# Overall Track Reconstruction at TESLA

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**Abstract.** A brief overview on the tracking detector configuration of the proposed TESLA linear collider detector is given, along with a description of the realistic track reconstruction software that has been developed for the GEANT3-based simulation of this device. The observed track reconstruction performance is discussed. It provides strong support for the expectation that the design requirements imposed by the Physics processes to be studied at a TeV-scale linear collider will indeed be fulfilled.

## INTRODUCTION

The performance goals for a tracking detector system for the TESLA linear collider are set by the extrapolation of Standard Model physics to the center-of-mass energy range between 500 GeV up to 1 TeV, and by reference reactions from a broad variety of models whose effects are expected to be accessible in this energy region. Measurements like the investigation of recoil mass spectra that are intrinsically limited by the Z width can for example be performed optimally if the mass resolution on the Z resonance is at least one order of magnitude smaller than the intrinsic width. This requirement transforms into a momentum resolution of $\sigma_{p_t}/{p_t}^2 = 6 \times 10^{-5}(\mathrm{GeV/c})^{-1}$. Another point, separation of b and c quark decays from each other and from light quarks, is essential for a large fraction of physics analyses. It requires good vertex reconstruction capabilities, and thus an impact parameter resolution of $5\mu\mathrm{m} \oplus \frac{10\mu\mathrm{m\ GeV/c}}{p \sin(3/2\Theta)}$. General requirements like hermeticity of the detector and redundancy to ensure a high reconstruction efficiency have to be taken care of.

## TESLA TRACKING DETECTOR DESIGN

The TESLA tracking detector design is based on components that independently provide full 3d track information. The main tracker is foreseen to be a TPC with 5.5 m length and a radius of 160 cm. Hits will be reconstructed in at least 118 pad rows, with a single hit resolution of 160 $\mu$m in r$\phi$, and 1 mm in z direction, and a double track resolution of 3.3 mm in r$\phi$ and 1.4 cm in z. The reconstruction of tracks in the forward region will be enhanced by 12 layers of straw tubes with 120 $\mu$m point resolution behind each TPC endcap, the so-called Forward Chamber (FCH). This chamber will primarily improve the momentum measurement of forward muons, which are not significantly deflected by the TPC endcap material.

A set of high-precision silicon-based detectors is foreseen close to the beam pipe. A pixel vertex detector, based on either CCD or CMOS devices, or hybrid active pixel sensors (APS), will provide excellent vertex reconstruction capabilities. Detailed technical designs exist for a 5 layer CCD detector with $3.5\,\mu$m point resolution, and a 3 layer APS device with $7\,\mu$m point resolution. The first layer will have a radius of 1.55 cm in all options. The vertex detector is extended radially up to 30 cm by two layers of double-sided silicon strip barrels, the Silicon Intermediate Tracker SIT, that significantly improves momentum resolution with its spatial resolution of $10\,\mu$m. 6 to 7 silicon disks (depending on the vertex detector option) on both sides, the FTD, are foreseen for extension of precision tracking into the forward region. The 2 or 3 disks closest to the IP will feature pixel detectors with a pixel size of $15\,\mu\text{m} \times 60\,\mu\text{m}$, whereas it is sufficient to use double sided strip detectors with $25\,\mu$m resolution for the outer disks. All tracking detectors will be immersed in a 4 T magnetic field.

All subdetectors mentioned are included in the GEANT3-based detector simulation software package BRAHMS [1], which includes full material description including support and cables. SIT and outer FTD are currently simulated as pixel devices instead of double sided strip detectors. Also available are a realistic track reconstruction software and an event display.

## TRACK RECONSTRUCTION

The track reconstruction software that is used for evaluation of the proposed TESLA detector performance comprises packages that have been adapted from ALEPH, DELPHI and OPAL code. It follows a three-stage concept. The first stage consists of local pattern recognition performed independently in the TPC, the FCH, and the silicon detectors. All combinations of local track candidates that fulfill certain minimal quality criteria are then combined to global track candidates in a second step. The track candidates constructed there are ambiguous, i.e. different track candidates may share the same components. The silicon track search is improved during this step using the full track information from all detectors. The third and final step resolves the ambiguities in the set of global track candidates by uniquely and optimally assigning the local track elements to final track candidates, where information on the whole event is taken into account. Criteria for optimization are for example the total number of final track candidates, the number of hits from all subdetectors that are actually used in the final set of tracks, and the $\chi^2$ probability of all track fits.

The full reconstruction chain is realistic in the sense that it does not use Monte Carlo information at any time. It is however currently being run on a simulation without background in the subdetectors except the TPC, where a background

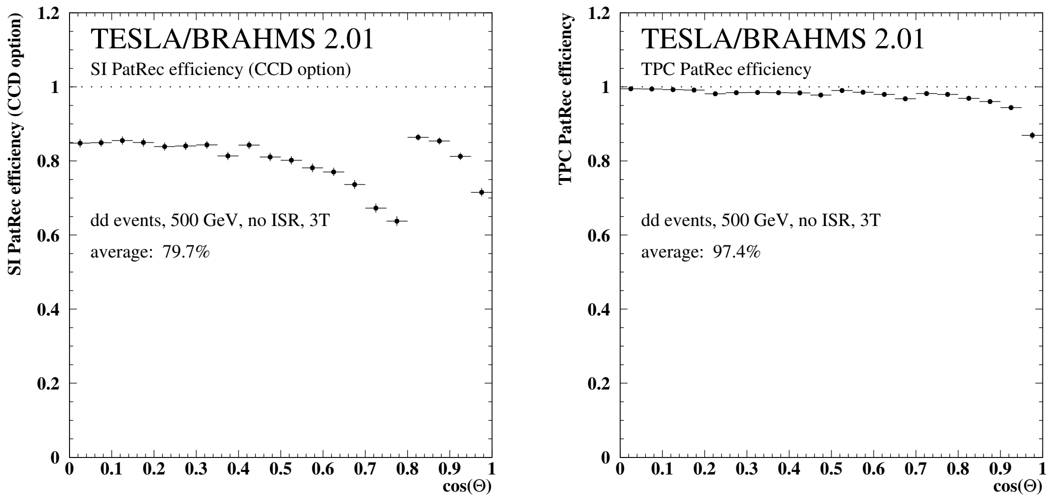


**FIGURE 1.** Dependence of the local track reconstruction efficiency on the cosine of the polar angle, for the silicon detector systems (left, CCD option) and the TPC (right).

occupancy of 1% has been conservatively assumed [2].

## PERFORMANCE ANALYSIS

The track reconstruction capabilities of the system described above are evaluated on a reference sample of $d\bar{d}$ events at a center-of-mass energy of 500 GeV without initial state radiation. This is considered as a pessimistic scenario, since light quark jets are comparatively narrow. A conservative assumption of a 3 T magnetic field strength instead of the 4 T foreseen in the detector design provides some additional safety margin.

The efficiency of the local track search in the silicon detectors and in the TPC is shown in figure 1. An efficiency of 97% is achieved in the TPC, whereas only about 80% of all tracks are reconstructed in the silicon detectors, where the numbers are very similar for CCD and APS vertex detector options. This latter efficiency is currently limited by technical problems, and work is ongoing to improve this. The Forward Chambers are mainly intended for improvement of muon reconstruction in the forward region, 99% of which are reconstructed. About 77% of other tracks in dense jet environments are found correctly (94% of all tracks with at least 10 GeV/c momentum).

The global track search combines the result of the local track searches without noticeable efficiency losses: About 97% of all tracks are reconstructed correctly, with a fraction of 2% fake tracks in the final track candidate sample (see figure 2). The largest contribution to the fake tracks comes from noisy TPC track candidates, mainly track fragments distorted by limited double track resolution. Incorrect merging of subdetector information accounts for less than 10% of the fake tracks.

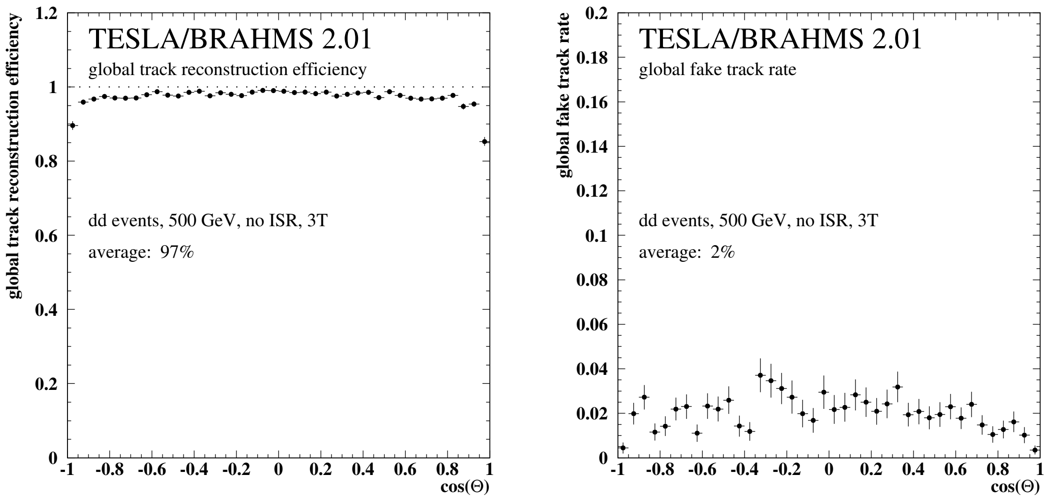


**FIGURE 2.** Dependence of the global track reconstruction efficiency (left) and the fraction of fake track candidates (right) on the cosine of the polar angle.

The momentum resolution obtained by applying realistic track reconstruction as described above to the detector implemented in the BRAHMS simulation package is $8 \times 10^{-5}$ GeV/c, thus slightly above the design goal of $6 \times 10^{-5}$ GeV/c. This is caused by the rather low efficiency of the silicon track search, since especially the largest SIT layer contributes significantly to the overall momentum resolution. The impact parameter resolution does however fulfill the targeted $5\,\mu$m constant term, with a resolution of $2.8\,\mu$m (CCD option), or $4.9\,\mu$m (APS option).

## CONCLUSIONS AND ACKNOWLEDGMENTS

The development of the GEANT3-based linear collider detector simulation BRAHMS is proceeding well. It already includes a fully realistic track reconstruction package, whose performance is good. The reconstruction efficiency is currently mainly limited by software problems, not by intrinsic limitations, and is thus still subject to improvements. The fulfillment of all design requirements has been proven to be a realistic expectation.

The tracking detector simulation and track reconstruction software has been written and/or adapted from LEP by Ties Behnke, Ivanka Božović-Jelisavčić, Grahame Blair, Markus Elsing, Richard Hawkings, Klaus Mönig, Harald Vogt, Daniel Wicke, and many more contributors, including the author.

## REFERENCES

1. Behnke, T., *BRAHMS: A detector simulation tool for TESLA*, these proceedings
2. Büsser, K., *Mask design and background studies for TESLA*, these proceedings