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Simple Tests of Jet Clustering in GEMFAST

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1 Introduction

While working on the compositeness search section of last year's preliminary physics report, I discovered two significant anomalies in FAST1, GEMFAST's predecessor. High energy pions from the most energetic jets were vanishing without a trace and whole jets were disappearing near the (0,2π) ϕ boundary. I traced both to minor errors in the jet response and clustering code. Having been burned once, I decided that one of the first things I should do, before embarking on any jet studies, would be to perform a series of tests on GEMFAST, all of which are exceedingly simple minded. Among the issues are:

- If a jet is created with a given p_t, η and ϕ, does the jet clustering algorithm find it in the same place with about the same energy?
- Clustering uniformity: Is there a smoothly varying distribution of jets with $|\eta|$ in QCD events? Or does the changing segmentation have any effect?
- angular resolution: What is the probability of distinguishing two jets as a function of their $\eta - \phi$ separation?
- Jet resolution: What is the expected jet resolution and response versus η?

Ultimately, studies such as these can be used to develop a jet energy (or P_t) response function, versus p_t, η, and clustering cone size, to correct for leakage out of the clustering cone and any detector shortcomings. In the case of GEMFAST, which has few significant cracks or dead regions, the last effect will be minor.

2 "Wherever you go, there you are" tests

In the first test, 5000 Pythia QCD events ($P_t > 200$ GeV) were generated, and jets made from final state particles (with Pythia's LUCELL routine, using corresponding parameters) and those produced by GEMFAST were compared. See figure 1. The rms difference in η (top left) or ϕ (top right) of the two views of a given jet is .03 units. The P_t difference of two jets is typically 9% (lower left). If I require the jet in question to have at least a quarter the P_t of the leading jet, this improves to 6% (lower right).

A related, and equally simple-minded test, is to compare the η distribution of jet clusters using LUCELL and the GEMFAST clustering algorithm. Figure 2 shows the ratio of the number of clusters found by LUCELL to those found by GEMFAST ($P_t > 25$ GeV). LUCELL finds about 10% more clusters but the ratio is flat across η. There is no marked change in cluster-finding efficiency as the tower segmentation becomes more coarse.

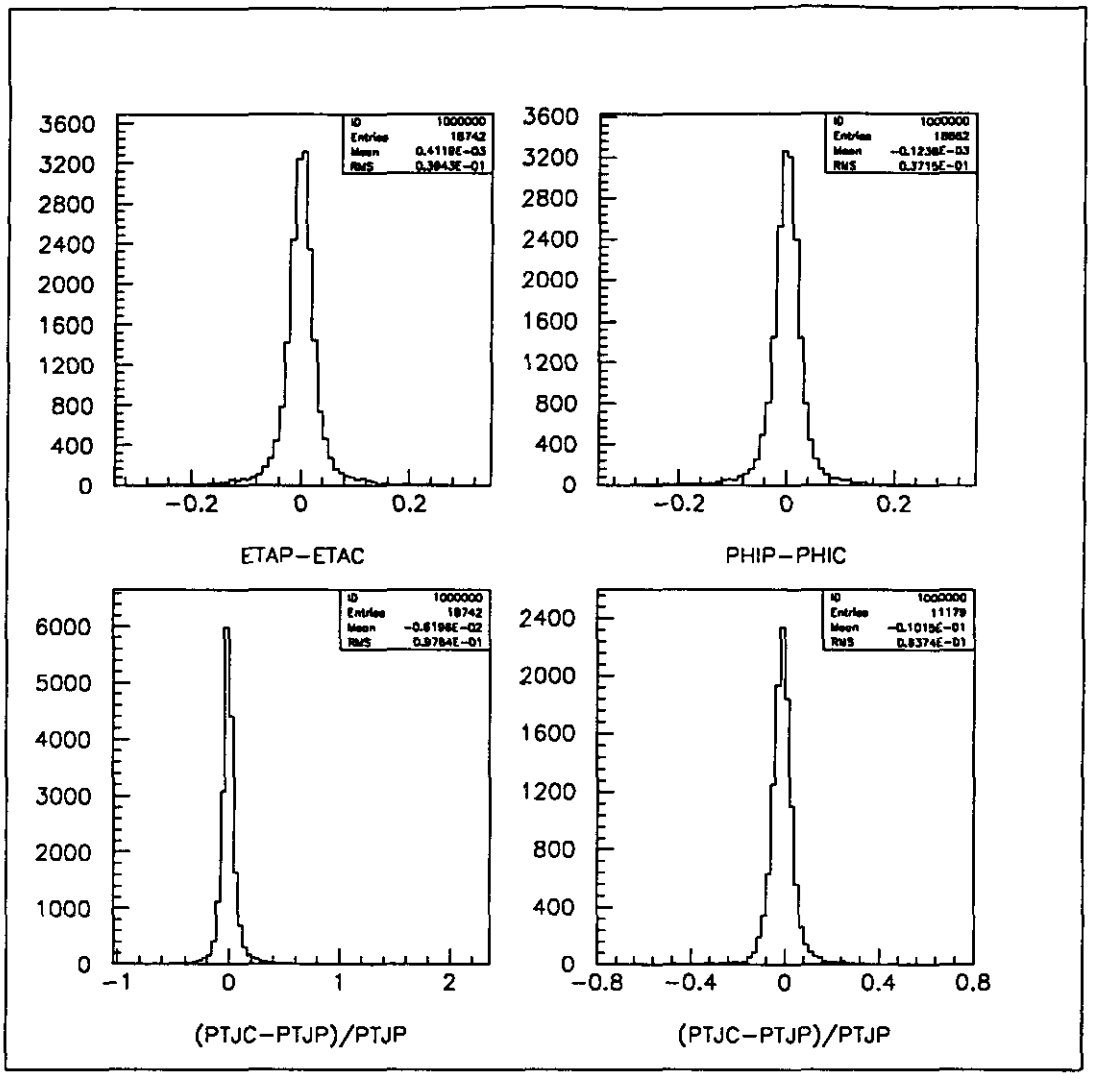

Figure 1: Comparing Pythia and GEMFAST clustering

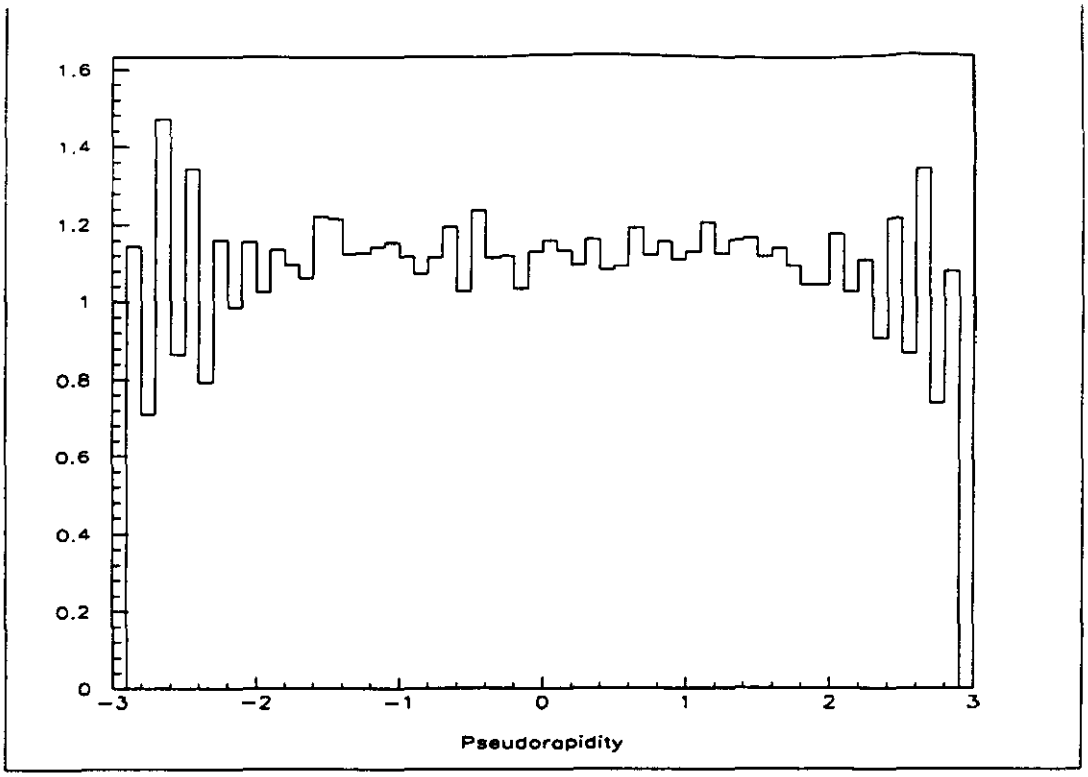

Figure 2: Ratio of number of clusters: Pythia/GEMFAST

Another obvious issue is the effect of the magnetic field on jets. For this test, 5000 QCD events were generated, simulated and clustered, with and without the magnetic field. The corresponding jets were then compared. In figure 3, at the top, we plot the fractional P_t difference of the jets as a function of the P_t measured with no magnetic field. As one would expect, the rms fractional difference decreases with increasing P_t. The lower plot, which shows the average difference vs P_t (no magnetic field), indicates that there is no offset. This means that we need not worry about the effect of the magnetic field in formulating our jet correction function.

3 Angular resolution

Any analysis involving more than two jets must address the question of angular resolution. A good jet clustering algorithm should have a well-defined angular resolution. The probability of two jets being merged should be 1 at small center-to-center separations and 0 and large separations. Fixed-cone algorithms tend to have a narrow transition region where this probability drops from .9 to .1 over a range of .2 in η, ϕ space. GEMFAST's clustering algorithm was tested in the usual way, by combining a jet from one QCD event with another full event, reclustering and then determining, as a function of the separation of the test jet and the jets from the original event, the fraction of the original jets which are merged with the test jet. The cluster cone size was .7. In figure 4, there is evidently a sharp fall-off at a separation of .8.

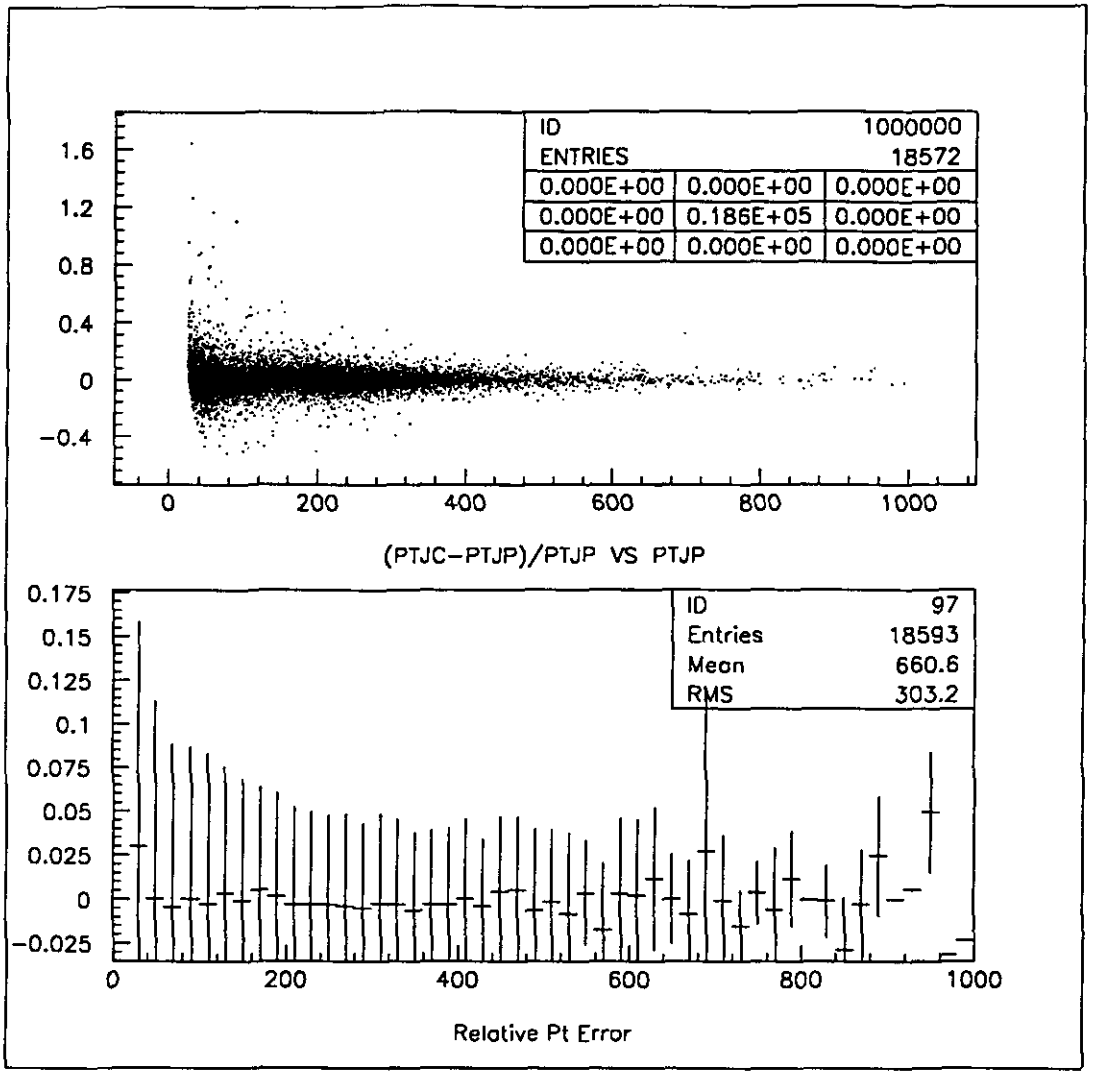

Figure 3: The effect of the magnetic field

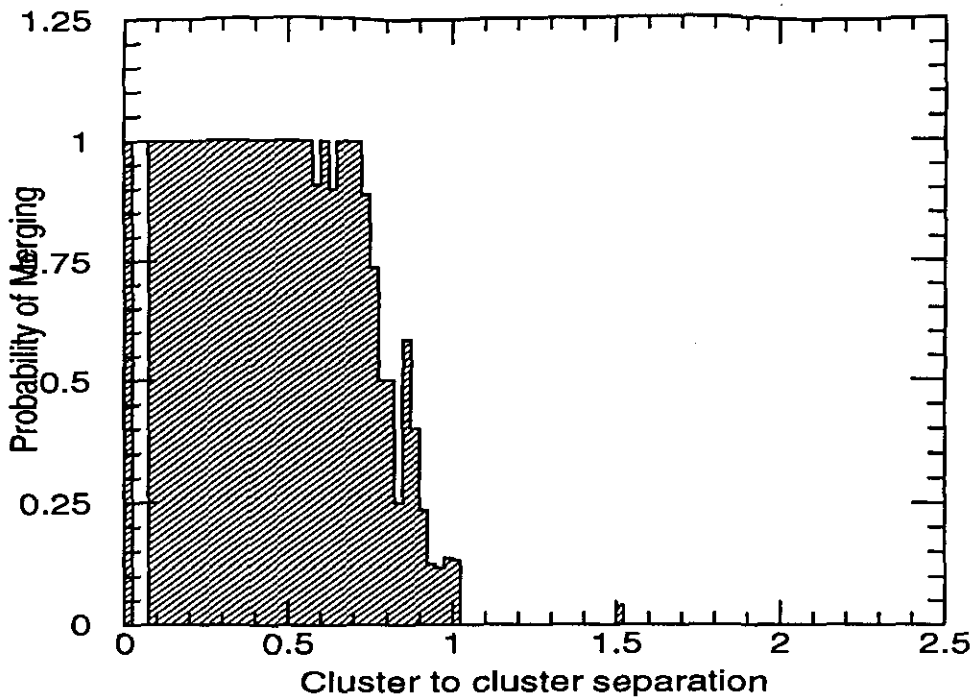

Figure 4: Jet angular resolution

4 Jet P_t resolution

For this test, 15000 two jet events were generated with Pythia's LU2ENT, out to $|\eta| = 2.9$, for P_ts of 100 and 500 GeV. Because the fragementation of the jets changed from event to event, the jet clustering P_t response (made with a clustering cone of .7) was normalized to the result of clustering with Pythia's LUCELL routine on a large grid ($|\eta| < 4.0$) with conesize 1.2. Thus the Gaussian sigmas plotted on the response curves in figure 5 include both clustering and calorimetric effects. For the 100 GeV jets, the average response is smooth, with occasional small dips, a tailing off in response at the endpoint, and a sigma which goes from 7% in the central region to 4% in the endcap, where a given P_t means much more E. For the 500 GeV P_t jets, figure 6, the same trends are evident, with the sigma dropping from 4% to 3% from the central to endcap regions.

5 Underlying Event

Another test, which involves more physics than properly belongs in this note, is a measurement of the underlying event, which is generally used to correct raw jet P_ts. Here the idea is to look for 2 jet events (minimum P_t = 100 GeV and no other jets above 10 GeV) and measure the P_t density at 90 degrees in ϕ from either jet. See figure 7. The horizontal axis is in GEMFAST tower pseudorapidity units, folded about $\eta = 0$, where the left edge corresponds to $\eta = 3$ and the right edge, $\eta = 0$. The underlying event density (no noise) is about 2.2 GeV per unit $\eta - \phi$ space in the central region, tailing off to 1.6 in the endcaps. This is about twice the size of the contribution from the typical minimum bias event.

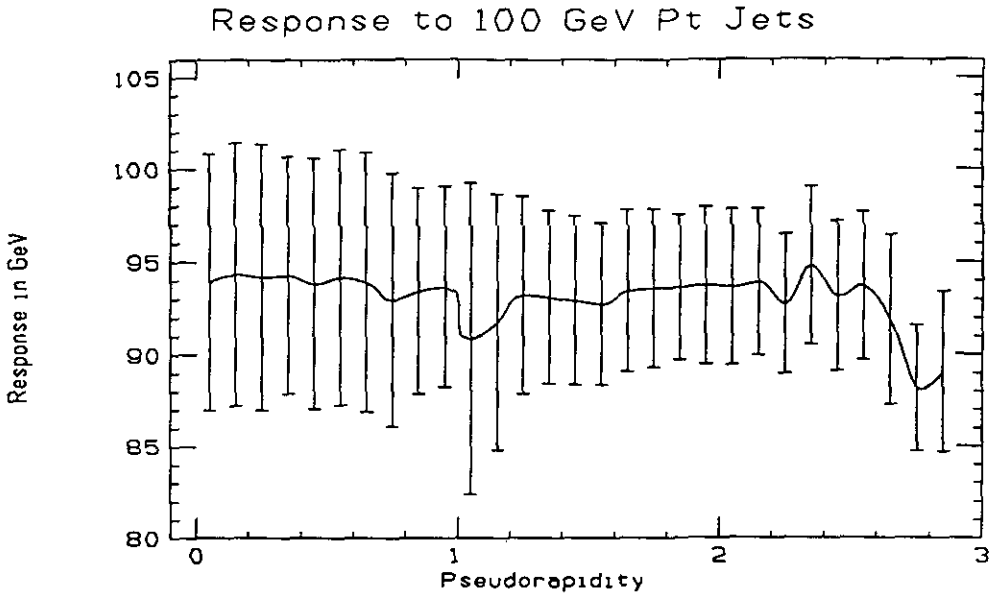

Figure 5: Jet P_t resolution: 100 GeV jets

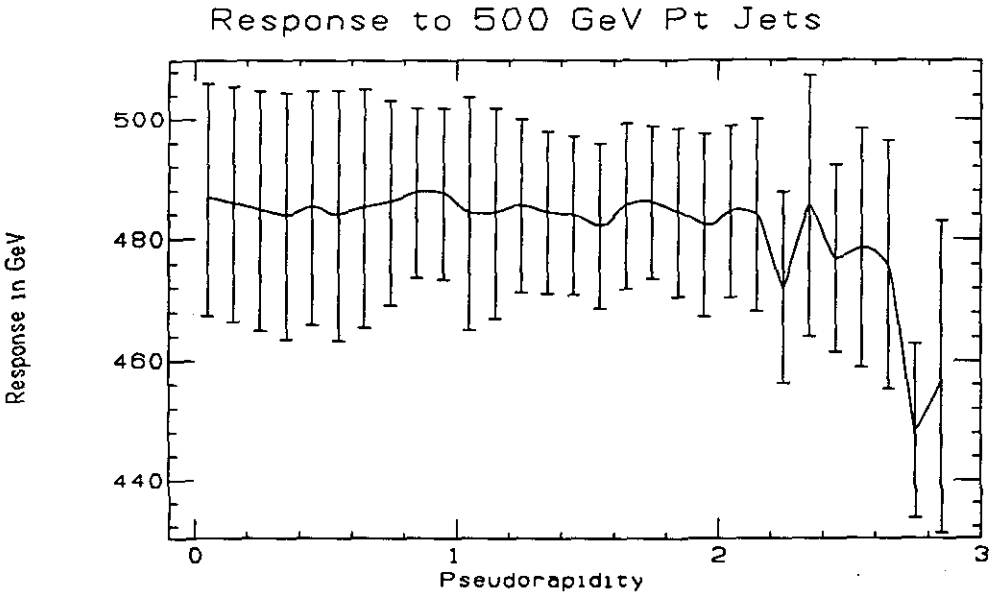

Figure 6: Jet P_t resolution: 500 GeV jets

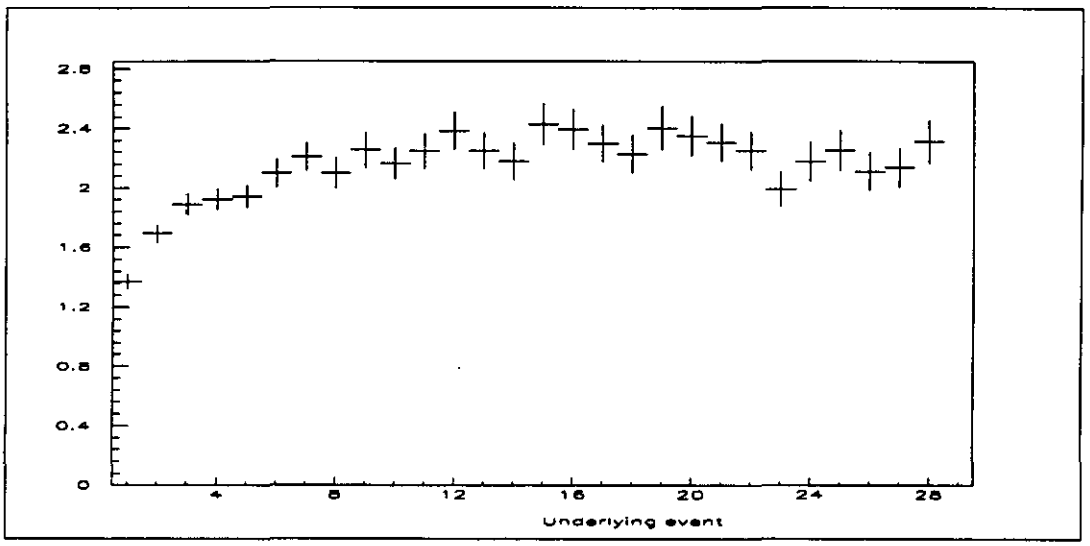

Figure 7: Underlying event density in QCD events vs. $|\eta|$

6 Conclusions

GEMFAST's jet clustering algorithm has no obvious flaws and its performance matches well, when appropriate, with LUCELL. The raw material and software infrastructure for a jet correction function now exists, should it be needed.