J-PARC

Electron cloud effects in the J-PARC Rings and related topics

T. Toyama

KEK

Thanks to K. Ohmi, S. Machida, K. Satoh, K. Oide, G. Rumolo, F. Zimmermann, K. Yokoya,

N. Hayashi, S. Igarashi, Y. Irie, S. Kato, T. Kubo, T. Miura, C. Ohmori, Y. Sato, Y. Saito, M. Shirakata, M. Tomizawa, M. Uota,

R. Macek

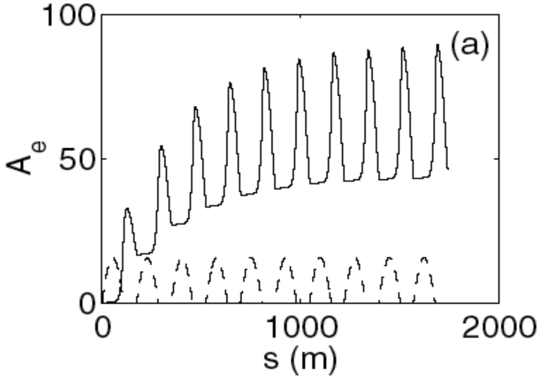
Contents

- E-cloud instability estimation
  - E-cloud build up with bunched / coasting beam
  - Instabilities
- Electron yield estimates
  - 3 GeV RCS
  - 50 GeV MR
- Observation in the KEK-PS MR
  - Bunched beam
  - Coasting beam

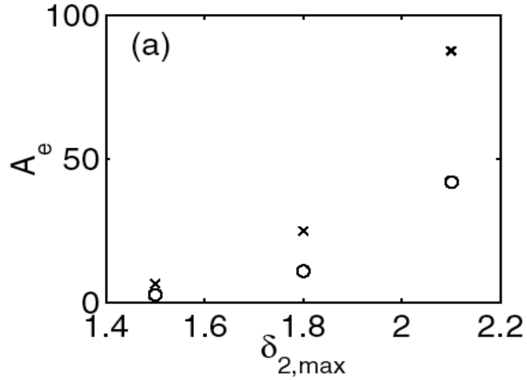
J-PARC Japan Proton Accelerator Research Complex

E-cloud instability in the RCS / bunched beam simulation

Primary e- production rate = 4.4x10^{-6} /m



Electron cloud build-up for **RCS** inj. and ext.



Electron cloud density vs secondary yield $\delta_{2,max}$.

	Injection	extraction
Neutralization factor	2-4.2%	0.67-2.3%
$\omega_e \ell /c$	133	182
Stability	0.07-0.15	0.23-0.78

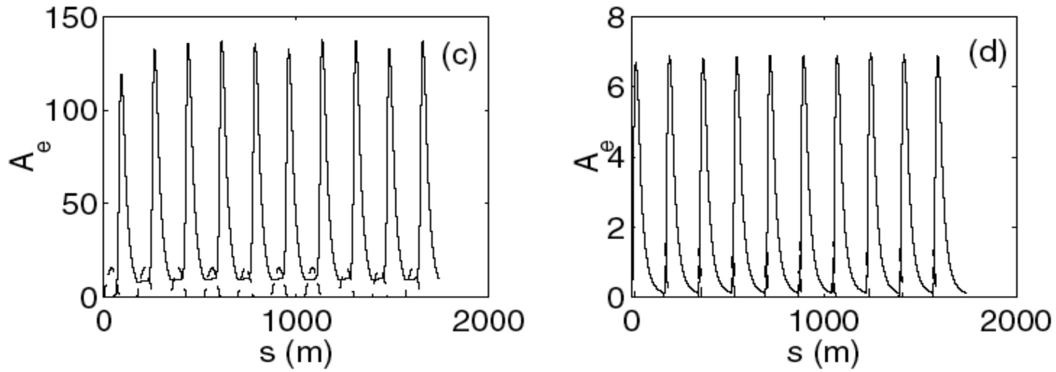
Neutralzation factor and stability (<1: stable) for $\delta_{2,max}$=2.1.

Electron cloud effect will be cured by TiN coating on ceramic chambers. (hollow cathode discharge)

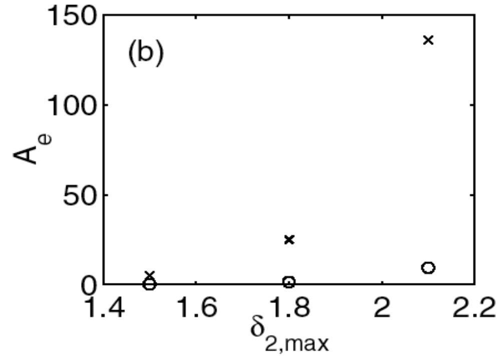
K. Ohmi, T. Toyama, C. Ohmori, PR ST-AB Vol 5, 114402 (2002), Vol 6, 029901 (2002)

E-cloud instabilty in the MR/ bunched beam simulation

Primary e- production rate = 4.4×10^{-6} /m



Electron cloud build-up for **MR** inj. and ext.



Electron cloud density vs secondary yield $\delta_{2,max}$.

	Injection	extraction
Neutralization factor	0.35-5%	0.01-0.05%
$\omega_e \ell /c$	199	276
Stability	0.07-0.15	0.23-0.78

Neutralzation factor and stability (<1: stable) for $\delta_{2,max}$=2.1.

Electron cloud effect can be mitigated by TiN coating.
But no coating is scheduled.

K. Ohmi, T. Toyama, C. Ohmori, PR ST-AB Vol 5, 114402 (2002), Vol 6, 029901 (2002)

J-PARC

Electron cloud effect / coasting beam

Coasting beam ← slow beam extraction from 50 GeV MR

Estimate with a linear theory

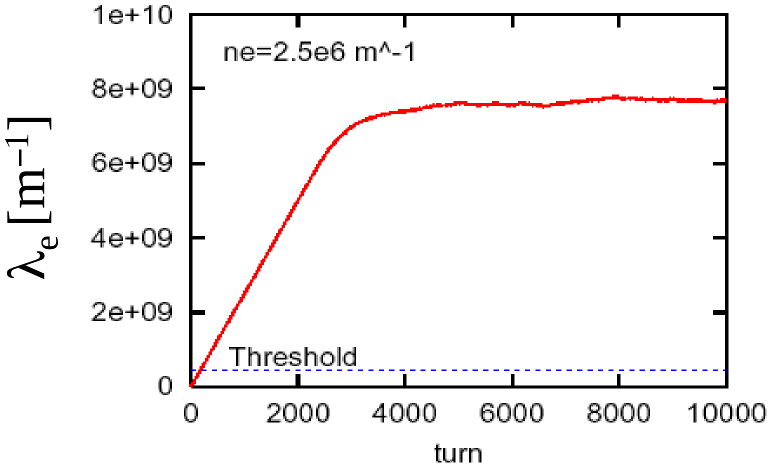
Transverse coasting beam instability,
"Wake" by e-cloud,
No B, Q magnets,
Threshold neutralisation obtained below:

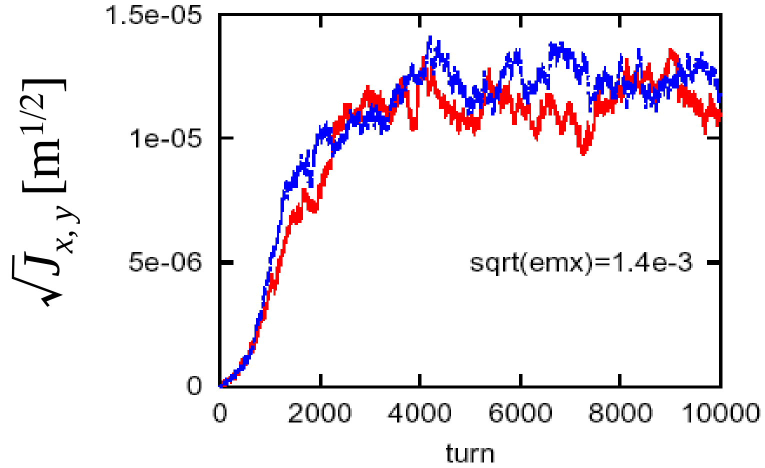
Variables	J-PARC MR	KEK-PS MR
Circumference [m]	1567.5	339
γ	54	12.8
$\lambda_p \times 10^{10}$ [m^{-1}]	21.2	0.74
beam radius [cm]	0.35	0.5
rms energy spread [%]	0.25	0.3
γ_t	31.6 i	6.76
slippage factor	–0.0013	0.016
$\omega_e L/c$	7740	225
f_{th} (Linear theory) [%]	0.21	4.0

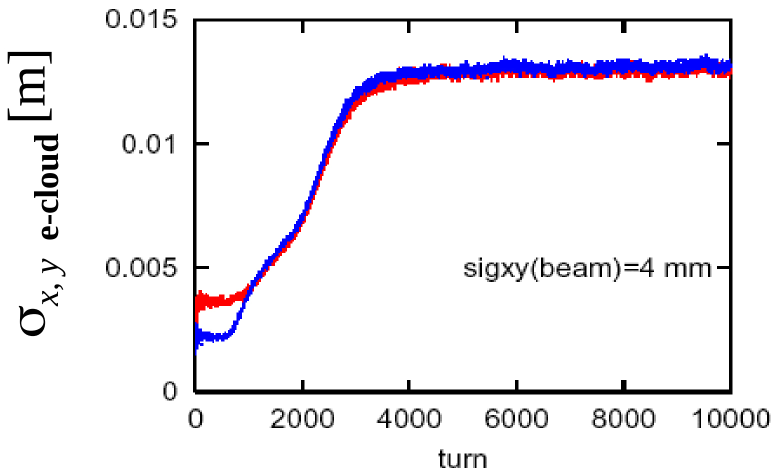
K. Ohmi, T. Toyama, M. Tomizawa, PAC2003, 3083.

J-PARC Electron cloud effect / coasting beam Simulation

Including diffusion of electron due to proton beam perturbation,
e- production rate = 2.6×10^{6} /m, P = 2×10^{-6} Pa (x10 of J-PARC value),
Instability looks very weak: ~1% oscillation.







☞ K. Ohmi,
Session F2, Thursday

K. Ohmi, T. Toyama, M. Tomizawa, PAC2003, 3083.

Electron yield estimates

- Compare

  the assumed primary e^- yield = 4.4×10^{-6} /m

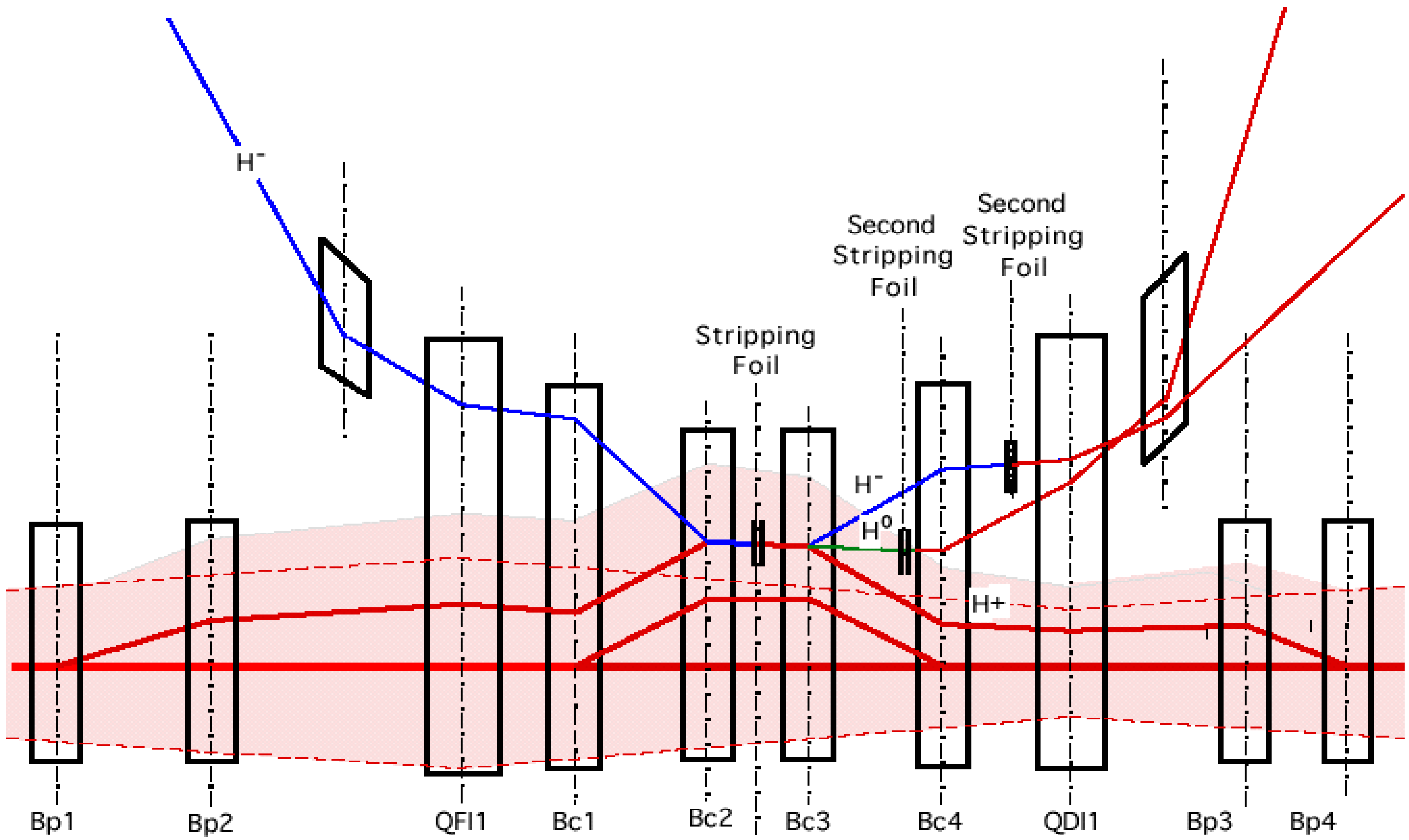
  to

  expected e^- yield

  in the 3 GeV RCS and 50 GeV MR

J-PARC Carbon stripping foil at the RCS injection

- **Injection area**



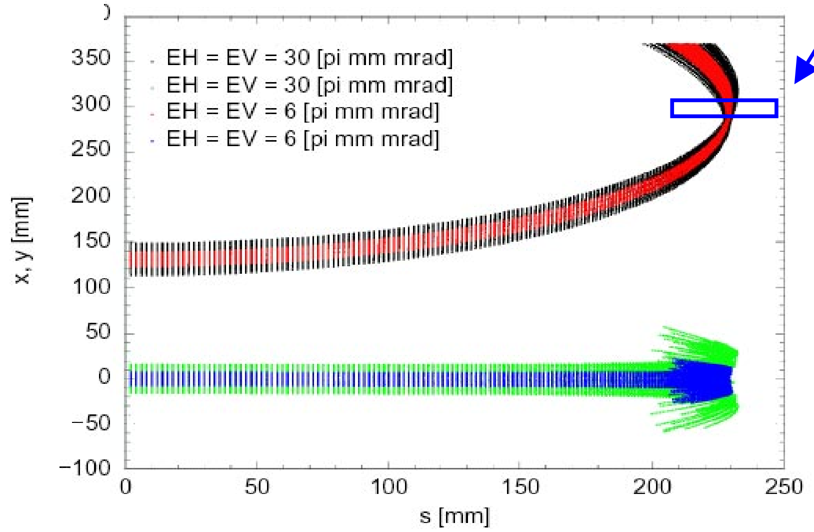
Schematic layout of the H^- injection system in horizontal plane

Electron trajectory @ stripping foil (RCS)

The injection parameters are as follows:

- 400 MeV proton $\Delta p/p = \pm 0.3\%$
- $\epsilon_x = \epsilon_y = 6$ or 30 [π mm mrad]
- $(x, x', y, y') = (131, -5.5, 0, -3.7)$ [mm, mrad] on foil
- painting area is 216 π mm mrad

electron collector to be set



Use collector with cooling and bias volatage

Energy deposit ~ 140 W

Stripped electron trajectory. The stripping foil is put at $s = 0$. Horizontal: black and red, Vertical: green and blue.

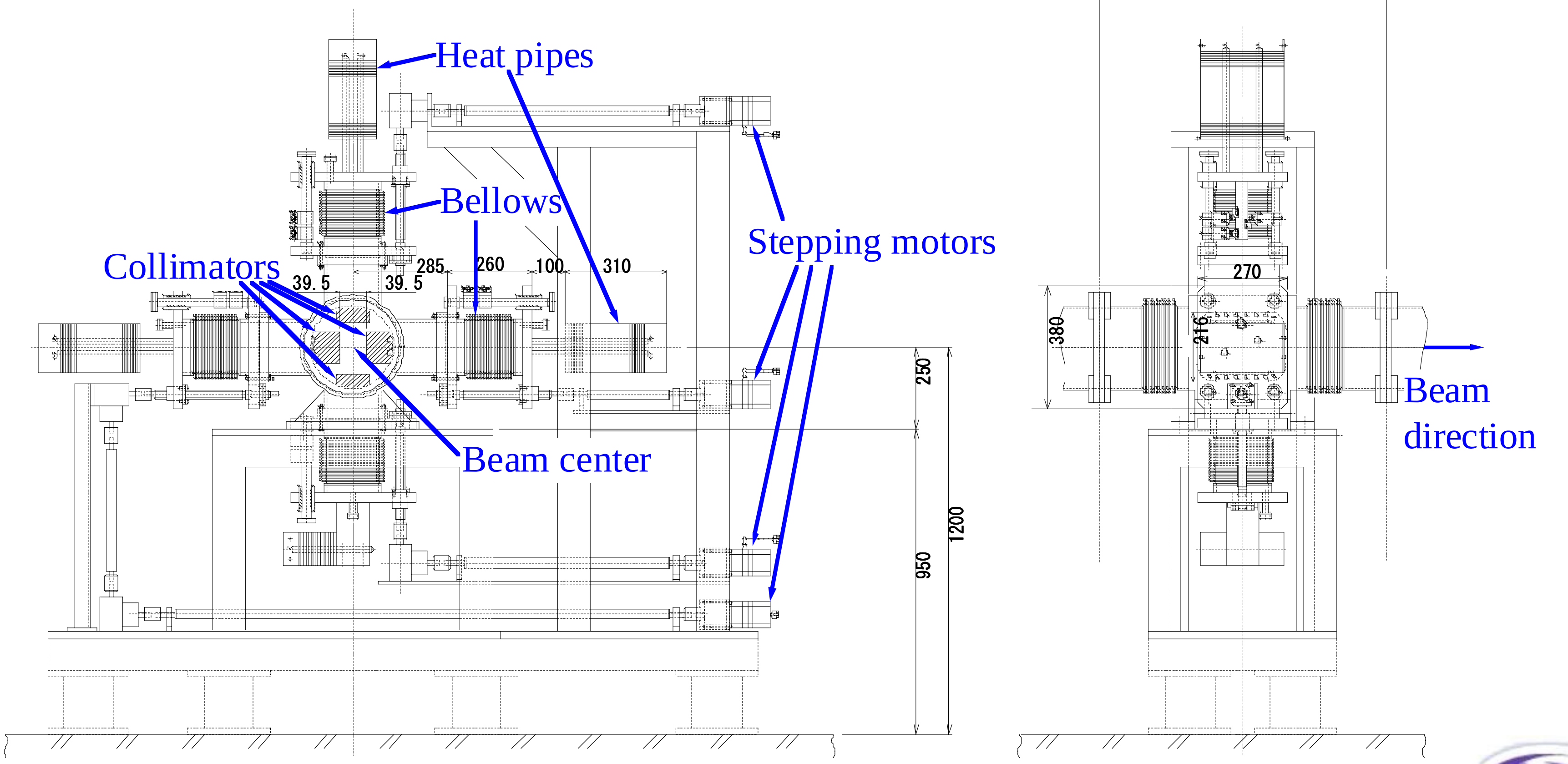
Halo collimator in the RCS

- **RCS**

Max. loss at Collimator

5.5×10^{12} for 181MeV injection

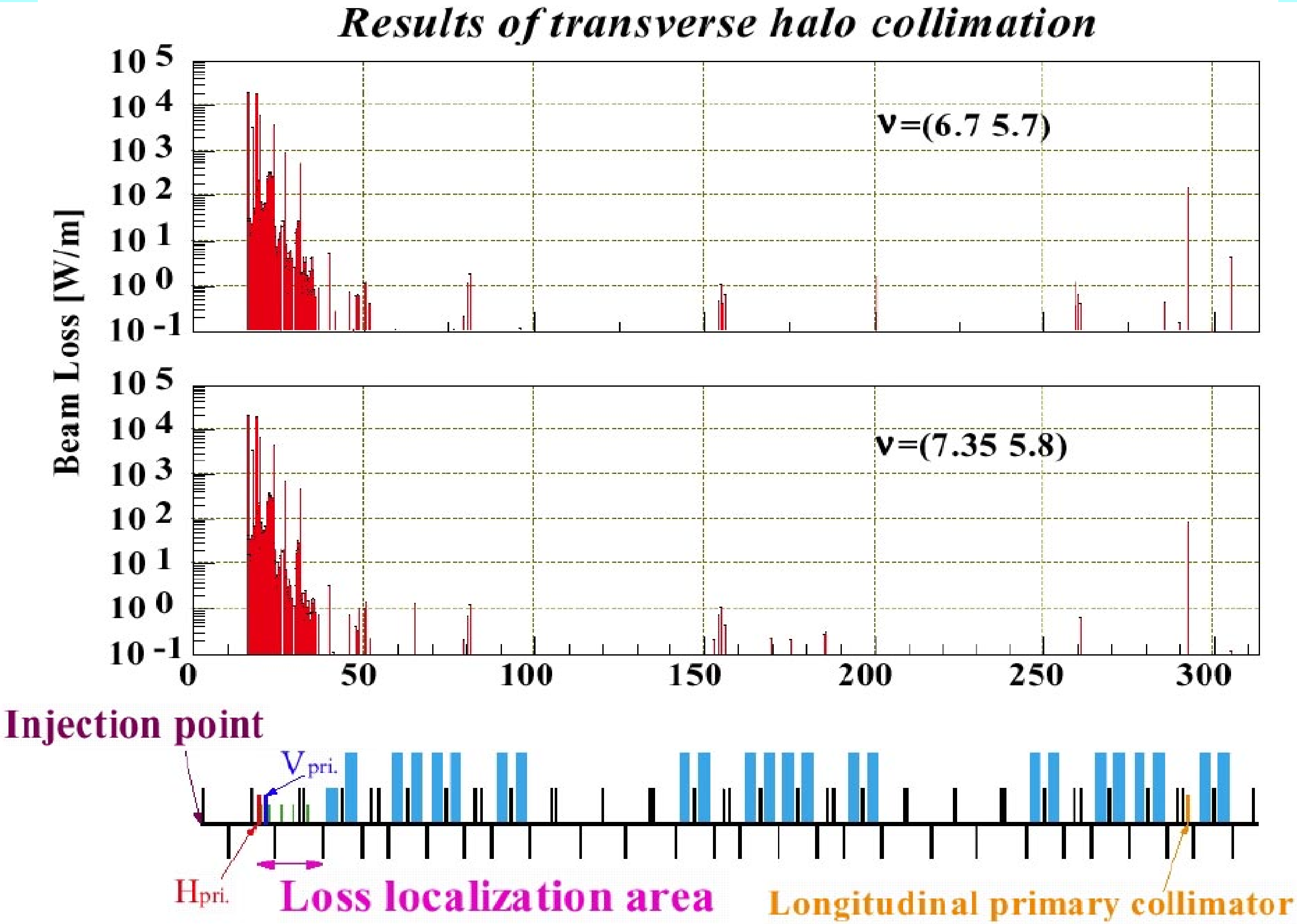
2.5×10^{12} for 400 MeV injection



prototype of the movable collimator

Halo collimator in the RCS

- **RCS**



K. Yamamoto, M. Kinsho, F. Noda, JAERI
Y. Irie, M. Shirakata, KEK
Proceedings of the 2001 Particle Accelerator Conference, Chicago

@ 4kW total loss 10^{12} loss

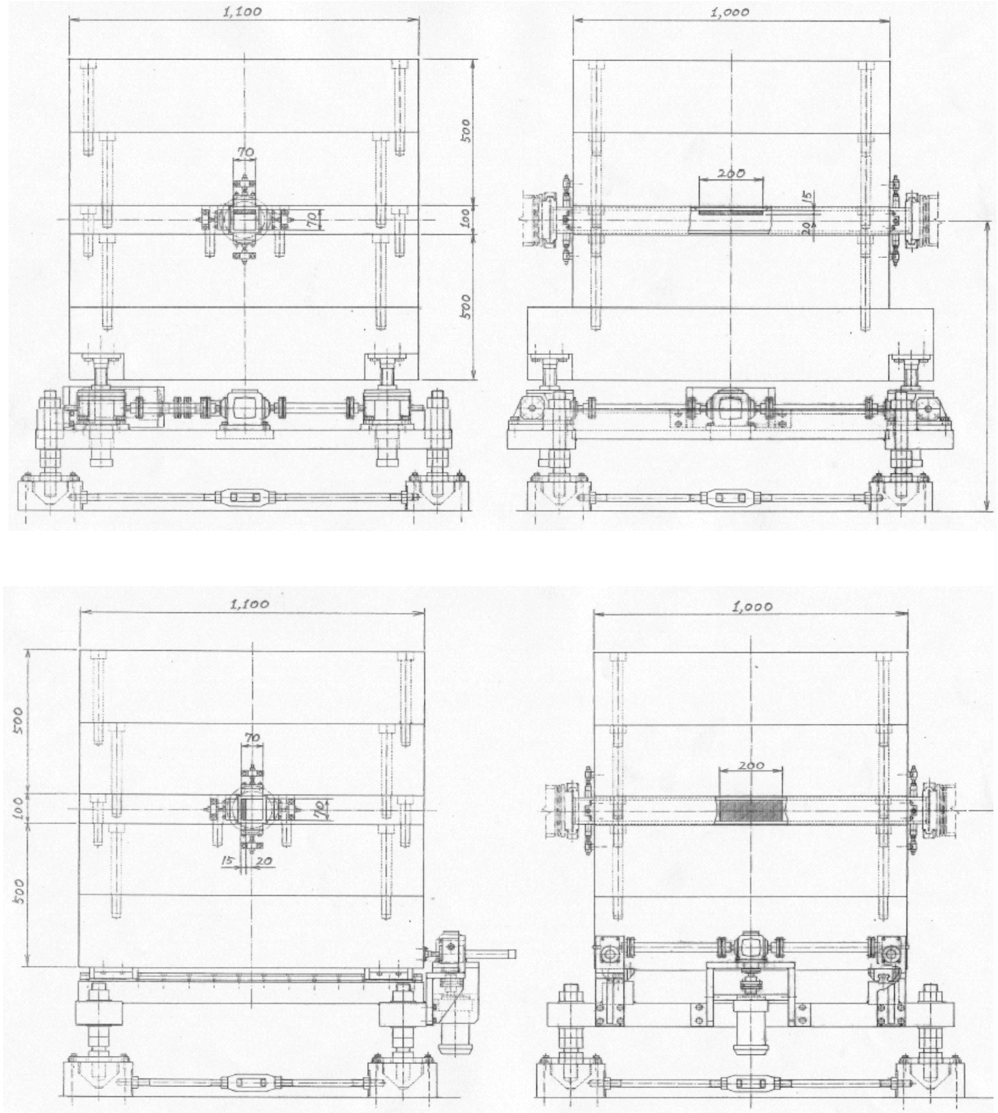
Halo collimator in the MR

- MR

(1) Shield Block	Iron
Dimension(mm)	1000(L) ~1100(W) ~1100(H)
Weight(T)	10
(2) Jaw	Tantalum
Dimension(mm)	200(L) ~70(W) ~15(H)
(3) Vacuum duct	Stainless steel
Dimension(mm)	70 ~70(in)[90 ~90(out)] ~1000(L)
(4) Jack	
Shiftspeed(mm/sec)	0.1

two - three scraper units/plane

Total beam loss in the system:
0.2 % of the injected beam
90 W



Prototype of the halo collimator

Electron yields

3GeV RCS and 50 GeV MR

		Proton loss	Electron yield	Power	Cure
Charge exchange Carbon fiol		-	1.7×10^{14}/500 μs	140 W (electron)	Electron catcher
Second stripping foils	H^0 H^-	-	5×10^{11}/500 μs	< 400 W (proton)	-
Halo collimator	181 MeV 400 MeV	< 5.5×10^{12} < 2.5×10^{12}	~5.5×10^{14} /500 μs ~2.5×10^{14} /500 μs	< 4 kW (proton)	Solenoid winding
Uncontrolled loss	181 MeV 400 MeV	< 1.1×10^{11} < 5×10^{10}	~1.1×10^{13} ~5×10^{12}	-	-
Halo collimator	controlled uncontrolled	< 5.3×10^{11} <1.3×10^{11}	~5.3×10^{13} ~1.3×10^{13}	~72 W (proton) ~18 W (proton)	Solenoid winding -

Uncontrolled losses: RCS ~ 1.6×10^{-6} e^-/m.p - 0.6×10^{-6} e^-/m.p (500 μs)

MR ~ 3.1×10^{-6} e^-/m.p (one turn, one bunch)

< 4.4×10^{-6} e^-/m.p (assumed production rate in cal.)

Summary

- Calculated

  e^- cloud build-up due to bunched and coasting beam

  e^- cloud instability due to bunched and coasting beam

  Instability not occur with the present parameters.

- e^- yield due to uncontrolled loss $< 4.4 \times 10^{-6}$ e^-/m.p

  assumption in calculation

- Collimator design may change a little ➡ need to follow

  Further loss estimates also needed

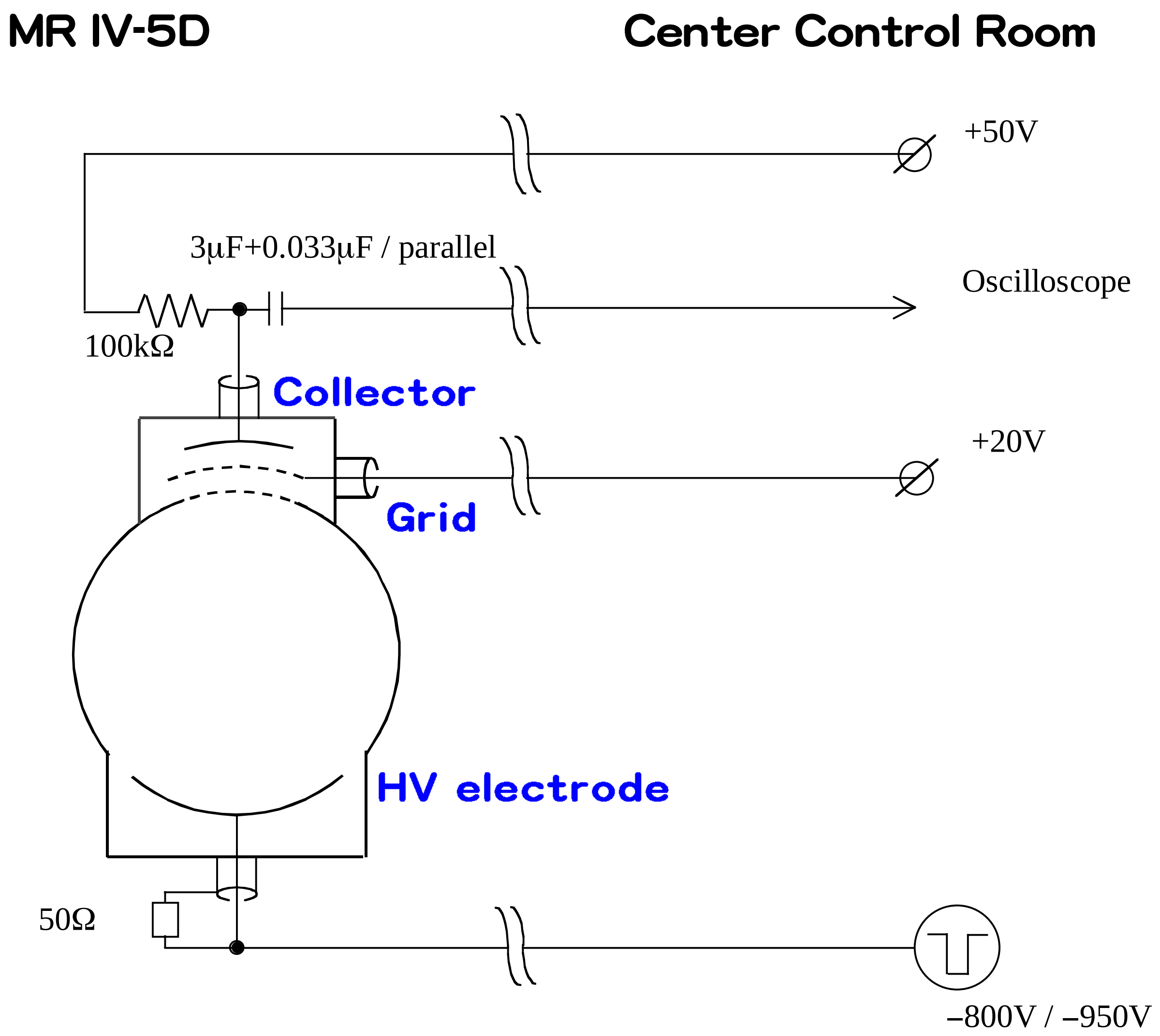
Observation in the KEK 12 GeV PS MR

- Electron cloud really exsist?
  - previous measurement was not clear (ECLOUD02)
- Install an electron sweeping detector

  scaled version of "LANL" design
- Bunched beam
  - around transition energy and flat top
- Coasting beam
  - at the flat top energy 12 GeV

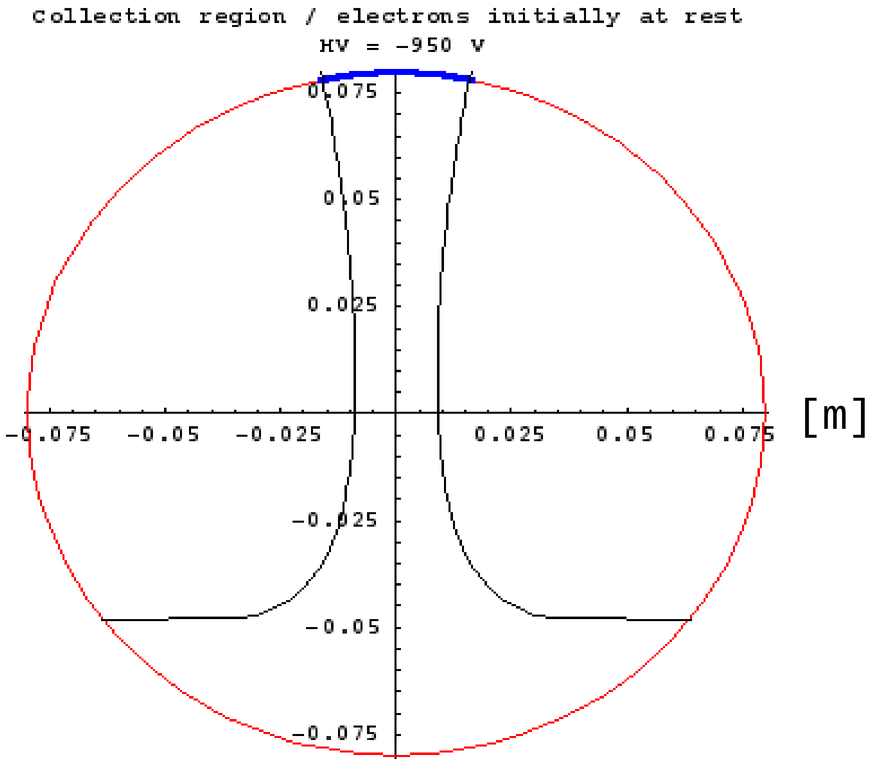
Observation in the KEK-PS MR

- **Setup**

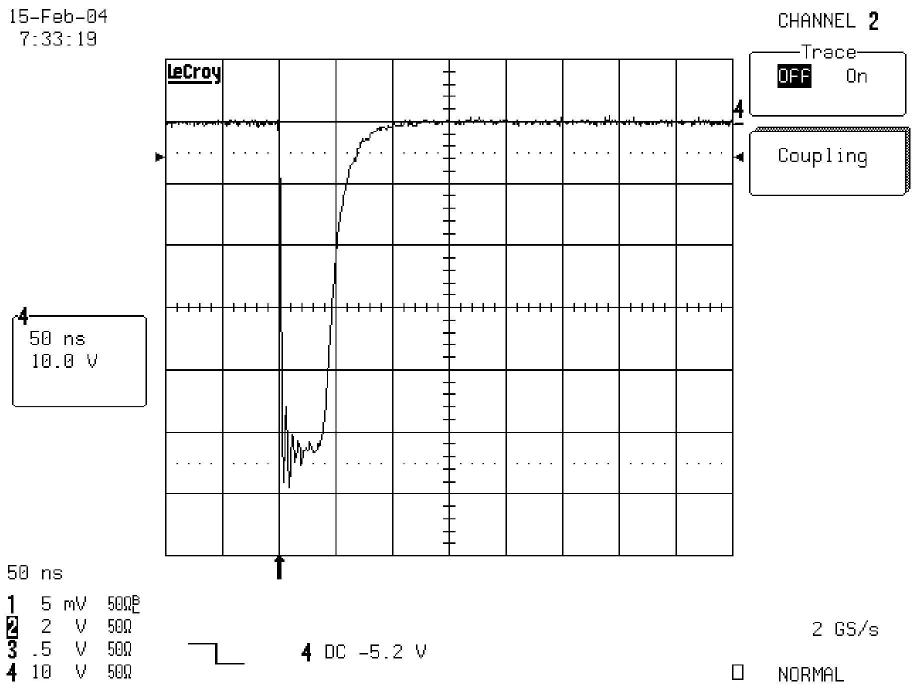


Courtesy R. Macek, LANL

Observation in the KEK-PS MR



HV waveform for the e⁻ sweeping detector measured at a pulser

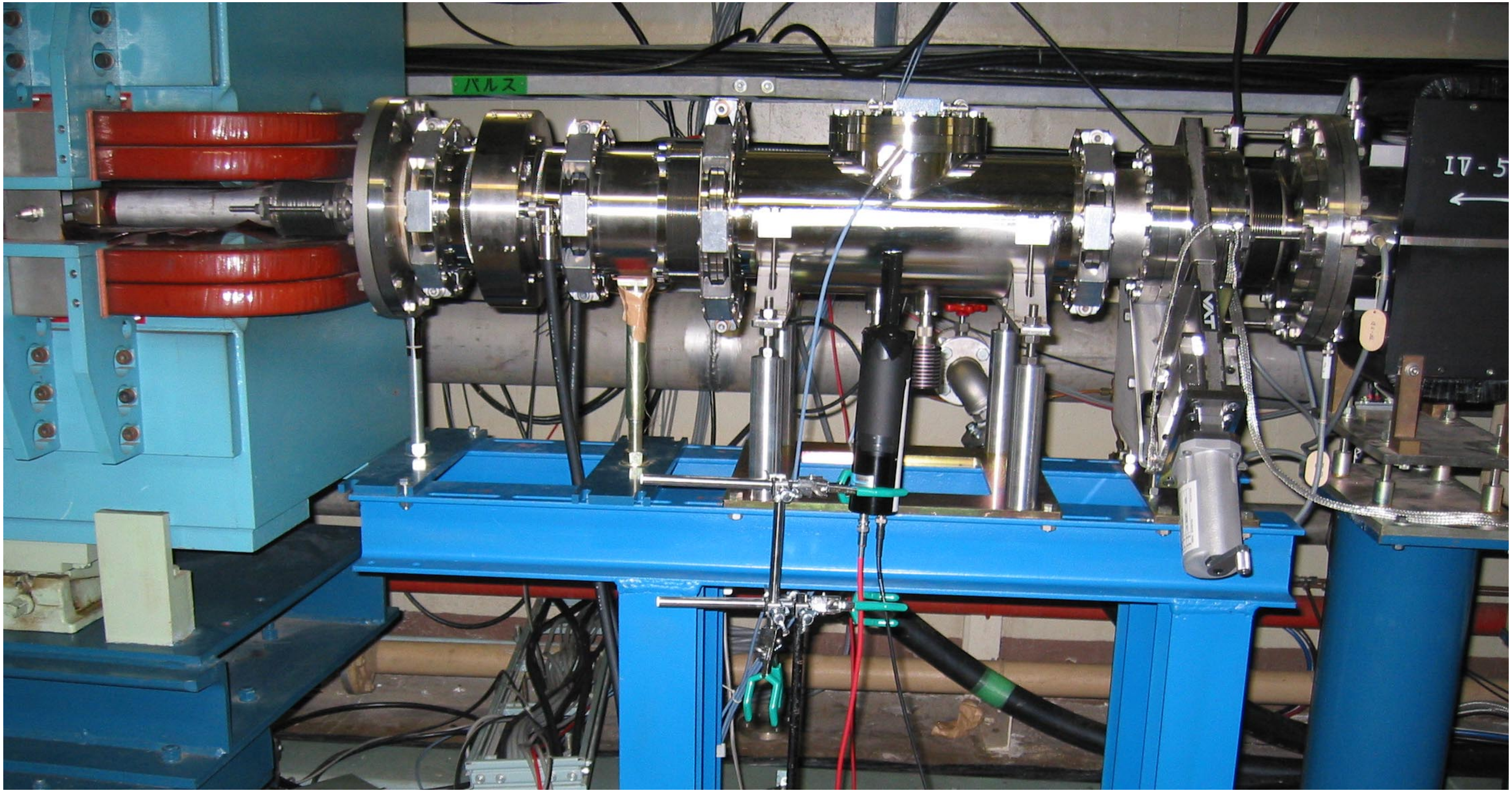


J-PARC

Observation in the KEK-PS MR

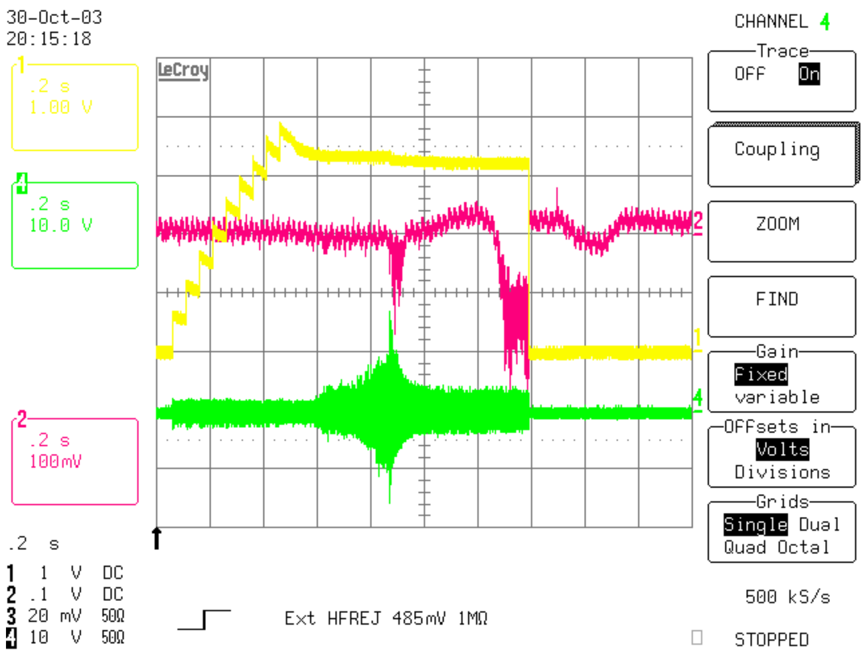
Electron sweeping detector

between a bending magnet and a steering magnet



J-PARC Electron build-up due to bunched beam @ KEK-PS MR

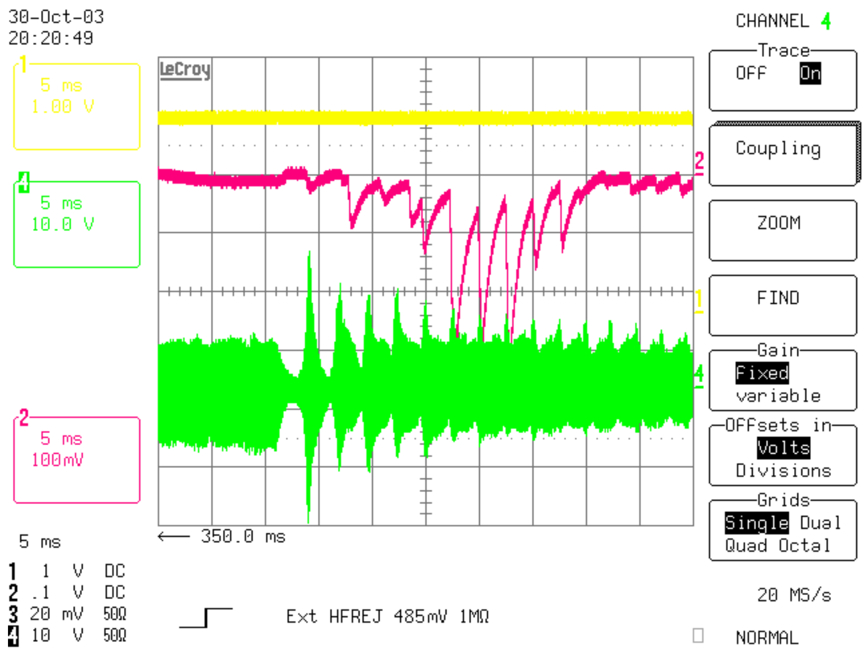
- Typical signal (with 1MΩ)



N_B

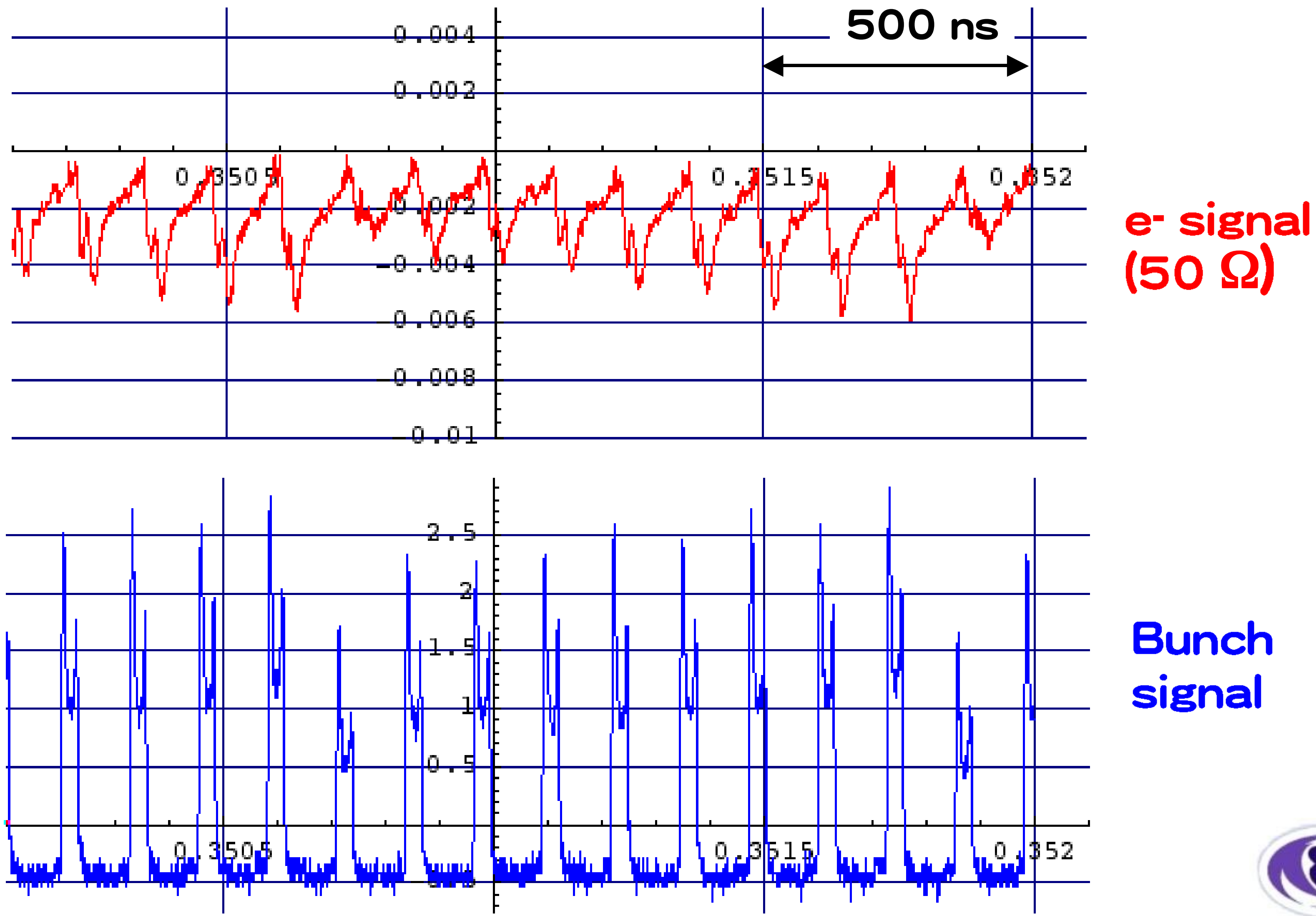
e^- signal (1MΩ)

Electrode signal



Electron build-up due to bunched beam @ KEK-PS MR

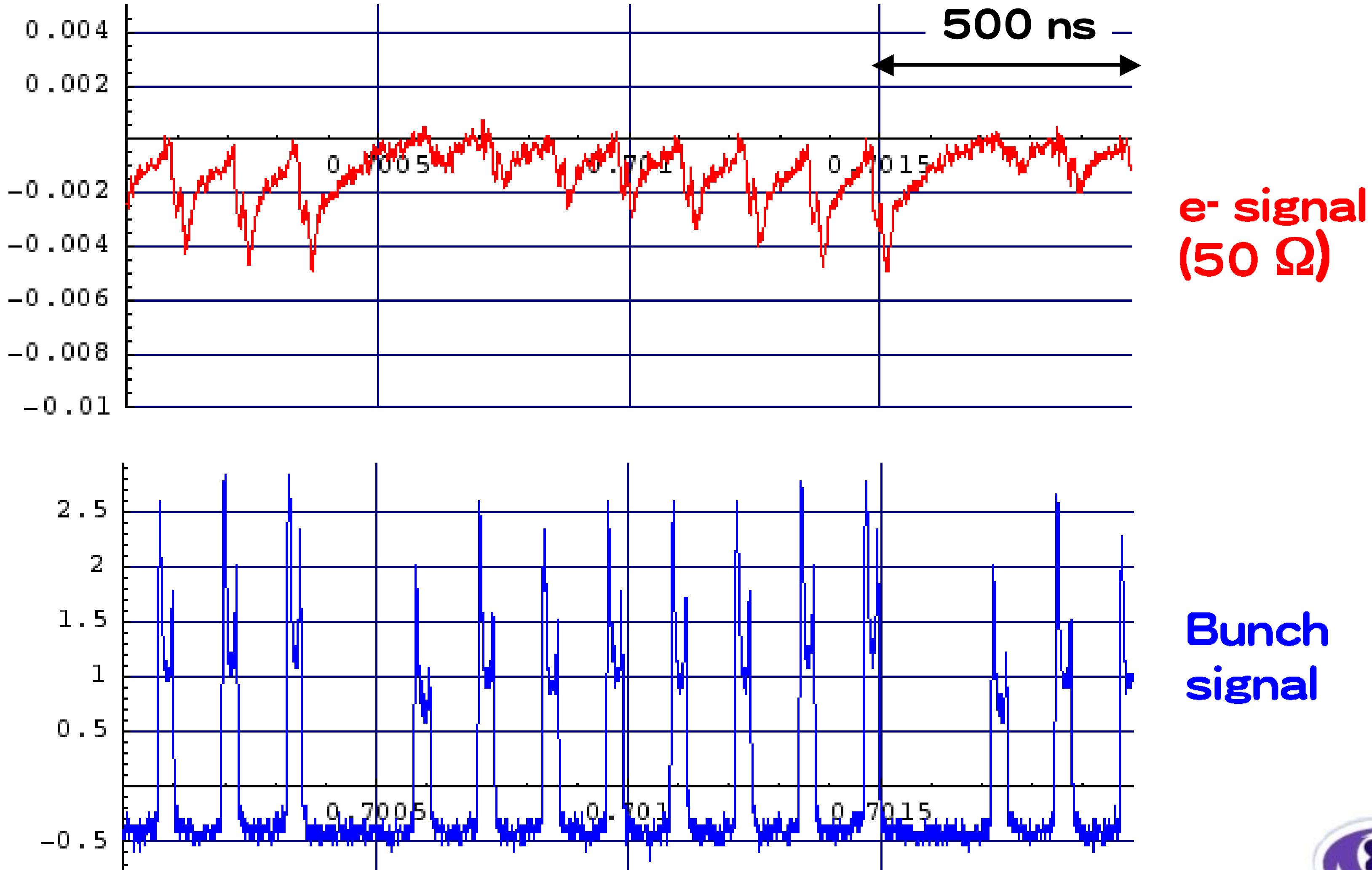
- Electron sweeping detector / 9 bunches



J-PARC

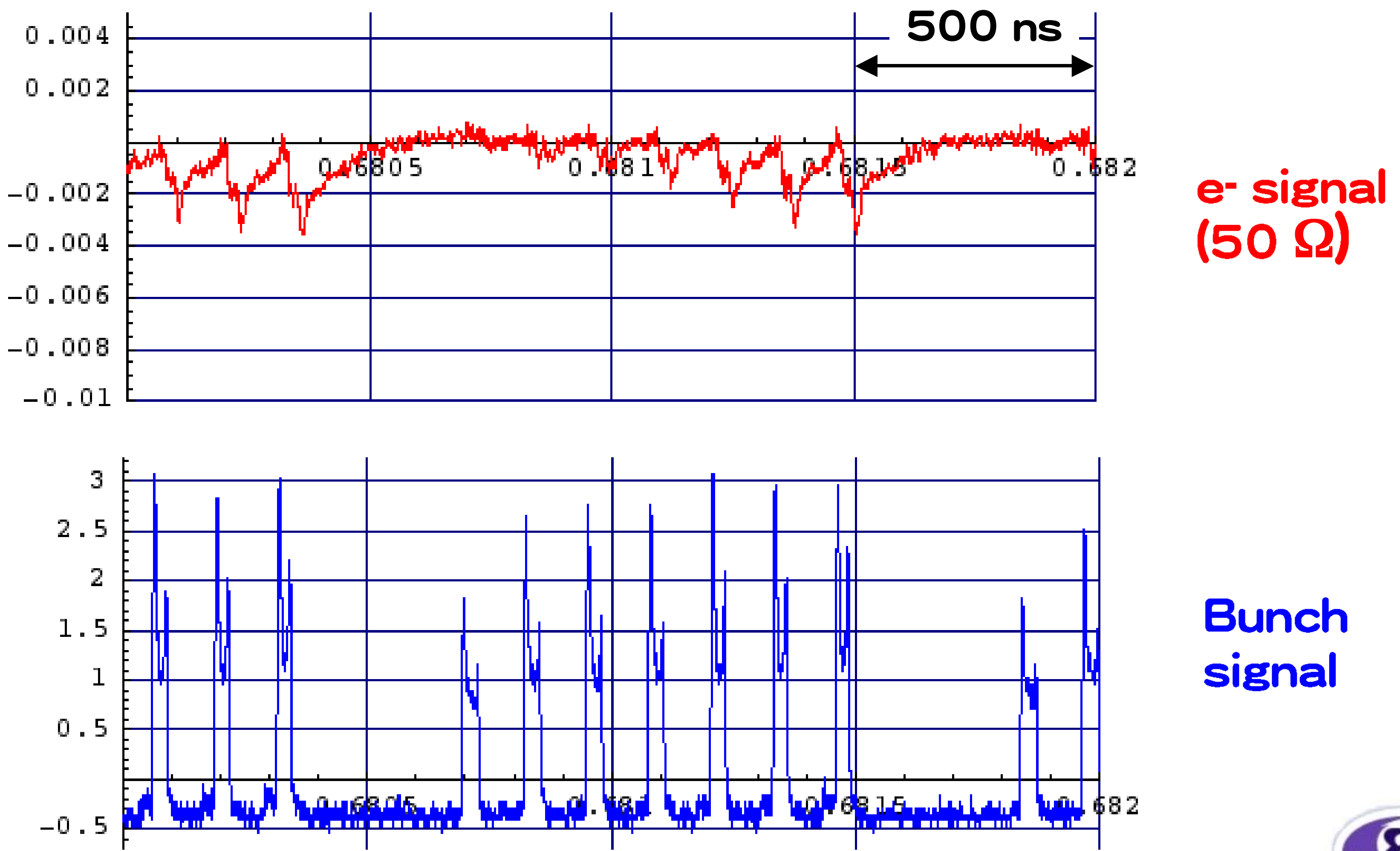
Electron build-up due to bunched beam @ KEK-PS MR

- Electron sweeping detector / 8 bunches



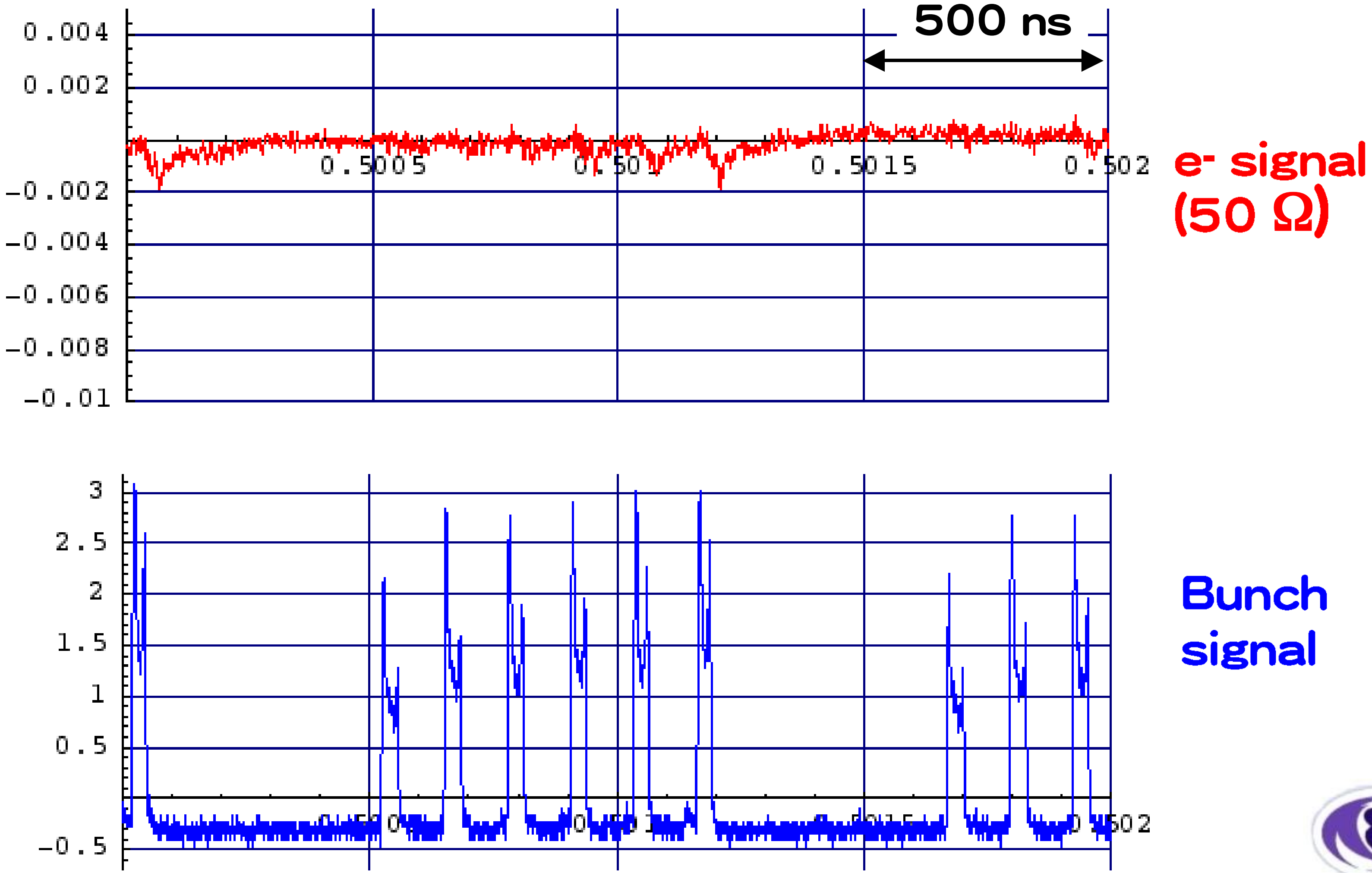
Electron build-up due to bunched beam @ KEK-PS MR

- Electron sweeping detector / 7 bunches



Electron build-up due to bunched beam @ KEK-PS MR

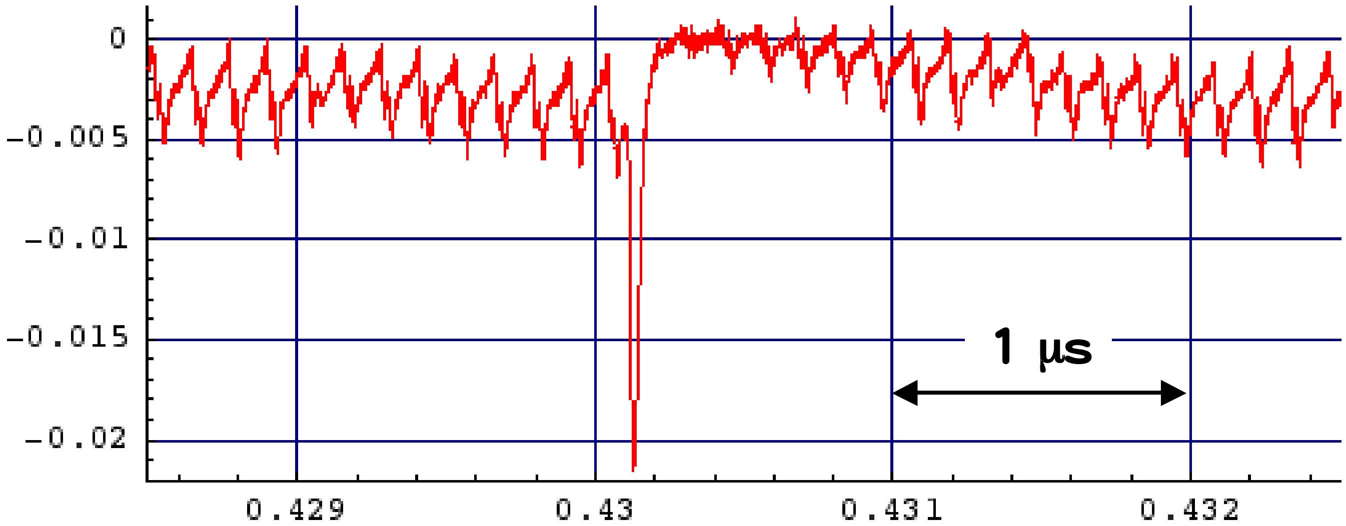
- Electron sweeping detector / 6 bunches
  No electron signal for < 5 bunches



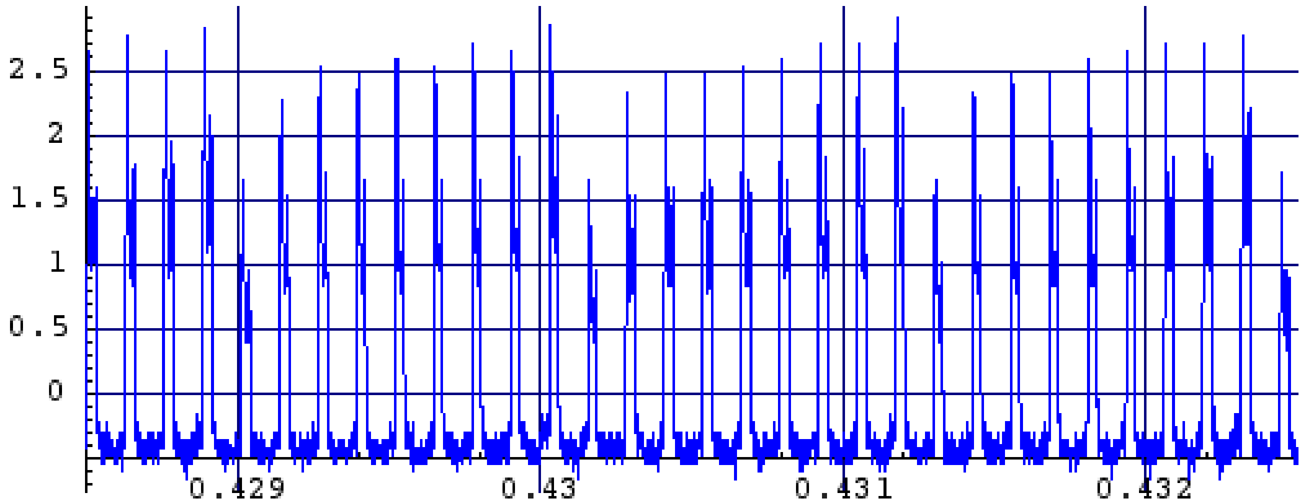
Electron build-up due to bunched beam @ KEK-PS MR

- **Electron sweeping detector / 9 bunches**

electron cloud is saturated within a few bunches



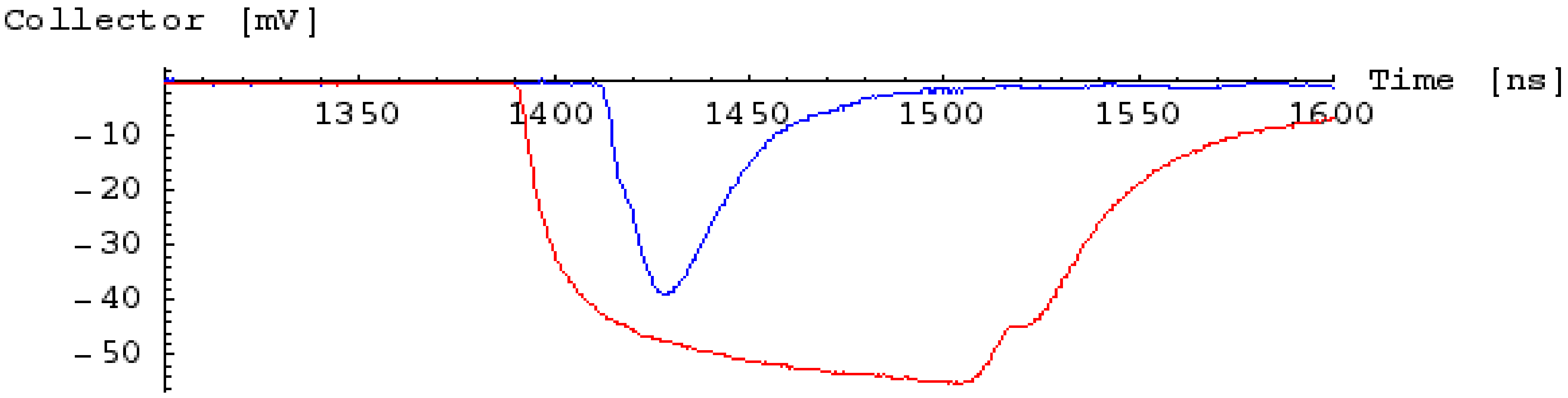
e- signal (50 Ω)



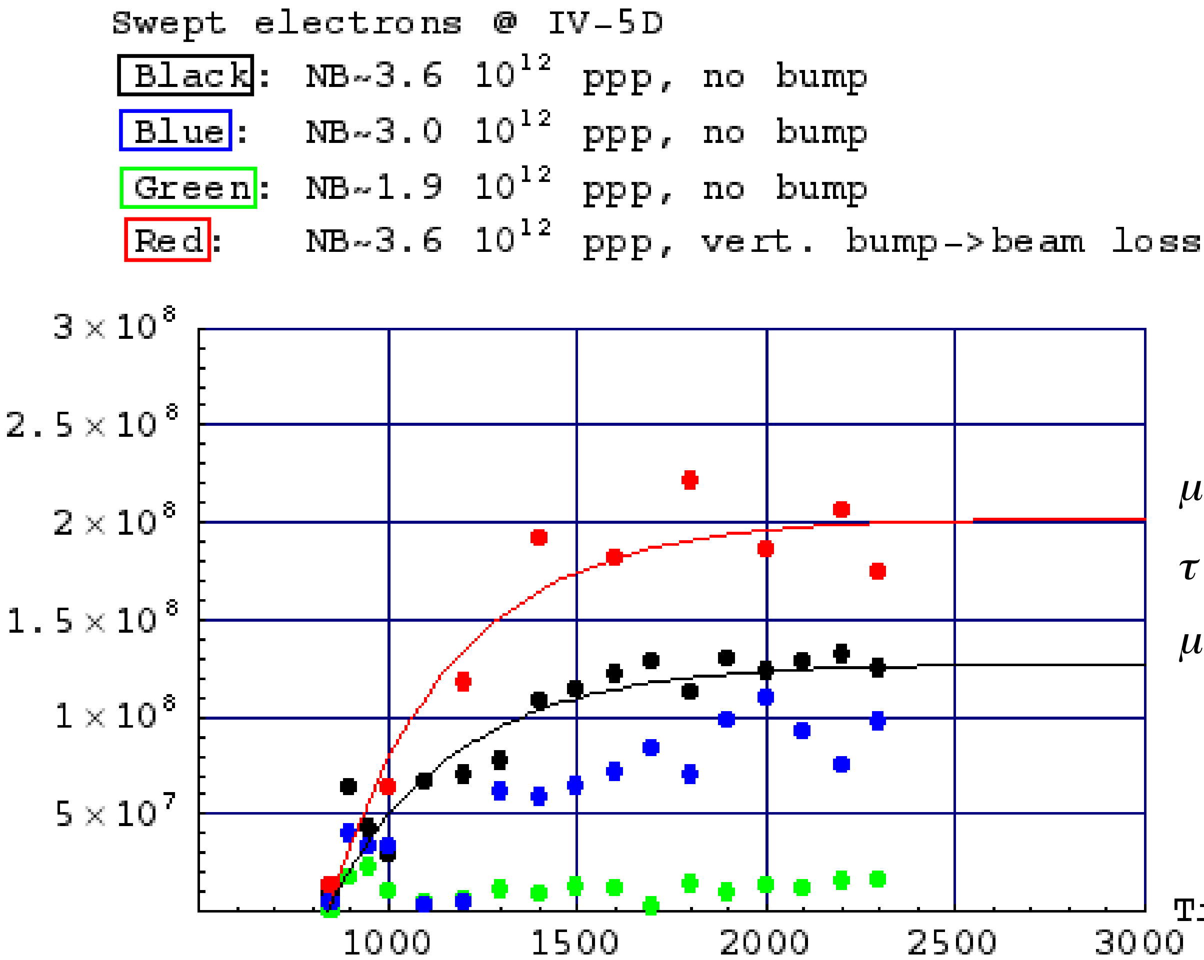
Bunch signal

J-PARC Electron build-up due to coasting beam @ KEK-PS MR

HV pulse (arb. scale), and electron signal



Electron build-up due to coasting beam @ KEK-PS MR



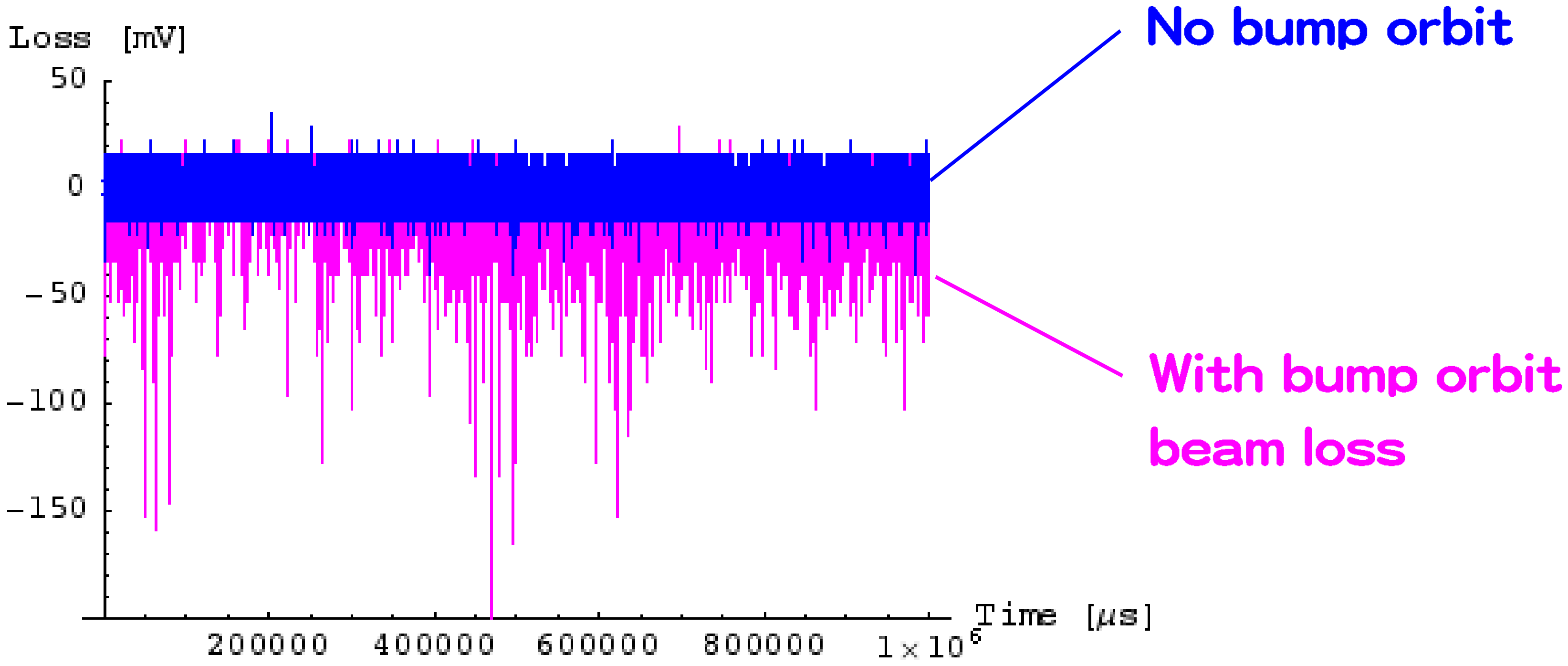
$\mu\tau\left(1-e^{-t/\tau}\right)$

τ : decay constant [s]

μ : production rate [e^-/ s]

Electron build-up due to coasting beam @ KEK-PS MR

Scintillation counter observe losses



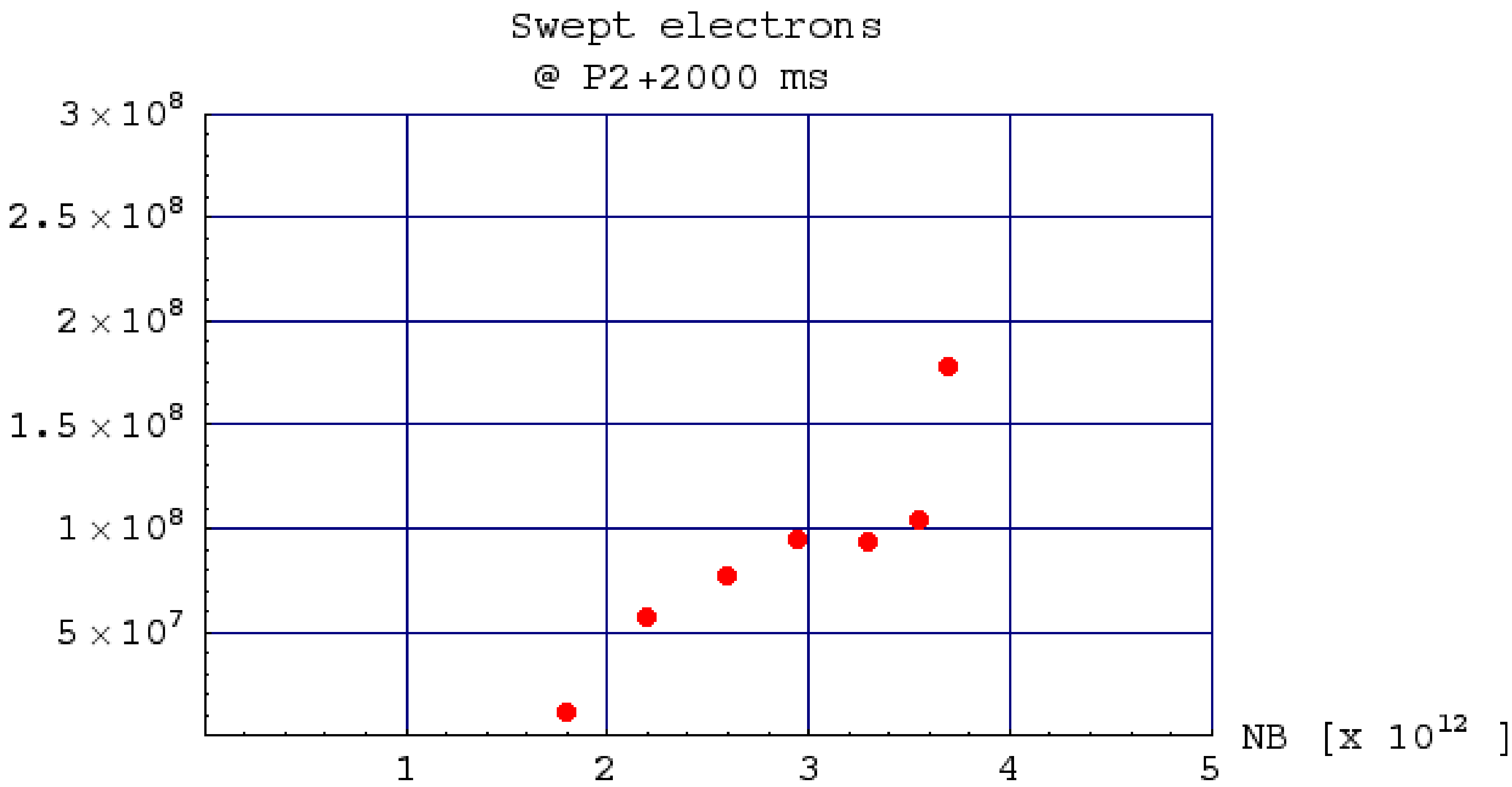
Electron build-up due to coasting beam @ KEK-PS MR

variables	KEK-PS MR
Energy [GeV]	12
N_B [protons]	3.6×10^{12}
f_{rev} [kHz]	882
P [Pa]	$2 - 6 \times 10^{-6}$
production rate [e^-/m.p]	3×10^{-9} ($6 - 17 \times 10^{-8}$ cal.)
production rate [e^-/m]	1×10^{4}
λ_e [/m]	3×10^{9}
λ_p [/m]	0.97×10^{10}
Neutralization @ saturation	0.3
Time constant [s]	0.3

⇧ Experiment
No visible instability

Electron build-up due to coasting beam @ KEK-PS MR

- **Beam Intensity vs Electron**



J-PARC

Observation in the KEK-PS MR

- E-cloud was observed in the bunched and coasting beam

<Bunched beam>

- E-cloud is saturated within a few bunches

<Coasting beam>

- E-cloud formation by coasting beam
  electron production rate $\mu \sim 1 \times 10^{10}$ e^{-}/s
  (assuming detector efficiency ~ 0.04)
  one order smaller than the calculated one with pressure data
  decay constant $\tau \sim 0.3$ s

- Intensity dependence of electron density has threshold

- Small amount of beam loss affects the e-cloud density

原研