Status Report: ntag and software

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13 Nov. 2020

HK mPMT Japan meeting

Status and update for n-tag algorithm

Reminder

- Compared different detector configuration (bottom-right)
  → mPMT hybrid case was worse than that expected from photo-coverage
- Concerned about missing characters of mPMT in variable relating to acceptances: cross section and dark-rate
  → Modified this variable (new update)

PMT Acceptance

Note) Now, I missed information about PMT's cross section, darkrate. These should be fixed future. For B&L only case, there are no problem

- Defined LLR for PMT acceptance

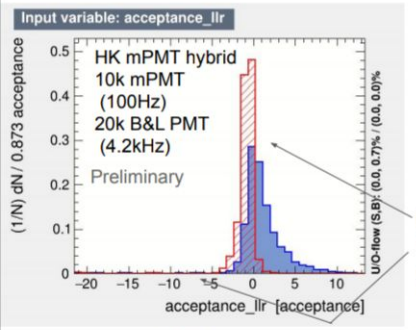
$$LLR := L_{\text{acc, B\&L, signal}} - L_{\text{acc, B\&L, darkhit}} + L_{\text{acc, mPMT, signal}} - L_{\text{acc, mPMT, darkhit}}$$

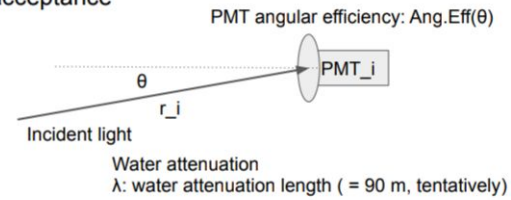
  - Where

$$L_{\text{acc., B\&L (mPMT), signal}} := \sum_{i}^{\text{all hit B\&L (mPMT)}} \log\left[\frac{\text{Ang.Eff.}(\theta_i)\exp(r_i/\lambda)/r_i^2}{\sum_j^{\text{all B\&L (mPMT)}} \text{Ang.Eff.}(\theta_j)\exp(r_j/\lambda)/r_j^2}\right]$$

$$L_{\text{acc., B\&L (mPMT), darkhit}} := \sum_{i}^{\text{all hit B\&L (mPMT)}} \log\left[\frac{1}{\#\text{ of B\&L (3 inch PMT in mPMT)}}\right]$$

Darkhits are not related with acceptance

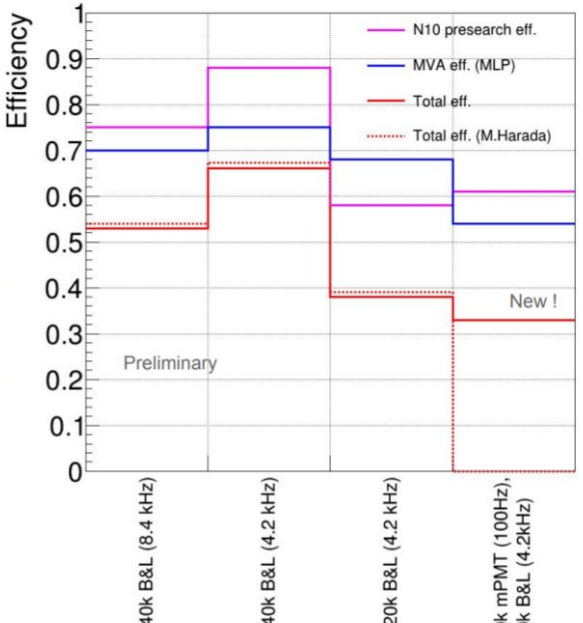




Good cutoff in BG (red)
However, there were events far away from main peak (under investigation)

Comparison of different detector config.

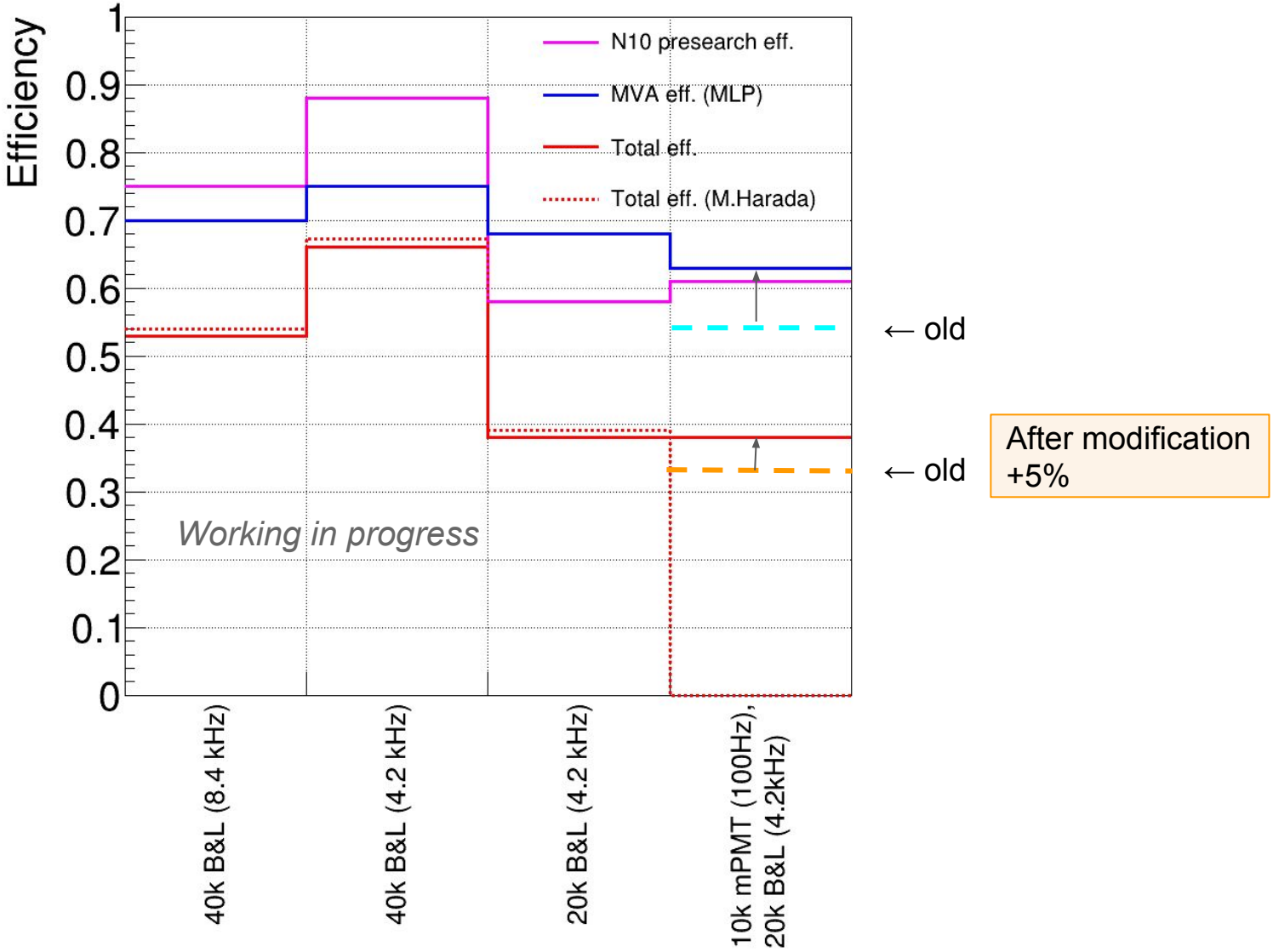
- Tested with other configurations:
  - 40k B&L PMTs
    8.4 / 4.2 kHz darkrate
  - 20k B&L PMTs
    4.2 kHz darkrate
  - 20k B&L PMTs of
    4.2 kHz darkrate
    + 10k B&L mPMTs of
    100 Hz darkrate/PMT
- Comparing to Harada-san's results, they look consistent within error (> 0.01)
- → As for mPMT, it looks not good
  - Under investigation



Comparison with different configuration

Reminder

- Recovered to almost same level with "20k B&L configuration"



Why no better efficiency with mPMTs

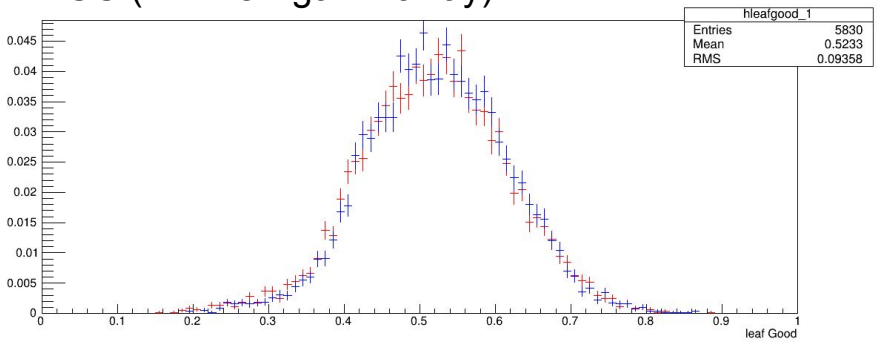
- Hybrid configuration has better N10 efficiency.
  - But BG is also increasing… (however, we can expect better S/B (?) since mean value of N10 of mPMTs ~ 0.18 hits)
  - In principle, MVA could get effect from this increased N10 efficiency
- Here, I checked variables used as MVA input
  - LEAF uses copied and pasted code from SK and not tuned for HK.
  - Comparison:
    - HK 20k B&L only (4.2 kHz)
    - HK mPMT hybrid: 10k mPMT (100Hz) + 20k B&L (4.2 kHz)

LEAF: goodness

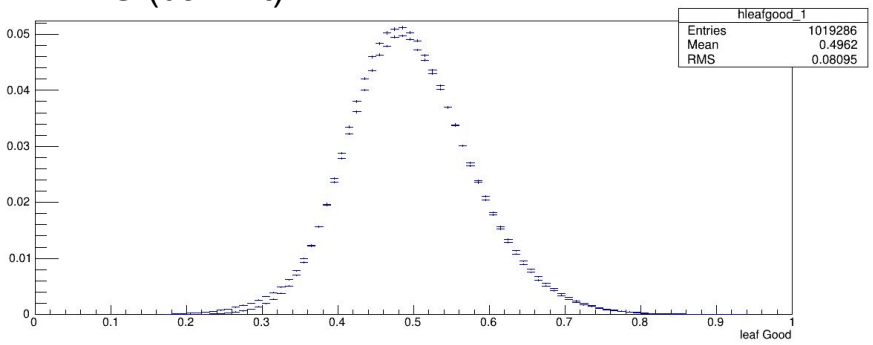
- Slightly wider distribution in hybrid-case
  → Less separation

Red: mPMT hybrid (B&L 20k, mPMT 10k)
Blue: B&L only 20k

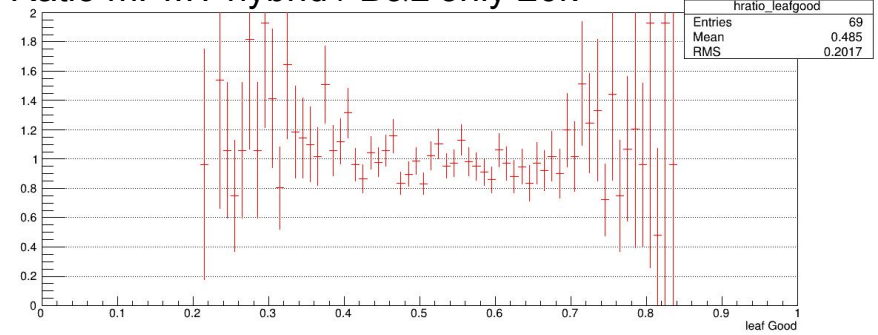
SG (2.2 MeV gamma-ray)



BG (darkhit)



Ratio mPMT hybrid / B&L only 20k



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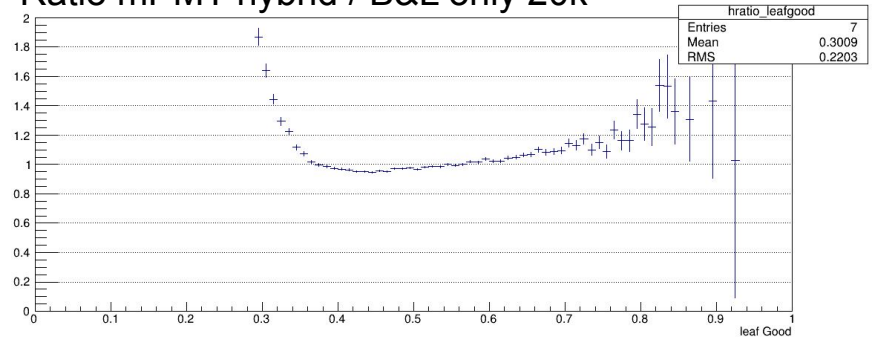

LEAF: dirKS

- Slightly wider in hybrid
  → less separation

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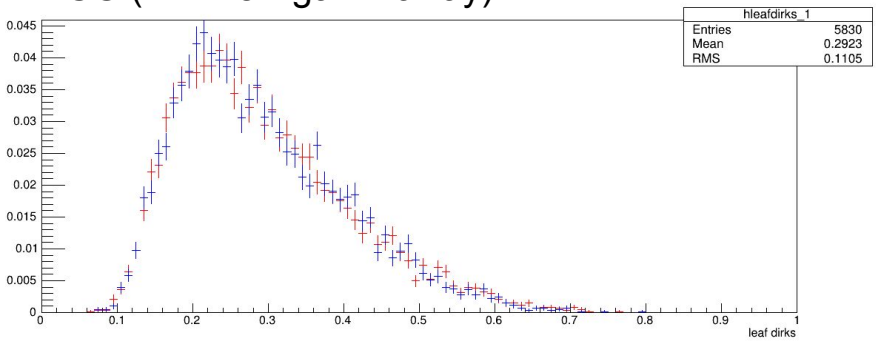
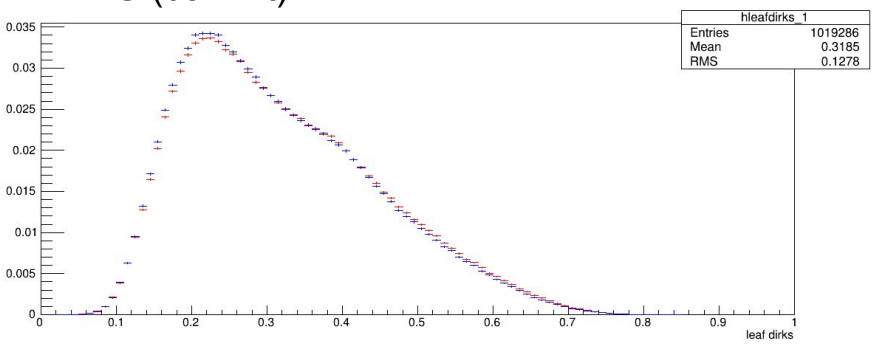
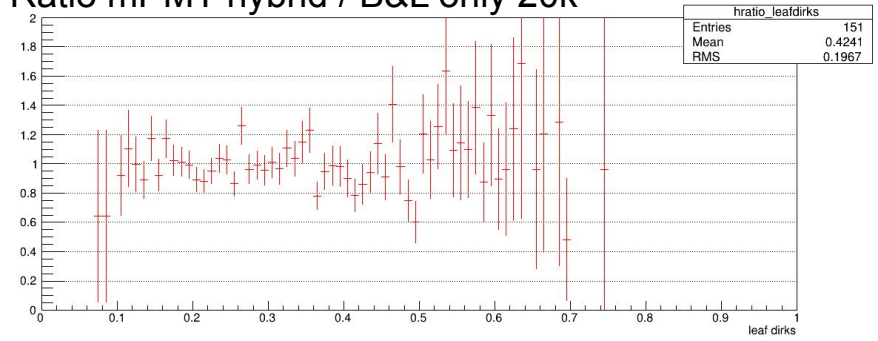
SG (2.2 MeV gamma-ray)



BG (darkhit)



Ratio mPMT hybrid / B&L only 20k



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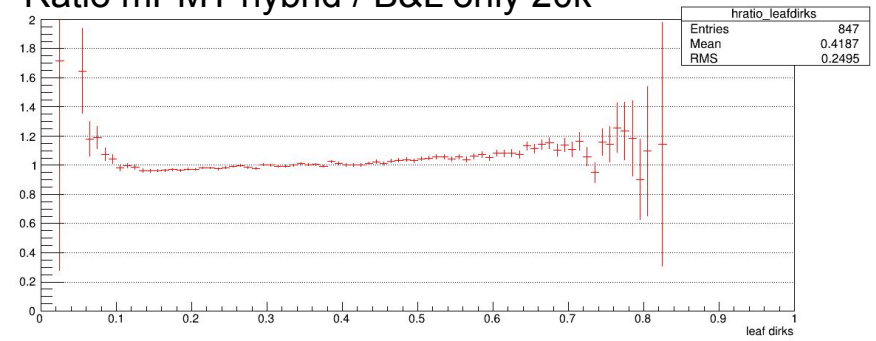
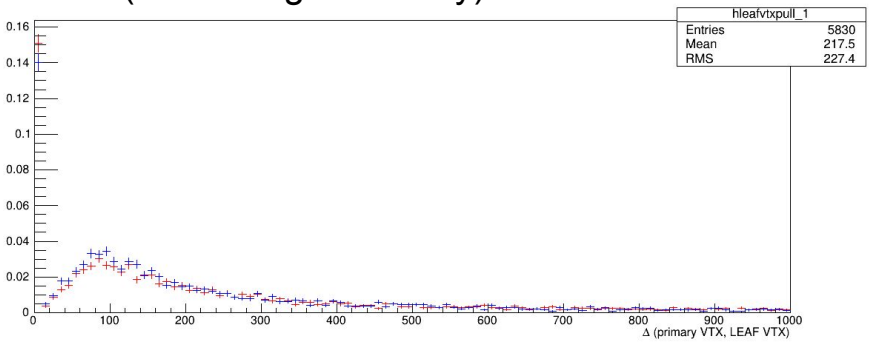


Distance(reconstructed VTX, primary VTX)

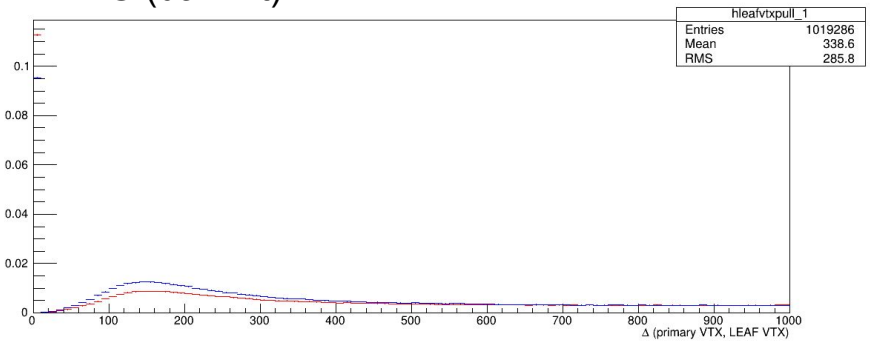
- mPMT has sparse BG vertices (?)
  - Note) BG does not have good vertices
- Need investigation

Red: mPMT hybrid (B&L 20k, mPMT 10k)
Blue: B&L only 20k

SG (2.2 MeV gamma-ray)



BG (darkhit)



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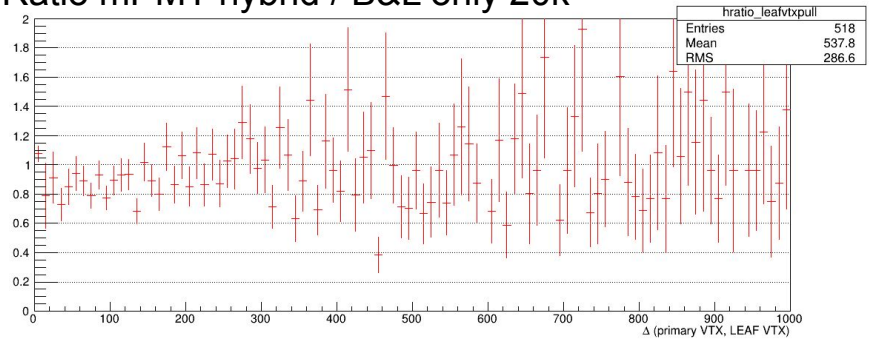
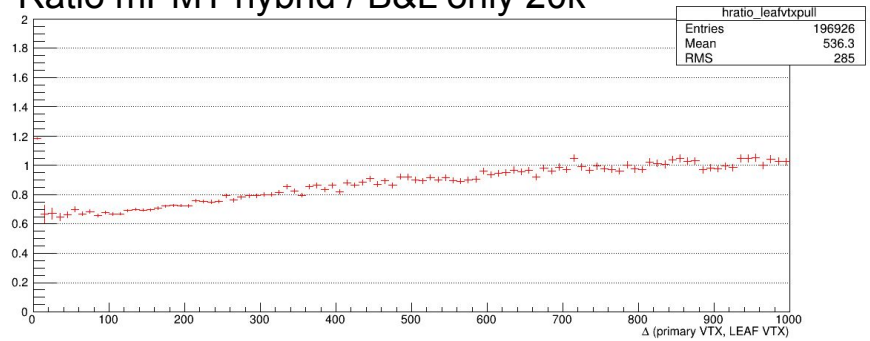


Ratio mPMT hybrid / B&L only 20k

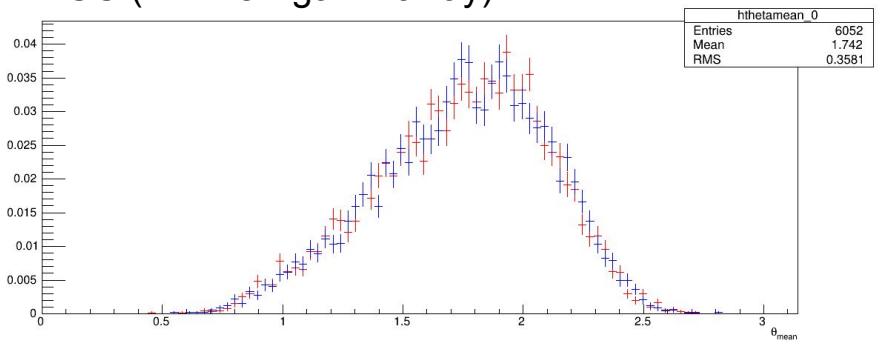


Mean of hit angle θ (opening angle)

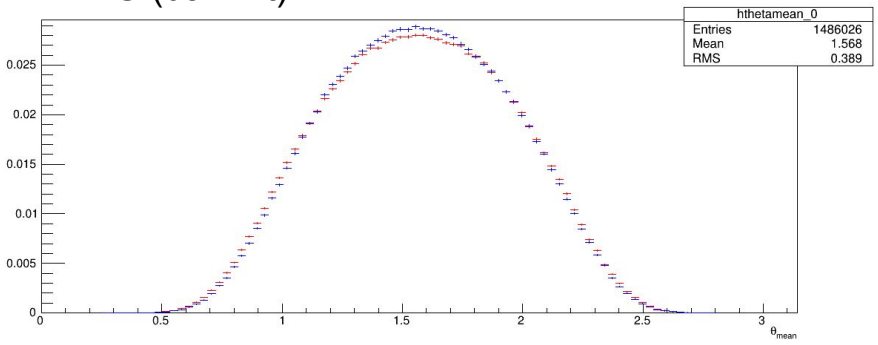
- Hybrid-case has wider distribution slightly, especially in BG

Red: mPMT hybrid (B&L 20k, mPMT 10k)
Blue: B&L only 20k

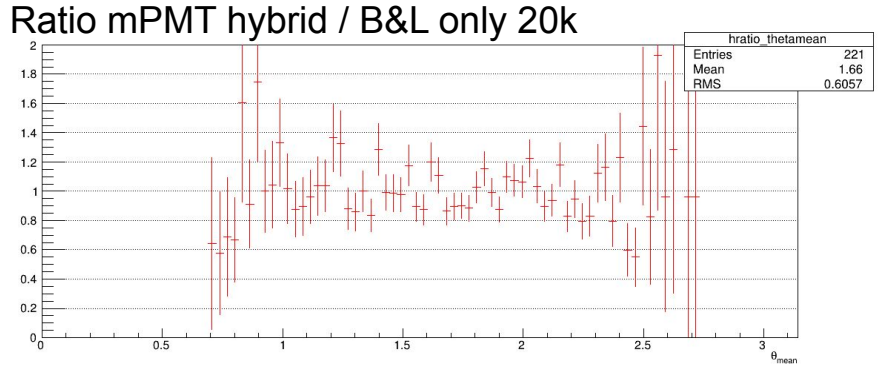
SG (2.2 MeV gamma-ray)



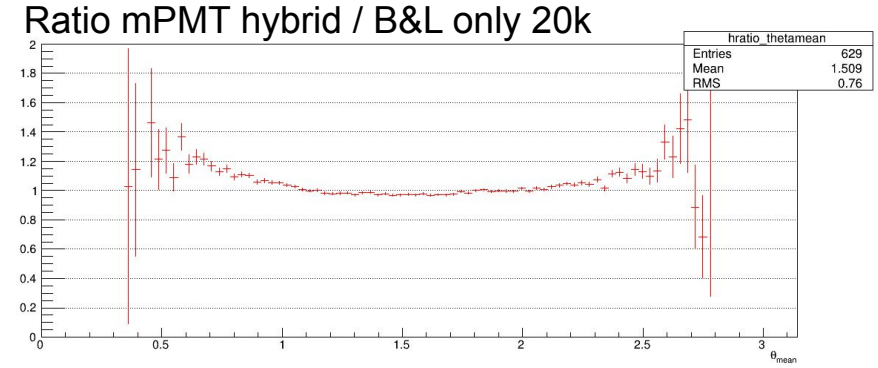
BG (darkhit)



Ratio mPMT hybrid / B&L only 20k



Ratio mPMT hybrid / B&L only 20k

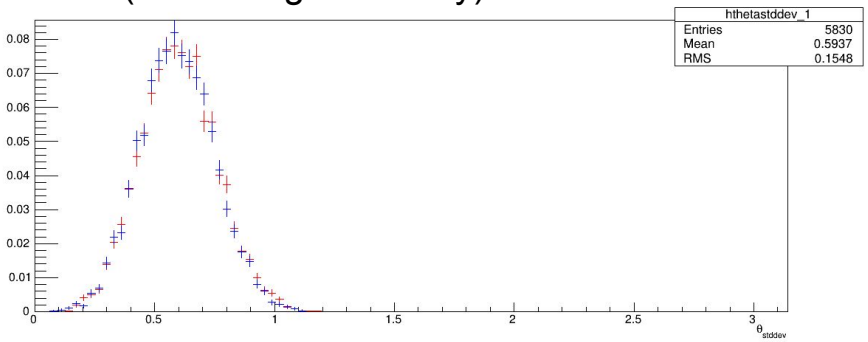


Std. dev. of hit-angle θ

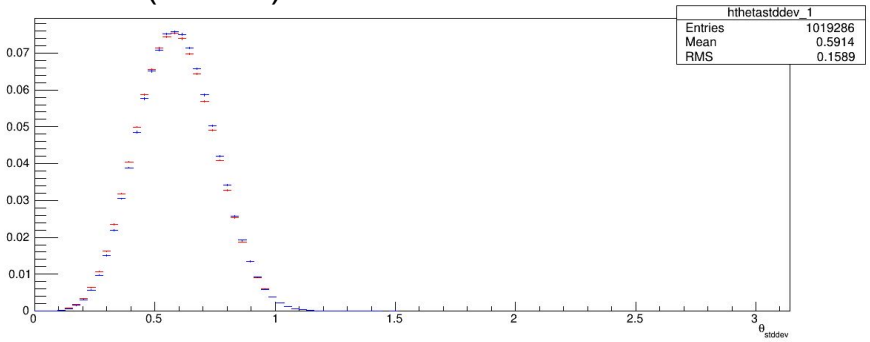
- Hybrid-case has more (but slightly) separated distribution

Red: mPMT hybrid (B&L 20k, mPMT 10k)
Blue: B&L only 20k

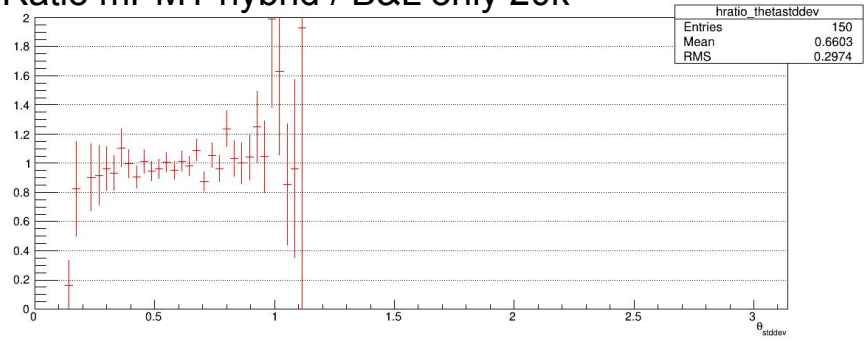
SG (2.2 MeV gamma-ray)



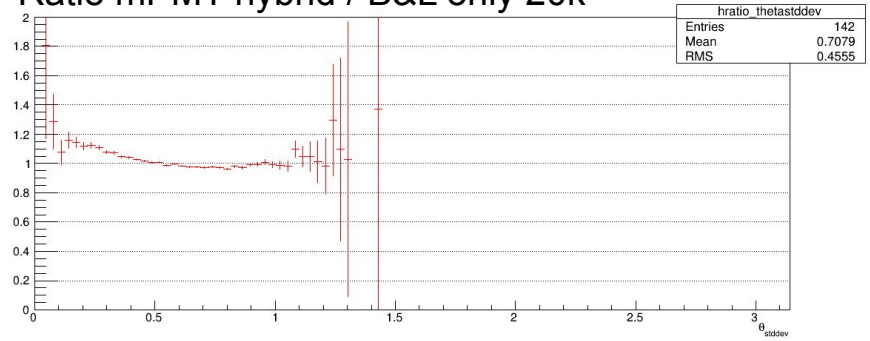
BG (darkhit)



Ratio mPMT hybrid / B&L only 20k



Ratio mPMT hybrid / B&L only 20k



Acceptance

- Hybrid-case has less separated distribution: SG has lower and BG is almost same with B&L only-case.
  - Note) This variable has efficient performance in MVA
  - Definition of the variable is not good for hybrid case
- It looks better to calculate mPMT-hits
  - Need some better definition...

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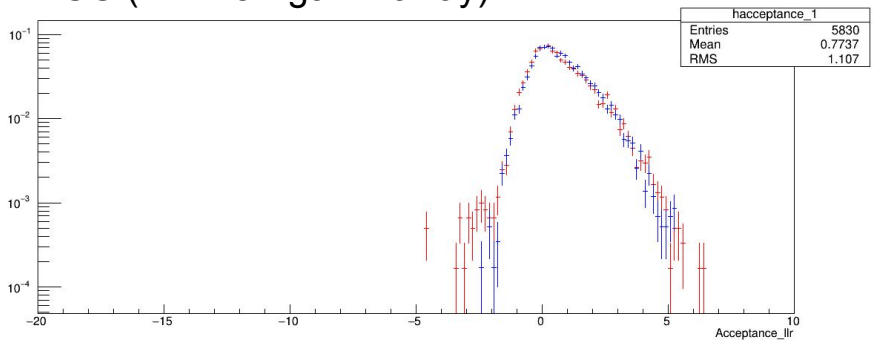
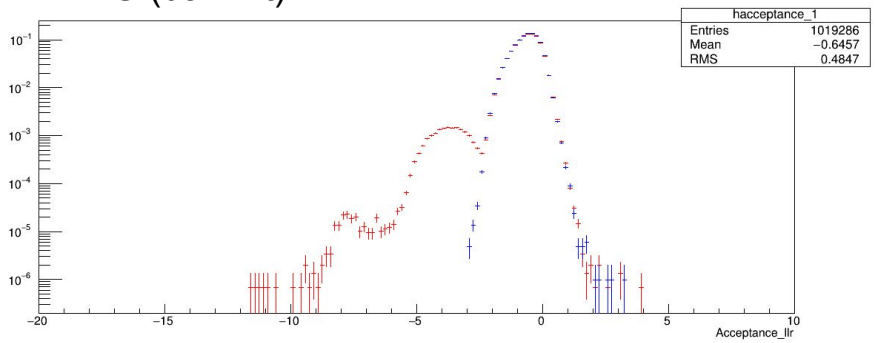
Blue: B&L only 20k

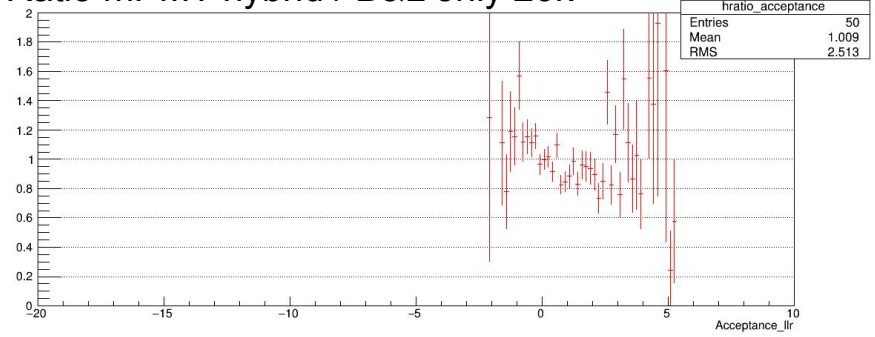
SG (2.2 MeV gamma-ray)



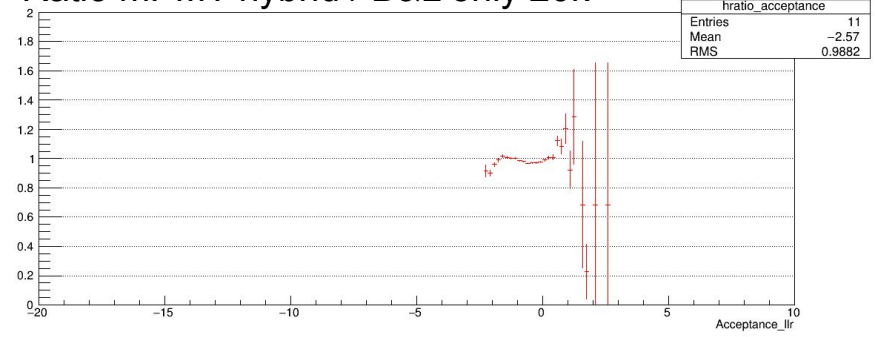
BG (darkhit)



Ratio mPMT hybrid / B&L only 20k



Ratio mPMT hybrid / B&L only 20k



Summary of the comparison

- Distributions for B&L only configuration and hybrid configuration look same qualitatively.
  - SK code works well for both
- But, mPMT hybrid case has less separated distribution in MVA input variables → There are less improvement in MVA.
- → Trying to add the variables which ignore mPMT hits

WCSim update for n-tagging

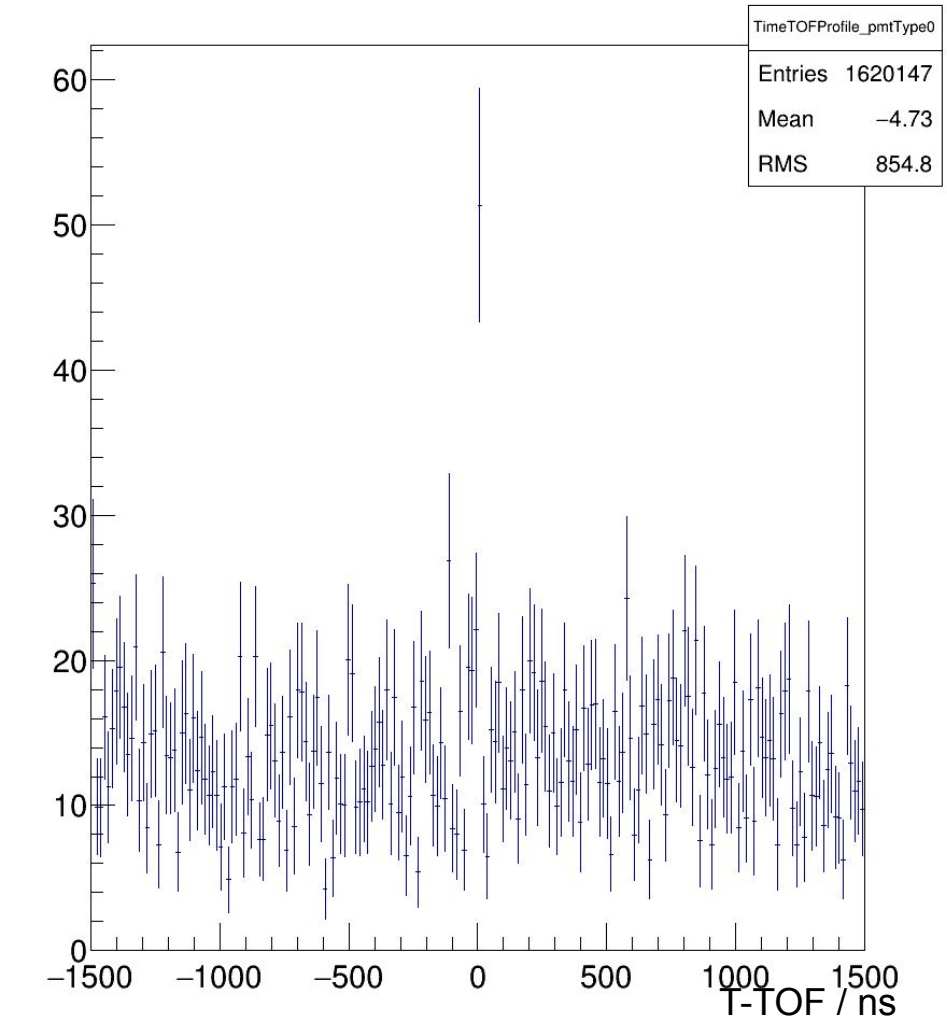
- Added new trigger class, called “NoTrigger”: this does not apply any trigger algorithm → catch small signal correctly.
  → I created new pull request, but I have some missing part and am modifying.
  - Here this is merging Rn simulation.

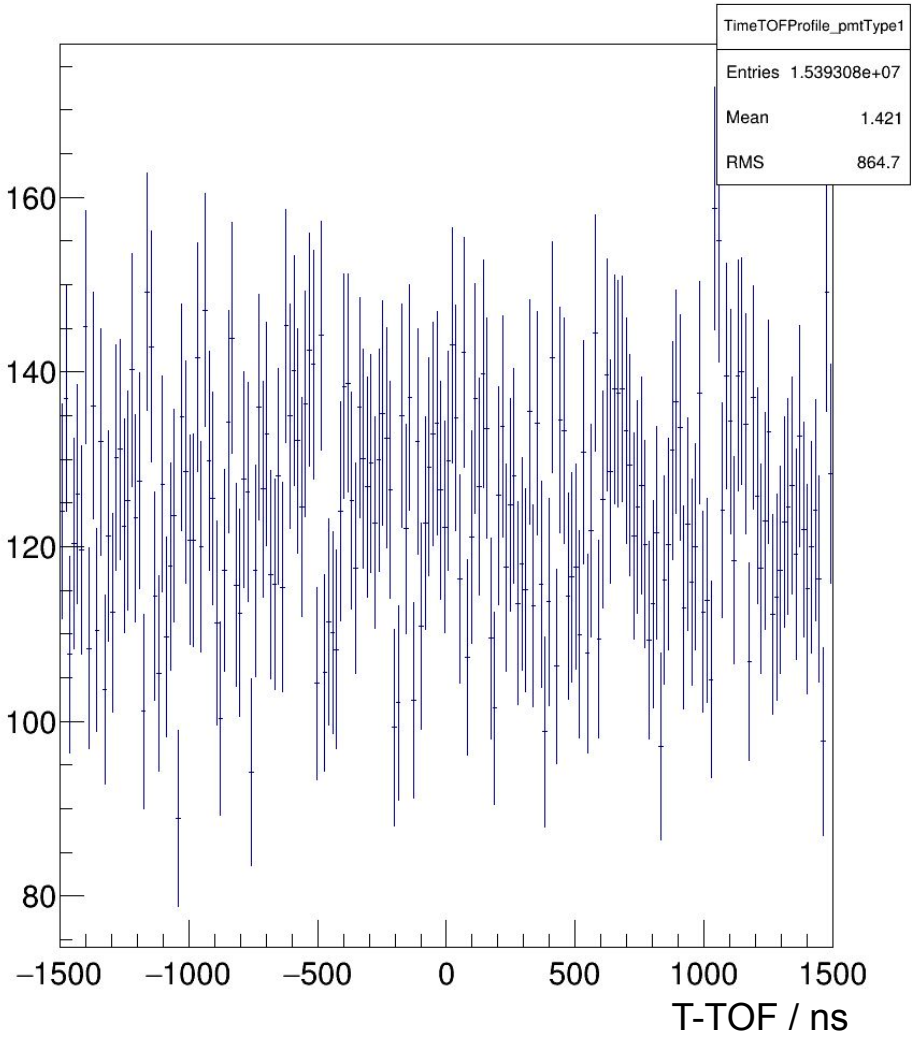
Issues in WCSim

- Detector configuration through mac-file:
  - Problem to change darkrate
    - /DarkRate/SetDarkRate command change darkrate for both of B&L PMTs and 3-inch PMTs
      → Now I need to change through src/WCSimPMTObject.cc
  - Is there any method to change DR of 3 inch PMT via mac-file?
    If not, I would like to add. Where can I do it?
- Geant4 compatibility:
  - hybridPMT branch: worked well with Geant 4.10.01.p03 but failed with 4.10.03.p03
  - RadonHybrid branch: worked well with Geant 4.10.03.p03 but failed with 4.10.01.p03
  - After merging, this could be solved. We need to move 4.10.02 or earlier as Guillaume said.

2.2 MeV gamma-ray, 10 events overlay

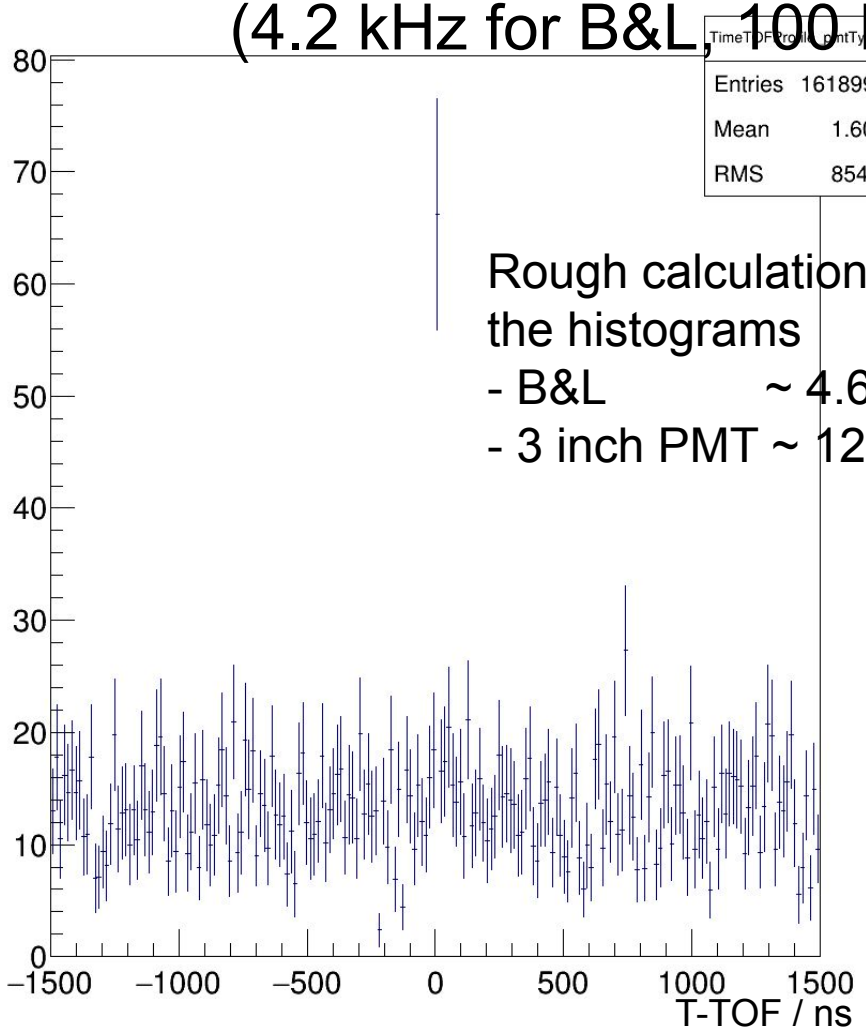
- Using “/DarkRate/SetDarkRate 4.2 kHz”
- “NoTrigger” class
  → 3 inch PMTs have large darkrate (~ 4.2 kHz)



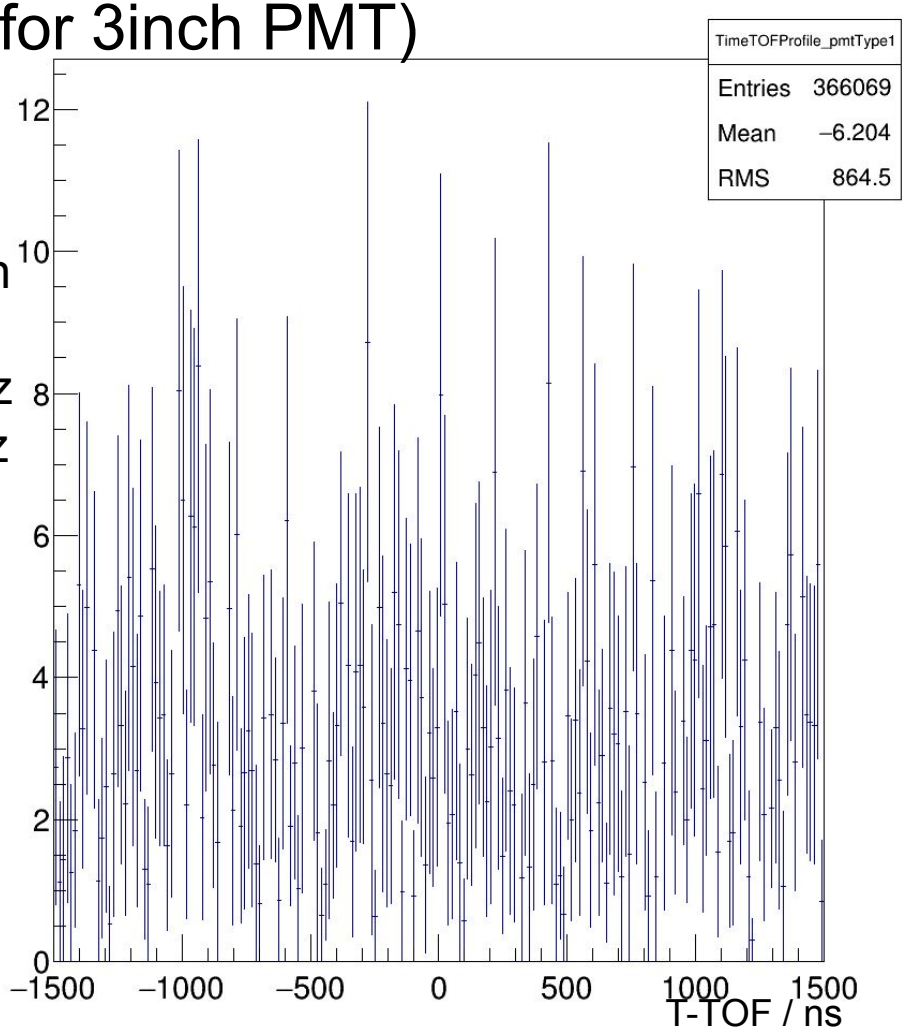


2.2 MeV gamma-ray, 10 events overlay

- Not using “/DarkRate/SetDarkRate” command
- “NoTrigger” class
  → Darkrate looks default value
  (4.2 kHz for B&L, 100 Hz for 3inch PMT)

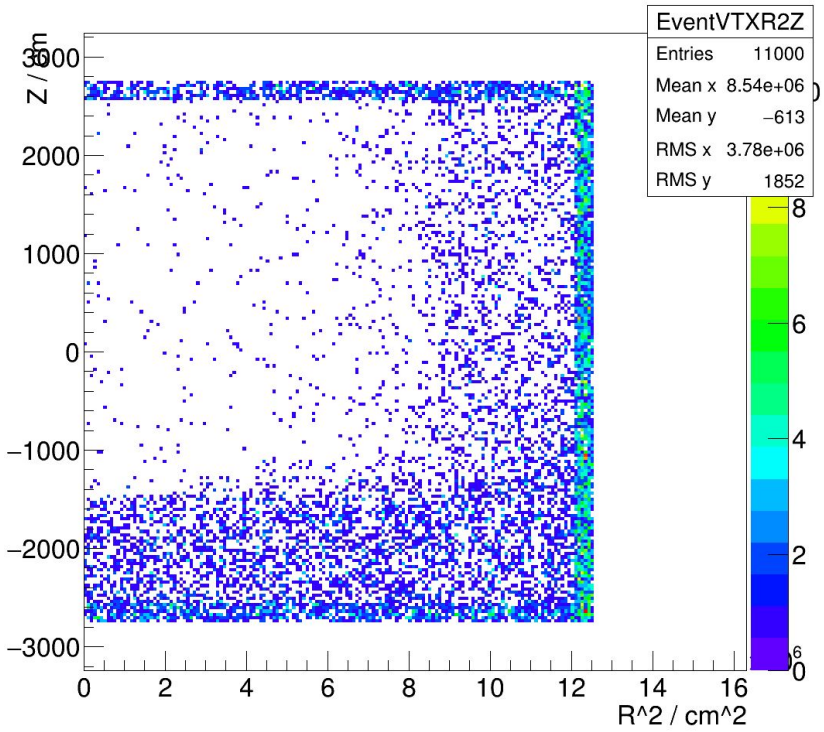


Rough calculation with the histograms
- B&L ~ 4.6 kHz
- 3 inch PMT ~ 120 Hz



Rn simulation

- I merge Rn simulation and just tried to run:
- Plan:
  - Evaluate Rn background for n-tagging
    (Started to consider how to evaluate. Now I have no concrete method.)
    - 1. Make events
    - 2. Perform n-tag algorithm
      - also check LEAF exactly (?) to evaluate lowe BG
    - 3. Maybe I need scaling to n-tagging time window
- Right plots: true Rn events vertex
  - I generated 100,000 events and, plotted 11,000 events
  - Looks woking well



Summary

- Checked MVA input variables
  - mPMT case has less separated distribution between SG and BG
  - Investigating how to improve efficiency
- Modifying WCSim, LEAF and ntag-code for HK MC production campaign
  - Added new trigger
  - Found some problem (we may ignore)
- Testing Rn simulation

Backup

e 10MeV, random in tank, 1000 events