Fast ion instability WP 15

Junji Urakawa (for collaborators)

KEK

Nov. 6 2007

at CI

The following work packages are proposed for the damping rings engineering design phase:

WP#	WP Title	Proposed WP Leader
1	Lattice design and acceptance	Louis Emery
2	Orbit, optics and coupling correction	David Rubin
3	Wiggler	Mark Palmer
4	Instrumentation, diagnostics, controls	Manfred Wendt/Margaret Votava
5	Impedance & impedance-driven instabs.	Gennady Stupakov/Cho Ng
6	Fast feedback systems	John Fox
7	Electron cloud	Mauro Pivi
8	Power systems	Paul Bellomo
9	Other collective effects	Marco Venturini
10	650 MHz RF system	Derun Li
11	Magnets and supports	Steve Marks
12	Systems integration and availability	Andy Wolski
13	Vacuum system	Oleg Malyshev
14	Injection and extraction systems	Susanna Guiducci
15	Ion effects	Junji Urakawa
16	Conventional facilities and cryogenics	Tom Lackowski/Alan Jackson

WP15

15 Institutions Returned DR EOI's

WP Title	ANL	Cornell	FNAL	SLAC	LBNL	LANL	LLNL	UIUC	UM	CI	DESY	LNF	KEK	IHEP	KNU	Approx Total FTE
Lattice design and acceptance	X	X			X				X			X		X	X	2.6
Orbit, optics and coupling correction	X	X		X	X				X	X		X	X			7.9
Wiggler		X			X											1.9
Instrumentation, diagnostics, controls		X	X		X								X	X		6.9
Impedance & impedance-driven instabs.	X			X	X					X			X	X		3.0
Fast feedback systems				X	X							X				1.5
Electron cloud	X	X	X	X	X	X						X		X	X	8.5
Power systems		X		X												0.3
Other collective effects		X	X	X	X							X		X		1.8
650 MHz RF system		X		X	X											1.2
Magnets and supports					X									X		0.2
Systems integration and availability										X						0.2
Vacuum system				X	X					X		X		X		3.1
Injection and extraction systems		X	X	X	X		X	X				X	X			7.6
Ion effects		X		X	X						X		X	X	X	4.7 4.7FTE
Conventional facilities and cryogenics	X		X		X									X		0.2
Global Systems Work Packages																
Survey and alignment	X															0.3
Installation and commissioning plans	X															0.3
Polarisation										X	X					0.3
Approximate Total FTE																52.1

Work Package Manager

Managing the Interfaces will be Critical

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lattice design and acceptance	1		op	ip		op	op	op		op	ip	io	io	op	io	op	op
Orbit, optics and coupling correction	2	ip			io							io	io				
Damping wiggler design	3	op						io	op				io	io			op
Instrumentation, diagnostics and controls	4		io										io	io			
Impedance and impedance-driven instabilities	5	ip					op				ip			ip	ip		
Fast Instability Control Feedback	6	ip				ip					ip			ip	ip		
Electron cloud	7	ip		io										io			
Power systems	8			ip								io	io				op
Other collective effects	9	ip															
650 MHz SRF cavity design	10	op				op	op						io				op
Magnets and supports	11	io	io						io				io	io	io		op
Systems integration and availability	12	io	io	io	io				io		io	io		io	io		io
Vacuum system	13	ip		io	io	op	op	io				io	io		io	io	op
Injection and extraction systems	14	io				op	op					io	io	io			
Ion effects	15	ip					io							io			
Conventional facilities and cryogenics	16	ip		ip					ip		ip	ip	io	ip			

ip: requires input from
op: provides output for
io: requires input from and provides output for

In an ideal world, the inputs and outputs are so clearly defined that the necessary exchange of information happens with complete reliability by direct communication between Work Package Managers, without any need for (intervention by) the Area System Manager.

Potential Investigators for WP15

CERN
Warner Bruns
Daniel Schulte
Frank Zimmermann
Cornell
Jim Crittenden
Mark Palmer
DESY
Eckhard Elsen
Guoxing Xia

LBNL
John Byrd
Christine Celata
Stefano de Santis
Marco Venturini
SLAC
Mauro Pivi
Lanfa Wang
KEK
Nobuhiro Terenuma
(Takashi Naito)
(Yosuke Honda)
(Hiroshi Sakai)
Junji Urakawa

Summary of Required Resources Objectives

S3 WBS	Objective	Priority
2.2.4.1	Characterize ion effects	Very High
2.2.4.2	Specify techniques for suppressing ion effects	Very High

Staff Effort (FTE; excludes operational support for Facilities)

S3 WBS	2007	2008	2009	2010
2.2.4.1 and 2.2.4.2	6.0	4.0	4.0	

M&S (US$k; excludes operating costs for Facilities)

S3 WBS	2007	2008	2009	2010
2.2.4.1 and 2.2.4.2	200?	20	20	

Travel (US$k)

Travel costs are estimated at the rate of US$10k per FTE-year.

S3 WBS	2007	2008	2009	2010
2.2.4.1 and 2.2.4.2	60	40	40	

Facilities

Experimental data from several machines (including CesrTA, KEK-ATF, ALS) will be needed for proper completion of all the Objectives.

The ultimate goal is to ensure that the design (including specification of feedback system, vacuum levels, and bunch train patterns) is such that the damping rings will be capable of delivering a beam with the required quality.

Achieving the Objectives will involve the following tasks:

1. Validate existing theoretical models and simulation tools for the fast ion instability by carrying out suitable measurements in available storage rings.
2. Refine existing simulation tools beyond their current state or develop new tools if necessary to achieve acceptable agreement with the experiments.
3. Demonstrate the existence of viable machine designs capable of meeting the specifications for beam quality and stability, and show experimental feasibility of these designs using existing machines if possible.
4. Explore the effectiveness of a variety of mitigation techniques (such as clearing electrodes), if necessary.

The main deliverables will be:

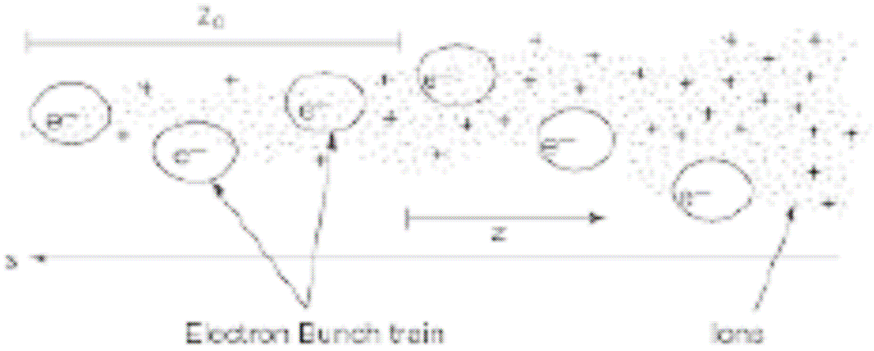
Experimental validation of theoretical models and simulation tools for the fast ion instability.

Indication of machine design parameters (including bunch filling patterns, lattice optics, feedback and vacuum specifications) capable of delivering a beam with the required quality and stability without limitations from ion effects.

Guidance for optimization of design of vacuum and feedback systems, and optimization of the optics design, to avoid limitations from ion effects.

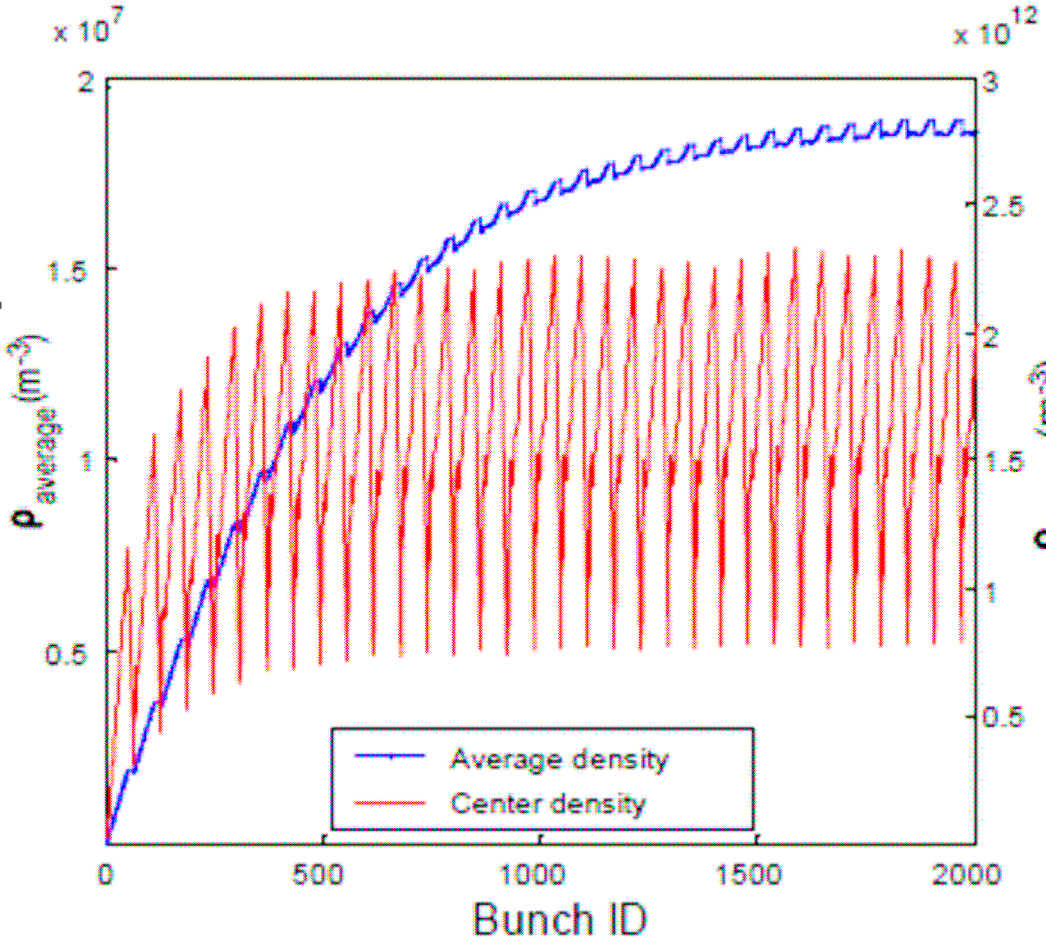
If the Objectives are not met, the ability to deliver the required beam specifications at extraction could be compromised, resulting in reduced luminosity.

Brief review of RDR



Schematic of the Fast-Beam Ion Instability

- Critical issues : ion-induced beam instability and tune shifts due to ultra-low vertical emittance.
- For mitigating bunch motion, a low base vacuum pressure less than 10^{-7} Pa and bunch-by-bunch feedback systems with a damping time of about 0.1 ms are necessary.
- To reduce the core ion density, mini-gaps in the train are essential.



The simulated growth time is 280μs.

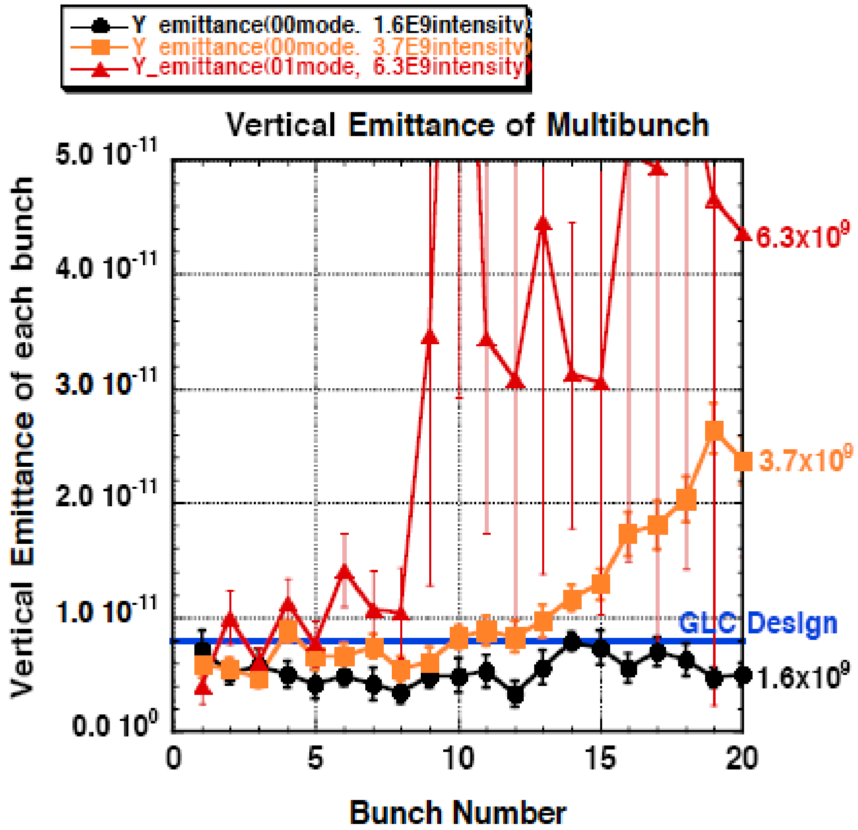
Buildup of CO^+ ion cloud at extraction. The total number of bunches is 5782 (118 trains with 49 bunches per train). The beam has a bunch separation of two RF bucket spacings, and a train gap of 25 RF bucket spacings. There are 0:97 x 10^{10} particles per bunch, and the partial vacuum pressure is 1 nTorr.

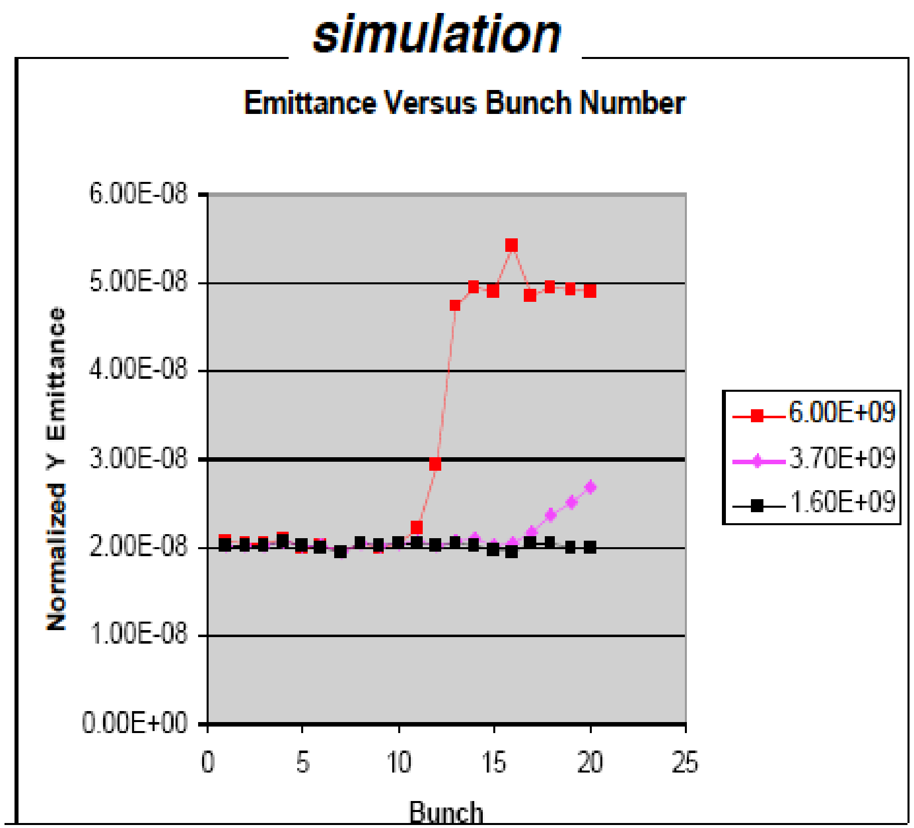
Plan and preliminary results for fast ion instability study at ATF

- Required information : ion density (related parameters include vacuum pressure, average beam line density, emittance, betatron function and beam fill pattern), bunch train gap, detail data to benchmark simulations with experiment.
- Deliverables : reliable simulation codes to evaluate the vacuum level, fill pattern and bunch-by-bunch feedback system.
- Schedule : see following slides.
- Resources : SLAC, LBNL, KNU, DESY, KEK, (Cornell, IHEP)

Preliminary result of Fast Ion Instability simulation

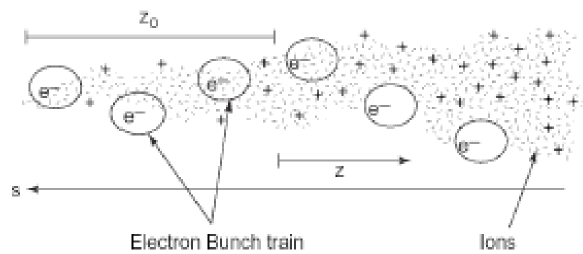
Results obtained in 2004





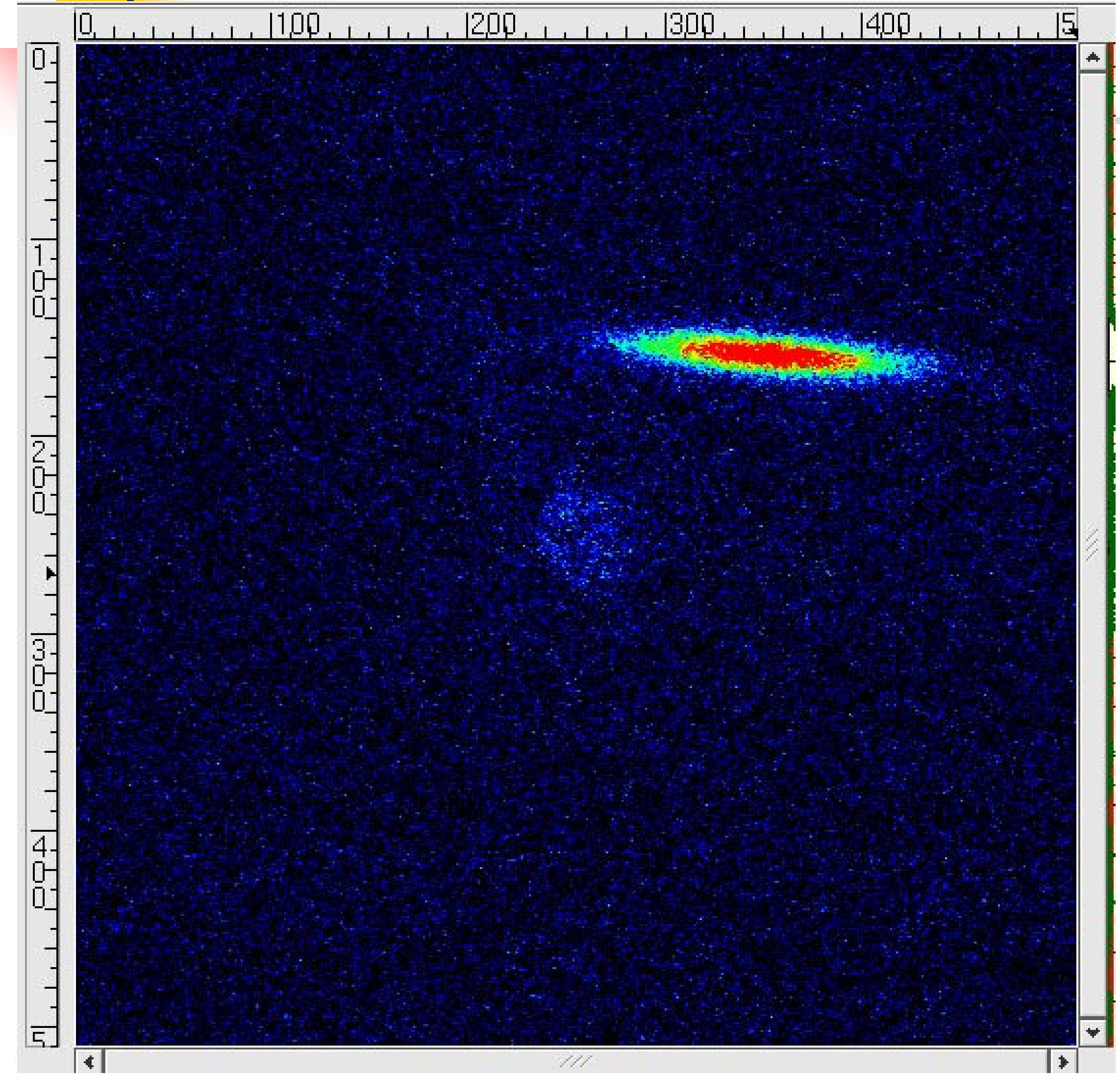
Behavior of Y emittance is very similar.

Problems: meas. of vacuum pressure,
Unknown gas species, extraction kicker heating



Schematic of the Fast-Beam Ion Instability

Measured beam profile by XSR monitor in normal vacuum condition



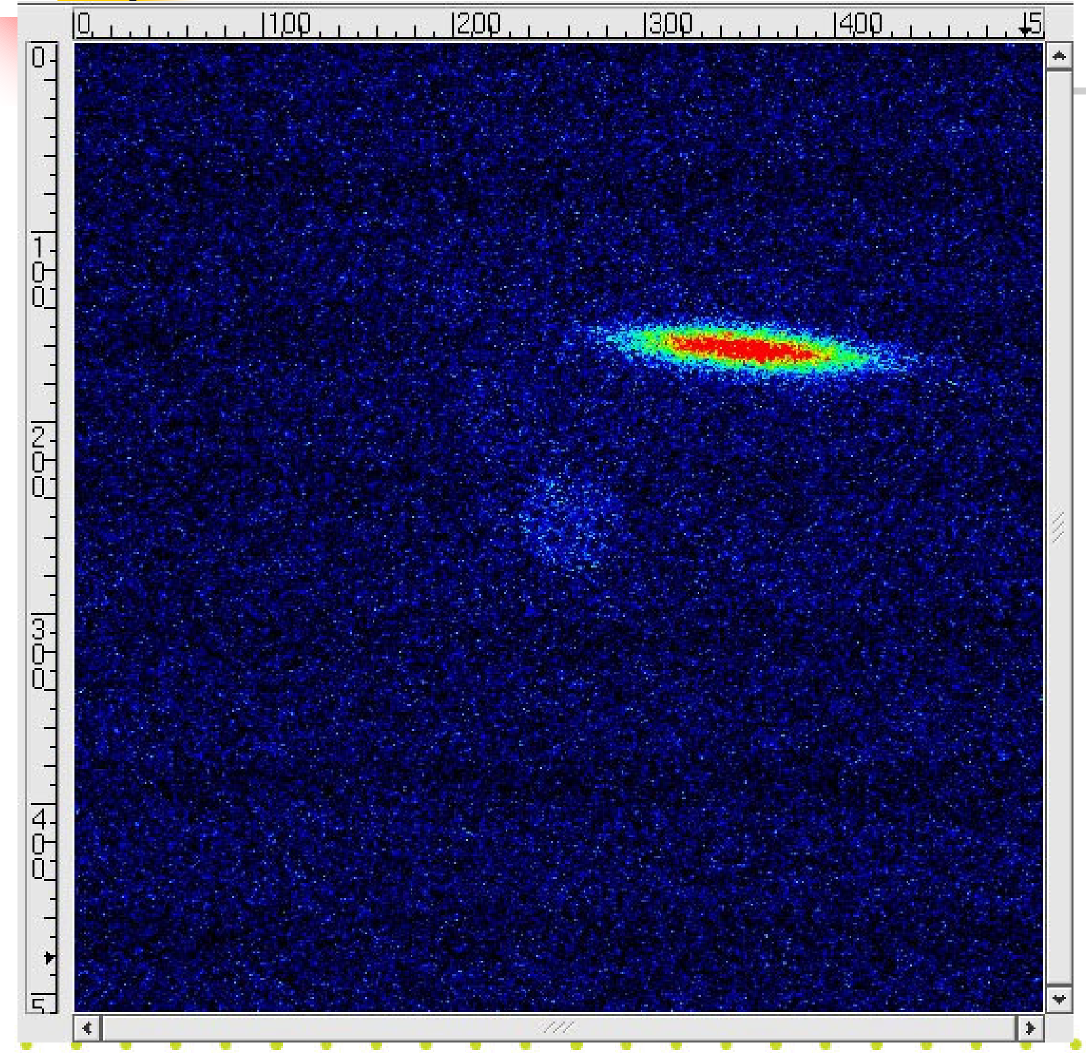
Single bunch/single train
2x10^{10} bunch/train

Ave: 2x10^{-7} Pa

X : 49.5 ± 2.3 µm
Y : 8.1 ± 0.7 µm

This profile was appeared on normal beam operation

Measured beam profile by XSR monitor in the vacuum condition with north ion pump off



Single bunch/single train
2×10^{10} bunch/train

Ave: 2×10^{-6} Pa (Maybe)

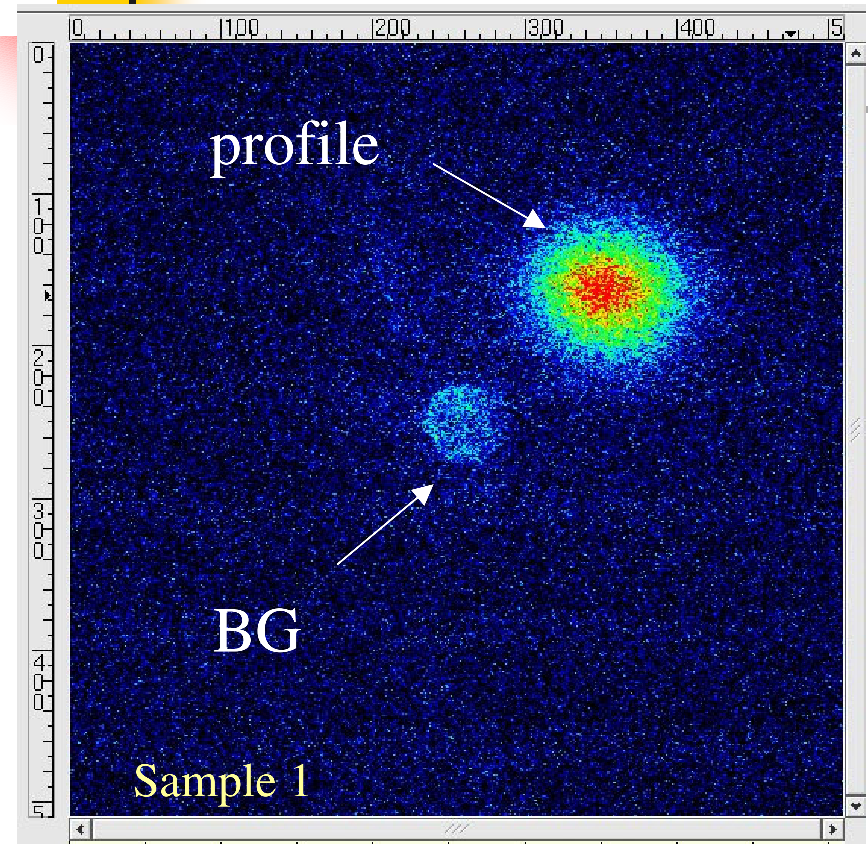
X : 46.8 ± 2.9 μm
Y : 8.4 ± 0.8 μm

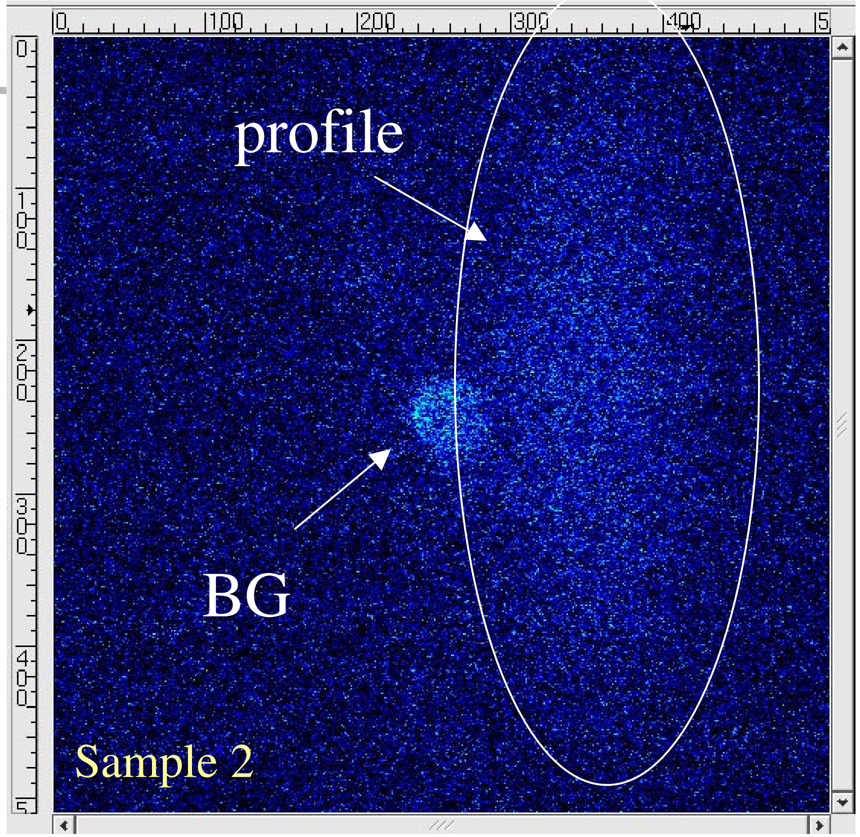
We have not found vertical beam size blow-up in this vacuum condition

Change 3train mode

Measured beam profile by XSR monitor on 3 train mode

Vacuum : 1×10^{-5} Pa

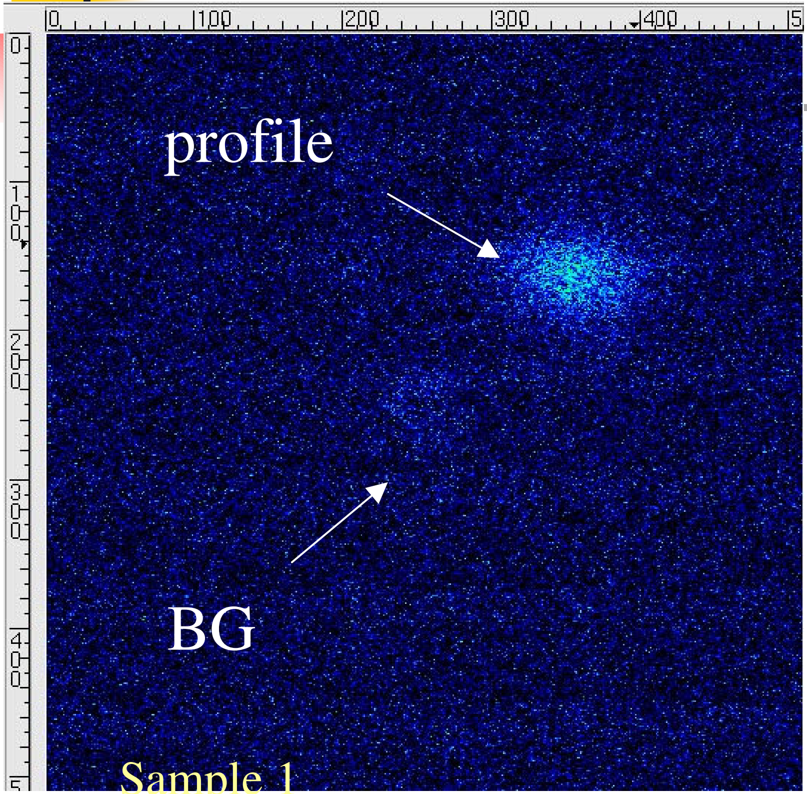


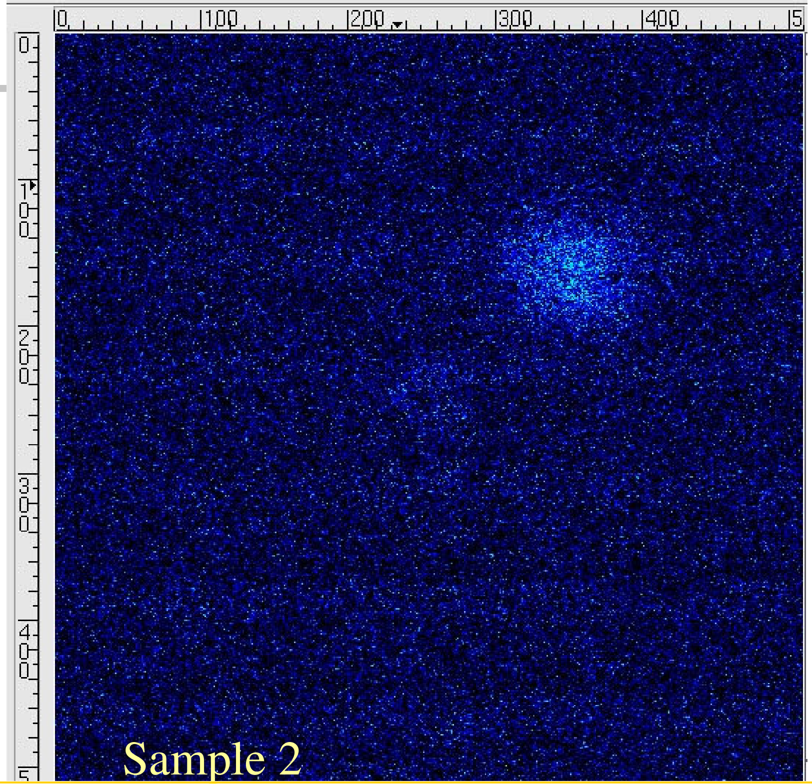


On a 3 train mode at 2×10^{10} /bunch, sudden large vertical beam blow-up appeared. On XSR monitor, measured vertical beam size was not fixed on same sizes. We also see a vertical beam oscillation by turn-by-turn monitor. **This is not FII?**

Measured beam profile by XSR monitor on 3 train mode (2)

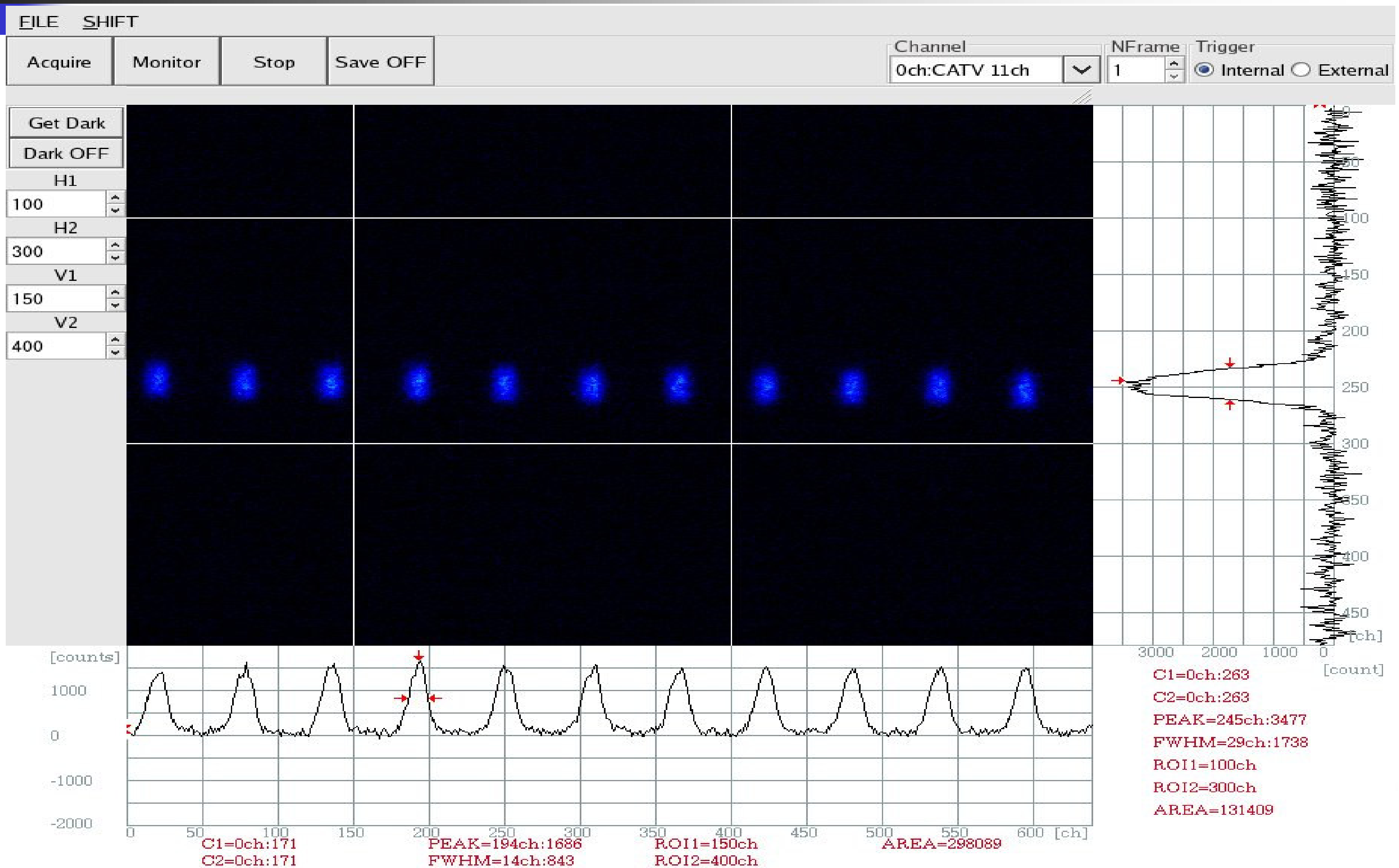
Vacuum : 2×10^{-6} Pa



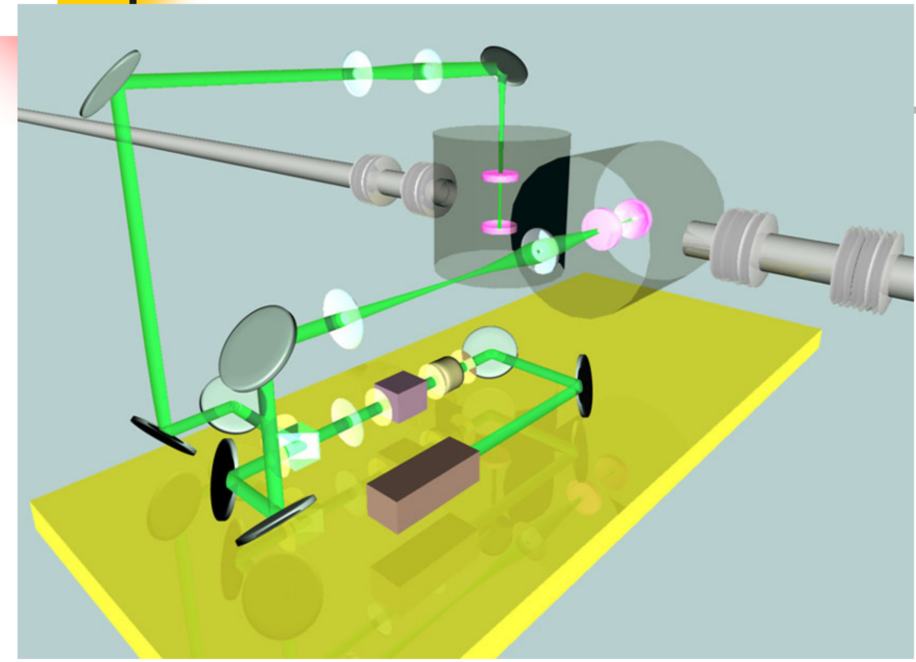


On a 3 train mode at 2×10^{9} /bunch (1/10 reduction than before), vertical beam blow up also appeared. But this amplitude was reduced on XSR monitor. The measured beam sizes were 32.5 ± 0.9 μm horizontally and 24.7 ± 4.7 μm vertically. After changing single train, we did not find this vertical beam blow-up.

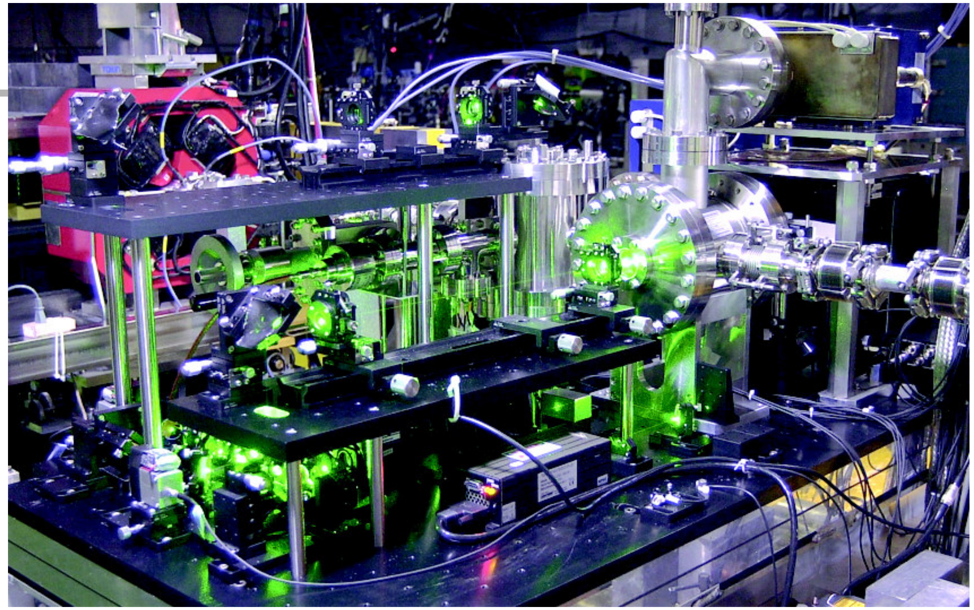
Bunch Length Measurement (Synchronized Streak Camera)



Laser wire beam size monitor in DR



300mW 532nm Solid-state Laser fed into optical cavity



14.7µm laser wire for X scan
5.7µm for Y scan
(whole scan: 15min for X, 6min for Y)

Experimental Condition

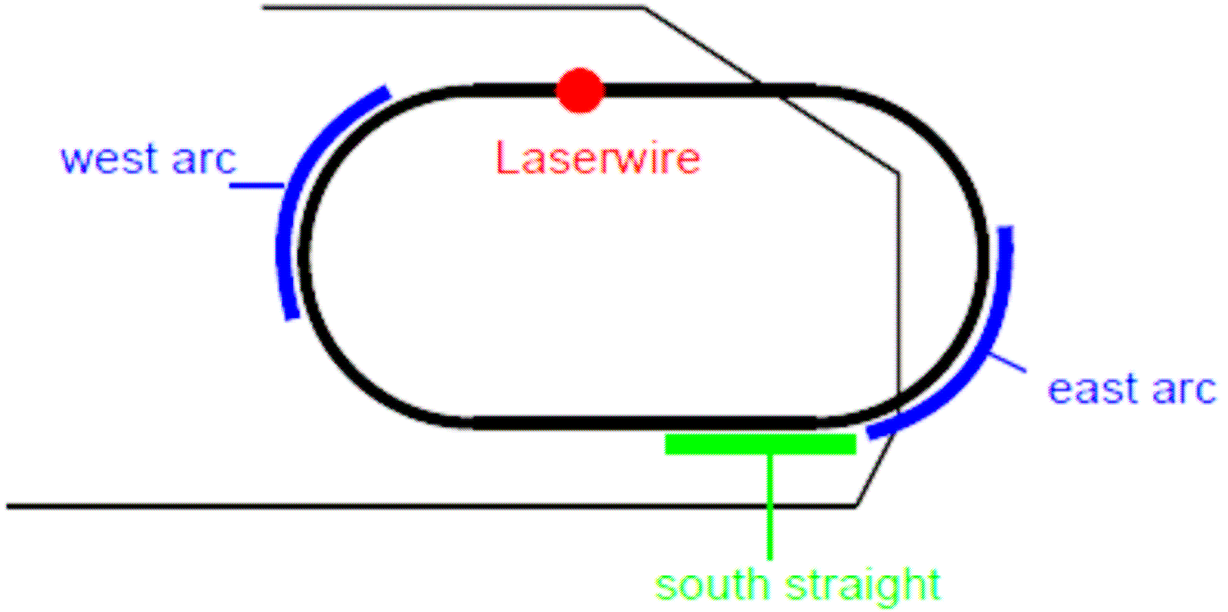


Figure 3: Sections that ion pumps were turned off in this experiment

Table 1: vacuum pressure in the measurements

ion pump status	5mA	10mA	20mA
normal	4.6×10^{-7} Pa	5.9×10^{-7} Pa	1.0×10^{-6} Pa
south straight OFF	2.0×10^{-6} Pa	2.7×10^{-6} Pa	5.5×10^{-6} Pa
both arcs and south straight OFF	3.4×10^{-6} Pa	5.2×10^{-6} Pa	

Experimental Results measured by laser wire in DR

Table 2: vacuum pressure in 2004

ion pump status	11mA	26mA	31mA
normal	4.0×10^{-6} Pa	6.0×10^{-6} Pa	6.5×10^{-6} Pa

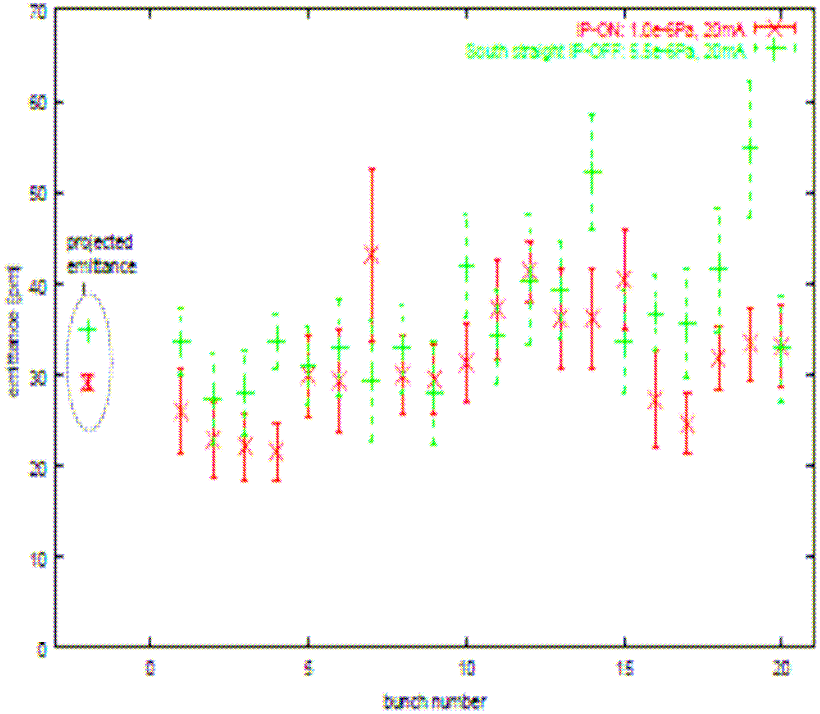


Figure 9: emittance of multi-bunch beam at 20mA/20bunches

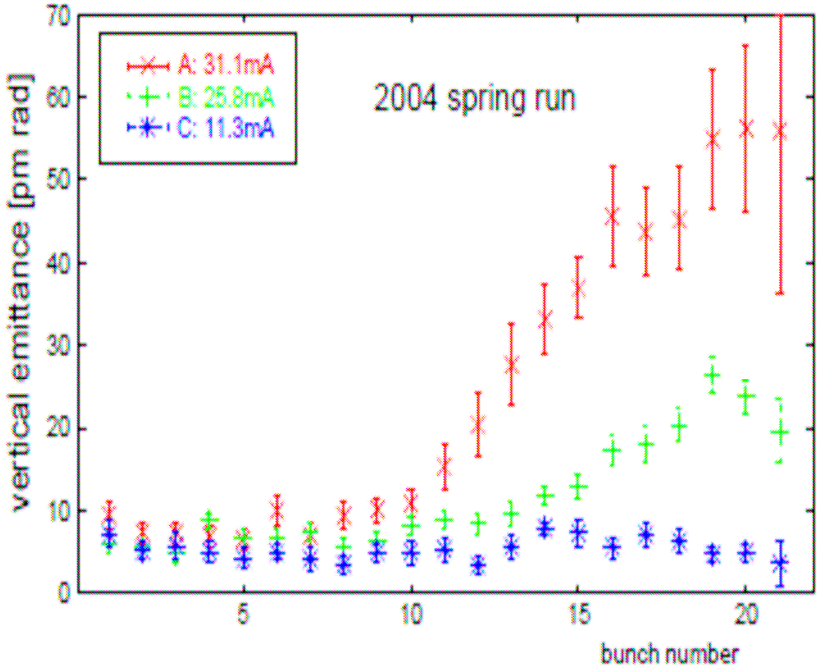
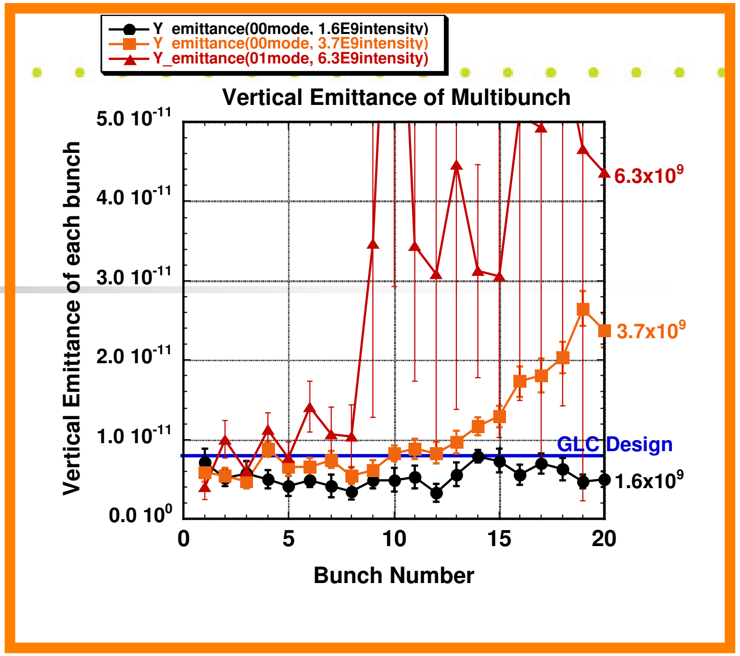


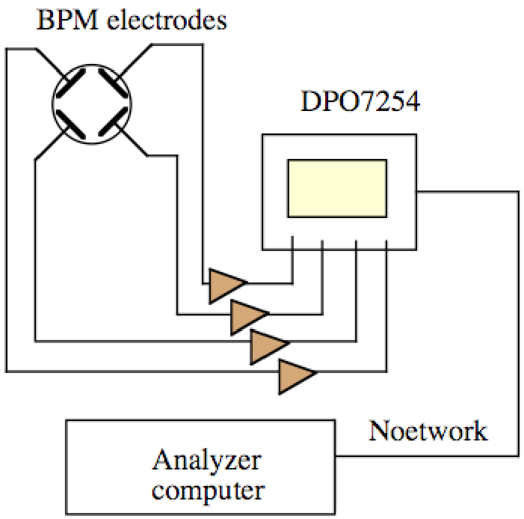
Figure 10: data taken in 2004

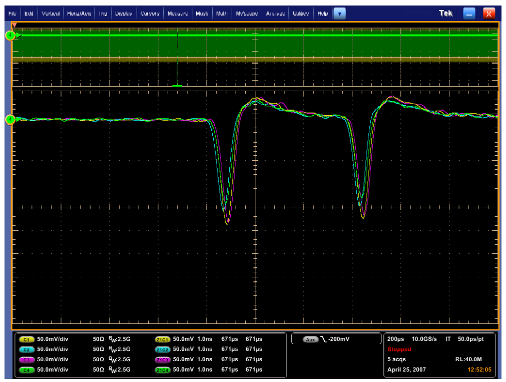
Multi-bunch Turn-by-turn monitor

T.Nato(KEK)

The beam blowup at tail bunches was measured by the laser wire in ATF, which is assumed come from FII effect. In order to observe the individual beam oscillation in the multi-bunch beam, multi-bunch turn-by-turn monitor is developing. This monitor consists of front end circuits(amplifier and filter) and DPO7254 scope. The scope can store the waveform up to 2ms with 100ps time resolution.

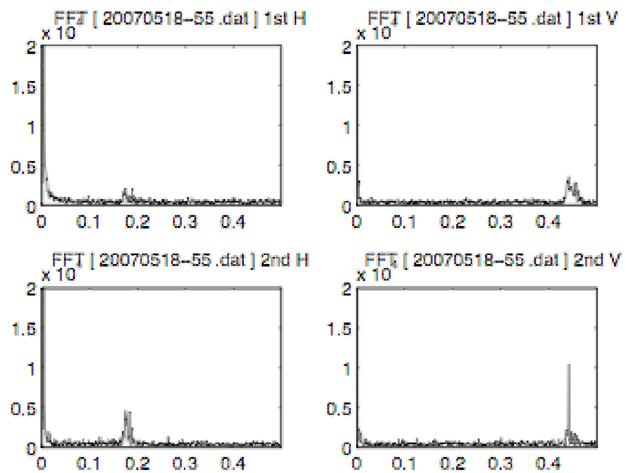






1st

2nd



Tune-X

Tune-Y

The preliminary results shows the different oscillation amplitude of the tune-X and the tune-Y for the 1st and 2nd bunches at just after injection.

Study from Feb. to April in 2007.

- **We found the vertical beam blow-up at 3 train mode above 2×10^{-6} Pa between 2×10^{9} and 2×10^{10} /bunch.**
- **We did not find the vertical beam blow-up at single bunch/ single train mode below 2×10^{-6} Pa.**
- **We measured vertical emittance of each bunch in a 20bunches train with a laser wire monitor. Even if we turned off ion pumps of several section of the DR to enhance ion effects, no clear blow-up in a train was seen up to 20mA/train beam current. One of the reason may be the bigger vertical emittance compared with the data taken 2004.**

Summary of Spring preliminary experiment for fast ion instability at ATF

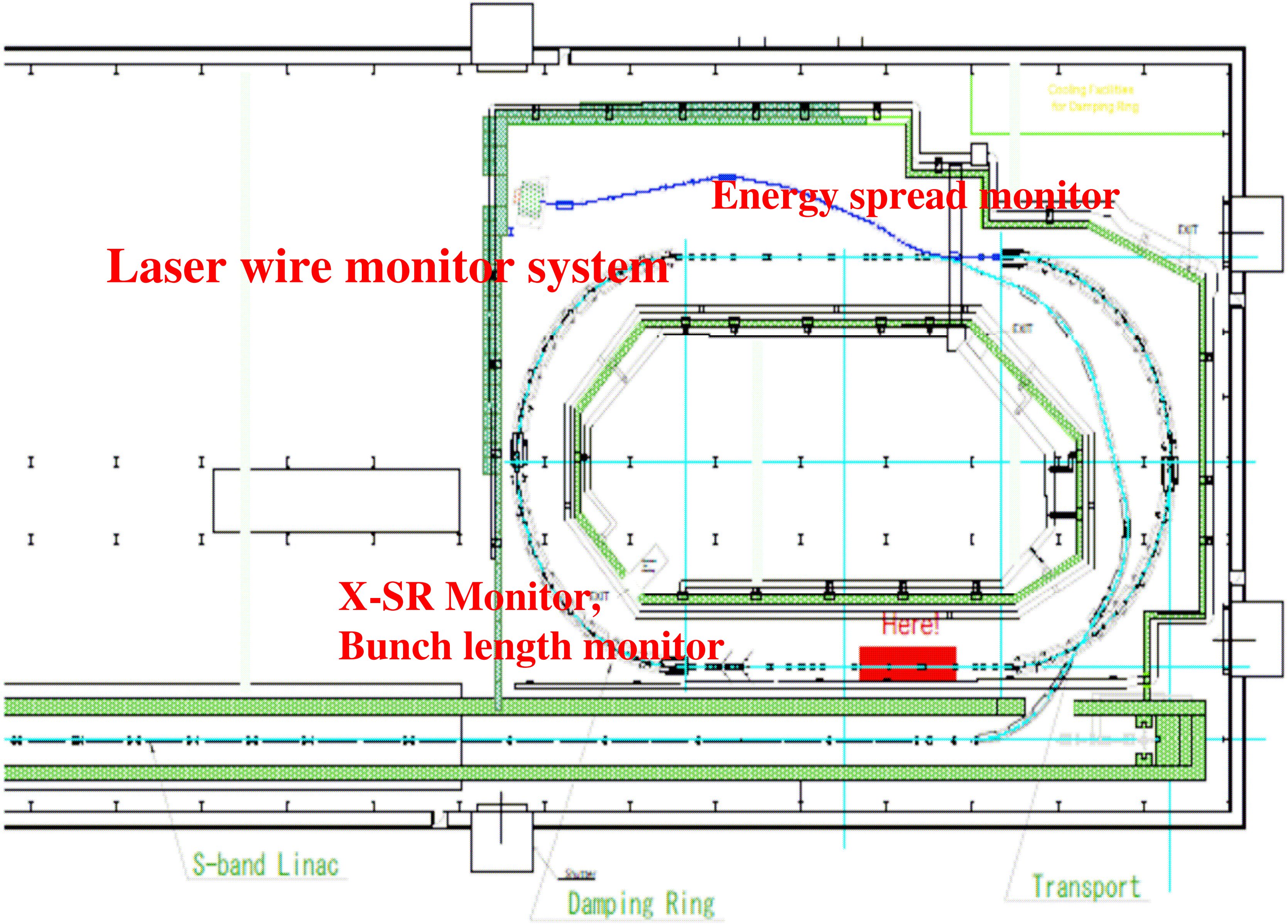
Our conclusion is that we need more total stored current than 20mA/train and should generate 5pm vertical emittance like 2004 beam experiment in order to realize the beam blow-up due to the fast ion instability.

Since reliable data for the study of FII are necessary, we continue this experiment from this Nov. operation with the installation of the Gas (N_2) inlet system.

Posssible location for Fast Ion Study

Gas Inlet Chamber : N2 etc.

2007/Mar/02 N.Terunuma, KEK



Possible location of Gas inlet chamber for fast ion study

South straight section of ATF damping ring

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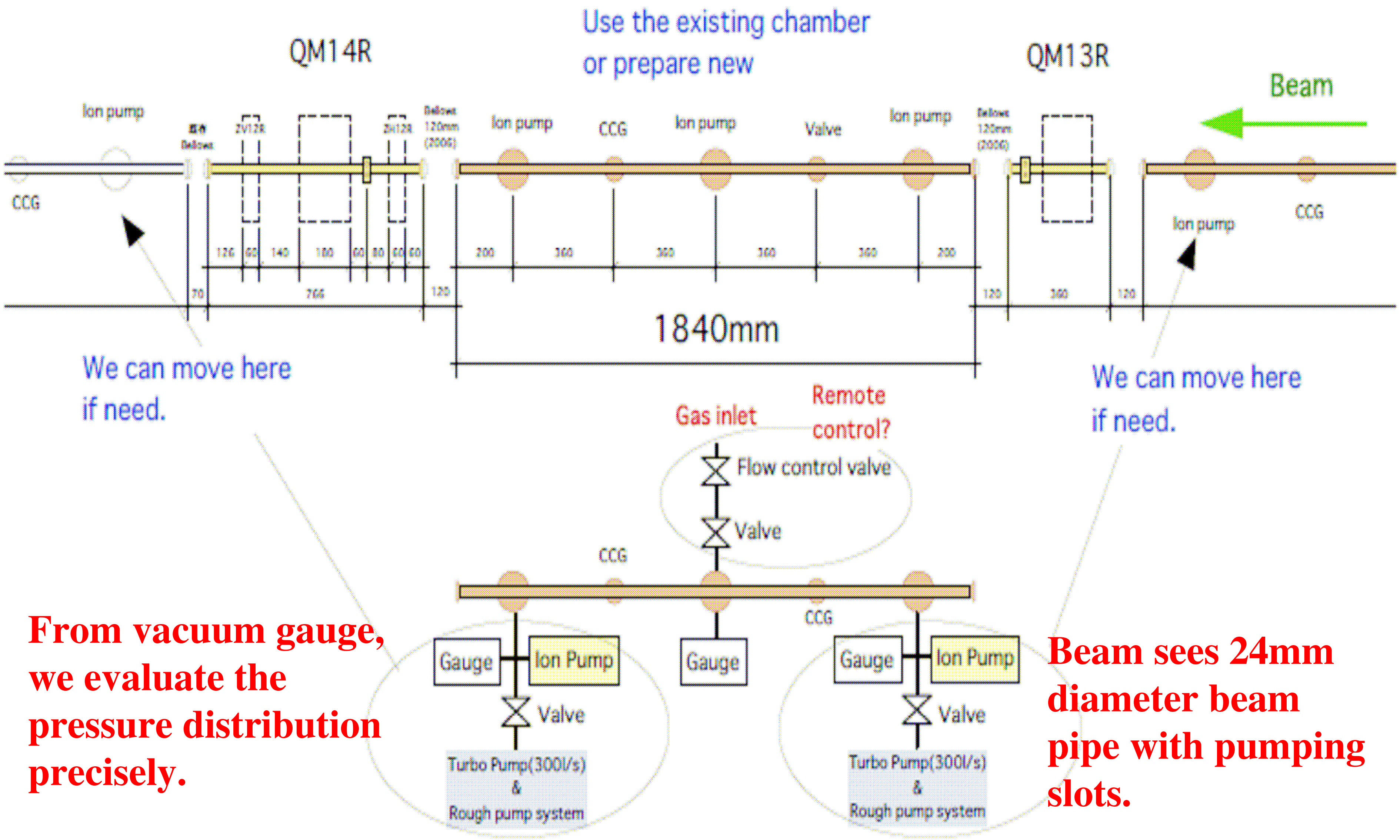
Good pressure bump



From vacuum gauge, we evaluate the pressure distribution precisely.

Beam sees 24mm diameter beam pipe with pumping slots.

Necessary preparation and good maintenance

- Multi-bunch energy compensation system in ATF Linac (We need energy margin.)
- Ready laser wire and X-SR monitor
- 10GHz signal sampling system in DR
- Tuning for high quality beam injection

(beam stability, high current injection more than 70mA/train)

Goals of the experiment
(according to Two proposals)
(L. Wang, T. Raubenhimer and G. Xia, E. Elsen)

- **Distinguish the two ion effects: beam size blow-up and dipole instability.**
- **Quantify the beam instability growth time and tune shift. The growth rate is related to the ion density (vacuum pressure, average beam line density, emittance, betatron function and so on).**
- **Quantify the bunch train gap effect**
- **Provide detailed data to benchmark simulations with experiment.**

Detailed Experimental plan

A. Measurement of vacuum pressure and the main components of gas species.

B. Effects of pressure and bunch current:

With different pressure conditions (2.0×10^{-5} Pa in pressure bump) by injecting nitrogen gas);

With different beam: 1 train, N of bunch =2~20, $5 \times 10^{9} \sim 2 \times 10^{10}$/bunch

C. Gap effect

- repeat B with 2 and 3 bunch trains,
- repeat B with different length of gaps.
- repeat above with a different emittance (emittance ratio :changed by skew quads from 0.5% to 10%.)

Experimental plan for fast ion instability study at LBNL-ALS (J. Byrd) and CersTA

Schedule is not fixed.
Maybe, it is same as ATF and complementary study will be planned.

Also, CersTA?

I need the information on FII study from Mark, Frank and J. Byrd to complete WorkPackageDeliverableSpecification-FII.doc and DampingRing-WP15.doc.

Announcement for efficient international collaboration

ATF Web is involving and making international data communication page.

- 5th Joint meeting of TB and SGCs on Dec. 21 at KEK
- Call for new R&D proposals at ATF
- Studies about the Fast Ion Instability
  - This is a starting point for data sharing within the collaboration of the fast-ion R&D program. It is just started. Therefore we have no tools converting the internal data format into your environment at present. Raw data are distributed in some computers at ATF because the developments of monitors are done by several groups. Each beam-monitor system has their own format on the different operating system, 8, 16, 32 or 64 bits. It is very difficult to gather them in a server at present. Your help or work to establish the data sharing tools for near future is necessary. Anyway, we will keep to upload the results for your works.

    by Nobuhiro Terunuma, March 1st, 2007.
  - Data and Summary
  - *Logging into the ATF web system is required. If you have no account on the ATF web system, please visit the user registration page .* (http://atf.kek.jp/collab/)
  - 2007/Feb/28
  - 2007/Feb/23 -----