Level-3 Trigger Update

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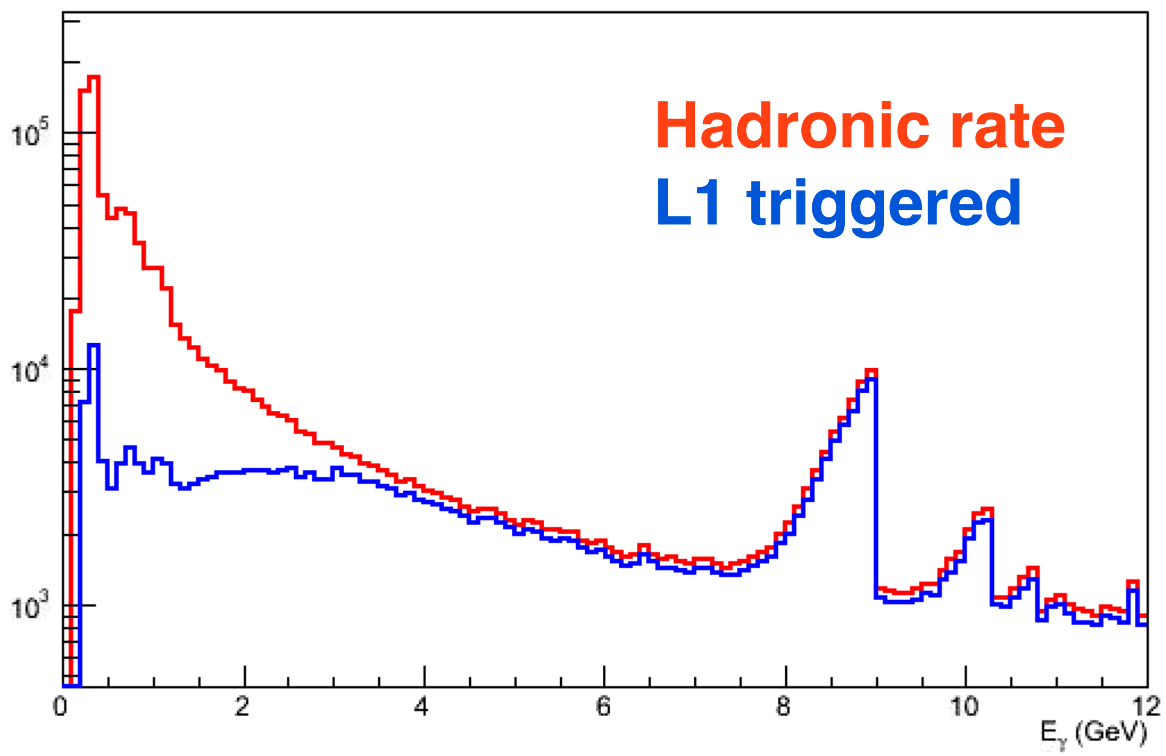
Trigger Working Group Meeting: 9.3.13

Level-1 Trigger

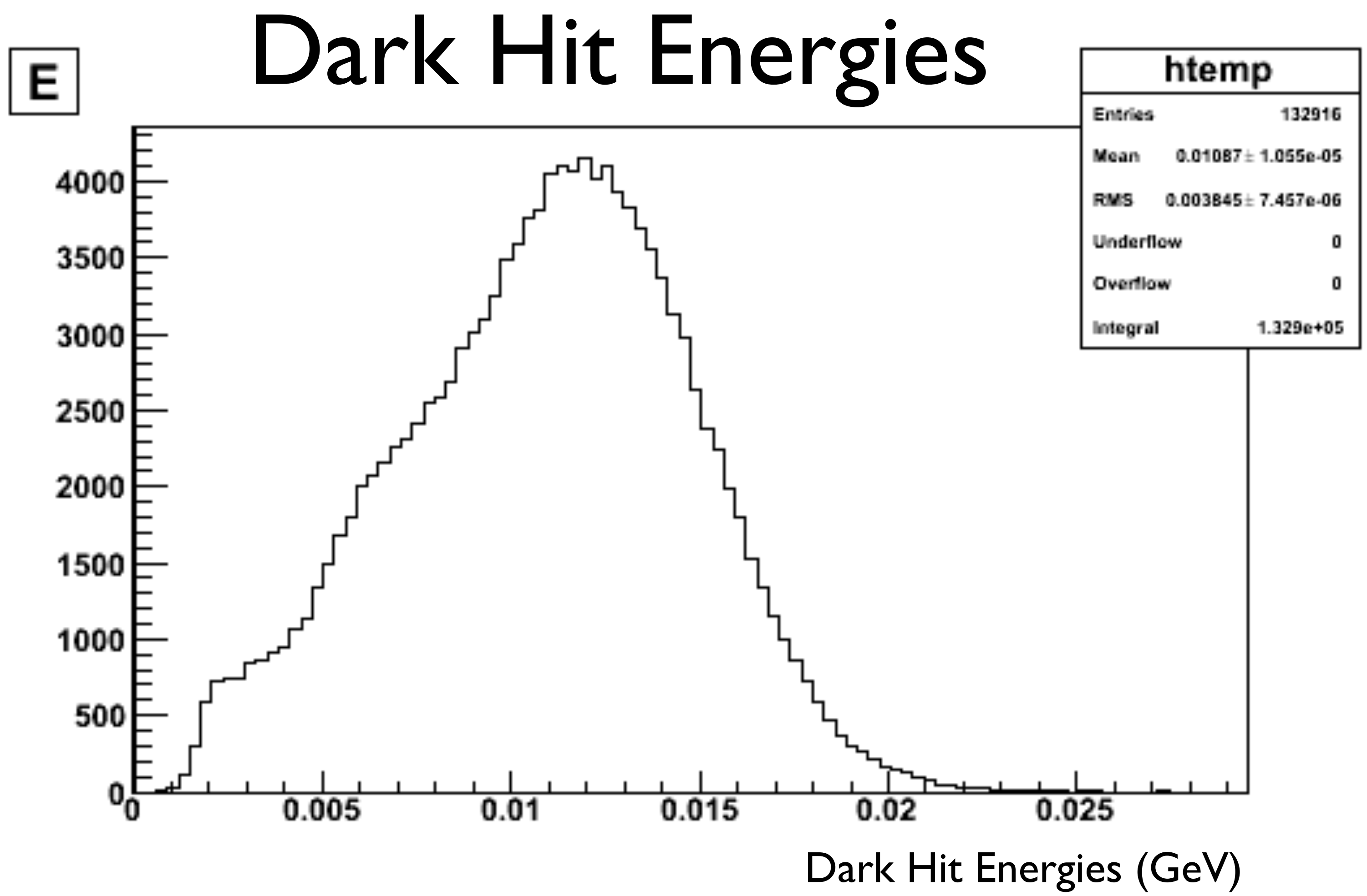
GlueX-doc-1043: Implemented in DMCTrigger



- Sample of bggen events with high-luminosity EM pileup
- Define "signal" as $E_\gamma > 7$ GeV and "background" $E_\gamma < 7$ GeV
- Accept events which fire L1a or L1b emulated trigger
- Reject ~77% of background with a signal efficiency of ~92%
- So far haven't considered EM background rate

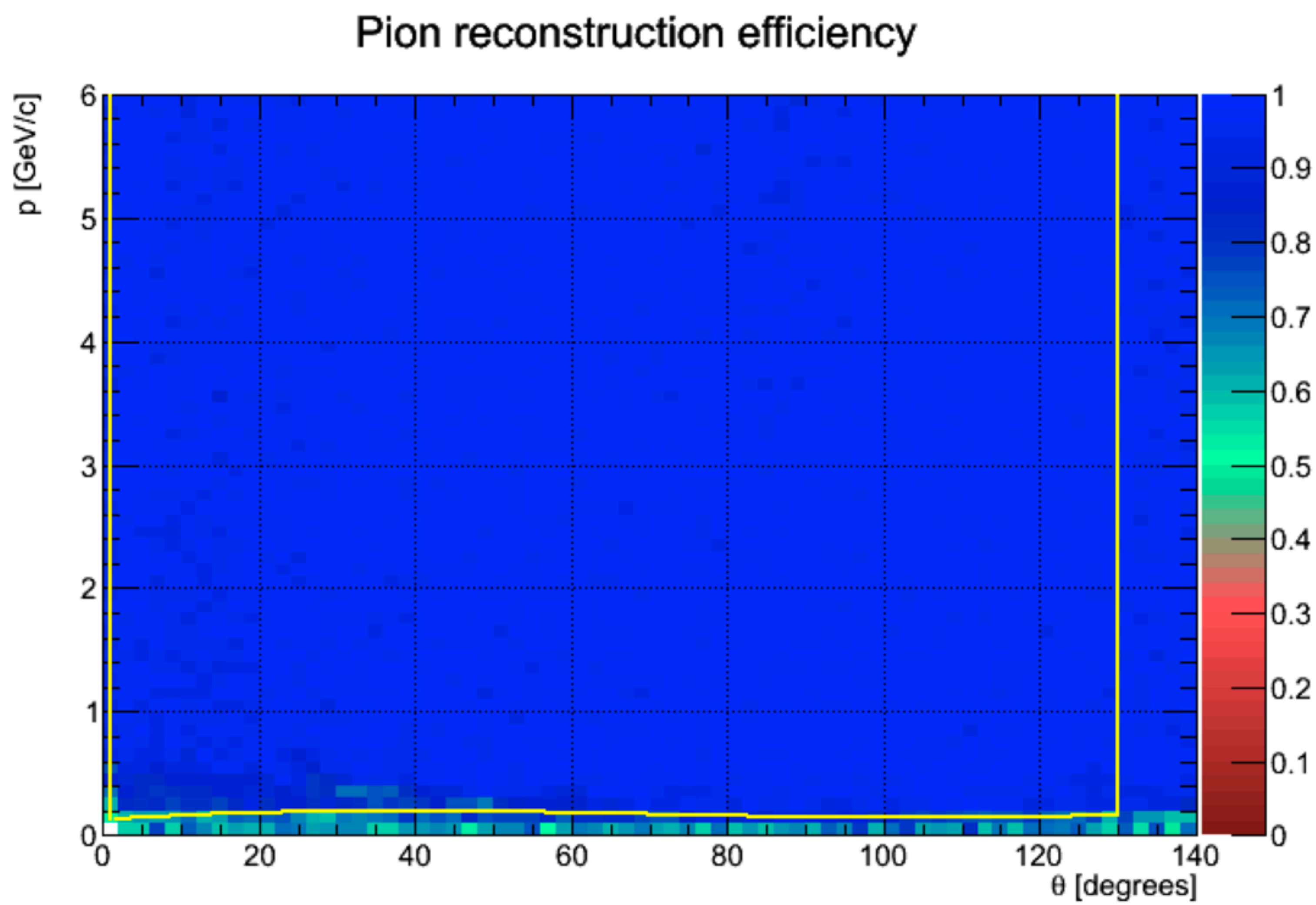
```
bool sum_cut = (Ebcal + 4.0*Efcal)>=2.0;
trig->L1a_fired = sum_cut && Ebcal>0.200 && Efcal>0.030;
trig->L1b_fired = sum_cut && Ebcal>0.030 && Efcal>0.030 && Nschits>0;
```

BCAL Dark Hits



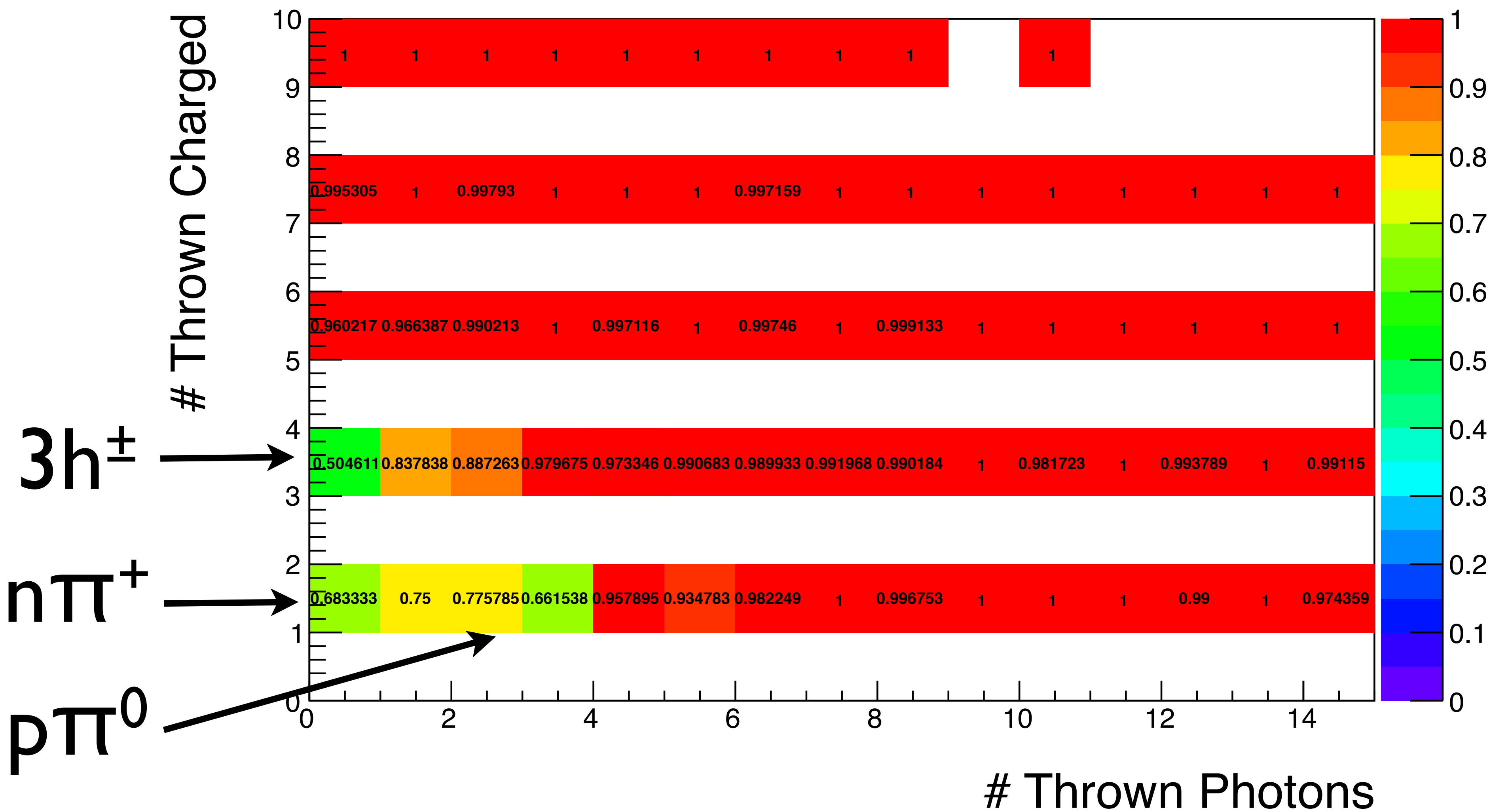
- Updates to BCAL simulation added a significantly larger number of dark hits (on average ~8% of channels per event)
- Eliminated by coincidence of up and downstream hits in point/cluster finder, but not required in current BCAL energy sum in simulated L1 trigger
- Currently using a threshold of 20 MeV to eliminate noise hits from L1 trigger

Track Acceptance



- Remove events with tracks lost due to acceptance from trigger efficiency estimation
- Track criteria: $1 < \theta < 130^0$ and $p > 150$ MeV for p, $\overline{p}$, $\pi^{\pm}$, $K^{\pm}$
- Criteria from weekly single track tests: https://halldweb1.jlab.org/single_track/
- Efficiencies in the slides today include this acceptance requirement

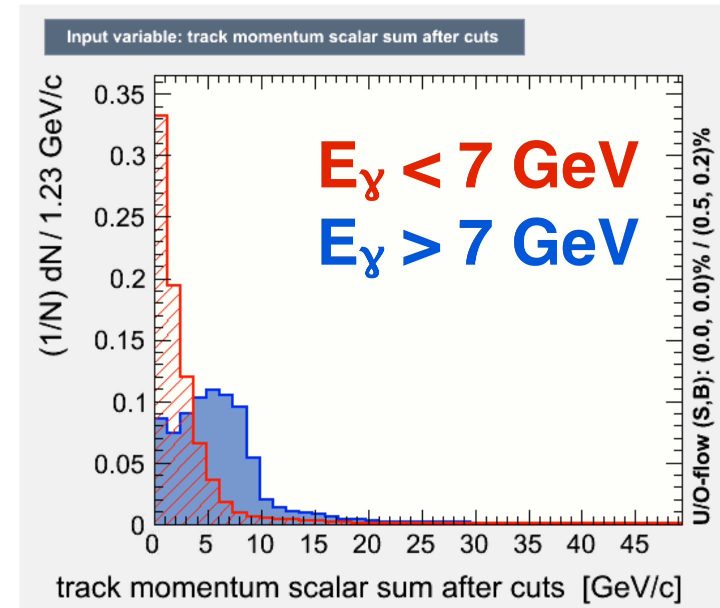
L1 Efficiency

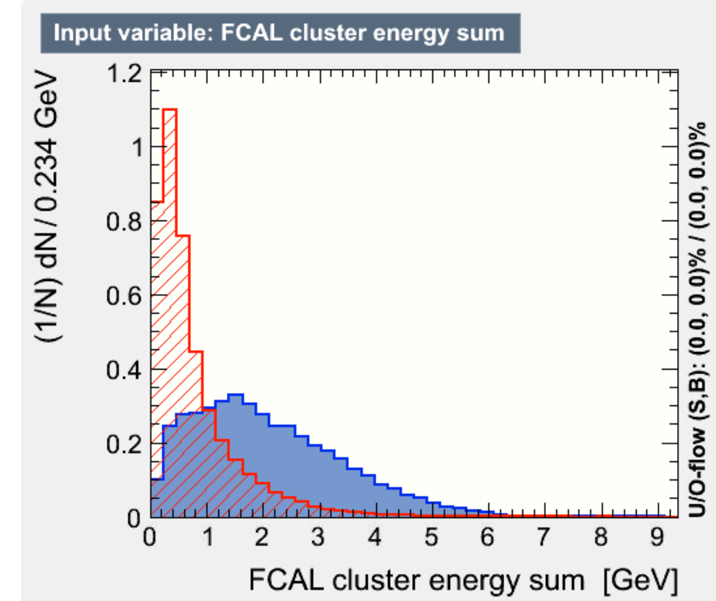


- After acceptance correction still lower than expected efficiency for $3h^{\pm}$ based on a study of specific exotic channels by Alex (GlueX-doc 1309)
- Efficiency for $\gamma p \to n\pi^+\pi^-\pi^+$ channel from July analysis workshop is ~83%, was and ~93% from previous study (kinematic assumptions probably different)
- In any case, BCAL hit simulation has changed recently, so may want to look again at thresholds and simulation of L1 trigger

Old Inputs

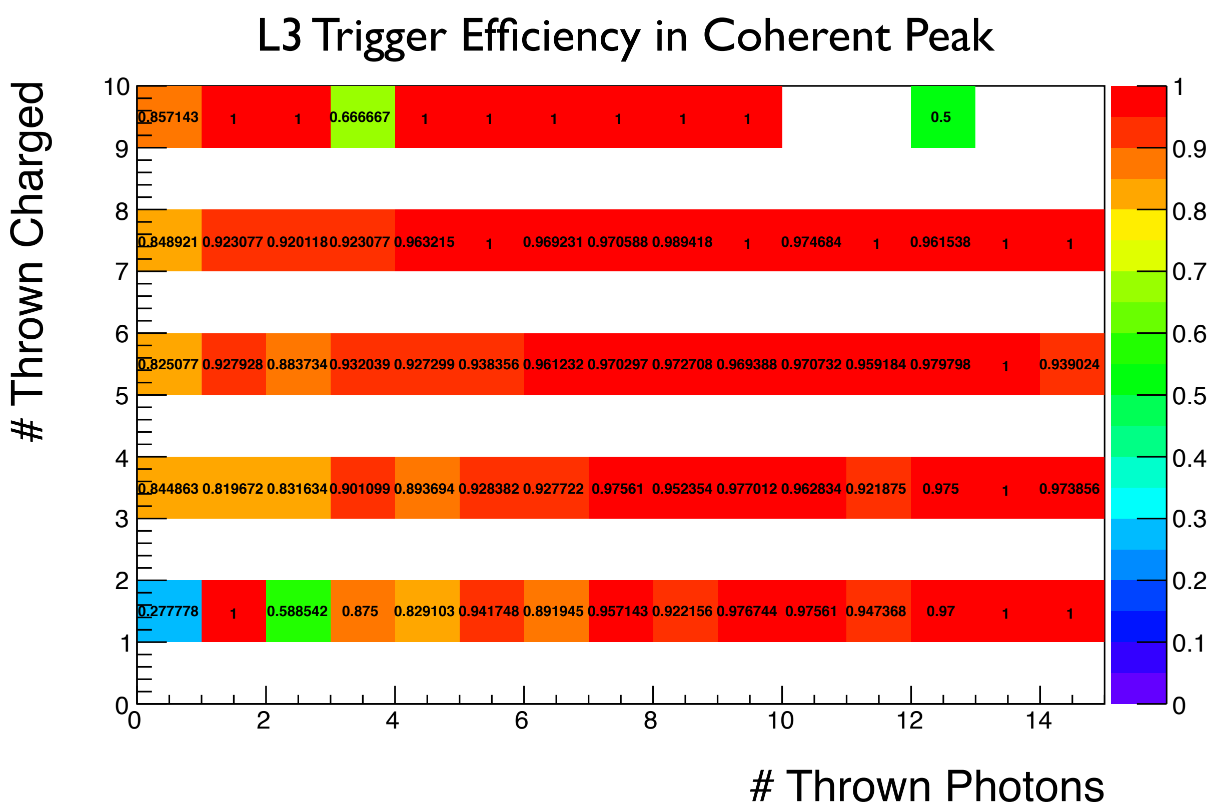
```
float Ntagger;            // Number of reconstructed tagger hits
float Nstart_counter;     // Number of start counter hits
float Ntof;               // Number of TOF hits
float Ncdc_layers;        // Number of different CDC layers hit
float Nfdc_planes;        // Number of different FDC planes hit
float Nfdc;               // Number of FDC hits (cathode + anode)
float Nfdc_pseudo;        // Number of FDC pseudo hits
float Ncdc;               // Number of CDC hits

float Nbcal_points;       // Number of BCAL points
float Nbcal_clusters;     // Number of BCAL clusters
float EbcalUnified;       // Total energy in BCAL (Unified Hits)
float EbcalPoints;        // Total energy in BCAL (Points)
float EbcalClusters;      // Total energy in BCAL (Clusters)

float Nfcal_clusters;     // Number of FCAL clusters
float Efcal;              // Total energy in FCAL
float EfcalClusters;      // Total energy in FCAL (Clusters)

float Ntrack_candidates_cut;  // Number of track candidates
float Ptot_tracks_cut;    // Scaler sum of total momentum from candidate tracks
```

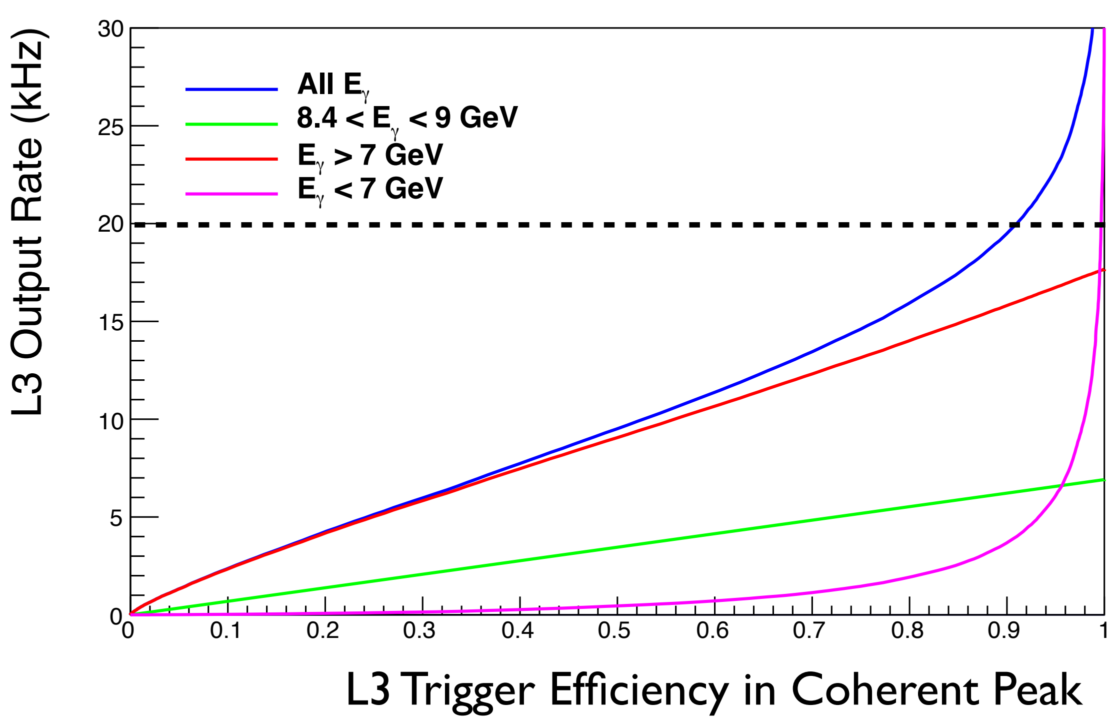




- This was a useful baseline but many variables here which may not be stable or poorly simulated offline

Old Inputs

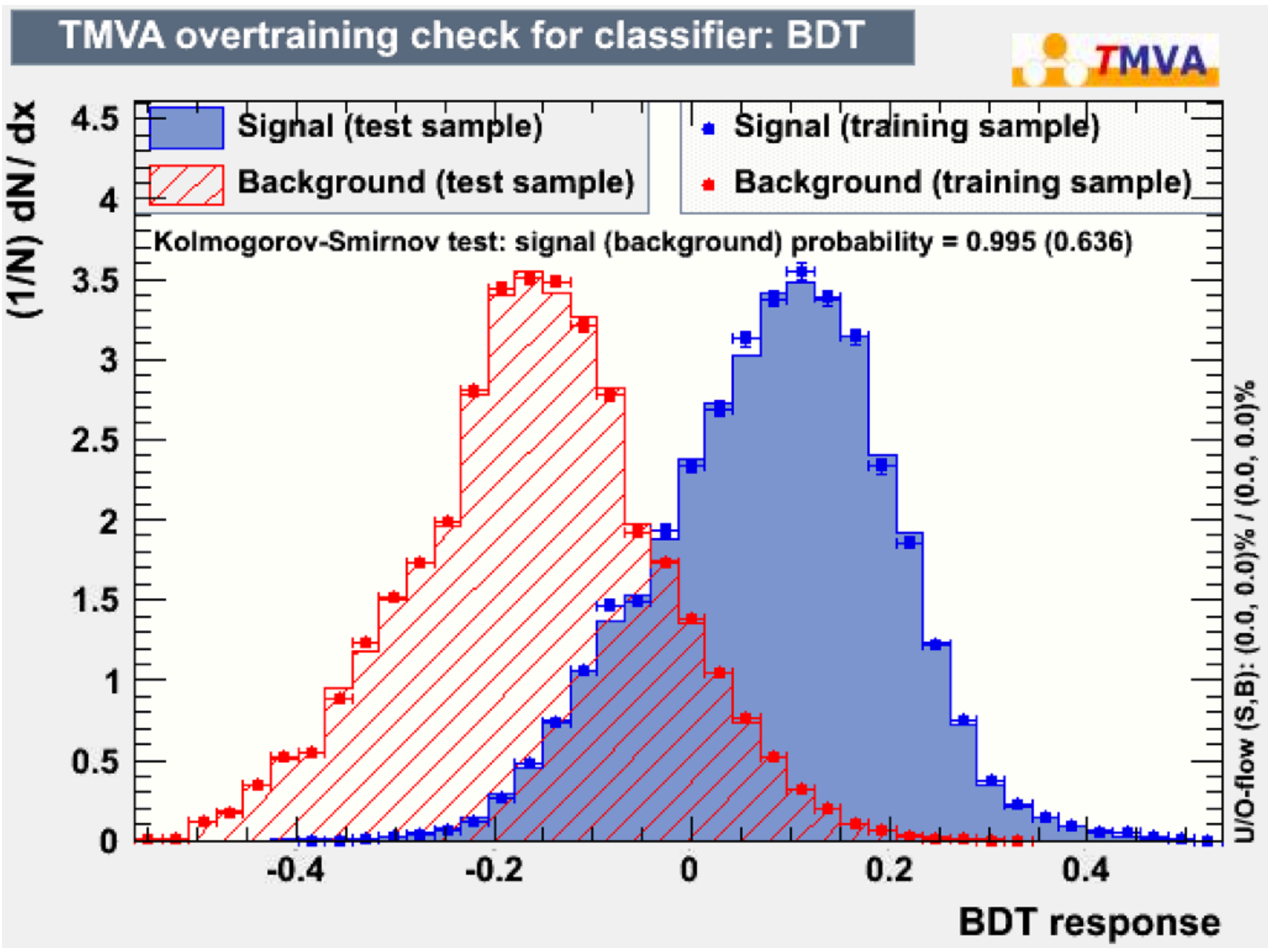





```
--- Factory    : Ranking input variables (method specific)...
--- BDT        : Ranking result (top variable is best ranked)
--- BDT        : -------------------------------------------------------
--- BDT        : Rank : Variable              : Variable Importance
--- BDT        : -------------------------------------------------------
--- BDT        :    1 : Efcal                 : 9.753e-02
--- BDT        :    2 : EfcalClusters         : 9.121e-02
--- BDT        :    3 : EbcalUnified          : 8.717e-02
--- BDT        :    4 : Ptot_tracks_cut       : 8.463e-02
--- BDT        :    5 : Ncdc                  : 7.115e-02
--- BDT        :    6 : Nfdc                  : 6.757e-02
--- BDT        :    7 : Nstart_counter        : 5.639e-02
--- BDT        :    8 : Nfdc_pseudo           : 5.503e-02
--- BDT        :    9 : EbcalPoints           : 5.090e-02
--- BDT        :   10 : Ntof                  : 4.931e-02
--- BDT        :   11 : Nfcal_clusters        : 4.455e-02
--- BDT        :   12 : Nbcal_points          : 4.133e-02
--- BDT        :   13 : Ntrack_candidates_cut : 3.713e-02
--- BDT        :   14 : EbcalClusters         : 3.707e-02
--- BDT        :   15 : Nbcal_clusters        : 3.473e-02
--- BDT        :   16 : Ncdc_layers           : 3.335e-02
--- BDT        :   17 : Nfdc_planes           : 3.122e-02
--- BDT        :   18 : Ntagger               : 2.973e-02
--- BDT        : -------------------------------------------------------
```

- For a rate of 20 kHz, achieve ~90% L3 average efficiency in the coherent peak
- Events with zero photons have lower efficiency of ~83%

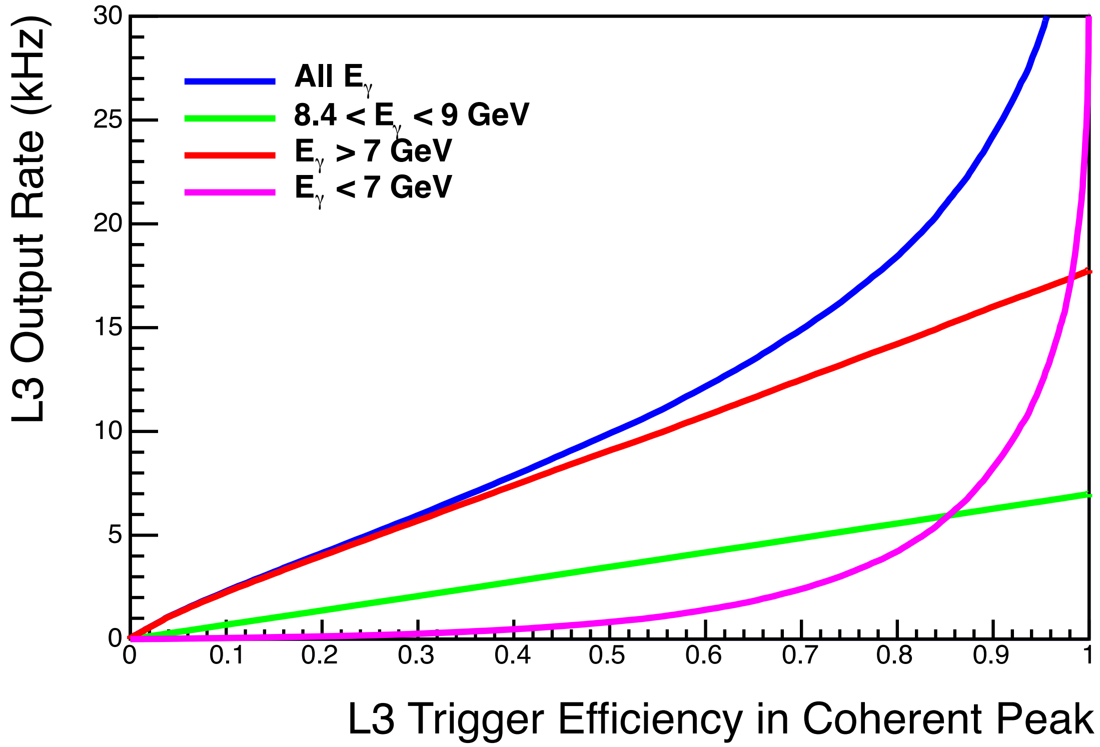
No Tracking

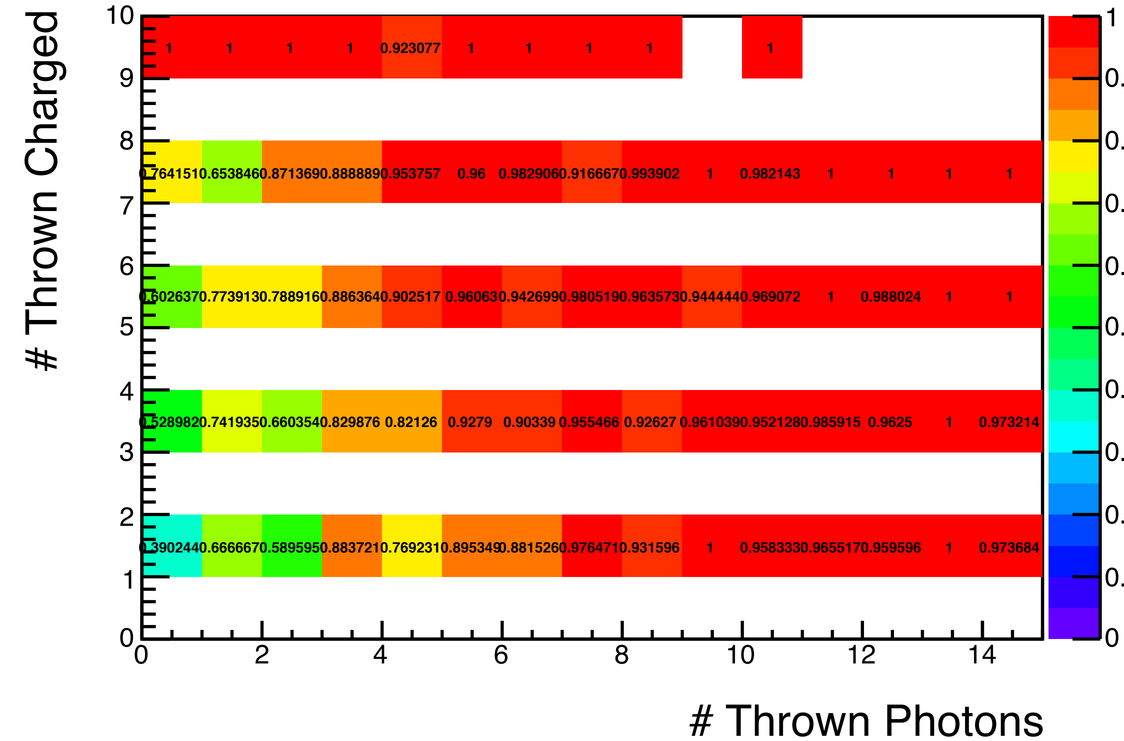


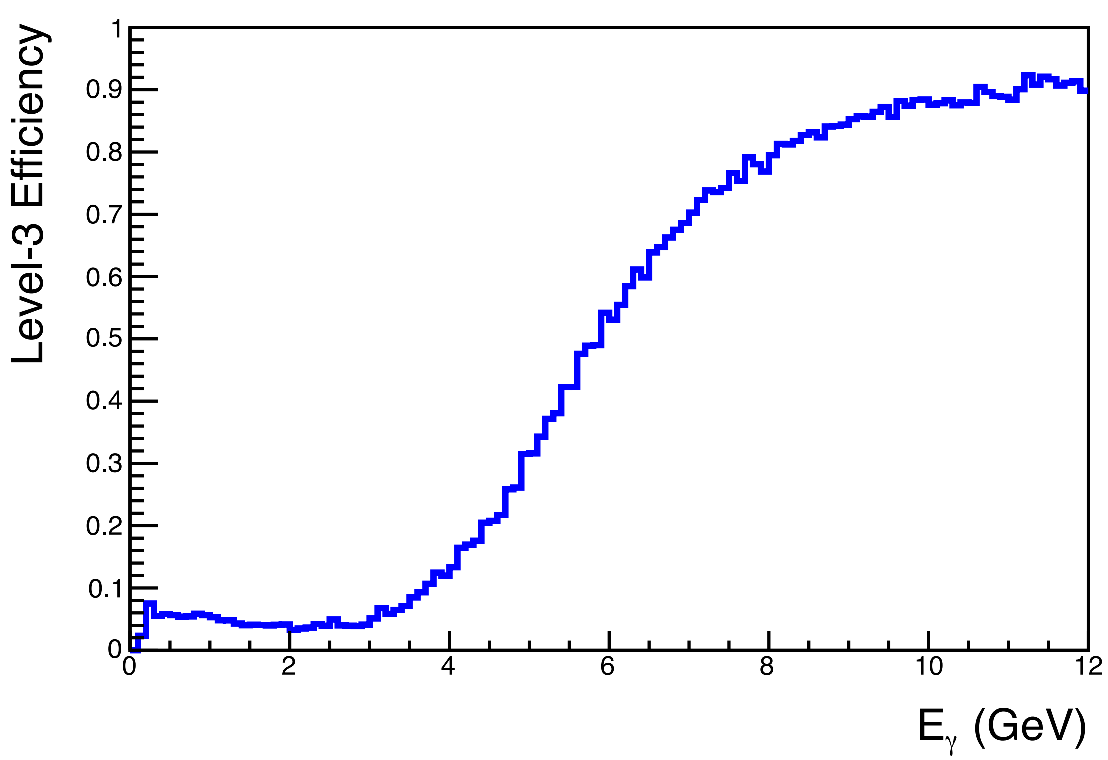

```
--- Factory   : Ranking input variables (method specific)...
--- BDT       : Ranking result (top variable is best ranked)
--- BDT       : -----------------------------------------------
--- BDT       : Rank :Variable        :Variable Importance
--- BDT       : -----------------------------------------------
--- BDT       :    1 : EbcalPoints     : 1.843e-01
--- BDT       :    2 : EfcalClusters   : 1.776e-01
--- BDT       :    3 : Nfcal_clusters  : 1.397e-01
--- BDT       :    4 : Nstart_counter  : 1.366e-01
--- BDT       :    5 : EbcalClusters   : 1.068e-01
--- BDT       :    6 : Nbcal_points    : 9.441e-02
--- BDT       :    7 : Ntof            : 8.755e-02
--- BDT       :    8 : Nbcal_clusters  : 7.302e-02
--- BDT       : -----------------------------------------------
```

- Try removing everything but SC, TOF, BCAL and FCAL
- Reconstruction is 2.5x faster than when tracking is included
- What kind of performance is possible?

No Tracking

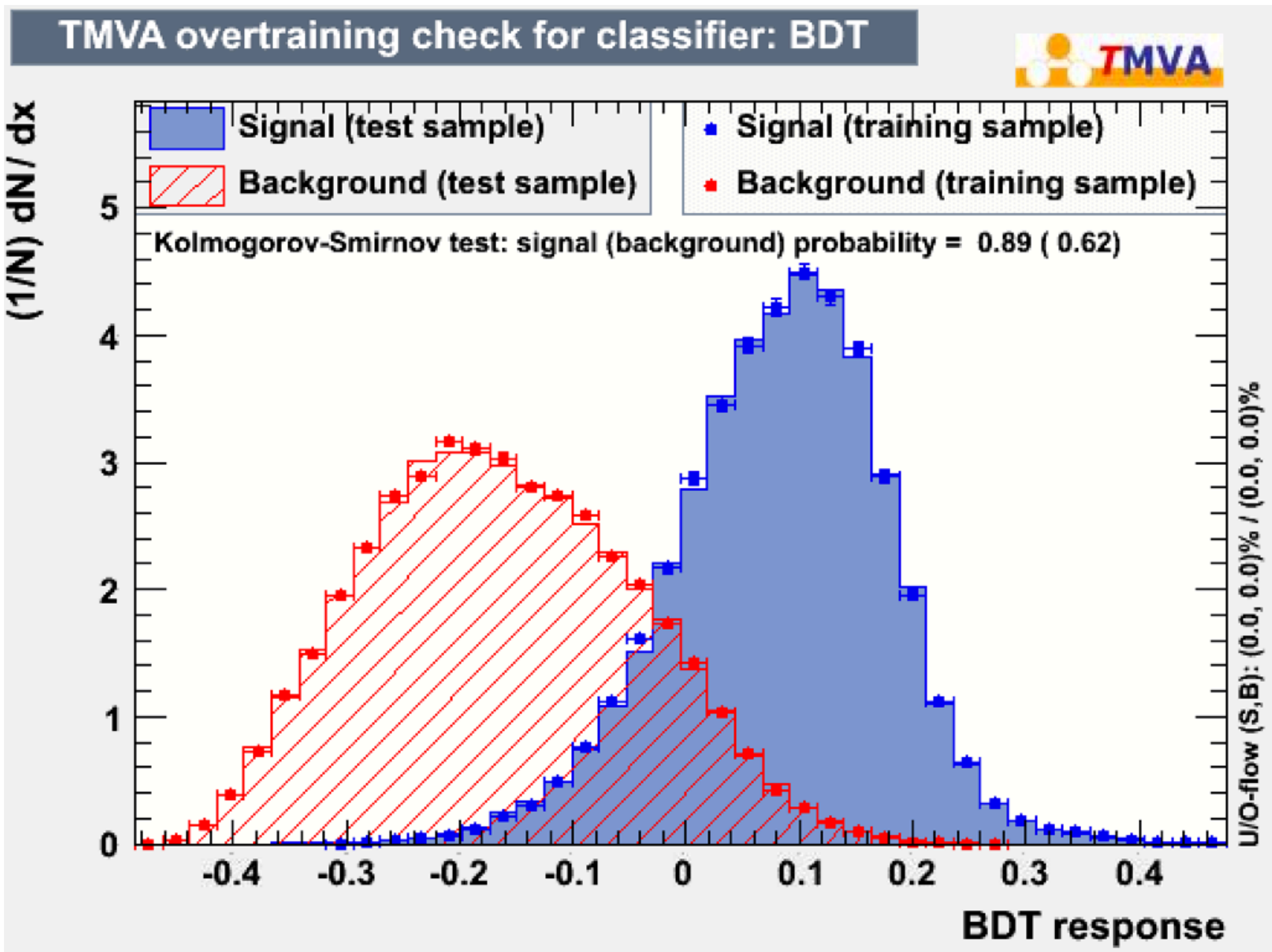






- For a rate of 20 kHz, achieve ~83% L3 average efficiency in the coherent peak
- Low track multiplicity events have rather low efficiencies, at about ~55% for zero photon events

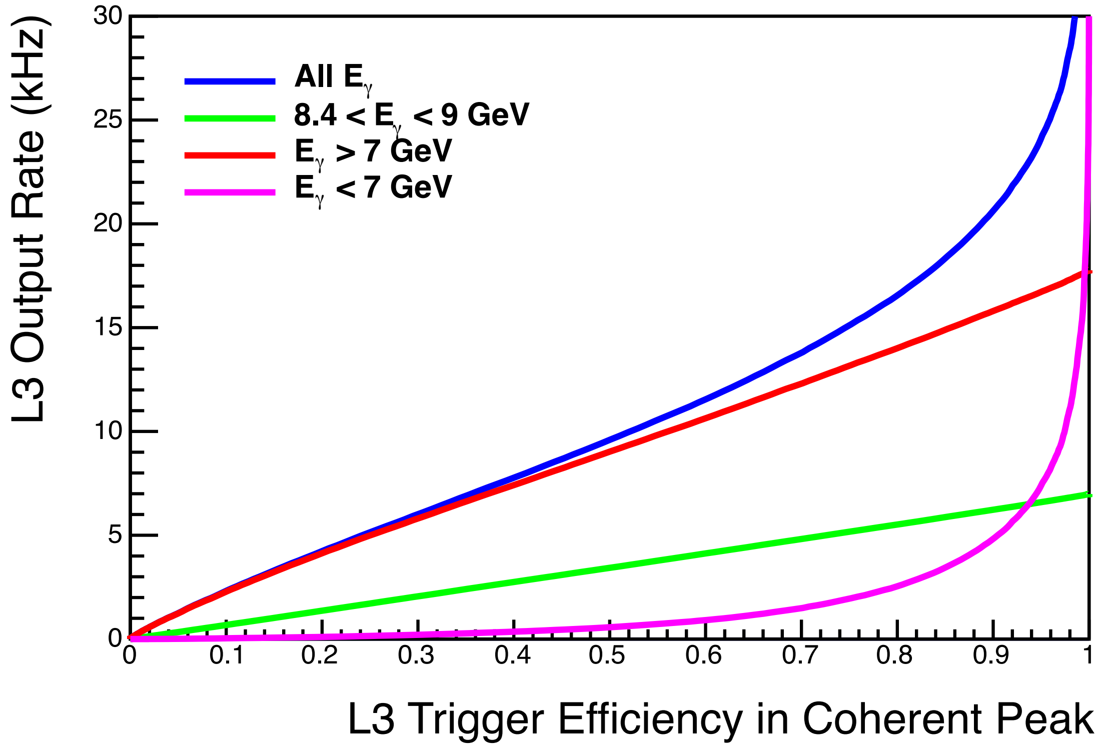
Add Track Sum

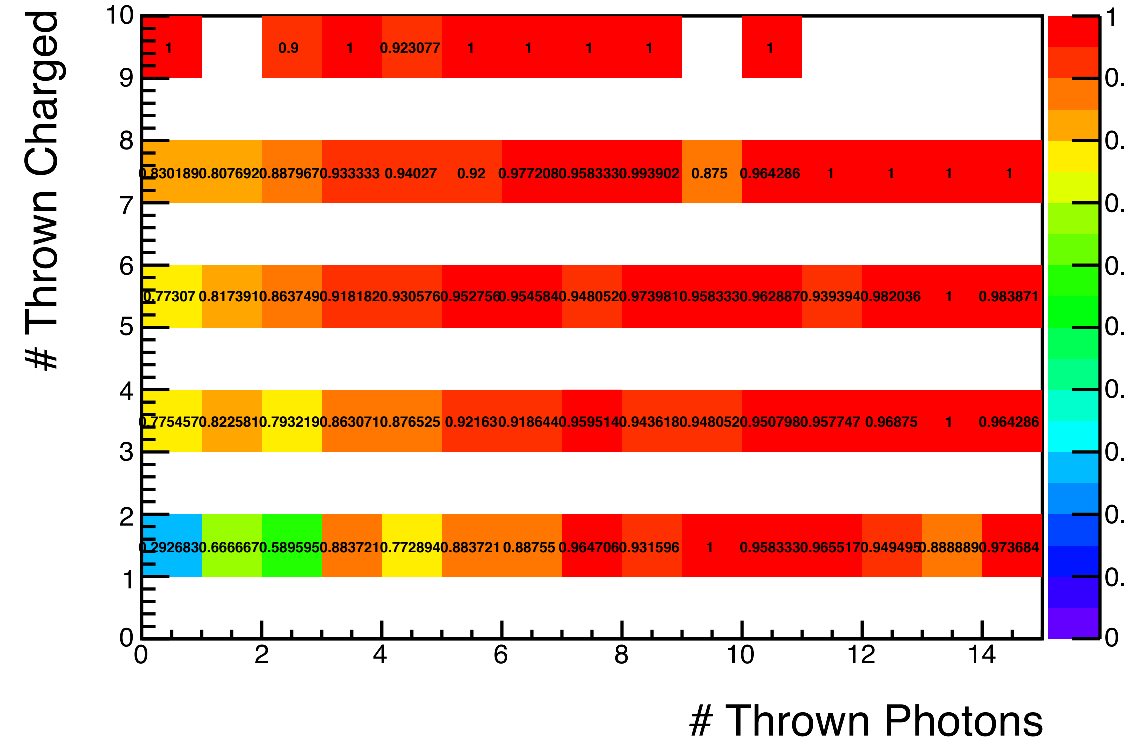


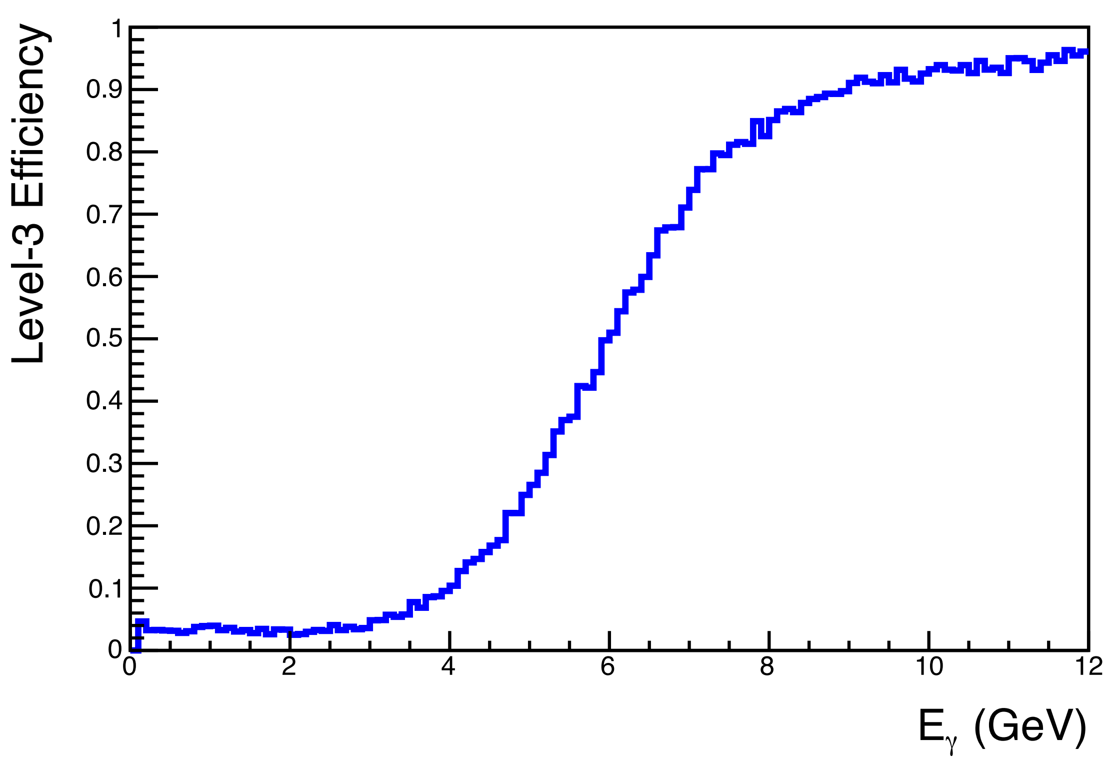
--- Factory : Ranking input variables (method specific)...
--- BDT : Ranking result (top variable is best ranked)
--- BDT : ---
--- BDT : Rank : Variable : Variable Importance
--- BDT : ---
--- BDT : 1 : EfcalClusters : 1.636e-01
--- BDT : 2 : **Ptot_tracks_cut** : 1.366e-01
--- BDT : 3 : EbcalPoints : 1.245e-01
--- BDT : 4 : EbcalClusters : 1.110e-01
--- BDT : 5 : **Ntrack_candidates_cut** : 9.658e-02
--- BDT : 6 : Ntof : 8.451e-02
--- BDT : 7 : Nfcal_clusters : 7.634e-02
--- BDT : 8 : Nstart_counter : 7.554e-02
--- BDT : 9 : Nbcal_points : 7.453e-02
--- BDT : 10 : Nbcal_clusters : 5.663e-02
--- BDT : ---

- Only use tracking variables expected to be “stable” and able to simulate offline: Sum of track momentum and # of tracks
- Quality cut for track variables: # of Hits ≥ 8
  - Wait to optimize tracking cuts until after Paul’s spiral track study to reduce ghost tracks
- This version of the algo was used in the online data challenge last week

Add Track Sum



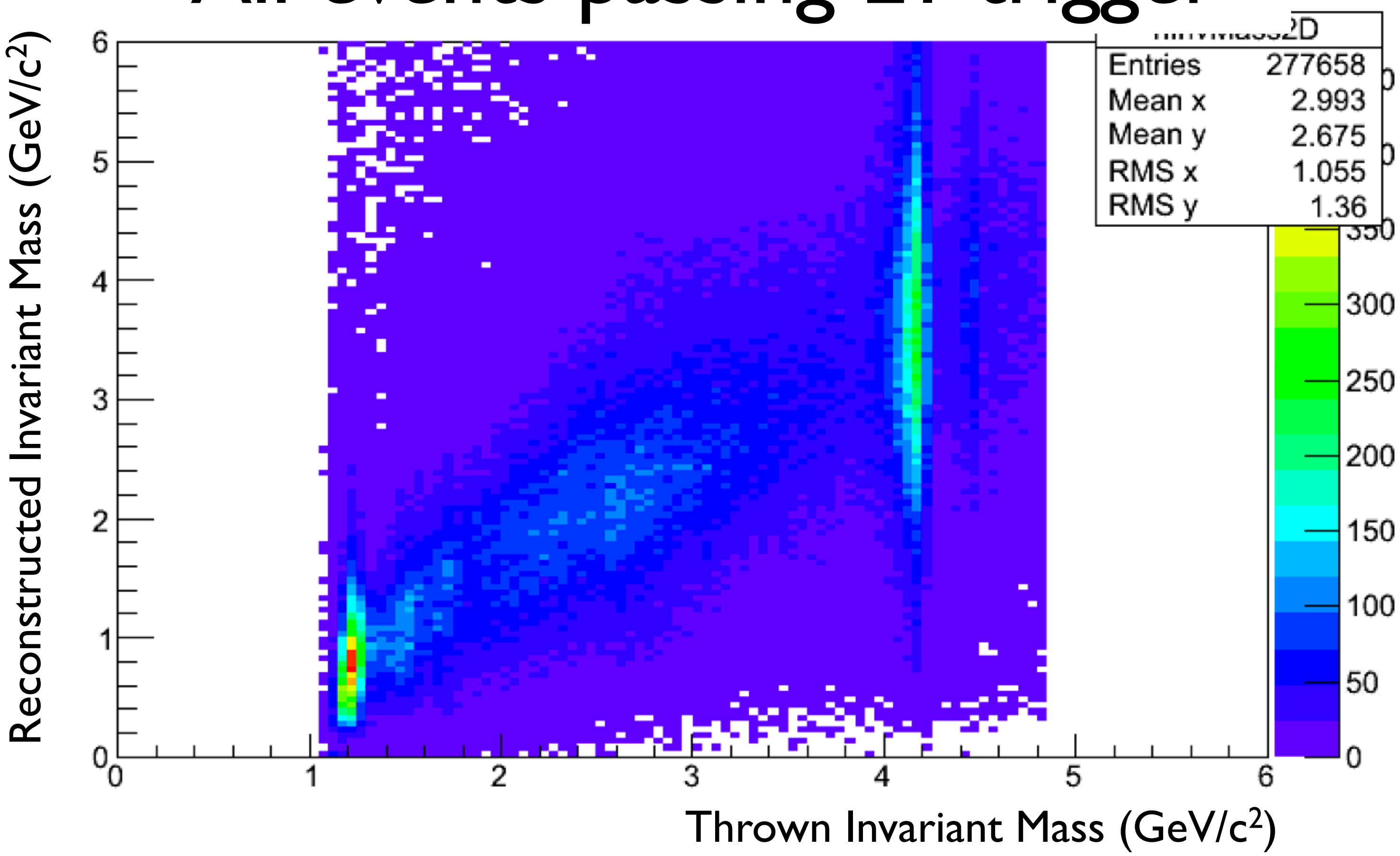




- For a rate of 20 kHz, achieve ~89% L3 average efficiency in the coherent peak
- Significant increase in efficiency for events with zero photons with tracking
- Removing variables like CDC/FDC hits results in slightly lower efficiency of for zero photon events

Invariant Mass

All events passing L1 trigger




```
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--- BDT       : -------------------------------------------------------
--- BDT       : Rank : Variable                : Variable Importance
--- BDT       : -------------------------------------------------------
--- BDT       :    1 : EfcalClusters           : 1.512e-01
--- BDT       :    2 : Ptot_tracks_cut         : 1.134e-01
--- BDT       :    3 : InvMass_cut             : 1.114e-01
--- BDT       :    4 : EbcalPoints             : 1.099e-01
--- BDT       :    5 : EbcalClusters           : 1.072e-01
--- BDT       :    6 : Nfcal_clusters          : 7.679e-02
--- BDT       :    7 : Nbcal_points            : 7.569e-02
--- BDT       :    8 : Ntof                    : 6.846e-02
--- BDT       :    9 : Ntrack_candidates_cut   : 6.612e-02
--- BDT       :   10 : Nstart_counter          : 5.999e-02
--- BDT       :   11 : Nbcal_clusters          : 5.985e-02
--- BDT       : -------------------------------------------------------
```
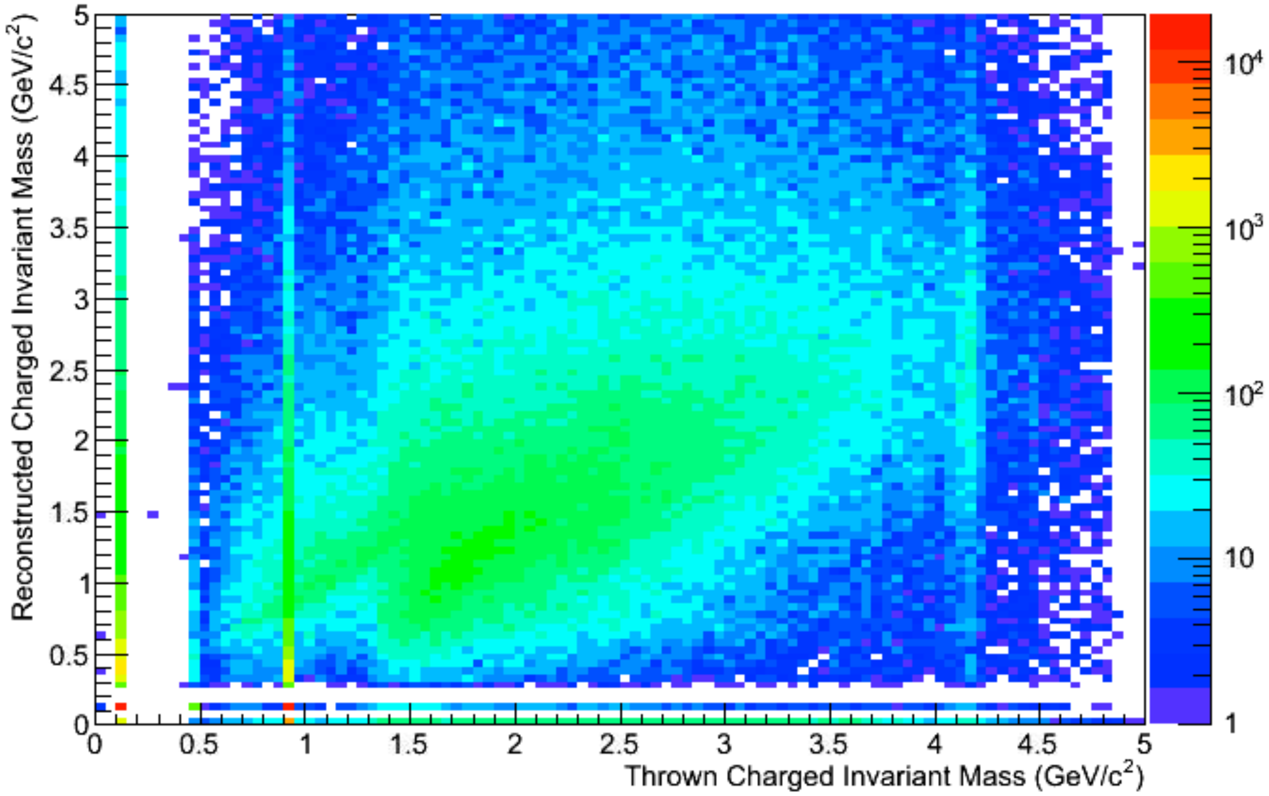
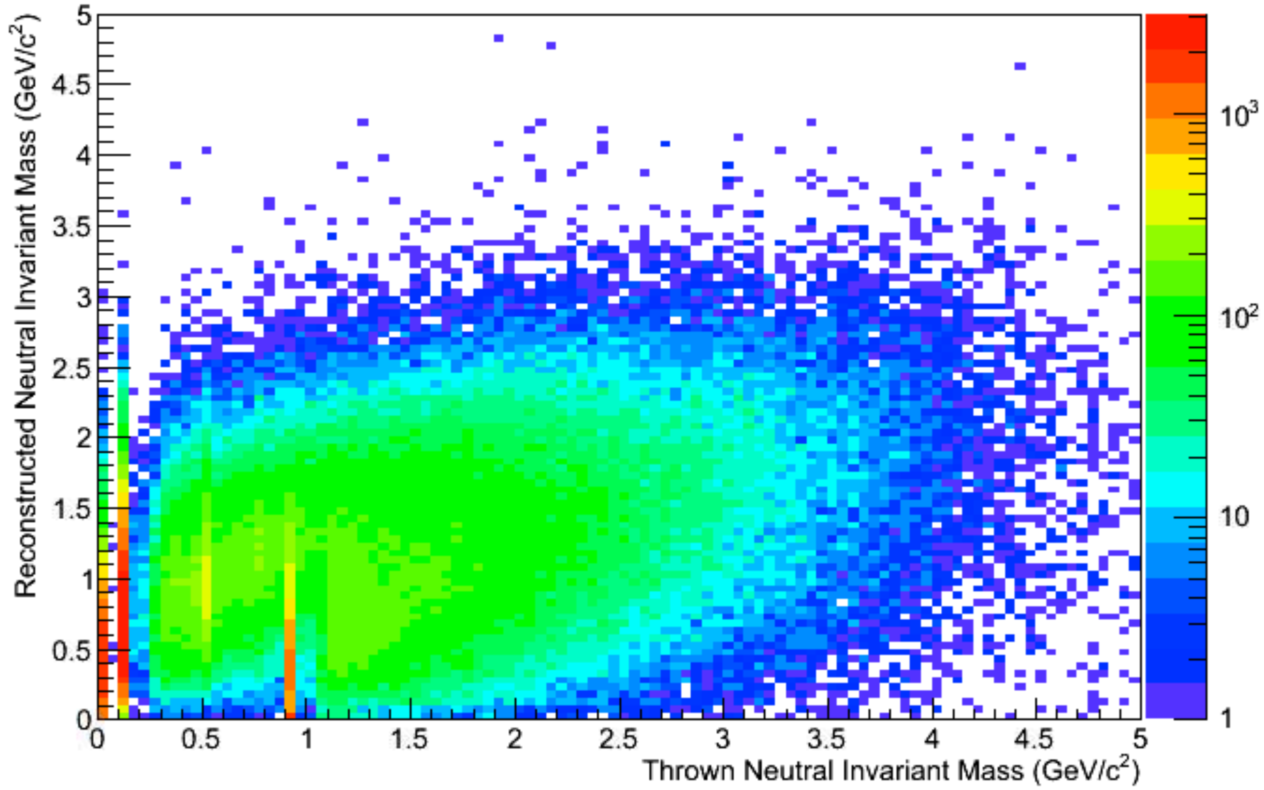

- Add 4-vectors of reconstructed objects
  - FCAL and BCAL cluster energies (assume photon)
  - Track candidates satisfying QA cuts (pion mass)

Invariant Mass

Charged Mass

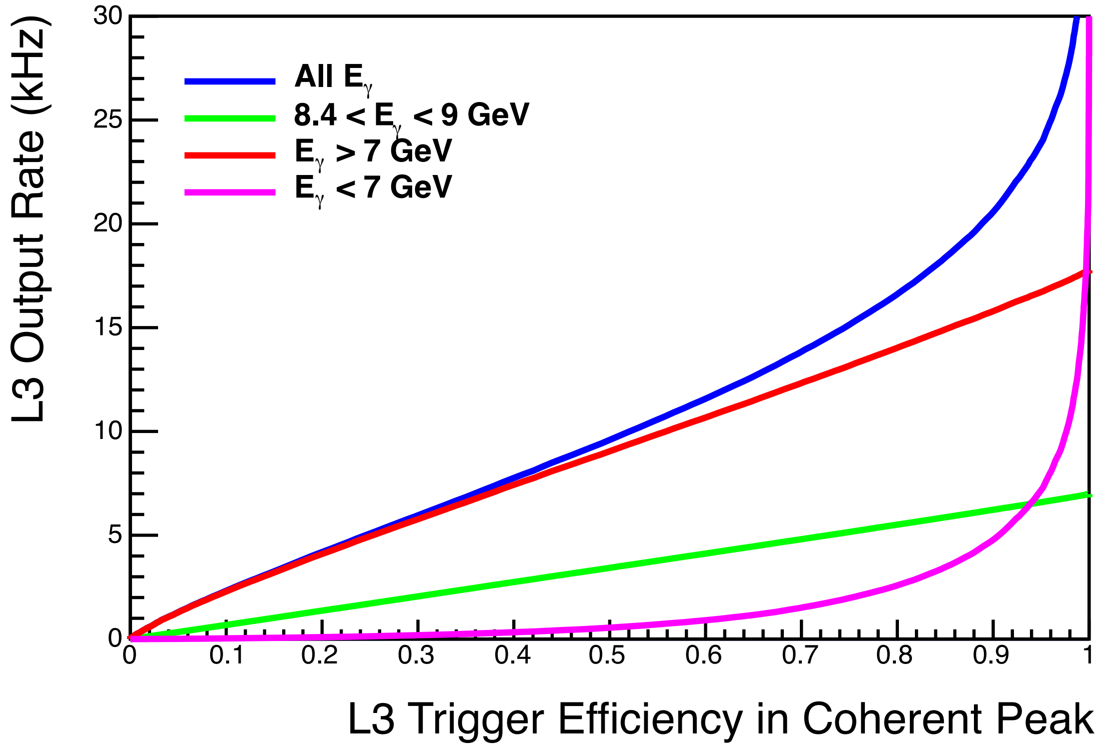


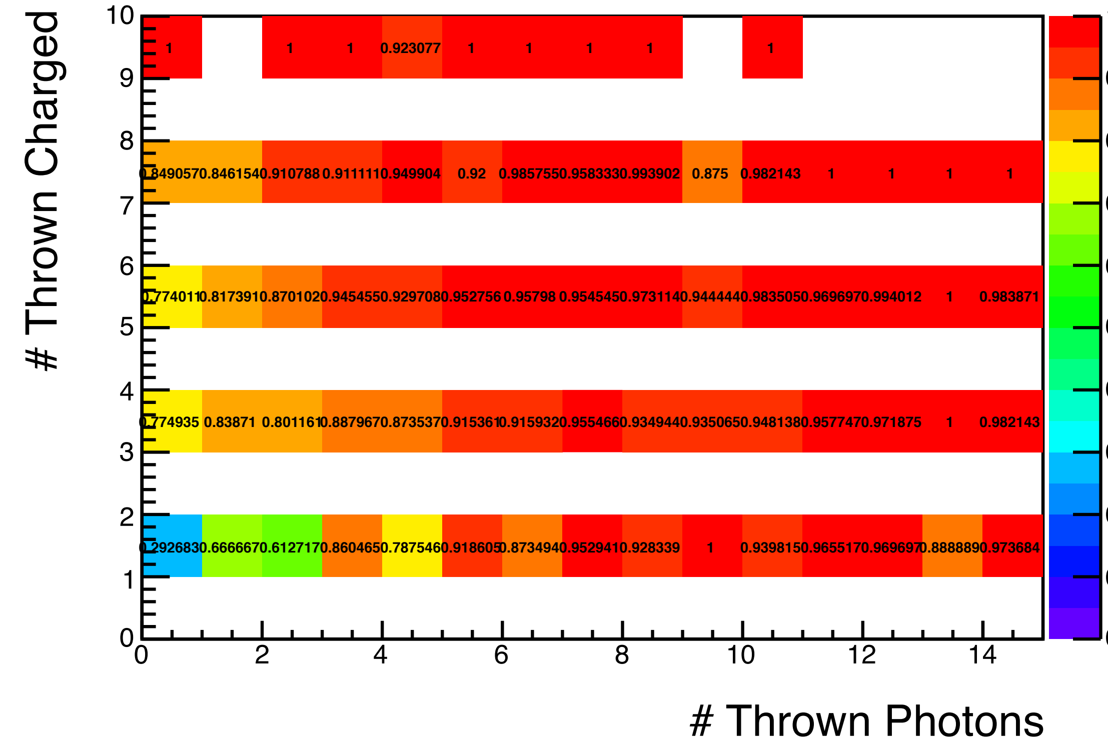
Neutral Mass

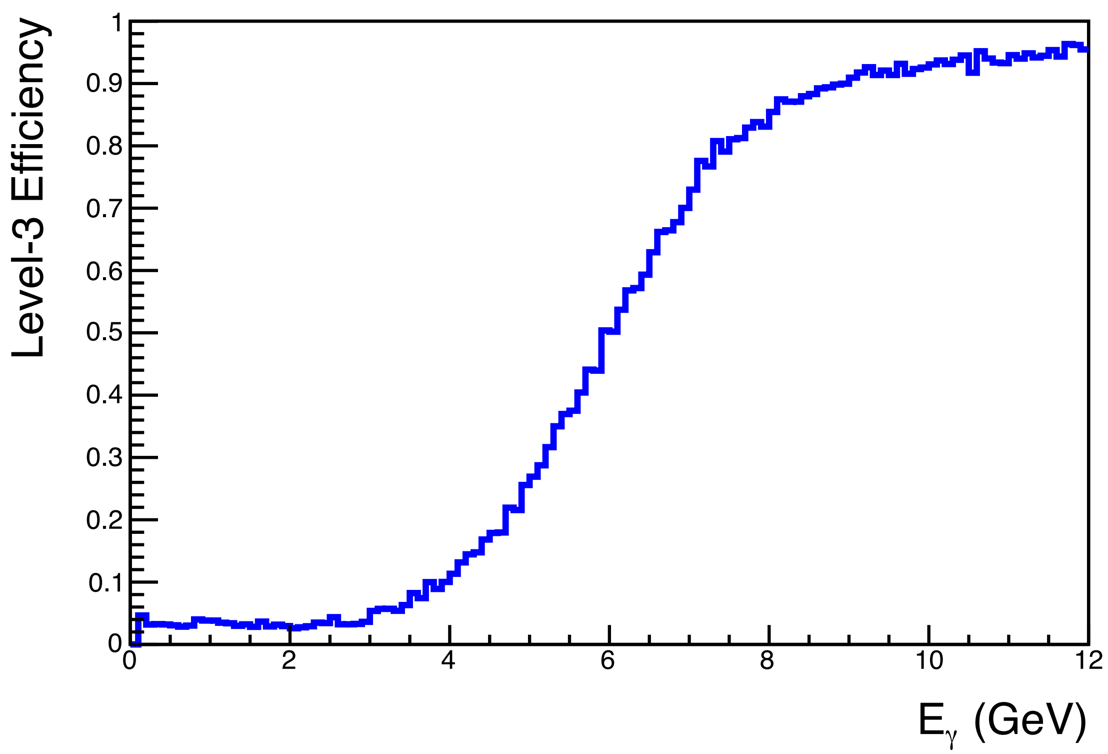


- Recoil proton/neutron contribution diminished since assume pion/photon mass
- Neither charged or neutral mass resolution is all that great with this simple approach

Invariant Mass







- For a rate of 20 kHz, achieve ~89% L3 average efficiency in the coherent peak
- Very little change from including invariant mass

Summary

- Applied acceptance criteria for charged tracks to be “reconstructable) which slightly increases trigger efficiencies
- As expected, without some sort of tracking in Level-3 events with zero photons will have a low efficiency
- The addition of a track momentum sum significantly increases the zero photon event efficiency
- Without an attempt at PID, the invariant mass resolution is pretty poor, so it doesn’t add much to the BDT at this point

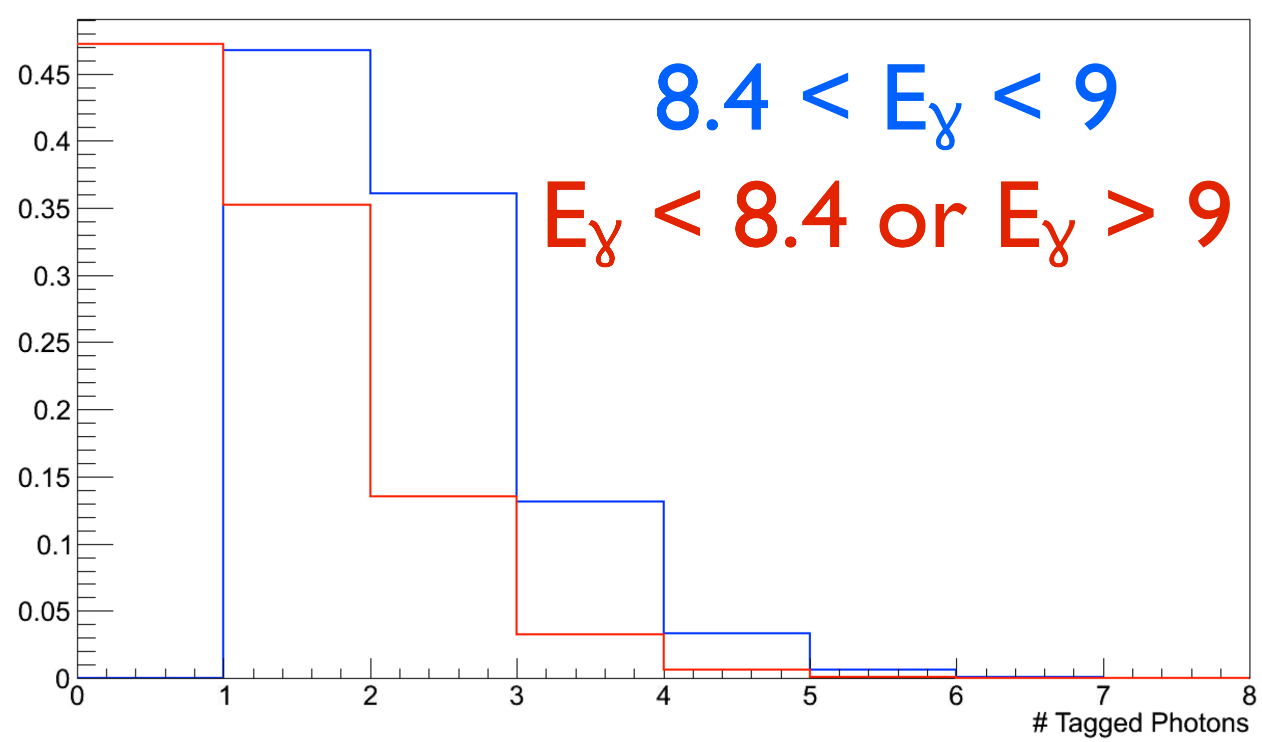
To Do

- Include EM only background sample
- Multiple stages to "pass through" events which don't need tracking
- Attempt some form of PID to improve invariant mass reconstruction
- Include fixed array information for higher energy photons

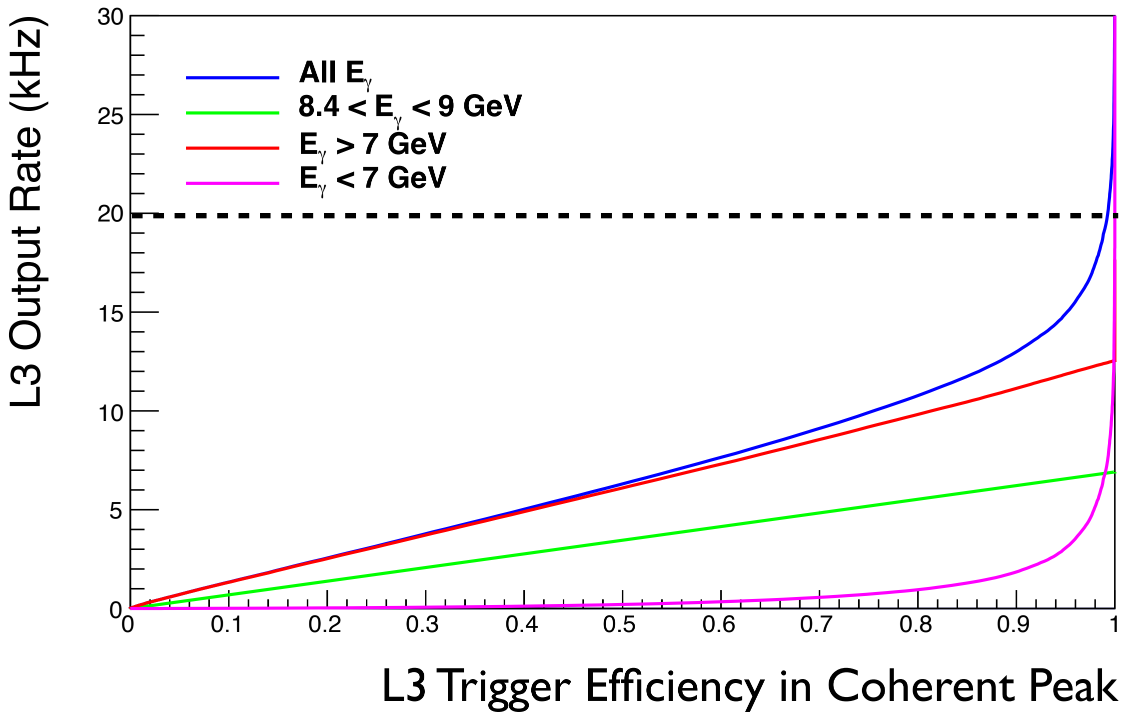
Backup

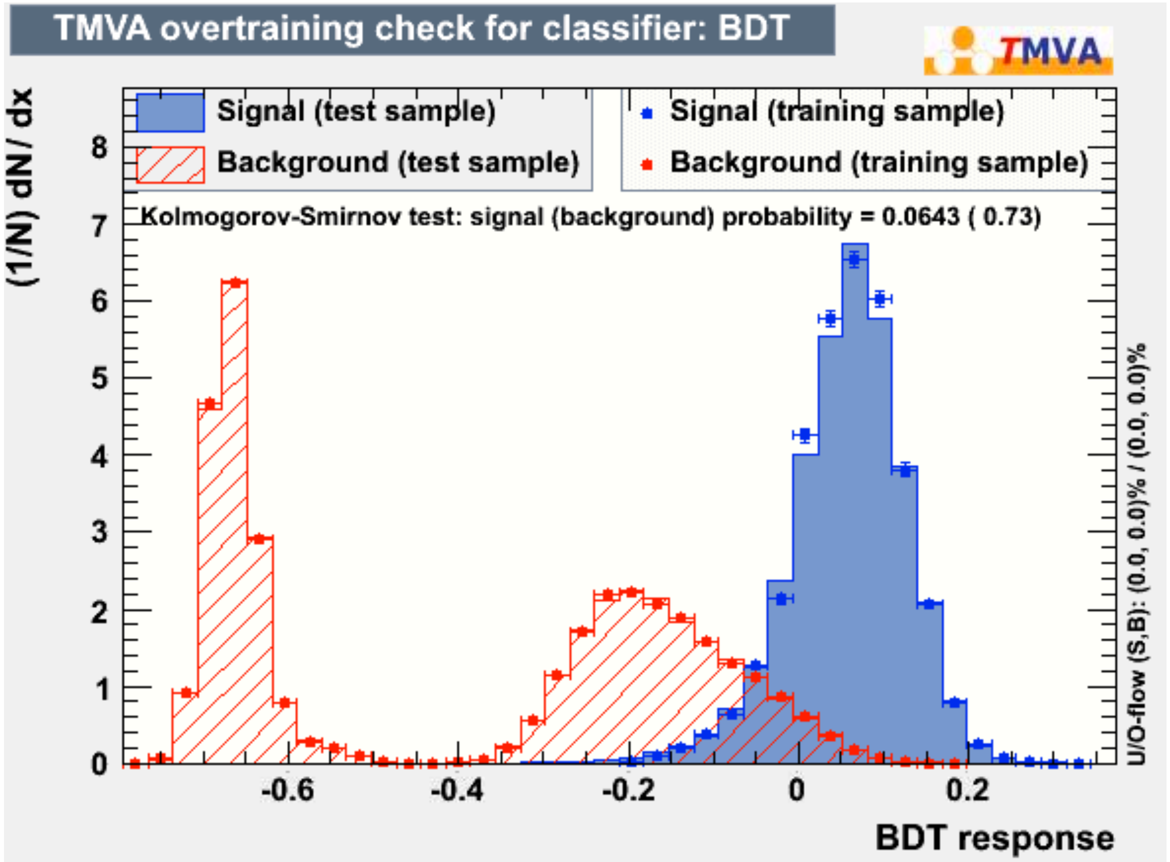
Tagger in L3

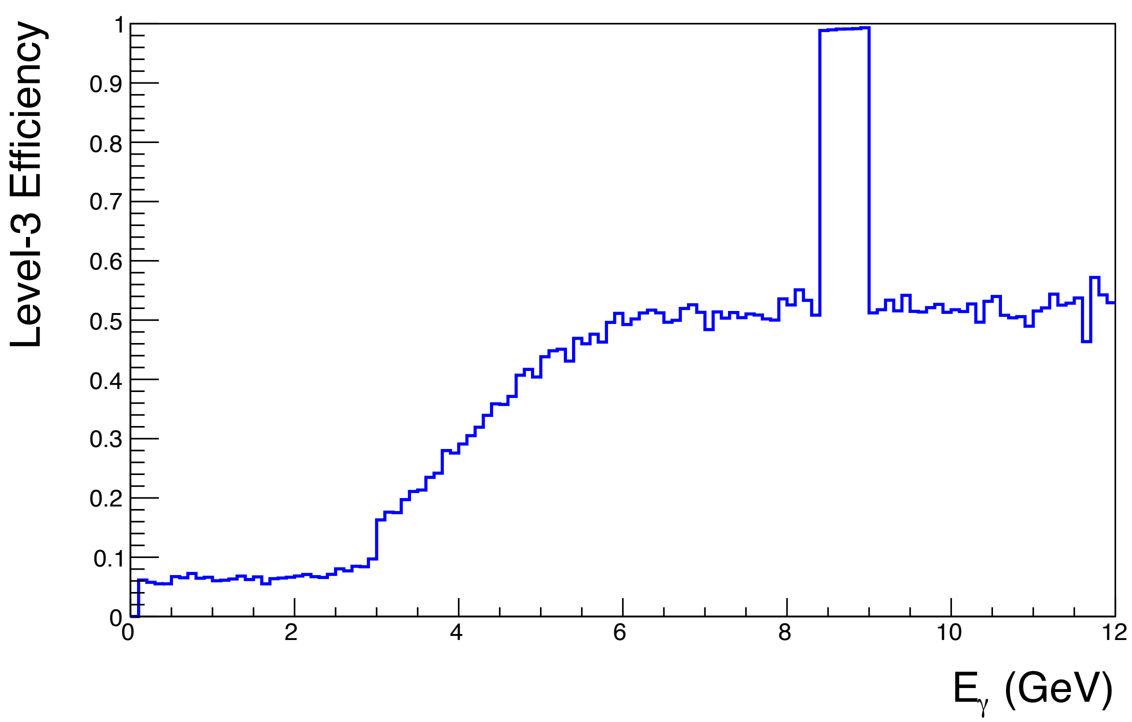
- Accidental tagged photon rate not currently in the simulation, but can model it with some numbers from Richard:
  - At 5×10^7 running, expect 0.25 accidental tags per beam bucket
  - Beam pulses every 2 ns, and tagger window of ±3 ns
- Summary: Use simple poisson statistics for (on average) 1 true + 0.75 accidental tagged photons for coherent peak events, and 0.75 accidentals for non-coherent peak events.
- Either cut on # of tagged photons or include in BDT



Tagger in BDT



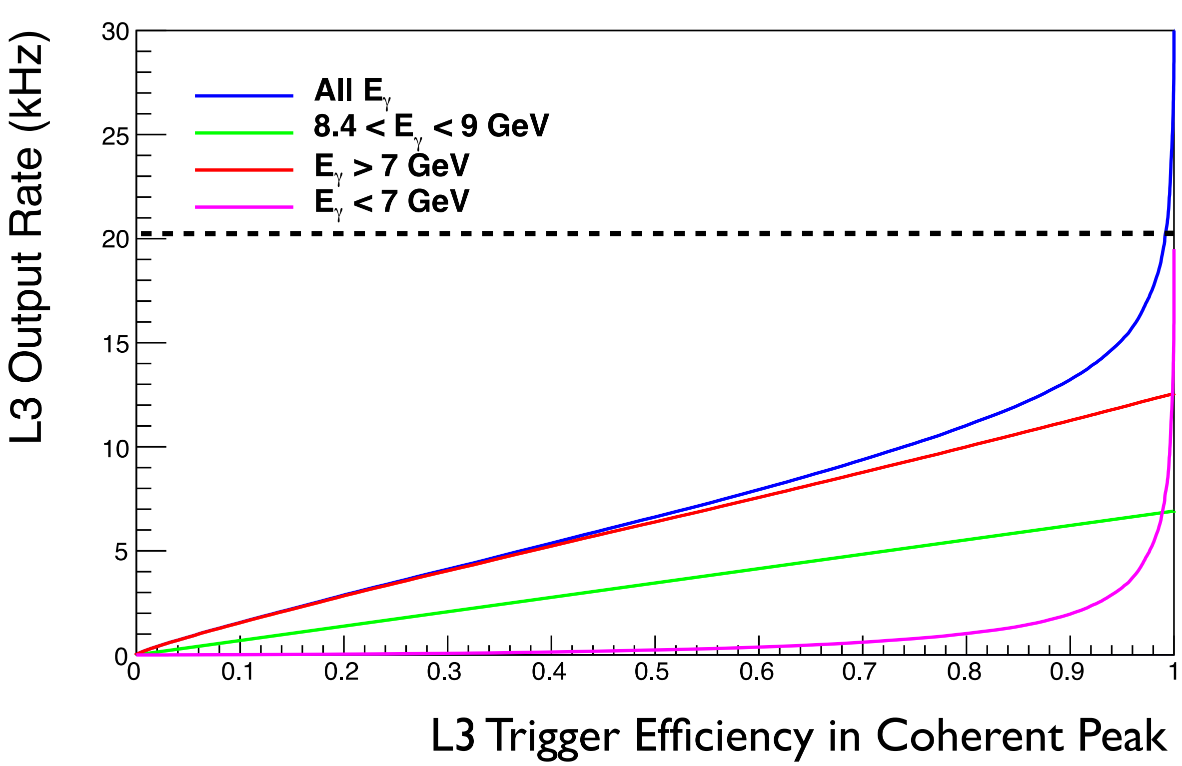


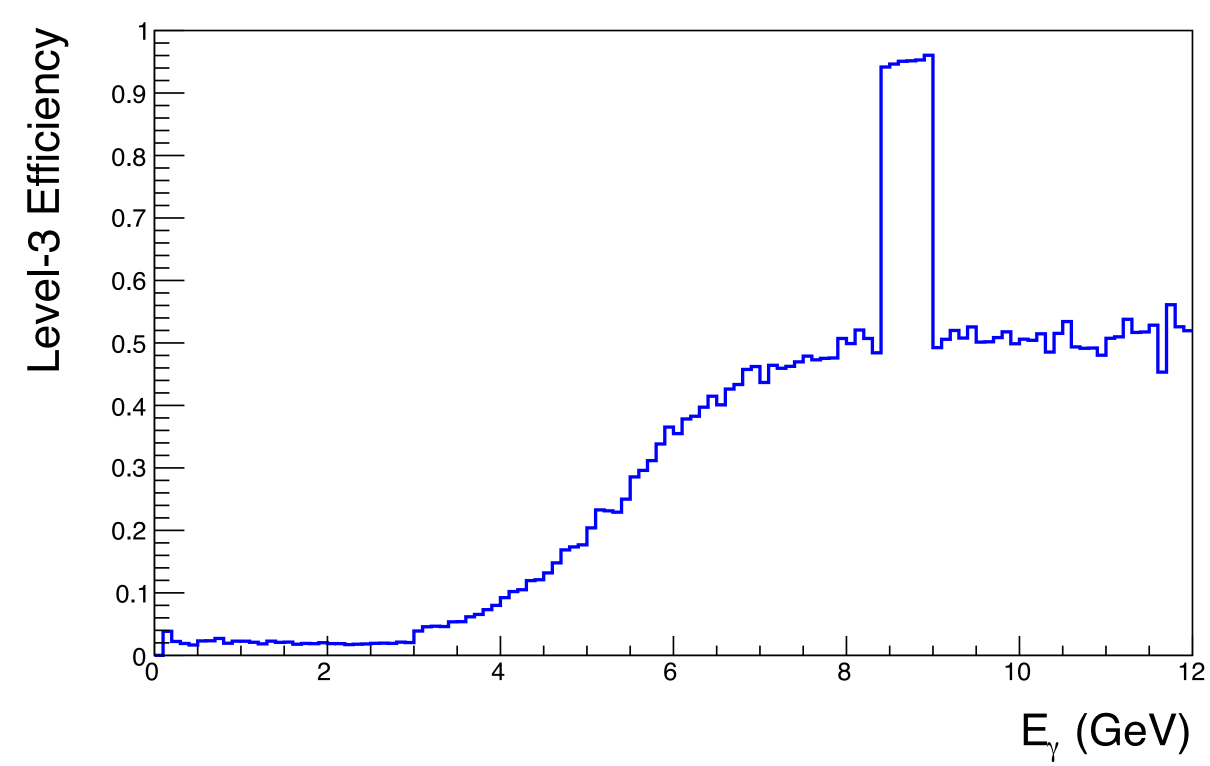


- For a rate of 20 kHz, achieve ~99% L3 average efficiency in the coherent peak
- Low efficiency for higher energy photons
- Events outside the coherent peak are biased towards a higher number of accidental tags

Cutting on Tagger

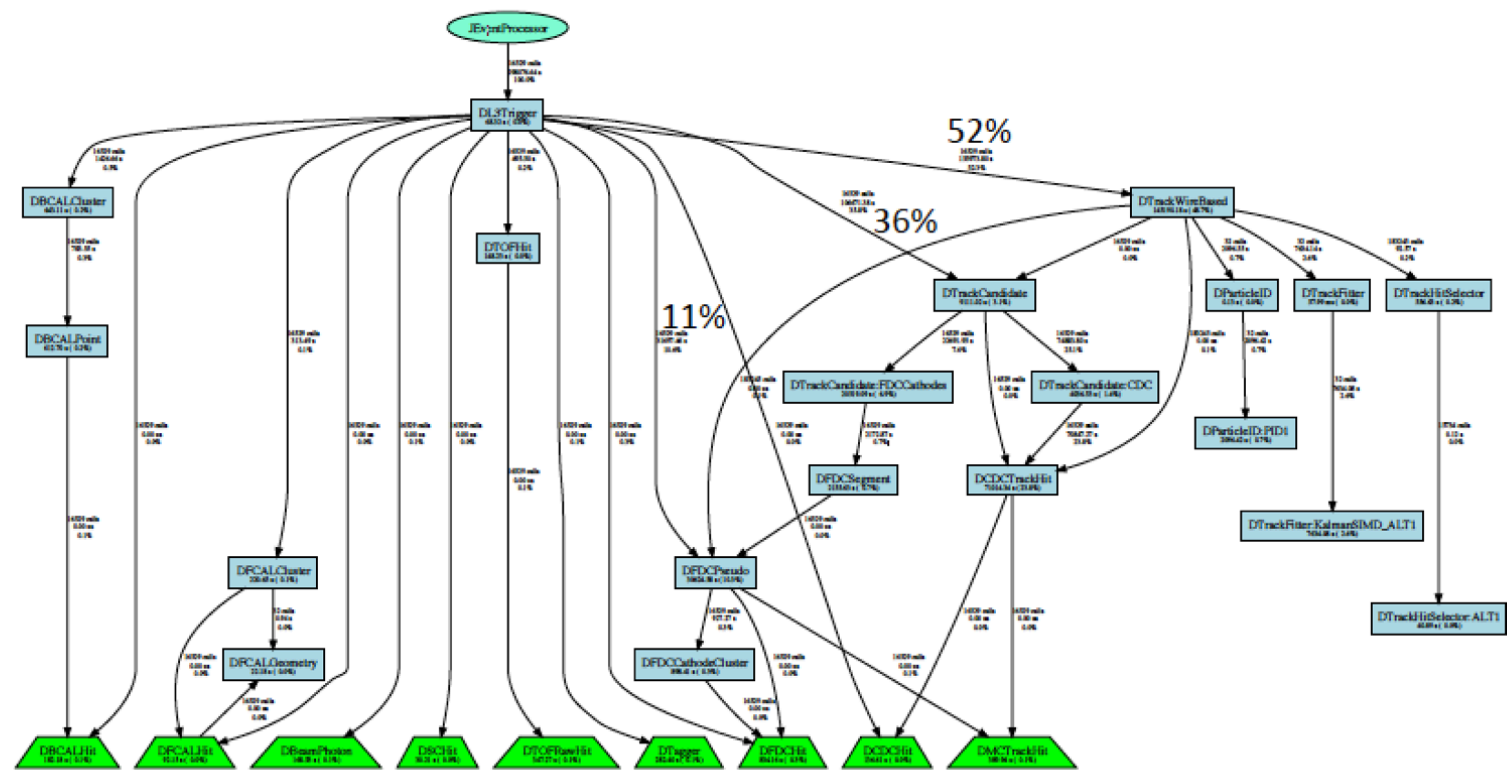
- Separate Level-3 into different trigger lines (or streams):
  1. # tagged photons > 0
     - Could run at 20 kHz rate to get highest coherent peak efficiency
     - Or choose BDT cut to give ~X% efficiency in the coherent peak and give bandwidth to other triggers
  2. # tagged photons = 0, but may still want high energy events





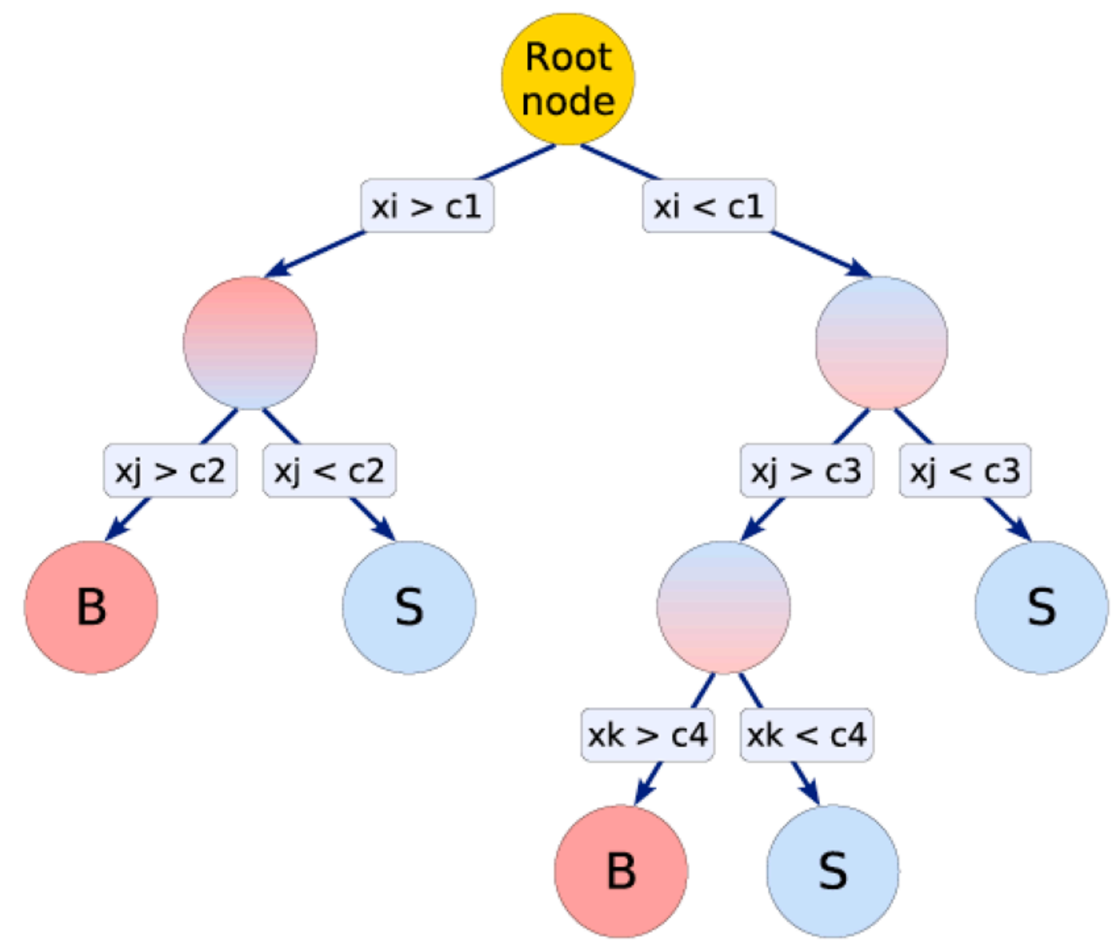
Level-3 Plan

- Start with a "min-bias" trigger for 5x10^7 γ/s running (all the coherent peak)
- Without doing full event reconstruction, obtain a set of variables to "quickly" make L3 decision
- Don't do wire-based tracking to cut CPU time in ~half with small loss in performance
- Processing rate of 77 Hz from David's earlier study
- Would require ~1300 cores for 5x10^7 γ/s with no speed improvements



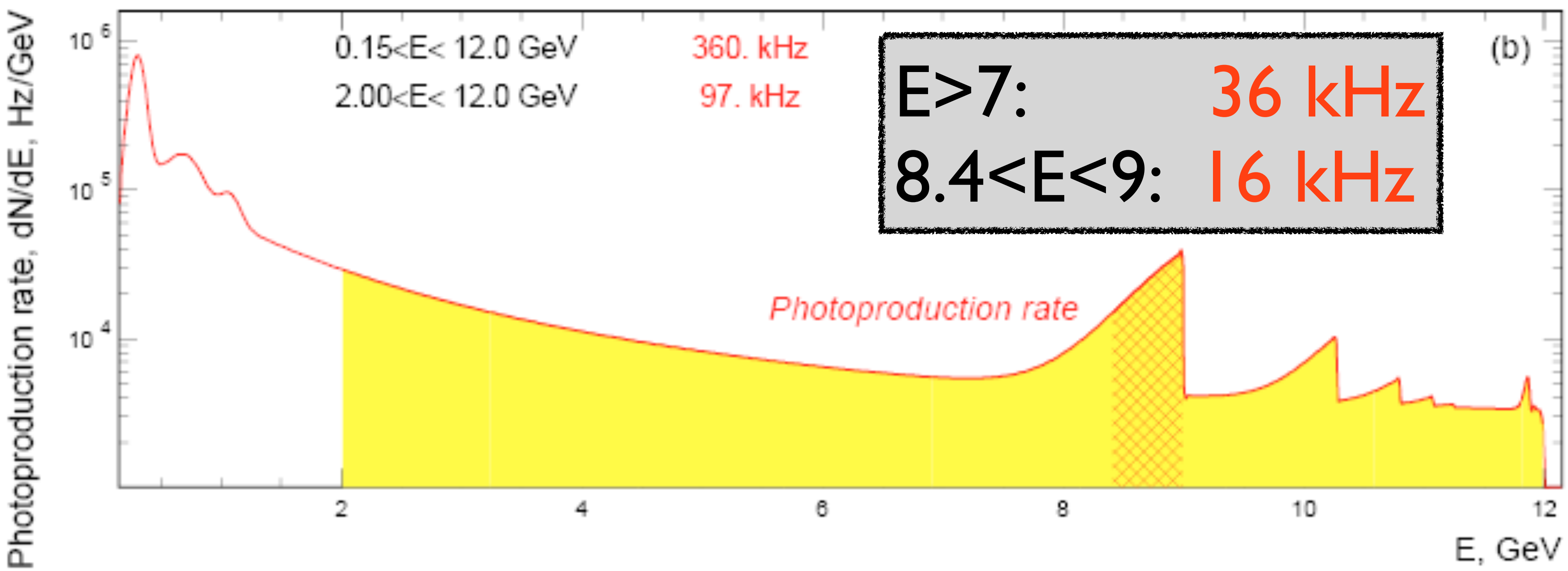
BDT for L3

- What background reduction can be achieved with a limited set of variables?
- Try a Boosted Decision Tree (BDT) as a possible “optimal” algorithm
- Used successfully in LHCb "Bonsai BDT" which converts the BDT response to a 1-D array lookup which contributes negligible CPU time



V. Gligorov and M.Williams, JINST 8 P02013 (2013) [arXiv:1210.6861]

High Intensity: 10^8



- Can't take all $E_\gamma > 7$ GeV in 20 kHz since $E_\gamma > 9$ GeV not easily separated from coherent peak
- Need to make choices about physics priorities, some options:
  - Identify lower interest channels (with huge statistics from earlier lower intensity running) to ID and prescale
  - Identify characteristics of interesting channels (eg. strangeness: displaced vertex, CKOV upgrade, etc) to select events