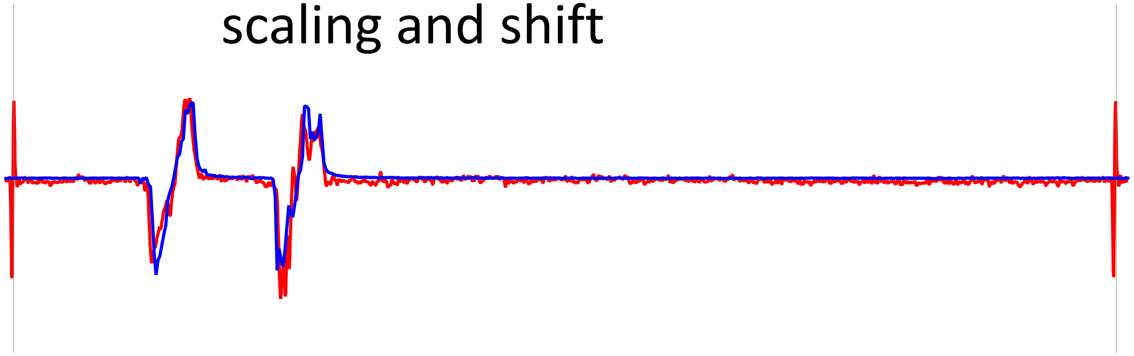
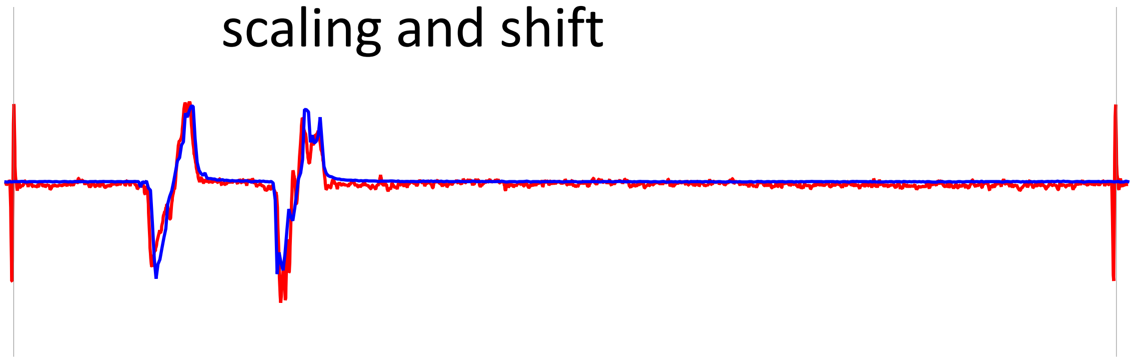


Unit in iGp12

RF CLK x 64

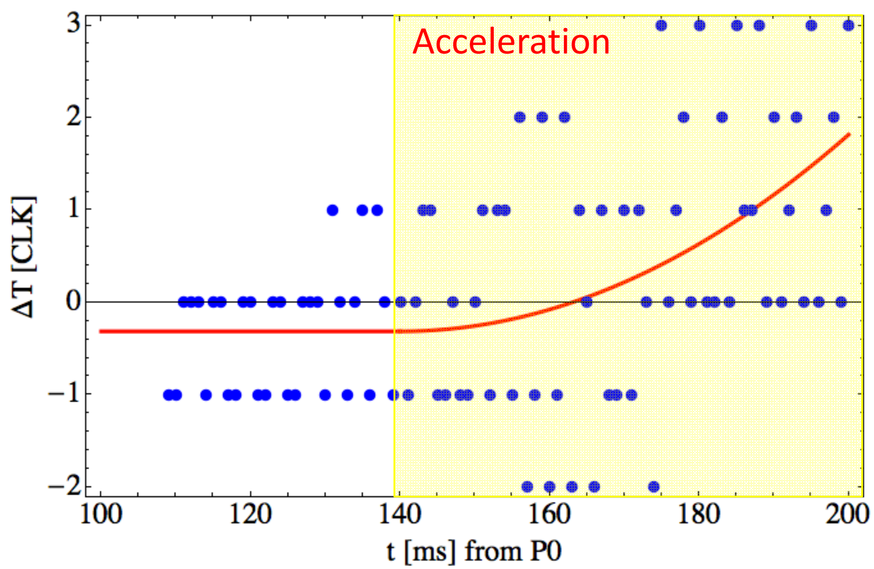
Unit in oscilloscope (kicker) = **time (sec)**

Referencing the marker #5, 570
scaling and shift

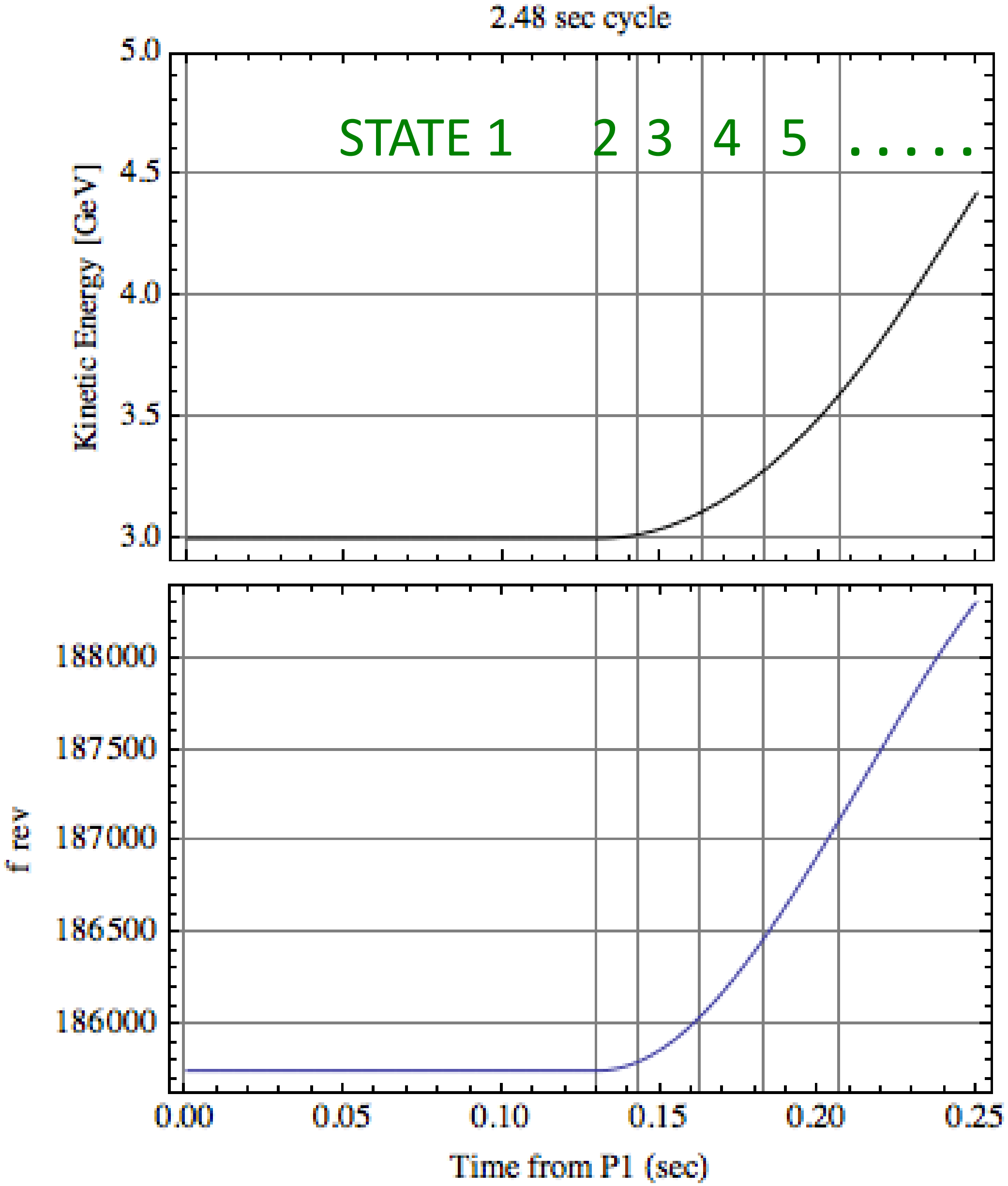


Unit in iGp12
RF CLK x 64

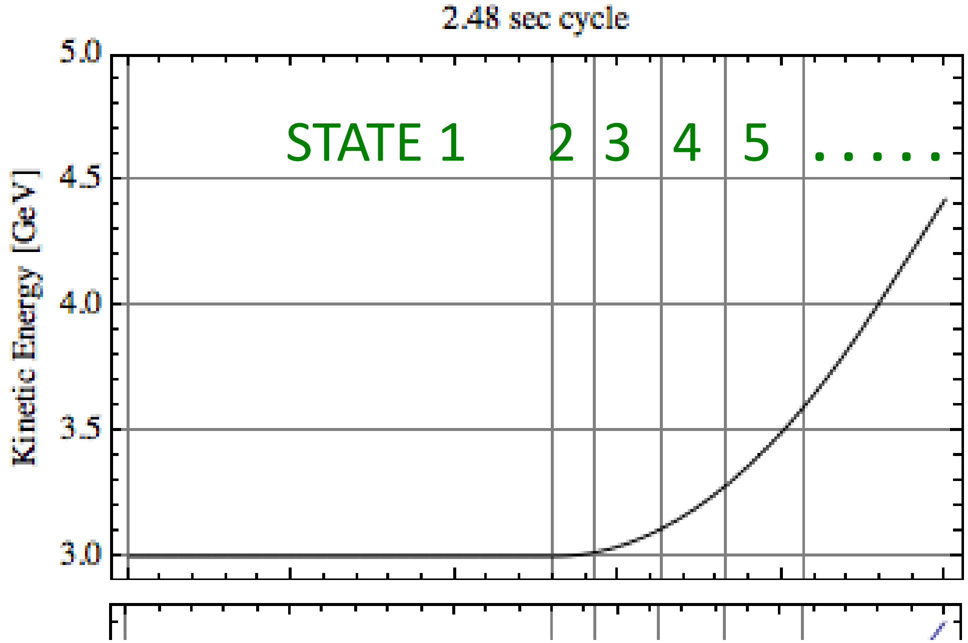
Finally superpose the beam signal by shifting horizontally
the amount of shift = the delay time that we want



Timing CNTL by preset table

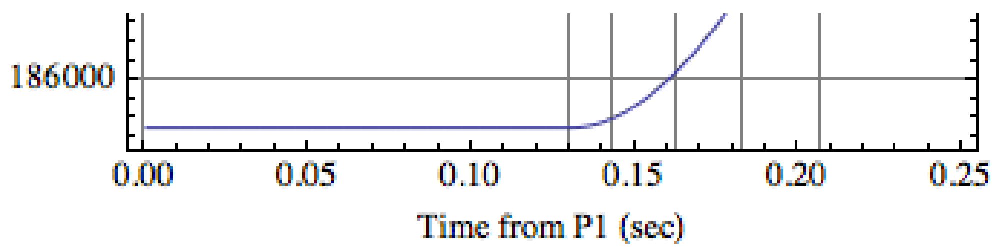


Timing CNTL by preset table

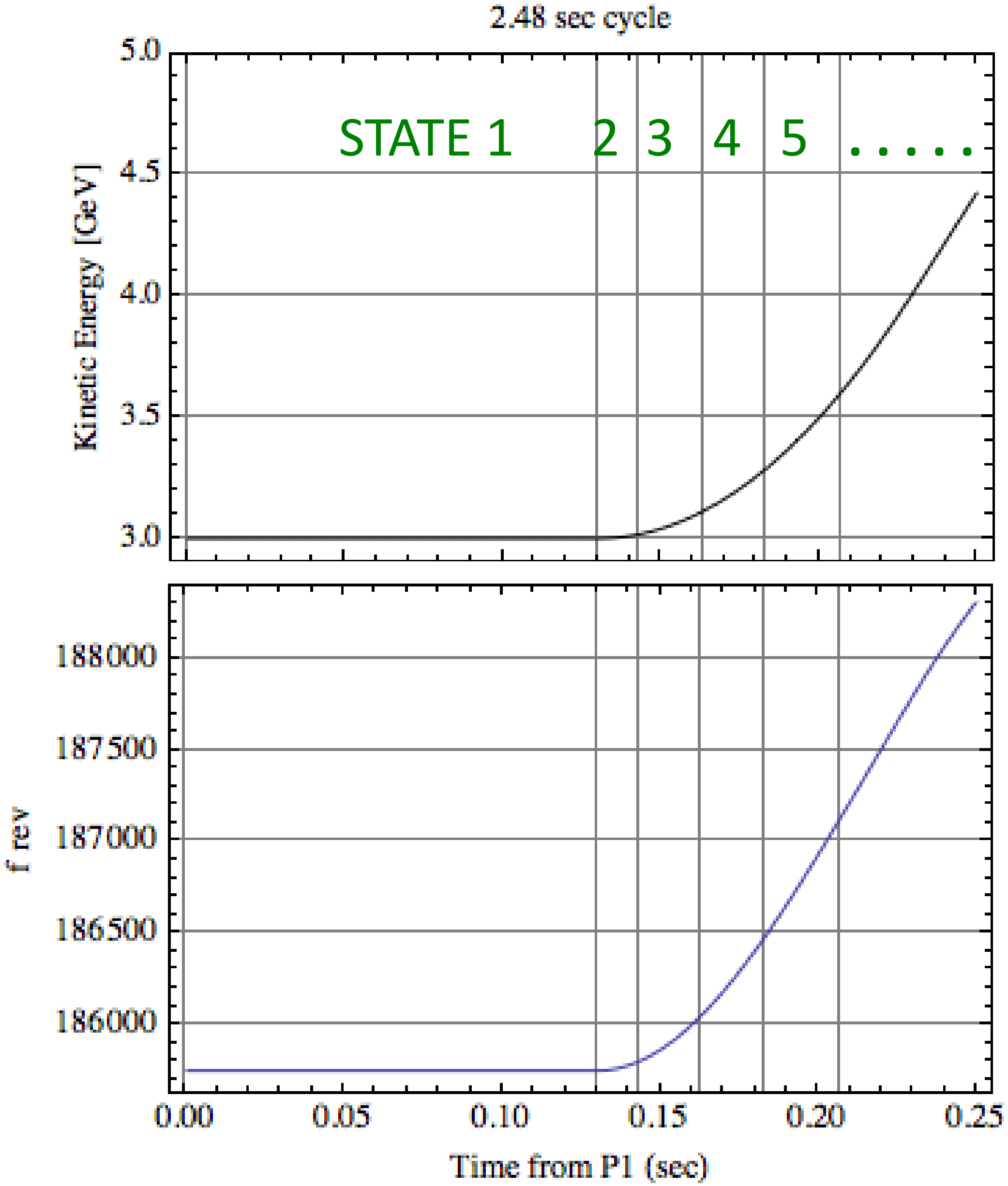


External trigger initiates each "STATE"
STATE specifies the delay, filter gain, phase, # of tap

a function of "iGp12"



Timing CNTL by preset table



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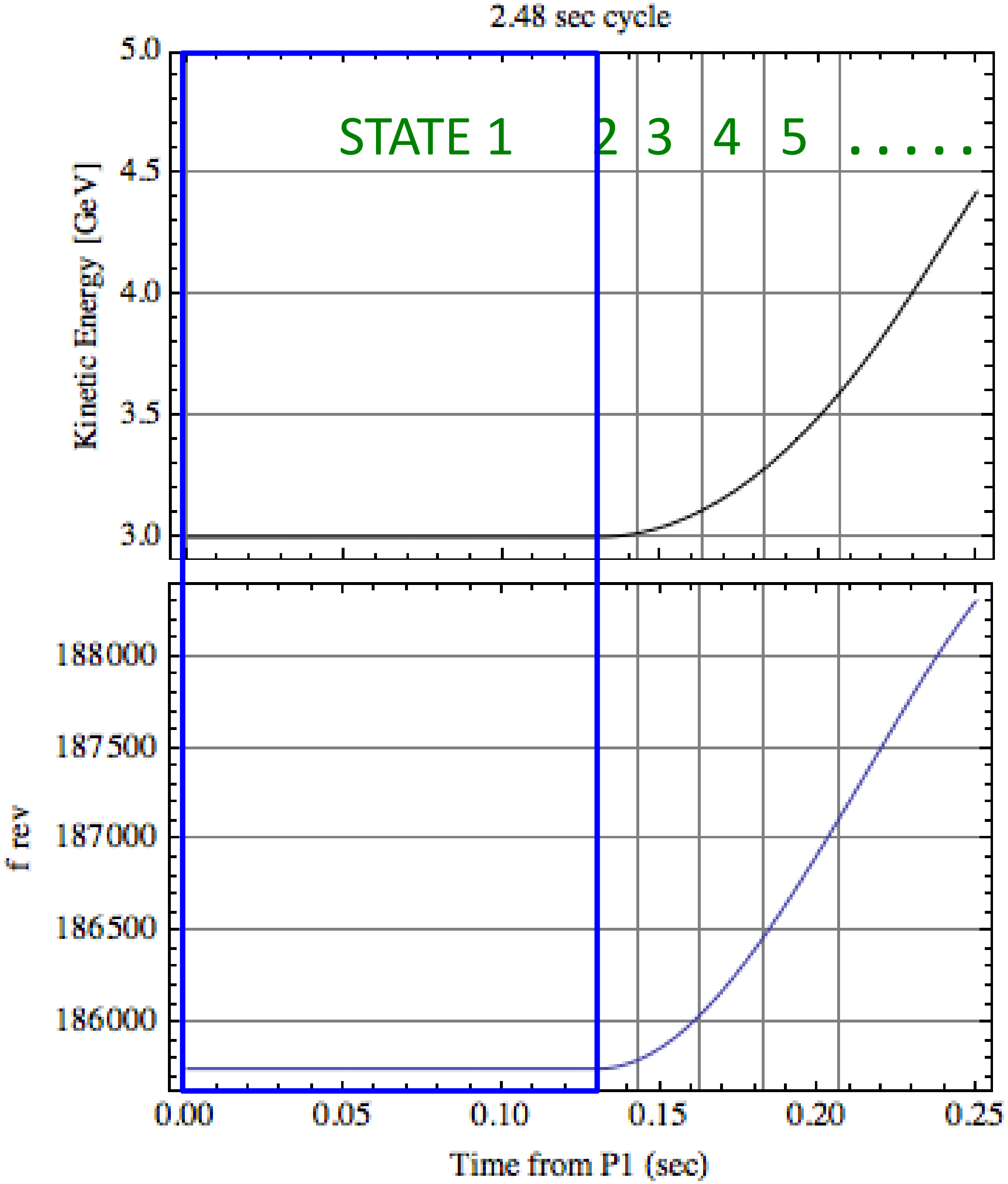

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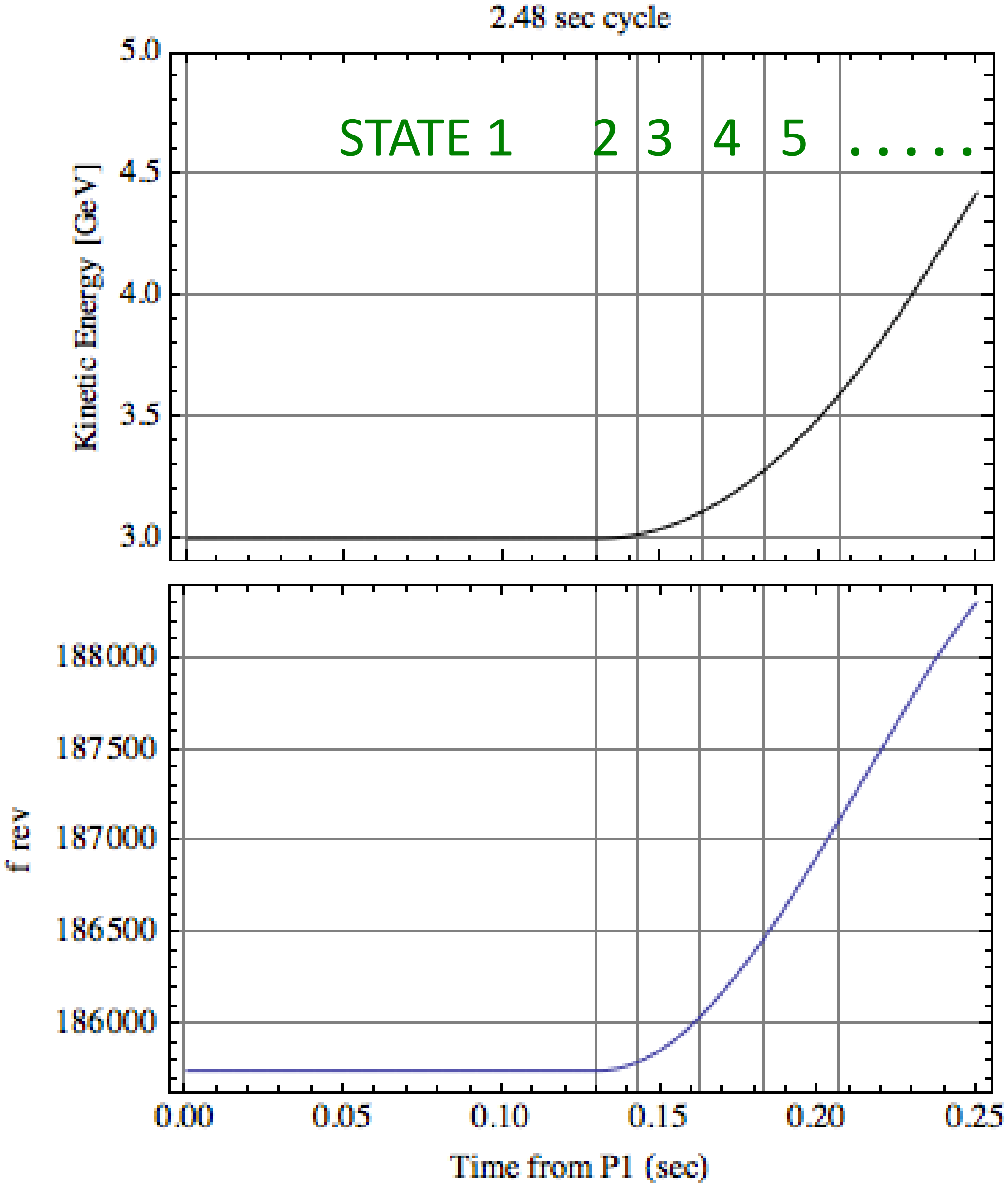

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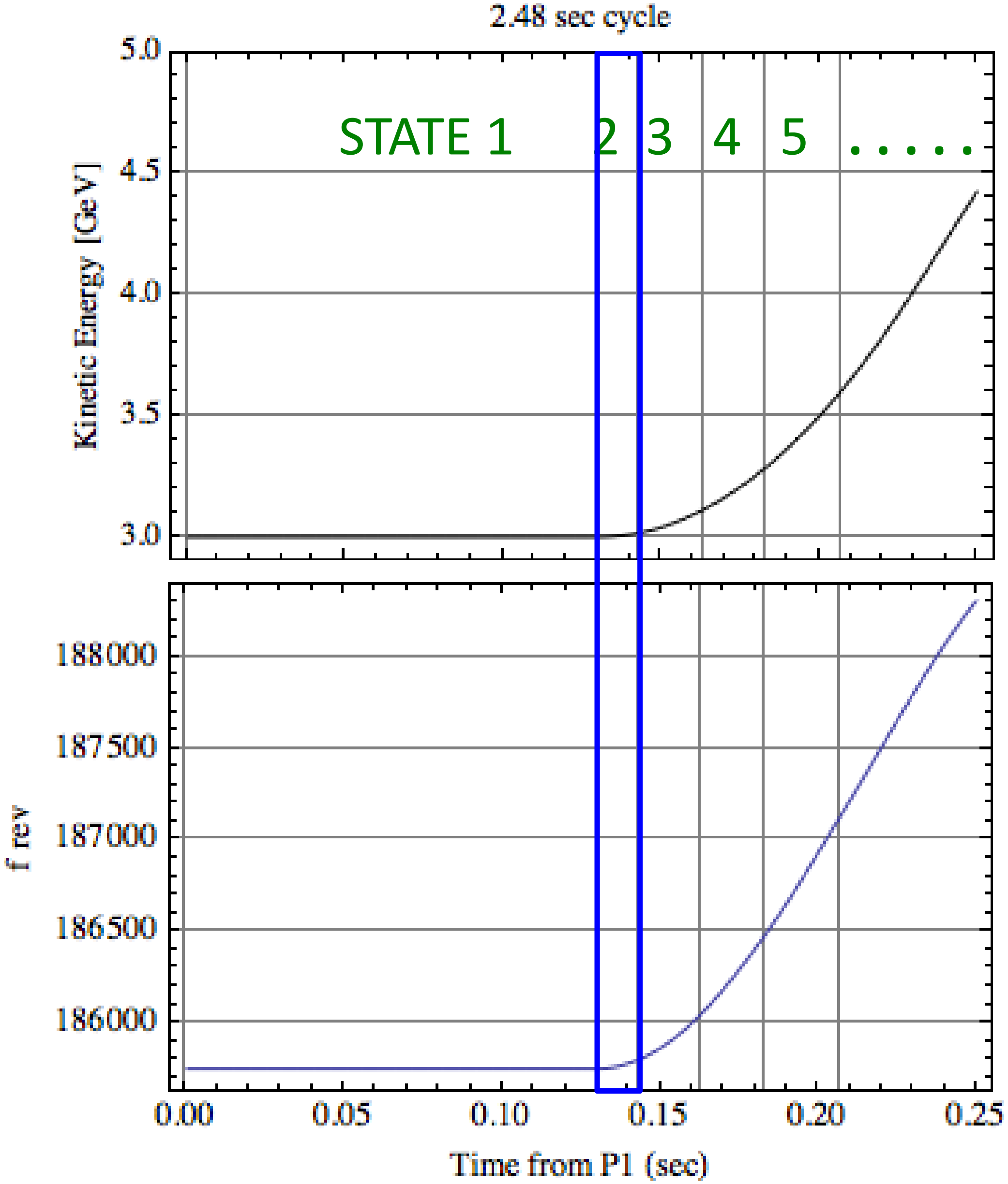

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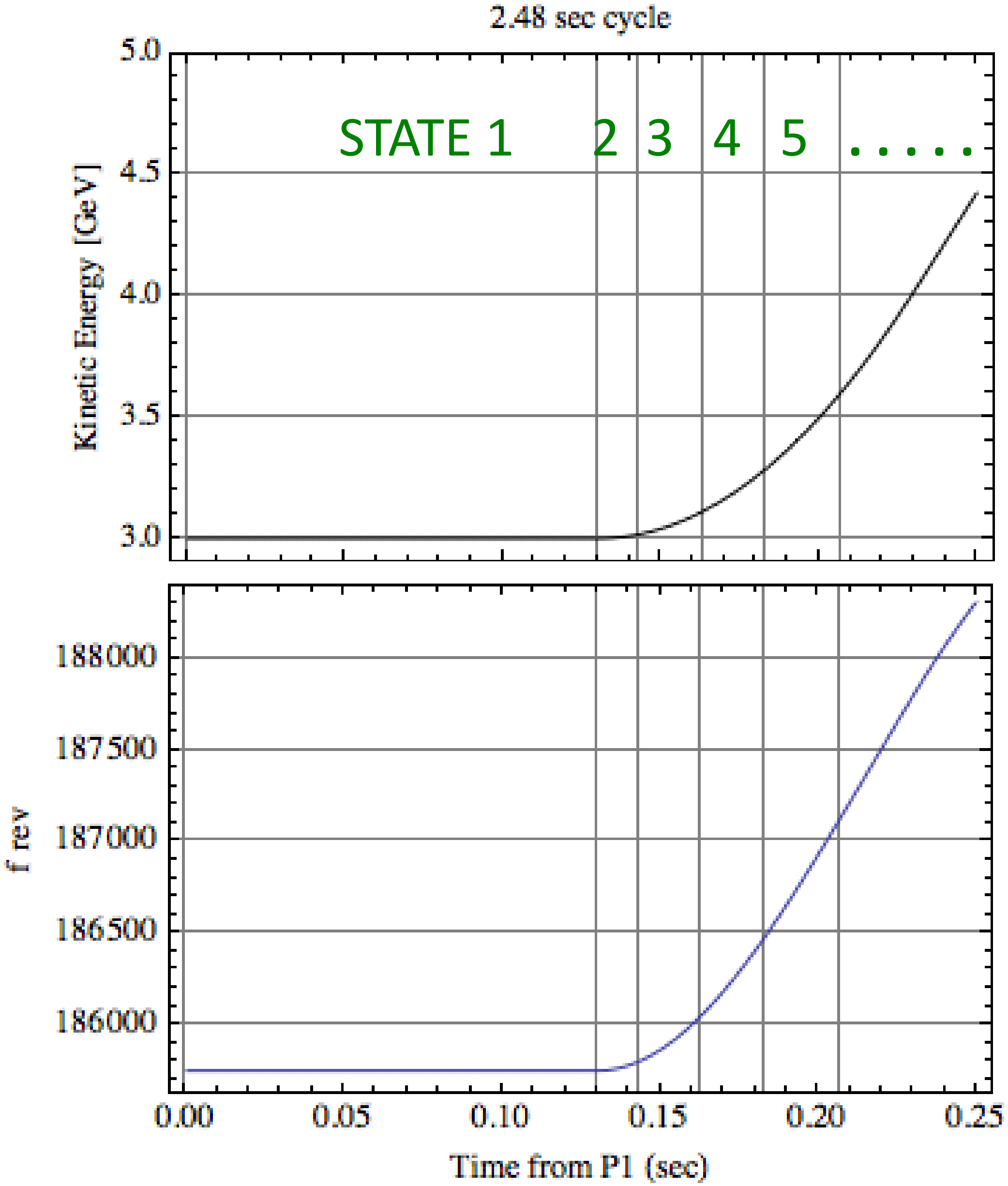

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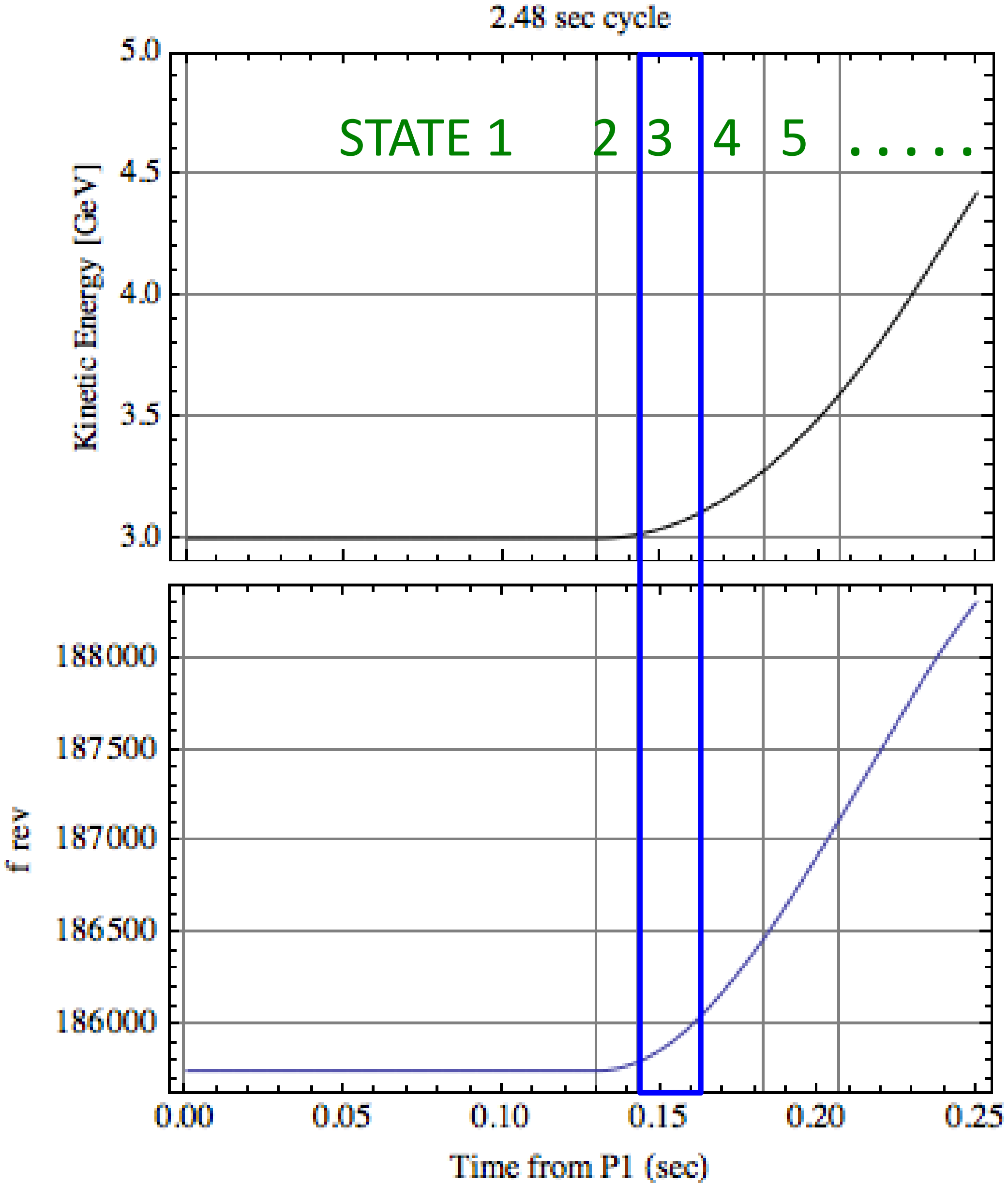

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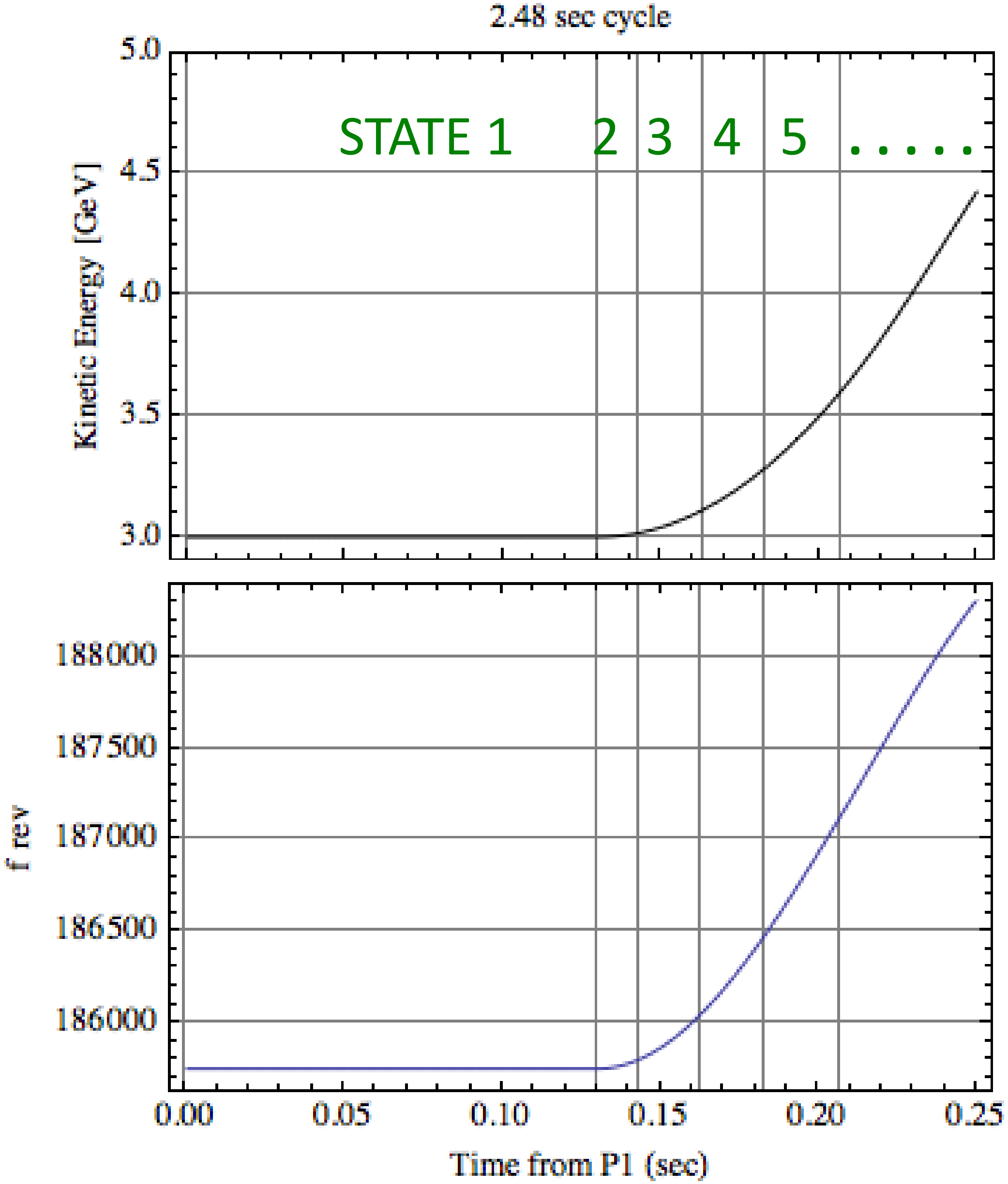

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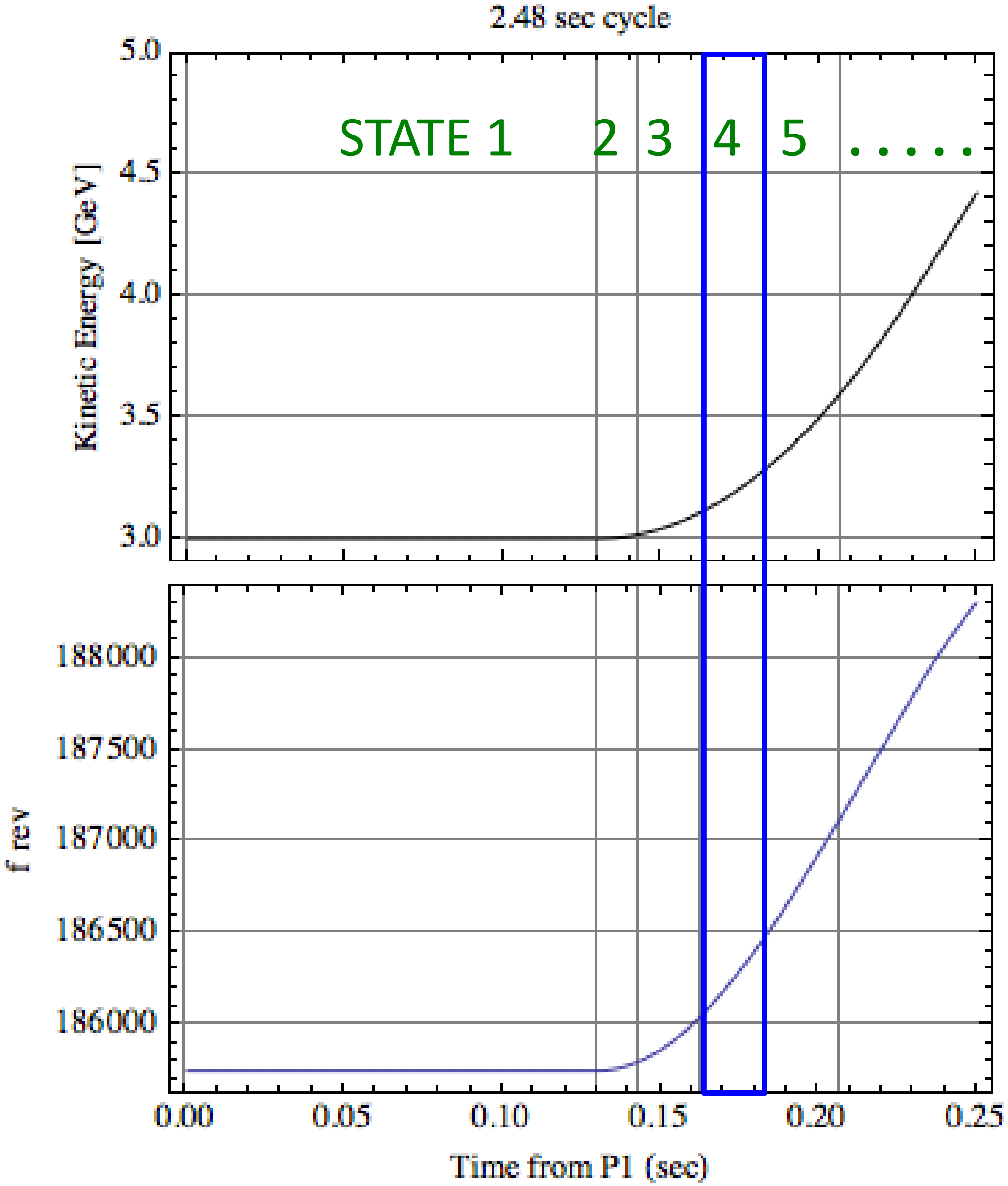
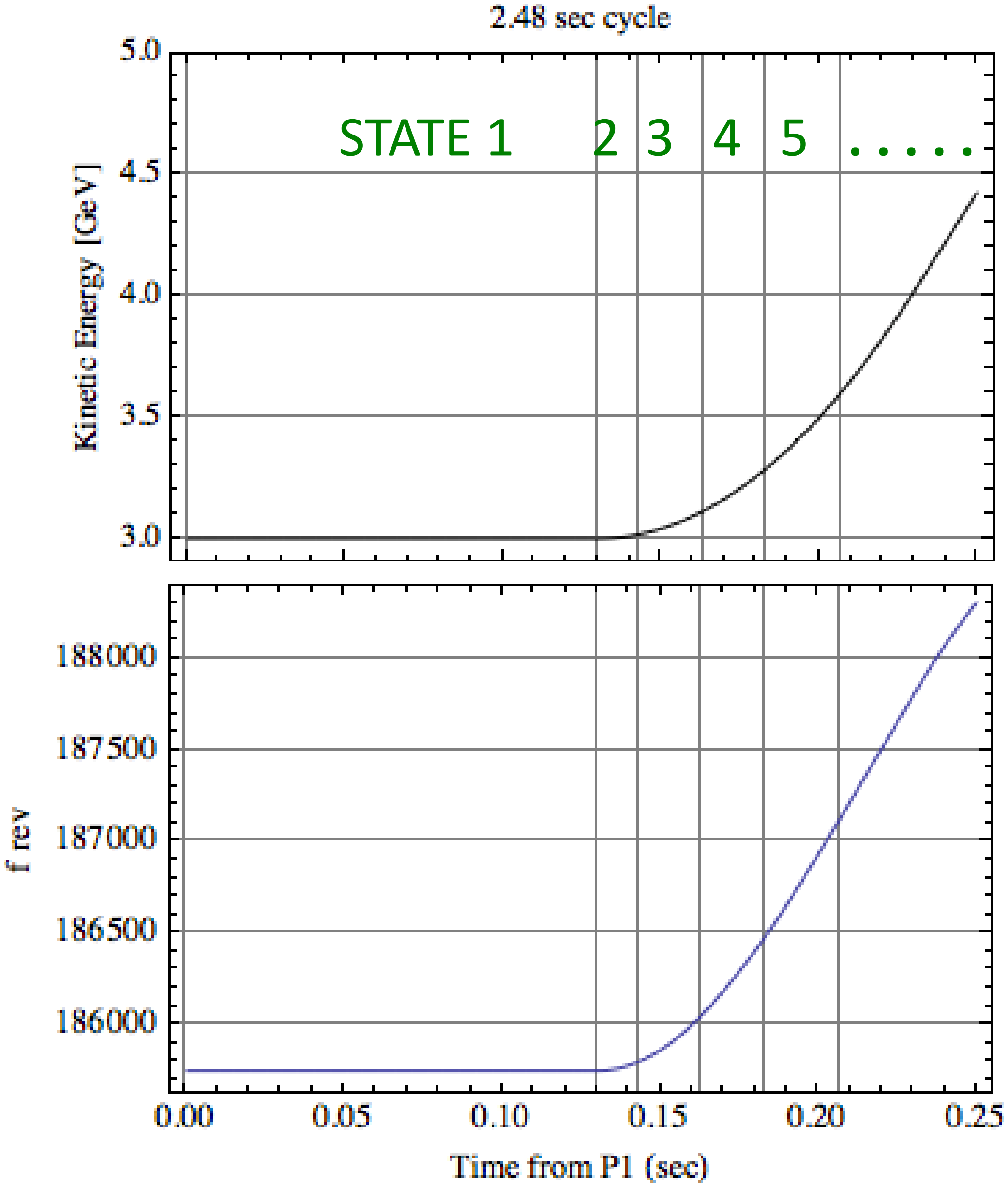


Timing CNTL by preset table



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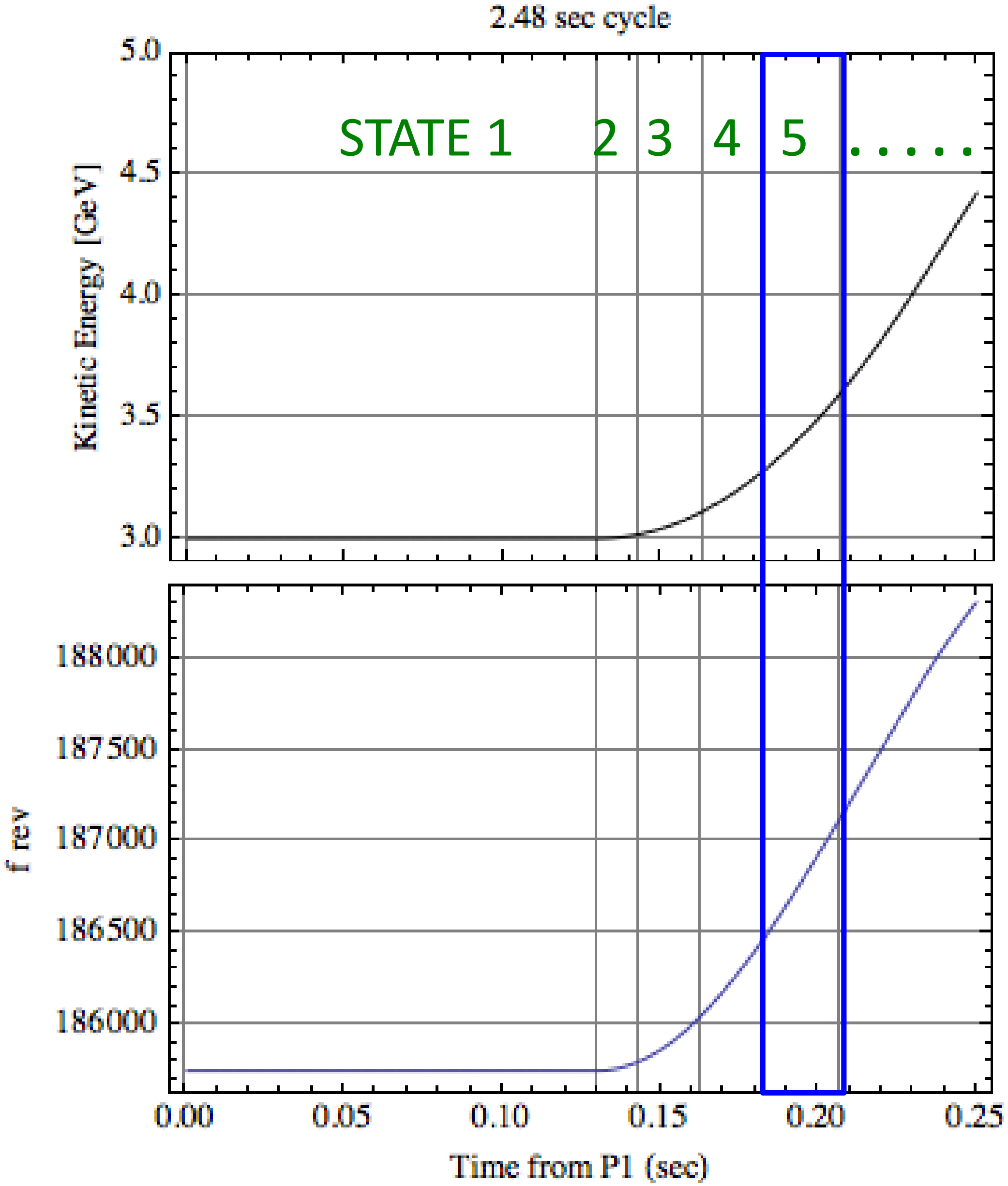
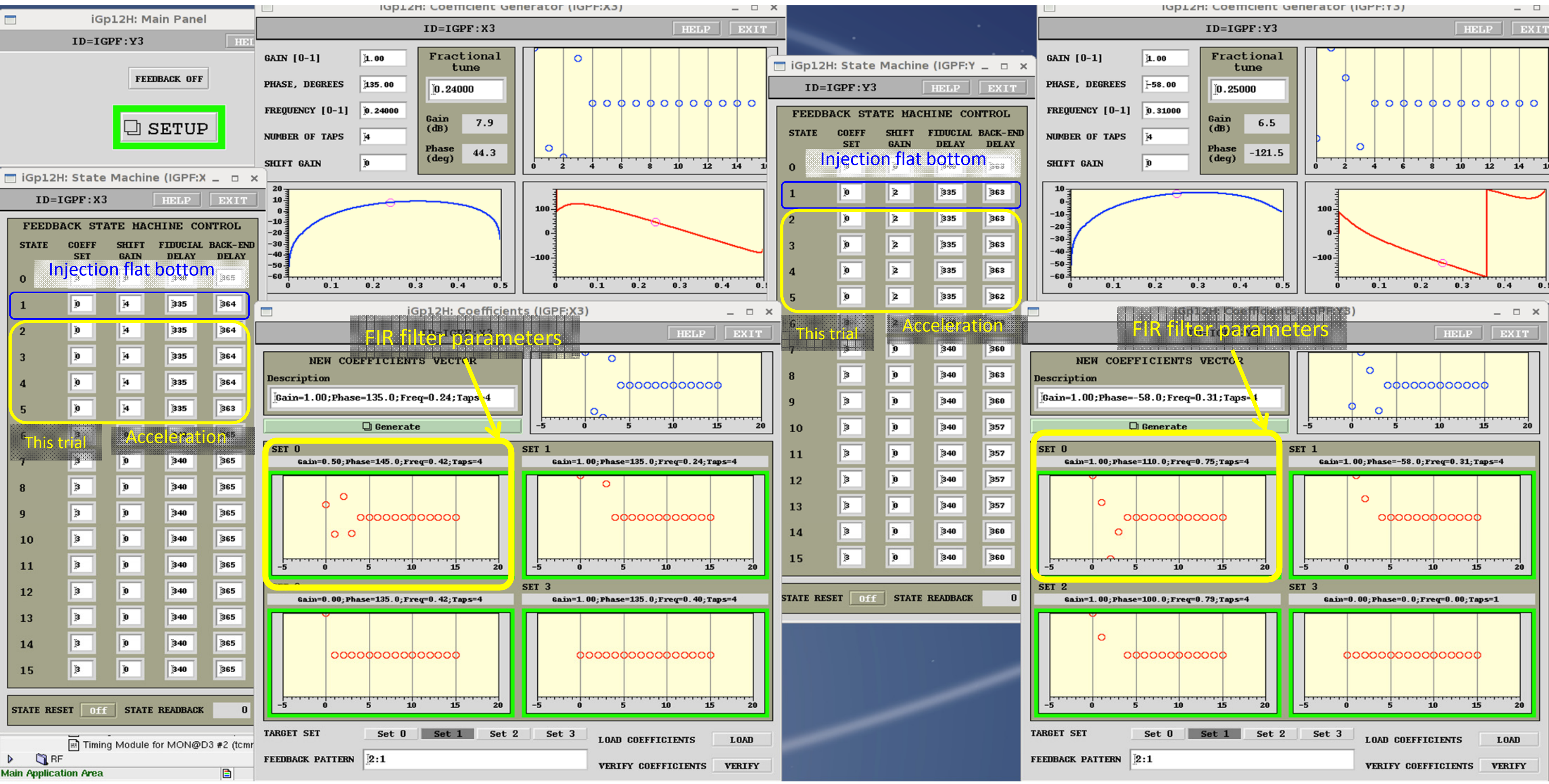


iGp12 parameter settings

X

Y

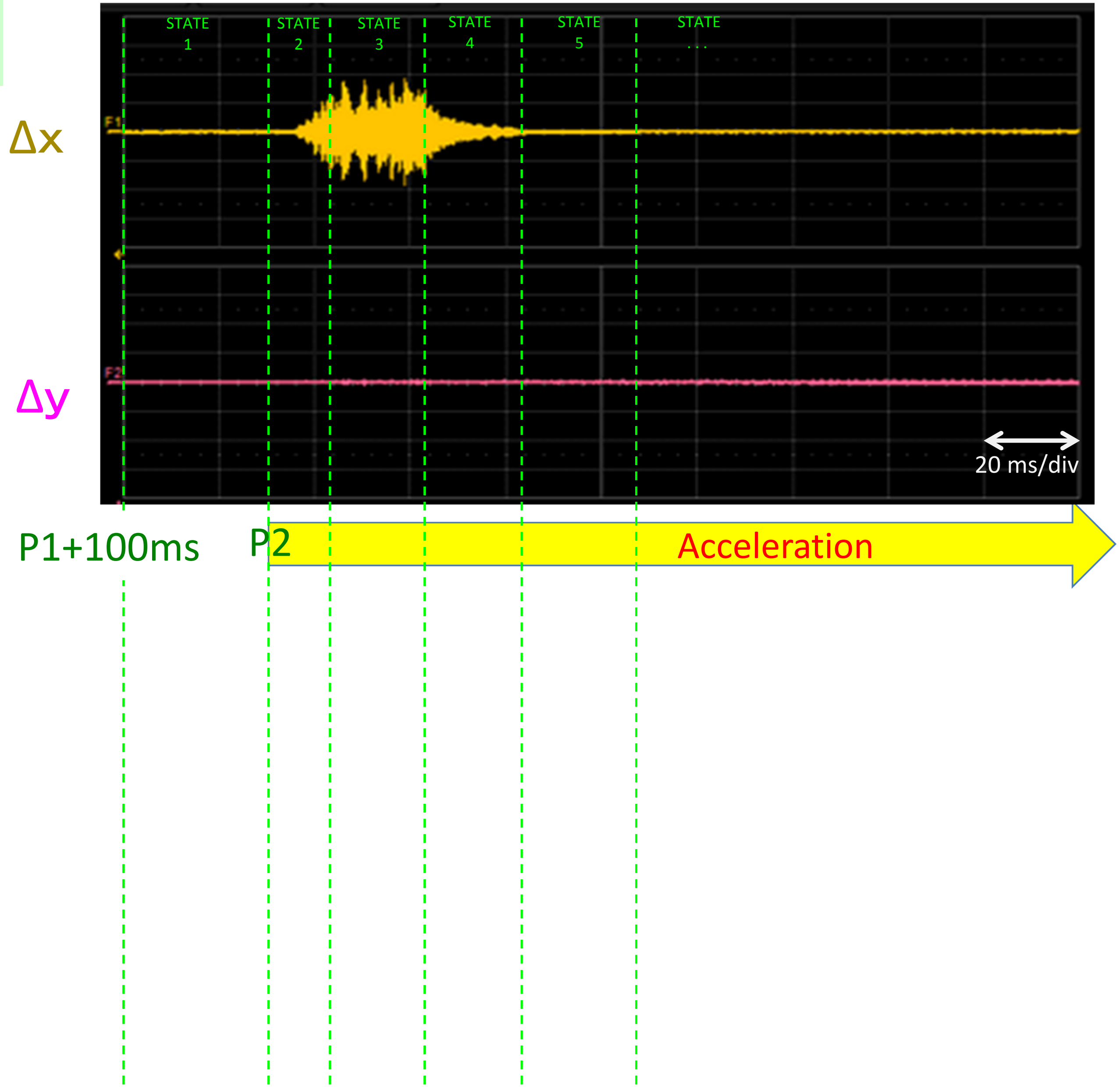


2015. 7. 1
2 bunches, ~80kW, ~4.2x10^{13} p

BEFORE

shot513300

$\xi x \sim -5.9$
$\xi y \sim -5.2$

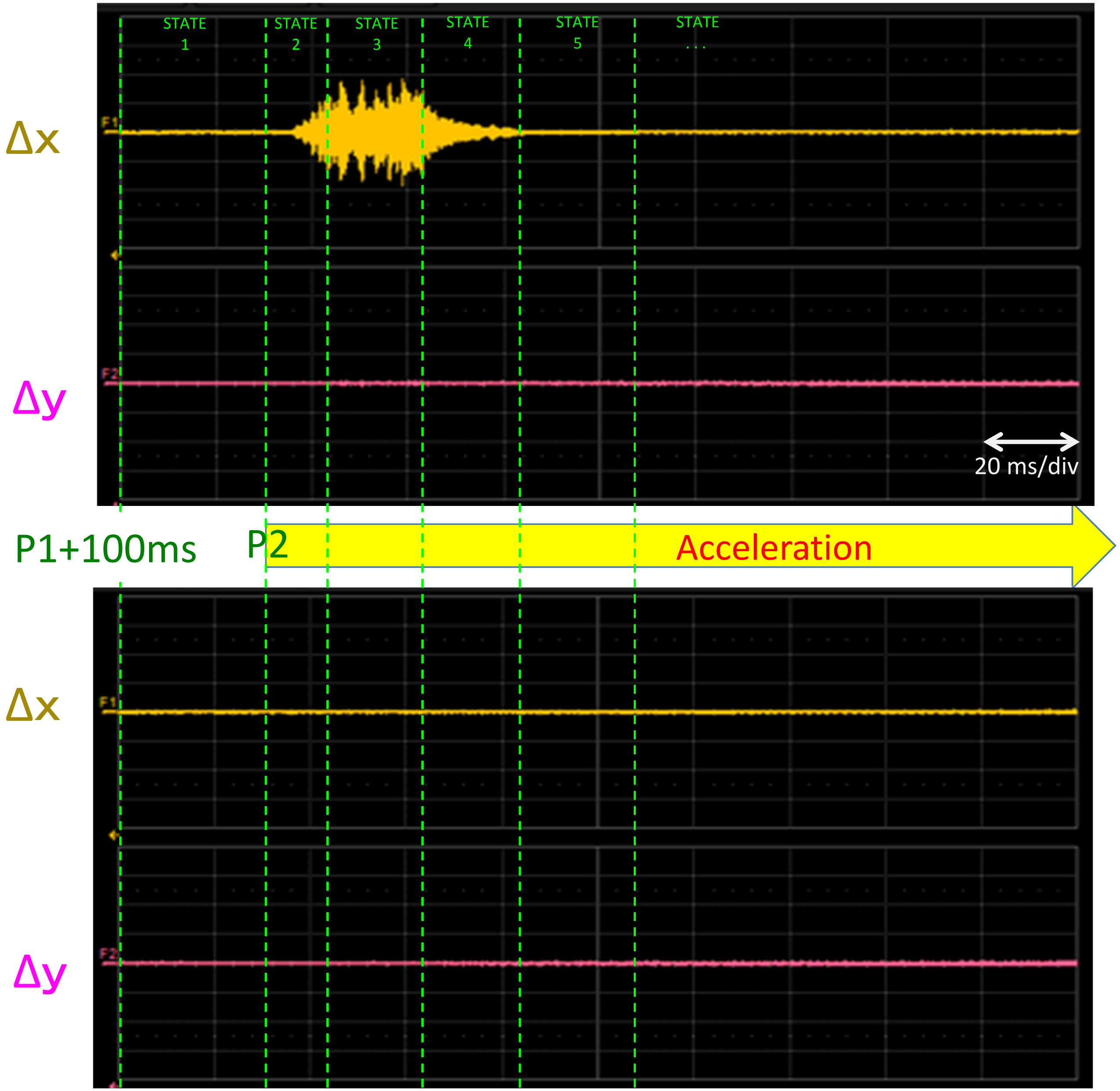


2015. 7. 1
2 bunches, ~80kW, ~$4.2x10^{13}$ p

BEFORE

shot513300

ξx ~ -5.9
ξy ~ -5.2



AFTER

shot513301

Stabilized
only by switching on
STATE 2

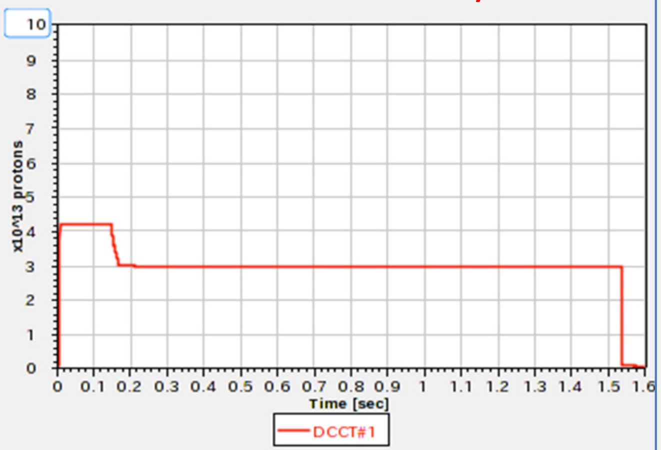
BEFORE

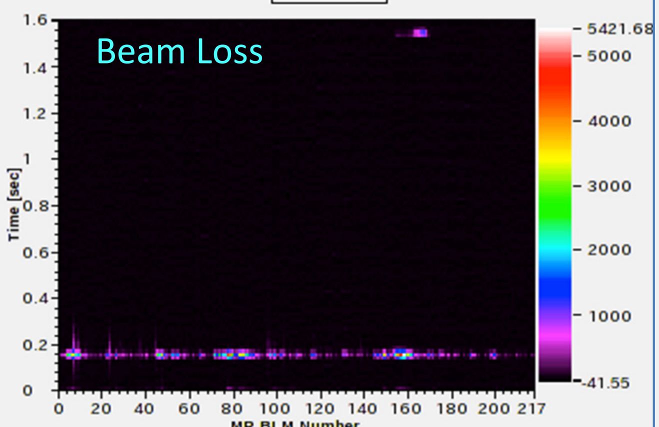
shot513300

15/07/01 01:28:44 Run

Run

Beam Intensity





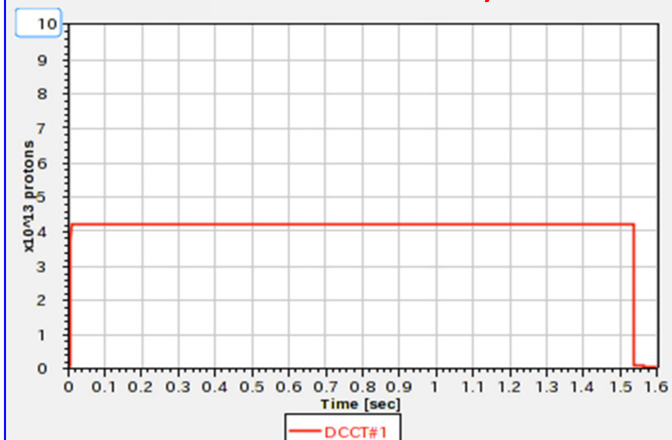
AFTER

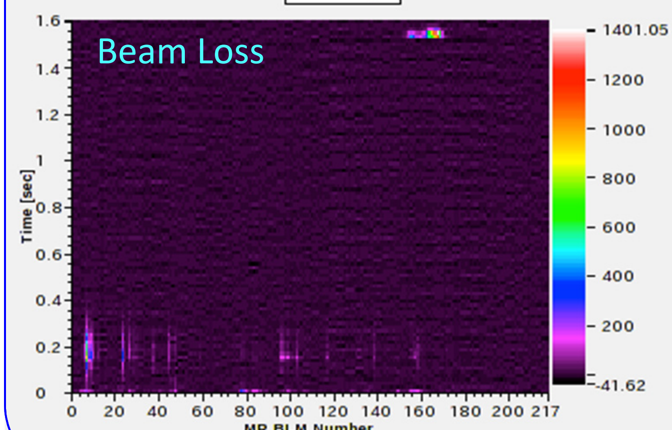
shot513301

15/07/01 01:31:42 Run

Run

Beam Intensity





ID=IGPF:X3 HELP EXIT

FEEDBACK STATE MACHINE CONTROL

STATE	COEFF SET	SHIFT GAIN	FIDUCIAL DELAY	BACK-END DELAY
0	3	0	340	365
1	0	4	335	364
2	0	4	335	364
3	3	4	335	364
4	3	4	340	365
5	3	0	340	365
6	3	0	340	365
7	3	0	340	365
8	3	0	340	365
9	3	0	340	365
10	3	0	340	365
11	3	0	340	365
12	3	0	340	365
13	3	0	340	365
14	3	0	340	365
15	3	0	340	365

STATE RESET Off STATE READBACK 0

Summary

✓Transverse intra-bunch feedback **during acceleration period** was successful **upto P2 + ~80 ms**.

- Horizontal instability at the beginning of acceleration was suppressed.
- Stable parameters (delay, gain, frequency) are obtained

Prospect

- Further parameter optimization for further accel. period
- Stability check both with experiments and simulations
- Contribute high beam intensity upgrade