CALORIMETRY WITH GAS PWC AND URANIUM

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The sense of the calorimeter group summary of the Snowmass 1986 workshop was a tilt toward liquid argon-uranium calorimetry. It seems desirable to elaborate briefly some of the L3 thinking and experiences with gas propoprtional chamber-uranium calorimetry and to project the consequences of that experience to the SSC detector application. The conclusion is that gas PWC detectors for calorimetry are alive and well and should be regarded as a serious option for SSC central detectors.

The LEP L3 collaboration working on the hadron calorimeter includes physicists from the University of Michigan, Aachen, and ITEP (Moscow), in addition to a Florence group working on the muon filter ("tail catcher"). The system of hadron calorimetry selected consists of gas proportional wire chambers of 5X10 mm^2 (rectangular) aperture brass tubes. In order to reduce uranium beta-induced background, the chambers are shielded by one mm brass plates. The brass tube cathodes are at high negative voltage (and the anode wires are at ground). The total clearance for the PWC is 8.0 mm, including 2 mm of shielding plates, insulation, etc. Signals are taken from 50μ diam. gold-plated tungsten anode wires. The uranium plates are 5.0 mm thick, nickel plated.

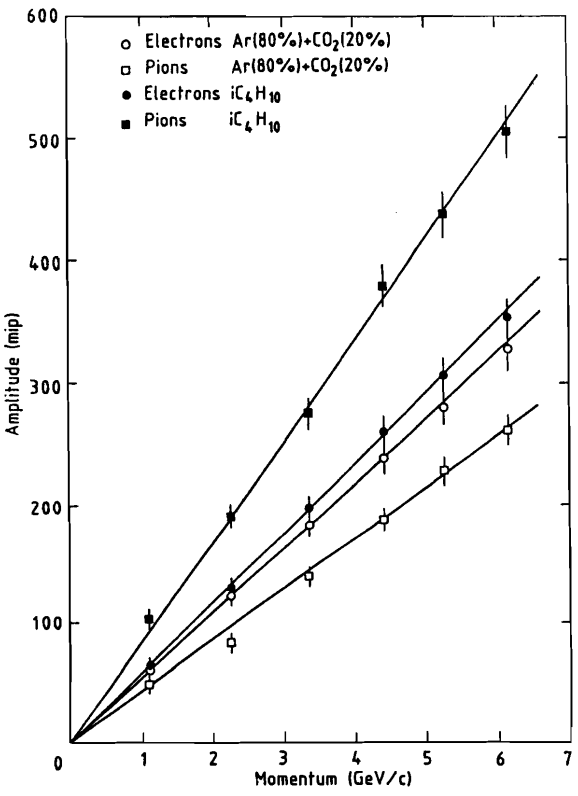

Figure 1. Compensation effect for uranium-gas calorimeter. Data give responses to electrons and pions between 1 and 6 GeV with two gas mixtures. Response is given in minimum ionizing particles (mip) equivalent.

It has been found that the compensation, e:π ratio, can be "tuned" by varying the gas mixture in its hydrogen content. Figure 1 shows results from electrons and pions in a test calorimeter at IHEP using pure isobutane and using an argon-CO_2 mixture. However the compensation is achieved with both a loss in resolution and a stretch-out in collection time as a result of fission neutron recoils on hydrogen. Further, as this calorimeter is preceeded by a 24 cm bismuth germanate electromagnetic detector, the e:π ratio in the calorimeter is academic save for its effect on resolution. Therefore it has been decided that argon-CO_2 will be used. Figure 2 shows some test beam and Monte Carlo results of resolution for different gases. To date there is no test-beam data with the calorimeter coupled to a preceeding BGO array, however Monte Carlo studies indicate that the combined hadron resolution is as indicated for the calorimeter alone except below about 2 GeV (Figure 2).

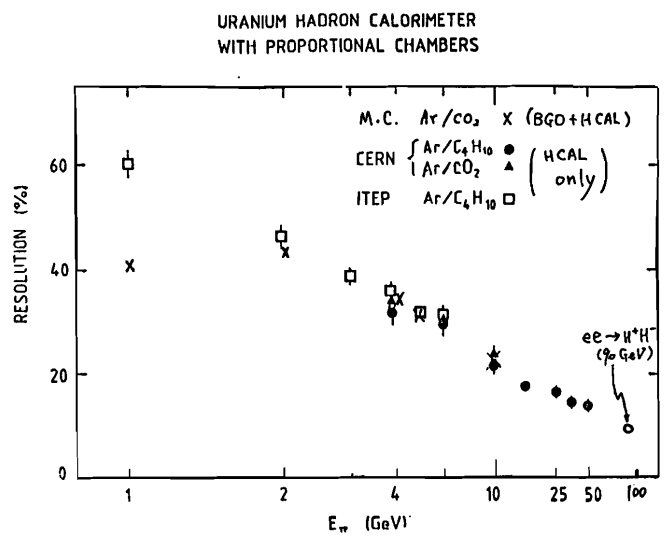

Figure 2. Measurements and Monte Carlo studies of uranium-gas PWC resolution with various gases, and (in the Monte Carlo studies) including 24 cm BGO.

For 5 mm gaps and 70 cm tubes wire centering is not a problem. The gain depends on: 1) gas mixture, 2) temperature, 3) pressure, and 4) amplifier gain stability. Past experiments with PWCs have used two simple means to determine and stabilize gain; muon calibration, and pulses (or chamber current) from a radioactive source in a test portion of chamber. Both were used in Fermilab E613 with very satisfactory results. For L3 several means are available. Test pulses will be available at the inputs of all preamplifiers. Gas temperature, pressure, and composition will all be controlled and monitored to well within limits required for resolution stability. And the current (or pulse height spectrum) from the ambient uranium noise from any subset of wires will form a check. Cosmic ray muons will also be available, although muon calibration will be less convenient than in typical Fermilab or CERN fixed-target experiments. Table I summarizes our experience with gain sensitivity to important variables.

Table I GAIN VARIATION OF GAS PROPORTIONAL CHAMBERS OF THE L3 DETECTOR

Variation in selected parameters for a gain shift of ± 5% from measurements at ITEP (Moscow) and EIR (Zurich), reported by Y. Galaktianov.

Parameter	Mean value	Variation, for a gain change of 5%
High Voltage	1680V	± 4.2V
Barometric Pressure	760 mm Hg	± 3.4 mm Hg
Kelvin temperature	293 K	± 1.7 K
Wire diameter	50 μ	± 0.35 μm
Chamber height, h	5.0 mm	± 64 μm
Chamber width, w	10.0 mm	± 2.5 mm
Wire centering, h	0	± 190 μm
Wire centering, w	0	± 750 μm

From these and other experiences and considerations, the following observations concerning calorimetry for the SSC are drawn by this author.

- Gain stability and calibration do not appear to be a problem for gas calorimetery, especially with the (often annoying) convenience of the ambient uranium background.

- Gas gains of about 10^4 render single muons easily visible with inexpensive electronics and anode readout. This is a comforting added calibration.

- The space required for gas calorimetry is 5mm as compared with 2 mm for liquid (gaps only), or about 3 mm more per detector plane.

- Liquid argon and some gas chamber systems utilize pad readout in order to quantize projective tower geometries. The L3 detector will use crossed anode wires in groups; Monte Carlo studies have shown this configuration to be as definitive as projective towers for the physics to be studied. An added possibility is the use of resistive wires with amplifiers at both ends; their pulse height ratio then localizes the center-of-gravity of the ionization along the wire. Resistive wire arrays have been used successfully in large experiments such as Fermilab E743.

- Gas PWC time resolution is 25-50 nonseconds for typical gases and 5 mm gaps. As with liquid argon, this time may be shortened somewhat by clipping or shaping the pulses, however in all probability with a loss in resolution.

- The resolution of gas PWCs is probably inherently worse than liquid ion chambers simply due to the statistics of the sampling; liquid is 1000 times denser than gas. However it is not clear that the simplistic $X\ \% / \sqrt{E}$ is the relevant consideration for the SSC. It may be that for the interesting jets of a fraction of a TeV and more, the resolution will be dominated by small constant terms relating to geometrical inhomogeneities, etc.

- The compensation question may be overworked. The L3-model should be considered wherein an EM detector, engineered for fine sampling and unity compensation, is surrounded by a coarser hadronic calorimeter engineered for stability, hermeticity, and (even) economy. It may be that the best combination of packing density and overall resolution would be achieved with a plate thickness increasing as the logarithm of the depth in the detector.

It will be valuable to gain experience with the very different calorimeter technologies to be employed in the large detectors to come on line with SLC, LEP, HERA, Tristan, and TeV I in determining the optimum design for an SSC detector. Perhaps the best alternative still awaits development.