IN2P3

INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE ET DE PHYSIQUE DES PARTICULES

irfu cea saclay

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

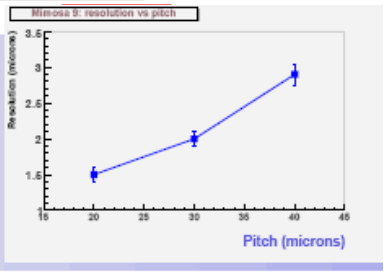
ilc France

R&D ILC Detectors

In France

CALICE Calorimeter for ILC

LC-TPC



CMOS-VD

SiLC International Collaboration

EUDET

Transparencies stolen from F.Richard, O.Napoly, Ph.Bambade, J-C Brient, M.Winter, A.Savoy-Navarro, V.Lepeltier, P.Colas , et al..

J-E. Augustin,11/02/2008

http://flc.in2p3.fr/

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Institut National de Physique Nucléaire et de Physique des Particules

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

ilc France






Labs involved and resps. :

IPHC Strasbourg Marc Winter
IPN Lyon Imad Laktineh
LAL Orsay Philip Bambade, Vincent Lepeltier, François Richard
LAPP Annecy Catherine Adloff, Yannis Karyotakis
LLR Palaiseau Jean-Claude Brient, Henri Videau
LPC Clermont-Ferrand Pascal Gay
LPNHE Paris Aurore Savoy-Navarro
LPSC Grenoble Jean-Yves Hostachy
IRFU Saclay Pierre Lutz

coordination JEA

& Theory Abdelhak Djouadi

http://flc.in2p3.fr/

In France: R&D Physics & Detectors

http://flc.in2p3.fr

-A) Calorimetry

CALICE Collaboration, Spkp. Jean-Claude Brient

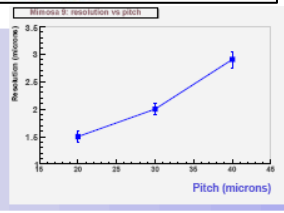
IPNL, LAL, LAPP, LLR, LPC-Ct, LPSC

-B) Vertex dets.: CMOS

Bilateral Collaborations, Resp. Marc Winter

IPHC, LPSC, IRFU

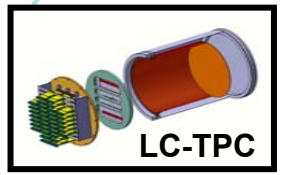
CMOS-VD

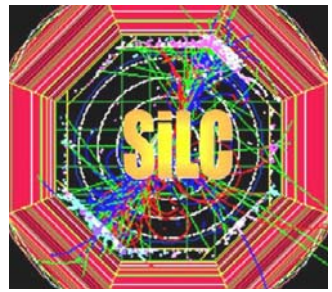


-C) Silicon TracK Dets.

SiLC Colln, Spkp. Aurore Savoy-Navarro LAPP, LPNHE

-D) TPC Paul Colas, Vincent Lepeltier IRFU, LAL





-E) Machine Detector Interface *(common with Accelerator R&D)*

Philip Bambade LAL

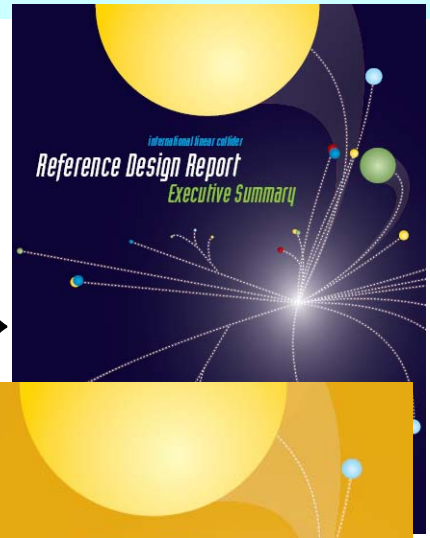
European funding: EUDET (**6**th cPRD)

ILC Progress

Authority: ICFA Comittee **ILCSC**, chairman E. Iarocci

The GDE (***Global Design Effort)*** Executive Committee (**B. Barish et al.**)
is coordonnating the world effort towards the ILC

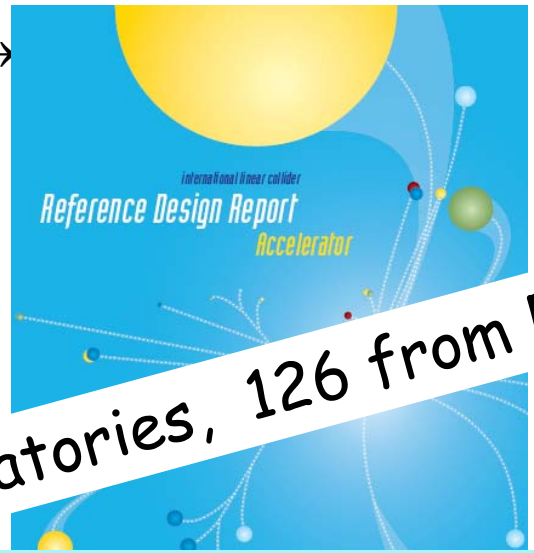
⇒**Reference Design Report** issued April 2007 (4 vols.)
allowed a **cost** Evaluation



Ex. Summary →

Physics with ILC →
(editors A. Djouadi et al.)

Accelerators →



Detectors→

1058 signatories, 126 from France

Research Director
Sakue Yamada

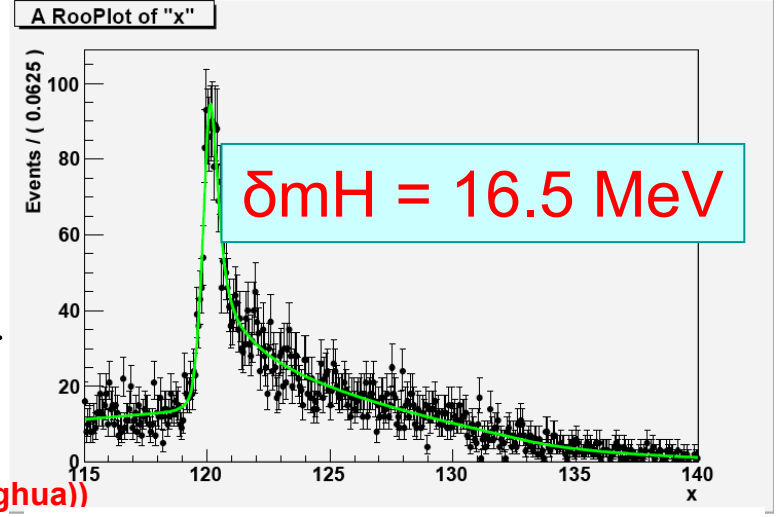
WWS:
François Richard
Jim Brau
Hitoshi Yamamoto

Next: Engineering Design Report
EDR – 2010

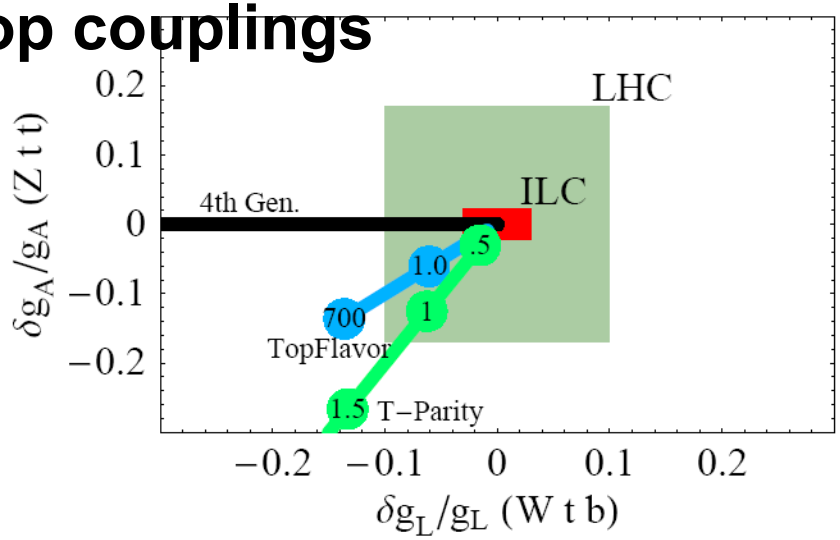
Physics at ILC:
Precision measurements for discovery physics

Exemples: **Higgs Invisible decay** → (e+e-→HZ→μμH)

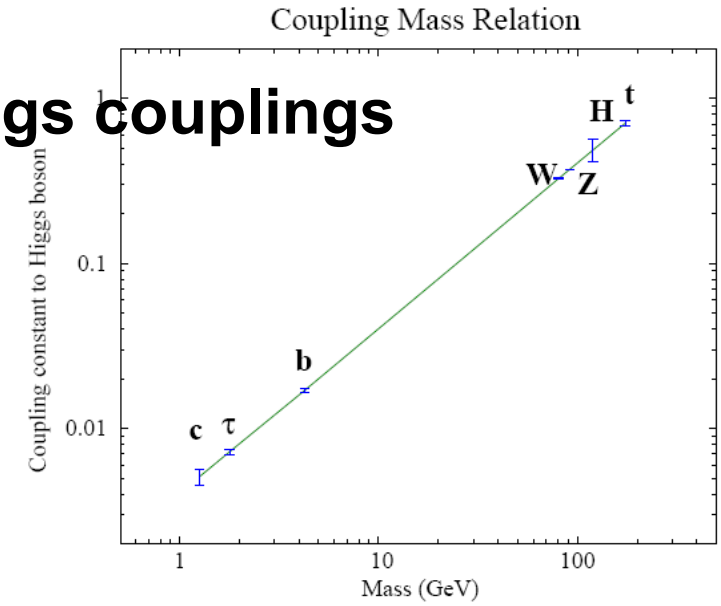
(Manqi Ruan, cotut. Z. Zhang (LAL) & Y. Gao (Tsinghua))



Top couplings



Higgs couplings



Determination of SUSY parameters

Example of mSUGRA, using all previous measurements at LHC/ILC

	SPS1a	LHC	ILC	LHC+ILC
m_0	100	100.03 ± 4.0	100.03 ± 0.09	100.04 ± 0.08
$m_{1/2}$	250	249.95 ± 1.8	250.02 ± 0.13	250.01 ± 0.11
$\tan\beta$	10	9.87 ± 1.3	9.98 ± 0.14	9.98 ± 0.14
A_0	−100	-99.29 ± 31.8	-98.26 ± 4.43	-98.25 ± 4.13

Brief summary of the French Machine R&D efforts

Coordination O.Napoly
GDE France: G. Wormser

- Main Linac – mostly **XFEL related**, but also FP7 « ILC Hi-Grade » and CARE 1&2:
  - Cavities (EP, Baking) — *Labs involved:* IRFU Saclay *(ex DAPNIA)*
  - **Input couplers** — LAL Orsay
  - **Cryomodules** (cold mass, string assembly, module integration transport engineering) — IRFU
  - **Cold BPMs** — IRFU
  - Alignment/stabilisation — LAPP Annecy-le-Vx
  - Other R&D
- Positron source
  - Compton source/polarisation (Alter.) — IPN Lyon, LAL
- Beam Delivery systems
  - ATF2 tests — LAL, LAPP, LLR Palaiseau
  - 2 mrad and 0 mrad (Alter.) — LAL, IRFU
  - MDI and machine background — LAL

ATF2 collaboration
(KEK accelerator test facility)

ATF2 collaboration, presently >88 people from 21 labs and institutions and growing

KEK, Tsukuba
IHEP, Beijing
BINP, Novosibirsk
CCLRC/DL/ASTeC,Daresbury
CEA, Gif-sur-Yvette
CERN, Geneva
Hiroshima University
Kyoto ICR, Kyoto
LAL, Orsay
LAPP, Annecy
LLR, Palaiseau
LLNL, Livermore
NIRS, Chiba-shi
North Carolina A&T State University
Oxford University
Pohang Accelerator Laboratory
Queen Mary University of London
Royal Holloway, University of London
DESY, Hamburg
SLAC, Stanford
UCL, London
University of Oregon
University of Tokyo

ATF2 as prototype of ILC Interaction region

LAL: Work on beam correction algorithms of ATF-2 beam line, commissioning, instrumentation developments.
LAPP: Studies to provide a suitably stabilized support for the final doublet, commissioning
LLR: Background study (algorithms, GEANT4, « event biasing technique»), commissioning

Construction
Measurements
Simulation
- synchrotron radiation
- diffusion on residual gas
- beam halo from beamstrahlung on vacuum chamber
- recils from beamdump

Comparaison aux mesures

BDSIM uses Geant4
physics process + beam optics

ATF2 proposal was web-released just after BDIR workshop in London,
=> KEK, SLAC, CERN, … preprints

Performances of ILC Detectors

comparison with a LEP detector:

- Jet energy resolution **x2**: $30\%/\sqrt{E_{jet}}$.
  - separated measurement of charged particles, photons, neutral hadrons
  - reconstruction using a Particle Flow Algorithme (PFA)

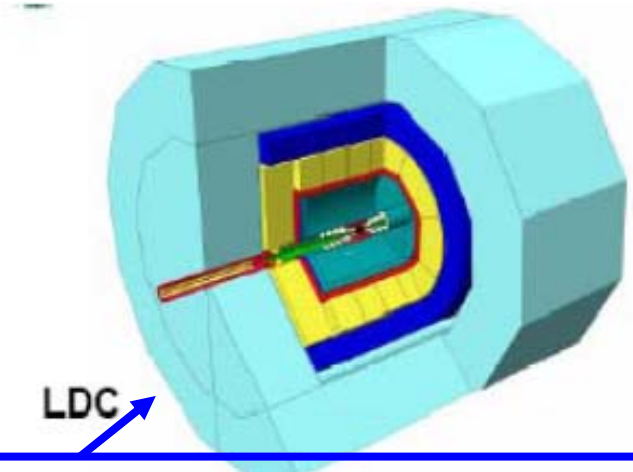
  Calorimeters with very small granularity, very large channel number
  forward jets, hermeticity
- Momentum accuracy**x10**: $\delta p_t/p_t^2 = a \oplus b/(p_t \sin\theta)$ a=4.10^{-5}, b = 1.10^{-3}
  and proper track separation
- Displaced vertices **x5**: tag **charm** quarks

  $\sigma_{ip} = a \oplus b/p_t$ a <5(μm), b <10(μm · GeV)
  precision et ultra-thinness
- Machine detector interface: crossing angle, used beams, pairs…

  Two experiments for one interaction region: push-pull
  mounting scénarios, links with acceletrator engineering

…require specific R&D's

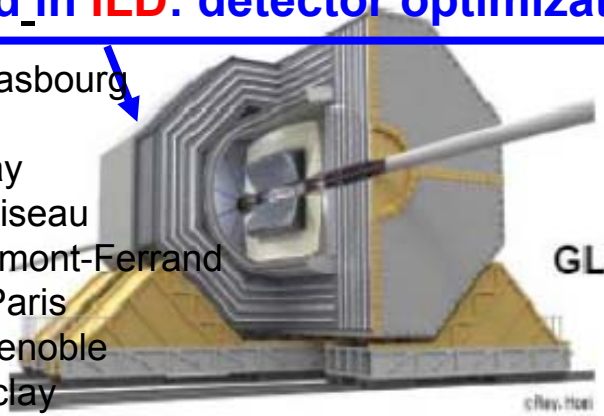
The 4 detector concepts

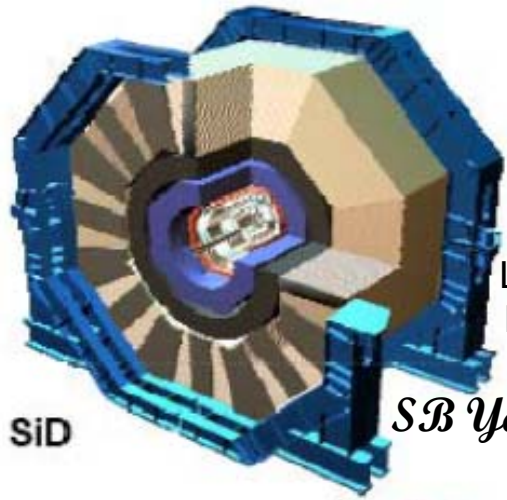


Merged in ILD: detector optimization

IPHC Strasbourg
IPN Lyon
LAL Orsay
LLR Palaiseau
LPC Clermont-Ferrand
LPNHE Paris
LPSC Grenoble
IRFU Saclay

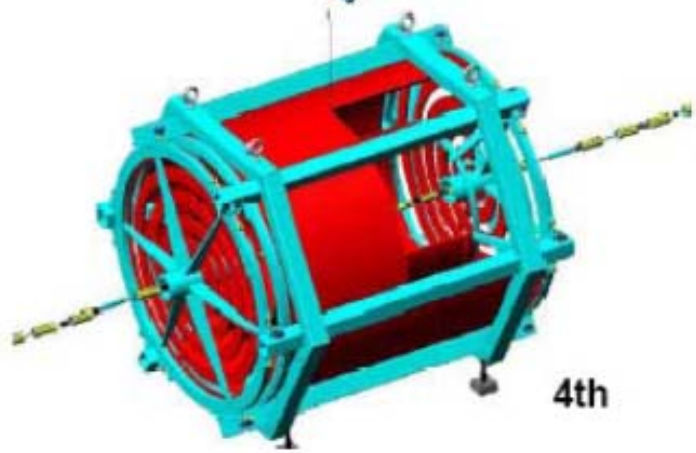
JSB Henri Videau





LAPP Annecy
LPNHE Paris
IRFU Saclay

SB Yannis Karyotakis



LOI's by 1 October 2008 (…)
Two detector LOI's to be selected by IDAG for an EDR by 2010

IN2P3
Institut National de Physique Nucléaire et de Physique des Particules

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

ilc France

ILC Detector R&D in France

- Electromagnetic and Hadronic calorimetry
  - Simulation
  - Electromagnetic Calorimeter
  - Digital Hadronic Calorimeter
- CMOS Microvertex MAPS
- Silicon strip Tracking
- TPC

CALorimeter for the LInear Collider Experiment

13 countries,
45 laboratories,
225 physicists/engineers ,

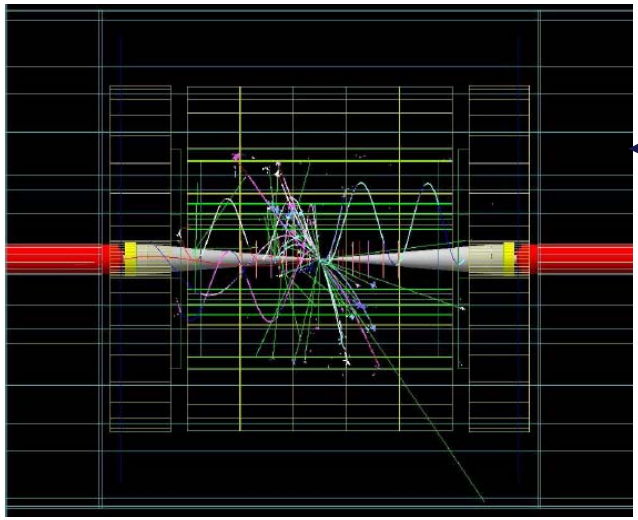
Spokesperson J-C Brient; LLR

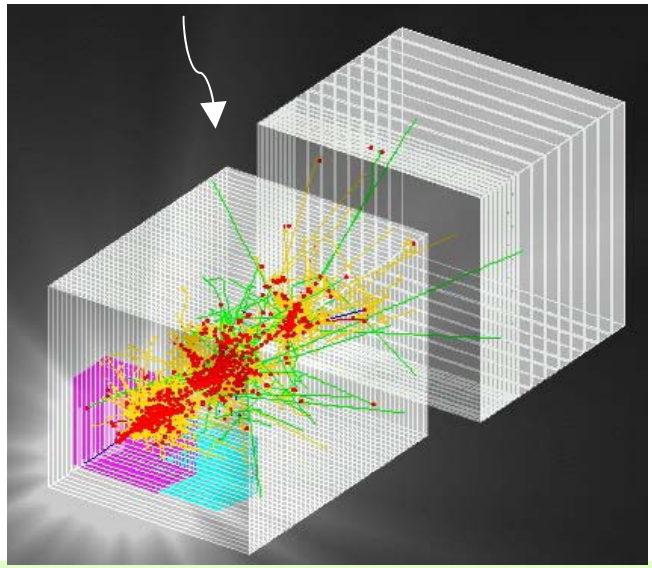
France
LAPP-Annecy, LPC-Clermont, LPSC-Grenoble,
IPNL-Lyon, LAL- Orsay, LLR-Palaiseau

- High granularity calorimeters for precision physics
  - Study of particle flow for $\sigma_E/E \sim 30\%/\sqrt{E}$
    - Validation of hadronic interaction models in MC

ILC-Calice offline

Mokka – **Geant4 simulation** to study ILC detectors and Calice prototypes

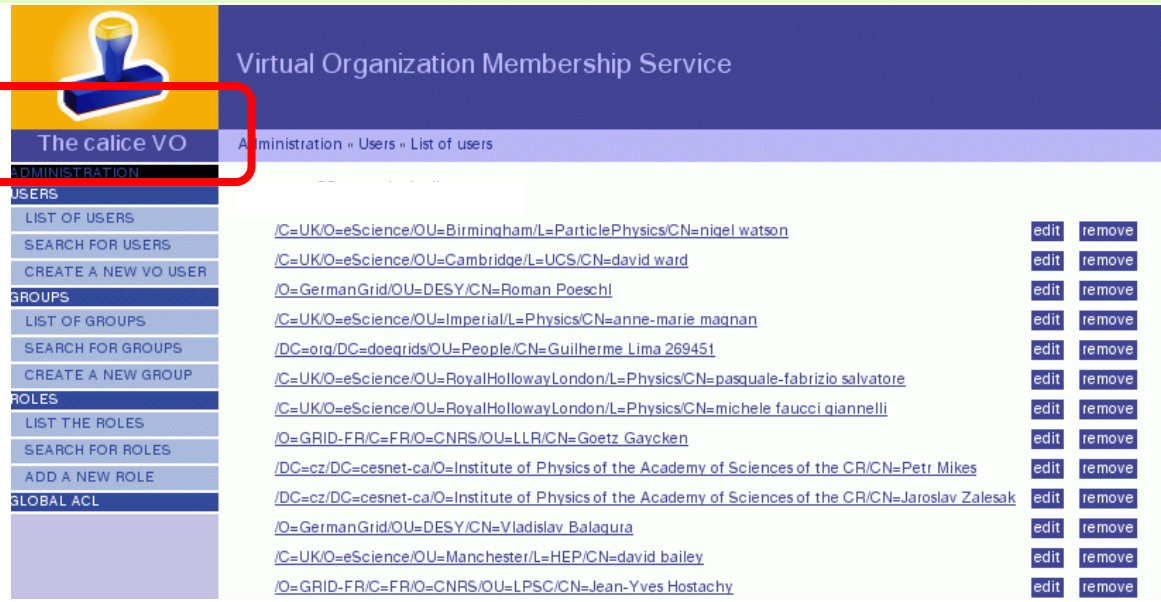




The Grid: ■25 Tbytes of data ■Xxx Tbytes of MC ■58 registered users and counting

Test beam data analysis

Calice Virtual Organization
«*First grid user for distributed data*»
(CALICE –RC are CC-Lyon, DESY, Manchester, KEK, FNAL et LAL,LLR, etc ….)



First ECAL prototype

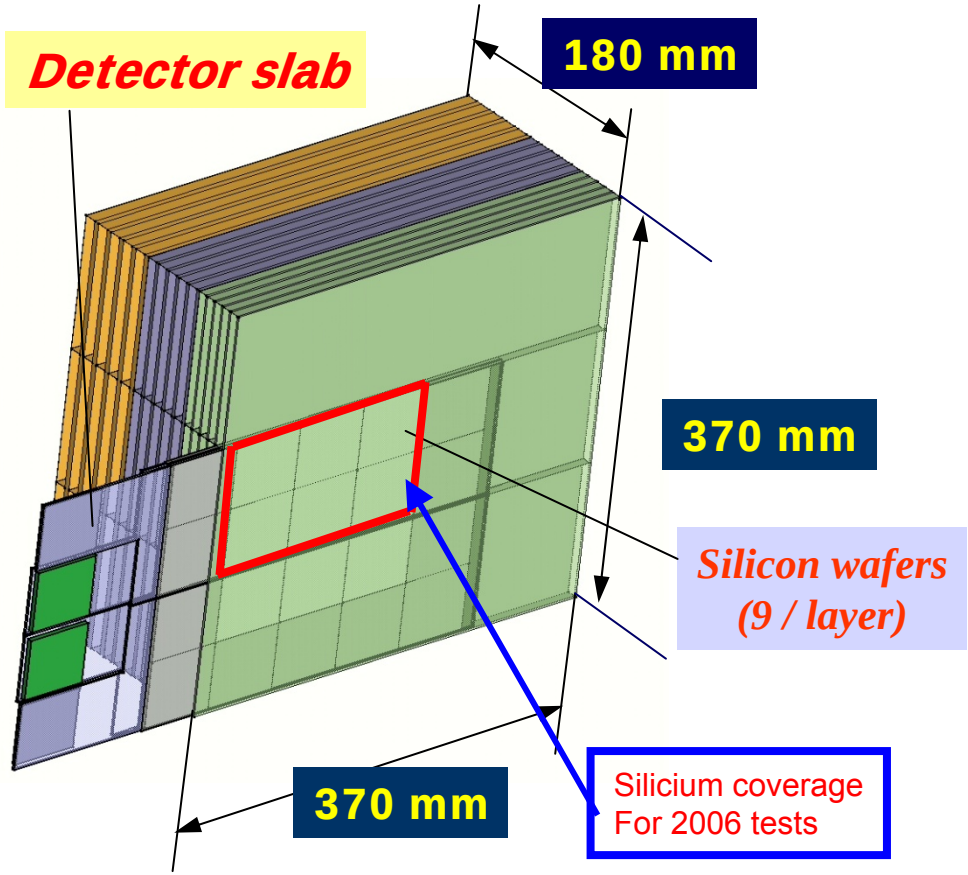
Why this prototype?

1 – Learn expertise on the technology
on calorimeters with high density of read-out channels

2 – Developpements guided by performances and
financial aspects of final project

3 – Comparison with GEANT4 in boundary zones
(between wafers, between alveols, etc…)

4 – Publicize the IN2P3 know-how on Calorimetry

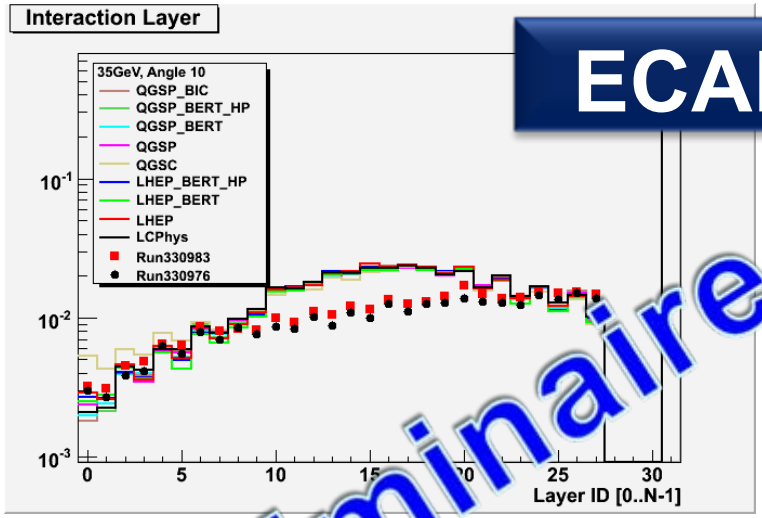


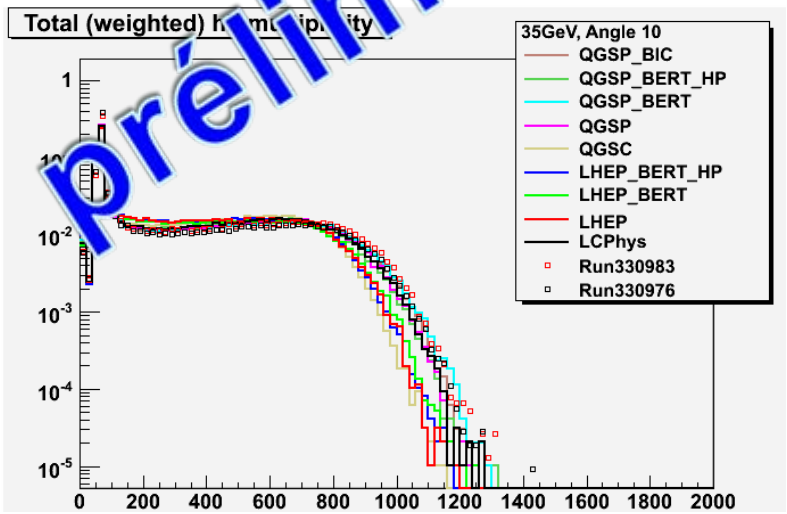
**10 GeV pion CERN test beam
in 2006 and 2007**

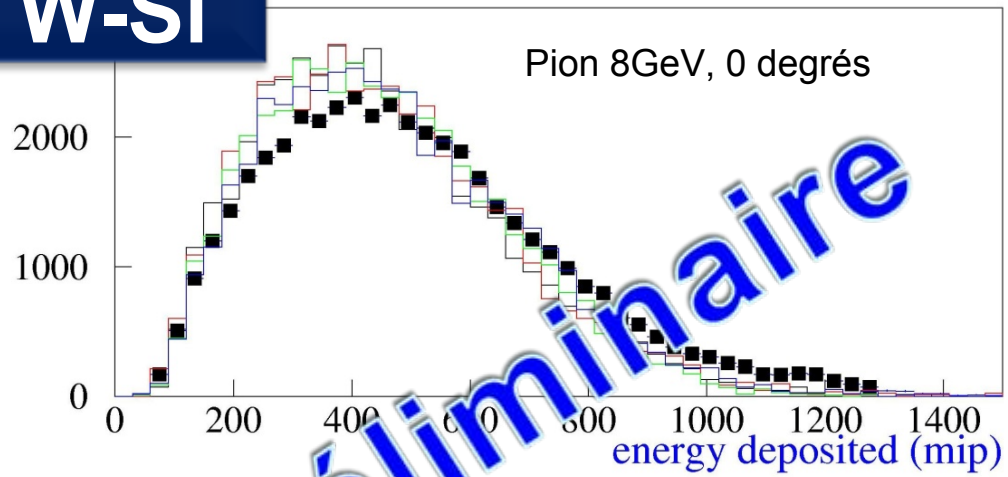
Analysis of the hadronic showers

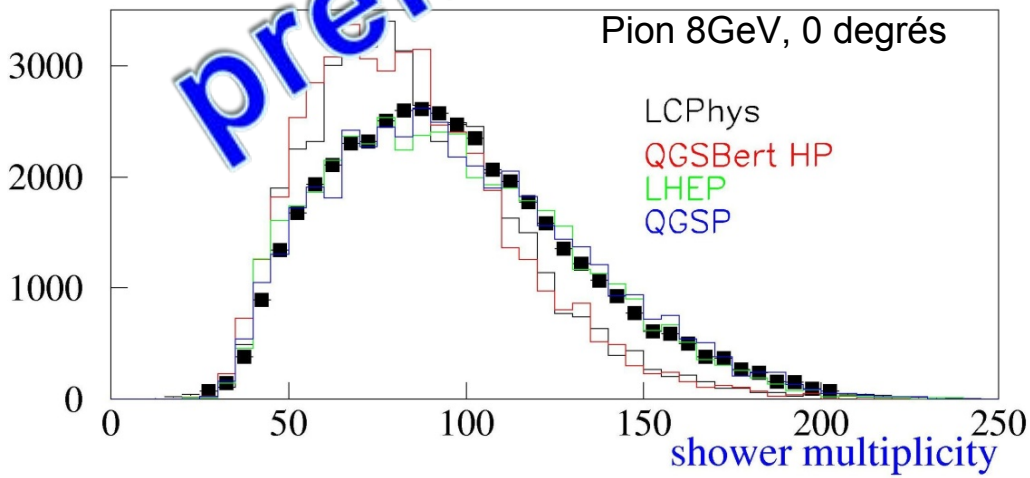
In progress.
Summer 2007 data are the only ones giving useful information

ECAL W-Si





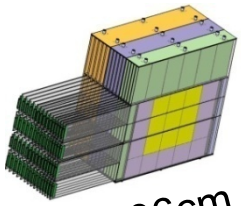




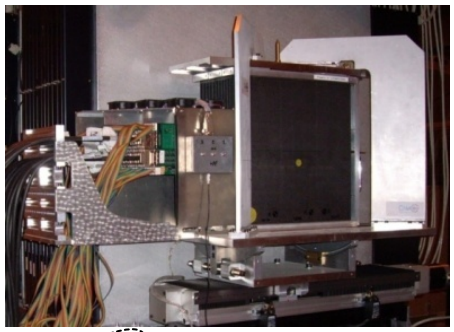
Advanced engineering prototype

1/48th of final barrel calorimeter

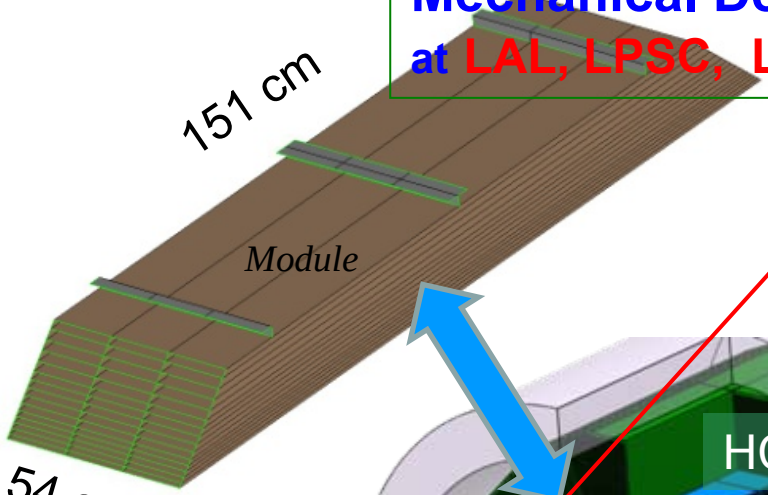
ECAL Prototype



36cm

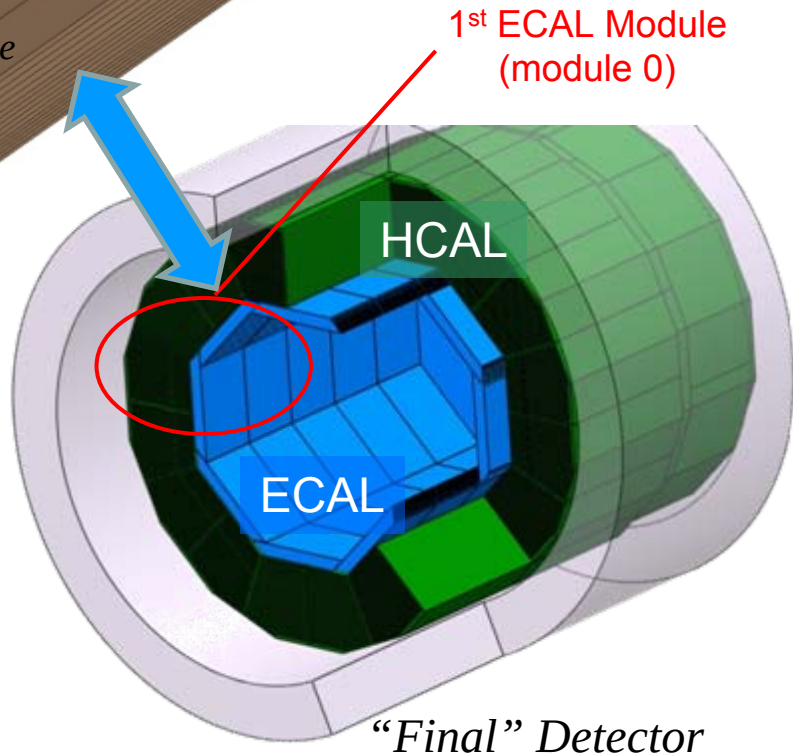


Mechanical Developments
at LAL, LPSC, LLR (IN2P3)



5/8 of CMS ECAL

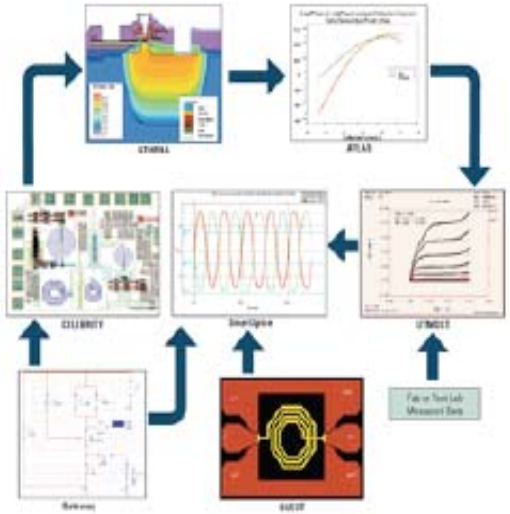
ECAL		
	1rst proto.	EUDET
number of channels	9720	45 360
Size (cm)	36 x 36	154 x 54
Tungsten (kg)	200	700
electronics VFE	external	internal



"Final" Detector

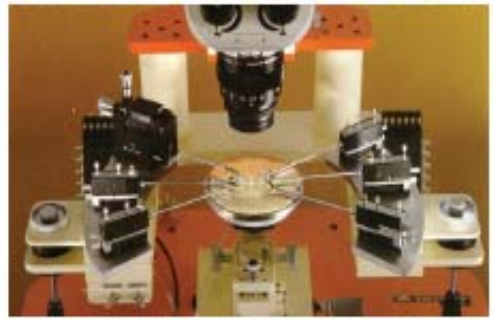
Progress on silicon pad matrices
LLR, LPC-Ct (IN2P3)

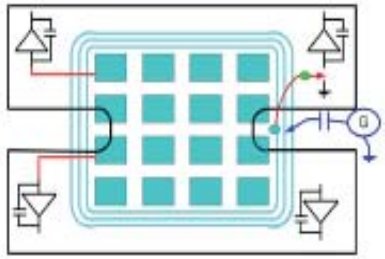
Simulation



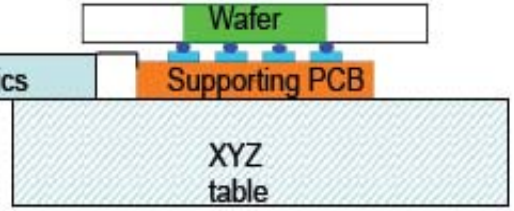
CAD verified

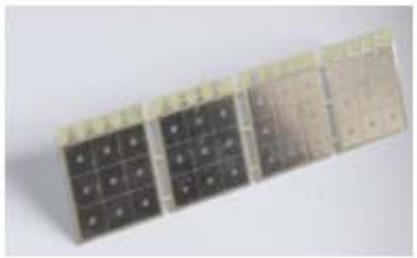
Test bench
- pulse generator
- micropositioner & probes
- shaper + scope

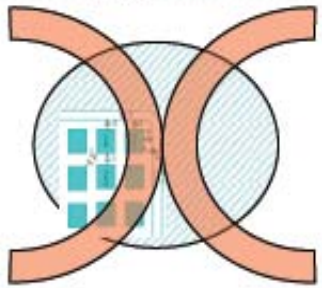




Characterization
- Charge injection
- pixel signal analysis







Needles accessible area

Digital Hadronic Calorimeter EDHCAL

ANR Contract 2008-2010

Aim : simultaneous tests with ECAL EUDET prototype (« ATLAS combined test beam »)

- Choose de active component (RPC, Micromegas..) IPNL, LAPP
  - Small size test plane
  - Choice for a 1m^2 part in 2008

- Development and test of VFE ASIC - HARDRoC LAL
  - produced, tested in-situ on a 4chips PCB (small test plane)
  - future development (VFE) IPNL

- DAQ for this system
  - for the 1 m² plane - Design done, being tested - LLR
  - R&D for an **M^3** prototype(70x70x100cm^3… 200 K canaux) LAPP, LLR, …

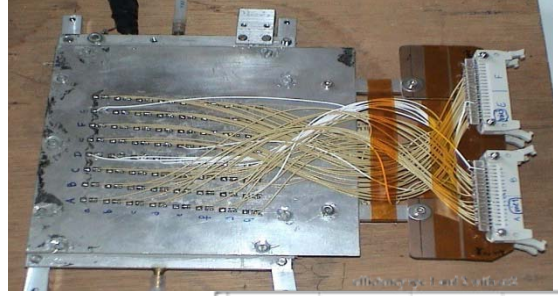
- The **M^3** prototype

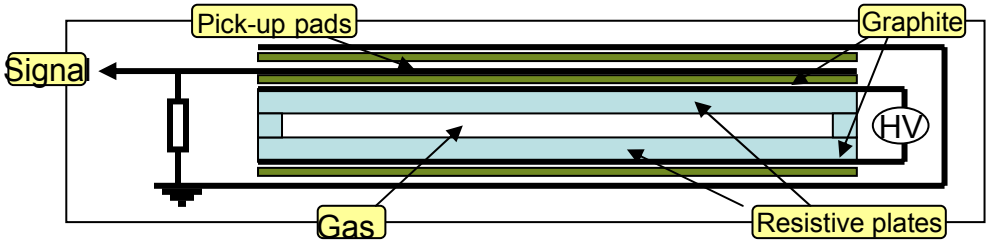
(40 planes detector+absorber, 200 000 channels) . Construction for 2008-2009 with ILC- type mechanical structure (**IPNL, LAPP, CIEMAT-Madrid**)

Gaseous detectors tests

GlassRPC : **made in Protvino , tested IPNL**

8X8 pads, 8X32 pads, 1m2



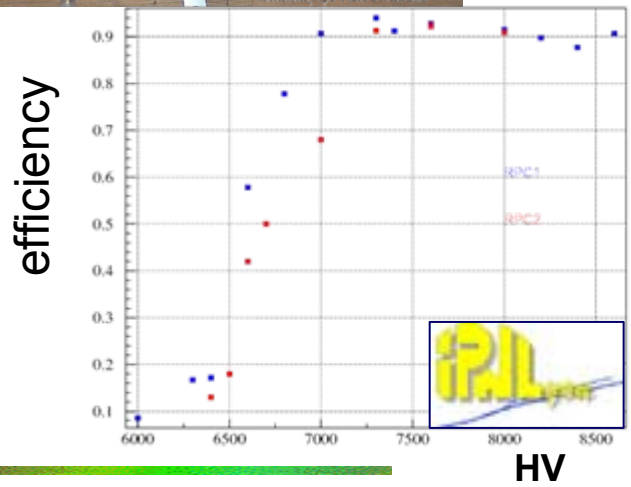


Measurements :

Efficiency, X-talk, homogeneity

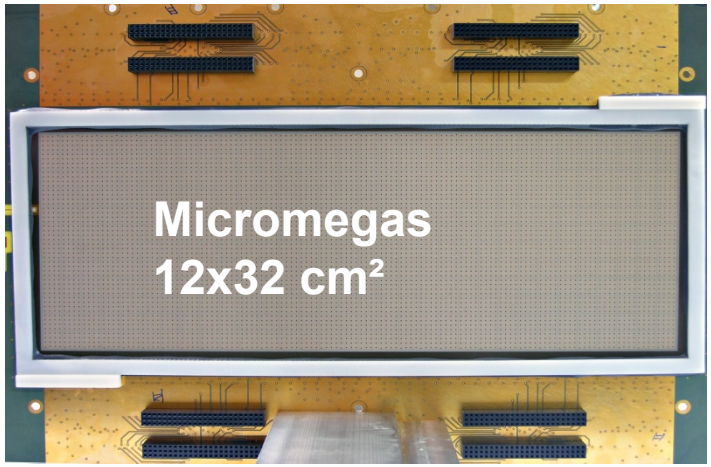
Study of new gas mixtures

(Isobutane->CO2)



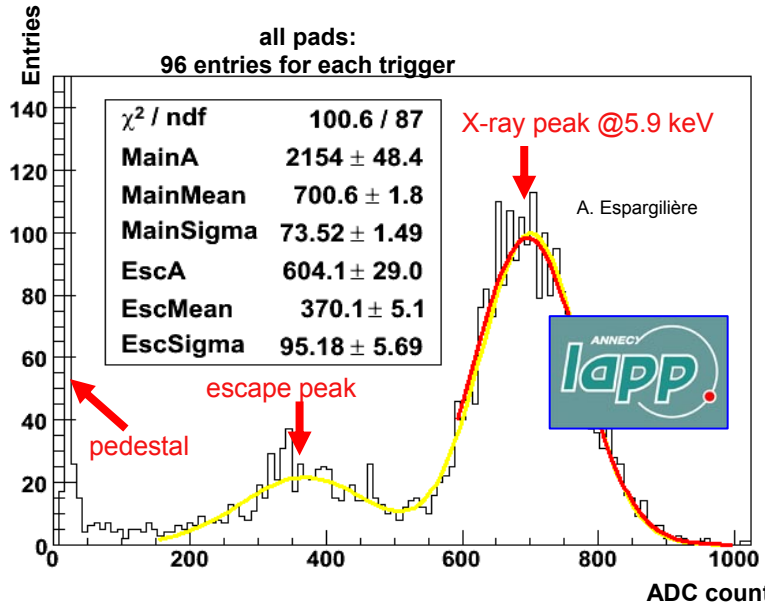
µMEGAS :

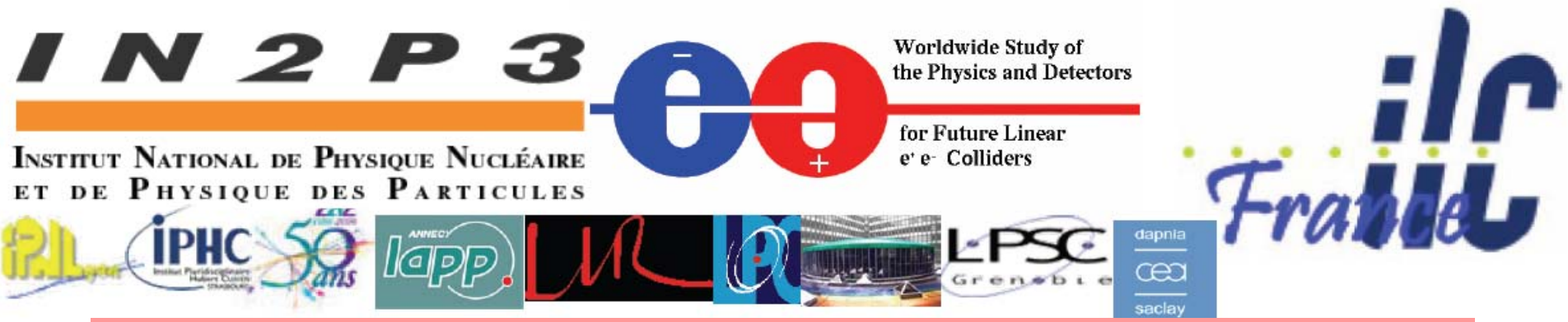
(collaboration with **LAPP,Saclay and CERN***)*



future

- Homogeneity,
- Stability , pressure …
- Various gas mixtures,
- Efficiency
- Construction of a large area detector



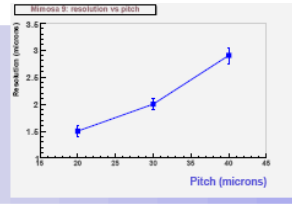


ILC Detector R&D in France

- Electromagnetic and Hadronic calorimetry
- CMOS Microvertex MAPS
- Silicon strip Tracking
- TPC

CMOS detectors optimized for ILC vertex detector

CMOS-VD



Marc Winter IPHC Strasbourg

LPSC/Grenoble, IPHC/Strasbourg

IRFU Saclay, DESY, Uni. Hamburg, JINR-Dubna

IPN/Lyon, Uni. Frankfurt, GSI-Darmstadt, STAR coll.(LBNL, BNL)

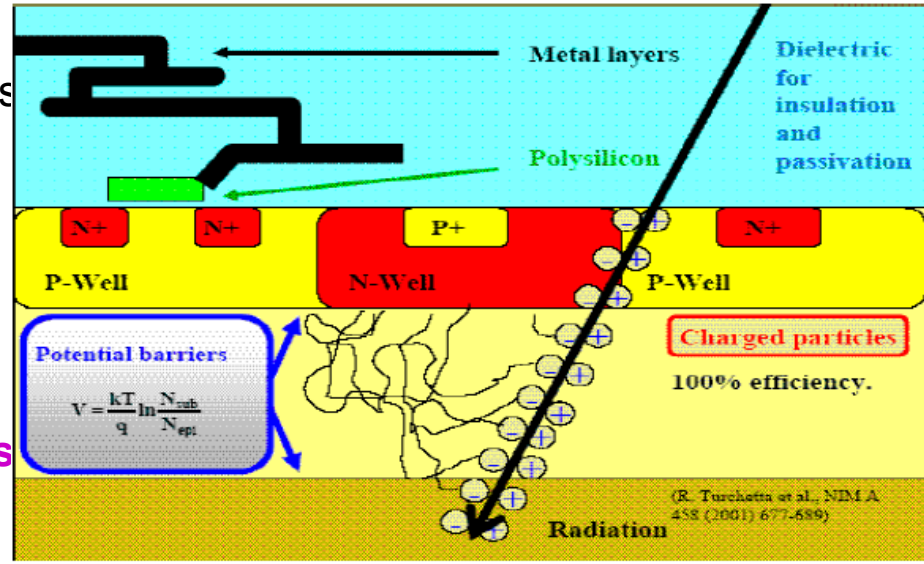
WWS R&D REVIEW PANEL on VERTEX DETECTORS, ALCPG'07, october 2007

Pixel detectors pixels

very accurate, **very thin,** very close to the beams

radiation resistant (pairs)

→CMOS technology, epitaxial detection layer



Parallel development of 3 parts:

- **Pixel columns for parallel Read Out one discriminator/pixel**
- **4-5 bits ADC's to replace discriminators**
- **Zero suppress circuits and output memories**

Two step development

1) **Short term applications less demanding that ILC innermost layer: EUDET & STAR**

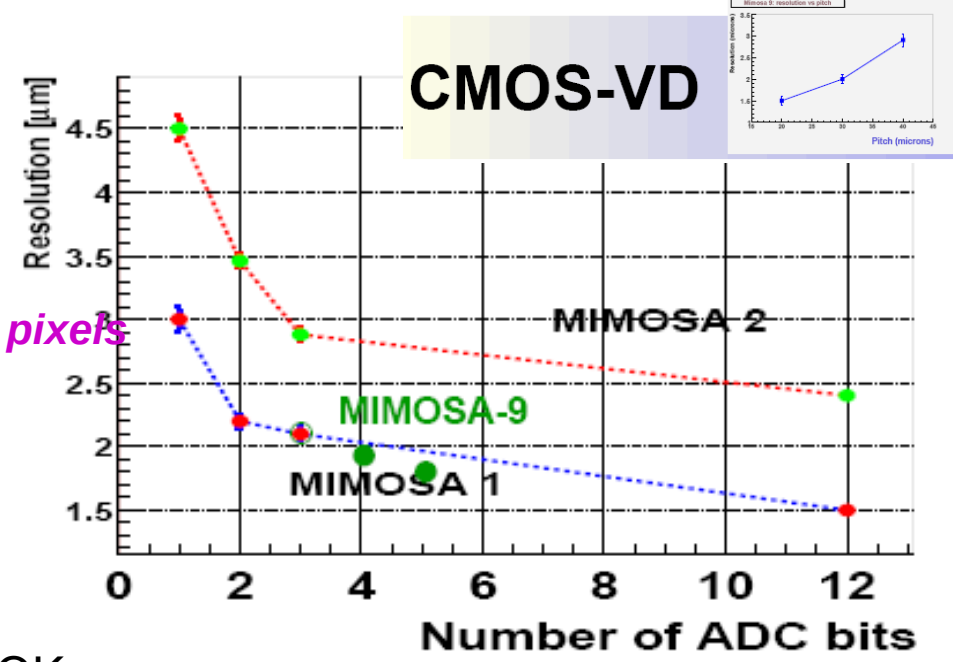
2) **Later produce ILC detectors with ADC's and higher RO frequency**

Present Results

Efficiency > 99.5 – 99.9% @ 10^{-5} ghosts

Resolution ~<1. µm,*(MIMOSA-18 : 512×512 pixels 10 µmpitch, analog output, S/N 30*)

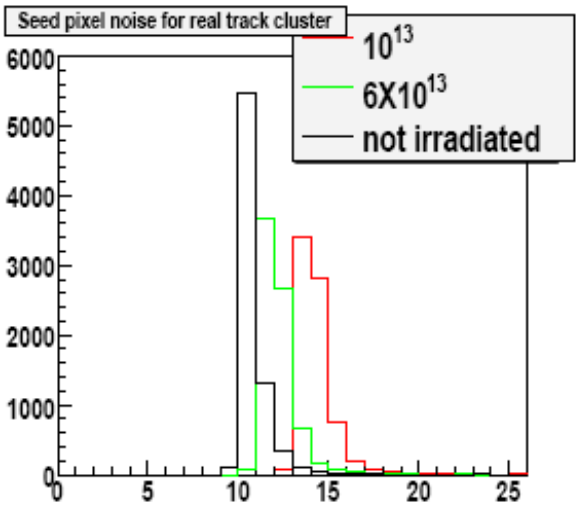
<2 µm avec ADC 4 bits→

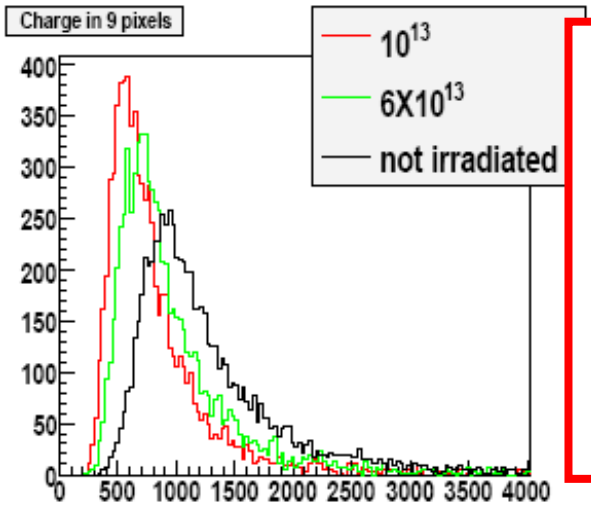


Radiation Tolerance (AMS-0.35 opto)

- ionizing:1 MRad –10^{13} e^- 10 MeV /cm^2 OK
- non-ionizing (été-automne 2007):

MIMOSA-18 irradiated with.10^{13} O(1 MeV) n/cm2 (+ 100–200 kRad gas)
tested with 120 GeV pions at SPS : 1.10^{13} Neq/cm**2→ det.eff. = 99.5 +- 0.1 %



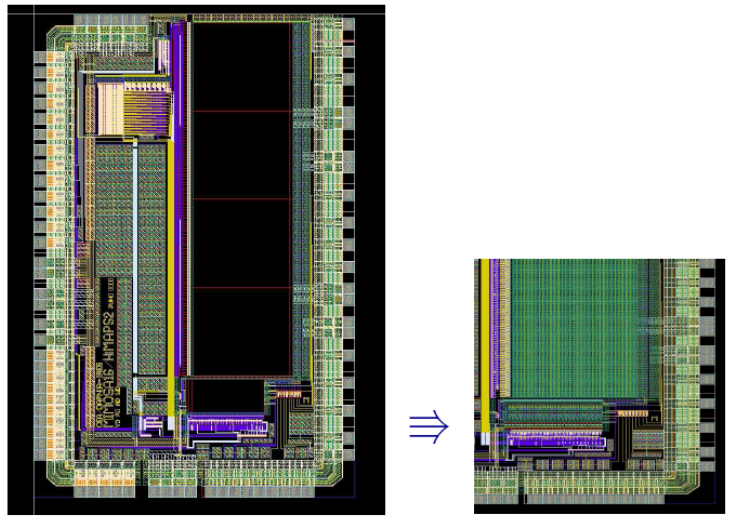


Conclusion:
CMOS detectors suitable for
5 to 10 yrs operation
at ILC,
Even if the machine background (beamstrahlung) is 3 to 5 X greater than expected from the GUINEAPIG_Monte-Carlo

High R.-O. Speed Architecture : 2nd Prototype = MIMOSA-16

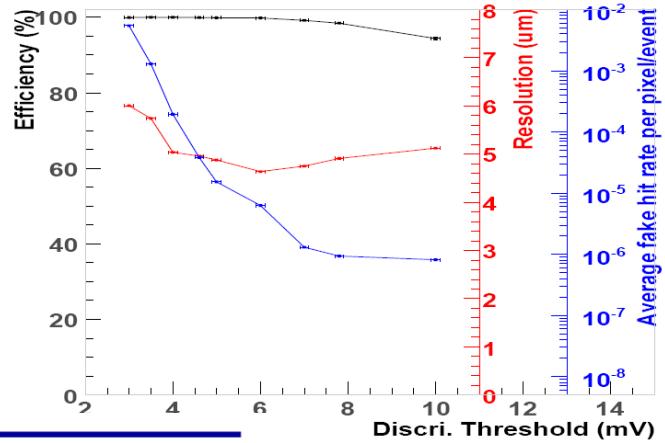
MIMOSA-16 design features :

- **AMS-0.35 OPTO translation of MIMOSA-8**
  $\hookrightarrow \sim$ **11–15** μm **epitaxy instead of** $\lesssim 7\ \mu m$
- **32 // columns of 128 pixels (pitch: 25** μm**)**
- **on-pixel CDS (DS at end of each column)**
- **24 columns ended with discriminator**



M.i.p. detection with Si-stip telescope studied at CERN in Sept. '07 $\longrightarrow$

- π^- **beam of** $\sim$ **180 GeV/c**



Noise performance satisfactory (like MIMOSA-8 and -15)

Efficiency , fake rate and resolution excellent

Discri. Threshold	*det. efficiency*	*fake rate*	*sgle pt resolution*
4 m V	99.96 ± 0.03 *(stat) %*	$\sim 2{\cdot}10^{-4}$	~ 4.8–$5.0\ \mu m$
6 m V	99.88 ± 0.05 *(stat) %*	$<10^{-5}$	$\sim 4.6\ \mu m$

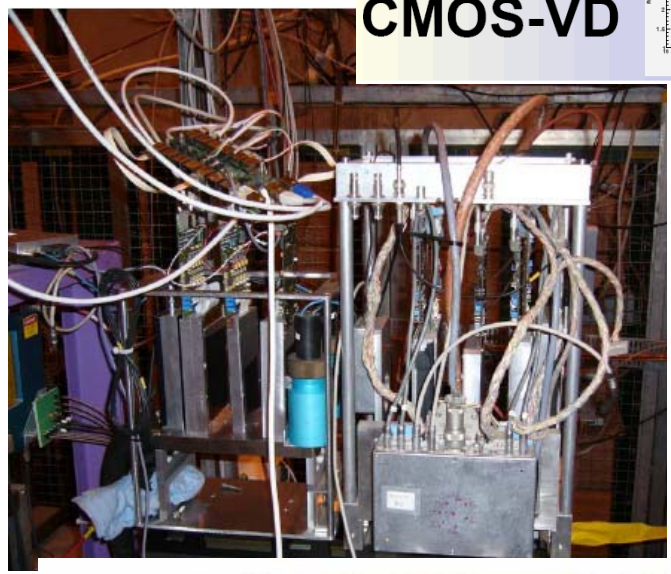
Present use of MIMOSAs

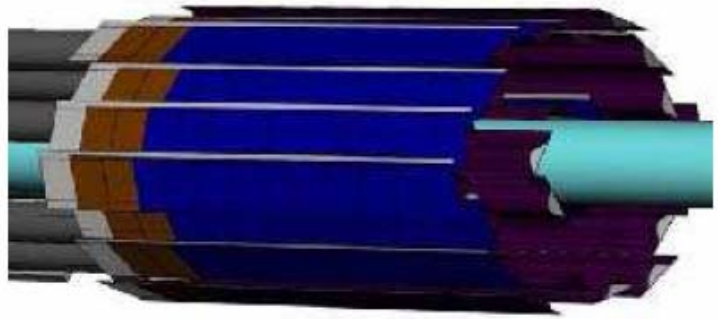
- *New pixel telescope : T.A.P.I.*
  - *3 or 4 MIMOSA-17 or/and -18 sensors (more in future)*
  - *Commissionning in June '07 at DESY*
  - *Real data taking in Sep. & Nov. '07 at CERN-SPS*
  - *R.o. freq. $\sim$ 10 (M-18) or 25 frames/s (M-17)*
  - *Running in front of Si-strip telescope ▷▷▷▷▷ ▷▷▷*

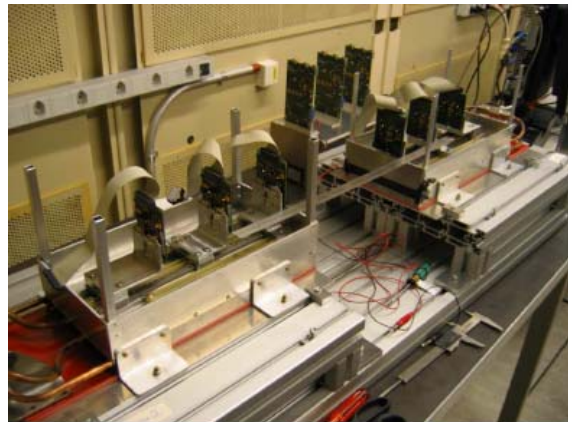
- Vertex Detector upgrade for STAR expt at RHIC
  - 2 cylindral layers : $\sim$ 1600 cm^{-2}
  - $\gtrsim$ 160 million pixels ($\leq$ 30 μm pitch)
  - 3 steps :
  - ▷▷ 2007: telescope (3 MIMO-14) $\longrightarrow$ BG meast, no pick-up !
    - 2008/09: digital outputs without $\emptyset$ ($\leq$ 640 μs)
    - 2010/11: digital outputs with integrated $\emptyset$ ($\leq$ 200 μs)

- Beam telescope (FP6 project EUDET)
  - 2 arms of 3 planes (plus 1 high resolution plane)
  - provide $\lesssim$ 1 μm resolution on 3 GeV e$^-$ beam (DESY)
  - 2 steps :
  - ▷▷ 2007: analog outputs
    - $\longrightarrow$ telescope commissionned & running ($\lesssim$ 100 tracks / frame)
      - $\longrightarrow$ used by non JRA-1 members at SPS (e.g. SILC)
    - 2008/09: digital outputs with integ. $\emptyset$ ($\sim$ 100 μs)

CMOS-VD

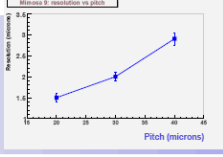






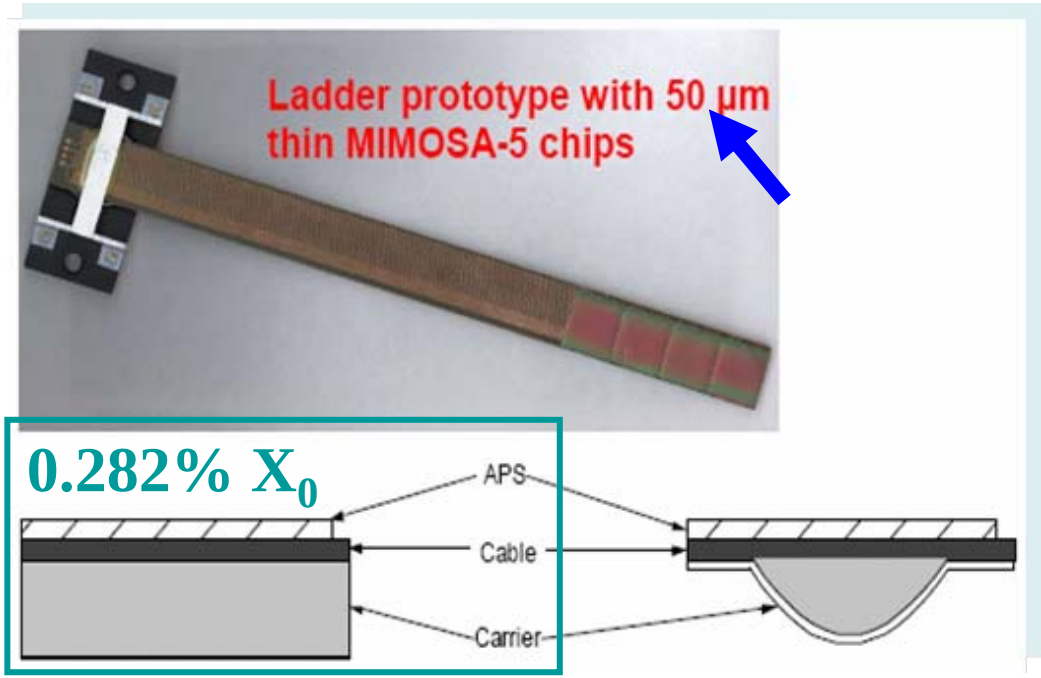
STAR HFT Ladder (LBNL)

CMOS-VD



Program of engineering design, construction and characterization of full ladder equipped with back-thinned CMOS pixel sensors based on experience from STAR HFT project and in collaboration with them;

STAR Low mass carrier: 50μm CFC+3.2mm RVC+50μm CFC (=0.11%X_0);



Component	Thickness (% X_0)
Pixel Chip	0.054
Adhesive	0.014
Kapton Cable	0.090
Adhesive	0.014
Carrier	0.110
Total	0.282

Still a factor ~ 2 better needed for ILC

ILC Detector R&D in France

- Electromagnetic and Hadronic calorimetry
- CMOS Microvertex MAPS
- Silicon strip Tracking
- TPC

Silicon Tracker for the Linear Collider

LAPP Annecy, U. of Michigan Ann Arbor, U. of Barcelona,
IMB-CNM/CSIC Barcelona, HIP Helsinki, VTT Helsinki, IEKP Karlsruhe U.,
U. of Liverpool, Moscow State U. Obninsk State U., LPNHE/IN2P3-UPMC Paris,
Charles U. Prague, SCIPP and UCSC in Santa Cruz, Yonsei U, Korea U,
Seoul National U, SungKyunKwan U., Kyungpook U, Daegu and Seoul,
IFCA/CSIC-U. of Cantabria Santander, INFN-Torino and Torino U.
IFIC/CSIC –Valencia U, HEPHY Vienna, HPK Hamamatsu City.
Collaboration with DESY (beam test & telescope) and CERN (beam test & bonding Lab)

Spokesperson A.Savoy-Navarro (LPNHE)

R&D Aim:

Decrease the material budget (%X_0)
& improve performances

R&D on silicon strip detectors
on electronics
on mechanics and cooling
Test benches and beam tests

WWS R&D REVIEW PANEL ON TRACKING, BILCW'07, ICHEP, Beijing, feb.2007

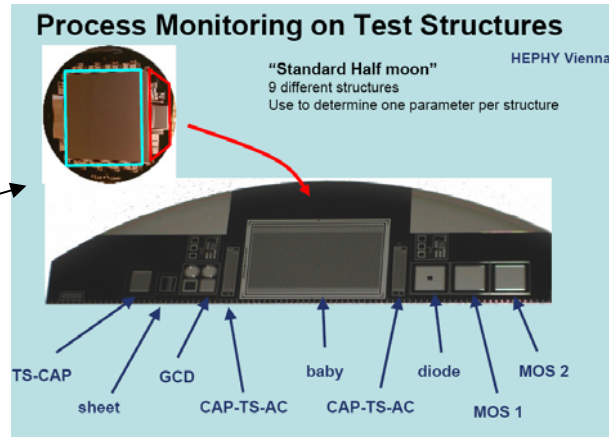
R&D on Silicon detectors:

- Collaboration with Hamamatsu Photonics (HPK) =>

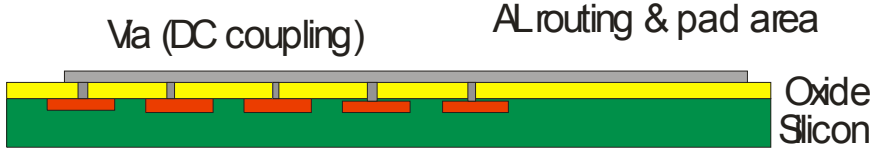
i) HPK for baseline: larger µstrips detectors (≥ 6''), single sided, thinner and smaller pitch (≤ 50µm) with alignment holes.

HPK detectors with test structures,

delivered: 1/10/07

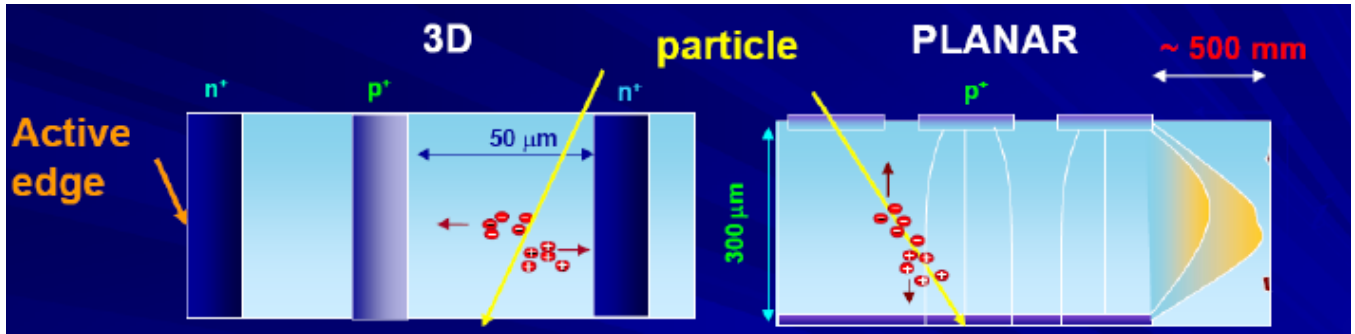


ii) Collaboration LPNHE-HPK on a new connection scheme: **bonding chip directly on strips.**

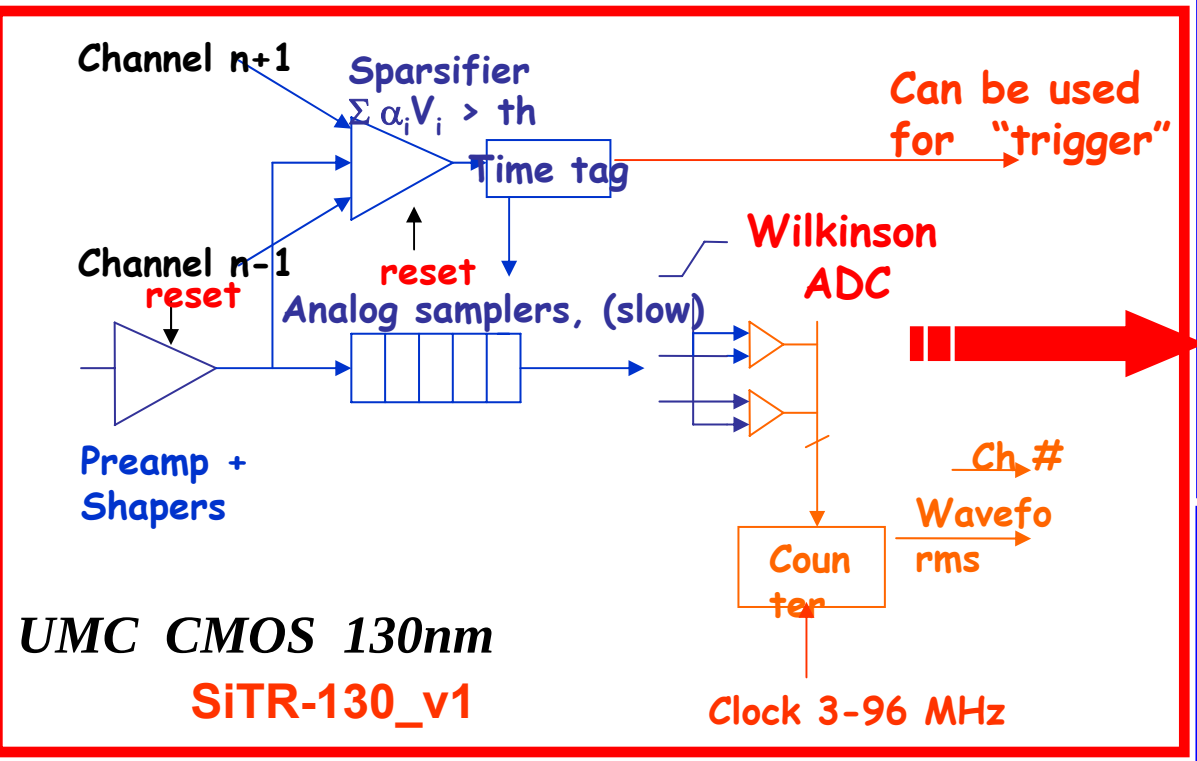


Use of test bench and test beams for trial ans measurements

iii) Collaboration with VTT **on 3D detector structure**



R&D Electronics FE: *LPNHE + LAPP+Barcelona U.*

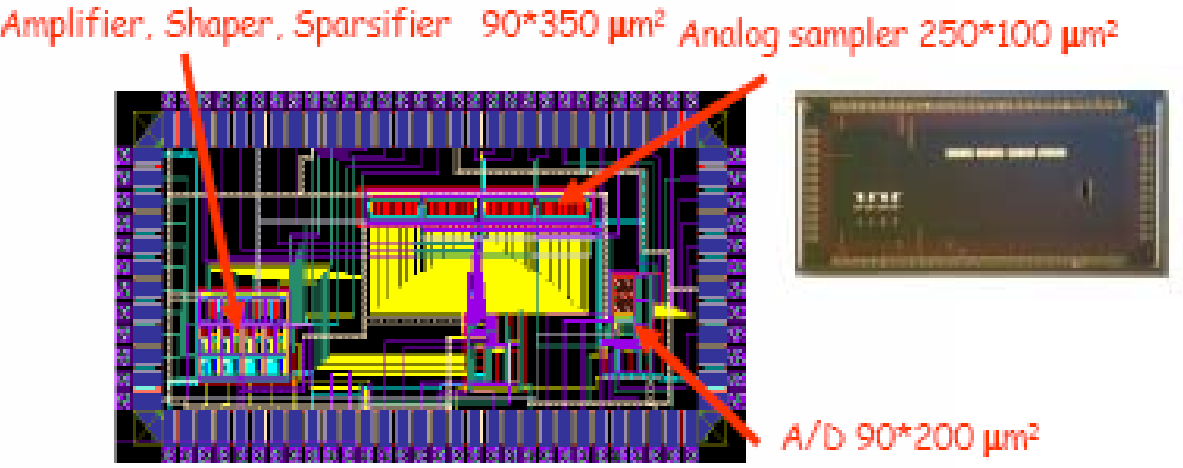


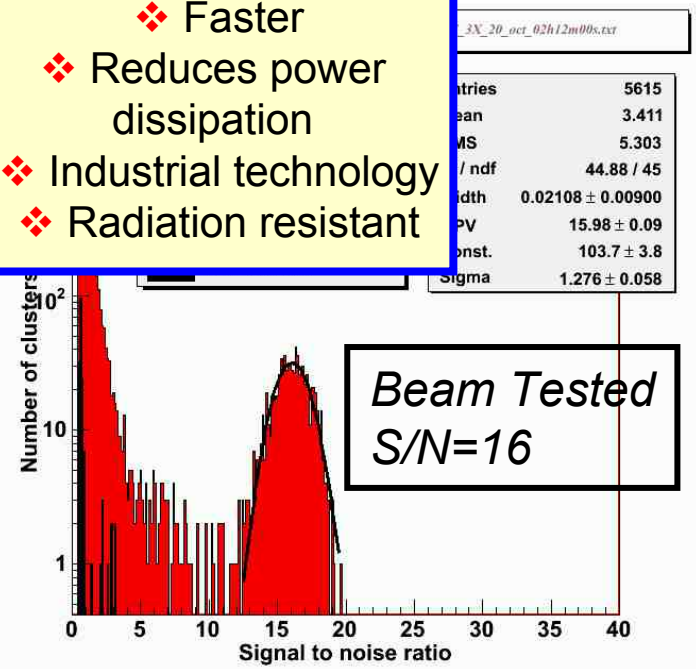
- Read out chain complete
- ***Digital Oscilloscopy*** (analog pipeline and A/D)
- Zero Suppress
- Power cycling (to avoid cooling)
- Internal circuit calibration
- Digital circuit management

DSM 130nm:

- ❖ More compact
- ❖ Faster
- ❖ Reduces power dissipation
- ❖ Industrial technology
- ❖ Radiation resistant

4 Channels demonstrator: chip layout & picture





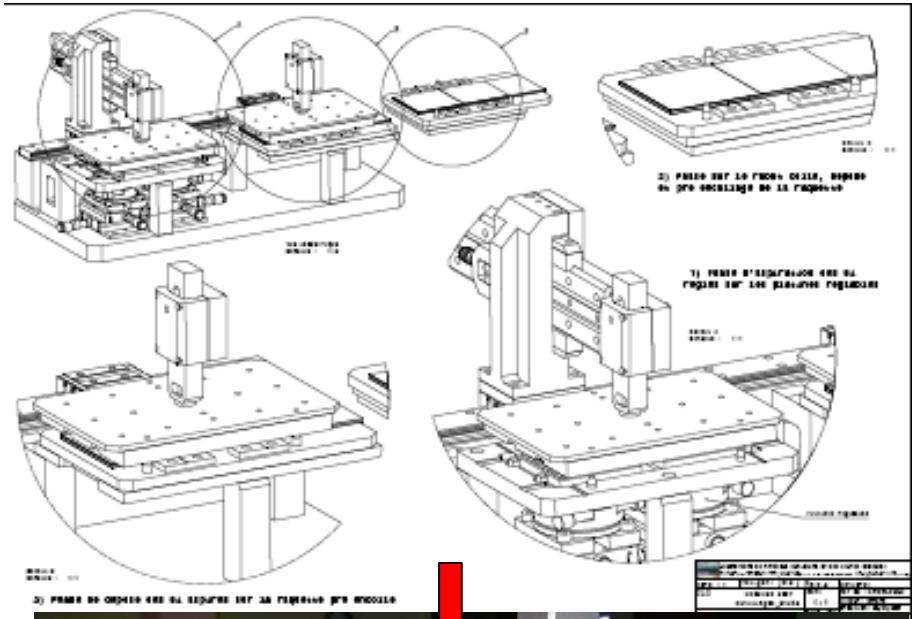
MECHANICAL R&D

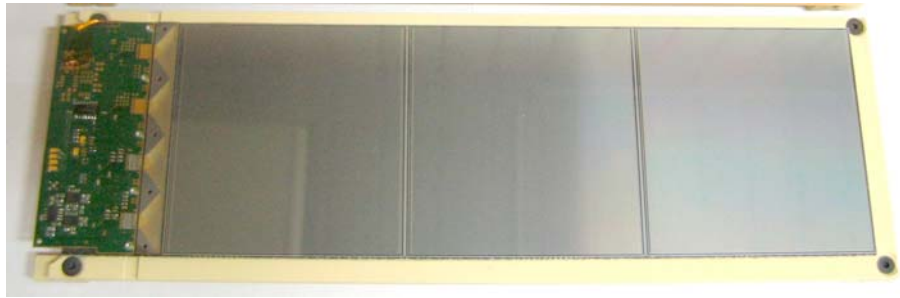
New much thinner structures

- Tooling development
- Modules & prototypes construction
- Study of new materials

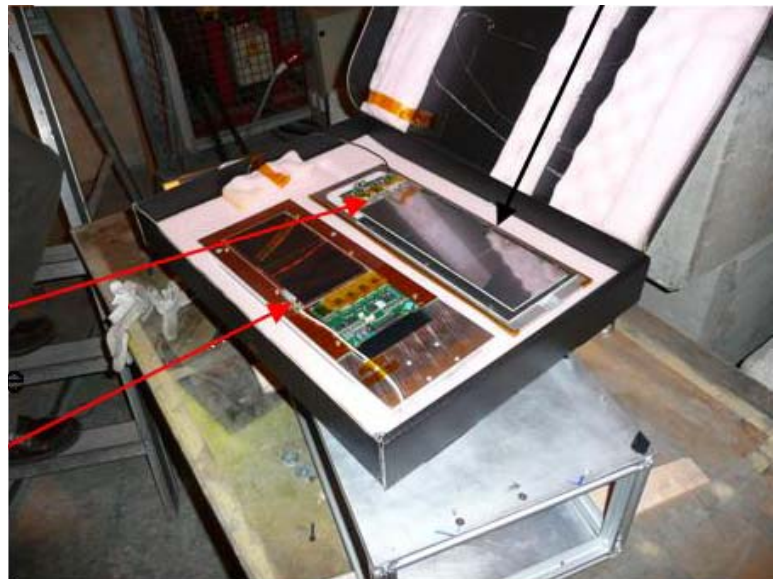
➢Getting know-how

➢Collaboration with CERN Bonding Lab





Construction at LPNHE of 2 & 3 Silicon Detector modules for beam tests.



IN2P3
Institut National de Physique Nucléaire et de Physique des Particules

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

ilc France

ILC Detector R&D in France

- Electromagnetic and Hadronic calorimetry
- CMOS Microvertex MAPS
- Silicium strip Tracking
- TPC

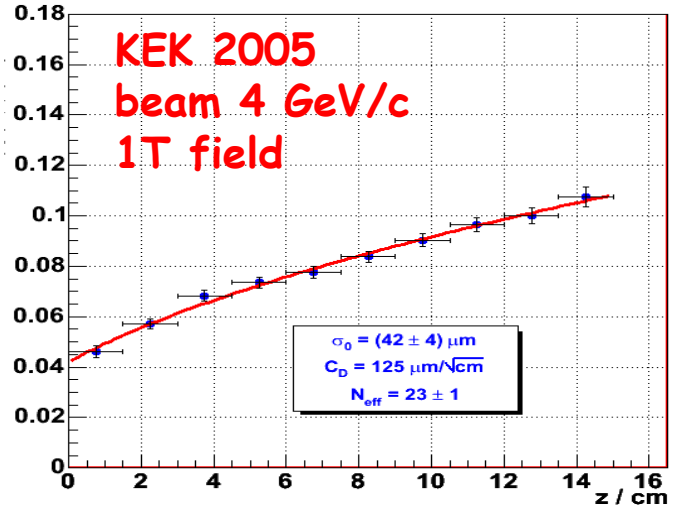
TPC: LC-TPC Collaboration

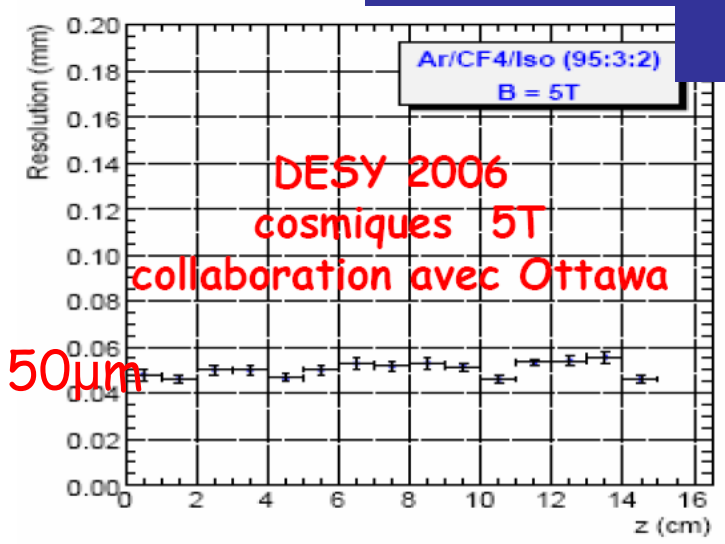
TPC with Micromegas read-out

IRFU SACLAY and LAL

Americas	Asia	Europe
Carleton	Tsinghua	LAL Orsay
Montreal	CDC:	CEA Saclay
Victoria	Hiroshima	Aachen
Cornell	KEK	Bonn
Indiana	Kinki U	DESY
LBNL	Saga	U Hamburg
Louisiana Tech	Kogakuin	Freiburg
Purdue (observer)	Tokyo UA&T	MPI-Munich
	U Tokyo	Rostock
	U Tsukuba	Siegen
	Minadano SU-IIT	NIKHEF
		Novosibirsk
		Lund
		CERN

Spatial resolution vs. drift distance





This program will go on in 2008 with the Large TPC Prototype cosmics and beam tests of 10 000 channels

WWS R&D REVIEW PANEL ON TRACKING, BILCW'07, ICHEP, Beijing, feb.2007

Conclusions

- There is consensus that ILC is after LHC the next Particle Physics machine.
- The R&D ILC *Accelerator, Physics and Detectors* is mandatory to reach the precision required by the physics
- Present results are very positive that this aim can be reached
- This activity has national and European support, it is pursued within fully integrated international collaborations
- Links with industry are active
- Synergy with other detector developments **(CLIC , SLHC, SuperB, neutrinos…) is evident**
- Loi's and detailed Enginneering design necessitate large advanced prototypes in coming years.
- ILC R&D is an excellent training ground for young physicists, particularly the work on beam tests data taking and analysis.