# NEW Z BOSON PHYSICS WITH A SPECIALIZED MUON DETECTOR OF THE L3 TYPE AT THE SUPERCOLLIDER

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## 1. Introduction

The discovery of a new Z boson is probably one of the main physics goals at the Supercollider. Its decay into lepton pairs would be a clear signature. Indeed, recent work in theoretical physics seems not to dislike the possibility of an enriched neutral current sector in the unbroken symmetry at the Planck mass scale[1] .

Should the new Z have a mass above or in the vicinity of 1 TeV, the background in the lepton pairs from conventional sources would be negligible at the energy of the SSC. On the other hand, a narrow resonance will probably require a good energy resolution for a precision study. In particular, it would be a great success if experiment could soon discriminate among all the different models by determining the vector and axial vector couplings of the new particle.

Measuring the electron decays is one alternative which offers the possibility of having good momentum resolution . I will study here some aspects of the muon alternative, which provides good lepton identification and allows to determine easily the charge sign. Conventional muon detectors using magnetized iron allow in principle to cover a large rapidity interval, being the total cost of the detector an actual limitation[2] . On the other hand, they have an intrinsic momentum resolution of at best 15 % in the TeV range. A precision detector of the L3 type can provide a better resolution, although over a limited rapidity range.

I will present here a possible way to optimize energy resolution and hermeticity in a realistic detector.

## 2. The L3 + 1 detector

Following the principles of external measurement of the sagitta and active alignment developed in the L3 detector at LEP[3] a proposal has been made[4] for a realistic scaling of its parameters (magnet and drift chambers) to operate in the TeV momentum range maintaining a resolution $\Delta p/p$ of 2 %. Fig. 1 shows the end view of the L3 + 1 detector. The momentum analysis is done over a length of 5.5 m in three sets of chambers having $32-64-32$ wires respectively, with single wire precisions of 150 $\mu$m. It is assumed that a 20 $\mu$m alignment accuracy can be achieved with appropriate optical monitors. The sagitta of a 0.5 TeV muon is 1720 $\mu$m in a 7.5 KG field, and the measurement precision with 20 $\mu$m alignment error is about 34 $\mu$m or 2%.

A multilayer Uranium and Tungsten calorimeter acts as hadron absorber, and also measures the muon energy loss in the TeV energy regime, which is needed to improve accuracy in the mass of the muon pairs. At the design energy of the Supercollider, a particle of mass 1 TeV (which decays into $\mu+\mu-$), will be produced in a rapidity interval between $-2.5$ and 2.5. Fig. 2 shows the geometrical acceptance for single muons and dimuons, as a function of the minimum detection angle. The acceptance for dimuons at 40 degrees is small (14%) . Moreover, since charge asymmetries arise in pp as a function of the rapidity, and only decay angles in the rest frame of the particle close to $\theta^* = \pi/2$ are detected, the observation of these charge asymmetries becomes very difficult. This is illustrated in Fig. 3.

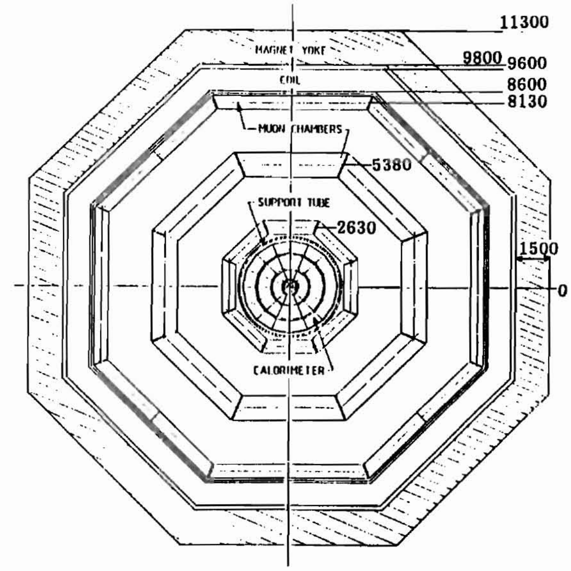


Figure 1. End view of the L3+1 detector, from Ref. 4

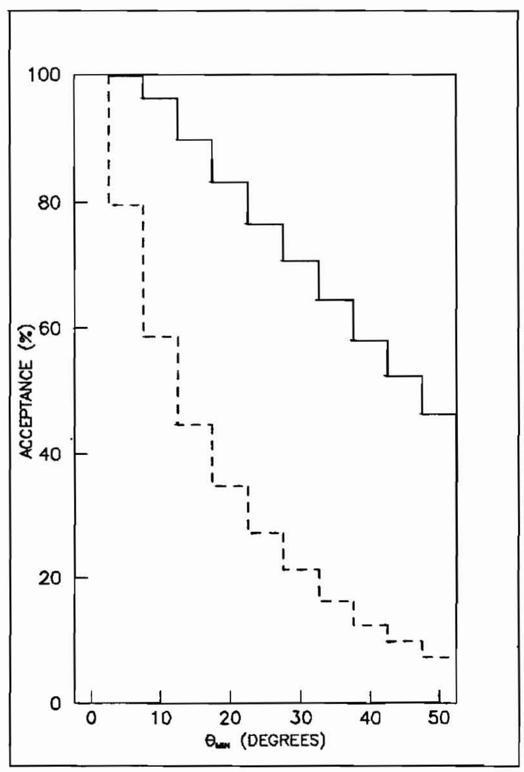


Figure 2. Geometrical acceptance for single muons (solid line) and dimuons (dashed line) decaying from a 1 TeV Z´boson

Being the total volume of the magnet at the limit of feasibility for a conventional one, because of the large energy dissipation, it does not seem a reasonable solution to increase its length by a factor of 2. Instead, an alternative is discussed bellow.

### 3. Momentum measurement in an extended geometry

Taking advantage of the relatively high (60%) single muon acceptance for decays of a particle of mass 1 TeV, it is worth to consider the insertion of a non-magnetic forward muon detector. A compact hadron calorimeter endcap followed by an array of muon chambers, as depicted in Fig. 4 , would provide angular coverage for forward (backward) muons down to 4 degrees in $\theta$ . The location of the chambers is not symmetrical around the interaction point because the support tube of the barrel detector must be made longer on one side for installation reasons. The construction of these large-surface drift chambers can be made following the design principles of those measuring the Z coordinate in L3 . Alternating planes with perpendicular wires can measure the X and Y coordinates and determine the $\theta$ and $\phi$ angles of the muon. I will neglect in this study the information on the momentum obtained from the chambers placed outside the magnet, which is limited by multiple scattering to be at best 16 % accurate. Wire resolutions in the range 0.5-1.0 mm would be enough to provide an error in $\theta$ and $\phi$ better than the multiple scattering.

Let us assume zero primordial $P_T$ of the heavy particle, and consider the typical event in which one muon is produced at high angle and the other muon at low angle. In this case, transverse momentum conservation implies that by measuring the angles of both muons and the $P_T$ of one of them, we have the full kinematical information of the decay. In the real case the particle will be produced with a certain transverse momentum, originated from initial state gluon bremstrahlung. A precise estimation of the expected $\langle P_T \rangle$ at the energy of the SSC for a particle of mass 1 TeV is not yet available, and I have assumed a value of 100 GeV as a conservative extrapolation of the UA1 and UA2 data for W± production[5] .

The resolution in the invariant mass which is achieved by this method (neglecting $P_T$ imbalance), will be a function of the acoplanarity angle of the muon pair, which is measurable. In addition, and more importantly, the transverse energy radiated from hard gluons can be measured in a specially dedicated hadron calorimeter, provided it is higher than a certain threshold. Given the occupancy numbers expected at the running conditions of SSC[6] it should be possible to measure hadron jets down to $E_T$ = 100 GeV, even in the case of pile-up of several events per beam-crossing. In fact, only the angle of the hadron jet would provide sufficient additional information to reconstruct the mass of the muon pair.

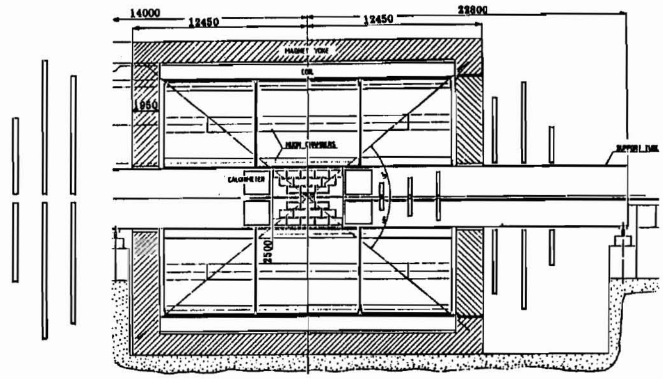


Figure 4. Side view of the L3+1 detector with additional muon chambers

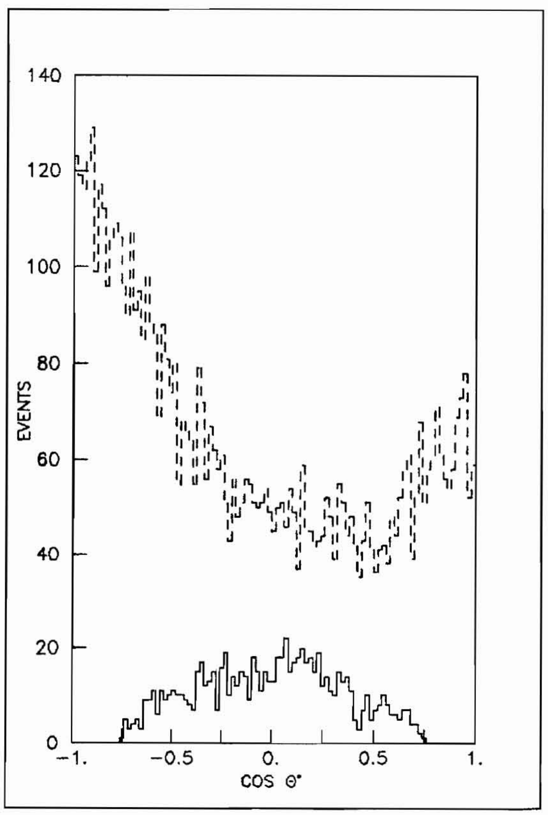


Figure 3. Distribution of the decay angle in the rest frame of the resonance assuming 4π acceptance (dashed line) and requiring both muons above 40 degrees (solid line).

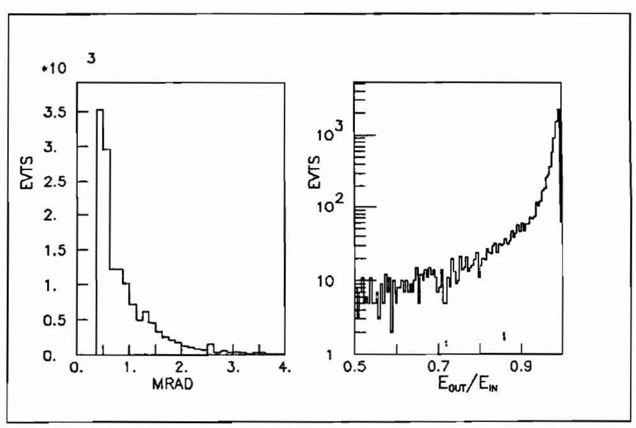


Figure 5. Deflection angle and fractional energy loss of the muons after 9.5 $\lambda_0$ of Uranium (average energy is 1 TeV)

In order to calculate the mass resolution and the ability of this detector to measure the couplings of a new narrow Z, by disentangling the interference pattern in the mass−dependent asymmetries[7] , I have performed a Monte Carlo simulation of the particle production and the detector response, using the GEANT3[8] program.

The following assumptions have been made :

a) momentum resolution in the precision detector is $\Delta P_T/P_T = 0.04\ P_T(\mathrm{TeV})$ .

b) full transport of the muon through the 9.5 absorption lengths of the Uranium calorimeter, which includes multiple scattering, photon bremstrahlung, delta rays, e+e− pair production and $\mu$−nucleus interactions, accurate within 5% in the TeV regime[9] .

c) muon energy loss is measured in the calorimeter with resolution $\Delta E/E = 0.5/\sqrt{E}$ .

d) angle resolution in the magnetic and non−magnetic muon detector is assumed to be dominated by the deflection angle of the muon.

e) hadron jets with $E_T > 100$ GeV are measured with a jet angular resolution of 2 degrees .

f) an exponential distribution $\exp(-P_T/100\mathrm{GeV})$ is used to describe the primordial $P_T$ .

In Fig. 5 are plotted the deflection angle of the muon and its fractional energy loss. Fig. 6 shows the mass resolution which is achieved by this method.

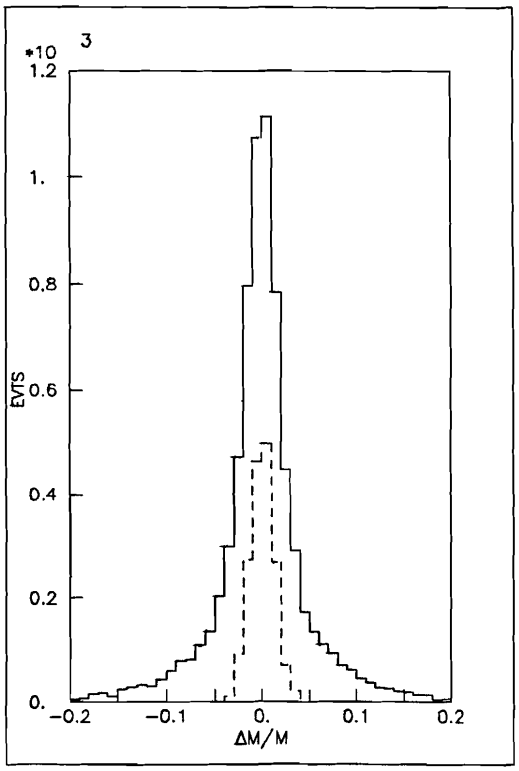


Figure 6. Mass resolution for muon pairs in an extended geometry to L3+1 (solid line), and in the precision detector only (dashed line).

## 4. Measurement of the vector and axial vector couplings

The kinematics of the previous Monte Carlo sample was generated according to a general $E_6$ superstring−inspired parametrization, which is described in ref. 10. Essentially, there are only 3 parameters to be determined, namely $\lambda$, $\theta_1$ and $\theta_2$ all the vector and axial vector couplings being determined by them. The first one is a ratio between coupling constants, and the other two are mixing angles for the neutral currents, in close analogy with the Weinberg angle $\theta_W$ .

A $\chi^2$−fit has been made to the Monte Carlo data leaving these 3 parameters free, using the information of the mass spectrum, the charge asymmetry as function of the mass , and the same as function of the rapidity. Fig. 7 shows the result of the fit, and Table 1 the "measured" values of the parameters and their errors. The number of events corresponded to the expectation after one year of running at the SSC. The errors quoted do not take into account the full correlation between the parameters. They have been obtained just by varying one of them, keeping the others fixed. The deviation of the measured values from the original ones may be a better estimation of the errors. In fact, such a systematic deviation could in principle be corrected in the real experiment.

*Table 1:*

| $\lambda$ | $\theta_1$ | $\theta_2$ |
|---|---|---|
| 1.5 | $45^0$ | $52.2^0$ |
| $1.49\pm0.02$ | $35^0\pm1^0$ | $77^0\pm1^0$ |

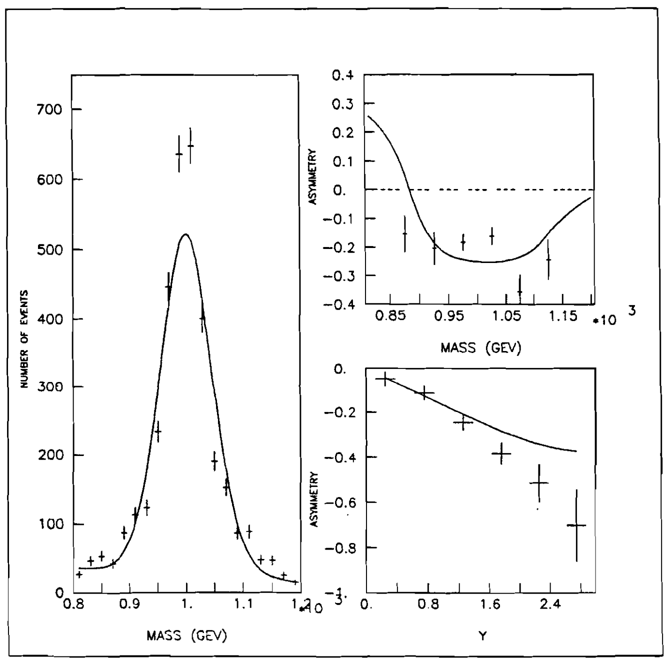


Figure 7. Measured mass spectrum and charge asymmetries after Monte Carlo simulation of the extended L3+1. The solid line shows the result of the -fit in a general E parametrization to determine the vav couplings.

## 5. Conclusions

I show that the L3 + 1 detector plus a non − magnetic forward extension can measure masses of muon pairs with 4 % resolution over a rapidity range of nearly 5 units. In addition, it can measure charge asymmetries and disentangle the interference pattern in the mass spectrum in case a new Z boson is found, thus providing a selective discrimination among all possible models for neutral currents.


## Acknowledgments

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