Bunch length measurements, and development of microwave detector for microwave instability experiments at ATF

J. Urakawa (KEK),

at ILC Damping Rings R&D Workshop – ILCDR06

1. Summary of results which were obtained by measurements from 1997 to 2001 at ATF.
2. New detector development
3. Experimental Plan

Summary of results which were obtained by measurements from 1997 to 2001 at ATF.

Measurement Tools: DCCT (DC Current Transformer), Accuracy : 0.05%
Streak Camera (Hamamatsu C5680) : Space charge effect inside was corrected by linear function with 15% ND filter.

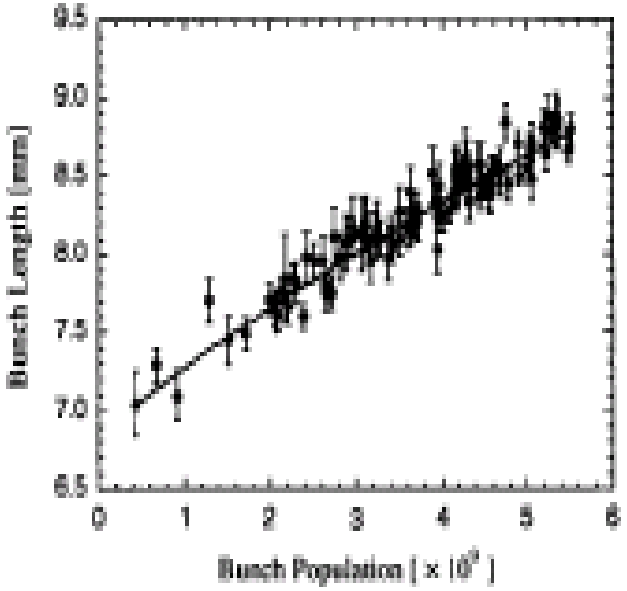


Fig. 4 The correlation plot for bunch population and the bunch length.

1997, measured by Okugi et al.
Assumption: Purely inductive Impedance Model, No correction regarding intra beam scattering.
Report : ATF-97-23
Conclusion : Consistent results with TBCI and ABCI codes

1998, measurement done by Ternuma et al.
Conclusion : Four times larger than that of the expected impedance.

Table 1: Impedance sources in the ATF damping ring; the bunch length was assumed to be 6.8 mm.

Components	Number	L(nH)
BPM	96	4.80
Bellows	64	2.03
Photon Masks	16	3.61
Tapers	5	1.42
Septum	1	0.62
RF cavity	2	0.69
RF absorber	4	0.67
Total		13.9

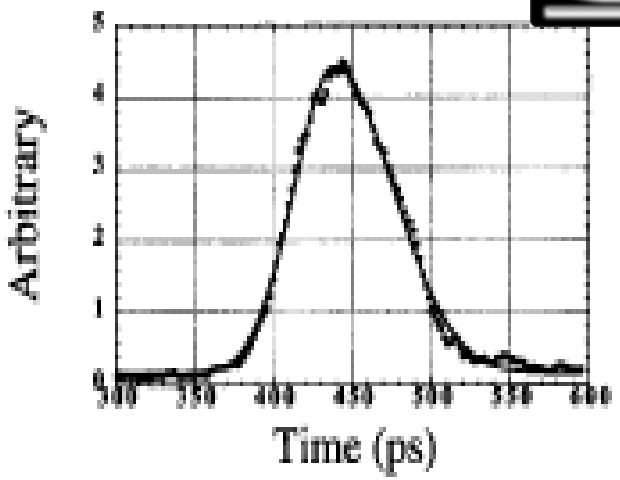


Figure 3: Longitudinal bunch shape at Vc=300kV and bunch intensity of 5×10^9 ppb.

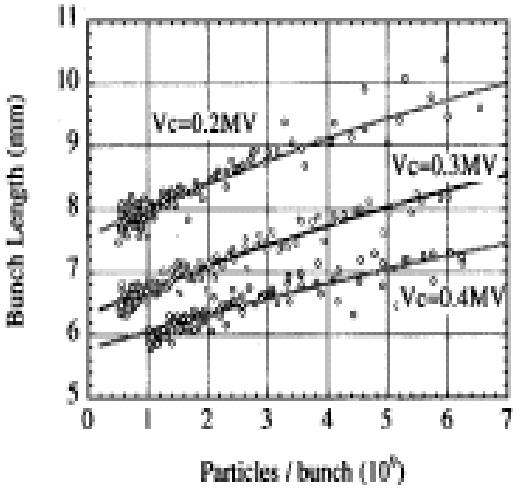


Figure 4: Measured bunch length as a function of the bunch intensity. Curves show the fitting results

However, ATF-98-21 report described the Results is consistent with calculation if we Include the effect of the intra beam scattering. At this time, several measurements indicated 1% coupling and about 30% emittance grouth By IBS.
Systematic error is large due to the streak camera system. Problem.

Energy spread measurement at high-dispersion point in the extraction line.
Beam operation on a (difference) coupling resonance was started.
From ATF-98-38 report by K. Bane et al,
Separating the effects of wakefields and IBS.

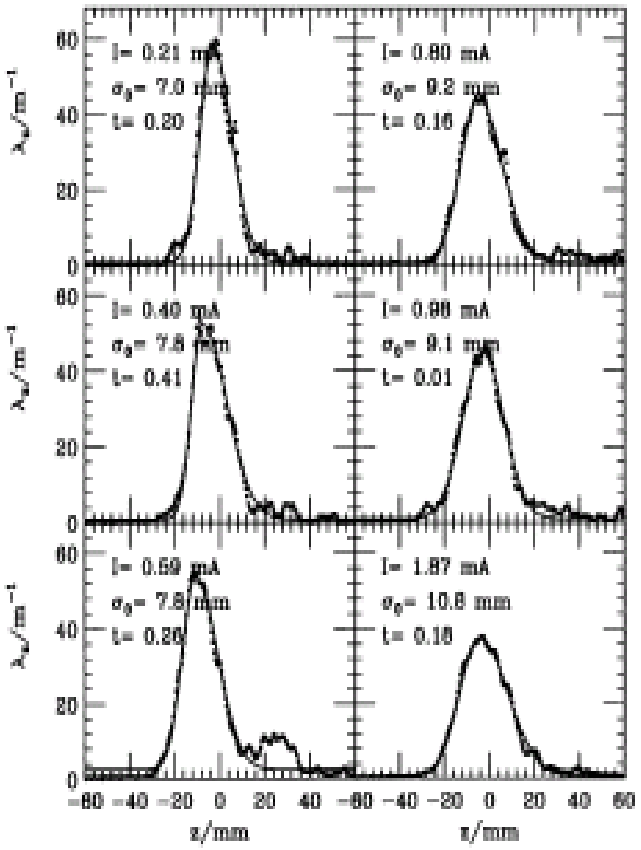


Figure 3. Representative bunch shape measurements with their fits with beam off the coupling resonance.

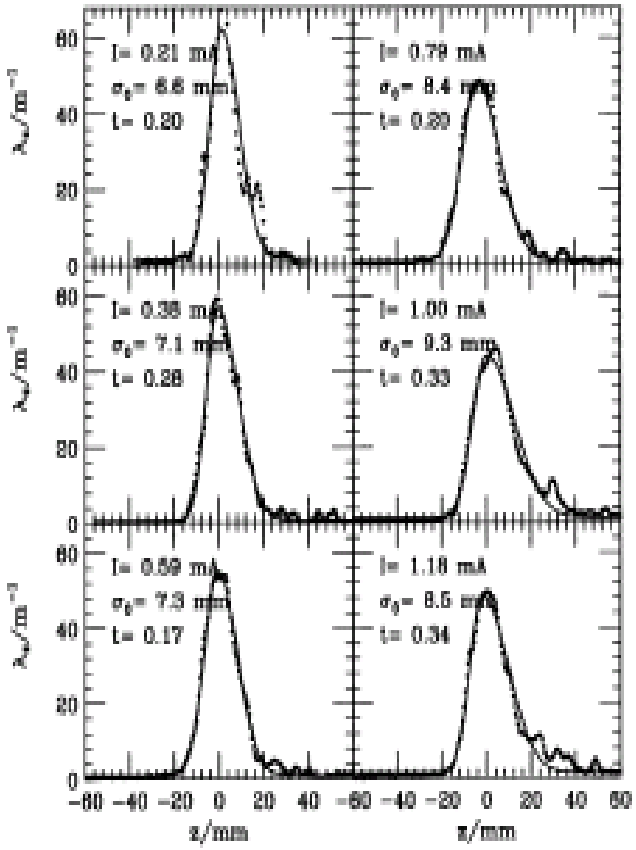


Figure 5. Representative bunch shape measurements with their fits with beam on the coupling resonance.

Conclusion : importance of emittance measurement.

From ATF-00-11 report by K.Bane et al,
Energy spread measurement on resonance and off resonance, more systematically.
Discussion on potential-well bunch lengthening and effect of the space charge in the camera, more.

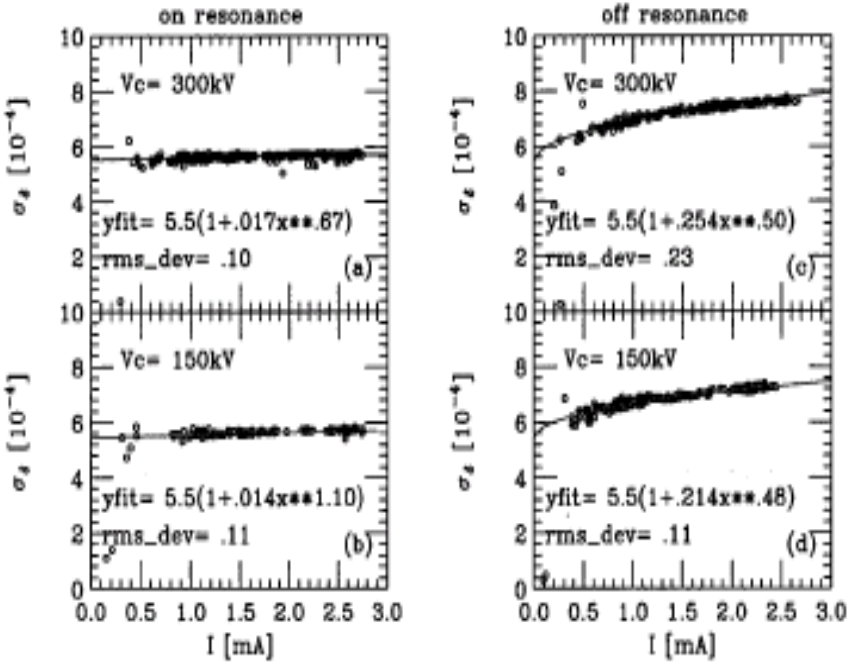


Figure 1: Energy spread as a function of current for various values of cavity voltage. The measurements were performed on 3/21-22/00. The curves give a simple fit to the data.

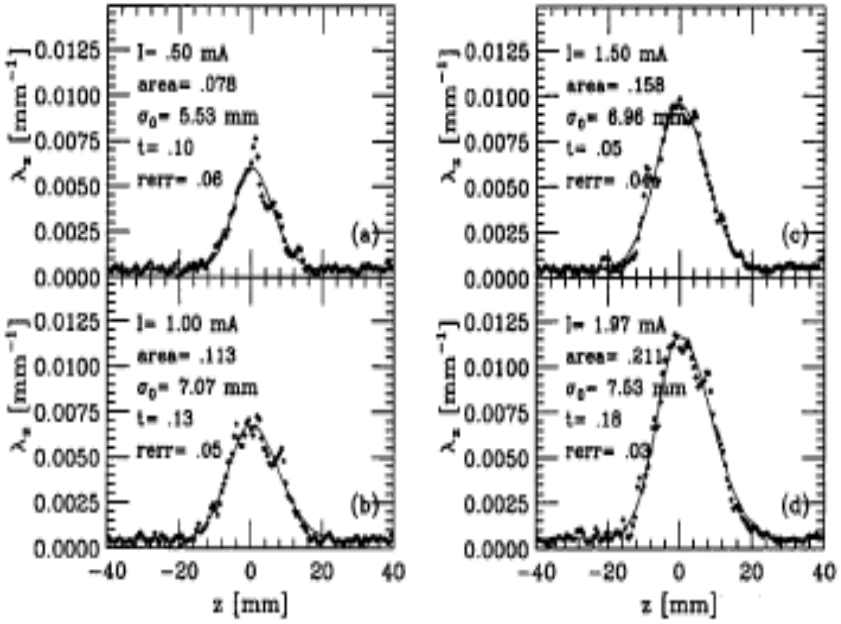


Figure 4: Four example scans, and their asymmetric Gaussian fits, for the beam on the coupling resonance with $V_c = 250$ kV. The horizontal axis has been shifted so that all peaks are at $z = 0$.

Conclusion: Potential well bunch lengthening is large, then large inductive component.
Measurements of energy spread, bunch length, transverse emittance both on resonance and off resonance are very important.

From ATF-01-01 report by Q. Qin et al,
Discuss both inductive impedance and resistive impedance.
Conclusion: measurement at on-coupling has still effect of IBS. The measured resistive impedance has big error but the simulation using Oide's code gave a Reasonable agreement.

Table 1 Main parameters of the ATF damping ring

Beam energy (*GeV*)	1.28
Circumference (*m*)	138.6
RF frequency (*MHz*)	714
Harmonic number	330
Momentum compaction factor	0.00214
Natural energy spread	0.055%
Bunch current (*mA*)	0.5 ~ 3.2
Transverse tunes in measurement	0.27/0.27 (H/V), fractional

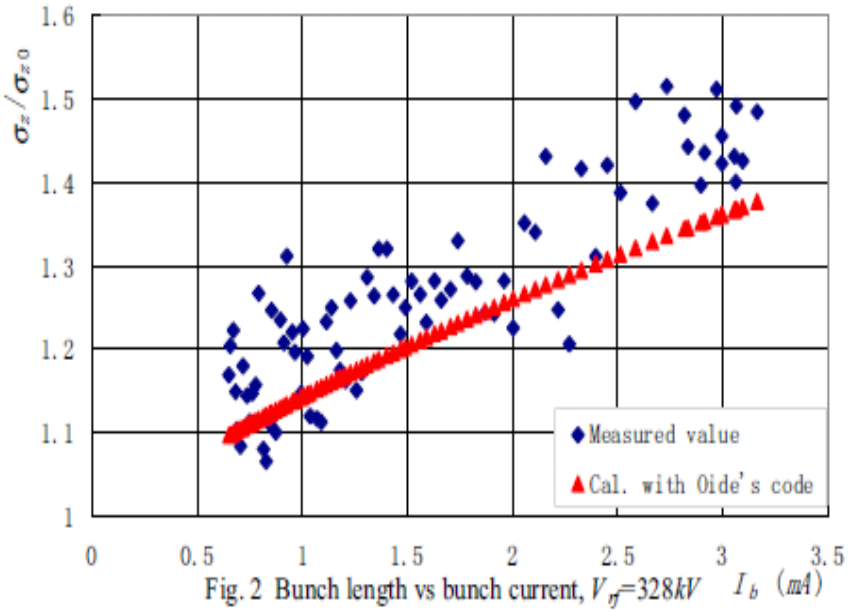


Fig. 2 Bunch length vs bunch current, V_{rf}=328*kV* I_b (*mA*)

Table 2. Results of the inductance got from bunch length measurement

Synchrotron tune	Natural bunch length (*ps*)	Inductance (*nH*)
0.004028	21.87±0.25	34.86±2.79
0.005005	17.60±0.20	29.76±1.84
0.005371	16.40±0.19	32.67±1.41
Average value		32.43±1.00

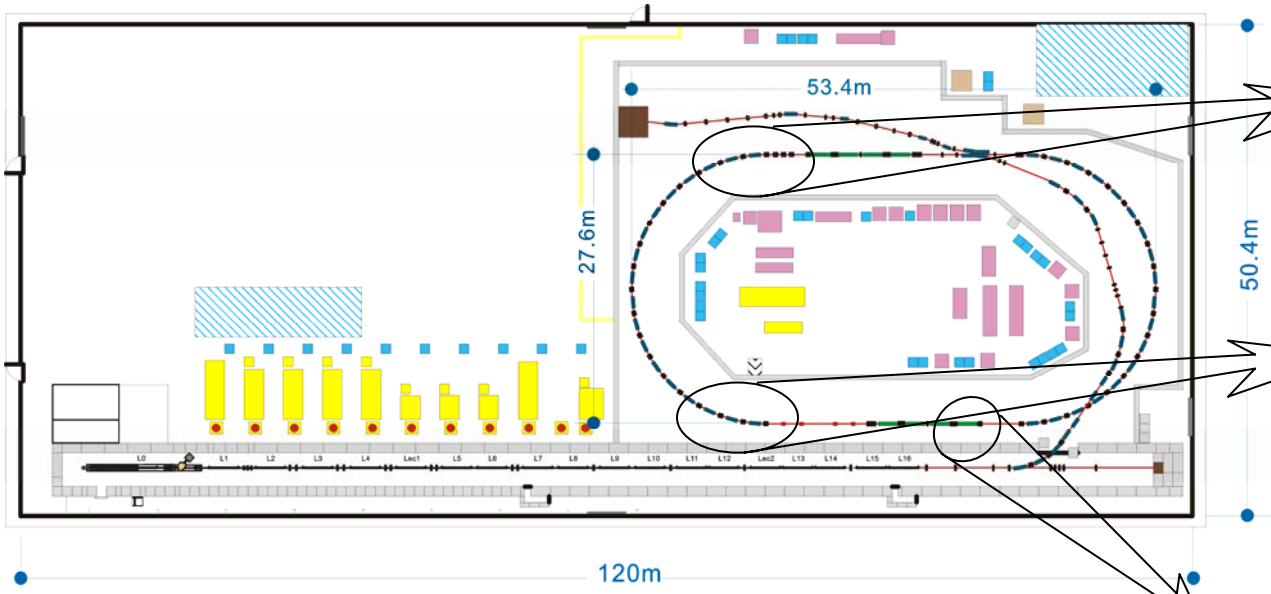
Table 3. Results of the resistance got from bunch length measurement

Synchrotron tune	Natural bunch length (*ps*)	Resistance (Ω)
0.004028	21.87±0.25	1783.78±677.14
0.005005	17.60±0.20	1561.64±444.04
0.005371	16.40±0.19	1609.38±450.03
Average value		1651.60±187.93

From SLAC-PUB-8846, International Journal of Applied Electromagnetic and Mechanics 14 (2001/2002) 197-202 by K.Bane et al,
Calculation: about 15nH, about 100Ω, Measurement: about 32nH, about 1.5kΩ
Pointed significant systematic error or problems with the model.

NIM A, 491, (2002) 1-8 by J.Gao,
Problem of the fitting with a theoretical model.

New Detector Development



Electron beam parameters

II. **Based on Schottky Barrier Diode (SBD) Detector**

I. **Silicon Bolometer As well as a SBD detector**

ICT

KEK-Accelerator Test Facility

I. Silicon Bolometer

belongs to LBL, manufactured by Infrared Lab. by Stefano de Santis

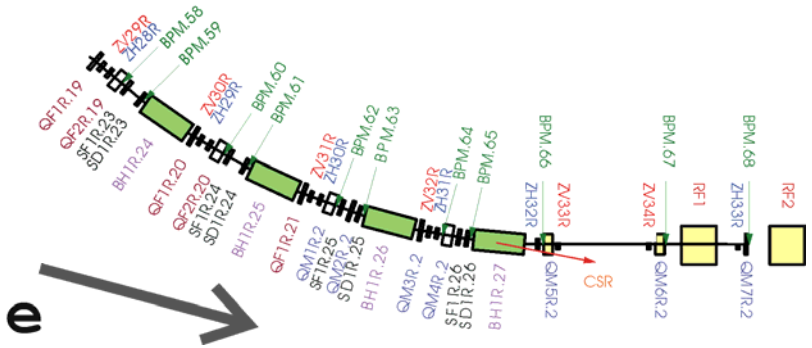
Equipped with low-noise
voltage preamplifier
Gain 200/1000 ± 5% (switched)

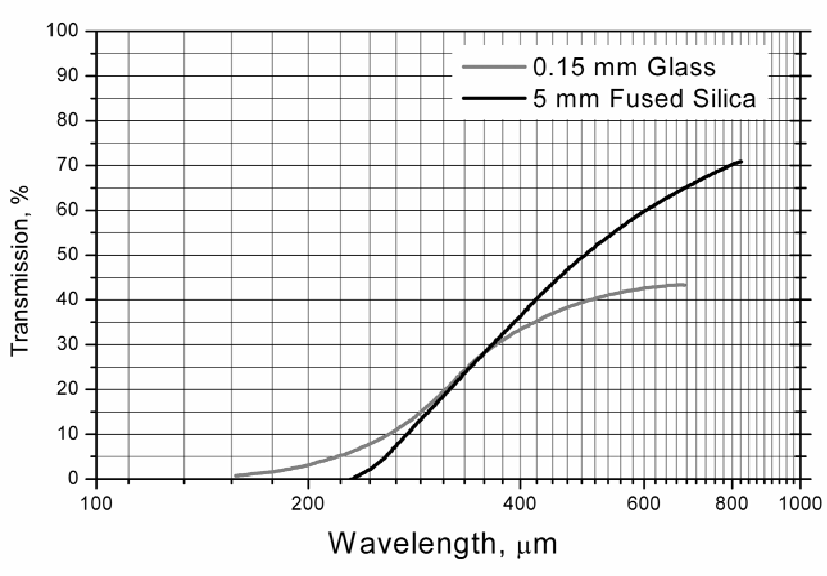
Liquid Helium – 1.2 liters

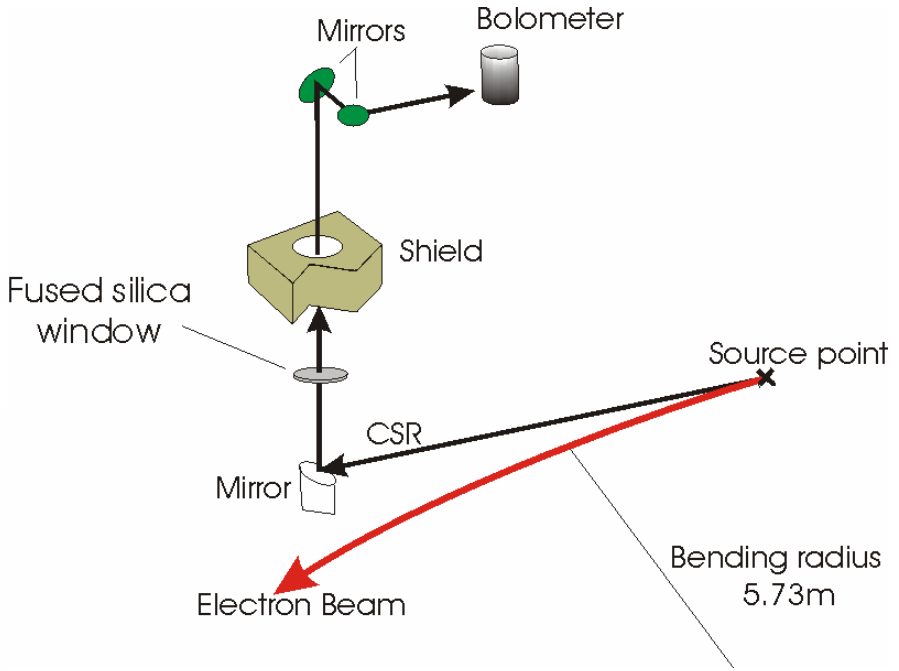
300μm > λ > 1mm

Maximum Responsivity
2.23E+07 V/W

Experimental layout

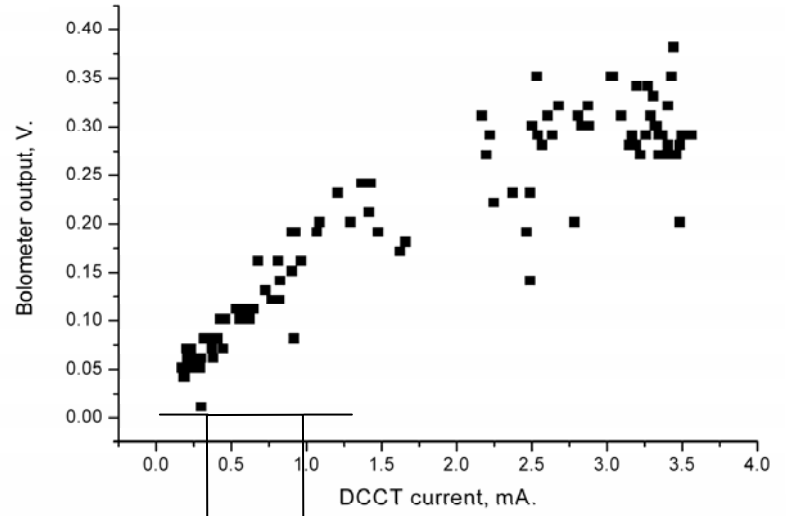


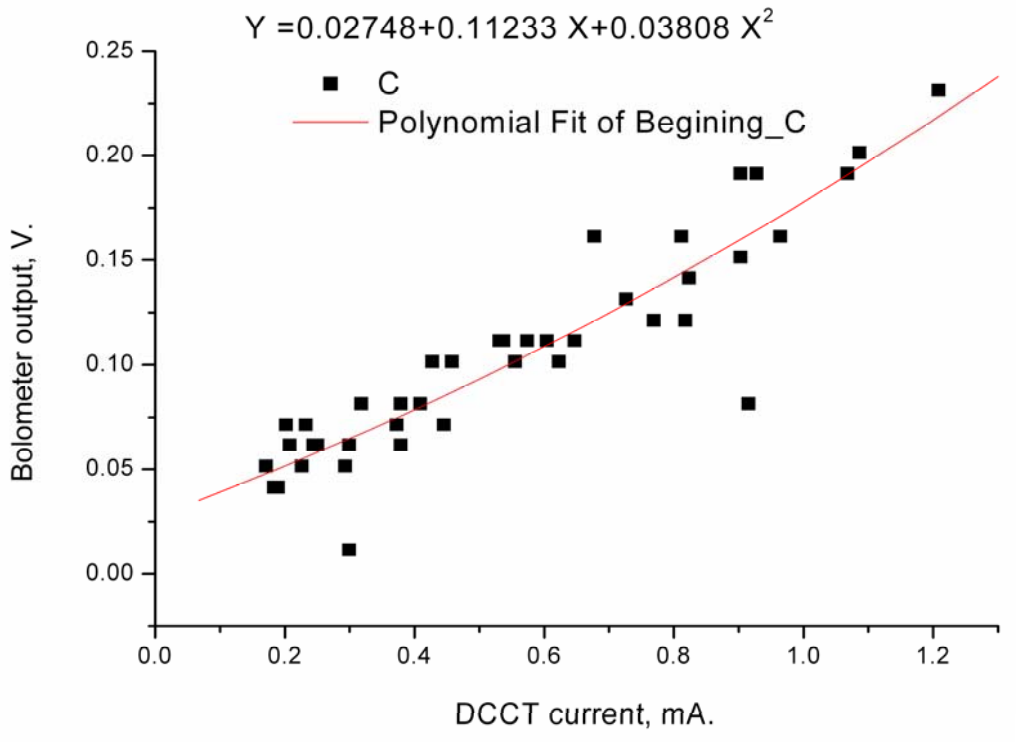




h – full vertical aperture, 24mm

SR current dependence





Bolometer conclusion

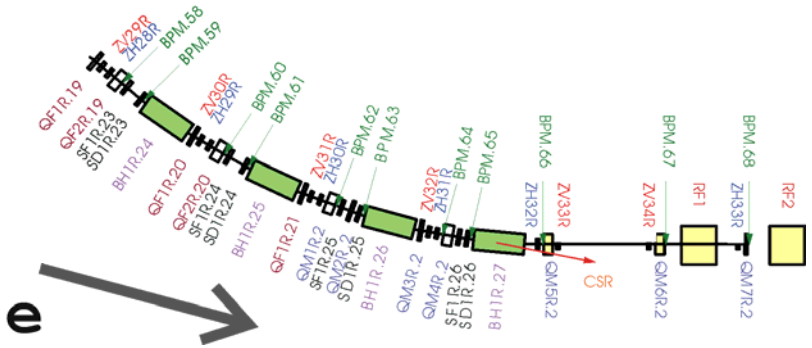
- The bunch length is too large and the coherency happened out of the Bolometer band
- The Bolometer is not fast enough to observe fast bunch density fluctuations
- Liquid He and Nitrogen are required

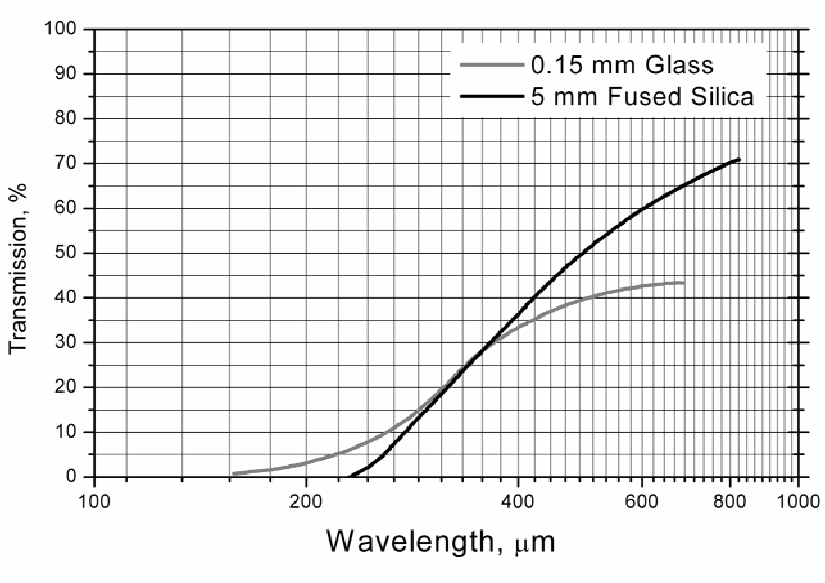
DPX-08, DXP-12 Performance

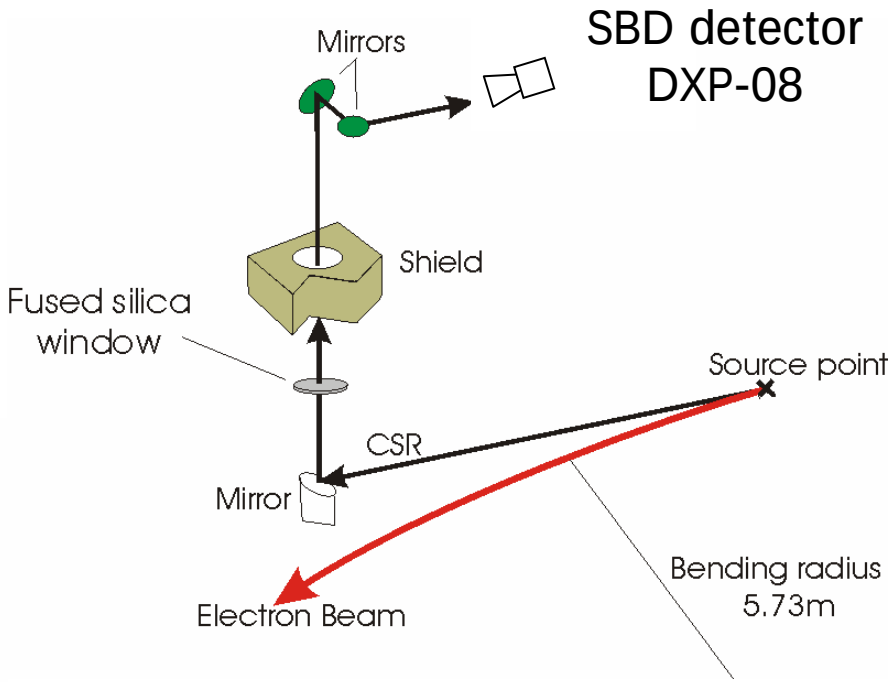
Schottky Barrier Diode

Model	DXP-08	DXP-12
Frequency Range (GHz, mm)	90-140, 2.14-3.33	60-90, 3.33-5
Sensitivity (mV/mW at –20 dBm input) typ.	1000	1250
Flatness (dB) typ.	± 3.0	± 2.0

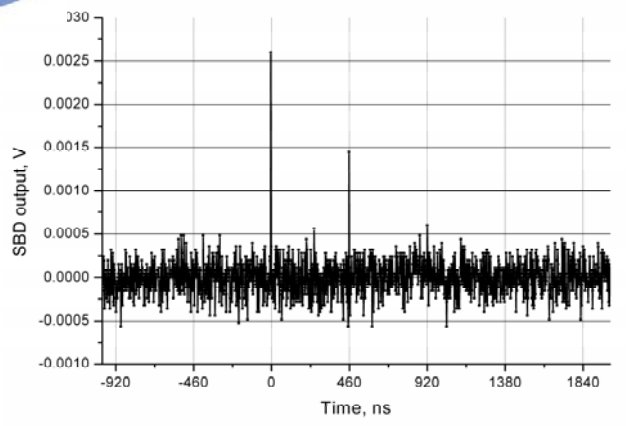
Experimental layout

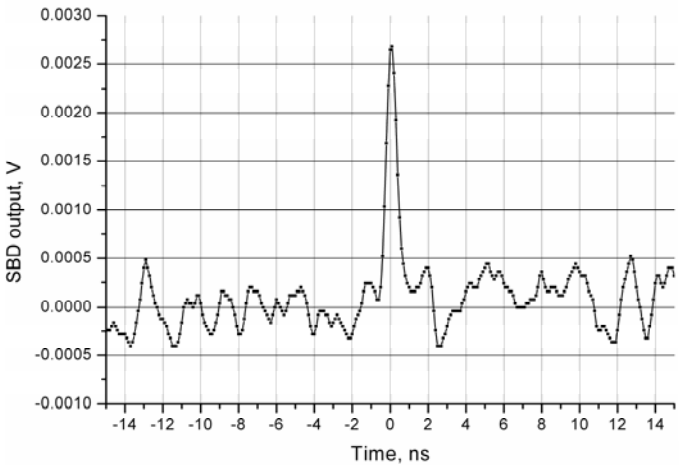






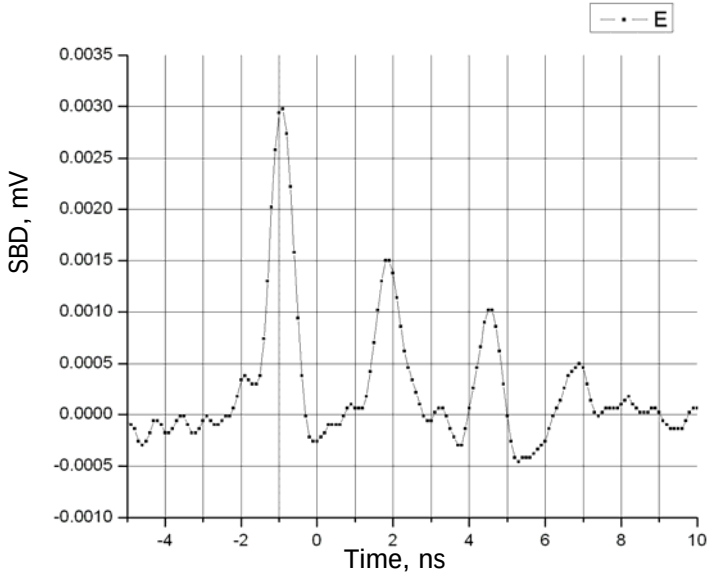
h – full vertical aperture, 24mm

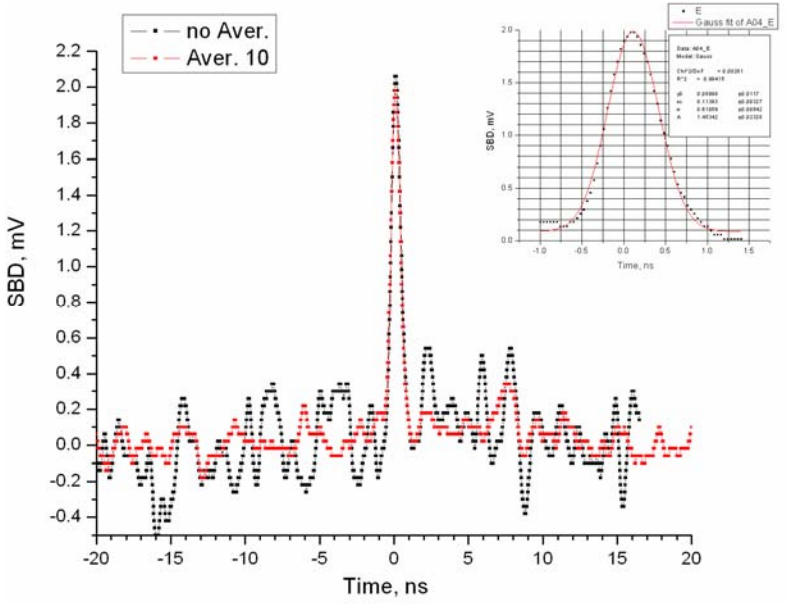




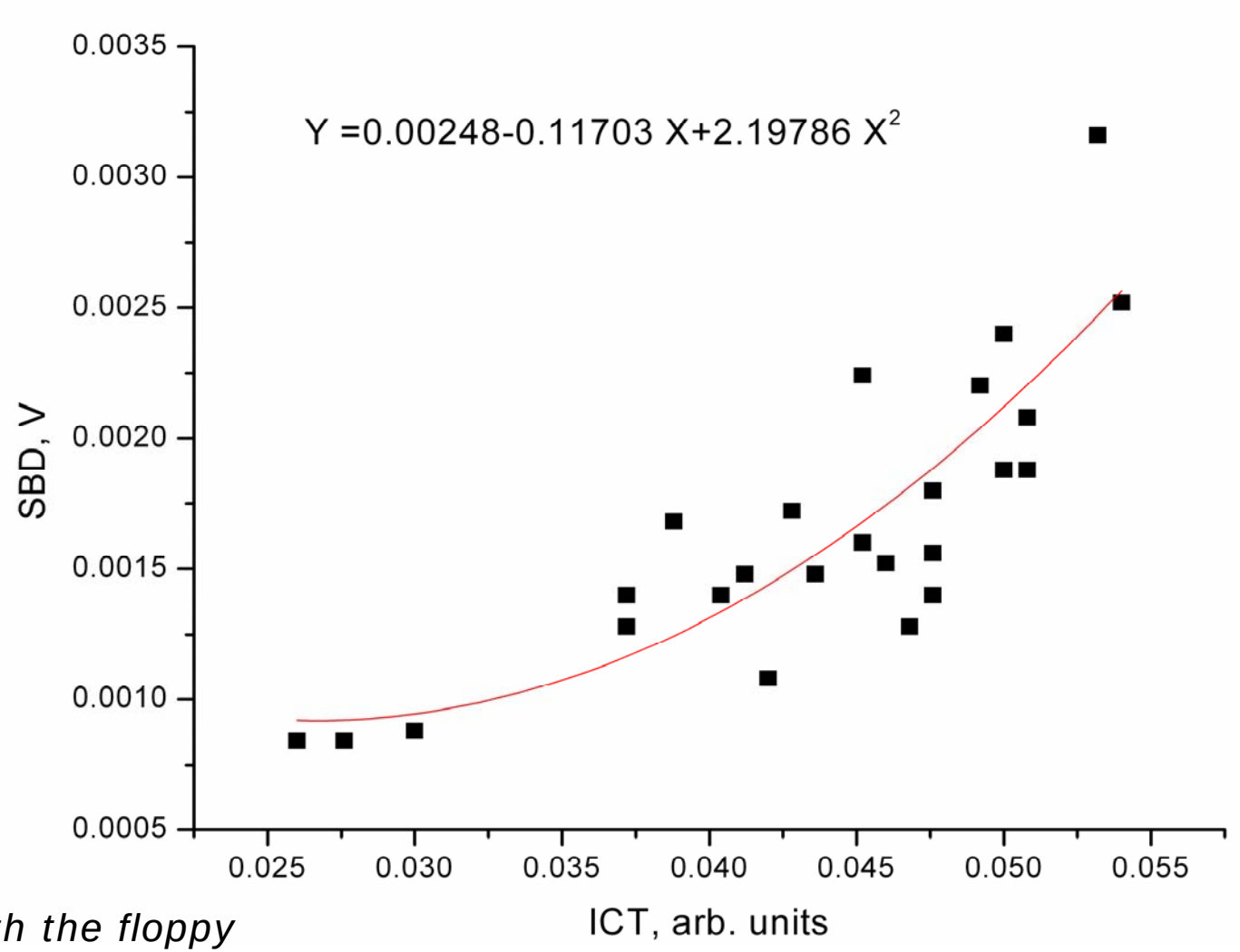
3 bunch in a train

+30dB





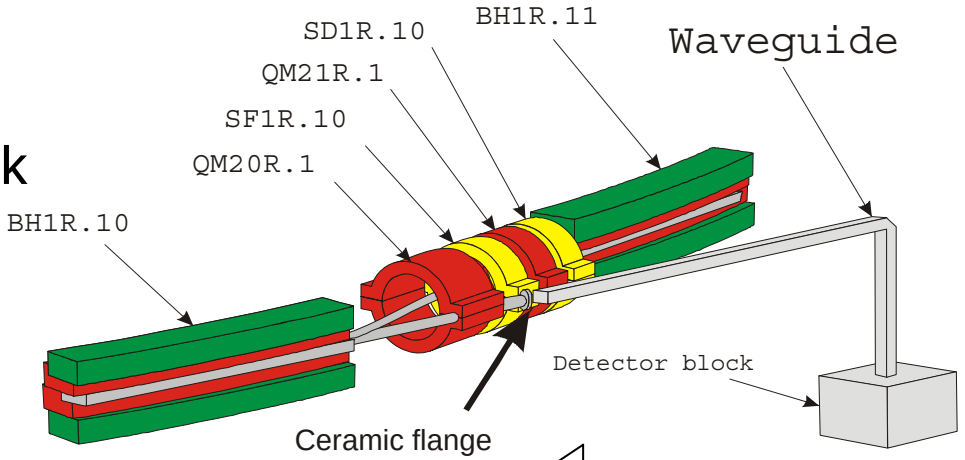
CSR current dependence



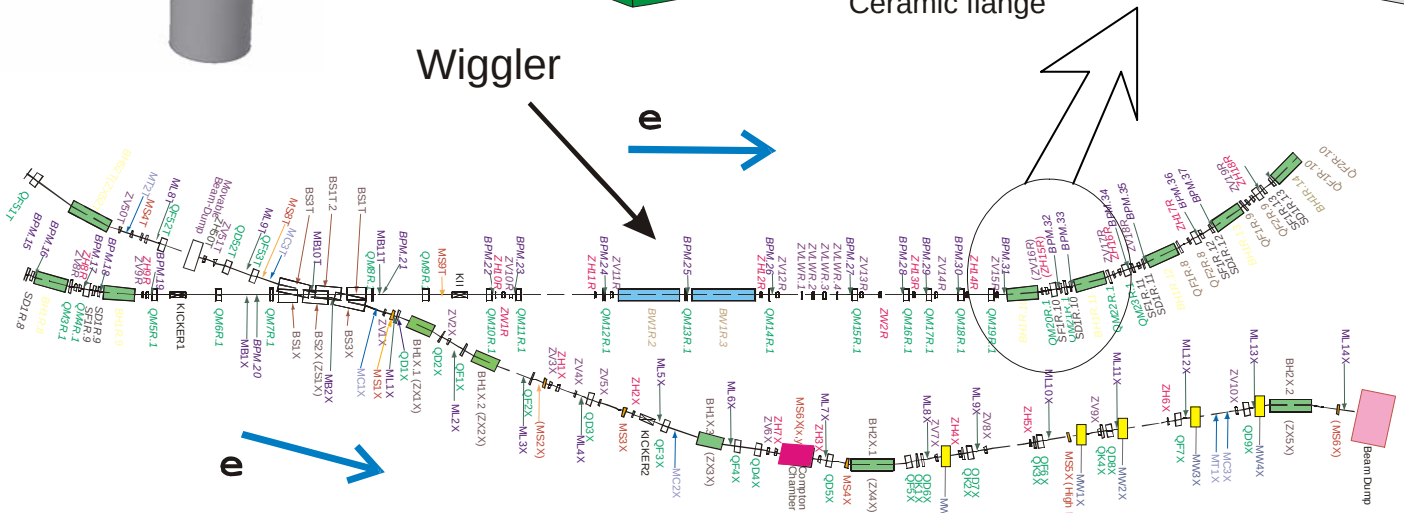
Taken with the floppy

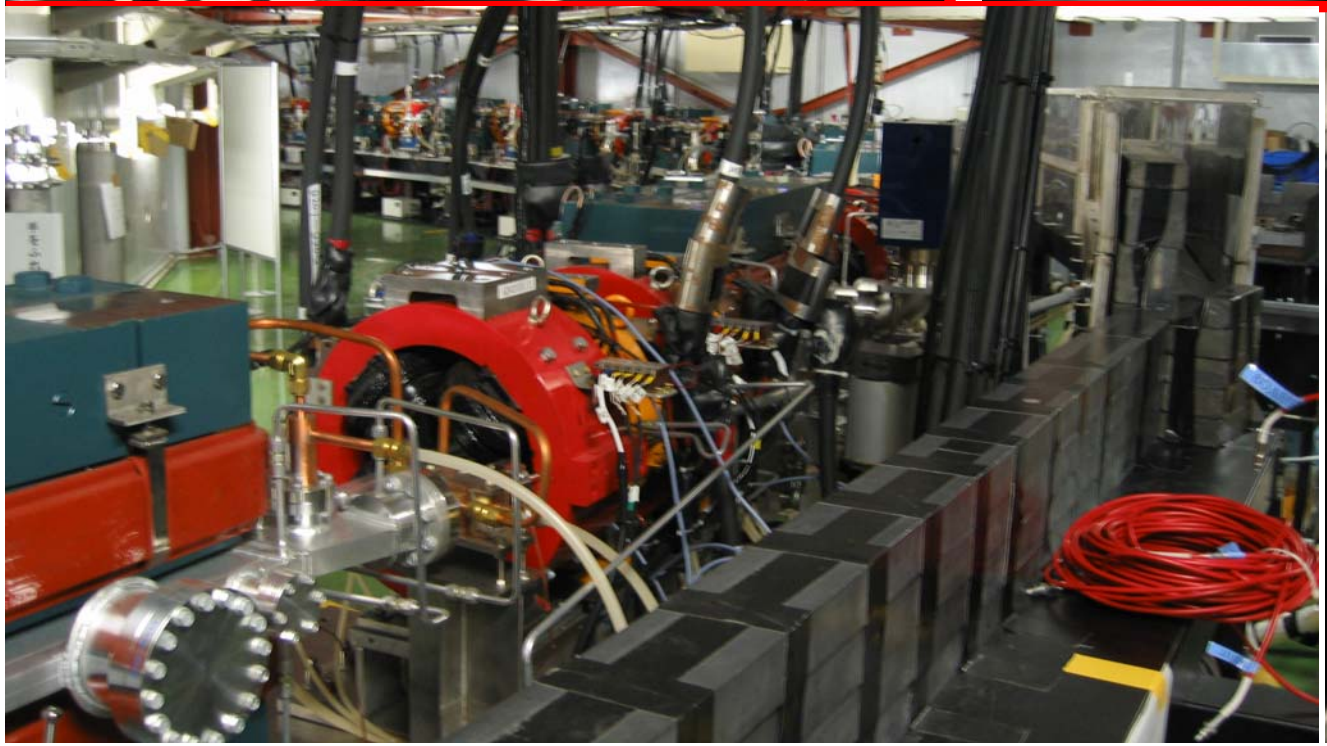
Experimental layout

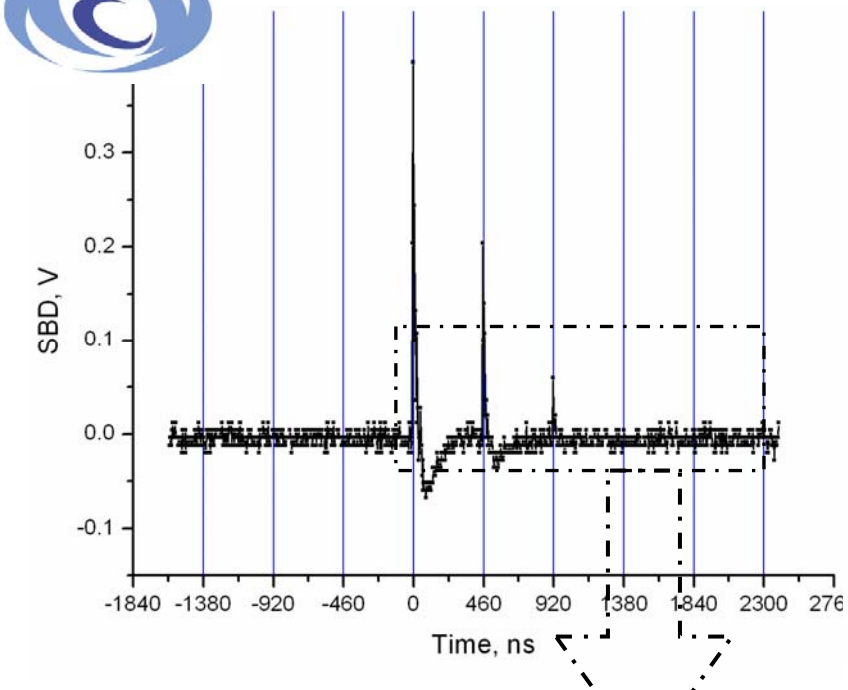
Waveguide corner block

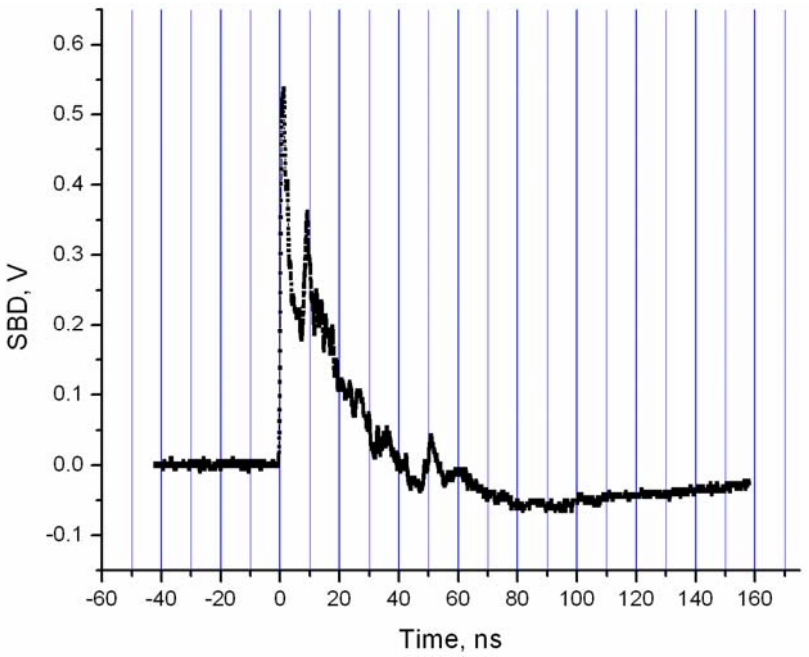


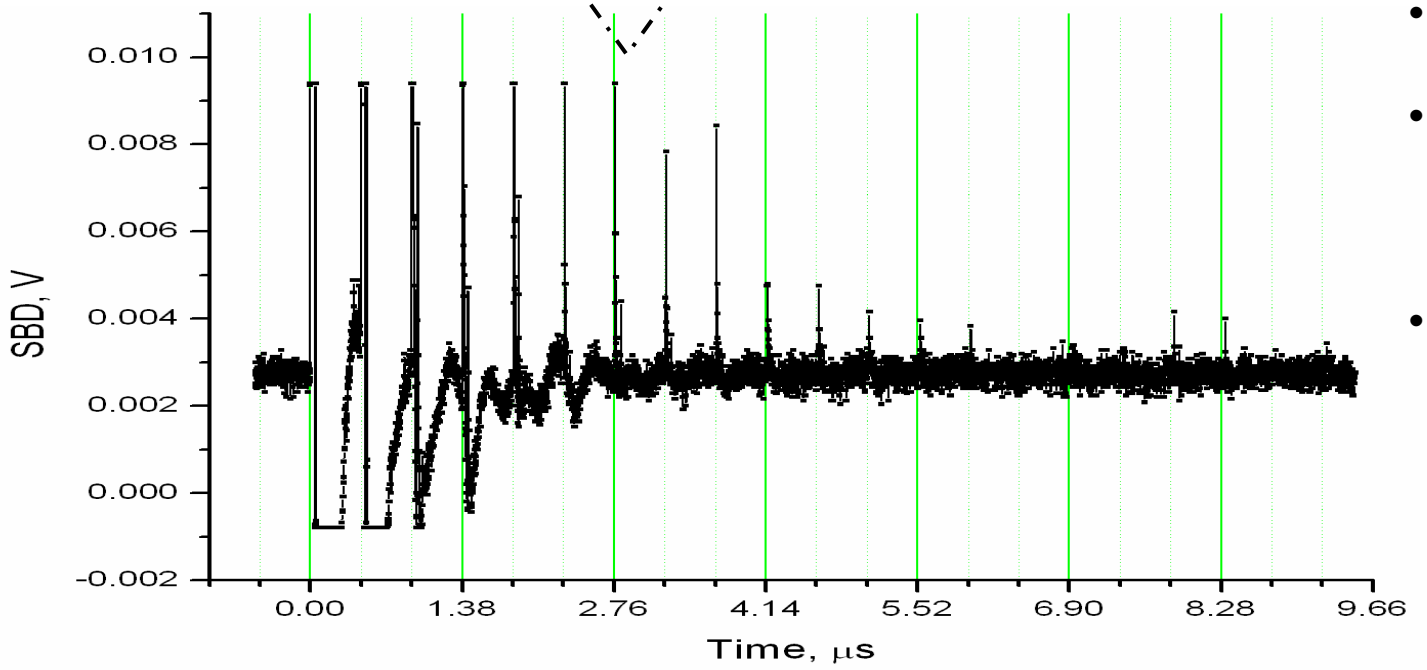
Wiggler







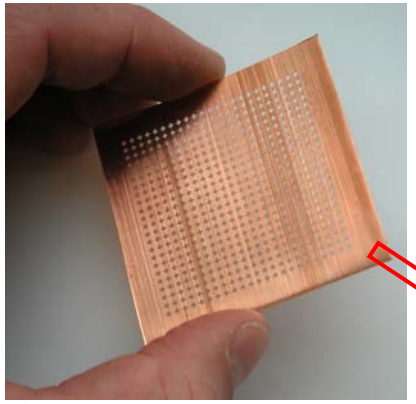


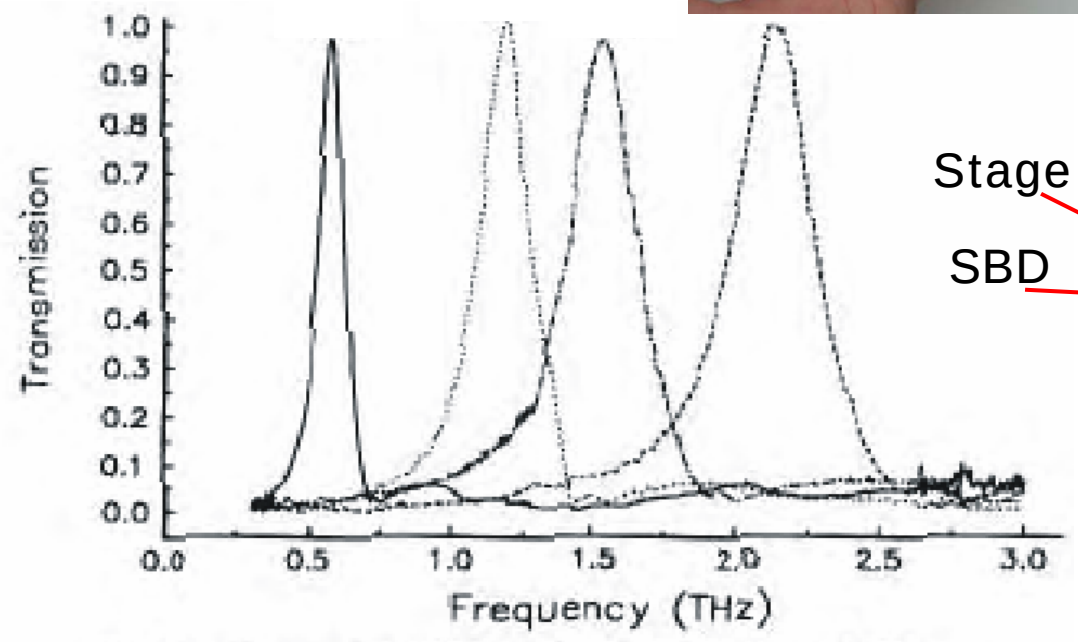


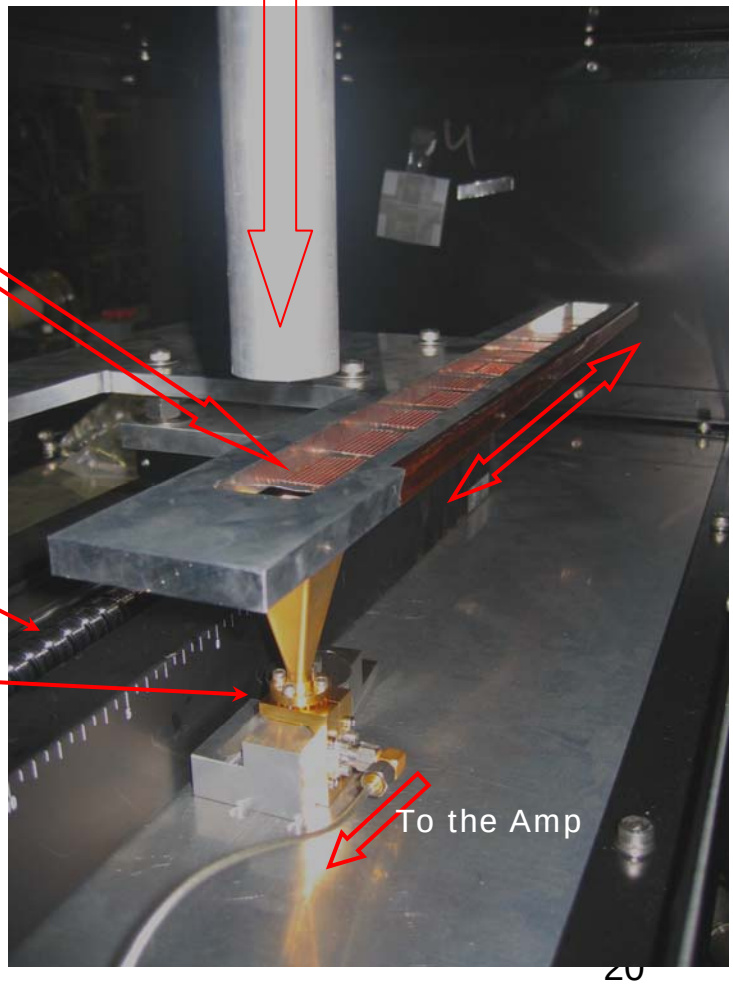
- The signal is wider and the amplitude is bigger
- We can see more turns even with +15dB amplification
- Reflections

Spectrometer

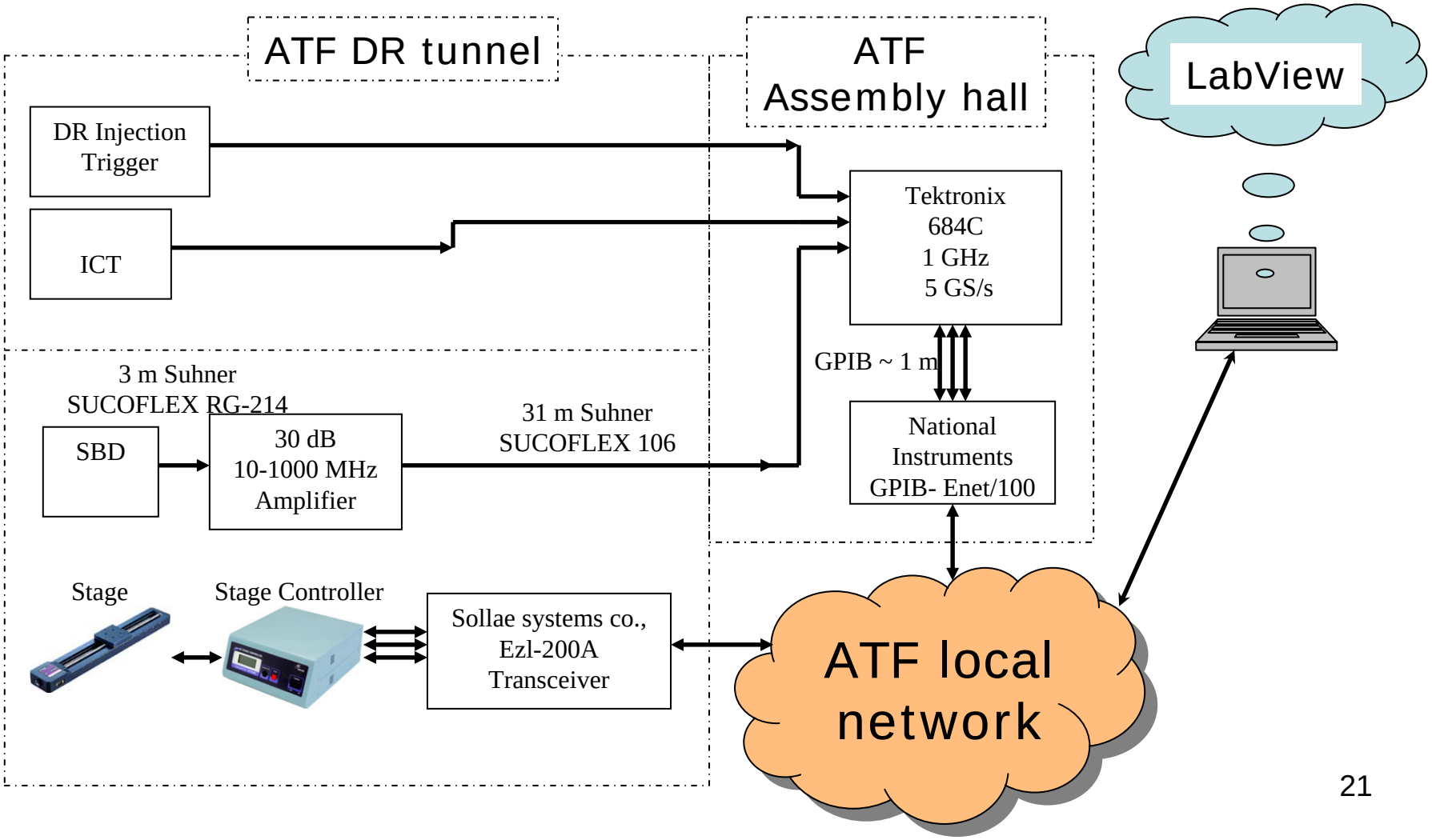
Set of 11 Mesh Filter
Freq. range 90 to 140GHz with 5GHz step on center frequencies
Specifications: 3dB attenuation at ± 5%
From center frequency
Center frequency transmission 100%
Dimensions: 30mm X 30mm



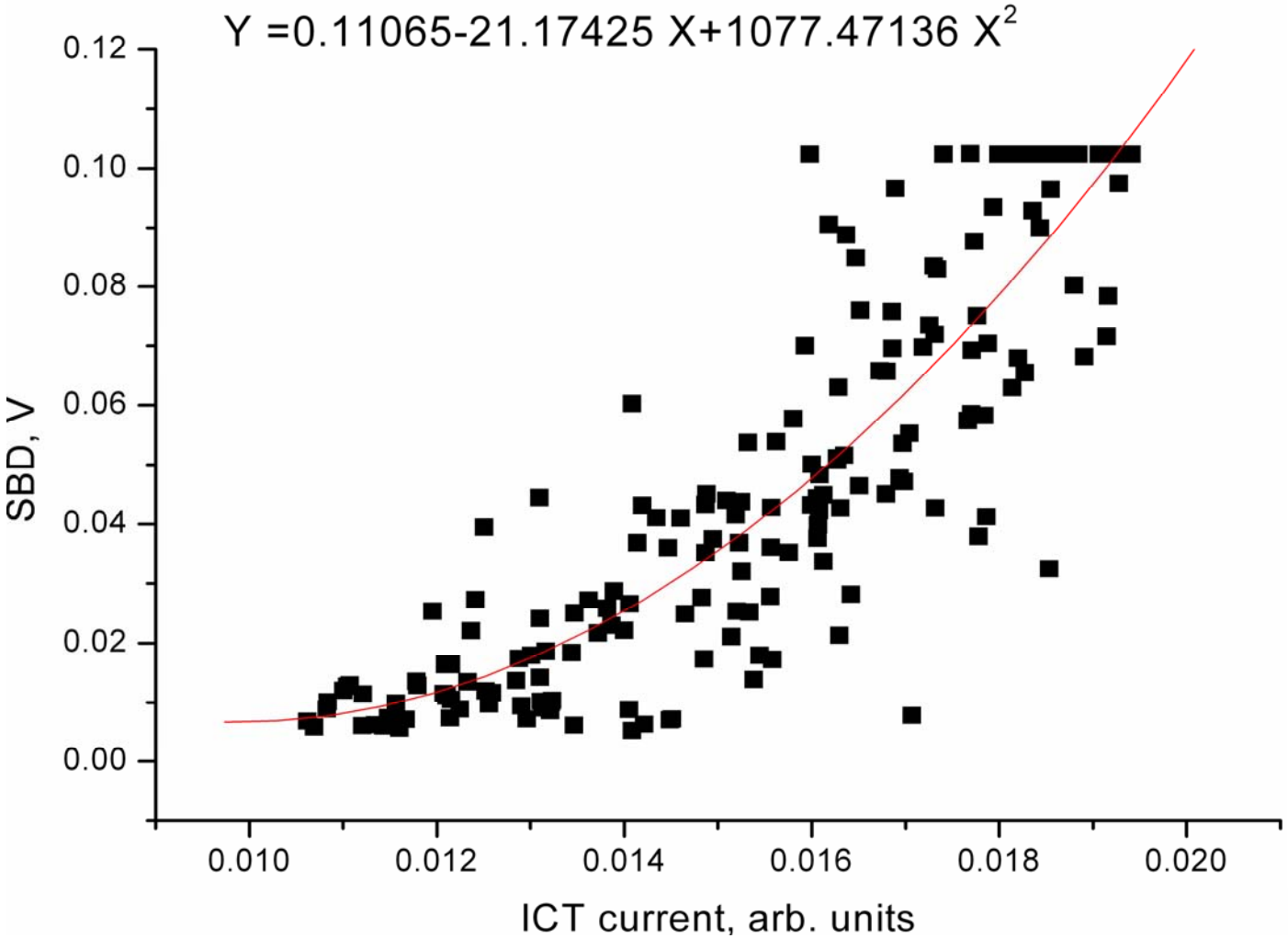




Present DAQ

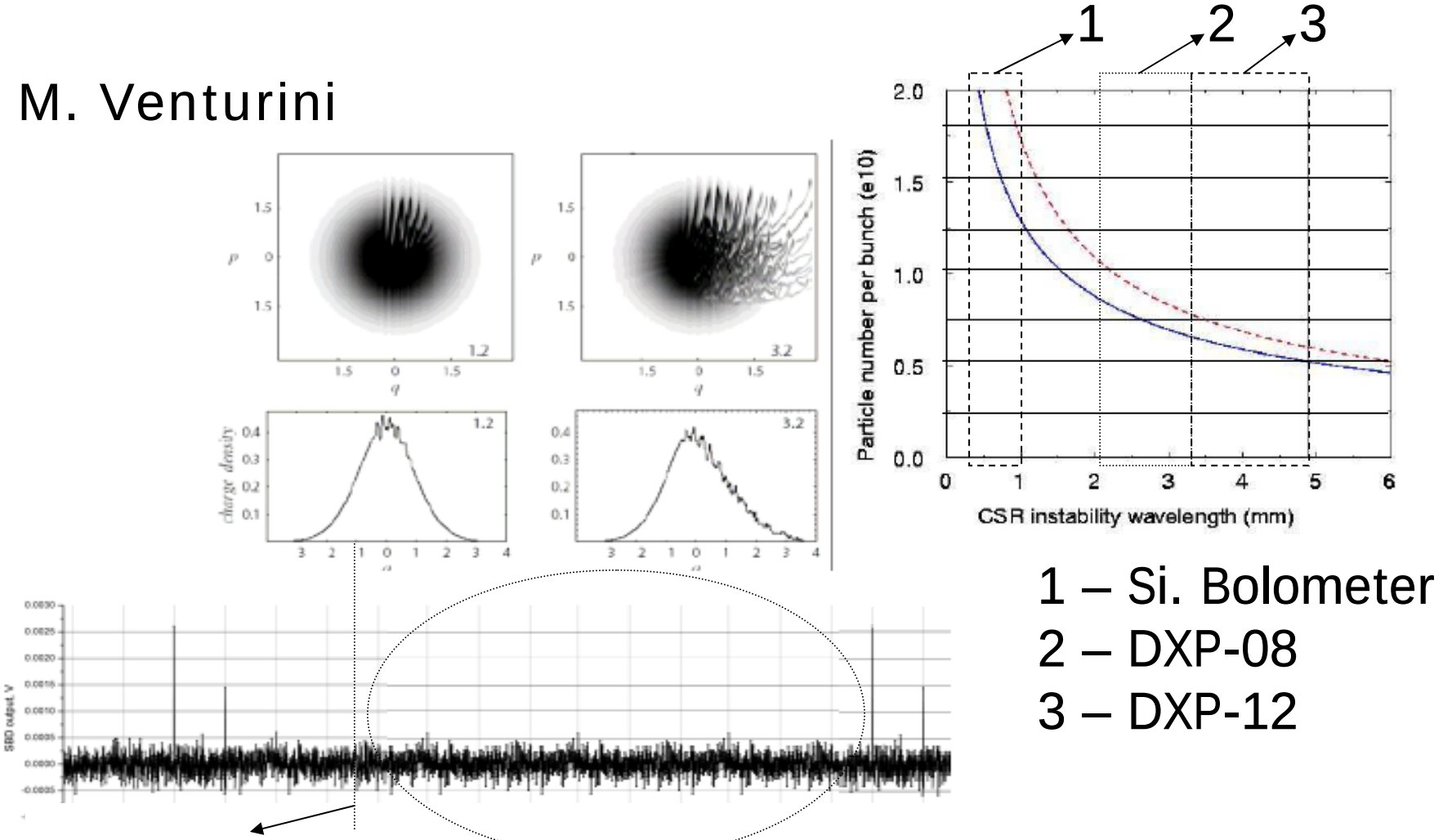

ATF DR tunnel
ATF
Assembly hall
LabView
DR Injection
Trigger
ICT
Tektronix
684C
1 GHz
5 GS/s
GPIB ~ 1 m
3 m Suhner
SUCOFLEX RG-214
SBD
30 dB
10-1000 MHz
Amplifier
31 m Suhner
SUCOFLEX 106
National
Instruments
GPIB- Enet/100
Stage
Stage Controller
Sollae systems co.,
Ezl-200A
Transceiver
ATF local
network

Current dependence



Basic Ideas to find an Instabilities

M. Venturini



1 – Si. Bolometer
2 – DXP-08
3 – DXP-12

Damping time

Searching area

Measured data

- ✓ Electron bunch current dependence of Synchrotron Radiation for different RF Gun Laser Phase (for both detectors). As an indication for coherent emission, the radiated power should grow with the square of the beam current. We confirmed it at the ATF damping ring.
- ✓ Spectrum of CSR:

  for different RF Gun Laser Phase

  for different electron bunch currents
- ✓ Searching for Micro-bunching-like instabilities

SBD conclusion

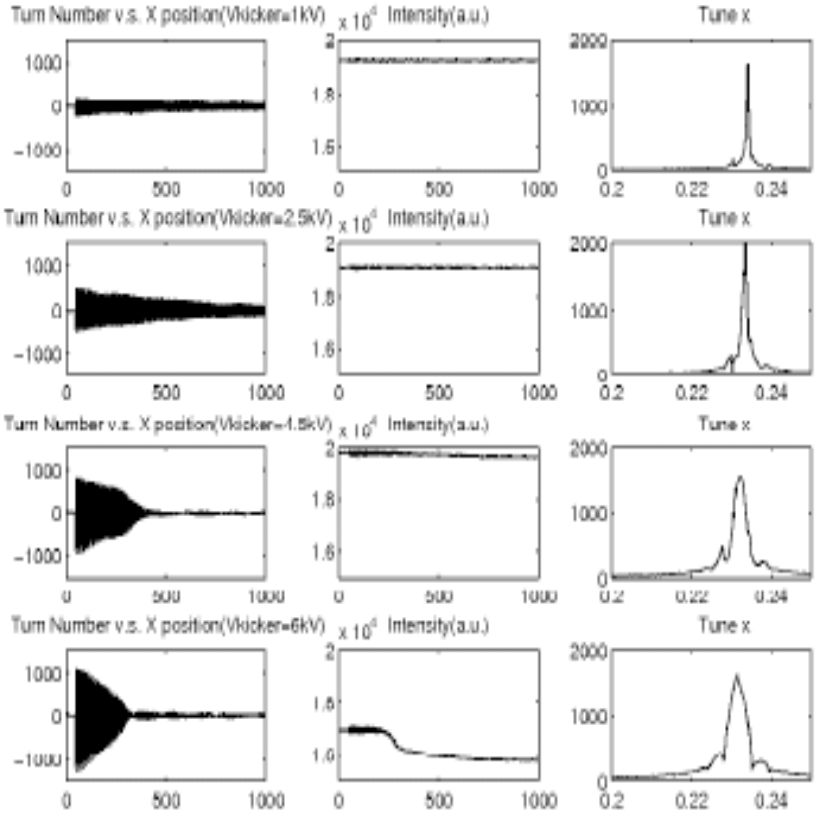
The SBD itself is very high-speed, easy-to-use, but maybe not enough sensitive device. In order to compensate the disadvantageous and take advantageous we need to:

- improve signal-to-noise ratio of SBD
- reject high frequency noise as well as a 50 Hz noise
- find out power calibration of SBD (already ordered)
- check ICT linearity (It is also possible to use BPMs as a current monitors (sum of 4 electrodes signal is proportional to the e-current)
- Further LabView software debugging

New powerful data acquisition system will be installed in Nov..

Tektronix, DPO7000, 20GS/sec, 500MHz to 7.25GHz,
1msec continuous signal measurements just after triggering
In the step of 100psec for fast kicker study.

Single kick result(Horizontal)



Single kick result(Verticall)

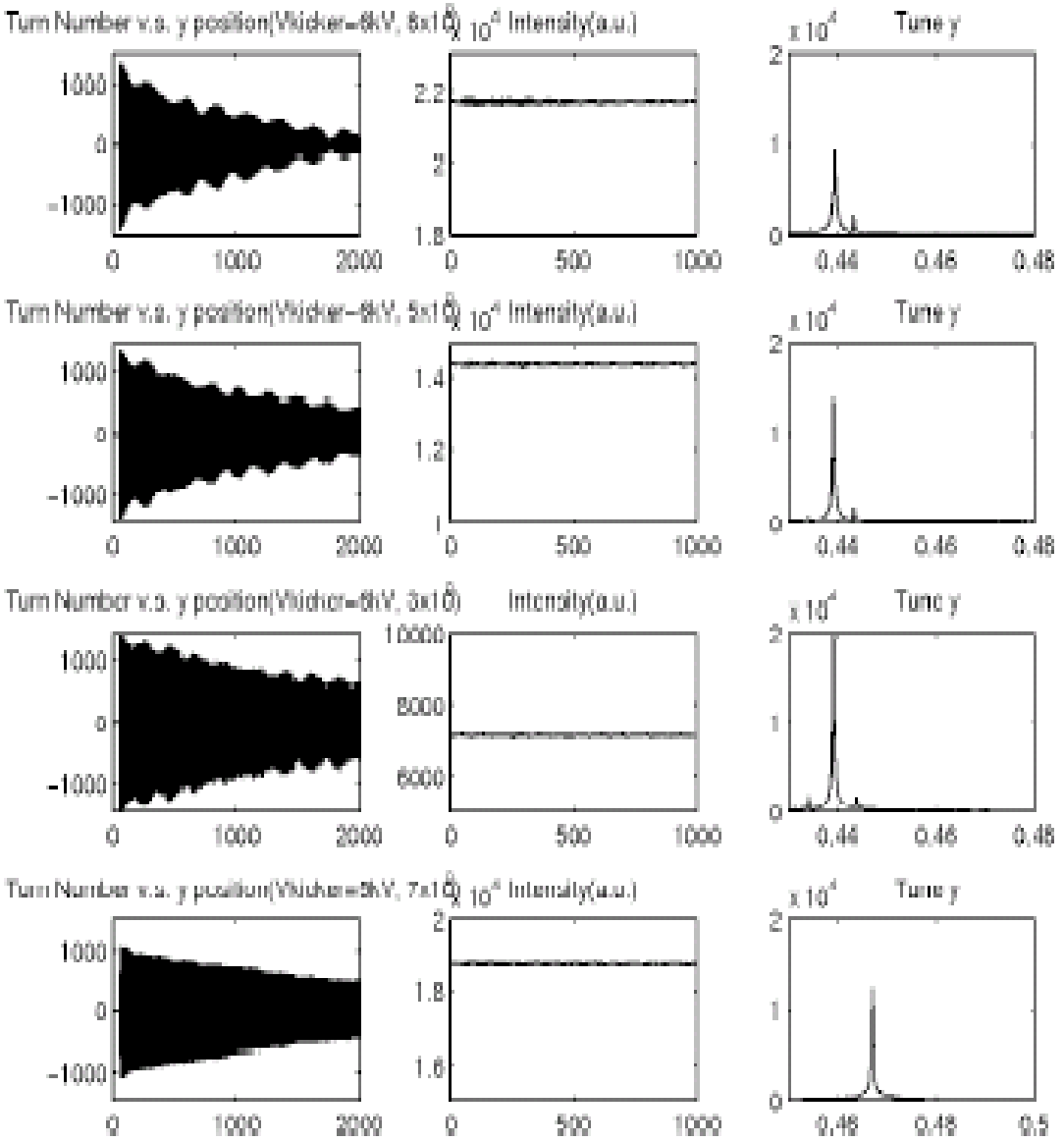


Fig.1, x vs. turn number for various initial kick angle, 0~300 turns

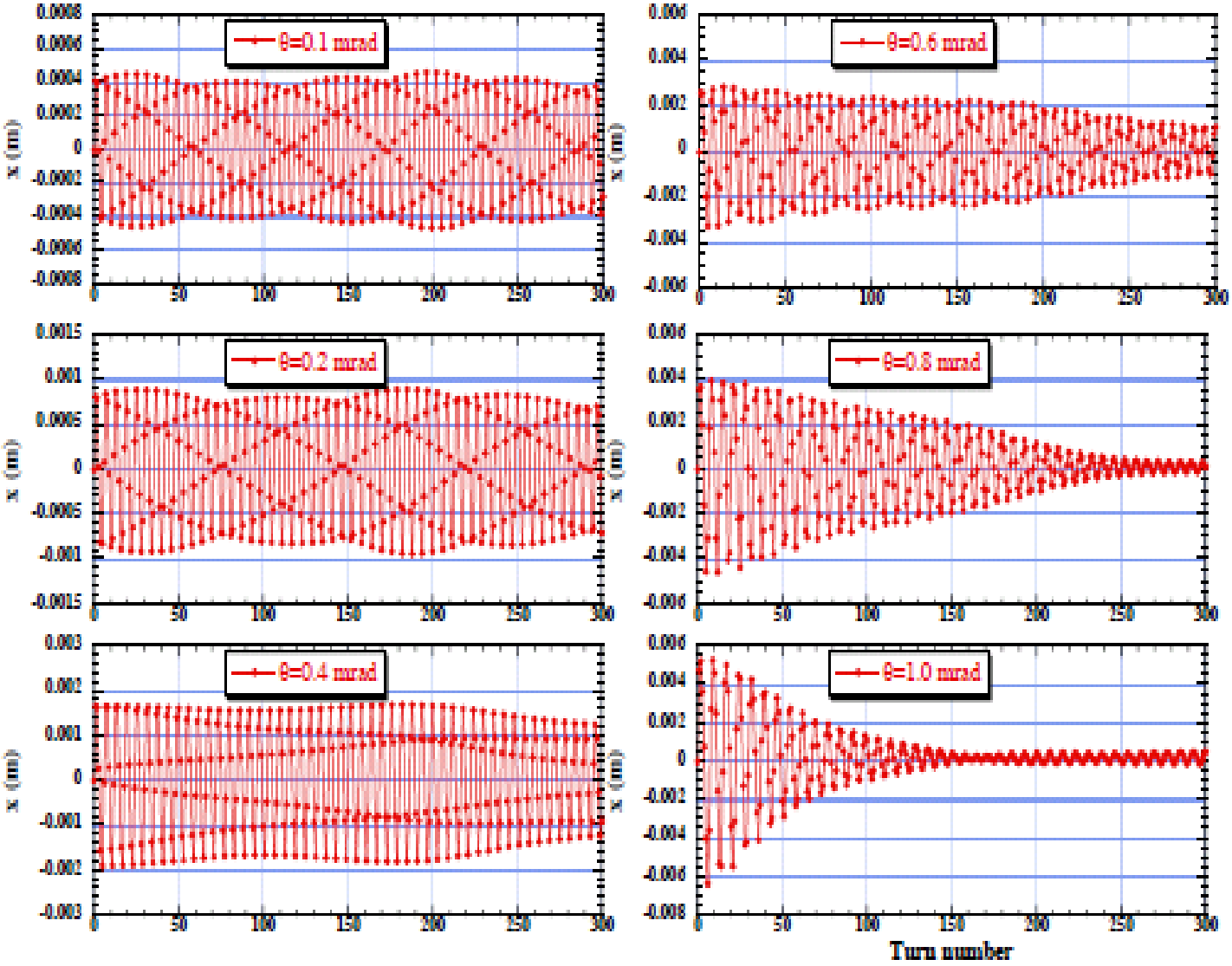


Fig. 3, Horizontal phase space distribution for large amplitude, turn 0 ~ 60

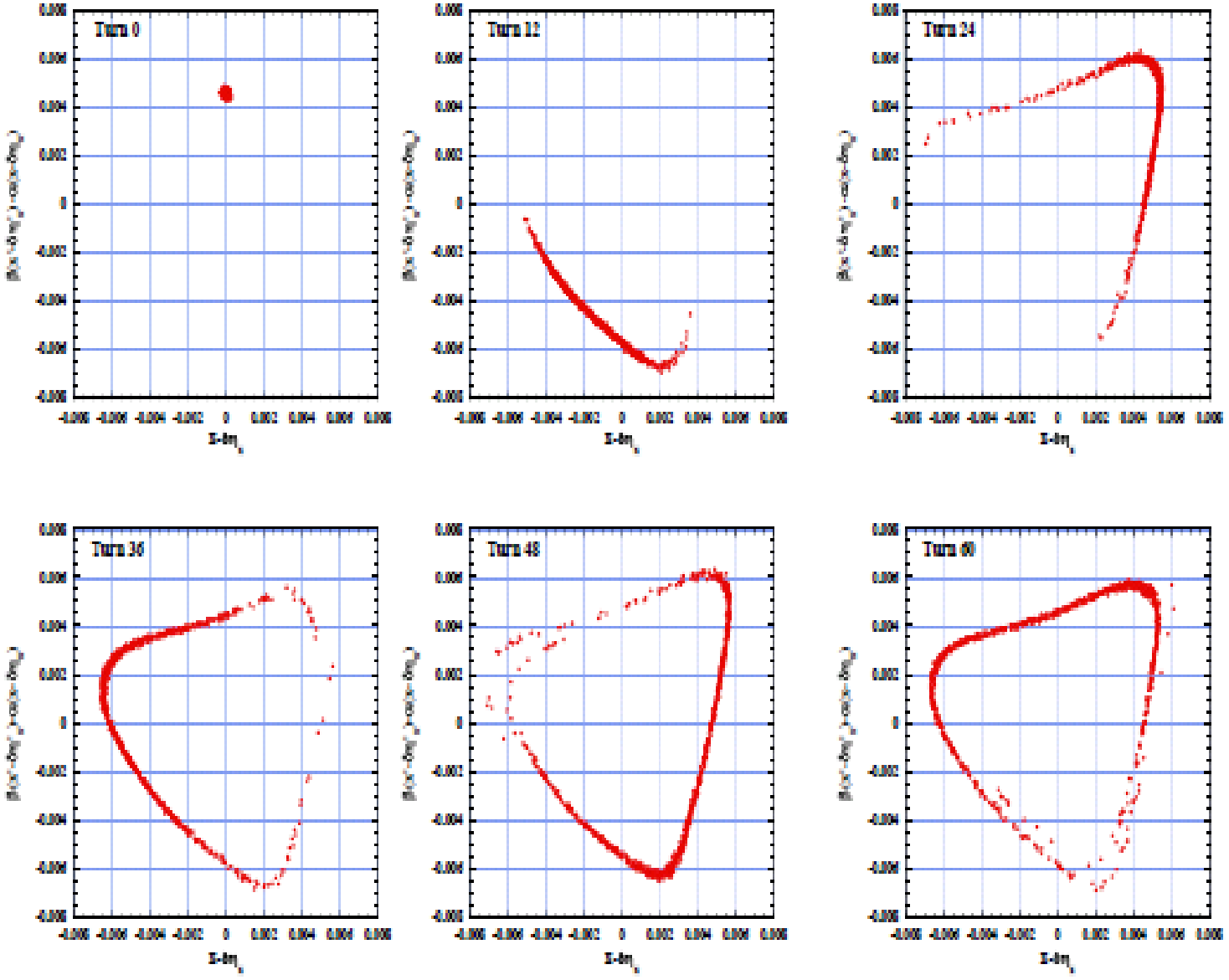
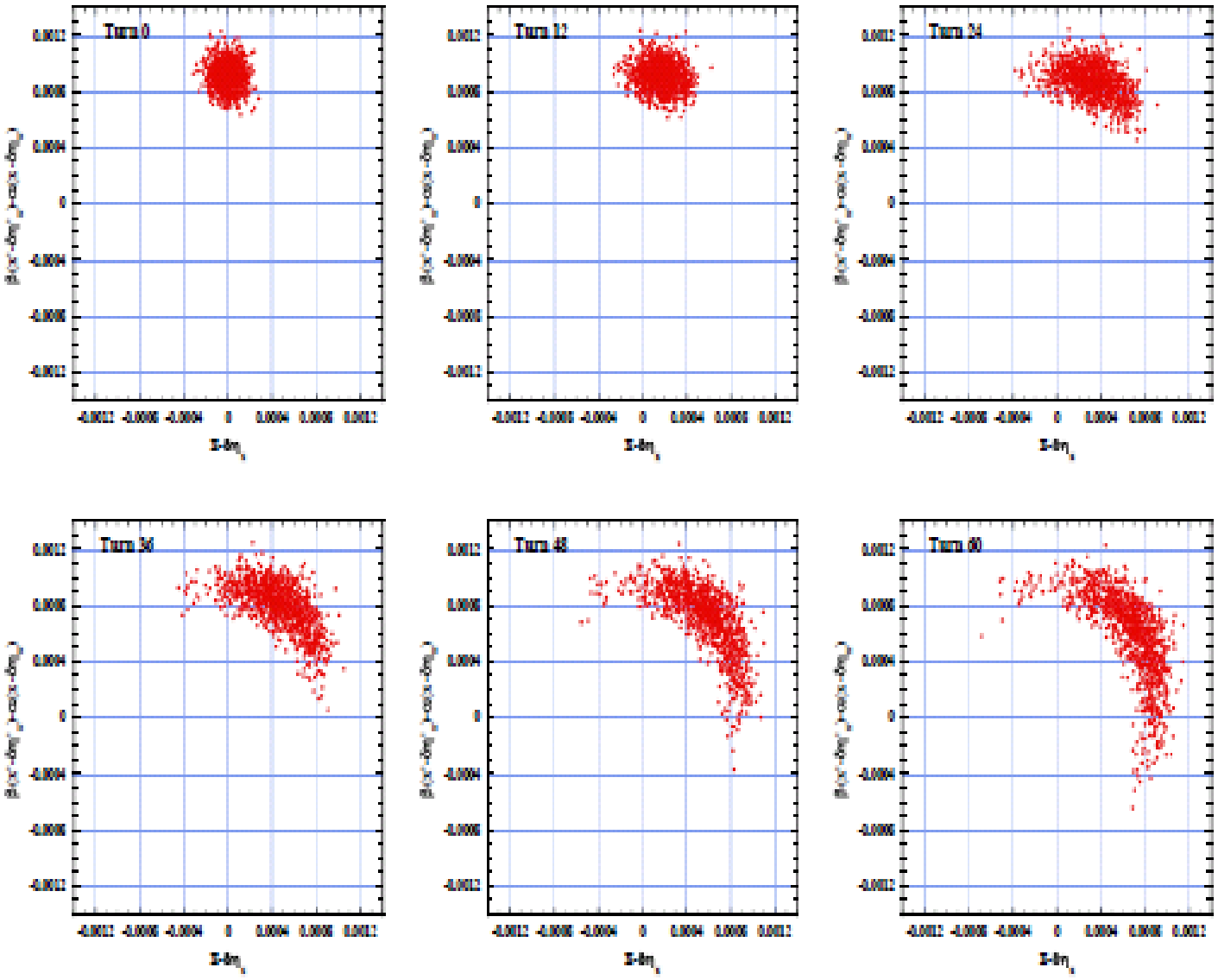


Fig. 4, Horizontal phase space distribution for small amplitude, turn 0 ~ 60



Future plans for CSR study

1. Study SBD detector noise as a function of its temperature.
2. Replace an existing amplifier with the low-noise one.
3. Introduce SBD signal noise rejection electronics.
4. Integrate CSR DAQ into ATF Main Software in order to synchronize ATF DR energy spread measurements, streak camera DR bunch length measurements and SBD detection system.
5. Recover a streak camera measurements.
6. Measure the electron beam energy spread synchronously.
7. Study Bunch lengthening in ATF DR.
8. Absolute power measurements.

Experimental Plan for study on bunch lengthening

Precise energy spread measurement at the extraction line
Accurate bunch length measurement systematically
Precise transverse emittance measurement
The range from several 10^9 to $3x10^{10}$ electrons/bunch
Precise tune measurement versus the bunch intensity
The measurement of CSR
Accurate beam position measurement during 1msec in the step of 100psec ; huge data will be obtained.

Appropriate period is Jan., Feb. and March in 2007 because all instrumentations require the check and fine tuning for three months from now and fast kicker R&D has first priority.
Anyway, I want to finish the study of bunch lengthening and CSR within 2007 and 2008 at ATF.