# ANTINEUTRINOS AND SNO+

**António Maschio & Miguel Avillez**

September 4, 2019

# Index

- Introduction to SNO+
- Antineutrinos and Signal Coincidences (MC Study for Scintillator)
  - Signal Description
  - Coincidences Selection
- Current Phase (water + scintillator):
  - Antineutrinos Detection Efficiency (MC data)
  - Searching Data for Antineutrinos (Real data)

# Brief Introduction to SNO+

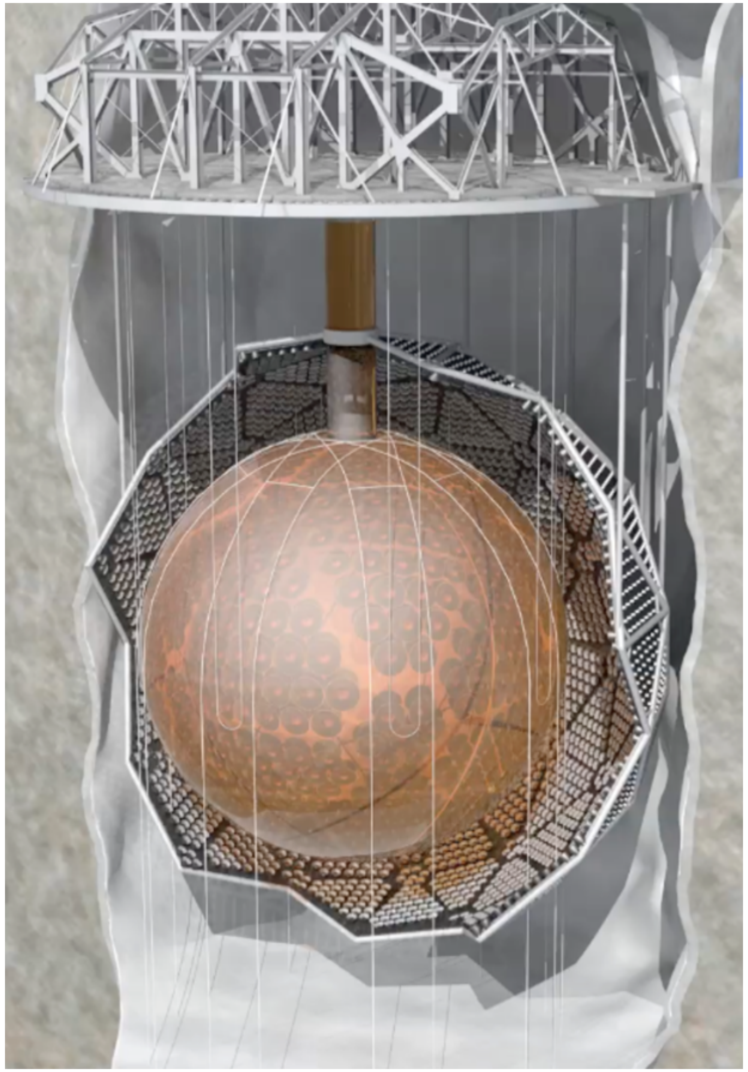
Located in Vale's Creighton mine in Sudbury, Canada.

Objectives:

- Search for neutrinoless double beta decay of $^{130}Te$ (main objective)
- Supernova neutrinos/antineutrinos
- **Reactor antineutrinos**
- etc.

Structure:

- Acrylic vessel (AV)
- Detectors sphere, with 9300 PMTs

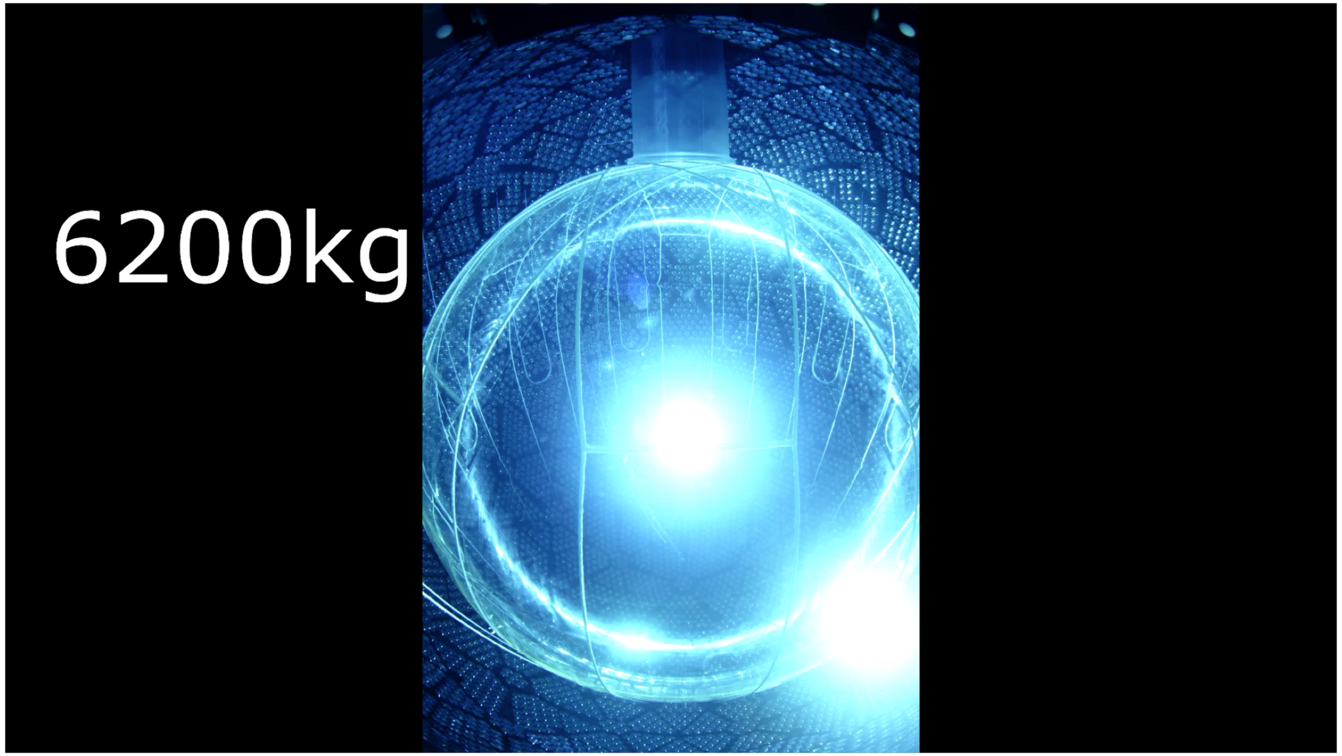


# Brief Introduction to SNO+

Three main phases:

1. Water phase
2. Scintillator phase
3. Scintillator loaded with Te phase

**Current situation:** transition between the 1st and 2nd phases, with scintillator being inserted in the AV

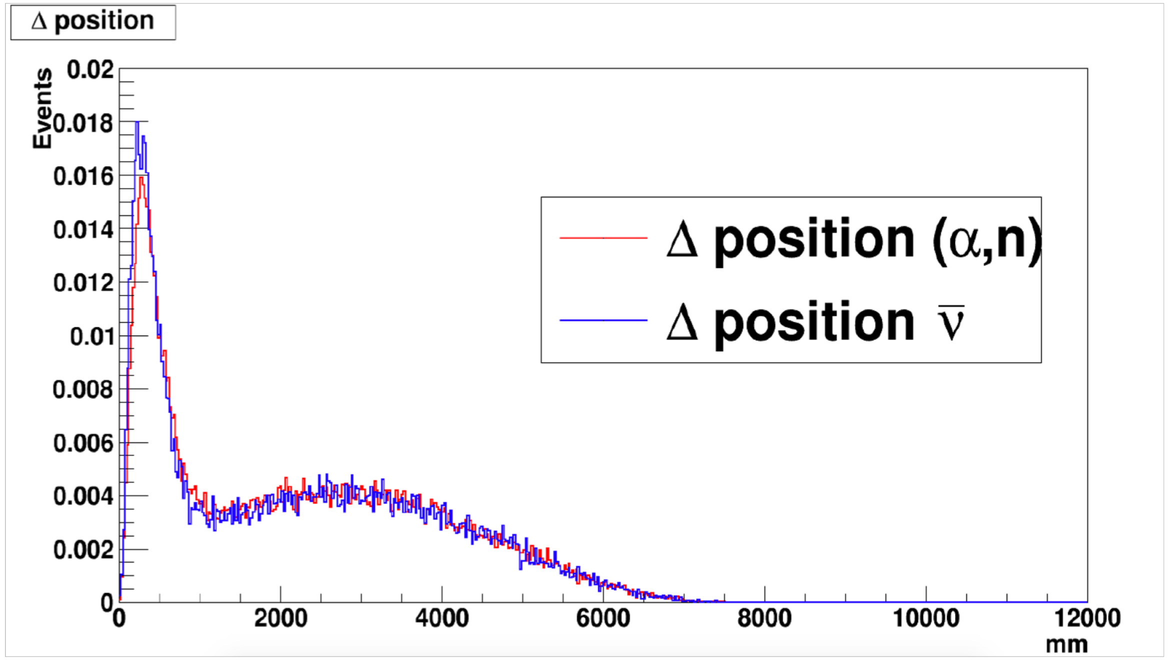


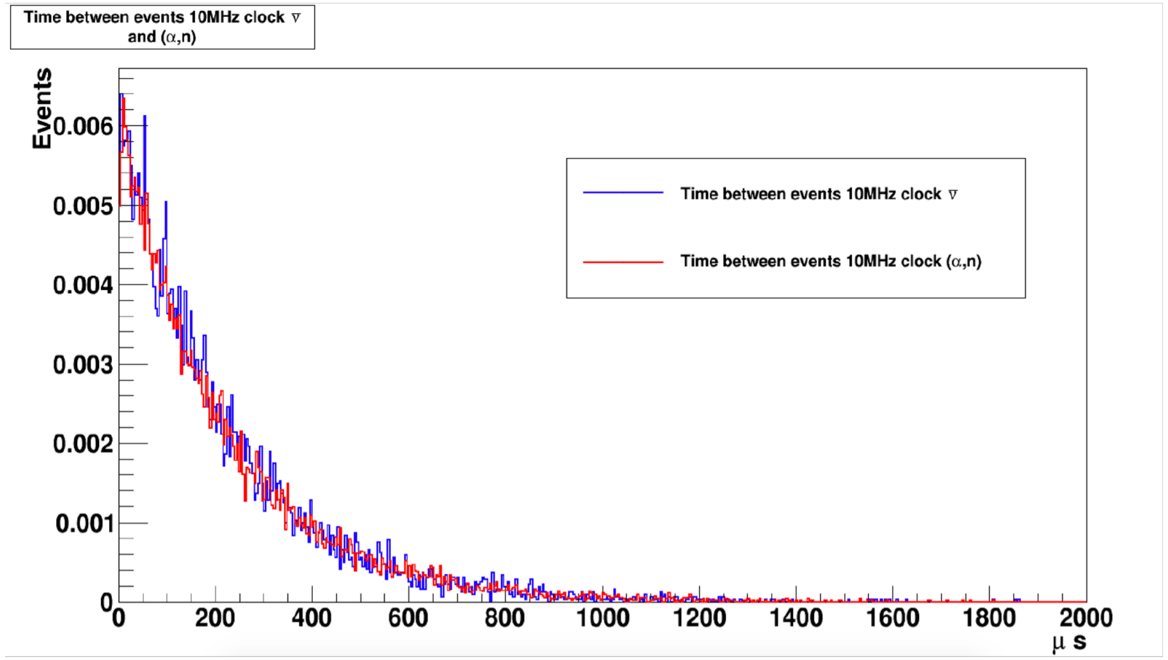
# Signal Description

AV with Scintillator (MC data)

# Position and Time Difference

AV with Scintillator (MC data)




**Reactor Antineutrinos**

$$\bar{\nu}_e + p \rightarrow n + e^+$$

**(α,n) Backgrounds**

$$\alpha + {}^{13}\mathrm{C} \rightarrow {}^{16}\mathrm{O} + \mathrm{n}\ (\sim 90\%)$$

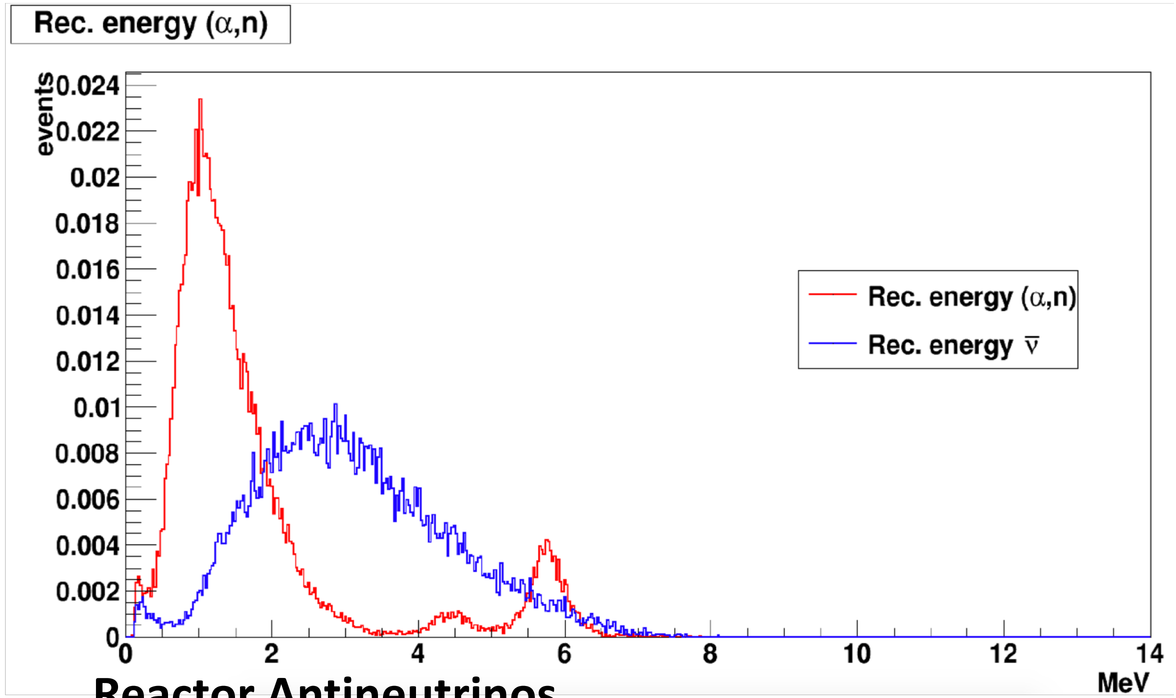
$$\alpha + {}^{13}\mathrm{C} \rightarrow {}^{16}\mathrm{O}^* + \mathrm{n}\ (\sim 10\%)$$

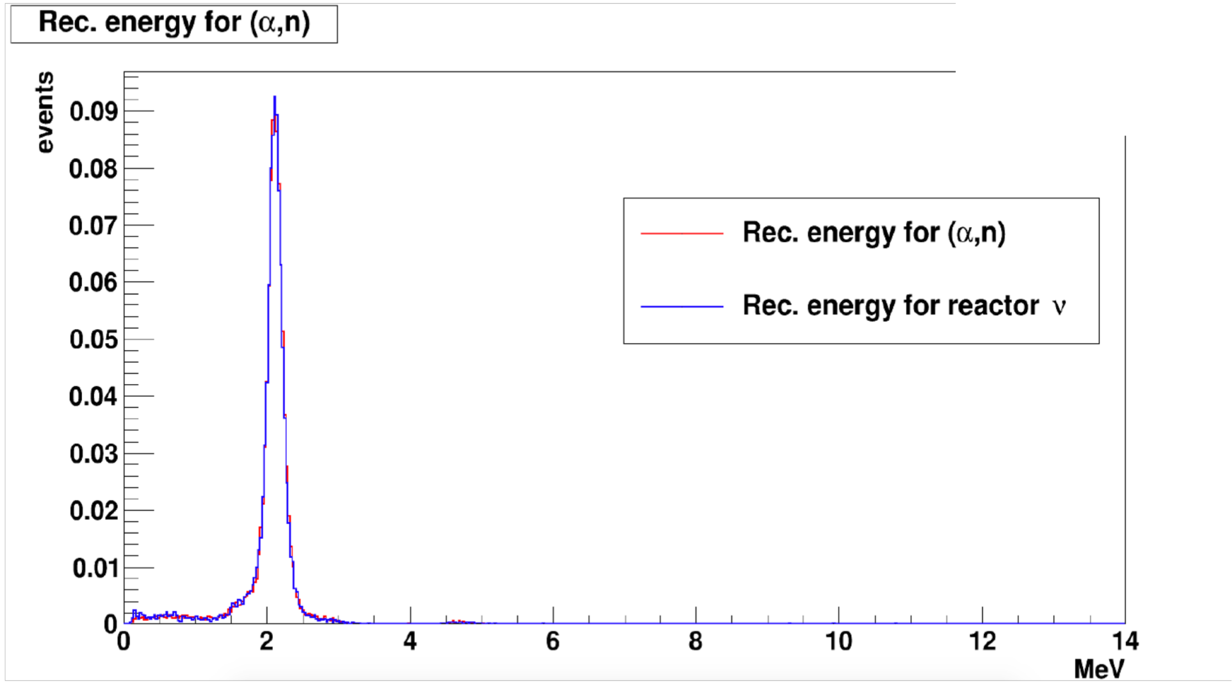
$${}^{16}\mathrm{O}^* \rightarrow {}^{16}\mathrm{O} + \gamma\ (\sim 1\%, 6.1\mathrm{MeV})$$

$${}^{16}\mathrm{O}^* \rightarrow {}^{16}\mathrm{O} + \mathrm{e}^+ + \mathrm{e}^-\ (\sim 9\%, 5\mathrm{MeV})$$

# Event's Energy

AV with Scintillator (MC data)




**Reactor Antineutrinos**

$$\bar{\nu}_e + p \rightarrow n + e^+$$

**(α,n) Backgrounds**

$$\alpha + {}^{13}\mathrm{C} \rightarrow {}^{16}\mathrm{O} + \mathrm{n}\ (\sim 90\%)$$

$$\alpha + {}^{13}\mathrm{C} \rightarrow {}^{16}\mathrm{O}^* + \mathrm{n}\ (\sim 10\%)$$

$${}^{16}\mathrm{O}^* \rightarrow {}^{16}\mathrm{O} + \gamma\ (\sim 1\%, 6.1\mathrm{MeV})$$

$${}^{16}\mathrm{O}^* \rightarrow {}^{16}\mathrm{O} + \mathrm{e}^+ + \mathrm{e}^-\ (\sim 9\%, 5\mathrm{MeV})$$

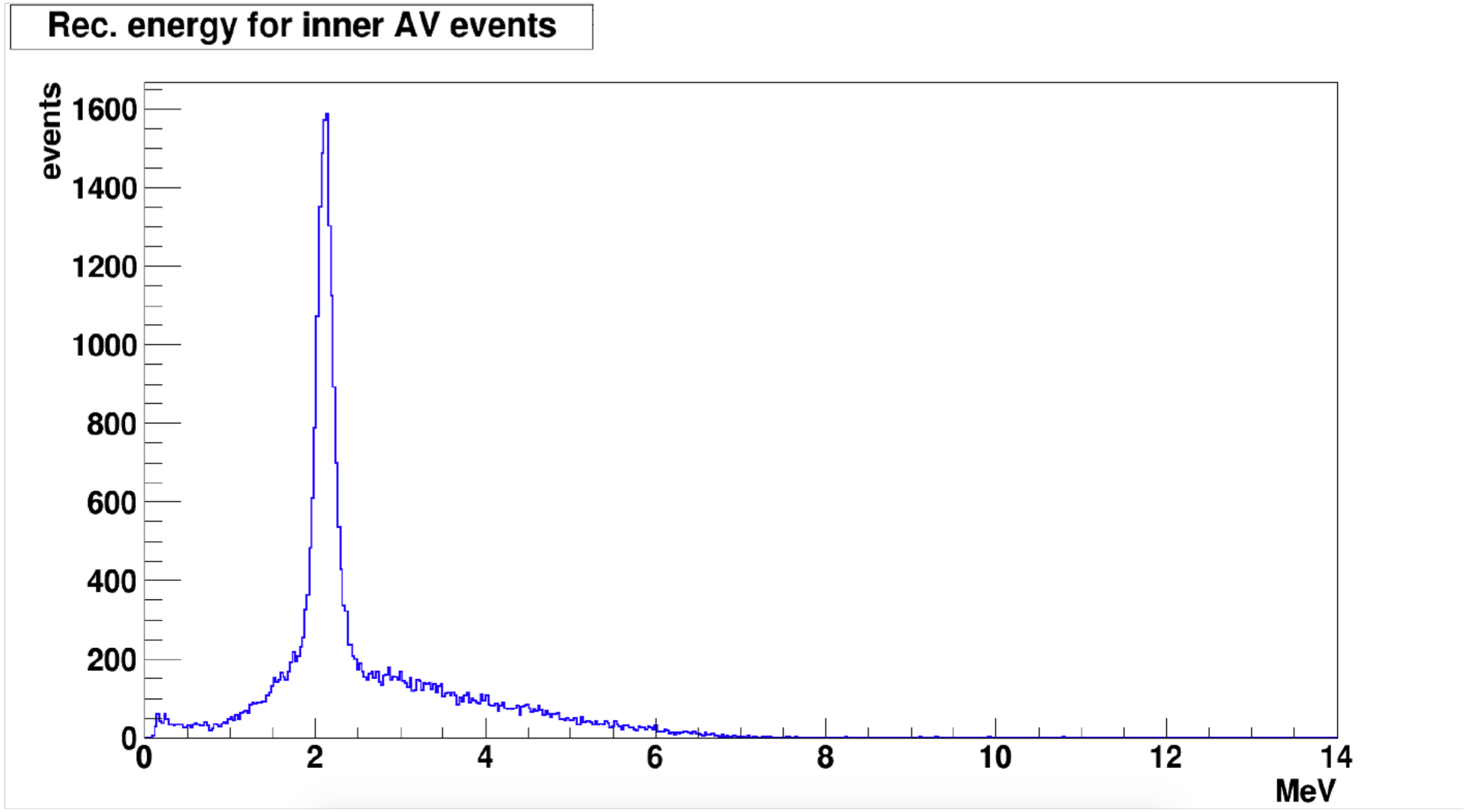
# Coincidences Selection

AV with Scintillator (MC data)

# Selecting Coincidences

AV with Scintillator (MC data)

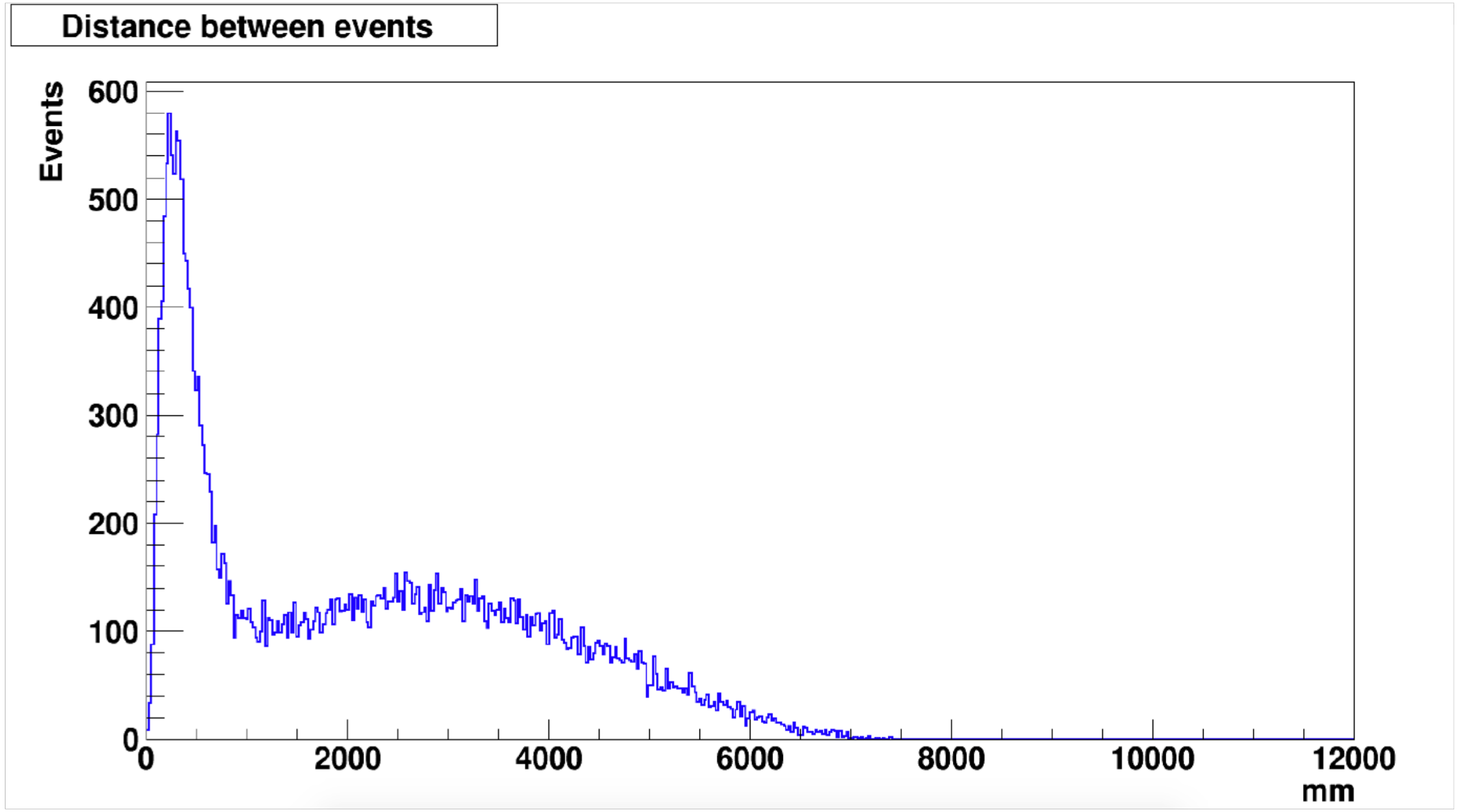
Raw reconstructed energy data from detector.



# Selecting Coincidences

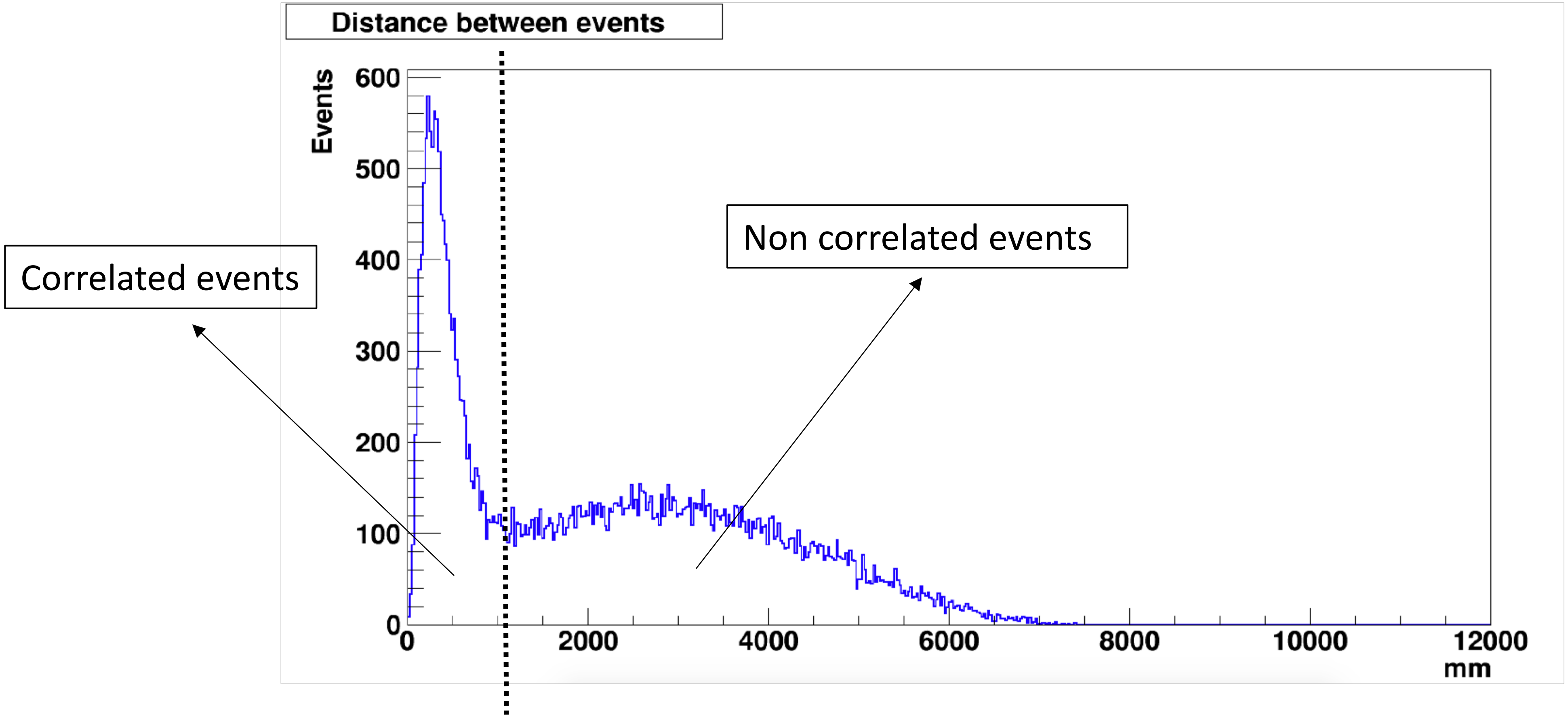
AV with Scintillator (MC data)

Correlated events are expected to have a distance smaller than ≈ 1m



# Selecting Coincidences

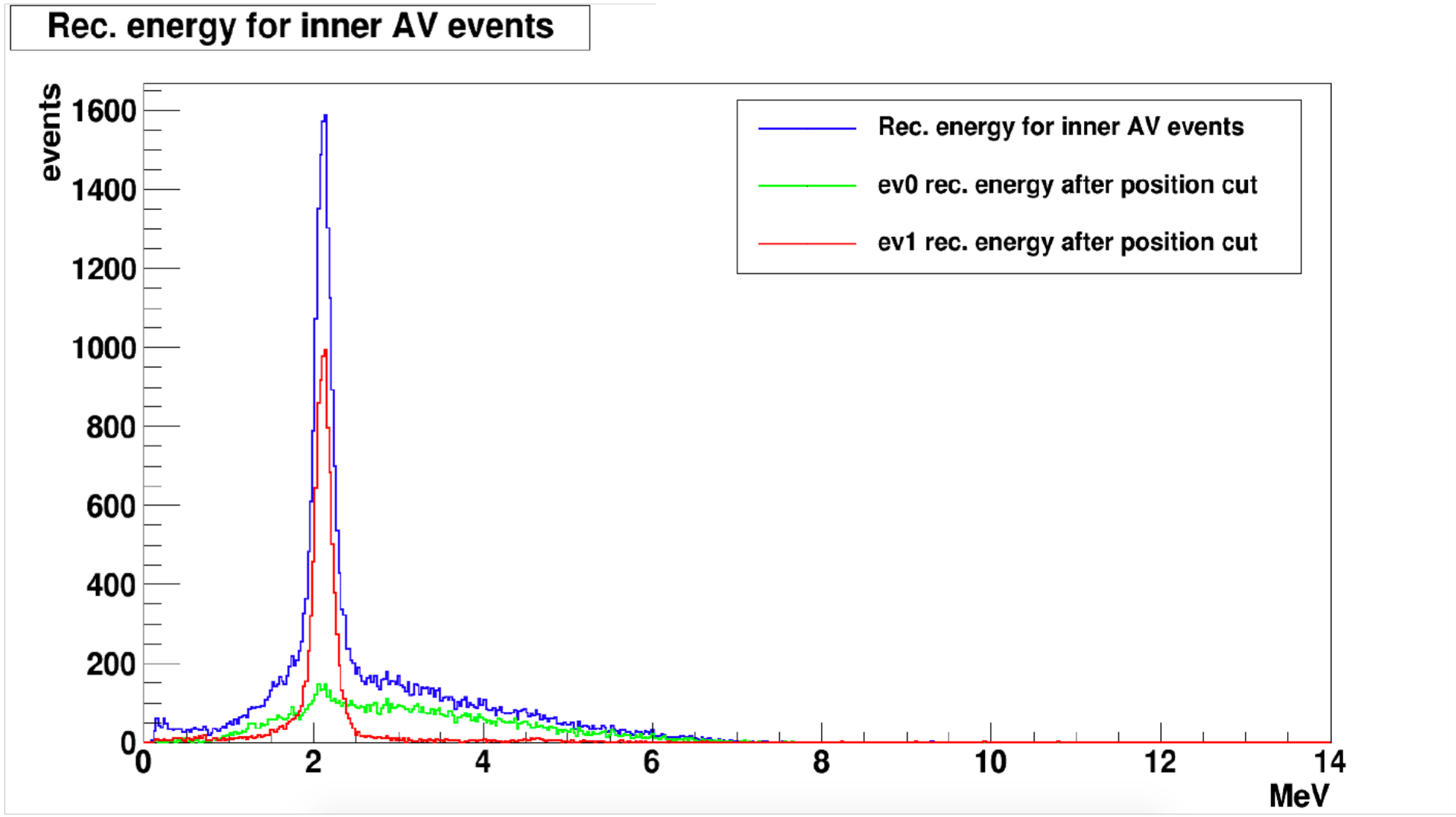
AV with Scintillator (MC data)



# Selecting Coincidences

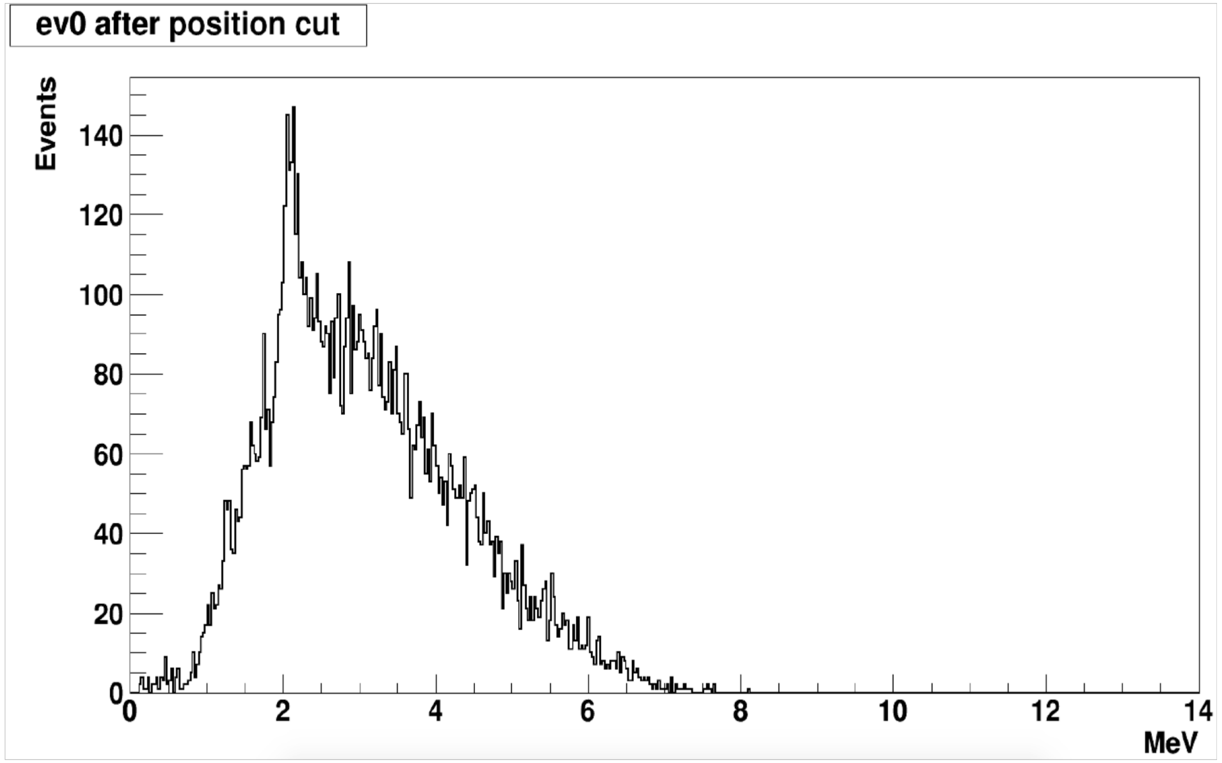
AV with Scintillator (MC data)

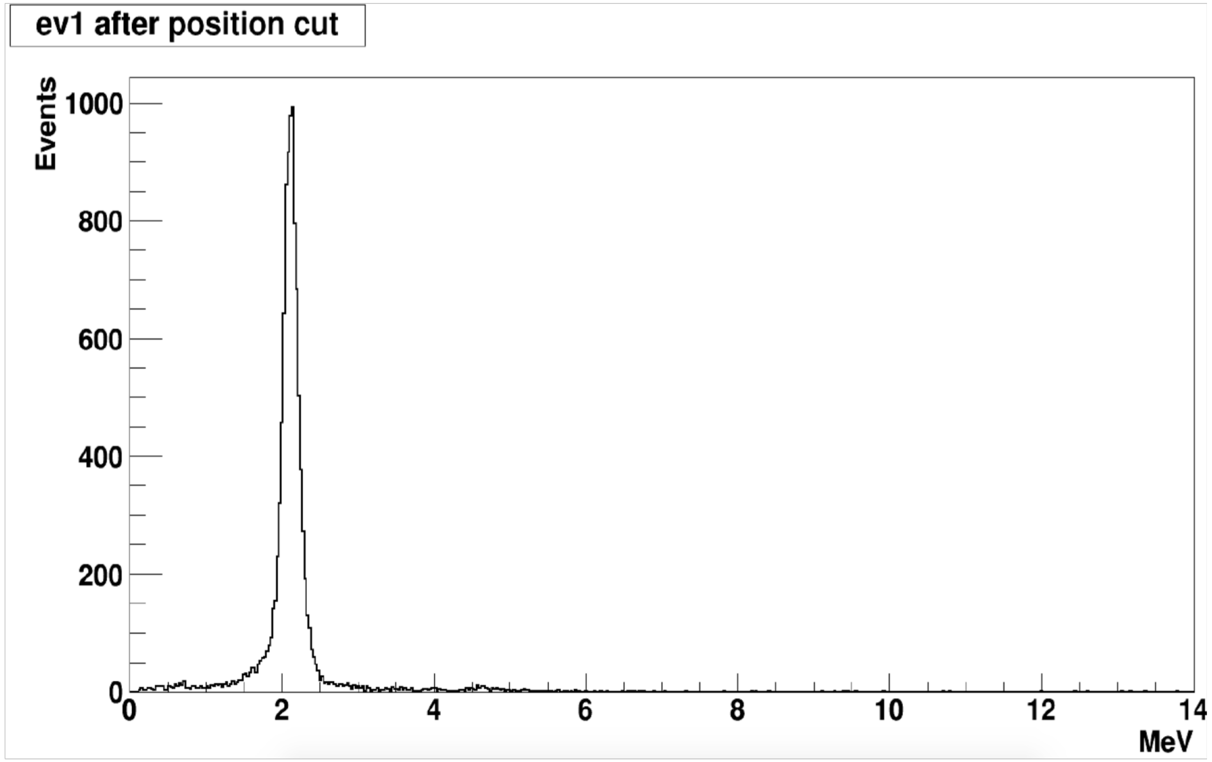
Position cut result



# Selecting Coincidences

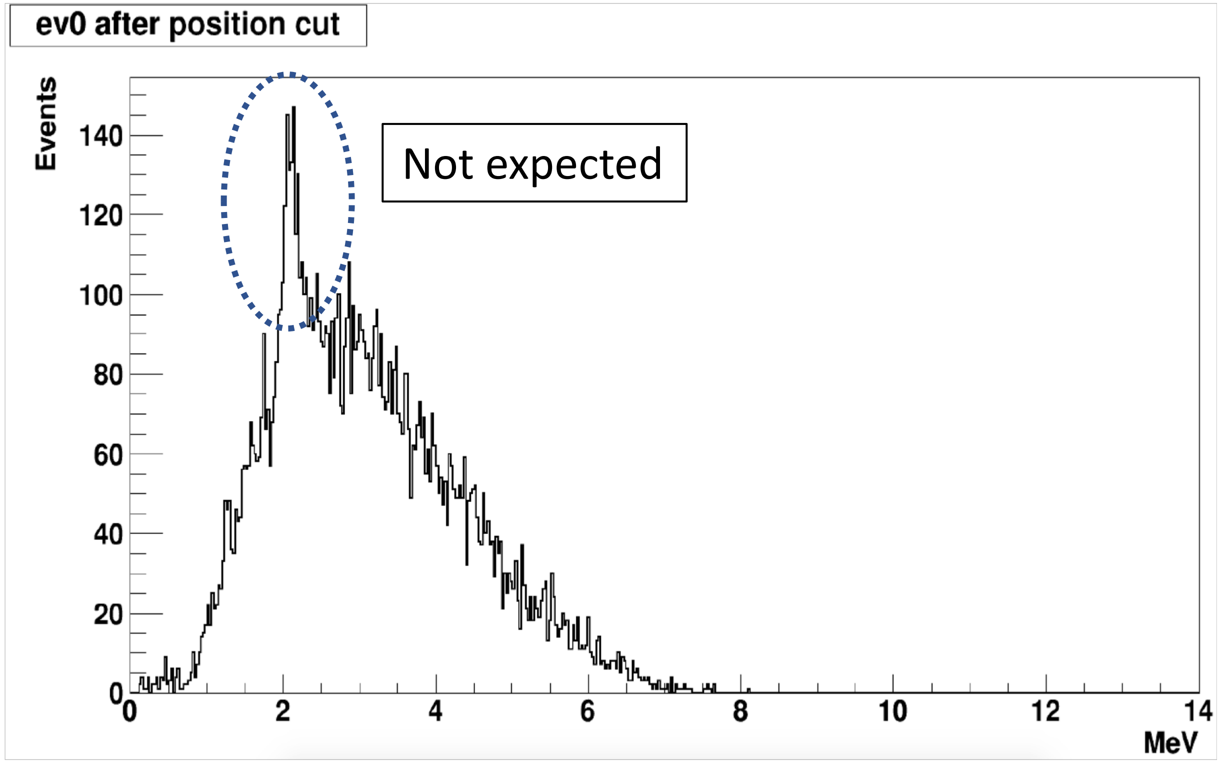
AV with Scintillator (MC data)

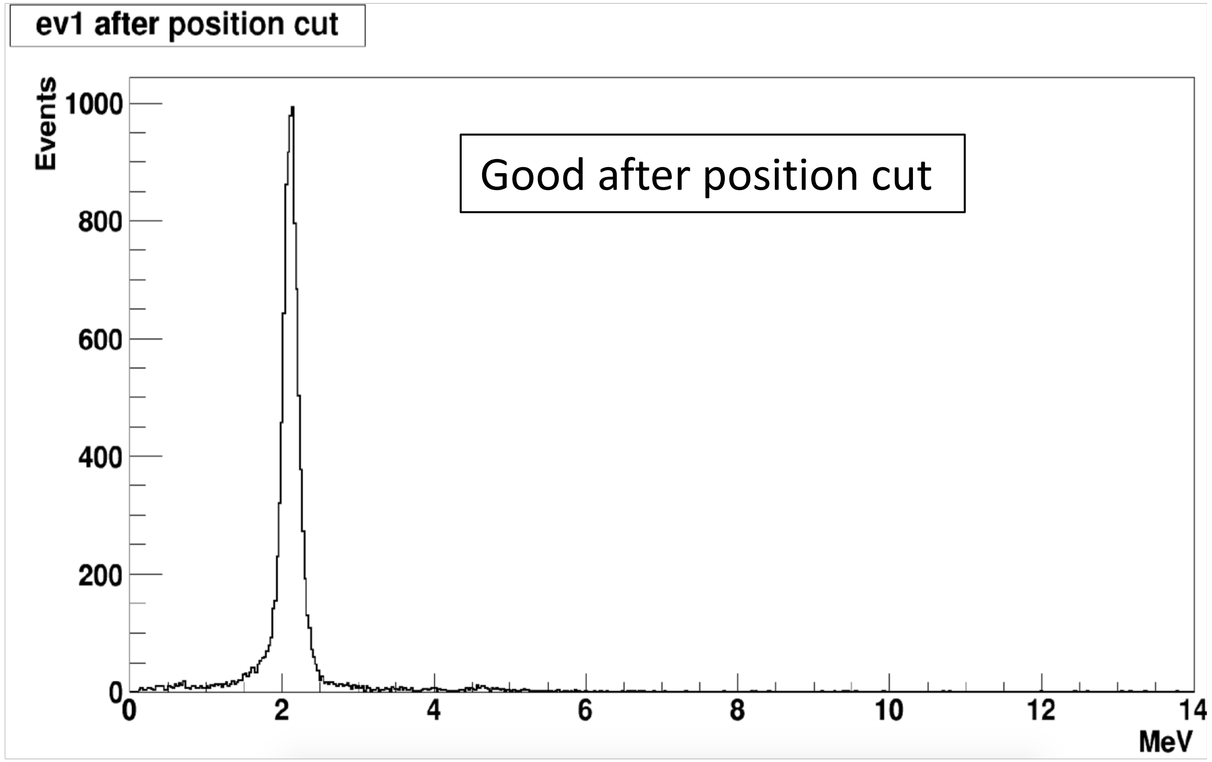


# Selecting Coincidences

AV with Scintillator (MC data)

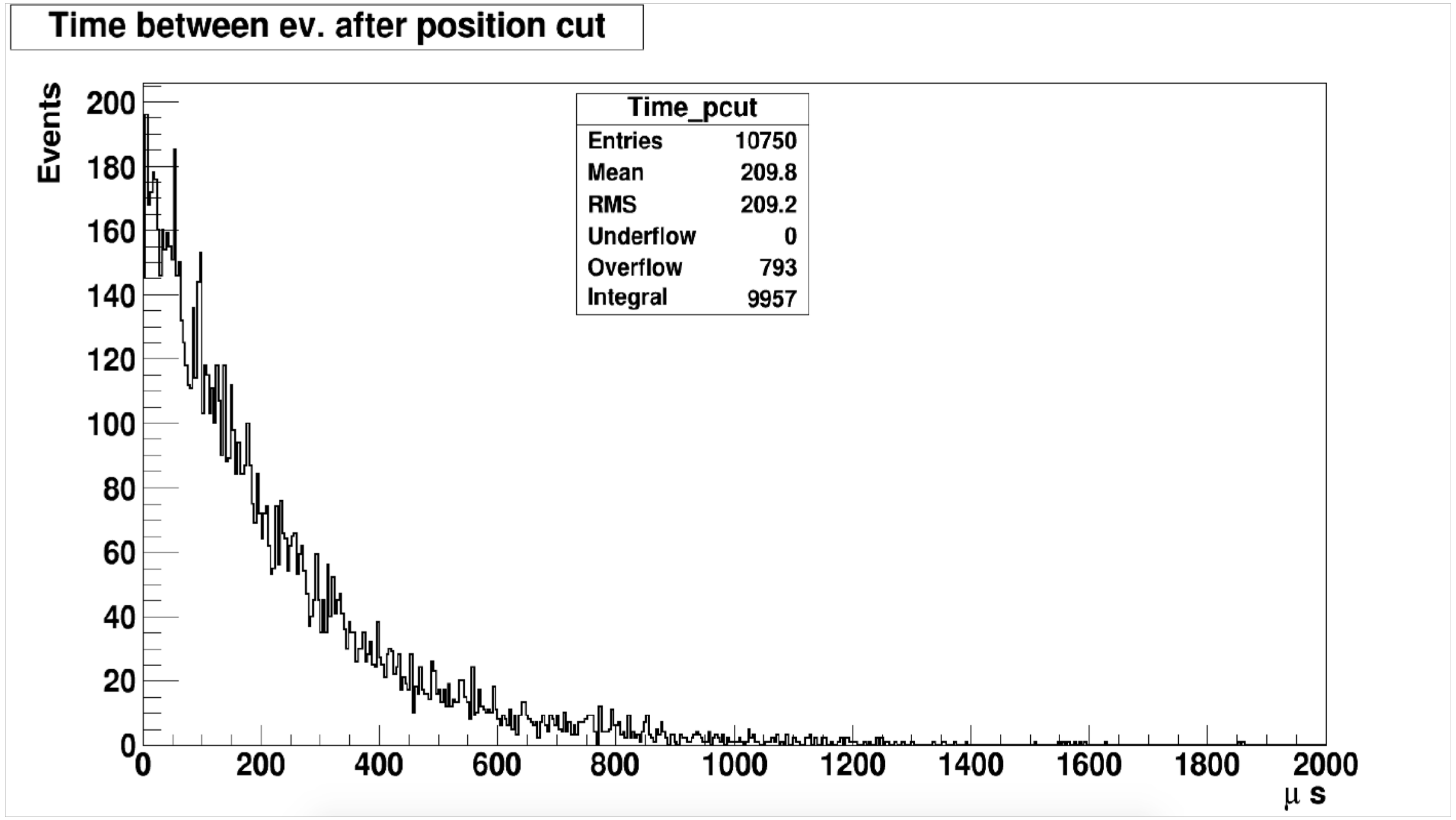


# Selecting Coincidences

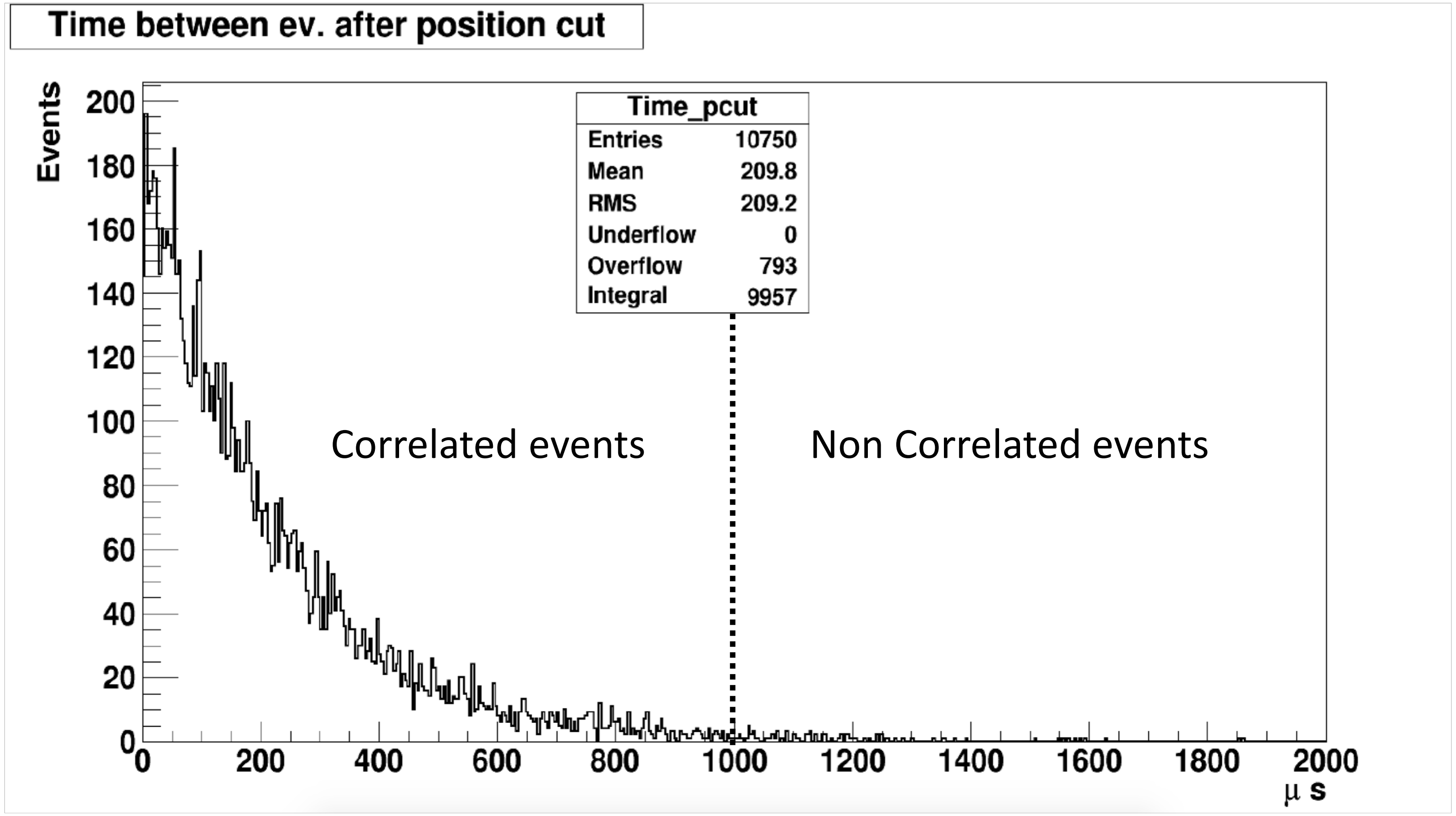
AV with Scintillator (MC data)

Correlated events have an average time difference of ≈ 200 μs



# Selecting Coincidences

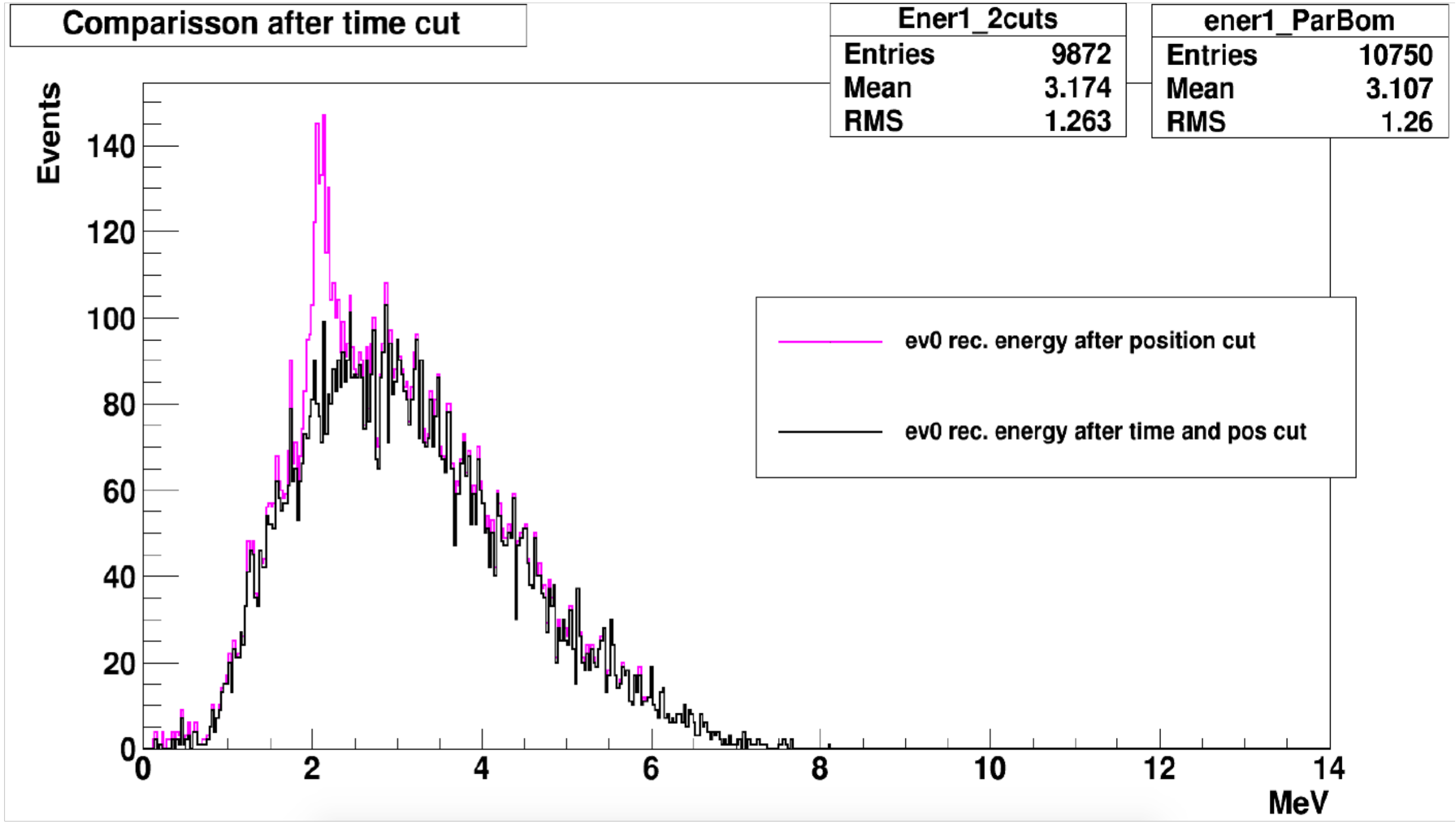
AV with Scintillator (MC data)



# Selecting Coincidences

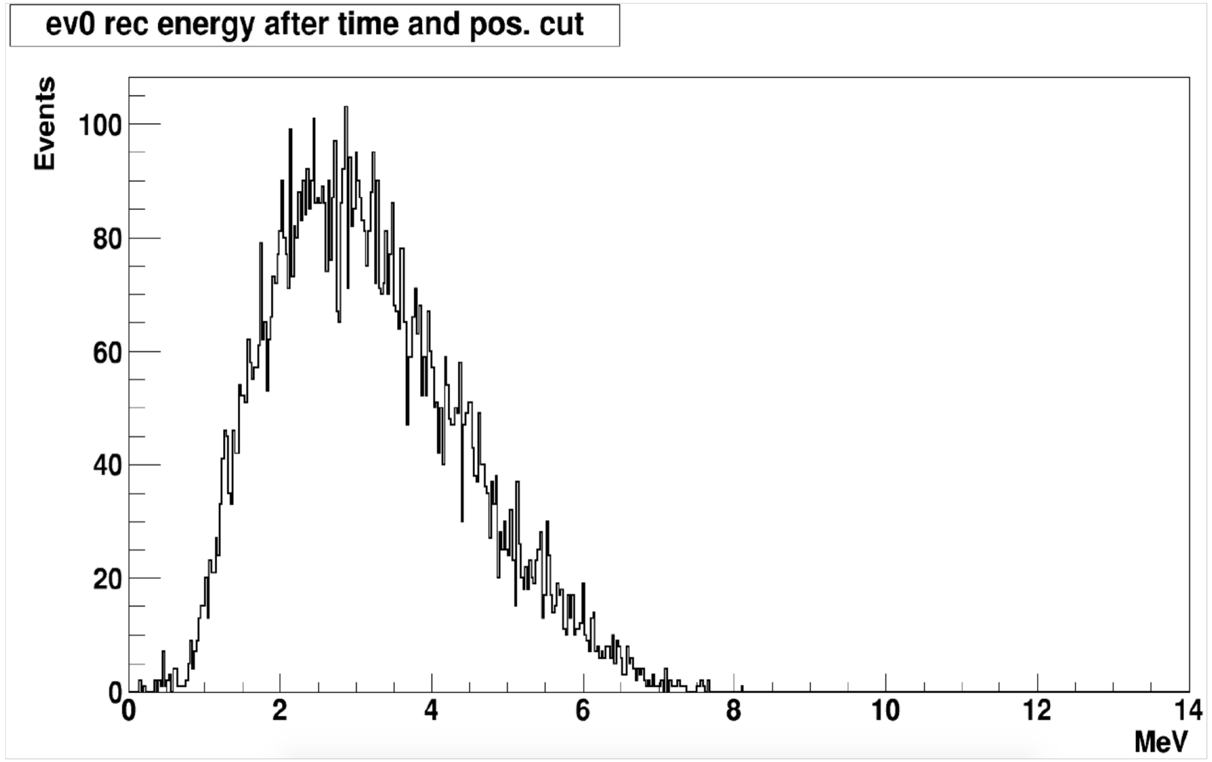
AV with Scintillator (MC data)

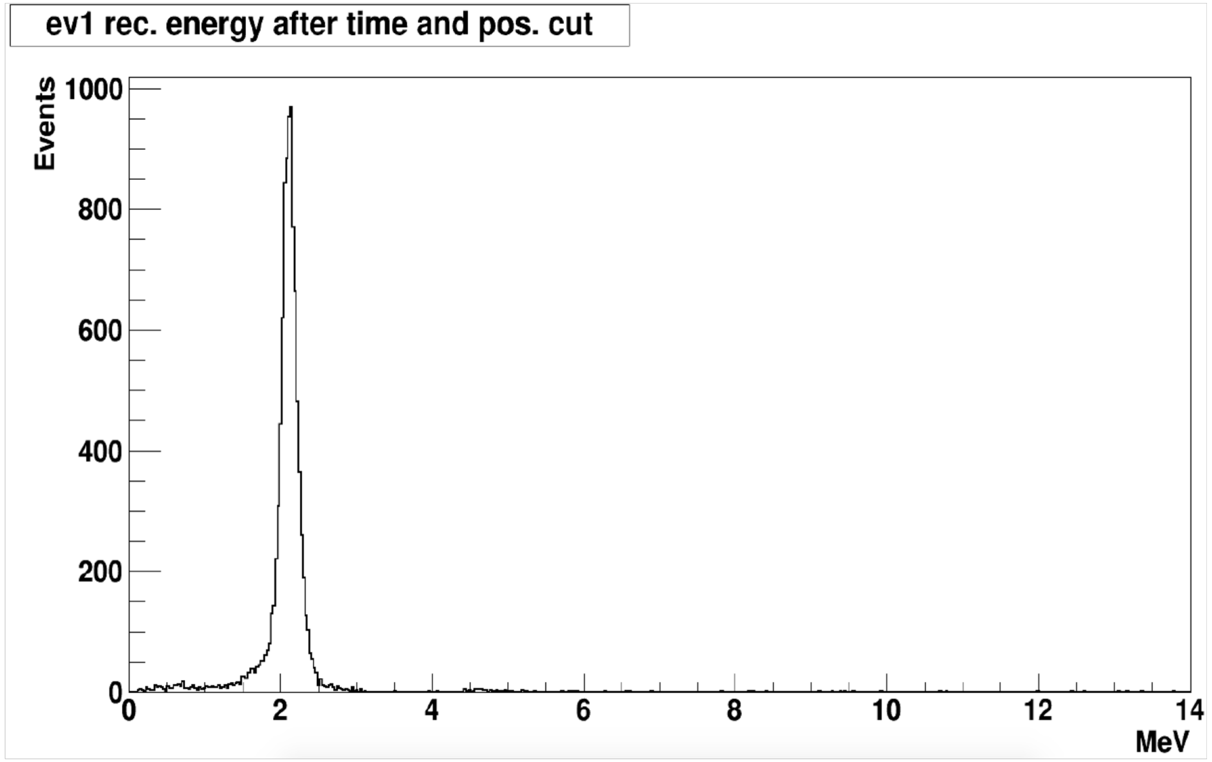
The peak events were removed



# Selecting Coincidences

AV with Scintillator (MC data)



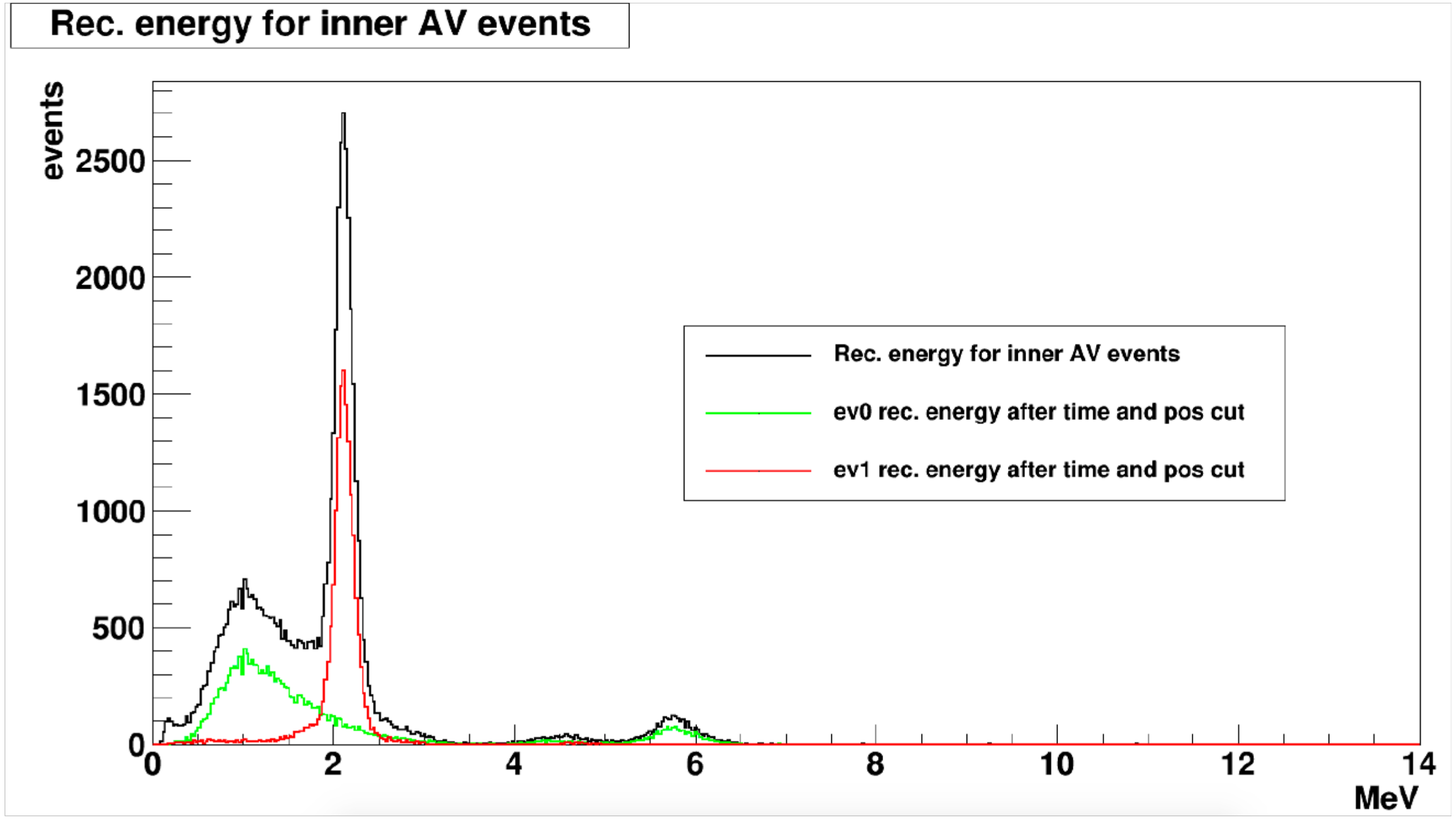



# Selecting Coincidences

AV with Scintillator (MC data)

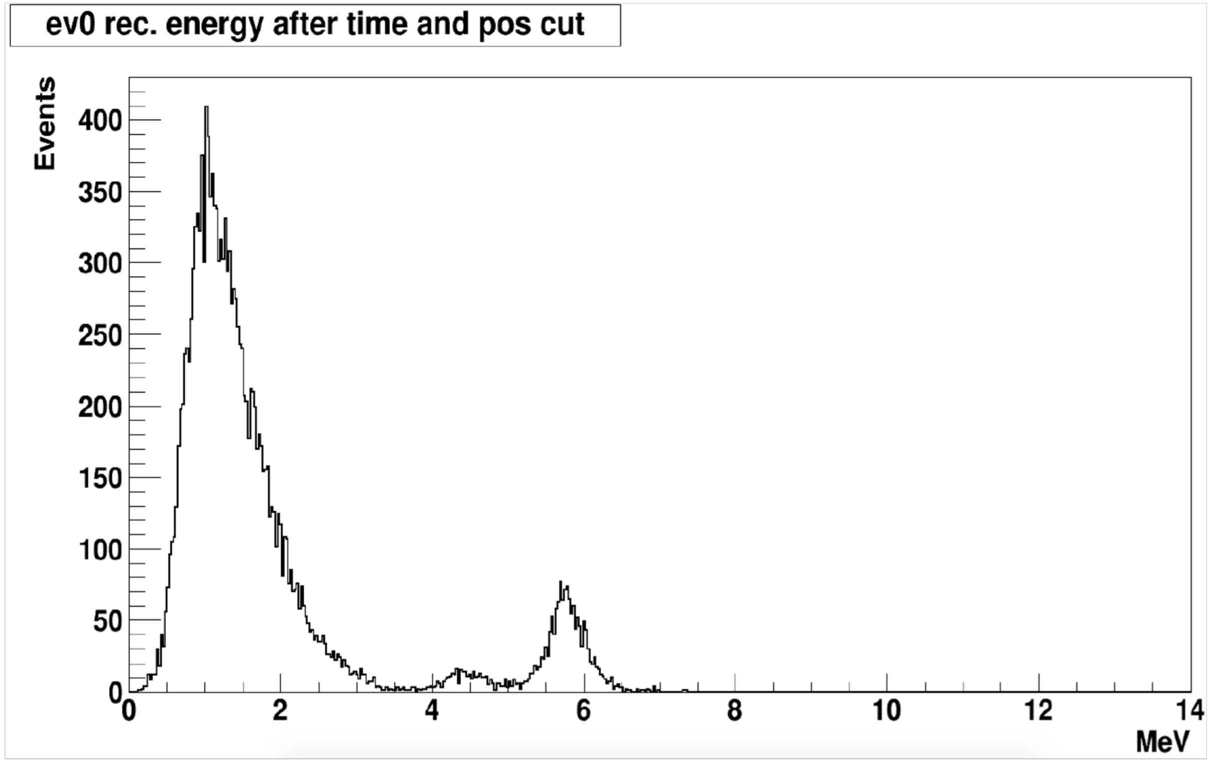
Applying the same process for (α,n) data

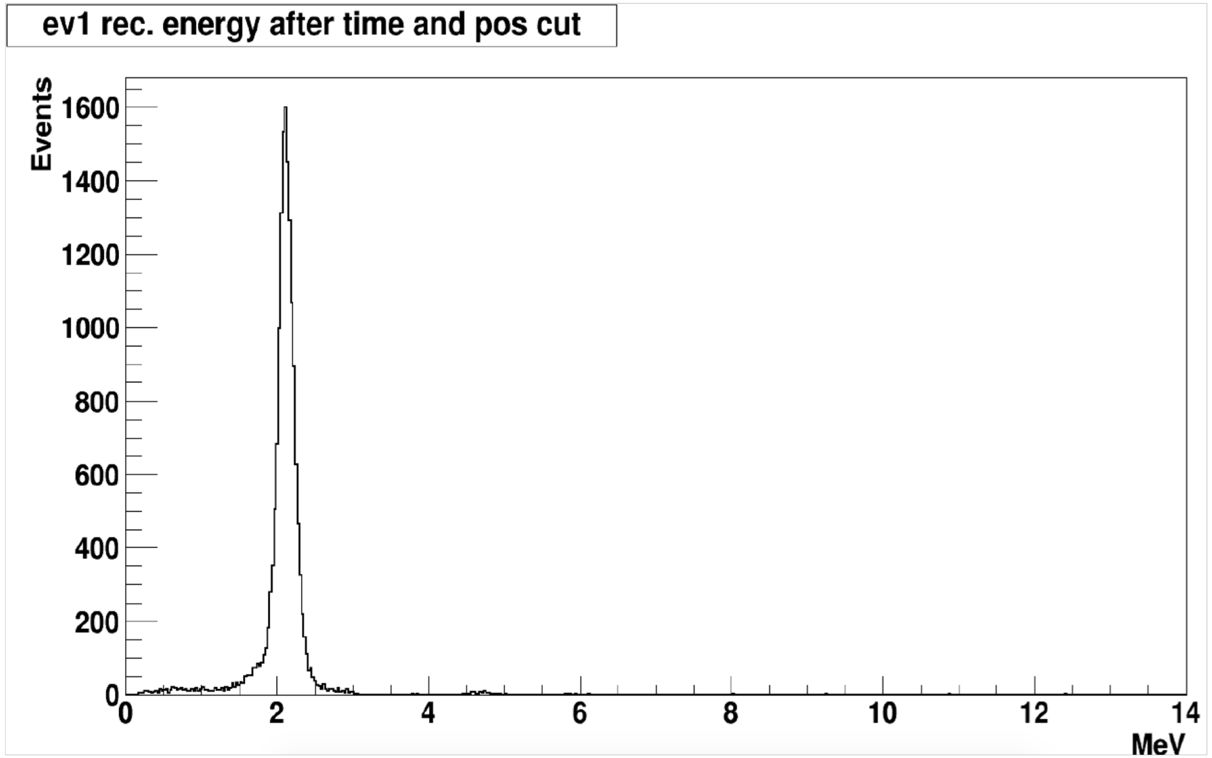
Indentifies events effectively



# Selecting Coincidences

AV with Scintillator (MC data)



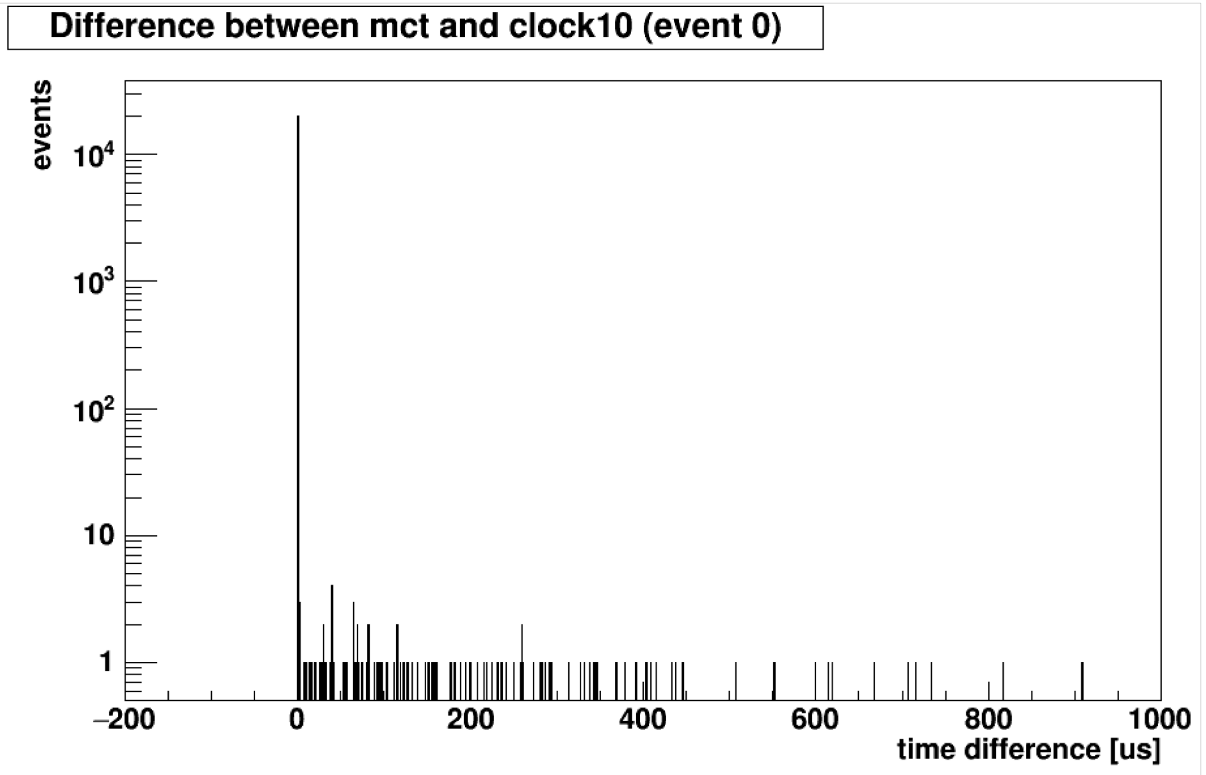



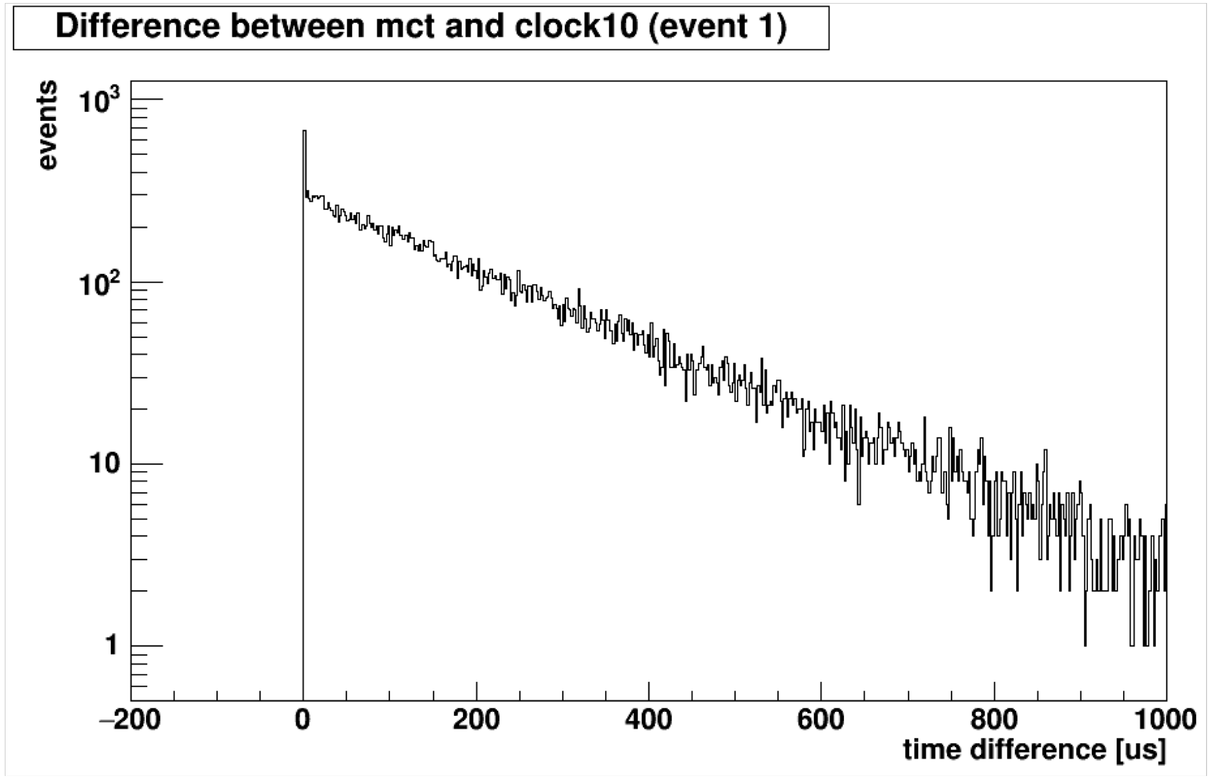
# Antineutrinos Detection Efficiency

AV with Scintillator + Water (MC data)

# Detector's Efficiency… Applying a Time Cut

AV with Water + Scintillator (MC data)

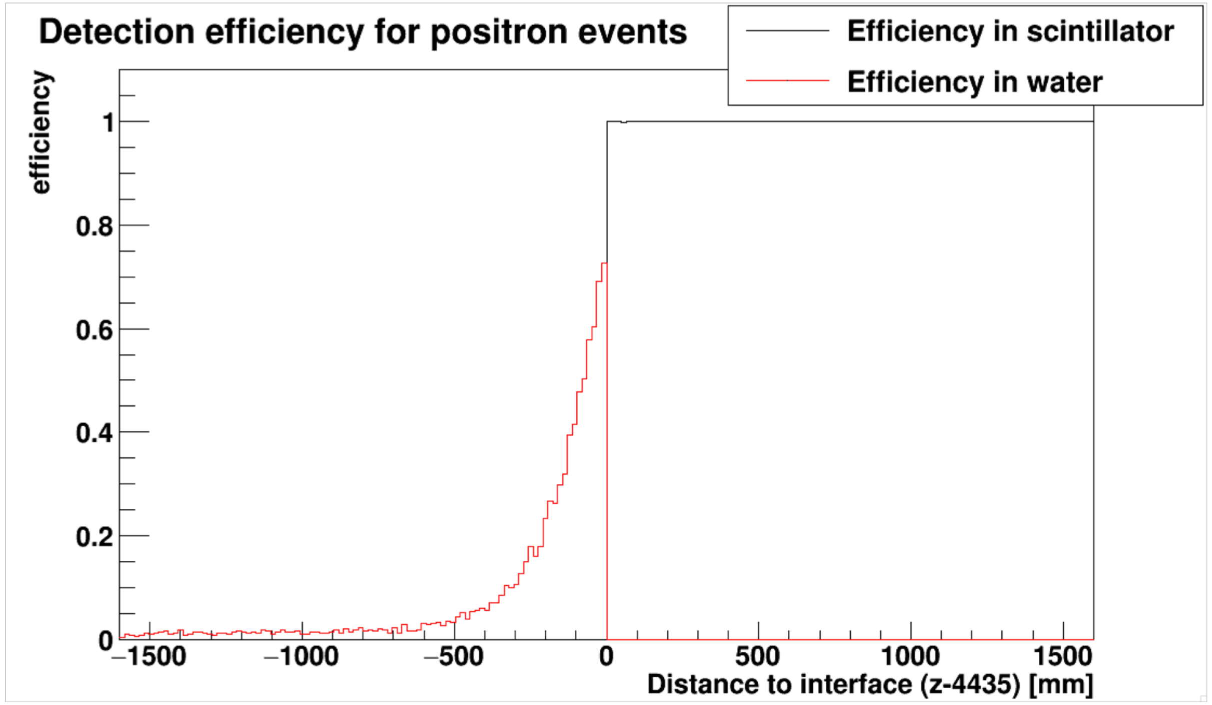


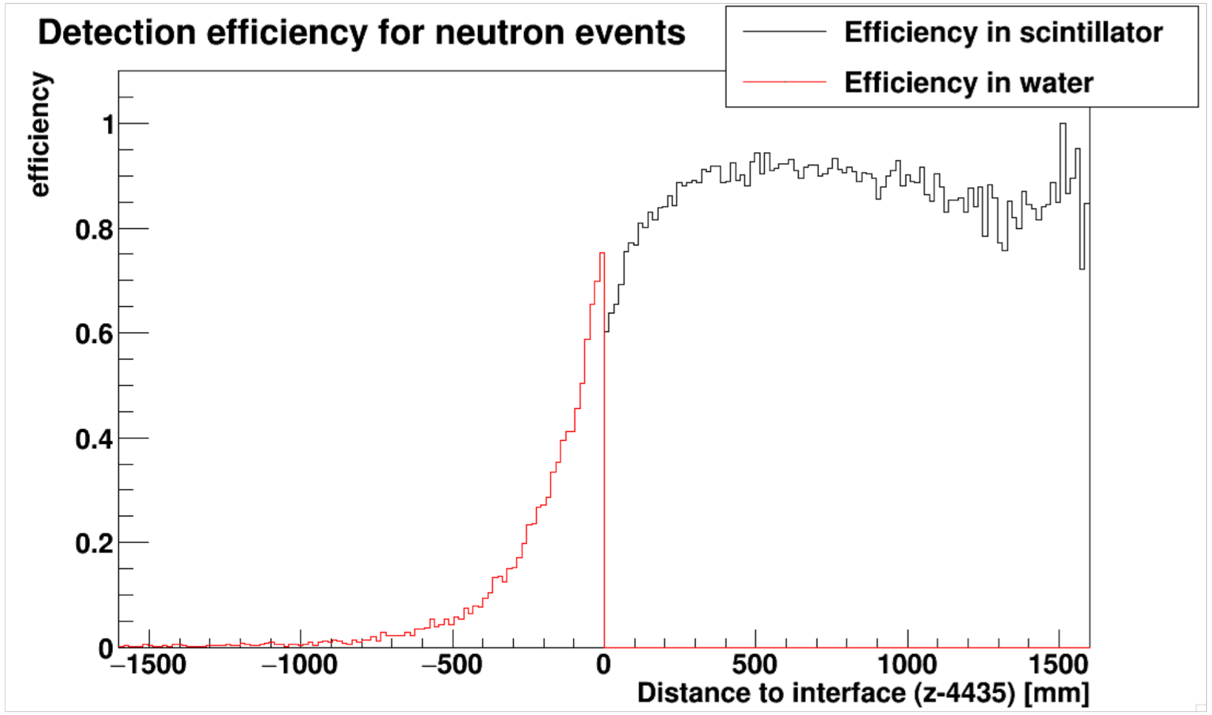




$$\bar{\upsilon}_e + p \rightarrow e^+ + n$$

# Detector's Efficiency

AV with Water + Scintillator (MC data)

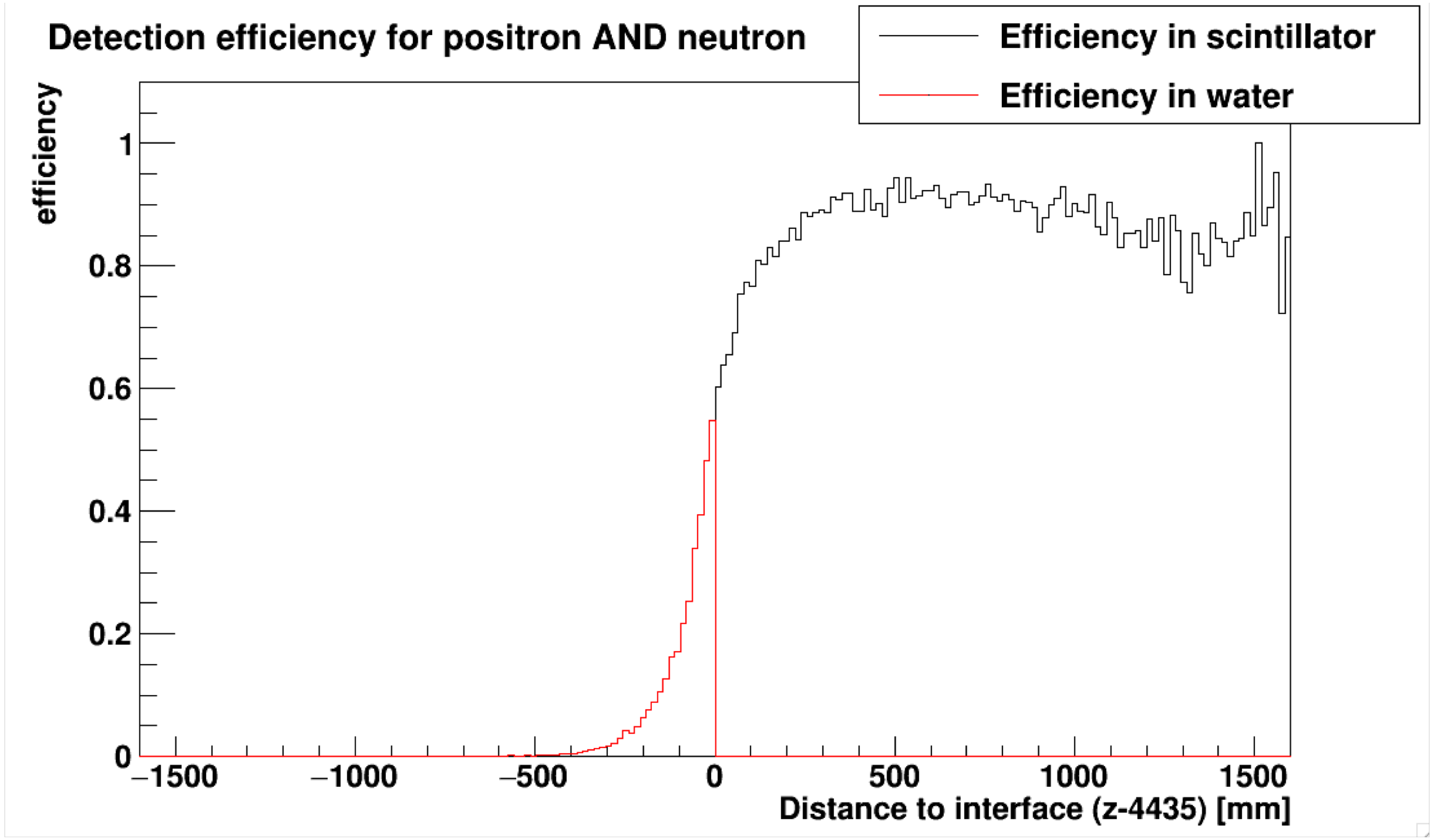



$$\bar{\nu}_e + p \rightarrow e^+ + n$$

# Detector's Efficiency – Both Events

AV with Water + Scintillator (MC data)

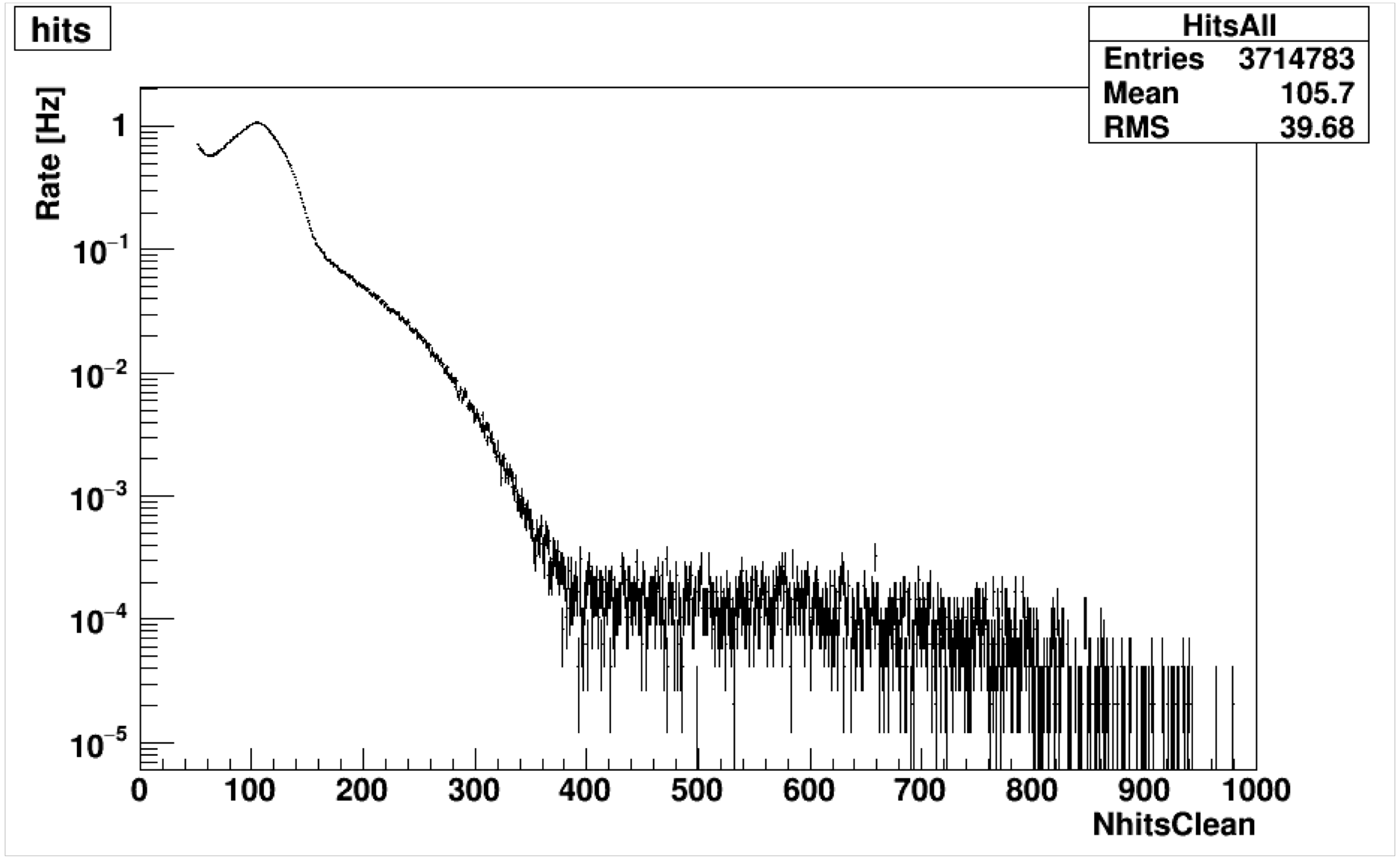


# Searching Data for Antineutrinos

AV with Scintillator + Water (Real data)

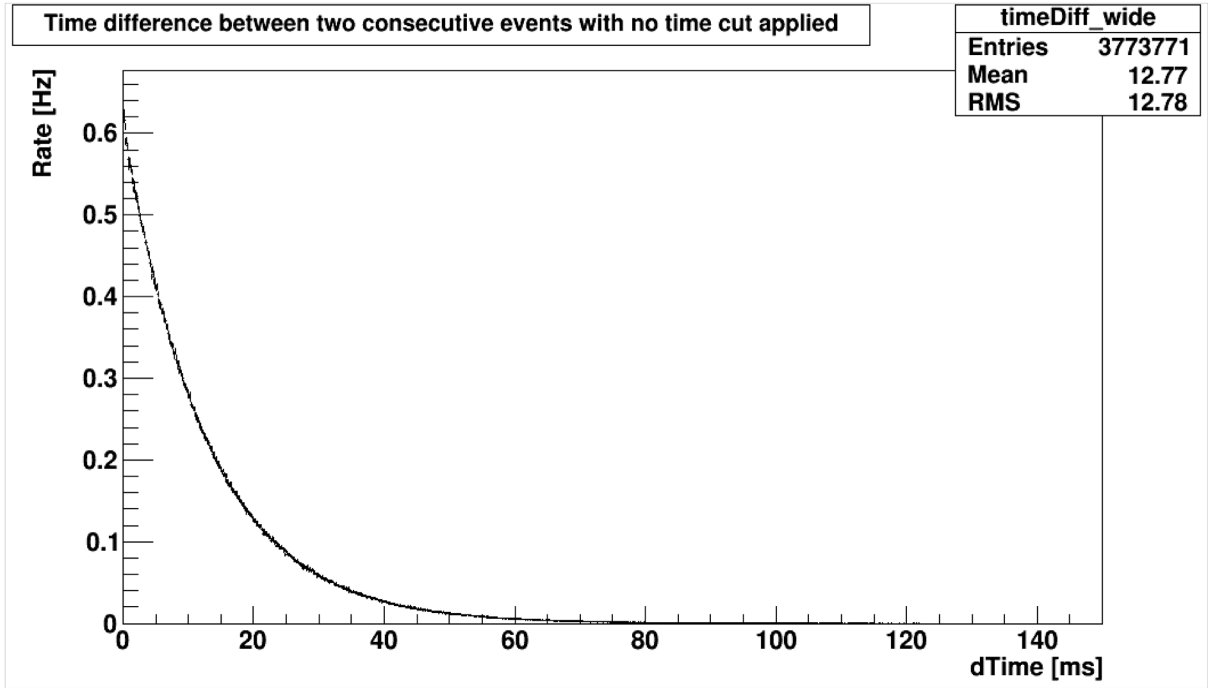
# Searching Antineutrinos Signal

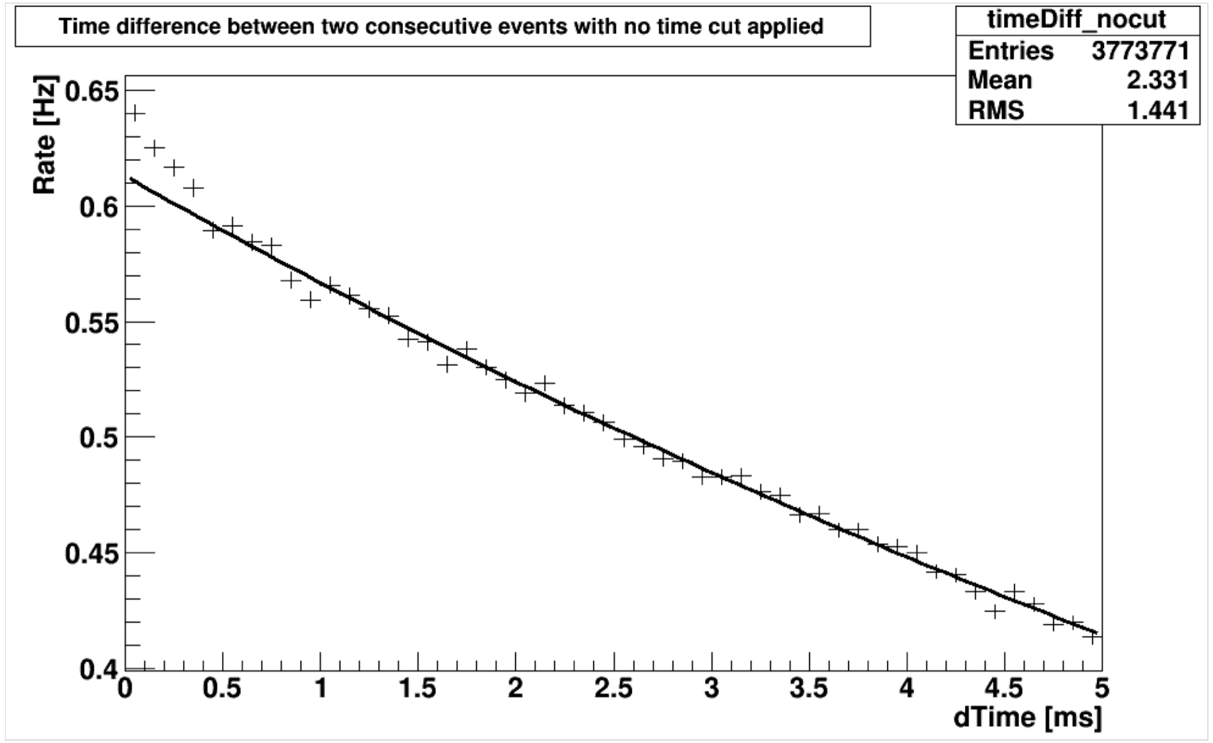
AV with Water + Scintillator (real data)



# Searching Antineutrinos Signal: Time Cut

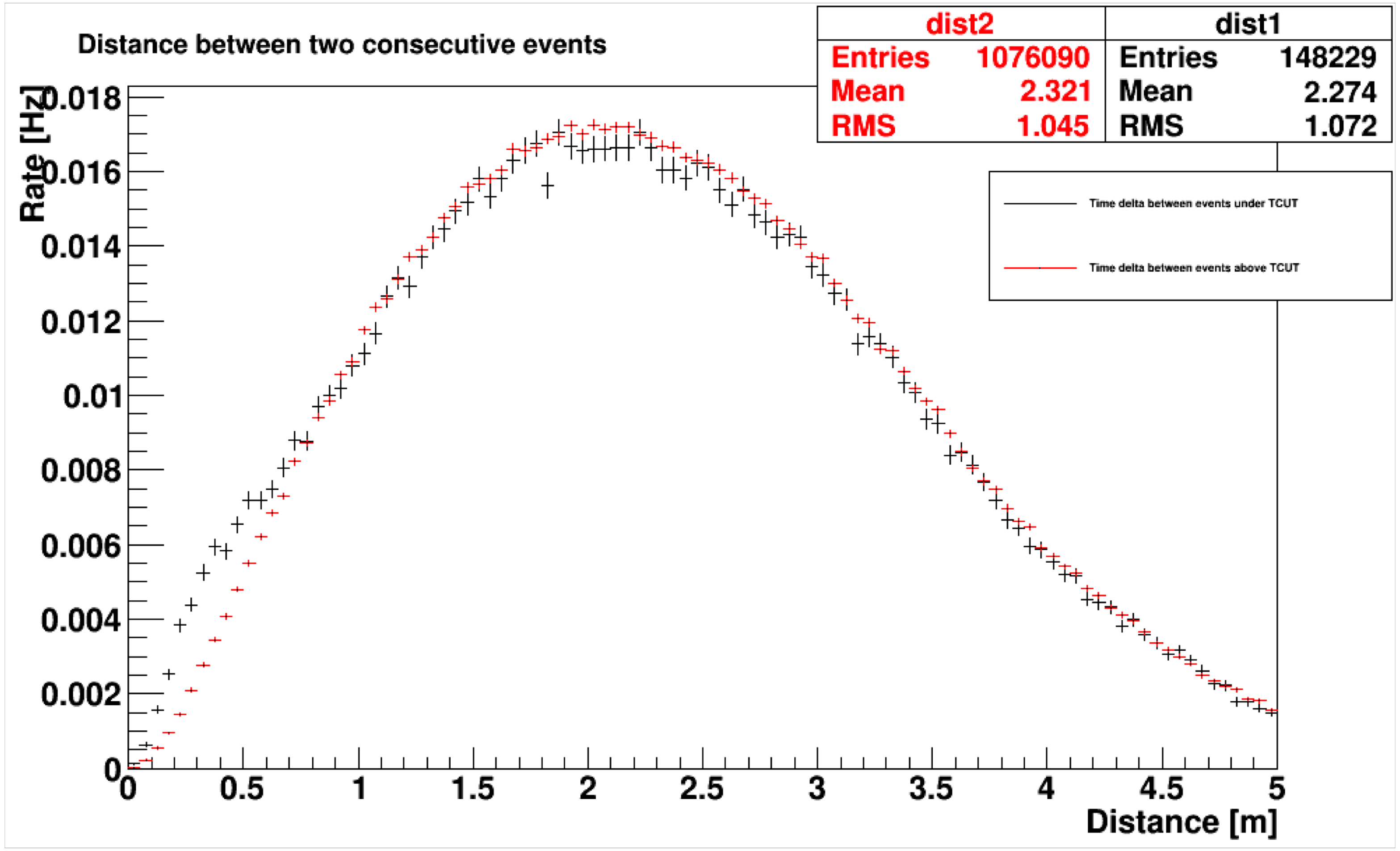
AV with Water + Scintillator (real data)



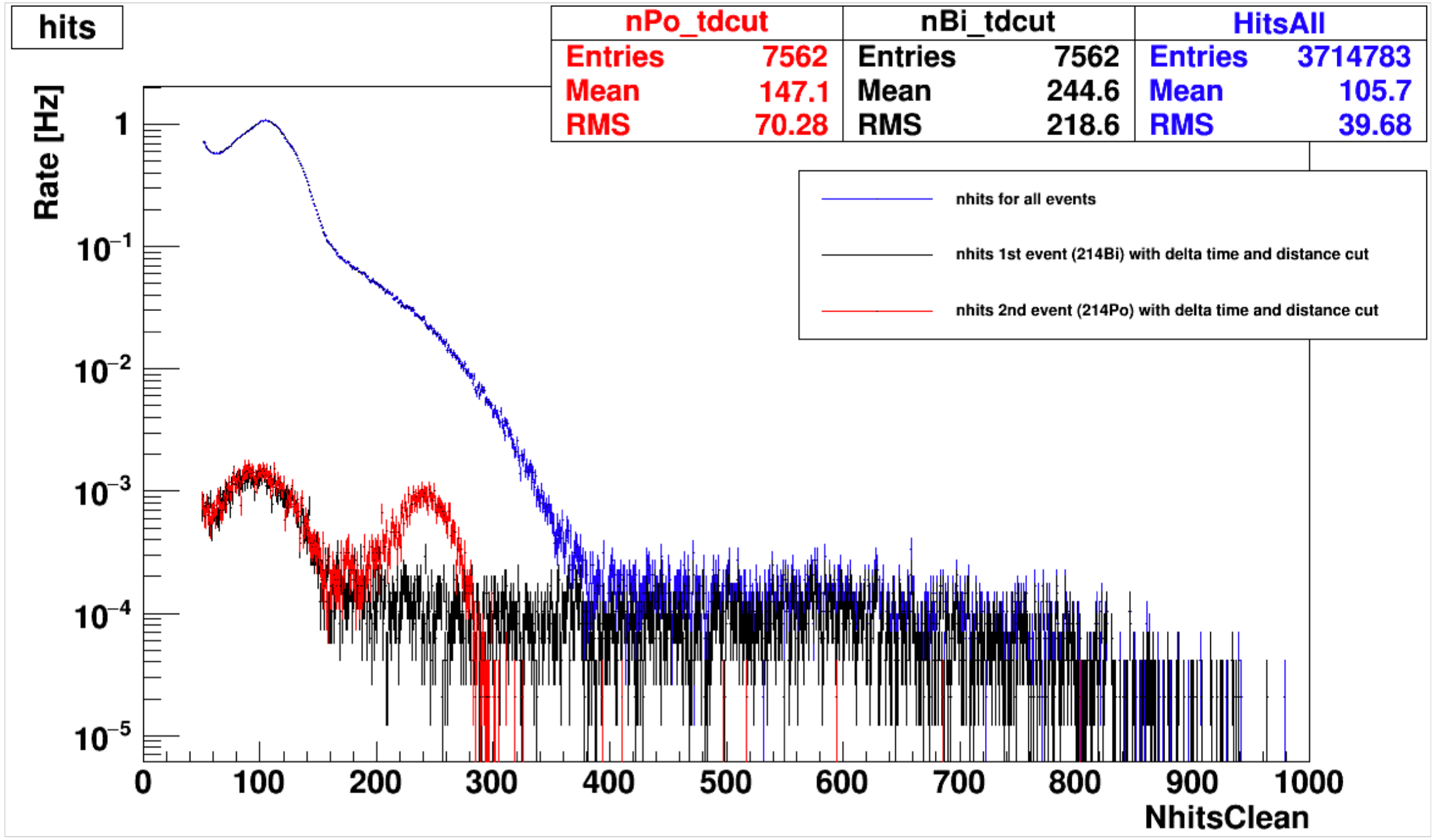
# Searching Antineutrinos Signal: Distance Cut

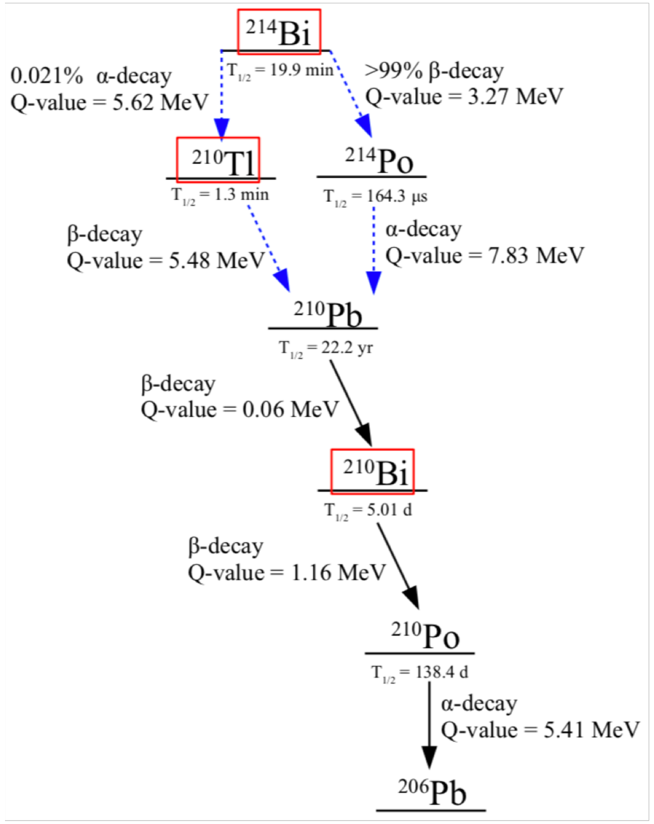
AV with Water + Scintillator (real data)



# Searching Antineutrinos Signal… Something Else Found

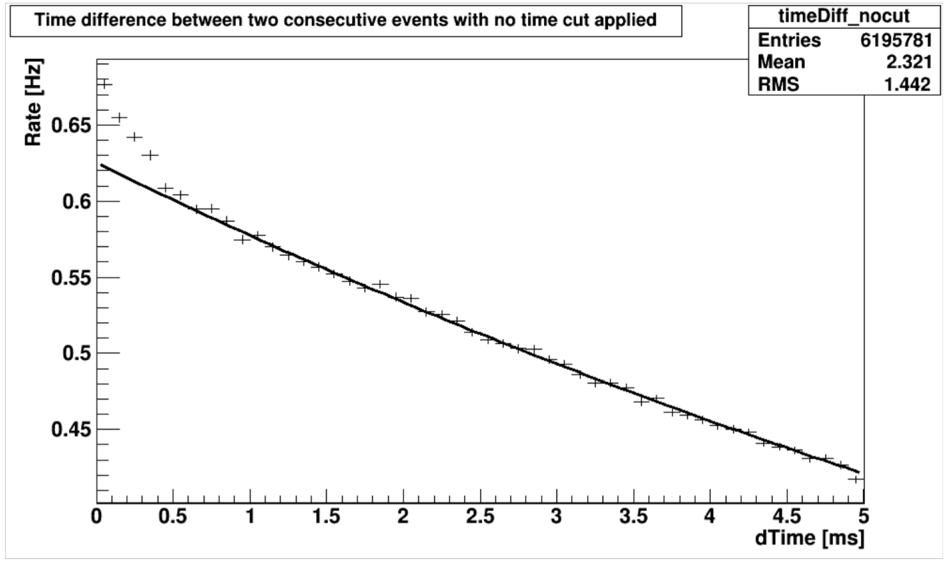
AV with Water + Scintillator (real data)

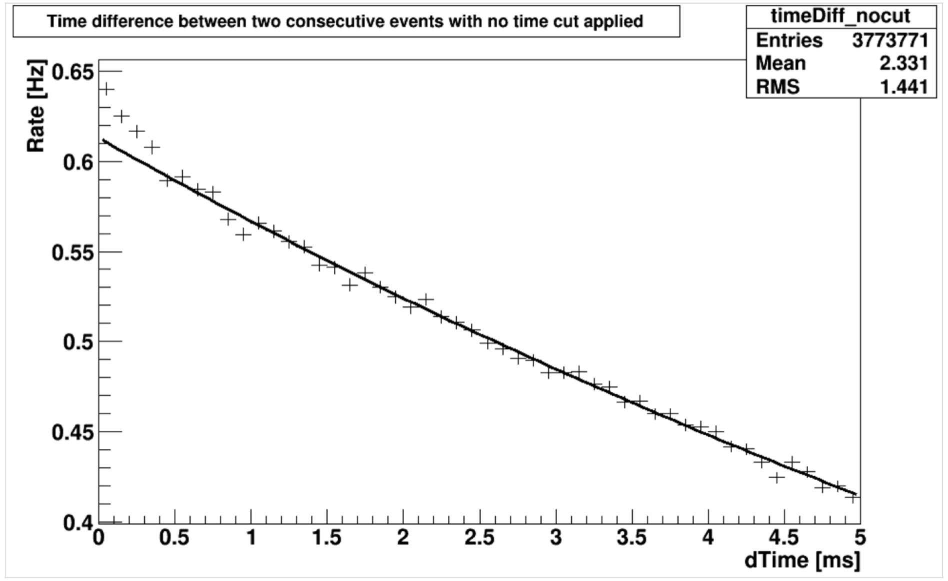


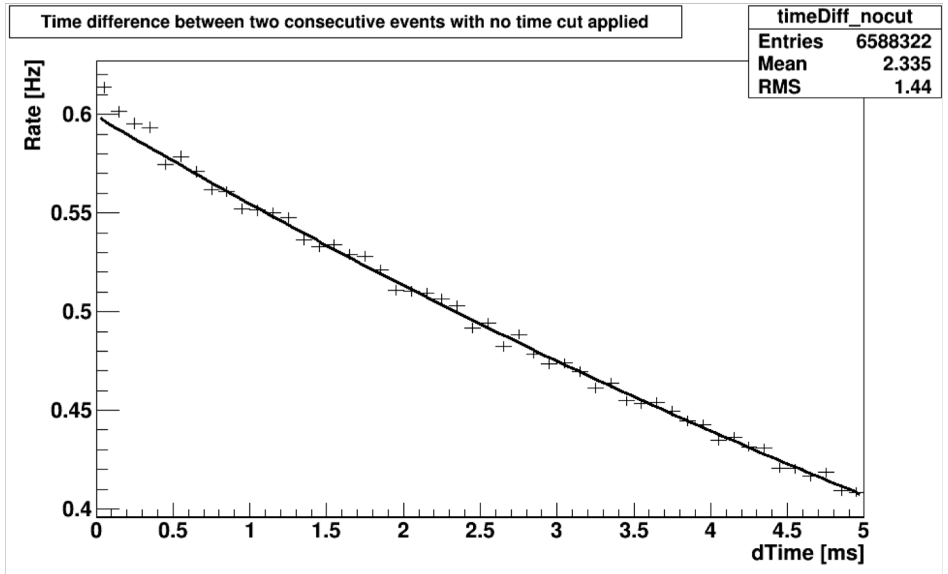



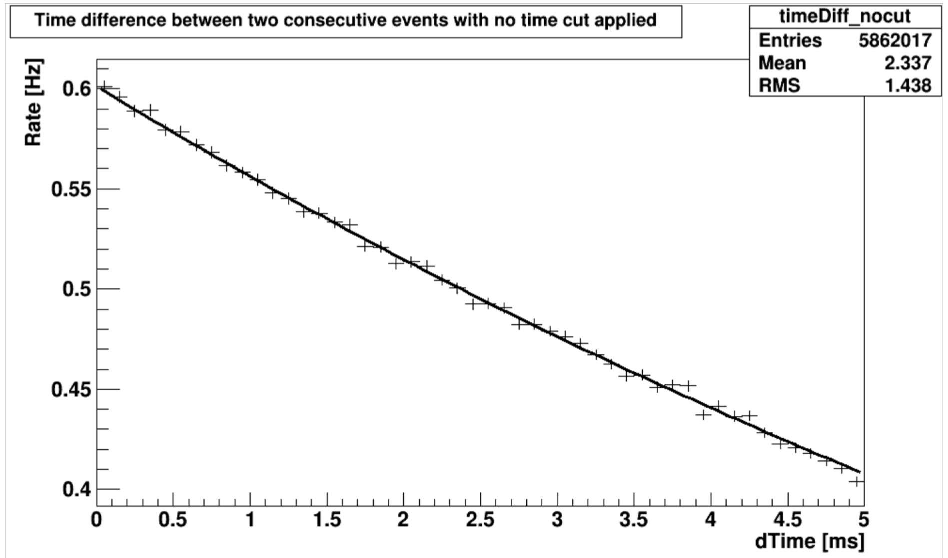
# Searching Antineutrinos Signal: Decay Chain

AV with Water + Scintillator (real data)



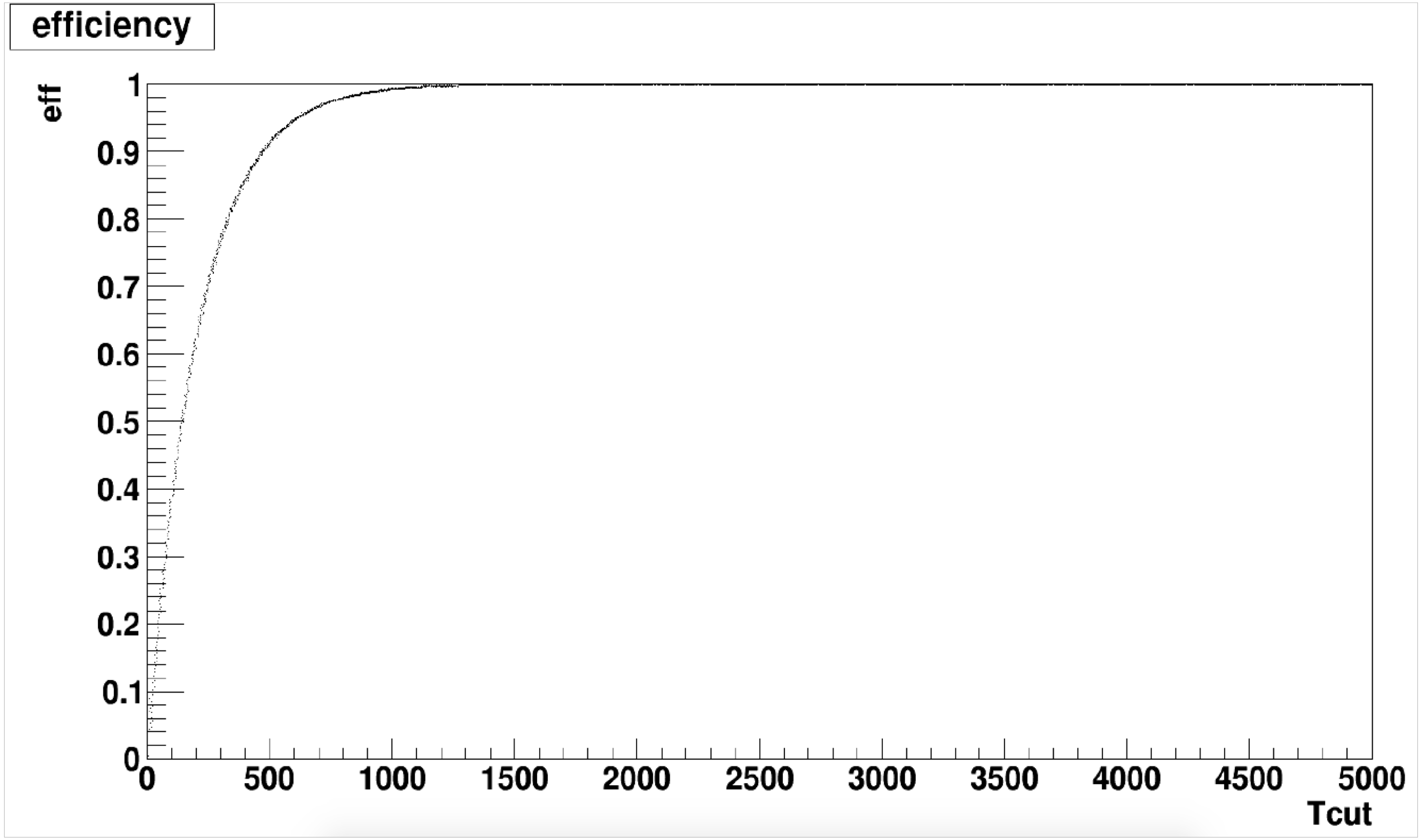



# Questions?

# Support Slides



# Support Slides