Summary of the Collective Effects/RF/Feedback Working Group

23rd Advanced ICFA Beam Dynamics Workshop on High Luminosity e+e- Colliders

V. Shiltsev and J. Rogers

Beam-beam interaction- observations

- M. Palmer (CESR)
- J. Seeman (PEP-II)
- Y. Funakoshi (KEKB)
- A. Valishev (VEPP-2M)
- R. Talman (Round beams/Möbius in CESR)
- J. Seeman, T. Sen (HERA-e high ξ result)
- E. Simonov (VEPP-4)

Beam-beam interaction- theory

- R. Talman
- B. Schmekel
- J. Rogers
- J. Seeman
- T. Sen
- V. Shiltsev

Beam-beam interaction- simulations

- Y. Cai
- J. Rogers
- A. Valishev

Beam-beam interaction- instrumentation

- V. Shiltsev

Other collective effects- observations

- T. Ieiri, J. Flanagan (KEKB)
- A. Temnykh (CESR)
- M. Boscolo (DAΦNE)
- J. Seeman (PEP-II)

Other collective effects- theory and simulations

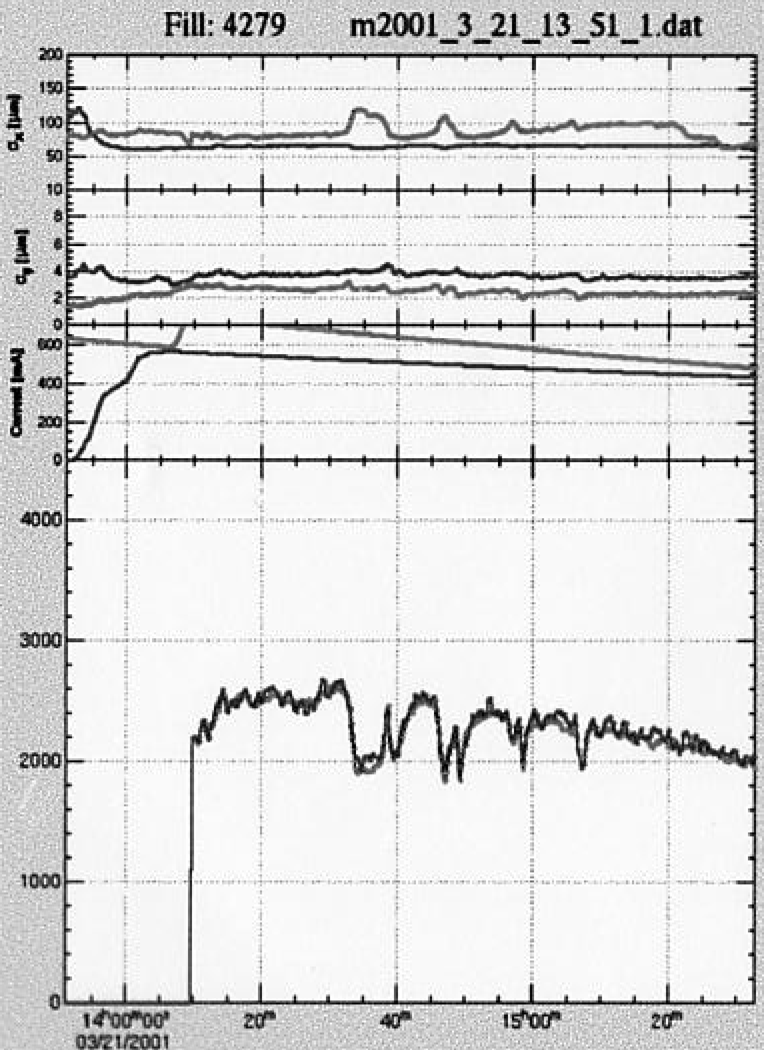
- S. Heifets- ECI/CSR
- J. Flanagan- electron cloud simulation

What are the problems and operational difficulties common to several machines?

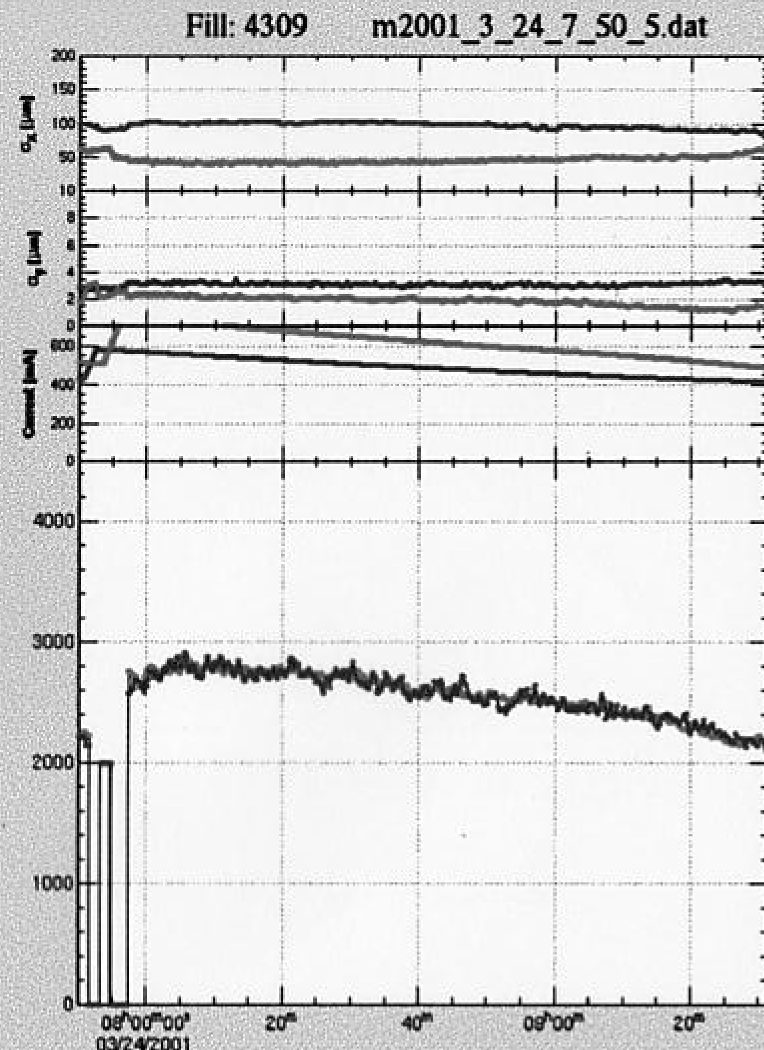
- Beam-beam effects (all machines) 
- ~~Electron cloud~~ →"2.5 ±0.5 stream instability" (B-factories only) 
- Geometrical impedance (B-factories) 

Flip-flop in KEK-B (Y. Funakoshi)

Luminosity instability: observation



Unstable fill

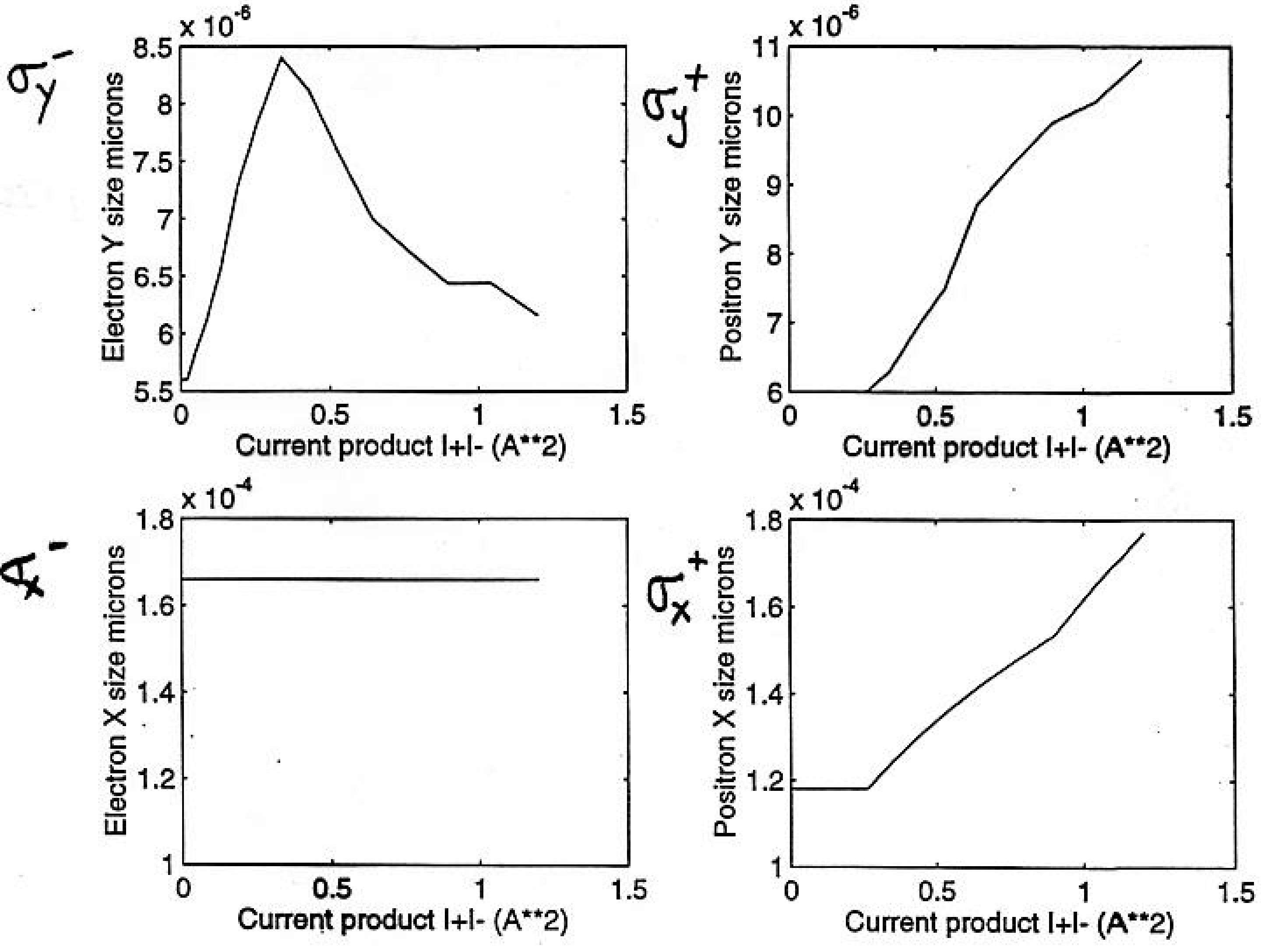


Good fill

PEP-II (J. Seeman)

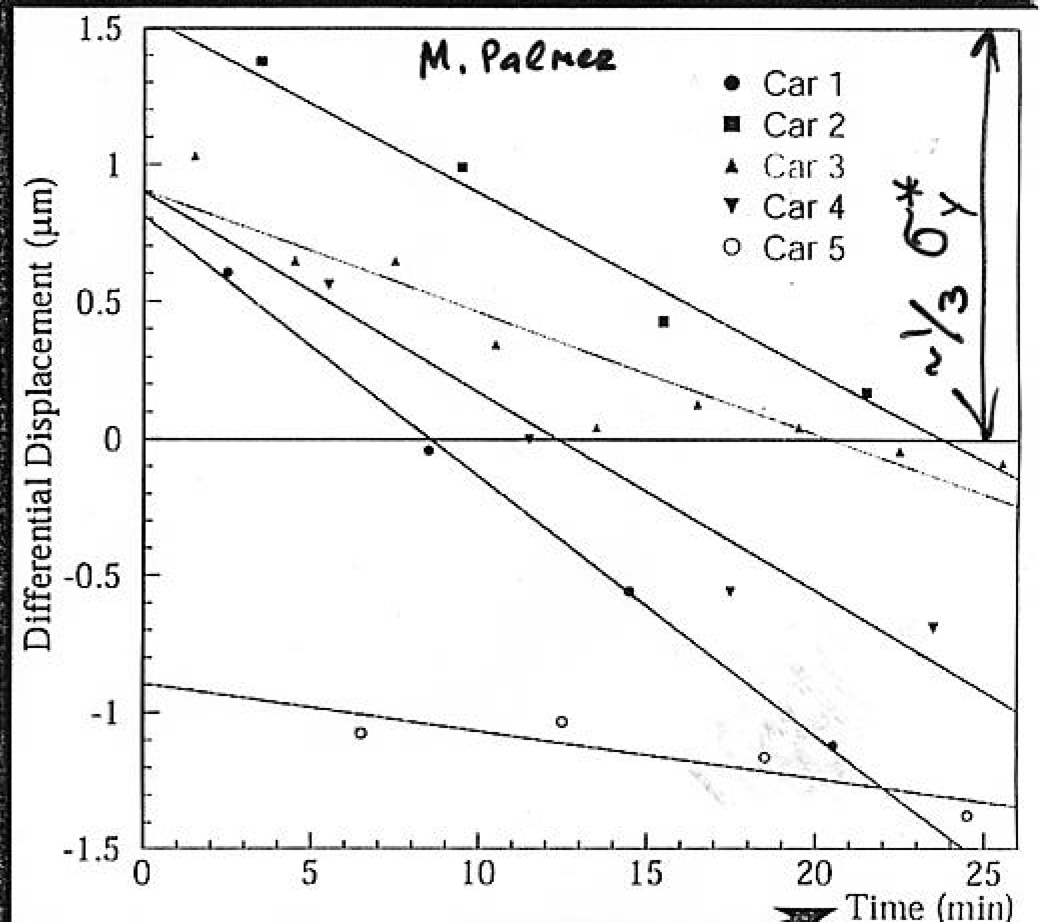
flip-flop

+ e-cloud



Bunch-to-Bunch Differential Orbits

- BBI Luminosity Monitor
  - Shake a particular bunch (or bunches) at a fixed frequency
  - Measure the BBI induced amplitude in the opposing bunch
  - Provides much faster response than CLEO luminosity measurement
- Adjust differential offset between e^- and e^+ bunches at IP (VCROSING 7 Knob)
  - Vary betatron phase advance in the vertical separator bump at the 2nd IP
  - Optimize collisions for each car
- Observations
  - Car-to-car orbit differences at the 0.5σ level ($\sigma_v \cong 4\mu m$)
  - Strong dependence on beam current
  - Consistent with machine operators having to actively tune VCROSING 7 through the course of a run



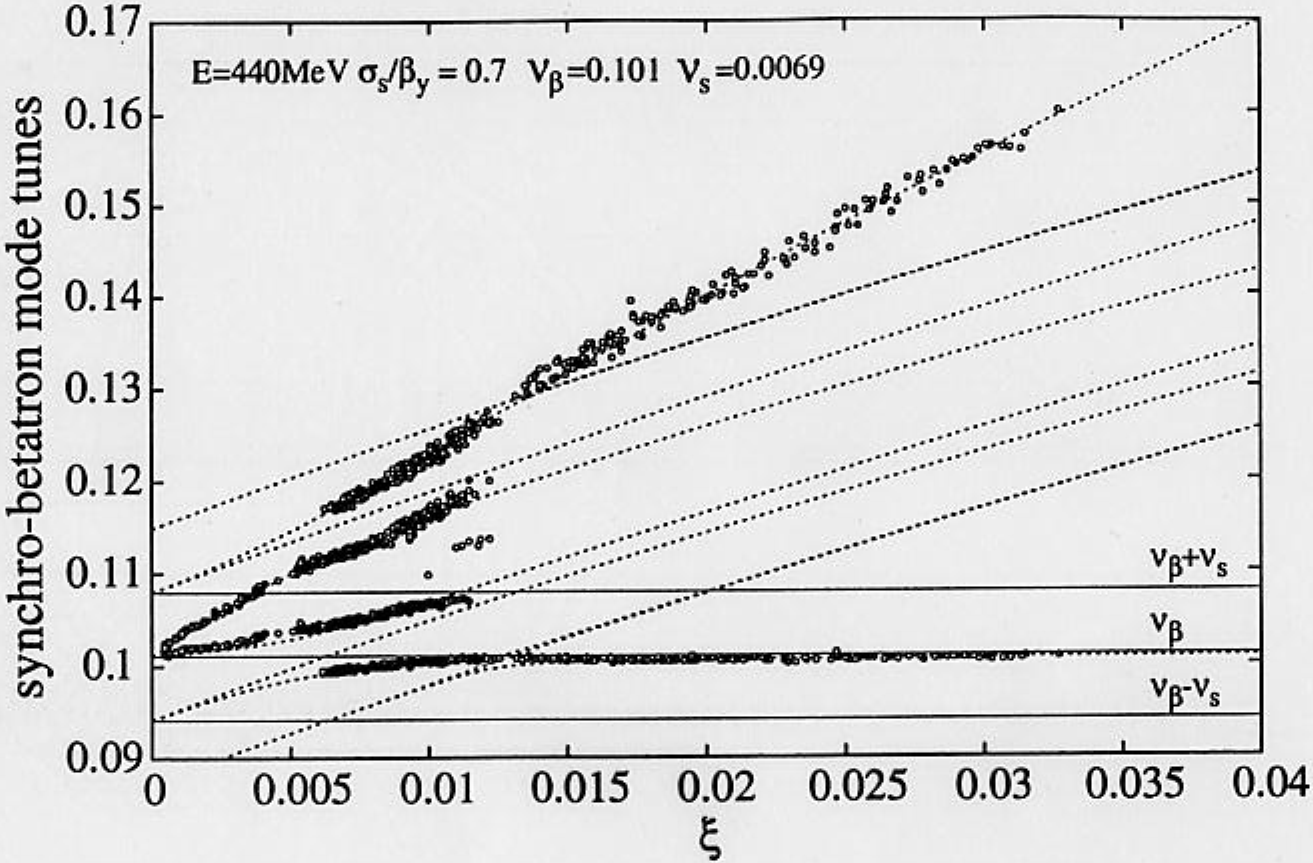
Increasing time ⇨ decreasing current

M. Zobov / M. Boscolo

DAΦNE COUPLING IMPEDANCE

		Design	Estimated	Measured	Comments
LONGIT. BROADBAND IMP.	**Z/n, Ω**	2	0.6 0.9	< 0.6 e+ < 0.9 e-	Additional 40 clearing electrodes in the e- ring
TRANSVERSE BROAD BAND	**Z_T, kΩ/m**	Below TMCI		~ 90	Betatron tune shift is a small fraction of synchrotron tune
LOSS FACTOR	**kl, V/pC**		0.52		For the bunch length of 3 cm
NARROW BAND LONG. IMP.	**Z_{HOM}, kΩ**	< 10		~ 2	From grow-damp feedback measurements
NARROW BAND TRANSVERSE IMP.	**$Z_{T\ HOM}$, kΩ/m**		~1000		HOM in the injection kicker. The instability is damped by the vertical feedback and due to beam-beam collisions.

VEPP-2M: BEAM-BEAM impedance (A. Valishev)



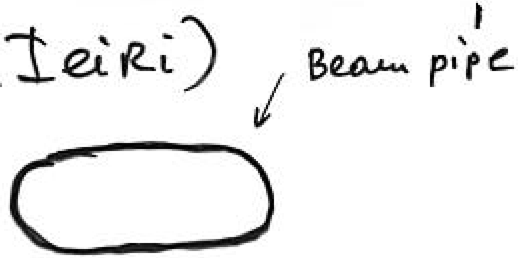
Synchrobetatron beam-beam mode tunes vs. ξ.

Comparison of measured (circles) and calculated (lines) data.

Impedance Measurements in KEKB (from T. Ieiri)

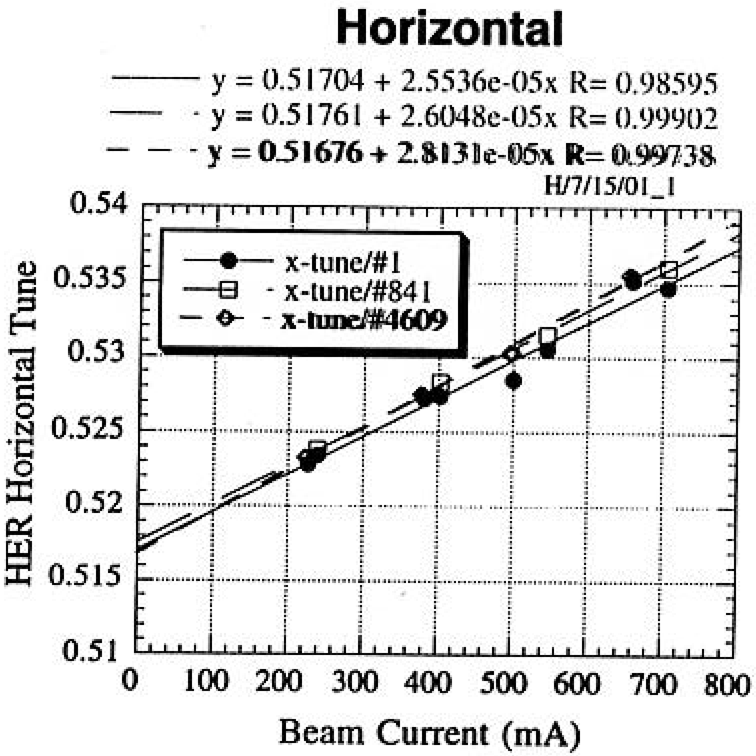
parameter	HER	LER	comments
$\lvert Z/n \rvert$ (measured)	0.076 Ω	0.072 Ω	from bunch lengthening
$\lvert Z/n \rvert$ (design)	0.015 Ω	0.015 Ω	does not include all installed elements
$\Delta\nu_x$ (measured)	-0.001/mA	-0.001 – -0.0015/mA	
$\Delta\nu_y$ (measured)	-0.004/mA	-0.0014/mA -0.0034/mA	mask open mask closed
$\Delta\nu_y$ (design)		-0.0004/mA	
k (measured)	20 – 30 V/pC	20 – 30 V/pC	at $\sigma_l = 6 – 7$ mm / design $\sigma_z \lesssim 4$ mm

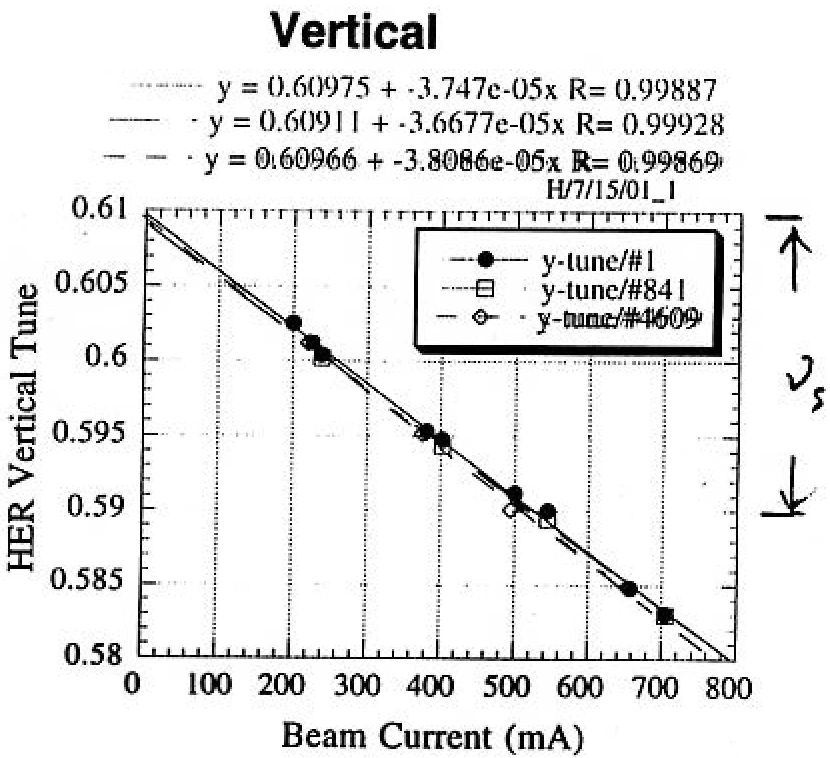
KEK-B (T.Ieiri)



Tune Shift in HER (Multi-bunch)

$\xi x=0.97$ $\xi y=5.41$





-> Tune shift depends on the beam current.

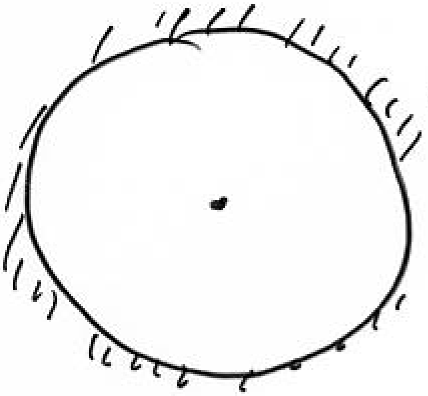
-> Focusing in horizontal and defocusing in vertical.

-> A quadrupole field is induced by the beam.

ON MULTI-BUNCH TUNE SHIFT in KEK-B HER

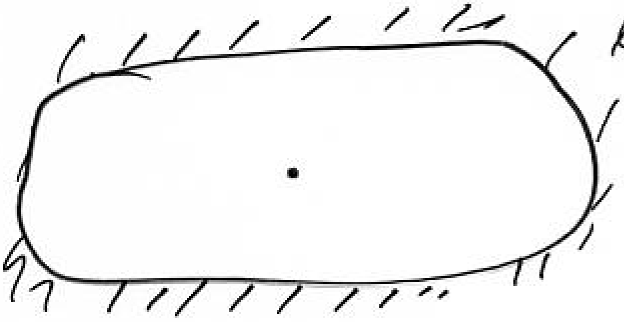
(similar effect observed in PEP-II ← J. Seeman)

- DETUNING WAKE in NON-ROUND vacuum chambers



in ROUND GEOMETRY force on tail particle

$$F_{x,y} = W \cdot (X_h, Y_h) + 0 \cdot (X_t, Y_t)$$



in flat pipe

$$F_{x,y} = W \cdot (X_h, Y_h) + \begin{cases} -D \cdot X_{tail} \\ +D \cdot Y_{tail} \end{cases}$$

↑ DETUNING WAKE

and $D = W$

→ for multibunch operation DETUNING force dominates

→ HOR. TUNE SHIFT is <u>positive</u>

→ Vert. TUNE SHIFT is NEGATIVE

How much further can parameters be pushed to improve machine performance?

- Current I — poor understanding of e-cloud
- β^*_y — require shorter σ_z ⇒ minimizing geometrical impedance + CSR
- Beam-beam parameter ξ_y
- Beam aspect ratio R

$$L = 2.2\times10^{29}\gamma\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\frac{\xi_y}{\beta_y}\frac{1+R}{2}I$$

Dependence of on damping decrement:

- Chao (~1980's) $\xi_y^{max} = \frac{1}{4\pi\alpha}\cdot\sqrt{\frac{\delta}{N_{IP}}}$ ← damping decrement, $\alpha \approx 0.03$ = function of tunes, distrib., etc
- Gao (1998) $\xi_y^{max} = \frac{H_0}{2\pi\gamma}\cdot\sqrt{\delta}$ $H_0 = 1/6\cdot10^6$???
- Assman (2000) $\xi_y^{max} = \frac{1}{2\pi}\cdot\sqrt{\frac{\delta}{2\Gamma}}$, Γ is UNKNOWN randomness parameter
- Talman

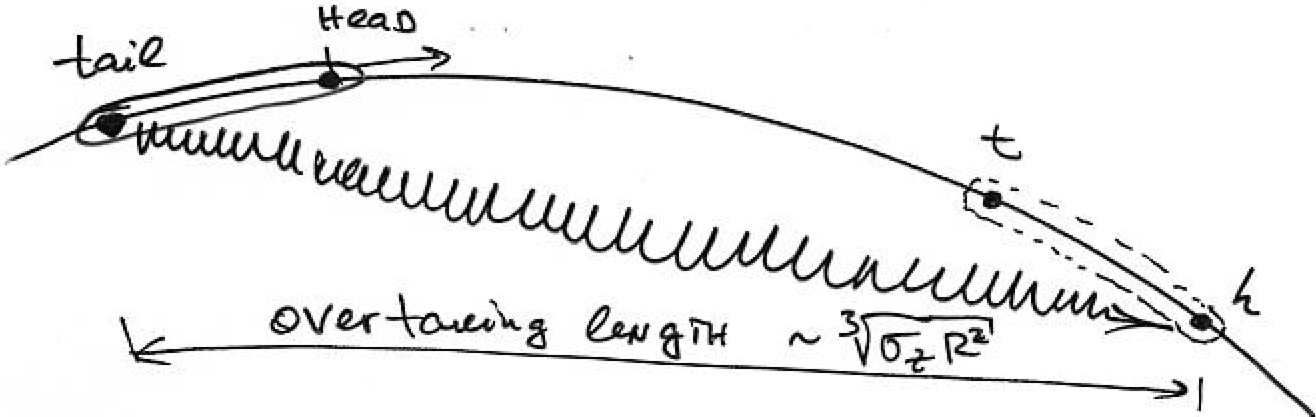
bad tunes: $\xi_y^{max} \simeq \frac{?}{\pi B_n}$ ← parametric res. strength

good tunes (2nd order): $\xi_y^{max} \sim \left(\frac{\delta}{B_n}\right)^{1/2}$

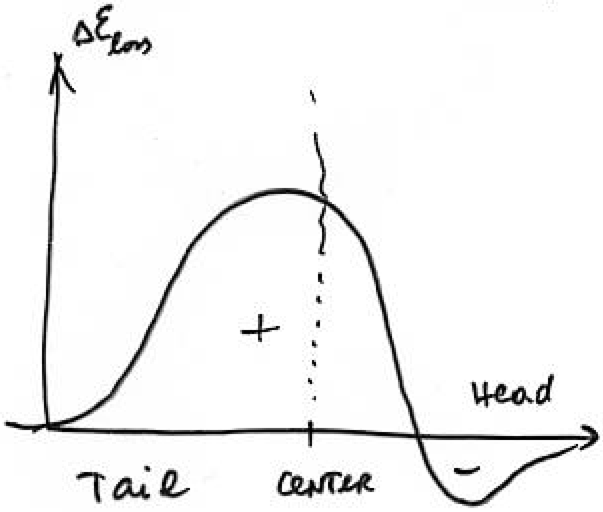
great tunes: $\xi_y^{max} \sim \left(\frac{\delta}{B_n}\right)^{1/3}$

Coherent Synchrotron Radiation Effects:

* overtaking "tail – head" interaction

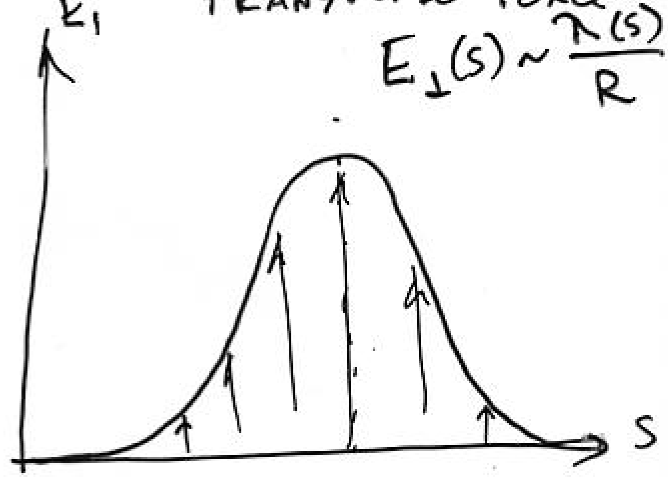


LONGITUDINAL FORCE



TRANSVERSE FORCE

$E_\perp(s) \sim \frac{\lambda(s)}{R}$

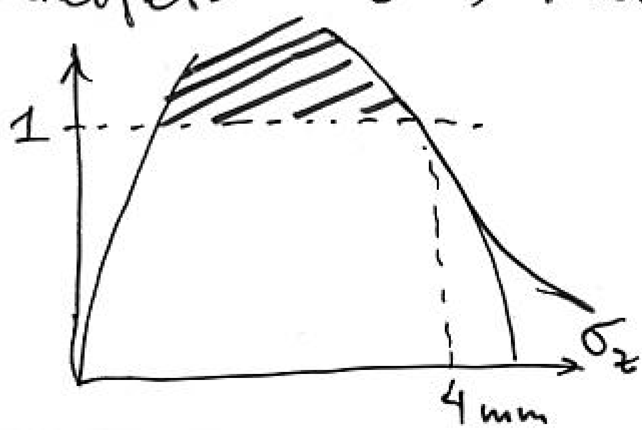


⇓ microbunching

⇓ ⊥ emittance growth

* IF BUNCHES ARE SHORT & INTENSE

→ S. Heifets: CRS will be a problem @ 10^{36}

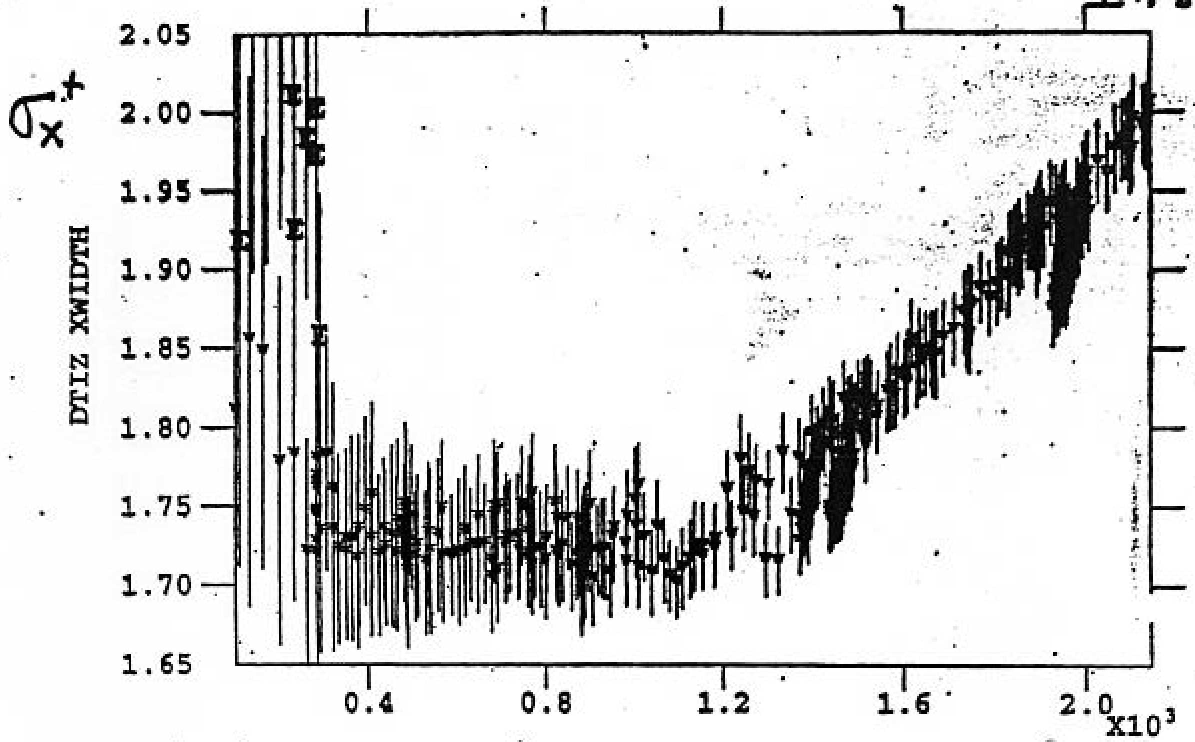


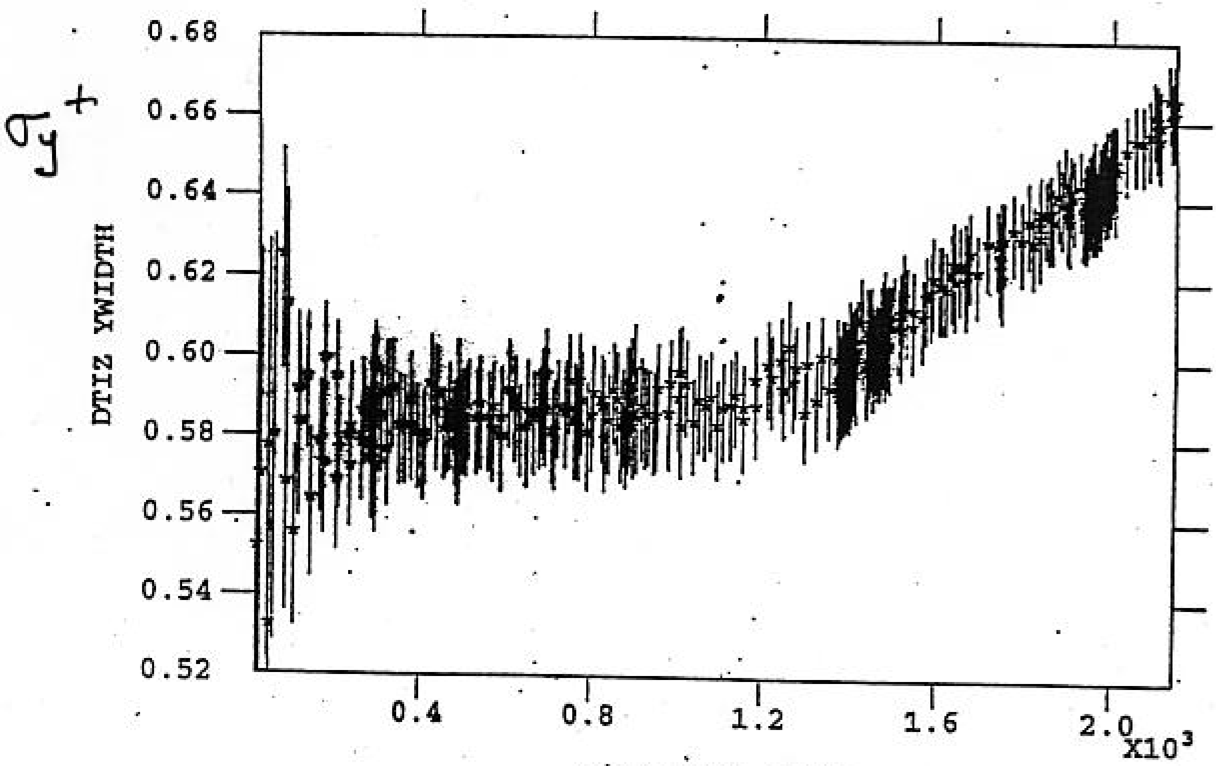
* μ-bunching
* no CSR screening if $\sigma_z < 4$ mm

PEP-II

(J. Seeman)

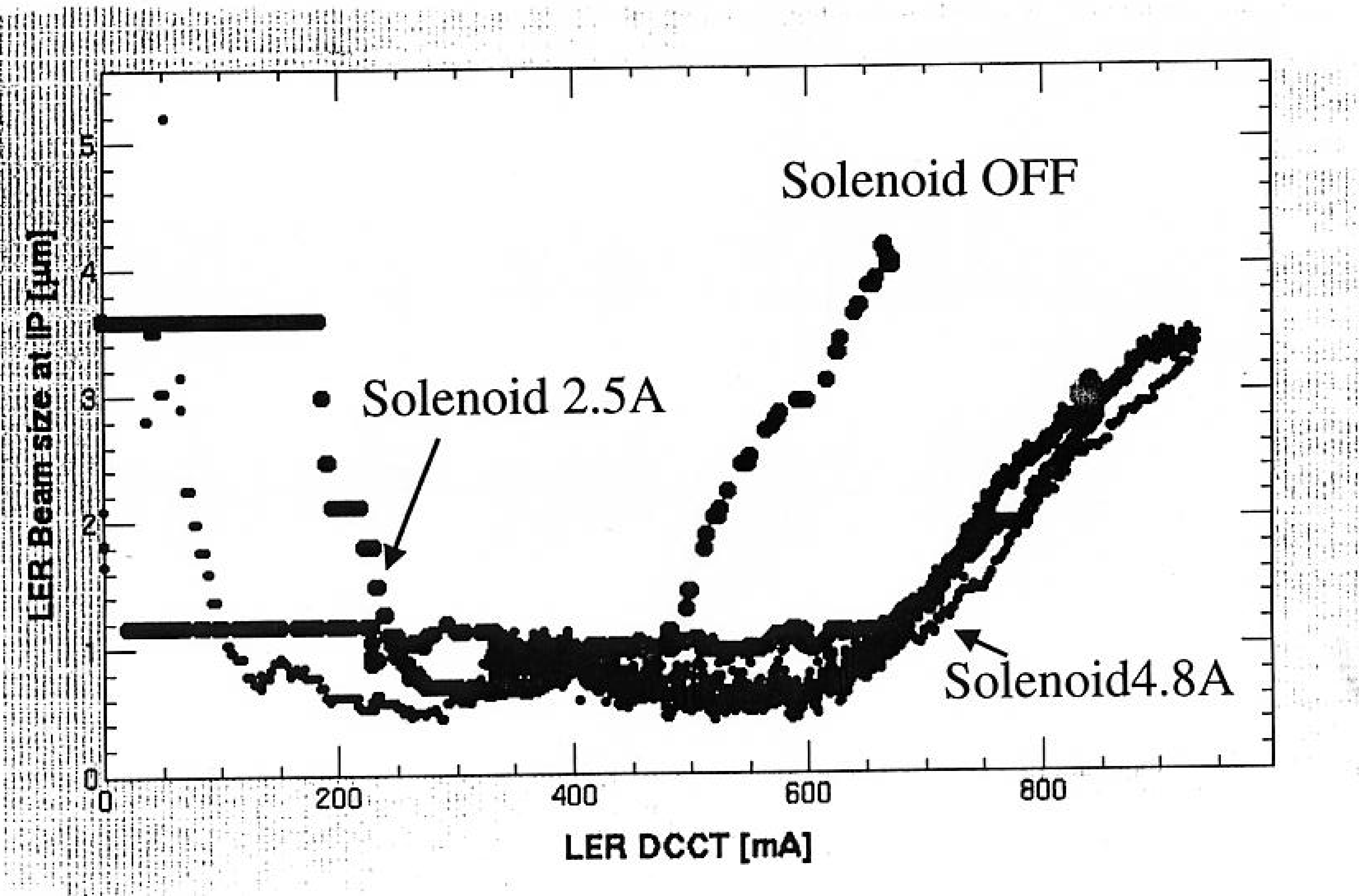
ECI: Electron Cloud Instability





KEK-B (Y. Funakoshi)

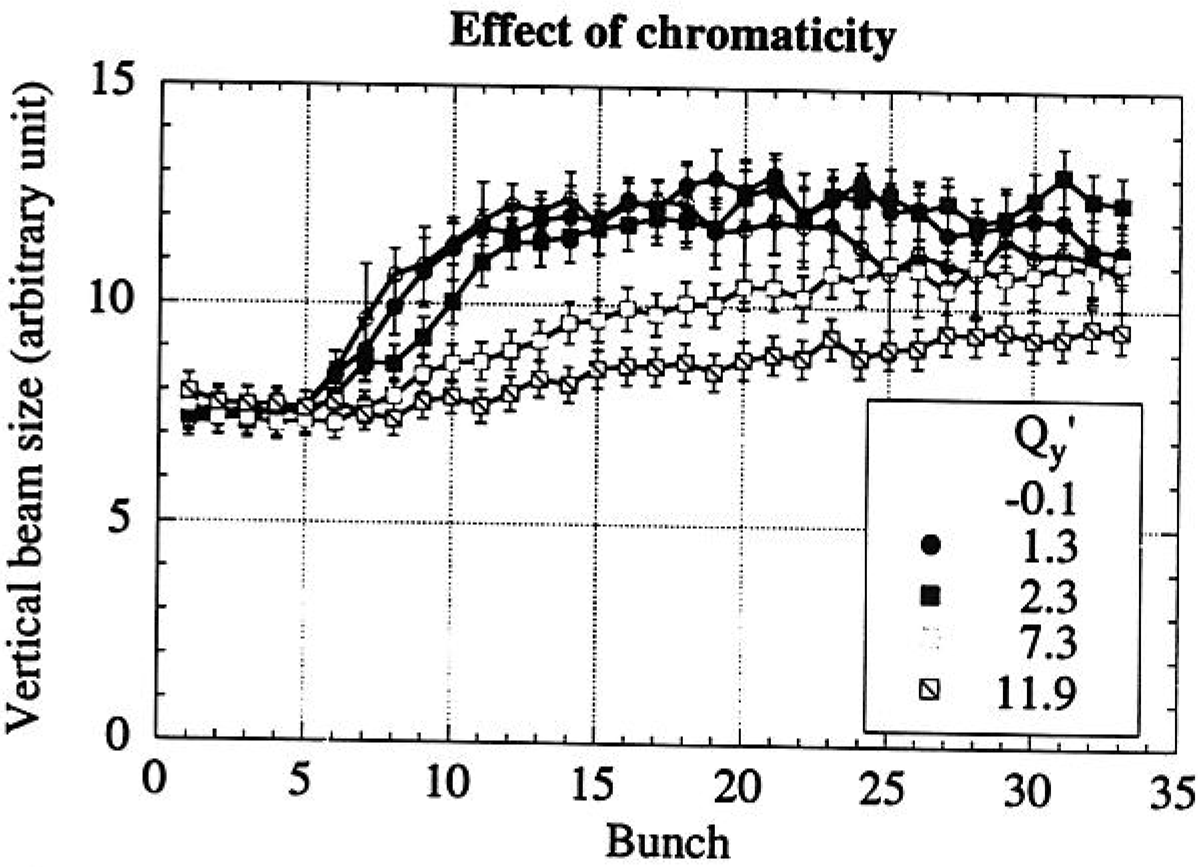
LER beam size measured by using a SR interferometer



KEK-B (Y. Funakoshi)

* Beam blow-up is a single-bunch effect

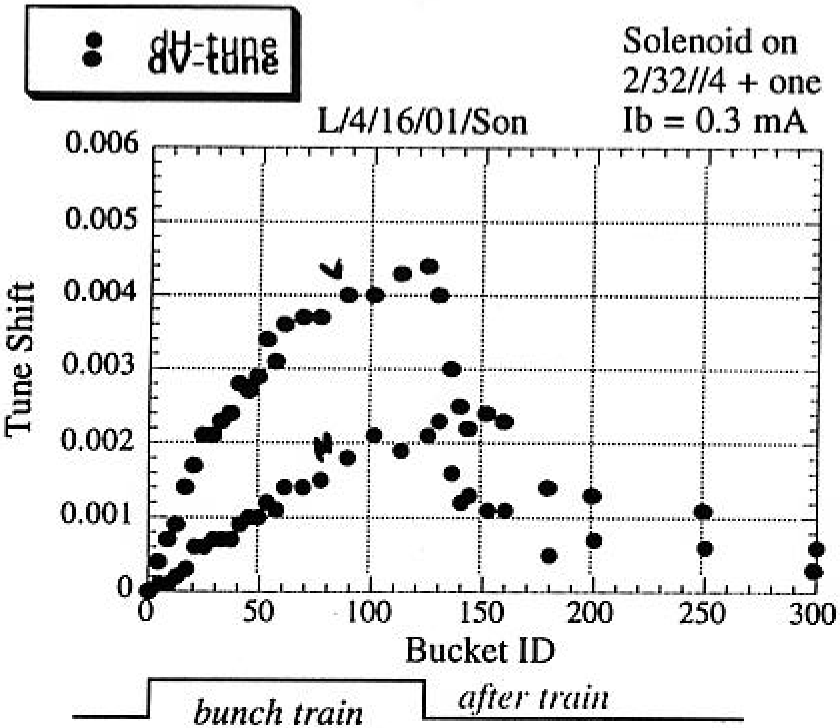
* but e-cloud density builds up along bunch train



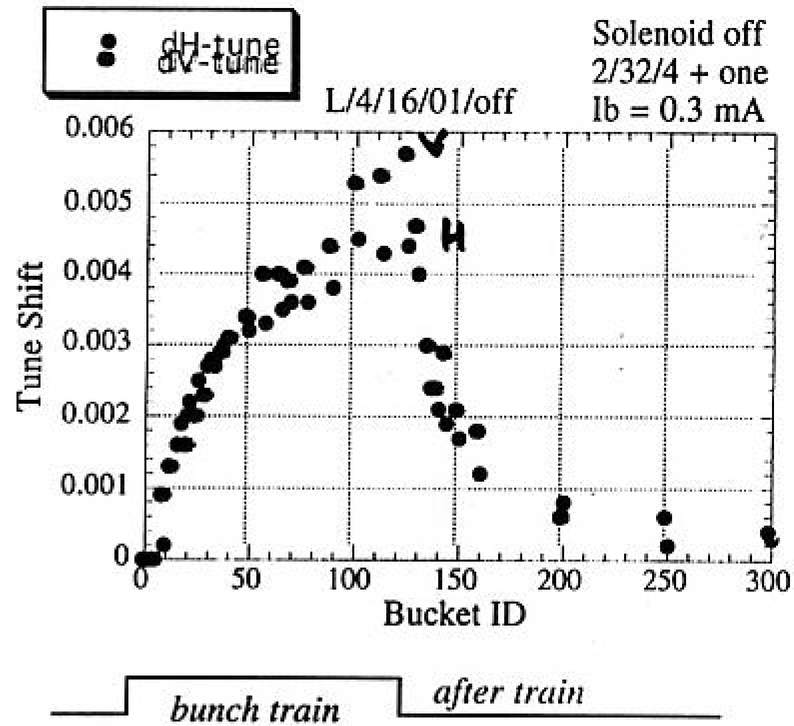
KEK-B (T-Ieiri)

Tune Shift in LER

Solenoids all on



Solenoids all off



measured in April 2001

-> The tune depends on where a bunch is placed, which is affected by the electron cloud.

Negative space-charge effects

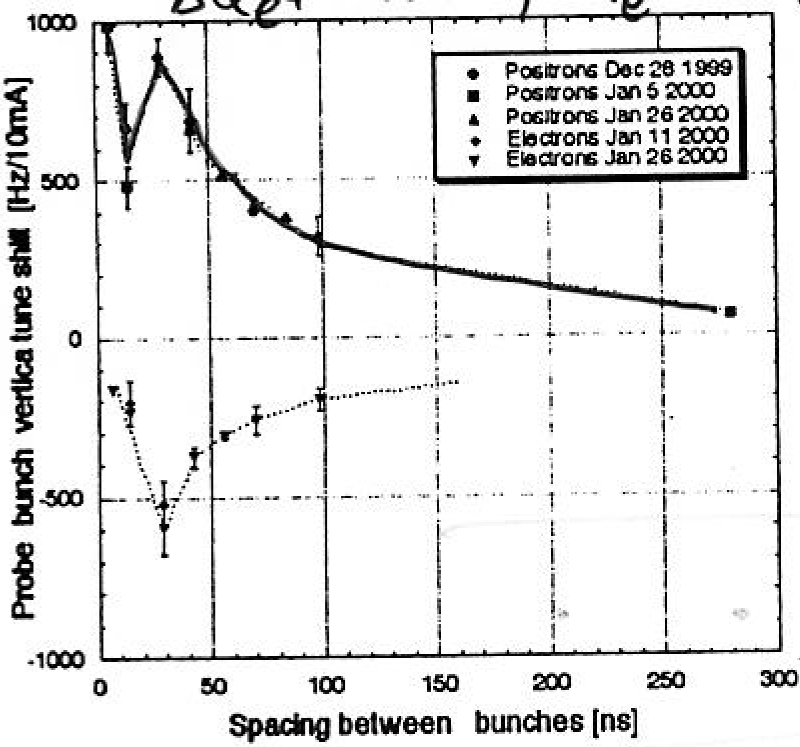
Observation (summary)

- Probe bunch tune shift versus bunch spacing

(normalized to 10mA of leading bunch current)

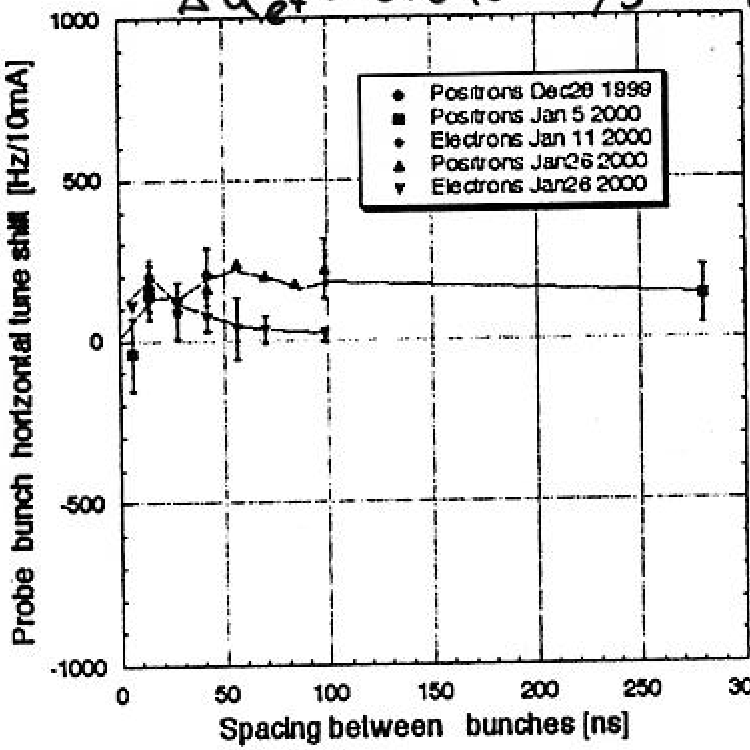
- Vertical tune shift

$\Delta Q^{y}_{e+} = 2.5 \cdot 10^{-3}$, $\Delta Q_{e-} = -\Delta Q_{e+}$



- Horizontal tune shift

$\Delta Q^{x}_{e+} = 0.5 \cdot 10^{-3} = 1/5 \cdot \Delta Q^{Y}_{e+}$



KEK LER:

	Sol OFF	SOL ON	Δ
ΔQ_V	= 0.006	0.0045	0.0015
ΔQ_H	= 0.0045	0.0025	0.0020

CESR : HOR / vert asymmetry

$$\Delta Q_V \approx (5-10)\,\Delta Q_H$$

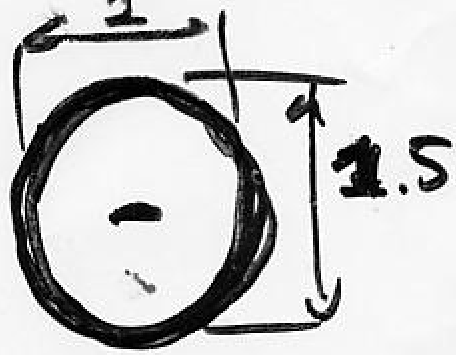
Explanation for KEK LER:

e-cloud in dipoles

HOR size > vert

e-cloud in straights

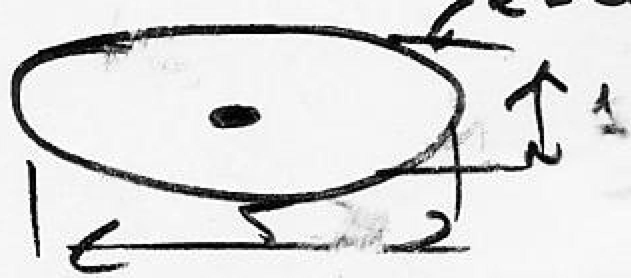
HOR size < vertical



Explanation for CESR

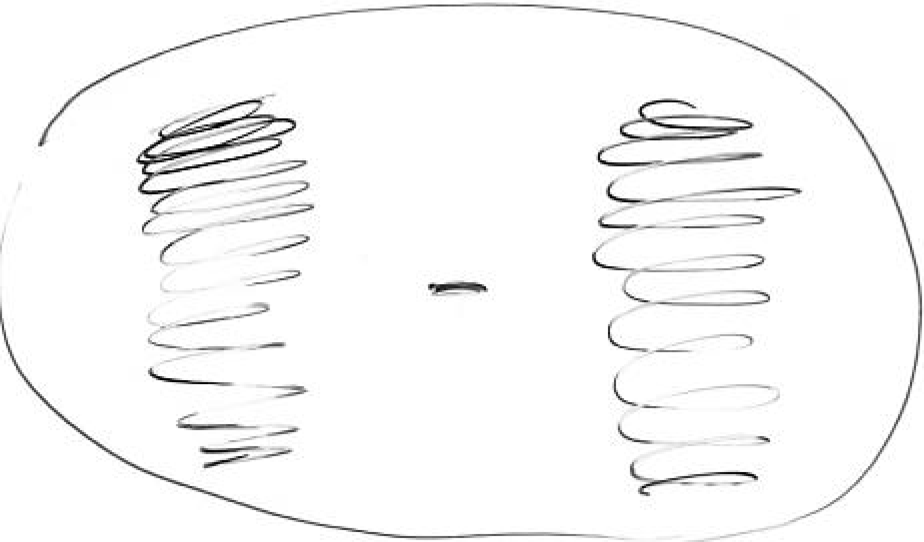
* or $\beta_V = 5\beta_H$

and



THAT CONTRADICTS

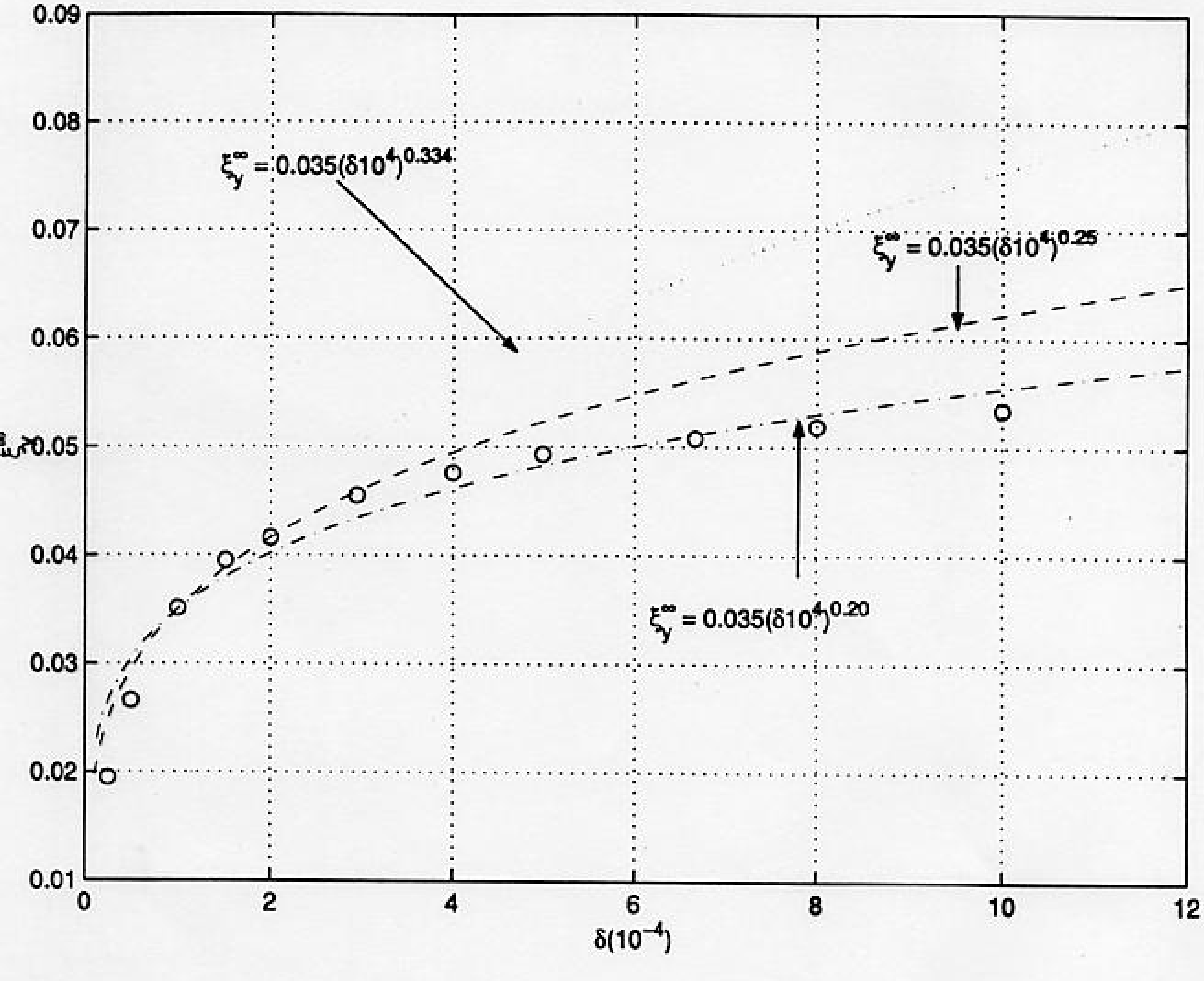
e-cloud simulations



Y. Cai

$\xi_y \sim \delta^{(\frac{1}{3} \to \frac{1}{5})}$

$\xi_x \sim \delta^{1/3}$



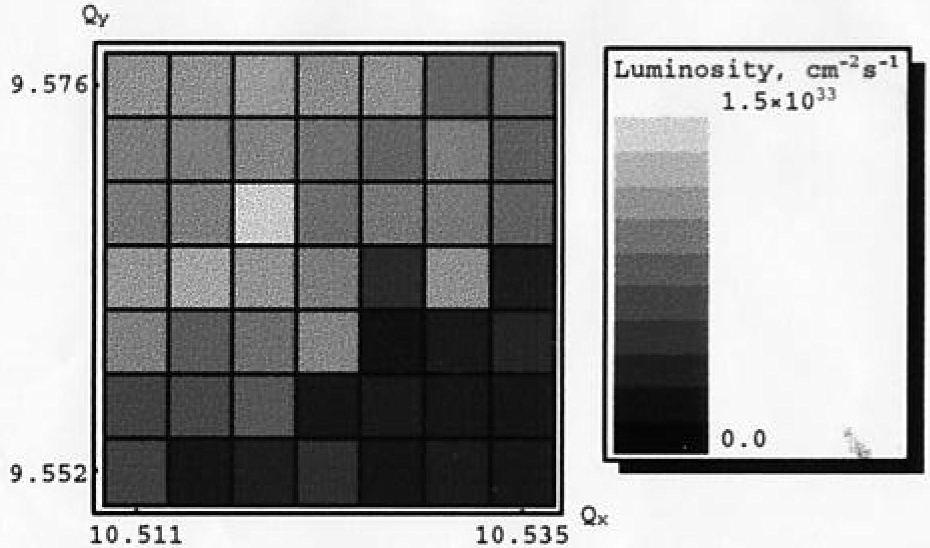
* code results ($\mathcal{L}, \xi, \sigma_{x,y}$) are in excellent agreement with PEP-II observations

* code is fast

J. Rogers

Benchmarking the code with CESR at 5.3 GeV:

Tune scan of luminosity using ODYSSEUS simulation:



Simulation conditions: perfectly linear lattice, no vertical radiation excitation.

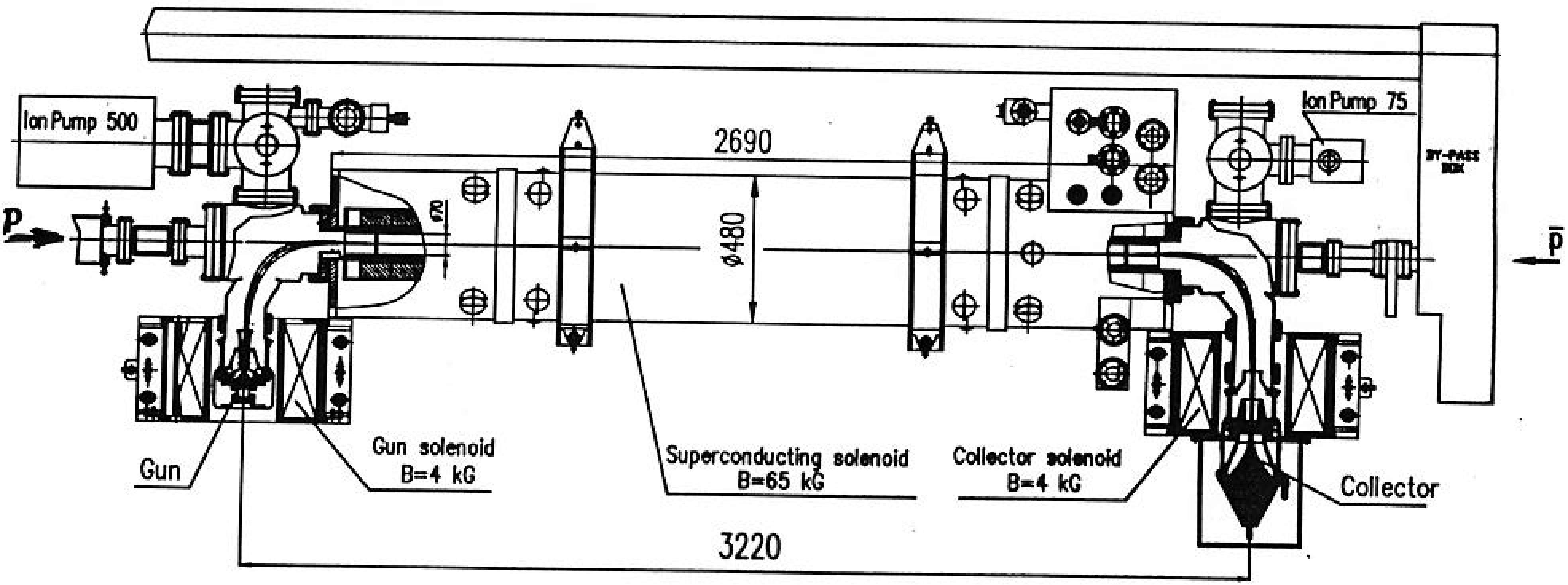
Beam allowed to find its own equilibrium vertical size due to the beam-beam effect.

Predicted luminosity is 1.02 × best observed CESR luminosity.

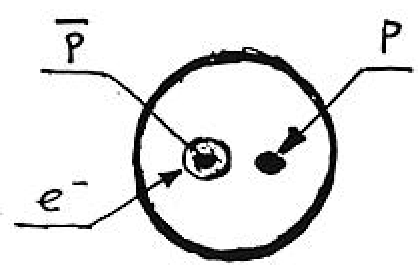
FNAL (V.Shiltsev)

Tevatron Electron Lens

- operates in Tevatron, produces $\Delta Q \sim 0.01$ in 980 GeV p's



* e-lens for electron mashines looks much simpler (less current, shorter, etc.)



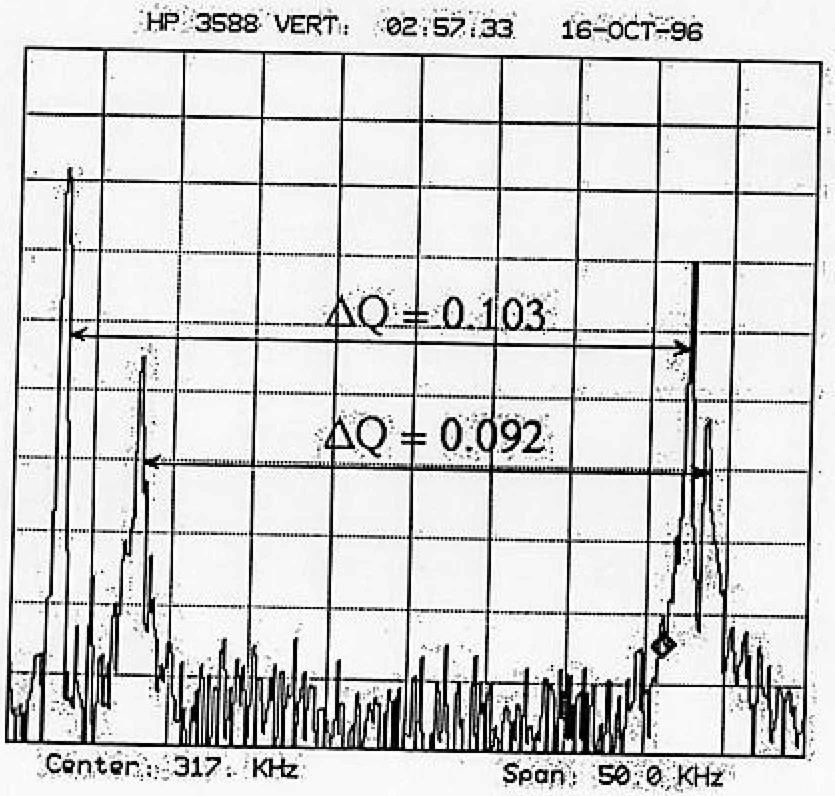
* flat e-beam is possible

R.Talman / E. Young

Π Mode Tune Shift

$$I_{\text{per beam}} = 21 \text{ mA}$$

$$\overline{\Delta Q_\pi} = 0.098$$



Round beam-beam studies

in coupling resonance

* Novosibirsk: VEPP-2000, round beams with proper optimized sextupole distribution → prospects for high $\mathcal{L}$

What are the critical steps in improving machine performance?

- Beam-beam interaction

  Work at beam-beam models until they are really predictive.
  Round beam option: explore limiting ξ (VEPP-2000, CESR-c,…).

- Two- (or three-) stream instabilities

  Simulations and models need to predict effect with much better precision. Need to make sure all important physics (ions? bunch length effects?) is included. Vigorous experimental programs help!

- Geometrical impedance

  3-D modeling of all (possibly long or complicated and non-axisymmetric) structures (IR chambers, collimators,…) is necessary to avoid surprises in impedance or loss factor.
  Investigate coherent synchrotron radiation effects.

- Feedback for BBI

  Long range BBI creates need for bunch-by-bunch correction of collision offset, tunes, (beam sizes…?). Hardware development: fast kickers, RFQs, electron lens,…?