# Damping Rings

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# Key luminosity issues for LC Damping Ring

## Electron cloud

- For baseline parameters of the ILC (5Hz, 1312 bunches) estimated cloud density ~ 1/10 instability threshold

Evaluation of ecloud effects in ILC DR are revisited in this recent submission

"Investigation into Electron Cloud Effects in the ILC Positron Damping Ring", (http://arxiv.org/abs/1311.2890) in which

- Cloud model is based on
  - TDR bunch parameters
  - Design mitigations and their measured properties (SEY, PEY, etc.)
  - Radiation pattern based on photon tracking, measured reflectivities, …
- Instability and emittance dilution threshold computed with CMAD

( Models of cloud growth and instabilities benchmarked with CesrTA measurements)

# Key luminosity issues for LC Damping Rings

## Electron cloud

What about the high luminosity mode ?

- Note that measurements to date of emittance dilution and instability thresholds are all at vertical emittances 5 – 10 times ILC- DR spec.
- Anticipate that the emittance dilution results from the pinch effect which depends on the bunch size and charge as well as the cloud density.
- => Extrapolation to high luminosity parameters may be a stretch

## Tests at lower emittance desirable

- CesrTA phase III? – instrumented to make the measurements, but minimum emittance to date ~ 6-10 pm
- SuperKEKB ?
- Further development and benchmarking of simulation is essential
- Including measurement of dependence of emittance diluting threshold on bunch charge and size (witness bunch measurements)

# CLIC DR challenges and adopted solutions

| Parameters, Symbol [Unit] | 2 GHz | 1 GHz |
|---|---|---|
| Energy, $E$ [GeV] | 2.86 | |
| Circumference, $C$ [m] | 427.5 | |
| Bunch population, $N$ [$10^9$] | 4.1 | |
| Basic cell type in the arc/LSS | TME/FODO | |
| Number of dipoles, $N_d$ | 100 | |
| Dipole Field, $B_0$ [T] | 1.0 | |
| Norm. gradient in dipole [$m^{-2}$] | -1.1 | |
| Hor., ver. tune, ($Q_x$,$Q_y$) | (48.35,10.40) | |
| Hor., ver. chromaticity, ($\xi_x$,$\xi_y$) | (-115,-85) | |
| Number of wigglers, $N_w$ | 52 | |
| Wiggler peak field, $B_w$ [T] | 2.5 | |
| Wiggler length, $L_w$ [m] | 2 | |
| Wiggler period, $\lambda_w$ [cm] | 5 | |
| Damping times, ($\tau_x, \tau_y, \tau_l$) [ms] | (2.0,2.0,1.0) | |
| Momentum compaction, $\alpha_c$ [$10^{-4}$] | 1.3 | |
| Energy loss/turn, $U$ [MeV] | 4.0 | |
| Norm. hor. emittance, $\gamma\epsilon_x$ [mm·mrad] | 472 | 456 |
| Norm. ver. emittance, $\gamma\epsilon_y$ [mm·mrad] | 4.8 | 4.8 |
| Energy spread (rms), $\sigma_\delta$ [%] | 0.1 | 0.1 |
| Bunch length (rms), $\sigma_s$ [mm] | 1.6 | 1.8 |
| Long. emittance, $\epsilon_l$ [keVm] | 5.3 | 6.0 |
| IBS factors hor./ver./long. | 1.5/1.1/1.2 | 1.5/1.1/1.2 |
| RF Voltage, $V_{RF}$ [MV] | 4.5 | 5.1 |
| Stationary phase [$^o$] | 62 | 51 |
| Synchrotron tune, $Q_s$ | 0.0065 | 0.0057 |
| Bunches per train, $n_b$ | 312 | 156 |
| Bunch spacing, $\tau_b$ [ns] | 0.5 | 1 |
| RF acceptance, $\epsilon_{RF}$ [%] | 1.0 | 2.4 |
| Harmonic number, $h$ | 2851 | 1425 |

- High-bunch density in all three dimensions
  - **Intrabeam Scattering** effect reduced by choice of ring energy, lattice design, wiggler technology and alignment tolerances
  - **Electron cloud** in $e^+$ ring mitigated by chamber coatings and efficient photon absorption
  - **Fast Ion Instability** in the $e^-$ ring reduced by low vacuum pressure and large train gap
  - **Space charge vertical tune-shift** limited by energy choice, reduced circumference, bunch length increase
  - Other **collective instabilities** controlled by low –impedance requirements on machine components
- Repetition rate and bunch structure
  - Fast damping times achieved with SC wigglers
  - RF frequency reduction @ 1GHz considered due to many challenges @ 2GHz (power source, high peak and average current, transient beam loading)
- Output emittance stability
  - Tight jitter tolerance driving kicker technology
- Positron beam dimensions from source
  - Pre-damping ring challenges (energy acceptance, dynamic aperture) solved with lattice design

## Electron cloud – CLIC

- CLIC design requires extremely effective photon absorption to adequately suppress the cloud ~ 99.9%   (vs 98% for ILC design)
- To be achieved by careful design of antechambers and development of chamber coatings/treatments that minimize photon scattering and quantum efficiency – (tests planned at CesrTA)

## Fast Ion instability

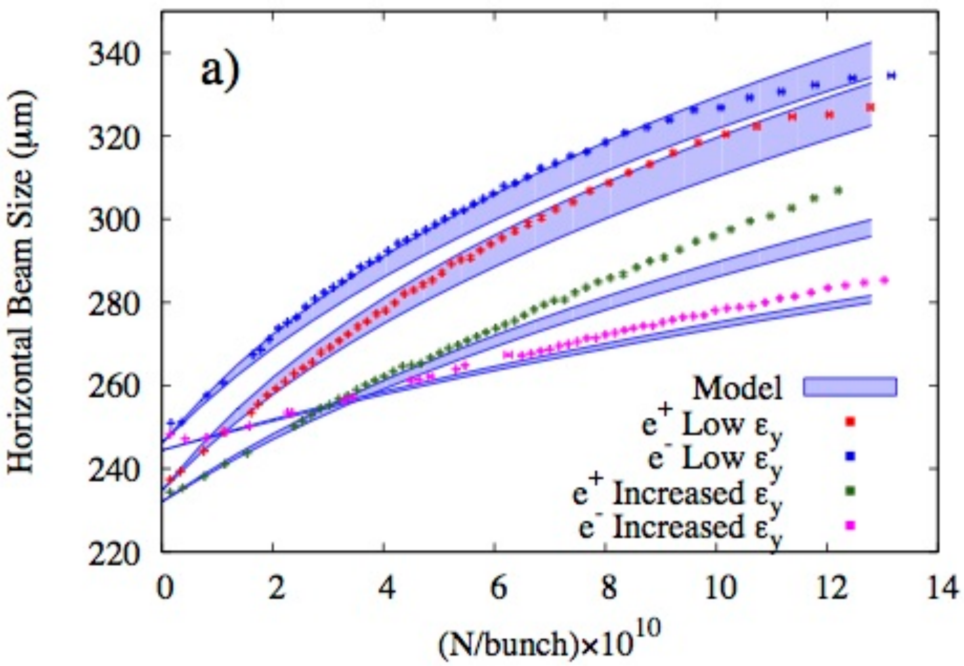
- In electron DR, FII constrains vacuum pressure to around 0.1nT/ 0.5nT CLIC/ILC
- Measurements at synchrotron x-ray sources (e.g. SOLEIL, SPEAR, ALS, SSRF …) are still relatively qualitative
- Simulations indicate multi-bunch feedback with ~ tens of turns damping times is required
- It would be best to have a measurement of instability threshold (without having to compromise machine vacuum)
- And to determine if there is emittance dilution (that can not be corrected with feedback)

## Quantitative measurements essential

- i.e., Measure bunch by bunch vertical size and amplitude in train with ~ 32 bunches
- Can be done at light source with few pm vertical emittance and appropriate instrumentation (bunch by bunch)
- A CesrTA study is planned for December 2013

# Intra-beam scattering

- Intra-beam scattering (small effect for ILC, 1.5 X for CLIC)
  - Measurements at CesrTA and SLS in reasonably good agreeement with theory

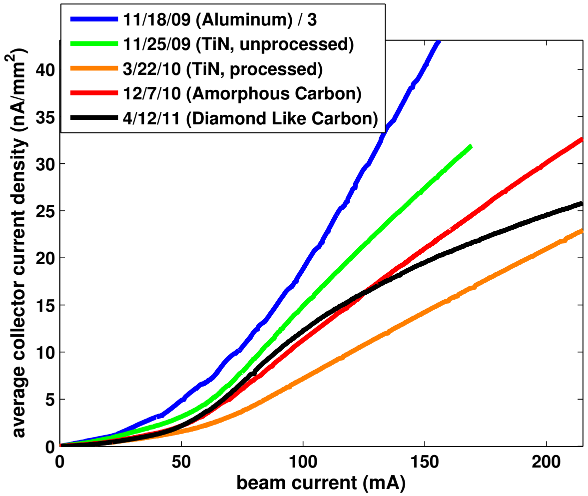



Horizontal beam size vs bunch charge for different "zero" current vertical emittances
Blue bands indiciate the uncertainty in the "zero" current vertical emittance

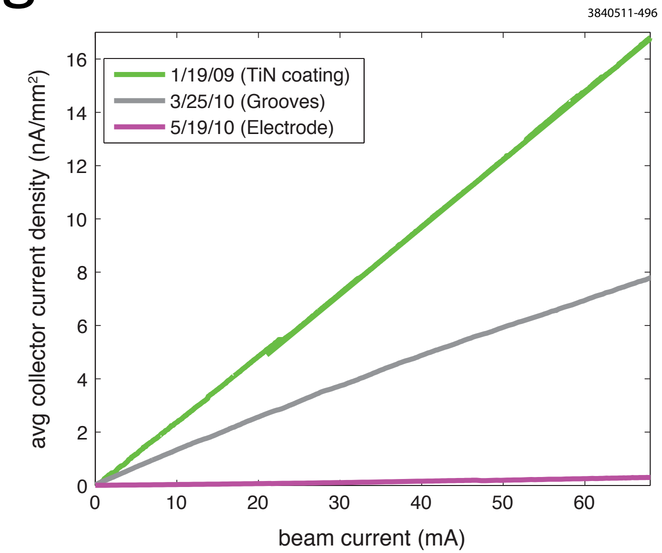
# Other collective effects

- Space-charge reduced <0.1 with combined circumference reduction and bunch length increase (CLIC) and higher energy (ILC)
  - Tests in future light sources
- Single bunch instabilities avoided with smooth vacuum chamber design (effect of coating)
  - Measurements at ESRF, SOLEIL, PSI, ALBA
- Coherent synchrotron radiation still needs to be fully evaluated (CLIC) and well below threshold for ILC-DR
  - Measurements in light sources (BESSY, ANKA)

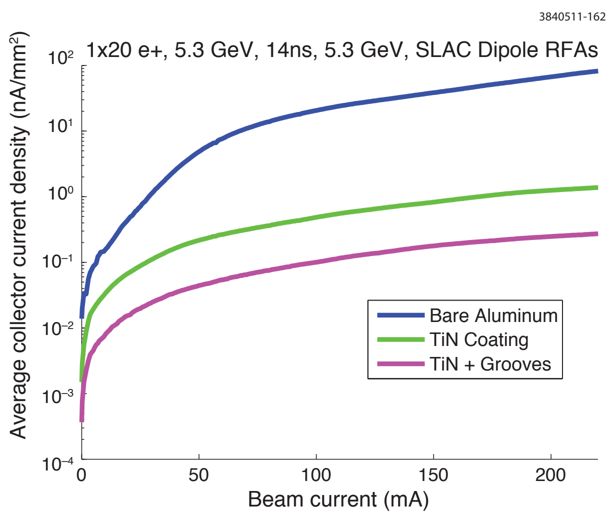
# Vacuum technology –
## characterization of ecloud mitigations




Drift




wiggler



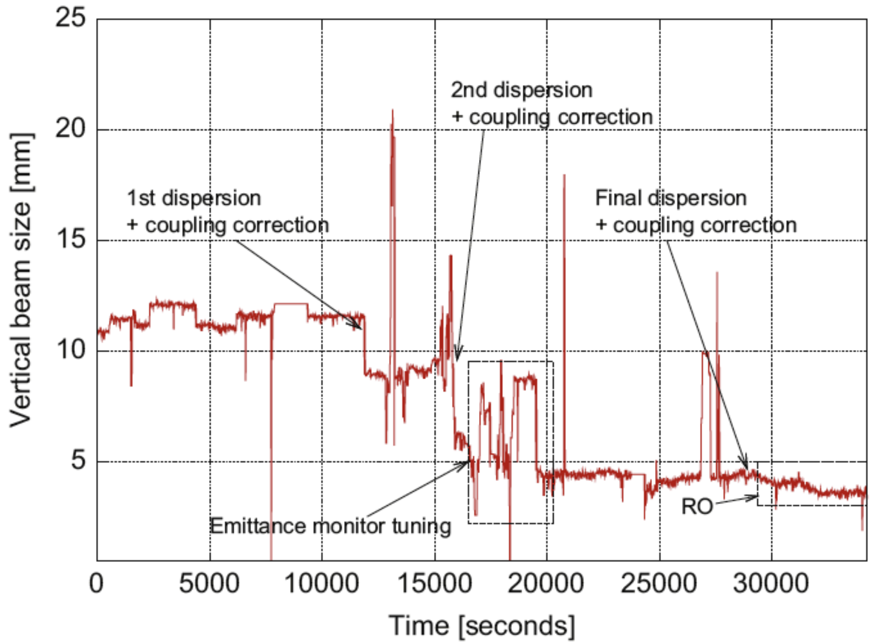

dipole

# Vertical emittance

- Damping ring vertical emittance targets (for both ILC and CLIC) have been achieved with electron beams at SLS, ASLS, Diamond, …
- Considerable progress in developing efficient, effective, reproducible emittance tuning instrumentation and techniques
- And in development of beam size monitors

# Emittance

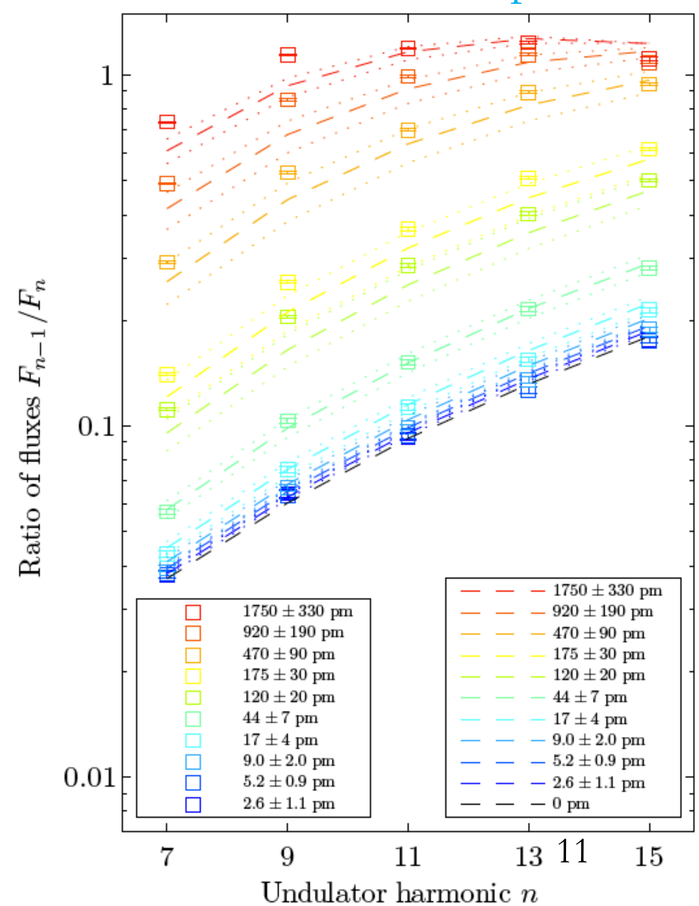
M. Aiba et al, NIM 2012



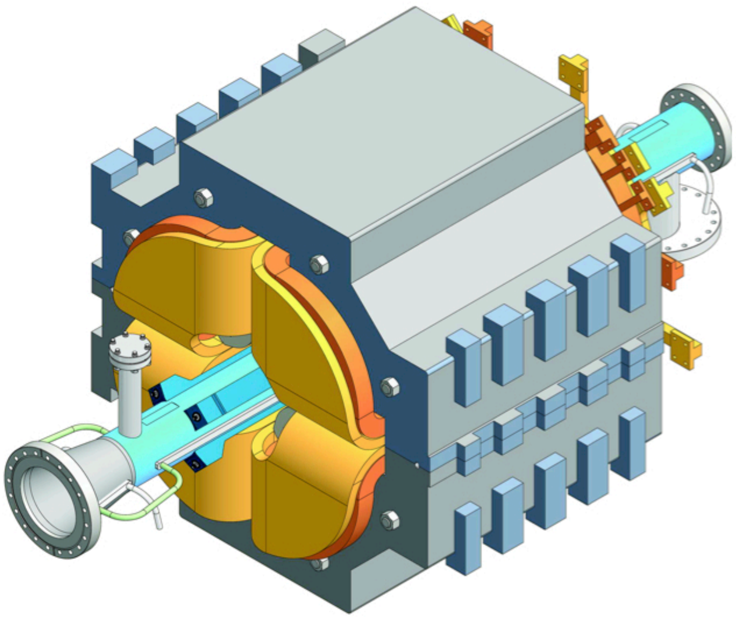

- SLS achieved $\varepsilon_y$ record of $0.9 \pm 0.4$pm (confirmed with different techniques)
- New emittance monitor for resolutions below 3µm (vertical polarized light) under installation for measurements in 2013

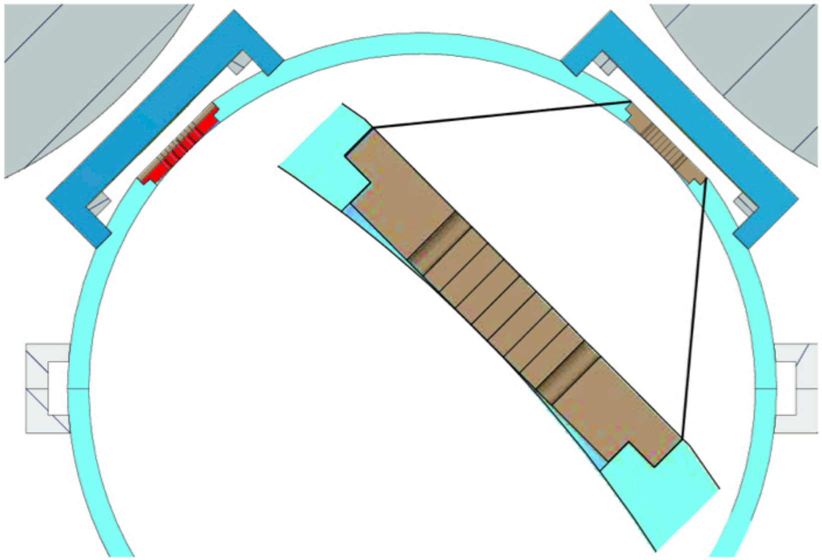
- Tousheck lifetime vs. RF voltage in ASLS points to $\varepsilon_y = 0.5$pm!!!
  - New technique for resolving ultra-low beam sizes using vertical undulator

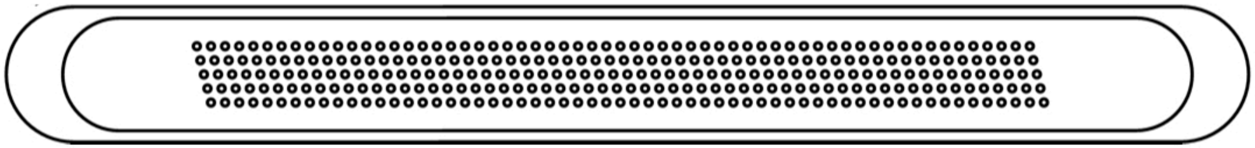
K. Wootton, et al, PRL, accepted

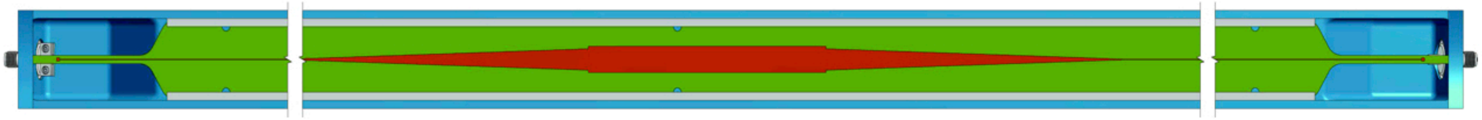


# Quadrupole EC pickup



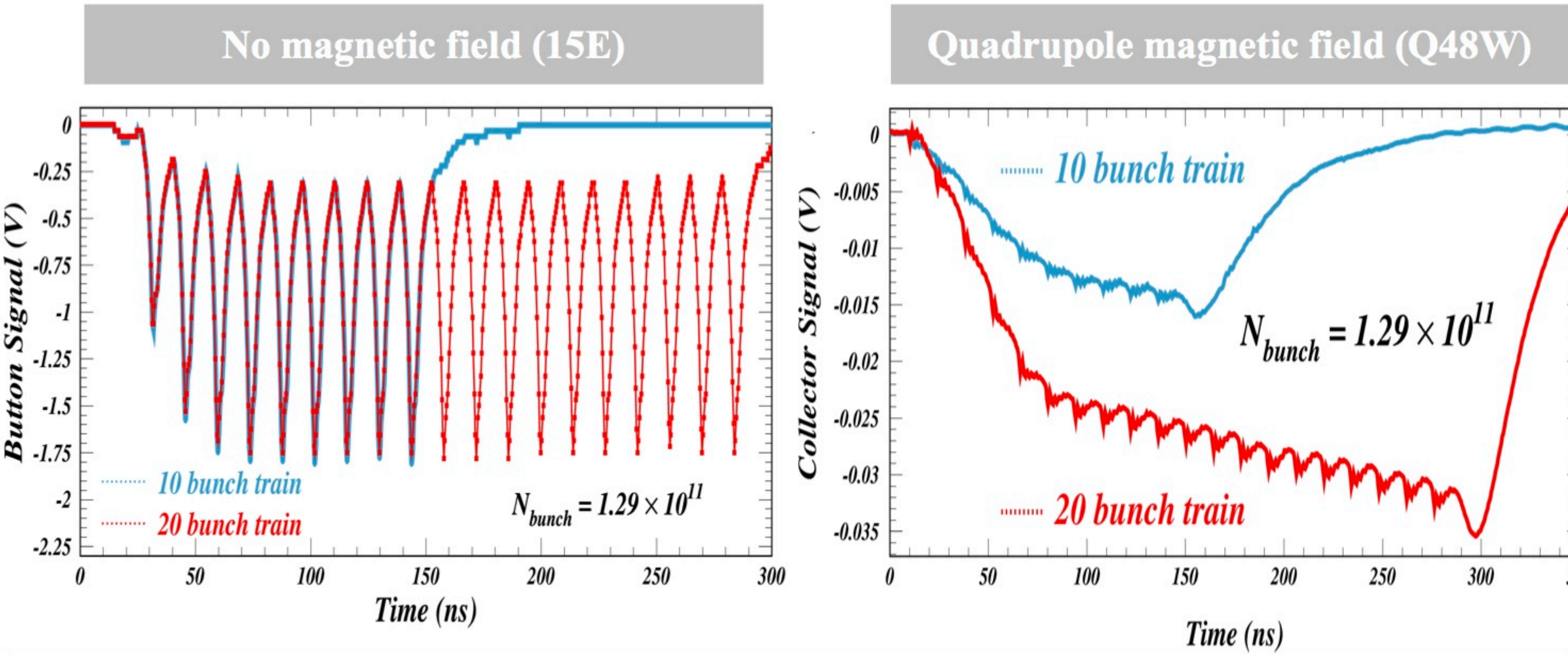






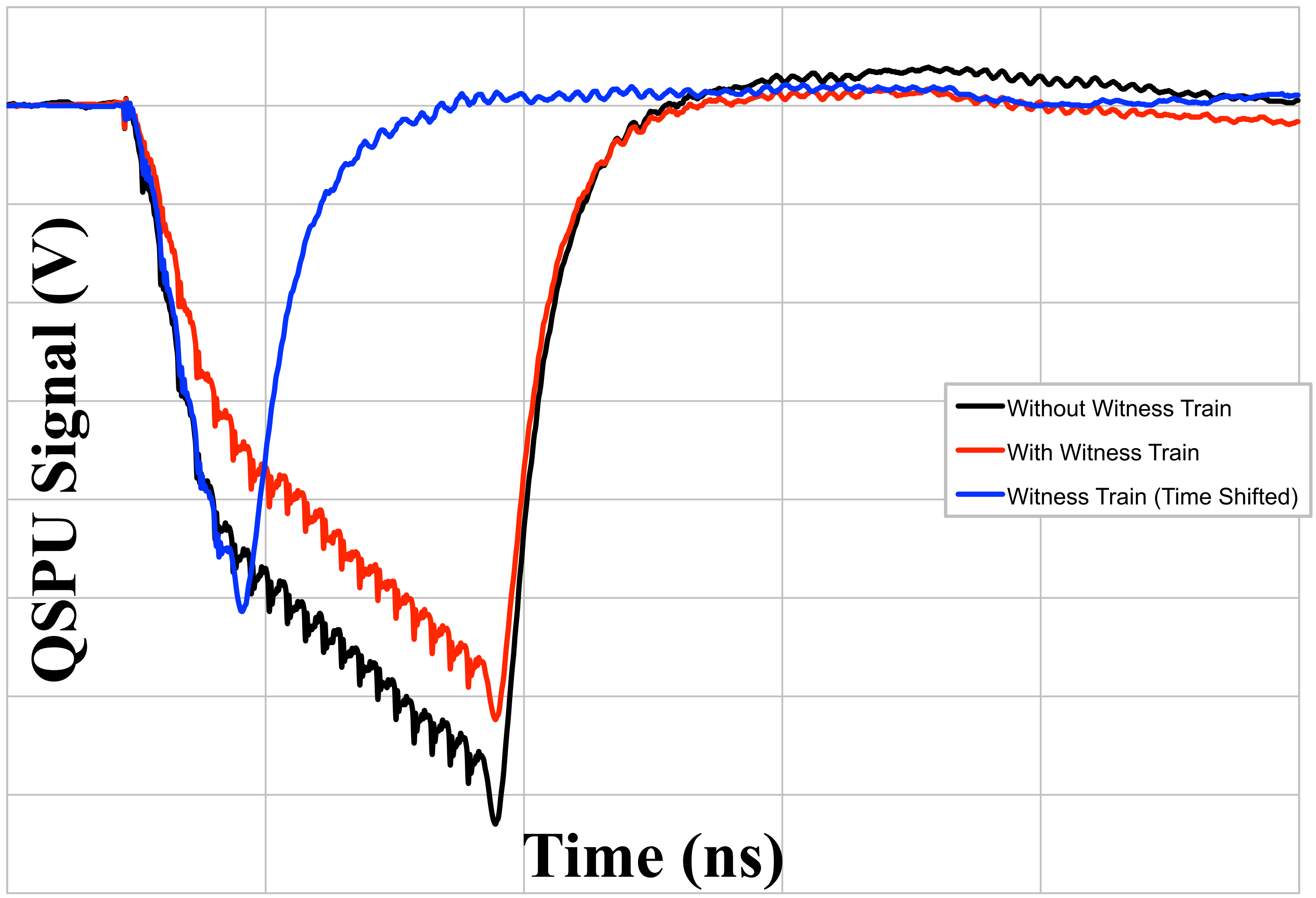
# Trapped electrons

**Comparison of shielded-pickup signals for 10-bunch and 20-bunch trains**

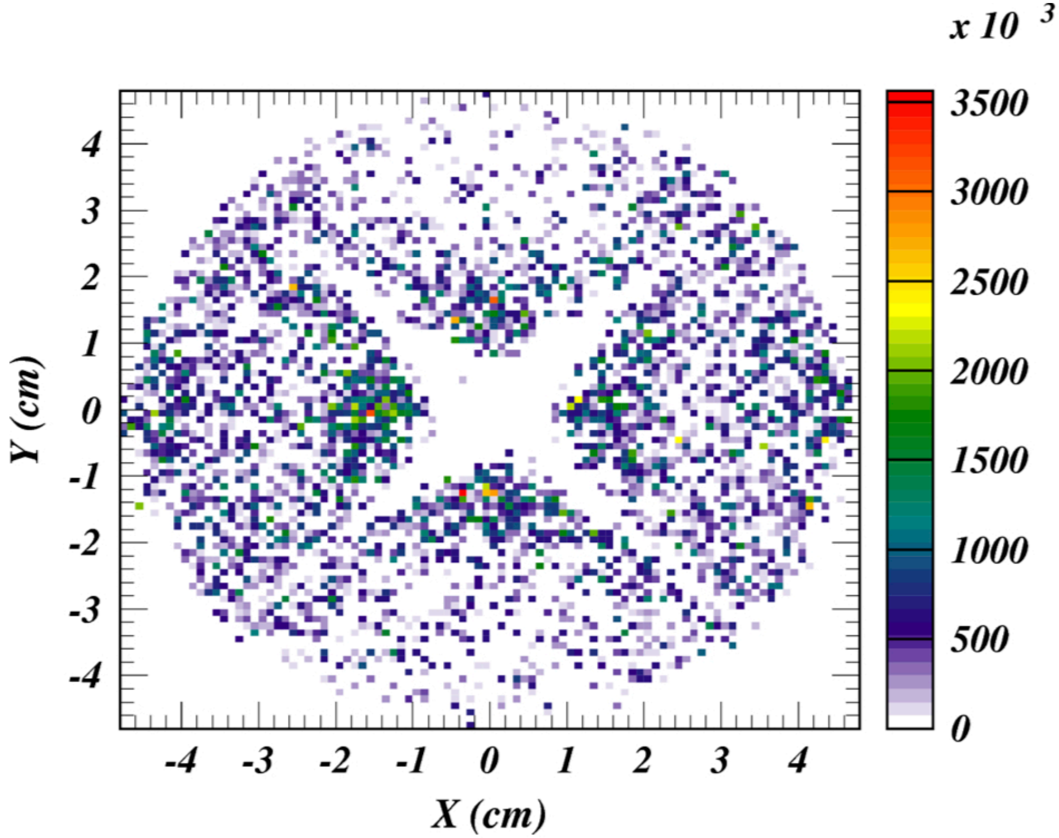



**How do the first ten bunches of a 20-bunch train know that they are in a 20-bunch train?**

# “Witness” train



# Modeled Electron Distribution




Few electrons on axis, but the injected positron bunch will fill the aperture

# CLIC - DR technology challenges

- **Super-conducting wigglers**
  - Demanding magnet technology combined with cryogenics and high heat load from synchrotron radiation (absorption)
- **High frequency RF system**
  - 1-2GHz RF system in combination with high power and transient beam loading

- Experimental program set-up for measurements in storage rings and test facilities
  - ALBA (Spain), ANKA (Germany), ATF (Japan), Australia Synchrotron (Australia), CESRTA (USA), SOLEIL (France),…
- Ideas for a DR test facility within a future LC test facility

# Common technology challenges

- **Coatings, chamber design and ultra-low vacuum**
  - Electron cloud mitigation, low-impedance, fast-ion instability
- **Kicker technology**
  - Extracted beam stability
- **Diagnostics for low emittance**
  - Profile monitors, feedback system

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## Value Engineering

- How many beam position monitors are required to tune and maintain ultra-low emittance?
- And how many corrector magnets to compensate alignment errors?
- Combined function dipole/quadrupole/sextupole as alternative to separated function magnets?

=> Paper studies are underway

Thank you for your attention