Fermilab

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GAS SAMPLING HADRON CALORIMETRY

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Even if the first hadron calorimeter prototypes for CDF have been built with scintillators, one feels that it is opinion of many group members that the gas sampling technique (especially using resistive tubes in the limited streamer mode) could still be a better suited technique. Main "guesses", which I was sensible to, are:

1. A gas sampling calorimeter is cheaper and, therefore, easier to be constructed.
2. It provides at least a comparable reconstructed energy linearity and resolution.
3. In addition, it provides excellent space resolution.

However, so far all these points have not been experimentally proven by anybody, and a definite answer can only come from the construction and operation of both detectors. It was my intention to fill, before the end of February, part of the large angle hadron calorimeter with resistive tubes used in the l.s.m. I intended to make use of the experience of colleagues in Frascati (E. Iarocci et al.), who first developed this technique and who are constructing, for a matter stability experiment, a 27 m^3 detector consisting of 100 iron plates (1 x 300 x 300 cm^3) interleaved with planes of 300 resistive tubes (1 x 1 x 300 cm^3), operated in the l.s.m. (being the cathode transparent, signals are read out by 600 x-y strips on both sides of each tube plane). In this way, I discovered that they already helped the CHARM Collaboration

at CERN to implement their experiment with such a calorimeter. It is already under test at CERN, and I obtained interesting figures (from V. Valente) about their first "very preliminary" results. The calorimeter consists of planes of Ca CO_3, 8 cm thick (1/3 of collision length) and 2.7 by 2.7 mt^2 wide, interleaved with planes of polyvynile scintillators read out directly. Thirty gaps have been additionally filled up with planes of 270 tubes (1 x 1 x 270 cm^3), read out individually. The sense wire is 50 μ, the gas mixture is 1:3 Argon and Isobutane. L.s.m. pulses (the sense wire is operated at 3700 V) are ∿ 15 mV into 50 Ω after about 50 mt of cable. This detector has already measured thousands of neutrino induced hadron showers and a few hundreds electron showers. The scintillators calorimeter performances are well known. It is linear at least up to 200 GeV, and its energy resolution is $\frac{\Delta\varepsilon}{E} \sim \frac{43\%}{\sqrt{E}}$ (the statistical contribution is $\sim \frac{9\%}{\sqrt{E}}$). A comparison was done between the two calorimetry techniques by using only those events where more than 90 percent of the shower energy is left in the 30 slots equipped with both tubes and scintillators.

Fig. 1 shows the average number of fired tubes $\langle n_{tot} \rangle$ versus the hadron energy as reconstructed by the scintillators. The gas calorimeter (with a granularity of 1 cm) starts saturating after 30/50 GeV.

Fig. 2 shows, in a given marble gap, the average number $\langle n \rangle$ of fired tubes versus the energy deposited in the scintillators filling the same gap. The local saturation of $\langle n \rangle$ probably accounts for the reconstructed total energy saturation.

Fig. 3 shows the measured (X) variance h (HWHM) of n_{tot} versus the energy as reconstructed by the scintillators. Here, the sampled shower

energy fluctuations should not contribute to h because the energy is measured by tubes and scintillators at the same positions. h should be given only the combination (dashed line in Fig. 3) of the photoelectrons statistical error (points) and the fired tube variance $\sqrt{n_{tot}}$ (squares). The fact that the measured h is significantly bigger could be accounted for by shower shape fluctuations folded with the tube energy saturation (in fact h tends to get bigger than expectations with increasing the shower energy). At 20 GeV, the gas resolution (without sampled energy fluctuations) is already worse than the resolution (52 percent/ $\sqrt{E}$ HWHM) obtained by the scintillator calorimeters. The same trend is shown by the few electron showers so far measured. Better results will be available in summer after the test beam measurement they are planning.

I then tried a costs evaluation by using the experience of the proton decay group and of the Frascati people in the CHARM Collaboration, who are also evaluating a l.s.m. gas calorimeter for LEP (jets have a much smaller energy than at a 2 TeV $\bar{p}p$) very similar to CDF. We considered a very reductive hypothesis, where one half of the CDF detector along the beam consists of 31 barrels of l.s.m. resistive tubes, 1 cm wide. By reading alternatively each barrel with longitudinal strips (1 cm wide, 2.5 mt long) all around the beam, and with azimuthal strips (4 strips, 1 cm wide, 4 mt long to cover 2 π) all along the beam, the cost is about 1.5 M$ to be compared with the price of 1.2 M$ we estimate for scintillators.

About Point 3 (good space resolution), we are ready (?) to spend 2.5 M$ for the tracking system.

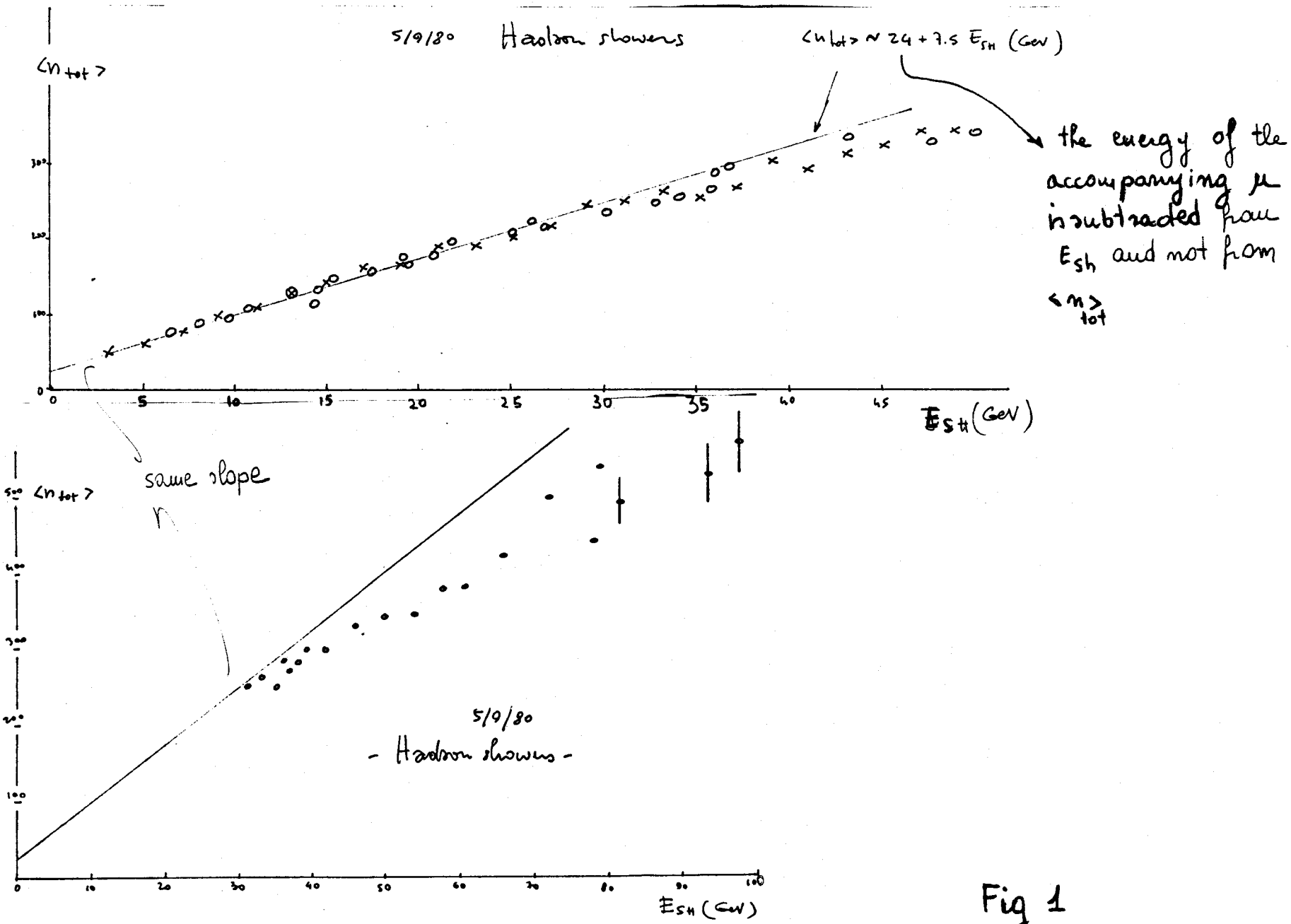
5/9/80 Hadron showers
$\langle n_{tot} \rangle \sim 24 + 7.5\, E_{sh}$ (GeV)
the energy of the accompanying μ is subtracted from E_{sh} and not from $\langle n \rangle_{tot}$
$\langle n_{tot} \rangle$
E_{sh} (GeV)
same slope
5/9/80
- Hadron showers -
$\langle n_{tot} \rangle$
E_{sh} (GeV)

Fig 1

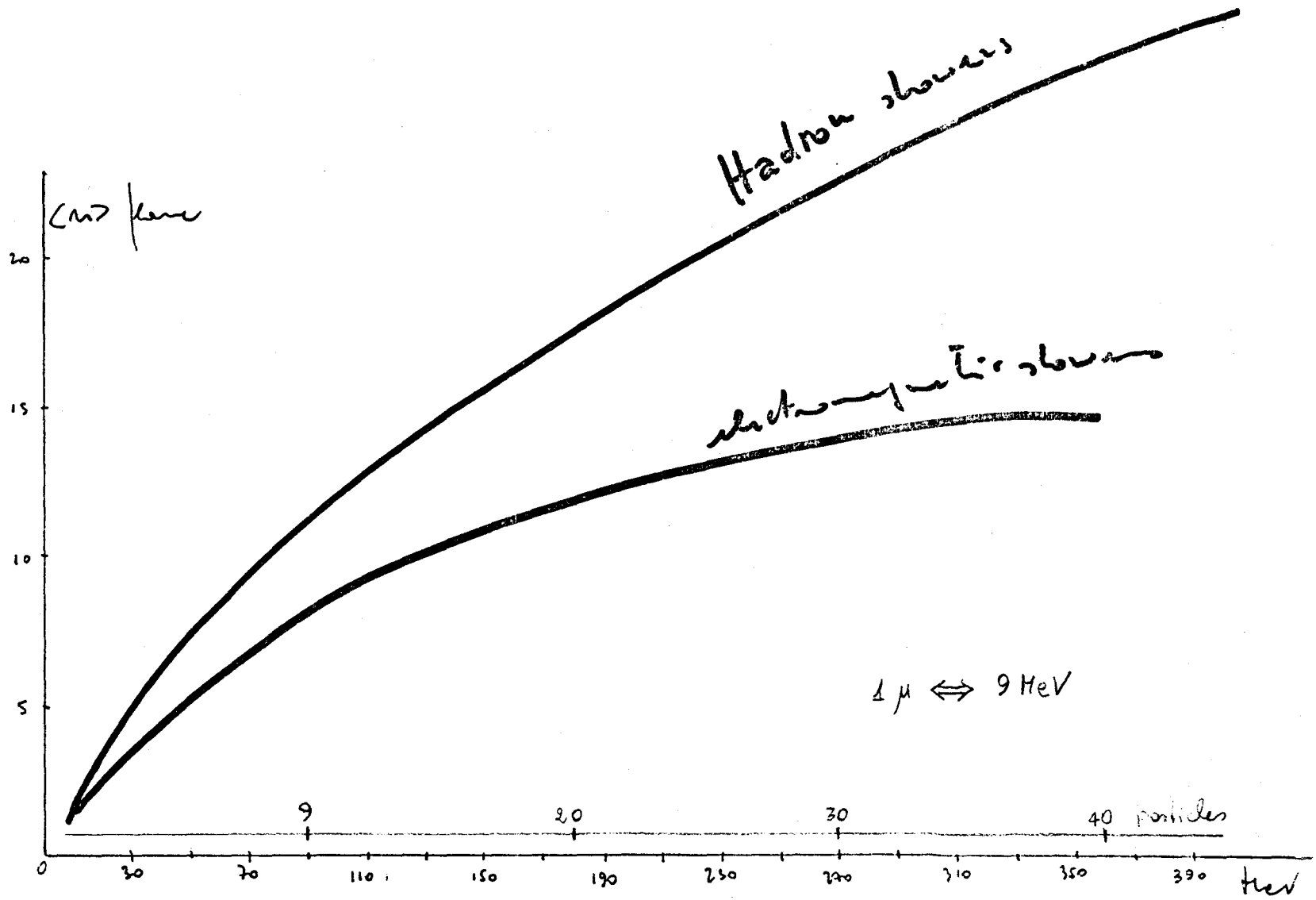
Hadron showers
electromagnetic showers
1 μ ⇔ 9 MeV
20
15
10
5
0
9
20
30
40 particles
30
70
110
150
190
230
270
310
350
390
MeV

Fig 2

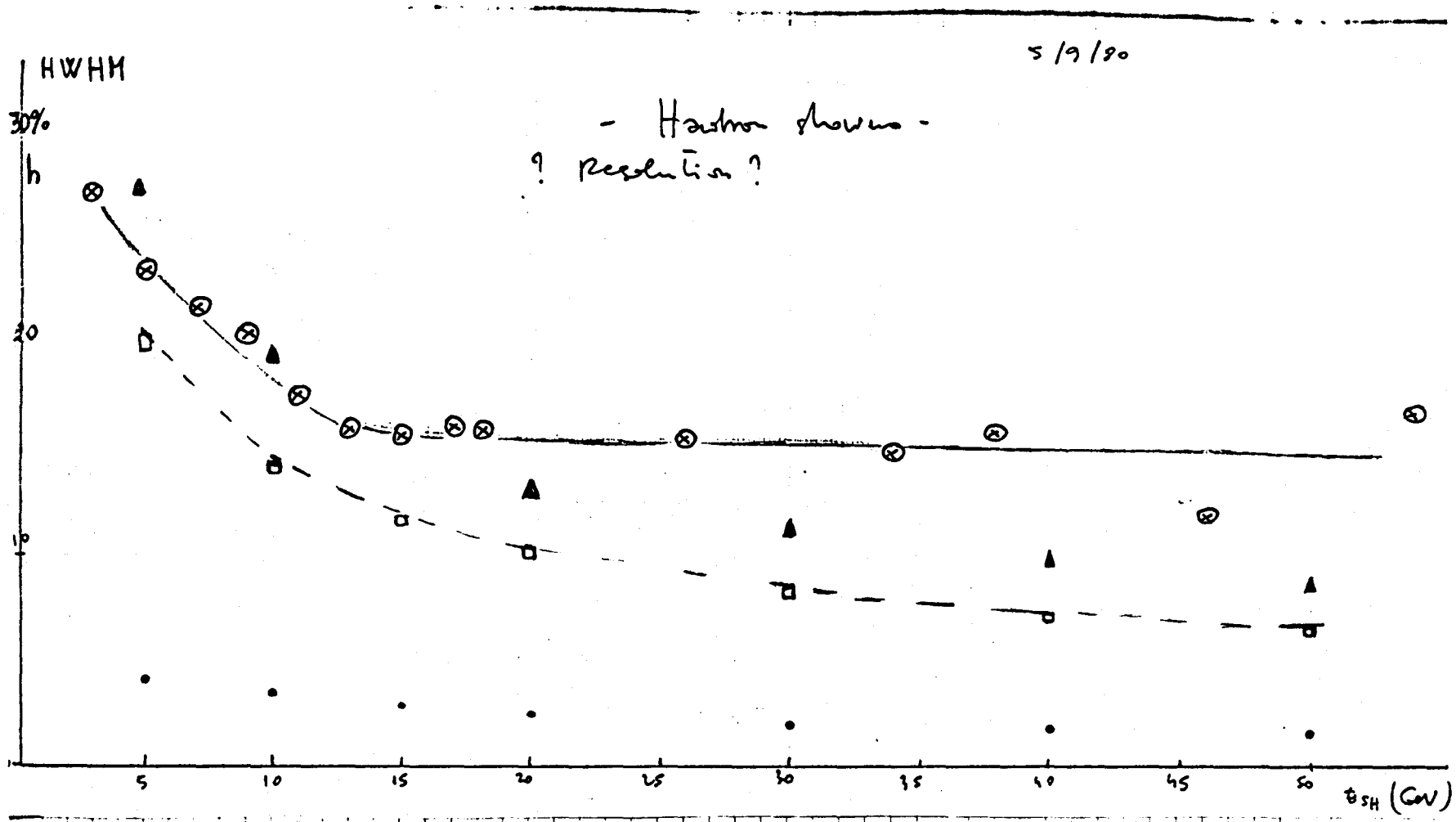
5/9/90
- Hadron showers -
? Resolution ?
HWHM
30%
20
10
5
10
15
20
25
30
35
40
45
50
E_{SH} (GeV)

Fig 3