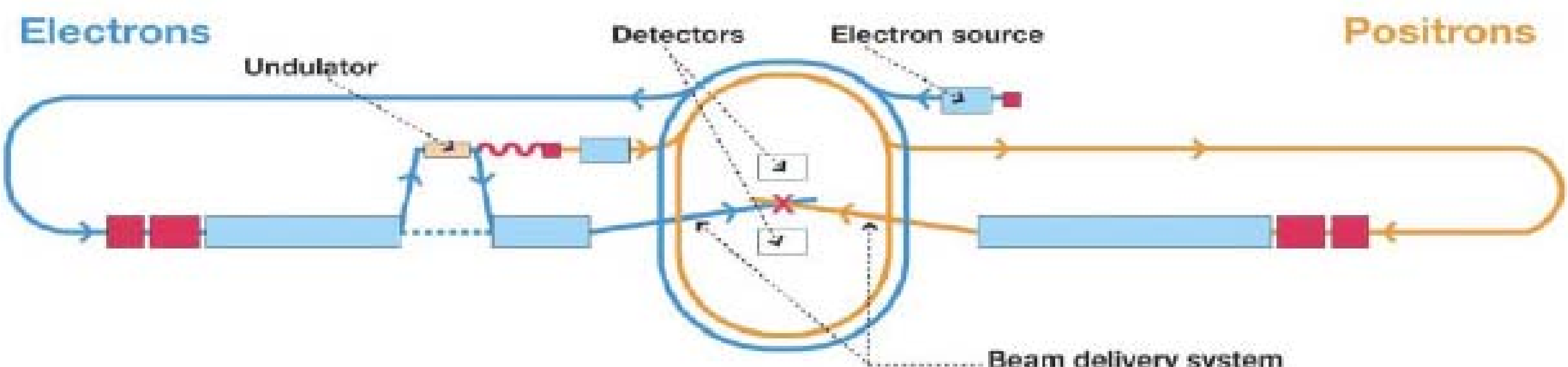
Japan France_Particle Physics Laboratory Workshop
FJPPL2008 - May 15th to 17th, 2008

PARTICLE PHYSICS JOINT LAB
JAPAN - FRANCE

R&D for the ILC detectors in France

Jean-Eudes Augustin 17 May 2008

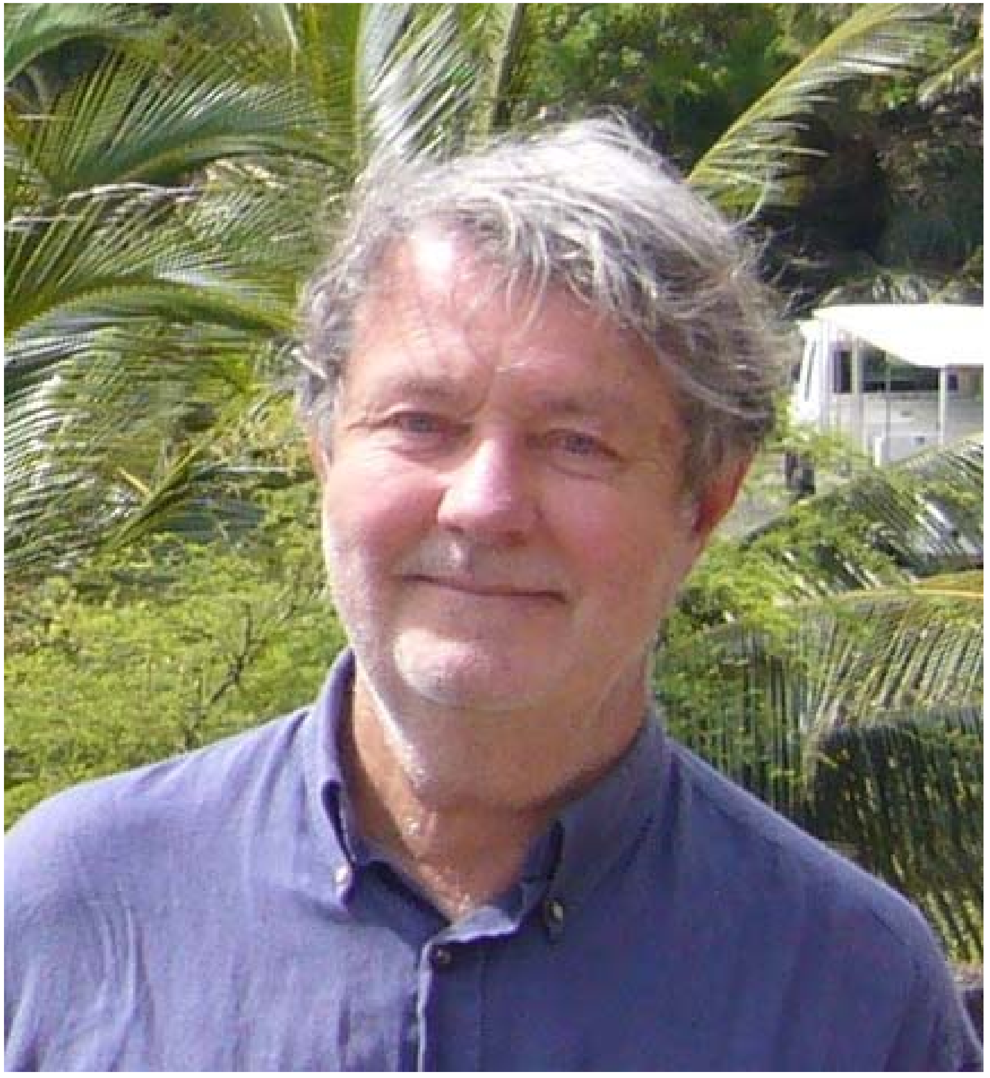
ilc International Linear Collider



Dedicated to Vincent Lepeltier

Our friend and colleague Vincent passed away suddenly on March 17, 2008

He made very important contributions in understanding the operation of MPGDs and worked within FJPPL for a TPC for the Linear Collider.



ILC Detector R&D in France

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

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

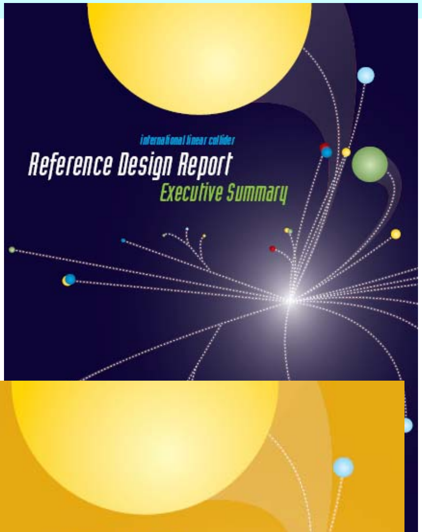
ILC Progress

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

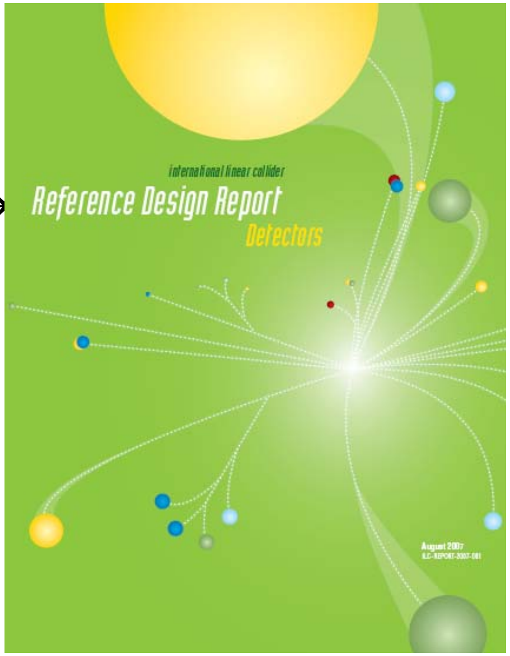
Ex. Summary →



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

Accelerators →

Detectors→



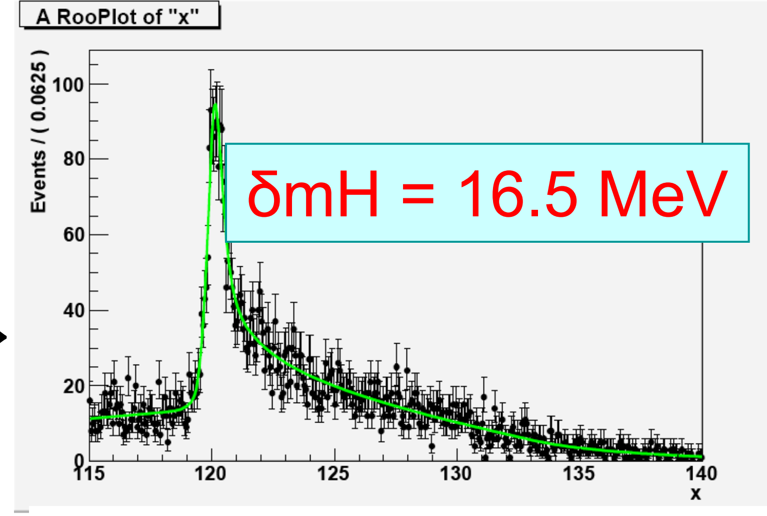
Next: Technical Design Phase
TDP – 2010 / 2012

Physics at ILC:

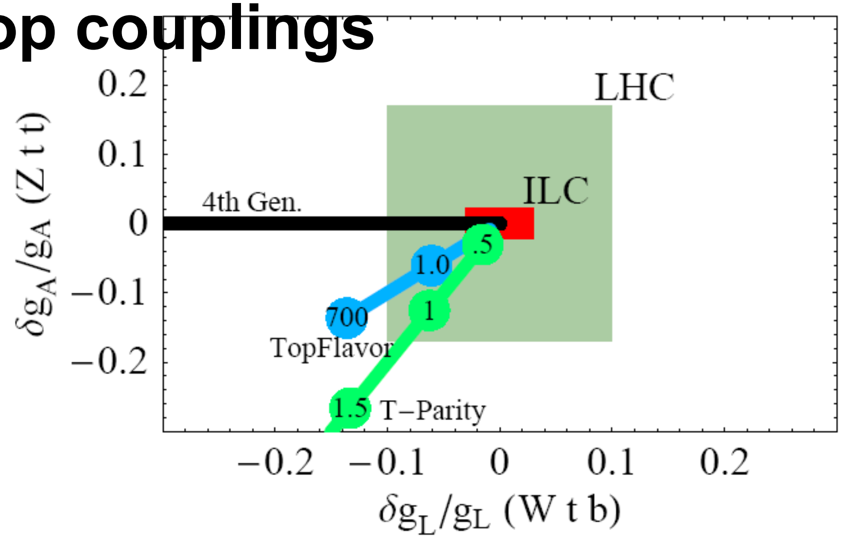
Precision measurements for discovery physics

Exemples: **Higgs Invisible decay** →

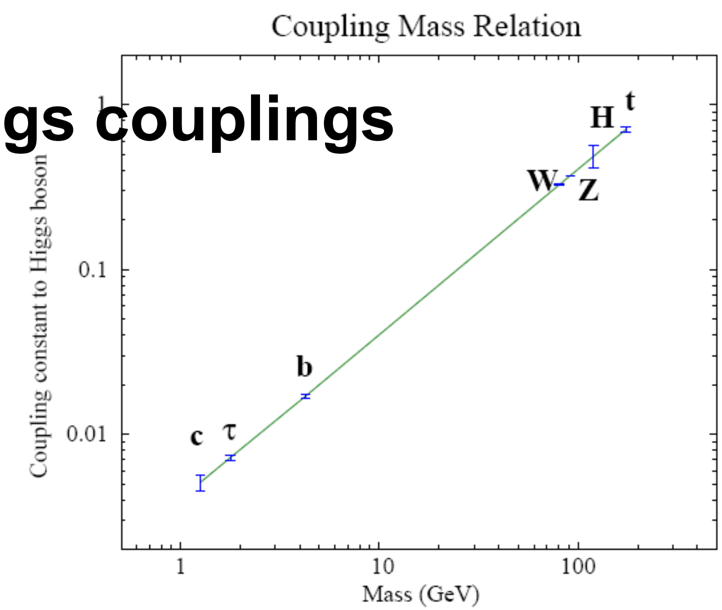
($e+e- \rightarrow HZ \rightarrow \mu\mu H$)



Top couplings



Higgs couplings



Determination of SUSY parameters

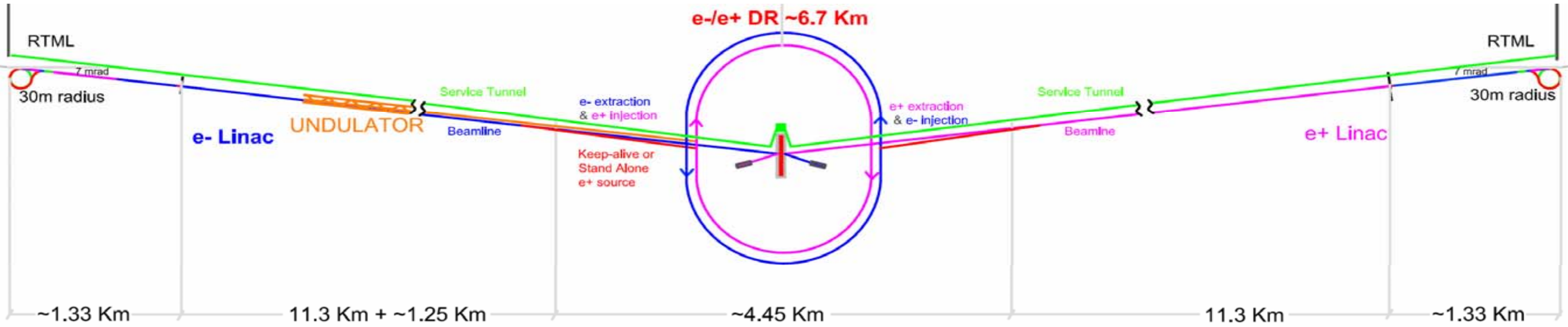
Example of mSUGRA, using all previous measurements at LHC/ILC

	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

International Linear Collider ILC

electron-positron collider, 200 à 500 GeV in e+e- c.m,
$L=2.10^{34}$ $cm^{-2}sec^{-1}$, 500 fb^{-1} in 4 yrs, Polarization e- 80% (e+ 50%)

- Two 11km supra-conducting Linacs, 31.5 MV/m at 500 GeV
- Central Injection
  - Damping rings for electrons and for positrons
  - Positron source form undulator
- One interaction region, 14 mrad crossing angle
- Two Tunnels, for safety and technical intervention
- 6,6 G$ + 14000 person•year: *"cost similar to LHC one"*
- Extension to 1 TeV foreseen from start



Schematic Layout of the 500 GeV Machine

The Roadmap

- Start a technical design phase (TDP) synchronously for the machine and the detectors
- Technically driven schedule aiming at ‘light TDs’ but sufficient to start the approval procedure in ~2010 - 2012
- For the machine the critical step is on cavities
- Very active machine & detector R&D worldwide
- A procedure is underway to have two detector designs by 2010 - 2012

Brief summary of the French Machine R&D efforts

- Main Linac – mostly **XFEL related**, but also FP7 « ILC Hi-Grade » and CARE 1&2:
  - Cavities (EP, Baking)
  - **Input couplers**
  - **Cryomodules** (cold mass, string assembly, module integration transport engineering)
  - **Cold BPMs**
  - Alignment/stabilisation
  - Other R&D
- Positron source
  - Compton source/polarisation (Alter.)
- Beam Delivery systems
  - ATF2 tests
  - 2 mrad and 0 mrad (Alter.)
  - MDI and machine background

ATF2 collaboration
(KEK accelerator test facility)

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 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 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

  $$\sigma_{ip} = a \oplus b/p_t$$

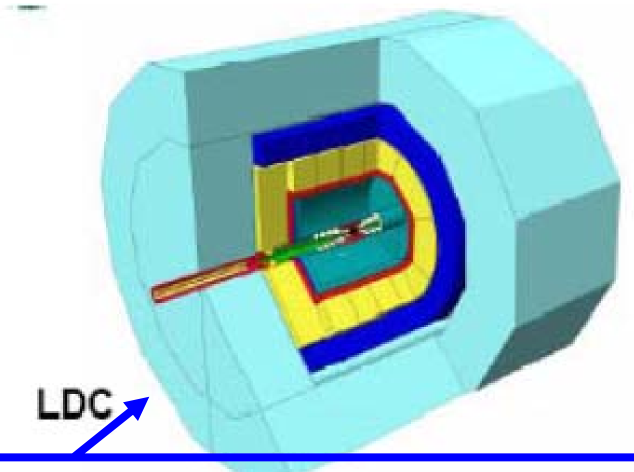
  a <5(μm), b <10(μm · GeV)

  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

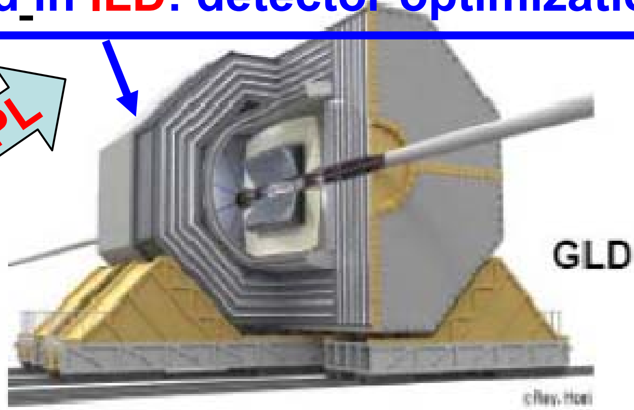
The 4 detector concepts

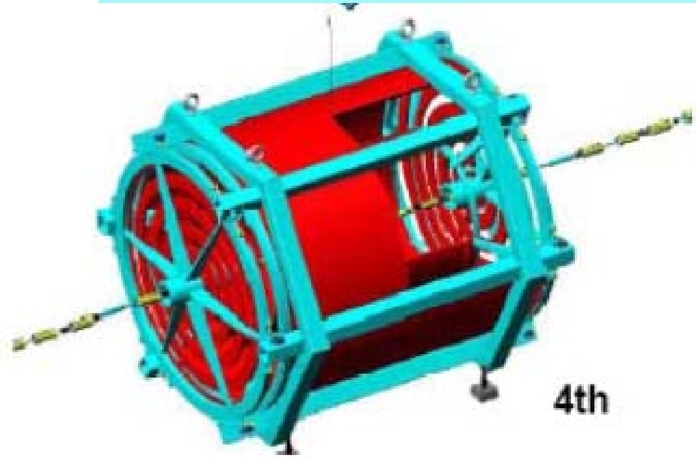


Y.Karyotakis, member of SiD SB

Merged in ILD: detector optimization

FJPPL





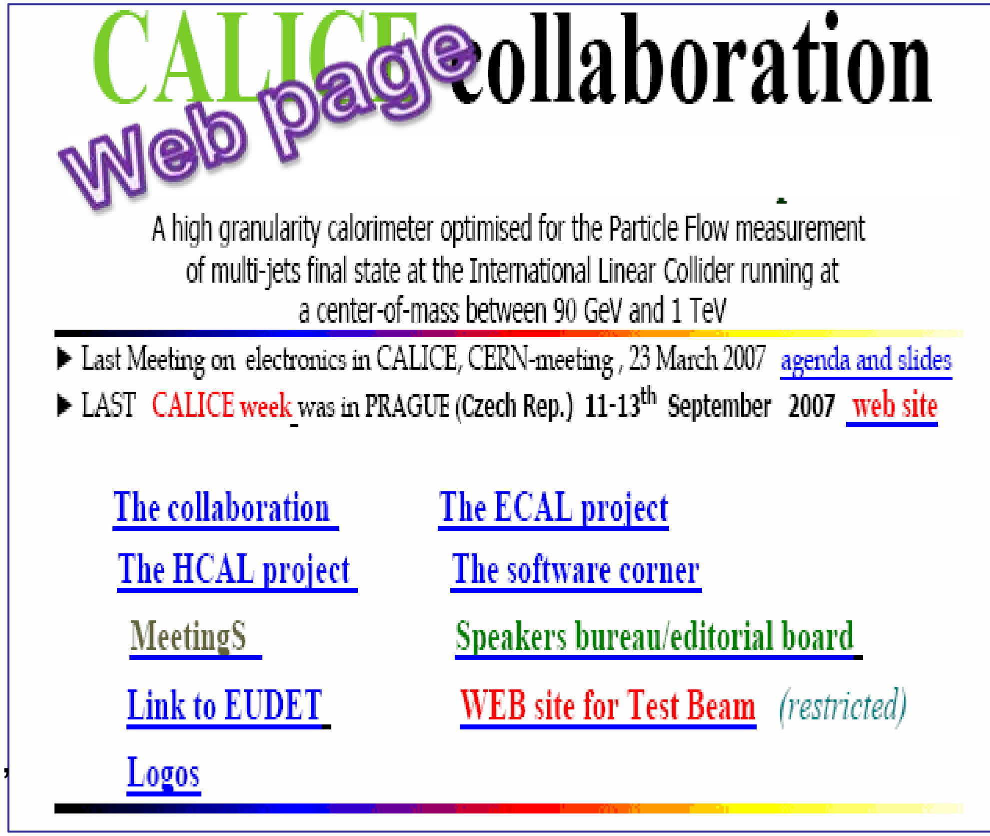
H.Videau, member of ILD JSB

LOI's by 31 March 2009
Detector LOI's to be evaluated by IDAG for a TDP

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

PFA studies

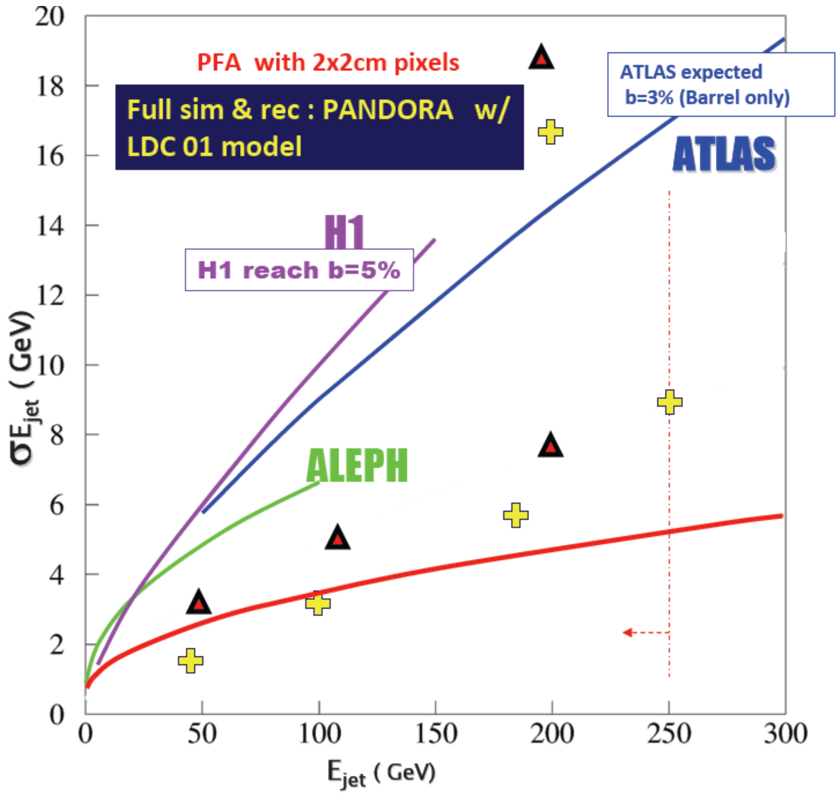
Particle Flow Analysis:

- Measure charged particle by trackers and neutral particles by calorimeter.
- High grain calorimeter and sophisticated algorithm is crucial to achieve a good jet energy resolution
- Performance goal was set at 30%/√E (GeV)

- Pandora PFA has achieved the goal: For E<100 GeV jets

E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
45 GeV	0.235	3.5 %
100 GeV	0.306	3.1 %
180 GeV	0.427	3.2 %
250 GeV	0.565	3.6 %

Summary of Pandora PFA performance
w. LDC01 model – SiD meeting, RAL april08



First ECAL prototype

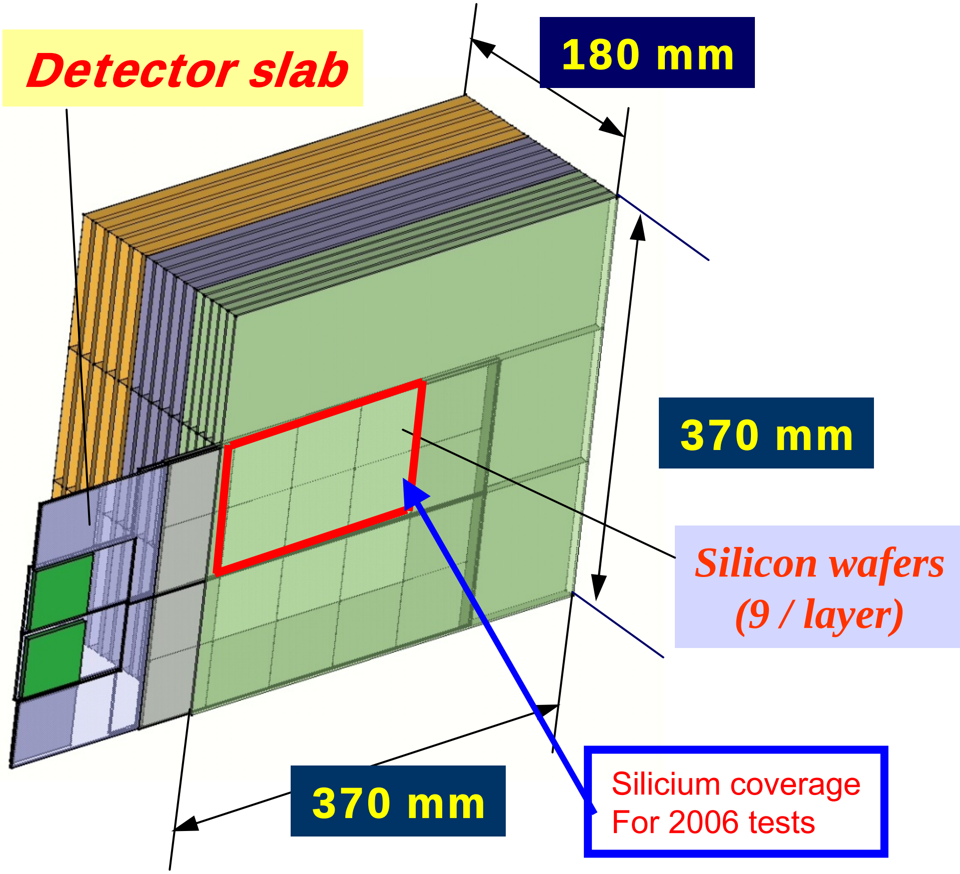
Why this prototype?

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

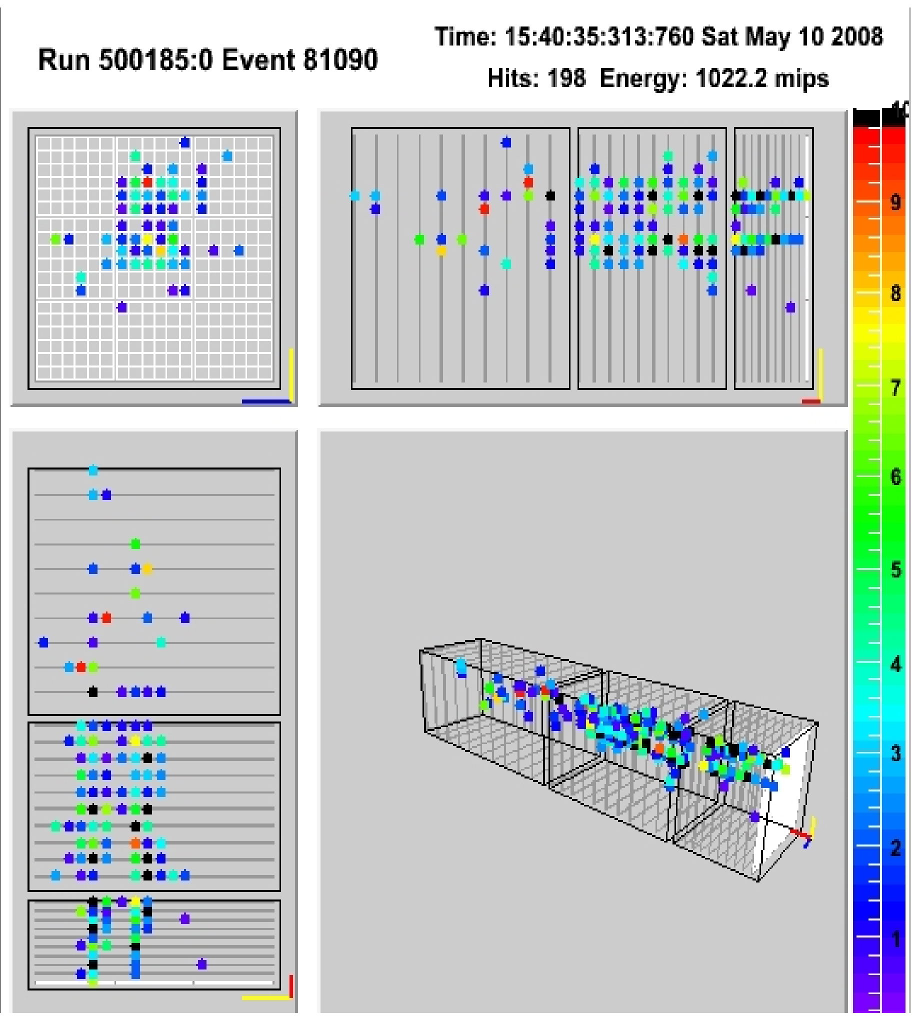
3 – Comparison with GEANT4 in boundary zones (between wafers, between alveols, etc…)

4 – Publicize the IN2P3 know-how on Calorimetry

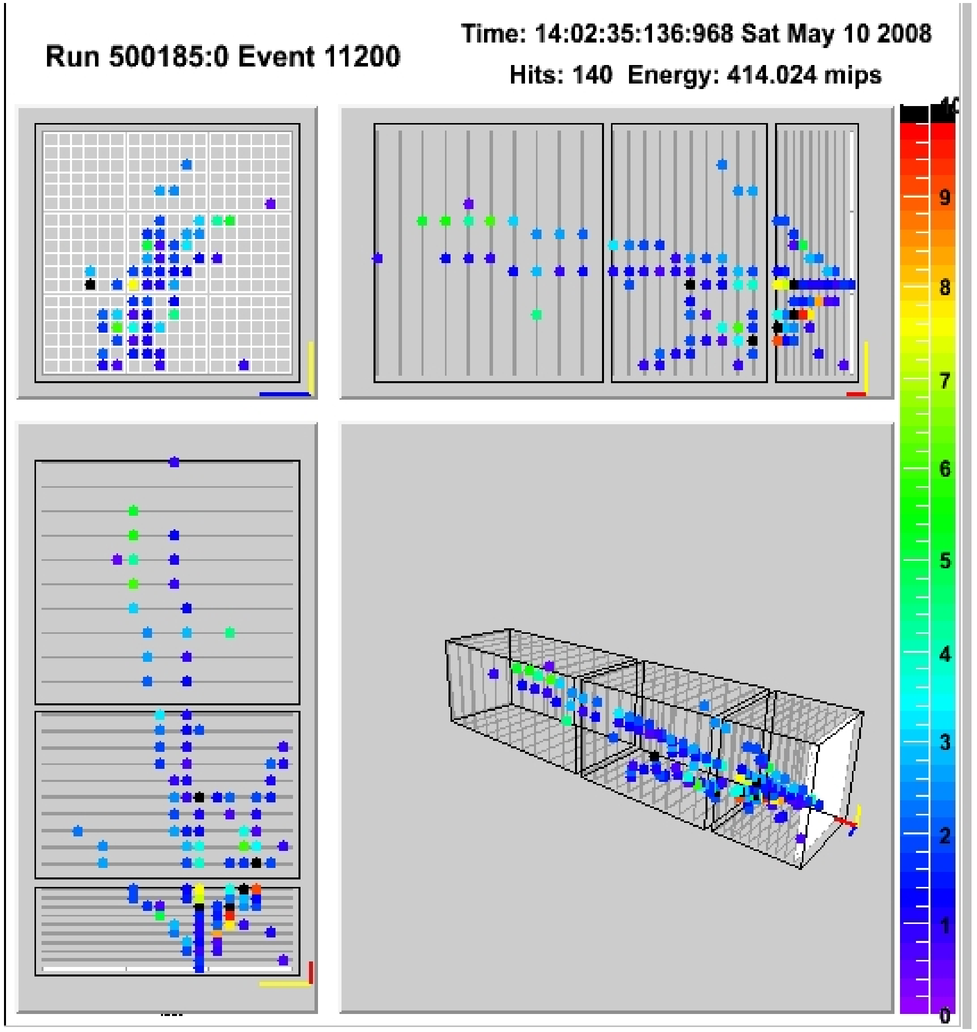


10 GeV pion CERN test beam in 2006 and 2007

8 GeV pion beam

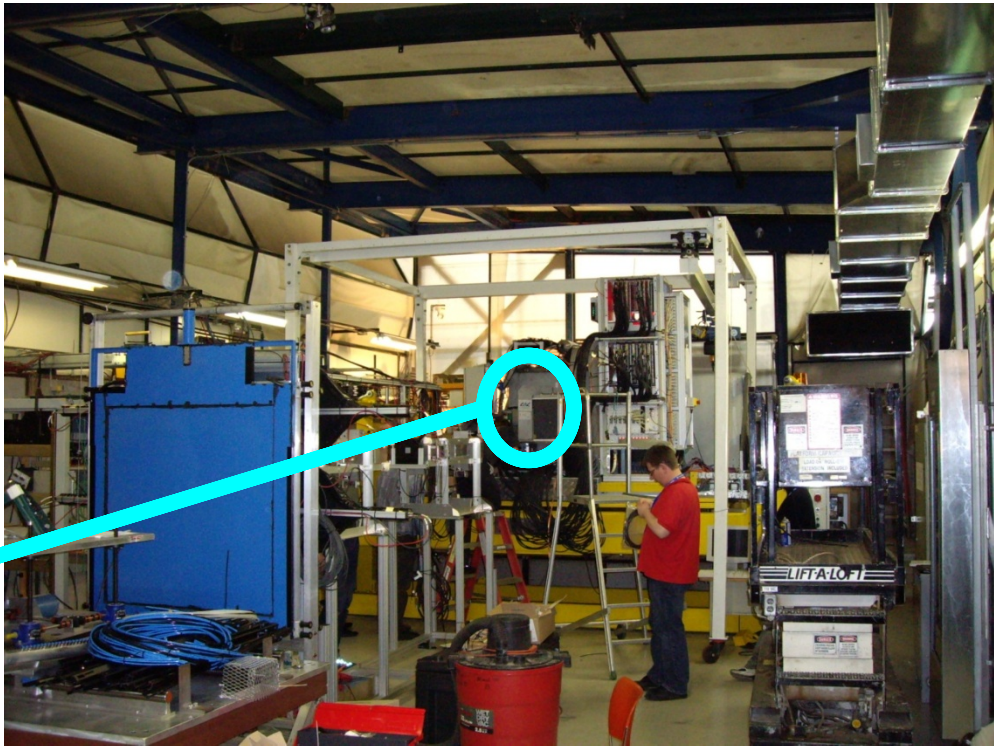


Simultaneous particle arrival



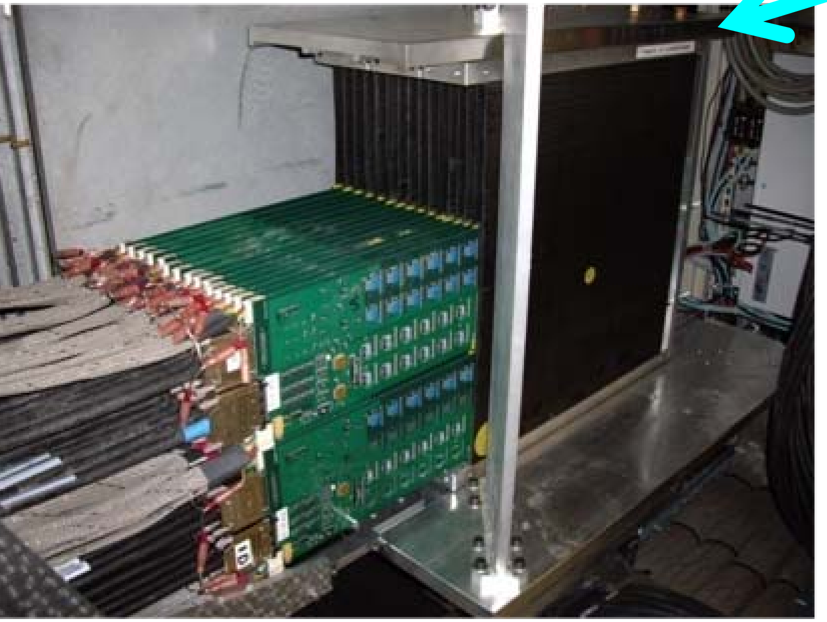
Hadronic shower of single pion

Calorimeter for ILC



Installation at MTBF-FNAL

DAQ , counting room,
services, trigger, etc...
First test with very low energy pions
We foresee comparison with Scint-W



R.Poeschl (LAL)

Goal of the ECAL 2008 TB

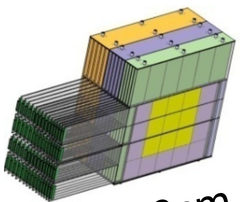
> Going down to 1 GeV pion

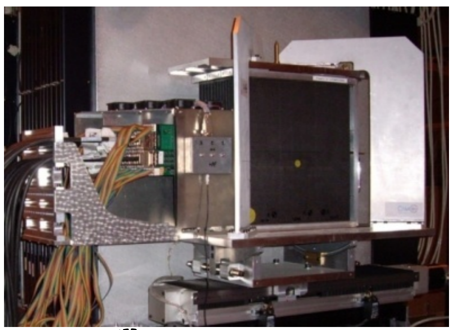
> Debuging the brand New Scintillator – tungsten ECAL

> Comparing for Scint-W and Si-W performances on
- electron
- pion at low and mid energy

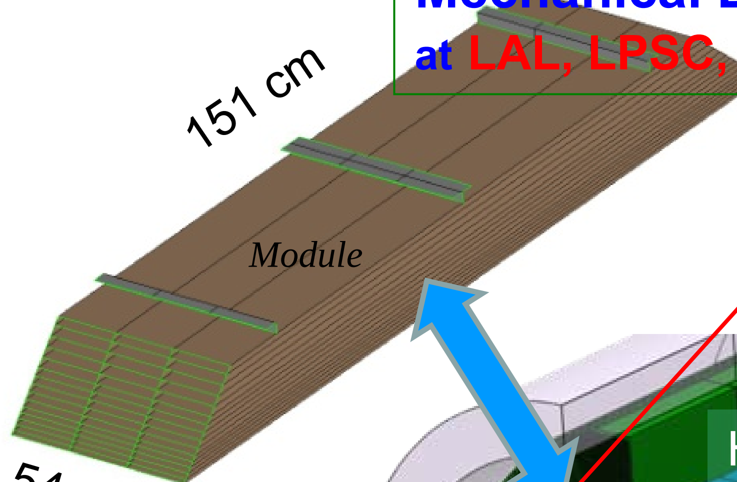
Advanced engineering prototype

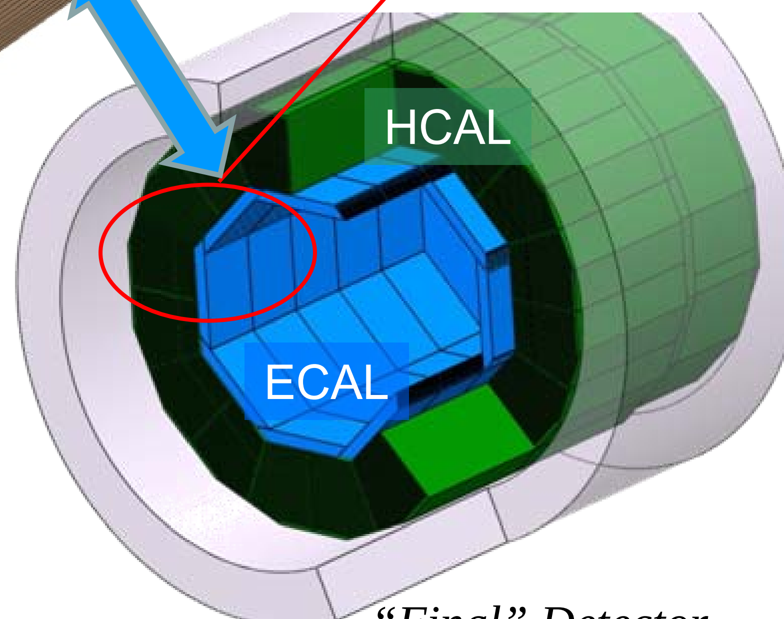
1/48th of final barrel calorimeter





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

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

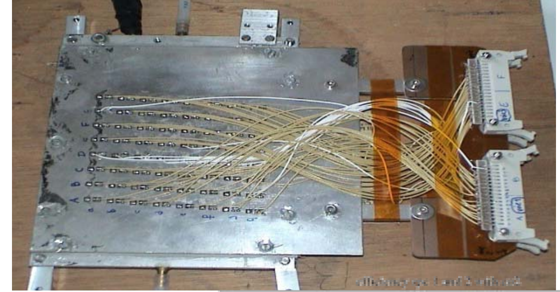
- Development and test of VFE ASIC - HARDRoC LAL
    - produced, tested in-situ on a 4chips PCB (small test plane)
    - future development (VFE) IPNL

- DAQ for this system
    - for the $1\ m^2$ plane - Design done, being tested - LLR
    - R&D for an **M^3** prototype($70x70x100cm^3$… 200 K canaux) LAPP, LLR, …

- The **M^3** prototype

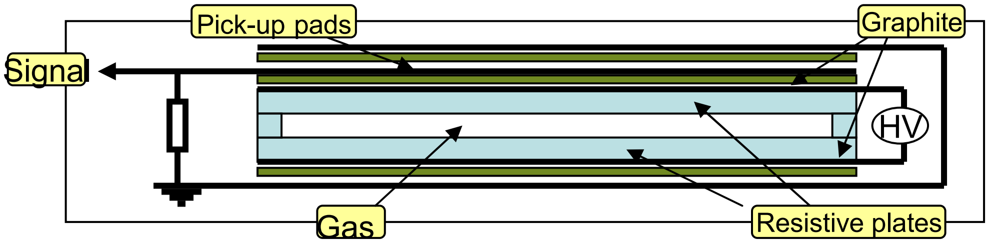
(40 planes detector+absorber, 200 000 channels) . Construction for 2008-2009 with ILC- type mechanical structure (**IPNL, LAPP**, **CIEMAT-Madrid**)

Gaseous detectors tests



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

8X8 pads, 8X32 pads, 1m2

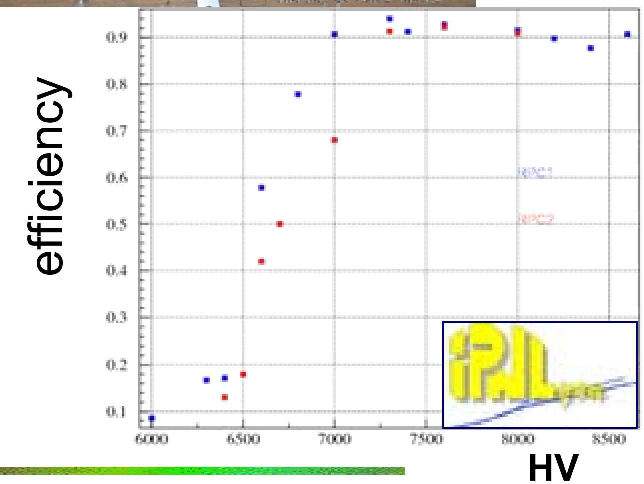


Measurements :

Efficiency, X-talk, homogeneity

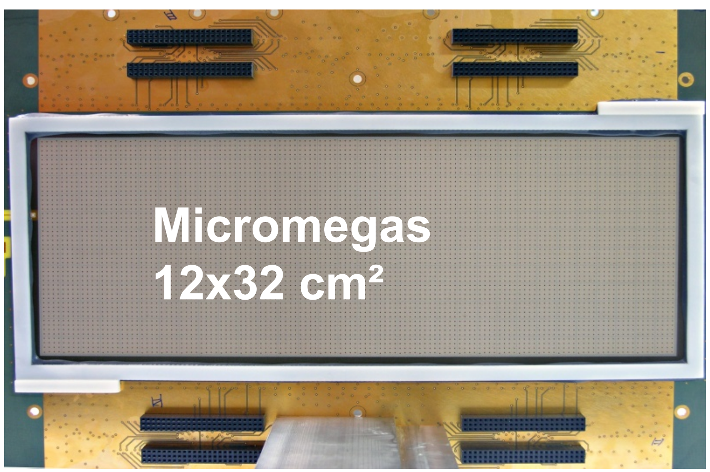
Study of new gas mixtures

(Isobutane->CO_2)



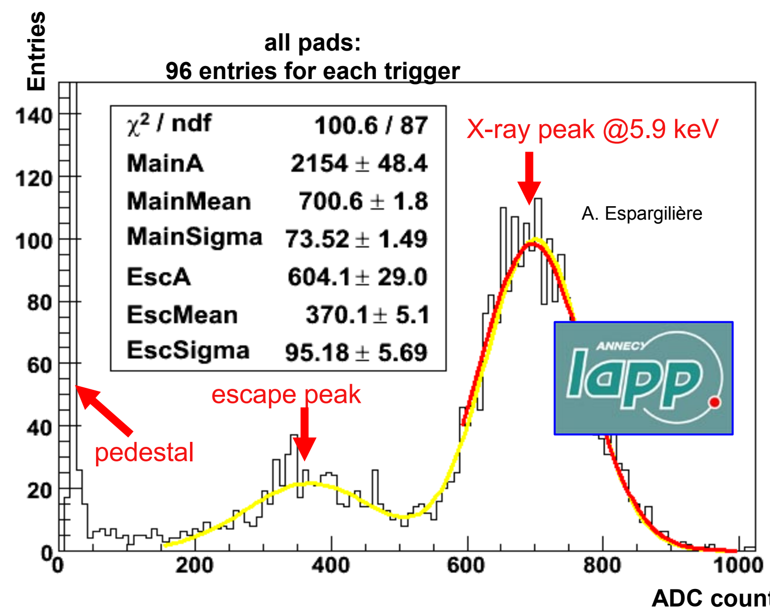
μMEGAS :

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

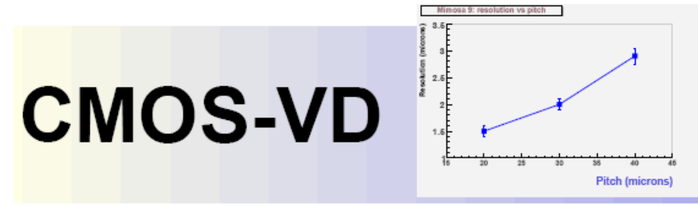


future

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



CMOS detectors optimized for ILC vertex detector



Marc Winter IPHC Strasbourg

LPSC/Grenoble, IPHC/Strasbourg

DAPNIA/Saclay, DESY, Uni. Hamburg, JINR-Dubna

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

g

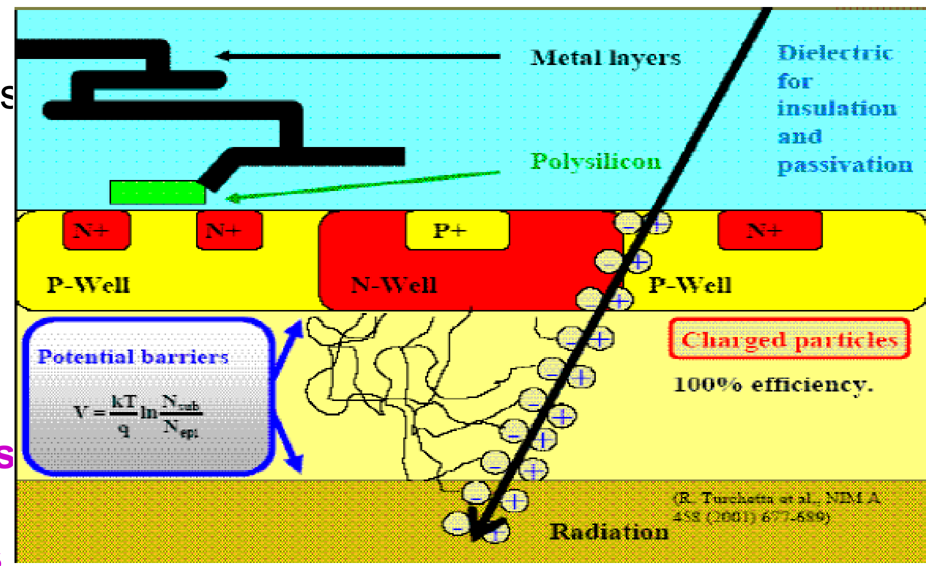
WWS R&D REVIEW PANEL on VERTEX DETECTORS, ALCPG'07, october 2007

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**

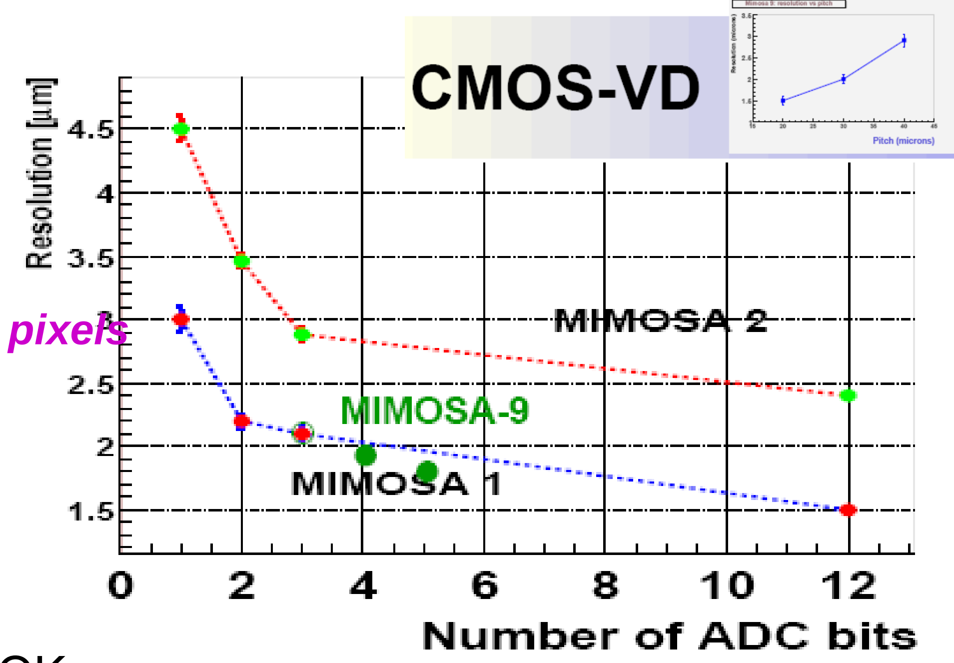
2) **Later produce ILC detectors with ADC's and higher RO frequency**

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→

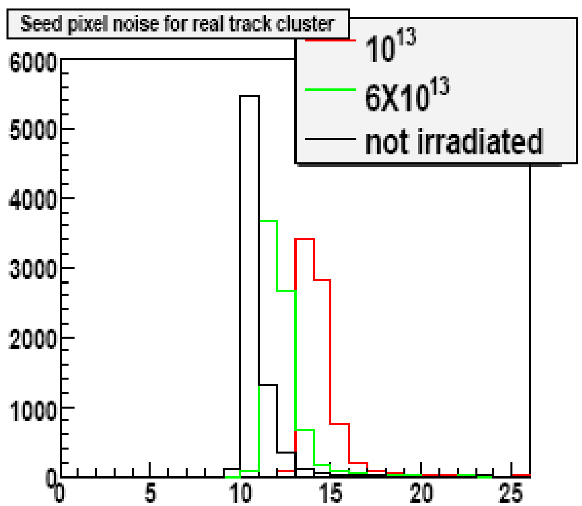


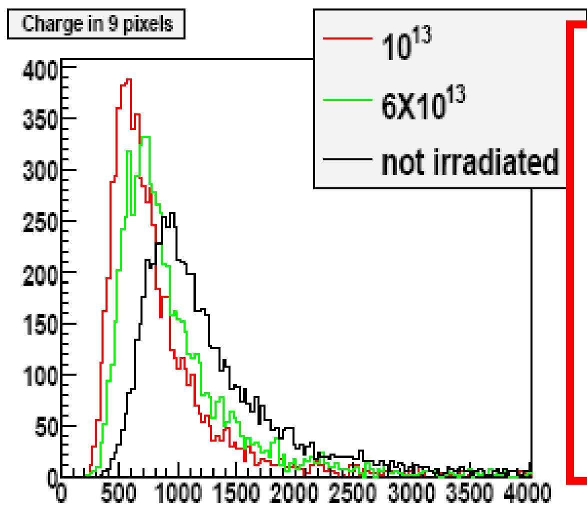
Radiation Tolerance (AMS-0.35 opto)

- 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

Present use of MIMOSAs

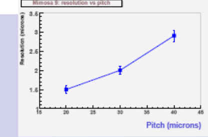
- *New pixel telescope : T.A.P.I.*
  - ◇ *3 or 4 MIMOSA-17 or/and -18 sensors (more in future)*
  - ◇ *Commissionning in June '07 at DESY*
  - ◇ *Real data taking in Sep. & Nov. '07 at CERN-SPS*
  - ◇ *R.o. freq. $\sim$ 10 (M-18) or 25 frames/s (M-17)*
  - ◇ *Running in front of Si-strip telescope ▷▷▷▷▷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

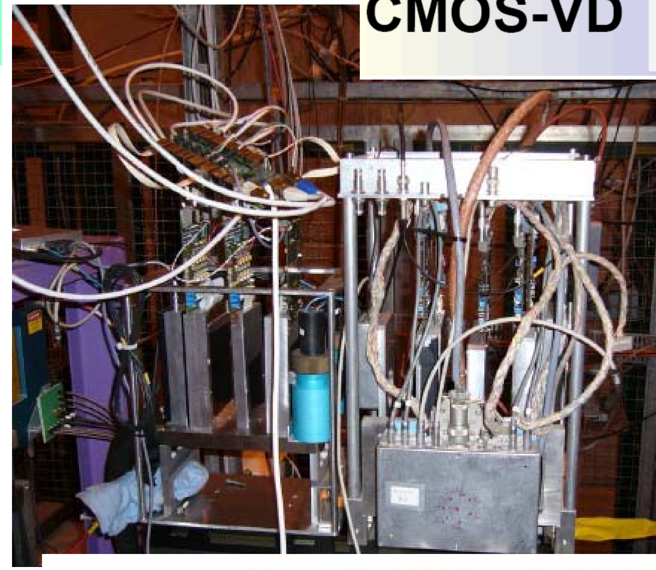
- **Vertex Detector upgrade for STAR expt at RHIC**
  - **2 cylindral layers : $\sim$ 1600 cm^2**
  - **$\gtrsim$ 160 million pixels ($\lesssim$ 30 μm pitch)**
  - **3 steps :**
  - ▷▷ **2007: telescope (3 MIMO-14) $\longrightarrow$ BG meast, no pick-up !**
    - ◇ **2008/09: digital outputs without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

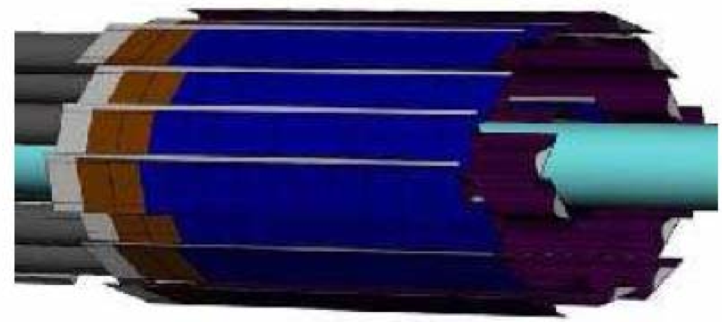
Beam telescope (FP6 project EUDET)

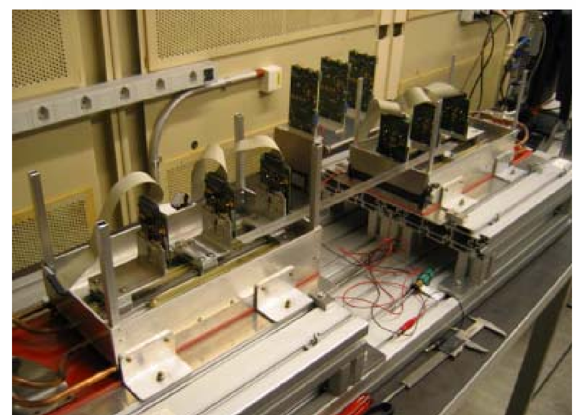
- **2 arms of 3 planes (plus 1 high resolution plane)**
- **provide $\lesssim$ 1 μm resolution on 3 GeV e$^-$ beam (DESY)**
- **2 steps :**
- ▷▷ **2007: analog outputs**
  - $\rightarrowtail$ **telescope commissionned & running ($\lesssim$ 100 tracks / frame)**
  - $\longrightarrow$ **used by non JRA-1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

CMOS-VD









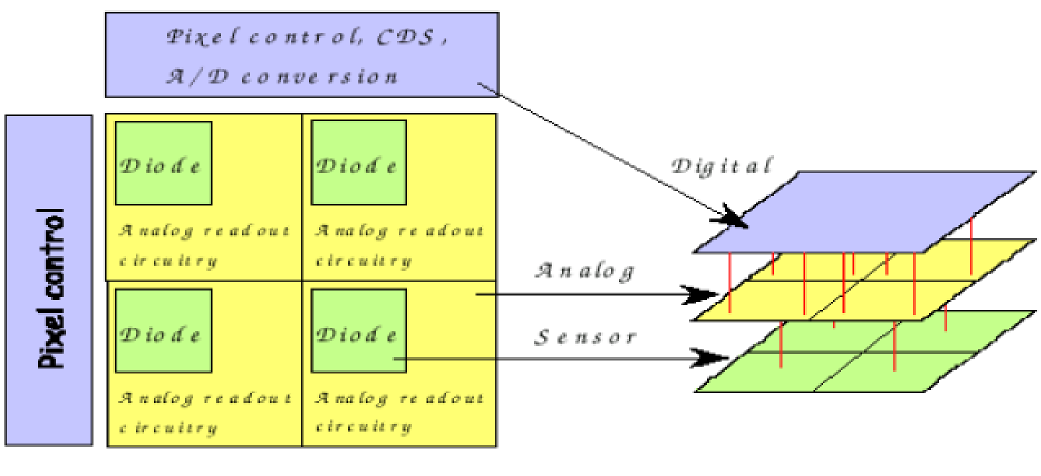
Use of 3-dimensions Integration Technology (3DIT)

Exploratory work in progress on 130nm IBM-like CMOS
in coll^{n} with Fermilab *(Tezzaron/Chartered)*

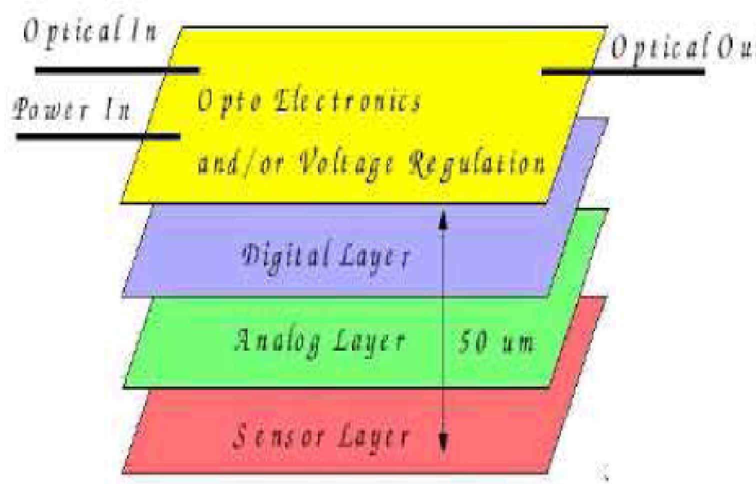
- **3DIT are expected to be particularly beneficial for CMOS sensors :**
  - *combine different fab. processes*
  - *alleviate constraints on transistor type inside pixel*

- **Split signal collection and processing functionnalities :**
  - *Tier-1: charge collection system*
  - *Tier-2: analog signal processing*
  - *Tier-3: mixed and digital signal processing*
  - *Tier-4: data formatting (electro-optical conversion ?)*

- **Use best suited technology for each Tier :**
  - *Tier-1: epitaxy, deep N-well ?*
  - *Tier-2: analog, low leakage current, process (nb of metal layers)*
  - *Tier-3 & -4 : digital process (nb of metal layers), feature size ⟶ fast laser (VOCSEL) driver, etc.*



Conventional MAPS 4 Pixel Layout   3D 4 Pixel Layout



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, Pékin, fév.2007

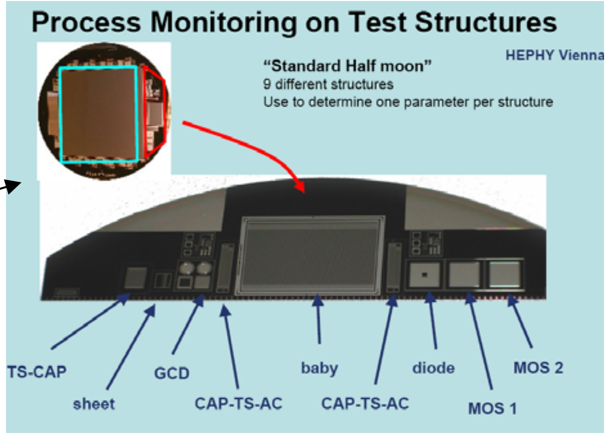
R&D on Silicon detectors:

- Collaboration with Hamamatsu Photonics (HPK) =>

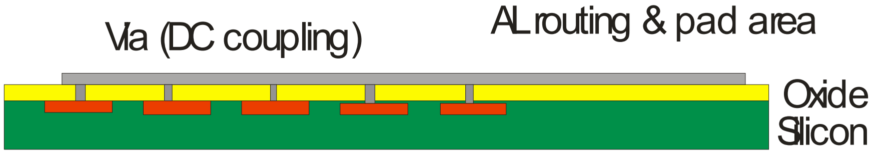
i) HPK for baseline: larger µstrips detectors (≥ 6''), single sided, thinner and smaller pitch (≤ 50µm) with alignment holes.

HPK detectors with test structures,

delivered: 1/10/07

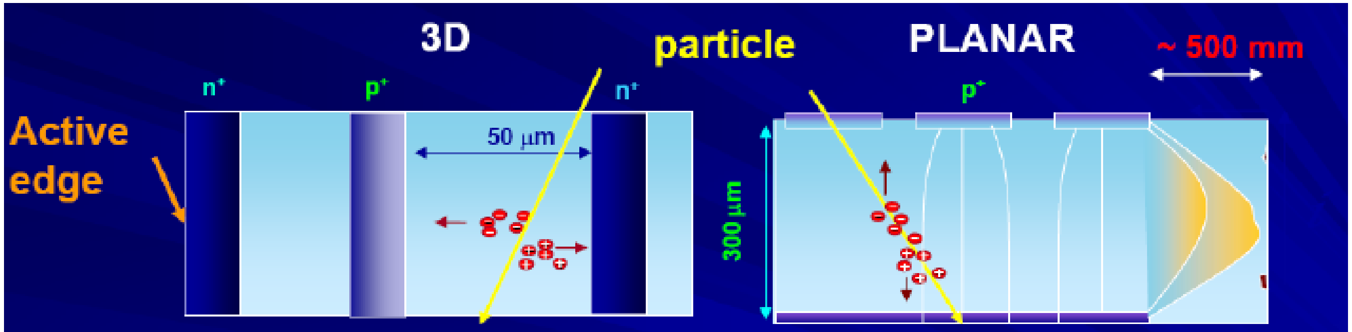


ii) Collaboration LPNHE-HPK on a new connection scheme: **bonding chip directly on strips.**



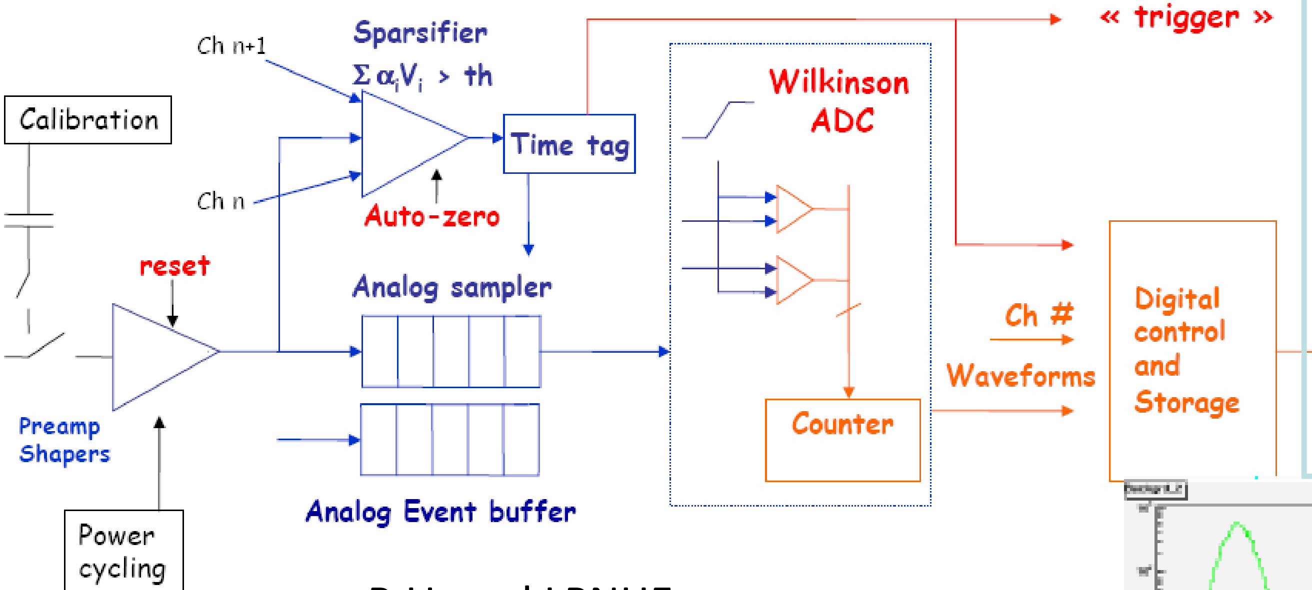
Use of test bench and test beams for trial ans measurements

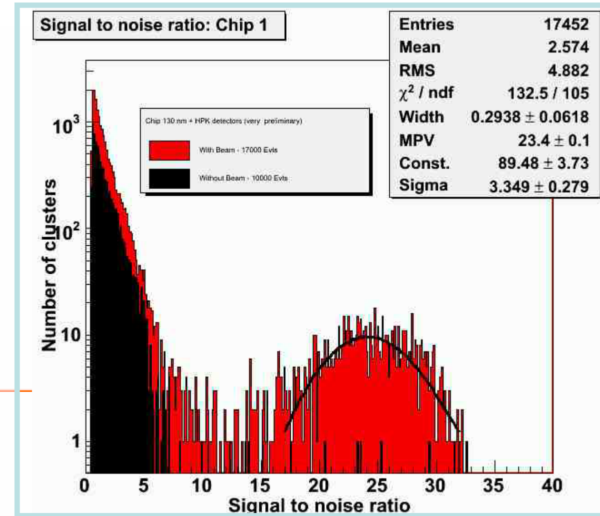
iii) Collaboration with VTT **on 3DIT detector structure**



LPNHE R&D on Electronics

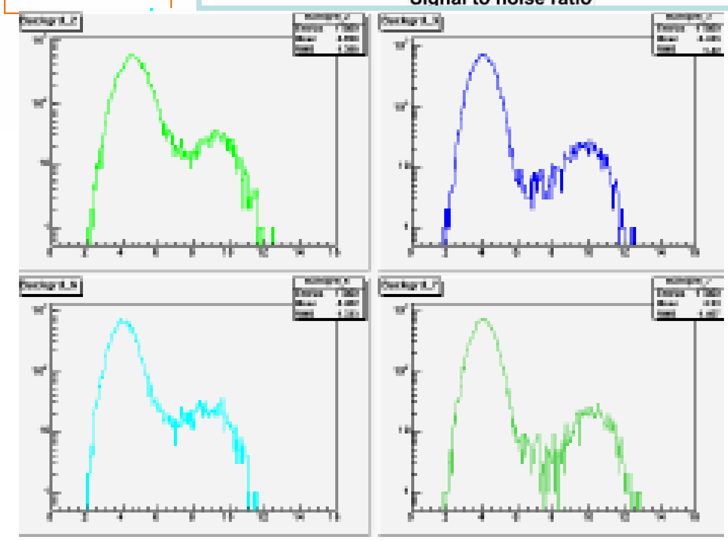
Advancement in a F.E. Readout fully digitized in 130 nm deep sub micron CMOS technology .
A new version will be sent for foundry (UMC) May 30th , with 86 channels/chip in 5x10mm2.





B.U. and LPNHE

A previous version with 4 ch/chip successfully tested
In 2007 at Lab test bench and CERN test beam: →



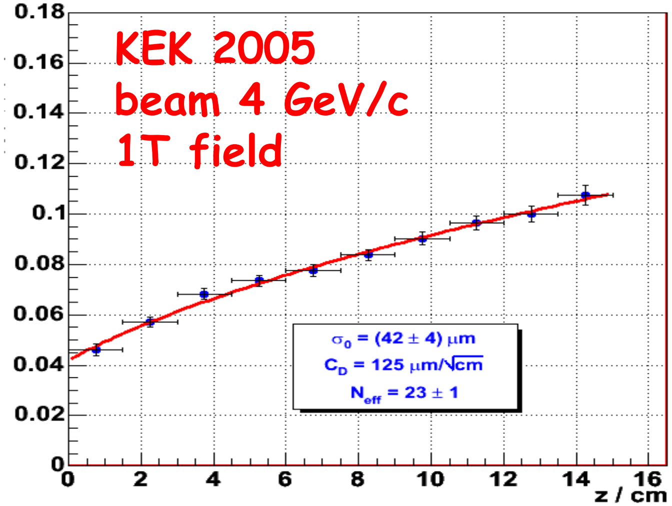
TPC: LC-TPC Collaboration

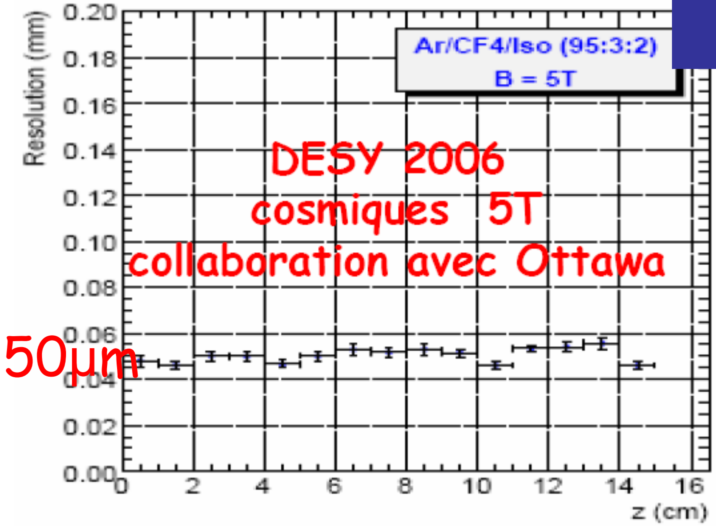
TPC with Micromegas read-out

IRFU SACLAY, (LAL, IPNO)

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

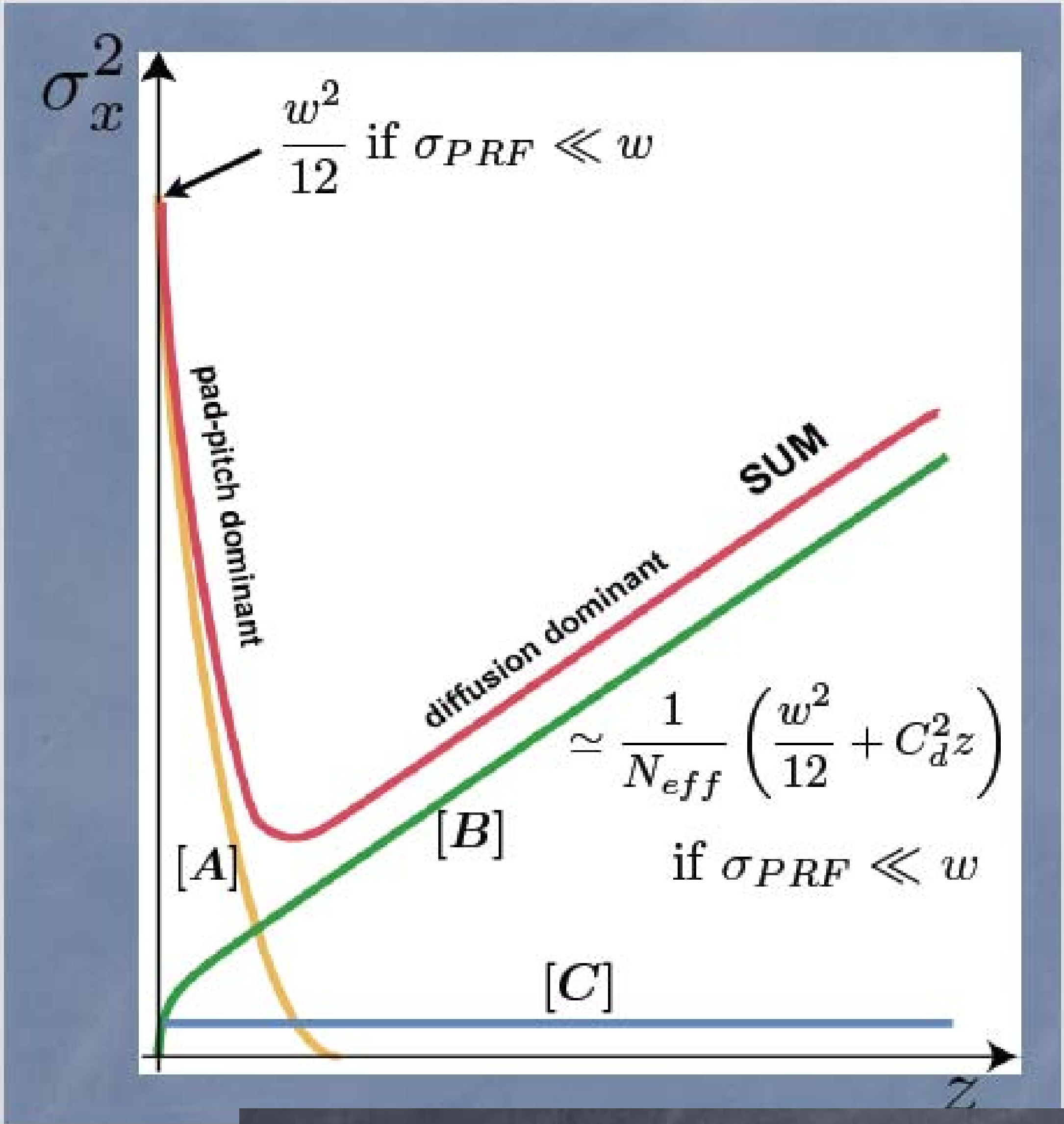
Spatial resolution vs. drift distance





→ Detailed understanding of spatial resolution

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



[A] Purely geometric term (S-shape systematics from finite pad pitch): rapidly disappears as Z increases

[B] Diffusion, gas gain fluctuation & finite pad pitch term: scales as $1/N_{eff}$, for delta-fun like PRF asymptotically:

$$\sigma_x^2 \simeq \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

[C] Electronic noise term: Z-independent, scales as $\langle 1/N^2 \rangle$

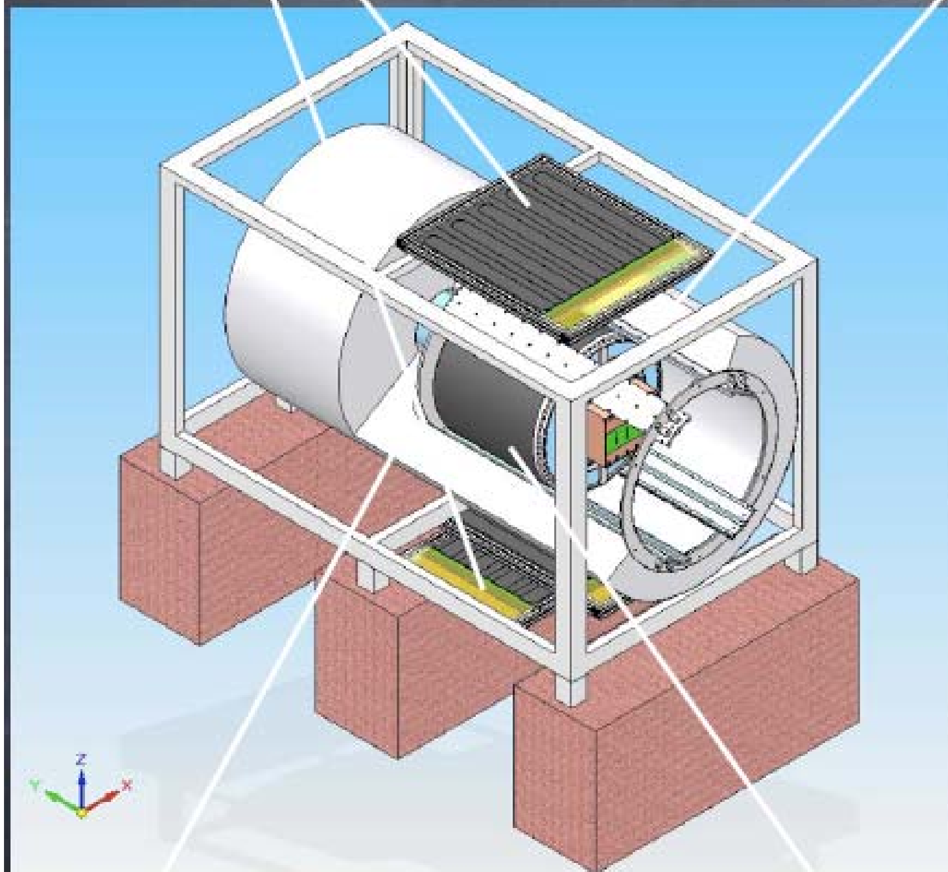
→ **Theoretical basis for how to improve the spatial resolution!**

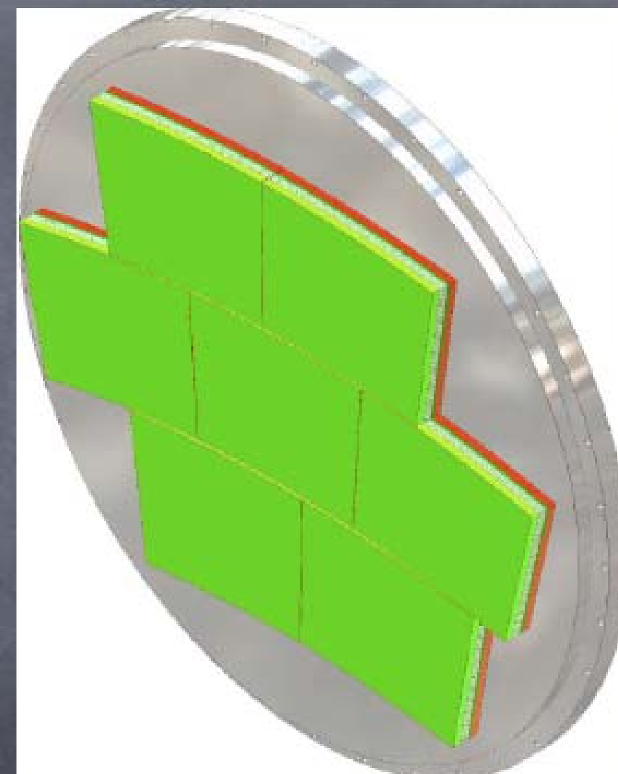
Large Prototype Tests

Cosmic ray trigger counters
with MPPC readout system

Endplate to house
7 Interchangeable readout modules

GEM+1mm pads, MM+RA, MM+TimePix





Field cage : 75 cm phi & 61 cm long

Thin (0.2X0) superconducting magnet (PCMAG from KEK) : B_max=1.25 T

Consolidation Phase
TPC Large Prototype Beam Test at DESY

Pixel beam telescope (EUDET)

Si strip detector (EUDET/SiLC)

Magnet: PCMAG (LC TPC/EUDET)

Field cage & All Mechanics (EUDET)

Test beam (DESY)

Endplate (LC TPC)

MPGD Detector Modules (LC TPC)

Gas system (EUDET)

DAQ & Monitoring (EUDET)

Cosmic trigger (LC TPC)

Readout electronics (EUDET & LC TPC)

Software development (EUDET & LC TPC)

Conclusions

- There is consensus that ILC is after LHC the next energy frontier 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 technical design necessitate large advanced prototypes in coming years.
- ILC R&D is an excellent training ground for young physicists, especially the work on beam tests data taking and analysis.