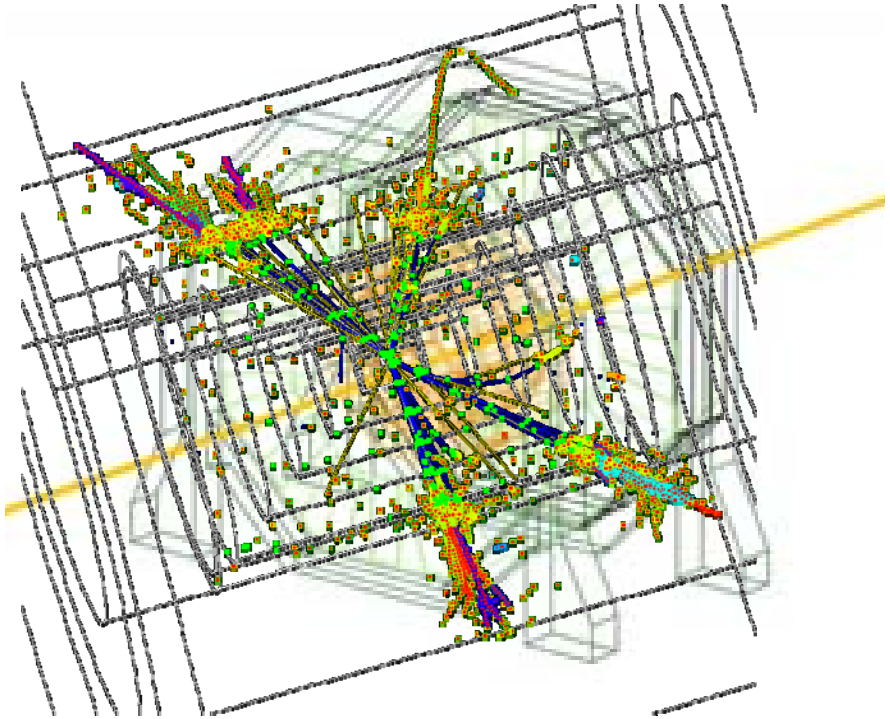
Detector R&D Common Task Group

Status Report



Marcel Demarteau

On behalf of he Detector R&D Common Task Group

PAC Review
Vancouver, May 9-10, 2009

Brief History

- At the ECFA 2008 meeting, the Research Director announced the formation of Common Task Groups:
  - "The LOI groups are not competing and are yet in the stage of R&D"
  - "There are many issues which can (and/or should) be addressed in common"
  - "Common task groups will work together cutting across the LOI groups"

- There was a strong desire from the LOI groups to make a good link between the detector R&D Panel and R&D collaborations
  - Contacted major R&D collaborations for suggestions over the summer. They responded positively and some offered to send representatives
  - The R&D Panel was enlarged inviting these representatives

- Membership and convenorship decided with formal announcement at LCWS08 in Chicago, November 08. First face-to-face meeting at LCWS08; second face-to-face meeting at TILC09

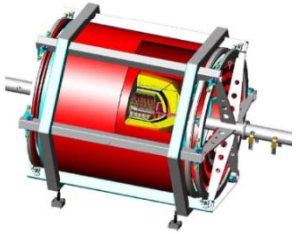
- WWS stopped its detector Panel, chaired by Chris Damerell, considering the overlap of its activity with the detector R&D common task group.

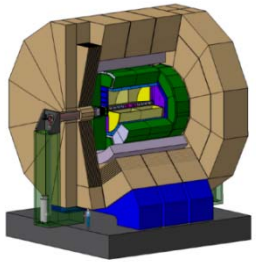
Common Task Group Membership

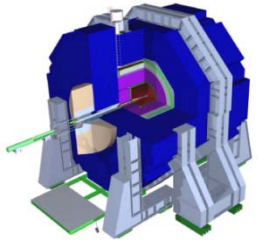
- 4th: Roberto Carosi
  Franco Grancagnolo (deputy)
  Yury Tikhonov

- 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

- **p.s. Jean-Claude Brient stepped down in February to cede position to current Calice spokesperson**

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

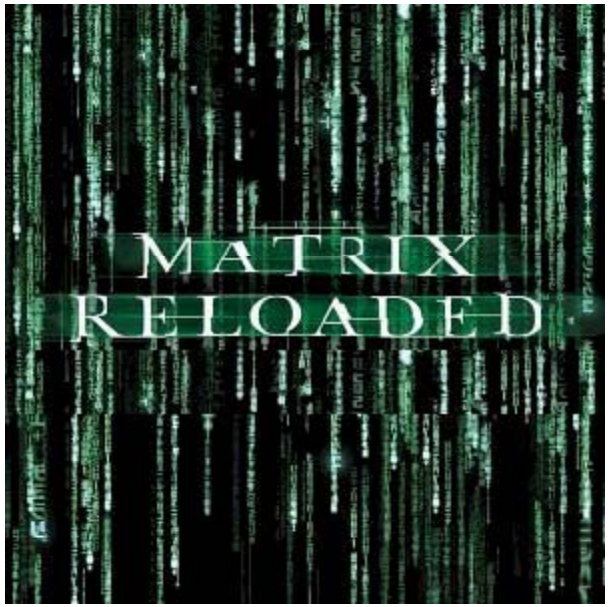
- We interpret our mission to be to help nurture the technologies needed to design and build the detectors that will be needed to advance the scientific goals of a Linear Collider.
- To this end, the detector R&D common task group invites the Detector Concept Groups and horizontal R&D collaborations to work together to build a program that will:
  - Be strengthened through collaborative effort
  - Ensure that all critical R&D is covered
  - Help and possibly facilitate the process of obtaining funding
  - Explore synergies between the multitude of efforts
  - Encourage common test infrastructures and in case these structures do not exist, work towards obtaining them
  - Help in formulating a cogent, coherent long-term plan for detector R&D
- We cannot and will not coordinate existing activities

Scope

- **The goal of the community is to be able to propose the ILC on a time scale of ~2012 (or before!) (from B. Barish's opening talk at TILC09)**
- **The detector concepts want the detector R&D to reach a point where a rapid decision can be made between options when the project is approved on the time scale of ~2012**

- **The first step of the common task group was to work with the detector concepts and the R&D collaborations to understand the plans and issues**

- **Outline of this presentation:**
  - **Reconstruct the Matrix**
  - **Critical Detector R&D**
    - Vertical and Horizontal
  - **Deconstruct the Matrix**
  - **First observations**



Detector Concepts Overview

- **Baseline / Reference choices for the detector concept**

Detector	4th	ILD	SiD
Premise	Dual Readout	PFA + TPC	PFA + Si Trkr
Vertex Detector	5-layer silicon pixel	5/6-layer silicon pixel	5-layer silicon pixel
Tracking	CluCou drift chamber	MPGD-TPC + Si	Silicon strips
EM calorimeter	BGO	Silicon-Tungsten	Silicon-Tungsten
Hadron Calorimeter	Dual/triple-readout Cu-scint/clear fibers	Analog- scintillator	Digital Steel - RPC
Solenoid	3.5 Tesla	3.5 Tesla	5 Tesla
Muon	Iron free dual solenoid with He drift tubes	Instrumented flux return	Instrumented flux return RPC
Forward Cal	Si-W	Si-W	Si-W

Detector Concepts Overview

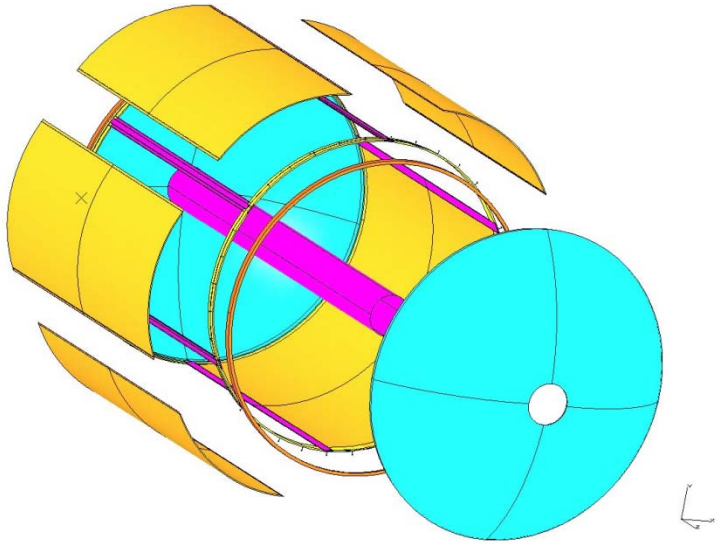
- **Remove those systems where no technology choice has been made**

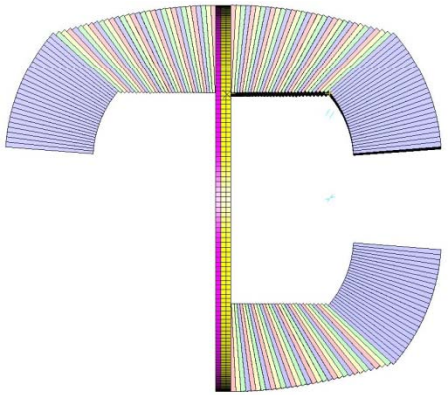
Detector	4th	ILD	SiD
Premise	Dual Readout	PFA + TPC	PFA + Si Trkr
Vertex Detector			
Tracking	CluCou drift chamber	+ Si	Silicon strips
EM calorimeter			
Hadron Calorimeter	Dual/triple-readout Cu-scint/clear fibers		
Solenoid	3.5 Tesla	3.5 Tesla	5 Tesla
Muon	Iron free dual solenoid with He drift tubes		
Forward Cal			

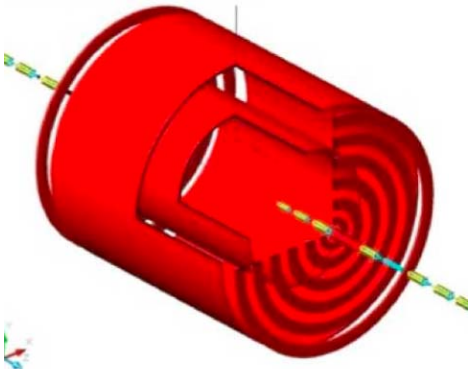
- **And R&D is needed on the still remaining systems**

Critical R&D: 4th

- Tracking
  - Multi-GHz 6-12 bit ASIC for cluster counting
  - Materials study for low-mass tracker
  - Prototyping
- Calorimetry
  - 1 m³ beam test of scalable DREAM module
  - GHz digitizer
  - Photo-detectors
  - Electronics Integration
  - R&D in crystal calorimetry
- Solonoid
  - R&D in the construction of low cost solenoids
- Vertex Detector
- Muon drift tube system test
- Engineering for detector design

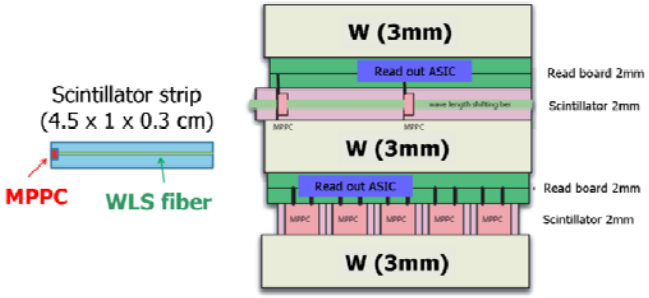






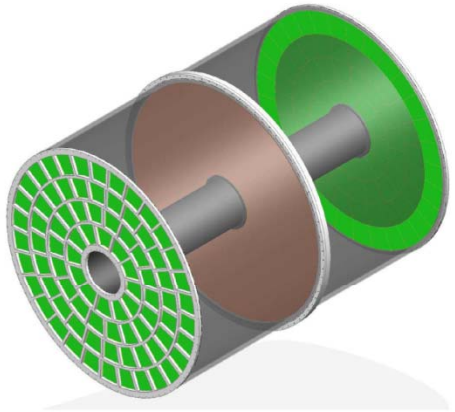
Critical R&D: ILD

- **Development of Particle Flow**
  - **Technological solutions for highly granular calorimetry**
  - **Develop scintillator, Si and MAPS based ECAL**
  - **Develop analog and digital HCAL**
    - Analog: scintillator and WLS fiber with MPPC readout
    - Digital: Glass resistive plate chamber (GRPC) with pad readout



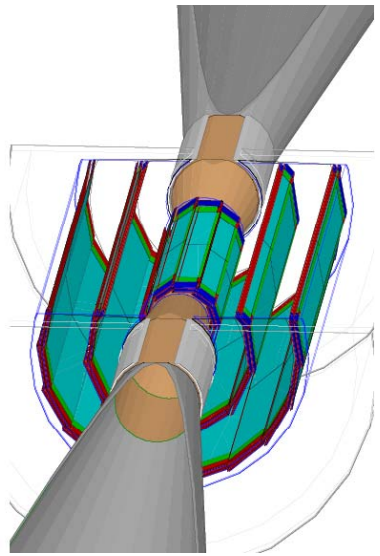
  - **Development of particle flow algorithms**
  - **Carry out an experimental program which can further demonstrate the feasibility of the particle flow concept**
    - Spectrometer (prototype TPC?) and calorimeter combined
    - Using high energy hadron beam

- **Tests of MPGD TPC technologies to demonstrate that it can achieve mass budget and required precision**
  - **GEM with small pad r.o.**
  - **MicroMEGAS with resistive anode r.o.**
  - **CMOS pixel r.o. (Ingrid TimePix)**



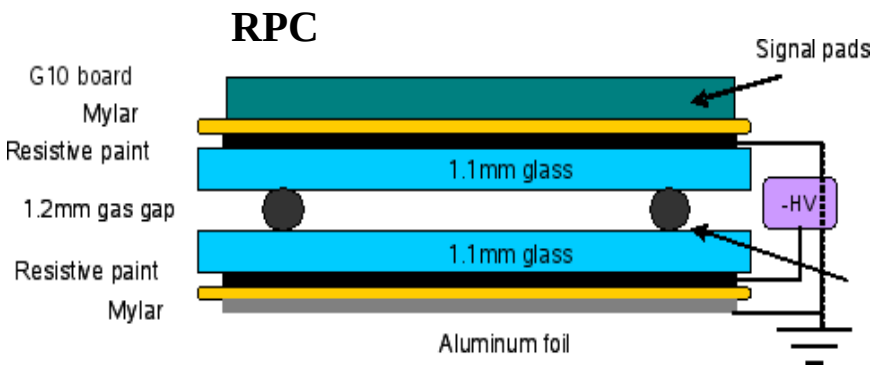
Critical R&D: ILD

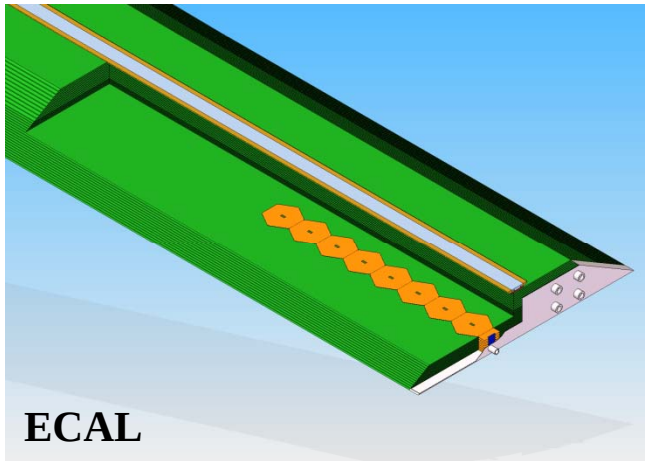
- Develop technologies for forward calorimetry
  - LumiCAL (Si/W)
  - BeamCAL (Si, GaAs, diamond / W)
  - Pair-monitor (Si (SOI?)
  - LHCAL (Si/W)
- Vertex detector technologies
  - FPCCD / CMOS / DEPFET / ISIS / 3D / …
  - Alignment and power pulsing
- Si tracker R&D
  - Material budget and power consumption
- Engineering solutions for subsystems and subsystem integration
- Advocates integrated test facility



Critical R&D: SiD

- **Identified 10 areas of critical R&D**
- **Hadronic Calorimetry**
  - **Feasibility of a fully integrated, full-size active layer within a ~8mm gap between absorber plates**
    - RPC, GEM, MicroMegas
    - Scintillator tiles/SiPM's
    - homogeneous crystal calorimetry with dual readout
- **Electromagnetic Calorimetry**
  - **Silicon-tungsten Ecal**
  - **MAPS technology**
- **Tracking detectors in 5T magnetic field with power pulsing, refining the track finding and fitting performance, understanding the optimal forward sensor configuration**
- **Vertex detector technology and low mass mechanical support, and pulsed power/cooling solutions**

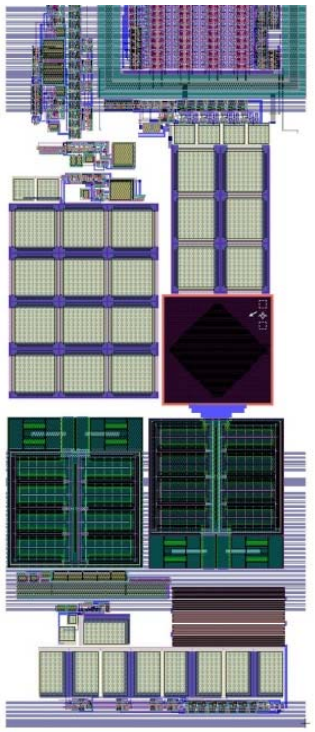


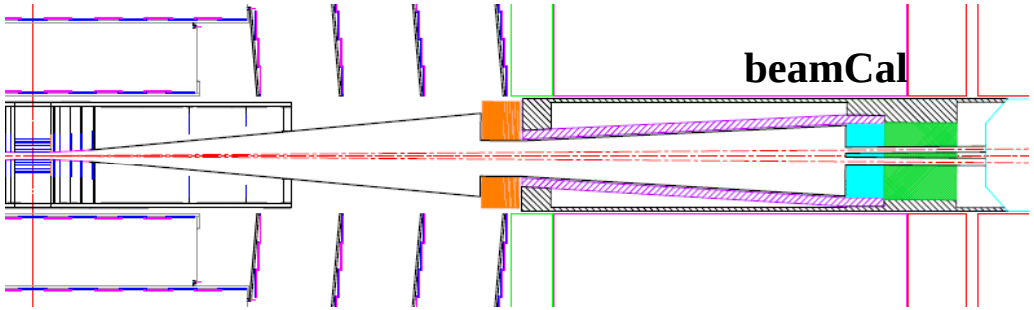


Critical R&D: SiD

- **Demonstration of the operation of 1024 channel version of the baseline KPiX chip.**
- **Development of power distribution schemes for the vertex detector and tracker with DC-DC conversion or serial powering.**
- **New superconductor for high field large solenoids**
- **Robust RPCs and SiPMs for scintillator strips for muon system**
- **Sensor development for forward calorimetry**
- **Engineering issues, notably for push-pull operation**
- **Overall detector performance**

kPix





Identified Areas of R&D

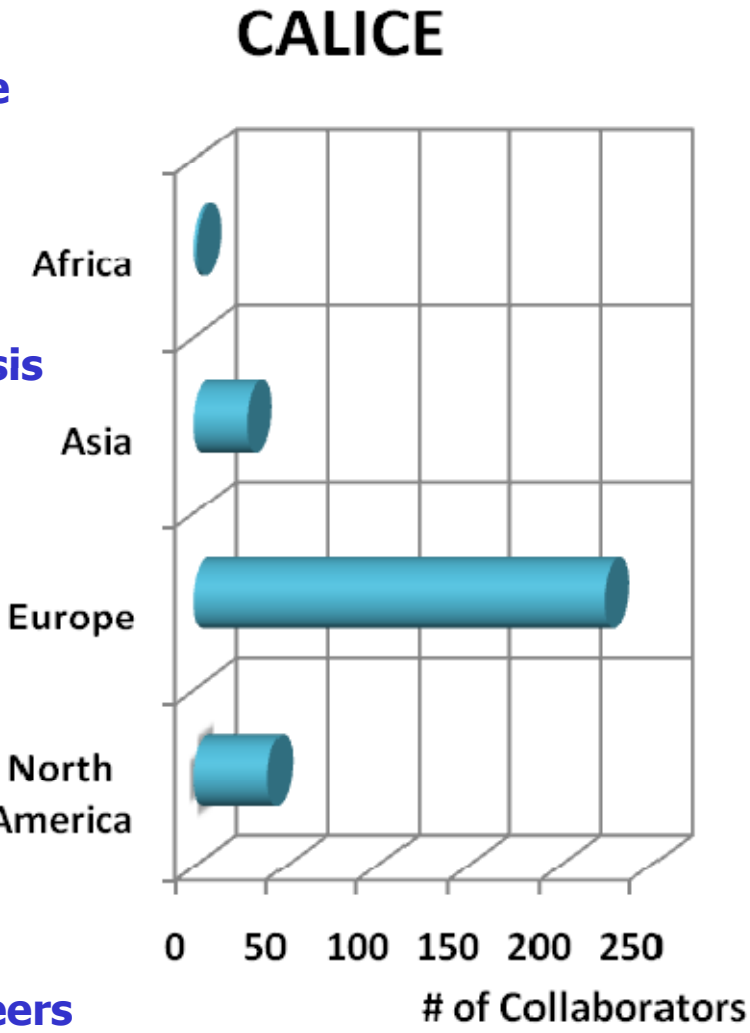
	R&D Area / Concept	4th	ILD	SiD
Vertex	CP CCD		X	
	FP CCD		X	
	SC CCD	X		X
	ISIS	X	X	X
	CMOS MAPS	X	X	X
	SOI	X	x	X
	DEPFET	X	X	X
	3D	X	X	X
Tracker	Silicon Strips		X	X
	GEM TPC		X	
	MicroMegas TPC		X	
	CMOS TPC		X	
	CluClou	X		

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

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

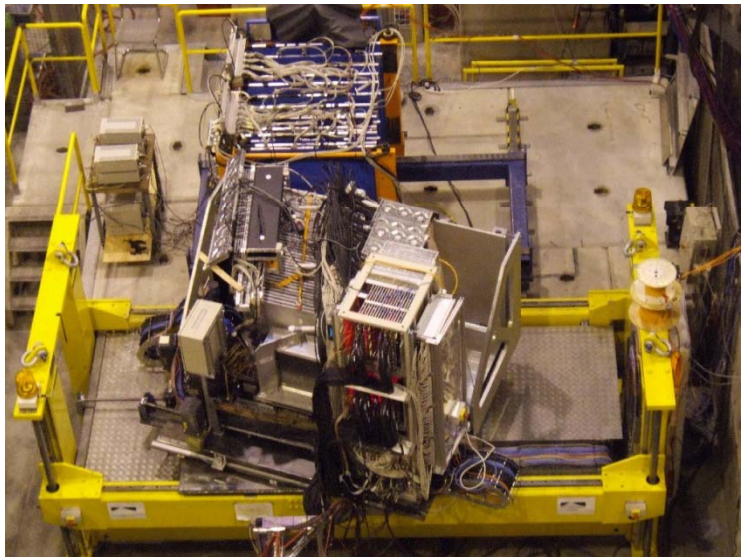
CALICE R&D Collaboration

- **Calorimetry for Linear Collider Experiments**
- **Goal: prepare a realistic proposal for particle flow based electromagnetic and hadronic calorimeters by 2012**
  - **Understand strong and weak points of different technology options**
- **Physics prototype test beam runs and analysis**
  - **Proof of principle**
  - **validate simulation and reconstruction**
- **Technical prototypes, realistic and scalable**
  - **Compact mechanical design, integrated electronics**
- **Shared infrastructure and frameworks**
  - **Mechanical structures, coherent FE, common DAQ, joint analysis**
  - **data in LCIO format (ILD, SiD)**
- **Large collaboration of 297 physicists/engineers**
  https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome

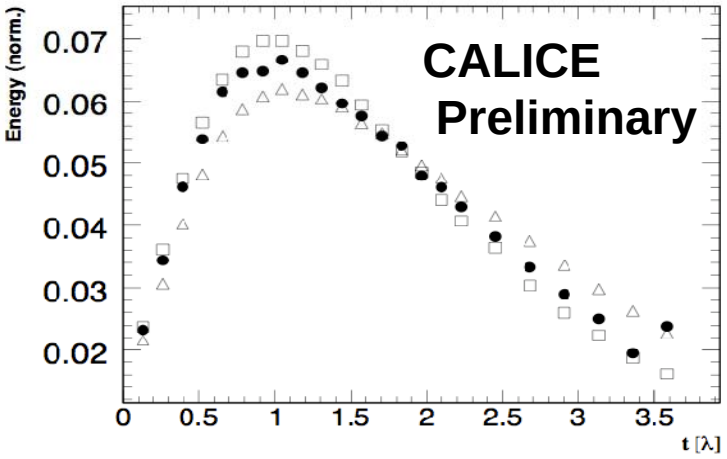


First Generation Test Beam

- Si W ECAL, scint Fe HCAL
  - 2006-07 CERN, 2008 FNAL; complete
- Scint W ECAL, scint Fe HCAL
  - 2008-09 FNAL; finish in May
- SiW ECAL, RPC Fe HCAL:
  - 2009-10 FNAL; under construction
  - GEM option: under discussion
- DECAL (MAPS) proof-of-principle in preparation

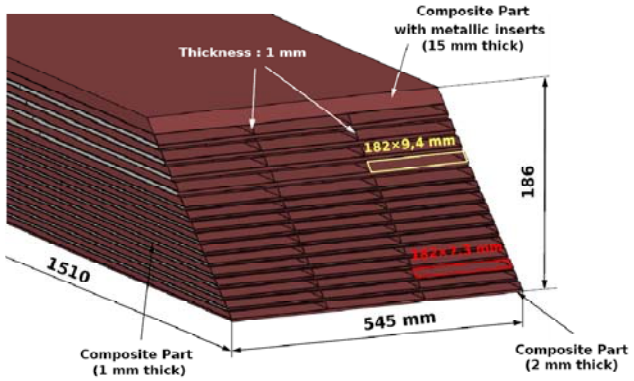


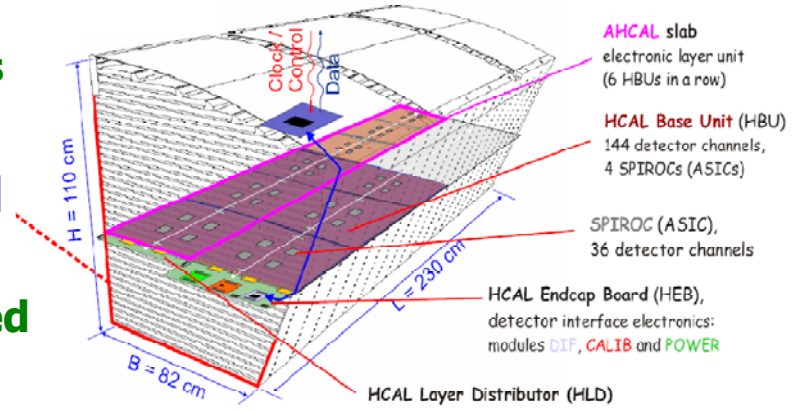
- Focussed on detector understanding
  - Calibration, corrections, simulations
  - Results for noise, resolution, linearity
- First quantitative comparisons with Geant4 models becoming possible
- Analysis of shower substructure just started
- Two-particle separation test possible with event overlay techniques (low occupancy)
- Will take up to 2012 to complete for all technologies



Second Generation Prototypes

- **Address critical integration issues for a hermetic and compact 4π detector**
- **Realistic estimates of dead spaces and cost**
- **SiW ECAL: full length stave**
  - **One tower instrumented**
  - **Demonstrator in 2009, beam test in 2010**
- **Scint ECAL**
  - **To be defined after 1st generation tests**
- **Scint Fe HCAL: vertical and horizontal cross sections**
  - **One full layer or EM tower instrumented**
  - **Several options for scintillator photo-sensor coupling**
  - **Demonstrator in 2009, full layer 2010**



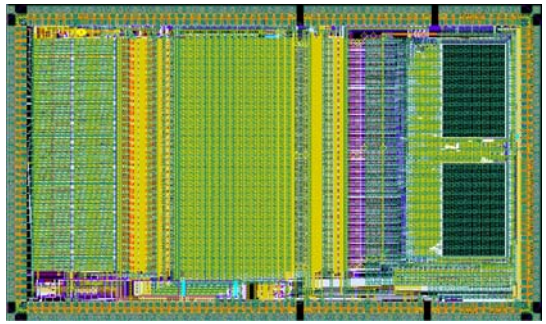


Second Generation Prototypes

- **Gaseous Fe HCAL**
  - **Scalable cubic meter structure**
  - **Fully instrumented**
  - **GRPC or MicroMegas option**
  - **Full layers in 2009, multi-layer in 2010**
  - **Alternative options: require at least full area and multi-layer tests**
- **Embedded electronics requires power pulsing, on-detector zero suppression and online control of thresholds and stability**
  - **Major operational challenge**
  - **needs full-scale system tests**
- **Instrumentation of required volumes presently not funded**

GRPC layer with ASICs

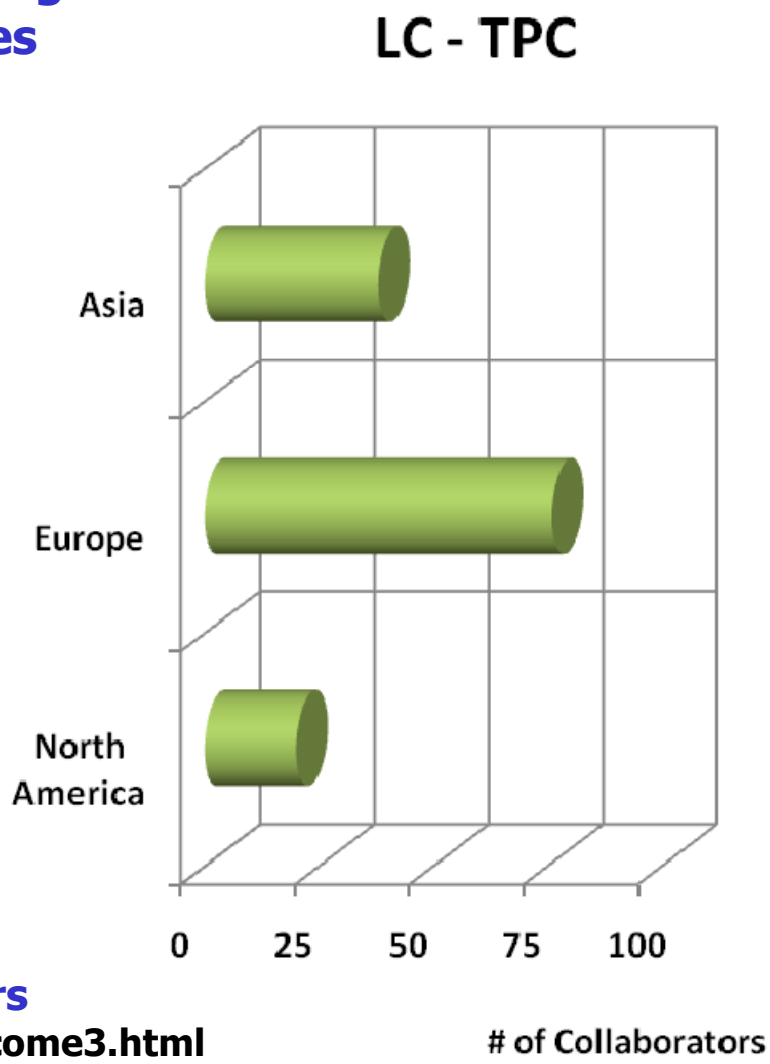
ECAL/AHCAL ASIC



LC-TPC R&D Collaboration

- **Goal: prepare a realistic proposal for high resolution TPC by 2012 in three phases**

- **Demonstration phase**
  - **Using small prototypes (SP) Φ~30 cm**
  - **basic evaluation of TPC with Micro Pattern Gas Detector (MPGD) gas amplification**
- **Consolidation phase**
  - **Design, build and operate Large Prototype (LP) at EUDET facility at DESY (Φ~1 m)**
- **Design phase**
  - **Start work on engineering design for final detector**



- **Collaboration of ~130 physicists/engineers**
  http://www.mppmu.mpg.de/~settles/tpc/welcome3.html

LC-TPC R&D Program

- **LP1 at DESY/EUDET (2008-09)**
  - **fieldcage + 2 endplates**
  - **GEMs, Micromegas, and pixels**
- **Goal**
  - **Test reconstruction techniques with 3k-10k Alice electronics channels (~2k T2K channels)**
  - **Demonstrate measurement at 6 GeV beam momentum over 70 cm track length**

- **LP1.5 at DESY, CERN/TeV (2010-11)**
  - **fieldcage + 2 endplates, GEMs, Micromegas, and pixels**
- **Goals**
  - **Demonstrate measurement at 100 GeV beam, in jet environment and with LC beam structure using LP1**

- **LP2 at CERN/TeV (2011-12)**
  - **Prototype of LCTPC including gating and other options**

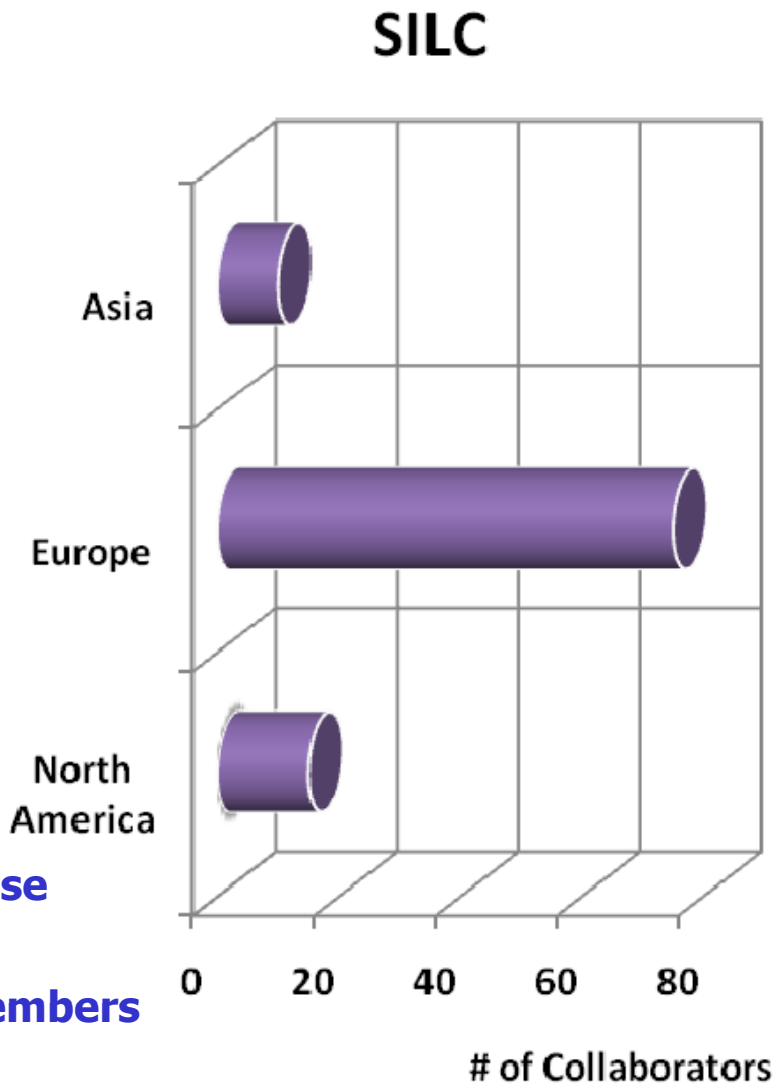
- **Small prototypes R&D (2008-2012)**
  - **Performance, power pulsing, gas tests, dE/dx measurements….**

SILC

- Silicon for a Linear Collider
- Generic horizontal R&D Collaboration

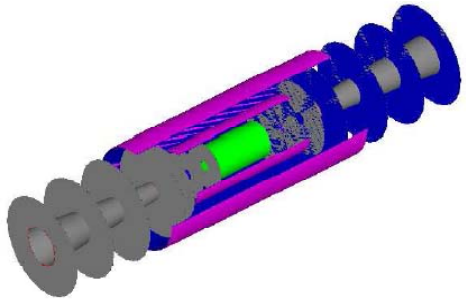
- Goal: To develop the next generation of large area Silicon trackers
- R&D Topics:
  - Sensors
  - Electronics
  - Mechanics
- At the same time developing dedicated tools:
  - Dedicated Lab test benches
  - Beam Tests plus infrastructure
  - Simulations
- Synergies with LHC construction and upgrades; starting to address the CLIC case

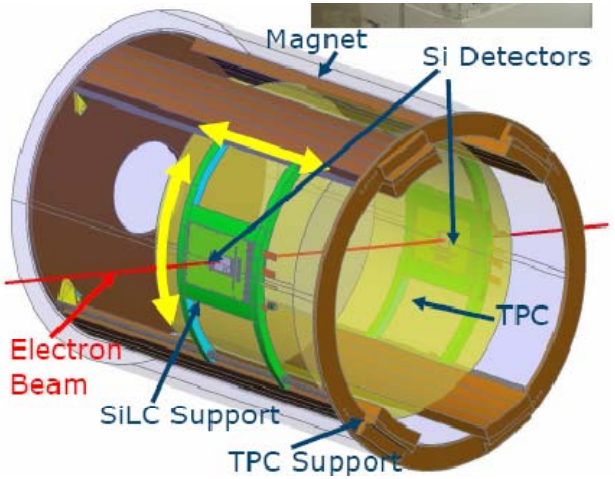
- International collaboration with ~100 members http://lpnhe-lc.in2p3.fr/
- In addition collaborative effort with industry



SILC R&D Program

- **Sensor R&D**
  - **Strip sensors on larger wafers 8”**
  - **Thinner sensors: 200 µm, 50 µm pitch**
  - **Edgeless**
  - **Strip sensors for alignment**
  - **R&D oriented on 3D pixels**
- **Readout R&D**
  - **Mixed-mode FE readout with pulse-height reconstruction, zero suppression, full digital control and power cycling (90 nm CMOS)**
  - **Move to 256 channels with 3D interconnect**
- **Mechanics R&D**
  - **Low-mass, robust, modular modules design and support structures**
- **Simulation Studies**
- **Test beam prototypes**
- **Integration studies**
  - **2009 – 2010: TPC and Si tracking system**
  - **2010 – 2011: combined test beam of SiLC and calorimeter and possibly beyond**



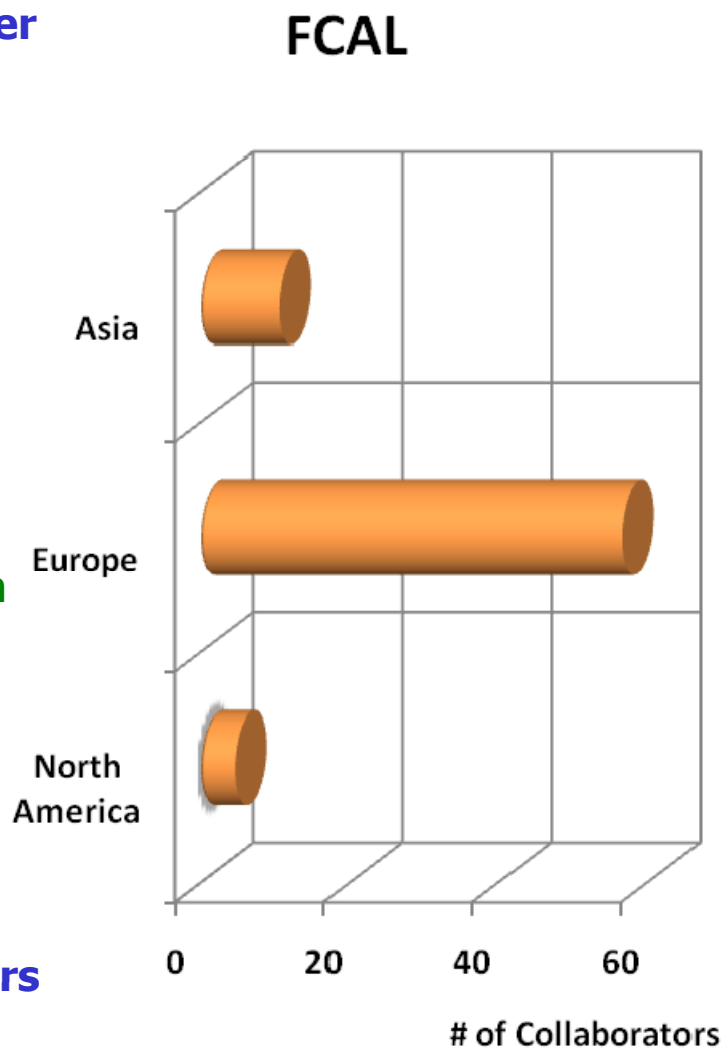


FCAL

- Goal is to develop the calorimeter technology for the far forward region at a lepton collider for the measurement of the luminosity, the veto of two-photon processes and the monitoring of beam properties

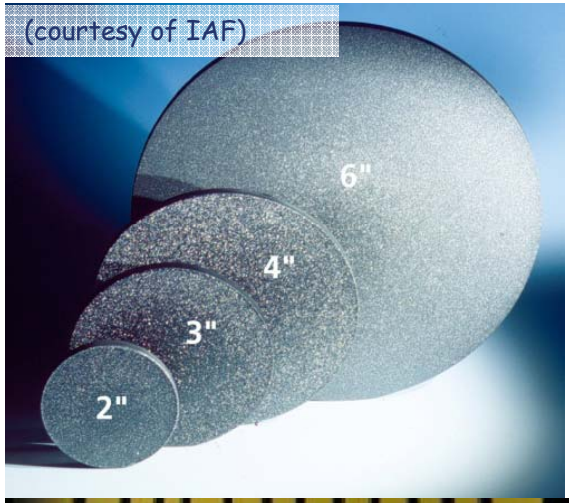
- R&D Topics
  - Design of compact EM sampling calorimeter, R_M ~ 1 cm (LumCal)
  - Large area radiation hard sensors for BeamCal, operational up to 10 MGy
  - Sensor planes for LumiCal with position monitoring at the micron level
  - Fast FE readout, digitization and data transfer, readout after each BX with low power dissipation and large buffering depth

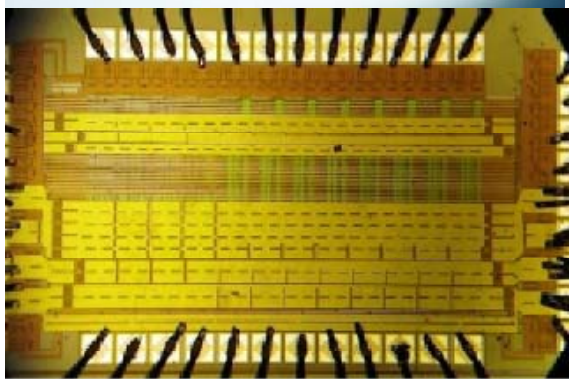
- International collaboration with 73 members http://www-zeuthen.desy.de/ILC/fcal/



FCAL R&D Program

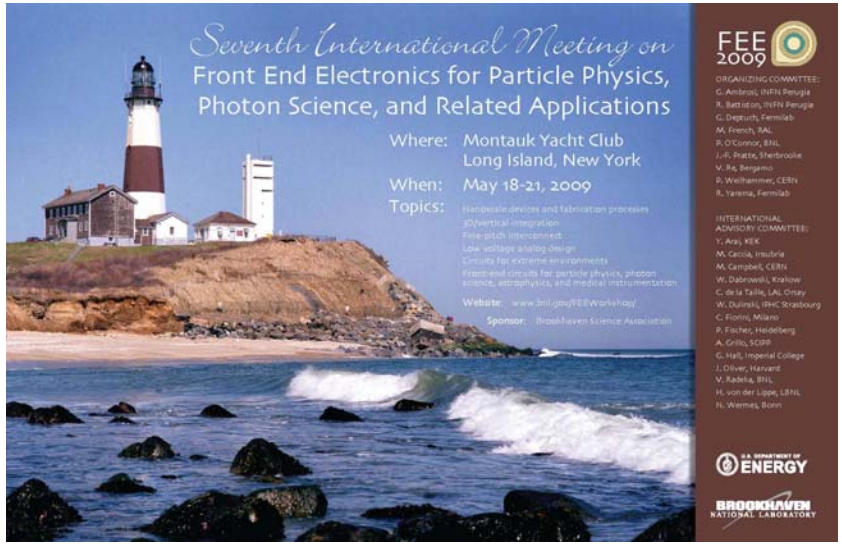
- Sensor R&D
  - pCVD diamonds
  - GaAs
  - SC CVD diamonds
- FE readout architecture for LumCal
  - ADC with pipeline architecture, 10 bit resolution, 35 MHz sampling
- FE readout architecture for BeamCal
  - Based on kPiX chip
  - Digital Buffering during bunch train, readout in between trains
- Pair monitor
  - Based on SoI technology
  - Sensor and readout ASIC integrated
  - Prototype in 2009
- GamCal is currently not covered
- Collaboration has lost members over the course of the last year





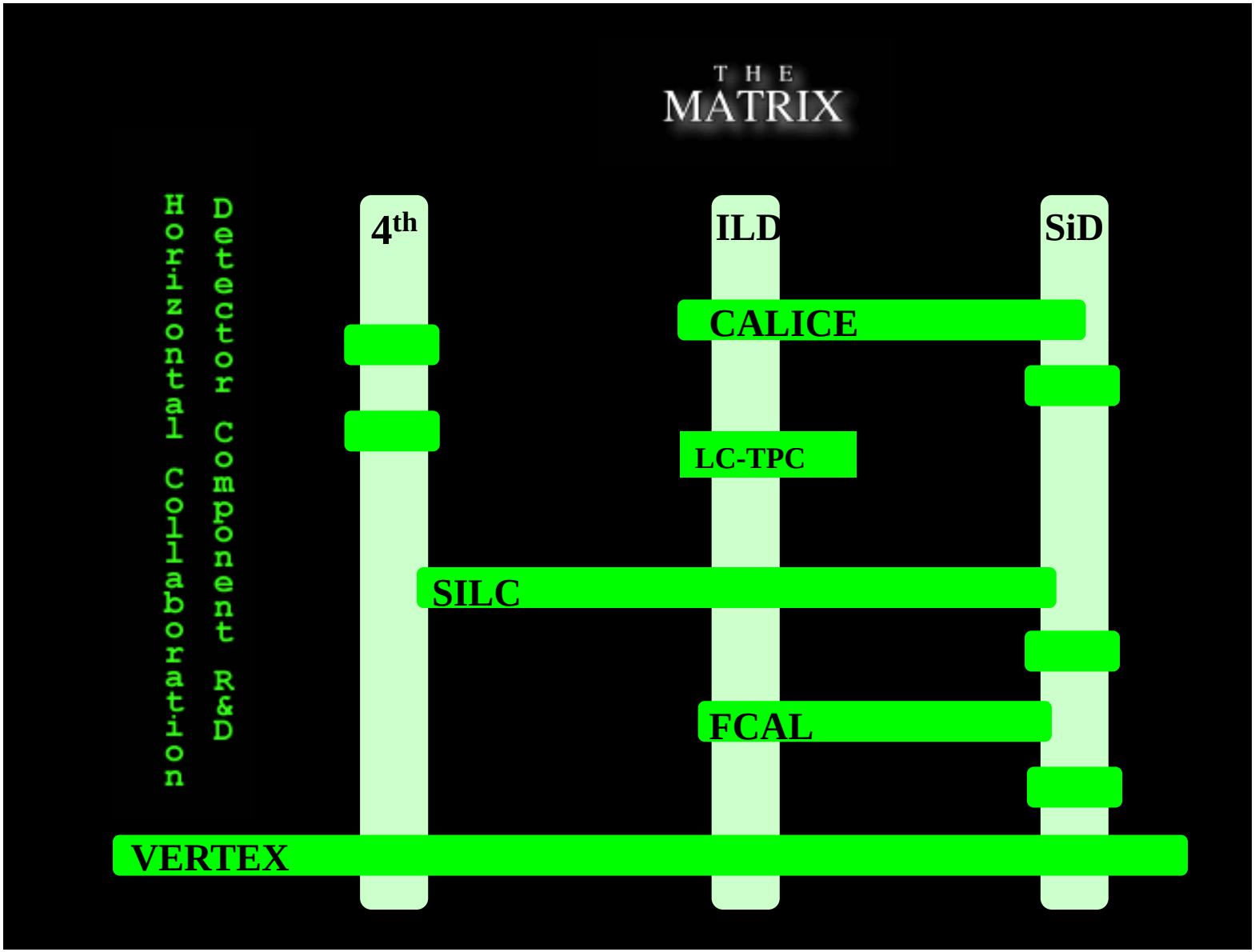
Vertex

- Recently a network for R&D on monolithic and vertically integrated pixel detectors was created
  - Initiated by Chris Damerell in 2008
  - Discussed at several workshops
- Idea supported by regional directors (Rolf Heuer, Young-Kee Kim, Fumihiko Takasaki) and they proposed to nominate 3 (6) regional "coordinators"
- Representative coordinators announced at TIPP09 (March 17, 2009)
  - Asia: Junji Haba
  - North America: Marcel Demarteau
  - Europe: Hans-Günther Moser
- First meeting with community at the FEE meeting, May 18-21, 2009

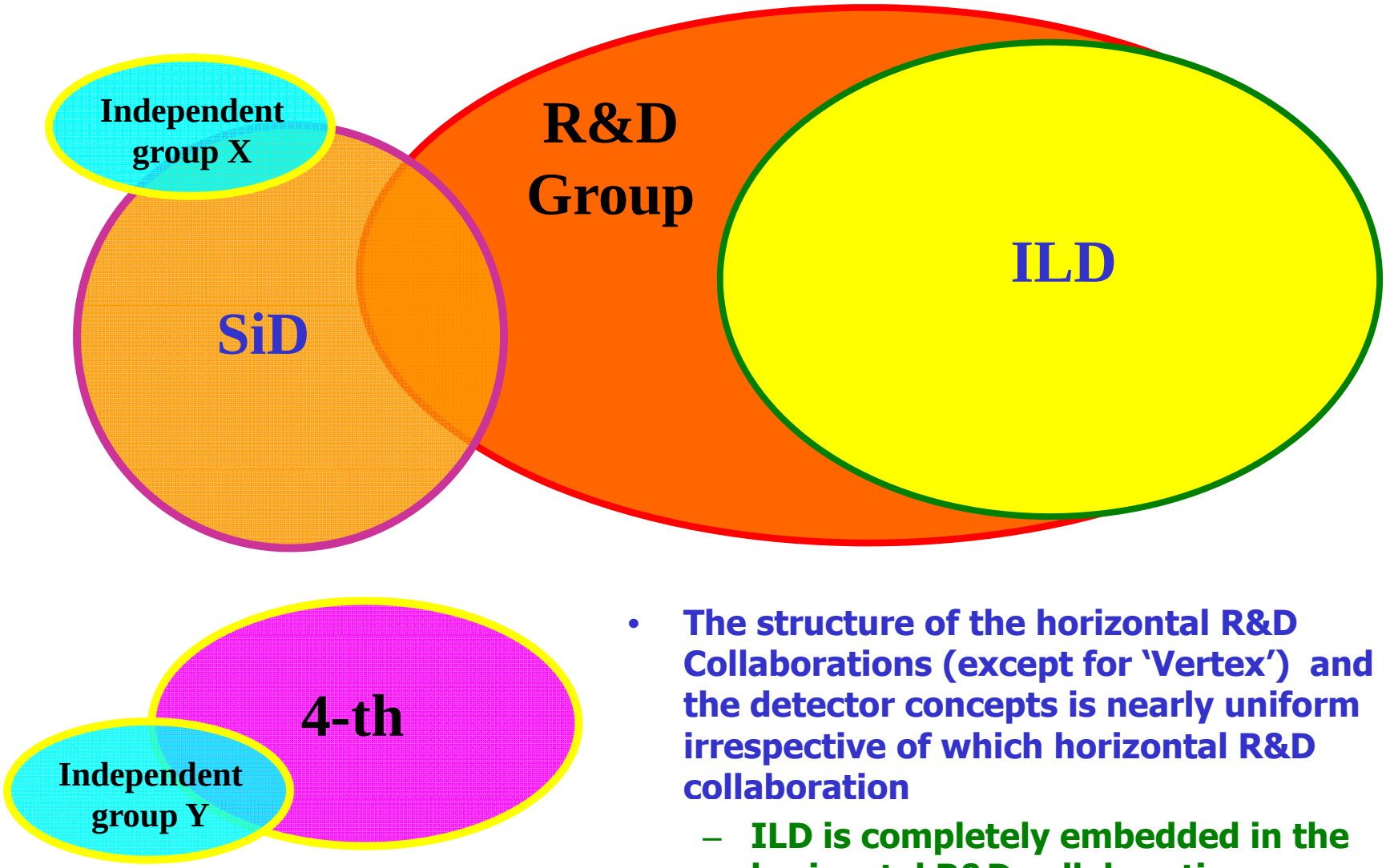


- Note that there is also the SOIPIX collaboration
- In general, the vertex community has had good communication all along, but with new emerging technologies closer communication is considered to be beneficial

The Matrix Revisited



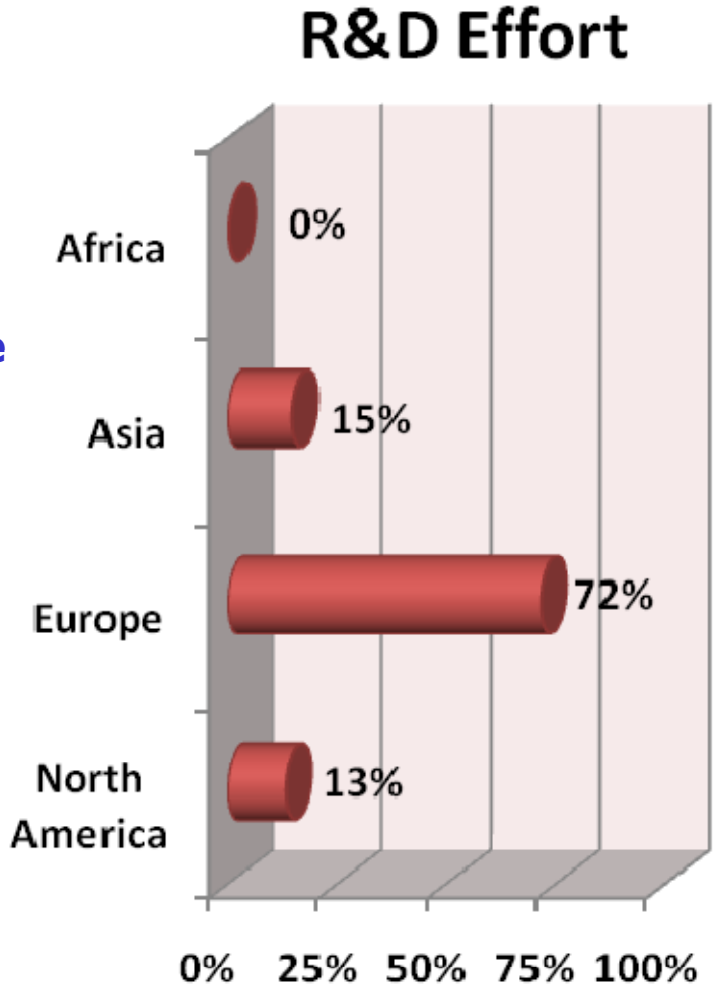
Horizontal R&D Collaborations and LOIs



- The structure of the horizontal R&D Collaborations (except for 'Vertex') and the detector concepts is nearly uniform irrespective of which horizontal R&D collaboration
  - ILD is completely embedded in the horizontal R&D collaboration

Regional Balance

- **Based on the composition of the four horizontal R&D collaborations, there is a very large imbalance between the regions**
- **Ignoring Africa, the effort in the Americas is the smallest**
- **That effort has shrunk over the last couple of years (for obvious reasons)**
- **The effort is becoming subcritical**
- **This situation as a whole is unsustainable for a healthy community**
- **The balance in the US between machine R&D and detector R&D may need to be revisited in view of the health of the whole project**



Observations

- **This measure of the regional balance is based upon the membership in the four horizontal R&D collaborations**
- **Efforts such as SLAC-Oregon-Brookhaven Si-W calorimetry, SiD Tracking, Dual Readout calorimetry, GOSSIP, to name a few, are not accounted for**
- **Also, for almost all the people in the horizontal R&D collaborations this is not their major responsibility**
- **Some horizontal R&D collaborations are actively engaged in collaborative R&D for LHC upgrades**

Lacunae

- Despite the large R&D efforts, there are some very important lacunae in the program
- Many detectors, and a large part of the physics program, depends on novel powering schemes such as power pulsing, serial powering or DC-DC conversion
- Yet there is very little R&D ongoing in the community addressing these issues
- Synergies with other experiments should be sought

- The lack of a common software platform, persistent beyond a single project, hampers progress

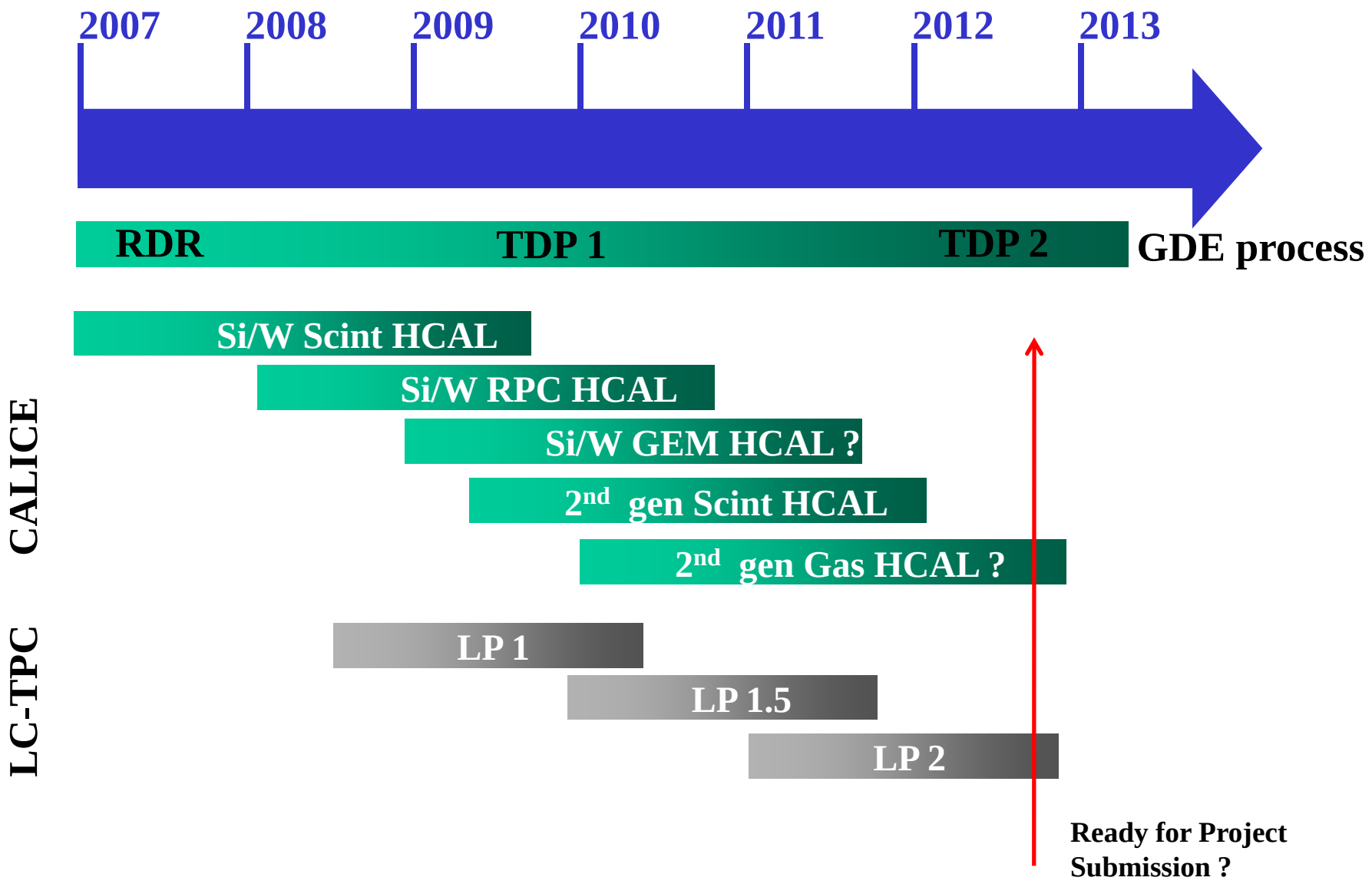
- The grid was highly successful for simulation studies. However, the grid is still very high-maintenance & very LHC-centric

Funding

- Schedules are contingent upon funding
- Funding situation rather complicated
  - Horizontal R&D collaborations funded through participating institutions and grants from organizations such as the EU
  - Collaborations themselves do not hold any funds
- All R&D collaborations have expressed their concern about resources, both material and manpower
- Funding has not yet been secured to carry out the complete R&D program as outlined
  - Significant changes in funding at the national level
  - EUDET funding will run out; Framework 7 proposal was not approved

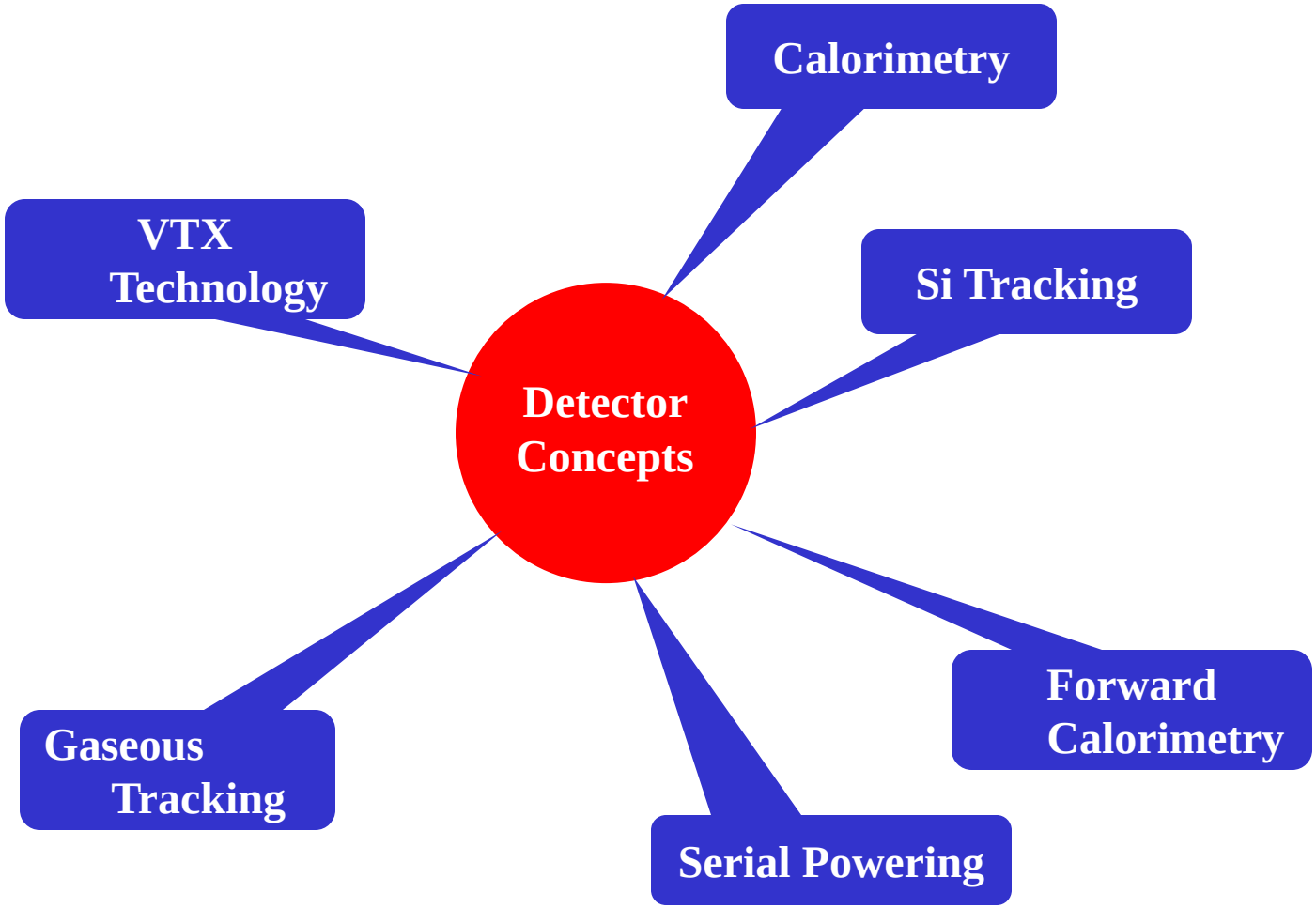
- Example: the recent submission by the US universities from the various detector concepts to the US funding agencies for linear collider R&D funds
  - 4^{th}: $720k
  - ILD: $894k
  - SiD: $1,914k
- Prospects for funding at a level of 30% of request from DOE and NSF

Schedule


2007
2008
2009
2010
2011
2012
2013
RDR
TDP 1
TDP 2
GDE process
CALICE
Si/W Scint HCAL
Si/W RPC HCAL
Si/W GEM HCAL ?
2nd gen Scint HCAL
2nd gen Gas HCAL ?
LC-TPC
LP 1
LP 1.5
LP 2
Ready for Project Submission ?

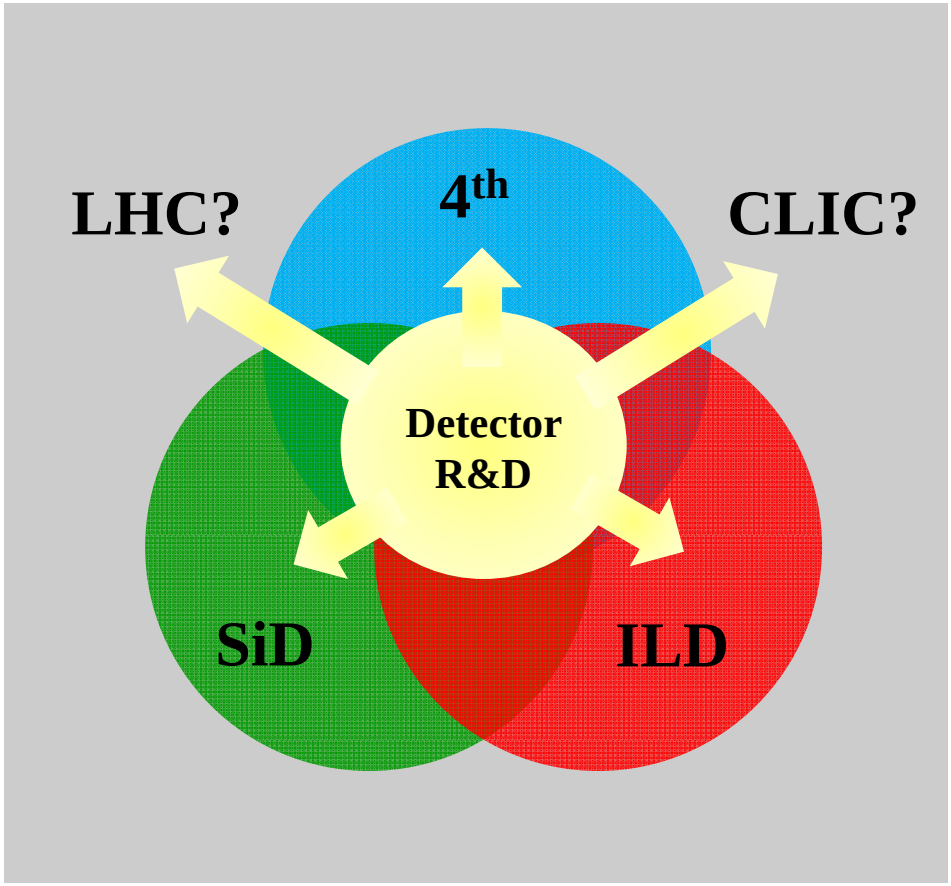
Path for R&D Elements ?

- **R&D has been centered around concept detectors**



Path for R&D Elements?

- **Until 2012, refocus to establish technologies across detector concept boundaries**
- **Diminish boundaries between technologies though joint beam test efforts with common infrastructure**
- **Exploit commonality of R&D efforts across the field**



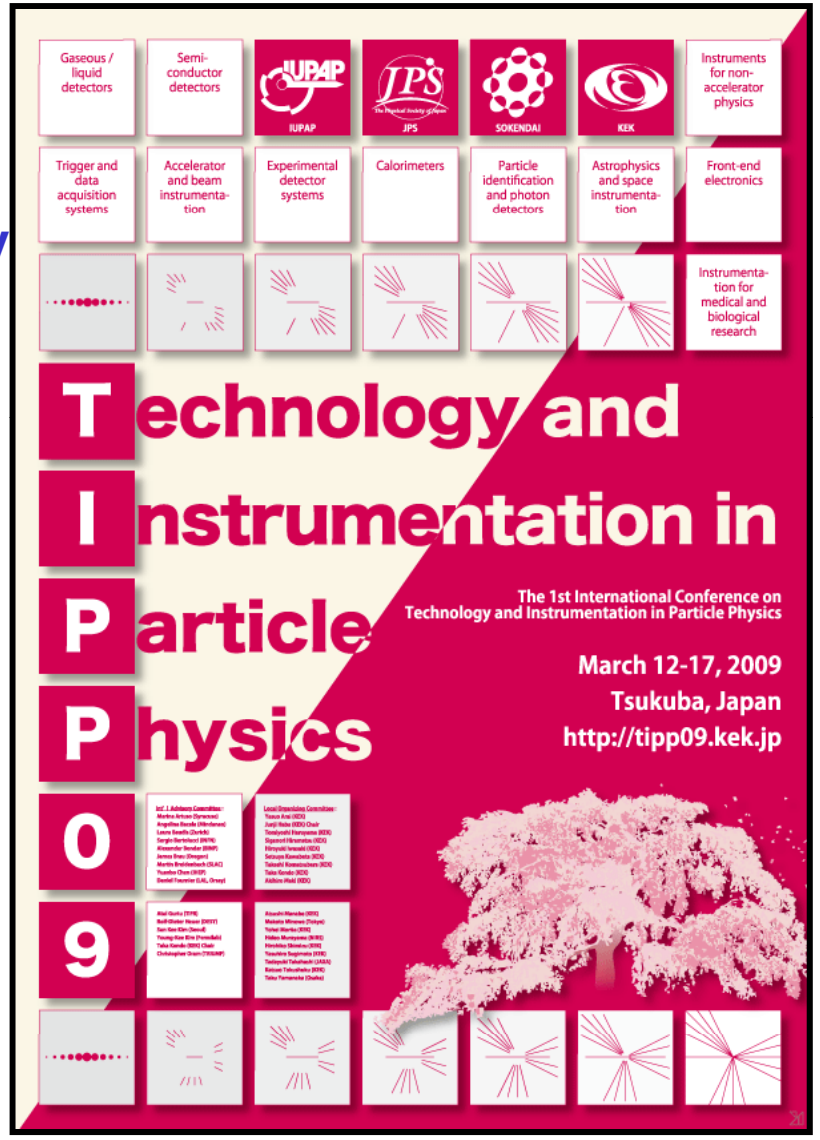
Validation ?

- **Yes!**
- **Many technologies on which the detector concepts fully rely, have not been established**
- **The premise of these technologies needs to be validated within a timeframe consistent with the GDE**
- **Although there are many signatories to the LOIs, the R&D collaborations are severely short of manpower**
- **There is a delicate balance allocating effort to validating and enabling new experimental techniques, which form the heart of the concepts, and benchmarking concepts**
- **It is safe to say that a technology needs to be validated before a detector will ever be built based on the premise of that technology**

TIPP

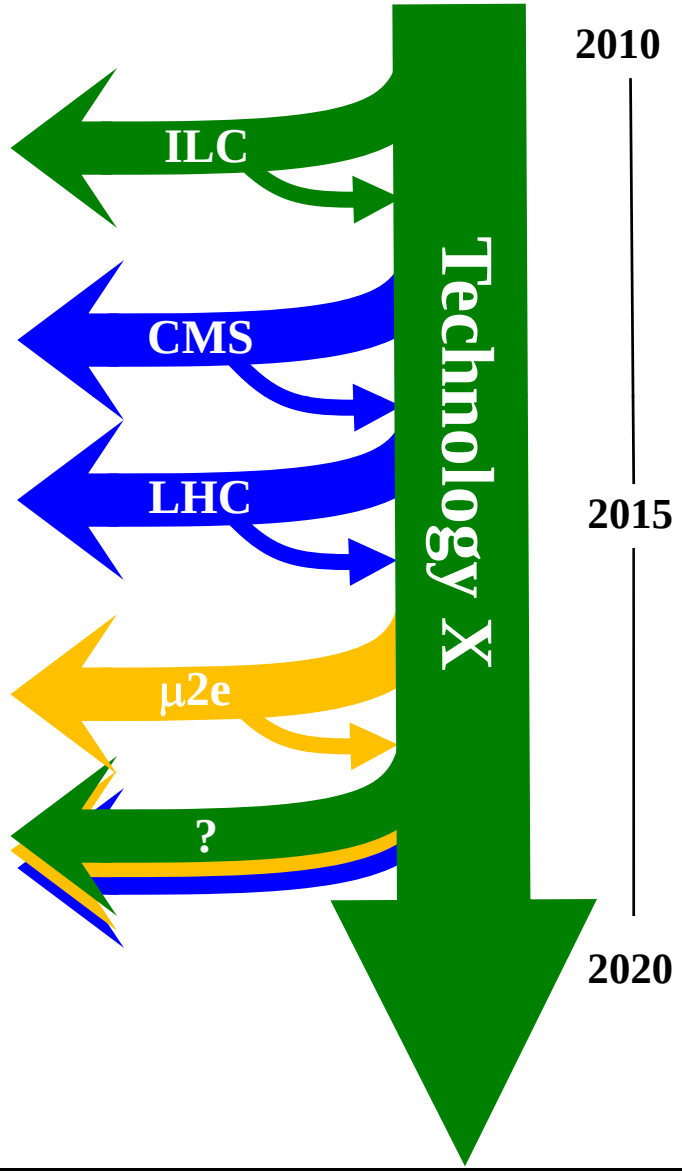
- Two month ago the first C11 conference on technology and instrumentation was held in Tsukuba: TIPP09
- Takasaki-san gave the welcome address and reminded the audience that ultimately it was the detectors – operating at state of the art accelerators – that revealed nature's secrets
- Imagine what if … your detector performs twice as well as …

Winners of the Nobel Prize in the fields of experimental particle physics and astro-particle physics since 1960



Innovation

- **Innovations in detector technology have contributed tremendously to the reach and success of experiments in particle physics.**
- **The community is working to define the next generation of (upgraded) experiments**
- **Unparalleled sensitivities are being probed; particle detectors with unprecedented precision will be required**
- **Now, after the submission of the LOIs a focused and balanced program of detector R&D should be a priority**



Final Remarks

- **The detector R&D common task group will continue to investigate what the expectations and needs of the detector community are and suggest means to foster collaboration across concepts and R&D groups**

- **The coordination of activities will stay within the concepts and R&D collaborations**

- **The resources are sparse and the community is fragile. It cannot afford to lose anyone**
  - **We believe that a fading of the sharp boundaries between the vertical detector concepts will benefit the detector R&D work**
  - **We advocate a fading of the boundaries between R&D groups and promote a common infrastructure for tests**
  - **We encourage reaching out to projects outside of the ILC community with common interest**
  - **This may be critical for the health of the community**

- **We look for your support and appreciate feedback !**