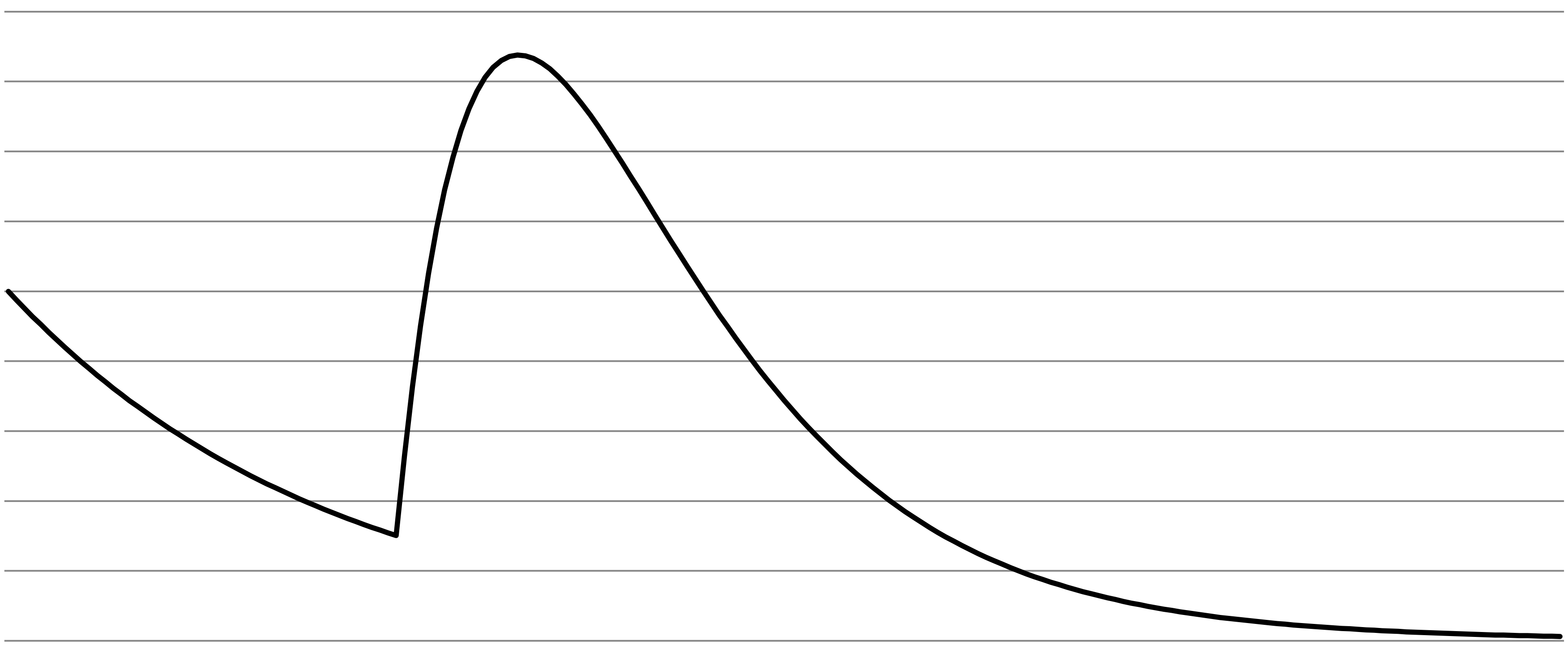
Calorimeter Trigger Hardware and Simulation Update

Flash Analog-to-Digital Converter (FADC)

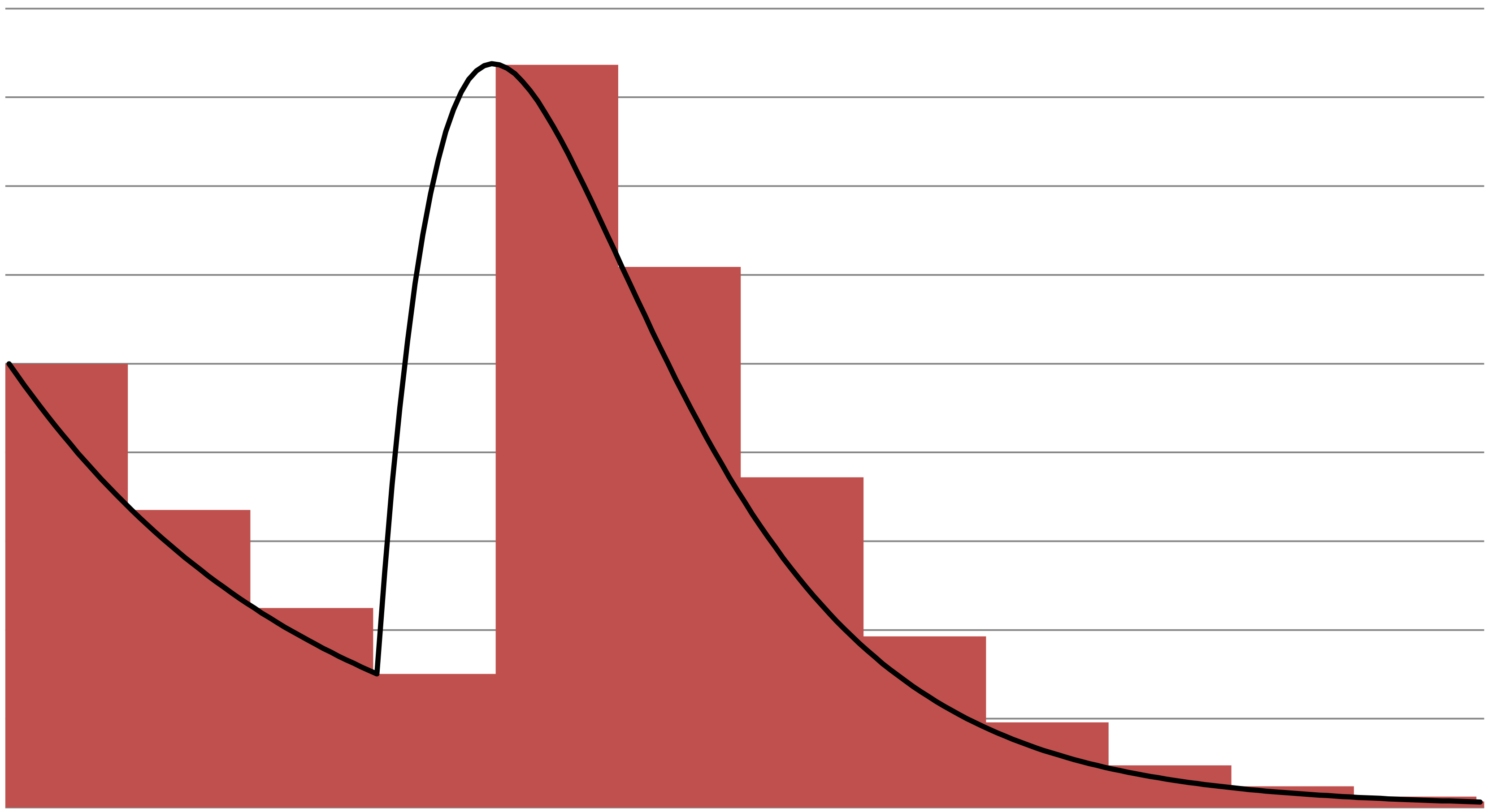
- Converts analog pulses on crystals into integrated hits
- Records hit time stamp

Consider the following hypothetical voltage for a crystal. (Note that this should not be taken as representative of an actual pulse shape.)



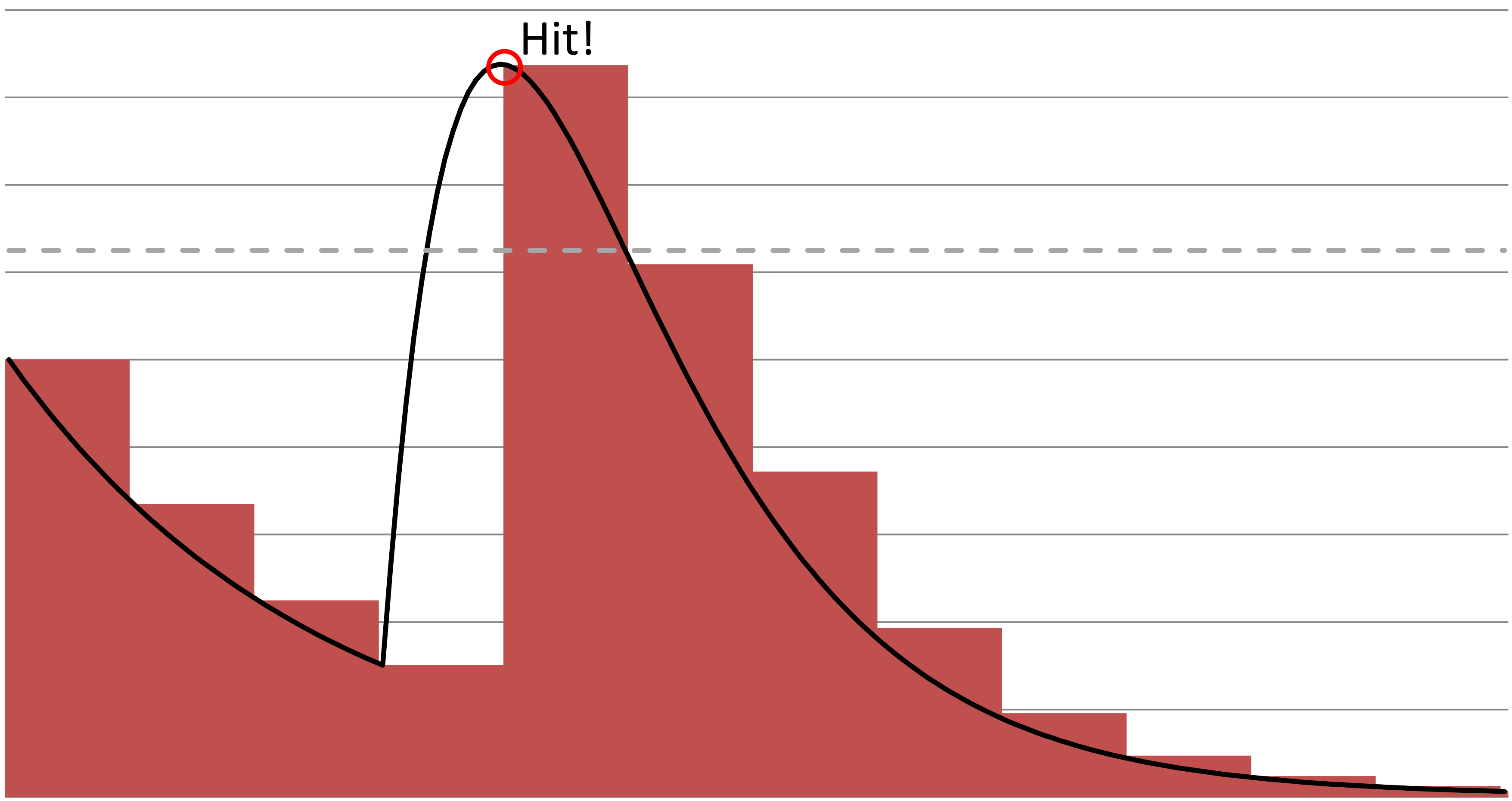
Flash Analog-to-Digital Converter (FADC)

- The FADC checks the voltage in each crystal once per clock cycle (4 ns)
- This breaks down the continuous voltage distribution as per the following graph



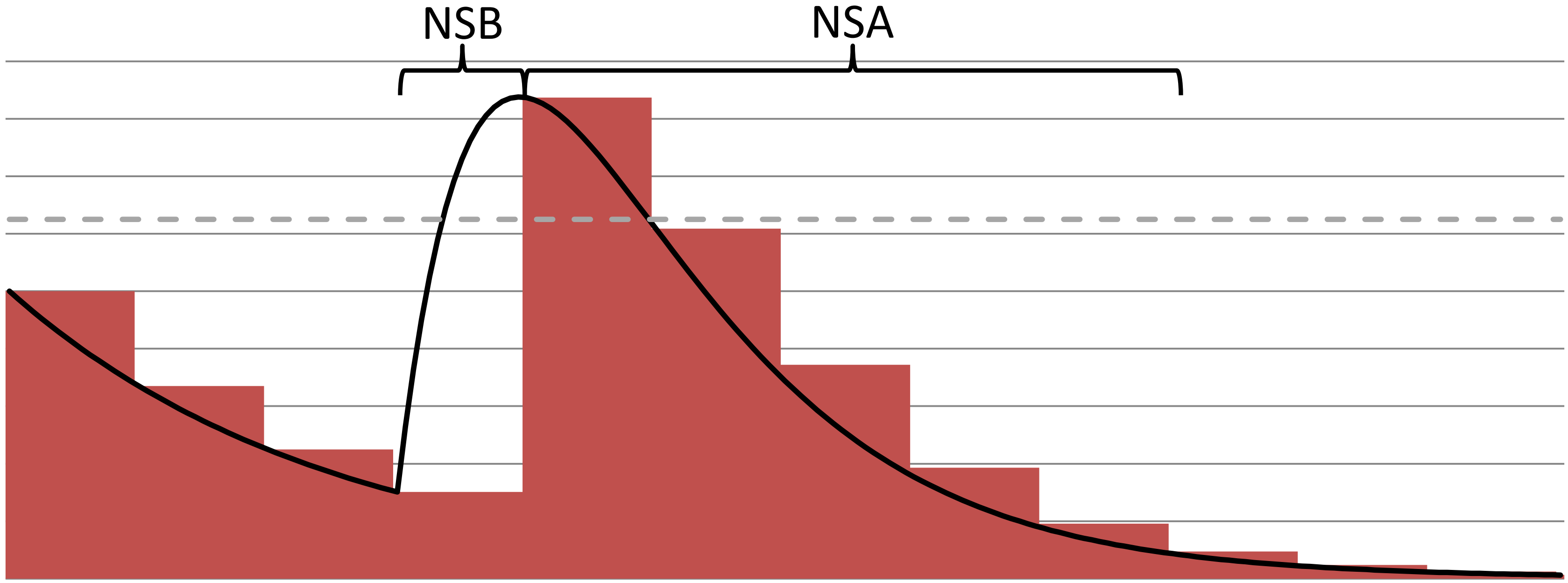
Flash Analog-to-Digital Converter (FADC)

- At a given clock cycle, we consider a "hit" to have occurred if the voltage exceeds some threshold. (Currently $\approx 5\ \mathrm{MeV}$). Call this a "threshold event."



Flash Analog-to-Digital Converter (FADC)

- The time stamp associated with a hit is the same as start time of the clock cycle in which the threshold event occurred.
- The total hit energy is the sum of the energy at the time of the threshold event, plus the energy of a certain number of clock cycles before the threshold event (NSB) along with the energy of a certain number of clock cycles after (NSA).
- Currently, we use $\mathrm{NSA} = 30$ and $\mathrm{NSB} = 5$.



Flash Analog-to-Digital Converter (FADC)

- Note that NSA and NSB may differ from one another.
- The integration period of one pulse may overlap with that of another.
- After a threshold event occurs, the crystal in which it occurred will not register any additional hits for 8 clock cycles (32 ns) even if a given clock cycle is over threshold.
    - Each crystal has a separate timer for this dead time, so other crystals may still register hits even if a given crystal is suppressed.
    - Note that this dead time is typically much smaller than the time it takes for a crystal to drop below threshold (and thusly be in a state where a new threshold event may occur).
- Normalization will be applied at this time if needed.
- Note that some behavior differs for the readout. For the readout
    - New hits will not be reported while pulse integration occurs.
    - Crystals without threshold events will not report a value.
    - Enforced dead time is not implemented.
    - Normalization does not occur.

Flash Analog-to-Digital Converter (FADC)

What is reported up the chain?

- Integrated and normalized hit energy
    - When not above threshold for a clock cycle, zero energy is reported instead.
- Time stamp for the threshold event

In The Simulation

- The FADC is simulated as FADCReadoutDriver and was written by Gabriel and Sho.

Global Trigger Processor (GTP)

- After each clock cycle, a snapshot of the calorimeter and its crystal energies is stored in a buffer.
- The size of the buffer is determined by the desired coincidence window that is to be used by the clusterer. Currently, we use three snapshots, but this is programmable.
    - Note that there will always be an equal number of snapshots both before and after the "current" event in the middle of the buffer.

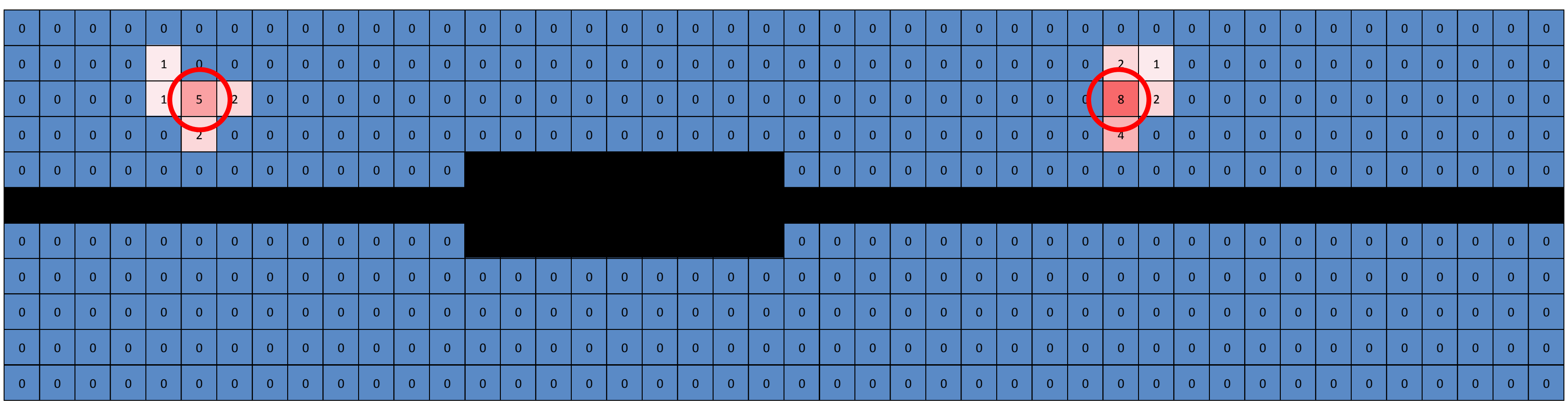
Sample Calorimeter Snapshot

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Global Trigger Processor (GTP)

- Clusters are calculated by finding local maxima in both space and time.
  - Spatially, a crystal may be a cluster center if it is larger than all of its neighbors within a given snapshot.
  - Temporally, a crystal must be larger than itself, along with its neighbors, in each of the snapshots stored in the buffer.
- Additionally, a cluster is required to have a certain minimum energy for both its seed hit and total energy. Crystals with energy below this threshold will be ignored regardless of whether they meet the local spatiotemporal maximum requirement.

Two Potential Cluster Centers



Global Trigger Processor (GTP)

- If a given crystal meets the aforementioned requirements, it is marked as a cluster.
  - The local maximum crystal is given as the seed hit.
  - The energy of the seed hit and its neighbors are summed together in each of the snapshots, which are then added together to form the cluster energy.
  - The "current" time in the snapshot buffer is the central snapshot. The time stamp of this snapshot is the time associated with the cluster.

In The Simulation

- GTP cluster processing is simulated in the GTPEcalClusterer driver.
- This was written by Kyle and Sho.

Important Note on Drivers

Both the FADCReadoutDriver and the GTPEcalClusterer do not output their respective LCIO collections at each event; instead they only output a collection on a clock cycle. Thusly, is important that analysis drivers be designed to handle the case of a non-extant event.

Sub-System Processor (SSP)

- The SSP is responsible for triggering off clusters
  - Note that the SSP also performs the actual energy cuts for clusters in the hardware, though the software simulation performs these cuts in the clusterer.
- The following trigger cuts are performed
  - Energy sum

$$E_{\text{min}} \leq E_{\text{top}} + E_{\text{bot}} \leq E_{\text{max}}$$

  - Pair coincidence time

$$\left| t_{\text{top}} - t_{\text{bot}} \right| \leq \Delta t_{\text{max}}$$

  - Energy difference

$$\left| E_{\text{top}} - E_{\text{bot}} \right| \leq \Delta E_{\text{max}}$$

  - Energy slope

$$E_{\text{min}} + R_{\text{min}} \times F_{\text{energy}} \leq \text{Threshold}$$

  - Coplanarity

$$\left| \text{atan}\left(\frac{x_{\text{top}}}{y_{\text{top}}}\right) - \text{atan}\left(\frac{x_{\text{bot}}}{y_{\text{bot}}}\right) \right| \leq \theta_{\text{co}}$$

Sub-System Processor (SSP)

- Number of component hits

$$N_{\text{hit}} \geq N_{\text{threshold}}$$

- Note that E_{max}, Δt_{max}, ΔE_{max}, F_{energy}, θ_{co}, $N_{\text{threshold}}$, and the energy slope threshold are all programmable parameters.
- These trigger conditions are identical to the previous trigger set-up, with the exception of the number of component hits threshold, which is new.
- Energy slope's variable represent
  - E_{min} – The energy of lowest energy cluster in the trigger pair.
  - R_{min} – The radial distance from $(0, 0)$ of the lowest energy cluster's seed hit.
  - F_{energy} – A scaling factor, defined by $F_{\text{energy}} = (0.5 \text{ GeV} \times E_{\text{beam}})/200 \text{ mm}$.

In The Simulation

- SSP trigger processing is simulated in the FADCTriggerDriver driver.
- This was written by Sho.

Clustering and Triggering Cuts

Clustering:

- Cluster seed hit minimum energy

$$E \geq 0.05\ \mathrm{GeV}$$

- Total cluster energy

$$E_{\mathrm{cl}} \geq 0.00$$

    - This appears to have been lost during one of the revisions – needs to be fixed!

- Cluster component count

$$N \geq 1$$

Most new clustering parameters have not been rigorously tested and are essentially allowing most any potential clusters at the moment. The effect of these parameters needs to be studied in more detail and the optimal values selected.

Clustering and Triggering Cuts

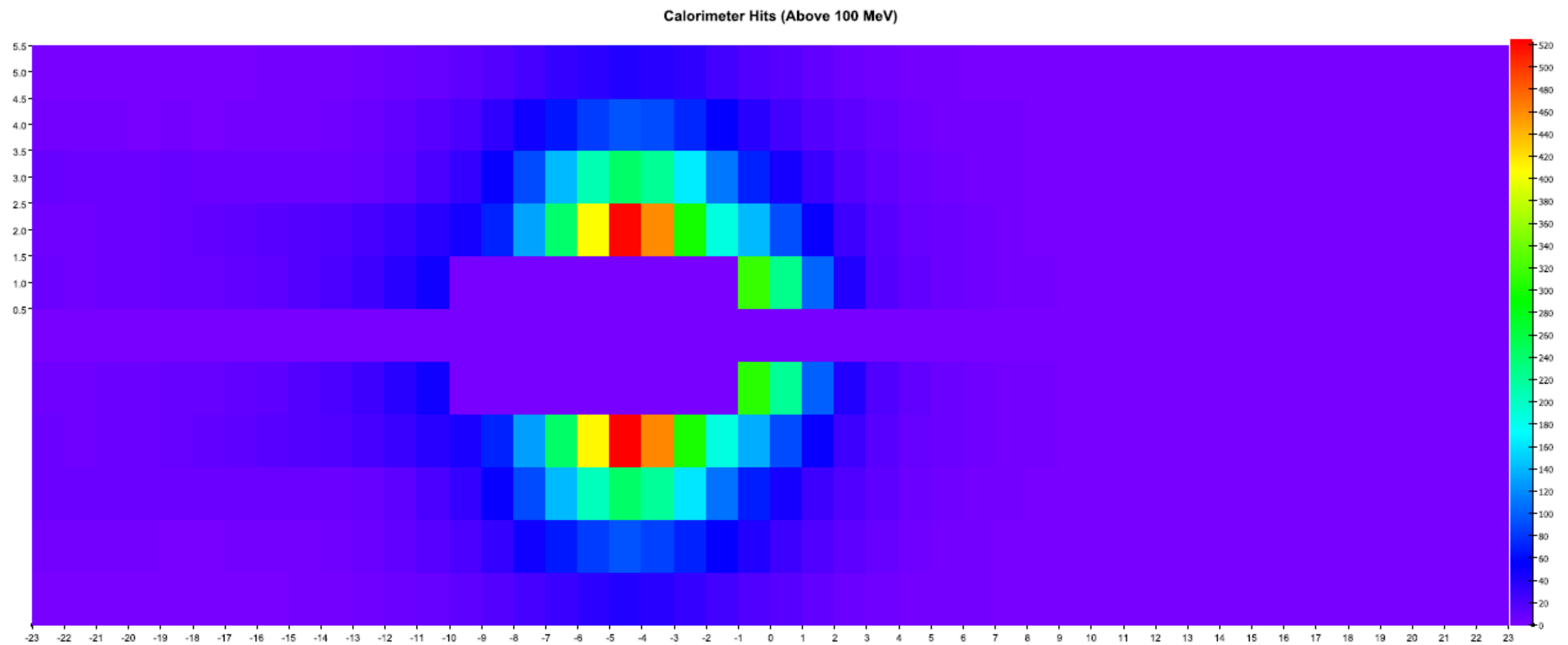
Triggering:

- Energy sum
  - $E_{\mathrm{max}} = 0.8\ \mathrm{GeV}$ (1.1 GeV)
  - $E_{\mathrm{max}} = 1.7\ \mathrm{GeV}$ (2.2 GeV)
  - $E_{\mathrm{max}} = 5.5\ \mathrm{GeV}$ (6.6 GeV)
- Pair coincidence time
  - $\Delta t_{\mathrm{max}} = 8\ \mathrm{ns}$ (2 clock cycles)
- Energy difference
  - $\Delta E_{\mathrm{max}} = 0.75$ (1.1 GeV)
  - $\Delta E_{\mathrm{max}} = 1.50$ (2.2 GeV)
  - $\Delta E_{\mathrm{max}} = 4.50$ (6.6 GeV)
- Coplanarity
  - $\theta_{\mathrm{co}} = 90$ (1.1 GeV)
  - $\theta_{\mathrm{co}} = 45$ (2.2 GeV)
  - $\theta_{\mathrm{co}} = 60$ (6.6 GeV)

2.2 GeV Calorimeter Background Rates

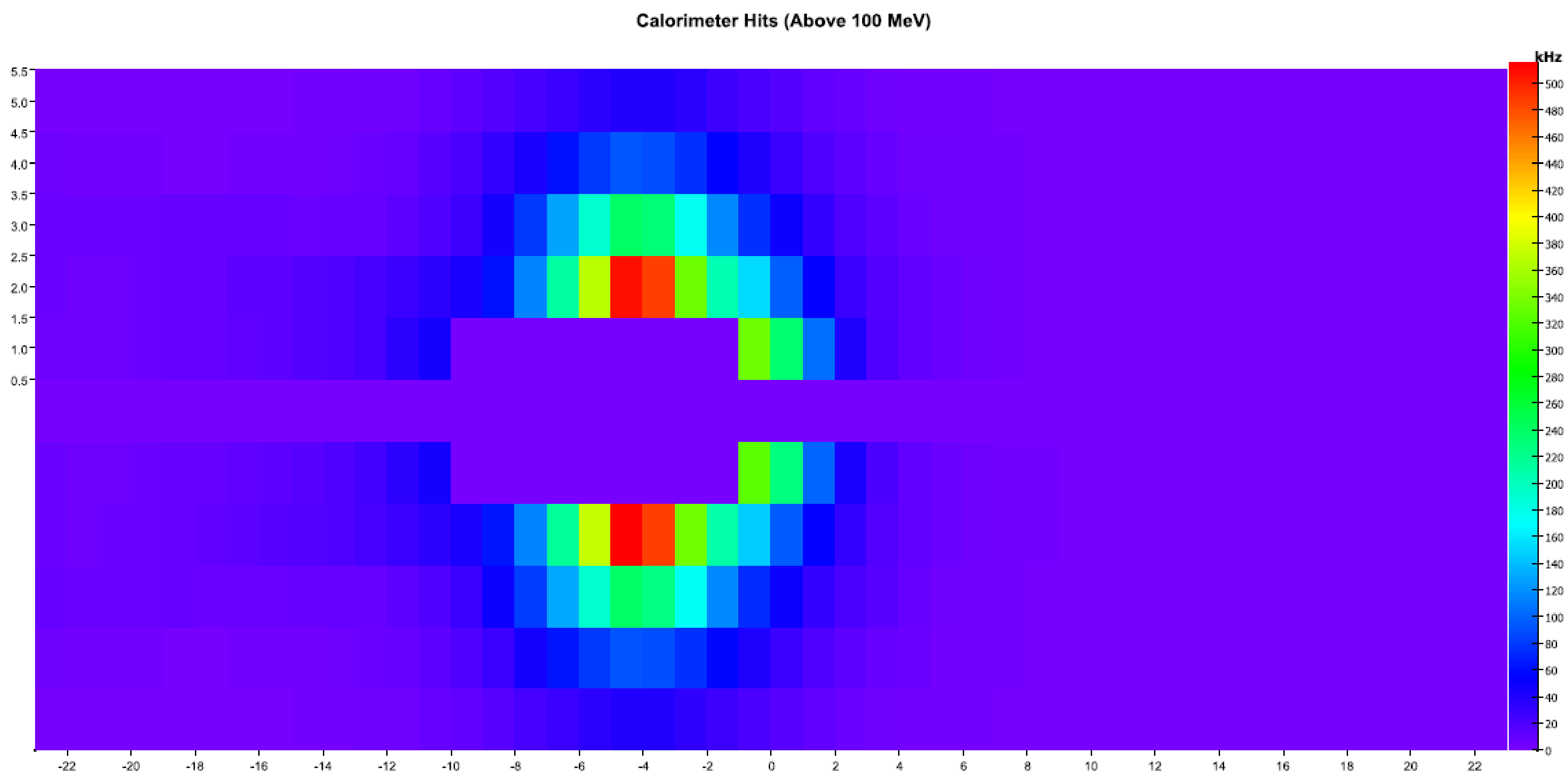
- Calorimeter rates for 2.2 GeV backgrounds have not changed dramatically between the version 4 geometry and the current (version 7) geometry.
- All rates are in kHz.

Version 7 Background Rates



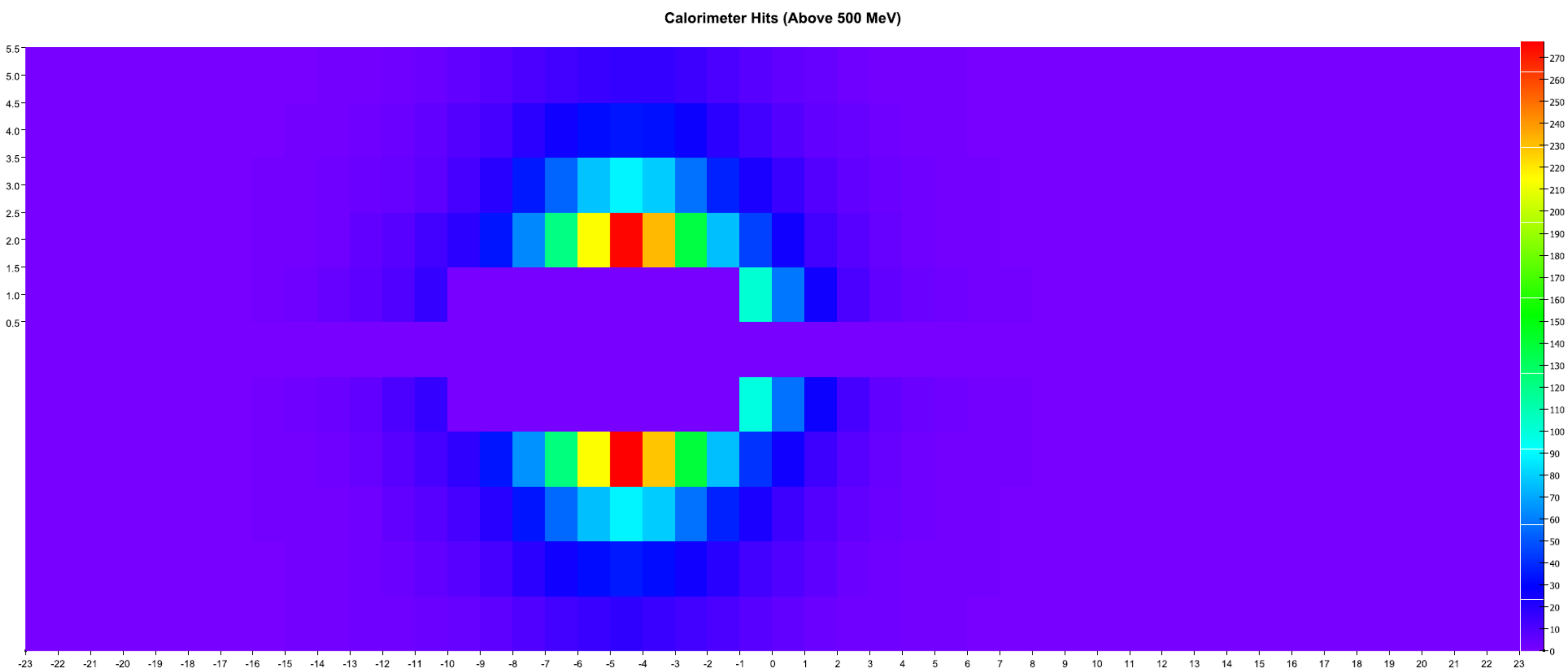
2.2 GeV Calorimeter Background Rates

Version 4 Background Rates



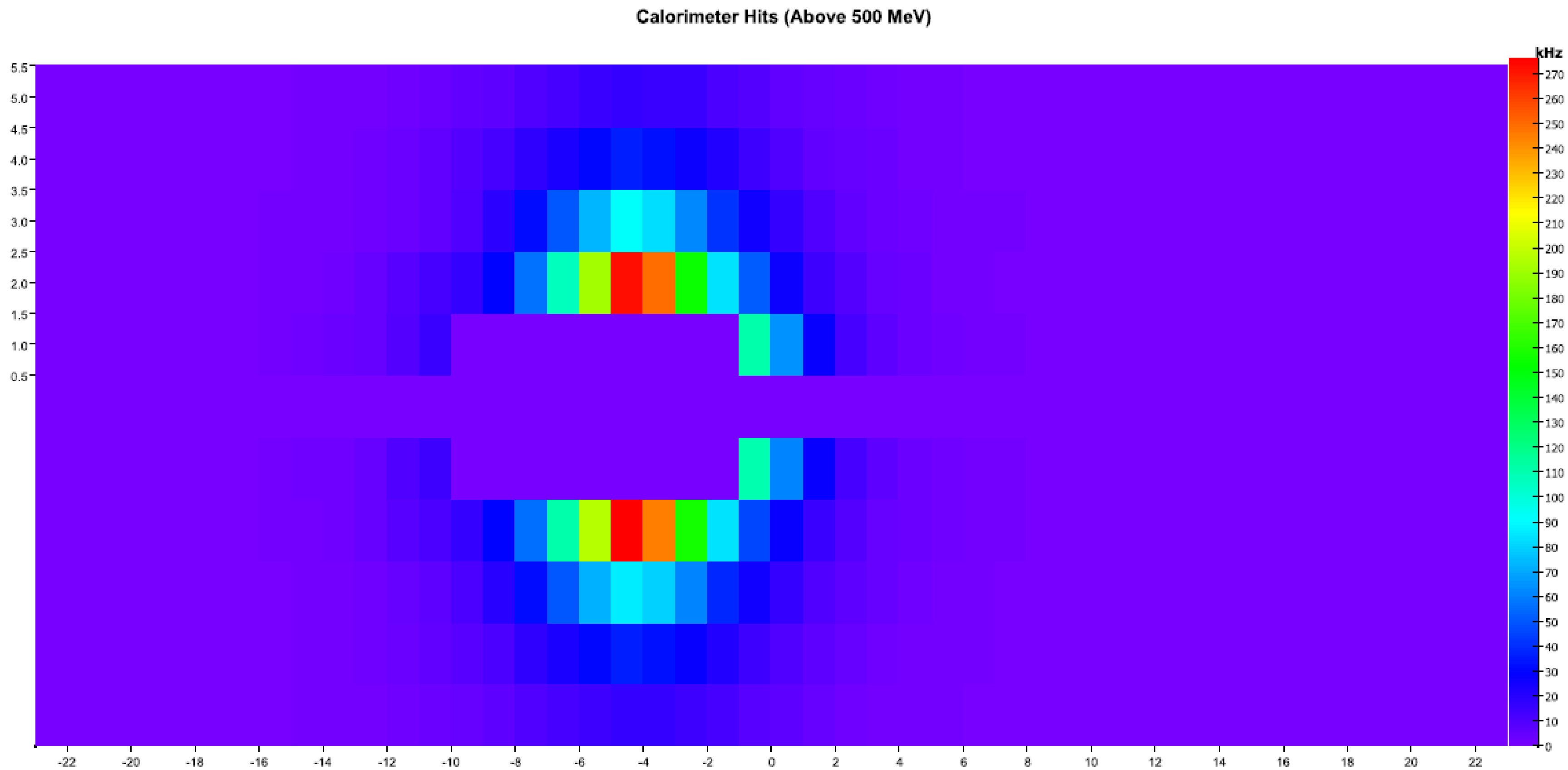
2.2 GeV Calorimeter Background Rates

Version 7 Background Rates



2.2 GeV Calorimeter Background Rates

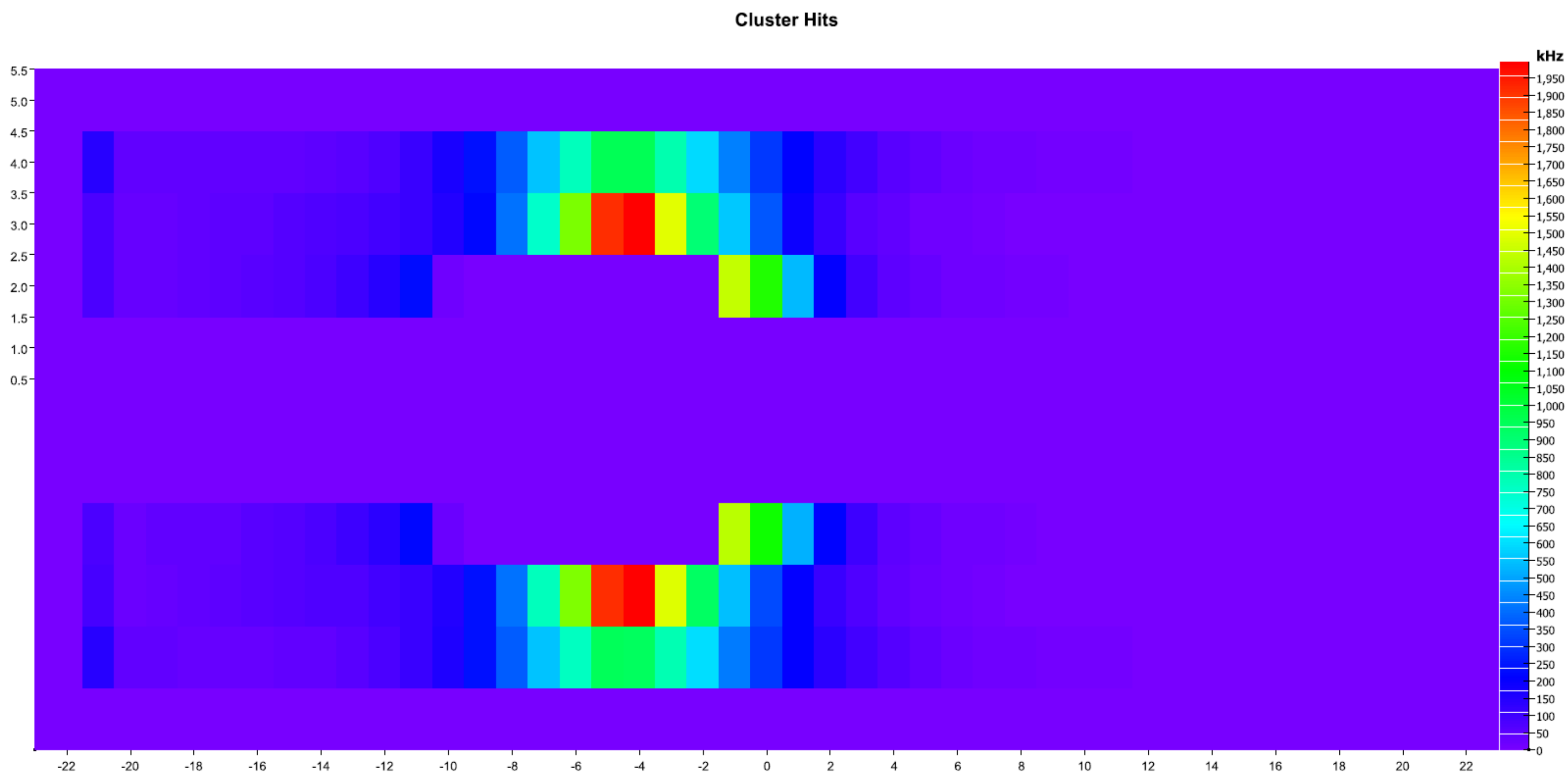
Version 4 Background Rates



2.2 GeV Calorimeter Background Rates

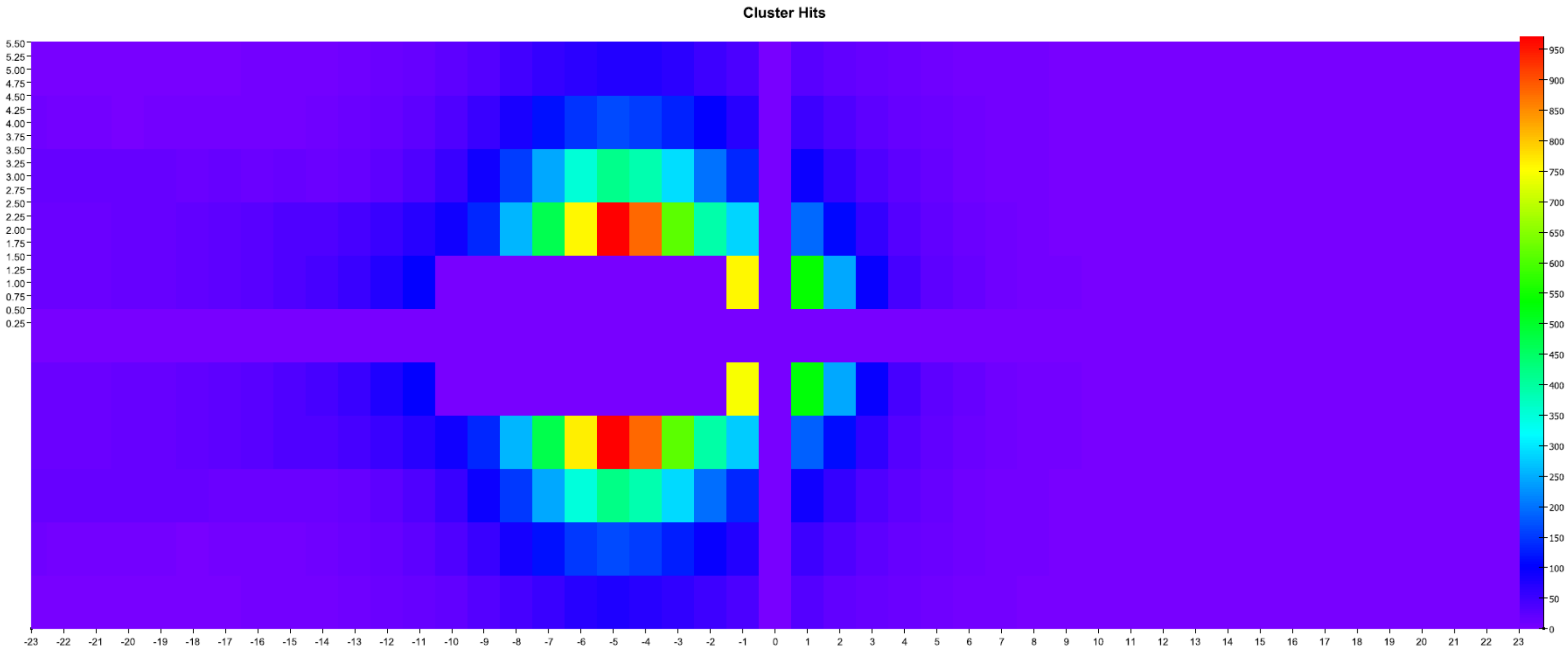
- The cluster center distribution has remained fairly constant.

CTP Clustering



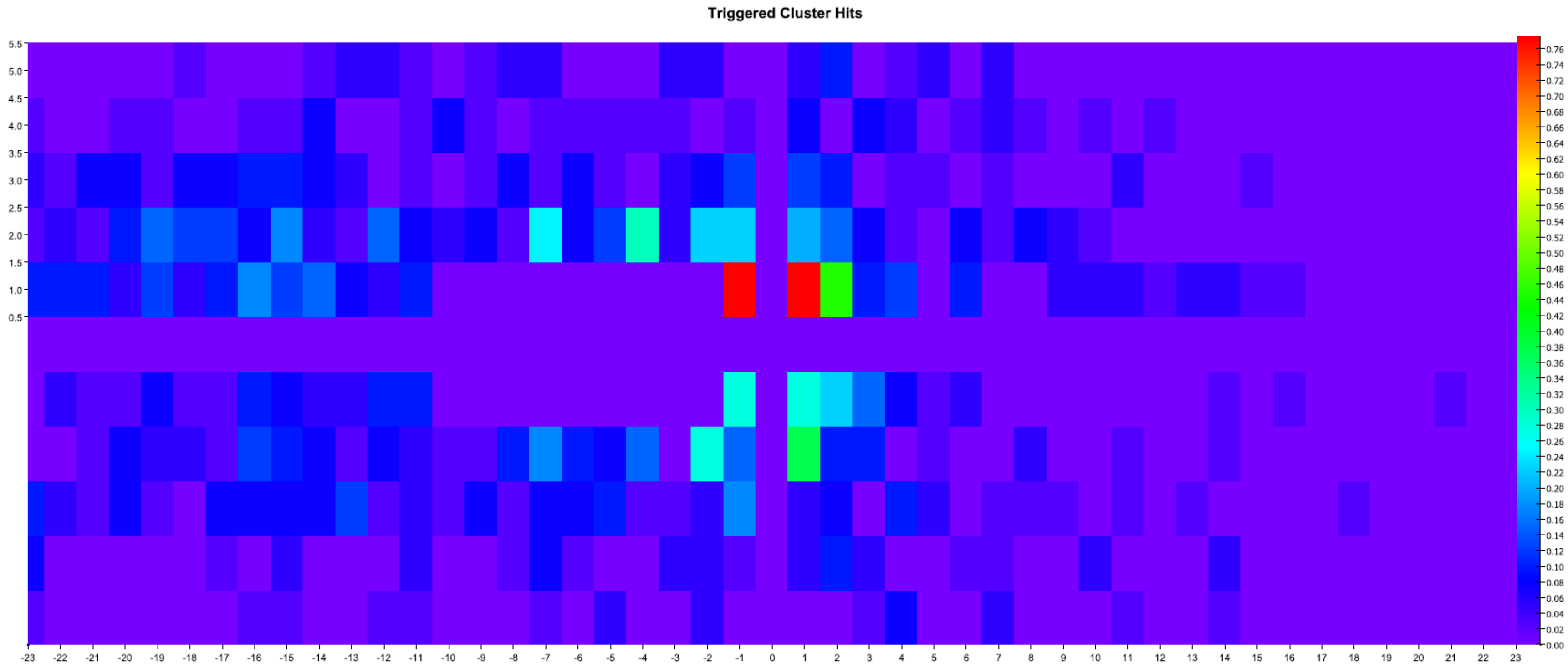
2.2 GeV Calorimeter Background Rates

GTP Clustering



2.2 GeV Calorimeter Background Rates

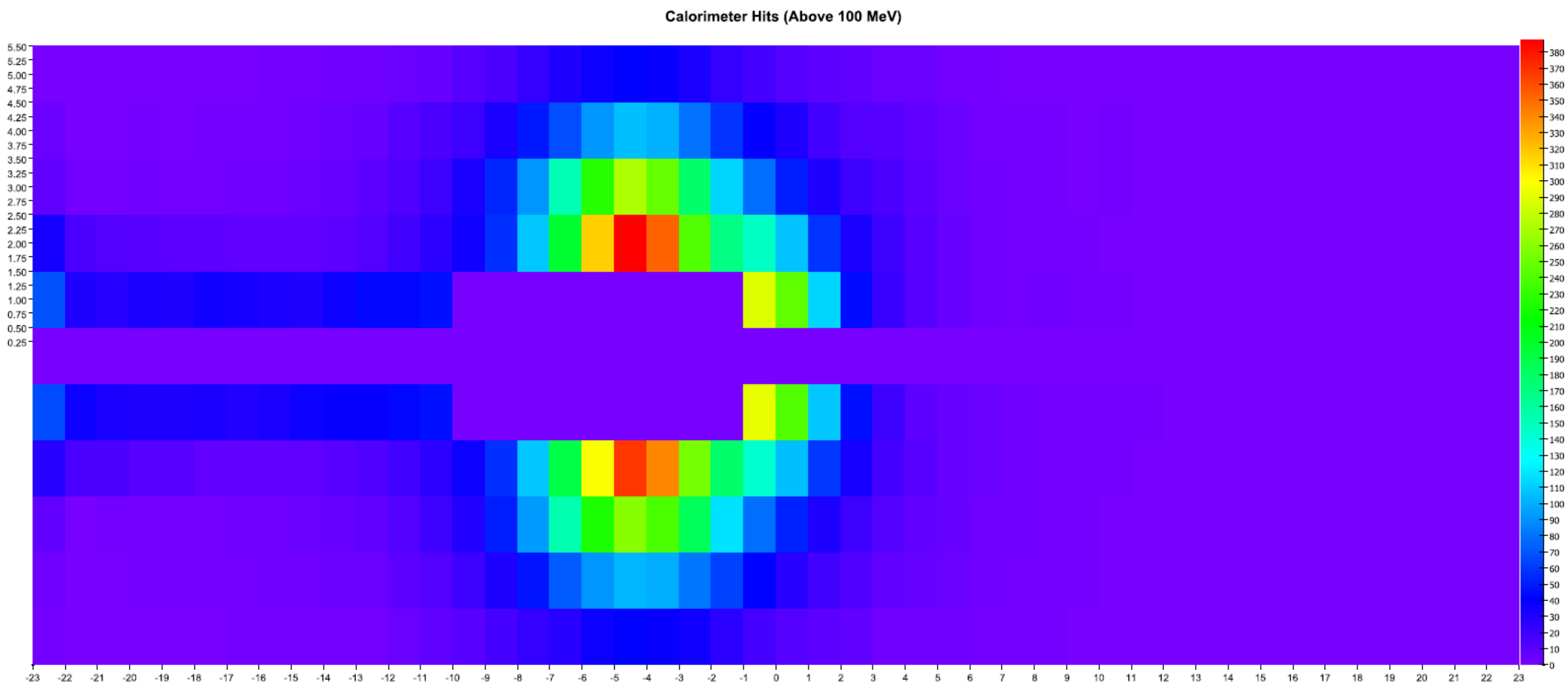
- Current trigger rate is approximately 25 kHz. This is up from the previous version, which had a trigger rate of approximately 10 kHz.
- There are two crystals which seem to be "hot spots" for triggers in the GTP version.



6.6 GeV Calorimeter Background Rates

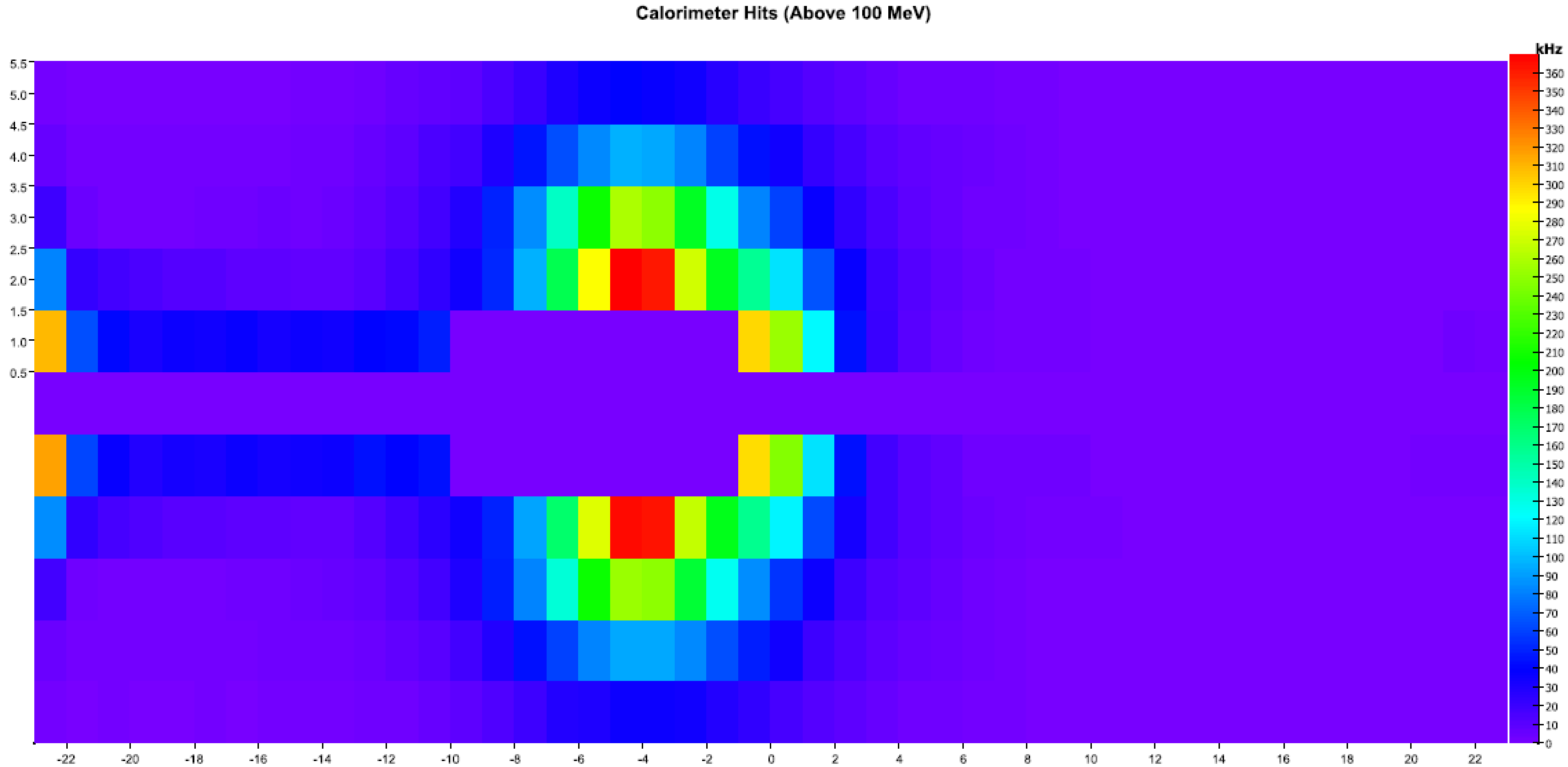
- Backgrounds rates are again very similar.
- The "hot spots" along the electron edge of the detector drop off much more rapidly as we increase the energy cut in the version 7 geometry.

Version 7 Background Rates



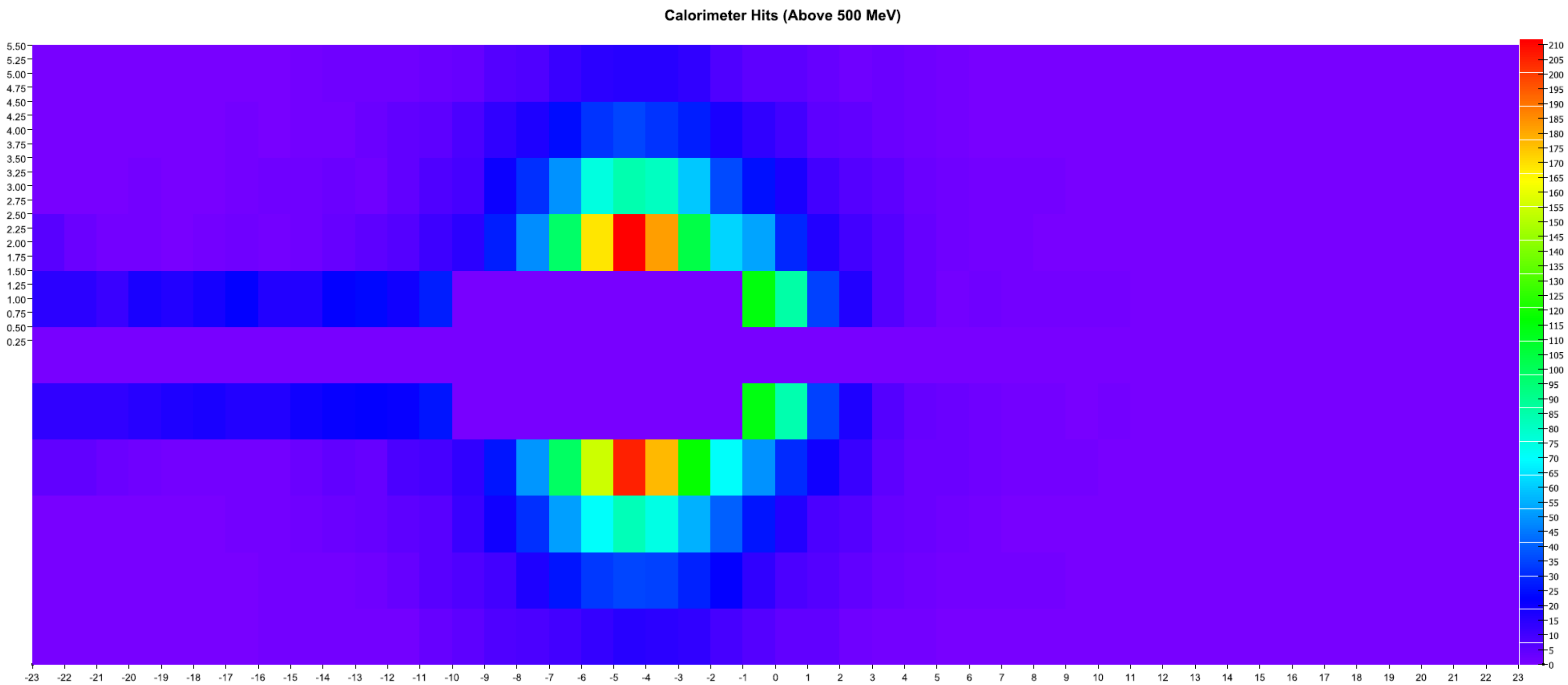
6.6 GeV Calorimeter Background Rates

Version 4 Background Rates

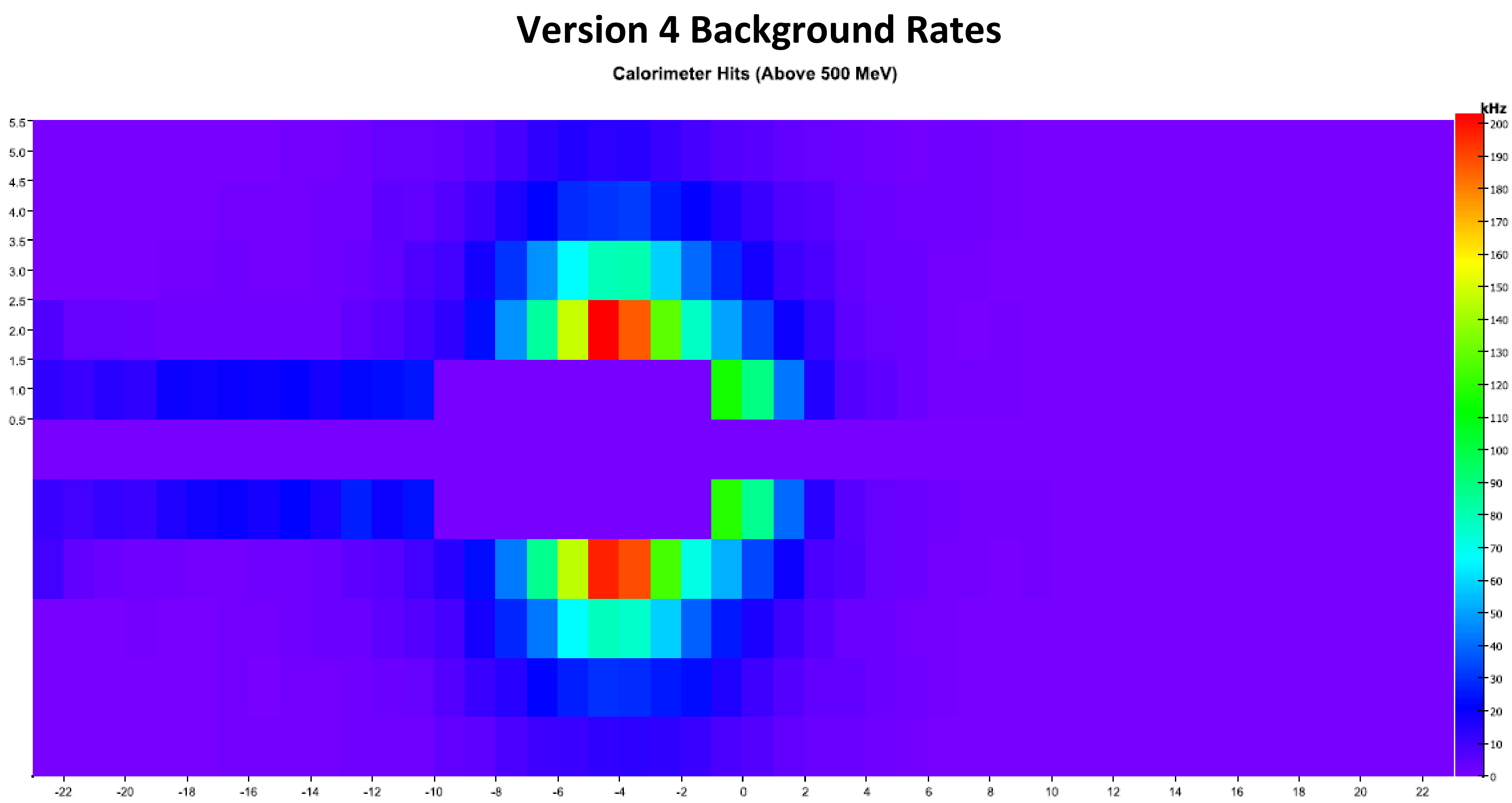


6.6 GeV Calorimeter Background Rates

Version 7 Background Rates

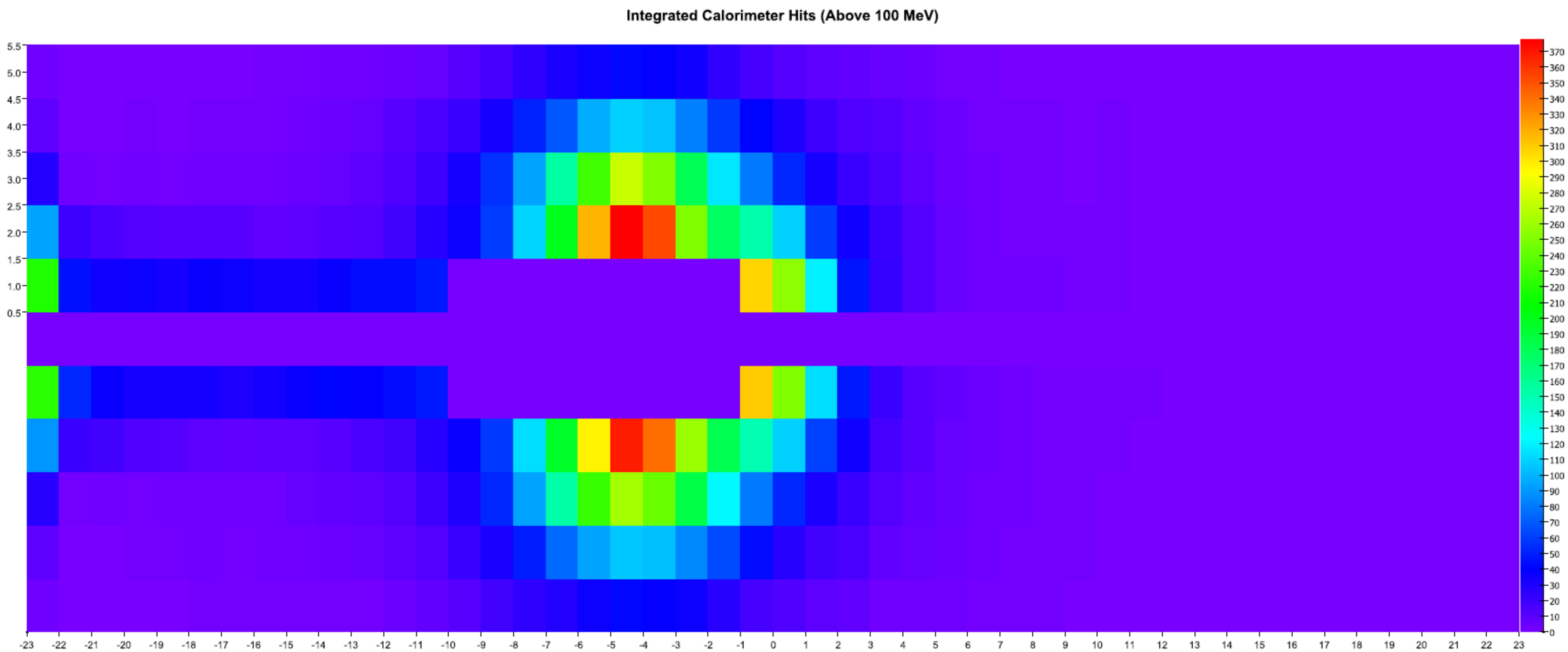


6.6 GeV Calorimeter Background Rates



6.6 GeV Calorimeter Background Rates

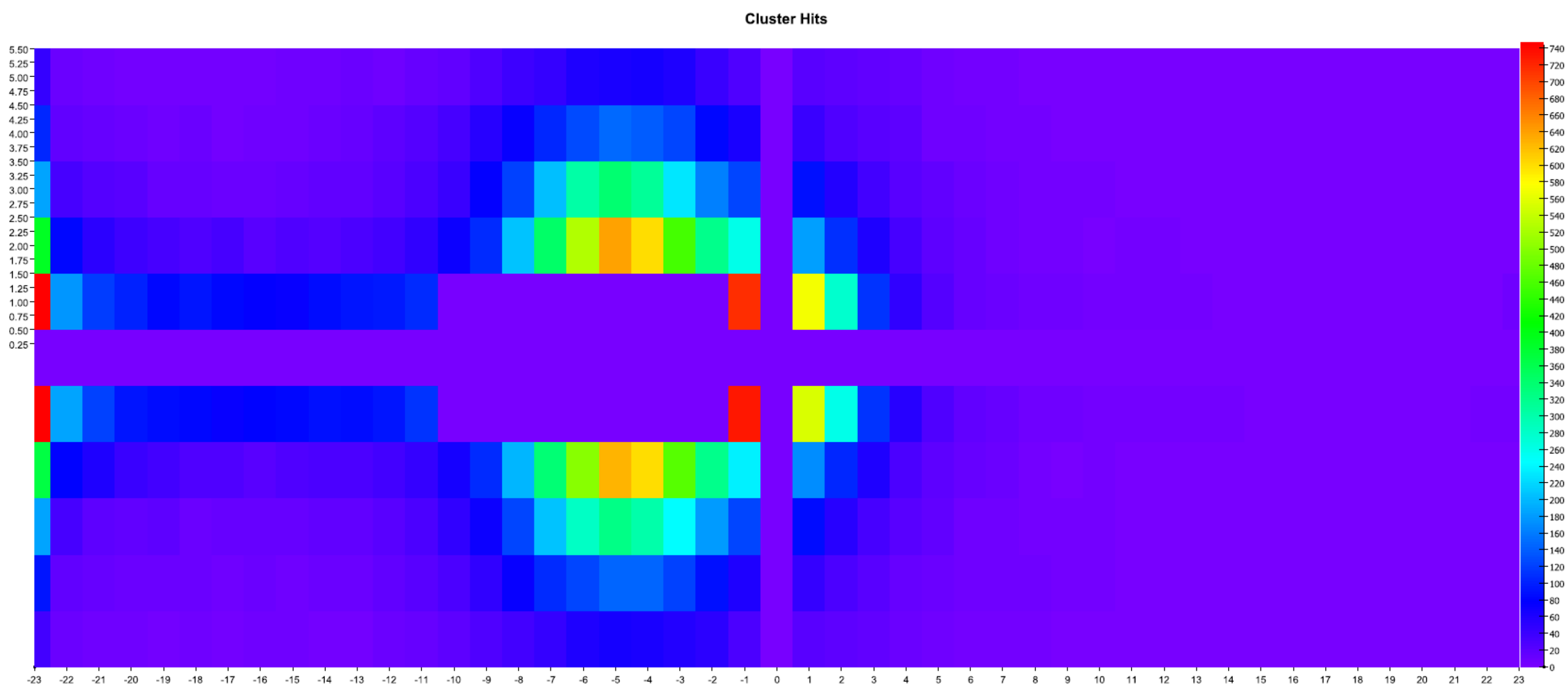
- The “corrected hits” for 6.6 GeV retain some of the electron side “hot spots” still.



6.6 GeV Calorimeter Background Rates

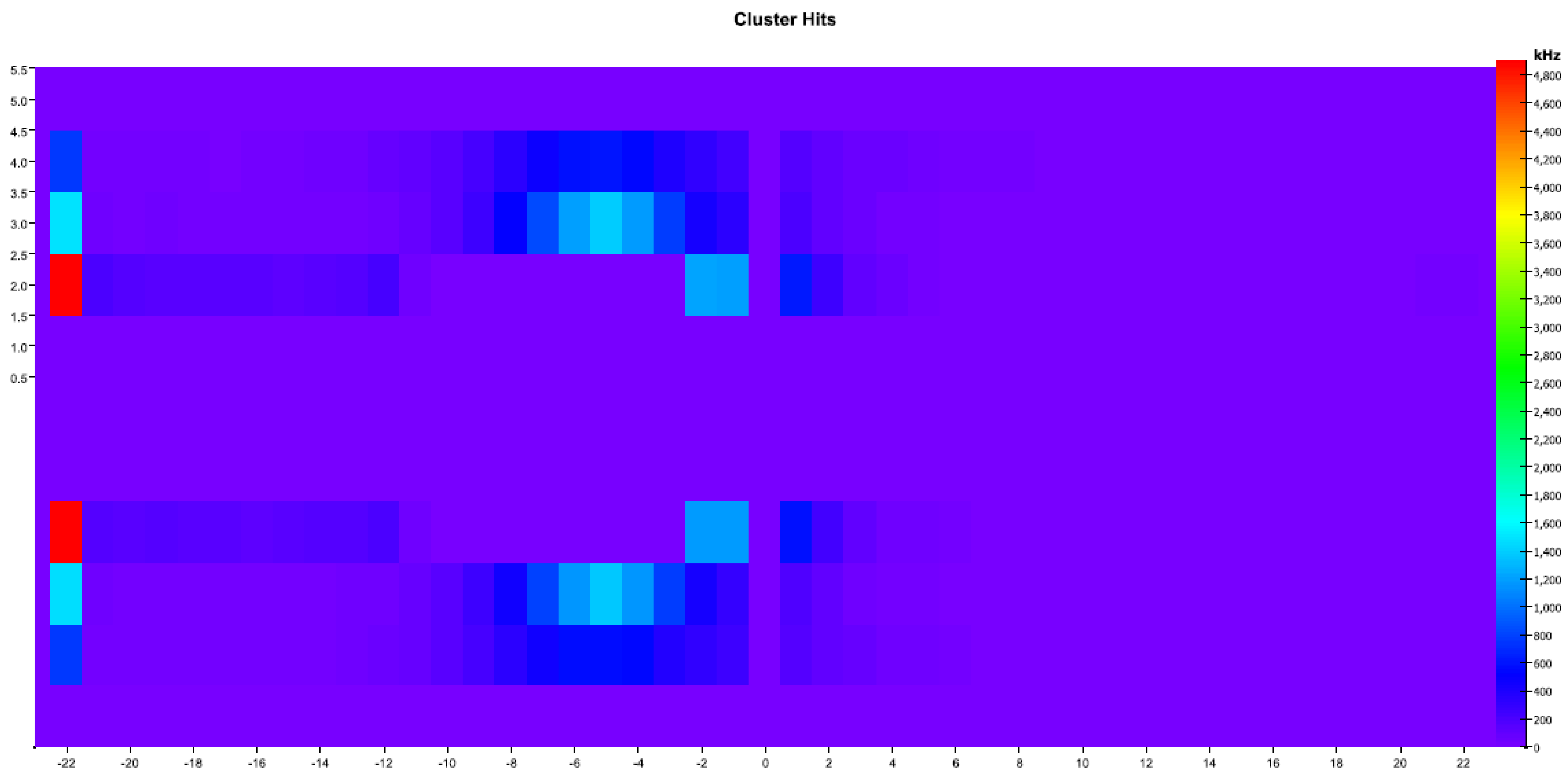
- Cluster distribution is similar, but the new geometry has less emphasis on the electron side "hot spots."

GTP Clustering



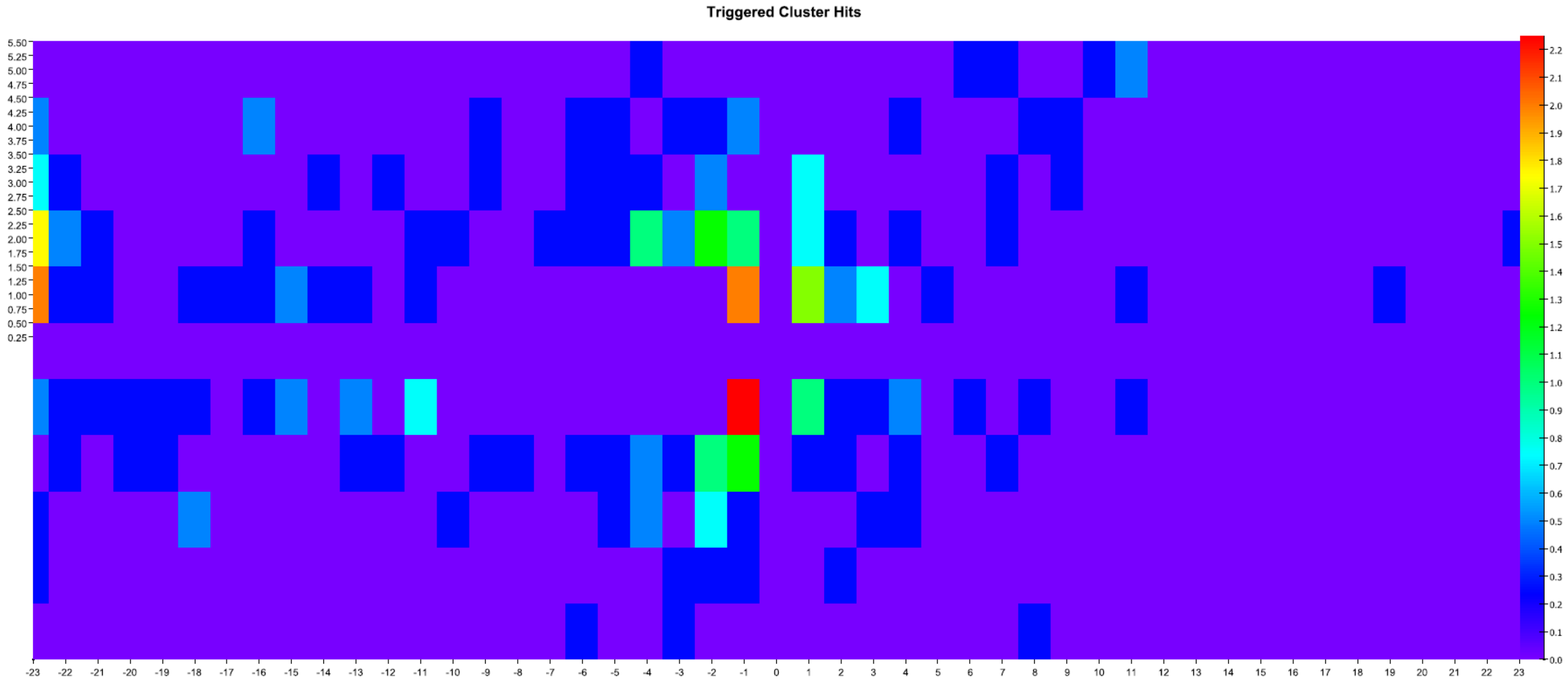
6.6 GeV Calorimeter Background Rates

CTP Clustering



6.6 GeV Calorimeter Background Rates

- A large set of triggers originate from clusters in the hot region.
- Trigger rates are comparable between the old versions and new version.



Work To-Be-Done

- Proper studies need to be done to determine the correct values for
    - Number of component hits trigger cut
    - Minimum seed hit energy
    - Minimum cluster energy
- Diagnostics
    - What do we need from the hardware to make sure everything is working?
    - What software do we need to make sure the trigger is optimized?
- A’ acceptance rates
    - How do these changes affect our acceptance of A’ particles?