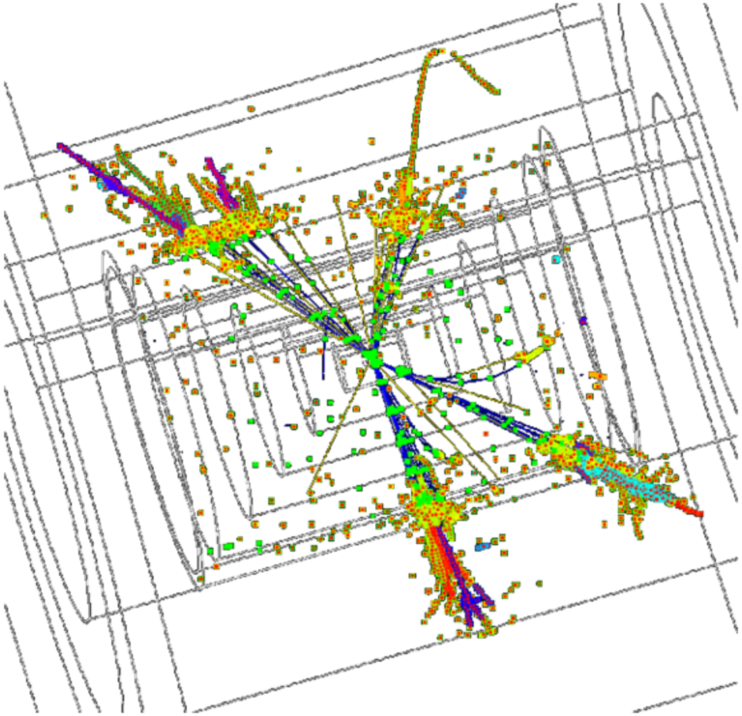
Detector R&D Common Task Group

Status Report



Marcel Demarteau

Fermilab

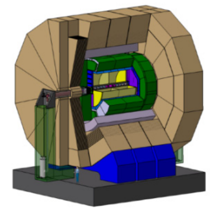
On behalf of the Detector R&D Common Task Group

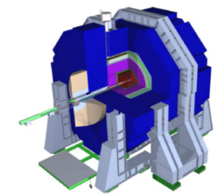
PAC Meeting
Pohang, Nov. 2-3, 2009

Outline

- Brief update on common task group for detector R&D
- Brief summary of achievements of concept detectors
- Detector R&D topics and priorities
  - ‘Short term’ goals
  - ‘Long term’ goal
- Status quo and goals

Common Task Group Membership





- **ILD: Dhiman Chakraborty**
  Tohru Takeshita

- **SiD Marcel Demarteau (convenor)**
  Andy White

- **CALICE: Felix Sefkow**
- **FCAL: Wolfgang Lohmann**
- **LC-TPC Jan Timmermans**
- **SILC: Aurore Savoy-Navarro**
- **VERTEX: Ron Lipton**
- **Dual Readout: John Hauptman**

- **The three representatives from the 4th detector concept, Roberto Carosi, Franco Grancagnolo (deputy), Yury Tikhonov, stepped down since the 4th concept has not been validated**

- **ILD, SiD and CLIC invited to add one member to the common task group. Nomination received from ILD: Marc Winter.**

Charge and Mission

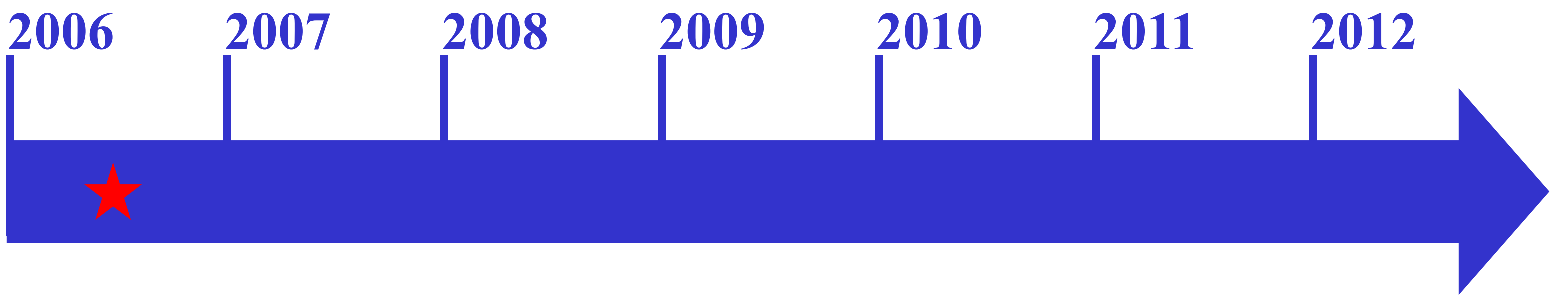
- The charge of the RD for the detector R&D common task group is to:
  - Coordinate cooperation of detector R&D
  - Respond to requests from IDAG and PAC on detector R&D
  - Facilitate communication between LOI groups and R&D collaborations
  - Survey R&D efforts and organize reviews when needed

- We interpret our mission to be to help nurture the technologies needed to design and build the detectors that will be needed to advance the scientific goals of a Linear Collider.

- To this end, the detector R&D common task group invites the Detector Concept Groups and horizontal R&D collaborations to work together

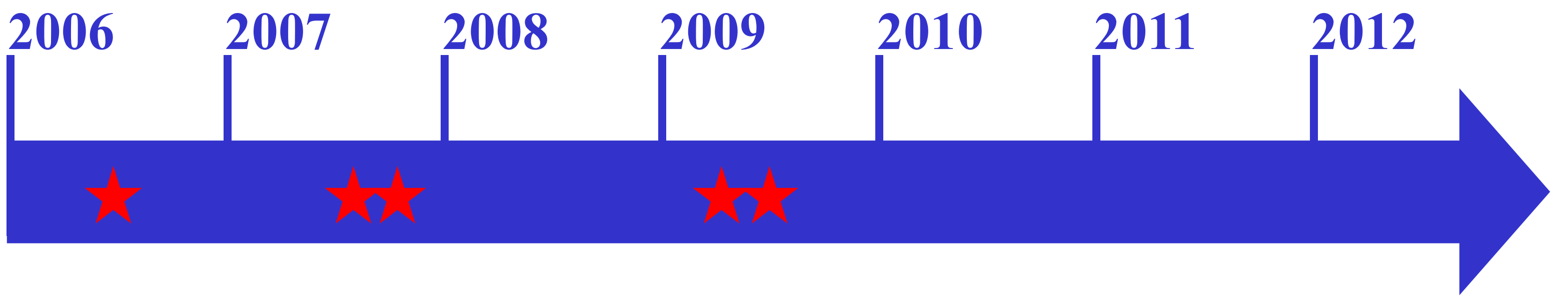
- We meet on average about once a month by webex and have a face-to-face meeting at every major ILC/GDE meeting. Proposals are put forward by consensus.

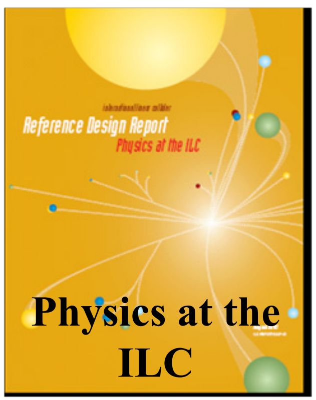
Recent Timeline

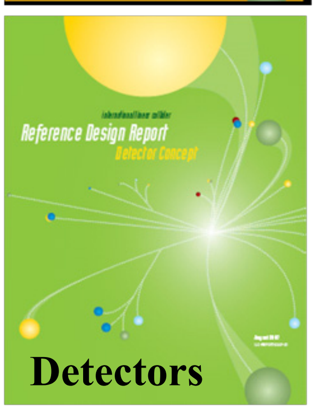


- **May 2006: Submission of Detector Outline Document by 4 concepts**

Recent Timeline







- **May 2006: Submission of Detector Outline Document by 4 concepts**
- **August 2007: Submission of Reference Design Report**
- **Fall 2007: Appointment of Research Director**
- **All of 2007: three independent WWS Detector R&D Reviews**
- **Spring 2008: IDAG formed**
- **ECFA WS June 2008: Start of IDAG validation process**
- **March 31, 2009: Submission of three LOIs**

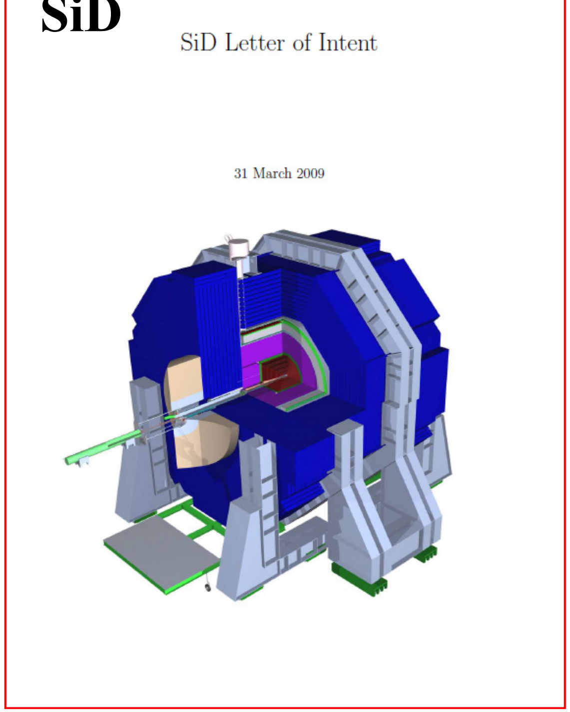
- **Today: validation process complete**

Culmination

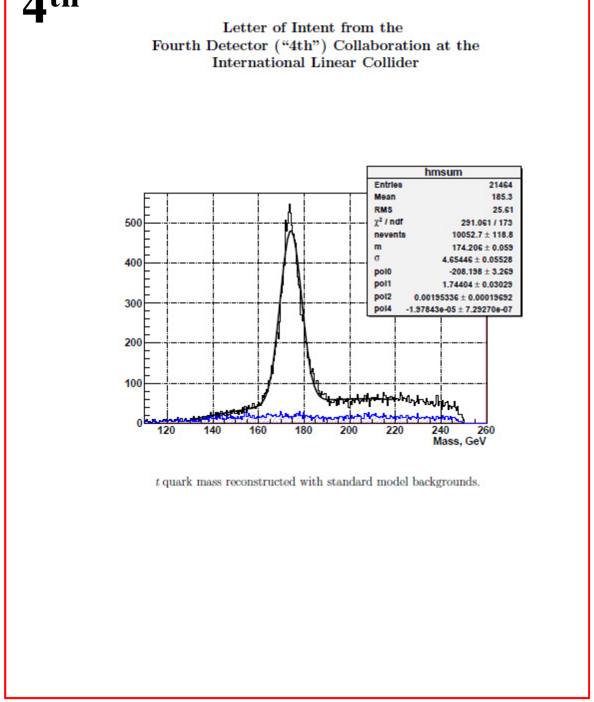
- **The efforts of the three ILC detector concepts culminated in the submission of the LOIs on March 31, 2009**

ILD

SiD



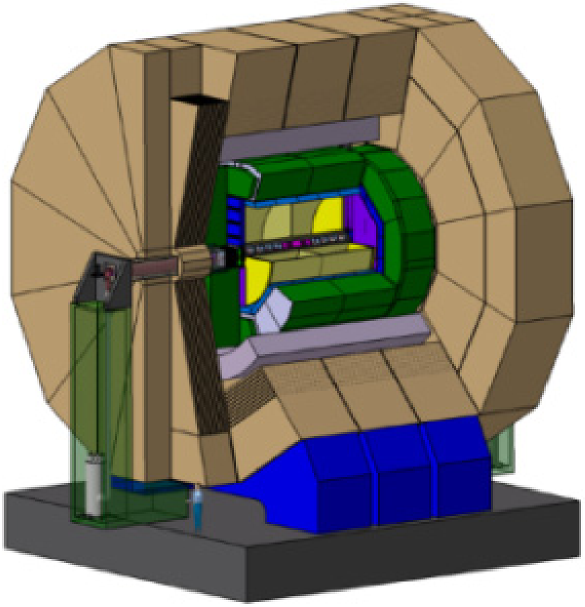
4th



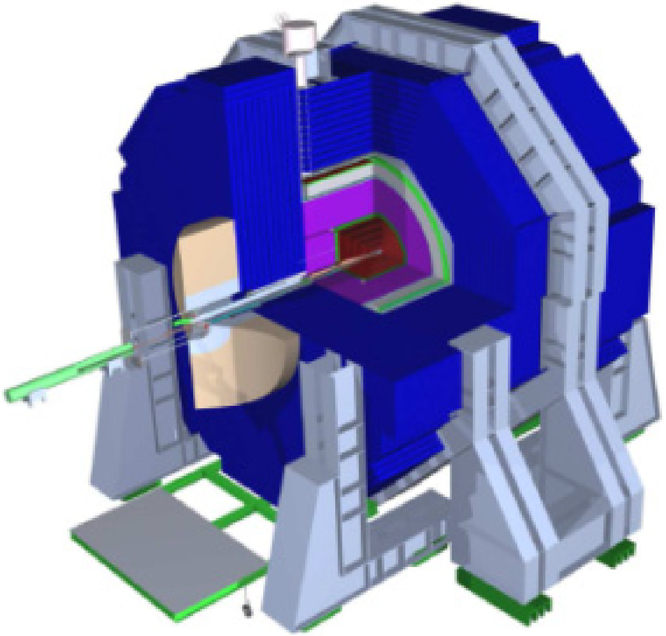
- **An incredible tribute to a very dedicated detector community!**
- **Accomplished on a shoestring budget in a difficult environment!**
- **LOIs now provide framework to extend studies to strengthen the case for the ILC!**

Validation

- **On August 17, 2009, the IDAG validated two concepts**
  - **"The ILD and SiD are validated and should be considered for the next phase of detailed baseline studies together with the GDE"**
  - **"The fourth concept is not validated. However, dual readout calorimetry should be supported in view of its potential for higher energy colliders"**



Detector X



Detector Y

R&D Collaborations

- **CALICE Collaboration**
- **FCAL Collaboration**
- **LC-TPC Collaboration**
- **SILC Collaboration**
- **VERTEX Detector R&D groups**
- **SiD Tracking**
- **SiD ECal**
- **Dual Readout Studies**
- **EUDET**
- **…**

- **Observation:**
  - **The LOI and subsequent validation process had an element of competition; It is NOT a competition anymore! Our job is to prove that the ILC can do the job and that it's the only option when the LHC says 'go'!**

Goal

- **Our goal is simple:**

  Be ready to make a realistic proposal for detectors that can execute the precision physics program, if the LHC indicates that the energy scale of the ILC can elucidate the new physics

  Readiness means that the technologies are well understood and proven to be scalable; it does not mean a fully engineered design

Identified Areas of R&D

Group	R&D Area / Concept	4th	ILD	SiD
Vertex	CP CCD		X	
Vertex	FP CCD		X	
Vertex	SC CCD	X		X
Vertex	ISIS	X	X	X
Vertex	CMOS MAPS	X	X	X
Vertex	SOI	X	x	X
Vertex	DEPFET	X	X	X
Vertex	3D	X	X	X
Tracker	Silicon Strips		X	X
Tracker	GEM TPC		X	
Tracker	MicroMegas TPC		X	
Tracker	CMOS TPC		X	
Tracker	CluClou	X		

Group	R&D Area / Concept	4th	ILD	SiD
Calorimetry	Si-W ECAL		X	X
Calorimetry	Scint ECAL		X	X
Calorimetry	MAPS ECAL		X	X
Calorimetry	Scint Analog HCAL		X	X
Calorimetry	RPC Digital HCAL		X	X
Calorimetry	GEM Digital HCAL		X	X
Calorimetry	MicroMegas Digital HCAL		X	X
Calorimetry	Fiber Dual Readout	X		
Calorimetry	Crystal Dual Readout	X		X
Muon	Drift Tube Muon	X		
Muon	Scint Muon		X	X
Muon	RPC Muon		X	X
FC	FCAL Sensors	X	X	X
Misc.	Alignment	X	X	X
Misc.	Serial Powering	X	X	X
Misc.	DC-DC Conversion	X	X	X
Misc.	Superconductors	X	X	X

- **Large part of the necessary R&D is carried out in horizontal R&D collaborations**

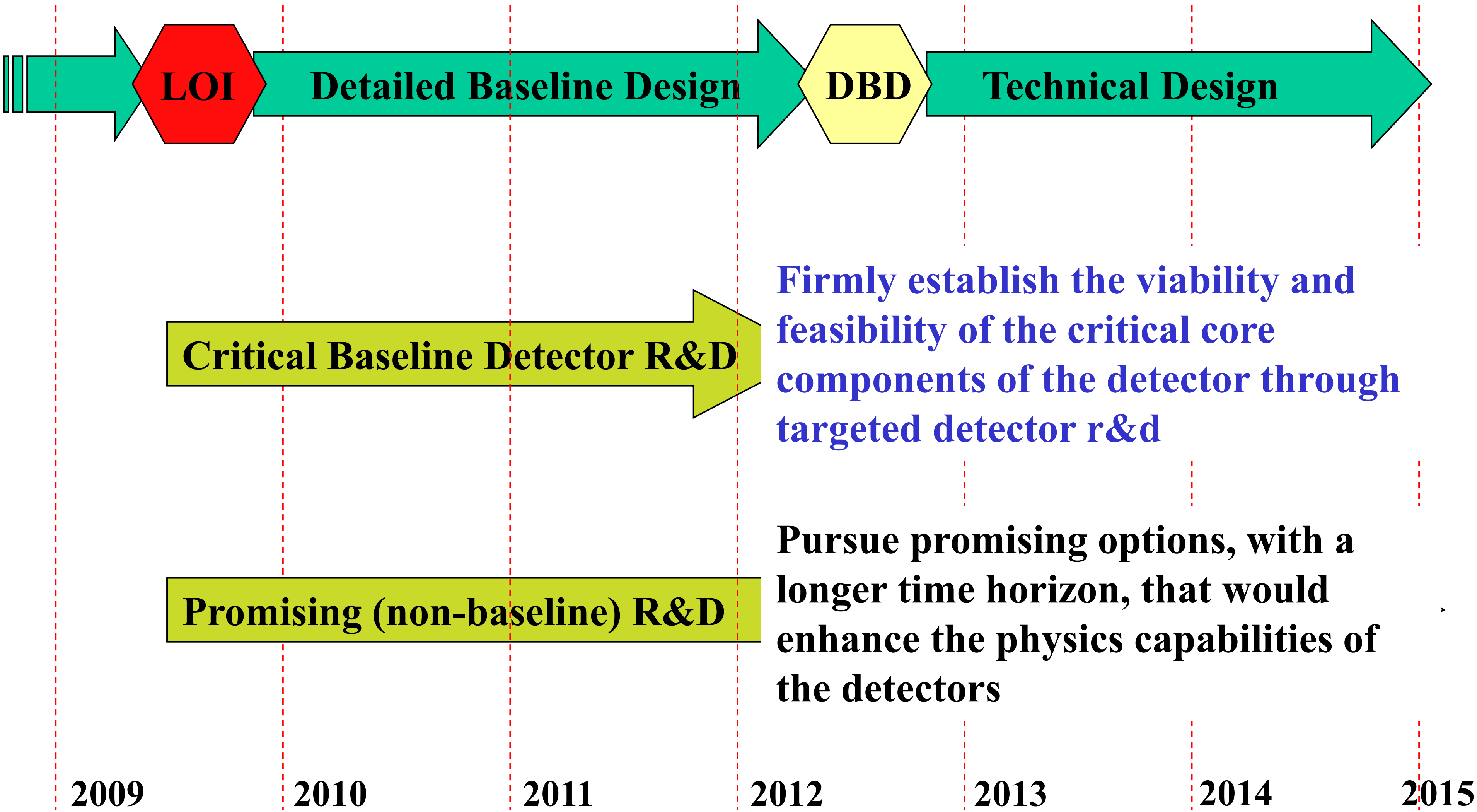
Observations

- **It is sometimes said that the ILC detector community has too broad an R&D program that is not well focused**

- **The breadth of the detector R&D program is needed to retain a viable detector community; its support needs to be maintained at a minimum at the same level**
  - **Relatively small projects with high science per dollar help ensure scientific breadth while maintaining program focus on the highest priorities.**

- **Having said that, a few key R&D areas have been identified that need additional support to be able to reach our goal to put forward a defensible detailed design report for the detectors by 2012**

A Two-Prong Approach



Firmly establish the viability and feasibility of the critical core components of the detector through targeted detector r&d

Pursue promising options, with a longer time horizon, that would enhance the physics capabilities of the detectors

Criteria for 'High Priority'

- The physics and detector goals addressed by the R&D are critical to the linear collider detector and physics program
  - R&D addresses detector performance that lies at the very heart of the ILC physics repertoire
- With adequate support, compelling results of at least one technology, or a preponderance of solid, important results, will be available by 2012.
  - Verification that the fundamental underlying premise of the technology is correct and achievable in real systems
- Detector technology should mainly be under the purview of the ILC detector community
  - Technologies that are vigorously being pursued by other projects, such as the LHC upgrades, are not considered unless it is believed that such R&D is not progressing at adequate pace
- Programmatic issues
  - Emphasis on cooperation vs. duplication/competition

Crucial Detector R&D Topics

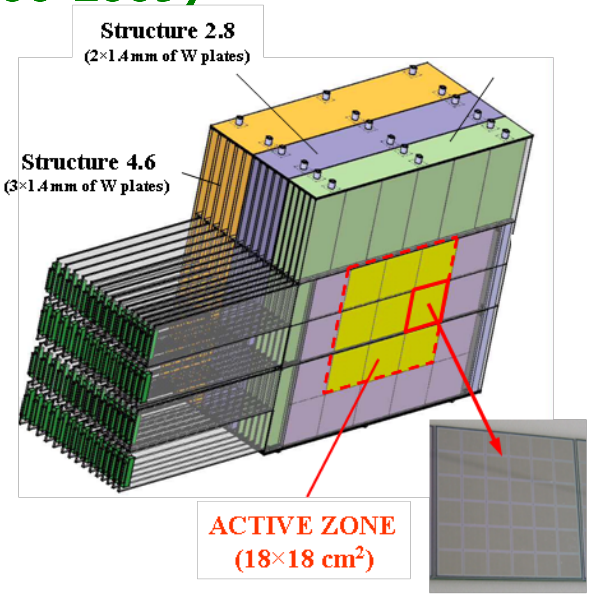
- Five areas have been identified as pillars of the detector concepts that need to be validated by 2012 to put a proposal for a concept detector on a firm scientific basis

1. Areas of Particle Flow Calorimetry within CALICE
2. Further development and understanding of two Particle Flow Algorithms
3. Three areas of LC-TPC studies
4. kPiX
5. Test Beams

- For the first four topics, will state
  - Goal of R&D and status
  - Areas that have been identified as critical and in need of additional resources

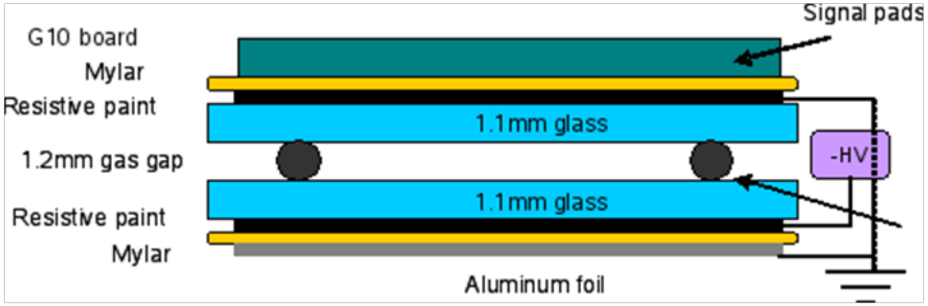
1. Particle Flow Calorimetry

- The goal of PF calorimetry is, among others, to show that
  1. Superior hadronic energy resolution can be achieved with highly granular, integrated calorimeters and
  2. That the technology can be applied to real detectors
- Technologies pursued:
  - Ecal: Si-W, Scintillator-W (analog); MAPS (digital)
  - Hcal: Scintillator (analog); RPC, MicroMegas, GEM (digital)
- To address 1, "physics prototypes" were built (1m^3 for hadronic):
  - Si-W Ecal with runs at DESY and CERN (2006-7)
  - Analog HCAL with runs at CERN and Fermilab (2006-2009)
  - Scintillator Ecal with run at Fermilab (2009)
- Globally coordinated R&D program through the CALICE collaboration has been very successful and analysis of data is in progress
- Data taking with second hadron calorimeter option is imminent: gaseous RPC based readout

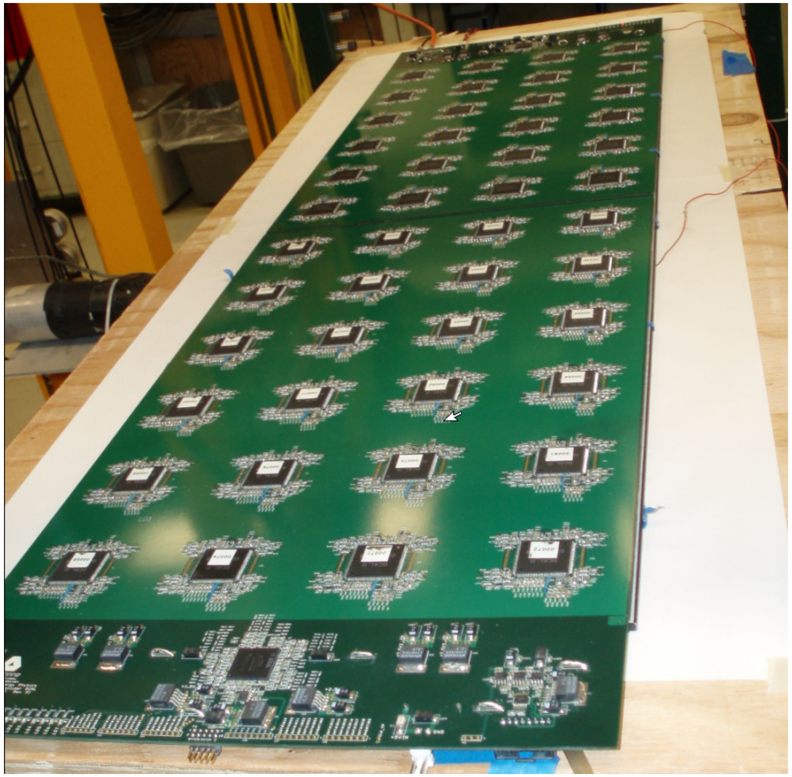


1. PF Calorimetry Priorities

- **Complete analysis of current data set**



- **Complete the ongoing m³ RPC test of the "physics prototype"**
  - **Provides first information on gaseous, digital calorimetry**
  - **Although not a technical prototype, it has more integration than previous prototypes**

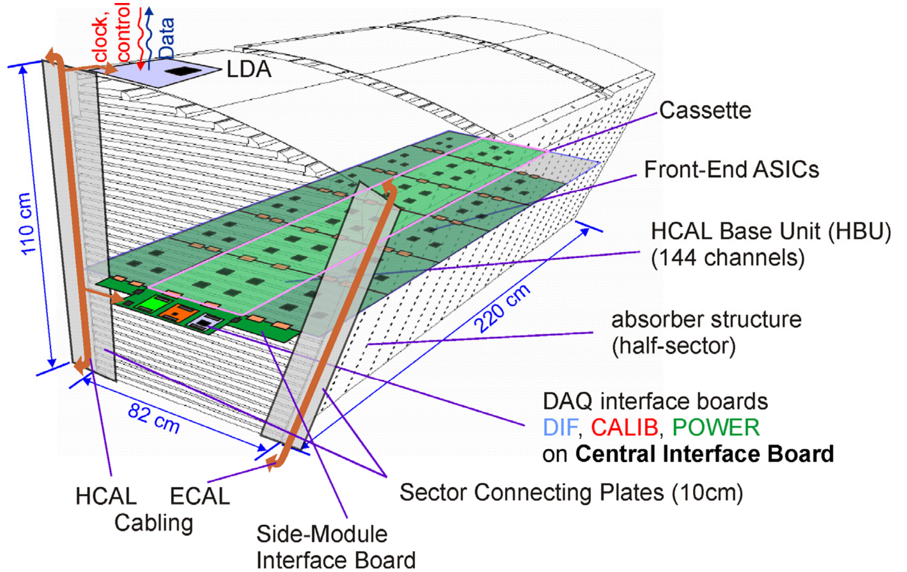


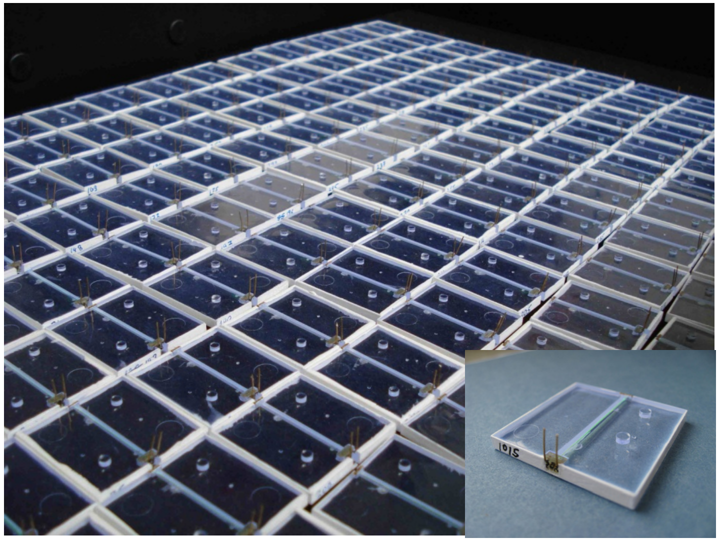
- **Scale**
  - **40 layers, each ~ 1 x 1 m²**
  - **3 RPCs/layer, each 32 x 96 cm²**
  - **1x1 cm² pads with one threshold**
  - **10,300 tested and packaged chips**
  - **400,000 readout channels**

1. PF Calorimetry Priorities

- **Move towards technical prototype for scintillator based HCAL:**
  - **Move ASICs into volume**
  - **DAQ in barrel endcap gap (or barrel coil gap)**
  - **No FE cooling with power pulsing**
  - **On-detector zero suppression**
- **Prototype does not need to be full m³, but principle of scaling should be demonstrated**
- **Full system integration**
  - **Electronics, mechanics**
  - **Incorporating tiles and SiPMs**
- **First prototype is being assembled**
- **Calibration and power issues being addressed**

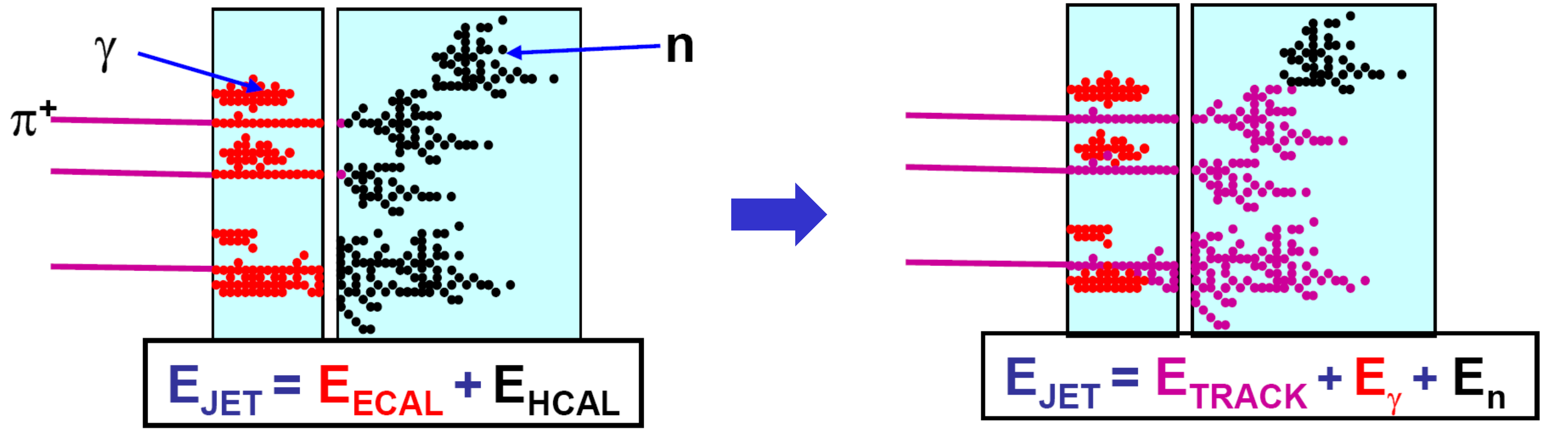
- **After completion**
  - **Two technologies studied**
  - **Feasibility of one technological prototype demonstrated**





2. PFA: Goal and Status

- Goal: obtain a jet energy resolution of 3-4% for 40 Gev < E_{jet} < 500 GeV, through a combined use of the tracking and ECAL system and using the HCAL to only measure neutrals



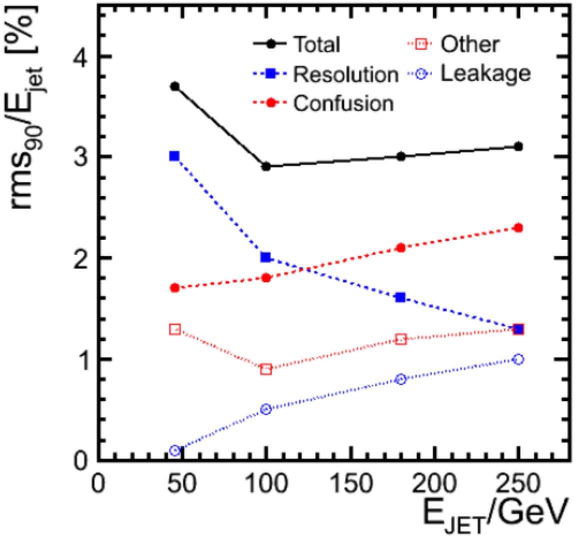
- Two robust PFA algorithms have been developed: PandoraPFA and IowaPFA
- LOI status: PandoraPFA meets, IowaPFA almost meets ILC goal

- But, a lot of work still remains

E_{JET}	σ_E/E (rms$_{90}$)	
	ILD	SiD
45 GeV	3.7 %	5.5 %
100 GeV	2.9 %	4.1 %
180 GeV	3.0 %	4.1 %
250 GeV	3.1 %	4.8 %

2. PFA Priorities

- To obtain a quantitative understanding of existing PFAs as applied to the ILC detector concepts. This involves a breakdown of the contribution to the energy resolution and biases and identifying their root causes.
  - May have been achieved already (see M. Thomson's Albuquerque talk)



Total Resolution	3.1 %
Confusion	2.3 %
i) Photons	1.3 %
ii) Neutral hadrons	1.8 %
iii) Charged hadrons	0.2 %

250 GeV Jets

- To develop a quantitative understanding of the differences in performance for the various detector technologies and various algorithms and carry out a cross-concept comparison.
- To carry out a quantitative assessment of fundamental limitations of particle-flow particularly as a function of jet energy and particle multiplicities. Study the importance of the uncertainties on an event-by-event basis as compared to averaged resolution.

2. PFA Priorities continued

- To establish and document a realistic implementation of at least single-layer geometrical descriptions and a test-beam validated response model in the simulations for mature sub-detector technological options, e.g. dead areas, cross-talk, noise.

- To analyze the test beam data and compare the results to Monte Carlo simulations. In particular, measure two-particle separation performance using test-beam overlay of separate single particle events and compare the results with Monte Carlo simulations.

- To further develop physics performance studies for physics channels where particle-flow performance is key

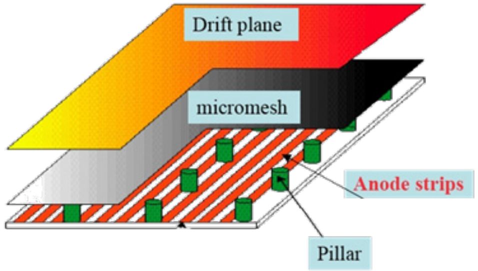
- To continue the development of the simulation and software tools needed to study particle flow in detail, and to continue to refine the particle flow reconstruction tools.

- To provide complete documentation of the Particle Flow Algorithms and their performance results

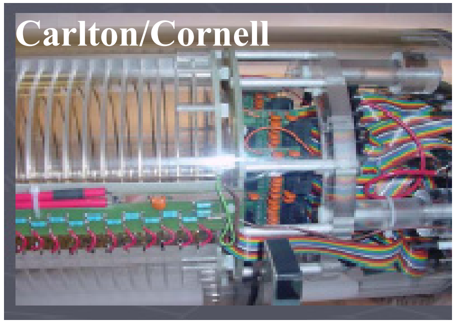
3. LC-TPC: Goal and Status

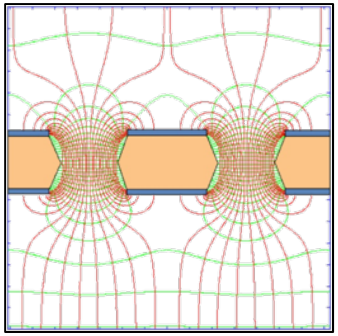
- **TPC with MPGD goals:**
  - **Point resolution in rφ / rz: 100μm / 500 μm (average)**
  - **Two hit resolution in rφ / rz: 2mm / 6mm (average)**
  - **Material budget drift volume / end plate: 4% X_0 / 15% X_0**
- **Technology options:**
  - **Two gas amplifications: MicroMeGas, GEM**
  - **Analog /digital TPC: standard pad readout / CMS pixel readout**

- **Many studies have been carried out over many years on small prototypes (SP) which have advanced the technology significantly**
  - **6 years of MPGD experience**
  - **Gas properties measured**
  - **Point resolution understood**
  - **Resistive anode charge dispersion demonstrated**
  - **CMOS pixel technology demonstrated (small scale)**
  - **Proof-of-principle of TDC-based electronics**



Y. Giomataris et al, NIM A376 (1996) 239



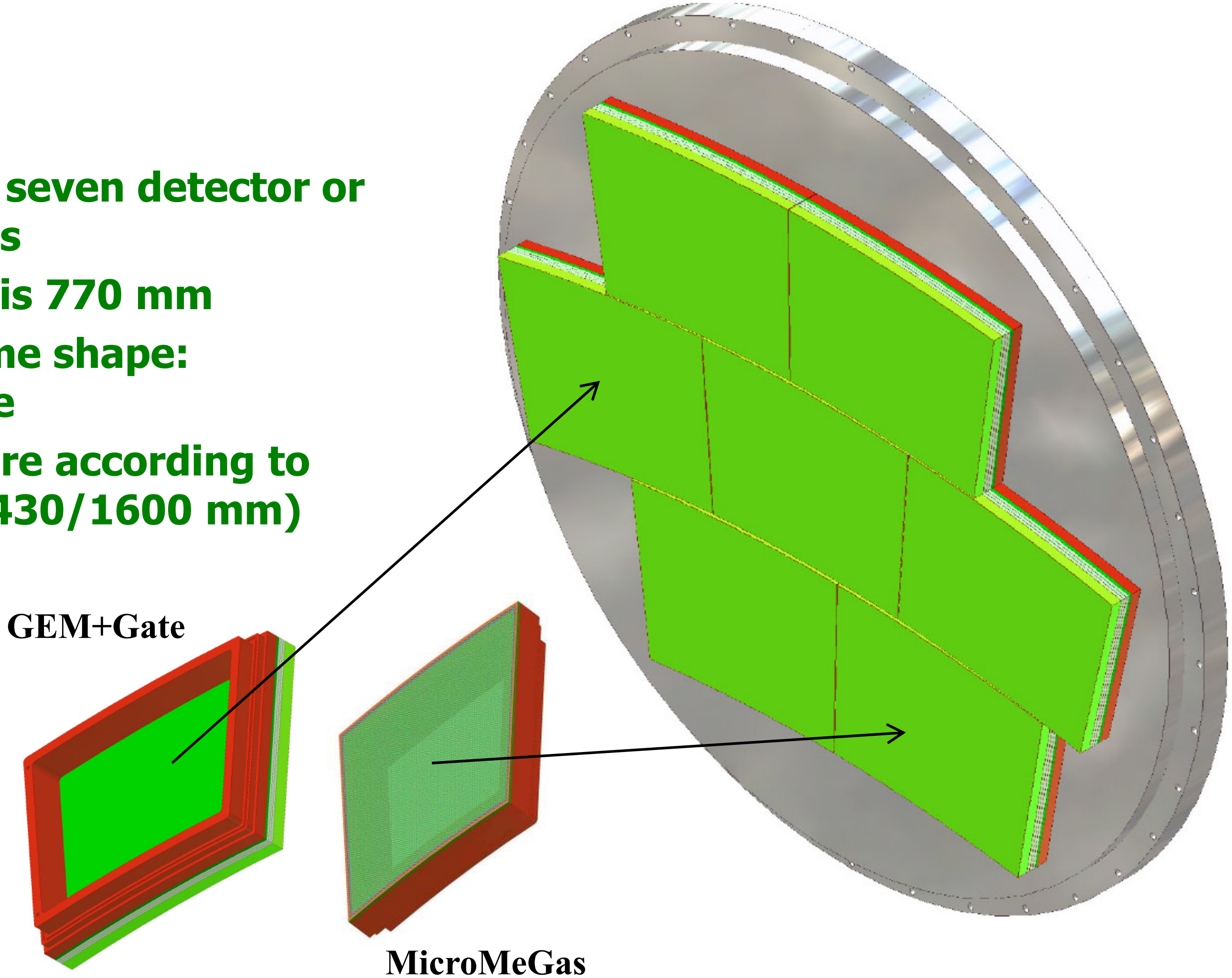


F. Sauli, NIM A386 (1997) 531

3. LC-TPC: Status

- **Construction of Large Prototype (LP) complete**

- **Endplate**
  - **Aluminum**
  - **Accommodates seven detector or dummy modules**
  - **Diameter of FC is 770 mm**
  - **All modules same shape: interchangeable**
  - **Module curvature according to ILC TPC (R = 1430/1600 mm)**



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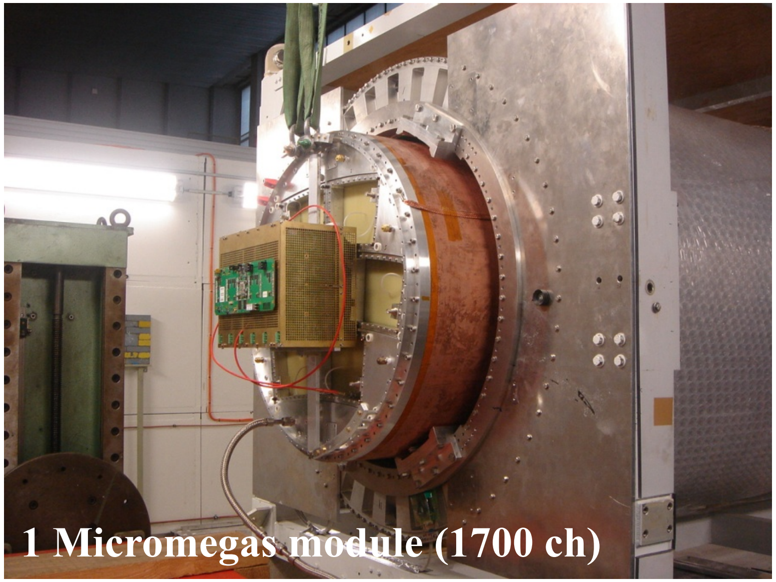
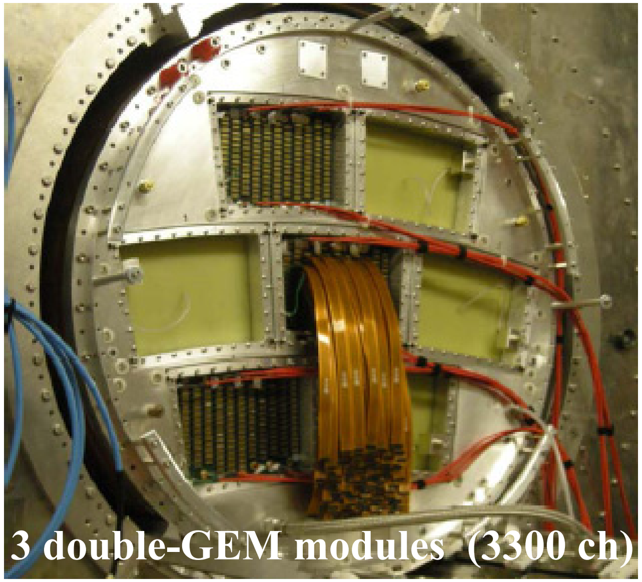
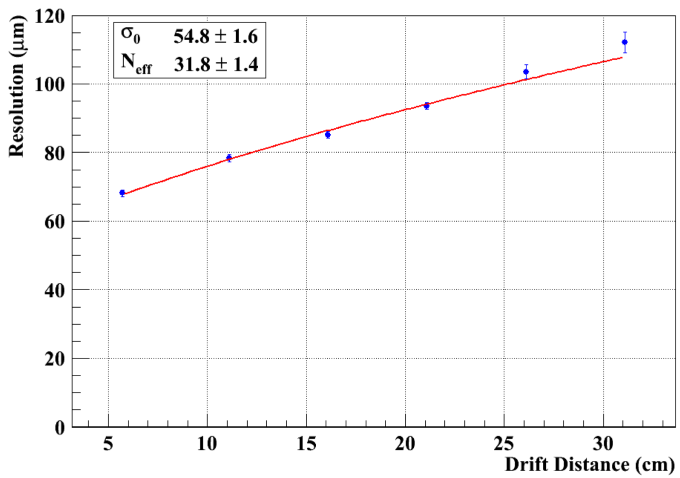
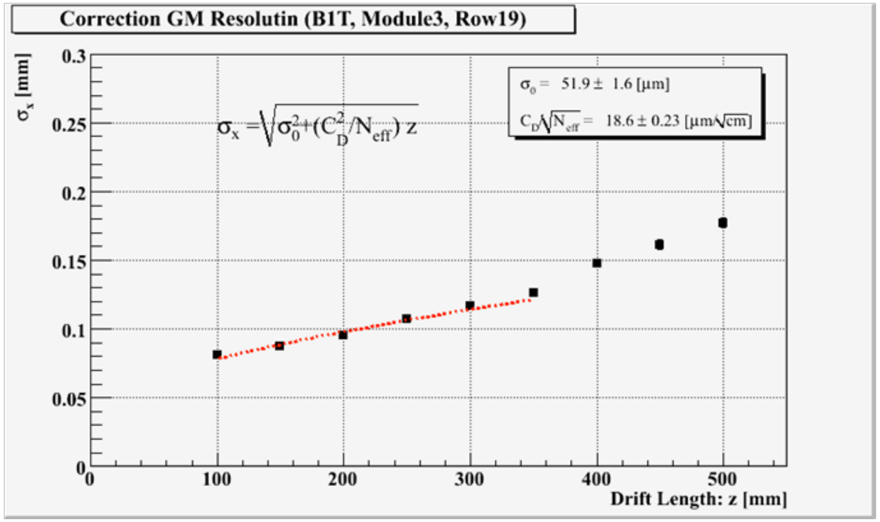








3. LP-TPC Priorities

- **Three point plan developed for TPC studies, in order of decreasing priority :**

  1a. Development of endplate with mass budget < 15% X_0 (including cooling) by 2011

  1b. Continue tests at with electron beam for correction procedures (2010)

  2a. Future tests of LP-TPC in hadron beam (CERN, 2011)
  - Momentum resolution
  - Two-track separation in a 'jet' environment

  2b. Power-pulsing and cooling tests both on LP and SP (2010+)

  3 Ion backflow studies (2010-2011)
  - Simulations of ion sheets for GEM, Micromegas
  - Development of gating device
  - Development of device for producing ILC-like ion sheet

4. kPiX: Goal and Status

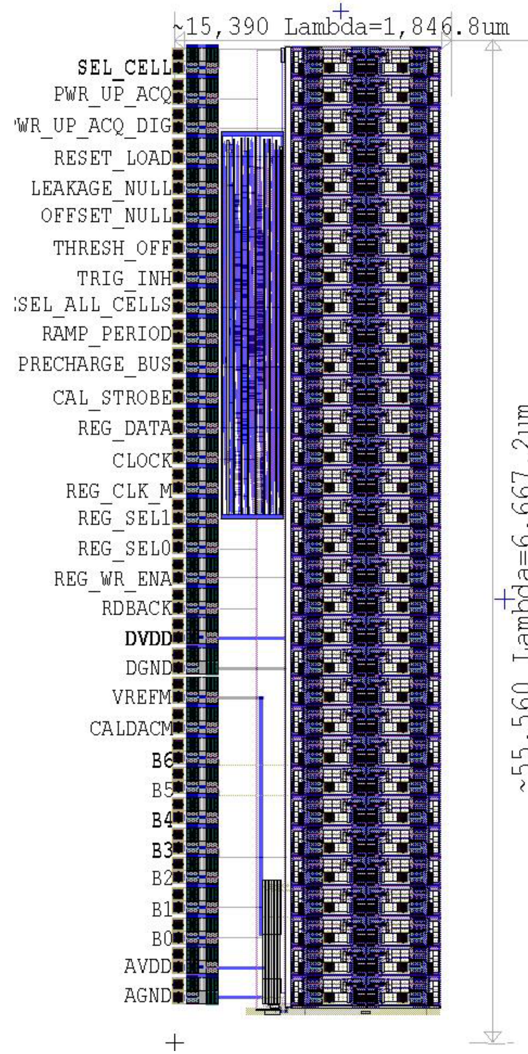
- **Goal is to develop a 1024 channel readout ASIC: kPiX**
  - **Dynamic dual gain select, 13-bit ADC**
  - **4-8 buffer pipeline depth for single bunch crossing time stamping**
  - **Power pulsing capability: average of 18 mW/ch**

- **Intrinsic to the kPiX development are:**
  - **Reliable, low-cost bump-bonding**
  - **Active signal and power routing and associated noise issues**

- **The kPiX ASIC is a the heart of the Si-W ECAL (SiD), Si tracker (SiD) and Forward Calorimetry readout (FCAL collaboration)**

- **Technology enables:**
  - **Integrated, low mass designs**
  - **Fast analog feedback**

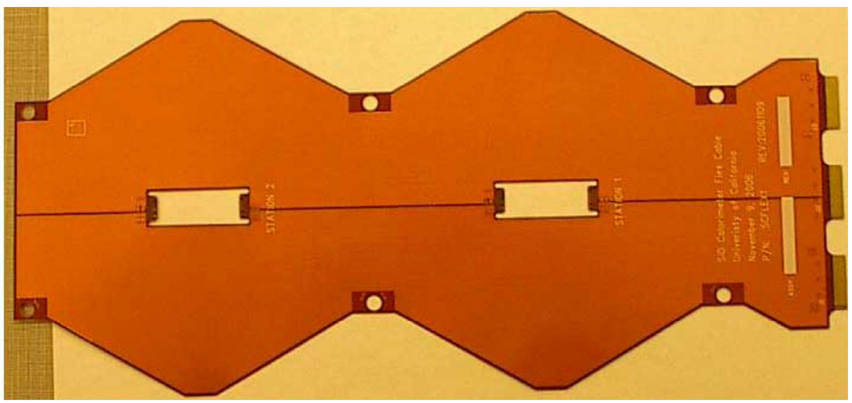
- **Currently a 64 channel version available and tested**

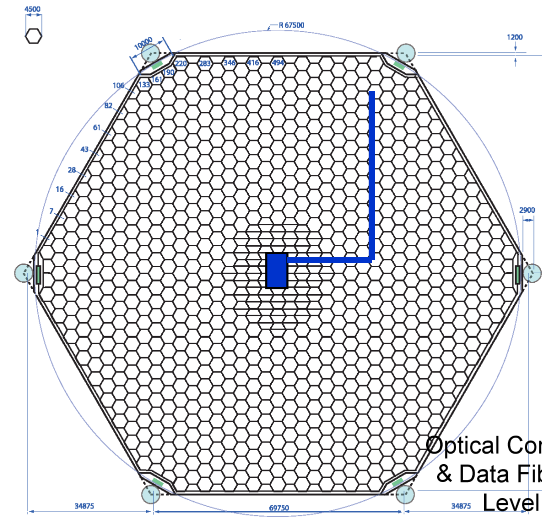


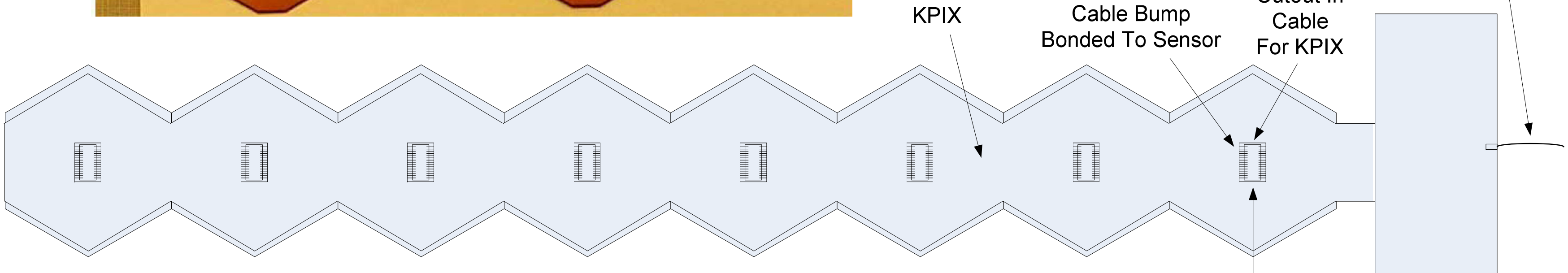
32-channel kPiX version: Dual range, time measuring, 13 bit, quad buffered

4. kPiX Priorities

- **Develop and bench test the 1024-channel device by 2011**
- **Field test the chip in as many applications as possible**
  - **Si-W ECAL with kPiX readout**
  - **Scale from two-Module system to full layer system (1.8m flex cable)**

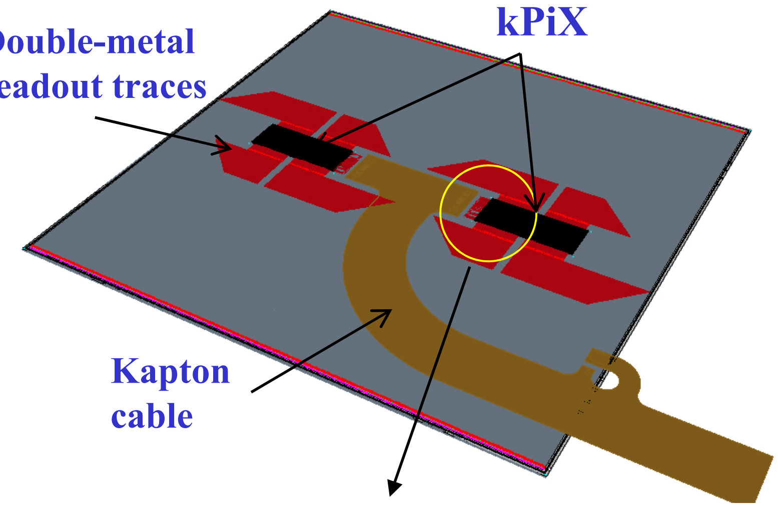


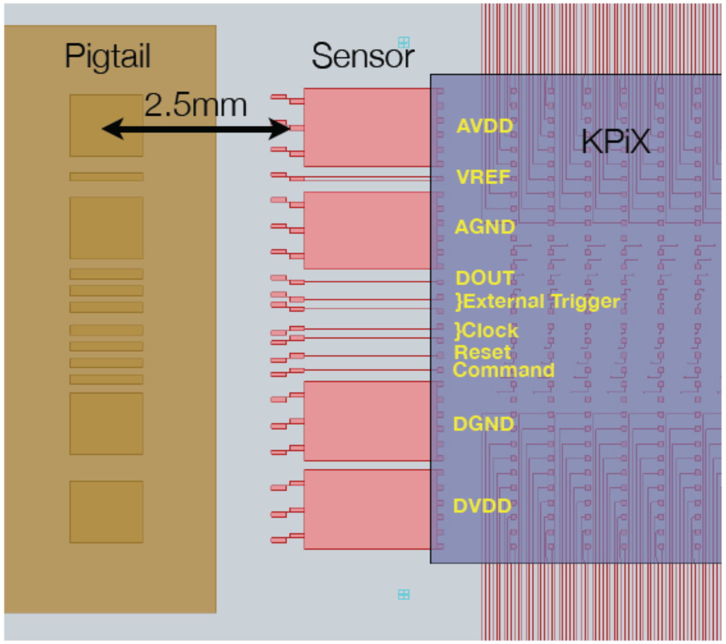




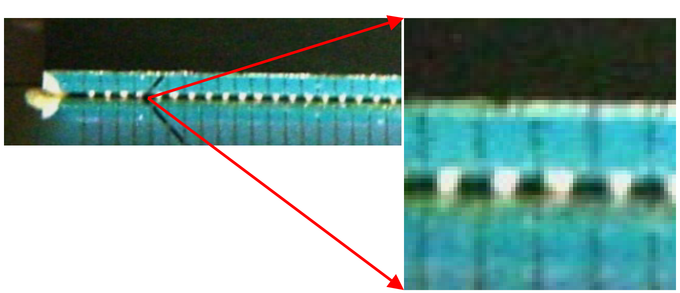
4. kPiX Priorities

- **Example of technical challenges: hybrid-less silicon readout**
  - 93.5 x 93.5 mm² sensor with 1840 (3679) readout (total) strips
  - Strip/Readout pitch = 25/50 μm
  - Read out with two 1024-channel asics bump-bonded to sensor
  - Routing of signals through 2nd metal layer
  - Power and clock signals also routed over the sensor





Example of 64-channel bump bonded kpix chip



5. Beam Test Infrastructure

- **An indispensible tool for detector testing is beam tests and carrying out these tests in a timely fashion is challenging**
- **To achieve the goals of critical detector R&D, it needs to be paired with the availability and adequate support of test beam infrastructure**
- **To support the detector R&D, and its priority topics, it needs to be paired with support in the following areas:**
  - **Dedicated test setups**
  - **Common beam instrumentation**
  - **Shared beam lines**
  - **Combined modular beam test (Slice Tests)**

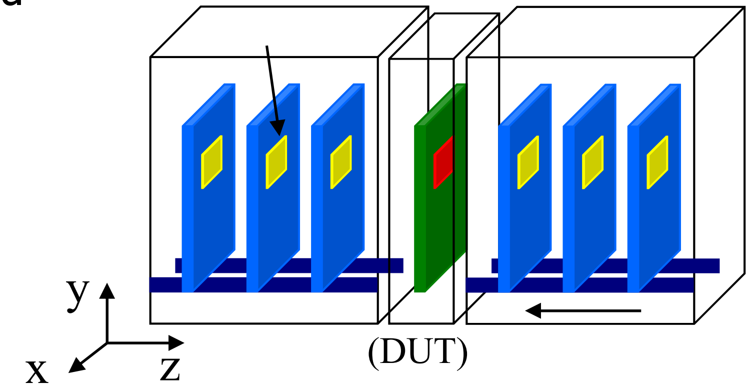
5. Dedicated test setups

- **An example of highly successful dedicated test setups are the irradiation facilities**
  – **US: Indiana cyclotron, US Davis, …**
  – **Europe: Louvain, Karlsruhe, Ljubljana, …**

- **The ILC community – and the community at large – would benefit from an investment in three areas:**
  1. **Test facility (-ies) with a beam structure that mimics the ILC beam structure**
     - The ILC (CLIC) detectors rely on power pulsing at 5 (50) Hz
       – Study power consumption
       – Mechanical and vibrational stability
  2. **A high field, large bore magnet with uniform magnetic field for dedicated tests; a field strength of 3T is preferred**
     - Allows study of real scale prototype tracking detectors in realistic conditions
  3. **A very high field, small aperture magnet for dedicated tests of small prototype detectors; a field strength of 6T is preferred**
     - Allows dedicated studies of special properties of sensor development

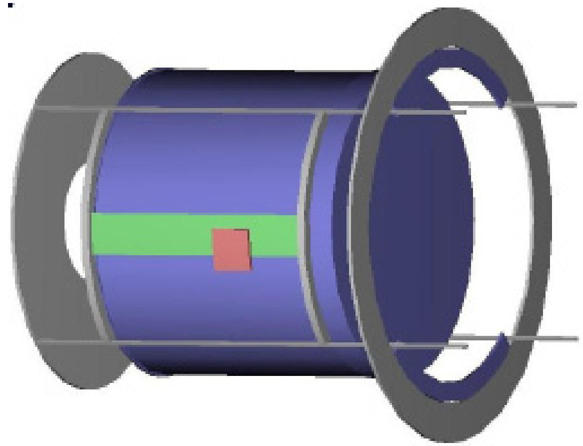
5. Common Beam Infrastructure

- **Test beam users often have the same demands in terms of beam instrumentation. If various beam lines would employ the exact same instrumentation, it would have distinct benefits:**
  - **Common instrumentation brings familiarity and users could go to any beam test facility in the world and find the exact same instrumentation for their device under test.**
  - **Since the instrumentation is identical, more people will contribute towards developing the peripheral software needed to use the data from the beam line elements in the analysis of the data.**
  - **Common instrumentation will eliminate one source of uncertainty in the comparison of data between different facilities.**
  - **The instrumentation can be based on prototype detector technologies. An example is the EUDET telescope based on MAPS Mimosa-26 pixel detectors**
    - Now available at DESY and CERN

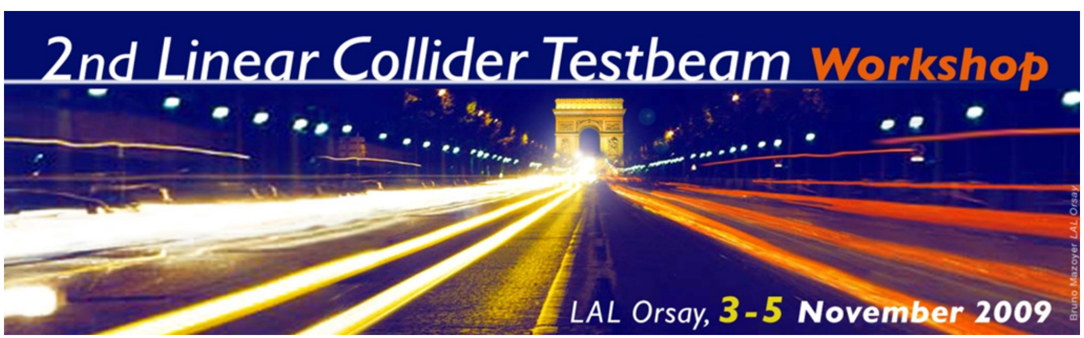


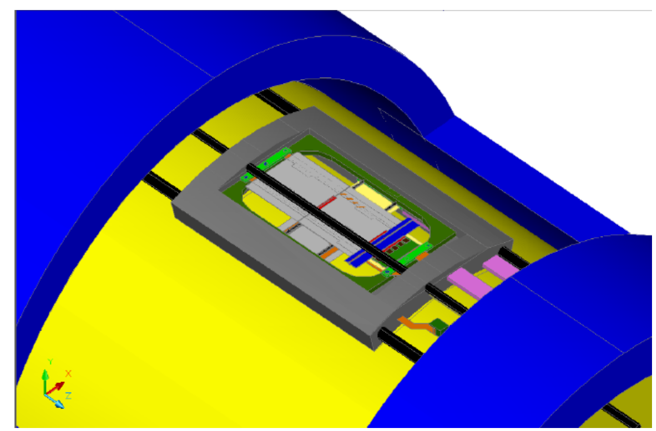
5. Slice Test

- ‘Slice test’ or ‘combined test beam’ refers to the beam test of various sub-detectors in one beam line at the same time.
- Combined beam tests can only be encouraged
- Plans being developed for TPC, Si-tracking, Calorimetry combined test beam
  - Allows studies of integration aspects
  - Beneficial for the development of a global simulation effort from which all parties will benefit



- Currently workshop in Saclay on these issues; asked for feedback from meeting





‘Long Term Priority’

- Criterion for long term detector R&D priority:
  Technologies that are transformational, that is, offer the potential for a large leap in key detector capabilities, resulting in significant increase in the discovery reach.

- One technology identified for ‘long term priority’

  6. Dual Readout Calorimetry

- Consistent with the IDAG finding and recommendation:
  “The fourth concept is not validated. However, dual readout calorimetry should be supported in view of its potential for higher energy colliders”

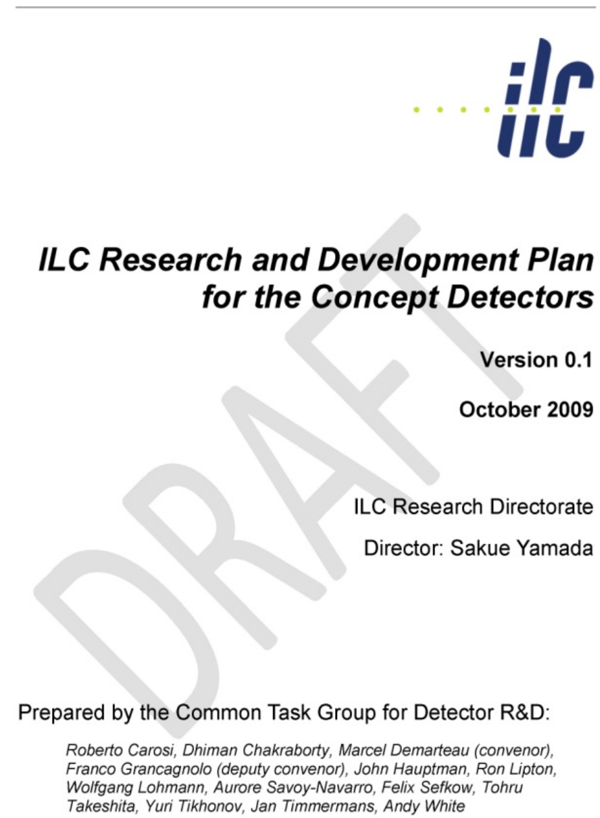
- Technology also option for the SiD calorimeter

Summary

- **By elevating the importance of these R&D topics and providing in a timely manner limited additional resources, the experimental foundation for the detector concepts would be on a much stronger basis by 2012**

- **Please note that, given the fragility of the detector community, it is equally essential to keep the other R&D programs at the current level**

- **A report is being drafted with these recommendations to the RD; We're almost close to a consensus!**



ILC Research and Development Plan for the Concept Detectors

Version 0.1

October 2009

ILC Research Directorate

Director: Sakue Yamada

DRAFT

Prepared by the Common Task Group for Detector R&D:

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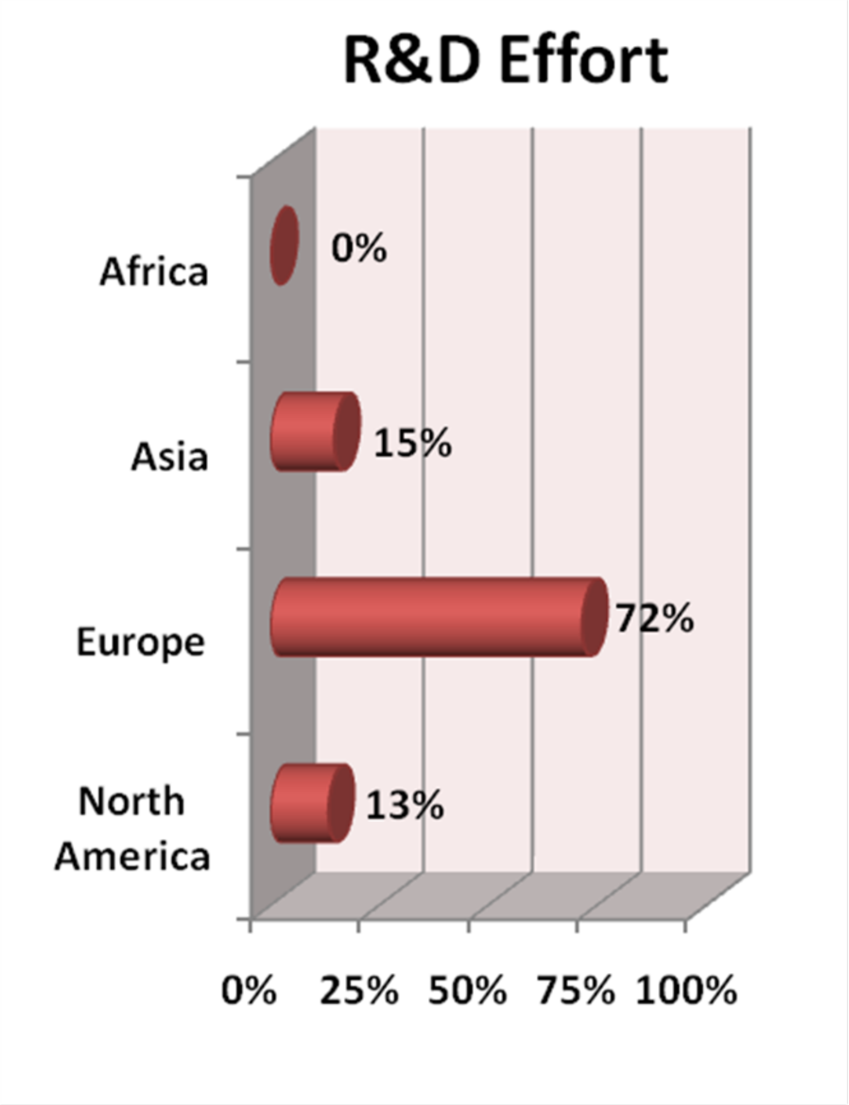
Regional Imbalance

- The graph shows the composition of the four horizontal R&D collaborations (CALICE, LC-TPC, SILC, FCAL) as shown at the last PAC meeting
- Noted then, that there is a very large imbalance between the regions
- This situation has only become worse over the course of the last 6 months
  - In the US the DOE Large Projects that are being considered for the future does not include the ILC
  - National Labs in the US are discouraged from working on ILC specific detector R&D
- The effort is becoming subcritical in the US



Resources Machine Side

- **Resource total: 2009-2012; numbers are per year**

FTE	SCRF	CFS & Global	AS	Total
Americas	243	28	121	392
Asia	82	9	51	142
Europe	108	17	64	189
	433	55	236	724
MS (K$)	SCRF	CFS & Global	AS	Total
Americas	18080	2993	6053	27126
Asia	23260	171	5260	28691
Europe	9890	921	530	11341
Total	51231	4085	11843	67158

From B. Barish's ALCPG09 talk

- **A mere fraction of 1-2% of this would help out the detector community enormously**

Status Quo

- The detector community has delivered three solid LOIs, accomplished on a shoestring budget in a difficult environment!
- A solid foundation and framework for continuing physics studies exists
- Key detector R&D areas have been identified, as suggested by the PAC in Vancouver

- However, the pressure on limited resources is increasing
  - LHC starting to take physics data
  - LHC upgrades
  - CLIC collaboration
  - Lack of support/recognition by US funding agencies
  - The situation in the US is close to subcritical
  - New EU proposal with most likely less funding than before

- One of the IDAG criteria for validation: “Is the group powerful enough to accomplish the required design work through the technical design phase”

Summary

- To mitigate the clear and present possibility of an erosion of the ILC detector R&D program
  - Identified few key technically enabling detector R&D areas
  - Put forward a very modest request for additional resources

- Funding agencies like to see a rapid return on their investment
  - Validation or falsification of viability of new technologies through publication in scientific journals
  - Providing infrastructure (e.g. EUDET)

- To avoid a (further) contraction of the community, we ask
  1. The PAC to recognize the dire situation of the detector community, especially in the US
  2. The PAC and ILCSC to support our recommendation for additional support
  3. Evaluate the balance in allocation of resources between the accelerator and detector, especially for those regions where the balance is precarious.