Challenges for the Forward Tracking

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on behalf of the Spanish ILC community

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Interest of the Forward Region

The Forward Region

$$6^o < \theta < 30^o \ (174^o > \theta > 150^o)$$

(0.1 rad $< \theta <$ 0.45 rad, $0.9 < cos\theta < 0.995$, $1.5 < \eta < 3$)

There is a serie of very relevant physics processes where final state particles are predominantly emitted at small polar angle. Mostly electrons, but also muons, t, b- and c-jets.

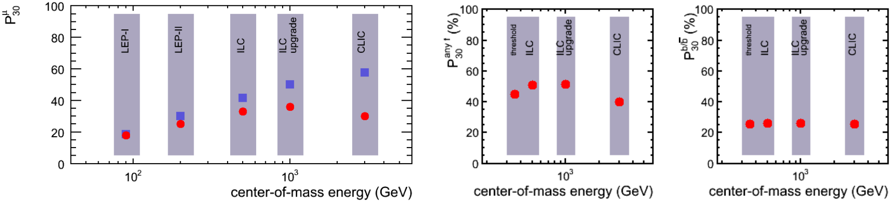
Interest of the Forward Region

Some Examples

P^X_{30}: Probability that final state product X is emitted at a polar angle $\theta < 30^o$ (blue) or $5^o < \theta < 30^o$ (red)

$e^+e^- \rightarrow Z/\gamma^* \rightarrow \mu^+\mu^-$

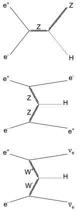
Multi-fermion final states

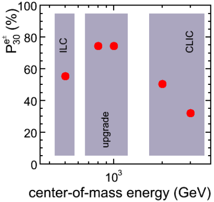


- At $\sqrt{s} \simeq M_Z \Rightarrow$ (almost all) muons emitted in the central region
- Increasing $\sqrt{s}$, more relevance to the forward region
- At $\sqrt{s} \gg Z_{mass}$, process $2 \rightarrow N$, $(N = 4, 6, 8)$ becomes more relevant
- In high-multiplicity final states, fermions to be more isotropically distributed

P_{30}^{X}: Probability that final state X is emitted at a polar angle $\theta < 30^o$ (blue) or $5^o < \theta < 30^o$ (red)

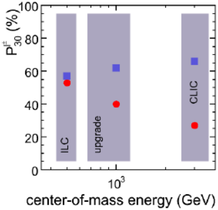
SM-Higgs production

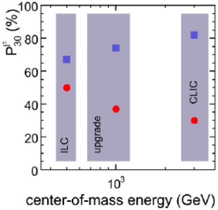


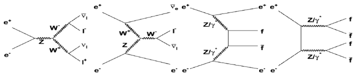


- Higgs-strahlung: dominant Higgs (low mass) production process at small $\sqrt{s}$
- But, Vector-boson fusion process dominates at high $\sqrt{s}$, outgoing e^- (e^+) preferably in the forward direction

Di-boson production







- The polar angle dist. of e^- (e^+) is extremely peaked in forward direction

Forward Tracking Physic Case

Forward tracking requirements at the next e^+e^- collider
part I: the physics case for forward tracking

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February 12, 2009

Abstract

In this note we explore the detector requirements of the forward tracking region for a future e^+e^- collider with a center-of-mass energy in the range from 500 GeV to 3 TeV. The relevance of the forward region is explored for a wide range of physics processes.

arXiv.org: hep-ex 0905.2038

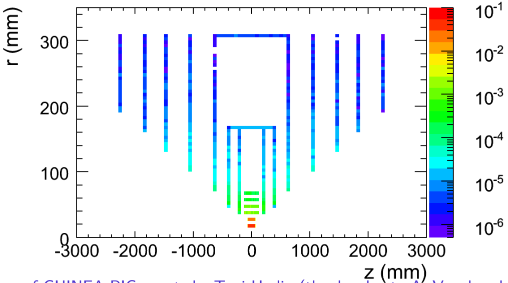
- All the examples shown are discussed in the paper together with many others analysis and channels
- These examples makes the physic case for forward tracking:

At a high-energy e^-e^+ collider several potentially very interesting physics analyses requires excellent tracking and vertexing performance

Challenges for the Forward Tracking

Pair Production

Beamstrahlung: one of major source of machine-induced background ⇒ important in the forward tracker



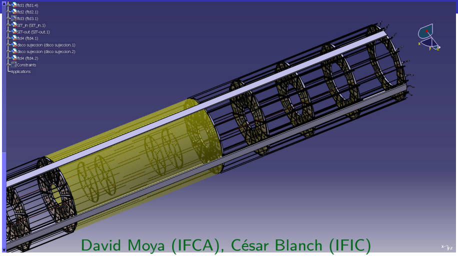
ILD GEANT4 simulation of GUINEA-PIG events by Toni Harlin (thanks also to A. Vogel and Katarzyna Wichman)

Hit density = number of GEANT4 energy deposits per unit area per ILC bunch crossing

	Typical area sensitive elements	time resolution LC
pixel	$25x25\,\mu m^2 = 6.25 \cdot 10^{-4}\,mm^2$	100 BX
strip	$50\,\mu m x10\,cm = 0.5mm^2$	1 BX

Challenges for the Forward Tracking

Time-Stamping



David Moya (IFCA), César Blanch (IFIC)

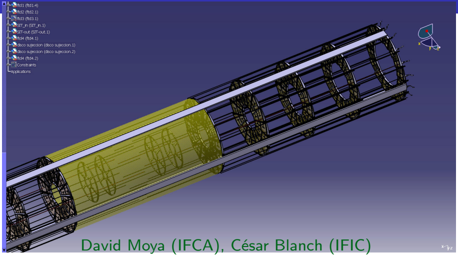
In the current design, the outermost FTD layers, equipped with micro-strip detectors, provide single BX identification

- Tracks at very small polar angle are time-stamped by these outer FTD layers.
- Tracks at larger angle are reconstructed by combining a Silicon (VXD+FTD) track stub with a TPC track. The combination yields an unambiguous assignment to a single BX.

Particle-level time-stamping is therefore guaranteed for all tracks.

Challenges for the Forward Tracking

Time-Stamping



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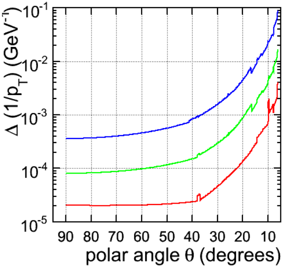
Challenges for the Forward Tracking

Momentum Resolution: Single Muons

ILC tracking specification: $\Delta(1/p_t) < 5 \cdot 10^{-5}\,(GeV/c)^{-1}$

Precision required to reconstruct the Higgs boson using the recoil method, and to reconstruct SUSY end-points

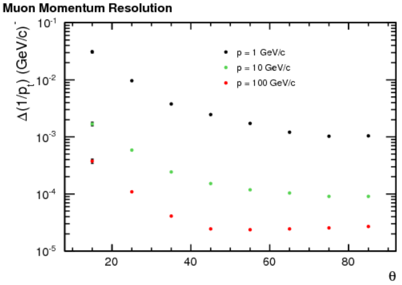


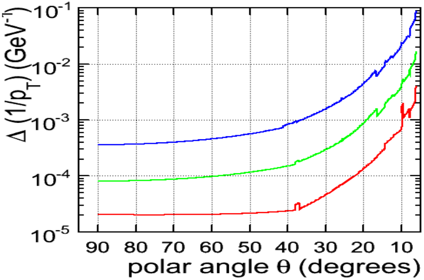
Model ILD_00
p = 1 GeV/c
p = 10 GeV/c
p = 100 GeV/c

Momentum resolution Single Muons

- Performance $\sim$ stable down to 36^o
- Sudden loss between $6^0 - 36^o$.
  - Magnetic field orientation (inevitable within 4π detector geometry)
  - loss of number of measurements in TPC

- Generated Single electron samples (private but available)
- Simulated with ILD_00 model and Reconstructed following the standard processors availables in the framework (Marlin, ..)
- Compared with LOI results for muons

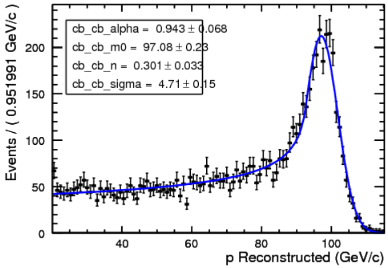




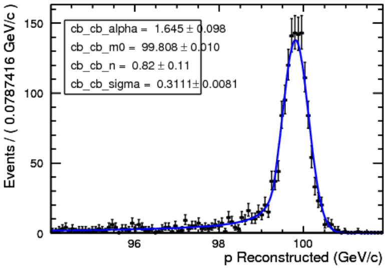
Challenges for the Forward Tracking

Momentum Resolution: Single Electrons

$5^o < \theta < 10^o$



$85^o < \theta < 90^o$



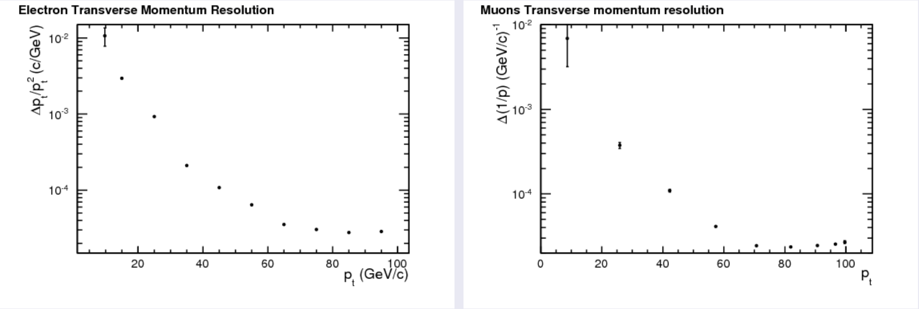
Energy Loss:

- 3 GeV/c in average (forward)
- 150-200 MeV/c in average (central)

Challenges for the Forward Tracking

Momentum Resolution: Single Electrons

Fixed p=100 GeV/c (ongoing study for differents shoots, p=1GeV/c, p=10GeV/c,...)



Worse resolution than muons in the forward region, but of the same order.

ILC specifications are yield in the central region $\theta \gtrsim 50^o - 60^o$

VXD: impact parameter resolution 5 - 10 μm.

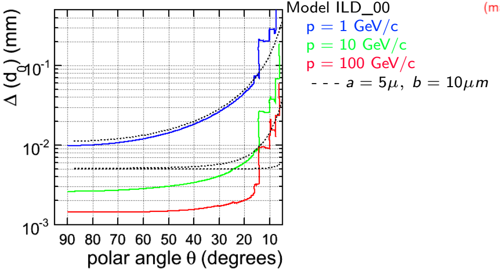
This precision is required to achieve excellent heavy flavour tagging, particularly for couplings of the Higgs boson to charm ($c\tau \sim 150\mu m$) and bottom ($c\tau \sim 450\mu m$)

$$\sigma_{IP} = a \oplus \frac{b}{p \sin^{3/2}\theta}$$

	a (μm)	b (μm GeV)
LEP	25	70
SLD	8	33
LHC	12	70
ILC	5	10

Unprecedented precision
(small pixels, 20x20 μm²)

Strongly reduce the multiple Coulomb scattering term
(material: 0.1 % X_0 / layer ~ 100 μm Si)



- Barrel: $a \simeq 1.7\mu m$
- forward: performance down

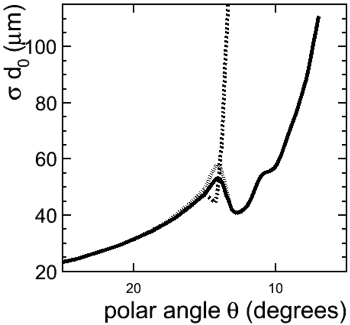
Challenges for the Forward Tracking

Impact Parameter Resolution

To improve performance in the forward region: routing the barrel VXD services

See talk A.Ruiz, M.Vos ALCPG Alburquerque of the Toy model for barrel+end-cap vertex detector

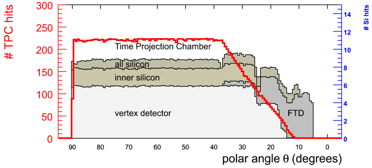
- The forward region clearly does NOT like the services routed along the beam pipe
- If anything close to a few radiation lengths comes in the the way between endcap and interaction point we can forget about forward vertexing



Challenges for the Forward Tracking

Pattern Recognition

- Clearly, 6-15 degrees is weakest region in ILD in terms of number of measurement
    - Ongoing study (C. Iglesias) evaluate hit densities in $t\bar{t}$ events per disk and per petal, subdividing disks in several single-wafers segments.



- The combinatorial algorithm on stand-alone FTD i able to efficiently and cleanly reconstruct tracks down to a p_t of 100 MeV/c (see M.Vos talk, ILC meeting Sendai)
    - R-segmentation: in innermost disks 500μm required, in outermost disks O $(1cm)$
    - Read-out speed: beyond several 10 sec of integrated bunch crossings the density of low momentum tracks prevents algorithm convergence
    - Material: an increase of the material beyond 1 %/disk has dramatic consequences on pattern recognition

Summary of Future Linear Collider Net of Spain

Ongoing activities in FLC-Spain:

- Definition of benchmarks for forward tracking
  - typical benchmarks do not constrain the design sufficiently
  - involve (Spanish) theorists
- Finish part II of of forward tracking paper (M. Vos)
  - including electron studies presented today (J. Duarte)
- Further develop ILD FTD Monte Carlo model
  - to be discussed with SiLC and Frank Gaede
- Optimize forward tracking design
  - forward vertexing, pattern recognition can be improved
- Forward tracking at 1 TeV, multi-TeV (CLIC)
  - physics tends to be more forward peaked
- Time vs. spatial resolution
  - forward region requires more aggressive time-slicing (but exactly how much?)

Identify manpower and responsabilities.

Conclusions

- A good forward tracking system can enhance the physics reach of the experiment
- Electron momentum resolution is worse a few per cent compared to muons but keeps the ILC requeriments
- Currently, the FTD region represents the weakest link of ILD pattern recognition
- An alternative design with several closely spaced high granularity disks could improve this aspect of the performance. We are ready to investigate this option (in close collaboration with the VXD group)