

Abstract:

LHC and CMS will be online in 2007 and therefore chambers need to be made and tested. These chambers must be efficient if any hope of finding exotic particles exists since these particles are only produced every trillion or so collisions. In this report I will give a brief overview of the Level-1 Trigger for the end cap detectors for CMS and investigate the efficiency for different modes and chamber arrangements recorded during a six-week beam test at CERN.

LHC and CMS:

The Large Hadron Collider (LHC) will collide protons at an unprecedented 14 TeV every 25 ns. That's seven times the energy of Fermilab's Tevatron. With that energy all sorts of new physics is expected. The most probable particle to be found is the Higgs boson (if it isn't found at the Tevatron first).

Anything with mass couples to the Higgs field; the more massive the particle, the stronger the coupling. The Higgs particle is very massive—more than 100 GeV—therefore, it is too massive for current accelerators to produce in any sizeable quantity. However, LHC should have no problem producing these particles.

The Higgs boson is not the most exotic particle that physicists hope to create at the LHC. One of the aesthetic problems with the Standard Model is that it requires special fine-tuning and doesn't unify the four known forces. It does a very good job of explaining sub-atomic physics with just the electromagnetic, electro-weak, and strong forces but without gravity. Supersymmetry and superstring theory (which is string theory with supersymmetry) are two possible candidates to include gravity. They require supersymmetric particles, or sparticles.

These sparticles, such as sleptons and squarks, or photinos, etc. are identical to normal particles except that they are bosons instead of fermions (selectrons and electrons) or vice versa (photinos and photons). If they do exist, they must be very massive, because we haven't observed any of these particles. So if they do exist, LHC should see them.

The Compact Muon Solenoid (CMS) is one of four detectors being built at LHC. CMS and ATLAS (A Toroidal LHC ApparatuS) are the two biggest, general-purpose detectors at LHC. CMS is the project that I am working on. Construction is scheduled to be finished in 2007.

Before a particle gets to any chamber in CMS it will have to make it through the detector's absorbers that form the calorimeter system (energy measurements). These absorbers will stop just about every particle except muons. Hundreds of different particles will spray from the collision point, but they are mostly hadrons (particles composed of quarks). Since hadrons interact strongly with matter (by the strong force), they cannot penetrate very far into the absorbers.

Since quarks are ruled out, that leaves leptons (which only react electromagnetically and through the electroweak force). Neutrinos will make it though the core because they travel through everything relatively unimpeded; the only way to detect neutrinos at CMS is by their absence. That means that we can say that there was a neutral particle because what we detected didn't add up to the total momentum. That only leaves three particles, electrons, muons, and taus. Electrons are very light particles so they don't travel through matter very well, but muons can easily make it through the absorbers being 200 times as massive. Taus are even more massive than muons (more than ten times). However taus cannot make it through before decaying.

This rejection is beneficial since it tags the charged particle as a muon. This is why we need to assure maximum efficiency in detecting muons.

Trigger Architecture:

It is impossible to record data for every collision since LHC will provide protons in bunches every 25 ns and approximately 17 collisions every bunch crossing (that's approximately one billion collisions every second). This means that we have to have a way of taking out uninteresting collisions—this is the basis for the Trigger. The Trigger literally triggers the storage of event data for a certain collision. The Trigger must reduce the 1GHz of collisions down to 100Hz; that's seven orders of magnitude!

There are three Trigger levels, which I will separate into the Level-1 Trigger (L1T) and High Level Triggers (HLT). The L1T will reduce the data by approximately four orders of magnitude and the HLT will reduce it three more orders of magnitude.

Cathode Strip Chamber (CSC) Design:

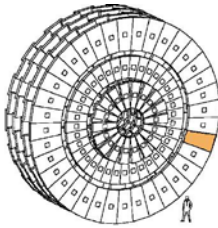


FIGURE 1: Stations 2,3, and 4 of the end cap CSC's

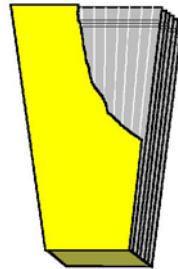


FIGURE 2: view of CSC

Fig. 2 shows what the CSC's look like. There are many different CSC's that go into different parts of the end cap section of CMS. There are four different stations or layers for the end cap section. Stations two, three, and four are shown in Fig. 1. These stations assure nearly 100% coverage of all possible angles. Each station contains a number of chambers and is labeled thusly. ME (muon end cap) is the name given to these chambers such as ME 1/1. The first number is the station, and the second is a label for the different types of chambers in each station.

The stations are broken up into 60° sectors, except for ME1/x, which is broken up into 20° sectors. Because of the location of each station, the design of the chambers for each station is slightly different.

Cathode strips run radially, while anode wires run approximately orthogonal to the strips. As a charged particle ionizes the gas electrons will be pulled to the wires and a signal can be seen on that wire. Since there are wires running orthogonal to each other we can determine where the particle “hit” the chamber by simply assigning Cartesian-like coordinates to the cathode strips and anode wires (although, actually the cathode strips represent the spherical coordinate φ , and anode wires represent the spherical coordinate η).

It is not good enough to just know that a particle passed by a certain point on the chamber—we need to know its path. This is why each chamber has six layers of identical panels or planes. A charged particle will leave a Local Charge Track (LCT) when traveling through any of these chambers. With the cathode strip and anode wires, these tracks can be correlated to make a 3-D picture of how the particle traversed the chamber.

Local CSC Level-1 Trigger:

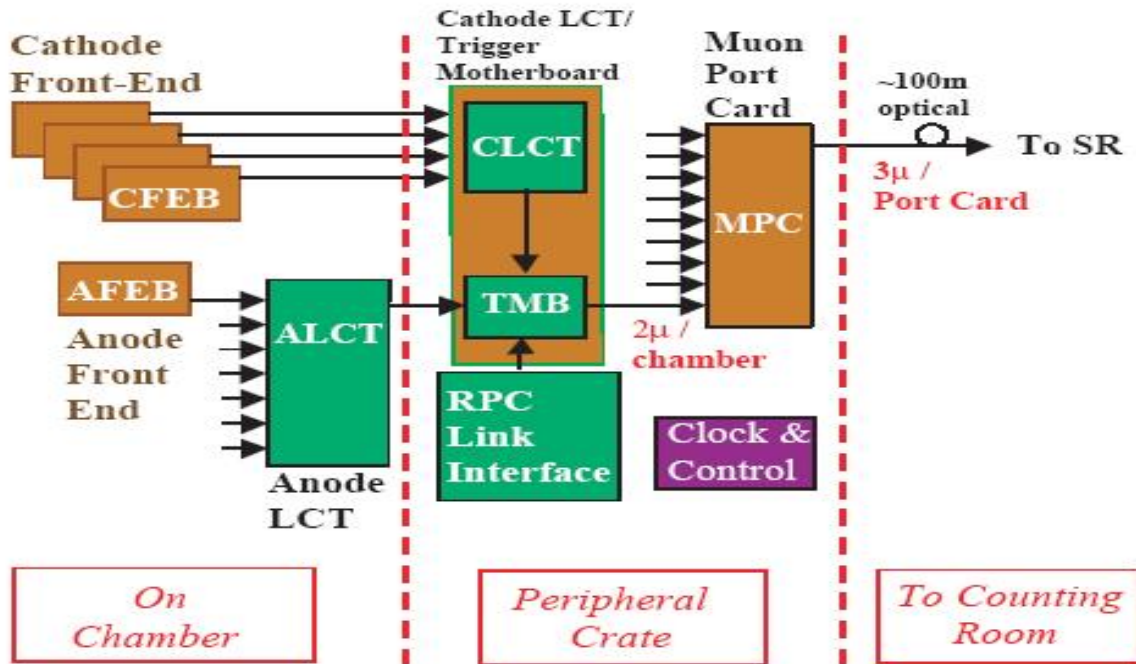


FIGURE 3: Block diagram for data flow in the CSC Local Trigger.

The local LIT consists of five parts: cathode front-end boards (CFEB), anode front-end boards (AFEB), anode LCT-finding boards (ALCT), cathode LCT-finding boards/trigger motherboard (CLCT/TMB), and muon port card (MPC) as shown in Fig. 3 above. The front-end boards amplify signals and send them to the proper LCT finding-board. Next these two signals are sent to the TMB which then sends a signal to the MPC which finally sends a signal to the sector receiver/sector processor (SR/SP).

The ALCT and CLCT boards work very similarly. They both compare LCT's found to certain preset patterns. These patterns represent what an "interesting" LCT would look like and are given numbers. The ALCT and CLCT boards identify all LCT's and send the best two (if there are more than two LCT's, by pattern number) to the TMB with information on those LCT's. The ALCT board differs from the CLCT board in that it is optimized to identify the bunch crossing (BX) or time.

The TMB takes the ALCT's and CLCT's and makes a 3-D correlated LCT (CorrLCT). This is done by time correlating an ALCT and CLCT (by BX). They can differ by at most one BX but if there is only one of each and the BX differs by more it will still send the CorrLCT but the large difference in BX will be noted.

If the TMB only receives either an ALCT or CLCT then it will send the zero LCT but will note it with an STA value which can run anywhere from 0-3. The next possibility is that there is two of one type of LCT but only one of the other. In this case it will merely copy the single LCT to each of the other types of LCT (i.e. it would copy the one CLCT to each of the distinct ALCT's). If there are two of each type of LCT's then the largest pattern numbers are combined. That means the best pattern for the ALCT will be combined with the best pattern for the CLCT and the remaining two will be combined.

Table I below shows the different possible values for the STA number.

STA value	Description
0	No CSC trigger data
1	There is CSC trigger data but no anode-cathode match is found
2	Two cathode and one anode LCT patterns, or vice versa
3	One or two LCT patterns, unambiguous assignment

Table I: STA values for TMB

The TMB, which is located on each chamber, sends up to two CorrLCT's to the MPC (one for each sector). In stations two, three, and four there are nine chambers for each sector and therefore the MPC receives up to 18 CorrLCT's. The pattern ID's that are sent from the TMB serve as addresses to the Look-Up Table (LUT). The LUT contains pre-computed quality numbers (because it takes too long to compute them in real time). The MPC chooses the three best CorrLCT's based on the LUT quality numbers and sends those three CorrLCT's to the SR/SP. Station one contains 8 chambers

for each sector (which act identical to the sectors described above). The only difference in performance is that the MPC selects two CorrLCT's from the possible 16 to send to the SR/SP. Fig. 4 below shows the different stations and sector slices.

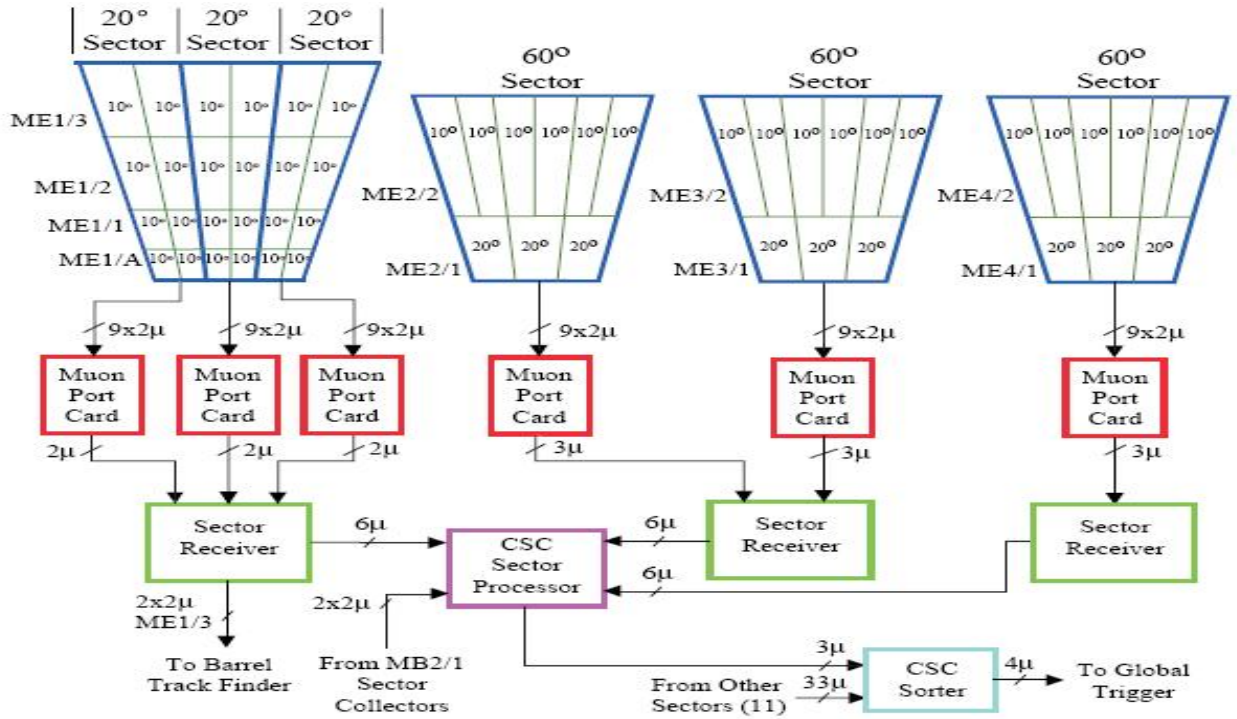


FIGURE 4: diagram showing the organization and data reduction of Level-1 Trigger

Test Beam Set-up:

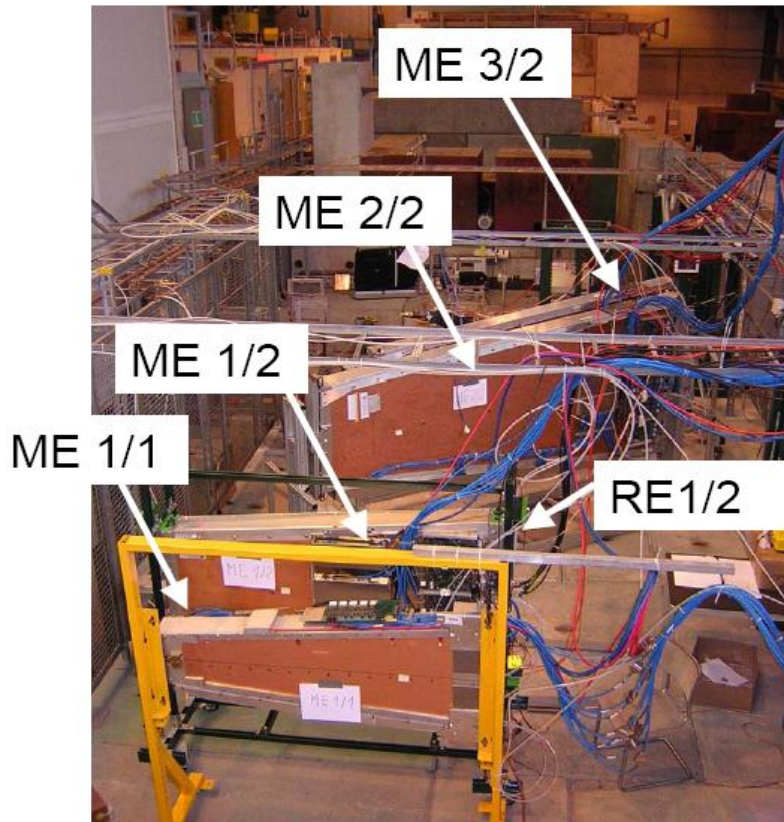


FIGURE 5: Chamber arrangement, with the second two chambers tilted by some angle

Fig. 5 shows a picture of the chambers and the order in which they were arranged for the test beam this May and June. The test beam was 100 GeV muons for the asynchronous period and both muons and pions were used during the synchronous period. Asynchronous means that the beam was not pulsed at the LHC frequency of 40MHz, so it was asynchronous with LHC whereas during the synchronous period the beam was pulsed at the LHC frequency of 40MHz. The asynchronous period ran for three weeks from May 17 through June 8 and the synchronous period ran for an additional three weeks from June 8 through July 1. Table II shows the labeling for both asynchronous and synchronous periods as they appear in the plots located in Appendix A.

changed on the TMB to accept different types of patterns. The different trigger modes are described in Table III on page 15 of this document. Along with trigger modes, different collision patterns were used inside these trigger modes (Default, Miss4, and Andrey). Angles were varied to simulate the different angles that muons will be hitting the chambers during the actual experiment. The number of layers in a pattern required for a chamber to report an LCT was varied from four to six. Another variable was that an iron block was placed in front of the beam for some runs to simulate the iron absorber in the center of the CMS detector. Because the CLCT takes longer than the ALCT to report an LCT the ALCT must wait for the CLCT and this time it waits was varied, which is noted as ALCT delay.

Results:

There are two types of efficiencies: observed and corrected. The observed efficiency is simply the number of LCT's found divided by the total number of events (for that chamber). The corrected efficiency takes into account di-muon events (which are instances where truly two different muons come through the chamber). Corrected efficiencies are calculated using laws of probability as described below.

T: total number of events

N_1 : number of actual single muon events

N_2 : number of actual di-muon events

n_1 : number of observed single muon events

n_2 : number of observed di-muon events

L: number of total events recorded

ε : Efficiency or probability of recording an LCT given there was one muon

$$L = n_1 + n_2 \tag{1}$$

$$T = N_1 + N_2 \tag{2}$$

$$n_1 = L - n_2 = \varepsilon N_1 + 2\varepsilon(1 - \varepsilon)N_2 \tag{3}$$

$$n_2 = \varepsilon^2 N_2 \tag{4}$$

Combining Eqs. (2), (3), and (4):

$$0 = \varepsilon^2 T - \varepsilon(L + n_2) + n_2 \tag{5}$$

Using the quadratic equation:

$$\varepsilon = \frac{L + n_2 \pm \sqrt{(L + n_2)^2 - 4Tn_2}}{2T} \quad (6)$$

We take the higher efficiency because the observed efficiency should be close to the corrected efficiency assuming there are very few di-muons, which there always was. We see the low di-muon rate in Fig. 5 below, which is indicative of all di-muons rates. The corrected efficiency is given by Eq. 7:

$$\varepsilon = \frac{L + n_2 + \sqrt{(L + n_2)^2 - 4Tn_2}}{2T} \quad (7)$$

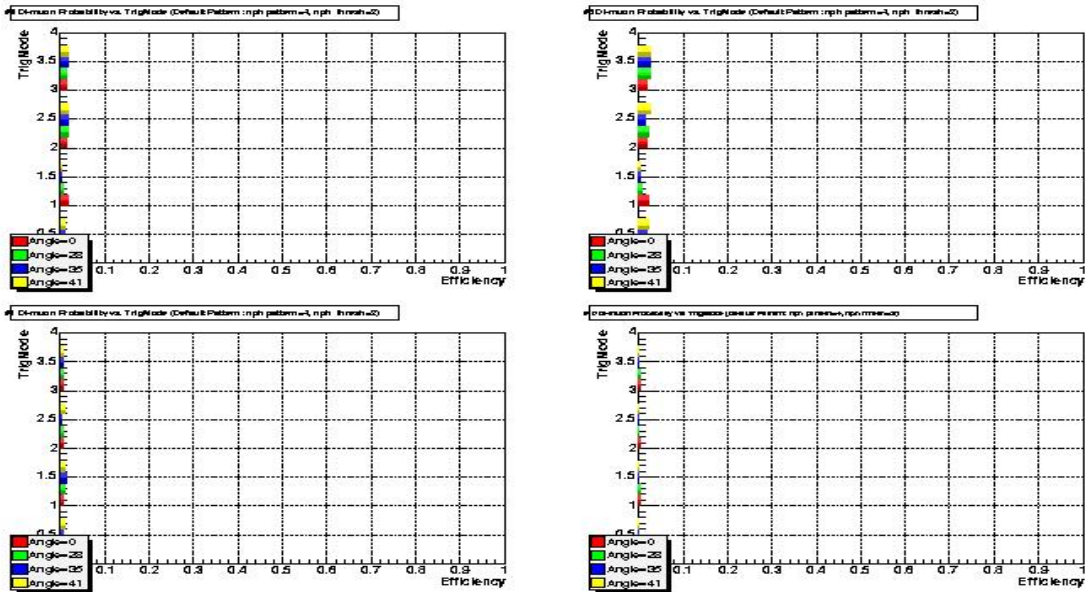


FIG. 7: di-muon probability for different trigger modes and angles

This is the efficiency that is plotted in the figures located in Appendix A.

There are also three more different efficiencies: untagged, tagged by chamber, and tagged by chamber and bunch crossing (BX). Untagged means that every event gets counted for every chamber, tagged by chamber means that an event is only counted (in the total number of events) if at least one other chamber recorded an event, and tagged by chamber and BX means an event is only counted if it is recorded in at least one other

chamber on the center BX. The center BX is the BX where most of the events lie. I used the efficiency calculated from tagged by chamber and BX for my plots.

Along with di-muon rates there is also a ghost muon probability. A ghost muon occurs when the TMB returns two LCT's but they both lie on the same strip or wire group. The wire group requirement is stricter—if the difference in wire groups is one or less then it is a ghost. Because of this definition, ghost probabilities vary between different trigger modes.

All plots are located in the appendix and I will refer to them by page number. Page 1 of the appendix shows plots of total efficiencies for the Default pattern varying trigger mode and the tilt angle (for asynchronous period). Looking at just trigger mode two and an angle of zero degrees we see that the efficiency is very high for all chambers. The efficiency (for same conditions) during the synchronous period is high except for ME3/2, which dies out when we require an ALCT. The ghost probabilities are also very low for this setup.

Firmware:

New ALCT firmware was introduced to lower the ghost probability, but the plots on page 4 show that neither the total efficiencies nor the ghost probabilities changed significantly.

Trigger Modes:

Trigger Mode 0: Acc. Pattern or Coll. Pattern
Trigger Mode 1: Acc. Pattern Only
Trigger Mode 2: Coll. Pattern Only
Trigger Mode 3: Acc. Pattern or Coll. Pattern (Acc. Pattern vetoes Coll. Pattern)

Table III: values for the different trigger modes.

The plots on page 1 show the angular dependence of efficiencies and the different trigger modes. Trigger mode 1 should be low at large angles because it only accepts straight patterns. The other three trigger modes all accept collision patterns and so should remain constant at all angles. When the tilt angle was 35° the efficiency was low for ME1/2 and ME3/2, which should not be, especially in ME1/2 because the angle was zero for all four runs. The next page shows the ghost probabilities for the same runs. Trigger mode 0 will be high for most runs because it is accepting the accelerator pattern or collision pattern with no cancellation. Therefore, as the angle increases and fewer accelerator patterns are seen, the ghost probability dies off. However, at 28° we see a jump for trigger mode 3. This should still be low, given, that ghost probabilities were low for accelerator only and collision only patterns because recall that if it sees both an accelerator and collision pattern, the accelerator pattern vetoes the collision pattern, so we shouldn't see the high ghost rates that we see in trigger mode 0.

Page 7 shows the efficiencies when an iron block was placed in the beam line. The plots show that the efficiencies did not change significantly with the iron. This is a good result because there will be iron in the path that the muons take before they get to the chambers.

These results show that there isn't significant scattering, which would cause the efficiency to drop dramatically in trigger mode 1. The ghost rates only significantly increased for ME1/2 (which was at normal incidence both runs) for trigger mode 0. This result could be due to the fact that trigger mode 0 is accepting both collision and accelerator patterns, which means that it has one of each (which would keep all other trigger modes low). The scattering is not as significant for the ME2/2 and ME3/2

because they were tilted at 28 degrees so accelerator patterns were already low, but at normal incidence the straight track could get tilted enough to be called a collision pattern as well.

Number of Layers Required:

There are six layers in the CSC—the default is that if a track matches a pattern for four of the six layers then it is an LCT. However, more than just 4 layers can be required. Page 10 shows plots at 0° for different numbers of layers. The result for the default pattern is that more layers significantly drop the efficiency. Going from four to five only drops the efficiency a few percentage points, but going from four to six drops the efficiency by almost 15%. More layers should lower the ghost rate because it requires the fit to the specific pattern to be very tight. However, for ME2/2 the efficiency seems to increase for trigger mode 0.

Page 13 shows the same plots but now at 28°. The results are similar to the above. The ghost rates drop significantly at 28° with increasing layers required. However, the layers were kept the same for ME1/2 and yet the efficiency shows a dramatic change in trigger mode 0, so that run might be bad.

Patterns:

There are three different sets of collision patterns, the Default, Miss4, and Andrey pattern. Page 16 shows plots for the different patterns at 35 degrees. Overall the different patterns are approximately the same, except for trigger mode 2 on ME3/2. The Miss4 pattern is very low for ME1/2, which is not too surprising since that chamber was

at normal incidence and recall that trigger mode 2 is for collision patterns only. The ghost rates are fairly normal. They are low for trigger mode 0 because the TMB didn't return very many collisions patterns and therefore is about the same as trigger mode 1.

Page 19 shows the effect of different layers required. The more layers required dramatically drops off the efficiency, much more so than in the default pattern. It drops off 20% and then another 50% for layers required equaling five and six respectively, for both chambers and all trigger modes. The ghost rates are low but the cost is lower efficiencies.

Page 22 shows the same plot as above but with the tilt angle set to -30° . The results are the same as above, but even lower efficiencies are reached.

Page 25 shows plots for the Andrey Pattern while varying layers required. With the Andrey pattern the layers required does not affect the efficiency nearly as badly. Going from four to five is at most (other than trigger mode 1) a couple of percentage points difference; from four to six, the difference is approximately 5%. As usual, the larger layers required significantly lowers the ghost rates, but in the case of Andrey we did not lose efficiency.

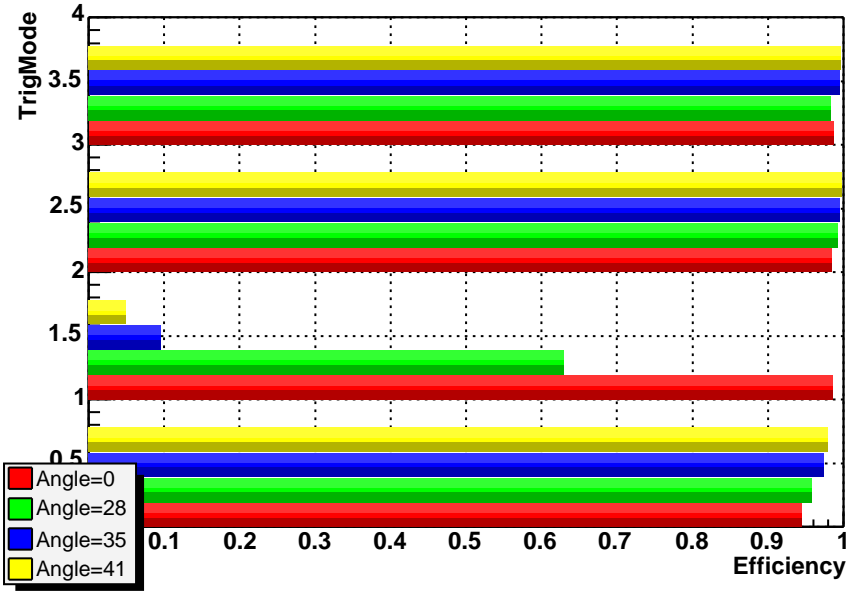
Conclusions:

Based on the data collected, the Andrey pattern seems to perform the best when the number of layers required is five. Number of layers required could even possibly go as high as six, but efficiency drops to about 93% with that requirement which is still too low. To really be sure of these conclusions more tests of the Andrey pattern need to be done with the number of layers required set to five and six.

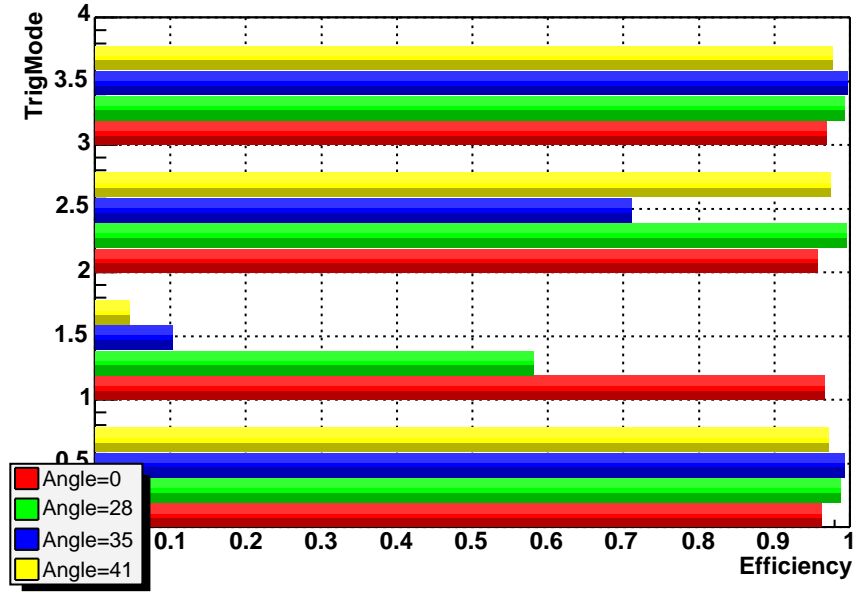
Acknowledgements:

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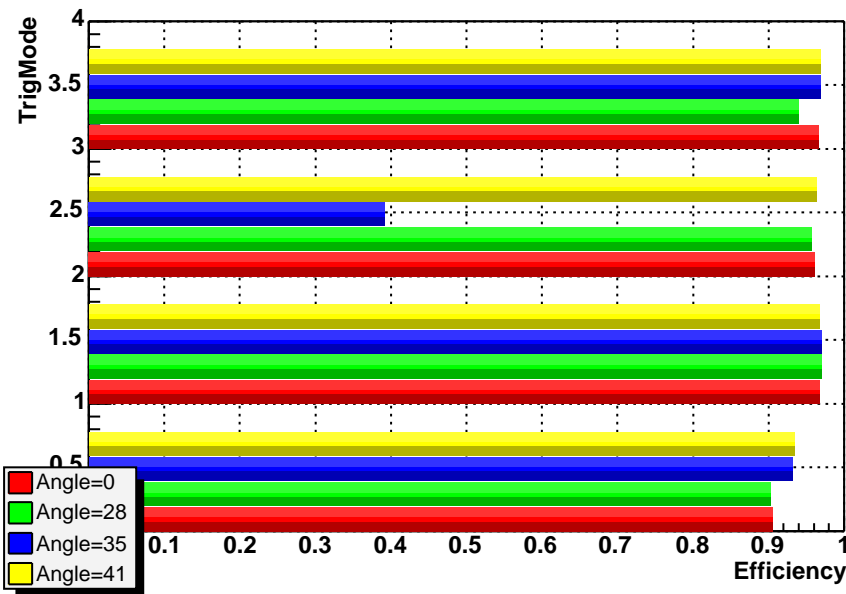
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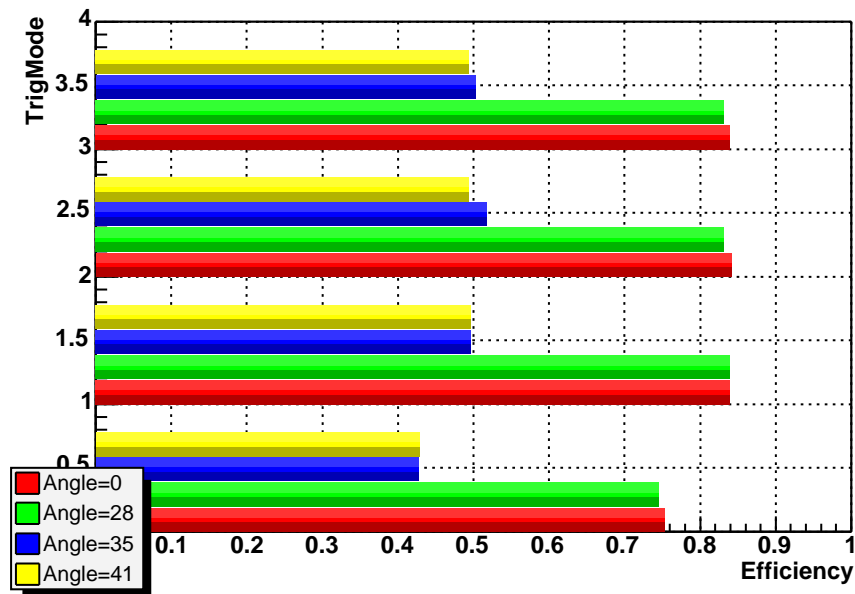
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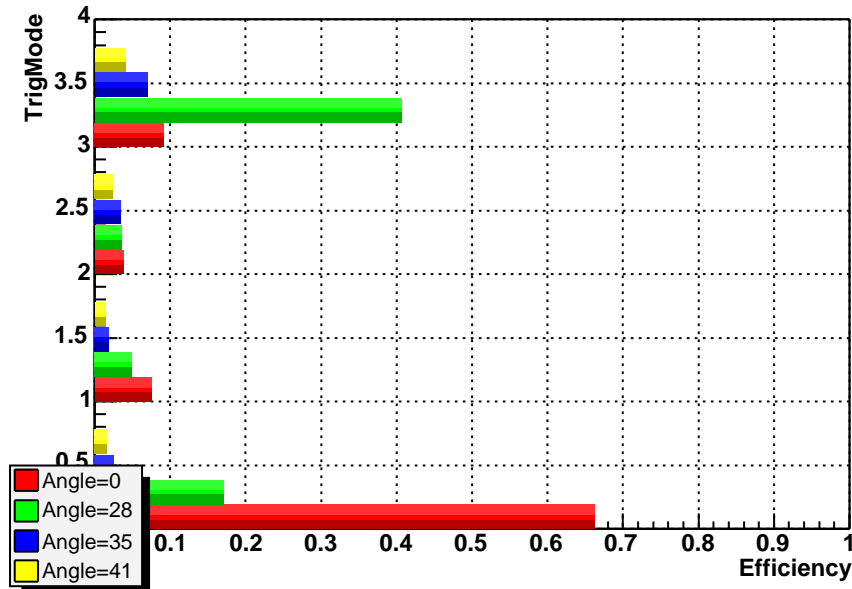
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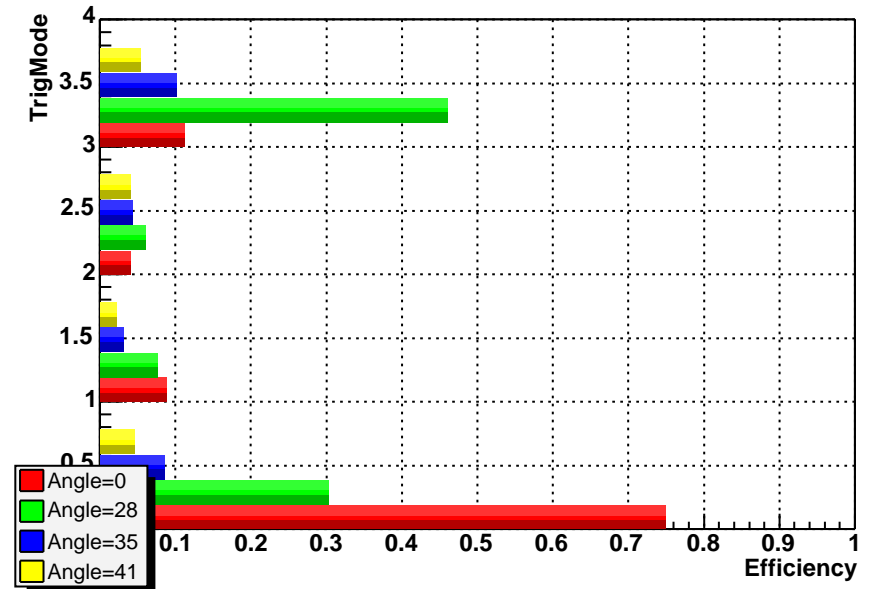
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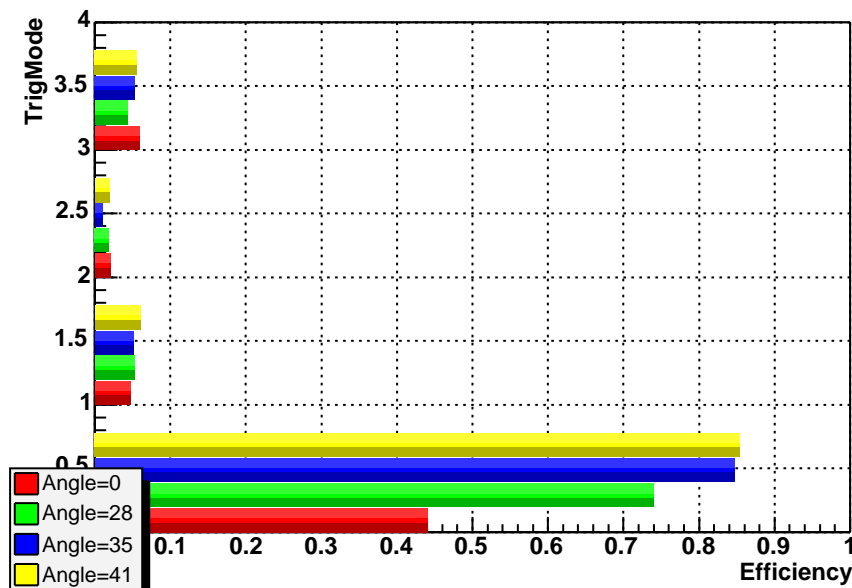
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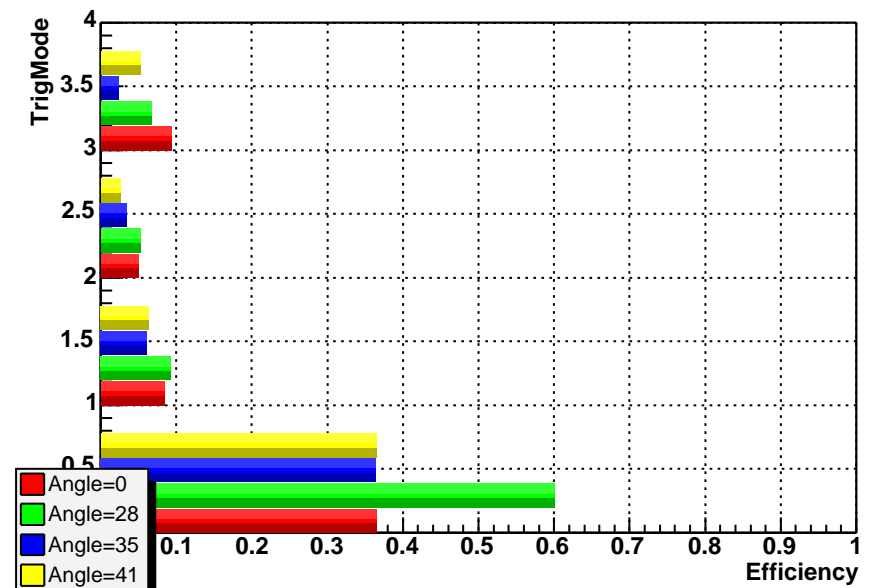
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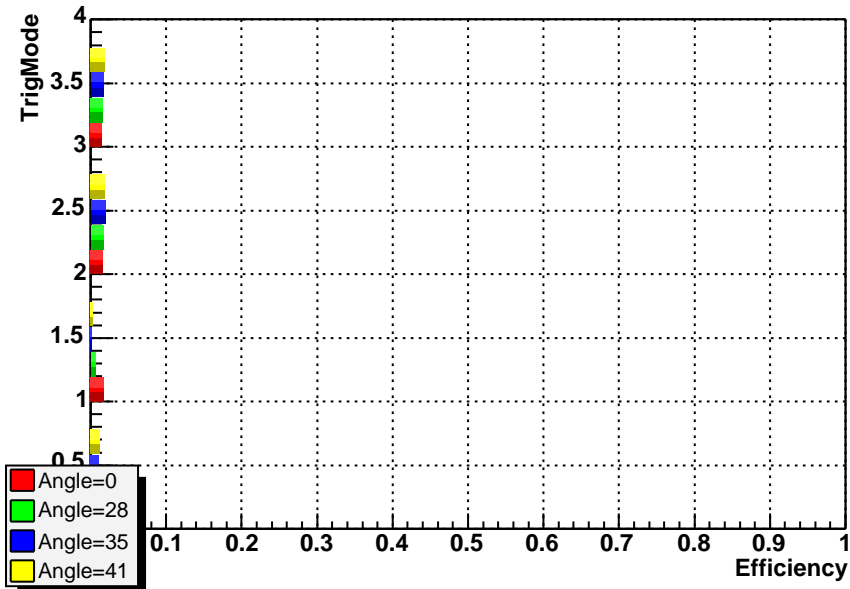
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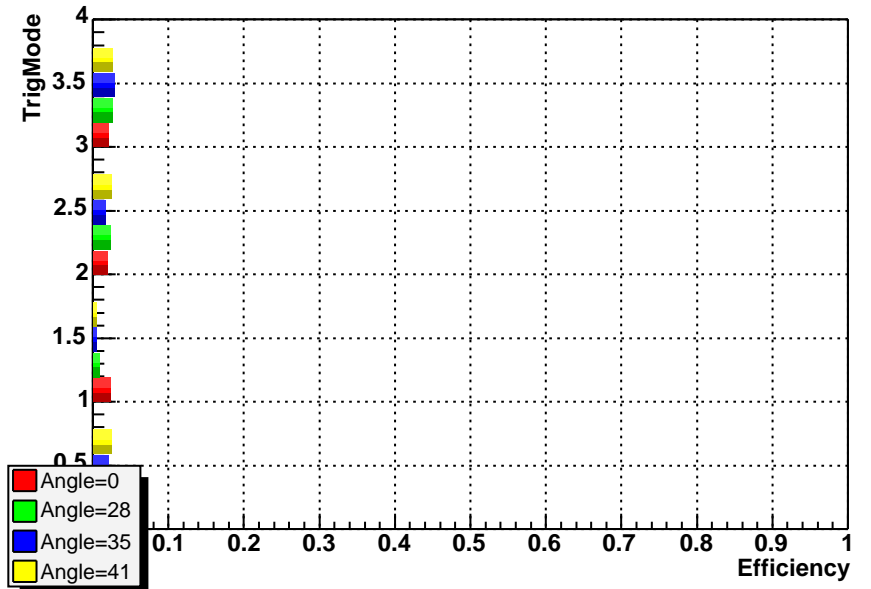
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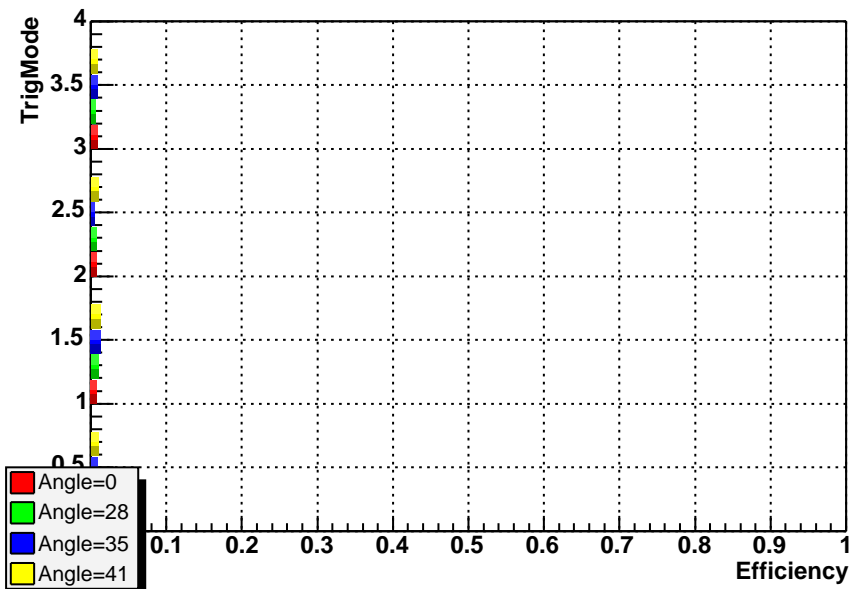
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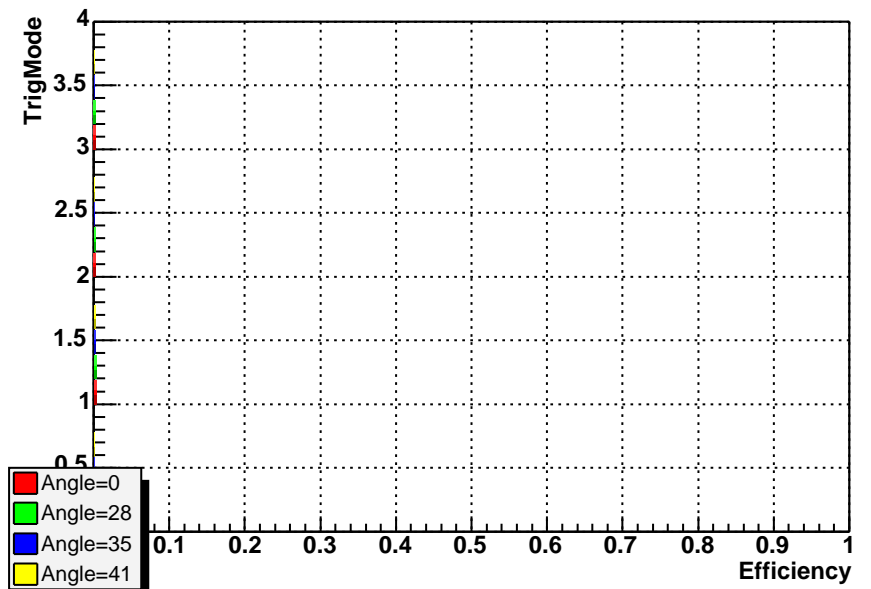
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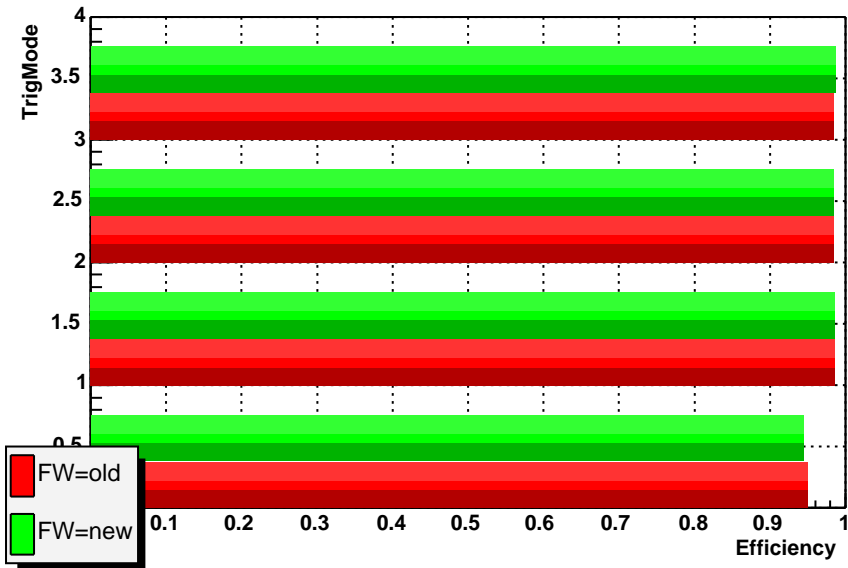
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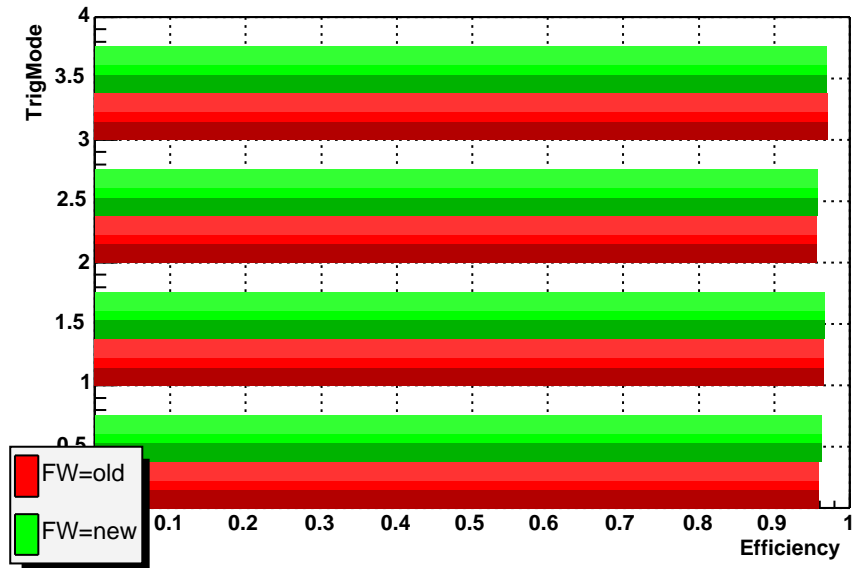
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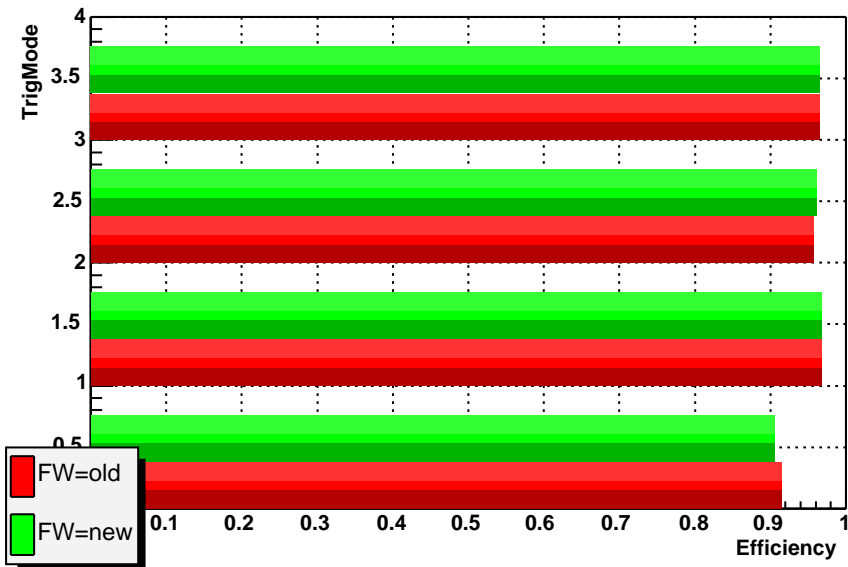
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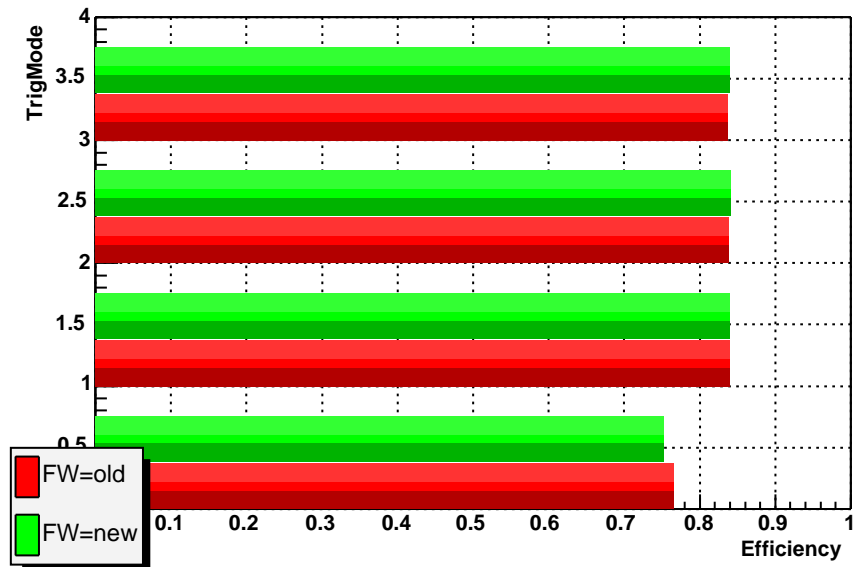
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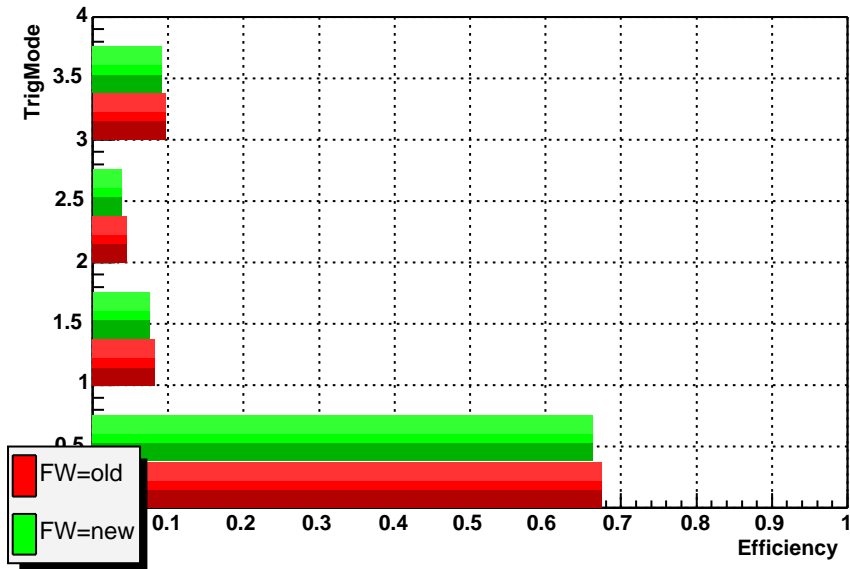
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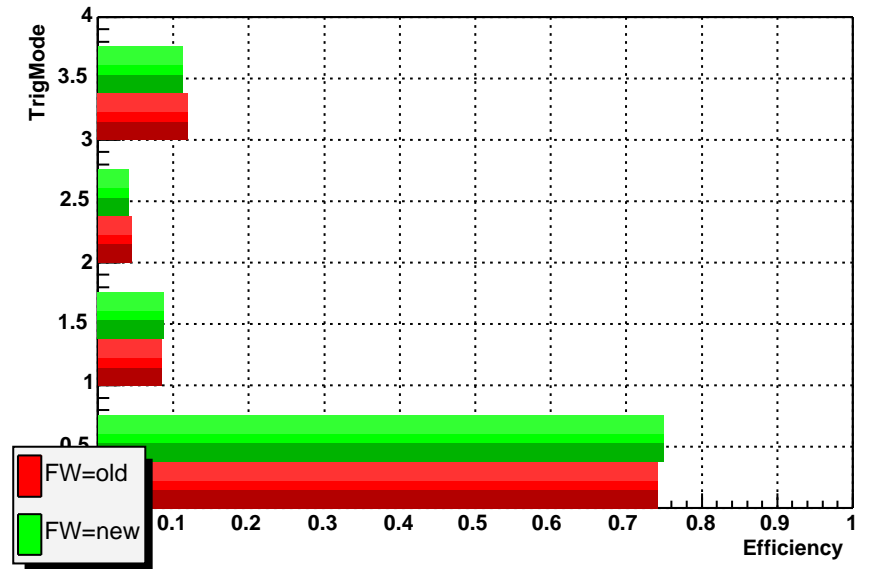
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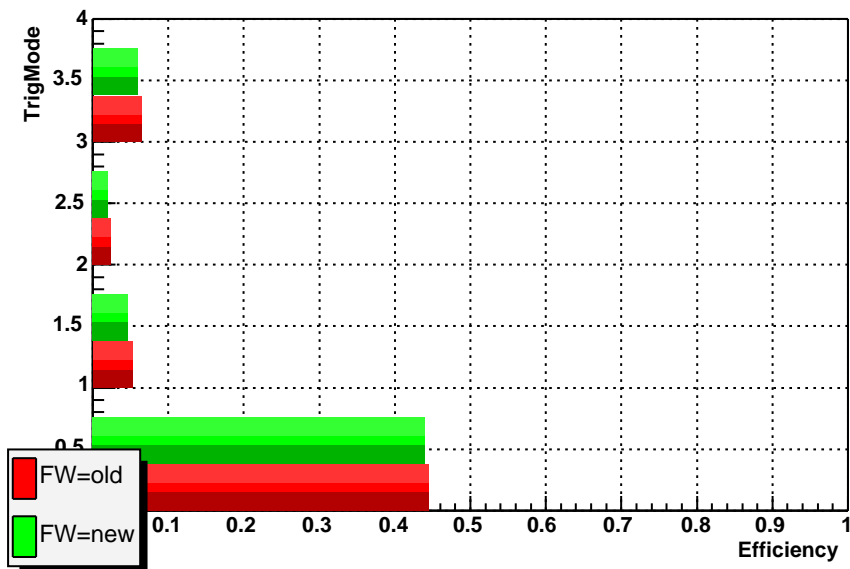
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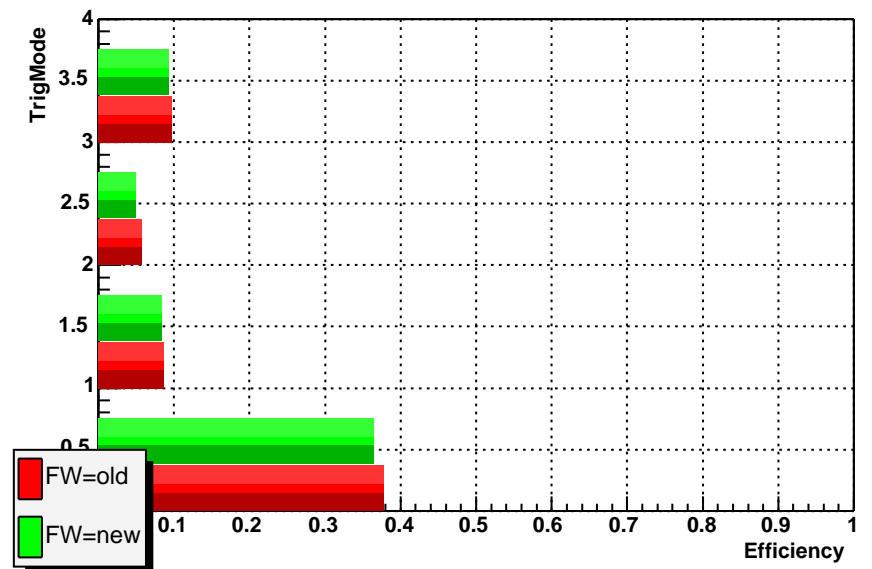
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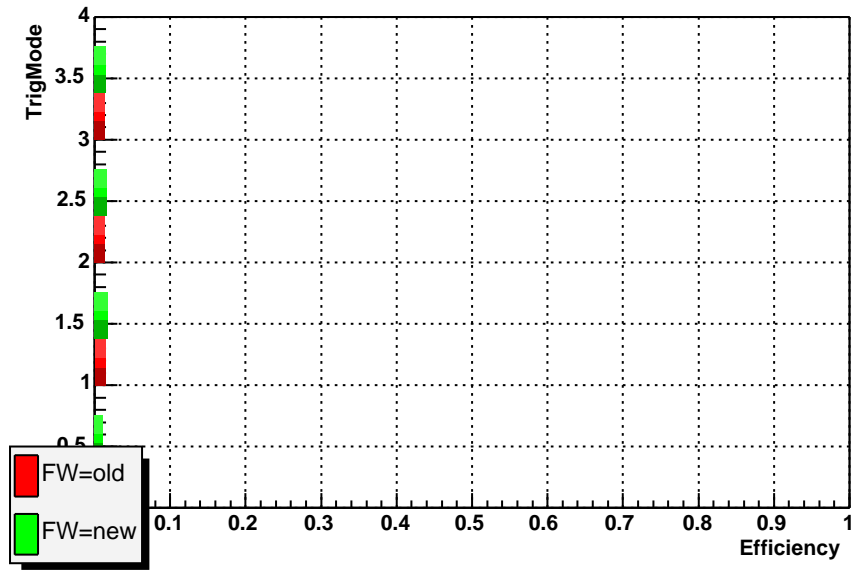
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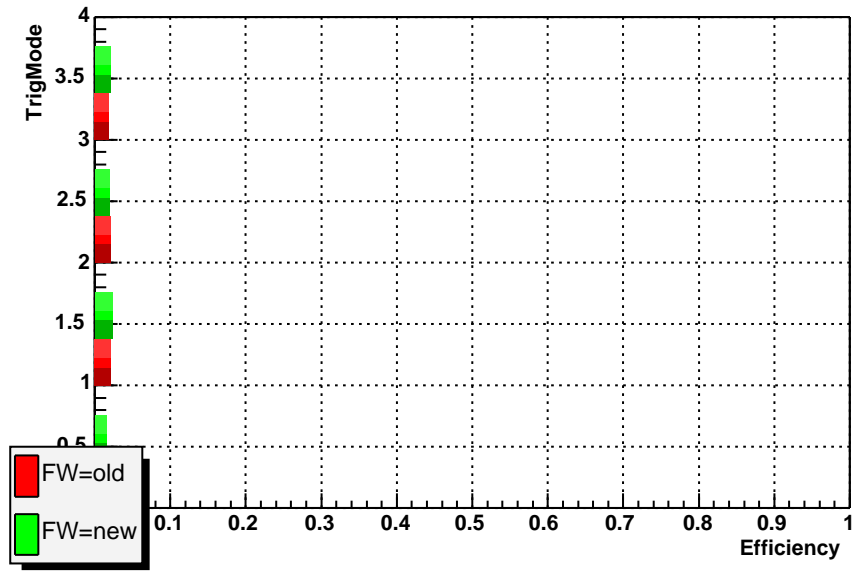
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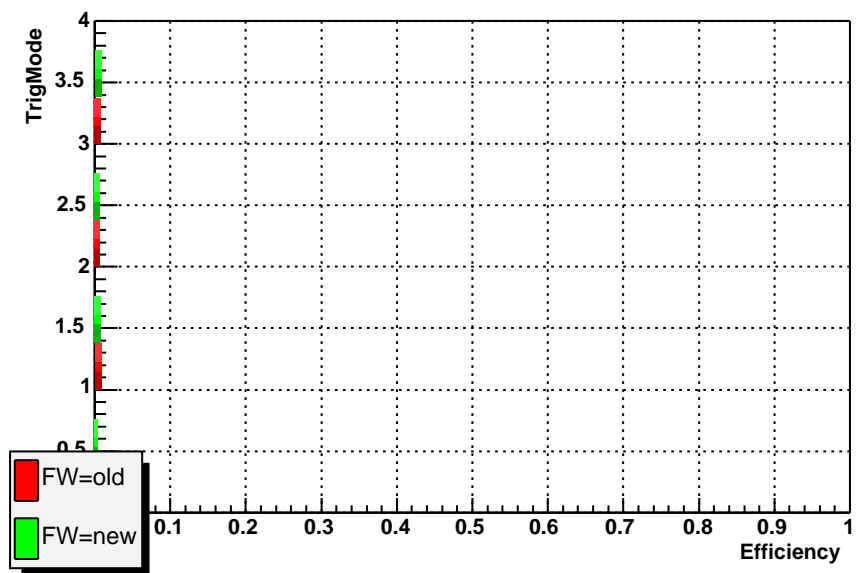
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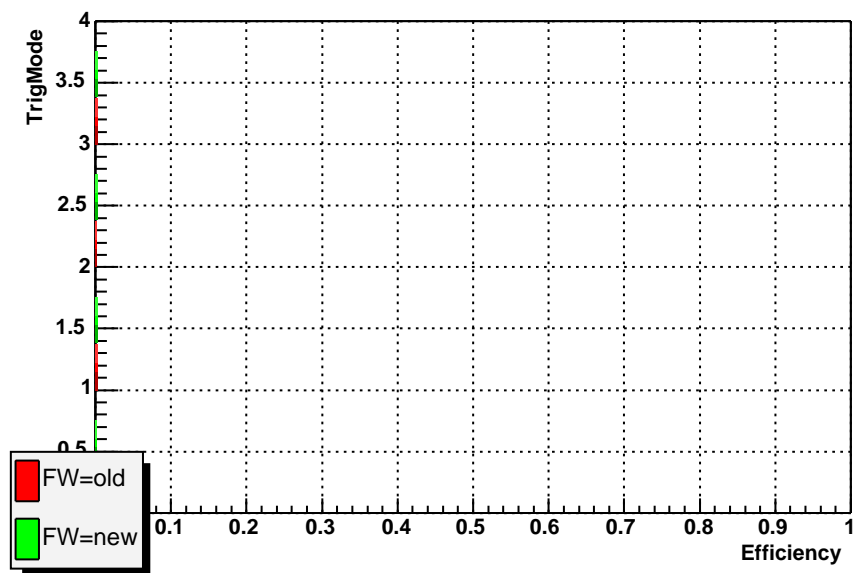
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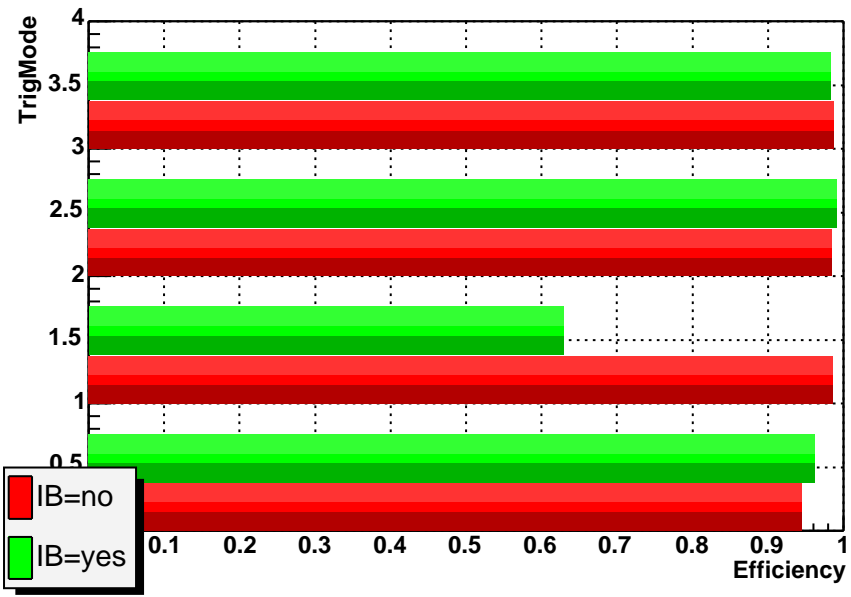
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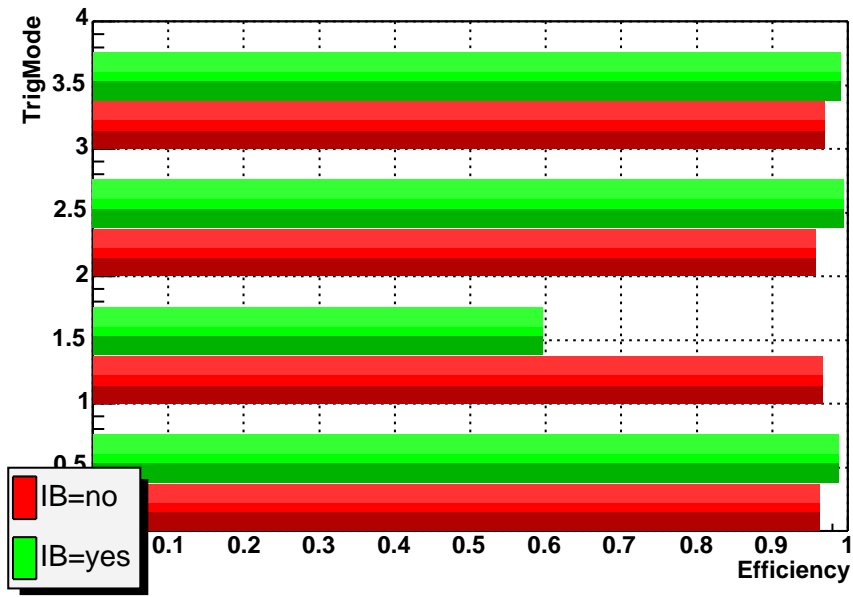
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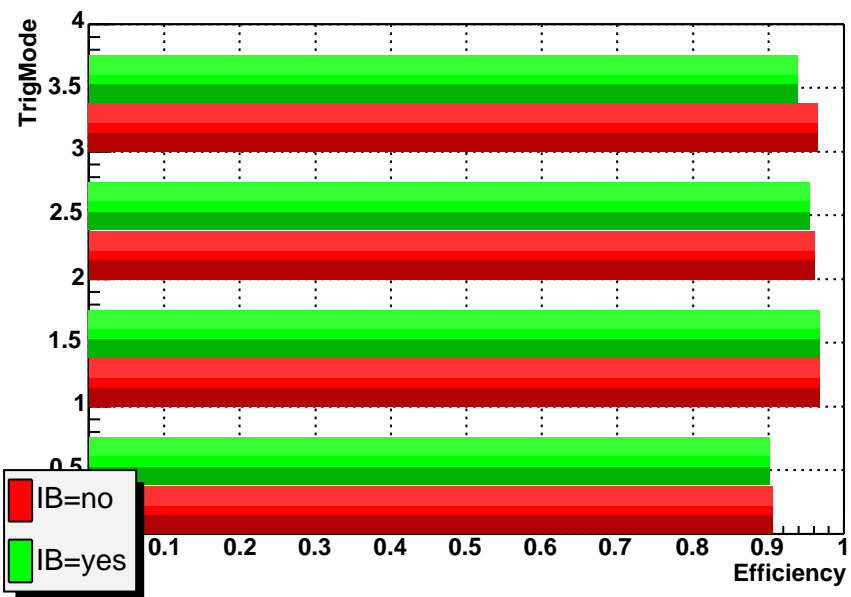
#3 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph pattern=4, nph thresh=2, theta=0)



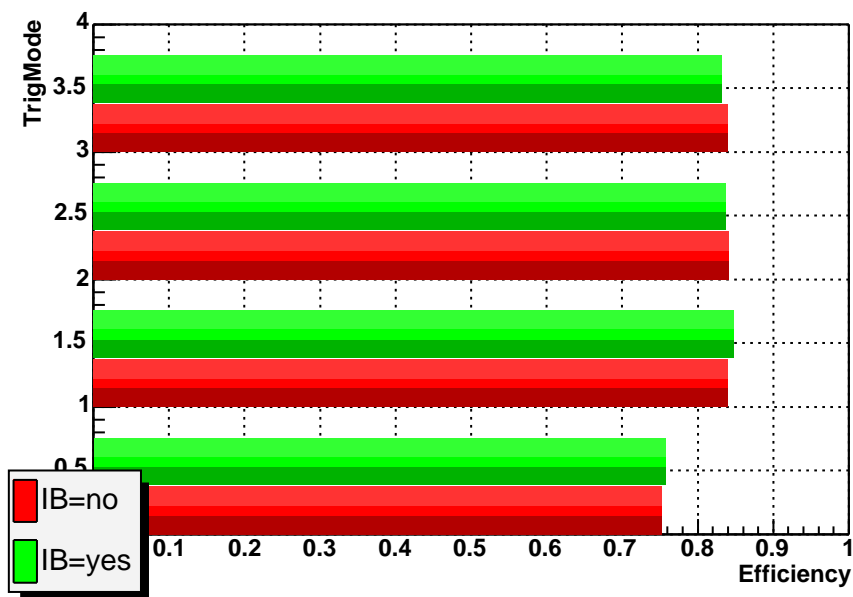
#8 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph pattern=4, nph thresh=2, theta=0)

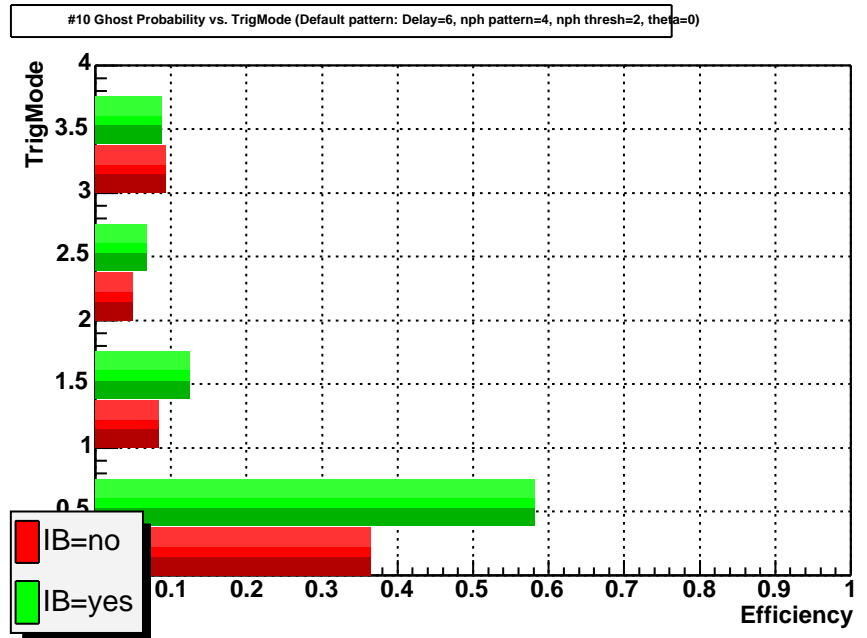
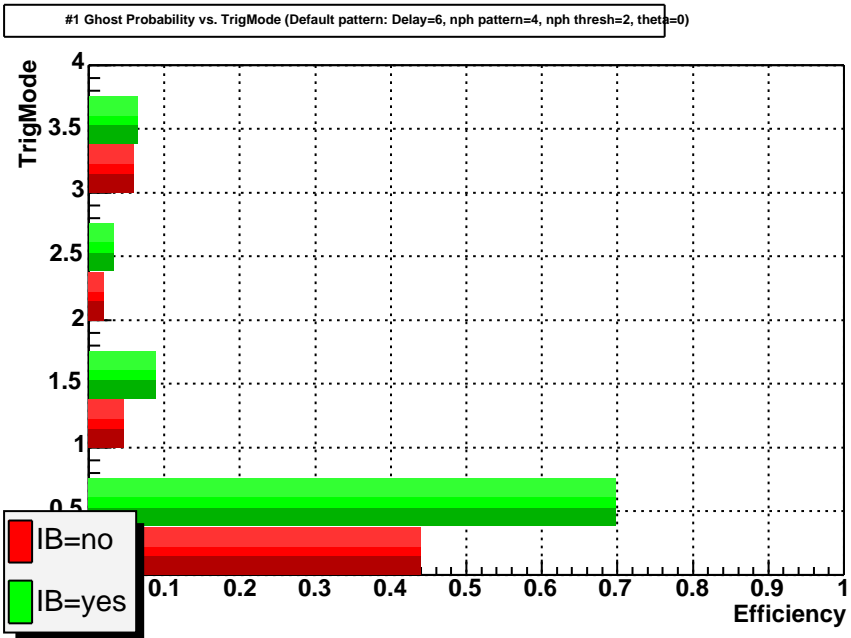
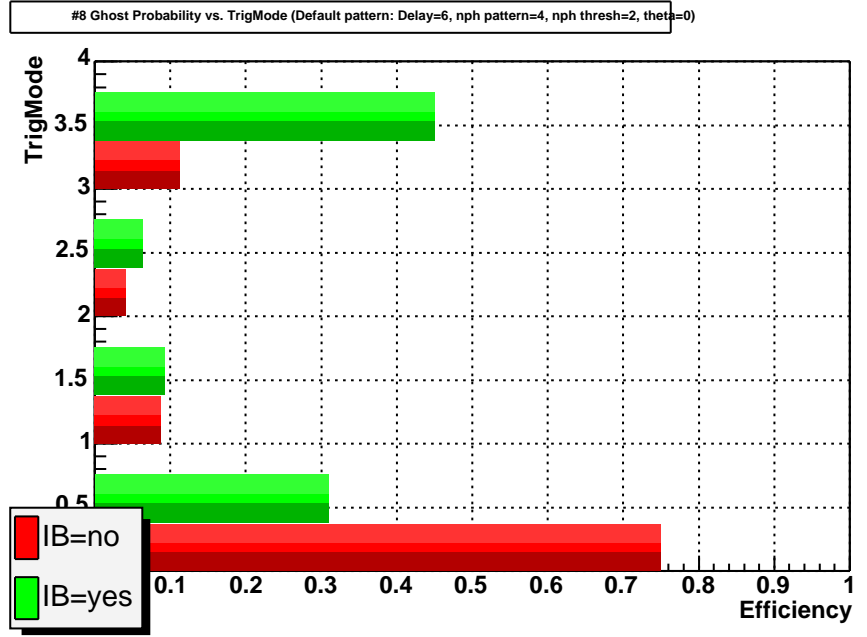
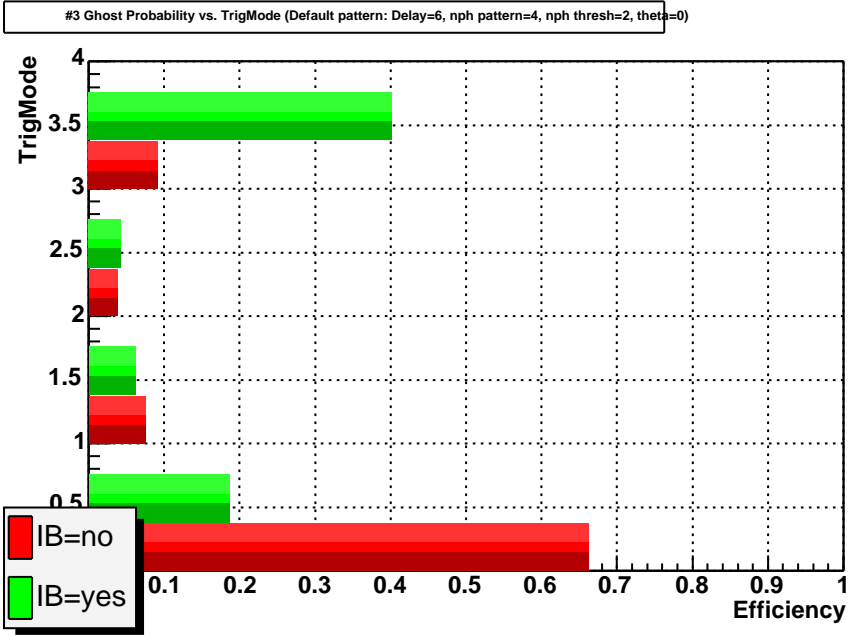


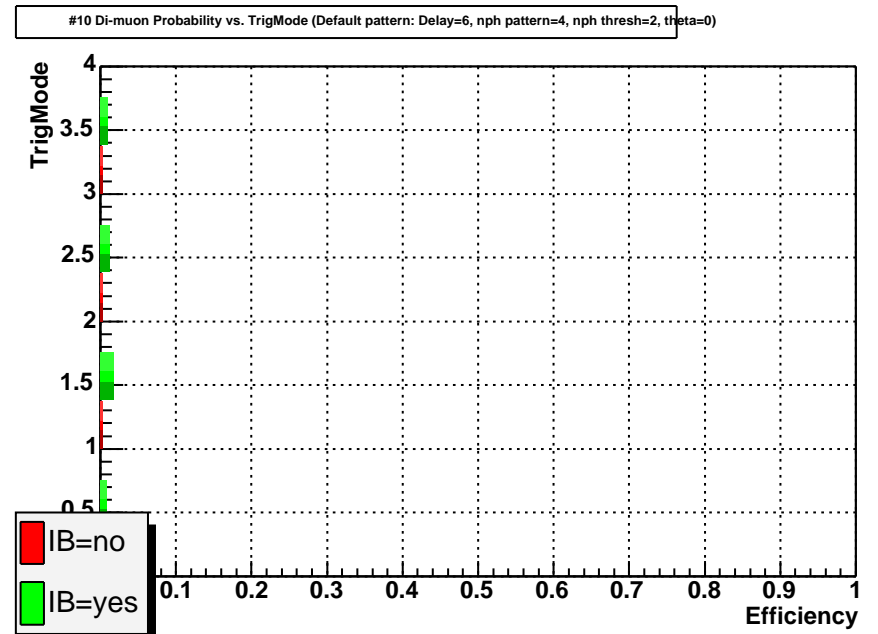
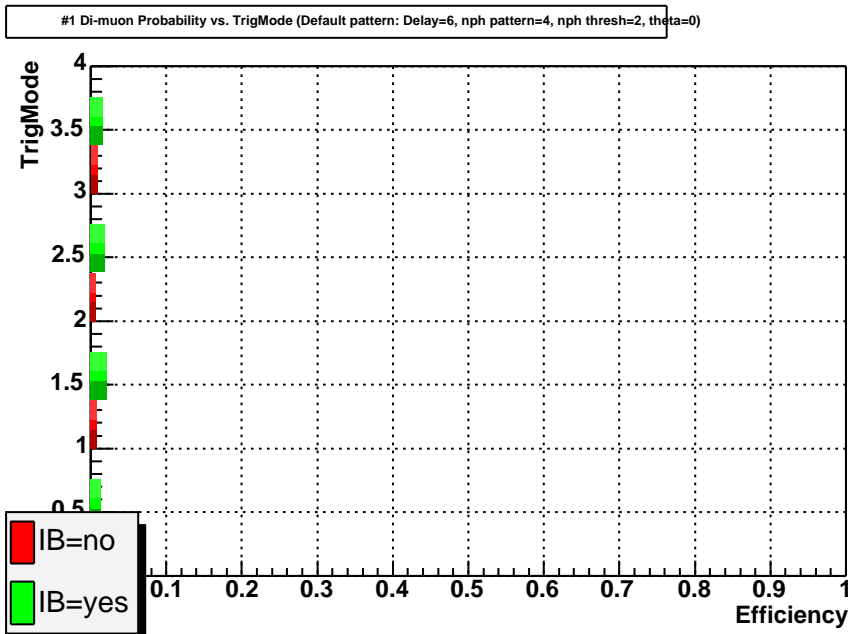
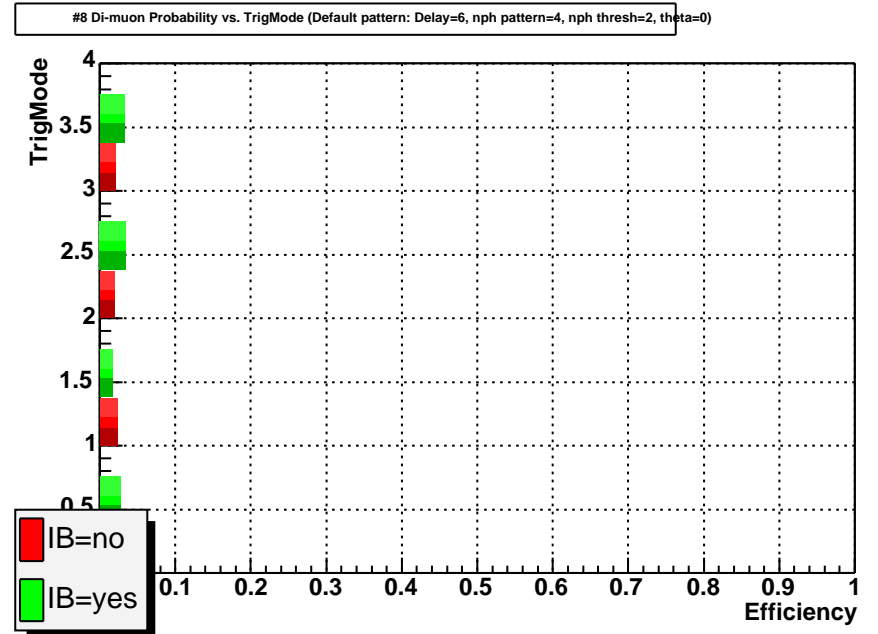
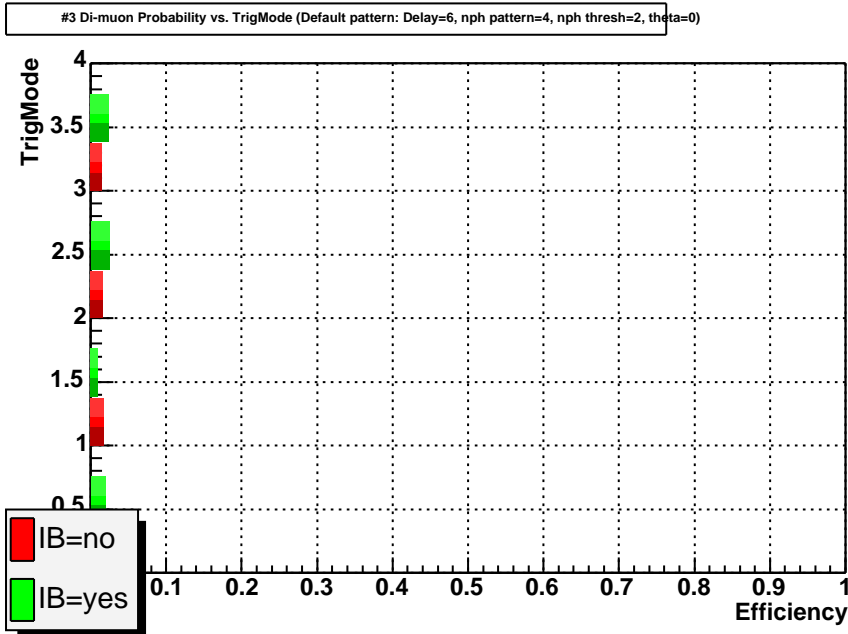
#1 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph pattern=4, nph thresh=2, theta=0)



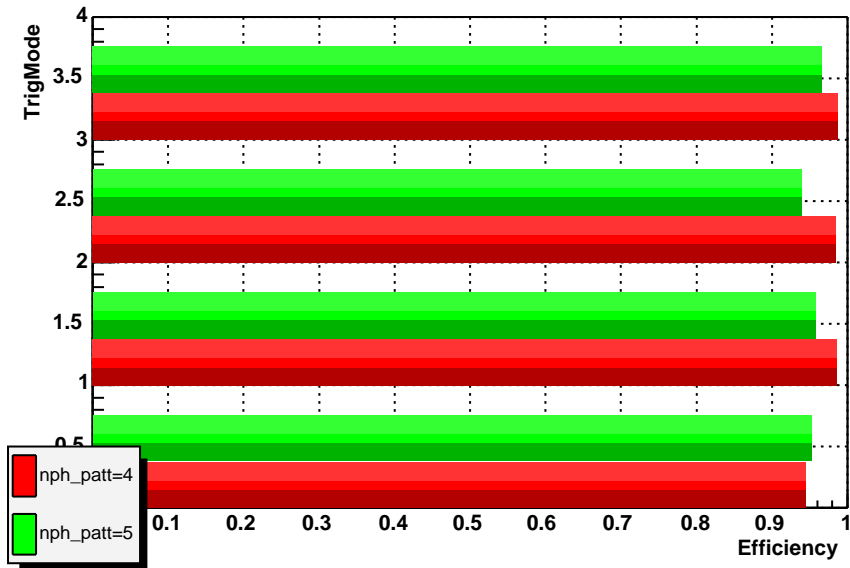
#10 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph pattern=4, nph thresh=2, theta=0)



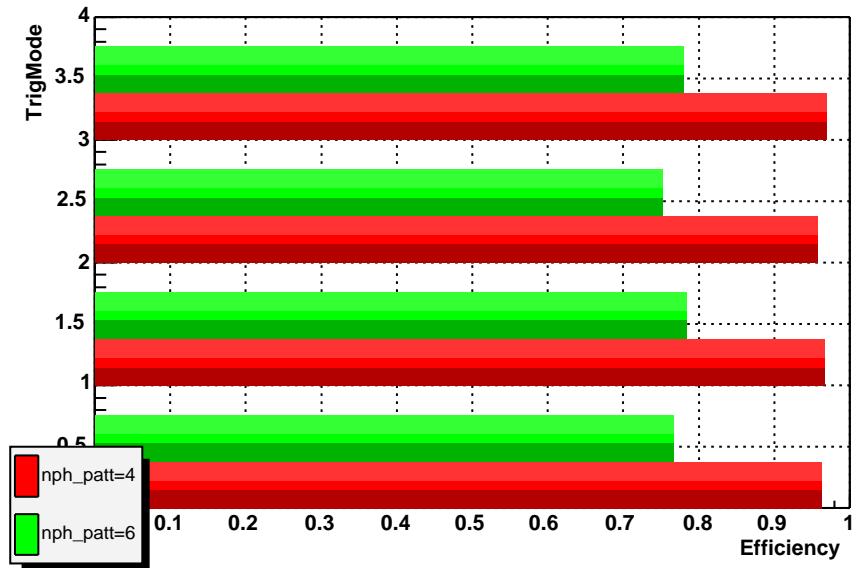




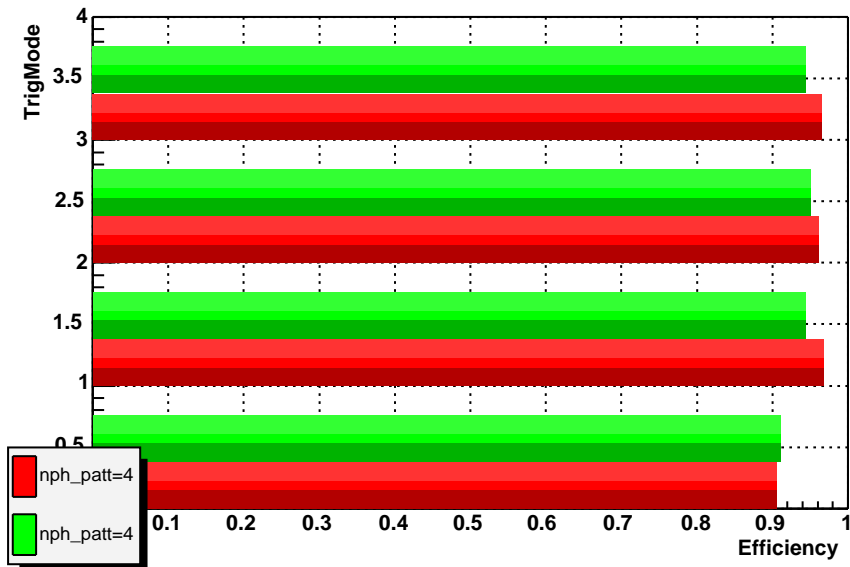
#3 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



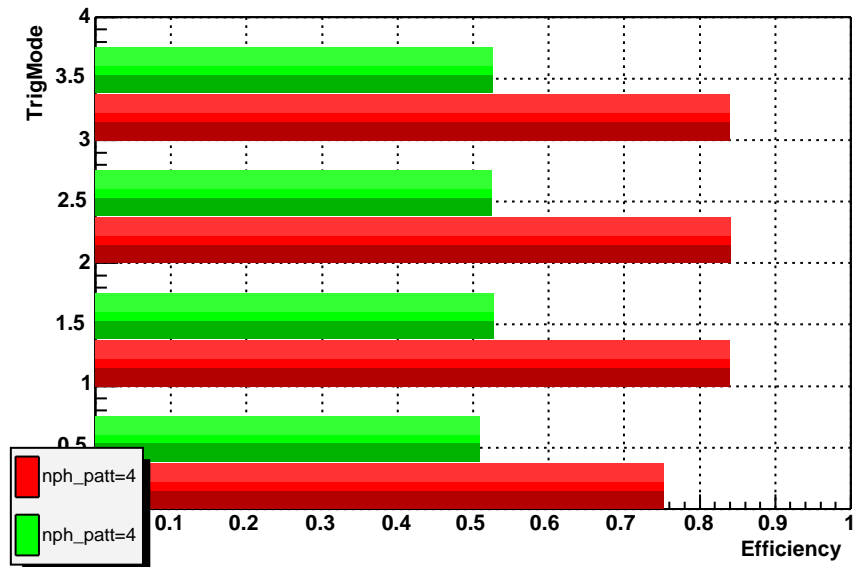
#8 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



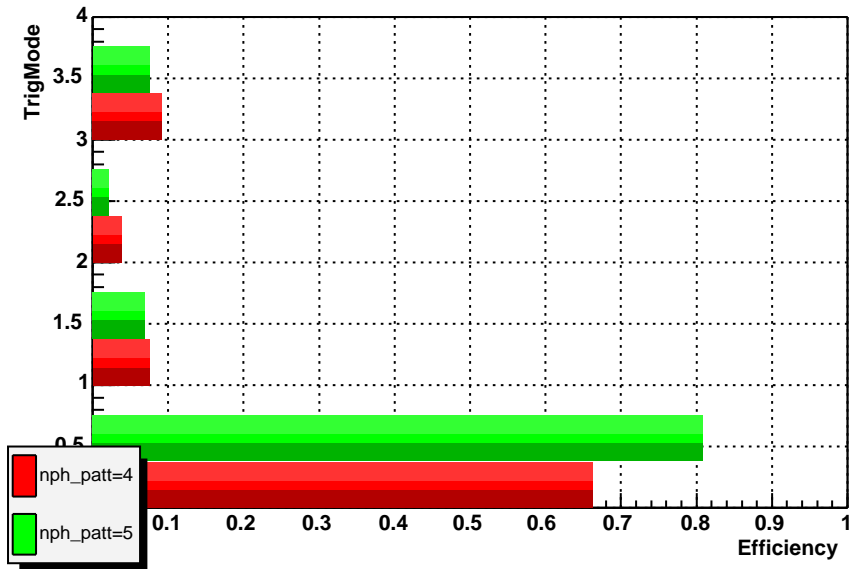
#1 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



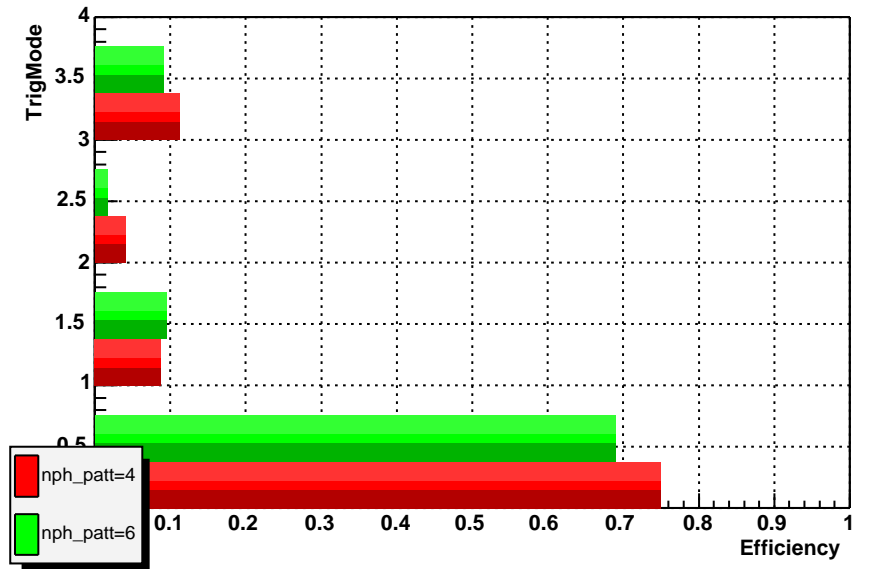
#10 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



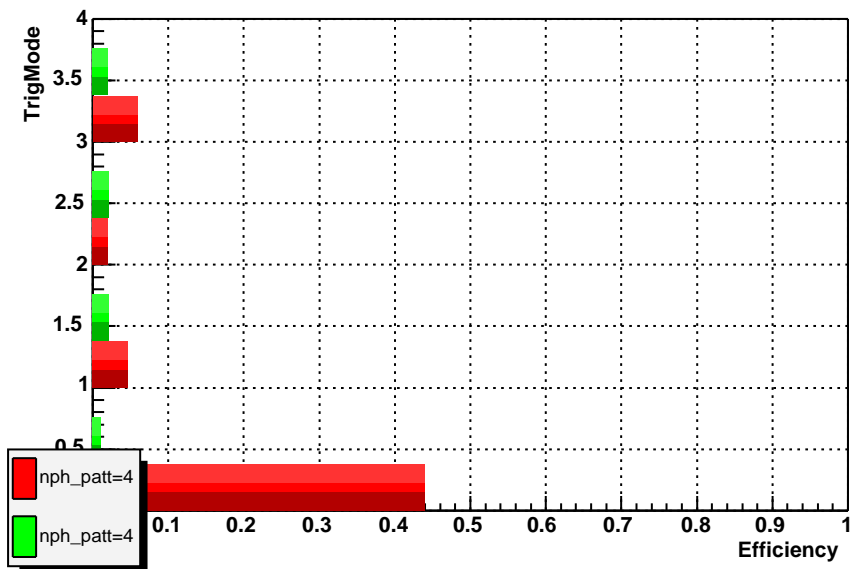
#3 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



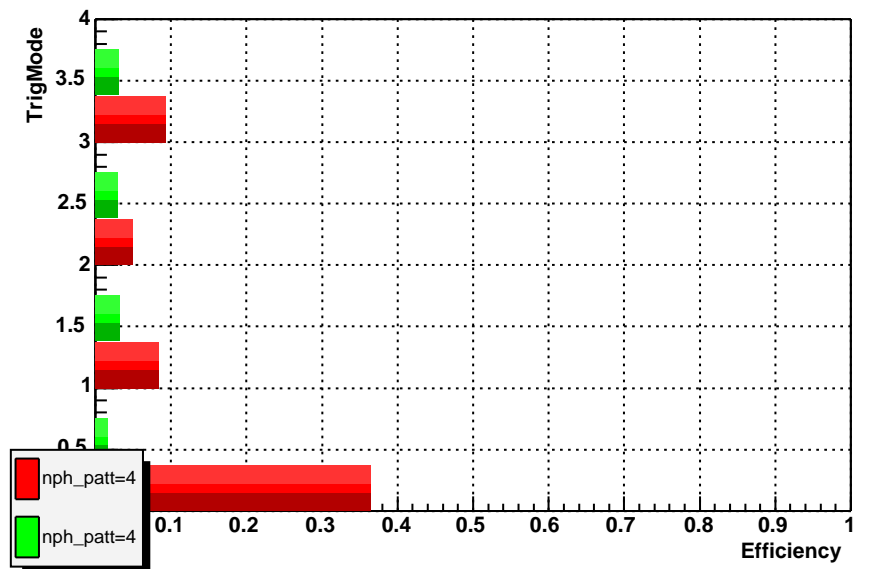
#8 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)

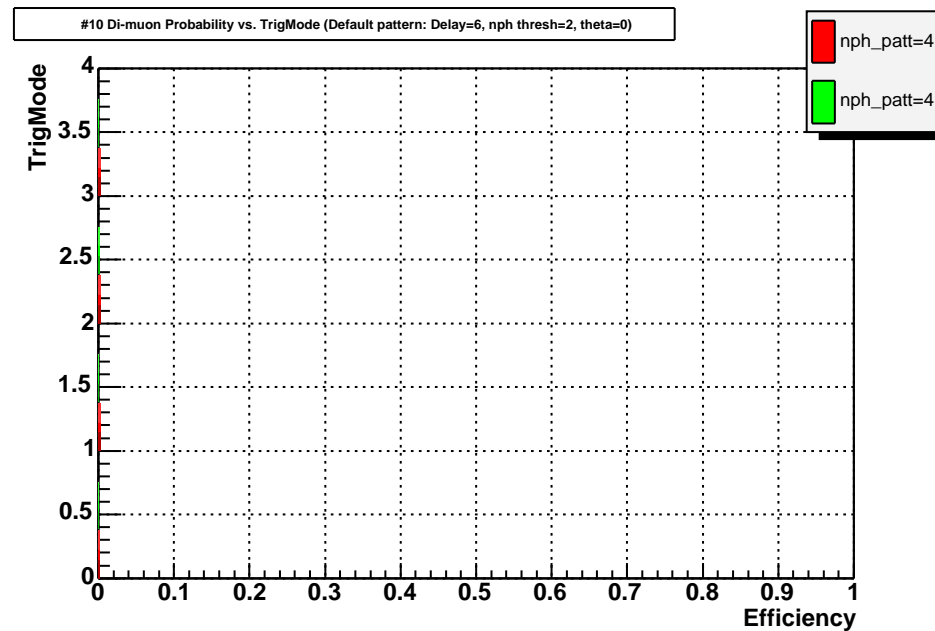
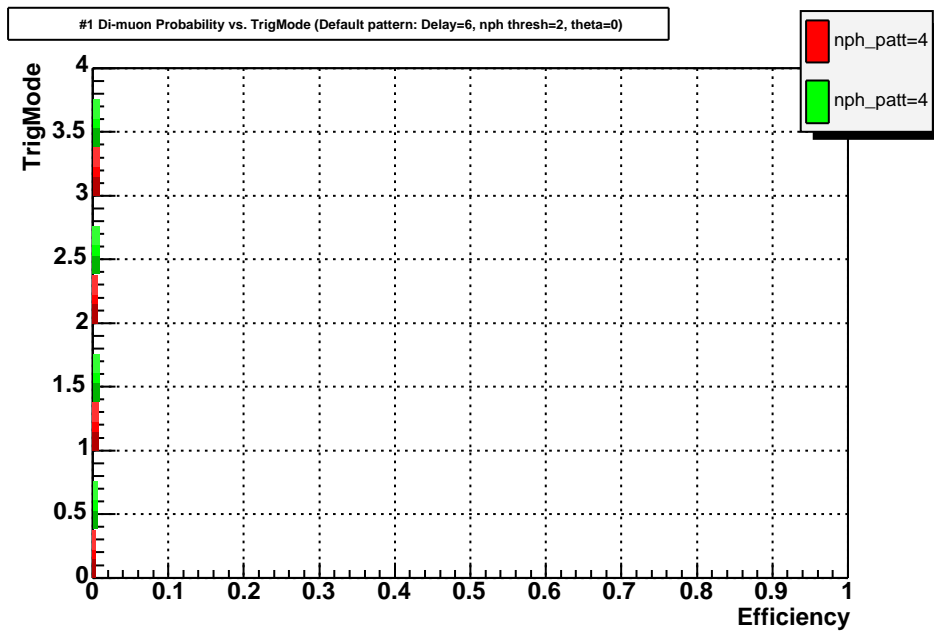
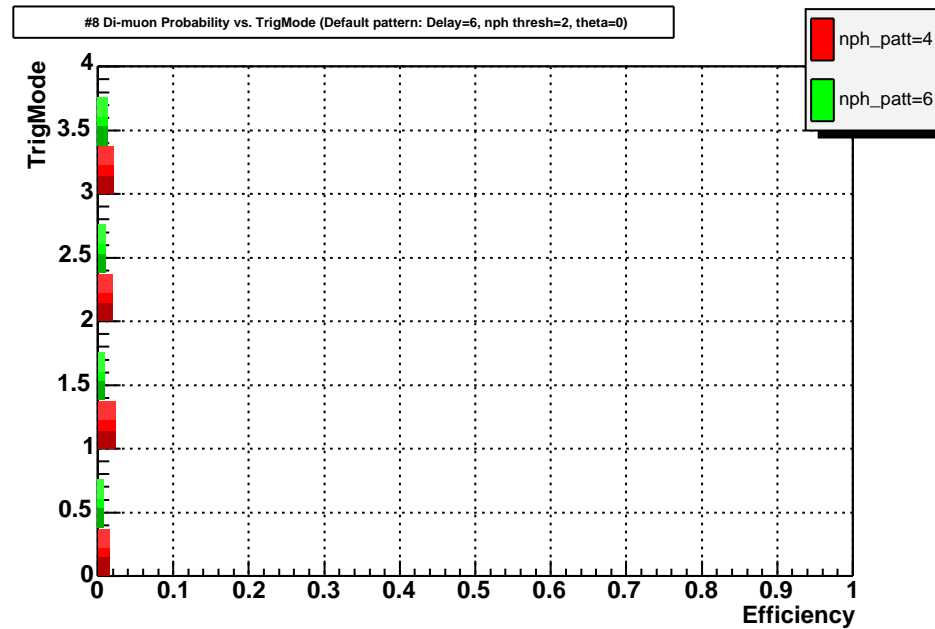
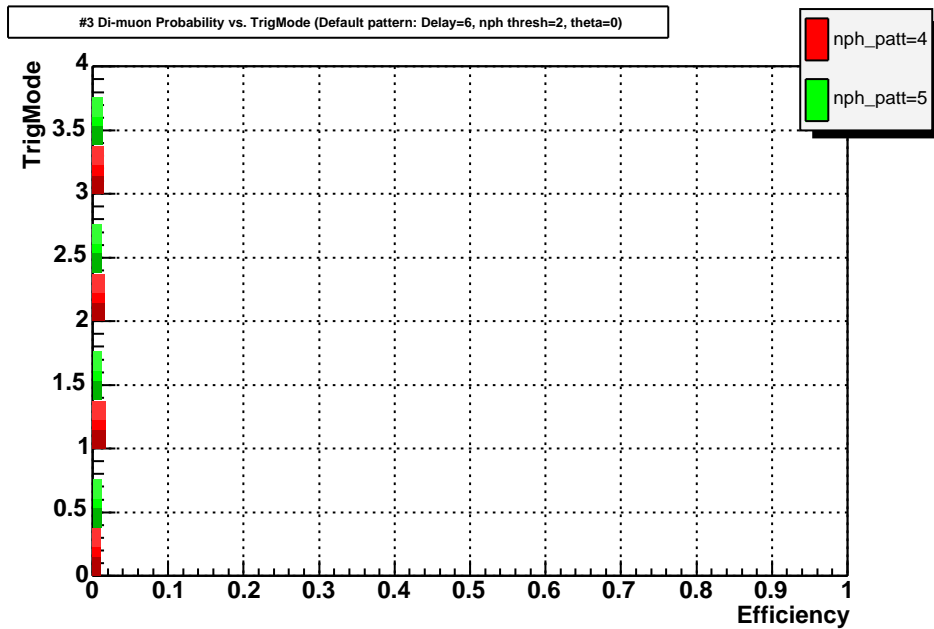


#1 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)

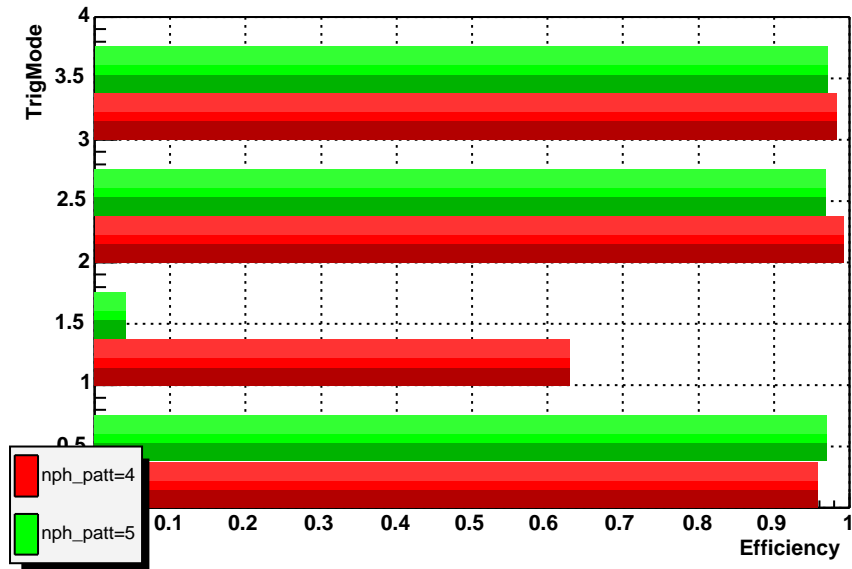


#10 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)

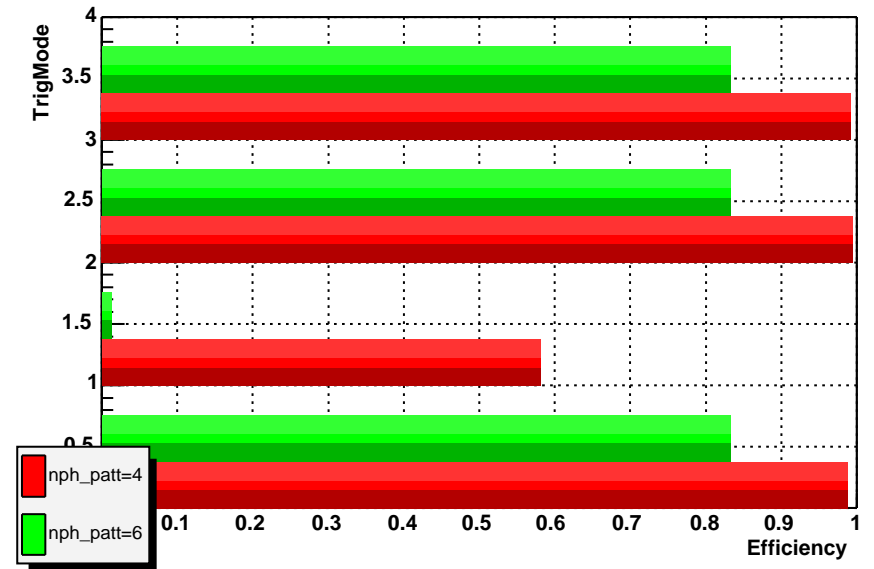




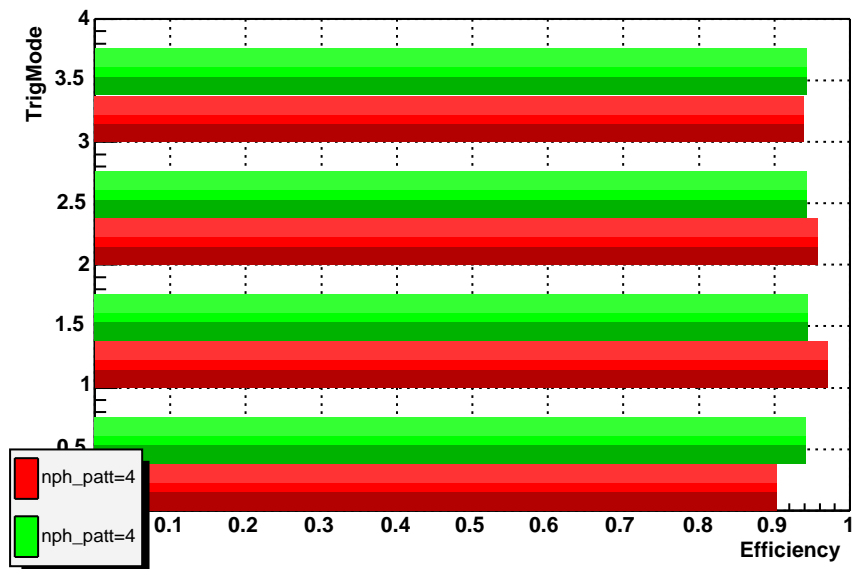
#3 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



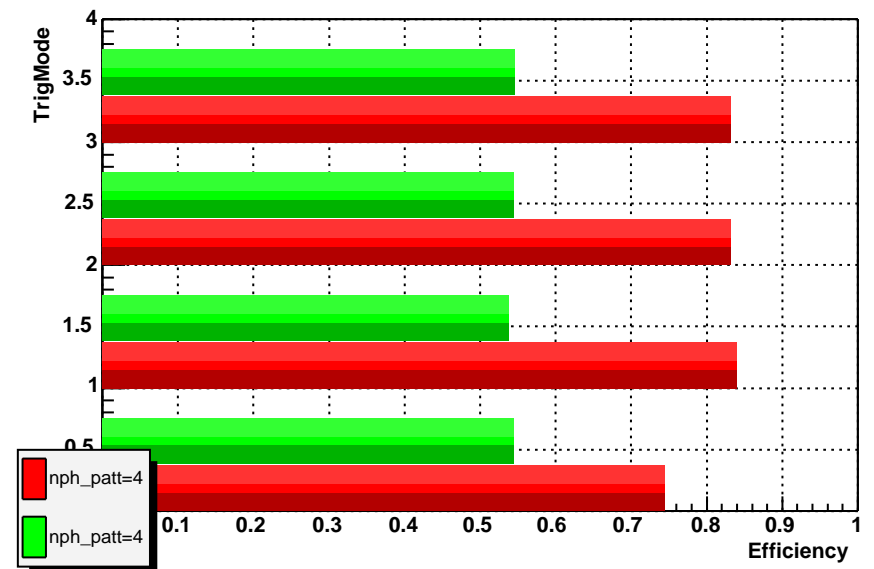
#8 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



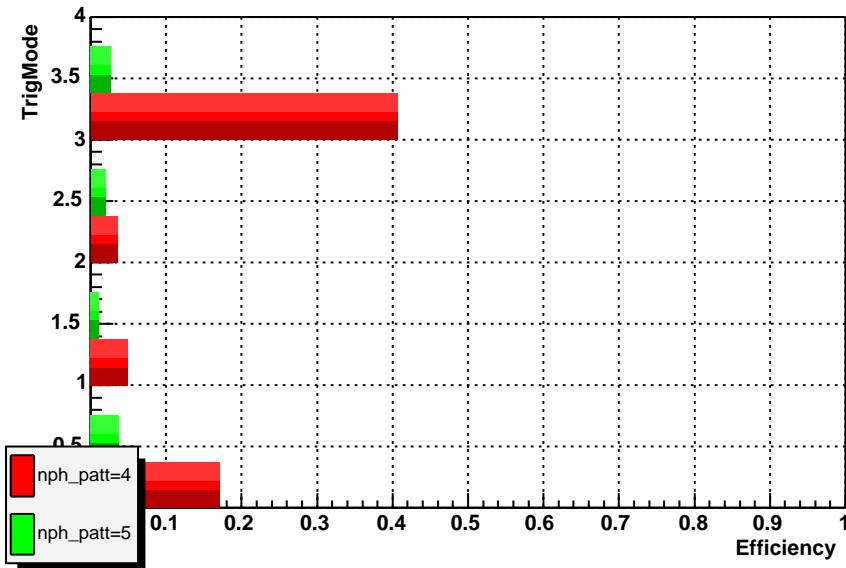
#11 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



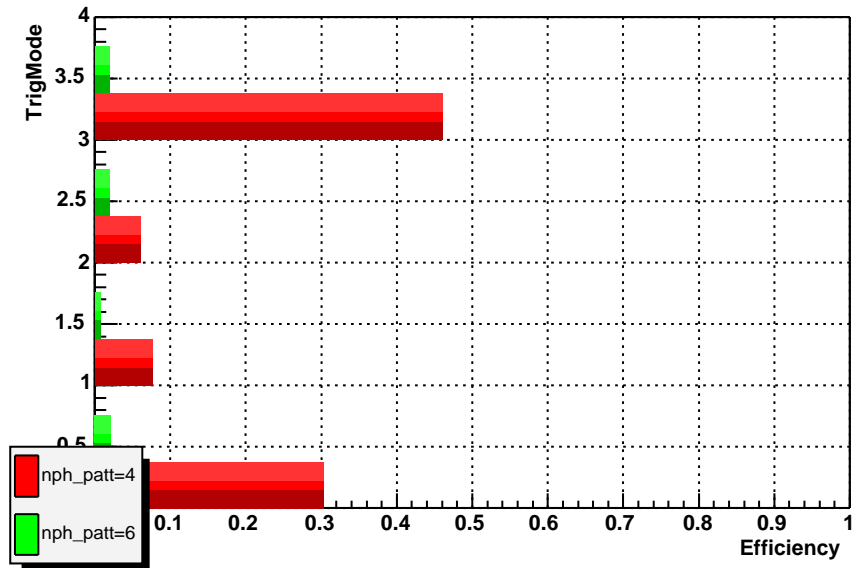
#10 Total Efficiency vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



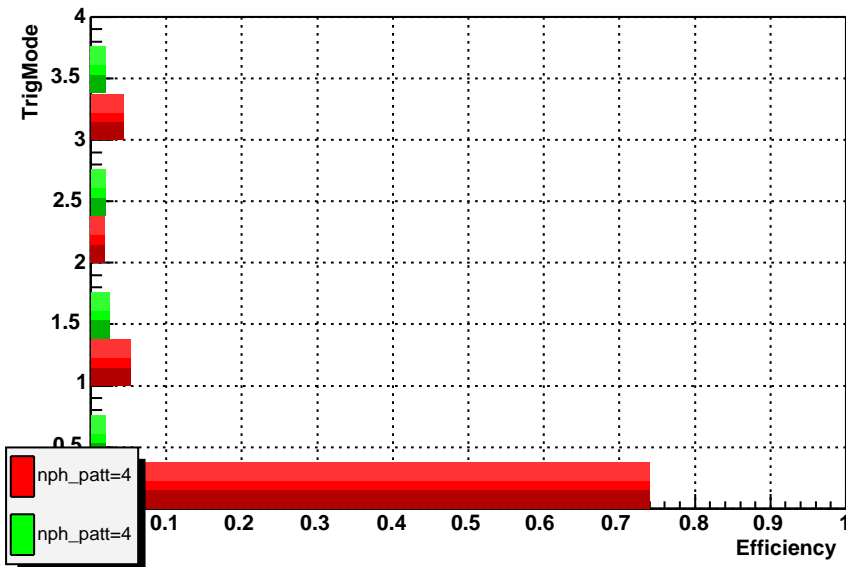
#3 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



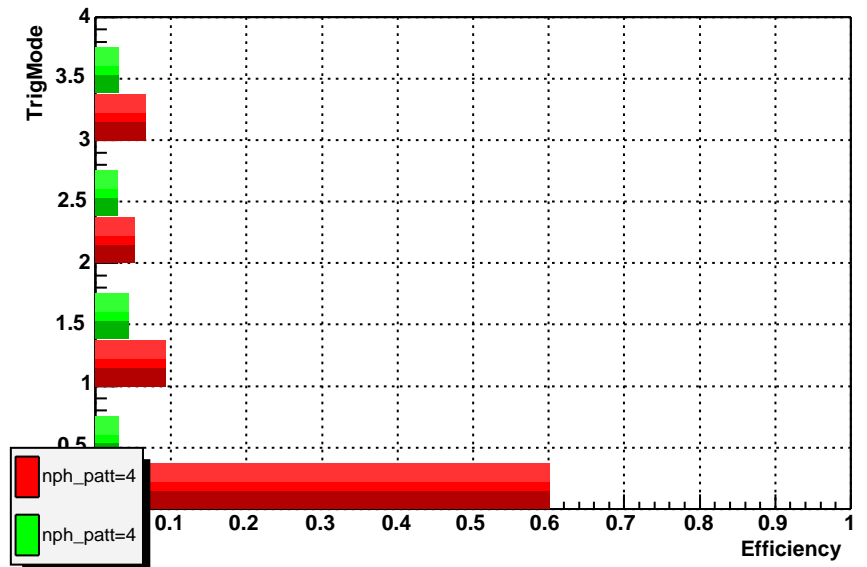
#8 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



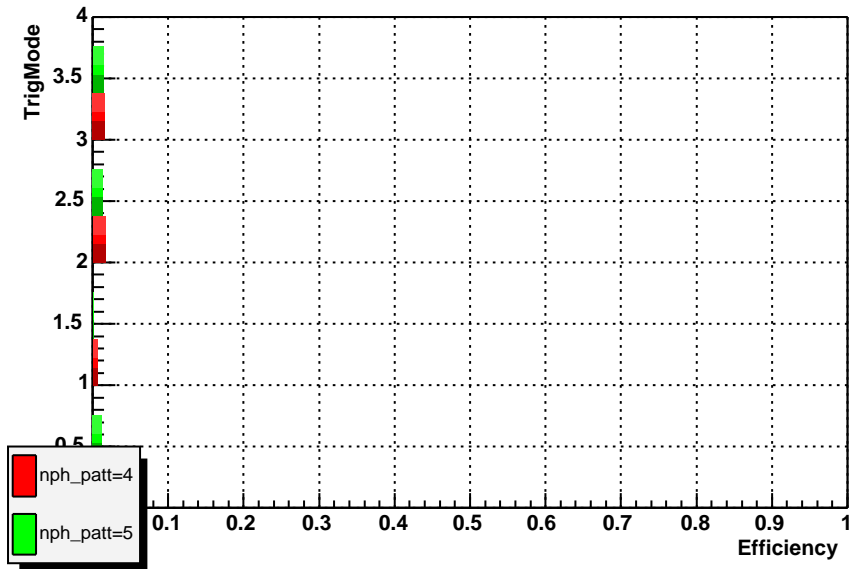
#1 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



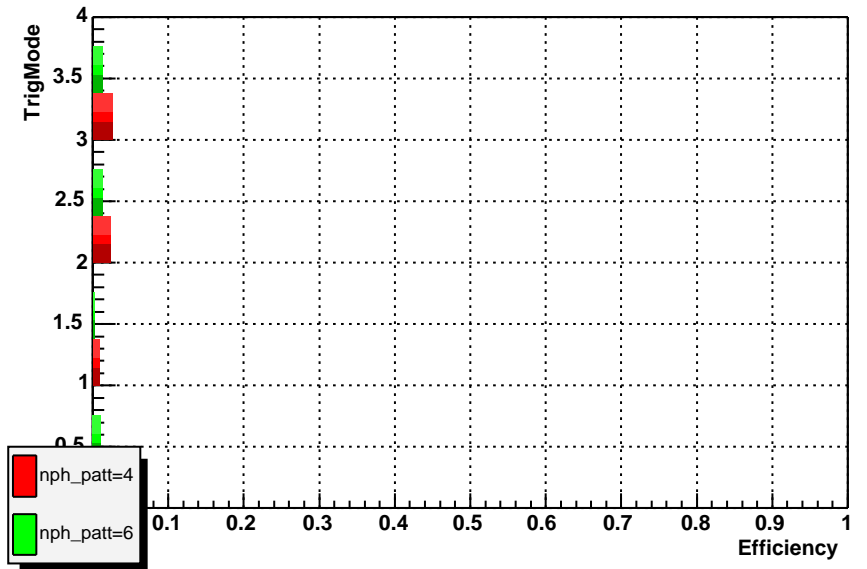
#10 Ghost Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



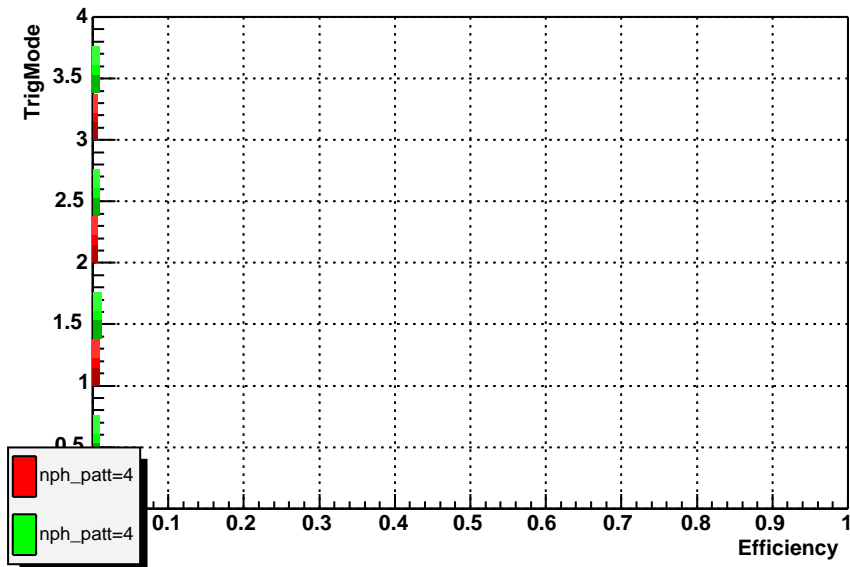
#3 Di-muon Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



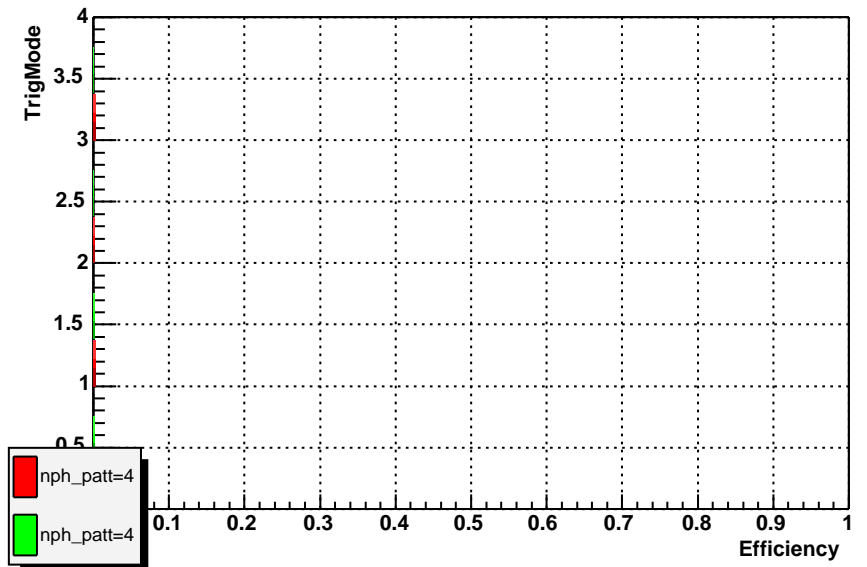
#8 Di-muon Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=28)



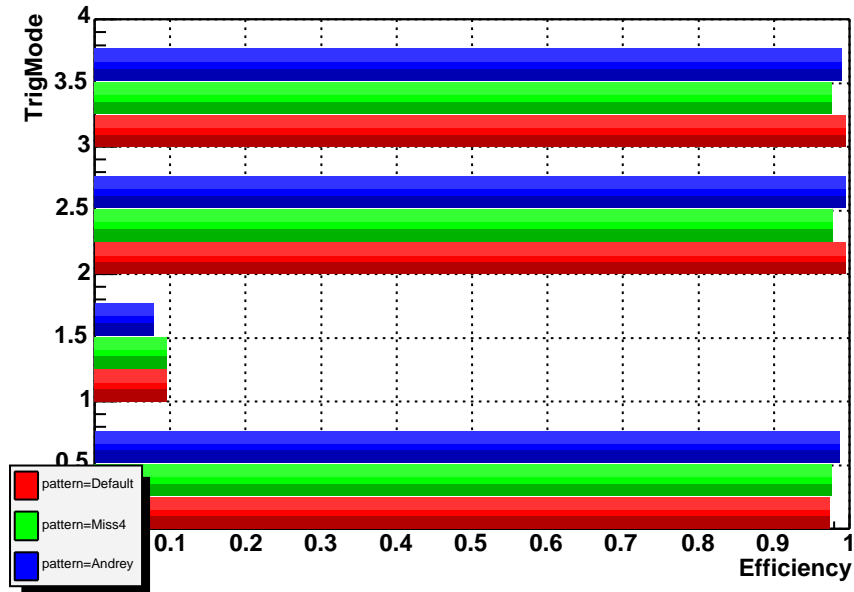
#1 Di-muon Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



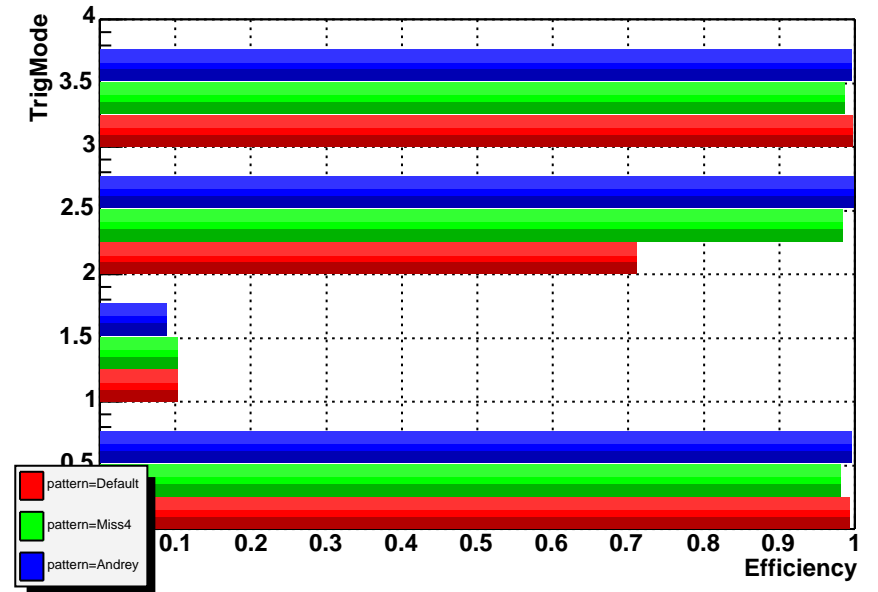
#10 Di-muon Probability vs. TrigMode (Default pattern: Delay=6, nph thresh=2, theta=0)



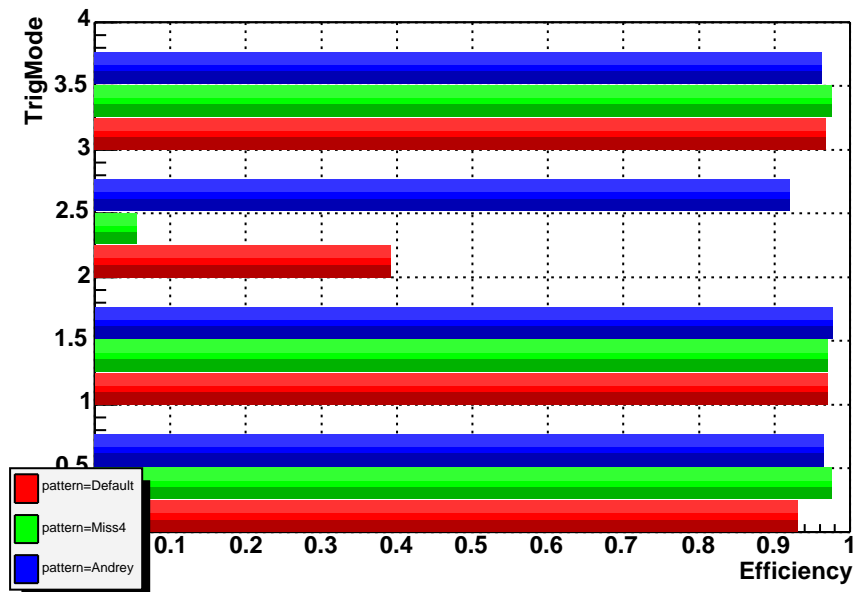
#3 Total Efficiency vs. TrigMode (Delay=6, nph pattern=4, nph thresh=2, theta=35)



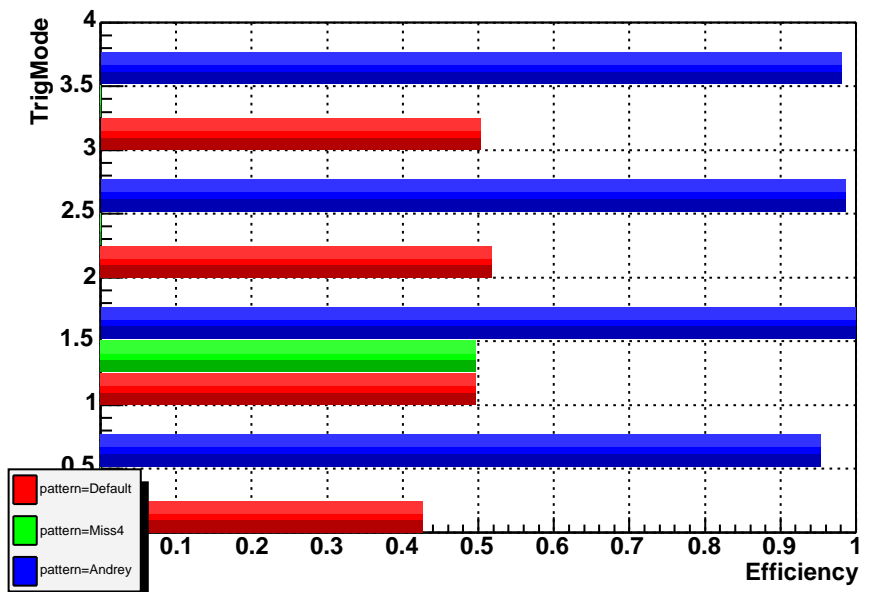
#8 Total Efficiency vs. TrigMode (Delay=6, nph pattern=4, nph thresh=2, theta=35)



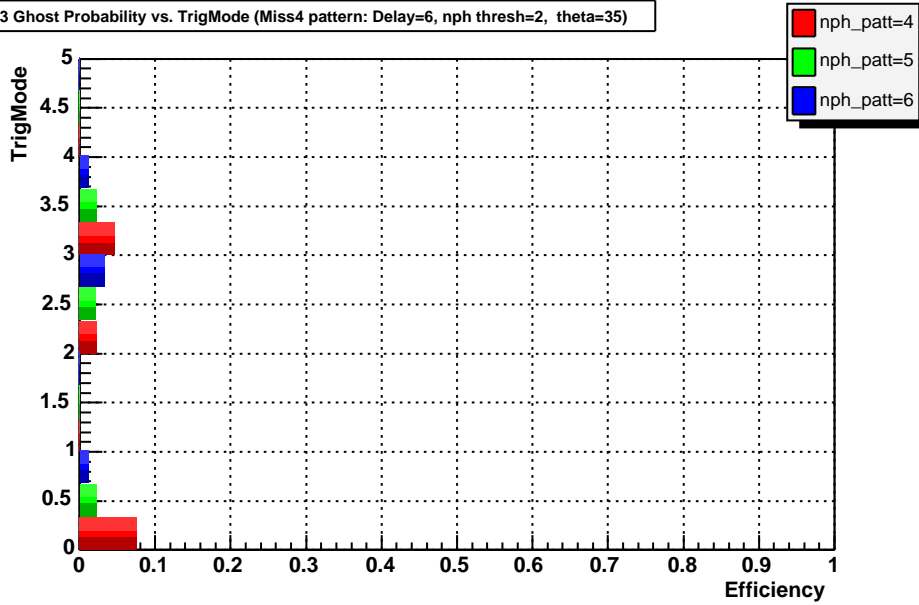
#1 Total Efficiency vs. TrigMode (Delay=6, nph pattern=4, nph thresh=2, theta=35)



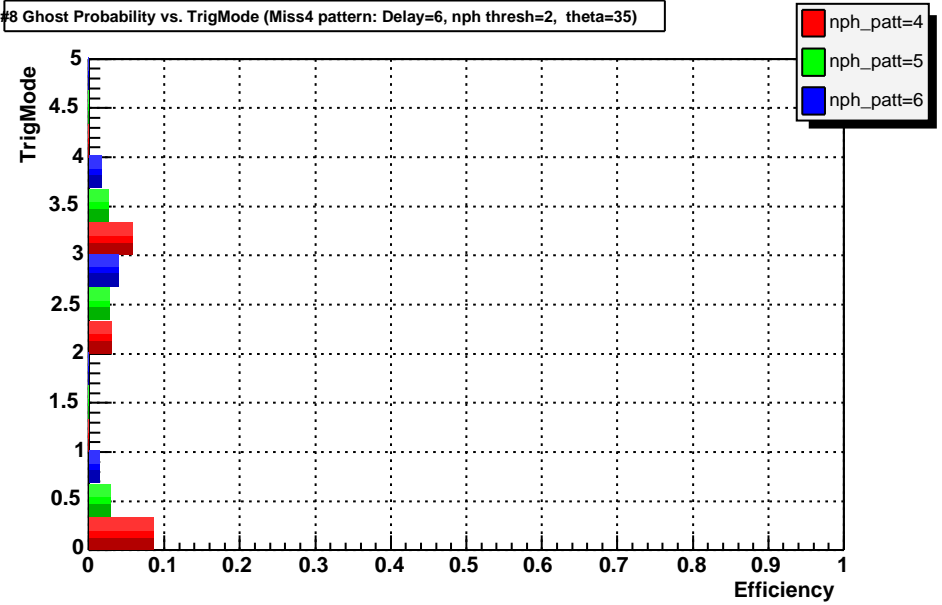
#10 Total Efficiency vs. TrigMode (Delay=6, nph pattern=4, nph thresh=2, theta=35)



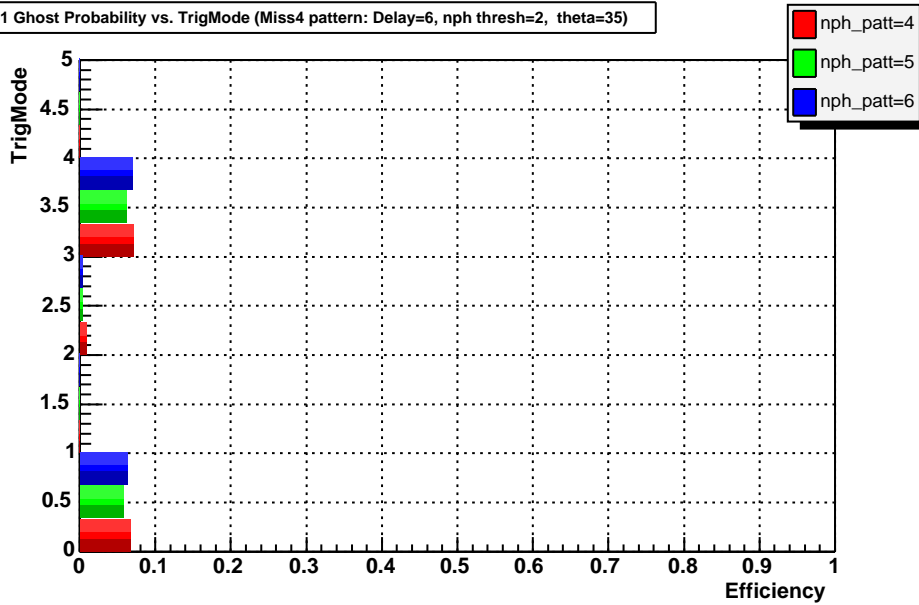
#3 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



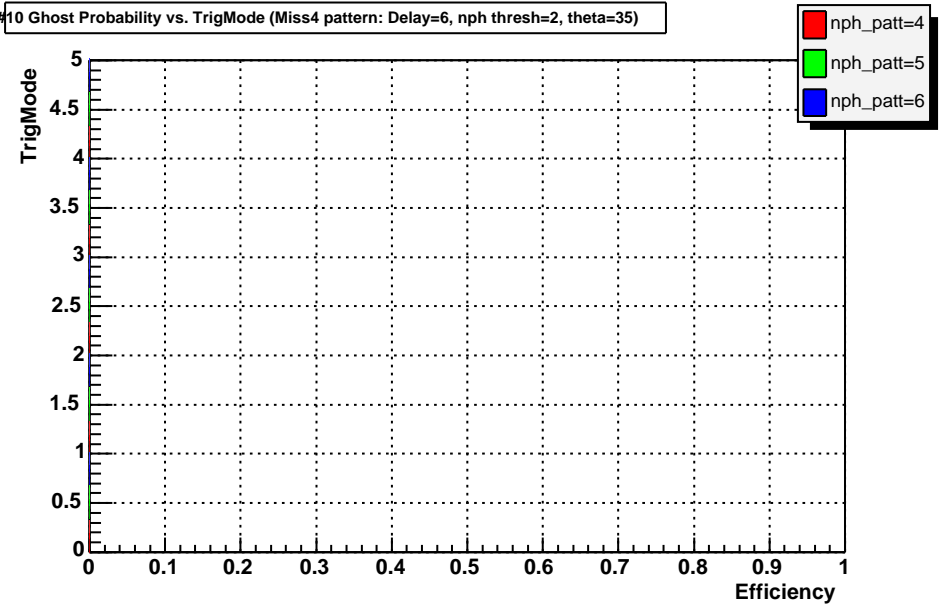
#8 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

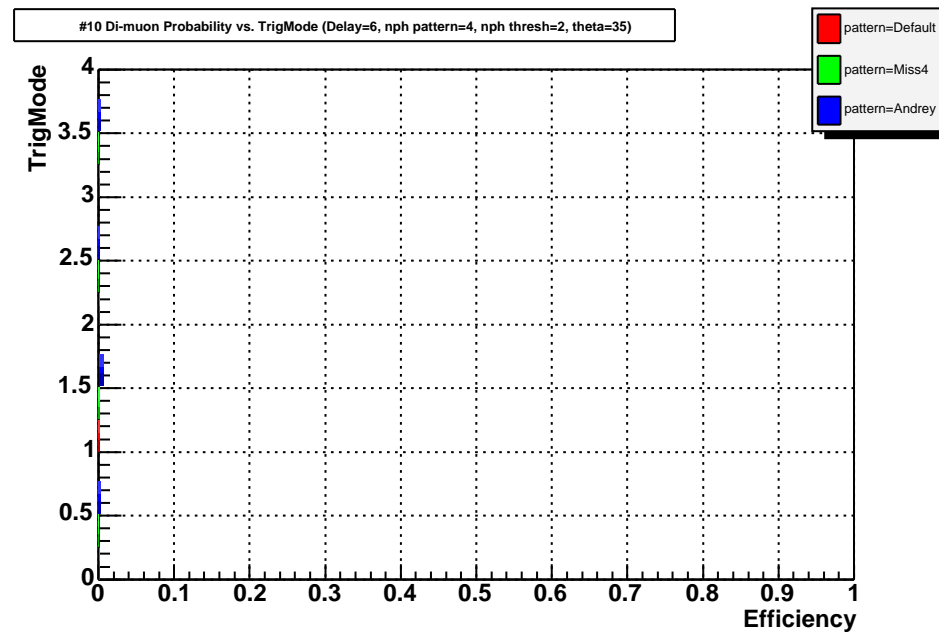
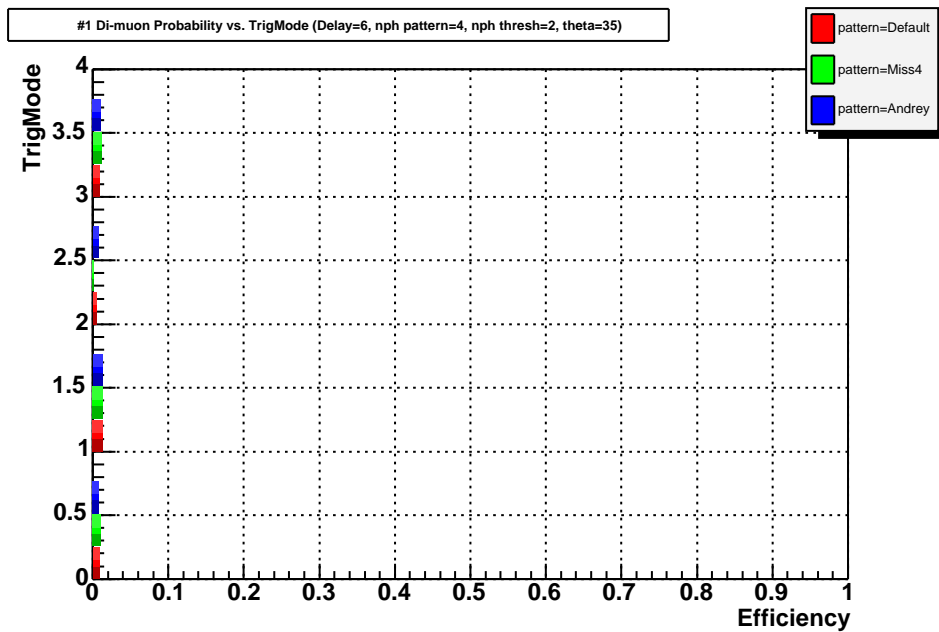
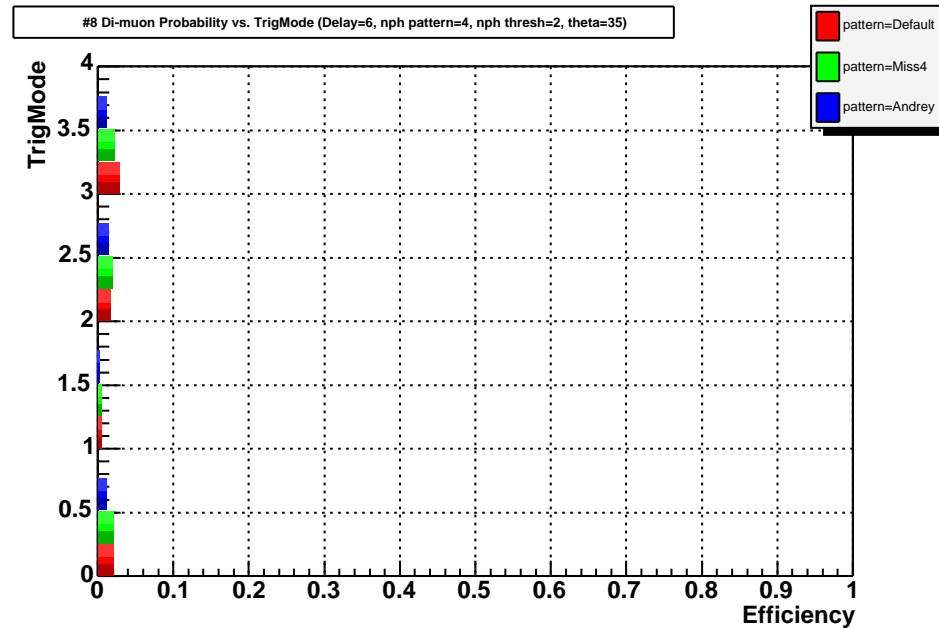
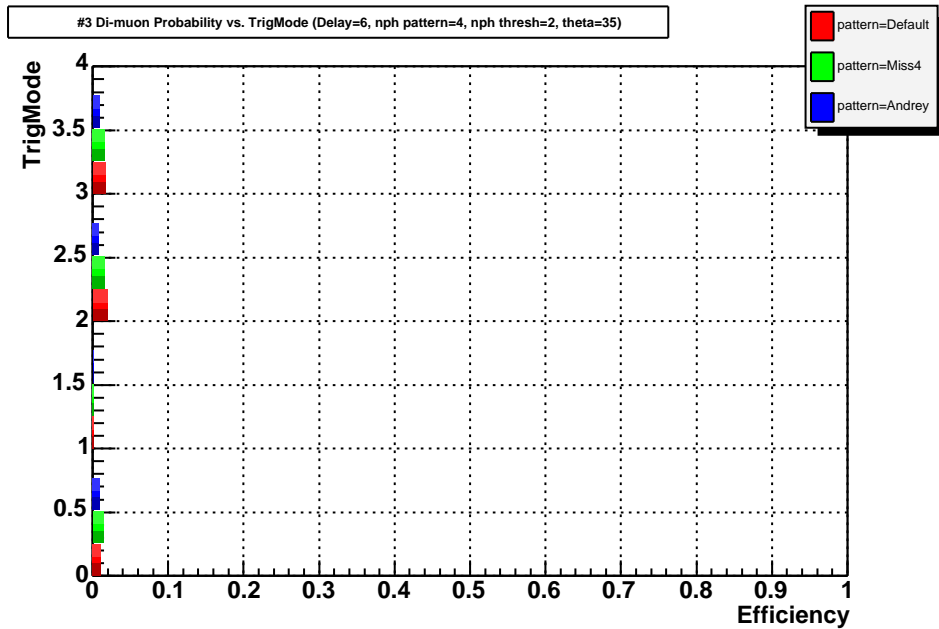


#1 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

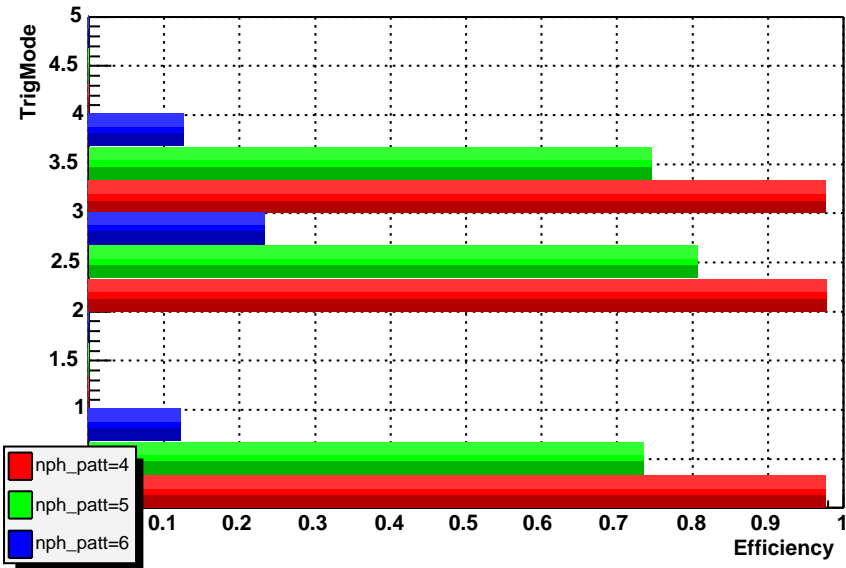


#10 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

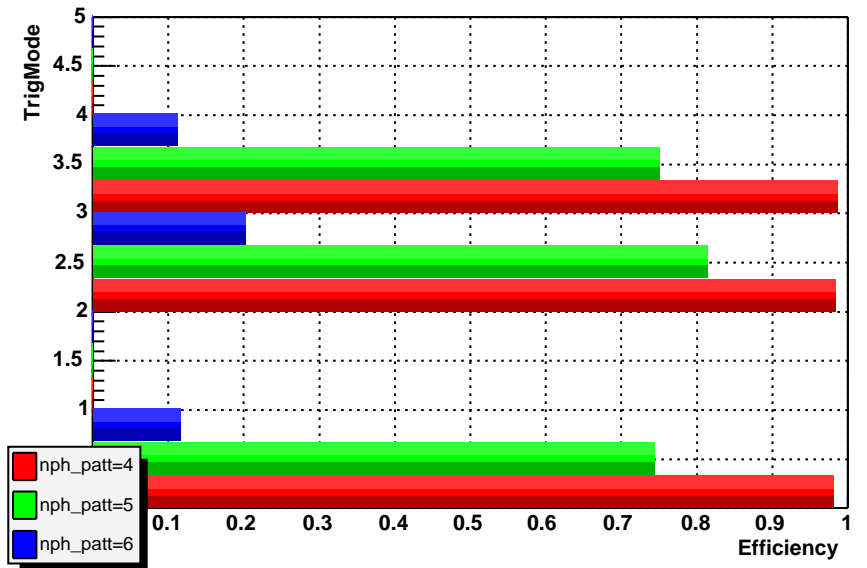




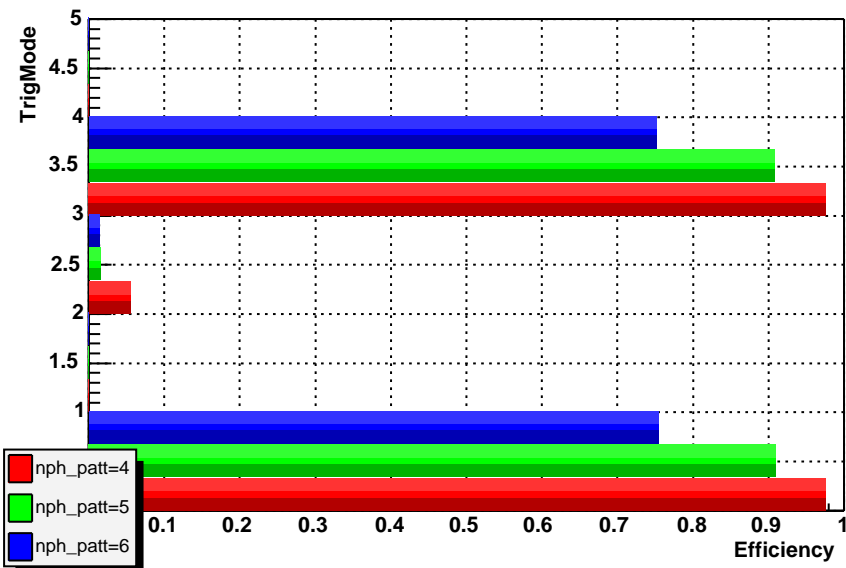
#3 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



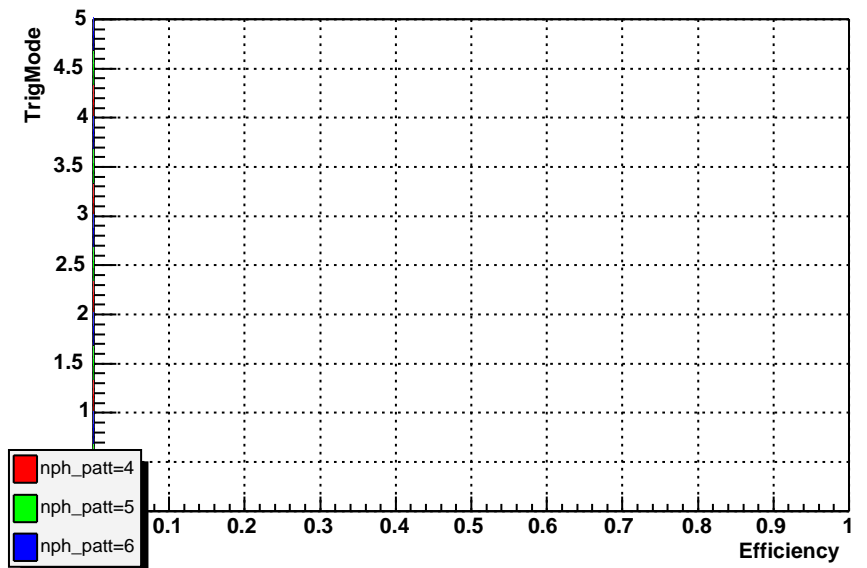
#8 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



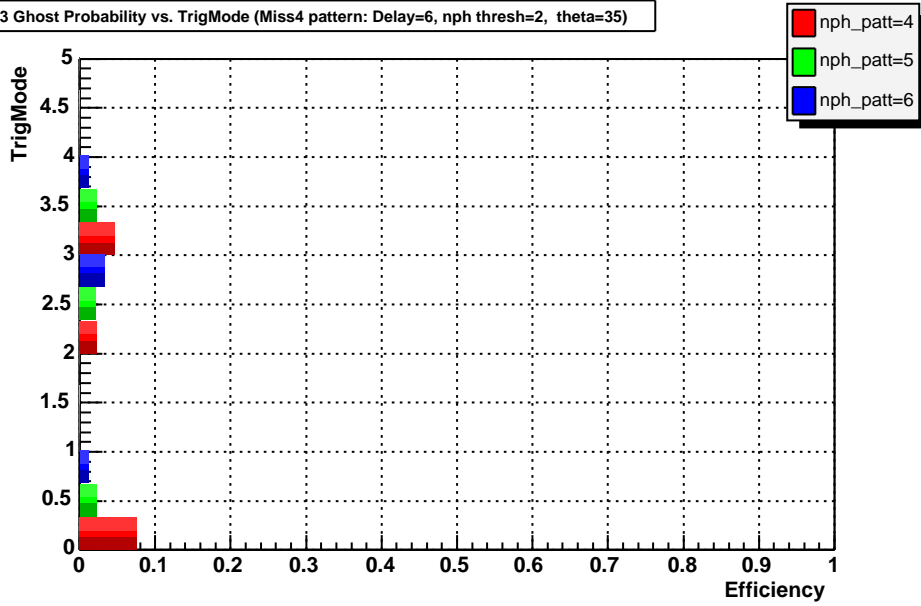
#1 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



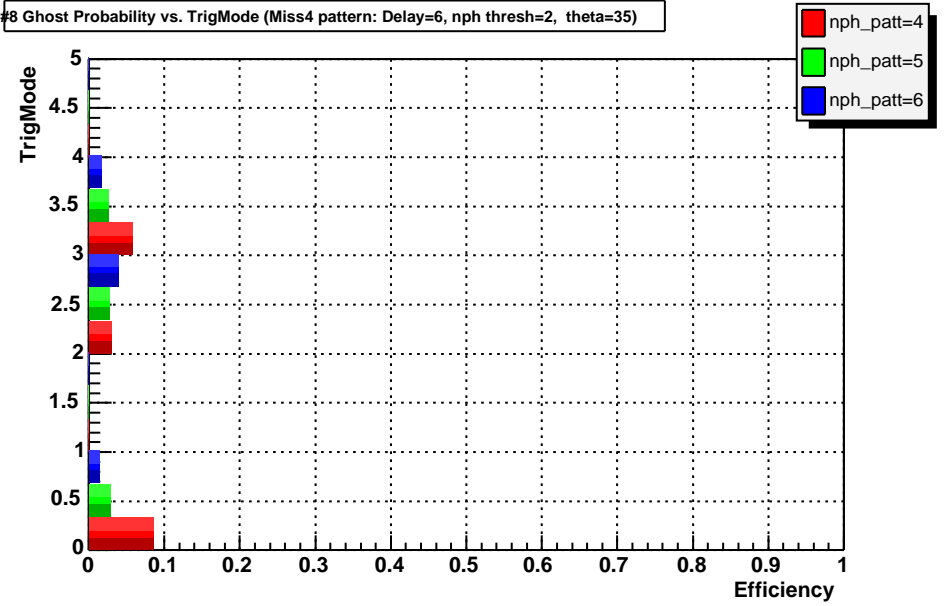
#10 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



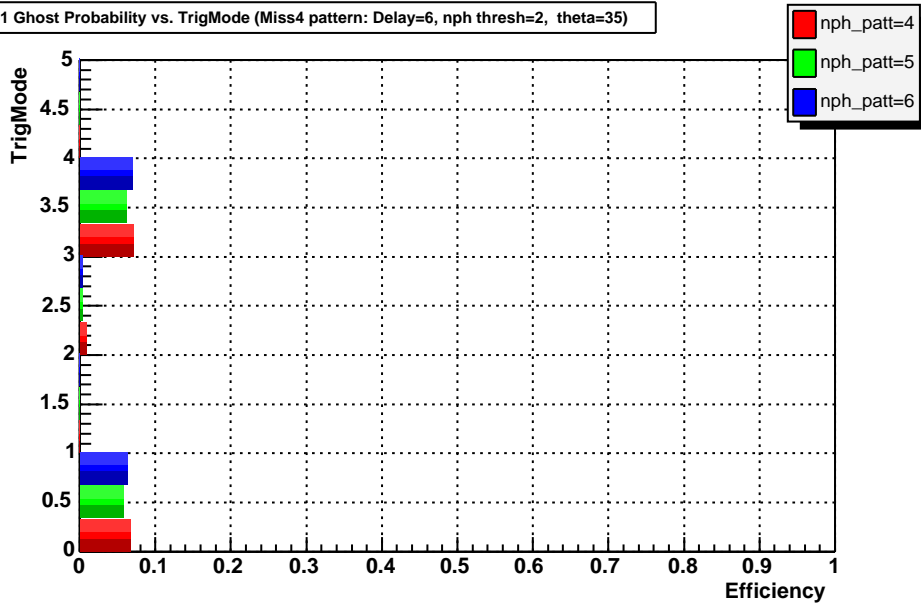
#3 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)



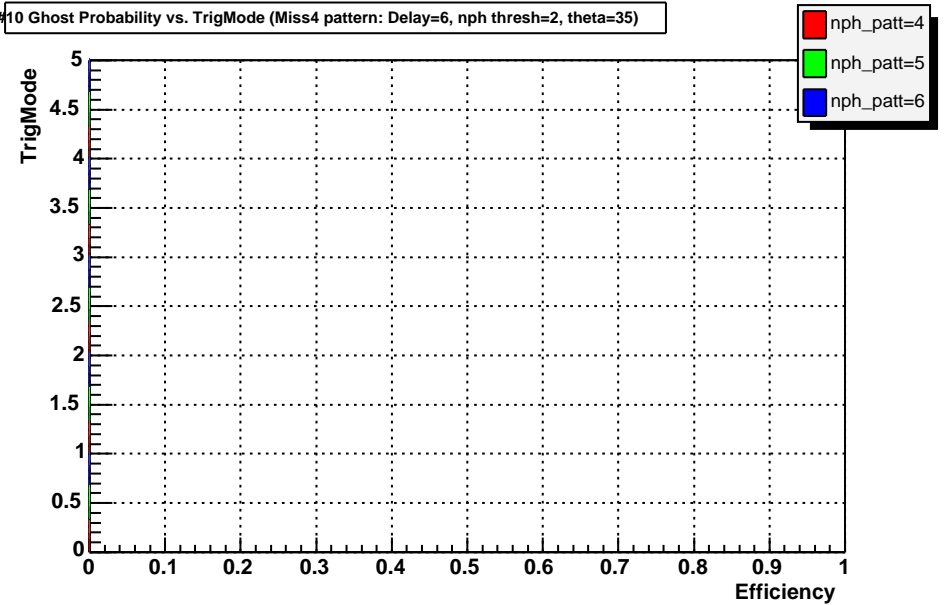
#8 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

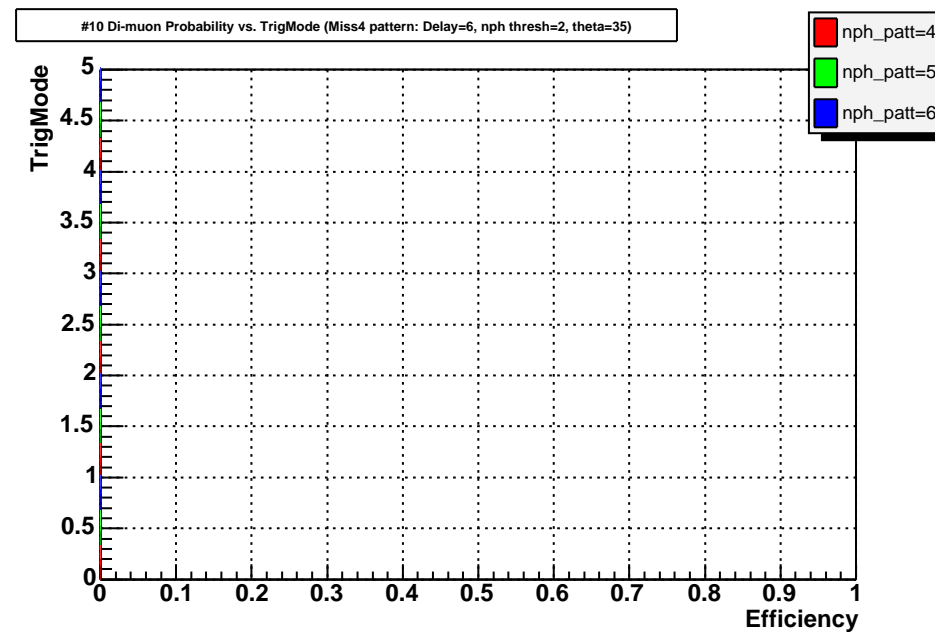
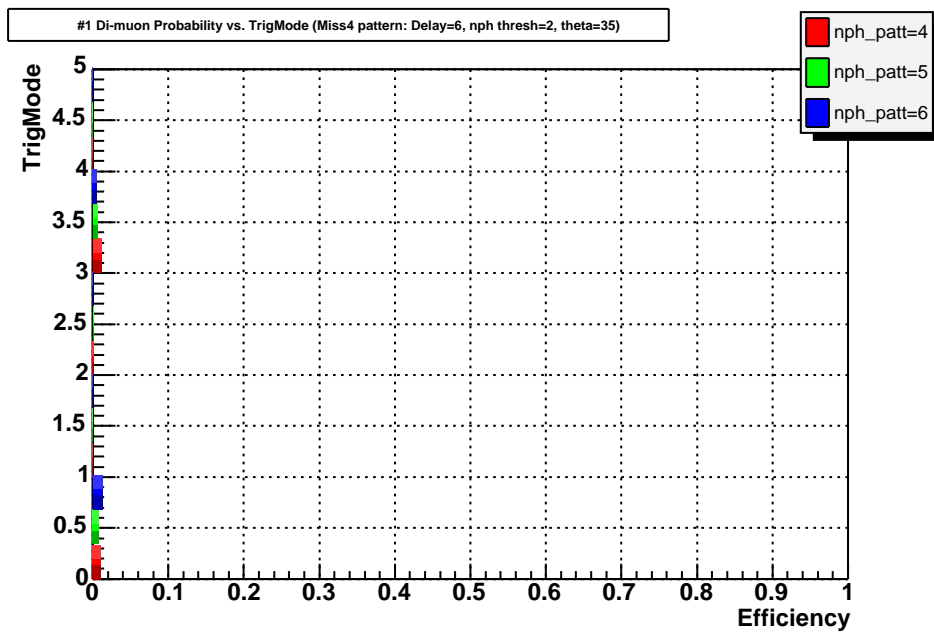
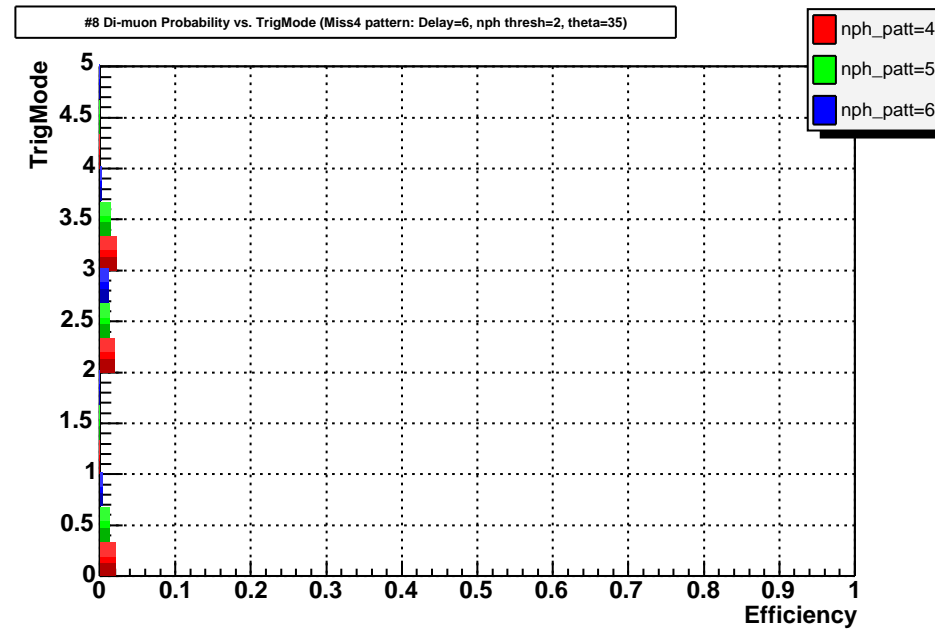
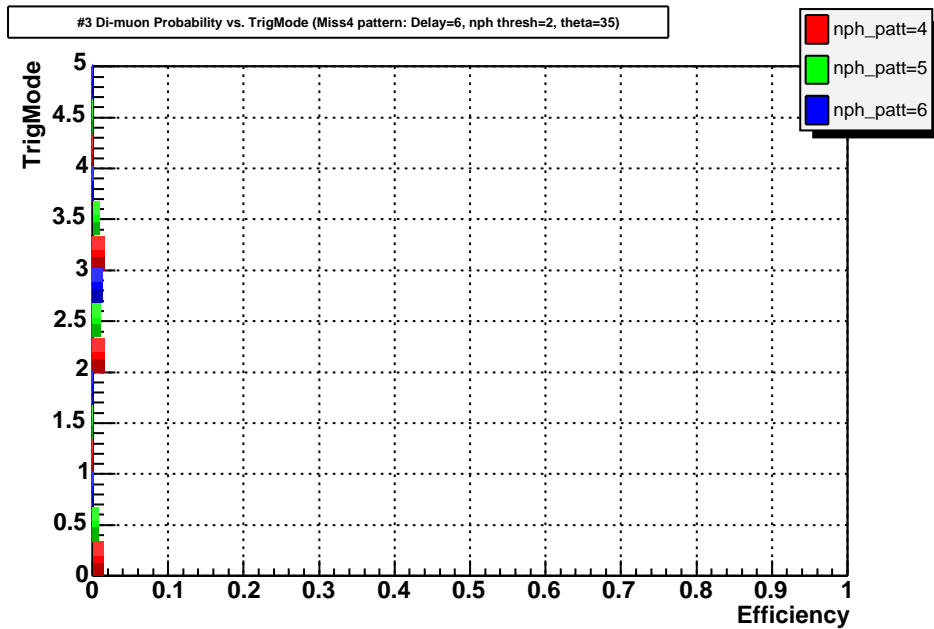


#1 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

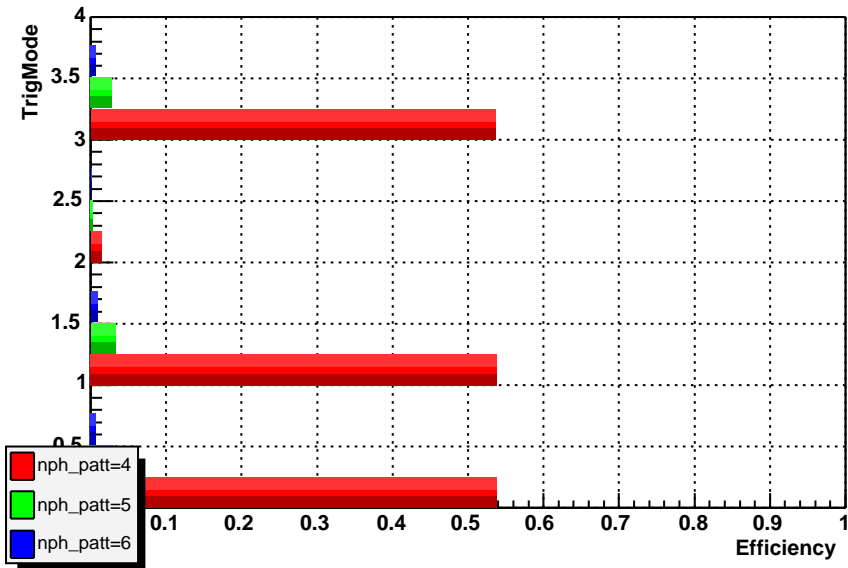


#10 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=35)

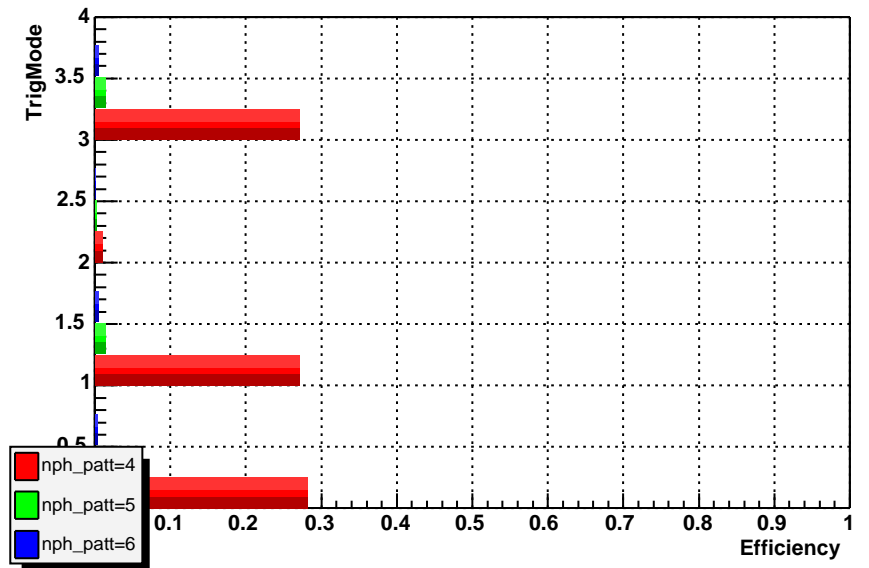




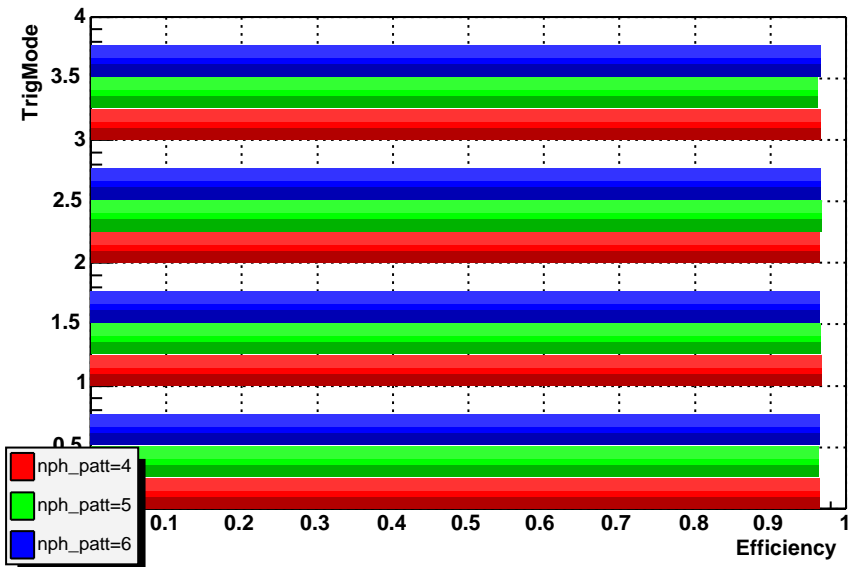
#3 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



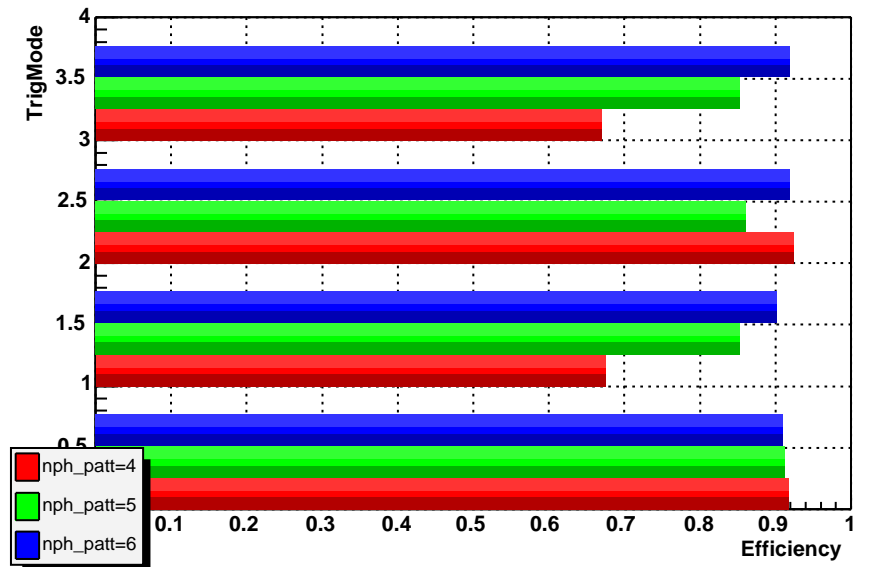
#8 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



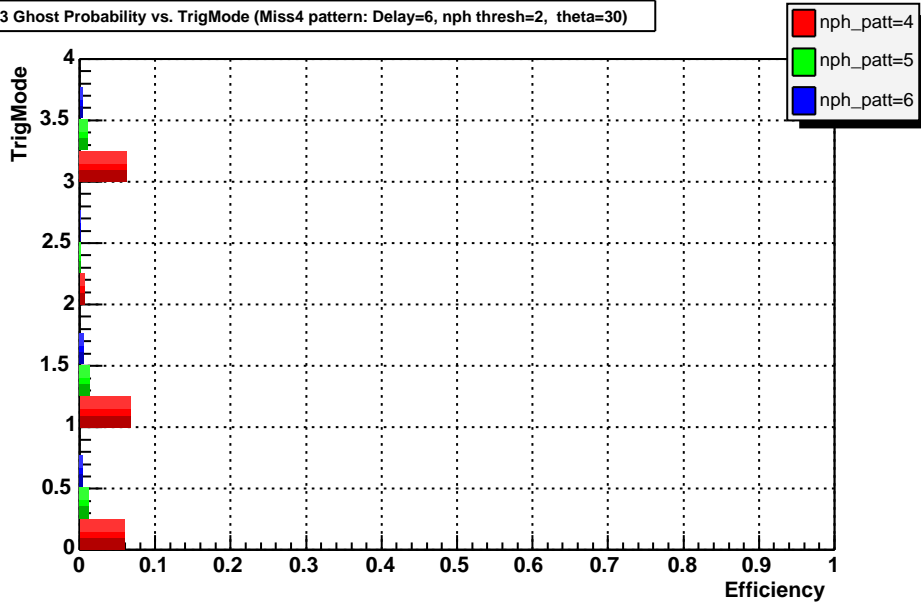
#1 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



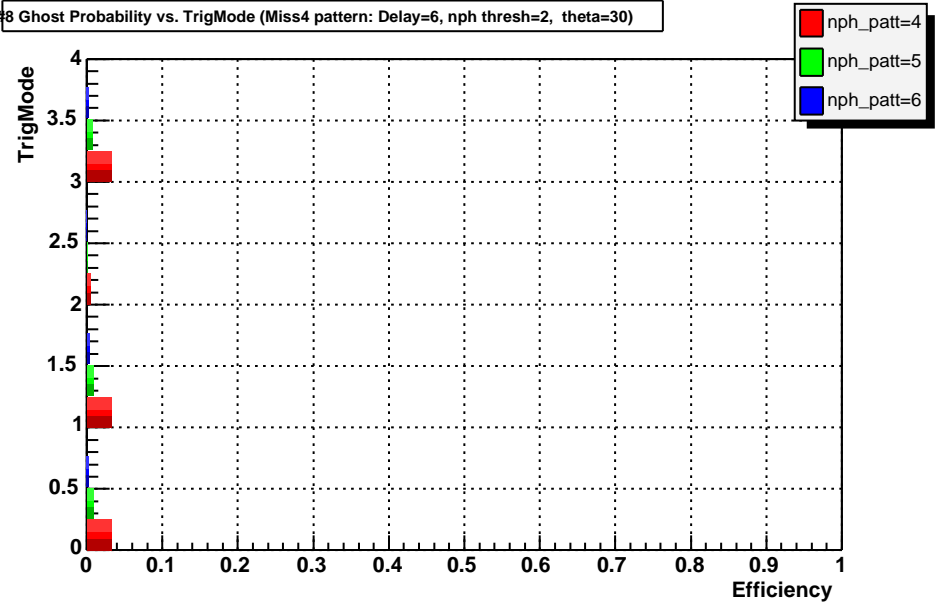
#10 Total Efficiency vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



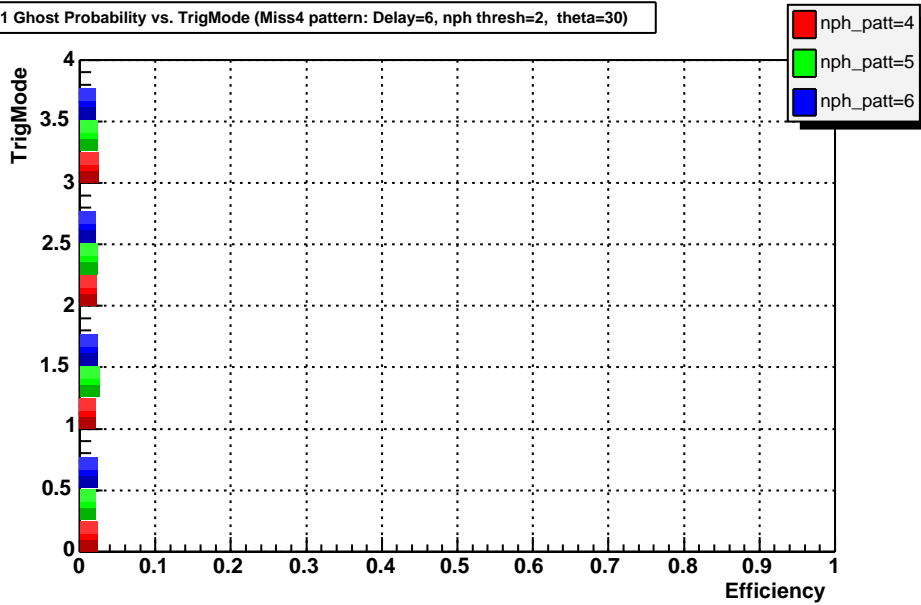
#3 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



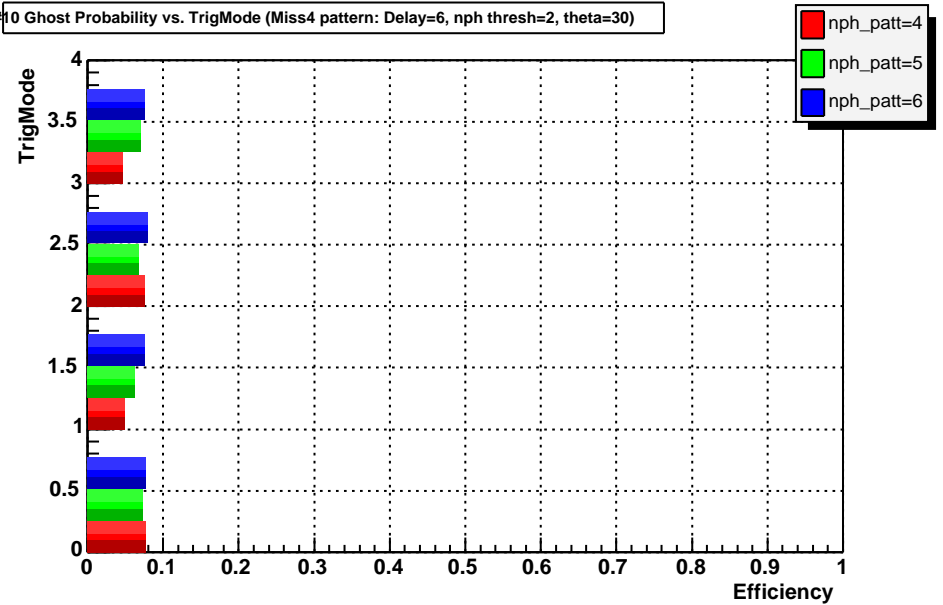
#8 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



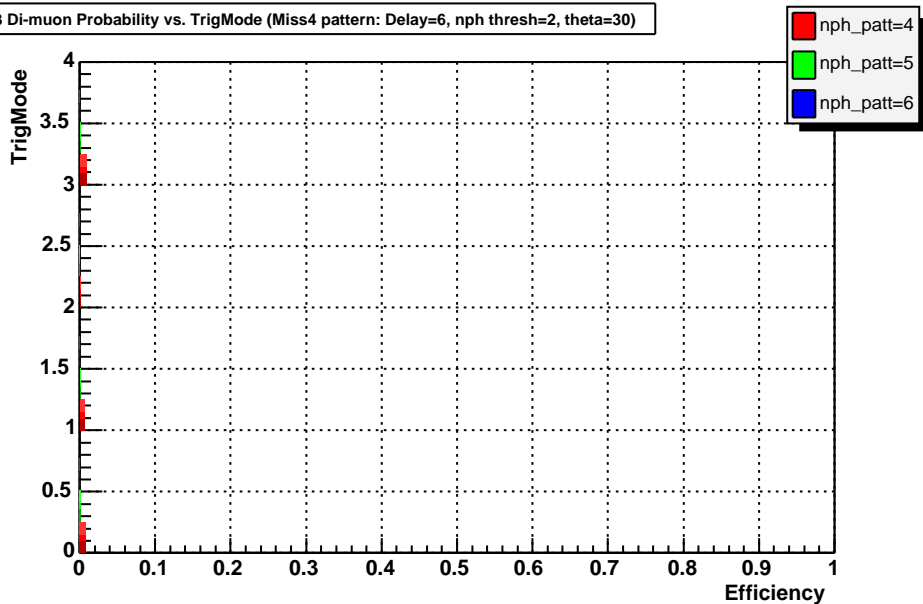
#1 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



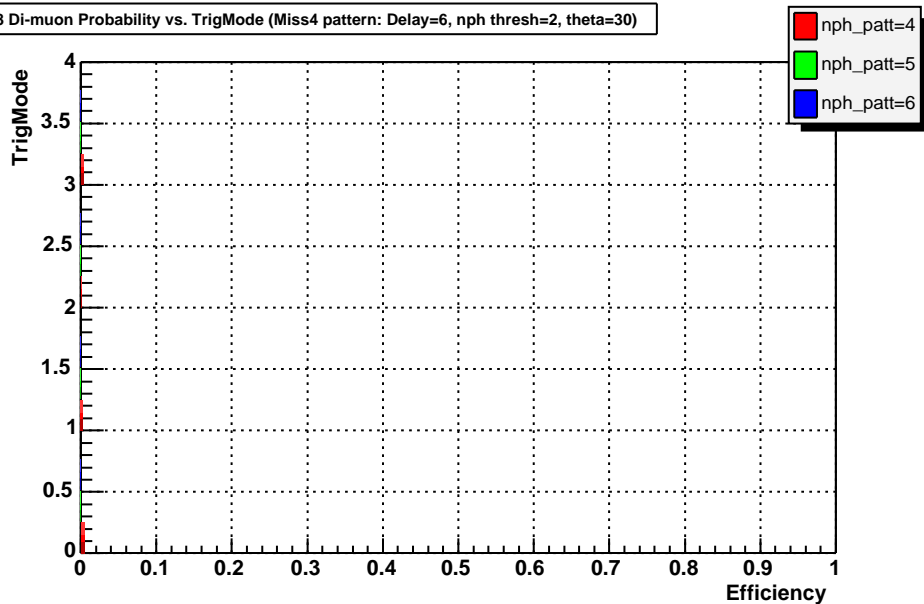
#10 Ghost Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



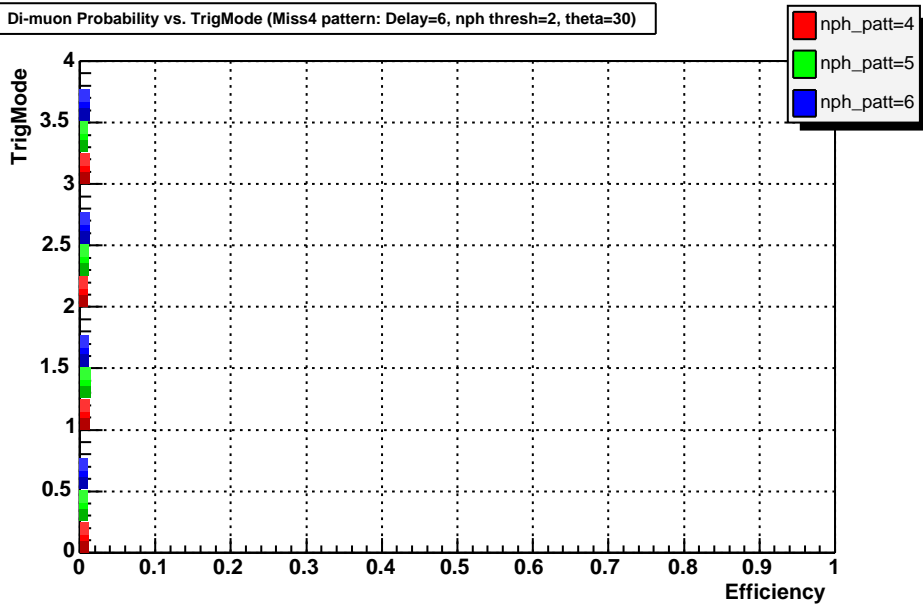
#3 Di-muon Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



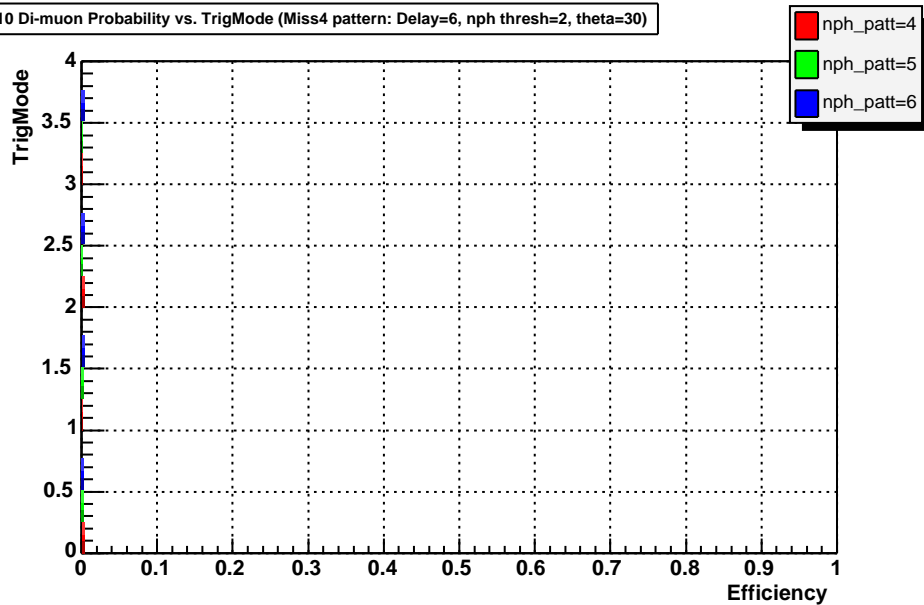
#8 Di-muon Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



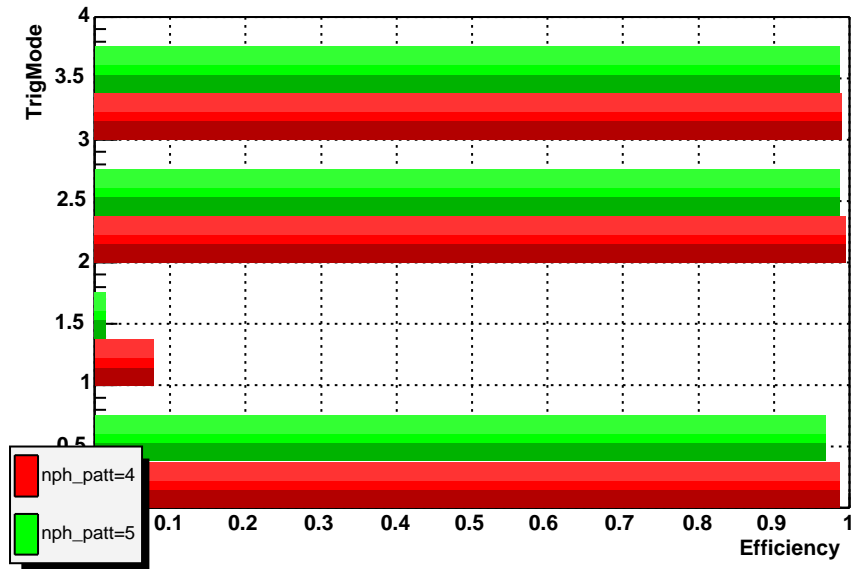
#1 Di-muon Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



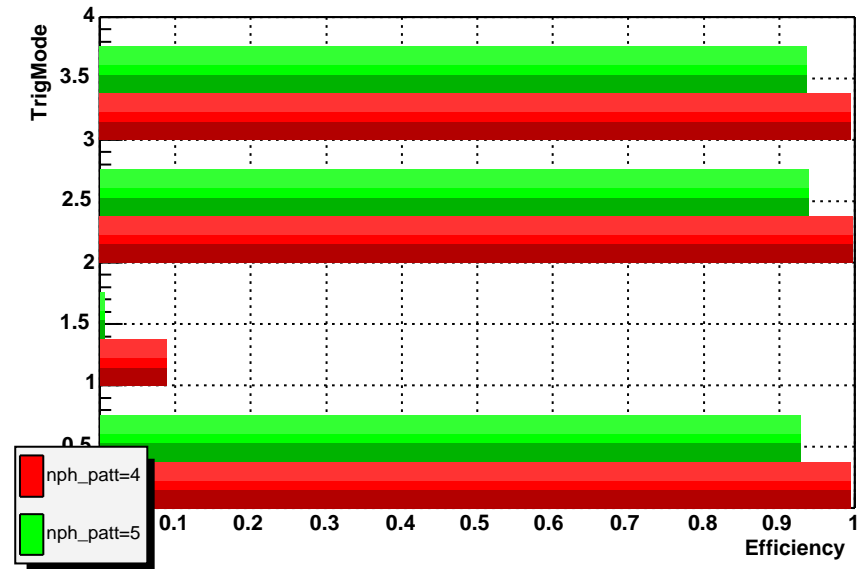
#10 Di-muon Probability vs. TrigMode (Miss4 pattern: Delay=6, nph thresh=2, theta=30)



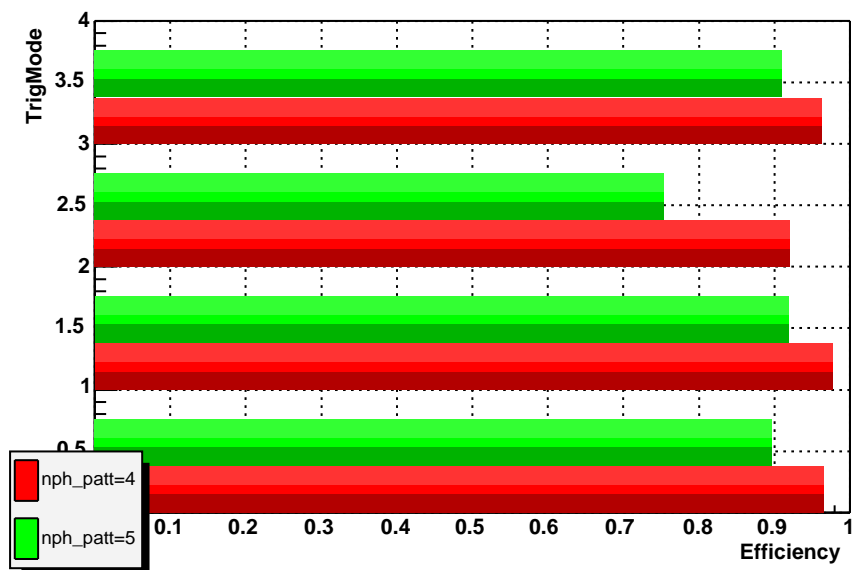
#3 Total Efficiency vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



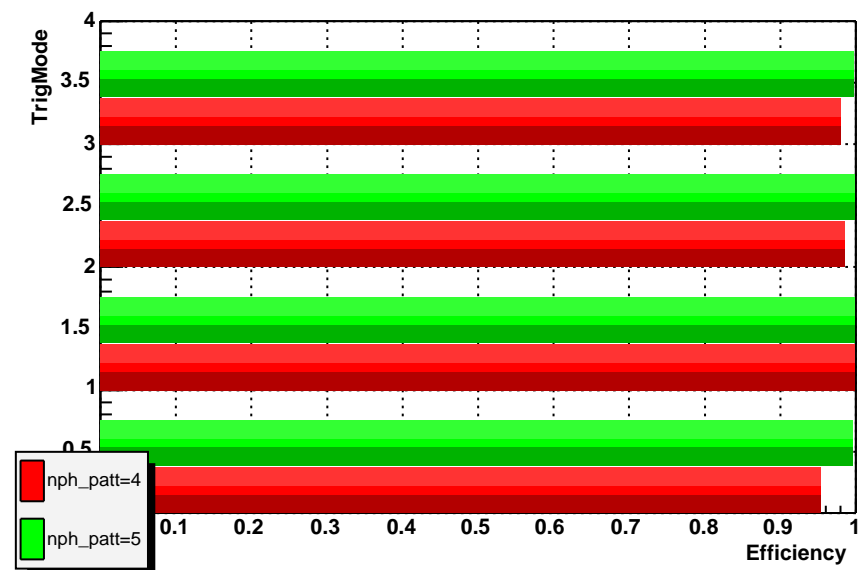
#8 Total Efficiency vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



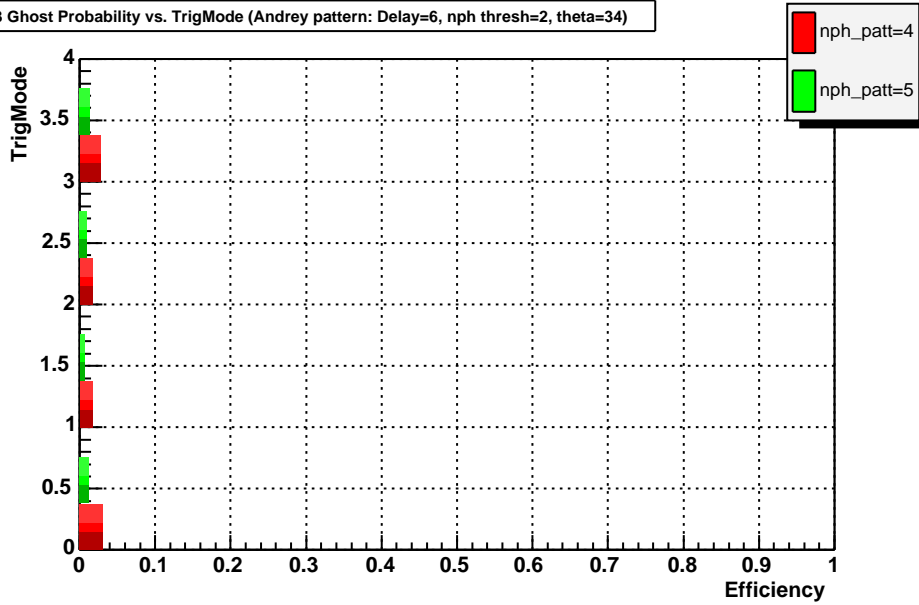
#1 Total Efficiency vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



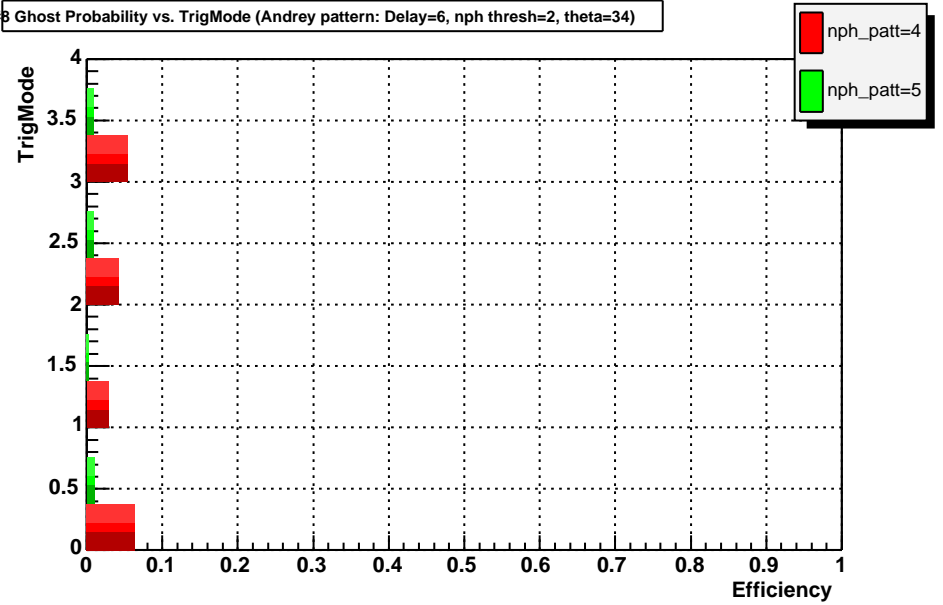
#10 Total Efficiency vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



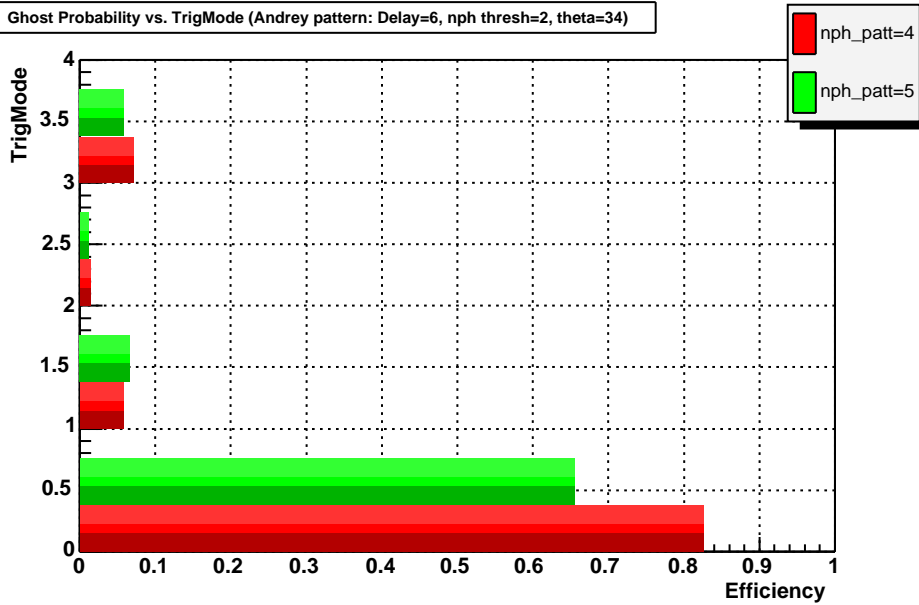
#3 Ghost Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



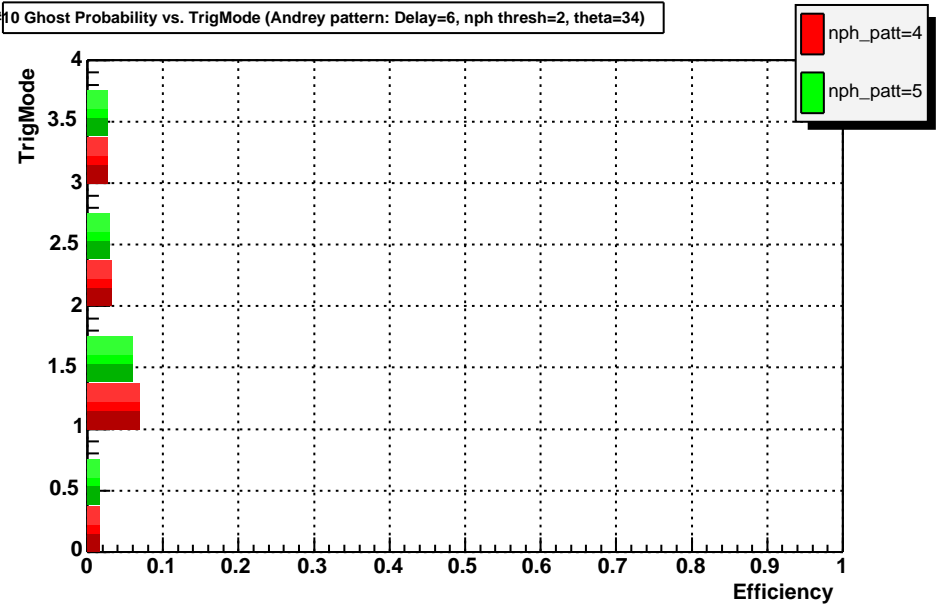
#8 Ghost Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



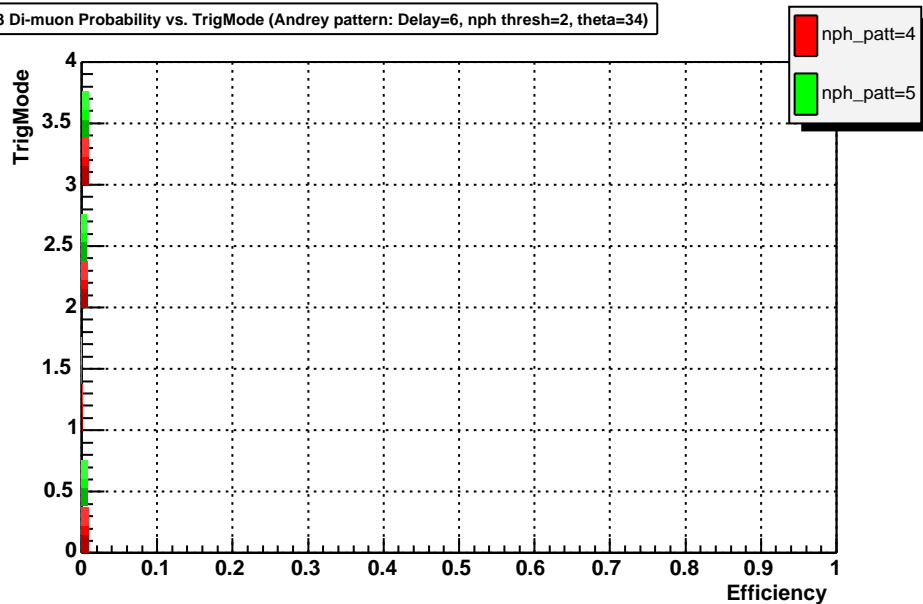
#1 Ghost Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



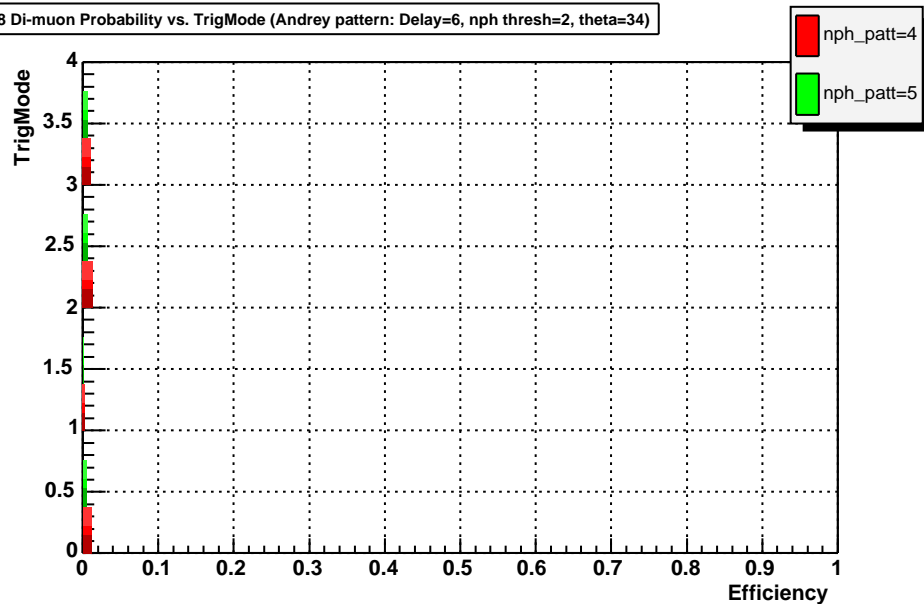
#10 Ghost Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



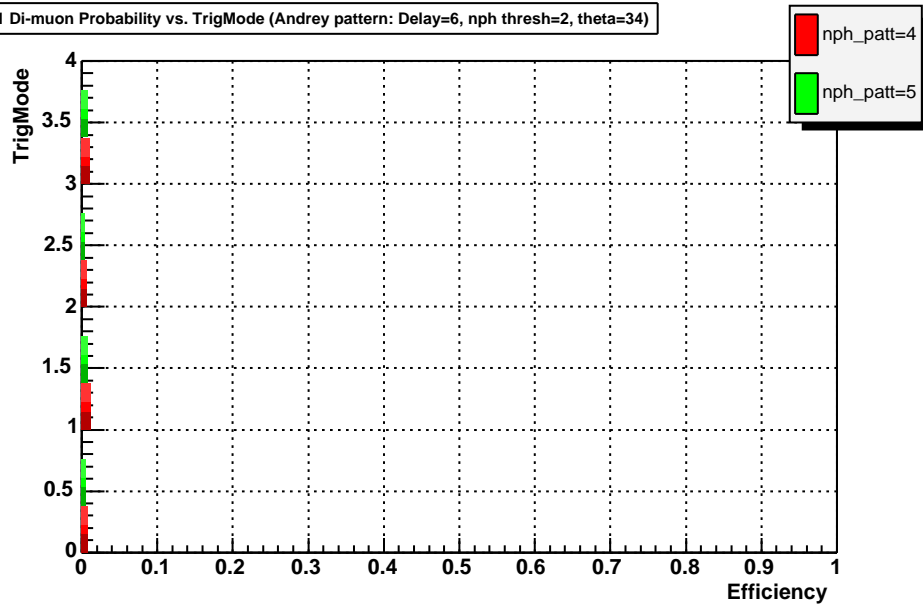
#3 Di-muon Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



#8 Di-muon Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



#1 Di-muon Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)



#10 Di-muon Probability vs. TrigMode (Andrey pattern: Delay=6, nph thresh=2, theta=34)

