Ultra-light Ladders for LC Vertex Detector

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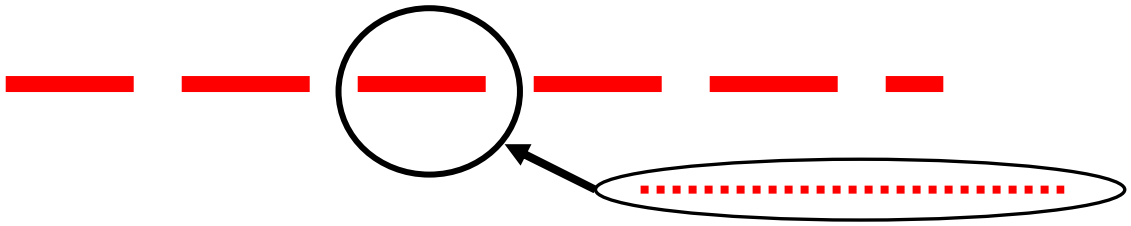
for the PLUME Collaboration,
PIXEL 2010
Grindelwald, 6-10 September 2010

Outline

- International Linear Collider and motivation for ultra-light vertex detector
- PLUME collaboration: status and results
- Ultra-light ladders in FP7 AIDA

International Linear Collider

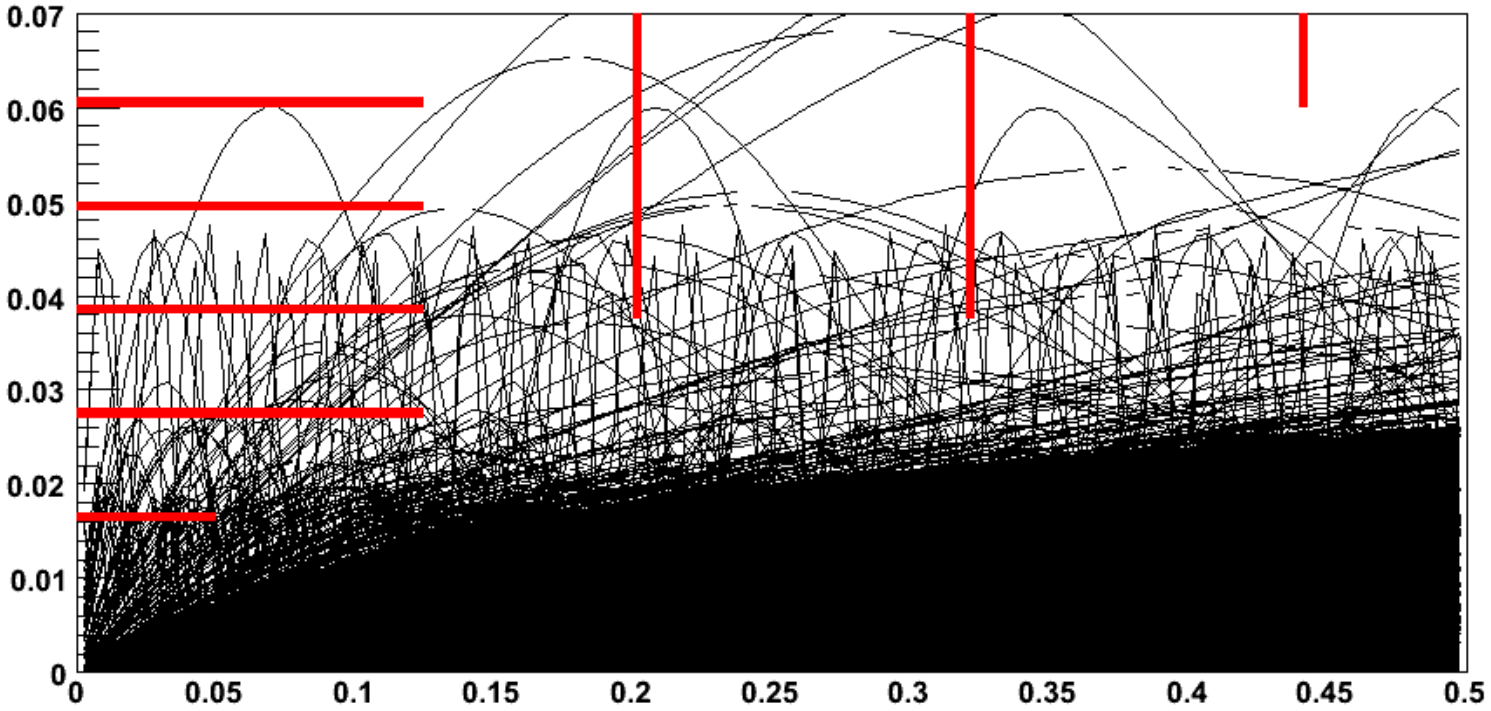
Bunch trains



ILC : 1 train = 2680 bunches 337 ns apart 5 Hz rate

- Energy up to 1 TeV
- Huge number of e^+e^- pairs produced in strong fields of beams (beamstrahlung)
- Need time-slicing within bunch trains to reduce detector occupancy
  - Trade-off of power and material

Vertexing at ILC

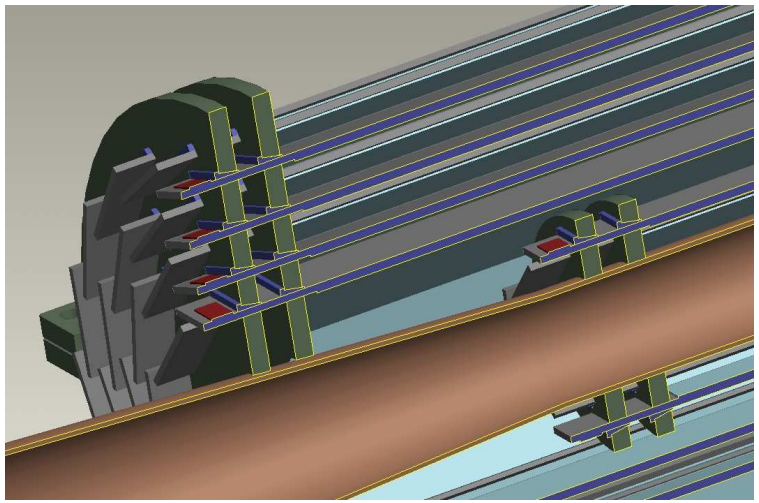


C Rimbaud et al. EUROTeV-Report-2005-016-1

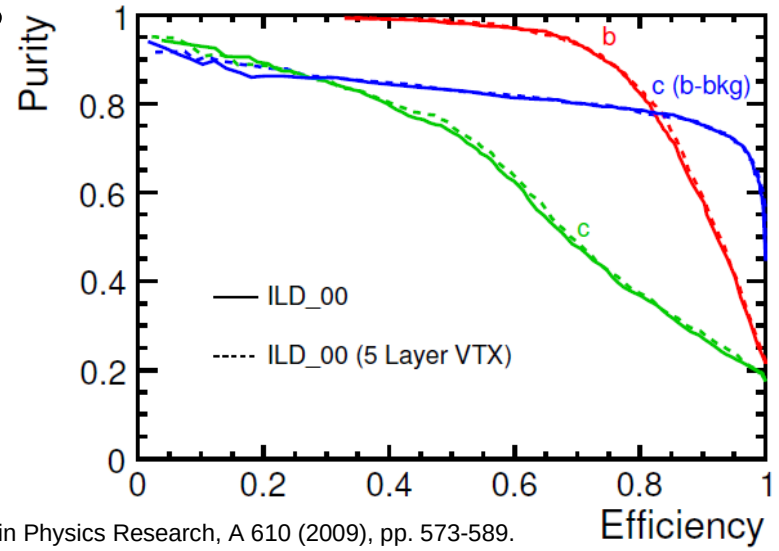
Simulation of e^+e^- pair production at ILC

ILC Vertex Detector

- 1 Giga channels of 20×20 μm pixels in 5 layers with fast readout
  - excellent IP resolution **$(5\ \mu m)^2 + (10\ \mu m/p)^2$**
  - Low material budget 0.1% X_0 per layer
    - Air cooling
  - Radiation tolerance 300krad, $10^{11} n_{eq}/cm^2$
  - Power < 0.1 – 2 W/cm^2



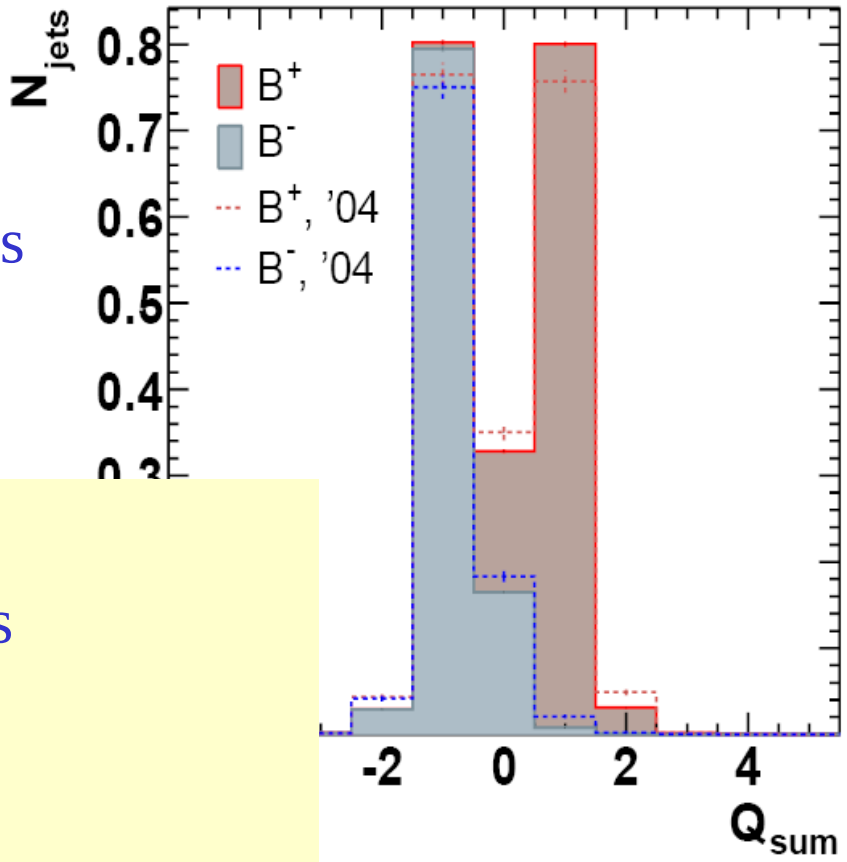
- Sophisticated algorithms using vertexing
  - Vertex mass
  - Vertex charge
  - Vertex dipole
- Flavour tagging
  - Excellent performance for b- and c-tagging



D. Bailey et al., Nuclear Inst. and Methods in Physics Research, A 610 (2009), pp. 573-589.

Vertex Charge

- Total charge of tracks associated with a vertex
  - Binary behaviour : a lost or wrongly assigned track changes the charge → every track is important



Sensitive to low pT tracks

Sensitive to material

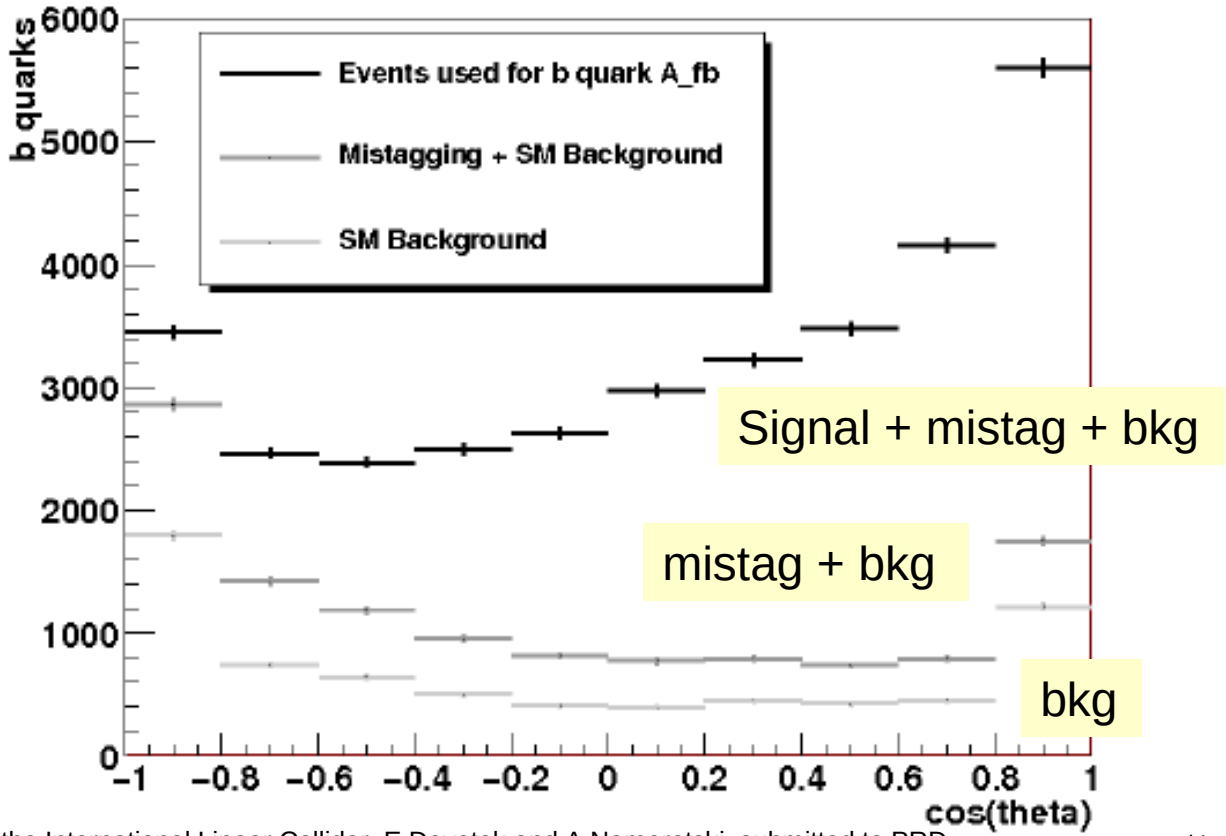
Where is it useful?

Example: Top Asymmetry

- Process: tt →WbWb → bbqqqq : two b-quarks in final state
- Deviations from SM predictions in asymmetry is excellent probe of new physics
  - One of benchmarking channels for ILC LOI

Note:

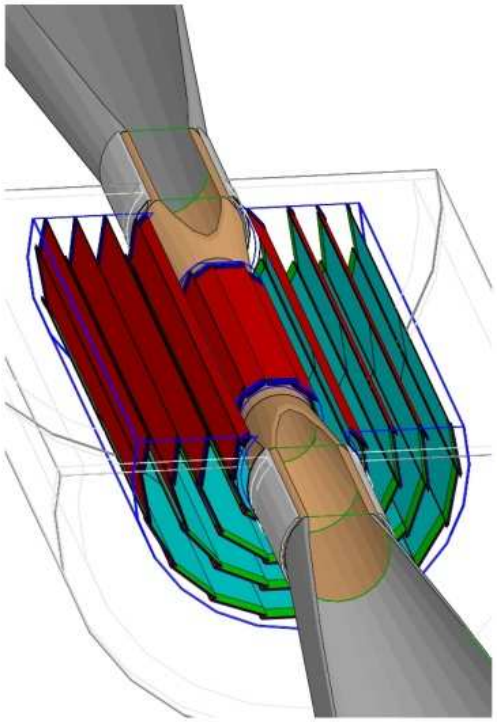
- Large asymmetry in forward region
- Large mistag rate in forward region

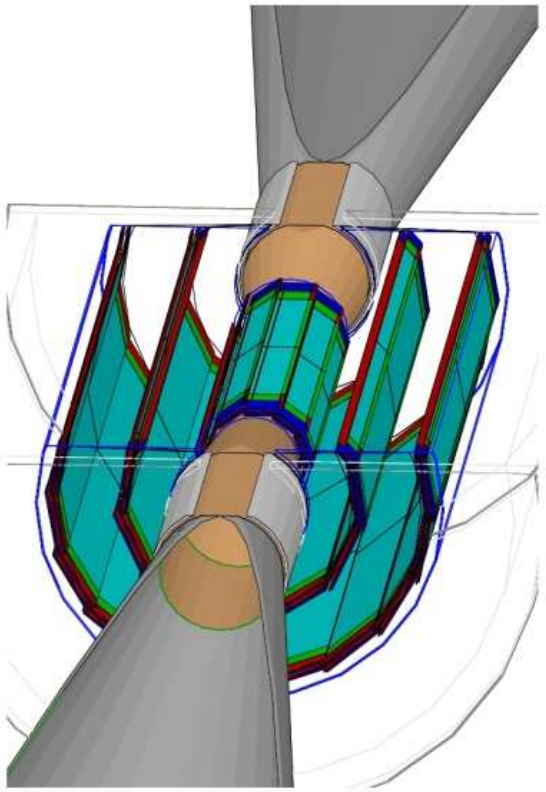


Top quark anomalous couplings at the International Linear Collider, E.Devetak and A.Nomerotski, submitted to PRD

ILC vertex detector

- Two options: single-sided vs double sided
  - Double-sided version: single support for two sensitive layers; track mini-vectors
- ILD vertex detector layout:





PLUME Collaboration

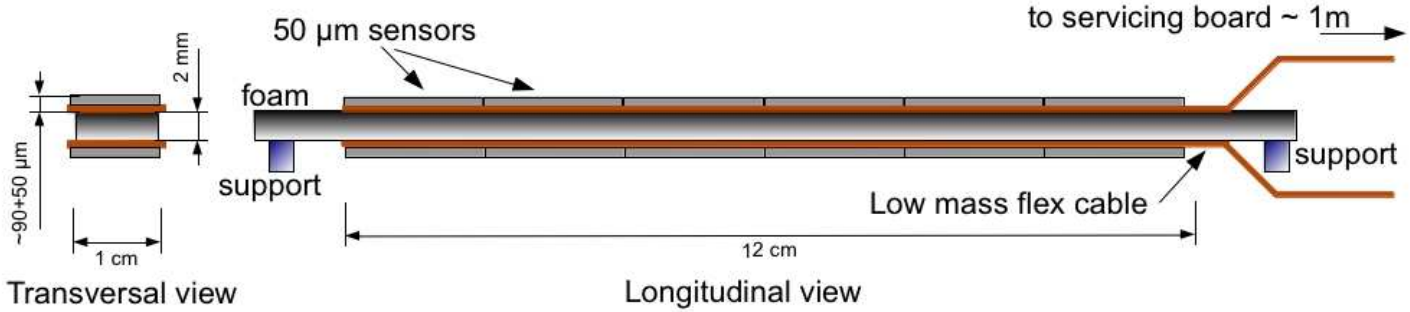
- PLUME = Pixelated Ladder with Ultra-low Material Embedding
  - Started in 2009

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

- Main aims
  - ultra-light double-sided VD ladder, 0.3% X0
  - Power pulsing in strong magnetic field with air cooling
    - 1/50 duty cycle
  - Study of alignment and spatial resolution
  - Study of mini-vectors

PLUME Ladder Concept

- Double-sided ladder, active area 1x12 sq.cm
- Six MIMOSA-26 sensors per side, thinned to 50 μm
- Kapton-metal flex cable
- SiC foam as support between two modules
- First servicing board ~1 m away

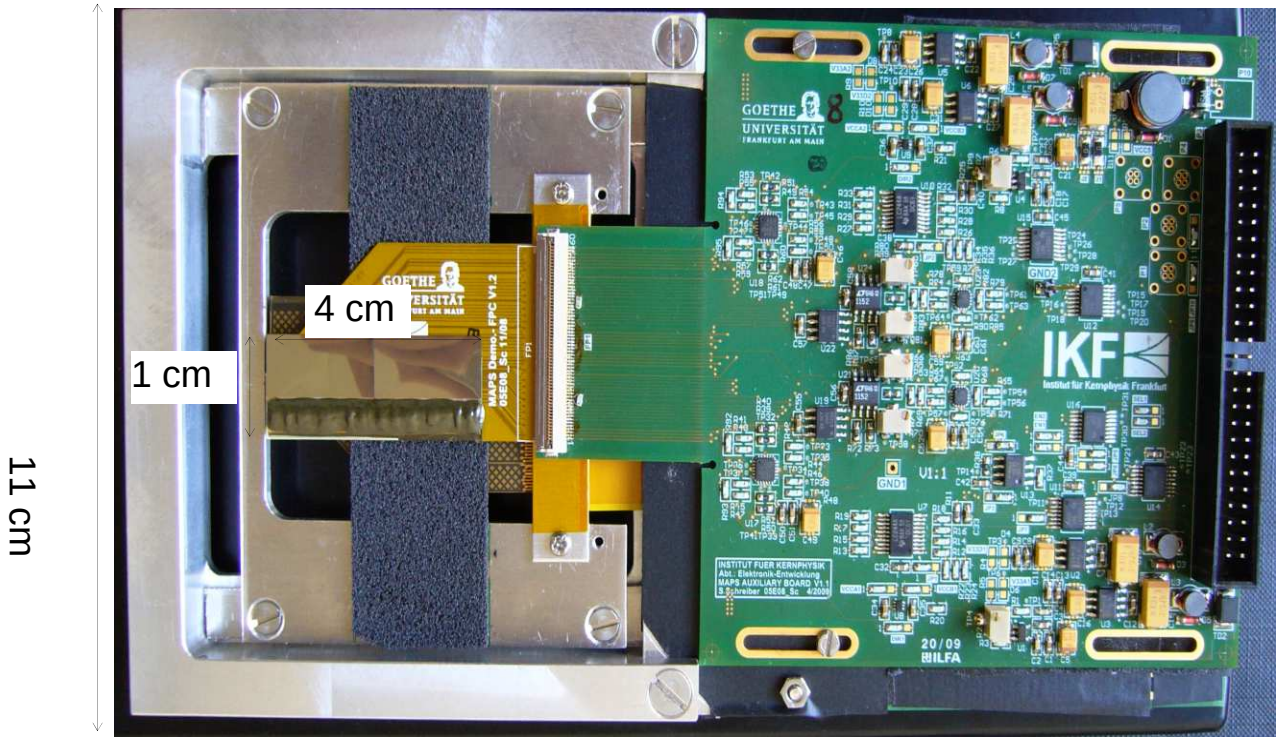


PLUME Ladder #1

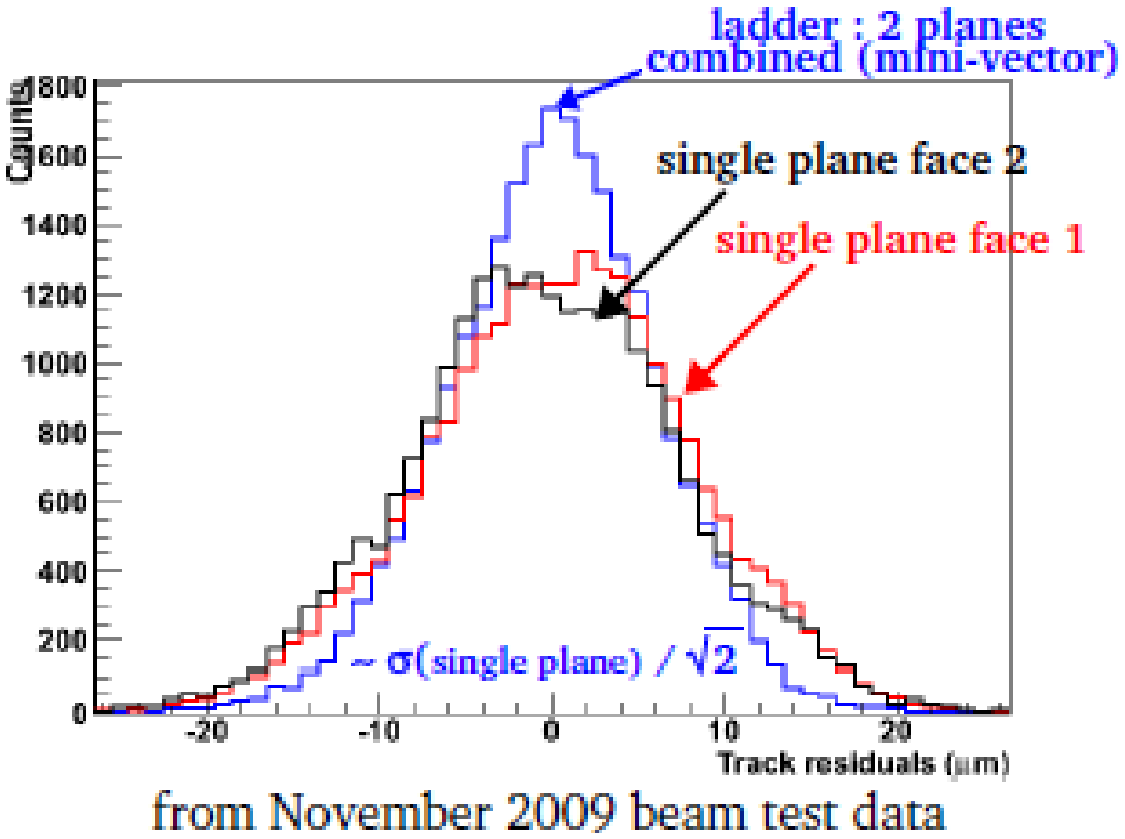
- Built and tested in beam in 2009

Aims:

- Build first double-sided ladder using off-the-shell components
  - Flex + two 50 um thick analogue MIMOSA20 (CMB@FAIR VD ladder)
  - 8% SiC foam (LCFI supplies)
  - Material budget 0.6% X_0 (SiC foam 0.18%, sensors 0.11%, glue 0.2%, flex 0.29 %)
- Nov 2009, CERN SPS, 120 GeV
- Study of track mini-vectors



Preliminary Testbeam Results

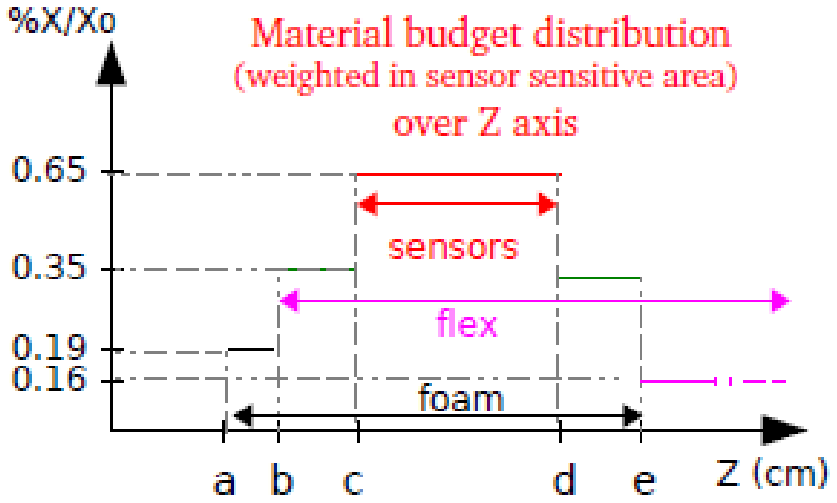


Development of ultra-light pixelated ladders for an ILC vertex detector. N. Chon-Sen *et al.* Jun 2010, arXiv:1006.5424

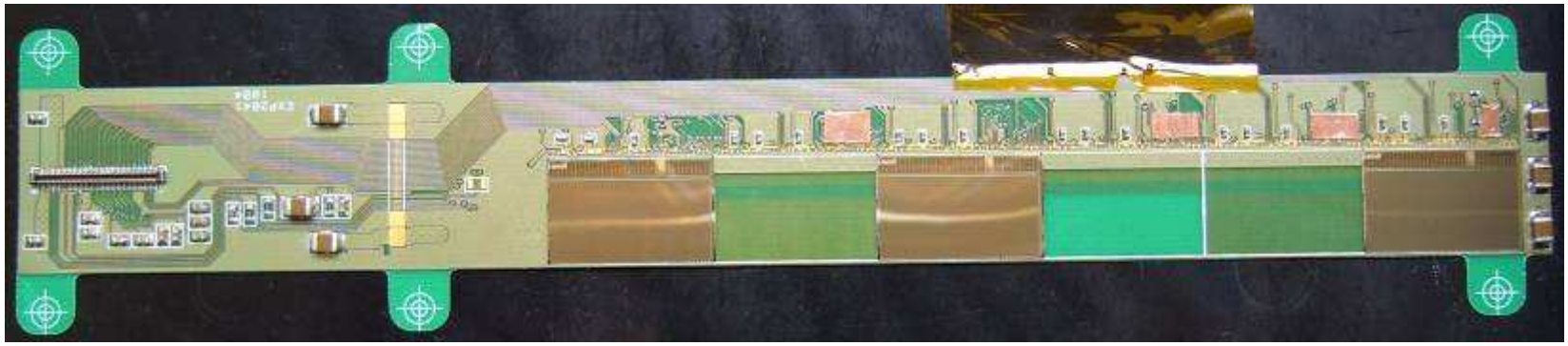
- Work in progress
- Single hit resolution ~7 micron
  - Pixel pitch 30 micron
  - mini-vectors have better resolution than single plane

PLUME Ladder #2 (1)

- Total material budget of double-sided ladder: 0.65% X_0
  - All components important

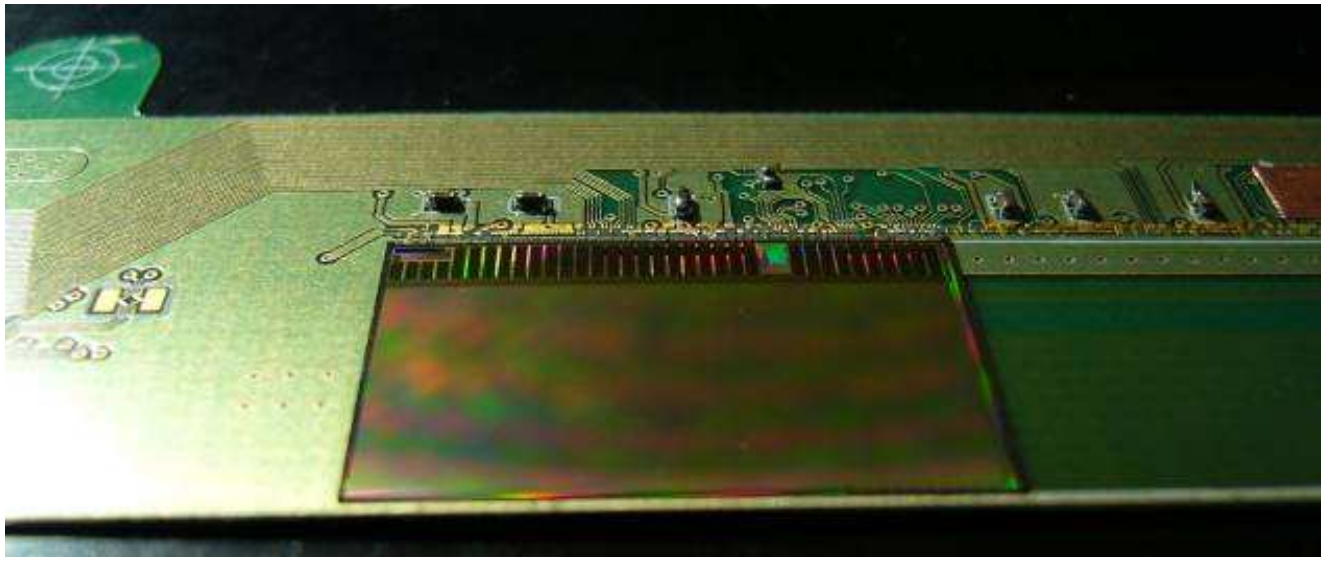


- Prototype prepared in 2010 using PCB version of flex



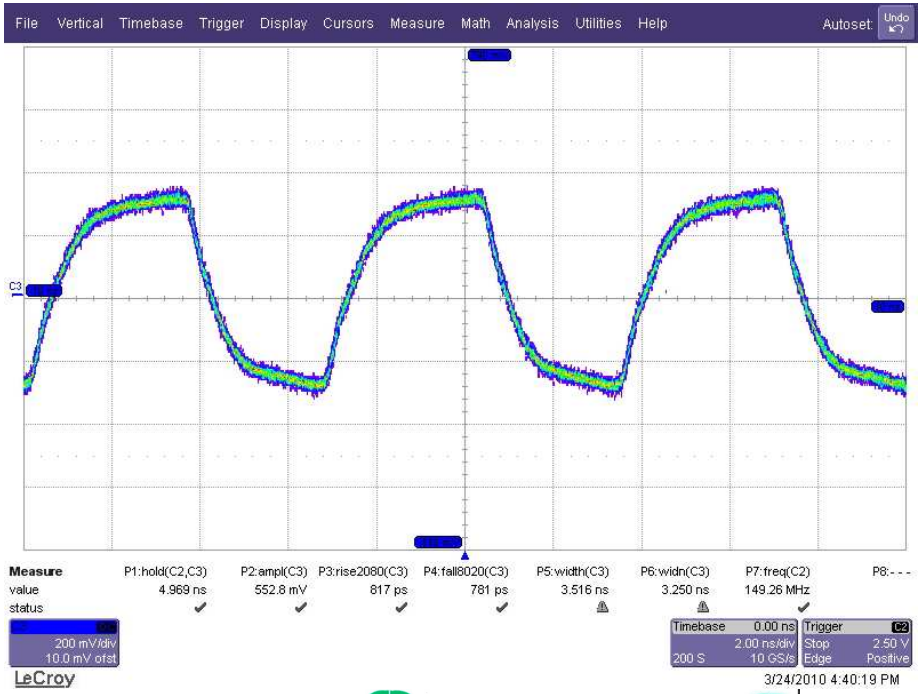
PLUME Ladder #2 (2)

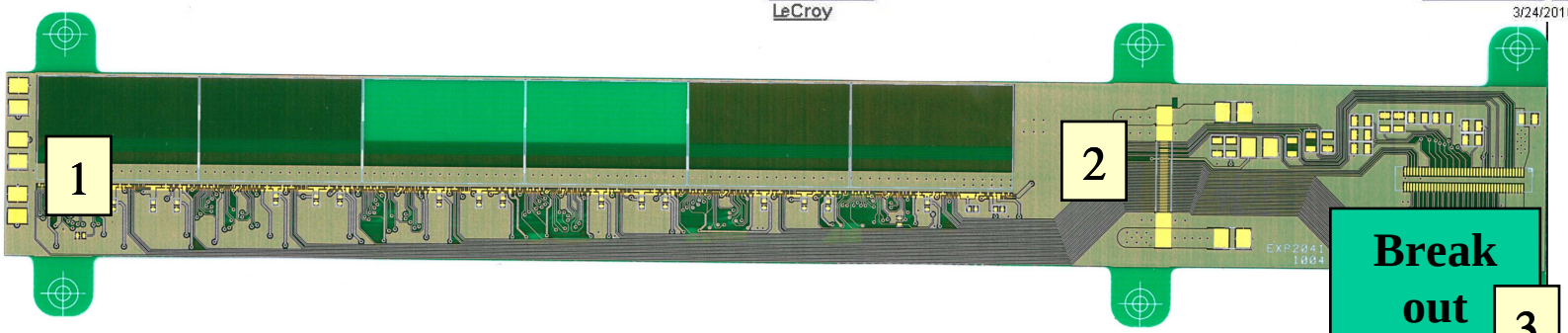
- MIMOSA26 (Strasbourg)
  - 18.4 sq.micron pixels in CMOS 0.35 micron process
  - Active area 10.6 x 21.2 sq.mm
  - Column-parallel readout, 115 microsec for 80 MHz clock
  - Zero suppression with binary output
- Testing of 3 MIMOSA26 sensors in progress

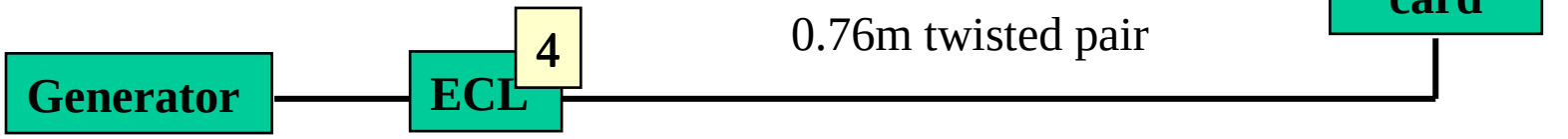


Clock Propagation

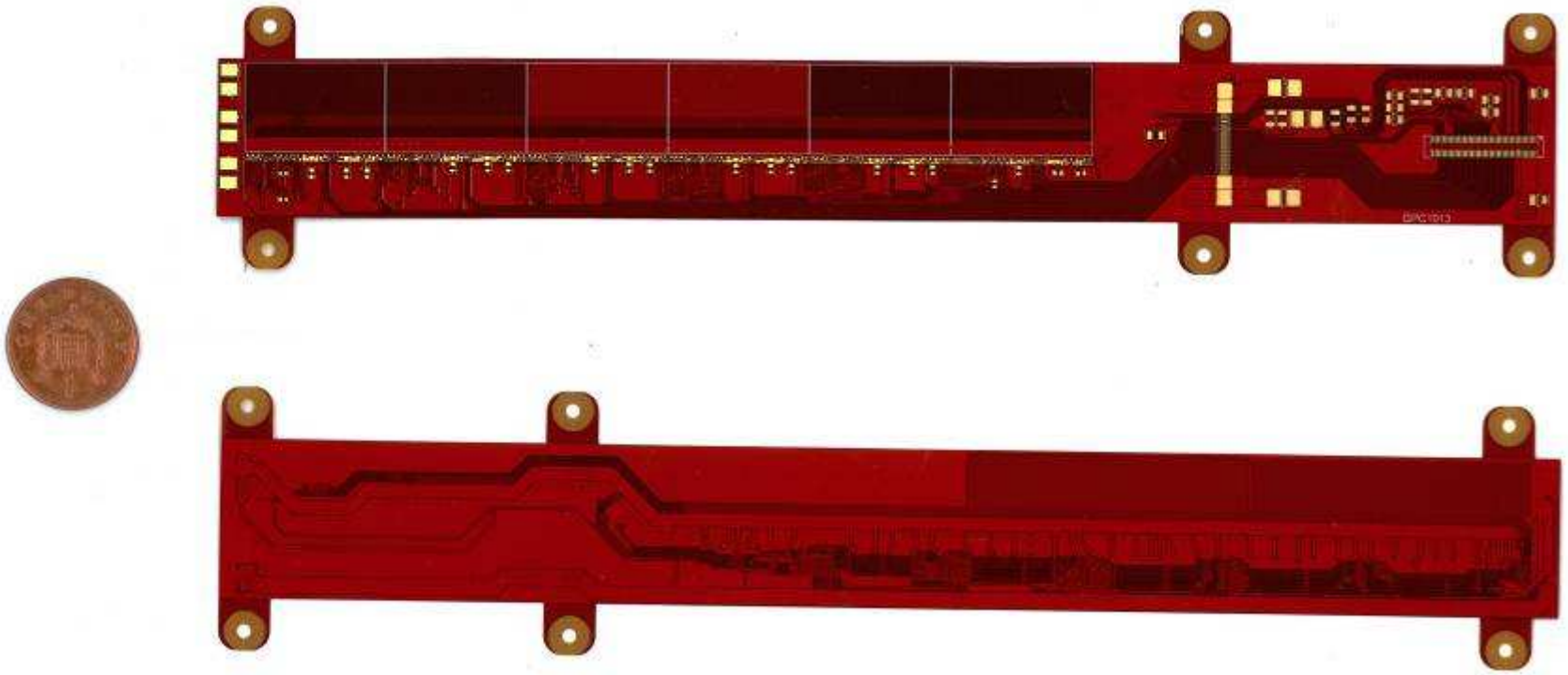
- PCB version of flex
- Good up to 150 MHz







Kapton Flex

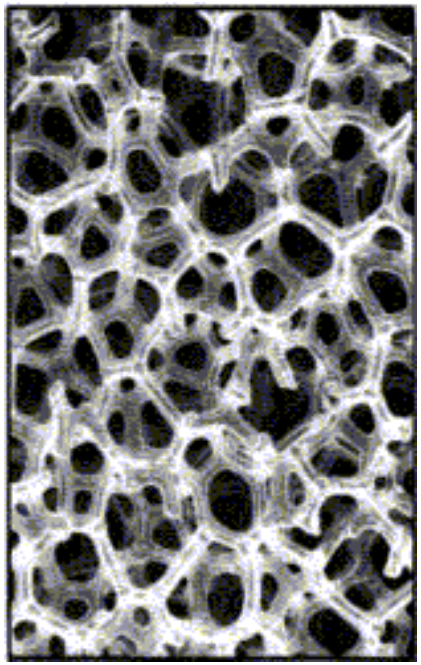


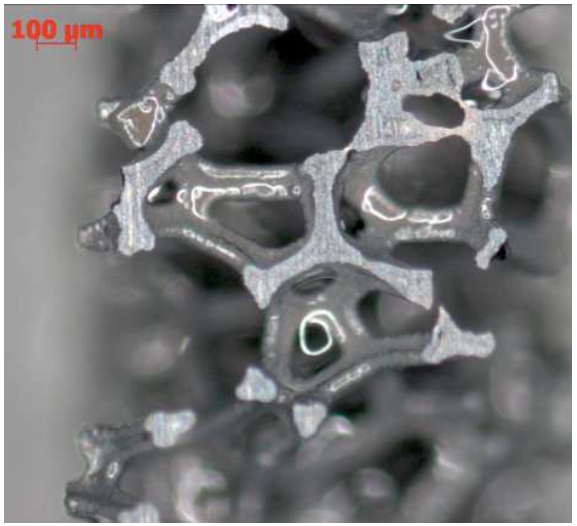
- Two vendors: Graphic (UK) and Optiprint (Switzerland)
- Received first flexes from both vendors, testing in progress

- Next steps
  - Build first ladder with 6 MIMOSA26, 50 micron thick, and kapton flex
  - Fabricate flexes with thinner kapton, thinner Cu traces, Al traces

Foam Support Structure

- Used as support in PLUME ladders
  - Follow-up work on LCFI (Bristol U.)
- Properties:
  - Open-cell foam
  - Macroscopically uniform
  - No tensioning needed
- Lightweight elements in silicon carbide (SiC) foam
  - 4 to 8 % fill factor
  - Can be machined





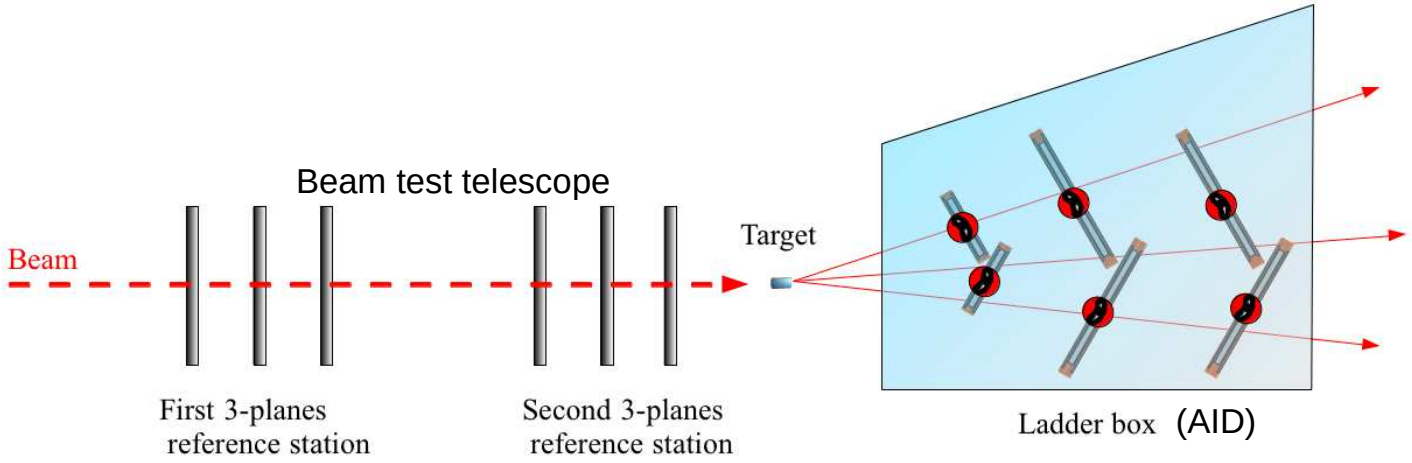
PLUME Plans

- Realistic ILC VD ladder prototype by 2012
  - ILC Detailed Baseline Design (DBD) due in 2012
- Steps:
  - 2010: 2x6 MIMOSA-26, 0.65% X_0
  - 2011: 2x6 MIMOSA-26, 0.4% X_0
  - 2012: 2x6 optimized MIMOSA's, 0.3% X_0
- Use PLUME ladders within FP7 AIDA project

ILC Vertex Detector in EU-FP7 AIDA

Collaboration :

PLUME collaboration + Geneva University + Warsaw University + ...



On-beam test infrastructure:

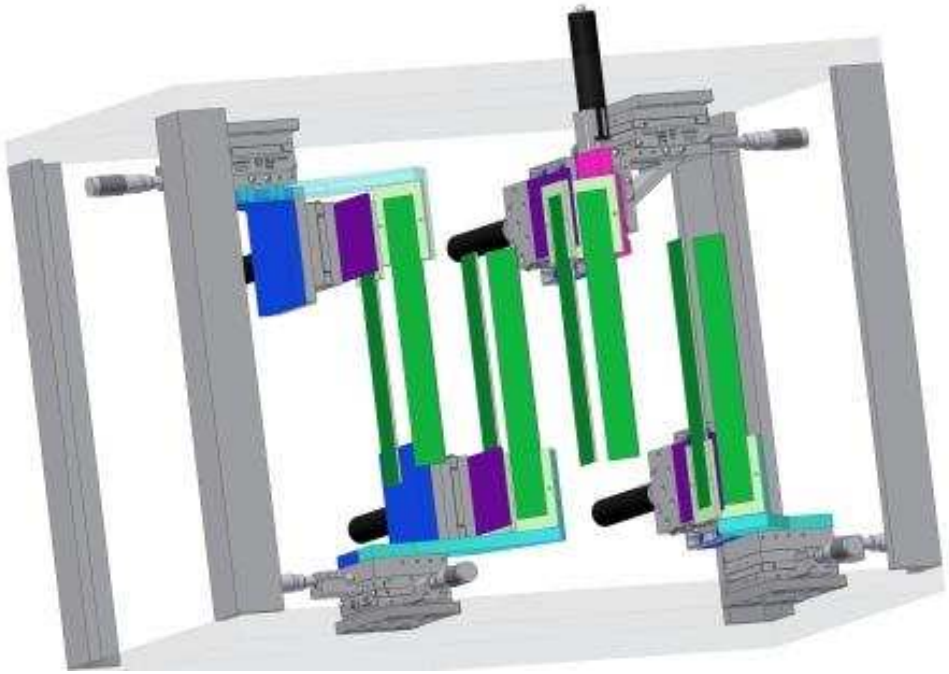
- Very thin removable target
- Large Area beam Telescope (LAT) : EUDET-like Beam Telescope
- Alignment Investigation Device (AID): ladder box

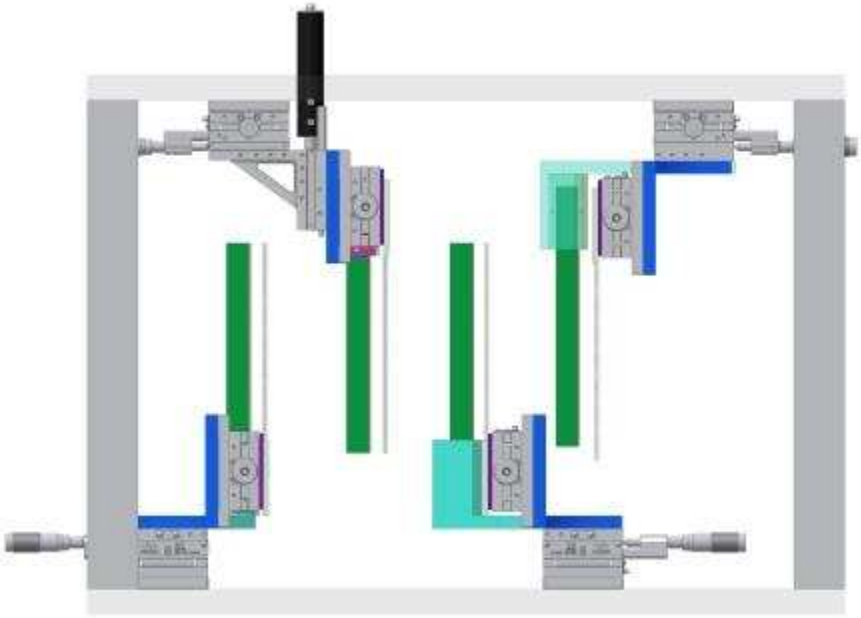
Off-beam test infrastructure:

- thermo-mechanical studies, including effect of air-flow colling
- power cycling effect in strong magnetic field: Lorentz forces on ultra-light PLUME ladders

AID Layout

- Aim: alignment studies for PLUME or any other VD ladders
- Four stations with precise adjustable stages
  - Two overlapping ladders in each station
  - Middle station with three additional degrees of freedom
- Conceptual drawing (S.Yang, Oxford U):





Summary

- Ultra-light detectors are critical for LC physics aims
  - Long lifetime of bottom and charm quarks
- Demonstration of a prototype ladder by 2012 required by ILC DCD schedule

- PLUME collaboration will address
  - Ladder material budget
  - Power cycling in magnetic field
  - Advantages of double-sided ladders
  - Alignment studies within FP7 AIDA project