(I)LC Test Beam Accomplishments

LCTB09 @ IN2P3 – LAL

Nov. 3, 2009

Jae Yu

- World-wide effort of ILC Detector R&D TB
- Facilities' Accomplishments
- Detector R&D Accomplishments
- Conclusions
- Epilogue….

World-wide ILC TB Coordination

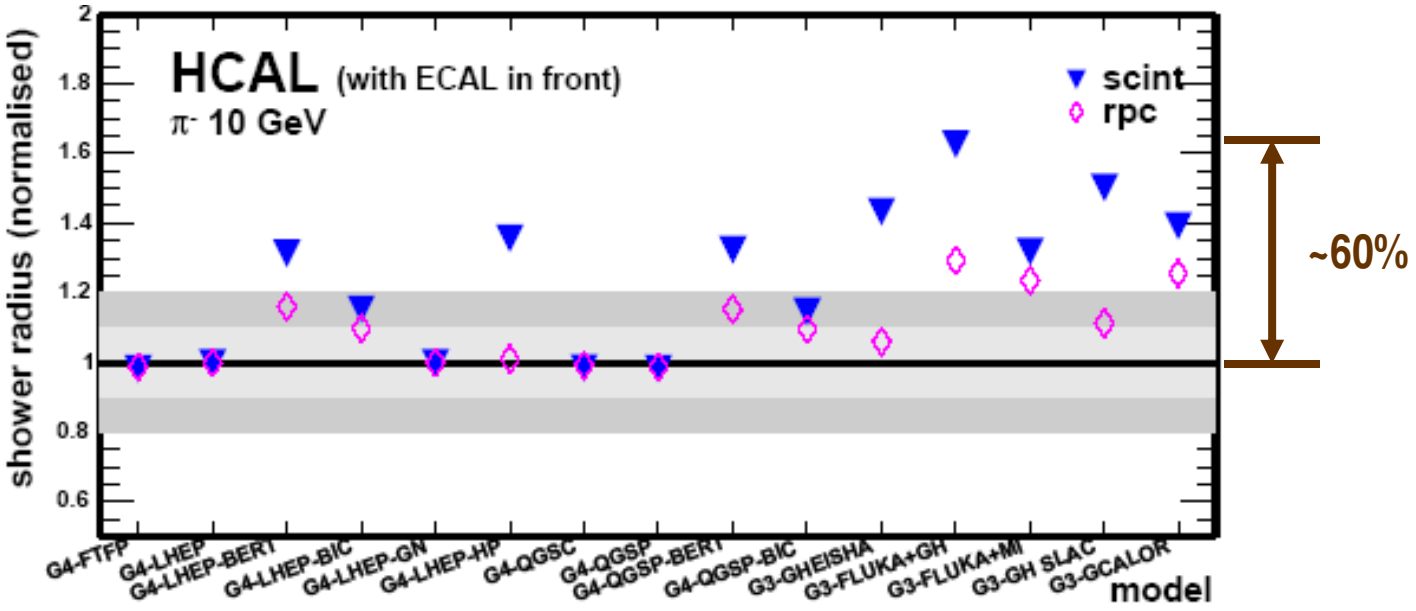
- Creation of GDE and faster pace of ILC accelerator R&D demanded detector R&D to keep up
- Many detector groups already have been performing beam tests but the intensity was brought up higher in 2003
  - Fragmented efforts, concerned only on our own projects
- Facilities needed to be able to provide the necessary beam capabilities to the R&D groups
- No clear requirements or demands were known

World-wide ILC TB Coordination

- Submitted a roadmap document to FNAL in 2006
  - Defined what calorimeter and muon groups' needs from the facilities
- Led to concerted efforts of world-wide ILC test beam working group and a subsequent IDTB07
  - Provided a forum for us to think about "US" and the common goals
  - Ways to share our expertise and specified facilities
- A lot of work have been done by the R&D groups and the facilities ➔ Apologies for not being able to cover them all!!

Some ILC Beam Test Goals in 2005

- Detector performance measurement – Phase I
  - Necessary to choose good detector technologies that meets the requirements optimized for PFA
- Better simulation tools for more sophisticated PFA development
  - Hadronic shower needs better understanding

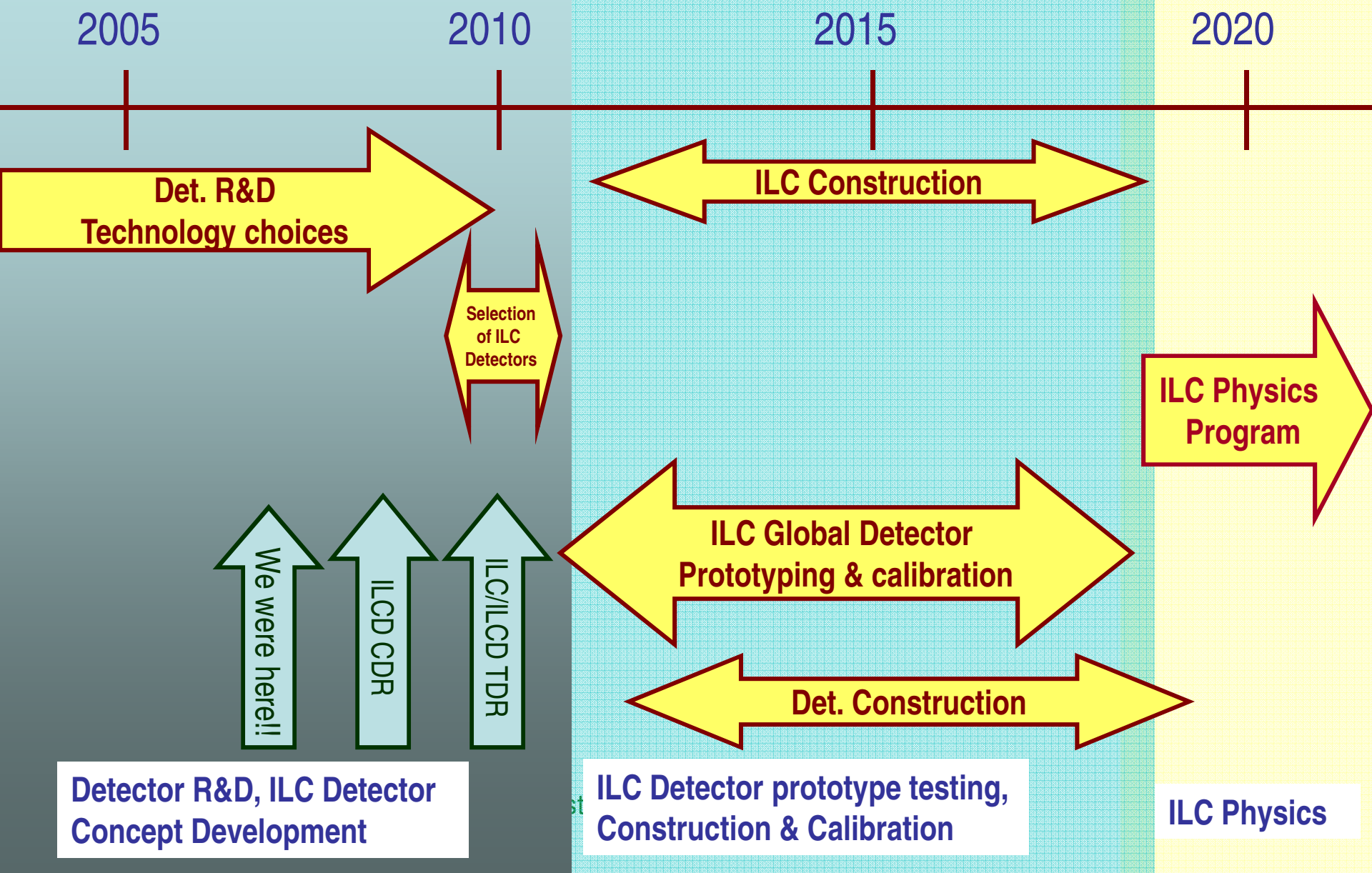


G. Mavromanolakis *et al.*

Goals at the IDTB07

- ✓ Review and assess the current status, capabilities and plans of facilities
- ✓ Review and assess the current and planned detector test beam activities
- ✓ Identify requirements for test beams to meet adequately the detector R&D needs
- ✓ Plan and discuss for the future beam test activities
  - ✓ What have we learned from LHC beam tests?
  - ✓ What can we learn from existing ILC test beam activities?
  - ✓ What should the future beam test activities focus?
- Put together a team to write the ILC detector R&D test beam roadmap document which includes all sub-detector systems and the anticipated demands to facilities
- This document was completed and released to the ILC leadership and to the facilities managers July 1, 2007

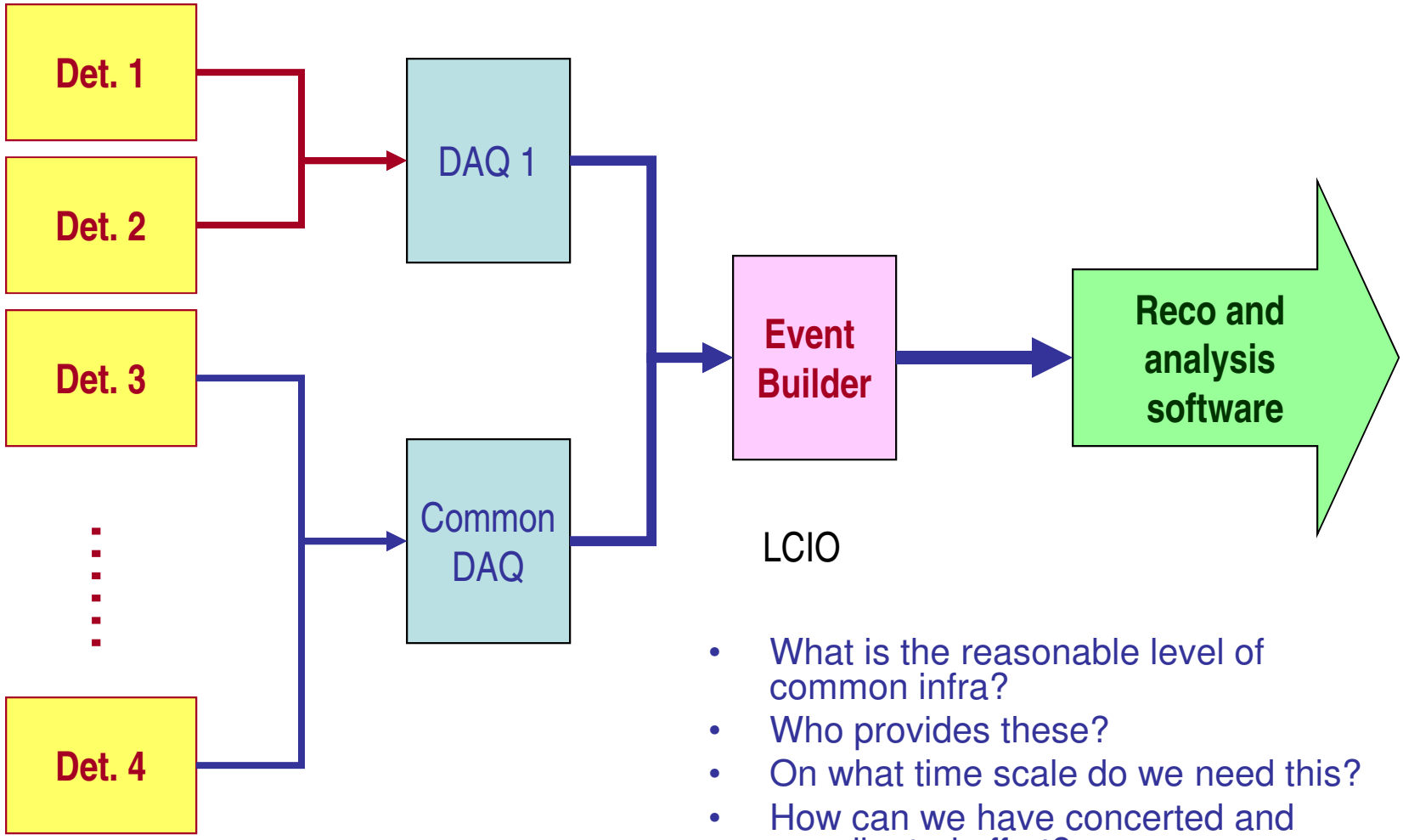
LC Detector Time Line in 2007



R&D Groups' Requests at IDTB07

- Large bore, high field magnet (up to 5T)
  - VTX and tracking groups
- ILC beam time structure (1ms beam + 199ms blank)
  - VTX, TRK and CAL electronics
- Mimicking hadron jets
  - VTX, TRK and CAL
- Common DAQ hardware and software
- Common online and offline software
  - Reconstruction and analysis software

Point of Merge for Commonality



- What is the reasonable level of common infra?
- Who provides these?
- On what time scale do we need this?
- How can we have concerted and coordinated effort?
- Do we need this at all?

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  - Reconstruction and analysis software
- Tagged neutral hadron beam

Neutral Hadrons Beams??

- Do we need beam test with neutral hadrons?
  - Successful PFA means the HCAL measures neutral hadrons
  - Simulation models need some neutral hadron data
  - Hadron calorimeter calibration can use momentum tagged neutral hadrons
- Can we trigger effectively?
- What energy range?
  - Which ones do we need to understand better?
- We have been busy with what we have!!
- FNAL moving forward with a proposal for this!

Detector R&D Needs @ IDTB07

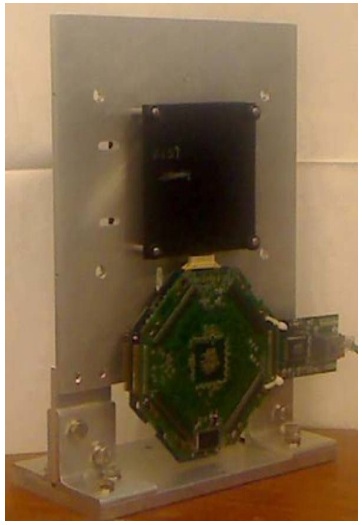
Detectors	N_Groups	Particle Species	P (GeV)	Magnet (Tesla)	N_Weeks/yr	ILC time structure	Note
BI&MDI	2E+8ESA+1F+2C+3BC	e	up to 100	Not specified	64		Mostly low E elec
Vertex	10	e, π, p; μ	up to 100	1 – 3	40	Yes	
Tracker	3TPC+ 2Si	e, π, p; μ	up to 100	1.5 - >3	20	Yes	
Cal*	5 ECALs+3 DHCALs + 5 AHCALs	e, n, π, K, p; μ	1 – >=120	Not specified	30 – 60	Yes	
Muon/TCMT	3	e, π, μ	1 – >=120	Not specified	12		

*Note: Most calorimeter R&D activities world-wide are organized under CALICE collaboration.

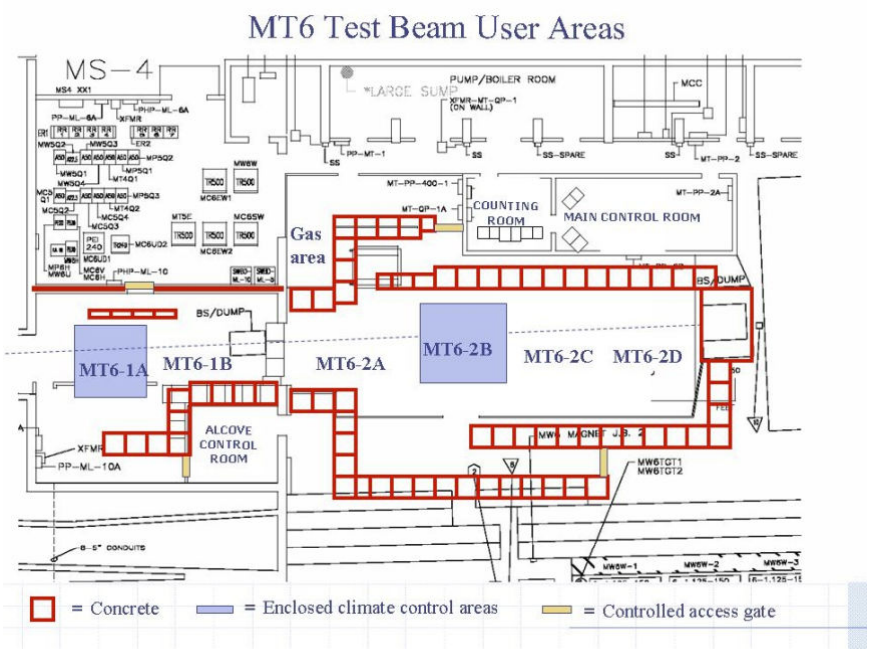
Some of these can work concurrently…

Facilities Accomplishments - FNAL

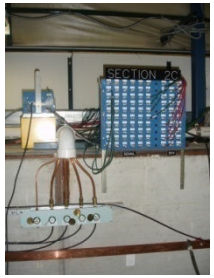
- By far the most responsive facility
  - Virtually all requests have been met
    - Increased duty factor: Average duty factor of 5% policy has been altered at times to facilitate expeditious completion of beam test experiments
  - Renovated MTBF user area (and fixed the roof leak problem…)
  - Tried out “ping” structures to accommodate ILC like beam structure
    - Not to the fine structure but to the macro-structure (1ms ping+199ms blank)
  - Hadron and electron beam energy to as low as 1GeV
  - High precision pixel telescope and TOF w/ 25ps resol.
  - Tagged neutral hadron availability
    - Meson Center Test Beam Facility Proposal



Fermilab Meson Test User Facility



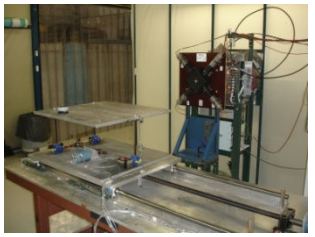
Spacious control room



Signal and HV cables

Gas delivery to 6 locations

4 station MWPC spectrometer



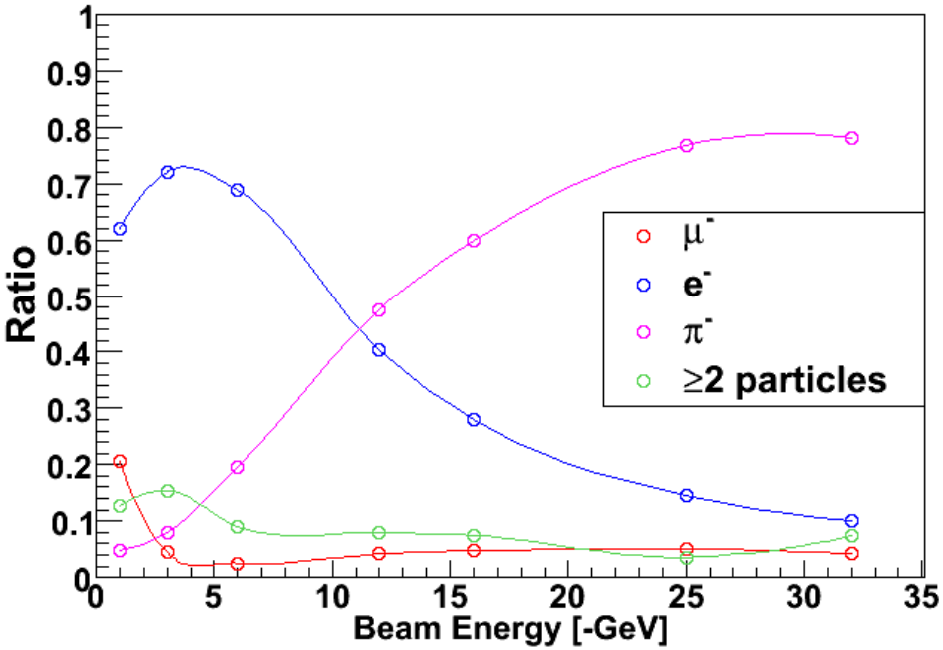
Two motion tables

Beam Delivery for CALICE

- The CALICE experiment (T978) has been the most comprehensive detector system to be installed at MTest and has summarized their results for beam composition.
- The Fermilab Accelerator Division has created beam tunes for CALICE as follows:

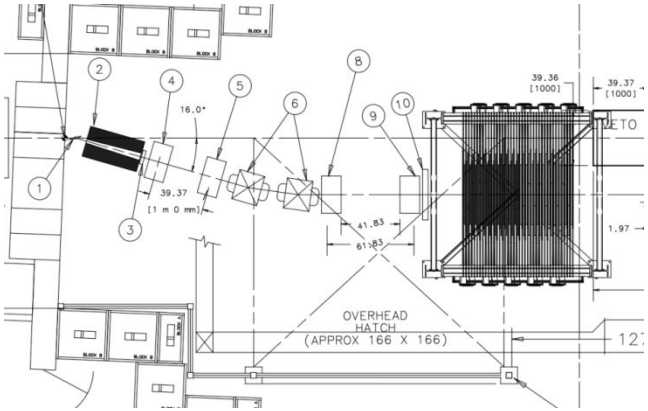
  Negative 1,2,3,4,6,8,10,12,15,20,30 GeV

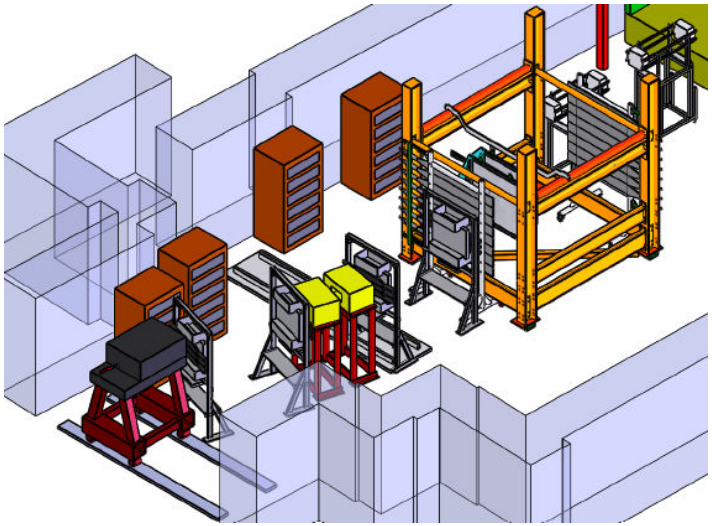
  Positive 32 GeV (high rate muon mode), 120 GeV (proton mode)



Tertiary 300 MeV/c Beamline for MINERVA

- The MINERVA experiment requested space to create a new tertiary beamline that could deliver pions down to 300 MeV/c momentum.
- The Particle Physics Division and Accelerator Division have agreed to help and are proceeding on installation.
- Full tracking and TOF will allow for momentum measurement and particle i.d.
- Target station rolls away for other users.
- The full spectrometer will be tested in November, 2009



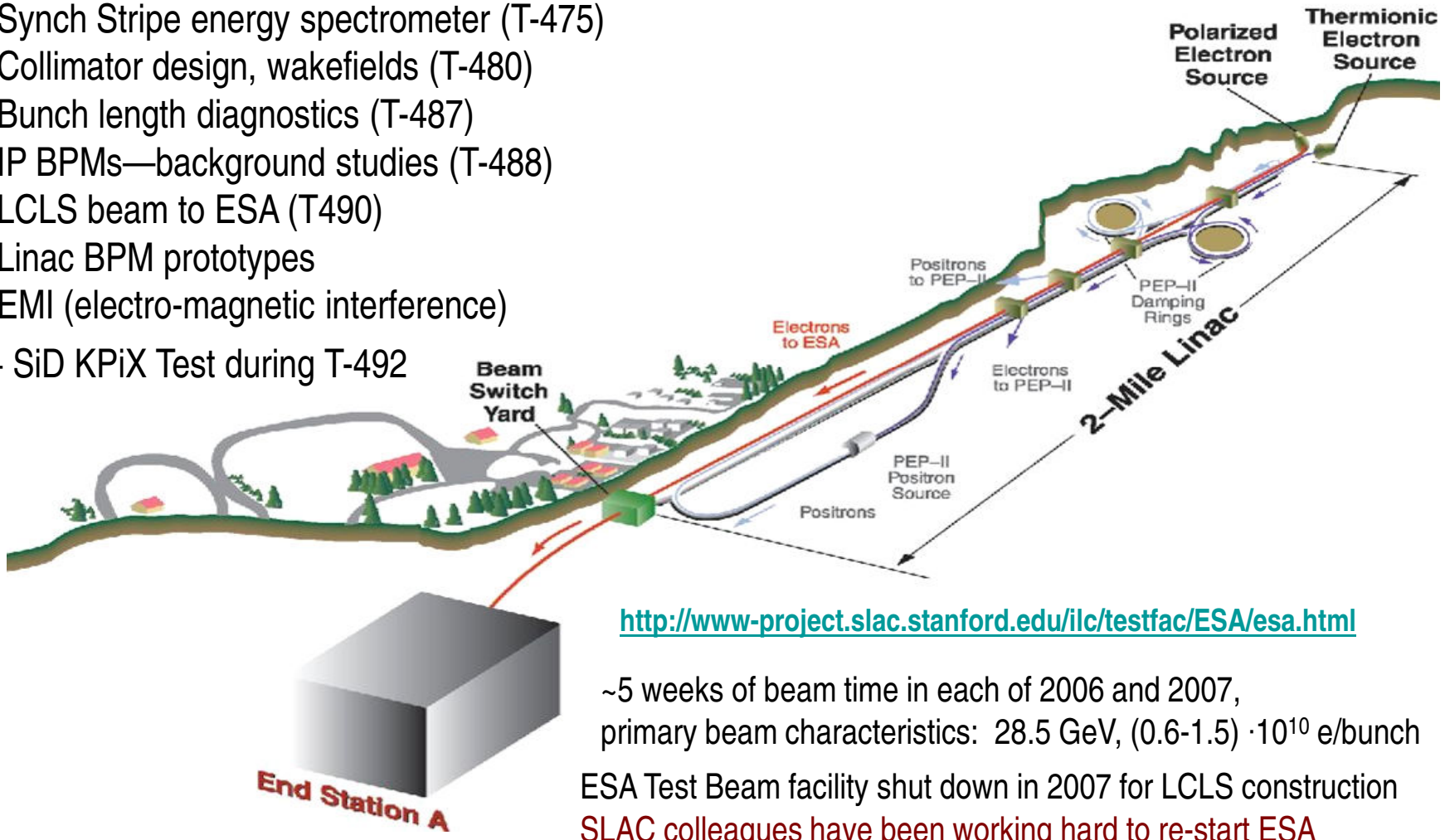


Facilities Accomplishments - SLAC ESA

Several beam monitoring and radiation damage beam test experiments in 2006 - 2007

- BPM energy spectrometer (T-474/491)
- Synch Stripe energy spectrometer (T-475)
- Collimator design, wakefields (T-480)
- Bunch length diagnostics (T-487)
- IP BPMs—background studies (T-488)
- LCLS beam to ESA (T490)
- Linac BPM prototypes
- EMI (electro-magnetic interference)

+ SiD KPiX Test during T-492



http://www-project.slac.stanford.edu/ilc/testfac/ESA/esa.html

~5 weeks of beam time in each of 2006 and 2007,
primary beam characteristics: 28.5 GeV, (0.6-1.5) $\cdot 10^{10}$ e/bunch

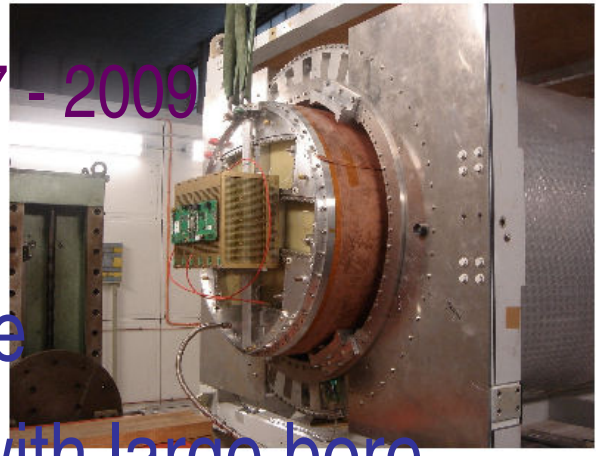
ESA Test Beam facility shut down in 2007 for LCLS construction
SLAC colleagues have been working hard to re-start ESA

Facilities Accomplishments - CERN

- Most frequently used facility for many ILC Detector R&D groups
- Many experimental areas allow access to wide energy range
  - PS: 5 areas with max E up to 3.5 GeV to 24 GeV
  - SPS: 4 areas with max E range up to 400 GeV
- Hosted several ILC detector beam tests
  - CALICE Si/W ECAL+AHCAL+TCMT tool data in 2006 and 2007
  - CALICE GRPC and micro-megas planes
  - Large number of VTX and Tracking groups, LCTPC, SILC…
  - DREAM calorimeter
- Accommodates R&D groups' needs and situations as much as possible
- Well equipped facility with helpful staff
- LHC's schedule puts strain on demand to AD manpower for significant changes ➔ Continued availability expected

Facilities Accomplishments - DESY

- Continued to provide 1 – 6 GeV e
  - CALICE Si/W ECAL ran in 2005 and 2006
  - CALICE AHCAL plane tests in 2006 – 2007
  - CALICE TCMT plane test in 2006
  - CALICE Scint/W ECAL test in 2007
  - Numerous TPC end-plate tests in 2007 - 2009
- Home of EUDET facilities
- Test area 21: EUDET Pixel telescope
- Test area 24: EUDET TPC Testing with large bore (1m dia) solenoid



Facilities: Asian and Russian

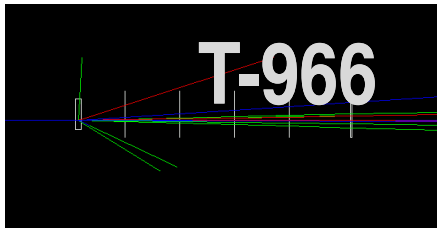
- KEK FTBL: One beamline w/ 0.4 – 3.4 GeV e
  - To be shut down for 3 years from 12/09 for KEKB upgrade
  - Future operation not yet decided
- JPARC: One beamline w/ 0.5 – 1.1 GeV hadrons
  - Funding secured and PAC endorsement on 6/09
  - Scheduled to complete mid 2010
- IHEP Beijing: 3 areas 0.4 GeV – 1.5GeV
  - Shut down 2008 – 2010 for upgrade
- IHEP Protvino: 8 beam lines with electrons up to 34 GeV and hadrons up to 50 GeV
  - Available 2 mo/year

Test Beam Availability

Laboratory	Energy Range	Particles	Availability (IDTB 2007)
CERN PS	1 - 15 GeV	e, h, μ	LHC absolute priority
CERN SPS	10 - 400 GeV	e, h, μ	LHC absolute priority
DESY	1 - 6.5 GeV	e^-	> 3 months per year
Fermilab	1-120	e, π, K, p; μ	continuous (5%), except summer shutdown
Frascati	25-750 MeV	e	6 months per year
IHEP Beijing	1.1-1.5 GeV (primary) 0.4-1.2 GeV (secondary)	$e^{\pm}$ $e^{\pm}$, $\pi^{\pm}$, p	Continuous after March 2008 (unavailable before then)
IHEP Protvino	1-45 GeV	e, π, K, p; μ	one month, twice per year
J-PARC	Up to 3GeV	????	Available in 2009 earliest
KEK Fuji	0.5 - 3.4 GeV	e	Available fall 2007, 240 days/year
LBNL	1.5 GeV < 55 MeV < 30 MeV	e p n	Continuous
SLAC	28.5 GeV (primary) 1.0 - 20 GeV (secondary)	e $e^{\pm}$, $p^{\pm}$, p	Parasitic to Pep II, non-concurrent with LCLS

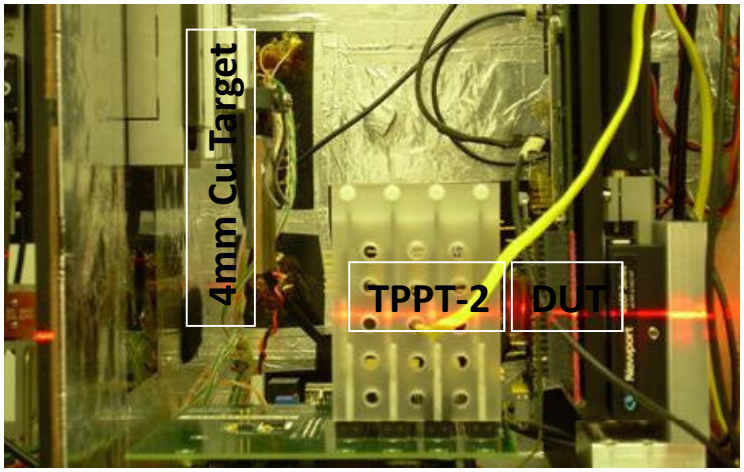
Detector R&D Accomplishments - VTX

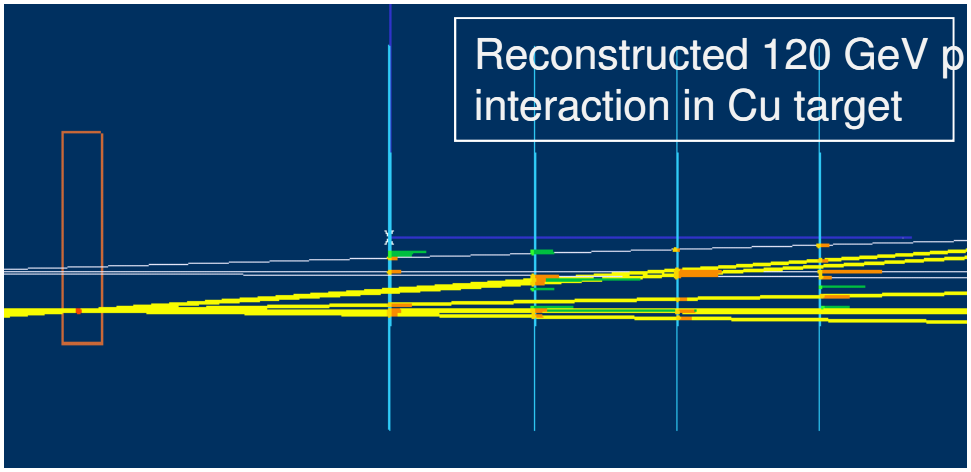
- Many options for vertex detectors
  - 3 CCDs, 2 MAPs, DEPFET, CronoPix, VIP, 3D…
- Performed beam tests of 1 – few weeks at CERN, FNAL, KEK, LBNL and INFN
  - Requirements
    - High energy beams
    - Beams with ILC time structure
    - High field (~3T) magnets needed
    - High density particle environment
  - An R&D collaboration would be helpful

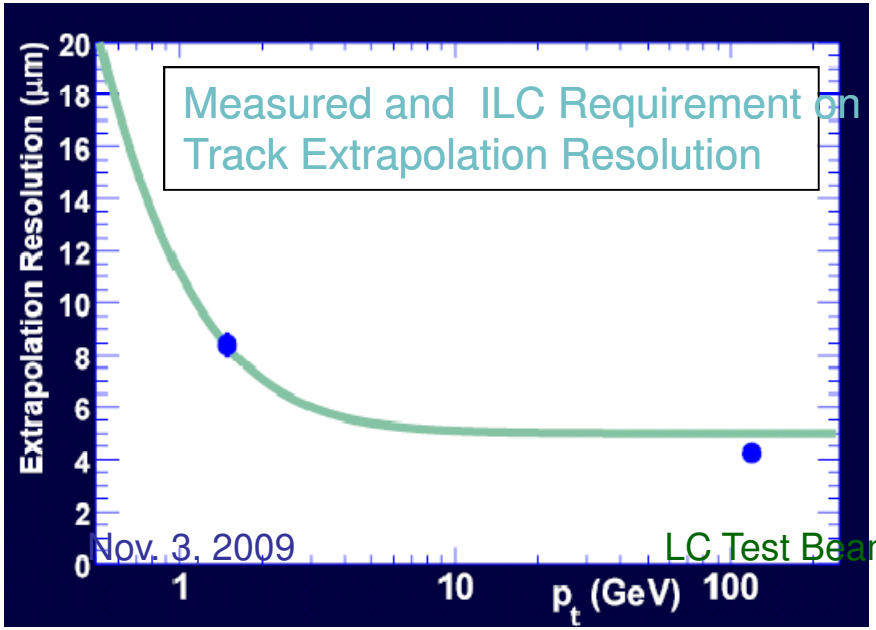


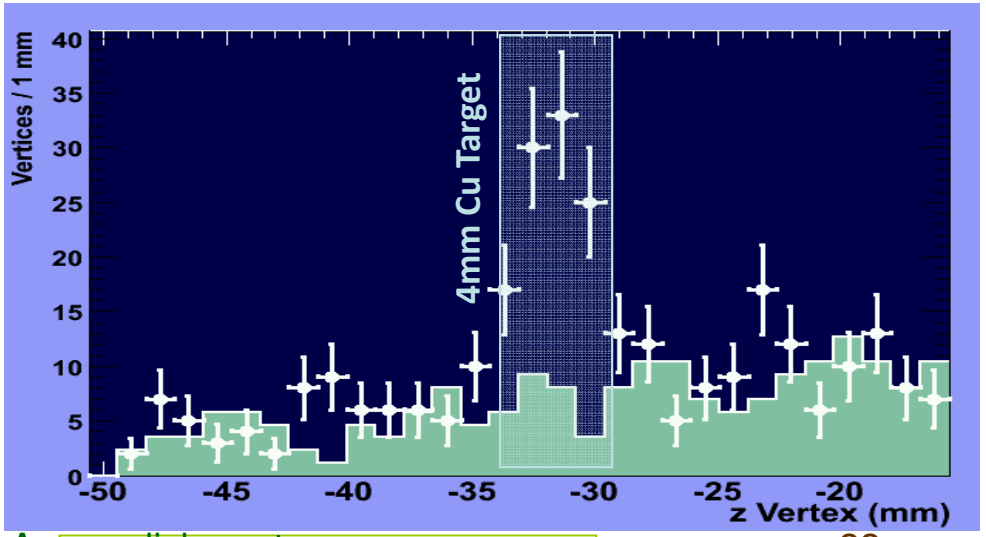
at FNAL MTest: Tracking and Vertexing

Tracking and Vertex Reconstruction with Thin CMOS Pixel Telescope (LBNL, Purdue U & INFN, Padova)



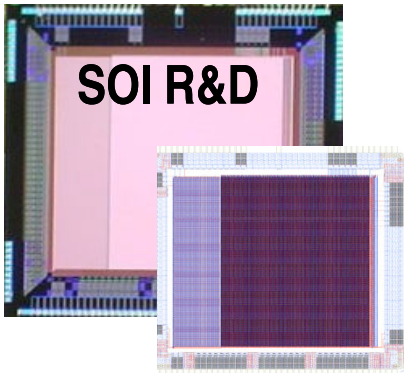






σ_z vertex = 230 μm

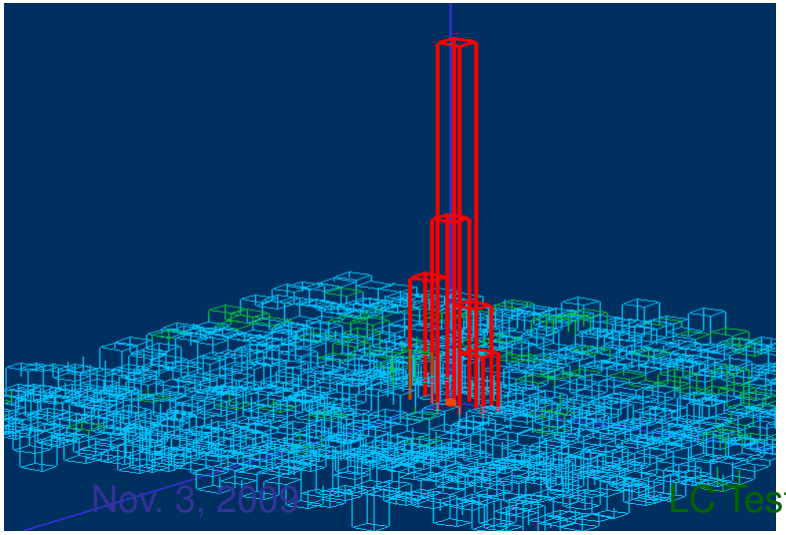
M Battaglia et al. NIM A593 (2008)

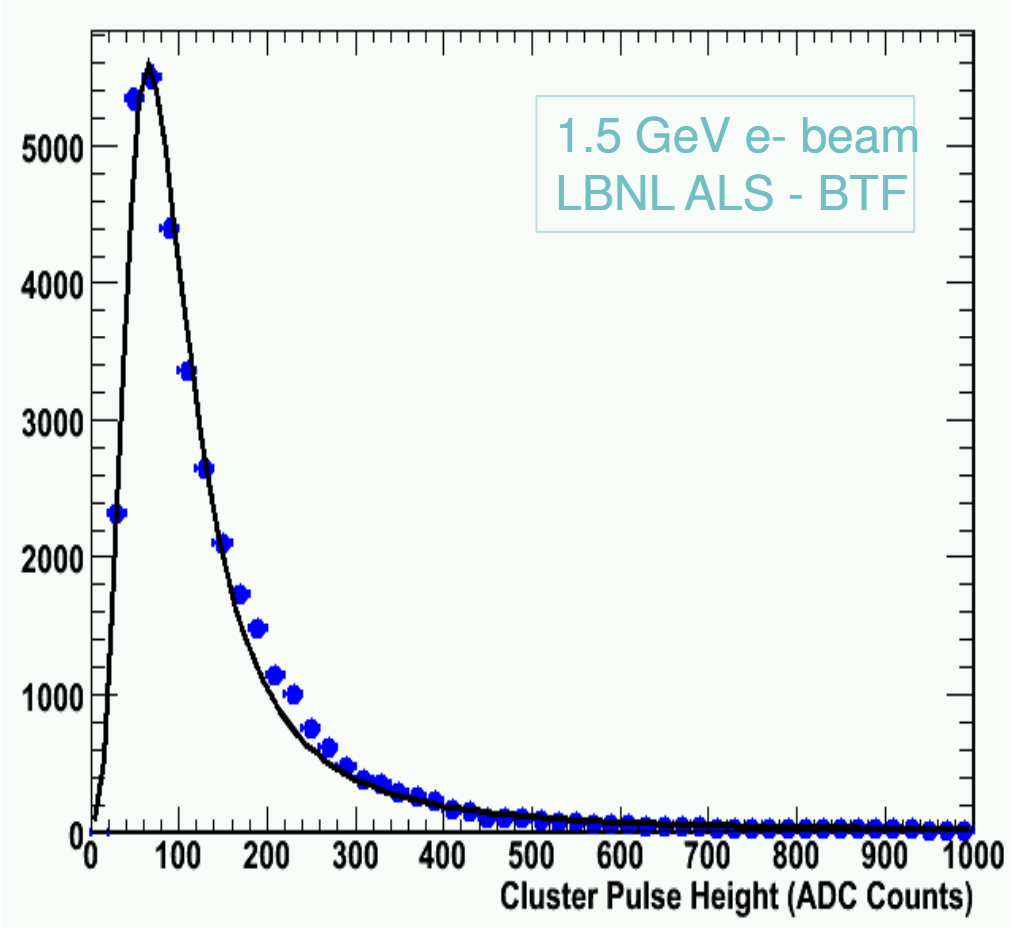


SOI Pixels Sensors Beam Tests at ALS

Test performance of novel SOI pixel sensors (LBNL, KEK, INFN Padova)

LDRD-SOI1 and LDRD-SOI2 successfully tested;
Analog and binary pixels;
First test of an SOI sensor on particle beam;
Measured S/N > 15



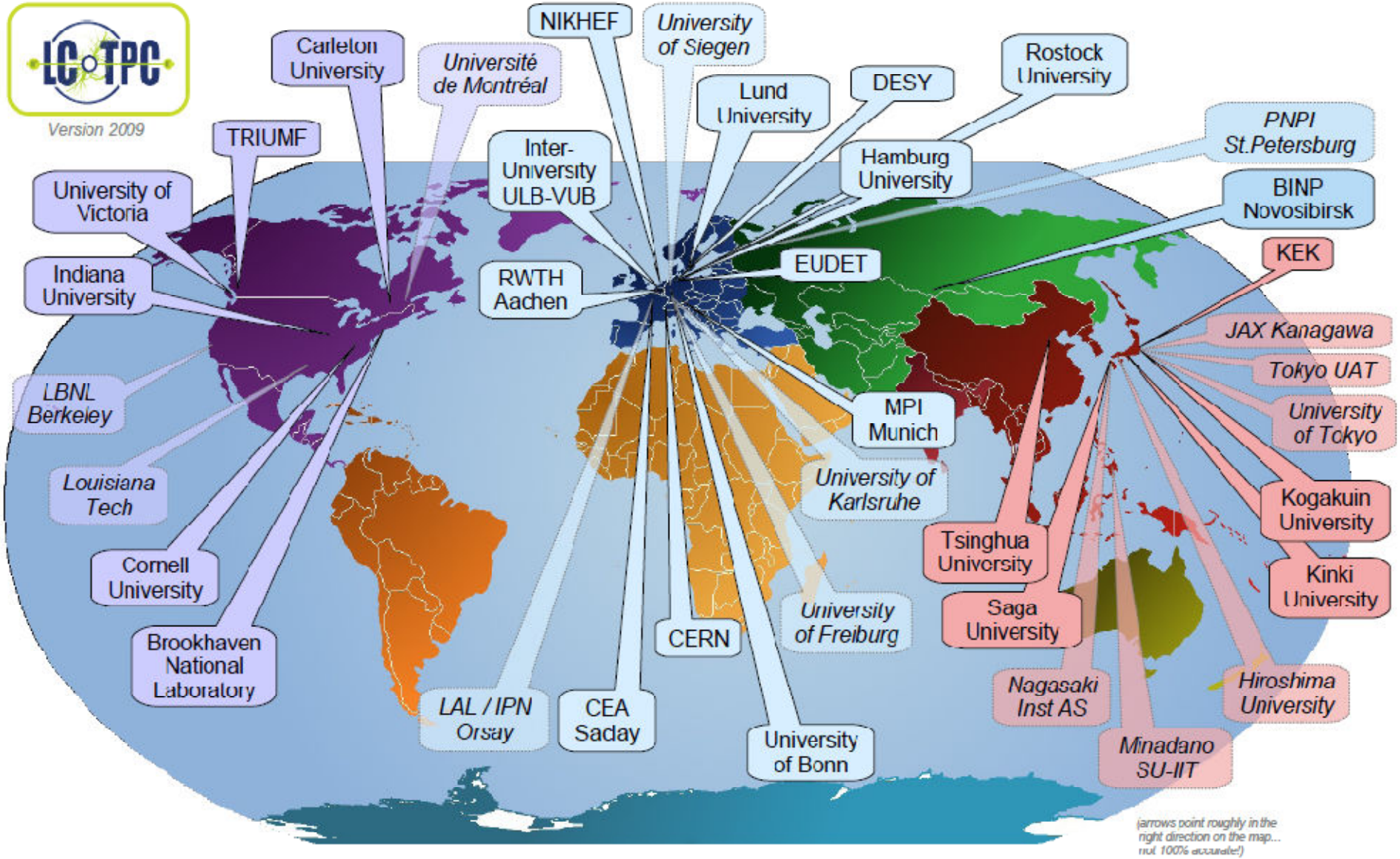


M Battaglia et al., NIM A583 (2007) and NIM A604 (2009)

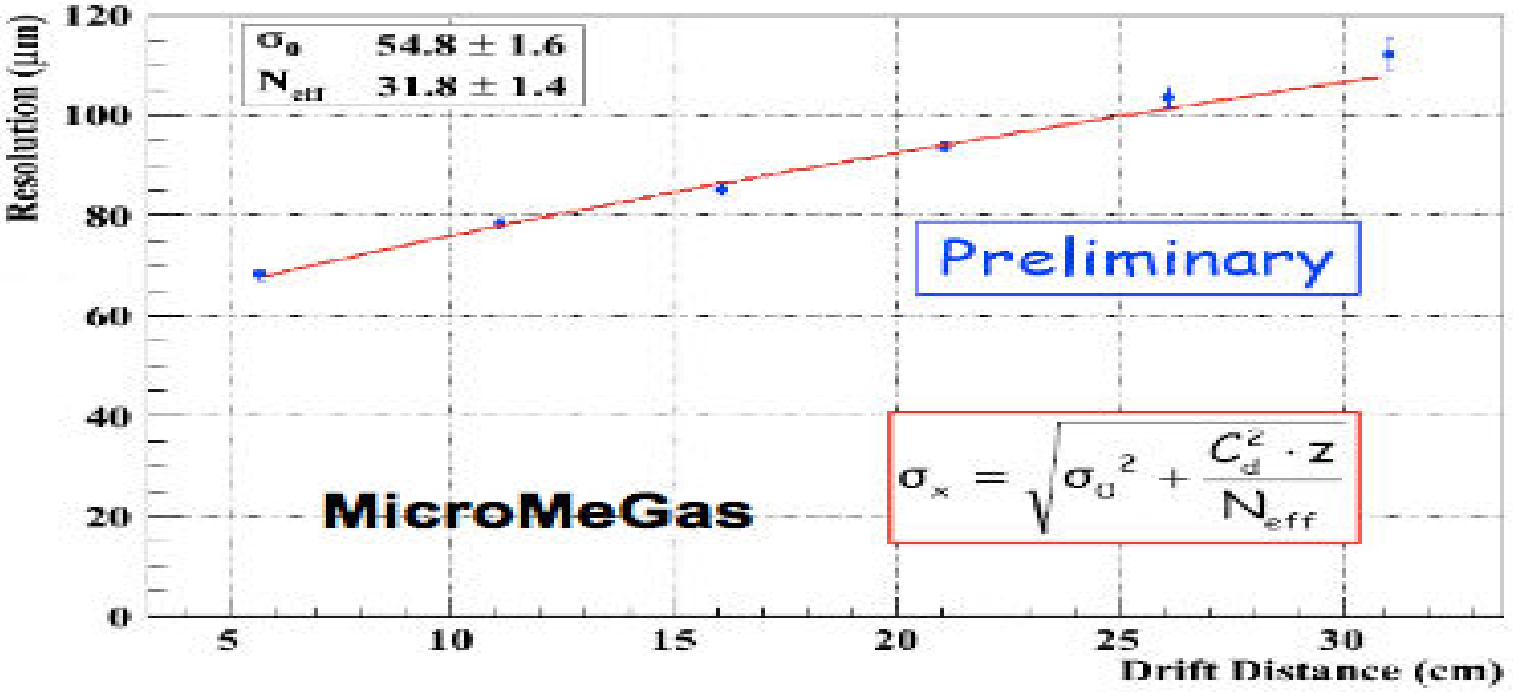
Detector R&D Accomplishments - TRK

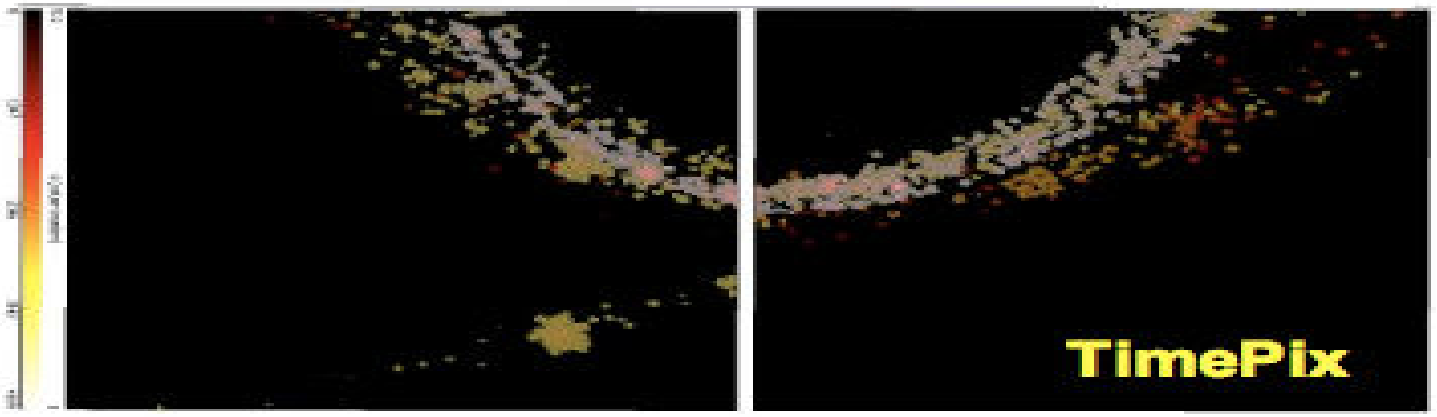
- Several collaborations formed
  - Silicon Tracker: SILC and SiD Si Tracker
  - LCTPC Collaboration formed with 38 institutions
    - LC TPC Collaboration performed many tests at KEK and DESY
    - 2007 – 2009: Tested field cage + 2 end plates (GEM + pixel and m-megas + Pixel configurations at DESY
  - Large bore 1.2T solenoid installed in DESY T24 as part of the EUDET facility installments

TPC Collaboration 2009 (38 institutions)



LCTPC Collaboration

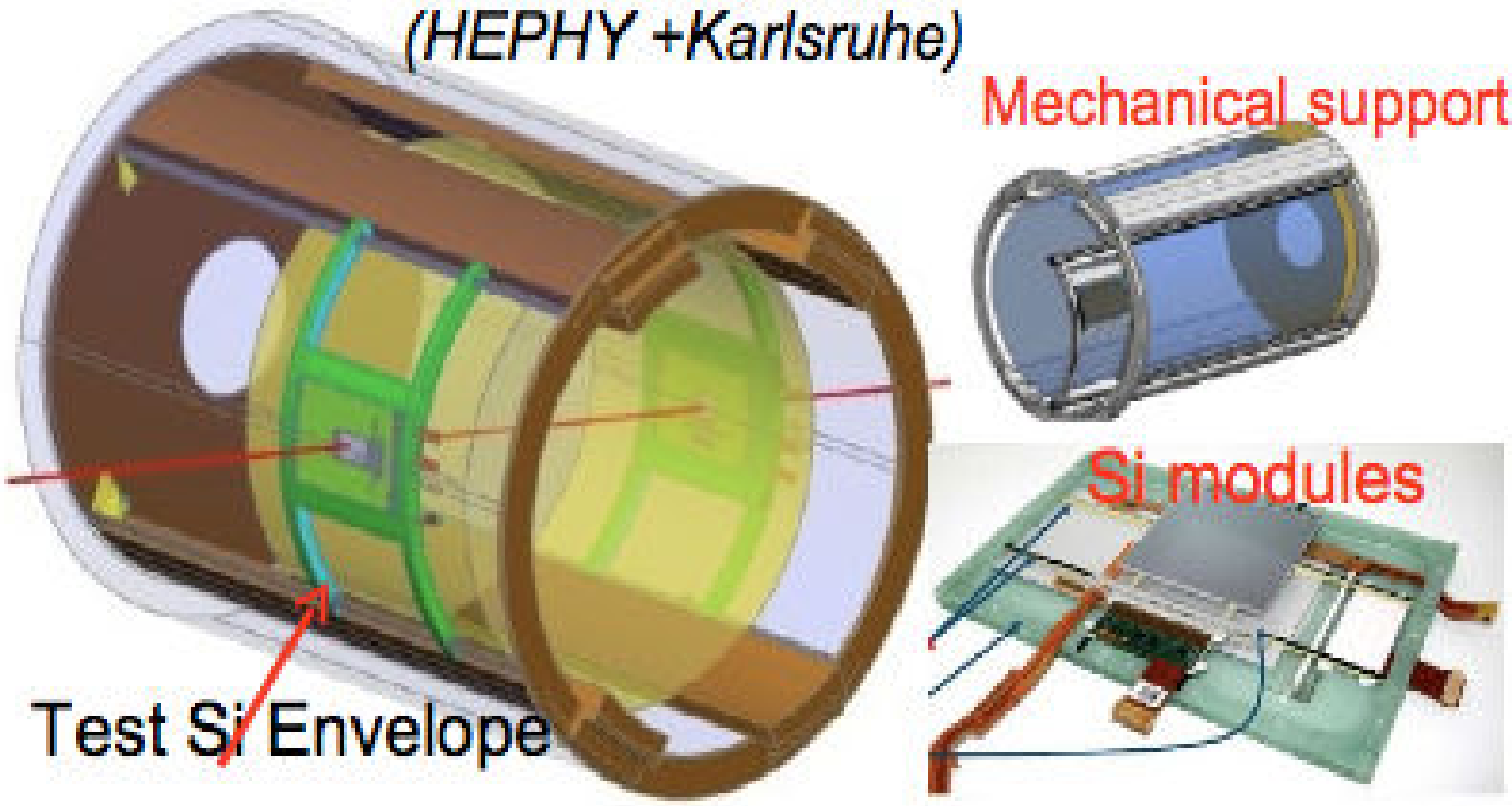




High Field Large Bore Magnets

- One of the requirements brought up in IDTB07
  - Some candidates but no facilities had sufficient resources to pursue
    - FNAL pursued somewhat
- PCMAG
- Triumf (Twist) Magnet (Madhu Dixit)
  - 2 T, 1m φ, 2.2m length
  - Was available
- KeK (Amy) Magnet (Takeshi Matsuda)
  - 3 T, 2.4m φ, 1.6m length
  - Available now (in principle)
- ~3 T magnet from CERN?
- A new solenoid with a hole on the side for beam incident?

VTX+TRK Collaborative Facility



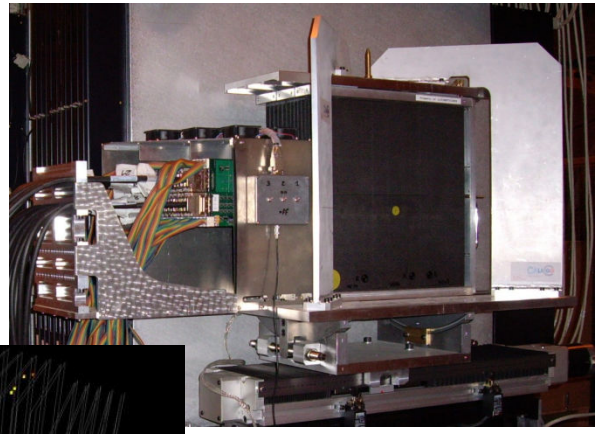
Large bore, high field magnet with Si tracker module on the beam position and large TPC inside the magnet

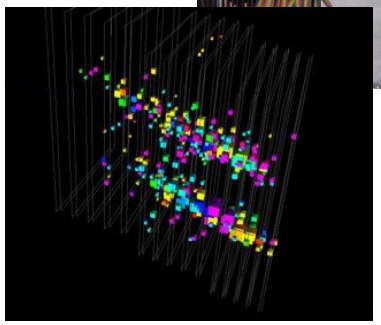
Detector R&D Accomplishments – CAL

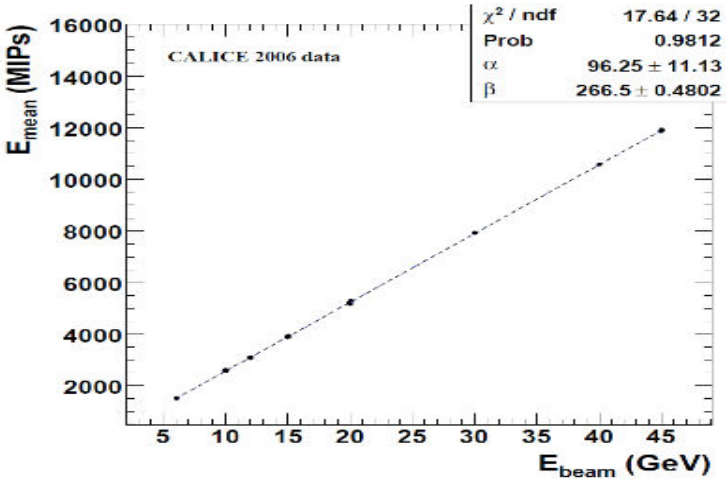
- CALICE
  - Performed combined Si/W ECAL + AHCAL + TCMT runs at CERN in 2006 and 2007 in addition to 2005 and 2006 DESY runs
    - Excellent opportunities for commissioning the system and performing high energy scans
  - Performed combined Si/W ECAL & Si/Scint+AHCAL+TCMT @ MTBF 2008 and 2009
  - RPC DHCAL slice test in 2007
  - Three GEM DHCAL prototype chamber tests in 2006 - 2007
  - Several GRPC single and multi-layers runs at CERN in 2007 – 2009
  - MicroMegas single layer testing @ CERN in 2008 - 2009

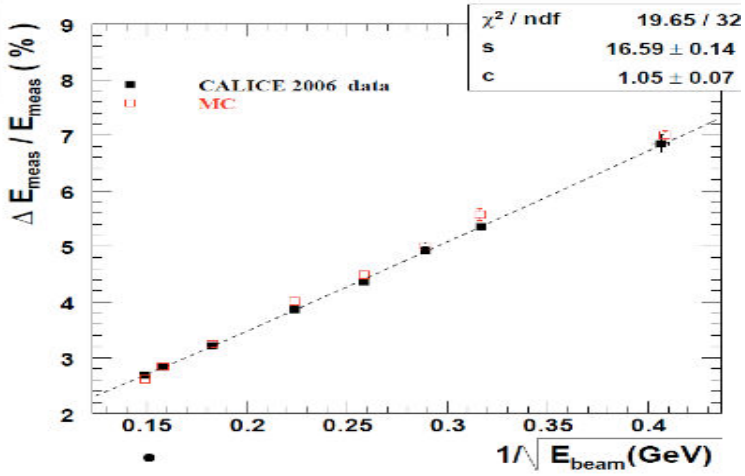
PFA ECAL: CALICE Si-W

- Features Si active layer with fine readout cells ($1x1cm^2 \rightarrow 0.5x0.5cm^2$)
- Tested at beams several times
  - At DESY 2005 and 2006
  - At CERN 2006 and 2007
  - At FNAL 2008
  - Standalone test + combined test with CALICE AHCAL
  - Analysis on-going
  - Comparison with MC simulation





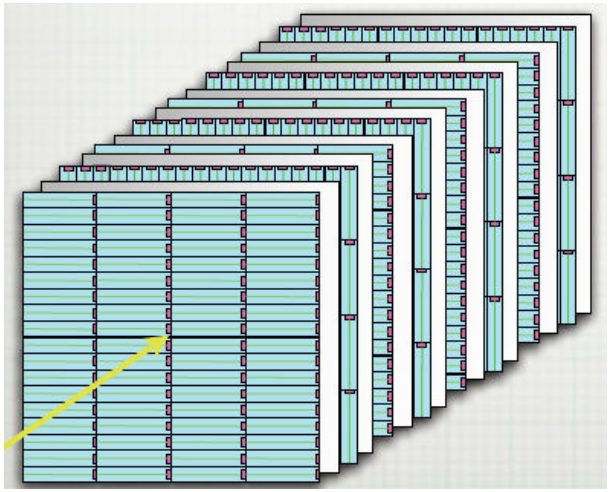


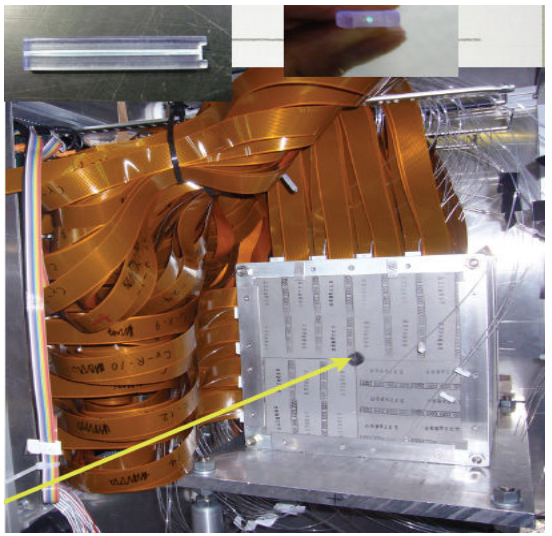


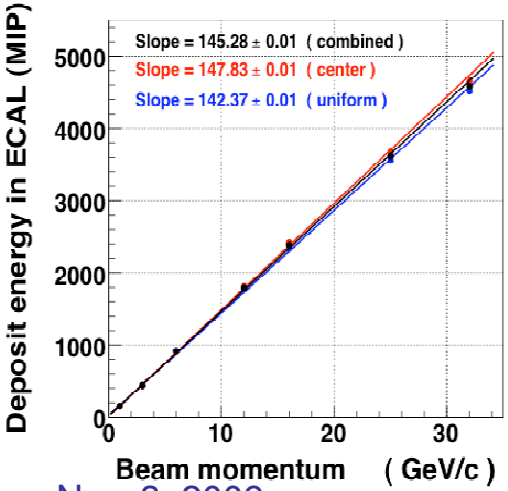
$$\frac{\Delta E_{\mathrm{meas}}}{E_{\mathrm{meas}}} = \left(\frac{16.6 \pm 0.1}{\sqrt{E(\mathrm{GeV})}} \oplus (1.1 \pm 0.1) \right) \%$$

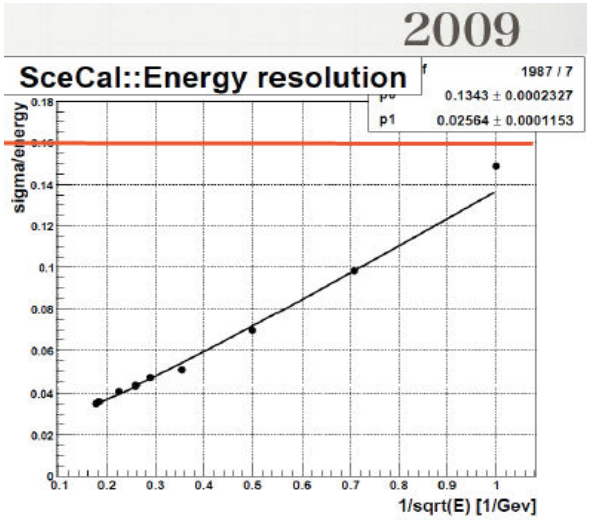
PFA ECAL: CALICE Scint/W ECAL

- Features 30 layers of planes with small scintillator strips ($10x45x3mm^3$) readout by MPP
- Physics prototype constructed and tested
  - At DESY in 2007 and at FNAL in 2008 and 2009



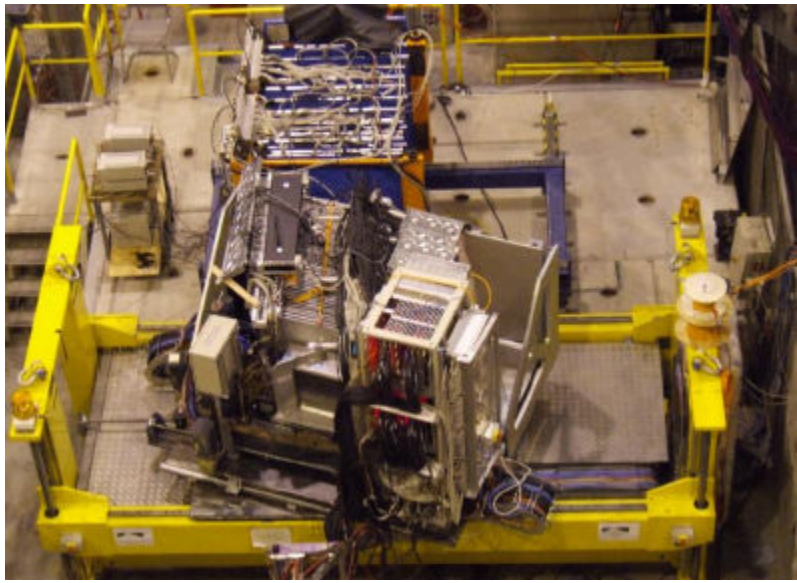


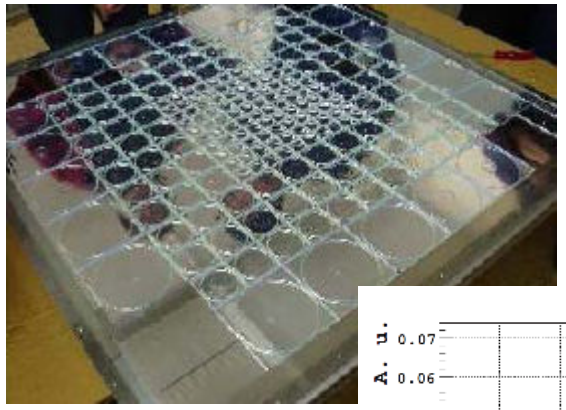


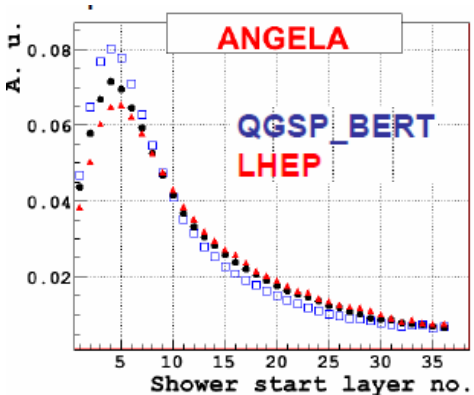


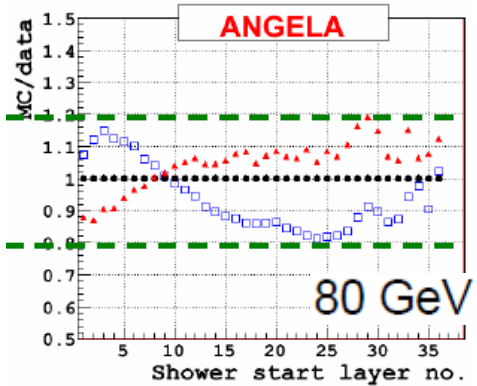
PFA HCAL: Scintillator AHCal

- Features 3x3cm^2 scintillator tiles and SiPM readout
- R&D well advanced: 1m^3 physics prototype beam test done
  - Scint plane tests at DESY starting 2005
  - Commissioning run at CERN 2006 followed by a high energy run in 2007and FNAL in 2008
  - Standalone and combined with Si/W and Scint/W ECALs

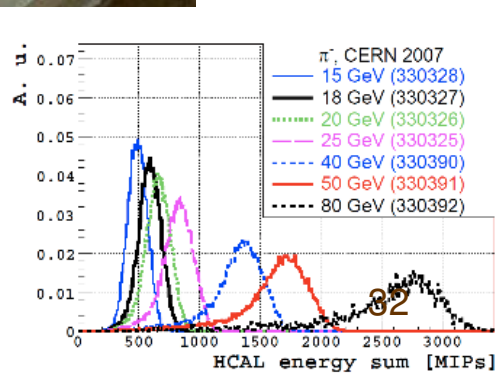






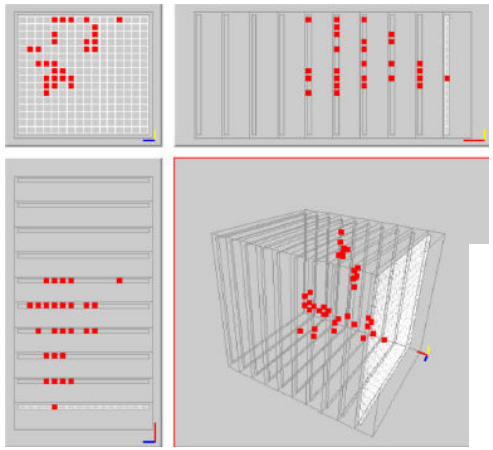


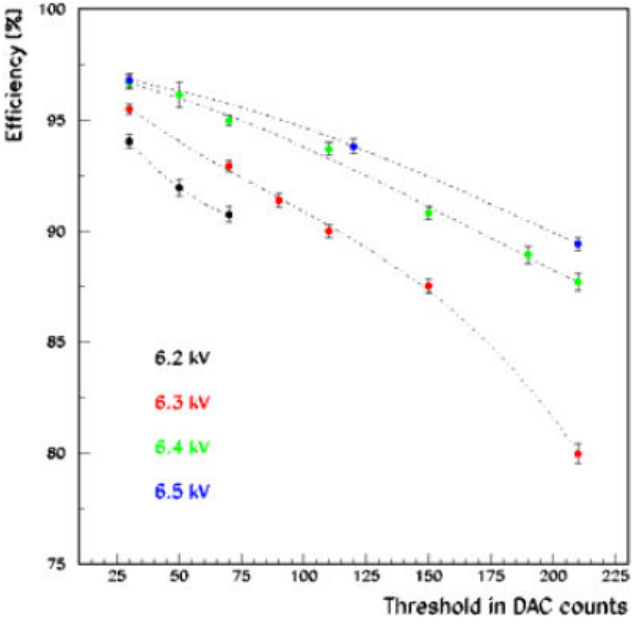
80 GeV pion run

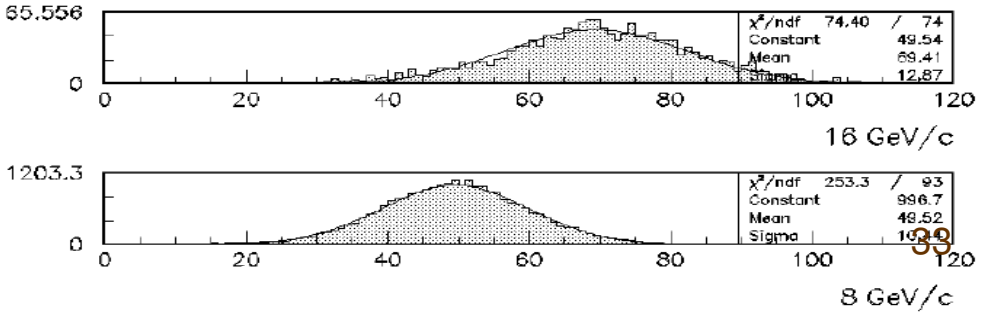


CALICE- RPC DHCAL Beam Test

- Performed a slice test at MTBF in 2007
  - Beams of 1 – 16 GeV hadrons and electrons
  - 120 GeV protons
  - Muons
- Published 4 papers in JINST
- One Ph.D. thesis expected shortly
- Another in the pipe
- 1m^3 run planned in 2010

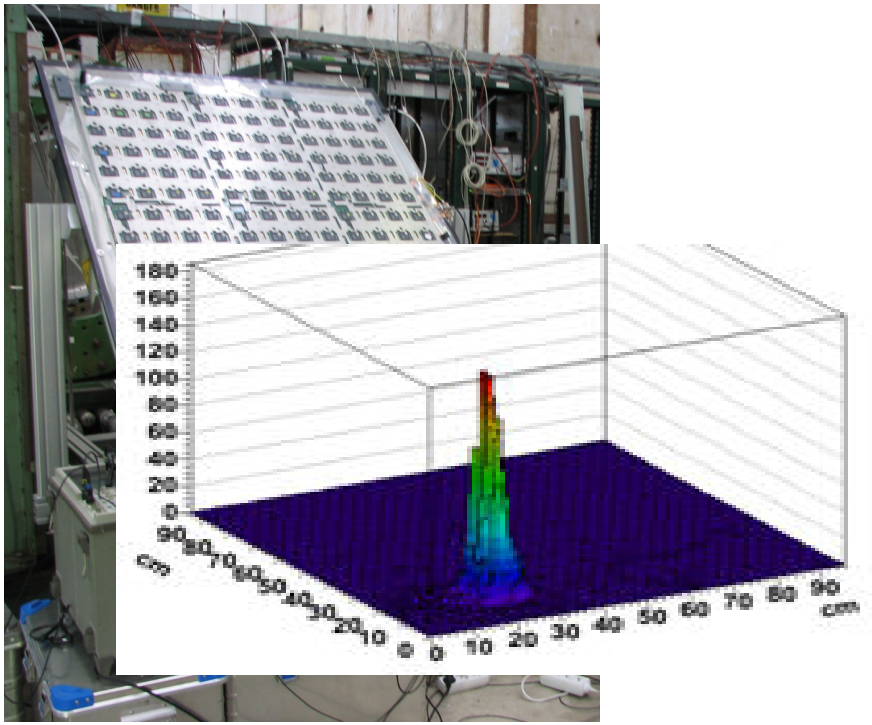






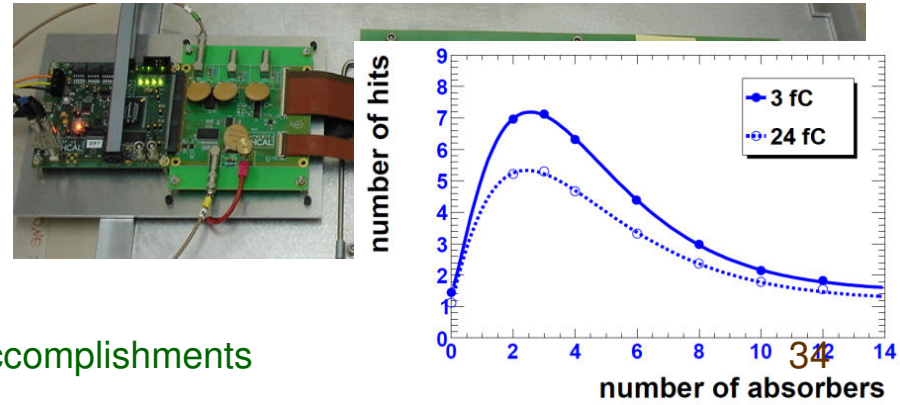
CALICE - Glass RPC and μ-megas DHCAL

- 2 beam tests @ CERN using mini-DHCAL with small GRPC
  - Efficiency/multiplicity
  - Hadronic shower study
  - High rate tests with semi-conductive glass (1010 Ω.cm)
  - 1m^2 plane tests



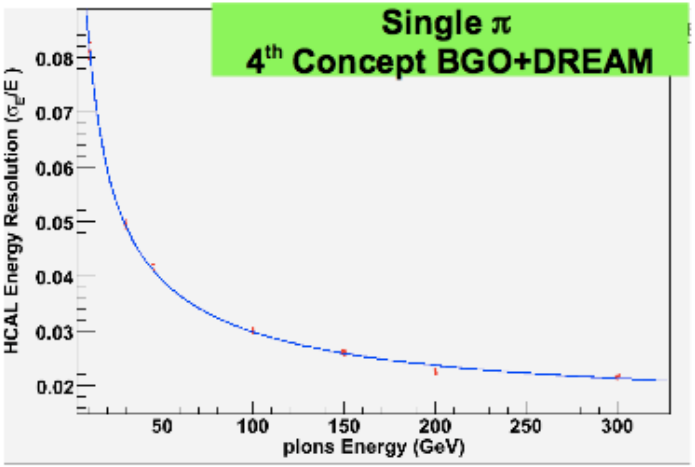
μ-Megas

- 2008 with 4 GASSIPLEX chambers at CERN
- 2009 with 4 GASSIPLEX + absorbers



Detector R&D - Calorimeter

- DREAM and 4th Concept
  - Several beam tests @ CERN since 2006
  - 17 NIM papers and 4 Ph.D. thesis



$$\frac{\sigma_E}{E} = \frac{29\%}{\sqrt{(E)}} \oplus 1.2\%$$

Detector R&D - Muons

- NIU+FNAL+WSU+UW team performed scintillation counter based muon system tests in 2007
- SiD Muon system performed a test on a few extruded scintillation counter strip prototypes in 2008 at MTBF
- New test on 284” strips using new electronics (TB4) with higher rate capability and double end readout being prepared
- But other teams seem to have become lower priority

Total of 12 CAL & Mu Projects in 2005

Calorimeter		Project	Lead institution
ECAL	1	Silicon-Tungsten (CALICE)	LAL, LLR
	3	Silicon-Tungsten (US)	SLAC, Oregon
	2	Silicon-Tungsten (Asia)	Ehwa Univ., Korea
	2	Scintillator-Tungsten	Shinshu
		Scintillator-Tungsten	Colorado
		Scintillator-Silicon-Tungsten	Kansas
		Scintillator-Silicon-Lead	Padova
HCAL	1	Scintillator-Steel AHCAL	DESY
	2	RPC-Steel (CALICE)	ANL
	3	GEM-Steel (CALICE)	UTA
Muon-detectors/tail catcher	1	Scintillator-Steel (CALICE)	NIU/DESY/FNAL
	2	Scintillator-Steel	FNAL/UCD/IU/NIU/ Notre Dame
	3	RPC-Steel	Frascati

Some activities merged and new activities arose since 2005!!

Detector R&D Needs

Detectors	N_Groups	Particle Species	P (GeV)	Magnet (Tesla)	N_Weeks /yr	ILC time structure	Note
BI&MDI	2E+8ESA+1 F+2C+3BC	e	up to 100	Not specified	64		Mostly low E elec
Vertex	10						
Tracker	3TPC+			→5~6			
Cal*	5 ECALs+3 DHCALs + 5 AHCALs	e, n, π, K, p; μ	1 → 120	Not specified	30 – 60	Yes	
Muon/TC MT	3	e, π, μ	1 → 120	Not specified	12		

Time to update this!!

*Note: Most calorimeter R&D activities world-wide are organized under CALICE collaboration.

Some of these can work concurrently!

ILC TB Roadmap Document Score Card

- Outcome of the 1st ILC TB Workshop at Fermilab
  - The document was released to the community, US funding agencies, facility managers and ILC leadership on Aug. 1, 2007
    - FNAL-TM-2392/KEK-Report-2007-3
- Recommendations
  - ✓ Urged to take actions on the loss of SLAC ESA
  - ✓ ILC-like beam time structure
  - ☑ Momentum Tagged neutral hadron beam
  - ☑ Trk-Vtx common beam test infrastructure w/ high field, large bore magnet
  - ☑ High test beam duty factor
  - ☑ Investigation into common DAQ hardware and software

Conclusions

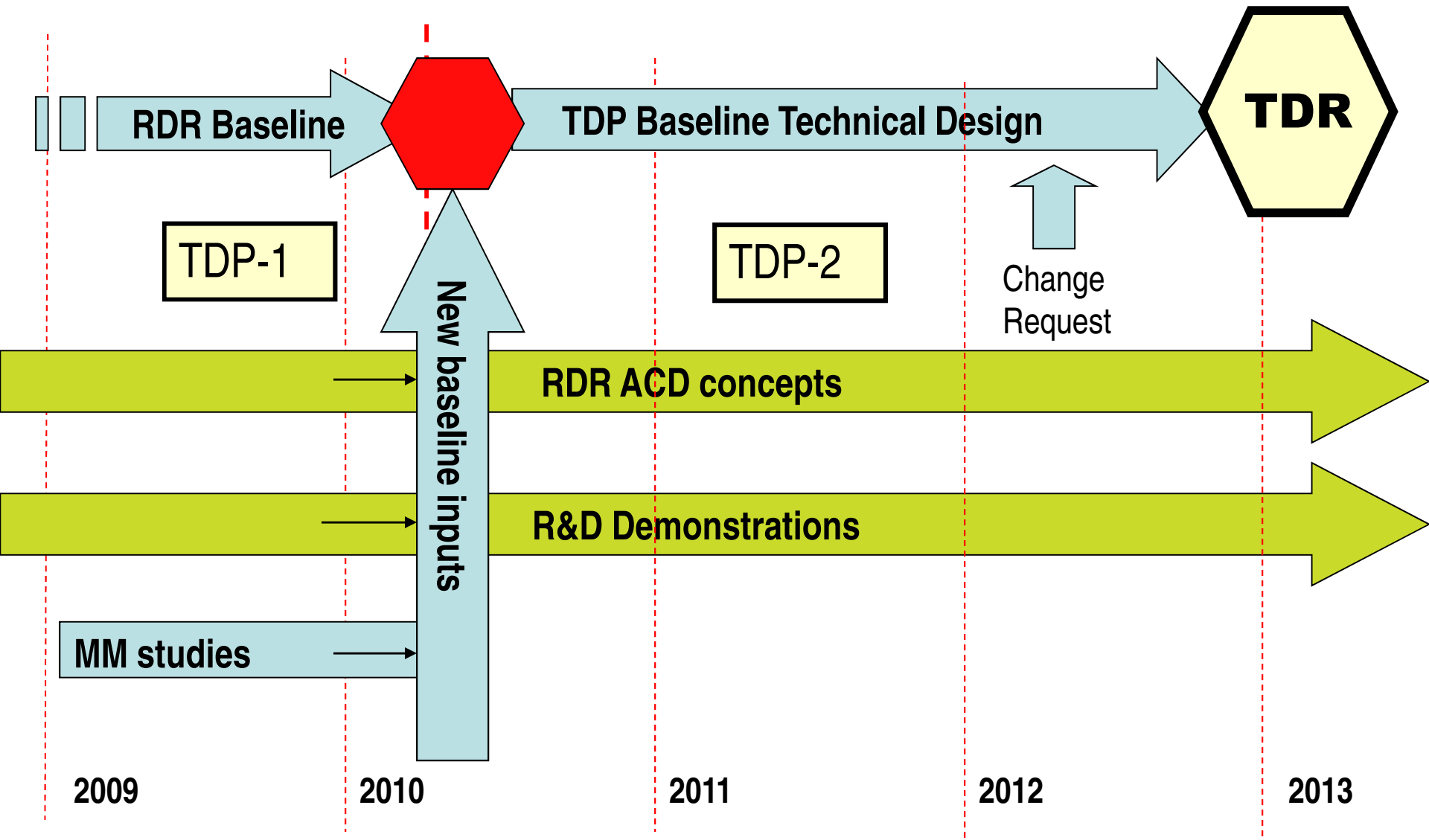
- Facilities have made continued improvements to meet the ILC detector R&D needs and are still working on making additional improvements
  - Success of SLAC's ESTB proposal will provide additional facilities in low E beams with LC time structure
- Shutdown of two Asian facilities would put more stress on existing facilities
- A lot of beam test activities in all detector groups
  - Beam test results are being published
  - Many R&D groups formed collaborations to take advantage of common needs
    - LCTPC, FCAL, CALICE, SILC, LC detector concept groups, etc

Conclusions, cnt'd

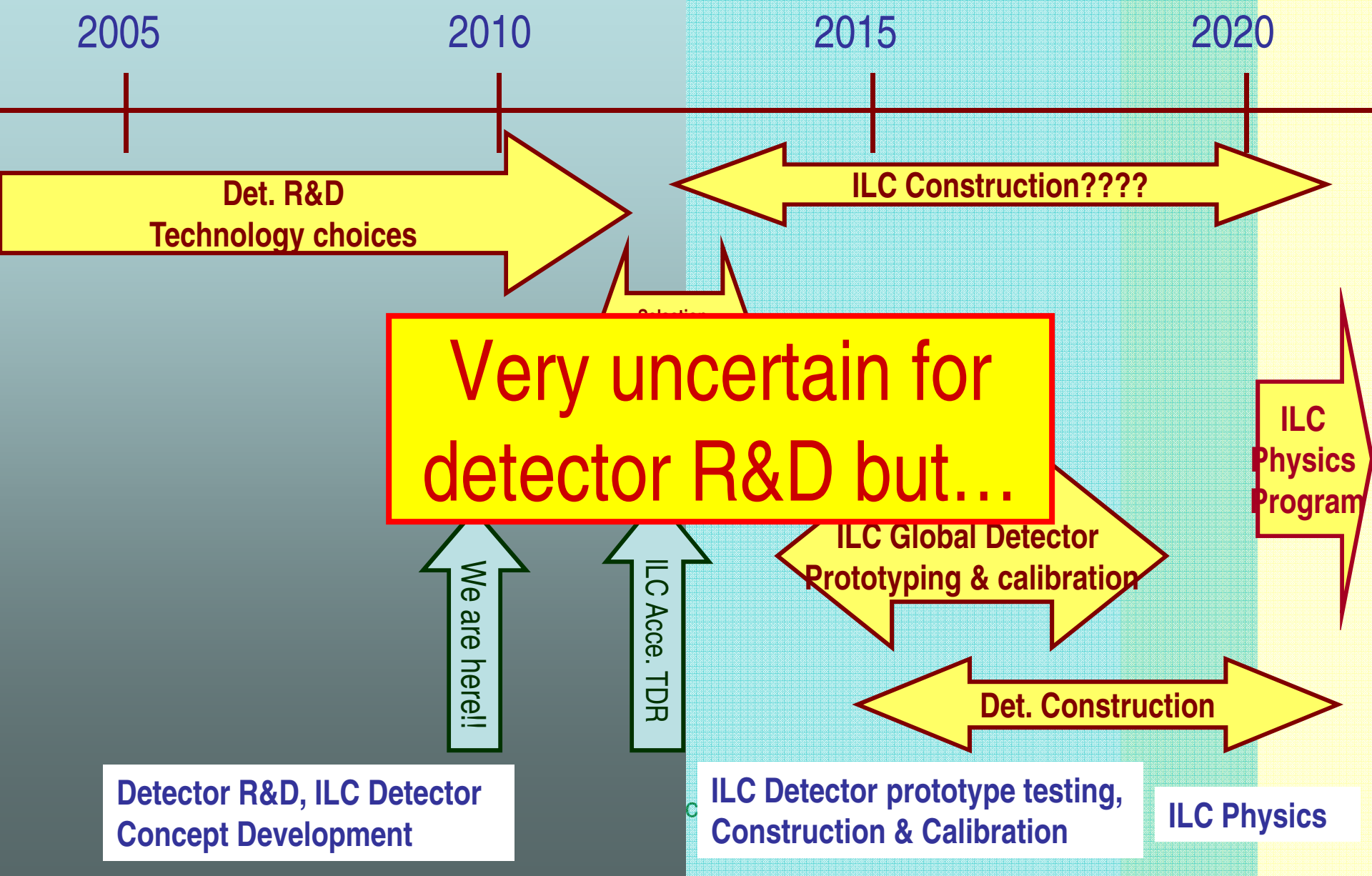
- Groups are moving toward larger scale technical prototype testing
- Collaborations are considering combined testing
  - TPC + SILC + VTX, CALICE ECAL+HCAL+TCMT

- Different kind of needs arises at different times ➔ Time for updates in beam test needs
- (I)LC's fate tightly coupled to the success of the LHC
- Times are hard and will not be easier but..
- Most these detector R&D and facilities upgrades are commonly usable for generic R&D
- Let's look ahead and keep making progress!!

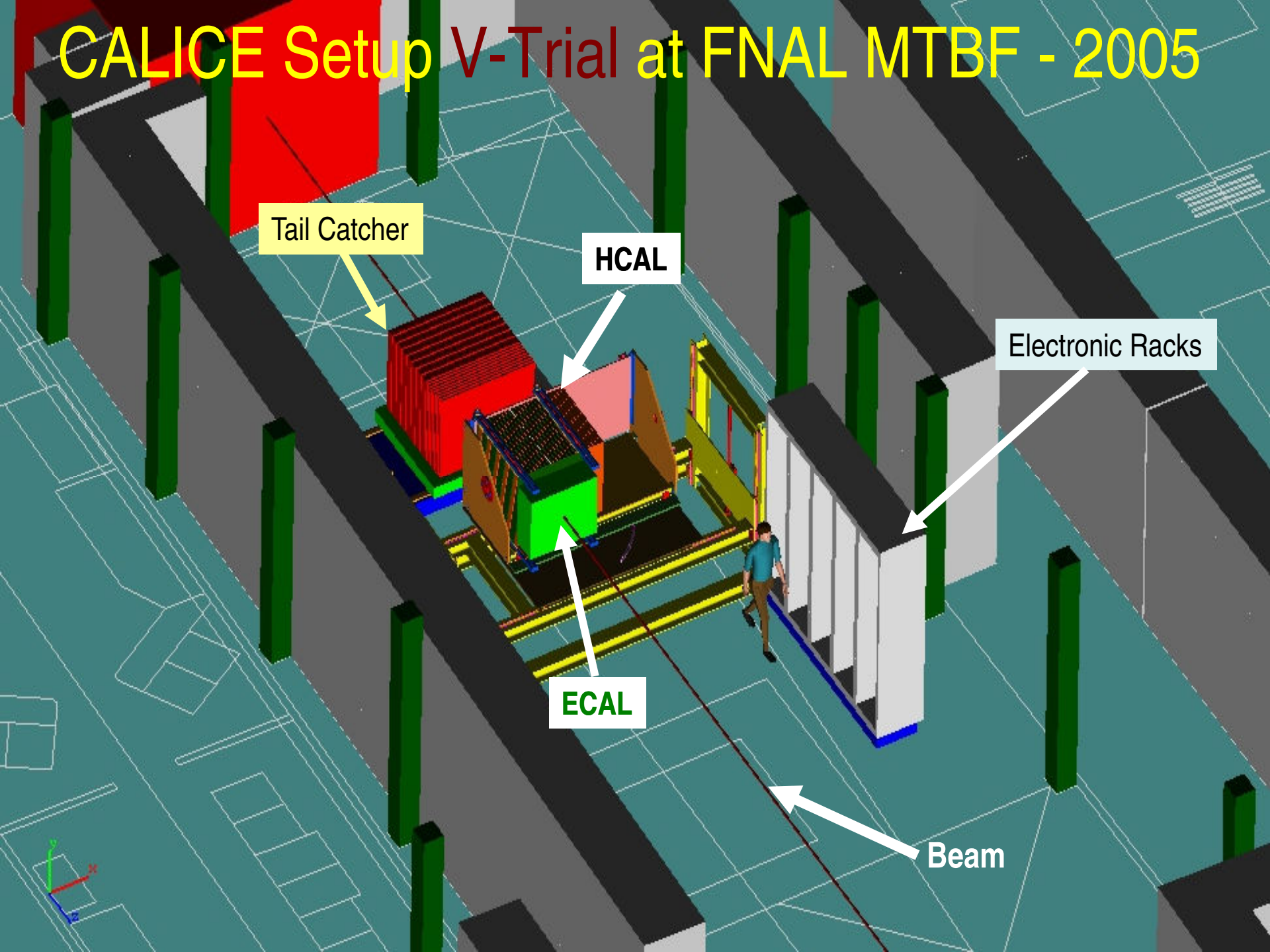
GDE ILC Technical Design Phase and Beyond



Epilogue… LC Detector Time Line in 2009???



CALICE Setup V-Trial at FNAL MTBF - 2005



CALICE 2008

We are real now and will continue to be!!!