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# Magnetic Monopole Search with ANTARES

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**On behalf of the Antares collaboration**

# *Outlines*

- Introduction
- Antares Neutrino Telescope
- Magnetic Monopole analysis
- Conclusion

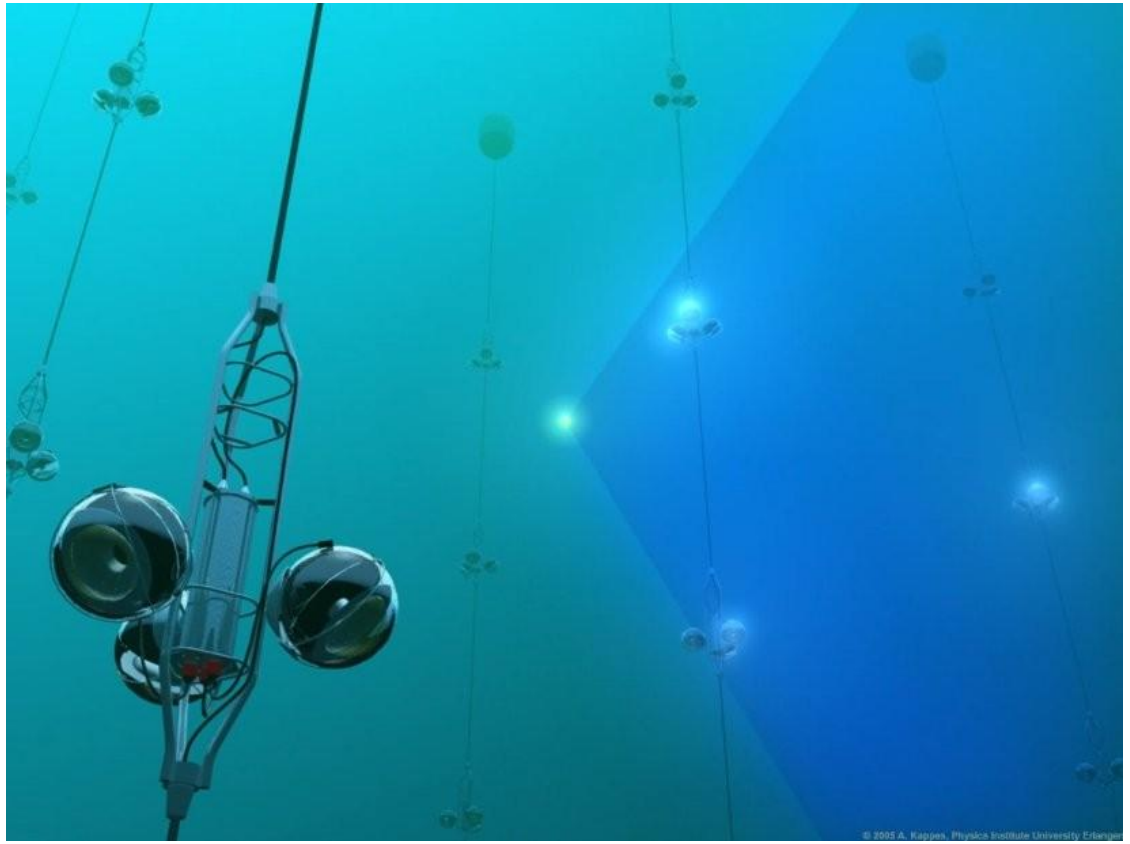
# *Introduction: Magnetic Monopoles*

- Particles with one magnetic pole : the magnetic counterparts of electric charges.
- MM discovery would lead to a Symmetry in Maxwell's equations.
- Quantization of the electric charge (Dirac in 1931).
- Grand Unification Theories : MM would be created after the Big Bang (during the phase transition of symmetry breaking).
- There are also MM with lower masses resulting from Electroweak transition.
- The mass of GUT MM could exceed $10^{14}$ GeV/$c^2$.
- The rarity of GUT MM is a motivation to the scenario of inflation.
- MM would only be expected as up going events in neutrino telescopes if their mass :

$$M \lesssim 10^{14}\ \mathrm{GeV}/c^2$$

# *Antares Neutrino Telescope*

- Antares :Astronomy with a Neutrino Telescope and Abyss environmental RESearch:
- Cherenkov based neutrino telescope
- 2475 m below the surface of the Mediterranean Sea
- 40km offshore from Toulon (France)
- 12 detection line of about 350m each
- Each line has 25 floor with 3 optical modules sensitive to the wavelength region λ~[300,600]nm,



# *Magnetic Monopole analysis*

- The simulations includes magnetic monopoles, atmospheric muons and neutrinos (latest MC production)

- The simulation based on Kasama, Yang and Goldhaber (KYG) model of cross section (***Y. Kazama et al., Scattering of a Dirac particle with charge Ze by a fixed magnetic monopole, Phys. Rev. D 15 (1977) 2287***), of magnetic monopoles has been performed, for $\beta = v/c = 1$.

- All productions are based on RBR V4 simulation which is a MonteCarlo simulation that follows a run-by-run processing taking into account the real acquisition conditions for each run including the degradation of the optical modules efficiency

- Magnetic Monopoles were simulated in the range of $\beta = v/c$ [0.817 , 0.995] split into 4 equaly distant intervals

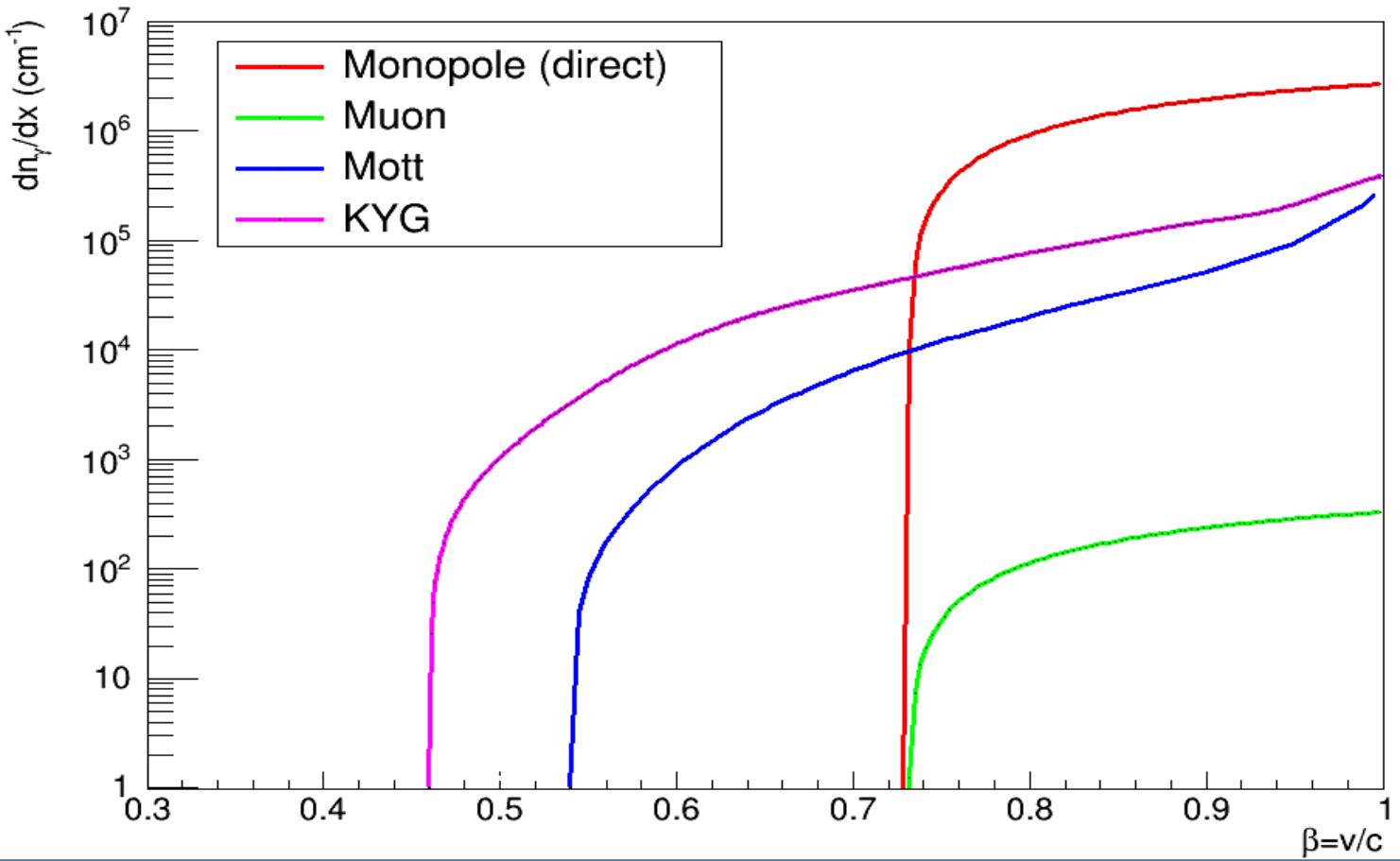
- Data considered are collected by the ANTARES telescope between January 2008 to December 2017.

# *Magnetic Monopole simulation*

- The MM simulation relies on the package **Simon** provided by the Antares collaboration.
- It is based on the ***genneu*** and ***geasim*** Monte Carlo generators used to simulate muons passage in the detector.
- The main programs in the package used for MMs simulation are named ***Genmon*** and ***Geamon***.
- 500 events were generated per run simulated as tracks.

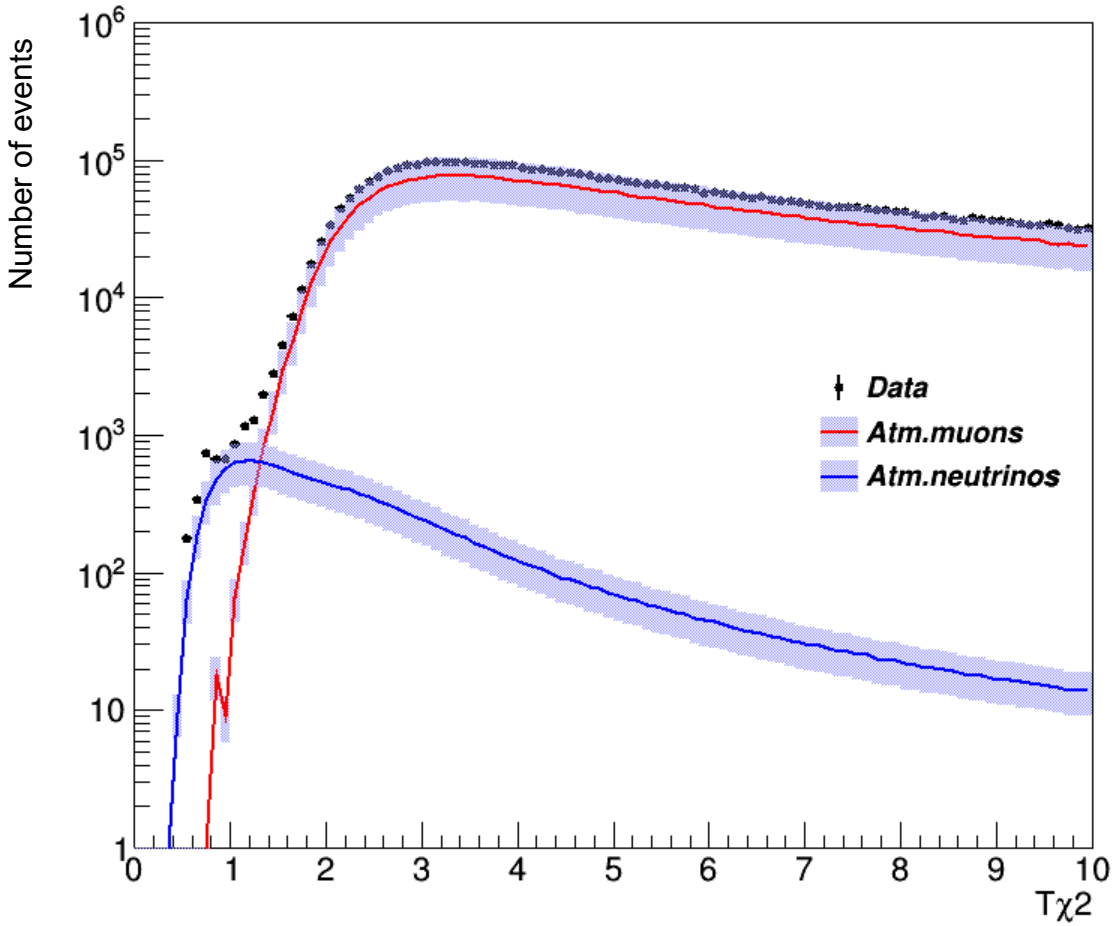
# *Light yield*

- Number of Cherenkov photons emitted per cm in the sea water




The new simulation of MM relies on KYG model for the emission of delta-rays giving a higher amount of light with respect to the Mott model of cross section

# Agreement plots




***Initial cuts :***
***nlines ≥ 2 & zenith ≤ 90 & tχ2 < 10***

**The first one is applied on the Zenith angle less than 90° and it aims to select only upgoing events**

**In the second one, we require only events reconstructed with at least 2 lines of the detector**

**The last primary cut chosen is that the quality of reconstruction is inferior to 10,**

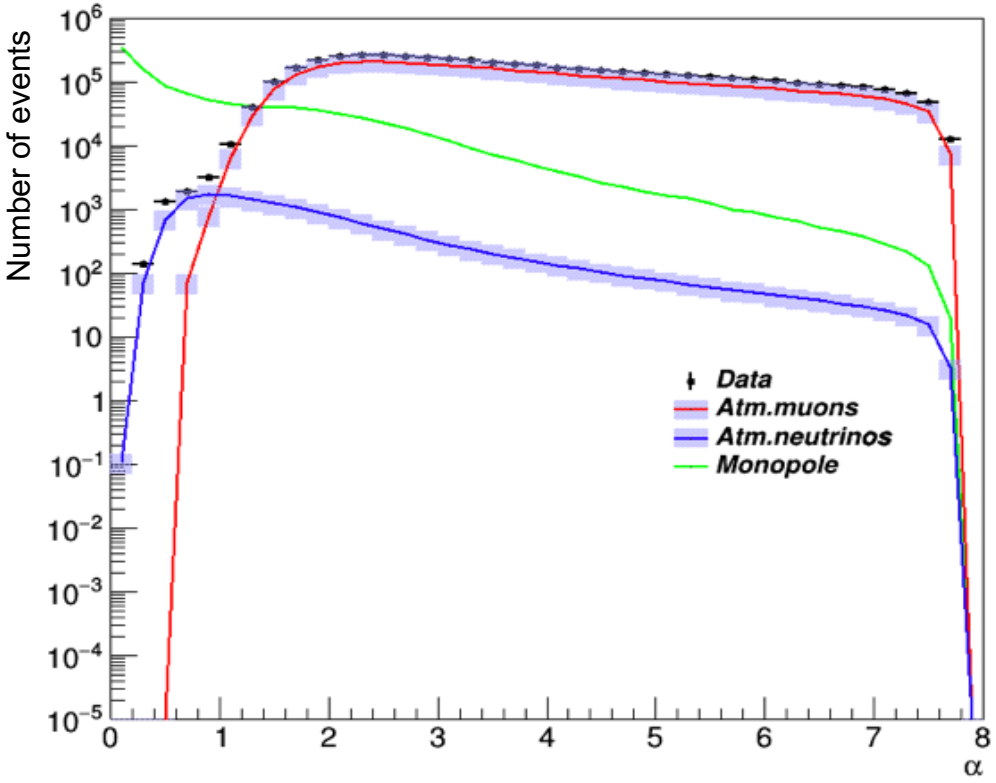
**tχ2 : Quality of reconstruction**

We are considering only 10% of the Data taken by the telescope in the agreement plots

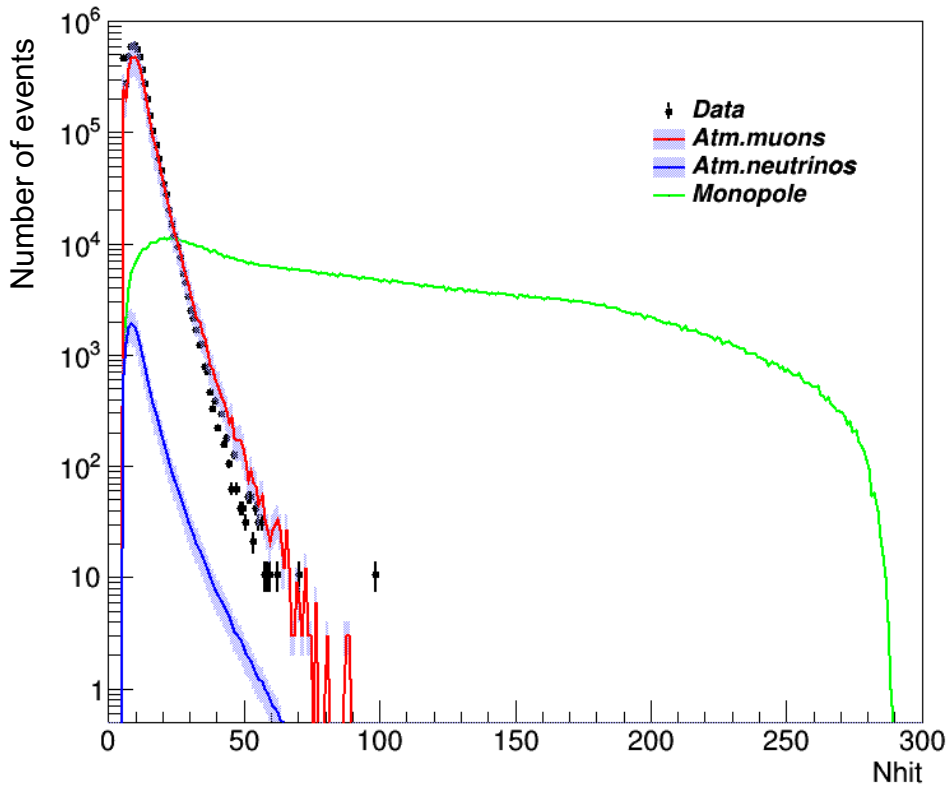
# Other plots

***Initial cuts :***
***nlines ≥ 2 & zenith ≤ 90 & tχ2 < 10***

**α = tχ2 / (1.3+(0.04×(Nhit-5)) 2 )**



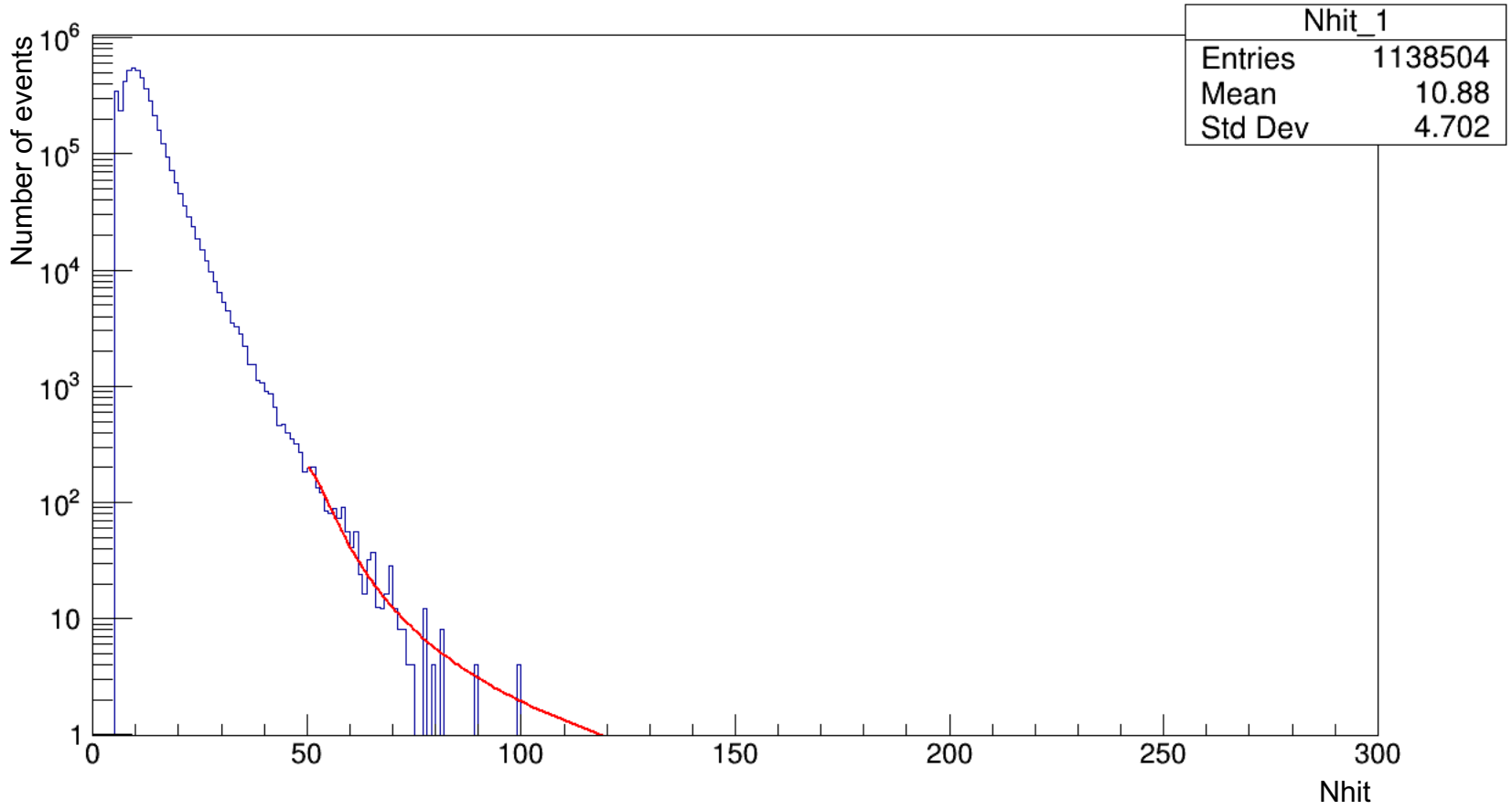

**Nhit : Number of floors with the chosen track hits**




β=[0.8615 , 0.906]

# Extrapolation of muon distribution

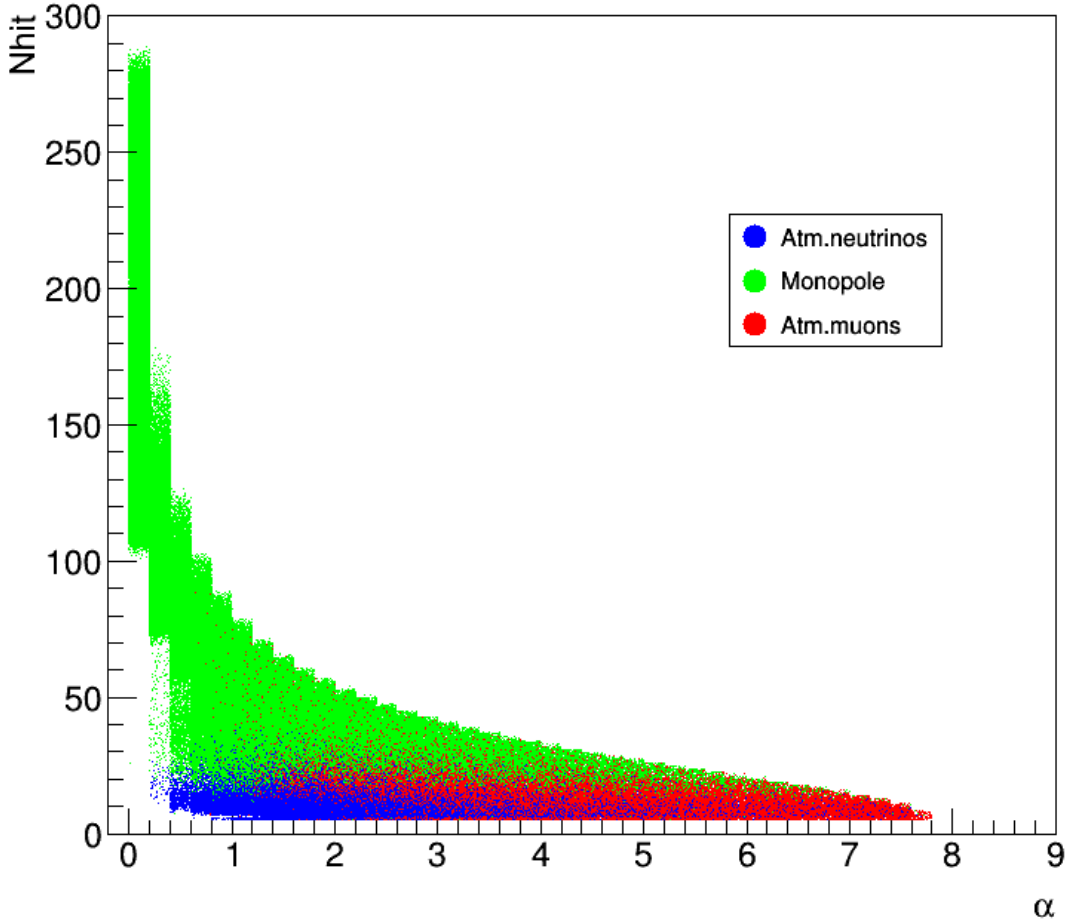
In order to compensate for the lack of statistics in the Nhit distribution for muons an extrapolation has been made in the region of signal




A Landau type function has been used

# Alpha_Nhit plots

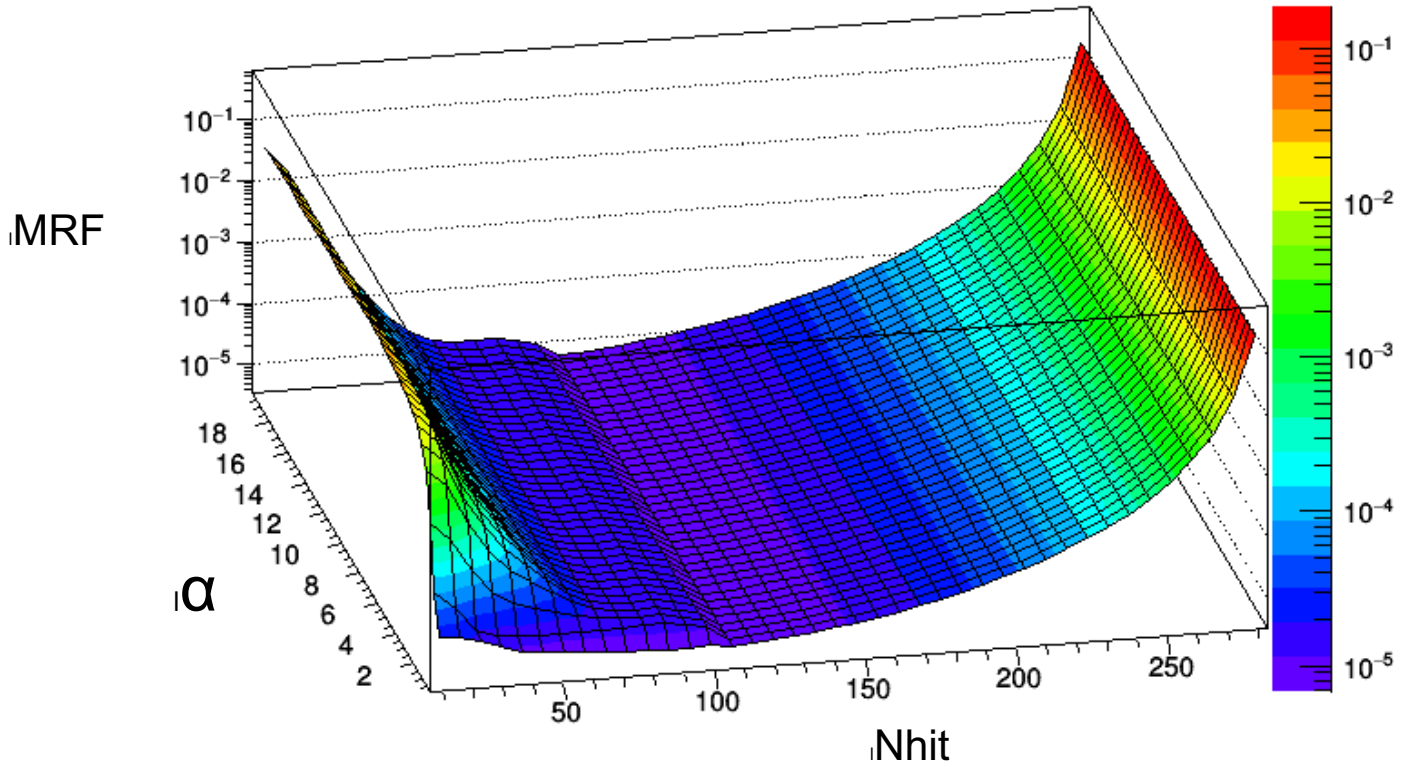
- A couple of cuts on Nhit and Alpha isolates the signal from the background




β=[0.8615 , 0.906]

# *MRF optimization*

➢ To obtain the best sensitivity we optimize the Model Rejection Factor for each velocity interval, by playing on α and Nhit cuts.




β = [0.8615 , 0.906]

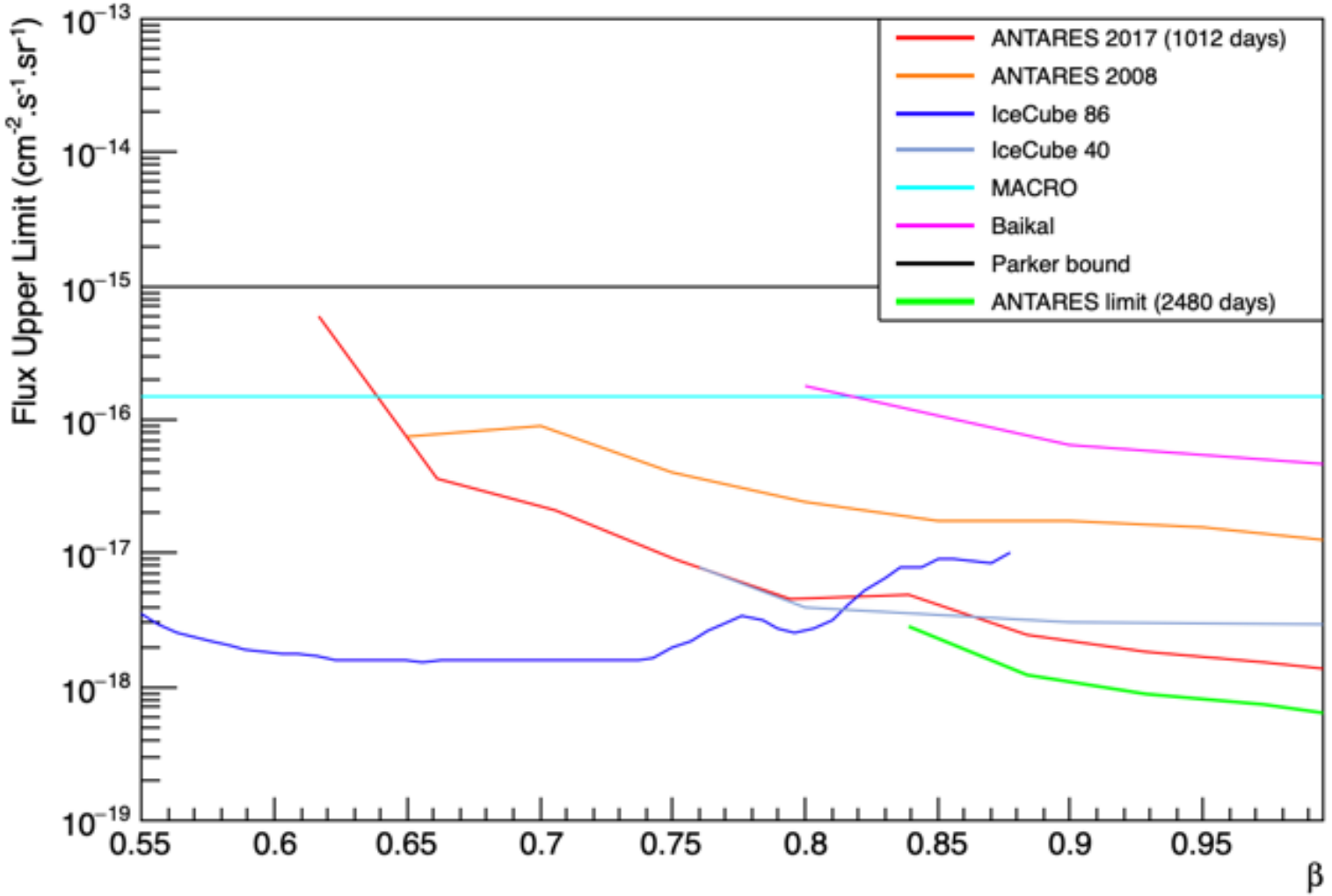
# *Sensitivity results*

➢ The following table presents the optimized cuts, the expected number of background events remaining after cuts and the sensitivity obtained in each β range at high velocity

| β interval | α cut | Nhit cut | Background events remaining | Sensitivity (cm-2.sr-1.s-1) | Events remaining after unblinding |
|---|---|---|---|---|---|
| **[0.9505 , 0.995]** | **< 0.3** | **≥ 105** | **0.18** | **7.3e-19** | **0** |
| **[0.906 , 0.9505]** | **< 0.3** | **≥ 105** | **0.18** | **8.8e-19** | **0** |
| **[0.8615 , 0.906]** | **< 0.3** | **≥ 105** | **0.18** | **1.2e-18** | **0** |
| **[0.817 , 0.8615]** | **< 0.6** | **≥ 102** | **0.3** | **2.9e-18** | **0** |

After unblinding, no event survived the optimal cuts for the studied region of β.

# *Preliminary Antares limit for the range of β =v/c [0.817 , 0.995]*



# *Conclusion*

- The limit for the Magnetic Monopole found in this analysis present a good improvement compared with the last limit found by the Antares Detector.

- The limit for other β ranges are being studied currently.