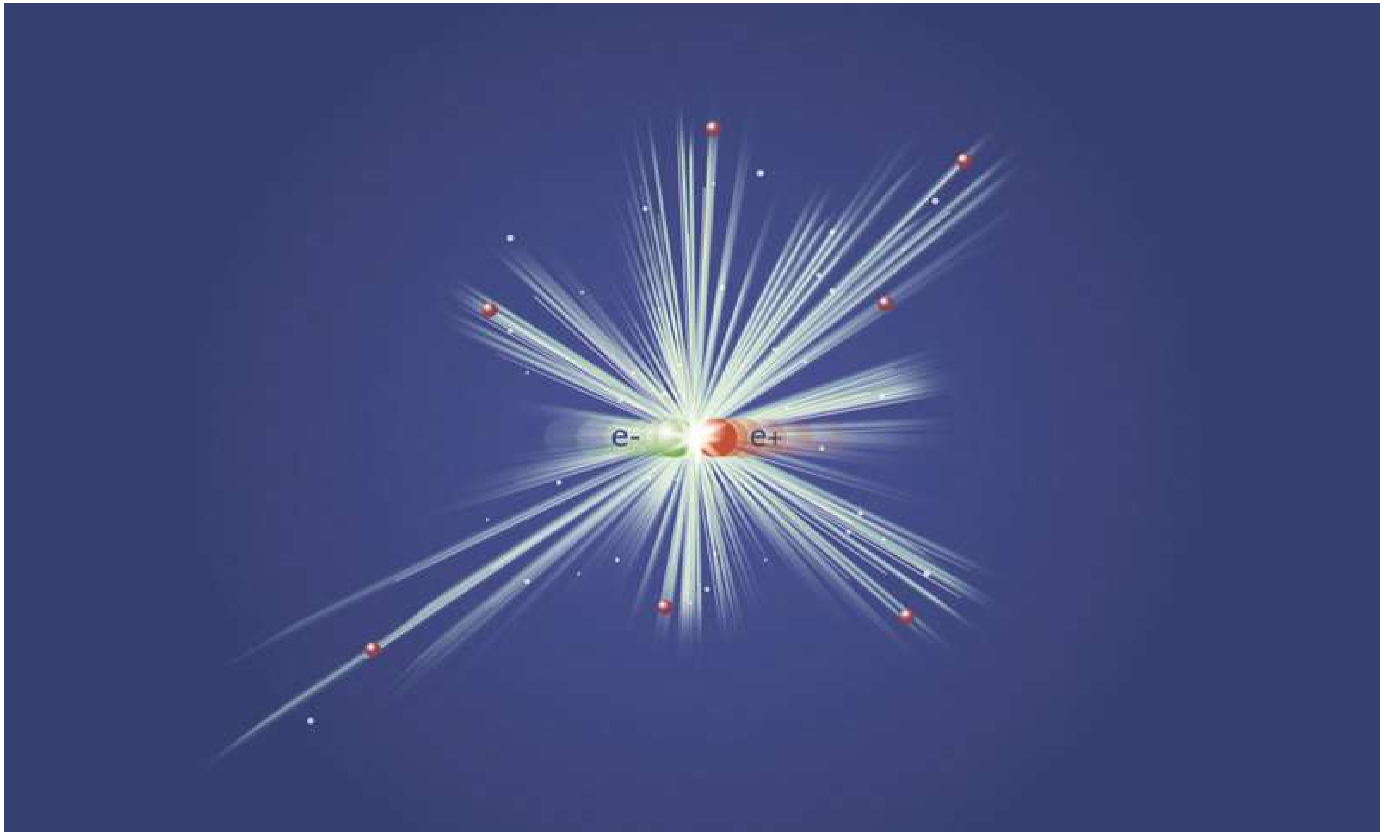
Status of ILC Project



A. Raspereza,

Project Review Meeting

MPI Munich, 18th December 2006

Outline

- Introduction
- ILC Project. General Overview
  - ILC Machine Design
  - Detector concepts and Detector R&D
- ILC Related Activities @ MPI
  - Simulation of DEPFET-based VXD
  - Prototyping DEPFET sensors, analysis of testbeam data, validation of simulation software
  - Development of reconstruction software (tracking in Silicon Detectors and TPC). ILC detector performance & optimization studies

Case for a Linear e^+e^- Collider

Key issues : Mechanism of EWSB, physics beyond SM

- **LHC potential**

- Capable to shed a light on EWSB mechanism ; discovery of at least one light Higgs boson
- Can probe physics beyond SM, e.g. explores QCD sector of SUSY (squarks, gluinos)
- But unable to fully explore both EWSB and physics beyond SM

- **Linear Collider potential**

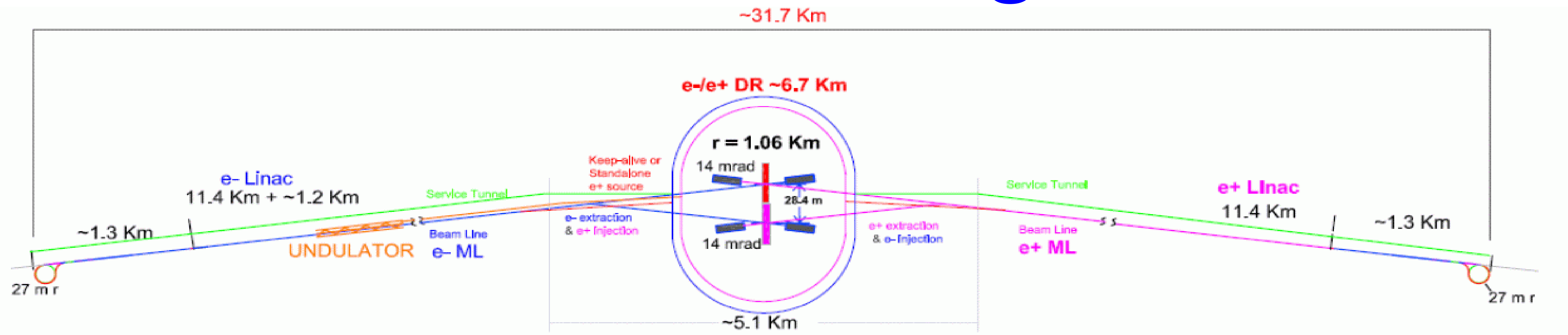
- Detailed investigation of the Higgs mechanism (accurate measurements of spin & CP numbers of Higgs, its couplings to SM particles, reconstruction of Higgs potential)
- Exploration of alternative EWSB mechanisms, e.g. strong EWSB
- Can probe physics beyond SM; gaugino & slepton sector of SUSY, Extra Dimensions, Models with the extended gauge symmetry, *etc*

We need LC to complement LHC data

Features of ILC Machine

- Energy range : Z pole – 1 TeV (coverage of EWSB range)
- High luminosity $L \approx 2 \cdot 10^{34}$ cm^{-2} s^{-1} ⇨ high precision physics
- Well defined initial state: interaction of point-like objects (no internal structure), beam energies known with relative precision of 10^{-4}
- Clean environment : SM backgrounds are well understood and controllable
- Possibility to tune both energy (threshold scans) and e beam polarisation (crucial for disentangling signals from SM backgrounds, e.g. SUSY processes)

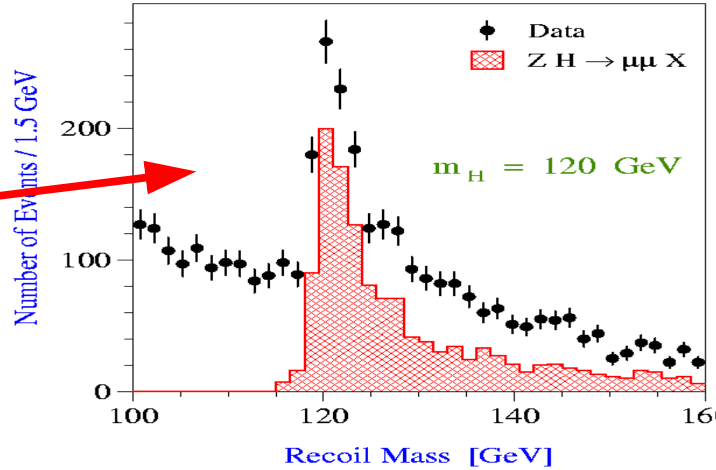
ILC Baseline Configuration



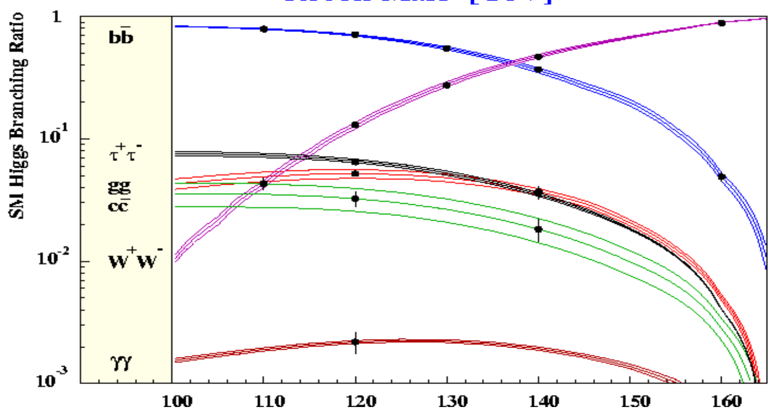
- Baseline parameters (Basline Configuration Document, Nov 2006):
  - Accelerating gradient: 31.5 MV/m for 500GeV, 36 MV/m for upgrade
  - # particles / bunch: $2 \cdot 10^{10}$; # bunches / pulse: 2820
  - Linac inter-bunch interval: 300 ns; pulse frequency: 5Hz
  - Bunch dimensions @ IP ($\sigma_x/\sigma_y/\sigma_z$) : 0.4$\mu$m / 3nm / 300 μm
- Luminosity=$2 \cdot 10^{34}$ cm^{-2}s^{-1} ; Energy reach in first stage : 500 GeV
- Two IR's with 14mrad crossing angle (baseline option) but for cost reasons an option with only one IR (2 detectors) is also under considerations ⇨ push-pull scenario for ILC detectors

Detector Requirements

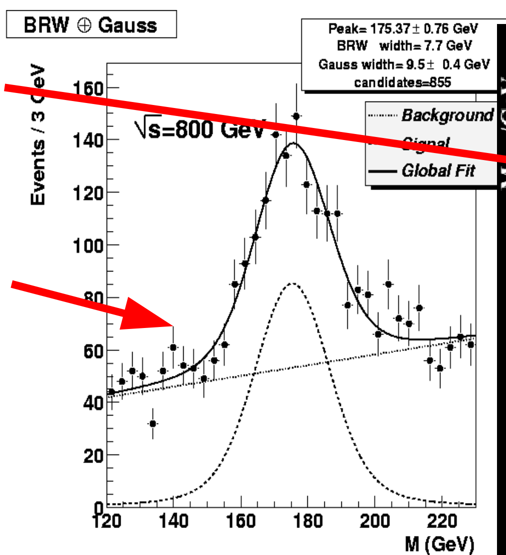
- Excellent momentum resolution ($\delta p/p^2 = 5\cdot 10^{-5}$ [GeV^{-1}c])
  - ➔ ZH➔$\mu\mu$X (model independent analysis)
  - ➔ sparticles masses from kinematic edges

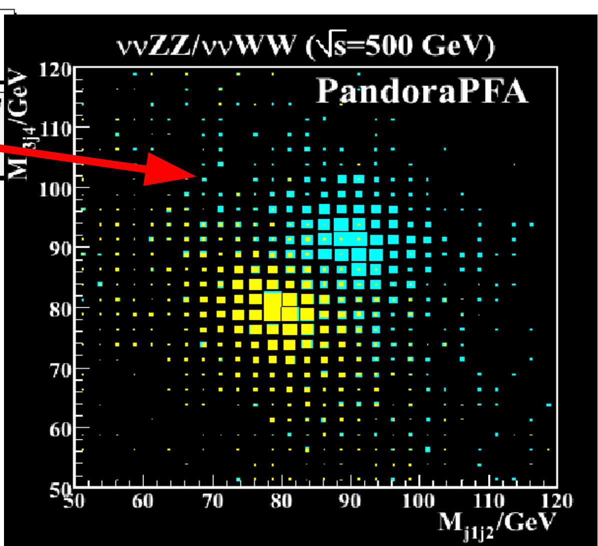


- Excellent performance of VXD ($\sigma_{d0} = 5\mu m \oplus 10\mu m/p[GeV/c]\cdot \sin^{3/2}\theta$)
  - ➔ measurements of H➔bb,cc,gg,$\tau\tau$ decays
  - ➔ reconstruction of tt➔WWbb final states



- Precise jet reconstruction in multi-jet final states ($\delta E/E = 30\%/\sqrt{E}$)
  - ➔ WW$\nu\nu$/ZZ$\nu\nu$ separation (strong EWSB)
  - ➔ Triple Higgs couplings (HHZ process)
  - ➔ Other signals: HA,HZ➔4jets, tt➔6jets



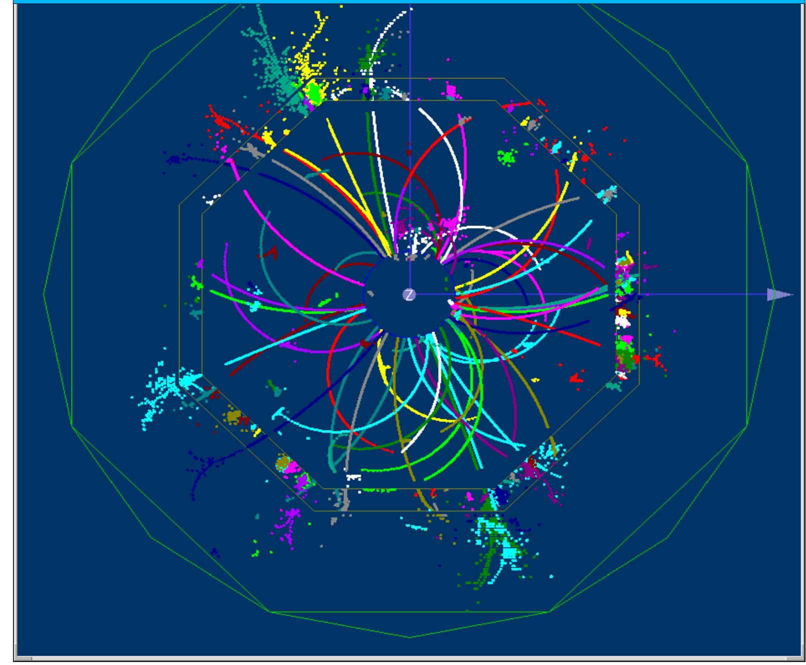


- Sensitivity to exotic signatures, e.g. photons non-pointing to IP (Anomaly Mediated SUSY Breaking Scenario)

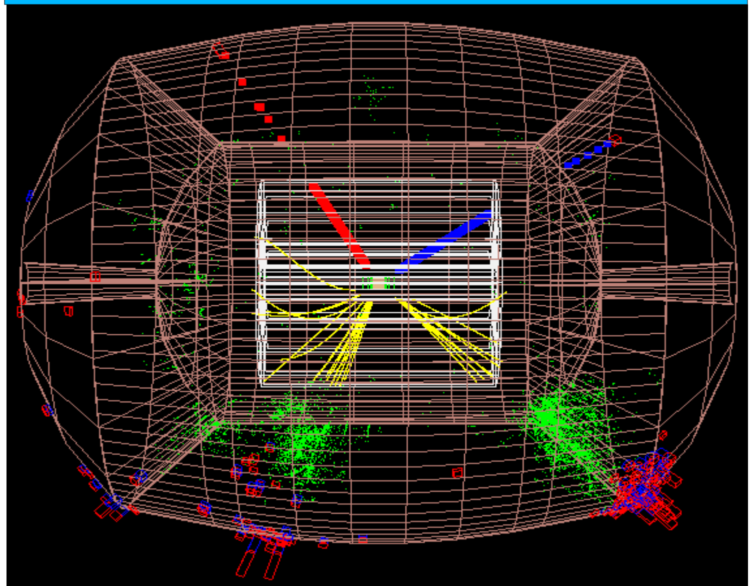
Detector Concepts

- SiD, LD & GLD driven by pflow, differ by size and B field
  - SiD/LDC/GLD : $R_{solenoid}$=3.3/3.8/4.4 m , B=5/4/3 T
- high granularity sandwich calorimeters (few cm^2 cell size) efficient shower separation & individual particle reconstruction in multi-jet events
- Pixelized VXD (5 layers, innermost layer at 1.5cm from IP)
- Central tracking : gaseous detector (TPC) : LDC & GLD; double-sided silicon strip layers : SiD
- Instrumented return yoke as muon detector

tt→6jets @ 500 GeV in LD



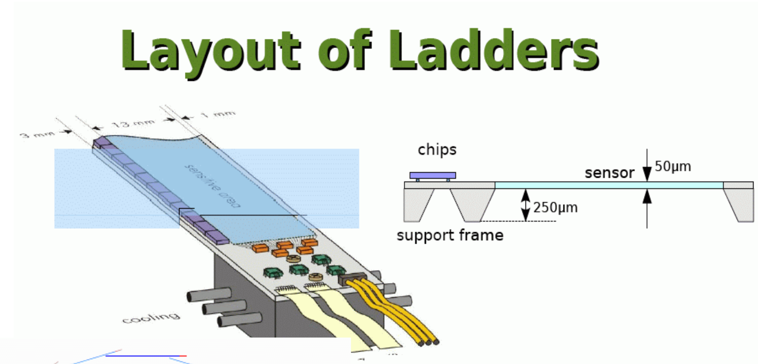
ZH→$\mu\mu$qq in 4th detector

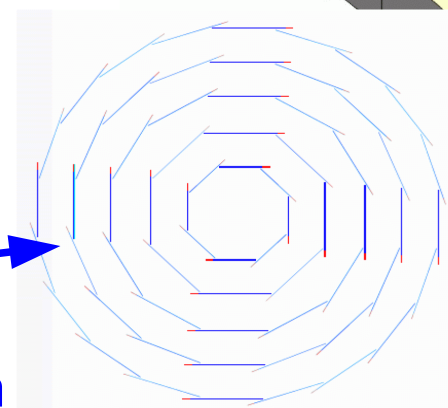


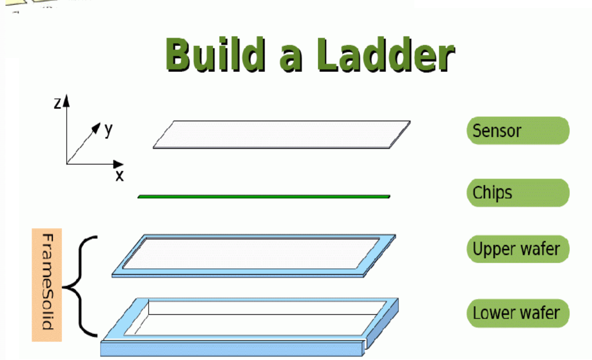
- 4th Concept : emphasis on calorimetry
- reconstruction of jet as a whole object with dual readout calorimeters; projective copper towers with embedded quartz and scintillating fibers enable to measure separately EM energy fraction within showers and thus improve energy resolution
- The same concept of tracking system as in LDC & GLD

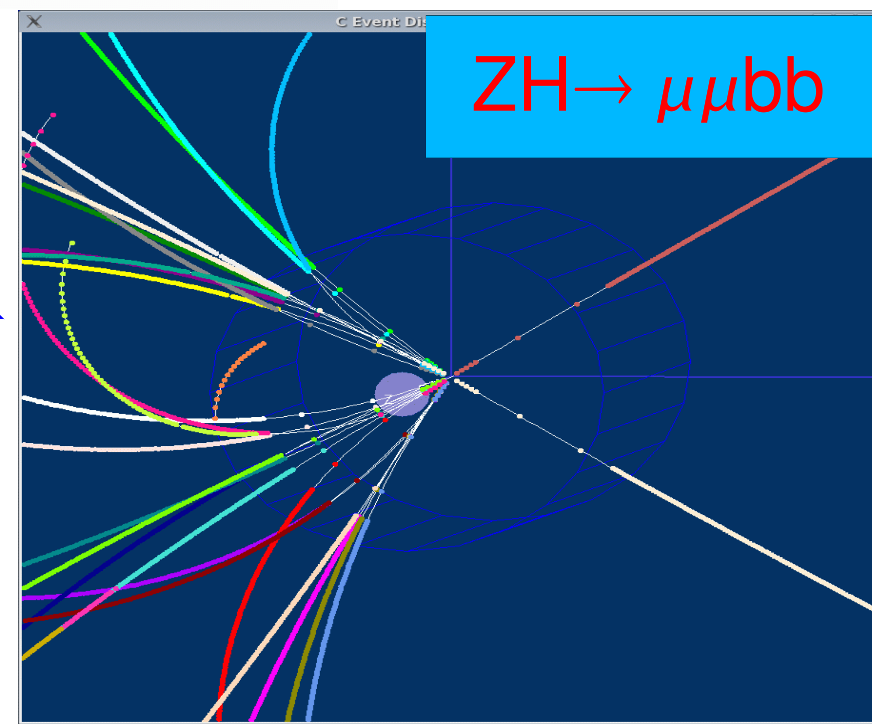
MPI Involvement

- Collaborative work with HLL on design of DEPFET based VXD for the ILC Detector (technical aspects of DEPFET design are covered in separate talk by Reiner Richter)
- Development of software tools to simulate DEPFET-based VXD
- Development of event reconstruction tools (track reconstruction) and their application in the detector performance and optimization studies and physics analysis
- Coordination of TPC related activities within ECFA (LCTPC Collaboration, R. Settles)

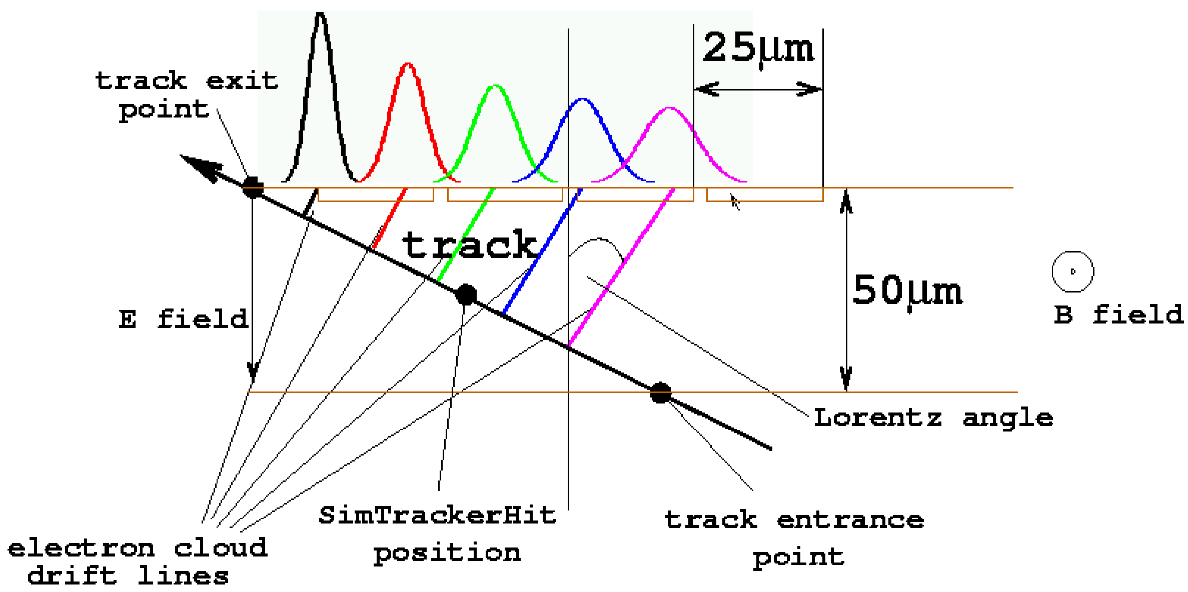


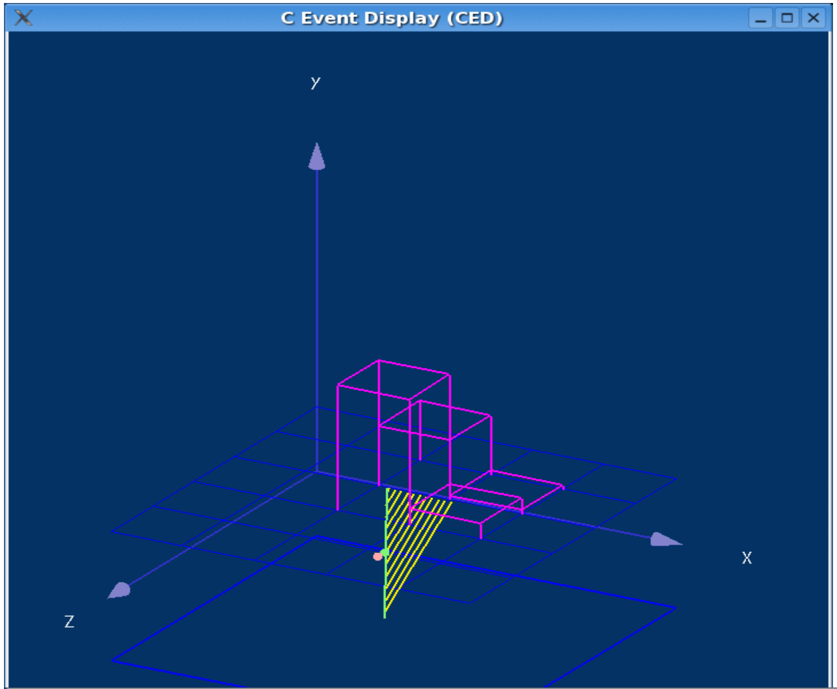


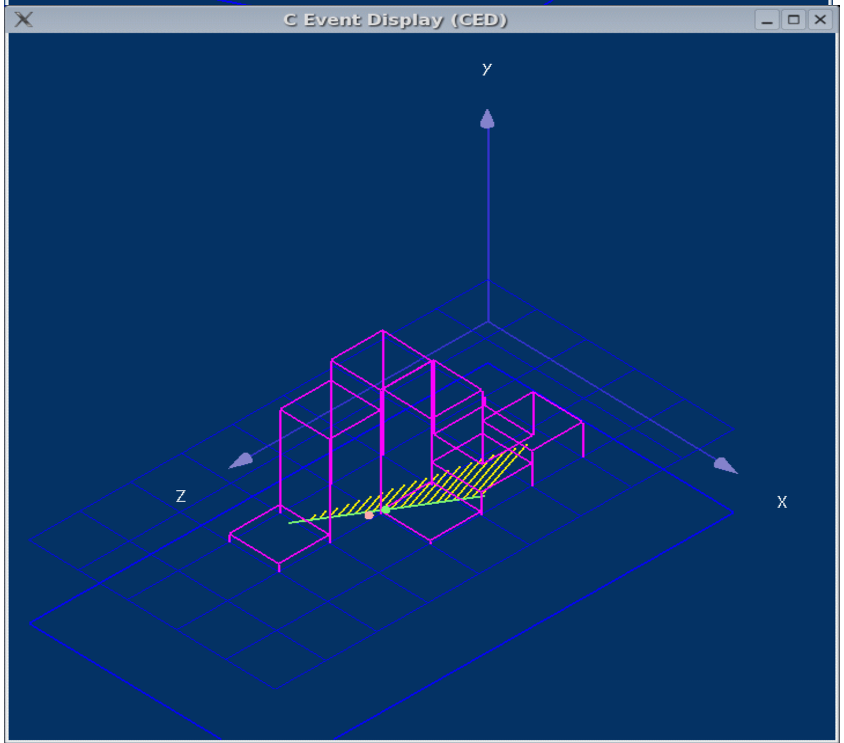




Simulation of DEPFET Sensors



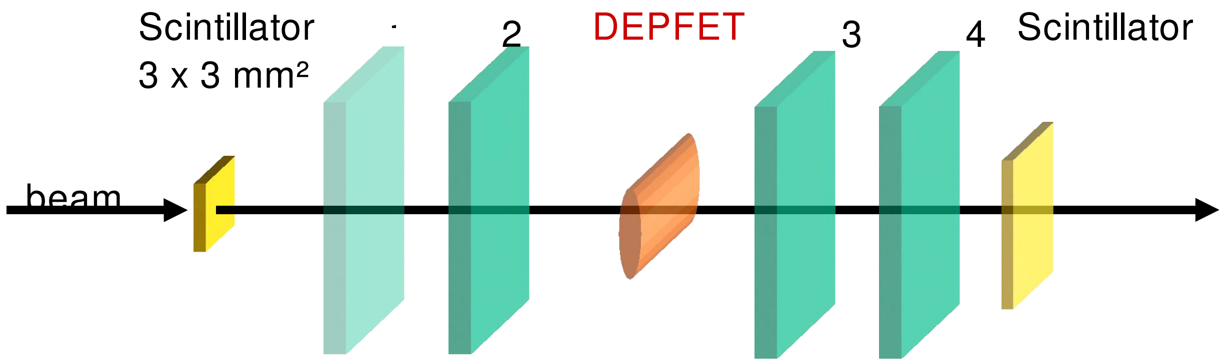




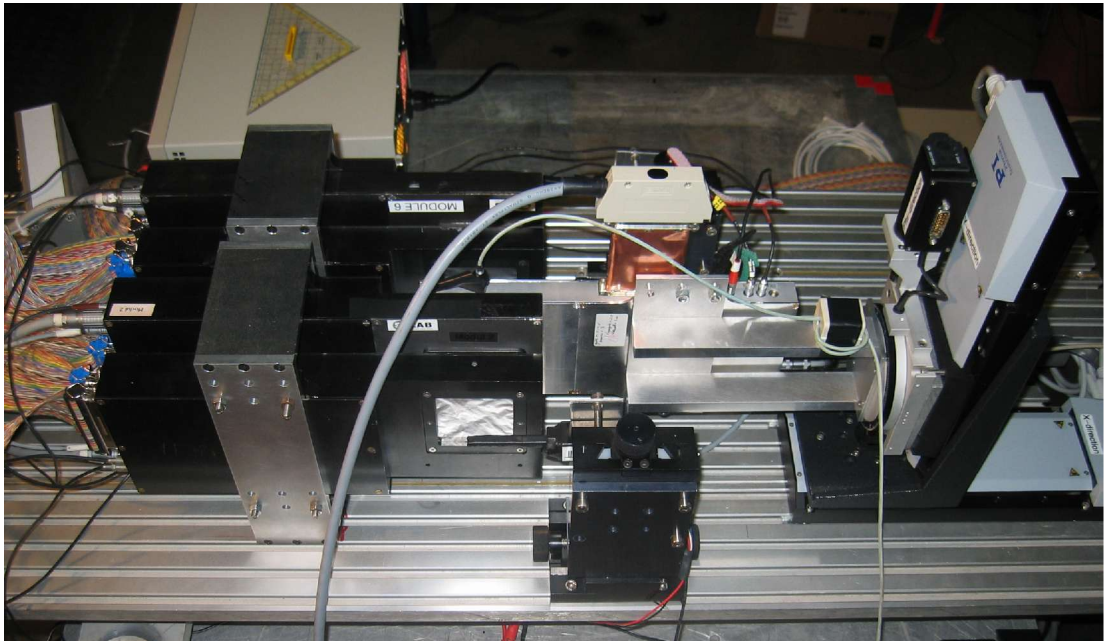
- Detailed DEPFET simulation includes
  - Energy loss fluctuations along particle trajectory
  - Diffusion of electron clouds
  - Lorentz shift in magnetic field
  - Electronic noise
  - Charge sharing between neigbouring cells

Testbeam @ DESY

- DESY test beam with 6 GeV e^-
- Bonn ATLAS Telescope system
  - four planes of 50 µm double-sided strip detectors
  - 4.5 kHz r/o rate
- DEPFET mounted on x-y-φ table

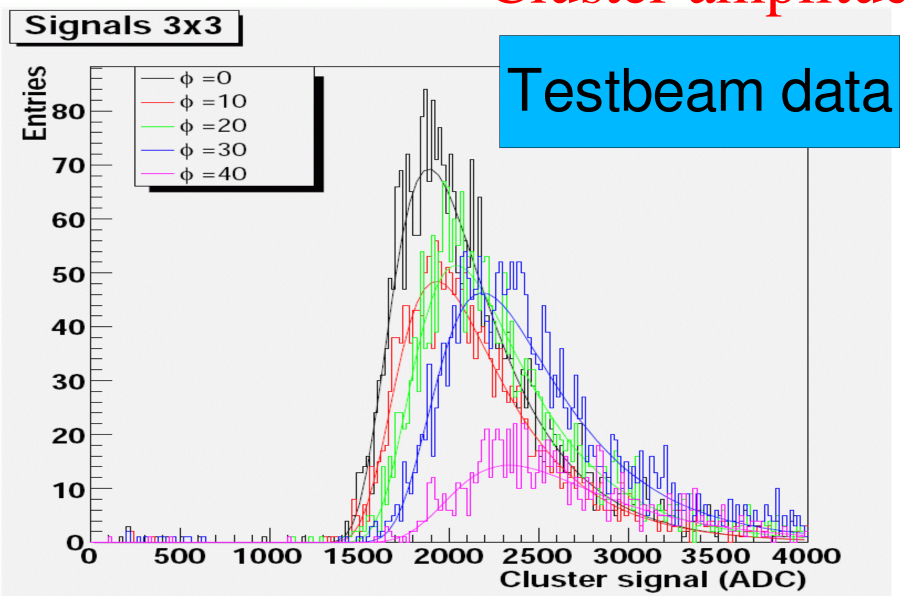


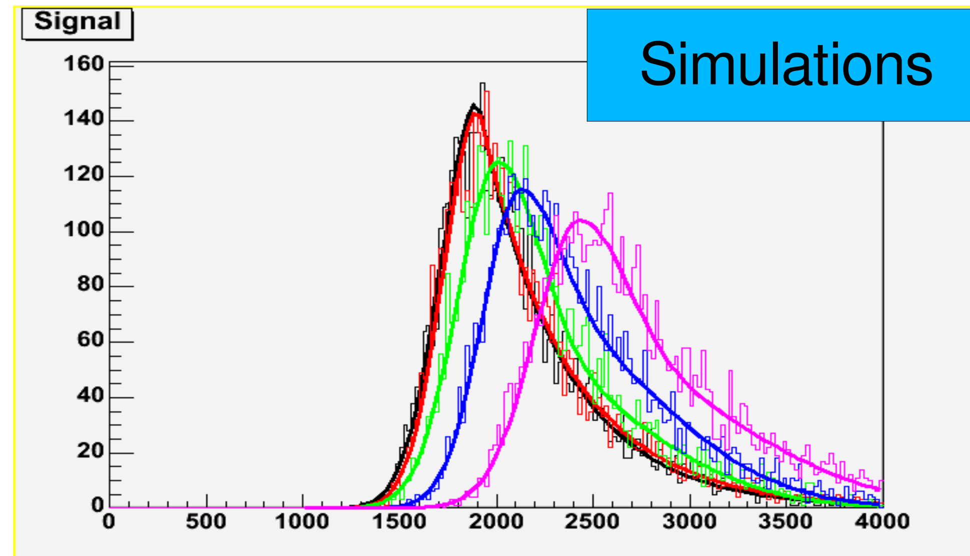
- Sensor characteristics
  - Thickness : 450 μm
  - Cell size : 36x22 μm^2
- Angular scans (0-40°) are made
- <u>Testbeam data are indispensible for validation, verification and tuning simulation software</u>
- Once validated & tuned, simulation software can be used in the VXD performance & optimisation studies



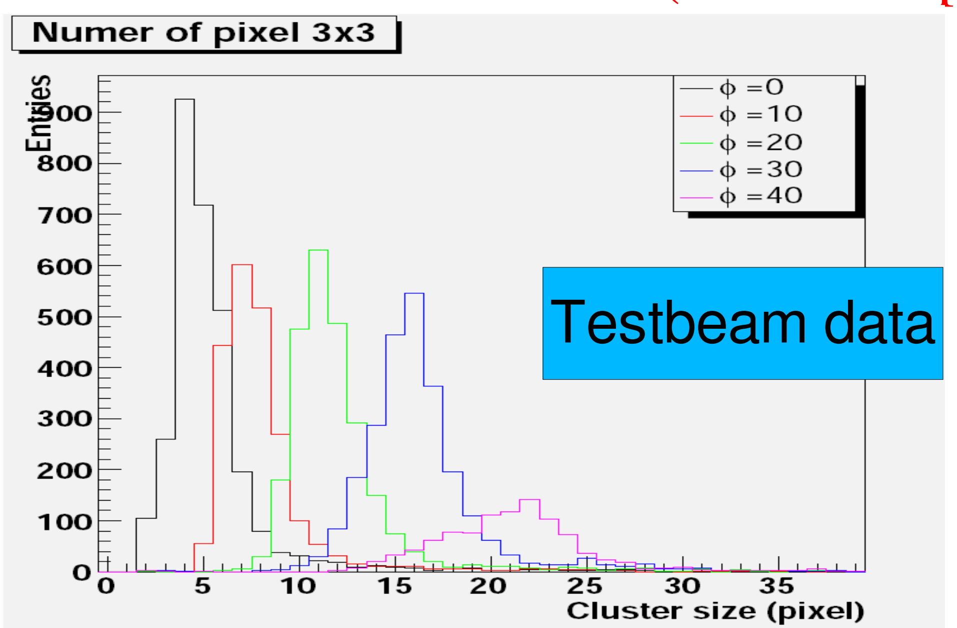
Testbeam Data vs Simulations

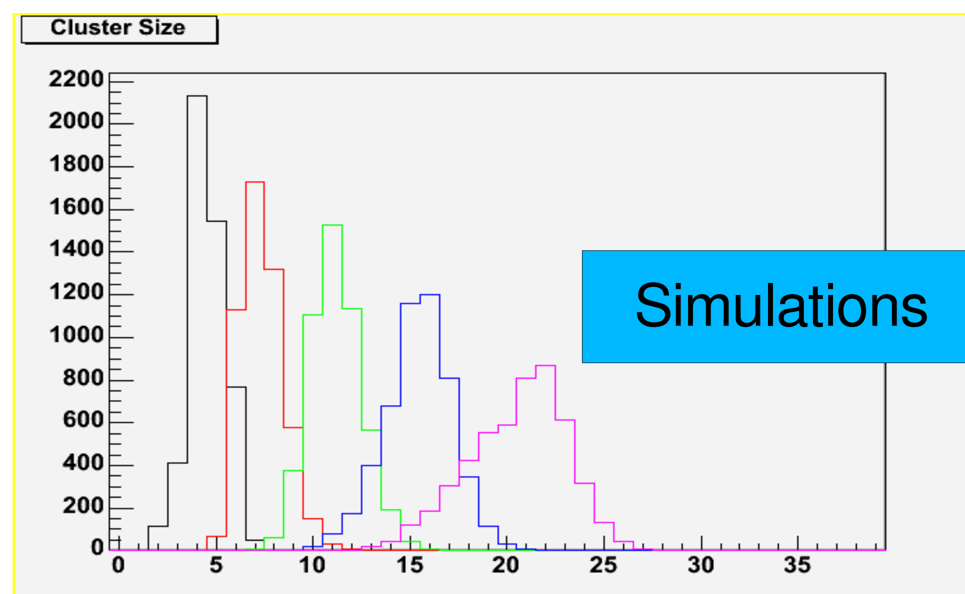
Cluster amplitude vs. incidence angle





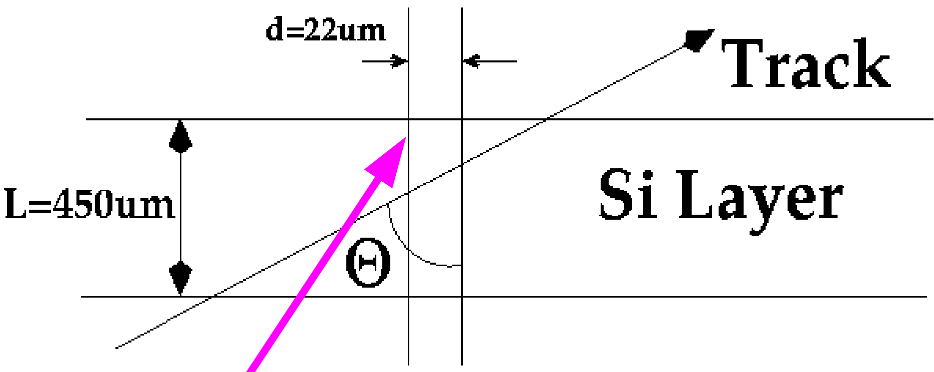
Cluster size (# of fired pixels) vs. incidence angle



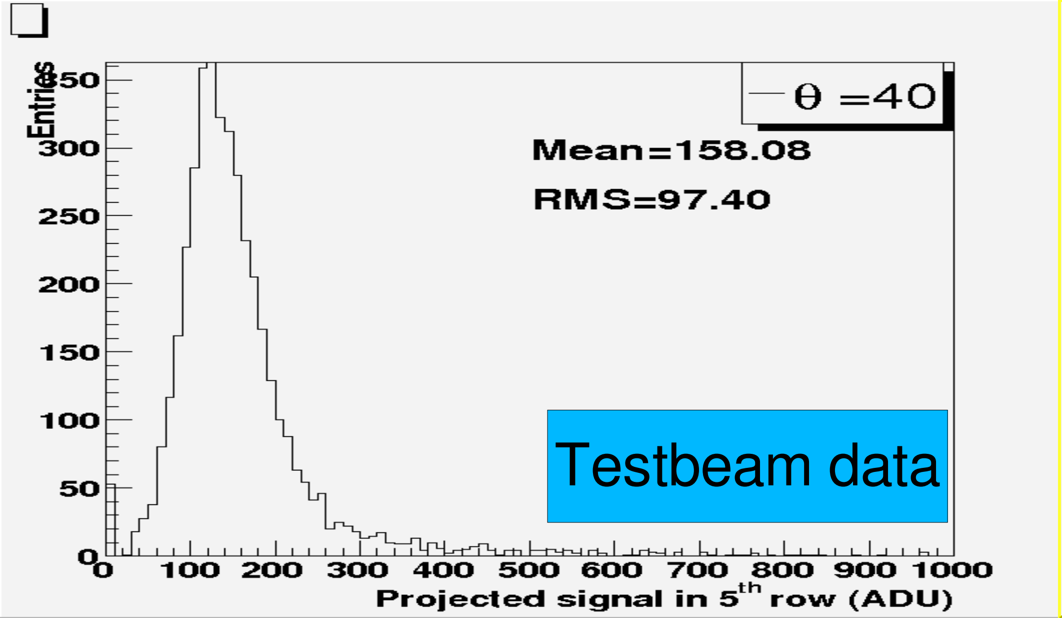


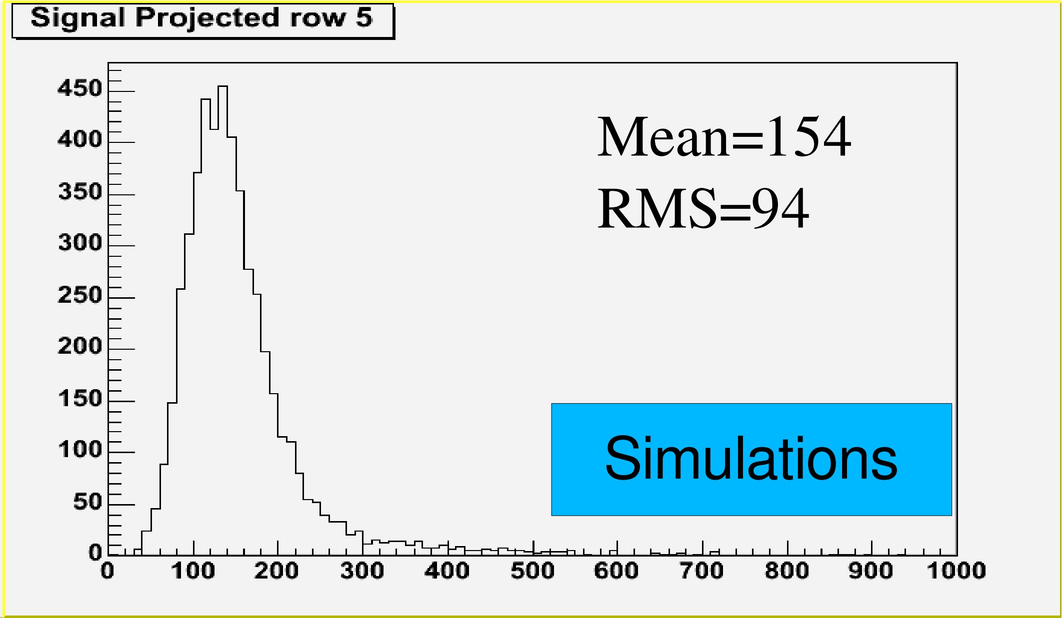
Probing modelling @ short flight distance

- Key question : how reliable simulation of E loss for thin sensors (short flight distance)
- Can be answered using testbeam data with inclined tracks
- Probed scale : **d/sinθ**
  d – pixel size; θ - track incidence angle



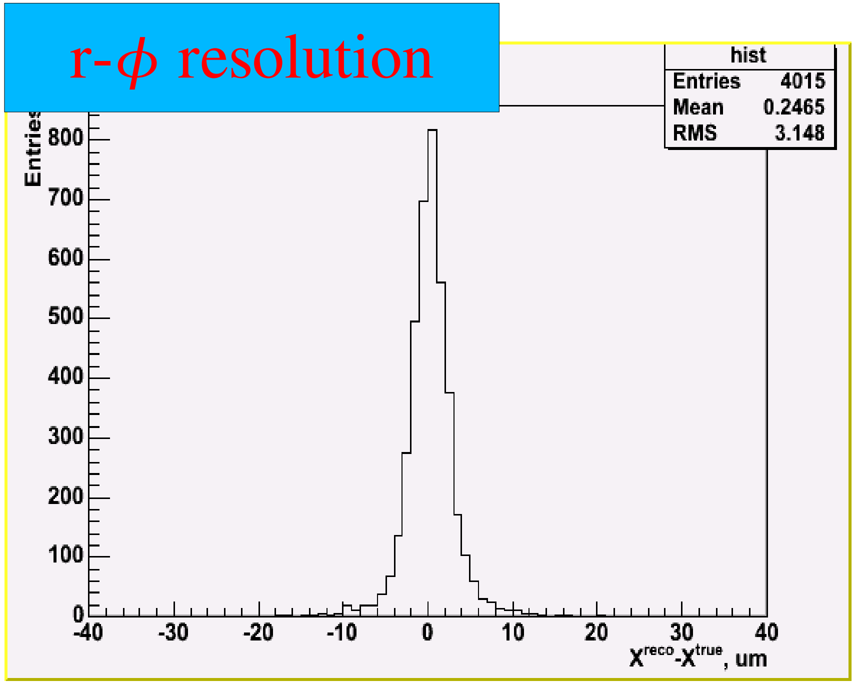
Compare cluster charge projected on row on pixels between simulation & testbeam data!

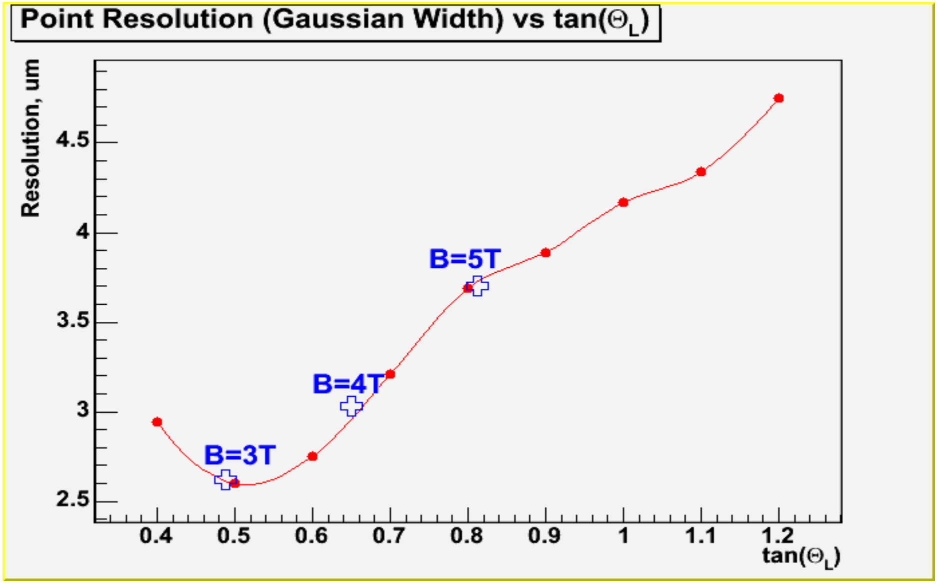


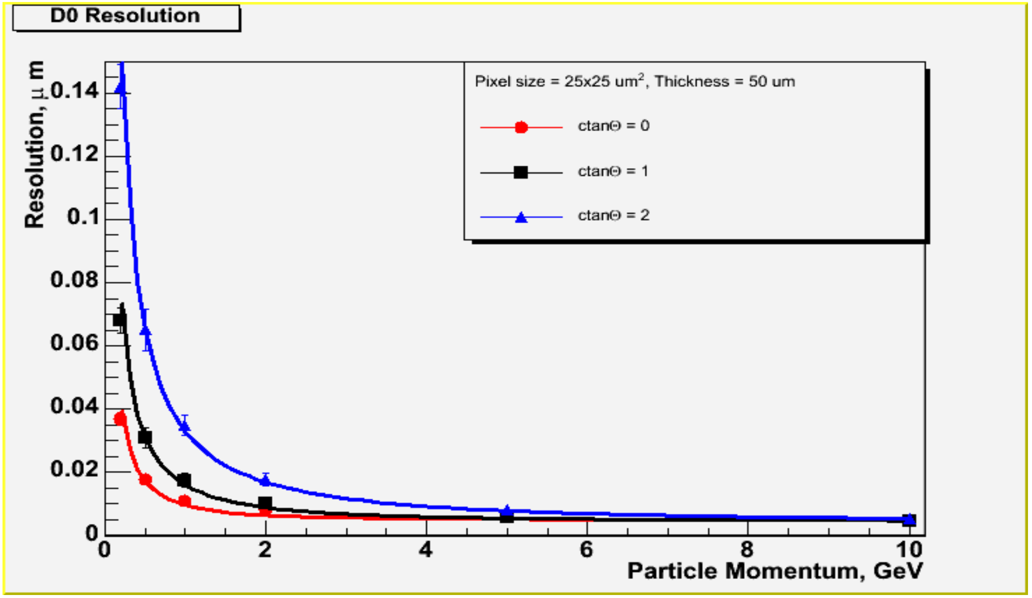


Using tuned & validated simulation to study VXD Performance

- Simulated VXD (G4 framework)
  - 5 barrel layers : r = **1.5/2.7/3.8/4.9/6.0 cm**
  - Layer thickness : **50μm**
  - Cell size : **25x25μm^2**
  - Assumed noise : **100 e-**
- Predicted performance in numbers
  - r-ϕ point resolution **3μm** (@ 4T magnetic field)
  - z point resolution : **3-6μm** (depending on θ angle)
  - IP resolution $4.6\mu m \oplus 8.6\mu m / p_T[GeV/c] \cdot \sin^{3/2}\theta$
  - Marginal degradation with increasing B-field

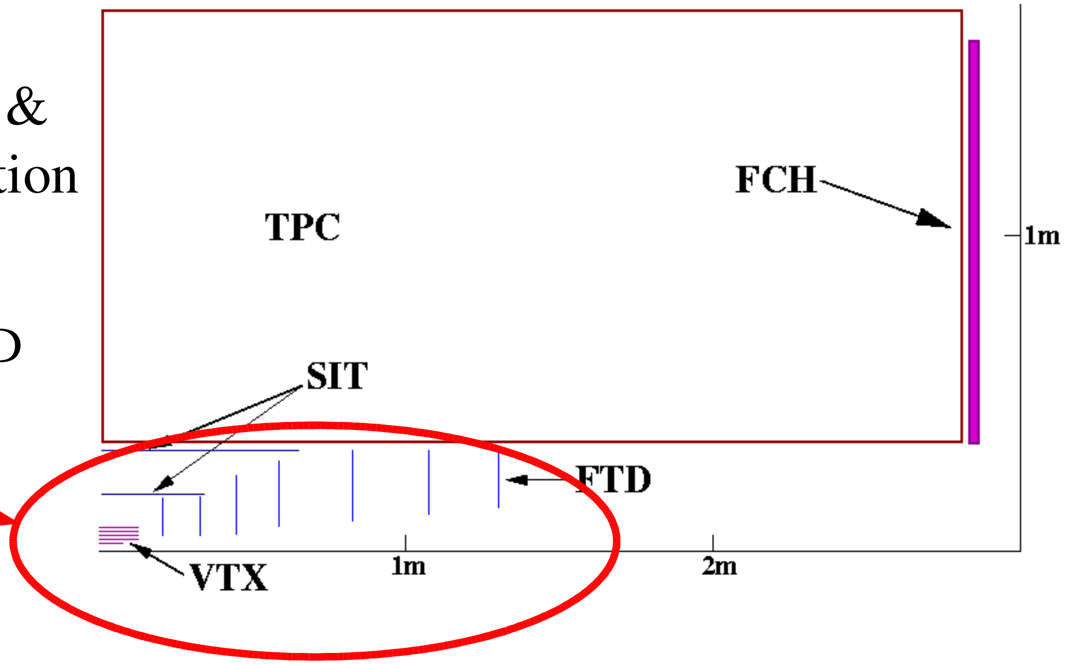




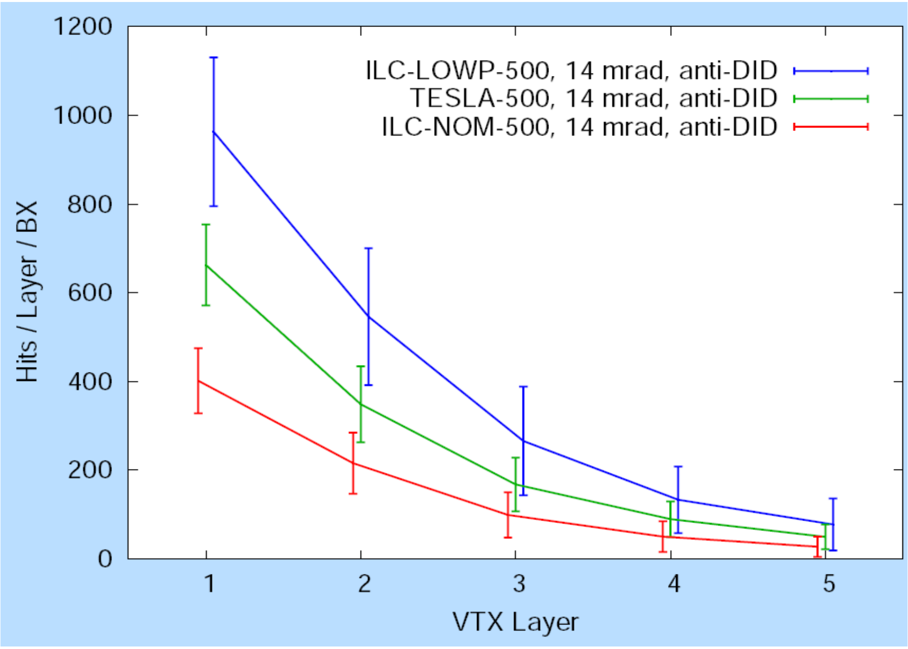


Tracking in Silicon Detectors & Beam Induced Backgrounds

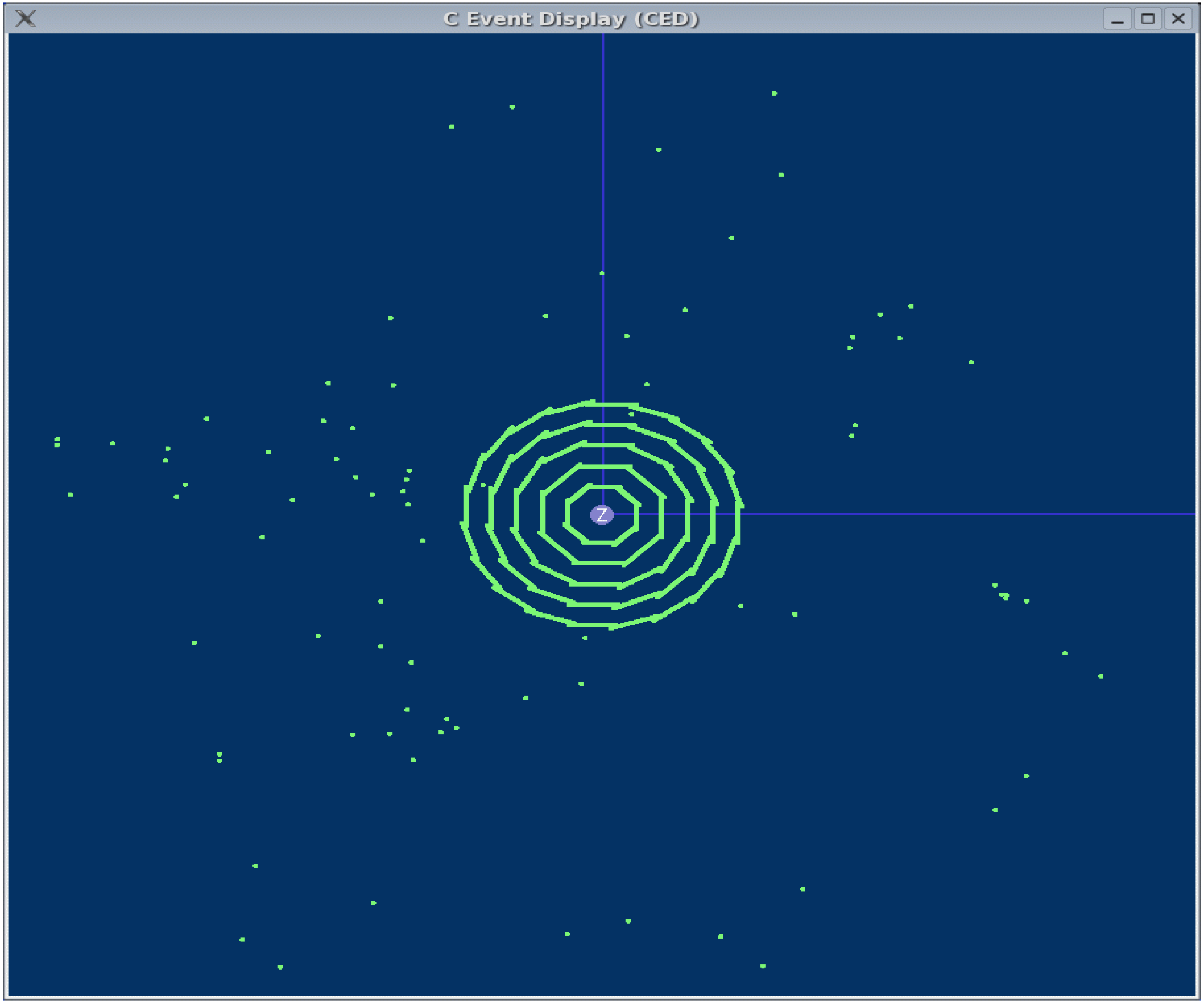
- Stand-alone track finding and track fitting procedure in silicon detectors is developed & integrated into the official LDC reconstruction package MarlinReco
  - part of the overall tracking in the LDC/GLD
  - includes VXD, forward silicon discs, intermediate silicon barrel layers
  - needed for alignment



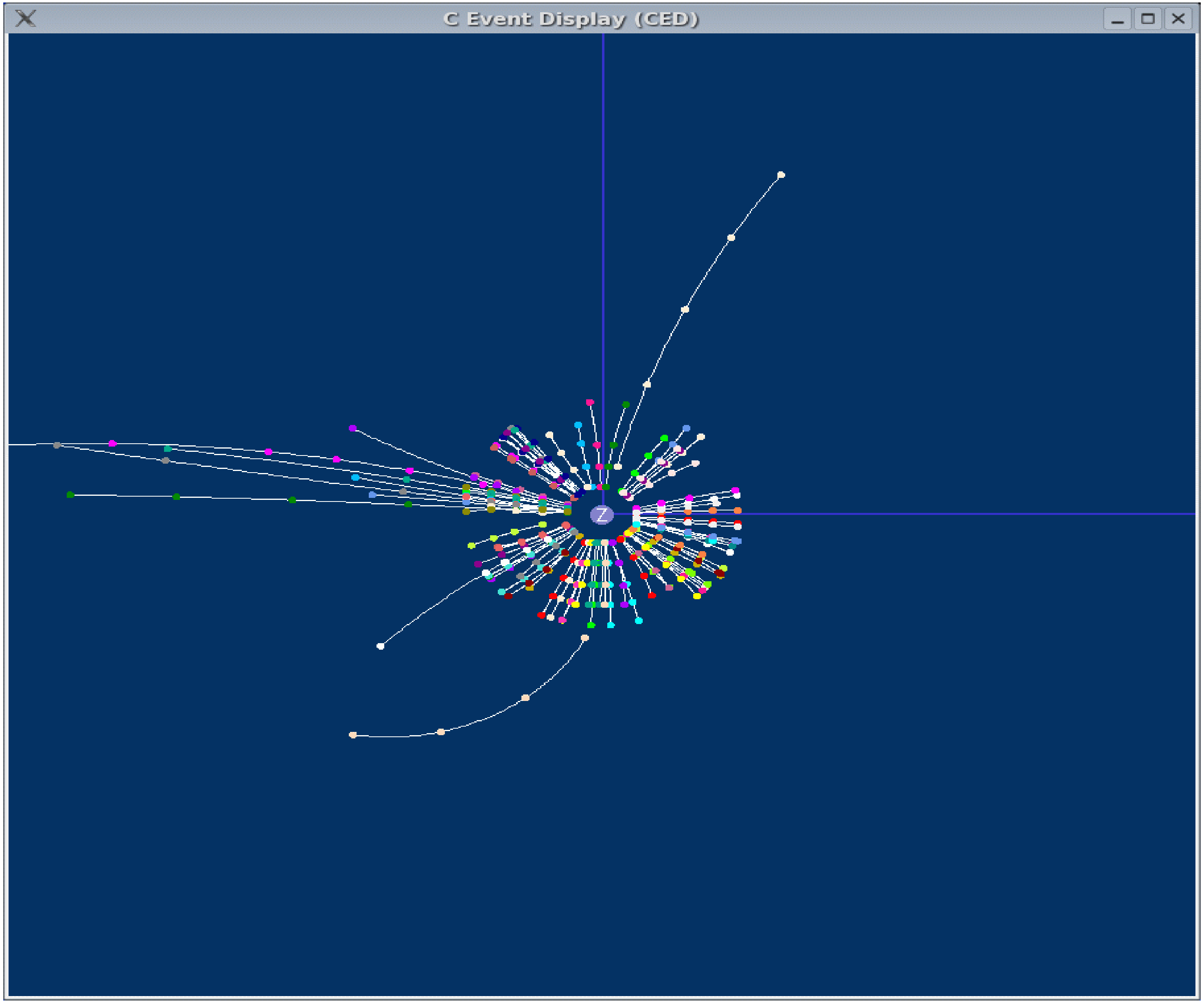
- Challenge : severe beam induced backgrounds in the detector region close to IP
  - Few hundred backgound hits / bx in the innermost VXD layers from ee pairs originating from beam-beam interactions
  - Readout time : ≈50-100 μs → integration of about 150-300 bunch crossings → ≈ 50000-70000 background hits per layer in the innermost layers of VXD



Event Display :
tt⇨6jet with background hits



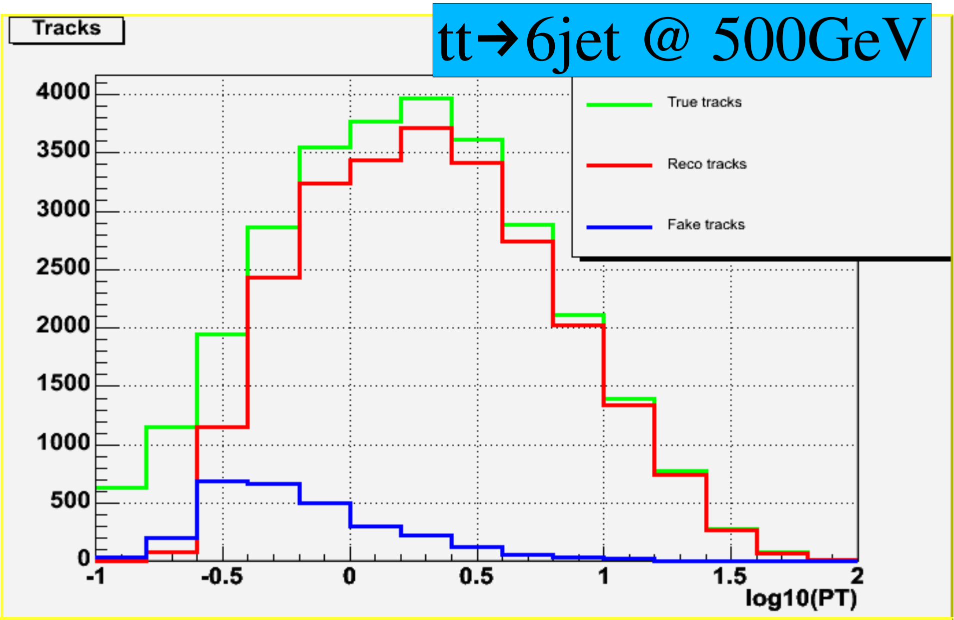
Event Display :
tt⇨6jet after reconstruction

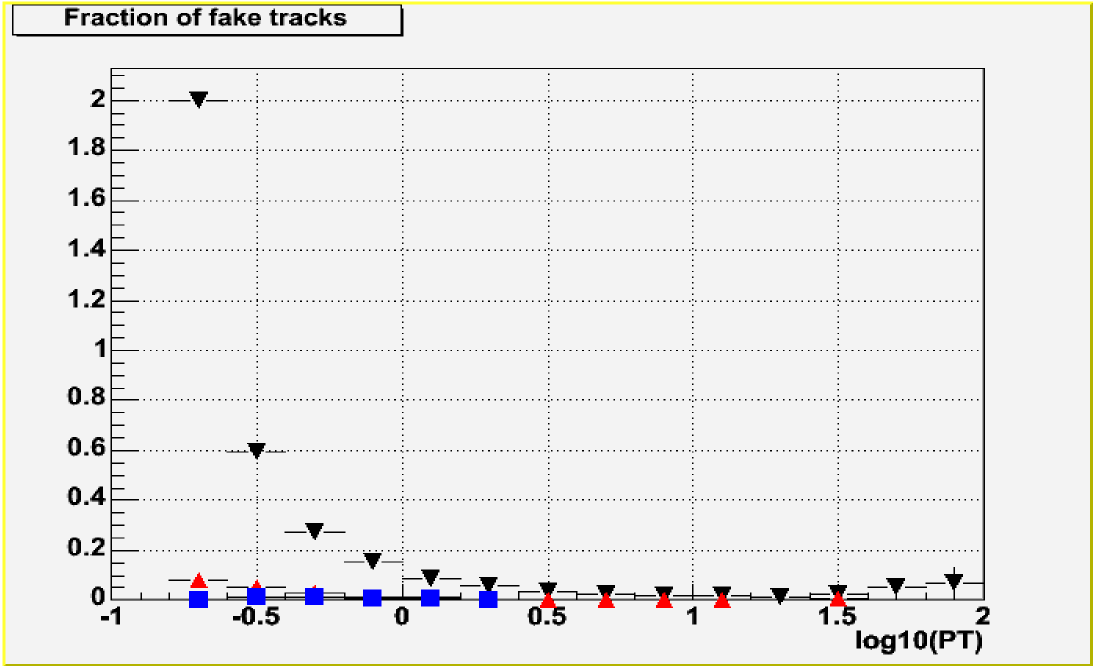


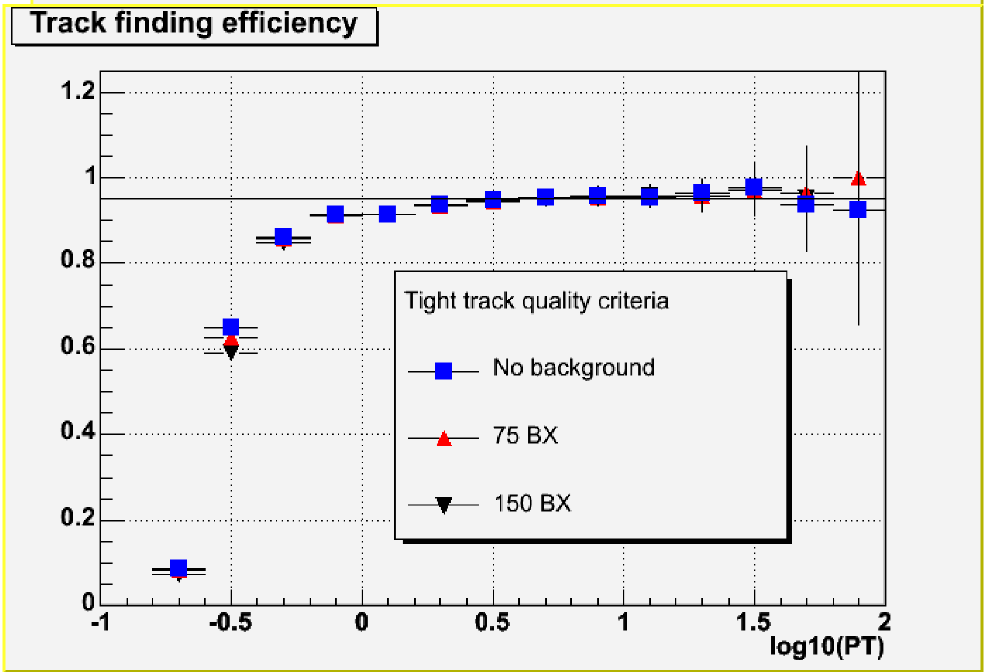
Tracking Performance in Silicon Detector in Presence of Background

- Efficiency > 95% (p > 1GeV) weakly depends on VXD integration time (up to 200 bx)
- Fake track < 5% @ integration of 75 bx
- High fake rate of 50% (low p fakes) when integration time corresponds to 150 bx
- Strict requirement on the readout time (faster than 50 μs in order to keep fake rate at perecnt level)

tt→6jet @ 500GeV





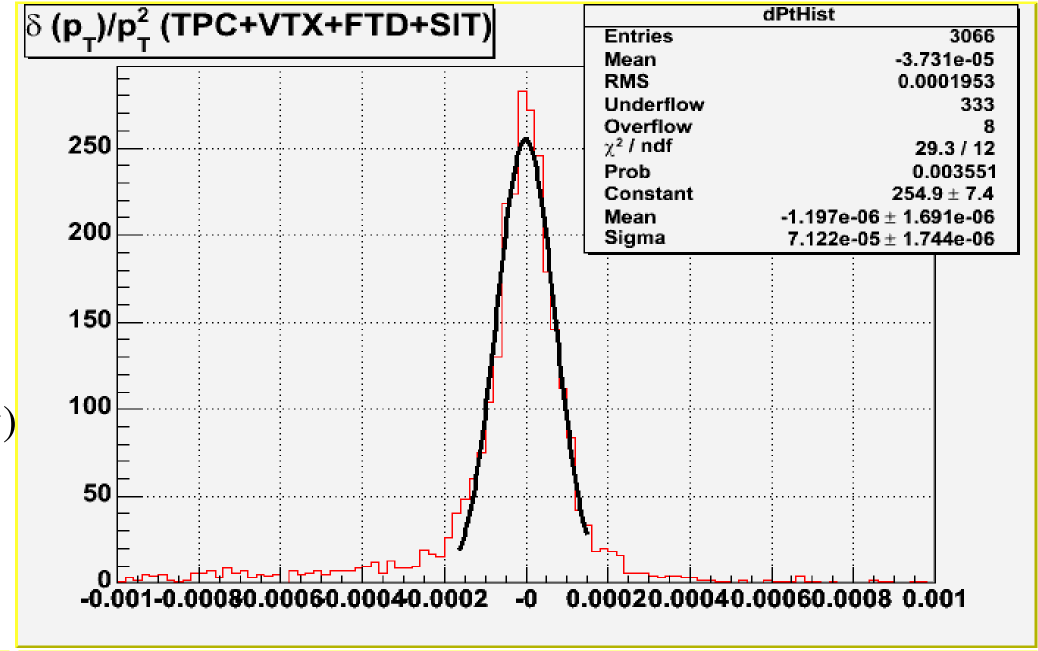


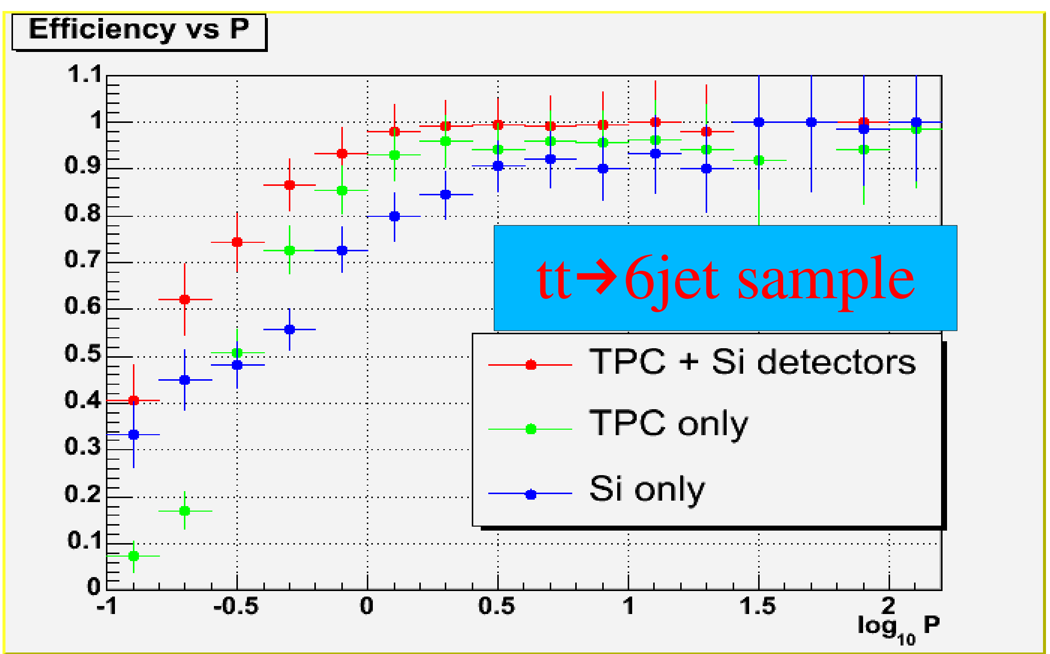
Combination of Si and TPC Tracks Segments. Full Tracking in Large ILC Detector

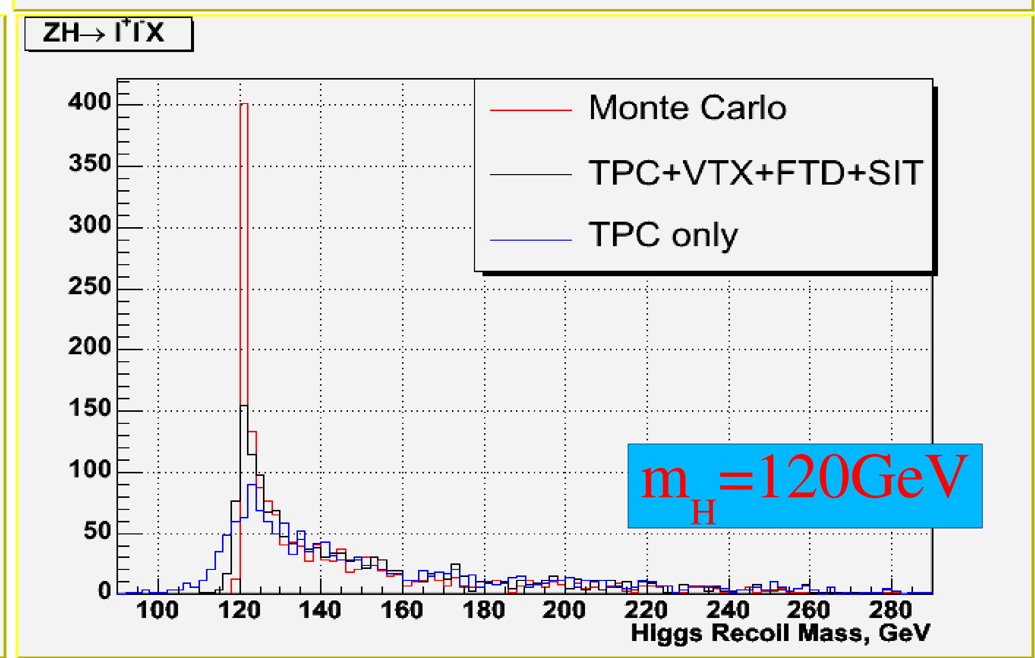
- **Code, combining TPC & Si track segments, is developed and integrated into official LDC reconstruction software package**

- **<u>Performance:</u>**
  - Efficiency > 99% (97%) for p>1(0.4) GeV
  - $\delta p_T/p_T^2 = 7\cdot10^{-5}$ (VXD+SIT+TPC) , $2\cdot10^{-4}$ (TPC only)

- **<u>This code represents a tool for future detector optimisation studies</u>**







Summary

- **ILC project gains momentum**
  - Intensive machine R&D resulted in Baseline Configuration Document (released Nov 2006)
  - Intensive detector R&D resulted in 4 Detector Concept Outline Documents SiD/LDC/GLD & 4th concept (released April-June 2006)
  - R&D is still ongoing (testbeam of high granularity W-Si ECAL and tile HCAL @ CERN, testbeams of VDX prototypes, detector optimisation studies with full simulation & reconstruction, physics analyses *etc)*
- **MPI takes active part in ILC project**
  - Design and optimisation of DEPFET based VXD
  - Development of Vertex Detector Digitization software and its application in performance studies & design optimization
  - Track reconstruction software and its application in detector performance & optimisation
  - **Simulation and reconstruction tools developed & MPI became a part of official software which is widely used within ILC community**