A method of using the HADTDC system to reject large MET events with out-of-time energy

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March 2004

Outline

- **Quick physics motivation**
  - **What HADTDC does and how it helps**
- **Why not use a Run I "style" HADTDC analysis?**
- **A Sleuth-like methodology**
- **Technical details**
- **Results**

HADTDC Overview

- **For every HAD tower (CHA, WHA and PHA) we measure the time of arrival with a TDC**
- **Correct this raw time for discriminator energy slewing as well as t0 of crossing relative to TDC t0**
  - **"in-time" with the collision has a corrected time of t=0 but smeared by the (energy dependent) system resolution**
- **Can be very helpful for rejecting cosmics, beam halo, beam-gas interactions etc. which can deposit lots of energy "out-of-time" and cause large MET**
- **My primary goal is to use HADTDC to search for GMSB SUSY in the γγ+Met final state, but this analysis should work for any search**

Run I Style Analysis

The naïve analysis we "want" to do goes like this:

1. **Pick a fixed timing window and for every tower decide if it is "out of time"**
2. **Add up the E_T of all the "out-of-time" towers and if this is a significant amount of energy throw away the event**

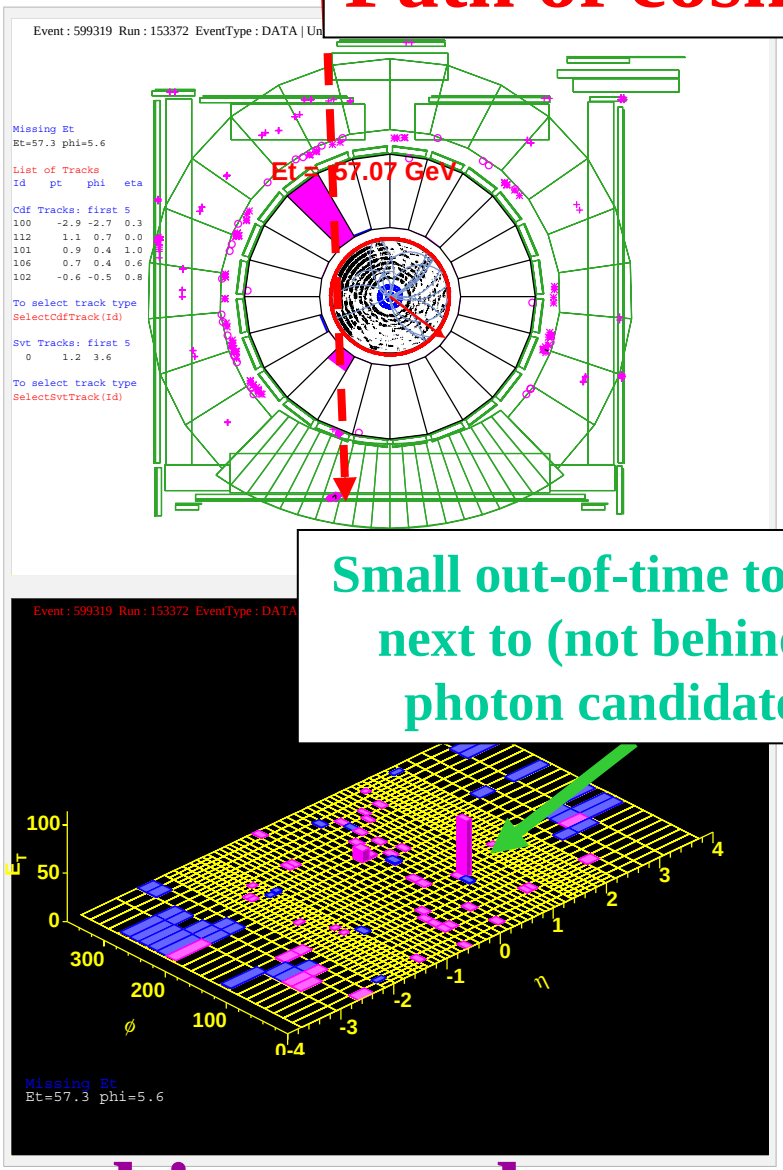
Problems with that method

1. **What if large fake energy is deposited in the EM and only small fake energy in HAD? Very vulnerable in SUSY=>γγ+Met searches**
2. **Timing resolution gets worse as the energy goes down, and for lower energies the distribution develops long tails. A fixed efficiency "Out-of-time" window has be energy dependent and asymmetric.**
3. **Fixed timing window is a bias against events with lots of towers (e.g. SUSY) since there is a larger probability for a tower to fluctuate out of the timing window**

1:Large Fake Met in EM

- **Much of the energy in a GMSB-SUSY event can be from the "photons" which aren't timed (yet), but could be from cosmics, beam-halo etc.**
- **In this case there could be very little (if any) deposited in the HAD**
- **Until there is EMTiming we need need to pay attention to single, small energy HAD towers**

Path of cosmic?



Small out-of-time tower next to (not behind) photon candidate

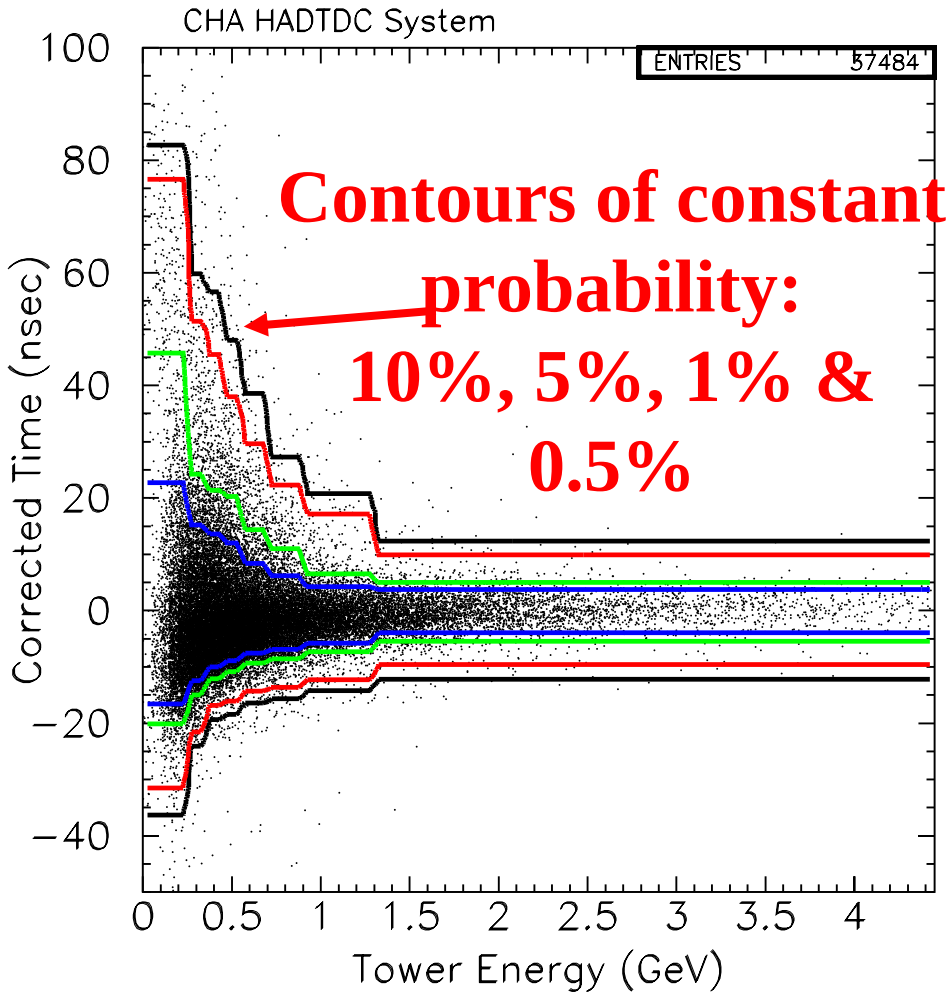
Will come back to this event later

2: Problems at low energy

As the energy goes down:

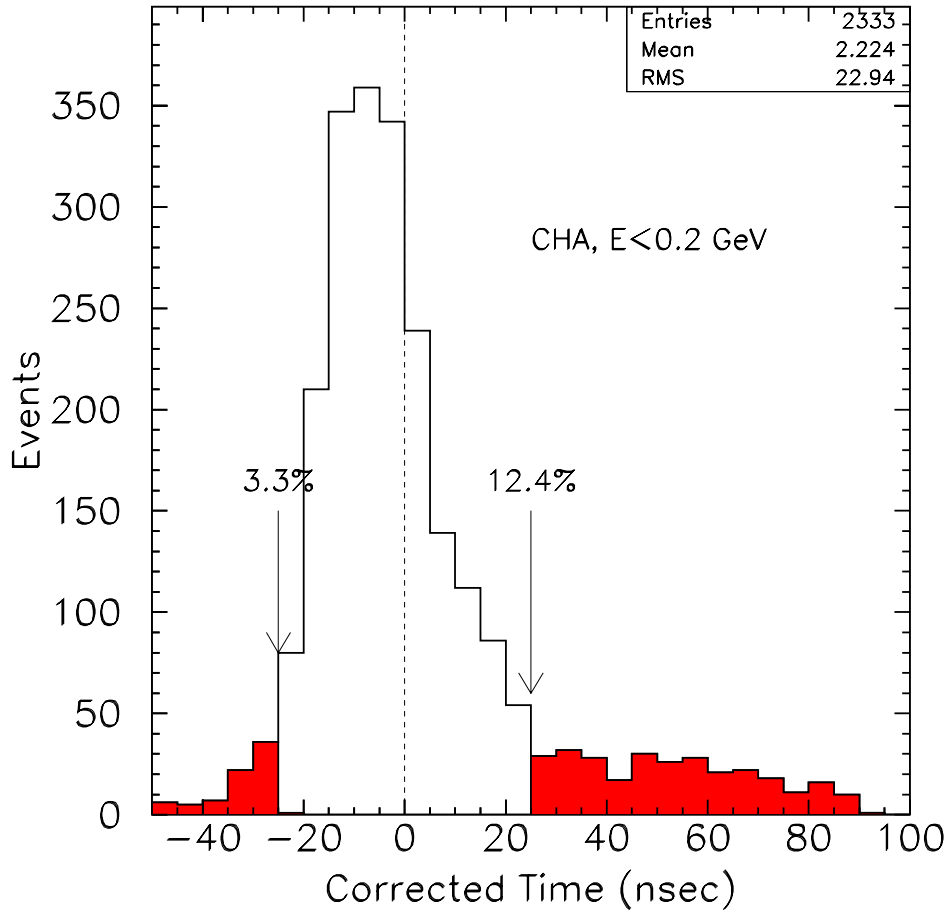
1. Resolution gets worse
2. Distribution becomes asymmetric

A fixed efficiency cut is possible, but not with a single, fixed timing window.



2: Low energy Continued…

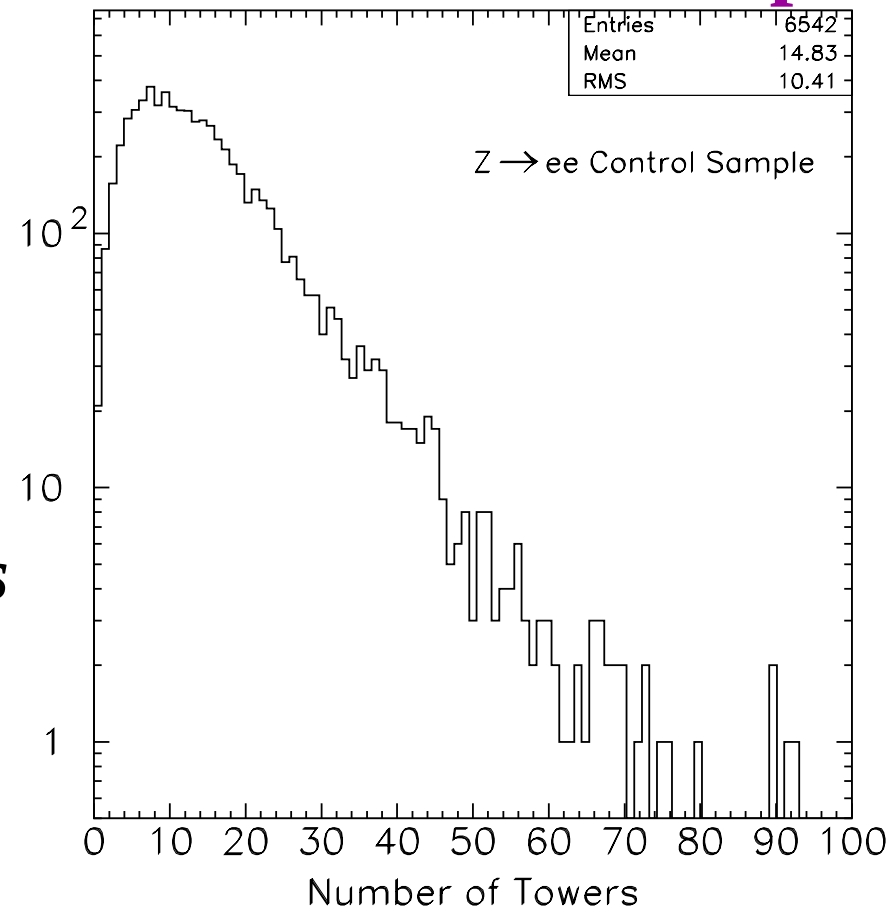
- **In this example, for low CHA energy, the median is about -5 nsec, but the mean is about 2.2 nsec**
- **Again, we could just ignore these, but we're looking for an indication that there is a cosmic which could be low energy**



3: Number of Towers Problem

- **For a 99% efficient timing window cut:**
  - **10 towers => ~10% chance that one of them will fluctuate to be outside the timing window.**
  - **100 towers=> >60% inefficiency**
- **A fixed-width cut gives a model dependent efficiency, and it is *less* efficient as the SUSY mass goes up (more towers)**

Z=>ee Control Sample



A better (Sleuth-like) methodology

For each event find the tower which is the most unlikely to be from a SM collision (lowest probability), and find the fraction of Hypothetical Similar Experiments which would produce this low a probability hit or lower

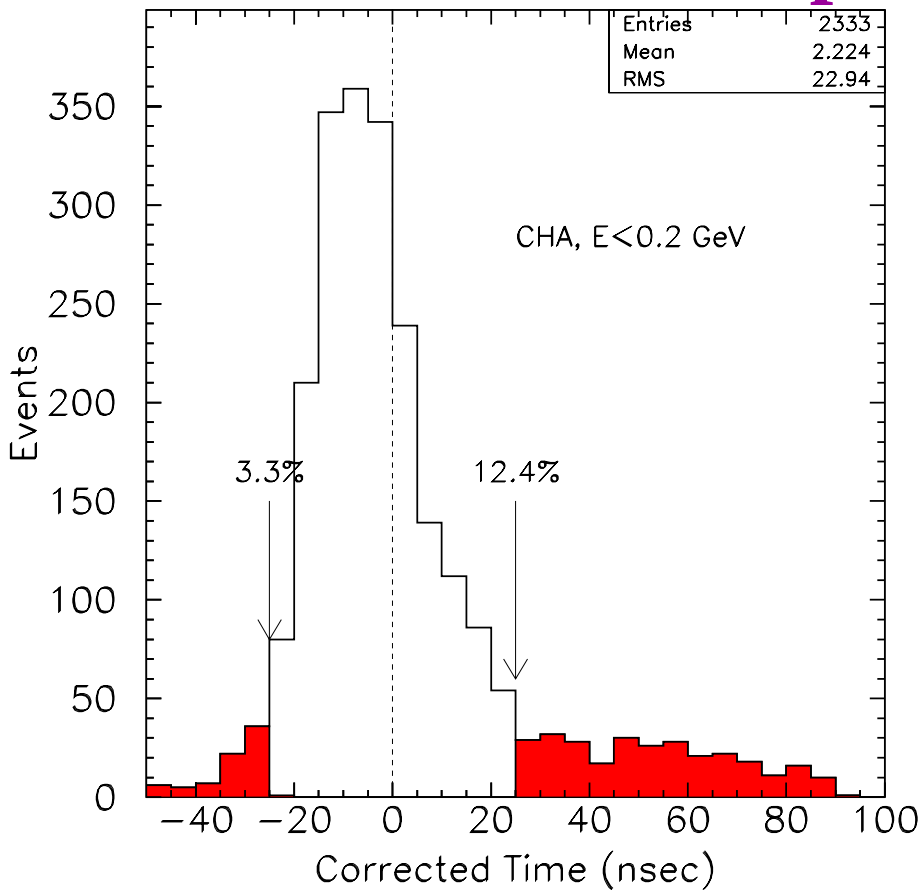
Translation

- **Looking for a tower which indicates this is a cosmic (pick the "worst" tower)**
- **Ask how likely is this tower to be a fluctuation?**
- **Take into account the energy dependent timing distributions**
- **Take into account the number of towers hit on an event by event basis**

The Algorithm

1. For each tower get the fraction of hits from SM which are at this time or above (below)
   - Do this as a function of 1) detector and 2) tower energy
   - Effectively converts each tower into a probability
   - For SM this produces a flat distribution between 0%-50%
   - Get SM from Z=>ee events

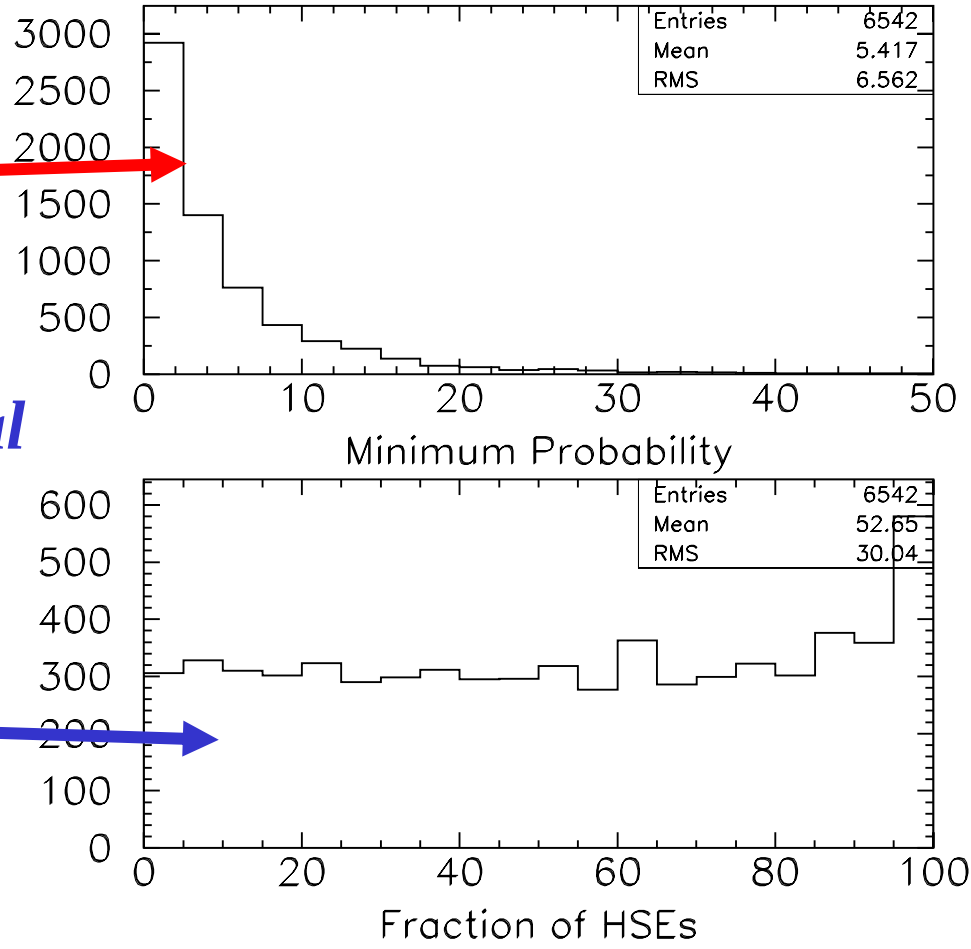
Z=>ee Control Sample



Methodology cont…

2. **Loop over all towers to find the one which is MOST UNLIKELY to be from the SM i.e., find the minimum probability**
   - **Very dependent on the number of towers**
3. ***Ask "what fraction of Hypothetical Similar Experiments with the number of observed towers would produce this minimum probability or lower."***
   - **Gets rid of NTower dependence**
   - **~Flat for SM between 0%-100%**
   - **Cut at 3% is ~97% Efficient**

Z=>ee Control Sample



Some technical details before results

Notes on getting the most up to date HADTDC information

- Pass 13 of the cal. calibration consts
- Remove towers with the badtdc bit not set to zero (now in hadtdc database)
- Ignore towers with zero energy (no energy correction possible)
- Use version 5.3.1pre2 or later of CalData to get proper correction of towers with only one PMT firing (e.g. Chimney in the CHA and WHA)

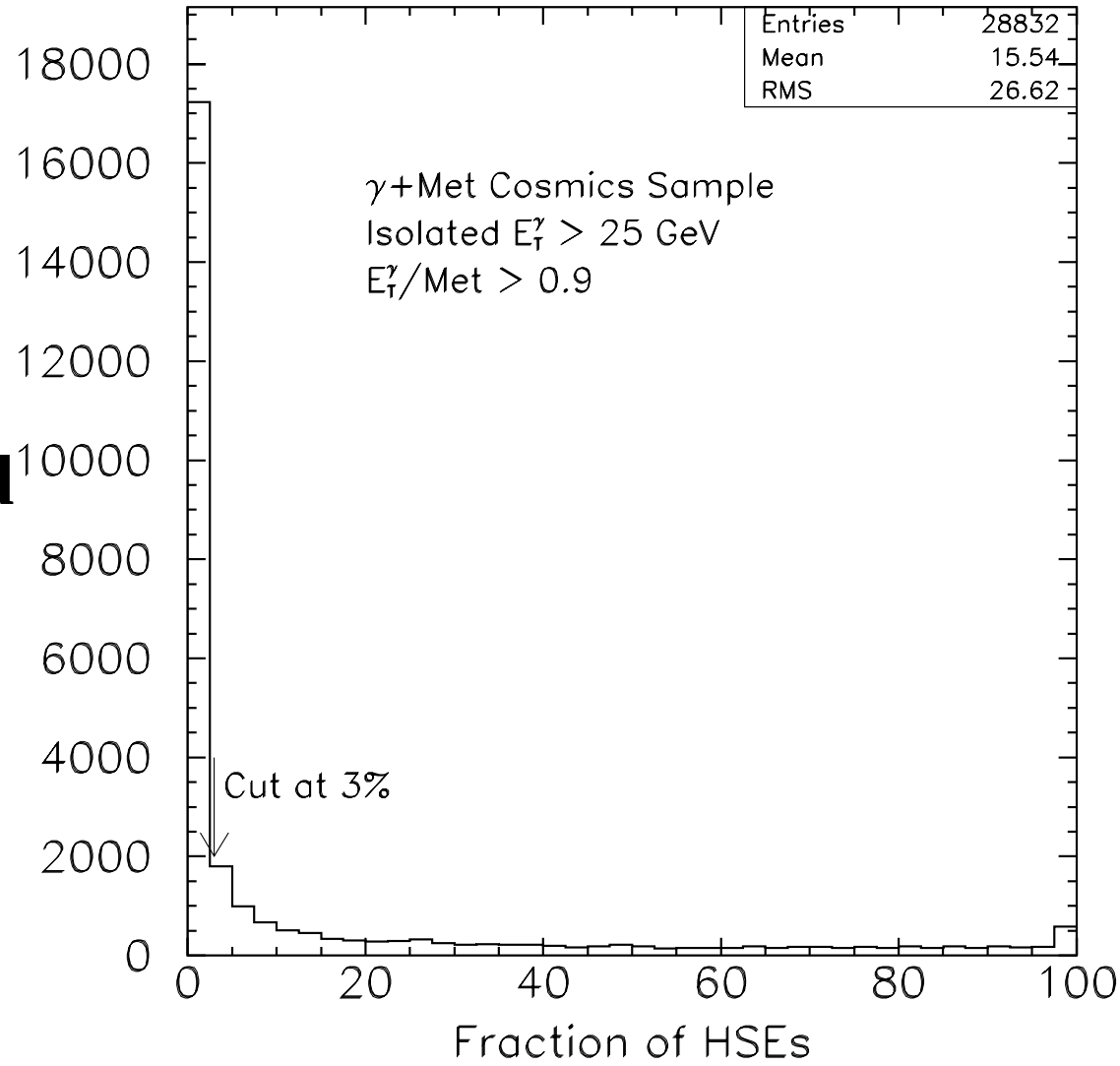
Technical details continued…

Notes on using HADTDC tower information

- **Only consider times during the energy integration window: (From Toni Munar). Outside can't affect the event**
  - **-50 nsec <CHA< 100 nsec**
  - **-30 nsec < WHA< 110 nsec**
  - **-40 nsec < PHA < 90 nsec**
- **Ignore second hits in the integration window**
  - **Would like to reject events where there is an indication of getting energy deposited twice in the same integration window**
  - **But, there are reflections on the transition boards which cause fake double firing for large (but not too large) energies**
  - **1% for CHA, 6% for WHA. Too large an inefficiency**
  - **Centered at ~70 nsec, Fixed for EMTiming**

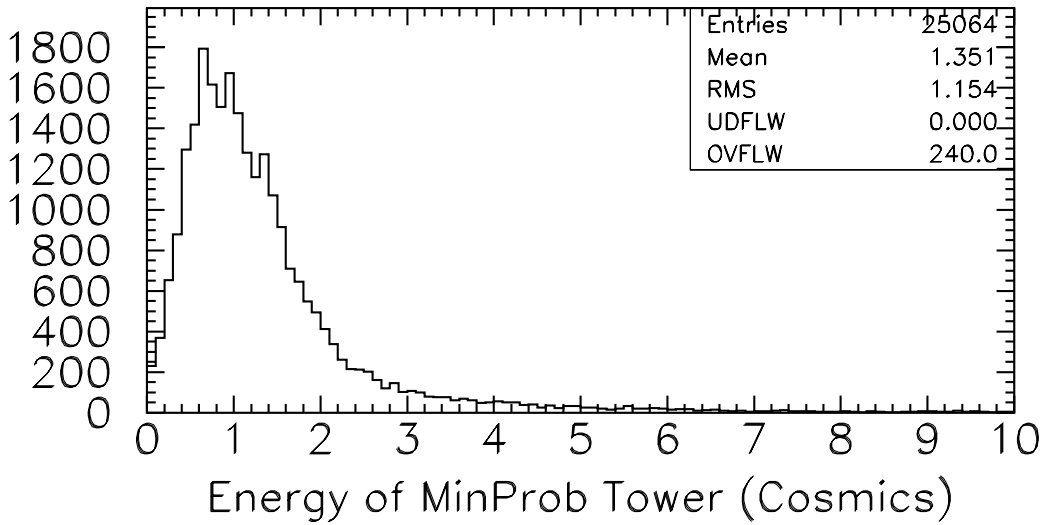
Looking at Cosmics

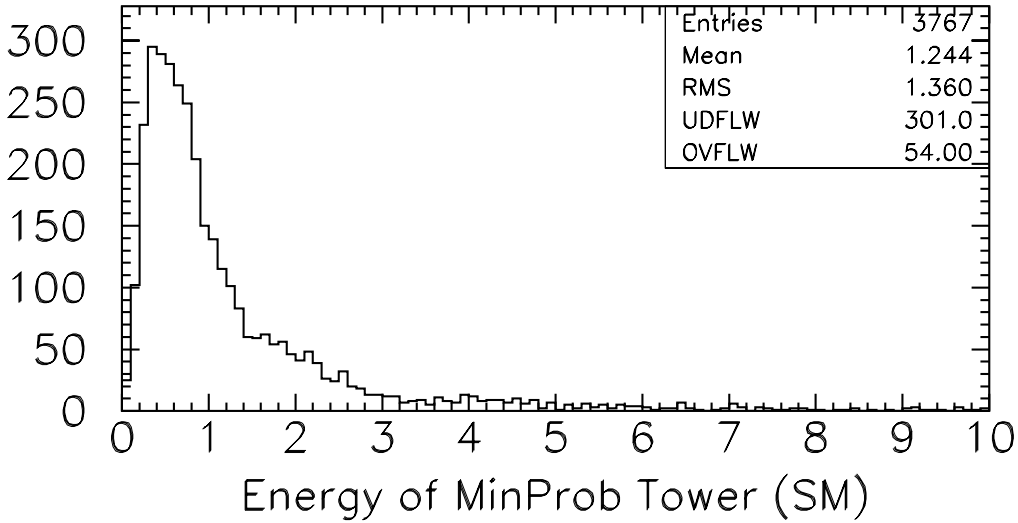
- **Use the method on a sample of cosmics events (isolated Photon+Met events with large Met)**
- **Clear spike at low probability as expected**
- **Cut at 3% gets rid of most of the events**
- **Long tail at high HSE due to SM contamination of sample**



Energy of Tower which Tagged

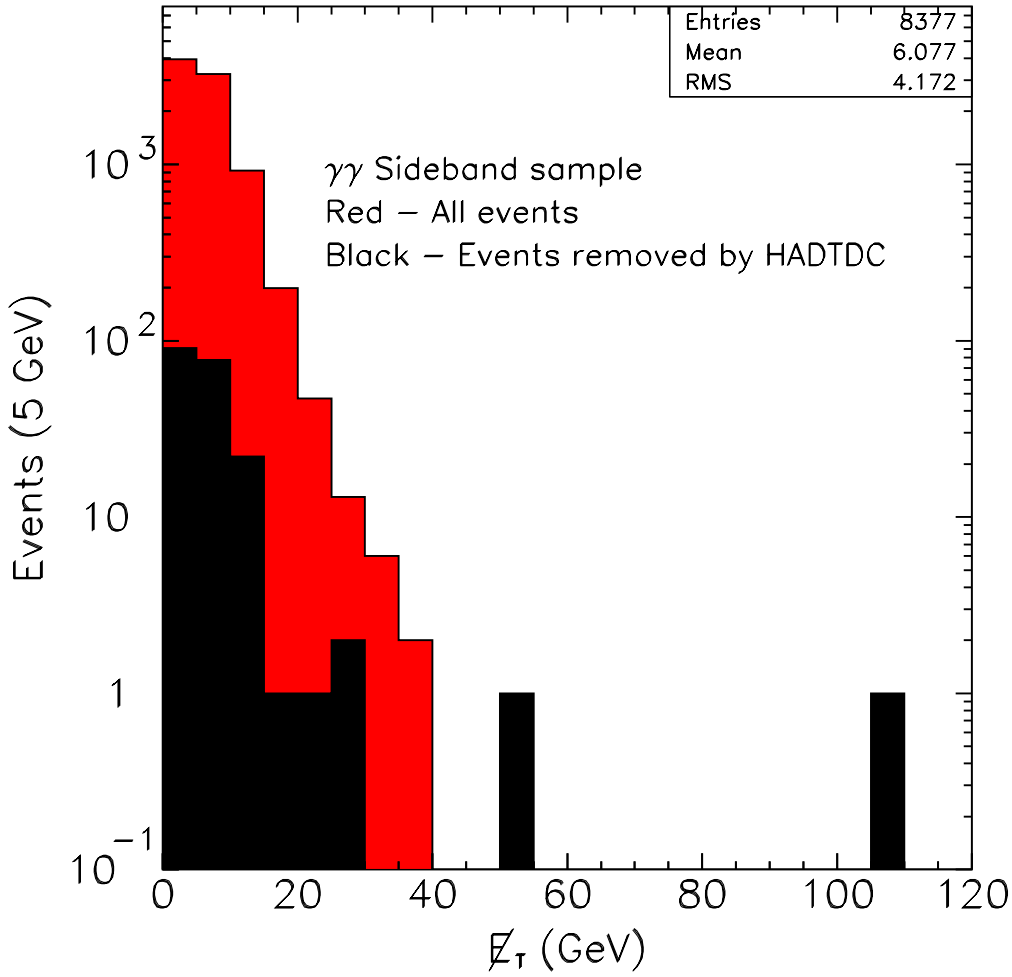
- **The energy of the single worst tower in the event for cosmics is low**
- **No substantive difference between cosmics and SM**
- **Inefficient to ignore low energy HAD towers to reduce the number of towers searched**





Look at γγ Background Data

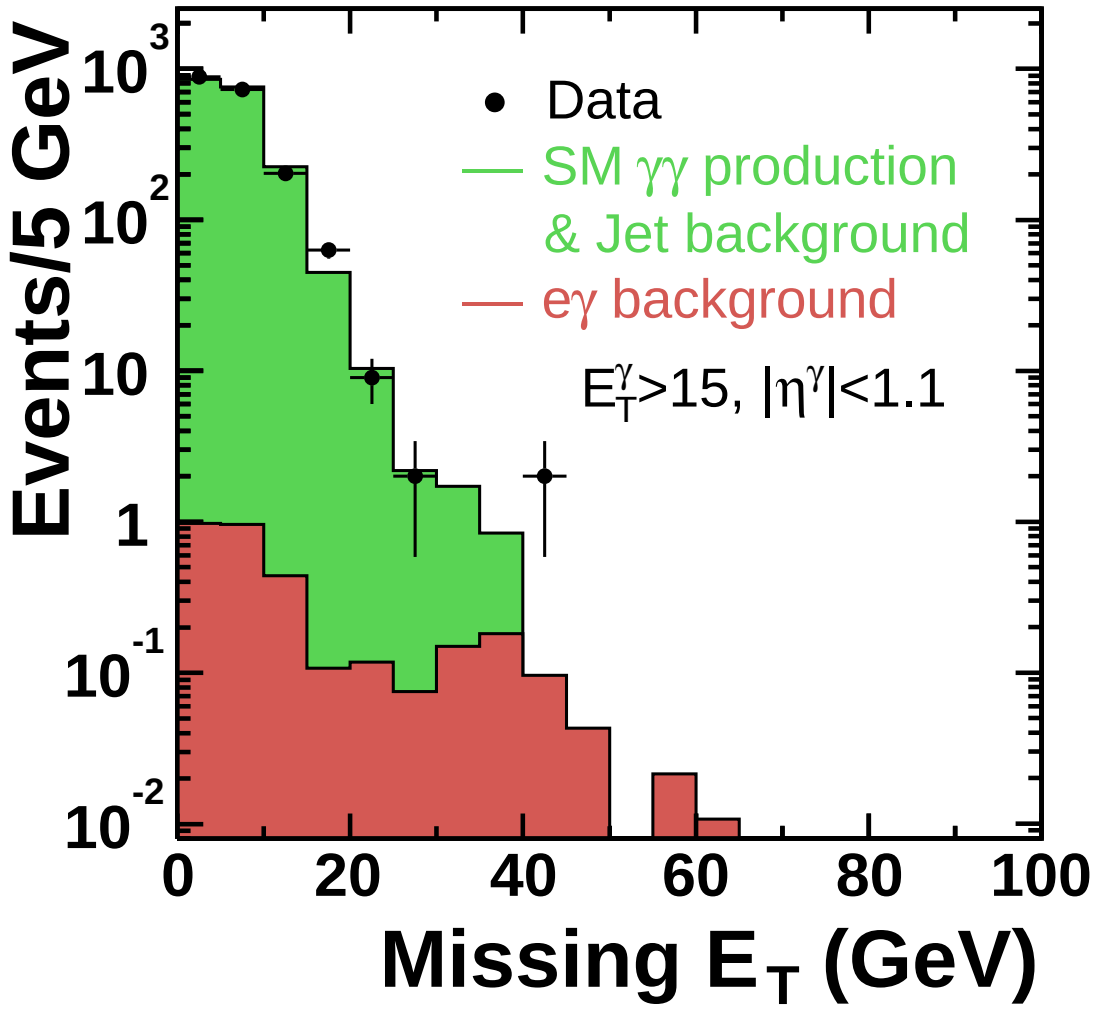
- **Look at the sideband data sample used to estimate backgrounds for the γγ+Met SUSY search**
- **The cut removes the remaining anomalous Met events in the background sample and leaves a smooth distribution**



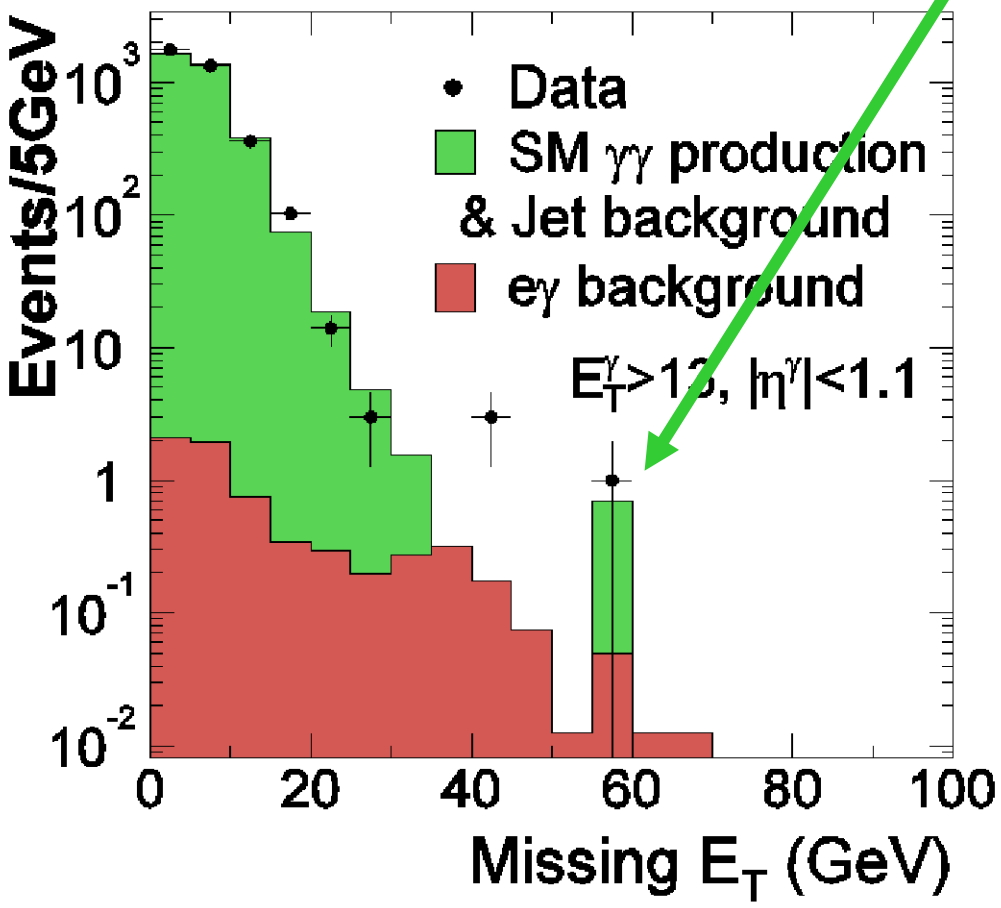
Final data plot: γγ+Met Analysis

- **After HADTDC rejection there are no remaining events with large Met in either the background or signal region samples**
- **Remaining large Met events appear to be consistent with SM expectations**

After HADTDC Rejection



Pre-Hadtdc SUSY γγ +Met analysis



The event I showed earlier

Has one tower (E=1.5 GeV) "near the photon" which is 85 ns out of time. No timing info for 75 & 14 GeV photons.

Can't tell if photons are in time, can't tell if Met is reliable

We reject this event, based on the small, poorly measured HAD energy rather than the well measured dominant part of the event

Conclusions

- **HADTDC system can be a very powerful tool to help reject non-collision based backgrounds to large Met searches like GMSB-SUSY =>γγ+Met**
- **New Sleuth-like methodology takes into account no EMTiming, Energy dependent timing distributions, as well as the number of towers in the event**
- **When EMTiming is fully instrumented we can stop looking for "hints" that there is large out of time energy in EM**
  - **Only look at high energy & well measured towers**
  - **Number of towers is reduced so the effective timing window becomes more restrictive**
  - **Better rejection power for the same efficiency**