



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

Takeshi Toyama  
KEK / J-PARC

*IBIC2015, Sep 12-17 2015, Melbourne Australia*



# Collaborators



Keigo Nakamura  
Kyoto University



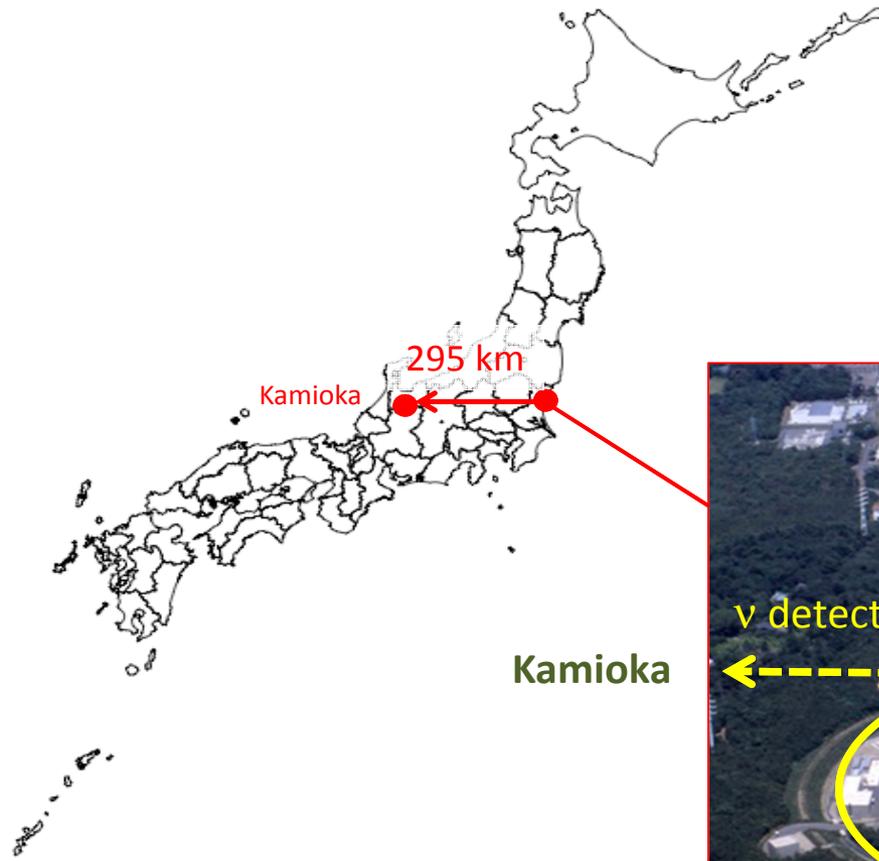
Makoto Tobiyaama, Masashi Okada,  
Yong Ho Chin, Takashi Obina, Tadashi Koseki  
KEK



Yoshihiro Shobuda  
JAEA

# Japan Proton Accelerator Research Complex

Tokai, Ibaraki



Kamioka





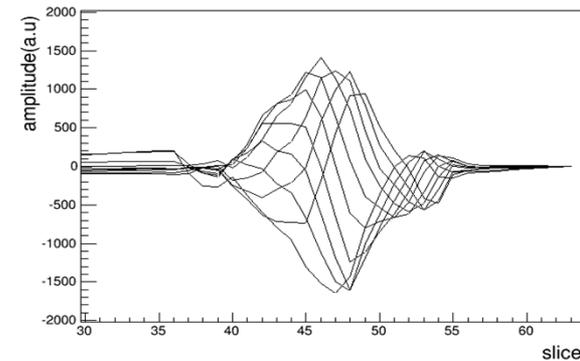
# Outline

- **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 5.384 $\mu$ s(185.7kHz) RF 1.67MHz
- Revolution at extraction 5.231 $\mu$ s(191.2kHz) RF 1.72MHz
- Harmonic number 9
- Repetition time for fast extraction 2.5 s

Transverse oscillation  
without FB



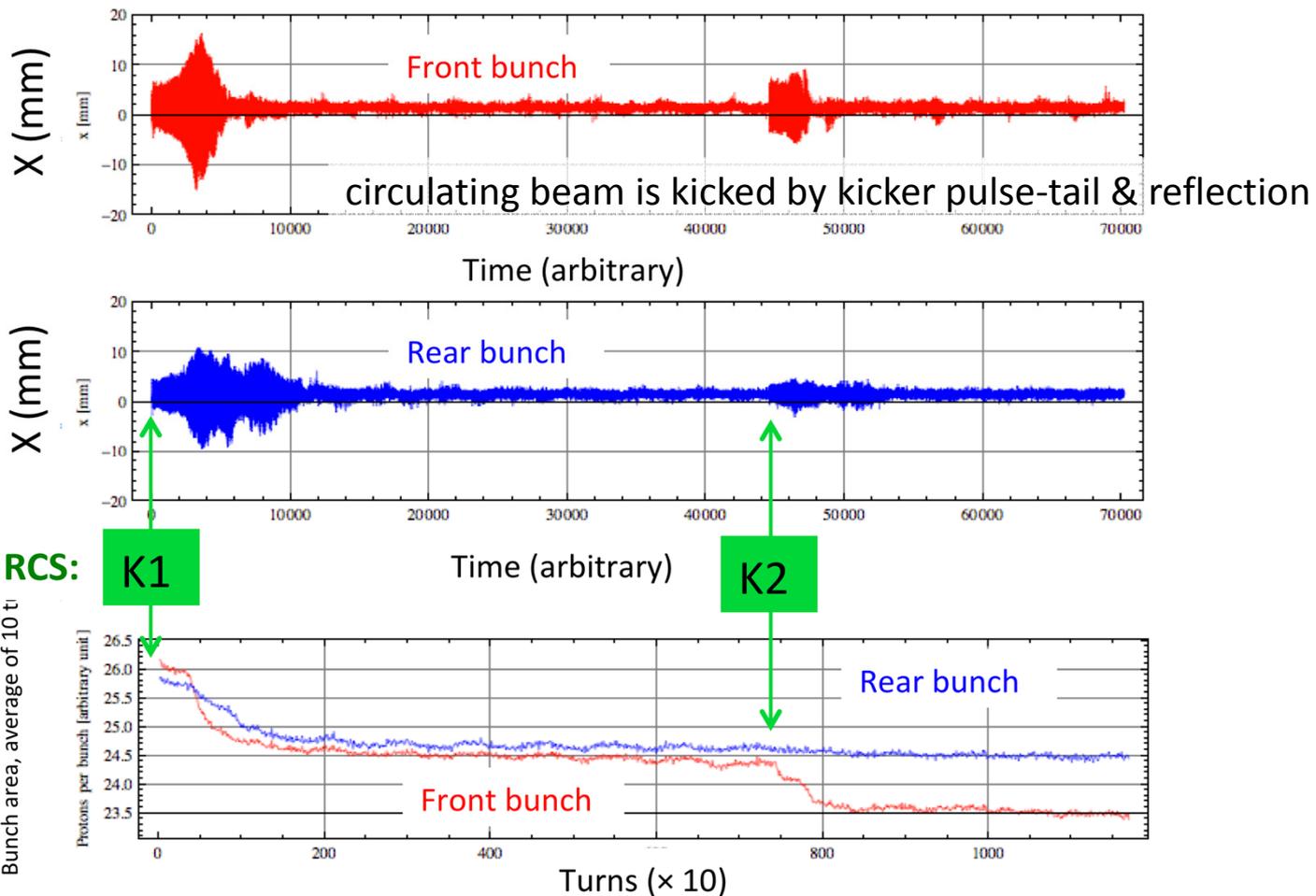
## At high beam power

- 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  
 $\xi_x \sim -7.5$   
 $\xi_y \sim -7.0$



Injection from the RCS:

Intensity

Bunch area, average of 10 t

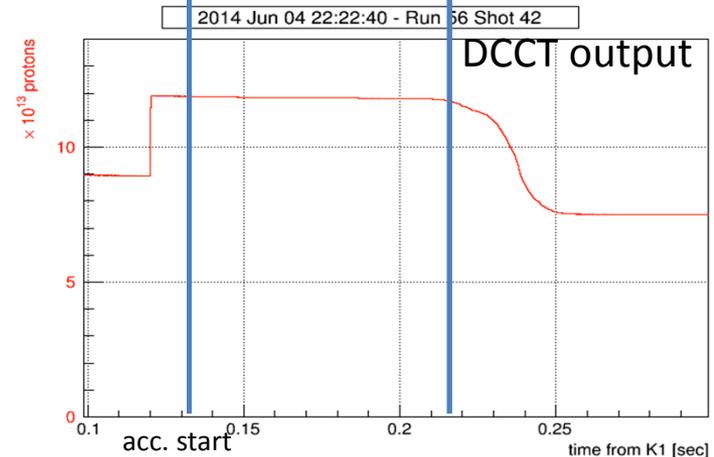
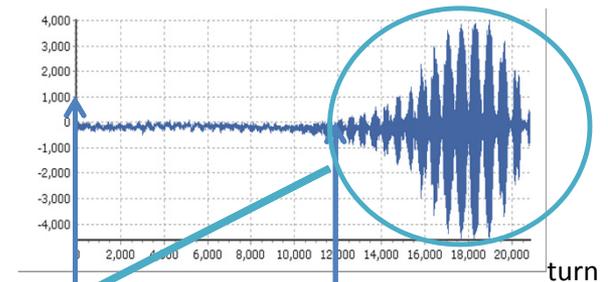
## (2) Instability during acceleration

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

Observed bunch motion

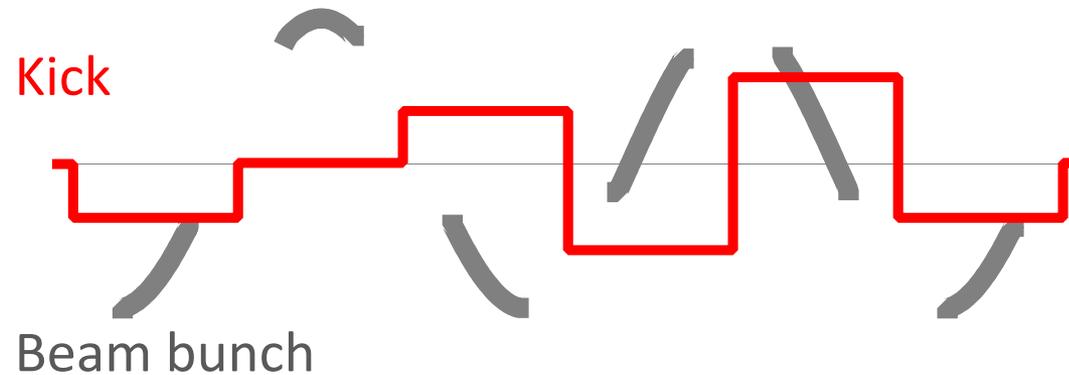


Vertical betatron oscillation amplitude



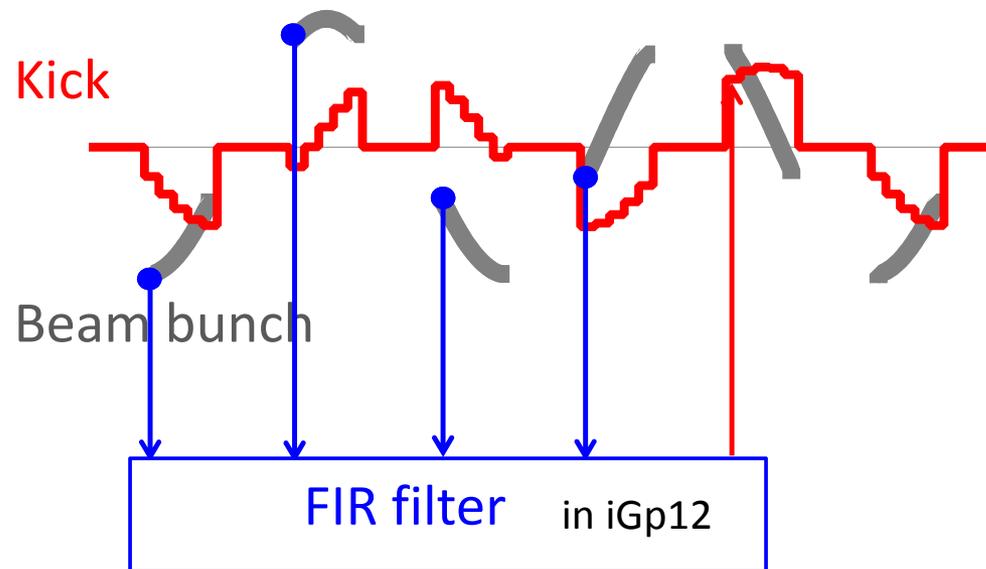
# B x B feedback

Bunch-by-bunch (BxB) feedback  
slice  $\sim 590$  ns



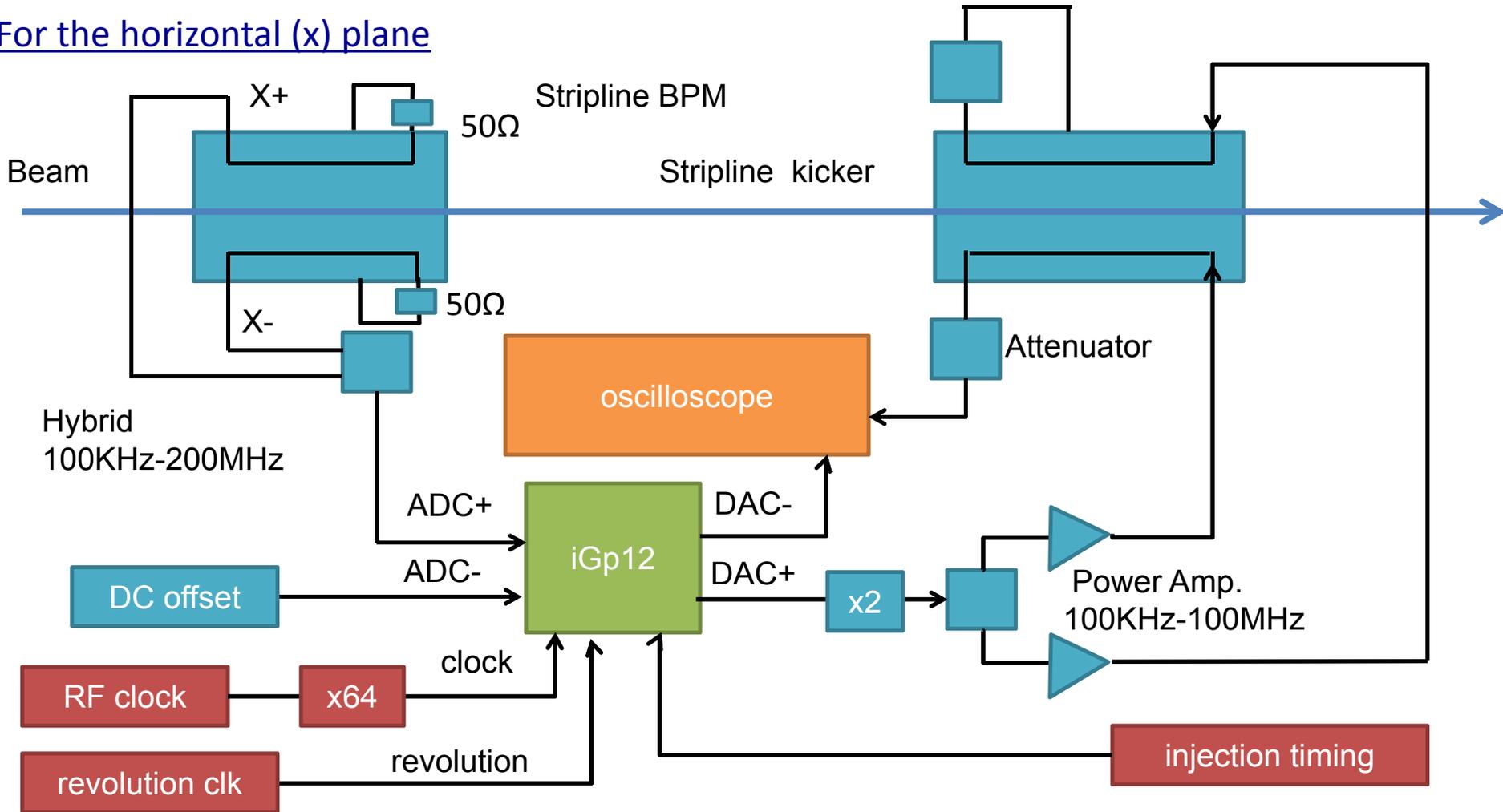
# Intra-bunch feedback

Intra-bunch feedback  
slice  $\sim 10$  nsec



# Schematic view

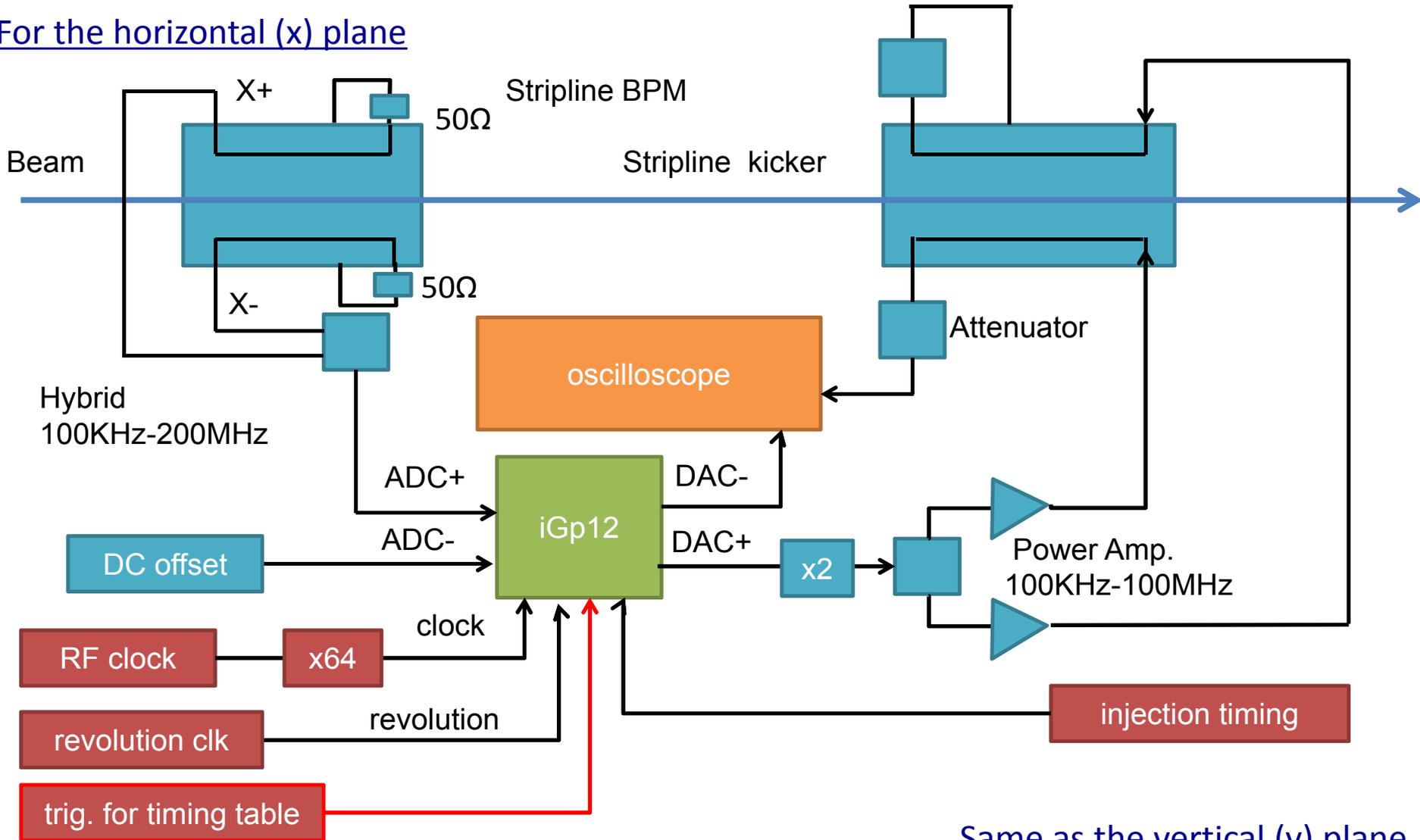
For the horizontal (x) plane



Same as the vertical (y) plane

# Schematic view

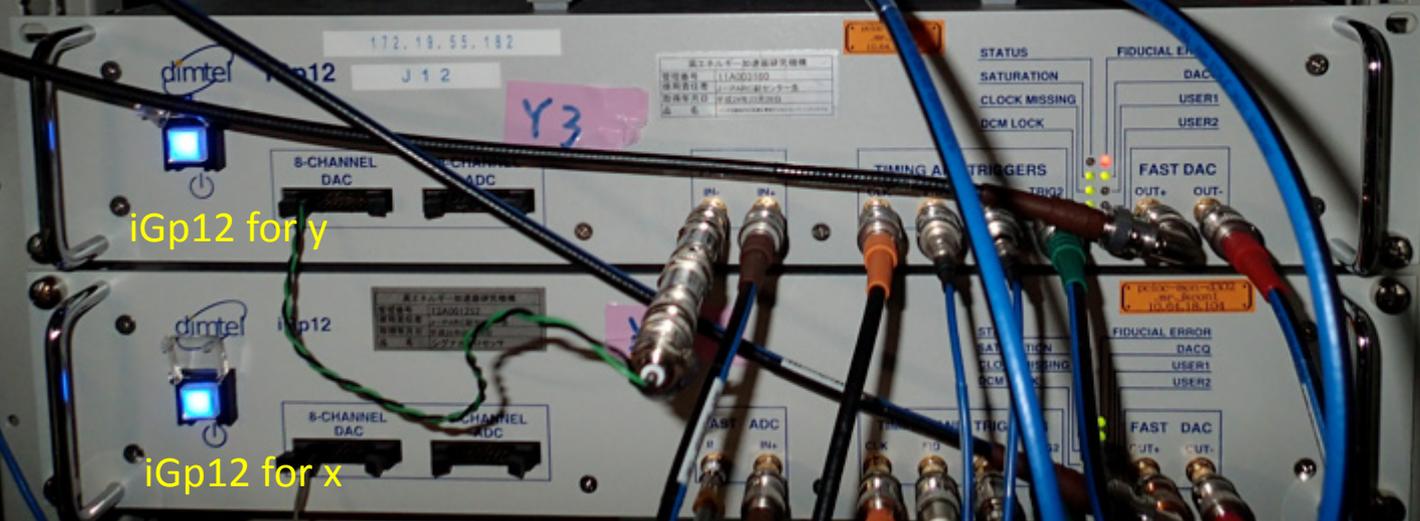
For the horizontal (x) plane



Same as the vertical (y) plane



Trigger  
for timing table



iGp12 for y

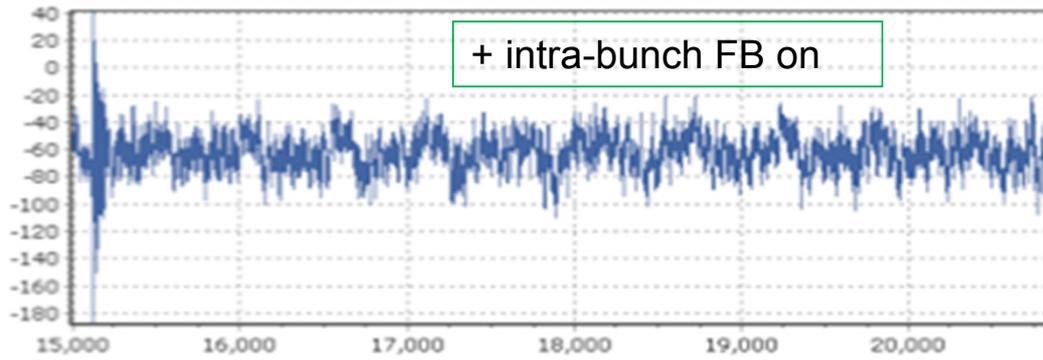
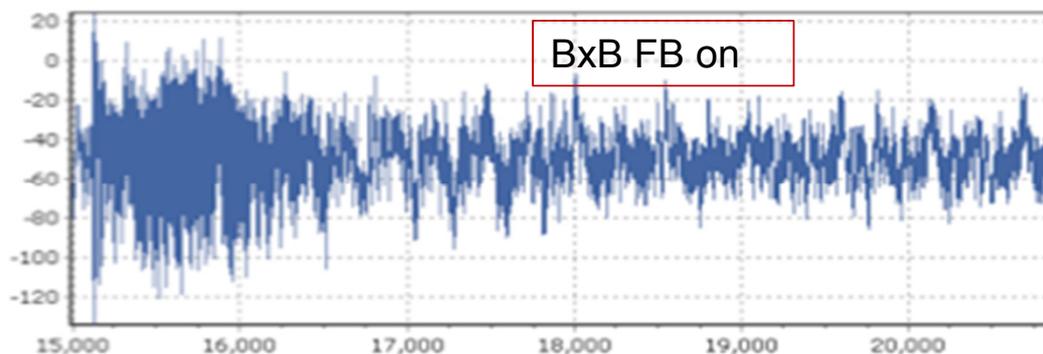
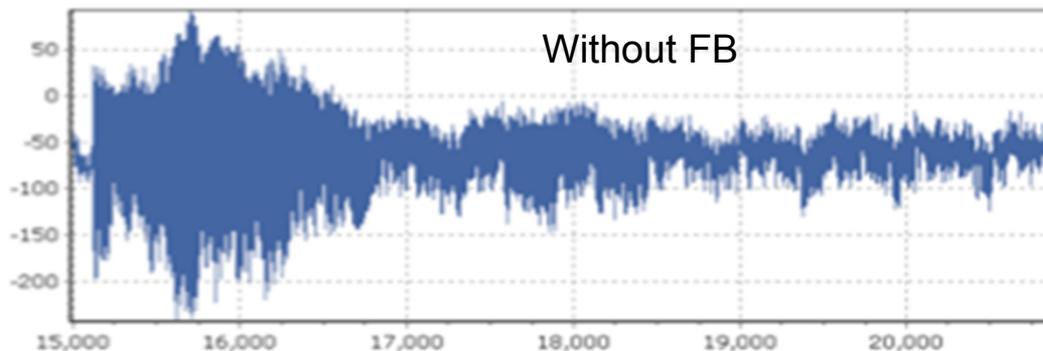
iGp12 for x

STATUS	FIDUCIAL ERROR
SATURATION	DACQ
CLOCK MISSING	USER1
DCM LOCK	USER2
TIMING AND TRIGGERS	FAST DAC
TRIG1	OUT+
TRIG2	OUT-

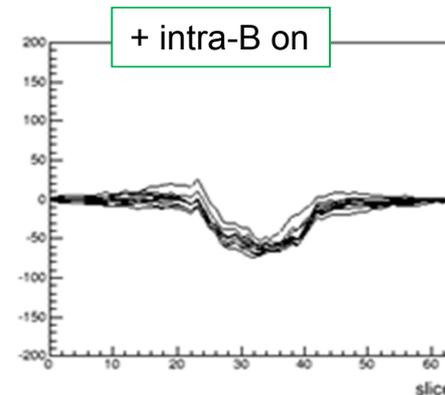
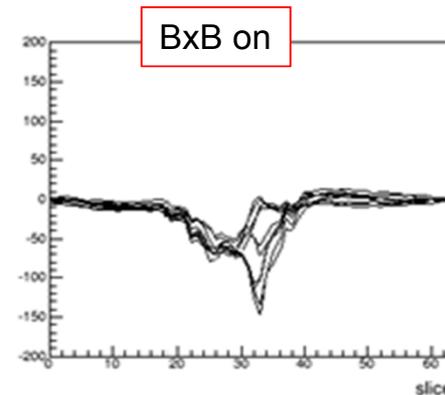
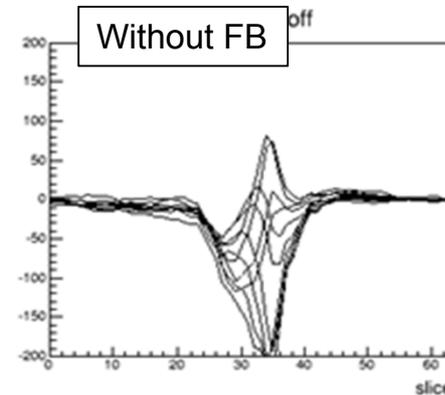
2015/01/13

# 3 GeV injection flat bottom

## Oscillation of one bunch slice

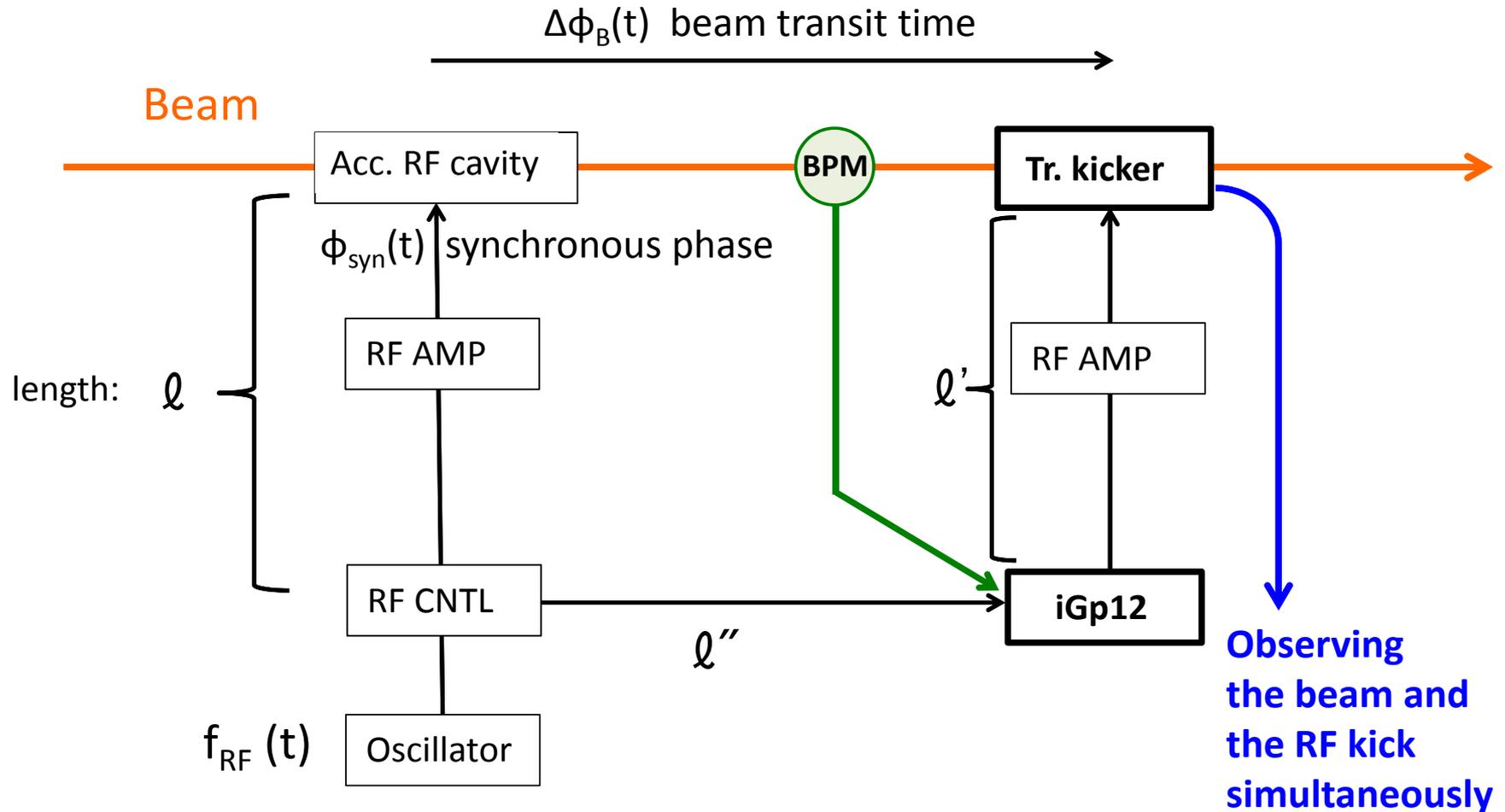


## Bunch signal every 5 turns

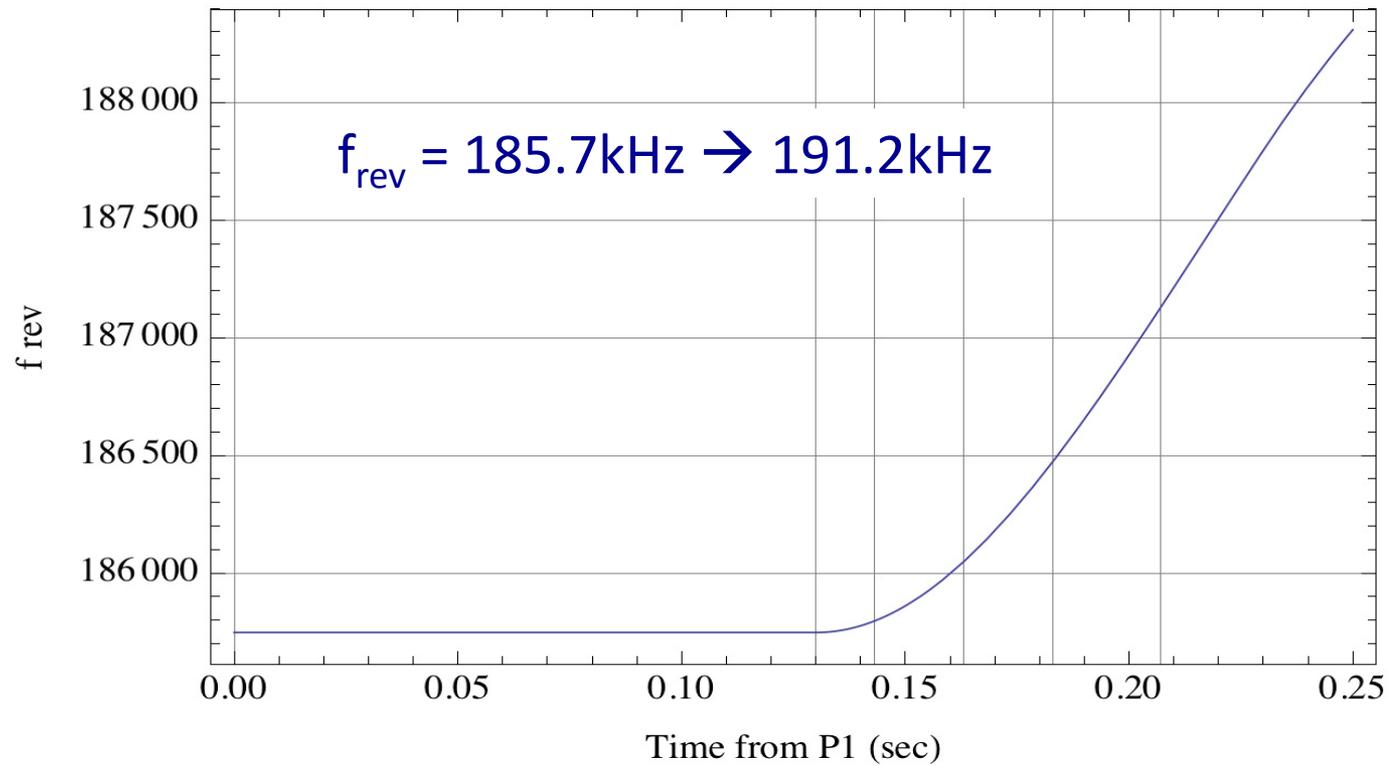


# Timing slip

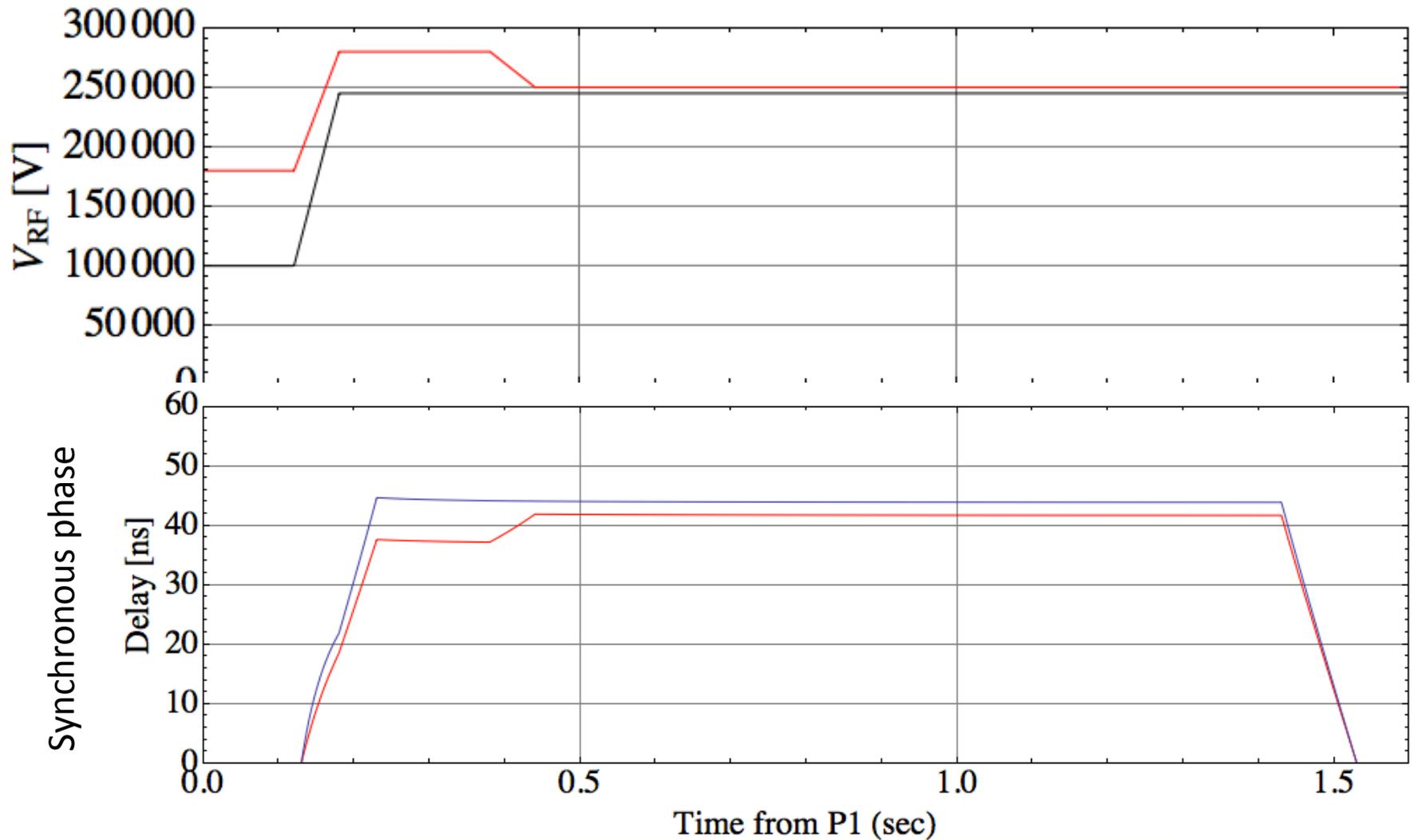
Parameters are changing during acceleration upto 30 GeV



## Example of revolution frequency



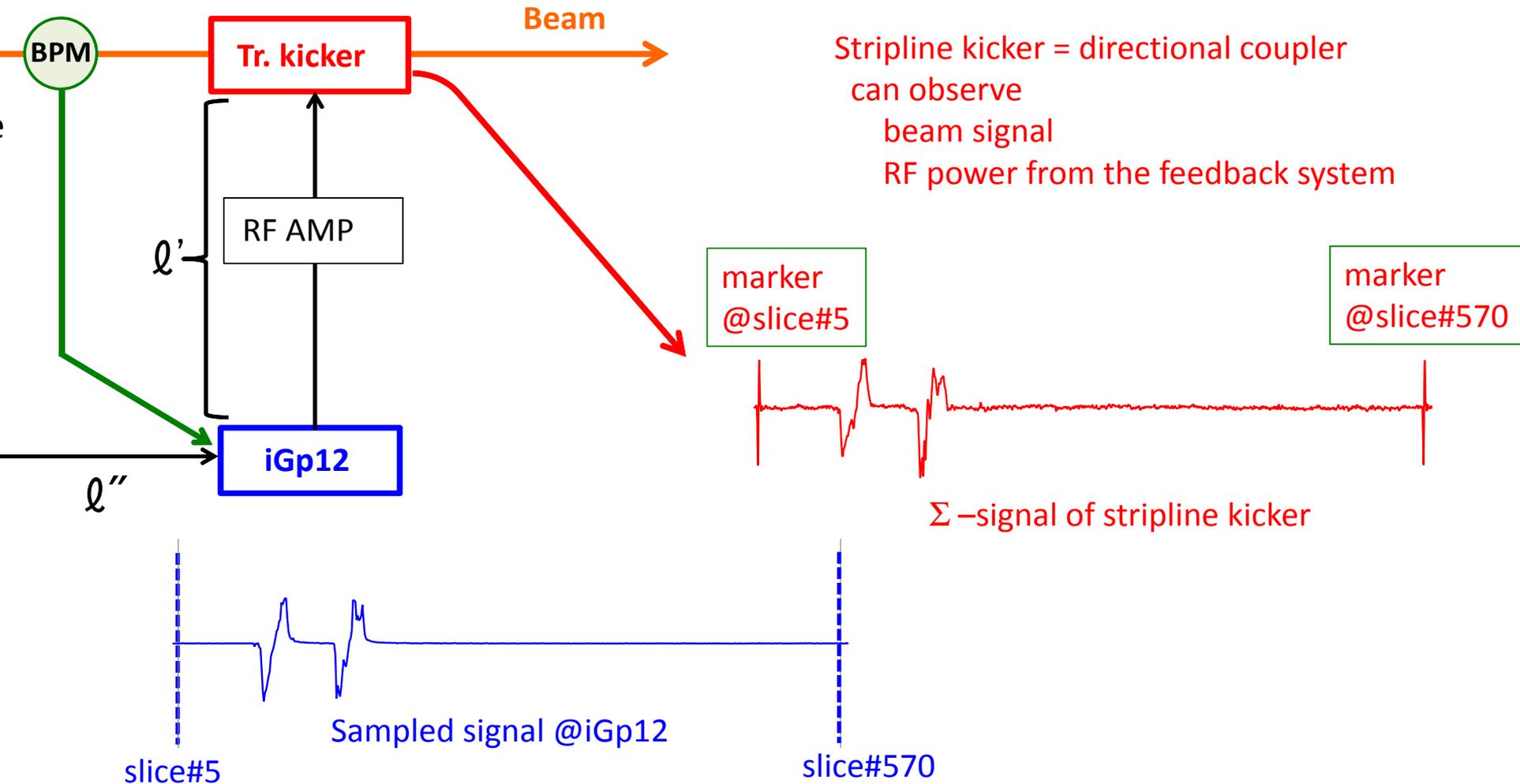
## Example of synchronous phase



We need rapid parameter optimization

# Sampled by iGp12 ← Compare → signals on the stripline kicker

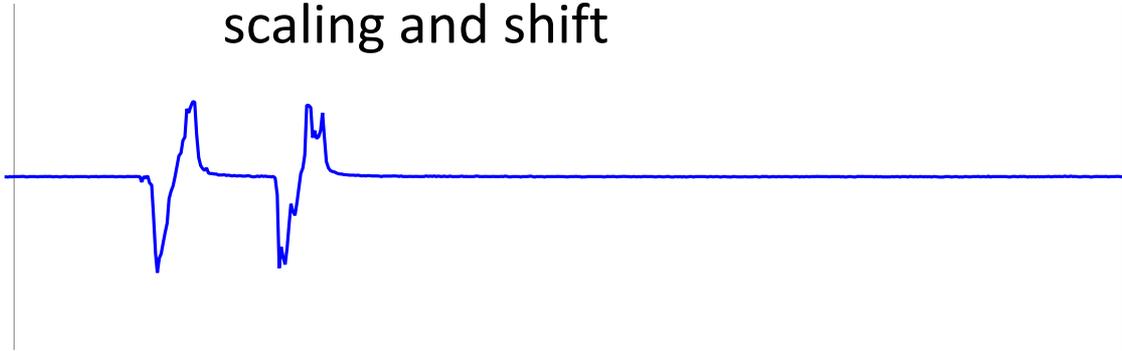
$\Delta\phi_B(t)$  beam transit time





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

Referencing the marker #5, 570  
scaling and shift

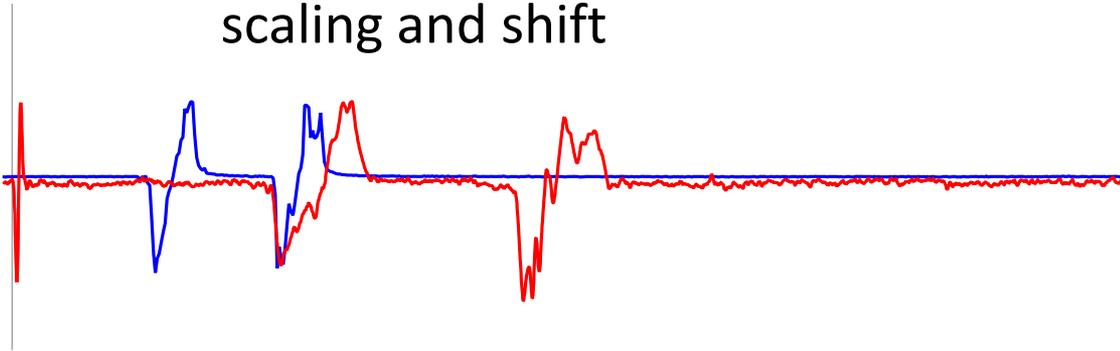


Unit in iGp12  
**RF CLK x 64**



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

Referencing the marker #5, 570  
scaling and shift

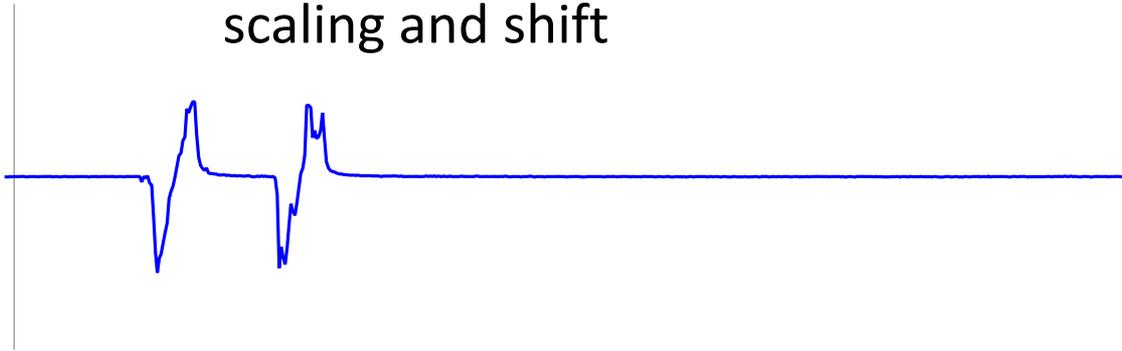


Unit in iGp12  
RF CLK x 64



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

Referencing the marker #5, 570  
scaling and shift



Unit in iGp12  
**RF CLK x 64**



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

Referencing the marker #5, 570  
scaling and shift

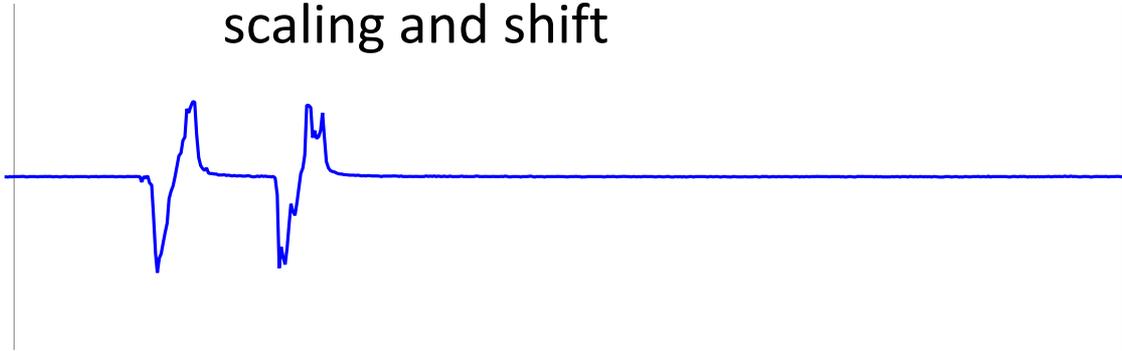


Unit in iGp12  
**RF CLK x 64**



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

Referencing the marker #5, 570  
scaling and shift

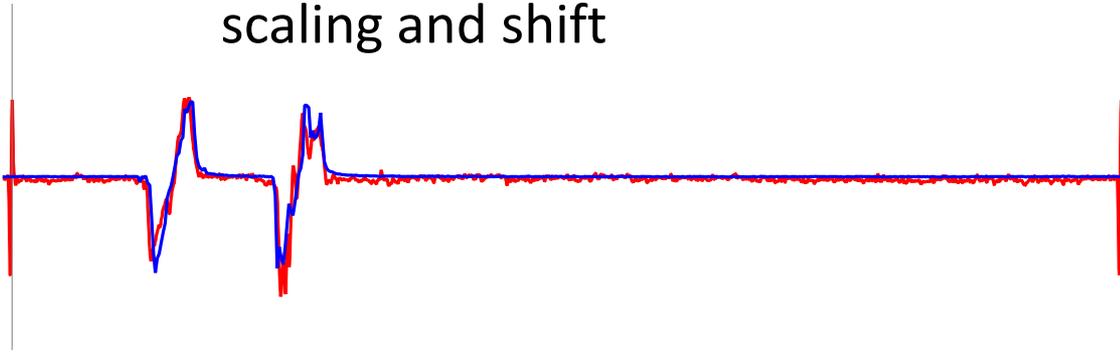


Unit in iGp12  
**RF CLK x 64**



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

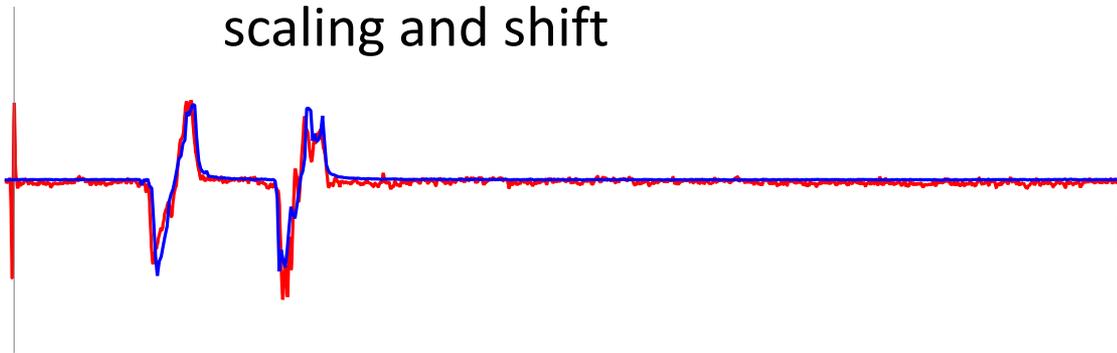
Referencing the marker #5, 570  
scaling and shift



Unit in iGp12  
RF CLK x 64

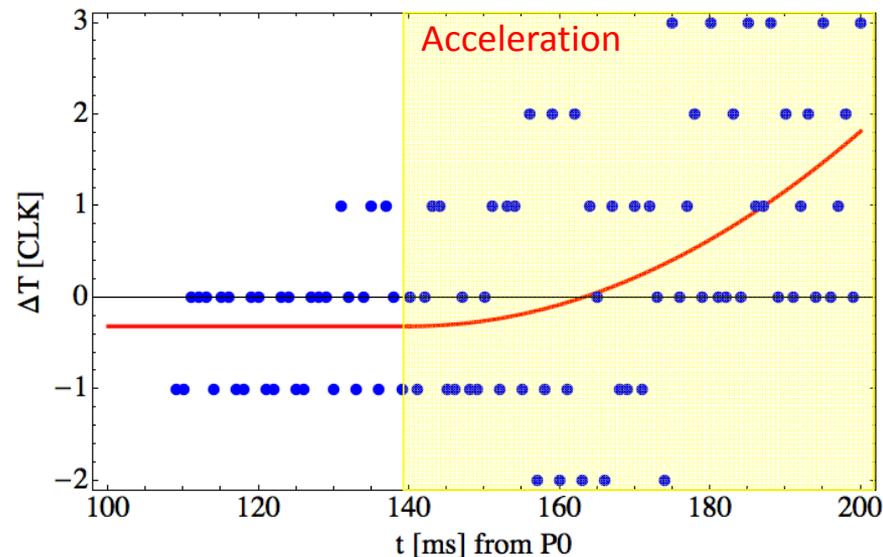
Unit in oscilloscope (kicker) = **time (sec)**

Referencing the marker #5, 570  
scaling and shift



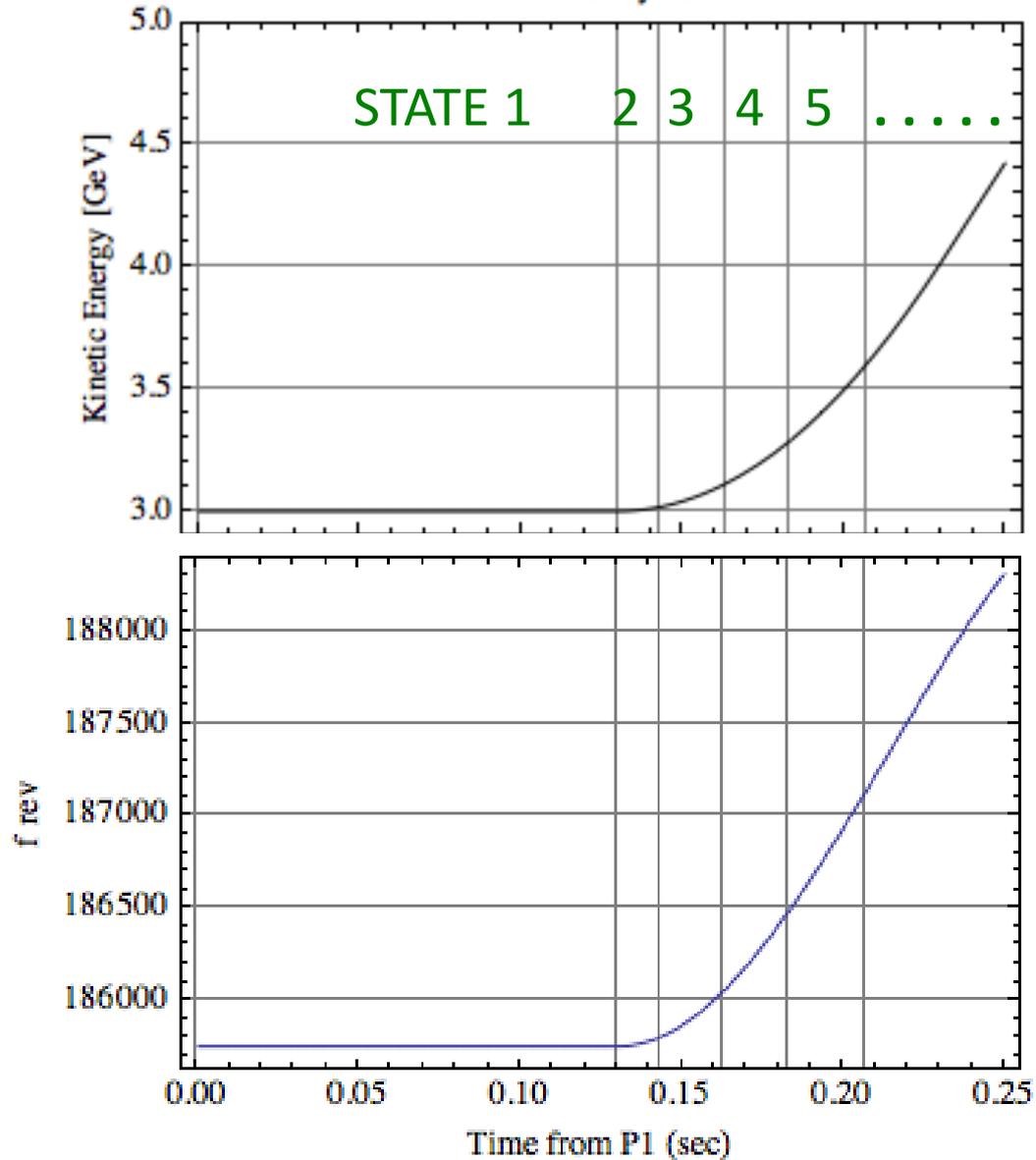
Unit in iGp12  
RF CLK x 64

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

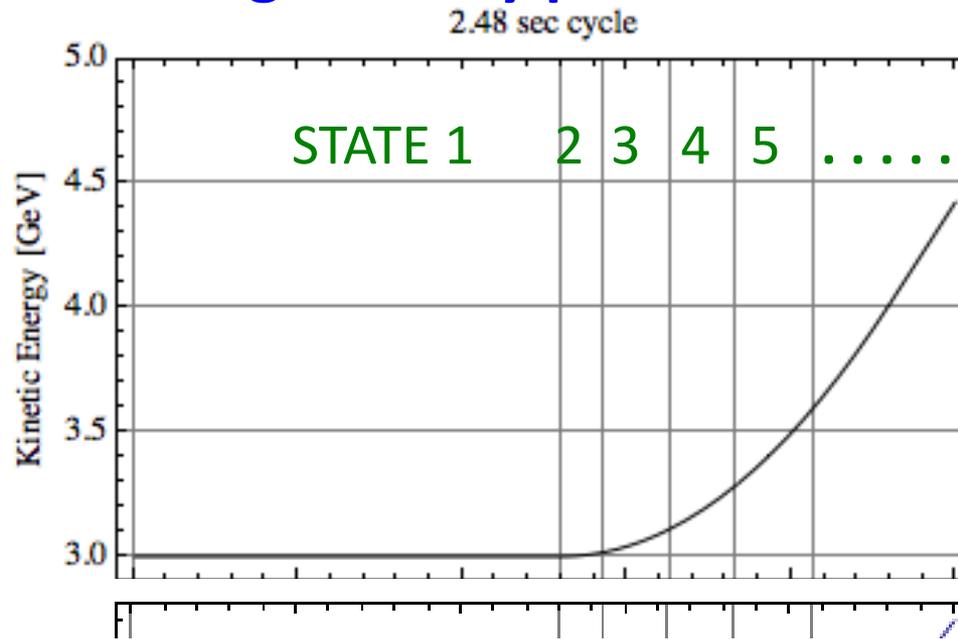


# Timing CNTL by preset table

2.48 sec cycle



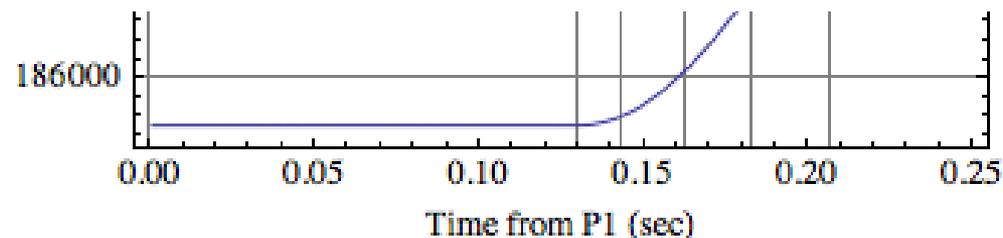
## Timing CNTL by preset table



External trigger initiates each "STATE"

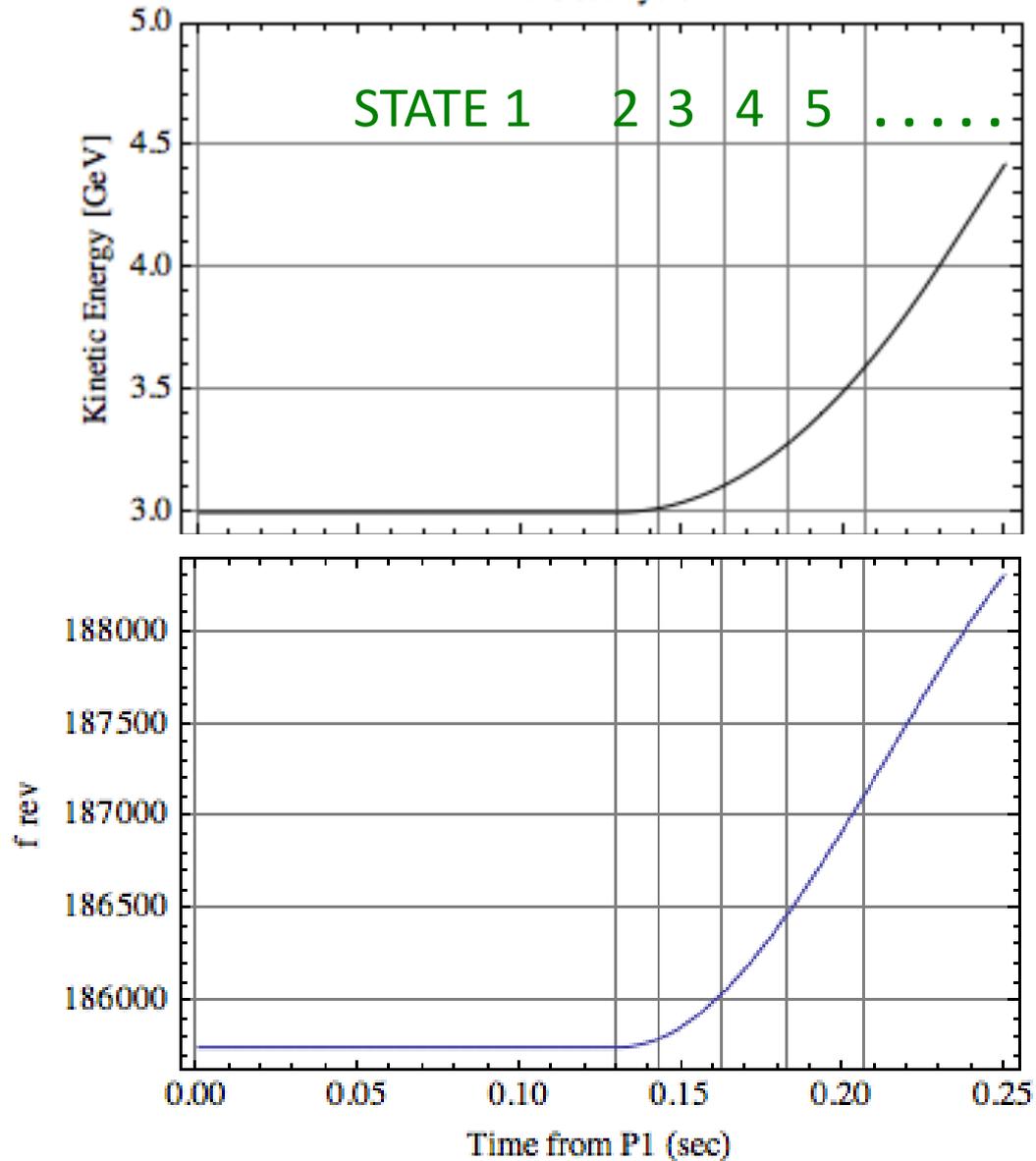
STATE specifies the delay, filter gain, phase, # of tap

a function of "iGp12"



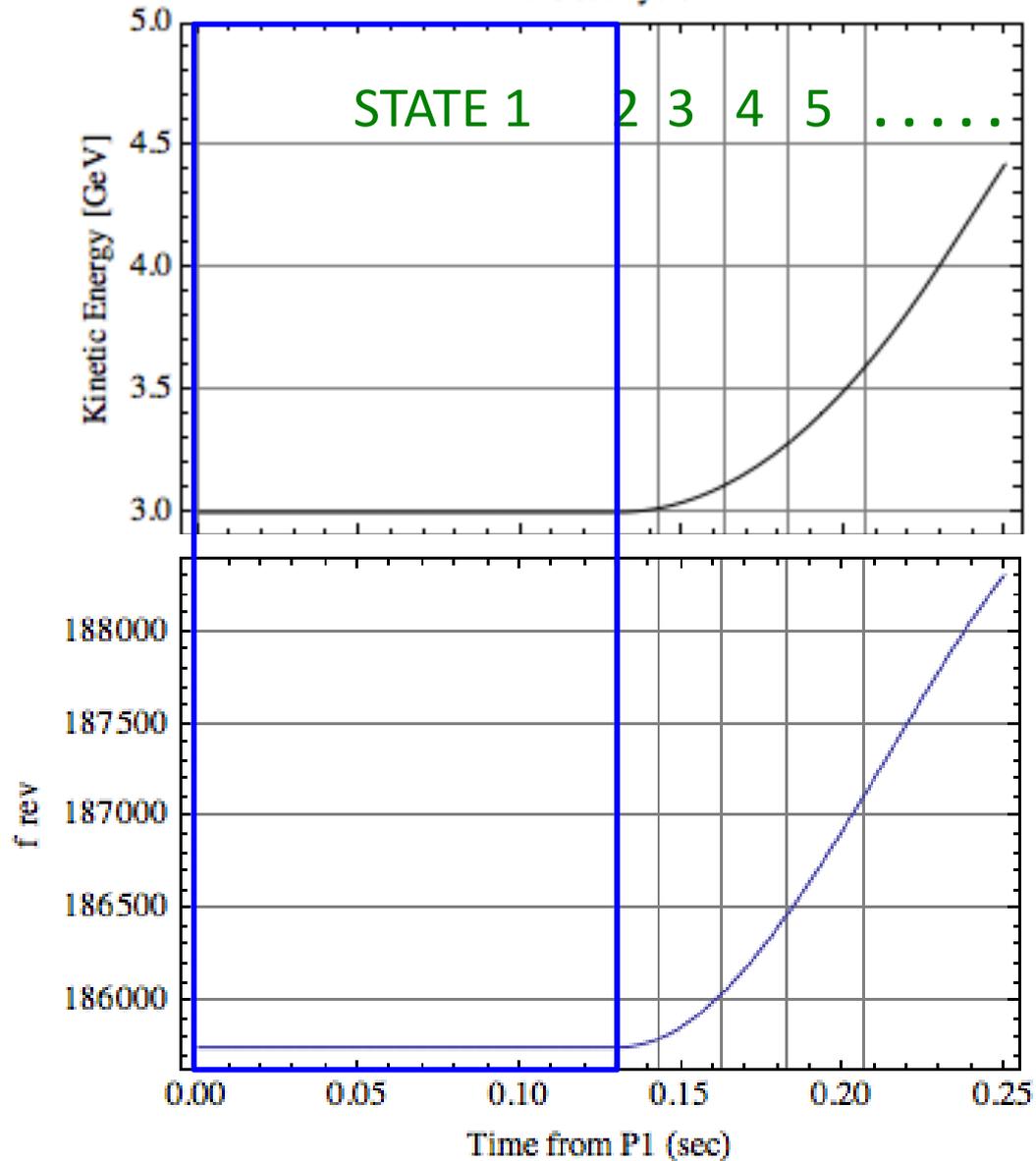
# Timing CNTL by preset table

2.48 sec cycle



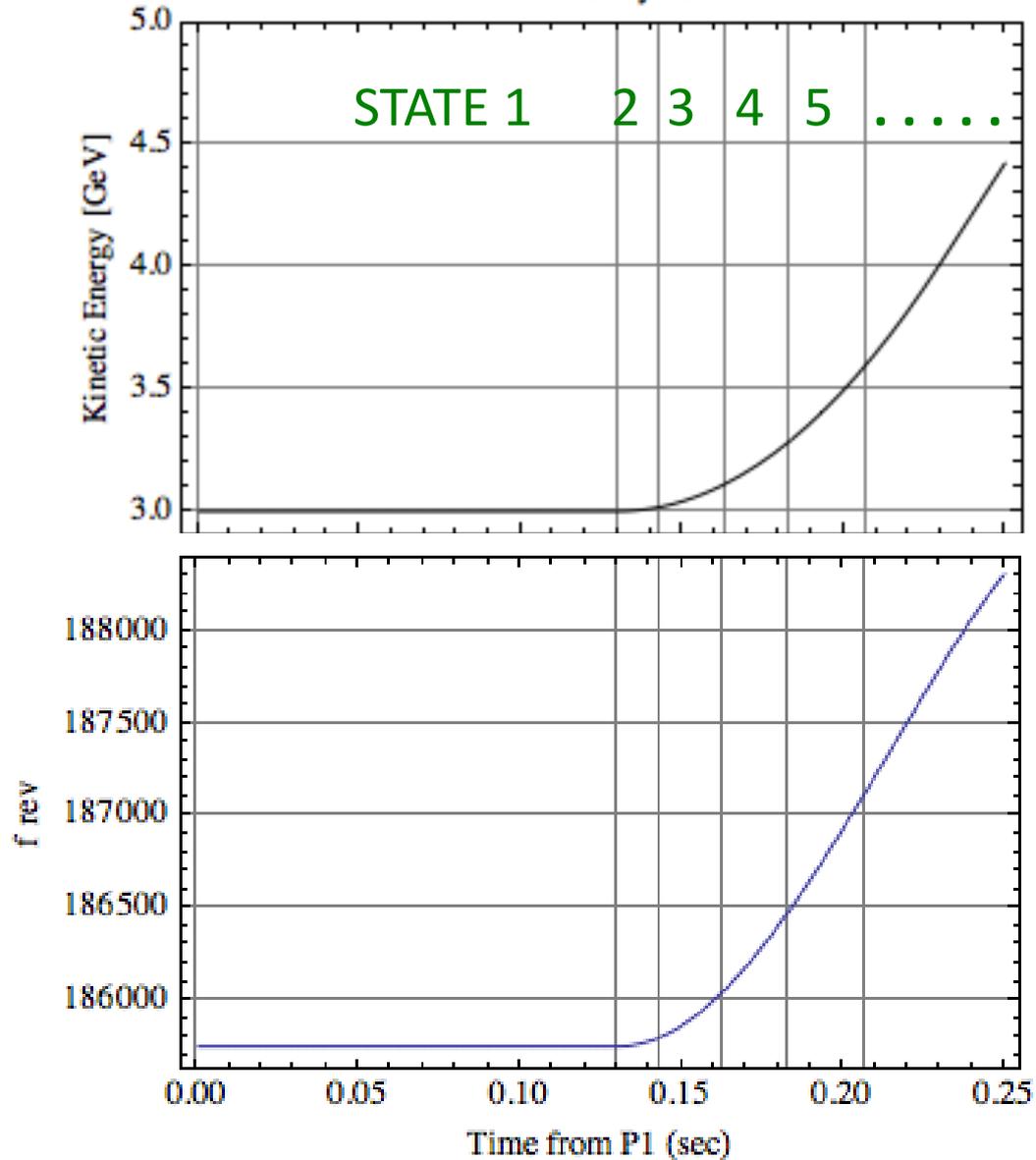
# Timing CNTL by preset table

2.48 sec cycle



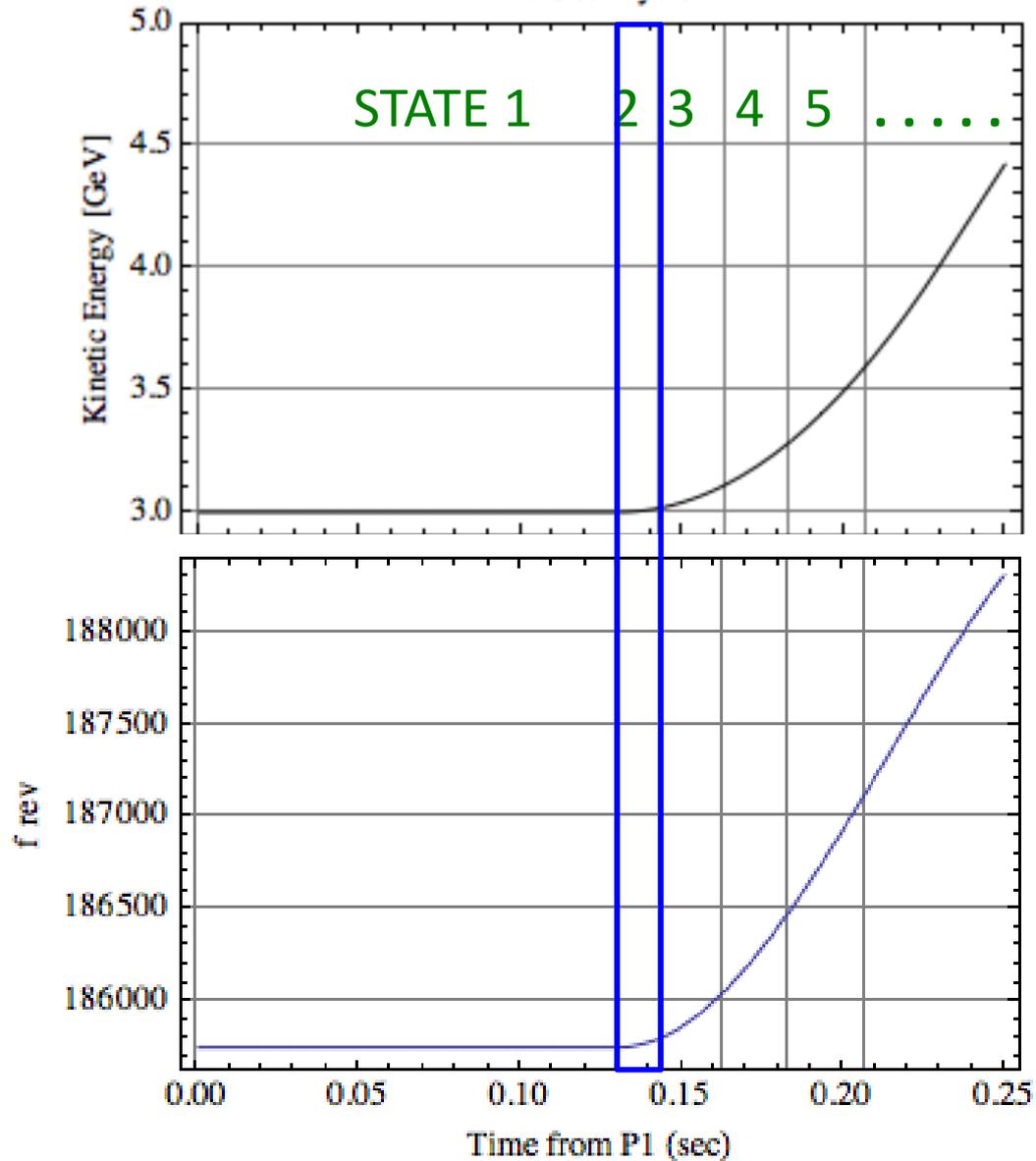
# Timing CNTL by preset table

2.48 sec cycle



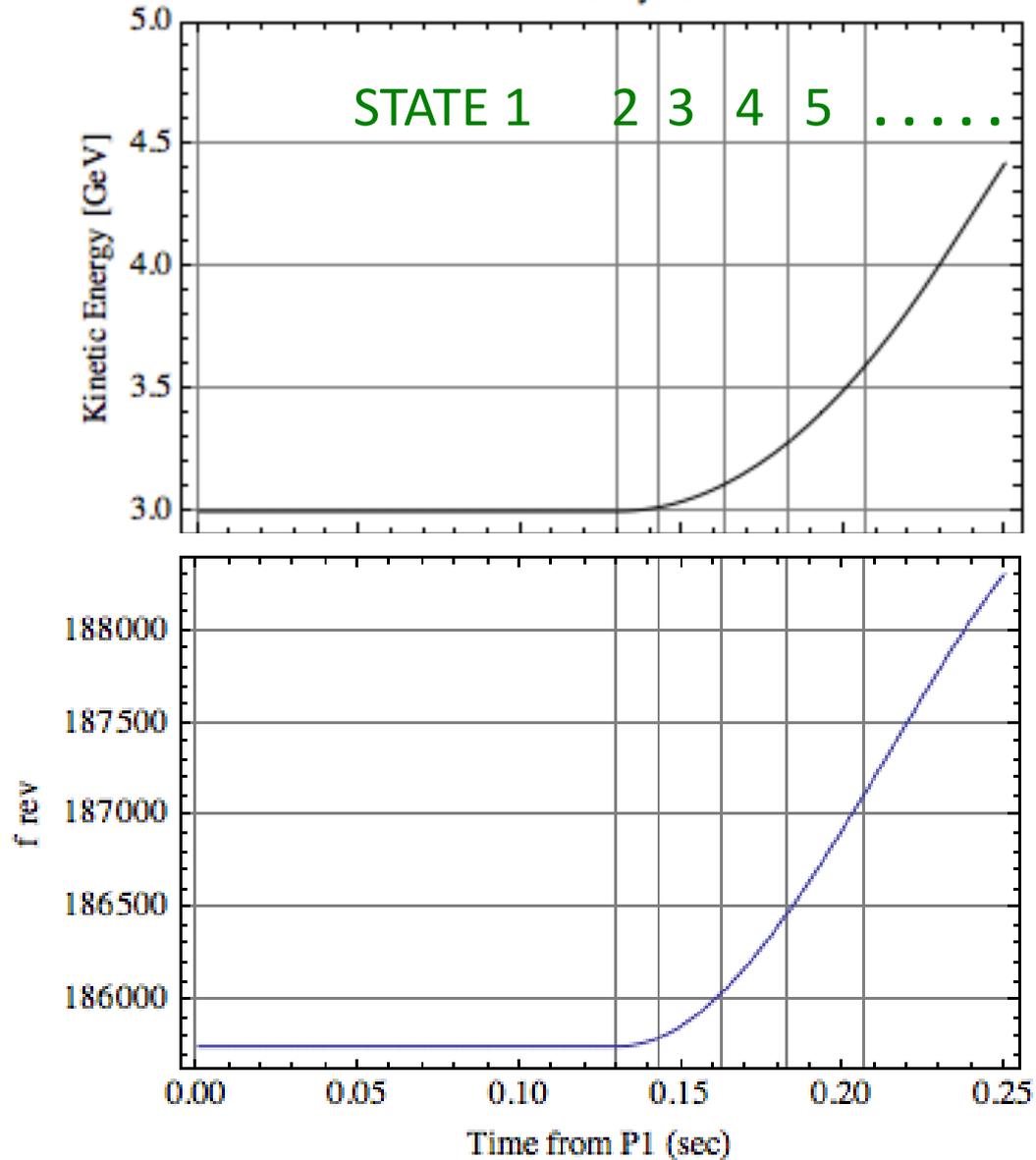
# Timing CNTL by preset table

2.48 sec cycle



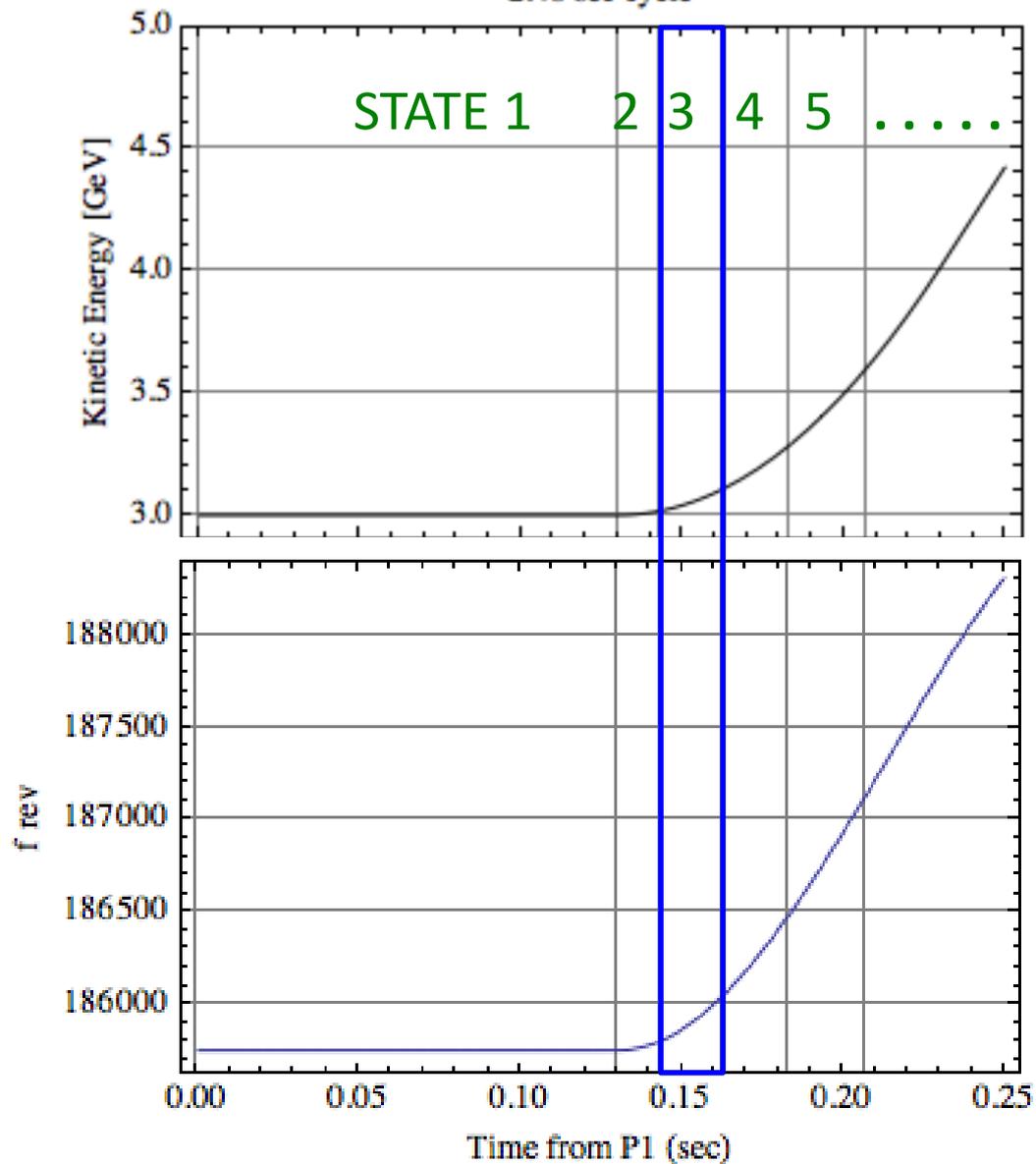
# Timing CNTL by preset table

2.48 sec cycle



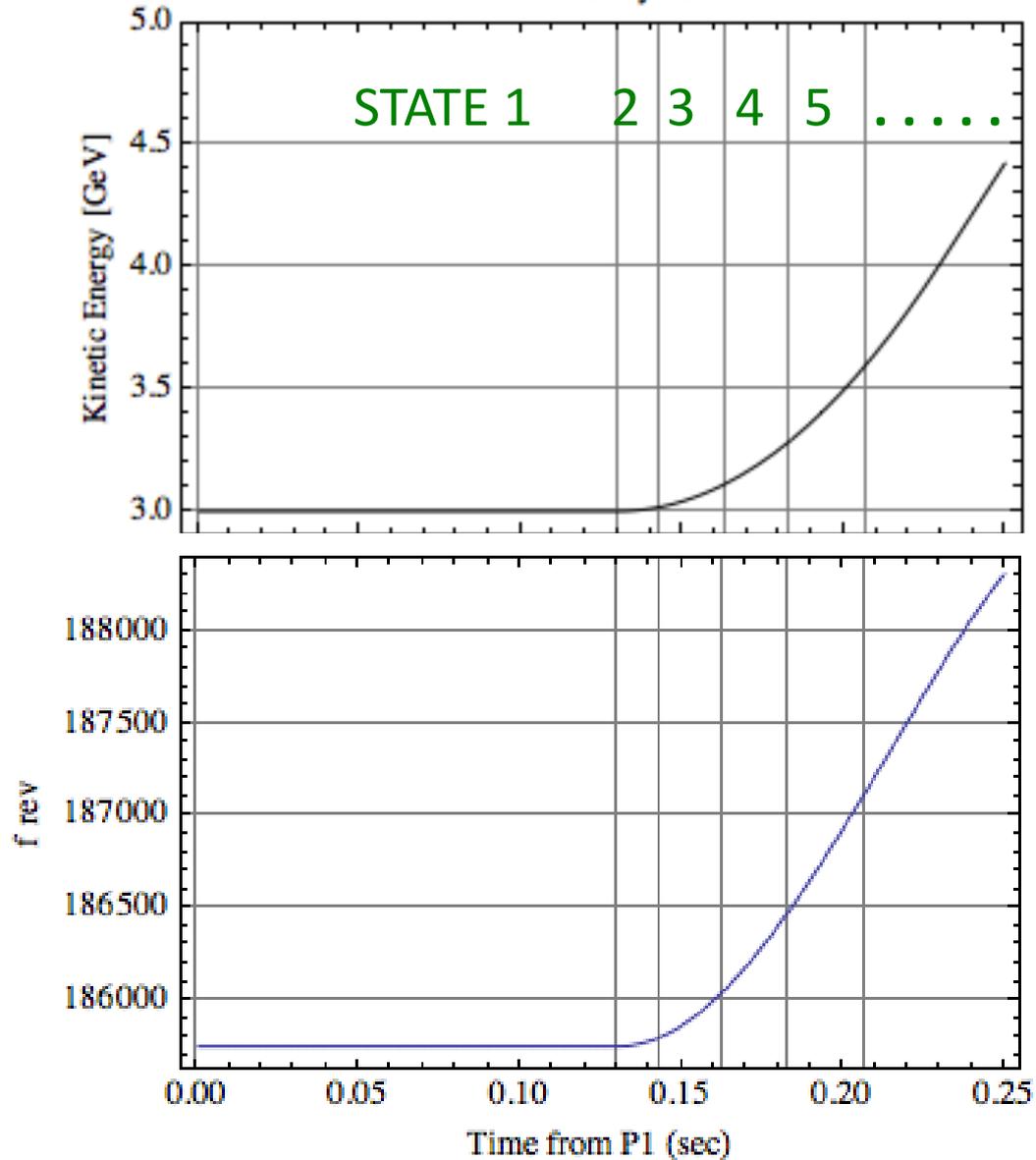
# Timing CNTL by preset table

2.48 sec cycle



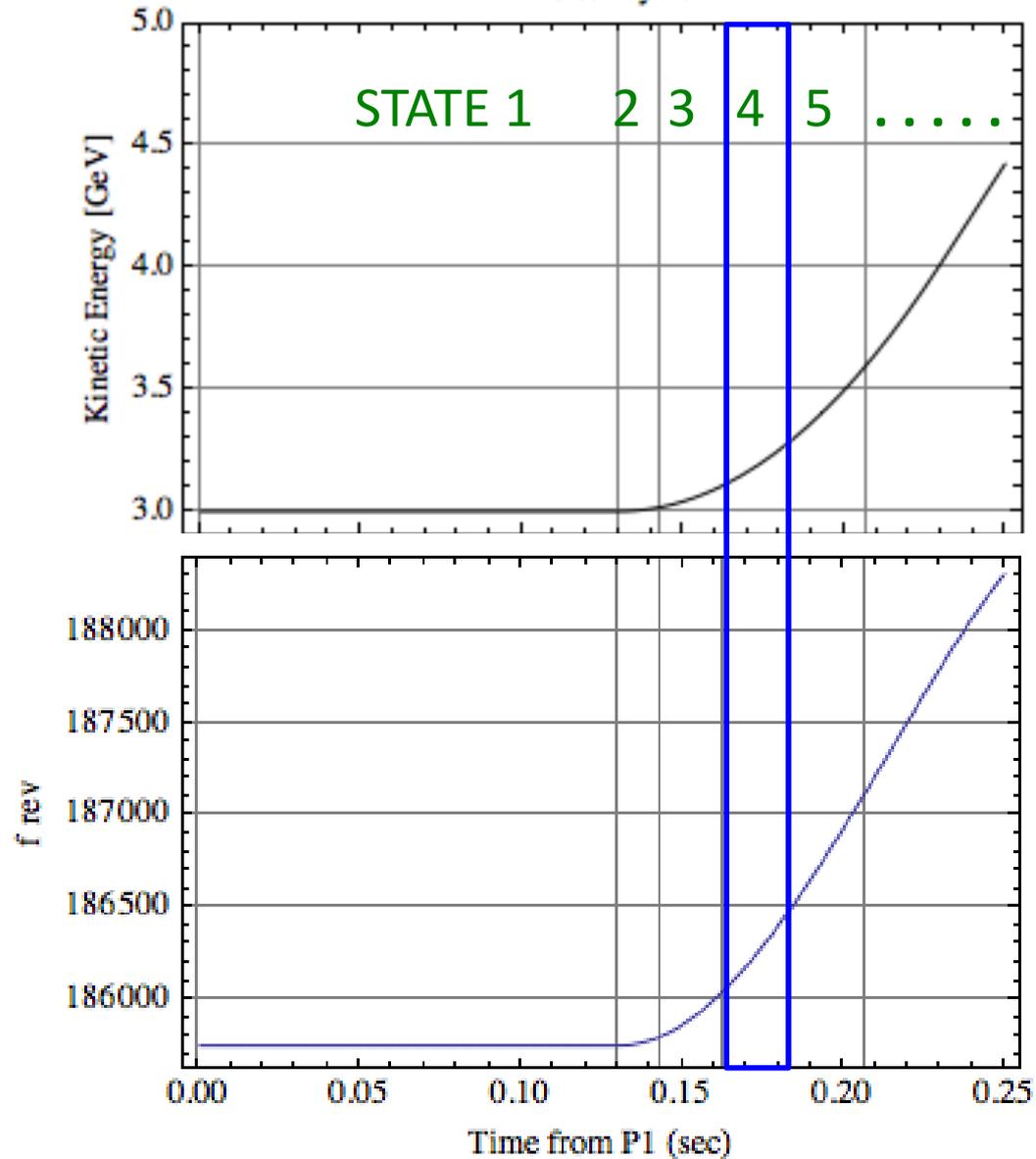
# Timing CNTL by preset table

2.48 sec cycle



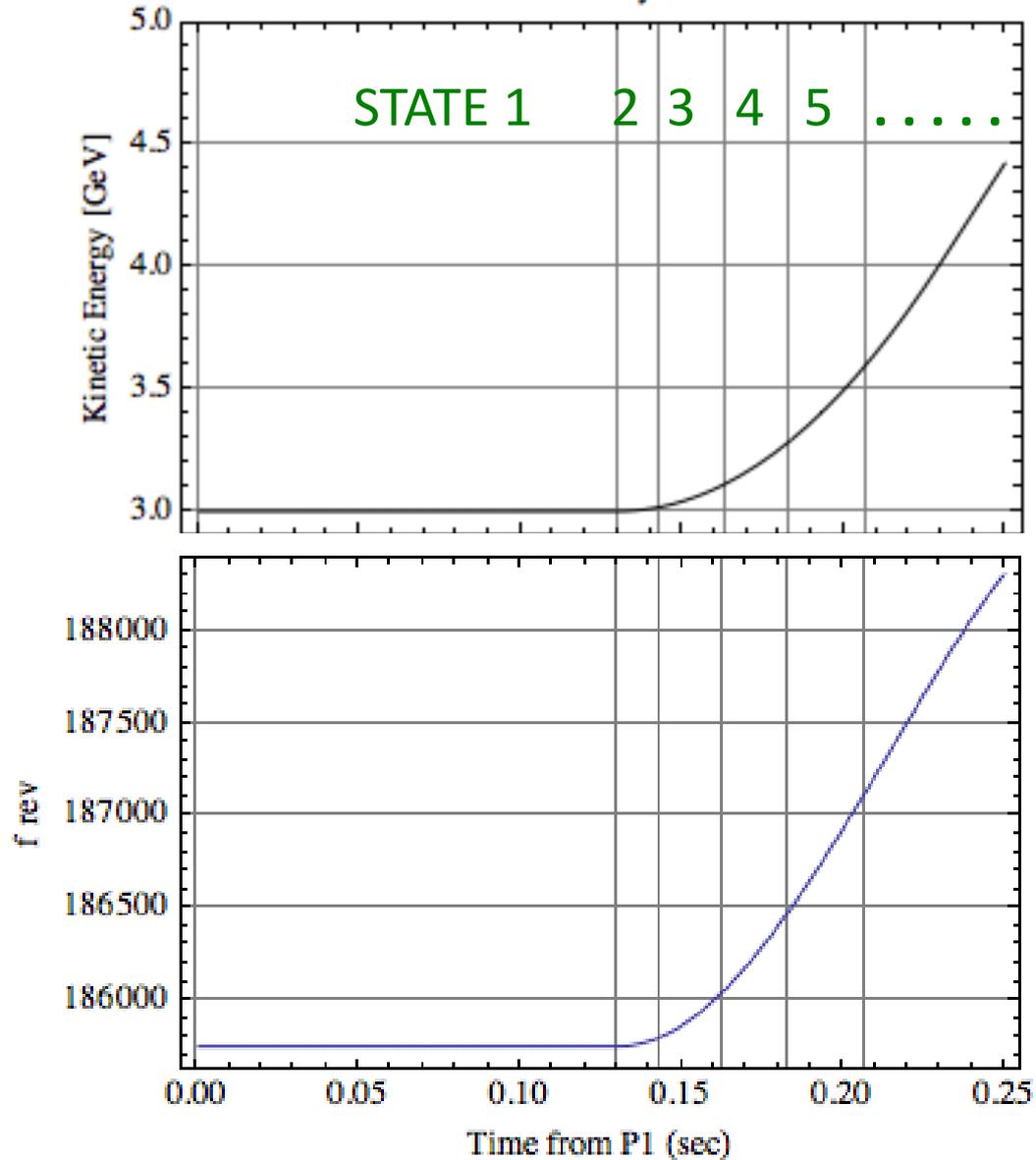
# Timing CNTL by preset table

2.48 sec cycle



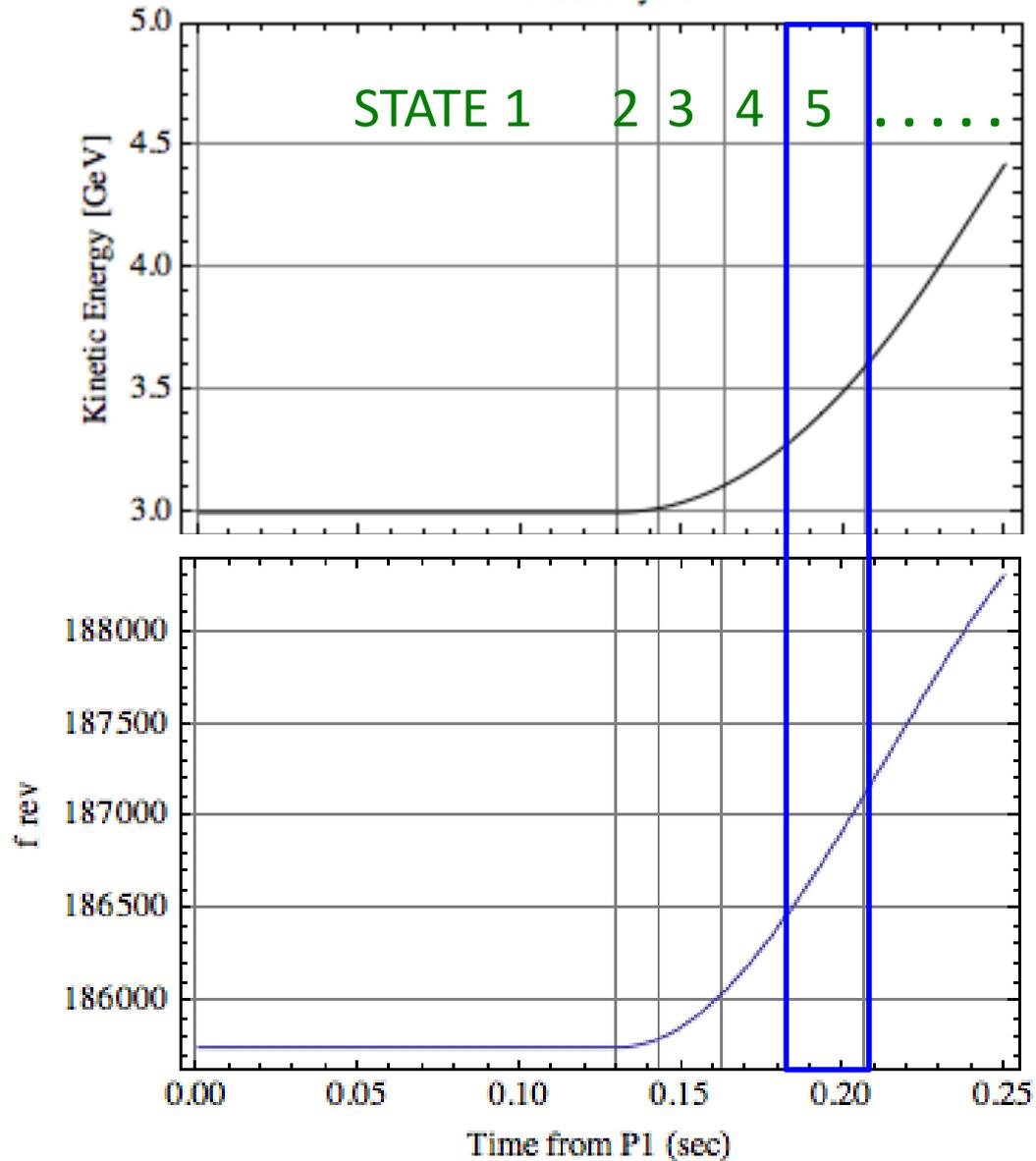
# Timing CNTL by preset table

2.48 sec cycle



# Timing CNTL by preset table

2.48 sec cycle



# iGp12 parameter settings

X

Y

The screenshot displays the iGp12 software interface, divided into two main sections: X (left) and Y (right). Each section contains several panels for configuring the system.

**Top Panels (X and Y):**

- iGp12H: Main Panel:** Shows a "FEEDBACK OFF" button and a "SETUP" button (highlighted with a green box).
- iGp12H: Coefficient Generator (IGPF:X3 / IGPF:Y3):** Contains input fields for Gain [0-1], Phase (Degrees), Frequency [0-1], Number of Taps, and Shift Gain. It also displays "Fractional tune" and "Gain (dB)" values. A plot shows the frequency response.
- iGp12H: State Machine (IGPF:X / IGPF:Y):** Features a "FEEDBACK STATE MACHINE CONTROL" table with columns for STATE, COEFF, SHIFT, FIDUCIAL, BACK-END, SET, GAIN, DELAY, and DELAY. The table is populated with values for states 0 through 15. A blue box highlights the "Injection flat bottom" text.

**Middle Panels (X and Y):**

- iGp12H: Coefficients (IGPF:X3 / IGPF:Y3):** Shows a "NEW COEFFICIENTS VECTOR" section with a description: "Gain=1.00;Phase=135.0;Freq=0.24;Taps=4". A "Generate" button is present. Below this are four plots for SET 0, SET 1, SET 2, and SET 3, each showing a frequency response plot. A yellow box highlights the "FIR filter parameters" text.

**Bottom Panels (X and Y):**

- Target Set and Feedback Pattern:** Includes "TARGET SET" (Set 0, Set 1, Set 2, Set 3), "LOAD COEFFICIENTS", "LOAD", "FEEDBACK PATTERN" (set to 2:1), "VERIFY COEFFICIENTS", and "VERIFY" buttons.

**Annotations:**

- Yellow boxes highlight the "FIR filter parameters" section in both X and Y channels.
- Blue boxes highlight the "Injection flat bottom" text in the State Machine Control tables.
- Text labels "This trial" and "Acceleration" are placed near the State Machine Control tables.

2015. 7. 1

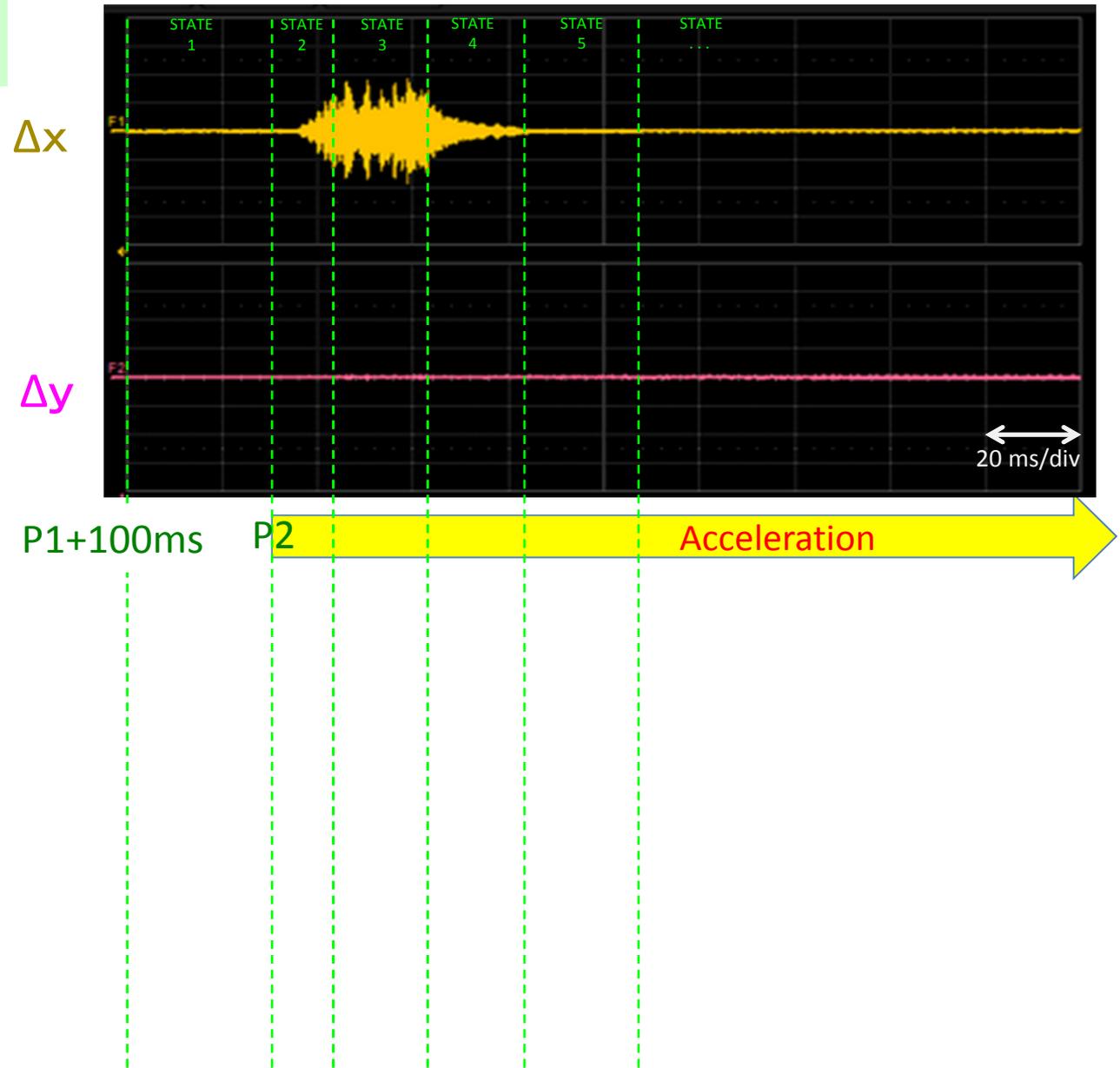
2 bunches,  $\sim 80\text{kW}$ ,  $\sim 4.2 \times 10^{13}$  p

BEFORE

shot513300

$\xi_x \sim -5.9$

$\xi_y \sim -5.2$



$\Delta x$

$\Delta y$

P1+100ms

P2

Acceleration

20 ms/div

2015. 7. 1

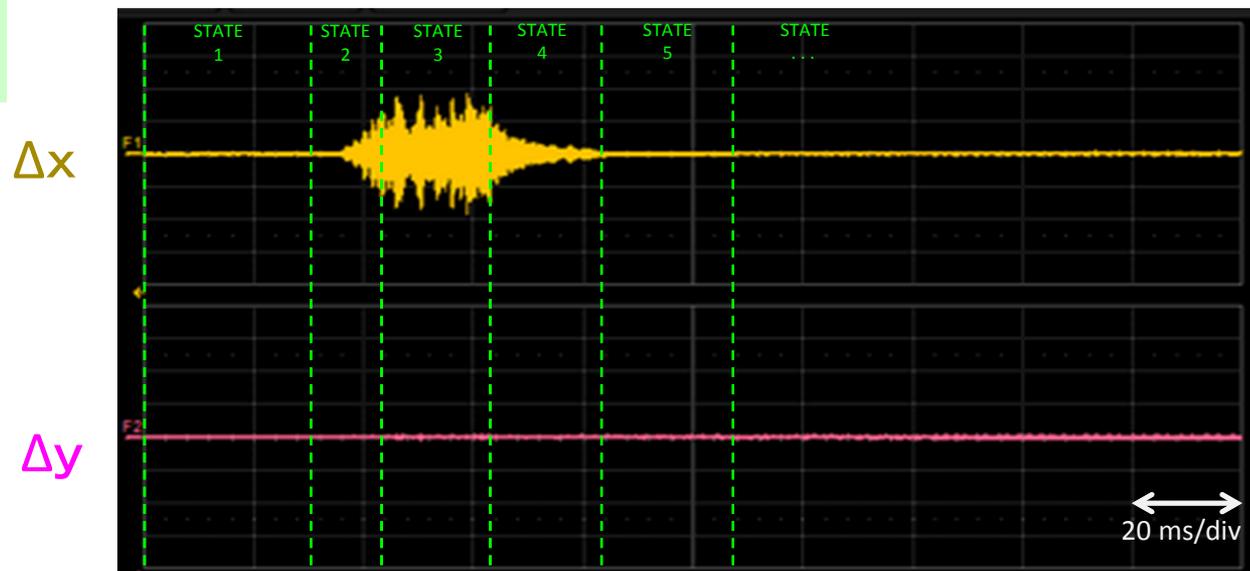
2 bunches,  $\sim 80\text{kW}$ ,  $\sim 4.2 \times 10^{13}$  p

BEFORE

shot513300

$\xi_x \sim -5.9$

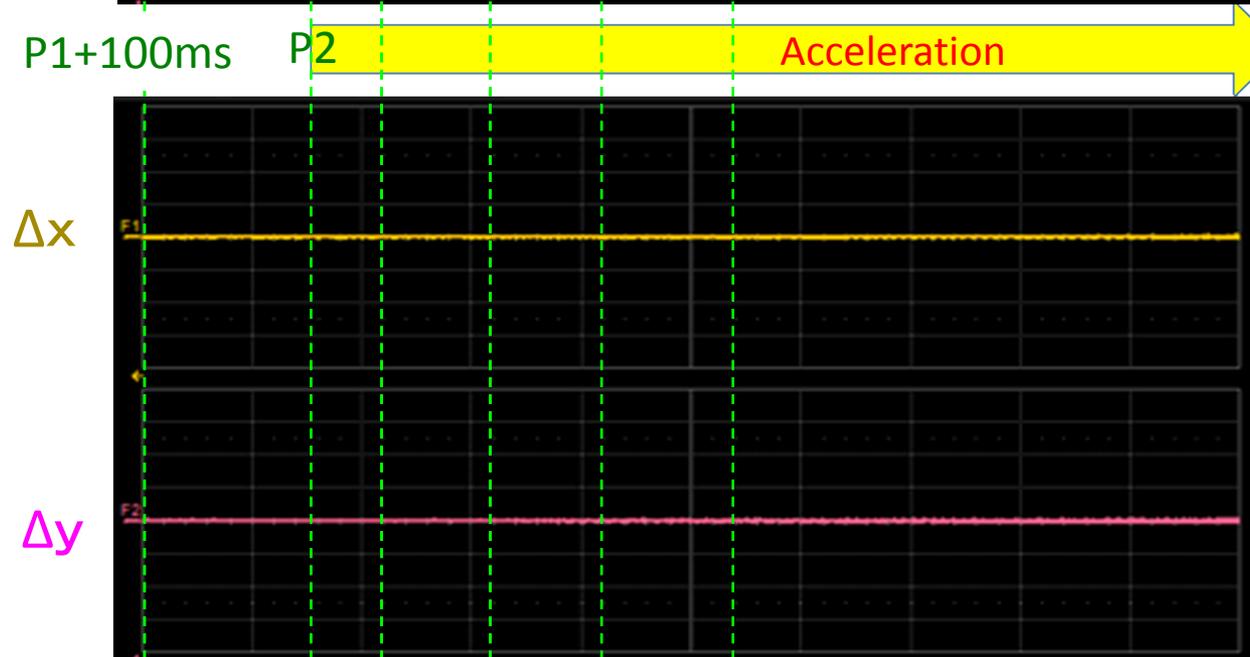
$\xi_y \sim -5.2$



AFTER

shot513301

Stabilized  
only by switching on  
STATE 2

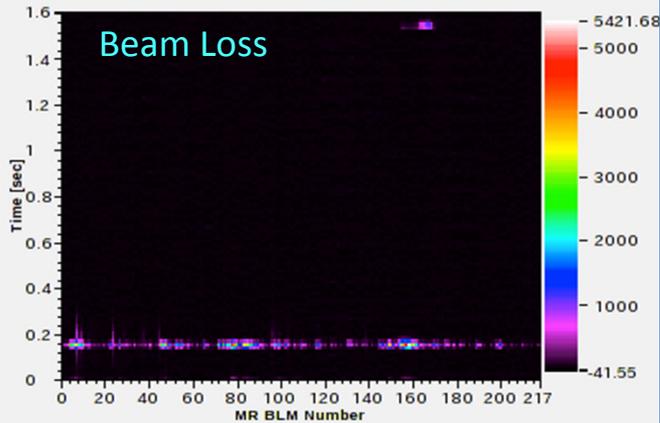
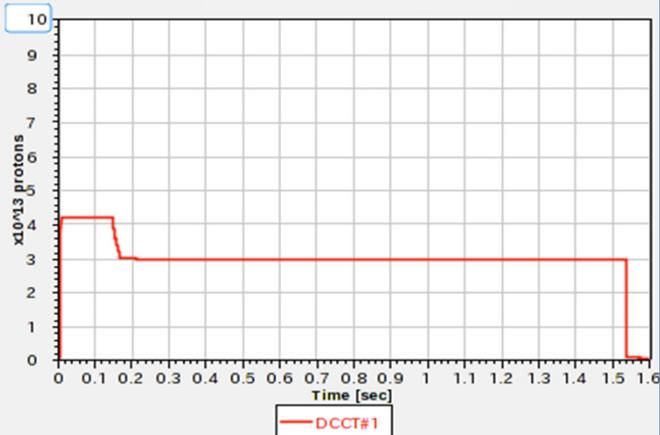


BEFORE  
shot513300

15/07/01 01:28:44

Run  
Run

Beam Intensity

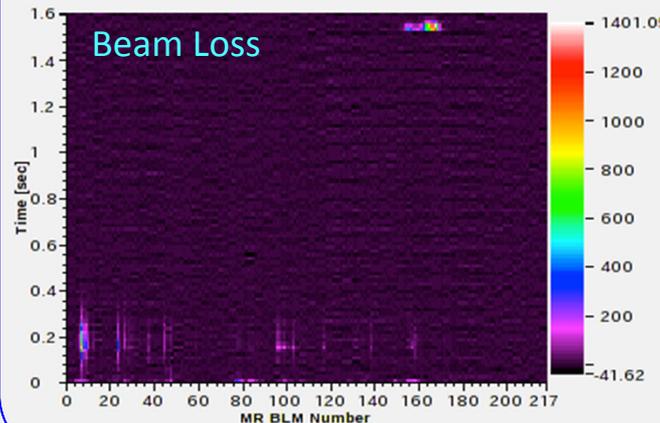
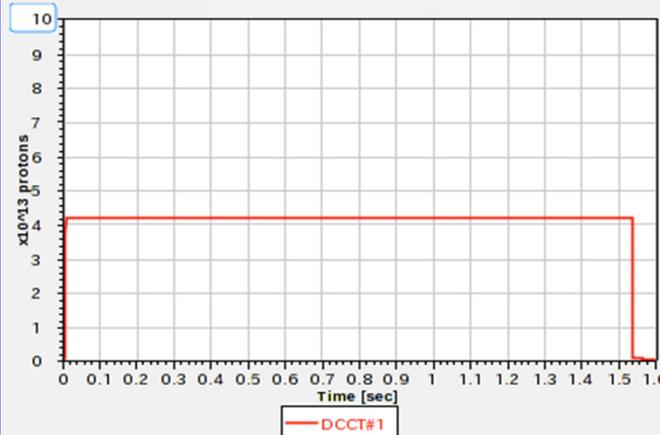


AFTER  
shot513301

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	00	00	040	065
1	00	04	035	064
2	00	04	035	064
3	00	04	035	064
4	00	04	040	065
5	00	00	040	065
6	00	00	040	065
7	00	00	040	065
8	00	00	040	065
9	00	00	040	065
10	00	00	040	065
11	00	00	040	065
12	00	00	040	065
13	00	00	040	065
14	00	00	040	065
15	00	00	040	065

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