Bunch Compression using the Transport Line
and
Short Bunch Revolving in NewSUBARU

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Introduction

Applications of Short Electron Bunch

- Short Pulsed X-Ray

  For time resolving experiments

  → Sub-ps (femto-second) pulse

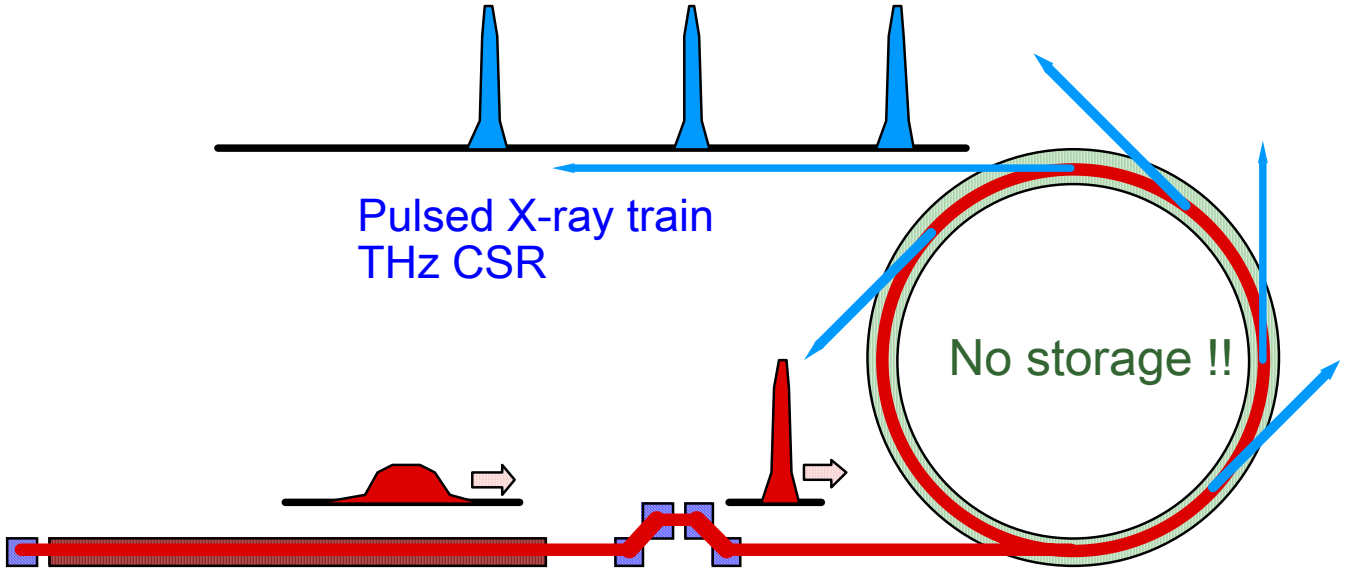
  → Intense ps pulse is still valuable

- Coheremt synchrotron radiation (CSR)

  → extremely strong THz radiation

The Concept

1. Make short and intense bunch in a linac
2. Let the bunch circulate in an isochronous ring
3. Use short pulsed X-ray train or THz CSR



Aims of the experiment

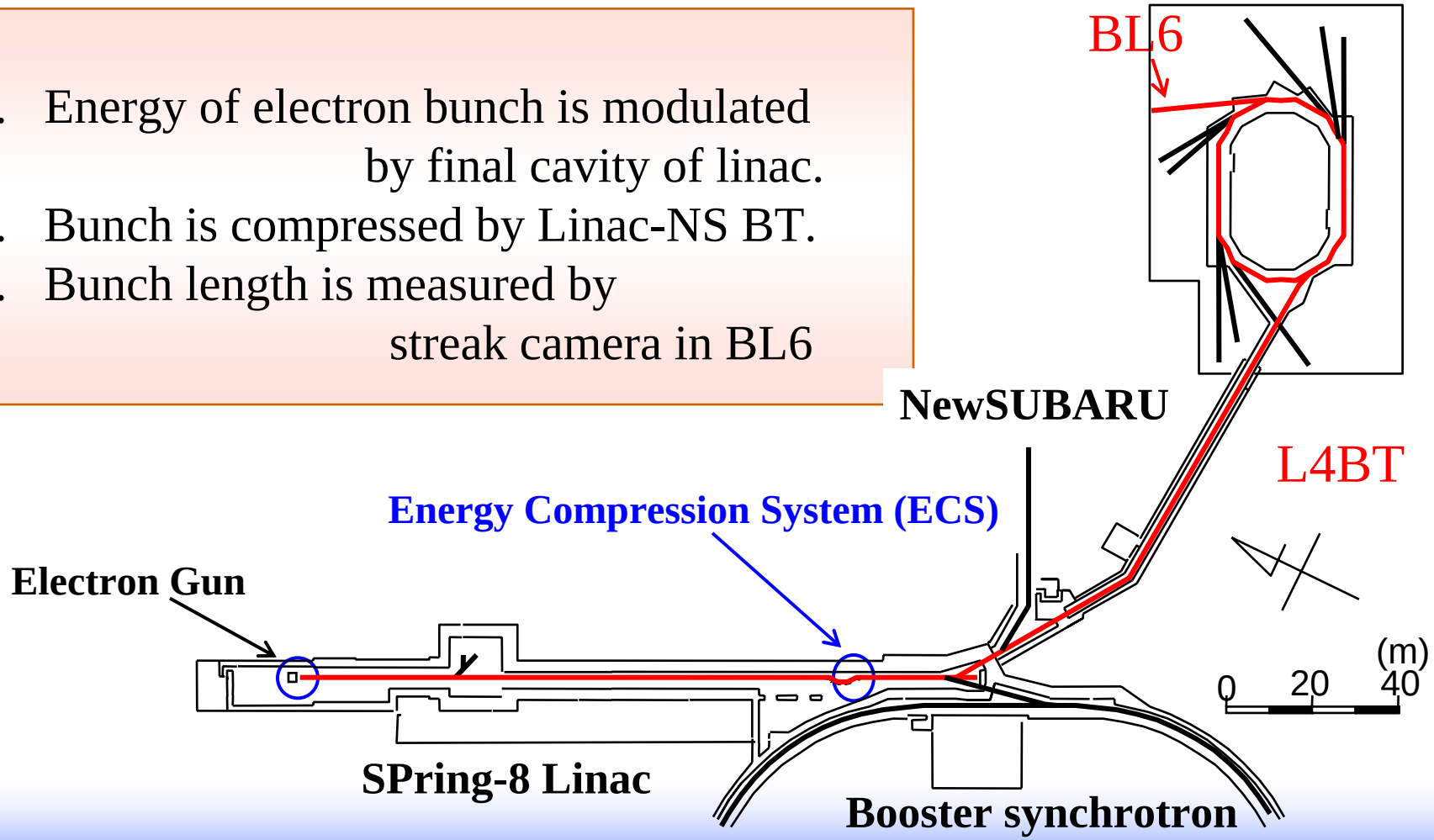
Demonstrate the method
using the SPring-8 linac and NewSUBARU

Establishment of this method for our machine

- Bunch compression at the linac.
- Multi-turn circulation in the ring.

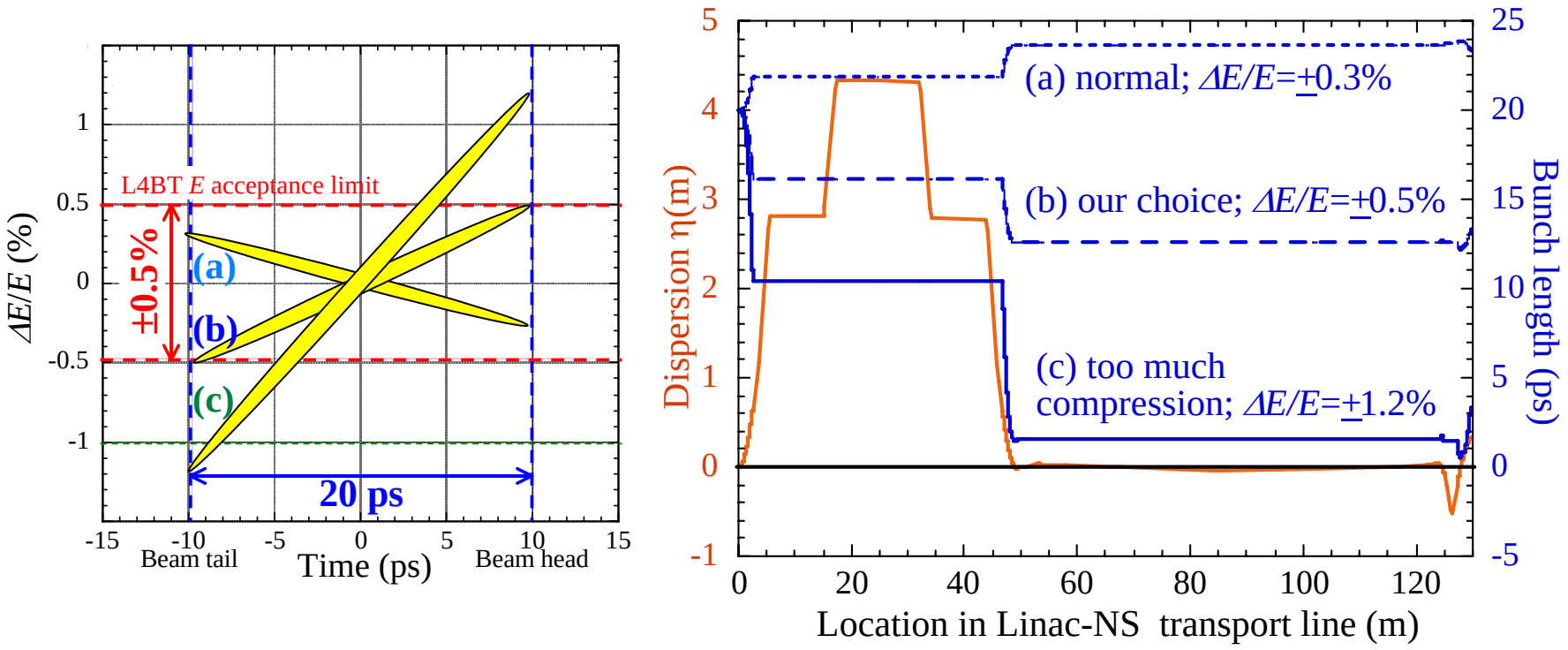
Production of Short Bunch

1. Energy of electron bunch is modulated by final cavity of linac.
2. Bunch is compressed by Linac-NS BT.
3. Bunch length is measured by streak camera in BL6



Optimization of bunch compression

Magnetic compression along the Li-NS transport

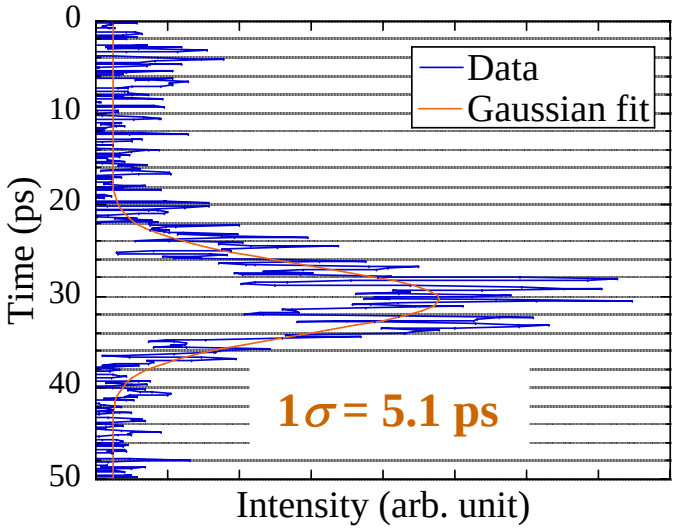


The bunch is modulated by final accelerator structure.
If the bunch is modulated like (c), the bunch is shorter.
But the beam can't transport for energy acceptance limit.

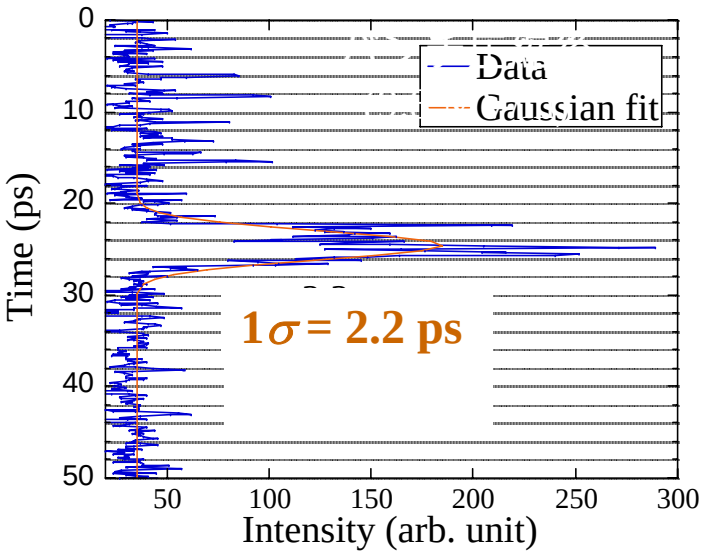
Bunch Length Measurement

Time profile at the initial turn in the ring with streak camera

Normal Operation Parameters



Bunch Compression Parameters



This compressed beam was injected to NewSUBARU of quasi-isochronous condition

Multi-turn Circulation

Energy dependence of path-length

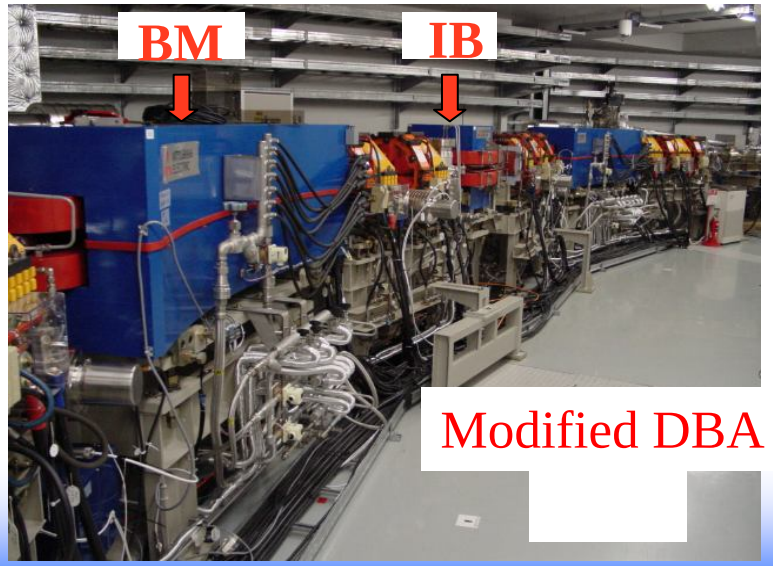
$$\Delta L = (\alpha_1\delta + \alpha_2\delta^2 + \alpha_3\delta^3 + \ldots)L \qquad (\text{here } \delta = \Delta E/E)$$

α_n : n-th momentum compaction factor

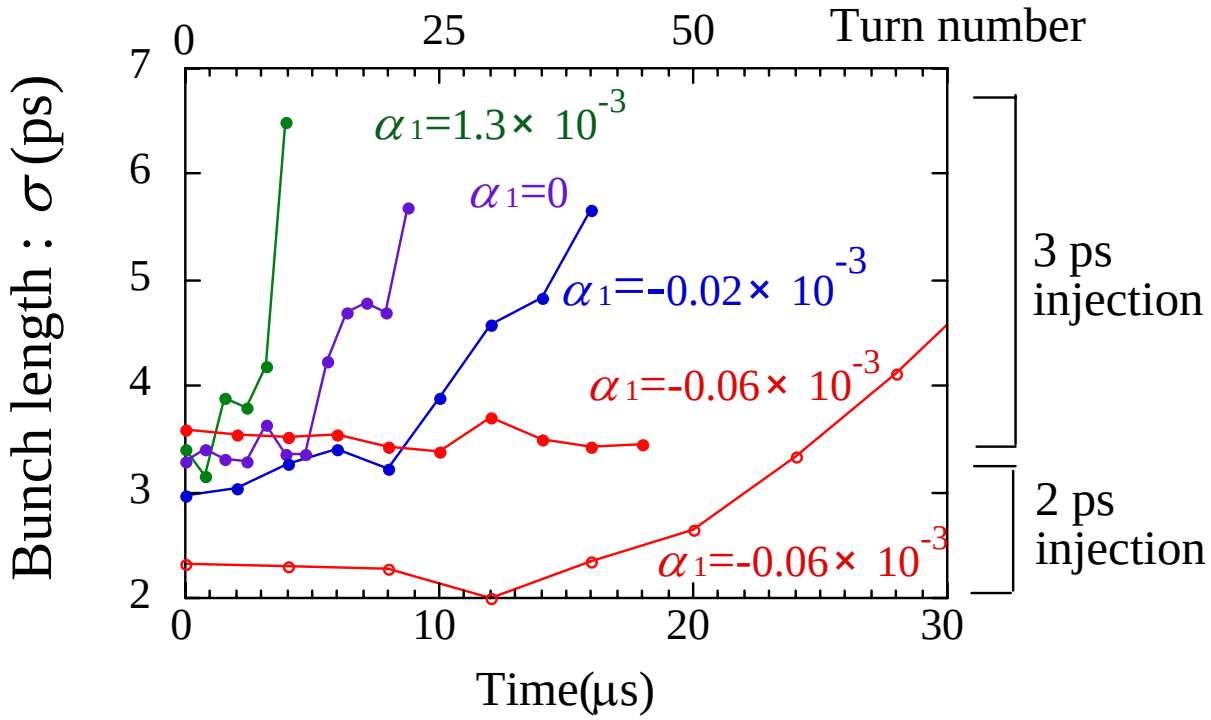
NewSUBARU storage ring has negative angle bending magnet.

→control α_1

- α_1 =1.3×10^{-3} (normal)
  → ≈ 0 (quasi-isochronous)
- α_2 = 0 (setting resolution ≈ 10^{-3})
- α_3 = 1 (fixed)



Bunch length measurement by streak camera at BL6



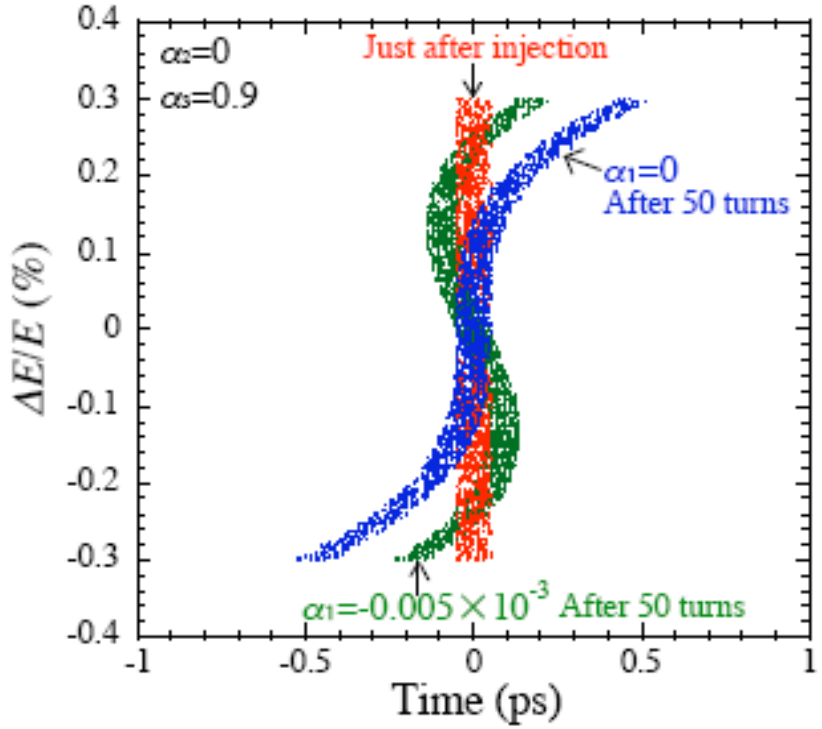
When $\alpha_1 = 0$, the bunch length become large soon.

Best tuning is $\alpha_1 = -0.06 * 10^{-3}$

The bunch length keeps for 50 turns after injection

Tracking simulation in the non-linear rf bucket

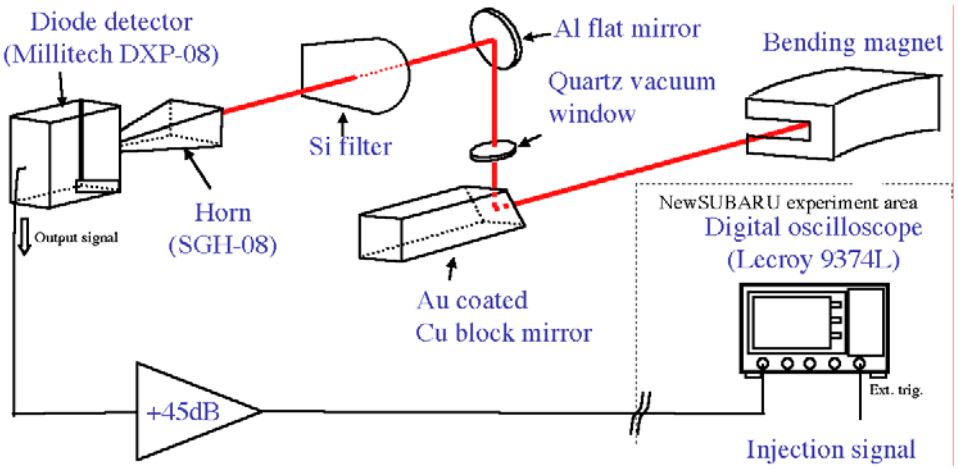
Beam occupancy at 50 turns after injection



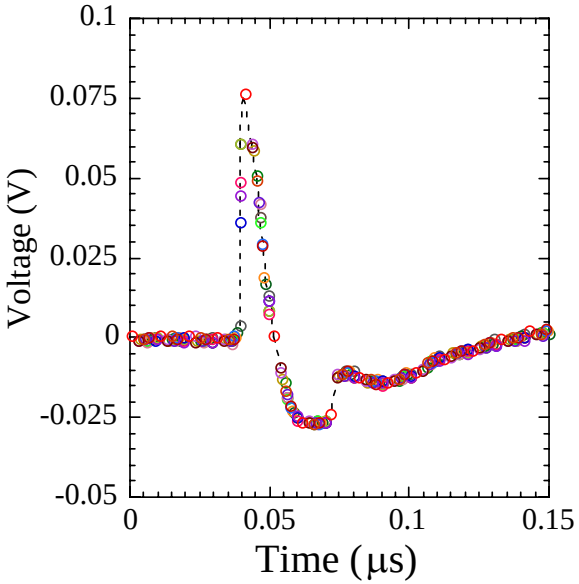
For higher order momentum compaction factor,
the bunch length is grown up by $\alpha_1 = 0$ lattice
than $\alpha_1 = -0.06 * 10^{-3}$ lattice.

CSR detection

Set-up of micro-wave detector (90-140GHz)

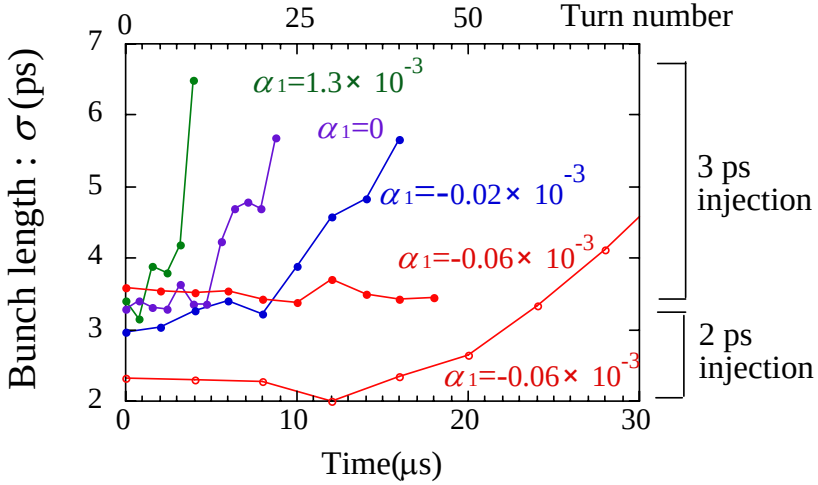


Signal waveform

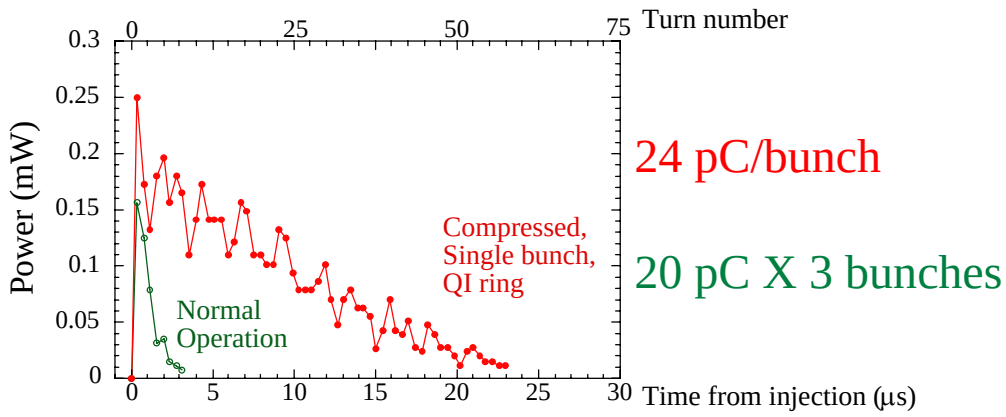


Revolution period=0.4μs

Turn by turn CSR power



Streak camera



Diode output

24 pC/bunch

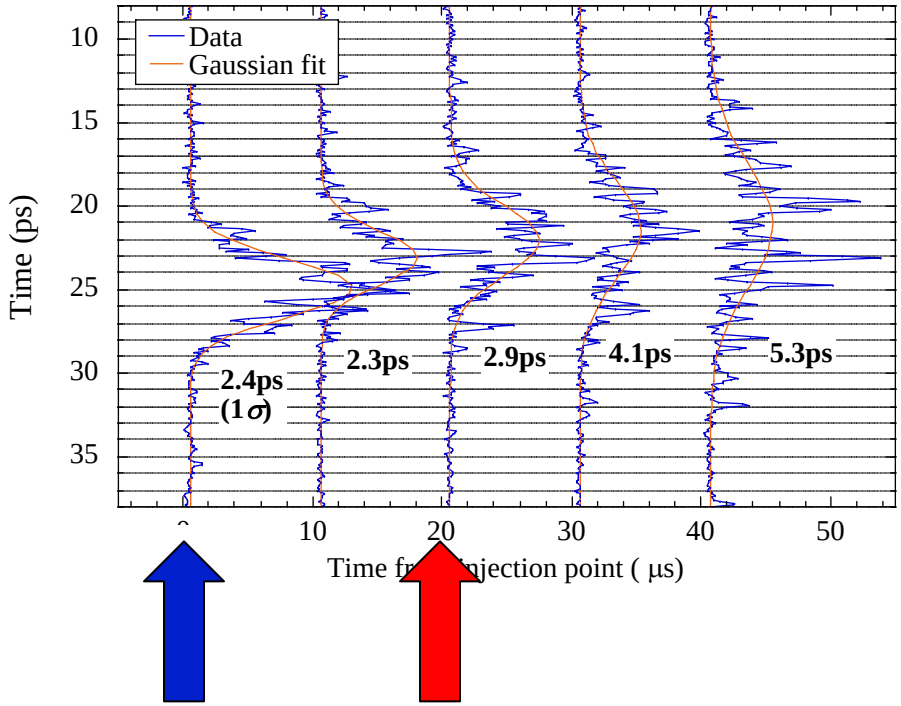
20 pC X 3 bunches

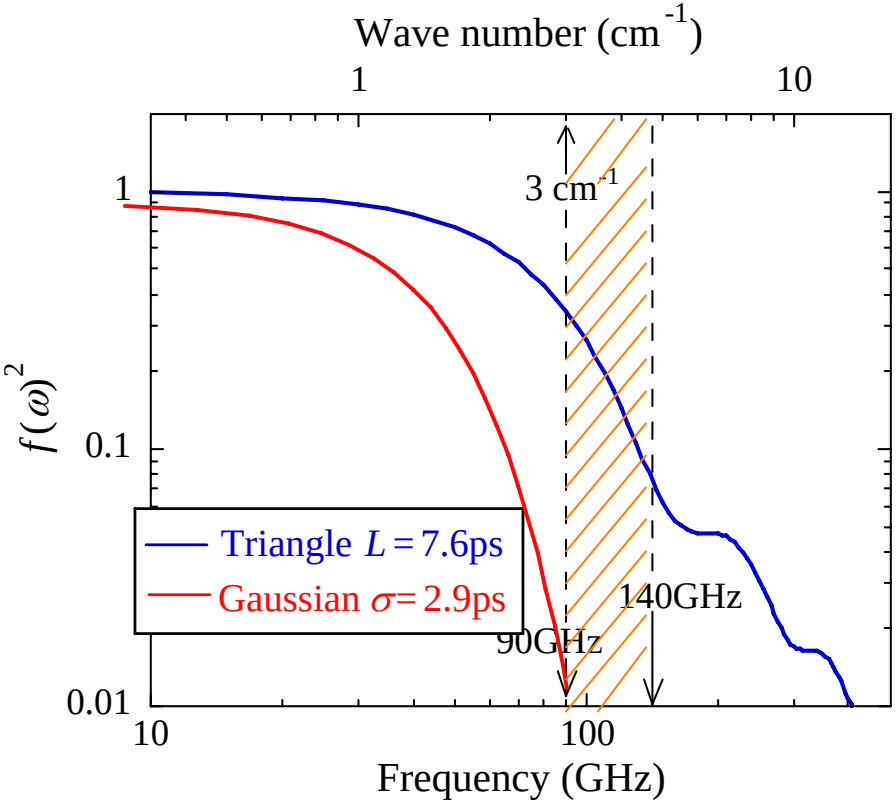
By the measurement of streak camera, bunch length is kept 50 turn.
But the CSR power is decreased turn-by-turn.

Decrease of CSR power

contribution of form factor $f(\omega)$

Evolution of time profile after injection





Time profile of the injection bunch look like triangle.
It is deformed from triangle to Gaussian turn-by-turn.

Results & Summary

Bunch comperession

- successfully get short bunch $1\sigma < 2.2$ps
  using the achromatic transport line.

Short Bunch Circulation

- successfully keep bunch length $1\sigma < 3$ps for 50 turns
  using the quasi-isochronous parameter.

Future Improvements

Linear Accelerator

- Lower emittance and high charge beam -> install Photocathode RF-Gun ?

Storage ring

- Better control of α_n .