STF-LLRF system and its study plan

Shin MICHIZONO (KEK)

Outline

I. STF system configuration
   - S1-Global (~2011 Feb.)
   - Quantum Beam (QB) (2012 Mar. ~)

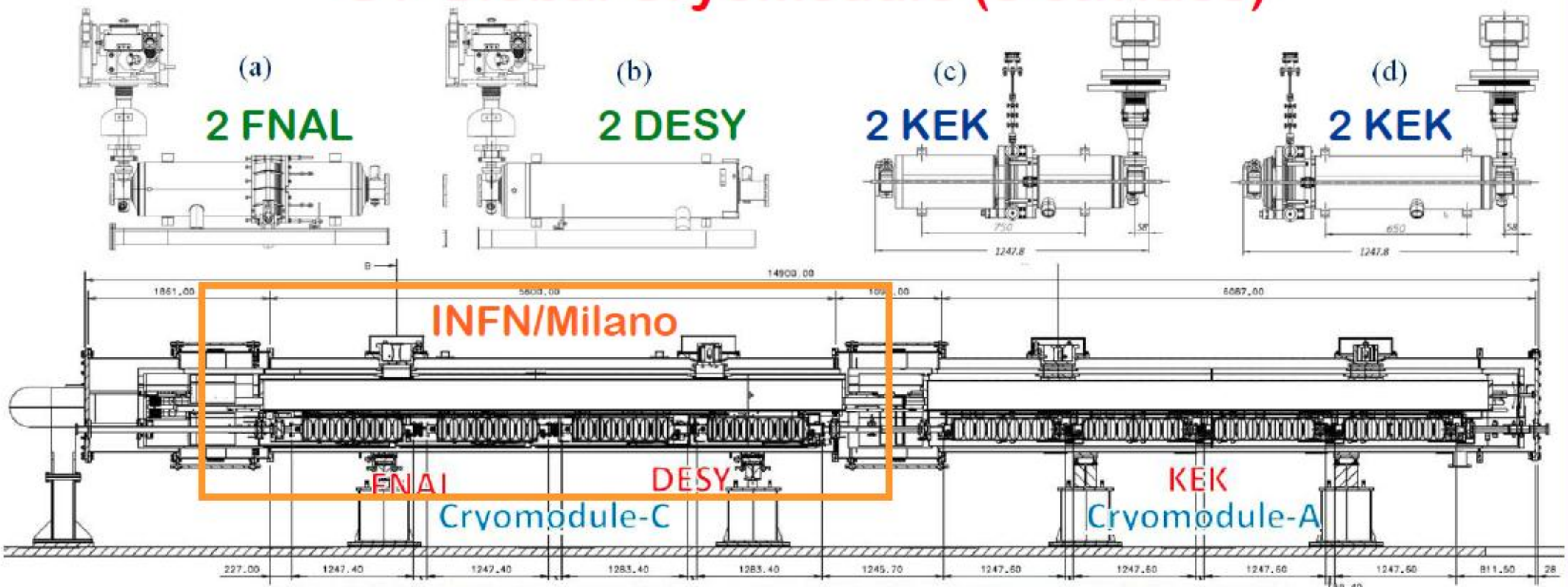
II. Digital feedback system at STF (cPCI, uTCA, IF-Mix)

III. Performance of llrf system upto S1-global

IV. Study plan during QB operation
   - Beam based calibration
   - PkQl control
   - High Ql operation
   - Other items

S1-Global *(2010,2011)*

S1-Global Cryomodule (8 cavities)

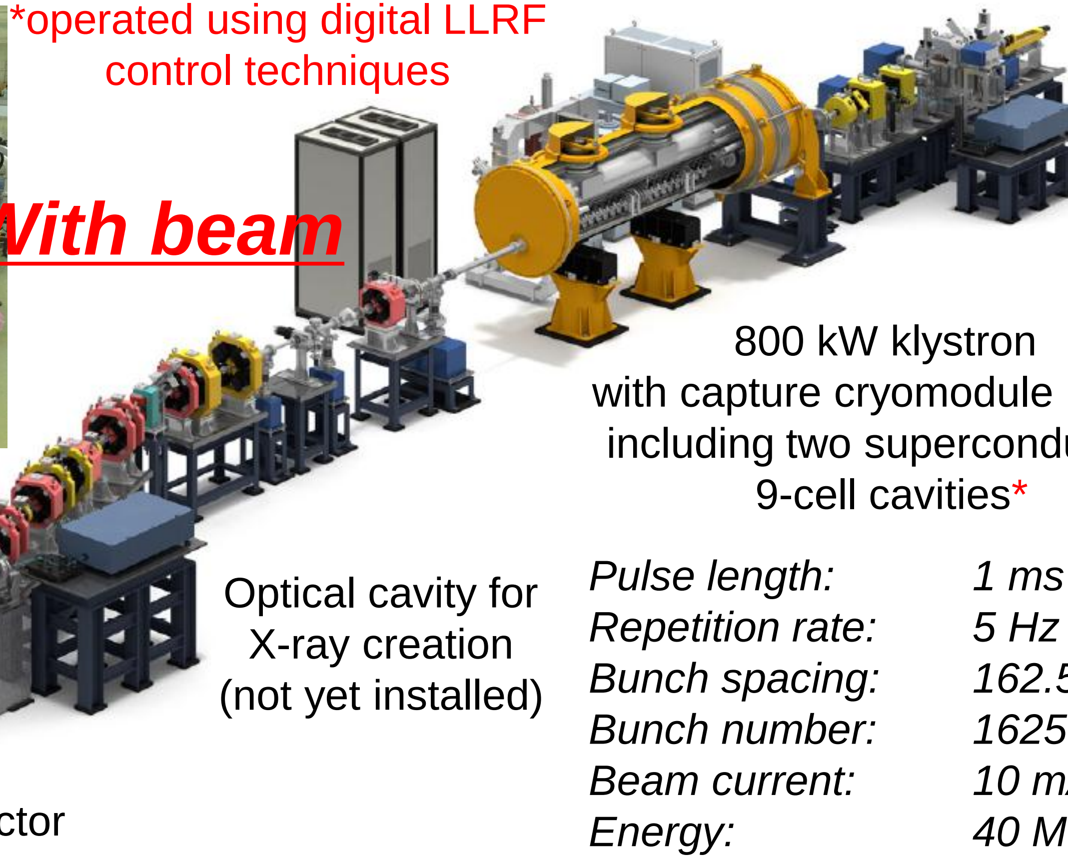


No beam

KEK STF Quantum Beam Project

(2012)

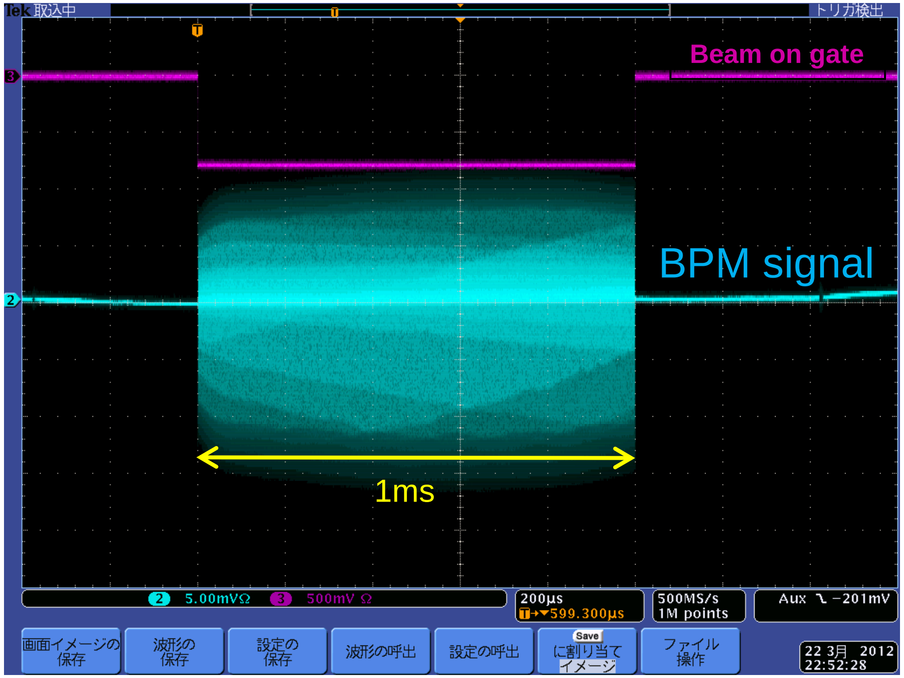
Demonstration of high brightness X-ray generation by inverse laser Compton scattering.



Pulse length:	*1 ms*
Repetition rate:	*5 Hz*
Bunch spacing:	*162.5 MHz*
Bunch number:	*162500*
Beam current:	*10 mA*
Energy:	*40 MeV*
Charge:	*62 pC*

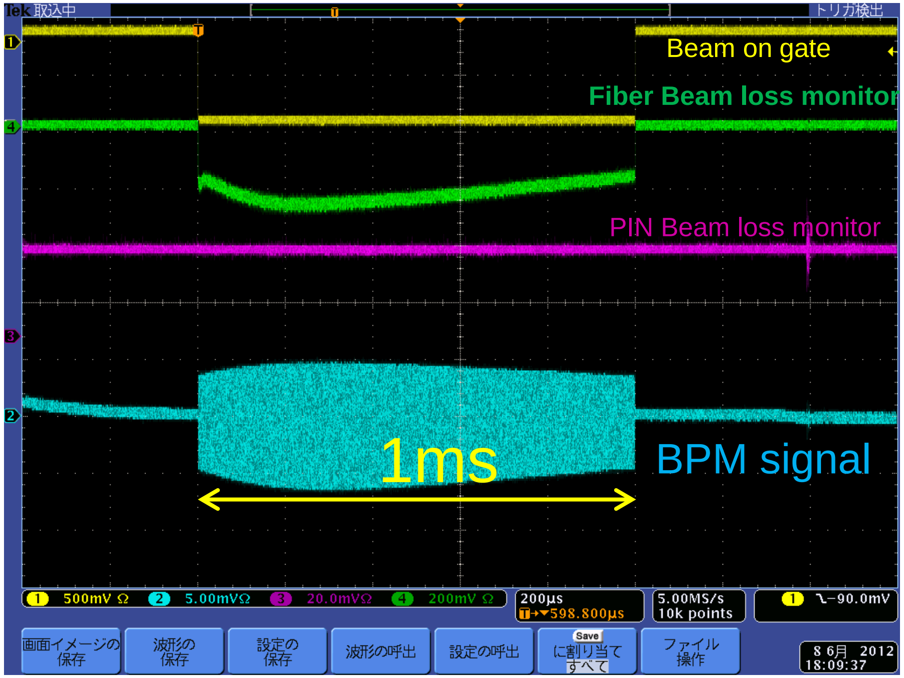
Beam Operation of STF Accelerator

RF Gun



Beam length of 1 ms at RF gun
（March/2012）

Capture cryomodule



Beam acceleration with 20% beam power
(40 MeV, 15 pC/bunch, 162500 bunches)
（June/2012）

⇒ Demonstration of ILC-like beam acceleration
(beam length: 1 ms, beam intensity: 3.2-6.5 mA)

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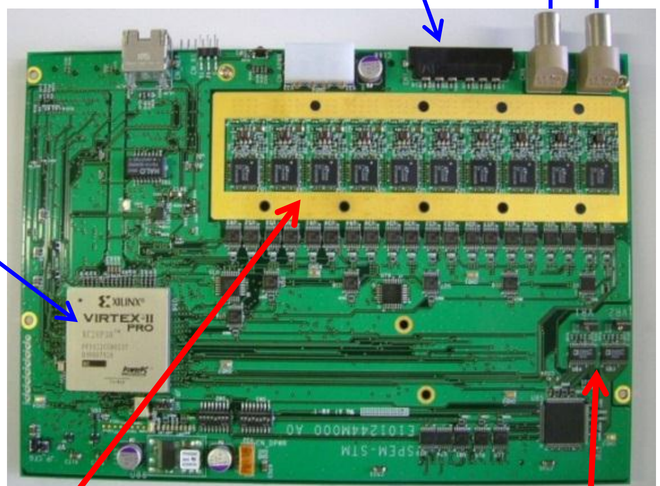
cPCI digital FB system (2007~)

cPCI system has been used from STF-1 (2007~).
FPGA board is a daughter card of a commercial DSP board.

ADC-inputs (Multi-connector)

I,Q DAC outputs

FPGA



10ch 16-bit ADC (LTC2208)

2ch 14-bit DACs (AD9764)

cPCI crate

CPU board

Digital I/O board

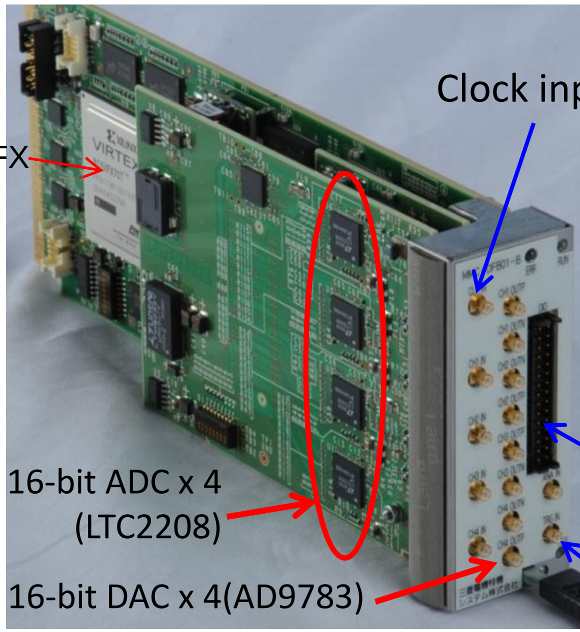
FPGA digital FB board

FB calc. → FPGA

Complex calc. like derivation of Q_L
Data communication
} → DSP

Micro-TCA digital FB system (2011~)

uTCA system is a new system developed for cERL and is used from 2011.
FPGA board is a inteligent EPICS-IOC.



AMC(Advanced Mezzanine Card)

Shelf

Data communication is performed through Gb Ethernet bus at the backplane.

The board has been developed for cERL-project (CW operation) at KEK.

For DRFS, the logic was changed for pulse operation.

EPICS was installed in the digital board for communication control.

EPICS: Experimental Physics and Industrial Control System

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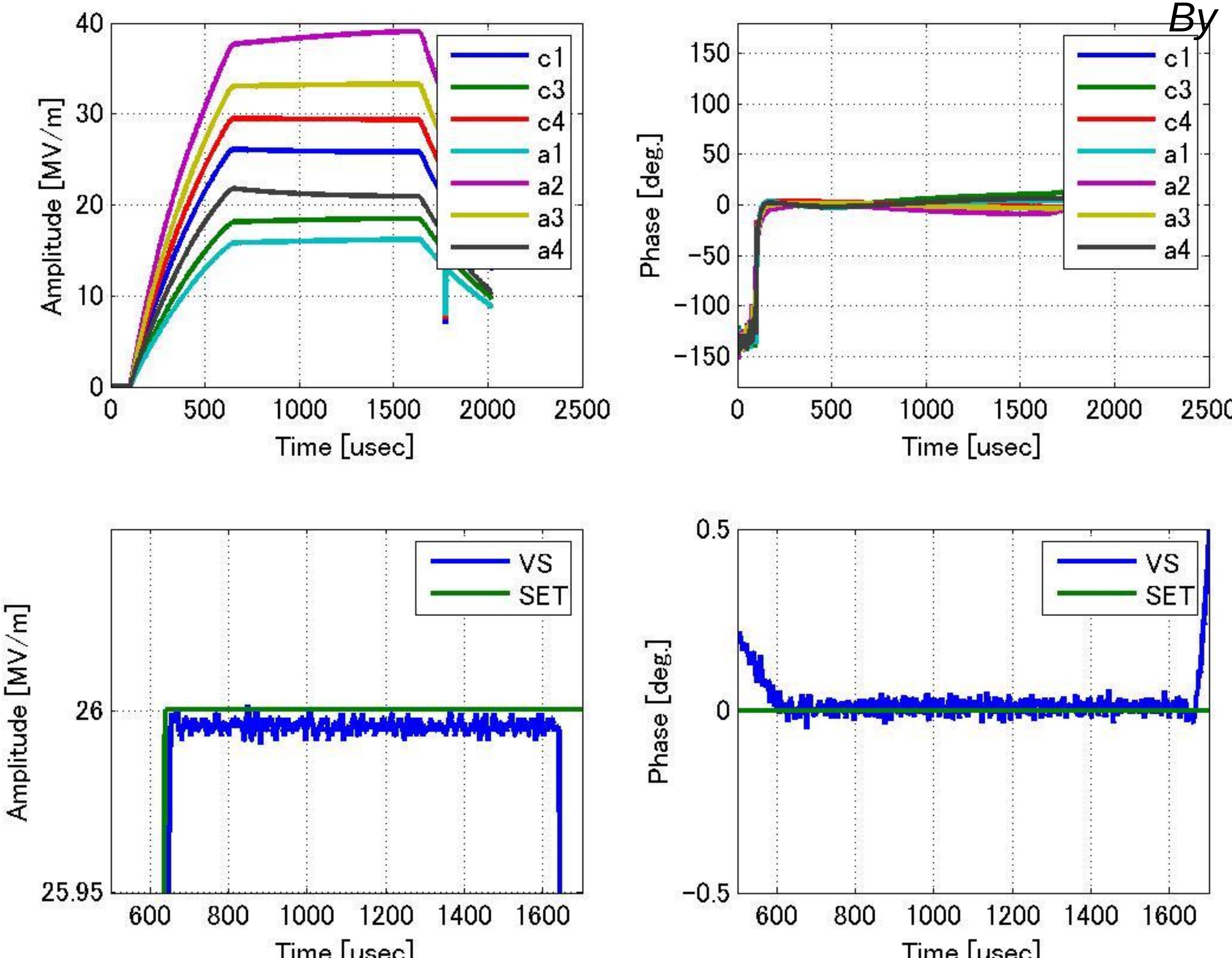
Stabilities at 26 MV/m operation

By T. Matsumoto



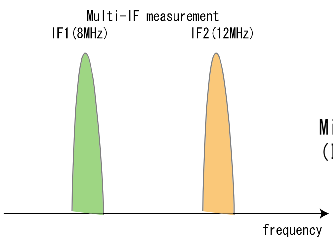
- **0.0067%rms（in amplitude),16.5mdeg.rms(in phase） @690～1590us**

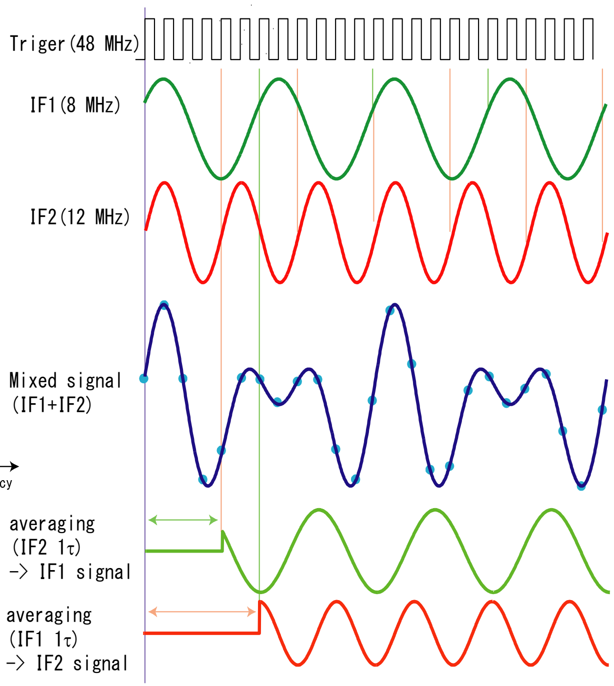
IF mixture

The number of ADCs in a FPGA board is limited due to the substrate. The idea is based on the 'digital radio' and obtaining cavity signals with a ADC.

$$I = \frac{2}{M}\sum_{n=1}^{M} x_i(n)\cdot\cos(\frac{2\pi\cdot N}{M}\cdot n)$$

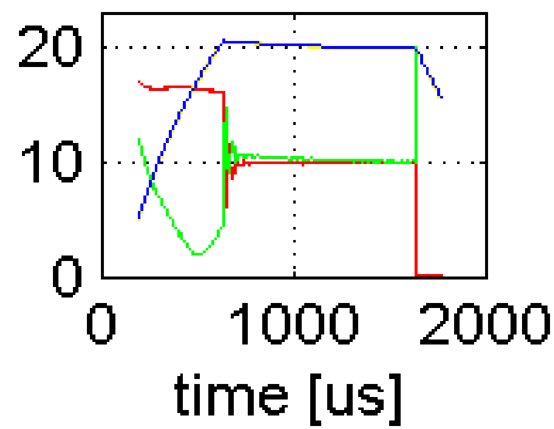
$$Q = \frac{2}{M}\sum_{n=1}^{M} x_i(n)\cdot\sin(\frac{2\pi\cdot N}{M}\cdot n)$$





Mixture of two signals decrease the resolution of analog signals but averaging increases the resolution.

Example of 3 signal IF-mix



Vector sum stabilities

⊿A/A : 7 × 10^-4(rms)

⊿φ : 0.06deg.(rms)

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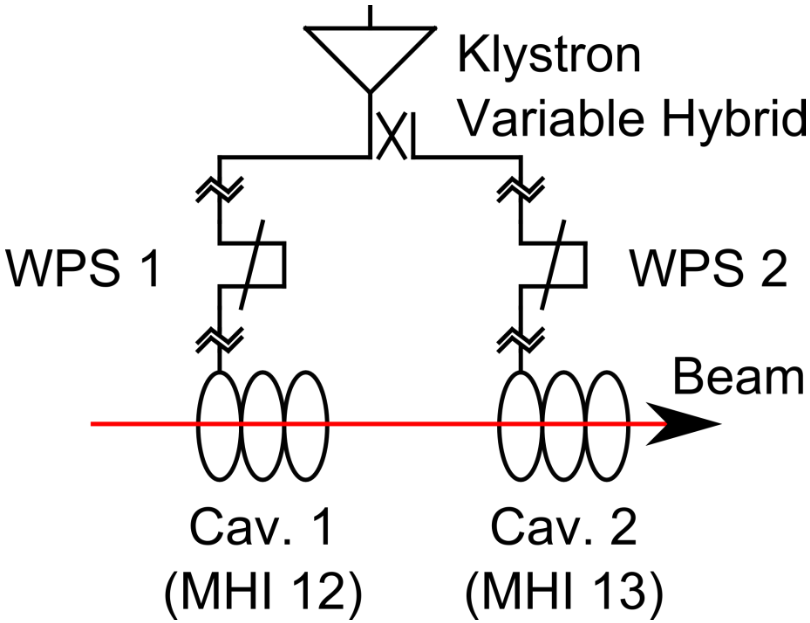
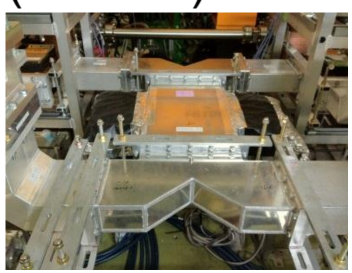
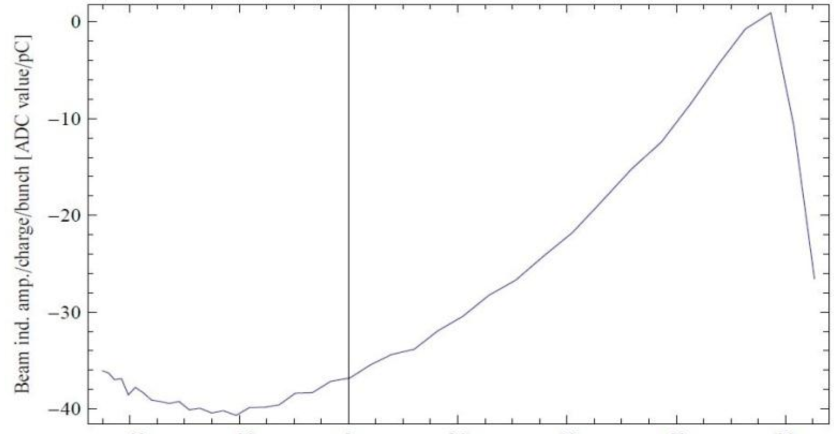
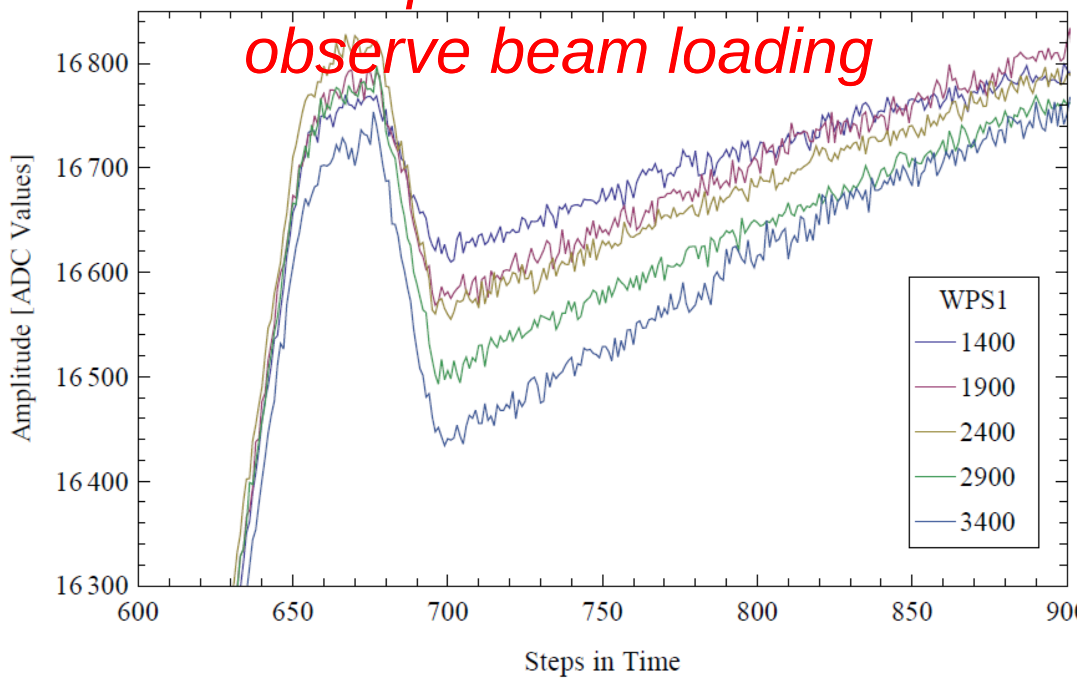
Beam based calibration







Scan phase shifter and observe beam loading



PkQl control

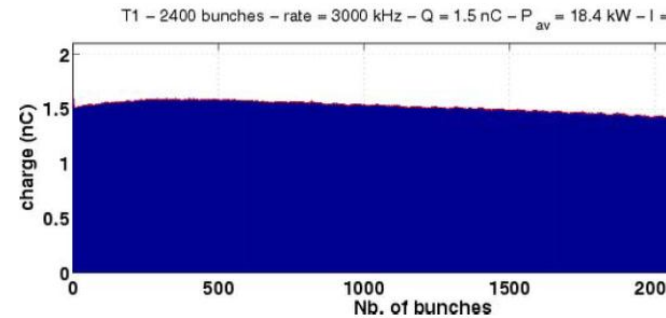
- In case of the Pk-Ql control near the quench limit condition, the values of Pks and Qls are calculated as followings.

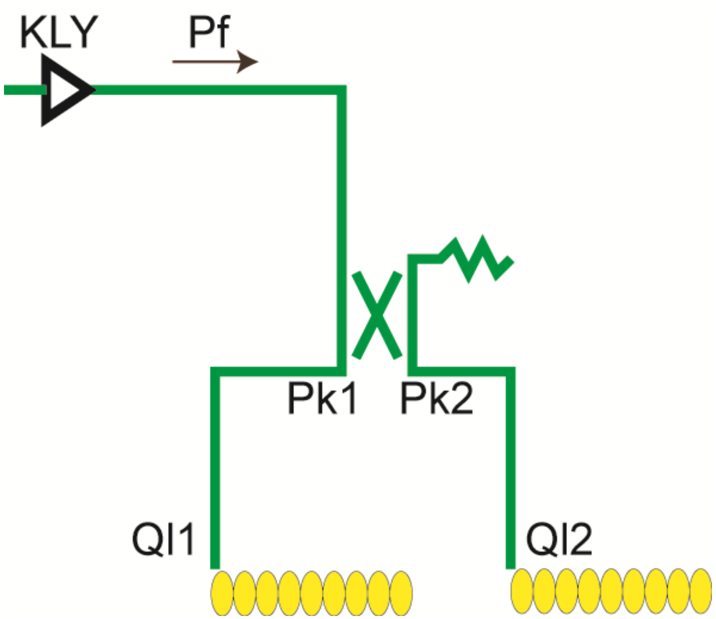
1. Select operational gradient of each cavity (Vcav)
2. Find out the Pk and Ql of each cavity under the specific beam current (Ibeam) and injection timing (Tinj).

$$\mathrm{Igen} = \mathrm{Ibeam} \cdot \exp\left(\frac{T_{inj}}{\tau}\right)$$

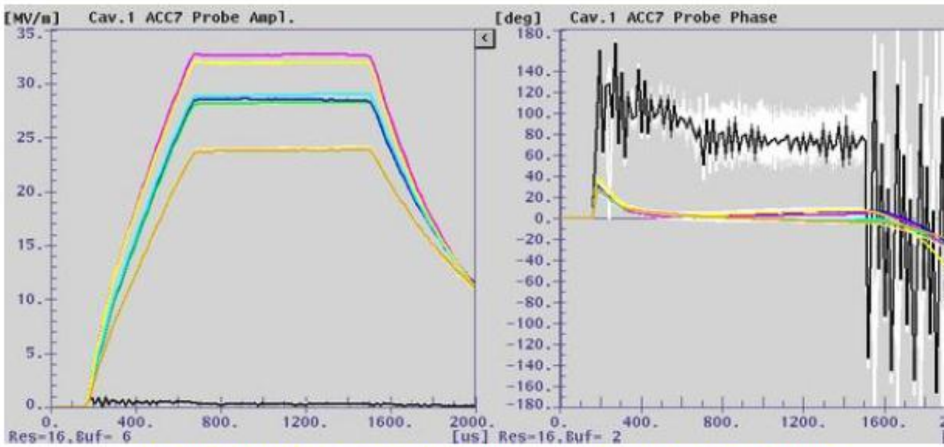
$$V_{cav} = \frac{r}{Q} Q_L \, \mathrm{Igen} \cdot \left(1 - \exp\left(-\frac{T_{inj}}{\tau}\right)\right)$$

$$\mathrm{Pk} = \frac{1}{4}\frac{r}{Q} Q_L (\mathrm{Igen})^2$$





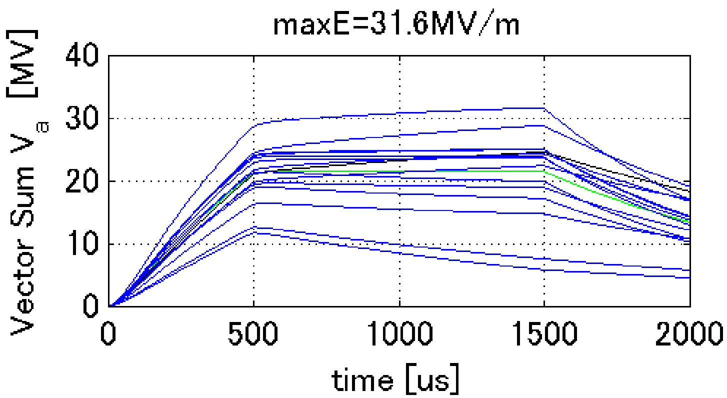
PkQl control at FLASH

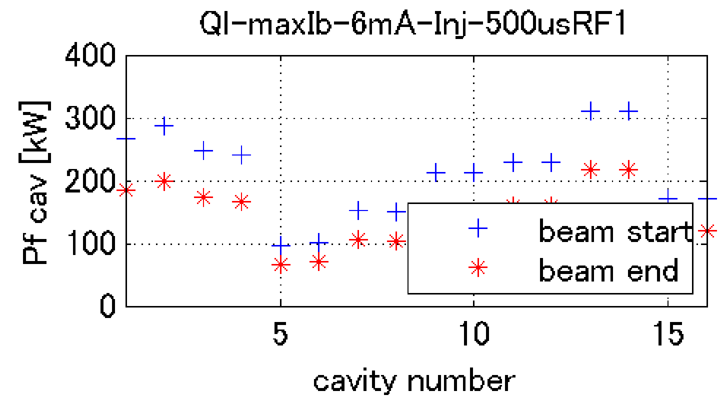


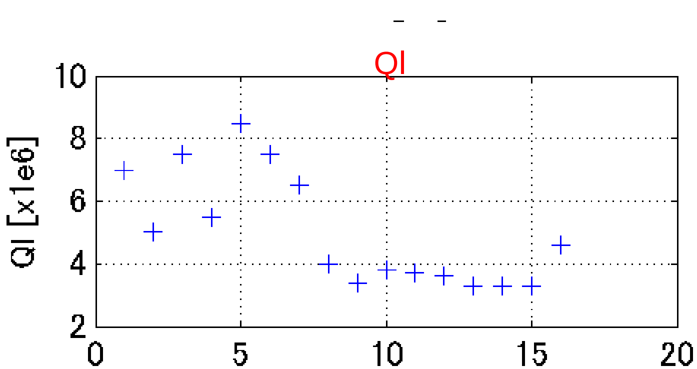
File: http://ttfinfo.desy.de/TTFelog/data/2012/08/26.02_a/2012-02-26T21:48:54-00.JPG

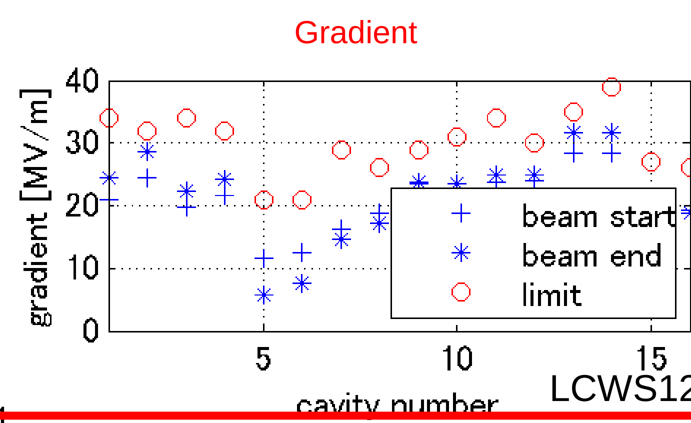
High Ql operation

- ilc operation requires high Q operation (Ql 6e6~1e7)
- It is difficult to examine at FLASH because of the limitation of Qls (some of them are max. 3e6) and fixed Pks.
- In KEK, we can change Qls ~1e7 and variable Pks.
- PkQl control at high Qls will be possible (same to ilc spec.)



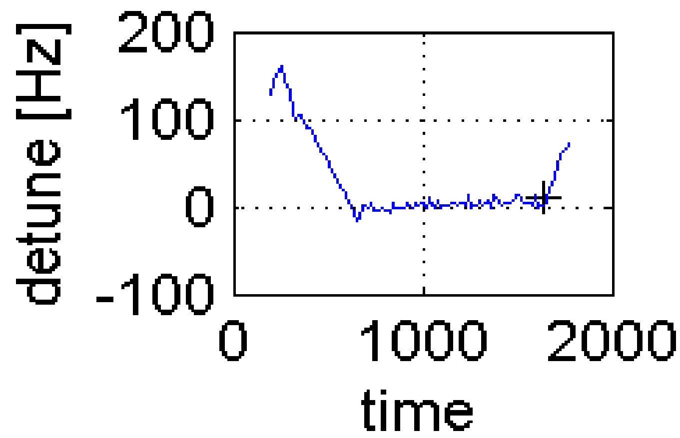




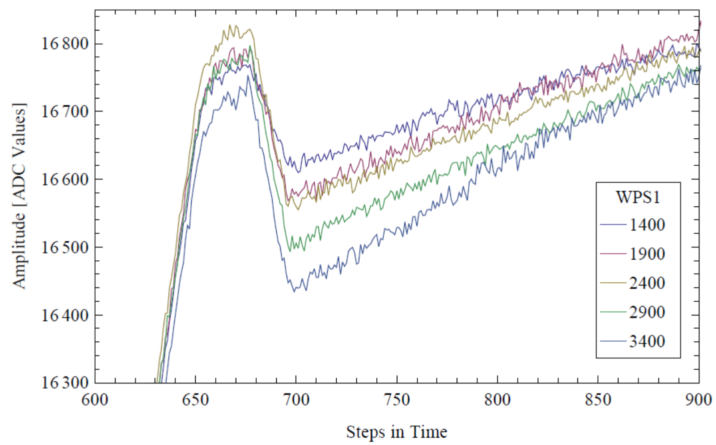


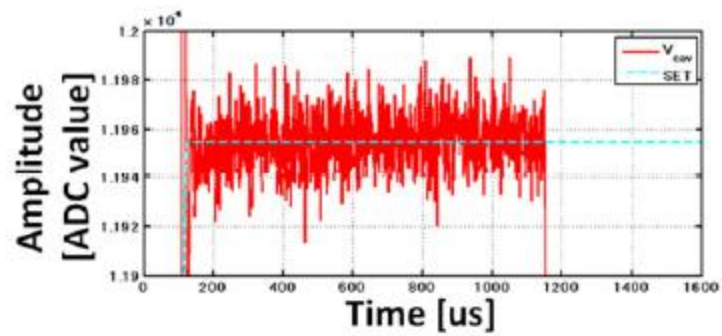
Other itmes (off-line studies)

- Detuning monitor with beam



- Beam based rf correction





- RF gun pick-up calibration (directivity compensation)

$$\begin{pmatrix} U_{\text{for}} \\ U_{\text{ref}} \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} U^*_{\text{for}} \\ U^*_{\text{ref}} \end{pmatrix} , \qquad (2)$$

where U^*_{for} and U^*_{ref} are measured values. It was shown that the cross talk is negligible small so that b and c can be considered as zero. There with equation (2) can be rewritten as

$$\begin{pmatrix} U_{\text{for}} \\ U_{\text{ref}} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & d/a \end{pmatrix} \begin{pmatrix} U^*_{\text{for}} \\ U^*_{\text{ref}} \end{pmatrix} . \qquad (3)$$