CesrTA Future Plans

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Summary- Electron Cloud R&D

- CESR converted for low emittance operation
- Developed and implemented a dozen lattice configurations for multiple energies, emittances, with varying numbers of wigglers, etc.
- Instrumented storage ring to study electron cloud growth and mitigation
- Anchored electron cloud models with extensive and complementary measurements
- Recommended complete set of mitigations for ILC damping ring
- Used models to evaluate tolerance of ILC positron ring to electron cloud

Summary – Low emittance

- Instrumented CESR for simultaneous measurement of bunch height, width and length
- Developed techniques for routine lattice correction and emittance tuning
- Exploited instrumentation and flexibility to make most extensive measurements to date of Intra-beam scattering in an electron/positron ring

Outstanding questions and investigations

- Completeness of electron cloud model
- Cloud induced emittance growth and instabilities
- Long lived cloud in quadrupoles/wigglers (precursor studies)
- TE wave measurement technique
- Minimum vertical emittance
  - Sources of emittance dilution
  - Emittance tuning techniques
- X-ray beam size measurement
  - optimization/interpretation of coded aperture images
- Visible light beam size measurement
  - horizontal and vertical – turn by turn
- Optical and Xray diffraction radiation beam size monitor
- Intra-beam scattering
- Fast Ion instability

Electron cloud model

- Is there a self consistent set of model parameters ?
  - Fit of model to measured tune shifts in a long train constrains model parameters
  - Simultaneous fits to multiple data sets with varying beam current, bunch configuration, beam energy, beam species further constrains parameters and tests the completeness of the model
  - Similarly, RFA and SPU measurements can be fit to ecloud models with different sensitivities to the various parameters
  - Time resolving RFA's (very recently installed) will give complementary data that can likewise be fit to the model

Our goal is simultaneous fit of all data sets

(RFA,SPU, tune shifts) to best constrain parameters and establish that the model does (or does not) include all of the relevant physics consistent with SEY data

Electron cloud model

Photon Reflectivity

- Development of cloud depends on nature of scattering of synchrotron radiation photons
- Angular distribution of scattering depends on details of the surface of scatter on the scale of photon wavelength
- That dependence is parameterized in the model

Reflectivity collaboration aims to measure dependence on

- Surface material and roughness
- Photon energy
- Angle of incidence

Electron cloud - dynamics

- Instabilities and emittance blow up
  - We observe cloud induced head tail instability and emittance dilution
  - Connection between the two is not entirely clear. Does head-tail instability contribute to emittance growth or are the phenomena unrelated ?
  - Simulations (CMAD, PHETS) and analytic calculations are in rough agreement with measurement of both growth and instability – although not in detail
  - We aim to better understand the cause of sub-threshold emittance growth, connection to instability, nature of instability

We would like to measure internal bunch motion

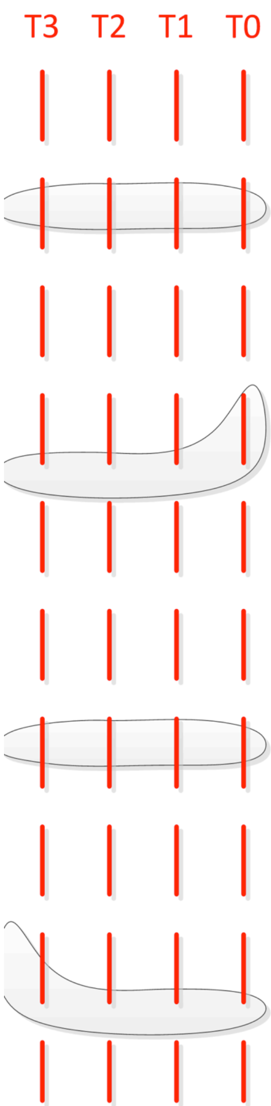
Instrumentation for investigation of instability

- xBSM bunch slicing
  - Measure vertical position and size versus longitudinal position along bunch
  - Fast diode array – 35 ps rise time
  - 4 size/position samples along the ~ 10 mm (30 ps) long bunch at 10 ps intervals

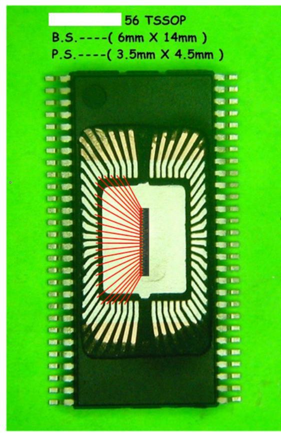
Component testing beginning this fall

Bunch slicing with xBSM

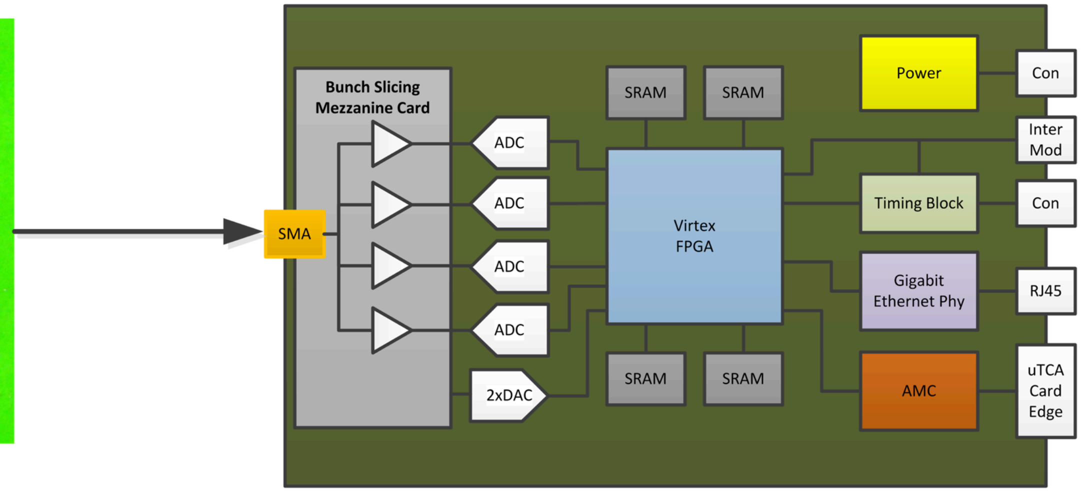
Bunch Slices



High speed Diode array



Multi channel data acquisition system with individual phase delay



Electron cloud dynamics

- Simulation of bunch/cloud interaction
  - Simulations (PHETS, CMAD) computationally intensive
  - Calculations of thresholds for instabilities and emittance growth
    - Typically based on hundreds of turns (fraction of a damping time)
    - Limited to cloud within 20 σ of beam
  - We need more efficient algorithms, and implementations to get at all of the physics

Long lived electron cloud

- Observation of Blowup of lead bunch
  - Effect is mitigated with the help of a precursor bunch
  - Depends on bunch spacing, number of bunches, total current, . . .

Hypothesis

Long lived cloud that accumulates along beam line in quadrupoles and/or wigglers, and is blown away by the precursor bunch

Evidence

The relatively high current measured in the quadrupole RFA suggests buildup over multiple turns

3-D modeling of cloud in wigglers indicates that electrons are trapped in strong longitudinal field component

Long lived electron cloud

- We plan to test that hypothesis with
  - Simulation:
    - Simulation of multi-turn effects is computationally intensive
    - 3 D model may be required if longitudinal magnetic fields in wigglers, or in fringing fields of quadrupoles are important
  - Instrumentation: Time Resolving RFA in quadrupole
  - Measurements:
    - Investigate dependence on various machine parameters, bunch configurations, species, etc.
    - How do other features (tune shifts, internal bunch motion) respond to precursor

A long lived cloud that is trapped in quadrupoles could have a significant impact on positron rings.

TE wave measurement technique

Noninvasive

- No special in vacuum hardware
  (Couple to TE wave via BPM buttons)
- Possibility of measurement of transverse distribution of cloud density

Requires:

- Better understand relation of side band amplitude to cloud density
- Details of spectrum of trapped modes

Emittance

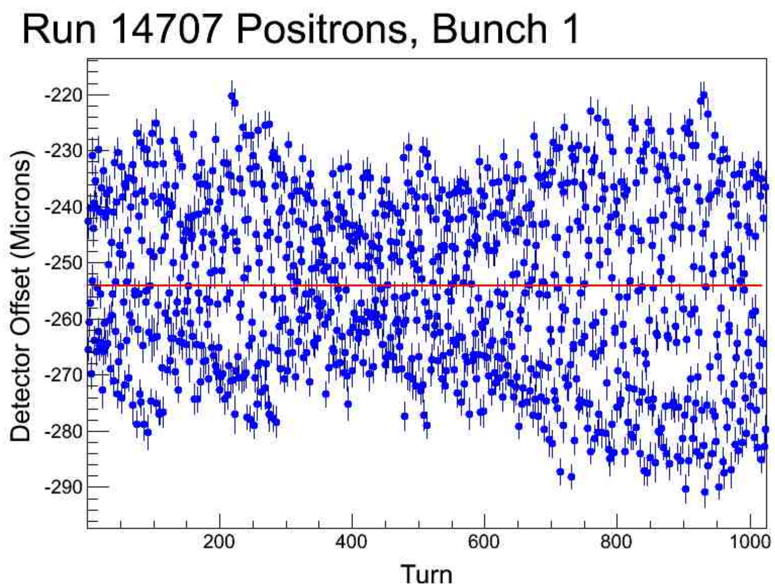
- We have achieved 10-15 pm-rad
- Theoretical zero current limit (quantum limit) is nearly 100 times smaller
- Measured residual vertical dispersion and coupling can not account for observed vertical emittance.
- Evidently there are other sources of emittance dilution
  - Magnet motion, detector motion, unstable corrector magnet currents, noise coupled to the beam through RF system, . . .
  - We observe significant motion at high frequencies. (Betatron tunes are self excited)
  - Perhaps there is an electron cloud or ion effect that is relevant even at very low bunch current

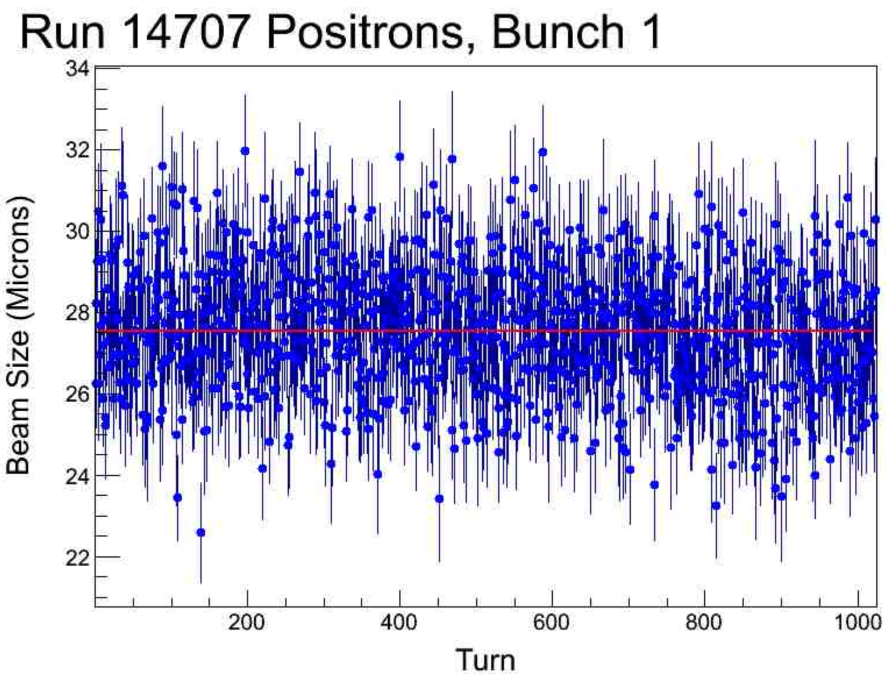
Our goal is to continue to identify and mitigate sources of emittance dilution and to approach the quantum limit

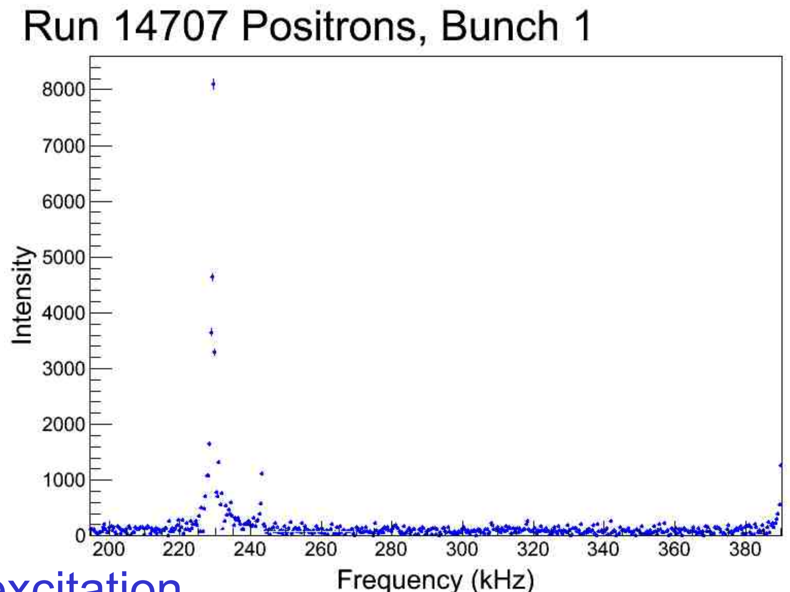
Emittance dilution due to beam motion

Turn by turn xBSM data
- ~30 micron variation in centroid position
- ~ 3 micron variation in beam size

FFT identifies vertical betatron motion

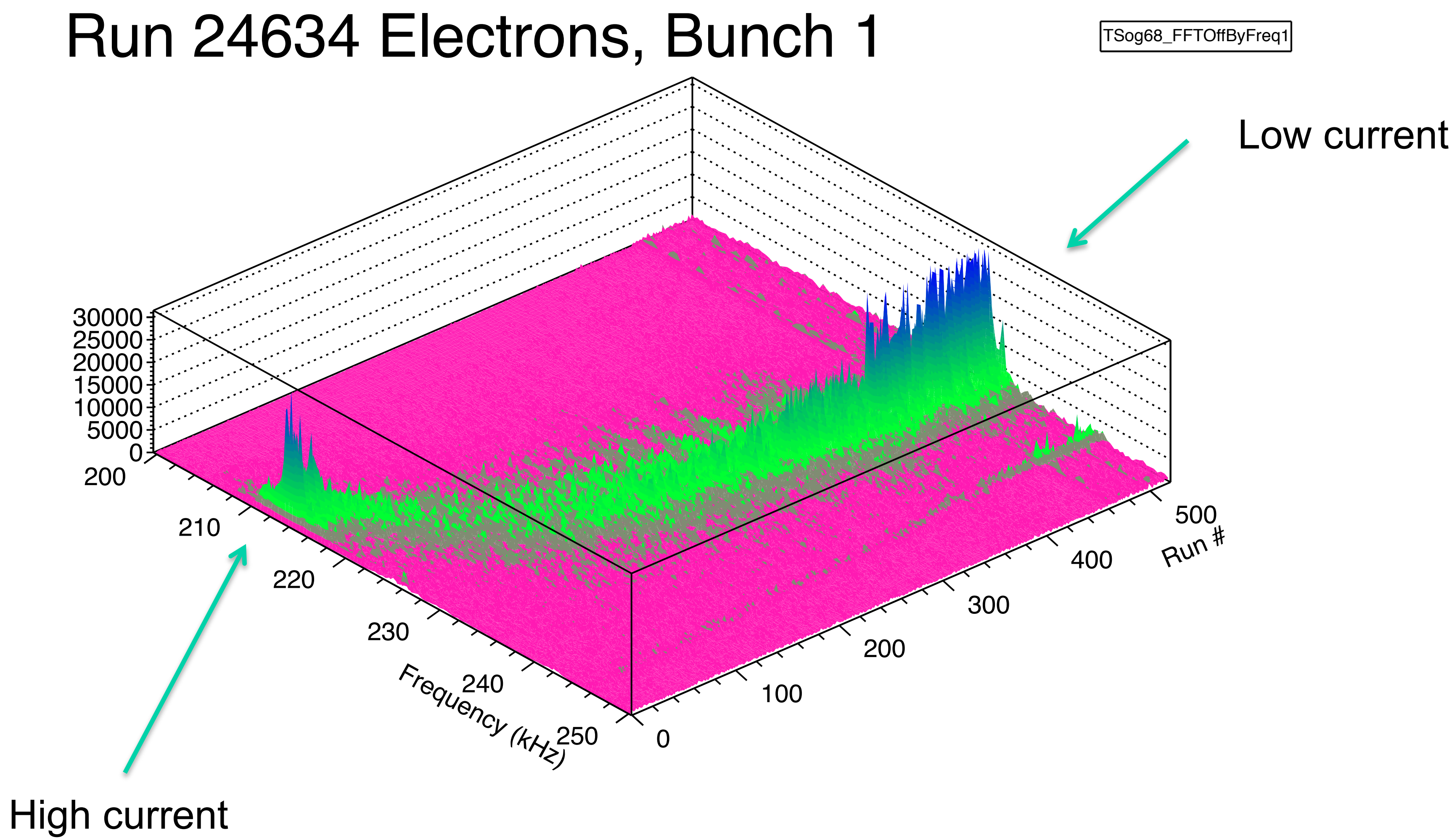






We need to identify (and eliminate) source of excitation

Emittance dilution due to beam motion



IBS run

- Real time emittance tuning
  - Measurement of lattice errors via resonant excitation affords the possibility to continuously monitor betatron phase/coupling and vertical dispersion (as well as orbit)
  - Drive a witness bunch using gated tune tracker at 3 normal mode frequencies
  - Turn by turn position at each BPM

=> Orbit, phase, coupling, dispersion

X-ray beam size monitor

- Optimize coded aperture for
  - X-ray energy spectrum
  - Bunch size
  - Intensity
- Match x-ray energy to diode and optimize layout of diode array
- Refine fitting techniques for extracting size from coded aperture data
- All vacuum x-ray beam lines for full sensitivity across the spectrum

Visible light beam size monitor

- Developing turn by turn capability based on linear array of photomultiplier tubes
- Exploring measurement of vertical beam size
  - Interferometry
  - Polarization

As complement and check of xray beam size monitor

- Goal
  – Measure vertical beam size with 1μm resolution

Phase I – optical diffraction radiation *(Dec. 2012)*

- 400μm and 1 mm diffraction slit width

=> image odr pattern from ~ 20 μm beam

Phase II – x-ray diffraction radiation *(Dec. 2013)*

- 10 μm slit width

=> image xdr pattern from ~ 1 μm beam

Depends on installation of mini-β insert

to achieve 1 μm beam in CESR

Collective effects

As we continue to achieve smaller vertical emittance, our sensitivity to collective effects (especially emittance diluting effects) is enhanced.

Intra-beam scattering

- Continue to explore IBS and test theory with ever smaller zero current emittance
- IBS has strong energy dependence.
  - Measurements at 1.8 and 2.3GeV planned for December 2012, will bracket the 2.1GeV data
  - Preliminary tests at 1.8/2.3 to explore dependence of xBSM on xray spectrum have been completed
- Anomalous blowup of vertical beam size at high current ?
- Dependence on dispersion in RF ?

New capability in next run =>
Synchronized single pass measurement of horizontal and vertical beam size

- Fast-ion instability
  - CesrTA well instrumented for study of fast-ion effect
  - Sensitivity expected to increase as vertical emittance shrinks
  - xBSM and beam position monitors provides bunch by bunch and turn by turn measure of vertical emittance and position spectra (similarly to investigation of ecloud emittance growth)

We plan direct measure of fast ion instability, and the threshold for emittance growth.

CesrTA Students

- Graduate students

  J. Calvey, N. Eggert, M. Ehrlichman, R. Helms, W. Hopkins, B. Kreis, J. Shanks, J. Urban, Y. Yariv

- Undergraduates

  K. Butler, H. Kaminsky, J. Kim, Z. Leong, H. Liu, J. Livezey, J. Makita, M. McDonald, G. Ramirez, S. Santos, R. Schwartz, S. Vishniakou, W. Whitney, H. Williams, L. Fabrizzio, M. Randazzo, R.Campbell, S. Roy, J. Ginsberg

- REU (Research Experience for Undergraduates)

  D. Carmody, C. Cude, P. Kehayias, M. Lawson, B. Carlson, D. Gonnella, E. Wilkinson, L. Hales, K. Hammond, N. Omcikus, Z. Warecki, J. Bonilla, D. Duggins, E. Hemingway, K. Williams

Funding

- Phase I (2008–2011)
  - 80% NSF(CESR Conversion), 20% DOE (ILC-ART)
  - Total of 240 days dedicated CESR running time
- Phase II (2011 – 2014)
  - NSF (Lepton Collider)
  - 40 days dedicated CESR running time/year
- Phase III (2014 – ?) Proposal due 9/13
  - Request
    - Beam physics and instrumentation for low emittance electron/positron rings
    - 40 days/year machine time
    - Details depend on CHESS upgrade plans

Conclusion

- CesrTA is a well instrumented laboratory for investigation of beam physics of low emittance rings
  - Flexible optics – mature interface of design/optimization/ measurement/analysis tools (BMAD/CESRV/Tao)
  - State of the art instrumentation, and ongoing development
  - Sophisticated modeling and simulation capability based on integrated library of accelerator modeling code (BMAD)
- Contributions
  - Electron cloud physics, emittance tuning, intra-beam scattering, materials characterization, beam instrumentation
- Collaborative effort (14 institutions)
- Accelerator physics education
- Compelling program of beam physics, experiment and theory

Thank you for your attention