A muon detector for TESLA

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Abstract. The conceptual design of the TESLA μ identifier is reviewed: experimental techniques and performances requirements are described. Environmental conditions are studied in connection with the expected event topologies for a 500-1000 GeV electron positron collider.

I INTRODUCTION

One of the main components for a general purpose detector operating at an e^+e^- facility, like the proposed TESLA [1] collider is the muon detector/identifier. Lepton detection and identification is one of the main requirement of the Physics program (as leptons allow charge identification of the parent parton/gauge boson) that will be carried out at an electron positron collider; in particular muons are the leptonic species easier to identify. Traditionally such a subsystem has always been built exploiting the iron of the magnetic field flux return suitably segmented.

II MUON DETECTION AND IDENTIFICATION

Muons are usually identified thanks to their *minimal* interaction with matter; general purpose detectors have calorimeters that absorb hadrons, electrons and γ's and identify, as candidate muons, the ones surviving with a well defined amount of energy. Calorimeters have an overall thickness between 5 and 7 λ's. The muon detector provides means of checking that the surviving candidate does show the typical energy loss pattern of a μ in a thick amount of material (4 to 6 λ's). Furthermore such a device is often required to measure candidate momenta if the latter, that can be also obtained with different detector subsystems, cannot be unequivocably associated with a candidate μ. Muon systems designed and under construction for LHC do have this capability: in the harsh environment of 14 TeV hadron hadron collisions the correct association of tracking segments with muon candidates cannot be a priori guaranteed. [2] [3] The simulations which have been run up to now [4] [5], show that track densities are substantially smaller in the e^+ e^- interactions @ 500 GeV, so that a *muon tagger* would serve the purpose to identify muon candidates whose momenta are measured by the tracking system. The association of tracks and muon candidates can be done without ambiguities. The muon identifier can also be seen as tracking calorimeter, and, in such capacity, can be used to back up the more specialized (hadronic) calorimeter either to measure the energy escaping out of it or just to tag non-contained events. Almost all the results reported in the following were obtained analyzing $q\bar{q}$ events, which are believed, in the energy range of interest, to produce the highest particle densities inside the various jets. Gauge bosons production has been studied as well, with minor differences noted. In order to get a visual feeling of how crowded a muon

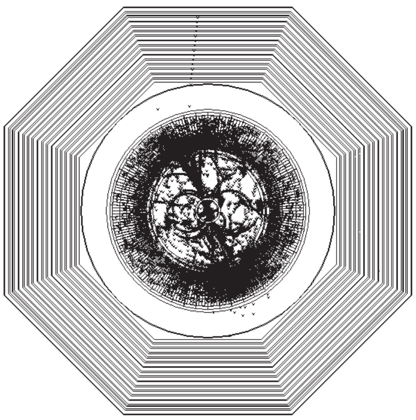

FIGURE 1. Display of a typical $b\bar{b}$ event. The muon system is based on uniform segmentation on the full thickness required to contain the magnetic flux.

identifier would be, fig 1 shows the topology of a $q\bar{q}$ event as seen in the general purpose detector described in ref [6]. The design of a muon identifier is coupled to the overall dimensions of the detector: the latter, together with the magnetic field value, set an effective cutoff in muon momentum, even if muons, which do not reach the barrel identifier, could be still be detected in the hadronic calorimeter. The overall design philosophy for the TESLA detector calls for a large set-up, that is an apparatus based on a large (gaseous) tracking volume and a calorimetry exploiting the energy flow algorithm, as a result the muon cutoff momentum is relatively high ($\approx$ 5 GeV/c). Large dimensions and difficulties in replacing active devices require reliable detectors, easy to build and relatively inexpensive; a possible choice would be a gas detector operated in a saturated regime. Resistive plate chambers (RPC's) [7] thanks also to their flexibility in construction (they can be shaped almost at will) would be the device of choice.

III OPERATIONAL CHARACTERISTICS

The operational regime one would use for RPC's depends on the environmental conditions: limited streamer operation is very attractive, given the big amplitude this mode of operation features; on the other hand saturated proportional modes offer higher local rate capability. A full simulation run on a $q\bar{q}$ final state shows that even the limited streamer mode of operation would easily cope with the local rate pertaining to quark jets: fig. 2 shows that maximum hit densities at the front face of the muon detector are small.

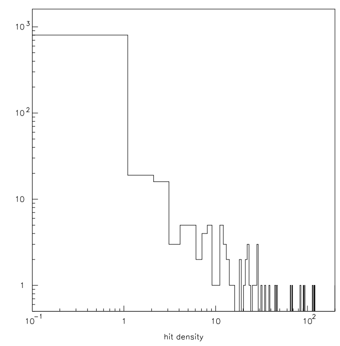

FIGURE 2. Hit density for $b\bar{b}$ events on the first detector plane: the histogram shows twice the inverse of the smallest area, in a given event, encompassing two hits.

As for what spatial resolution is concerned the scale is essentially set by multiple scattering the material in front of the muon identifier causes: fig.3 shows the spatial uncertainty that this phenomenon introduces for non interacting particles of 20 GeV/c (average momentum for muons originating from b quark decays). A resolution $\mathcal{O}(1 \text{ cm})$ would be matched to the width of the distribution shown in fig.3

IV DESIGN AND PERFORMANCES

The overall thickness of the flux return iron, with a 4 T magnetic field and a coil of $\approx$ 4 m. radius, is 1.5 m. In order to obtain not only muon tagging capabilities, but also some calorimetric ability for this system one may choose to segment the iron in a non uniform way: a relatively fine segmentation in front (10 cm) would provide some means of measuring energy escaping from the calorimeters and coil. A tenfold sampling (a total of 1 m. of Fe) would be enough both for calorimetry and energy loss sampling for muons; the last half a meter of iron would not be segmented and one single sensitive plane would be added on the outside to tag and measure particles passing through. Performances of such an arrangement in the

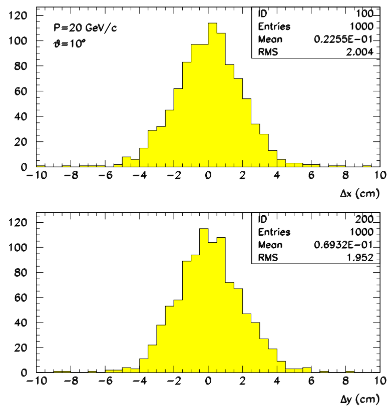

FIGURE 3. X and Y impact points distribution for 1000 monochromatic 20 GeV/c muons emitted at $\theta = 10^0$.

barrel part are shown in fig. 4: the cutoff at ≈ 5 GeV/c, as already noted, depends on both magnetic field (4 T) and coil radius (4 m.).

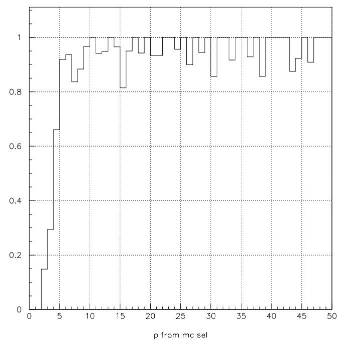

FIGURE 4. Muon detection efficiency vs momentum in the barrel region for the TESLA detector design ($b\bar{b}$ events).

As for what calorimetric performances are concerned the configuration described above does allow measurement of leakage energy with a scaled resolution of $\frac{150\%}{\sqrt{E}}$. This would translate into a 40% resolution at 20 GeV.

V CONCLUSIONS

Today technology allows the design and construction of a muon detector for a general purpose apparatus, meeting all the requirements the high energy physics

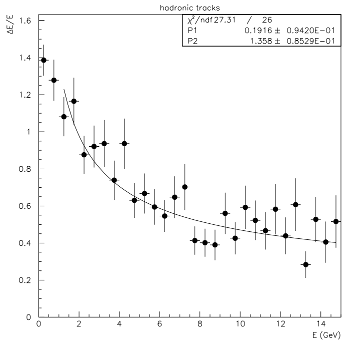

FIGURE 5. Fractional energy resolution vs energy obtained with hit counting technique: 5% of all tracks deposit energy in the muon system.($b\bar{b}$ events).

program poses. The TESLA detector design calls for a tenfold segmentation of the flux return iron and RPC's as active detector.Expected performances are such that full muon detection efficiency is reached above 5 GeV/c momentum; the relatively high segmentation allow calorimetric capabilities that would help tagging and/or measuring leakage energy in event not completely contained by the calorimetric system.

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