



# Progress Toward the International Linear Collider



1. **The Physics Case**
2. **The need for the Linear Collider in the LHC era**
3. **Designing the Collider and moving toward construction**  
**BIG STORY – MAIN LINAC RF CHOSEN – Superconducting RF**
4. **International planning of support by the Governments**
5. **Progress on R&D for the Detectors**
6. **Workshops**
7. **Outreach**



# The Universe and the Linear Collider



- **The physical universe is a curious place**
  - ↪ **Symmetry in Leptons/Quarks**
    - ❖ broken □ Very Heavy Top - why?
    - Quark and neutrino mixings different - ??
  - ↪ **Standard Model-like Electroweak couplings**
    - ❖ but unsatisfying Standard Model
  - ↪ **Evidence for light Higgs boson - can we find it?**
  - ↪ **Dark Matter - what is it?**
  - ↪ **Dark Energy - WHAT IS THIS??**
  - ↪ **Extra dimensions? - can we “see” them?**
- **The Linear Collider has a significant role in exploring and uncovering the underlying reasons for these effects**

## 1. The Physics Case



# History of Support for the Linear Collider



- **The Physics case for the Linear Collider has been clear for years now**
  
- **Motivated by this, a broad segment of the community has joined in support of the goal to realize the Linear Collider (selected list)**
  - ↵ **ICFA Statement on Linear Colliders – 1999**
    - ❖ Recommends vigorous R&D to be ready in a few years  
[http://www.fnal.gov/directorate/icfa/icfa\\_LCstatement.html](http://www.fnal.gov/directorate/icfa/icfa_LCstatement.html)
  - ↵ **Snowmass Consensus Statement – 2001**
    - ❖ strongly recommends the expeditious construction of a Linear Collider as the next major international High Energy Physics project
  - ↵ **DOE/NSF Subpanel Report – 2002**
    - ❖ recommends that the highest priority of the U.S. program be a high-energy, high-luminosity, electron-positron linear collider
  - ↵ **“Understanding Matter, Energy, Space and Time: The Case for the  $e^+e^-$  Linear Collider” - 2003/4**
    - ❖ ~2700 signatories
  - ↵ **2004 – ACFA, ECFA, and HEPAP reaffirm their commitment to the Linear Collider**  
**J. Dorfan, ICFA Chair**

## 1. The Physics Case



# Quantum Universe



## 1. The Physics Case



# The Linear Collider and the LHC



- **The Linear Collider will be an essential complement to the LHC**
  - ✦ We know now the energy regime of the new physics from virtual effects at lower energy
  - ✦ The Linear Collider data will enhance the value of the LHC data
  - ✦ There are scenarios where the physics value of the Linear Collider is unique to that of the LHC
  - ✦ The momentum and technical know-how cannot easily be re-established – don't delay
  
- **The LHC / LC Study Group was established in Spring, 2002, to investigate how analyses at the LHC could profit from results obtained at a LC and vice versa.**
  - ✦ World-wide, collaborative effort of Hadron Collider (HC) and Linear Collider (LC) communities
  - ✦ About 190 working group members from ATLAS, CMS, LC Working Groups, theory + Tevatron
  - ✦ Working Group coordination: R. Godbole, F. Paige, G. Weiglein
  - ✦ Web page: [www.ippp.dur.ac.uk/~georg/lhclc](http://www.ippp.dur.ac.uk/~georg/lhclc)

## 2. The need for the LC in the LHC era



# International Scope Document



**Important step in moving to a final design for the Linear Collider was to establish the Physics Motivated Linear Collider Scope**



## ↪ **BASELINE MACHINE**

- ❖  $E_{CM}$  of operation 200-500 GeV
- ❖ Luminosity and reliability for  $500 \text{ fb}^{-1}$  in 4 years
- ❖ Energy scan capability with  $<10\%$  downtime
- ❖ Beam energy precision and stability below about 0.1%
- ❖ Electron polarization of  $> 80\%$
- ❖ Two IRs with detectors
- ❖  $E_{CM}$  down to 90 GeV for calibration

## ↪ **UPGRADES**

- ❖  $E_{CM}$  about 1 TeV
- ❖ Allow for  $\sim 1 \text{ ab}^{-1}$  in about 3-4 years

## ↪ **OPTIONS**

- ❖ Extend to  $1 \text{ ab}^{-1}$  at 500 GeV in  $\sim 2$  years
- ❖  $e^-e^-$ ,  $e^+e^+$  positron-polarization
- ❖ Giga-Z, WW threshold

Parameters for the Linear Collider

September 30, 2003

[http://www.fnal.gov/directorate/icfa/LC\\_parameters.pdf](http://www.fnal.gov/directorate/icfa/LC_parameters.pdf)

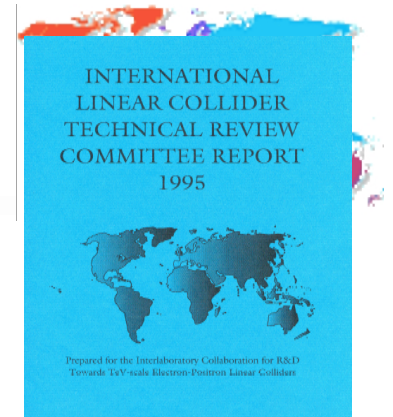
### 6.1 List of subcommittee members

Asia: Sachio Komamiya, Dongchul Son  
Europe : Rolf Heuer (chair), Francois Richard  
North America: Paul Grannis, Mark Oreglia

**3. Designing Collider / moving to construction**



# Steps To a Technology Selection



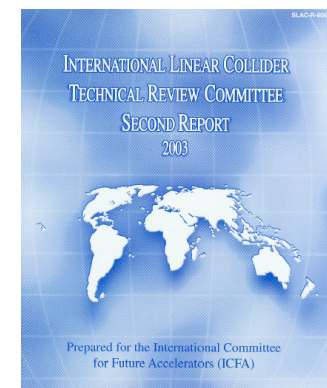
**1994 - A Technical Review Committee was created in 1994**

**1995 - report**

**2001 – ICFA requested a second report – new committee – same chair: G. Loew**

- **To assess the present technical status of the four LC designs at hand, and their potentials for meeting the advertised parameters at 500 GeV c.m.. Use common criteria, definitions, computer codes, etc., for the assessments**
- **To assess the potential of each design for reaching higher energies above 500 GeV c.m.**
- **To establish, for each design, the R&D work that remains to be done in the next few years**
- **To suggest future areas of collaboration**

**2004 – ITRP reviews technologies and recommends a choice**



**3. Designing Collider / moving to construction**



## Accelerator Technology Selection (ITRP)



- **International Technology Recommendation Panel (ITRP) asked to recommend to ILCSC/ICFA the RF technology of the main linacs**
- **Committee set up in Nov, 2003 - held 6 intensive meetings in 2004**



### 3. Designing Collider / moving to construction





## Accelerator Technology Selection (ITRP)



- **International Technology Recommendation Panel (ITRP), asked to recommend to ILCSC/ICFA the RF technology of the main linacs, held 6 intensive meetings**

**Jean-Eudes Augustin  
Jonathan Bagger  
Barry Barish (Chair)  
Giorgio Bellettini  
Paul Grannis  
Norbert Holtkamp  
George Kalmus  
Gyung-Soo Lee  
Akira Masaike  
Katsunobu Oide  
Volker Soergel  
Hirotaka Sugawara**

### Meetings

January 27-28, 2004 –

Rutherford Appleton Laboratory

April 5-6, 2004 - DESY

April 26-27, 2004 - SLAC

May 25-26, 2004 – KEK

June 28-30, 2004 – Caltech

Aug 11-13, 2004 – Korea

**3. Designing Collider / moving to construction**



## ITRP Recommendation



- **At the Beijing ICHEP meeting, the ITRP recommendation was presented to the ILCSC/ICFA, which accepted it, and it was announced by ICFA chair Jonathan Dorfan**

- **We recommend that the linear collider be based on superconducting rf technology (from Exec. Summary)**
  - This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).
  - The superconducting technology has features that tipped the balance in its favor. They follow in part from the low rf frequency.

Barish for the ITRP



## Advantages of Superconducting RF



### Some of the Features of SC Technology

- The large cavity aperture and long bunch interval reduce the complexity of operations, reduce the sensitivity to ground motion, permit inter-bunch feedback and may enable increased beam current.
- The main linac rf systems, the single largest technical cost elements, are of comparatively lower risk.
- The construction of the superconducting XFEL free electron laser will provide prototypes and test many aspects of the linac.
- The industrialization of most major components of the linac is underway.
- The use of superconducting cavities significantly reduces power consumption.

*Both technologies have wider impact beyond particle physics. The superconducting rf technology has applications in other fields of accelerator-based research, while the X-band rf technology has applications in medicine and other areas.*

Barish for the ITRP



## ITRP Report (cont.)



### Remarks and Next Steps

- The linear collider will be designed to begin operation at 500 GeV, with a capability for an upgrade to about 1 TeV, as the physics requires. This capability is an essential feature of the design. Therefore we urge that part of the global R&D and design effort be focused on increasing the ultimate collider energy to the maximum extent feasible. (from Exec Summary)
- A TeV scale electron-positron linear collider is an essential part of a grand adventure that will provide new insights into the structure of space, time, matter and energy. We believe that the technology for achieving this goal is now in hand, and that the prospects for its success are extraordinarily bright. (from Exec Summary)

Barish for the ITRP



## Forming an International LC Design Group



- **ILCSC established a task force in 2003 to recommend how best to establish an internationally federated design group**
  - ↪ **Start the globalized machine design as soon after the technology decision as possible, early next year.**
  - ↪ **First step in internationalizing the LC.**
  - ↪ **The goal was to have the structure of this design group agreed upon by ICFA and the funding agencies prior to finalizing the technology choice.**

### **Members of the task force were**

**Satoshi Ozaki (Chair), Jonathan Dorfan, Brian Foster, Won Namkung, Yoji Totsuka, Albrecht Wagner .**

**[http://www.fnal.gov/directorate/icfa/04-03-31\\_GDI\\_TF\\_Report.pdf](http://www.fnal.gov/directorate/icfa/04-03-31_GDI_TF_Report.pdf)**

**3. Designing Collider / moving to construction**



## Global Design Initiative



- **The Global Design Initiative proposed by the task force, will work to move quickly toward a TDR following the technology decision**

[http://www.fnal.gov/directorate/icfa/04-03-31\\_GDI\\_TF\\_Report.pdf](http://www.fnal.gov/directorate/icfa/04-03-31_GDI_TF_Report.pdf)

- **2004 International technology selection. Multi-laboratory MOU's to define and initiate the Global Design Effort.**
- **2005 Complete the accelerator CDR, including site requirements, and initial cost and schedule plan.**
- **2006 Initiate detailed engineering designs under the leadership of the Central Team.**
- **2007 A complete detailed accelerator TDR with the cost and schedule plan, establish the roles & responsibilities of regions, and begin the process for site proposals.**
- **2008 Site selection and approval of international roles & responsibilities by the governments.**

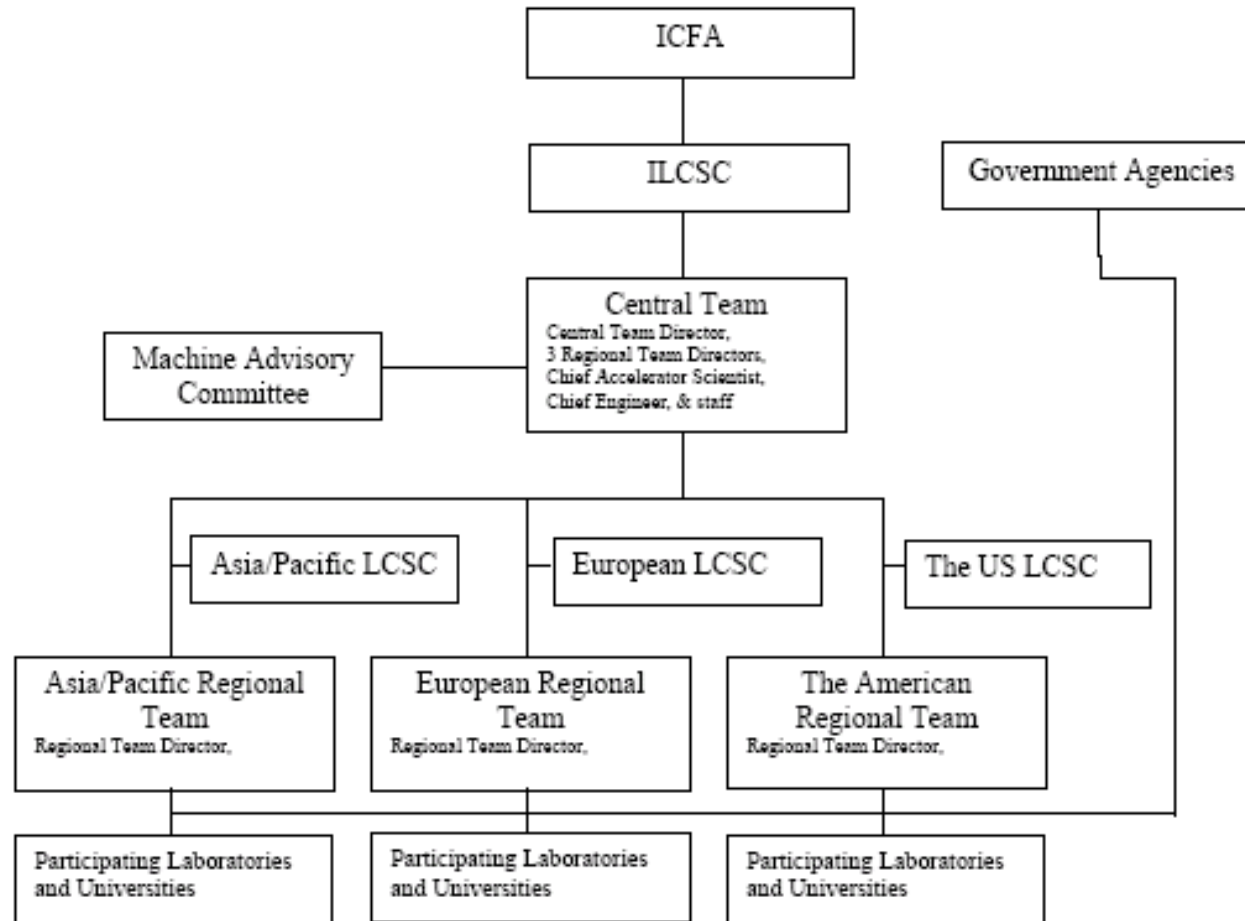
**3. Designing Collider / moving to construction**



# Global Design Effort



Figure 1: Schematic for the Global Design Effort: the early phase of the GDI



## 3. Designing Collider / moving to construction



# Organisation for Economic Co-operation and Development



- **OECD Global Science Forum analysis of particle physics (July 2002)**
  - ↪ agreed with the world-wide consensus on LC – concurrent operation with LHC
  - ↪ recommends continuation of consultations in preparation of the meeting of the OECD science ministers in 2004.

- **Meeting of the OECD Science Ministers**

- ↪ January 28-29, 2004



- Acknowledged the importance of ensuring access to large-scale research infrastructure and the importance of the long-term vitality of high-energy physics.
- Noted worldwide consensus of the scientific community for an electron-positron linear collider as the next accelerator-based facility to complement and expand on the discoveries of the LHC
- Agreed that the planning and implementation should be carried out on a global basis, and should involve consultations among scientists and representatives of science funding agencies from interested countries.
  
- Noted the need for strong international R&D collaboration and studies of the organisational, legal, financial, and administrative issues required to realise the next major accelerator facility, a next-generation electron-positron collider with a significant concurrent running with the LHC.

## 4. International Plan of support by the Govts





## Funding Agencies Meetings



- **July, 2003** “premeeting” of Agency folks (Europe and N.America) in London to enumerate the challenges and questions facing creation of agency based governance for an international project organization.
  - ↪ This meeting was an informal body to share views and opinions on prospects and issues in each of the states involved. The group discussed the status of current funding for a linear collider (LC) and their perceptions of the prospects for the future.
- **April, 2004** **Second meeting of “Agency folks” in London**
  - ↪ UK, Germany, France, Italy, US, Canada, Japan, CERN
  - ↪ Stressed importance of ITRP in 2004. Discussed three year R&D, followed by engineering design phase with completion of design in 2010. Earliest operation of linear collider 2015. Commissioning of a LC in 2015 could provide 5 years of concurrent running with the LHC. Timetable is consistent with the OECD Ministerial announcement of 29 – 30 January 2004.
  - ↪ **Minutes on the web: <http://www-jlc.kek.jp/licopo/documents/FALC/LC.april04.htm>**
- **Third meeting held in July, and fourth is planned in September**

### 4. International Plan of support by the Govts



## Two Detectors



- **International Scope Document specifies two operational detectors from the start**
- **Why two?**
  - ↪ **Competition**
  - ↪ **Cross-check**
  - ↪ **Efficiency**
  - ↪ **Insurance**
  - ↪ **Scientific opportunities**
- **What two?**
- **How do we get there?**

### 5. R&D for the Detectors



## Two Detectors

- **Several detector concepts have been or are under study**
  - ↗ **GLC Detector**
  - ↗ **TESLA TDR Detector**
  - ↗ **Silicon Detector**
  - ↗ **American Large Detector**
  
- **Global Organization in preparation for the Experimental Program**
  - ↗ **WWS organizing committee has drafted a proposal which was presented to the ILCSC in Beijing**

### 5. R&D for the Detectors



## Proposed Timeline



### GDI Timeline

- 2004 – ITRP Technology Recommendation
- 2005 – Accelerator CDR
- 2007 – Accelerator TDR
- 2008 – LC Site Selection
- Site selection + 1 year

### Experimental Program

- Single preliminary costing document for at least one whole-detector
- CDR's from each detector concept team (expect/encourage individuals to participate in multiple concepts)
- Collaborations form and submit LOIs for proposal to the Global Lab (or GDO?)
- Global lab selects experiments and asks for TDRs (ILCSC parameters document calls for 2)



### **5. R&D for the Detectors**



## Detector Design Studies

- **Detector efforts must be inter-regional**
- **Silicon Detector Design Study**
  - ↪ **Design study launched in Victoria**
  - ↪ **Subsequent meetings planned at Durham ECFA Study (Sep 3) and at Taiwan ACFA Workshop (November)**
- **Large Detectors**
  - ❖ TESLA TDR
  - ❖ GLC Very Large
  - ❖ American Large
  - ↪ **Each of these originates as regional efforts.**
  - ↪ **Some difference in the choices**
    - ❖ eg. GLC Very Large employs more cost effective calorimetry, allowing larger tracking volume.
  - ↪ **Discussing how to develop as a unified, global study**
- **Individuals are encouraged to participate in multiple studies at this time, if they are interested and have the time.**

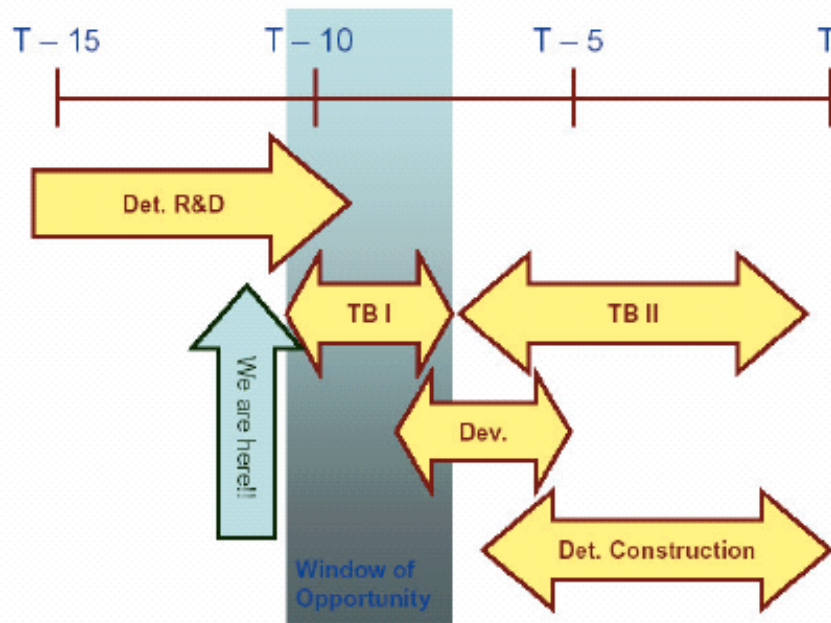
### 5. R&D for the Detectors



# Detector R&D is Critical



## LC Detector Time Scale



Graphically summarized  
by Jae Yu

Time	T=2015	Tasks
T ->10~11	Before 2005	Detector R&D
T - 10~11	2005~6	Test Beam I
T - 8~9	2006~7	•Detector Technology chosen. •Detector Development and design begins
T - 6	2009	Detector Construction begins Test Beam II (Calibration)
T	2015	LC and Detector ready

### 5. R&D for the Detectors



# Workshop of the ALCPG



American Linear Collider  
Physics Group

- **The July Victoria workshop was the sixth semi-annual workshop since Snowmass 2001**

- ↖ Chicago – Jan, 2002
- ↖ Santa Cruz – Jun, 2002
- ↖ Arlington – Jan, 2003
- ↖ Cornell – Jul, 2003
- ↖ SLAC – Jan, 2004
- ↖ Victoria – Jul, 2004

<http://blueox.uoregon.edu/~lc/alcpag>

- **This frequency has help us to intensify our efforts**

- **Beyond Victoria:**

- ↖ **The next LCWS (Worldwide Study) will be in the Americas in March, 2005**
  - ❖ At Stanford – final dates will be set soon.
- ↖ **The next ALCPG workshop is tentatively planned for August, 2005**
  - ❖ Two weeks
  - ❖ Snowmass
  - ❖ Still planning and tentative

**6. Workshops**



# The World-wide Workshops (LCWS)



- Saariselka, Finland - September 9 - 14, 1991
- Hawaii, USA - April 26 - 30, 1993
- Morioka, Japan - September 8 - 12, 1995
- Sitges, Spain - April 28 - May 5, 1999
- Fermilab, USA - October 24-28, 2000
- Jeju Island, Korea - August 26-30, 2002
- Paris, France - April 19-23, 2004
  
- LCWS 2005 will be at Stanford in March, 2005
  - ↪ Dates will be fixed soon.



## 6. Workshops

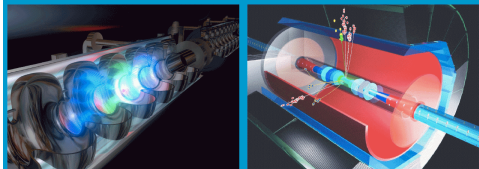




## Coordinating with European and Asian Partners

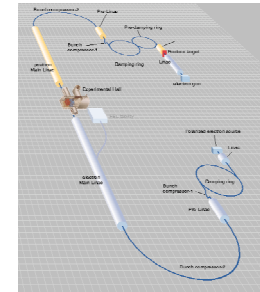
- **ECFA Study on Physics and Detectors for a Linear Electron-Positron Collider**

↳ **Durham, September 1-4, 2004**



- **ACFA Workshop series**

- **November 9-12, 2004 - 7th ACFA Workshop on Physics/Detector at the Linear Collider**
- **Taipei, Taiwan**



There has been a good interchange of participants between the regions.

### 6. Workshops



# Outreach



- **Think about your elevator speech on Particle Physics**
  - ↪ **See talks at Cornell and SLAC ALCPG meeting by Neil Calder and Judy Jackson**

- **Tell the story to politicians and public whenever possible**

- **Use the Quantum Universe**



- **Remember the Linear Collider and other particle physics projects are just a part of the needed investments in the physical sciences. Congress has been sensitized to the need. Let's get them to carry through with increased support.**

## 7. Outreach



## Summary



- **The past two years have seen many important advances toward realizing the linear collider (incomplete list)**
  - ↗ **Regional Steering Groups Formed**
  - ↗ **International Steering Committee Formed**
  - ↗ **Scope Defined Internationally**
  - ↗ **Consensus Document Expressed Physics Goals and Drove Scope**
  - ↗ **TRC Evaluation of Technologies**
  - ↗ **ITRP Commissioned and Nearing Recommendation**
  - ↗ **Central Design Group Being Planned (GDI)**
  - ↗ **Office of Science designates LC as “top priority” mid-term project**
  - ↗ **OECD and Governmental Attention and Deliberation**
    - ❖ Very positive outcomes of discussions
- **Many of the necessary steps are being taken**
- **We can realize a linear collider running concurrently with the LHC**



*We Need a LINEAR COLLIDER*





## Extras





# Regional Structure



## US Linear Collider Steering Group (J. Dorfan - speaks Monday)

### Physics and Detectors Subcommittee

### Accelerator Subcommittee chair: G. Dugan

### International Subcommittee chair: M. Tigner

American Linear Collider Physics Group  
http://blueox.uoregon.edu/~lc/alcpg

**Detector and Physics Simulations:**  
N. Graf/M. Peskin

**Vertex Detector:**  
J. Brau /N. Roe/M Battaglia

**Tracking:**  
B. Schumm/D. Karlen/K. Riles

**Particle I.D.:**  
B. Wilson

**Calorimetry:**  
R. Frey/A. Turcot/D. Chakraborty

**Muon Detector:**  
G. Fisk

**DACq, Magnet, and Infrastructure:**  
U. Mallik

**Interaction Regions, Backgrounds:**  
T. Markiewicz/S. Hertzbach

**IP Beam Instrumentation:**  
M. Woods /E. Torrence/D. Cinabro

**LHC/LC Study Group**  
- chaired by H. Schellman/F. Paige

**Working Group Leaders**  
Co-chairs: Jim Brau and Mark Oreglia

**Executive Committee**  
E. Blucher  
D. Gerdes  
L. Gibbons  
D. Karlen  
Y-K Kim  
H. Murayama  
J. Richman  
R. VanKooten

**Higgs:**  
R. Van Kooten/M. Carena/H. Haber

**SUSY:**  
U. Nauenberg/J. Feng /F. Paige

**New Physics at the TeV Scale and Beyond:**  
J. Hewett/D. Strom/S. Tkaczyk

**Radiative Corrections (Loopverein):**  
U. Baur/S. Dawson/D. Wackeroth

**Top Physics, QCD, and Two Photon:**  
Lynne Orr/Aurelio Juste

**Precision Electroweak**  
Graham W. Jones

**gamma-gamma**  
Jeff Gronberg

**e-e-**  
Clem Heusch

**Liaison to accel. R&D**  
T. Himel, D. Finley, J. Rogers

**Global Detector Network**  
M. Hildreth/R. Van Kooten

### UCLC and LCRD

D. Amidei, G. Dugan,  
G. Gollin, J. Jaros,  
U. Mallik, R. Patterson,  
J. Rogers, S. Tkaczyk  
J. LeCompte,  
G. Fisk, J. Yu



Canadian support as well

Linear Collider.ca



# World-wide Structure



International Linear Collider Steering Committee  
(est. 2002) (M. Tigner - Wednesday)

## Physics and Detectors Subcommittee

Organizing Committee of the World-wide Study of Physics and Detectors for Future Linear e+e- Colliders (est. 1998, ICFA)

J. Brau, D. Miller, H. Yamamoto, co-chairs

(past co-chairs C. Baltay, S. Komamiya)

- Coordinates three regional studies
- Organizes LCWS (Paris, April 19-23, 2004)
- Fills subcommittee role to ILCSC

Accelerator Subcommittee  
Greg Loew, chair

Parameters Subcommittee  
Rolf Heuer, chair

Communications Subcommittee  
N. Calder et al

ACFA Joint Linear Collider  
Physics and Detector Working Group



American Linear Collider  
Physics Group



<http://blueox.uoregon.edu/~lc/wwstudy>

2004

American Linear Collider Physics Group		Working Group Leaders	
<a href="http://blueox.uoregon.edu/~lc/akpg">http://blueox.uoregon.edu/~lc/akpg</a>		Co-chairs: Jim Brau and Mark Oreglia	
<b>Detector and Physics Simulations:</b> N. Graf/M. Peskin	<b>Vertex Detector:</b> J. Brau /N. Roe/M Battaglia	<b>Executing Committee:</b> E. Blucher D. Gerdes L. Gibbons D. Karlen Y.-K. Kim	<b>Hiogs:</b> R. Van Kesteren/M. Corradi/H. Haber
<b>Tracking:</b> B. Schumm/D. Karlen/K. Riles	<b>Particle ID:</b> B. Wilson	<b>Colorimetry:</b> R. Frey/A. Turcot/D. Chakraborty	<b>SLUJY:</b> U. Nauenberg/J. Feng /F. Paige
<b>Muon Detector:</b> G. Fisk	<b>D.Acy, Magnet, and Infrastructure:</b> U. Mallik	<b>Interaction Regions, Backgrounds:</b> T. Markiewicz/S. Hertzbach	<b>New Physics at the TeV Scale and Beyond:</b> J. Hewett/D. Strott/S. Tkaczyk
<b>TP Beam Instrumentation:</b> M. Woods /E. Torrence/D. Grubro	<b>ILC/IC Study Group:</b> co-chaired by H. Schellman/F. Paige	<b>IP Beam Instrumentation:</b> M. Woods /E. Torrence/D. Grubro	<b>Radiative Corrections (Loop-level):</b> U. Baur/S. Dawson/D. Wackerath
		<b>Global Detector Network:</b> M. Hildreth/K. Van Kesteren	<b>Top Physics, QCD, and Two Photon:</b> Lynne Orr/Aurelio Juste
			<b>Precision Electroweak:</b> Graham Wilson/Bill Marciano
			<b>gamma-gamma, e-gamma Options:</b> Teff Gronberg/Maria Velasco
			<b>e-e-:</b> Clem Heusch
			<b>UIC and LCRB:</b> D. Amidei, G. Dugan, G. Gollin, J. Jarvis, A. Kneefeld, U. Mallik, R. Patterson, J. Rogers
			<b>Testbeams:</b> G. Fisk, J. Yu
			<b>Global Detector Network:</b> M. Hildreth/K. Van Kesteren
			<b>Testbeams:</b> G. Fisk, J. Yu



## National Academies Study: EPP 2010

At the dawn of the 21st century, elementary particle physics is poised to address some of the most basic questions in science. Obtaining the answers to these questions will require a global effort of great scale and complexity. The committee is charged to construct a plan for U.S. participation in this effort. In particular, the committee will

Identify, articulate, and prioritize the scientific questions and opportunities that define elementary-particle physics.

Recommend a 15-year implementation plan with realistic, ordered priorities to realize these opportunities.

### Committee Membership (provisional)

**Harold T. Shapiro**, Princeton University, *Chair*

**Sally Dawson**, Brookhaven National Laboratory, *Vice Chair*

**Jonathan Bagger**, Johns Hopkins University, *BPA Liaison*

Other committee members are being nominated and will be recommended for appointment; the full committee is expected to be identified by September 2004.

<http://www7.nationalacademies.org/bpa/EPP2010.html>

To send comments or suggestions to the committee, please send e-mail to [epp2010@nas.edu](mailto:epp2010@nas.edu).

### 1. The Physics Case