Test Beam Facility Requirements for Vertexing and Tracking

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Motivation

- Test beam requirements for tracking and vertex were discussed more than once
- Found document: http://www-lc.fnal.gov/lc_testbeams/tbpage.html (2004)

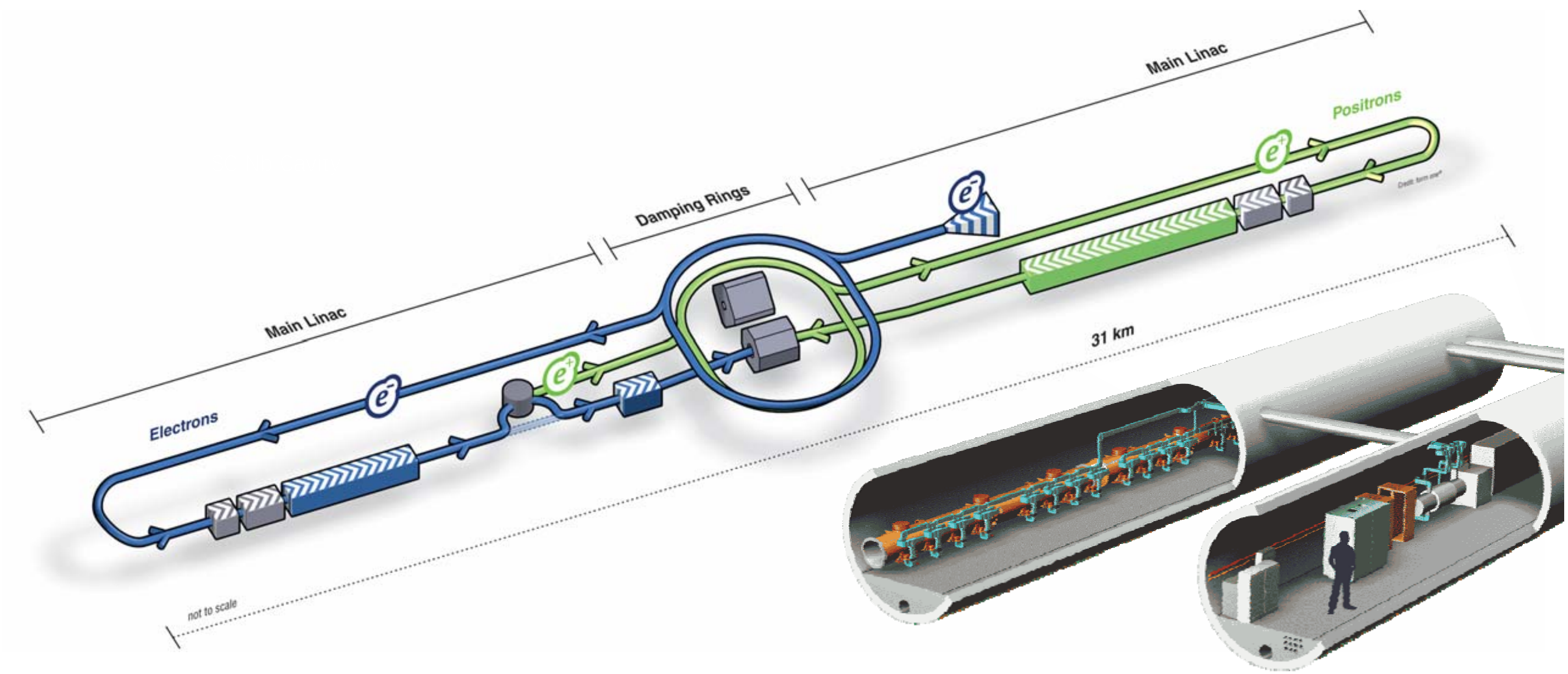
- In the mean time EUDET enabled some infrastructure, but will not cover all aspects

  - What are the requirements ? (vertex and tracking)
  - What infrastructure is needed ?
  - What else would we like to have ?

If you do not agree, please let me know!

Outline
- Introduction
- Vertex test beams
- Tracking test beams
- “EUVIF”
- Outlook

The International Linear Collider



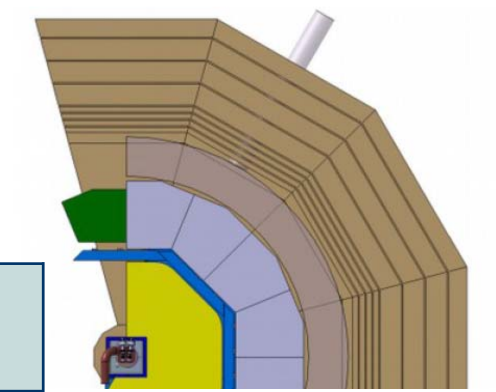
- e^--e^+ collider: two 11 km SC linacs at 31.5 MV/m
- Dual tunnel configuration (safety and accessibility)
- Single IR, crossing angle 14 mrad, two detectors in push-pull operation

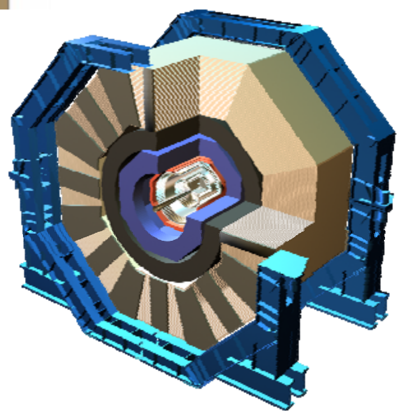
Parameters:

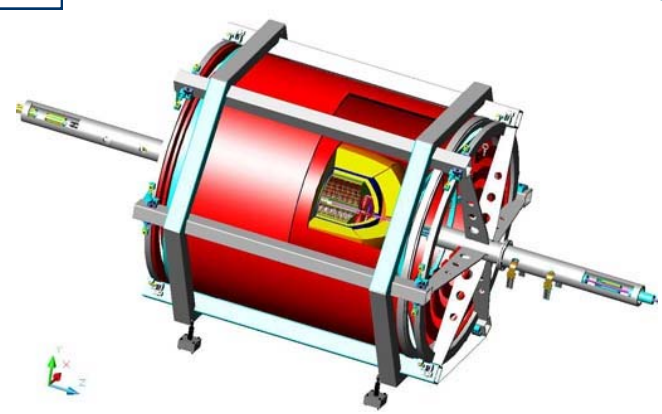
- $\sqrt{s}$ = 500 GeV, tunable from 200 to 500 GeV, upgradeable to 1 TeV
- $\int Ldt$ = 500 fb^{-1} in 4 years (peak luminosity $2 \cdot 10^{34}$ $cm^{-2}s^{-1}$)

The Three ILC Detector Concepts

	Premise	Vertex Detector	Tracking
ILD	PFA	3 double or 5 layer pixels	TPC + ext. Silicon
SiD	PFA	5-layer pixels 4 discs	Silicon strips
4th	Dual Readout	5-layer pixels	TPC Gaseous







The Vertex Detector at the ILC

Measure impact parameter, charge for every charged track in jets, and vertex mass.

Need:

- Good angular coverage with many layers close to vertex:
  - $|\cos\theta| < 0.96$.
  - First measurement at r ~ 15 mm.
  - Five layers out to r ~ 60 mm.
- Efficient detector for very good impact parameter resolution
- Material ~ 0.1% X_0 per layer.
- Capable to cope with the ILC beamstrahlungs background
- Modest average power consumption < 100W
- Hit resolution better than 5 µm.

- **small pixels, thin sensors, thin r/o electronics, low power (gas cooling)**

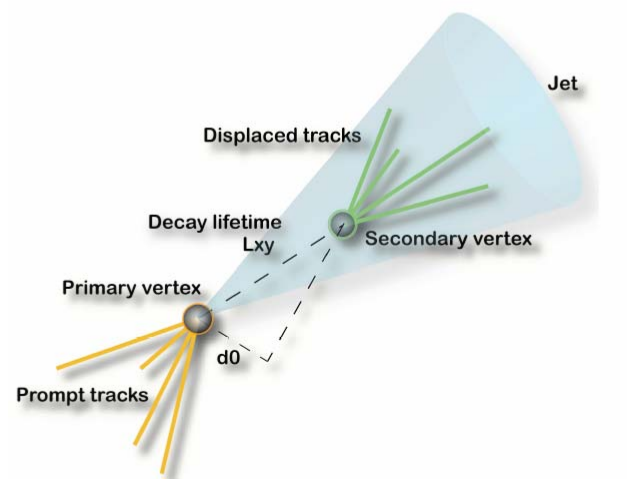


Figure of merit for the VXD:

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
LHC	12	70
RHIC-II	15	19
ILC	**<5**	**<10**

(Marc Winter)

Pixel Technologies: What's on the market?

- Currently there are about 10 candidates for the ILC VTX Detector.
- see VXD Review Report at http://www.linearcollider.org/wiki/doku.php?id=drdp:drdp_home

These technologies have different approaches to cope with beam induced background at the ILC:

single-bunch time stamping
"hybrid pixels w/o bumps"

- 3D integrated pixels (Fermilab)
- SOI (Fermilab, LBNL)
- ChronoPixels (Yale/Oregon)
- Deep N-Well MAPS SDR (INFN Milan, Pavia, RomaIII Uni. Bergamo, Insubria, Pavia)

Accumulation of ~70-150BX

1. cont. r/o during train

- CPCCD (LCFI)
- DEPFET
- Mimosa (Strasbourg at al.)

2. store and r/o in pause

- CAPs (Hawaii)
- ISIS (LCFI)

Accumulation of about 3000BX

- FP-CCD (KEK, JAXA/ISAS, Tohoku Uni)

→ different needs for the test beam structure, telescope, etc. ..

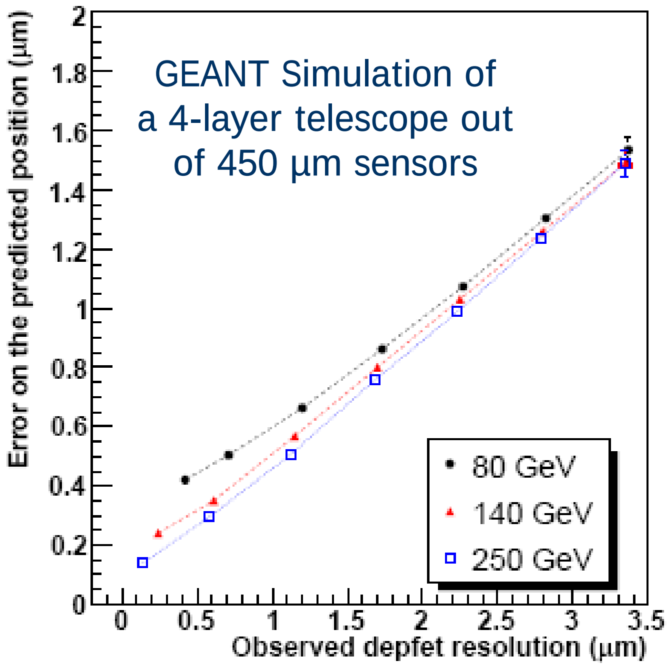
(Laci Andricek)

Vertex Testing

at the level of single ladders:

- S/N, single point resolution, efficiency
- double hit separation
- homogeneity of the detection
- read out and data handling
- May be of interest to run within "sizeable“ magnetic field in order to assess effects on cluster characteristics (e.g. single point resolution)

L. Reuen, Uni Bonn



with multiple layers:

- standalone tracking capabilities
- tracking under high occupancy
- low momentum tracking

Possible further tests:

- Homogeneity of the performances over the ladder surface
- Test multi-channel + multi-chip operation
- Test chip electrical servicing
- Test cooling system operation : mechanical properties and influence on performances,
  - e.g. sagitta & vibrations vs. single point resolution
  - heating versus S/N ratio or fake hits (noisy pixel rate)
- Data flow management

Needed Beams

- **high energy hadron beam** (~100 GeV) for position resolultion testing **and low energy** beam for the low momentum tracking.
- beam spot should be adjustable from ~mm^2 to ~cm^2
- For all candidate technology:"ILC-like" spills (1ms beam at 200ms intervals) to see the effects on the read out when particles arrive and to allow a read out during a "quite" phase (not needed for all tests).

Facilities with hadron beam in right range:

Laboratory	Energy Range	Particles	Availability
CERN PS	1 - 15 GeV	e, h, m	LHC priority
CERN SPS	10 - 400 GeV	e, h, m	LHC priority
Fermilab	1-120	e, p, K, p; m	continuous (5%), except summer shutdown

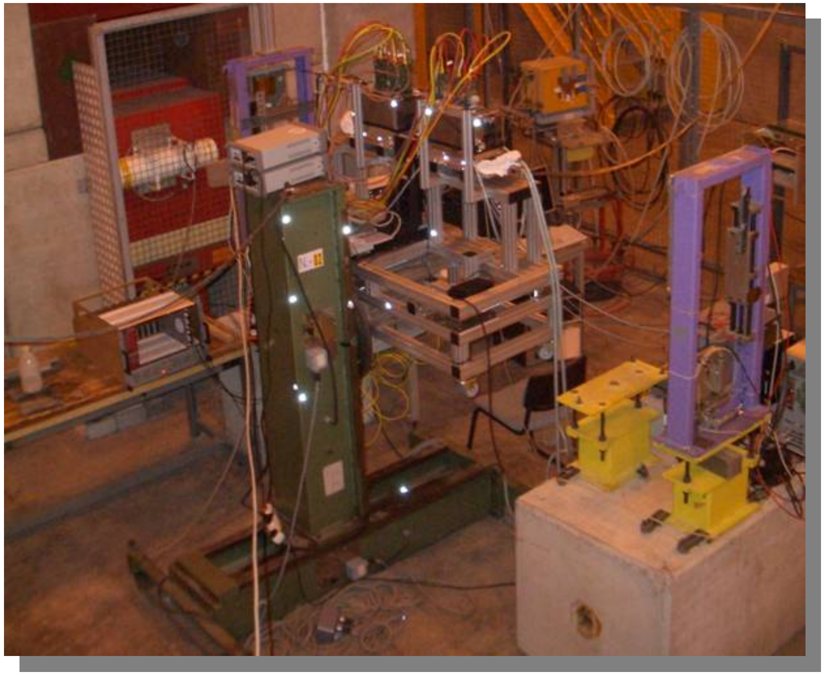
ILC like bunch structure?

- Such a beam would give the opportunity to test all technologies under ILC like conditions
  - Might be necessary close the technology decision
  - Interesting for all technology options

- Such test beam not available right now and investment would be needed
- Technically feasible

Needed for most tests: Beam Telescope

- Strasburg, Bonn, LBNL have already their own telescope,
  EUDET JRA1: high precision, low mass MAPS telescope, available now
- Usable for single layer and multiple layers tests



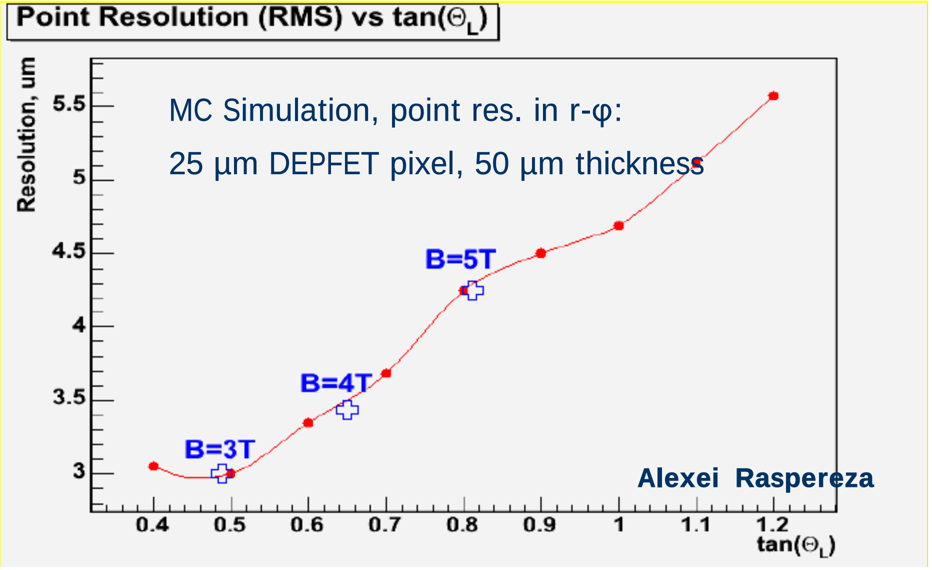
But:

- For technologies which use the single BX structure of the ILC for time stamping and are only sensitive for a short period, one would need to tag a subset of particles of a spill (on a time scale of tens of ns)

Tests with Magnet ?

at the level of single ladders:

- Single point resolution in various magnetic fields (Lorentz angle effects)
- Robustness against power pulsing in magnetic field (mechanical forces)



with multiple layers:

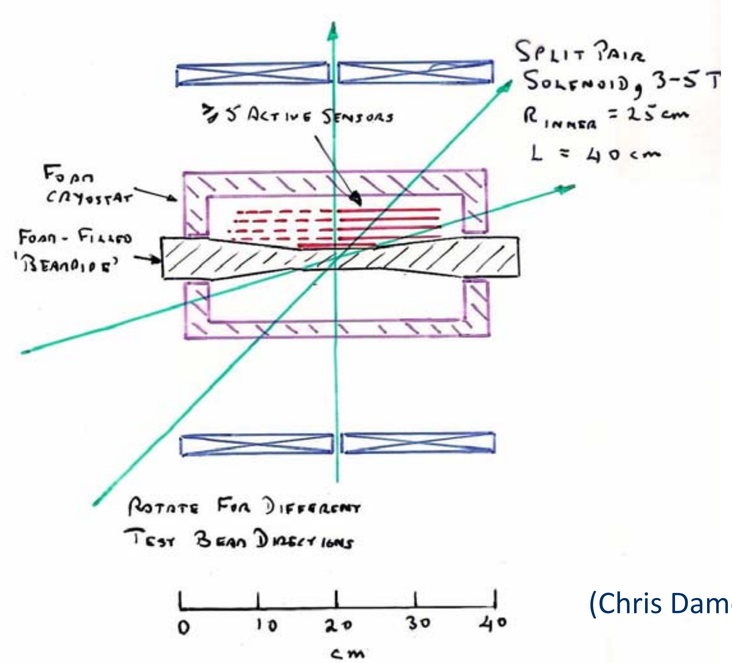
- combined tracking in magnetic field
- mechanical stability in the field

What magnet is needed?

- Adjustable magnetic field from (3 to 5 T)
- Large enough to accommodate a multi-layer assembly, small enough to be rotatable

Split pair super-conduction solenoid

- 3-5T, R_{inner}=25cm, L=40cm
  - Test ladders in a very realistic environment
  - assess effects on cluster characteristics
  - Costs?



(Chris Damerell)

Robustness against Dominant Beam Background

- Performed with individual sensors and with ladders installed on a 10 MeV electron beam, like in the TH Darmstadt
- Study influence of beamstrahlung electrons on tracking performances (study response to representative electron energies)
- Test the pattern of the low energy electrons in a 4 T magnetic field, i.e. with the multiladder device

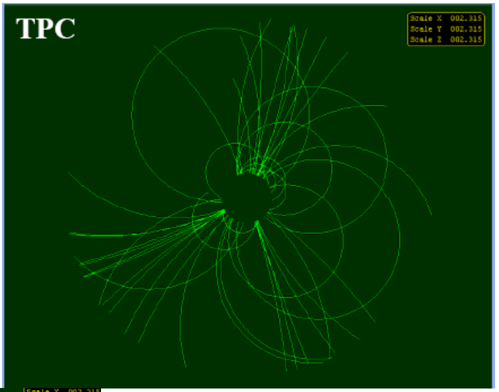
several beams may be of interest: high energy for alignment, low energy for low momentum tracking performance assessment, etc.

Tracker …

- ILC tracker resolution $\Delta(1/p_T) \sim 5 \times 10^{-5}$ $(GeV/c)^{-1}$ (10 times better than at LEP!)
- Small cross sections < 100 fb, low rates, no fast trigger.
- Higgs measurements & SUSY searches require:
  - High granularity continuous tracking for good pattern recognition.
  - Good energy flow measurement in tight high multiplicity jets.
  - Excellent primary and secondary b, c, τ decay vertex reconstruction.

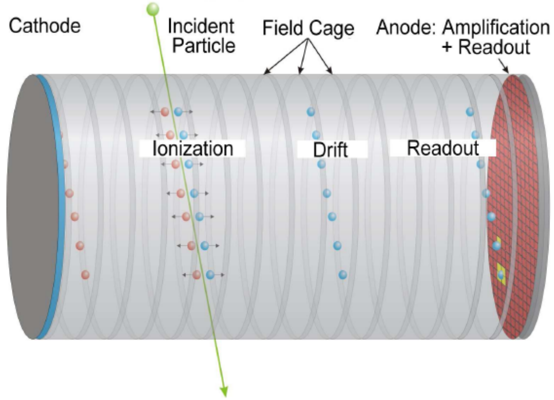
Options considered:

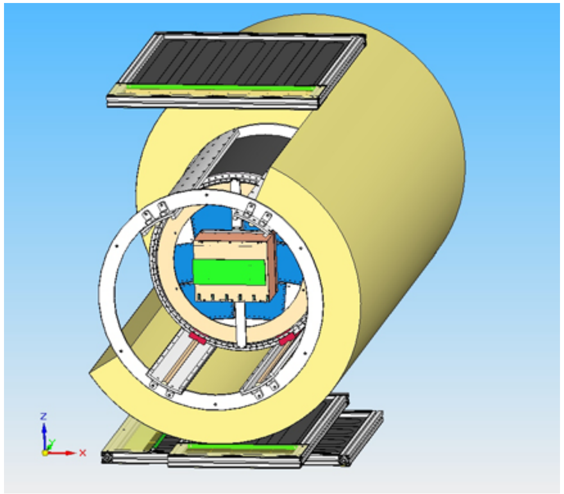
- Large silicon trackers (à la ATLAS/CMS)
- Time Projection Chamber with ≈ 100 μm point resolution (complemented by Si – strip devices)



LCTPC Performance Goals

- Continuous 3D tracking, easy pattern recognition throughout volume
- ~98-99% tracking efficiency in presence of backgrounds
- Time stamping to 2ns together with inner silicon layer
- Minimum of X_0 inside ECAL (~3% barrel, ~15% endcaps)
- σ_{pt} ~50μm (rϕ) and ~500 μm (rz) @ 4T
- 2-track resolution <2mm (rp) and <5mm (rz)
- dE/dx resolution <5% -> e.g. e/pi separation
- Design for full precision/efficiency at 10 x estimated backgrounds





Gaseous Detectors Wish List

- Next years - Eudet infrastructure helps to start:
  - 6 GeV electrons at DESY, B = 1 Tesla (PC magnet)

- Need for tests with hadron beams after initial tests.
- Momentum ≥ 50 GeV/c, wide or narrow (~1%) momentum bites
- Mixed hadron beams, particle ID if possible (for dE/dx)
- Intensity - variable from low to high
- External high resolution silicon tracker (in LCTPC prototype already included)
- Large volume high field magnet, with B ~ 2 T and above (but not necessarily at beam facility)

- Ability to rotate and, translate the magnet platform
- Beam telescope

- RD51 is planning a dedicated beam area for micro gas detectors at CERN SPS
  - also want to provide infrastructure to help test of gaseous detectors

Si-Tracker Wish List

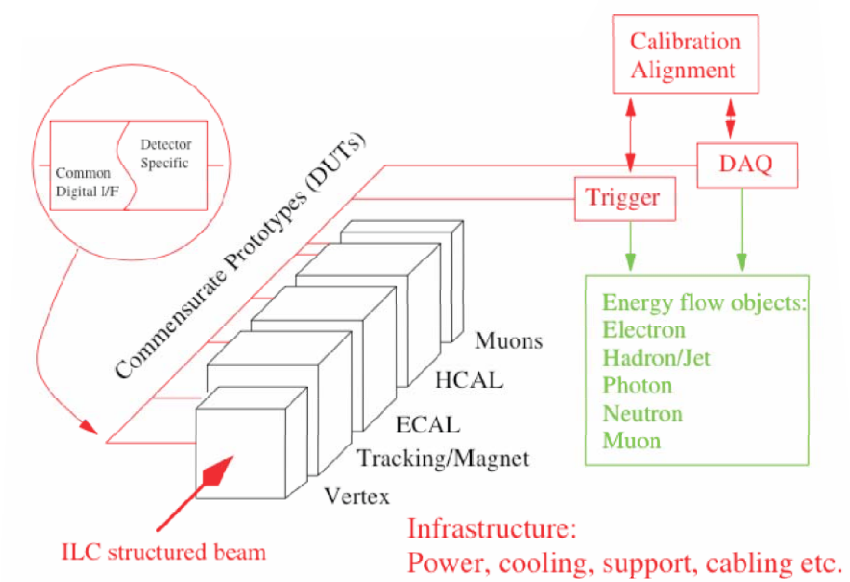
- Beam telescope and associated DAQ and trigger logic
- General DAQ framework
- High Field magnet > 3 Teslas (no necessarily for all test beams)
- Mechanics workshop access and support for last minute needs during installation
- 3D Table(s) to install and properly move the prototypes wrt beam.
- Easy access to computing facilities and LabNet
- Control room(s) with enough space (for several users) and needed infrastructure: racks, computing, storage places
- Lab staff responsible for the good running of the test beam.
- Crane to install and move heavy prototypes

Beyond the Immediate Needs

DEVDET (EUVIF) proposal as follow up for EUDET
-> not approved by EU

- The next logical step for ILC: assess system aspects of the proposed detector concepts.
- The principle integrating factor in linear collider event reconstruction is the concept of "energy flow": reconstructed objects from different detectors are combined into physics objects such as leptons, photons, or jets.

- Established how to form these particle-flow objects, mechanical integration, DAQ.
- Requires the definition of interfaces and their implementation.

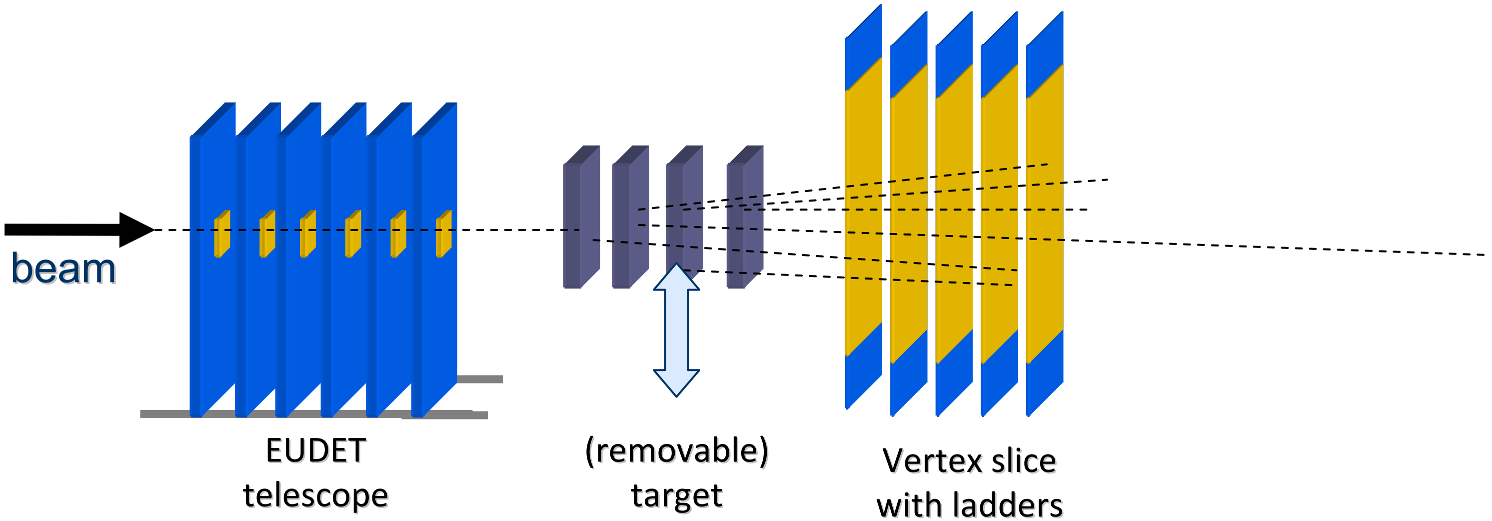


- EUVIF idea: unique infrastructure to integrate commensurate prototypes of LC detector components -> test beam; different particles and appropriate energy range
- Dedicated beam line at CERN was foreseen

- Particle flow approach relies on robust identification and precise momentum measurement of charged particles
- ILC: charge particle identification
- -> vertex, intermediate silicon strip detector and a large volume TPC

Vertex infrastructure

- Provide small-scale full vertex detector -> interface to be able to replace the ladders by different type ladders
- Building a global mechanical infrastructure to host multi-layer modules for vertex detectors in different technologies (design independent)
- Developing the data acquisition system including hardware from EUDET to suit the new infrastructure
- Software for reconstruction and analysis (calibration, alignment, pattern recognition) -> based on existing software for EUDET telescope
- Producing a target system to create jet-like structures
- Integrating the EUDET telescope upstream of the target



Tracker infrastructure

Intermediate Tracker infrastructure

- Lightweight structures for both module carrier and overall support
- Prototype silicon small area modules equipped with single sensors up to daisy-chained ladders
- Overall support structure for modules/ladders arranged in layers (leightweigth, ultra-thin)
- Improving the existing EUDET readout chip and developing a front-end hybrid prototype suitable for testing silicon sensors with conventional (wire-bonding) or novel (bump-bonding) techniques
- Integration of the front-end electronics developed in EUDET into the central DAQ system

Gaseous Tracking infrastructure

- Providing the EUDET TPC infrastructures for combined tests of the particle flow concept -> allowing optimization of overall detector design
- Interfaced to common DAQ and slow control system

- Develop and provide readout software
- Improve slow control system and integrate in overall EUVIF system
- Pixel based diagnostic facility (EUDET) will be upgraded and integrated

Summary

- Preparation for this talk showed that the different groups have different opinions about the immediate requirements at the test beam facilities

- What is for sure needed (tracking and vertex):
  - **High energy beam for resolution studies (~100 GeV)**
  - **Low energy for additional studies (~5 GeV)**
  - **Magnet: 1 T to start with, later ~4Tesla**
  - **High precision telescope with adequate readout speed**

- At later stage (when?): test beam with ILC bunch structure -> significant investment necessary

Please send me your suggestions and idea and I will include it in the proceedings.

DESY

Why? What Test Beams?

Role of Test Beams in the Design and Construction of a HEP Experiment

- Lifecycle of the Experiment:
  - Conception
  - Conceptual design, choice of detectors/technologies
  - Technical design, prototypes construction and testing
  - Detector construction
  - Calibrations
  - Commissioning
  - Data taking
  - Analysis, systematics studies

Test Beams

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Beam Test Facilities

Laboratory	Energy Range	Particles	Availability
CERN PS	1 - 15 GeV	e, h, m	LHC absolute priority
CERN SPS	10 - 400 GeV	e, h, m	LHC absolute priority
DESY	1 - 6.5 GeV	e^-	~10 month per year
Fermilab	1-120	e, p, K, p; m	continuous (5%), except summer shutdown
Frascati	25-750 MeV	e	6 months per year
IHEP Beijing	1.1-1.5 GeV (primary) 0.4-1.2 GeV (secondary)	$e^{\pm}$ $e^{\pm}$, $p^{\pm}$, p	Continuous after March 2008
IHEP Protvino	1-45 GeV	e, p, K, p; m	one month, twice per year
J-PARC			Available in 2009
KEK Fuji	0.5 - 3.4 GeV	e	Available fall 2007, 240 days/year
LBNL	1.5 GeV < 55 MeV < 30 MeV	e p n	Continuous
SLAC	28.5 GeV (primary) 1.0 - 20 GeV (secondary)	e $e^{\pm}$, $p^{\pm}$, p	Parasitic to Pep II, non-concurrent with LCLS