# Trigger Studies for ORCA

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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

## Overview

- The ORCA Detector
- Event Selection
- Trigger Algorithms
- Trigger Performance
- Katerina’s Studies
- Outlook

# The ORCA Footprint

50 strings, each holding 20 optical modules (OMs).

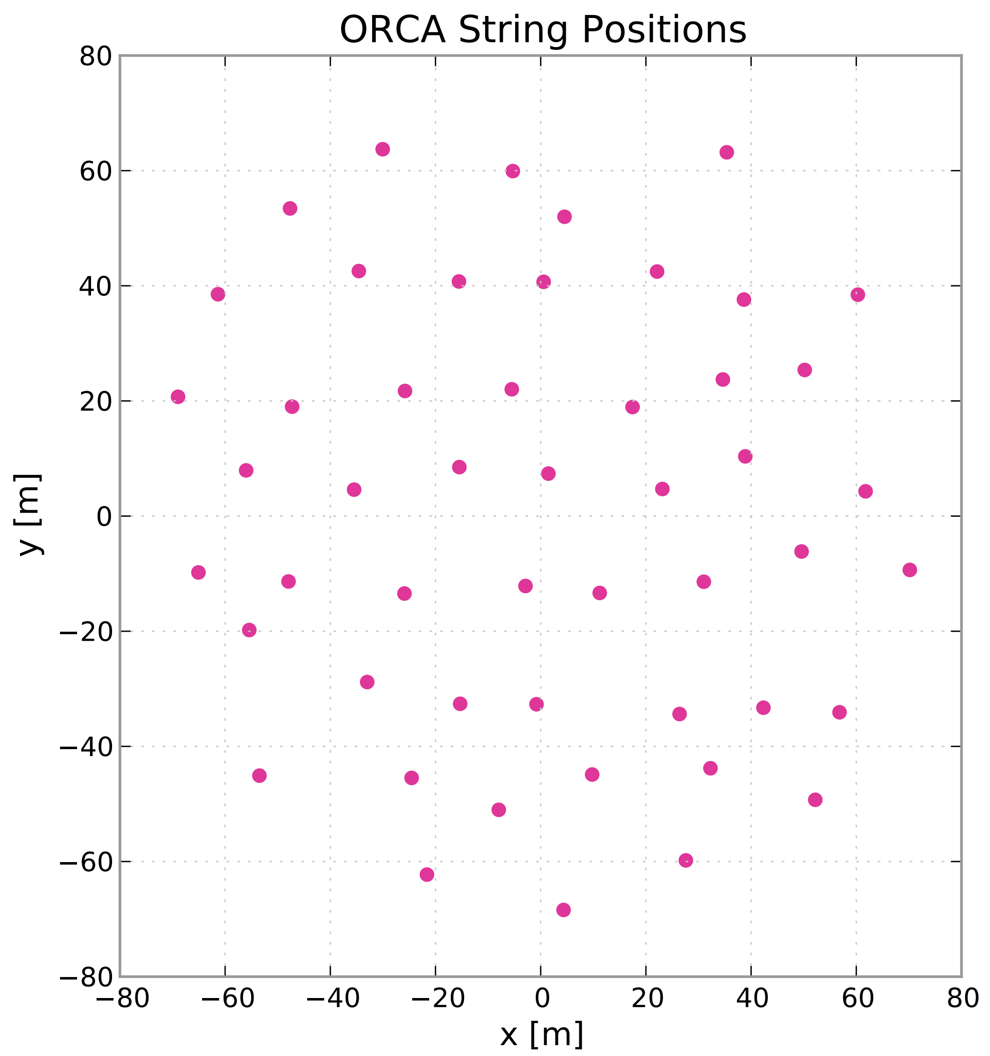
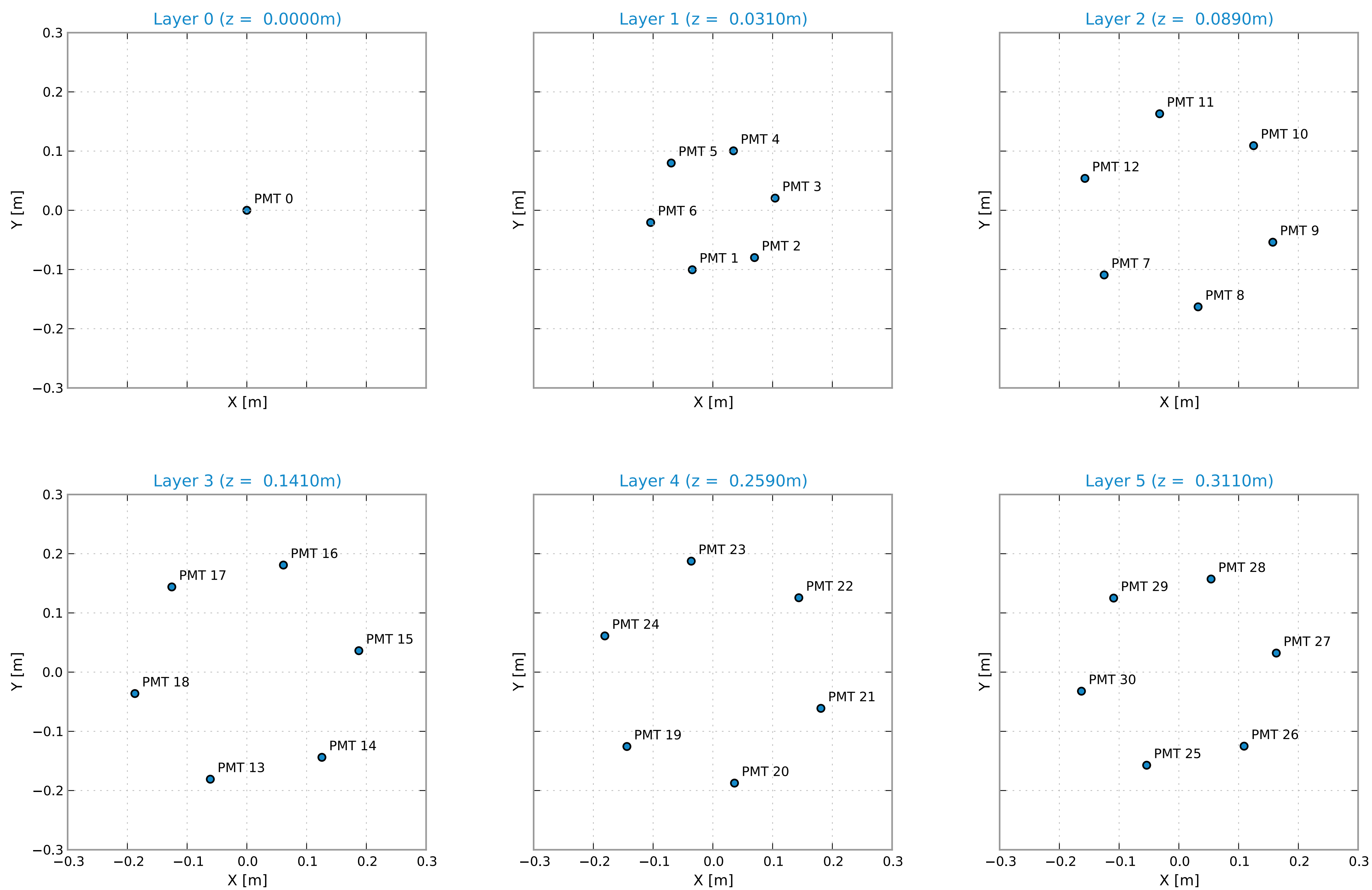
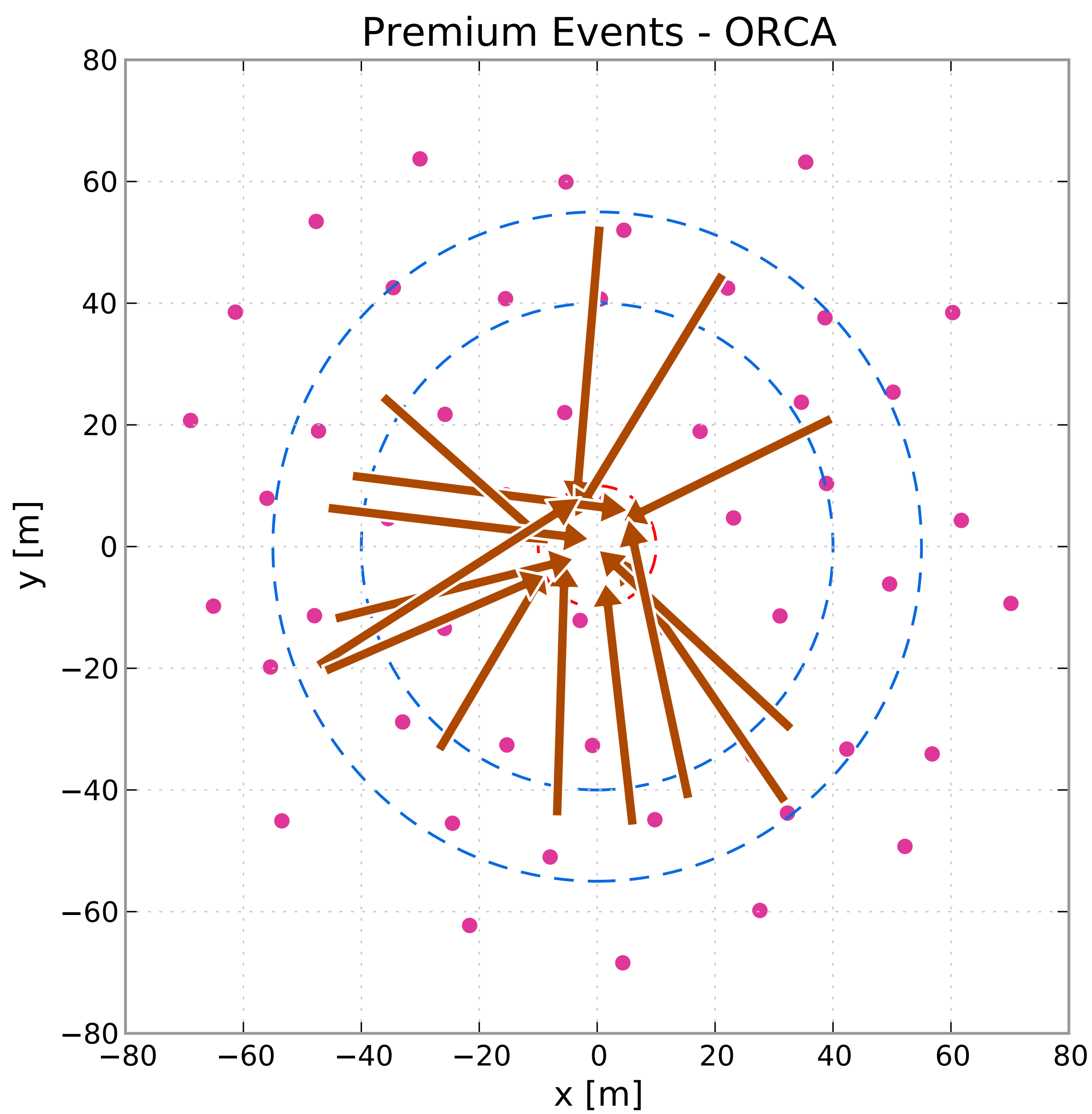



Photo from www.km3net.org

# 31 PMTs in the ORCA OM



# Event Selection




generated by plot_premium_volume.py on 2013-10-12 // Tamas Gal

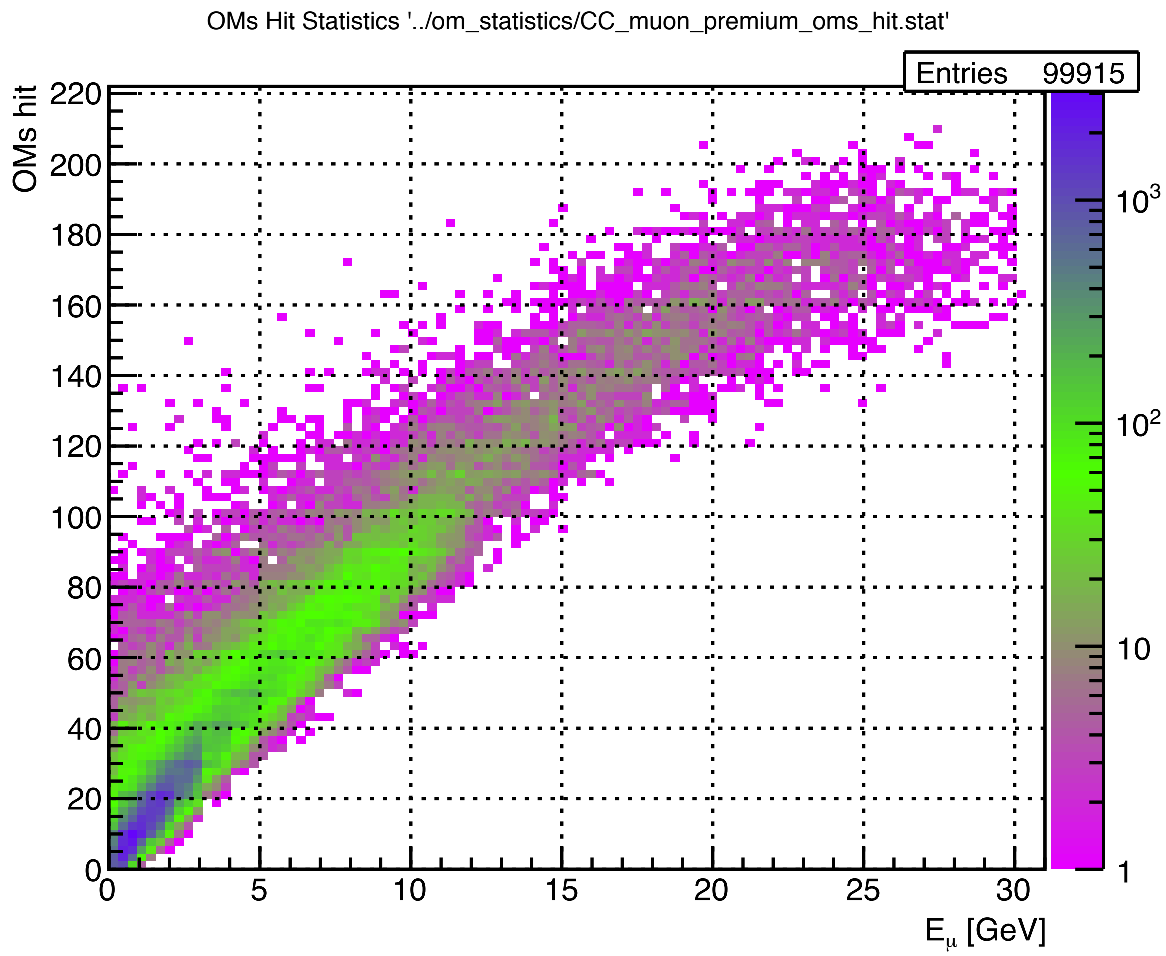
## Premium Events

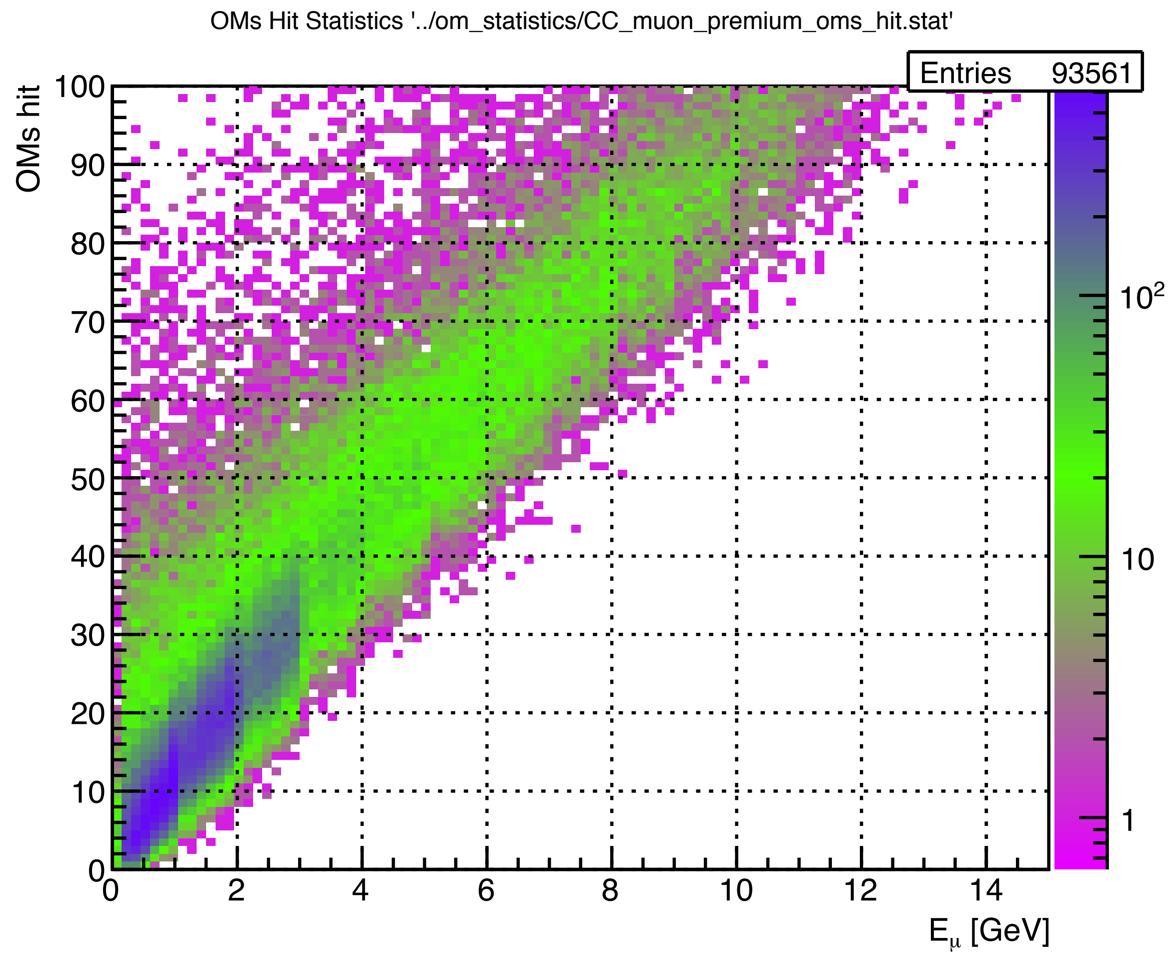
proposed by Jannik Hofestädt

- **interaction vertex** within two concentric spheres around the center of the detector (R1 = 40m, R2 = 55m)
- **neutrino** pointing **towards** the **detector center** (with a random offset of maximum ~10m)
- only “**up-going**” neutrinos

a negligible amount of photons escapes the instrumented volume

# Number of OMs hit in CC Muon Events



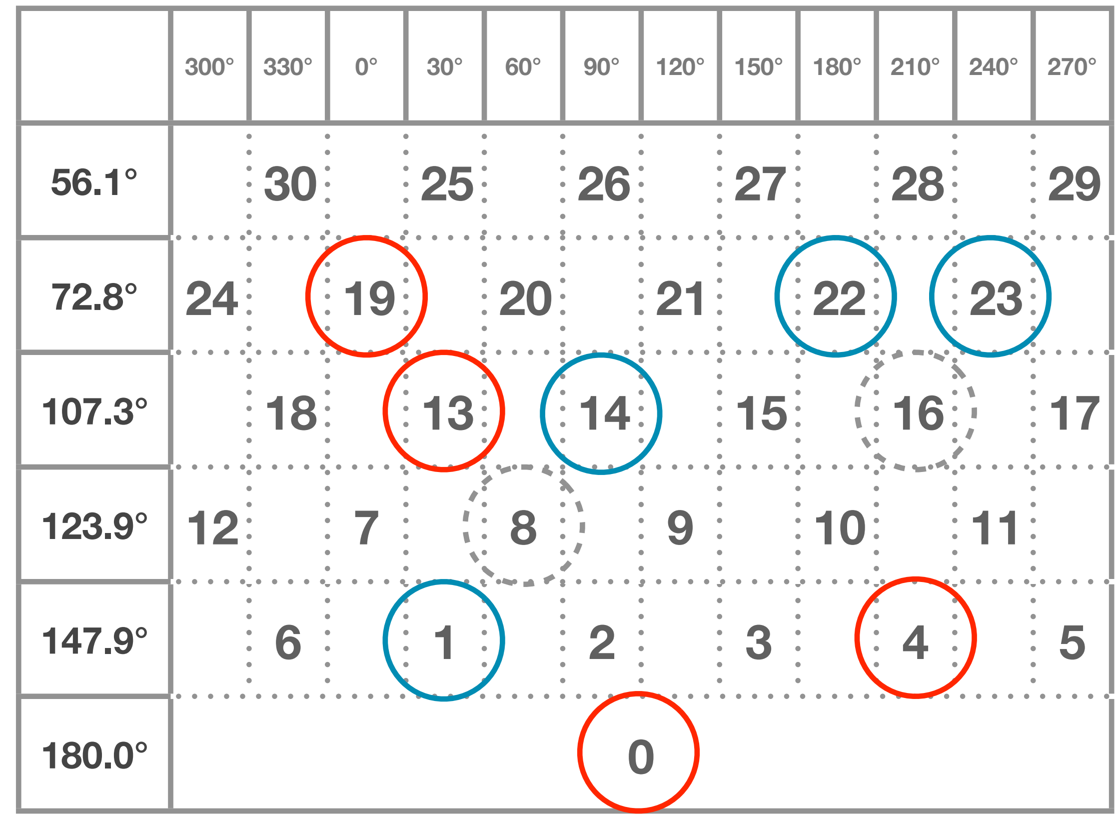




OMs hit

muon energy

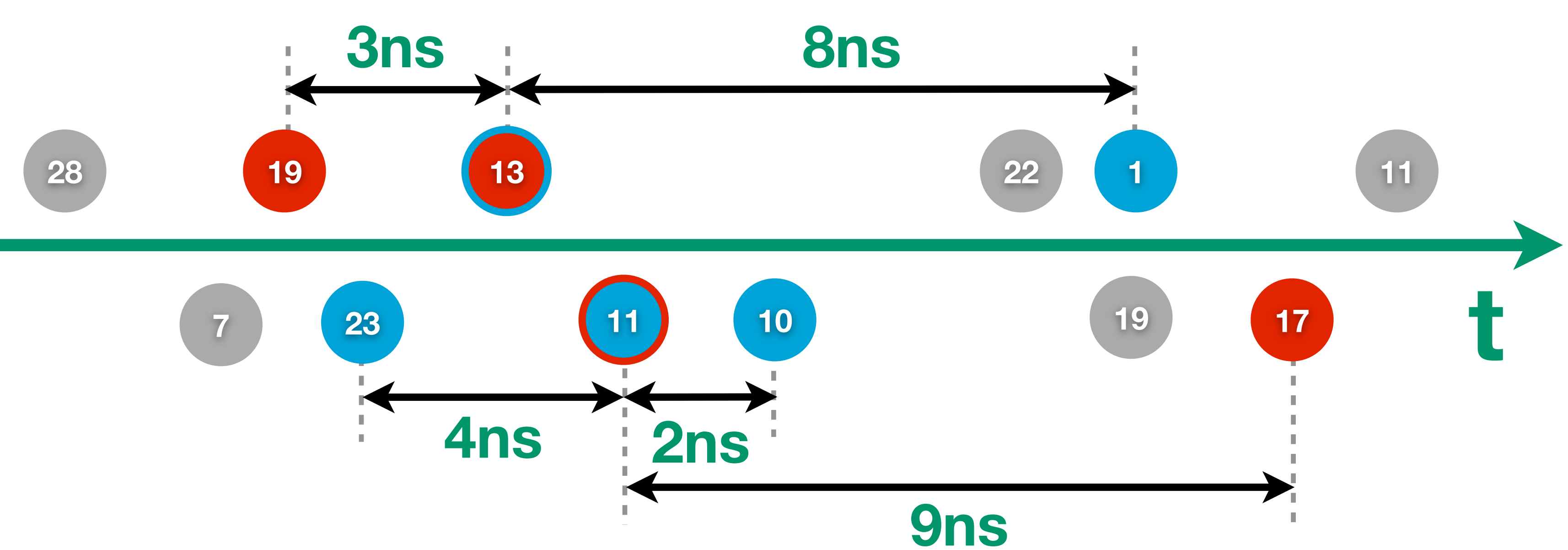
# Trigger Algorithm TnOMm

- at least **n** OMs with hits
- at least **m** pulses on PMTs correlated in
  **time** (Δt < 10ns between pulse pairs) and
  **space** (neighboured or next-to-neighboured)




Example 1: **TnOM3**
**3 coincident PMT pulses**

Example 2: **TnOM4**
**4 coincident PMT pulses**



## Trigger Algorithm TnSm

- at least **n** strings *with*
- at least **m** OMs hit on each of them
- (optional: time and space correlation of the OM hits -> causality condition)

➡ loose trigger condition without time and space correlation

➡ intended to be combined with **TnOMm** to force a minimum number of coincidences per string

**Example: T4OM2+T1S2**

➡ 4 OMs with at least 2 coinc. PMT pulses, where 2 of the OMs are on the same string

# "Noise Inefficiency" *

Trigger setups tested on **45k** pure ***modk40*** noise events.

**5 kHz** overall $^{40}$K noise rate

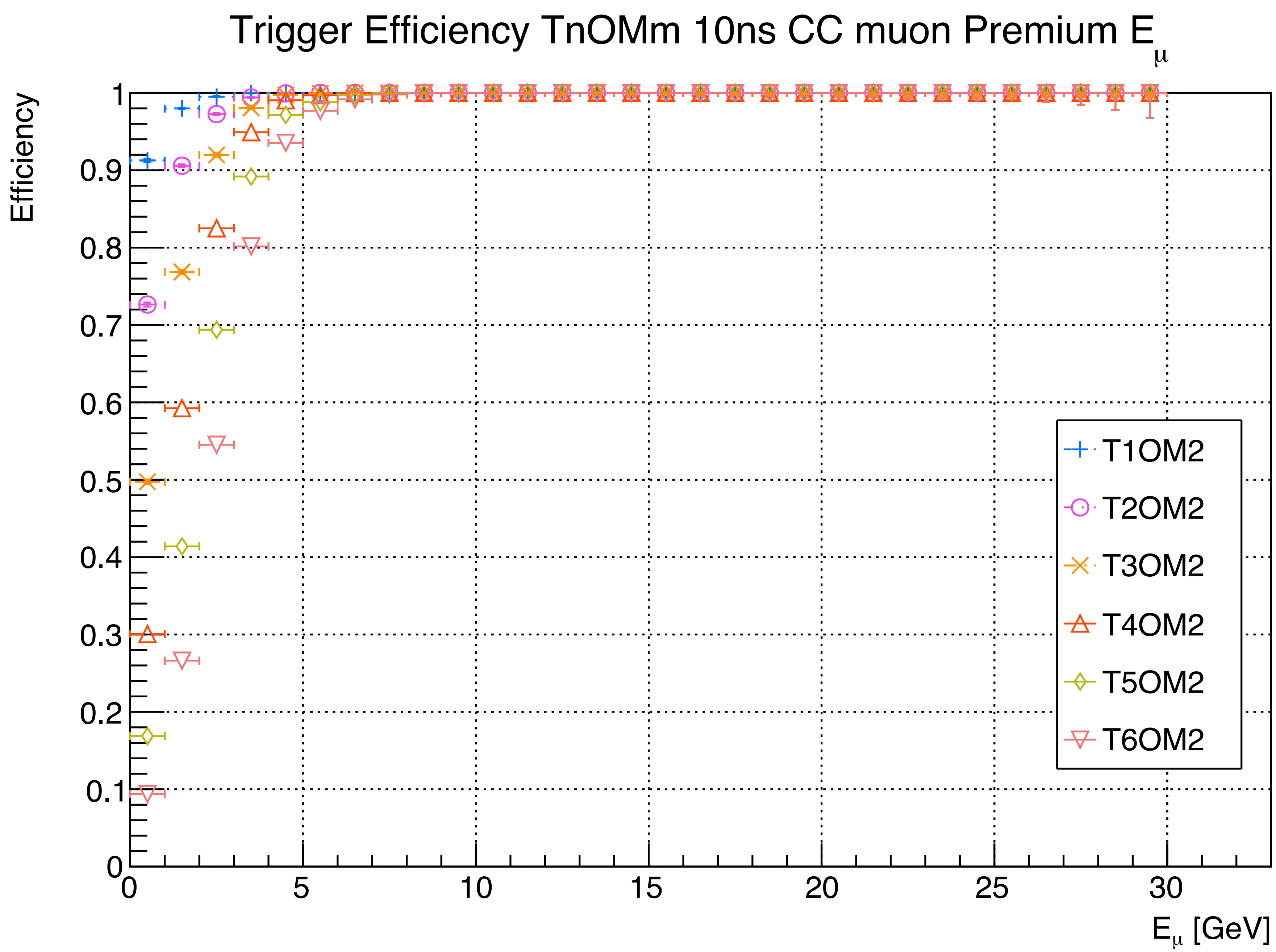
**500 Hz** coincidence rate
(two hits within 20 ns on the same OM)

$$\text{Noise Inefficiency} := 1 - \frac{N_{triggered}}{N_{events}}$$

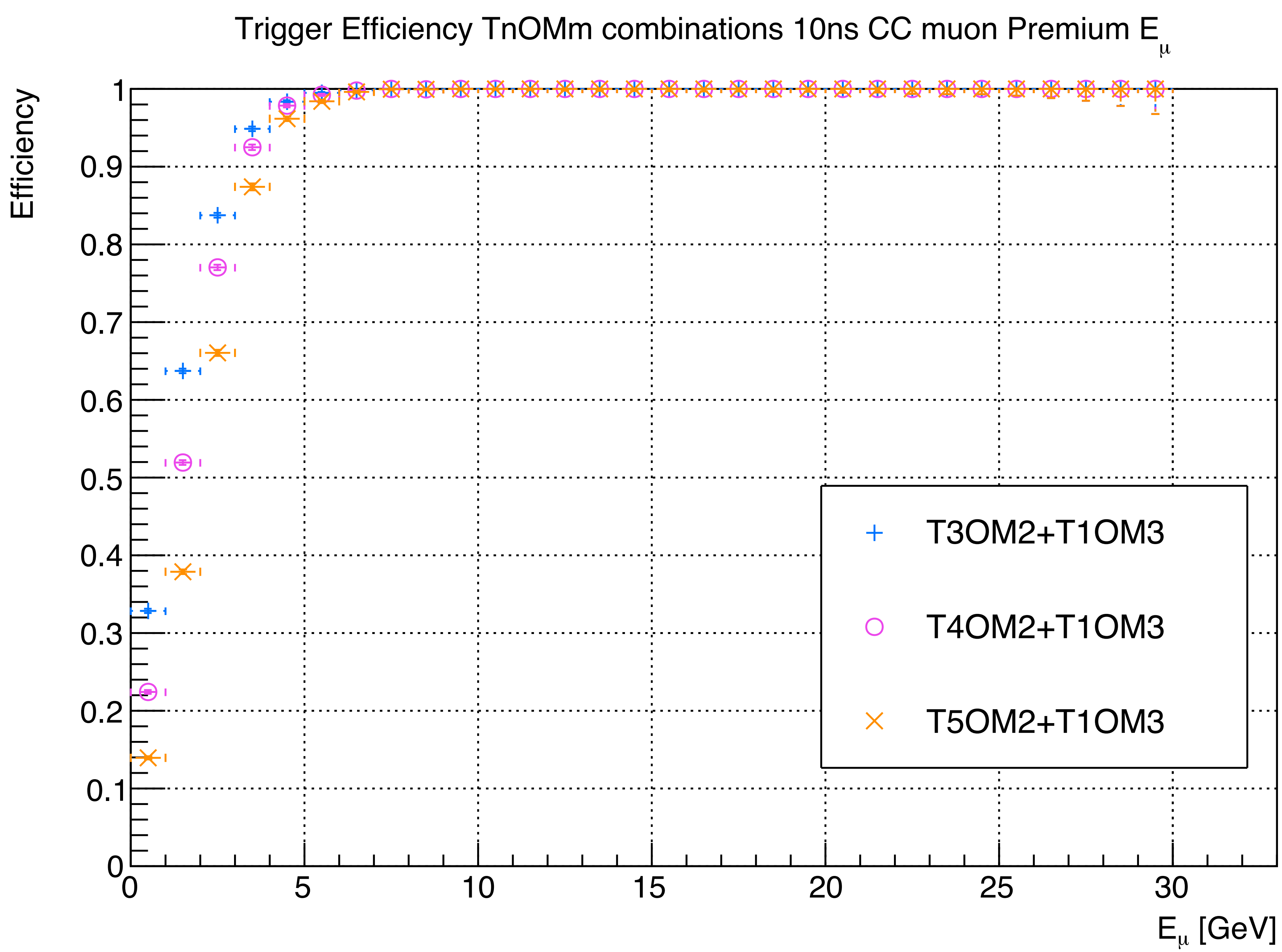
| Trigger Setup | $N_{triggered}$ | Noise Inefficiency | Rate |
|---|---|---|---|
| T1OM2 | 6696 | 85.26% | 68 kHz |
| T2OM2 | 484 | 98.93% | 4.9 kHz |
| T3OM2 | 20 | 99.96% | 202 Hz |
| T4OM2 | 1 | 99.99% | 10 Hz |
| T5OM2 | 0 | 100% | 0 Hz |
| T6OM2 | 0 | 100% | 0 Hz |
| T3OM2 + T1OM3 | 0 | 100% | 0 Hz |
| T4OM2 + T1OM3 | 0 | 100% | 0 Hz |
| T5OM2 + T1OM3 | 0 | 100% | 0 Hz |
| T2OM2 + T1S2 | 12 | 99.97% | 121 Hz |
| T3OM2 + T1S2 | 1 | 99.99% | 10 Hz |
| T4OM2 + T2S2 | 0 | 100% | 0 Hz |

* thanks Tino ; )

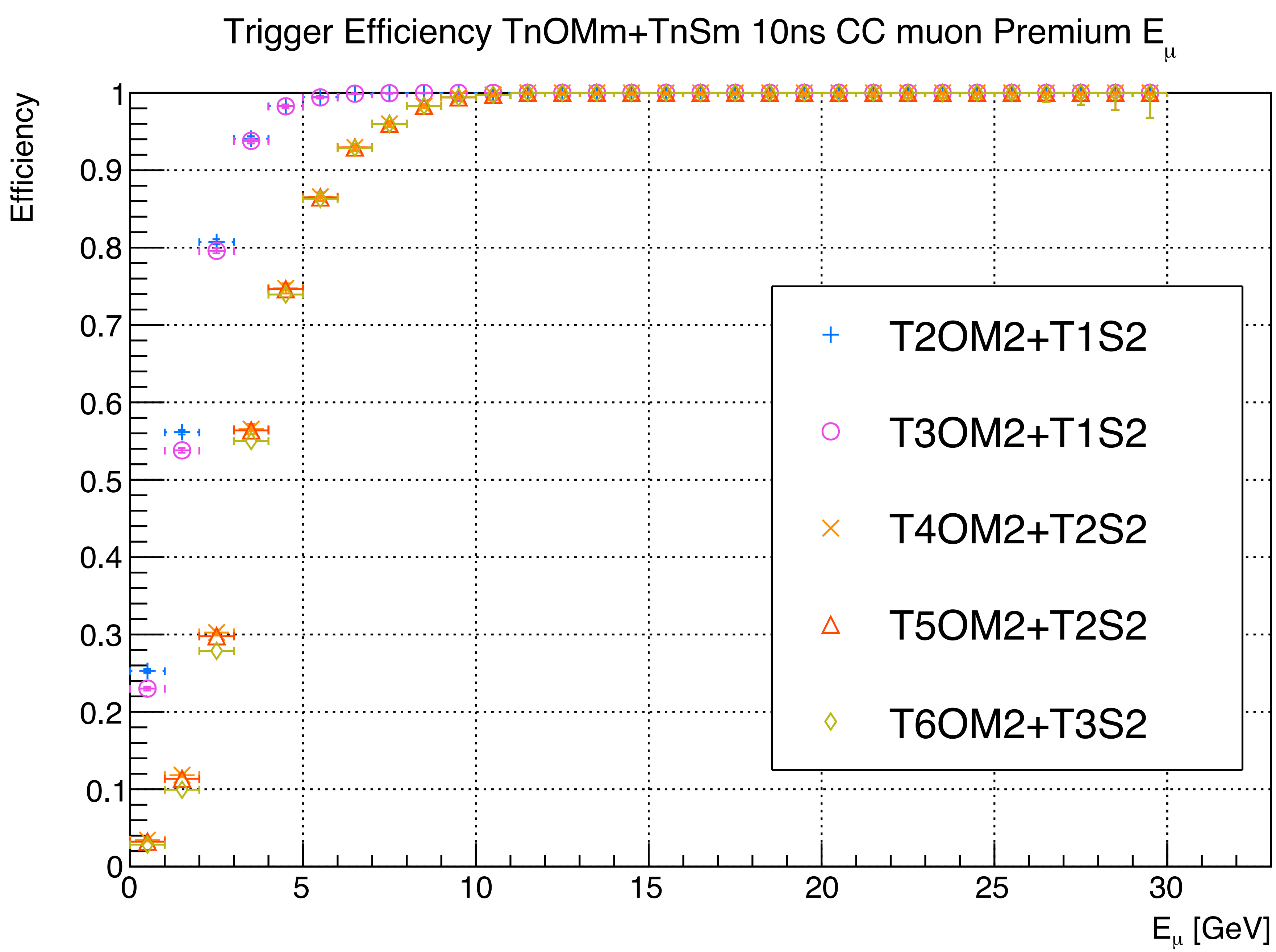
# Trigger Efficiencies – CC Muon – TnOMm



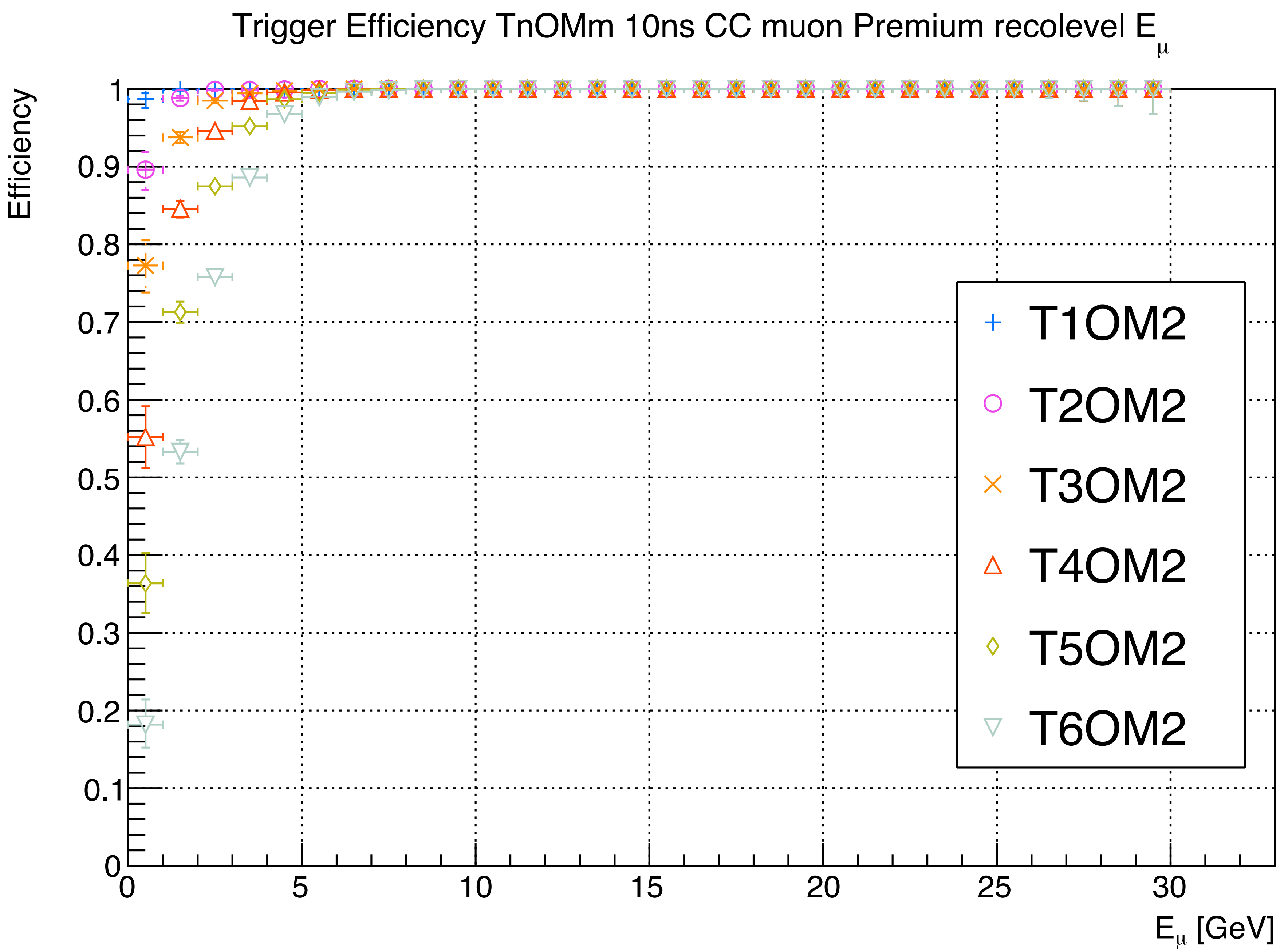
# Trigger Efficiencies – CC Muon – TnOMm Combinations



# Trigger Efficiencies – CC Muon – TnOMm+TnSm



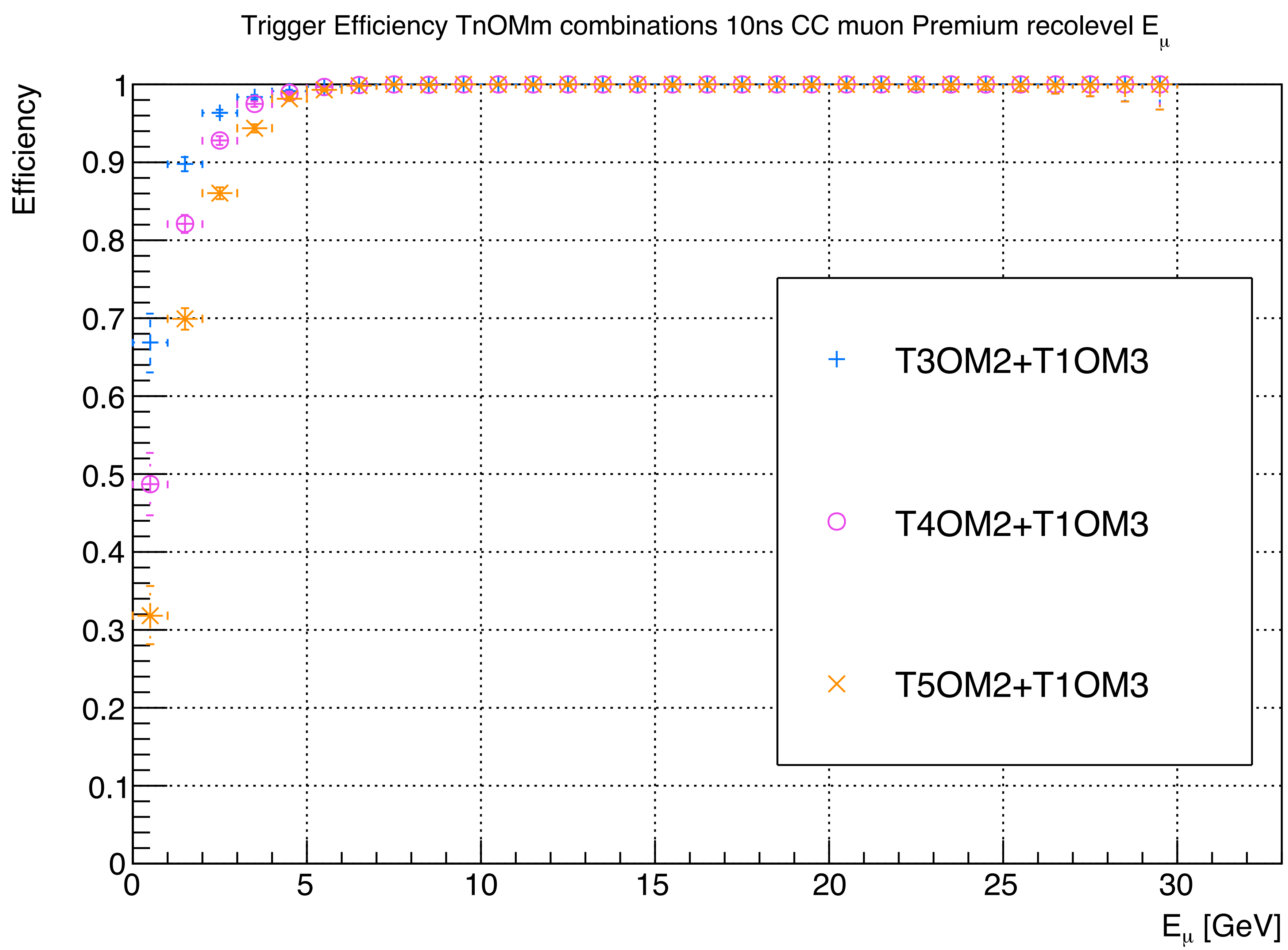
# Trigger Efficiencies - CC Muon – TnOMm (Reco Level)




**Event selection:**
reconstructed events (via FilteringFit) with

$$\Delta\theta_{MC,reco} < 5^\circ$$

# Trigger Efficiencies - CC Muon – TnOMm Combs. (Reco)




**Event selection:**
reconstructed events (via FilteringFit) with

$$\Delta\theta_{MC,reco} < 5^\circ$$

# Trigger Rates

Trigger rate estimations on **1.96M MUPAGE** generated **atmospheric muon events** with **25.7h lifetime.**

**5 kHz** overall $^{40}$K noise rate

**500 Hz** coincidence rate
(two hits within 20 ns on the same OM)

| Trigger Setup | N | Percentage | Rate [Hz] |
|---|---|---|---|
| T1OM2 | 1603027 | 81.49% | 17.32 |
| T2OM2 | 1084252 | 55.12% | 11.72 |
| T3OM2 | 701970 | 35.69% | 7.59 |
| T4OM2 | 501211 | 25.48% | 5.42 |
| T5OM2 | 411174 | 20.90% | 4.44 |
| T6OM2 | 369900 | 18.80% | 4.00 |
| T3OM2 + T1OM3 | 372793 | 18.95% | 4.03 |
| T4OM2 + T1OM3 | 365903 | 18.60% | 3.95 |
| T5OM2 + T1OM3 | 357018 | 18.15% | 3.86 |
| T2OM2 + T1S2 | 427465 | 21.73% | 4.62 |
| T3OM2 + T1S2 | 417885 | 21.24% | 4.52 |
| T4OM2 + T2S2 | 321515 | 16.35% | 3.47 |
| T5OM2 + T2S2 | 320947 | 16.32% | 3.47 |
| T6OM2 + T3S2 | 265769 | 13.51% | 2.87 |

# Katerina Tzamarioudaki's Studies

## INP Demokritos, Athens

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# Definition of the Trigger Requirements

- take advantage of the MultiPMT OM

➢ require at least 5 OMs with 2 hits correlated in space and time ( neighbouring or next-to-neighbouring pmts within 20ns )

L1pm3

➢ require at least N OMs with 3 hits correlated in space and time ( neighbouring or next-to-neighbouring pmts within 20ns )

N = 3 ORCA

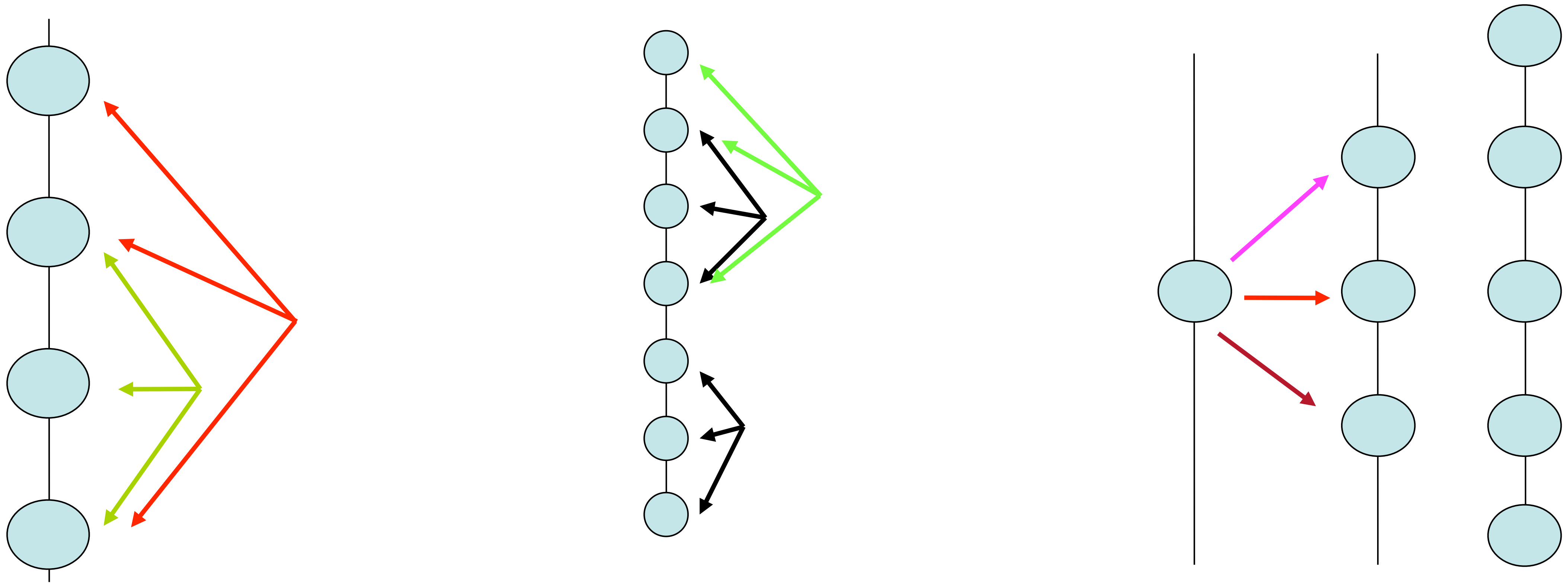
Comparable to **T5OM2+T3OM3** with **Δt < 20ns** instead of 10ns.

# Definition of the Trigger Requirements

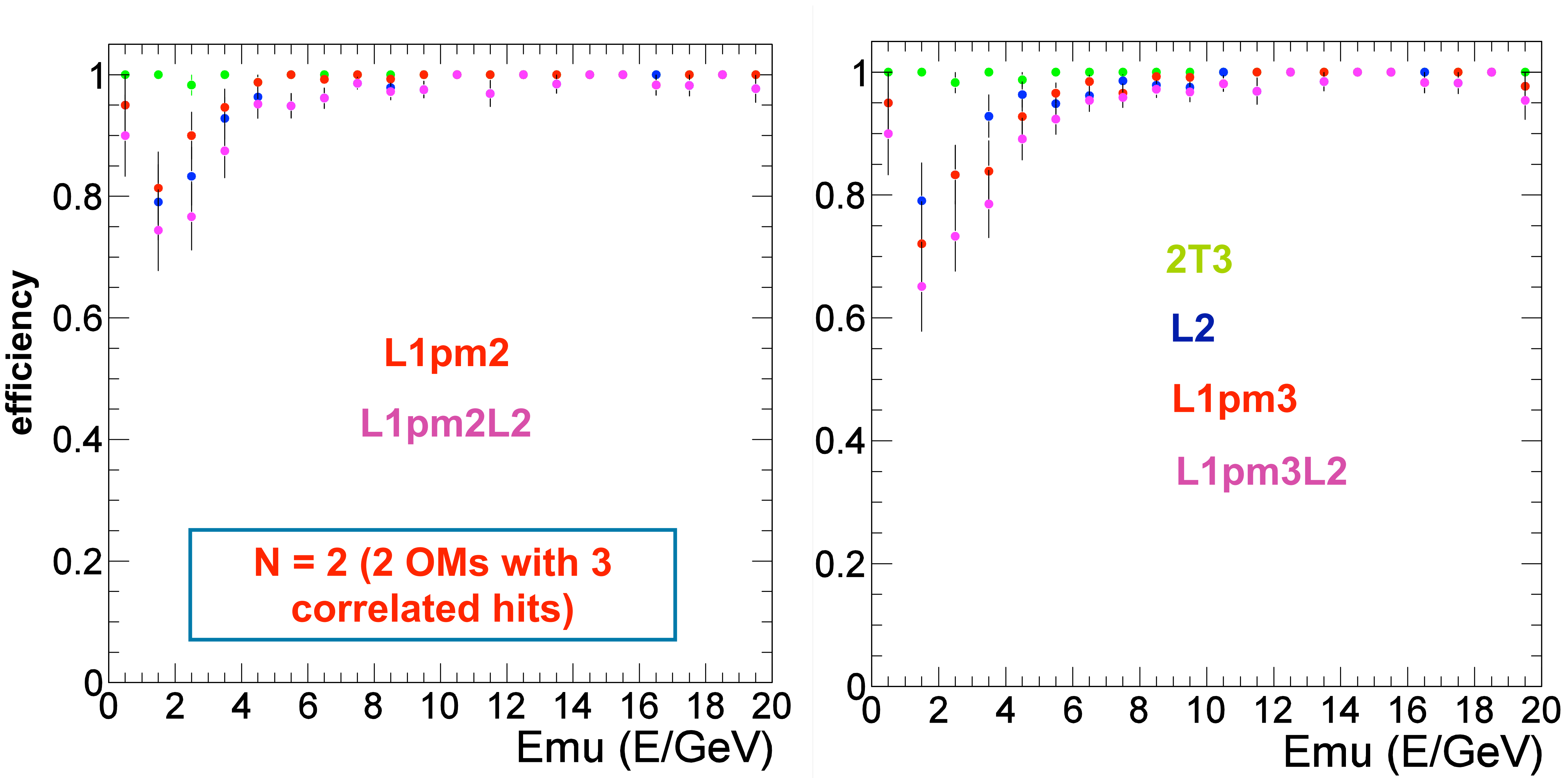
- require clusters of hits

L2

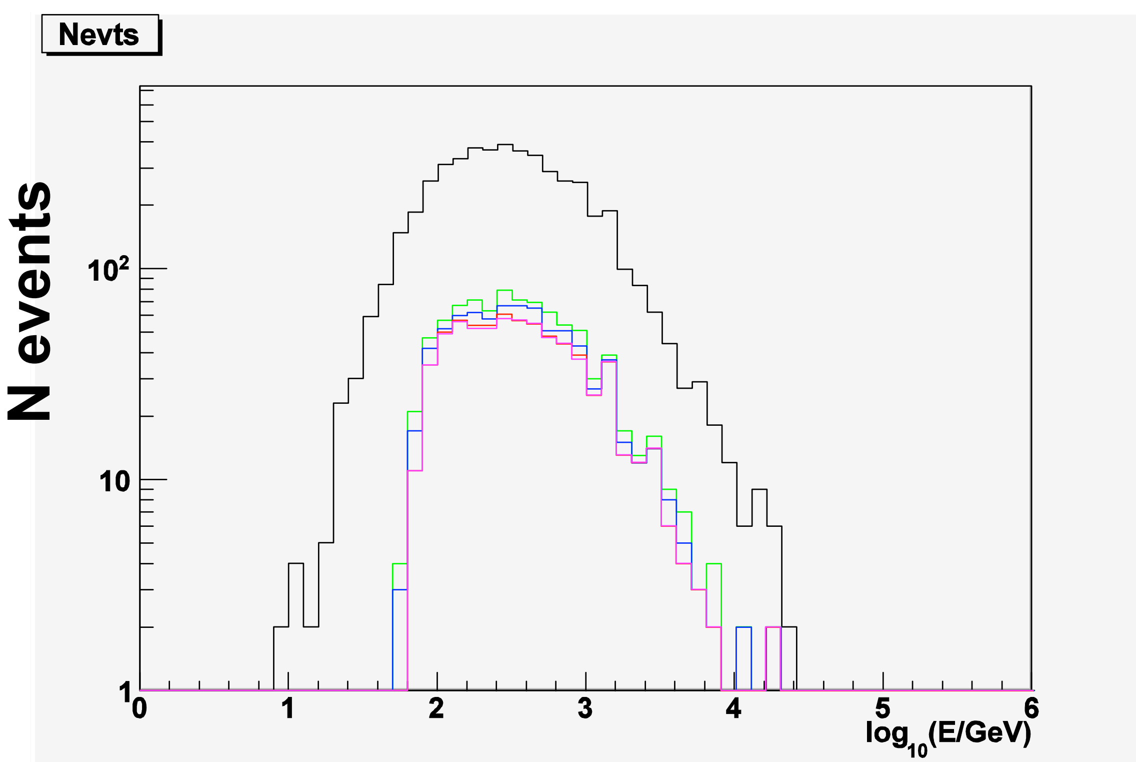
apply new filtering algorithms
- at least 3 clusters of 3 OMs or 4 clusters of 2 OMs
- at least 2 clusters of 3 OMs on the same string (vertical tracks)
- cluster of neighbouring strings with neighbouring OMs hit (horizontal tracks)



# Trigger Efficiency on Reconstruction Level

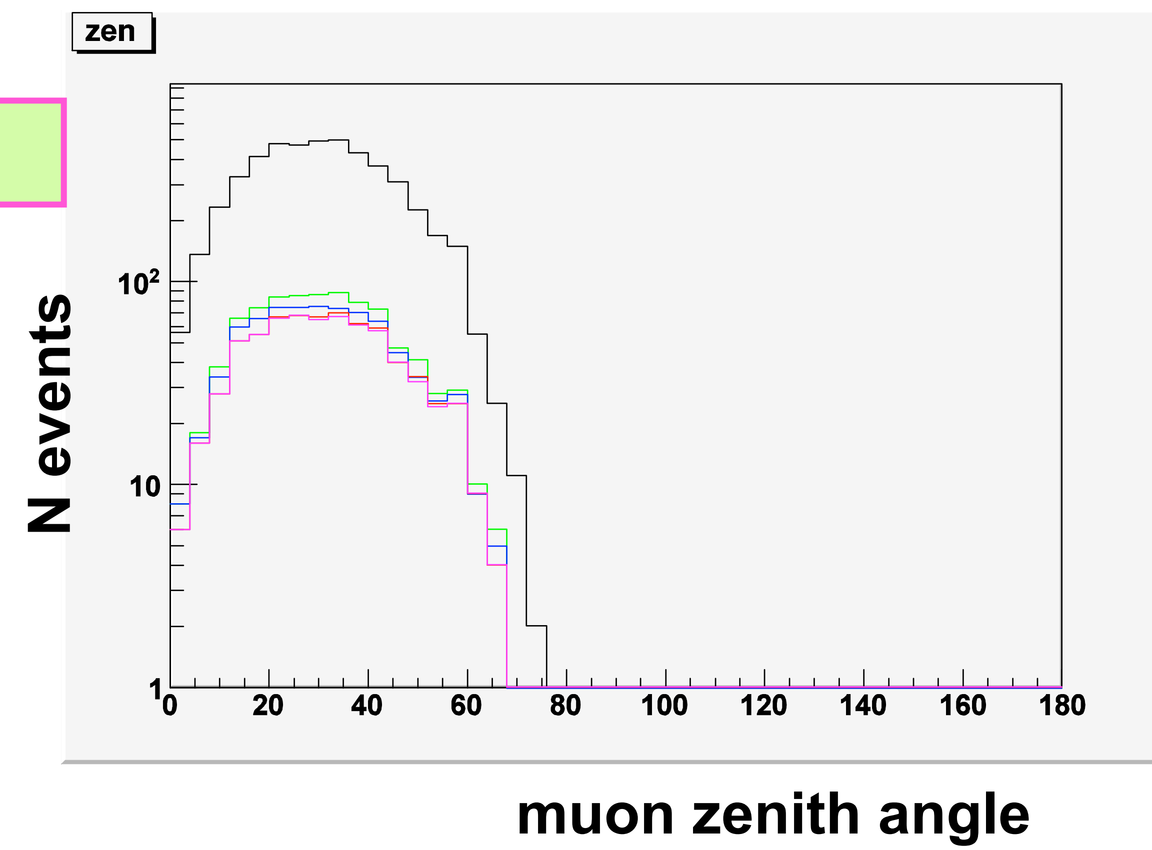


## Atmospheric Muon Events




**trigger level**

- L1
- 2T3
- L2
- L1pm3
- L1pm3L2




**use veto layers to check if the atmospheric muon background can be further reduced**

## Conclusions

- flexible and simple low level trigger system
- significantly reduces simulated noise,
- while still being efficient on keeping interesting events
- both Katerina's and my work on ORCA triggers are consistent so far

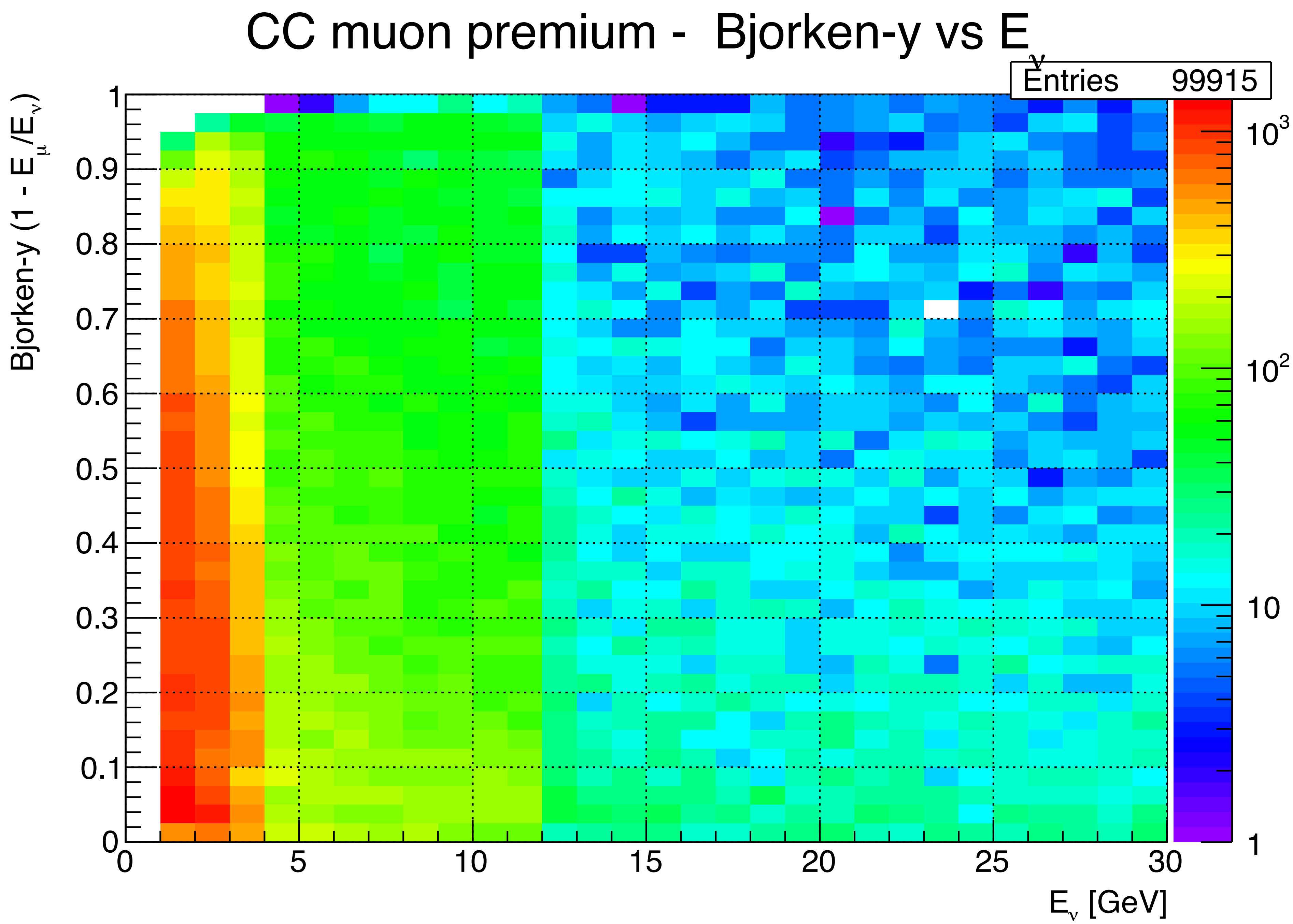
## Next Steps

- evaluate trigger performance & rates on real data (bioluminescence noise?)
- develop higher level trigger algorithms with respect to the
  - directionality of the PMTs and
  - distances between OMs and strings (TnCmOM)
- consider veto…

Thank you for your attention!

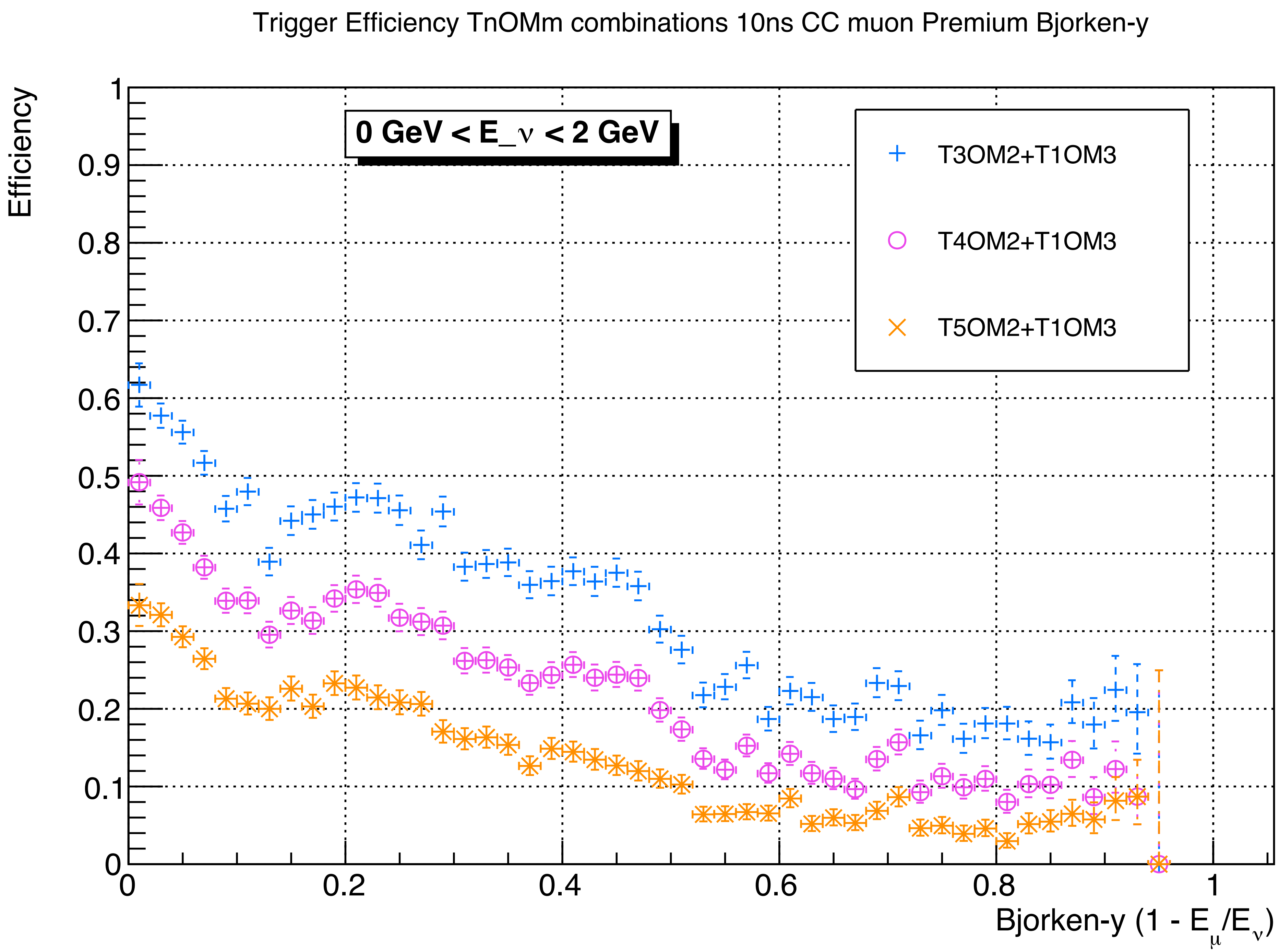
# Backup

# Bjorken-y



CC muon premium - Bjorken-y vs $E_\nu$
Entries 99915
Bjorken-y $(1 - E_\mu/E_\nu)$
$E_\nu$ [GeV]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
1
10
$10^2$
$10^3$

# Trigger Efficiency – CC Muon Bjorken-y



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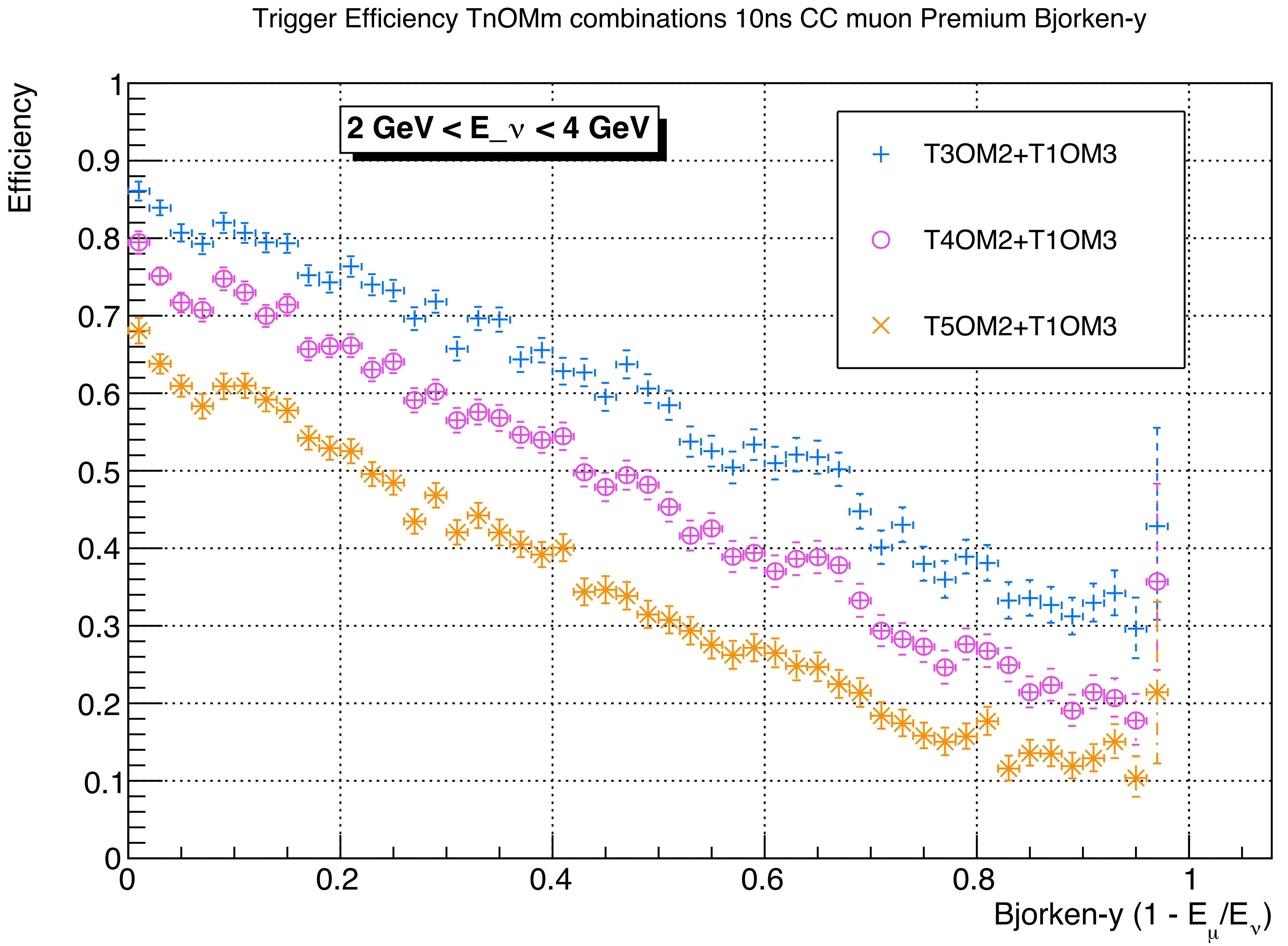

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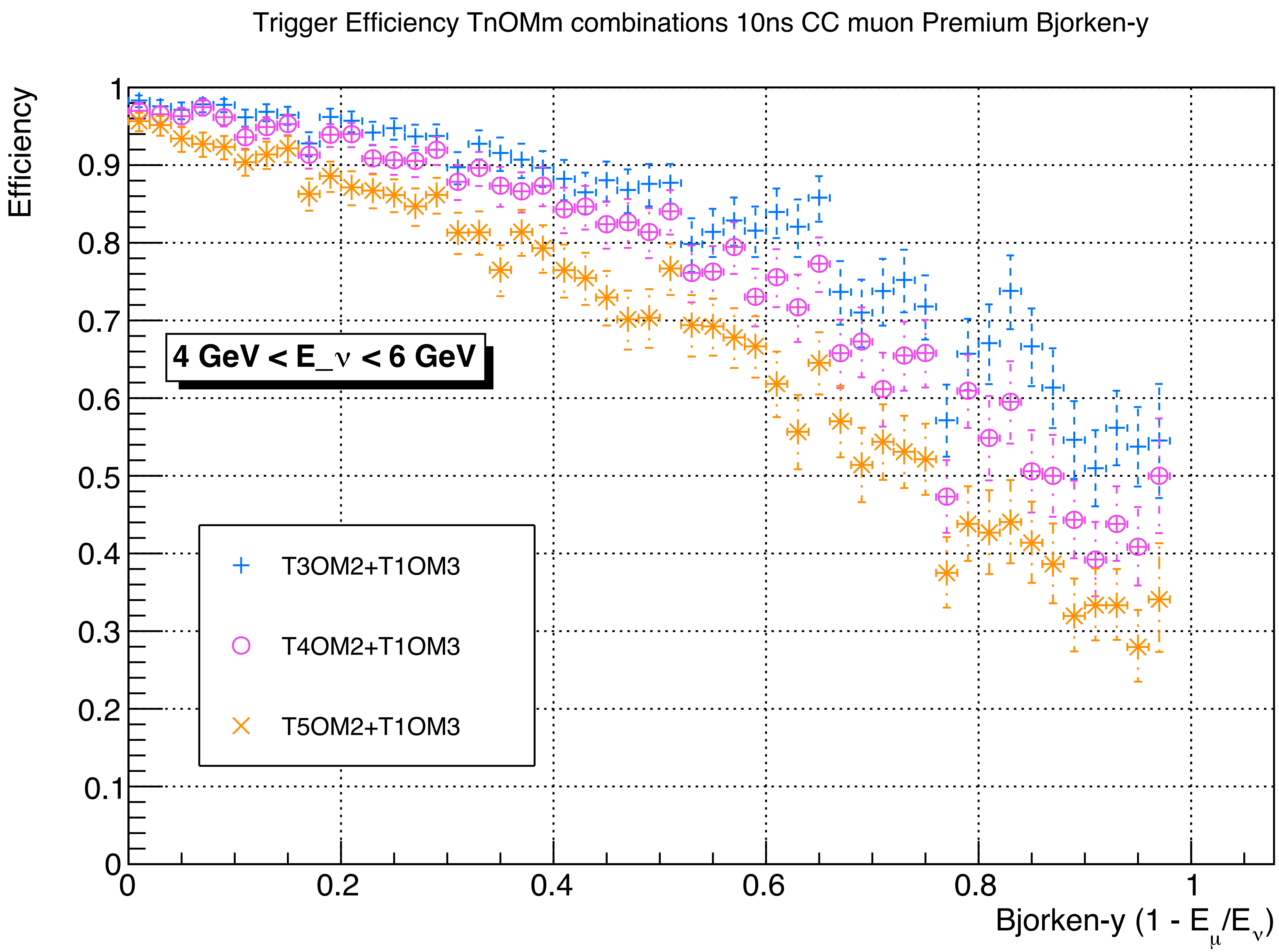

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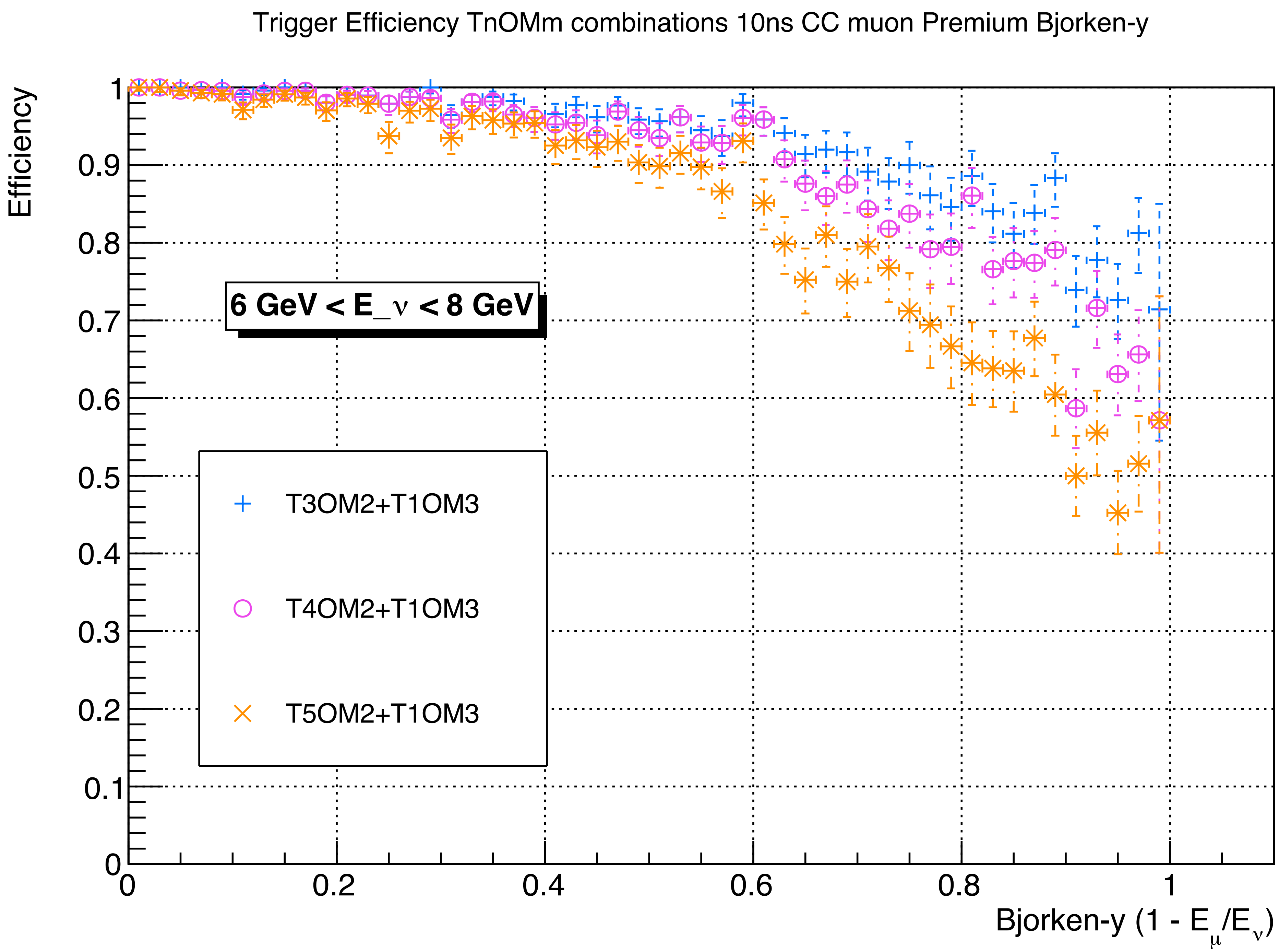

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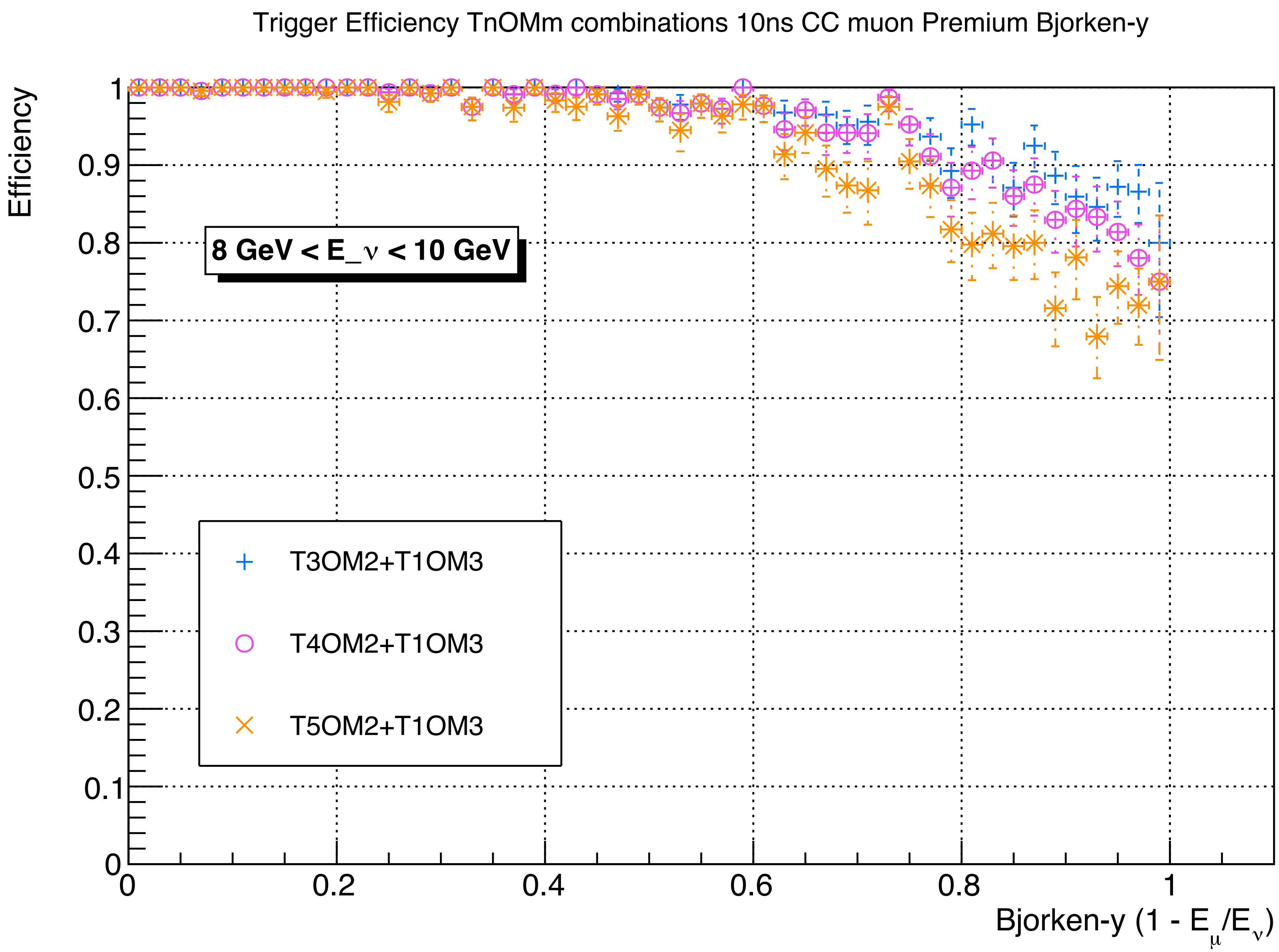

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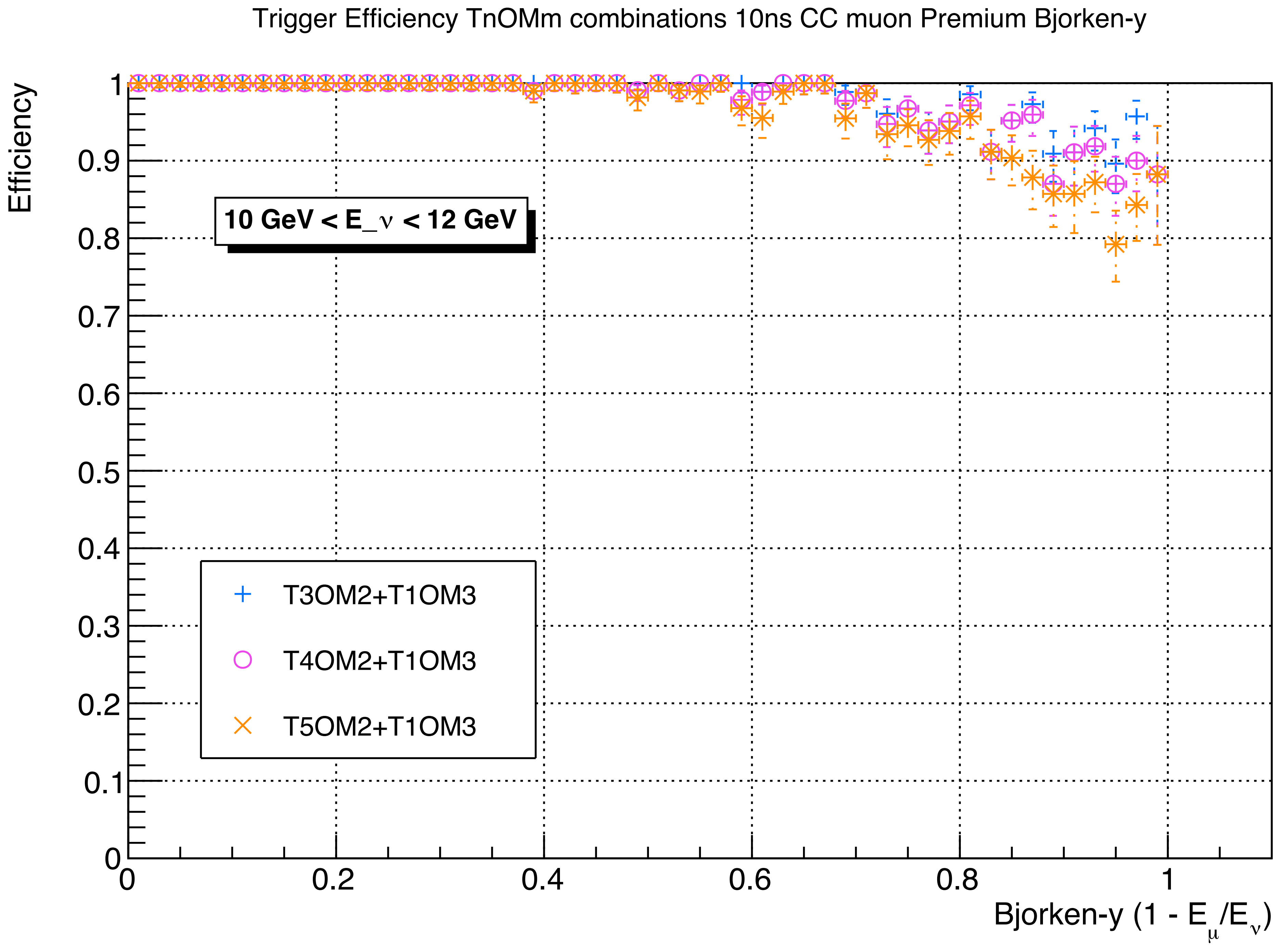
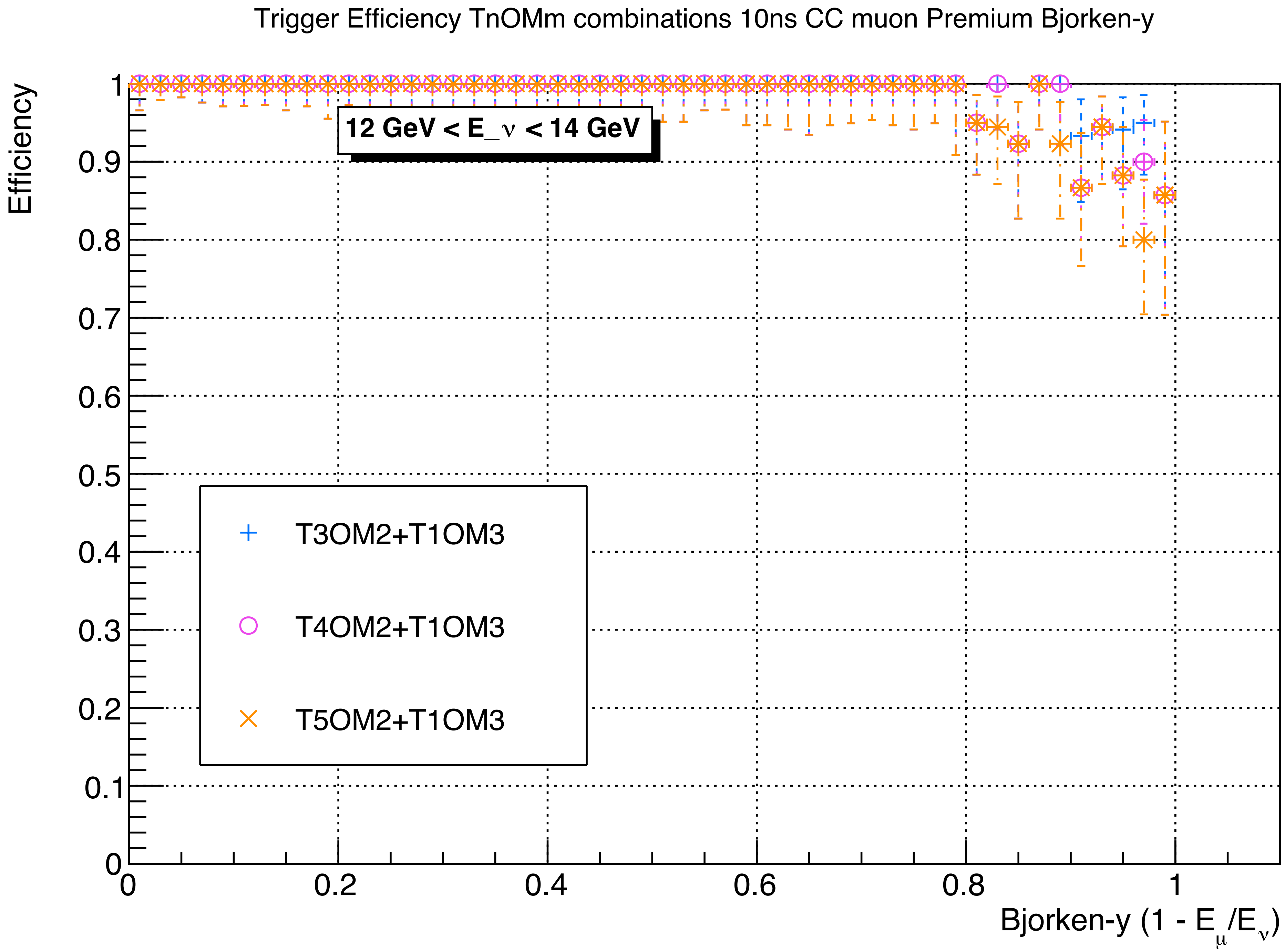
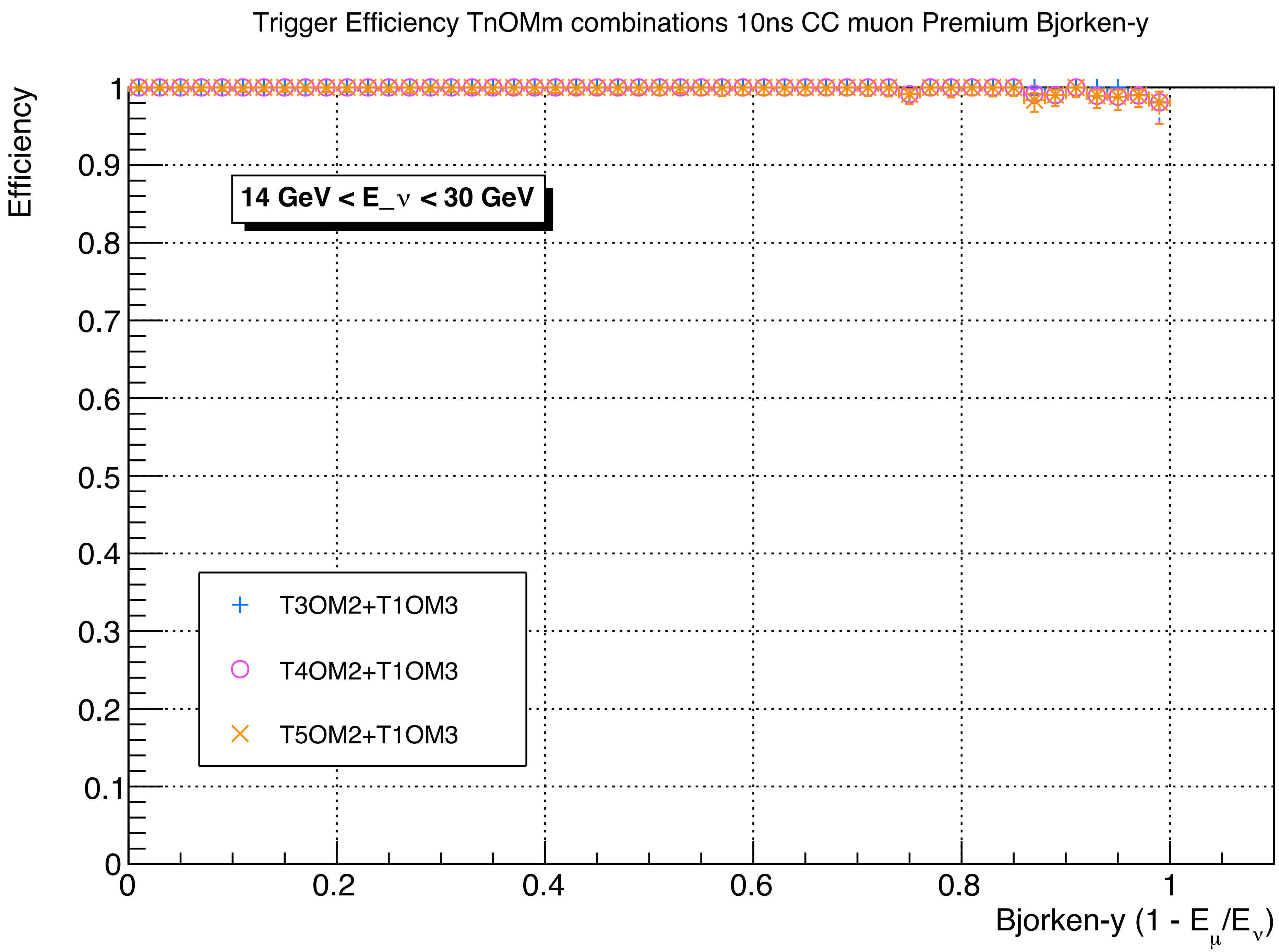


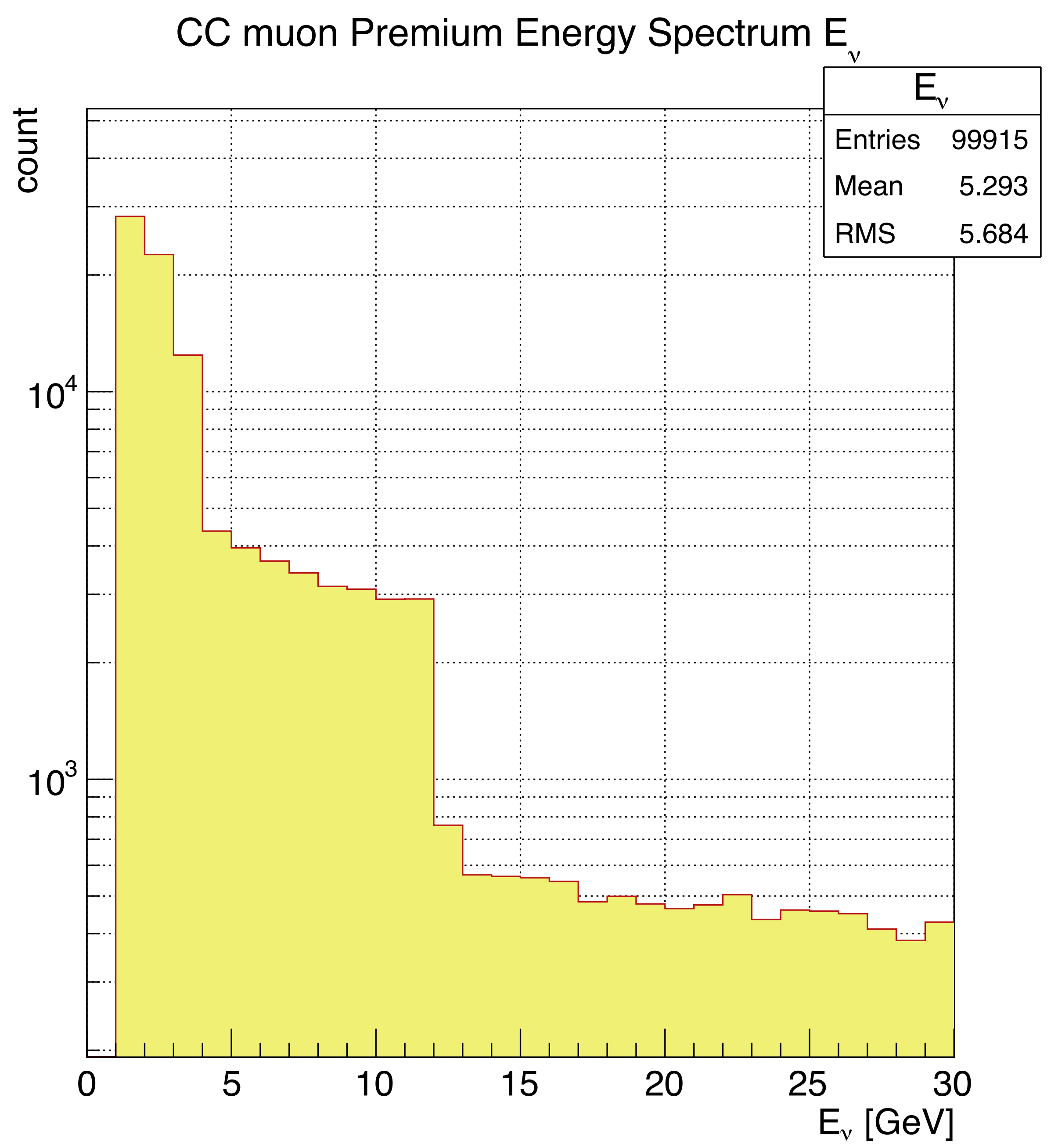
# Trigger Efficiency – CC Muon Bjorken-y



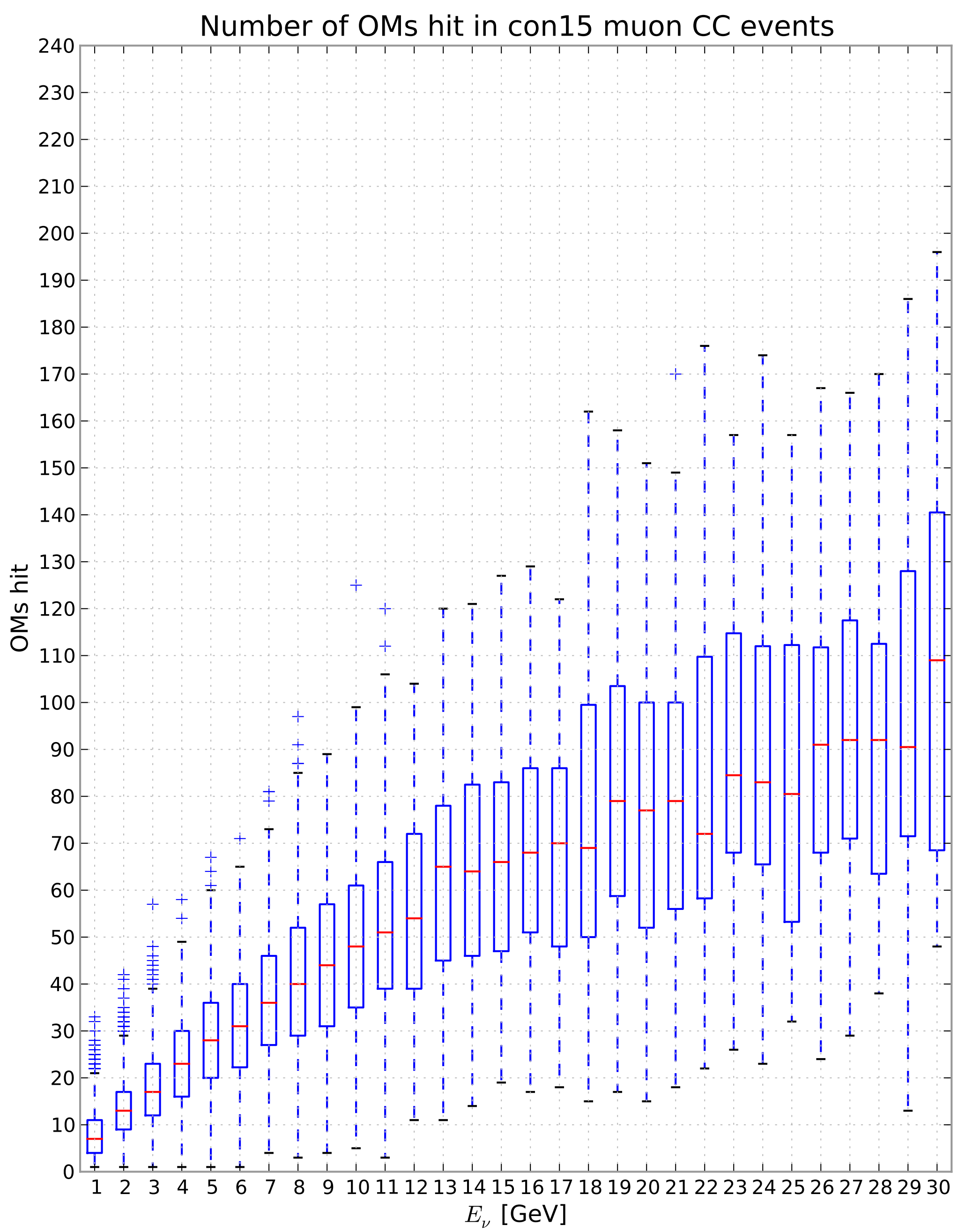
## Trigger Efficiency – CC Muon Bjorken-y

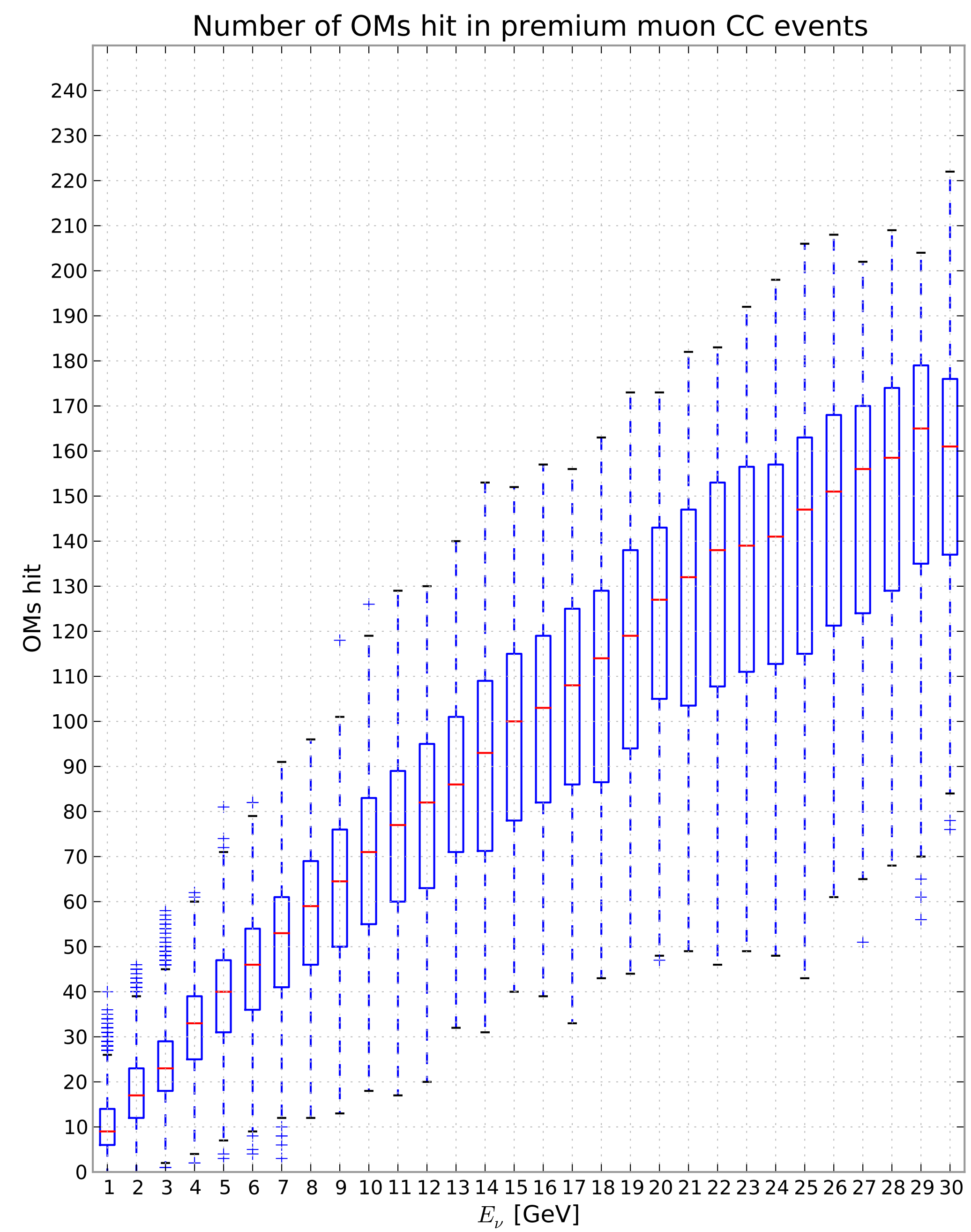


# Premium Events – Neutrino Energy Spectrum

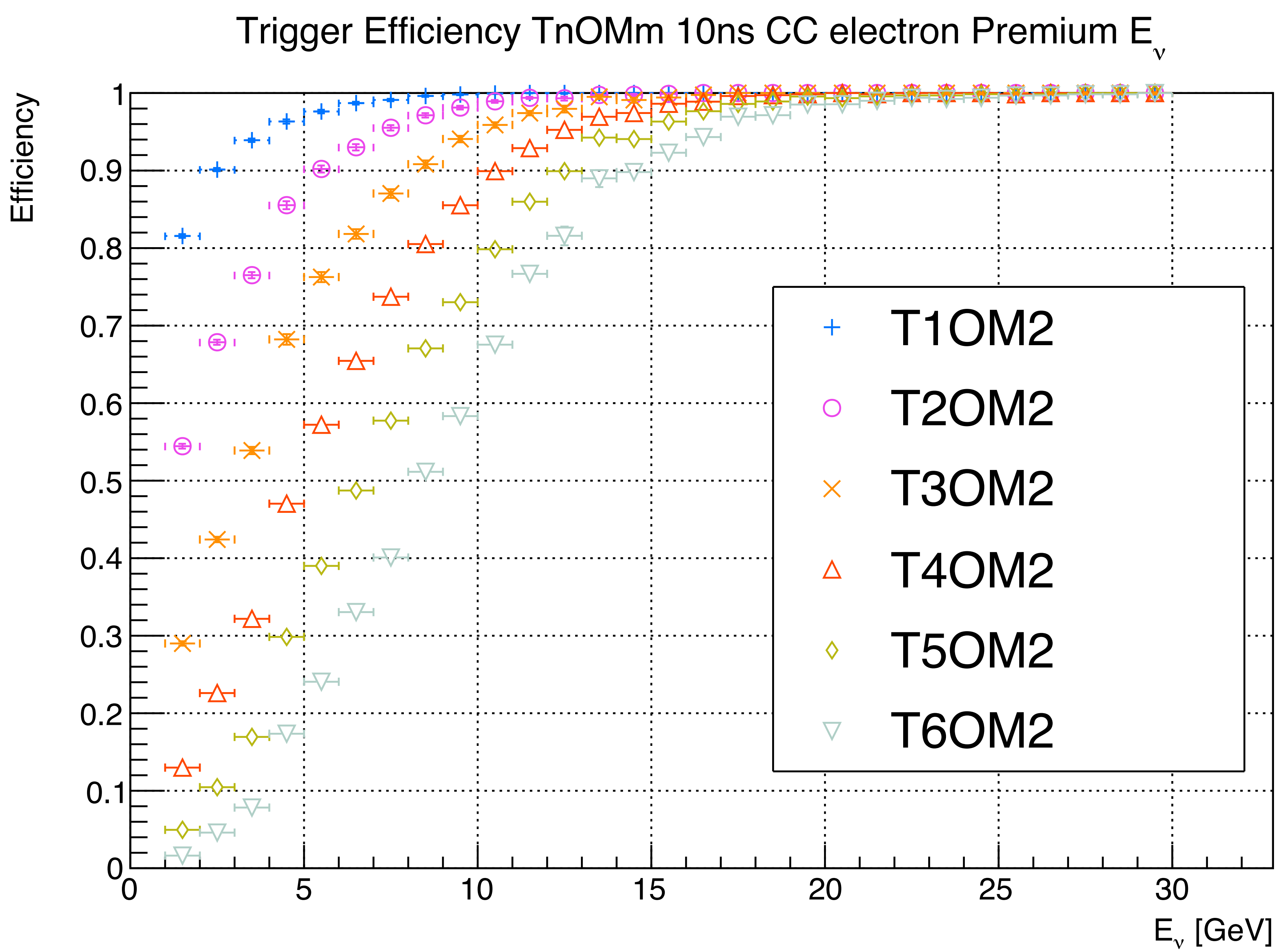


# Number of OMs hit in Muon CC Events



# Trigger Efficiencies – CC Electron – TnOMm



# Overall Trigger Performance (4.5 GeV < $E_\mu$ < 5.5 GeV)