The FMS Trigger at STAR

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STAR Collaboration

A Word About STAR

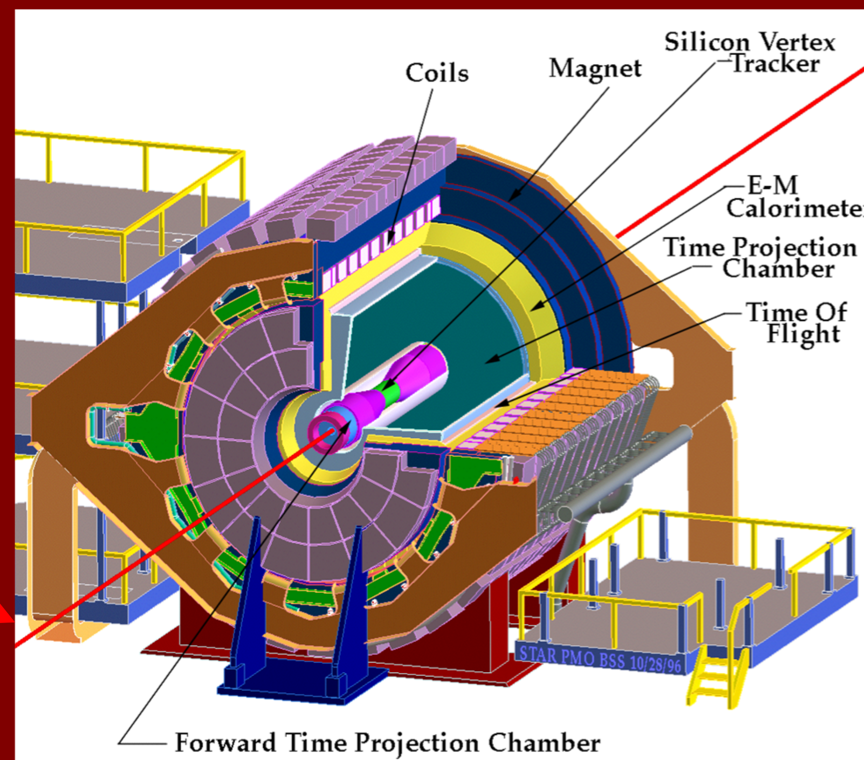
STAR is one of the two large physics experiments going on at Brookhaven National Laboratory. STAR uses the Relativistic Heavy Ion Collider (RHIC) to accelerate protons, deuterons, and heavy ions, such as gold (Au), to extremely high energies in two counter rotating beams. The beams cross at six points around RHIC, and STAR is situated at one of these crossing points. When the beams cross, the particles in the beams collide with center of mass energies up to 500 GeV.

Part of the STAR experiment is investigating the structure of the proton. Particularly the origin of: proton mass, proton spin, and large transverse single-spin asymmetries in p+p collisons. STAR is also studying phases of matter, under extreme conditions, such as the quark gluon plasma, which exists at high densities, and extremely high temperatures.

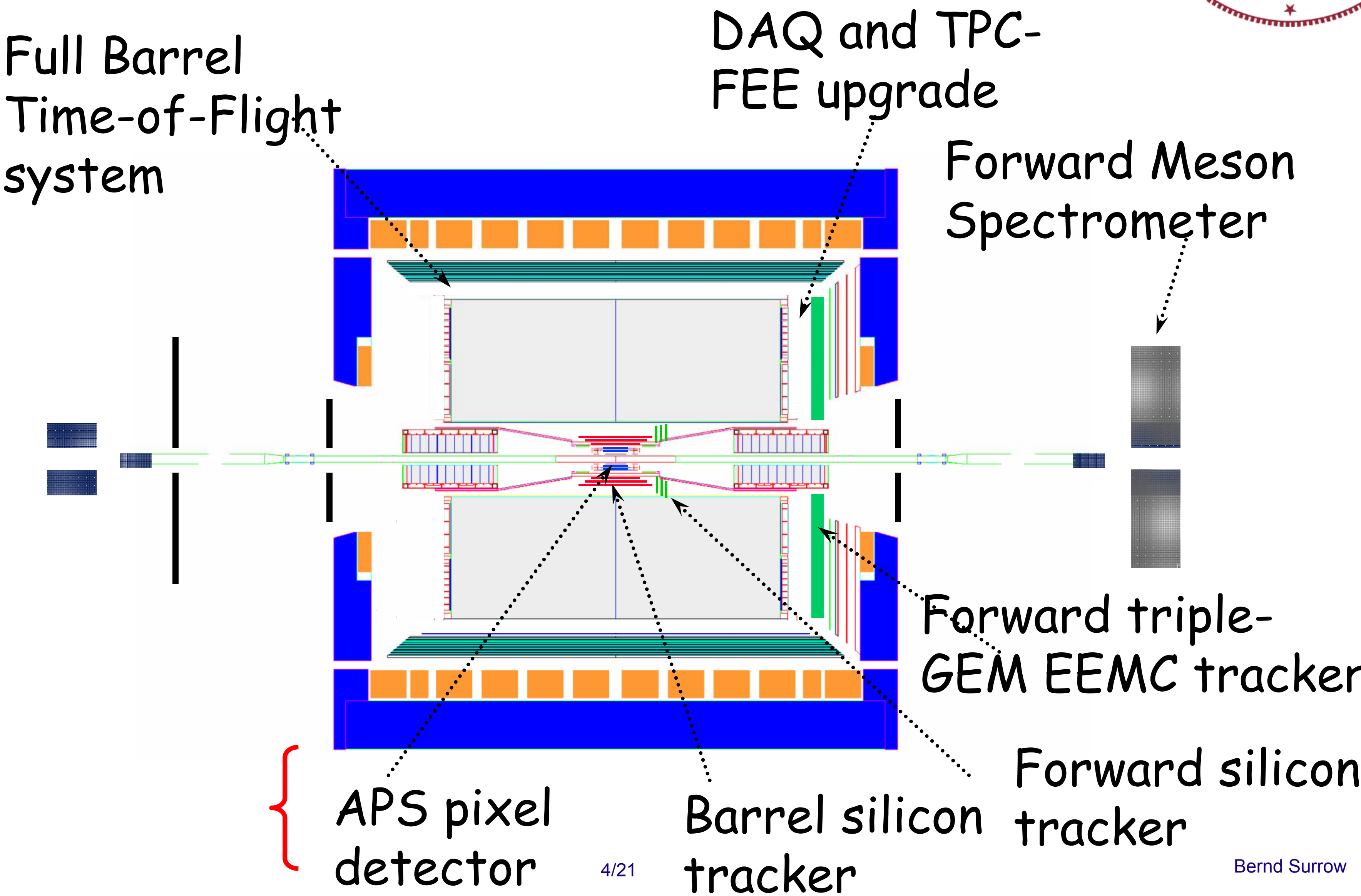
Pictures of STAR and RHIC

Aerial view of RHIC (now famous)

STAR main Detector



STAR Detector



Physics: Forward Meson Spectrometer (FMS)

The FMS was built with three research goals in mind

1. Measure gluon distributions xg(x) in protons and gold nuclei from $0.001<x<0.1$

   Check universality of xg(x) in region of overlap with Deep Inelastic Scattering (DIS) ($0.02<x<0.1$)

2. Characterize correlated pion distributions as a function of Q^2 to search for onset of saturation effects

   Is Au a Color Glass Condensate (CGC)?

3. Resolve the origin of large transverse spin asymmetries in $p_{\uparrow}+p \rightarrow \pi^0+x$ for forward π^0 production

Current Status

- Preliminary results are available for correlated pion distributions (related to goal 2.)

- The large spin asymmetries mentioned in goal 3 have been observed, and two different explanations have been proposed
  - Sivers effect: An initial-state phenomenon related to quark or gluon orbital motion
  - Collins effect: is a final-state phenomenon related to quark transverse polarization

The work I have been doing will facilitate studies in this area, by allowing closer study of η (etas) and jet like events.

What is the FMS?

The FMS is an electromagnetic calorimeter. It is located 706 cm down beam, to the west, of the main STAR detector; it is a subsystem of the STAR detector. The FMS is primarily a Physics detector, meaning that it collects useful Physics data. However, it can also serve as a trigger for the rest of STAR when it detects an event of interest.

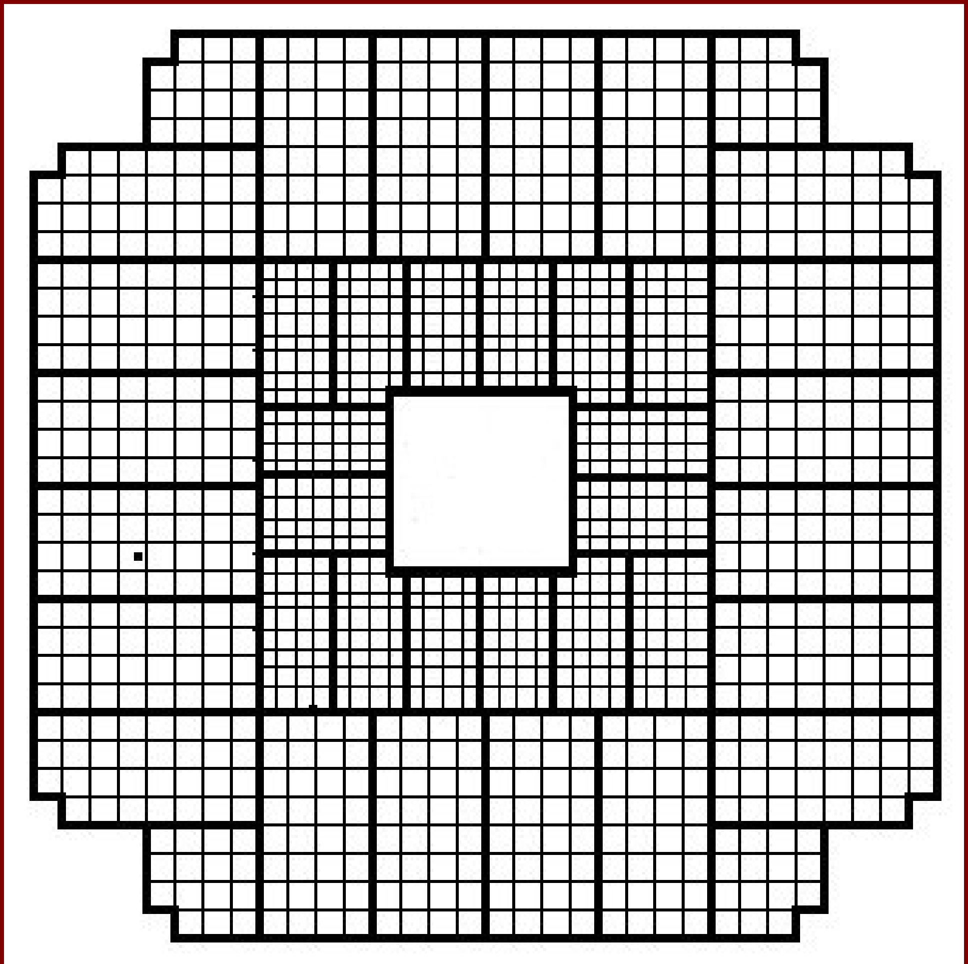
The FMS is an array of lead-glass, Pb-gl detectors. The Pb-gl acts as a cherenkov detector, which is connected to a phototube that generates an electric signal, which is read out of an ADC channel.

What does the FMS do?

- The FMS extends the coverage of STAR.
- It is used to measure photons and mesons produced roughly in line with the beam direction (high pseudo-rapidity). This is useful, for example, in attempting to measure the gluon distribution function.
- Correlation measurements between the FMS and other parts of STAR are facilitating analysis of spin dependent jet structure. (Collins & Sivers effects)

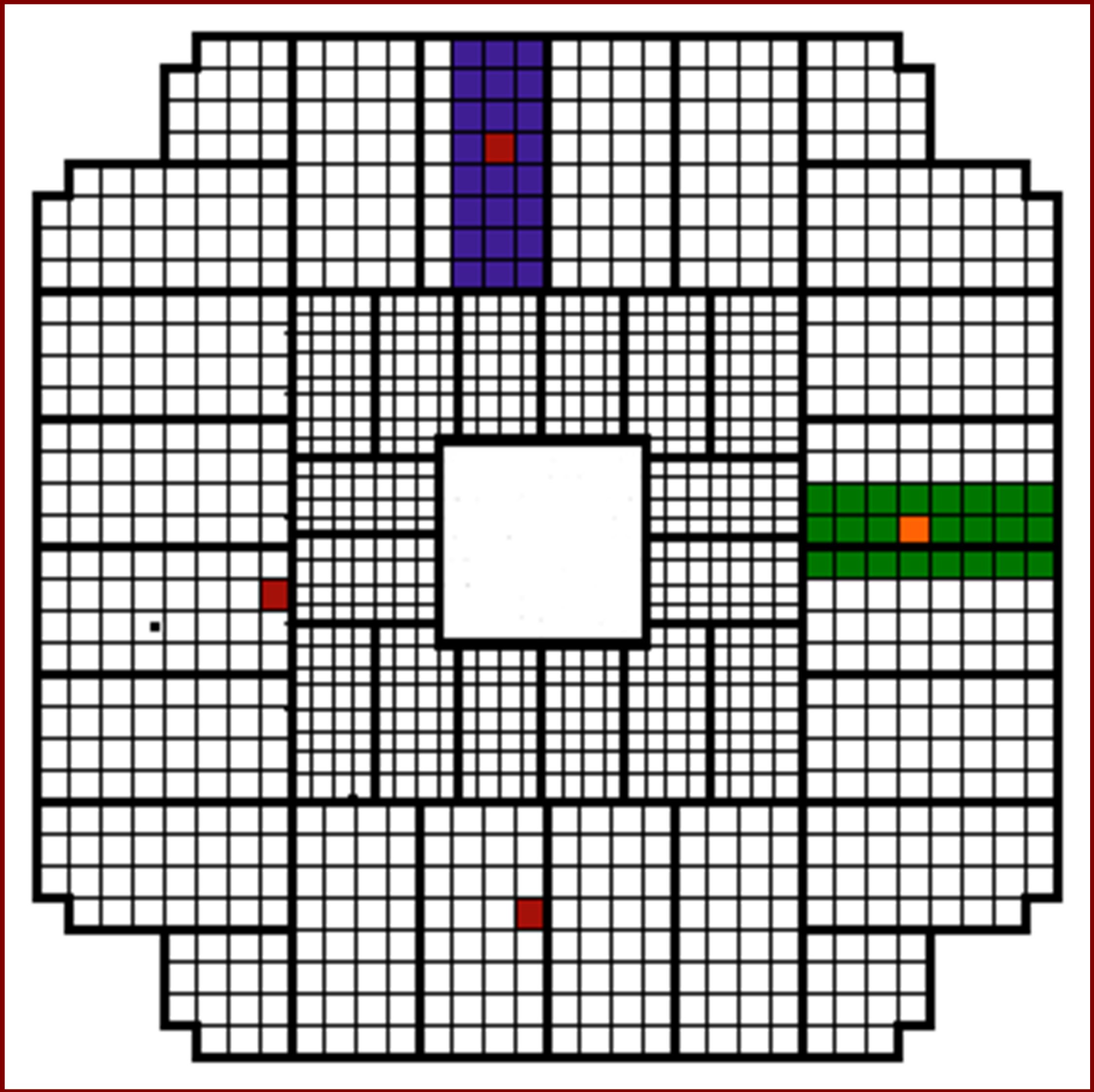
The FMS Detector
QT Boards

The detector cells in the FMS are grouped into QT boards containing up to 32 detector cells. The QT boards read the ADC values from the cells, perform basic data manipulation, then outputs the data. All told, there are 1264 detector cells and 40 QT boards.



Current FMS Trigger Logic

The Run 9 (Spring 2009) trigger was a cluster trigger, it looked for a high ADC, High Tower (HT), then summed the ADC's from the detector strip with the HT and the two adjacent strips.



FMS Cluster Trigger

This trigger worked well for triggering on localized events, such as energetic π^0 decay, or single photons.

The trigger did not work nearly as well for events that are separated in space, such as η decays and jets, which appear as two less energetic photons, but come from a highly energetic event.

Illustration of Eta Decay

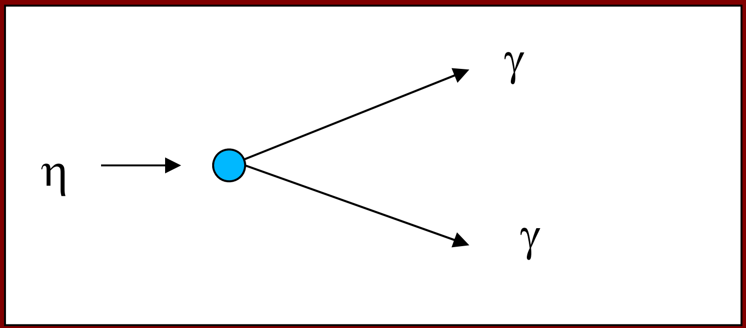
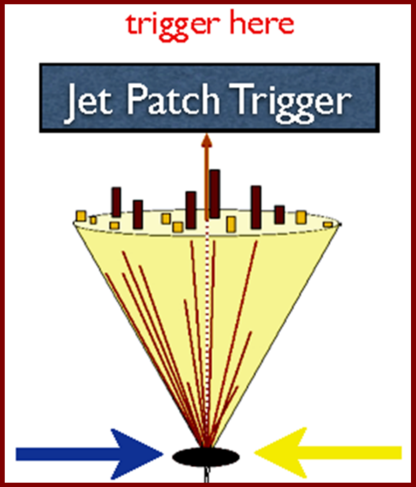


Illustration of Jet like event



My Involvement with the FMS

My assignment regarding the FMS was to develop a new trigger algorithm.

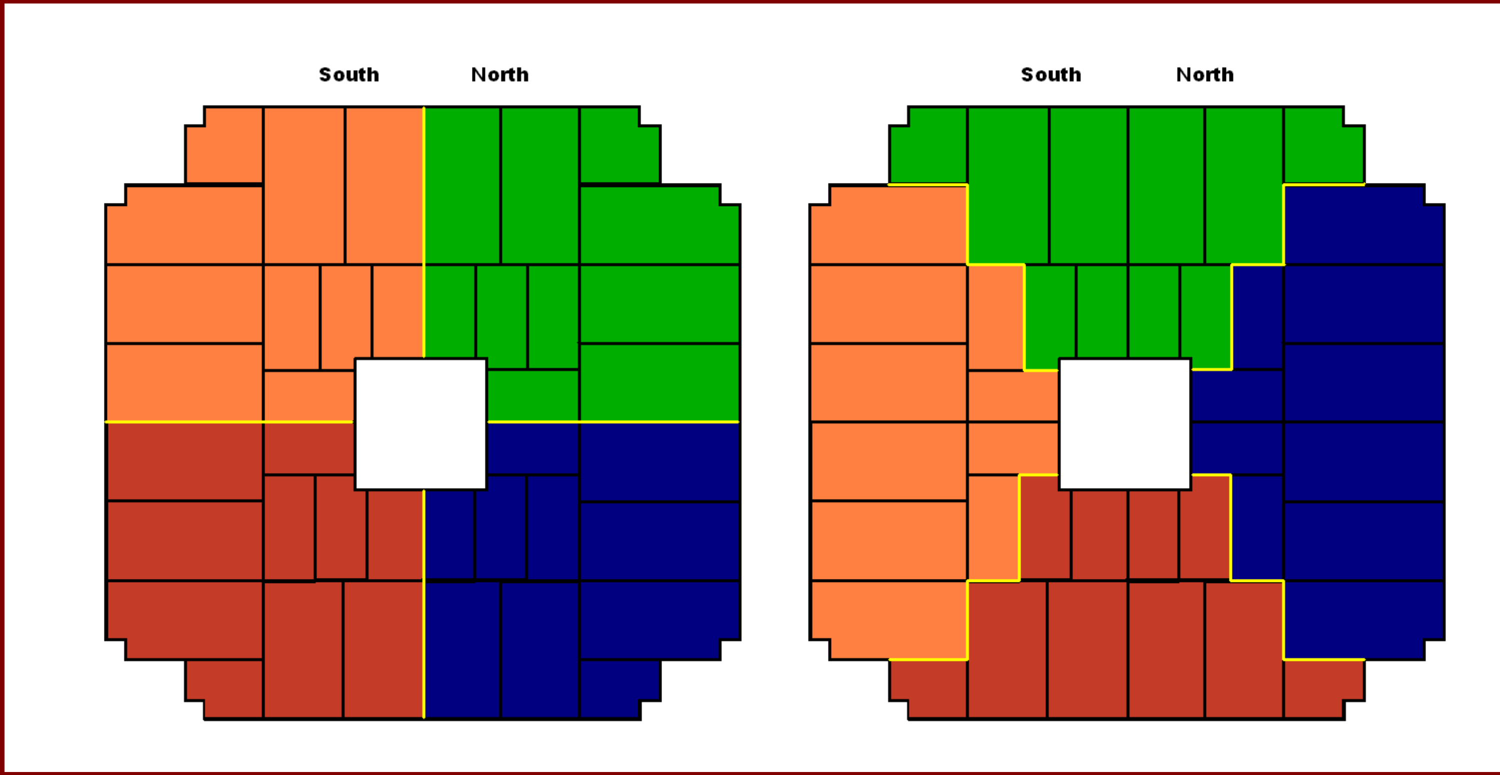
The new algorithm is intended to increase the versatility of the FMS by allowing it to trigger on events in 1 of 8 overlapping jet patches or a board sum. (Jet Patch defined later)

Once the new logic scheme had been worked out, it needed to be tested, so I modified the simulation code for the old trigger algorithm to reflect the new algorithm.

After the simulation code was complete we ran several simulations over the equivalent of 2.6B p+p collisions at 200 GeV and 50M p+p collisions at 500 GeV, to analyze the behavior of the new trigger.

The Jet Patch Trigger

In order to increase the triggering efficiency on η's and jet-like events, the detector needs to sum the observed energy over a larger area. This inspired the concept of a jet patch trigger.



Jet Patch Trigger

Basic Idea

The new triggering algorithm for the FMS is based on overlapping lapping jet patches. This should improve the efficiency of detecting non localized events such as, etas and jets.

Key Differences

- Triggers on large area instead of three strips surrounding the HT
- The jet patch trigger crosses the large and small cell boundaries, as well as the North South boundary in the large and small cell regions
- Also triggers on 'clusters' within a single board
- Potential for a Di-jet trigger

The FMS Detector

Threshold Logic

There are three distinct complementary triggers, the High Tower (HT), Boardsum (Bsum), and Jet Patch (JP) triggers.

The JP triggers on the energy deposited in any one of the 8 jet patches.

The Bsum triggers on the energy deposited in a single QT board. (A compromise that approximates the Cluster Trigger)

The HT triggers on the energy in a single cell. This is useful for calibration and diagnostics.

Each trigger compares a value, usually a sum, to three user defined energy thresholds.

How does it work?

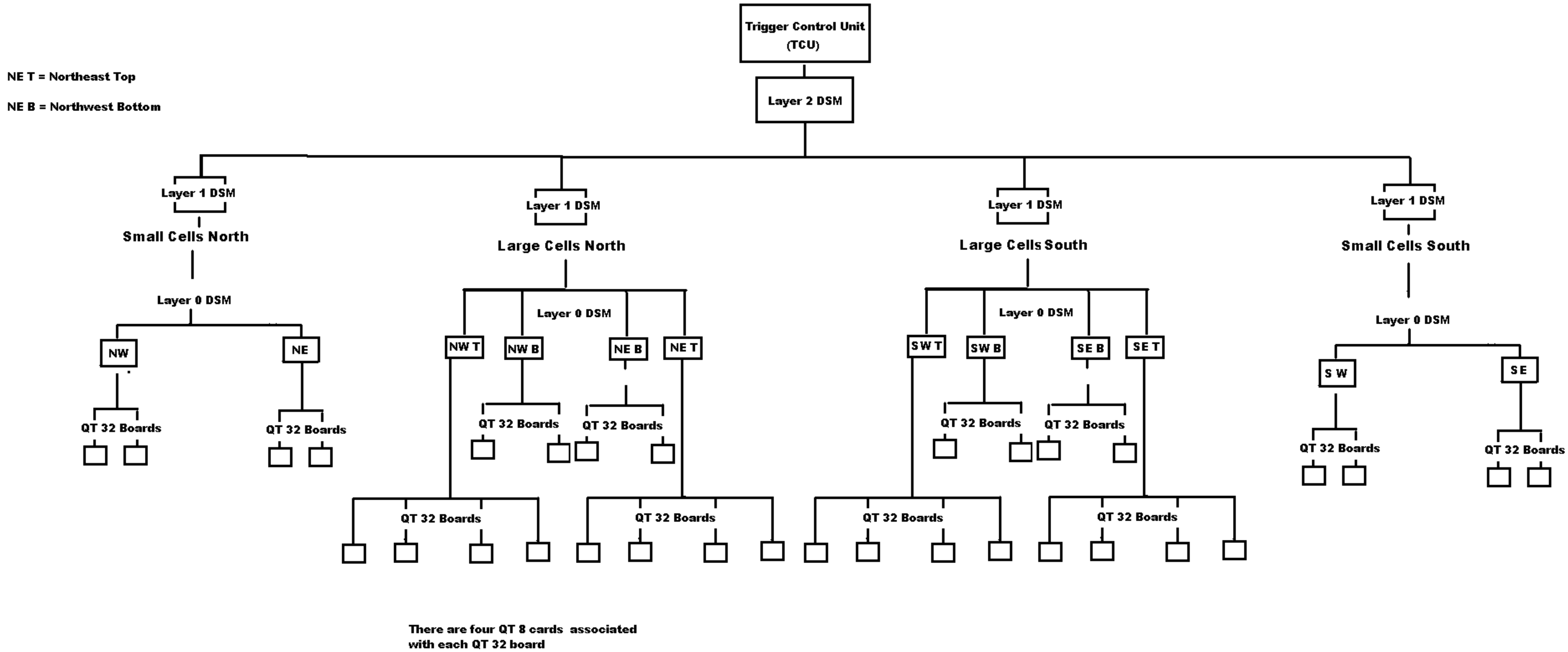
- When particles or jets strike the Pb-gl detector cells the phototube generates a signal proportional to the energy, E, deposited in the cells.
- The ADC values from the cells in a single QT board are summed and that sum is passed up the logic tree, along with highest value recorded in a single cell, and an ID for that cell.

The Challenge

- The QT boards output to Data Storage and Manipulation (DSM) boards for further processing
- Each DSM board can receive up to 128 bits of input
- Each DSM or QT board can only output 32 bits
- There are 40 QT boards to readout the detector cells. Each QT board outputs 32 bits, 40 x 32 = 1280 bits.
- This data must be condensed to 16 or fewer bits, while maintaining the usefulness of the data and changing as little of the existing hardware as possible.

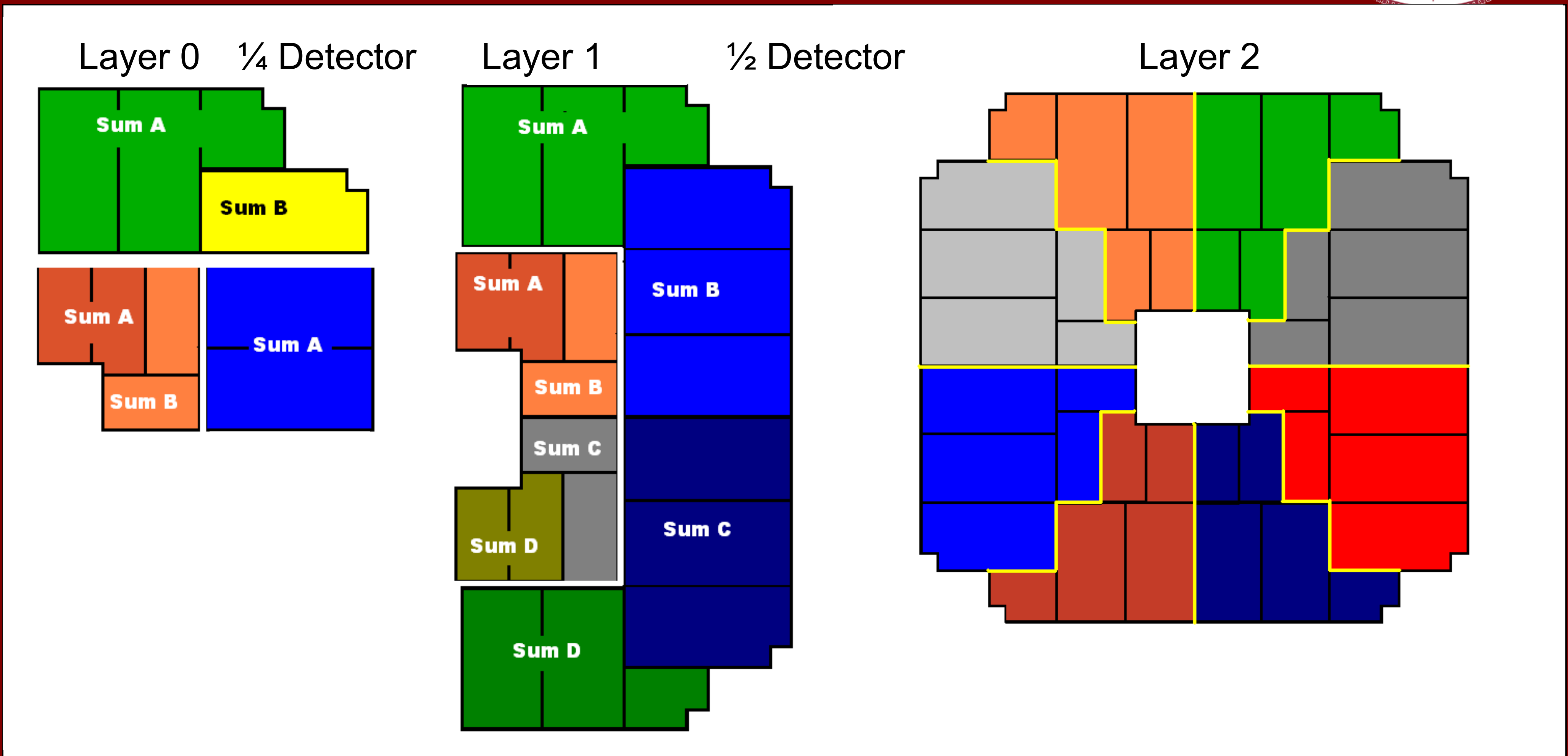
How we go from 1280 bits to 10 bits

Configure a DSM Tree with Three Layers.



The final output from the Layer 2 DSM is 10 bits, 3 from the HT, 3 from the Bsum, 3 from the JP, and 1 for the Di-jet trigger.

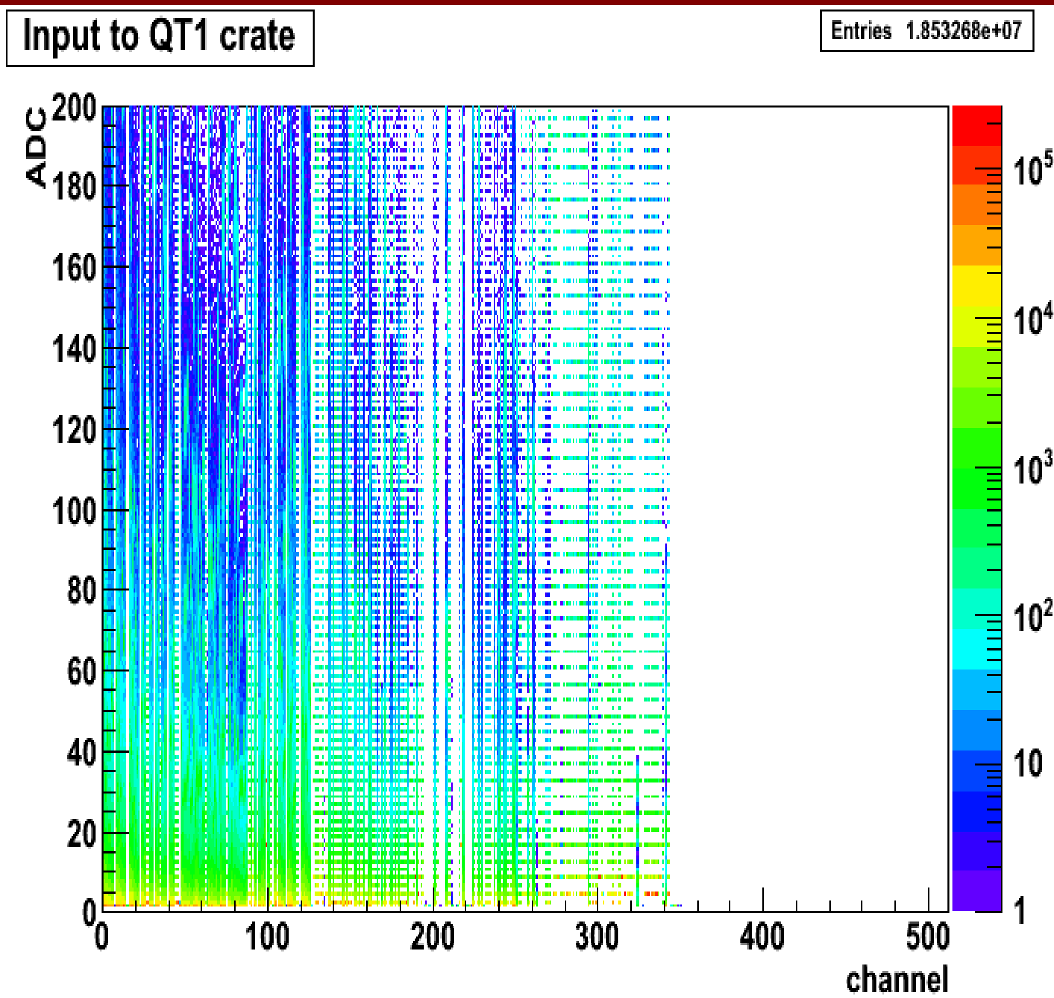
Creating Sums
New Summing Algorithms



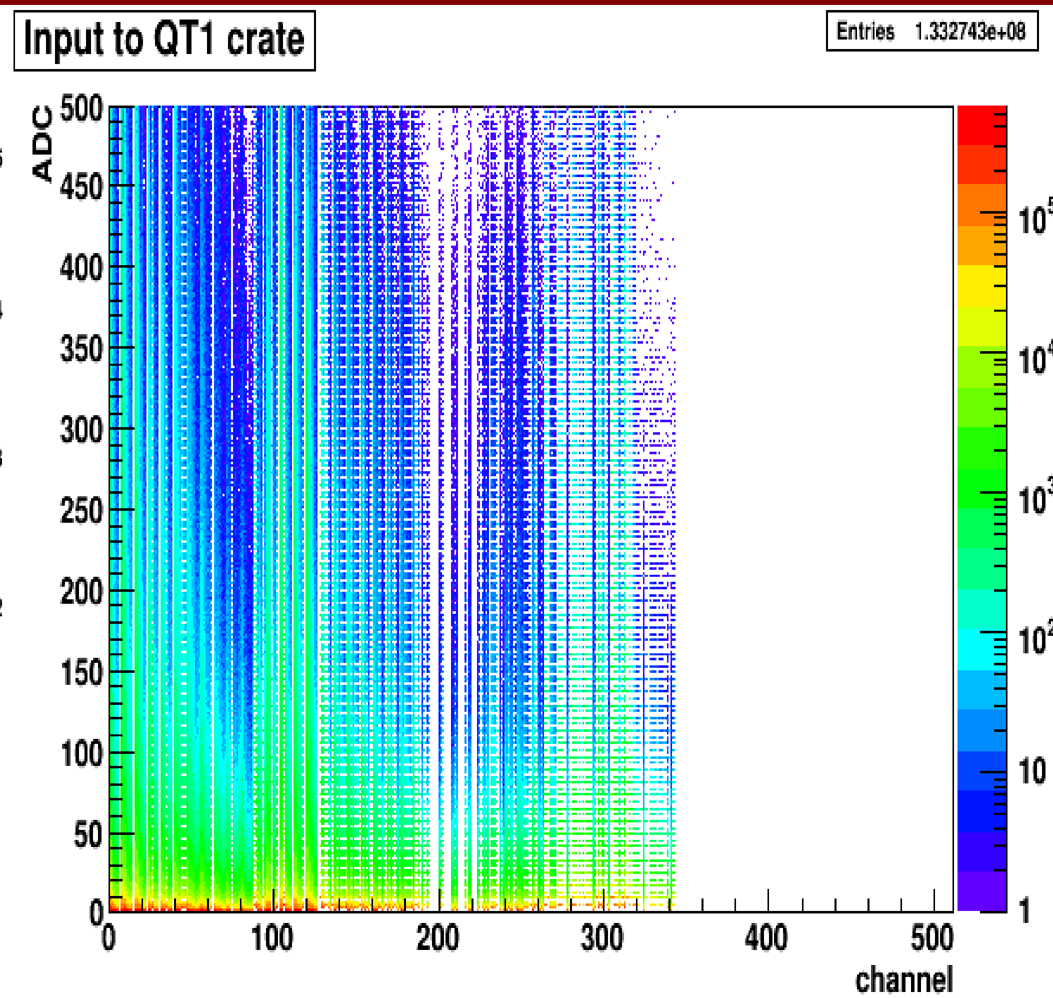
The figure shows which boards are summed to create a 2 or 3 board region at Layer 0. At Layer 1 all regions required to construct JP's have been created.

Data vs. Simulation

2009 Data at 200 GeV



FMS Simulation at 200 GeV



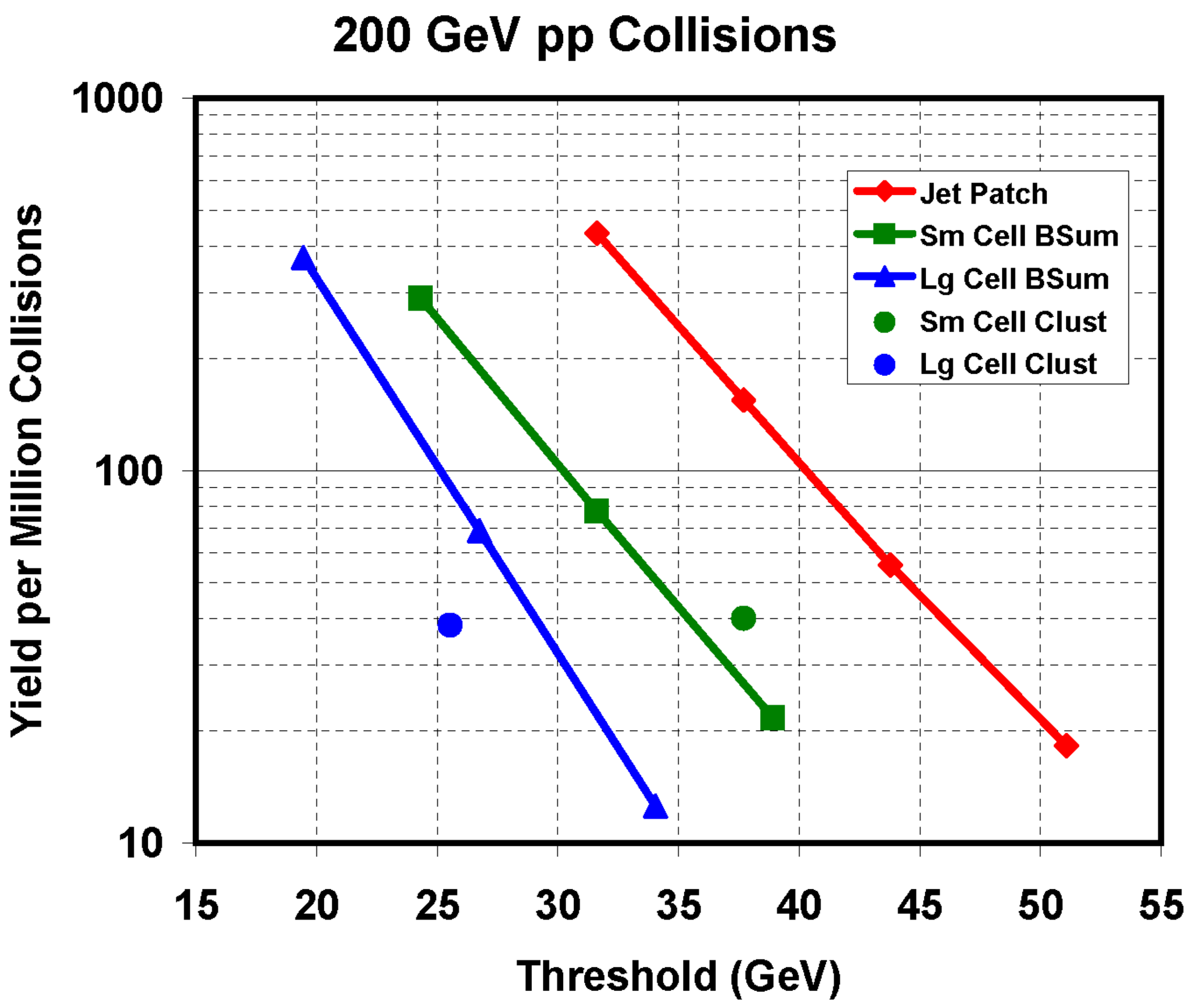
Comparing Predicted Trigger Rates

JP and Bsum Trigger vs. Cluster Trigger at 200 GeV

The firing rates are compared using the same simulated data.

The JP Trigger fired at a significantly higher rate than the Cluster Trigger,

The Bsum Trigger Fired at a higher rate than the Cluster Trigger in the large cells, but at a lower rate in the small cells.



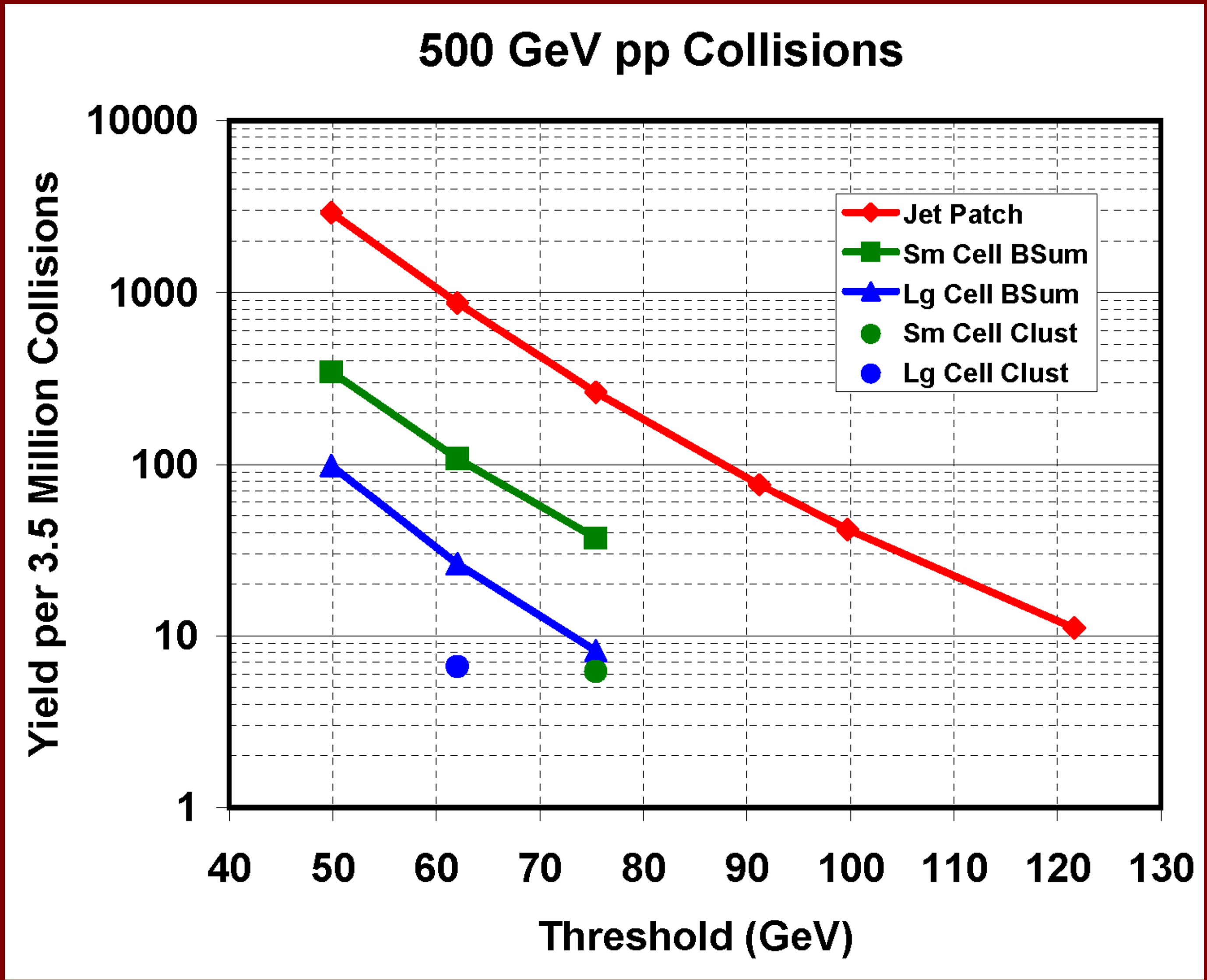
Comparing Predicted Trigger Rates

JP and Bsum Trigger vs. Cluster Trigger at 500 GeV

This diagram is similar to the previous, but compares the simulated rates at 500 GeV.

The Higher rate for the JP Trigger indicates that there are energetic events that deposit energy over too broad an area to fire the cluster trigger.

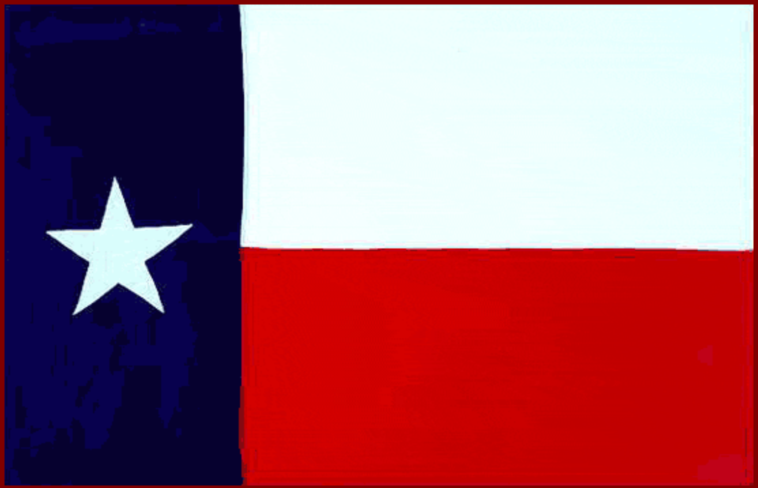
These events are being picked up by the broad reach of the JP Trigger



Conclusions

- The Jet Patch Trigger appears to be functioning as intended, and shows improved efficiency over the Cluster Trigger.
- The Boardsum Trigger roughly approximates the Cluster Trigger, which means the ability to trigger on clusters will not be significantly reduced.
- The Di-jet trigger works, though implementation depends on the logic capabilities of the actual hardware in the detector.

Acknowledgments



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