Fast Ion Instability (Feedback)
Electron Cloud Instability in ILC damping ring

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Present ILC DR lattice design

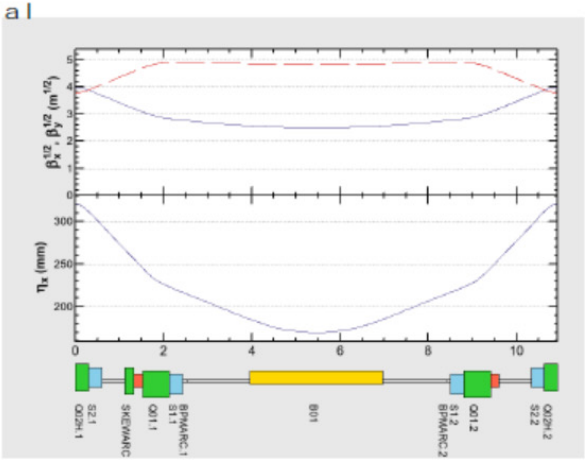
presented by K. Kubo at AWLC2017

Bending magnet was lengthen
with same TDR DR lattice.

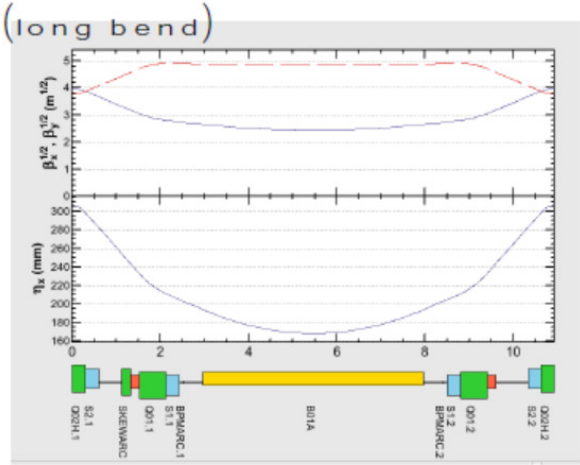
	Original	New (long bend)
Horizontal normalized Emittance (um)	5.74, 6.27 (IBS)	3.14, 3.97 (IBS)
Tune x/y	48.26/26.76	49.33/26.86
phase adv./cell /2pi x/y	0.21891 /0.08098	0.2250 /0.0808
Damping time x/y/z (ms)	23.9/23.9/11.9	25.5/25.5/12.8

Optics of Arc Cell

Original



New (long bend)

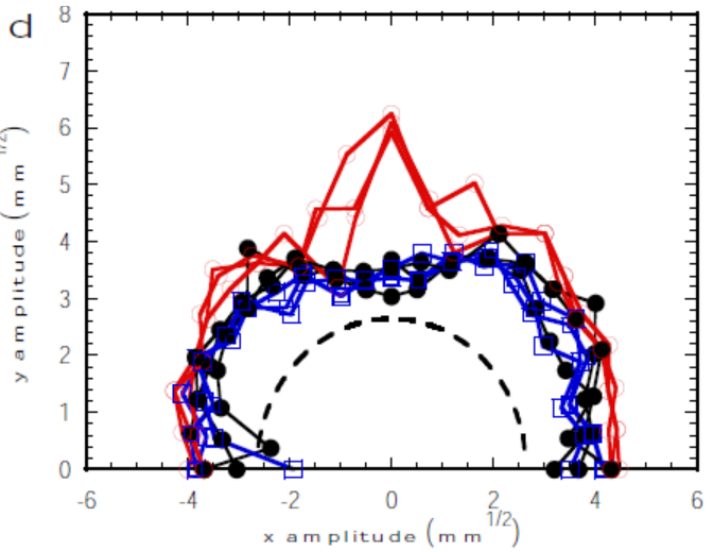


Dynamic aperture: long bend

Misalignment + correction

New arc cell: long (5 m) bend
tune/cell: x.225 y.0808
Tune: x49.33 y26.86

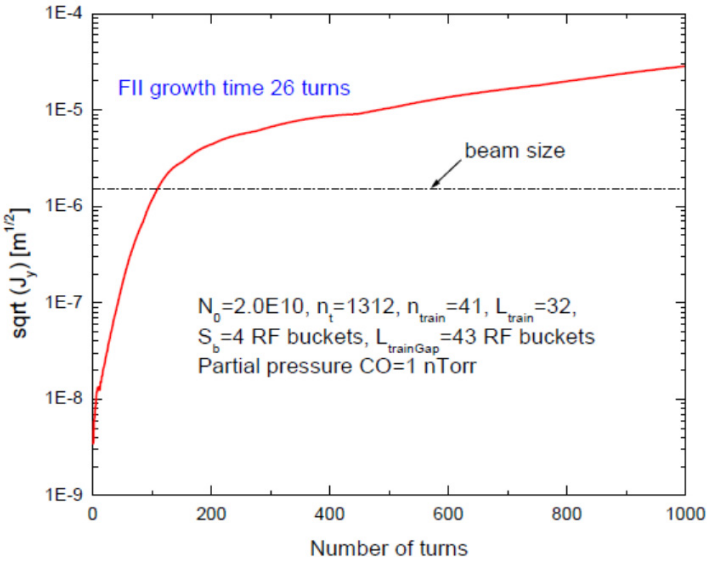
Quadrupole & sextupole offset: 50 um
Quadrupole roll: 100 urad
BPM offset: 100 um
BPM roll: 10 mrad
COD & Dispersion correction



Dynamic range of the feedback for FII

(TDR notation)

- ✓ *The dynamic range of the order of 90dB*
- ✓ *To minimize the quantization noise,*
  14-16 bit signal processing system



(Private discussion with Makoto Tobiyama)

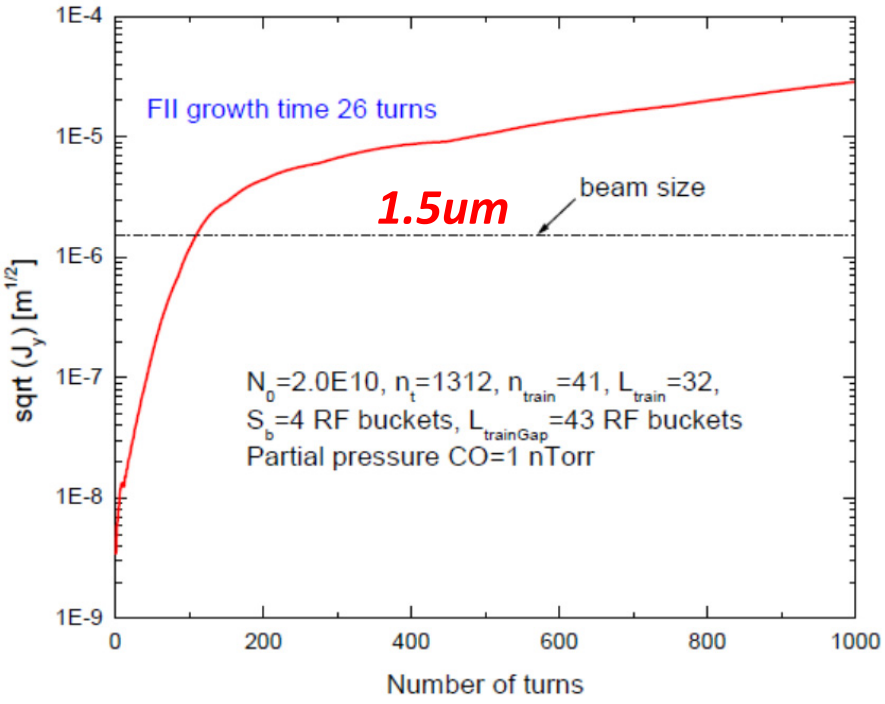
Dynamic range of the processing system

- ✓ *KEKB used 8 bit processing system.*
- ✓ *SuperKEKB upgraded to 12 bit processing system.*
- ✓ *There are 14-16 bit processing system in the world,*
  but the frequency of the processing is fixed (That for SuperKEKB is flexible up to 1GHz),
  and the processing time will be slower.
- ✓ *When we will use 14-16 bit processing system, we must develop the system.*

Do we need the 14-16 bit processing system from KEKB, SuperKEKB experience ?

- ✓ *Since the center offset is subtracted by analog circuit for the FB,*
  the dynamic range is enough only for the amplitude of the beam oscillation.
- ✓ *Since the amplitude is nonlinear, and the growth time is large for the large amplitude,*
  the 8-bit processor is basically enough for SuperKEKB, too.
- ✓ *However, the upgrade from 8 bit to 12 bit was very helpful for SuperKEKB.*
  Since the COD and the injection position are sometimes changed,
  they must tune the analog parameters for 8 bit system (12 bit is not).
- ✓ *It seems enough for the usual machine for 12 bit processing system.*

FII growth time evaluation in ILC TDR



◆ Simulation 1

- ✓ Vacuum : 1×10^{-7} Pa with CO
- ✓ Filling pattern was a little bit different with ILC DR
- ✓ Evaluated growth time : **26 turn**

◆ Simulation 2

- ✓ Vacuum : 0.5×10^{-7} Pa (based on SPEAR3)
  (48% H_2, 5% CH_4, 16% H_2O, 14% CO, 17% CO_2)
- ✓ Evaluated growth time : 56 and 84 tune
  37 turn for high luminosity

(Private discussion with Kyo Shibata)

- ✓ 0.5×10^{-7} Pa is too low for I=0.4A storage ring
- ✓ Vacuum composition seems different for NEG pump.

- ➢ *The growth time of the FII is strongly depends on the beam size.*
- ➢ *The FII instability was evaluated to*
  - ✓ *sigmaY = 1.5 um*
  - ✓ *6 um @ minimum at arc section*
  - ✓ *5.5um assumed for Electron Cloud Instability .*
- ➢ *Is the evaluation of the growth time reasonable ??*

We should carefully reevaluate the growth time of FII.

Damping time of the feedback system

- ***KEKB***
  - ✓ *TDR description : 20 turns (the performance of the gain)*
  - ✓ *Nominal operation gain : 100 turns*
- ✓ ***SuperKEKB***
  - ✓ *Nominal operation gain : 100 turns*
  - ✓ *In the SuperKEKB, 100 turns is enough to dump not only FII, but also beam-beam effect.*
  - ✓ *Champion data : 50 turns*
  - ✓ *Actual performance is much better,*

    but the performance was not yet evaluated the data sampling system.

The problem is in the damping time of the FB,
when the TDR description was correct.

What we should do in the ILC preparatory phase

Fast Ion Instability

Simulation of FII

- ✓ *The simulation should be included the appropriate vacuum pressure and composition.*
- ✓ *The simulation should be included the appropriate DR filling pattern.*
- ✓ *The simulation should be included the appropriate beam size.*

➢ ***Do we need the simulation study in the ILC preparatory phase ?***

➢ ***If YES,***

- ✓ *Which institute will it be able to do (potential) ?*

- ✓ *How much cost will it need (except for the human resource) ?*
  - *Non (only simulation work) ??*

- ✓ *How many human resource will it need ?*

What we should do in the ILC preparatory phase

DR orbit feedback system

Dynamic range evaluation of FB system

- ***Do we need the development of the processor system with higher precision.***
- ***If YES,***
  - ✓ *Which institute will it be able to do (potential) ?*
  - ✓ *How much cost will it need (except for the human resource) ?*
  - ✓ *How many human resource will it need ?*
- ***If NO,***

  We need to have scientific documentation that the processor used by SuperKEKB is sufficient.
  - ✓ *Which institute will it be able to do (potential) ?* ***KEK***
  - ✓ *How much cost will it need (except for the human resource) ?* ***Non***
  - ✓ *How many human resource will it need ?* ***0.1-0.2 FTE ?***

What we should do in the ILC preparatory phase

DR orbit feedback system

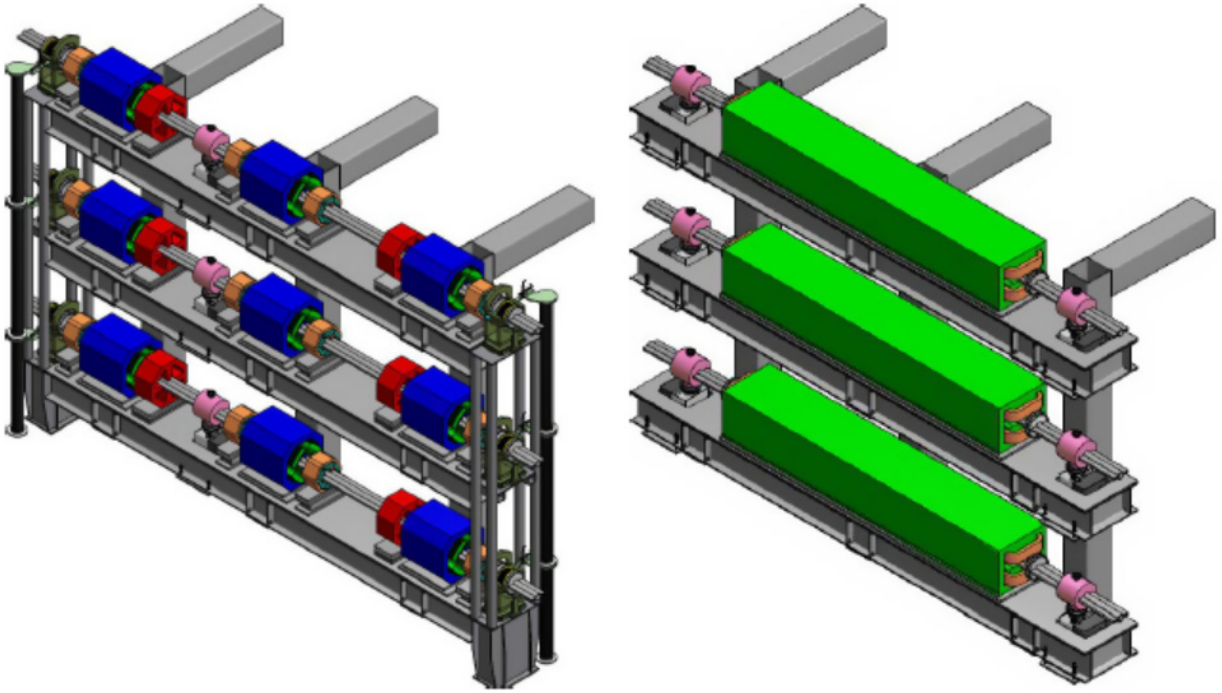
Damping time evaluation of FB system

- ***Do we need the evaluation of the damping time of the feedback system ?***
  - ✓ *It depends on the evaluation of the fast ion instability (simulation).*
  - ✓ *Is the damping time test for SuperKEKB system is enough ?*
  - ✓ *The damping time of FB system is done as FII reduction by changing vacuum pressure.*
- ***If YES,***
  - ✓ *Which institute will it be able to do (potential) ?*
    DAΦNE (Frascatii)
  - ✓ *How much cost will it need (except for the human resource) ?*
    - *The cost of the SuperKEKB FB system*
      - *Monitor chamber : 30 kUSD*
      - *FB kicker chamber : 40 kUSD*
      - *Cable : 50 kUSD*
      - *BPM circuits (2) : 60 kUSD*
      - *FB digital filter (2) : 100 kUSD*
      - *Amplifier (4) : 130 kUSD*
      - ***Total : 410 kUSD***
    - *Other ..*
  - ✓ *How many human resource will it need ?*
    - ???

Electron Cloud Instability

6.4.4.3 EC Instability

The above estimates of cloud density place an upper limit on the ring-averaged density of about $4 \times 10^{10}\mathrm{m}^{-3}$, about a factor of three below the expected single bunch instability threshold [110]. Thus operation in the baseline configuration is expected to have negligible emittance dilution from the EC. This operating margin should also minimize the possibility of any adverse impacts from sub-threshold emittance growth on the positron beam. For the high-luminosity upgrade, a second positron ring may be added if insufficient operating margin remains with a single ring.



2nd Positron DR
(only the space prepared for high luminosity upgrade)

Electron DR

Positron DR

Chamber design of ILC is same to that for SuperKEKB, except for the aperture

- ✓ *Evaluated SEY is also same*
- ✓ *SuperKEKB is very good sample accelerator for ILC DR.*

Figure 6.10
(a) Wiggler vacuum chamber with clearing electrode and 20 mm tall antechambers with recessed NEG strips. (b) Wiggler section photon stop showing sloping and grooved photon-absorbing walls [116].

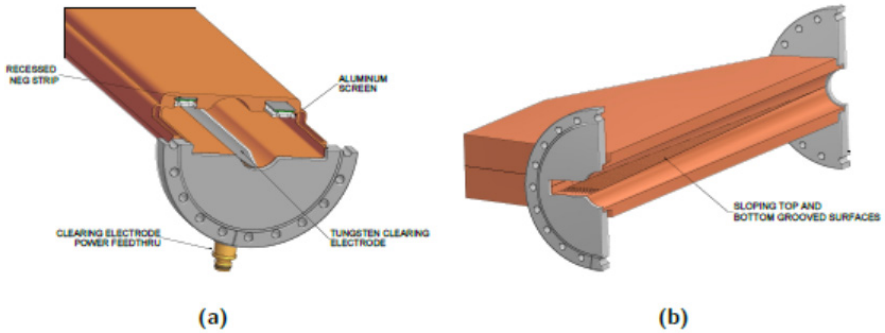
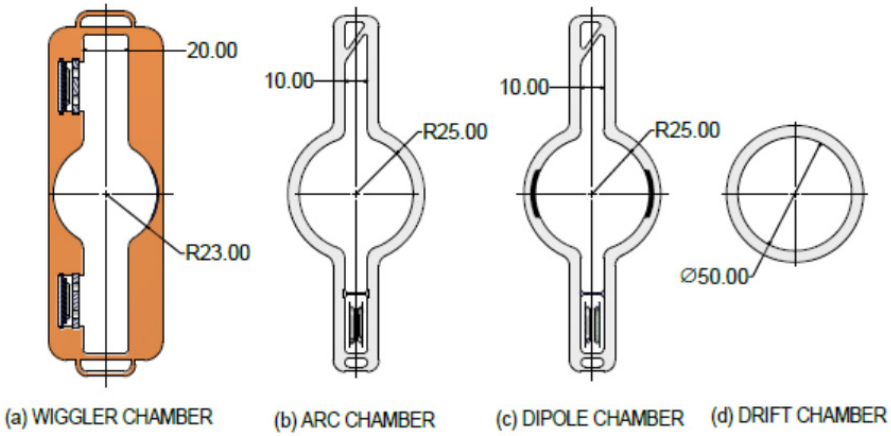


Figure 6.11
Side-by-side comparison of ILC DR vacuum chamber profiles. Dimensions are in millimeters [116].

(TDR)



- ➢ *They experience a fast ion instability at their 1st stage of commissioning at 1A beam current.*
  - ⇒ *They cured the problem*
    - ✓ *by covering the solenoid magnets to the bellows chambers.*
    - ✓ *by putting the permanent magnets to the straight pipes.*
  - ⇒ *After that, they have not had the fast ion instability.*
    (but current was 0.9A for collision experiment)
- ➢ *It seems good agreement with the evaluation and experiment.* ***(No problem for ILC, too ??)***

What we should do in the ILC preparatory phase

Electron Cloud Instability

Detail simulation, include the high luminosity upgrade.

- ✓ *The simulation for nominal parameter for the present ILC DR design.*
- ✓ *The simulation for high luminosity option.*
  - $\Rightarrow$ *Possibility to remove 2nd DR.*

- ➢ Do we need the simulation study in the ILC preparatory phase ?

- ➢ If YES,
  - ✓ Which institute will it be able to do (potential) ?
  - ✓ How much cost will it need (except for the human resource) ?
    - Non (only simulation work) ??
  - ✓ How many human resource will it need ?