High precision tracking in ILC experiments

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Precision measurements at the International Linear Collider [1] on physics channels of crucial interest are demanding for resolution of the order of $\delta p_T/{p_T}^2 = 10^{-5} GeV^{-1}c$ up to momenta as high as 50 GeV/c. So far, the elective choice which has been mostly proposed to reach such performances, has been the state-of-the-art TPC, with GEM readout and possibly a few extra layers of Si tracking devices. However, the studies on the specific case of the ILC 4th Concept [1], shows that the TPC suffers of an irreducible degradation of its resolution due to multiple scattering, because of the gas used, the mechanical structure, the high density front-end electronics, and the additional use of at least 5 layers of Si-strips. The *CluCou* Collaboration is advancing in the proposal of a light weight He-based drift chamber with cluster counting capabilities as a precision central tracker of the ILC 4th Concept apparatus able to reach the required momentum resolution. In order to check if any improvement in momentum measurement resolution can be achieved with a classic drift chamber in the ILC 4th Concept apparatus, a simulation has been performed in the ILCRoot framework [2], developed from the architecture of AliRoot [3]. The study was done in the momentum range up to 50 GeV/c, based on a 100 μm spatial resolution, typical of a KLOE-like drift chamber. The chamber here designed draws advantage [4] from the use of very light gas mixture, 90% $He + 10\%\ iso - C_4H_{10}$, together with 20 μm thick tungsten sense wires and 80 μm thick aluminum field wires. The resulting cells, sketched in Fig. 1, are arranged in 20 super-layers, with full stereo angles $\pm 72 - 180\ mrad$.

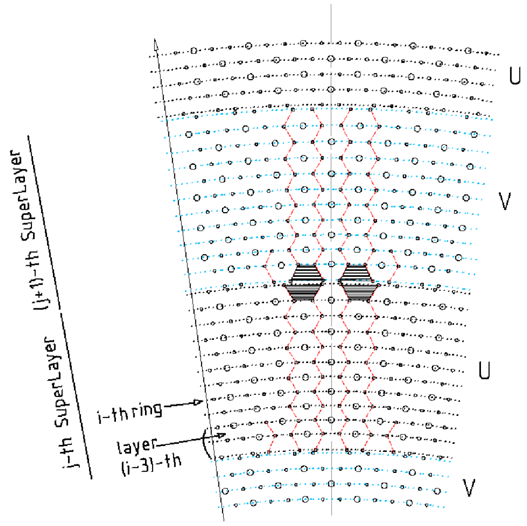

Figure 1. Drift cells layout of the *CluCou* chamber.

Given the dimension of the drift chamber, having a radius of 1.5 m, the dimension of cells ($0.6 - 0.7\ cm$) and the consequent number of wires (60000 sense and 120000 field), the resulting multiple scattering effective thickness of the chamber is as low as $5.5 \times 10^{-3} X_0$, mostly due to the wires. The mechanics of the chamber is, in addition, based on carbon fiber technology for both barrel and endcaps, thus introducing a further perturbation as low as $4 \times 10^{-2} X_0$, which does not harm the subsequent calorimeters position resolution. Results from the first study, based on the previous input parameters for the drift chamber, are illustrated in Fig. 2 (red points and curve), where the improvement of resolution for momenta up to $\sim 25\ GeV/c$ is direct consequence of the damping of the multiple scattering along the particle path, as compared to the TPC (black points and curve, simulated within the same framework with identical benchmark tracks).

Based on the discussions reported in Ref. [4, 5], the *CluCou* drift chamber proposal, in addition, aims at further improvement of resolution at high momentum, by pushing the point position resolution to the ultimate level of 50 μm by means of the cluster counting technique [6]. This improvement (blue points and curve in Fig.2) would be of great advantage in the $25 - 50\ GeV/c$ momentum range, where goldplated measurements at ILC are expected. One of those is the observation of Higgs-strahlung production process of the standard model Higgs, $e^+e^- \rightarrow ZH \rightarrow l^+l^- + X$ as sketched in Fig. 3.

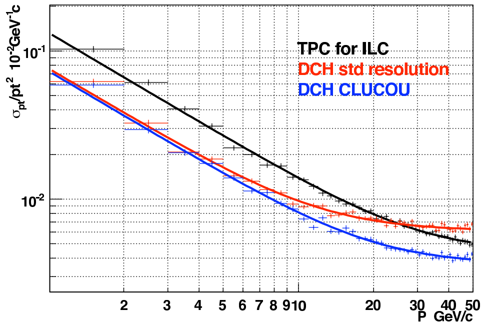

Figure 2. Momentum resolution comparison in the 4th Concept central tracker. In black, the simulation for the TPC plus 5 layers of Si strips. In red, a light weight KLOE-like drift chamber with $\sigma = 100$ μm. In blue, the same drift chamber with cluster counting and $\sigma = 50$ μm.

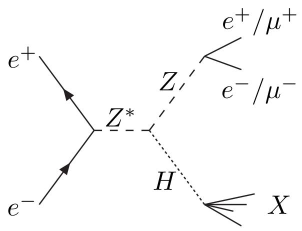

Figure 3. Z^0 Higgs-strahlung Feynman diagram.

From an experimentalist's point of view this is an essentially unbiased process, since, regardless of the decay channel of the Higgs, and owing to the constrained kinematics, one can reconstruct the mass spectrum of the recoiling particle without ambiguities, if he measures with sufficient precision the invariant mass of the l^+l^- system, and knows the energy of the beams with comparable accuracy, as it will be the case at ILC. Finally, we can see that with the momentum resolution of the *CluCou* drift chamber the Z mass is reconstructed with a precision of $\lesssim 150$ MeV/c^2, as expected from the Linear Collider design, and the Higgs mass can be reconstructed with a $\sigma \simeq 330$ MeV/c^2 and a systematic shift of $\simeq 110$ MeV/c^2 (Fig. 4). In the case of a drift chamber with low resolution, the Z mass is reconstructed with a precision of $\lesssim 230$ MeV/c^2 and the Higgs mass with a $\sigma \simeq 450$ MeV/c^2 and a systematic shift of $\simeq 170$ MeV/c^2.

The chamber can also be applied to the SuperB factory for particle identification by means of ionization density measurements, with a potential 2% resolution on dN_{cl}/dx. Potentialities of new materials (carbon fiber, polyester, kevlar)

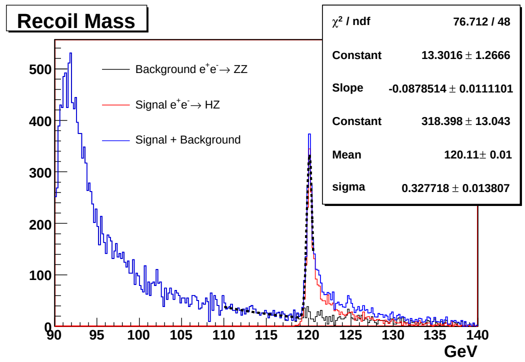

Figure 4. Recoil mass spectrum for the $e^+e^- \rightarrow ZH \rightarrow l^+l^- + X$ process, as expected from measurements with *CluCou* drift chamber in the ILC 4th Concept with 50 μm spatial resolution.

are being explored, for wires as thin as 10 μm.

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