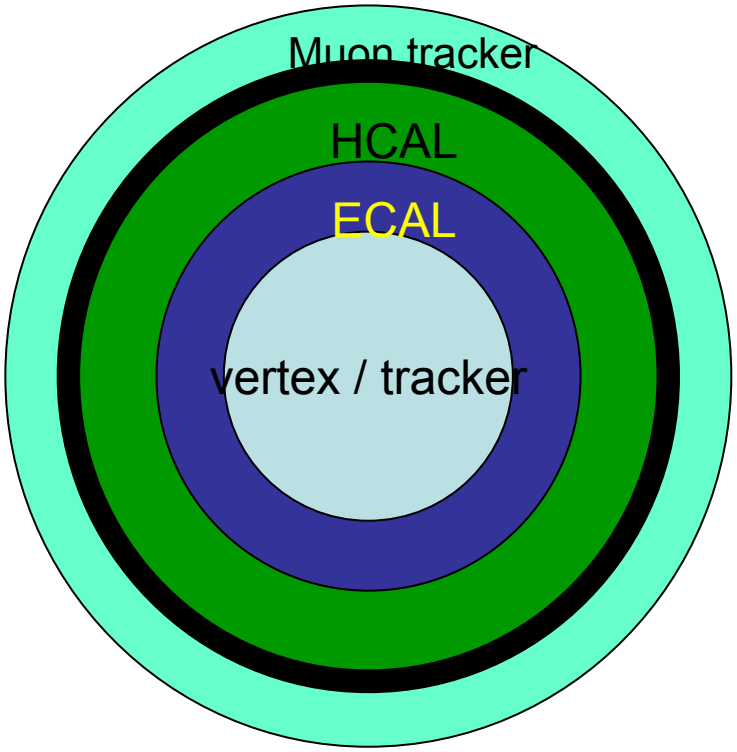
Status of Calorimetry at ECFA , Valencia

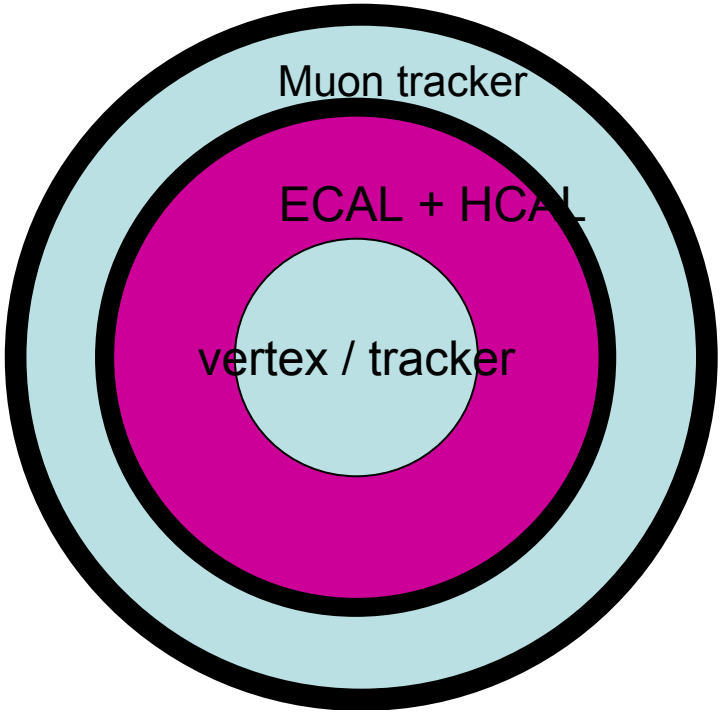
Erika Garutti (DESY)

Where do we stand in the design of a calorimeter system for an ILC detector?



Highly segmented
Highly granular
Calorimetric system

Optimized for Particle flow



Dual / Triple readout to
separate EM / hadronic showers

particle flow not mandatory

Where do we stand in the design of a calorimeter system for an ILC detector?

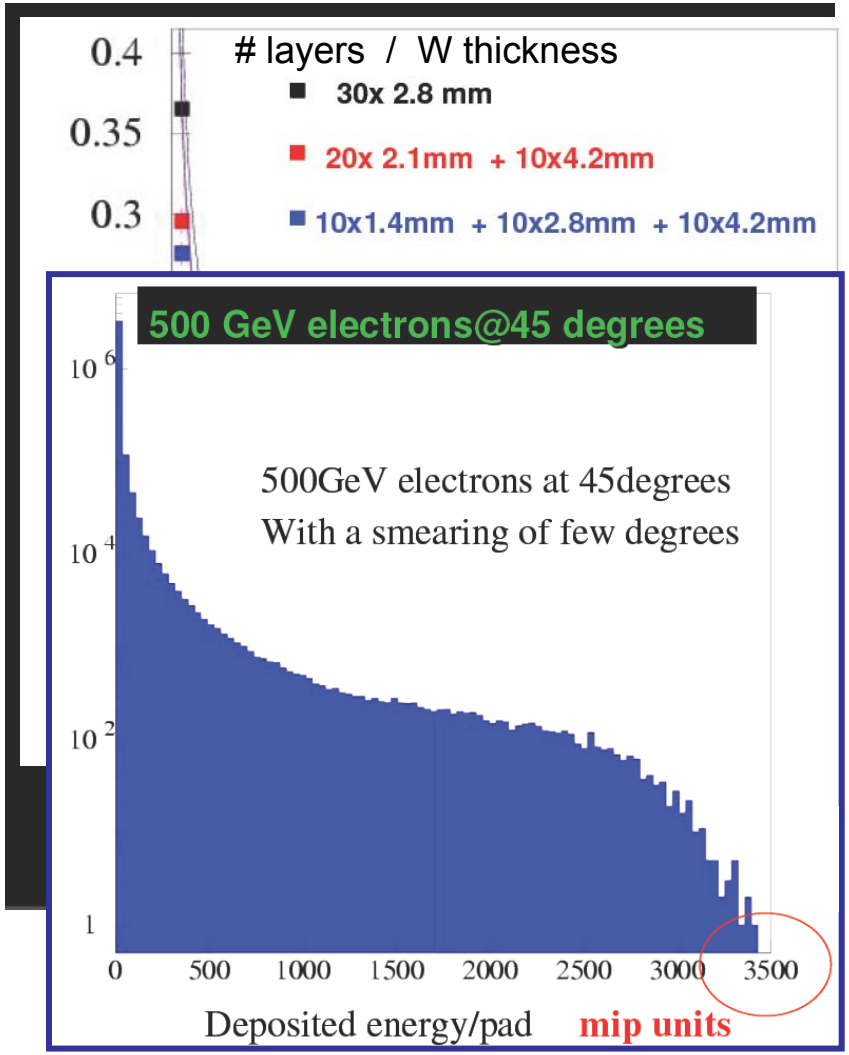
The ECAL

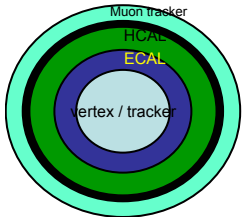
The recommendations from Henri:

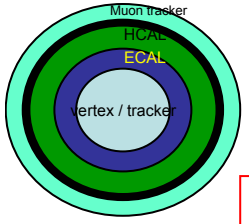
1) mind the gap !
   - gap < 5 cm (?)
   - extend end cap (+8 cm)

2) many samples but not too many samplings
   for W ECAL 2 samplings are a good compromise
   E <2 GeV for 30% γ in $\nu\nu$WW
   ➔ thinner sampling in first layers

3) pay good price for electronics
   dynamic range up to 3500 MIPs in one 5x5 mm pad (from 500 GeV e @ 45 deg)





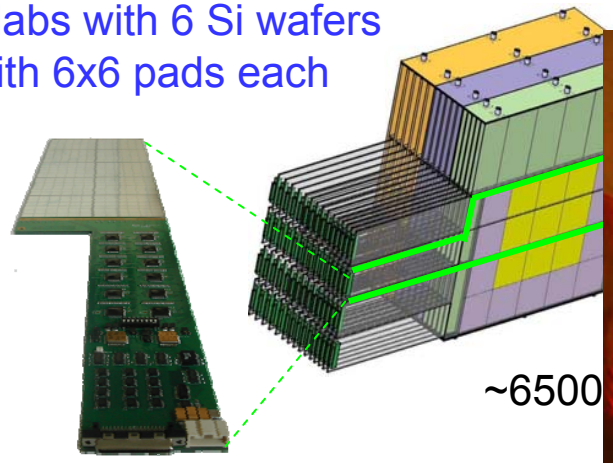


The CALICE Detectors

…"gone" to the CERN test beam … end of this talk

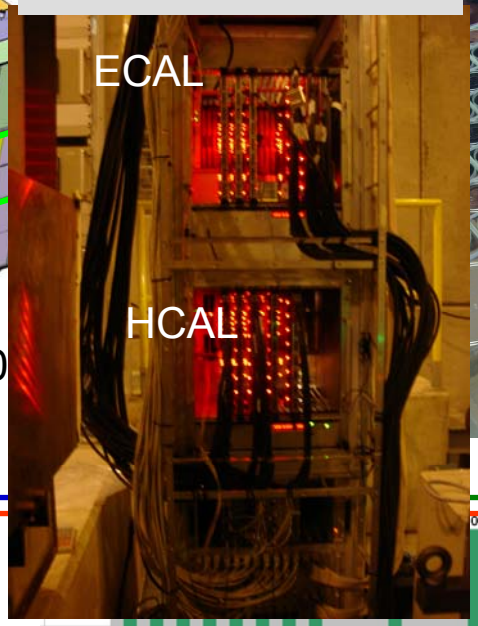
The Si-W ECAL:
- 30 layers of W with variable thickness ($24X_0$~1λ)

Slabs with 6 Si wafers with 6x6 pads each

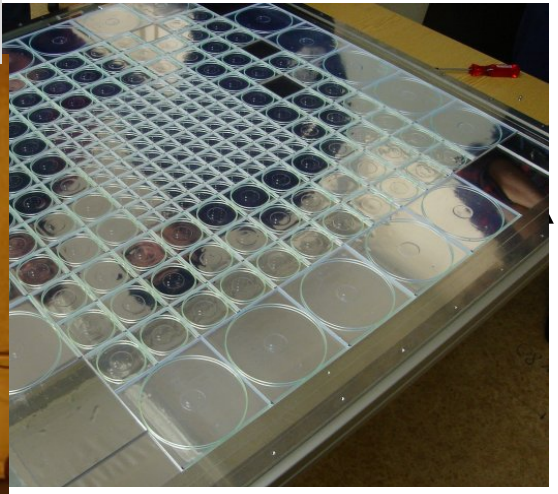


~6500

Common VME DAQ
18'000 ch

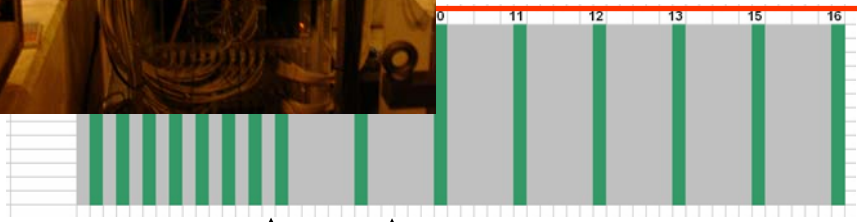


The A-HCAL, Scintil. Tiles+SiPM r/o:
38 active layers, segmentation 2 cm steel, ~4.5 λ
~8000 channels

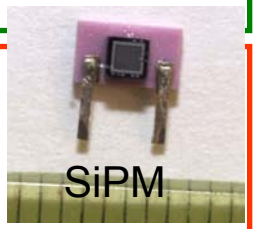


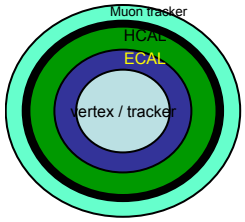
The Tail Catcher (TCMT),
Scintil. Strips+SiPM r/o:
fully equipped with 16 layers ~5.5 λ

= 320 channels



2 / 10 cm steel plates





The Digital HCAL

Only one contribution in Valencia (largely an American effort)

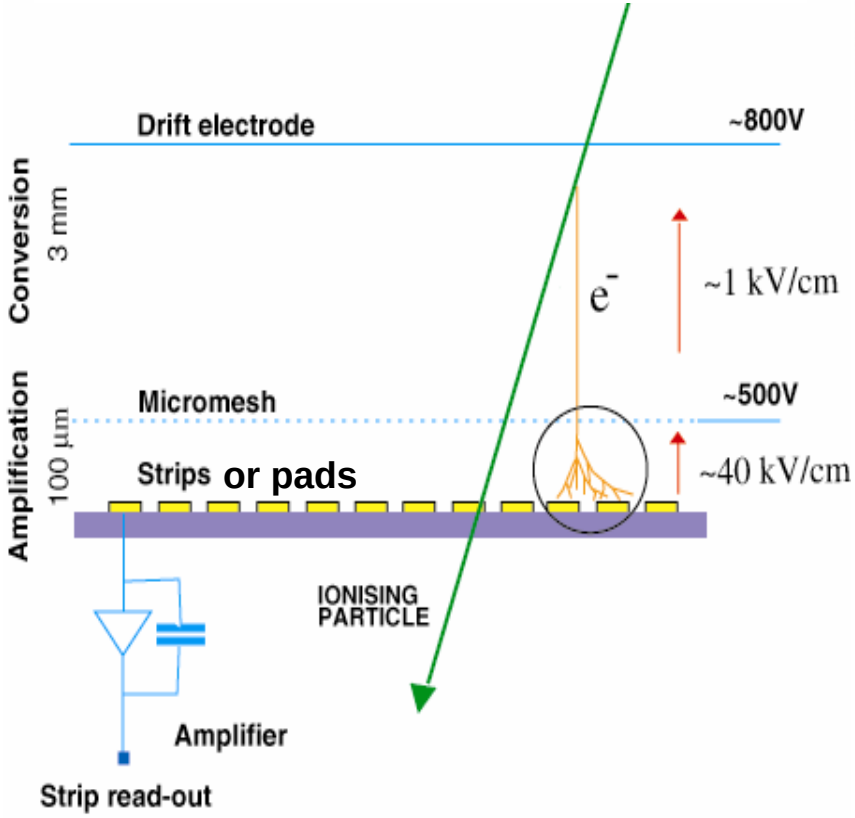
Already established R&D projects for DHCAL with:

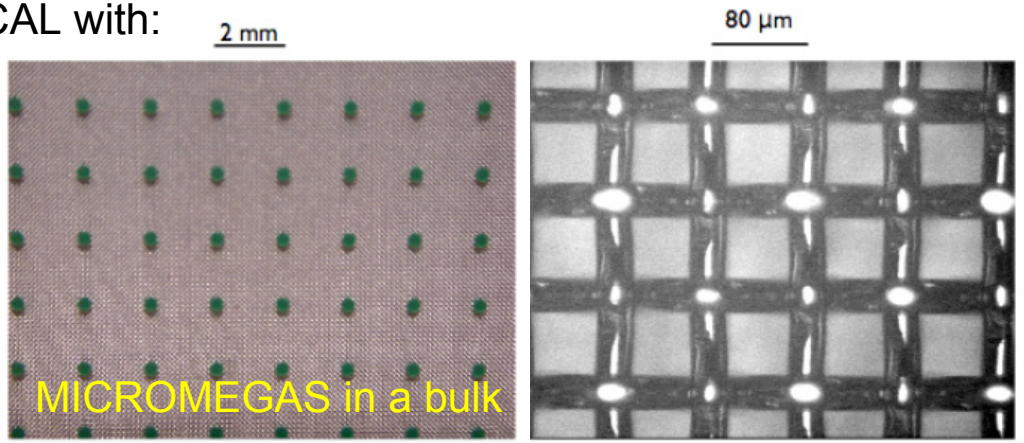
Resistive Plate Chamber (RPC)

Gas Electron Multiplier (GEM)

now

Micro mesh gaseous structure





Pillars: 400u Ø, 100u height

Ampl. gap 25-150µm → narrow avalanches excellent spatial and time resolution

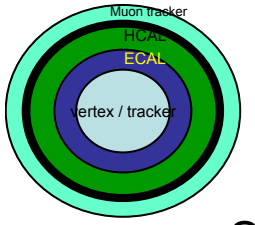
<u>3 sizes R&D</u>:

√ 16x6 cm² - 96 pads

- 48x48 cm2 - 2304 pads

-2x ~50x100 cm2 -4608 channels

➔equip one layer of the sandwich steel structure available for all technology comparisons

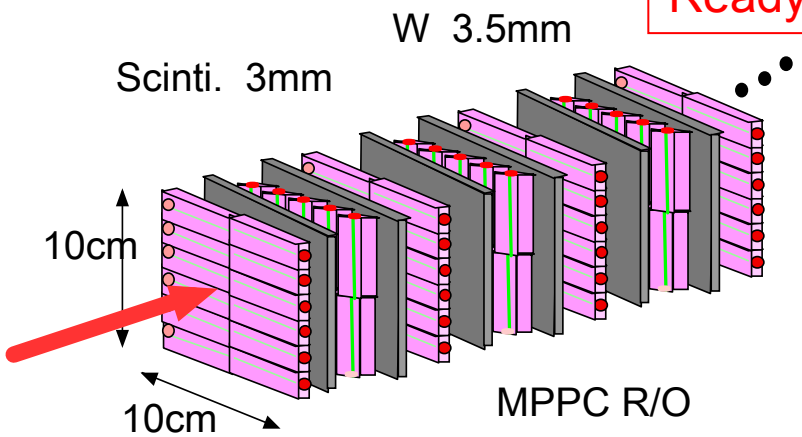


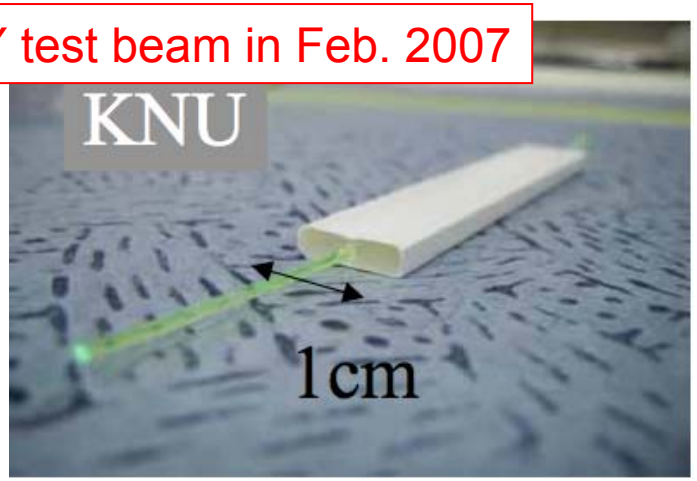
The ECAL: alternative R&D

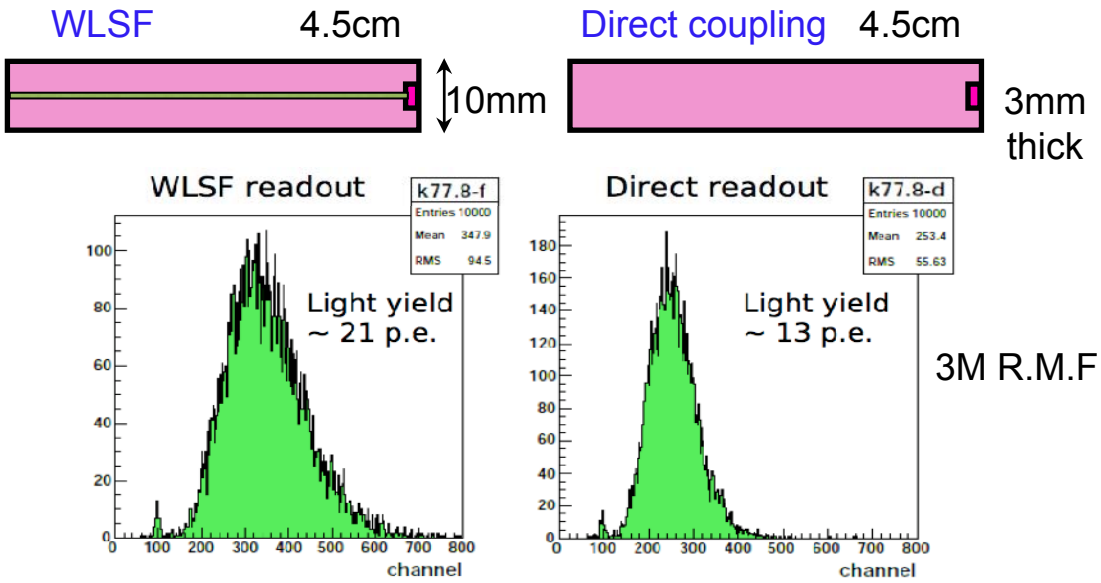
CALICE Calorimeter for ILC

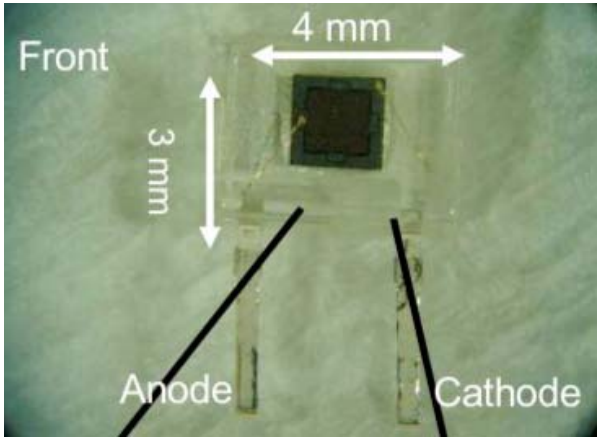
Scintillator – Tungsten sandwich structure

Ready for DESY test beam in Feb. 2007

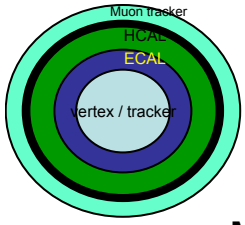








Multi-Pixel Photon Counter from Hamamatsu

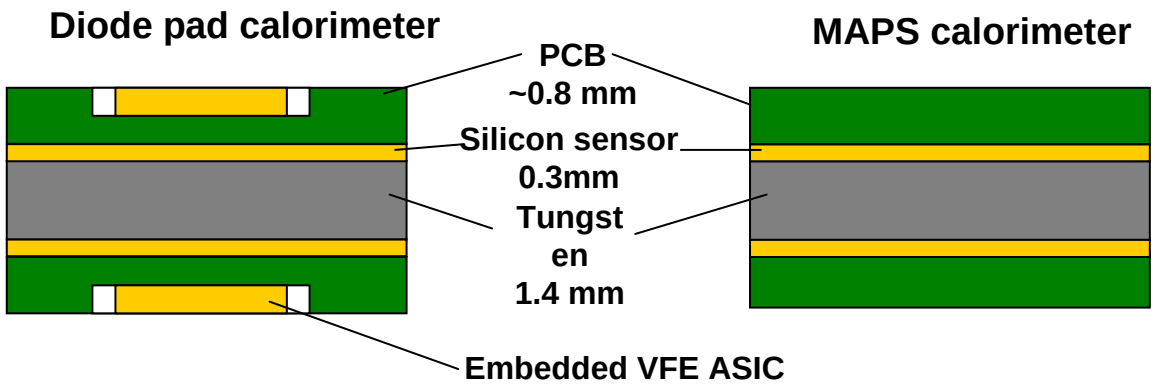


The ECAL: alternative R&D

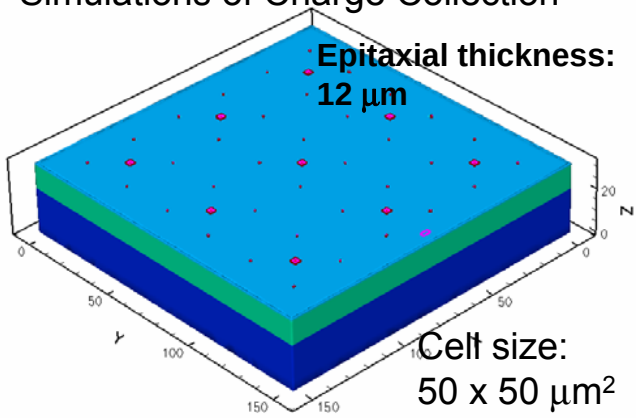
CALICE Calorimeter for ILC

MAPS based ECAL design

Monolithic Active Pixel Sensor



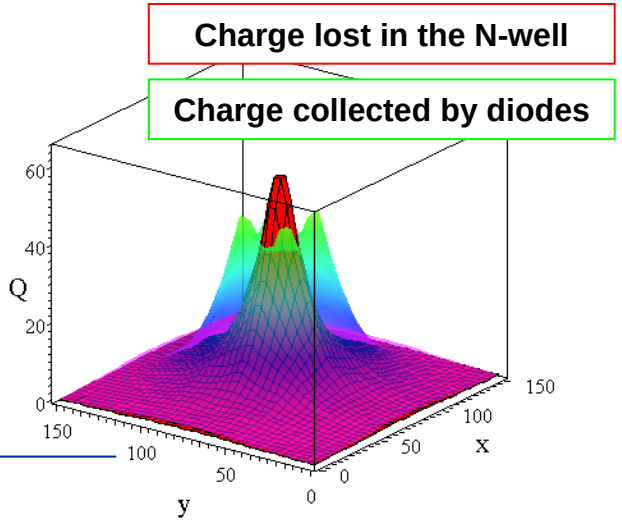
Pixel Design:
Simulations of Charge Collection



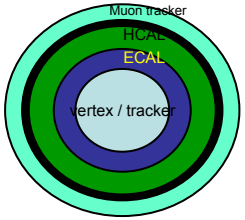
Full 3D simulation (TCAD Sentaurus)

Advantages in the MAPS design:

- High granularity: 50x50um² ➔ reduce the number of layers (??)
- uniform thermal dissipation from larger area
- MAPS + binary readout
- Cost saving (possible factor 2 between CMOS & Si wafers)
- Simplified assembly (single sided PCB, no grounding substrate)



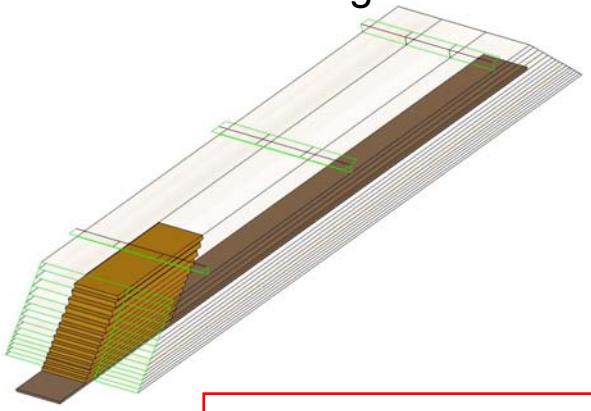
- Optimization of diode position and size for maximum signal and minimum crosstalk
- Goal is S/N > 15 by design



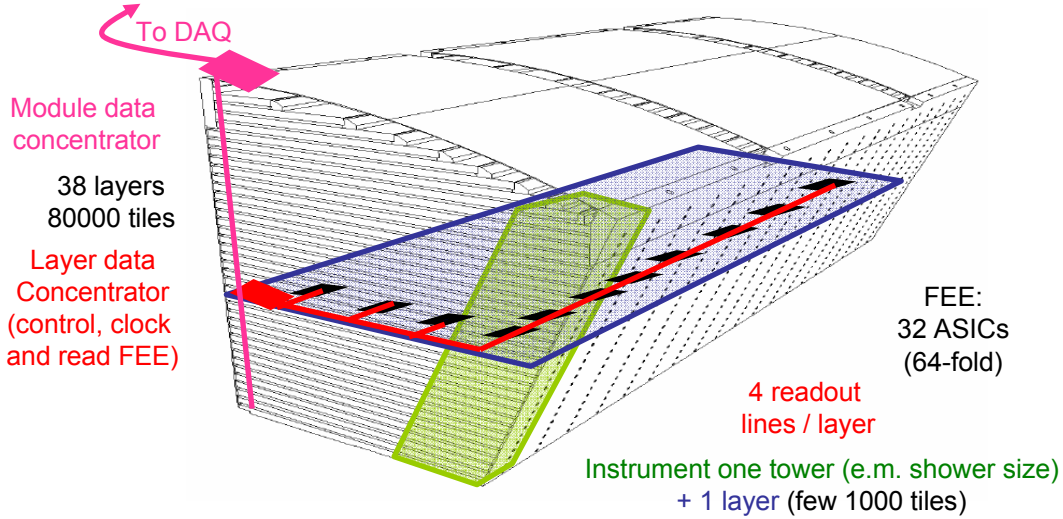
Generation II calorimeters

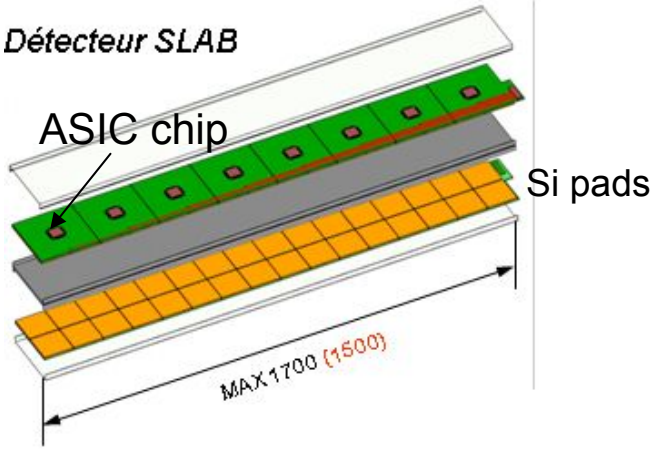
Scalable prototype for ILC detector

Si-W ECAL with integrated electronics



Elementary motherboard
'stitchable' 24*24 cm ~500 ch.





Second generation of ASICS now being designed

- -Power pulsing, Zero-suppress, Auto-trigger…
- -HArDROC for DHCAL Readout submitted sept 06
- -ECAL chip to be submitted in nov 06
- -AHCAL SiPM ASIC to be submitted in mar 07

System aspects to progress in parallel

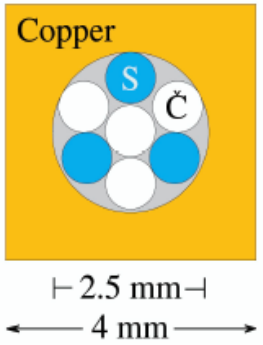
- -"Stitchable" PCBs for large module
- -Second generation DAQ
- -Power supplies ! Mechanics, reliability…
- -Low power low cost essential target

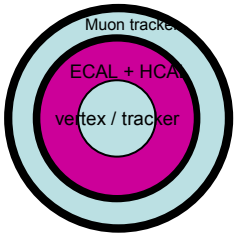
Where do we stand in the design of a calorimeter system for an ILC detector?

The Dual / Triple readout approach

Idea: complementary measurements of every shower suppresses fluctuations

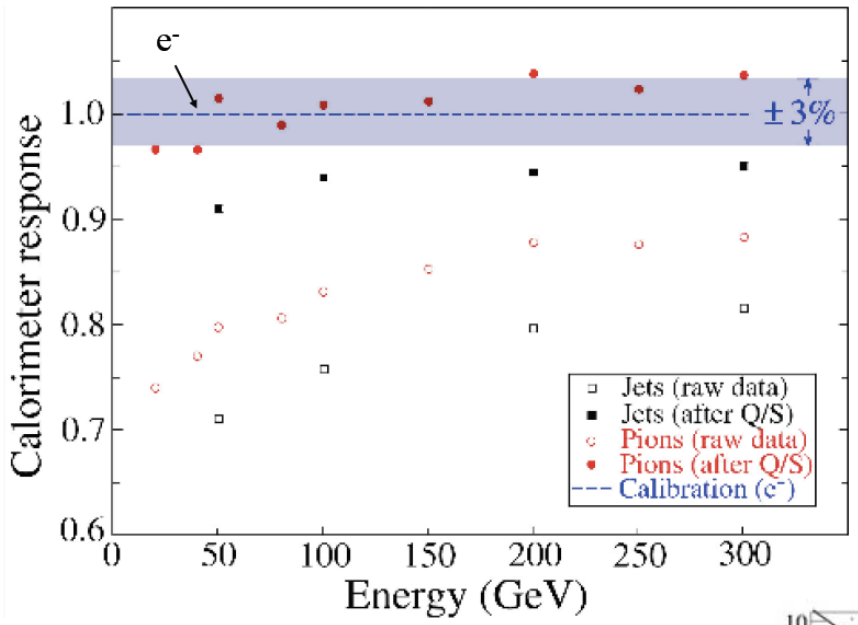
•Spatial changes in density of local energy deposit	•fine spatial sampling with SciFi every 2mm	• Like SPACAL (H1)
•Fluctuations in EM fraction of total shower energy	•clear fibers measuring only EM component of shower via Cherenkov light from electrons (E_{th} = 0.25 MeV)	• Like HF (CMS)
•Binding energy losses from nuclear break-up	•measure MeV neutron component of shower.	• Triple Readout





Also DREAM went to CERN test beam
… awaiting very interesting results at the next ECFA!

The Dual / Triple readout: the advantages



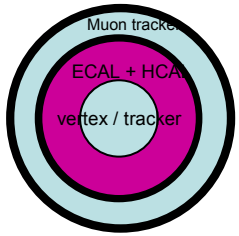
DREAM calibrated with 40 GeV e- into center of each tower
Using scint.+Ch amplitude

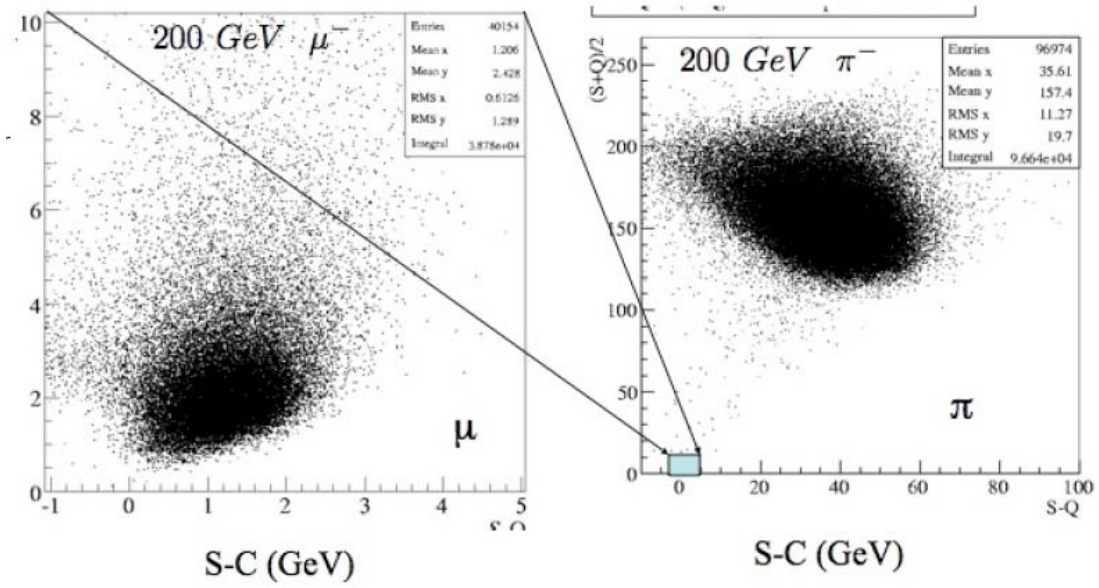
$$f_{EM} \propto (C/E_{shower} - 1/\eta_C)$$

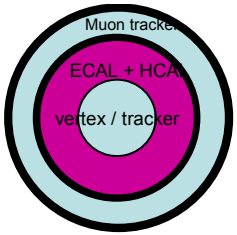
➔Linearity of hadronic response

π / μ separation in DREAM

π rejection:
10^{-3} (10^{-4}) @ 20 (200) GeV



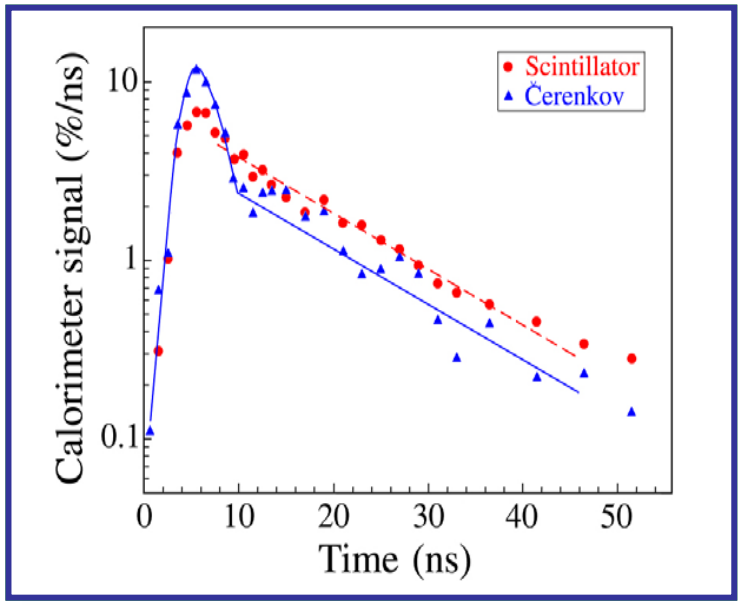


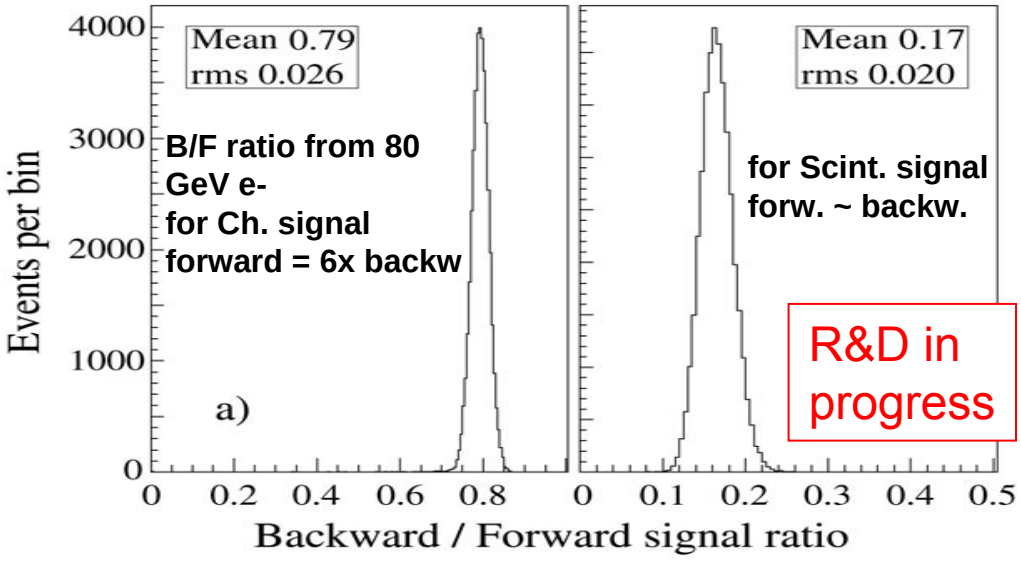


Identified open issues

1. Photon separation / reconstruction
   - electrons and photons limited by photo-statistics
   - study dual readout of single $PbWO_4$ crystal of smaller area (1x1 cm^2 ?)
2. Readout of MeV neutrons from hadronic shower (reduce binding energy fluctuation)
   - Fast-Slow discrimination on time spectra of Scint. and Ch. light pulses
   - using a third type of scint. fiber: "hydrogen-rich", Lithium-loaded or Boron-loaded

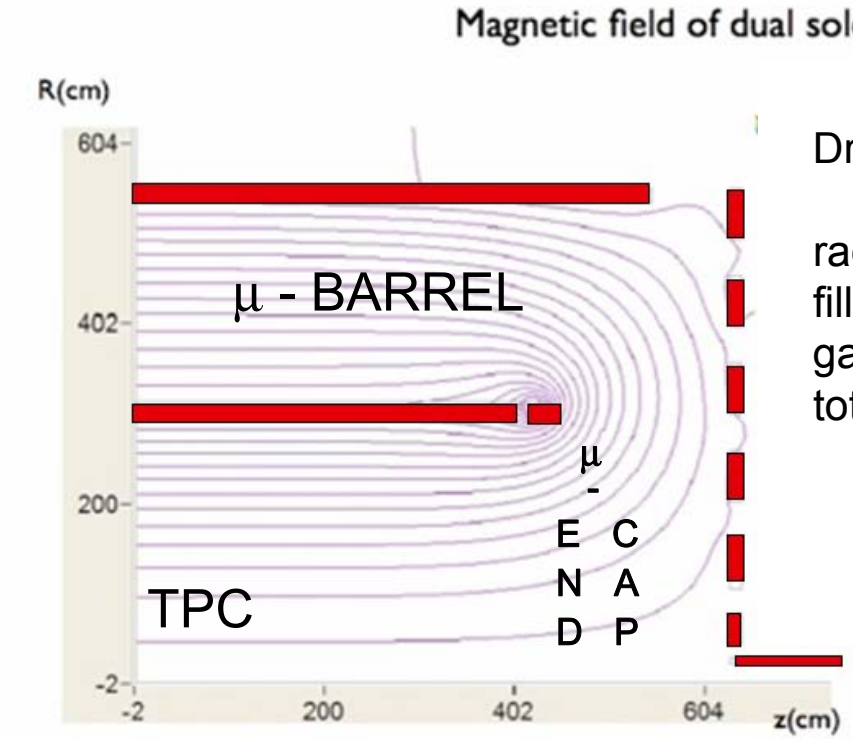
3. New R&D:
   - separation of scint. and Ch light using light direction info
   - SiPM with integrated electronics, FADC (B field sensitivity)





R&D in progress

The muon system



Drift Tube system:

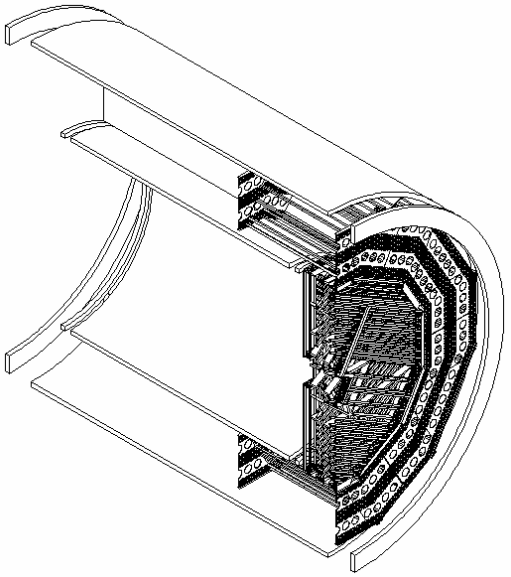
radius 2.3 cm
filled with 90% He – 10% iC_4H_{10} @ NTP
gas gain few × 10^5
total drift time 2 μs

Advance design
Mechanical considerations

Barrel:
31500 tubes
21000 channels
840 cards

End caps:
8640 tubes
9792 channels
456 cards

Total:
40140 tubes
30792 channels
1296 cards

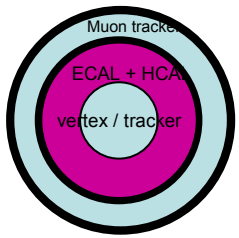


Expectred transverse momentum resolution from cluster counting

$\Delta p_\perp/p_\perp = 3.0 \times 10^{-4}\, p_\perp \oplus 1.6 \times 10^{-2}$

(barrel)

dominated by multiple scattering

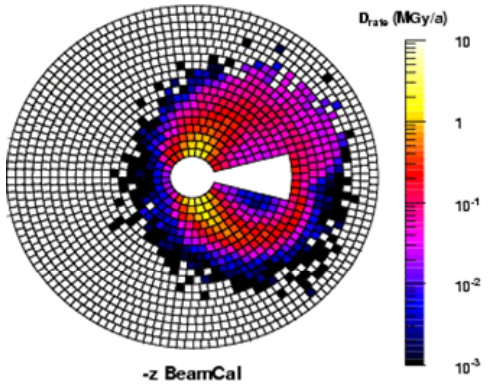


Forward calorimetry: the BeamCal

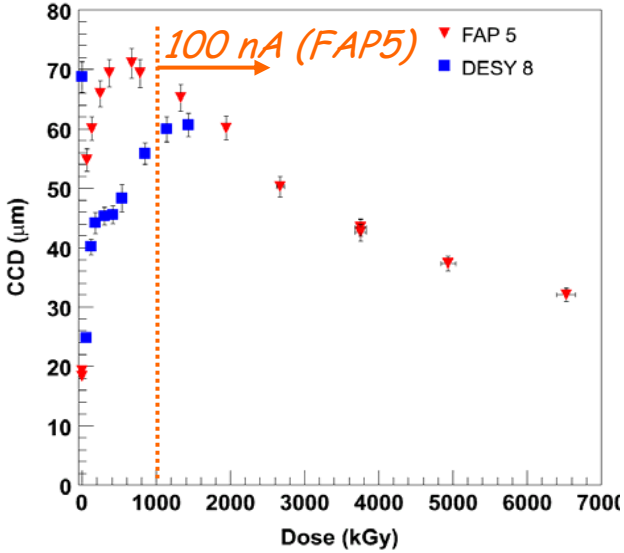
~15000 e^+e^- per BX from beamstrahlung into BeamCal

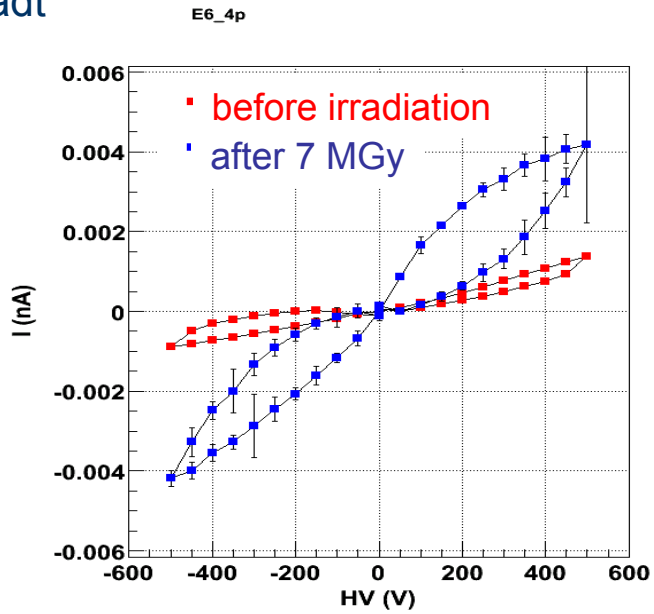
~ 10 MGy per year ➔ radiation hard sensors

≈ 5 MGy/a



Test beam at CERN PS and at
Superconducting DArmstadt LINear ACcelerator
Technical University of Darmstadt





Polycrystalline
Chemical Vapor Deposited
Diamonds

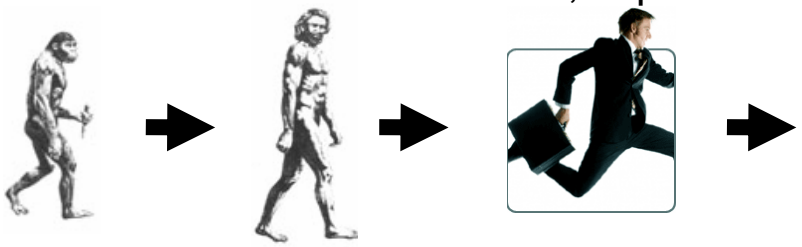
High dose from 10MeV electrons shows:
-all CVD diamonds stay functional after 7MGy
-degradation of the signal at high doses
-wide variation of the signal sizes as a function of the absorbed dose is an issue

Conclusion

-Investigate also other materials (GaAs, SiC)
-Successfull irradiation-testbeam at S-DALINAC to be repeated with other types of sensors

The Future of photo-detection
Geiger mode silicon photomultiplier

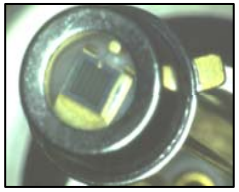
MPPC from Hamamatsu, Japan

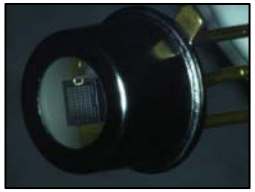


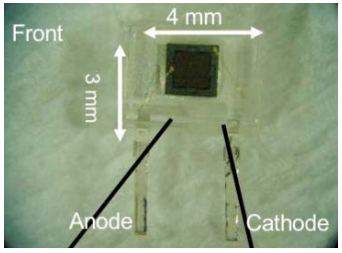
Mar. 2005
.100/400 pixels

Jan. 2006
up to1600 pix

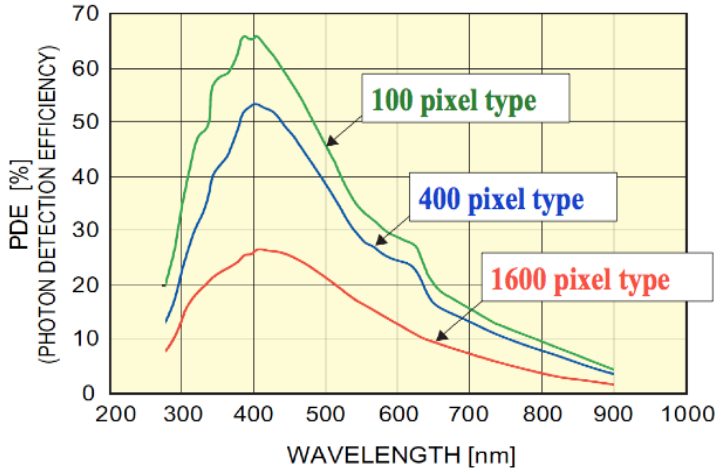
Oct. 2006
100/400/1600 pix







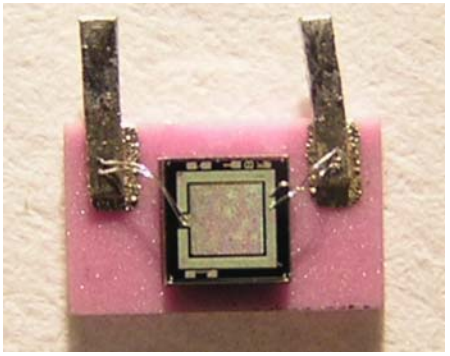
Blue sensitive !!!



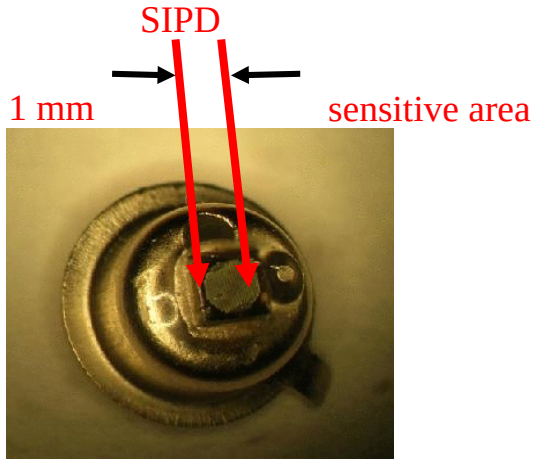
http://jp.hamamatsu.com/en/hamamatsu/press/2006/2006_10_26.html

Hamamatsu
MPPC
are on the
catalogue!

SiPM MEPHI / PULSAR, Moskow

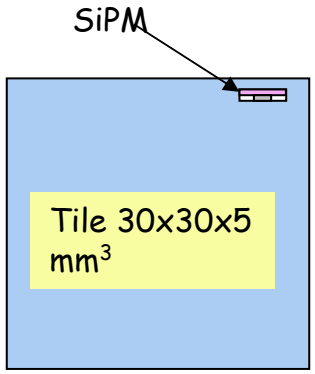


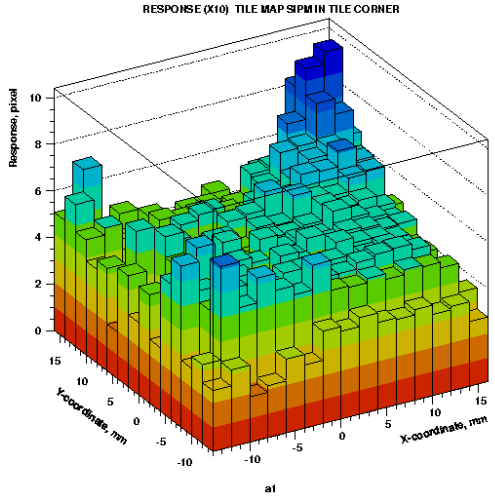
CPTA from Photonique, Switzerland



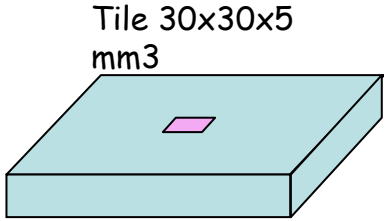
SENSL, Irland
Is coming…

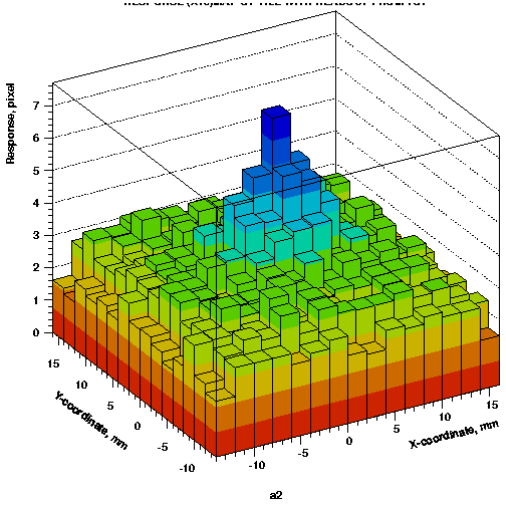
SiPM coupling to tile/strips

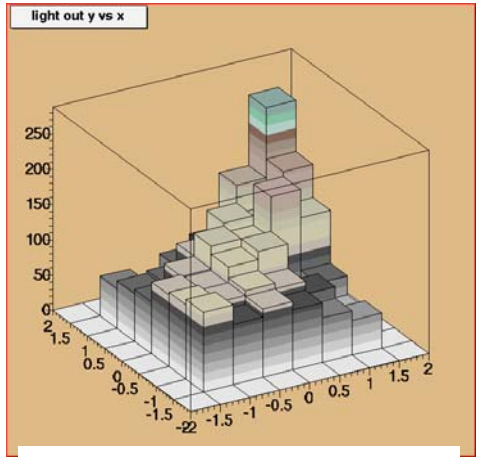




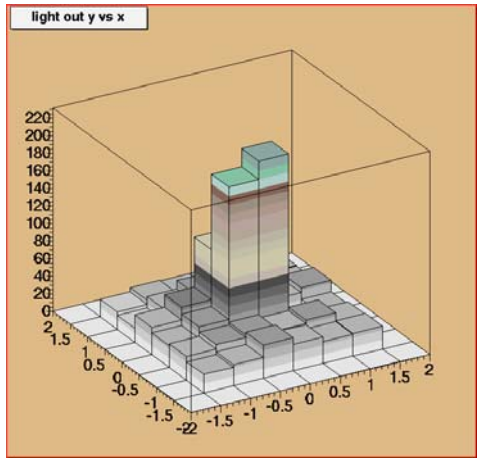
Data from ITEP Test beam







G4 photon simulation



New forces joining the field:

welcome to INFN groups: Frascati, U. of Rome, “La Sapienza” and INFN Rome

INFN R&D on SiPM Applications to ILC Calorimetry:

- Present INFN activities (CSN-5)
  - FACTOR, V. Bonvicini et al., (Trieste/Udine/Catania) - SiPM for readout scintillating-fibers, development of readout electronics.
  - DASIPM2, G. Del Guerra et al., (Pisa, Bari, Bologna, Perugia, Trento) - medical applications (high resolution PET), space physics, HEP

- New founded activities (CSN-1)
  - Realization of small prototypes using various SiPM with different scintillator types...
  - Test opportunityat the Frascati Beam Test Facility to study:

➔ Good collaborative relations INFN groups - Italian producer of SiPM: ITC-IRST

ILC Detector Test Beam Workshop

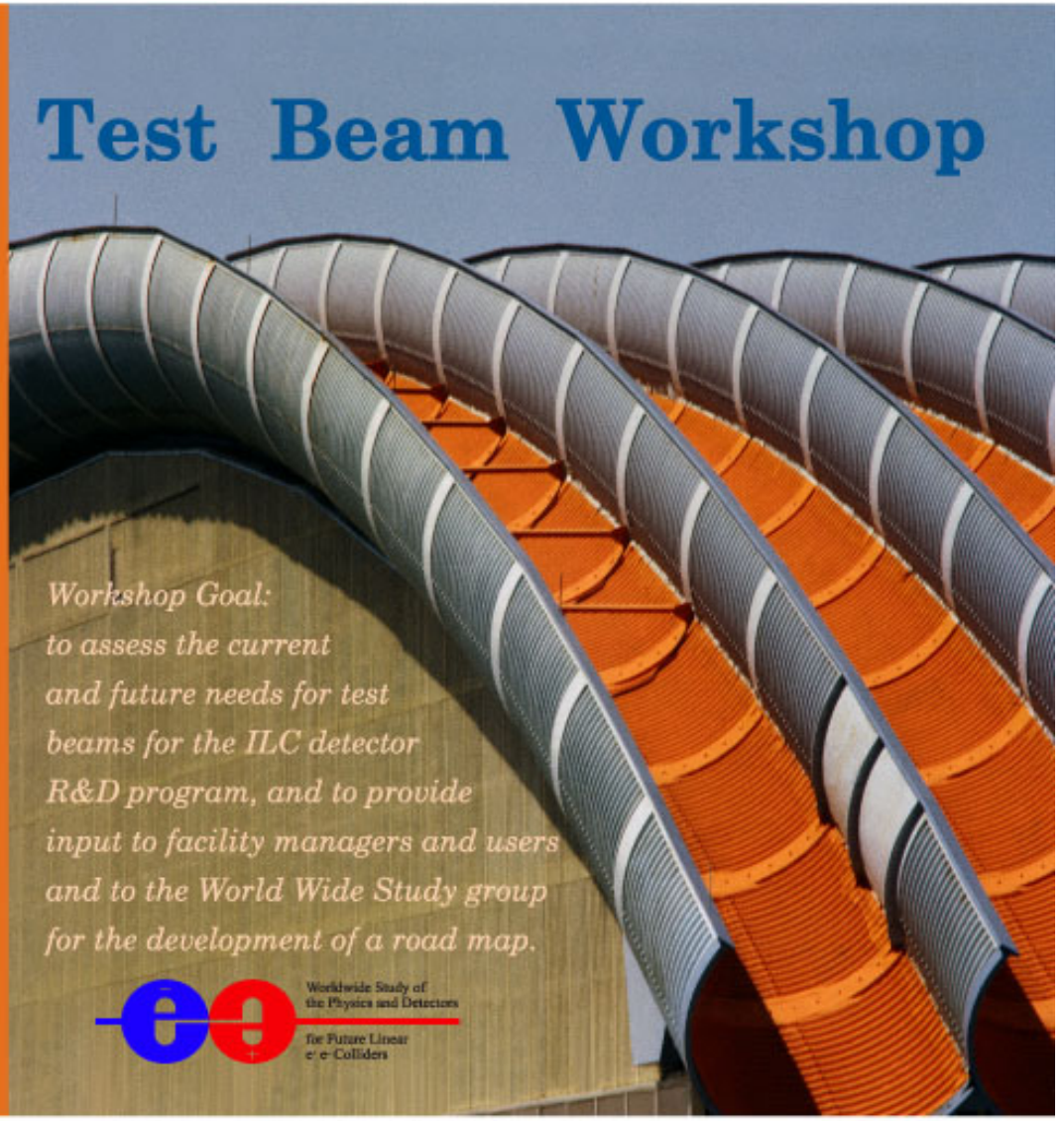
January 17 - 19, 2007

Fermilab, Batavia, Illinois, USA

Organized by

World Wide Study Test Beam Working Group

http://conferences.fnal.gov/IDTB07/

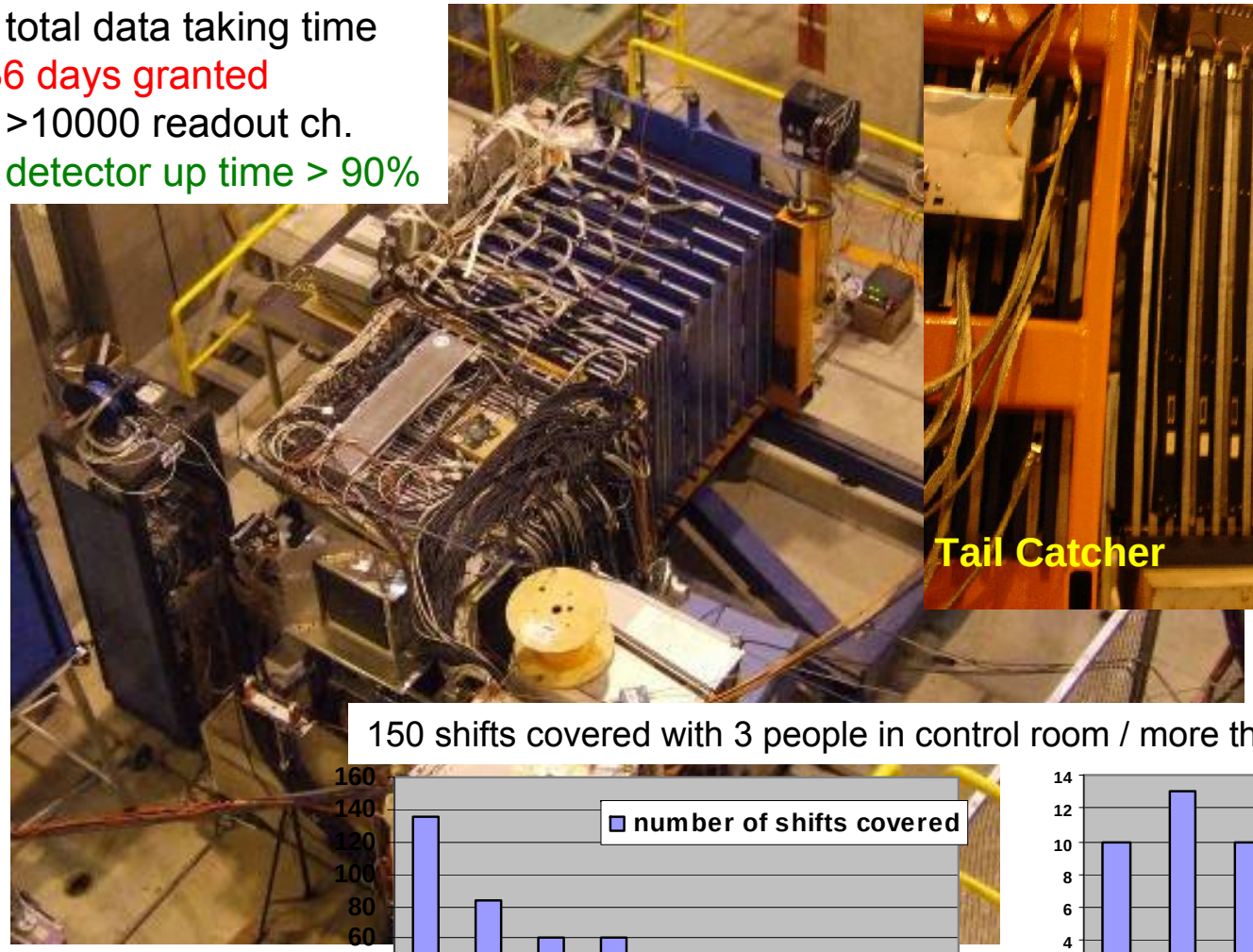


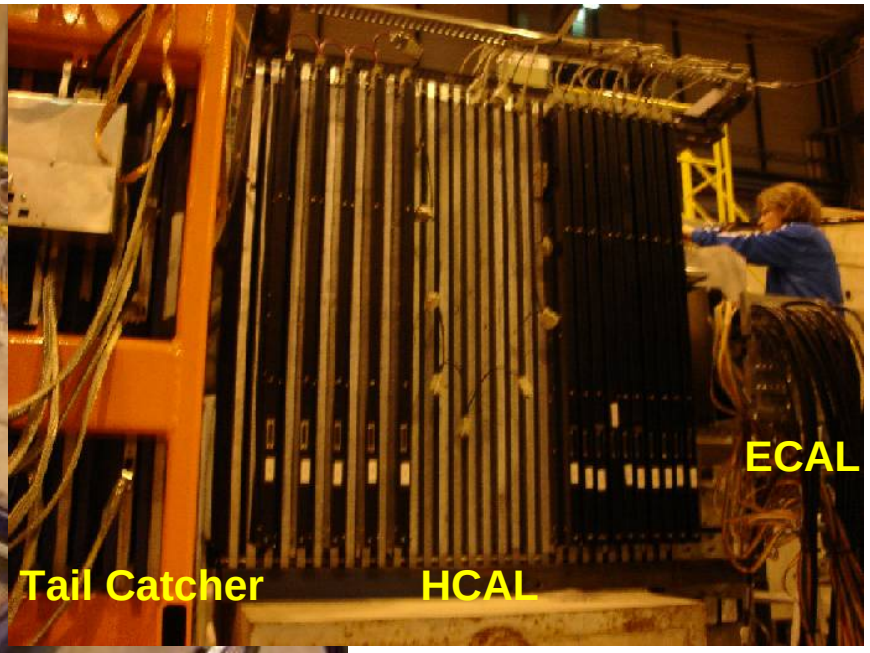
Workshop Goal:
to assess the current and future needs for test beams for the ILC detector R&D program, and to provide input to facility managers and users and to the World Wide Study group for the development of a road map.

Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

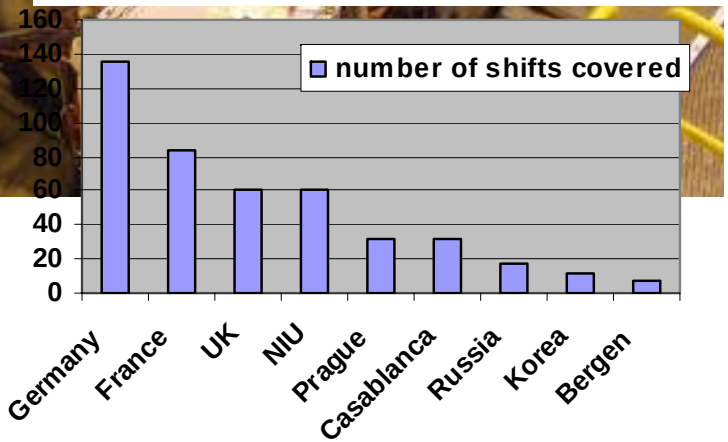
“Large scale” Test Beam activity

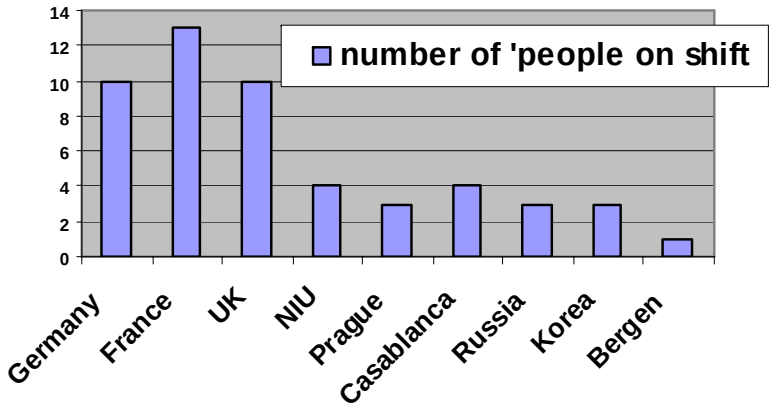
- total data taking time
36 days granted
- >10000 readout ch.
- detector up time > 90%





150 shifts covered with 3 people in control room / more than 50 people from all institutes

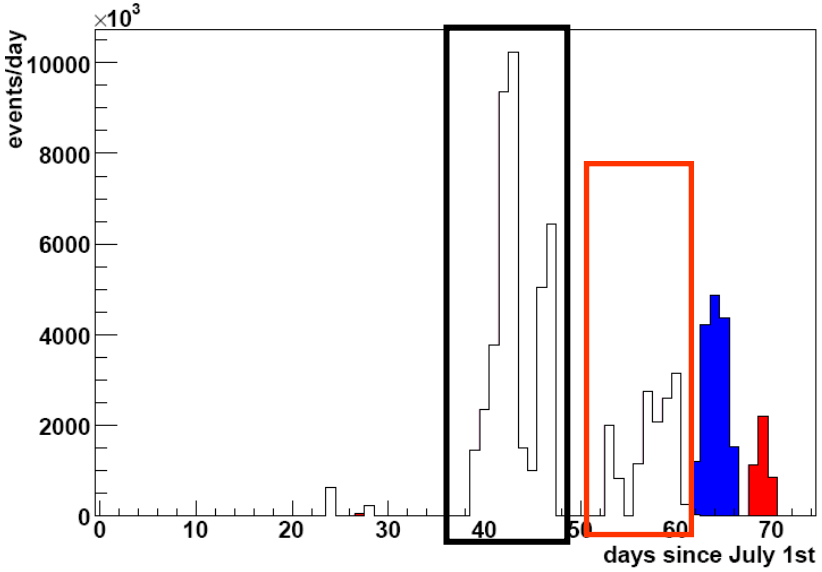


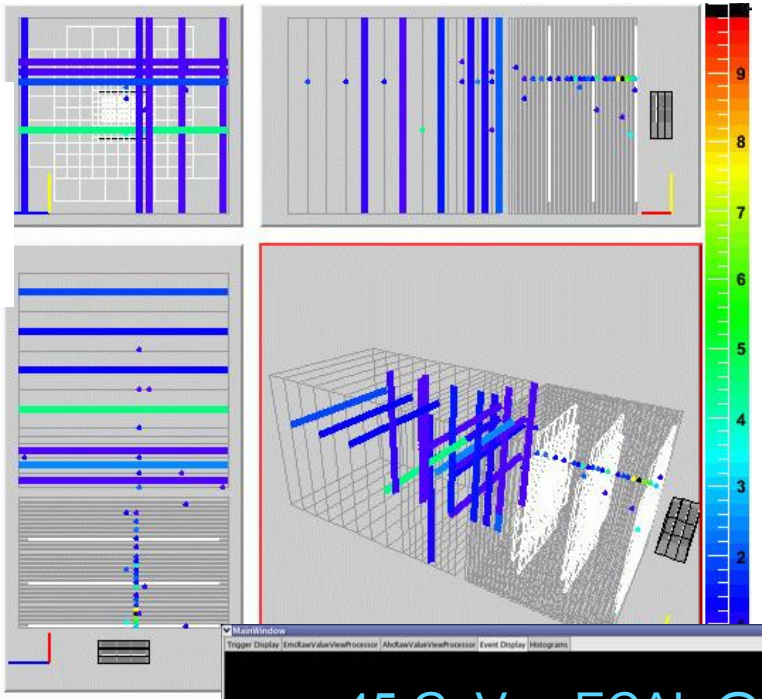


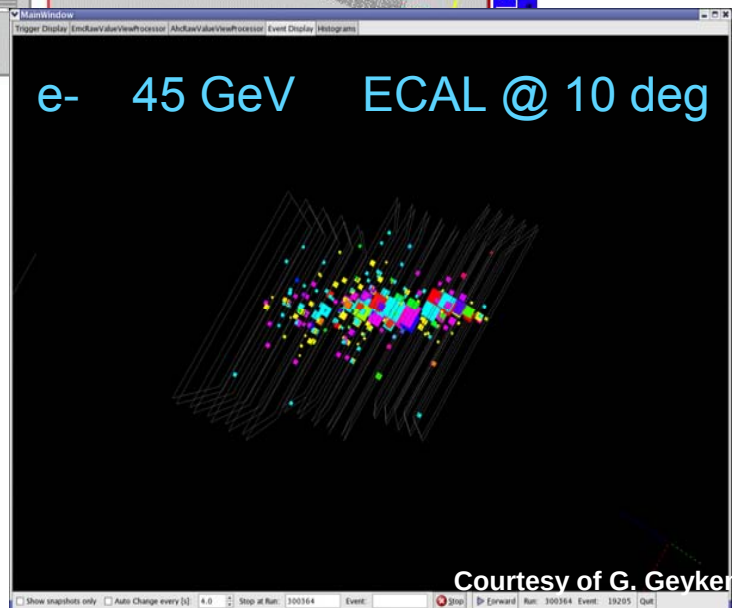
CALICE
Calorimeter for ILC

The data taken (1st period)

parasitic muon calibration:
- high intensity (DAQ @ max rate, 130Hz)
- wide distribution (1x1 m^2 covered uniformly)
- high statistics (> 50 M events)

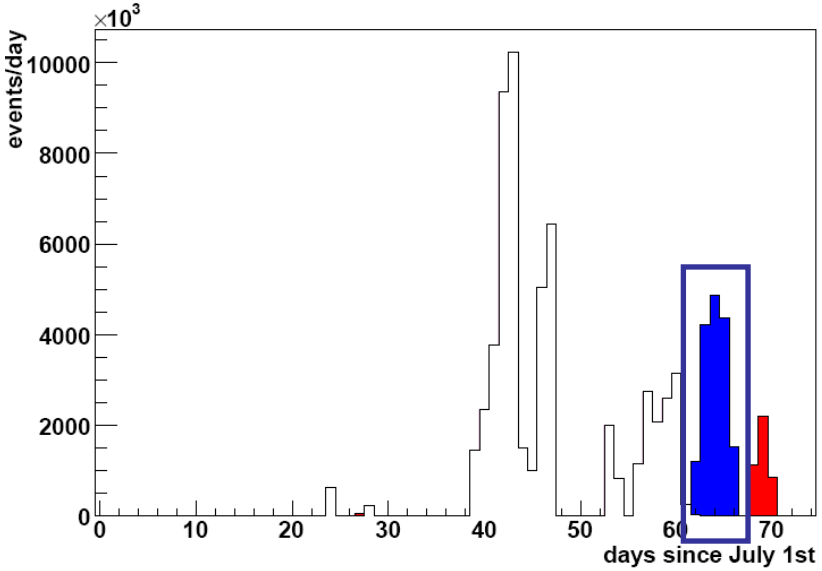






ECAL em program
- Tertiary e- 10-45 GeV, from 50 GeV beam
- ECAL rotation: 0,10,20,30 deg

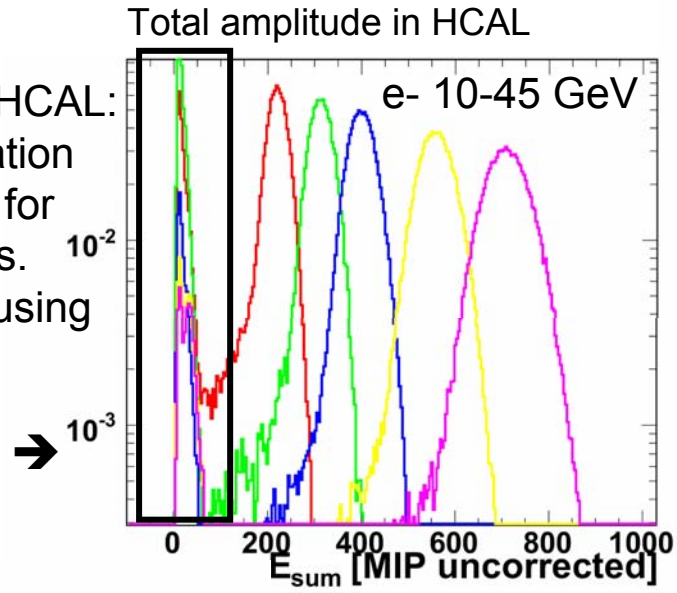
The data taken (1st period)



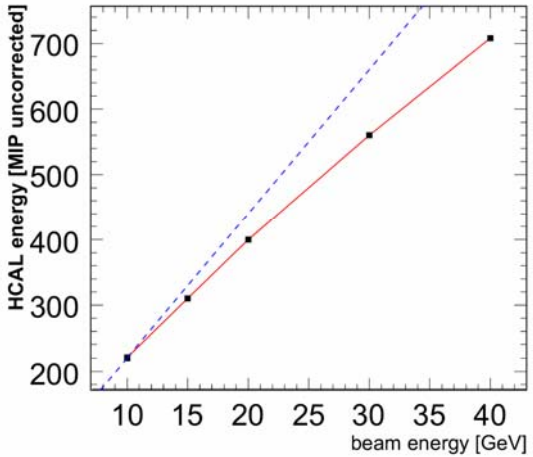
AHCAL stand alone, ECAL removed
- 1 day @ 10 GeV secondary beam
  tested π / e 6,10,15,20 GeV
- 3 days @ 50 GeV secondary beam
  e 10-45 GeV and π 30-80 GeV

EM program in HCAL: establish calibration and corrections for understood phys. processes and using established MC

No PID cut ➔



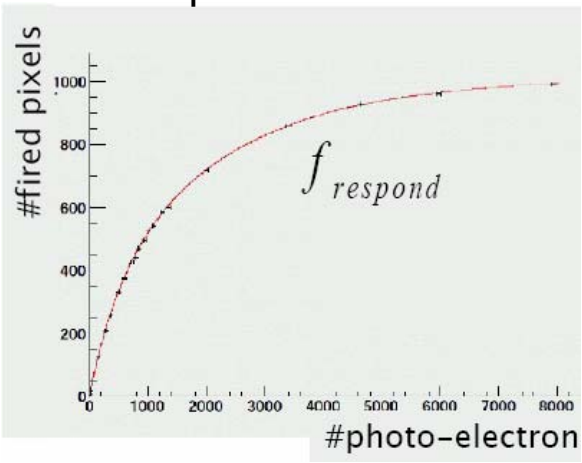
Courtesy of M. Groll

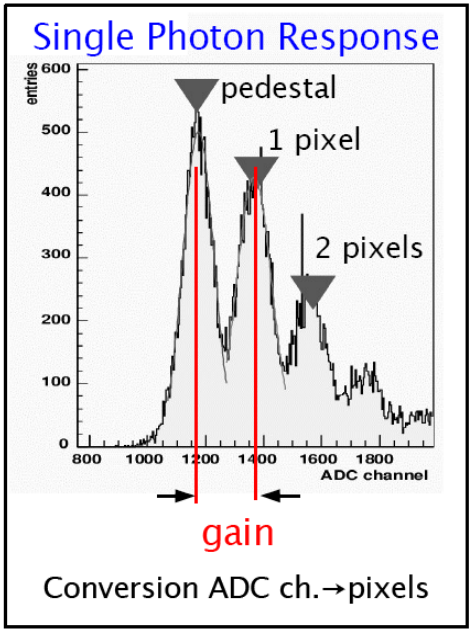


➔ uncorrected linearity curve

Importance of monitoring/calibration system in a SiPM based calorimeter under development

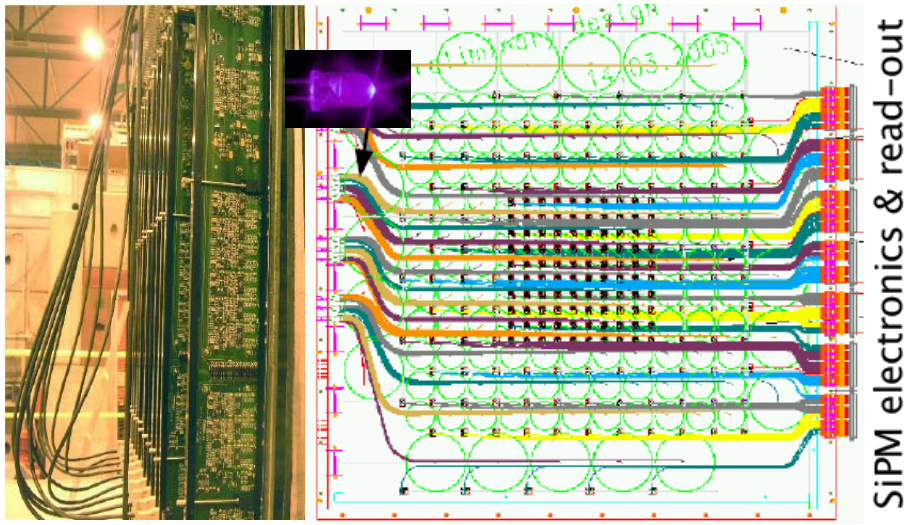
SiPM response is non-linear





Calibration system should deliver:
-Low intensity light for SiPM Gain calibration
-High intensity of light for saturation monitoring
-Medium intensity light for monitoring T,V variations

AHCAL layer = 216 tiles

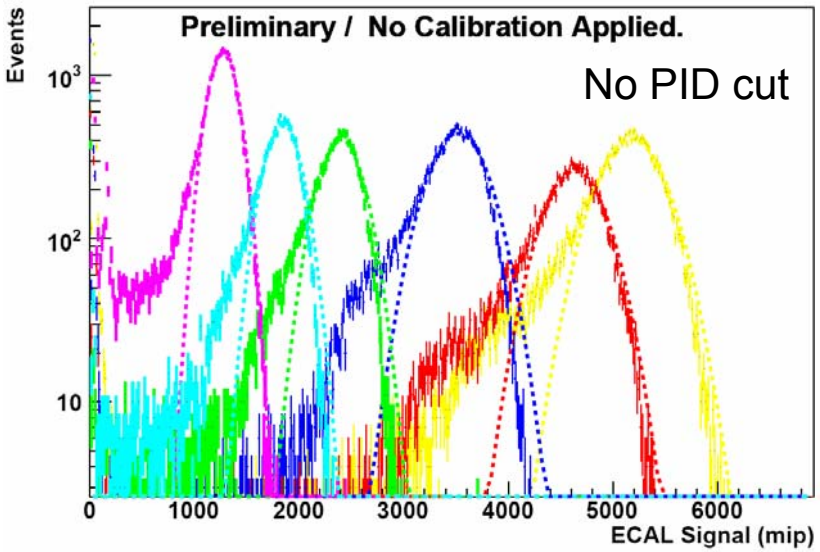


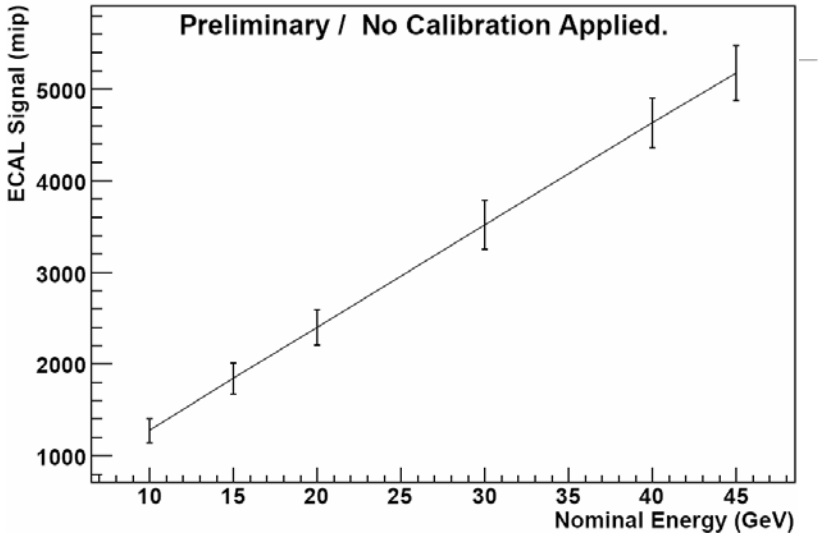
light intensity for 8000 channels within factor 2
>94% calibration efficiency on full calorimeter

AHCAL calibration on the way … physics will follow

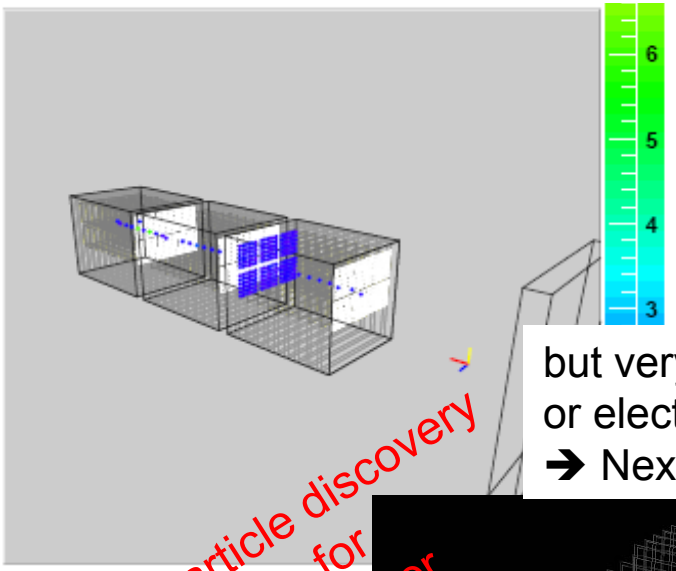
ECAL performance

electron beam 10-45 GeV, 0 deg



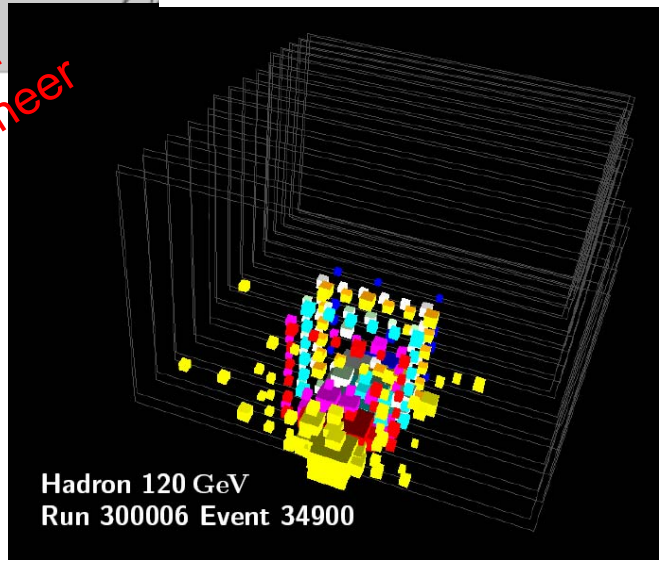


with much less effort, straight away linearity

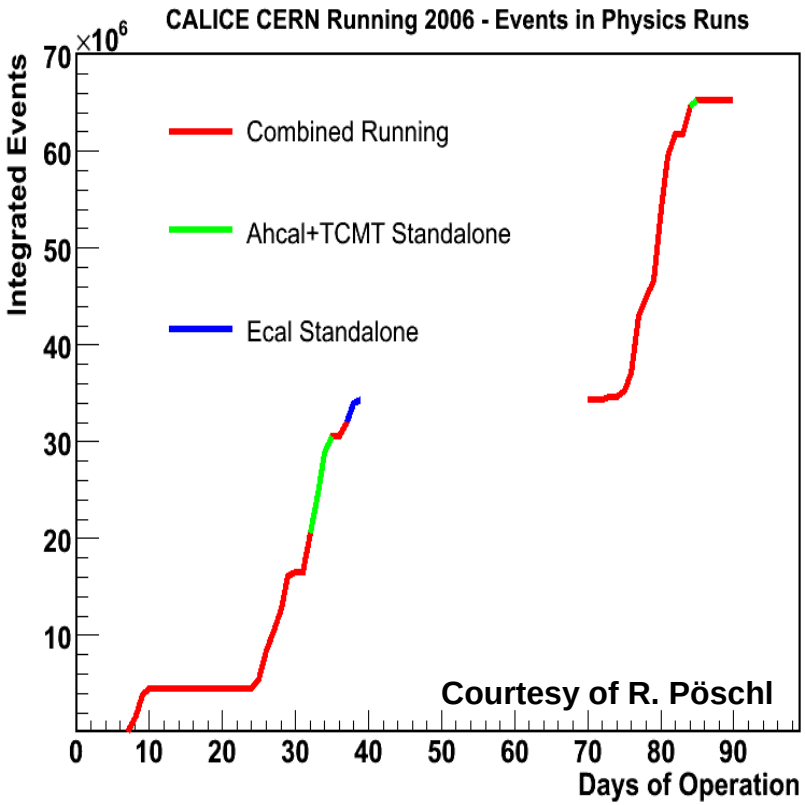


but very peculiar noise or electronics effects
➔ Next challenge

No new particle discovery only headache for electronics engineer

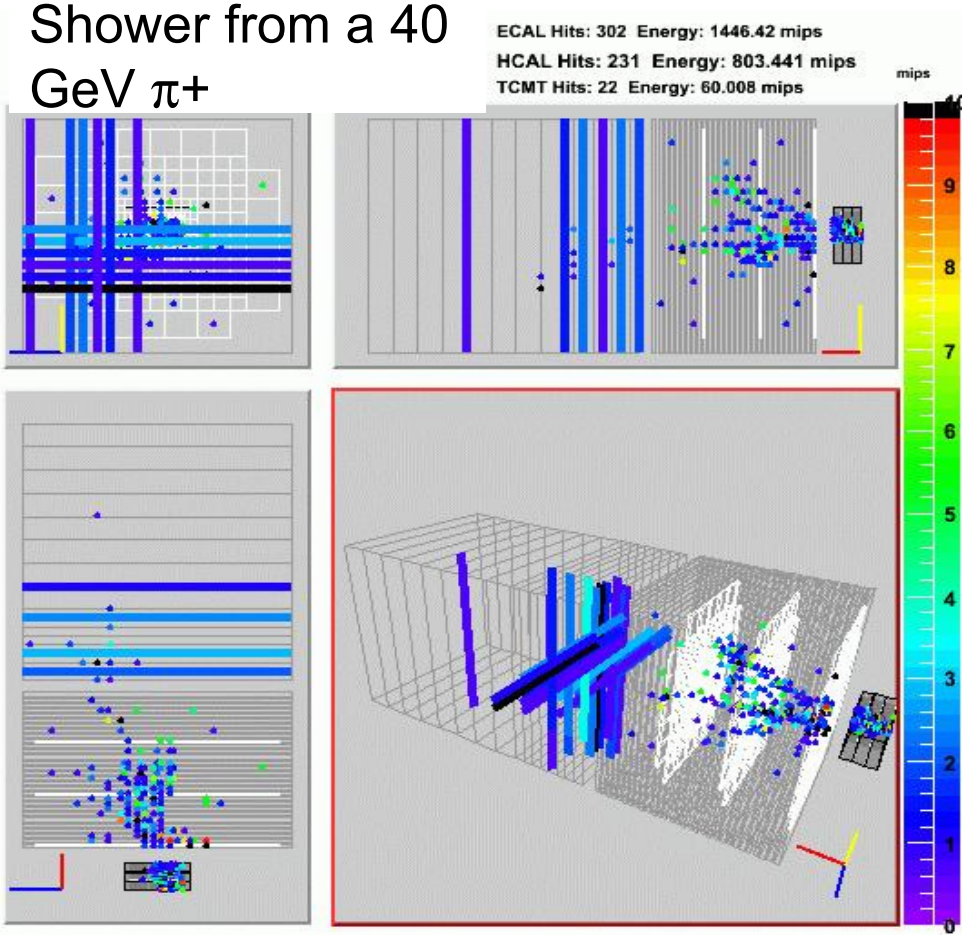


Impressive data rate



The physics is there ➔
Now starts the fun !!

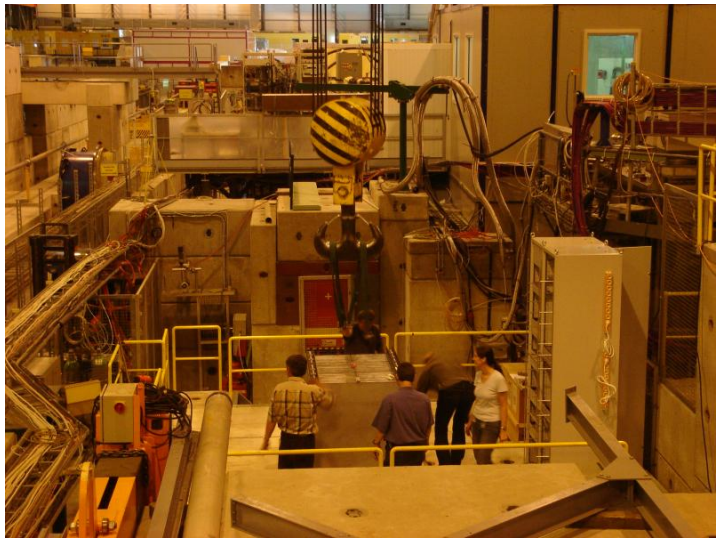
Shower from a 40 GeV π+

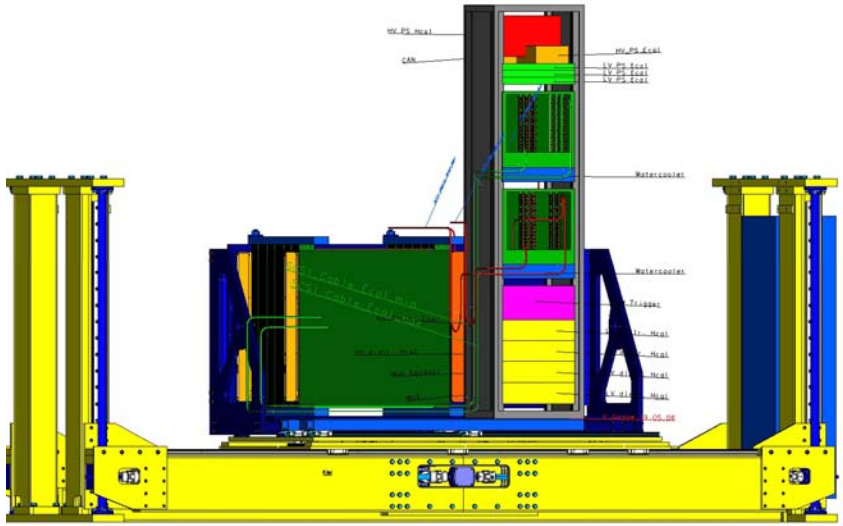


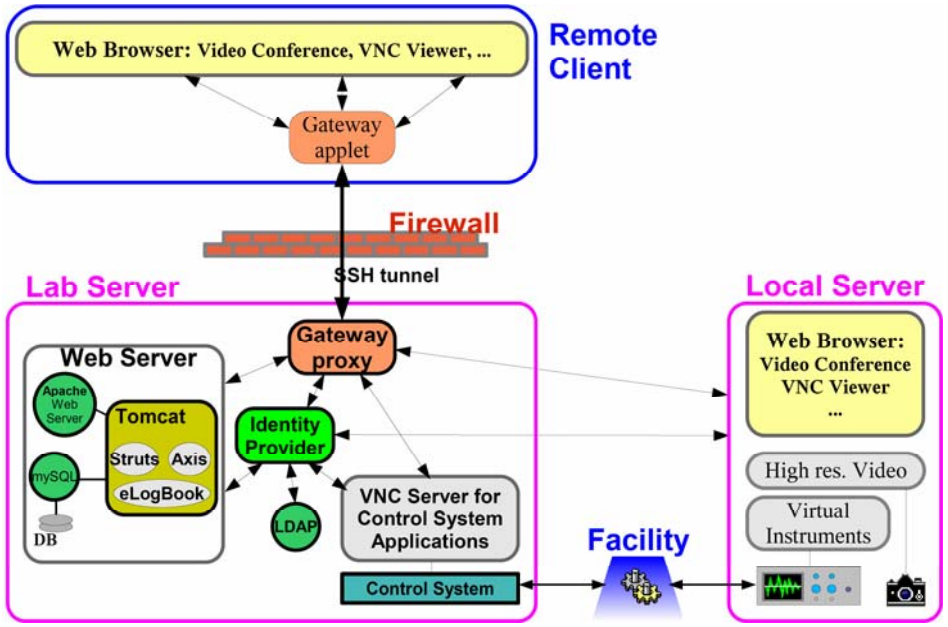
Global Accelerator Network / Global Detector Network
Multi Virtual Laboratory

GAN / GDN MVL

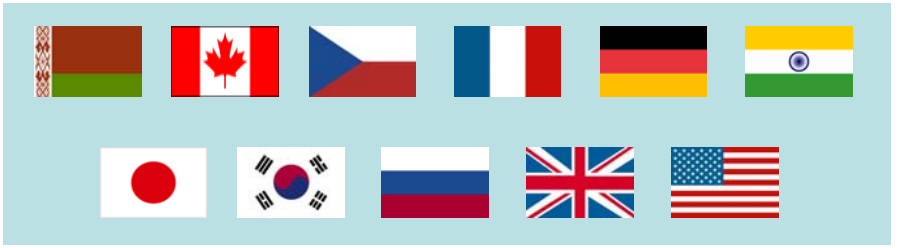
Live test during the CALICE test beam

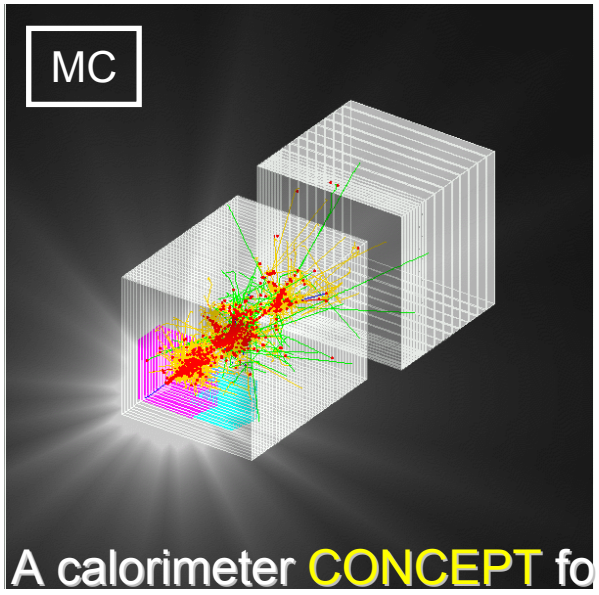


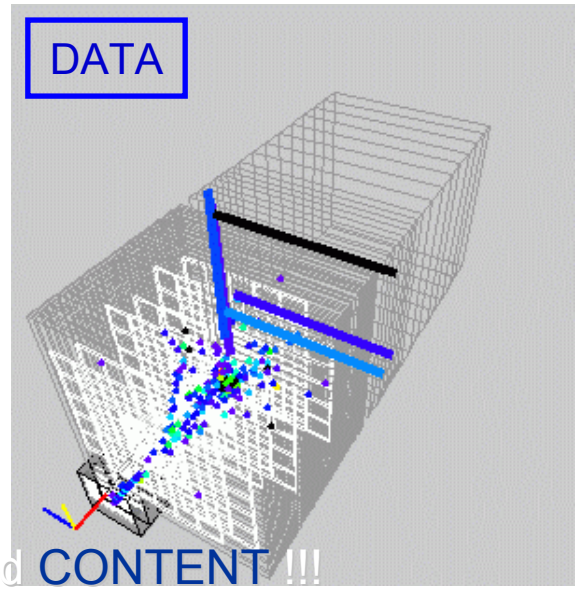




CALICE
Calorimeter for ILC







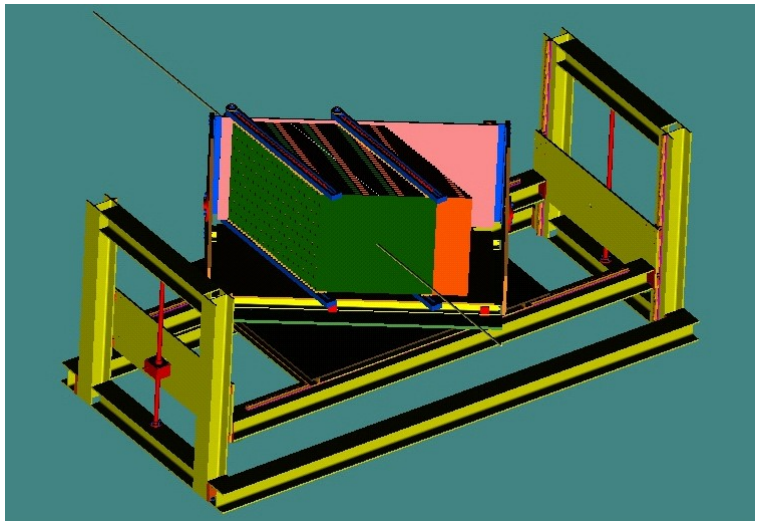
A calorimeter CONCEPT for the ILC is gaining FORM and CONTENT !!!

Near future program:
- fully commissioned detectors
- movable stage for AHCAL ➔

➔ hadronic showers from 0º to 30º

Also wanted: Pion / proton separation
Low energy hadrons (< 6 GeV ?)

Proposal submitted to CERN for May-Sept. 2007
… FermiLab is next at the end of summer 2007



Thank you to the “co-authors” of this talk:

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Henri Videau (*Ecole polytechnique*)
Catherine Juliette Adloff (*Universite de Savoie - LAPP*)
John Hauptman (*Iowa State U*)
Aldo Penzo (*Laboratory of Research Sezione di Trieste - Istituto Nazionale d*)
Francesco Grancagnolo (*INFN-LE*)
Riccardo de Sangro (*INFN*)
Christian Grah (*DESY*)
Konstantin Stefanov (*RAL*)
Uriel Nauenberg (Colorado University)
Christophe De La Taille (*LAL*)
Ivo Polak (*Institute of Physics - Academy of Sciences of the Czech Republic*)
Erika Garutti (*Deutsches Elektronen Synchrotron (DESY)*)
Anne-Marie Magnan (*Imperial College - University o London*)
Sebastian Schaetzel (*Deutsches Elektronen Synchrotron (DESY)*)
Benjamin Lutz (*DESY*)
Sebastian Schmidt (*Deutsches Elektronen Synchrotron (DESY)*)
Evgeny Tarkovsky (*ITEP*)
Satoru Uozumu (*Shinshu*)
Tohru Takeshita (*Shinshu University*)
Valeri Saveliev (*Moscow Physical Engineering Institute (MePhI)*)

= 21 speakers in 5 sessions ➔ a very alive and active community!!!