PLUME

Ultra-light double-sided ladders for a LC vertex detector

Outline:

- Motivation for ultra-light vertex detector
- PLUME collaboration: status and results
- Ultra-light ladders in FP7 AIDA

Ingrid-Maria Gregor, DESY
for the PLUME Collaboration
IWLC 2010
Geneva, October 2010

ILC vertex detector

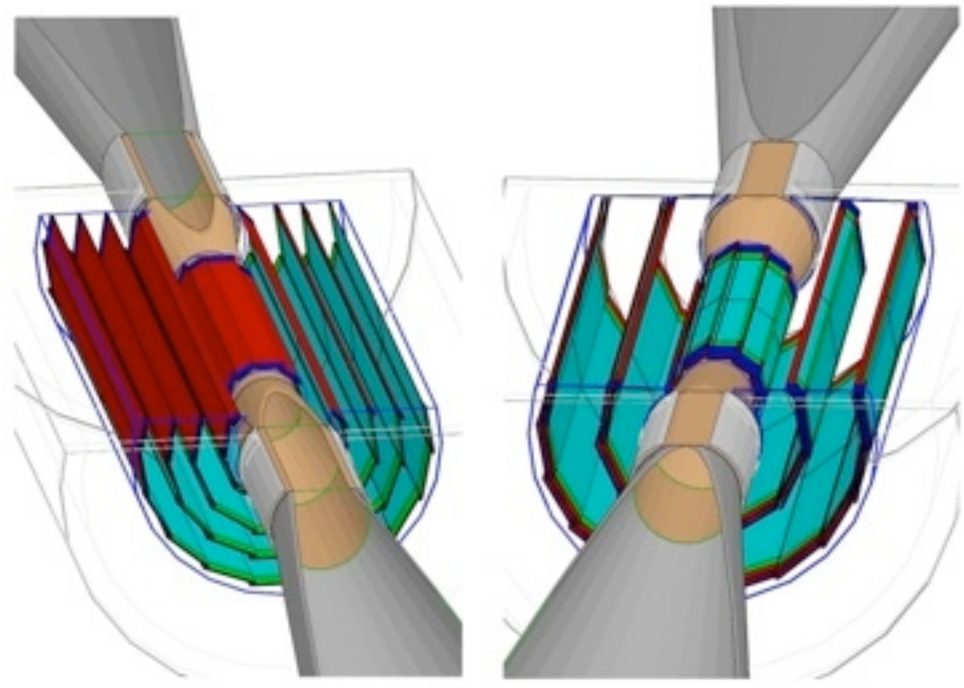
Figure of merit for the VXD:
Impact Parameter Resolution

$$\sigma_{r\phi} \approx \sigma_{rz} \approx a \oplus b/(p\sin^{3/2}\vartheta)$$

Accelerator	a (μm)	b (μm)
LEP	25	70
SLD	8	33
Tevatron	10	40
LHC	12	70
RHIC-II	12	19
ILC	**<5**	**<10**

(Marc Winter)

ILD vertex detector layout:



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

What is PLUME?

- Material budget request
  - 0.16% X_0 for double layer
  - 0.11% X_0 for single layer
- Operation mode (ILC)
  - Power pulsing (200ms period)
  - Air cooling (100mW/cm^2)

PLUME collaboration:
- Bristol University
- Oxford University
- DESY (Hamburg)
- IPHC (Strasbourg)

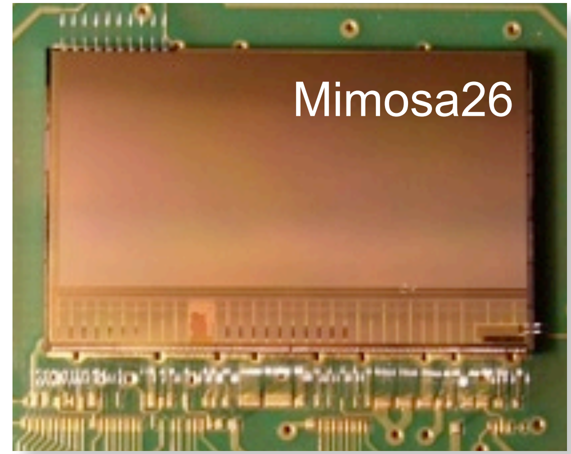
✤ Synergy with
- IK Frankfurt (CBM@FAIR vertex det.)
- LBNL Berkeley (STAR@RHIC vertex det.)

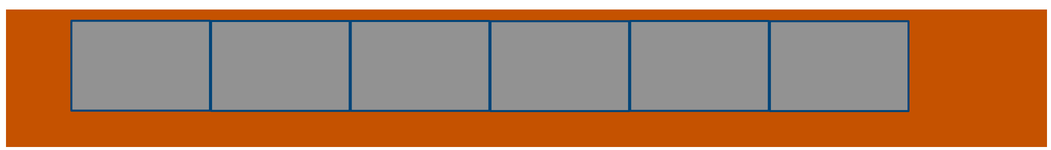
PLUME = Pixelated Ladder with
Ultra-Low Material Embedding

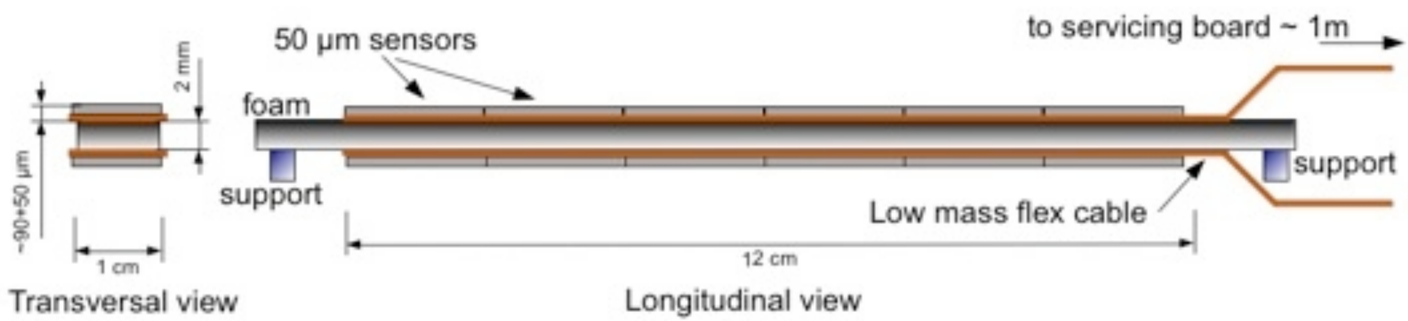
- Fabrication
  - Knowledge of full process
  - Identify critical steps
  - Develop expertise in labs
    - Testing
    - Validating
    - Mounting
- Expected Performances
  - For a single layer:
    - Single point resolution <3µm with efficiency ~ 100%
  - For both layers:
    - evaluate pointing resolution of mini-vectors

PLUME Ladder Concept

- Double-sided ladder, active area $1 \times 12 cm^2$
- Six MIMOSA-26 sensors per side, thinned to 50 µm
- Kapton-metal flex cable
- Silicon Carbide foam as support between two modules
- First servicing board ~1 m away
- Prototyping in a staged approach
- 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







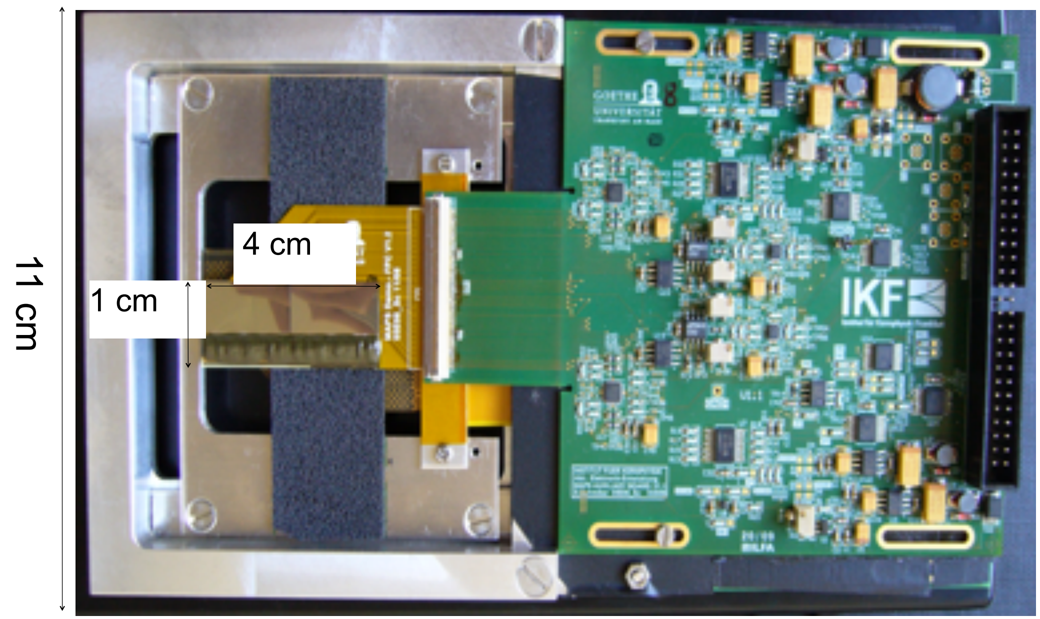
PLUME Ladder #1

- Built and tested in beam in 2009

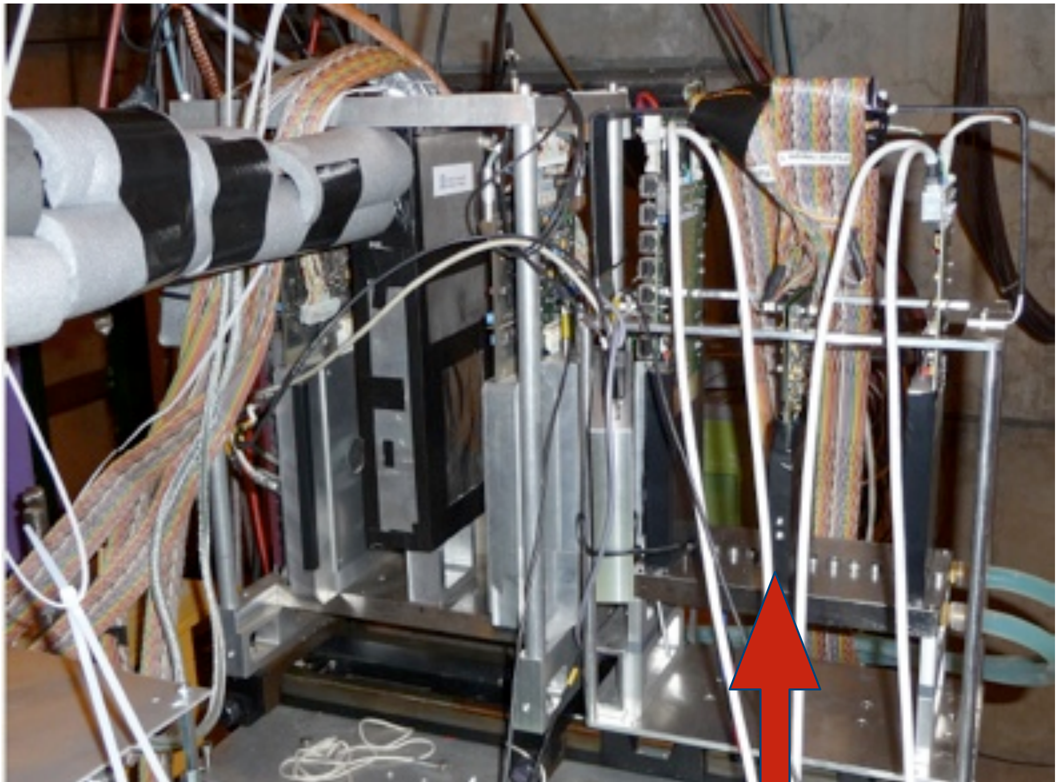
Aims:

- Build first double-sided ladder using off-the-shell components
  - Flex + two 50 um thin analogue MIMOSA20 (CBM@FAIR VD ladder)
  - 8% SiC foam (LCFI supplies)
  - Material budget 0.6% X_0 (SiC foam 0.18%, sensors 0.11%, glue 0.02%, flex 0.29 %)

- Nov 2009, CERN SPS, 120 GeV
- Study of track mini-vectors



CERN Test Beam Nov 2009

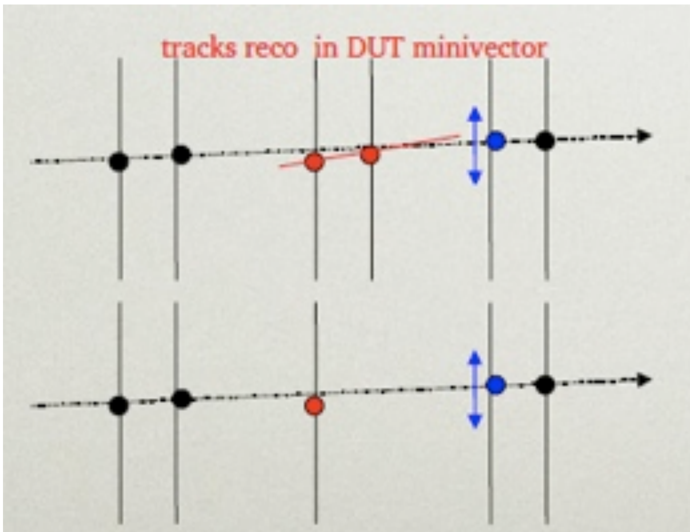


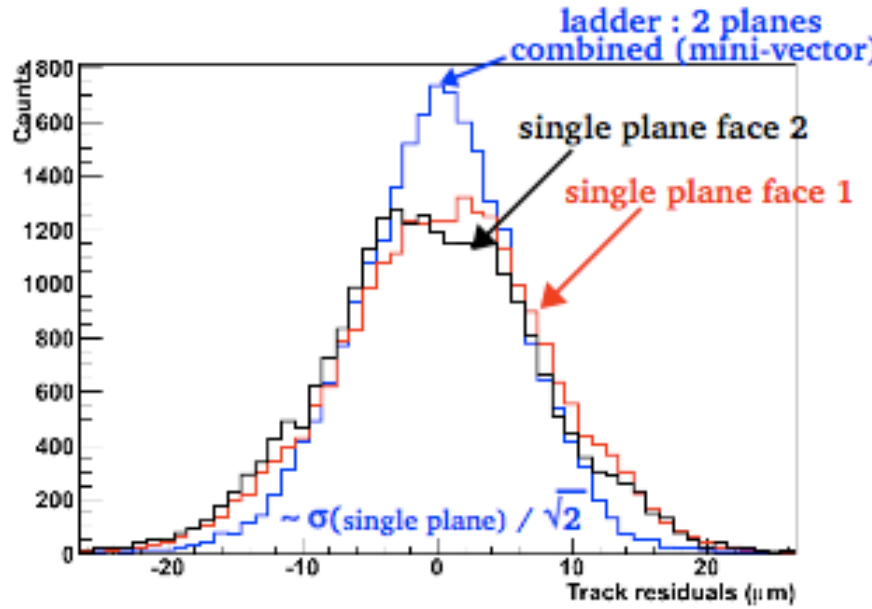
PLUME ladder #1

- TAPI telescope with 4 reference planes of unthinned Mimosa 18 (~11e noise, ~100% efficiency, ~1 um spatial resolution).
- Evaluate the tracks reconstruction precision in PLUME ladder
  - to quantify the benefits of mini-vectors concept on the impact parameter resolution

Preliminary Test Beam Results

- Two hits on double sided ladder can be correlated and used to reconstruct a mini-vector





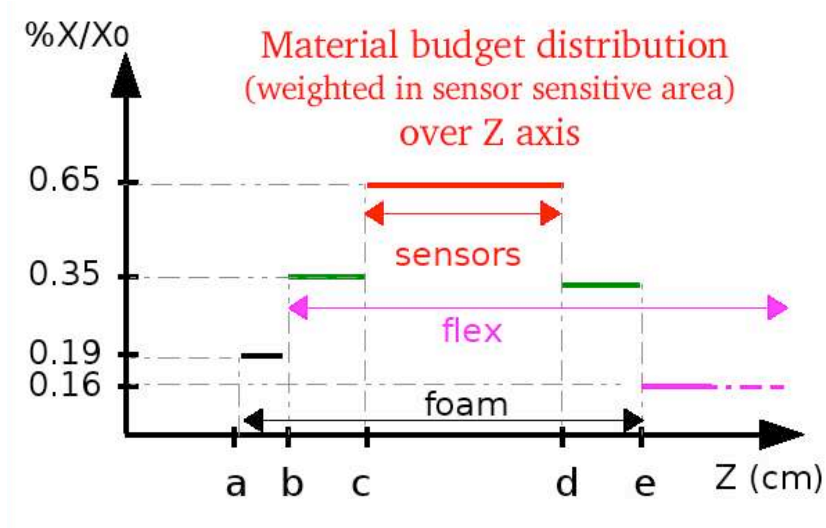
from November 2009 beam test data

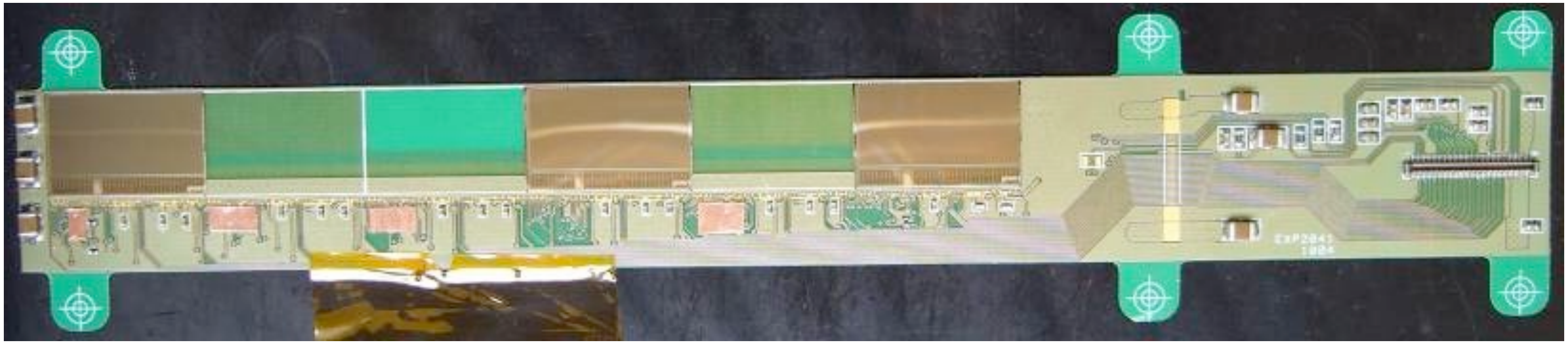
Development of ultra-light pixelated ladders for an ILC vertex detector. N. Chon-Sen *et al.* Jun 2010, arXiv:1006.5424

- Work in progress
- Single hit resolution ~7 micron
  - Pixel pitch 30 micron
  - mini-vectors have better resolution than single plane (20-30%)

PLUME Ladder #2 - PCB Version

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



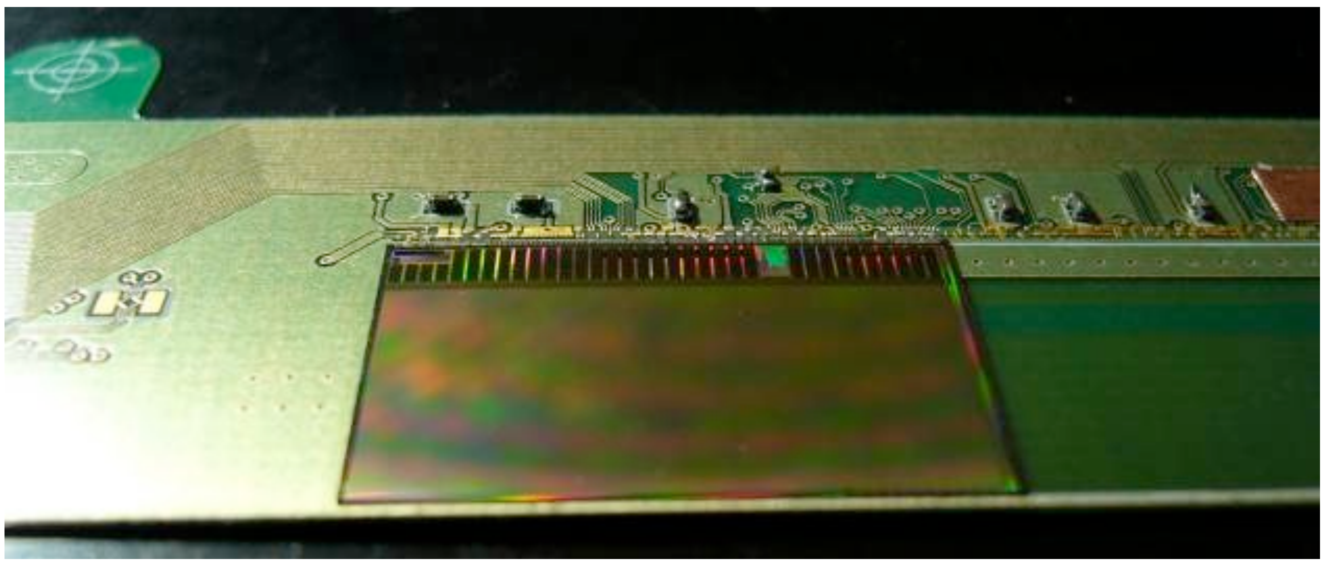


Prototype prepared in 2010 using PCB version of flex

PLUME Ladder #2

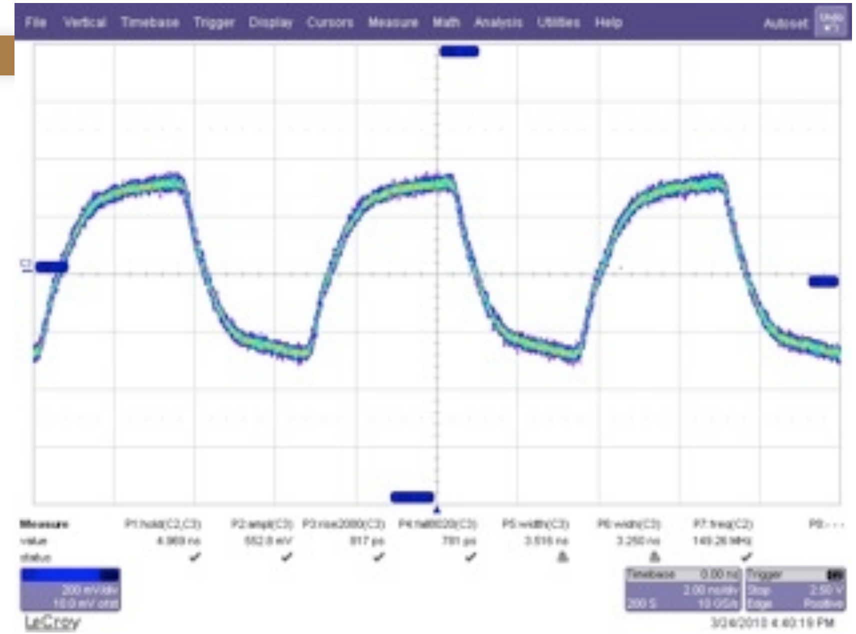
- Sensor: MIMOSA26 (Strasbourg) [used in EUDET telescope]
  - 18.4 um pixel pitch in CMOS 0.35 micron process
  - Active area 10.6 x 21.2 mm^2 (663k pixels)
  - Column-parallel readout, 115 microsec for 80 MHz clock
  - Zero suppression with binary output
- Testing of three MIMOSA26 sensors in progress

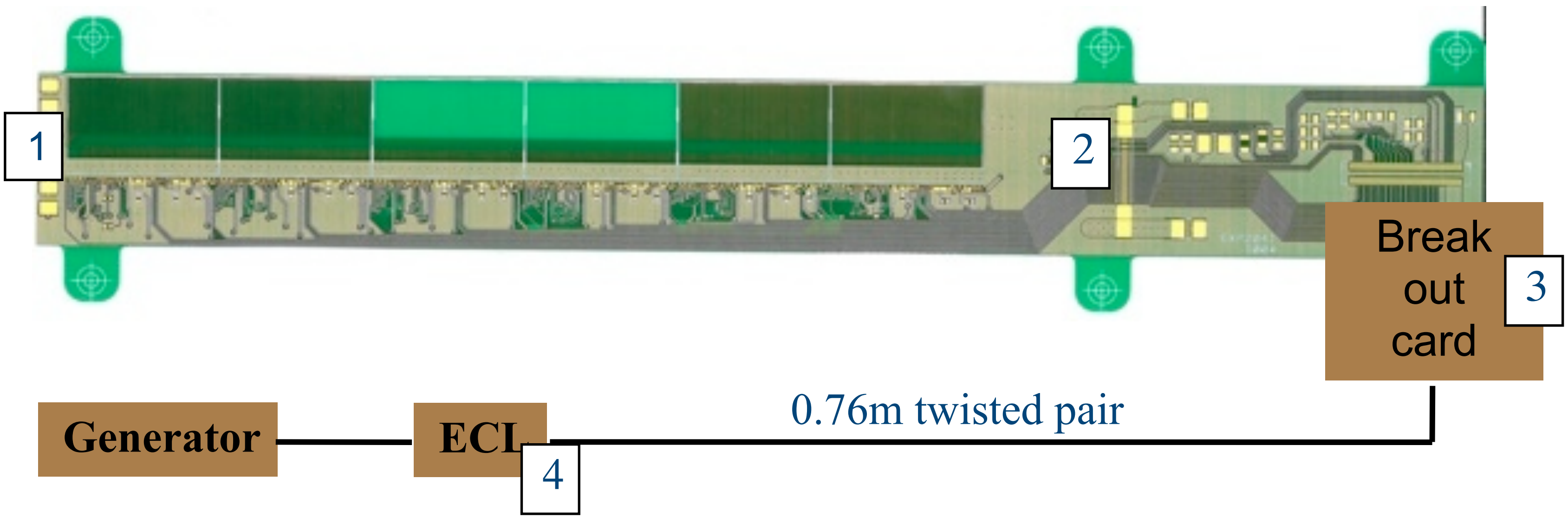
More details see talk of Jerome Baudot



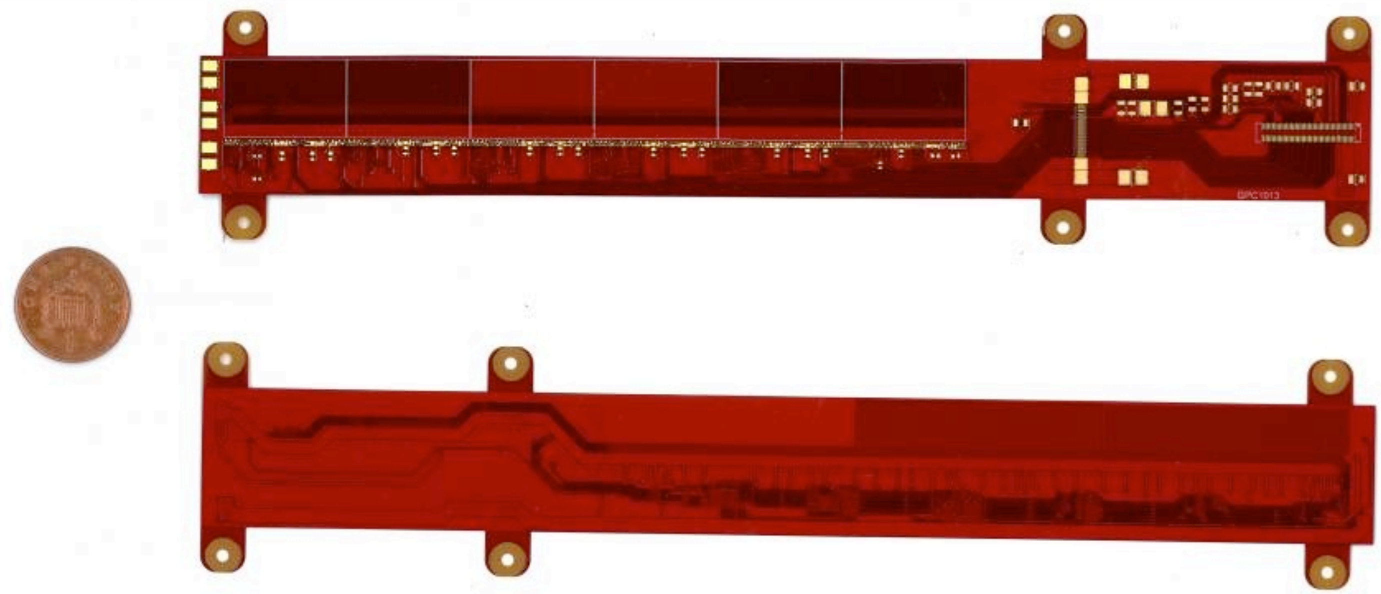
Clock Propagation

- PCB version of flex
- Clock terminated with one 100 Ohm near the left end
- 0.76m of twisted pair from TTL-ECL converter to break out card
- LeCroy SDA6000A 20 Gsample/sec scope, 7 GHz differential active probe
- Measured 80 MHz signal shapes in 4 points
- Good up to 150 MHz





Kapton Flex

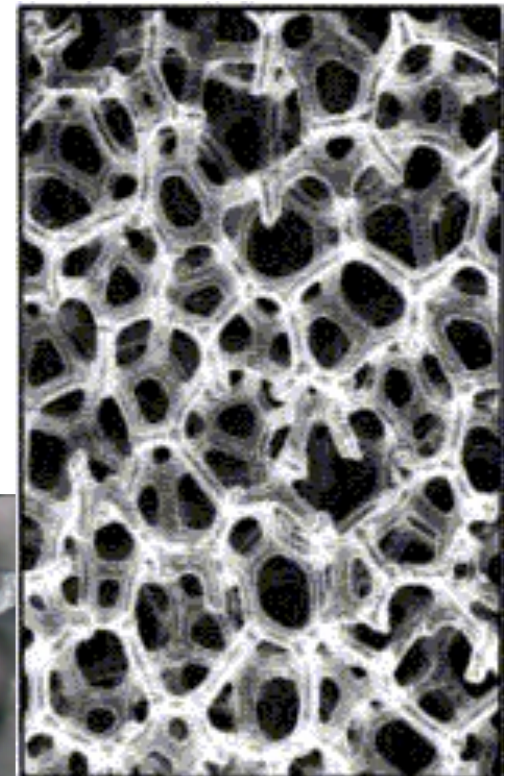


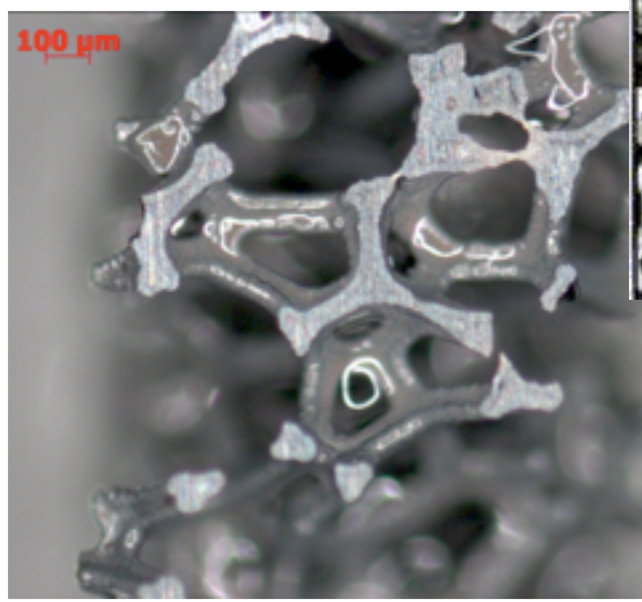
- Two vendors: Graphic (UK) and Optiprint (Switzerland)
- Received first flexes from both vendors, testing in progress

- 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



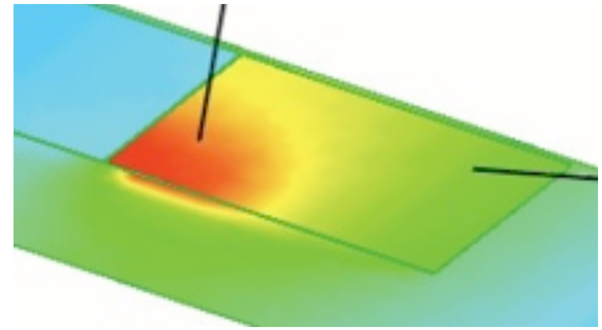


More details see
Joel Goldstein's talk

PLUME Ongoing Work and Plans

Ongoing Work

- Measurements with PCB ladder (3 sensors connected).
- Preparation and tests of flex kapton ladder with 6 thin sensors.
- Mechanical studies of carbide support and flex prototype.
- Thermal simulations and measurements of heat transfer (with air cooling).
- Power pulsing tests with source and laser.
- Investigation of alternative flex vendors.
- Material optimization of flex design.

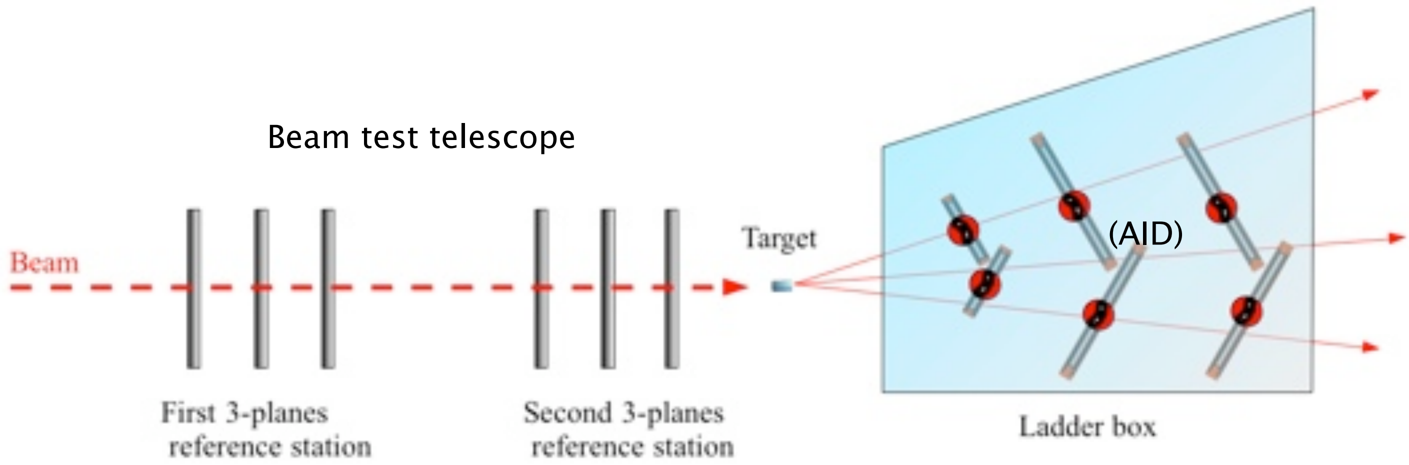


Plans

- 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 effects of air-flow cooling
- Power cycling effect in strong magnetic field: Lorentz forces on ultra-light PLUME ladders

AID Layout

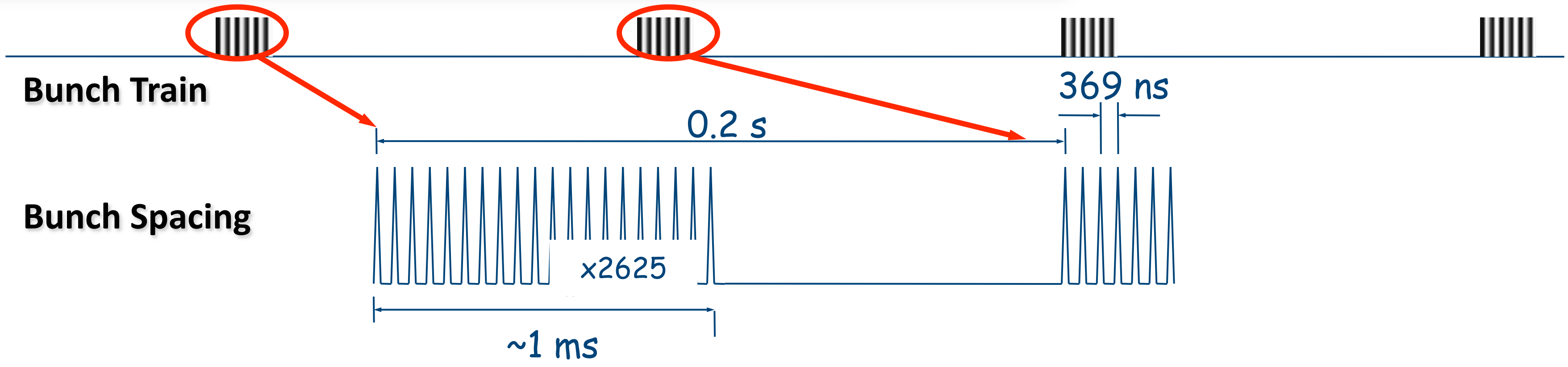
- Aim: alignment studies for PLUME or any other VD ladders
- Four stations with precise adjustable stages
  - Two overlapping ladders in each station
  - Middle station with three additional degrees of freedom
- Conceptual drawings:

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

International Linear Collider

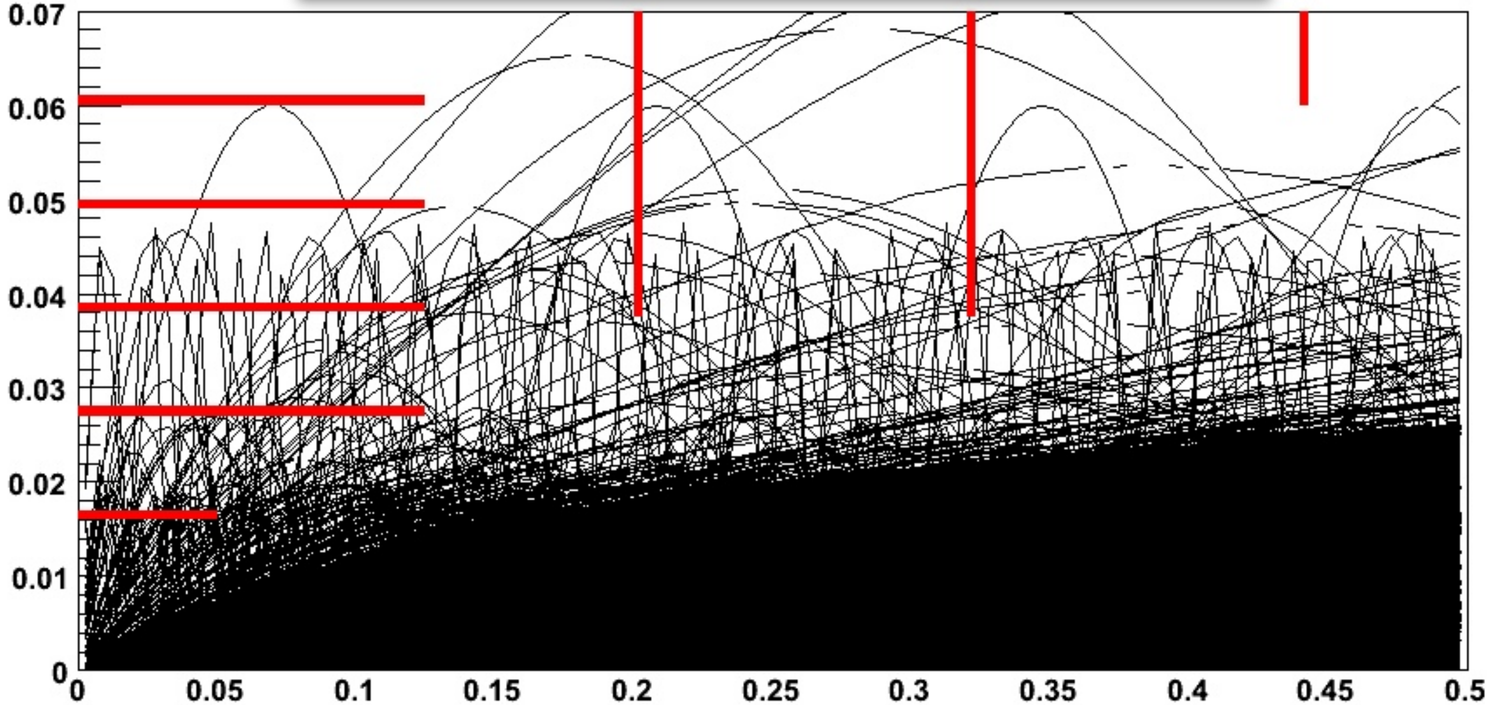


ILC : 1 train = 2680 bunches 337 ns apart 5 Hz rate

- 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

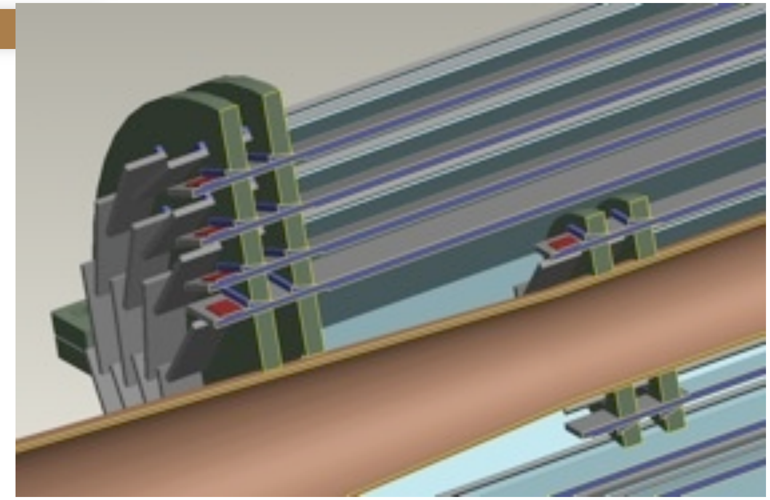
Vertexing at ILC

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



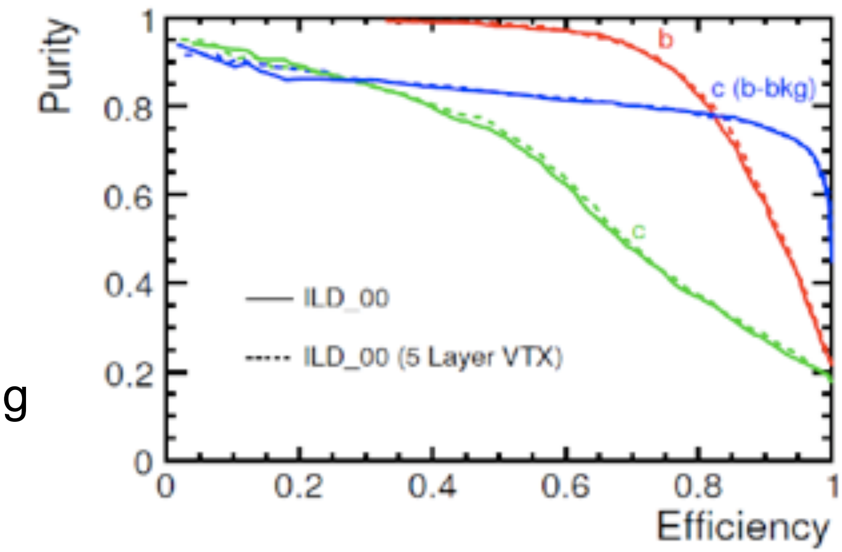
C Rimbaud et al. EUROTeV-Report-2005-016-1

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, $10^{11} n_{eq}/cm^2$
  - Peak power < 0.1 – 2 W/cm^2

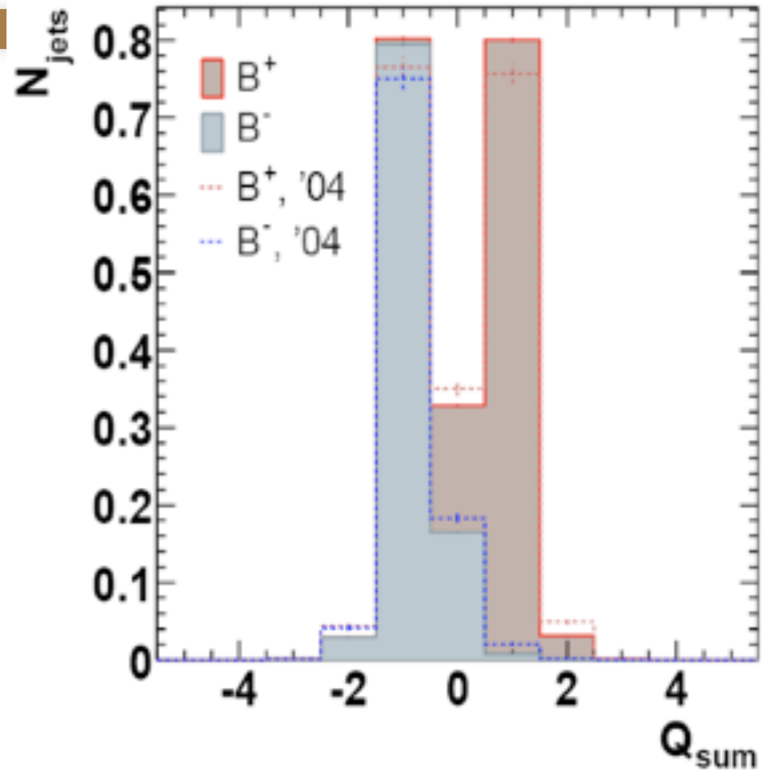
- Sophisticated algorithms using vertexing
  - Vertex mass
  - Vertex charge
  - Vertex dipole
- Flavour tagging
  - Excellent performance for b- and c-tagging



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

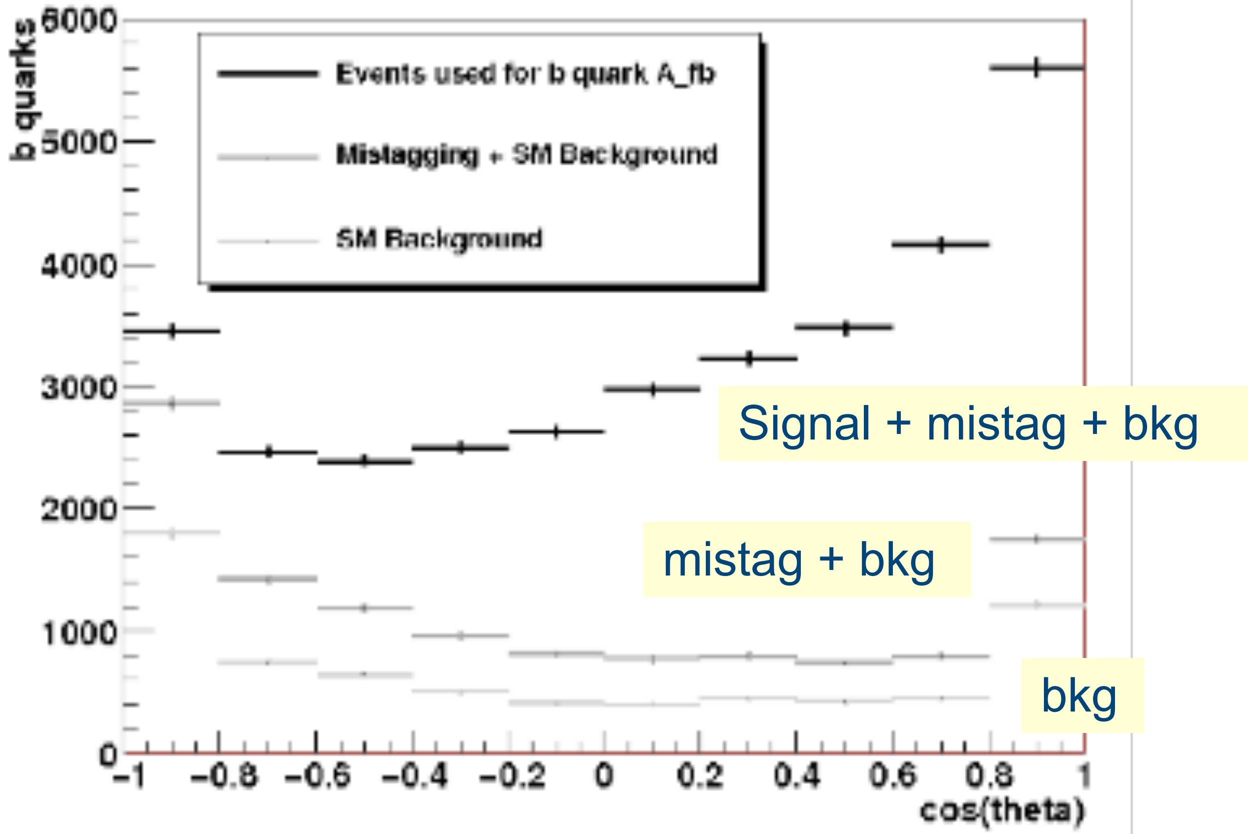
Where is it useful?

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

PLUME Ladder #1