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Results from the Calypso chamber on an Ar 80% CO_2 20% gas mixture and Ar 91% N_2 4% CH_4 5% gas mixture, April 1997 Test Beam

C.Bini, P.Oberson, L.Pontecorvo and S.Rosati
Universita' di Roma "La Sapienza" and INFN Roma

M.Cambiaghi, C.Conta, M.Fraternali, A.Lanza, G.Polesello
Universita' di Pavia and INFN Pavia

Abstract

We present results on the maximum drift time, the resolution and the drift velocity obtained on the H8 test beam with the Calypso chamber using an Ar 80% CO_2 20% gas mixture and we compare them with those obtained using the Ar 91% N_2 4% CH_4 5% gas mixture.
We also present the method used to align the chamber with respect to the beam without the use of optical devices and the method used to obtain a fast determination of the drift velocity.

1 Introduction

In the ATLAS experiment the MDT have to provide the muon tracking on most of the detector's solid angle during the full LHC operation period of more than 10 years. The high irradiation due to photons and neutrons present on the chambers [1], could reduce their performance. Ageing tests on the tube materials and on the gas mixture have been performed [2],[3]. The results, though not conclusive, seem to indicate that the gas used so far for the MDT chambers (Ar 91% N_2 4% CH_4 5%, Datcha gas in the following) is quite sensitive to ageing problems. It was suggested that mixtures with no hydrocarbons could be less prone to ageing effects, and this led us to study the general characteristics of an Ar 80% CO_2 20% gas mixture. We report on this note the measurement of the maximum drift time, the space resolution as a function of the distance from the wire and the local drift velocity. Using the same data we will study the possibility of autocalibration using highly non linear mixtures as the one we used for this test.

In the following we present the experimental set up, the alignement method, the analysis togheter with the results and the conclusions.

2 Experimental set-up

The test was performed on the H8 B test area at CERN SPS, using 180 GeV/c muons. The test area was kept in free access during the test, and the beam was passing through an iron absorber 3.2 m thick before reaching the detectors. The beam dimensions in front of the block were about 2.5 mm r.m.s. in both directions and the angular spread was about 0.3 mrad. Behind the iron block the beam spread was more than 1.0 mrad, and the beam r.m.s. at the trigger position was about 6 cm. The trigger was given by the coincidence of the signals of two scintillators 10×10 cm^2 and 10×15 cm^2, the jitter of the trigger signal was about 0.3 ns and was dominated by the jitter of the 10×10 scintillator. The Calypso chamber has been already described in detail in [4]. It is a BIL chamber with 192 tubes organized in two multilayers of three staggered layers of tubes each. There are 32 tubes per single layer. Due to the small area covered by the trigger, only about four tubes per layer were illuminated by the triggered beam. Each tube was read by an electronic chain composed by a charge preamplifier, a shaper with 12 ns peaking time and a discriminator whose threshold was set to the equivalent of the charge produced by the arrival of 25 electrons, at a fixed gain of 2×10^4. The HV was set to 3615 V to obtain the required gain with the used Ar 80% CO_2 20% gas mixture at 3 bar absolute pressure (gas flow about 150 Nl/hr equivalent to about 4 volume changes per day). The discriminated signals were fed in 6 KLOE TDCs [5] with a 1.042 ns LSB. The TDCs were operated in common stop mode, the stop signal was given by the trigger signal delayed by about 2 μs by a dual timing unit. To take into account the jitter of the delayed signal with respect to the trigger signal we measured also the arrival time of the trigger signal. In such a way we can correct on event basis for the time fluctuation of the signal coming from the dual timing unit. In the following this correction was not applied because, since for this analysis we calculate only time differences, the jitter of the common stop signal is not relevant.

In Fig.2 we schematically show the experimental set up and we define the reference system; the X axis is taken as the direction of the muon beam, the Y axis is the direction of the wires while the Z axis is the coordinate along the chamber, wich is also the measured coordinate.

3 Alignement method

To obtain a fast determination of the space resolution, it is possible to study the distribution of the time difference between events recorded in two tubes (t_1 and t_3) placed at the same Z position with respect to the beam. As a matter of fact, for well aligned tubes, this distribution should be centered at zero, and its width divided by $\sqrt{2}$ is the individual tube intrinsic time resolution. Instead for a non aligned tube pair, if the R-T relation of the used gas mixture is non

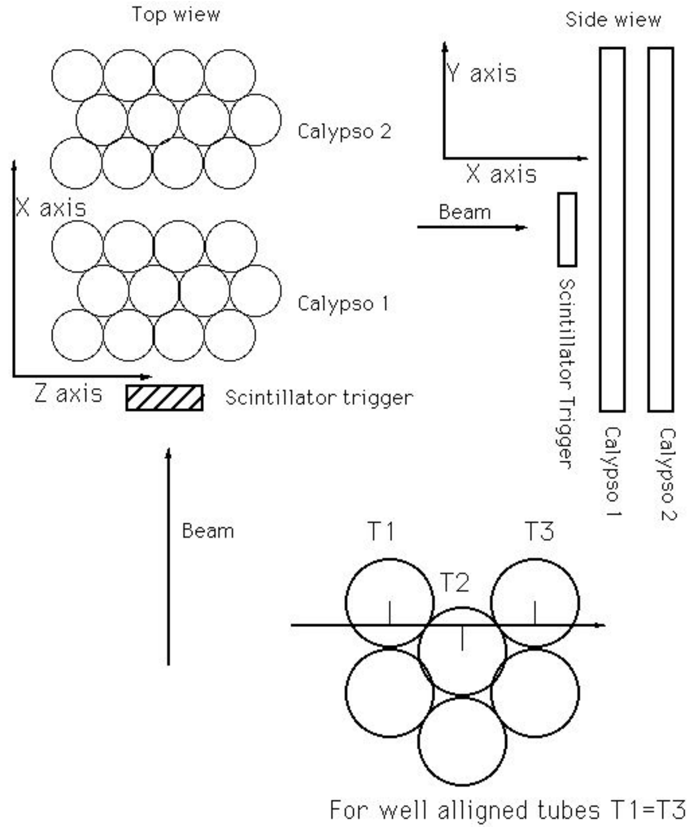
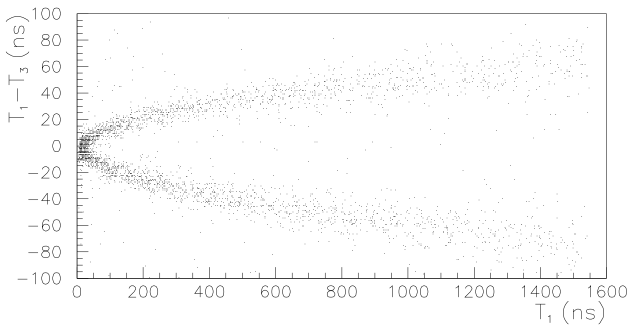


Figure 1: Schematic view of the experimental set up, the figure is not to scale.

linear, this width is systematically enlarged and a deeper and longer analysis, including tracking, is needed to obtain the intrinsic resolution. First we made a rough alignement using an oscilloscope. As previously explained, we expect that the signals from an aligned pair of tubes should arrive at the same time, so we rotated the chamber until this was accomplished with the resolution of the scope measurement (few ns). Then, to get a better alignement, we took data (typically 10000 events) and we studied the distribution of the time difference of the signals of the two tubes as a function of the drift time measured in the first tube.

In Fig.3 we show this distributions at the beginning and at the end of the alignement procedure. The two arms of the plots are due to the opposite sign of the time difference $t_1 - t_3$ for tracks going above and below the wires. The distance between the two arms is directly related to the angle between the beam and the chamber, and the aim of the alignement procedure is to minimize this distance. After the alignement the angle between the beam direction and the chamber was about 1 mrad.



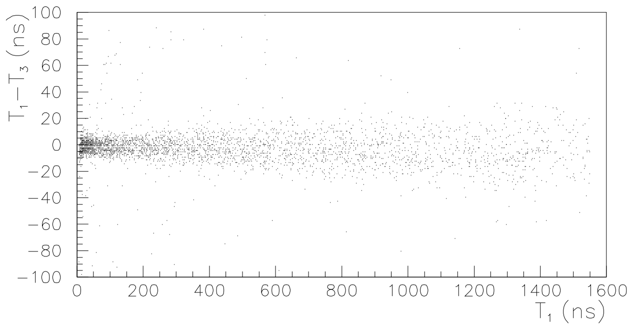


Figure 2: Plot of the time difference between tube 1 and 3 (see Fig. 1) vs the measured time in tube 1 before alignement (upper plot) and after alignement (lower plot)

4 Analysis and Results

The maximum drift time was measured studying the raw time spectrum of the tubes. We fit these spectra by appropriate functions [6] containing two Fermi-Dirac functions, describing the rise and the fall of the time spectra. It is then obtained by summing about 30 ns to the difference between the two Fermi-Dirac parameters giving the inflection points of the rise and the fall of the spectrum.

In Fig. 4 are shown the fitted spectra for the two gas mixtures. Since the gas was flowing in a series of nine tubes we checked whether the width of the spectrum was the same for all the tubes. The result of this measurement is shown in Fig. 4 where no systematic difference in the width of the spectrum is observed for the tubes.

A simple method based on the correlation of the times of two almost aligned tubes (tubes 1 and 3 in the following) has been used to get (i) the drift velocity profile and hence a first step R-T relation and (ii) the space resolution of the drift

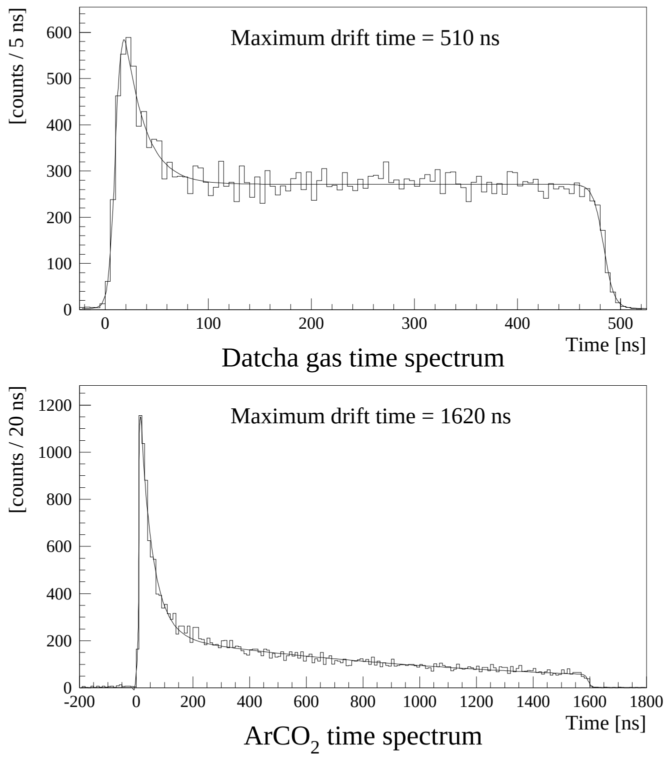


Figure 3: Raw time spectrum with superimposed fit for Ar CO_2 (upper plot) and Datcha Gas (lower plot).

tube as a function of the drift distance r. In the following we first describe the method to measure the drift velocity profile and the R-T relation and then the measurement of the space resolution. Finally we describe how we have evaluated the beam angular spread in order to subtract it in the determination of the space resolution.

4.1 Drift velocity and space-time relation measurement

Suppose to have a beamline forming a small average angle θ with the chamber axis. The average time difference Δ between the tube 1 in the first layer and the tube 3 in the third layer at a distance d from tube 1 along the beamline, is the function of t, $\Delta(t) = \Delta r / v_d(t)$, where $\Delta r = \theta \times d$ and $v_d(t)$ is the local drift velocity averaged over a distance Δr. The drift velocity profile is then given by:

$$v_d(t) = \frac{\theta \times d}{\Delta(t)} \tag{1}$$

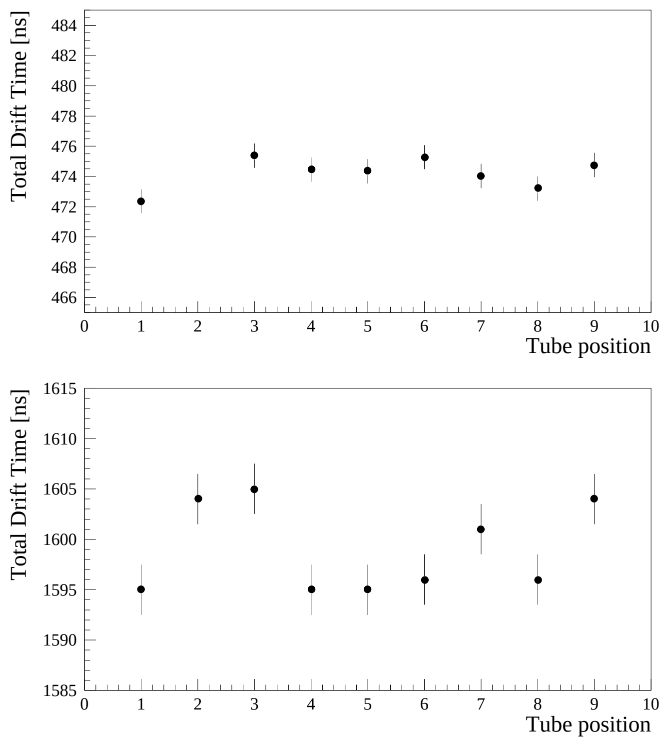


Figure 4: Width of the time spectrum measured on nine tubes of Calypso 1 as a function of the tube position on the gas flow chain for Datcha gas (upper plot) and for Ar CO_2 (lower plot)

If the angle θ is such that Δr is of the order of the bin size used for the tube calibration (that is $\sim 300\mu m$) an average drift velocity can be evaluated for every bin. In order to get θ that is normally not well known, the integral of the function $v_d(t)$ between $t = 0$ and $t = T_{max}$ can be imposed to be equal to the maximum drift length $R - \epsilon$, R being the tube outer radius and ϵ the wall thickness. The condition to be imposed can be written as follows:

$$\int_{T_h}^{T_{max}} v_d(t)dt = R/2 - \epsilon \quad (2)$$

where we have introduced T_h that is the drift time corresponding to the passage of the particle at the distance of $R/2$ from the wire that can be simply evaluated using the staggered second layer tube 2. In this way the evaluation does not depend on events passing close to the wires where the behaviour of the drift tube is less well established. If we divide the radius R in bins of width $\sim \Delta r$

the integral in (2) becomes a sum over all the time bins between T_h and T_{max} and (2) gives:

$$\theta = \frac{(1/d) \times (R/2 - \epsilon)}{\sum_{i=i_h}^{i_{max}} \frac{\delta}{\Delta(t)_i}} \quad (3)$$

with δ the bin size. So putting the obtained value of θ in (1) we get the drift velocity profile.

Integration of (1) gives directly the R-T relation according to the:

$$x(t) = R/2 + \sum_{i_h}^{i_t} \frac{\Delta r}{\Delta(t)_i} \delta$$

if $t > T_h$ and

$$x(t) = R/2 - \sum_{i_t}^{i_h} \frac{\Delta r}{\Delta(t)_i} \delta$$

if $t < T_h$.

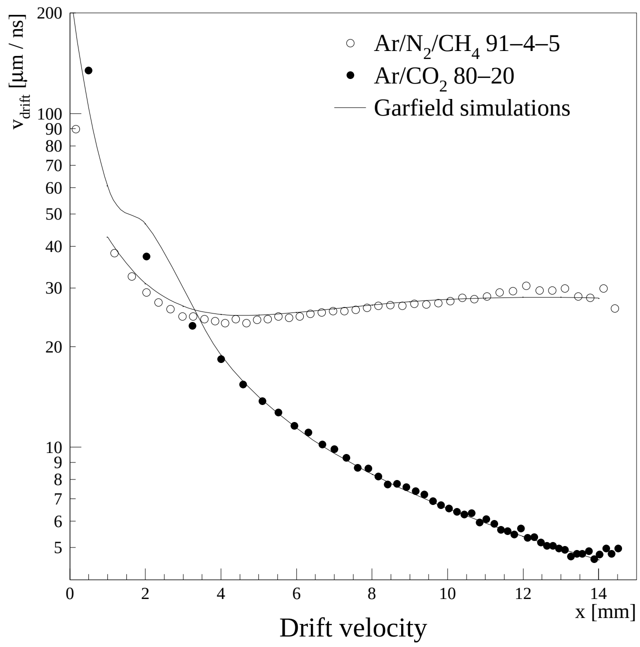


Figure 5: Measured drift velocity as a function of drift distance from the wire for Ar CO_2 and Datcha Gas. The measurements are compared with GARFIELD calculations

In Fig.4.1 the drift velocity profiles thus obtained were compared with Monte Carlo simulations for both gas mixtures [7],[8]. The agreement turns out to be quite good for the Ar CO_2 mixture, while an overall discrepancy of the order of 15% is observed for the Datcha gas. The latter is essentially due to the larger maximum drift time obtained in the data with respect to the simulation.

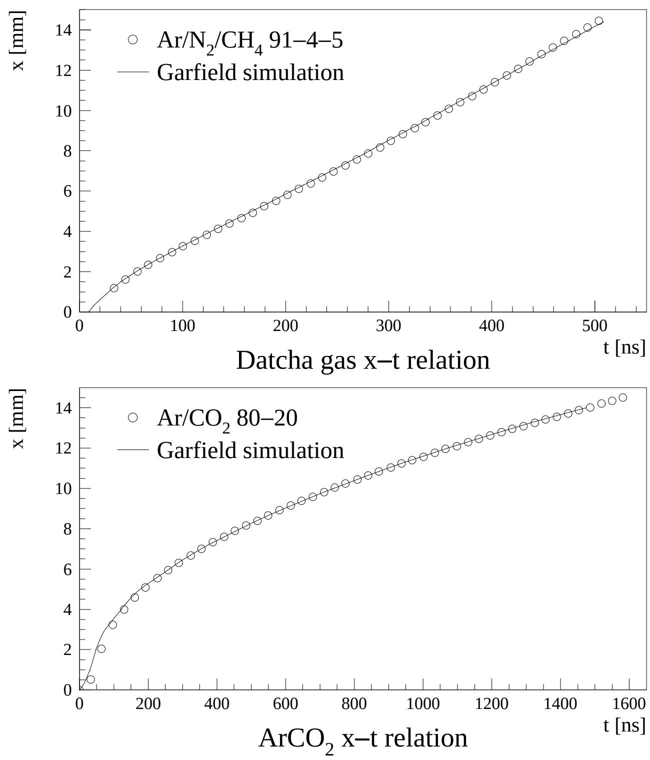


Figure 6: Measured R-T relation for Datcha gas (upper plot) and Ar CO_2 (lower plot). The measurements are compared with GARFIELD calculations

Finally Fig.4.1 shows the same comparison for the space-time relations. We stress here that this evaluation of the space-time relation has not the required level of accuracy for tracking. In any case it is accurate enough to get the space resolution (see next subsection) and can be used as the step 0 R-T relation in the autocalibration procedure.

4.2 Space resolution evaluation

For every measured value of the drift time t, r is obtained by means of the R-T relation. So a given time spread $\sigma(t)$ is related to a spread in the space coordinate

r through the local drift velocity

$$\sigma(r) = v_d(t) \times \sigma(t)$$

$\sigma(t)$ can be obtained by measuring the $\sigma(t1 - t3)$ for every value of r and dividing it by $\sqrt{2}$.

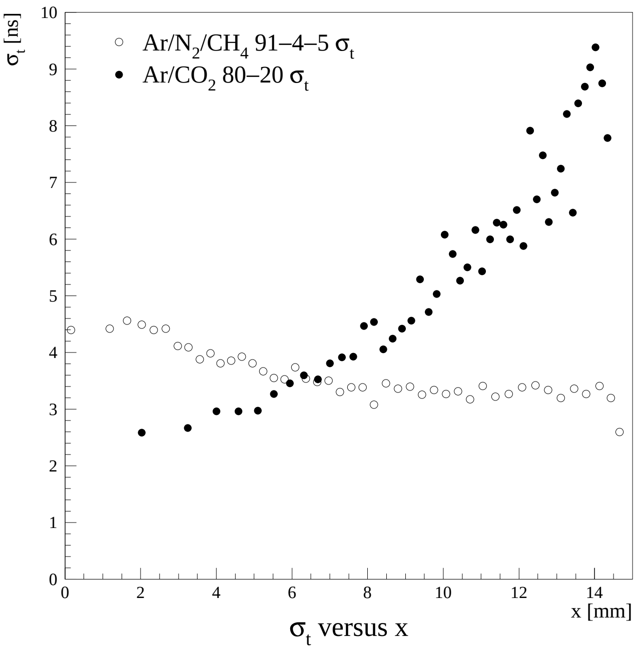


Figure 7: Measured time resolutions as a function of the distance from the wire for Ar CO_2, and Datcha Gas.

Fig.4.2 shows the dependence of $\sigma(t)$ on r for both gas mixtures.

4.3 Beam angular spread subtraction

The angular spread of the beam affects directly the measured space resolution of an amount given by the convolution of the intrinsic resolution with $\alpha \times d$, α being the r.m.s. of the angular spread.

In order to evaluate this contribution, the resolution as a function of the distance d has been measured, by using two other aligned tubes belonging to the same line. In this way we have a value of $\sigma(r)$ corresponding to 4 different values of d.

Fig.4.3 shows the resolution as a function of d measured at distances of about $R/2$ and R from the wire. The resolution can be fitted with a dependence like

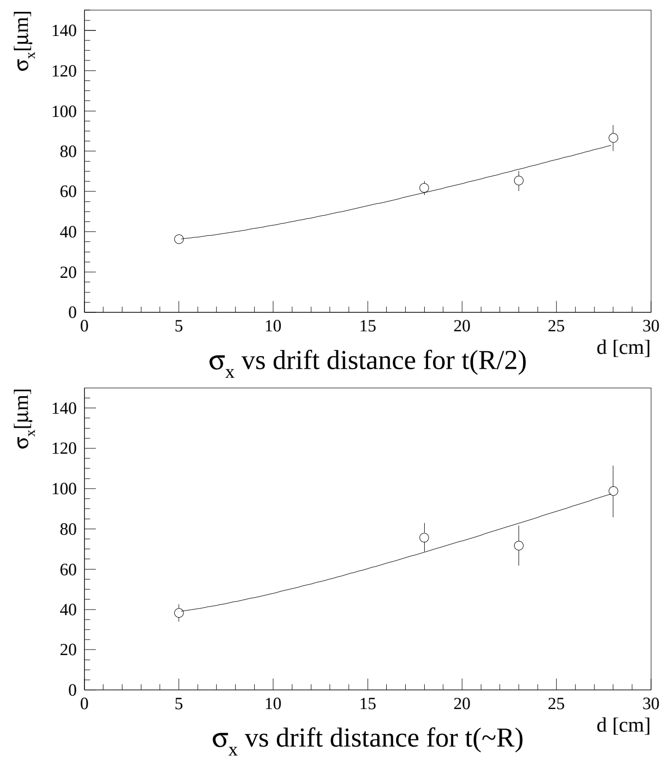


Figure 8: Measured resolution as a function of the distance between two aligned tubes. From this we measured the beam divergence.

$\sqrt{\sigma^2(d=0)+\alpha^2 d^2}$. From the fit α turns out to be 300 μrad hence the value to be subtracted is $\sim 15\mu m$. After subtracting the beam spread contribution we obtain the measured tube resolution for the two gas mixtures, and we plot them in Fig.4.3 with the results of the Monte Carlo simulation. We note that this measurement has to be refined by a more complete analysis including tracking.

5 Conclusions

We have operated the Calypso chamber with an Ar 80% CO_2 20% gas mixture at a voltage of 3615 V corresponding to a gain of 2×10^4. We have measured the maximum drift time and obtained a determination of the space resolution, of the local drift velocity and of the R-T relation. As it was expected the maximum drift time (1550 ns) is too long for LHC operation and the R-T relation is highly non linear, but on the other hand we have a mixture that is much less sensitive on ageing problems and that has a good spatial resolution. It would be very

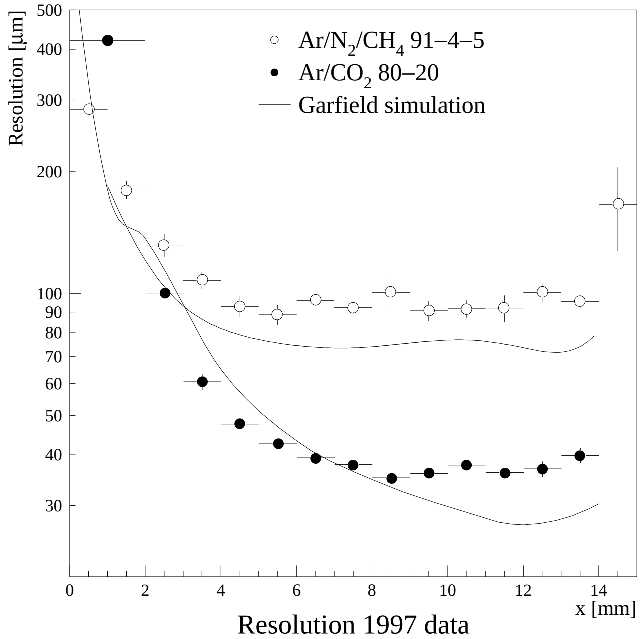


Figure 9: Measured resolution as a function of the distance from the wire for Ar CO_2 and Datcha gas. The resolution is compared with results from Monte Carlo calculation

interesting to investigate other Ar CO_2 based mixtures, with smaller maximum drift time and better R-T relation, while profitting of the high spatial accuracy of this kind of mixtures.

References

[1] G. Battistoni et al. Background calculation for ATLAS detector and hall. ATLAS internal note GEN-NO-10 1994, also in Atlas technical proposal, Cern\lhcc\94 -43 lhcc\P2 15 Dec 1994

[2] M. Spegel et al. Detector physics meeting, Communications CERN 1997

[3] W. Mohr et al. Detector physics meeting, Communications CERN 1997

[4] A. Biscossa et al. The first full scale prototype of a BIL MDT chamber for the ATLAS muon spectrometer Muon note N 136 1997

[5] M. Passaseo, E. Petrolo, S.Veneziano private communications

[6] P. Bagnaia et al. Measurement of the maximum drift time in the CALYPSO chamber MUON note 158 1997

[7] W. Riegler MDT resolution simulation, front end electronics requirements MUON note 137

[8] R. Veenhof GARFIELD CERN program library w 5050