*May 2019, Schoorl*
*Group outing*

# Pointsource Searches with ARCA


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Contributions

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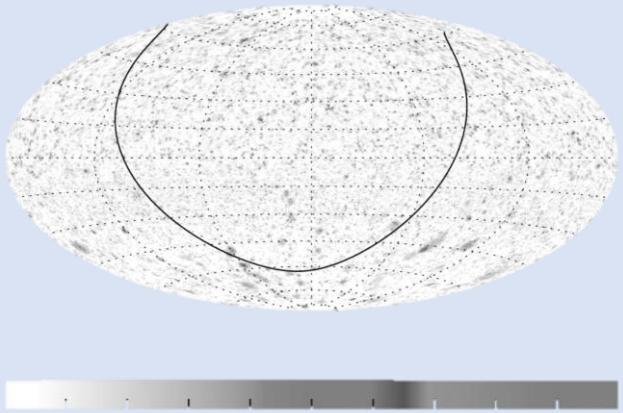
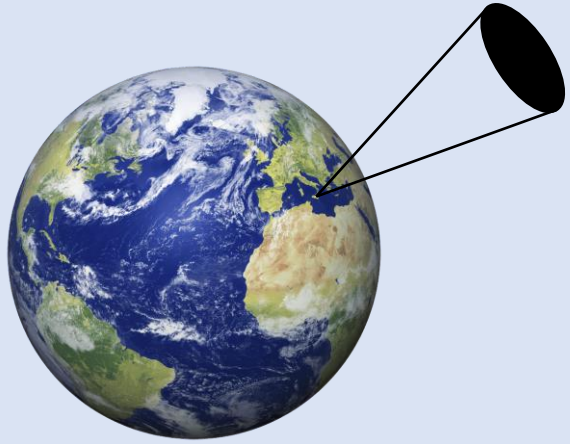
*May 2019, Schoorl*
*Group outing*

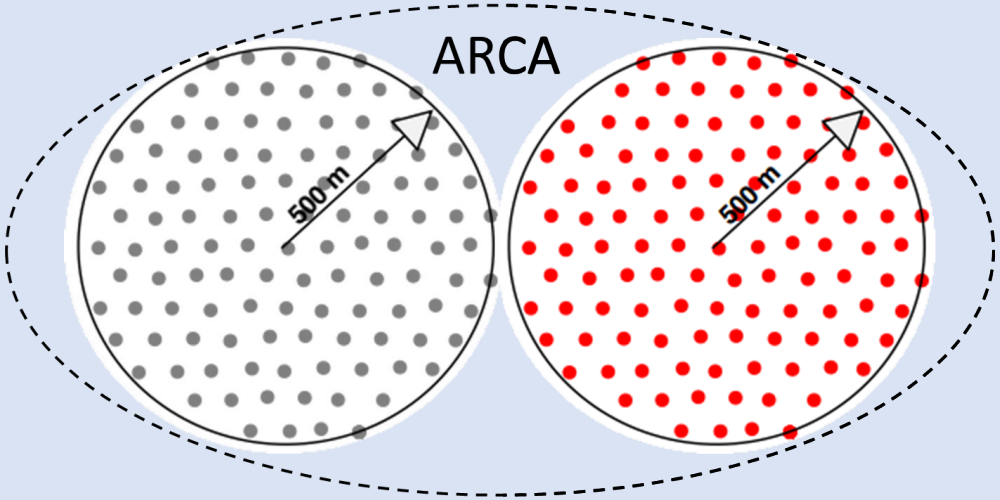
# Pointsource Searches with ARCA





# Pointsource Searches with ARCA

- Astroparticle physics
- Understanding high-energy objects in Universe
- Multi messenger




mcv5.1.genhen: 1 block, 1 year

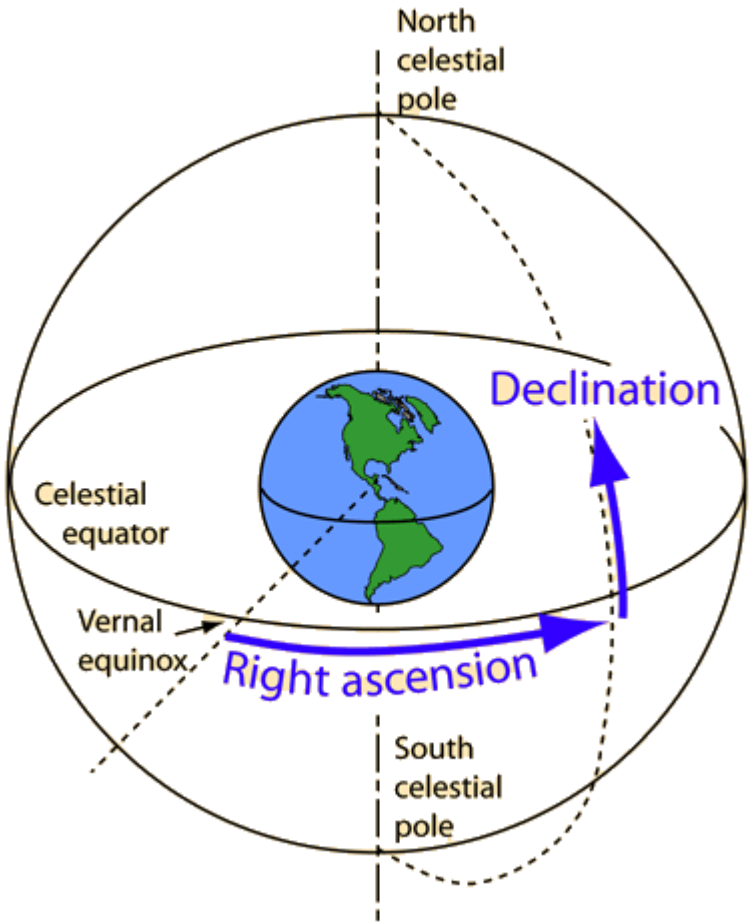
# Questions to answer:

1. What is the effective area?
2. How does the number of measured background events depend on declination?
3. What is the expected angular resolution of KM3NeT ARCA?

4. Given the duration of measurement: which fluxes of pointsources can be discovered? / Given the flux of a source: how long do we have to measure to detect it?
5. What is the ‘sensitivity’ of KM3NeT ARCA for a specific signal?

# Some definitions

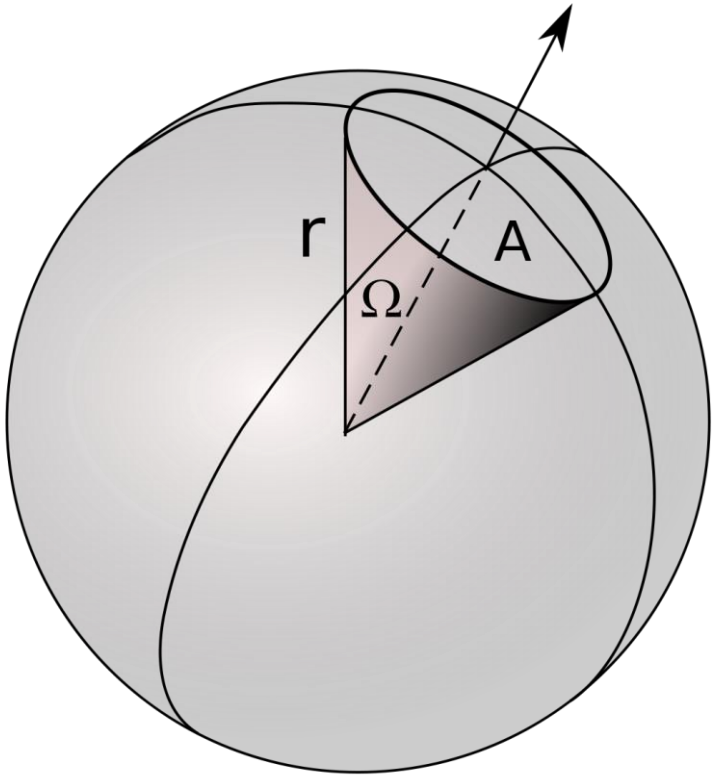
- Equatorial coordinate system
  - Declination (decl / δ) $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$
  - Right Assension (ra / α) ⇔ time [0, 24h]



# Some definitions

- Solid angle
  - How much field of view is covered by an object?
  - Unit sphere
  - Expressed in steradian [sr]
  - 1 sr = $\left(\frac{180}{\pi}\right)^2$ square deg

- *Same principle as radians in unitcircle*



# Analysed MC files

- mcv5.1.genhen_anumuCC.km3_AAv1.jte.jchain.aashower.<nr>.root

  numuCC

  anumuNC

  numuNC

- Atmospheric (background) ⇔ Honda flux in w[2]
- Cosmic (signal) ⇔ apply flux * w[1]
  - Diffuse / pointsource

# Questions to answer:

1. **What is the effective area?**
2. How does the number of measured background events depend on declination?
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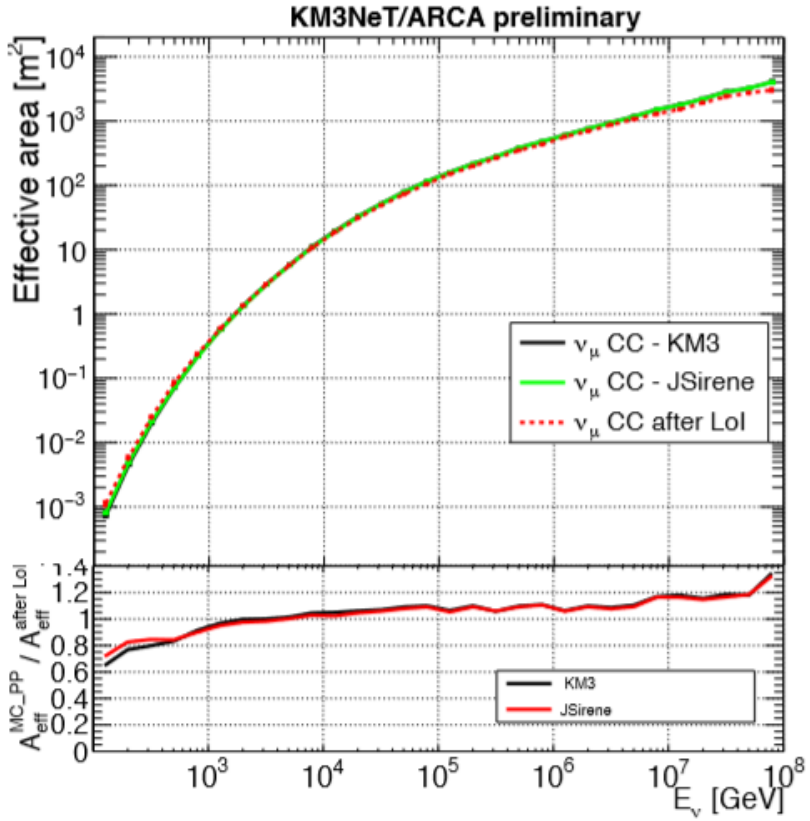
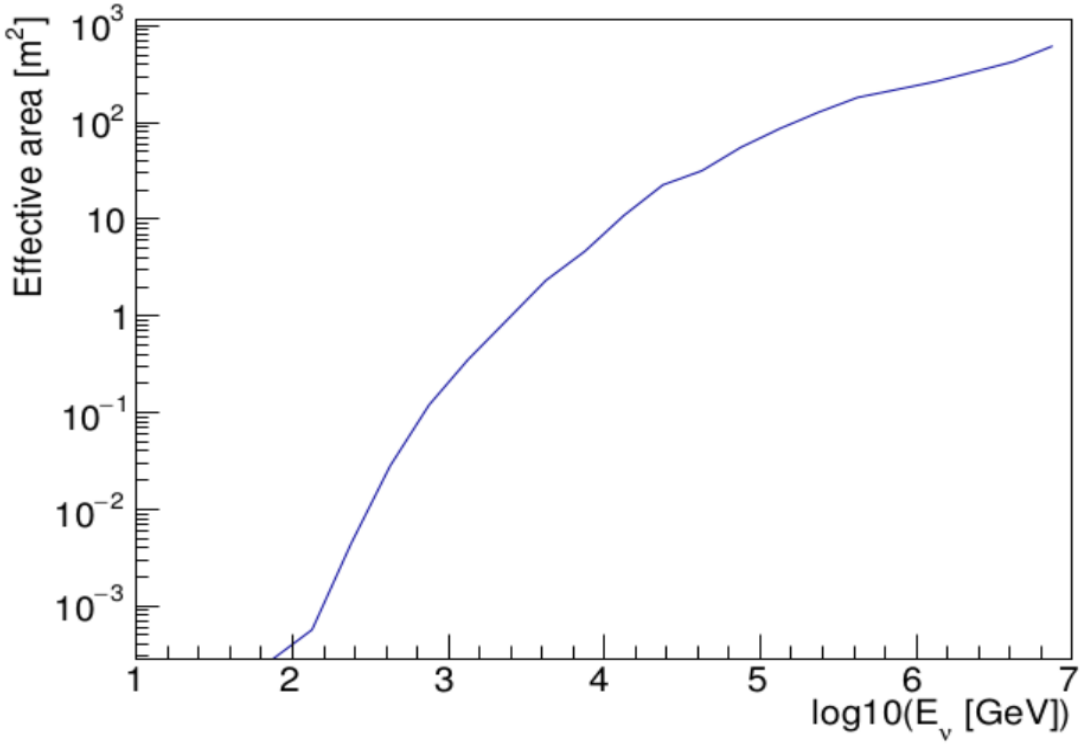
# Effective Area = ratio between the rate of detected events and the total flux of neutrinos

**numuCC by Rosa Coniglione**
*(slides Casserta, okt 2018, p.8)*




**Succesfully reproduced**



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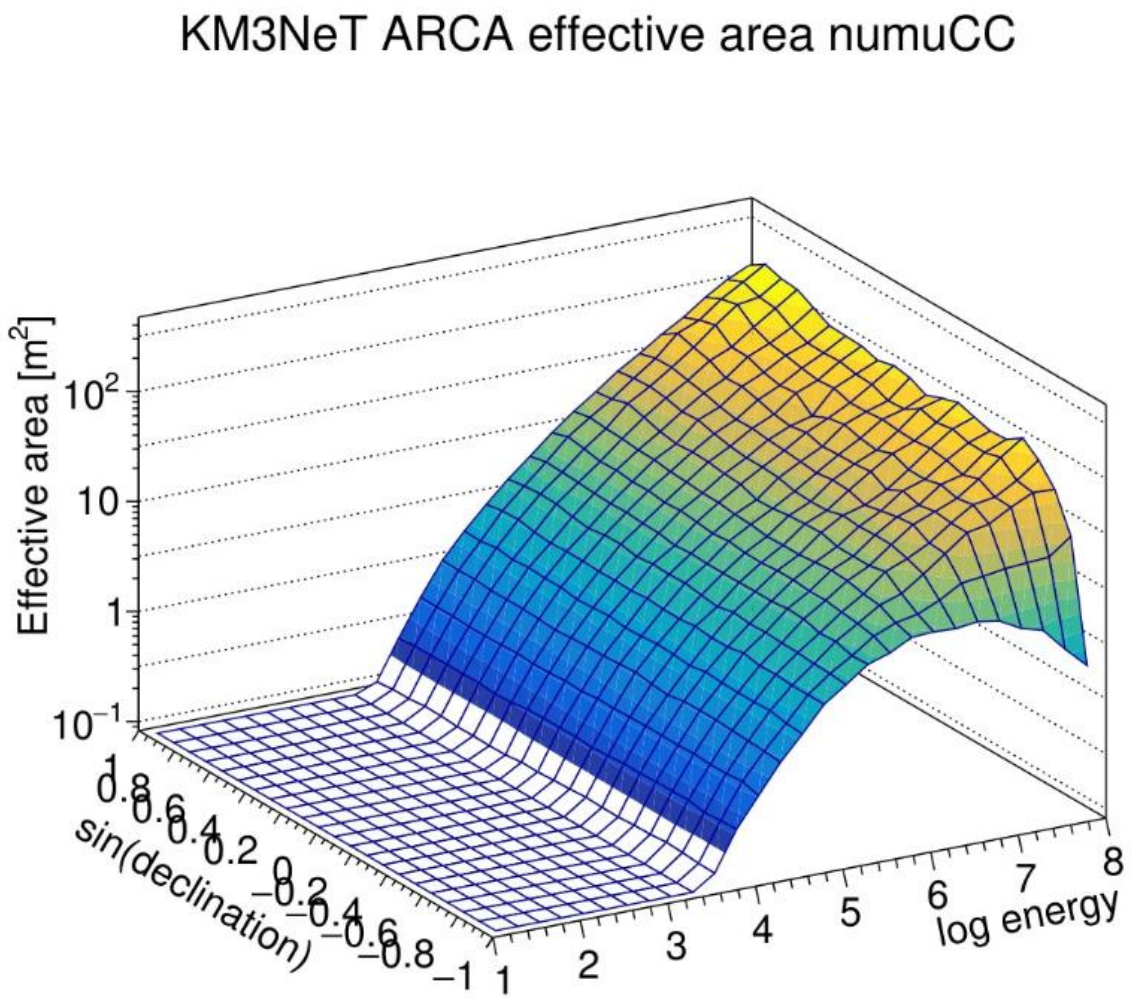


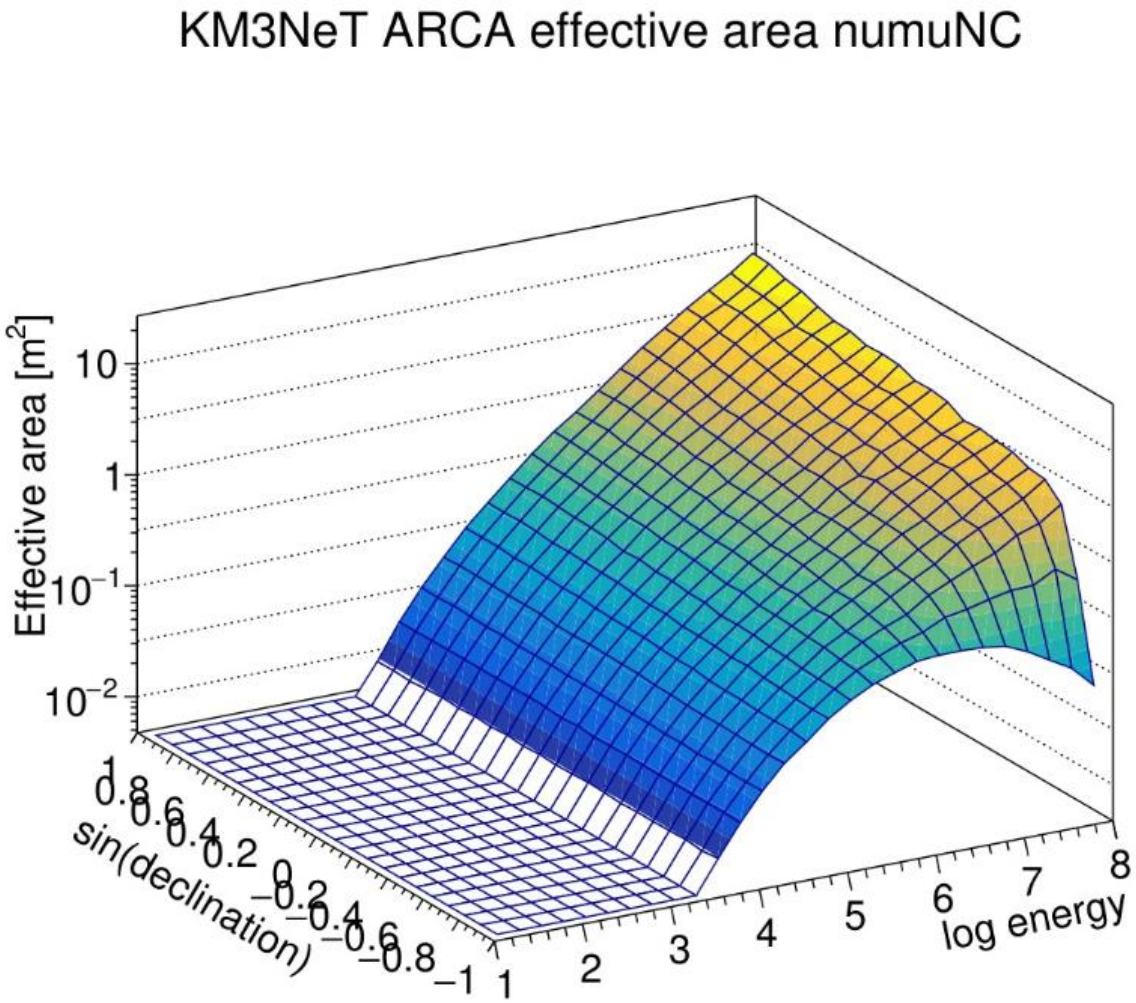

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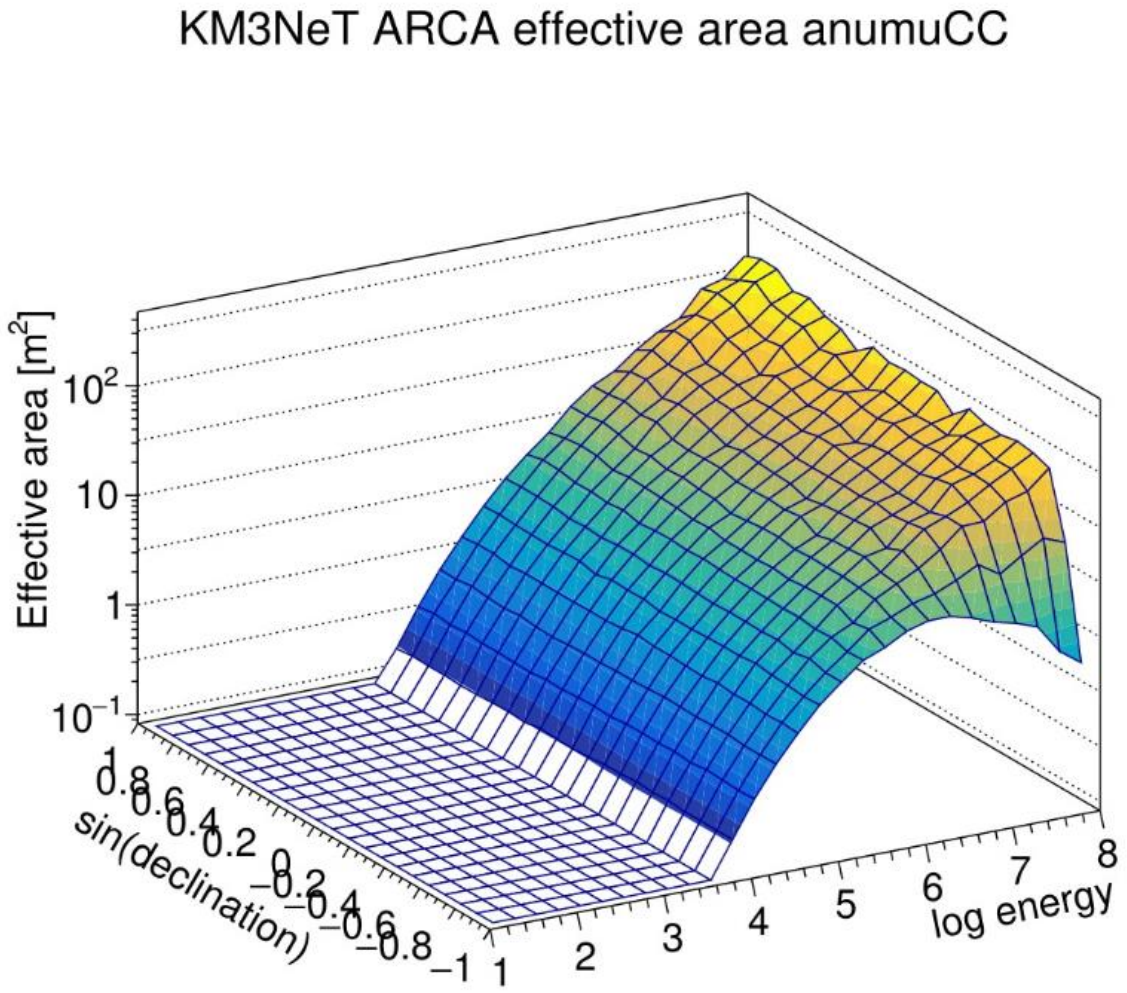
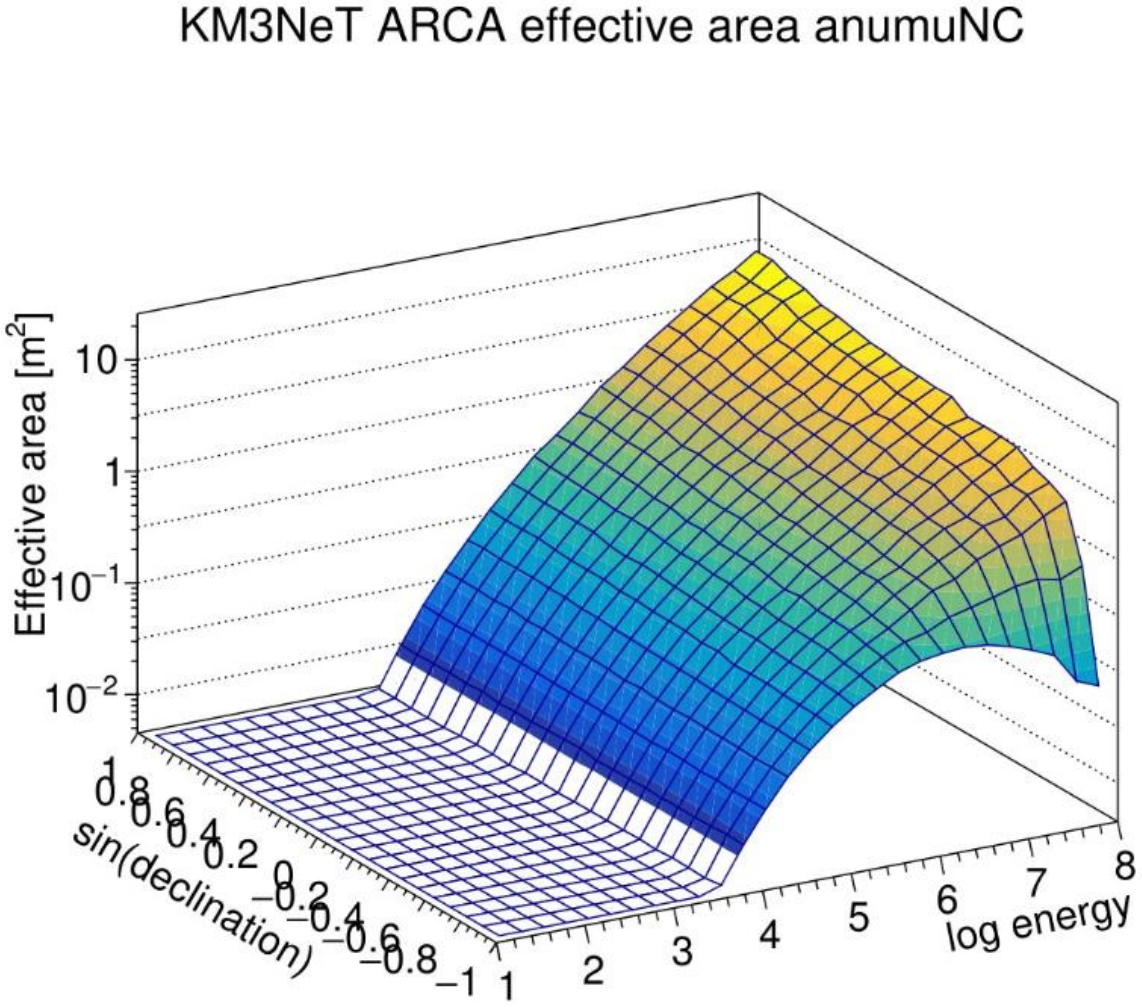
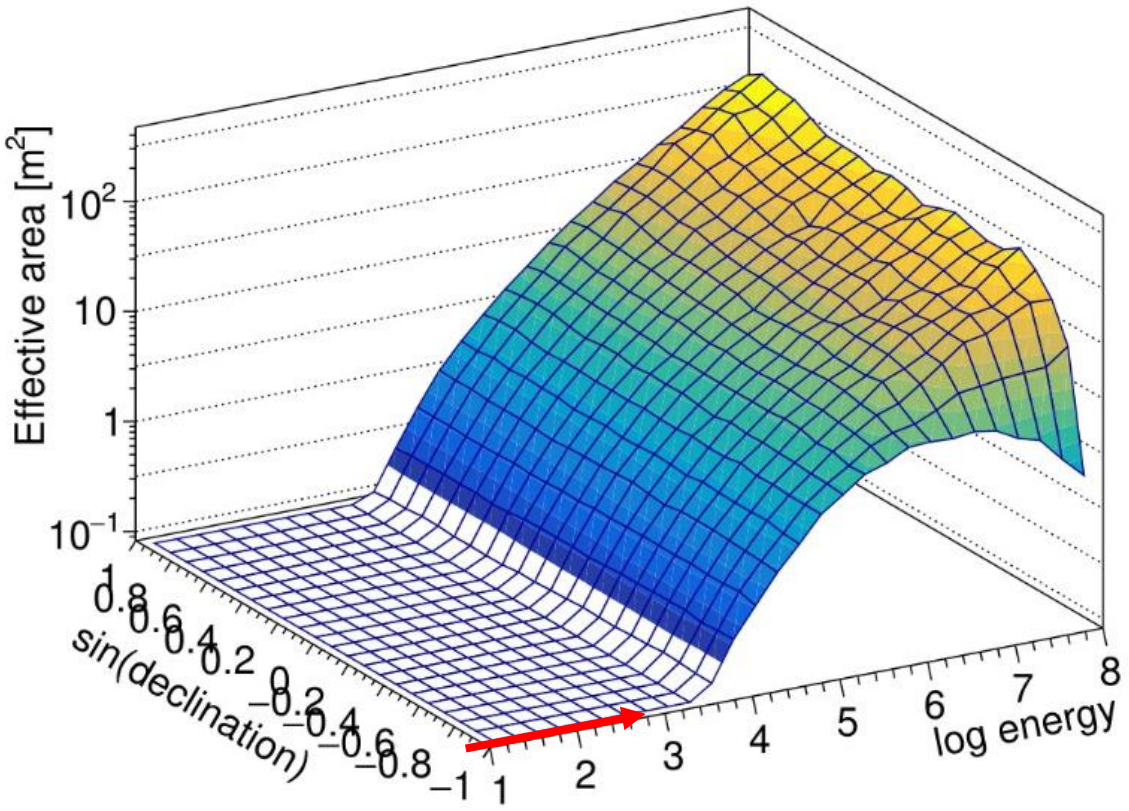


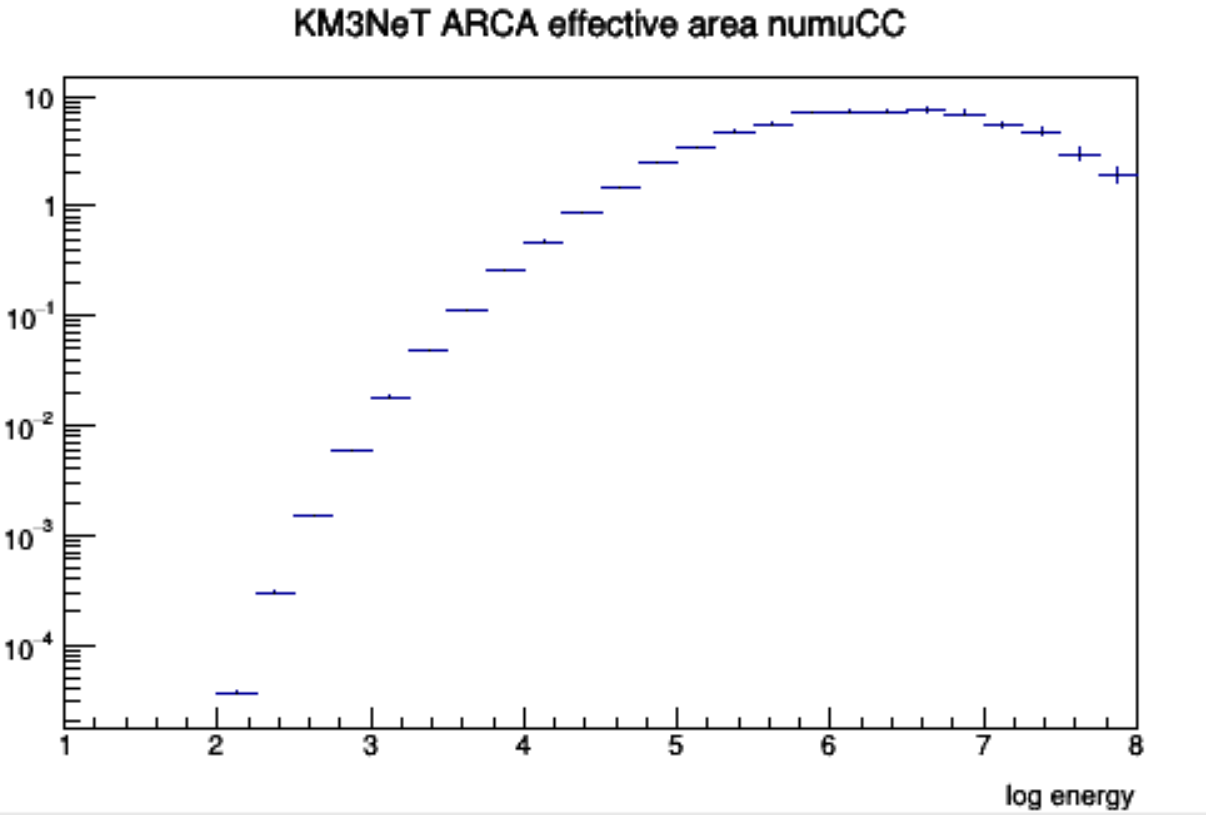



# Effective Area = ratio between the rate of detected events and the total flux of neutrinos

KM3NeT ARCA effective area numuCC




1st bin: sin(dec) = -1.05



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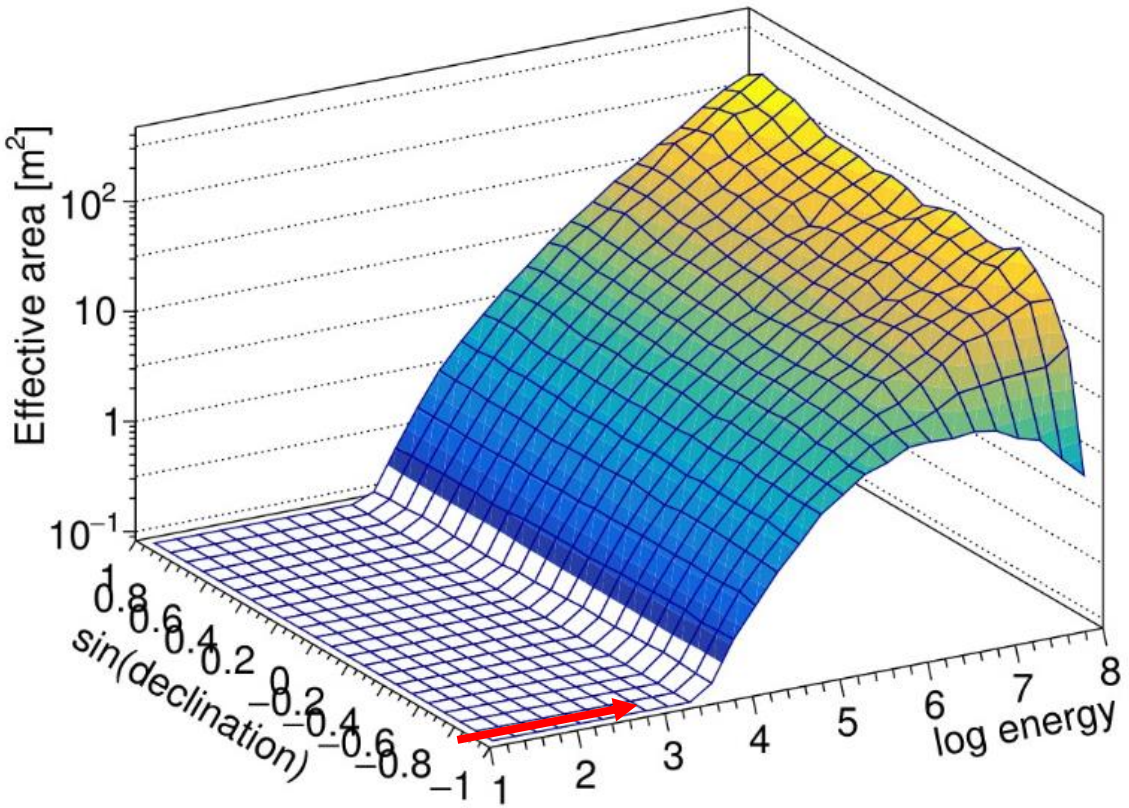
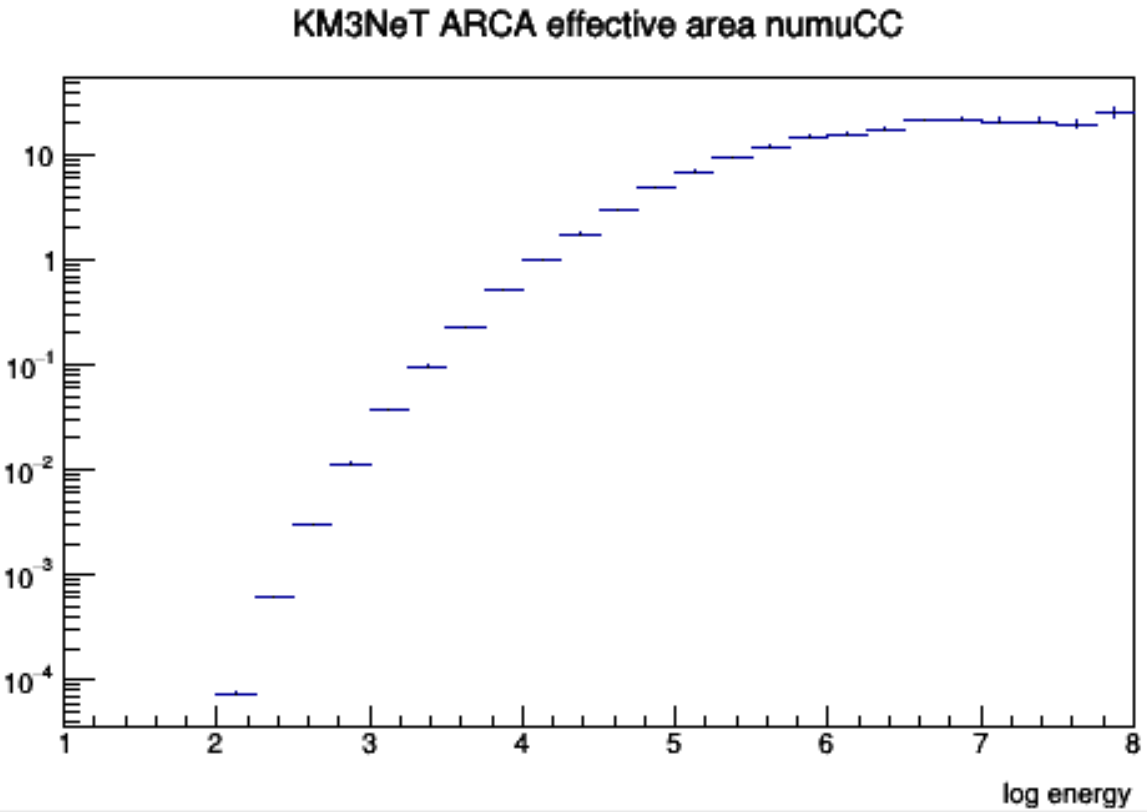



$2^{nd}$ bin sin(dec) = -0.95



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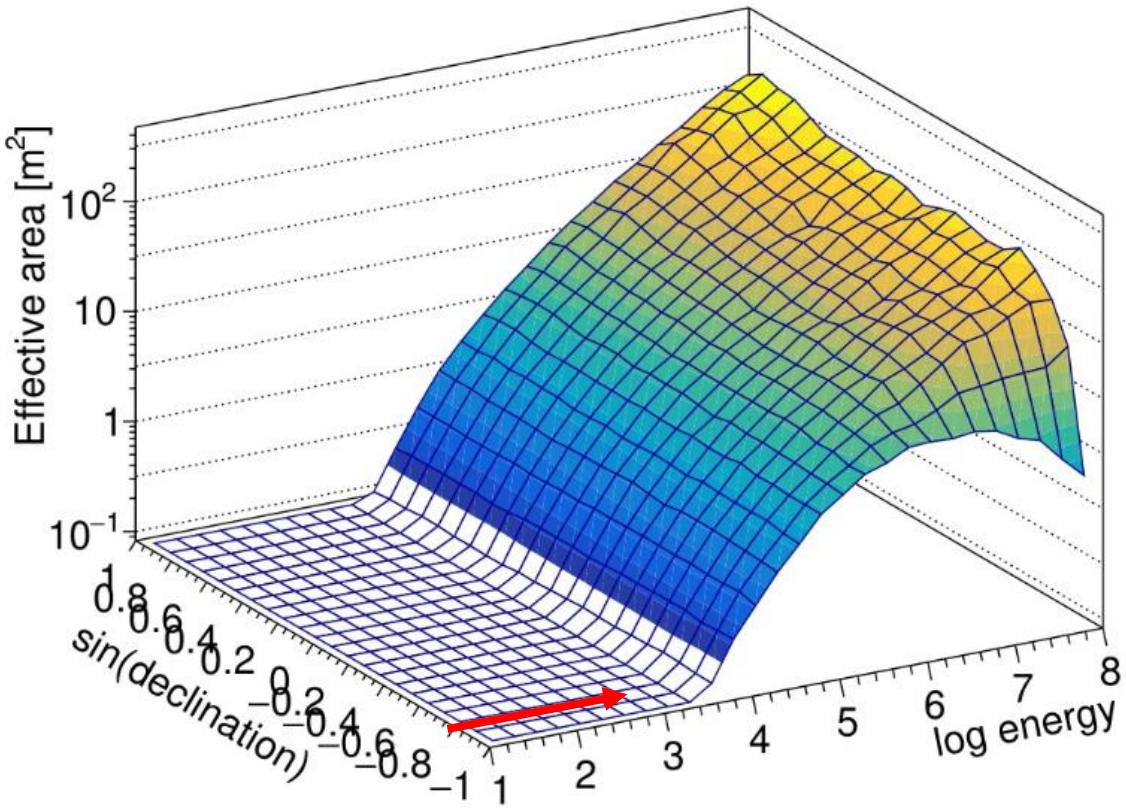
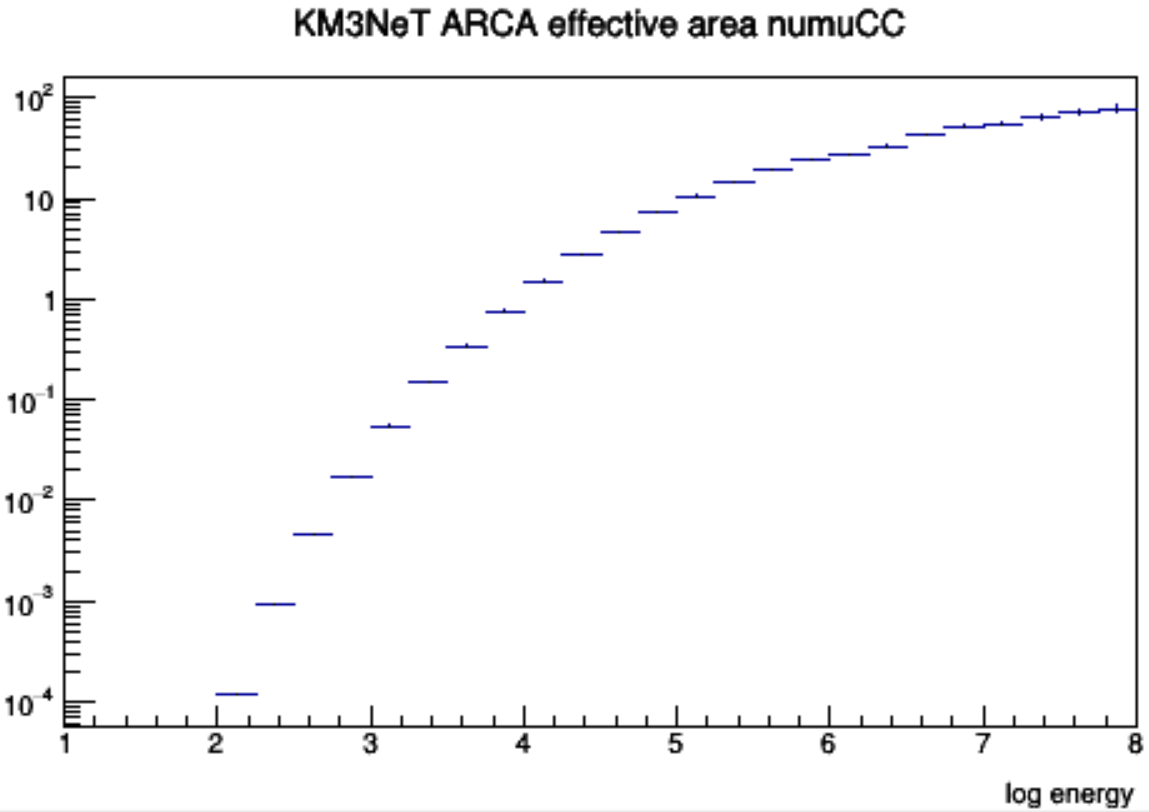



3rd bin sin(decl) = -0.77



# Questions to answer:

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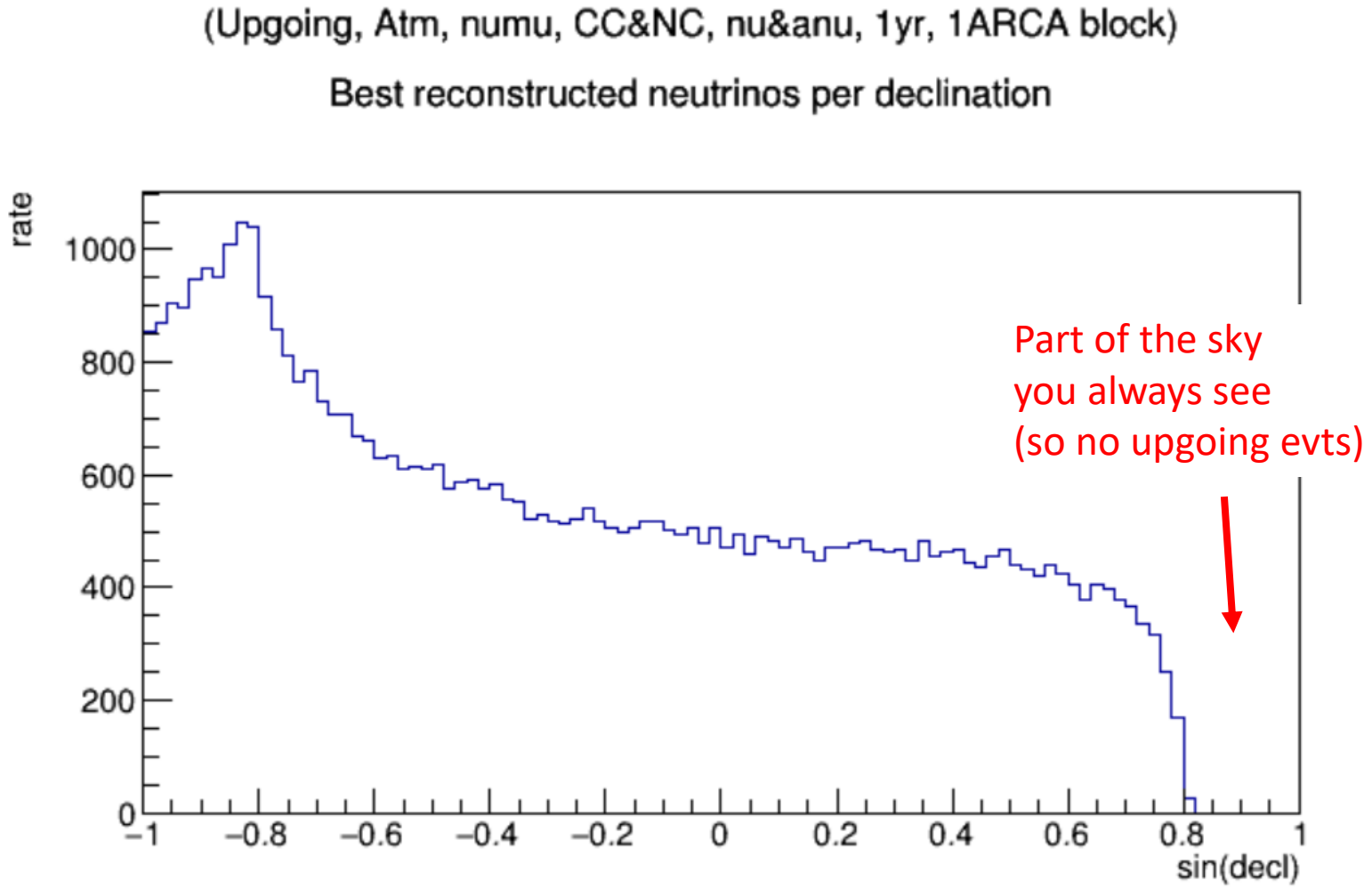
# Background events per declination

- Atmospheric background neutrinos (Honda Flux)
- "With the ARCA telescope 87% of the sky will be mapped including most of the Galaxy and the Galactic Center" (km3net.org)



# Background events, total #

| Atmospheric neutrinos | | MC output * (1block 1yr) | 2 blocks & 5yrs | NC & CC together | LOI 2016 |
|---|---|---|---|---|---|
| **All directions** | **numuCC** | 62586 | 826518 | 8.67e5 | 1.6e6 |
| **All directions** | **anumuCC** | 20066 | | | |
| **All directions** | **numuNC** | 3281 | 40094 | | |
| **All directions** | **anumuNC** | 729 | | | |
| **Upgoing** | **numuCC** | 36663 | 484760 | 5.08e5 | |
| **Upgoing** | **anumuCC** | 11813 | | | |
| **Upgoing** | **numuNC** | 1932 | 23628 | | |
| **Upgoing** | **anumuNC** | 431 | | | |

** Of all available 200 MC files*

# Background events, total #

Quantify/ Check!

*"What was changed from the LoI to the new MC is the trigger that mainly affect the low energy part and the can size that gives up to 20% more effective areas at high energy." […] "for atmospheric neutrino the effect at low energy is the predominant." (Rosa)*

| Atmospheric neutrinos | | MC output * (1block 1yr) | 2 blocks & 5yrs | NC & CC together | LOI 2016 |
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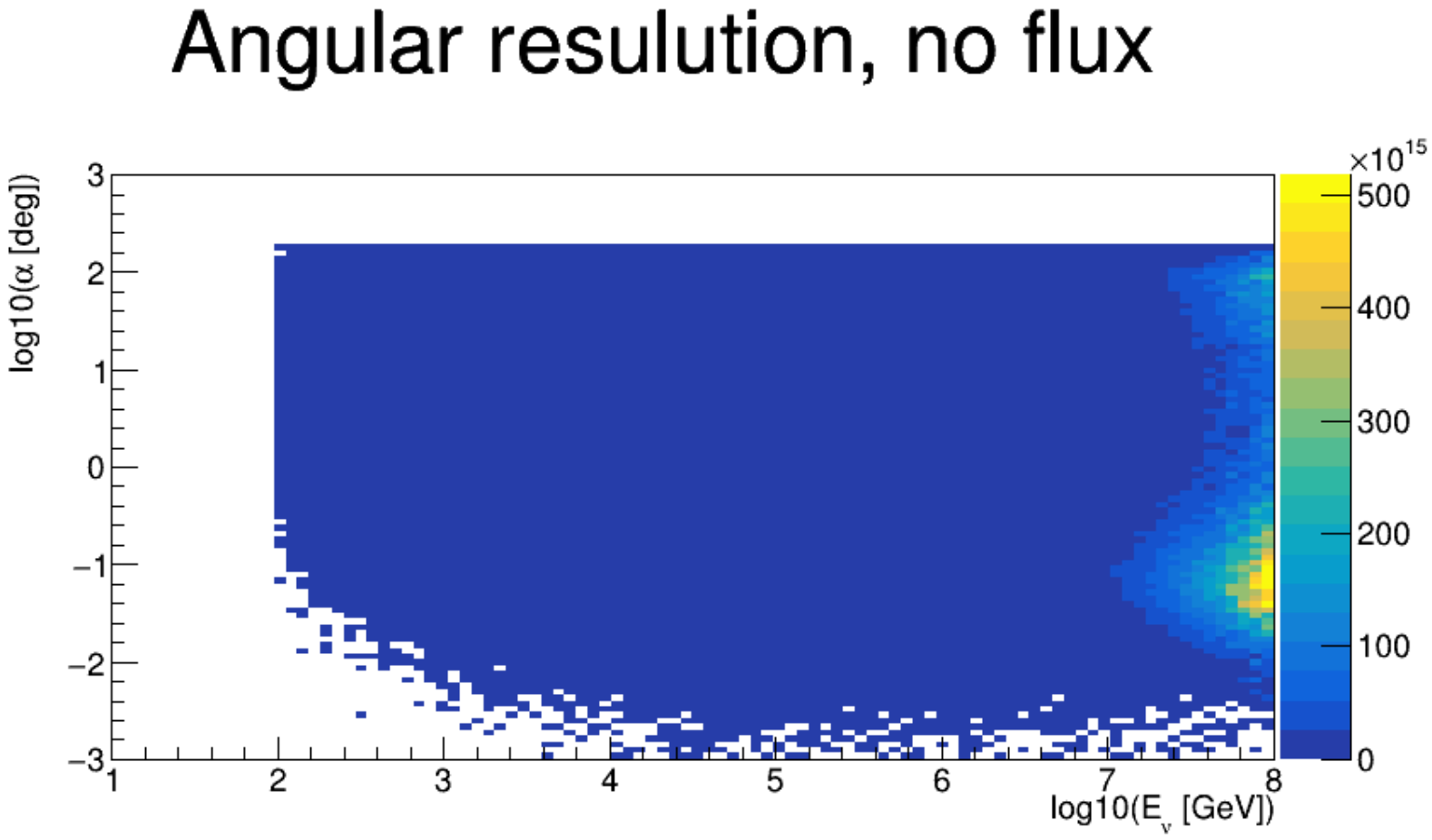
# Angular resolution of ARCA

- Angle between best reconstructed track, and the primary neutrino

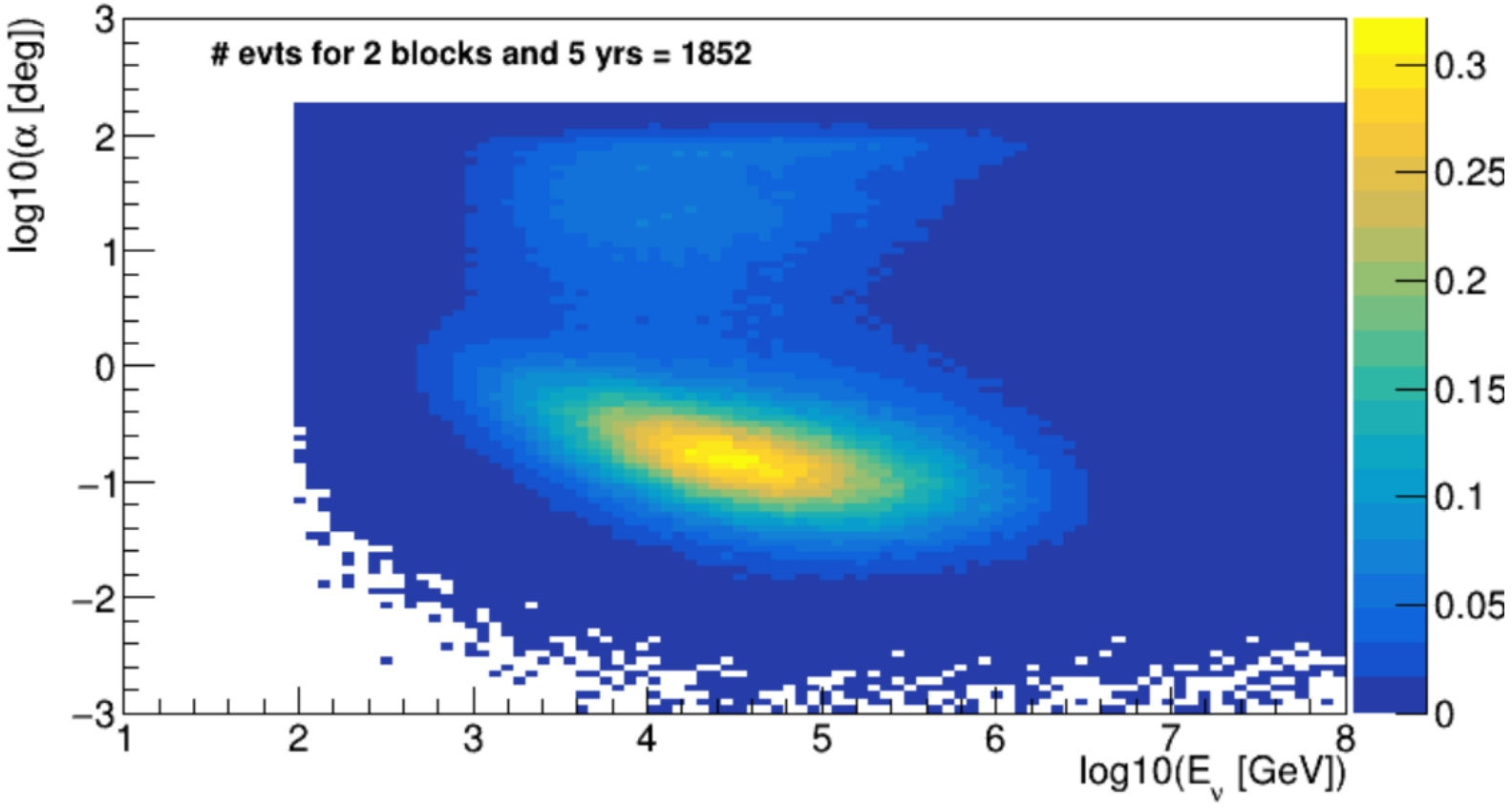


# Angular resolution of ARCA

- Angle between best reconstructed track, and the primary neutrino

- Cosmic neutrinos -> choose flux

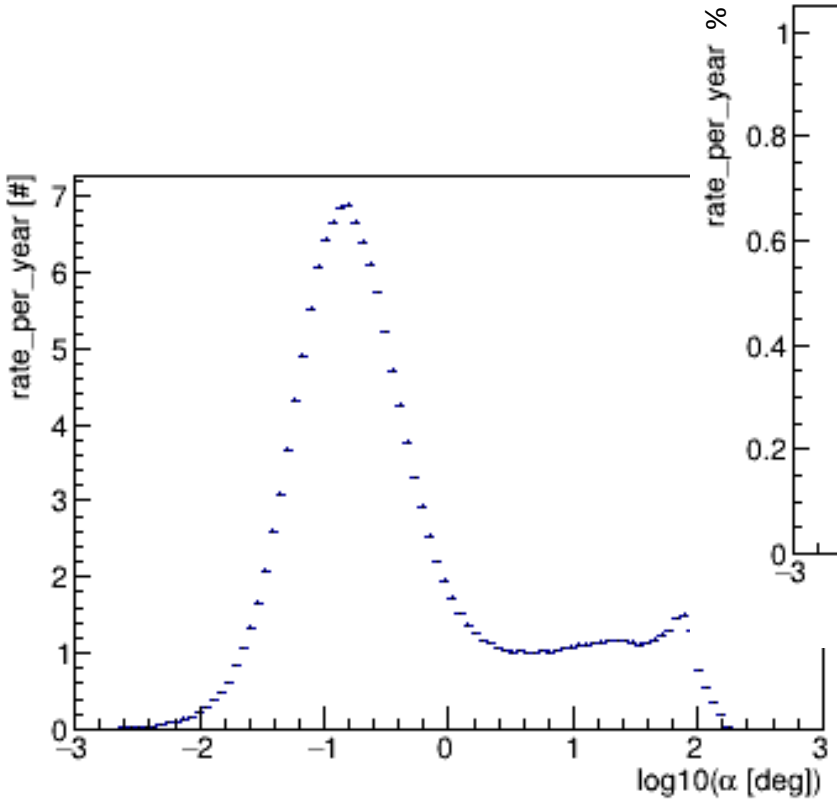
$$\Phi(E_\nu) = 1.2 \times 10^{-8} \cdot \left(\frac{E_\nu}{\mathrm{GeV}}\right)^{-2} \cdot \exp\left(-\frac{E_\nu}{3\,\mathrm{PeV}}\right) \quad \mathrm{GeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$$

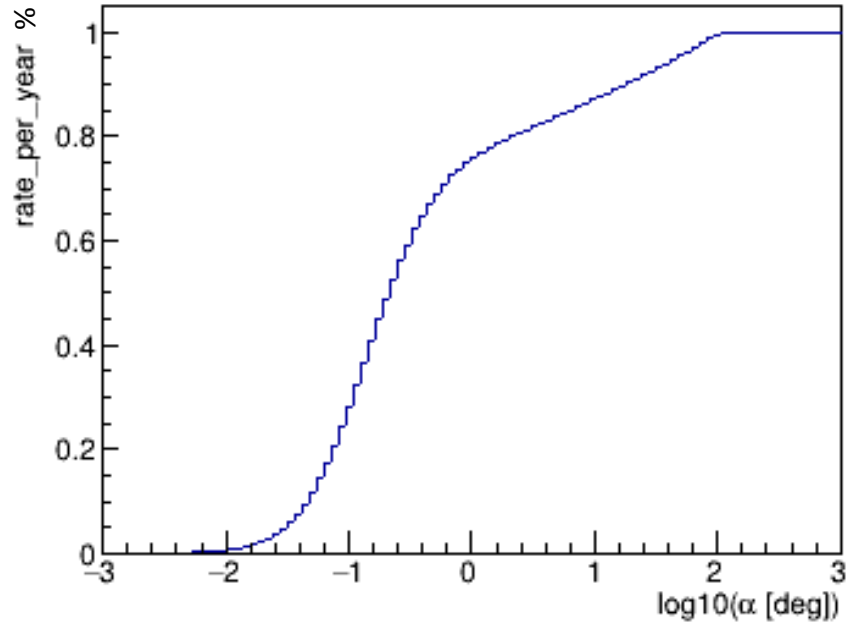


# Angular resolution of ARCA

- Angle between best reconstructed track, and the primary neutrino
- Cosmic neutrinos -> choose flux
- ~ 80% better than 1 degree

$$\Phi(E_\nu) = 1.2 \times 10^{-8} \cdot \left(\frac{E_\nu}{\mathrm{GeV}}\right)^{-2} \cdot \exp\left(-\frac{E_\nu}{3\,\mathrm{PeV}}\right) \quad \mathrm{GeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$$



# Angular resolution of ARCA, total #

$$\Phi(E_\nu) = 1.2 \times 10^{-8} \cdot \left(\frac{E_\nu}{\mathrm{GeV}}\right)^{-2} \cdot \exp\left(-\frac{E_\nu}{3\,\mathrm{PeV}}\right) \quad \mathrm{GeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$$

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| All directions | anumuCC | 77 | | | |
| All directions | numuNC | 6 | 102 | | |
| All directions | anumuNC | 4 | | | |
| Upgoing | numuCC | 48 | 859 | 9.1e2 | |
| Upgoing | anumuCC | 37 | | | |
| Upgoing | numuNC | 3 | 51 | | |
| Upgoing | anumuNC | 2 | | | |

** Of all available 200 MC files*

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$$\Phi(E_\nu) = 1.2 \times 10^{-8} \cdot \left(\frac{E_\nu}{\mathrm{GeV}}\right)^{-2} \cdot \exp\left(-\frac{E_\nu}{3\,\mathrm{PeV}}\right) \quad \mathrm{GeV}^{-1}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$$

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| Upgoing | numuNC | 3 | 51 | | |
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** Of all available 200 MC files*

**Quantify/ Check!**

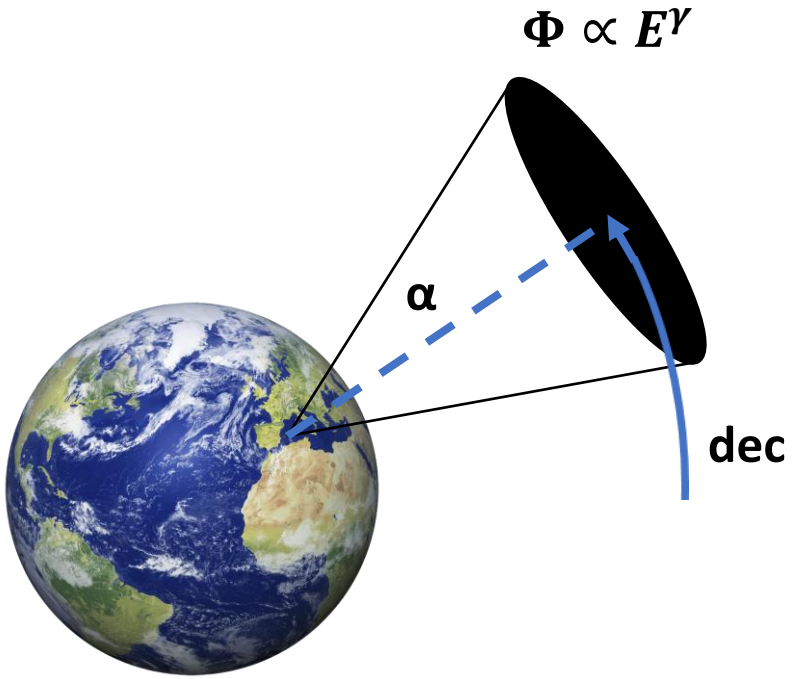
*"I think that for the source spectrum, that have a different slope compared to atmospheric neutrinos, the two effects are compensated" (Rosa)*

# Questions to answer:

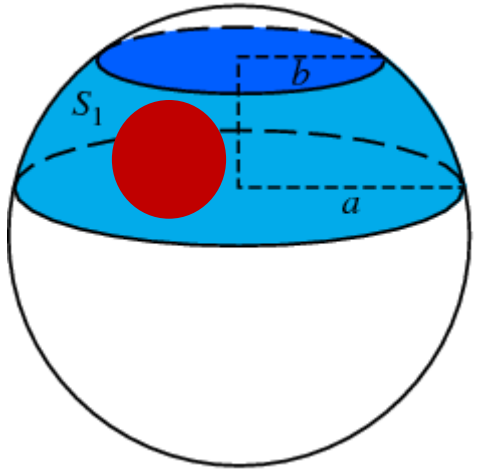
1. What is the effective area?
2. How does the number of measured background events depend on declination?
3. What is the expected angular resolution of KM3NeT ARCA?

4. **Given the duration of measurement: which fluxes of pointsources can be discovered? / Given the flux of a source: how long do we have to measure to detect it?**
5. What is the expected performance of the detector aka what is the ‘sensitivity’ of KM3NeT ARCA for a specific signal?

# Pick searchcone (dec, α) & spectral index (γ)

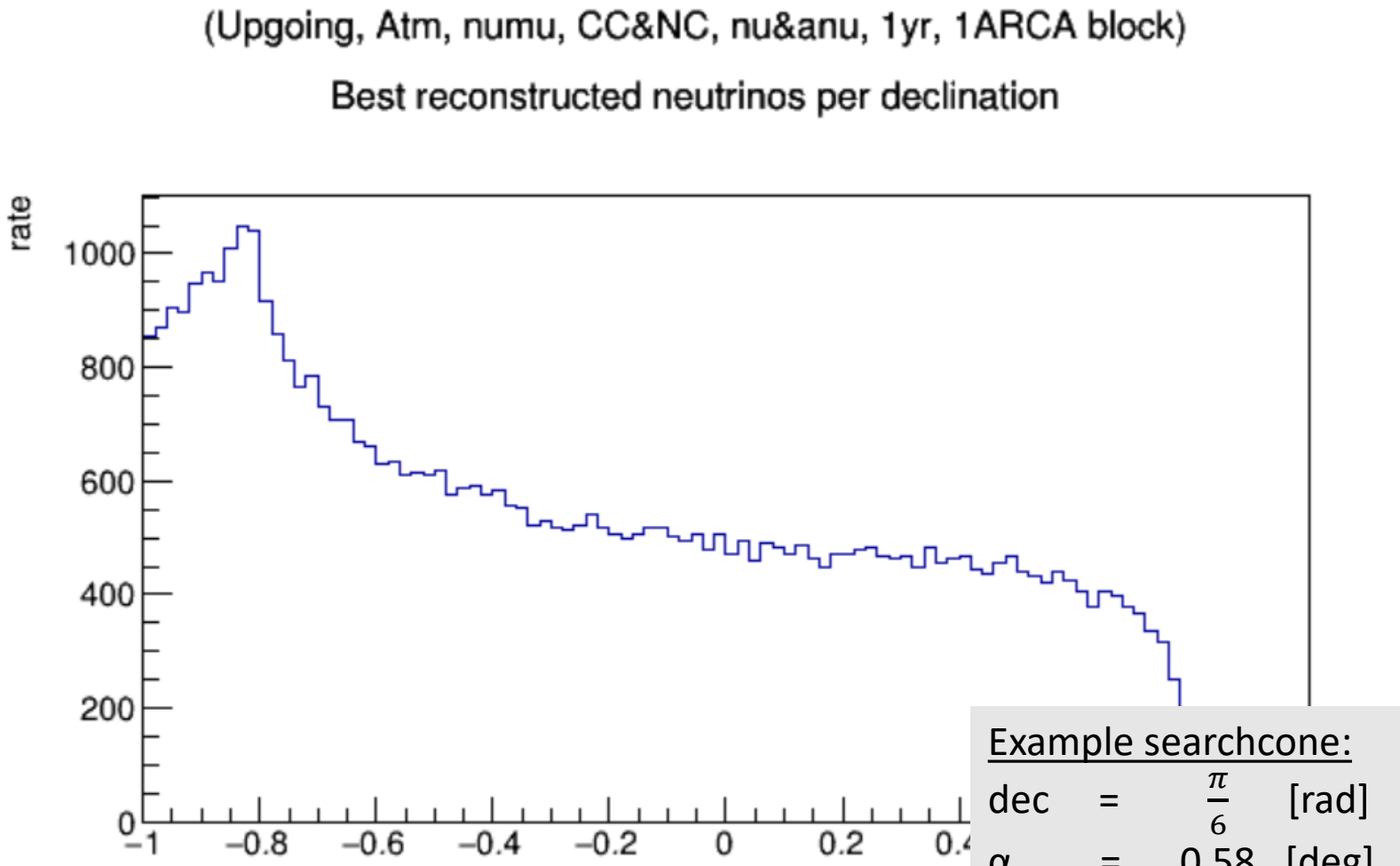


# # bkg ν's in search cone in *nyears* block$^{-1}$




in x year:

$$\langle N_{bkg} \rangle = x \cdot 1.106$$




Example searchcone:

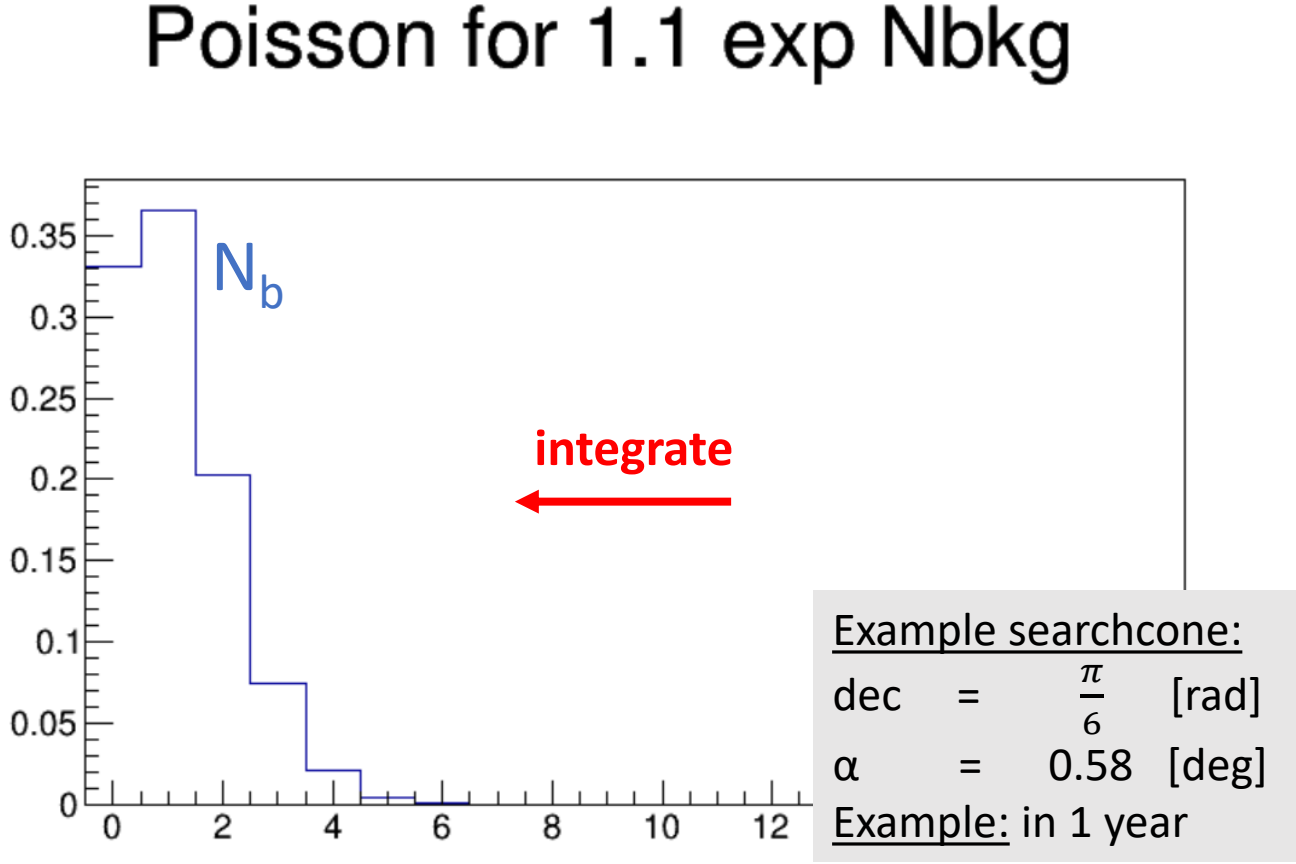
dec = $\frac{\pi}{6}$ [rad]

α = 0.58 [deg]

# For given SC & bkg, how much sig for 3σ/5σ?

- **Discovery potential** = signal strength which leads to 3σ/5σ discovery

- 3σ ⇔ 2.7 e -3
- 5σ ⇔ 5.7 e -7

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Example: in 1 year

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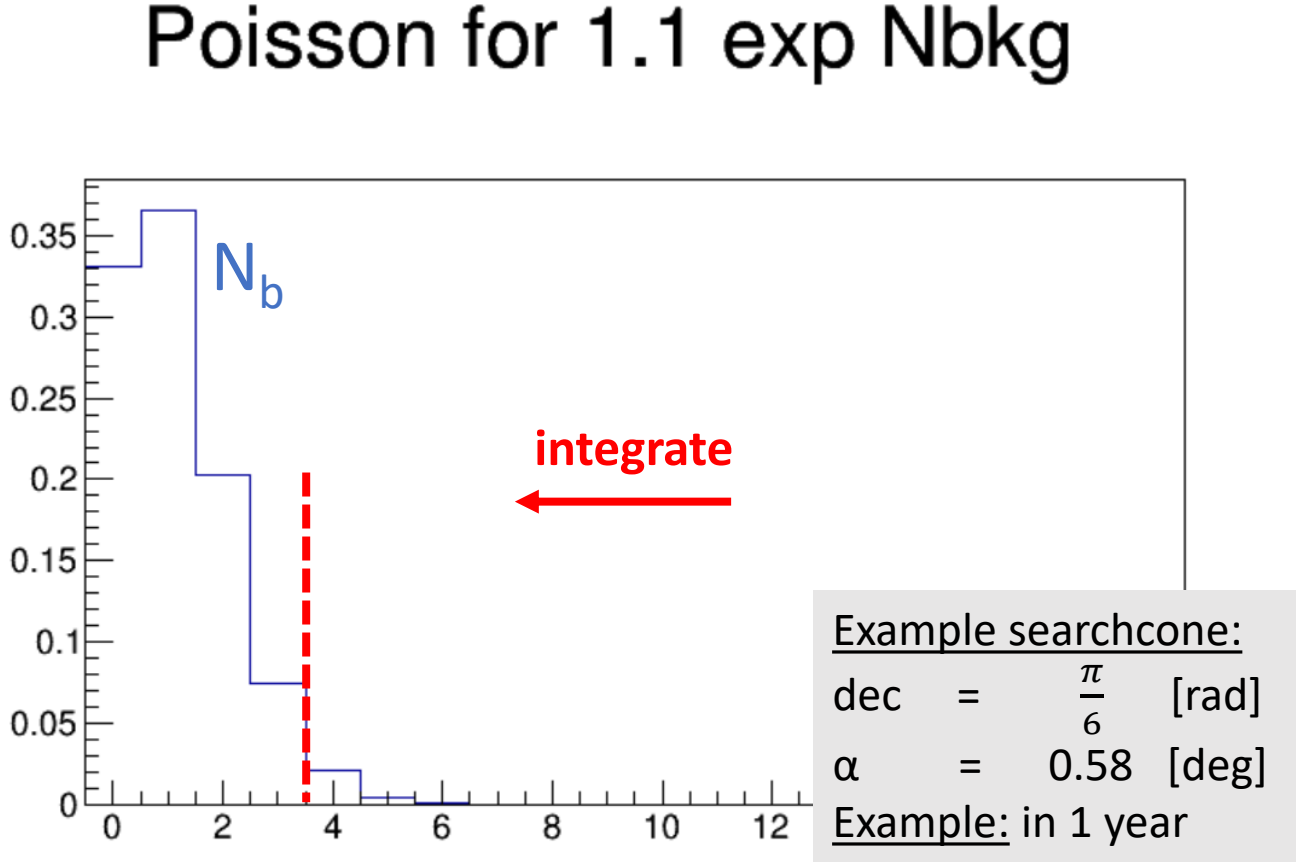


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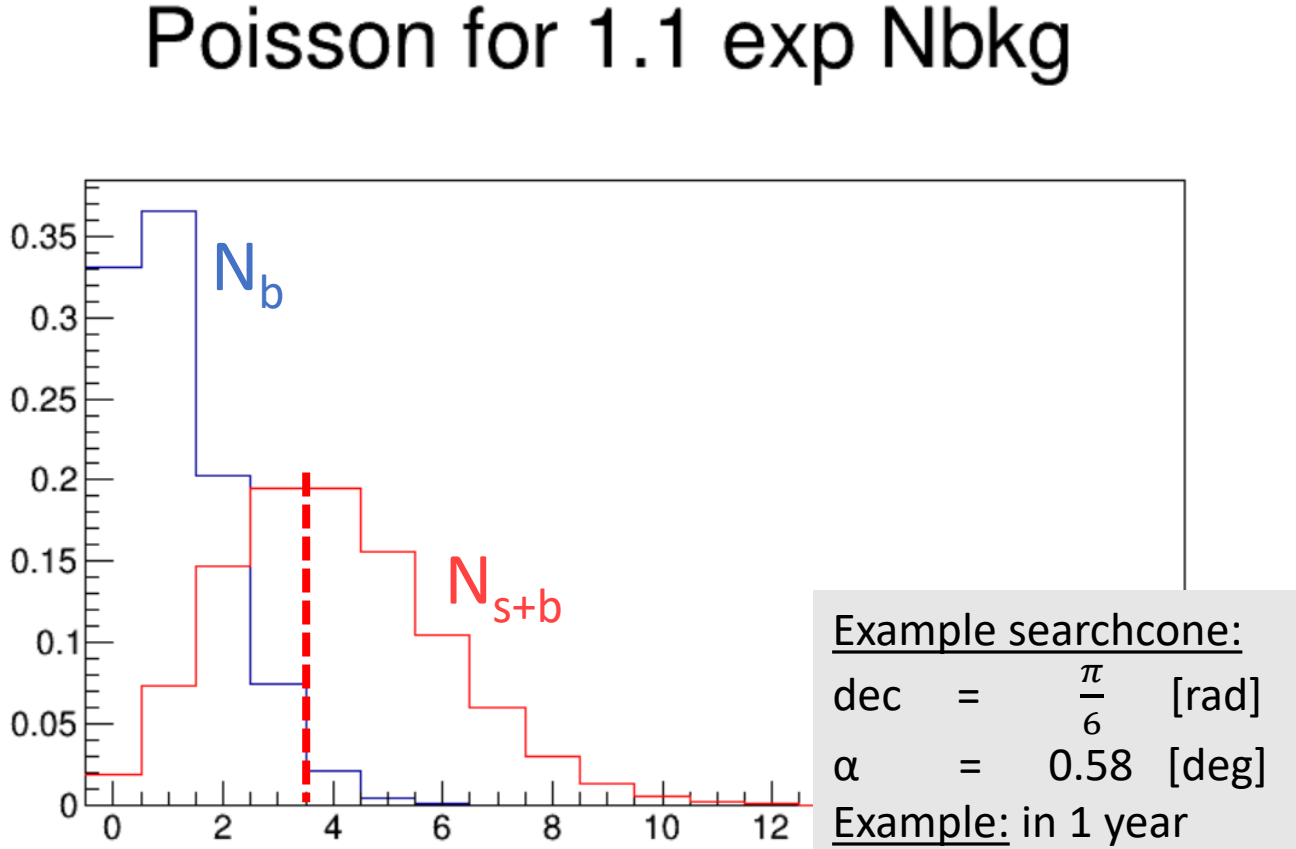



Example searchcone:

dec = $\frac{\pi}{6}$ [rad]

α = 0.58 [deg]

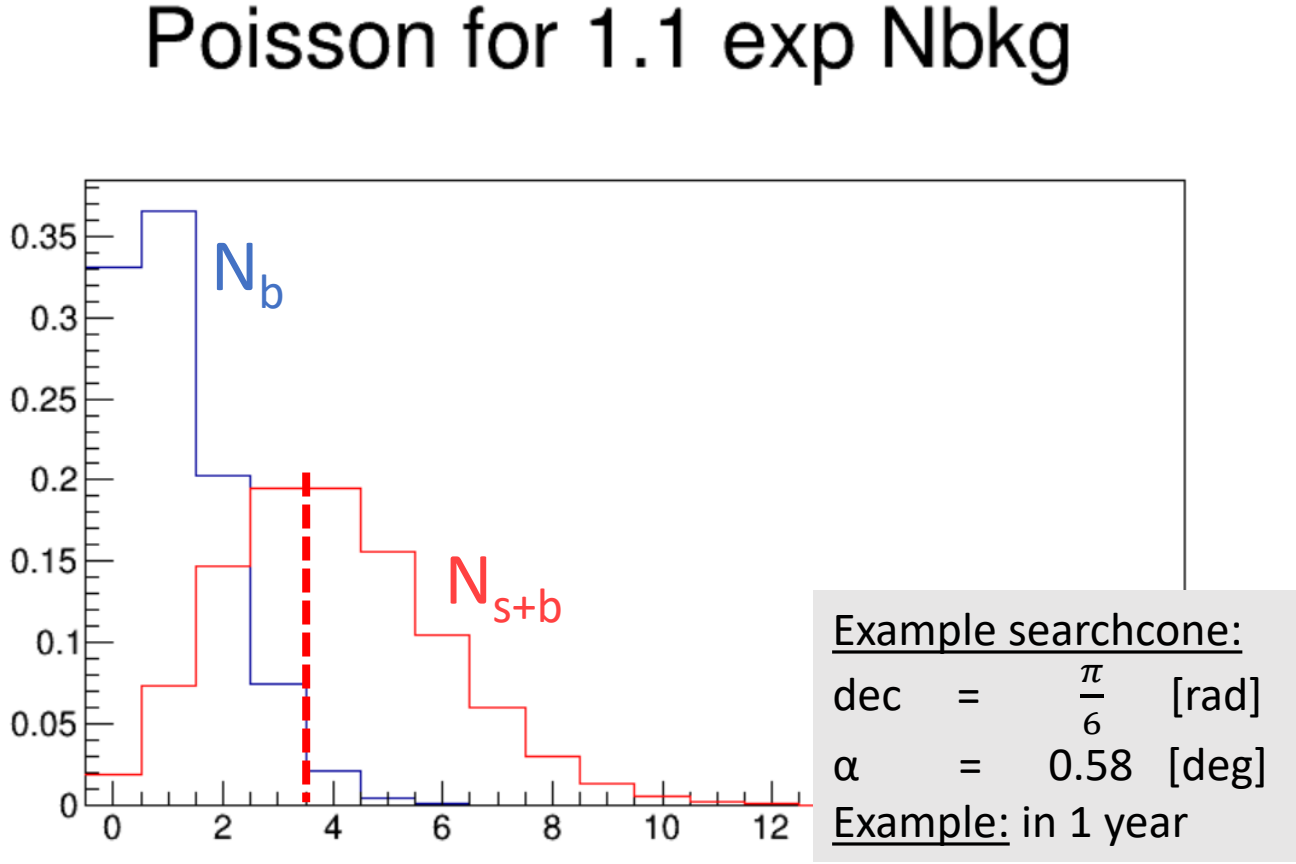
Example: in 1 year

# For given SC & bkg, how much sig for 3σ/5σ?

- **Discovery potential** = signal strength which leads to 3σ/5σ discovery

- 3σ ⇔ 2.7 e -3 ⇔ 2.89
- 5σ ⇔ 5.7 e -7 ⇔ 6.89

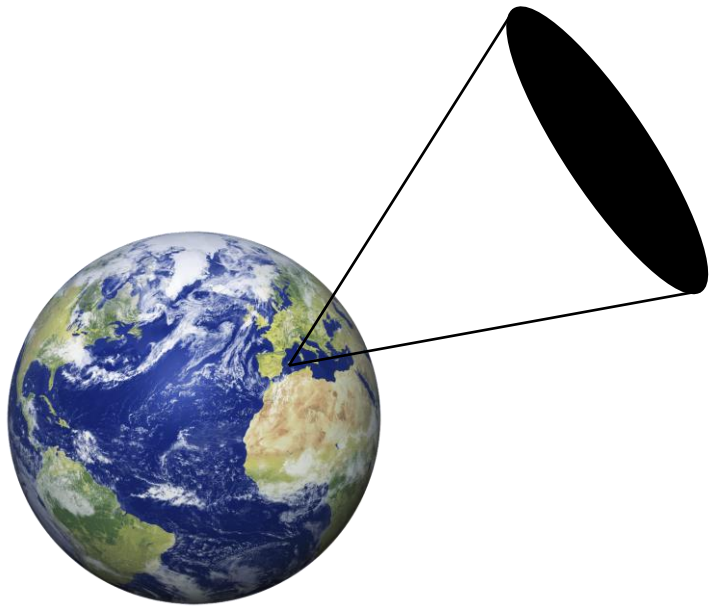
- $N_{s+b} - N_b = N_s$



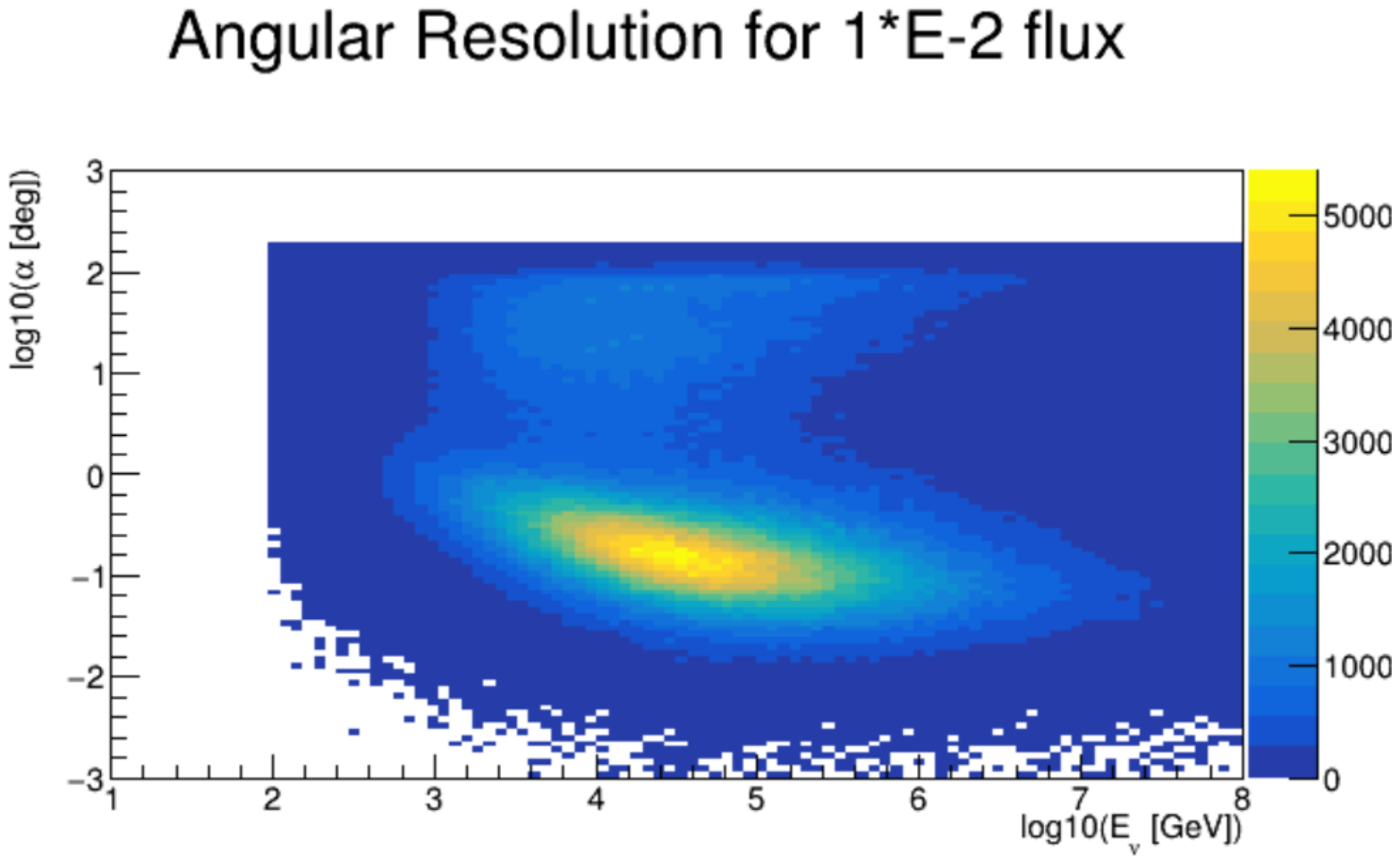

Example searchcone:
dec = $\frac{\pi}{6}$ [rad]
α = 0.58 [deg]
Example: in 1 year

# # cosmic ν's $yr^{-1}$ $block^{-1}$

$\Phi = c \cdot E^{-2}$ [$GeV^{-1}s^{-1}m^{-2}$]



**Prefactor Flux ($c$)** = ratio Nsig / NsigE-2



# Fluxes of pointsources to discover

Example searchcone:

dec = $\frac{\pi}{6}$ [rad]

α = 0.58 [deg]

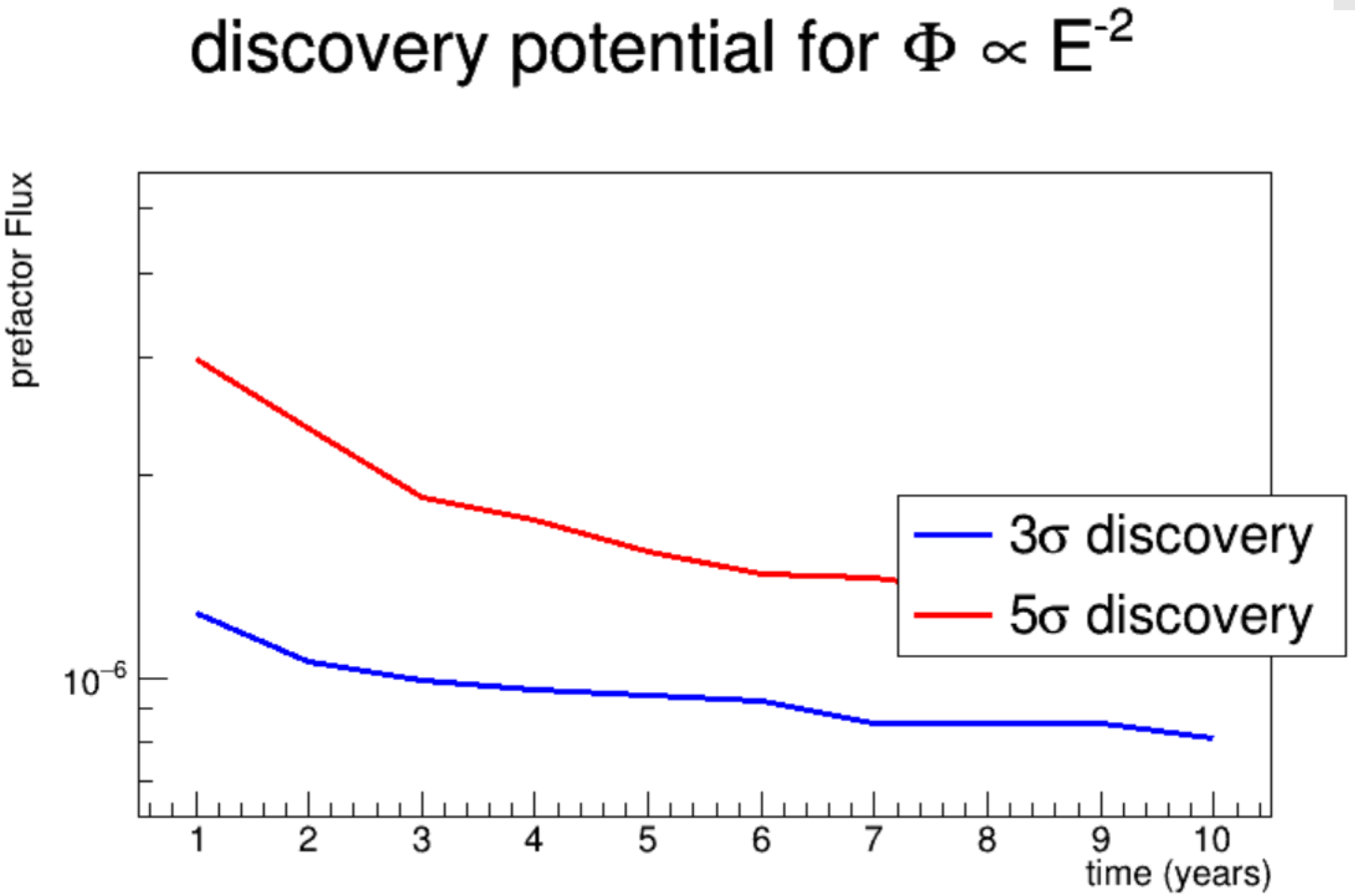
| # years | $\langle Nbkg \rangle$ in sc | $\langle Nsig \rangle$ $3\sigma$ | $3\sigma$ Flux prefactor | $\langle Nsig \rangle$ $5\sigma$ | $5\sigma$ Flux prefactor |
|---|---|---|---|---|---|
| 1 | 1.106 | 2.894 | 1.247e-06 | 6.894 | 2.970e-06 |
| 2 | 2.212 | 4.894 | 1.054e-06 | 10.894 | 2.347e-06 |
| 3 | 3.318 | 6.894 | 9.901e-07 | 12.894 | 1.852e-06 |
| 4 | 4.424 | 8.894 | 9.580e-07 | 15.894 | 1.712e-06 |
| 5 | 5.530 | 10.894 | 9.387e-07 | 17.894 | 1.542e-06 |
| 6 | 6.636 | 12.894 | 9.259e-07 | 19.894 | 1.429e-06 |
| 7 | 7.742 | 13.894 | 8.552e-07 | 22.894 | 1.409e-06 |
| 8 | 8.848 | 15.894 | 8.560e-07 | 24.894 | 1.341e-06 |
| 9 | 9.954 | 17.894 | 8.566e-07 | 26.894 | 1.287e-06 |
| 10 | 11.060 | 18.894 | 8.140e-07 | 28.894 | 1.245e-06 |

# Fluxes of pointsources to discover

Example searchcone:

dec = $\frac{\pi}{6}$ [rad]

α = 0.58 [deg]



# Future plans: check check double check

- Quantify & explain contribution of NC to muon signal
- Quantify Rosa's statements over number of evts compared to LOI
- What if opening angle is bigger than binsize sin(decl)
- Float ⇔ Integer number of events
- Work with median instead of mode of poisson
- Also include declination dependency of cosmic sources
- Fluxes with changing spectral index over E
- Flux vs time for X years => also within 1 year => first discoveries?

- How to compute sensitivity curve! => literature?

# Future plans: more interesting

- How do these answers depend on size of source/searchcone → Optimise searchcone
- How do our results/the KM3NeT sensitivity compare to other experiments?
- Make predictions for existing sources: Catalogsearches
- Not only $\nu_\mu$ but also $\nu_e$ and $\nu_\tau$
- Other possible background sources
- Unbinned
- Full sky search
- Include results from reconstruction etc.
- Prepare first 'real data' analysis

- *Any other suggestions are always welcome*

Thank you