# Input for likelihood framework for HE MM analysis with ARCA

I should rename it cause it's much more than just effective area's…

https://git.km3net.de/rmuller/effective_area/

***Last update: corrected -1 mistake on skydirection axis & reduced #bins from 100 to 80 for more statistics per bin**

# What is in Git?

# Script + root output @ git

https://git.km3net.de/rmuller/effective_area/

AtmCosm_nus_Suzan_v8_FINAL.py

I should rename this too… sorry

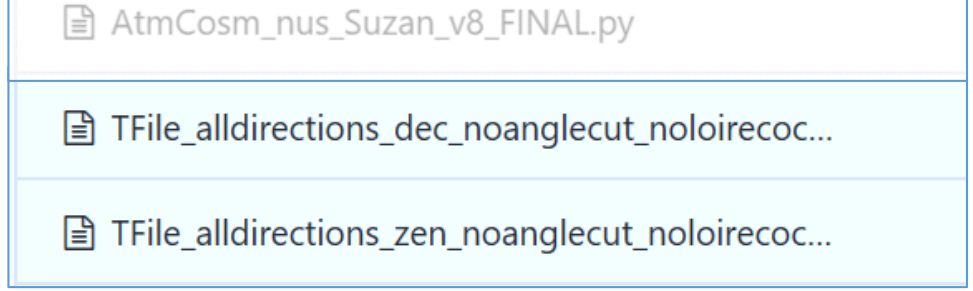
- Script

See APPENDIX of these slides for **How to run the script**

# Script + root output @ git

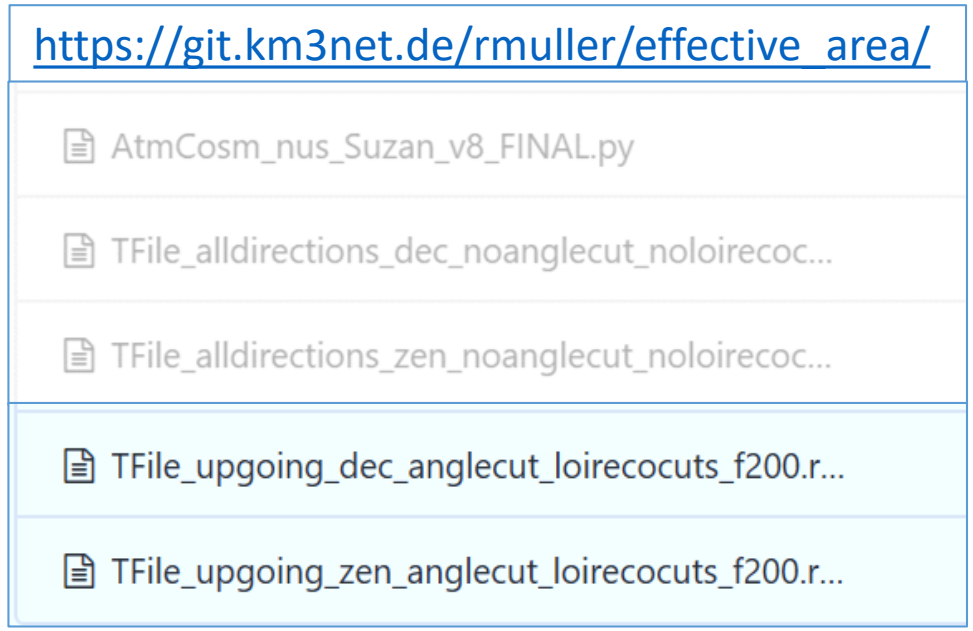
- Script
- 2 Output files at trigger level
  - As a function of E, and declination
  - As a function of E, and zenith

https://git.km3net.de/rmuller/effective_area/



# Script + root output @ git

https://git.km3net.de/rmuller/effective_area/




- Script
- 2 Output files at trigger level (no cuts)
  - As a function of E, and declination
  - As a function of E, and zenith
- 2 Output files with 'all' cuts applied:
  - As a function of E, and declination
  - As a function of E, and zenith

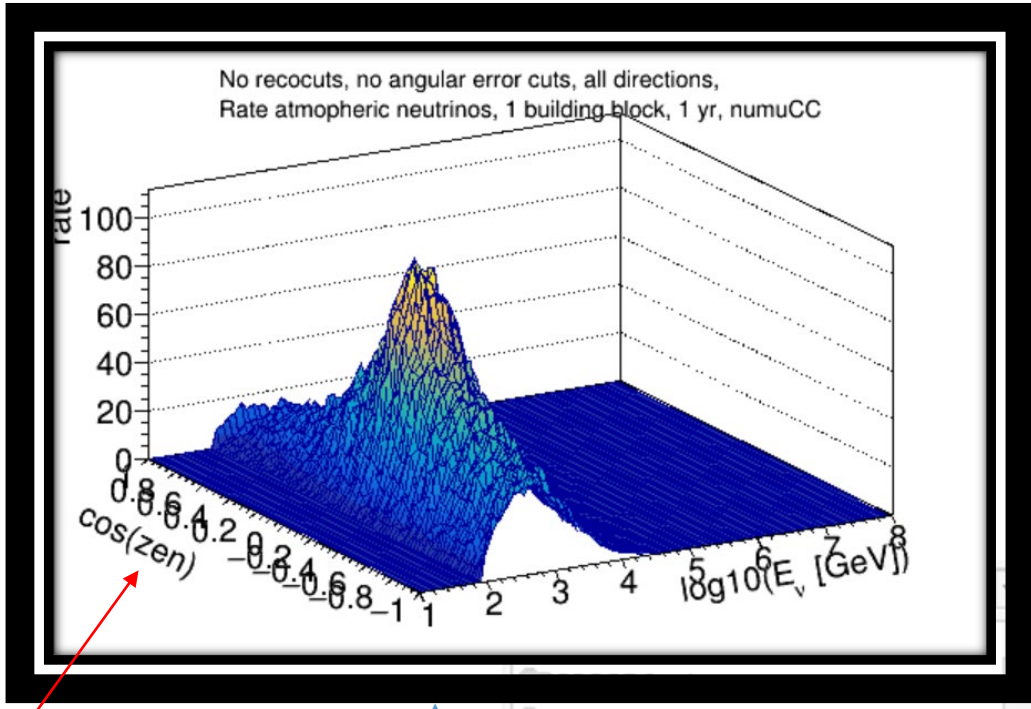
- Direction cut: only upgoing events
- Angular error cut: only include anular error < 1(10)deg for tracks(showers)
- LOI reconstruction quality cuts:
  For trackreco ($\mu$-events): $\Lambda > 60,\ \log^{10}(\beta_0\ [°]) < -1.0$
  For showerreco (e-events): $\Lambda > 2200,\ \mathrm{R}^2 < 250.000,\ \mathrm{z} < 600$

Now booleans. In future: optimise

# What is in rootfile?

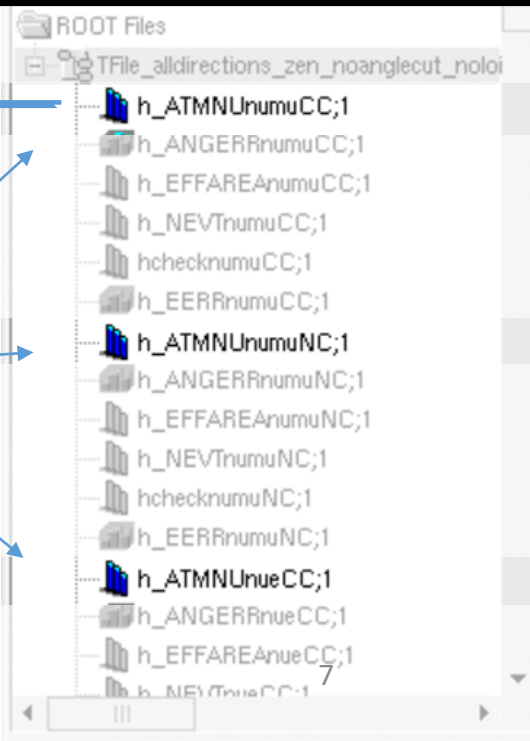
# In each ouput root-file

- TH2D <u>Rate atmospheric neutrinos</u>
  (based on weights & AAflux.dNdEdOmega())
- TH3D Angular error
  (angle between true and reco $\nu$)
- TH2D Effective Area
  (made with $E^{-1}$ flux)
- TH2D Rate cosmic neutrinos
  (based on weights & LOI flux)
- TH2D Rate cosmic neutrinos check
  (Effective Area * LOI flux)
- TH3D Energy error
  (best_trk.E/Nu.E)




These plots have on skydir-axis:
best_reco_trk direction info
All other plots have on skydir-axis :
true neutrnio info
I will make that more clear in the future

For every situation



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  (based on weights & AAflux.dNdEdOmega())
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  (angle between true and reco $\nu$)
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  (made with $E^{-1}$ flux)
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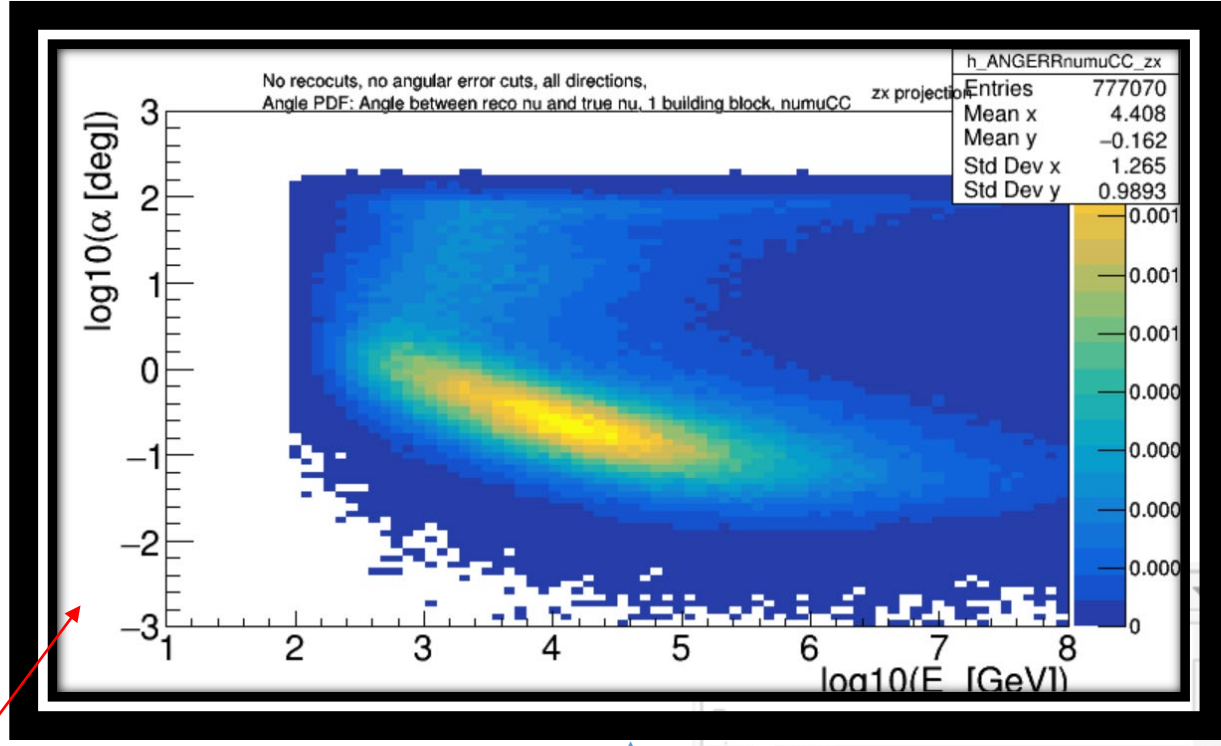
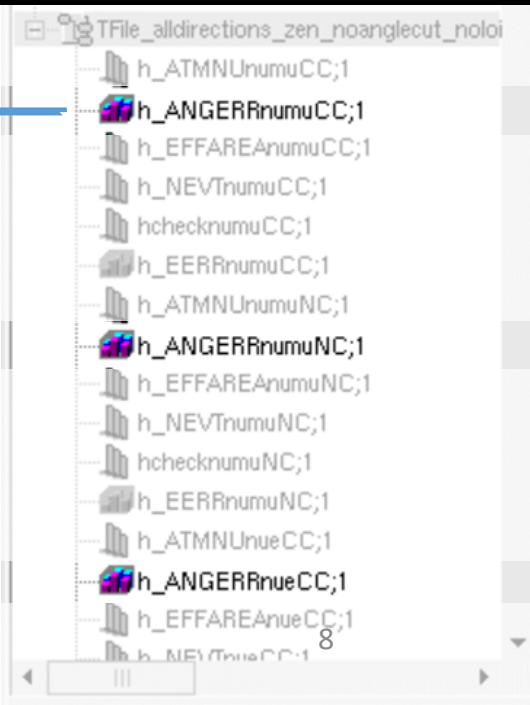
- TH2D Rate cosmic neutrinos check
  (Effective Area * LOI flux)
- TH3D Energy error
  (best_trk.E/Nu.E)




Replace by / add pointspread function?

Project3D("zx")



# In each ouput root-file

- TH2D Rate atmospheric neutrinos
  (based on weights & AAflux.dNdEdOmega())
- TH3D Angular error
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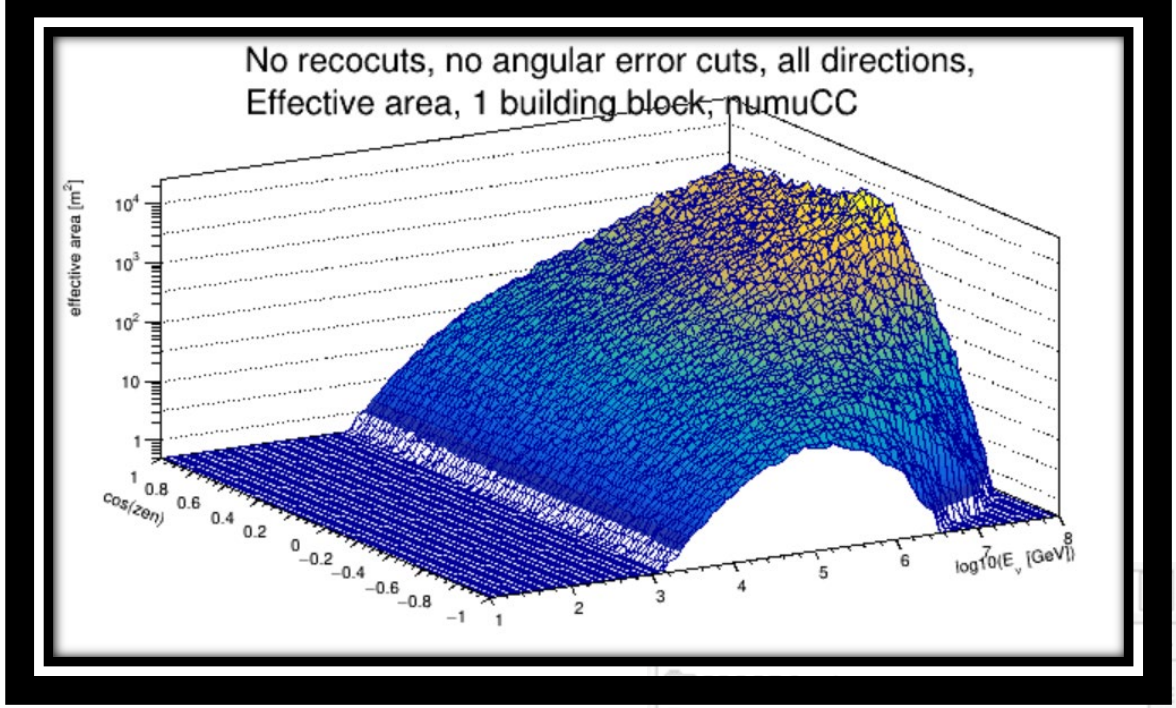
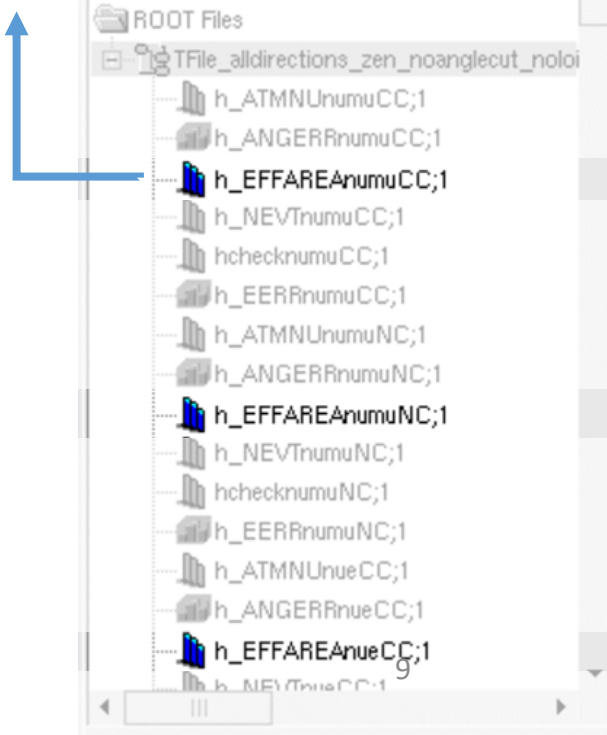
  (best_trk.E/Nu.E)



# In each ouput root-file

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  (based on weights & AAflux.dNdEdOmega())
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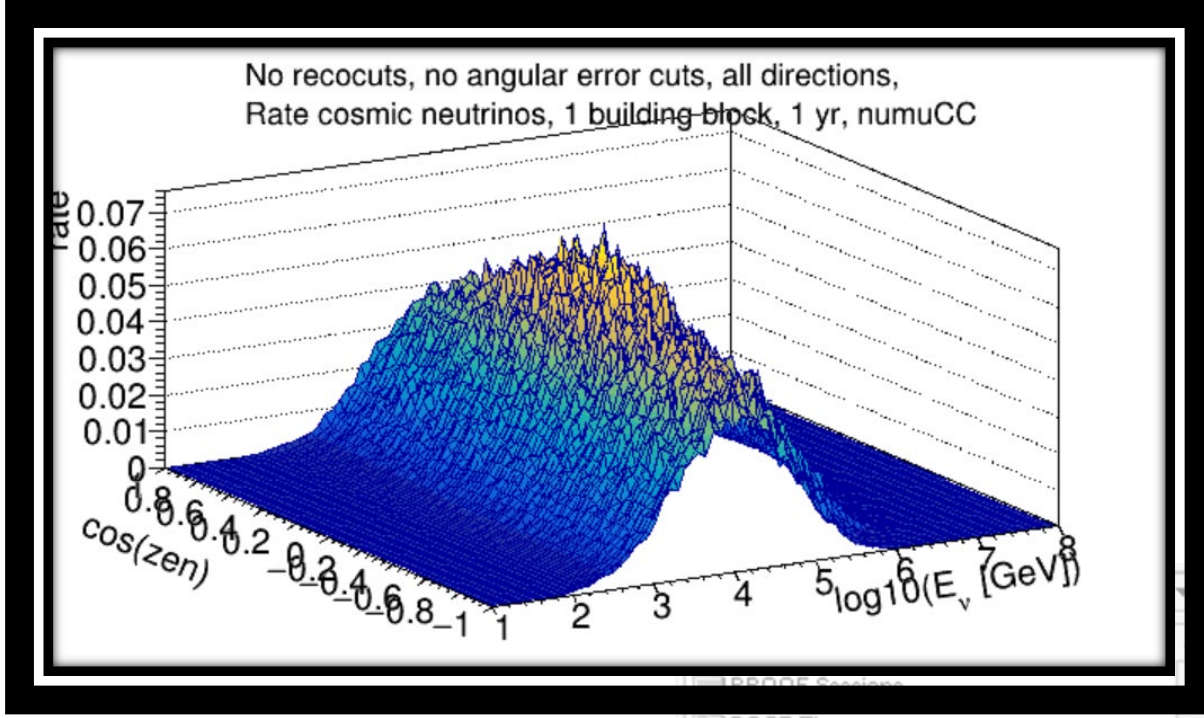


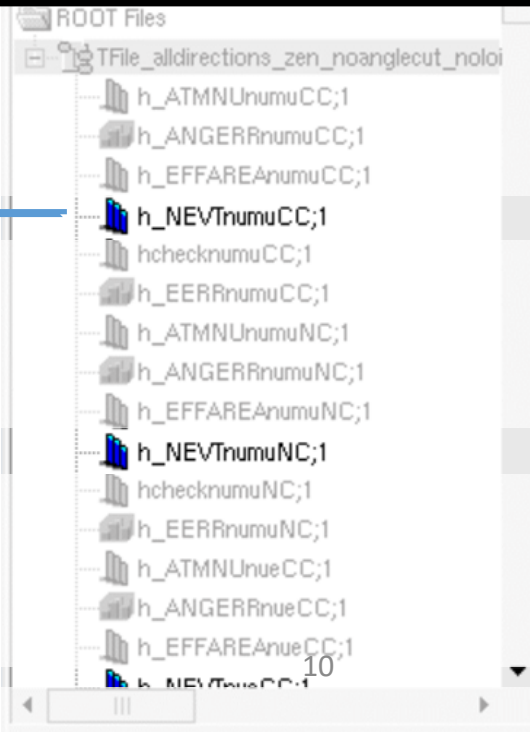

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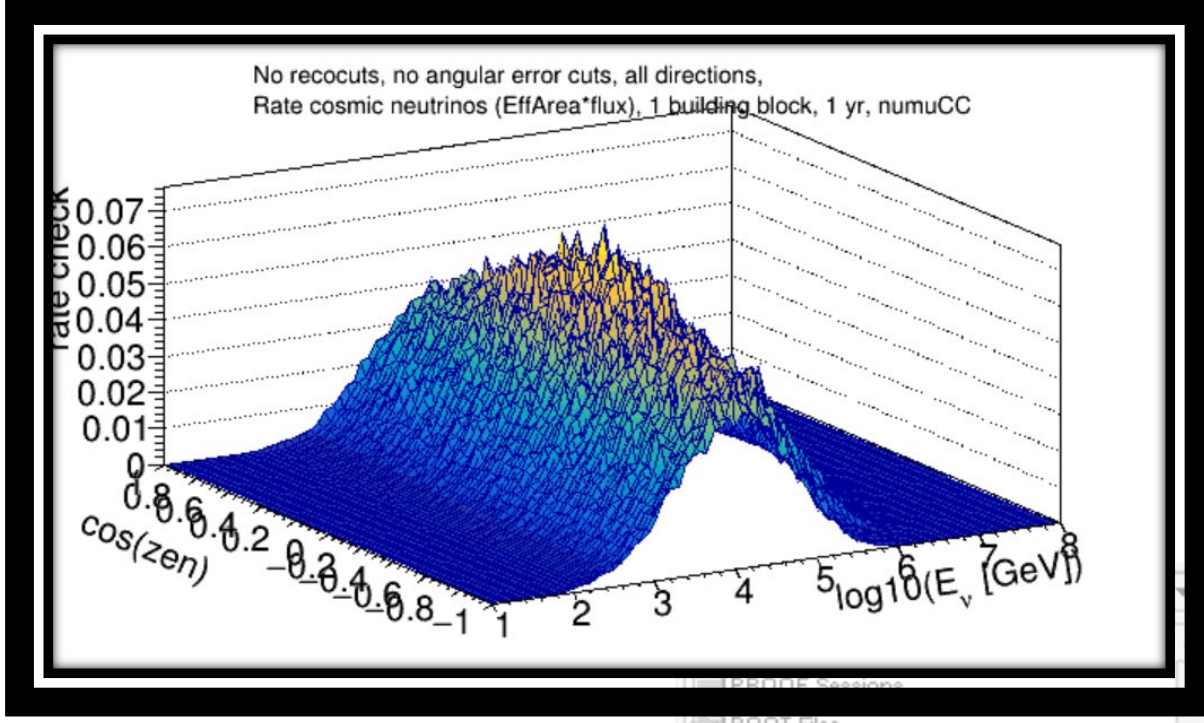


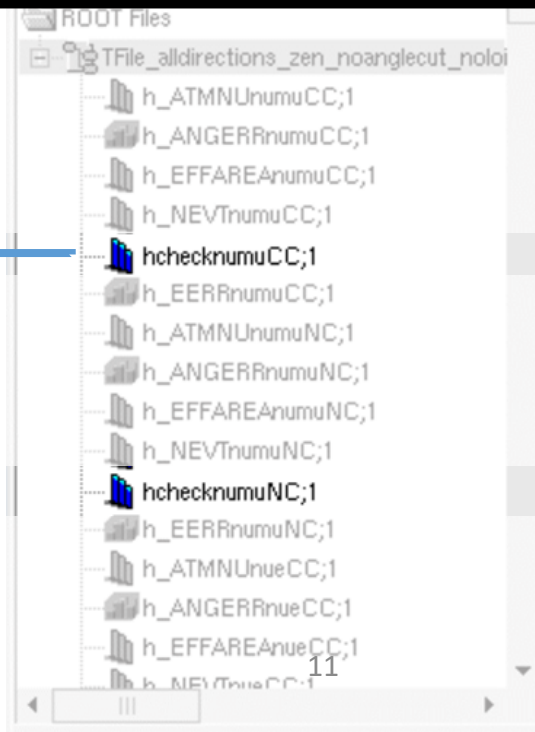

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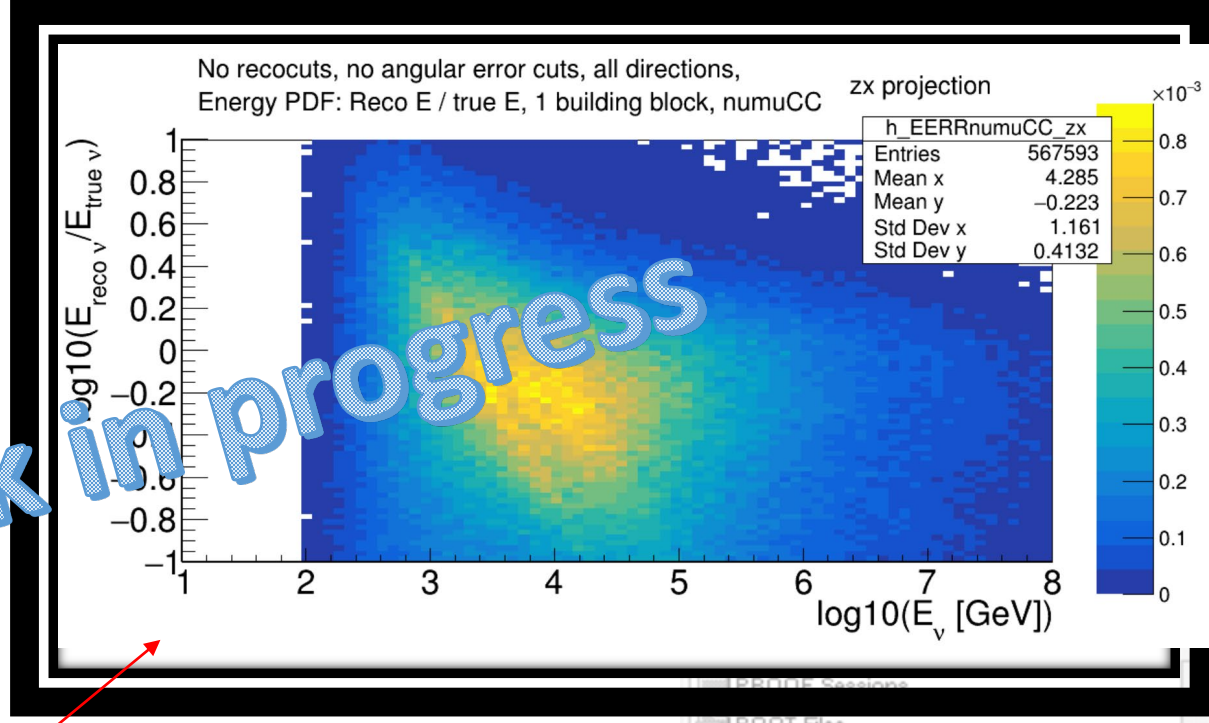
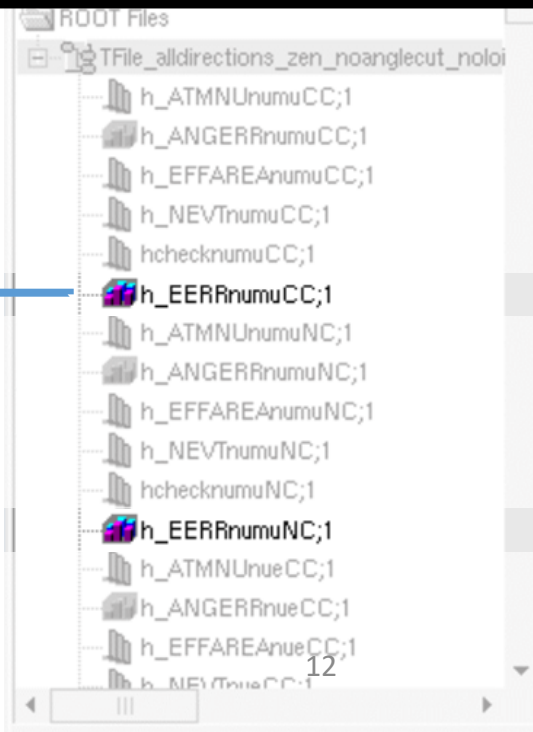



Apply energy correction (?)
For framework: better if just
E.reco instead of E.reco/E.nu

Project3D("zx")

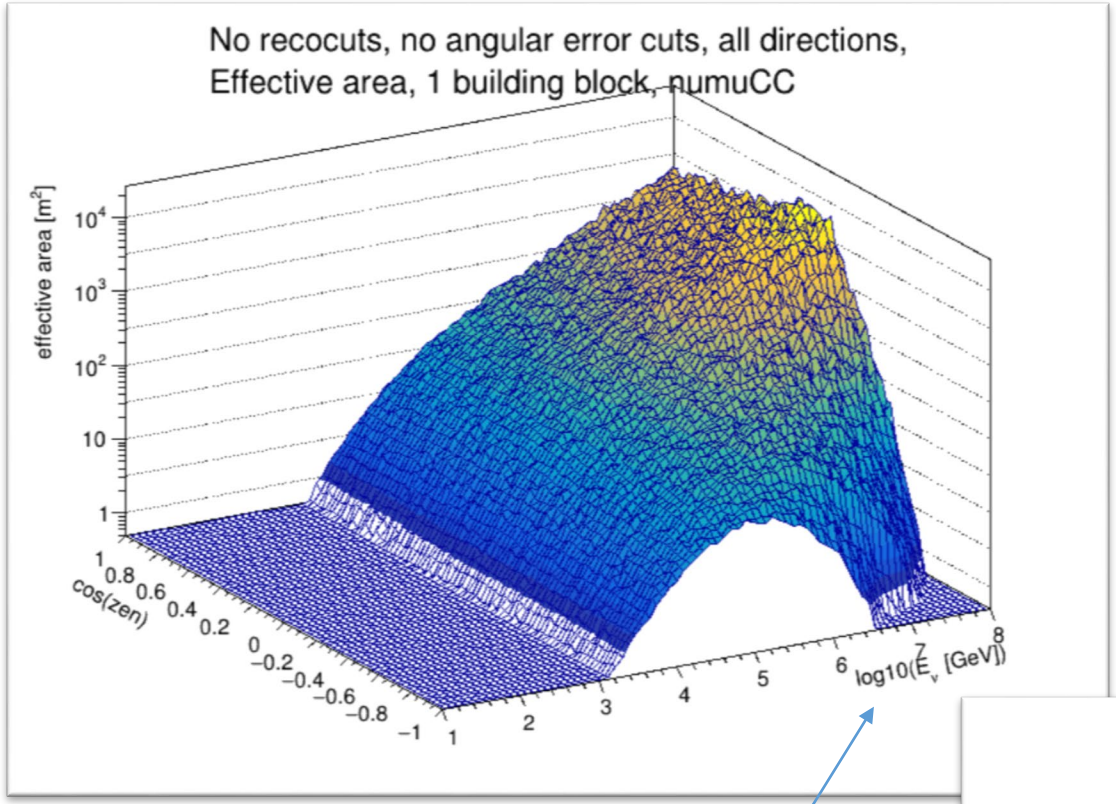


# Check if everything is correct

Disclaimer: I didn't look at all the plots individually yet, as there are 6 type of plots * 8 type of interactions * 4 output files = 192 plots!

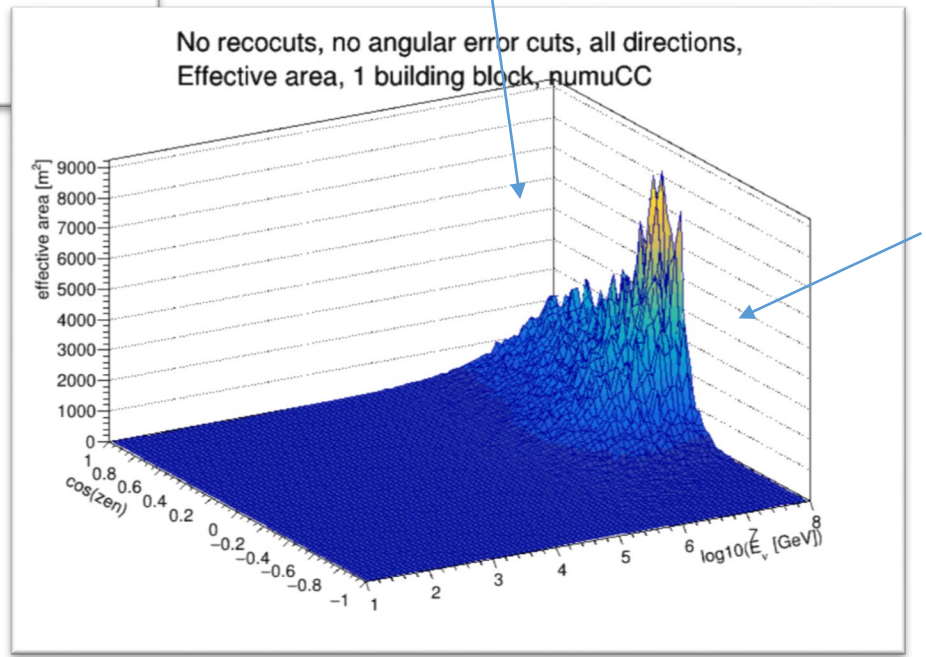
But: I made a nice start ➔ check APPENDIX of these slides for numbers!

# Playing with Effective Area’s




**Effective area** represents detector area for hypothetical instrument with 100% efficiency for detecting the passage of neutrino's. Values are small due to small crossection of neutrino's [*]

NB: it's mostly shown on log-scale
Don't forget what that actually means:

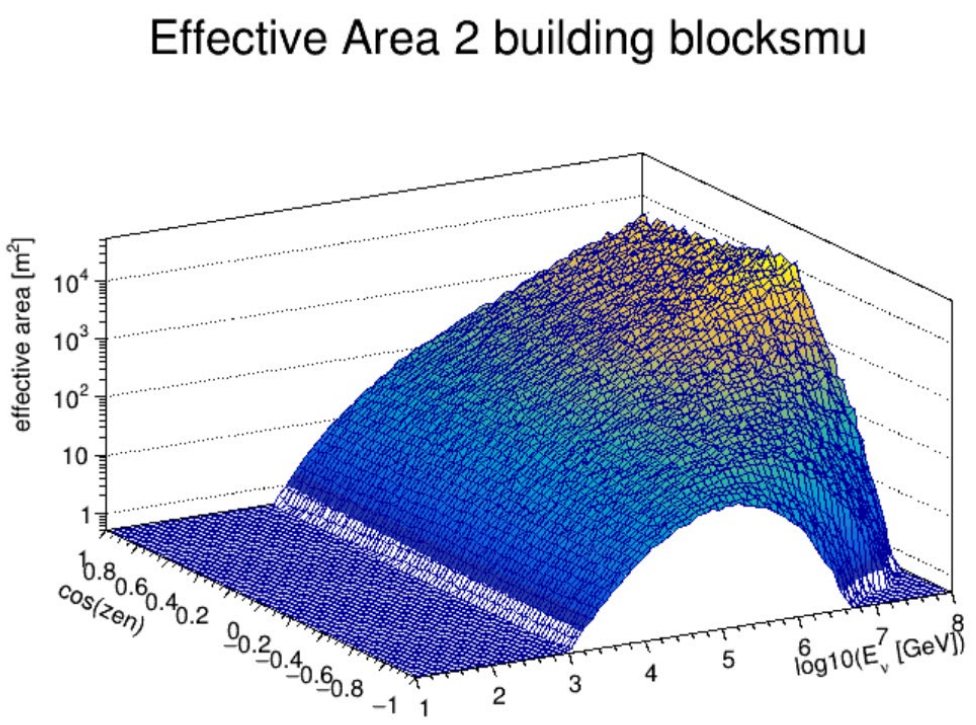


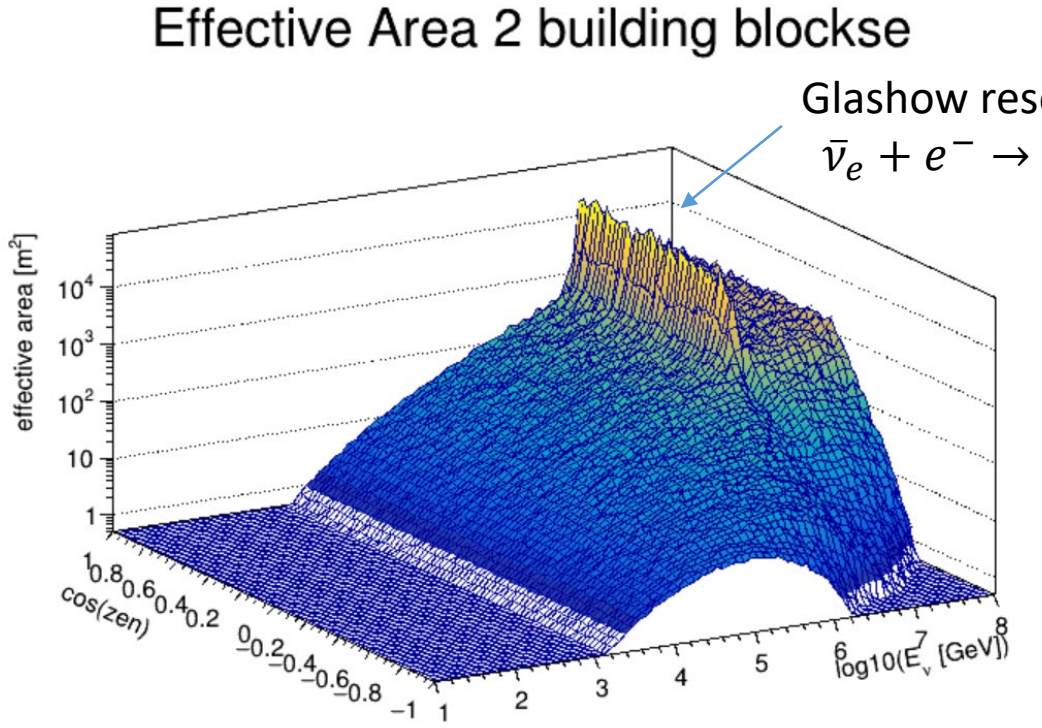

At very high E, and upward going events effective area drops due to neutrino absorption when travelling through the Earth

Effective Area is biggest
at high E, and
for neutrinos
from above

* https://arxiv.org/pdf/0801.1604.pdf

# Compute total effective area per flavour



# How to compute total Effective Area?

- Different for NC ⇔ CC
  than for $\nu \Leftrightarrow \bar{\nu}$

- Due to flux treatment per flavour $\nu_l$:
  - There is no such thing as $\Phi_{\nu_l CC}$ and $\Phi_{\nu_l NC}$
    Difference between NC and CC is implemented in crossection
  - Whereas there we can talk about $\Phi_{\nu_l}$ and $\Phi_{\bar{\nu}_l}$

**NC + CC**

$$N_{\nu_l CC} = A^{eff}_{\nu_l CC} * \Phi_{\nu_l}$$

$$N_{\nu_l NC} = A^{eff}_{\nu_l NC} * \Phi_{\nu_l} \quad +$$

---

$$N_{\nu_l CC+\nu_l NC} = N_{\nu_l CC} + N_{\nu_l NC}$$

$$= A^{eff}_{\nu_l CC} * \Phi_{\nu_l} + A^{eff}_{\bar{\nu}_l NC} * \Phi_{\nu_l}$$

$$\boldsymbol{A^{eff}_{\nu_l CC+\nu_l NC} = A^{eff}_{\nu_l CC} + A^{eff}_{\nu_l NC}}$$

# How to compute total Effective Area?

**$\nu + \bar{\nu}$**

$$N_{\nu_l} = A^{eff}_{\nu_l} * \Phi_{\nu_l}$$

$$N_{\bar{\nu}_l} = A^{eff}_{\bar{\nu}_l} * \Phi_{\bar{\nu}_l} \quad +$$

---

$$N_{\nu_l+\bar{\nu}_l} = N_{\nu_l} + N_{\bar{\nu}_l}$$

$$= A^{eff}_{\nu_l} * \Phi_{\nu_l} + A^{eff}_{\bar{\nu}_l} * \Phi_{\bar{\nu}_l}$$

If you assume: $\Phi_{\nu_l} = \Phi_{\bar{\nu}_l} = \frac{1}{2} \Phi_{\nu_l+\bar{\nu}_l}$

$$N_{\nu_l+\bar{\nu}_l} = N_{\nu_l} + N_{\bar{\nu}_l}$$

$$= (A^{eff}_{\nu_l} + A^{eff}_{\bar{\nu}_l}) * \frac{\Phi_{\nu_l+\bar{\nu}_l}}{2}$$

To get the wanted

$$N_{\nu_l+\bar{\nu}_l} = A^{eff}_{\nu_l+\bar{\nu}_l} * \Phi_{\nu_l+\bar{\nu}_l}$$

we conclude that :

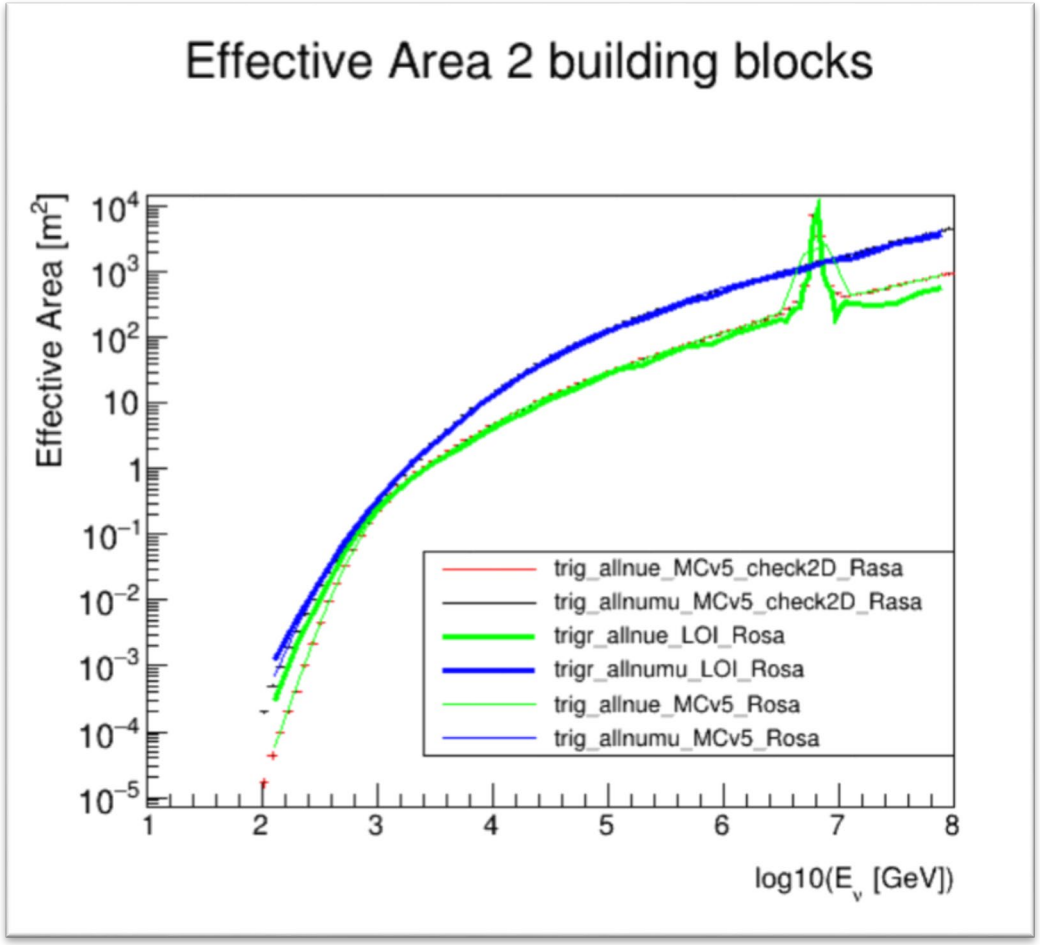
$$\boldsymbol{A^{eff}_{\nu_l+\bar{\nu}_l} = \frac{A^{eff}_{\nu_l} + A^{eff}_{\bar{\nu}_l}}{2}}$$

**To conclude:**

for a single flavour:

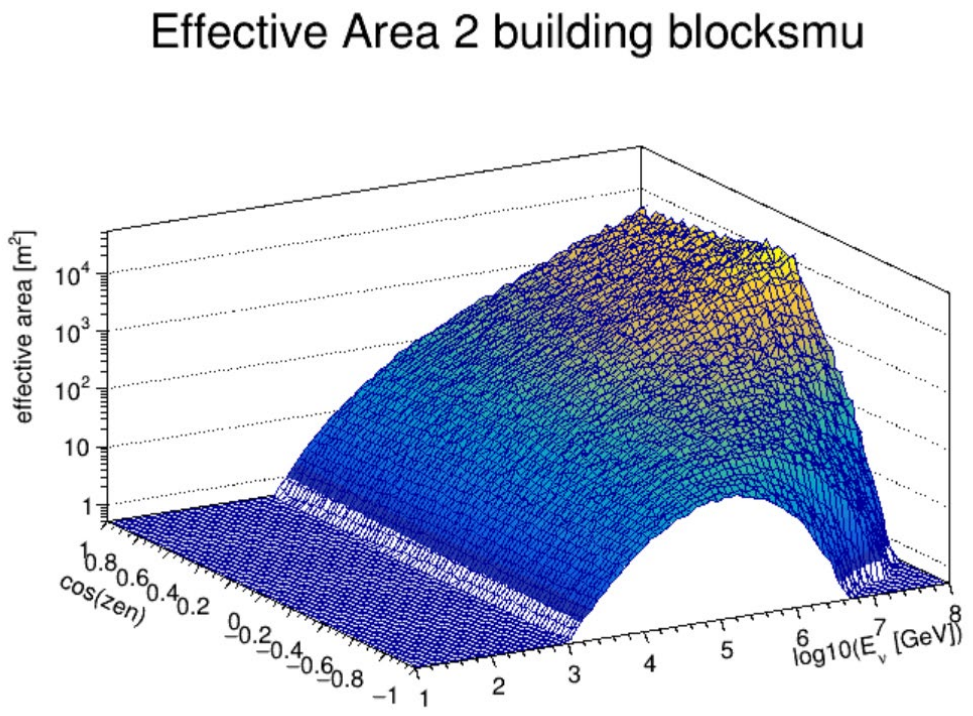
- **Add** NC and CC
- **Average** between $\nu$ and $\bar{\nu}$

# Compare results with LOI & MCv5 benchmark



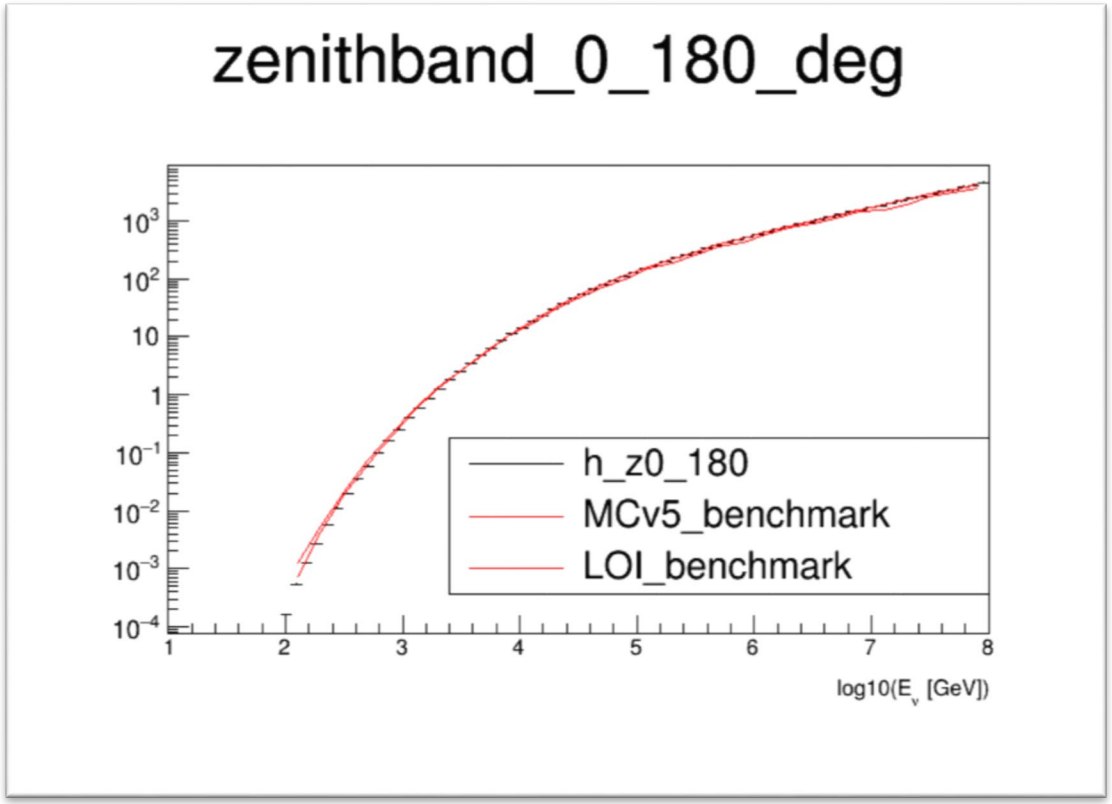
# Sky bands (here: muon events)

**Make slice in this 2D hist:**




Smoothning option??

**First: compare with Rosa**



NB: trigger level; cannot simply compare

# Sky bands (here: muon events)

## Zenithbands from IceCube paper[*]

Nb: from 2008

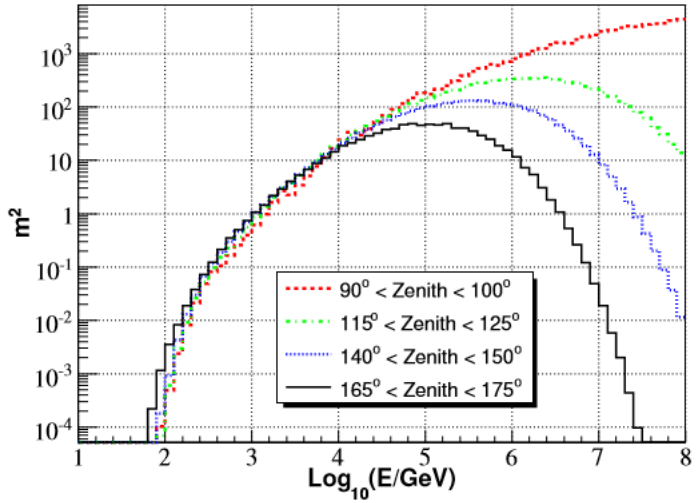
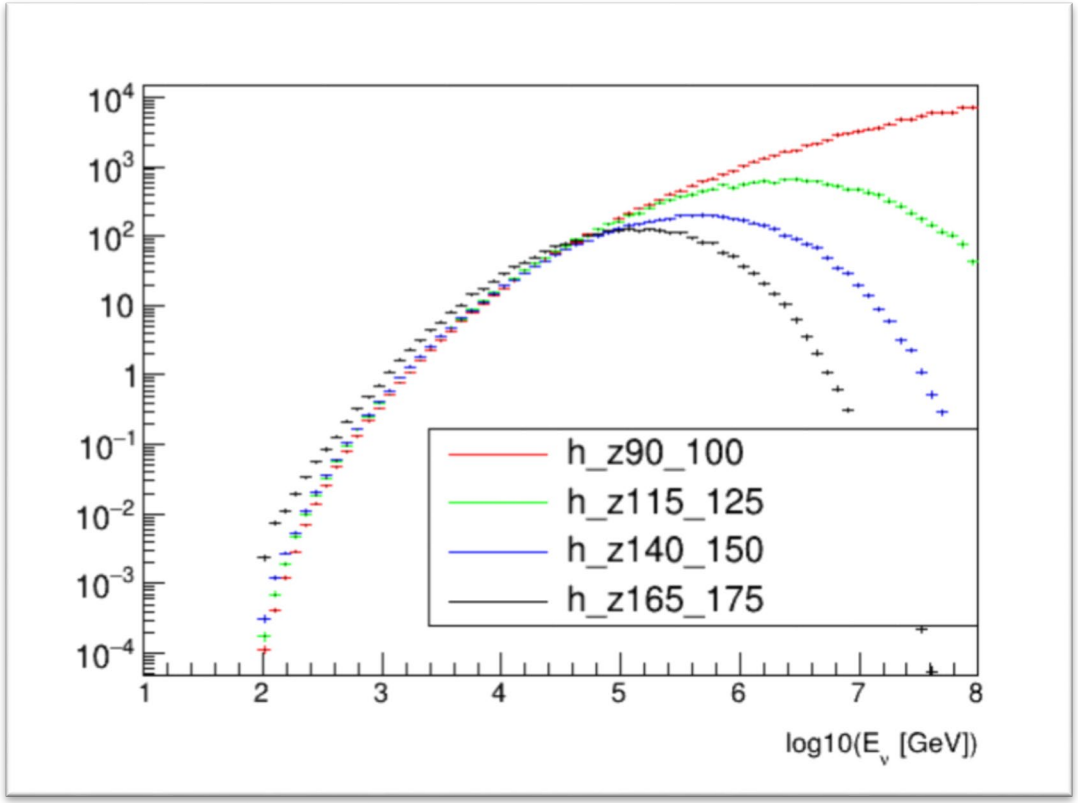



Fig. 3. Neutrino effective area at trigger level for several zenith bands.

## Reproduced for KM3NeT



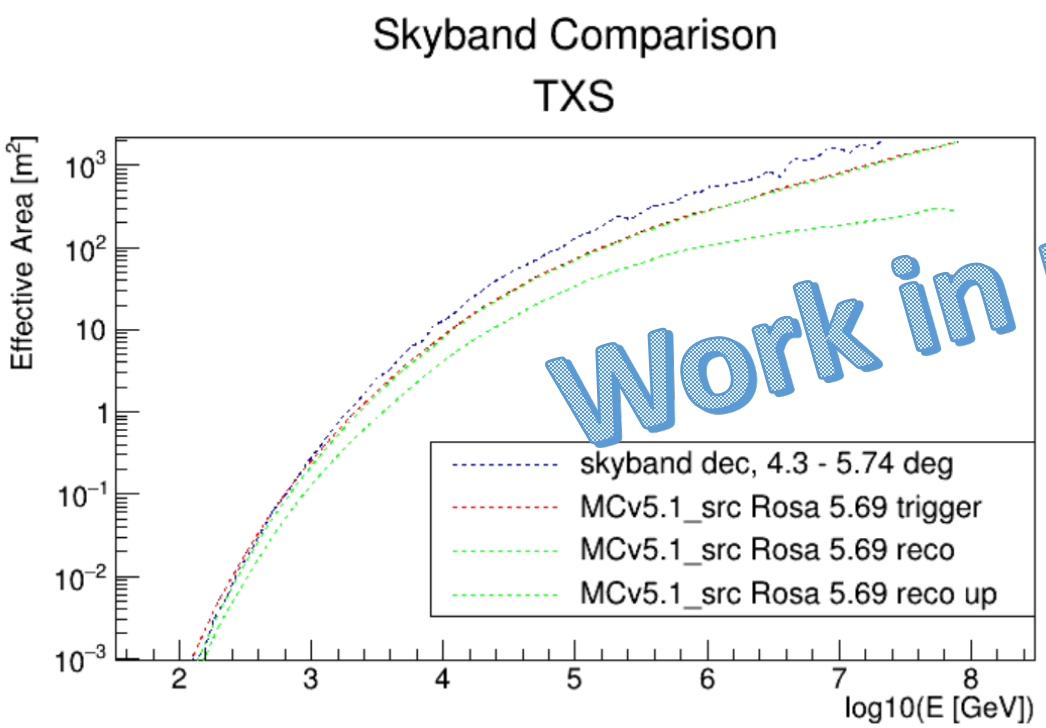



* https://arxiv.org/pdf/0801.1604.pdf

# Sky bands in declination

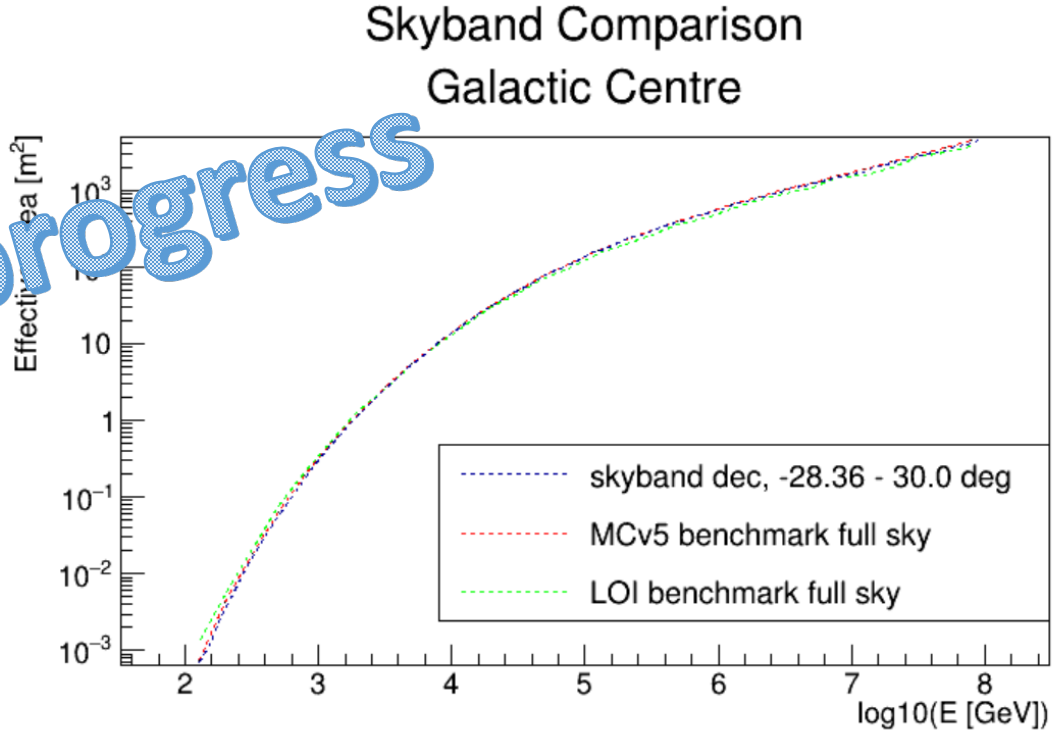
- in arguments:
error In aa.Options

**TXS ($\delta = 5.69\ °$)**




Interpolate option??

**Galactic Centre ($\delta = -28.94\ °$)**




Work in progress

# Appendix

- A1: How to run script to get output files

- A2: Shell output to check atmospheric and cosmic event rates

# A1: Script + root output @ git

- How to run script to get output files:

```
python -i path/AtmCosm_nus_Suzan_v8_FINAL.py
```

Default settings:

Sky direction expressed in zenith , trigger level, make plots on screen, run locally

Define different settings:

```
python -i path/AtmCosm_nus_Suzan_v8_FINAL.py
                        -a dec
                -cd True -cr True -ca True
                 -g False -l lyon
```

cos(zenith): “zen”

sin(declination): “dec”

Cut direction (cd)

Cut reconstruction quality (cr)

Cut angular error (ca)

Graphical output

Run @lyon/locally

# A2: Shell output to check atmospheric and cosmic event rates

- shell output when running the code with eventrates from
  - Atmospheric neutrino’s
  - Cosmic neutrinos
    - Based on weight and LOI flux
    - Based on Effective area * flux

- (some pieces are a bit of a mess, because if you upload it on the super computer @ lyon, the output is not in order…) sorry

# The 3 Eventrante histograms match with tables Thijs and me made for number of events project! Some slightly different?

TFile_alldirections_zen_noanglecut_noloirecocut_f200.root

nu interactions

```
reconstruction algorithm used                                  = 4000
analysed angle coordinates                                     = zen
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 1 degree(s)              = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
   55141.66393021938   55302 ?
- Number of cosmic neutrinos (in loop):
   97.92610132034284
- NUMBER of cosmic neutrinos (EffArea * flux):
   98.26280067915133
    '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                             = numuNC
reconstruction algorithm used                                  = 4000
analysed angle coordinates                                     = zen
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 1 degree(s)              = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
   2900.118647485514   2920 ?
- Number of cosmic neutrinos (in loop):
   5.9727339816832945
- NUMBER of cosmic neutrinos (EffArea * flux):
   5.993506988575404
    '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                             = nueCC
reconstruction algorithm used                                  = 101
analysed angle coordinates                                     = zen
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 10 degree(s)             = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
   1390.792221223496
- Number of cosmic neutrinos (in loop):
   27.862373825157916
- NUMBER of cosmic neutrinos (EffArea * flux):
   27.961737313794737
    '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                             = nueNC
reconstruction algorithm used                                  = 101
analysed angle coordinates                                     = zen
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 10 degree(s)             = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
   138.1146640074618
- Number of cosmic neutrinos (in loop):
   6.086397059389299 5
- NUMBER of cosmic neutrinos (EffArea * flux):
   6.108384196890528
    '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

## The 3 Eventrante histograms match with tables Thijs and me made for number of events project! Some slightly different?

TFile_alldirections_zen_noanglecut_noloirecocut_f200.root

anu interactions

```
analysed situation                                          = anumuCC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 1 degree(s)           = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    21950.00826757428        21889 ?
- Number of cosmic neutrinos (in loop):
    76.8885908680678
- NUMBER of cosmic neutrinos (EffArea * flux):
    77.16403713178508
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                          = anumuNC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 1 degree(s)           = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    833.5564663280836      839 ?
- Number of cosmic neutrinos (in loop):
    4.1295512188629
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.144022213076359
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                          = anueCC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 10 degree(s)          = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    647.2231389868411
- Number of cosmic neutrinos (in loop):
    20.872836069398627
- NUMBER of cosmic neutrinos (EffArea * flux):
    20.899380599388145
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.13%
```

```
analysed situation                                          = anueNC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 10 degree(s)          = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    52.24139051232574
- Number of cosmic neutrinos (in loop):
    4.253515695048068
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.269240087006938
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.37%
```

In the tables Thijs and me made for number of events project, no cut is made on upgoing, so cannot compare with them

TFile_upgoing_zen_anglecut_loirecocuts_f200.root

nu interactions

```
reconstruction algorithm used                                = 4000
analysed angle coordinates                                   = zen
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 1 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    6672.482959673497
- Number of cosmic neutrinos (in loop):
    21.85475380410832
- NUMBER of cosmic neutrinos (EffArea * flux):
    21.92623891071622
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.33%
```

```
analysed situation                                           = numuNC
reconstruction algorithm used                                = 4000
analysed angle coordinates                                   = zen
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 1 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    0.7457026006363695
- Number of cosmic neutrinos (in loop):
    0.006578709176260529
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.006587875971885725
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.14%
```

```
analysed situation                                           = nueCC
reconstruction algorithm used                                = 101
analysed angle coordinates                                   = zen
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 10 degree(s)           = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    51.692584479793794
- Number of cosmic neutrinos (in loop):
    4.1170952957923275
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.1320943288057626
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                           = nueNC
reconstruction algorithm used                                = 101
analysed angle coordinates                                   = zen
N analysed files                                             = 200
N bins in all dimensions                                     = 80open
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 10 degree(s)           = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    5.169233035689267
- Number of cosmic neutrinos (in loop):
    0.8084059727906838
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.8113250361893646
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

In the tables Thijs and me made for number of events project, no cut is made on upgoing, so cannot compare with them

TFile_upgoing_zen_anglecut_loirecocuts_f200.root

anu interactions

```
analysed situation                                          = anumuCC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 1 degree(s)           = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    3193.3412719471926
- Number of cosmic neutrinos (in loop):
    18.282261354043207
- NUMBER of cosmic neutrinos (EffArea * flux):
    18.349762093555007
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.37%
```

```
analysed situation                                          = anumuNC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 1 degree(s)           = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    0.5205113854525484
- Number of cosmic neutrinos (in loop):
    0.006808390438705138
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.006837698689560627
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.43%
```

```
analysed situation                                          = anueCC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 10 degree(s)          = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    26.22889525335061
- Number of cosmic neutrinos (in loop):
    3.083512902998298
- NUMBER of cosmic neutrinos (EffArea * flux):
    3.093738412530312
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.33%
```

```
analysed situation                                          = anueNC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = zen
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 10 degree(s)          = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    2.171000067904611
- Number of cosmic neutrinos (in loop):
    0.5818986674660324
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.5840033475504498
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

# The 3 Eventrante histograms match with tables Thijs and me made for number of events project! Some slightly different?

TFile_alldirections_dec_noanglecut_noloirecocut_f200.root

nu interactions

```
reconstruction algorithm used                                  = 4000
analysed angle coordinates                                     = dec
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 1 degree(s)             = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    55141.66393021928   55302 ?
- Number of cosmic neutrinos (in loop):
    97.92010132034291
- NUMBER of cosmic neutrinos (EffArea * flux):
    98.26280067915152
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                             = numuNC
reconstruction algorithm used                                  = 4000
analysed angle coordinates                                     = dec
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 1 degree(s)             = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    2900.2186474855243   2920 ?
- Number of cosmic neutrinos (in loop):
    5.972733981683331
- NUMBER of cosmic neutrinos (EffArea * flux):
    5.993606988575436
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                             = nueCC
reconstruction algorithm used                                  = 101
analysed angle coordinates                                     = dec
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 10 degree(s)            = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    1390.7922212234982
- Number of cosmic neutrinos (in loop):
    27.862387382515772
- NUMBER of cosmic neutrinos (EffArea * flux):
    27.962737313794907
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                             = nueNC
reconstruction algorithm used                                  = 101
analysed angle coordinates                                     = dec
N analysed files                                               = 200
N bins in all dimensions                                       = 80
CUT out down-going neutrinos                                   = False
CUT out out angular error worse than 10 degree(s)            = False
CUT on reconstruction quality parameters like in LOI           = False
show graphics                                                  = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    138.1466400746087
- Number of cosmic neutrinos (in loop):
    6.086297059389342
- NUMBER of cosmic neutrinos (EffArea * flux):
    6.108838419689052
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

## The 3 Eventrante histograms match with tables Thijs and me made for number of events project! Some slightly different?

TFile_alldirections_dec_noanglecut_noloirecocut_f200.root

anu interactions

```
analysed situation                                          = anumuCC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 1 degree(s)           = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    21950.00826757425        21889 ?
- Number of cosmic neutrinos (in loop):
    76.88864714845417
- NUMBER of cosmic neutrinos (EffArea * flux):
    77.16409683437247
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                          = anumuNC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 1 degree(s)           = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    833.1564663280876   839 ?
- Number of cosmic neutrinos (in loop):
    4.129585121886275
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.144022130763568
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.35%
```

```
analysed situation                                          = anueCC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 10 degree(s)          = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    647.2231389868346
- Number of cosmic neutrinos (in loop):
    20.87283606939848
- NUMBER of cosmic neutrinos (EffArea * flux):
    20.89938059938813
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.13%
```

```
analysed situation                                          = anueNC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = False
CUT out out angular error worse than 10 degree(s)          = False
CUT on reconstruction quality parameters like in LOI        = False
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    52.2423905123258
- Number of cosmic neutrinos (in loop):
    4.253515695048096
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.269240087006907
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.37%
```

In the tables Thijs and me made for number of events project, no cut is made on upgoing, so cannot compare with them

TFile_upgoing_dec_anglecut_loirecocuts_f200.root

nu interactions

```
reconstruction algorithm used                                = 4000
analysed angle coordinates                                   = dec
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 1 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    6672.482959673508
- Number of cosmic neutrinos (in loop):
    21.854753804108384
- NUMBER of cosmic neutrinos (EffArea * flux):
    21.92623891071609
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.33%
```

```
analysed situation                                           = numuNC
reconstruction algorithm used                                = 4000
analysed angle coordinates                                   = dec
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 1 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    0.7457026006363696
- Number of cosmic neutrinos (in loop):
    0.006578709176260543
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.00658787597188574
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.14%
```

```
analysed situation                                           = nueCC
reconstruction algorithm used                                = 101
analysed angle coordinates                                   = dec
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 10 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    51.692584479793766
- Number of cosmic neutrinos (in loop):
    4.1170952957923435
- NUMBER of cosmic neutrinos (EffArea * flux):
    4.132094328805761
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

```
analysed situation                                           = nueNC
reconstruction algorithm used                                = 101
analysed angle coordinates                                   = dec
N analysed files                                             = 200
N bins in all dimensions                                     = 80
CUT out down-going neutrinos                                 = True
CUT out out angular error worse than 10 degree(s)            = True
CUT on reconstruction quality parameters like in LOI         = True
show graphics                                                = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    5.1692330356892695
- Number of cosmic neutrinos (in loop):
    0.8084059727906837
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.8113250361893668
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```

In the tables Thijs and me made for number of events project, no cut is made on upgoing, so cannot compare with them

TFile_upgoing_dec_anglecut_loirecocuts_f200.root

anu interactions

```
analysed situation                                          = anumuCC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 1 degree(s)           = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    3193.3412719471908
- Number of cosmic neutrinos (in loop):
    18.28226135404315
- NUMBER of cosmic neutrinos (EffArea * flux):
    18.349762093554958
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.37%
```

```
analysed situation                                          = anumuNC
reconstruction algorithm used                               = 4000
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 1 degree(s)           = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    0.520511385452548
- Number of cosmic neutrinos (in loop):
    0.006808390438705132
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.0068376986895606374
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.43%
```

```
analysed situation                                          = anueCC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 10 degree(s)          = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    26.22889525335065
- Number of cosmic neutrinos (in loop):
    3.0835129029982924
- NUMBER of cosmic neutrinos (EffArea * flux):
    3.0937384125303
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.33%
```

```
analysed situation                                          = anueNC
reconstruction algorithm used                               = 101
analysed angle coordinates                                  = dec
N analysed files                                            = 200
N bins in all dimensions                                    = 80
CUT out down-going neutrinos                                = True
CUT out out angular error worse than 10 degree(s)          = True
CUT on reconstruction quality parameters like in LOI        = True
show graphics                                               = False

PRINT OUT SOME NUMBERS:

All numbers below are per year, for 1 building block, ARCA115:
- Number of atmospheric neutrinos:
    2.171000067904629
- Number of cosmic neutrinos (in loop):
    0.5818986674660327
- NUMBER of cosmic neutrinos (EffArea * flux):
    0.5840033475504524
     '--> difference in loop and EffArea * flux is: 0.0 events, or 0.36%
```