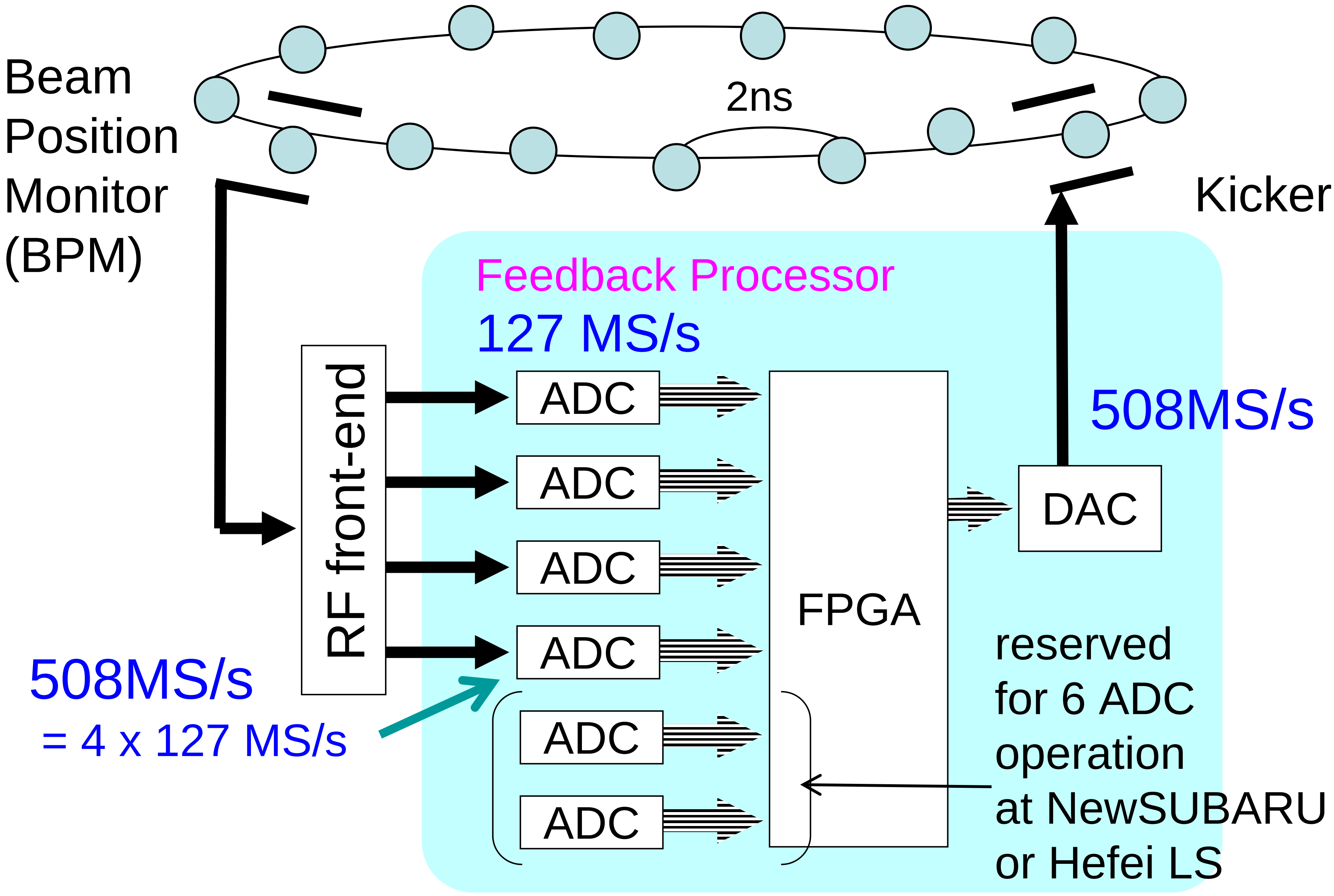
Status of SPring-8 Feedback and related topics

another topic on ERL

T. Nakamura

SPring-8

SPring-8 Bunch-by-bunch Feedback



FPGA Based Digital Bunch-by-bunch Transverse Feedback (EPAC '04)

2003 Sep.   first operation, 508.58MS/s

2004, Jan.   for user operation

prototype 7 FPGA (<= 24 DSP) with 7 boards => simple and low-cost

World First FPGA based bunch-by-bunch feedback above 350MS/s?

* New FPGA based Digital Feedback Processor (ICALEPCS '05)

1 FPGA with 1 board, 2x 20-tap FIR, 50-tap FIR

* Single-Loop Two-Dimensional (H,V) Feedback (EPAC '06)

One Signal from BPM to Kicker, One Processor

Photon Factory (2005, Sep.)

Taiwan Light Source (2005, Nov.)

SOLEIL (2006, Dec.)

* RF direct sampling (KASOKUKI '07□□(Japan□□□), EPAC '08)

ADC samples BPM signal without Down Conversion Circuit

Less tuning points, less cost

2007, Feb. ~ for user operation

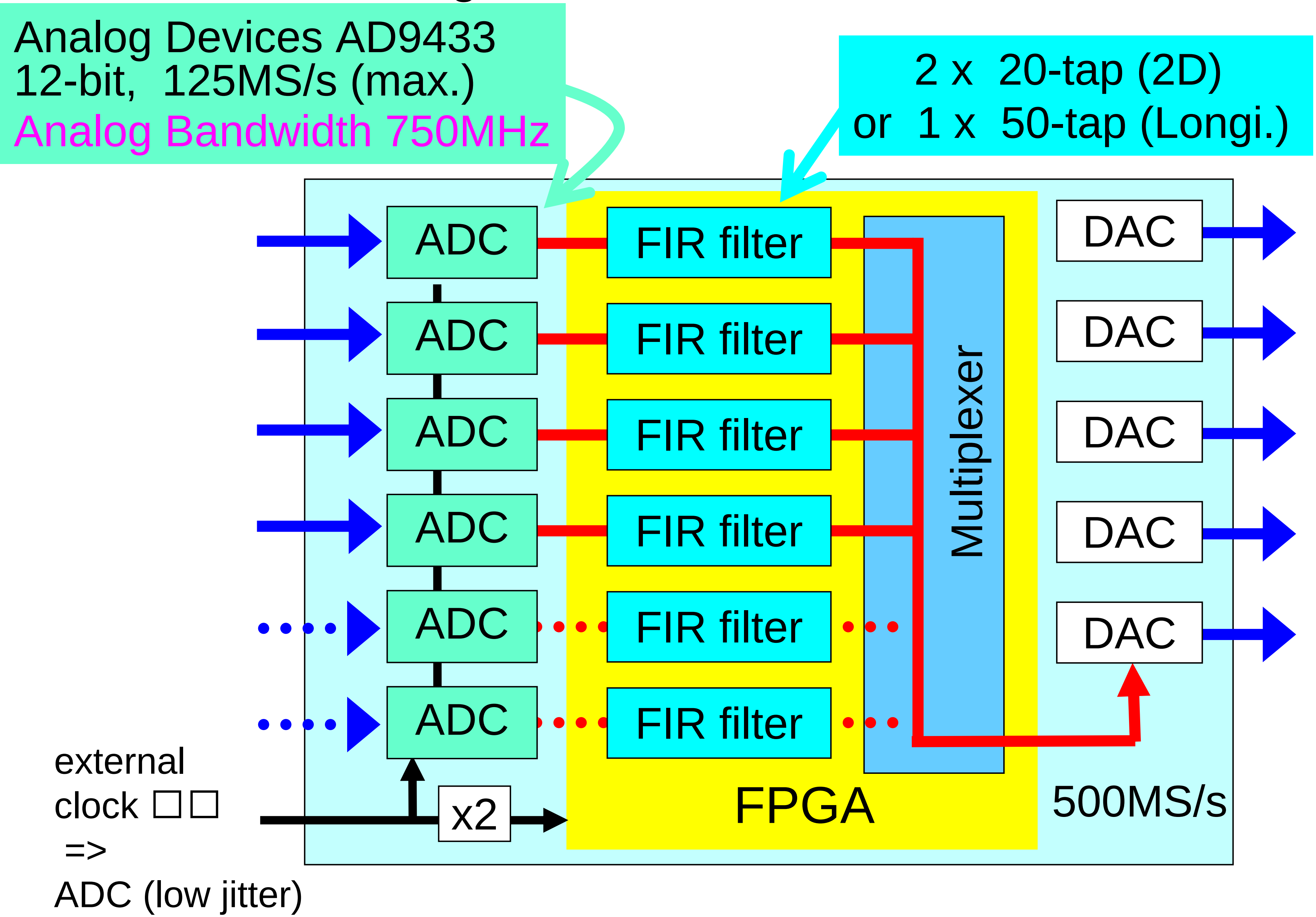
* Automatic Attenuator (Bunch Current Sensitive)

Hybrid Filling with High Contrast Bunch Current   (EPAC '08)

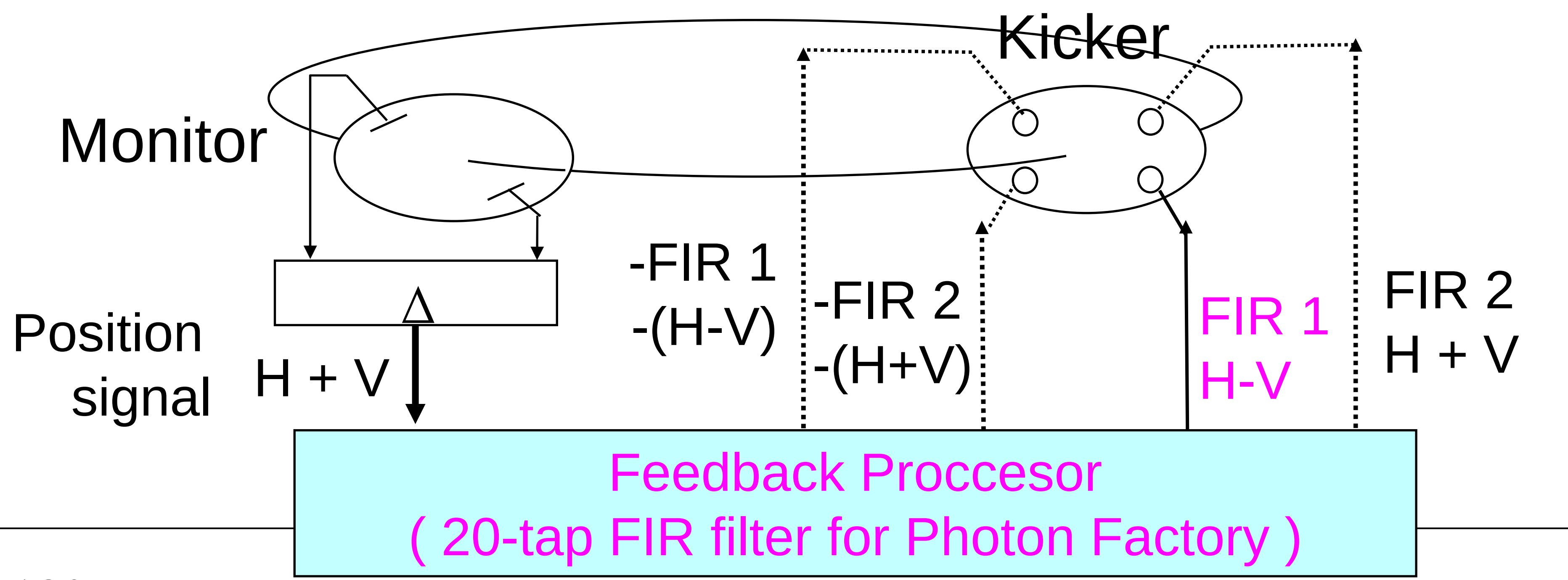
In Progress : SSRF(China), Hefei Light Source (China), NIRS(Japan, Ion ring)

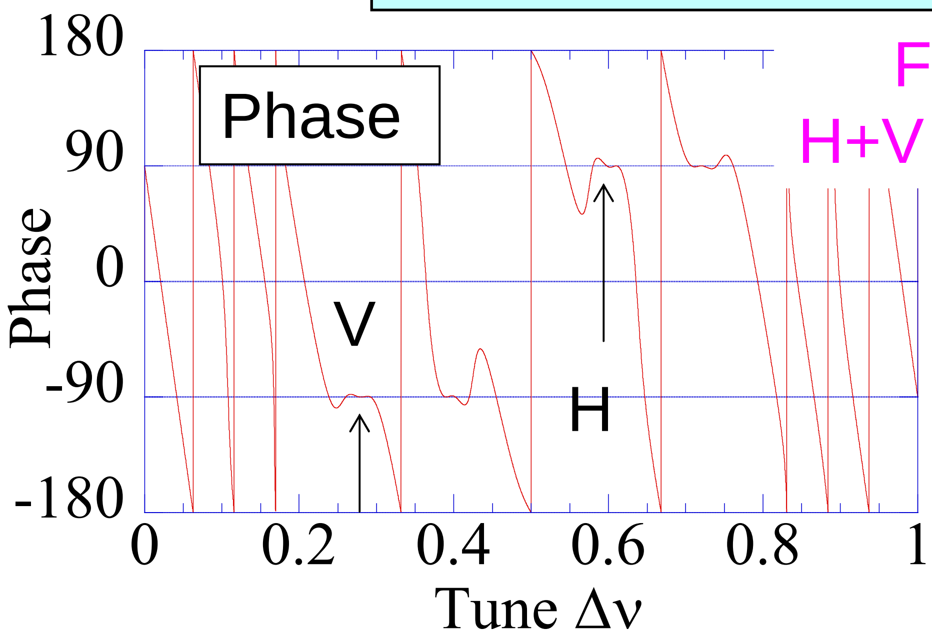
Tested : S-LSR(Japan, proton)□

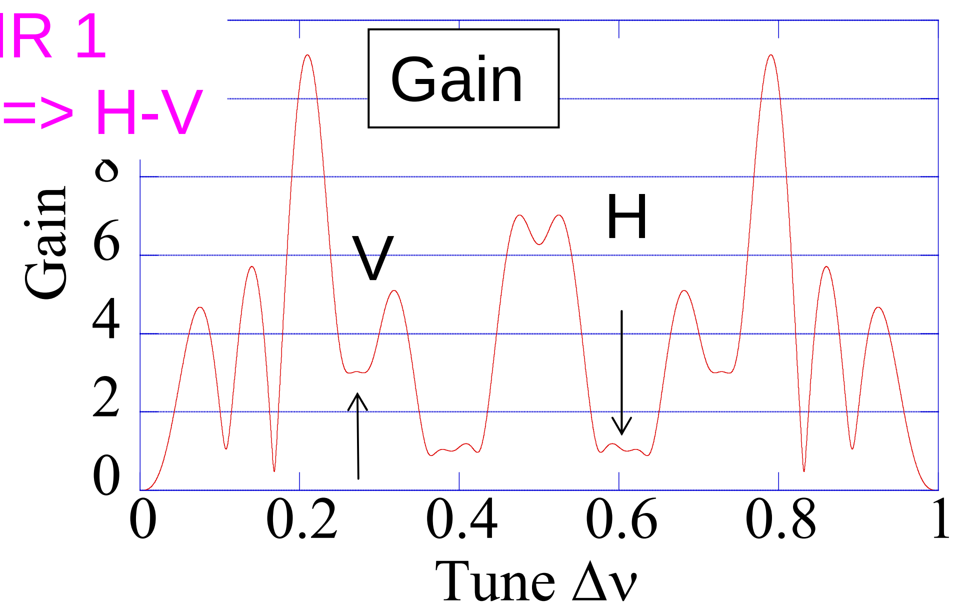
SPring-8 Feedback Processor



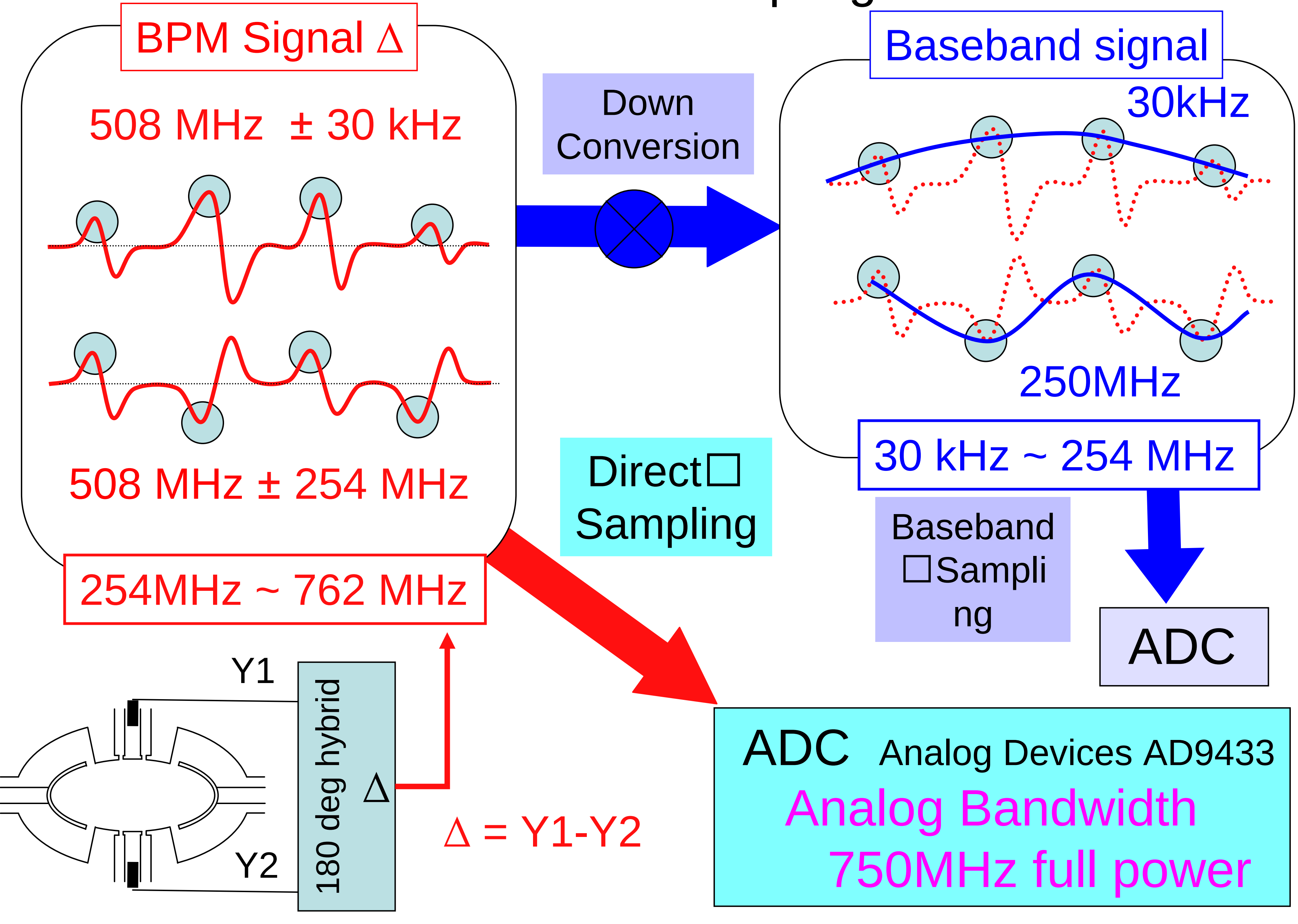
Single-Loop Two-Dimensional Transverse Feedback



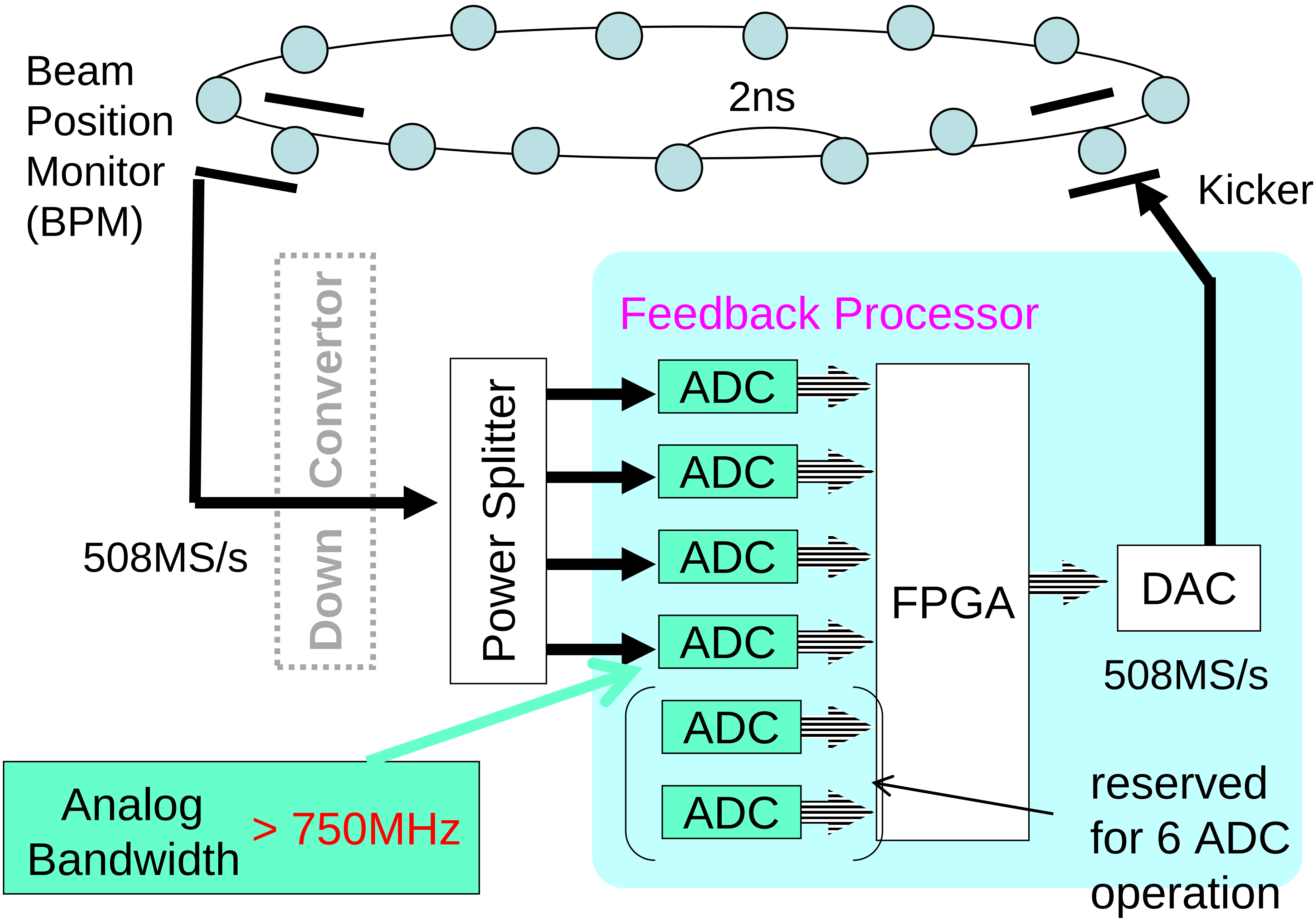




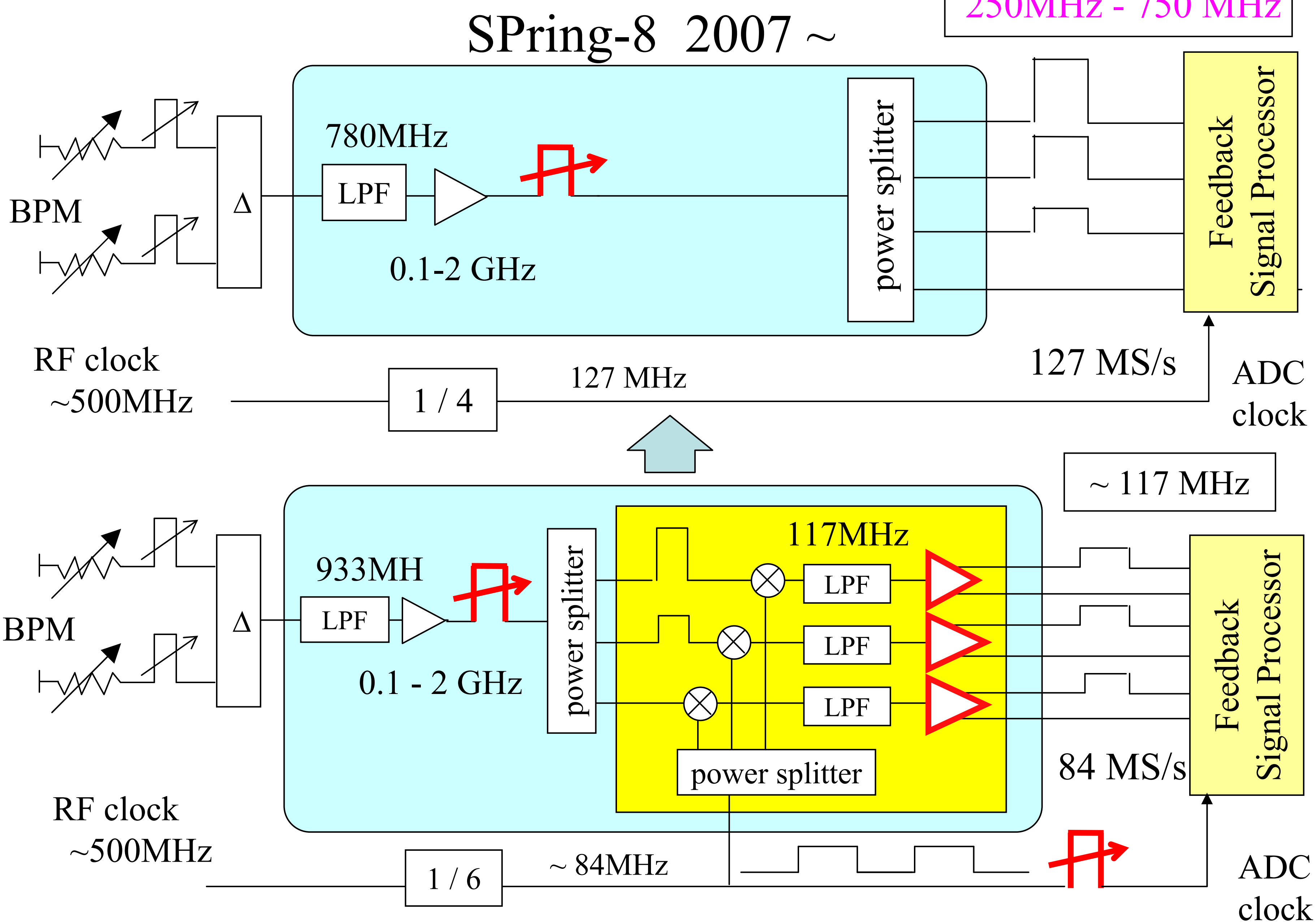
RF Direct Sampling



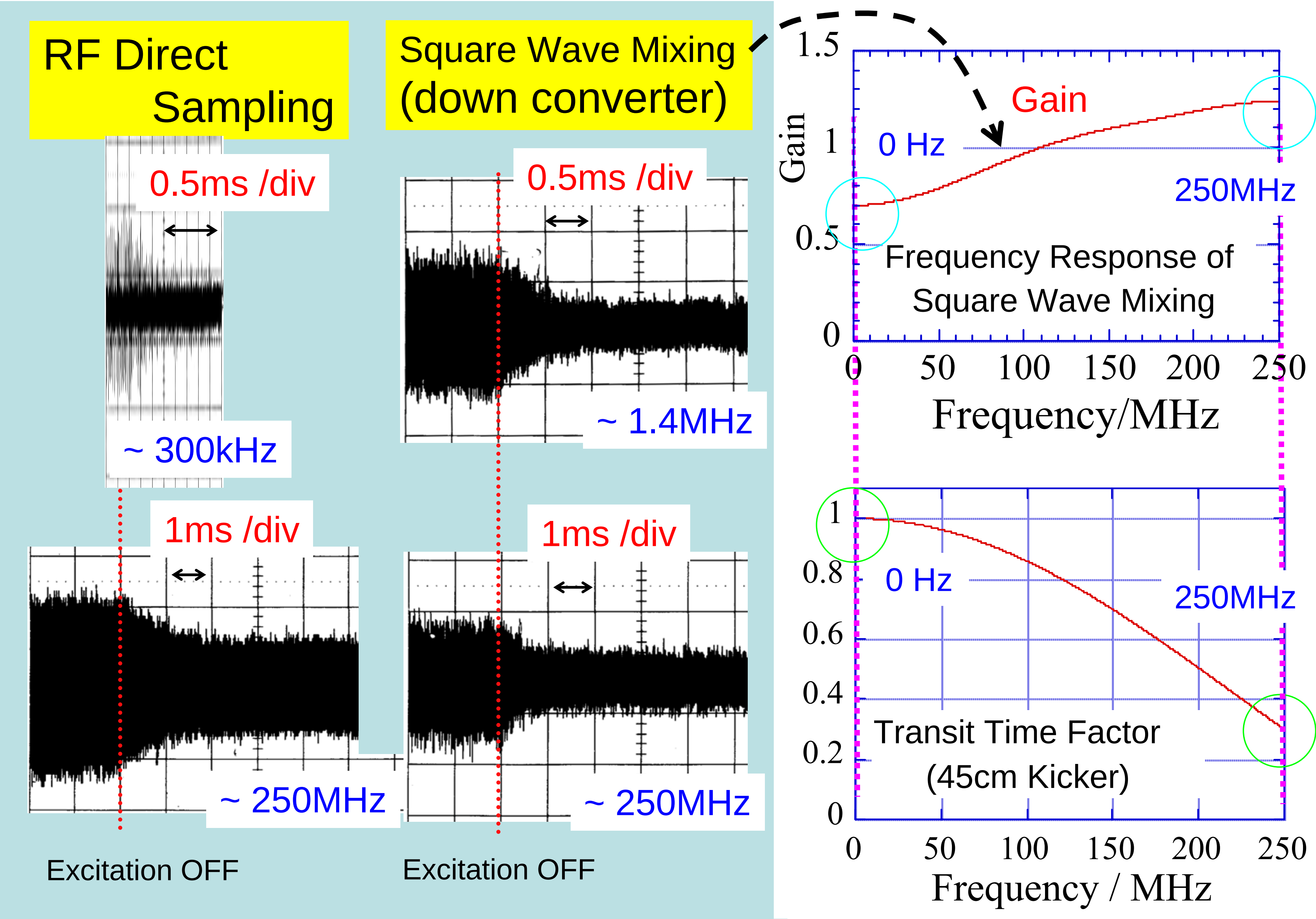
RF Direct Sampling Feedback



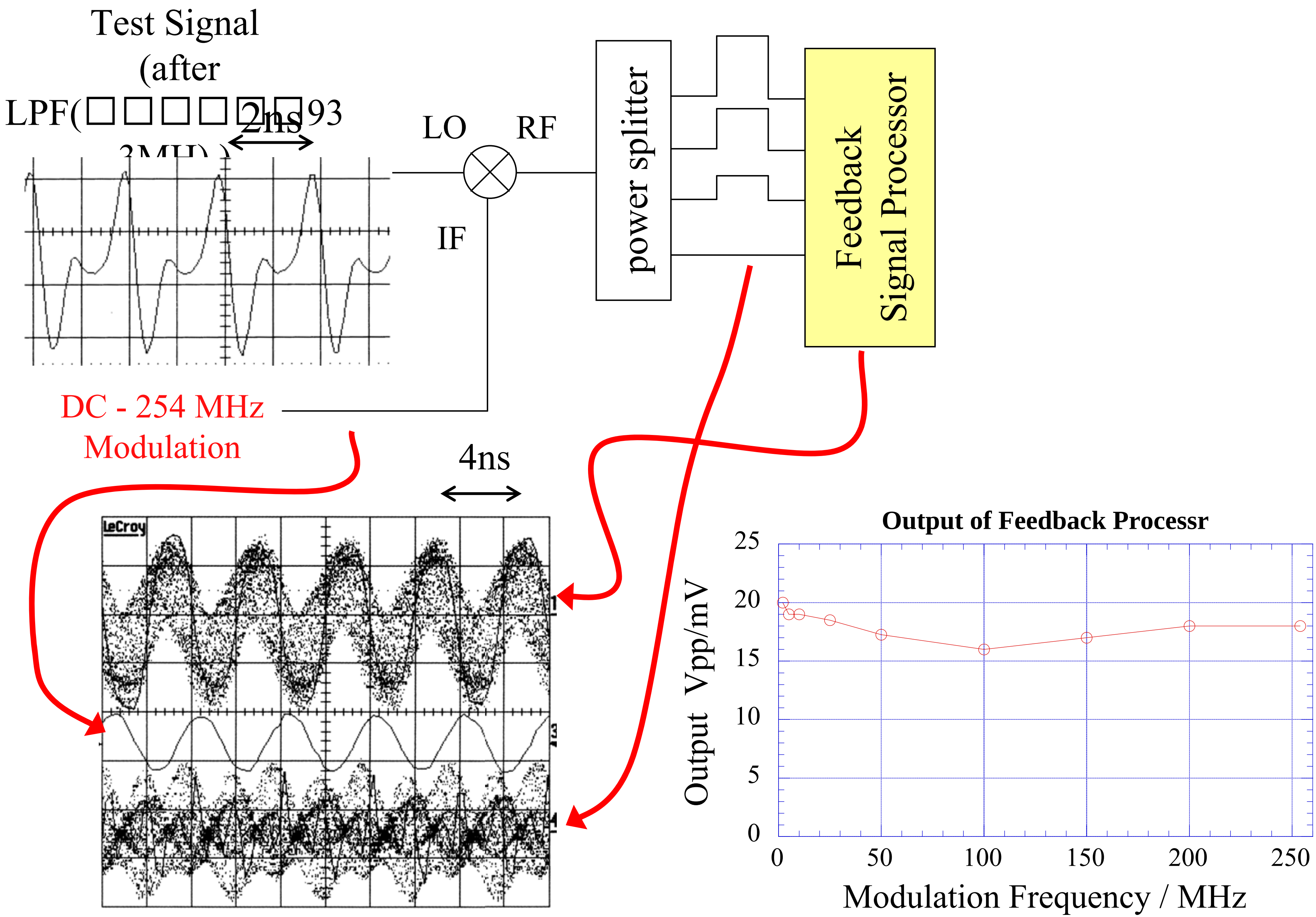
RF Direct Sampling



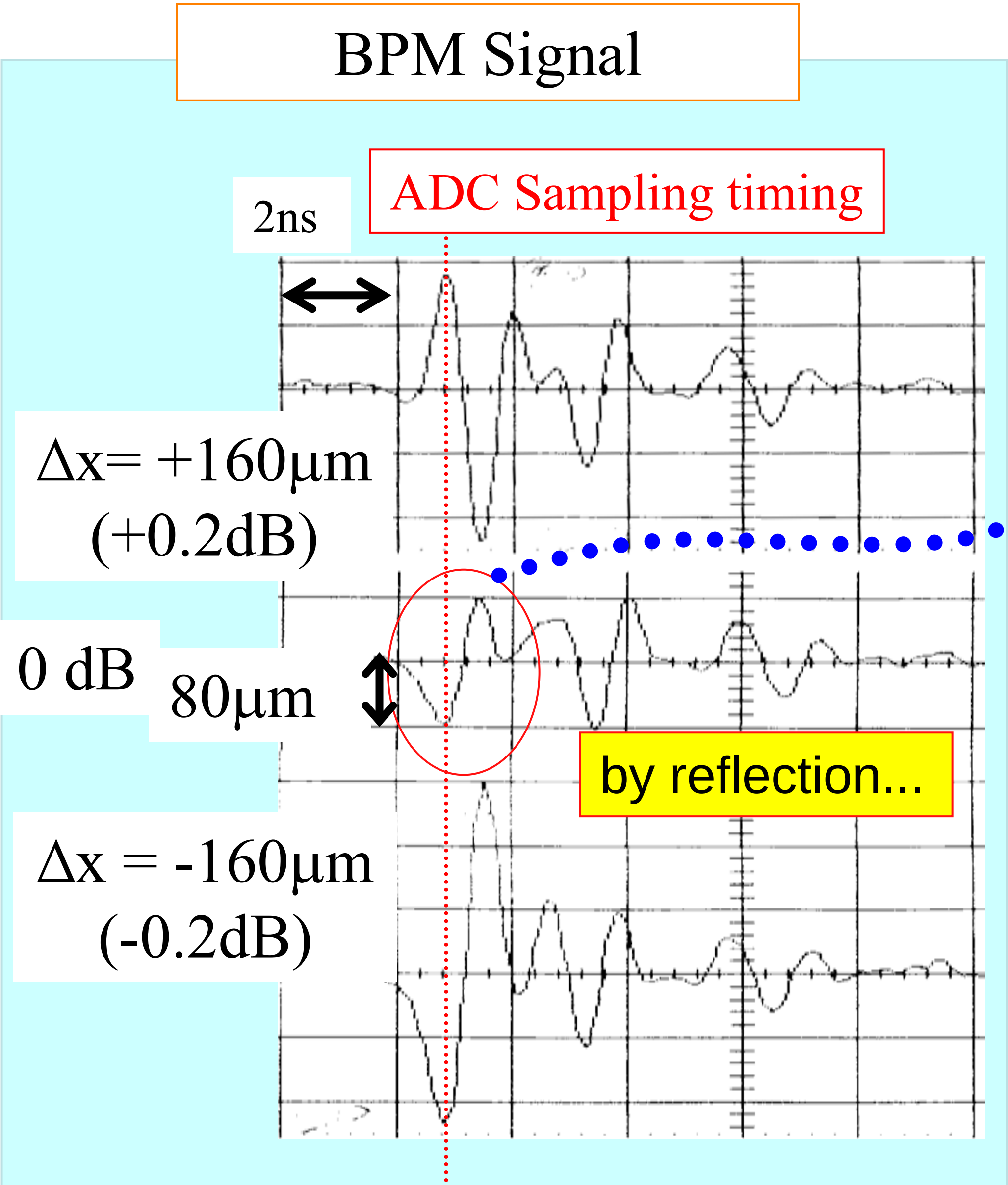
Damping Time Measurement (Vertical)



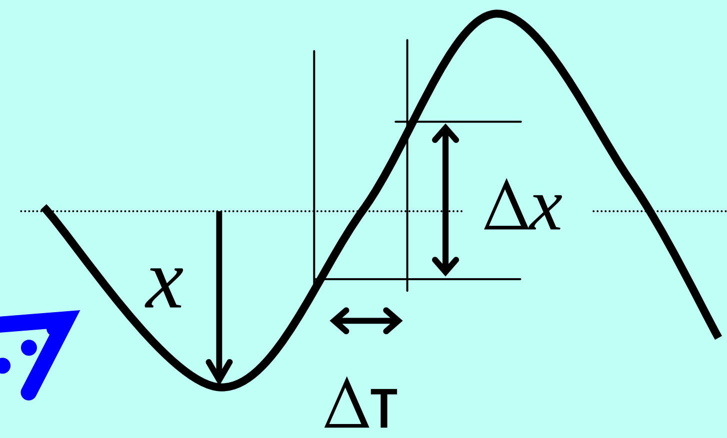
Frequency Response of Feedback Signal Processor



Residual Signal and Effect of Sampling Jitter



Noise by Sampling Jitter



Frequency $f = 1$ GHz

Jitter $\Delta\tau = 10$ ps

residual signal $x = 80$ μm

$$\frac{\Delta x}{x} = 2\pi f \Delta\tau = 0.06$$

Δx = 4.8 μm (max.)

=> σ_x = 0.5 μm (max.)

Residual Motion by Noise

Measured Position with Noise δ

$x = x_{\beta} + \delta$ → Feedback → Kicker

Derived formula for residual motion

$$\sigma_x = \frac{\sqrt{T_0 \tau}}{\tau_{FB}} \sigma_\delta = 0.1 \sigma_\delta$$

$<<$ □□□□□□□□ 5 μm

~ 1 μm Diffraction Limit Sizeof Hard x-ray

$\tau \sim \tau_{FB} = 0.5\text{ms}$

$T_0 = 4.8\ \mu\text{s}$

→ $\sigma_\delta \sim 5\ \mu\text{m}$

Single-Bunch

Single-Bunch current at $\xi \sim 0$

limited by mode-coupling instability (horizontal, vertical)

4 mA / bunch at $\xi \sim 0$ <u>without feedback</u>

↓ beam lost at injection => 1~2mA

4 mA / bunch at $\xi \sim 0$ <u>with feedback</u>

↓ beam lost at injection => 1~2mA

12 mA / bunch at $\xi \sim 0$ <u>with feedback</u>

<u>with Higher Horizontal Feedback Strength</u>

(amplifier power, # of kickers 2 -> 4)

↓

short Damping Time against Instability

wide Dynamic Range against saturation at injection perturbation or noise

Hybrid Filling

□

High Bunch current singlet ⇄ Low Bunch current train

Saturation
Too high gain

High Contrast

low position resolution (noise, ADC bits)

Automatic Attenuator (Bunch current sensitive)

user mode 2.8 mA/bunch + 0.25 mA/bunch

increase Horizontal Feedback Strength

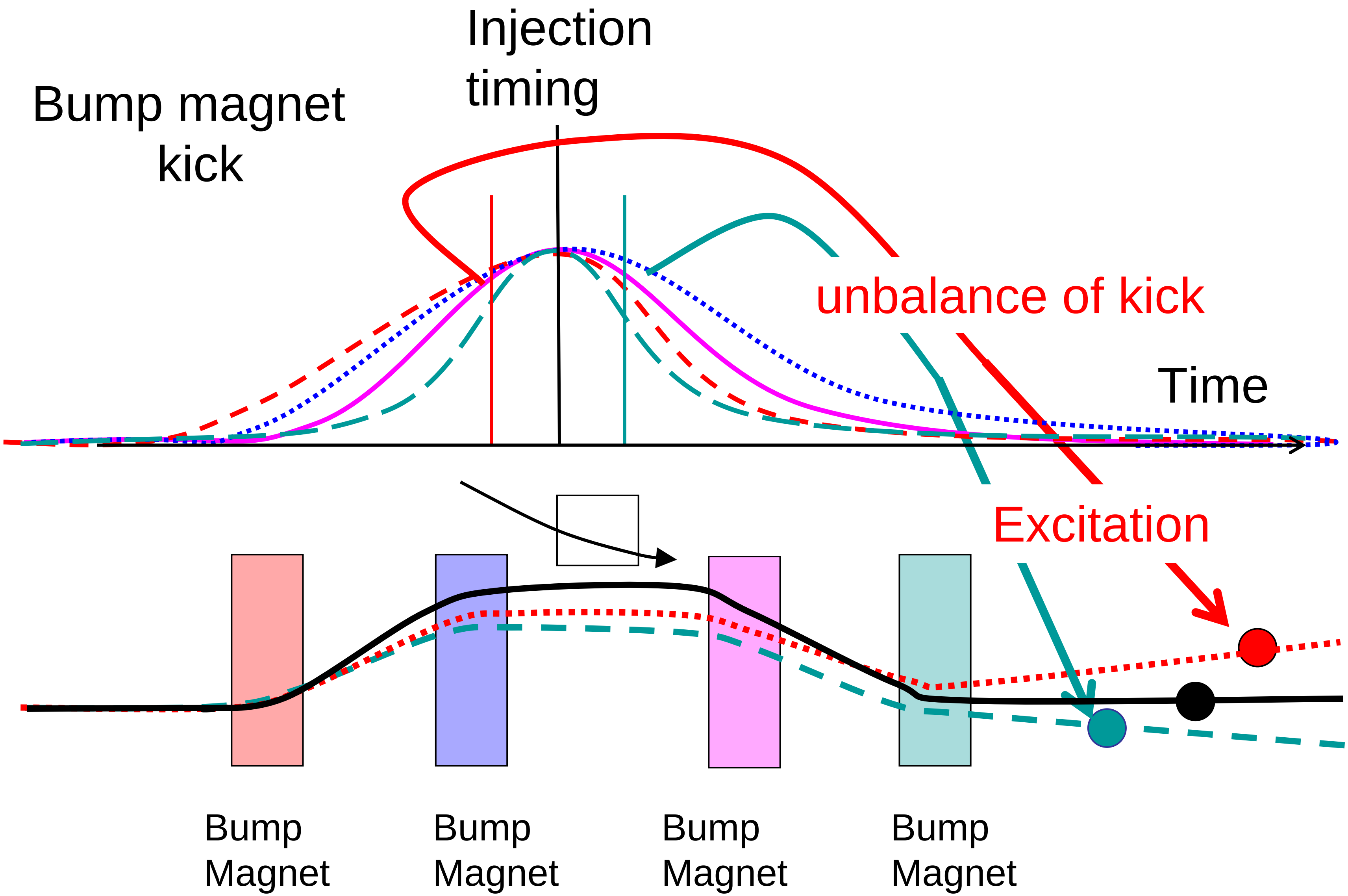
achieved 10 mA/bunch + 0.5 mA/bunch (study)

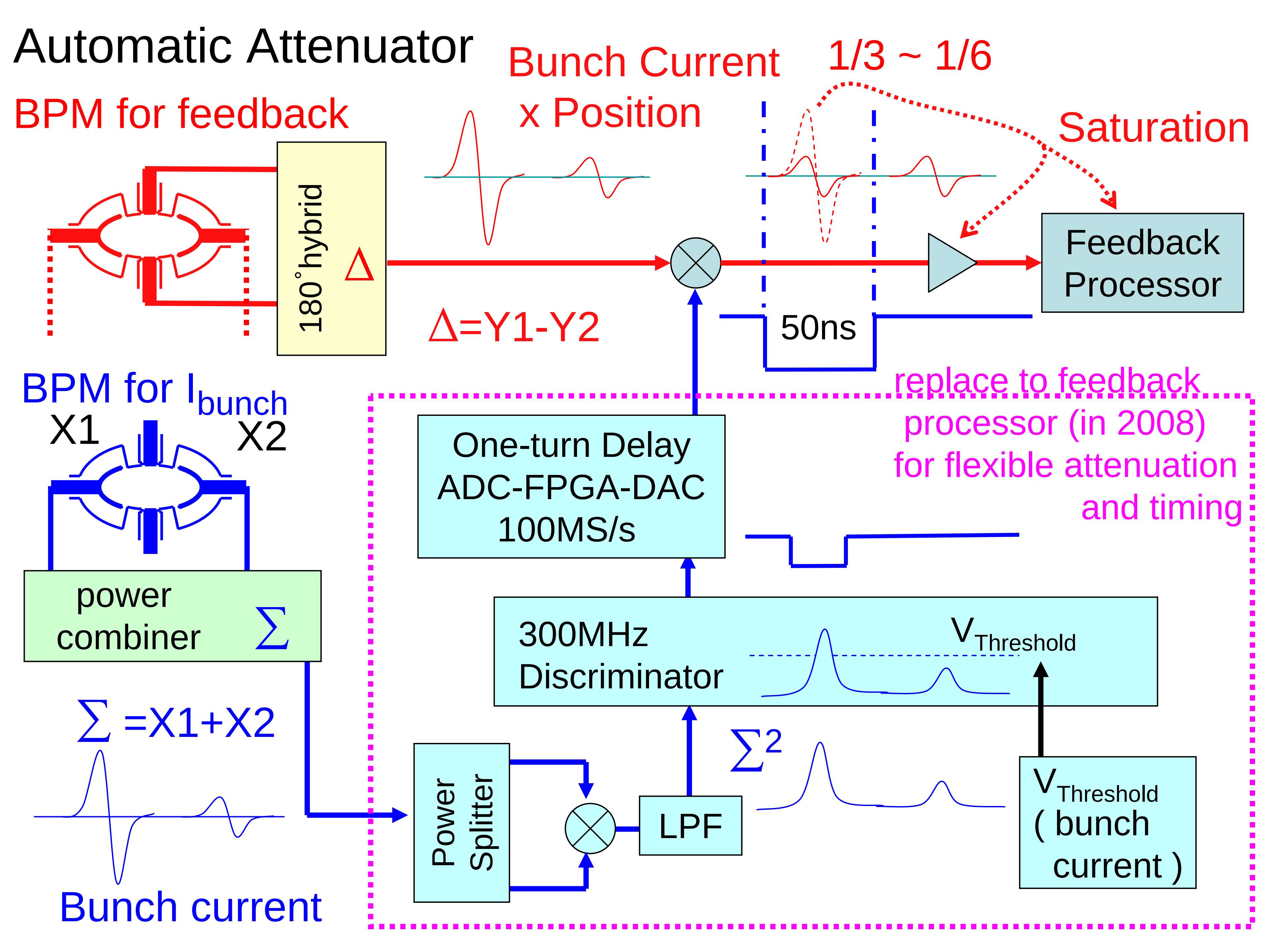
target 10 mA/bunch + 0.05 mA/bunch

improve Automatic Attenuator

BIG Horizontal Motion by Bump orbit
=> More Feedback Strength
<= New High Efficiency
Horizontal Kicker (in 2008)

Horizontal Motion excited by Bump




Automatic Attenuator
BPM for feedback
Bunch Current
x Position
1/3 ~ 1/6
Saturation
180°hybrid
Δ
Δ=Y1-Y2
Feedback
Processor
50ns
BPM for I_bunch
X1
X2
replace to feedback
processor (in 2008)
for flexible attenuation
and timing
One-turn Delay
ADC-FPGA-DAC
100MS/s
power
combiner
Σ
300MHz
Discriminator
V_Threshold
Σ =X1+X2
Σ2
Power
Splitter
LPF
V_Threshold
(bunch
current)
Bunch current

System for Multiturn Circulation of ERL beam in Storage Ring

Two-turn : $I_{ERL} = I_{Ring} / 2$

Four-turn : $I_{ERL} = I_{Ring} / 4$

Cascading : /2 /2 /2 ...

Low I_{ERL}

=> Less Beam Break Up

Low I_{Gun}

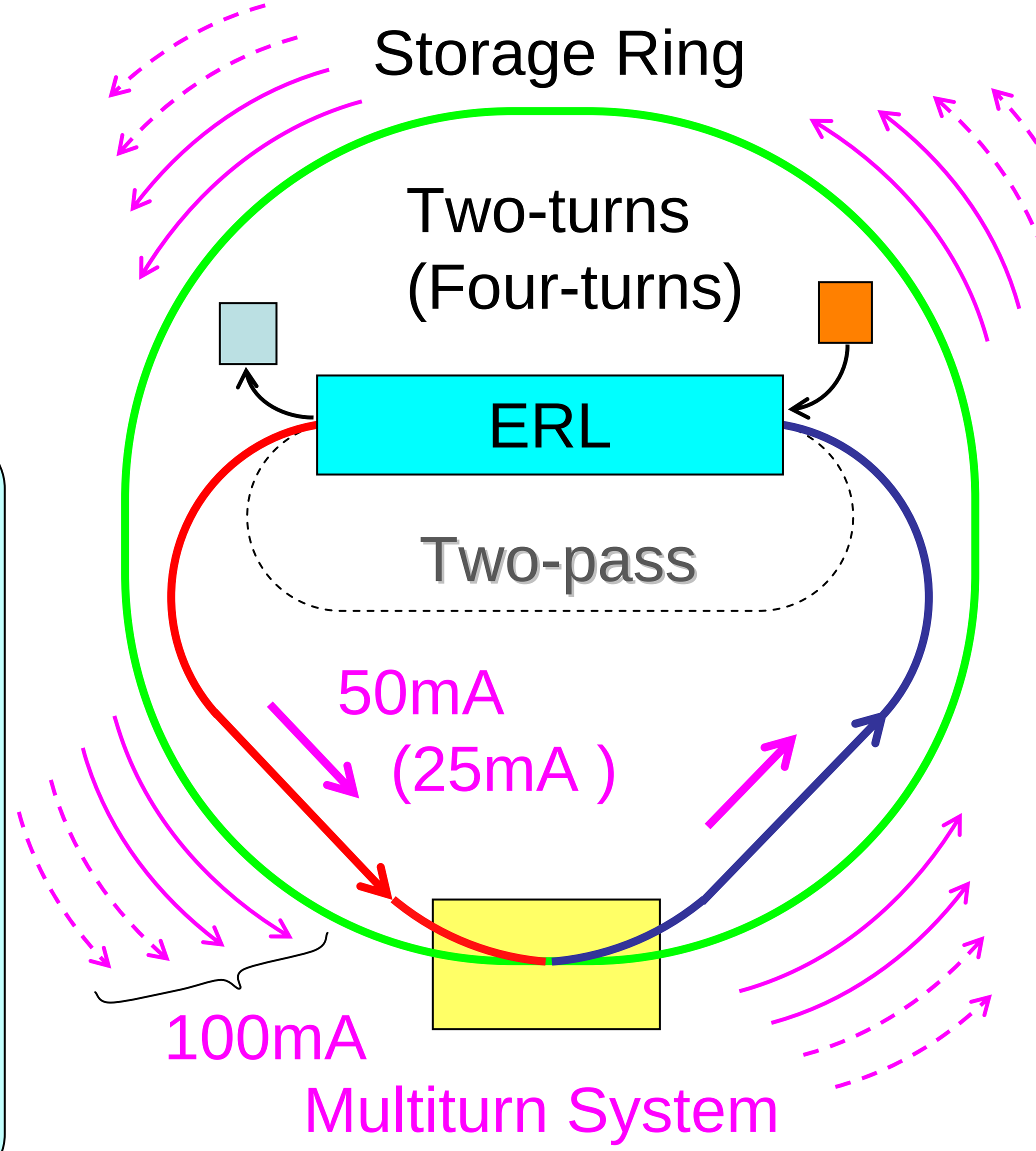
Low bunch charge

=> Better emittance

Shorter bunch

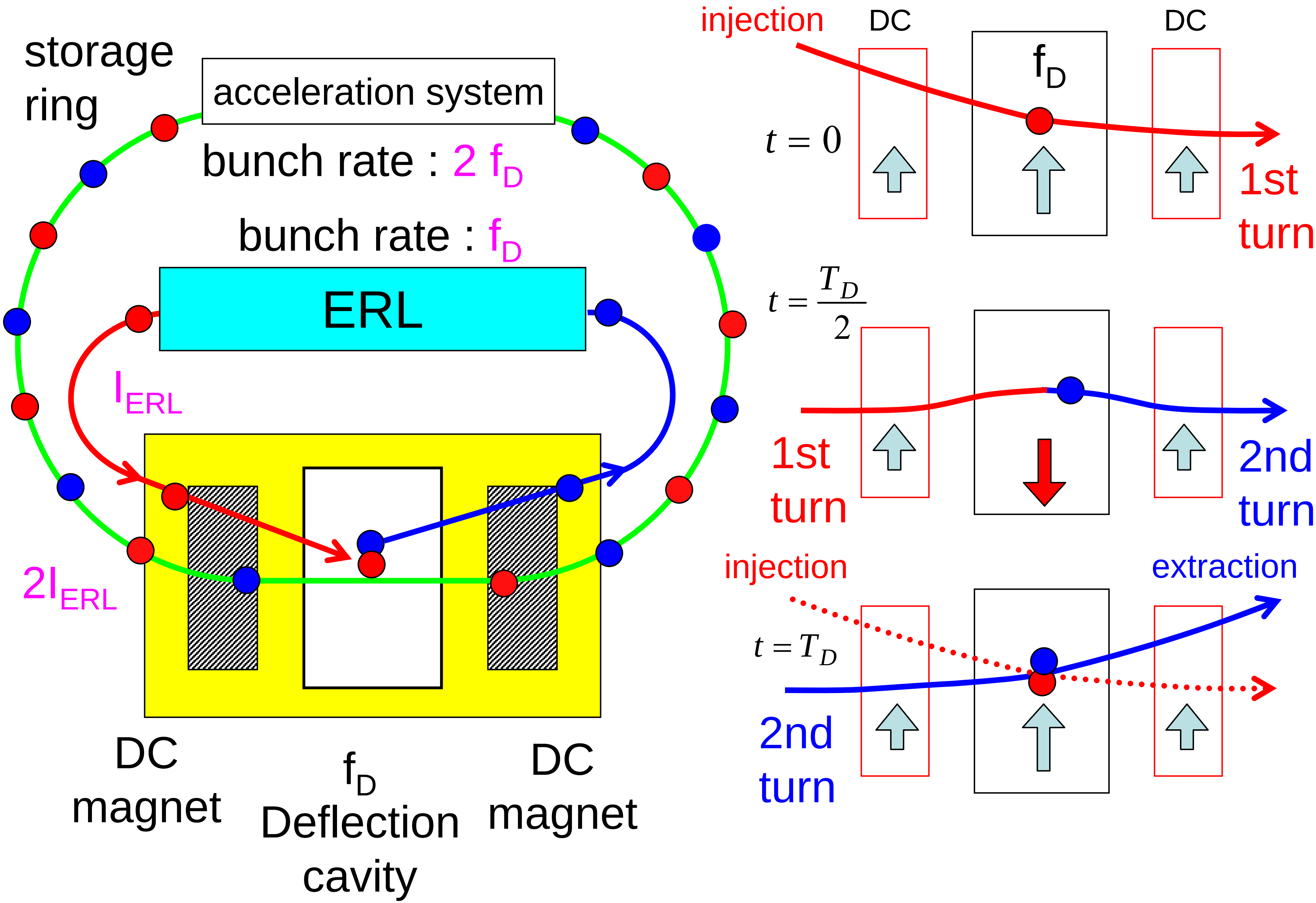
Multi-Pass ERL

=> Less Cost, Length



T. Nakamura, Phys. Rev. ST Accel. Beams 11, 032803 (2008)

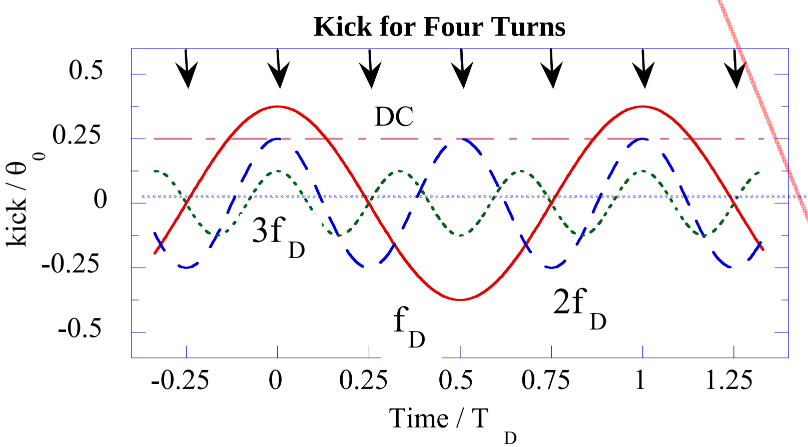
Two-turn System with RF deflection Cavity

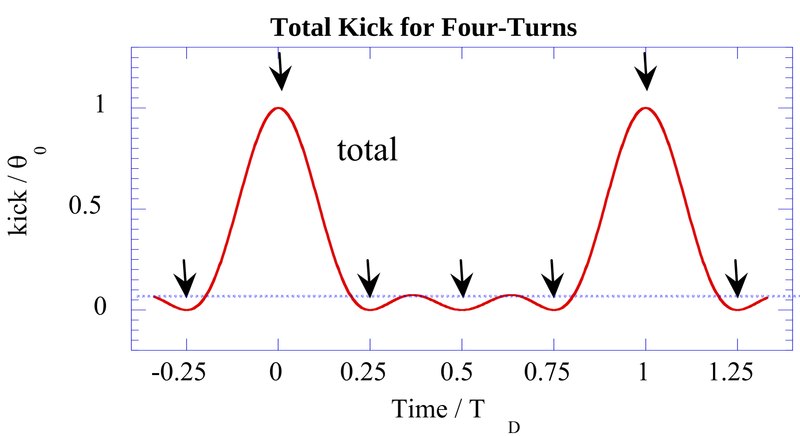


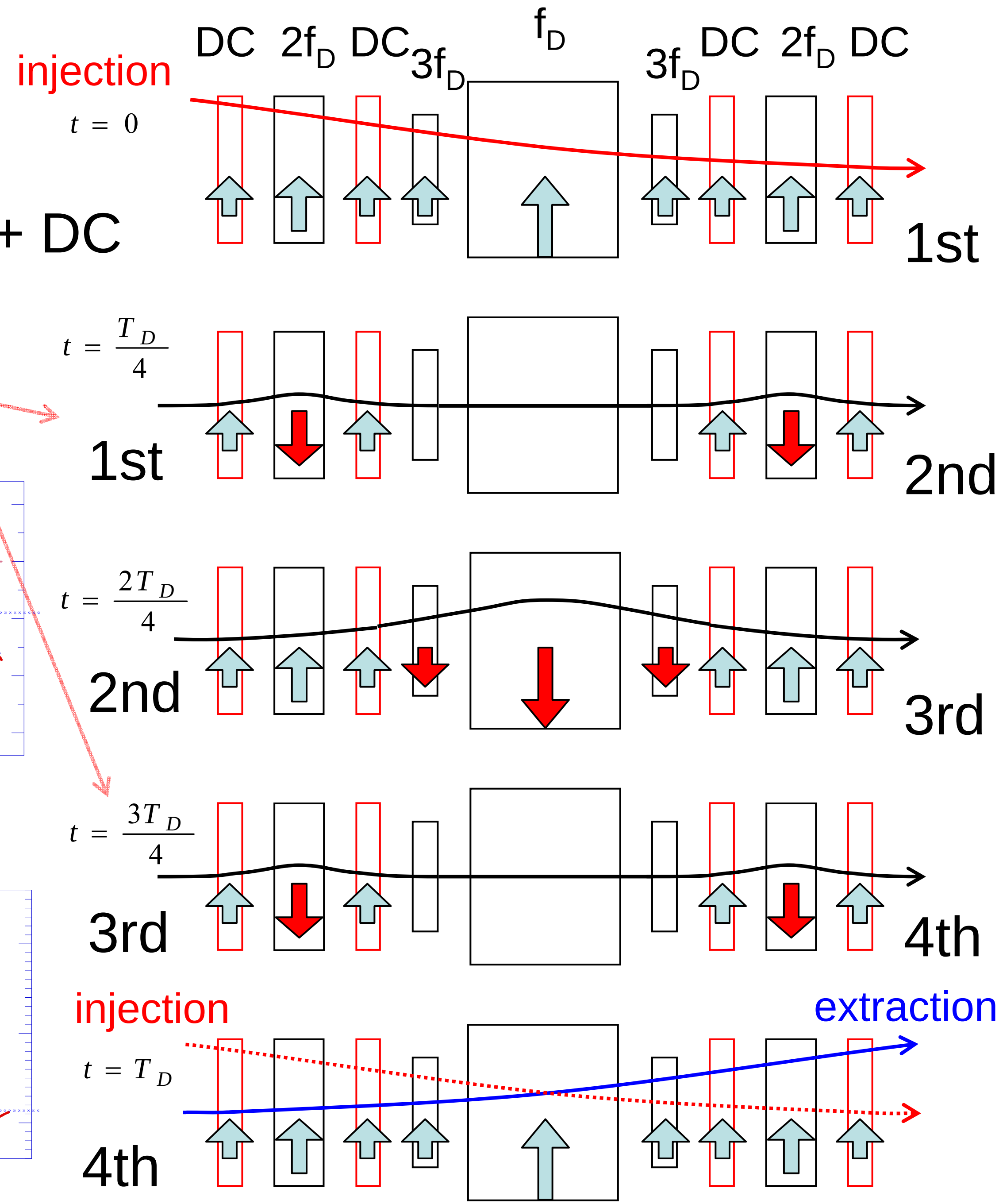
Four-turn System

f_D cavity + (□$2f_D$) cavity
+ (□$3f_D$) cavity + DC

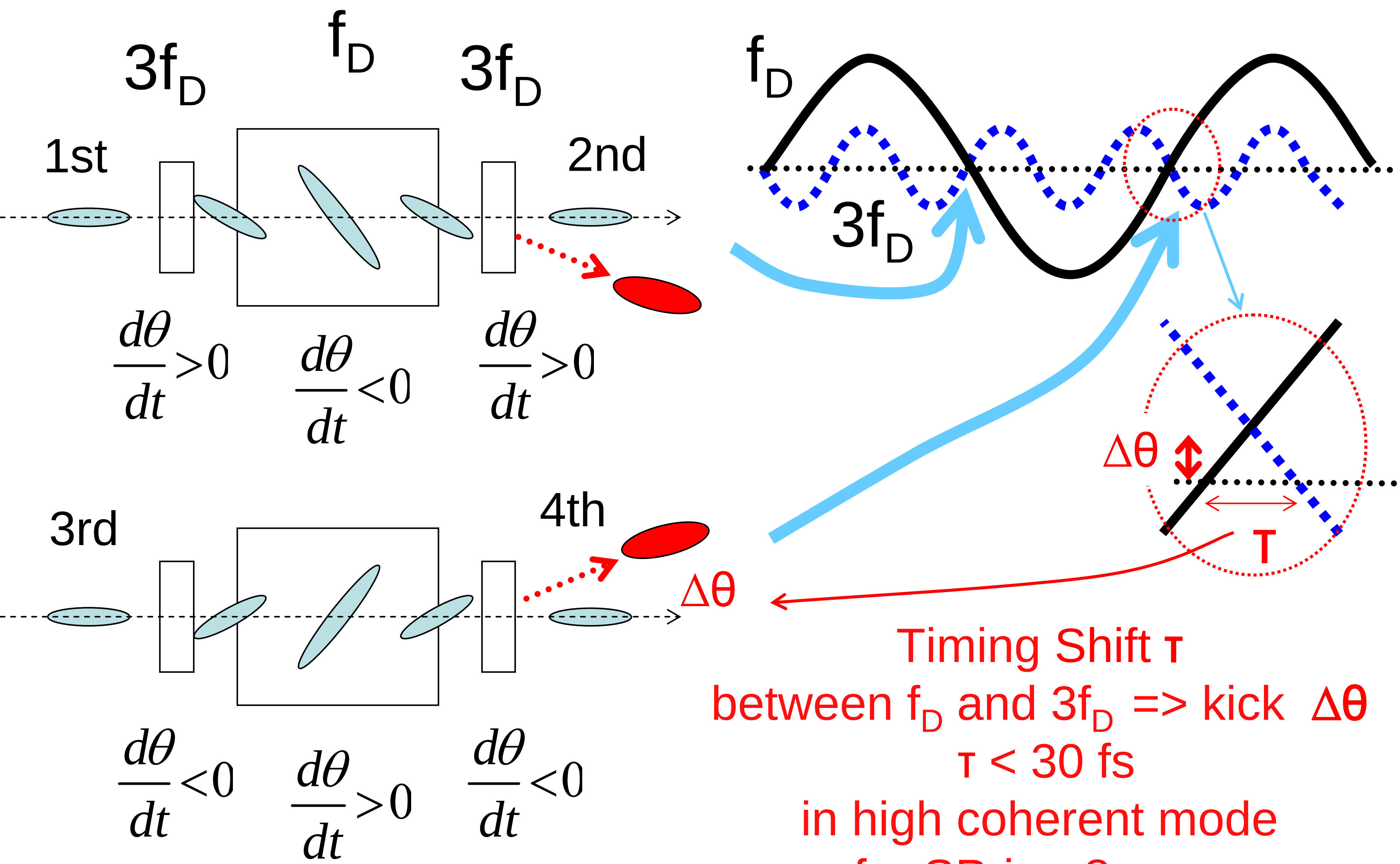
Precise Timing Adj. ~ 30 fs !
for high coherent mode op.







Cancellation of Crab Motion by ($3f_D$) cavities



Timing Shift τ

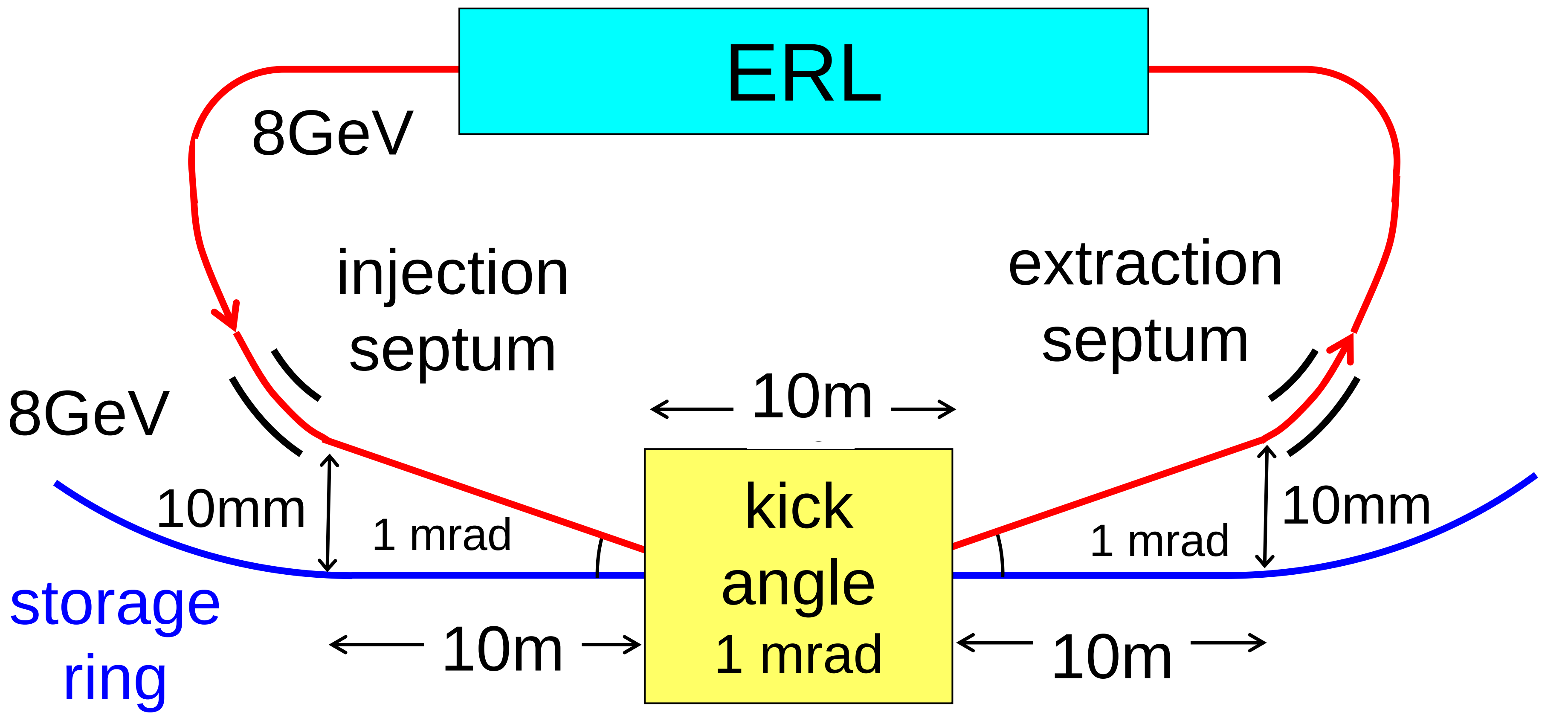
between f_D and $3f_D$ => kick **Δθ**

τ < 30 fs

in high coherent mode

for SPring-8 case

Example: SPring-8 30m straight section



Two-turn system

Kick Voltage by f_D Cavity = 8 GeV x 1mrad / 2 = 4MV

KEKB Crab Cavity 2MV

APS short pulse X-ray ~ 4MV)