Super*B* Beam Stability

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Introduction

- Super*B* = high-current, many bunches, small ε
- To estimate instability thresholds, use *B*-Factories as guidance
    - Scale instability thresholds from PEP-II observations
    - Expect some gain in threshold from lower impedance.
- Some effects significant in Super*B* that were not in PEP-II
    - Intra-beam scattering (IBS) & Touschek life time
    - Ion- and electron-induced instability (after mitigation)
    - ILC DR work has investigated some of these in great detail

Scaling Super*B*/PEP-II

	SuperB HER	PEP-II HER	**Factor *HER***	SuperB LER	PEP-II LER	**Factor *LER***
E (GeV)	7	9	**0.78**	4	3.1	**1.29**
R (m)	286	353	**0.81**	286	353	**0.81**
$<\beta>$ (m)	5.5	14.5	**0.37**	5.5	10.1	**0.53**
α_p	3.8e-4	2.41e-3	**0.16**	3.2e-4	1.24e-3	**0.26**
ν_s	0.0141	0.048	**0.29**	0.0133	0.03	**0.44**
$\delta p/p_{\mathrm{rms}}$	5.6e-4	6.4e-4	**0.88**	7.9e-4	6.23e-4	**1.27**
ε_x (nmr)	1.6	50	**0.03**	2.8	28	**0.1**
ε_y (nmr)	4e-3	1	**0.004**	7e-3	1	**0.007**
σ_l (cm)	0.5	1.2	**0.42**	0.5	1.1	**0.45**

Single-Bunch Instabilities

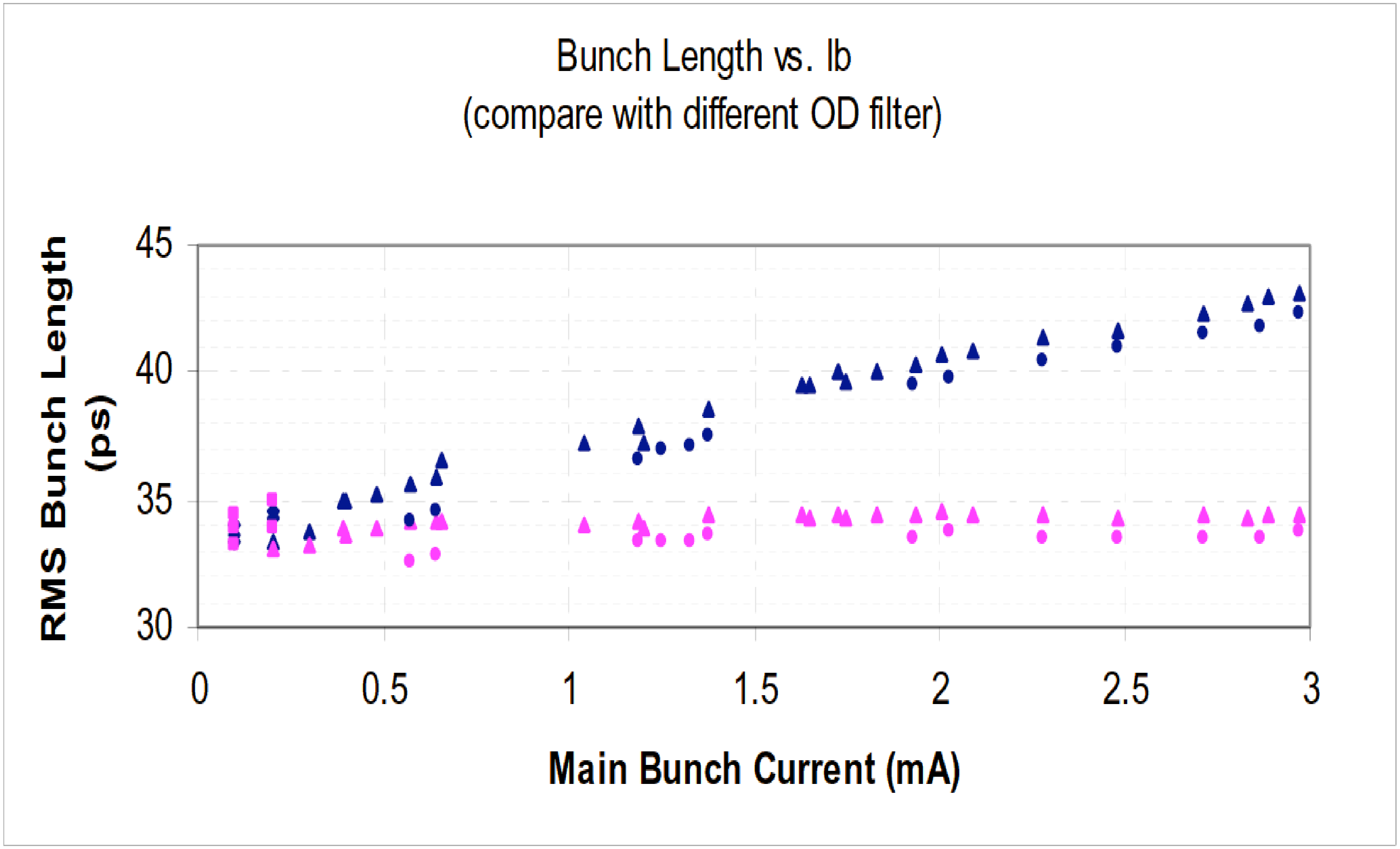
Instab-ility	Threshold	Super*B* HER/ PEP-II HER	PEP-II HER observed (mA)	Super*B* LER/ PEP-II LER	PEP-II LER observed (mA)
μwave	$\hat{I} = \frac{2\pi\lvert\eta\rvert\left(\frac{E}{e}\right)(\beta\delta p/p)^2}{\left\lvert\frac{Z_\parallel}{n}\right\rvert_{eff}}$	0.1	>18	0.54	>3
TMCI	$I_b = \frac{16\sqrt{\pi}\left(\frac{E}{e}\right)\nu_s\sigma_l}{3\langle\mathrm{Im}(Z_\perp)\beta_\perp\rangle R}$	0.38	>18	0.66	>3

Super*B* will operate at 1.47 mA/bunch in both rings.

With modest improvements in ring impedance the single-bunch instabilities should be sufficiently controlled (but see S.N. Talk!)

PEP-II LER Bunch Length

W.Cheng,
SLAC



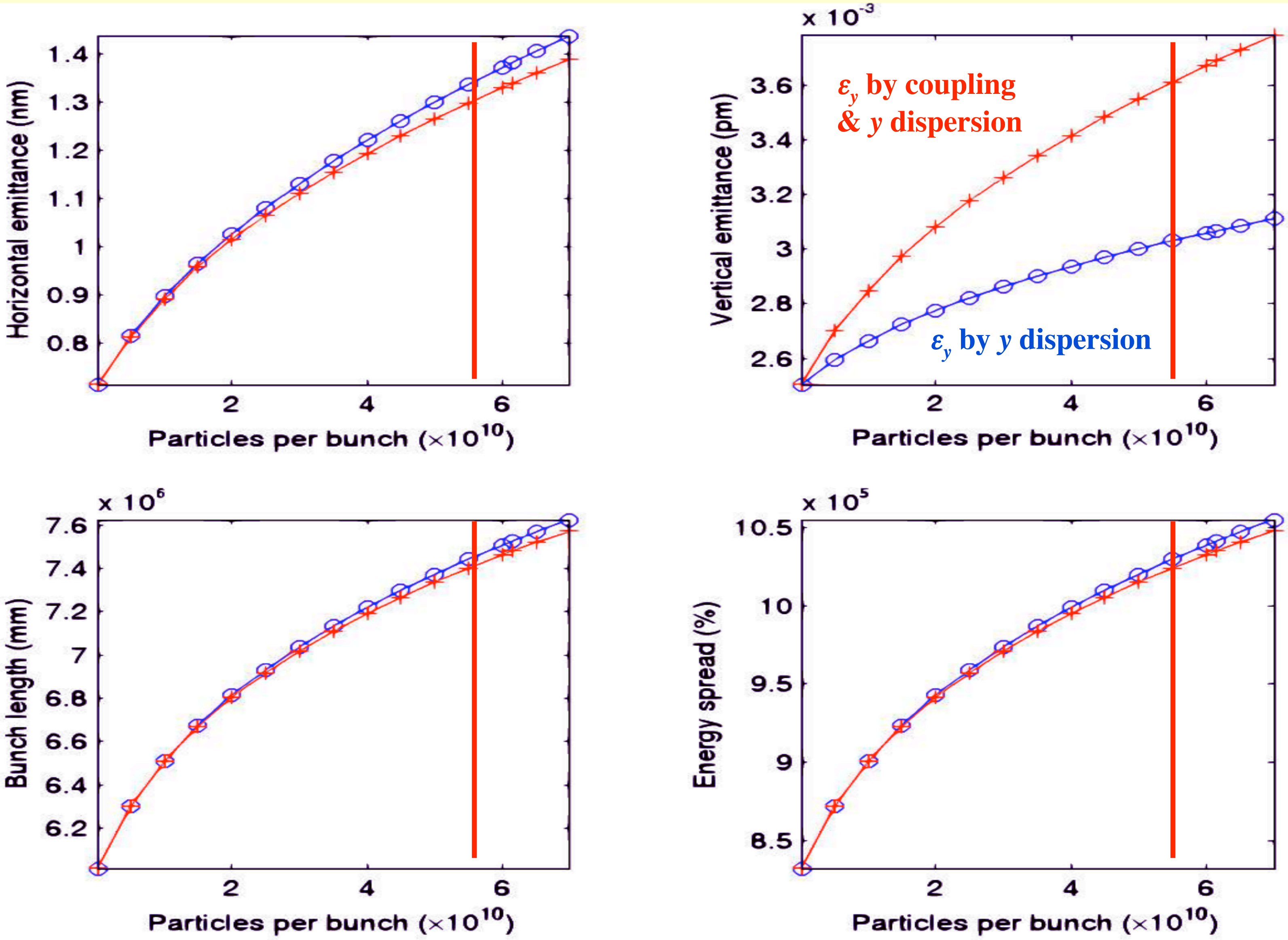
Low-Emittance Specifics

- The small emittance affects IBS and Touschek life time
  - – IBS not seen in PEP, Touschek lifetime seen in LER but not dominant
  - – > scaling is not so easily done
  - – Beam size ratios (x•y): 1% (HER), 2.5% (LER)
- We estimated IBS emittance growth & Touschek life time by simulation.
  - – The IBS simulations use the same code as used for ILC DR studies (Wolski).
  - – Touschek simulations done with DaΦne code (➥Boscolo)

IBS (Super*B* LER)

A. Wolski, Liverpool, Super*B* CDR.

New lattice has ex=2.8 nmr, ey=4 pmr, => expect less growth



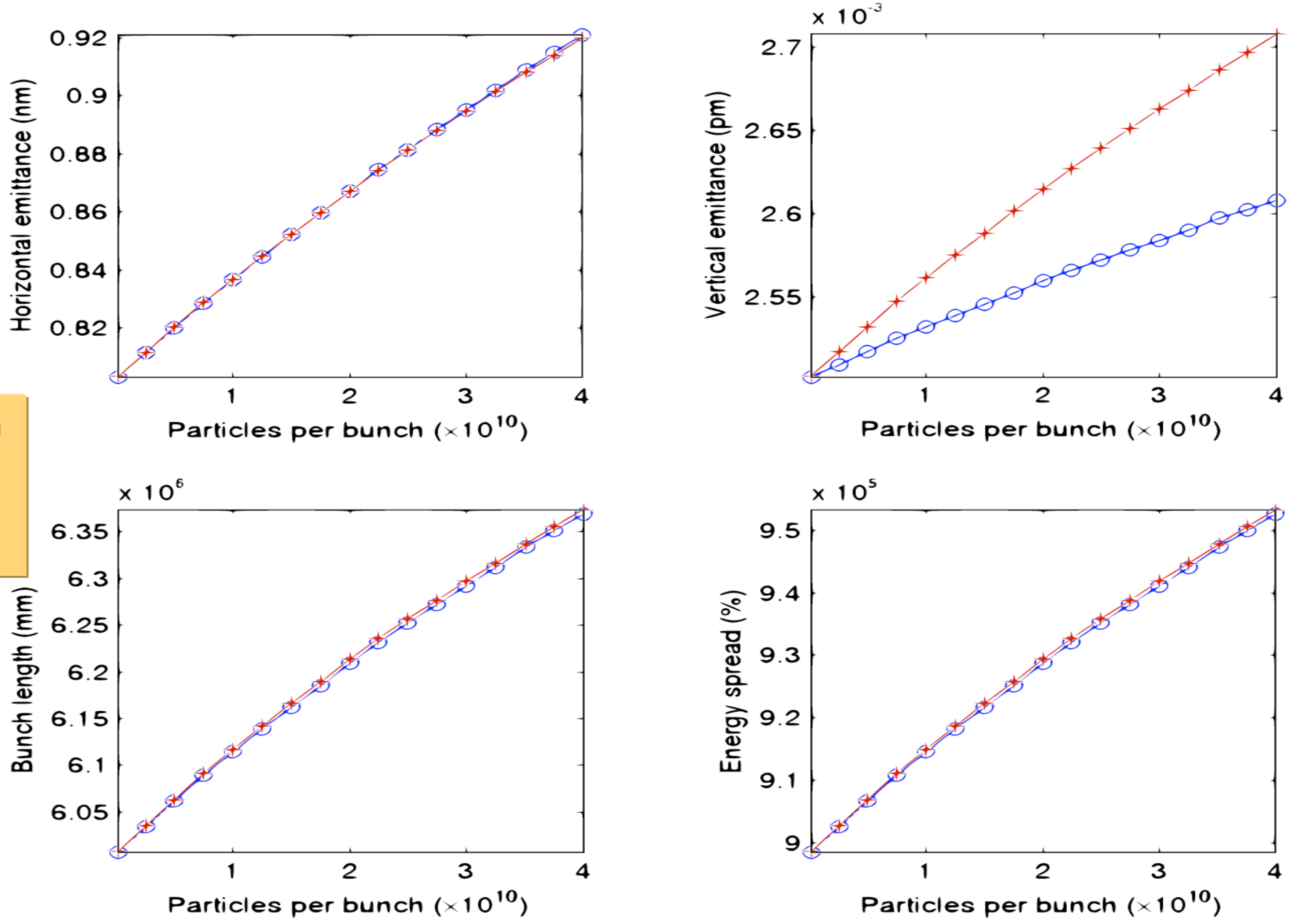
Space Charge Effects

- The small emittance can lead to the somewhat unusual manifestation of space-charge effects esp. in the LER.
  - $\propto 1/\varepsilon_x/\sigma_l$ in x (≈20), $\sqrt{\beta_y}/(\sqrt{\beta_x}\bullet\sqrt{\varepsilon_x}\bullet\sqrt{\varepsilon_y}\bullet\sigma_l)$ in y (≈100)
- Tune shifts estimated to reach -0.18 in *y*
  - emittance growth depending on tune space
- Effect studied in detail for ILC DR designs
  - SuperB LER studied with the same code.

Space-Charge Effect in LER

A. Wolski Liverpool, in SuperB CDR

New design parameters will reduce this



Summary Single Bunch

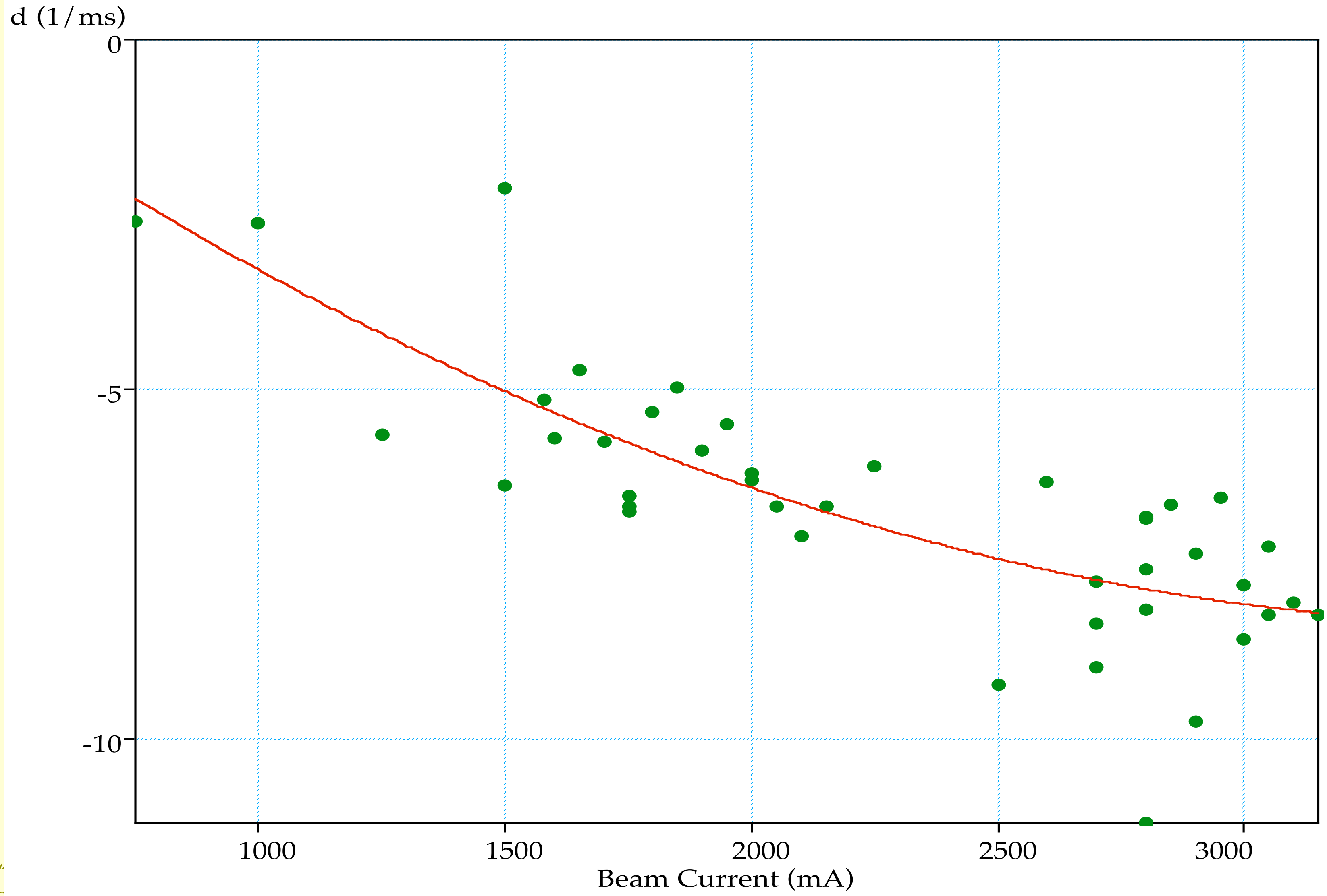
- Microwave & TMCI thresholds appear to be manageable.
  - Esp. if we keep the impedance lower than at PEP
- Touschek beam lifetime is short in the LER.
  - 20…25 min with the new lattice parameters
  - Trickle charge an integral part of Super*B* design
  - Touschek background will have to be dealt with
- IBS appears to be a potentially serious challenge for maintaining beam emittance.
  - predicted growth up to 50% in *y*, 100% in *x* (CDR latt.)
  - likely much less with new lattice parameters

Multibunch Instability

- Both PEP-II rings exhibit strong low-mode transverse multibunch instability.
  - Thresholds are 100 mA or less total beam current
  - Growth rates of up to 2/ms have been observed in the LER, somewhat less in the HER.
  - Modal spectrum suggests resistive wall.
- One cause is likely the stainless steel chambers in the straight sections
  - also some hints of resonant enhancement of growth rates in the LER in y
- Transverse bunch-by-bunch feedbacks control this
  - damping rates as strong as -8/ms (17 turns) observed

PEP-II LER y TFB Damping

0 mode

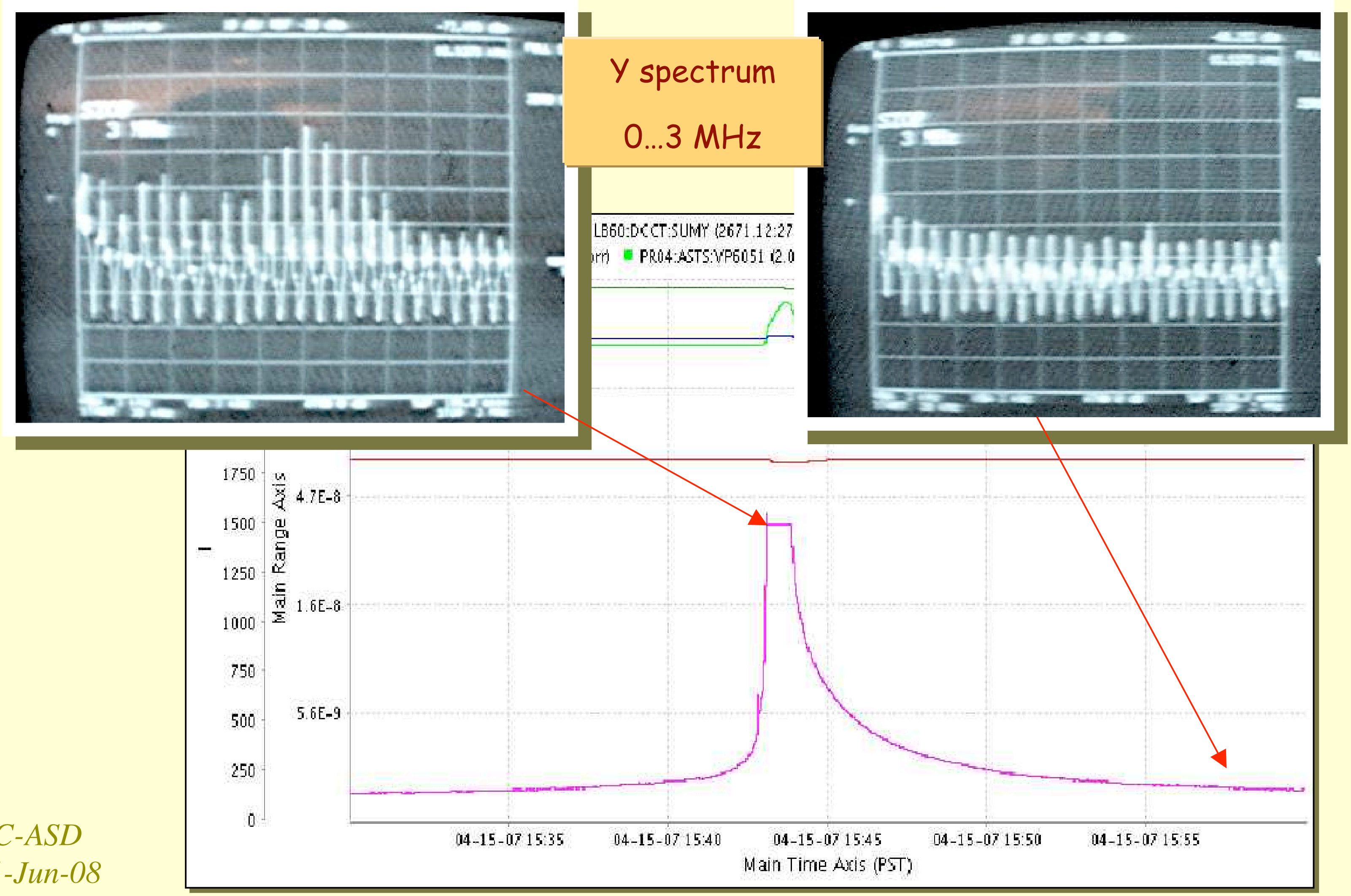


Ion Effects (HER)

- Ion trapping can occur in the strong beam potential of the Super*B* HER.
- Remedies known to be effective:
  - Ion-clearing gap in the beam
  - Low gas pressure in the vacuum system
  - Clearing electrodes
- In the PEP-II HER, ions have been clearly seen when vacuum conditions are bad
  - Despite clearing gap (1.4%) => likely a fast-ion (single-turn) effect
  - Characteristic multibunch instability spectrum
- Reducing gap too much also causes instability.

PEP-II HER Ion Instability (DIP Storm)

PR04 VDIP 6082 (a number of other DIPS do this as well)



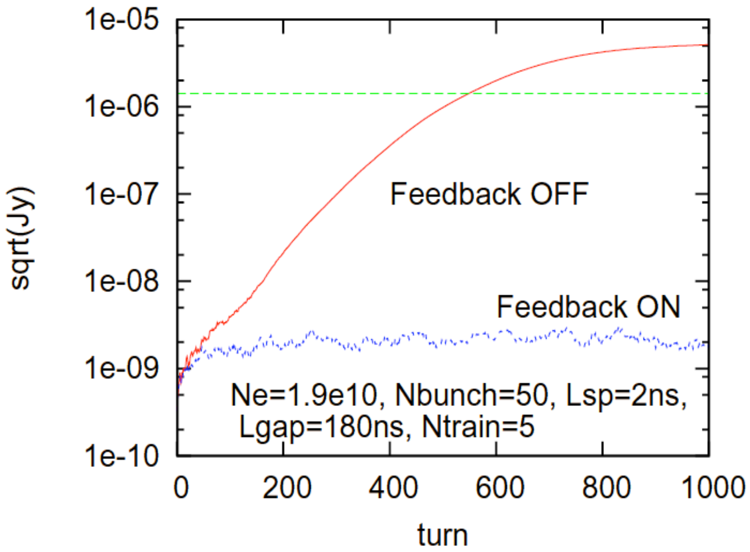
Y spectrum

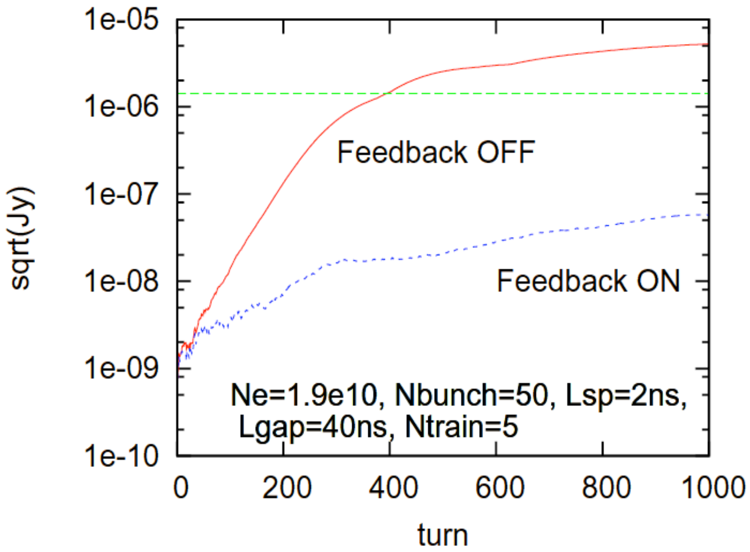
0…3 MHz

U. Wienands, SLAC-ASD
SuperB WS, Elba 1-Jun-08

- Feedback is *not* able to completely damp the beam motion
  - Growth rate at small amplitude is too high
  - Instability present even in collision with strong Landau damping from beam-beam (luminosity drop)
  - Multiple gaps in beam reduce this effect
- For Super*B*, relative effect may be much larger because of the small beam size
- Will likely need better vacuum than in PEP-II
  - May need multiple gaps in the beam
  - May need clearing electrodes

Ions in Super*B* HER

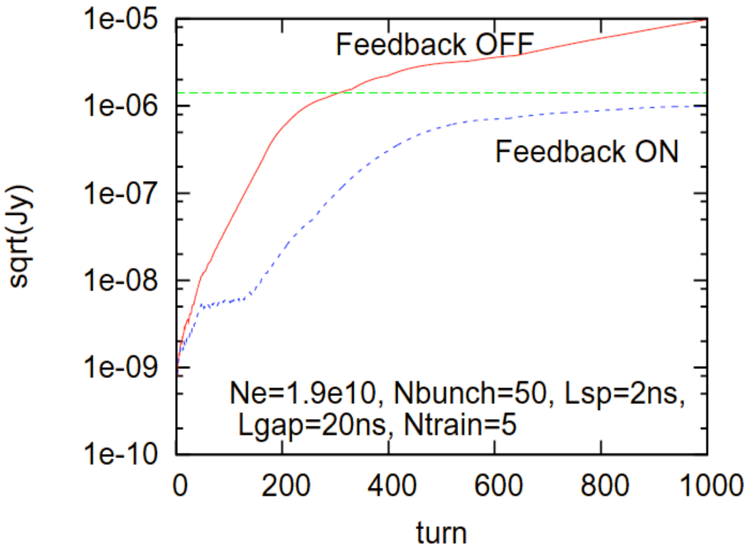




0.25 nTorr pressure

beam of bunch trains

1.9×10^{10} ppb



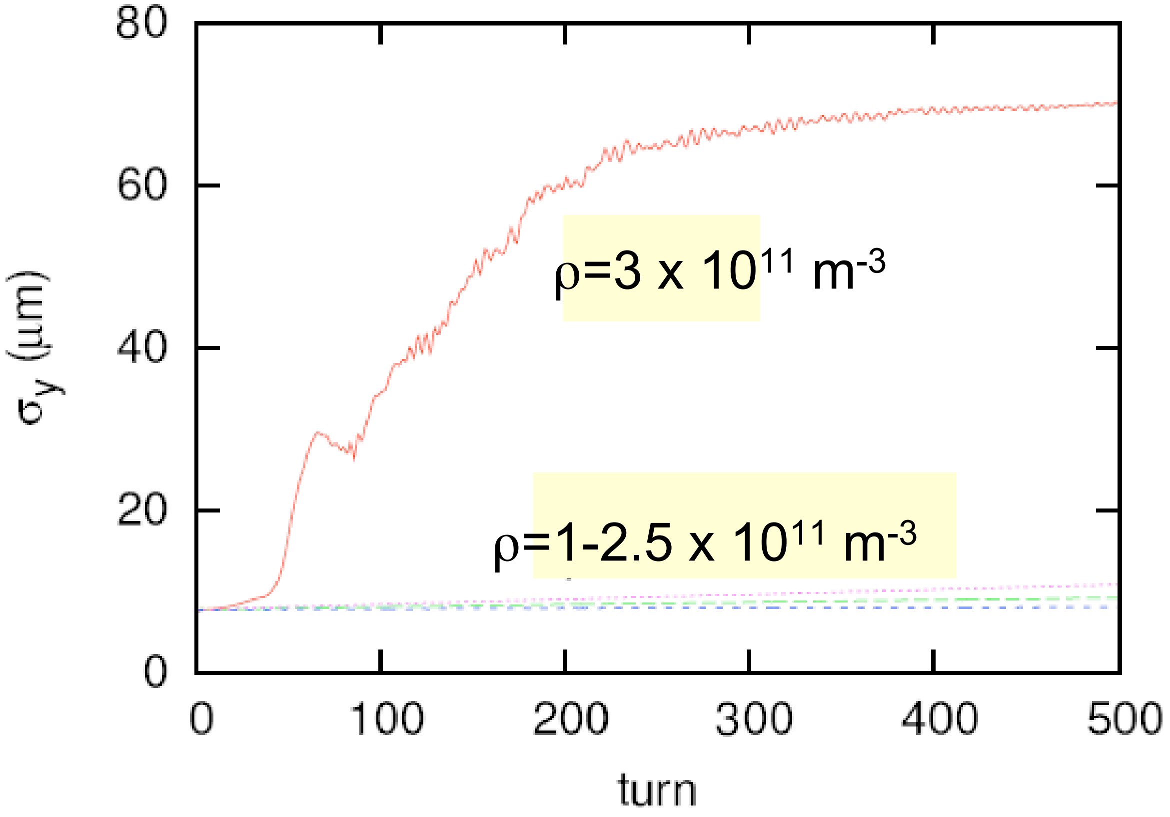
Electron Cloud Effect

- Electron-cloud instability (ECI) has been seen in both PEP-II and KEKB.
- Solenoids, antechambers, TiN coating effective to varying degree in reducing ECI
  - But residual effects most likely remain
- Again, the small beam size in Super*B* will likely cause it to be more sensitive that PEP-II or KEKB
- More powerful mitigation measures:
  - Reduce secondary emission with grooved chambers
  - Use clearing electrodes

Electron Cloud Instability

K. Ohmi, KEK

Emittance growth from single-bunch instability driven by electron cloud in the SuperB positron ring (nominal parameters of the 2.25 Km LER). Instability threshold set tolerances on maximum allowed SEY.

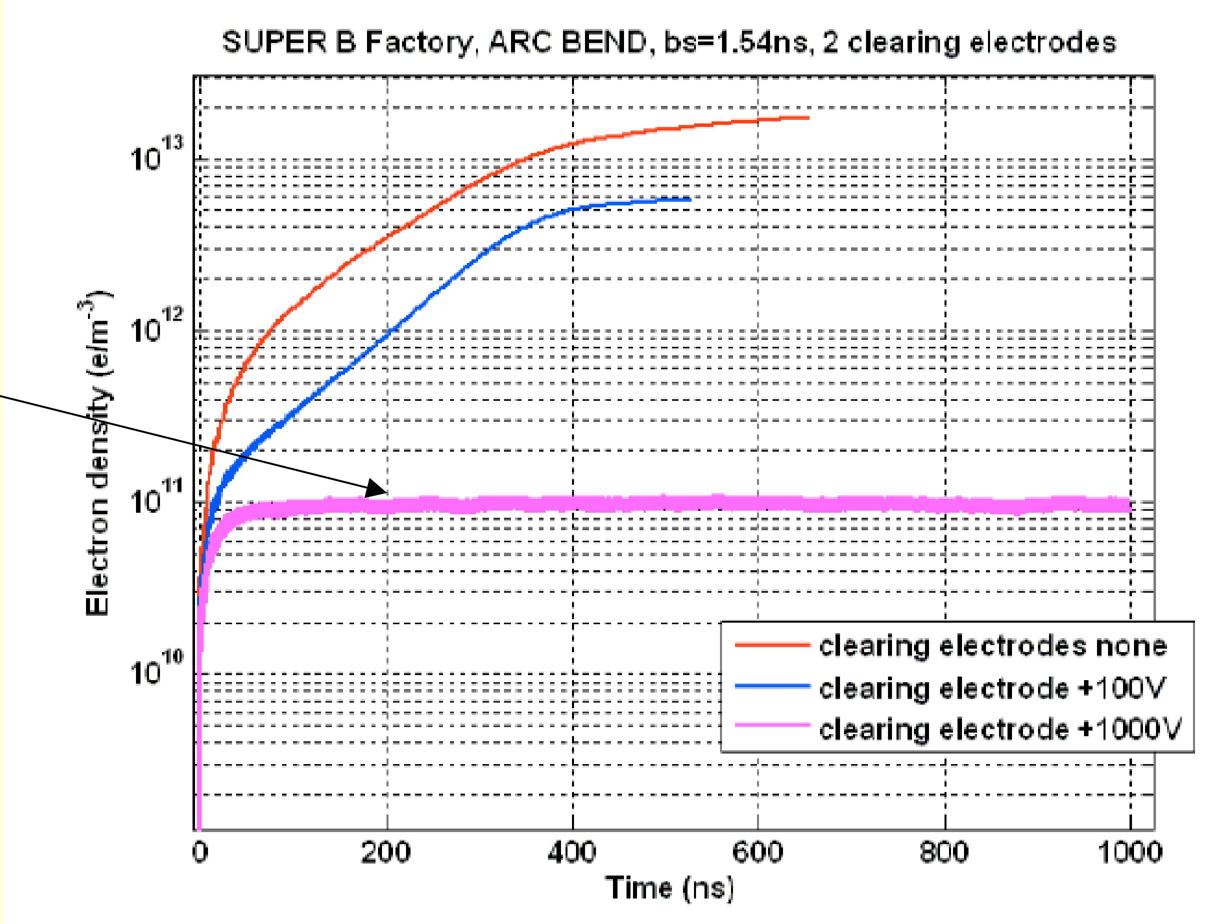


Electron Cloud Density

M. Pivi,

SLAC

Buildup of the electron cloud and the suppression effect of clearing electrodes in an arc bend of the SuperB positron ring (nominal parameters of the 2.25 Km LER).



Below threshold in Ohmi's simulations

Summary Multibunch

- Resistive wall instability unlikely to limit Super*B*
  - – SuperB vacuum chamber should have lower impedance, thus smaller growth rates
  - – Landau damping due to beam-beam further helps
  - – TFB is very effective against this instability
    - but noise impressed on beam could be problematic due to the small beam sizes
- Ions in the HER & electrons in the LER may be problematic
  - – lower pressure feasible but at great effort
  - – need for gaps in beam unattractive for upgrades
  - – need to investigate need for clearing electrodes

Conclusion

- The Super*B* low-emittance storage rings clearly present challenges for beam stability & emittance preservation.
- Fortunately,
  - from *B*-Factory data we know the impedance requirements can be met.
  - *B*-Factory data also allow validation of estimates for ion and electron-induced instabilities.
  - Dafne provides an important testing ground for Touschek & IBS estimates.
- A significant amount of work remains to be done but the issues appear tractable.