IN2P3

Development of ultra-light pixelated ladders for an ILC vertex detector

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on behalf of the PLUME & HP2-WP26 collaborations

http://www.iphc.cnrs.fr/-CMOS-ILC-PLUME.html

OUTLINE

PLUME *Pixelated Ladder with Ultra-low Material Embedding*
SERWIETE *SEnsor Raw Wrapped In Extra-Thin Enveloppe*
AID *Alignment Investigation Device*

Introduction

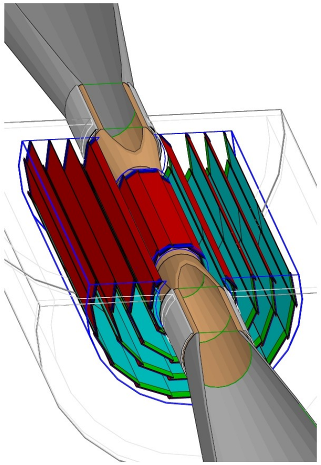
Study motivated by the development of the ILD vertex detector at ILC

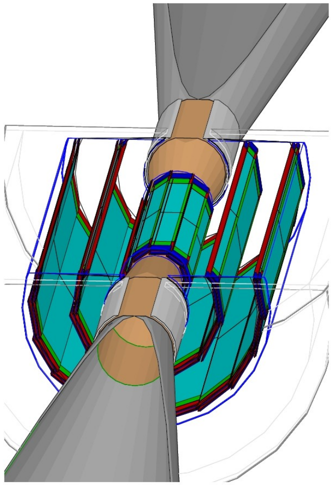
* sensitive area for a ladder : 12×1 cm^2

* material budget : ~ **0.16%X_0** (ILD LOI Target Value) double-sided
~ **0.11%X_0** (ILD LOI Target Value) single-sided

- How to fabricate a ladder ?

- Compatibility with running conditions ? (e.g high magnetic field)
- Alignment issue ?
- Investigate the advantages of double-sided ladders against single-sided ones





2 geometry options for ILD

PLUME *Pixelated Ladder with Ultra-low Material Embedding*

Geometry for an ILD vertex detector, 2009-2012

Objectives :

- achieve a double-sided ladder prototype for an ILD vertex detector by **2012 (DBD)**
  material budget : $\leq$ **0.3% X_0** (final goal for 2012 prototype)
- quantify power pulsing and air-flow cooling effects on final sensor spatial resolution
- evaluate benefits of double-sided concept (mini-vectors) :
  $\sigma_{i.p}$, alignment, shallow angle pointing (<15-30°), elongated vs squared pixels

Baseline :

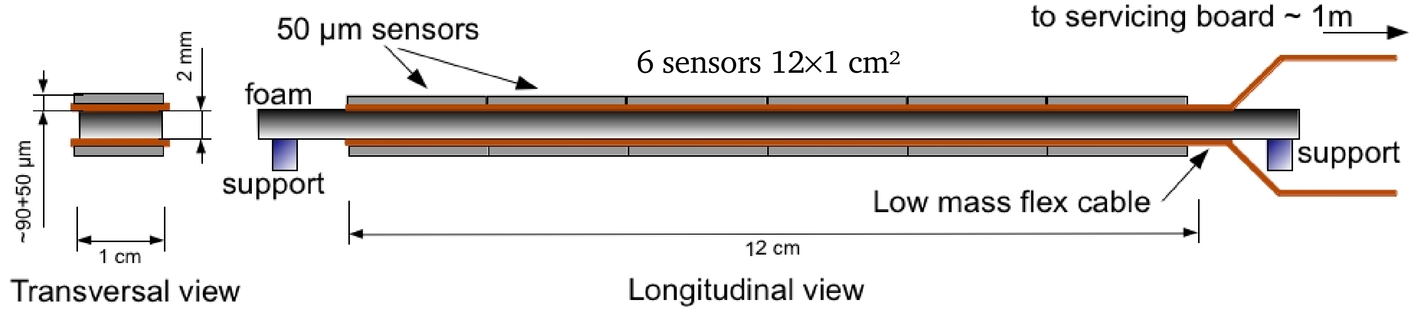
- MIMOSA-26 CMOS sensor (developed for EUDET-BT)
- Power pulsing (≤ 200ms period, ~1/50 duty cycle)
  and power dissipation (100mW/cm^2)
- Air cooling

PLUME collaboration :

- Bristol University
- Oxford University
- DESY (Hamburg)
- IPHC (Strasbourg)
- Synergy with
  * IK Frankfurt (CBM @FAIR vertex det.)
  * LBNL Berkeley (STAR @ RHIC vertex det.)

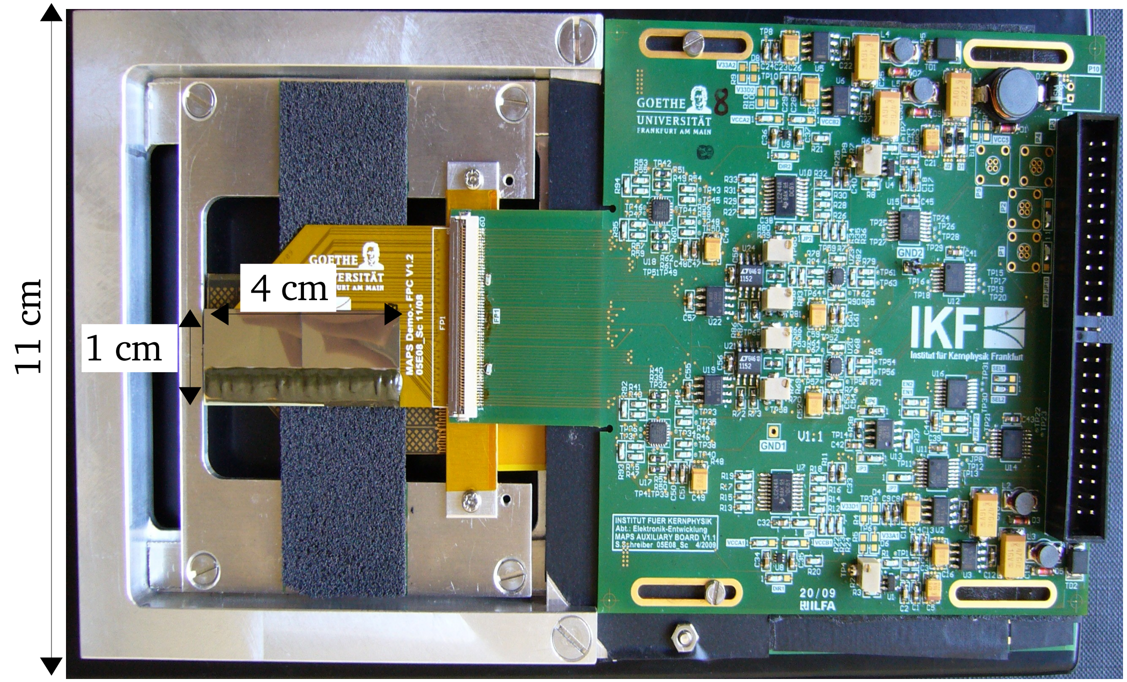
Current concept :

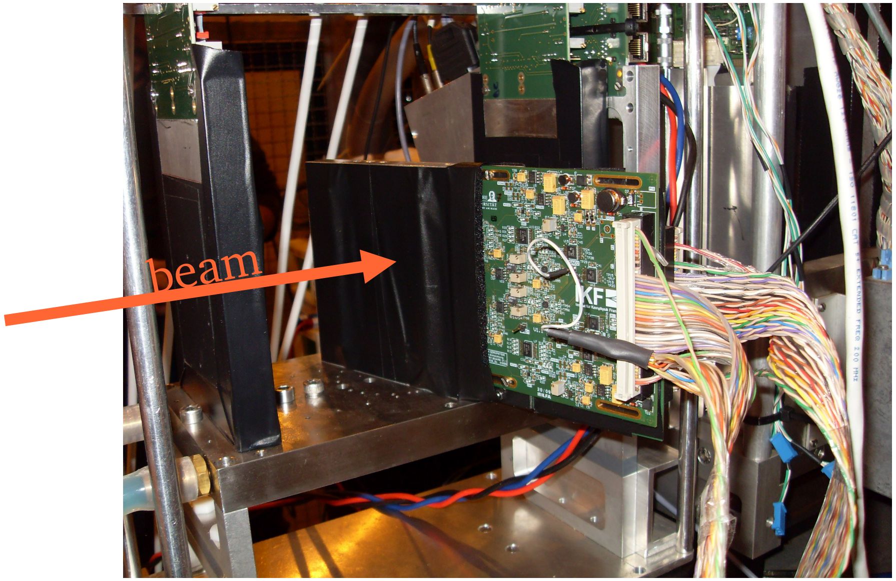
- 6 × MIMOSA-26 thinned down to 50 μm
- Kapton-metal flex cable
  (SMD components on flex for decoupling/termination)
- Silicon carbide foam (8% density) stiffener, 2mm thickness
- Wire bonding for flex – outer world connection
- Digital readout + servicing board ~ 1 m away
  (standard PCB board)



PLUME 2009

Goal : *to settle the fabrication & beam test procedure*



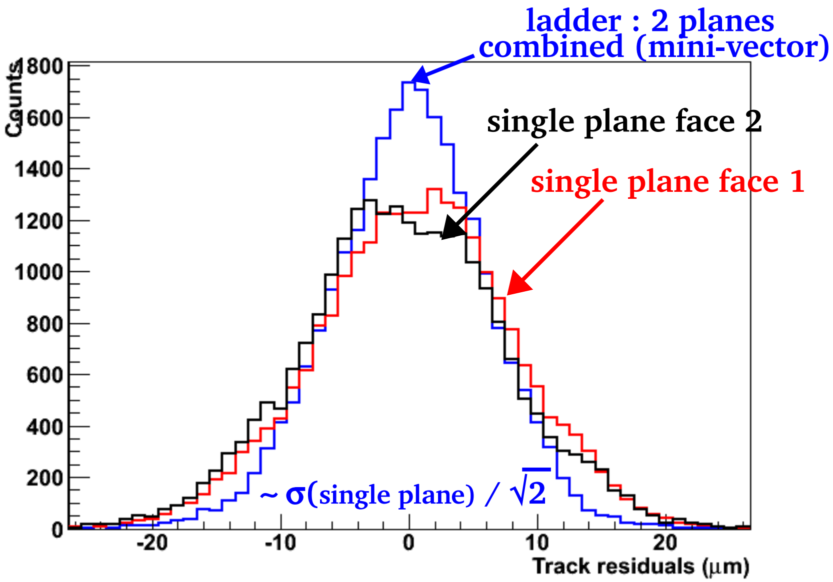


- 2 × MIMOSA-20 analog sensors, thinned down to **50 µm** with **1 × 4 cm²** sensitive area

- material budget **~ 0.6 % X_0**
(SiC foam 0.18%, sensors 0.11%, glue 0.2%, flex 0.29 %)

- tested @ SPS-CERN, π- 120 GeV

- preliminary mini-vector study

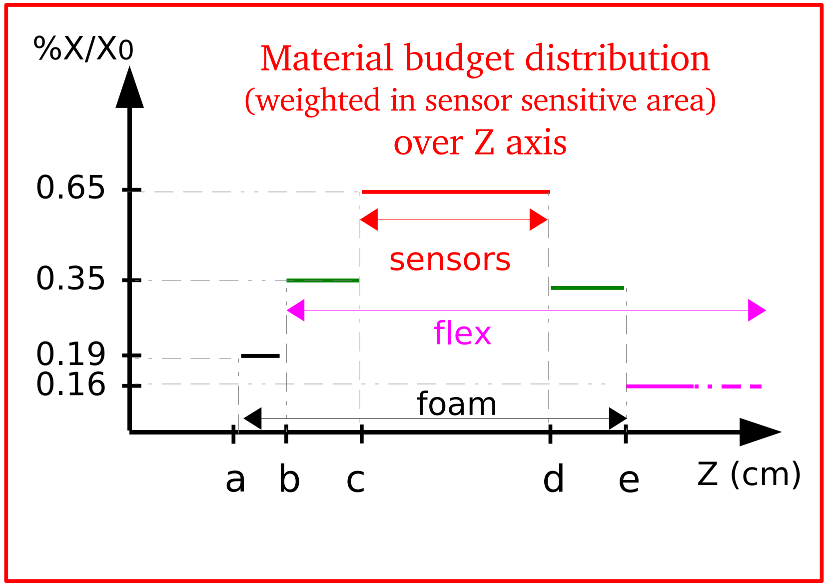


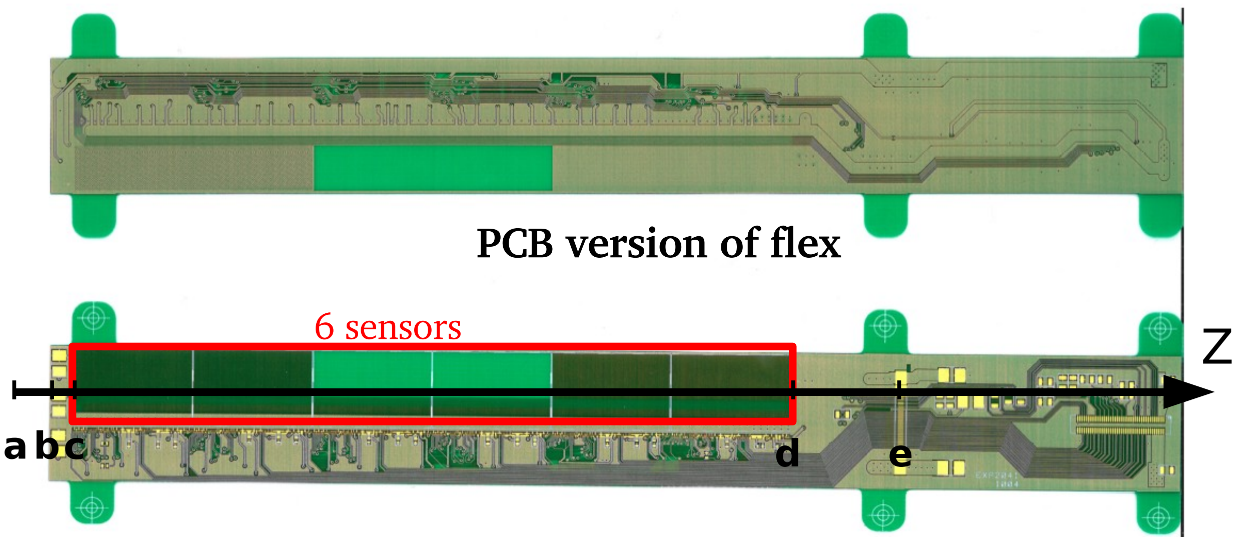
from November 2009 beam test data

PLUME 2010 and onwards

***Goal :** to realize & test the first version of the full device (relaxed specifications)*

- First simultaneous operation of 6 × MIMOSA-26 binary sensors (**12 × 1cm², 50 µm thickness**) on the same flex cable
- Test-setup implementation





2010 Planning :

March : All parts to be delivered at IPHC
April : DAQ tests + mounting sensors on the flex
May-August : Tests of the ladder
(electrical, air flow cooling, power pulsing)
From September : Beam tests

Current status :

- Flex design (Oxford)
- Tools to glue the sensors on the flex (IPHC)
  Mechanical support for transportation & tests
  DAQ & servicing board (power pulsing)
- Silicon carbide foam (Bristol)
  Mechanical support of the ladder
- Power pulsing first (sensor level) tests (DESY)

Material budget ~ **0.65 % X_0**

PLUME Planning (aggressive goals)

Main objectives (2010-2012, DBD) :

- production : material budget, mechanical stability
- sensor : architecture, integration time (see talk of C.HU-GUO)

	Sensors	Material Budget	tr.o	Target
2010	2×6 MIMOSA-26	0.65 % X_0	~100 µs	
2011	2×6 MIMOSA-26	0.4 % X_0	~100 µs	
2012	a) 1×6 MIMOSA-IN 1×6 MIMOSA-IN (elongated pixels) Double-sided ladder with 2 different read-out times	0.3 % X_0	<50 µs ~10 µs	Inner Layer
	b) 2×6 MIMOSA-OUT with ADC	0.3 % X_0	<100 µs	Outer Layer

Perspectives :

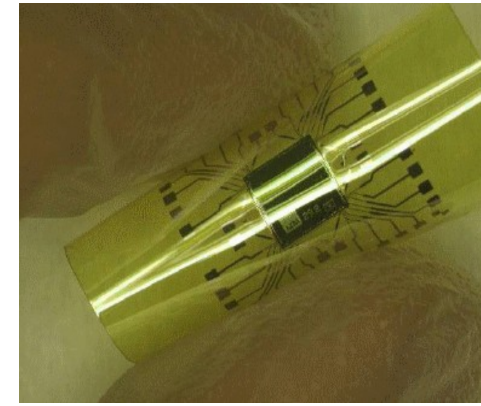
- to be studied within the infrastructure envisaged for AIDA project (e.g alignment)
- interests for (s)LHC experiments ?
  (e.g ALICE vertex detector upgrade (during “2018 (long) shutdown”))
- possibility to integrate other sensors (ex : ISIS, FPCCD)

SERWIETE *SEnsor Raw Wrapped In an Extra-Thin Enveloppe* (HP2, EU-FP7)

Goals :

- to achieve a sensor assembly mounted on flex and wrapped in polymerised film with **<0.15 % X_0** for 1 **unsupported layer** (sensors – flex cable – film)

- to evaluate the possibility of mounting supportless ladder on cylindrical surface like beam pipe (used as mechanical support). Proof of principle expected in 2012

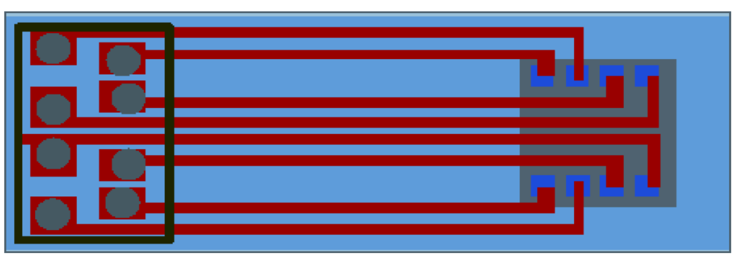


Fully functional microprocessor chip in flexible plastic envelope. Courtesy of Piet De Moor, **IMEC company**, Belgium

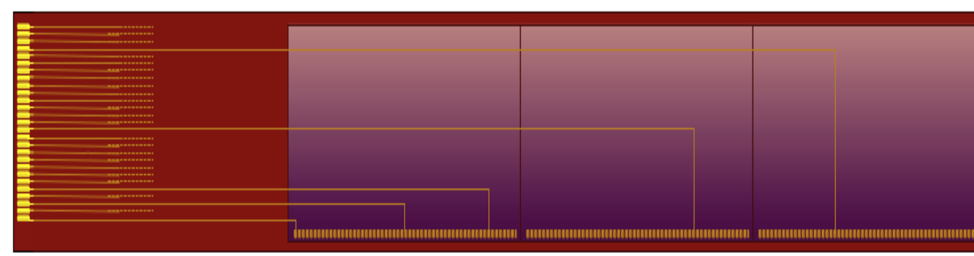
Working program :

- prototype Nr. 1 (2010) made of 1 **analog** sensor :
  MIMOSA-18 (analog output, ~4 ms @16MHz)

- prototype Nr. 2 (2011) made of 3 **digital** sensors :
  MIMOSA-26 (binary output, ~100 µs @80MHz)



prototype Nr. 1 : April 2010



prototype Nr. 2 : summer 2011

Context of development :

- Collaboration with IK-Frankfurt and GSI/Darmstadt (CBM coll.) within **HP2 project** (WP26)
- Synergy with Vertex Detector R&D for CBM, ALICE (?) etc.

(current) IMEC technology for SERWIETE

Thickness budget :

6.5 µm backend (metal and oxide on chip)
= **6.5 µm** Si equivalent

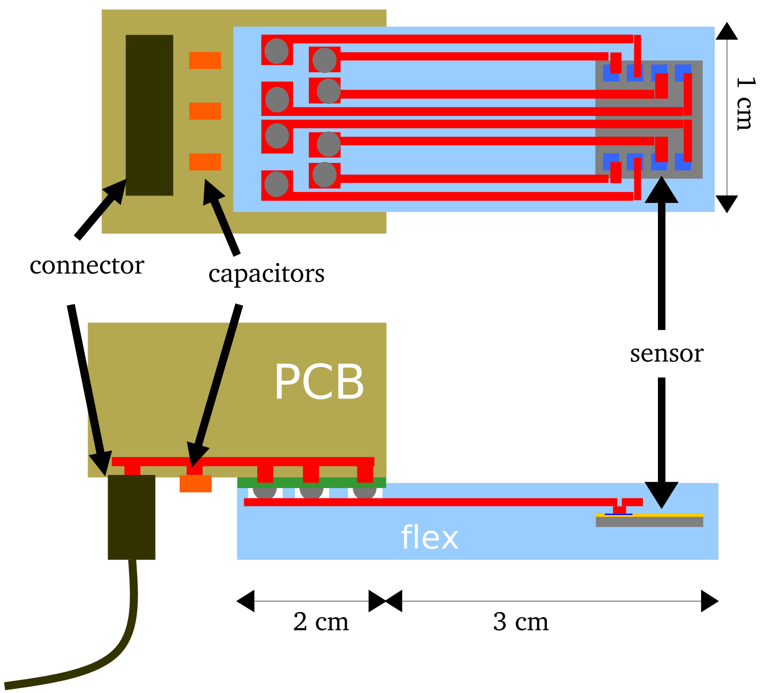
20-25 µm Si (14 µm epitaxial layer)
= **20-25 µm** Si equivalent

Sensor thinned down to 30 µm

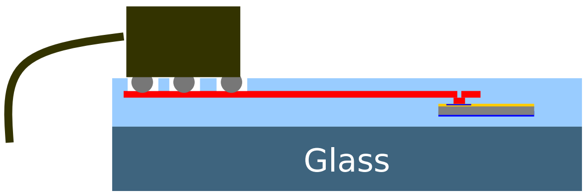
2× 20 µm polyimide + Solder mask (25 µm)
= **22 µm** Si equivalent

Total = 48.5 – 53.5 µm Si equivalent

Flex bump bonded to PCB



SERWIETE on a support



glass carrier (CBM, feasibility study) as a mechanical support and thermal conductor (vacuum operation)

Schedule :

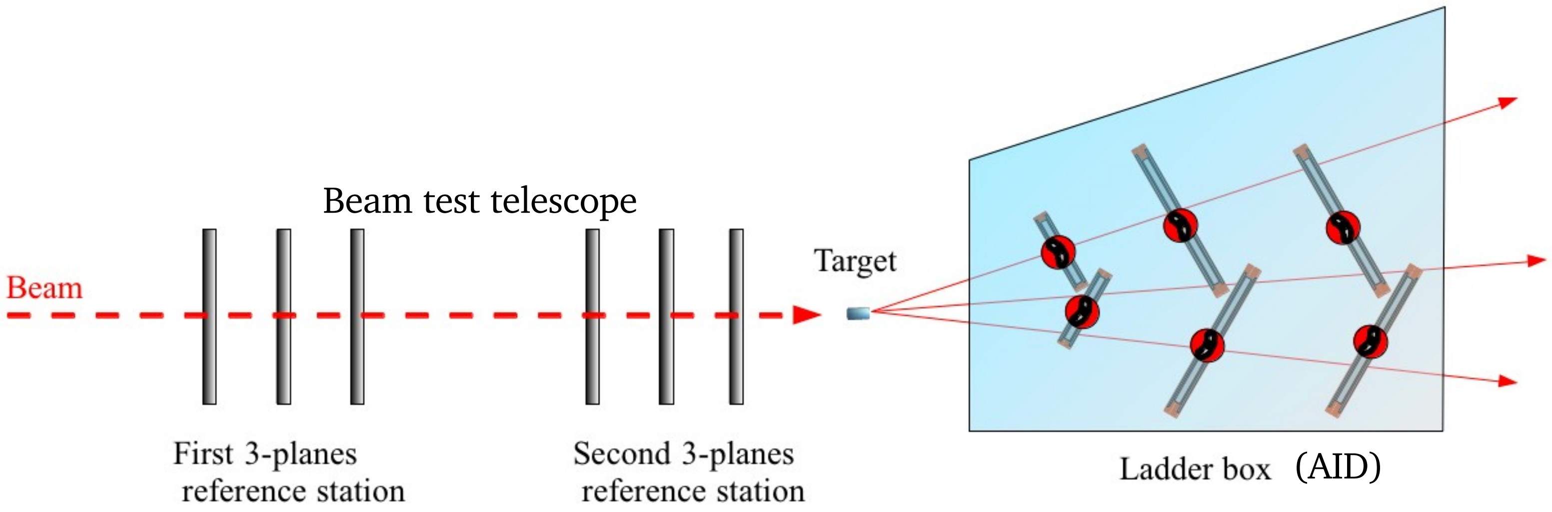
January-February :
Tests on line width and spacing
Fabrication of the PCB acquisition board

April : First prototype of the device equiped with one MIMOSA-18 CMOS sensor

VTX Oriented Infrastructures Proposed for EU-FP7 AIDA project WP-9.2

Collaboration :

PLUME collaboration + Geneva University + Varsaw University + ...



On-beam test infrastructure:

- Very thin removable target
- Large Area beam Telescope (LAT) (4×4 – 6×6 cm^2): EUDET-like Beam Telescope
- Alignment Investigation Device (AID): ladder box (2010, 2^{nd} semester)

Off-beam test infrastructure:

- thermo-mechanical studies, including effect of air-flow based power extracting system
- power cycling effect in strong magnetic field, e.g. Lorentz forces on ultra-light ladders

Summary

VTX system integration studies under way to provide answers to the questions raised in perspective of the DBD (2012)

- Ultra-light ladders development ongoing
  - double-sided option : PLUME
  - unsupported option : SERWIETE

- Questions addressed :
  - Ladder material budget
  - Added value of double-sided ladders
  - Alignment issue (Alignment Investigation Device)
  - power-cycling (in magnetic field)
  - air cooling, etc

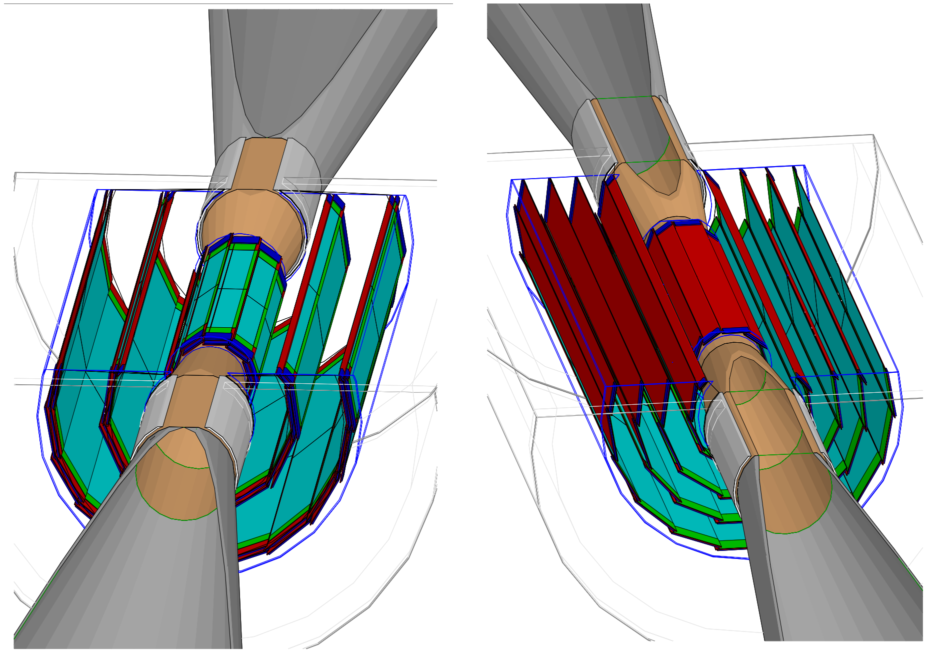
BACKUP

ILC vertex detector

Physics goals & running conditions

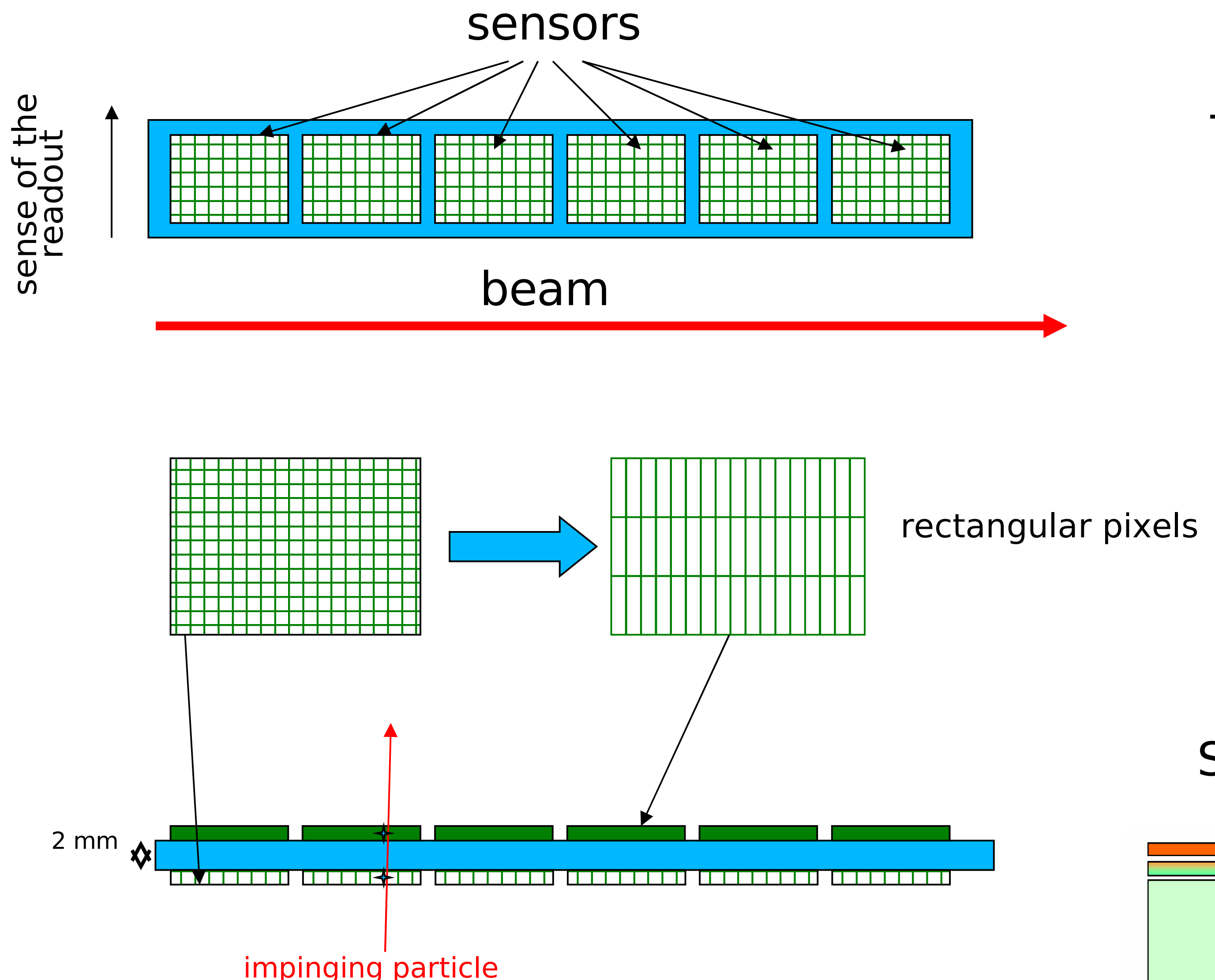
- single point resolution ~ 3µm
- material budget ~0.2% X_0/layer
- integration time 25 – 100µs
- radiation tolerance > 300Rad, few $10^{11} n_{eq}/cm^2$
- P < 0.1 – 2 W/cm²

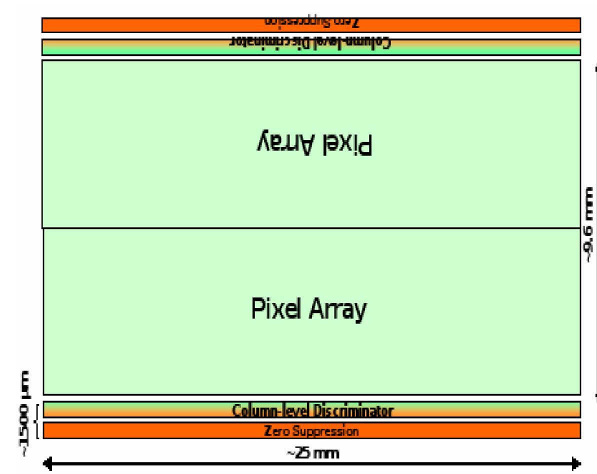
$$\sigma_{IP} = a \oplus b/p\sin^{3/2}\theta$$
$$a = 5\mu m,\ b = 10\mu m\ GeV$$



Radius:
16 – 60 mm for double-sided ladders,
15 – 60 mm for single-sided ladders

Improve time resolution with double-sided structure





From 15µm to 60µm pitch
→ from 40µs to 10µs readout time