Beam Stabilization using Energy Compression System in SPring-8 Linac

Japan Synchrotron Radiation Research Institute (JASRI)

Takao Asaka

Stability of the rf equipment

Phase of klystron drive system -> Adjustment of the air conditioner

10deg./4˚C (10hrs periodical) -> <1deg./1˚C

Phase of the klystron -> Continuous regulation type of cooling system

2.4deg./3˚C (27min periodical) -> <0.5deg./0.5˚C

Fluctuation of the klystron beam voltage -> Adjustment of deQing circuit

0.3% (rms) -> 0.04% (rms)

Stability of the beam energy

Stability of the beam current

>20% -> 1.9% (rms)

Stability of the beam energy

>1% -> 0.06% (rms)@4hrs, 0.03% (rms)@10min

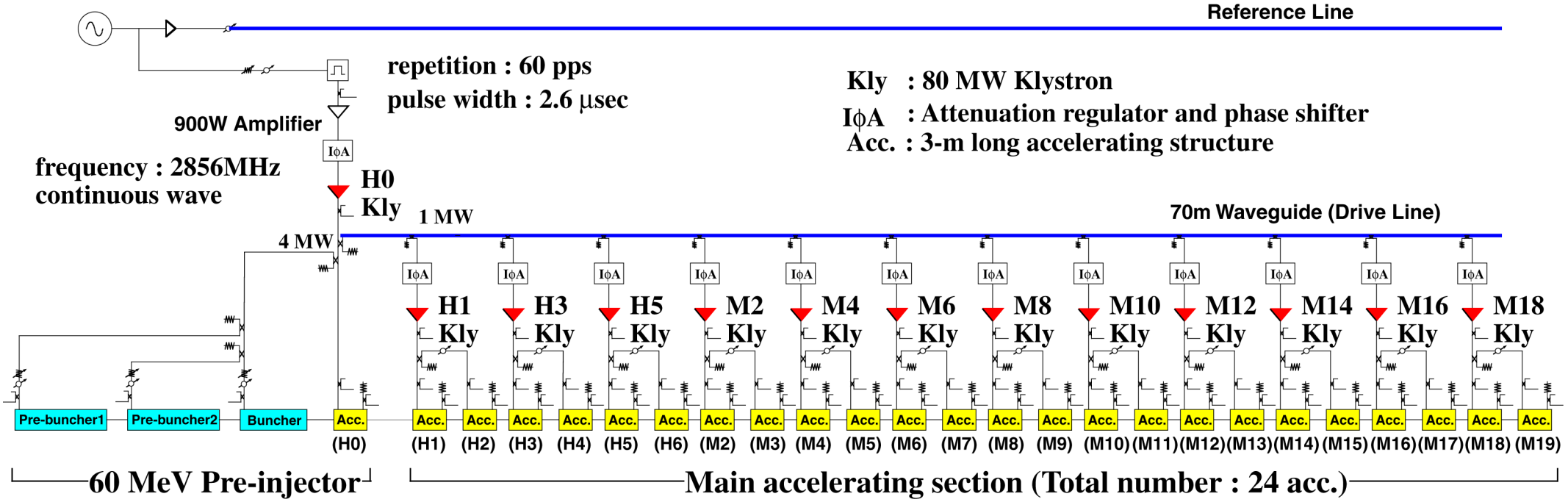
Energy Compression system

Stability of the beam energy

0.03% (rms) -> 0.01% (rms)

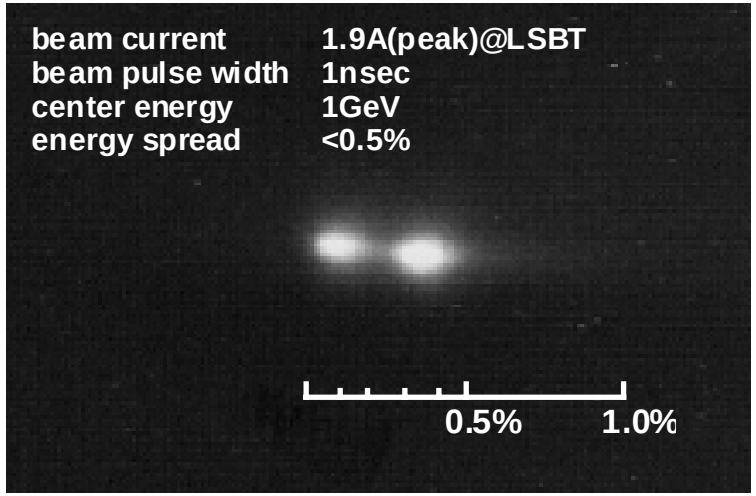
Beam parameter and rf system of the SPring-8 linac

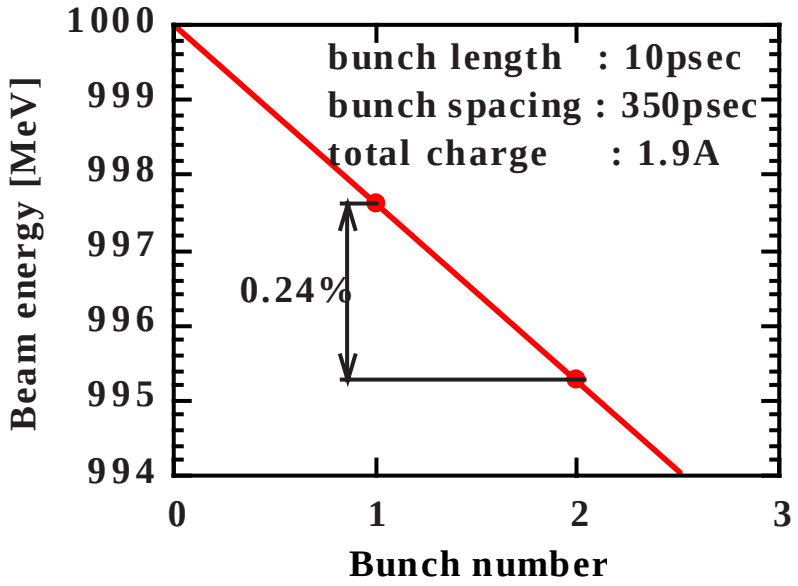
	Synchrotron		New SUBARU
Pulse width	**40 nsec**	**1 nsec**	**1 nsec**
Peak current	**~ 140 mA**	**~ 2 A**	**~ 200 mA**
Beam energy (Maximum)	**1.2 GeV**	**1.2 GeV**	**1 GeV**
Energy spread	**± 0.8 %**	**± 0.3 %**	**± 0.2 %**
Normarized emittance (90%)	**<240 π mm mrad**	**<160 π mm mrad**	**<200 π mm mrad**
Bunch length	**15 ~25 psec**	**15 ~25 psec**	**15 ~25 psec**



Beam loading at the accelerating structure

Accelerating structure	**2π/3 mode constant gradient**
Total number	**25**
Operation frequency	**2856 MHz**
Number of cell	**81**
Shunt impedance	**54 MΩ/m**
Unloaded Q	**13500**
Effective length	**2.88 m**
Filling time	**610 nsec**
Input power (usual operation)	**35MW**





Compression factor of ECS

Energy acceptance of the synchrotron : ±1.0 %

Energy acceptance of the New SUBARU : ±0.2 %

The required time jitter of the synchrotron : ±100 psec

The required time jitter of the New SUBARU : ±50 psec

Beam timing jitter (rms) : 6.8 psec

Bunch length : 20psec -> 50 psec

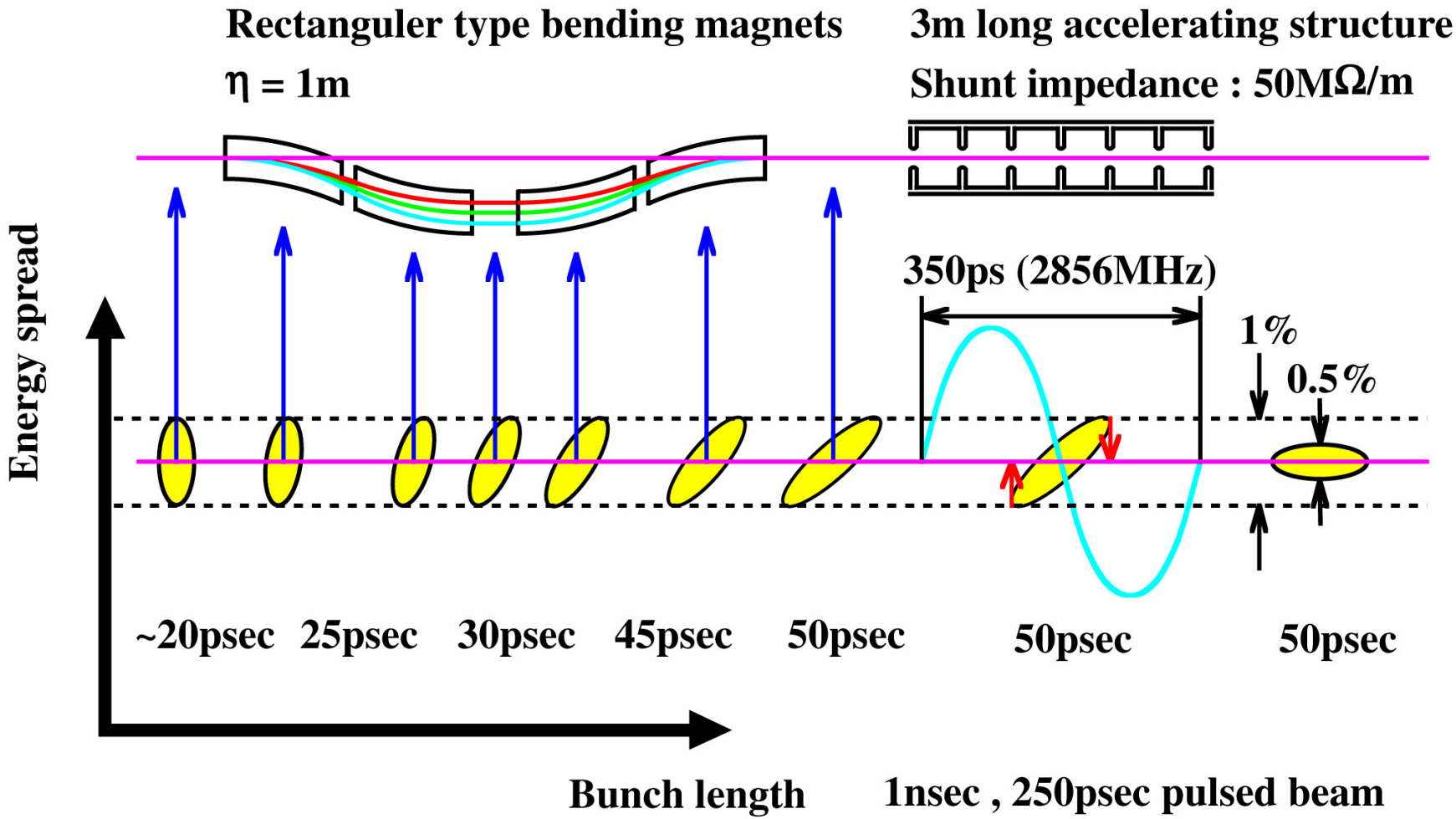
Energy spread : 1 % -> 0.5%

@beam current : 5A

@beam pulse width : 1nsec

Compression factor : 25 deg./%

Energy compression diagram



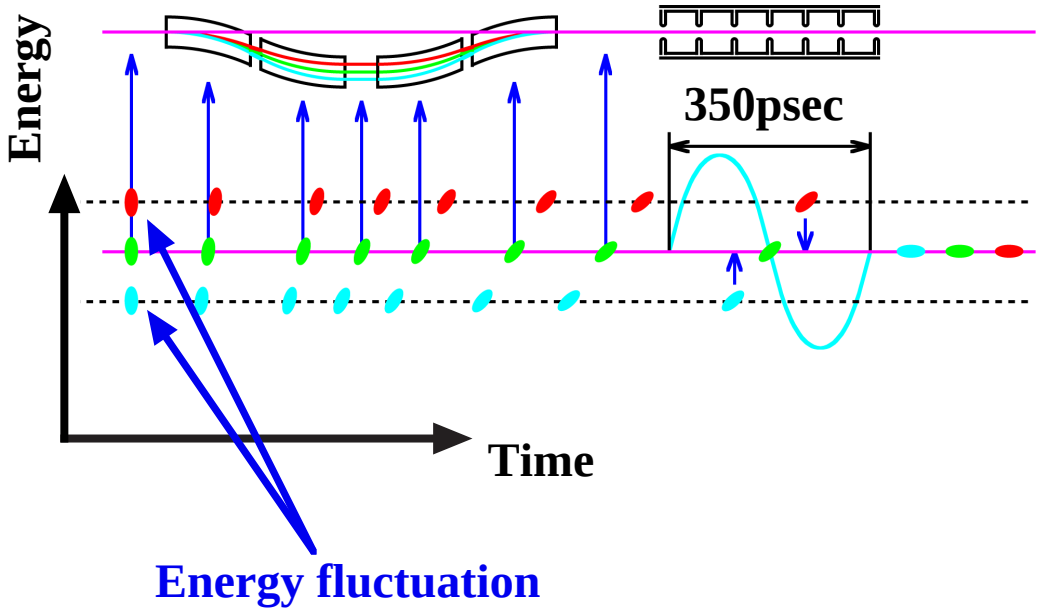
1nsec , 250psec pulsed beam

beam current : ~ 2A (peak)

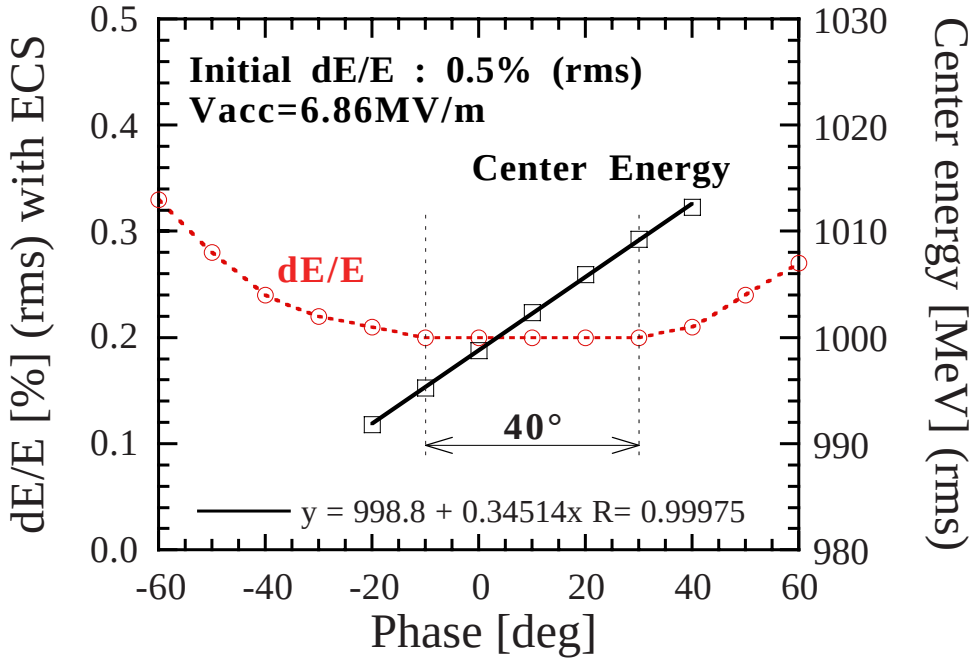
energy spread : < 1%

Energy stabilization & control by ECS

1 GeV chicane **Accelerating strucure**



Center energy dependence on the phase of the ECS

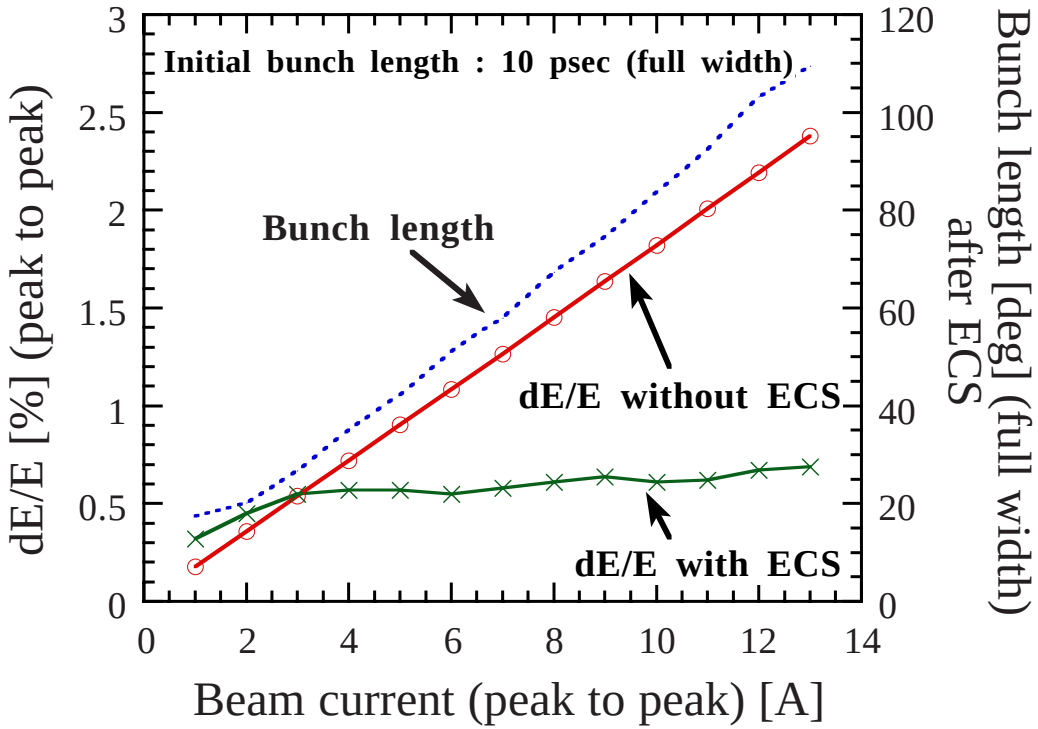


Energy dependence on the phase of ECS **0.35% / 1deg.**

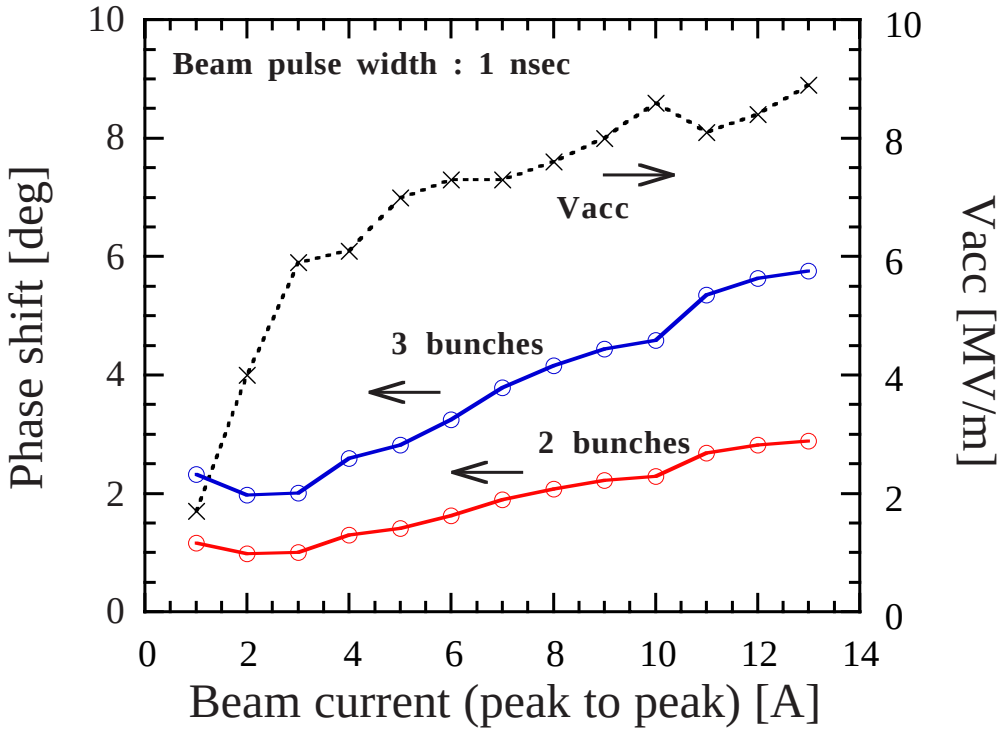
Stability of the excitation current for chicane magnet **< 1e-4**

Stability of the phase of ECS **< 0.5 deg. (rms)**

Simulation of the energy compression



Beam loading effect of the ECS's
3 m long accelerating structure



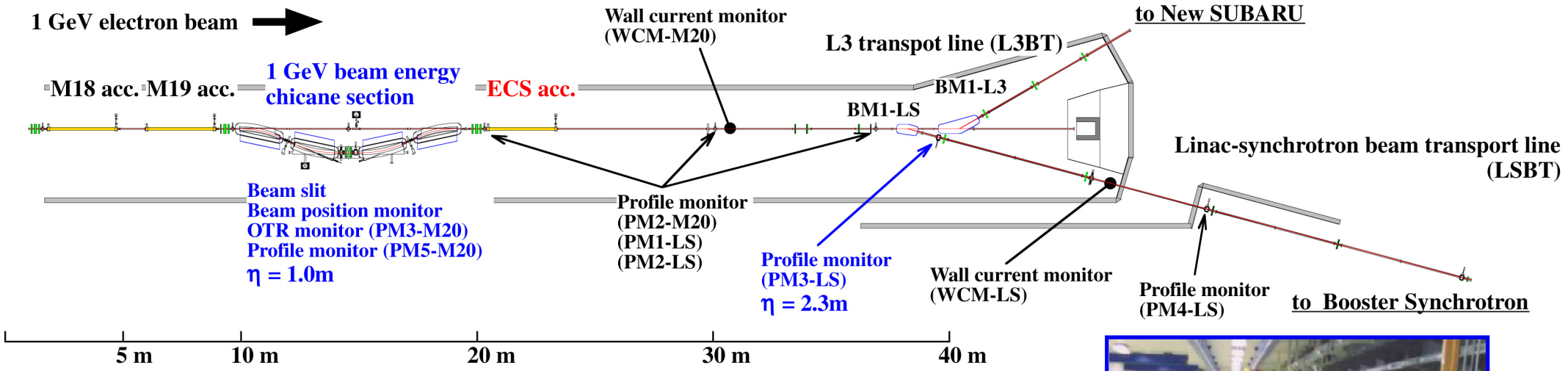
Beam pulse width : 1nsec

Beam current : ~5A (peak to peak)

Energy spread :±0.3% with ECS

Phase shift : < 3deg.

Energy compression System (ECS)



Schedule

1999/1~	Calculation of the input power and phase of ECS' acc.
1999/2~	Design of low power rf system
1999/7~8	Installation and mesurement of the low power rf system
1999/10~	Design of high power rf system
2000/6~8	Installation and mesurement of the high power rf system
2000/10/10~17	rf aging
2000/10/31~	Beam test
2001/3~	Operation start

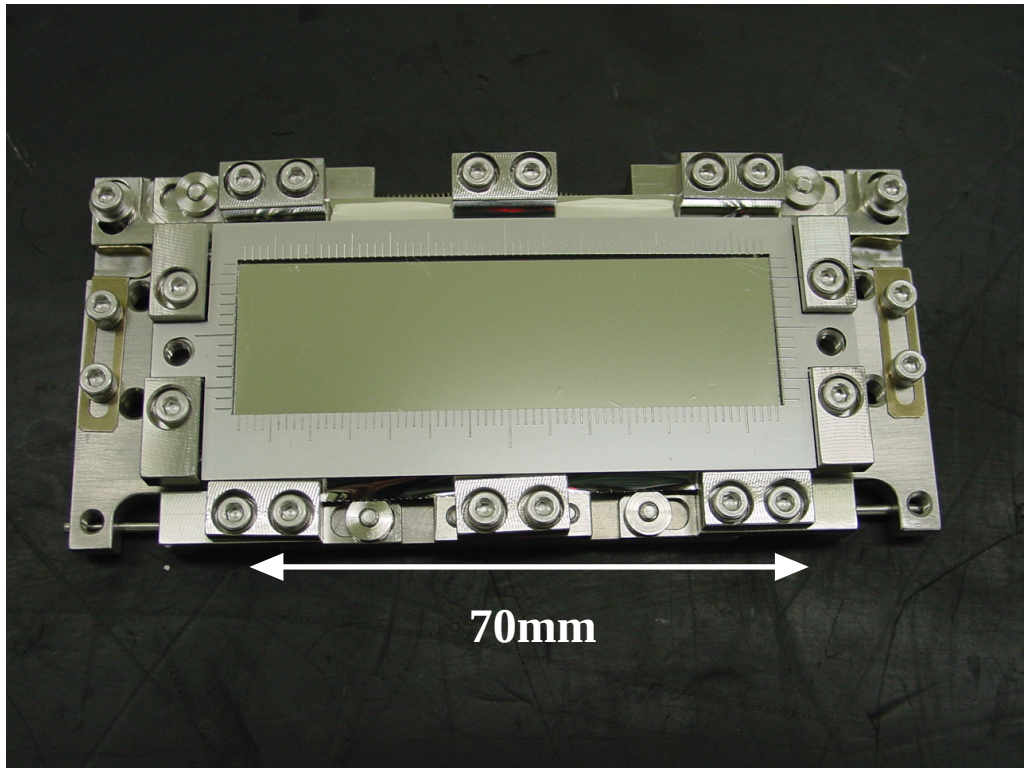
1 GeV chicane rectangular magnets

3 m long accelerating structure of ECS

Energy monitor at chicane section

Optical transition radiation (OTR) monitor@1 GeV chicane section (η = -1 m)

(Al + Kapton foil target) + ϕ80 mm telecentric lens + Random shutter camera



Kapton foil

thickness : 12.5 μm

Vacuum evaporation

: 0.4 μm (aluminum)

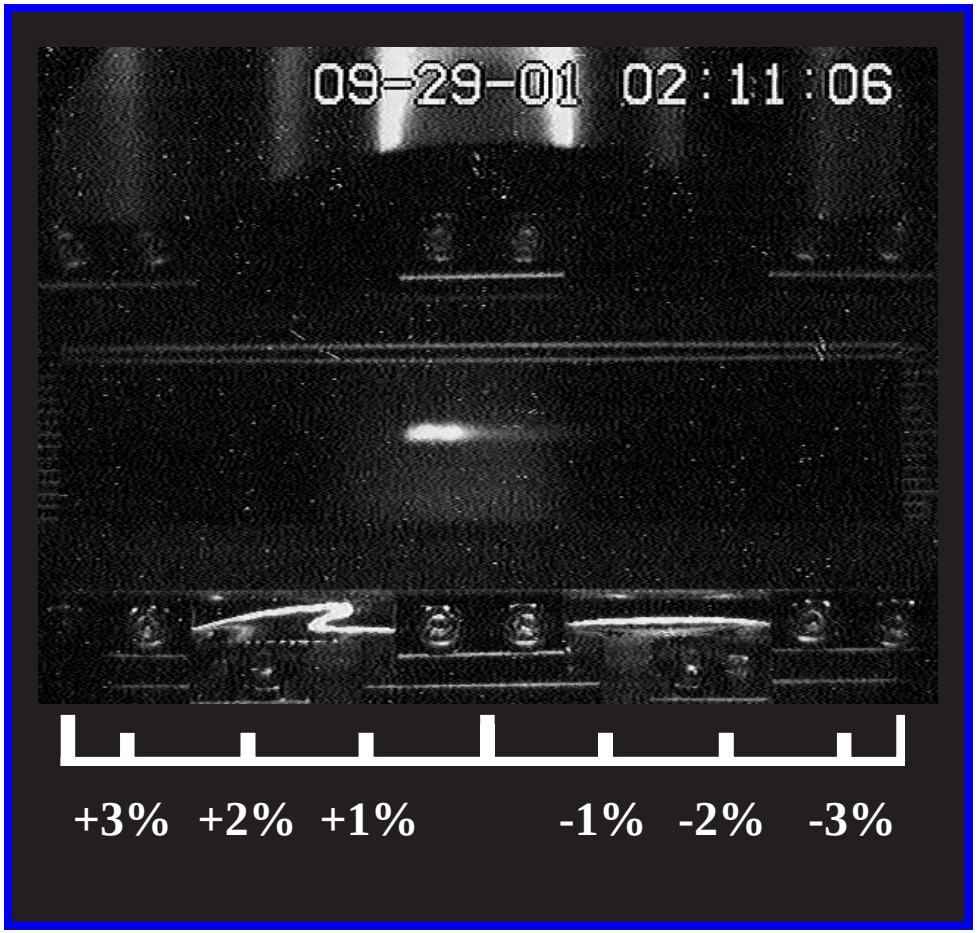
Deterioration in the emittance with OTR monitor

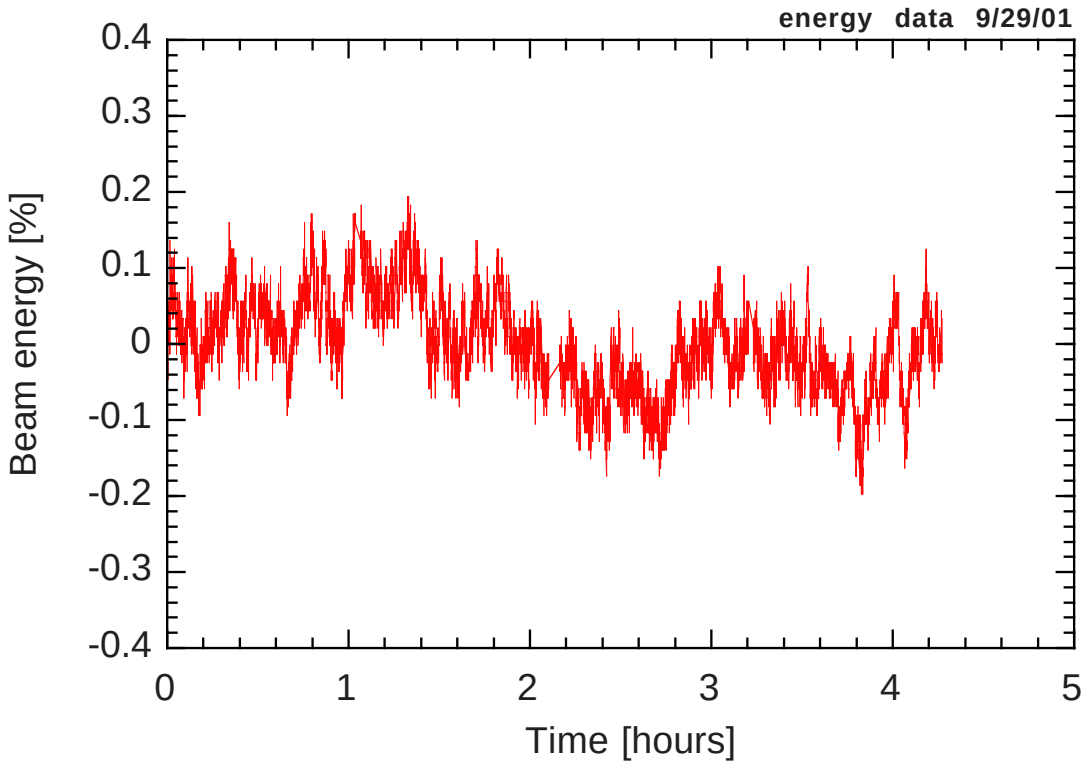
5e -8 ~ 3e -7 m rad -> 5e -7 m rad@1 GeV

Injection beam current

beam loss : negligible

OTR monitor at chicane section



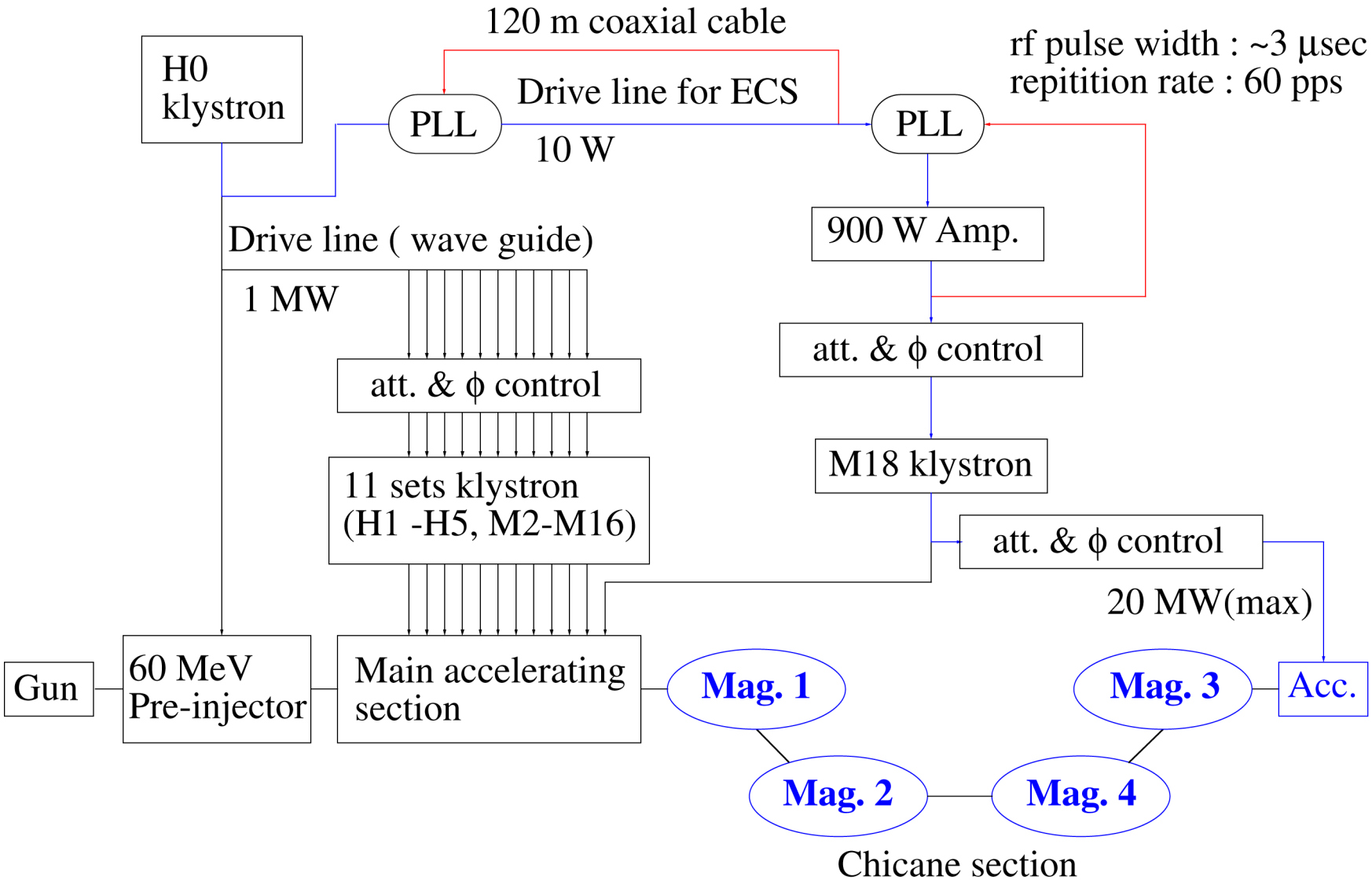


Beam current : 1.5A

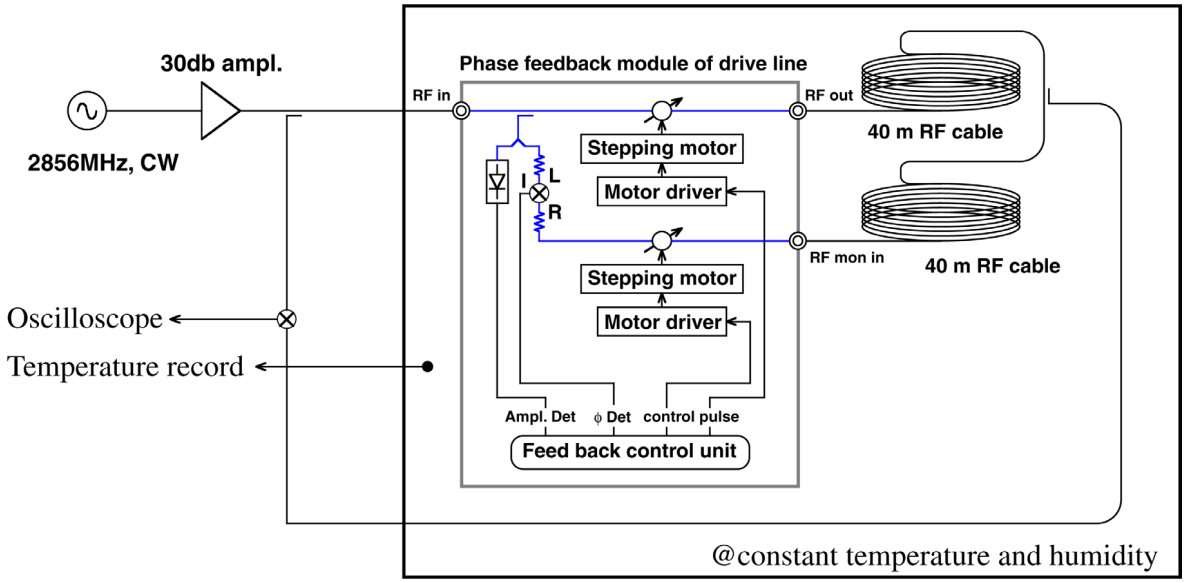
Beam pulse width : 1nsec

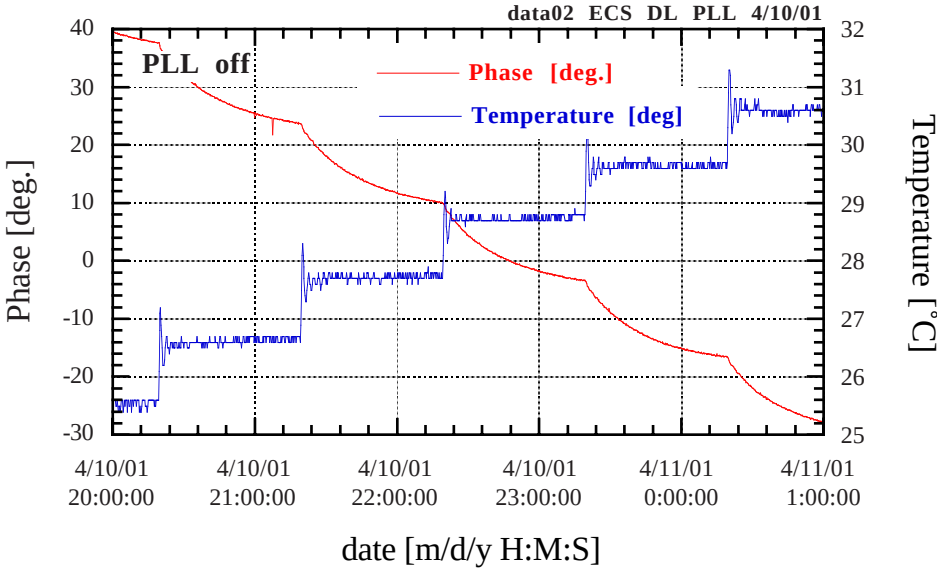
Energy stabilizaton : 0.06% (rms)

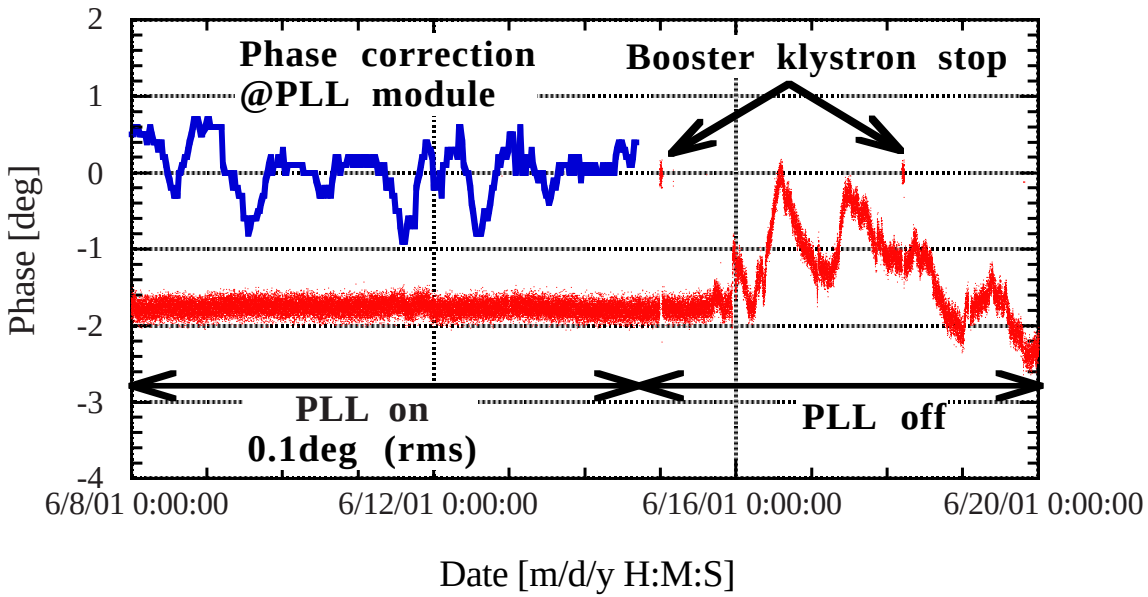
Block diagram of the RF system for ECS

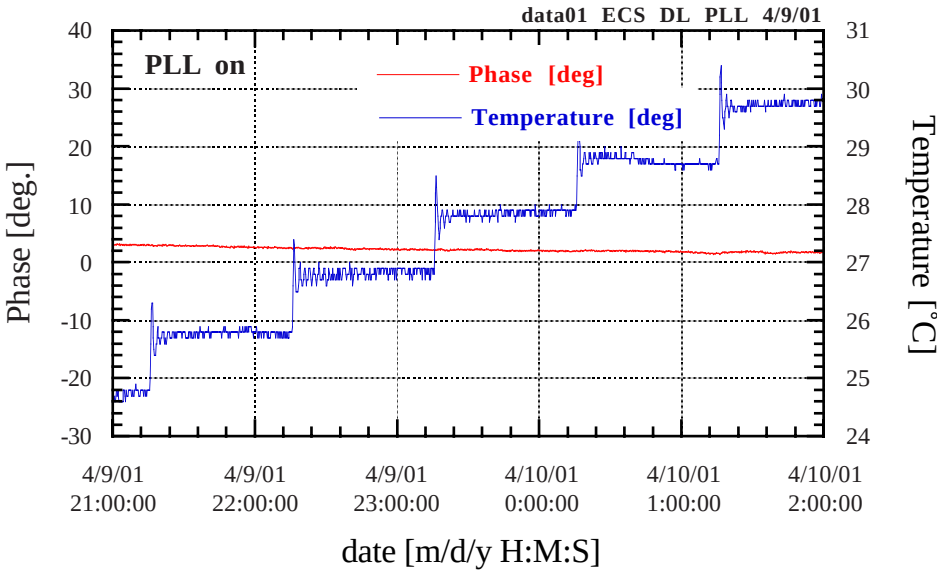


Characteristics of the PLL for the Drive line of ECS

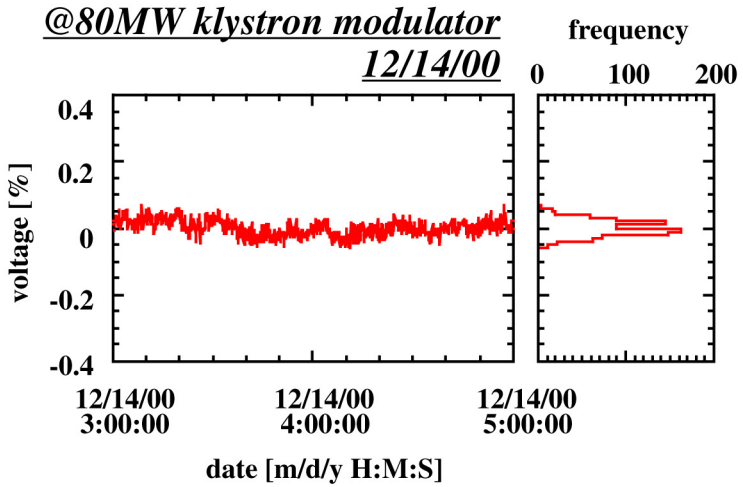




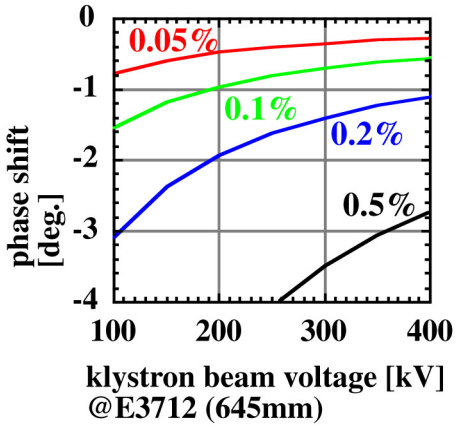




Stability of the high power rf component for ECS

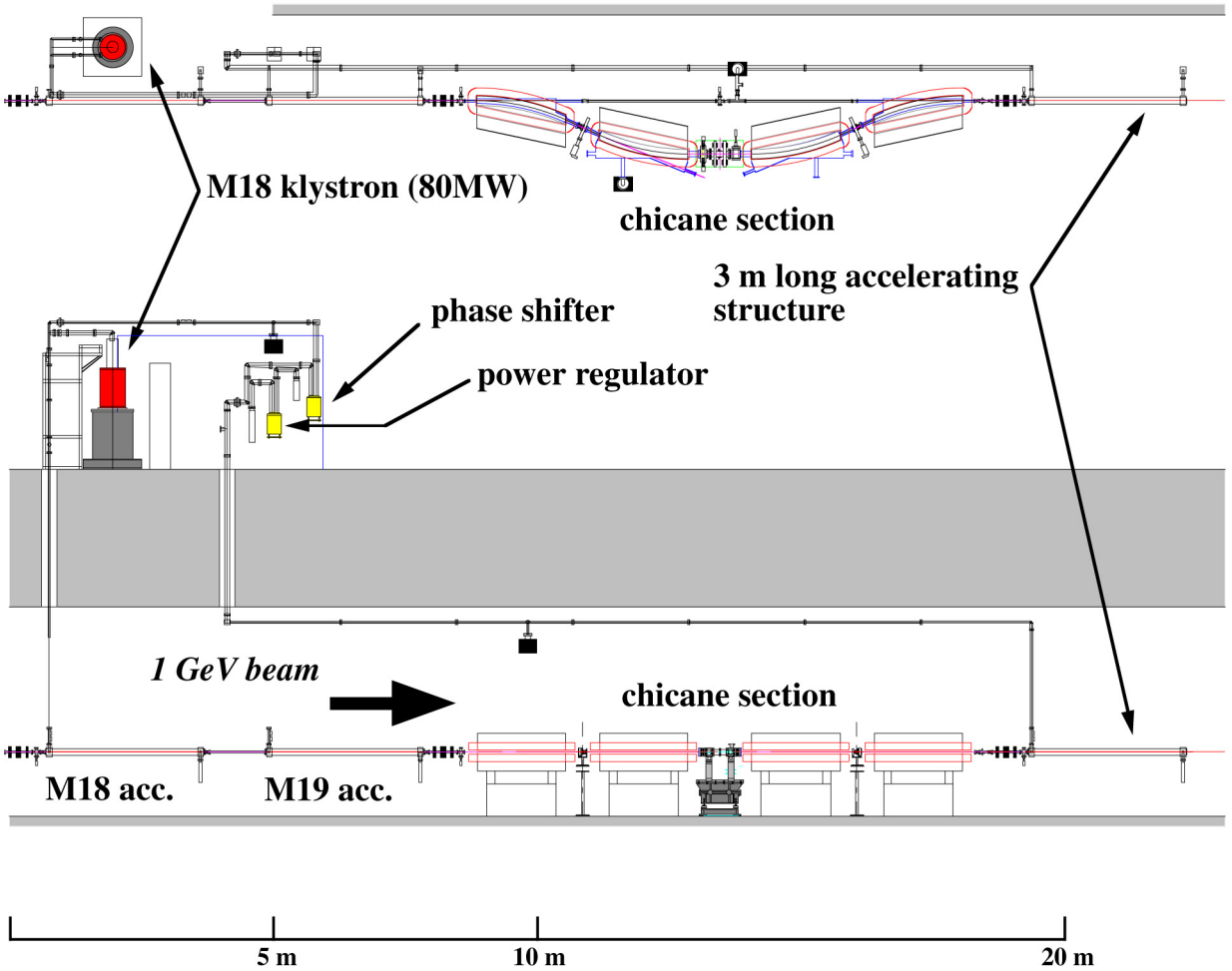


klystron beam voltage : 358.5 kV
voltage fluctuation : 0.03% (1 σ)



Vacc@ECS = 7MV/m

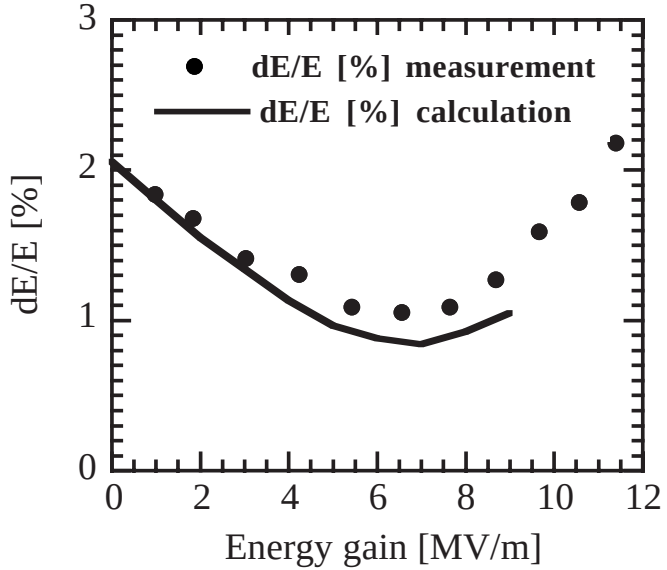
Energy stability -> 0.018%/0.5deg.



Beam test of ECS

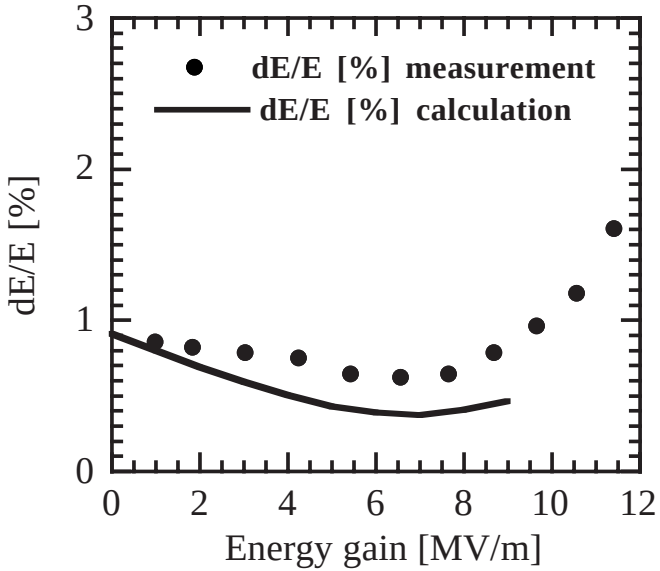
beam pulse width

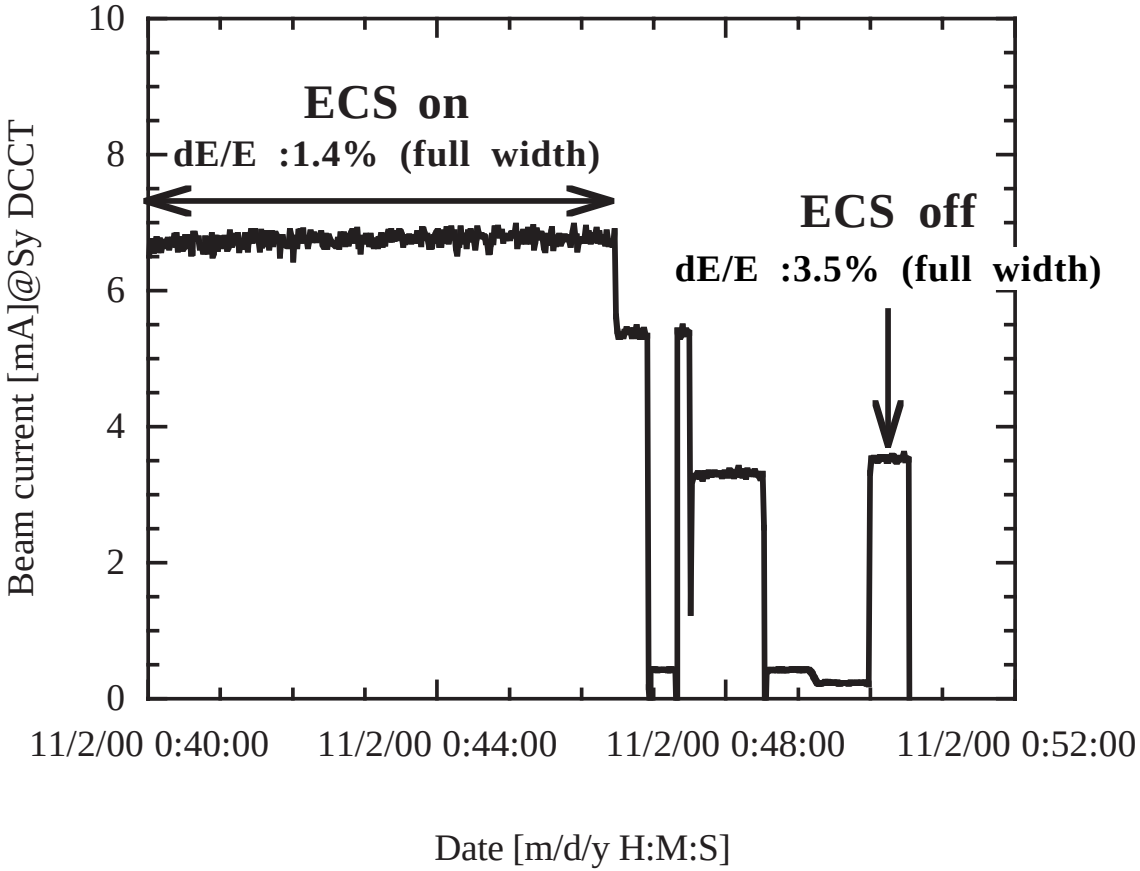
40nsec



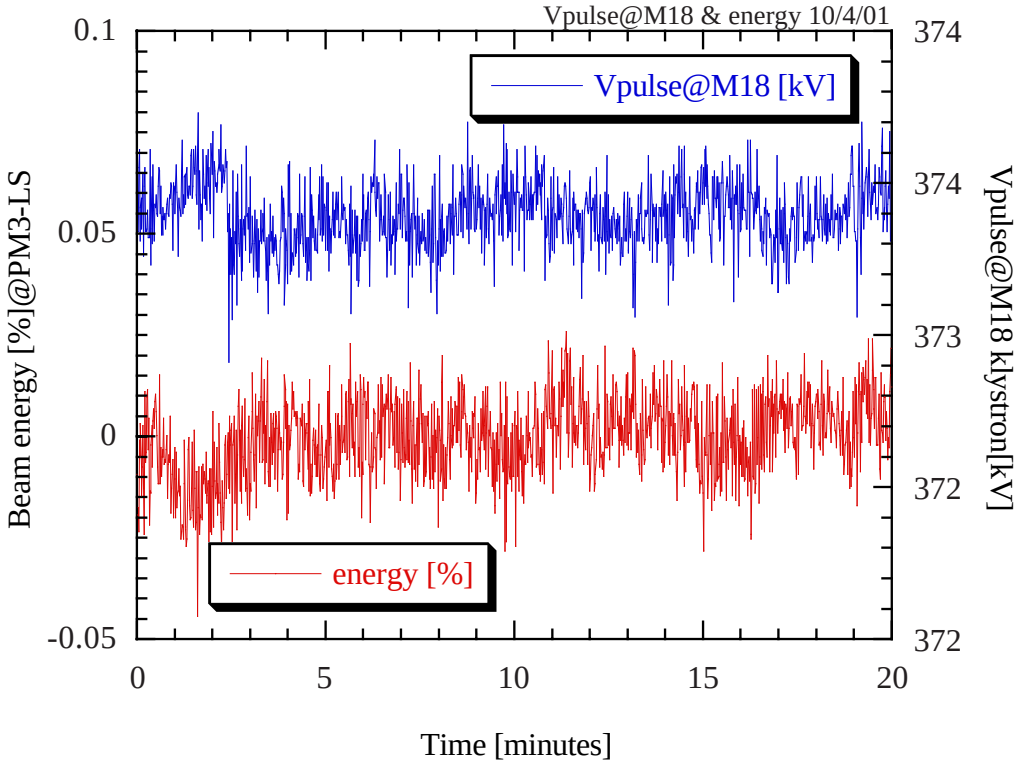
beam pulse width

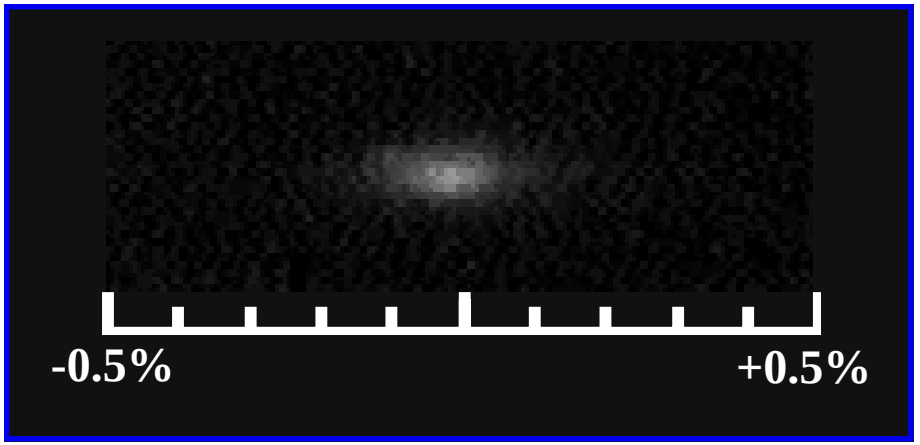
1nsec





Measurement of the beam energy stability



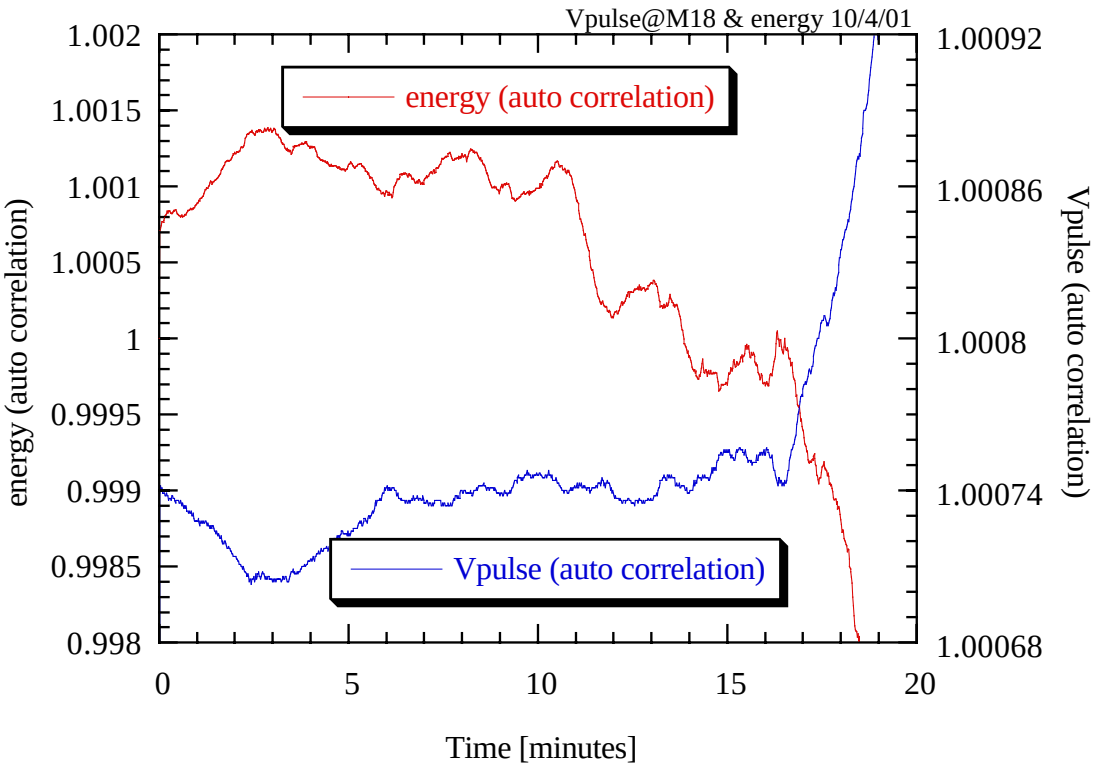


Beam pulse width : 1 nsec

Beam current (peak) : 200 mA

Energy stabilization

: < 0.01% (rms)



Summary

The installation of the ECS were completed in summer of 2000.

As results of rf measurement of ECS, it could operated with the phase stability of 0.5deg. (rms).
The energy stability with ECS reached to 0.01% (rms).

In operation of long time, energy stability improves from 0.06% to 0.01% by using the ECS.

Stability of the energy and energy spread in accelerator facilities

SLC Linac	**0.03% (jitters(rms)), without feedback control [1]**
	1.5% (day - night) [2, 3]
	-> rf amplitude and phase as the source of drift
KEK 8 GeV Linac	**0.1% (jitters(p-p)) [4]**
MIT/Bates 1 GeV Linac	**0.4% -> 0.01% (rms) with feedback control [5]**
SPring - 8 1 GeV Linac	**> 1% -> 0.01% (rms) with ECS**

[1] E. J. Soderstrom, G. S. Abrams, A. J. Weinstein,
in Proceedings of the 1989 Particle Accelerator Conference, Cicago, IL, 1989.

[2] F.J. Decker, R. Akre, M. Byne, Z. D. Farkas, H. Jarvis, K. Jobe,
R. Koontz, M. Mitckell, R. Pennacchi, M. Ross and H. Smith,
in Proceedings of the 1995 Particle Accelerator Conference, Dallas, TX, 1995.

[3] F.J. Decker, R. Akre, R. Assmann, K.L.F. Bane, M.G. Minty, N. Phinney and W.L. Spence,
in Proceedings f the 1997 Particle Accelerator Conference, Vancouver, BC, 1997.

[4] . Enomoto,
in Proceedings of the 2000 European Particle Accelerator Conference, Vienna, Austria, 2000.

[5] D.H. Barkhuff, S.P. Wells, T. Averett, D.H. Beck, E.J. Beise, D. Cheever, G. Dodson, S. Kowalski,
R.D. McKeown, B.A. Mueller, M. Pitt, D. Spayde, C. Tschalaer and A. Zolfaghari,
Nucl. Instr. and Meth. A 450 (2000) 187-193.