

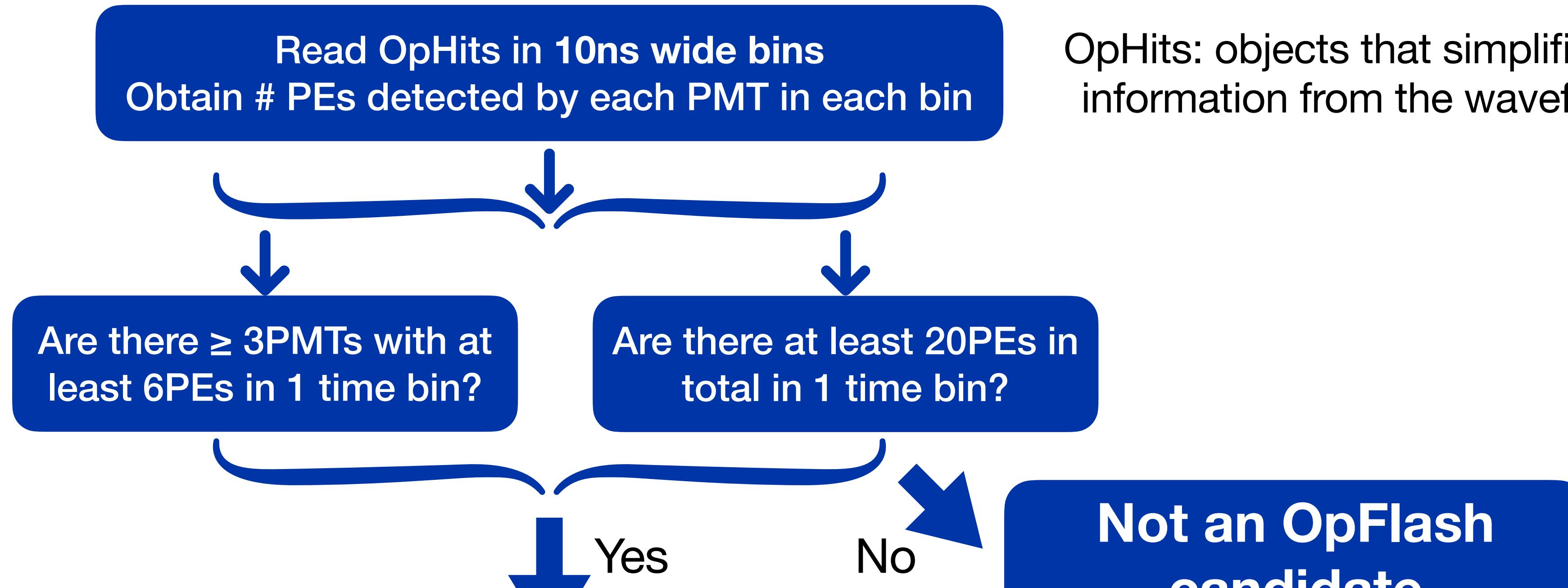
OpFlash inefficiencies and veto window

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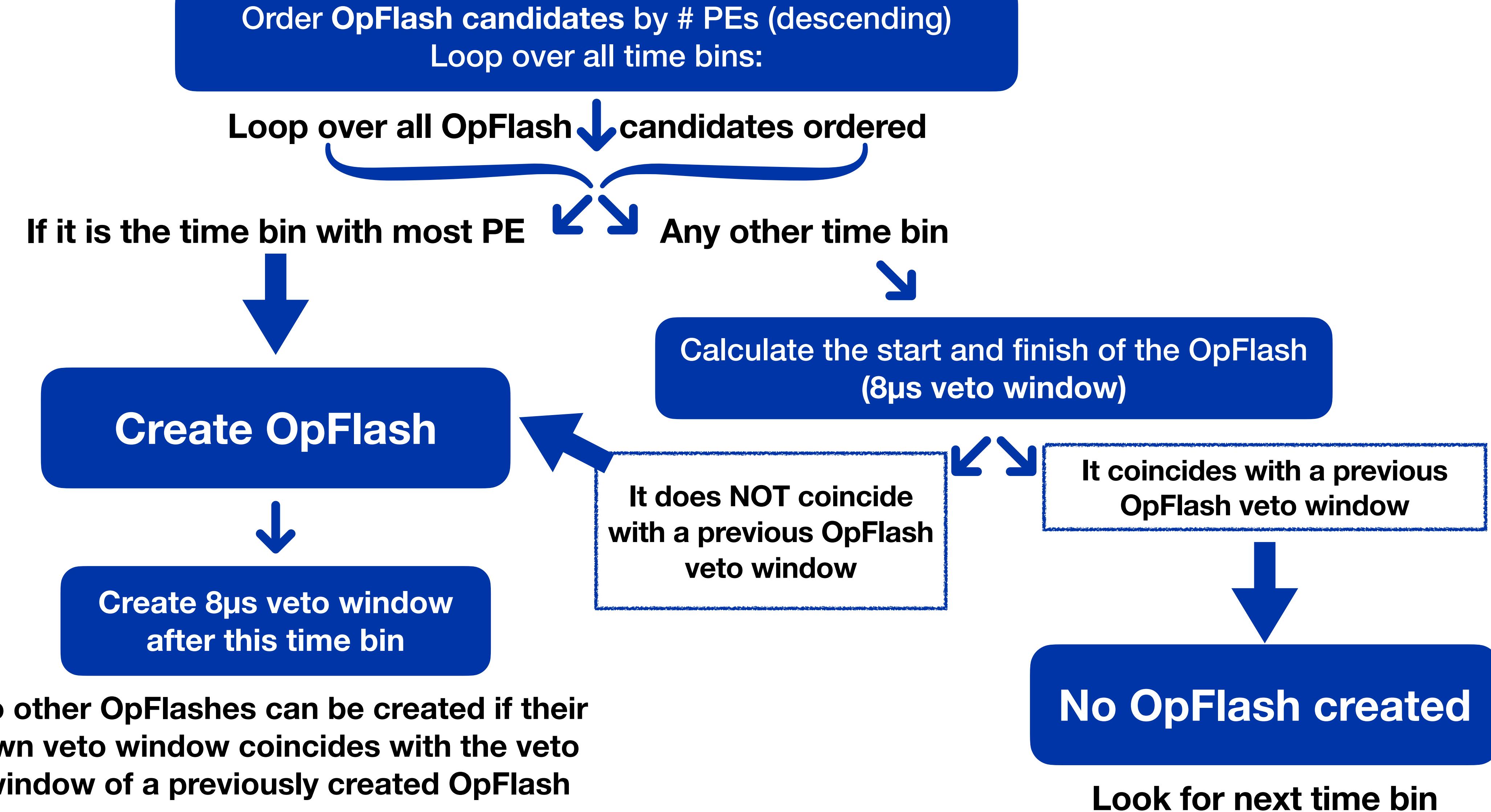
OpFlash definition (I)



OpHits: objects that simplifies the information from the waveforms

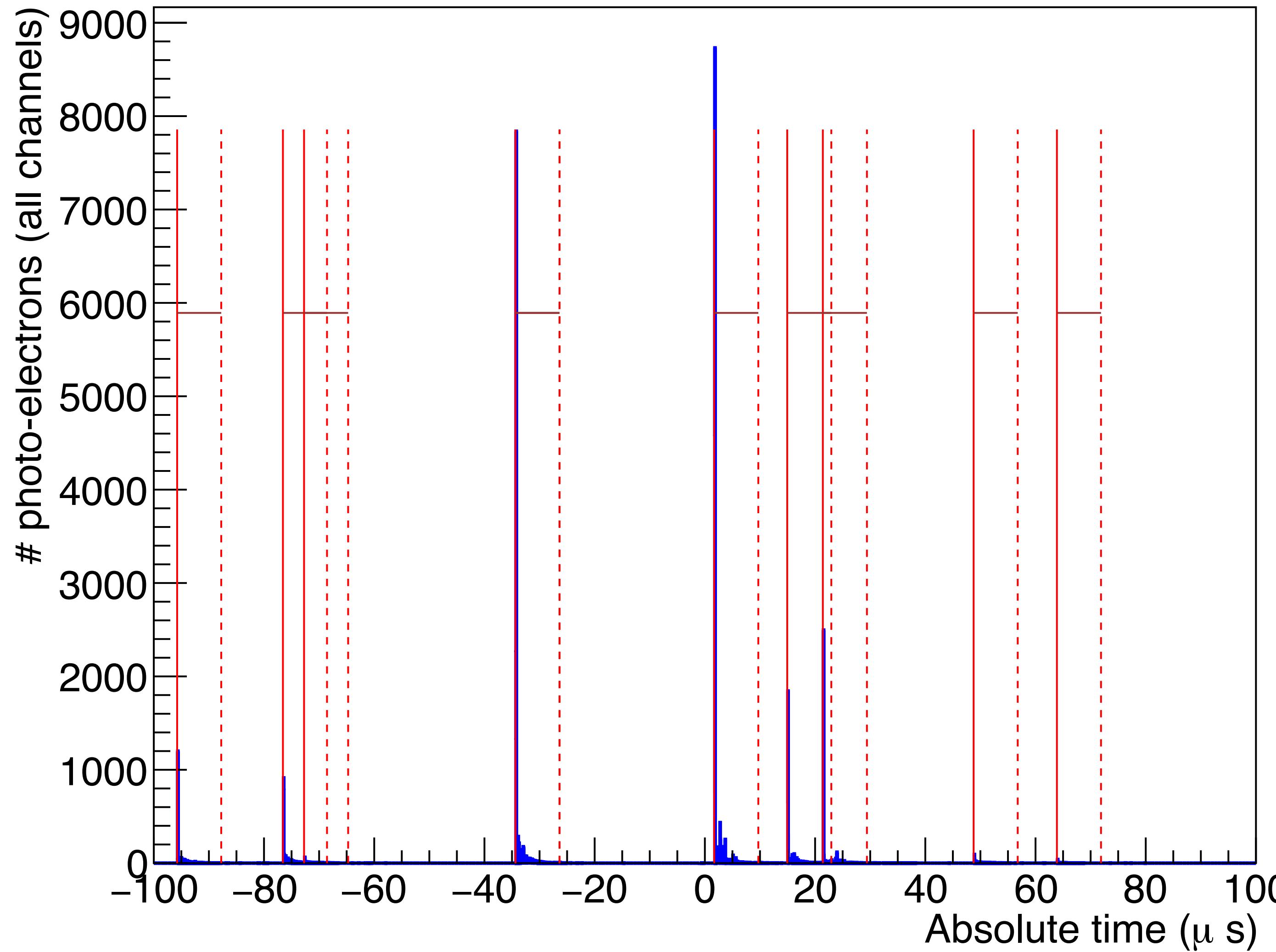
This bin could create an OpFlash
corresponding to an interaction

OpFlash definition (II)



Time distribution of OpFlashes

OpHit distribution

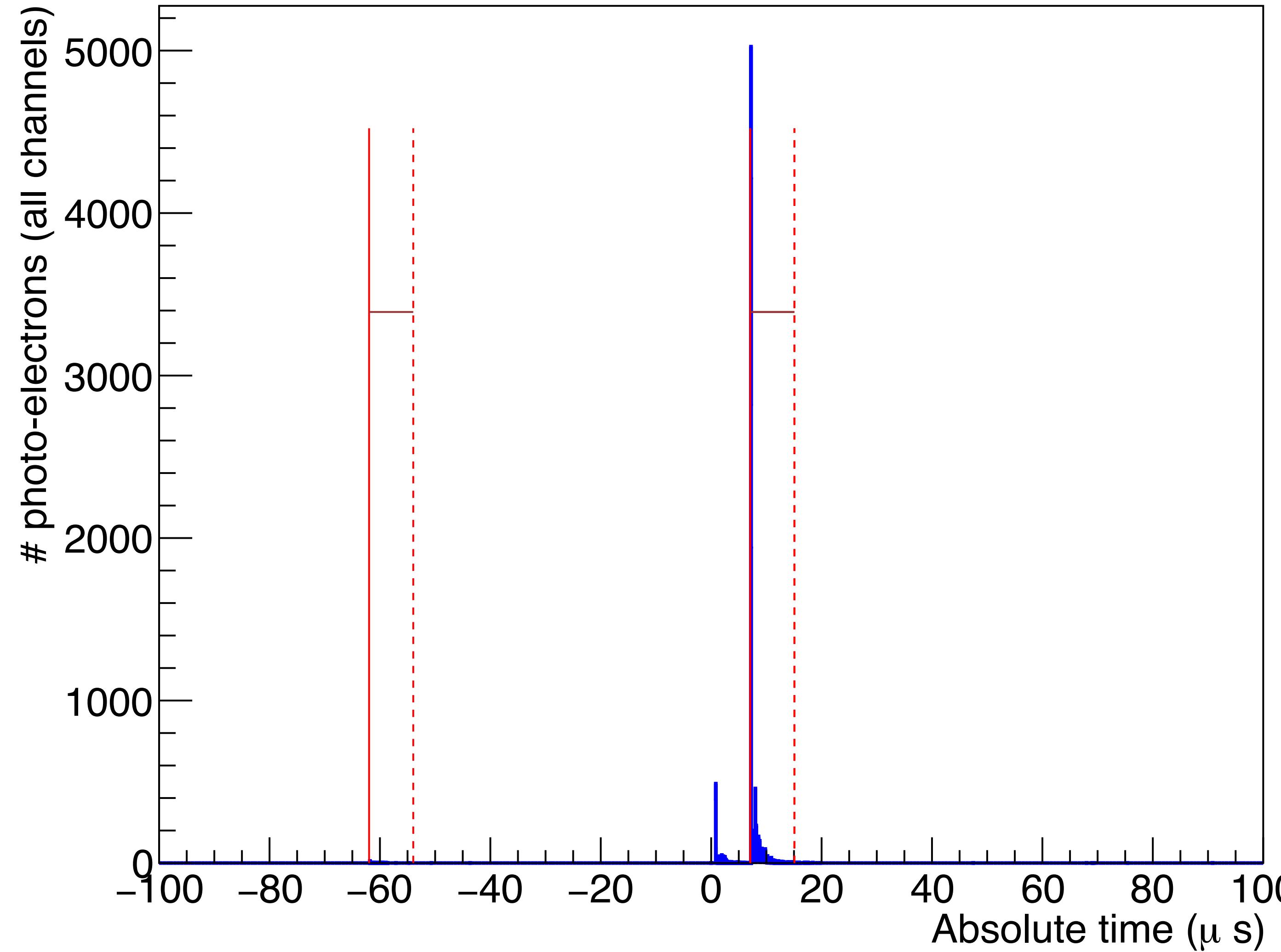


Usually, there are ~40 interactions (BNB+cosmics) in each 3ms detection time

In this example, despite having many interactions close in time to each other, all of them create an OpFlash!

Time distribution of OpFlashes

OpHit distribution

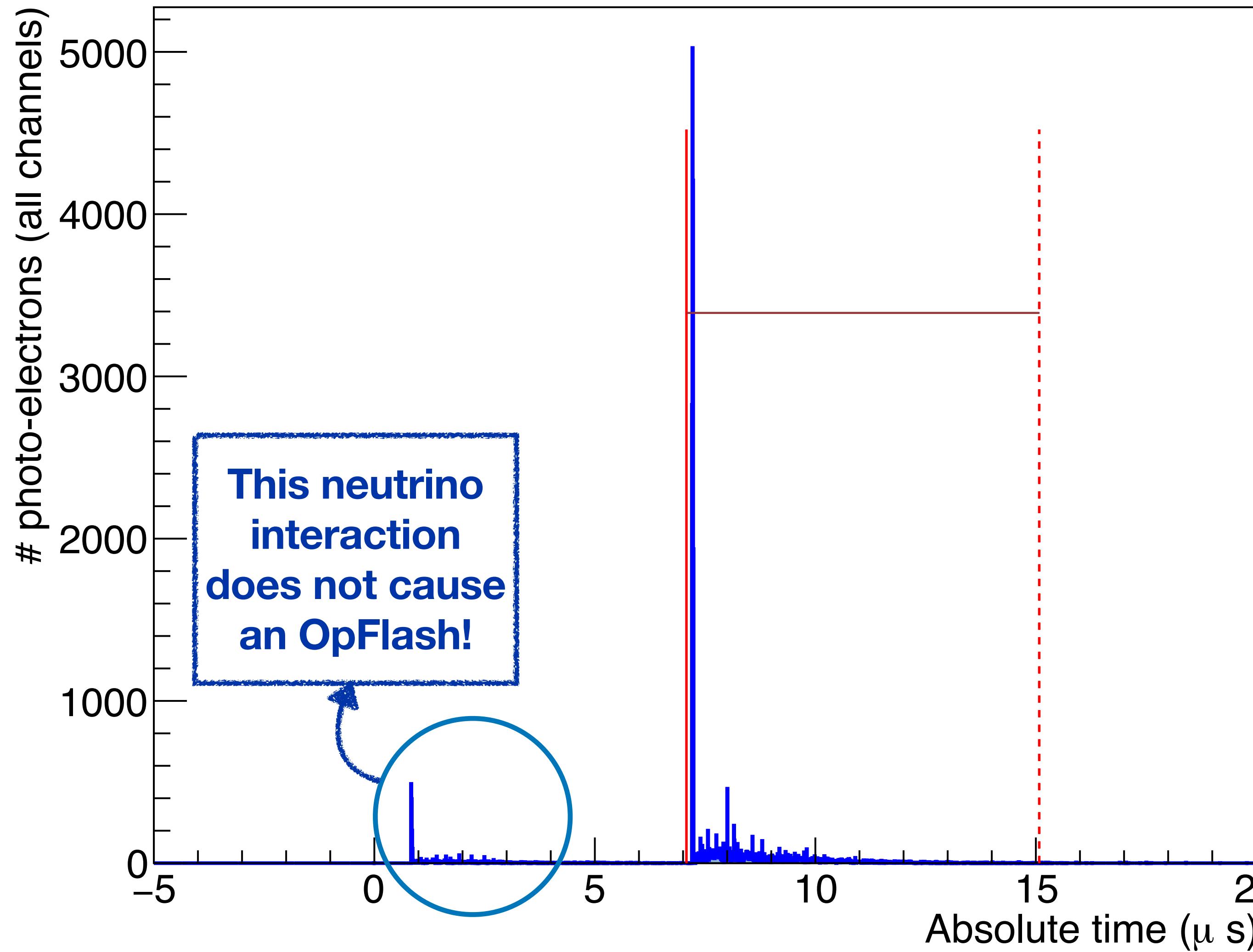


Usually, OpHit time distributions look like this (less interactions in the same amount of time)

But if we zoom in this example...

Time distribution of OpFlashes

OpHit distribution



The **veto window (total of 8 μ s)** from the cosmic interaction at ~7 μ s makes the algorithm not create an OpFlash for the previous interaction

These kind of situations cause an inefficiencies in the OpFlash algorithm

BNB + cosmics OpFlash Efficiency

How many interactions (neutrino or cosmic) create an associated OpFlash

Efficiency

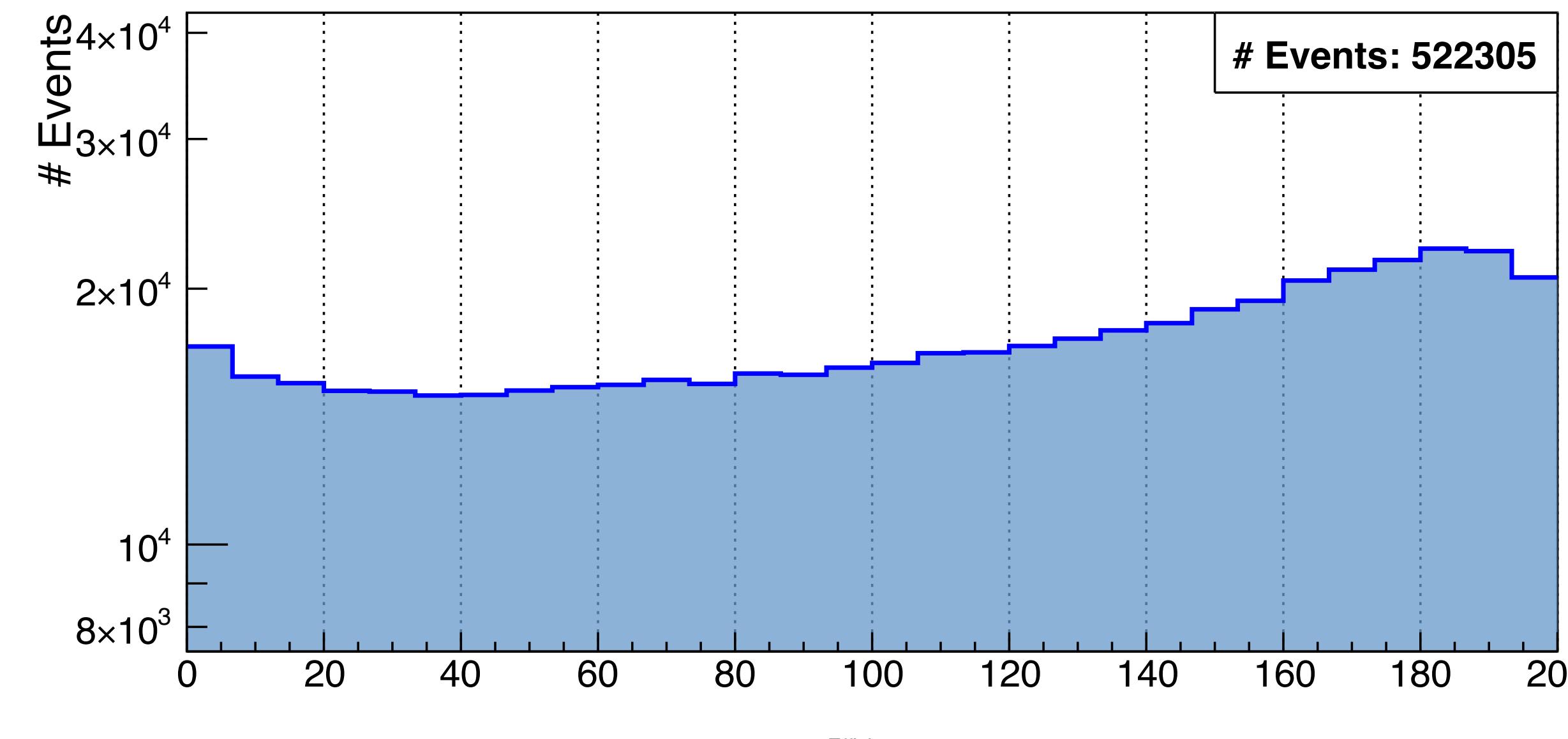
$$\frac{\text{\# interactions with corresponding OpFlash}}{\text{\# true interactions}}$$

As we will see, **inefficiencies can be caused by:**

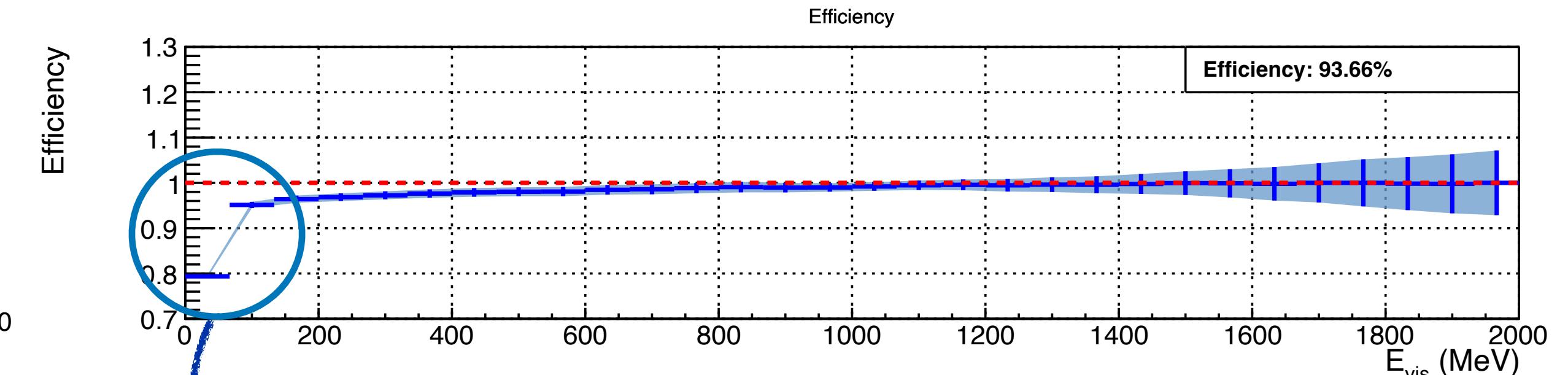
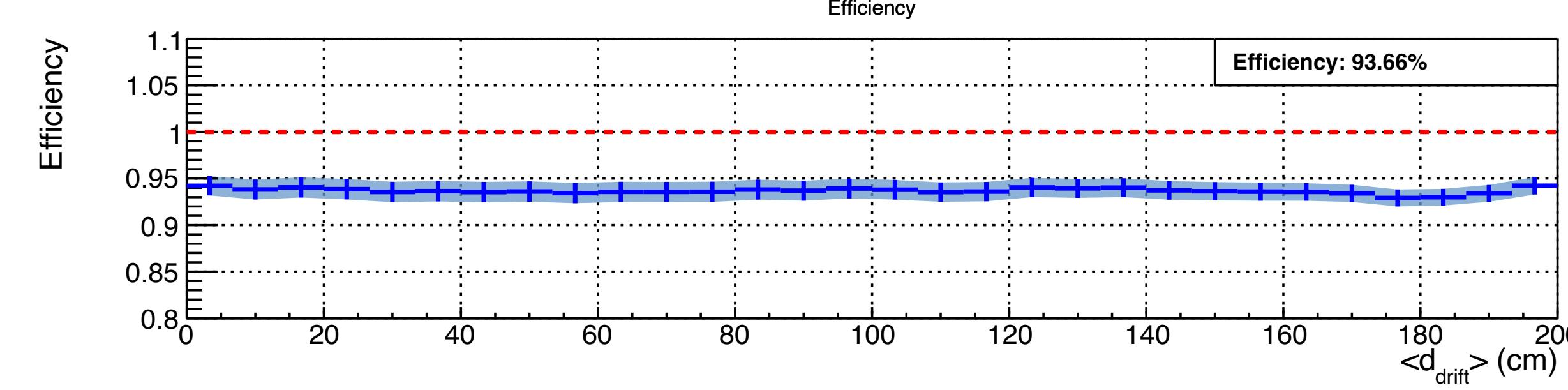
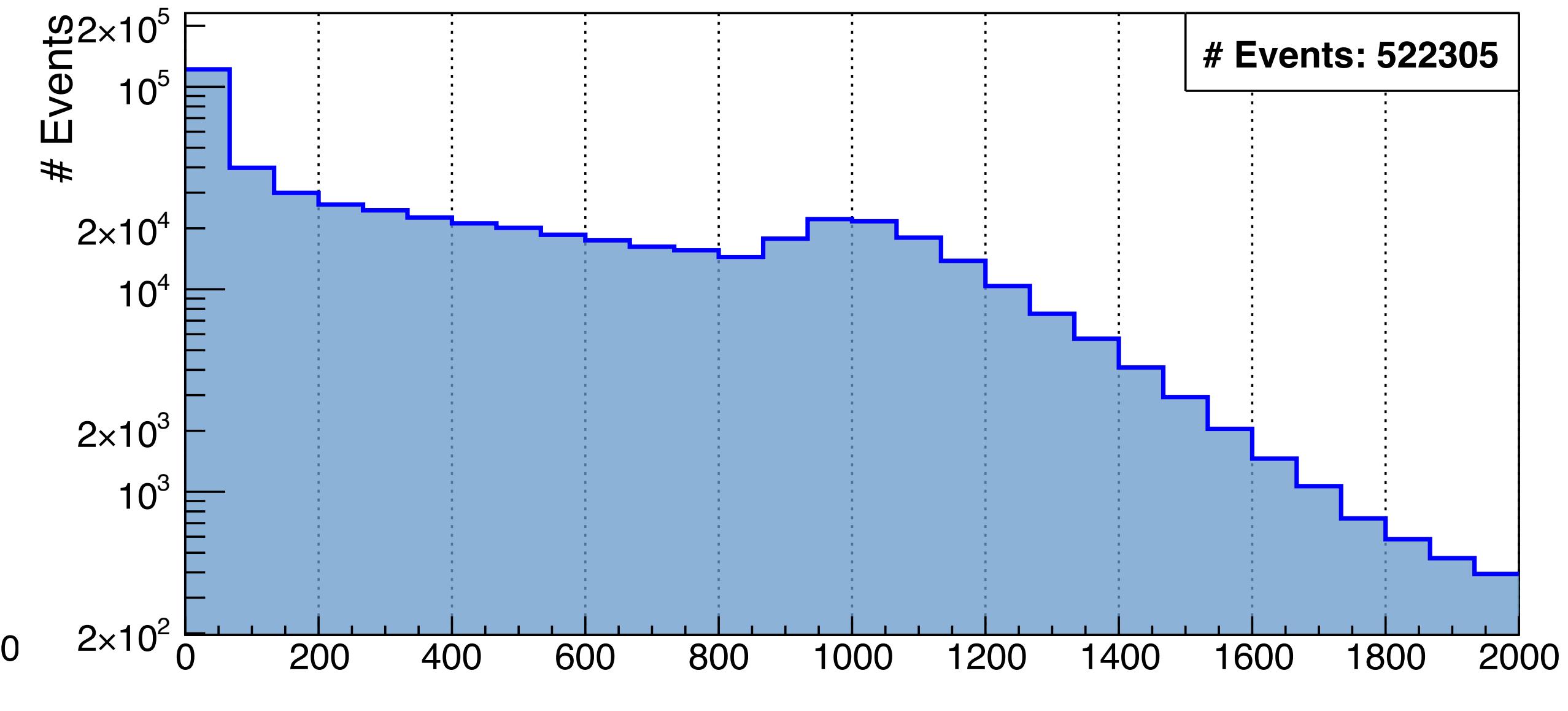
1. Interaction with larger light emitted than a different **later** interaction inside its veto window.
2. Interaction with larger light emitted than a different **previous** interaction. The veto window of the second collapses with the first one (what I showed before).
3. Interaction with not enough energy deposition to create an OpFlash.

BNB + cosmics OpFlash Efficiency

Fall Production BNB+cosmics



Fall Production BNB+cosmics

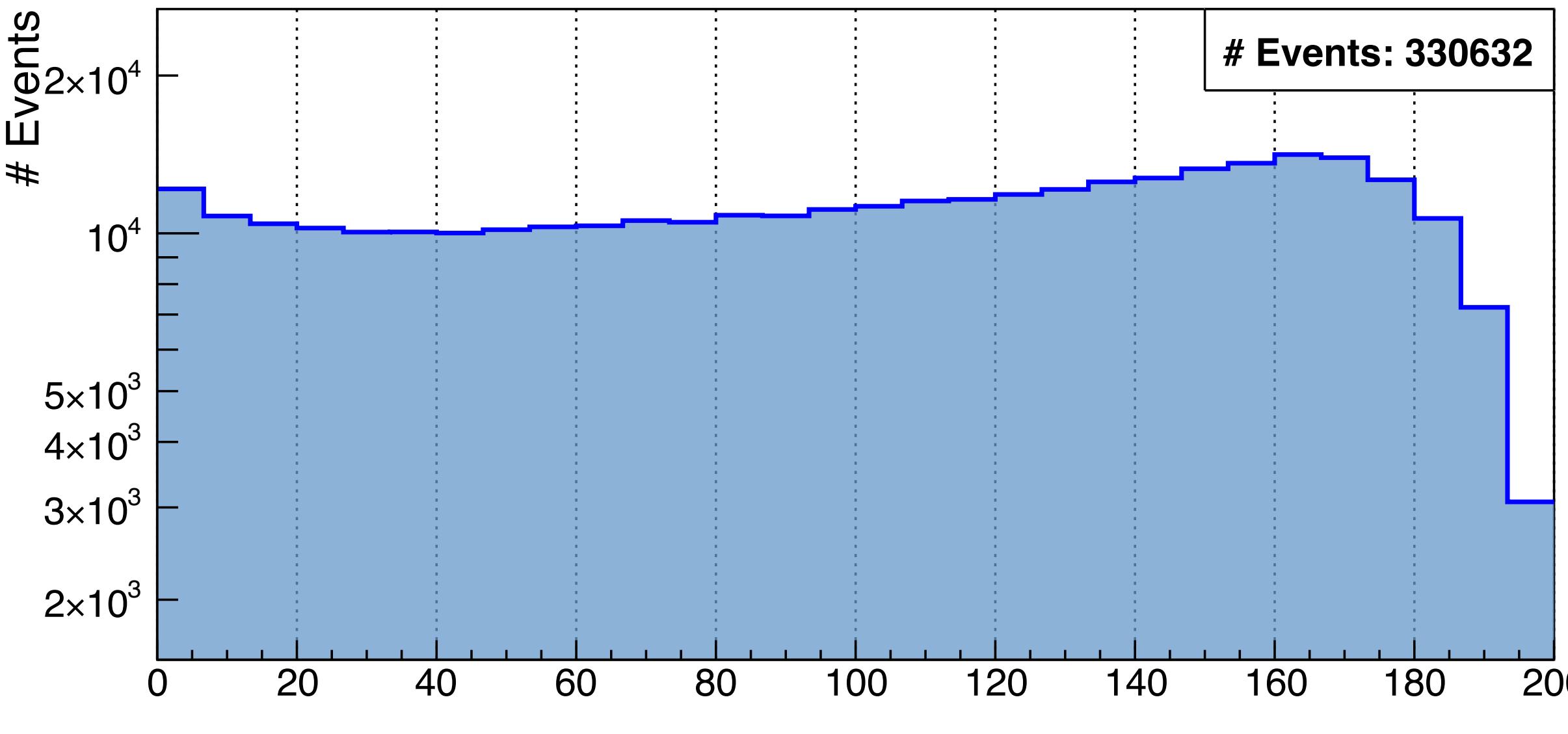


- Efficiency: **93.66%**
- Fraction lost due to coincident interactions: **2.634%**

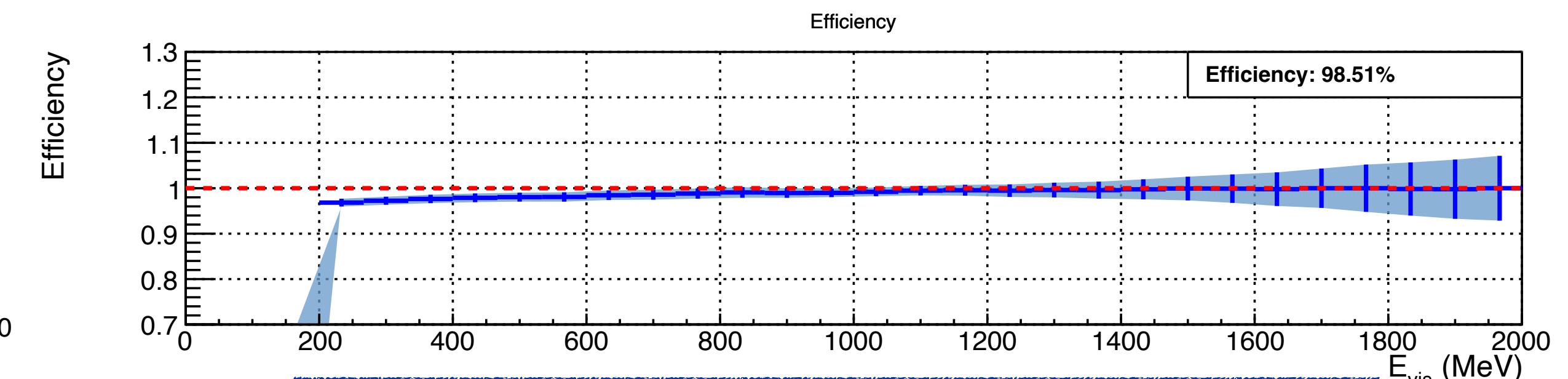
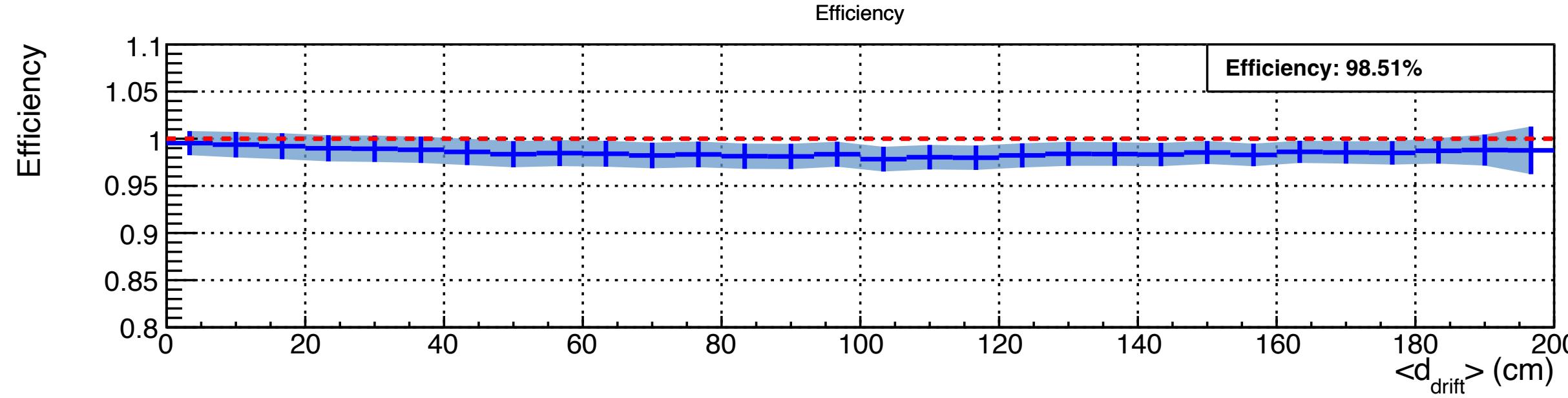
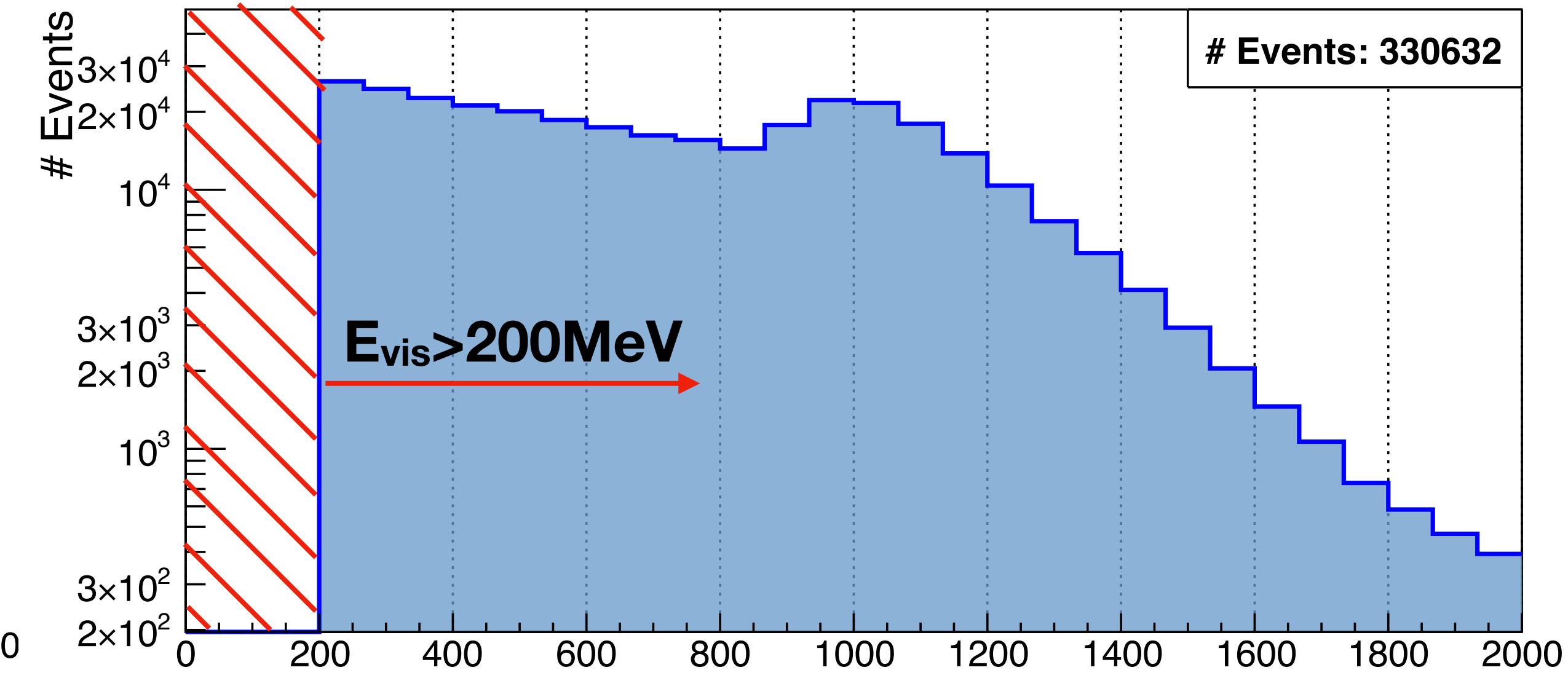
**Biggest lose in efficiency comes from
very low energy deposition interactions
(very low scintillation light deposition)**

BNB + cosmics OpFlash Efficiency

Fall Production BNB+cosmics



Fall Production BNB+cosmics



- Efficiency: **98.51%**
- Fraction lost due to coincident interactions: **1.38%**

Biggest problem to solve: reduce the inefficiency from coincident interactions
(cases 1, 2)

Neutrino OpFlash Efficiency

How many neutrino interactions create an associated
OpFlash

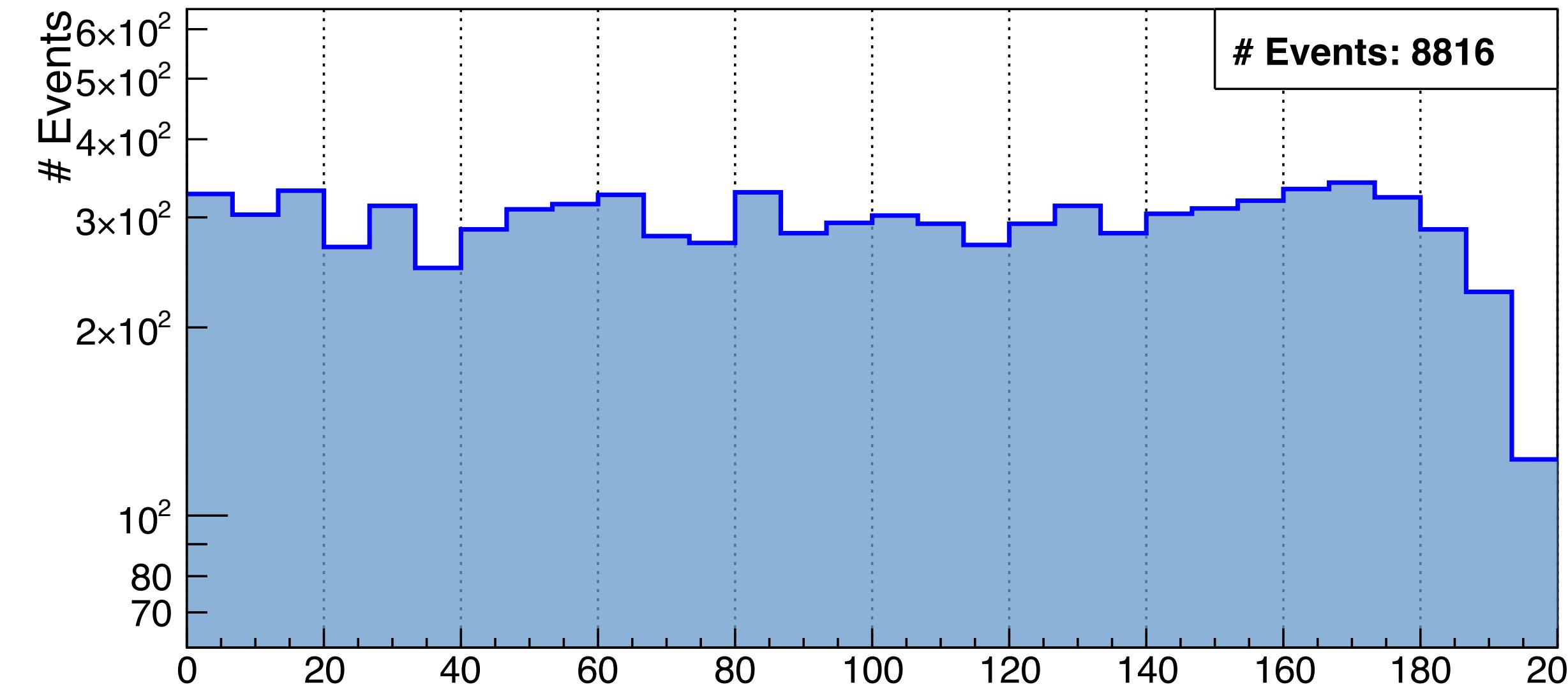
Efficiency

$$\frac{\text{\# neutrino interactions that create an OpFlash}}{\text{\# true neutrino interactions}}$$

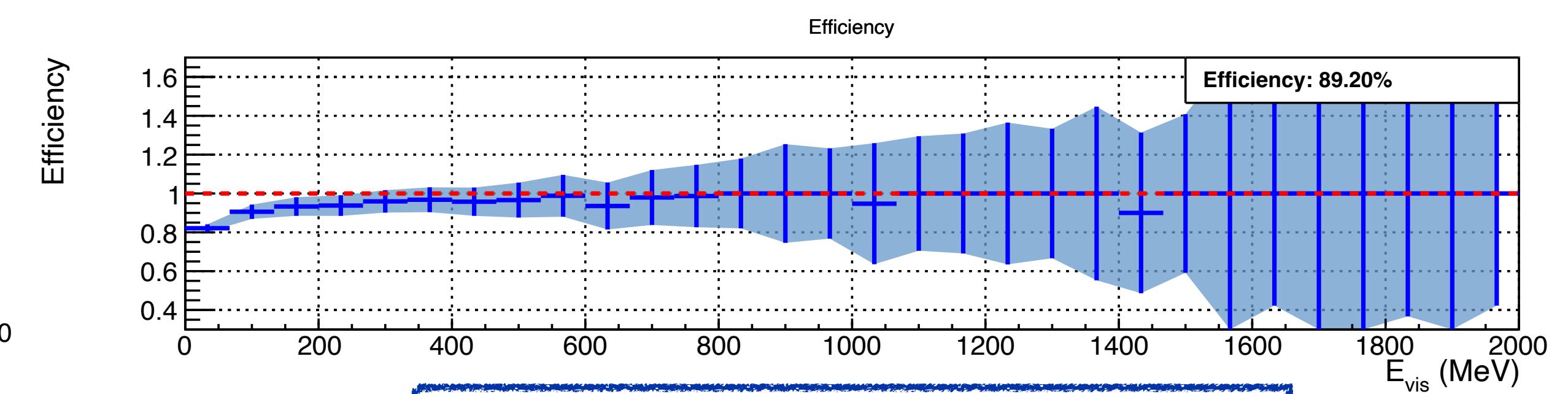
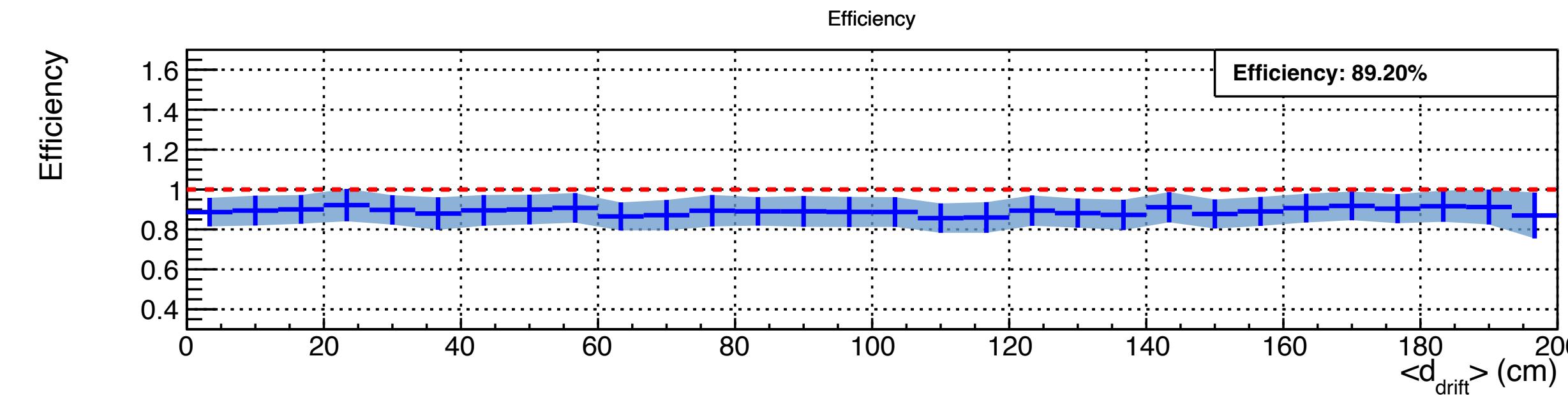
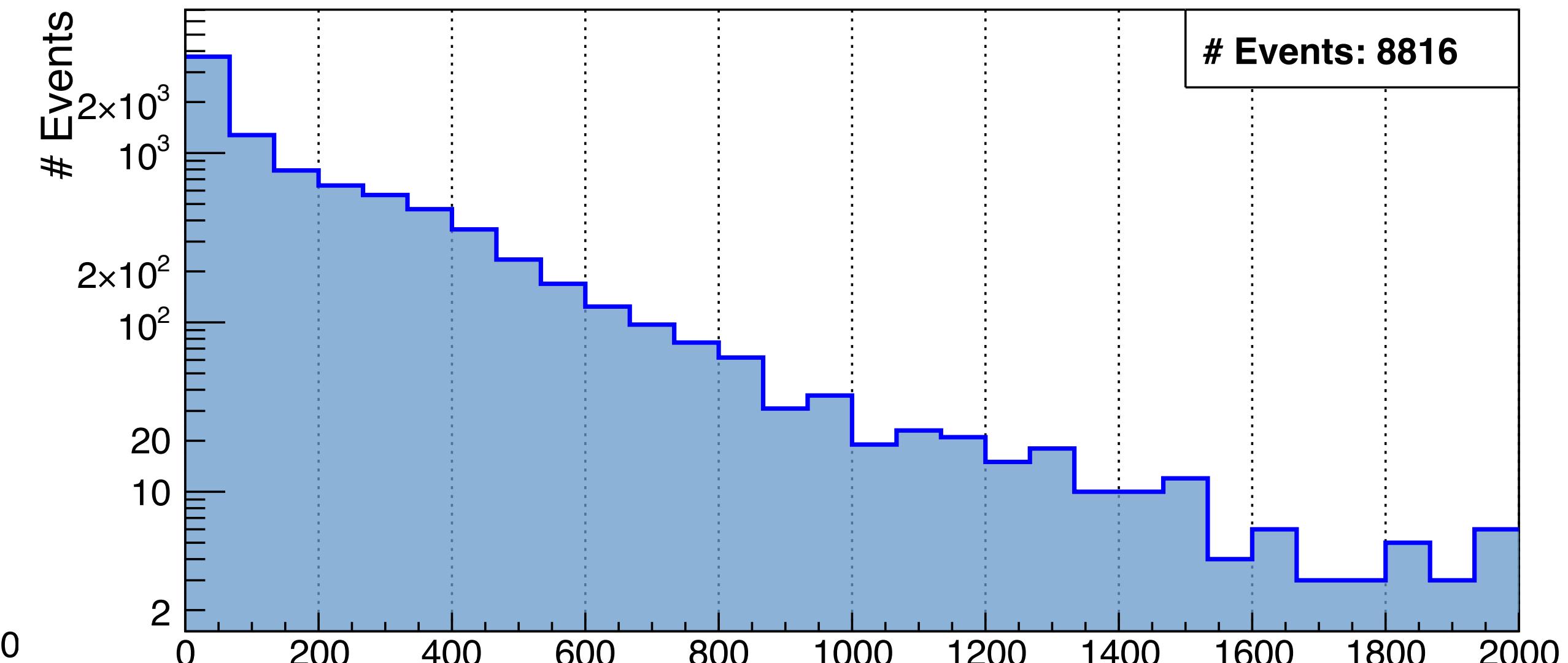
The neutrino detection efficiency might be worse than
the cosmic+neutrino efficiency because of the
neutrino pile-up possibility

Neutrino OpFlash Efficiency

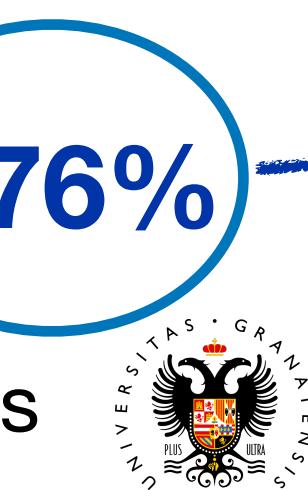
Fall Production BNB+cosmics



Fall Production BNB+cosmics



- Efficiency: **89.20%**
- Fraction lost due to coincident interactions: **7.76%**



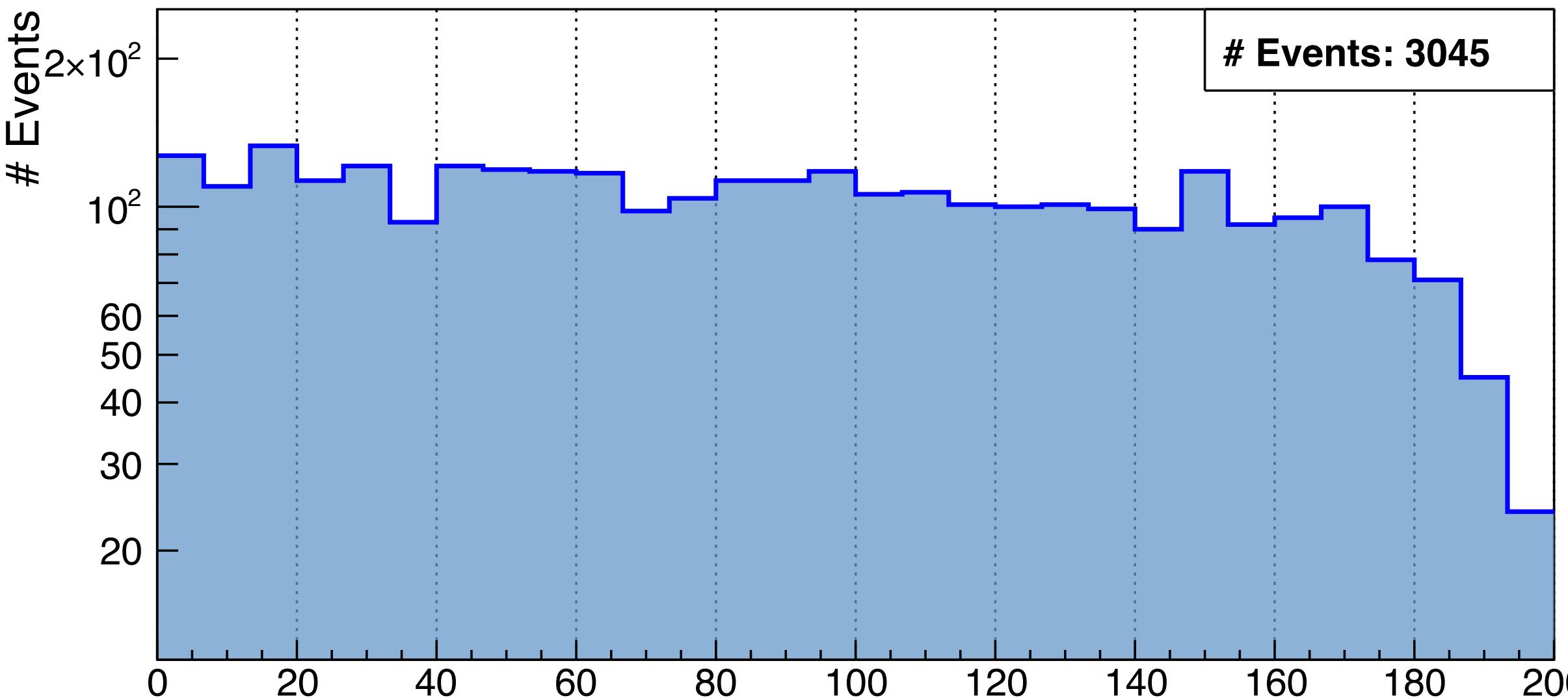
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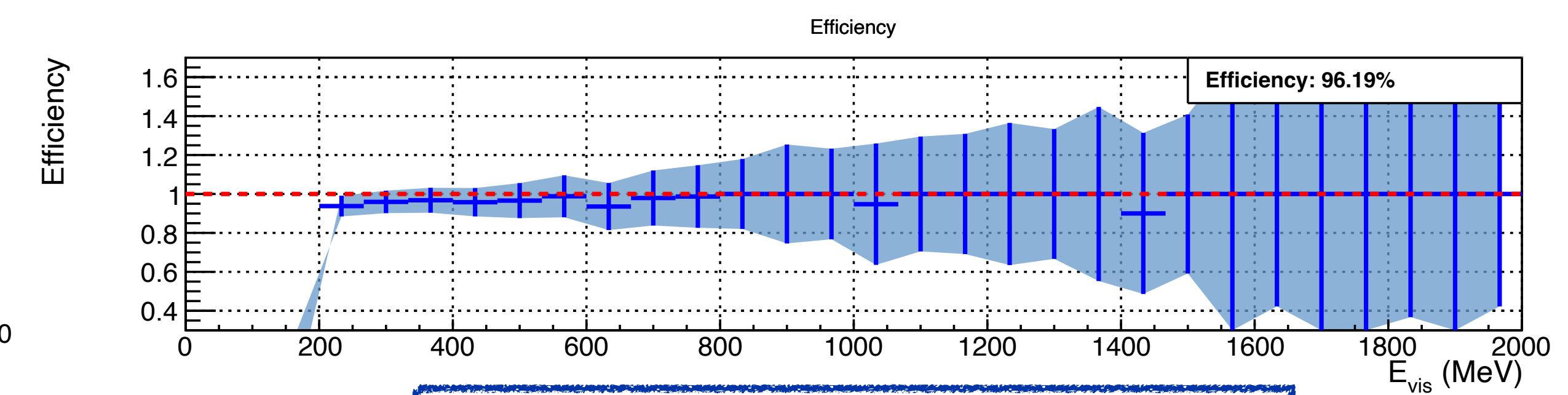
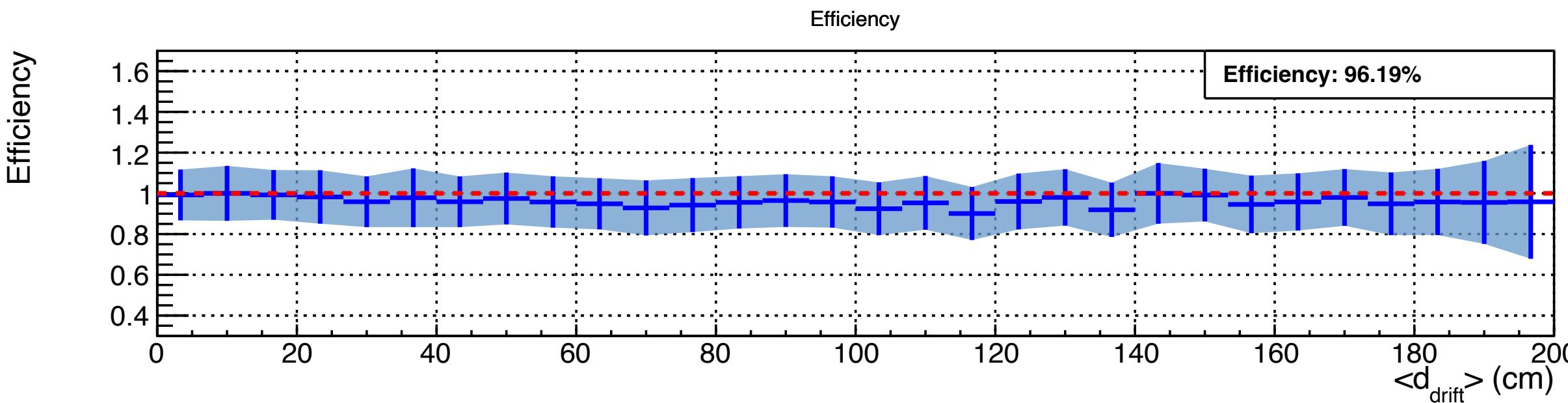
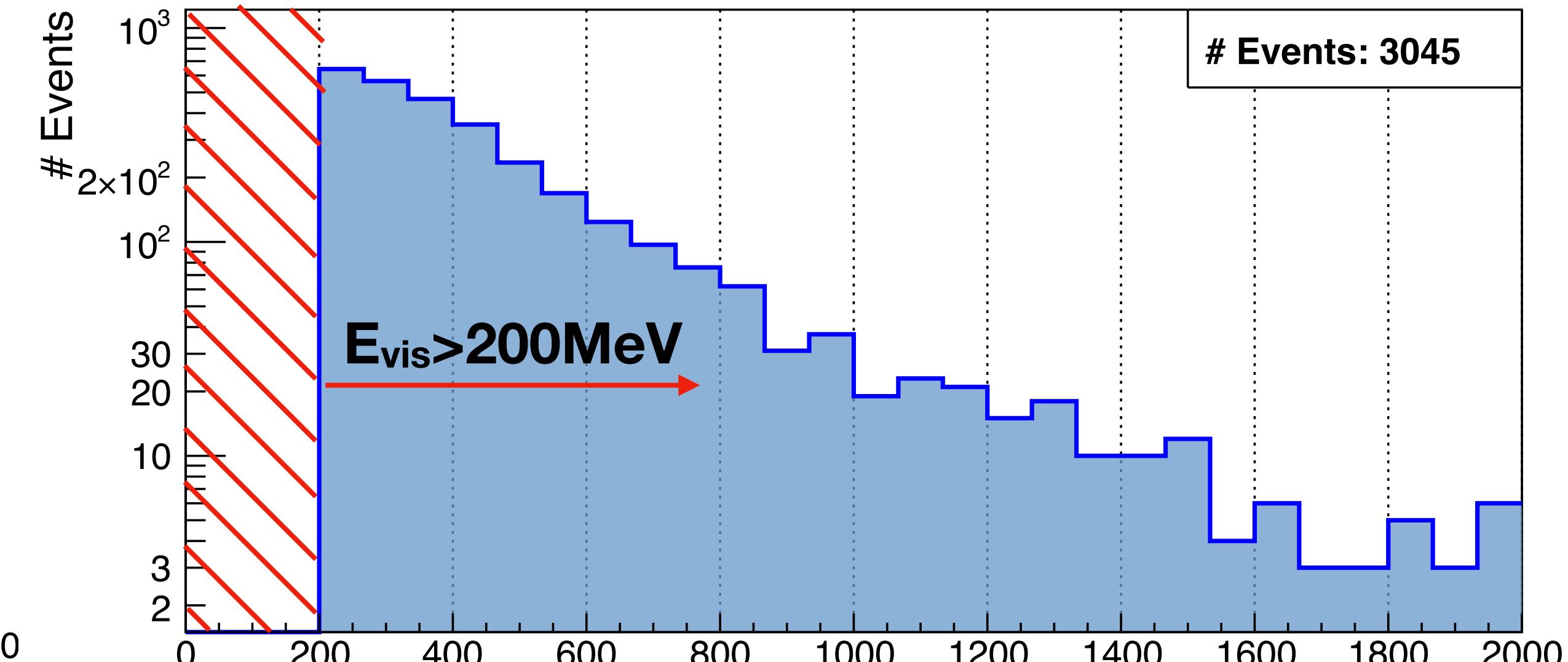
As expected (neutrino pile-up),
neutrino interactions are
coincident in time more often

Neutrino OpFlash Efficiency

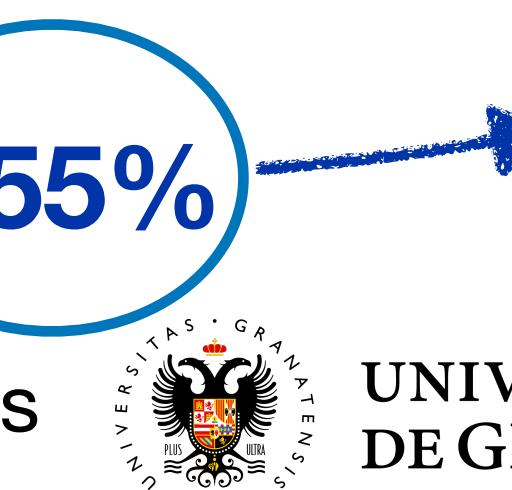
Fall Production BNB+cosmics



Fall Production BNB+cosmics



- Efficiency: **96.19%**
- Fraction lost due to coincident interactions: **3.55%**



When $E_{\text{vis}} > 200\text{MeV}$, (almost) all inefficiencies are due to coincident interactions

OpFlash Efficiency

All interactions

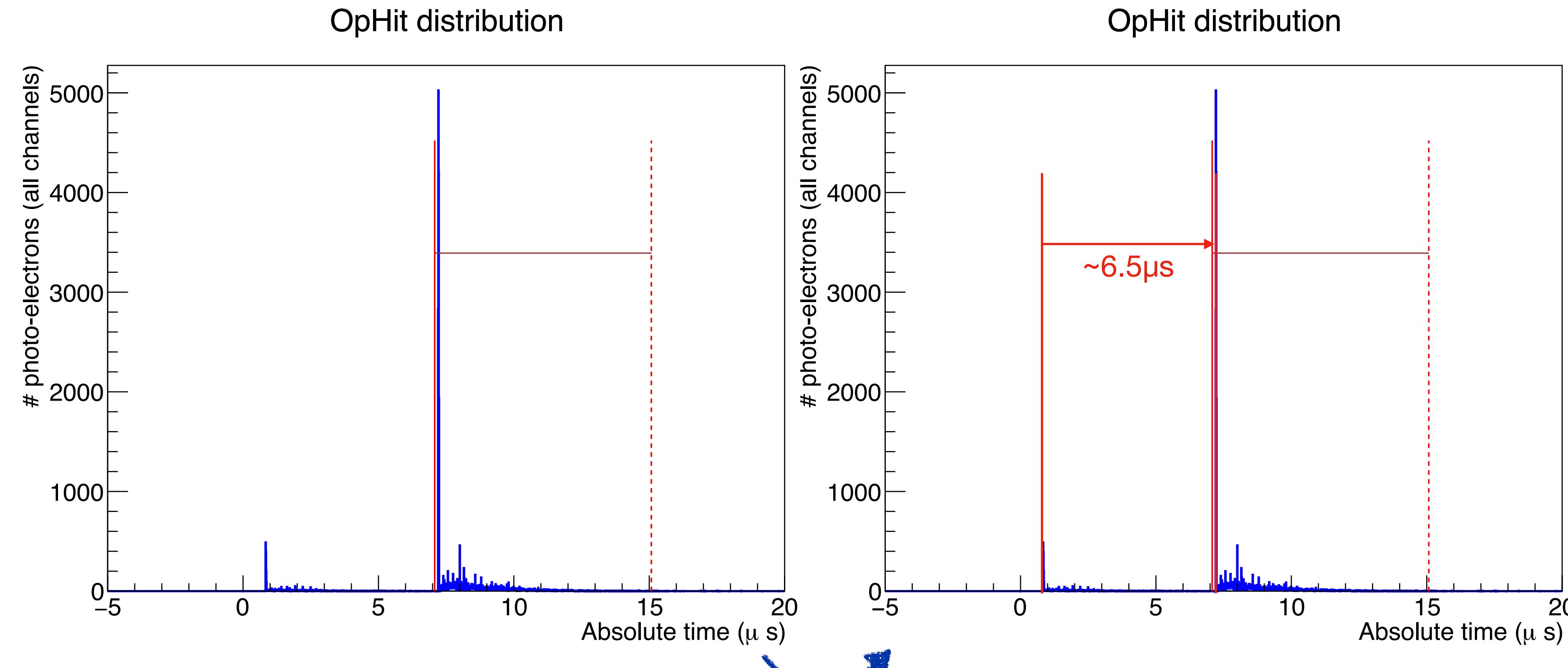
- Interaction with OpFlash: **93.66%**
- **Case 1** (interaction after OpFlash): $\sim 0.55\%$
- **Case 2** (interaction before OpFlash): $\sim 0.9\%$
- **Case 3** (Light emitted does not create OpFlash): $\sim 5\%$

Neutrino interactions

- Neutrino interaction with OpFlash: **89.20%**
- **Case 1** (interaction after OpFlash): $\sim 3.64\%$ 
 - Cosmics: 70%
 - Beam: 30%
- **Case 2** (interaction before OpFlash): $\sim 4.11\%$ 
 - Cosmics: 59%
 - Beam: 41%
- **Case 3** (light emitted does not create OpFlash): $\sim 3.13\%$

Revisiting OpFlash building algorithm

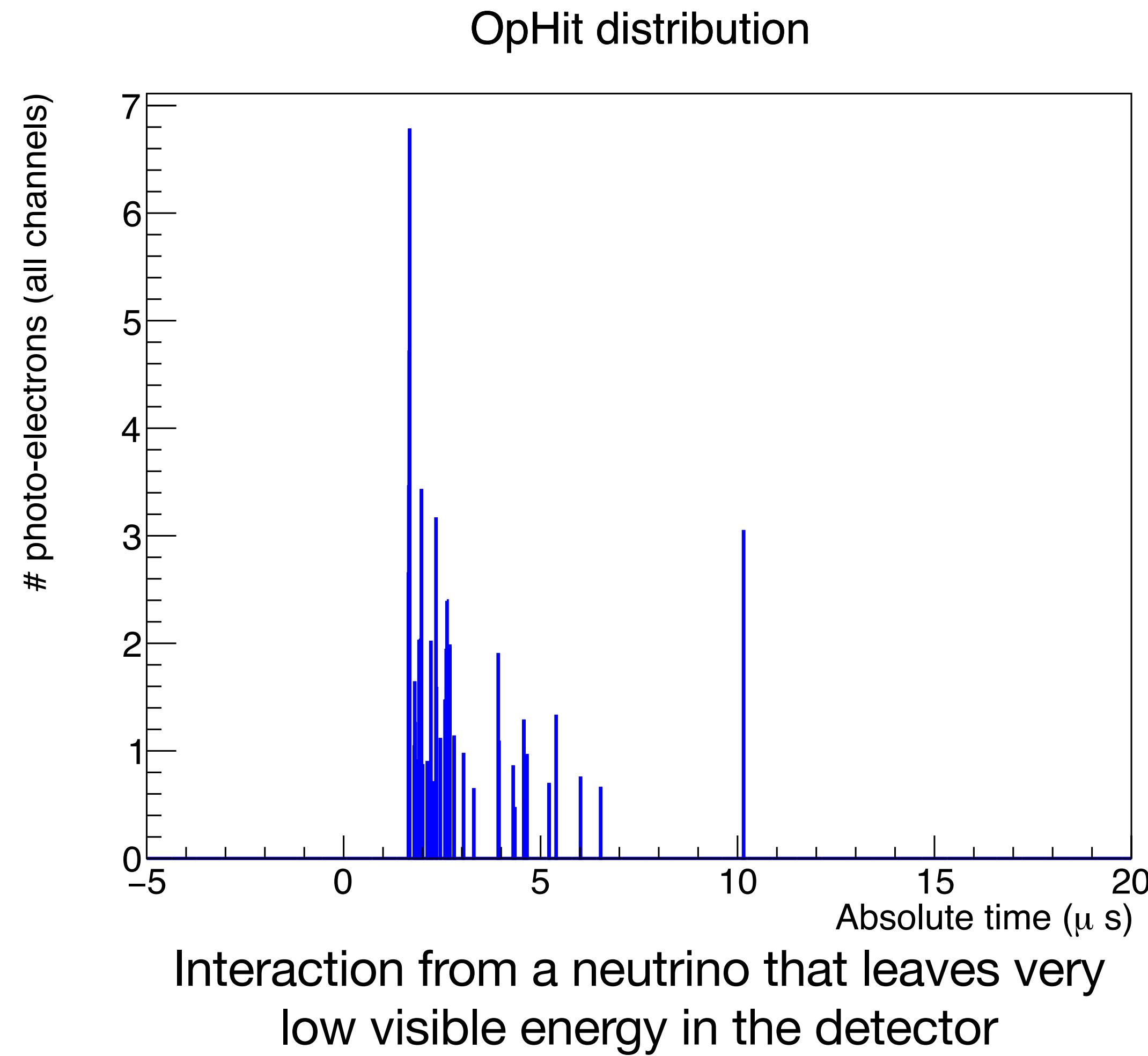
- **Case 2: Interaction with larger light emitted than a different previous interaction:** the veto window of the first interaction would coincide with the veto window of the second one (which has priority for having larger #PE)



A **possible solution** would be identifying these interactions and **creating an OpFlash with a shortened veto window for them**

Revisiting OpFlash building algorithm

- **Case 3: Interaction with not enough energy deposition to create an OpFlash**



- Including these events would require lowering the threshold for the creation of an OpFlash.
- The present thresholds come from previous studies (by Fran) to make sure that **noise never creates an OpFlash**.
- Changing the threshold would require to repeat Fran's analysis.

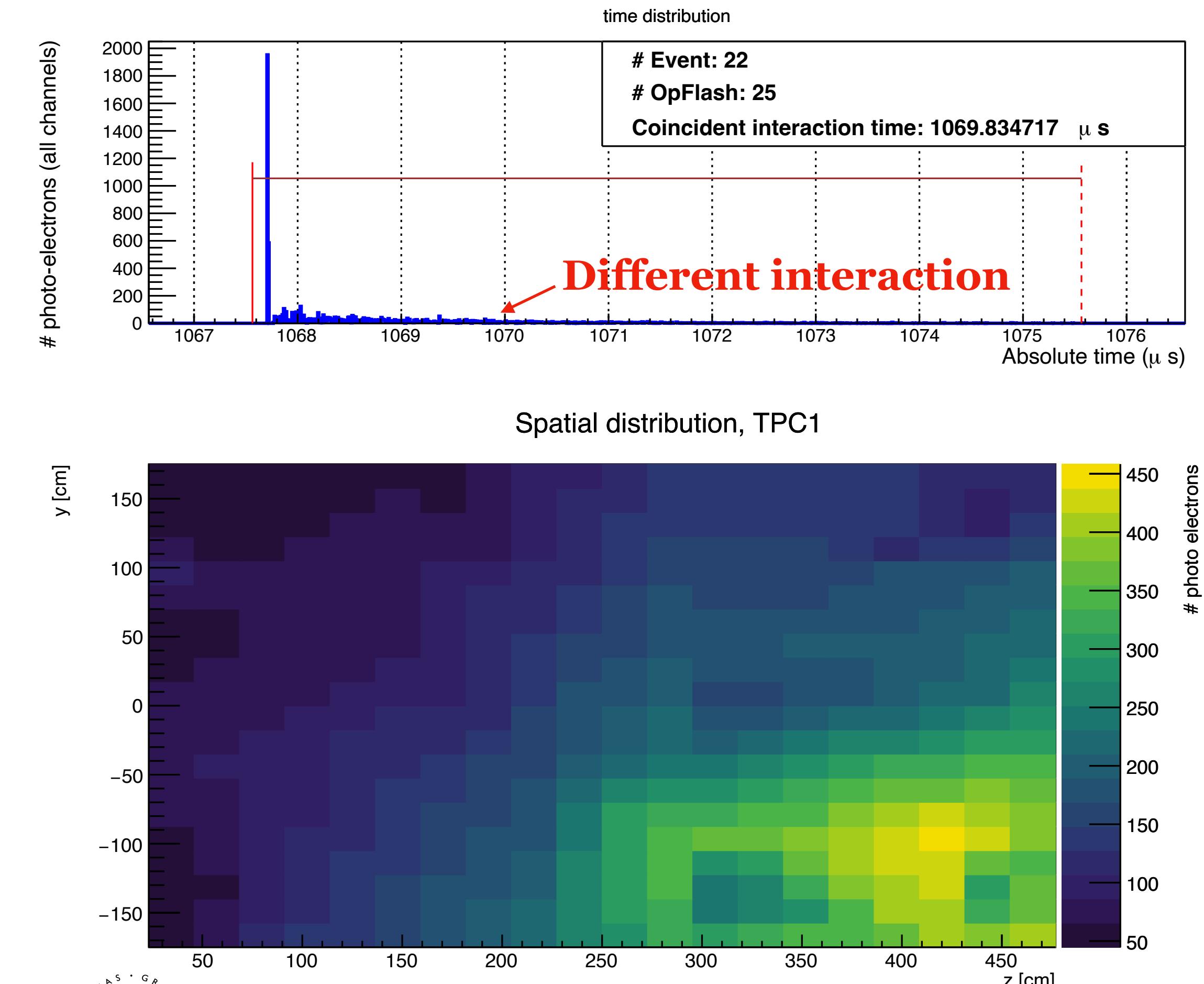
We are not planning to modify the thresholds in this iteration

Revisiting OpFlash building algorithm

- **Case 1:** Interaction with larger light emitted than a different later interaction inside its veto window.

→ Most difficult case

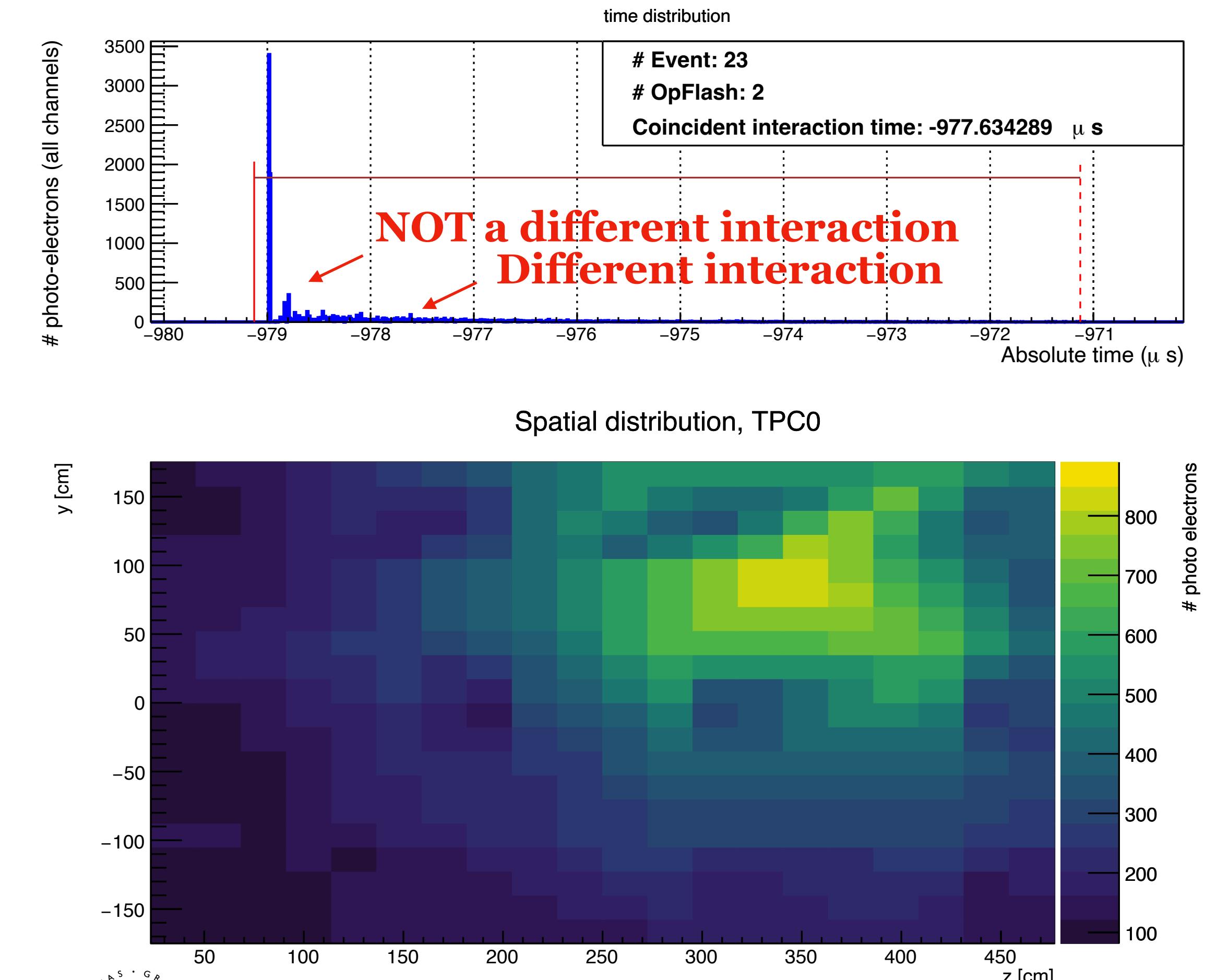
- Many times, the second interactions **cannot be distinguished from the tail of the light distribution of the previous one.**
- In general, the **density of PMTs** in the TPC is not high enough to distinguish two different interactions using the spatial distribution of the OpHits.



Revisiting OpFlash building algorithm

- **Case 1:** Interaction with larger light emitted than a different later interaction inside its veto window.

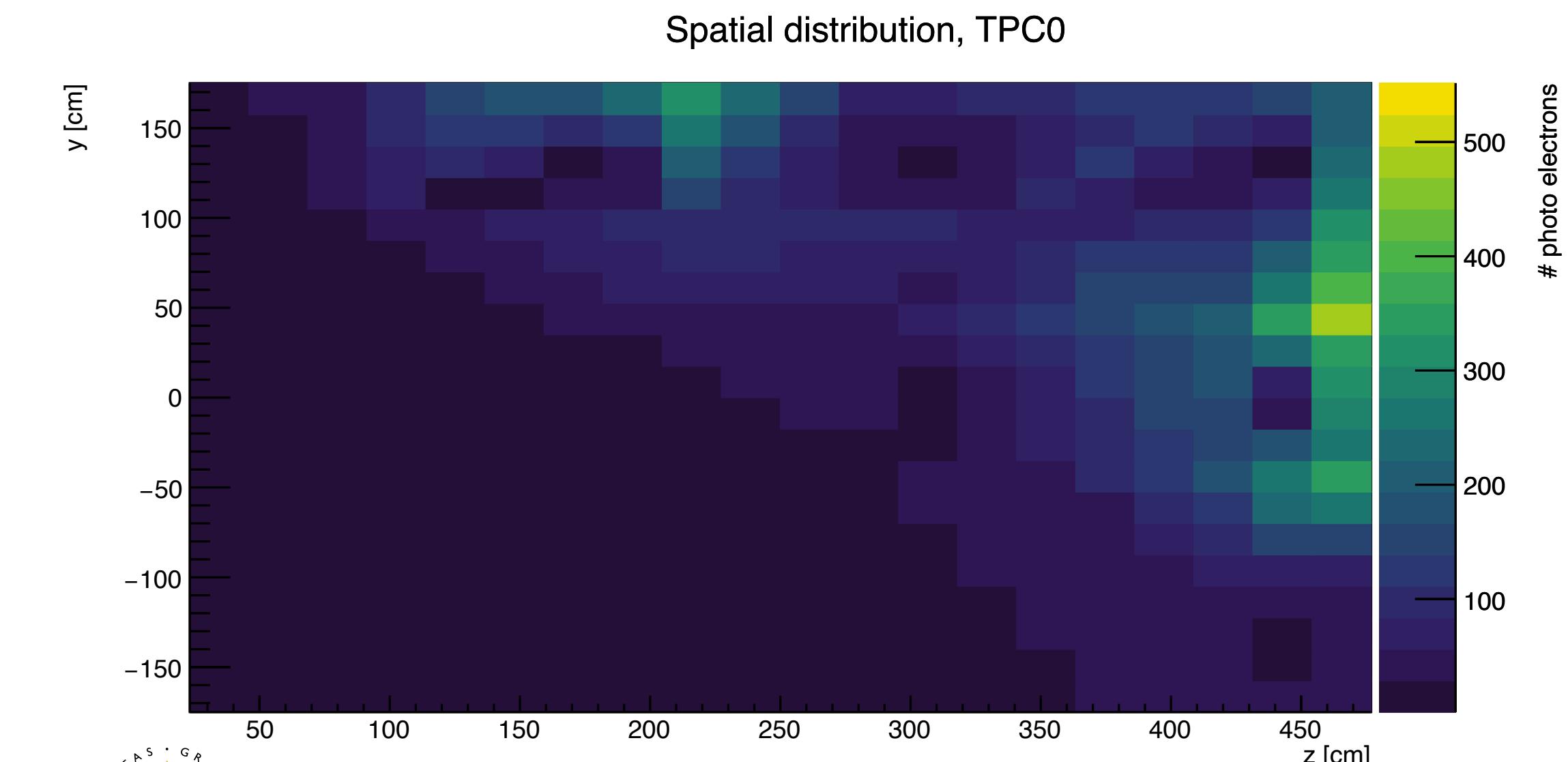
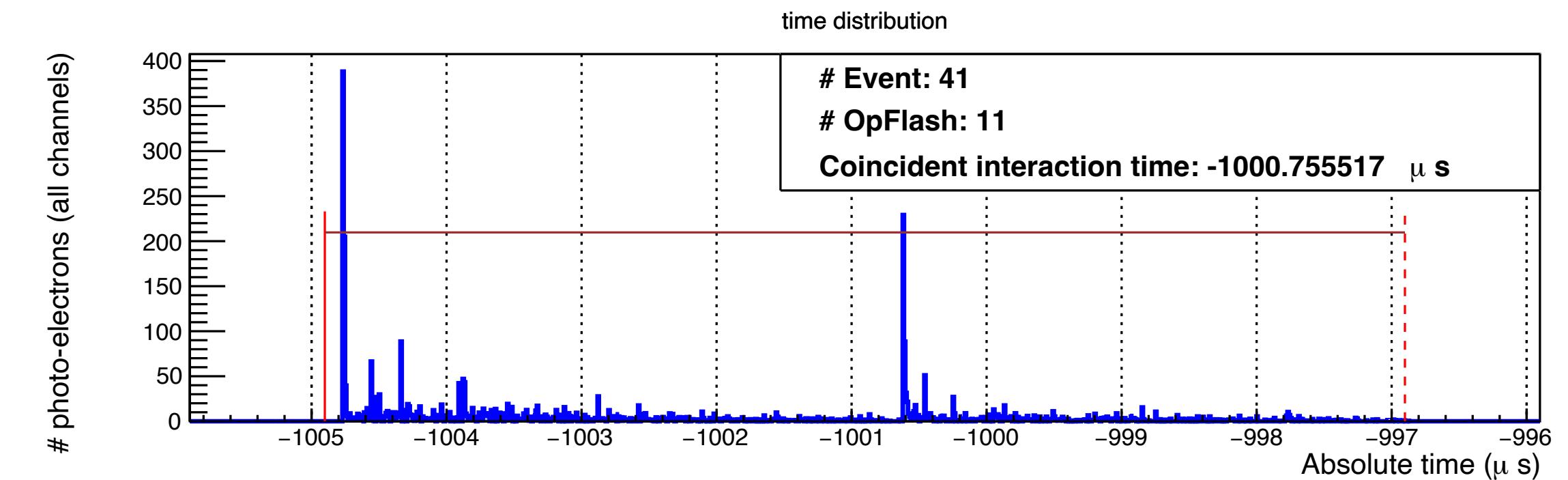
- We have to **avoid double counting**: one interaction should **never** create more than one OpFlash
- The new threshold for this case should be restrictive enough so double counting interactions never happens.



Revisiting OpFlash building algorithm

- **Case 1:** Interaction with larger light emitted than a different later interaction inside its veto window.

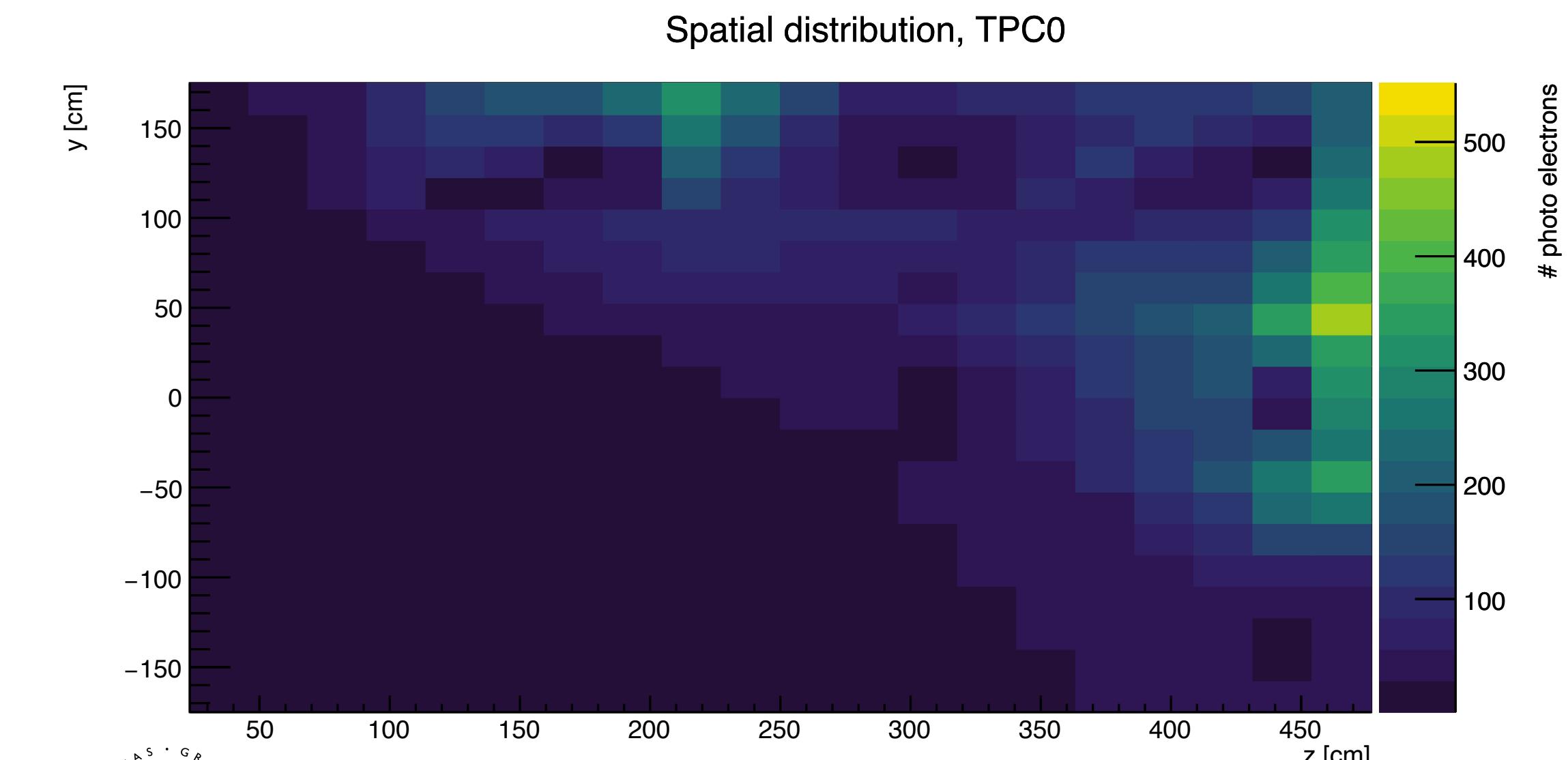
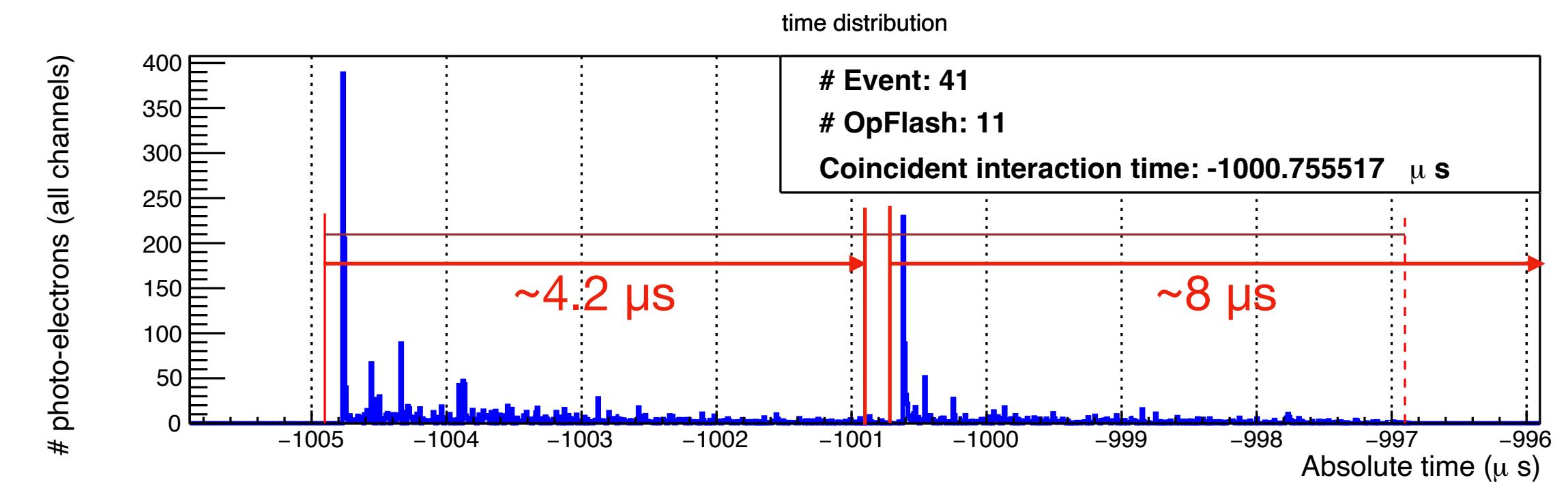
- In the spatial distribution, two different interactions are visible
- This example (and similar ones) **should** create 2 different OpFlash
- **Solution:** shorten the veto window for the first interaction and create an OpFlash for the second interaction



Revisiting OpFlash building algorithm

- **Case 1:** Interaction with larger light emitted than a different later interaction inside its veto window.

- In the spatial distribution, two different interactions are visible
- This example (and similar ones) **should** create 2 different OpFlash
- **Solution:** shorten the veto window for the first interaction and create an OpFlash for the second interaction



Summary

OpFlash inefficiencies have been quantified:

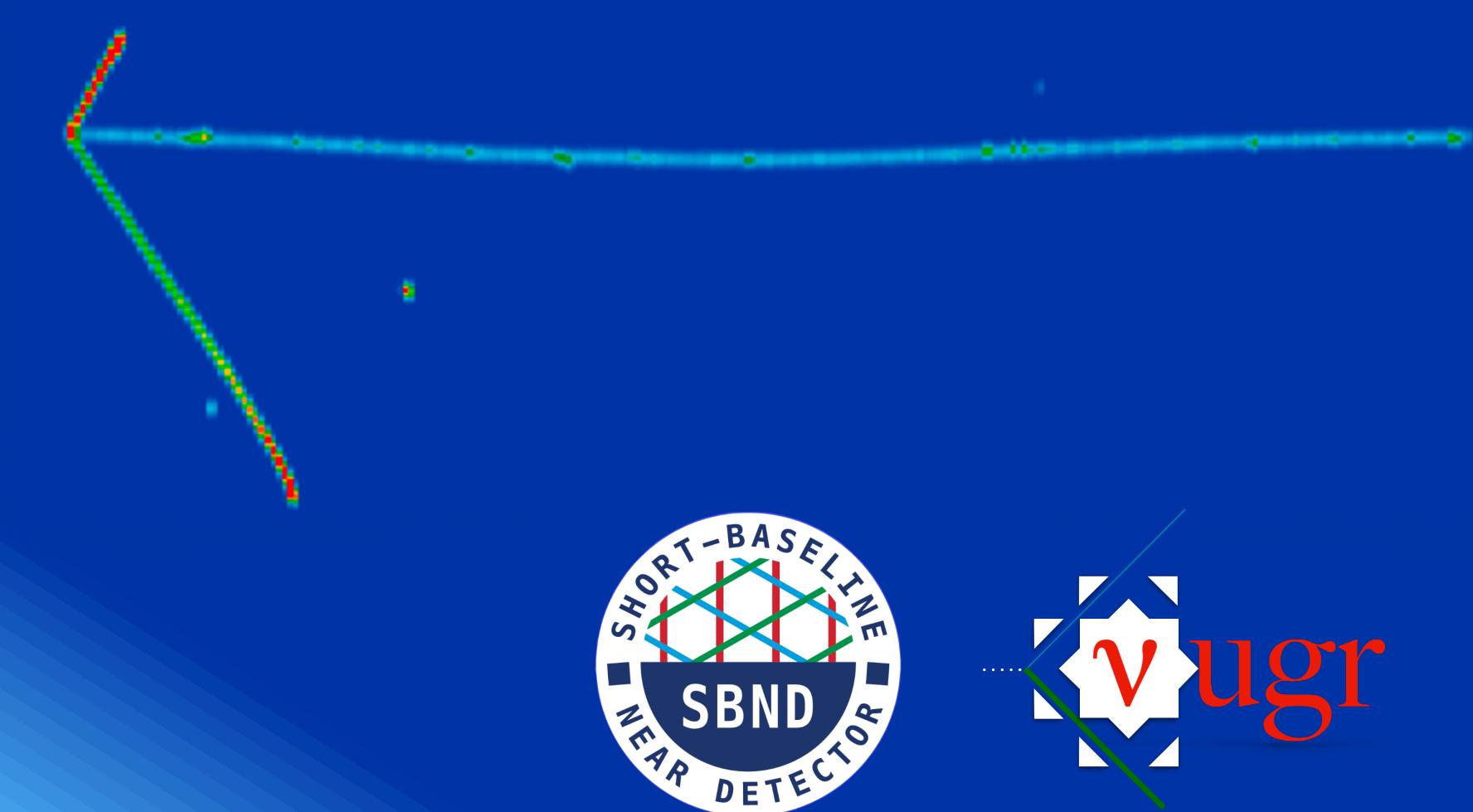
- **93.66%** of interactions (beam + cosmic) have a corresponding OpFlash
- **89.20%** of neutrino interactions have a corresponding OpFlash

The 3 cases that produce inefficiencies have been identified:

- **Case 1:** interaction after OpFlash
- **Case 2:** interaction before OpFlash
- **Case 3:** Low light emitted, which does not create OpFlash

Future work:

- Redefine how the veto window applies for case 1 events
- Find an algorithm that is able to recover as many case 2 events avoiding double counting.



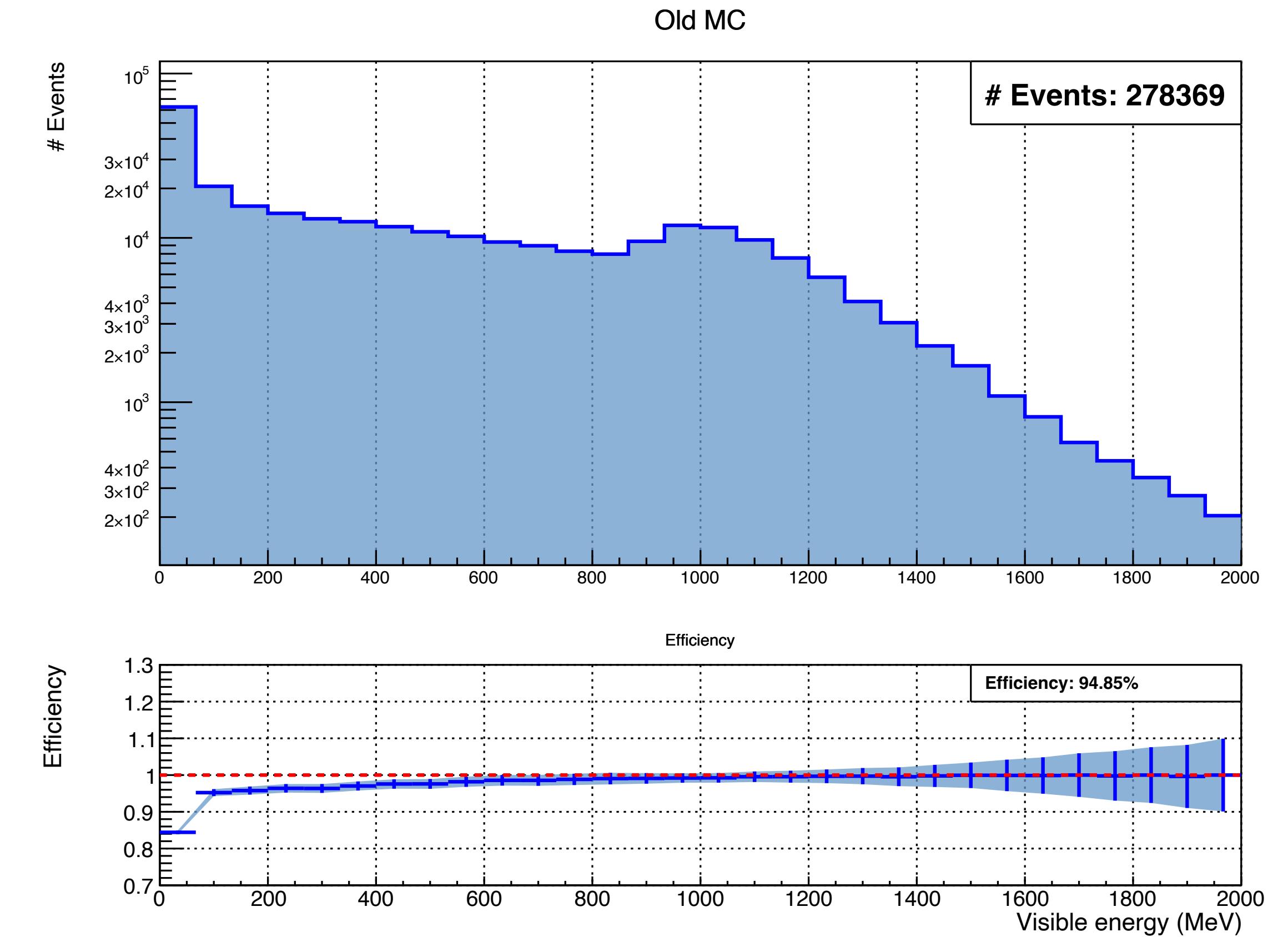
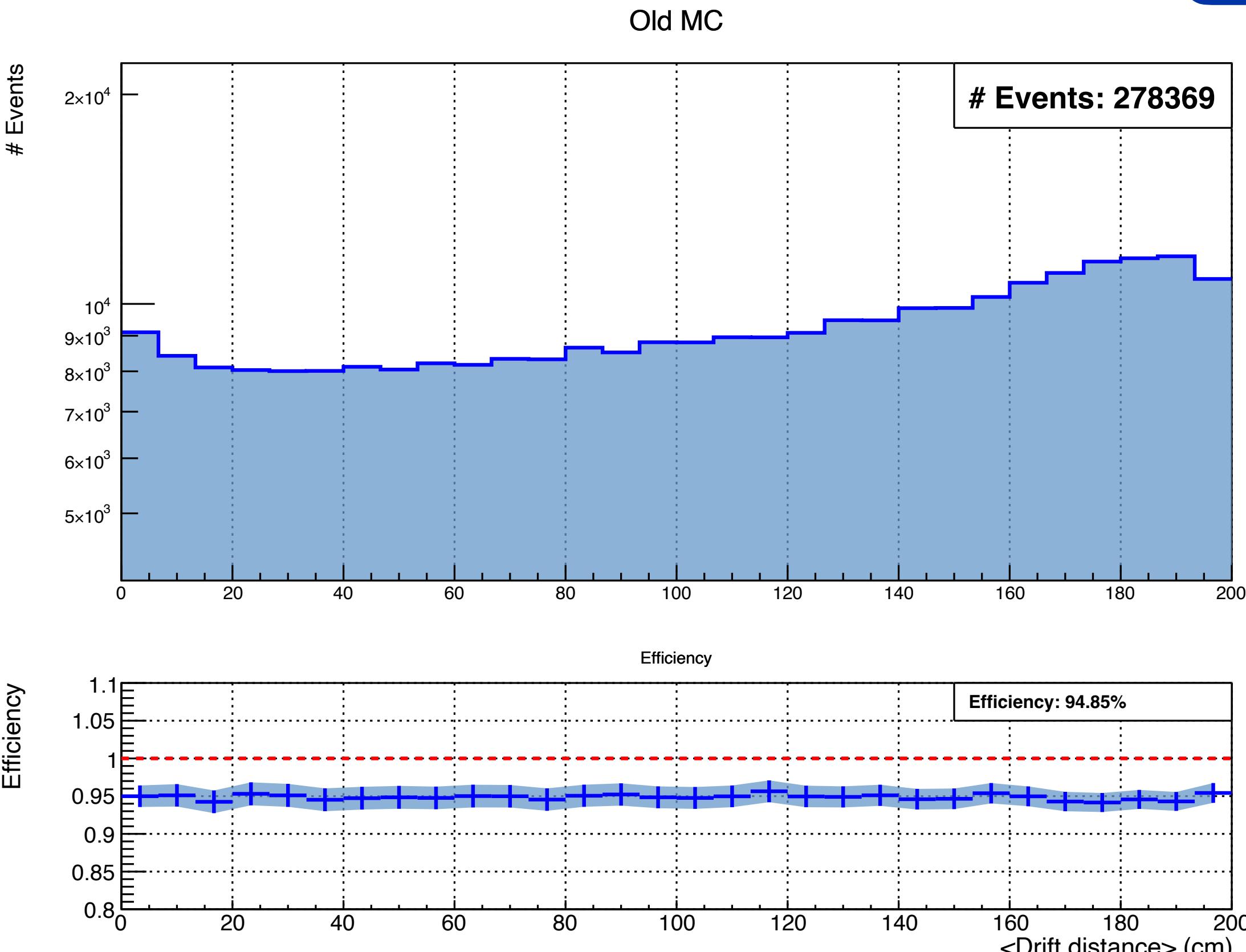
Backup



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OpFlash Efficiency

Old MC

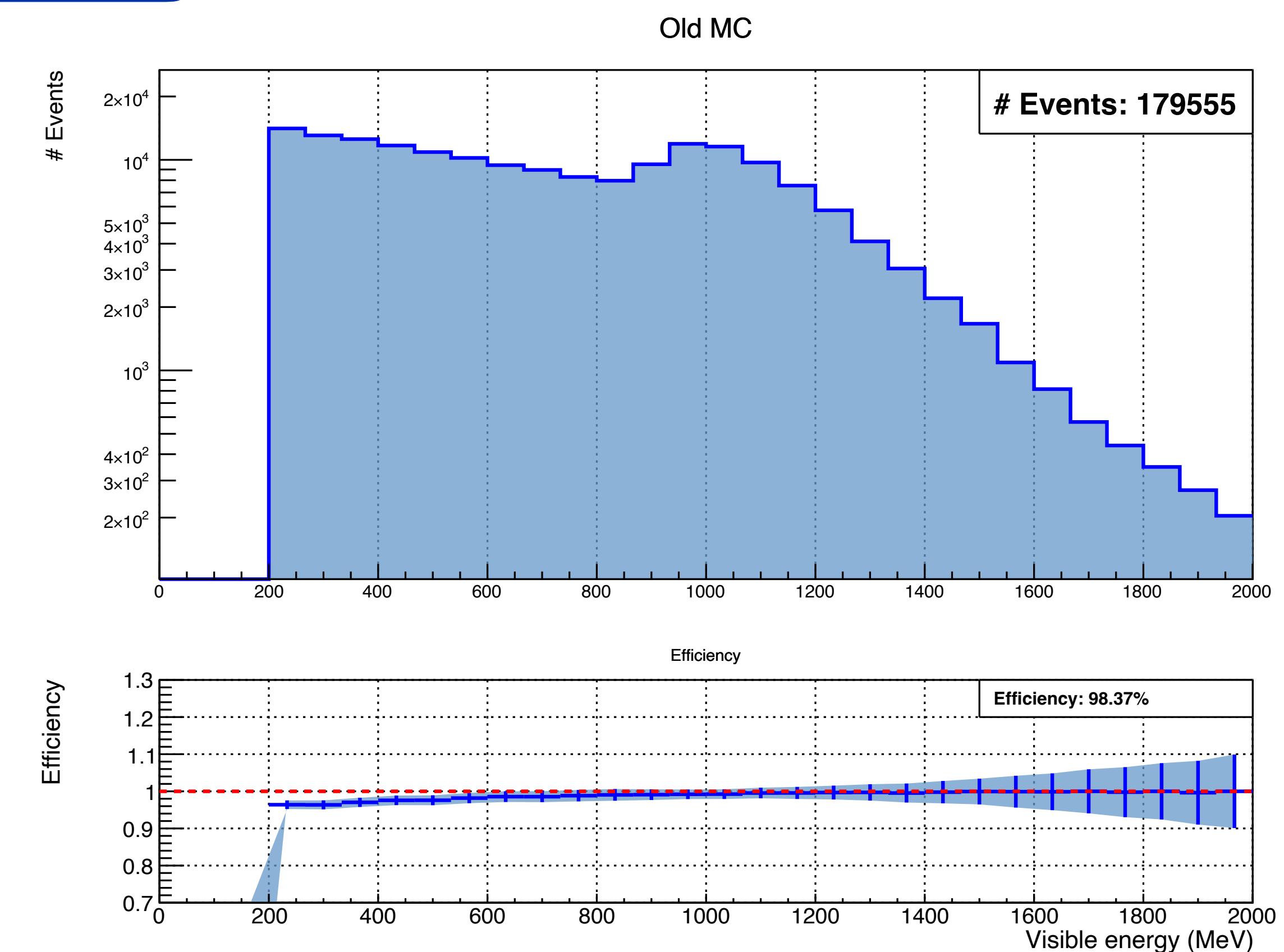
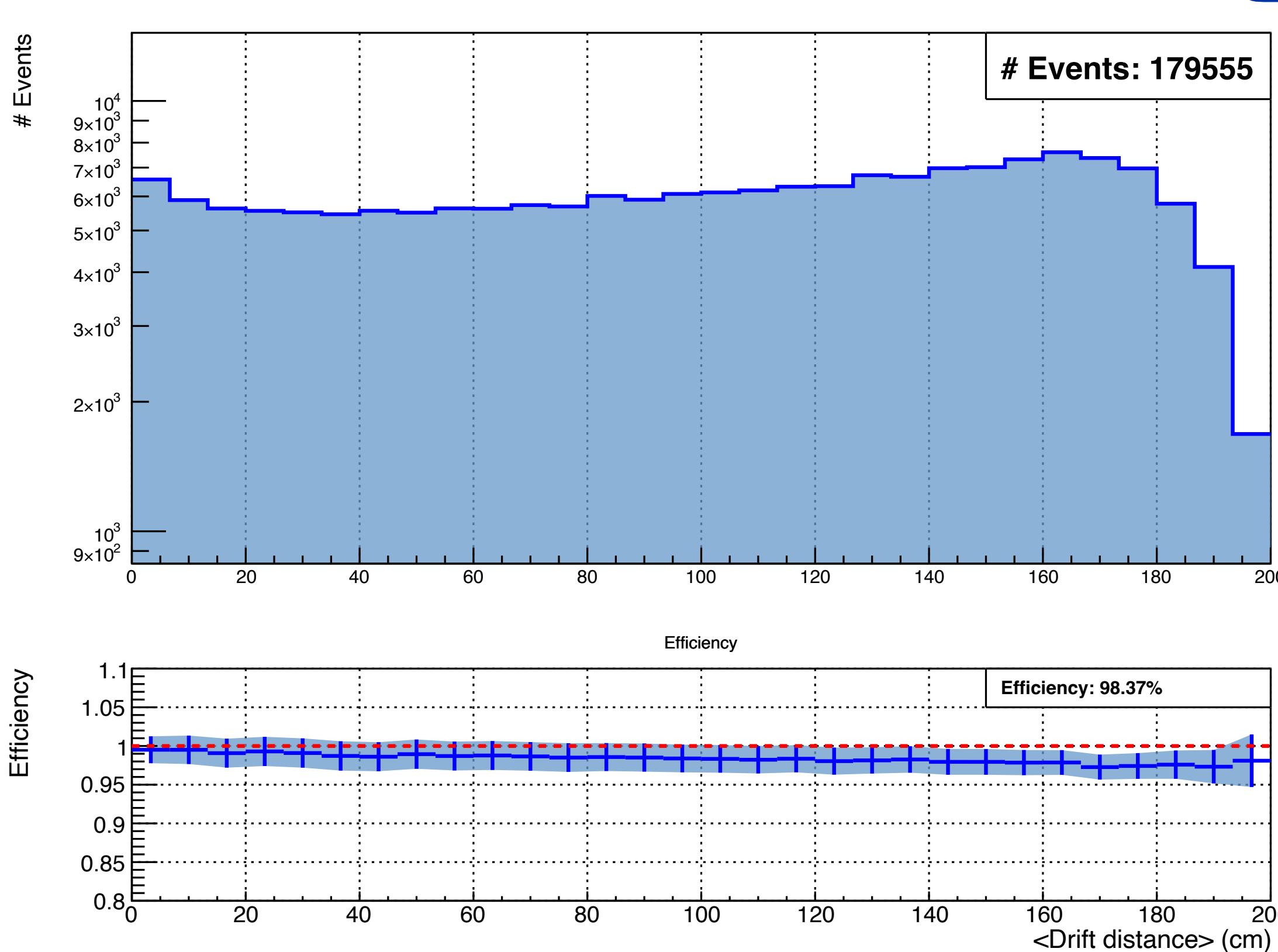


Fraction lost due to coincident interactions: **2.83904%**

OpFlash Efficiency

Are all high energy ($E_{\text{vis}} > 200 \text{ MeV}$) lost interactions due to coincident interactions?

OldMC



Fraction lost due to coincident interactions: **1.569%**

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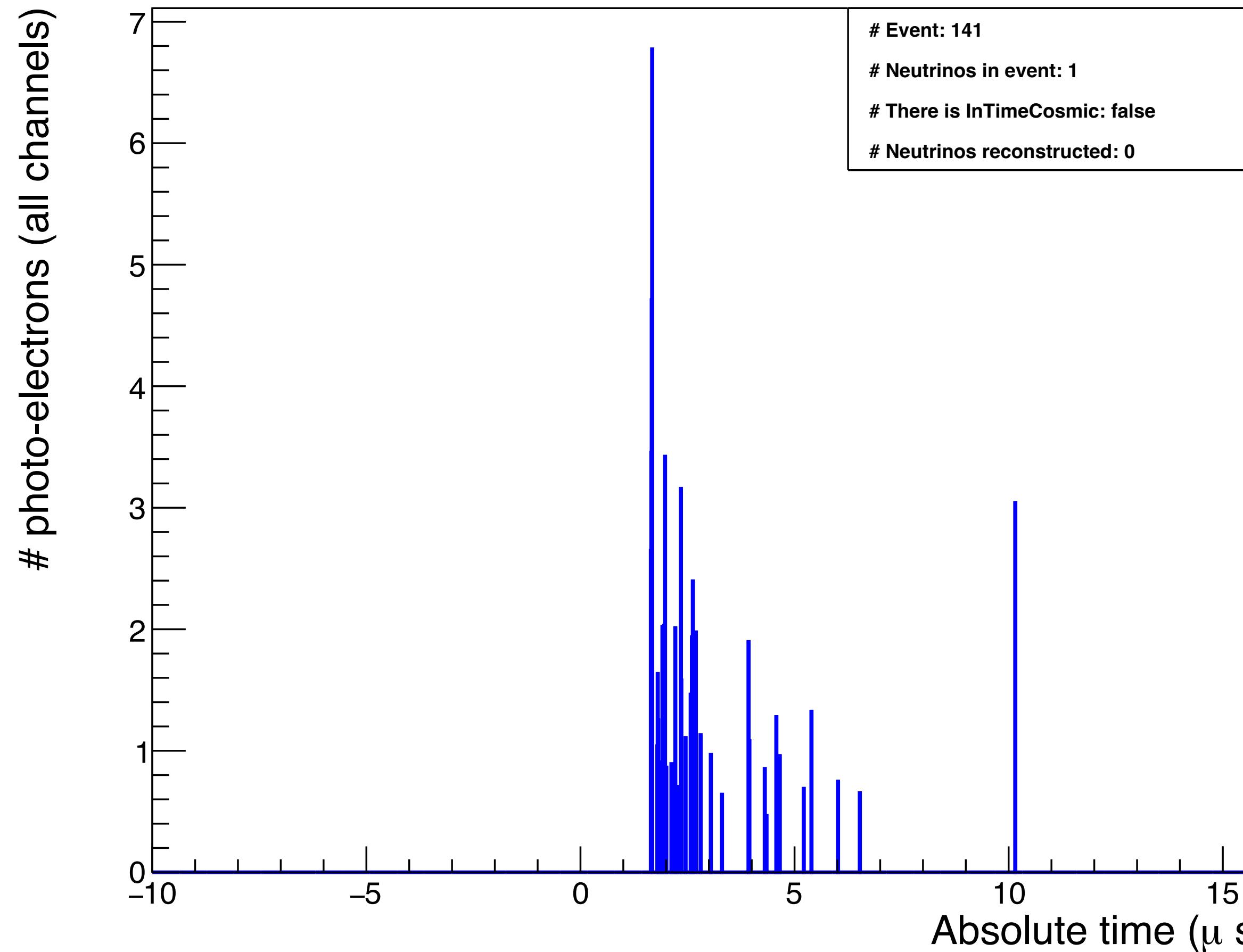


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Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash

OpHit distribution



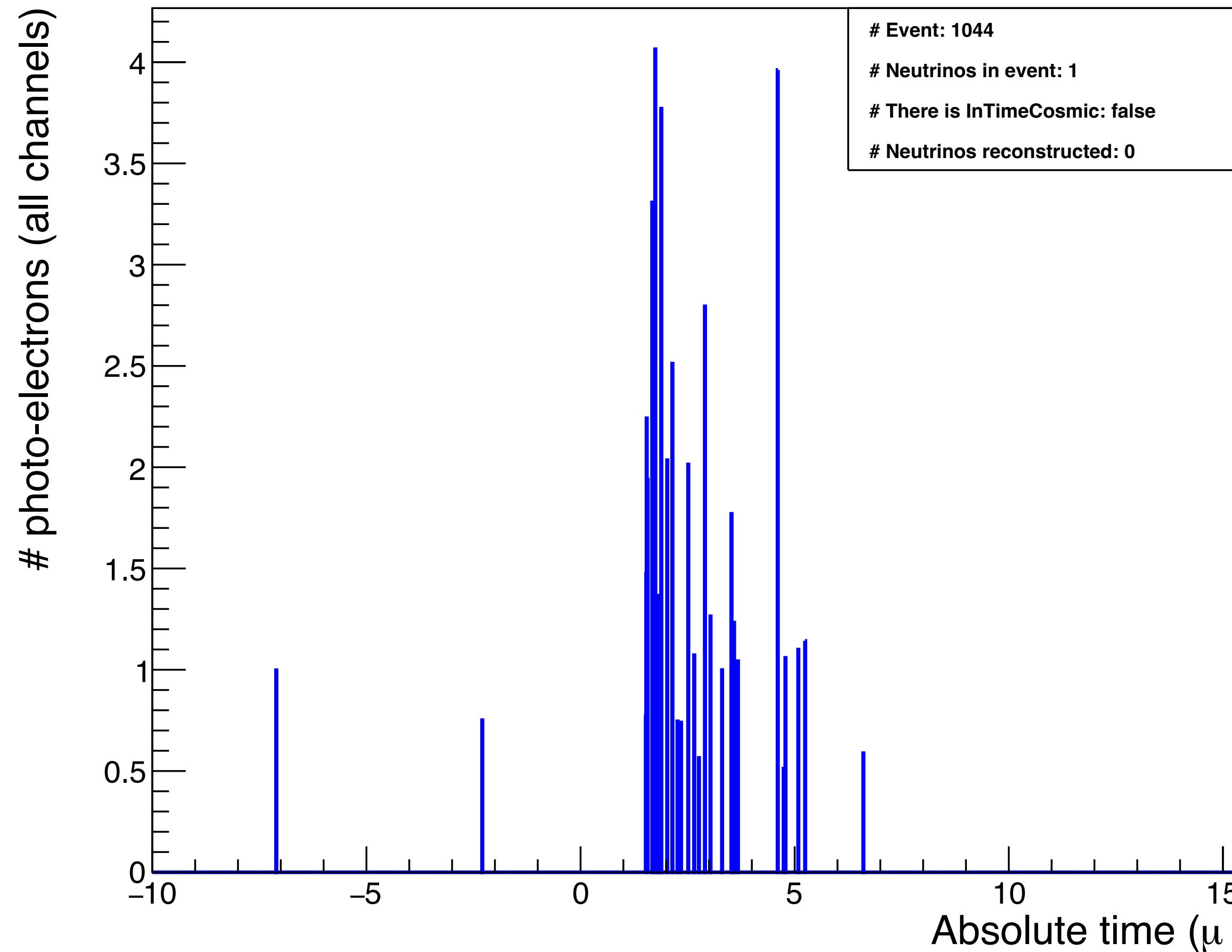
(14)

Too few PE in the interaction

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash

OpHit distribution

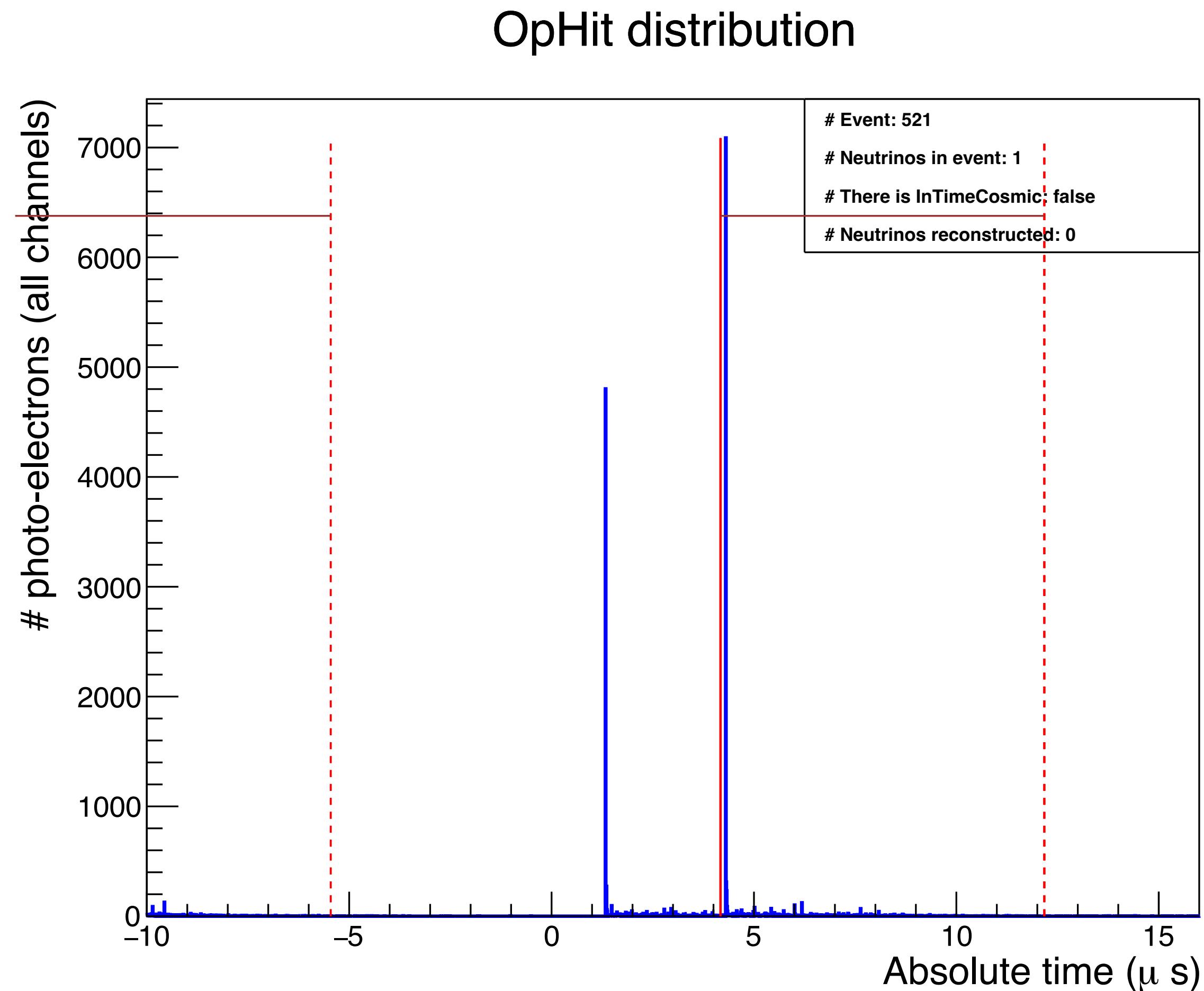


(154)

Too few PE in the interaction

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash

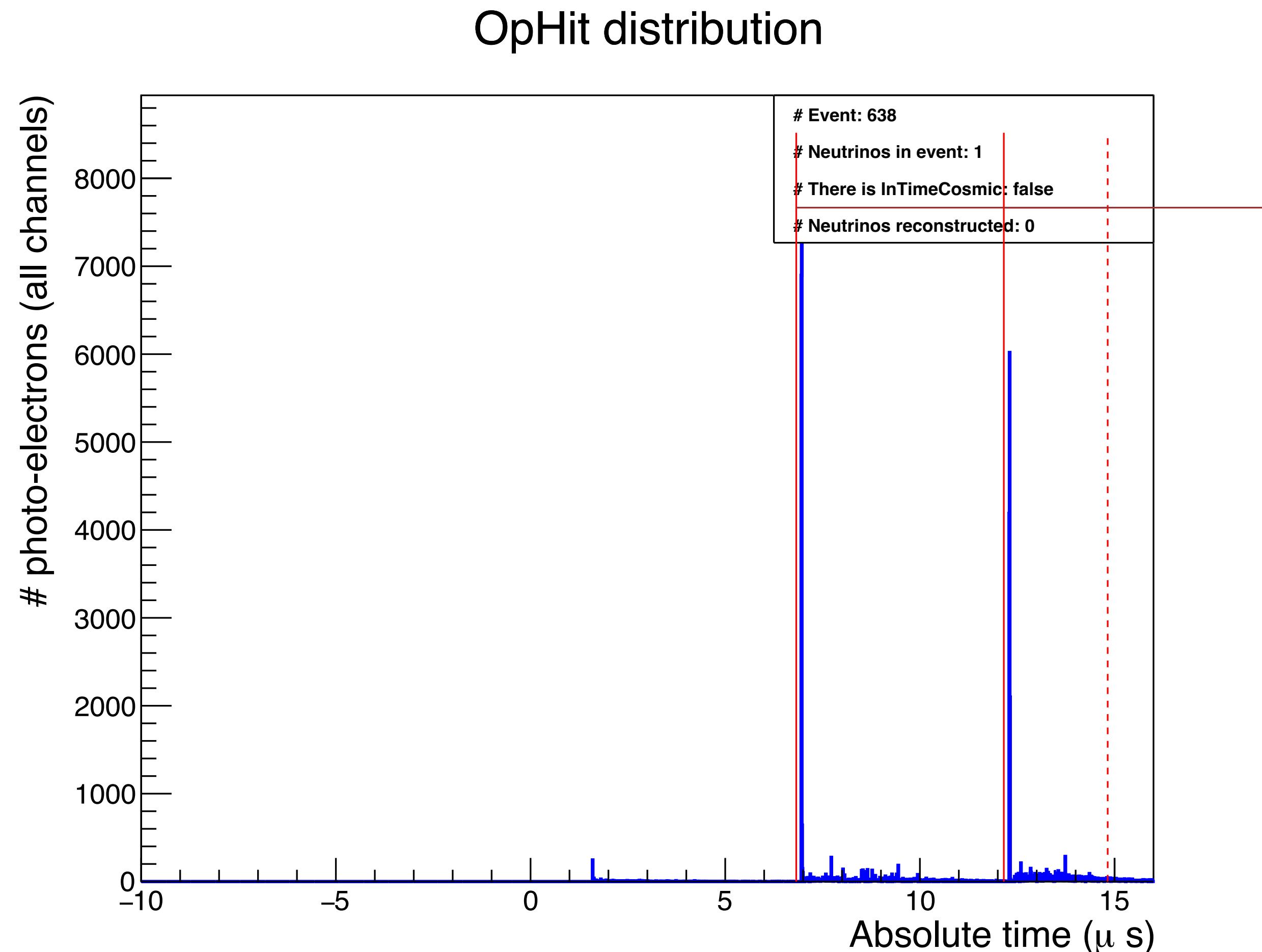


(74)

Cosmic after the neutrino

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash

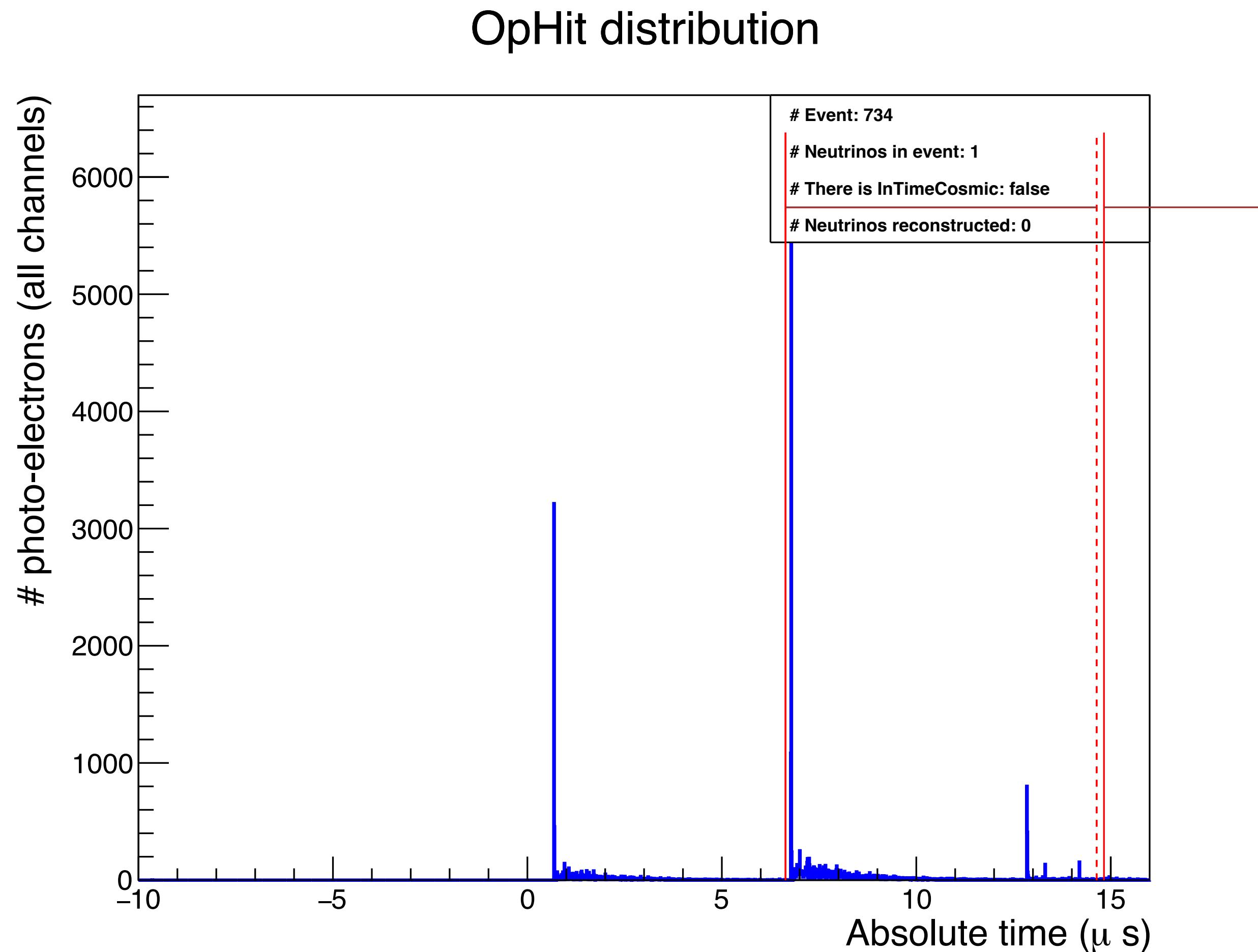


(94)

Cosmic after the neutrino

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash

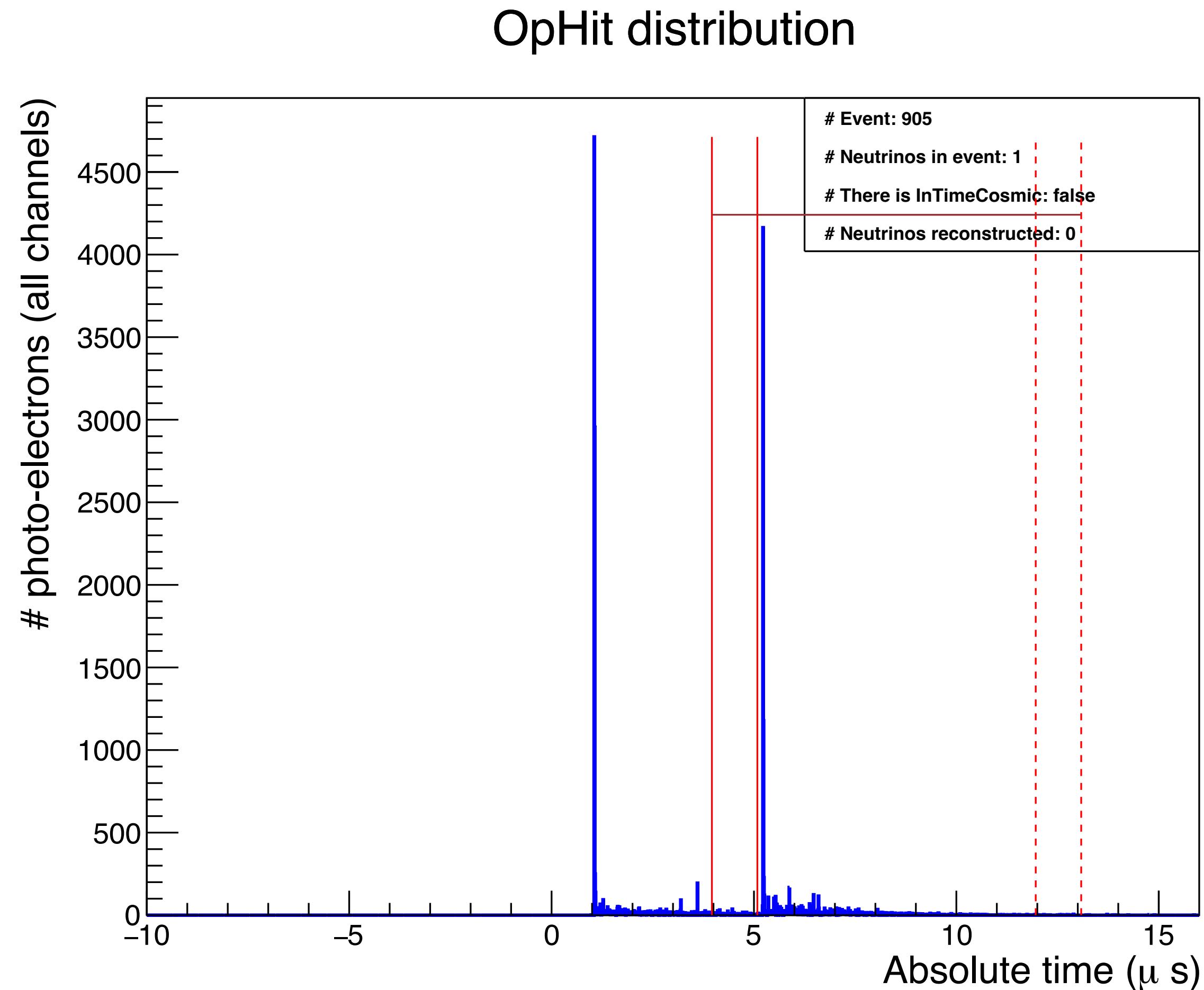


(107)

Cosmic after the neutrino

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash



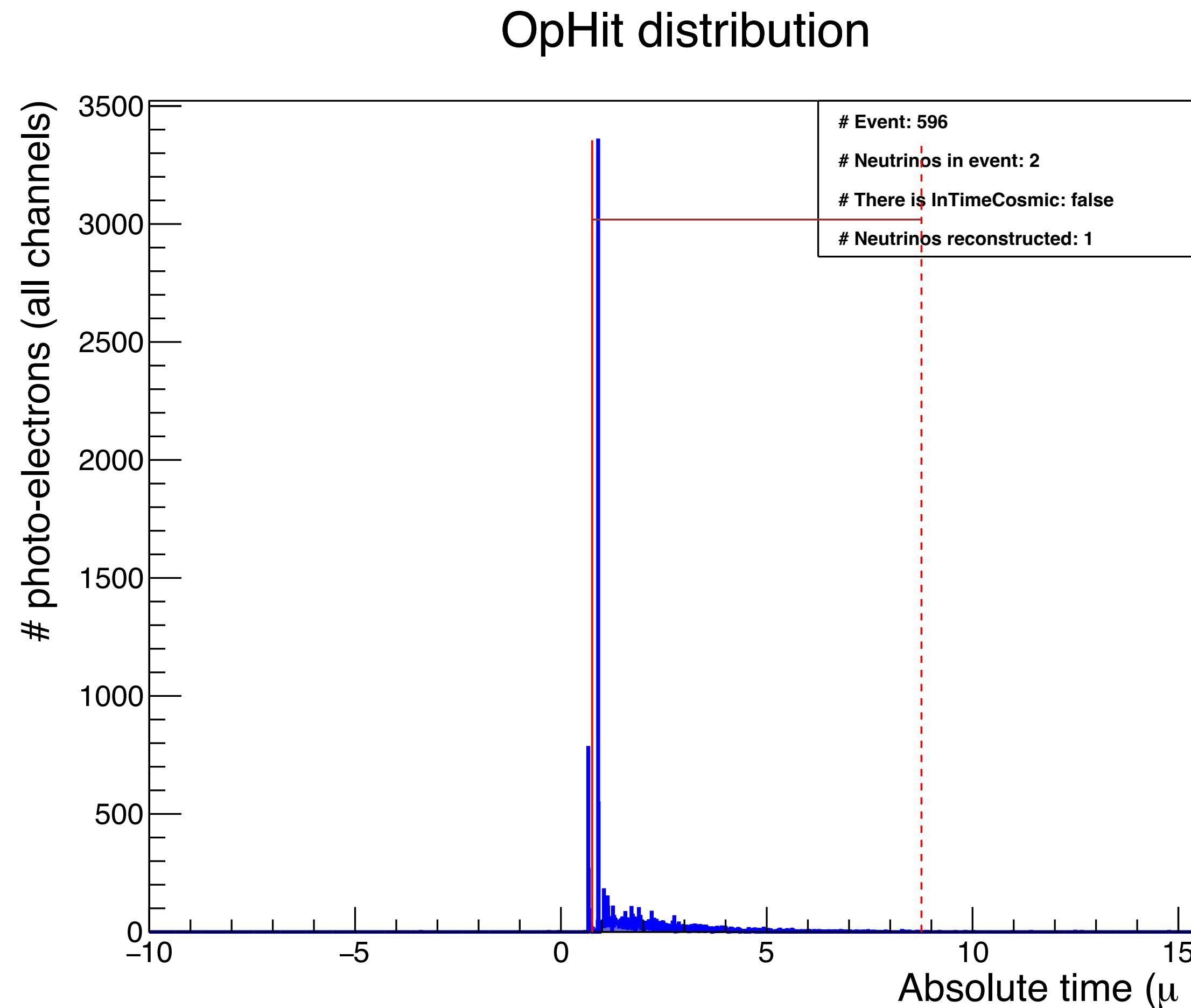
(129)

Cosmic after the neutrino

The integrated PE of the second one are bigger than the first one

Bad OpFlahs reconstruction examples

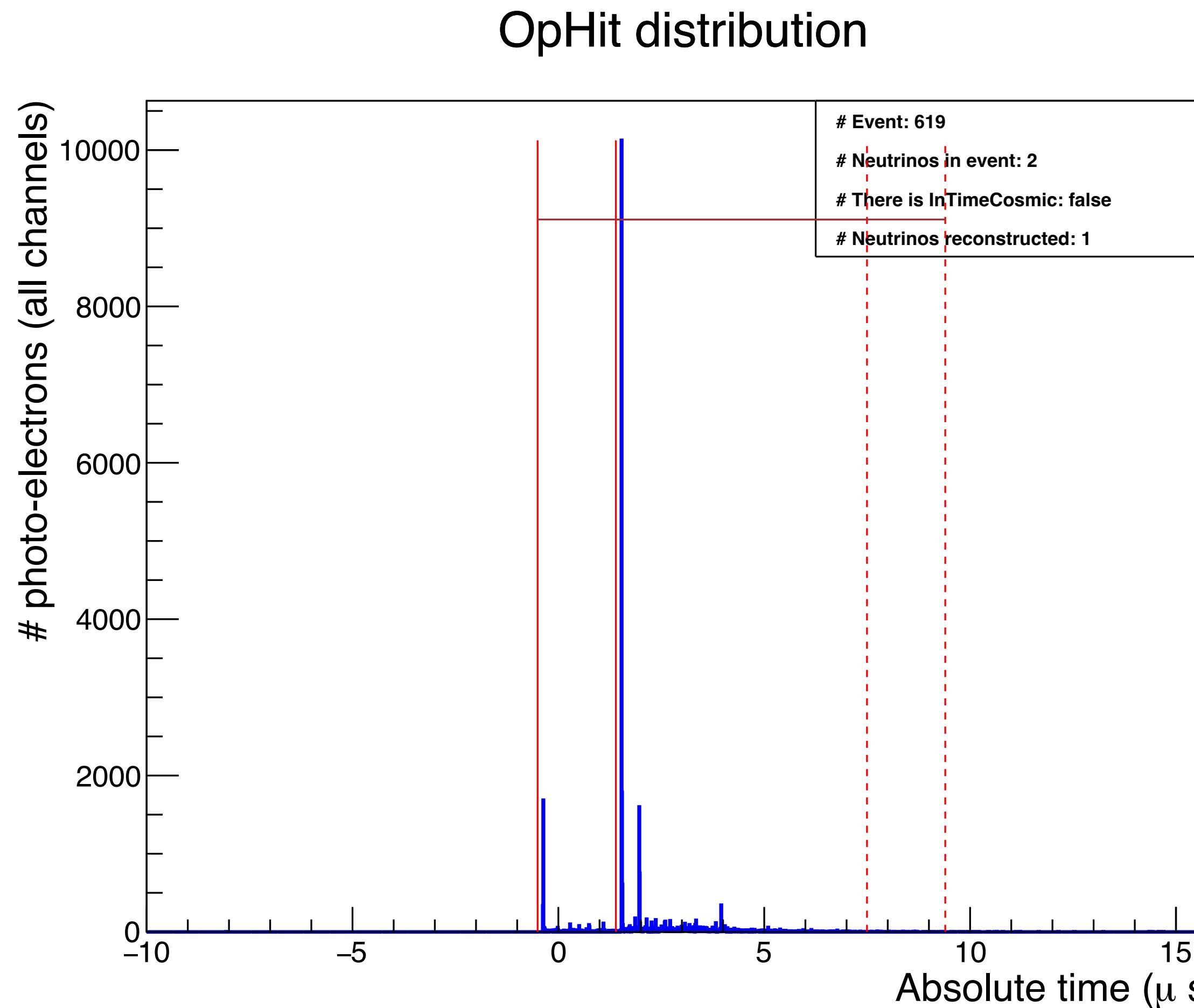
I look for examples in which the interaction did not create an OpFlash



(90)
Interaction pile-up

Bad OpFlahs reconstruction examples

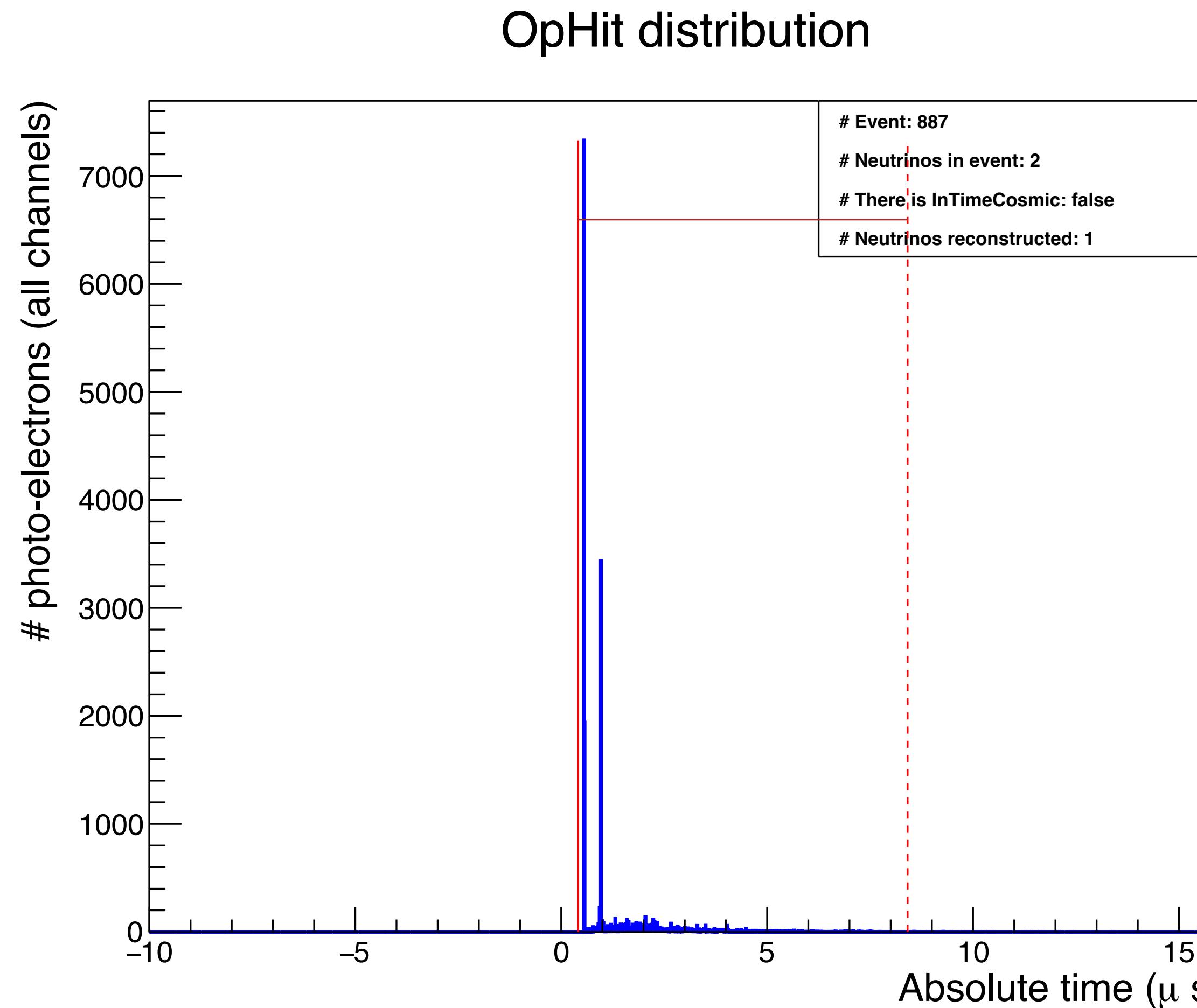
I look for examples in which the interaction did not create an OpFlash



(93)
Interaction pile-up

Bad OpFlahs reconstruction examples

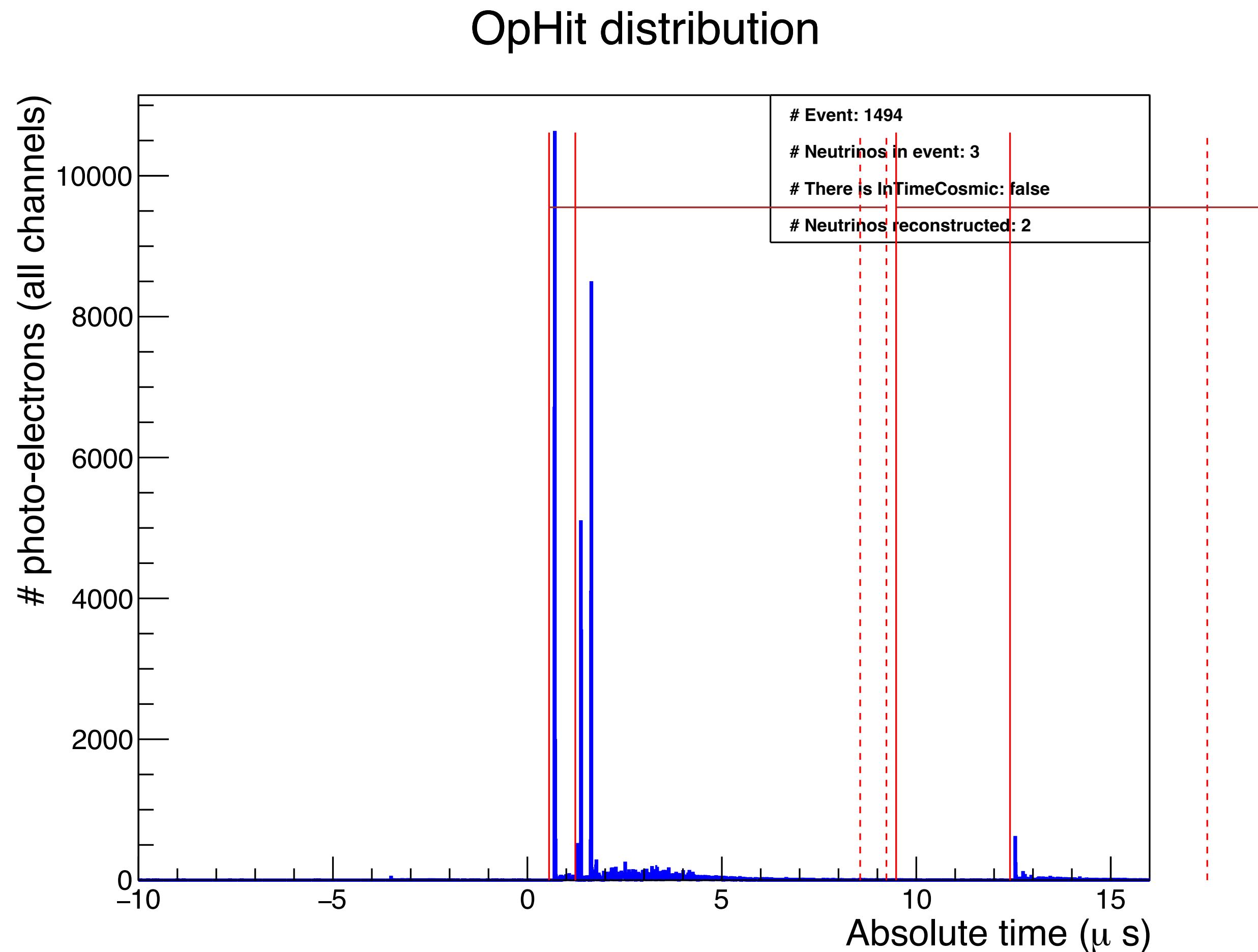
I look for examples in which the interaction did not create an OpFlash



(126)
Interaction pile-up

Bad OpFlahs reconstruction examples

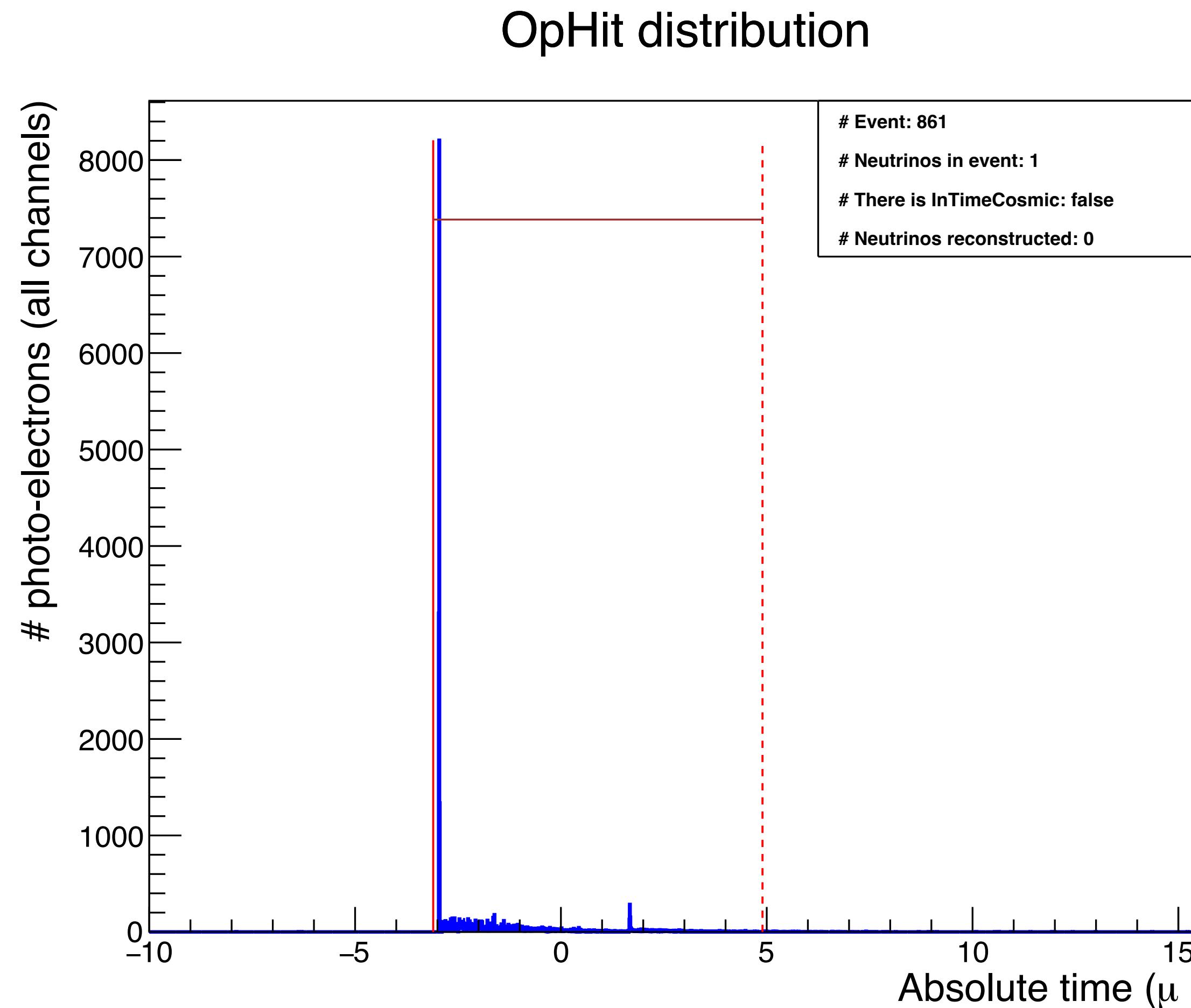
I look for examples in which the interaction did not create an OpFlash



(216)
Interaction pile-up

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash



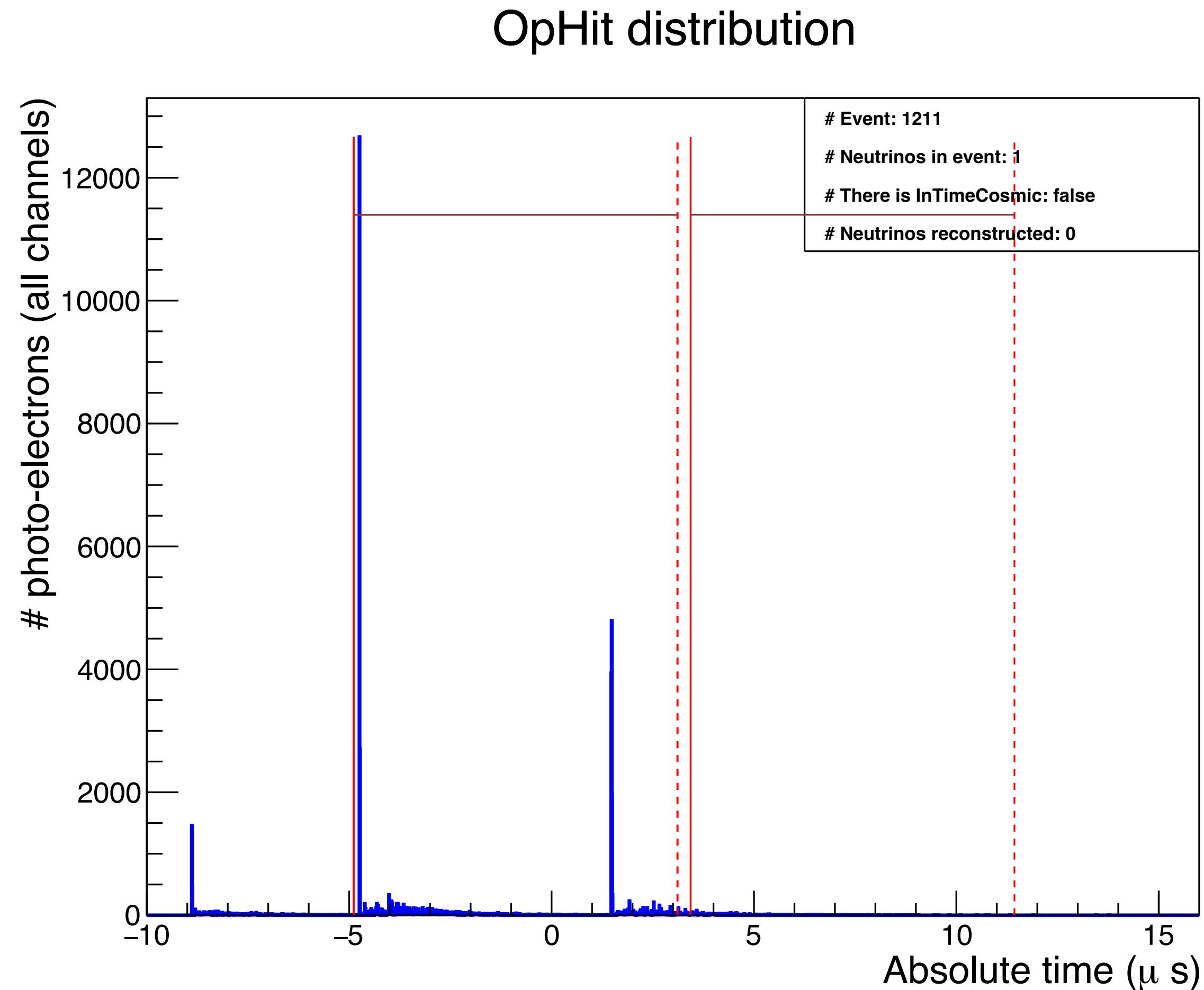
(121)

Cosmic before neutrino

The neutrino creates an Opflash
way later than it should

Bad OpFlahs reconstruction examples

I look for examples in which the interaction did not create an OpFlash



(169)

Cosmic before neutrino

The neutrino creates an Opflash
way later than it should

Neutrino efficiency and purity

Efficiency*

$$\frac{\# \text{ true neutrinos (inside TPC) reconstructed}}{\# \text{ true neutrinos (inside TPC)}}$$

**How many of the true neutrinos
create an OpFlash**

(Purity)*

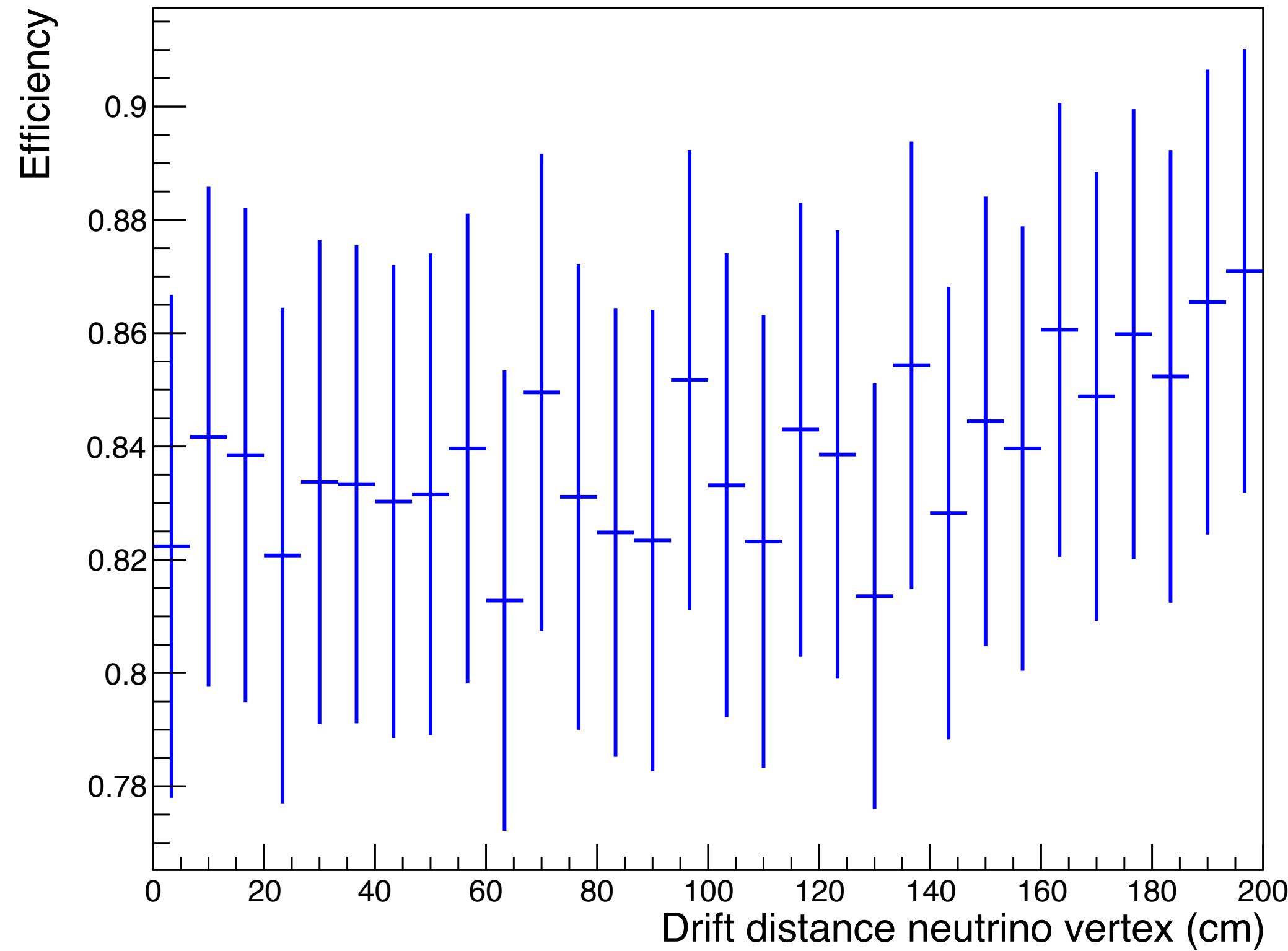
$$\frac{\# \text{ true neutrinos (inside TPC) reconstructed}}{\# \text{ true neutrinos reconstructed}}$$

**Some neutrinos might interact outside
of the TPC, but create an OpFlash. This
tells us how it affects to the in-TPC
neutrinos reconstruction**

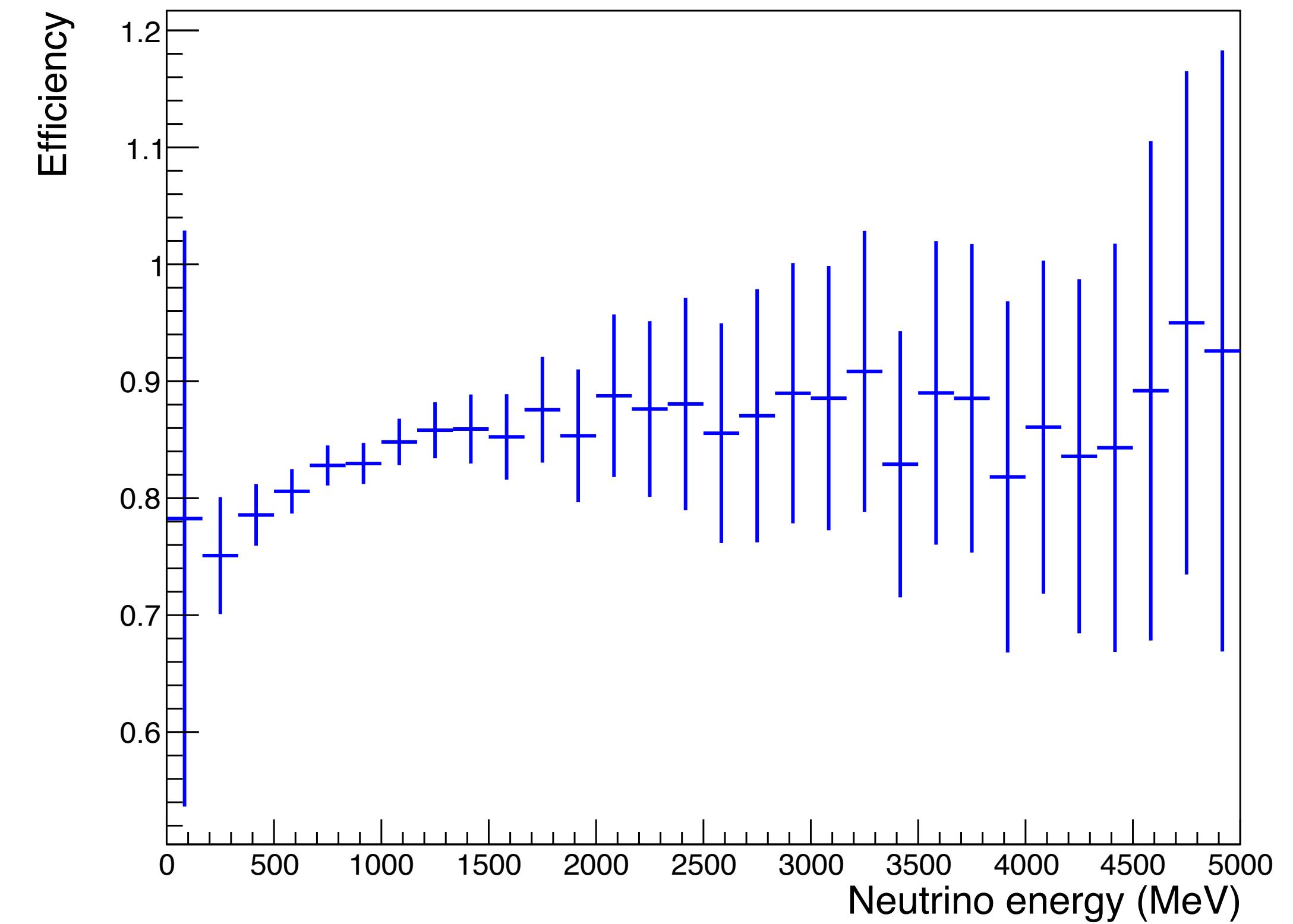
*Only interactions with a neutrino inside the TPC

Neutrino Efficiency

Efficiency vs drift



Efficiency vs Evis



EFFICIENCY: 83.0654 %
PURITY: 91.571 %

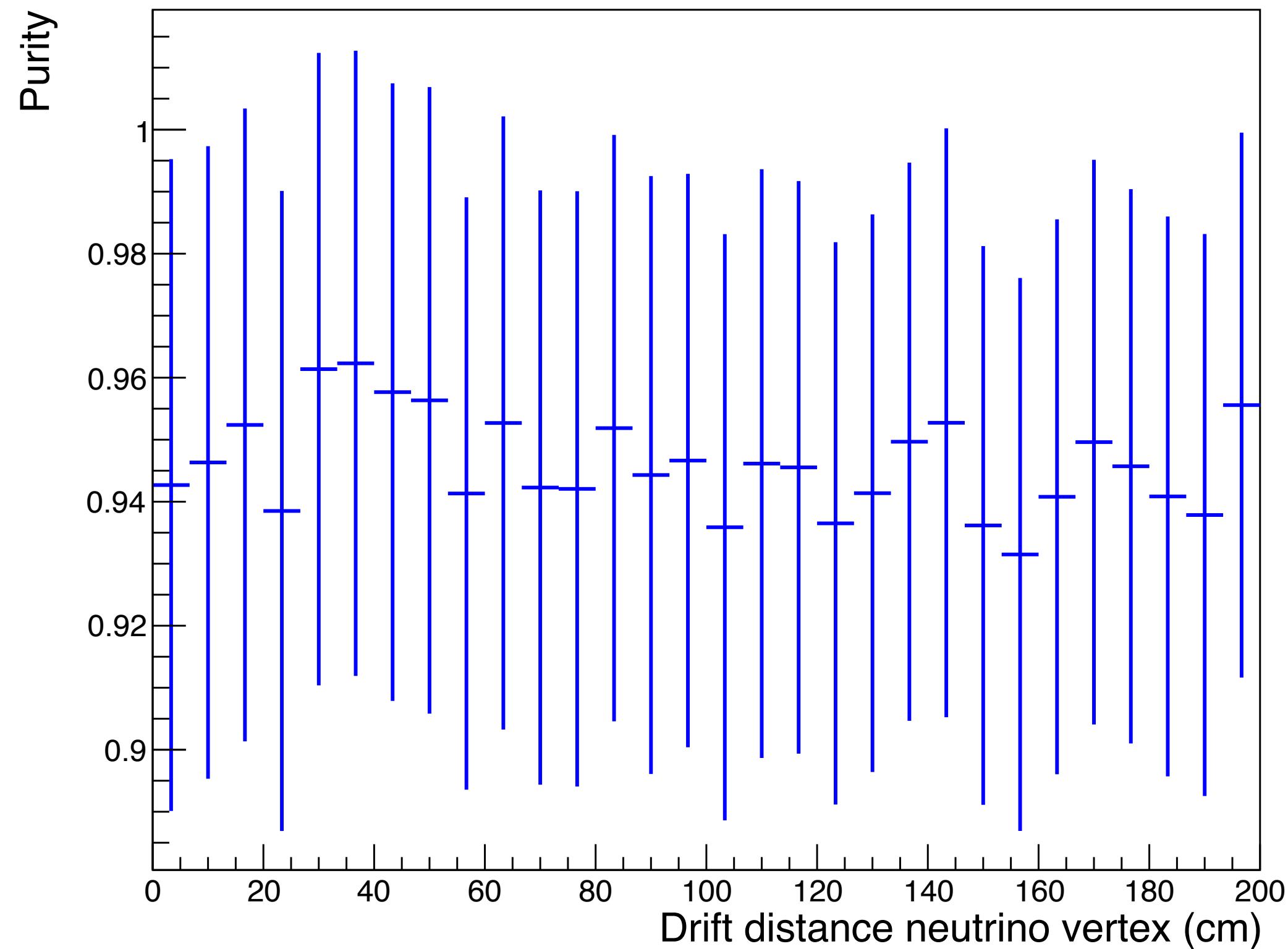
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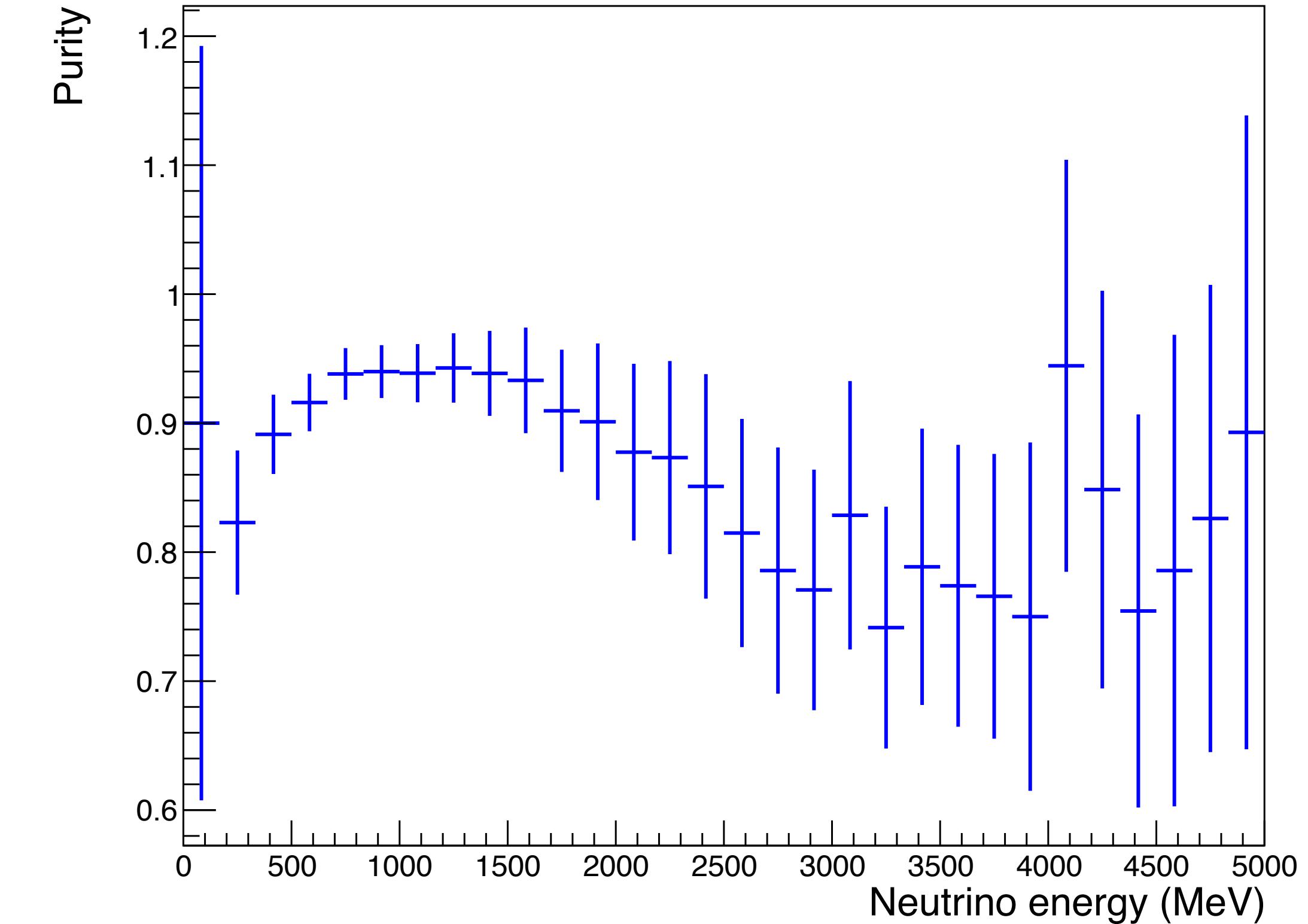
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Neutrino Purity

Purity vs drift



Purity vs Evis



EFFICIENCY: 83.0654 %
PURITY: 91.571 %

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