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First Results from a Test in Magnetic Field of a Prototype of the KLOE Drift Chamber

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ABSTRACT

We present preliminary results from the analysis of data collected at the CERN X7 beam. The purpose of the test was to study the response of a prototype ($3 \times 3\,\mathrm{cm}^2$, $\mathcal{R}_{\mathrm{fs}}=3$) of the KLOE drift chamber under the effect of a 0.6 T magnetic field. We show that, as expected given the low drift velocity of He-based gas mixtures, the cell spatial resolution is not degraded in the presence of a magnetic field. Furthermore, the results indicate that the spatial resolution is better than the specifications of $200\,\mu$m quoted in the KLOE proposal.

1 Introduction

A drift chamber prototype consisting of a matrix of 7×7 square cells with sides of 3 cm, hereafter called prototype 0.3, was tested on a 50 GeV/c particle beam at the CERN SPS. A system of aluminum tubes operated in streamer mode provided an external tracking system with a spatial resolution better than $100\,\mu$m, while the trigger for the passage of a particle was given by the coincidence of two scintillator counters upstream and downstream of prototype 0.3. The counters also provided the t_0 for the drift time measurements in the tracking detectors. The whole system was located inside a magnet, which could produce the requested field, with orientation parallel to the wires. In the following we report on a preliminary analysis of two of the data samples collected.

2 Space-Time-Relation

The profile histograms of the space-time relation in one cell of prototype 0.3 is shown in fig. 1, together with the fit performed with a 2nd order symmetric polynomial.

The parabolic form used in the fit is not able to follow the data for the whole range of drift distances inside the cell. We nevertheless use it in the following, for the sake of simplicity and with the purpose of comparing to previous measurements. The linear coefficient (parameter B in the plot of fig. 1) has the usual meaning of the inverse of the drift velocity for high electric fields (i.e. short drift distances). The fitted value would correspond to $v_{\mathrm{drift}}=(33.8\pm0.2)\,\mu$m/ns, where the error is statistical only. There is actually a larger uncertainty, amounting to a few %, due to t_0 determination, which will need a more accurate study. This determination compares to $v_{\mathrm{drift}}=(33\pm3)\,\mu$m/ns, (this error does include the effect of the t_0 jitter) in prototype 0.1 [1] .

3 Spatial Resolution for B=0

The spatial resolution is measured inverting the space-time relation and either comparing the predicted drift distance with the track reconstructed by the external tracker, or via the stagger method. This second method has been extensively used in the past: since the main motivation of this note is to make a first, quick comparison of the present test with older results, we will use it in this analysis. The quantity ($y_{\mathrm{stag}} \equiv y(4) - y(14) + \Delta x \cdot \mathrm{slope}$) is shown in fig. 2, vs $y(4)$, the reconstructed distance from wire 4. For an exact space-time relation, y_{stag} ought to lie on a horizontal straight line, whose position should equal the stagger between the relevant cells (-0.222 cm in this case). A few comments are in order:

1. The deviations at large drift distances are due to the use a simplified fitting function.[1]
2. The lack of data points in some 'central' region is due to the dead area ($2 \times 500\,\mu$m) between the aluminum tubes of the Mini Tracker. We use the information from the external device to solve the left-right ambiguity in the cells of prototype 0.3, since the drift distance reconstructed from the drift time has obviously no sign.
3. The coefficients used to invert the space-time relation are common to all the cells (after being fitted on another cell), and we did not make any attempt to take into account cell-dependent effects, like wire positions or t_0's.

Making slices (1 mm wide in this case) of the plot in fig. 2 and projecting them onto the y axis, one gets distribution of the stagger function at different drift distances. We fitted these distributions with a gaussian [without any parametrization of the (low) background]. The black points of fig. 2 are the fitted mean values of the gaussian functions, while the corresponding r.m.s. are shown in fig. 3 scaled by factor $\sqrt{2}$, since the measured dispersion is due to the combined resolutions of the two cells involved. The stability of these results has been tested making similar plots with other pairs of cells, without finding any difference among them.

To check the "long term" reproducibility of these results, we also used the coefficients obtained for the space-time relation of prototype 0.1 from data collected on a comic ray bench at the L.N.F. with the same gas mixture $90\%\mathrm{He} - 10\% i\mathrm{C_4H_{10}}$ and at the appropriate HV. The results are shown in figs. 4–5. The mean value of the residuals is only slightly deteriorated by the use of this 'old' space-time relation, while as expected the local resolution is not.

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(1) To cope with this problem more complicated functions or even numerical approximations can be used. We tried for example a 4th order symmetric polynomial, which allows to extend the fit to the whole cell range $|y - y_{\mathrm{wire}}| \leq 1.5$ cm, and correspondingly straightens the residuals in the 'large distance' region.

4 Spatial Resolution for B=0.6 T

The effect of the magnetic field is twofold:

1. Bend the charged tracks: the sagitta over a track length L is $s = L^2/(8\varrho)$, where the curvature radius $\varrho = p/(0.3B) = 50/0.18 = 278\,\mathrm{m}$ in our case. This corresponds to $s = 113\,\mu\mathrm{m}$ for $L = 50\,\mathrm{cm}$ (the distance between our external Mini Trackers), and is completely negligible inside prototype 0.3 when using the stagger method.
2. Change the drift velocity: the effect of the Lorentz force is dependent on the velocity itself, and is expected to be small for low velocities.

Using the same coefficients as in the previous section for the space-time relation, we repeated the same analysis. The results are shown in figs. 6– 7 for the same set of cells. The mean value of the residuals remains (relatively) straight, while the absolute value is changed by a quantity $\Delta r \simeq \Delta v \cdot \Delta t_{1-2}$, proportional to the change in drift velocity Δv due to the magnetic field. $\Delta t_{1-2} \simeq 90\,\mathrm{ns}$ is the difference between the drift times of the two cells. From the measured stagger difference ($\Delta r \simeq 180\,\mu\mathrm{m}$) the estimate $\Delta v \simeq 2\,\mu\mathrm{m/ns}$ is obtained, corresponding to a Lorentz angle $\alpha_{\mathrm{L}} \simeq 23°$; this is roughly consistent with the simple calculation $\alpha_{\mathrm{L}} \sim \mathrm{atan}\left(\frac{3B \cdot v_{\mathrm{drift}}}{2E}\right) \simeq 16°$, also confirmed by more complete results [2] . The resolution is not degraded by the magnetic field itself.

5 Conclusions

We performed an analysis on a restricted sample of the data collected at the CERN test of prototype 0.3. The results are preliminary in the sense that almost no refinements have been attempted, neither in the optimization of the performances of the external Mini Tracker (especially when operated inside the magnetic field), nor in the fitting of the space-time relation in prototype 0.3.

However, some of the important questions which motivated the test have been answered: the upper limit (for the reasons mentioned in the paragraph above) to the spatial resolution is $\simeq 120\,\mu\mathrm{m}$ in the regions of the cell where a reasonably good space-time relation has been fitted, and the effect of the magnetic field confirms the expectations: the performance in terms of spatial resolution is not degraded.

REFERENCES

1. A resumé of the work done in this field can be found in *Leonida Bucci, Tesi di Laurea, Università di Roma "La Sapienza"*, A.A. 1993-94.
2. A.Sharma, F.Sauli, *Low mass gas mixtures for drift chamber operation*, CERN/PPE 93-51, 1993

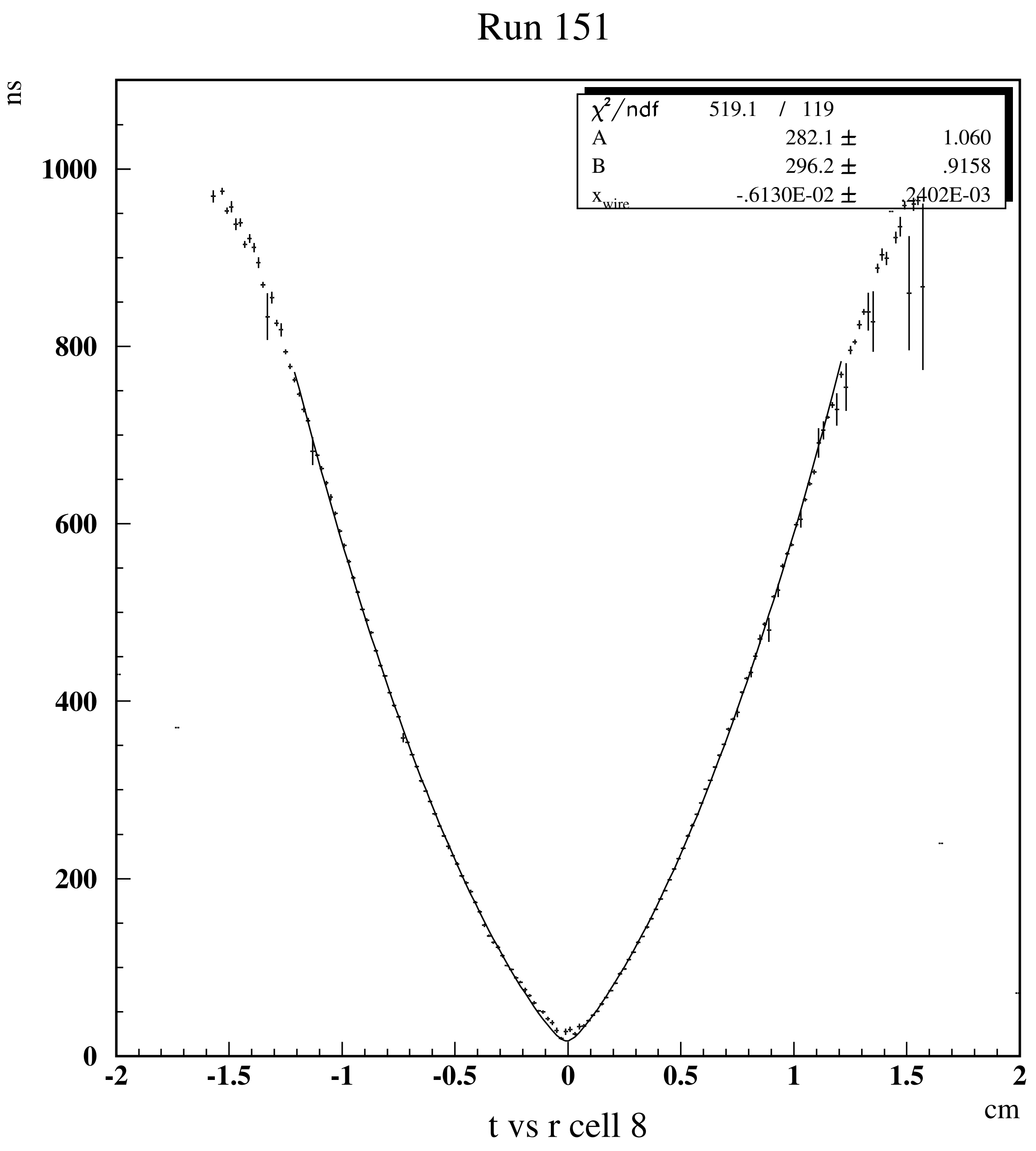

Fig. 1: *Example of space-time relation in a cell of prototype 0.3.*

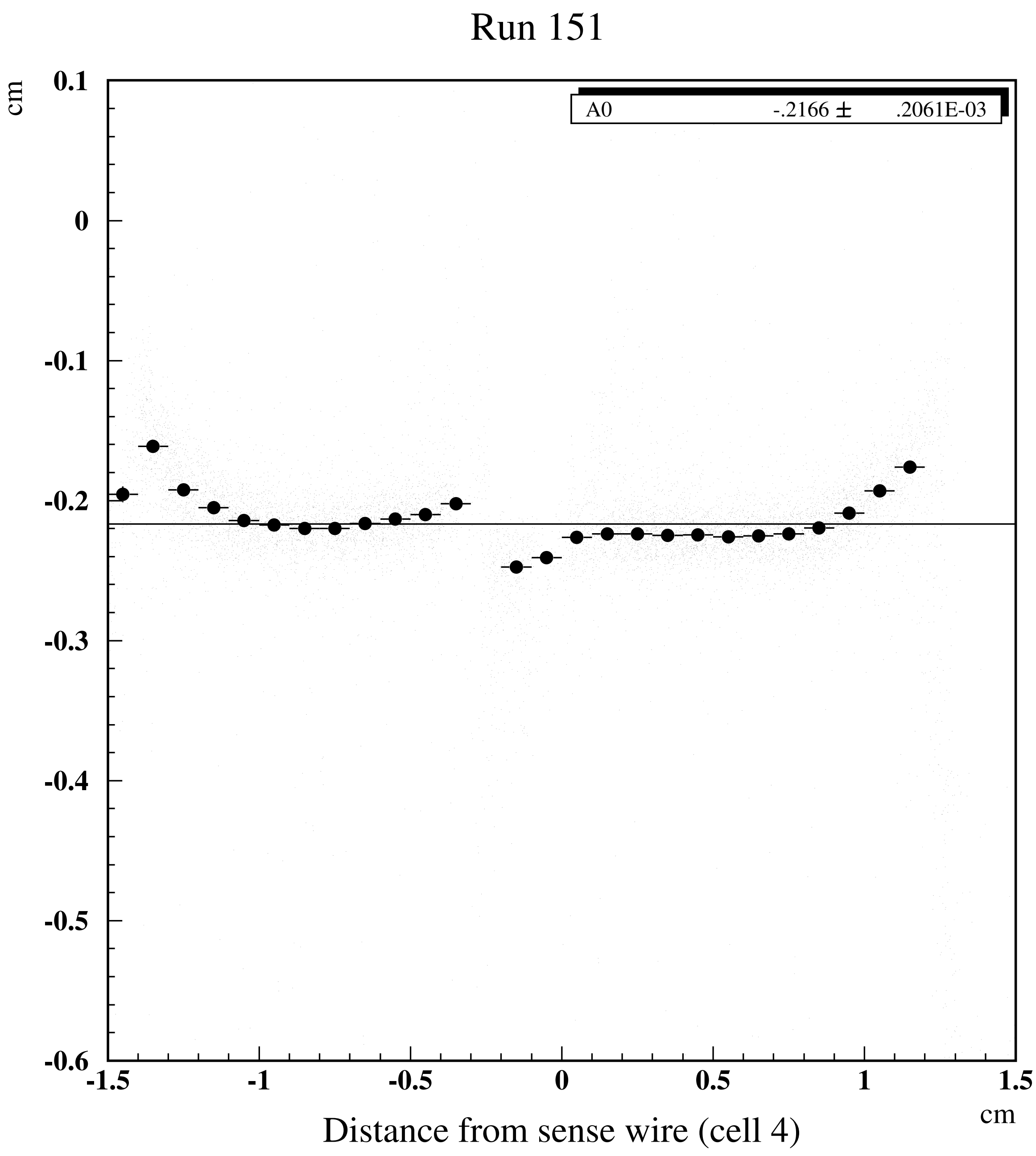

Fig. 2: *Residuals of the stagger between cells 14 and 4, vs. the distance from wire 4. B=0.*

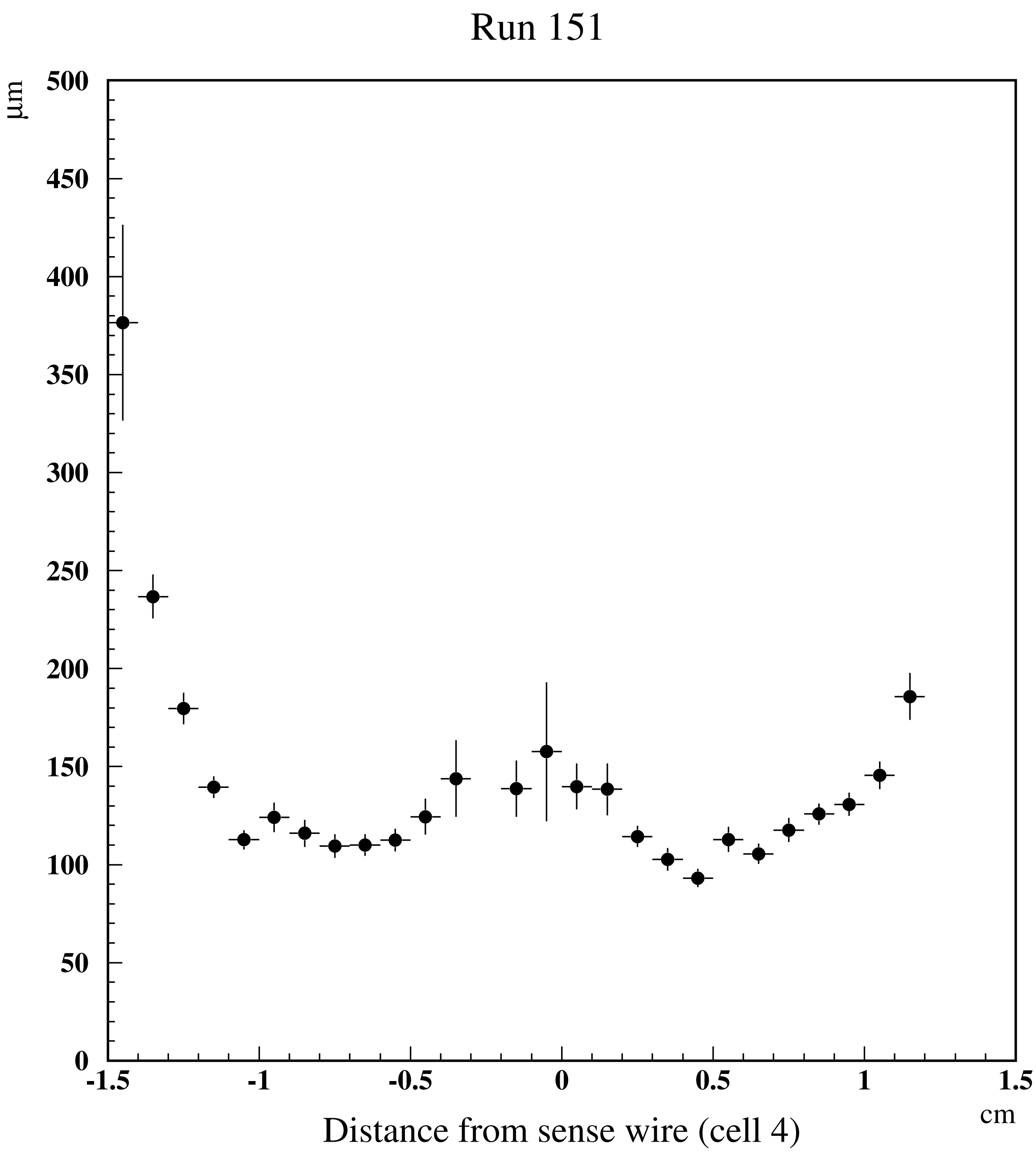

Fig. 3: *Sigma of the residuals of the stagger between cells 14 and 4, vs. the distance from wire 4. B=0.*

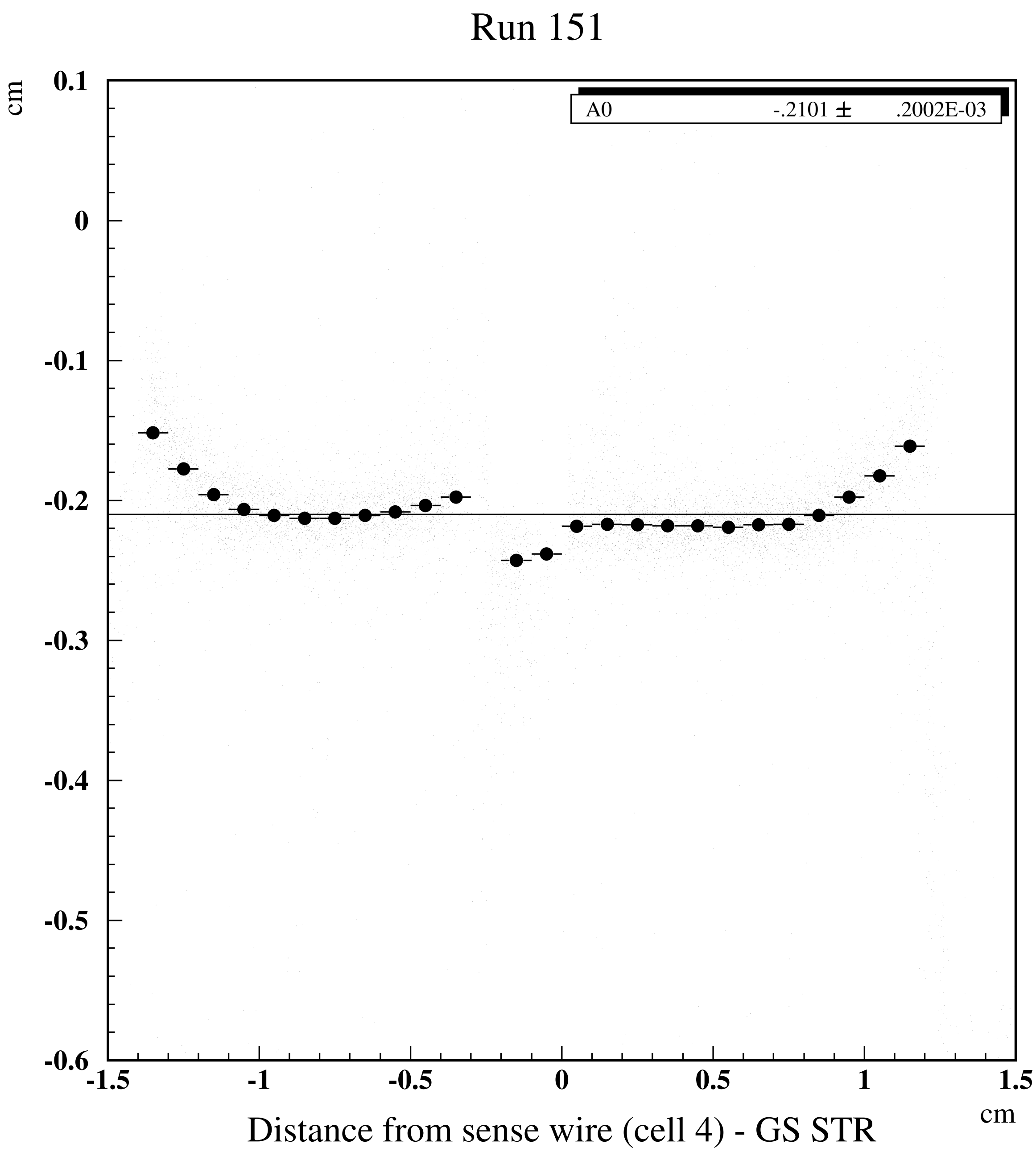

Fig. 4: *Residuals of the stagger between cells 14 and 4, vs. the distance from wire 4, using a space-time relation determined on a cosmic ray bench in prototype 0.1. B=0.*

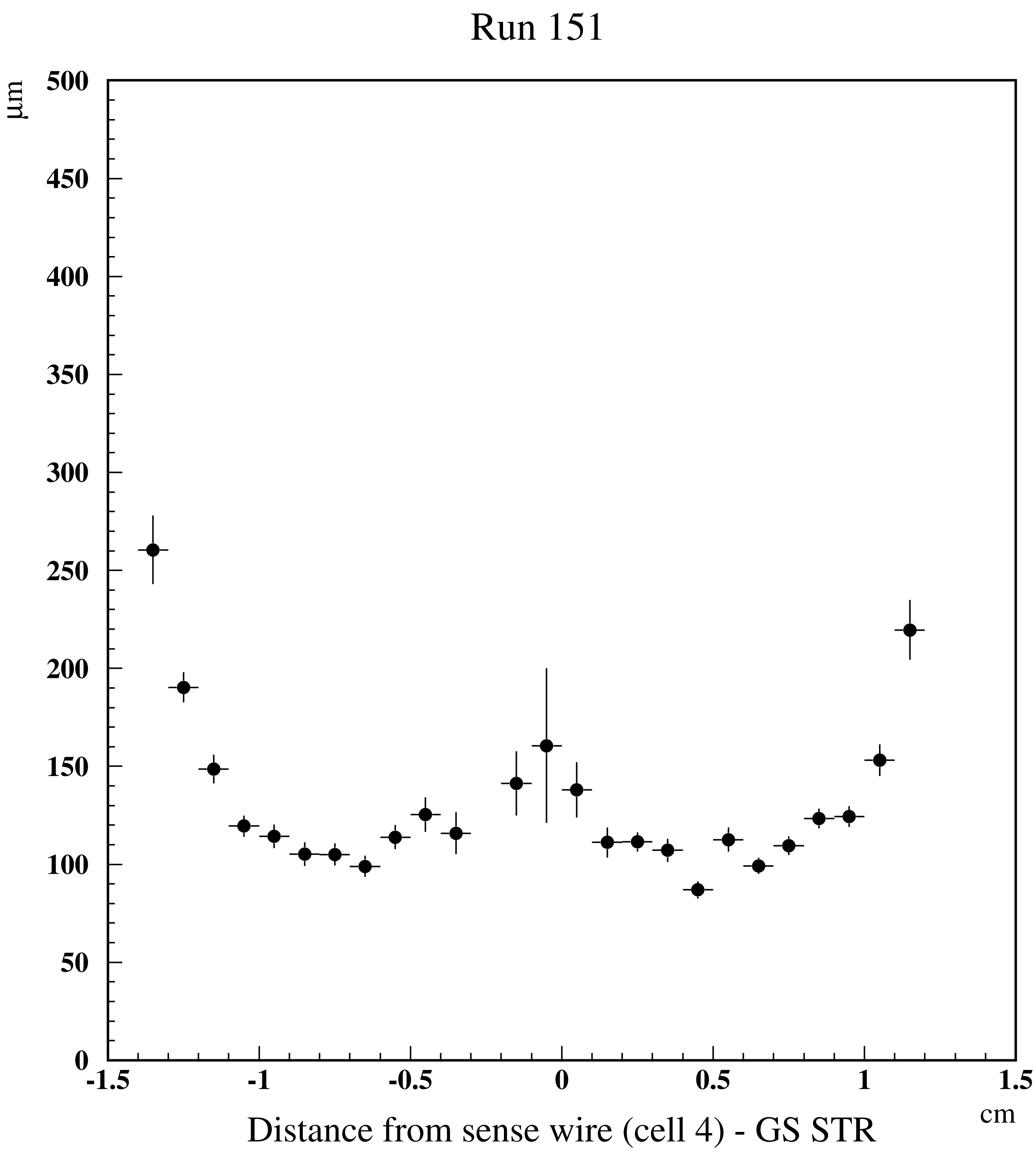

Fig. 5: *Sigma of the residuals of the stagger between cells 14 and 4, vs. the distance from wire 4, using a space-time relation determined on a cosmic ray bench in prototype 0.1. B=0.*

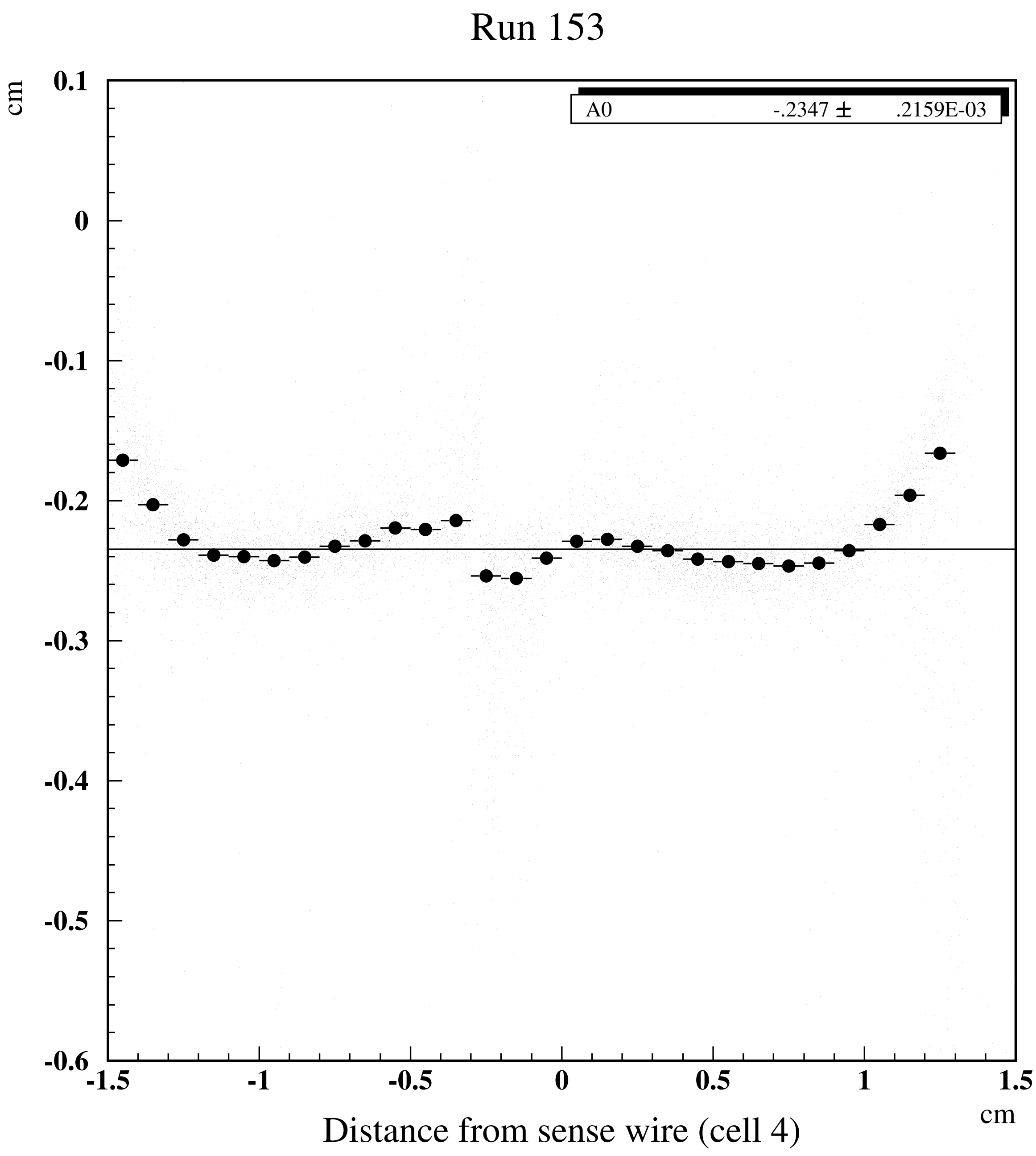

Fig. 6: *Residuals of the stagger between cells 14 and 4, vs. the distance from wire 4. B=0.6 T.*

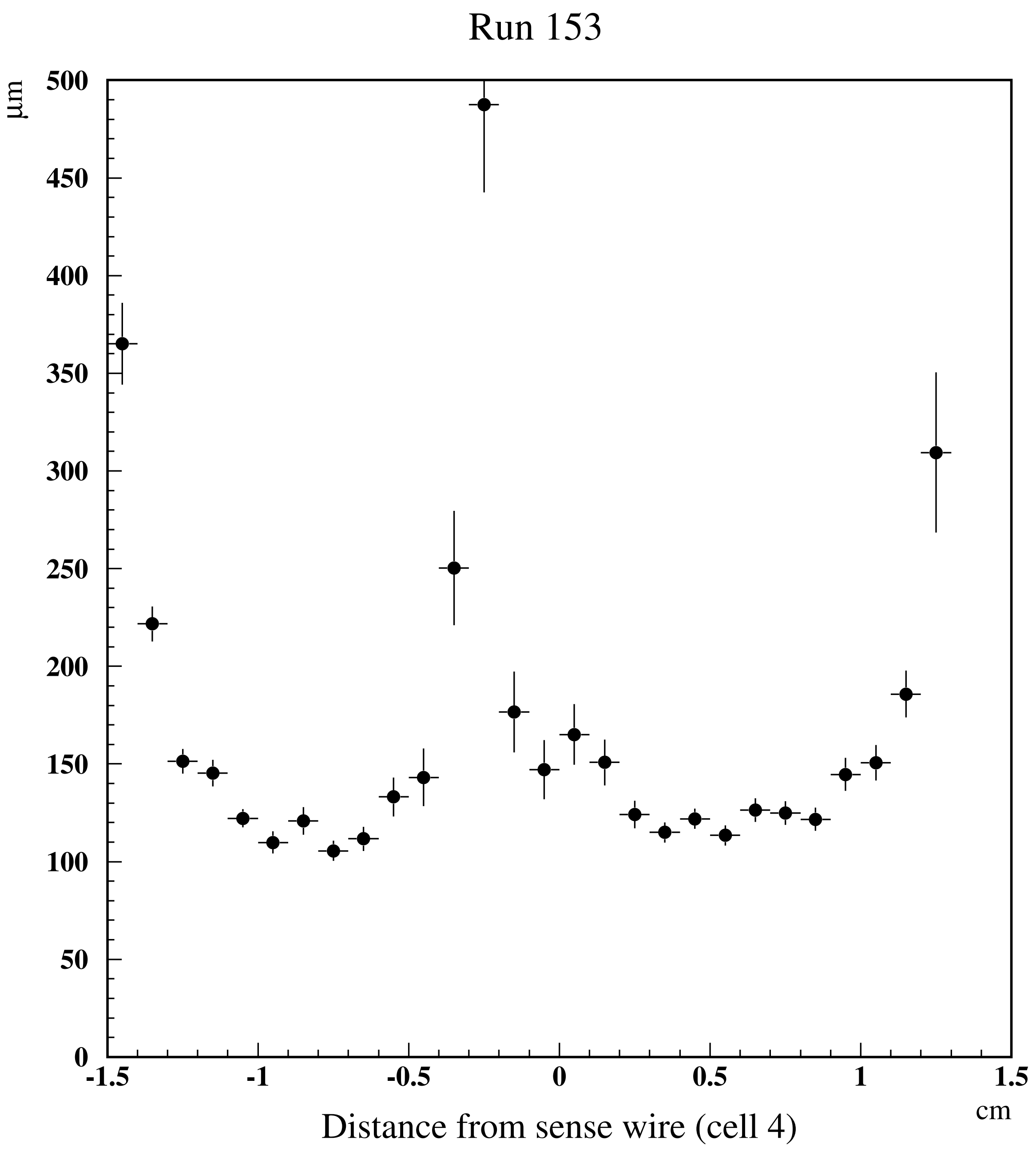

Fig. 7: *Sigma of the residuals of the stagger between cells 14 and 4, vs. the distance from wire 4. B=0.6 T.*