RESEARCH DIRECTORATE

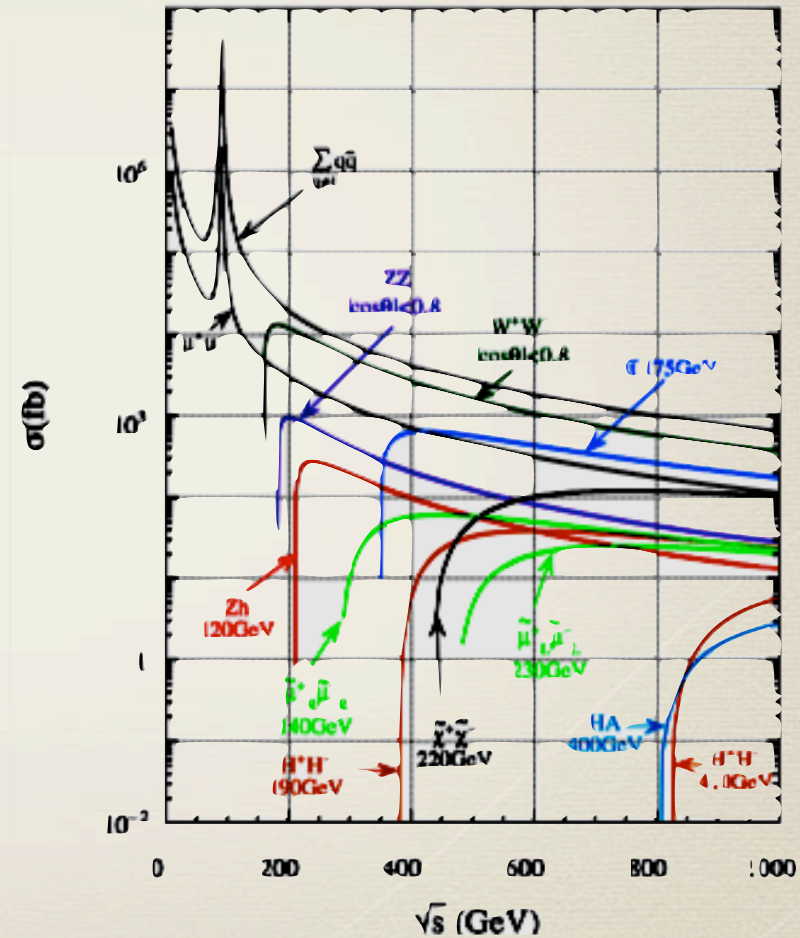
Preparing the ILC Experimental Program

Jim Brau

RESEARCH DIRECTORATE

Preparing the ILC Experimental Program

- ✳ Physics
- ✳ Detectors
  - ✳ LoIs, DBDs, CTGs, SB2009
- ✳ Detector R&D
- ✳ ILC / CLIC Cooperation
- ✳ Interim Report
- ✳ Outreach
- ✳ Future



Physics Goals at the Terascale

- Electroweak Symmetry Breaking
  - Standard Model Higgs?
- Hierarchy Problem
  - SUSY, XDimensions, New Strong Dynamics, Unparticles, Little Higgs, Z', ...
- ILC explores these and other theoretical propositions
  - Precision mass couplings (including the Higgs)
  - Direct production of new states
  - High energy behavior of cross sections

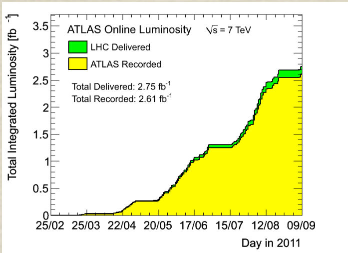
    (including asymmetries, CP violation, etc.)

Uniqueness of the Linear Collider

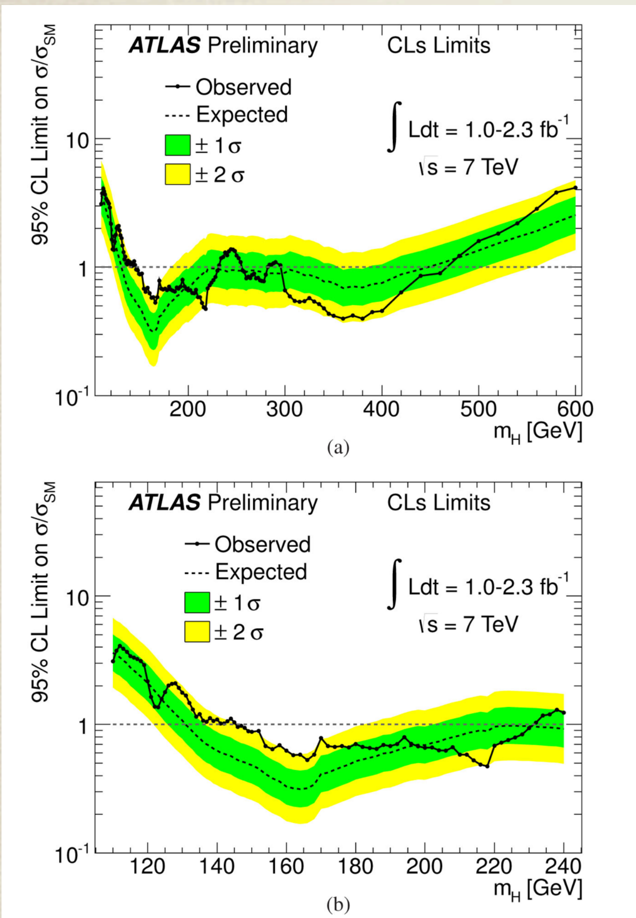
- ✳ Elementary interactions at known E_{cm}*
  - eg. e^+e^- Z H   * beamstrahlung manageable
- ✳ Democratic Cross sections
  - eg. (e^+e^- ZH) ~ 1/2 (e^+e^- d d)
- ✳ Inclusive, Trigger-free data
  - total cross-section
- ✳ Highly Polarized Electron Beam
  - ~ 80%   (positron polarization – R&D)
- ✳ Calorimetry with Particle Flow Precision
  - σ_E/E_{jet} ~ 3% for E_{jet} > 100 GeV
- ✳ Exquisite vertex detection
  - eg. $R_{beampipe}$ ~ 1 cm and σ_{hit} ~ 3 μm
- ✳ Advantage on precision measurements
  - eg. $H \to c\bar{c}$

1. Precision measurements of $e^+e^- \to f\bar{f}$
   relevant to Z' models, extra dimensions, compositeness
2. Precision measurements of $e^+e^- \to W^+W^-$
   relevant to strongly interacting Higgs sectors
3. Precision measurements of m_t and $e^+e^- \to t\bar{t}$
   relevant to precision electroweak and/or
   strongly interacting sectors with Higgs and top
4. Precision measurements of the Higgs boson couplings
   testing whether this particle actually gives 100% of the
   mass of all quarks, leptons, and bosons
5. And, for any new particles discovered or suggested by LHC
   their detailed characterization and measurement of
   quantum numbers -- and relevance to cosmic dark matter

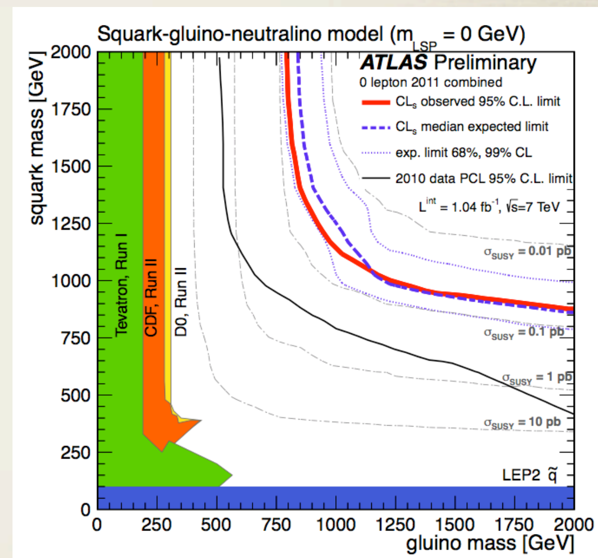
M. Peskin, Nov 2010



"Early" LHC Results



- ✳ SM Higgs has little room left to hide



- ✳ cMSSM in trouble!

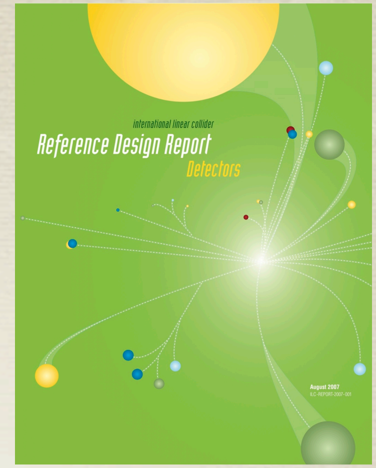
Experimental Strategy

- Waiting for first LHC discoveries
- Then - refine strategy to apply ILC uniqueness
- Some possible scenarios
  - SM-like Higgs - nothing else so far
  - Higgs and other new physics
  - no Higgs - other new physics
  - Nothing found by LHC, ruling out SM Higgs
- In each case, a linear collider with the tuned parameters, would advance fundamental understanding

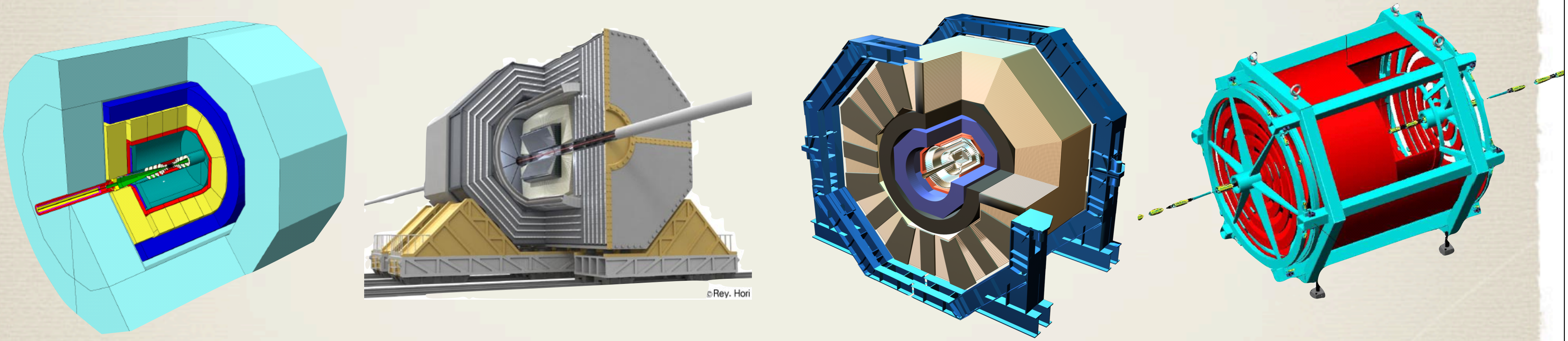
Detector Challenges

Physics Process	Measured Quantity	Critical System	Critical Detector Characteristic	Required Performance
$H \to b\bar{b}, c\bar{c}, gg$ $b\bar{b}$	Higgs branching fractions b quark charge asymmetry	Vertex Detector	Impact parameter ⇒ Flavor tag	$\delta_b \sim 5\mu m \oplus 10\mu m/(p\sin^{3/2}\theta)$ Precise
$ZH \to \ell^+\ell^- X$ $\mu^+\mu^-\gamma$ $ZH + H\nu\bar{\nu}$ $\to \mu^+\mu^- X$	Higgs Recoil Mass Lumin Weighted E_{cm} BR ($H \to \mu\mu$)	Tracker	Charge particle momentum resolution, $\sigma(p_t)/p_t^2$ ⇒ Recoil mass	$\sigma(p_t)/p_t^2 \sim few \times 10^{-5} GeV$ Superb
ZHH $ZH \to q\bar{q}b\bar{b}$ $ZH \to ZWW^*$ $\nu\bar{\nu}W^+W^-$	Triple Higgs Coupling Higgs Mass BR ($H \to WW^*$) $\sigma(e+e- \to \nu\nu\ W+W-)$	Tracker & Calorimeter	Jet Energy Resolution, σ_E/E ⇒ Di-jet Mass Res.	~3% for E_{jet} > 100 GeV $30\%/\sqrt{E_{jet}}$ for E_{jet} < 100 GeV Excellent
SUSY, eg. $\tilde{\mu}$ decay	$\tilde{\mu}$ mass	Tracker, Calorimeter	Momentum resolution, Hermiticity ⇒ Event Reconstruction	Maximal solid angle coverage Full

Detector Roadmap



- Aug 2007 Detector Concept Report
  - Four (4) detector concepts
  - LDC, GLD, SiD, 4th



- Oct 2007 ILCSC calls for LOIs and appoints Research Director

Research Directorate

* Prof. Sakue Yamada appointed by the ILCSC in 2007 to develop the ILC experimental program
* Leading preparations of the physics and detector R&D aimed toward the eventual project proposal
* Regional contacts

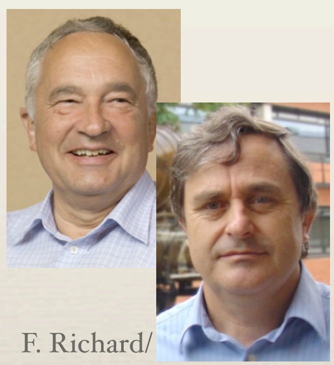
Americas

J. Brau

Asia

H. Yamamoto

Europe



F. Richard/ J. Fuster

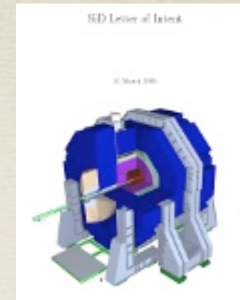
Advised by the International Detector Advisory Committee (IDAG)

IDAG

* International Detector Advisory Group (IDAG)
  * monitors the ILC detector research and development
  * advises the Research Director (now meets twice/year)
  * reviewed 2009 Letters of Intent / recommended validation

  * IDAG membership includes
    * experienced experimentalists
      * Michael Danilov (ITEP), Michel Davier (Chair, Orsay), Paul Grannis (Stony Brook), Dan Green (FNAL), Dean Karlen (Victoria), Sun-Kee Kim (SNU), Tomio Kobayashi (Tokyo), Weiguo Li (IHEP), Richard Nickerson (Oxford), Sandro Palestini (CERN)
    * active phenomenology theorists
      * Christophe Grojean (CERN & CEA-Saclay), Rohini Godbole (IIS), JoAnne Hewett (SLAC)
    * ILC accelerator experts
      * Thomas Himel (SLAC), Nobukazu Toge (KEK), Eckhard Elsen (DESY)

Detector Roadmap

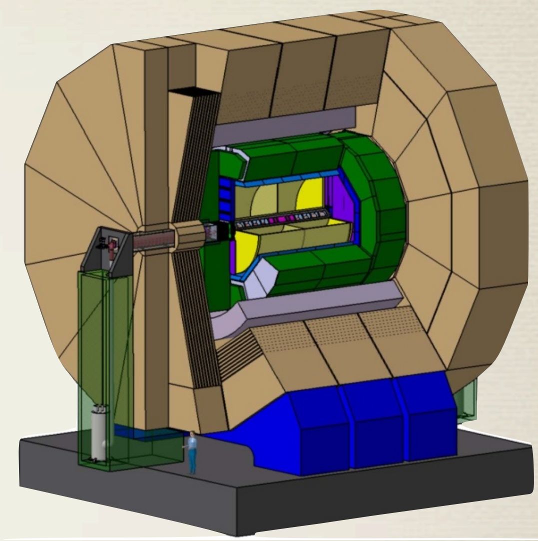


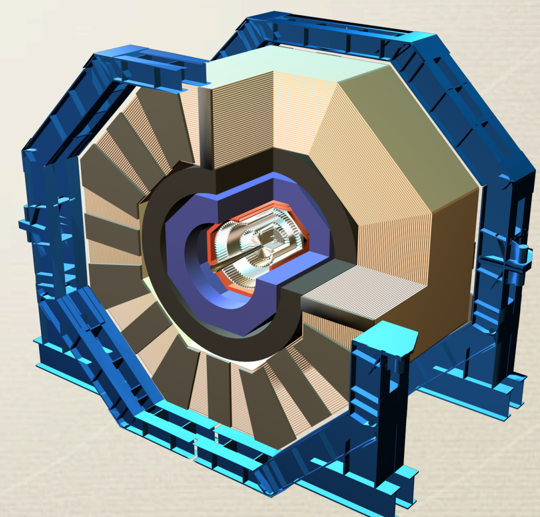
Validated LOIs

* Aug 2007 Detector Concept Report
  Four (4) detector concepts
  LDC, GLD, SiD, 4th
* Oct 2007 ILCSC calls for LOIs and appoints Research Director
* Jan 2008 RD forms detector management
* Mar 2008 IDAG formed, Three (3) LOI groups identified
* Mar 2009 Three (3) LOIs submitted
  detailed detector description, status of critical R&D, full GEANT 4 simulation, benchmark analysis, costs
* Aug 2009 IDAG recommends validation of Two (2) and ILCSC approves
* Oct 2009 Work plan of the validated groups
* Mar 2009 IDAG began monitoring the progress
* 2011 Interim report being produced
  final editing now
* End 2012 Detailed Baseline Design Report
  including physics case for ILC

Validated Detectors ILD and SiD

* Both 4π detectors - complementary designs
  * common sys. - thin pixel vxd, Si-W Ecal
* ILD
  * TPC tracking aided by silicon
  * Scintillator-steel hadron calorimeter
  * Excellent tracking and calorimetry for best possible event reconstruction
* SiD
  * Silicon tracking
  * Gaseous (RPC) digital hadron calorimeter
  * Fast tracking and calorimeter for robustness





Letters of Intent & Detailed Baseline Designs

* ILD and SiD LoIs validated (2009) - next phase Detailed Baseline Designs (DBD) of detectors for ILC project proposal demonstrating convincing physics research capability based on feasible, cost effective, demonstrated detector technologies

1. Demonstrate proof of principle on critical components.
   When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility.
2. Define a feasible baseline design.
   While a baseline will be specified, options may also be considered.
3. Complete basic mechanical integration of the baseline design accounting for insensitive zones such as the beam holes, support structure, cables, gaps or inner detector material.
4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations.
5. Develop a push-pull mechanism, working out the movement procedure, time scale, alignment and calibration schemes in cooperation with relevant groups.
6. Develop a realistic concept of integration with the accelerator including the IR design.
7. Simulate and analyse updated benchmark reactions with the realistic detector model. Include the impact of detector dead zones and updated background conditions.
8. Simulate and study some reactions at 1 TeV, including realistic higher-energy backgrounds, demonstrating the detector performance.
9. Develop an improved cost estimate.

\- 20 August 2009 Research Director's Report

DBD plans

- Both detectors presented DBD plans to the IDAG in Eugene in March, and to the ILCSC's Project Advisory Committee (PAC), and will discuss the plans again in Granada in two weeks
- IDAG/PAC comments:
  - dealing with baseline options (ILD)
  - resource shortages (both groups)
  - match goals for DBD with resources (SiD)
  - IDAG is concerned that the costs are not yet fully coordinated between groups - do cost differences impact physics performance?
    - costing group has been formed to work on improving this coordination (including informal linkage to CLIC detectors)
      - agreement on unit costs for Si-det, W, Fe, stainless steel

Common Efforts

* There are many common efforts within the two detectors, which can benefit from direct common work
* Since just after the appointment of the RD, common task groups (CTGs) have been organized to provide formal, direct interactions
  * Machine Detector Interface (MDI)
  * Engineering Tools
  * Detector R&D
  * Software
  * Physics

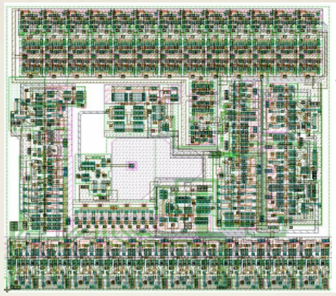
Common Efforts

* **Machine Detector Interface (MDI) CTG**
  * found common solution to push-pull (platform)
* **Engineering Tools CTG**
  * agreed on EDMS, in common with GDE
* **Detector R&D CTG**
  * surveyed detector R&D, assessed needs, aims to get attention focussed on need for more resources
  * prepared spin-off document

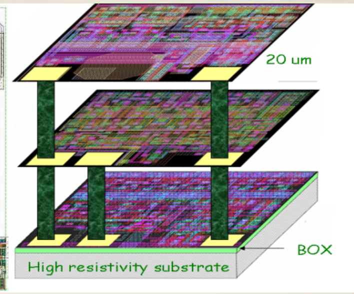
Detector R&D

Vertex Detectors

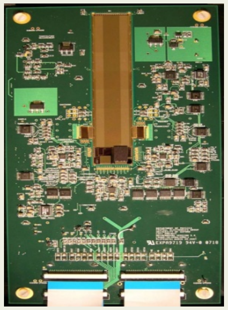
- Development of candidate VXD sensors have produced prototypes.
- Integration issues have been addressed (mechanics, power, heat,…)
- Tough requirements
  High resolution, fast readout, low mass, low heat
- Technical demonstration still needed.



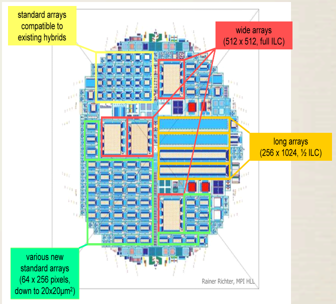
CMOS/Chronopix



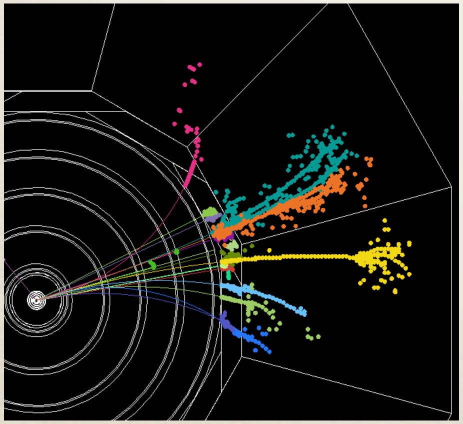
3D-SOI



CPCCD



DEPFET



Particle Flow Calorimetry

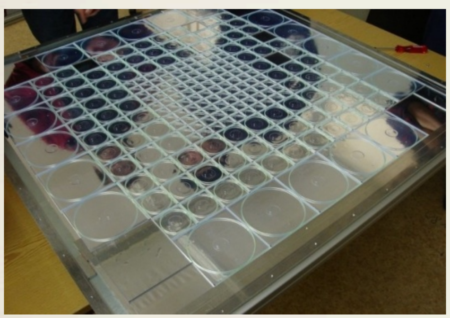
- Pandora PFA gives $\Delta E/E$ = 3-4% in full simulation
- Experimental confirmation coming from CALICE
- PFAs have become a design tool, useful for detector optimization.

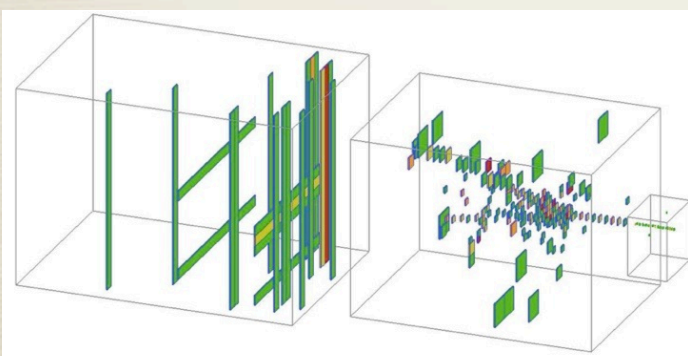
Detector R&D

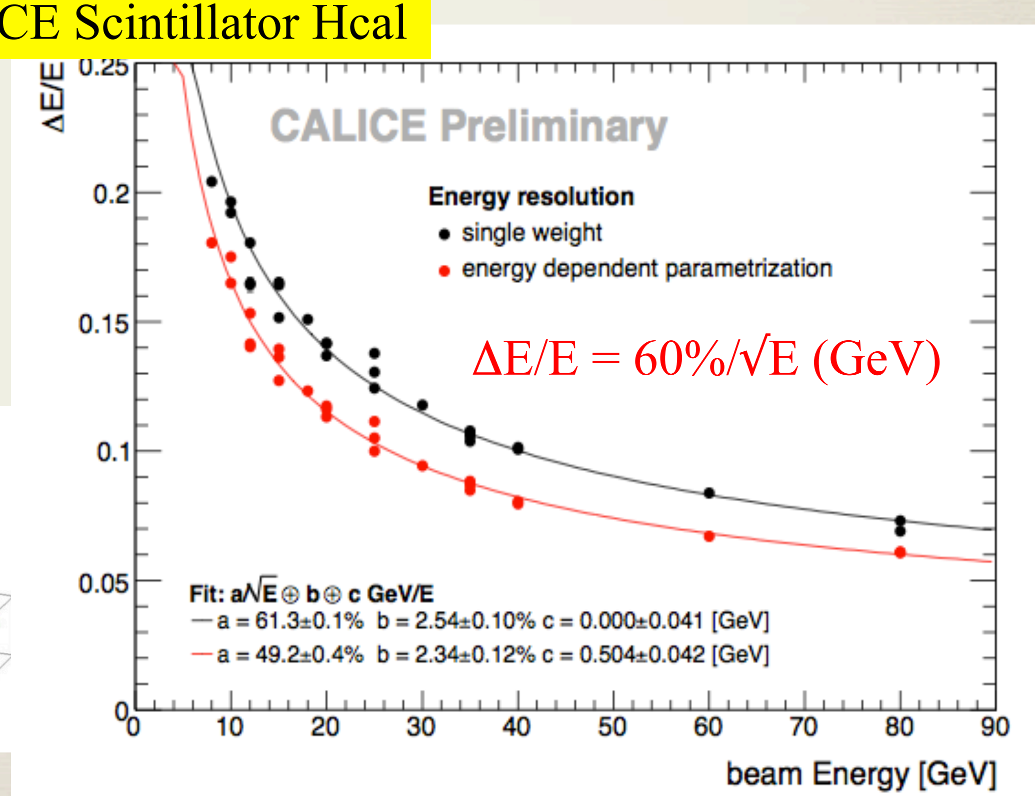
Hadronic Particle Flow Calorimetry

- 1 x 1 m^2 Scintillator Hcal (3 x 3 cm^2 pixels) has been beam tested
- 1 x 1 m^2 RPC digital Hcal (1 x 1 cm^2 pixels) also tested
- Hardware demonstrated, but "particle flow" is harder to prove!

CALICE Scintillator Hcal



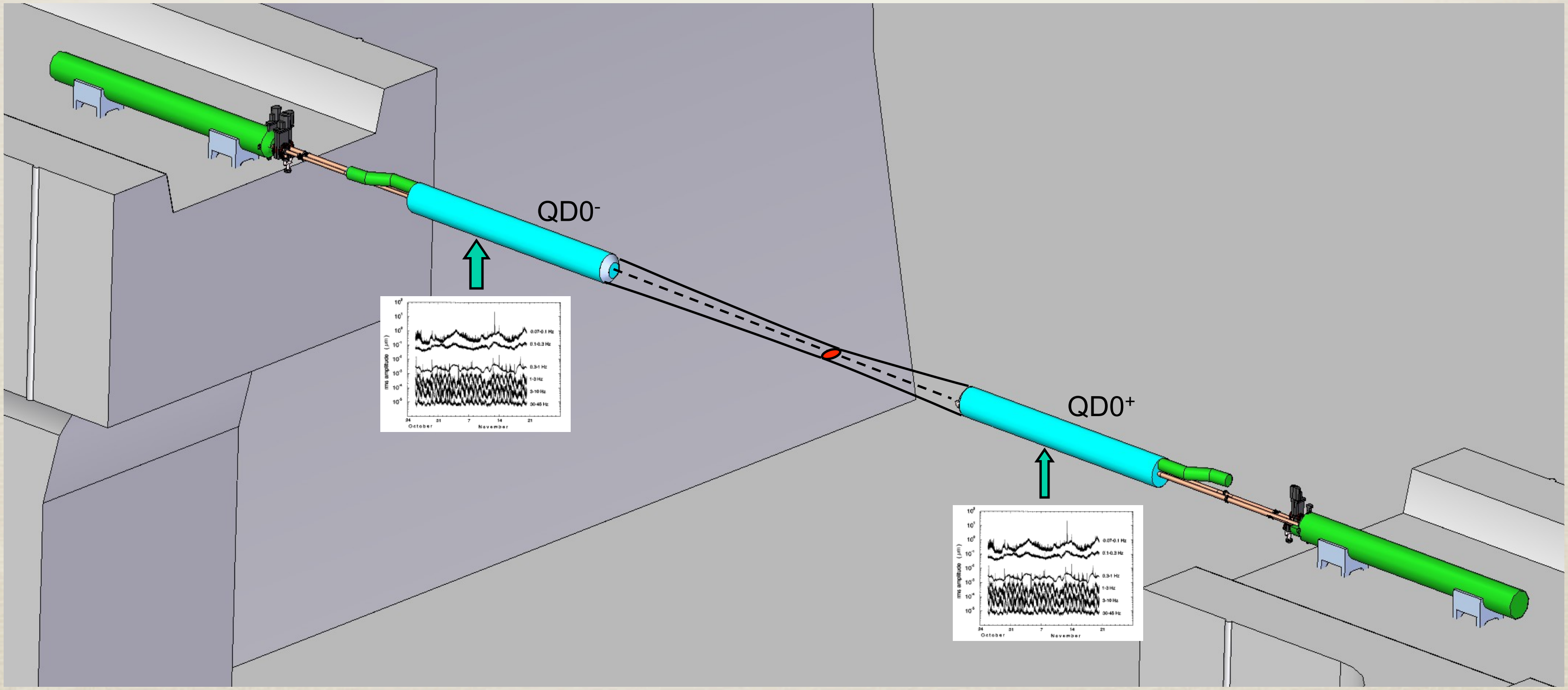




MDI R&D

ILC Critical R&D: Vibrations and Support

- Challenge: Stabilize final quads to 10's of nm against ground motion while allowing for detectors to move on and off beamline
- Engineering studies underway



Common Efforts

* **Software CTG**
  * coordinating tools for simulation
  * communicates with CLIC simulation
  * supports assessment of machine design changes
  * preparing for 1 TeV simulations
* **Physics CTG**
  * updates physics case (eg. interim report)
  * led benchmarks discussion in cooperation with Software CTG.
  * plans report for the DBD next year

DBD Benchmarks

1 TeV processes with 1 ab^{-1}

- e+ e- → ν ν H : Higgs branching ratio @1TeV
  - Test detector performance for simplest context
- e+ e- → t t H : Top Yukawa coupling @1TeV
  - Detector performance for complex (8 jet) events
- e+ e- → W+ W- : In-situ polarization measurement @1TeV
  - Detector performance for high energy jet
  - Capability of forward detector elements

- **Each group repeats one of the LOI processes @500 GeV with the final detector configuration,**

  and with the same event sample
- Beam polarization taken into account
- All relevant physics back grounds to be included

ILC Design Optimization

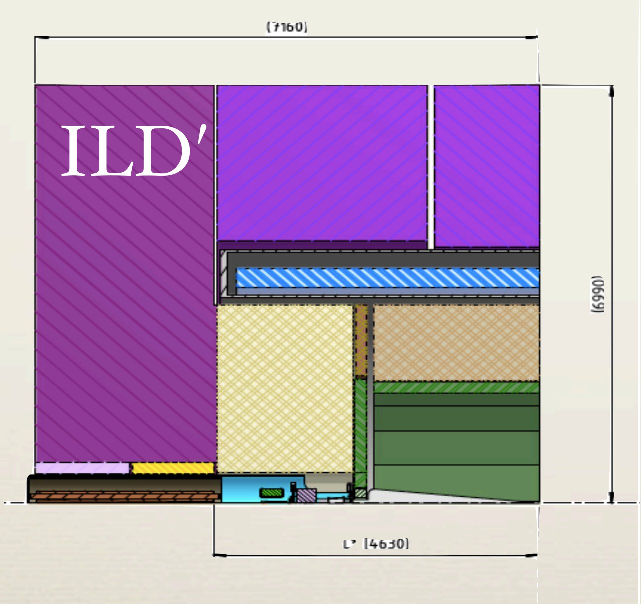
* 2009 - GDE revised accelerator parameters, to improve optimization of tradeoffs in cost to performance to risk (SB2009)
* Physics/detector SB2009 WG (JB convener) to assess impact
* Studies by the physics/detector community led to improved design (for physics) confirmed at the Baseline Assessment Workshops (KEK, 2010 & SLAC, 2011)
* Now the GDE studies the 1 TeV optimization, and this WG is in process of assessing its physics/detector impact

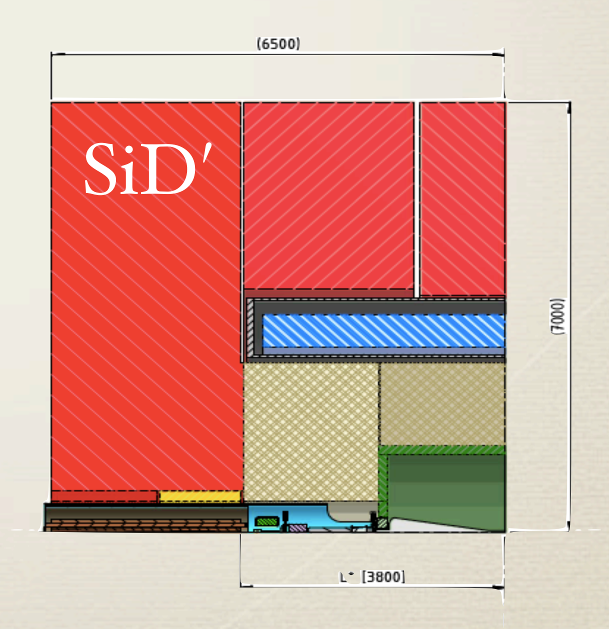
Physics & Experiment Board

* Leaders of the RD organization meet monthly to discuss and plan activities
  * RD: Yamada, Brau, Fuster, Yamamoto
  * ILD: Behnke, Sugimoto
  * SiD: Jaros, White
  * CTGs: Buesser, Clerc, Demarteau, Miyamoto, Peskin

ILC/CLIC Cooperation

* The CLIC Concept Design Report (CDR) has drawn on prior ILC work
* Detector Concepts





ILC/CLIC Cooperation

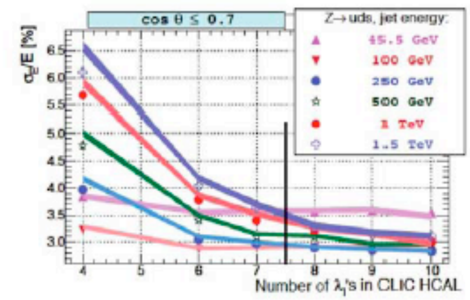
Core Software development

Core software Mokka/Marlin	Improvements to the geometry descriptions in Mokka/Marlin (involving mostly members of CERN, DESY, LLR)
Pandora_PFA_new	New Pandora architecture allows use of Pandora in ILD and SiD (SLAC, N. Graf). Participation in the re-write of Pandora, in particular the photon clustering algoritm (Cambridge univ, with help from CERN). The SiD version (interface) is called SLiCPandora.
Pandora_PFA_new	Assesment of performance of Pandora PFA new in jet reconstruction (Barklow), PFO lepton-id
GRID production tools	Setting up of automatic GRID production tools and file database for Mokka/Marlin and for SLIC/LCSim (using the LHCb DIRAC framework)
TPC pattern recognition and track reconstruction	Development of improved TPC pattern recognition and track reconstruction with the aim of providing parametrisations which can be used in the ILD TPC tracking
Hadronisation in Geant4	Study and improvements to the hadronisation models in Geant4

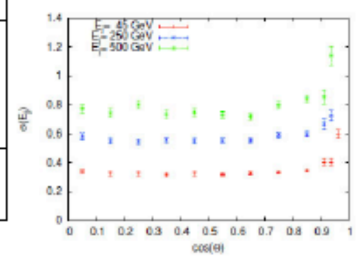
Work on overlay of background and physics

Overlay of incoherent pairs and gg=> hadron events	Work on overlay of background and physics events, gaining experience that is also of use for ILC
Forward region background studies	Detailed forward region simulations with study of backscattered particles in Mokka/Marlin
Muon background from machine	Study of (horizontal) muon background from the machine and its rejection in the tracking/calo codes

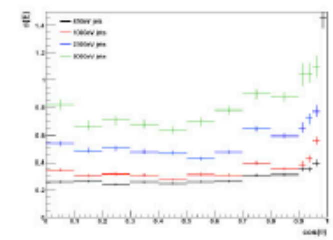
Pandora based optimization

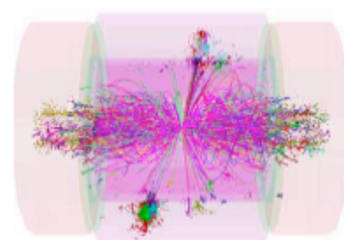


CLIC SID



CLIC ILD (J.M.)





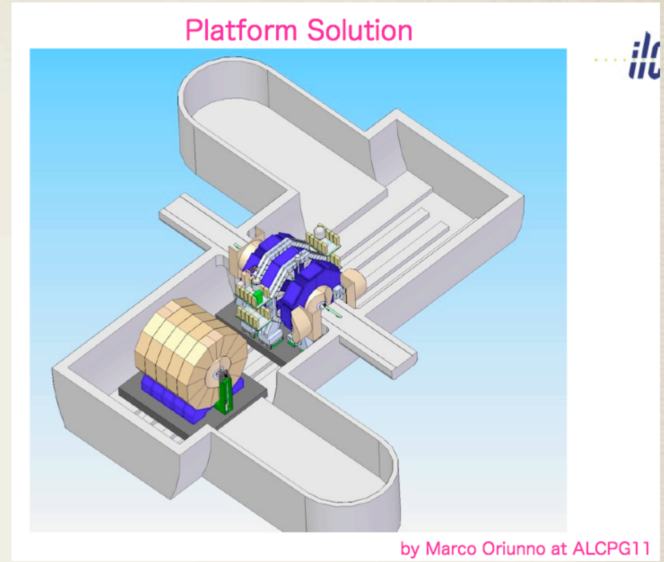
ILC/CLIC Cooperation

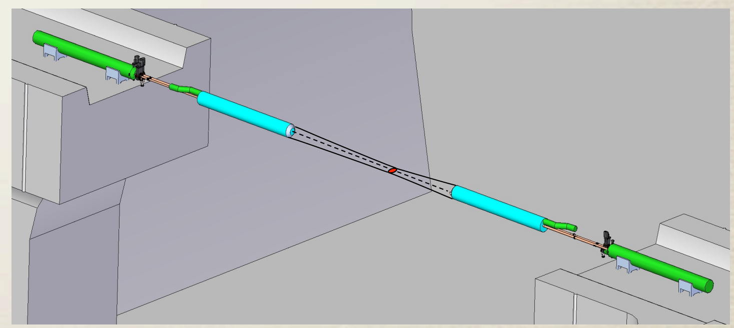
Assessment of high energies, with clear interest for future 1 TeV ILC work

SiD tracking at high energies	Assesment of SiD tracking at high energies and with background overlay
Muon id and muon optimisation	Study of muon-id, dramatic energy loss by muons, hadron shower leakage
Tau finder	Development of a tau finder and tau reconstruction (currently in Marlin, but can extend to SiD software)
SiD and ILD detector adaptations for higher energies	For the CLIC study, the ILD and SiD concepts are adapted to higher energies (and of course also to CLIC background conditions). These adaptations will provide useful input to define 1 TeV detector strategies for the ILC.
Optimisation of physics observables	For the CLIC study we work on the optimisation of physics observables at 3 TeV. The corresponding adaptations to the various codes will serve the ILC as well.

Engineering studies

Vibration studies, forward region quadrupole suspension	Vibration studies at LHC locations, study of QD0 suspension including FEA and design, corresponding opening scenarios (this is partly CLIC-specific, due to the severe CLIC requirements)
Push-pull studies and requirements for experimental area	Push-pull studies and requirements for experimental area and its services
Solenoid magnet studies	Solenoid magnet (4T and 5T) caluculations and design parameters
Solenoid services	Studies of solenoid services and quench protection compatible with push-pull





ILC/CLIC Cooperation

Electronics developments

TPC pad readout	Development of TPC pad readout electronics, based on S-Altro (microelectronics) design
TPC pixel readout	Design of pixel chip for TPC readout (Timepix2 chip)
Microelectronics support	Microelectronics support, training, foundry services, design reviewing for LC community

HCAL R&D

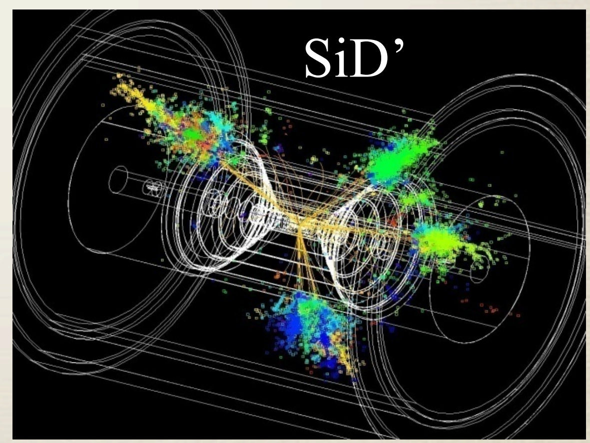
Tungsten-based HCAL studies within CALICE	Preparation of beam tests of a large HCAL prototype, based on Tungsten absorbers and various CALICE active media

FCAL

Beamcal and lumical simulation models	Setting up and maintenance of Mokka/Marlin/Geant4 simulation model of Beamcal and Lumical; software support for ILC FCAL members

Benchmarks

e+e -> $h\nu_e\bar{\nu}_e$ e+e -> H^+H^- e+e -> H^0A^0 e+e -> $q_R\bar{q}_R$ e+e -> $\ell^+\ell^-$, ℓ = e, μ e+e -> $\chi^+_i\chi^-_j$; $\chi^0_i\chi^0_j$ e+e -> $t\bar{t}$ (0,5 TeV)	Cambridge (chair), CERN, MPI Munich, LAPP, UCSC, Prague, Barcelona, SLAC, RAL, DESY



ILC/CLIC Cooperation

- There are many common areas for cooperation between ILC and CLIC
  - eg. concept design, simulation, push-pull, etc.
- Several key ILC experimentalists contributing significantly to the CLIC CDR - this is an informal choice by individuals
- Topics for even increased cooperation have been identified
  - eg. pulse powering workshop last Spring
- When CLIC CDR is completed, CLIC team will be free to contribute to the ILC DBDs.

Interim Report Physics/Detectors

* Summary of progress and status of detector effort
  * Physics prospect as seen presently
  * Overview including chronological development and organization
  * R&D status and DBD preparation
  * Update of physics simulation since RDR
  * Accomplishments of each common task groups & SB2009 WG
  * CLIC-ILC cooperation
* Nearly completed
  * ILC communicators working on final review and layout

Outreach

- Public
  - science <u>AND</u> technology
- Scientific Community
- Policy makers
- Funding agencies

<u>Particle Physics Slam - ALCPG11 - Eugene - March 22, 2011</u>

Particle detectors: they're nearer than you think, **Marcel Demarteau**
Seeking hidden dimensions, **Brian Foster**
Neutrinos from outer space! **Garabed Halladjian**
An illumination of dark matter, **JoAnne Hewett**
Why physics, dude? **Marc Wenskat**

Outreach - Spinoffs

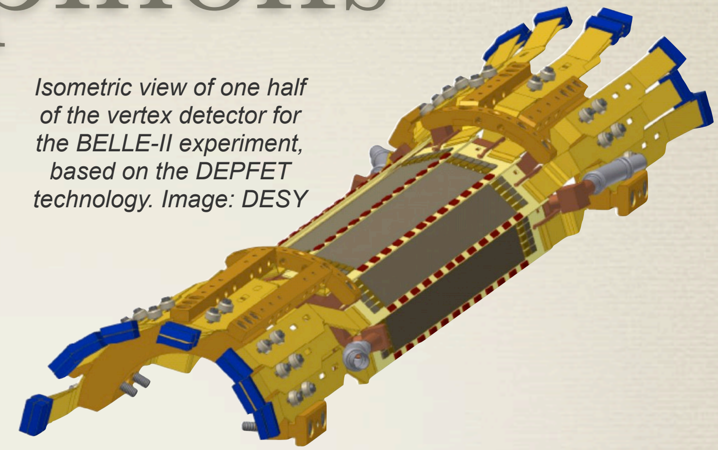
ilc newsline

RESEARCH DIRECTOR'S REPORT

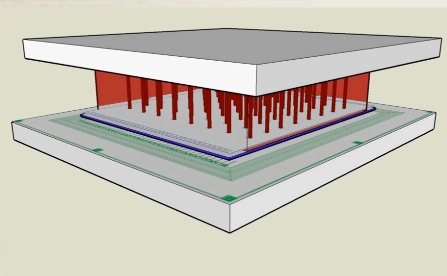
The impact of ILC detector R&D

This month's Research Director's Report was written by Marcel Demarteau, chair and convener of the ILC Detector Common Task Group

Marcel Demarteau | 18 August 2011

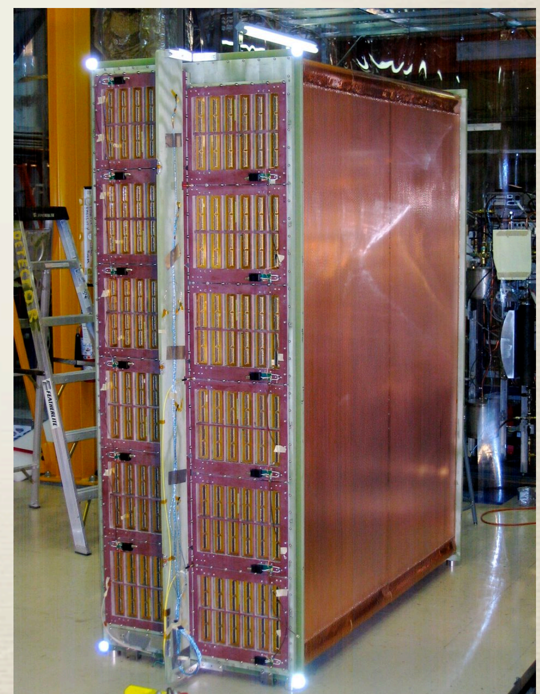


Isometric view of one half of the vertex detector for the BELLE-II experiment, based on the DEPFET technology. Image: DESY



Conceptual view of a 3-D silicon assembly for a track trigger for an LHC upgrade showing a silicon sensor at the top and bottom interconnected through an interposer. Image: Ron Lipton

Beam telescope in the CERN and DESY test beam lines based on the MIMOSA-26 pixel sensors. Image: DESY



MicoMegas-based time projection chamber for the T2K experiment in Japan, based on ILC detector R&D. Image: T2K

Looking Beyond 2012

- Comprehensive Project Design Guidance (CPDG)
- ILCSC discussions
- New leadership structure being considered (post 2012)
  - physics/detector effort will be an important element in the new organization

Conclusion

* We are on a long road aimed at realizing a global project - the linear collider
* We are well into the long journey
    * 1991 - Linear Collider Workshop, Saariselka, Finland
    * 2003 - "Understanding Matter, Energy, Space and Time: the Case for the Linear Collider" - consensus statement
    * 2004 - Technology choice, ITRP
    * 2007 - Reference Design and Detector Concepts Report
    * 2012 - Technical Design and Detailed Baseline Designs
* We must continue our intense, structured efforts to be prepared when we can start building the linear collider and our experiments