THE ORION CENTER
for ADVANCED ACCELERATOR AND BEAM PHYSICS
Bob Siemann
Presentation to Dept. of Energy, Nov 7, 2001

The ORION Center - Background

• Tigner subpanel (1980) – Documented the need for increased advanced accelerator research
  – Led to establishment of the advanced accelerator program that has made important contributions - superconducting materials, plasma beat-wave acceleration, beam dynamics, optical bunching of electron beams, …
• Today, the importance to & challenge from high energy physics have increased significantly. This has been recognized by the recent HEPAP subpanel.
• Today, a larger community devoted to accelerator innovation is needed to impact the future of accelerator-based particle physics
  – Issues are sufficiently complex that they require closely interacting, critical-mass groups with breadth of knowledge.
  – Combine intellectual contributions, resources and infrastructure from universities and national laboratories - particle physicists & people at the forefront of other sciences and technologies
• The ORION Center has been formed by a university/laboratory collaboration to meet the challenge from high energy physics.

High Energy Physics Discoveries ♦ Accelerator Innovation

“Starting from the 1930’s, accelerator energy has increased – about a factor of 10 every six to eight years … this spectacular achievement has resulted from a succession of technologies rather than from construction of bigger and better machines of a given type.” W. K. H. Panofsky, 1997

Particle Physics Discoveries
• \(2\nu\)'s
• CP violation
• \(J/\psi\)
• \(\tau\)
• quarks in p, n
• W & Z
• bottom
• top

Fundamental questions and the experimental facilities that can address them. M. Tigner, Jan 2001 PHYSICS TODAY (figure adapted from one by P. Drell)

The ORION Center
• Shared Goal – The Energy Frontier
• Shared Techniques and Technologies Forming a Foundation
• Complementary Research
• Outstanding People
• Unique Facilities
• Opportunities for the General User Community
• International Support from CERN, DESY & KEK

“This proposal is outstanding in its synergy. The assembling of the physical and intellectual resources proposed will make possible progress that cannot otherwise be achieved.”
Advanced accelerator research is exciting to students and young scientists

The ORION Center – The People

• PI’s with diverse scientific backgrounds, shared interests in advanced accelerator research & recognized leaders in their fields
  – Bob Byer, Chan Joshi, Tom Katsouleas, Warren Mori, Jamie Rosenzweig, Bob Siemann
  – Expertise in lasers, plasmas, simulations, source physics, conventional accelerators, beam diagnostics
• Experienced, motivated associates
  – Chris Clayton, Eric Colby, Viktor Decyk, Mark Hogan, Jean-Noel Lebouf, Ken Marsh, Patric Muggli, Bob Noble, Dennis Palmer, Chuang Ren, Jim Spencer, Frank Tsung, Dieter Walz

“The groups involved are first rate and, if progress is to be made in this important area, this collaboration will be the one to do it.”

The ORION Center – The Facilities

• Unique facilities for advanced accelerator research

FFTB – 30 GeV e- & e+ beams. New potential of e- beams with σ<sub>z</sub> < 100 µm

“The initial use of the FFTB and subsequently ORION facilities will allow a range of experiments impossible elsewhere.”

The Final Focus Test Beam (FFTB)

The only place in the world where e+ experiments can be performed!

NEW!
  • A new compressor that will give σ<sub>z</sub> < 100 µm for e-’s is being designed.
  • SLAC Proposal E-164 would use this short bunch & would be the first FFTB activity that is part of the ORION Center.

The ORION Facility – An Upgrade to the NLCTA for Advanced Accelerator Research

The ORION Facility (to be constructed in part with funds from the ORION Center Proposal) based on the NLCTA ~65 & 350 MeV e- beams

Chicane and beam transport used for tailoring longitudinal phase space

E-162 Plasma Chamber and Experimenters

LOW ENERGY

INJECTOR

LOW ENERGY HALL

HIGH ENERGY

EXPERIMENTAL HALL

LASER ROOM 1

LASER ROOM 2

100 ft

The ORION Facility – The People

The Final Focus Test Beam (FFTB)

The ORION Facility – The People
Table 2.2: General Design Parameters of the ORION Facility

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energies</td>
<td>7 MeV (Source); 7-67 MeV (LE Hall); 67-350 MeV (HE Hall)</td>
</tr>
<tr>
<td>Charge per Bunch</td>
<td>0.25 nC optimum, adjustable up to a nominal maximum of 1 nC</td>
</tr>
<tr>
<td>Number of Bunches</td>
<td>1 or 2 (split charge)</td>
</tr>
<tr>
<td>Transverse Emittance</td>
<td>≤2×10⁻⁶ m, normalized rms (0.25 nC)</td>
</tr>
<tr>
<td>Bunch Length</td>
<td>1.8 ps, rms (0.25 nC, from source); 0.3 ps, rms (0.25 nC, compressed)</td>
</tr>
<tr>
<td>Energy Spread</td>
<td>0.8% rms for 1.8 ps bunch length</td>
</tr>
<tr>
<td>Charge Stability</td>
<td>±2.5% pulse-to-pulse</td>
</tr>
<tr>
<td>Bunch Timing jitter</td>
<td>0.50 ps, rms</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Average Beam Power</td>
<td>0.67 W at 67 MeV; 3.5 W at 350 MeV (1 nC bunches)</td>
</tr>
<tr>
<td>Electron Source</td>
<td>1.6 cell, S-band (2.856 GHz) Photoinjector</td>
</tr>
<tr>
<td>Drive Laser</td>
<td>Commercial Ti:Sapphire, 266 nm wavelength, 1 mJ output</td>
</tr>
<tr>
<td>Source RF System</td>
<td>SLAC 5045 Klystron; Solid-State, NLC-type Modulator</td>
</tr>
<tr>
<td>Injector Linac</td>
<td>Two X-band (114 GHz), 0.9 ps, 30 MV, NLC structures</td>
</tr>
<tr>
<td>High-Energy Linac</td>
<td>Four X-band, 1.8 m, 92 MV, NLC structures</td>
</tr>
</tbody>
</table>

These parameters have come from anticipated experimental beam requirements.

Flexible Electron Source ⇒ Opportunities (Two Examples)

1. High transformer ratio plasma acceleration can be studied by using bunch compression ($R_m < 0$) to produce a ramped profile with a sharp cutoff
   - Multi-GeV/m gradients!

2. Laser acceleration requires low Q and low $\sigma_E/E$ ($\propto \sigma_t^2$)
   - Photoinjector drive laser will be capable of $\sigma_t = 300$ fs to reach $\sigma_E/E < 0.1\%$
   - A photoinjector with reduced performance is part of the E-163 proposal to begin laser acceleration experiments at the NLCTA. It has the potential to be upgraded to the flexible ORION injector.

The ORION Center Proposal

The ORION Center will bring people together in a collaborative environment where facilities and resources are available for rapid progress.

- SLAC will host the ORION Center and provide
  - Routine operation and maintenance
  - User support including training, office & lab space
  - 60 MeV, 350 MeV & 30 GeV beams
- Available technical equipment – e.g. klystrons & modulators
- Proposal includes support for the university based PI’s to perform research at ORION. This will be a major part of their activities.
- It also includes some of the funds needed to construct the ORION Facility at the NLCTA.
- Available SLAC equipment and infrastructure will leverage these funds
The ORION Center Proposal

• There will be beam time, experimental support, instrumentation, etc. for a general user community
  – This will include help with staging experiments, data acquisition, advanced diagnostics, beam preparation techniques, …
• Closely coordinated computer simulations and real-time analysis
  – One of the keys to understanding experimental results
• Education and outreach
  – Partnership programs with local community colleges, Classic graduate education, WWW site based on SLAC “Virtual Visitor Center”

International Collaboration

• A. Wagner – “The ORION facility at SLAC, proposed as a user-driven facility for efficient testing of advance accelerator concepts, will provide the elements needed for combining the non-laboratory talent with large accelerator laboratory infrastructure.”
• H. Sugawara – “We have found that the project is important and useful for advanced accelerator research and so we are very much interested in the ORION project.”

Statements of Support

• Max Nikias, USC Dean of Engineering
  – “This proposal takes advantage of recent advances on advanced accelerators at these institutions and the availability of a unique beam physics facility at SLAC to carry out cutting-edge physics on beams and plasmas.”
  – USC has a strong commitment to and interest in interdisciplinary research of the type proposed here
• Charles Kruger, Stanford Vice Provost & Dean of Research and Graduate Policy
  – “It would bring faculty, staff and students to SLAC to work with unique, state-of-the-art facilities in a research area crucial for high-energy physics.”
  – “We are especially supportive of the ORION Center because it builds bridges between SLAC and the Stanford campus in fundamental physics research.”
• Jonathan Dorfan, SLAC Director
  – “My laboratory as well as the potential User community of ORION strongly support the promotion and construction of this facility and the exciting future research to be done there.”
  – Letter of support has major commitments that make the ORION Center feasible
• Attendance at this meeting by Roberto Peccei & Maury Tigner
Summary of Requested DOE Support

<table>
<thead>
<tr>
<th>Activity</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>5 Year Total</th>
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<tbody>
<tr>
<td>MRC 1 - Experiments at the FFTB (T. Katsouleas, USC &amp; C. Joshi, UCLA)</td>
<td>$600K</td>
<td>$600K</td>
<td>$150K</td>
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<td>MRC 2 - Construction and Operation of ORION, an Advanced Accelerator Research Facility (R. Siemann, Stanford)</td>
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<td>MRC 3 - Electron Sources (J. Rosenzweig, UCLA)</td>
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<td>MRC 4 - Laser Acceleration (R. Byer, Stanford)</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$1,350K</td>
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<td>MRC 5 - Plasma-Beam Physics (C. Joshi, UCLA &amp; T. Katsouleas, USC)</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$1,650K</td>
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<td>MRC 6 - Full-Scale Computer Modeling of Advanced Accelerators (W. Mori, UCLA)</td>
<td>$300K</td>
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<td>Shared Experimental Facilities</td>
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<td>Education and Human Resources and Outreach [1]</td>
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<td>Administration [1]</td>
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<td><strong>Total</strong></td>
<td>$2,300K</td>
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<td>$2,300K</td>
<td>$2,300K</td>
<td>$2,300K</td>
<td>$15,000K</td>
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</table>

1) Included in the MRC’s above

A Unique Opportunity

Progress in accelerators is inexorably linked with advances in particle physics

- New investments in accelerator research are critically important today.
- Recommendation 5 of draft subpanel report: “We recommend that vigorous long-term R&D aimed towards future high-energy accelerators be carried out at high priority within our program. ...”

The ORION Center is a unique opportunity to establish a university/national laboratory collaboration in this field that is vital for the future of particle physics

- Has had extensive, very positive reviews
- Brings together a critical mass of individuals with a passion for advanced accelerator physics
- Builds on the resources and investments that have been made in facilities at SLAC