LBNL Damping Ring R&D Activities

Michael S. Zisman

ILC Program Leader

Center for Beam Physics

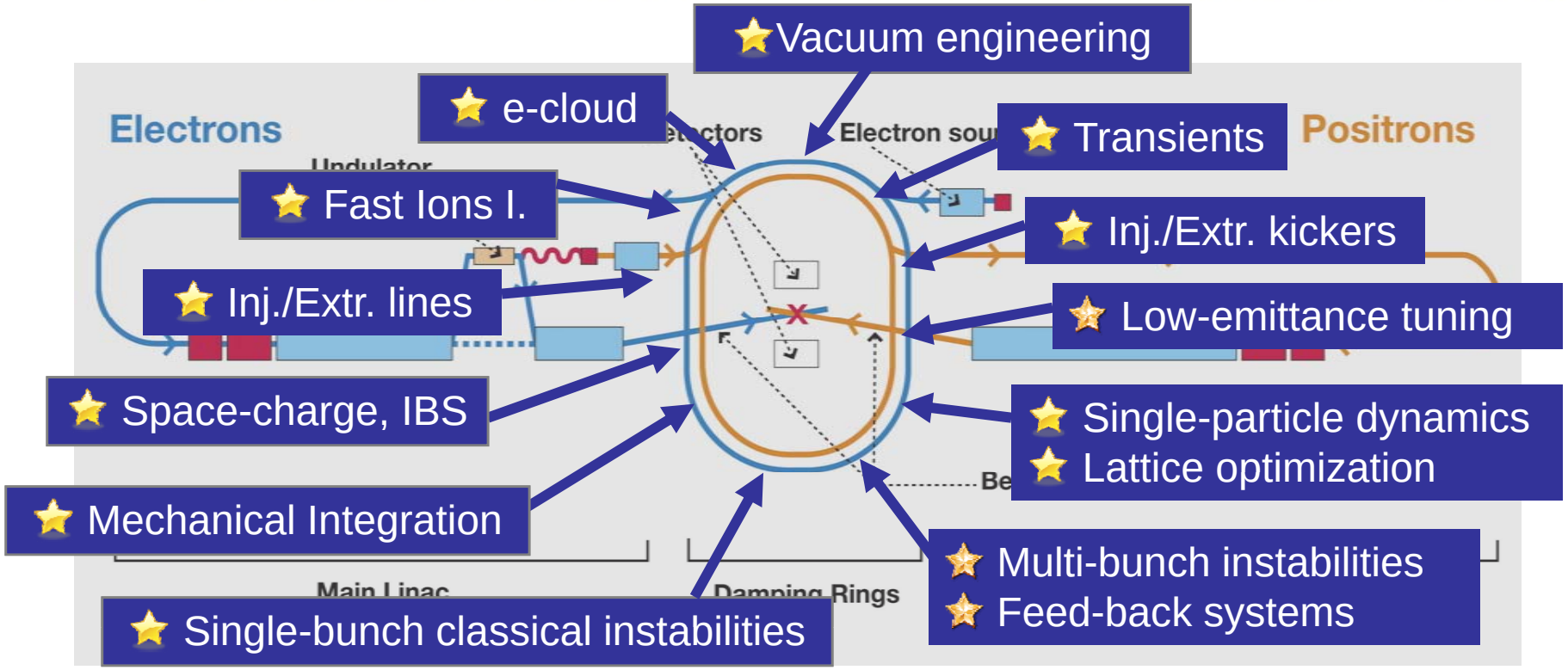
Accelerator & Fusion Research Division

Lawrence Berkeley National Laboratory

Introduction

- LBNL support of DR R&D effort remained constant in FY07
  - received $0.8M (cf. $0.8M last year)
    - essentially all is for DR work
      - this is where we wish to focus
    - engineering effort is presently sub-critical
- Anticipate enhanced effort in FY08 and beyond
  - subject to success in obtaining the anticipated budgets for the ART
    - which is <u>not</u> a given
- Participated in global planning effort via S3

Overview of Activities



Other ILC activities

- Leadership/coordination within DR community
- Involvement in ILC-related R&D at other facilities (PEP-II/SLAC, ATF/KEK, CESR/Cornell)
- Generic development of diagnostics, instrumentation

People & Resources

- ILC-ART resources
  - $681k in FY06
    - 2.0 scientist FTEs
    - 0.6 engineer FTEs
    - 1 student assistant
  - $795k in FY07
    - 2.2 scientist FTEs
    - 0.4 engineer FTEs
- Additional support from core program
- People contributing:
  - J. Byrd, D. Bates, C. Celata, D. Grote, S. de Santis, M. Furman, S. Marks, D. Plates, G. Penn, I. Reichel, R. Schlueter, C. Steier, M. Venturini, J-L Vay, M. Zisman (program leader)

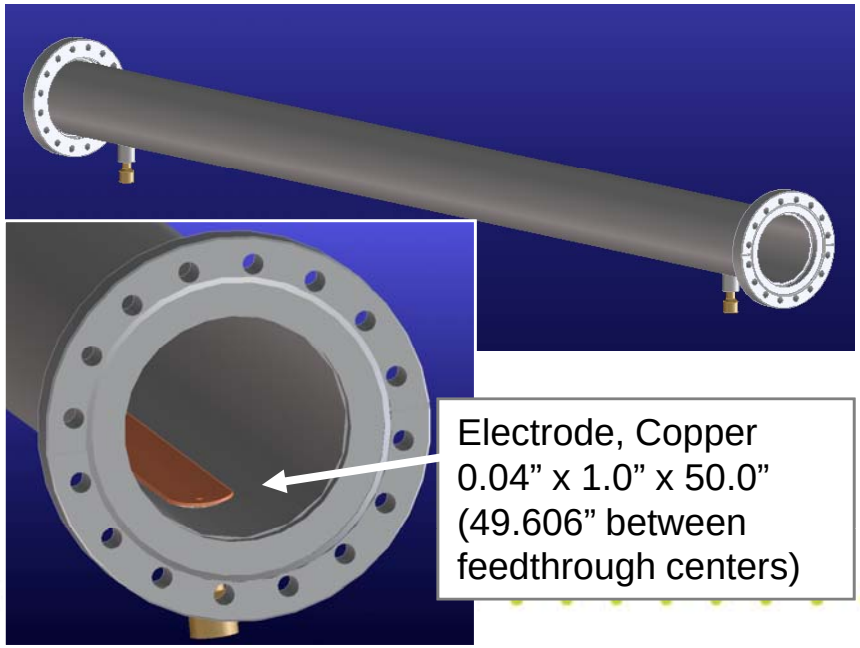
Responding to R&D Priorities

- We continue to contribute to critical areas of DR R&D by developing new capabilities and leveraging existing LBNL expertise and resources
- Already engaged in, or plan to start, activities in the following very high-priority R&D areas:
  - Electron cloud (ongoing)
  - Fast ion instability (measurements at ALS planned later this year)
  - Single-bunch instabilities (ongoing)
  - Low-emittance tuning (to resume in 08, augmenting work carried out in previous years)
- Additional activities include
  - Lattice optimization, single particle dynamics, wiggler modeling (ongoing)
  - Characterization of space-charge effects (mostly completed)
  - Design of prototype of kicker meeting DR specification to be tested at ATF/KEK (ongoing); characterization of CSR at ATF/KEK (ongoing)
  - Multi-bunch instability, feedback systems, transients (08)
- Vacuum design and mechanical integration (RDR, EDR)

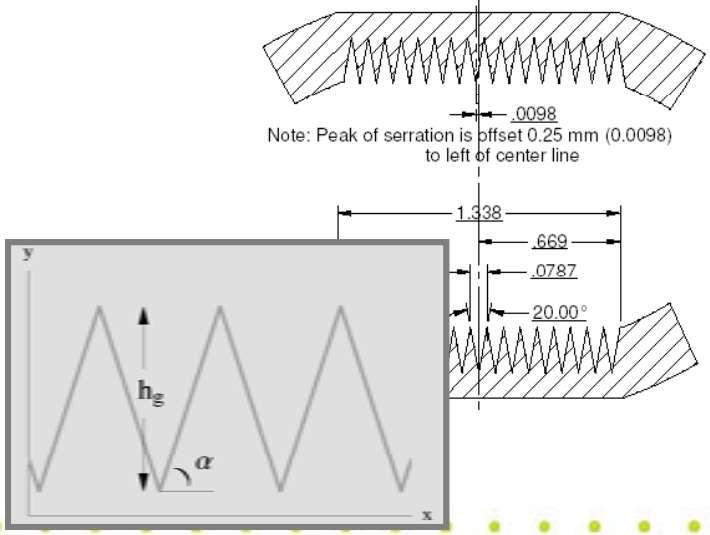
Suppression of e-cloud

- Change of baseline has elevated rank of e-cloud R&D
  - must demonstrate that e-cloud build-up can be suppressed to the level where it is harmless
- Suppression techniques being investigated include grooved chambers and clearing electrodes (+ more "conventional" surface coatings)
  - measurements conducted at PEP-II will test both proposed remedies.

Design of chamber w/ CE for experiment at PEP-II by D. Plate, LBNL



Proposed design of grooved chamber for PEP-II experiment

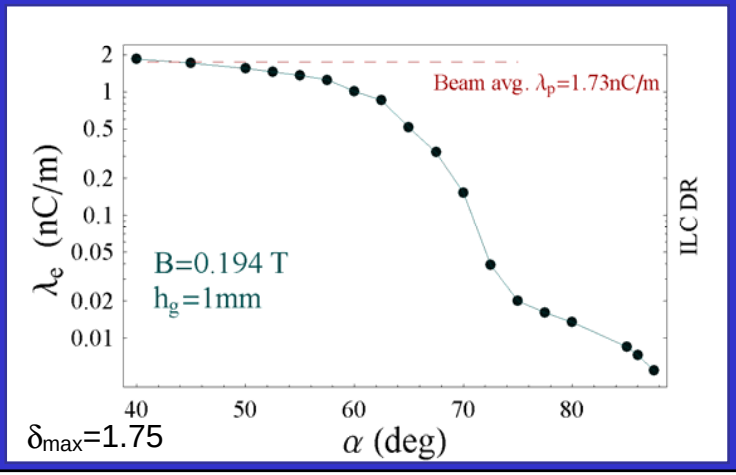


e-cloud in Grooved Chambers

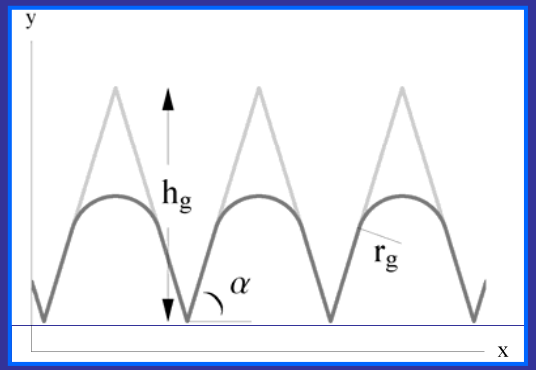
- **Simulations show that triangular groove geometry with a sufficiently steep angle can suppress e-cloud effectively**

Max. longitudinal density of e^- accumulated through a 111 e+ bunch train in DR dipoles drops by 100 for $\alpha=75^o$

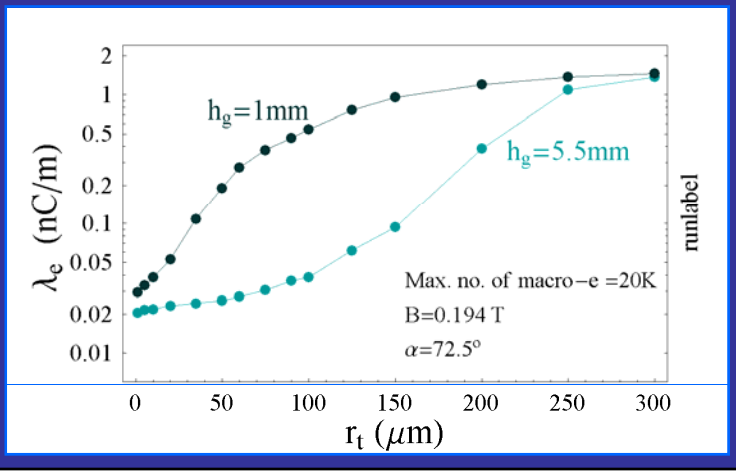
Simulations done w/ augmented version of POSINST (Venturini, Furman)



To mitigate impedance, rounding the tips would be desirable …



… but it spoils the effectiveness of grooves



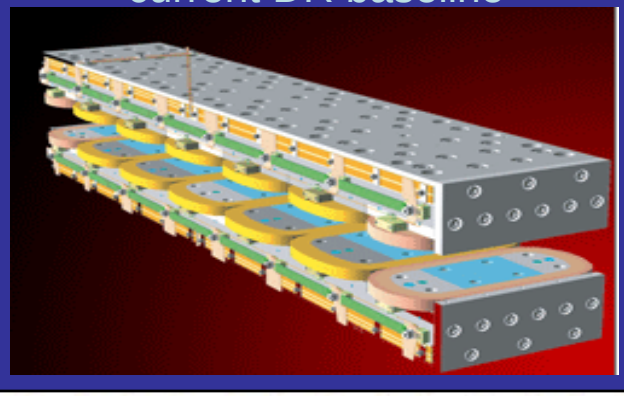
Wiggler Modeling and Simulations

- Progress in e-cloud **experiments/measurements** and **simulations** must go hand in hand
- Making a substantial investment in characterizing e-cloud in wigglers, a significant issue for DRs
  - use/expand integrated code suite WARP/POSINST (already successfully tested for HCX heavy ion experiment here at LBNL)
  - study both e-cloud build-up and e-cloud induced instabilities
  - ultimate-goal, a fully self-consistent simulation, very challenging but within reach

Proposed e-cloud experiment at CesrTA

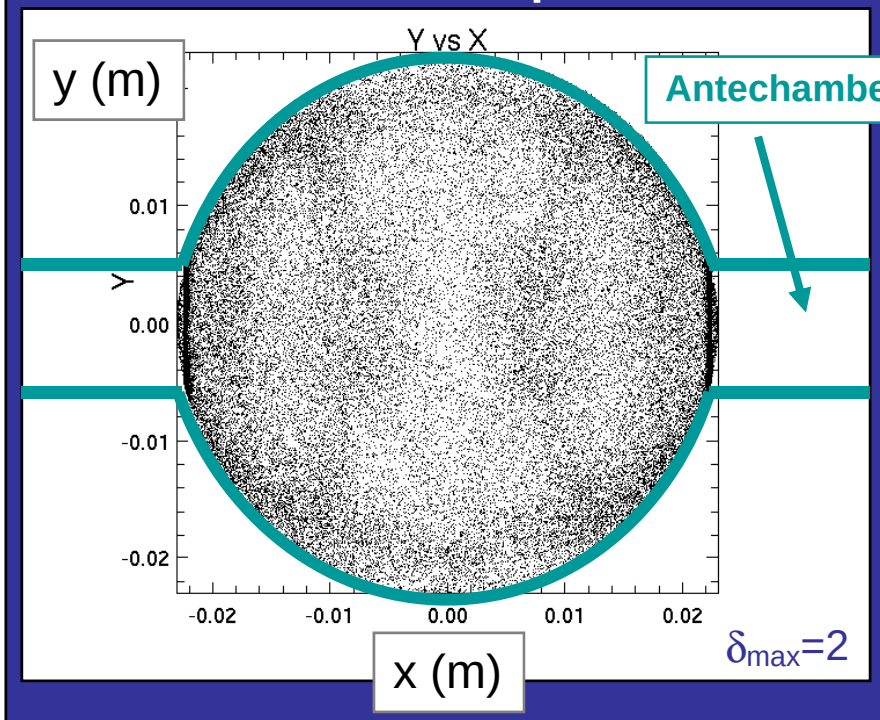
- LBNL to
  - model e-cloud measurements in wigglers
  - design wiggler vacuum chamber with clearing electrodes

Wigglers installed at CESR-c have inspired the technology choice for current DR baseline



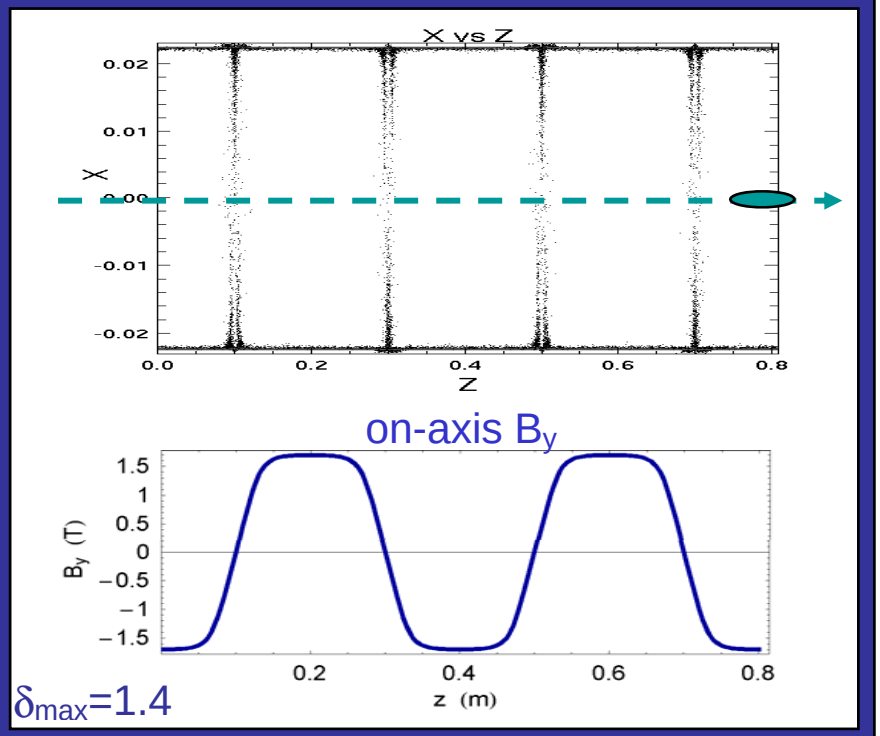
e-cloud Build-up in Wigglers

Projection of e-cloud in transverse plane



20% of photons hitting the edges of the antechamber are reflected

Snapshot of e-cloud in two wiggler periods seen from above



No photon reflection by the wall in the model for this calculation

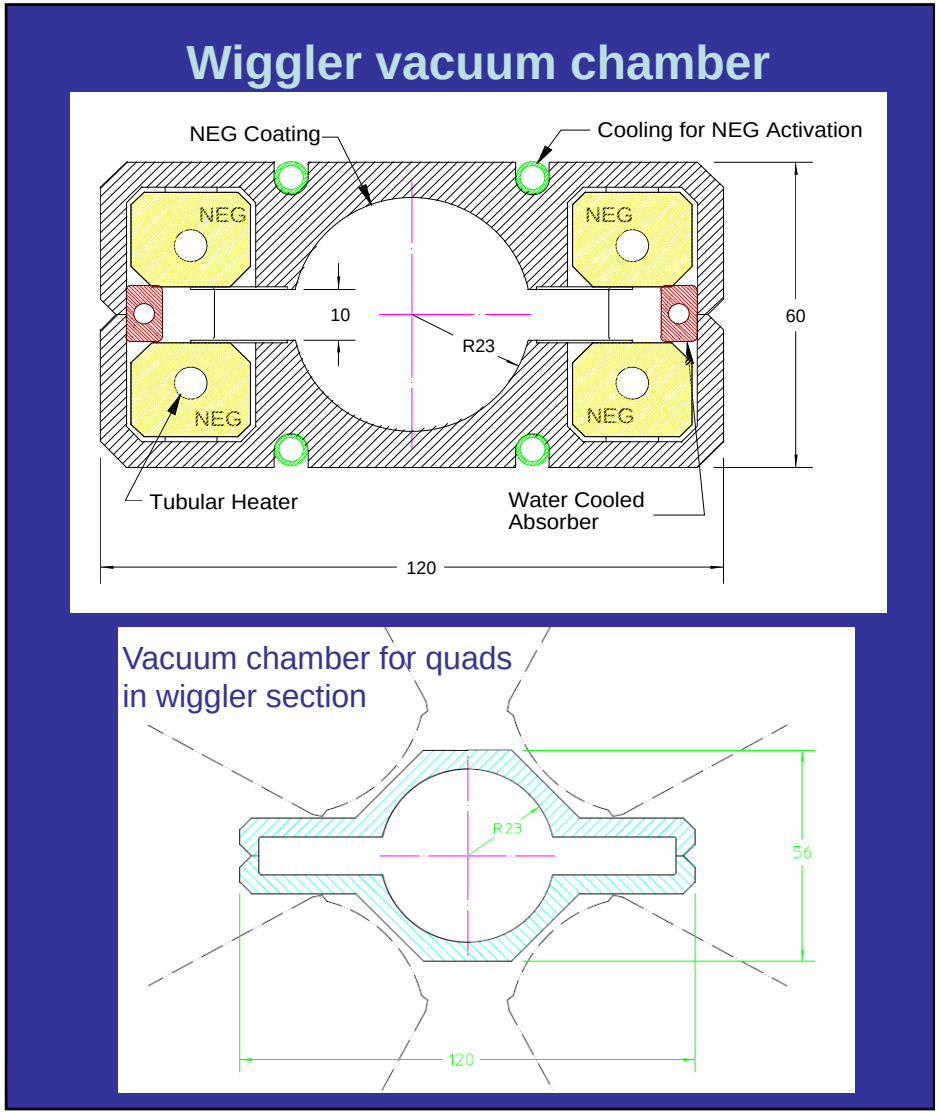
Snap-shots taken after passage of 50 bunches (preliminary)

C. Celata, J-L Vay, D. Grote

Wiggler Vacuum Chamber Concept

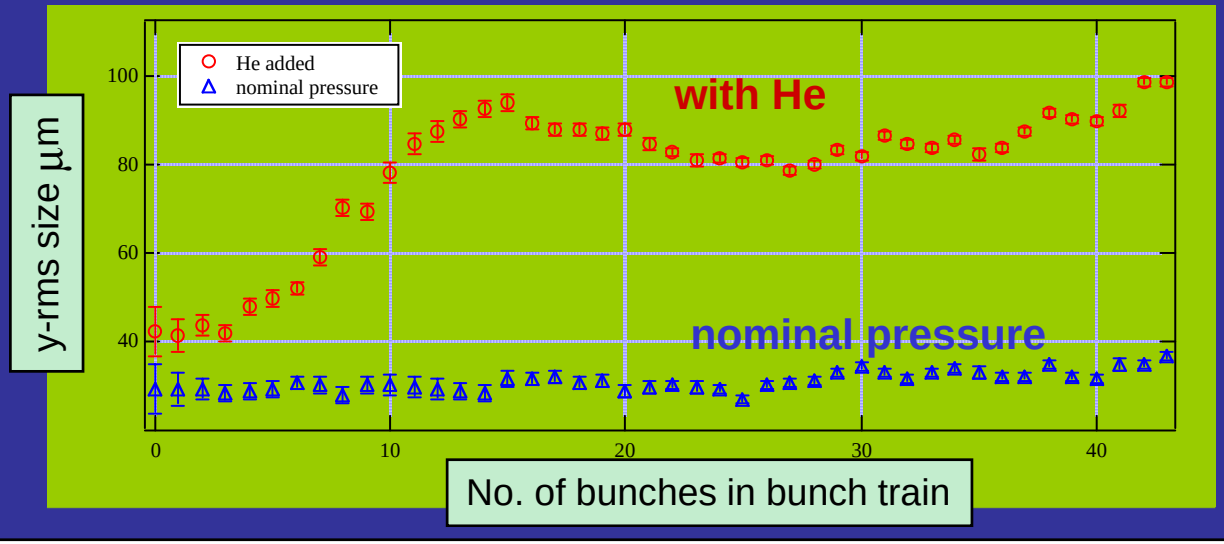
- **Wiggler vacuum chamber is a warm-bore insert**
  - not integral to cryostat
- **Design assumptions:**
  - machined, welded aluminum with antechamber
  - photon power absorbed within chambers by copper absorber
  - pumping: NEG wafers mounted on heater for regeneration
  - integral cooling to minimize thermal load during regeneration
  - NEG coating for reduction of secondary electrons
- **LBNL providing mechanical integration for the DRs**

S. Marks, D. Plate, R. Schlueter



Fast Ion Instability

- First experimental evidence of Fast Ion Instability produced at ALS (ca. 1996, J. Byrd *et al.*)



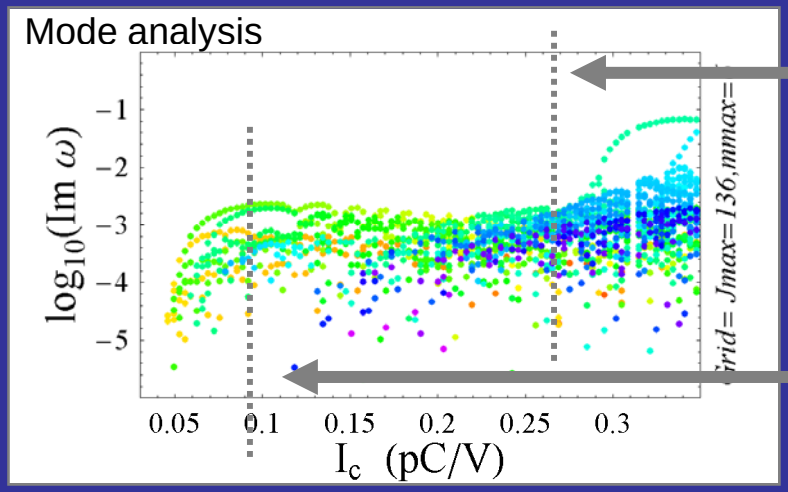
- Experimental validation of present fast ion instability models essential for DRs but largely unaccomplished
- New set of measurements planned for ALS promises to provide the required validation (Byrd, Steier)
- Use grow/damp techniques to measure growth rate under varying machine conditions and bunch train structure.

Single-bunch Longitudinal Instabilities

- To avoid unacceptable emittance degradation down the linac, collective instabilities can't be tolerated
  - otherwise, DRs can be "source of all evil" (Anonymous from SLAC)
- Collaboration w/SLAC for characterization of single-bunch dynamics based on detailed modeling of impedance sources

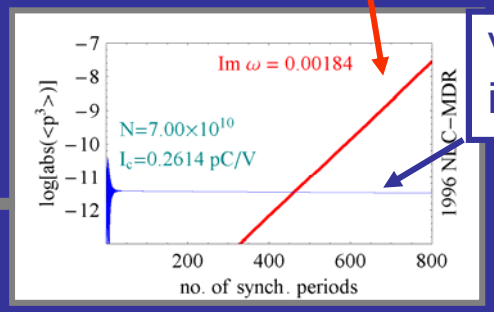
Mode analysis of linearized Vlasov Eq. for longitudinal motion may fail to give accurate characterization of instability

Venturini, ILC-DR06 Workshop

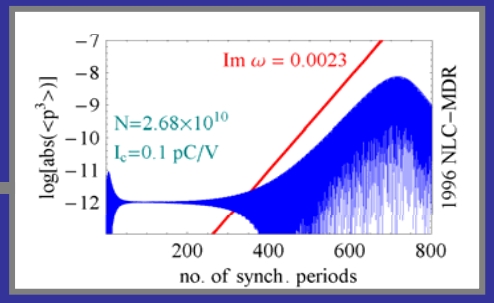


Mode analysis

Vlasov Eq. solution in time domain



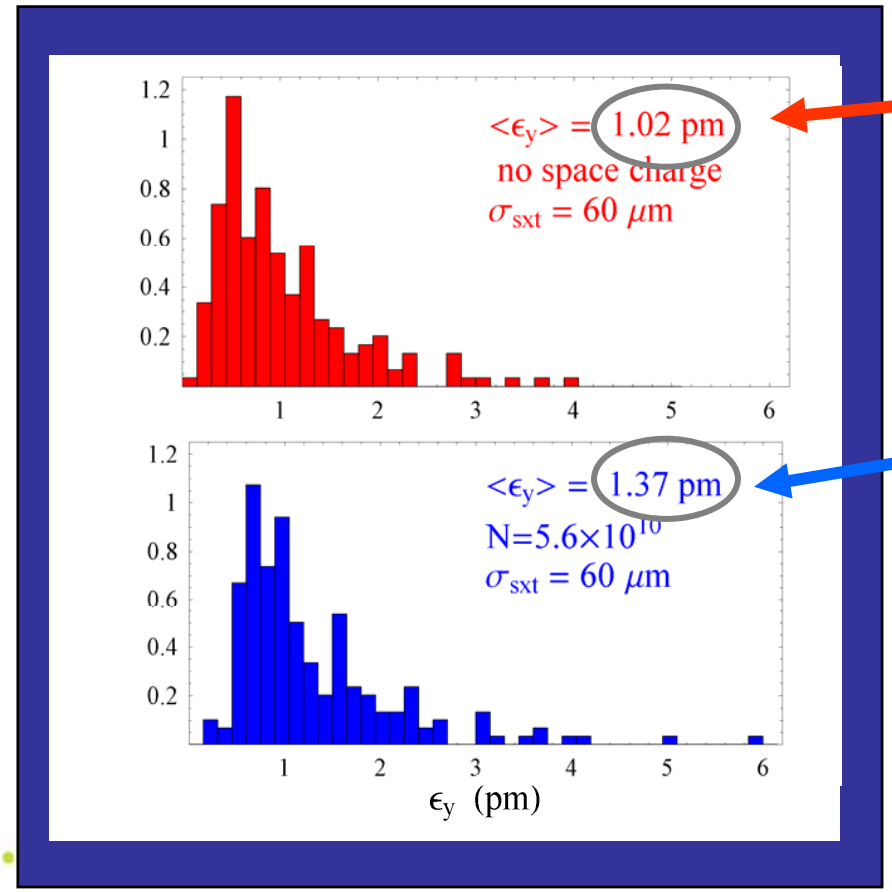
No agreement



Good agreement

Influence of Space-charge

- **Equilibrium emittance in a non-ideal lattice modified by space charge**
  - radiation envelope formalism extended to account for effective modification of linear lattice due to space charge (*Venturini et al.*)



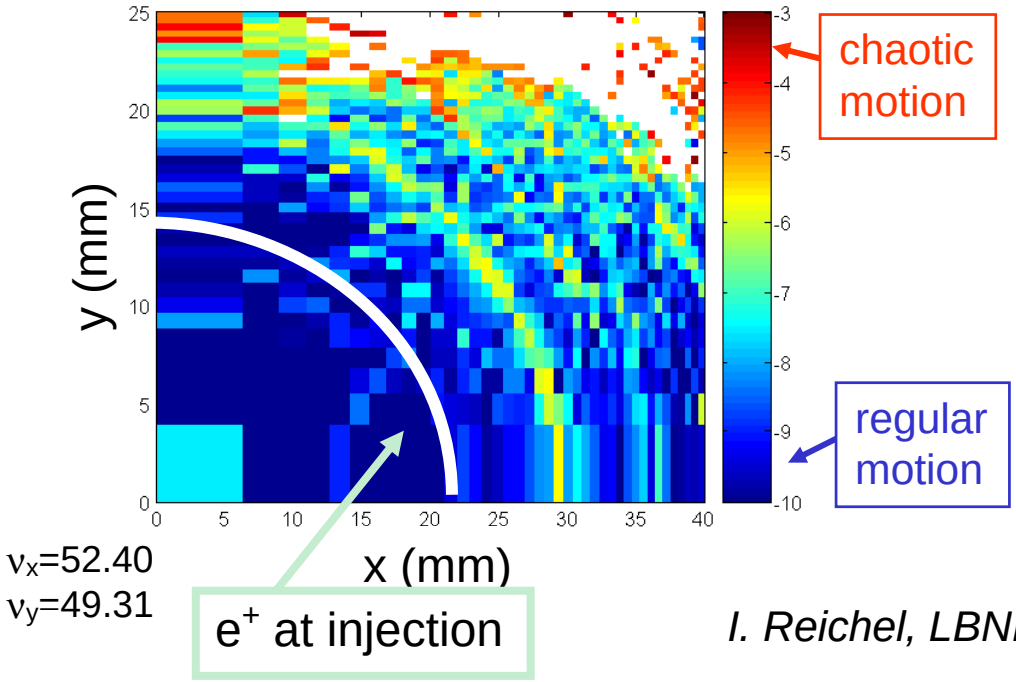
Equilibrium vertical emittance for 200 random realizations of sext. displacement **w/o space charge …**

… with space charge. Effect is small (current lattice)

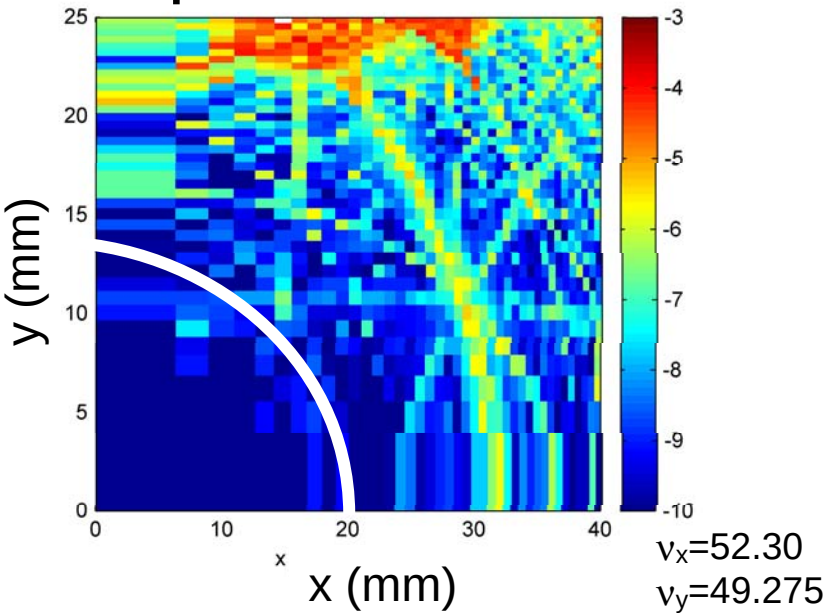
- **Formalism being extended to include IBS**

Dynamic Aperture Studies

Nominal DR lattice



Improved lattice



I. Reichel, LBNL

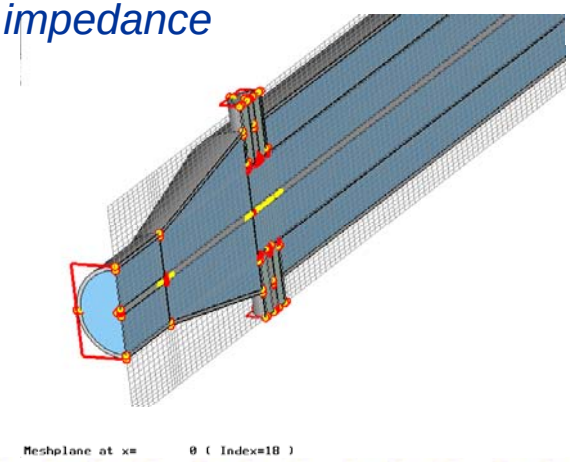
- **Frequency maps indicate presence of harmful resonances and suggest ways for lattice optimization**
- **OCS6 lattice suffers from reduced degree of symmetry**
  - **different working point and harmonic sextupoles improve dynamic aperture**

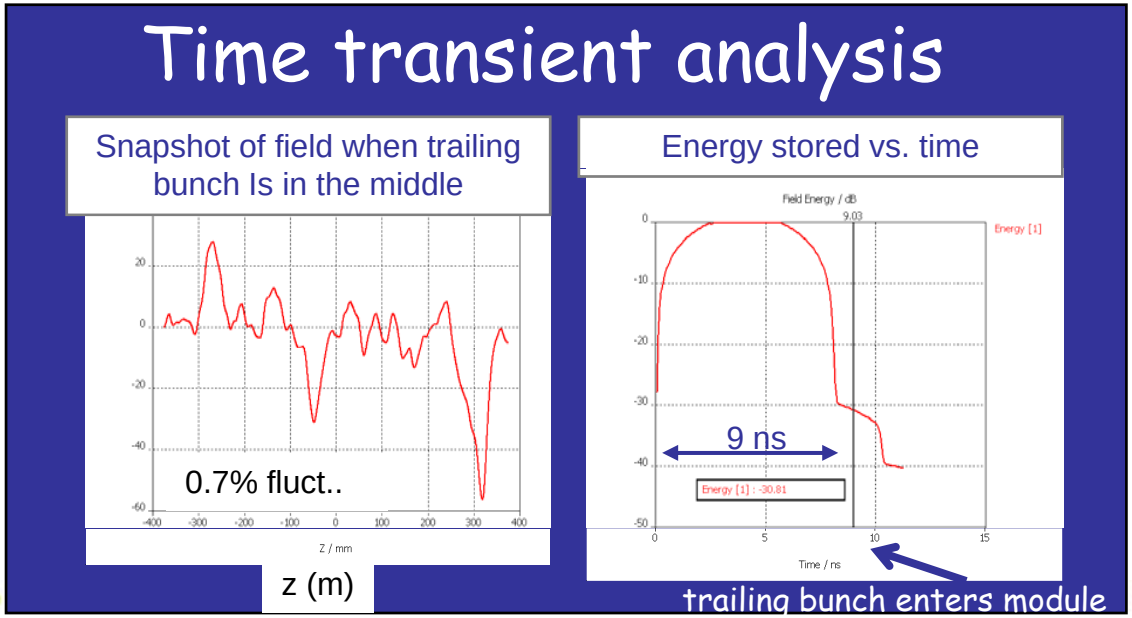
Kicker Technology

- ATF/KEK is test bench for DR kicker technologies (pulsers, striplines, loads, feedthroughs…) with specification close to or exceeding DR requirements
- Contributing to design of ATF striplines kicker structures:
  - demonstrate 5 mrad deflection, 2.8/5.6 ns bunch separation; stringent requirements on field decay time (DR specs: 3.1/6.2 ns; 0.6 mrad)
  - transform voltage pulse into a deflecting field efficiently w/o introducing undesired beam impedance
  - produced a kicker design; estimated impedance; transients analyzed

S. De Santis

Detail of the mesh (with coax for modeling bench measurement of impedance

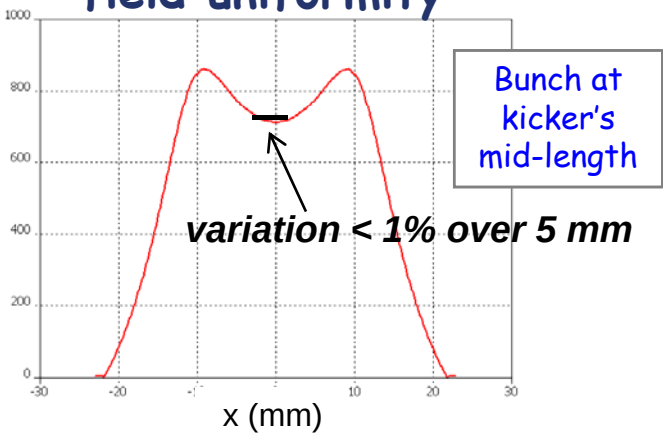




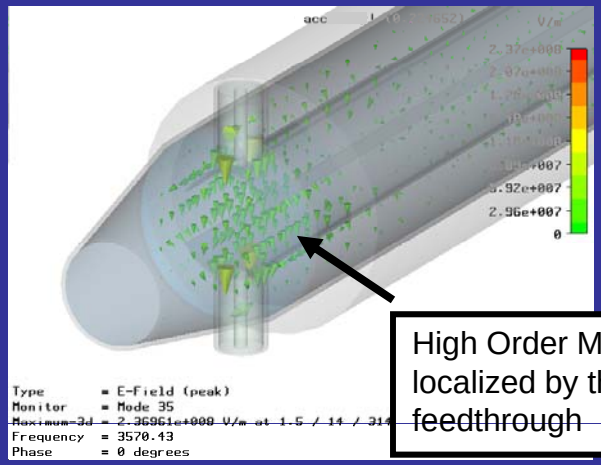
Meeting Kicker Specifications

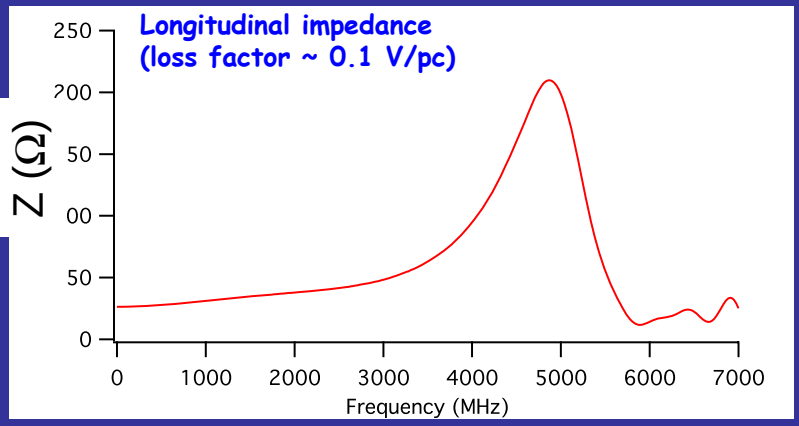
- Specifications likely to be met for 5.6 ns
  - no pulser currently available with required rise/fall time characteristics at 2.8 ns
- Residual uncertainty mainly connected with the development of high-voltage, high-repetition rate feedthroughs

Analysis of deflecting field uniformity



Minimizing impedance and high-order modes

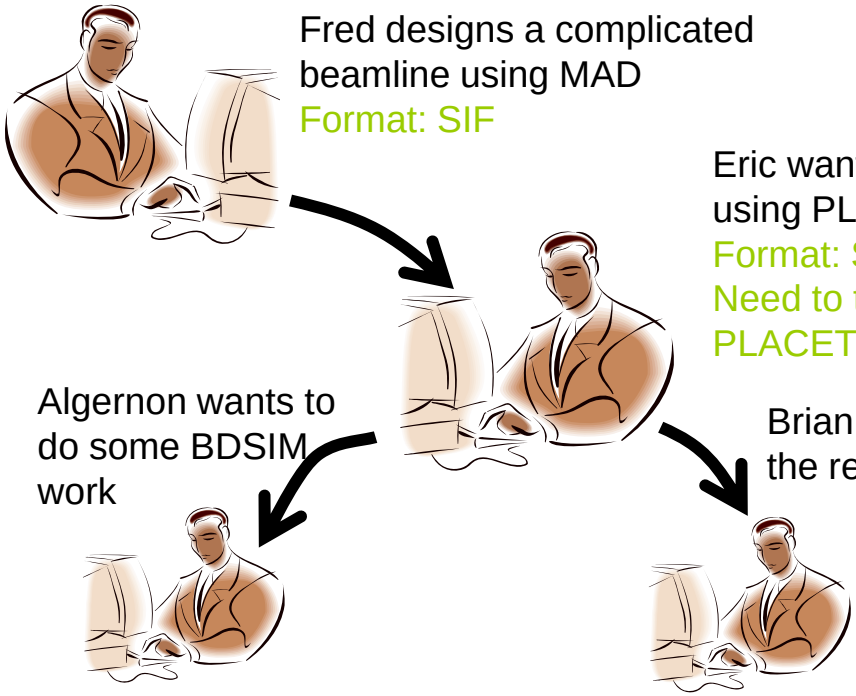




Universal Accelerator Parser: Undoing the Tower of Babel

- Different accelerator analysis programs use different input formats to describe a lattice
- The UAP library will provide a way to translate input files between various accelerator codes

A Tower of Babel:



Ease the way of using multiple platforms to study a complex accelerator system

D. Bates in collaboration with D. Sagan, A. Wolski

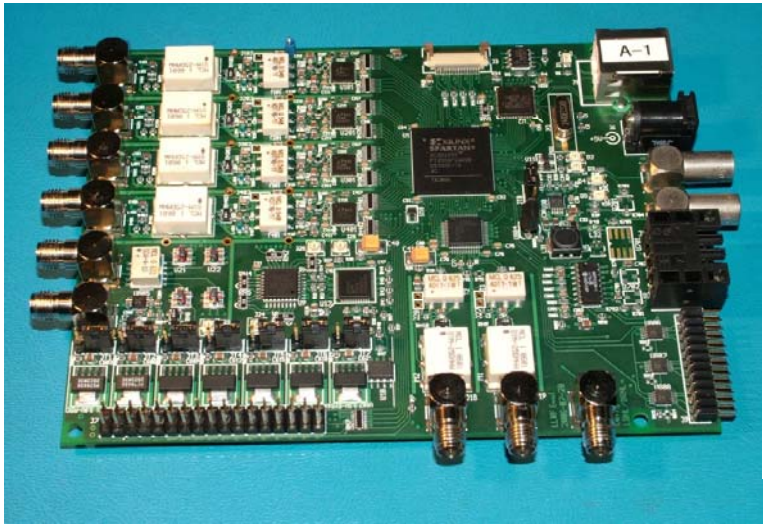
Instrumentation and Feedback

- **Transverse feedback [Barry, Byrd]**
  - develop model to assess noise, gain, phase margins
  - design prototype low-noise receiver

- **Injection noise [Byrd, Penn]**
  - characterize sources of jitter and develop tools for transient analysis
  - assess implications for feedback system design

LLRF Activities (1)

- Continued work on LLRF design for HINS
  - suitable for ILC also
- Objectives
  - determine stability with multiple loads (HINS)
  - characterize state-of-the-art components (HINS)
  - examine scalability + high-volume production capability



- In collaboration with SNS
- 4 14-bit 80 MS/s digitizers
- 2 14-bit DACs
- Xilinx Spartan-3 FPGA
- USB interface
- Bench tested and working

LLRF Activities (2)

- **Initial test results**
  - 2.5 bits rms wideband noise
  - clock jitter < 0.5 ps rms
- **Modeling**
  - goal: to improve understanding of single klystron with multiple cavities
    - study microphonics noise at klystron and cavity
    - understand feedback configuration and system stability

Summary

- LBNL has made significant contributions to the DR design as documented in the Baseline Configuration Report and Reference Design Report

- We wish to play a leadership role for ILC-DR activities and stay focused on critical R&D areas needed for completion of Engineering Design Report (EDR) :
  - Beam dynamics:
    - **Electron cloud** (characterization of e-cloud in wigglers; assistance with design of experiments and data analysis)
    - **Fast Ions** (measurements and validation of theory)
    - **Collective effects** (space-charge effects for RTML lines; estimate of single-bunch threshold instabilities based on numerical impedance modeling)
    - **Low-emittance tuning**
    - **Study of transients** at injection/extraction
  - Engineering, design of technical systems
    - **Kickers, feedback, LLRF, vacuum**
    - **Mechanical integration**

LBNL and IHEP have recently signed MOU to collaborate on DR R&D