Commissioning of the KEKB B-Factory

MAC2001
February 23, 2000

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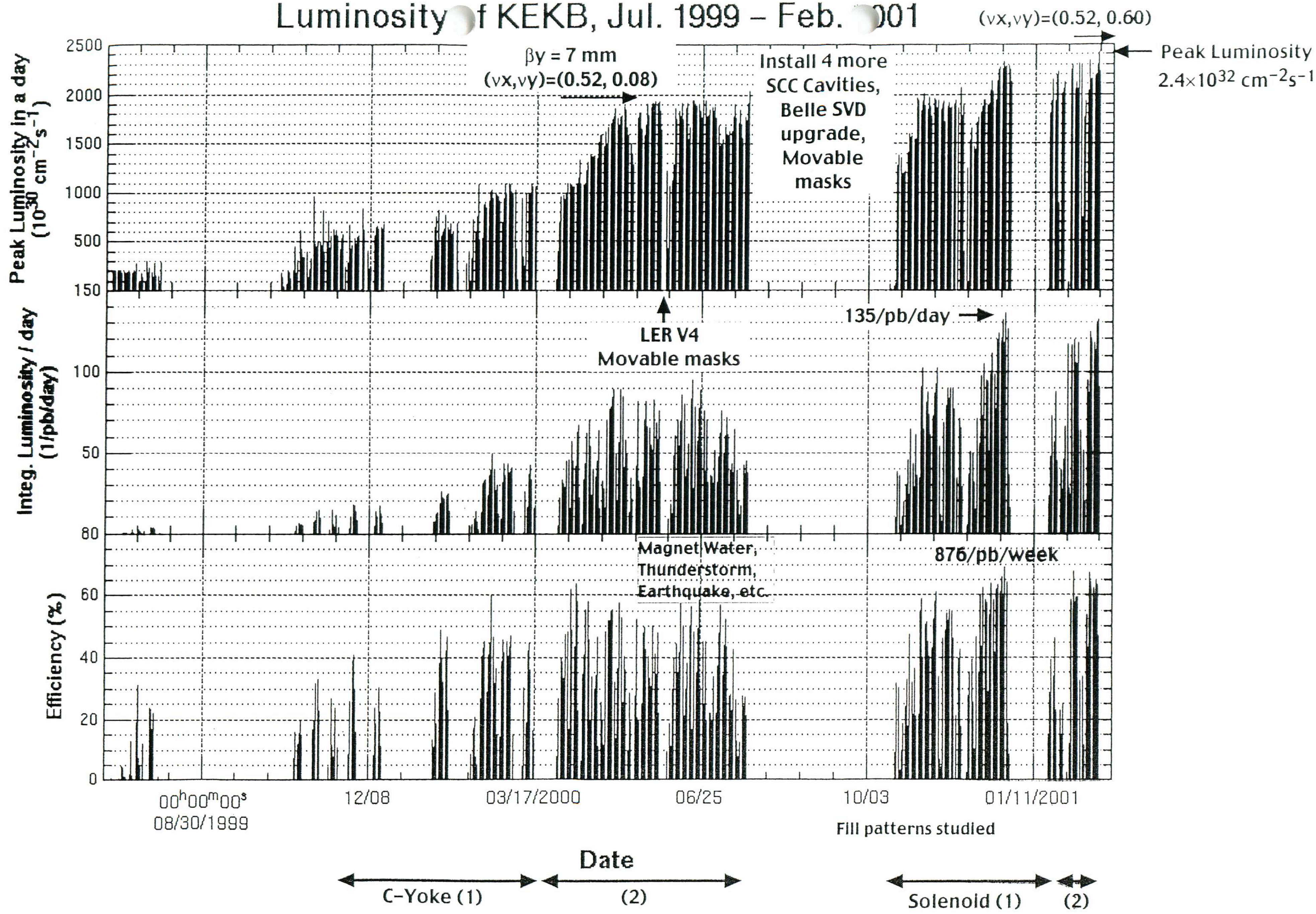
**Thank E. Perevedentsev, Y. Z. Wu, F. Zimmermann,
and all members of Belle/KEKB/KEK.**

Luminosity of KEKB, Jul. 1999 – Feb. 2001

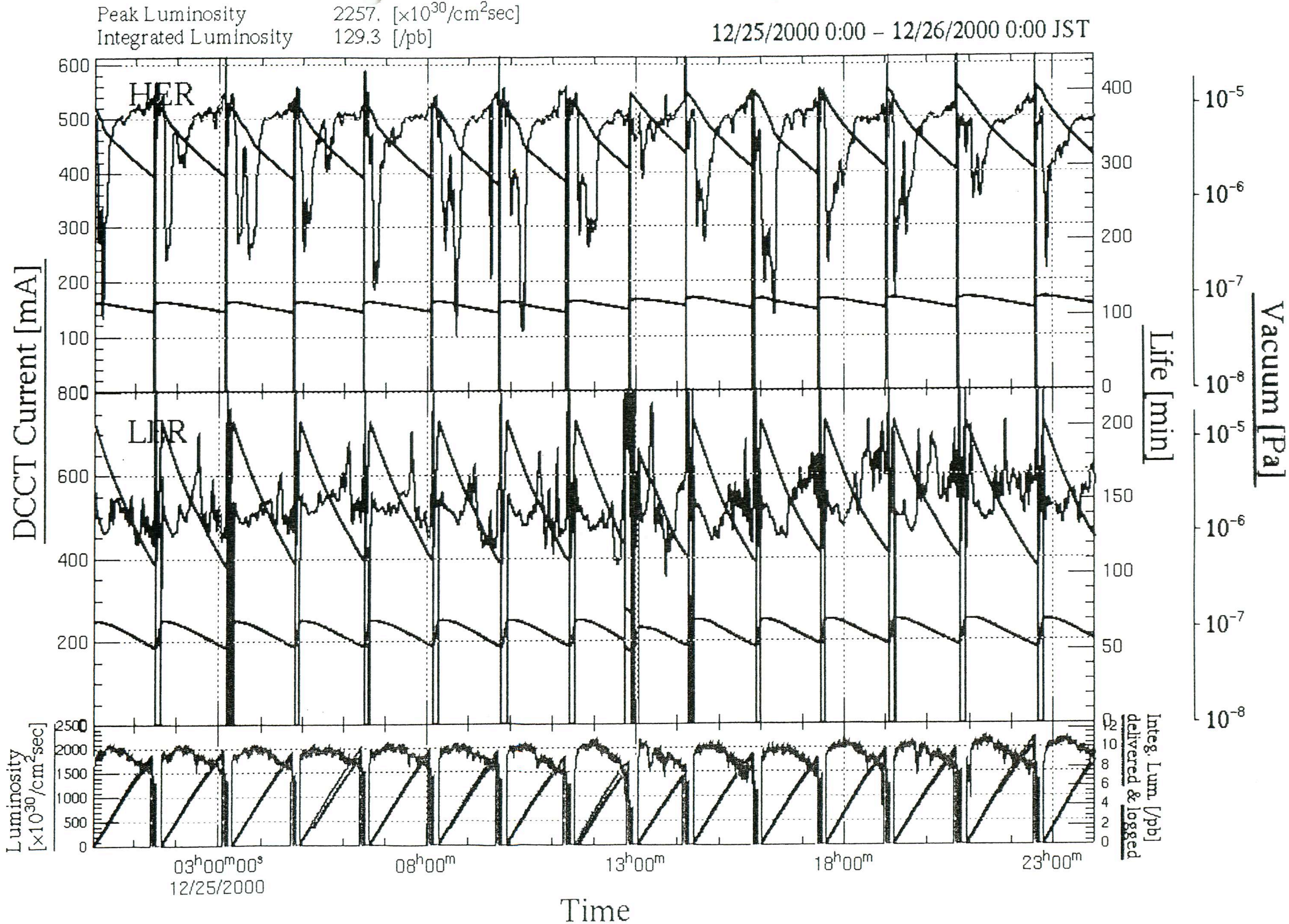


Machine parameters of the KEKB

(At the maximum peak luminosity recorded on Feb. 19/2001)

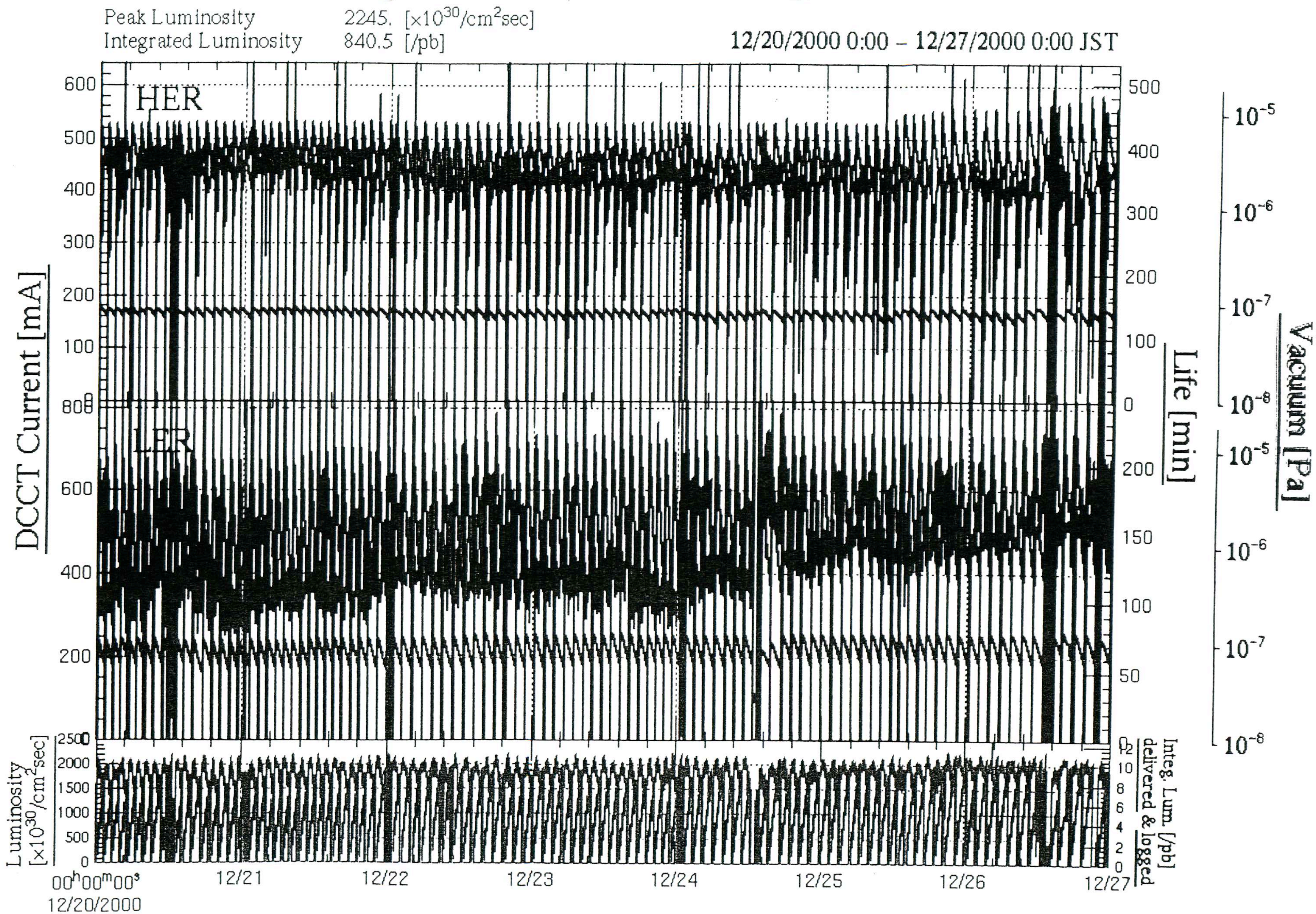
	LER	HER	
Horizontal emittance	18	24	nm
β_x^* / β_y^*	0.59/0.007 (0.33/0.01)	0.63/0.007 (0.33/0.01)	m
Beam current	677	559	mA
# of bunches/ring	1153 (2700)		
Bunch curret	0.596	0.484	mA
# of trains	1	1	
# of bunches/train	1153	1153	
Bunch spacing	8 (2)	8 (2)	nsec
Bunch length (calc)	5.5@6.0	5.7@11.0	mm@MV
ξ_x / ξ_y	0.052/0.027 (0.039/0.052)	0.038/0.023 (0.039/0.052)	
ν_x / ν_y	45.513/43.574 (45.52/44.08)	44.519/41.617 (44.52/42.08)	
Lifetime	120@677	274@559	min@mA
Luminosity from Belle CsI	$24.7 * 10^{32}$ $(1 * 10^{34})$		/cm²/sec

The Best Day



Peak Luminosity 2257. [×10^30/cm^2sec]
Integrated Luminosity 129.3 [/pb]
12/25/2000 0:00 – 12/26/2000 0:00 JST
HER
LER
DCCT Current [mA]
Life [min]
Vacuum [Pa]
Luminosity [×10^30/cm^2sec]
Integ. Lum. [/pb] delivered & logged
03h00m00s 12/25/2000
08h00m
13h00m
18h00m
23h00m
Time

The Best Week



Progress, Mar. 2000 – Feb. 2001

1. Better collision parameters:

- Reduce βy^* to 7 mm.
- Betatron tunes around (0.52, 0.08) since Mar. 2000, and (0.52, 0.60) since Feb. 2001.
- Higher HER current than the energy transparent condition (necessary when LER current is limited by the single–beam blowup).
- Asymmetric LER/HER emittances.

2. Suppression of single–beam blowup by the C–Yoke and Solenoid:

- Blowup due to head–tail was enough suppressed, but ...
- The "slow" blowup remains to limit the specific luminosity as a functin of LER total current.

3. Sophistication in the tuning of luminosity:

- Dispersion/x–y coupling/beta–beat correction.
- Continuous orbit correction (every 20 seconds).
- IP orbit feedback by 4D dipersion–free steering.
- Programmed beam size control to minimize the flip–flop, using the interferometers and a bump orbit.
- Programmed betatron tune changers.
- Programmed ... changers.
- IP dispersion/crossing angle/x–y coupling knobs.
- More diagnostics (interferometers, gated camera, gated tune meter, bunch–by–bunch oscillation, photo–electron monitors, etc.).

4. Improved Macine Stability:

- Improved efficiency up to 70%.
- New V4 movable masks in LER = virtually no current limit to store in LER.
- Improvements in magnet cooling water system.
- Improvements in machine protection/abort system against earthquake, magnet failure, beam loss, rf trip, etc.

5. Stable injection

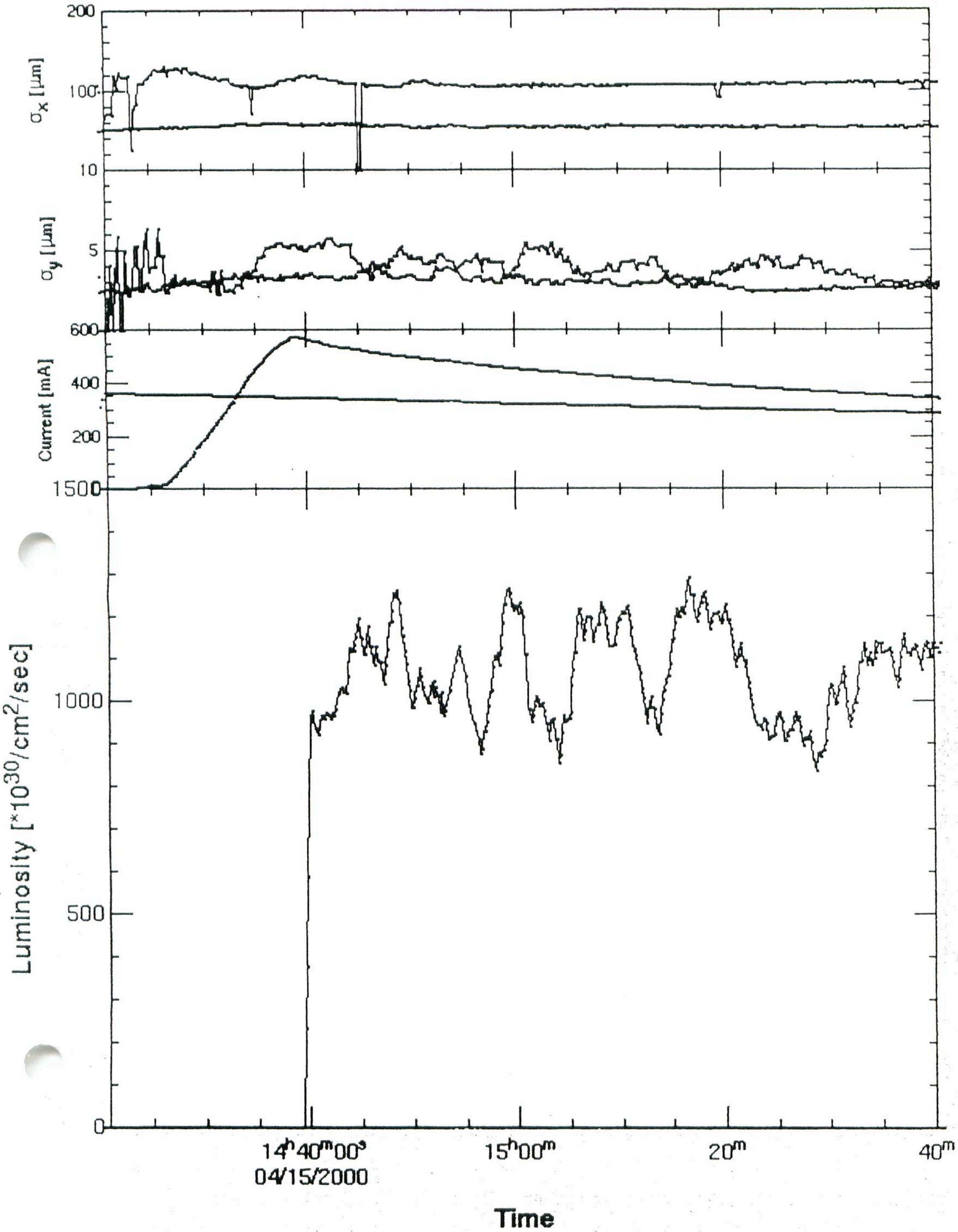
- Improved injection rate up to 2 mA/s for positron, 4 mA/s for electron.
- Many feedbacks in Linac and Beam Transport.
- More diagnostics (wires, streak cameras, etc.)

6. Other improvements

- More SCC cavities to have the capability to store the design current in HER.
- Stability in the control system.
- Improved data logging system.

- People, esp. the operators from Mitsubishi, were trained day by day.

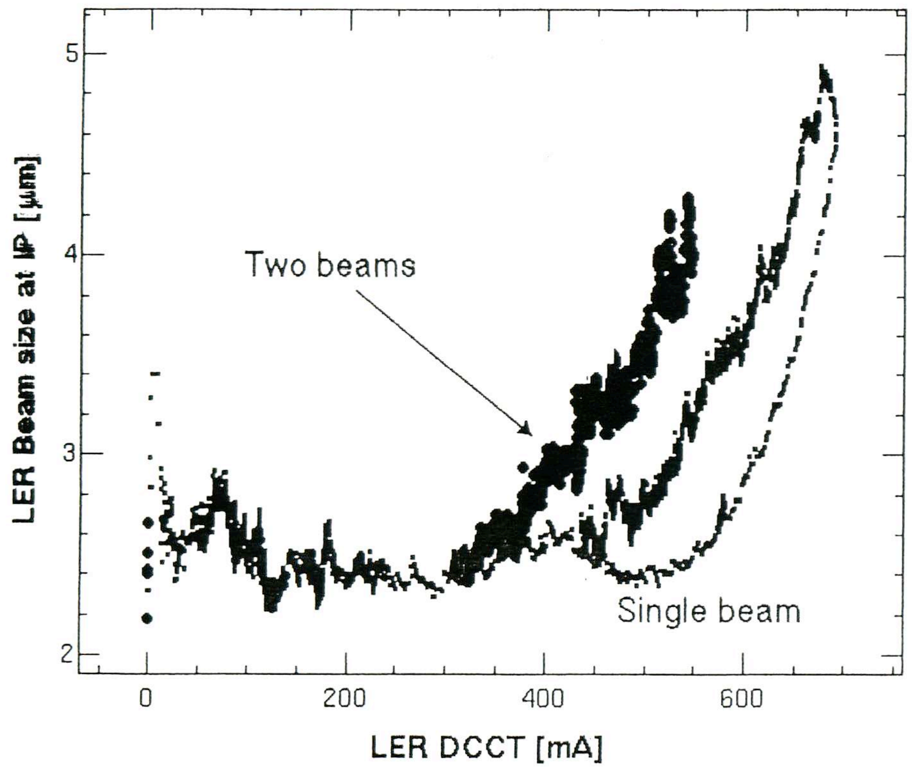
Fill: 1141 Lum2000_4_15_12_9_45.dat

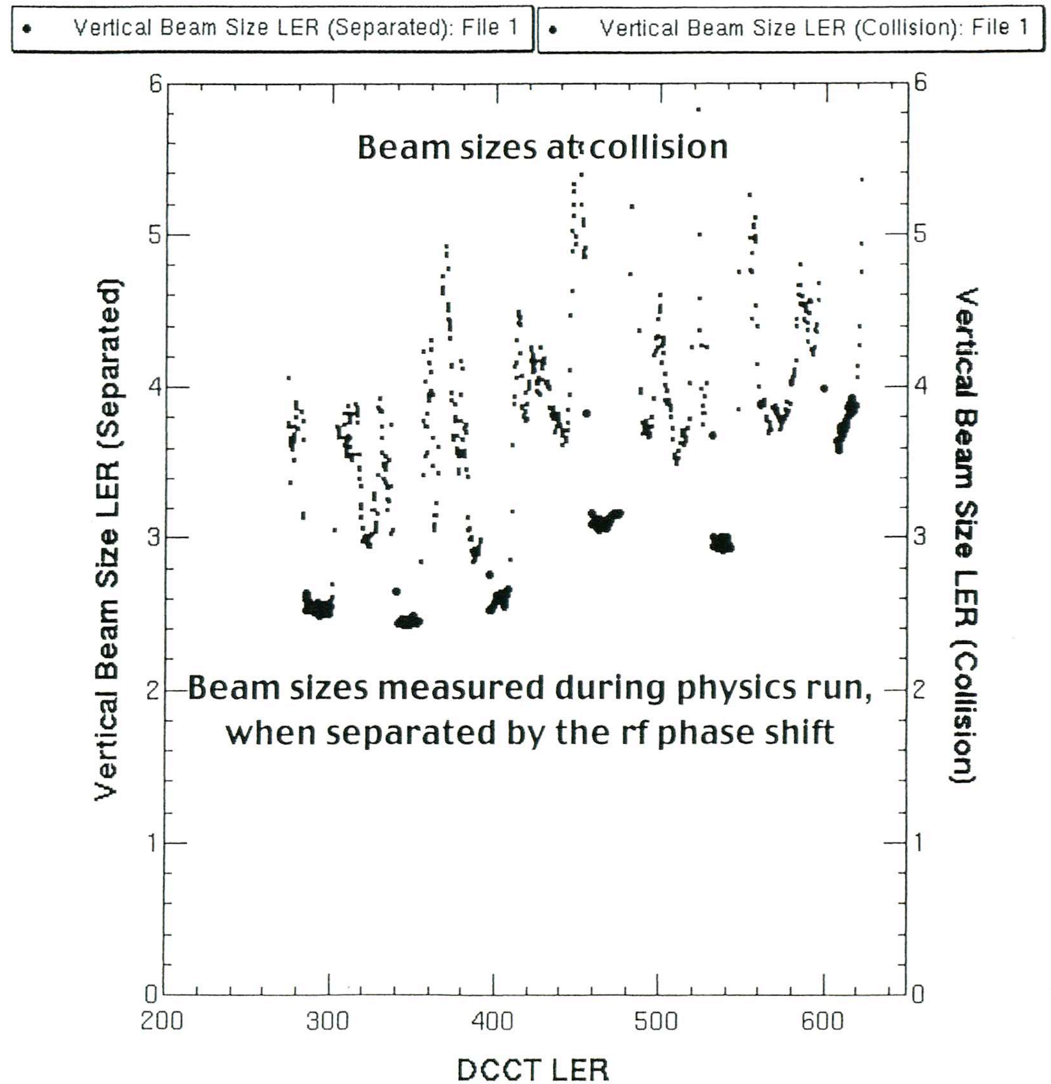


beam size at collision = single beam blowup + beam beam blowup

Single beam: mons_11_02_2000_22:21:36.dat
(16/80/4)

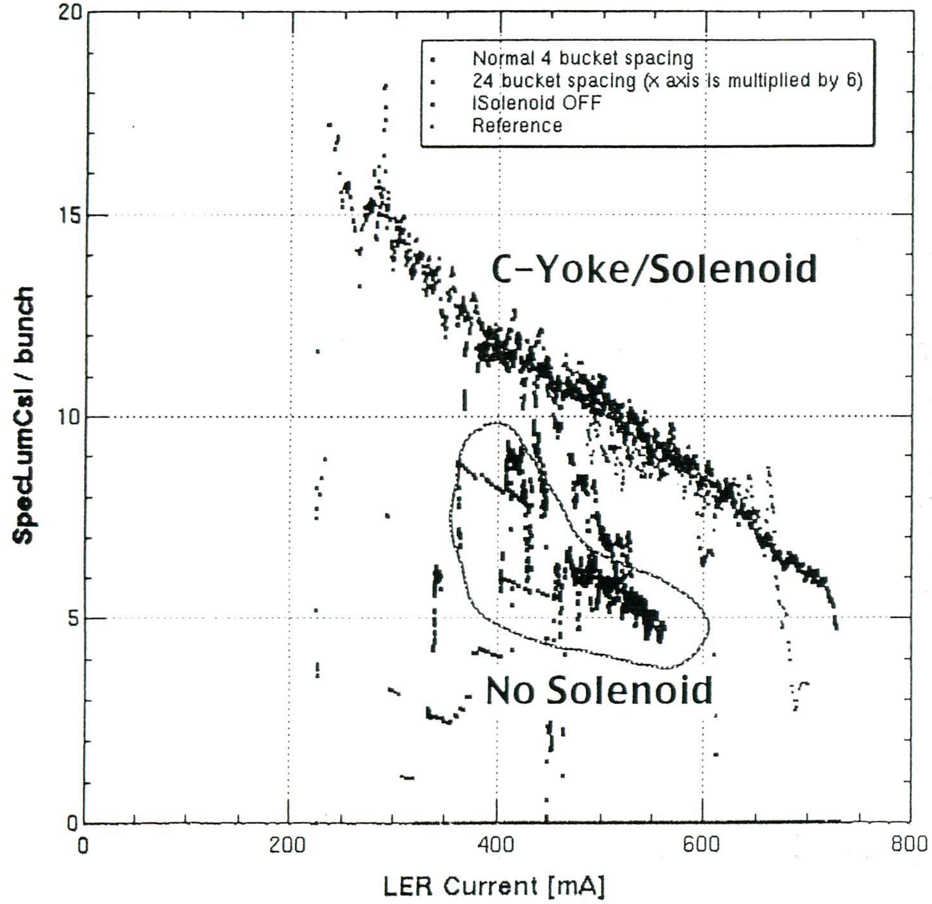
Two beams: Lum2000_11_2_7_58_11.dat
(16/80/4)



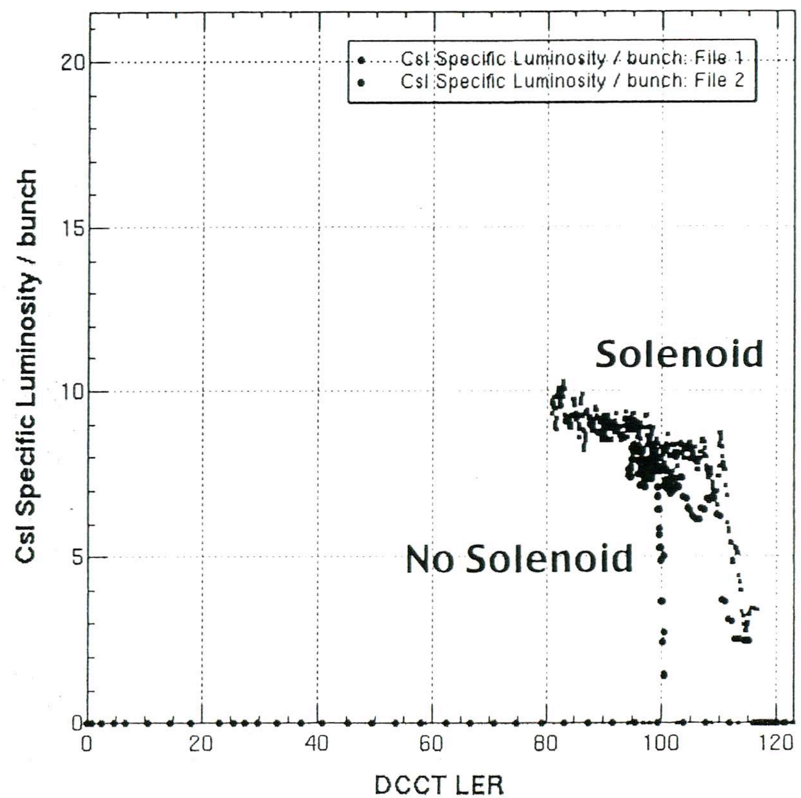


Effect of Solenoid/C–Yoke magnet

4 bucket spacing



24 bucket Spacing



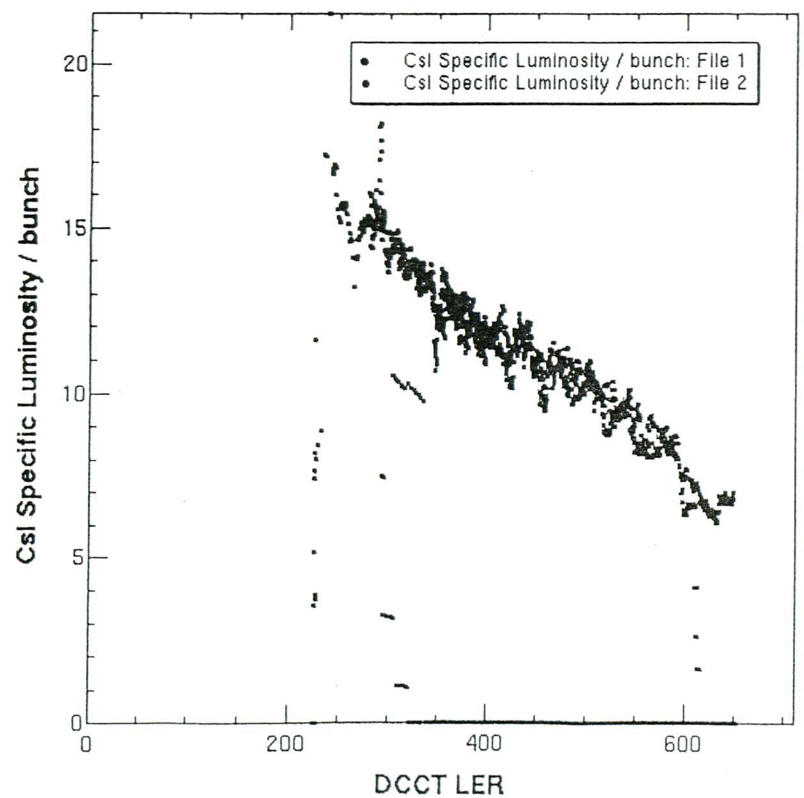
For longer bucket spacing, the effect of solenoid on the luminosity was weaker.

The specific luminosity/bunch (i.e. $1/\sigma_x\sigma_y$)

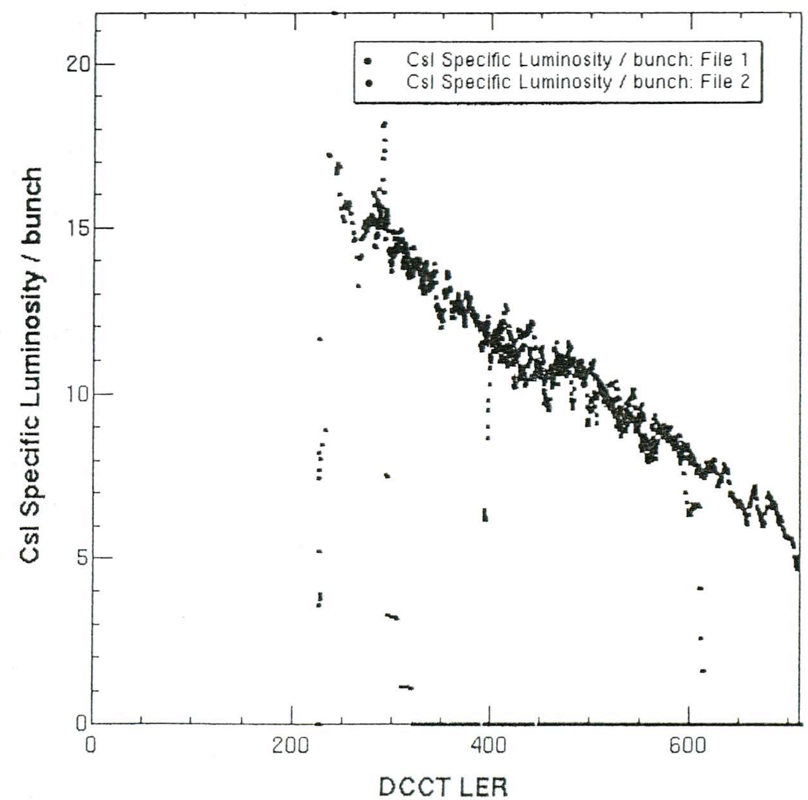
is a unique function of LER total current,

- **for 2,3,4-bucket spacings,**
- **same for C-Yoke and Solenoid.**

File 1	Fill#: 1426	m2000_5_9_8_21_34.dat	File 1	Fill#: 1426	m2000_5_9_8_21_34.dat
File 2	Fill#: 3094	Lum2000_12_3_20_14_6.dat	File 2	Fill#: 3180	Lum2000_12_10_17_18_31.dat



"1100" (red) & 4 bucket (green)



3 (red) & 4 (green) buckets

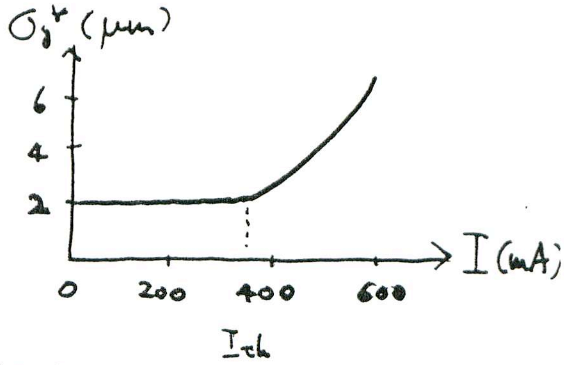
Items consistent with the single-bunch head-tail model (Zimmermann-Ohmi):

- Single beam phenomenon.
- Blowup depends on the single-bunch intensity.
- No dipole oscillation, at least in the low frequency region.
- The threshold scales by (bunch current)/(bunch spacing).
- No dependence on betatron tunes/optics.
- Blowup starts within 5-6 bunches at the head of a short train.
- The effect to the next train disappears by having 24-60 bucket gap, in the case of short train.
- The bunch-by-bunch tuneshift agrees with the model.
- No dependence on the vacuum pressure.
- The C-Yoke and the solenoid were effective.

Items cannot be explained by the single-bunch head-tail model:

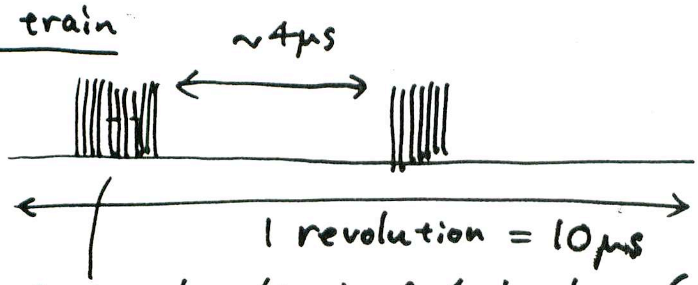
- Blowup starts at the head of the train, for a long train.
- The abort gap (500 buckets) is not enough to suppress the effect, for a long train.
- Slow blowup along a train exists, even with the solenoid field.
- The bunch by bunch luminosity becomes flat for I < 650 mA, while the specific luminosity continuously decreases as LER current increases.
- The blowup builds up with a time delay of 30-100 seconds.

Blowup of the vertical beam size in LER



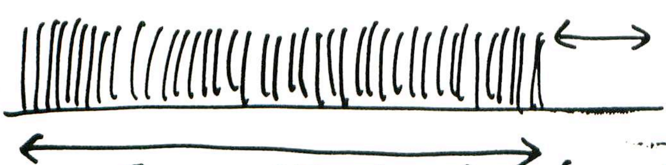
- single-beam effect
- no dipole oscillation ($\xi_y > 0$)
- no dependence on β-tron tunes
- no bunch-by-bunch orbit difference
- no dependence on β^*, ε_x
- no dependence on the vacuum pressure, with an artificial rise by ×100 - ×1000.
- no dependence on wiggler on/off at least at injection
- the threshold scales as N_b/S_b = (particles/bunch) / (bunch spacing)

<u>short train</u>



~ 60 bunches/train 2~4 bucket (4~8 ns) spacing

<u>long train</u>



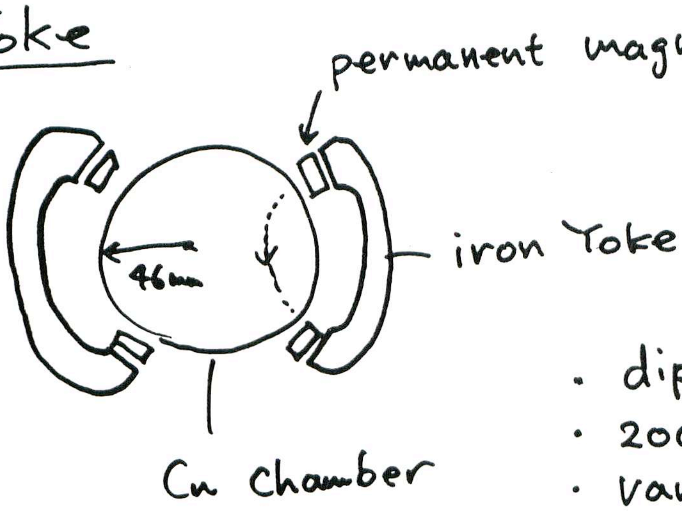
1150 bunches for 4 bucket spacing.

The model:

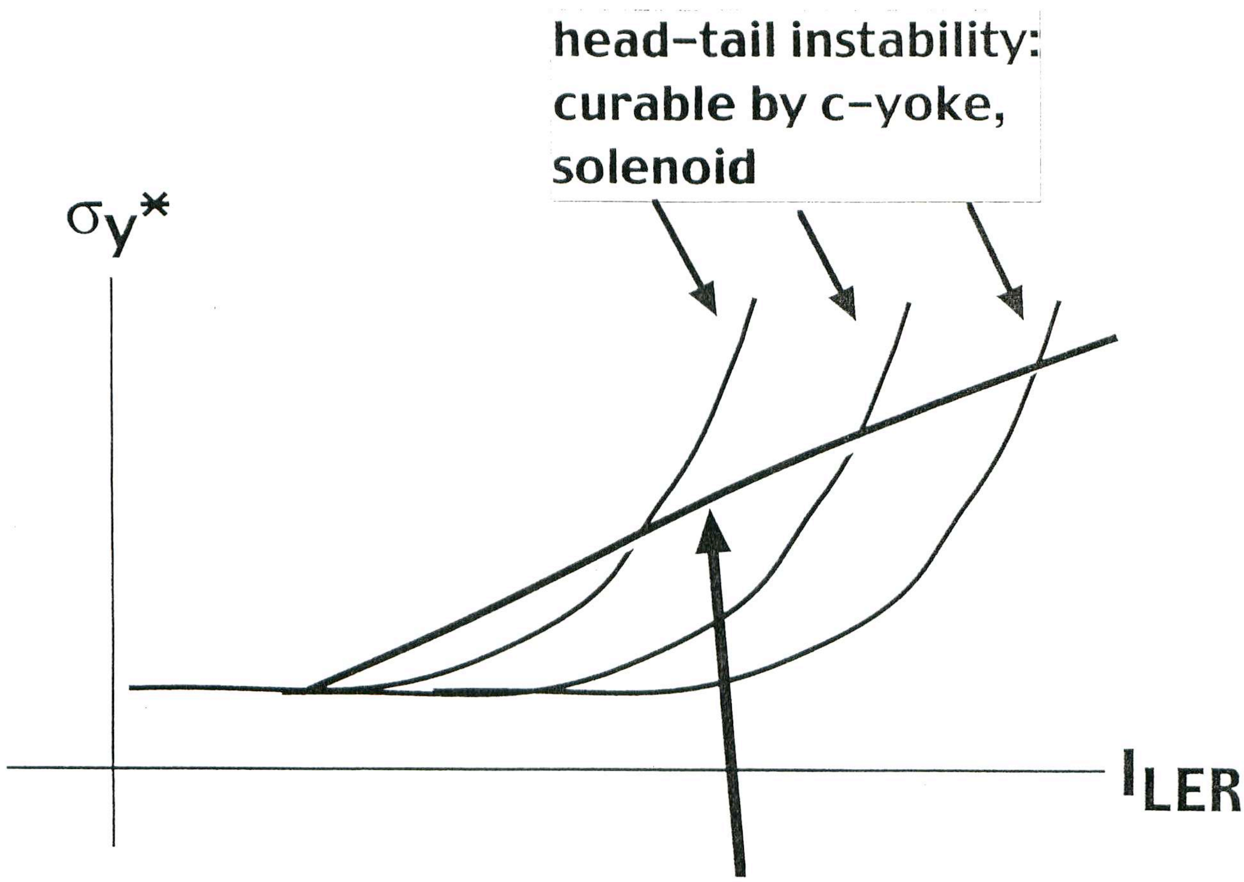
◉ Single-bunch head-tail instability caused by the photo-electron cloud (F. Zimmermann-K. Ohmi)

- consistent with the scaling of the threshold
- consistent with the bunch-by-bunch tune shift ($\Delta\nu_y \sim 0.01$)
- C-Yoke (permanent magnets with dipole or qudrupole arrangement) was effecitive (but a little).
- Solenoid (45 Gauss, 800m in the arc) had clearly improved the threshold, for short trains at injection. (but weaker for long trains)

<u>C-Yoke</u>



- dipole or quadrupole
- 200 Gauss @ chamber
- various periodicity

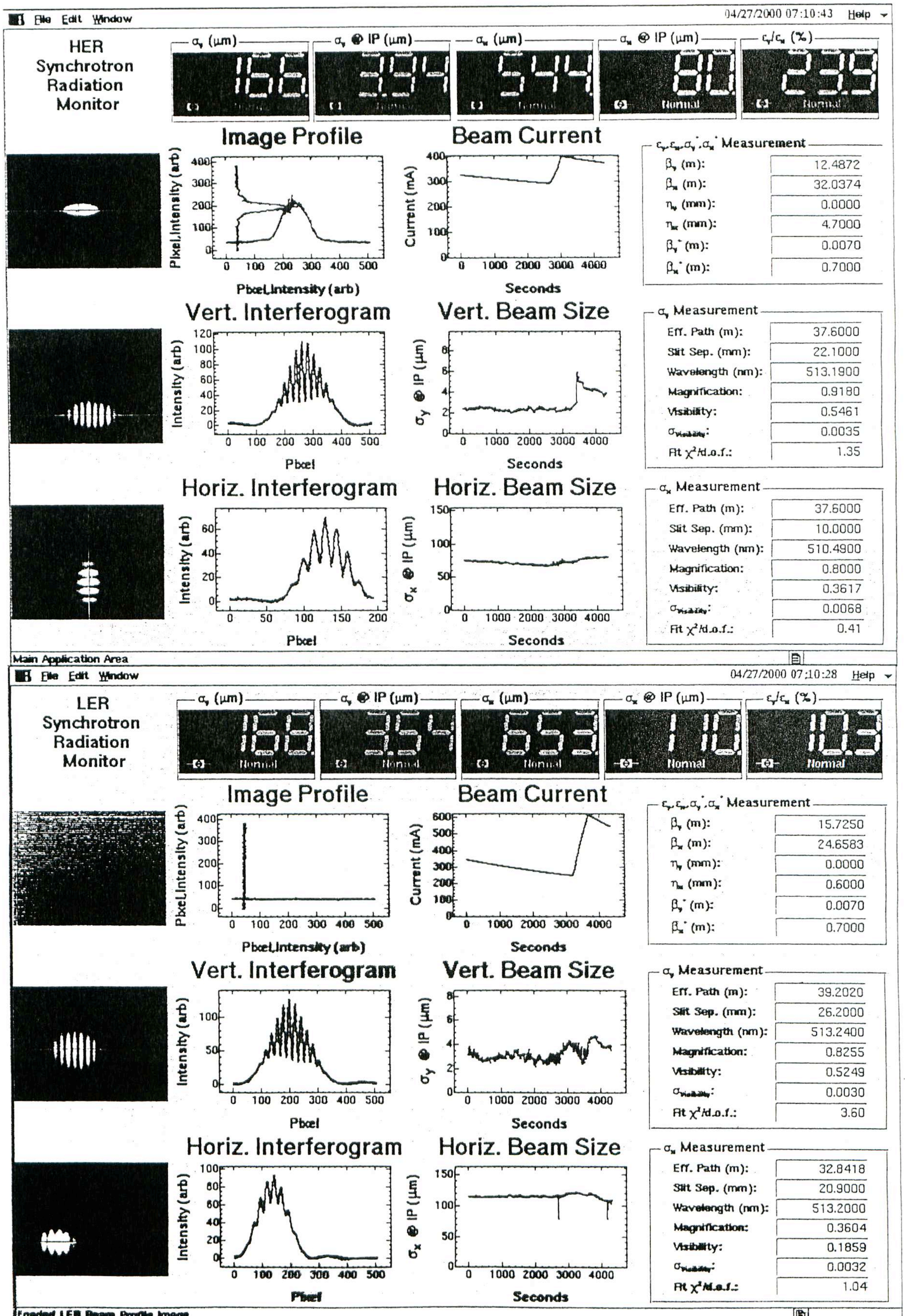


Something else to cause the blowup for a long train??

- bend /wiggler
- Fuji crossing Al + V bend
- multipactoring
- elastic scattering
- negative ion ??
- "maki" ~100 sec delay

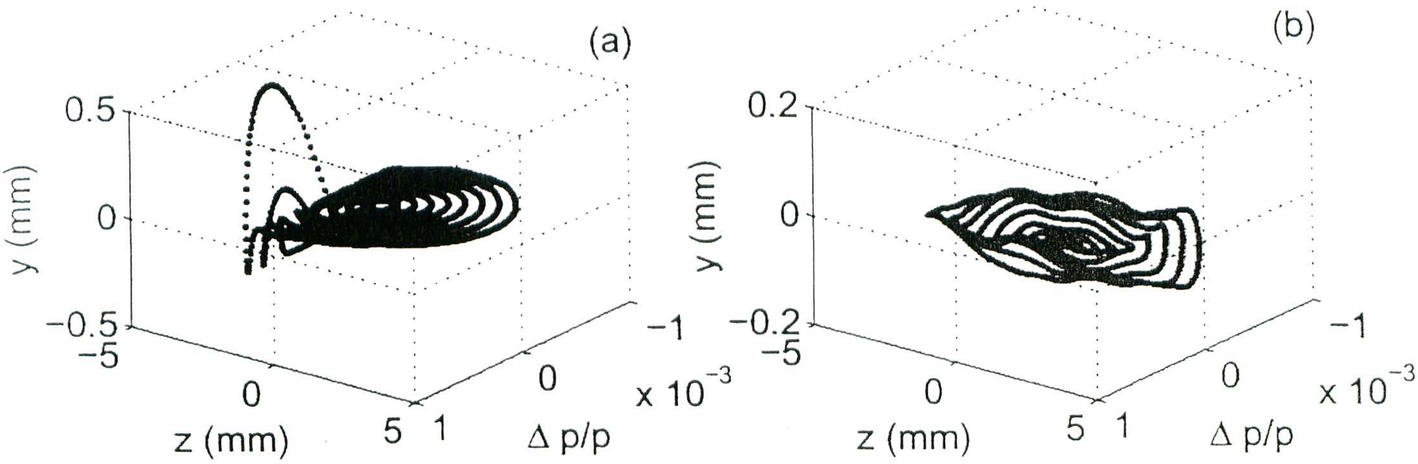
① simulation
② model

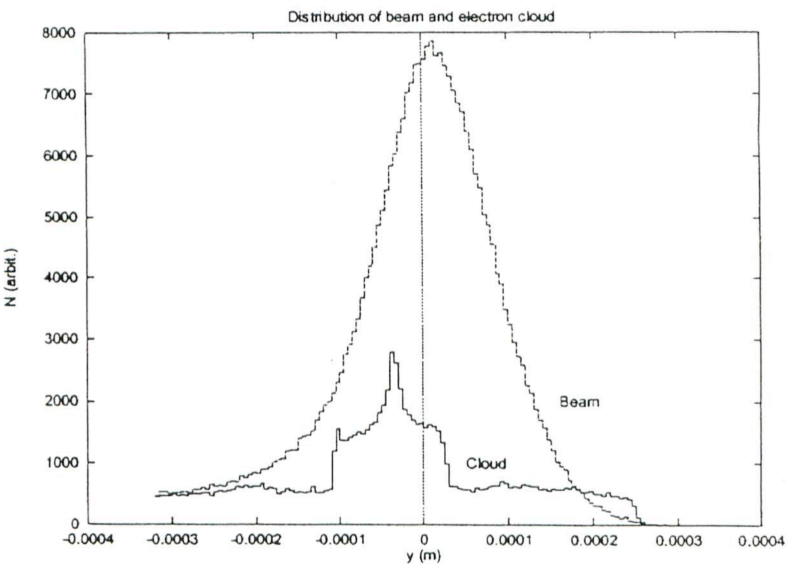
Synchrotron Light Interferometers

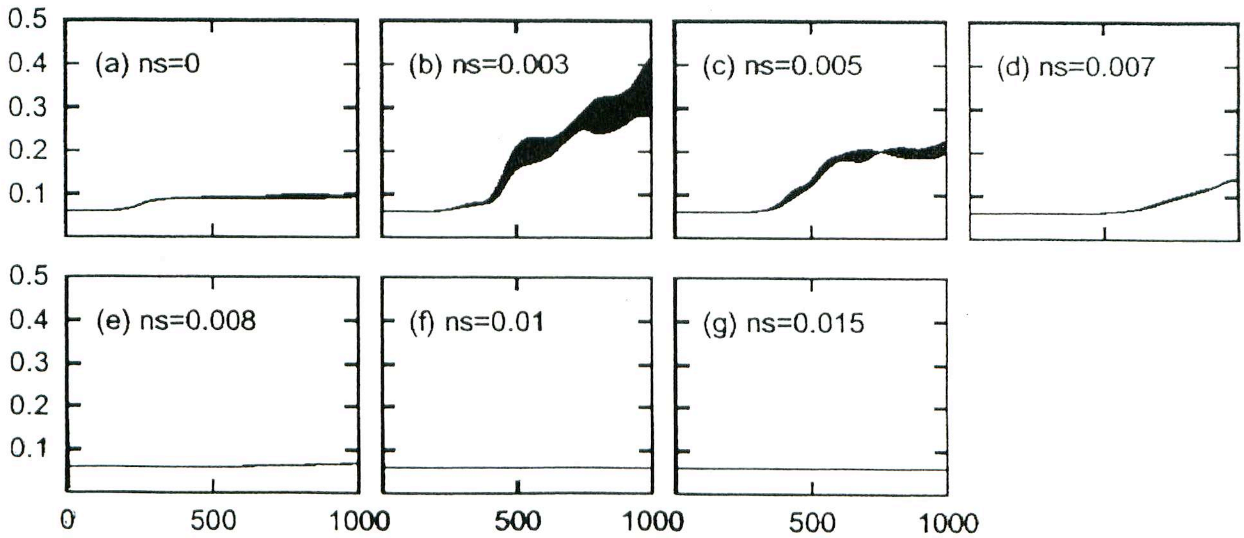


Mitsuhashi / Flanagan

Single-bunch head-tail model (Zimmermann/Ohmi)



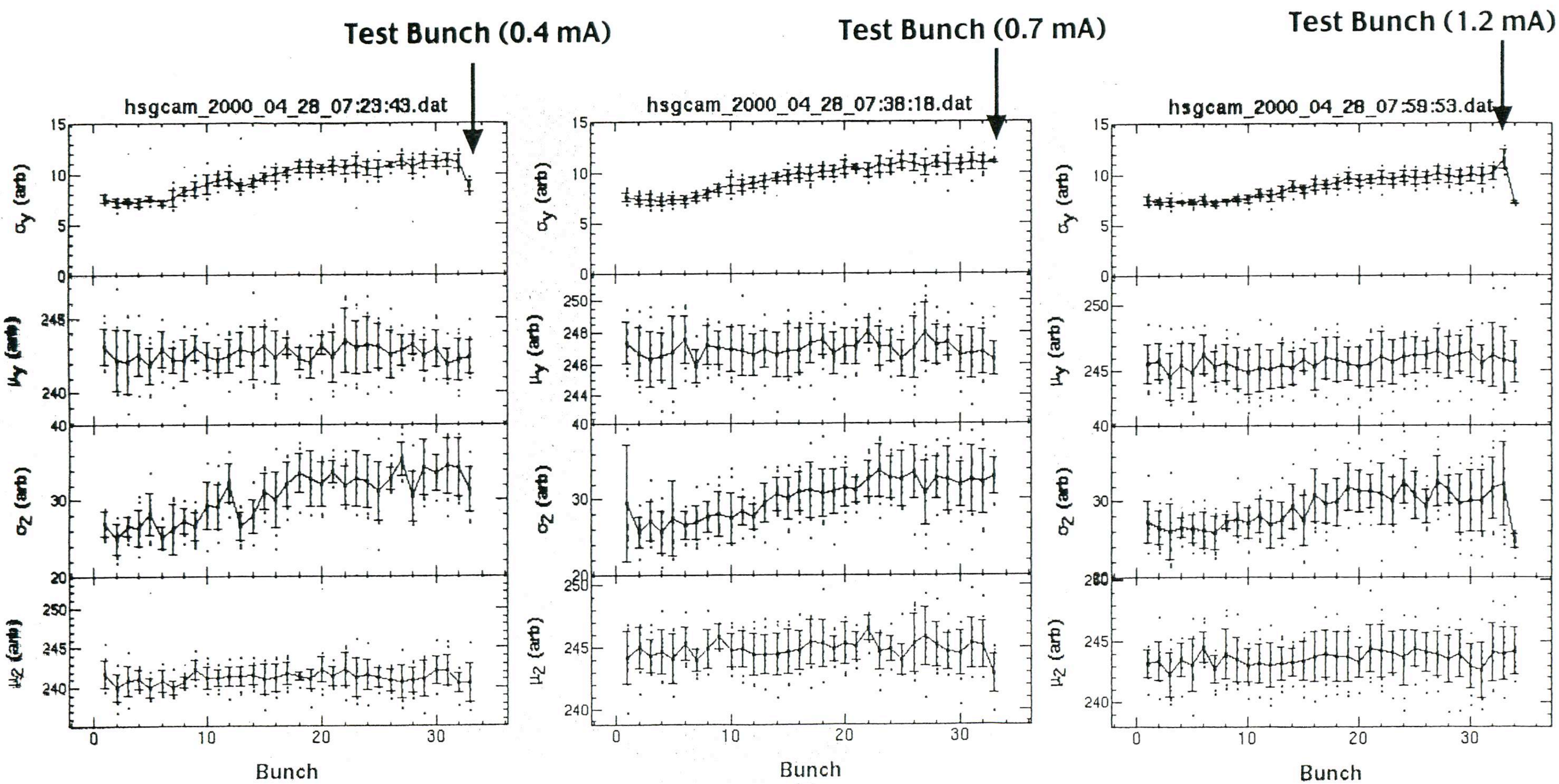




K. Ohmi

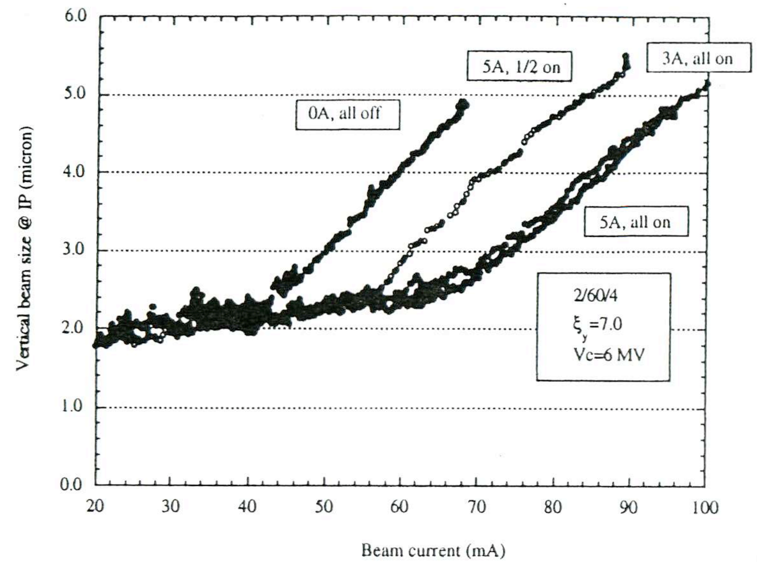
The blowup depends on the charge of the test bunch. This blowup is a single-bunch effect!

Measured by a Gated Camera

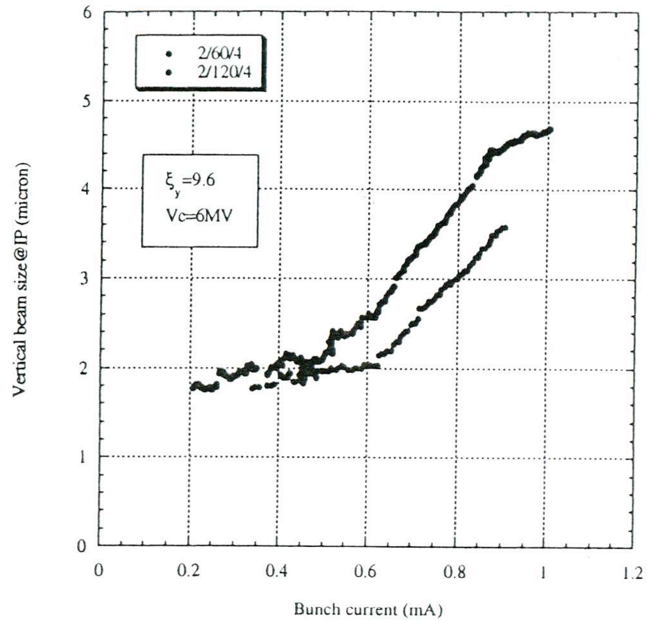


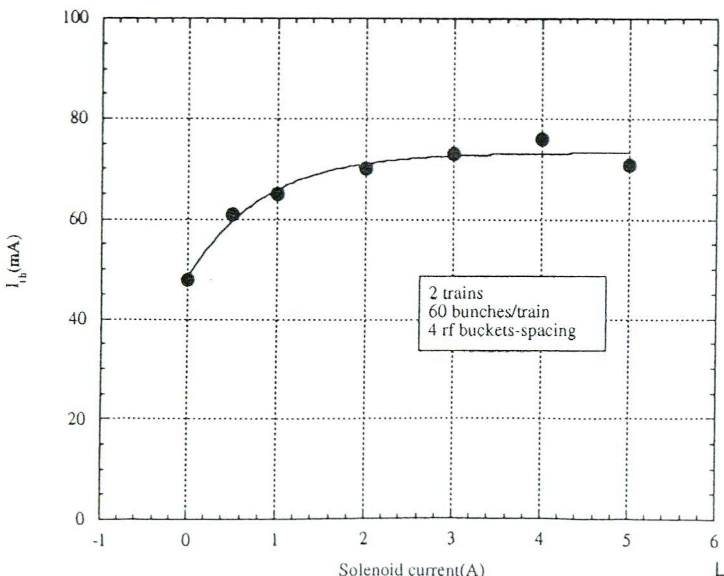
1 train/ring, 32 bunches/train
4 bucket spacing, 0.7 mA/bunch

Effect of solenoid on vertical beam size (LER)

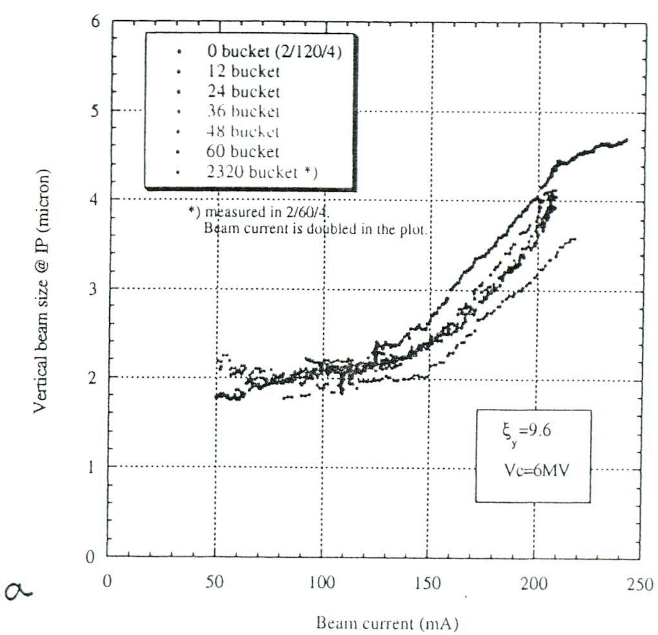


Effect of train length on the blow-up



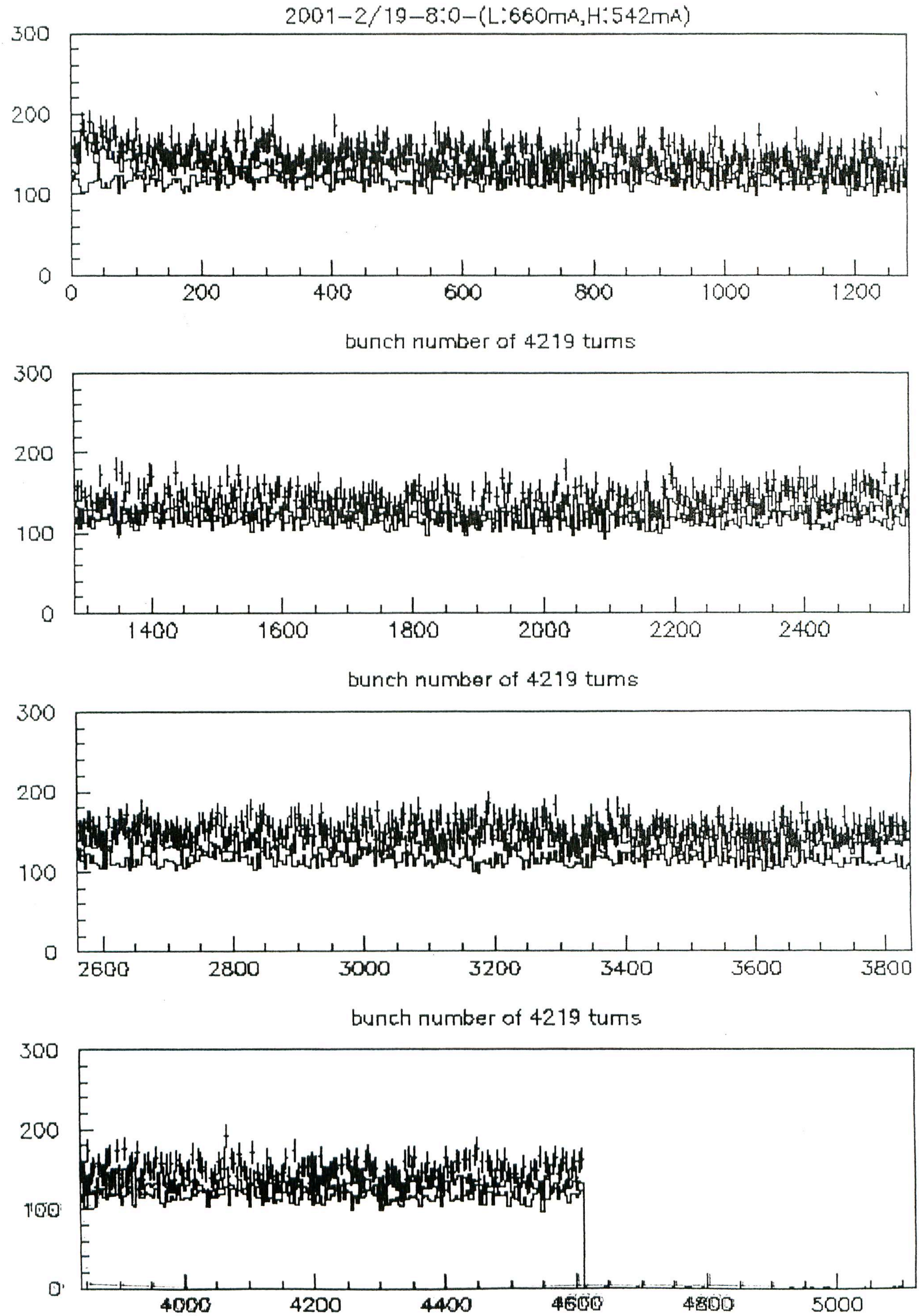


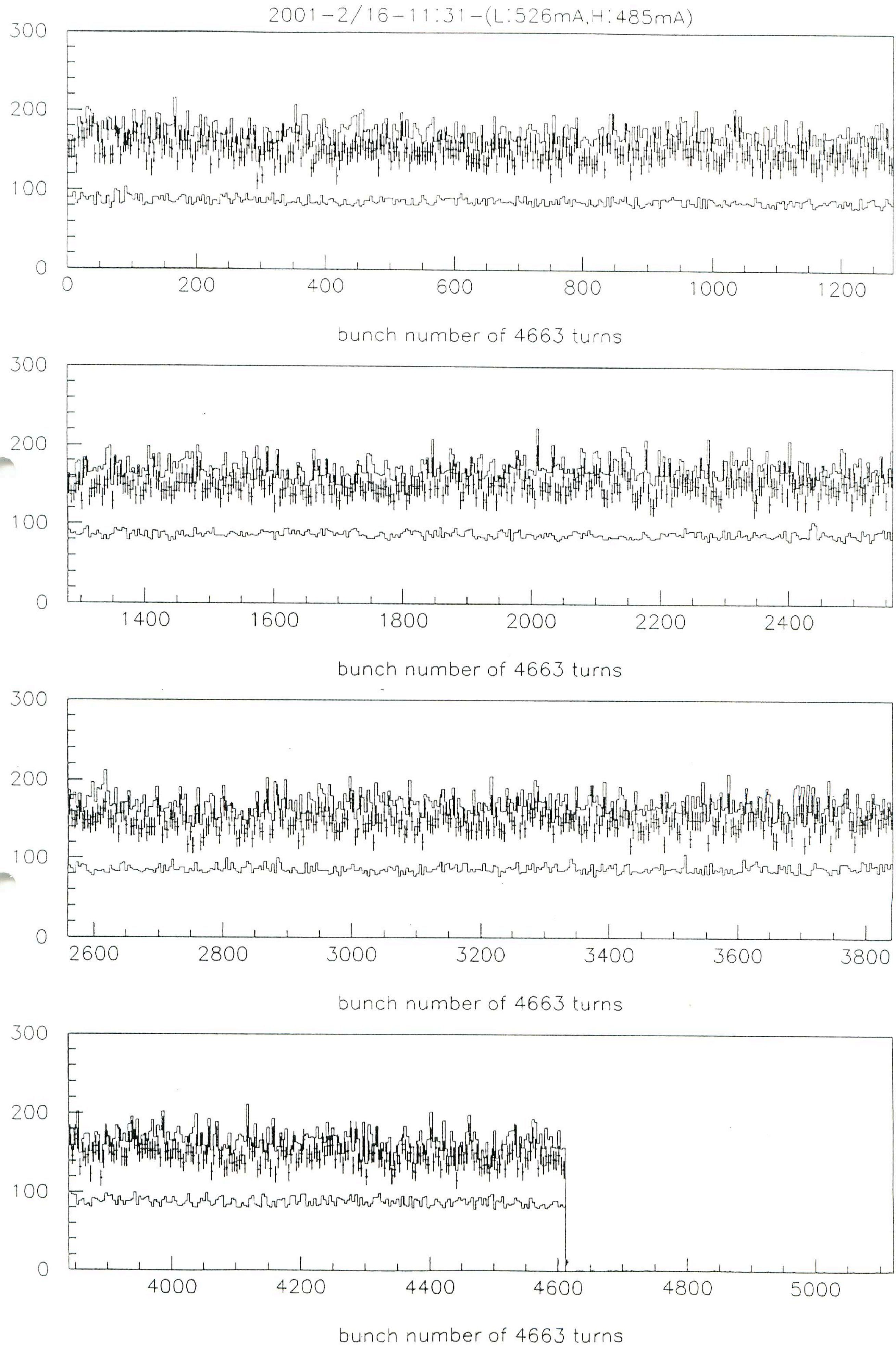
Effect of train gap on the blow-up



H. Fukuma

KEKB Belle ZDLM Bunch-by-Bunch Luminosity



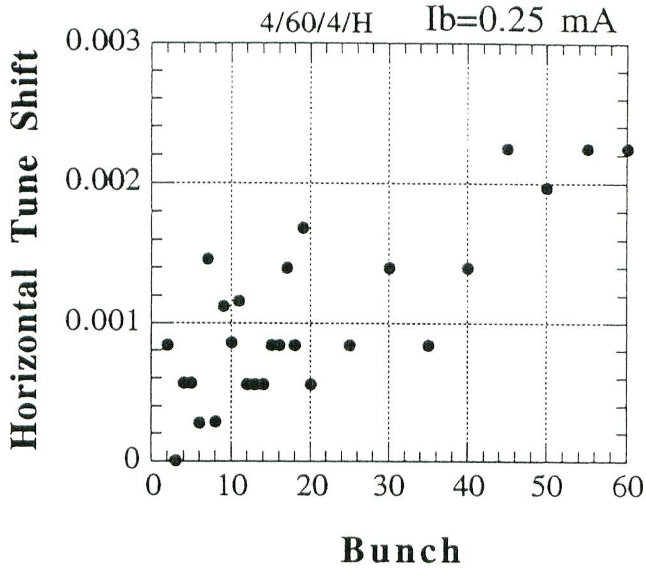

2001-2/16-11:31-(L:526mA,H:485mA)
0
100
200
300
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
bunch number of 4663 turns
bunch number of 4663 turns
bunch number of 4663 turns
bunch number of 4663 turns

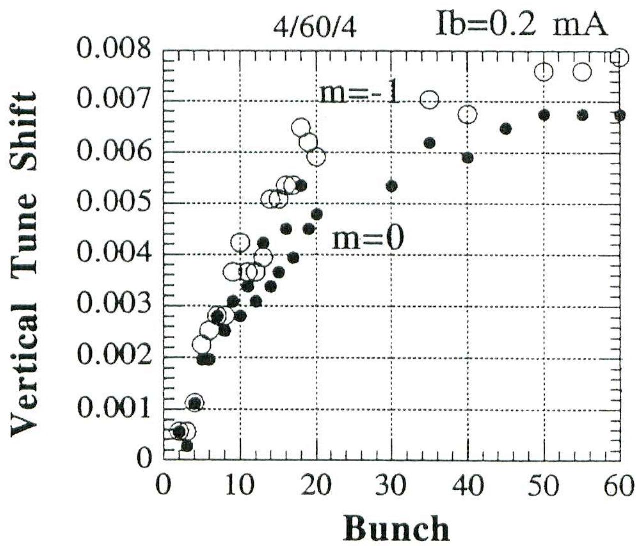
Jan. 26, 2000

Tune Shift along Bunch Train

4-bucket spacing, $\xi_y = 5.0$, $\nu_s = 0.011$

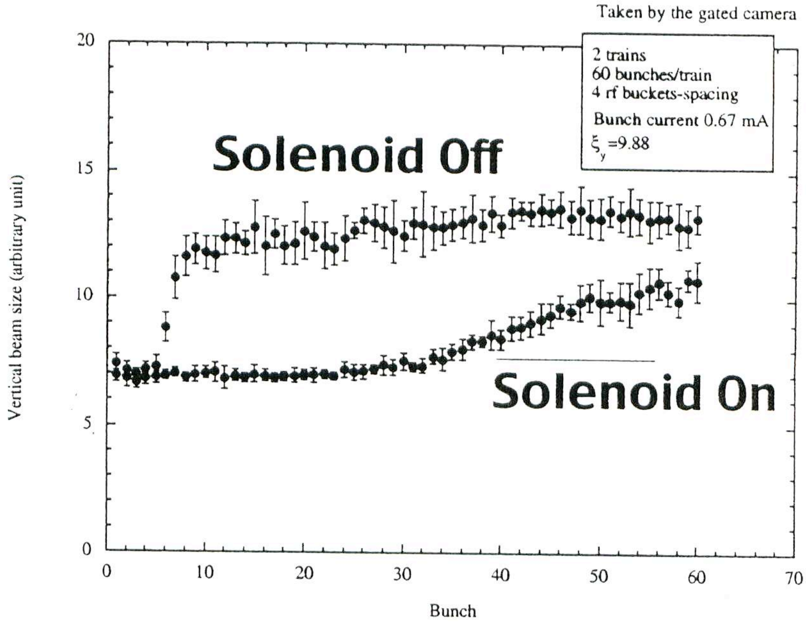
$\xi_x = 3.75$

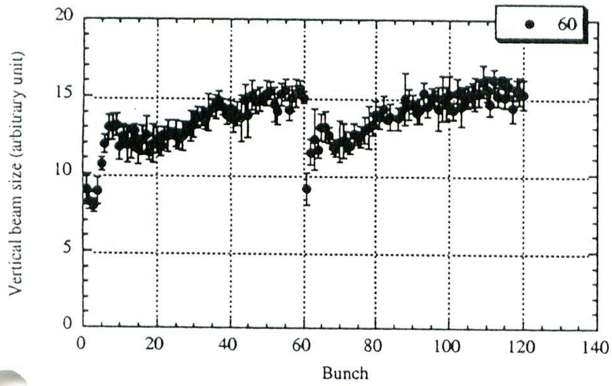


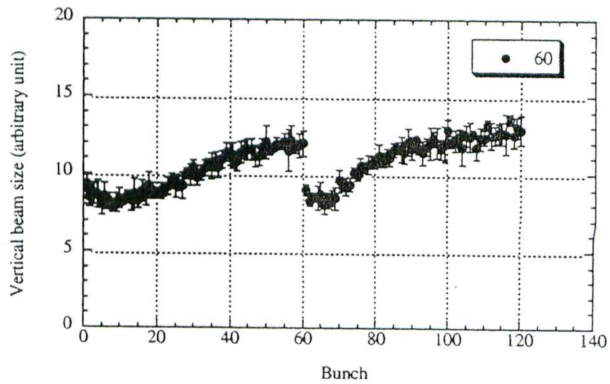


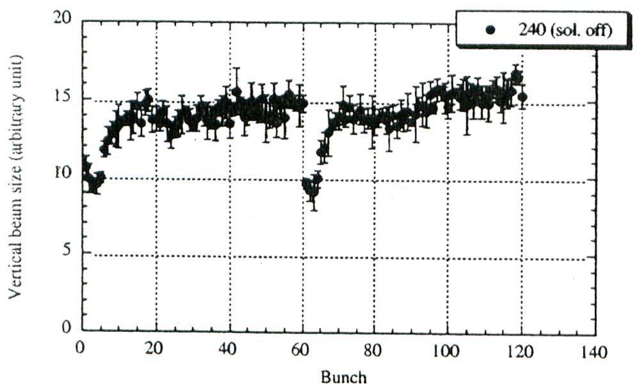
T. Ieiri

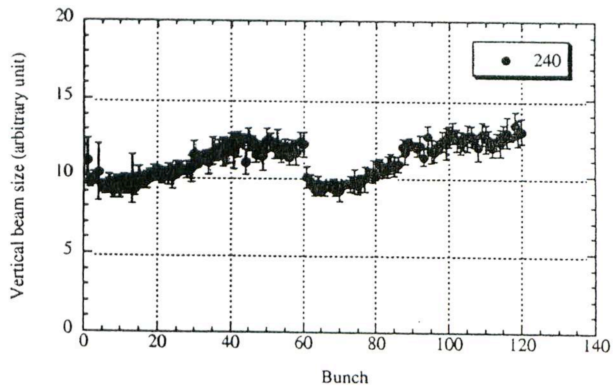
Beam size of each bunch by the Gated Camera





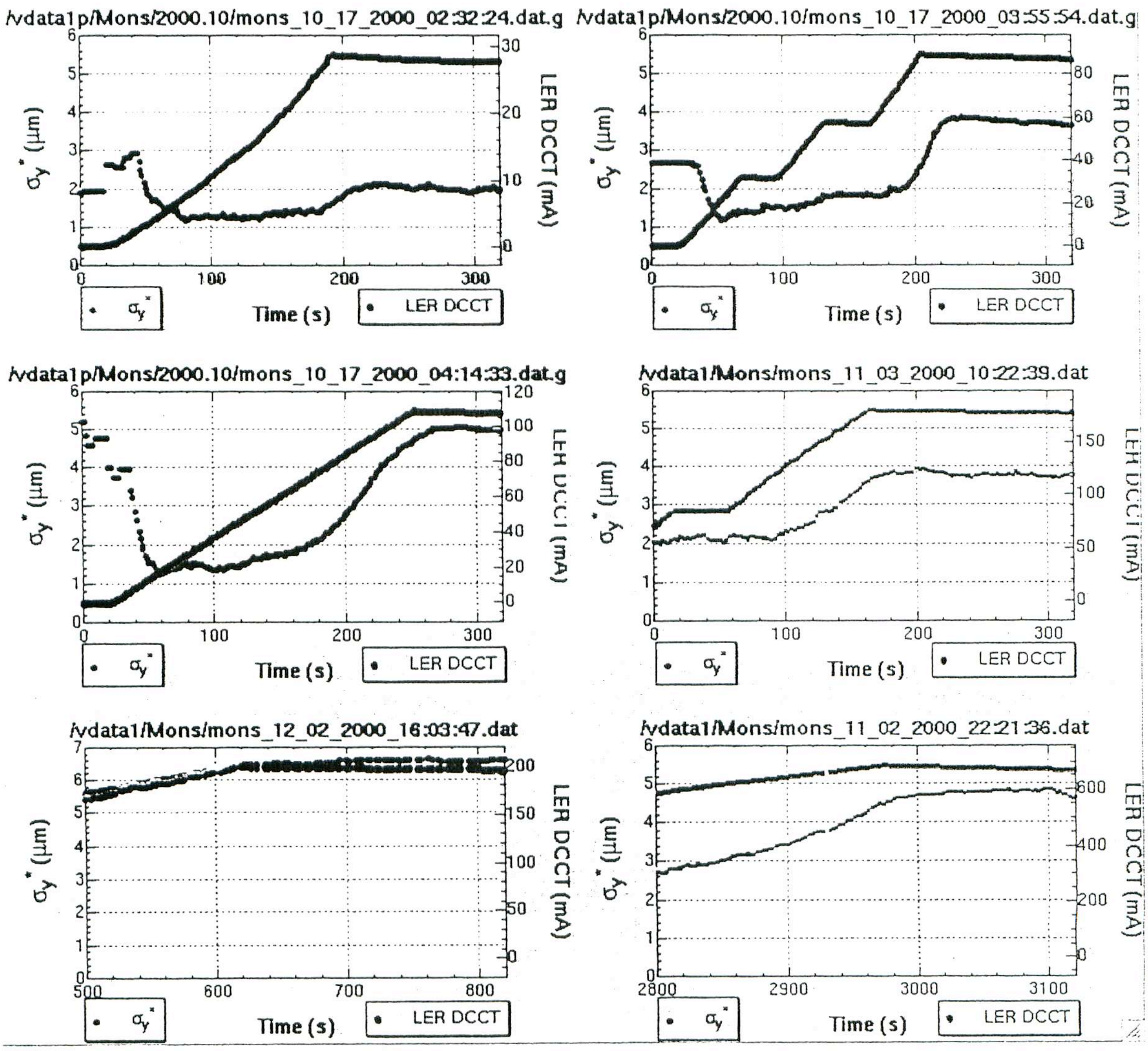


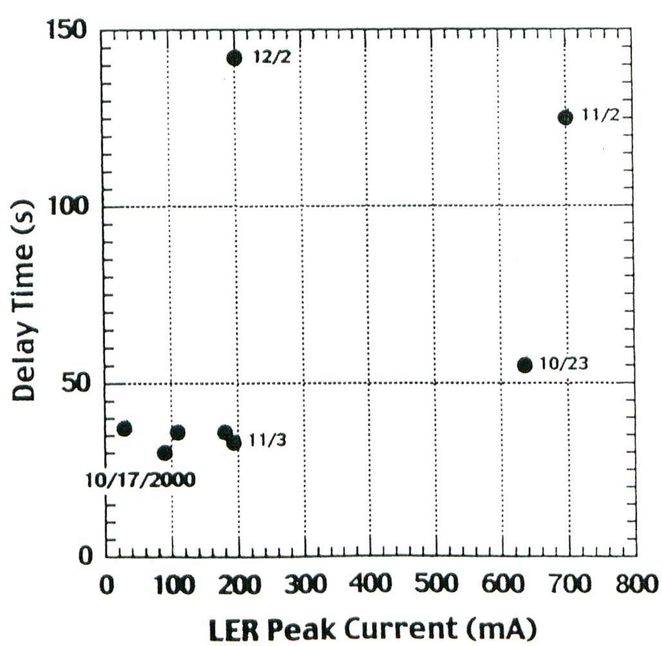




Solenoid Off **Solenoid On**

Variation of the delay of the beam size against the beam current

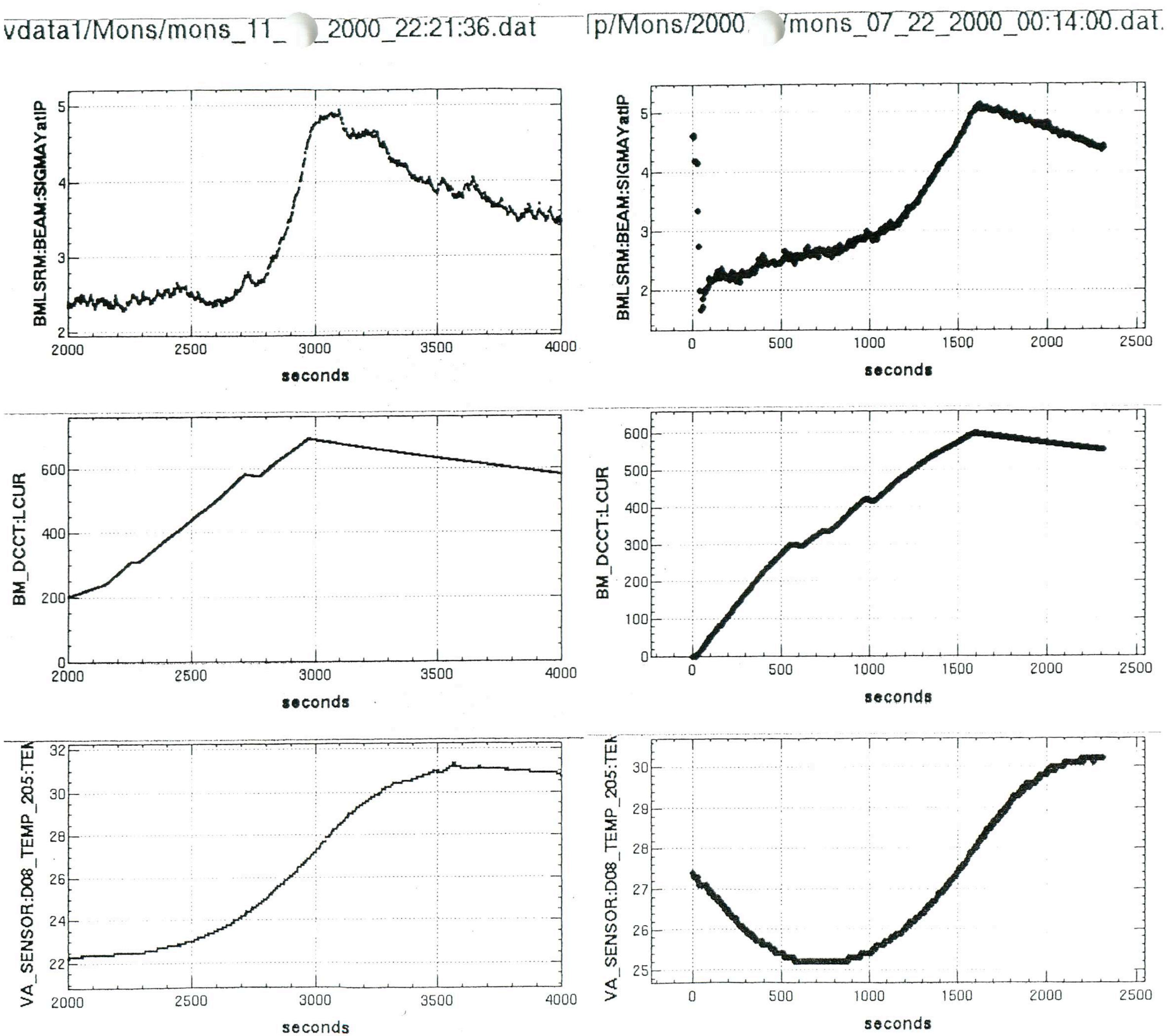




σ_y^*

LER DCCT

Temperature of the mirror chamber

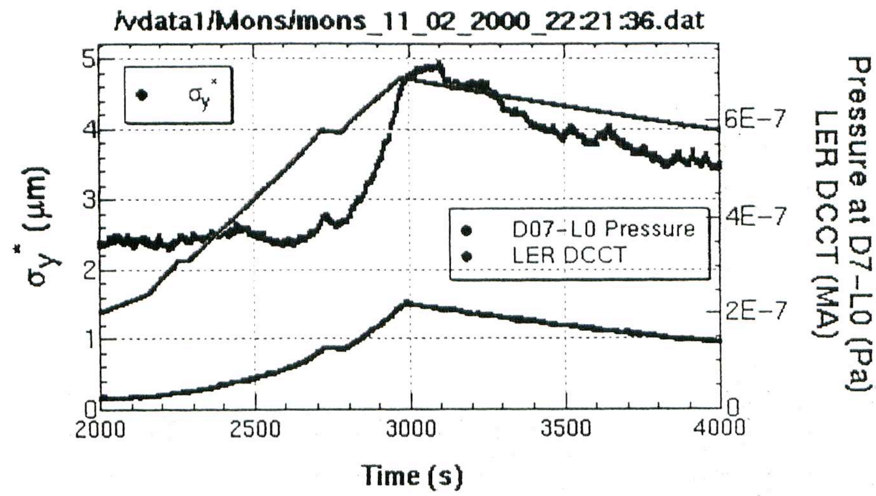


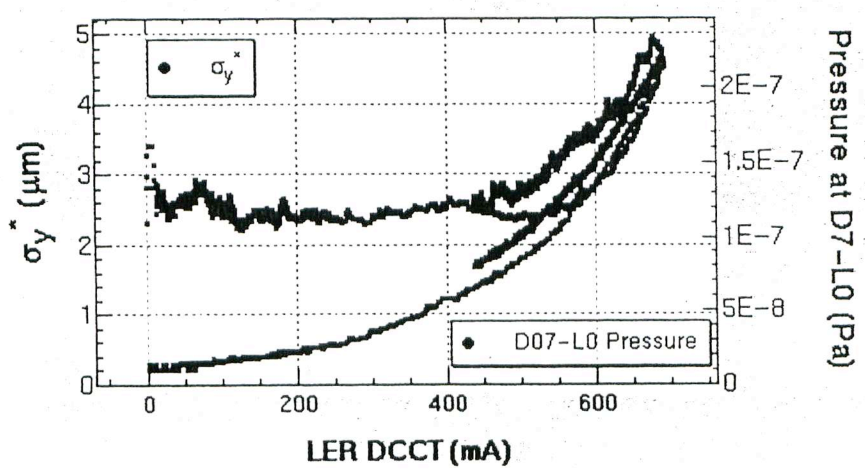
Nov 2, 2000

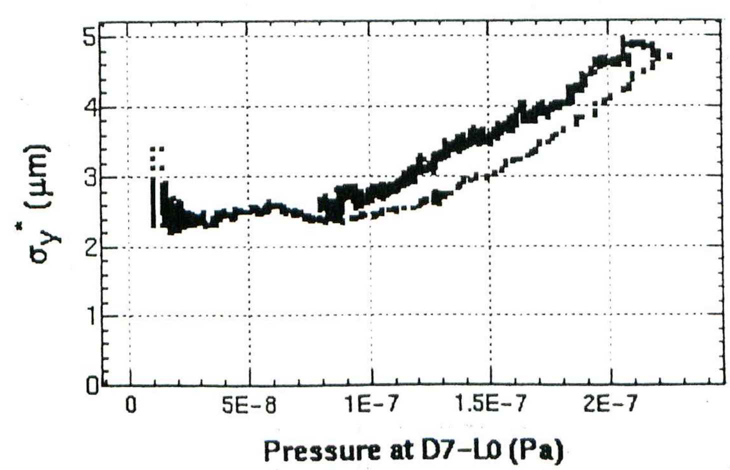
Jul 22, 2000

Some vacuum gauges show a similar pressure curve against the beam current, but

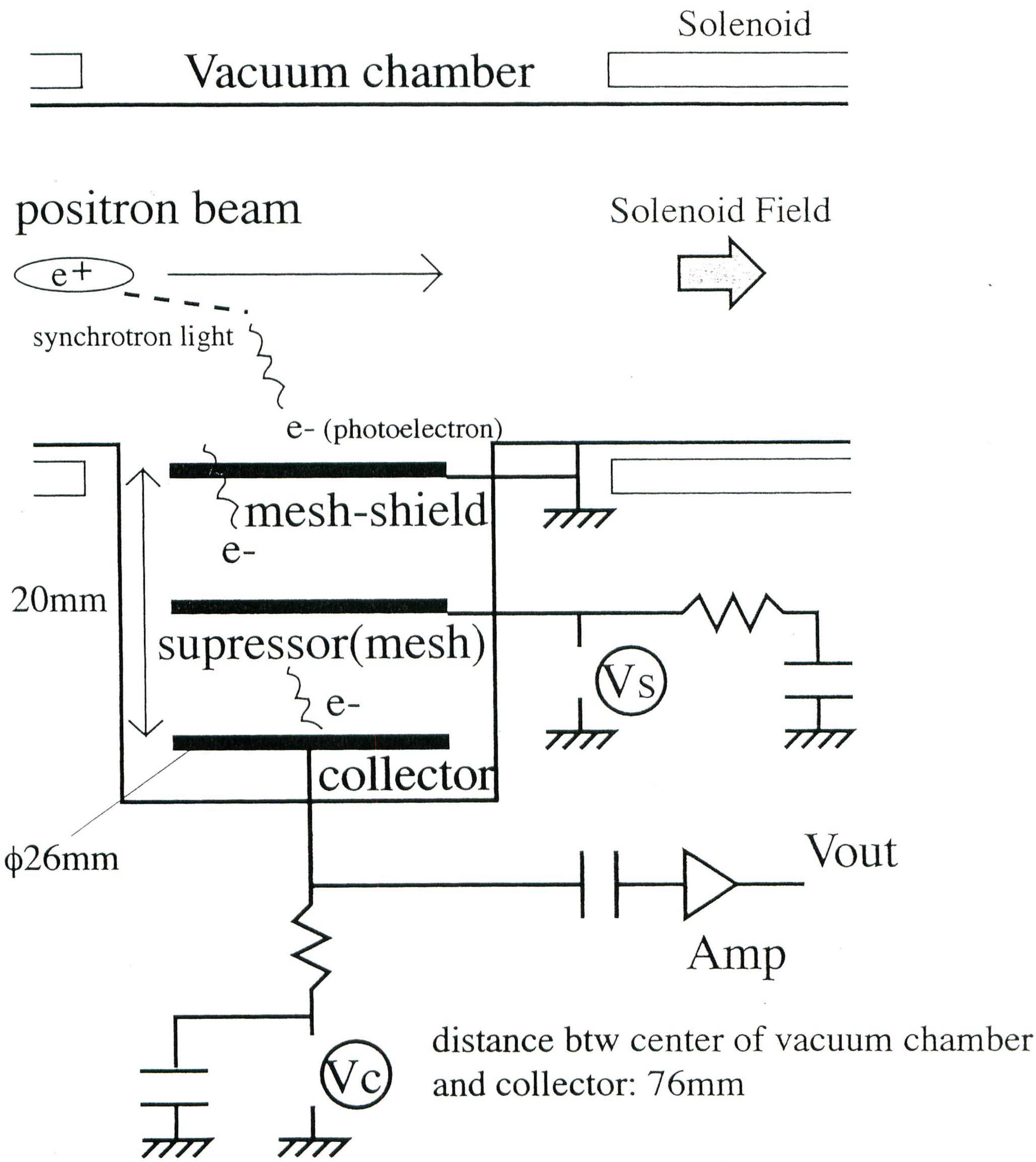
- their delay times look much shorter than the beam size's
- shapes are different from sizes in detail





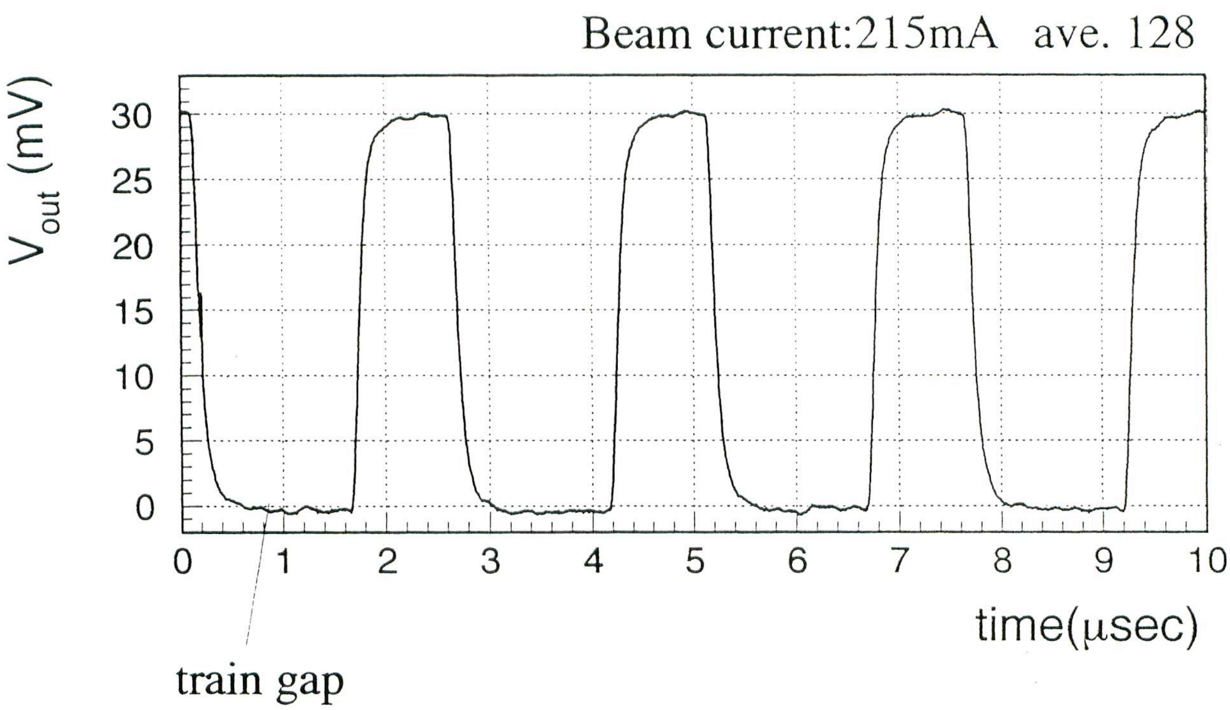


Schematic view of Photoelectron Detector

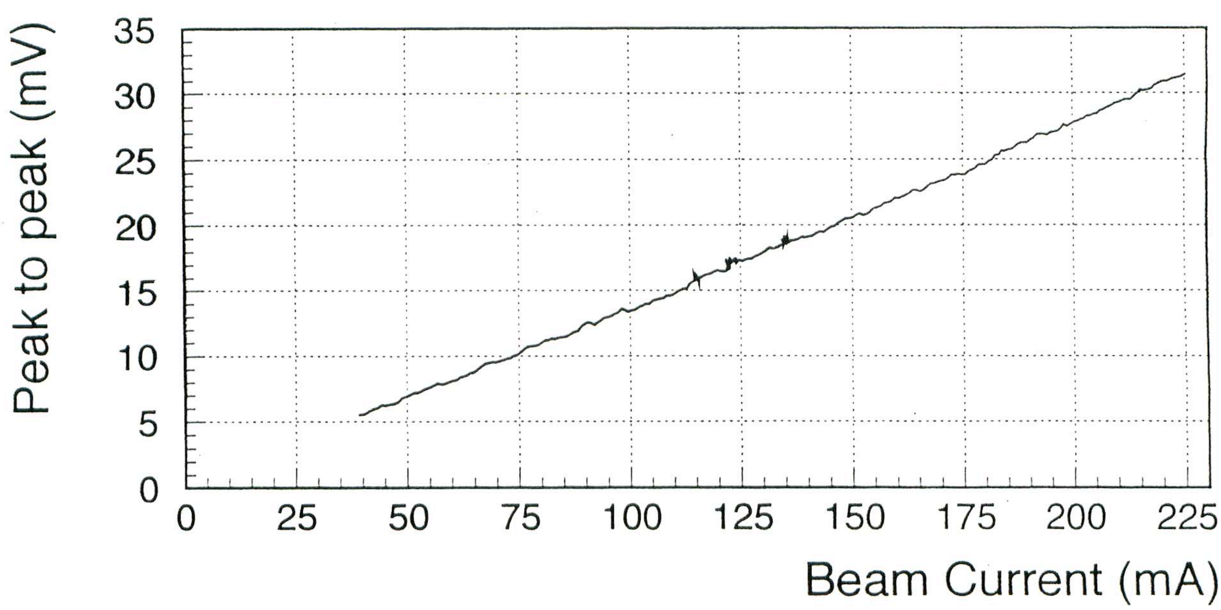


Y. Ohnishi

Pick-up current vs time

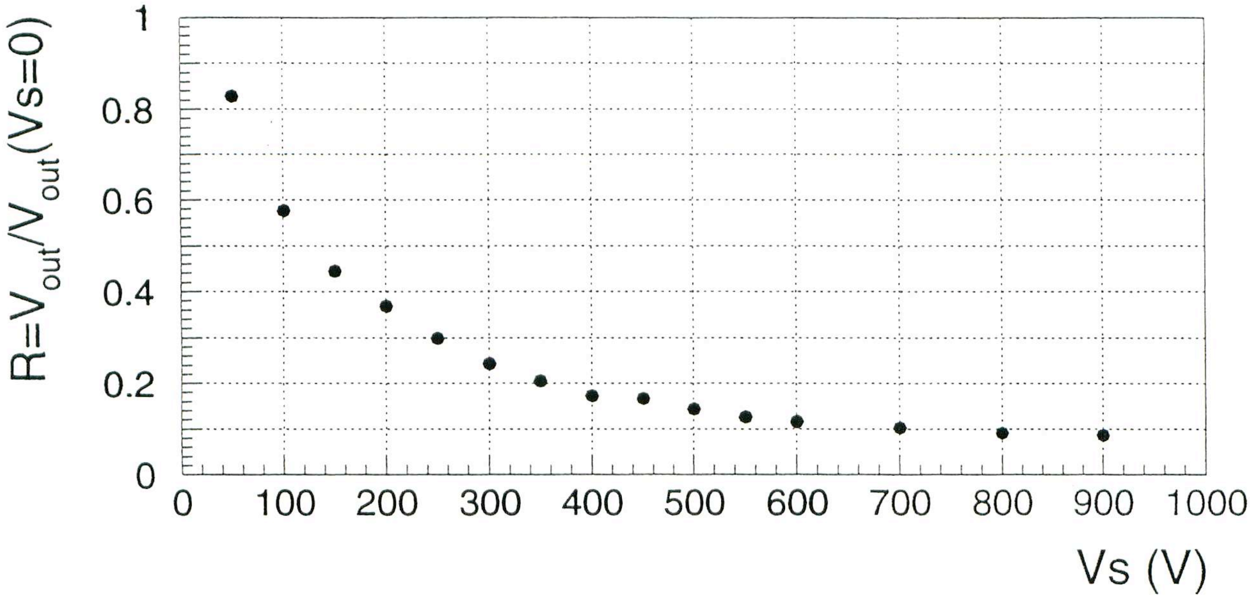


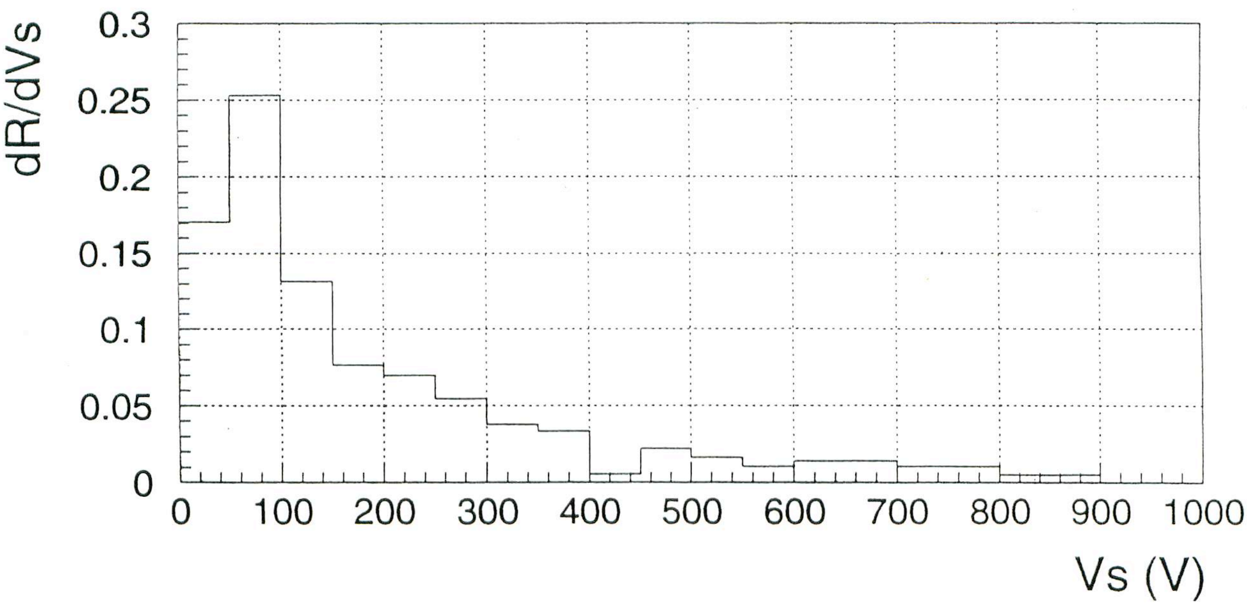
Pick-up current vs Beam Current



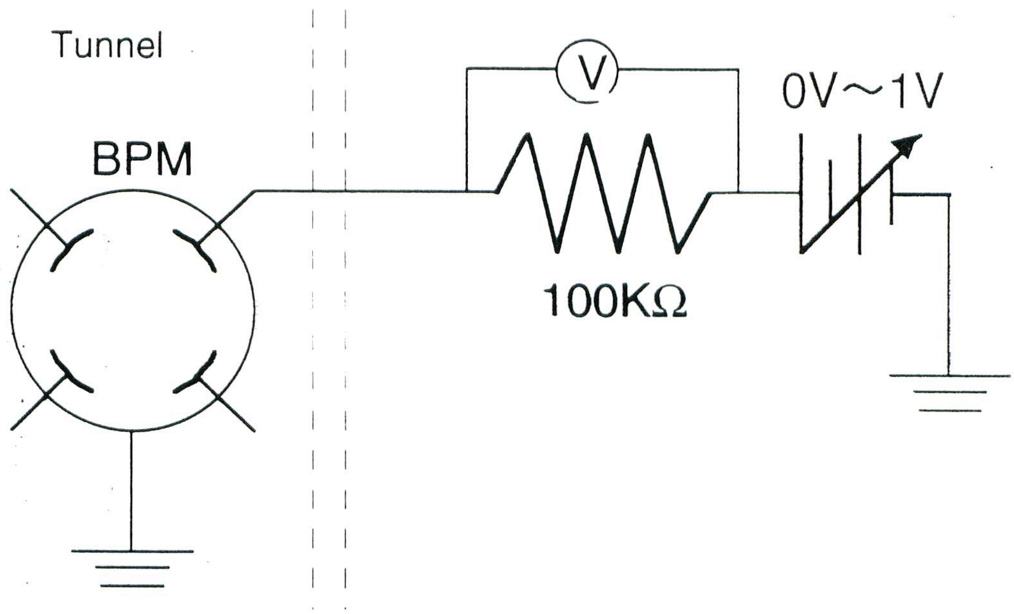
Y. Ohnishi

Energy Spectrum of Photoelectrons

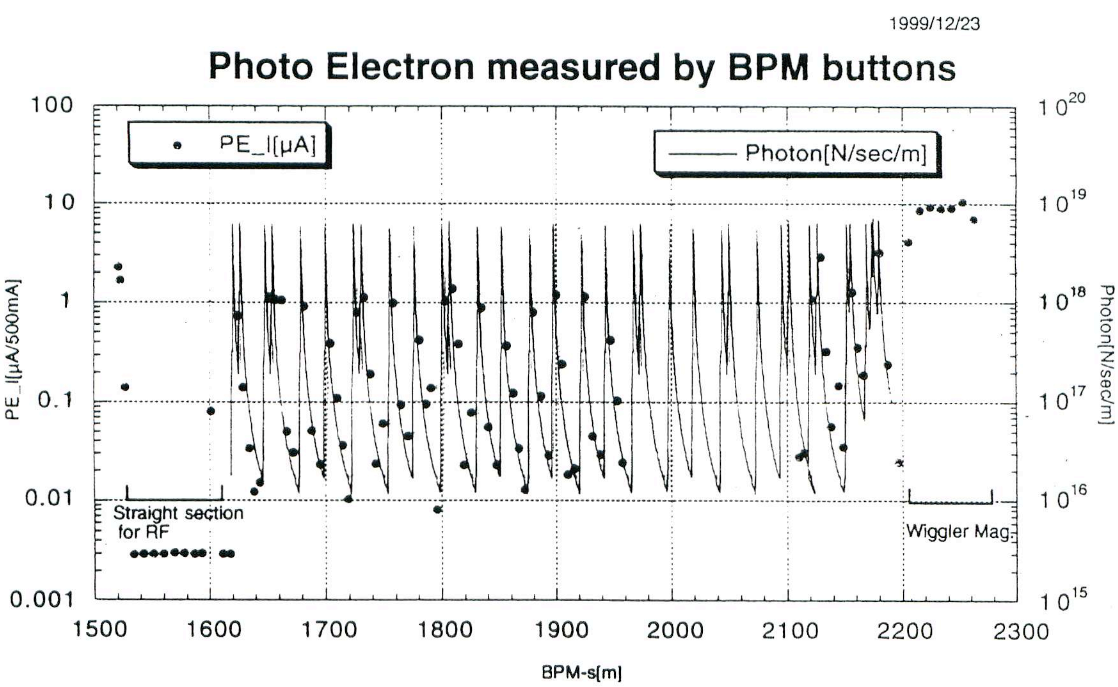




Y. Ohnishi



Setup for PE Measurement



M. Tejima