Track reconstruction and resolution for DESY test beam environment

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This work aims to determine the resolution of the tracking system for the DESY test beam, proving that we can achieve a good performance using only three of the four available points.
The DESY test beam is shown in figure 1. There are four drift chambers in front of the calorimeters that are used to reconstruct the track. The distance of the track from the wire is give by:

$$x_i = \frac{\Delta t}{v_d}$$

where Δt is the measured signal time and v_d is the drift velocity of electrons in the gas.
Since the cathodes of two consecutive chambers are at the opposite ends of the chambers (if chamber 1 has the x wire on the right, chamber 2 has the wire on the left), the distance between wires (72mm) divided by the total drift time, gives the drift velocity.

$$v_d = \frac{72mm}{t_1 + t_2}$$

From the sum of the two times we can also determine the drift chambers resolution. Since the two chambers are identical and are filled with the same gas, the resolution of each is given by:

$$\sigma_{DC} = \frac{\sigma_{sum}}{\sqrt{2}}$$

The average value obtained from the fit is $\sigma_{sum} = 67$ ns (figure 2), hence $\sigma_{DC} = 47$ ns is the value used in the smearing of the MC points at the digitization stage.

There are several other factors to be taken into account in the simulation. The beam has a spread, the signal from the drift chambers must be digitized and smeared and possible misalignments of the chambers have to be taken in consideration. All these effects have been analyzed to tune the simulation and calculate the effect of each of them on the track resolution.
The spread in beam position is primarily determined by the 10 mm collimator. Figure 3 shows the [x, y] distribution at the front face of the calorimeter for the data and the Montecarlo with a 10 mm Gaussian spread of the beam position at the point of generation, 10 m in front of the calorimeter. The data distribution is slightly wider but the 10 mm spread is used to demonstrate that this parameter doesn't affect the resolution. No energy or angular spread is considered; the latter may be the responsible for the higher spread observed in the data.
The next stage in the simulation is the digitization of the signal in the drift chambers. At this stage a smearing is introduced according to the sigma obtained above. To crosscheck the used value, the sum of the time of two consecutive chambers is plotted. The result from the simulation is good agreement with the data (figure 2).
At this stage it is possible to reconstruct the tracks using a linear fit; the reconstructed impact point at the calorimeter surface extrapolated from the fit can be compared with the real value from the Montecarlo.
To better understand all the contribution to the resolution a first sample with no smearing at drift chamber digitization stage, no beam spread and no misalignment between chambers is simulated. The resolution, due only to multiple scattering in air is shown in figure 4 and the sigma (σ_{MS}) is 0.65±0.02 mm.
The smearing in the chambers is then added and a sigma (σ_{Smear}) of 1.70±0.05 mm (see figure 5) is obtained. Thus the contribution from the drift chambers resolution is

$$\sigma_{DC} = \sqrt{\sigma^2_{Smear} - \sigma^2_{MS}} = 1.57 \pm 0.05\,\text{mm}$$

The chambers are aligned with a precision of 0.2 mm, thus this effect is negligible on the resolution, as can be seen from the plots.
As last check the beam spread is added; as described above, this should not affect the resolution. In fact the the resolution is 1.64±0.05 mm, in agreement with the previous result (figure 6).

Due to the low efficiency of a wire in chamber 3 (see M.F.G. et all, “Drift Chamber efficiency measurement in test beam area 21”), it is important to establish if the resolution is affected when only three points are used. Therefore the resolution is recalculated by excluding a chamber at a time. The following results are obtained:
σ_4 = 1.96±0.05 mm
σ_3 = 1.64±0.05 mm
σ_1 = 1.80±0.05 mm
σ_2 = 2.89±0.09 mm
where the number indicate the missing chamber.

The results (figure 7) suggest that three hits to reconstruct a track can be used requiring at least the last one (chamber 2) to be present. Fortunately the chamber with the lowest efficiency is the second on the beam line and the resolution is not affected if the hit is missing. Moreover the best working chamber is the last one on the beam line, the one this analysis showed play the most important role.

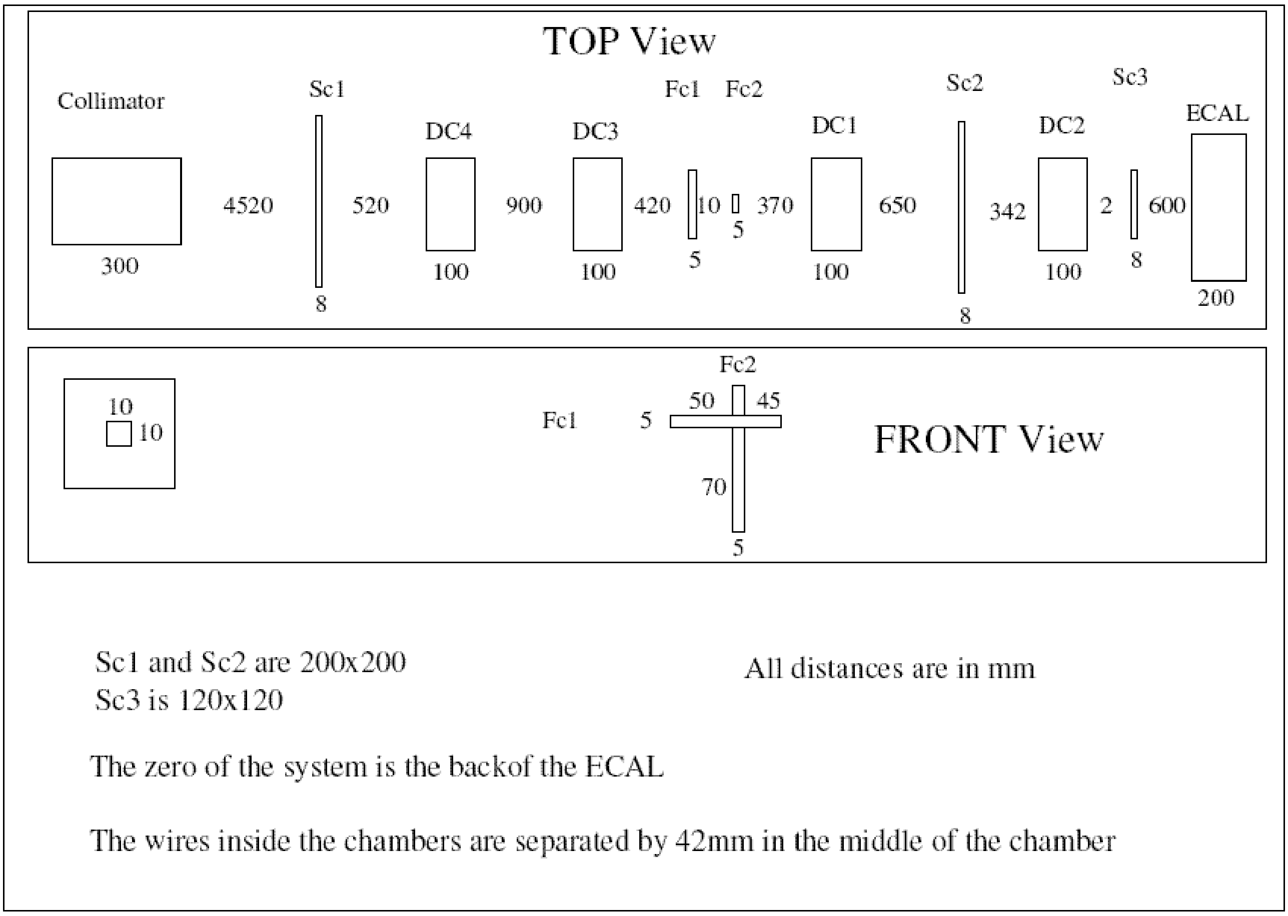

Figure 1, Test beam schematics

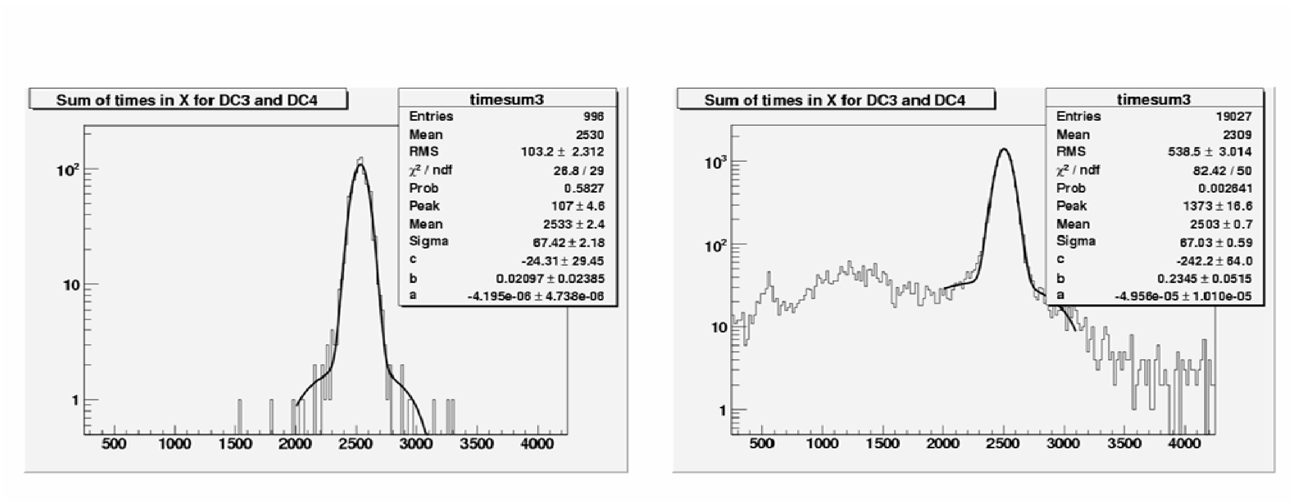

Figure 2 MC (left) and data (right) distribution for the sum of two consecutive wires

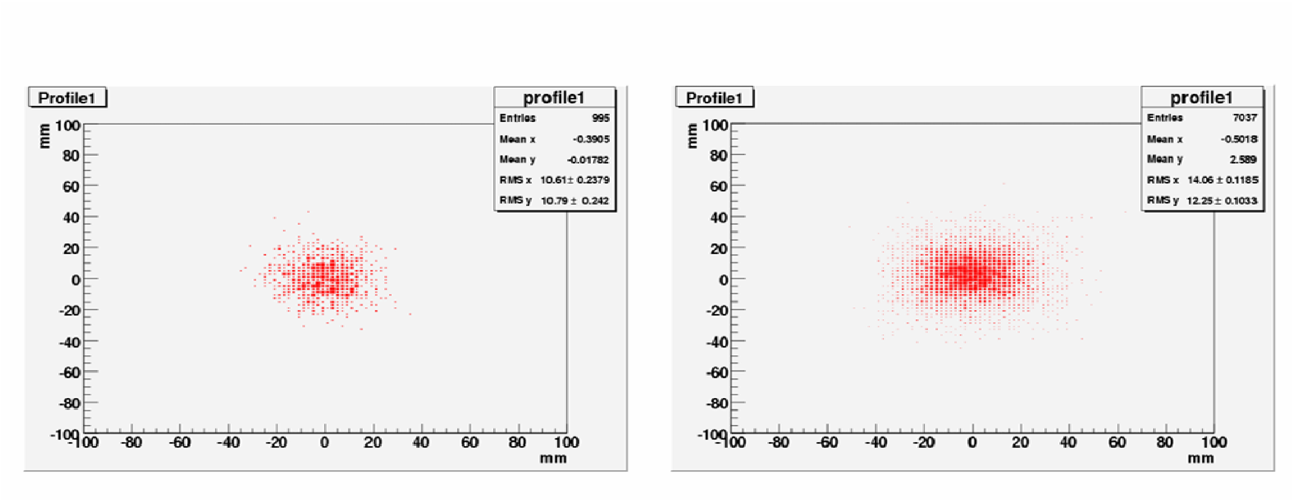

Figure 3 Beam profile at the calorimeter face for MC sample (left) and data sample (right)

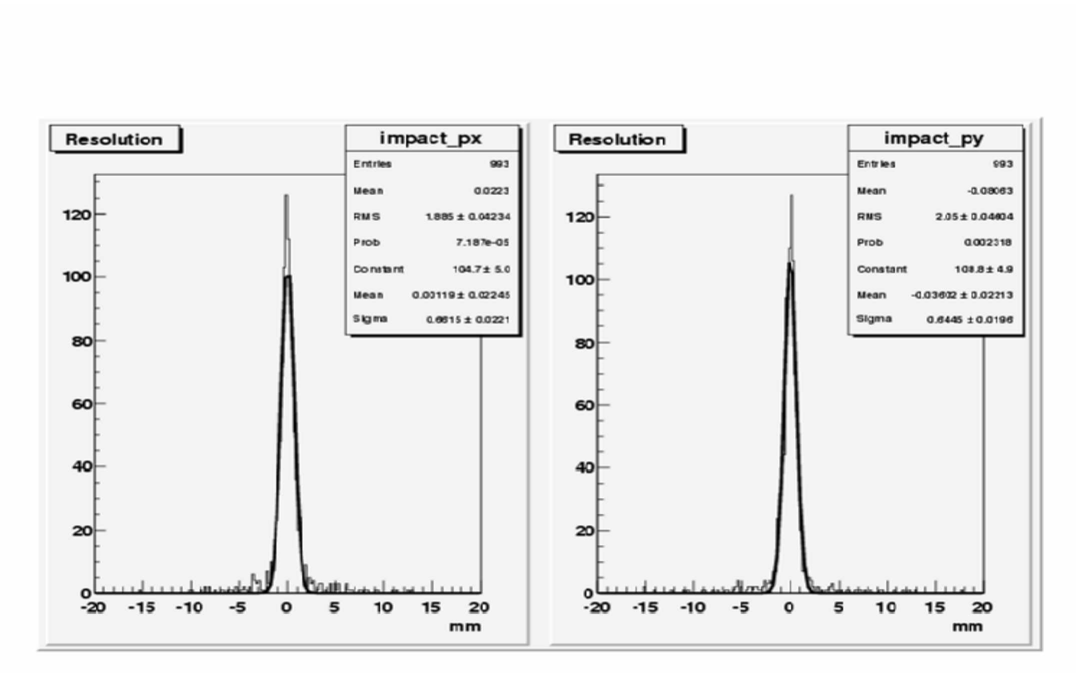

Figure 4 Distribution of the difference between fitted and real point at calorimeter surface

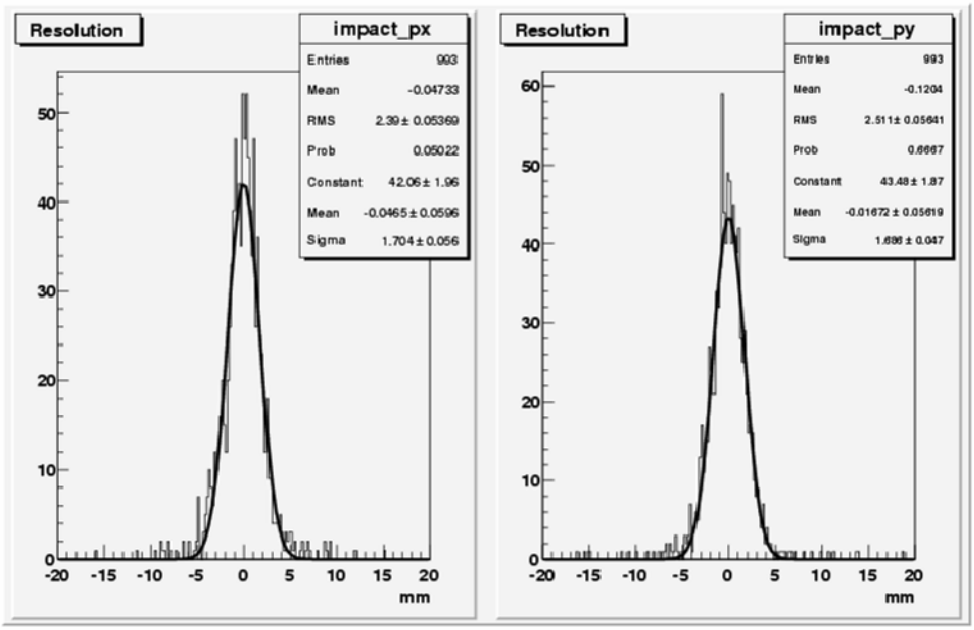

Figure 5 Distribution of the difference between fitted and real point at the calorimeter surface, DC smearing on.

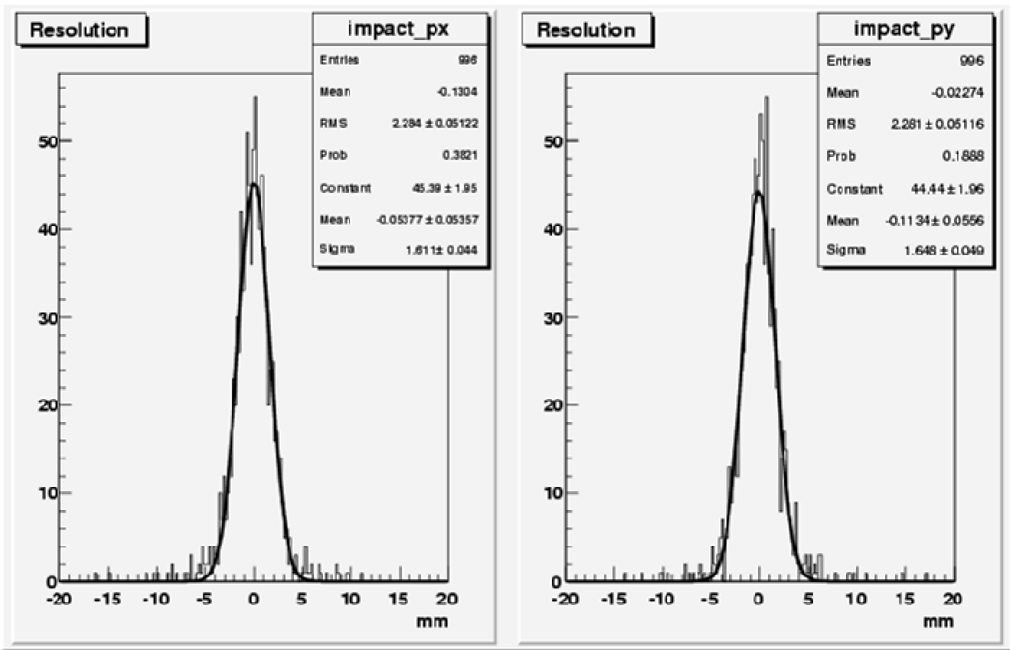

Figure 6 Distribution of the difference between fitted and real point at the calorimeter surface, all effects on.

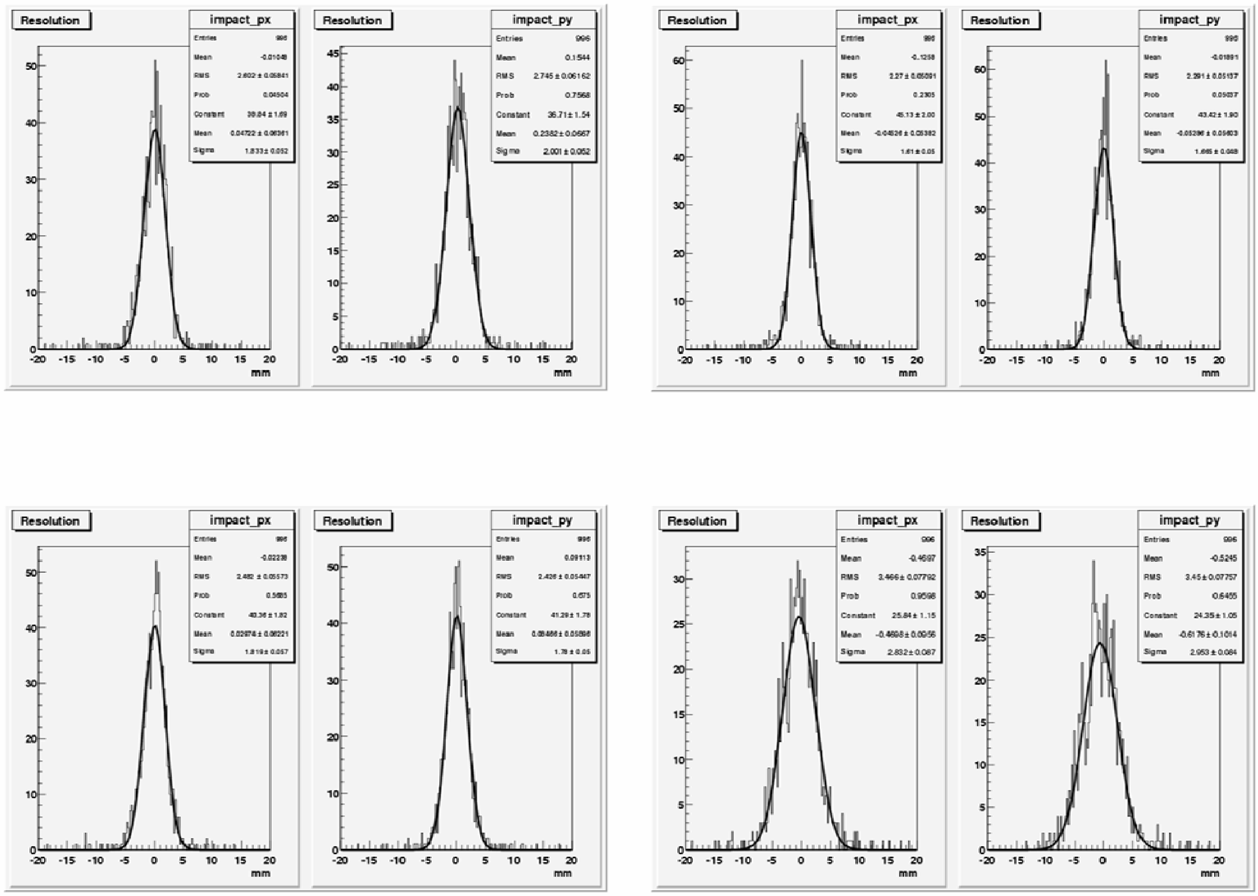

Figure 7 Distribution of the difference between fitted and real point at the calorimeter surface, 3 hit only. From top left, the missing chamber is DC4, DC3, DC1 and DC2.