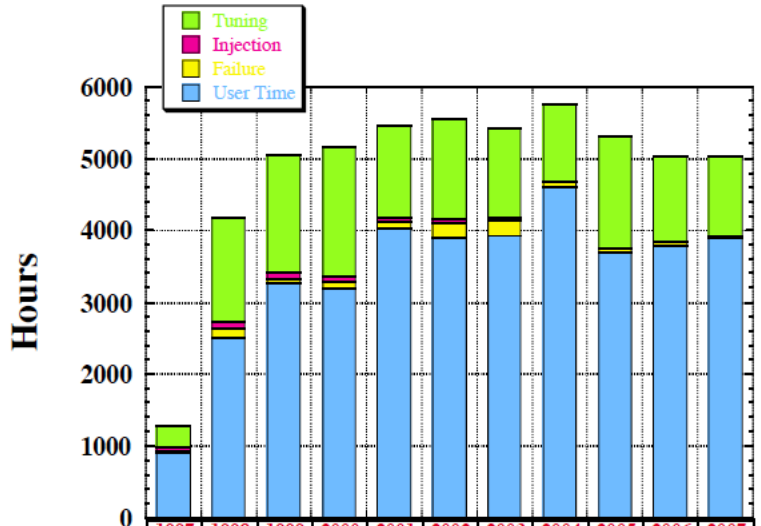
Overview of Recent Accelerator Development and Near Future

Accel. Div. of JASRI/SPring-8 H. Ohkuma

1. Operational Status
   - Statistics
   - Down Time
   - Filling Mode
2. Improvement of Top-up Operation
3. Improvement of Beam Performance
4. Topics
   - Short Pulse Generation
   - Diagnostics Beamlines

Operation Statistics



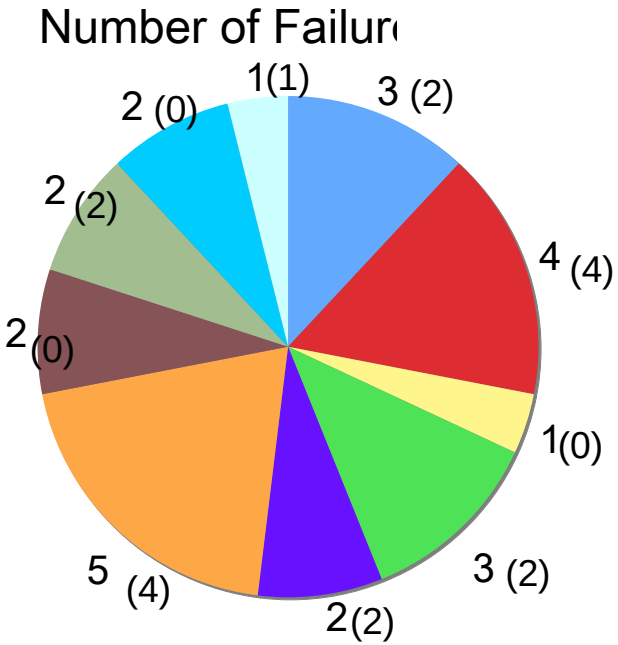
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Acc. Operation Time	1286	4189.6	5051.6	5167.5	5456.1	5542.9	5419.5	5759.2	5317.1	5026.2	5027.9
Sr Operation Time	1270.6	4135.4	4863.9	4972.9	5340.6	5484.1	5328.5	5736.7	4781.3	5008.5	5019.6
Tuning& Study (Acc. &BL)	304	1457.6	1624.2	1815	1276.5	1394.9	1245.8	1085.9	1559.2	1193.6	1100.3
Injection	50	110	95.2	70.4	59.3	60.8	39.2	0	0	0	0
Failure	26	110	57.2	88.7	87.1	190.5	208.5	82.4	59.7	42.5	27.6
User Time	906	2512	3275	3193.4	4033.2	3896.7	3926	4590.9	3698.2	3790.1	3900
Planning User Time	984	2712	3432	3352	4176	4152	4176	4680	3762	3840	3936
Availability (%)	97.2	96.7	98.2	97.4	98	95.3	95	98.1	98.3	98.7	99.1

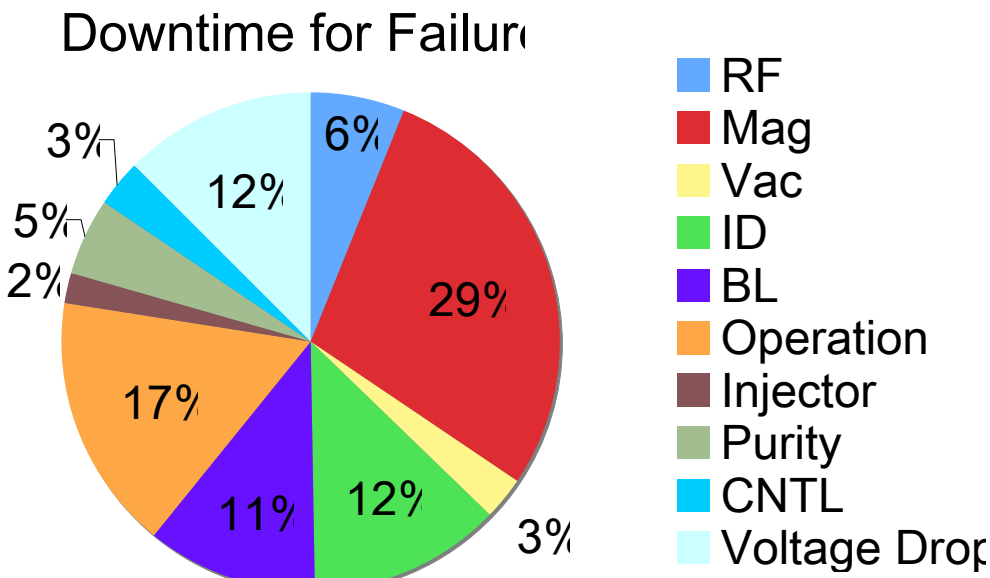
In 2007, the total operation time of accelerator complex --- 5027.9 hours
storage ring operation time --- 5019.6 hours
user time --- 3900 hours (77.7% of Sr operation time)
down time due to accelerator trouble during user time
--- 27.6 hours (0.7% of user time)

The availability (ratio of the net user time to planning user time) is 99.1%.
Since 2004, loss time by beam injection is zero by top-up operation.

Downtime

- **Number of Downtime 25 (17 with Beam Abort)**
- **Total Time of Downtime 27.6 hours**





Longest down time : Voltage Drop by Thunder : 3.5hours

Filling Mode & Lifetime in 2007

	bunch current	lifetime
Multi-bunch (160 bunch-train x 12)	0.05 mA	~ 200 hr
203 bunches	0.5 mA	25 ~ 30 hr
11 bunch-train x 29	0.3 mA	35 ~ 50 hr
1/7-filling + 5 single bunches	2.8 mA (single)	18 ~ 25 hr
1/14-filling + 12 single bunches	1.6 mA (single)	
2/29-filling + 26 single bunches	1.4 mA (single)	
4/58-filling + 53 single bunches	1.0 mA (single)	

Multi-bunch : 17.0 %
Several-bunch : 51.9%
Hybrid : 31.1%

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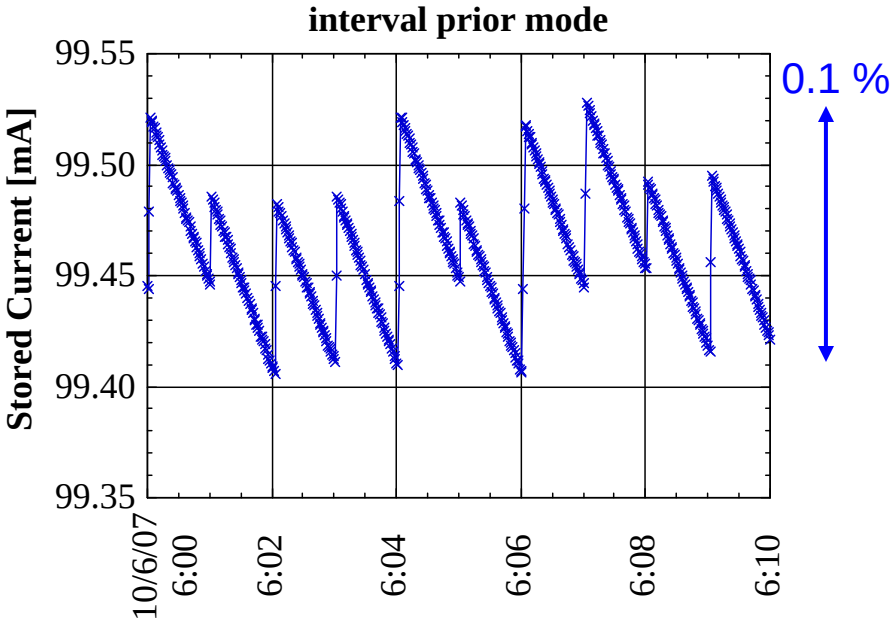
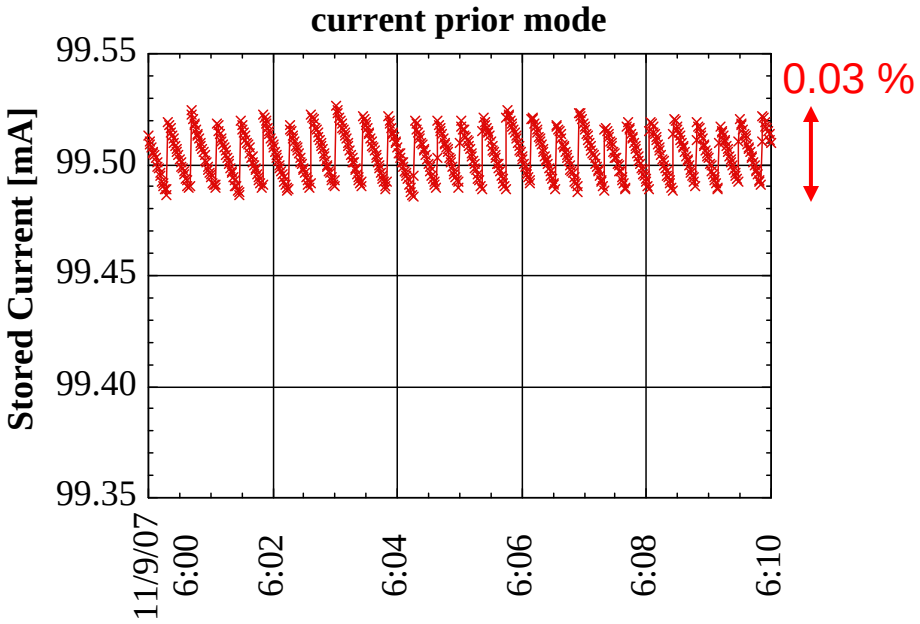
Top-up Operation

- **Interval Prior Mode (~ Oct. '07)**
  - **Fixed Interval 1 min (several, hybrid) or 5 min (multi-bunch)**
  - **Current stability 0.1 %**
- **Current Prior Mode (Nov. '07 ~)**
  - **Variable interval depending on lifetime 20 sec ~ 2 min.**
  - **Current stability 0.03 %**

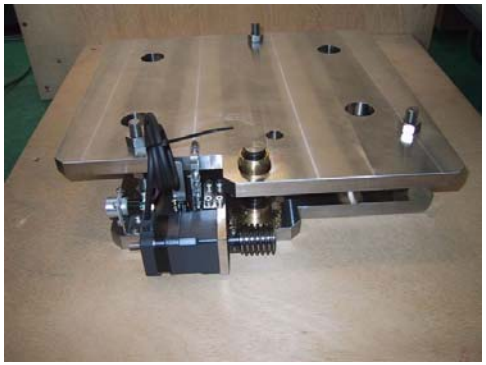


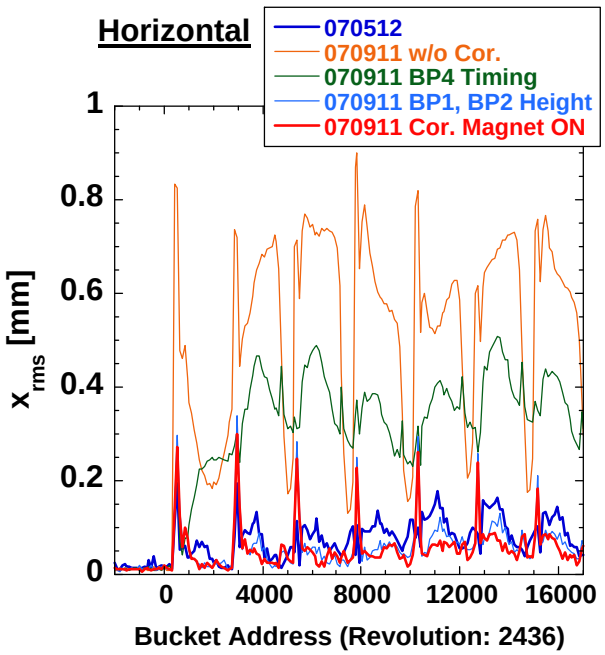


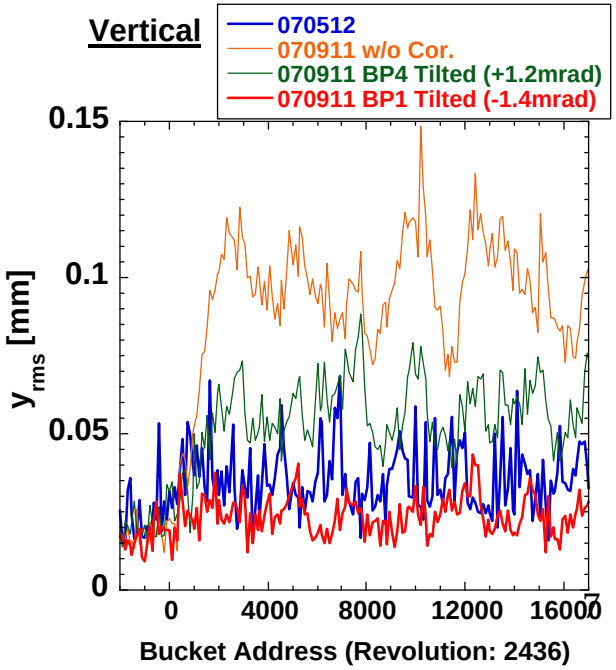
Suppressing Oscillation of Stored Beam at Top-up injection

Remote Tilt-Control of Bump Magnets for Suppressing Vertical Oscillation

Range: ±4mrad
Resolution: 8.7μrad/1000pulses
Backlash: 0.83 mrad
Reproducibility: 6.4μrad







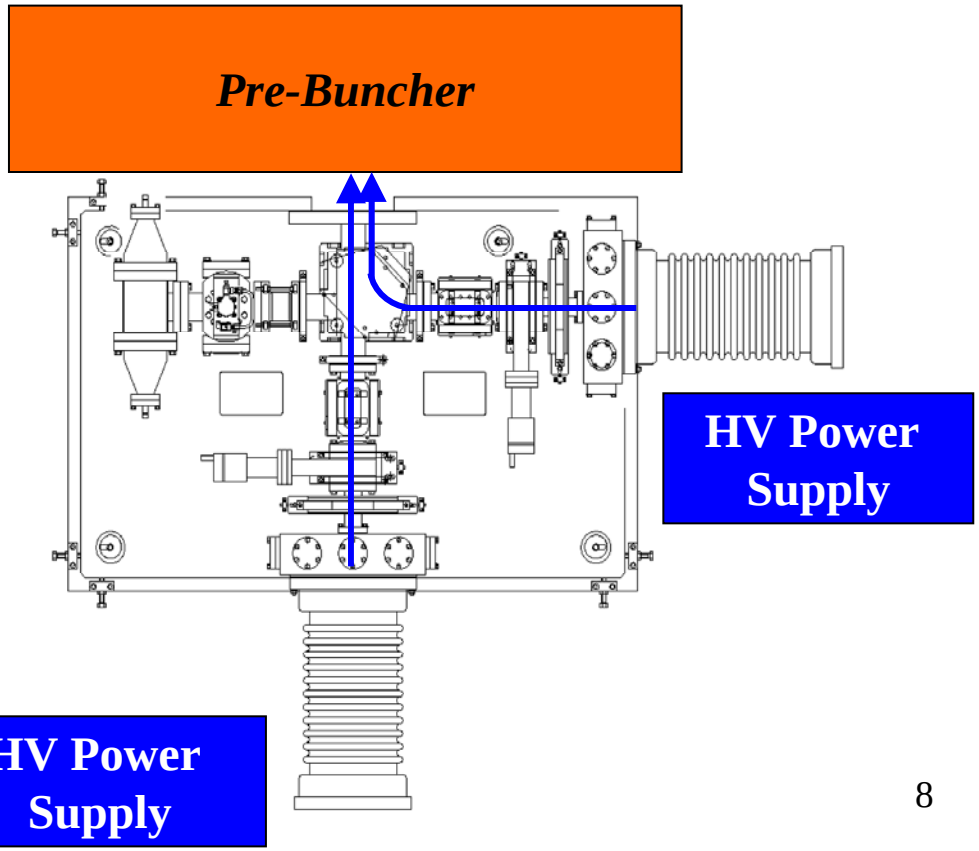
Twin electron gun system

Electron gun failure

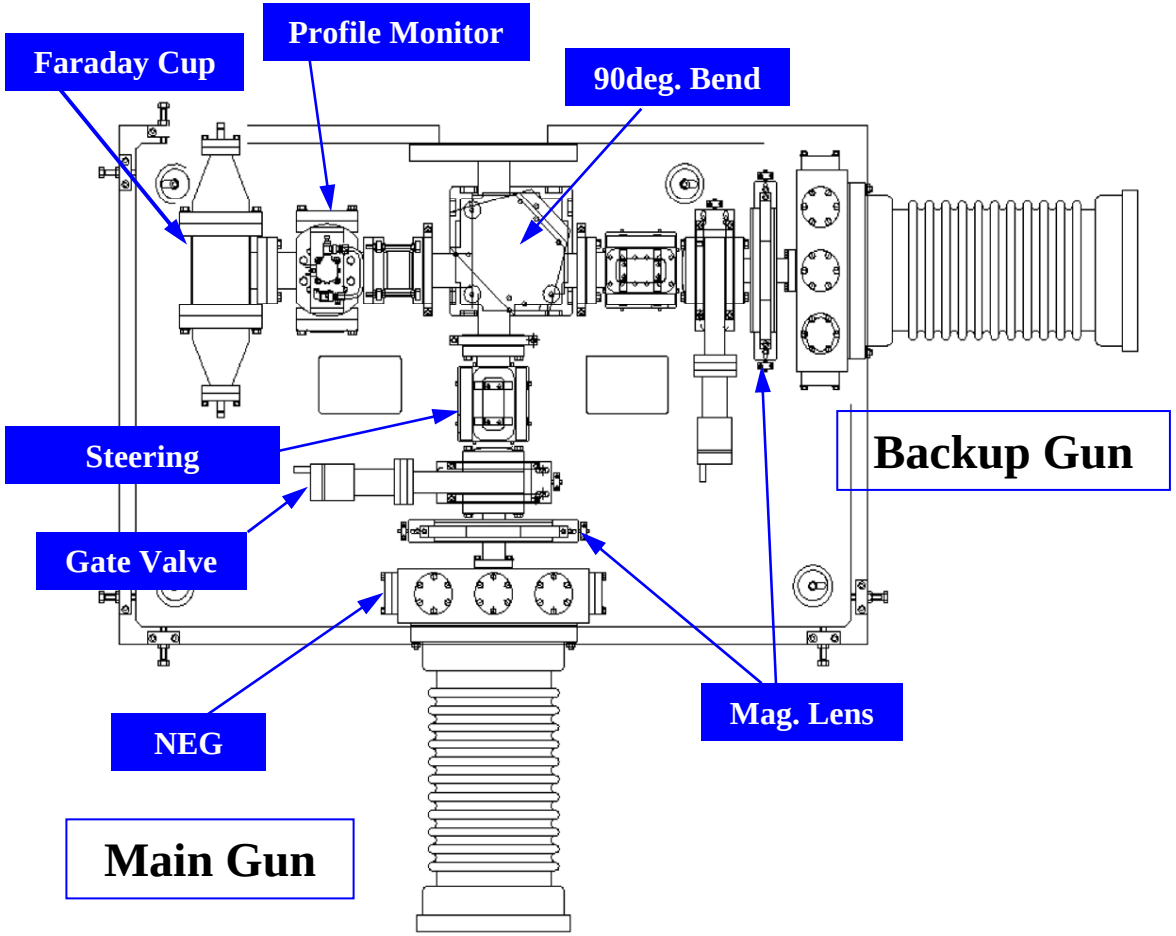
For example, a replacement of a cathod assembly requires at least a few days

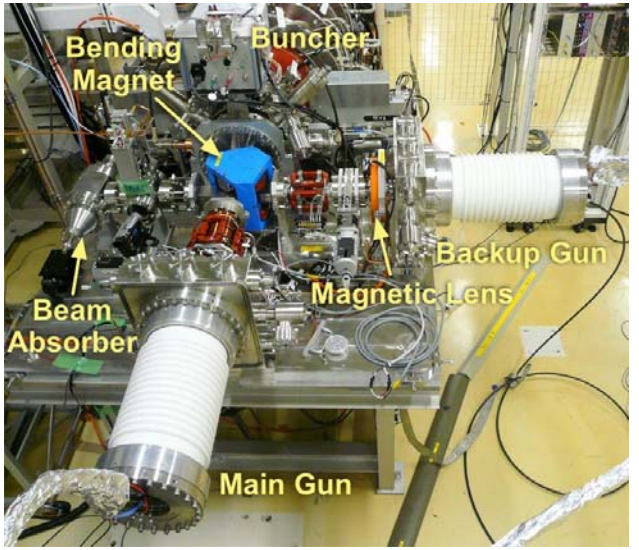
To enhance the reliability of the electron gun system

To reduce the down time of the beam injection



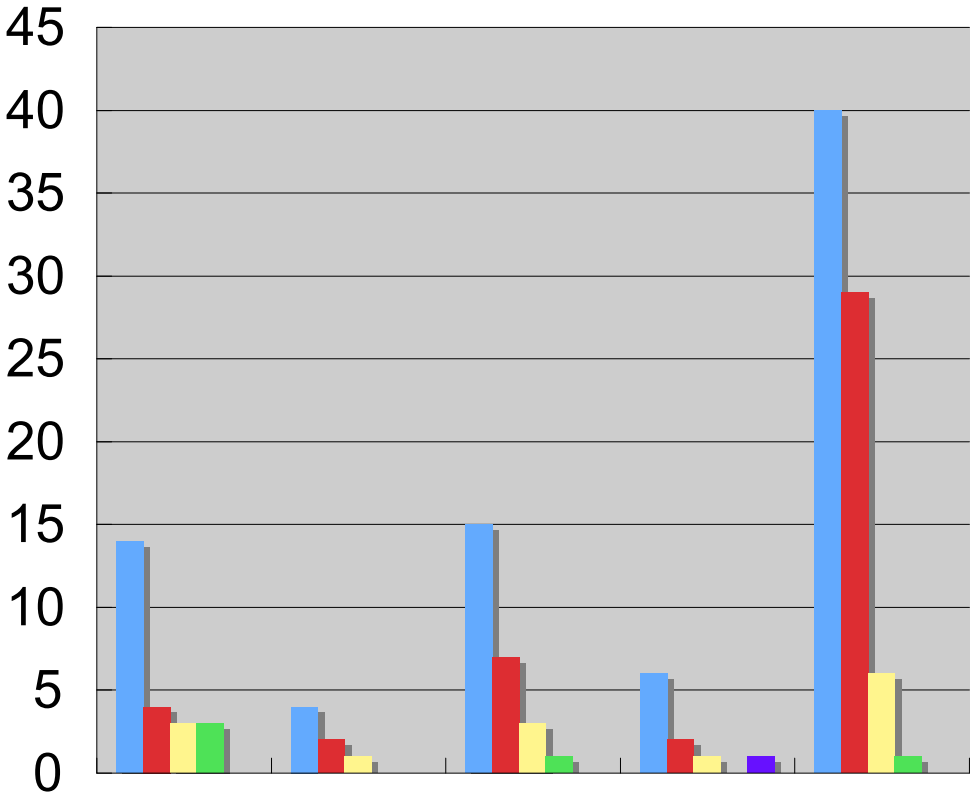
Composition of Twin e-gun system

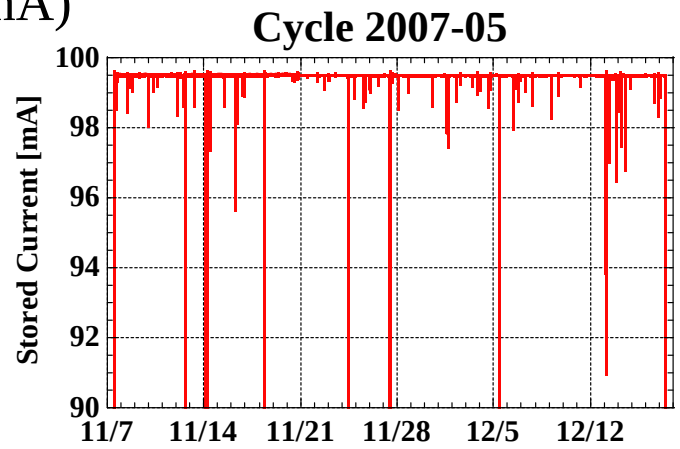




Interruption of Top-up Operation

- Number of interruption (current drops over 0.1 mA)





Current drop up to

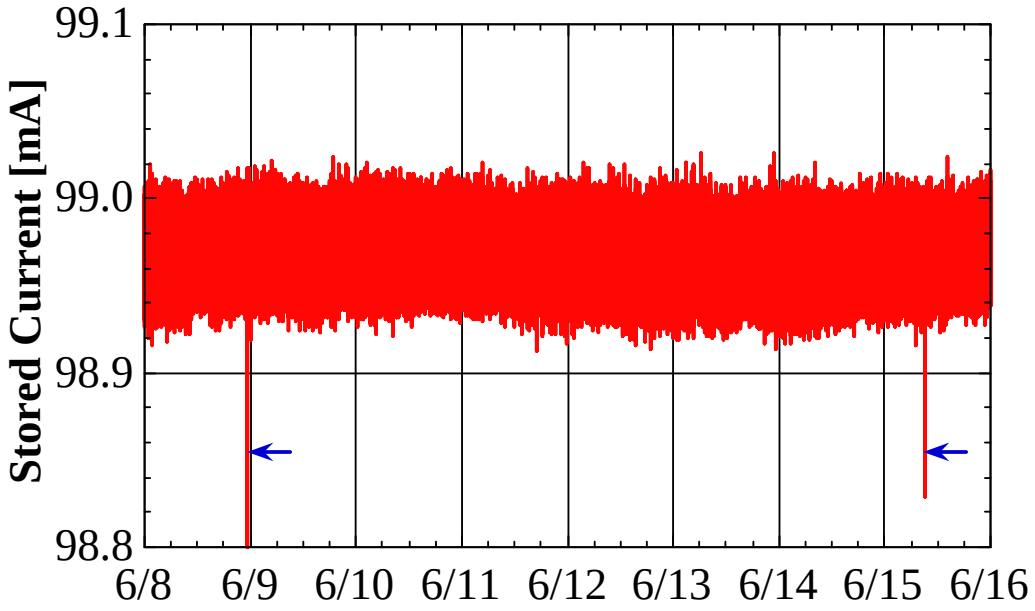
- ~ 0.5 mA
- ~ 1 mA
- ~ 5 mA
- ~ 10 mA
- ~ 20 mA

cycle	07-01	07-02	07-03	07-04	07-05
#shift	77.4	50.7	177.9	74.3	107.1

1 shift = 8 hours

Best Performance of Top-up Operation in 2007

- **No interruption over 6 days from June 9 to 15, 2007.**
  - **Filling mode: 203 bunches**
  - **Injection**
    - **interval: 1 min. (Interval Prior mode)**
    - **times: 9180**
    - **shots: 23256**



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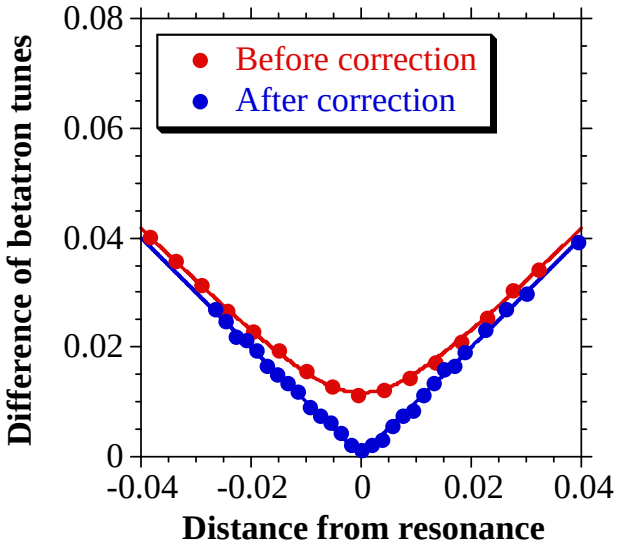
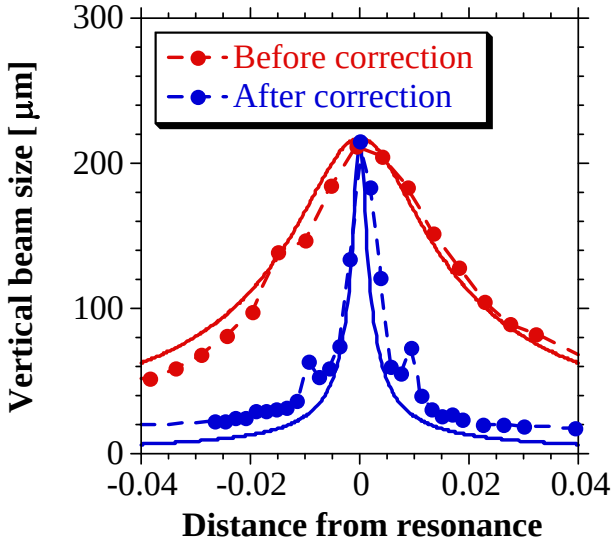
Coupling Correction

- **Error magnetic field generates vertical beam spread**
  - **Linear resonance coupling**
- **Corrector skew quadrupole magnets (2 family : 90 deg. of phase difference)**
  - **20 @ arc section in even normal cells**
  - **8 @ both ends of long straight sections**
- **Effects of skew quadrupole magnets**
  - **Reducing coupling strength form 0.012 to 0.0012**
  - **20 % vertical beam size reduction @ normal op. point (40.15, 18.35)**





$$|\nu_x - \nu_y| = \sqrt{\Delta^2 + |C|^2},$$

$$\sigma_y = \sqrt{\frac{|C|^2/2}{\Delta^2 + |C|^2}}\beta_y \varepsilon_0,$$

C : coupling strength,

Δ : distance from resonance

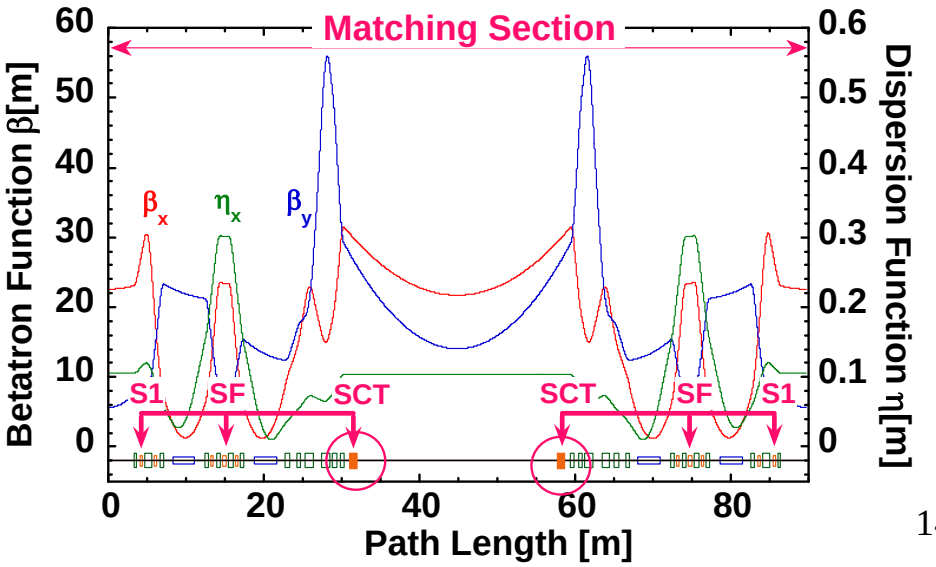
Counter-Sextupoles in Long Straight Sections

Four Magnet-Free Long Straight Sections in the Ring

* **Betatron Phase Matching**: $\Delta\psi_x = 4\pi$, $\Delta\psi_y = 2\pi$ for Stability of **On-Momentum** Electrons
* **Local Chromaticity Correction** with Weak SF for Stability of **Off-Momentum** Electrons

To minimize the effect of non-linear kick due to SF ...

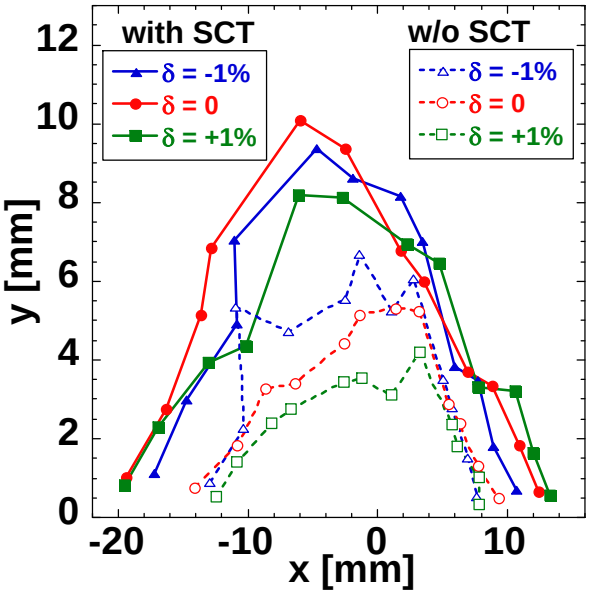
Counter-sextupoles (SCTs) were installed approximately π apart in phase ψ_x from SF in every LSSs.

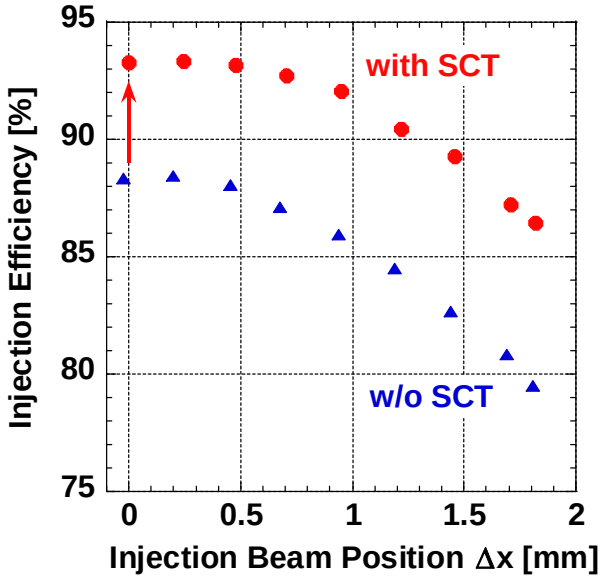


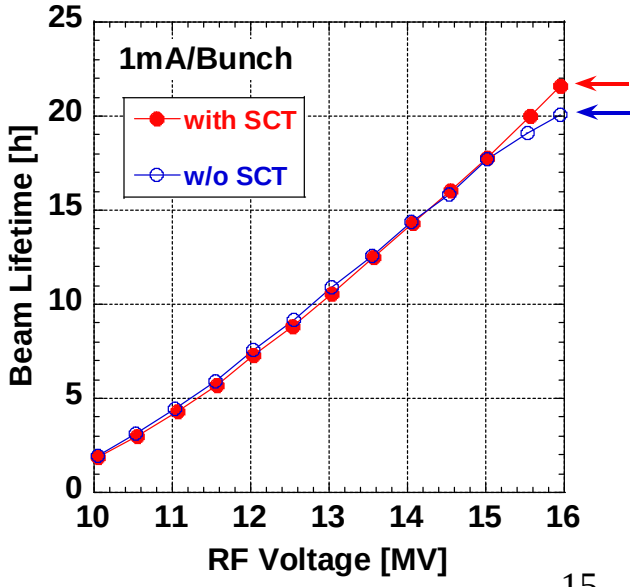
Counter-Sextupoles in Long Straight Sections

* **Dynamic aperture** was improved.
  => Higher Injection Efficiency

* **Momentum acceptance** was enlarged.
  => Longer Touschek Beam Lifetime



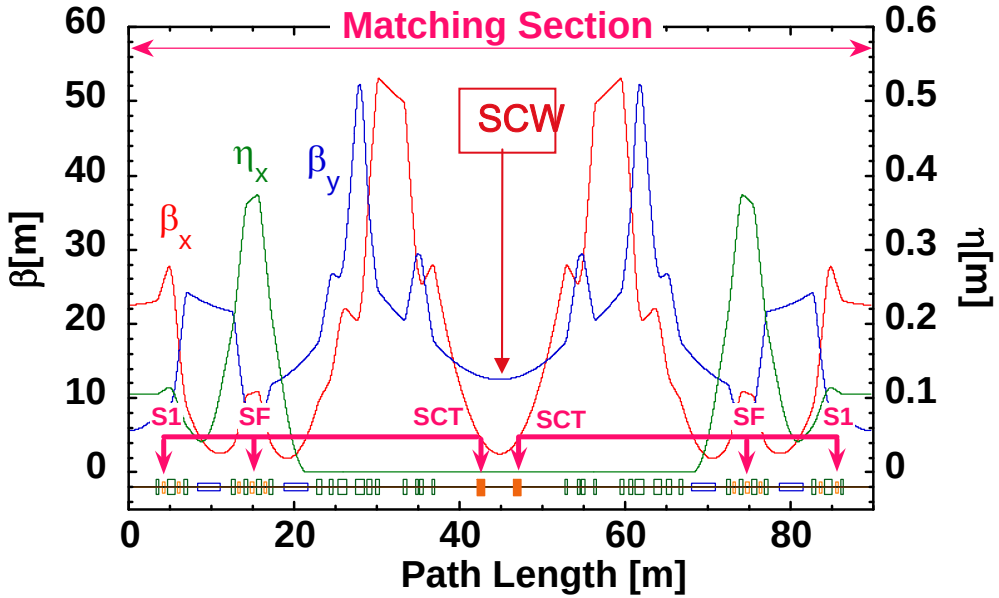




Counter-Sextupoles in Long Straight Sections

*** Local Modification of LSS Optics is possible.**

Example: Low-Beta Section for 10T S/C Wiggler



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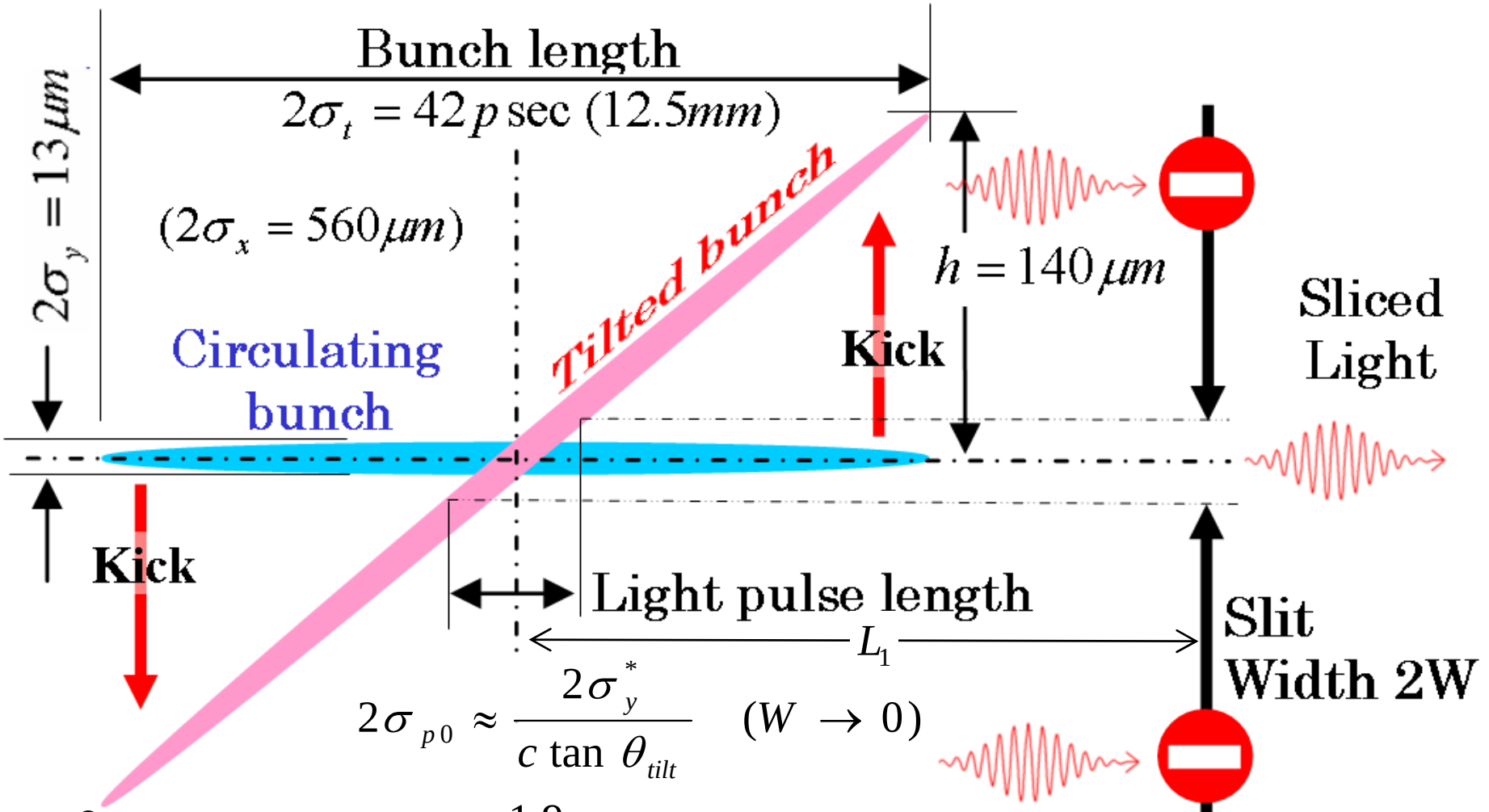
Generating a short light pulse from a bunch

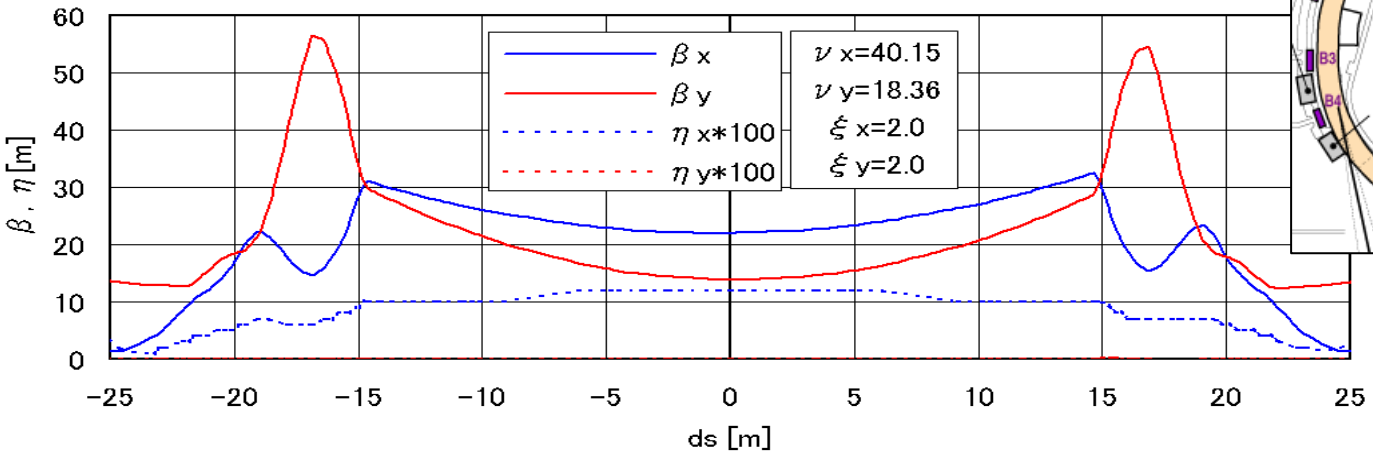


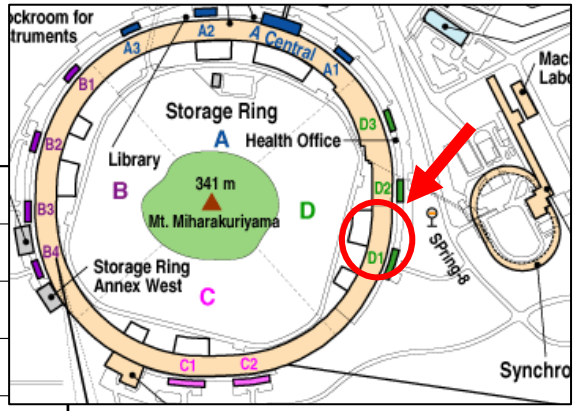
$$2\sigma_{p0} \approx \frac{2\sigma_y^*}{c\tan\theta_{tilt}} \quad (W \to 0)$$

$$= 1.9\mathrm{psec}$$

$$\tan\theta_{tilt} = \frac{h}{c\sigma_t} = 0.022$$

Concept design of a short pulse generator





$\lambda_u = 10mm$

$Gap = 5mm$

$N_u = 101$

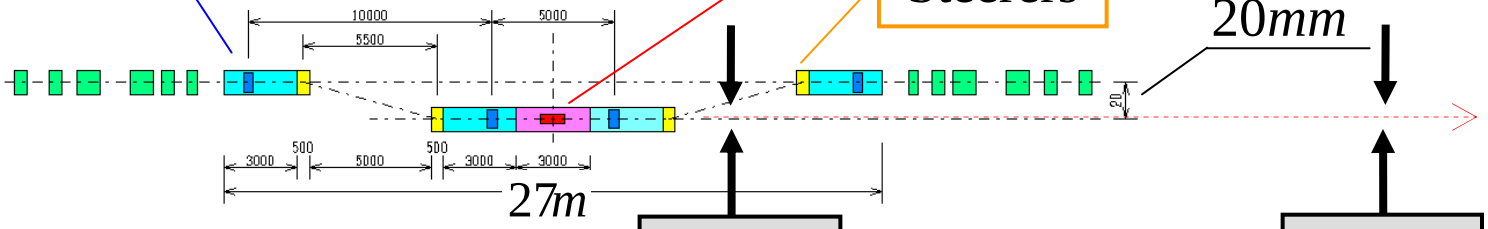
Superconducting Crab Cavities (4 Sets)

Mini-pole Undulator

$V_\perp = 1.67MV$

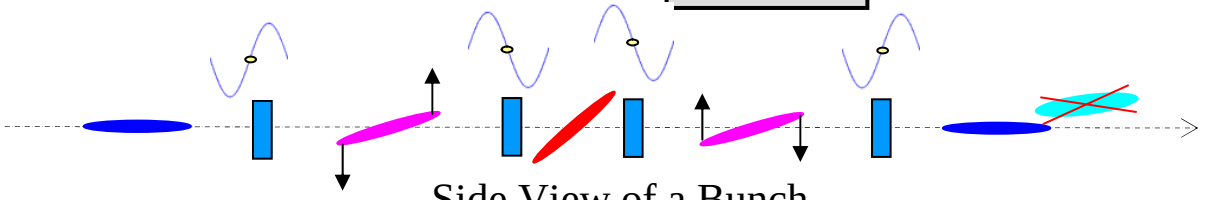
Steerers

20mm



Slit #1

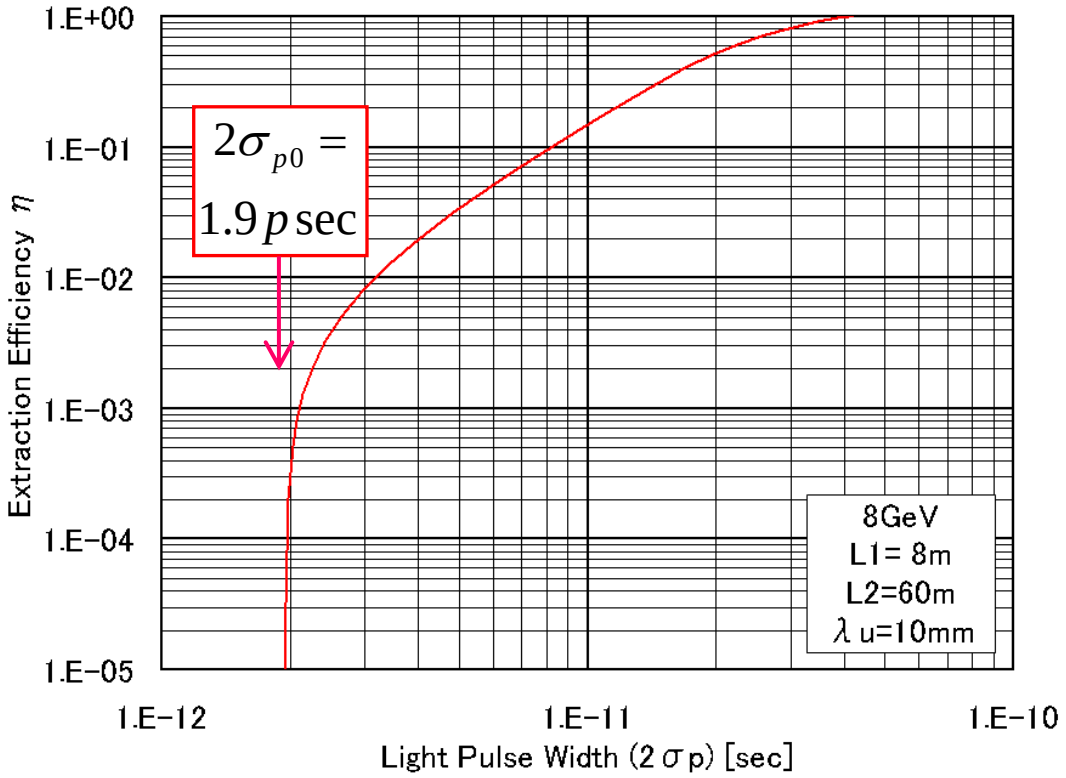
Slit #2

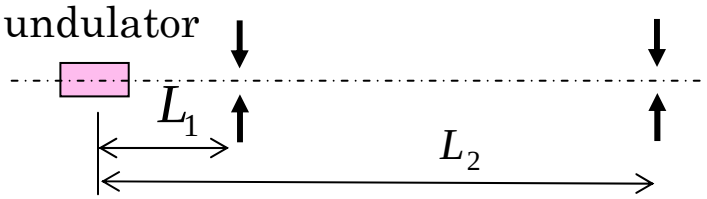


Side View of a Bunch

Required
RF phase stability
14 mdeg (0.24mrad) !

X-ray pulse width and extraction efficiency





$$\sigma_p^2 \approx \sigma_{p0}^2 + \frac{\pi}{3}\frac{h\Sigma'_y L_{12}}{c^2 \tan^2\theta_{tilt}}\eta$$

$$\sigma_{p0} = \frac{\sigma_y^*}{c\tan\theta_{tilt}}$$

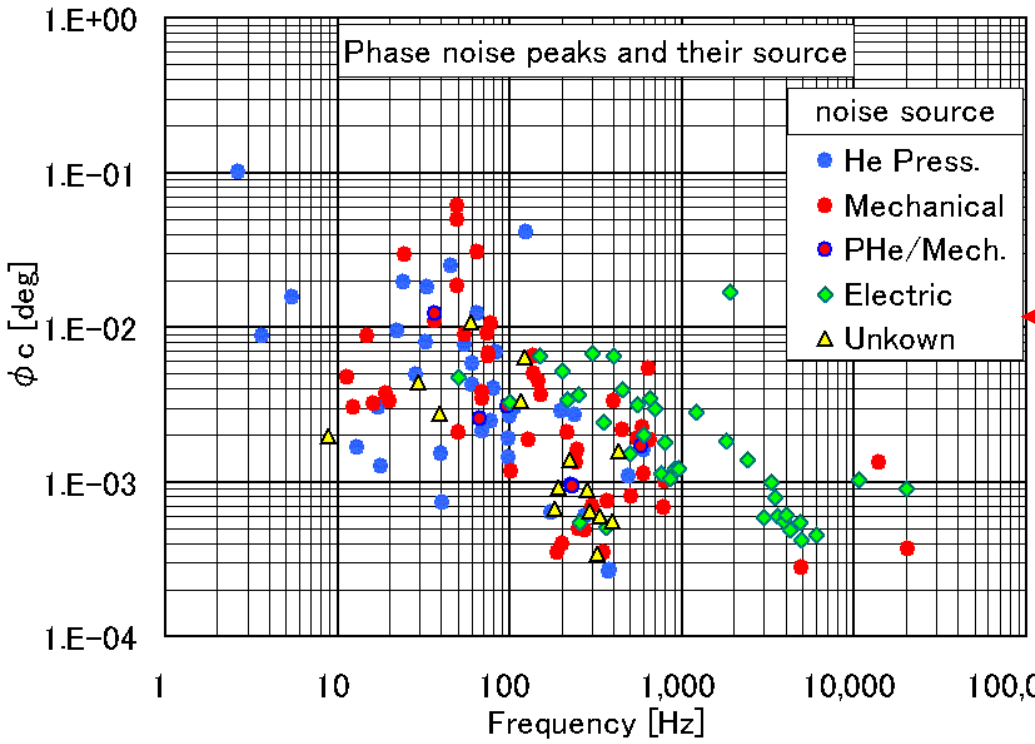
$$\frac{1}{L_{12}} = \frac{1}{L_1} - \frac{1}{L_2}$$

(for slit #1 width << η)

L_1, L_2 : Distance from emission point to the slit #1 and #2.

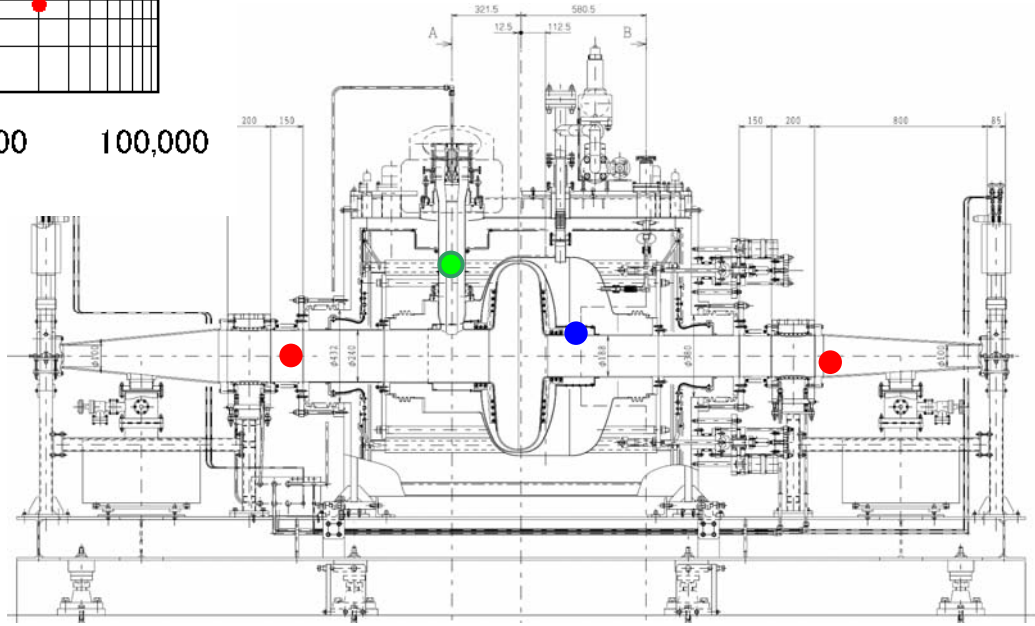
Σ'_y : Width of radiation angular distribution.

Phase vibration source identification (KEK collaboration)

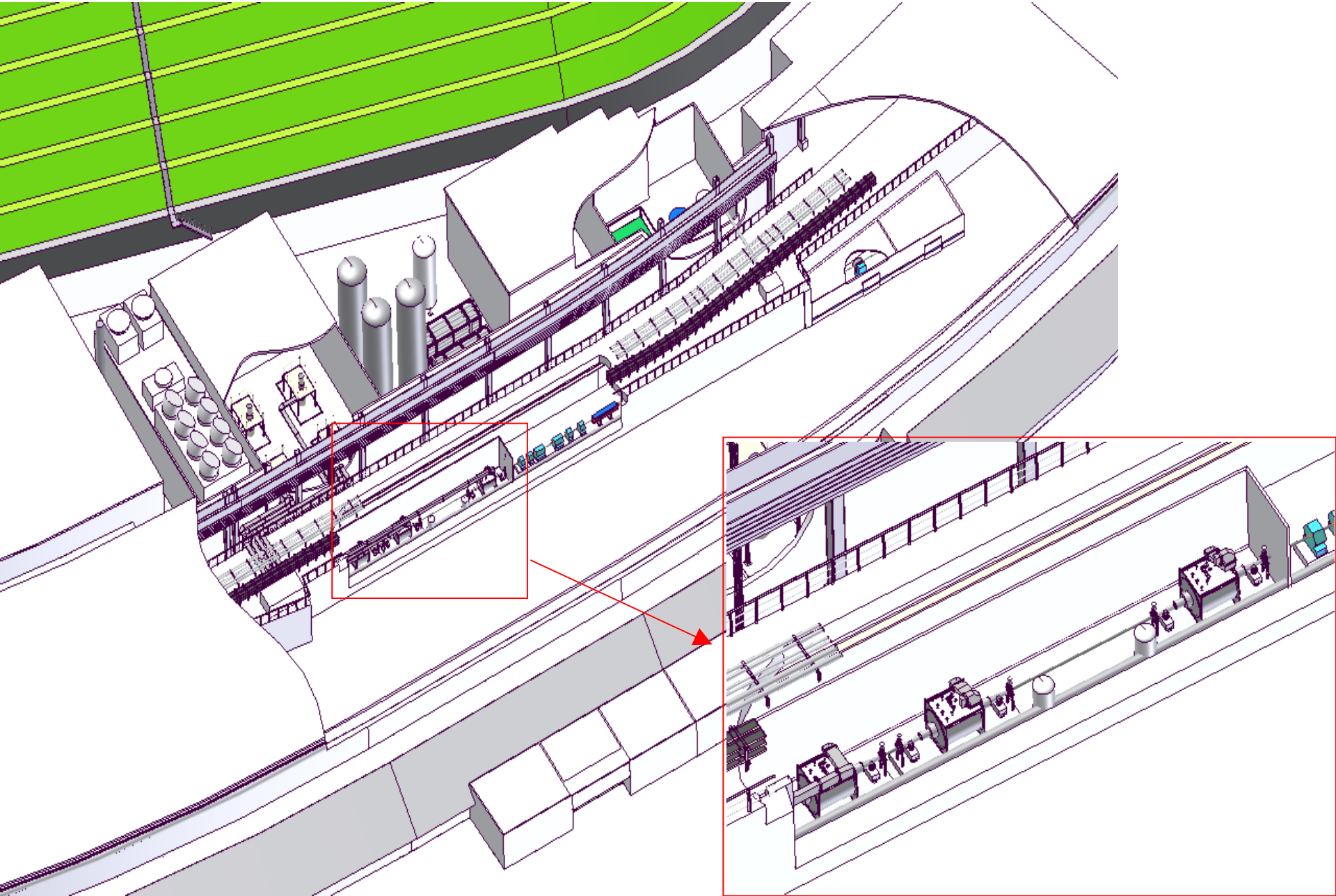


Required
RF phase stability
14 mdeg (0.24mrad) !

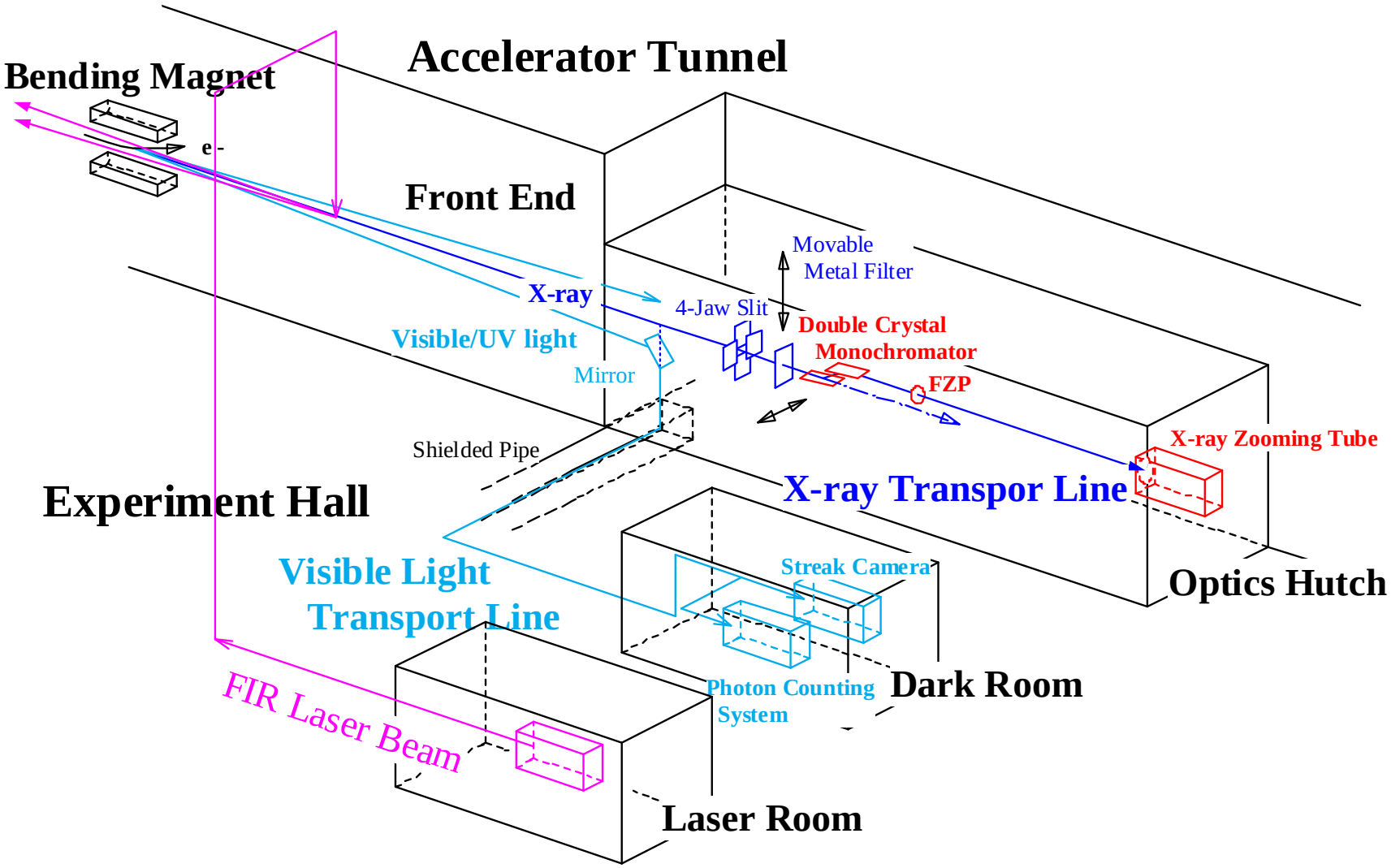
Red : mechanical vibration
Blue : Pressure of Liq. He
Green : RF Phase noise



Planning of FSX system

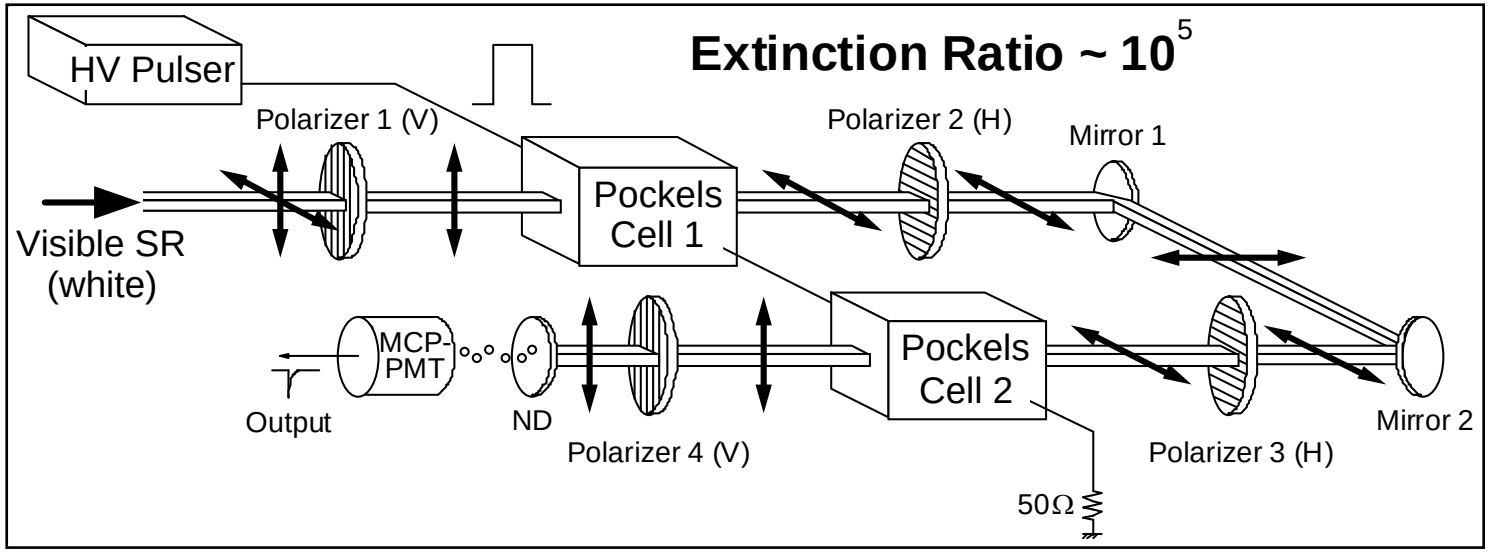


Diagnostics Beamline I (BL38B2)



Bunch Purity Monitor

Gated photon-counting system with fast light shutters in visible light region



- **Achieved bunch impurity at SPring-8**

  10^{-10} level or less (measurement time ~20 min)

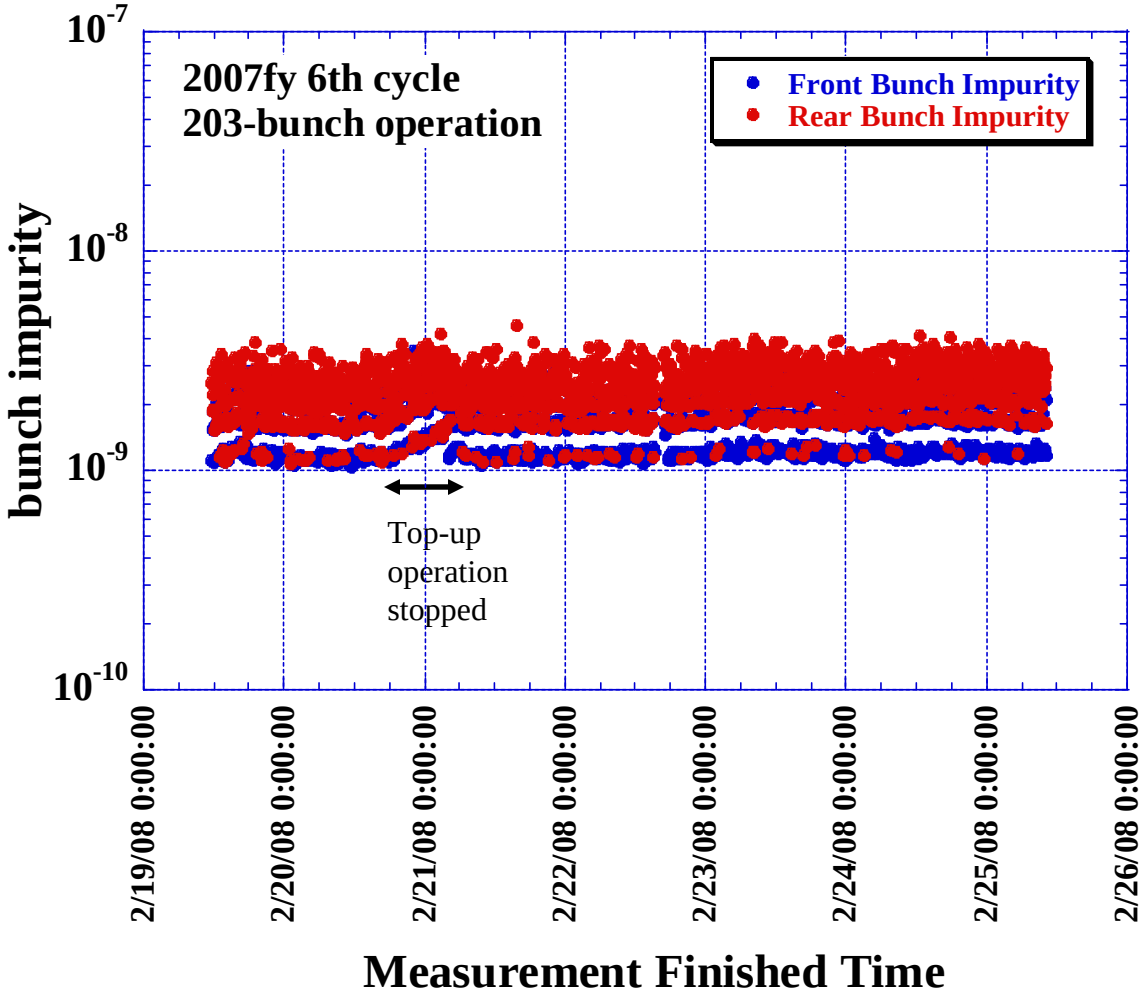
- **Bunch impurity of the electron beam of the user experiments continuously monitored with the sensitivity ~ 10^{-9}**

  (measurement time ~4 min)

Example of bunch purity measurement

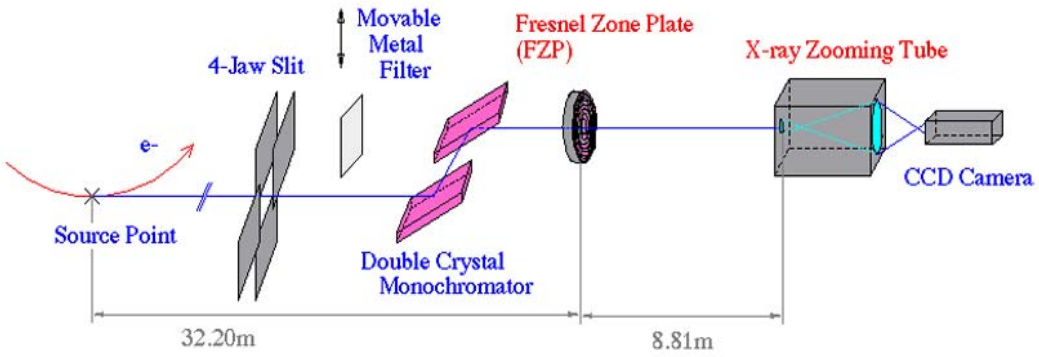
Filling: 203-bunch mode (0.5mA/bunch: ~1.5×10^{10} e$^-$/bunch)

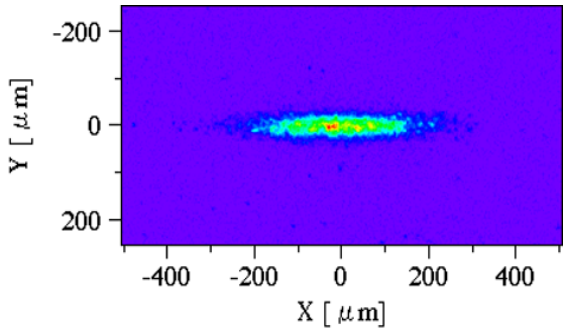
Measurement time: ~4 min

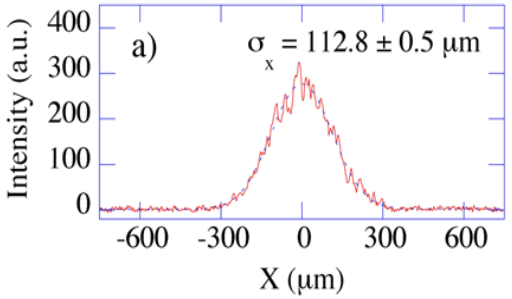


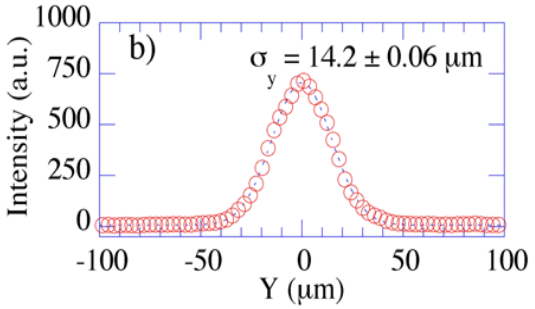
X-ray Beam Size Monitor @ BL38B2

Single FZP + X-ray Zooming Tube









Spatial Resolution	4.1 μm (1σ)
Time Resolution	1 ms
Field of View	≥ ϕ 1.5 mm (vignetting-free)
Magnification Factor	13.7 (FZP & XZT)
Observing Photon Energy	8.2 keV (λ = 0.15 nm)

Diagnostics Beamline II (BL05SS)

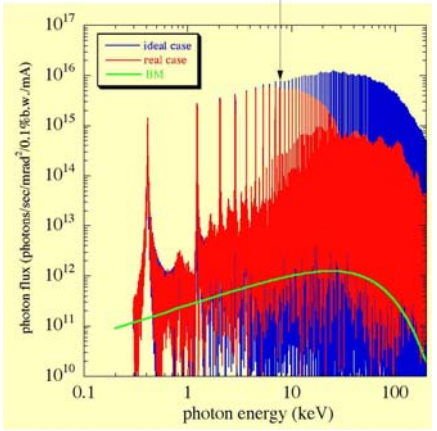
Insertion Device

Multipole Wiggler

76mm × 51 periods

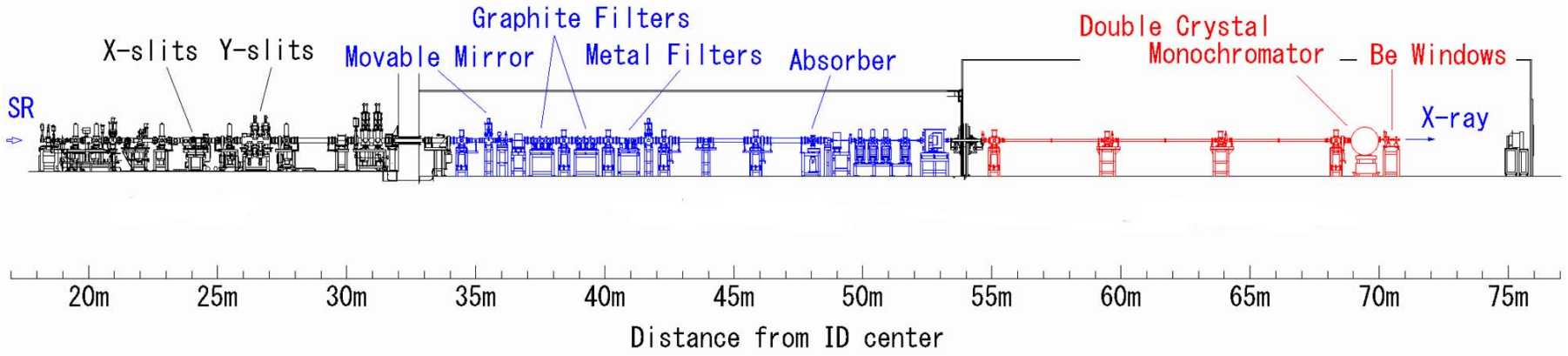
K_{max} = 5.8

19th harmonics



K=5.8
zero emittancce
zero energy spread

Front End **Optics Hutch I** **Optics Hutch II**



Beam Diagnostics Plans @ BL05SS

- **Turn-by-Turn and Bunch-by-Bunch Diagnostics**

  SR from the ID

  X-ray Streak Camera → Bunch length

  Fast X-ray Camera → Angular Divergence

  Energy spread

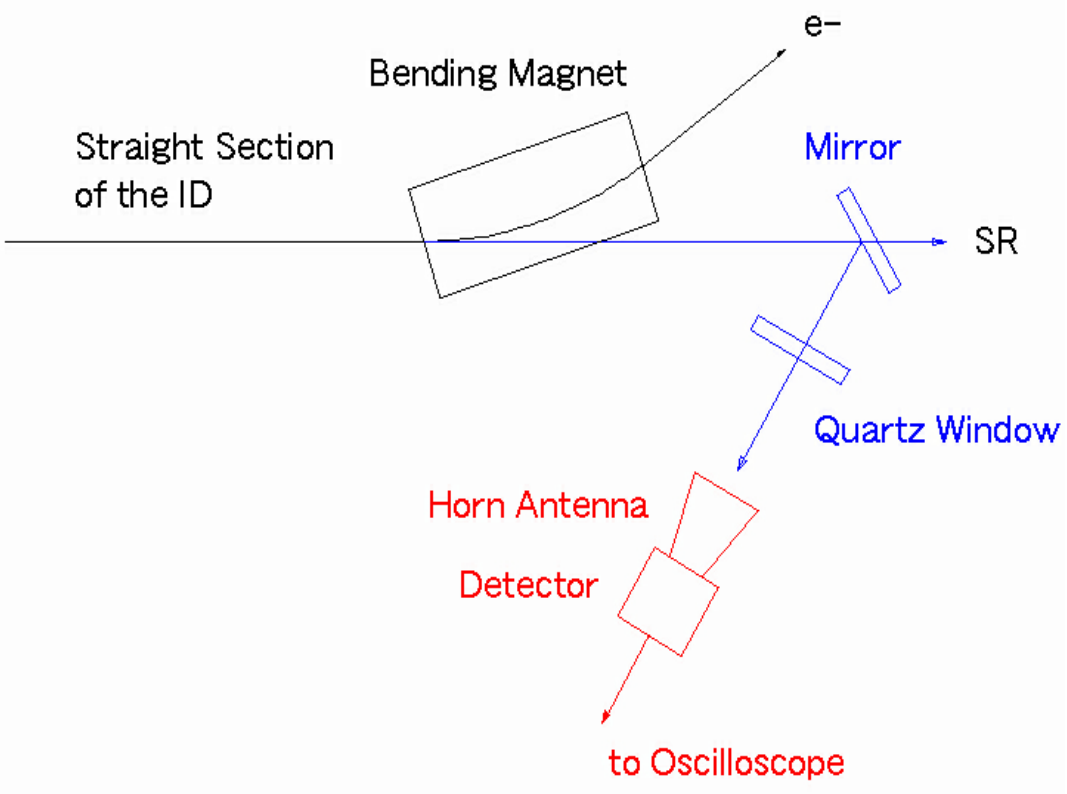
  for Injection Beam Tuning of Topping-Up Operation etc.

- **R&D's of diagnostics of short-bunched beam**

  Observation of CSR from the BM

Observation of CSR @ BL05SS

Setup of the CSR Experiments



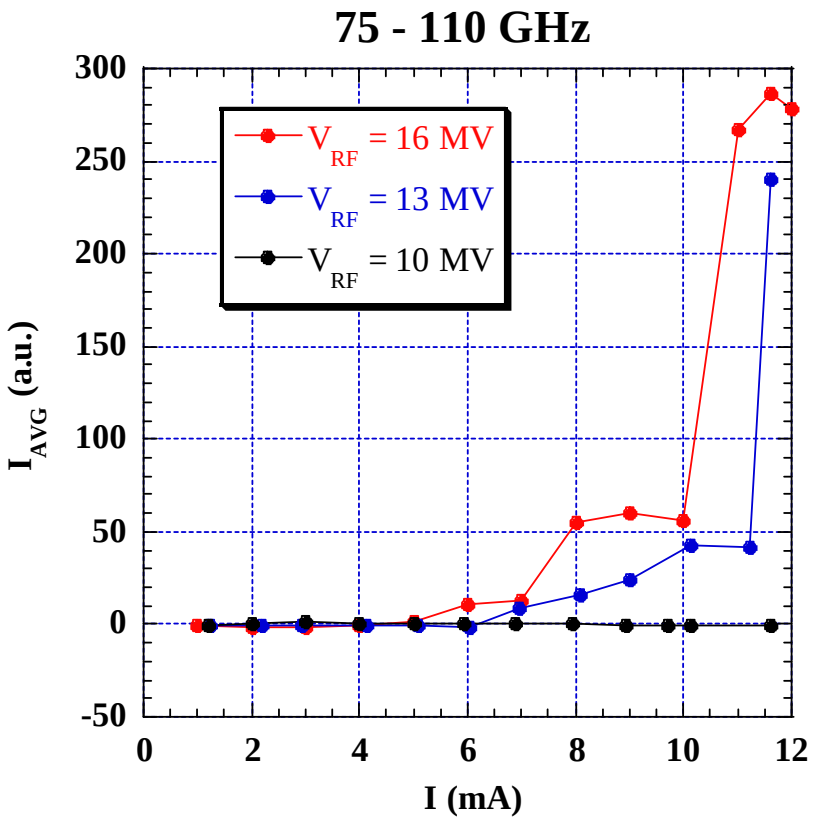
Two Schottky Barrier Diode Detectros

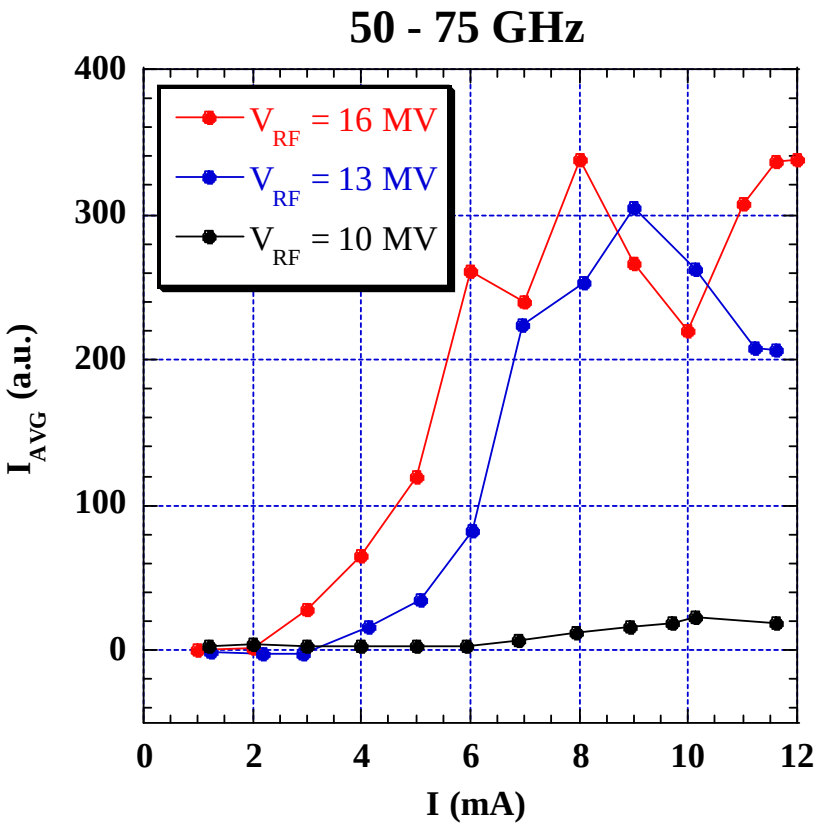
Frequency Bands are

1) **75 - 110 GHz (2.7 – 4.0 mm)**
2) **50 -75 GHz (4.0 - 6.0 mm)**

Results of CSR Observation: Single Bunch

- **Time Averaged Intensity vs. Bunch Current**

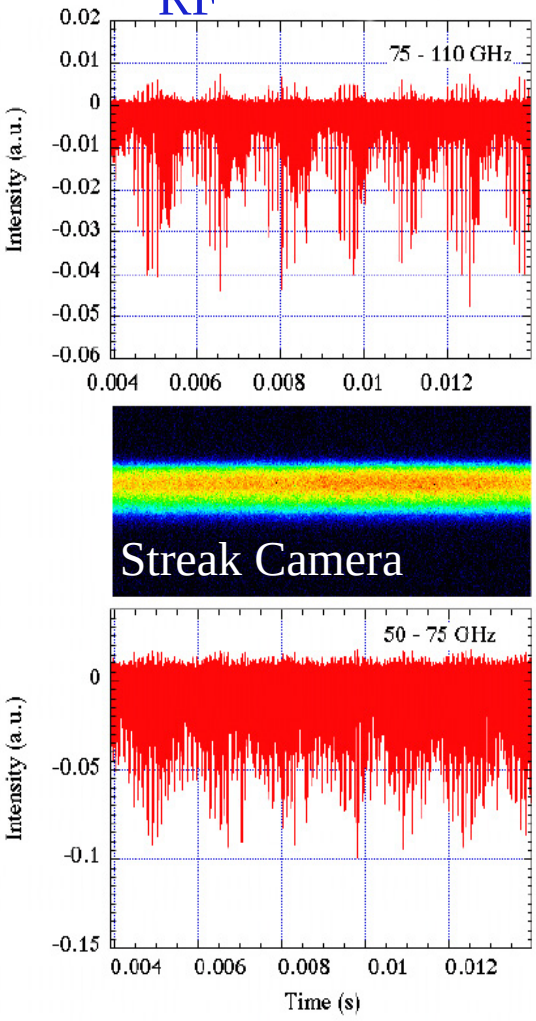




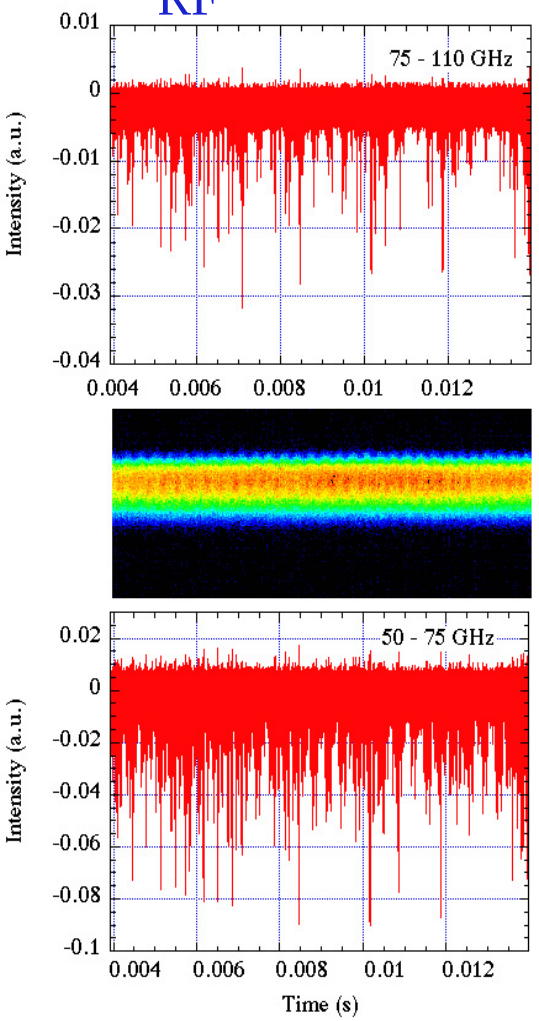
CSR Observation Results: Single Bunch

- Time Structure @ I = 11.5 mA

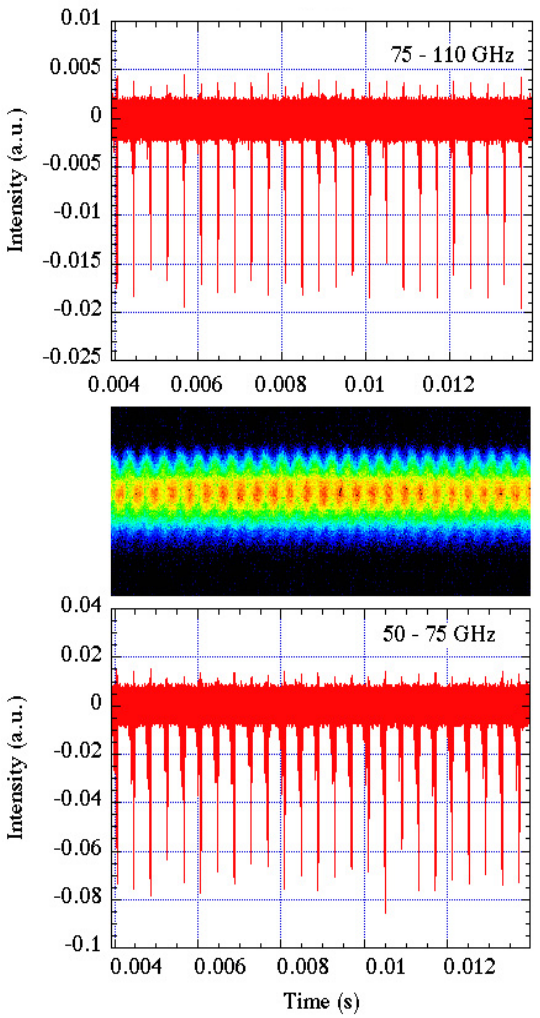
V_{RF} = 16 MV



V_{RF} = 13 MV



V_{RF} = 11 MV



Other Topics

- **Low Energy Operation (Soutome)**
- **Low-α Operation (Soutome)**
- **Bunch-by-bunch Feedback (Nakamura)**