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PROPOSED TEST OF A LIQUID ARGON γ AND HADRON IONIZATION CALORIMETER

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Willis at Yale (now at CERN) proposed a detector for Isabelle to detect all particles except neutrinos. It consists of a flys eye of many parallel hexagonal plates immersed in liquid argon. The gaps are 2mm of liquid argon and the cells are $\sim$ 22 cm in diameter. High voltages of about 2 KV are put on alternate plates. Incoming γ's, e's and hadrons shower and deposit a fraction of their energy in the argon ionizing it. The charge from ionization is collected with no multiplication, amplified externally and pulse heights measured by ADC's. The charge collection time is 300 ns but could be improved by a factor of three with small amounts of CH_4.

He built a first model with 200 steel plates 2 mm thick and placed it in an unseparated 7 GeV negative beam. He saw a narrow μ peak, a broad π bump since it was only 3 interaction lengths long, and a narrow electron peak. The resolution was 2.6% RMS for 7 GeV close to that of lead glass.

It has been my belief for some time that high energy physics has suffered badly from not being able to reconstruct final states due to missing neutrals. Inclusive reactions give only limited information on the nature of the interaction as energies go up the fraction of 4 C or 1 C events go down and one is left with the ability to completely analyze only a small fraction of the events collected.

For this reason I began to look for a detector that would be able to reconstruct the position and energy of γ's. Conventional methods are lead glass arrays and shower counters. Both of these techniques are expensive if one wishes to cover areas such as 4 m $\times$ 2 m the downstream area of the streamer chamber magnet. For this reason I decided to look at Willis's calorimeter. It seemed promising enough to try a test. I decided to separate the calorimeter into two parts, one for e's and γ's and the second for hadrons. My preliminary design consists of 201 Pb (actually Babbitt metal for strength) plates 30$\times$30 cm, 1/2 mm thick, or about .09 X_0. This totals to about 21 X_0 with the argon.

The γ detector is followed by 200 steel plates 60 × 60 cm 3.2 mm thick each plate being .025 collision lengths thick. The Pb adds another 0.73 collision lengths in total. Liquid Argon z = 18 has density of 1.4 boils at 87.4^{o}K and freezes at 83.9^{o}K. For reference nitrogen boils at 77.3^{o}K. The radiation length is about 19 gm/cm^2. The collision length is about 90 gms/cm^2. Thus the 400 gaps of argon add another 1.23 collision lengths making a total of 7 collision lengths. The steel plates are 60 × 60 cm to get a diameter of about 4 collision lengths.

To test localization possibilities, 30 × 30 cm one lead plate at about 4 X_0 is divided into strips of different widths, 30 cm by 0.5 cm, 1 cm, 1.5 cm, 2 cm perhaps three of each kind. The rest of the lead plates are connected to form several subgroups to be determined later. Some of the possible connections are (a) every other signal plate tied together so that one can form the sum and difference distribution (b) four groups each of 50 plates to study shower formation or (c) groups of different number of plates.

One of the 60 × 60 cm steel plates is also broken into strips at a depth to be determined. The grouping is also to be determined.

<u>Readout Electronics</u>

First consider the lead parts of the calorimeter. There is 10 cm of lead and 40 cm of argon. A minimum ionizing particle loses 128 MeV in the lead and 88 MeV in the argon. Even though in a shower the energy is not uniformly deposited, the sampling of about 0.1 X_0 is fine enough so that the ratio of energy loss in the argon to the total is 88/216 or 41%. Thus a 16 eV electron will lose 410 MeV in the argon. At 30 eV/ion pair, 13.7×10^6 electrons are created which if all collected have a charge of 2.2 pico coulombs. The 201 plates form a capacitor of about 80 nf ϵ where ϵ is the dielectric constant of liquid argon. I haven't found it but believe it to be close to 1. With this assumption, if all the plates are tied together the voltage v = Q/C = 27.5 μ volts/GeV. The interesting thing is that the voltage on the strips is larger than this. One can see this if one remembers that the charge collected by an average plate is 1% of the total (there are 100 signal plates) and the capacity is 1% of the total, giving the same voltage. The strips however which are in the shower collect the total charge of the plate on a much smaller capacity giving a larger voltage.

The steel part of the calorimeter has 63.5 cm of steel and 40 cm of argon. A minimum ionizing particle loses 737 MeV in the steel and 88 MeV in the argon.

The fractional energy loss in the argon is 88/825 = 10.7%. A 1 GeV energy loss in the second part of the calorimeter gives 107 MeV in the argon or 3.6×10^6 ion pairs or 0.57 pico coulombs.

Since the plates have four times the area, the capacity is 320 nf giving a voltage of 1.8 μ volts/GeV.

Several possible amplifier designs are being considered. One with discrete components consists of a grounded base transistor with a low $\sim$100 Ω emitter resistor, and a 3K collector resistor giving a voltage gain of 30. The grounded base transistor is followed by a Darlington emitter follower or a voltage follower. This first stage is capacitively coupled to a similar second stage for an overall gain of $\sim$1000. The rise time should be $\sim$300 ns and the fall time quite long depending upon the capacity of group plates used. Using a capacitively coupled input one could short out the calorimeter with an FET after the ADC samples the output until just before the next machine gate.

The amplifiers for the strips must have higher impedances as the capacity is much less. Two fed back loops or perhaps just one should suffice for these.

The hadron calorimeter requires more gain. Either more stages or stages of higher gain or a step up transformer in the input is required.

Other possibilities include FET's.

If the test is successful, a proposal for a large calorimeter will be made, $\sim$ 4 m $\times$ 2 m, finely segmented in crossed strips, $\sim$2 cm $\times$ 100 cm, with like strips in depth connected together. FET's can be used to multiplex many strips to the same amplifier and the same ADC. Other FET's could be used to mix all strips together to get a total energy signature which could be used as a trigger.

I would appreciate comments, ideas and any assistance I can get.