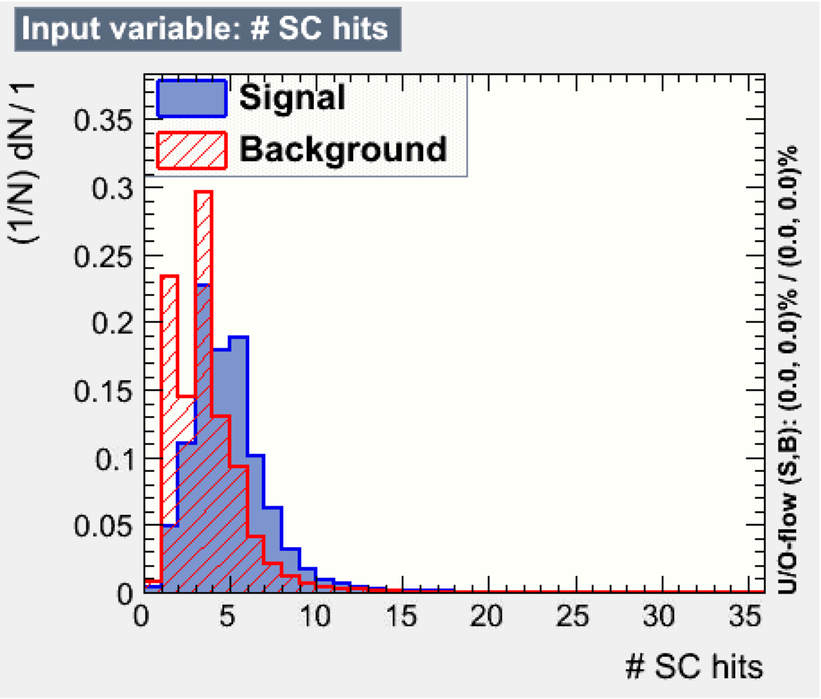
Level-3 Trigger Update

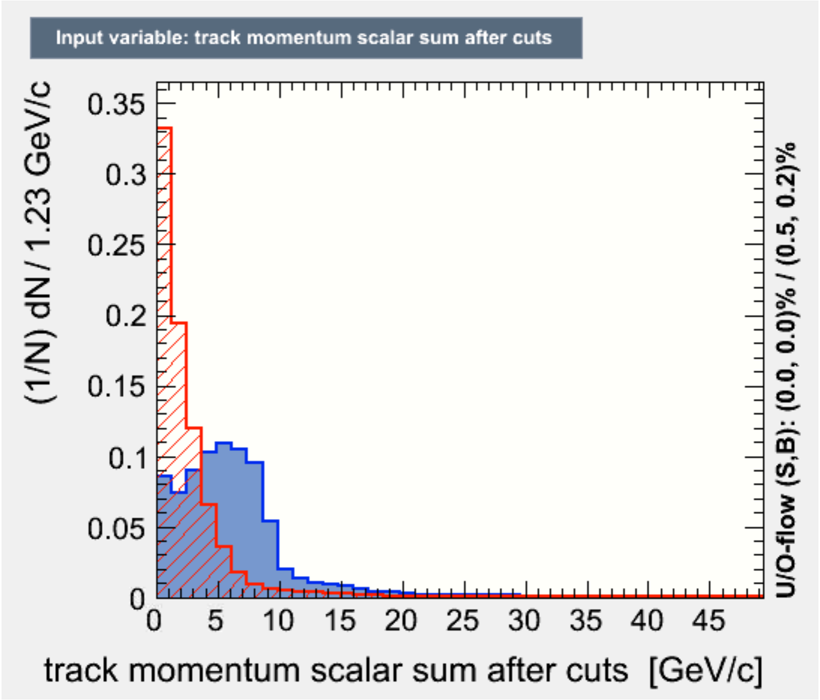
Justin Stevens

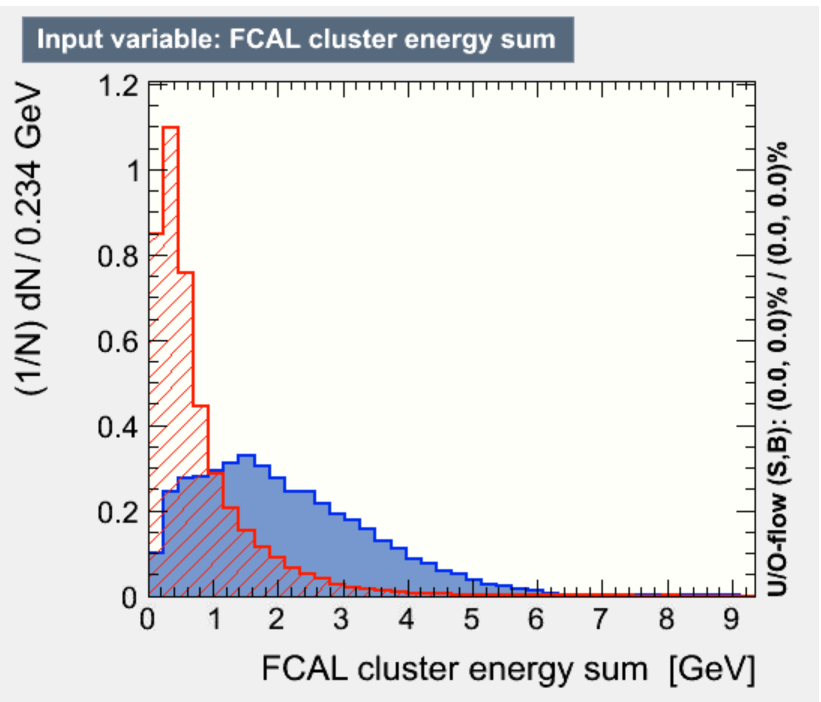
Trigger Meeting 9.2.14

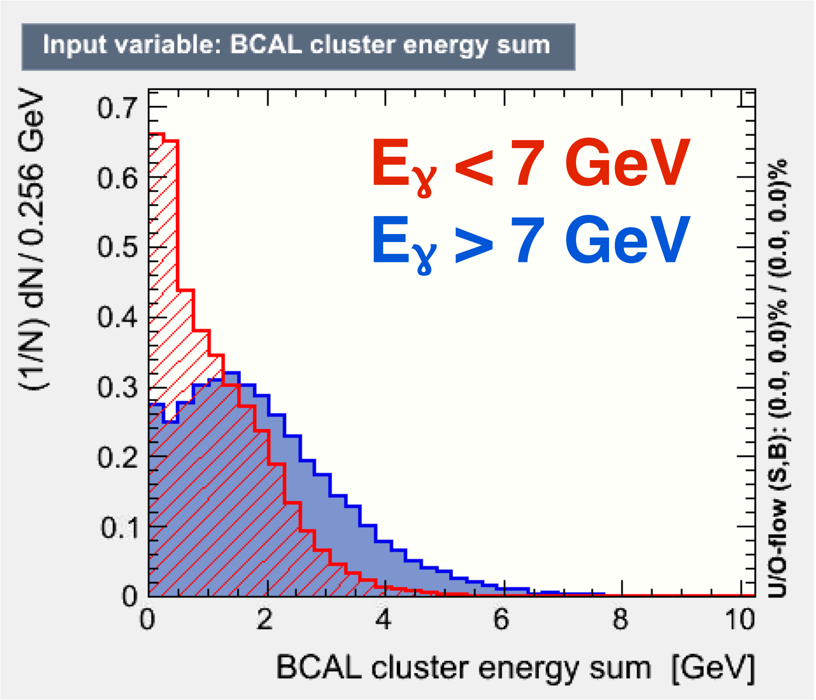
Level-3 BDT Inputs Reminder

```
float Nstart_counter;      // Number of start counter hits
float Ntof;                // Number of TOF hits

float Nbcal_clusters;      // Number of BCAL clusters
float EbcalClusters;       // Total energy in BCAL (Clusters)

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

float Ntrack_candidates;   // Number of track candidates
float Ptot_tracks;         // Scaler sum of total momentum from candidate tracks
```

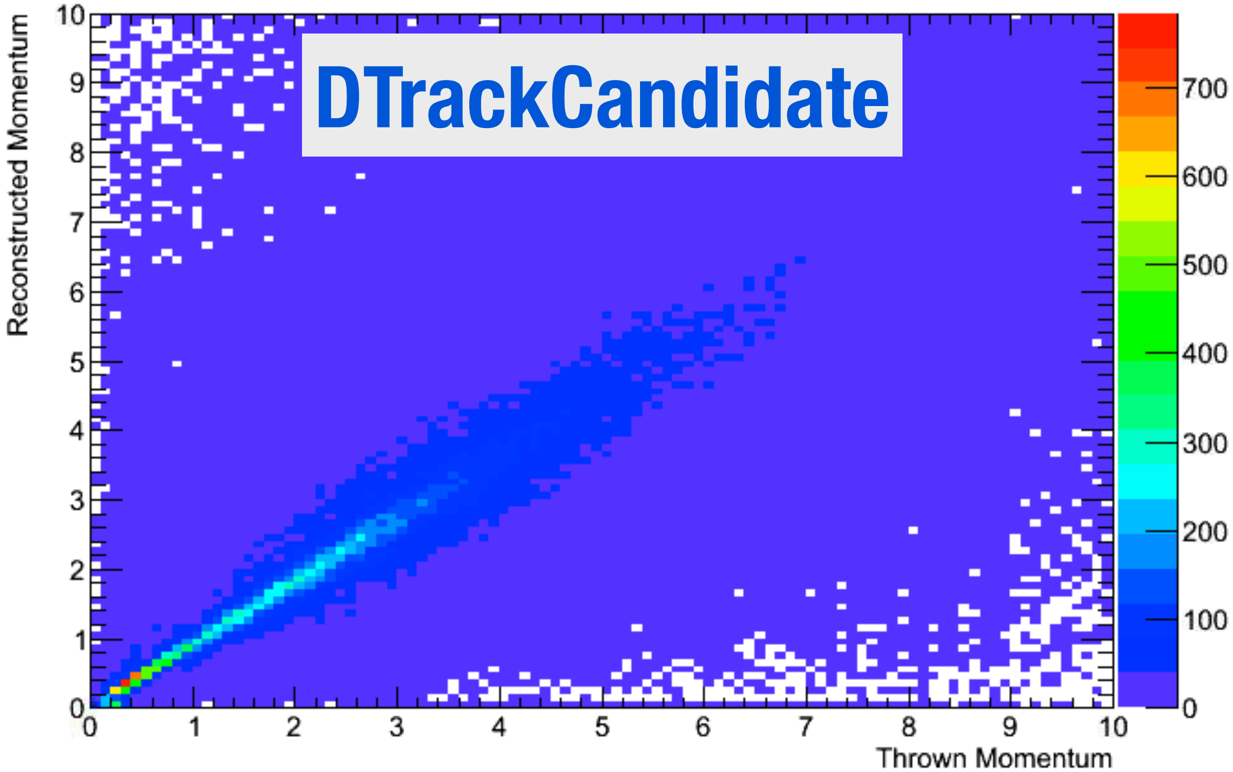


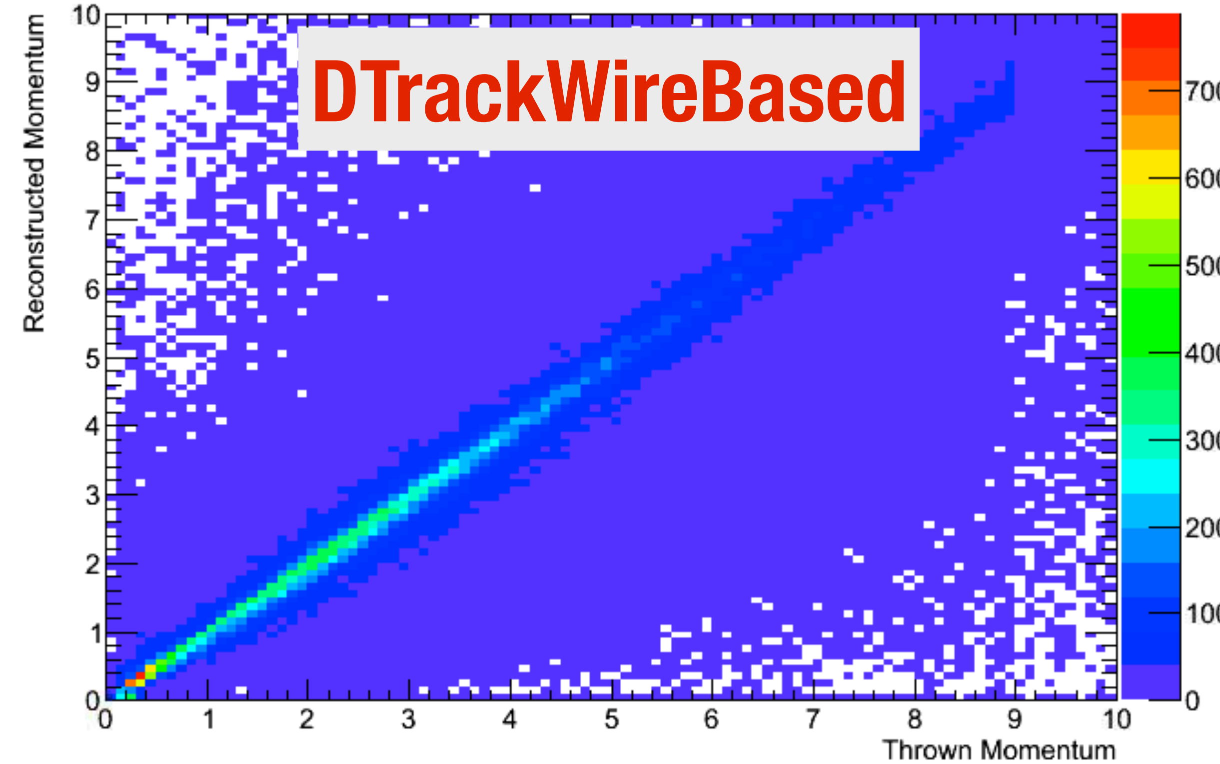




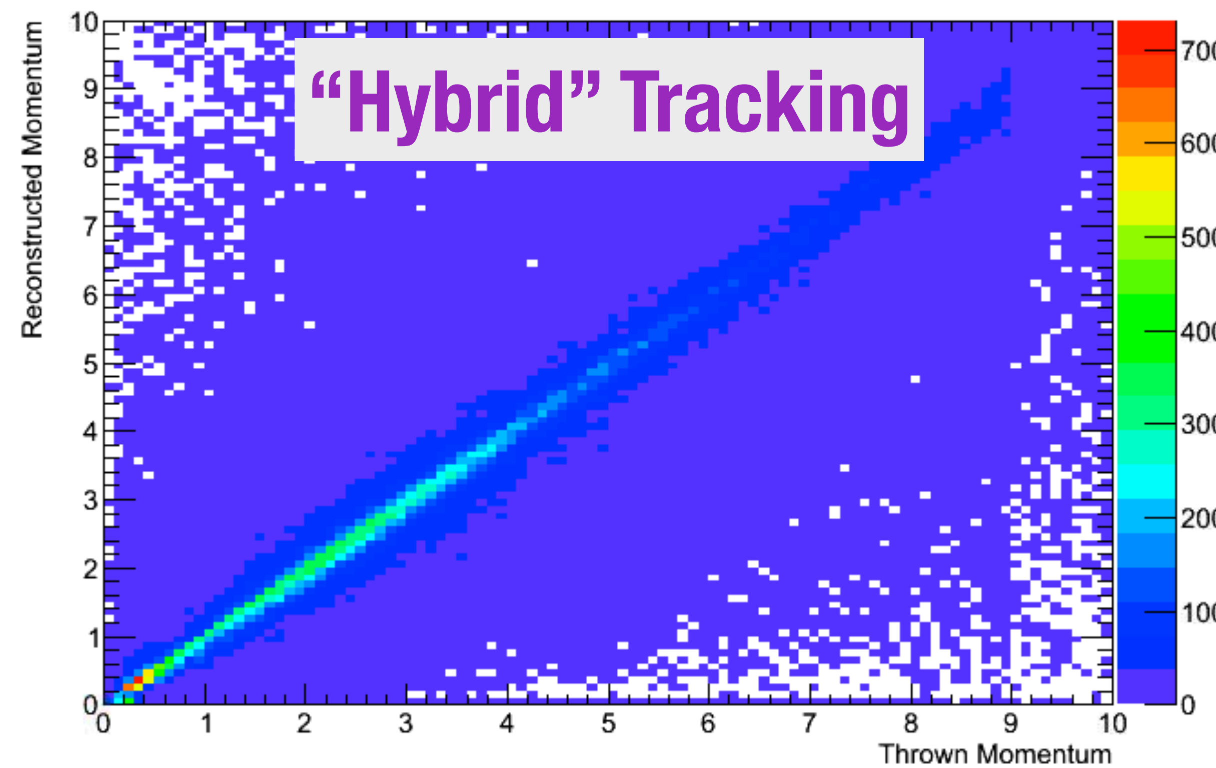


Track momentum sum resolution

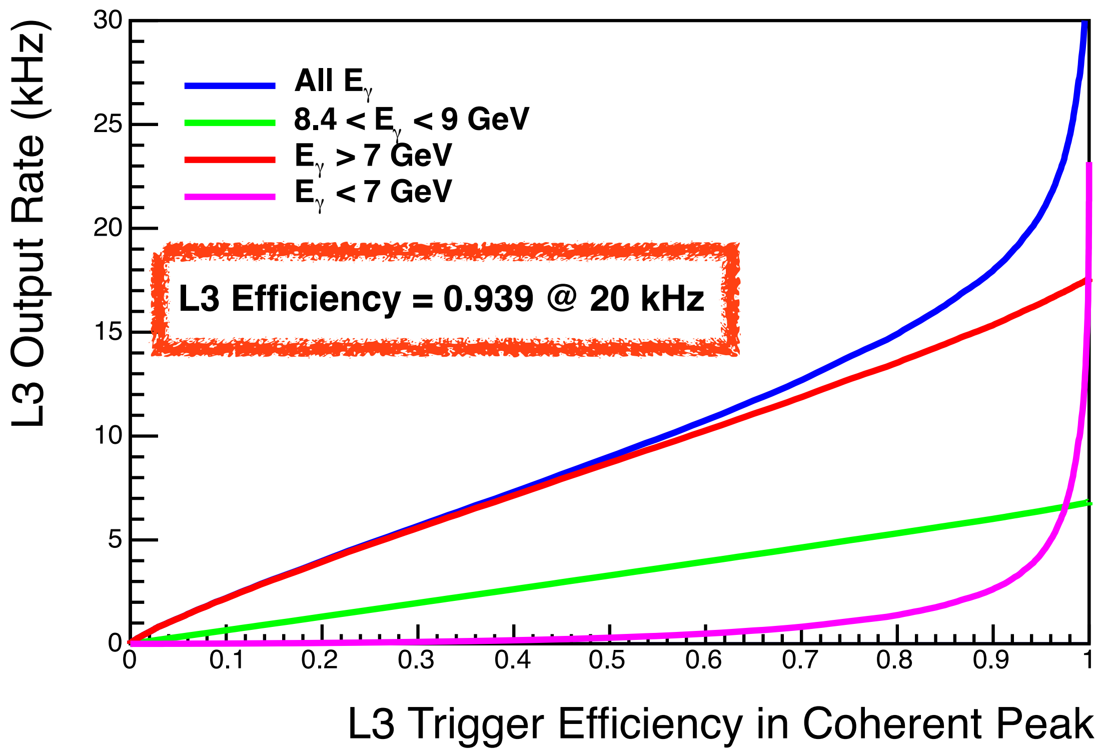


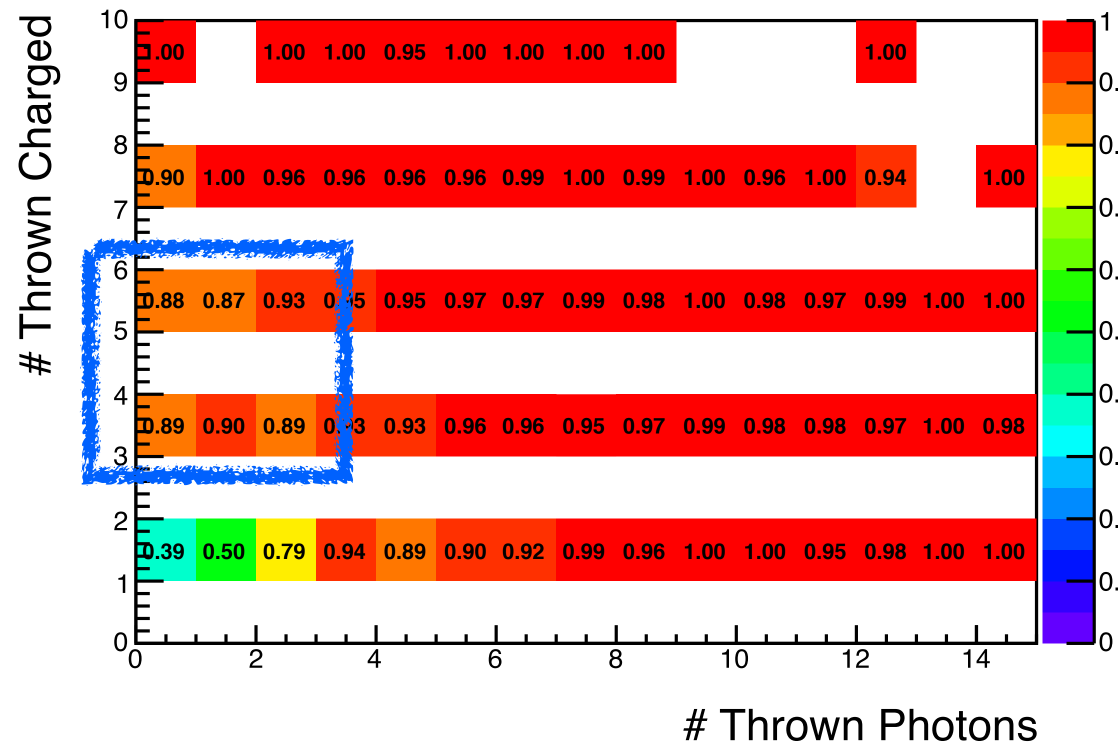


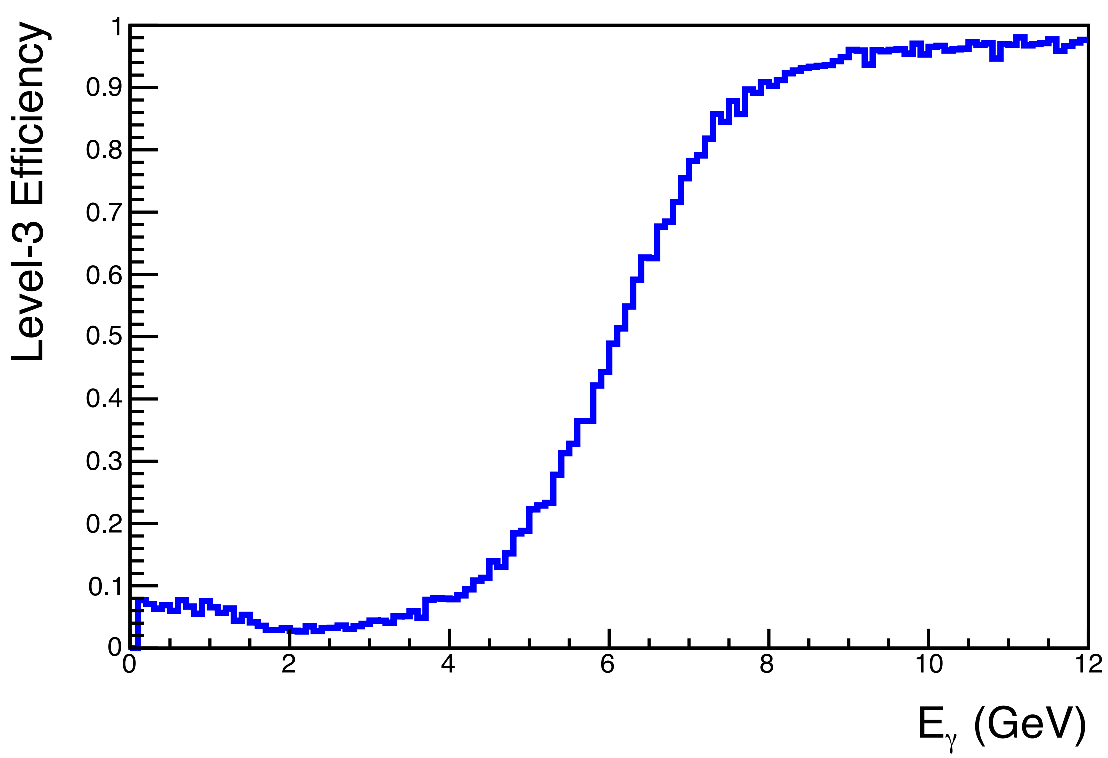
- Wire-based fit only improves track resolution for θ < 15
- **"Hybrid" approach**: for DTrackCandidate's with θ < 15 do wire-based fit and use that in track momentum sum



Hybrid tracking approach



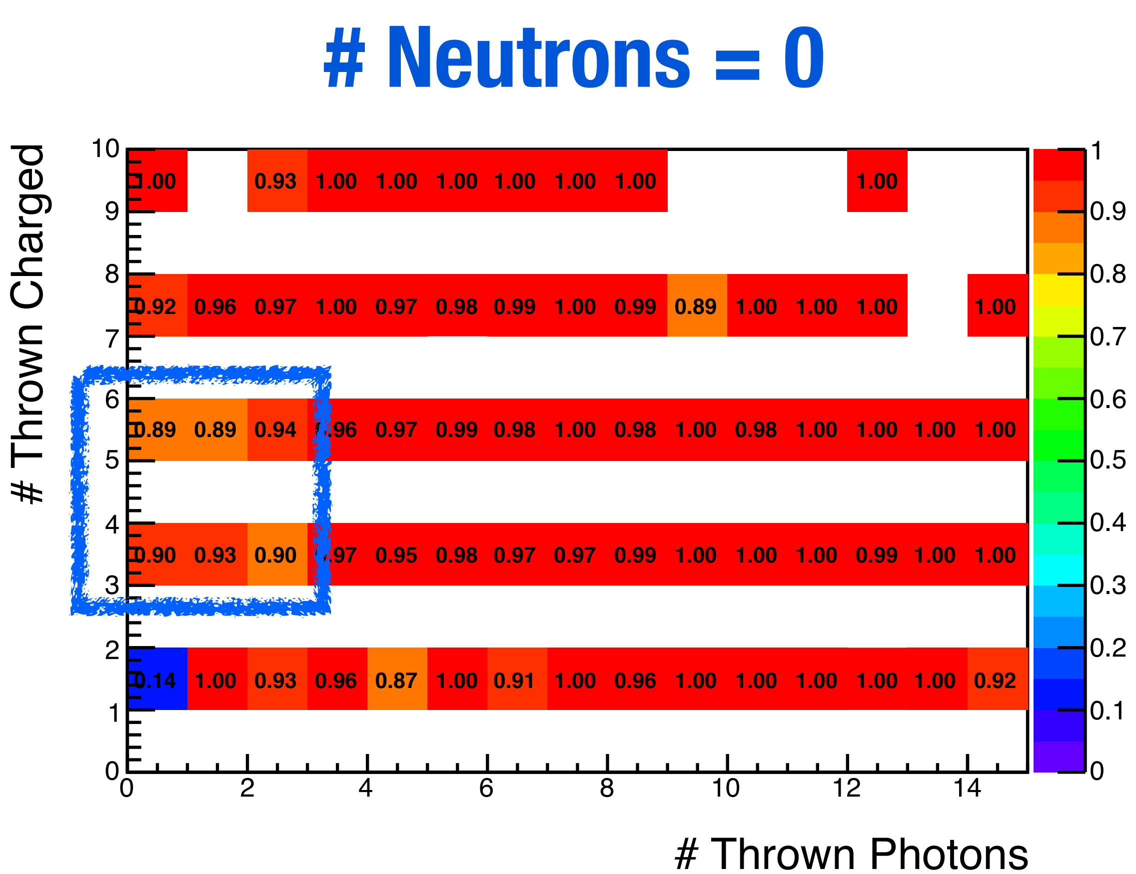


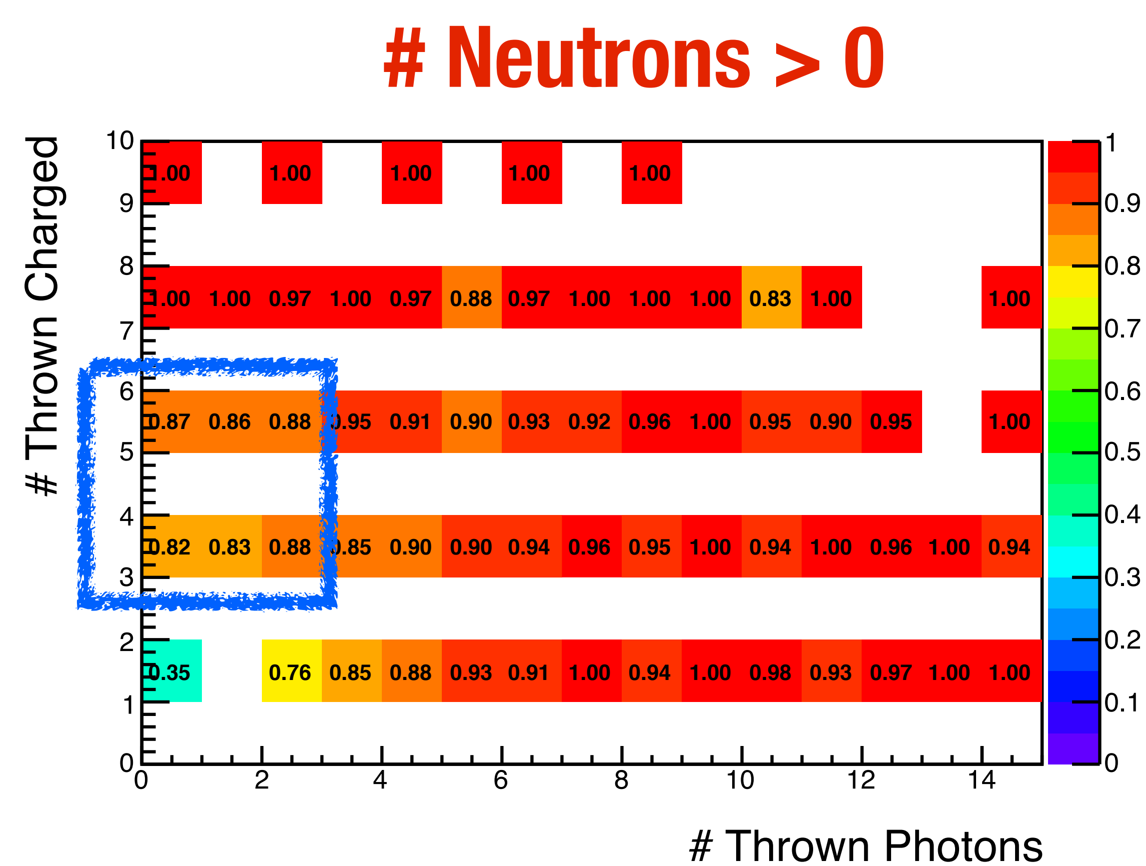


- Using **hybrid tracking** approach
- For a rate of 20 kHz, achieve ~94% L3 average efficiency in the coherent peak
- For # neutrons = 0, have ~96% effic
- 89% efficiency for zero photon events
- Performance is similar to doing full wire-based tracking (with less CPU)

Looking more in depth at topologies

- Generated a sample of 2M bggen events with $E_\gamma > 7$ GeV with EM background turned on
- Need lower level objects for L1 and L3 trigger simulation so can't use data challenge files in REST format
- L3 efficiency lower in low photon multiplicity final states, but need to study these for "reconstructable" events





Studying the trigger in physics analyses

final states	Nsignal	fPYTHIA	ϵ(reco)
$p\pi^+\pi^-$	219201	10.96	0.27
$p\pi^+\pi^-\pi^0$	93802	4.69	0.26
$p\pi^+\pi^-\pi^+\pi^-$	47092	2.35	0.14
$p\pi^+\pi^-\pi^+\pi^-\pi^0$	121003	6.05	0.10
pK^+K^-	6747	0.34	0.22
$pK^+K^-\pi^0$	3841	0.19	0.26
$pK_sK^-\pi^+$; $K_s\to\pi^+\pi^-$	2022	0.10	0.10
$pK_sK^-\pi^+\pi^0$; $K_s\to\pi^+\pi^-$	3056	0.15	0.08
$pK_sK^+\pi^-$; $K_s\to\pi^+\pi^-$	1759	0.09	0.12
$pK_sK^+\pi^-\pi^0$; $K_s\to\pi^+\pi^-$	2214	0.11	0.09
$pK^+K^-\pi^+\pi^-$	7539	0.38	0.12
$pK^+K^-\pi^+\pi^-\pi^0$	10571	0.53	0.09
ΛK^+; $\Lambda\to p\pi^-$	41	0.00	0.10
$\Lambda K^+\pi^0$; $\Lambda\to p\pi^-$	323	0.02	0.05
$n\pi^+\pi^-\pi^+$	24203	1.21	0.41
$n\pi^+\pi^-\pi^+\pi^0$	69037	3.45	0.28
$n\pi^+\pi^-\pi^+\pi^-\pi^+$	12512	0.63	0.12
$n\pi^+\pi^-\pi^+\pi^-\pi^+\pi^0$	33030	1.65	0.08
nK_sK^+; $K_s\to\pi^+\pi^-$	253	0.01	0.32
$nK_sK^+\pi^0$; $K_s\to\pi^+\pi^-$	916	0.05	0.19
$nK^+K^-\pi^+$	2569	0.13	0.36
$nK^+K^-\pi^+\pi^0$	4402	0.22	0.26
$nK_sK^+\pi^+\pi^-$; $K_s\to\pi^+\pi^-$	1443	0.07	0.10
$nK_sK^+\pi^+\pi^-\pi^0$; $K_s\to\pi^+\pi^-$	2309	0.12	0.06

- To understand trigger inefficiencies related to track reconstruction need to evaluate in relation to offline event reconstruction
- Idea: quantify expected Level-1 and Level-3 trigger efficiencies for some set of physics channels reconstructed offline
- I picked a “reasonable” set of final states; focusing on low photon multiplicity final states (ie. # $\pi^0 < 2$) which is ~30% of the total cross section

“Reconstructable” events

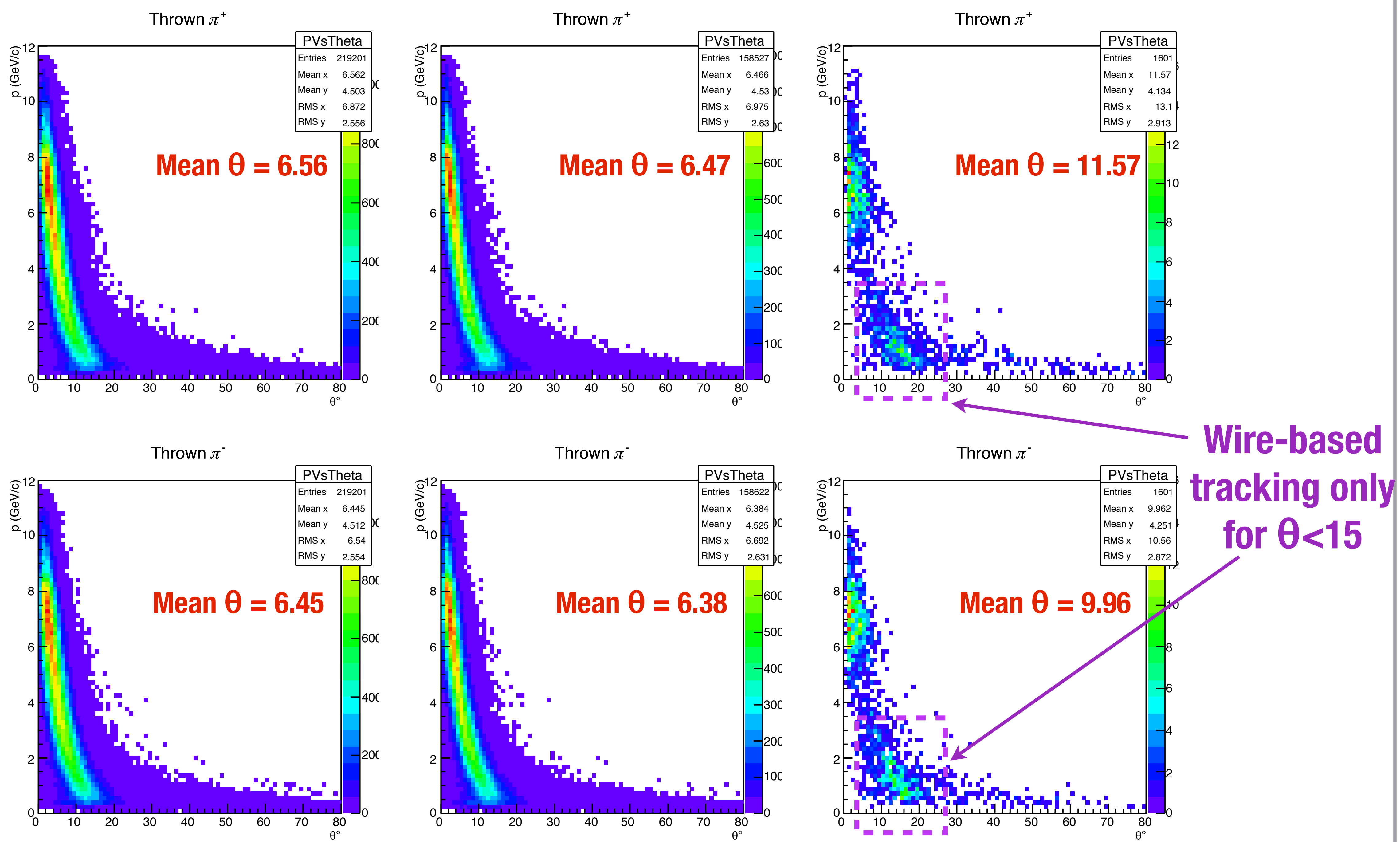
- Want to understand the impact of the trigger on event yields in the case of realistic physics analyses
- The only loss in statistics (due to the trigger) come from events which can be reconstructed properly, but fail to satisfy the trigger
- Need to define a set of cuts for events that are “reconstructable” offline for an end user analysis
- Use Paul’s suggested cuts from the data challenge:
    - Tracking FOM 3σ
    - Track has detector match (SC/TOF/BCAL/FCAL)
    - Photon PID FOM 5σ
- No kinematic fit or other exclusivity cuts applied

Efficiency summary

final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$p\pi^+\pi^-$	219201	10.96	0.40	0.89	0.27	0.53	0.97
$p\pi^+\pi^-\pi^0$	93802	4.69	0.81	0.92	0.26	0.88	0.96
$p\pi^+\pi^-\pi^+\pi^-$	47092	2.35	0.91	0.86	0.14	0.95	0.93
$p\pi^+\pi^-\pi^+\pi^-\pi^0$	121003	6.05	0.98	0.92	0.10	0.99	0.95
pK^+K^-	6747	0.34	0.35	0.77	0.22	0.56	0.93
$pK^+K^-\pi^0$	3841	0.19	0.86	0.84	0.26	0.91	0.93
$pK_sK^-\pi^+$; $K_s\to\pi^+\pi^-$	2022	0.10	0.84	0.84	0.10	0.87	0.94
$pK_sK^-\pi^+\pi^0$; $K_s\to\pi^+\pi^-$	3056	0.15	0.98	0.89	0.08	0.98	0.96
$pK_sK^+\pi^-$; $K_s\to\pi^+\pi^-$	1759	0.09	0.86	0.85	0.12	0.91	0.96
$pK_sK^+\pi^-\pi^0$; $K_s\to\pi^+\pi^-$	2214	0.11	0.99	0.90	0.09	1.00	0.95
$pK^+K^-\pi^+\pi^-$	7539	0.38	0.91	0.82	0.12	0.95	0.91
$pK^+K^-\pi^+\pi^-\pi^0$	10571	0.53	0.99	0.89	0.09	1.00	0.96
ΛK^+; $\Lambda\to p\pi^-$	41	0.00	0.32	0.76	0.10	0.75	1.00
$\Lambda K^+\pi^0$; $\Lambda\to p\pi^-$	323	0.02	0.71	0.82	0.05	0.82	0.88
$n\pi^+\pi^-\pi^+$	24203	1.21	0.76	0.83	0.41	0.79	0.89
$n\pi^+\pi^-\pi^+\pi^0$	69037	3.45	0.94	0.87	0.28	0.96	0.91
$n\pi^+\pi^-\pi^+\pi^-\pi^+$	12512	0.63	0.95	0.79	0.12	0.98	0.85
$n\pi^+\pi^-\pi^+\pi^-\pi^+\pi^0$	33030	1.65	0.98	0.85	0.08	0.99	0.88
nK_sK^+; $K_s\to\pi^+\pi^-$	253	0.01	0.70	0.79	0.32	0.80	0.90
$nK_sK^+\pi^0$; $K_s\to\pi^+\pi^-$	916	0.05	0.91	0.80	0.19	0.98	0.87
$nK^+K^-\pi^+$	2569	0.13	0.75	0.78	0.36	0.78	0.86
$nK^+K^-\pi^+\pi^0$	4402	0.22	0.94	0.82	0.26	0.96	0.88
$nK_sK^+\pi^+\pi^-$; $K_s\to\pi^+\pi^-$	1443	0.07	0.93	0.77	0.10	0.98	0.93
$nK_sK^+\pi^+\pi^-\pi^0$; $K_s\to\pi^+\pi^-$	2309	0.12	0.99	0.84	0.06	1.00	0.89

$\gamma p \rightarrow p\pi^+\pi^-$

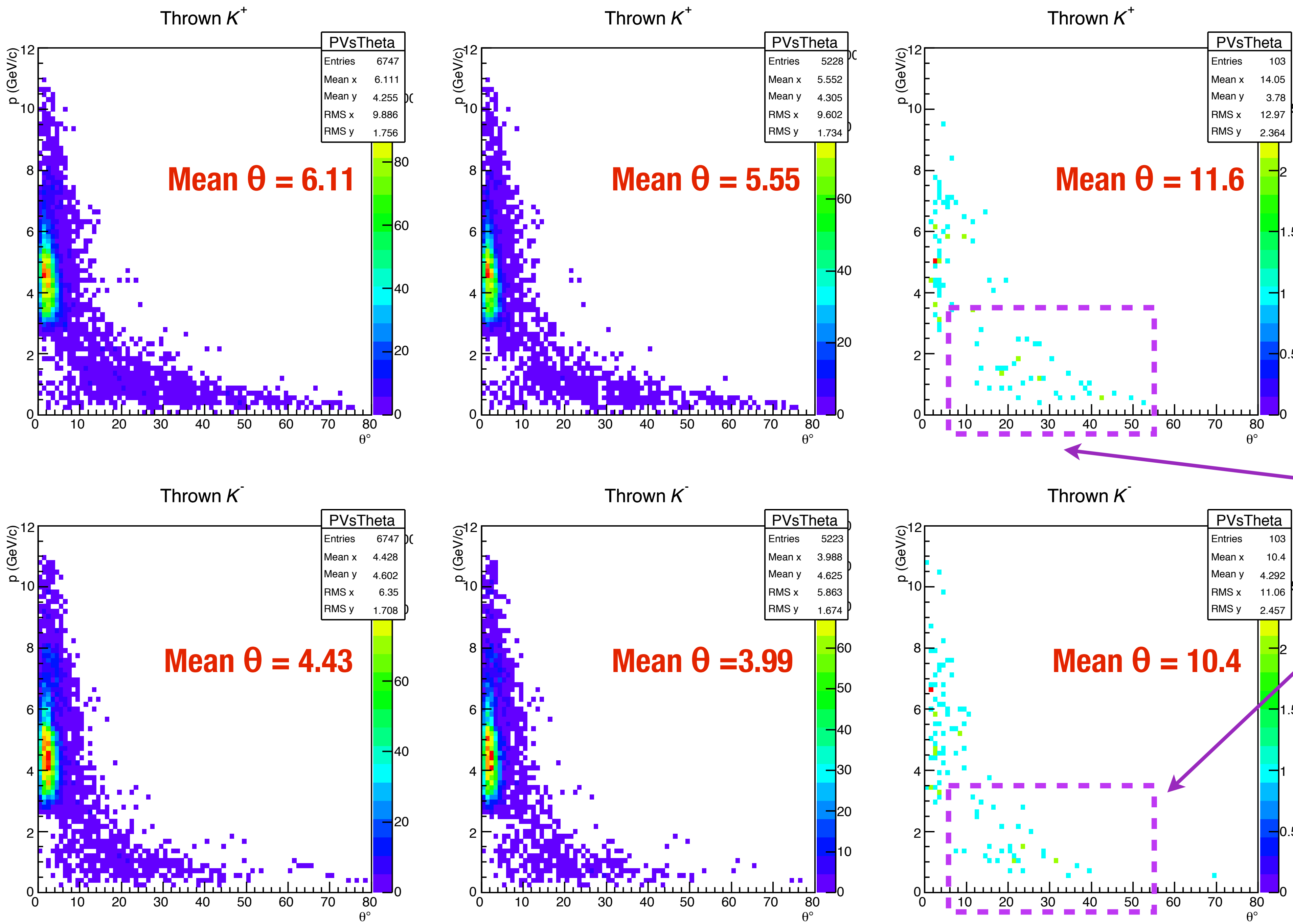
Generated | **Fail reco** | **Pass reco, but fail L3**



final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$p\pi^+\pi^-$	219201	10.96	0.40	0.89	0.27	0.53	0.97

γp→pK⁺K⁻

Generated | **Fail reco** | **Pass reco, but fail L3**

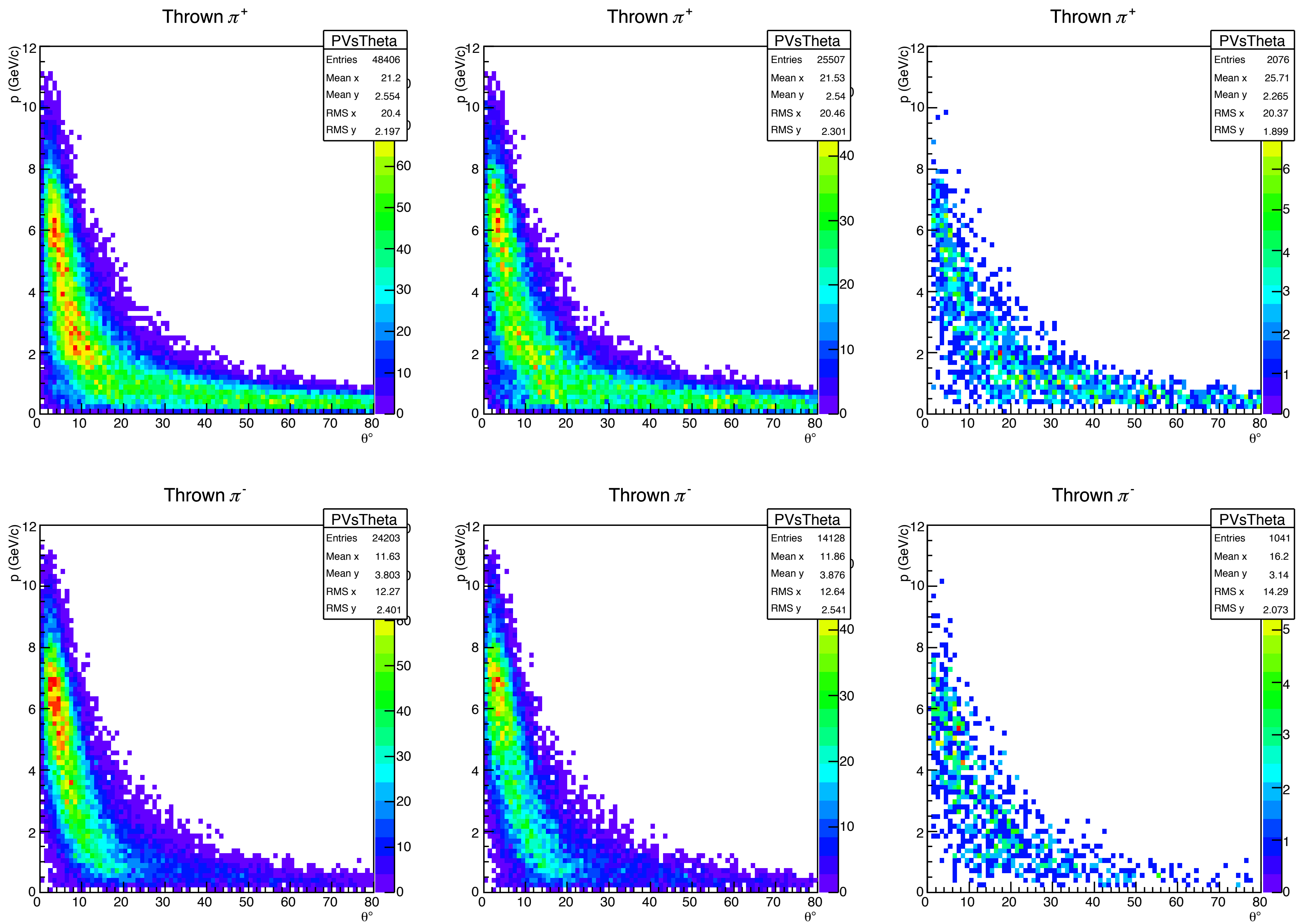


Wire-based tracking only for θ<15

final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
pK⁺K⁻	6747	0.34	0.35	0.77	0.22	0.56	0.93

$\gamma p \to n\pi^+\pi^-\pi^+$

Generated | **Fail reco** | **Pass reco, but fail L3**



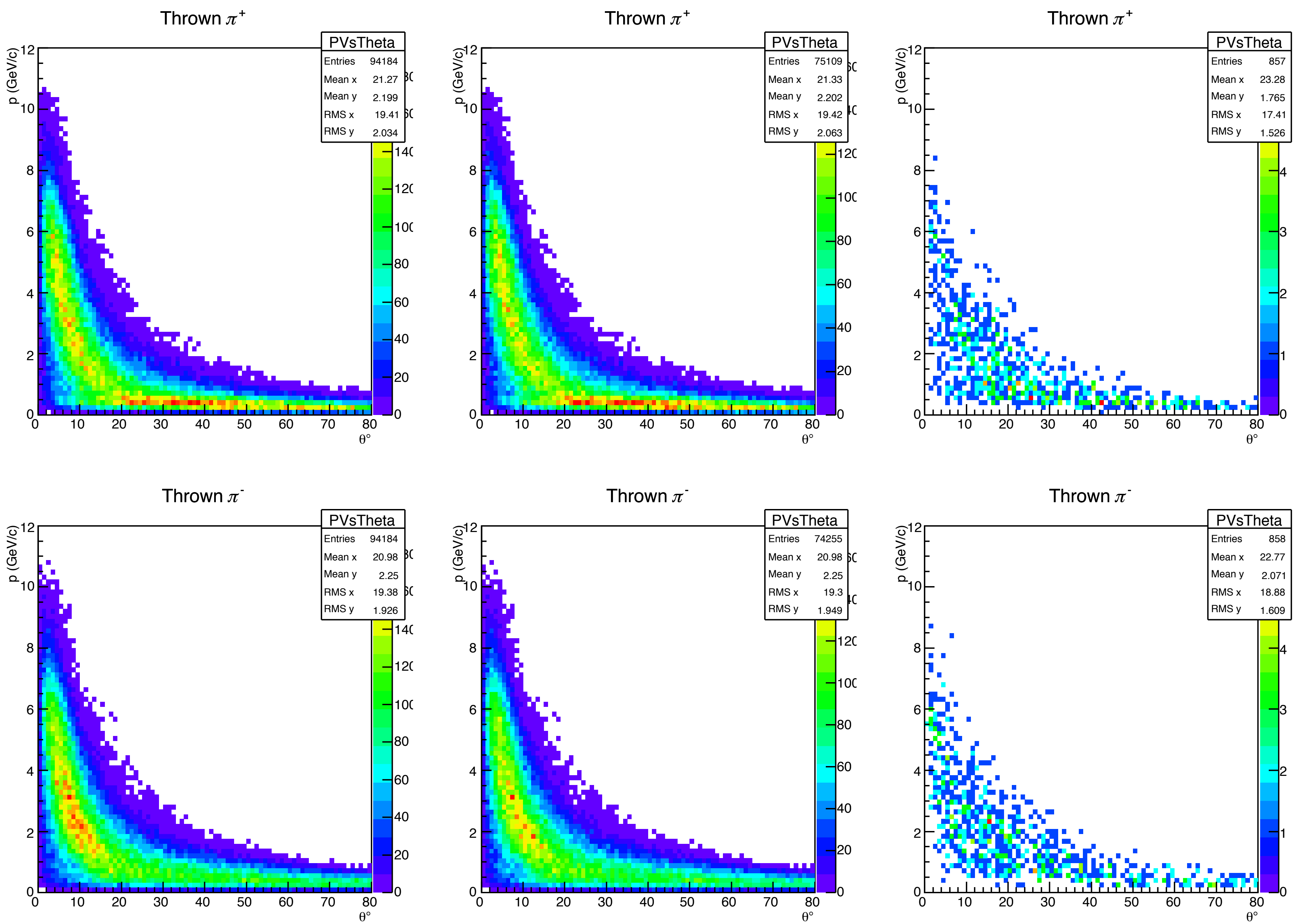
final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$n\pi^+\pi^-\pi^+$	24203	1.21	0.76	0.83	0.41	0.79	0.89

$\gamma p \rightarrow p\pi^+\pi^-\pi^+\pi^-$

Generated

Fail reco

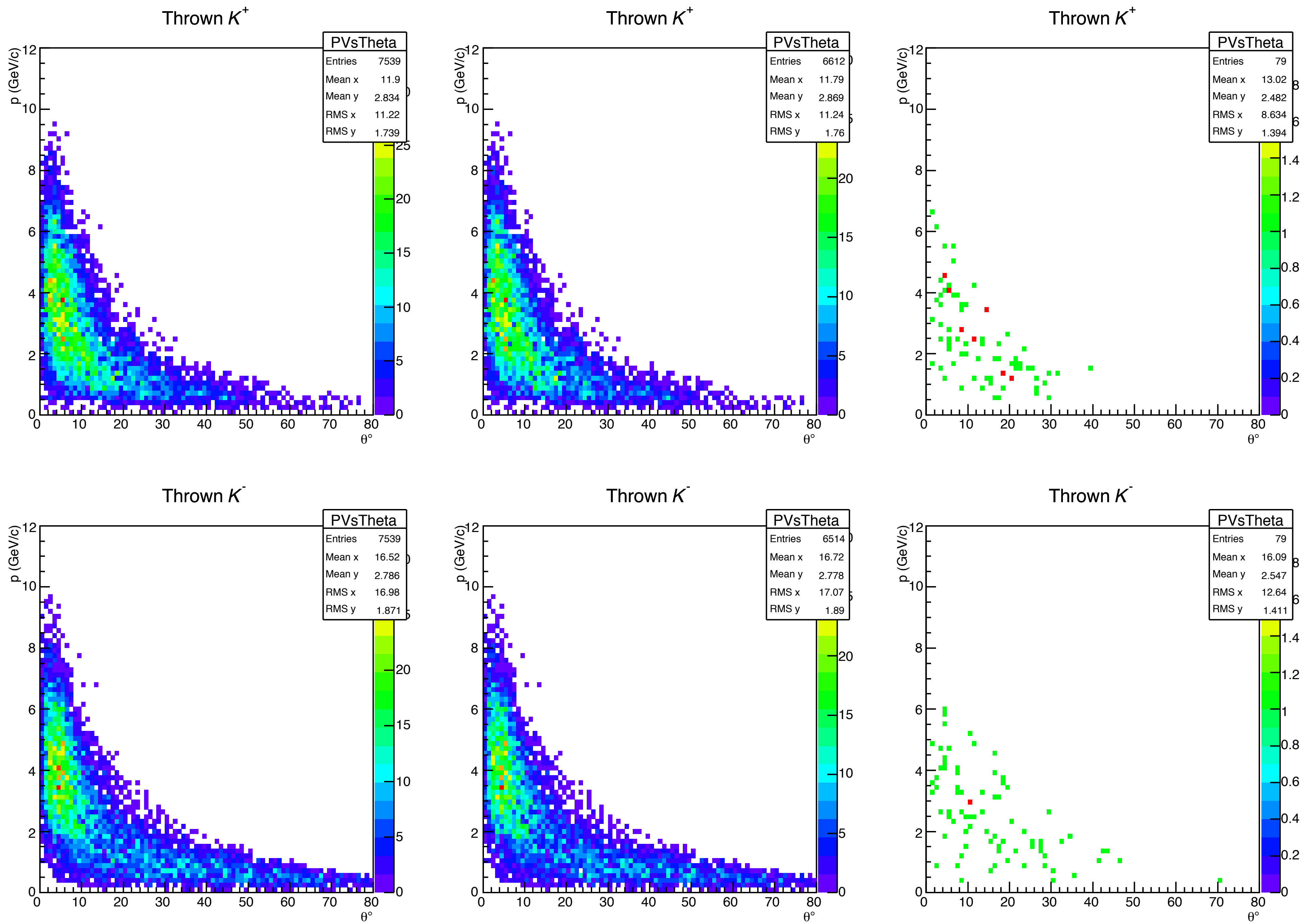
Pass reco, but fail L3



final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$p\pi^+\pi^-\pi^+\pi^-$	47092	2.35	0.91	0.86	0.14	0.95	0.93

$\gamma p \to p K^+ K^- \pi^+ \pi^-$

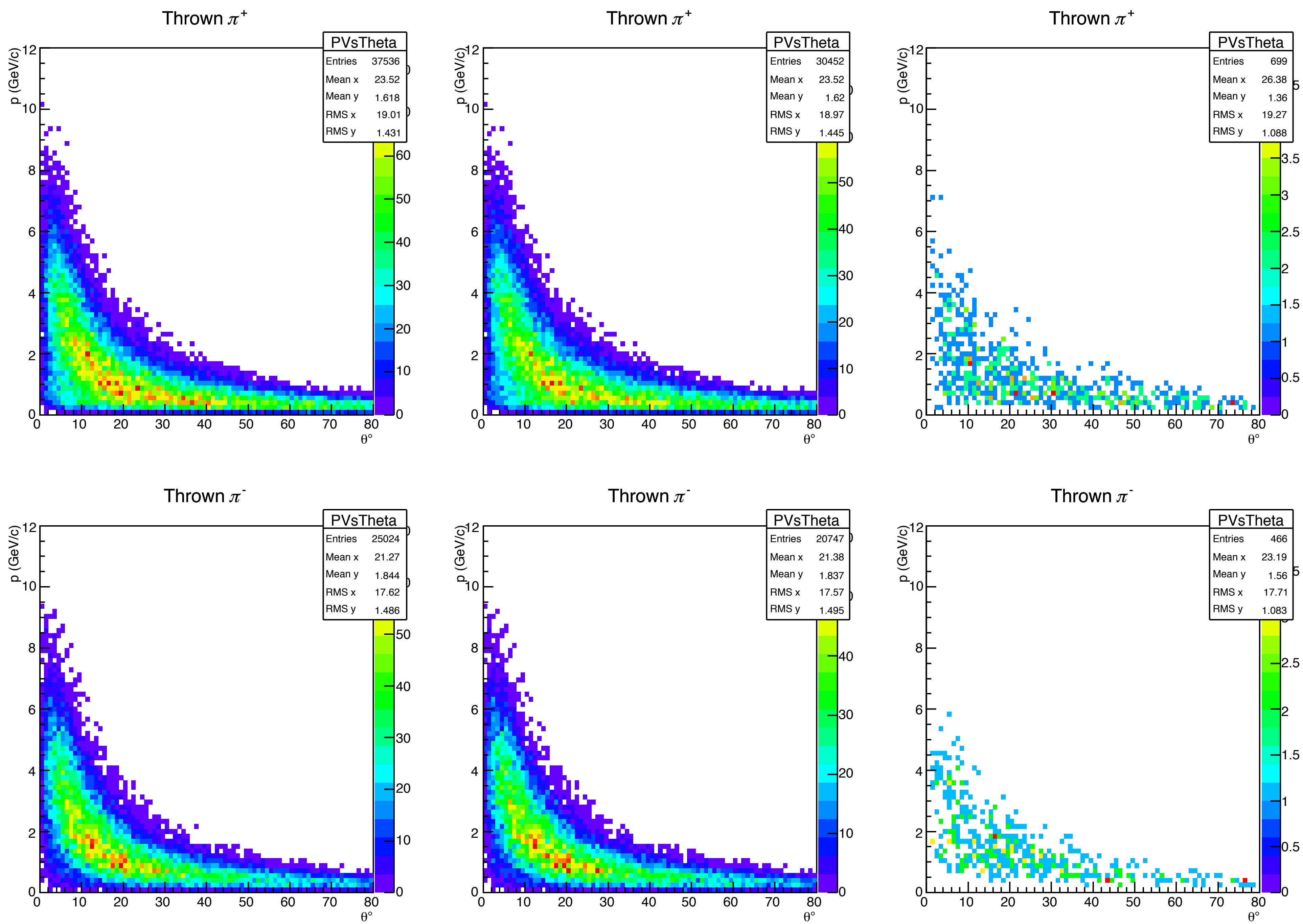
Generated | **Fail reco** | **Pass reco, but fail L3**



final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$pK^+K^-\pi^+\pi^-$	7539	0.38	0.91	0.82	0.12	0.95	0.91

$\gamma p \rightarrow n\pi^+\pi^-\pi^+\pi^-\pi^+$

Generated | **Fail reco** | **Pass reco, but fail L3**



final states	Nsignal	fPYTHIA	ϵ(L1)	ϵ(L3)	ϵ(reco)	reco ϵ(L1)	reco ϵ(L3)
$n\pi^+\pi^-\pi^+\pi^-\pi^+$	12512	0.63	0.95	0.79	0.12	0.98	0.85

Summary

- Studied trigger efficiency for low photon multiplicity final states with and without requiring events to be reconstructed offline
- See increase in efficiency for “reconstructable” events relative to all generated events, as expected
  - L3 efficiency for these events is at ~0.95 for proton topologies and ~0.88 for neutron topologies
- Remaining events which fail L3 trigger appear to be related to poor DTrackCandidate resolution for $\theta>15^0$

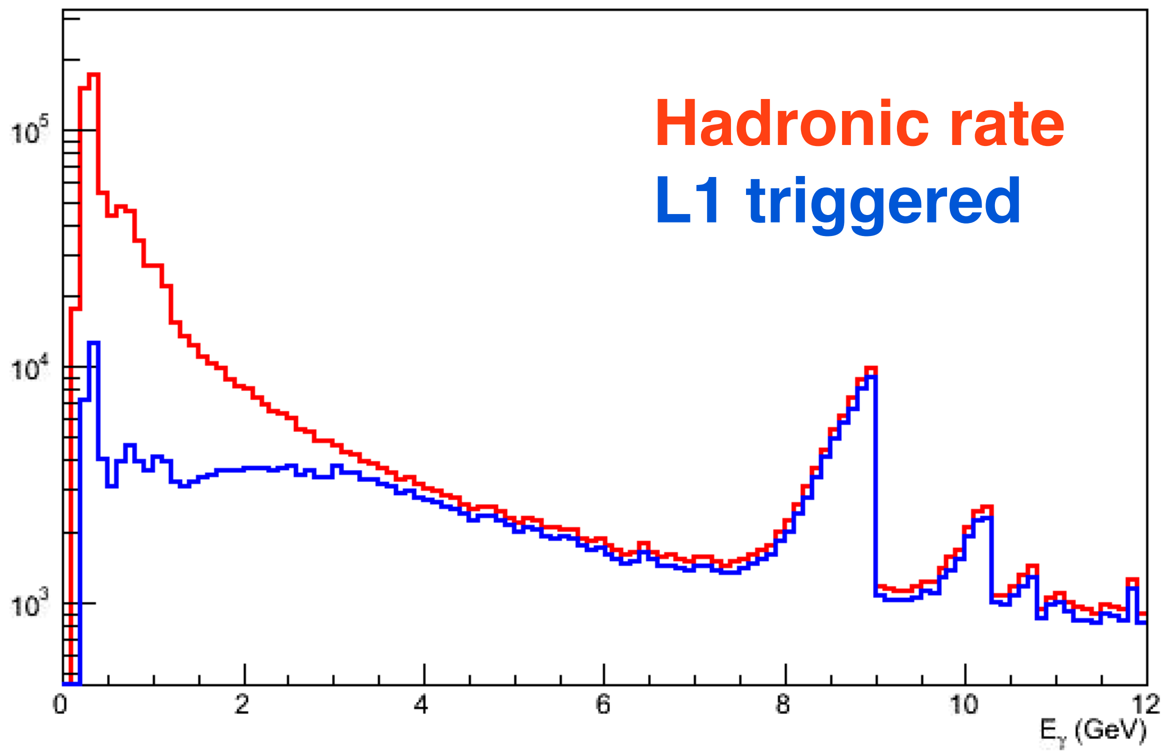
Thoughts for discussion another time

- Fall commissioning run:
  - Will L3 be included in passthrough mode?
  - Any use for low-level L3 algorithm for testing/monitoring later in the fall?
- L3 information in event stream:
  - Starting to think about usefulness of storing information used in L3 decision for use in offline analysis
  - eg. pointer to raw hits used in tracking could be useful to emulate L3 decision offline with improved calibrations

Backup

Level-1 Trigger

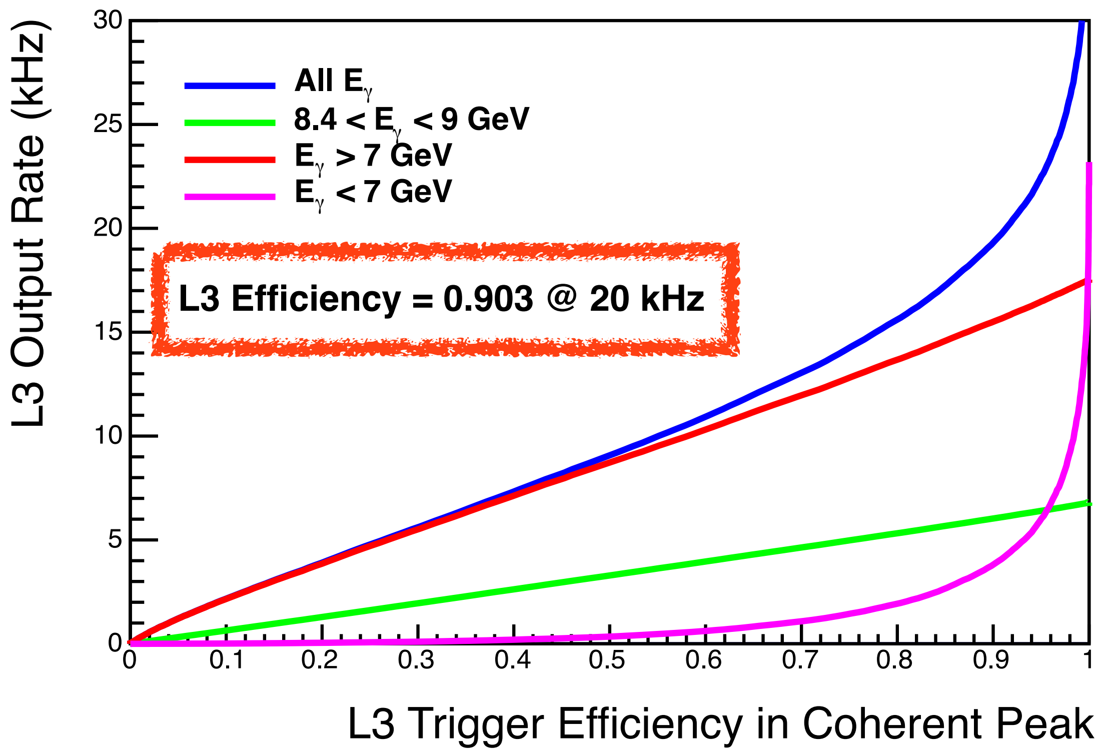
GlueX-doc-1043: Implemented in DMCTrigger

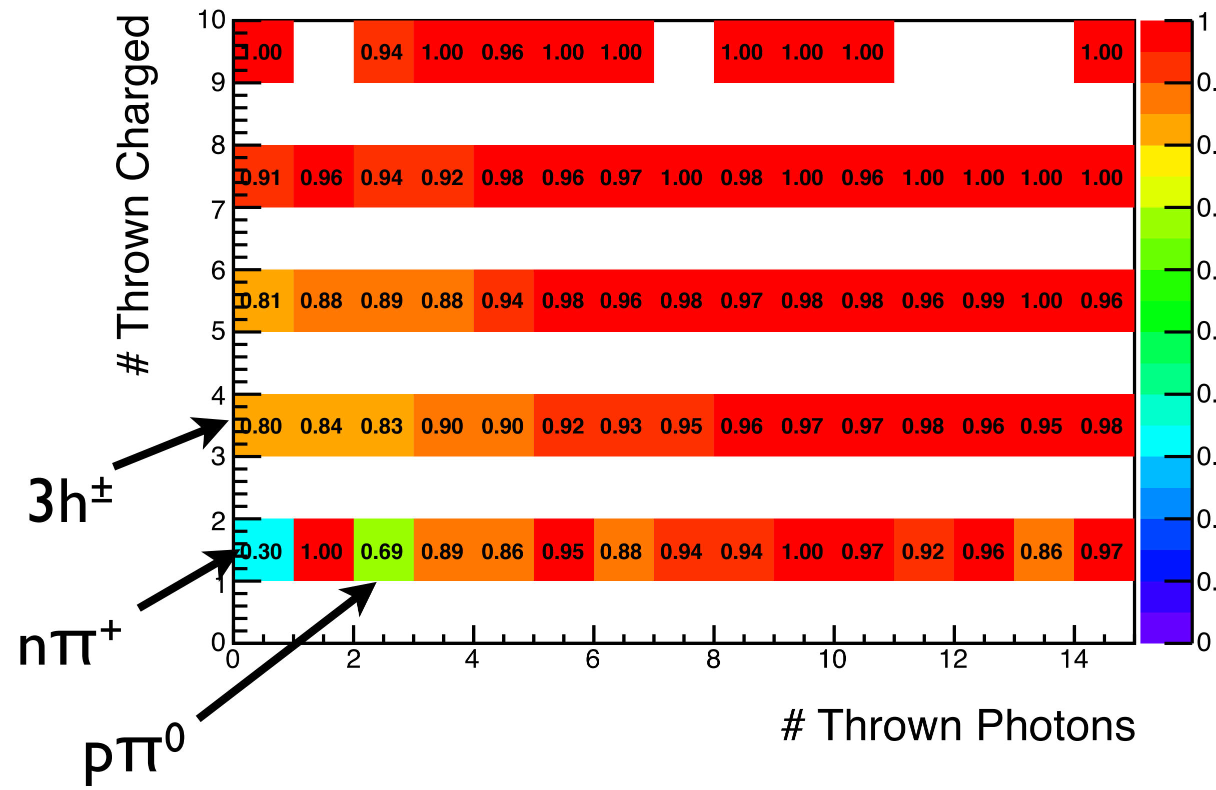


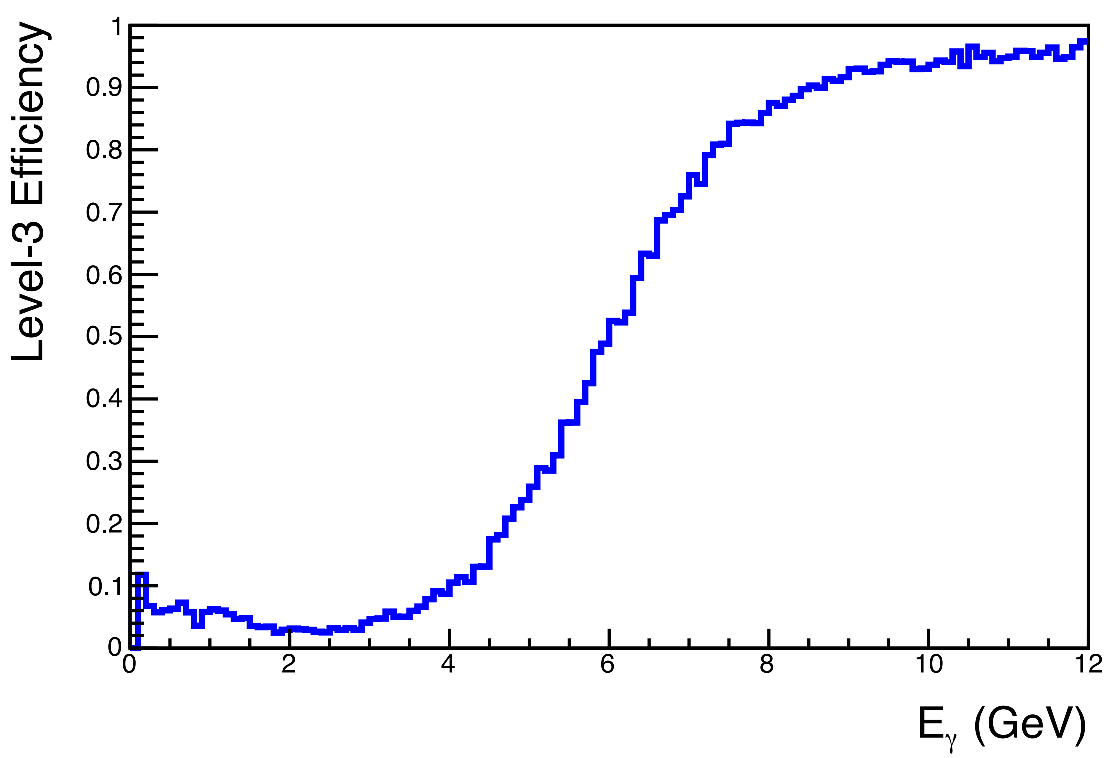
- Sample of bggen events with high-luminosity EM pileup
- Define "signal" as $E_\gamma > 7$ GeV and "background" $E_\gamma < 7$ GeV
- Accept events which fire L1a or L1b emulated trigger
- Reject ~77% of background with signal efficiency of 92%
- So far haven't considered EM only background rate

```
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;
```

Level-3 Evaluation Reminder



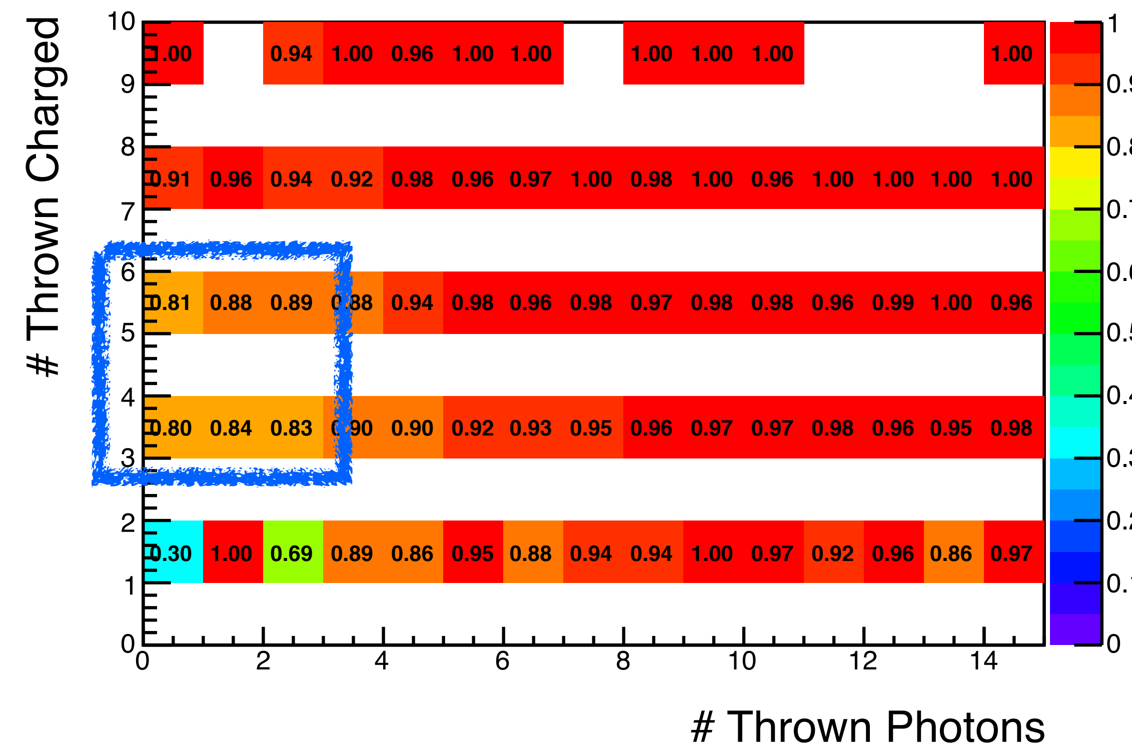


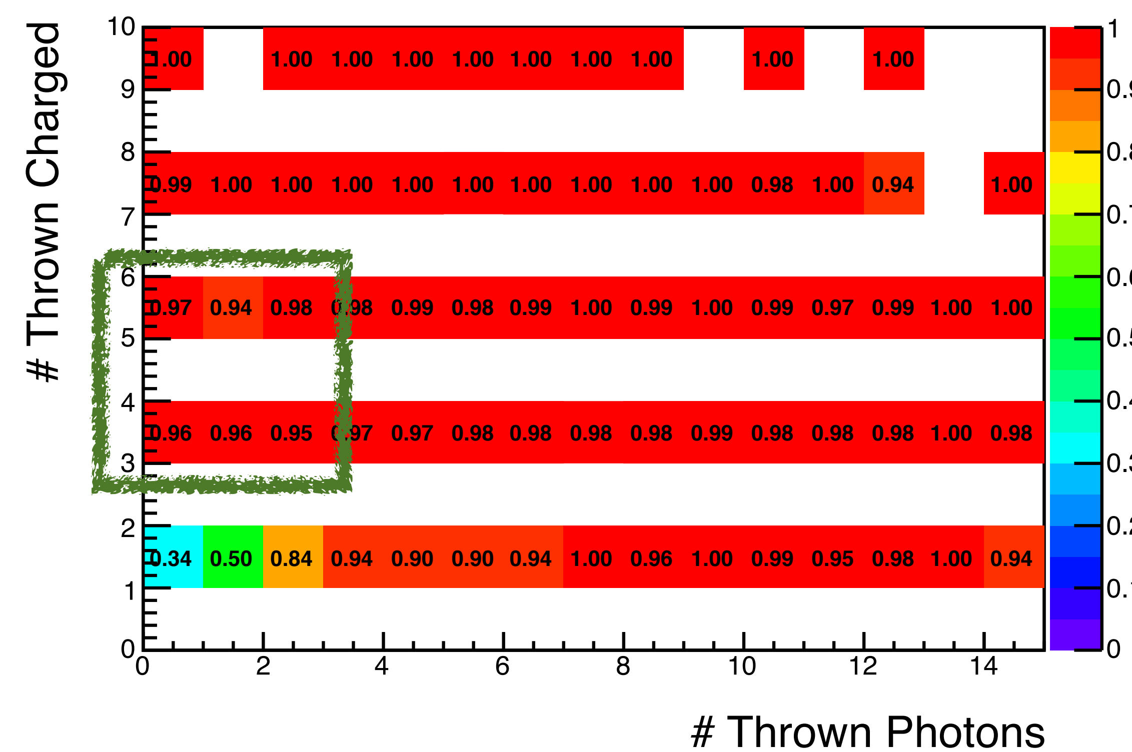


- Critical variables for BDT are sum of BCAL and FCAL energy as well as track momentum sum
- For a rate of 20 kHz, achieve ~90% L3 average efficiency in the coherent peak
- Events with less photons have lower efficiency (~80% for zero photons)

Algorithm Improvements

- Lowest efficiency for channels with low photon multiplicity, which have been the focus of many physics analyses (n3π, PAC40, PID upgrade)
- Using DTrackCandidates is limiting the L3 trigger, not calorimeter reconstruction
- To confirm use the MC truth information for charged particles, and get much higher L3 efficiency (no neutron info)
- Try using more sophisticated track reconstruction algorithm (DTrackWireBased) keeping in mind the CPU penalty





Algorithm timing: A staged approach

- I've been testing the algorithms on the online "gluon" cluster (using one of the nodes designated for the L3 farm)
- So far only testing the reconstruction portion of the algorithm, *ie.* not converting from EVIO using translation tables, etc.
- The new algorithm uses hybrid tracking and is also "staged" by:
  - Training multiple BDTs, using subsets of the variables from the fast detectors
  - Reject background events which fail a cut on the BDT response at each stage, while maintaining 99% efficiency for the signal events (reduces event rate for track reconstruction from ~50 kHz input rate to ~38 kHz)

Stage	BDT Variables	Output Rate (kHz)
1	SC+FCAL	42.8
2	SC+FCAL+TOF	41.6
3	SC+FCAL+TOF+BCAL	38.3

- Although we've added a more CPU intensive tracking algorithm, the net processing rate compared to the algorithm used in the ODC ***is only ~10% slower***

Level-3 Node Count

- During the Fall 2013 Online Data Challenge (ODC) achieved an L3 processing rate of ~1.6 kHz/node with borrowed machines (includes ~25% hyperthread gain)
- Currently have 10 nodes (16 cores each) in the counting house with better specs (8 assigned to L3 at the moment)
- Scaling by increased performance for the new nodes corresponds to an L3 processing rate of ~3.9 kHz/node
  - The version of the L3 algo used did not do any "staging" to make decisions based on SC/TOF/FCAL/BCAL before spending time on tracking
  - It also only used DTrackCandidates instead of DTrackWireBased (would slow down by factor of ~2-3 if wanted to use wire based for all tracks)

Phase	Photon Rate	Nominal L1 Rate	Required Nodes
III	$1x10^7$	20 kHz	5
IV	$5x10^7$	100 kHz	25
IV+	$1x10^8$	200 kHz	50

The 10 nodes we have now will allow us to tag events with L3 in 2016

ODC info: http://argus.phys.uregina.ca/cgi-bin/private/DocDB/ShowDocument?docid=2341