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SDC
SOLENOIDAL DETECTOR NOTES

ON IMPLICATIONS OF $e/h \neq 1$

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There is a considerable literature of studies of compensation in calorimeters at the microscopic and macroscopic level. I doubt that the exercise described here adds any fundamental understanding to previous studies, but it can be helpful in organizing thinking. Previous attempts at motivating the expense of a compensating calorimeter for an SSC detector have tended to show that noncompensation effects get buried by cone corrections and such. A marginally significant resolution increase was found in Z/Z' study for the LOI.[1] Despite the certainty of reinvention, I opted to study the effects of e/h ≠ 1 in dijet balance, which will undoubtedly be used to extend calibrations across boundaries and study detector jet resolution. Although this is not a physics process which could offer some requirement for what is good enough, it does allow jet resolution to be reasonably defined.

The study of dijet balance as done in CDF is discussed by Rick StDenis.[2] Cross calibrating separate detectors and investigating cracks were prime motivations. Jet resolution is defined by removing the angular contribution from the two jet energy difference in quadrature to take out QCD k_T and then to extrapolate as a function of say the cut on the 3rd jet E_T. In the absence of both the SDC and the SSC, I use ISAJET dijets with a modified version of the built in theoretical calorimeter.[3] The modifications are discussed in a note on electron isolation which I append. For this study the jet finding algorithm was modified to iterate the jet center and nonlinearity was put in according to the Don Groom prescription.[4] The EM was kept at 24 X0 and inherent resolutions at $15\%/\sqrt{E} \oplus 1\%$ EM and $50\%/\sqrt{E} \oplus 1.5\%$ HAD, E in GeV.
A quite simple test beam simulator allowed normalization factors which were take to be 100 GeV electrons give <100 GeV> as do 100 GeV pions. Note that this returns an 3.6% resolution for 100 GeV pions with no resolution put in, only depth fluctuation and e/h=1.4. Unfortunately, to define a jet resolution A by describing the dijet resolution as $A/\sqrt{E}$ extracted from dijets requires considerable statistics even before thinking about extrapolation. In

order to make noncompensation effects significant, the same events are reconstructed in 14 ways.

The cases considered are repeated for jet cones of 0.7 and 1.0. Only dijets with the two leading jets inside $|\eta| < 2.5$ are used. With linear reconstruction and a cone of 0.7, the leading jet must reconstruct to at least 50 GeV E_T, the deviation from back to back must be 30° or less in phi, and a variable cut is placed on the E_T of the 3rd jet. The resulting sample is recycled through all cases. The nth or (n+7)th case refers to 1) linear reconstruction, 2) e/h = 1.2, 3) e/h =1.4, 4) e/h=1.6, and with the EM compartment taken to have e/h=1, the hadronic compartment only was given 5) e/h=1.2, 6) e/h=1.4 and 7) e/h=1.6. In each case an energy scale is taken to give the same average energy as case 1. Undoubtedly wrong, it is at least always the same, so resolutions may be compared.

CASE	A CUT 12	A CUT 15	A CUT 20	1/SCALE 12
1	72.13	83.53	102.31	1.
2	73.28	85.14	103.86	1.038
3	78.86	90.11	108.56	1.065
4	81.87	93.13	111.75	1.089
5	73.72	84.88	103.67	1.020
6	73.38	85.98	105.11	1.036
7	74.81	86.99	106.09	1.049
8	49.23	55.18	64.87	0.937
9	53.97	58.67	68.27	0.970
10	57.24	62.09	72.25	0.999
11	58.51	64.85	75.06	1.023
12	51.62	56.79	67.11	0.953
13	53.35	57.99	68.98	0.967
14	54.51	58.98	69.89	0.980

TABLE 1. For the 14 cases described in the text, the effective coefficient of a $1/\sqrt{E}$ in % is given for 3rd jet cuts of 12, 15 and 20 GeV. Absolute statistical errors are 6-7% (12), 5-6% (15) and 5-6% (20). The inverse of the average relative energy scale for the 12 cut is also listed.

These results are better illustrated graphically. Fig. 1 shows the resolution coefficient for the cases with a 15 GeV 3rd jet cut: noncompensation clearly hurts, and a compensating EM compartment gets a lot back. The hazards of extrapolating to a 0 GeV jet cut are shown in Fig. 2 which shows that the effective basic jet resolution is perhaps something like 30%/√E.

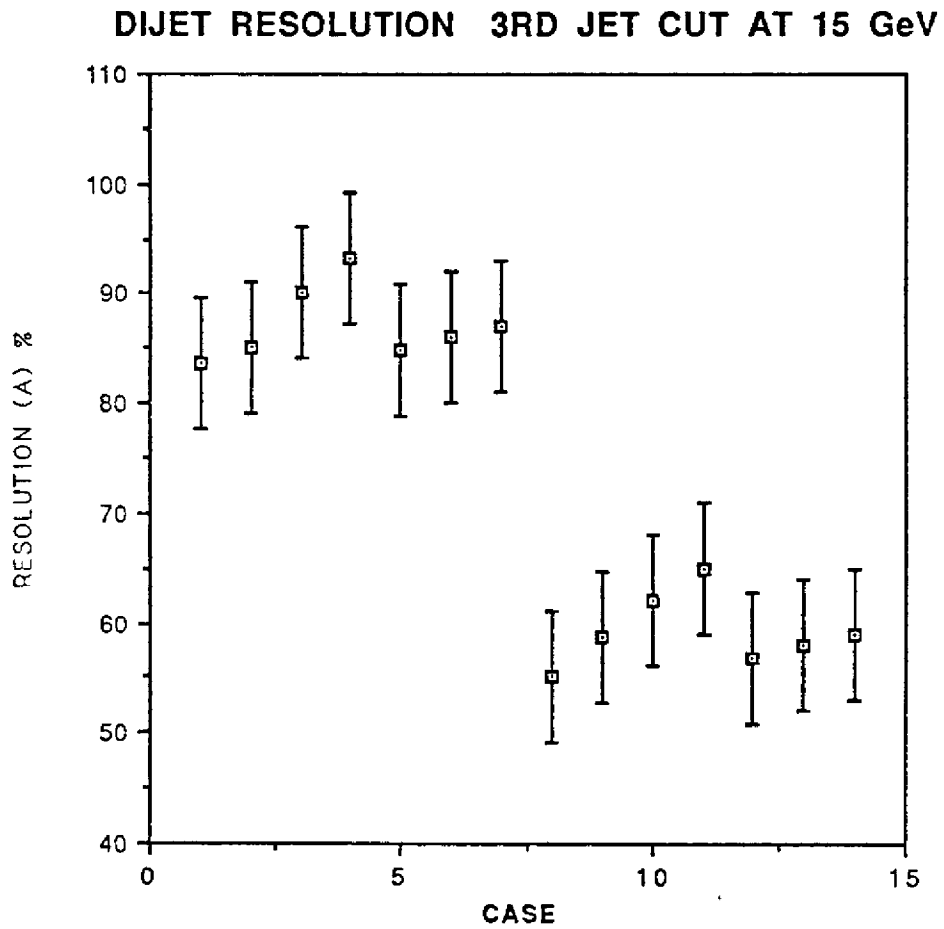

Fig. 1. Resolution coefficients for the 14 cases for a 15 GeV 3rd jet cut. The first 7 have cone size 0.7. The errors are the absolute statistical error which is NOT applicable point to point. The degree of preference for the cone of 1.0 is an artifact of ISAJET not having extra events, etc.!

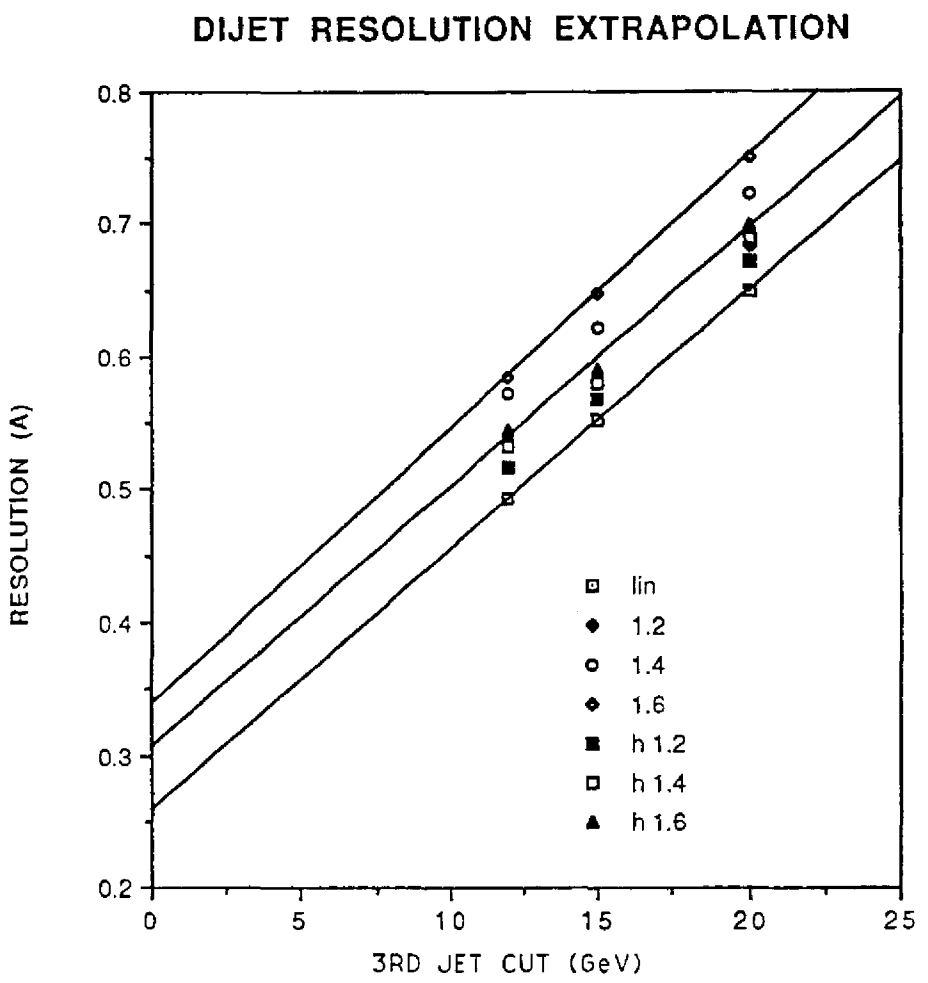

Fig. 2. The hazards of extrapolation to a 3rd jet cut of zero. These are for a cone of 1.0. Lines are for linear, h 1.6 (&EM 1.0), and 1.6. Note that 1.4 would extrapolate worse than 1.6! If you take this seriously, e/h of 1.6 gives about 26% worse intrinsic jet resolution than 1.0.

The scale changes have been trivially extended by generating higher energy jets in order to reinvent the compositeness nonlinearity as quoted in the EOI.[5] This is shown in Fig. 3. For e/h of 1.4, the difference between 1 and 5 TeV is 2%. The EOI takes a conservative 100% error on it. Although most of the nonlinearity is at the low end, this can be calibrated out using, for example, high p_T Z

production. For 5 TeV, some 1 TeV test particles would lend confidence.

As the Groom parameterization neglects ionization, I used the degradation for 6 GeV particles for all hadrons below 6 GeV. As an estimate of systematic this can be redone cutting off at 1 GeV; the deviations from linearity are amplified by 14% (of themselves). Turning off all hadrons below 1 GeV to mock the magnet changes the scale of 200 GeV jets by 0.8% and 1.2% for the 0.7 and 1.0 cones respectively.

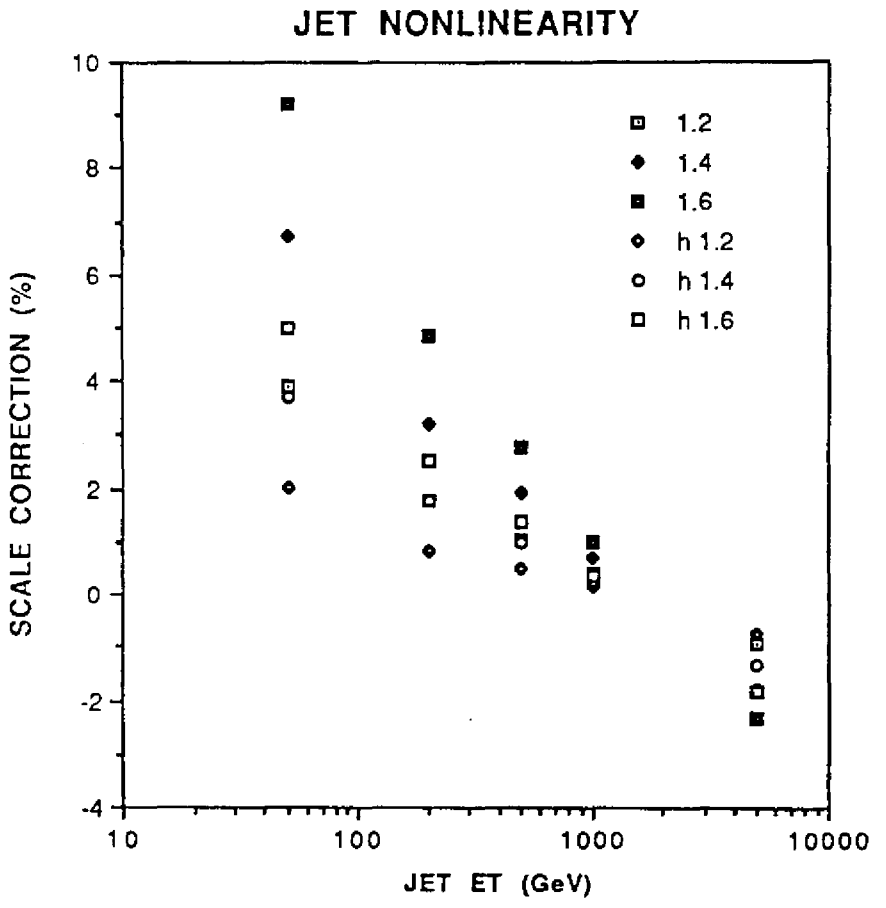

Fig. 3. Relative scale corrections needed for cone of 0.7 (linear≡1.). Normalization is at 100 GeV (test beam). Hadron response for particles below 6 GeV is taken to be the same as that for 6 GeV. As in Fig. 2, the h cases refer to EM compartments with e/h = 1.0.

1 SDC Letter of Intent, SDC-90-00151, p38. A somewhat less pronounced effect (to put it politely) is noted by Adam Para & co.

2 R. D. StDenis, PhD Thesis (Harvard 1988), ANL-HEP-TR-89-02. See particularly Appendix C.

3 Frank Paige was most gracious in helping me to mangle his code.

4 Don Groom, proc. Workshop on Calorimetry for the SSC (Tuscaloosa 1989) p 59.

5 SDC Expression of Intent, p 82, from M. D. Shapiro, SSC-SDE-37.

APPENDIX

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2/1/90

A TOUCH OF REALITY FOR THE ISAJET THEORETICAL CALORIMETER

Many studies of the viability of various SSC physics studies have been made using a theoretical calorimeter attached to the ISAJET generator. This simply involved associating the energy of each particle with a grid of cells in rapidity and azimuth while handling leptons explicitly. In order to expand the scope of what can be studied this way, the calorimeter model needs to be improved without major time penalty. To do this involves making explicit assumptions, hopefully reasonable, to keep things simple and fast. The main changes are to make an explicit EM section of the calorimeter and implement a simple electron algorithm which will lose those electrons buried by other energy, and to give showers a transverse extent.

The overall calorimeter, for simplicity is assumed to be infinitely deep. The EM section is assumed to be 24 radiation lengths of lead with enough say plastic and aluminum mixed in to make it 0.92 nuclear absorption lengths thick, both for any angle of incidence. The code can be easily modified for 22 or 20 or 18 radiation lengths, and can be regenerated for any arbitrary configuration. The fraction of energy deposited in the EM section is allocated from a lookup table allowing various depth before interaction and incident energy. The tables are calculated for EM showers from the particle data book longitudinal shower parameterization and for hadrons by the Bock et al. parameterization. The only randomizing is the exponential placing of the point of first interaction. The fractions vary smoothly allowing the lookup table to have linear extrapolation between logarithmically placed momentum values. The code to generate the tables is run at initialization and should be transparent to anyone desiring modifications..

The electron algorithm is quite simple. A 4 by 4 region around an electromagnetic seed tower is formed optimizing the EM energy in the inner 4 cells. The seed tower is required to be above 1 GeV and be >90% EM. The overall cluster must be above 10 GeV Et and >93% EM. This is safe given the generation above; in a real calorimeter the EM fraction requirements will need to be more strict but

relaxing as the electron energy becomes very high. The central 4 towers are required to contain >80% of the EM energy. To avoid confusion and also avoid worrying about tracking and matching, the electron candidate is required to match with an electron on the generated lepton list. The match is quite crude, within 6 cells in both rapidity and azimuth and within 40% in energy. The electron finding precedes jet finding and consumes the towers involved. The found electrons are written out as jets. An ID word has been added which is the number of the matched electron on the lepton list and is zero for jets.

Relatively trivial changes are that a 1% (1.5%) independent constant resolution is added for EM (hadronic) particles and muons no longer put any energy in the calorimeter. The study of muons is its own problem.

Transverse size is applied as a simple triangle. The half base for EM showers is taken to be 1 cm, for hadrons 5 cm. These parameters may be varied trivially. Some assumptions need to be made about overall detector geometry. The front face cylindrical radius is take to be 2 meters. The corner is turned at 4 meters absolute z (longitude). At rapidity 3., as setback of a factor of 2.5 to 10 meters is taken. Despite this, the inner cells of the backed off section become as small as 2.2 mm. For ease of code, the triangles are cut off at covering 11 cells. The electron algorithm will get screwed up above rapidity of 4.5, but that is probably reasonably realistic.

Test jobs show that the added "sophistication" in simulation adds negligible overhead to the generation.

The effect of this minimal, inherent level of isolation requirement is quite small for a priori isolated electrons. In the region of |pseudorapidity| < 3 and p_t > 10 GeV/c, for four detected electrons from a 300 GeV/c^2 Higgs, the four electron efficiency is 98.9%. This corresponds to individual electron losses of about 0.26%. On the other hand, looking at 4 lepton background from top pairs with forced t and b decays, for a 200 GeV/c^2 top mass, the overall efficiency for 4 electrons is reduced to 2.4% due to the immersion of b decay electrons. This corresponds to about 16% efficiency for b electrons. For a top mass of 100 GeV, the b jets are less collimated and the electron efficiency moves up to about 40%.