EH1 Muon studies

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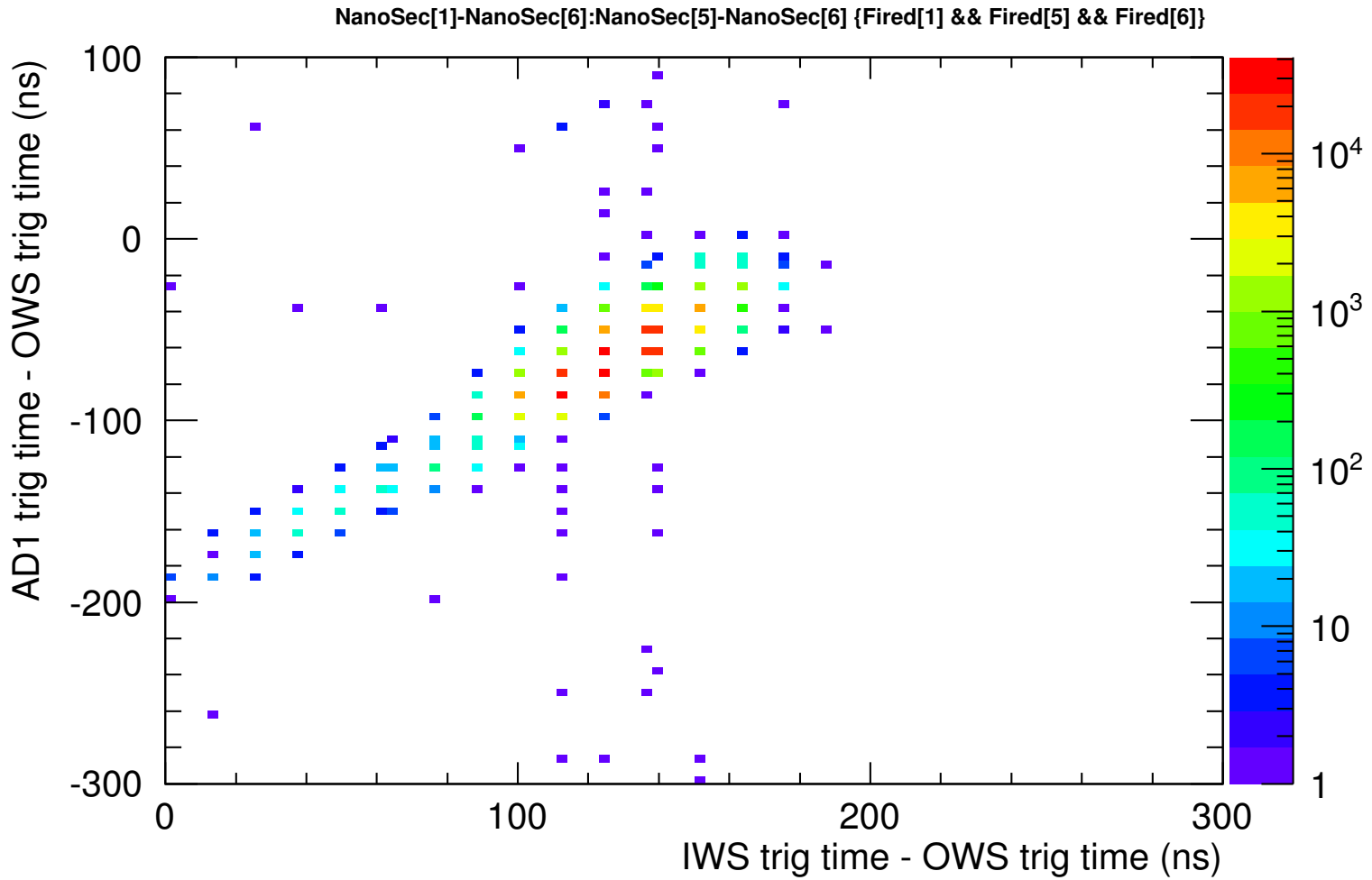
Introduction

- Try to understand muon data.
- Cross check muon veto efficiency (Doc6836)
- Data sample: Run 14996 (about 30 files)
  - IWS NHit: 5, ESum: 40
  - OWS NHit: 7, ESum: 45
  - Random and Cross triggers

Muon Event

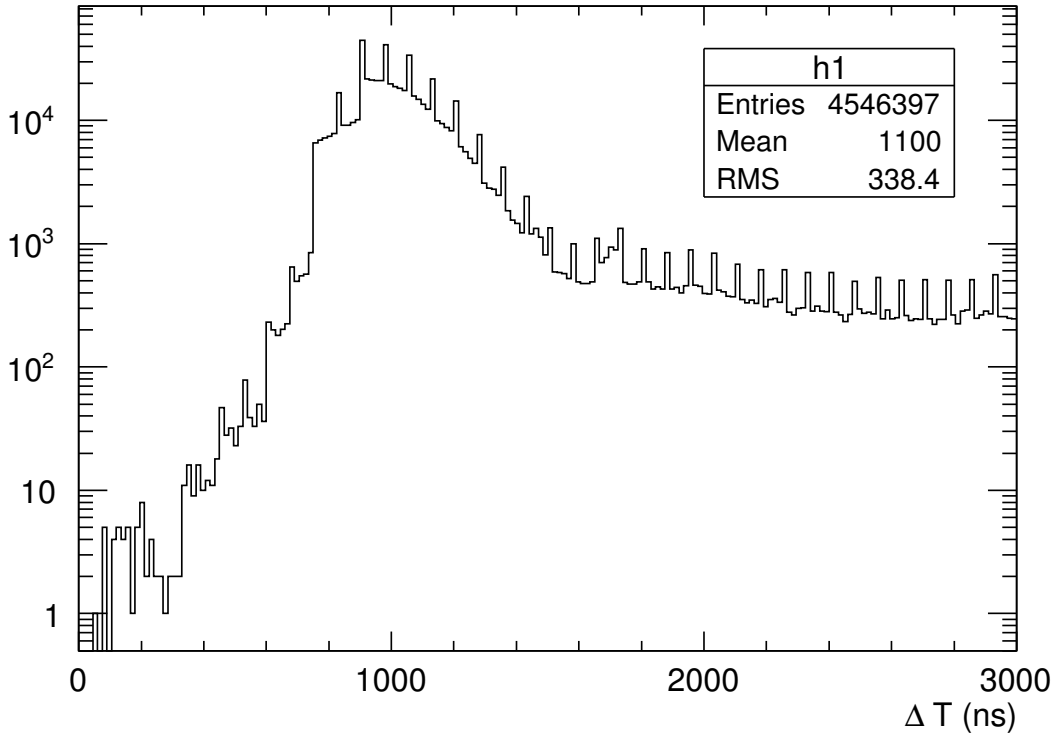
- Try to relate AD and water pool triggers of the same muon event
- Muon trigger selection: No cut for IWS or OWS triggers, rough cut for AD: nPE>2000, nHit>100
- Select a first muon trigger, any subsequent triggers with $\Delta T < 0.6\mu$S is considered as associated with the same muon event.

Trigger time difference



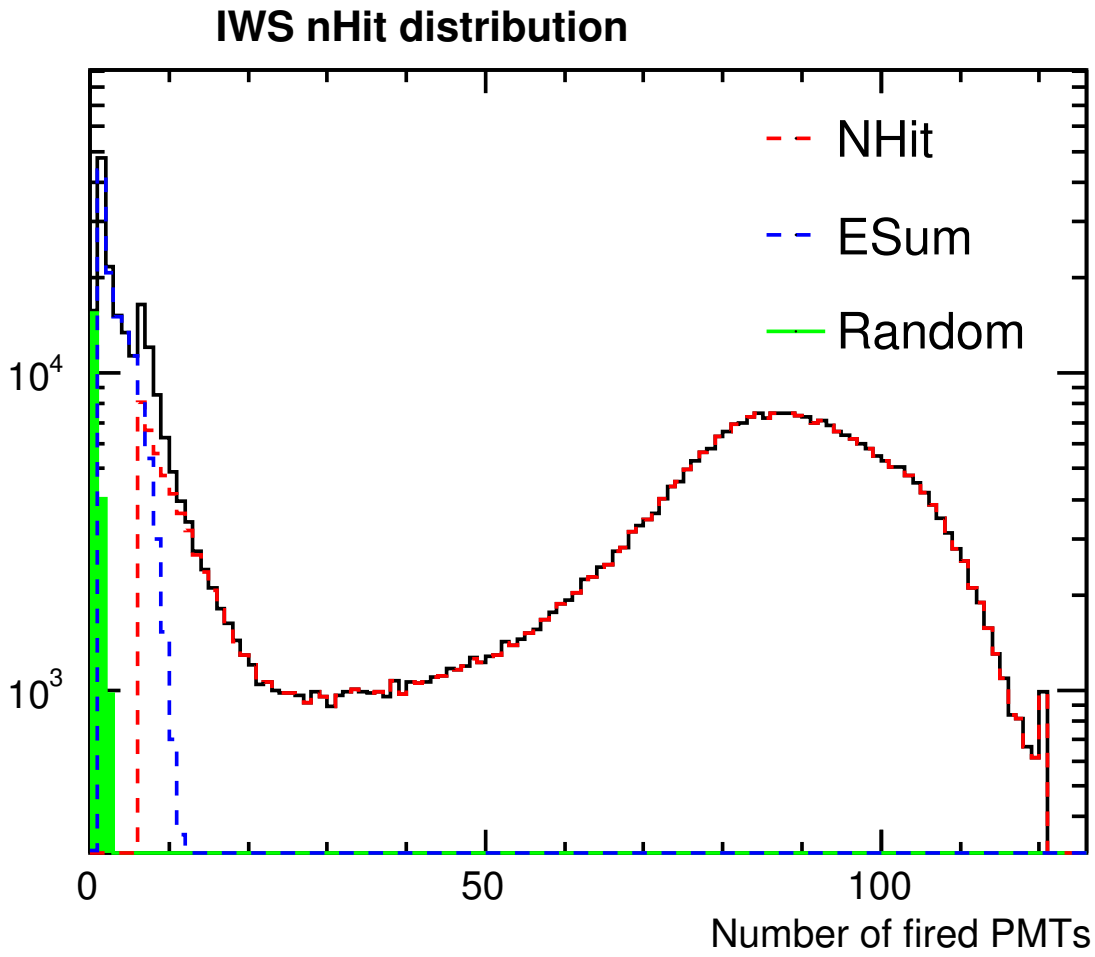
- If AD, IWS, and OWS all triggered, AD trigger is about 60 ns earlier than OWS trigger and IWS trigger is about 120 ns later.

Any mis-grouped muon events?



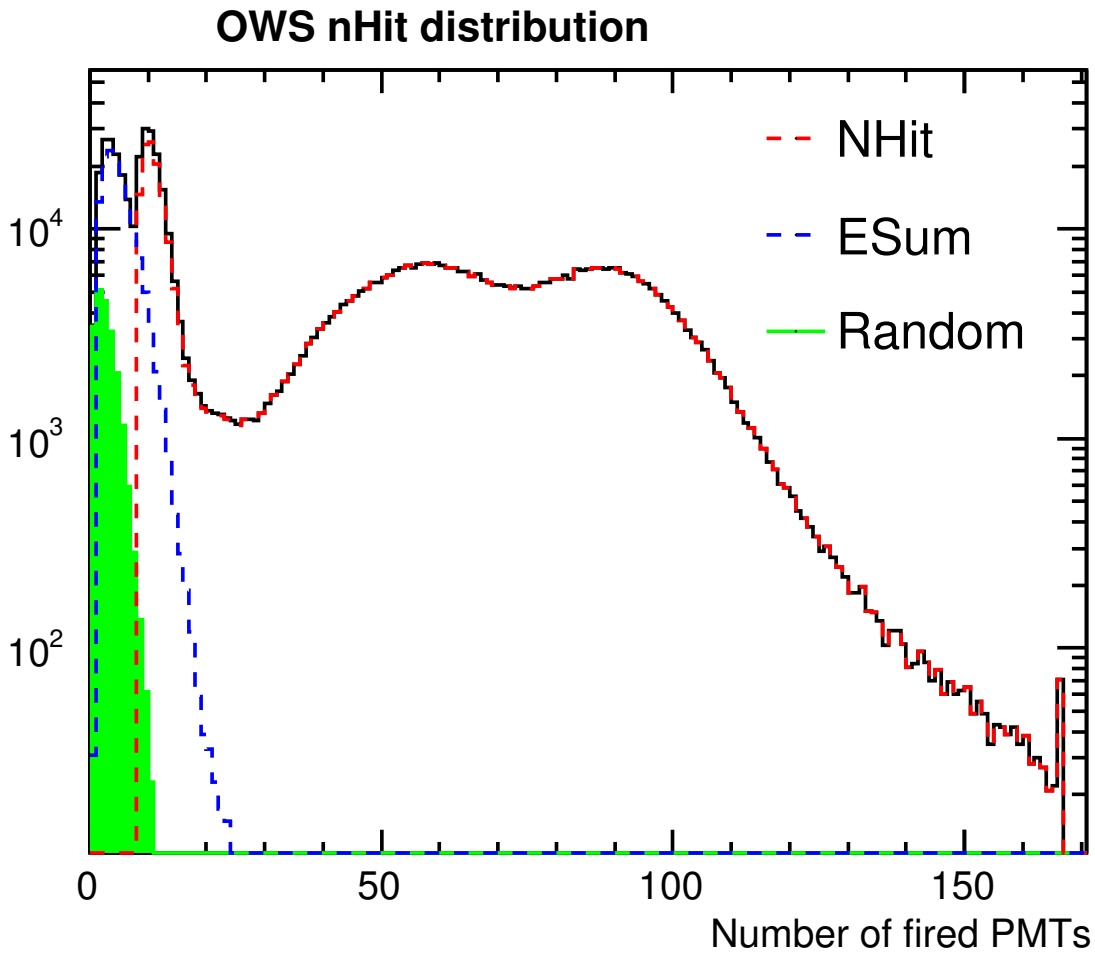
- ΔT distribtuion between the last muon trigger and the next earliest muon trigger.
- $< 1/100000$ events with $\Delta T < 0.4\mu S$

IWS nHit distributions



- Tried to rescale random trigger, however, shape is not consistent with the low end peak of multiplicity trigger.

OWS nHit distributions



- There is a peak at ∼10 for multiplicity trigger, rather than exponential distribution.

Question

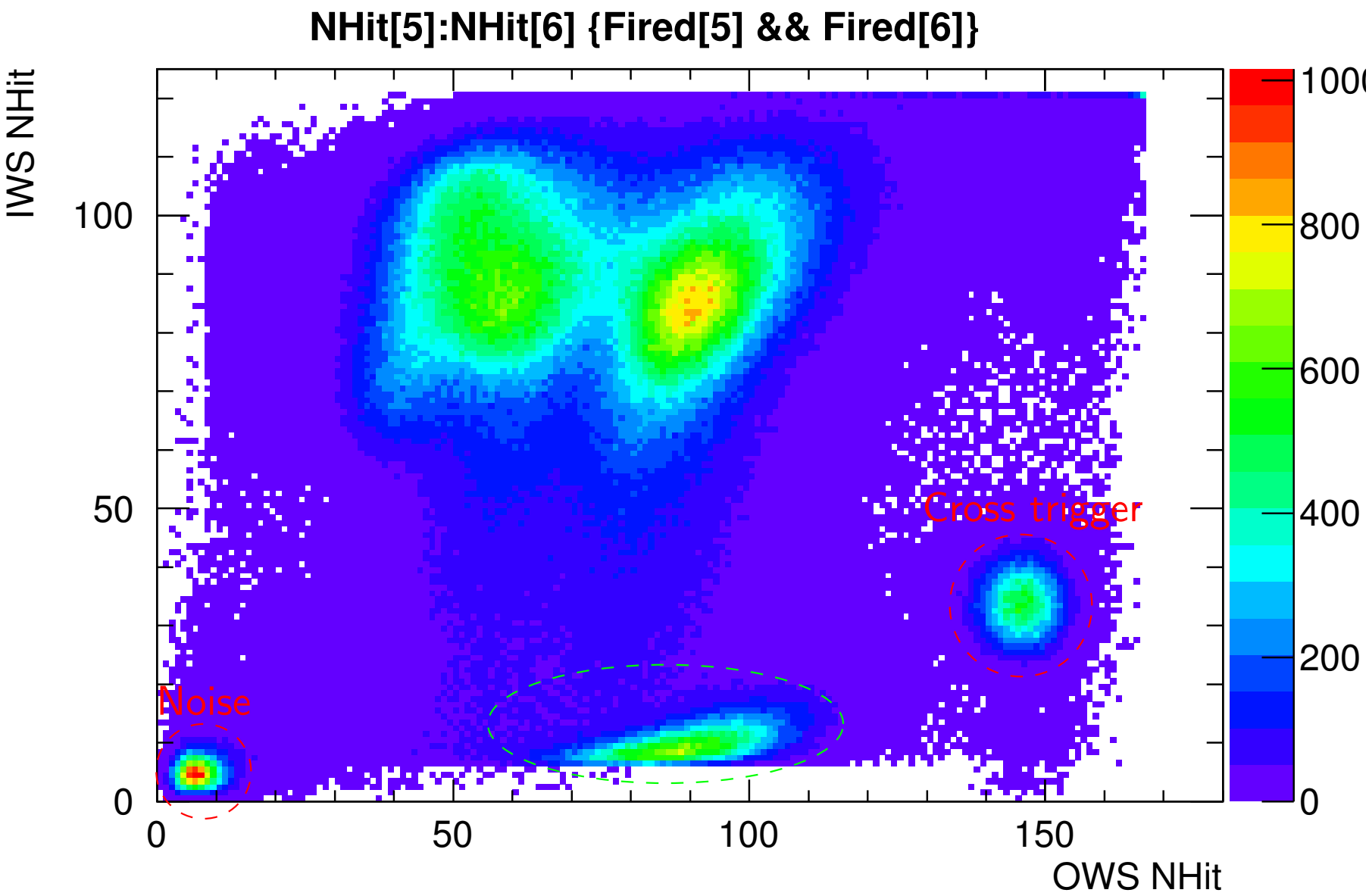
- Are the low end peak events all from random noise?
- How big the random noise contribution should be? it should follow binomial distribution, 121 PMT in IWS and 167 PMTs in OWS, average dark rate for IWS is 8K, and 13K for OWS. Trig time window is 800*1.5625 nS.

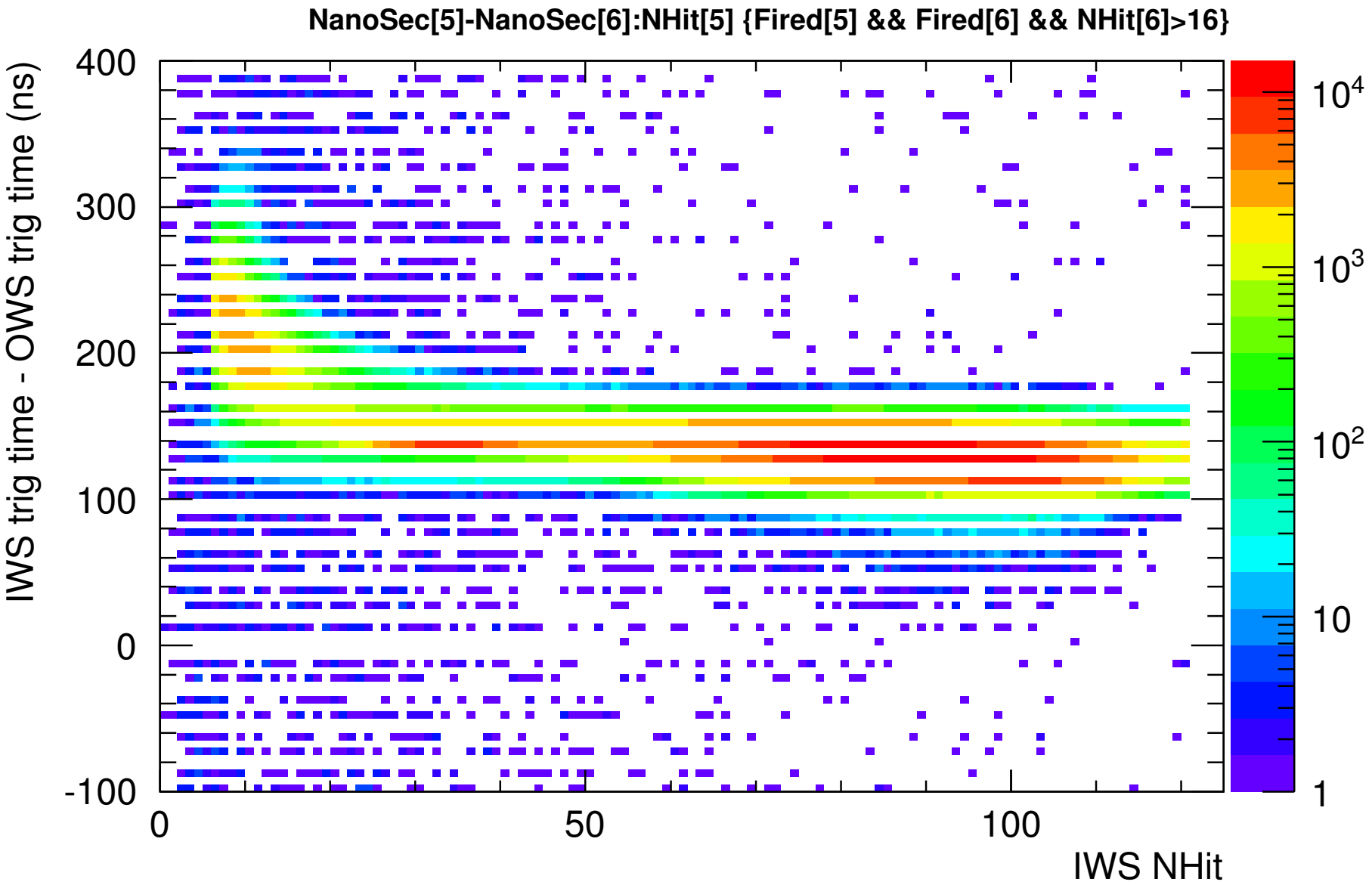
$$121 \times \frac{8K \times 800 \times 1.5625}{10^9} \approx 1.2 \tag{1}$$

$$167 \times \frac{13K \times 800 \times 1.5625}{10^9} \approx 3.4 \tag{2}$$

  The random trigger has no peak in IWS, and peak around 1.8 in OWS. The above calculation is a little bit overestimate.
- Why there is a peak in OWS nHit distribution rather than cut off exponential distribution? The shape of random trigger events can hardly explain the peak. There might be some physical events.

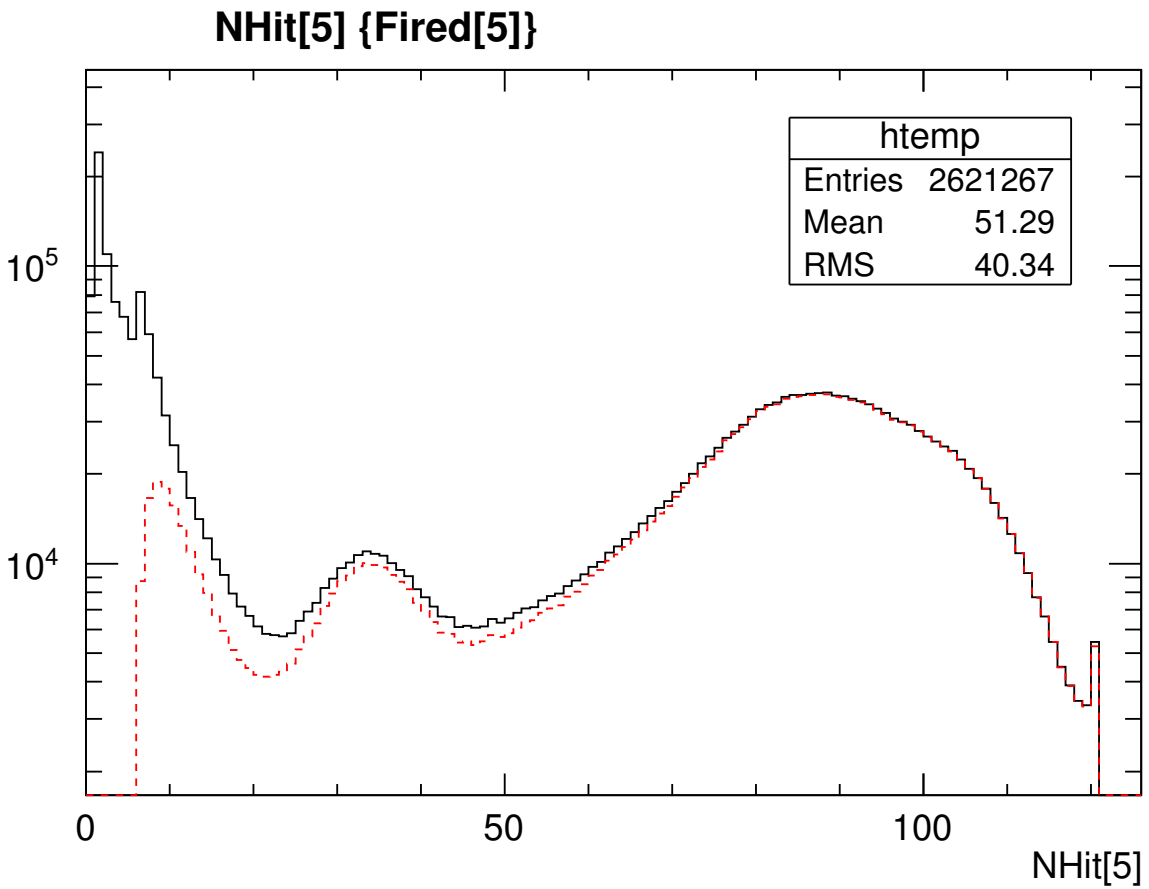
NHit distribution





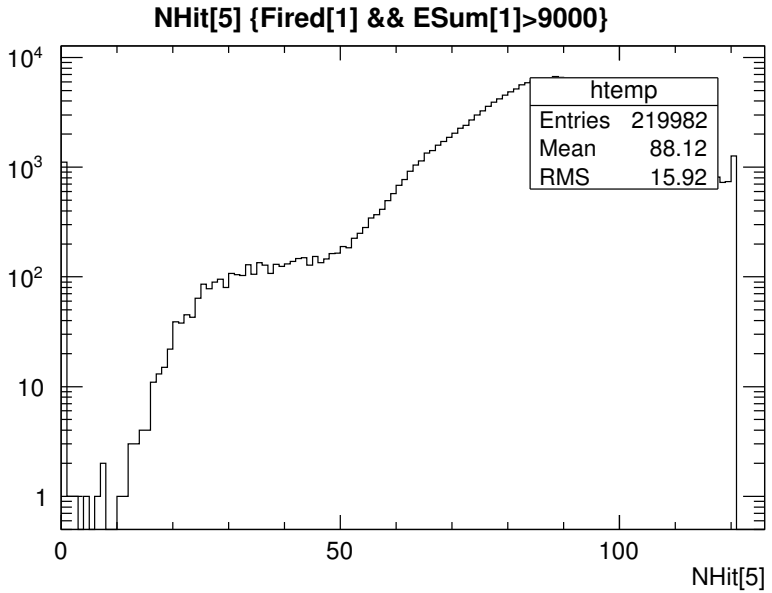
- IWS has longer delays in trigger time for low multiplicity events

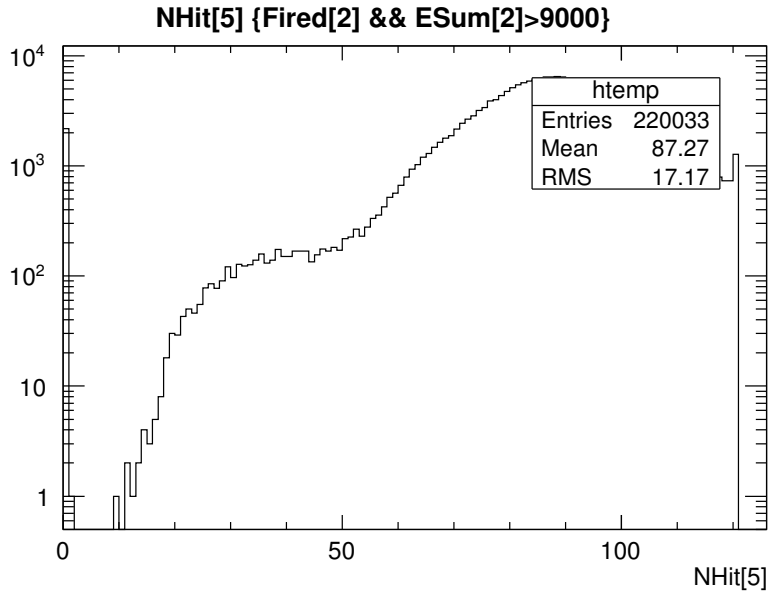
IWS nHit distribution



- Black: All IWS triggers
- Red: Require OWS nHit>16
- There is a peak at around 10. Edge muons in IWS?

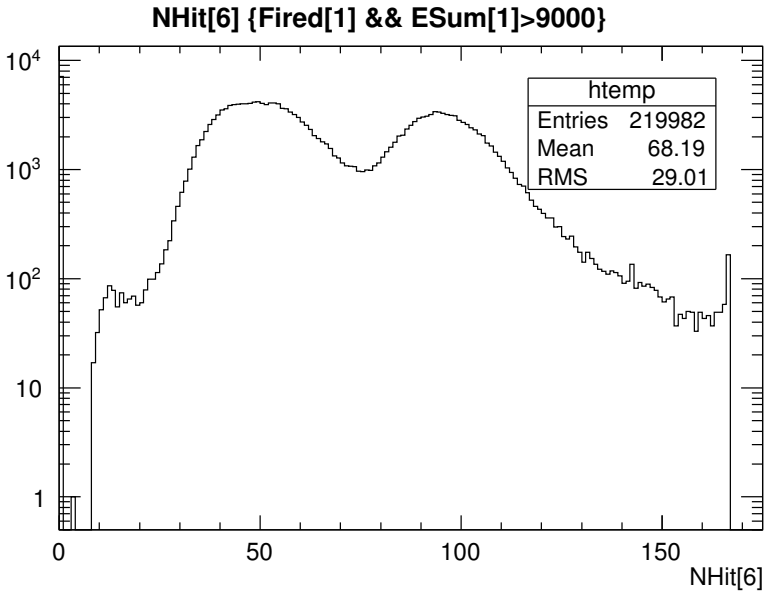
IWS nHit distribution for muon events

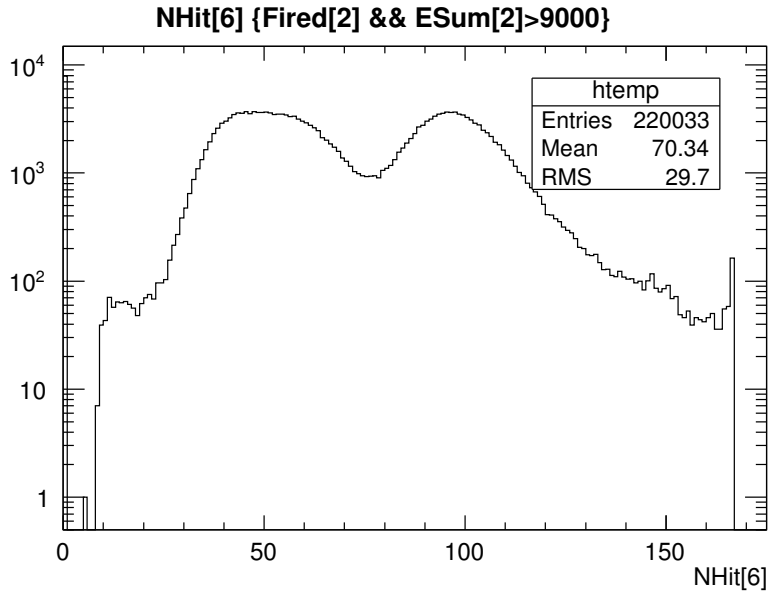




- Left: Require ESum(AD1)>50 MeV, right: Require ESum(AD2)>50 MeV
- For muons which pass through AD, most have nHit> 20 in IWS.

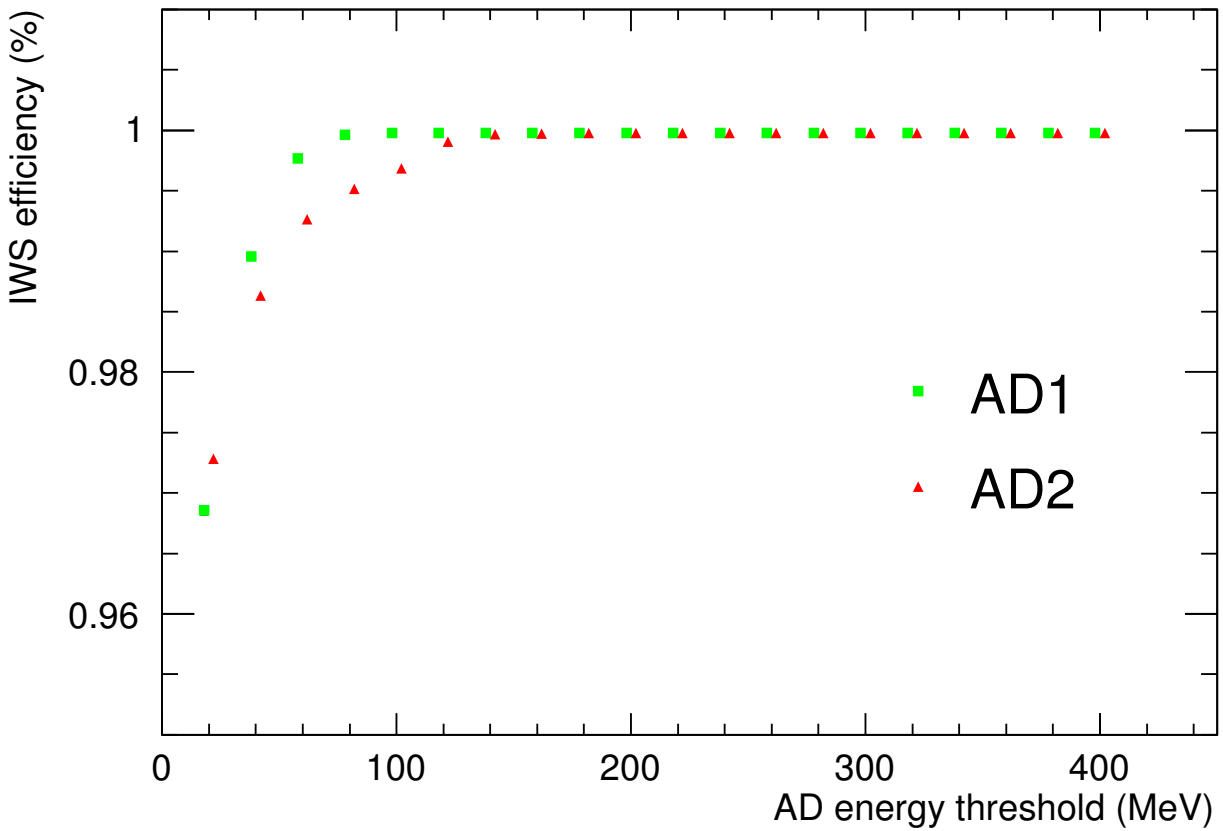
OWS nHit distribution for muon events





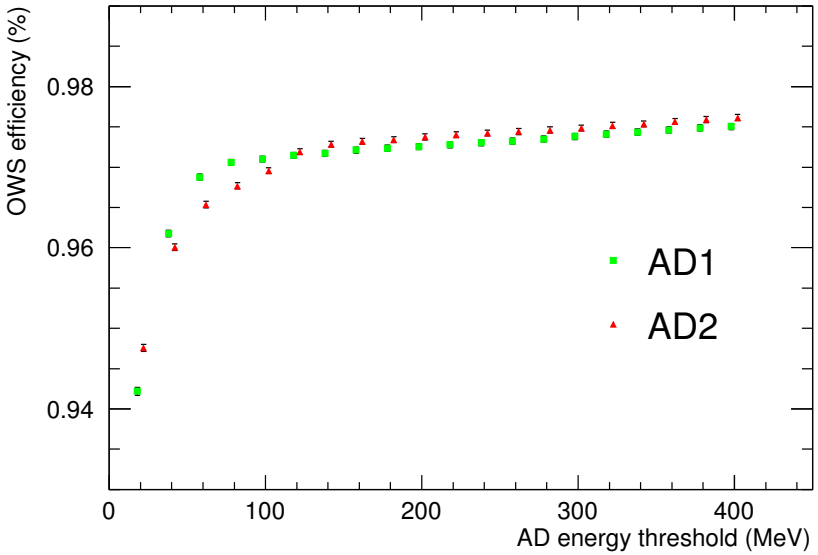
- Left: Require ESum(AD1)>50 MeV, right: Require ESum(AD2)>50 MeV

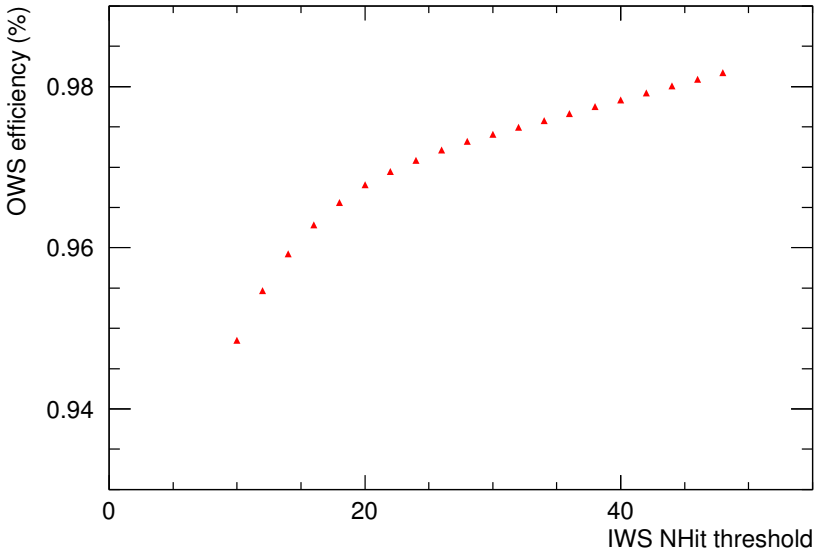
IWS Muon veto efficiency from AD muon



- Require nHit$>$ 12. Almost 100% veto efficiency for muons passing through AD.
- Effiency drop at low AD energy is most likely due to non-muon events in AD.

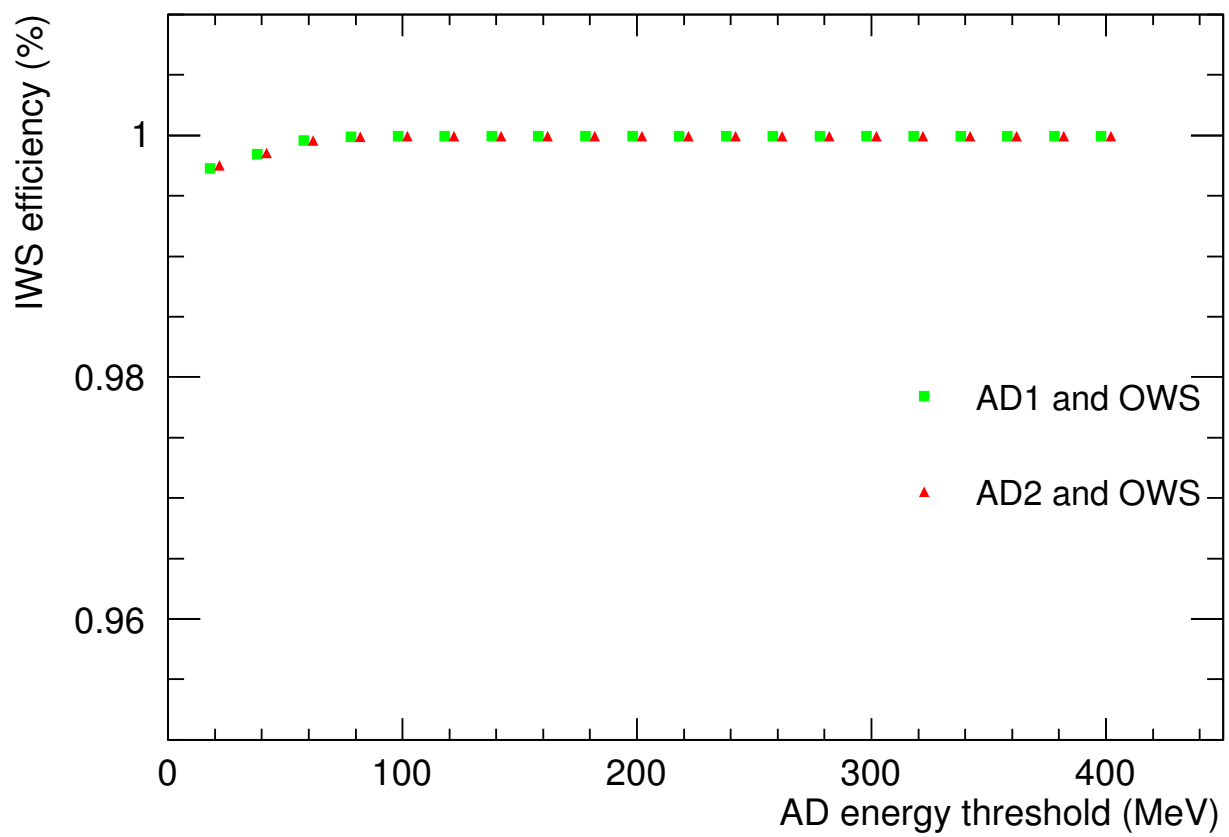
OWS Muon veto efficiency





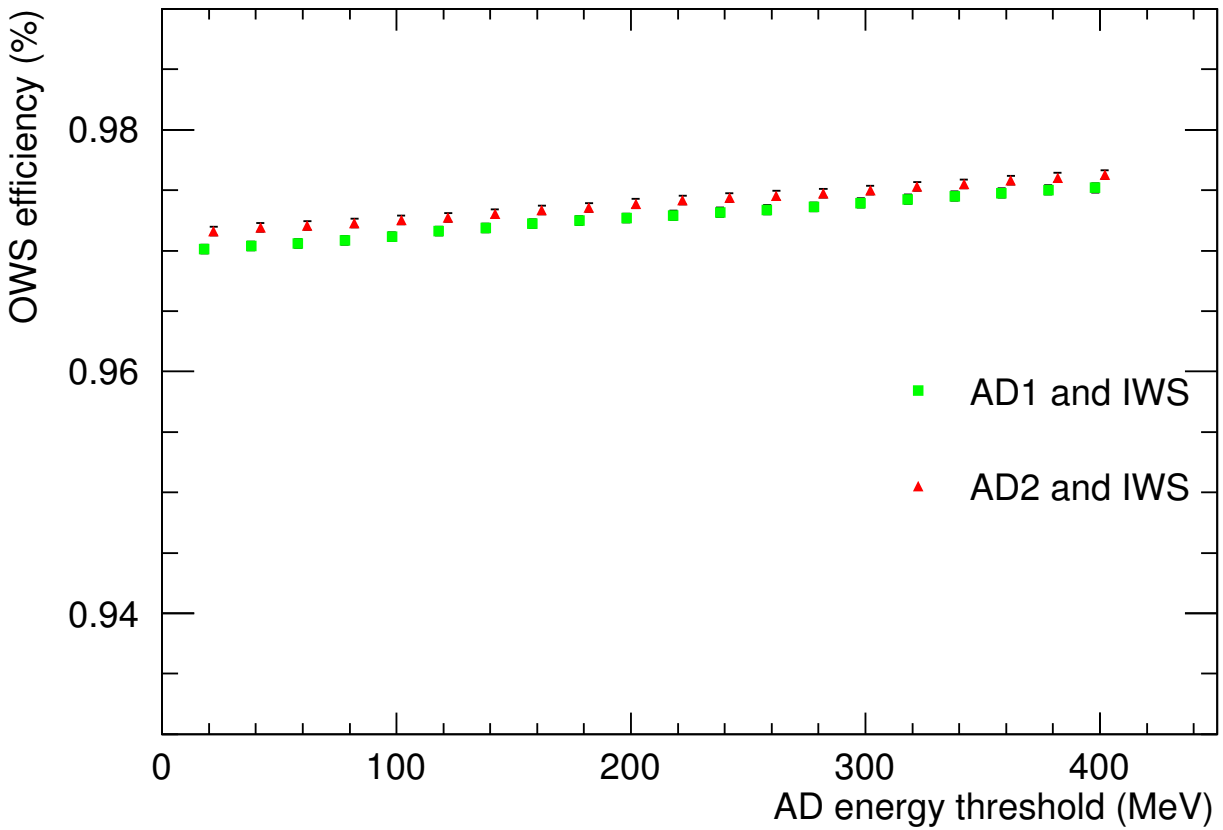
- OWS muon veto efficiency for muons passing through AD
- OWS muon veto efficiency for muons passing through IWS

IWS Muon veto efficiency



- Require both AD and OWS (nHit>12) triggers present to get more clean muon samples
- Effiency is stable for AD energy threshold cut.
- AD1 and AD2 smaples are consistent
- IWS muon veto efficiency for muons pass through AD is $> 99.6\%$

OWS Muon veto efficiency



- Require both AD and IWS (nHit>12) triggers present to get more clean muon samples
- A little bit linear dependency on AD energy threshold cut.
- OWS muon veto efficiency for muons pass through AD is $> 97\%$

Muon rate

- Require AD and IWS triggers, then corrected by IWS efficiency.
  - AD1 muon rate: 21.72±0.05 Hz
  - AD2 muon rate: 21.66±0.05 Hz
- Require IWS and OWS triggers, then corrected by OWS efficiency. IWS muon rate: 158.0±0.1 Hz
- OWS muon rate: 217.6 Hz

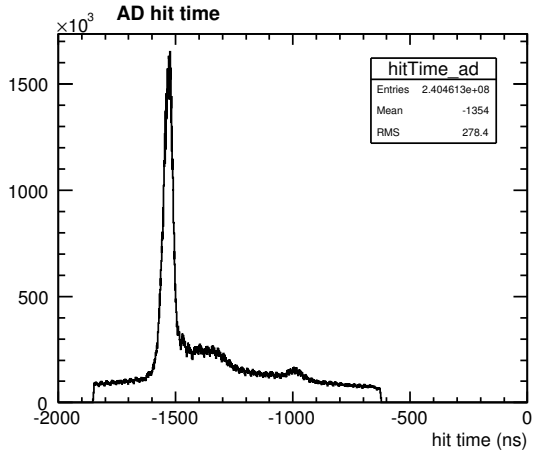
Detector	Rate (Hz)	Top (m^2)	Side (m^2)	Total (m^2)	Rate (Hz/m^2)
AD1	21.72	12.3	49.4	28.8	0.75
AD2	21.66	12.3	49.4	28.8	0.75
IWS	158.0	96.8	227.6	172.3	0.92
OWS	217.6	138.0	302.7	238.9	0.91

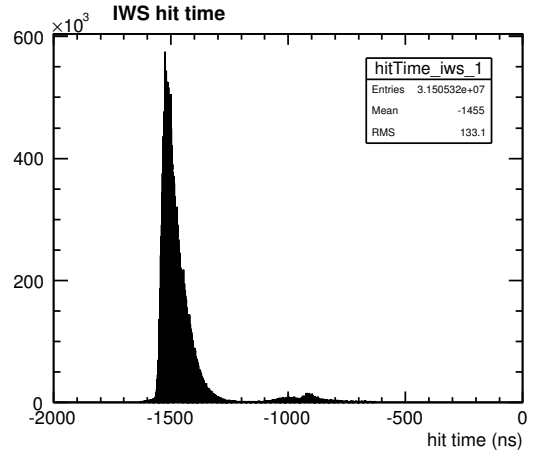
- effective area: $R_H/R_V \sim 3$
- Effective area for AD may be wrong.
- Muon rate for IWS and OWS is consistent, around 0.91 Hz/m^2, lower than TDR 1.16 Hz/m^2.

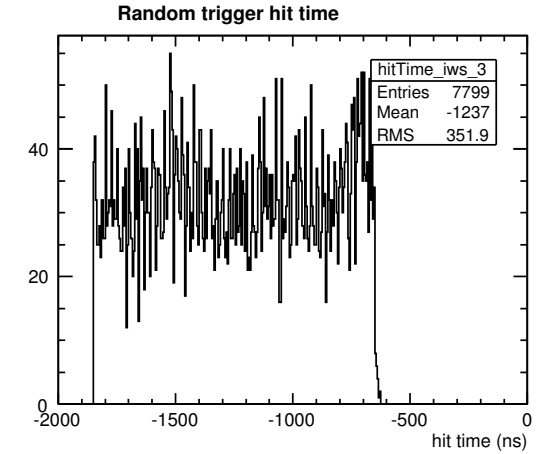
Summary

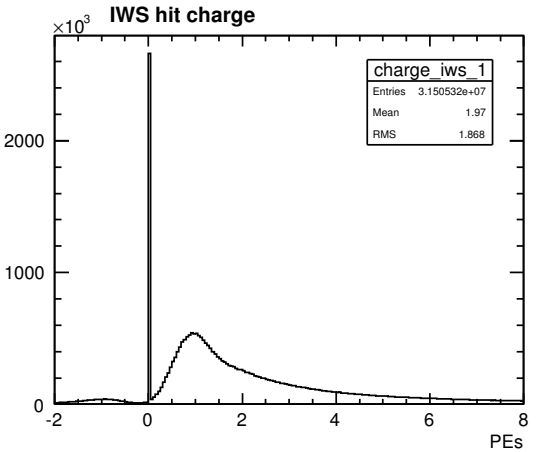
- IWS muon veto efficiency for muons passing through is $> 99.6\%$
- OWS muon veto efficiency for muons passing through AD and IWS is $> 97\%$
- Low multiplicty peak is not pure noise, some are from edge muons.

Noise cut



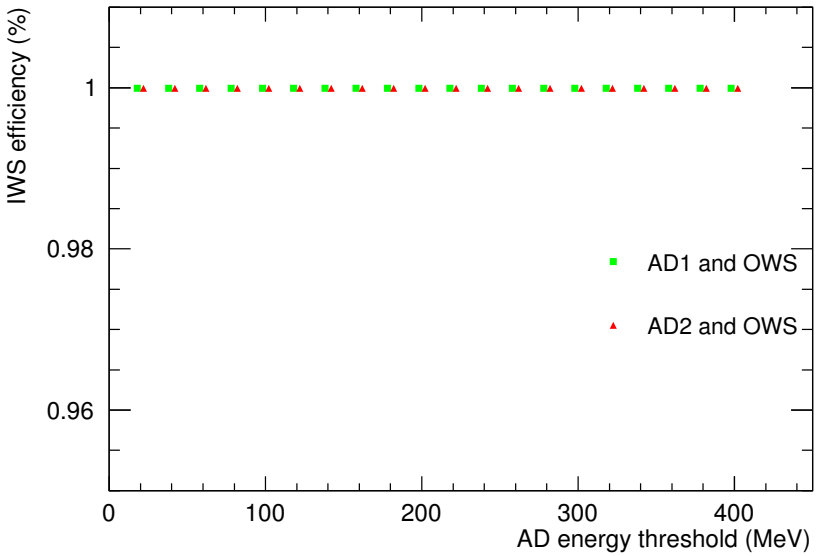


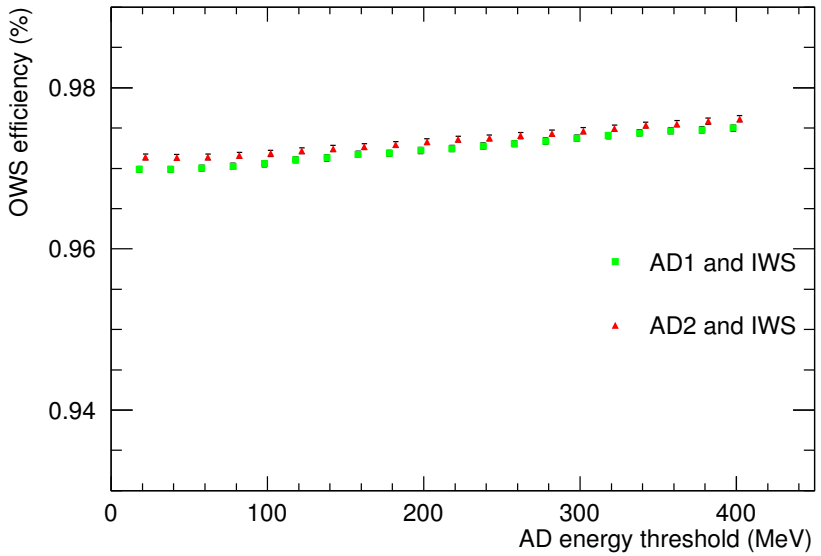




- Require $-1620 < \mathit{hittime} < -1350$ to remove noise
- Some hits in water pool have exactly 0 PE (?)

Muon efficiency with noise cut





- Similar to results without noise cut