# US Collaboration on High Gradient Research for a Multi-TeV Linear Collider

Plans and Status

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# Motivation

- The ILC will reach ½ to 1 TeV cm energy.
- Advanced Accelerator research looking far beyond this, exploring laser and plasma acceleration
- Multi-TeV energy appears to be reachable with extension of normal conducting high gradient technology.
- The CLIC Two-Beam approach offers a power source which is not so frequency specific—from 11-30 GHz at least.
- After extensive development, NLC achieved reliable 65 MV/m for collider-ready structures (achieved much higher gradients in selected tests!).
- Multi-TeV colliders need higher gradient—CERN specifications have been 150 MV/m loaded.
- This collaboration should aspire to build the bridge to span this gap.

# Charge from DOE

- The US collaboration should:
  - Leverage past and ongoing research efforts towards high gradient acceleration and high power generation in order to develop the highest practical acceleration gradient and to establish a working accelerator frequency for a multi-TeV linear collider.
  - Collaborate with CERN and our other non US colleagues to leverage two beam accelerator development.
- Approach—Understand the science:
  - Perform controlled experiments to address the key aspects of accelerator structures which affect the achievable gradient.
  - Develop an understanding of all the issues.
  - Use this information to design and then test high gradient structures.

# Process

- Bring the US community working on these issues together
  - Leverage substantial infrastructure
  - Scientists
  - Facilities
- Take stock of where we are in this process
- Form a Collaboration to address these questions.
- Collaborate with CERN to couple to two-beam power source development for the long term.

# What would success look like?

- In 2009-2011
  - Several accelerator structures operating at low breakdown rate.
  - Pulse lengths, wake fields compatible with LC application
  - Gradient substantially higher the NLC baseline
    - Let's say well above 100 MV/m.
    - Perhaps up to 200 MV/m.
  - Frequency: accessible for two-beam power source
    - Probably 11.4 GHz $\leq f_{rf} \leq$ 30 GHz.

# US High Gradient Collaboration Goals

- The purpose of this collaboration is to perform research to determine the gradient potential of normal-conducting, rf-powered particle beam accelerators, and to develop the necessary accelerator technology to achieve those high gradients.
- Harnessing the momentum of the concluded NLC/JLC development programs and working in conjunction with the ongoing CLIC studies, the collaboration will explore the possibility of pushing the useable acceleration gradient from the 65 MV/m reliably achieved in NLC structures up towards 180 MV/m or higher.
- Advancing the state-of-the-art in this area is essential to the realization of a post-ILC, multi-TeV linear collider using two-beam rf power generation.

# Goals cont.

- This research and development effort will include studying the rf breakdown phenomenon itself, theoretically and experimentally.
- It will aim to establish a better understanding of the frequency scaling of the limiting gradient, as well as its dependence on material, surface preparation, structure design, pulsed heating, etc.
- It will explore the high gradient barriers due to parameter choices made in linear collider programs to date.
- The experimental side of this effort will entail the upgrade of test facilities and the development of new high-power rf sources specifically designed for high gradient testing.
- The final goal is to produce and successfully test at very high gradient an accelerator structure suitable for use in a multi-TeV two-beam linear collider.

# We must lay a technical and theoretical foundation

- Our research should be systematic and thorough, but it must be targeted due to limited resources.
- We have to address fundamentals early.
- These include, but are not limited to
  - Frequency scaling
  - Geometry dependence
  - Energy, power and pulse length
  - Materials
  - Surface processing technique (etching, baking, etc.)
  - Theory
  - …

# Scope

- The High Gradient Collaboration research effort is limited to the scope defined in the introduction.
- This collaboration should not be viewed as an umbrella for general research into RF accelerator technology or other advanced accelerator techniques.
- For example, the general development of RF sources, modulators, and RF components are not included in this effort.
- Specific technology may be included, provided that it is required for achieving the goals expressed in the introduction.
- As our research proceeds, the collaboration may enhance or limit the scope of our work plan to include additional techniques or technologies which address the primary goal of the achievement of high acceleration gradient.

# Governance Structure

- Participants
  - Collaborators
    - Laboratories
    - Universities
  - Business Associates
    - Businesses with recognized expertise
  - Foreign Colleagues

# Organization and Management

- Biannual Meetings of Collaboration
- Collaboration activities are expected to extend over a period of about five years.
- During this time, the collaboration will hold bi-annual general meetings.
- At these, participants can report progress, share results, consult with colleagues, refocus efforts, make/modify proposals, and influence the direction of the overall program.
- At least one representative from each Collaborating Institution participating in this collaboration should be present at each meeting.
- Other interested parties, such as researchers and businesses proposing contribution to the effort, may attend after requesting and receiving an invitation.
- It is hoped that representatives of foreign groups engaged in related research, such as CLIC and KEK, will also attend when possible.
- These meeting are perhaps the most important ingredient.

# Governance

- Spokesman
- Advisory Council
  - Members, including a Technical Coordinator
  - Scientific Secretary

# Initial Term and Members

- Initial duration of collaboration: 5 years
- Host Institution: SLAC
- Collaboration Spokesman:
  - Prof. Ronald Ruth, SLAC
- Advisory Council:
  - Prof. Sami Tantawi, SLAC (11.4 GHz research/overall technical coordination);
  - Dr. Richard Temkin, MIT (high frequency research and RF source development);
  - Dr. Gregory Nusinovich, UMD (theory and code development);
  - Dr. Wei Gai, ANL (other experimental programs).
  - CERN and KEK are each invited to name a representative to serve as an associate member of the Advisory Council.
  - Scientific Secretary: Dr. Chris Nantista, SLAC

# Collaborators: initial list

- Laboratories
  - Argonne National Laboratory
  - Lawrence Berkeley National Laboratory
  - Naval Research Laboratory
  - Stanford Linear Accelerator Center
- Universities
  - University of Maryland
  - Massachusetts Institute of Technology

# Business Associates

- Business Associates
  - Omega-P, Inc.
  - Calabazas Creek Research, Inc.
  - Haimson Research Corporation
  - Tech-X Corporation
  - Communications and Power Industries

# Foreign Collaboration

- Input from experts at foreign institutions with similar goals and programs will be essential and welcome.
- In particular, CERN in Switzerland and KEK in Japan are encouraged to collaborate with us, to follow our progress, and to share their own results and insights.
- Active work from foreign collaborators should be funded by their home institutions, but the collaboration is open to joint activities, such as the testing of high gradient structures with US facilities.

# Overview of work plan

- Year 1 and 2 –Phase I
  - Focused controlled experiments on key issues—materials, geometry.
  - Existing test facilities
  - Primarily x-band, but selected tests at higher frequencies
    - Possiblity: Single cell test set ups at three frequencies—SW?
  - Develop theoretical understanding.
  - Explore alternative structure types.
  - Develop power sources for two frequencies.
- Year 2 through 4 –Phase II
  - Implement/expand test facilities—new or upgraded power sources.
  - Test promising ideas on realistic full scale structures.
  - Continue small scale experiments.
  - Narrow/finalize frequency choice.
  - Explore variation of parameter sets for full linear collider.
- Year 4 though 5—Phase III
  - Final testing of full scale structures.
  - Multiple structures tested.

# Phase I: Basic Physics of RF breakdown In Vacuum Structures

- Frequency scaling
  - This can only be addressed by selected tests at three frequencies, probably SW initially.
- Geometry dependence
  - Can the long structure dependence which was seen be replicated at the single cell test setup?
  - Need to check again the scaling with frequency for a ‘good’ fixed geometry.
- Energy, power and pulse length
  - There is an empirical relation which has been determined by long structure tests at x-band
  - Verify in the single cell test set up.
  - Verify relation at other frequencies—may not be possible in this phase—CLIC power?
- Materials
  - Systematic materials tests in single cell test set up.
  - Benchmark copper, fixed geometry, power, pulse length etc.
  - Parameter space close to LC ready conditions—physics may be very different in other cases.

# Phase I: Basic Physics of RF breakdown In Vacuum Structures

- Surface processing technique (etching, baking, etc.)
  - For TW it appears that starting with short pulse and moving to long works rapidly.
  - May also work for SW.
  - Is this a requirement of test set up?
- Theory and Modeling
  - We need predictive power to make significant advances.
  - Need to combine efforts.
- Instrumentation
  - Innovative techniques for the diagnosis of breakdown events are needed
  - Can we see the breakdown event in real time—similar to work done with DC plasma spots.

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  - Frequency accessible for two-beam power source
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- In the same time frame—CTF3 demonstrating two beam power production.