Electron-Positron Colliders Activity

M.Winter / 15 March 2013

on behalf of the Irfu and IN2P3 LC communities

RESTRICTED ECFA VISIT OF FRANCE

Outline

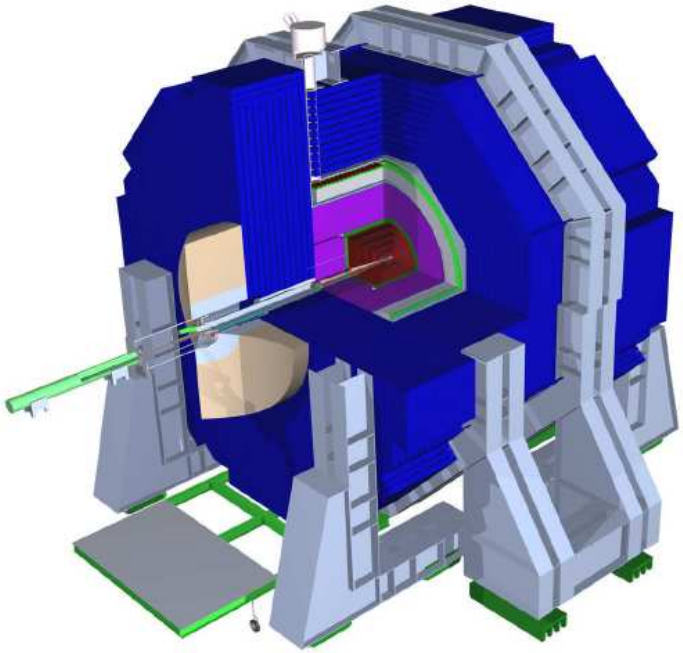
- Introduction : *framework of activities reported, experimental challenges*
- Physics performance assessments : *examples*
- R&D : *experiment and beam instrumentation*
- Summary - Outlook

  - **Overview of the French LC community :** *compositions and main activities*

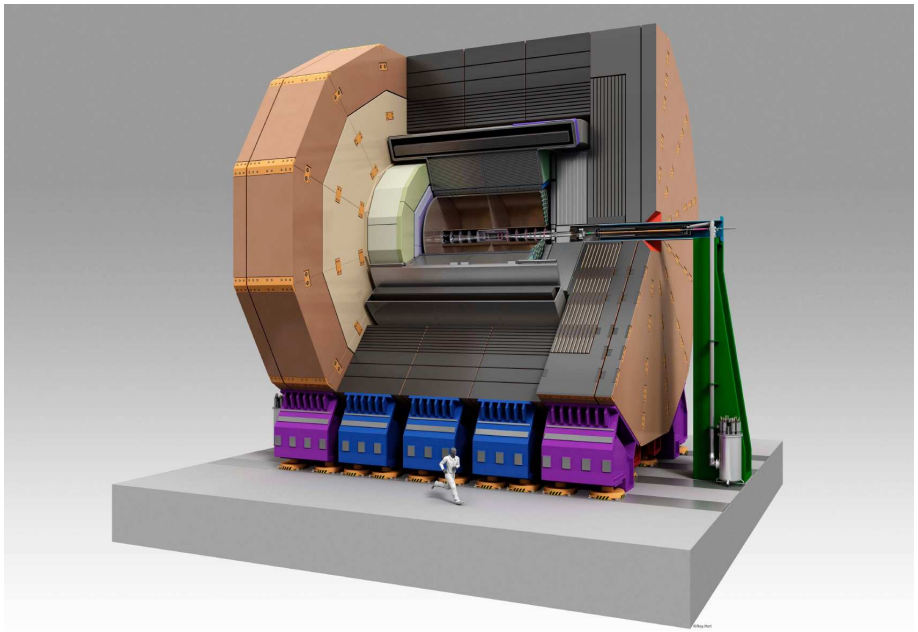
  - **Related talks** ▷ Detector R&D: M.Titov, Accelerator R&D: M.Baylac, Theory: J.Orloff

Framework of Activities Reported

- PHYS. GOALS : precision measurements & NP search in New Boson sector, top quark sector, energy frontier, ...
- MACHINE : focus on ILC (200 GeV $\longmapsto$ 1 TeV) + several direct & indirect contributions to CLIC ($\longmapsto$ 3 TeV)
- 2 DIFFERENT DETECTOR CONCEPTS : SiD and ILD adaptable from ILC to CLIC



SiD : All Si



ILD : TPC $\equiv$ main tracker

- NUMEROUS CONTRIBUTIONS TO :
  - Physics performance studies
  - Detector & machine R&D
  - Detector Integration & Costing

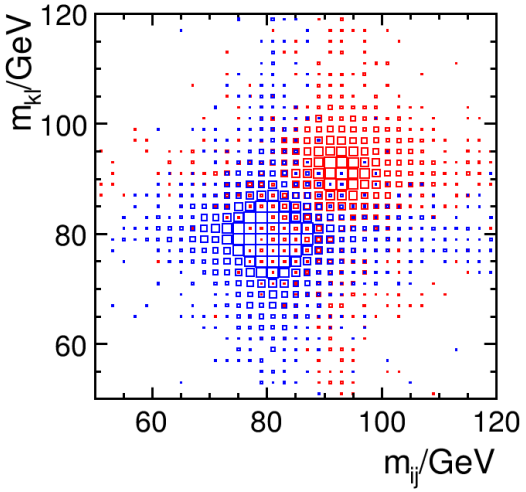
  ⁕ ILC physics & detectors : LoI (2009), DBD (2012)

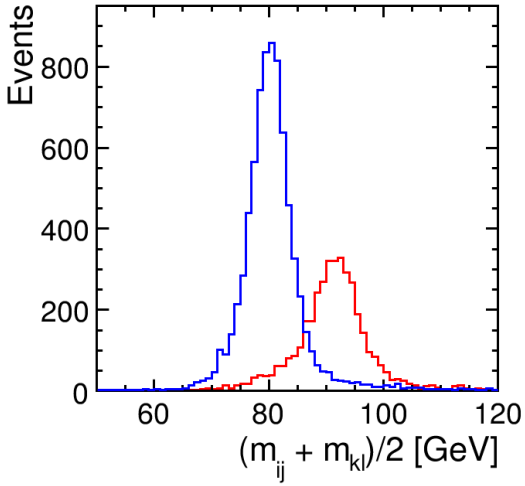
  ⁕ CLIC physics & detectors : CDR (2012)

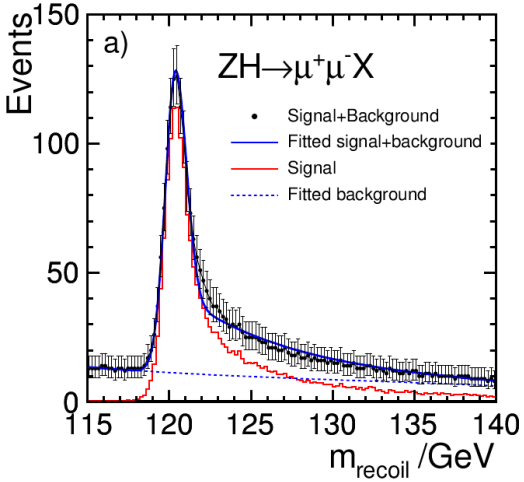
  ⁕ ILC machine : EDR (2008), TDR (2012)

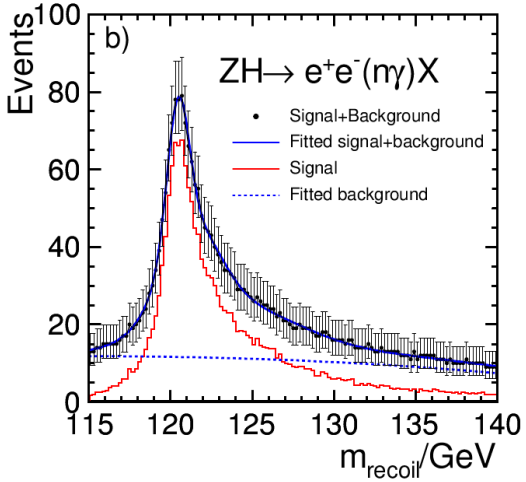
Experimental Challenges Addressed

- PARTICLE FLOW : reconstruct ALL particles individually
  - ✳ topological reconstruction of multi-jet events
    - ⟹ R&D on highly segmented calorimeters :
      ECAL (24 layers) & HCAL (48 layers)
    - ▷ Ex: W/Z separation in $\nu\nu WW/ZZ$ final states
      ⟹ $\Delta E/E \simeq$ 3-4% at 100 GeV





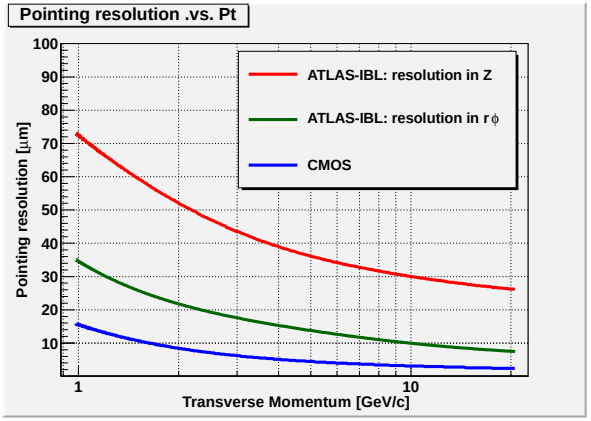


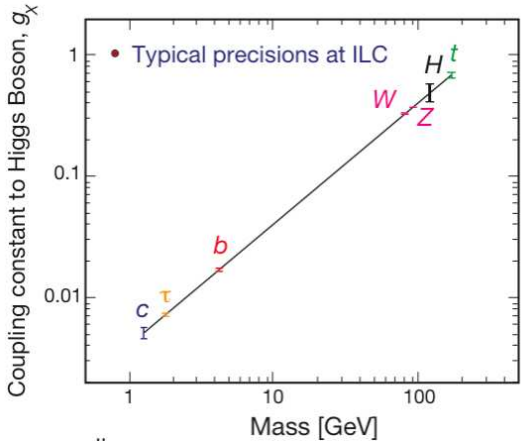


- HIGH RESOL. CHARGED PART. MOMENTUM RECONSTRUC.:
  - ✳ R&D on very light high resolution tracking system :
    mainly TPC (ILD) (also Si-strips)
    - ▷ Ex: $e^+e^- \rightarrowtail ZH \Rightarrow M_H^2 = S + M_Z^2 - 2 \cdot E_Z \cdot \sqrt{S}$
      ⟹ $\sigma_{1/P_t} \simeq 2 \cdot 10^{-5} GeV^{-1}$

- HIGHLY GRANULAR AND LIGHT VERTEX DETECTOR:
  - ✳ R&D on new pixel techno. & ultra-light mechanical supports
    - ▷ Ex: Hxx couplings from $e^+e^- \rightarrowtail ZH$
      ⟹ $\sigma_{IP} \lesssim 5 \oplus 10/p \cdot sin^{3/2}\theta\ \mu m$

▷▷▷ **Power cycling (≡ saving)**
exploiting machine duty cycle (< 1%)



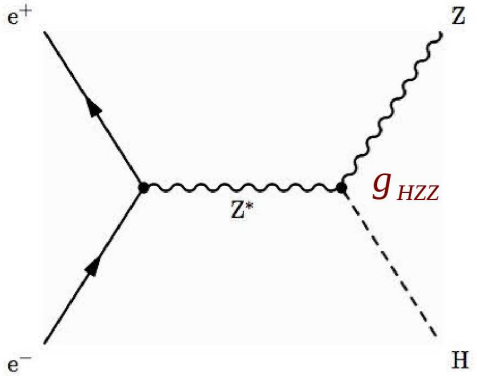


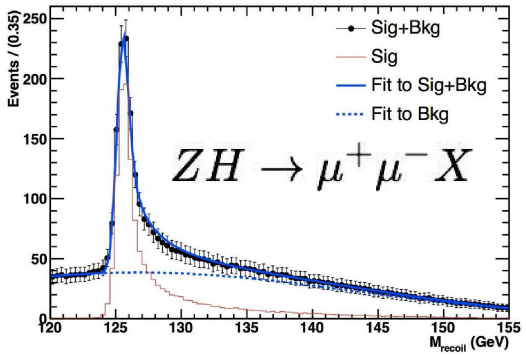
Physics Peformance Studies

- PHYS. PERFORMANCE ASSESSMENTS : exploiting tunable (E_{cm} & Pol.($e^{\pm}$)), low background, precise E_{cm} machine
  - optimise detector design $\rightarrowtail$ high precision
  - assess experimental perfo. with detailed & realistic simulations

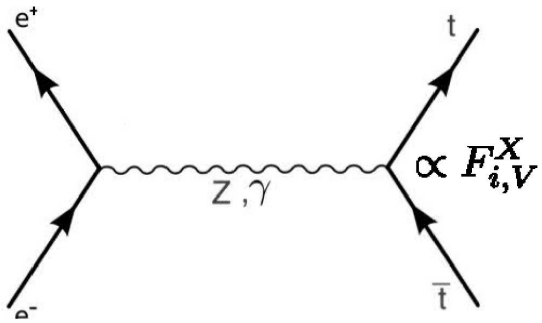
  $\Rrightarrow$ inputs to Detector Baseline Document, etc.

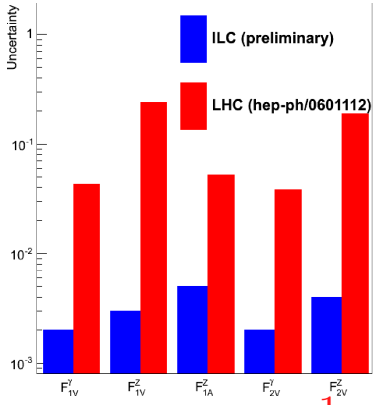
- SM-LIKE LIGHT HIGGS CHARACTERISATION AT ILC
  - Higgs-strahlung tagged via Z $\rightarrowtail \mu\mu, e^+e^-$ reconstruction
    - $\hookrightarrow$ study phase space opposite to Z
      - $\Rrightarrow$ derive "X/Higgs" characteristics
  - Ex: precision expected on $g_{HZZ} \simeq$ 1–2%





- TOP QUARK PRODUCTION AT ILC :
  - low background top-pair production (tunable $e^{\pm}$ polarisations)
  - Ex: search for anomalous top couplings to γ and Z (form factors)
    - $\hookrightarrow$ comparison to LHC sensitivity (300 fb^{-1}) $\rightsquigarrow$
      - $\Rrightarrow$ $\gtrsim$ 10 X more precise than at HL-LHC



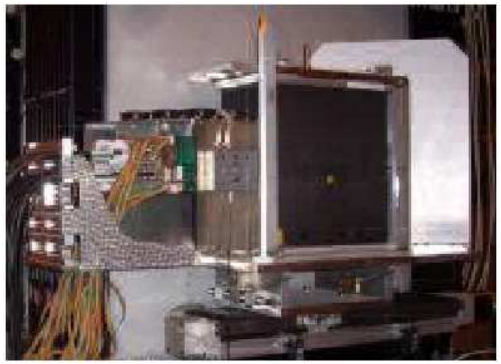


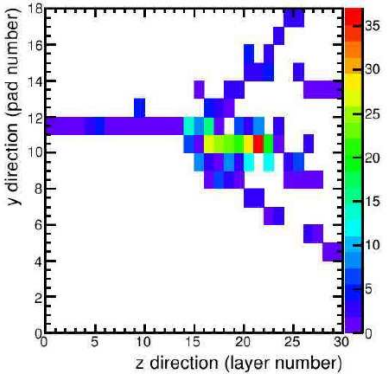
LHC - 300 fb^{-1}

- NEW PHYSICS AT ILC AND CLIC : extra-dimensions, slepton and Z' productions, ...

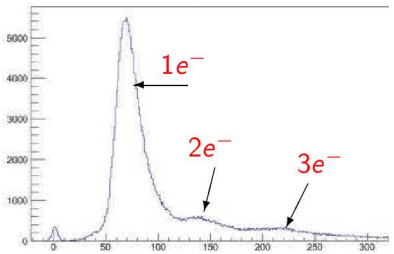
EM Calorimetry

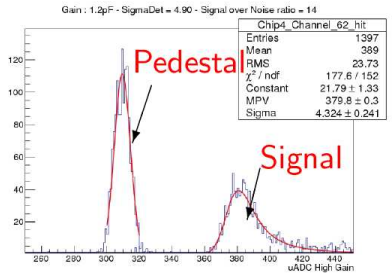
- SiW optimised for PFA: separation of neighbouring showers (γ, nascent hadronic showers)
  - $\hookrightarrow$ highly granular: $\sim 10^8$ ch. (ATLAS: 10^5 ch.), up to 2500 m^2 Si (PIN Diodes)
- French labs : LLR, LAL (& Omega), LPSC, LPNHE, LPCCF $\Rightarrow$ CALICE coll. ($>$300 members, 57 labs, 17 countries)
- Physics prototype : 2003–2011 ▷ ▷ ▷
  - 10^4 r.o. ch., 200 kg $\rightarrowtail$ beam tests (vs GEANT-4)
  - $\Rightarrow$ established proof of principle :
    $\sigma_E/E = (16.5/\sqrt{E} + 1.1)\%$, SNR $\simeq 8$

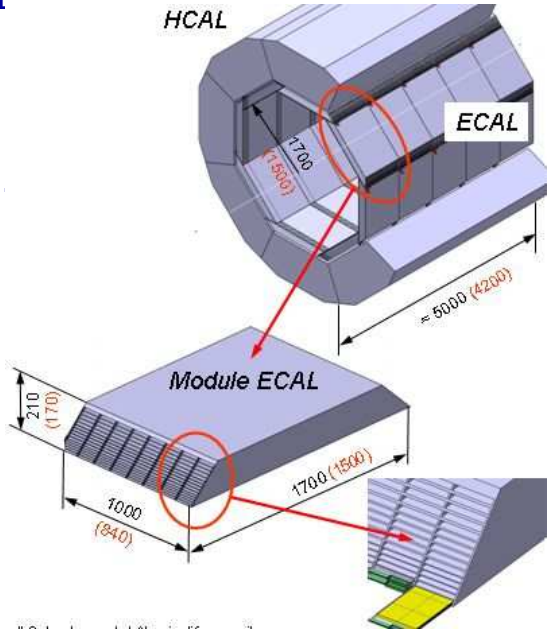


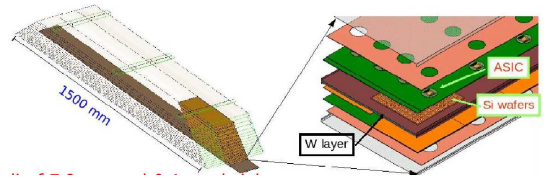


- Technological proto. : $\gtrsim$ 2011
  - $4{\cdot}10^4$ r.o. ch., 700 kg
  - $\rightarrowtail$ V1 beam tests (DESY) in 2012
  - $\Rightarrow$ 1st results on E calib., SNR, ..

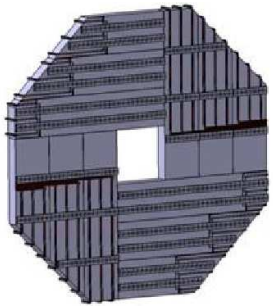






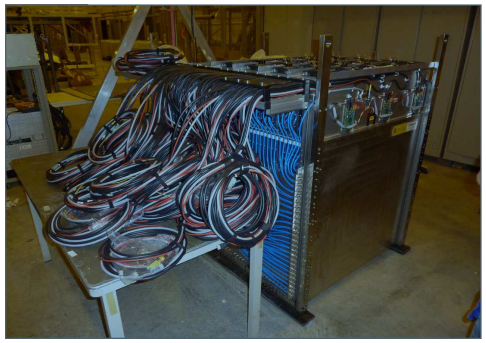


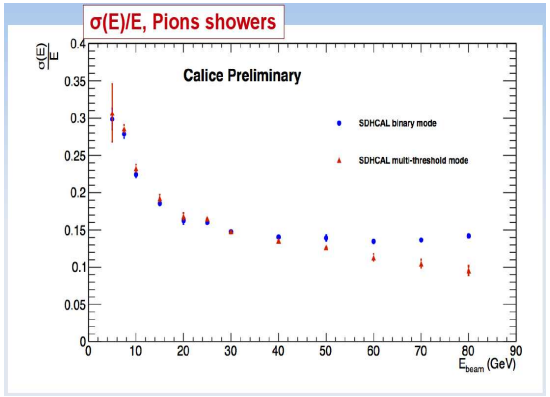
- Detector integration studies :
  Ex: ECAL end-cap structures
  - design & assembly
  - cooling system

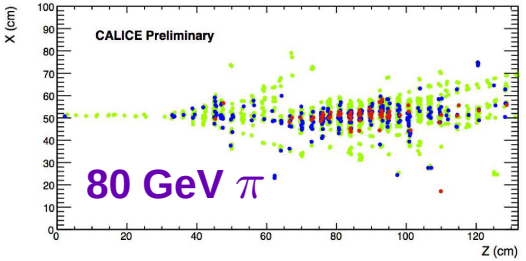


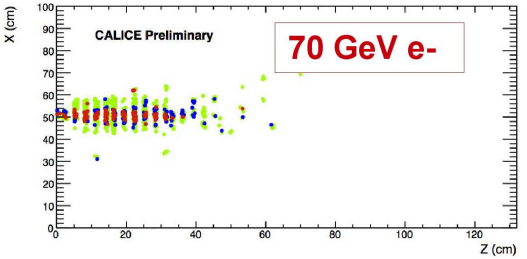
Hadron Calorimetry

- SEMI-DIGITAL READ-OUT HCAL OPTIMISED FOR PFA : measure E(neutral hadrons) in showers
  - ↪ highly segmented active components : GRPC, MPGD (MicroMegas)
- FRENCH LABS : IPNL, LAPP, LLR, LAL (& Omega)
- GRPC DHCAL PROTOTYPING: beam tests (CERN) in '12
  - ✳ 1 m^3 prototype with 48 RPC planes (450,000 ch.)
    power pulsed w.r.t. beam spill and triggerless
  - ✳ concern: space charge effects
    - ↪ R&D: thinner, less resistive electrodes & lower gain
      - ⇒ multi-ch. threshold mode (3 discriminators)
        carries significant improvement $\gtrsim$ 50 GeV

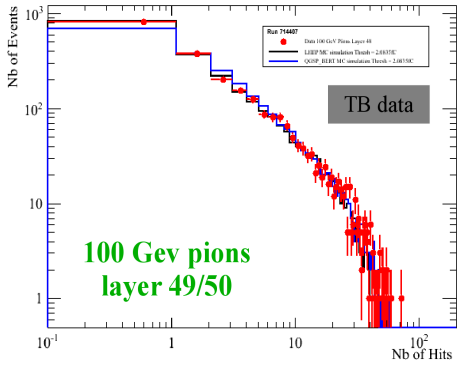


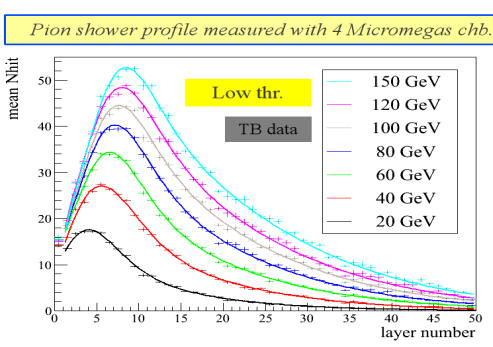


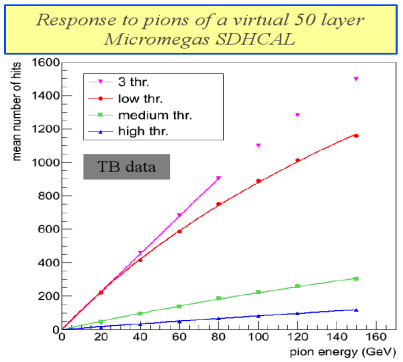




- μMEGAS DHCAL PROTOTYPING: same beam test
  - ✳ rate capability ≫ GRPCs but spurious sparks ⇒ FEE !
  - ✳ 4 chambers (1 m^2) inserted in 1 m^3 proto : successfull data taking ↘





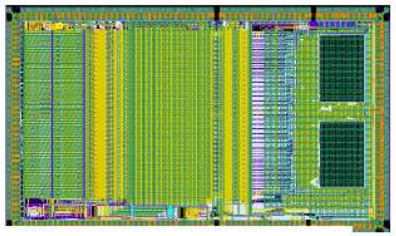


Read-Out Chip Developments

- STRONG INVOLVEMENT IN ECAL & HCAL R.O. ASICS : **Omega** + contributions from Michrau & LPSC (ADC)

- Auto-trigger, analog storage, digitization and token-ring readout
- Power pulsing : <1 % duty cycle
- Optimize commonalities within EUDET (readout, DAQ…)
- Dedicated run produced in **March 2010 (CALICE, EUDET, Jem Euso, External users)**
  - 25 wafers received in June
  - 20 000 chips packaged in the US

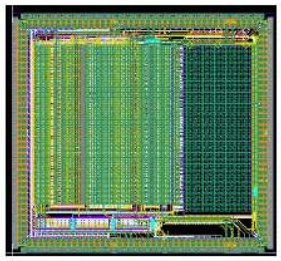
- Status in 2012:
  - CALICE DHCAL: 8000 HR2b (400000 ch.) equip the 40 layers of the cubic meter. TB using the power pulsing mode
  - CALICE DHCAL (µmegas): 1100 MICROROC1, TB in 2012
  - CALICE ECAL: SKIROC2, TB in 2012
  - CALICE AHCAL: 200 SPIROC2b, TB next fall



SPIROC2
Analog HCAL (AHCAL)
(SiPM)
36 ch. 32mm²
June 07, June 08, March 10

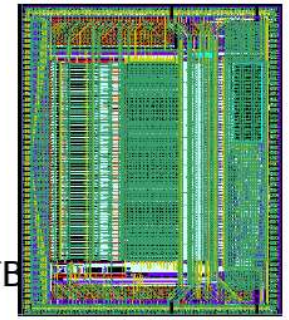
AIDA

CALICE Calorimeter for ILC

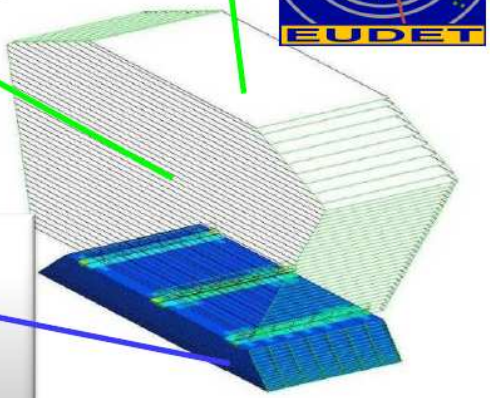


HARDROC2 and MICROROC
Digital HCAL (DHCAL)
(RPC, µmegas or GEMs)
64 ch. 16mm²
Sept 06, June 08, March 10

EUDET



SKIROC2
ECAL
(Si PIN diode)
64 ch. 70mm²
March 10



Coming years will see production of 3rd generation ASICs

Tracking with MPGD

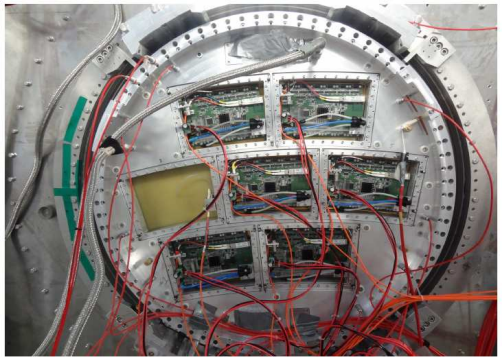
- MAIN TRACKING R&D : Large TPC read-out with high precision μMegas chambers (ILD concept)

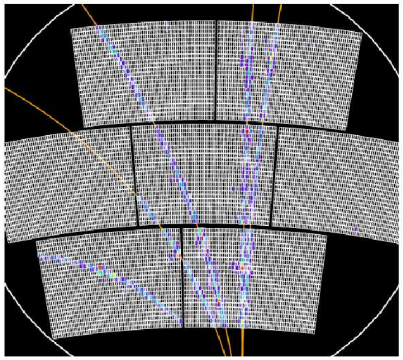
  $\Rightarrow$ $>$ 200 pts/traversing track $\triangleright$ $\lesssim$ 100 μm/pt, material $\sim$ 5%X_0 (resp. 25%X_0) in barrel (resp. end-caps)

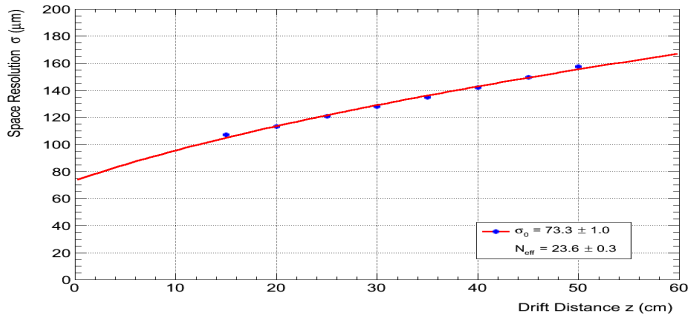
- FRENCH LABS : Irfu with contributions from LAL

- MICROMEGAS WITH RESISTIVE FOIL ON INSULATOR : 2 approaches

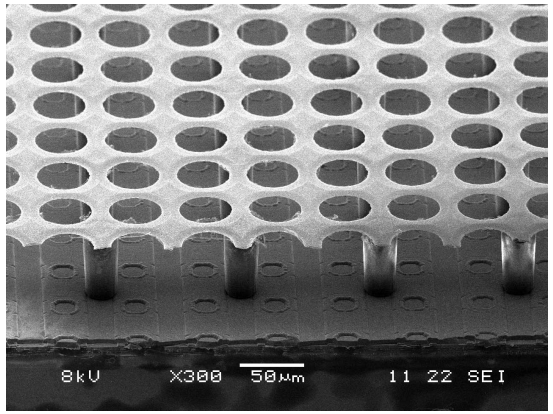
  - **Coarse pad dimensions : few mm**
    - 7 module proto. tested at DESY: 12,000 ch., 3$\times$7 mm^2 pads
    - performance studied with "large" proto. TPC in 1 T field $\Rightarrow$ Ex of result: resolution coming close to target value ($\lesssim$ 100 μm)







  - **Sub-millimetric pad dimensions : O(100) μm**
    - assets : no charge sharing needed,
      integrated FEE, time stamping
    - performance studied with INGRID device,
      based on TimePix r.o. chip & extensions
    - design optimisation against discharges, power consumption, ...



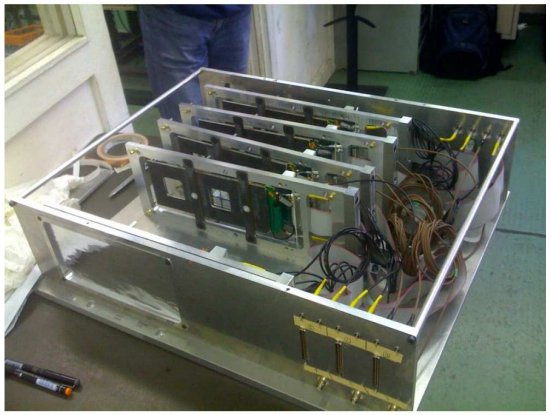
Tracking & Vertexing with Si Devices

- TRACKING DEVTS : Si-strip (incl. 3D, edgeless) sensors & FEE

  $\Rightarrow$ very low material devices for ::

  - SiD main tracker and FW trackers
  - ILD auxillary and FW trackers

  - **French Lab :** LPNHE (until 2010)



Beam test set-up within EUDET

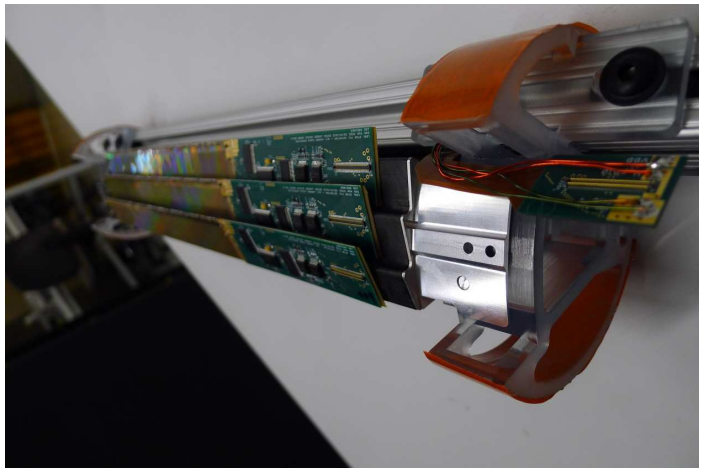
- MAIN VERTEXING R&D : Vertex det. based on CMOS pixel sensors & ultra-light 2-sided ladders

  - **French labs :** IPHC with contributions from Irfu
  - CPS technology validated for position detectors
  - architecture with integrated sparsification validated

    $\Rightarrow$ used in EUDET BT, STAR-PXL, upgrade of ALICE-ITS, ...
  - ex. of achieved performances :
    - full size, 50 μm thin sensors with integrated SDS

      $\hookrightarrow$ $\sigma_{SP} \simeq 3\ \mu m$ (about target value)
    - 0.6%X_0 2-sided ladder (8 Mpix) tested on beam

      $\rightarrowtail$ 0.35%X_0 ladder in construction (target value $\lesssim$ 0.3%X_0)

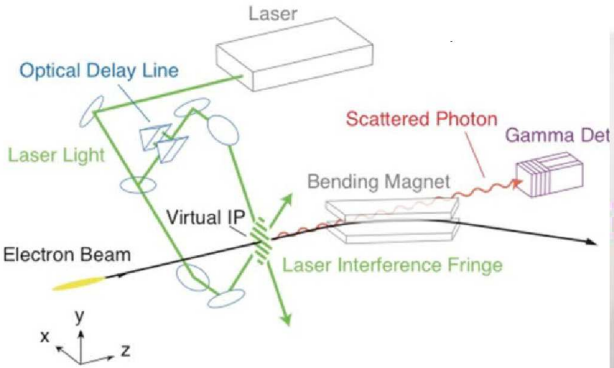


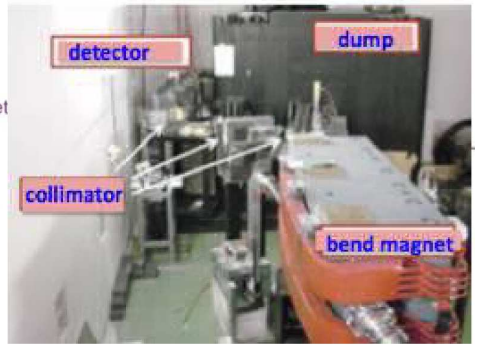
STAR-PXL sector

PLUME ladder

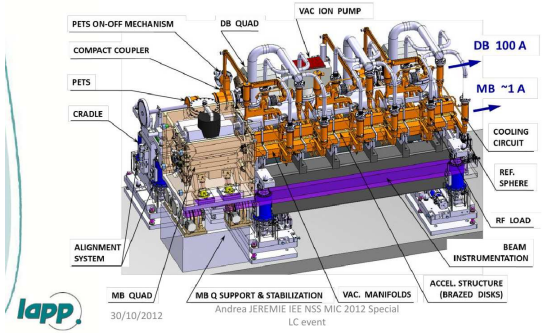
Beam Diagnostics & Instrumentation

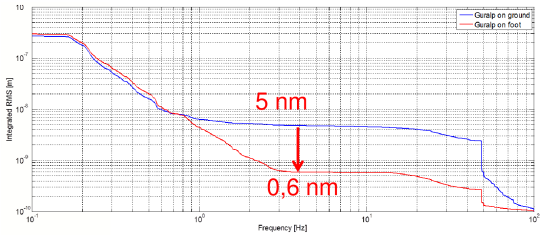
- ATF2 AT KEK : prototype of ILC, CLIC, ... final focus
  - ⁕ contributions to project from LAL, LAPP, LLR
  - ⁕ 70 nm vertical size achieved
    ↪ ILC-like target value: σ_Y = 37 nm
  - ⁕ contributions to O(10) nm beam alignment device :
    ↪ vacuum chamber for high precision BPM positionning
  - ⁕ measurement of beam halo & recoil Compton electrons :
    development of detectors using diamond sensors
    ↪ tests at PHIL/LAL





- LINEAR COLLIDER MODULE CONTROL AND STABILIZATION :
  - ⁕ contributions from LAPP
  - ⁕ module control : development of dedicated multi-purpose FEE board
  - ⁕ module stabilisation against mouvements generated
    by ground motion, human activity, ... ($<$ 100 Hz)
    ⇛ development of system incl. sensor⊕analysing board⊕actuator





SUMMARY – OUTLOOK

- LC HAS BEEN A DRIVING TOPIC for French community since late 90's ($\gtrsim$ 100 phys. Engine & tech. involved)

- FRENCH LC COMMUNITY $\equiv$ major task force for **ILC** project $\rightarrowtail$ CLIC
  - ILC physics performance & detector R&D $\Rightarrow$ LoI (2009), DBD (2012) $\mapsto$ proof of feasibility
  - extension towards CLIC : CDR (2012)
  - accelerator R&D : ILC-EDR (2008) & -TDR (2012) $\rightarrowtail$ see talk by M.Baylac
  - initiated several international coll. : CALICE, RD-51, LC-TPC, ILD, SiD, EUDET, AIDA, PLUME, ...

- DETECTOR R&D DEFINING STATE-OF-THE-ART ON BROAD RANGE OF HIGH-PRECISION DETECTORS $\rightarrowtail$ talk by M.Titov
  - highly segmented calorimetry : SiW ECAL, (semi-)digital HCAL
  - high resolution & "light" TPC : MicroMegas, Ingrid
  - high precision ultra-light vertex detector : CMOS pixel sensors, 2-sided ladders

  $\Rightarrow$ numerous spin-offs :
  - technological frontier expertise
  - detectors for subatomic physics AND social applications
  - numerous theses (some translating into perm. CNRS positions)

- MULTIPLE EXPERTISE FOR AN 200-1000 TEV ILC, AS WELL AS FOR (FARER AWAY) CLIC

  $\hookrightarrow$ community ready to play a central role in ILC in case of positive decision

- NOT ADDRESSED IN THIS TALK : physics prospect and PID R&D activities for the SuperB project, nascent interest for other e^+e^- machines (e.g. TLEP at Irfu), etc.

LC Activity Overview

- INSTRUMENTATION ACTIVITIES PER LABORATORY :

Labs	IPHC	IPNL	Irfu	LAL	LAPP	LLR	LPCCF	LPNHE	LPSC
ECAL				X		X	X	X	X
DHCAL		X		X	X	X			
TPC			X						
VXD	X		X						
Det. Integ.				X		X			X
Beam Instru.			X	X		X			

- HUMAN RESOURCES INVOLVED : $\gtrsim$ 100 people $\longmapsto$ 40-50 FTE
  - Permanent : 20 Physicists & 60-70 Engineers + Technicians
  - Non-permanent : 10 Post-docs & 10 PhDs
- PHDS :
  - Defended since 2006 : $\gtrsim$ 20 PhDs
  - On-going : $\gtrsim$ 10 PhDs
- $>$ 100 publications and talks at international conferences