Single Bunch Impurity Measurement at SPring-8 Storage Ring

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Outlilne

- ## Overview of SPring-8
  - accelerator complex
  - operation modes

- ## Bunch Purity Monitor
  - light shutter system
  - performance

- ## Results of Bunch Impurity Measurements
  - performance of top-up operation

- ## Summary

SPring-8 Accelerator complex

New SUBARU

8GeV Booster Synchrotron

1GeV Linac

8GeV Storage Ring

Beam Energy	8 GeV
Circumference	1436 m
Radio Frequency	508.58 MHz
Harmonic Number	2436
Revolution Frequency	209 kHz
Stored Current	100 mA
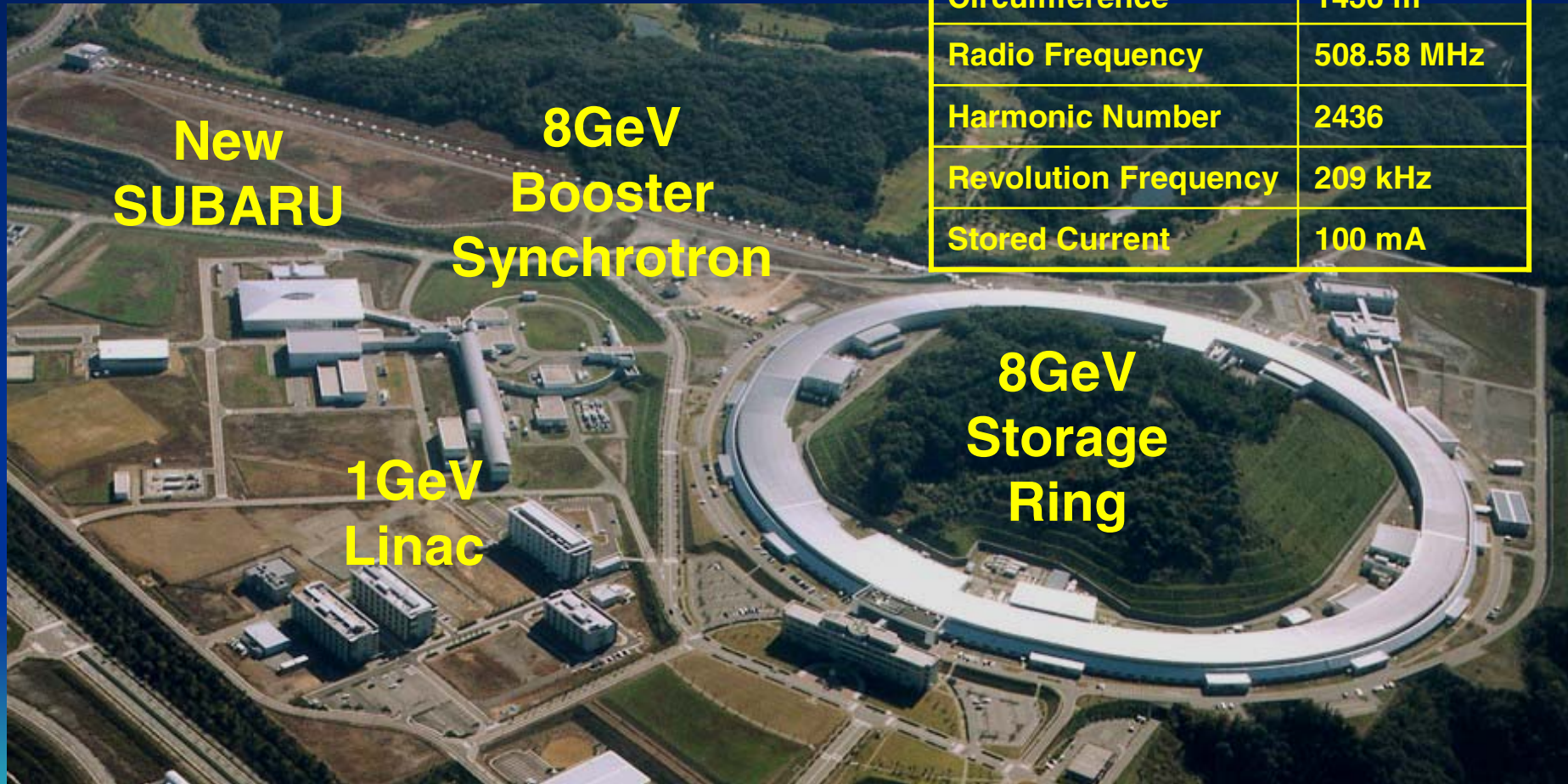
Operation Modes of the SPing-8

Three different filling patterns have been delivered to the user-time

    a) multi-bunch mode

        160-bunch train×12 (total 1780 bunches are stored)

    b) several bunch mode

        203-bunch (203 equally spaced bunches)

        29×11-bunch train (29 equally spaced 11-bunch trains)
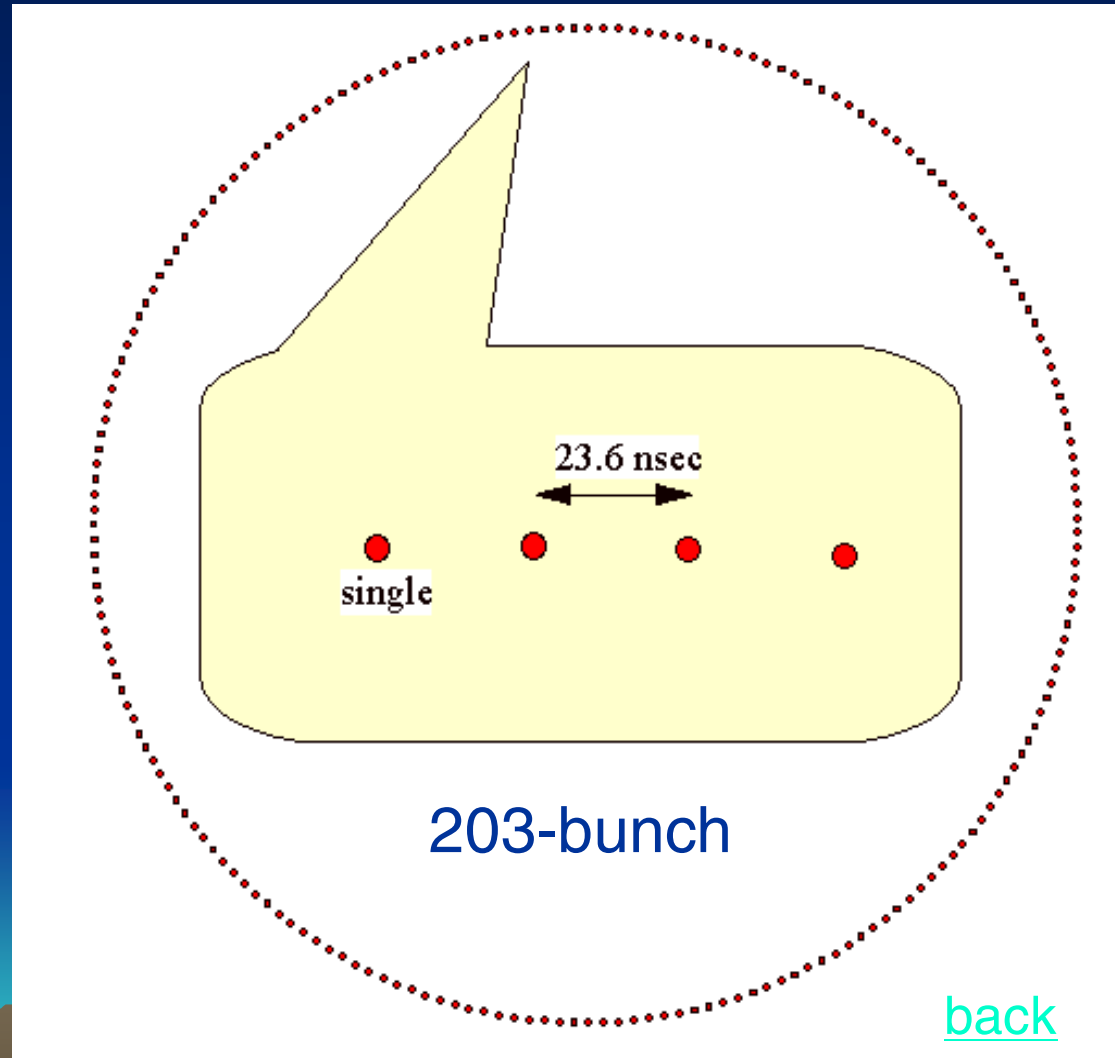
    c) hybrid filling mode

        2/21-filling + 18 isolated bunches
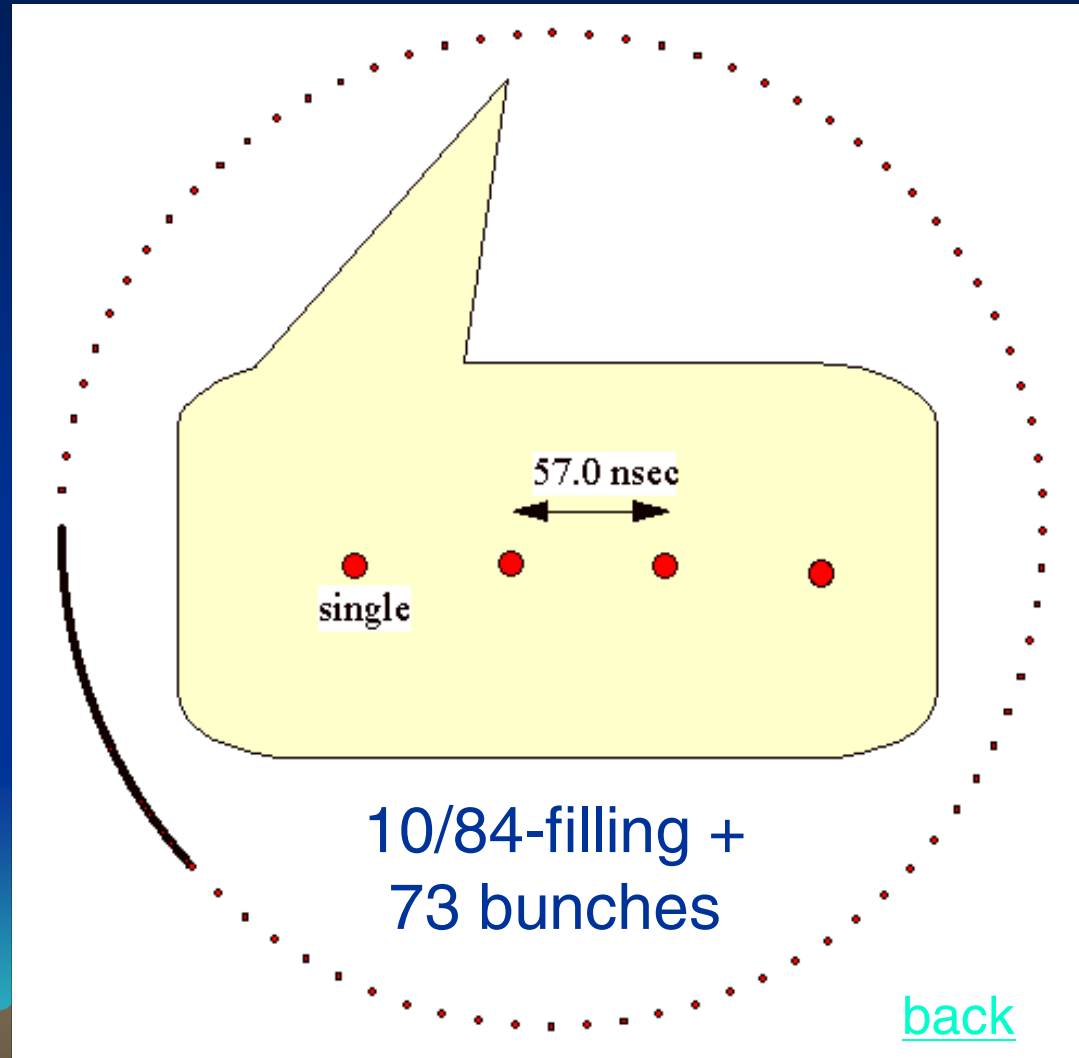
        10/84-filling + 73 isolated bunches

        etc

Highly purified single bunch (~10^{-9} level or less) is required for modes b) and c)

Example of operation mode (1)

Example of operation mode (2)

57.0 nsec

single

10/84-filling +
73 bunches

back

Formation of Purified Single Bunch

in the 8-GeV storage ring

- Very difficult to develop a bunch cleaning system due to high operation energy of electrons
- Electrons diffused from main bucket are hardly recaptured by satellite buckets due to the severe momentum acceptance
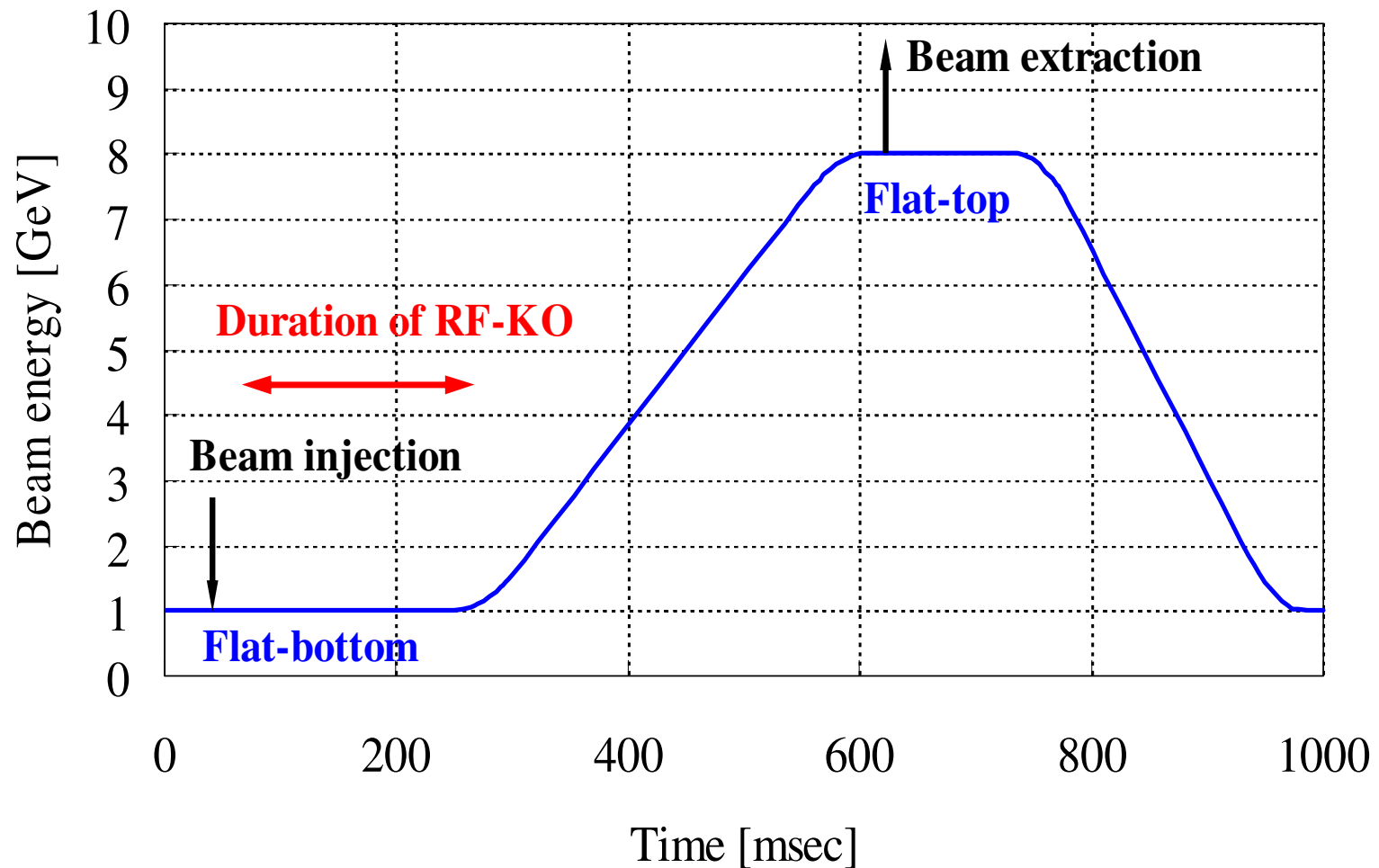
➔ An RF-KO system in the booster synchrotron has been developed to inject a purified single bunch into the storage ring

➔ Suitable for TOP-UP Operation !!
    No need to perturb the stored beam in the storage ring after TOP-UP injections
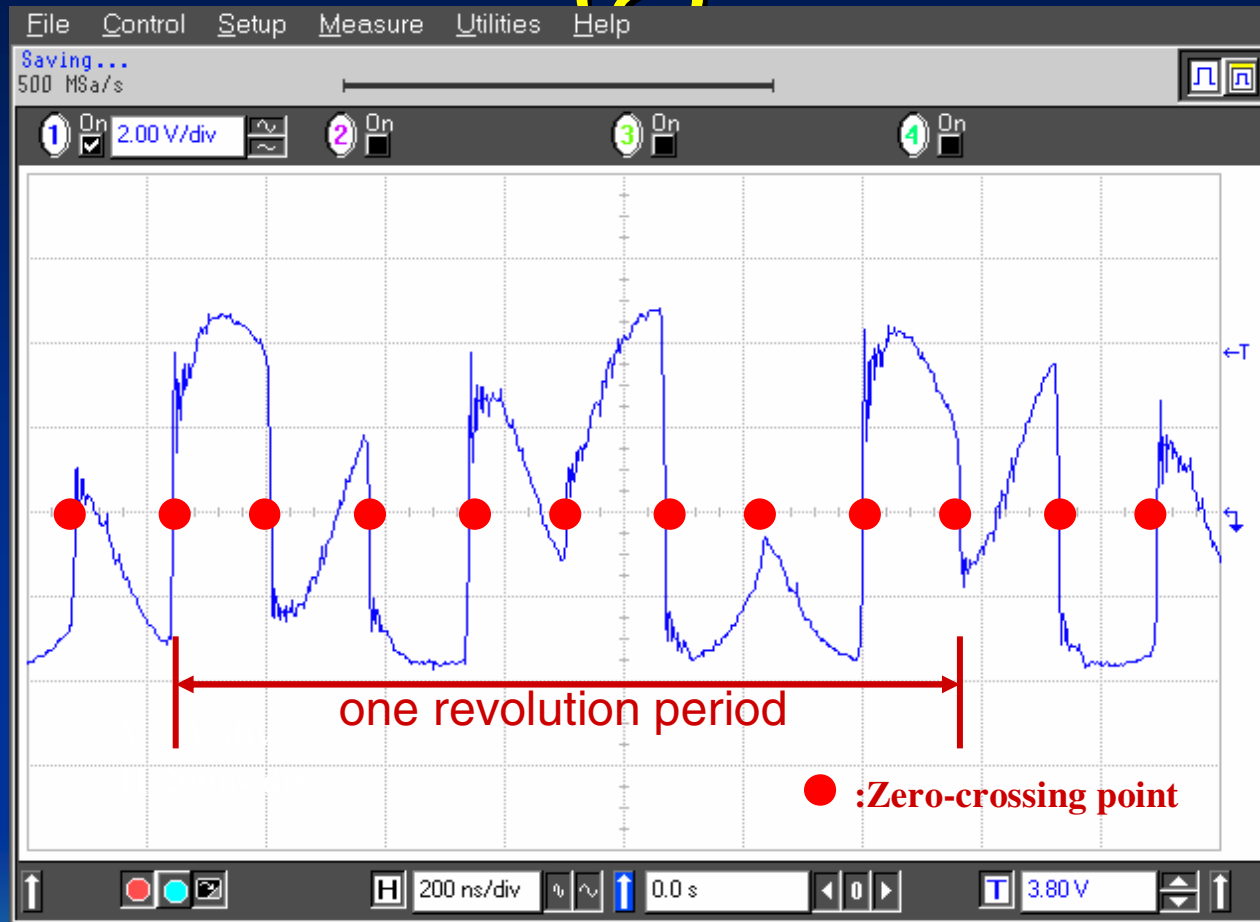
RF-KO system in the Booster

Beam energy pattern of the booster and timing chart of RF-KO

by T. Aoki

RF-KO system in the Booster (2)

one revolution period

● :Zero-crossing point

by T. Aoki

RF-KO waveform of beam-kicker

Bunch Purity Monitor

Evaluation of bunch impurity of 10^{-9} order

→A monitor with a dynamic range of over 10^{10} is required!!

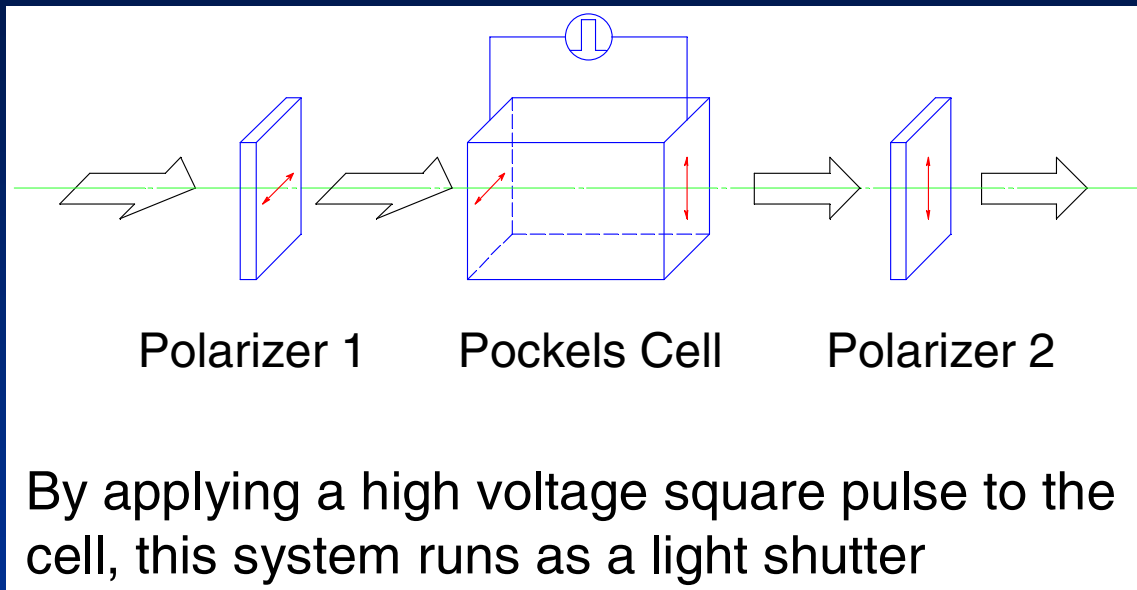Photon counting method

= Method with an excellent dynamic range, but,

A long counting time is required

Time response and S/N ratio of the detector limit the sensitivity

→ practical dynamic range: 10^6~10^7 （insufficient）

→A fast light shutter system in visible light region was developed, and combined with the photon counting method.

Principle of Light Shutter

Polarizer 1   Pockels Cell   Polarizer 2

By applying a high voltage square pulse to the cell, this system runs as a light shutter

Basic Components

Two polarizers

whose polarization angles are perpendicular to each other

Fast Pockels cell

placed between the polarizers

High Voltage Pulser

driver of the cell

Opening timing of the shutter == a satellite bunch

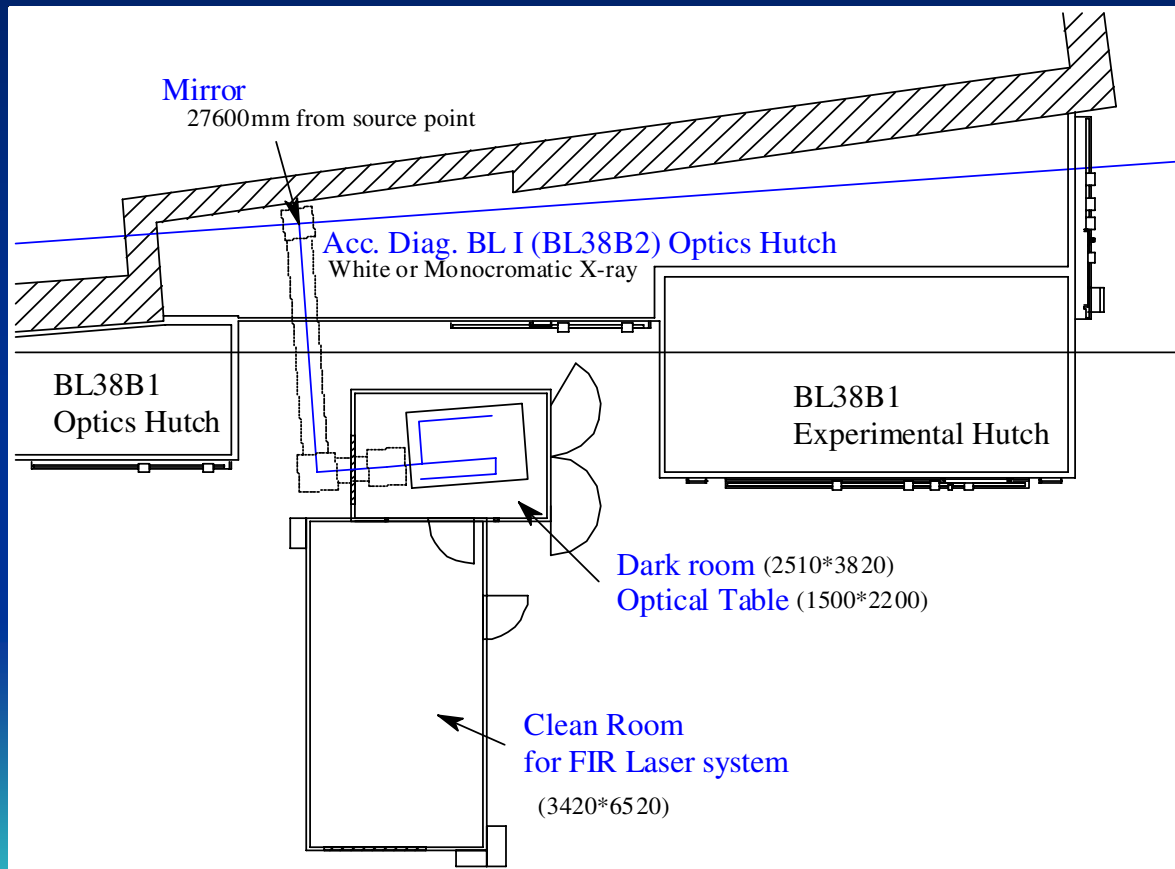→Light pulse from the main bunch : weakened (impossible to cut the light completely)

➔Contrast between the light pulse from the satellite bunch and that from the main bunch can be decreased

➔Hard situation of the bunch impurity measurement can be eased !!

Acc. Diag. BL #I(BL38B2)

light source: Bending magnet

wideband spectral availability (from visible/UV to hard X-ray)

Mirror
27600mm from source point

Acc. Diag. BL I (BL38B2) Optics Hutch
White or Monocromatic X-ray

BL38B1
Optics Hutch

BL38B1
Experimental Hutch

Dark room (2510*3820)
Optical Table (1500*2200)

Clean Room
for FIR Laser system
(3420*6520)

Visible synchrotron light is extracted by a mirror in a vacuum chamber and transported to a dark room on the experimental hall

→ longitudinal diagnostics

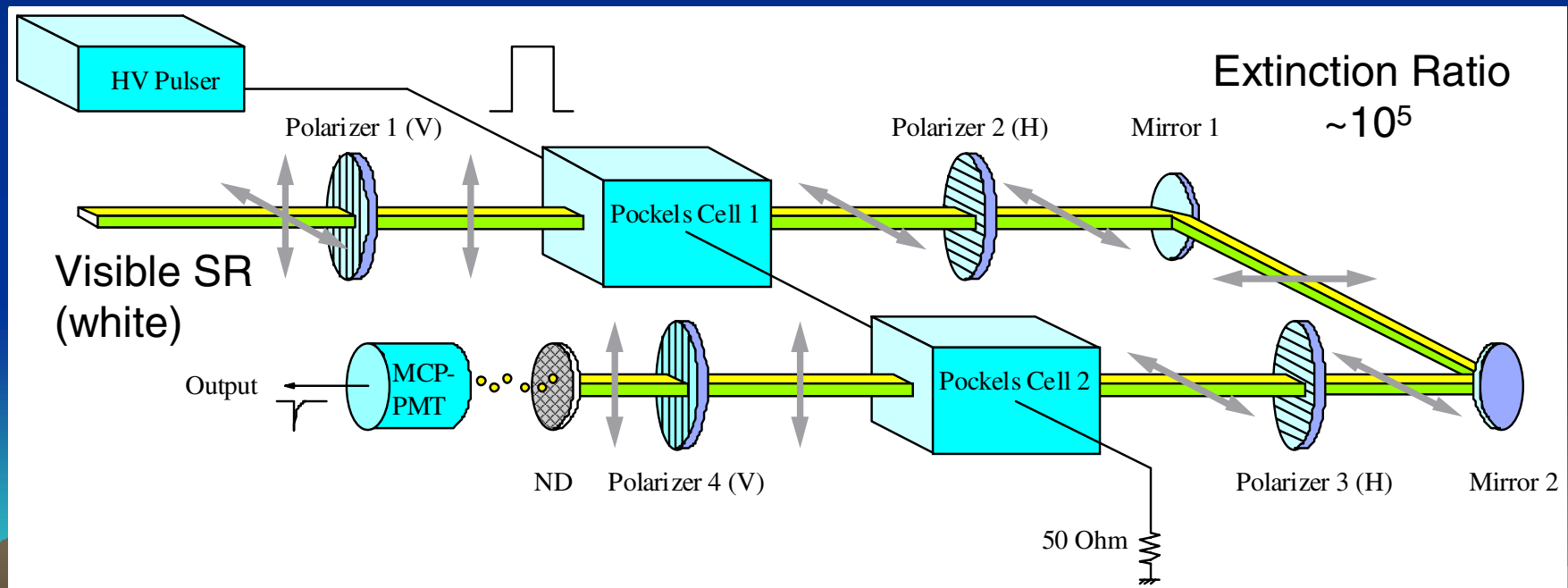bunch impurity

bunch length

SPring-8 Bunch Purity Monitor

Two light shutter systems

arranged in tandem to achieve the high extinction ratio ($\sim 10^5$)

Photon counting system

a micro channel plate type photo-multiplier tube (MCP-PMT) is used as a photon detector (dynamic range $\sim 10^6$)

designed sensitivity $\sim 10^{-11}$

HV Pulser

Extinction Ratio $\sim 10^5$

Polarizer 1 (V)

Polarizer 2 (H) Mirror 1

Pockels Cell 1

Visible SR (white)

Output

MCP-PMT

ND Polarizer 4 (V)

Pockels Cell 2

Polarizer 3 (H) Mirror 2

50 Ohm

Performance of Light Shutter

High Voltage Pulser

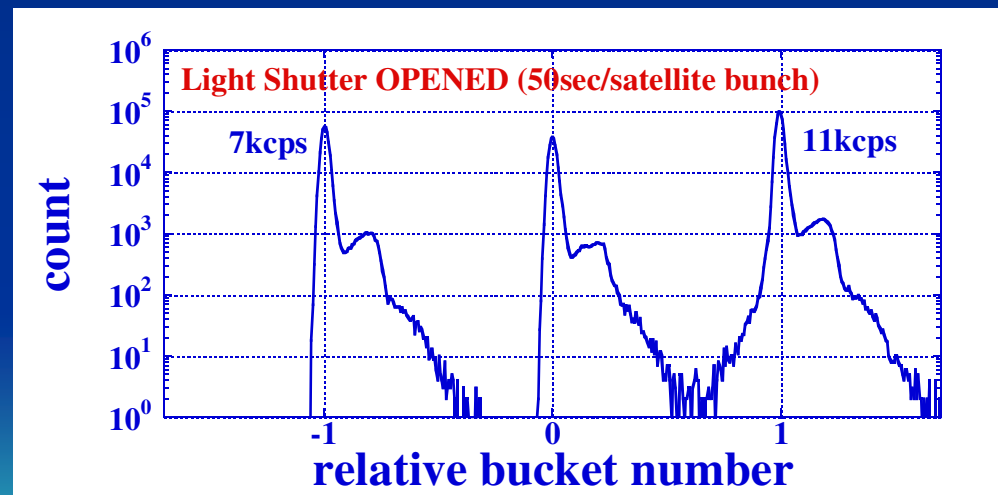|	
repetition rate	209 kHz (=frev)
voltage	1.5 kV (variable)
rise/fall time	<2ns (bunch spacing)
flat top	6~10 ns (variable)

500V/div, 2ns/div
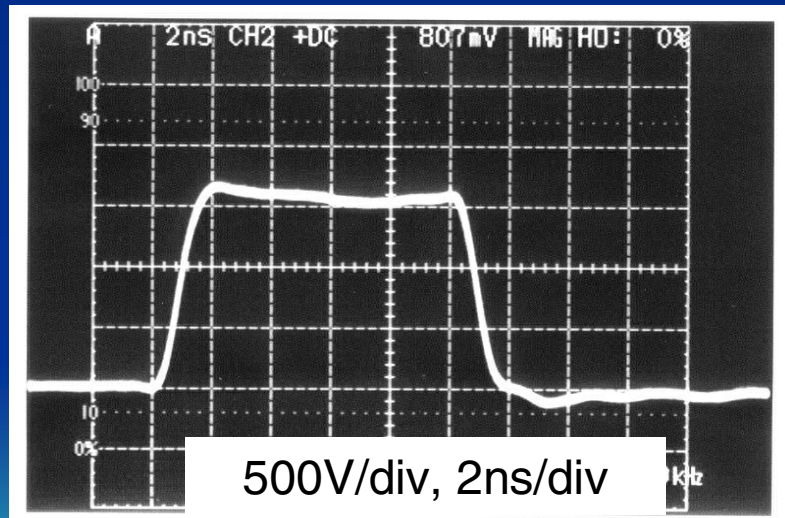
Time Profile of Light Shutter
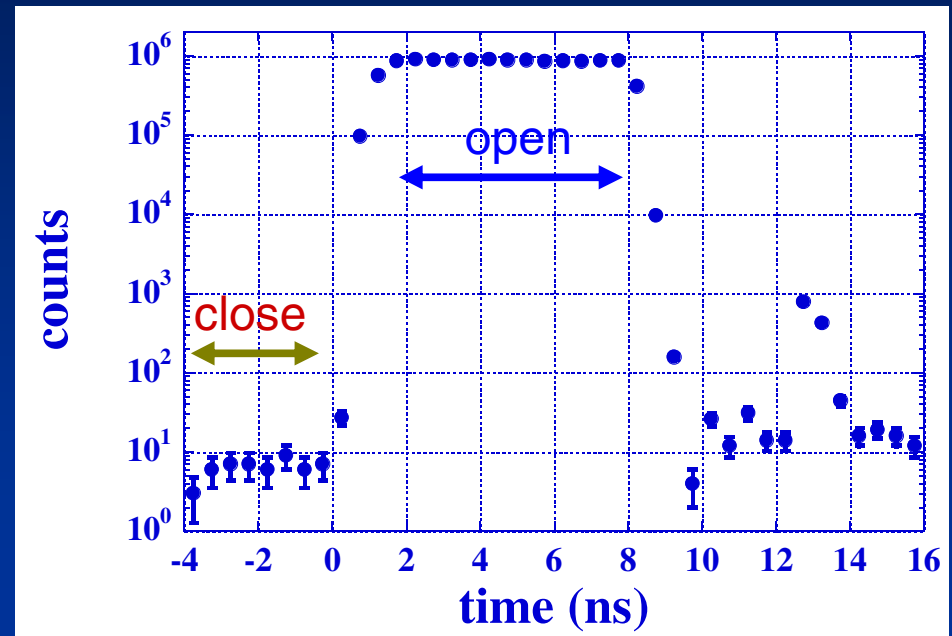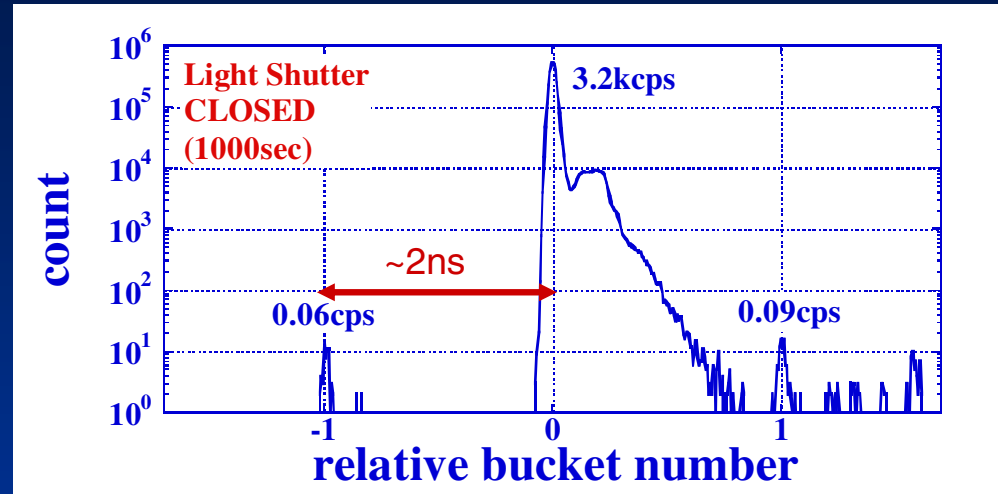
Performance of Light Shutter (2)

Evaluation of Extinction Ratio

Extinction Ratio=
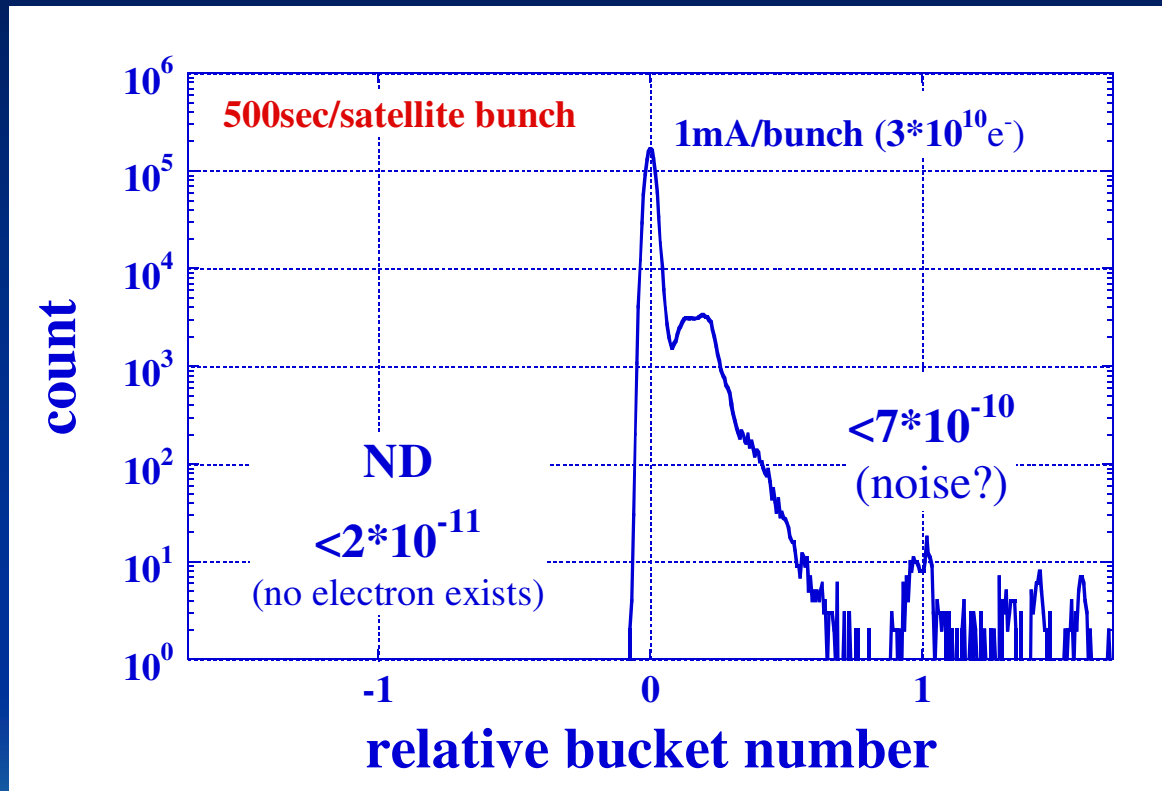
Transmitted light @open

/ Leaked light @close

- Injected a single bunch beam into the storage ring without RF-KO (impurity $\sim 10^{-5}$ typ.)

- Measured the counting rates of satellite bunches with the shutter closed or opened

- Compared the counting rates and obtained the extinction ratio of $\sim 10^5$

Light Shutter CLOSED (1000sec)

10^6 10^5 10^4 10^3 10^2 10^1 10^0

count

3.2kcps

~2ns

0.06cps

0.09cps

-1   0   1

relative bucket number

Light Shutter OPENED (50sec/satellite bunch)

10^6 10^5 10^4 10^3 10^2 10^1 10^0

count

7kcps

11kcps

-1   0   1

relative bucket number

Sensitivity of Purity Monitor

Single Bunch operation

500sec/satellite bunch

1mA/bunch ($3*10^{10}e^-$)

ND

$<2*10^{-11}$
(no electron exists)

$<7*10^{-10}$
(noise?)

count

relative bucket number

-1st bucket

no signal detected

→ no electron exists

sensitivity of the monitor

$<2 \times 10^{-11}$

+1st bucket

not distinguished whether the peak was real bunch or noise yet

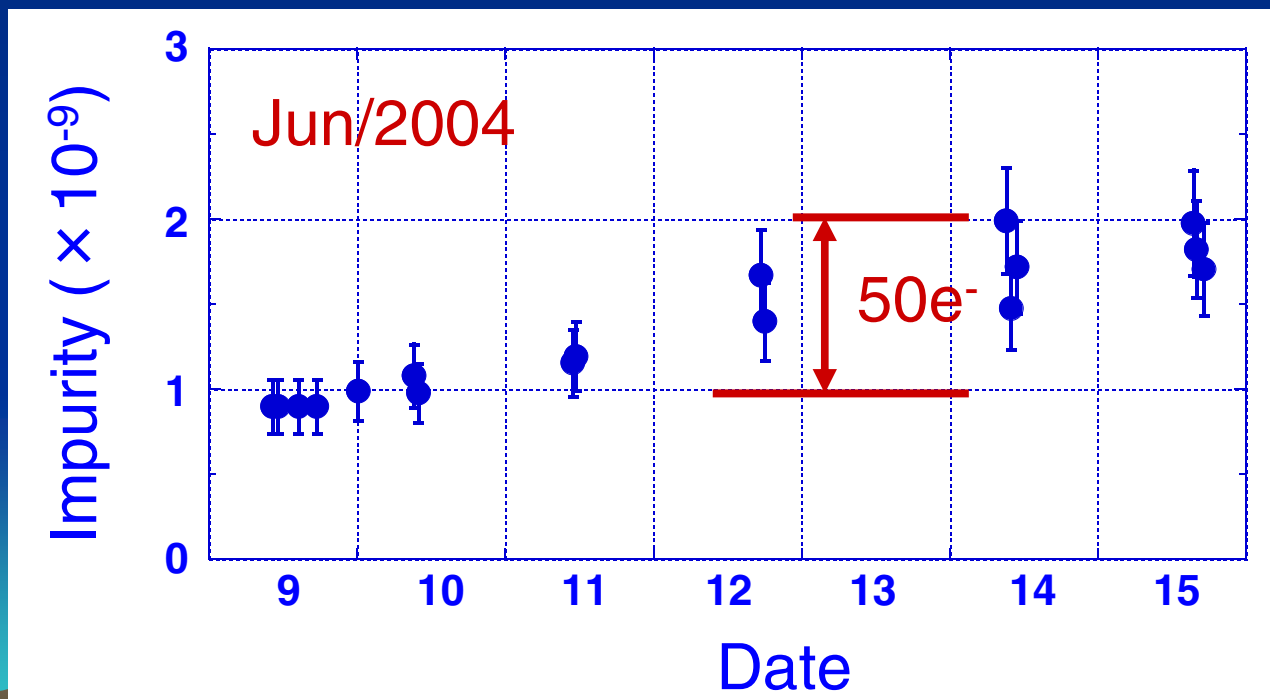sensitivity of the monitor

(upper limit of impurity)

7×10^{-10}

Bunch Impurity Measurement (1)

During TOP-UP operation (1)
- Date   2004/Jun/9~15
- Filling   2/21-fill + 18 isolated bunches (1.5mA/bunch)

Impurity at +1st bucket just behind a particular isolated bunch was continuously measured

Jun/2004

50e⁻

# of top-up injection into this isolated bunch

480 times

Total injected current

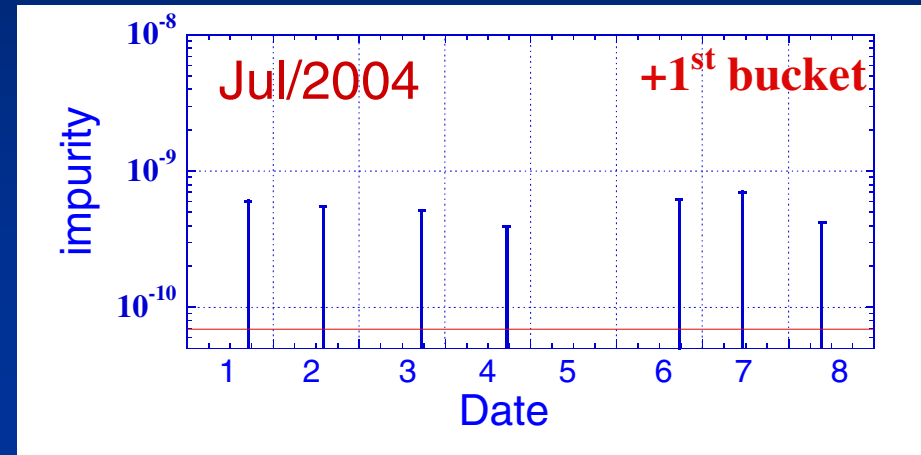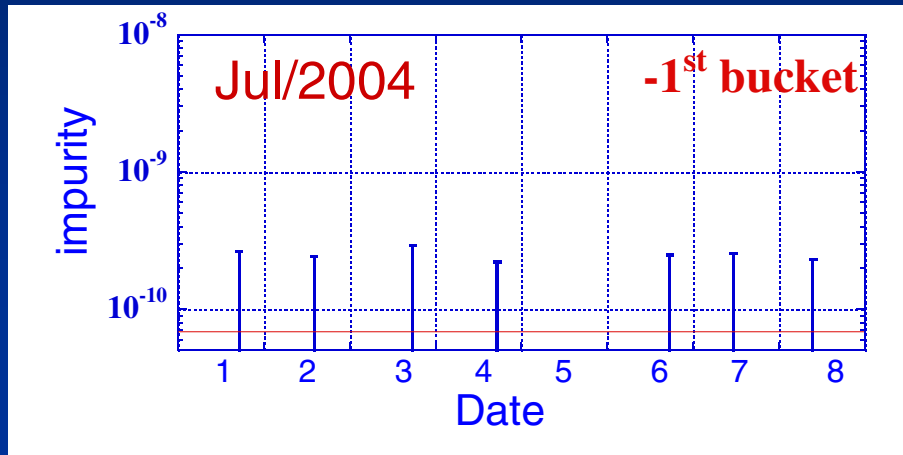~15.5mA (4.7×10¹¹e⁻)

Avg. impurity of injected single bunch

~1×10⁻¹⁰

Bunch Impurity Measurement (2)

During TOP-UP operation (2)

- Date   2004/Jul/1~8

- Filling   203-bunch (0.5mA/bunch)

Impurities at $+1^{st}$ bucket just behind and -1st just before a particular isolated bunch were continuously measured

# of top-up injection into this isolated bunch: 60 times

Total injected current: ~2.5mA ($7.5 \times 10^{10} e^-$)

No growth of impurity was observed and impurity at -1st bucket kept at about 3×10^{-10} level

Summary

- The SPring-8 bunch purity monitor that utilizes the fast light shutter system with the extinction ratio of 10^5 has been in operation, and impurity measurement with the sensitivity of 10^{-10} order is realized.

- The bunch cleaning system of SPring-8 booster synchrotron works very well, and the bunch impurity of the storage ring has been kept 10^{-9} level or less during the TOP-UP operation, which is a sufficiently small level to user experiments.