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Studies of the expected TPC performance at $Ecm = 140$ GeV for different sense wire voltages

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Abstract

The performance of the ALEPH TPC detector at $Ecm = 140$ GeV is studied with a Monte Carlo simulation and an experimental set-up using a test chamber with different sense wire high voltages. Figures of track efficiency, momentum resolution and dE/dx resolution are presented.

Contents

1 Introduction

Late this year it is planned to increase the energy at LEP to 70 GeV per beam. A consequence of increasing the energy is that the synchrotron radiation will increase, despite the currently installed shieldings. In order to be prepared, we have studied the TPC performance in case we will be forced to decrease the sense wires voltage if problems in charge collection due to background appear.
To find out the track efficiency, momentum resolution and dE/dx resolution for different values of voltages, we have simulated the TPC track detection at different values of the charge amplification factor at the sense wires. After the simulation, it is necessary to relate the charge amplification to the sense wire voltage, in order to find the TPC performance for different voltages. That relation can only be found by means of an experimental study. Test chamber T1 was used to find the relation assuming it behaves in the same fashion as TPC sectors.

2 Monte Carlo simulation at $Ecm = 140\ GeV$

2.1 Samples

Two samples of Monte Carlo events at this energy have been generated with KINGAL software. With the DYMU02 generator we have produced a sample of 1000 di-muon events wich we used in the study of TPC momentum and dE/dx resolutions. Also, with LUND04 we have generated a sample of 50 hadronic events. From this sample, we got the dE/dx resolution for minimum ionizing particles. Track efficiency has been measured using all tracks with momentum greater than 2 GeV from the hadronic events. Both generators use the JETSET generator program.

2.2 TPC simulation

GALEPH and TPCSIM software have been used in the TPC simulation. Gas amplification factor or gas gain is one of the most important parameters of the TPC detector. In TPCSIM that parameter is controlled by a data card (*AMPLI* data card) [1]. Then, several TPC simulations have been produced with different values of gas gain in order to study the TPC performance in each case. The values of the gas gain have been varied from 8000 to 500.
The value of the amplification factor in normal TPC conditions is equal to 6750 that corresponds to 1250 V applied to the sense wires.

2.3 Track reconstruction

Gas gain variations not only modify the TPC track reconstruction performance, but they also change the track identification. After JULIA reconstruction, we have measured track efficiency, momentum resolution and dE/dx resolution for each TPC simulation using the corresponding track samples.

2.3.1 Track efficiency

We can define track efficiency as the following ratio:

Number of JULIA reconstructed tracks associated to true tracks/ Number of Monte Carlo tracks

As we can see in figure 1 a, track efficiency at the normal gas gain value is about 96 %. Gas gain is normalized to the nominal value 6750. Small variations in gas gain do not change track efficiency.
Also, track efficiency is related with the number of pad hits (or coordinates) found per track. We have evaluated this efficiency with the ratio:

Number of hits for the JULIA track / Number of expected hits for the associated Monte Carlo track

In figure 1 b we show this efficiency; we can see it is more sensitive to gas gain variations than the other efficiency.

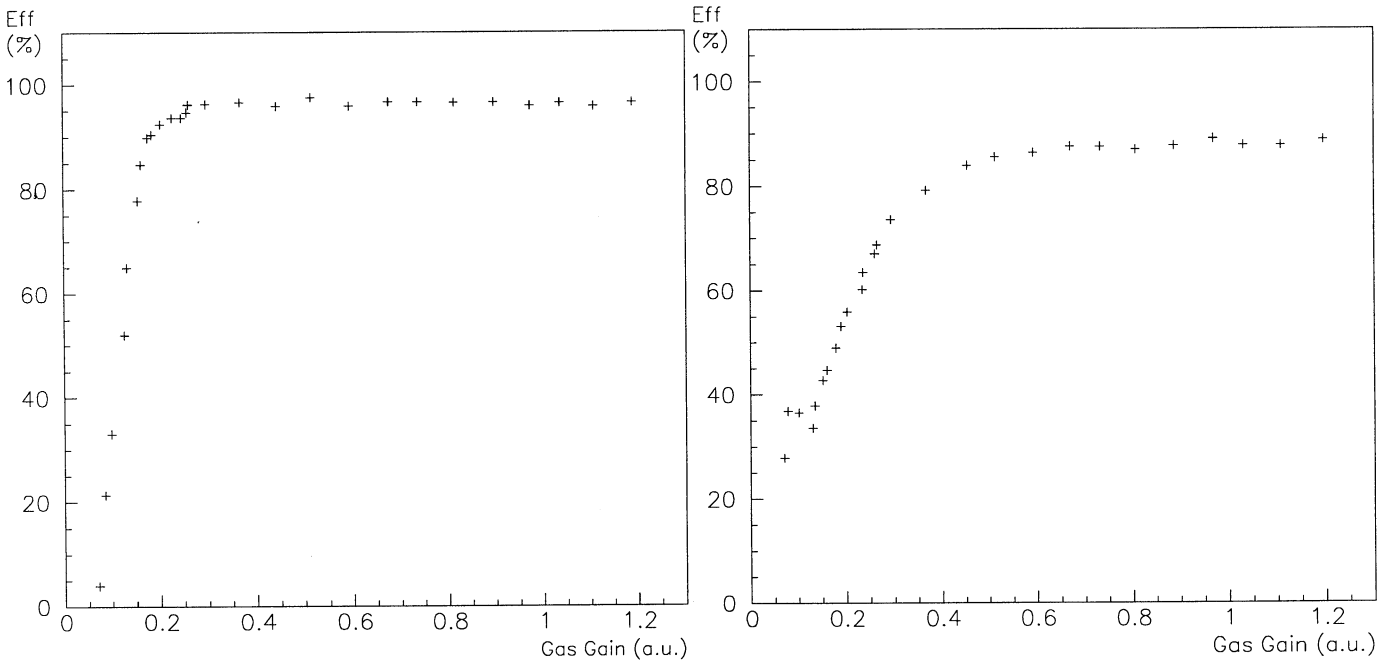

Figure 1: Track efficiency: (a) ratio of tracks number (in %) versus gas gain, (b) ratio of hits number (in %) versus gas gain

Momentum resolutions for each TPC simulation have been measured with the sigma and the mean of the distributions of the ratio:

Measured muon momentum / Monte Carlo muon momentum

The distributions of the momenta ratio for some values of gas gain are plotted in figure 2. The mean and the sigma of the distributions are found with a gaussian fit.

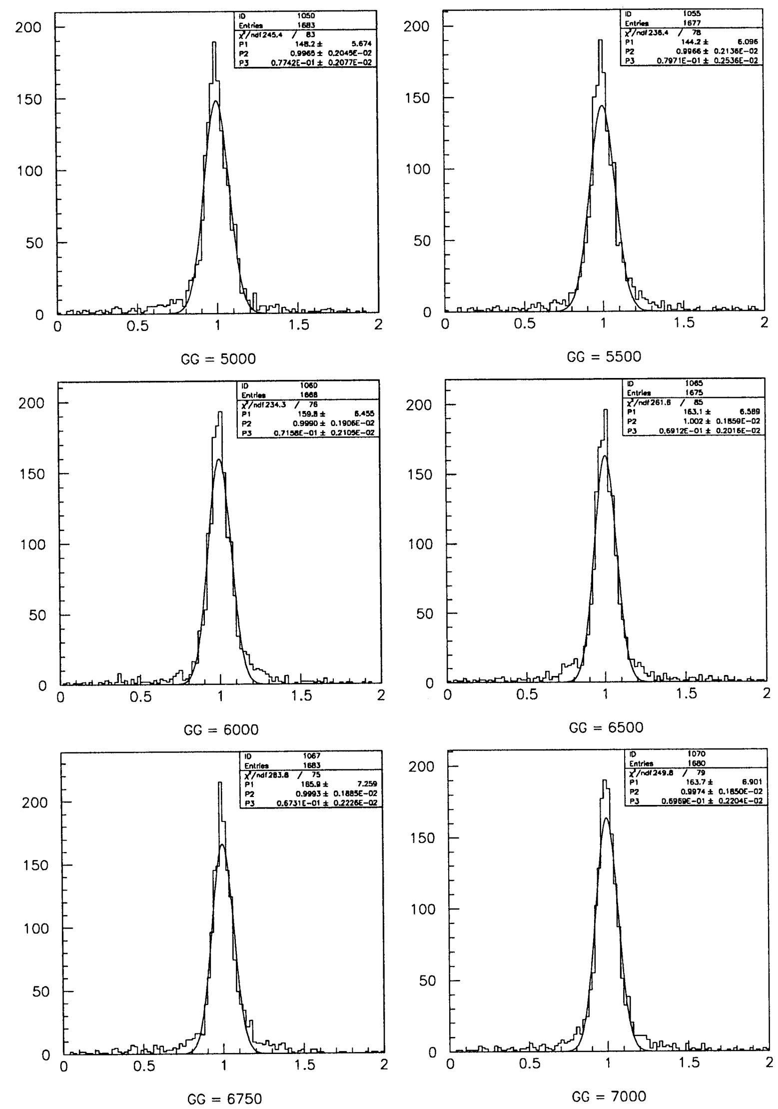

Figure 2: Momentum distributions for muons from $Z^0 \rightarrow \mu^+\mu^-$ decays

In figure 3 we can see the resolution loss. For gas gain equal to 1, this corresponds to a resolution of about 7 %.

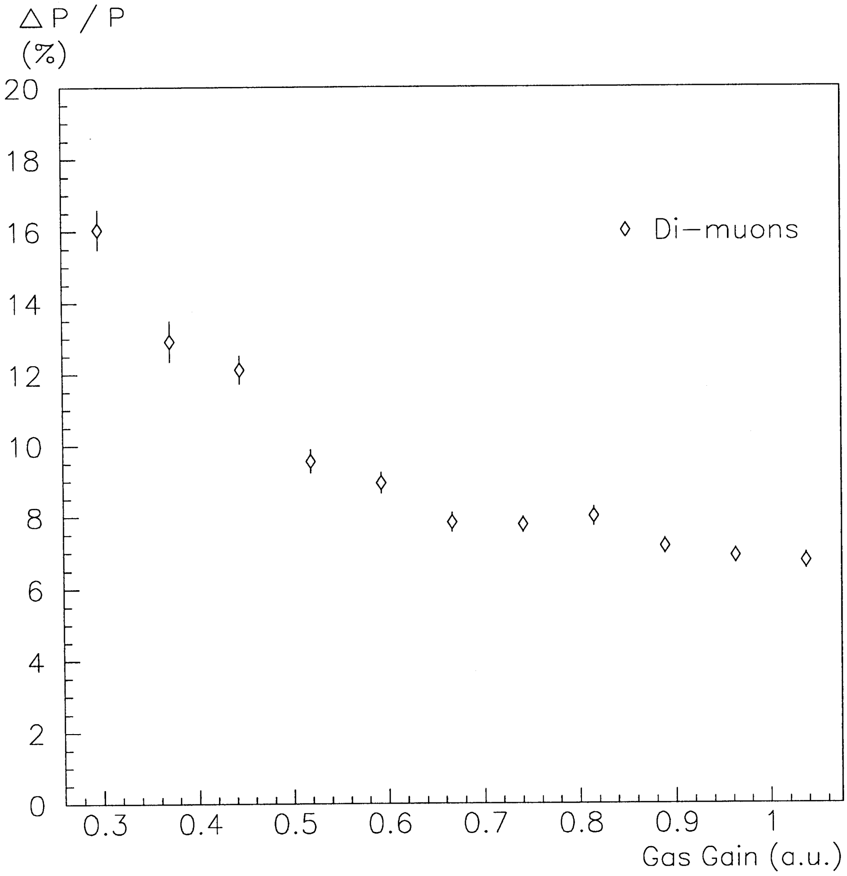

Figure 3: Momentum resolution (in %) for muons from $Z^0 \rightarrow \mu^+\mu^-$ decays versus gas gain.

2.3.2 *dE/dx* resolution

To measure the *dE/dx* resolution, we have produced the *dE/dx* distributions of the double truncated mean ionizations (calculated with the *QDEDX* ALPHA [2] routine) for the sample of di-muons, and for the sample of minimum ionizing particles (mips). Muon distributions for some values of gas gain and the gaussian fits are shown in figure 4.

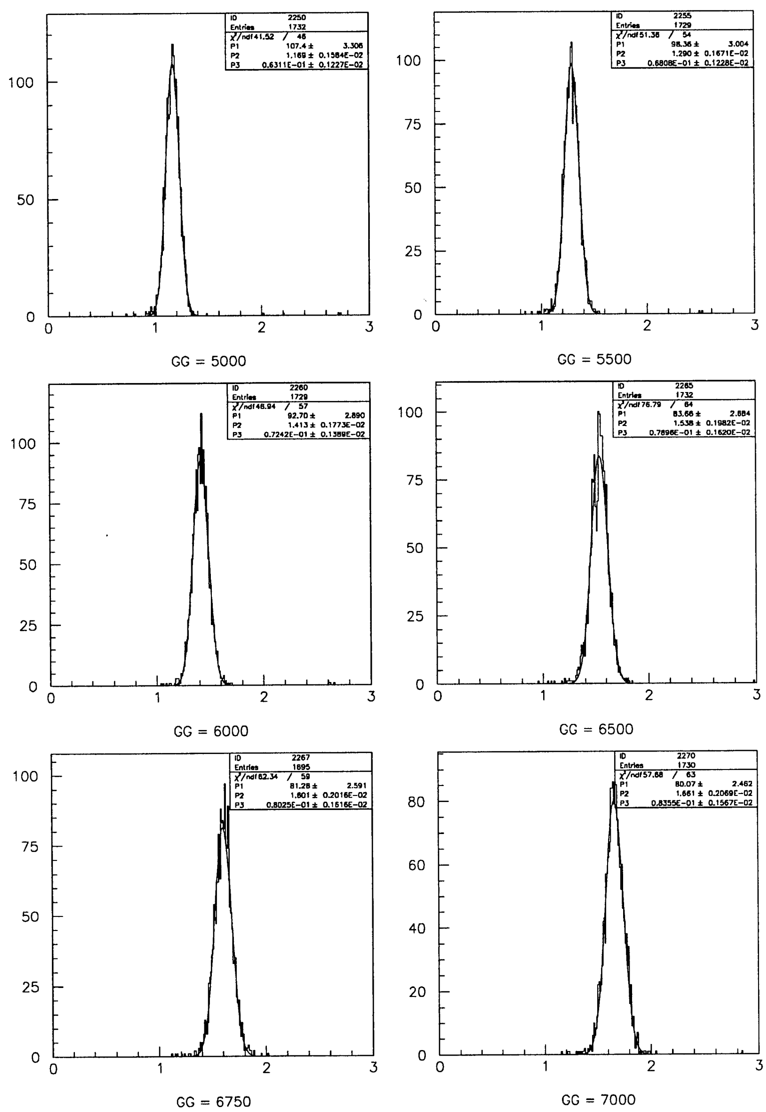

Figure 4: dE/dx distributions for muons from $Z^0 \rightarrow \mu^+\mu^-$ decays

Some mip distributions are shown as well in figure 5. A mip is a "good track" with: $0.3GeV < momentum < 0.6GeV$

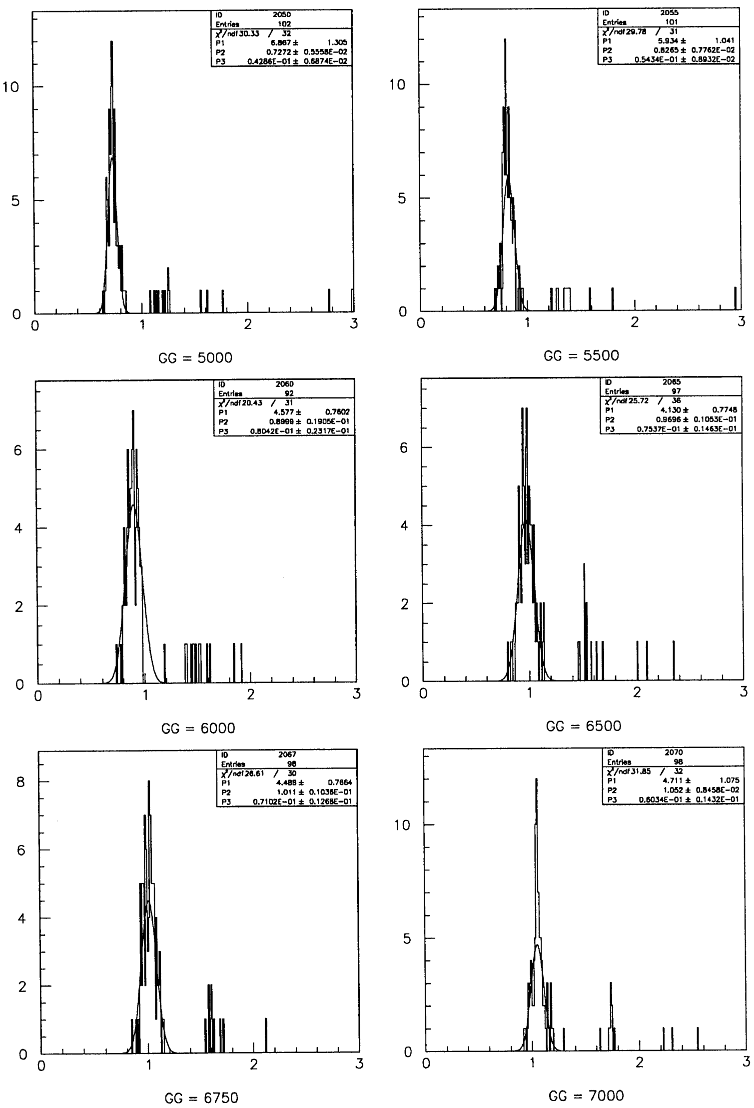

Figure 5: dE/dx distributions for minimum ionizing particles

Figure 6 shows the resolutions of the distributions versus gas gain. Note the error bars for mips due to the statistics.
At the normal gas gain value, the resolution for mips is about 7 %, and for di-muons it is about 5 %.

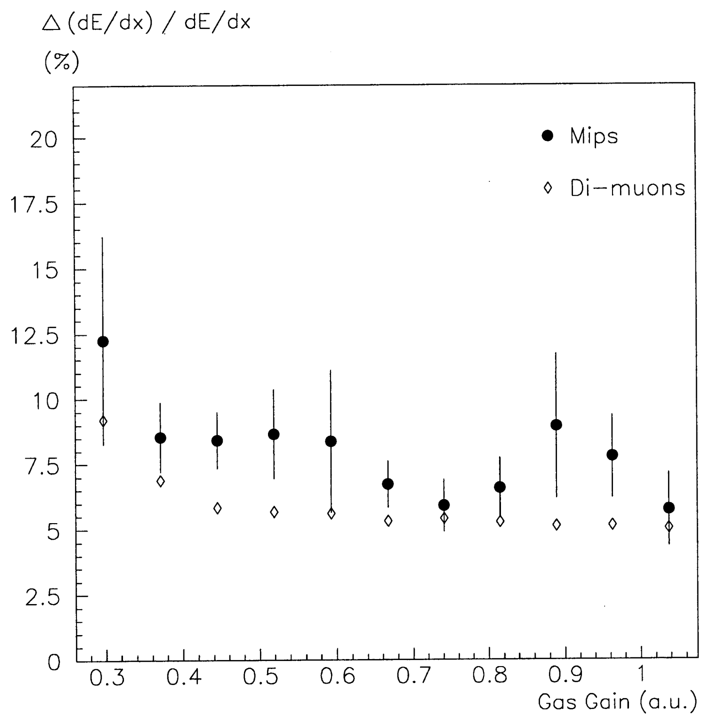

Figure 6: dE/dx resolution (in %) for dymuons and mips versus gas gain.

3 Voltage dependence of gas gain for the ALEPH TPC test chamber T1

In order to understand the relation between gas gain and sense wire voltage in TPC sectors, we have used the test chamber T1 at the Meyrin Site and have varied the sense wires voltages. The test chamber has the same wire geometry and it is filled with the same gas mixture as the TPC sectors.

3.1 Experimental set-up

Test chamber is described in [3]. With a radioactive source of Fe^{55} (gamma source) in the test chamber, we control gas gain by measuring the photopeak's mean in the energy spectrum. The photopeak's energy corresponds to the charge deposited on the sense wires after the avalanche produced by argon photoelectrons. In figure 7, we see the Fe^{55} energy spectrum when the voltage of the sense wires is equal to 1250 V.

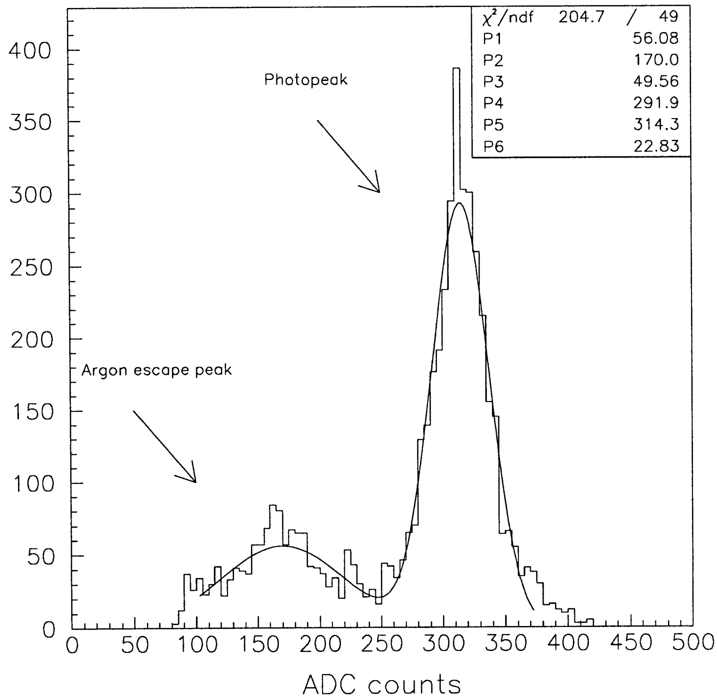

Figure 7: Fe^{55} energy spectrum. ADC count is the energy unit.

As in a TPC sector, the charge from the sense wires is transformed into a proportional pulse with the preamplifier. Then, the pulse is amplified and shaped with the shaping amplifier. The height of all the shaped pulses (gaussian-like pulses) are measured by a *LeCroy 3512 ADC* placed in a *CAMAC* crate.
The *ADC* is read using a Macintosh computer which is connected to the *CAMAC* crate by means of a *MacVEE* card in the Mac and a *MacCC* card as a *CAMAC* crate controller. The *LABVIEW* application software is used to perform the data acquisition.

3.2 High voltage dependence

The relationship between gas gain **G** and sense wire voltage **V** has been found fitting the values of gas gain measured for several high voltages. The fit corresponds to the following relation:

$$\frac{\Delta G}{G} = k \, \Delta V$$

The range of voltages studied is [1130 V, 1250 V]. In figure 8 we show the exponential fit which gives the value of the slope $\mathbf{k} = \mathbf{0.01239}$. It corresponds to a reduction of a factor 2 for the gas gain when the voltage is reduced by about 60 V.

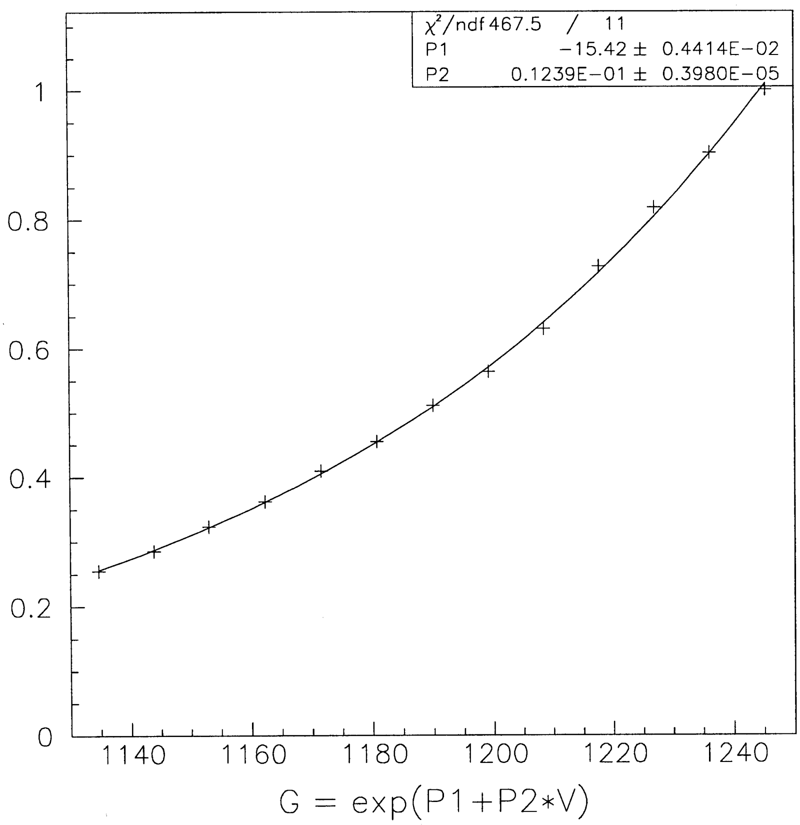

Figure 8: Gas gain versus voltage for the TPC test chamber T1. The fit is an exponential and the slope is equal to 0.01239

4 Final results

Assuming that the dependency between voltage at the sense wires and gas gain found for the test chamber is equivalent to that of the TPC sectors, the TPC performance studied in section 2 is now related to sense wire voltages.
First, track efficiency has been represented as a function of voltage as we see in figure 9.

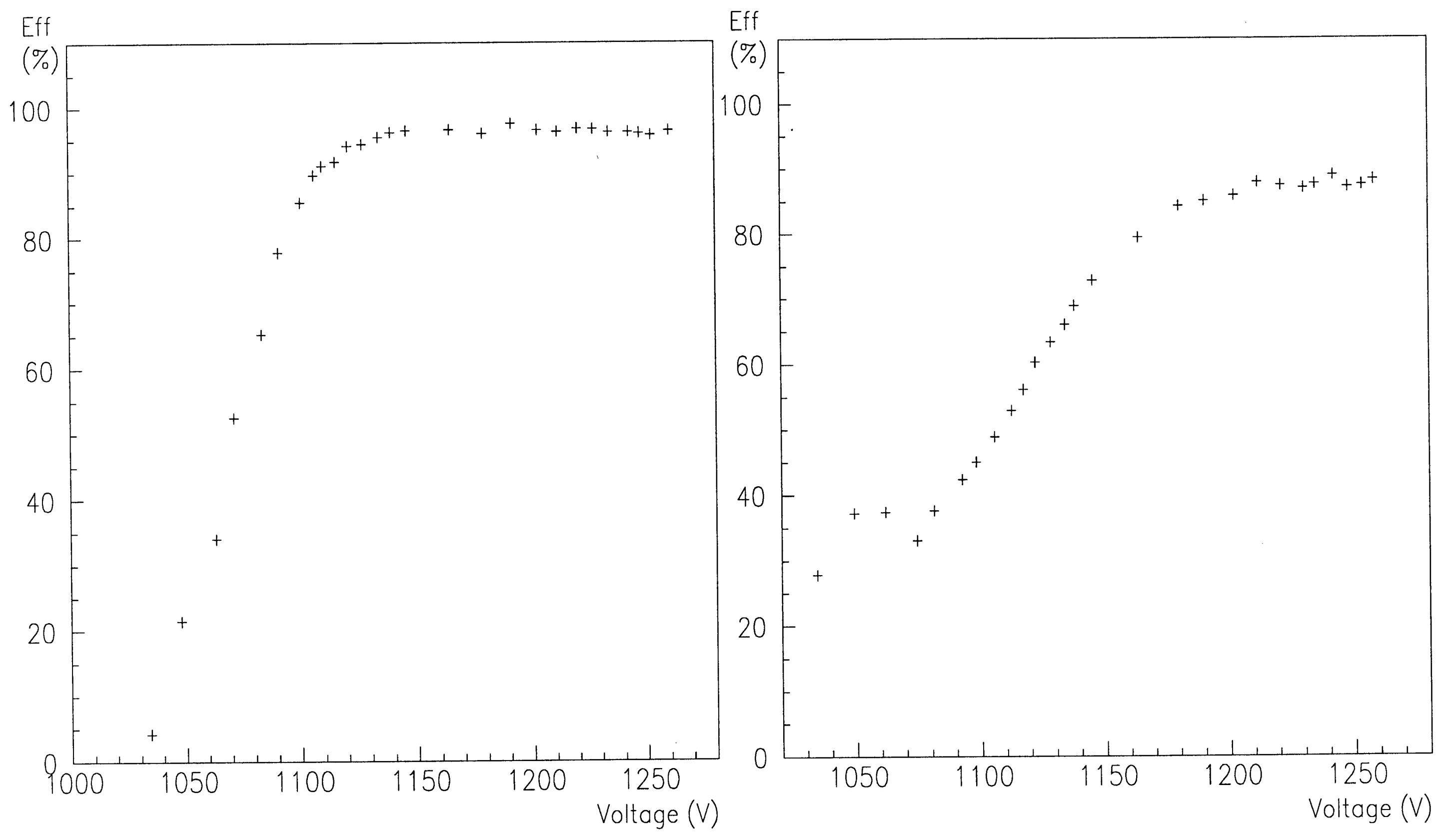

Figure 9: Track efficiency: (a) ratio of tracks number (in %) versus voltage, (b) ratio of hits number (in %) versus voltage

Momentum resolution has been also represented in relation to voltage, as shown in figure 10.

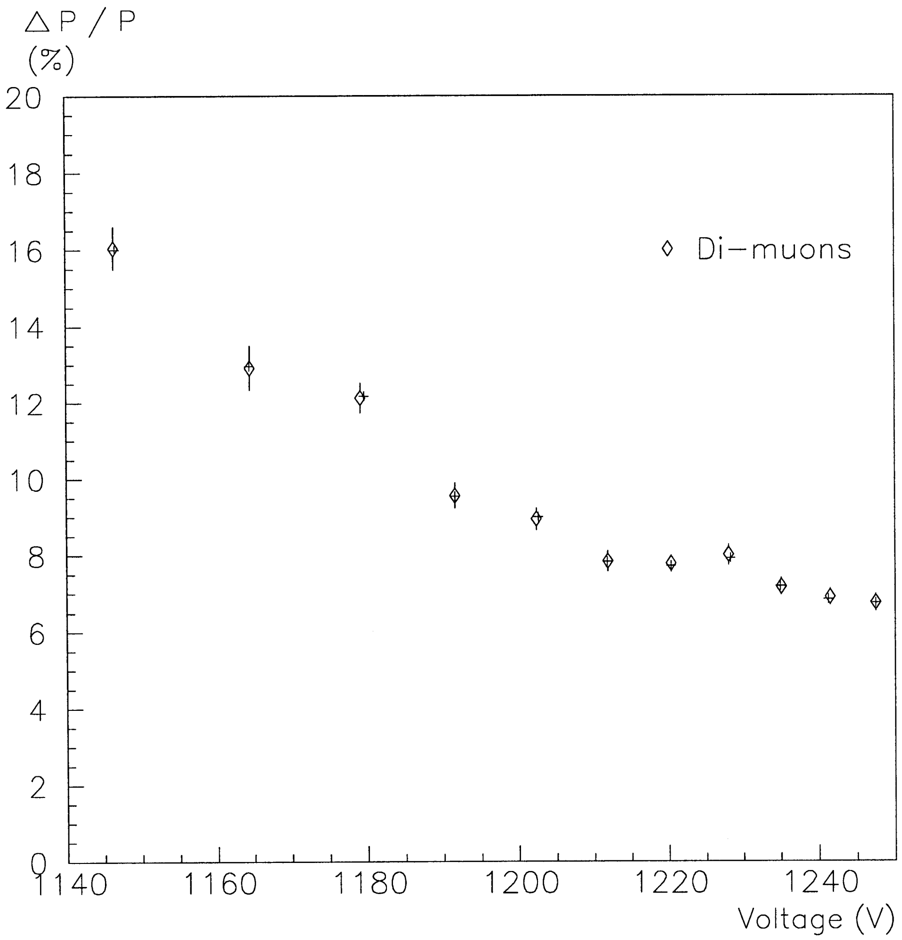

Figure 10: Momentum resolution (in %) for di-muons versus sense wires voltage (in V)

Finally, in figure 11 we have plotted dE/dx resolutions.

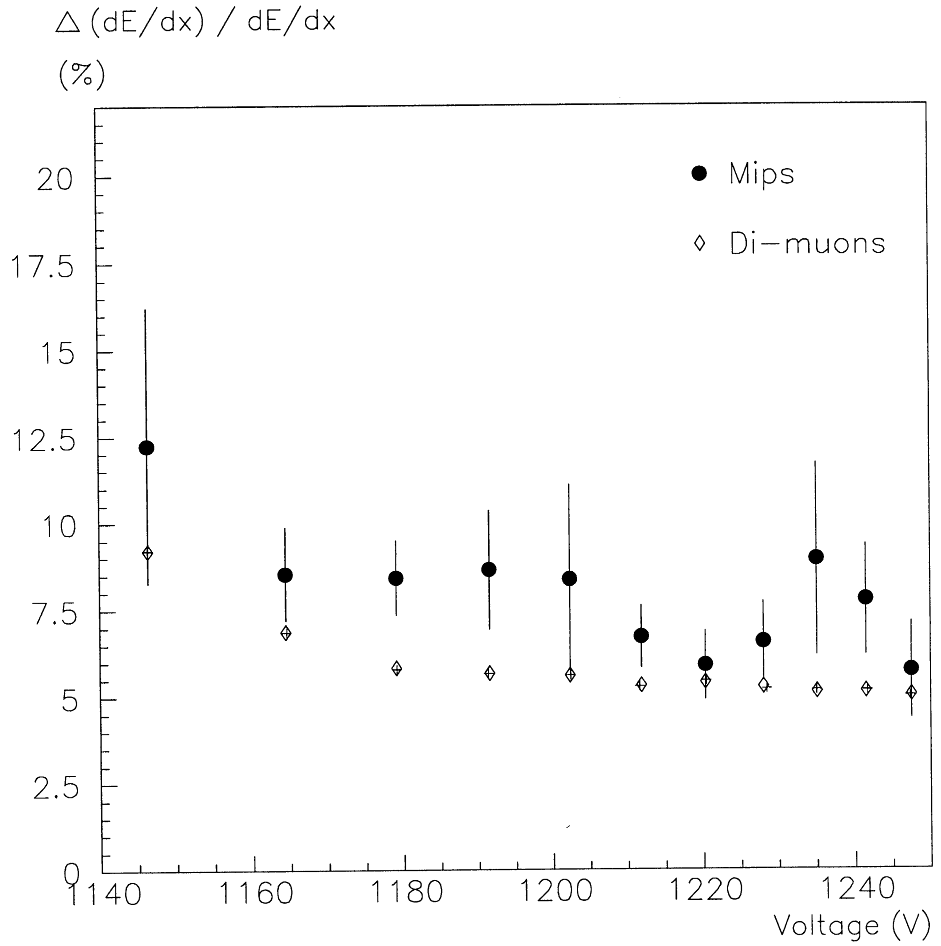

Figure 11: dE/dx resolution (in %) for di-muons and mips versus sense wires voltage (in V)

References

[1] D. Cowen et al. *TPCSIM V2.01* ALEPH 88-42, March 1988

[2] J.Boucrot et al. *ALPHA user's guide. Version 117/118* ALEPH 94-092, June 1994

[3] O. Gómez. *Gas Gain for the ALEPH TPC Test Chamber* ALEPH 93-158, Oct 1993