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The search of magnetic monopoles with the ANTARES neutrino telescope

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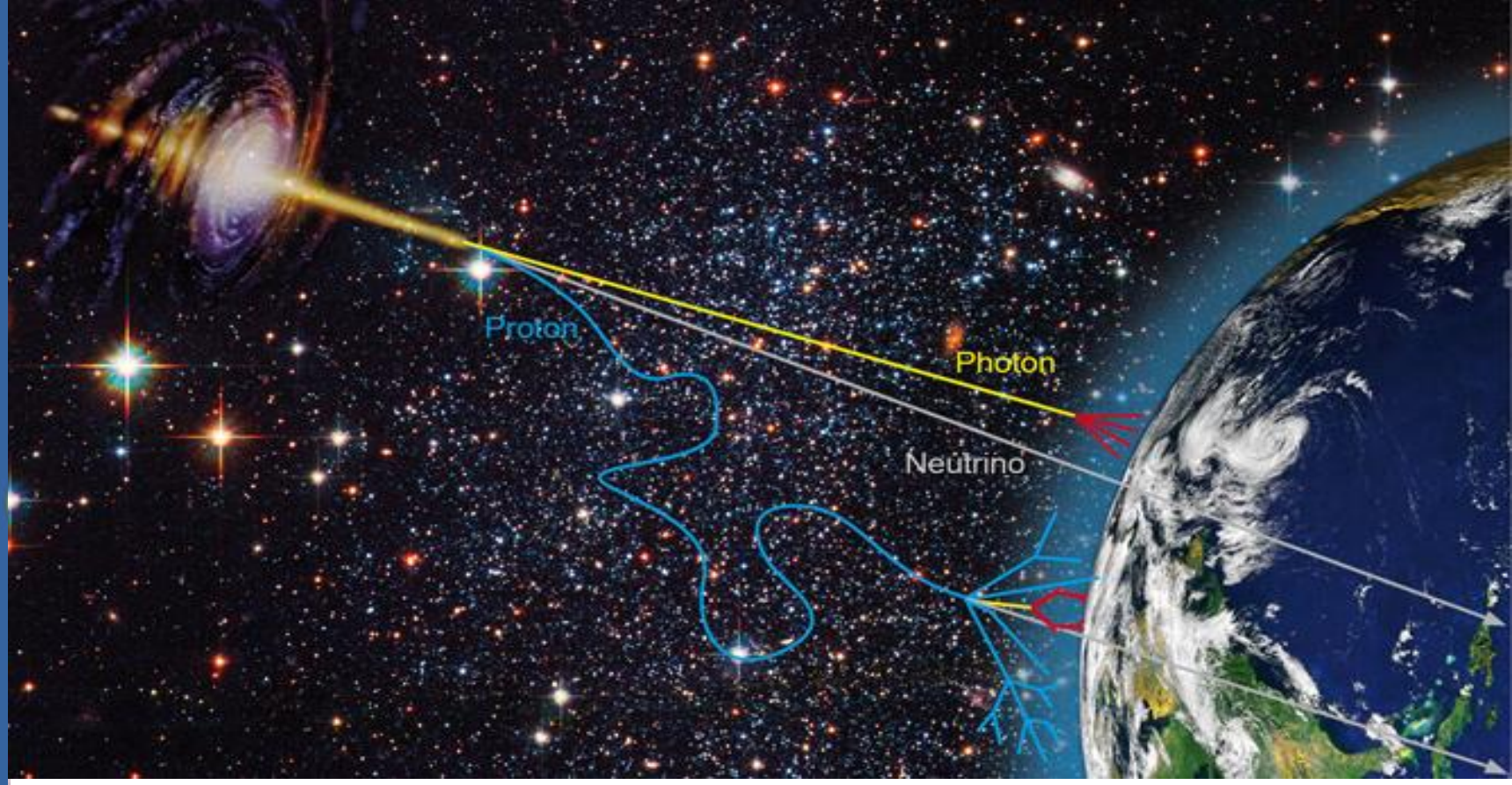
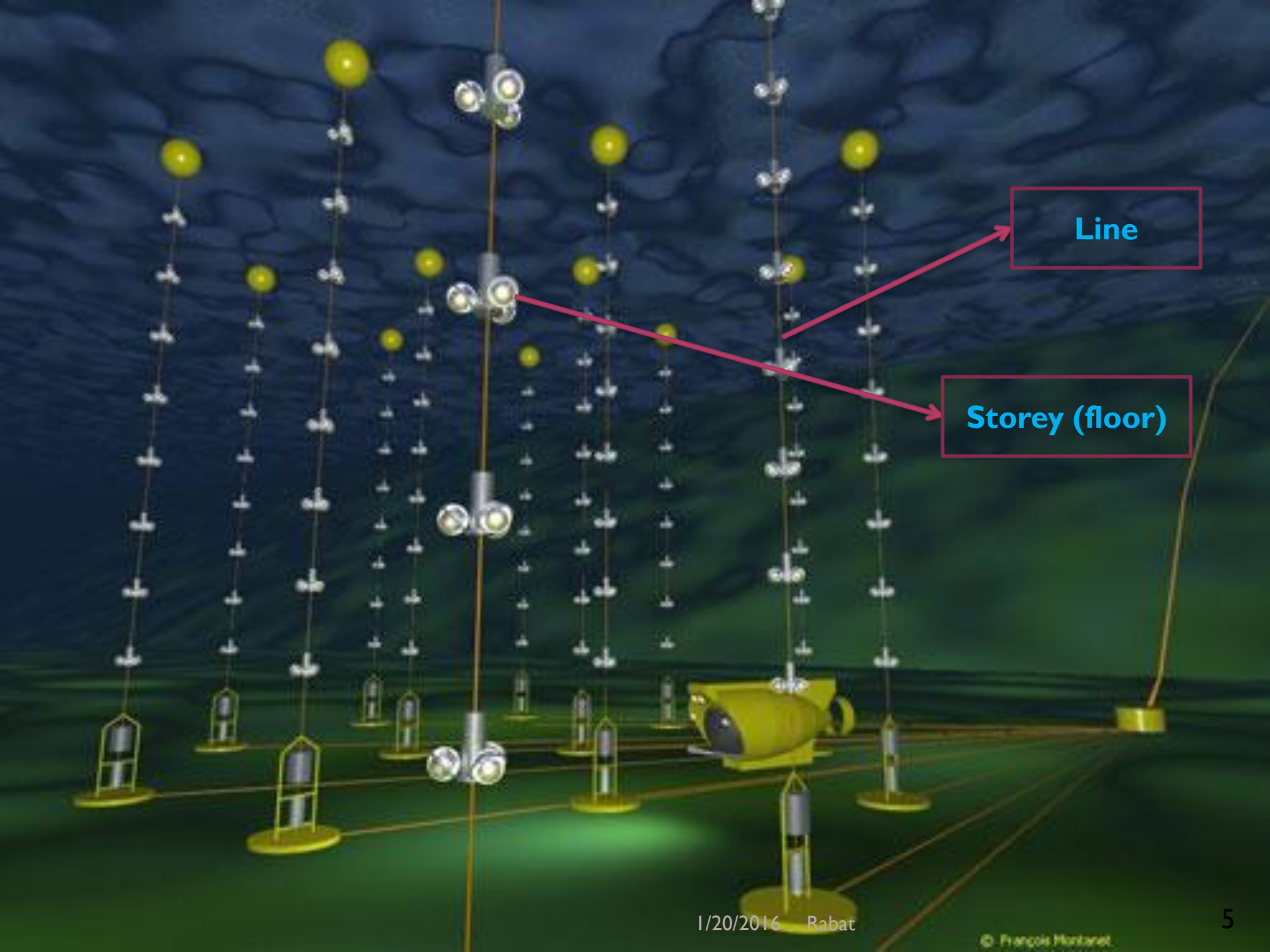
Introduction

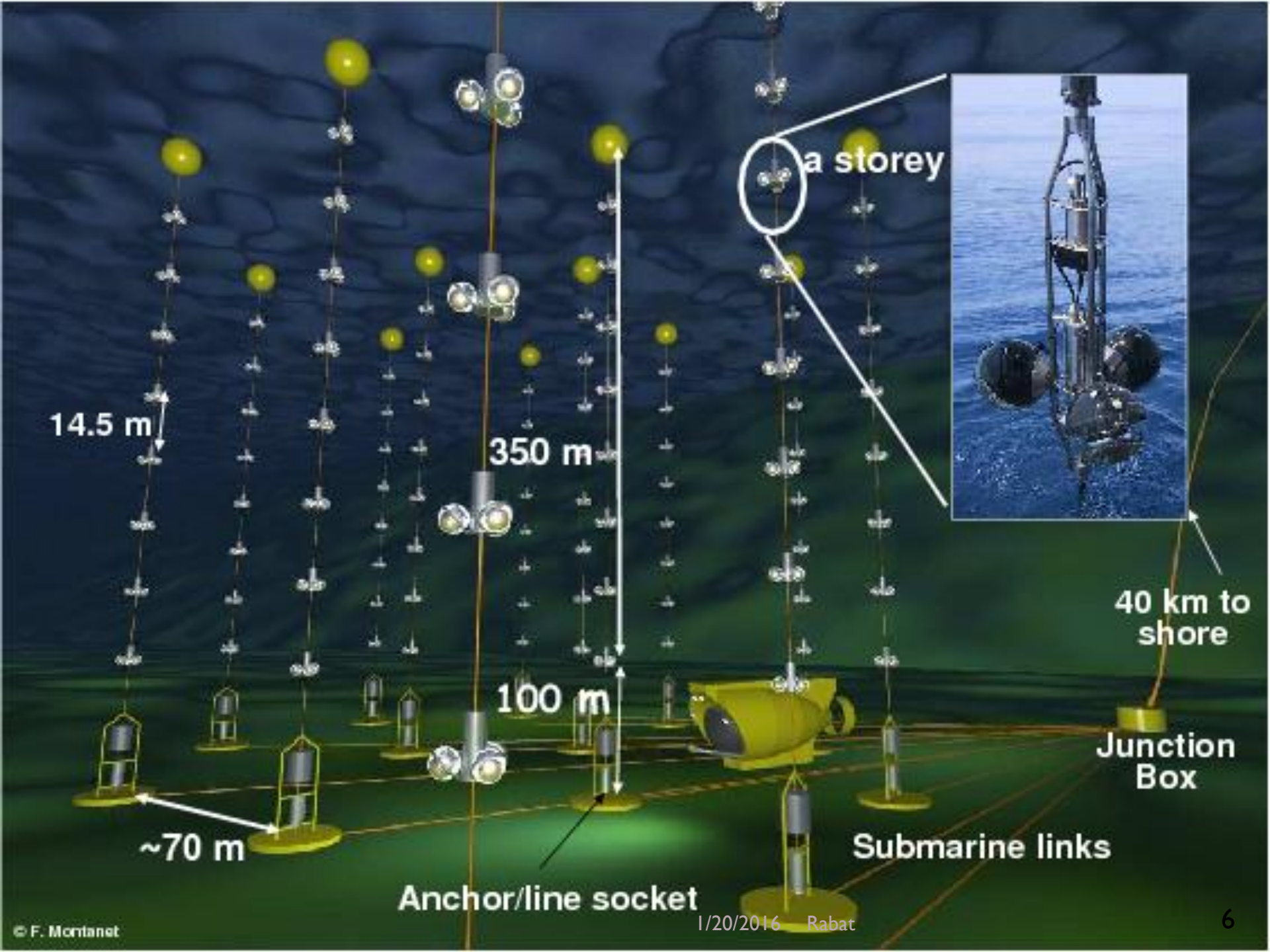


Most of our current knowledge of the Universe comes from the observation of particles.

Among all particles, the neutrino is the best messenger because it is elecrically neutral, stable and weakly interacting.

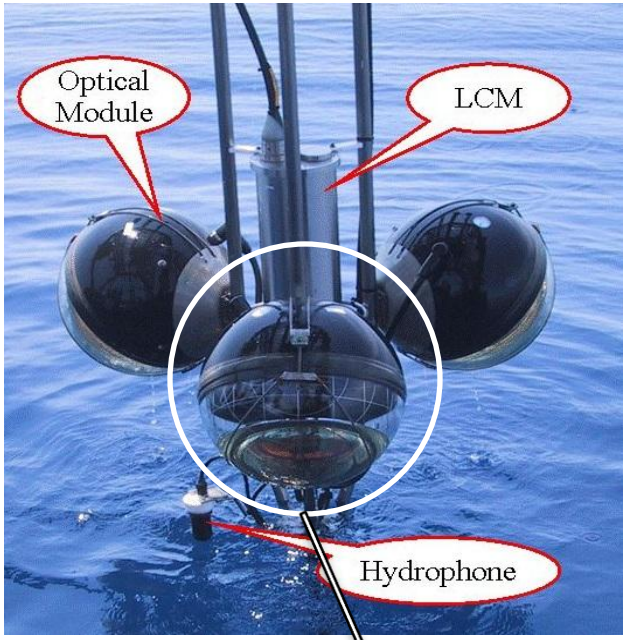
The ANTARES telescope


Line
Storey (floor)
© François Montanet


a storey
14.5 m
350 m
100 m
40 km to shore
Junction Box
~70 m
Submarine links
Anchor/line socket
© F. Montanet

A storey contains :

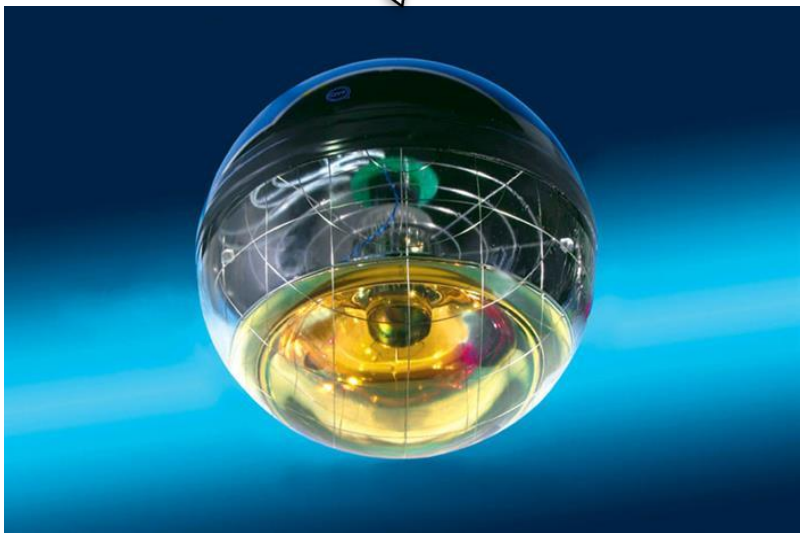
- LCM (Distribution of current for OMs, Signal Processing, sending data)
- 3 Optical Modules (OMs)



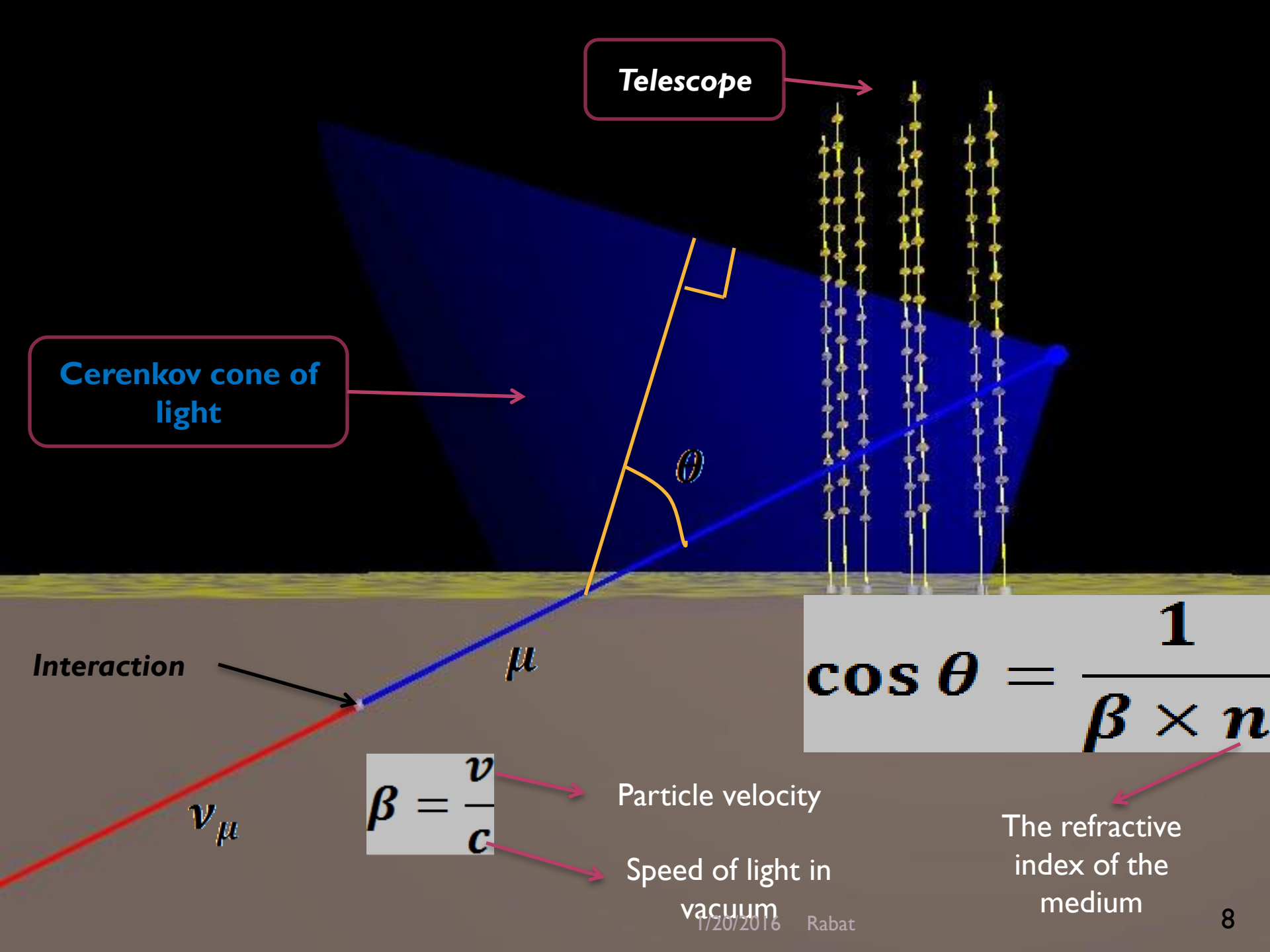
Storey

An Optical Module contains :

- Photomultiplier
- Metal grid to protect PMs
- LED



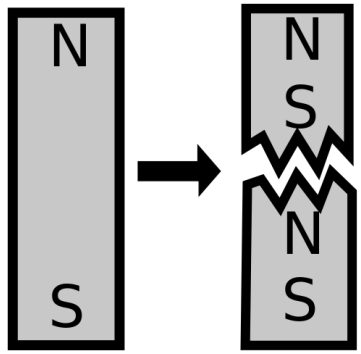
Optical Module


Telescope
Cerenkov cone of light
θ
Interaction
μ
ν_μ
$\cos\theta = \frac{1}{\beta \times n}$
$\beta = \frac{v}{c}$
Particle velocity
Speed of light in vacuum
The refractive index of the medium

Magnetic monopoles

You can not get 2 independent magnetic poles from breaking a magnet !

Magnetic monopole is a particle carrying one magnetic charge (one magnetic pole)



- ***It is a hypothetical particle predicted to be created in the early Universe***
- ***Range of mass : from 10^8 to $10^{17} GeV$ (accelerated by the atmospheric magnetic field)***
- ***It can pass through the Earth and emit a signal in a neutrino telescope***

The existence of such particle can explain the quantization of electric charge and symmetry breaking in some gauge theories (according to Dirac, t'Hooft and Polyakov)

Monte Carlo simulation

Before anything !

A simulation of the telescope and different particles passing through is needed.

Events simulation

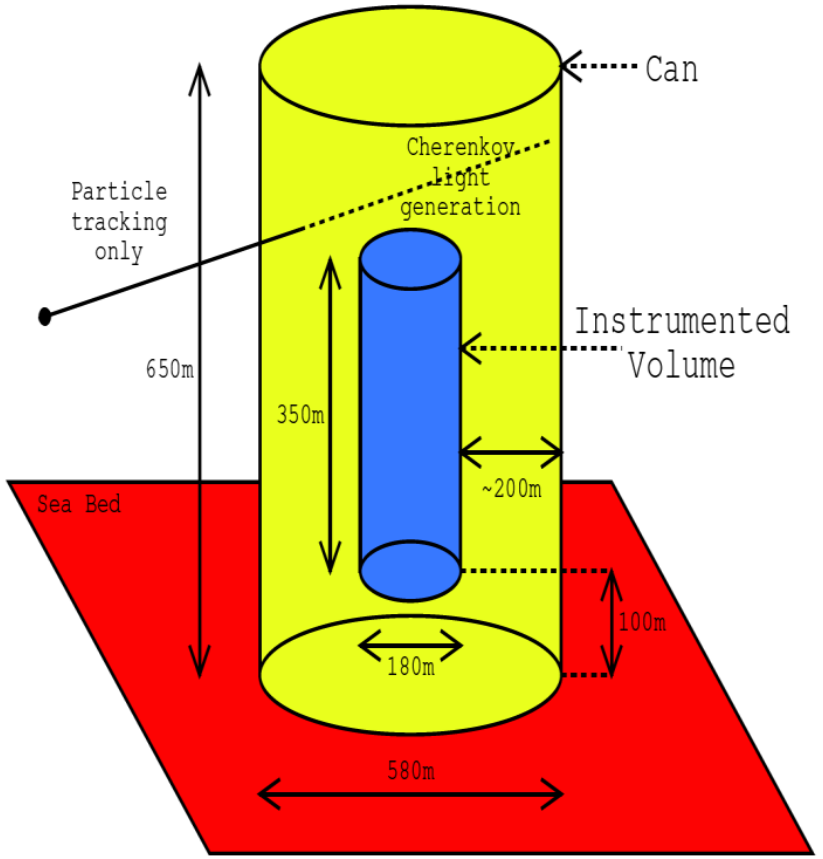
❖ ***Monopoles (signal)***

- 10 intervals of velocity in the region β = [0.55,0.99]
- The program genmon is used to generate monopole events
- The program geamon is Used to simulate the emission of light and the response of the detector.

❖ ***Atmospheric muons and neutrinos (background)***

- The ANTARES Monte Carlo generators are used

Telescope simulation



Reconstruction

At this stage we need to reconstruct some parameters for the events simulated (direction, velocity, …)

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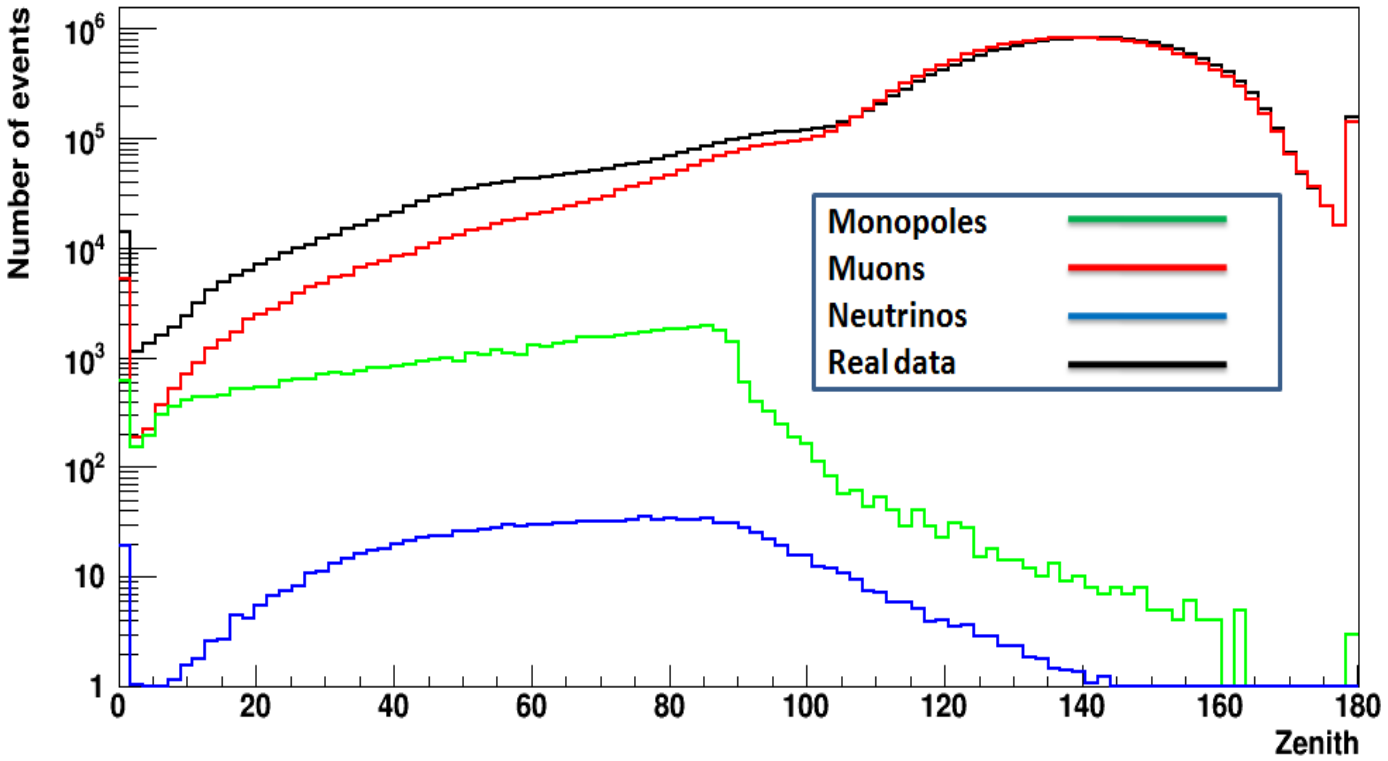
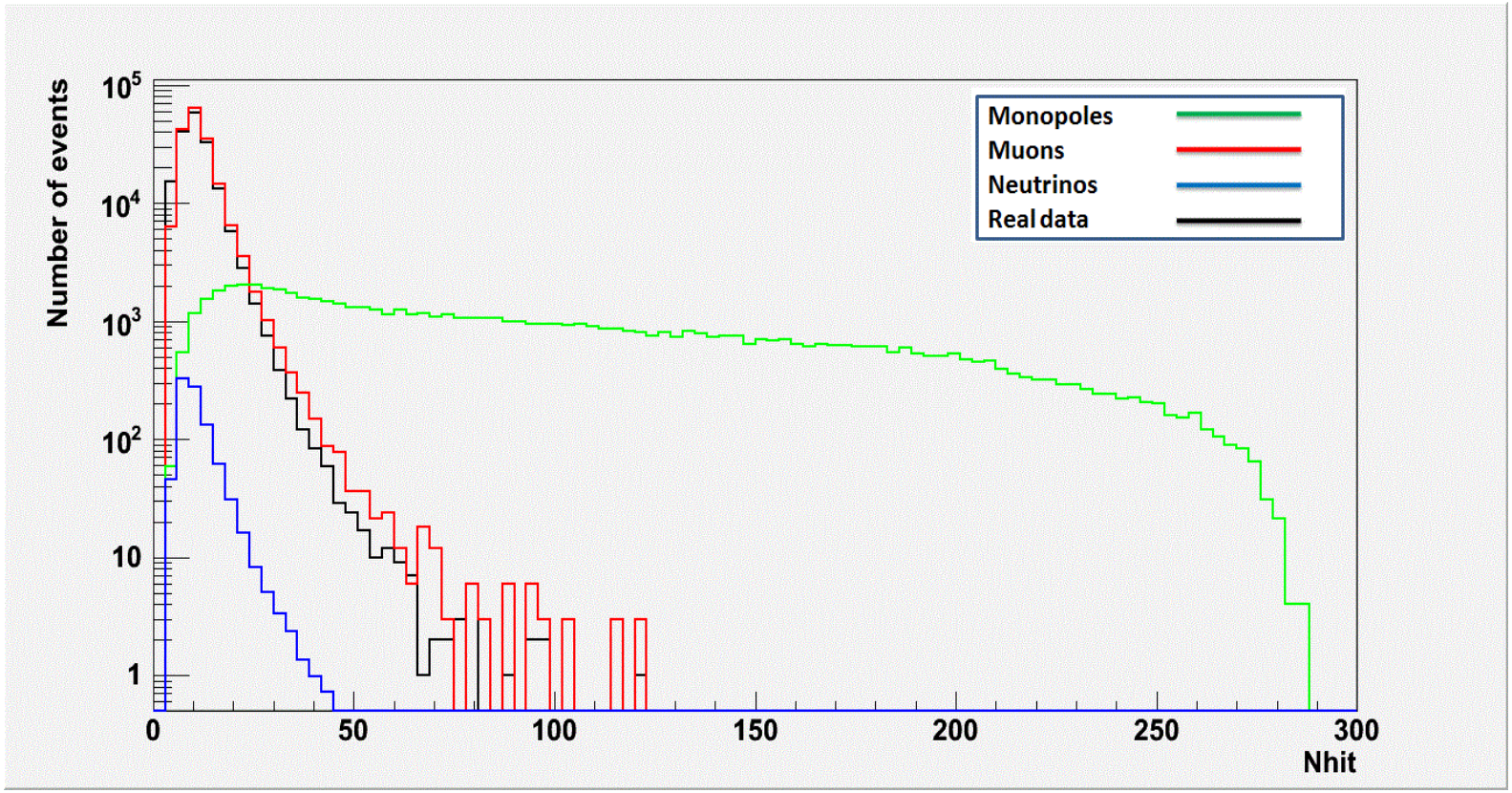


Example : *the zenith angle which refers to the angle of incidence of the event*

At this stage we need to reconstruct some parameters for the events simulated (direction, velocity, …)

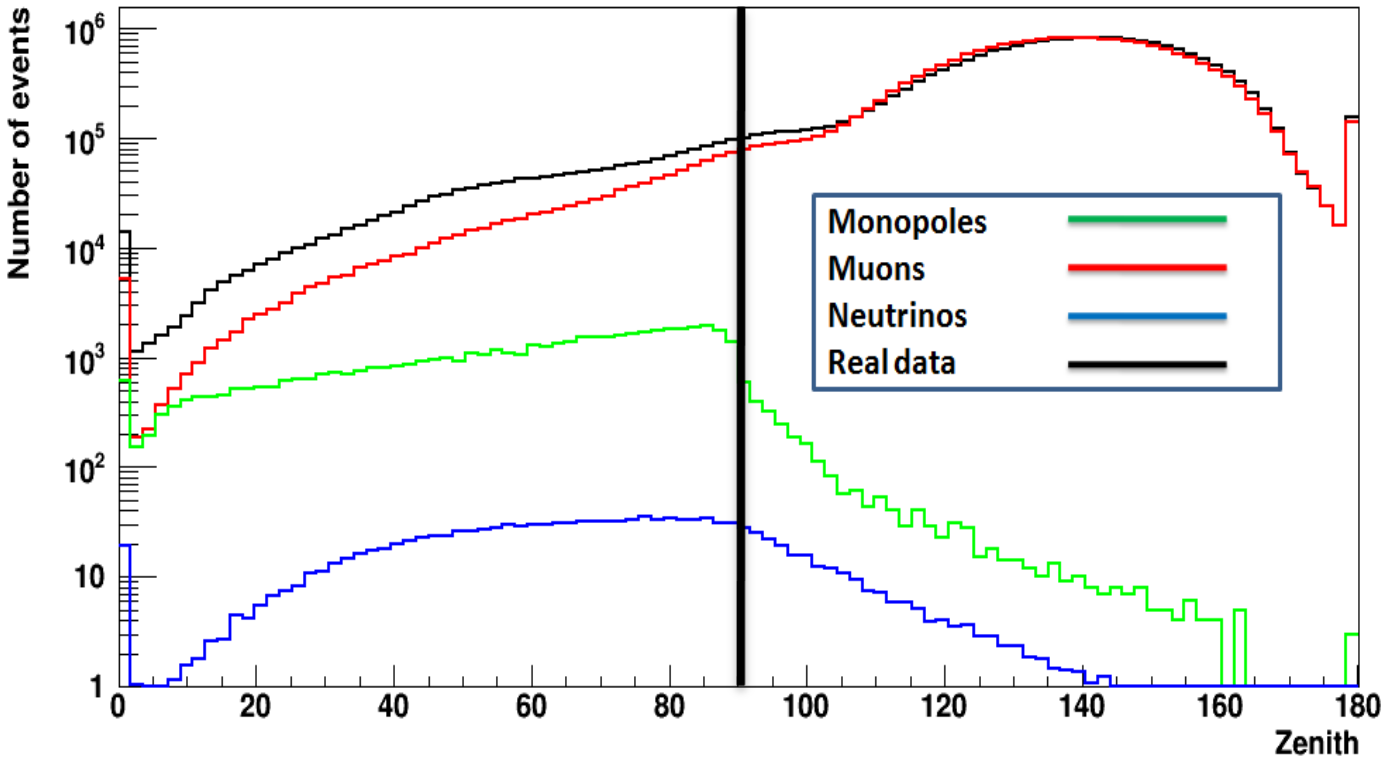


***Example** : Nhit*

The number of storeys touched by the emitted light

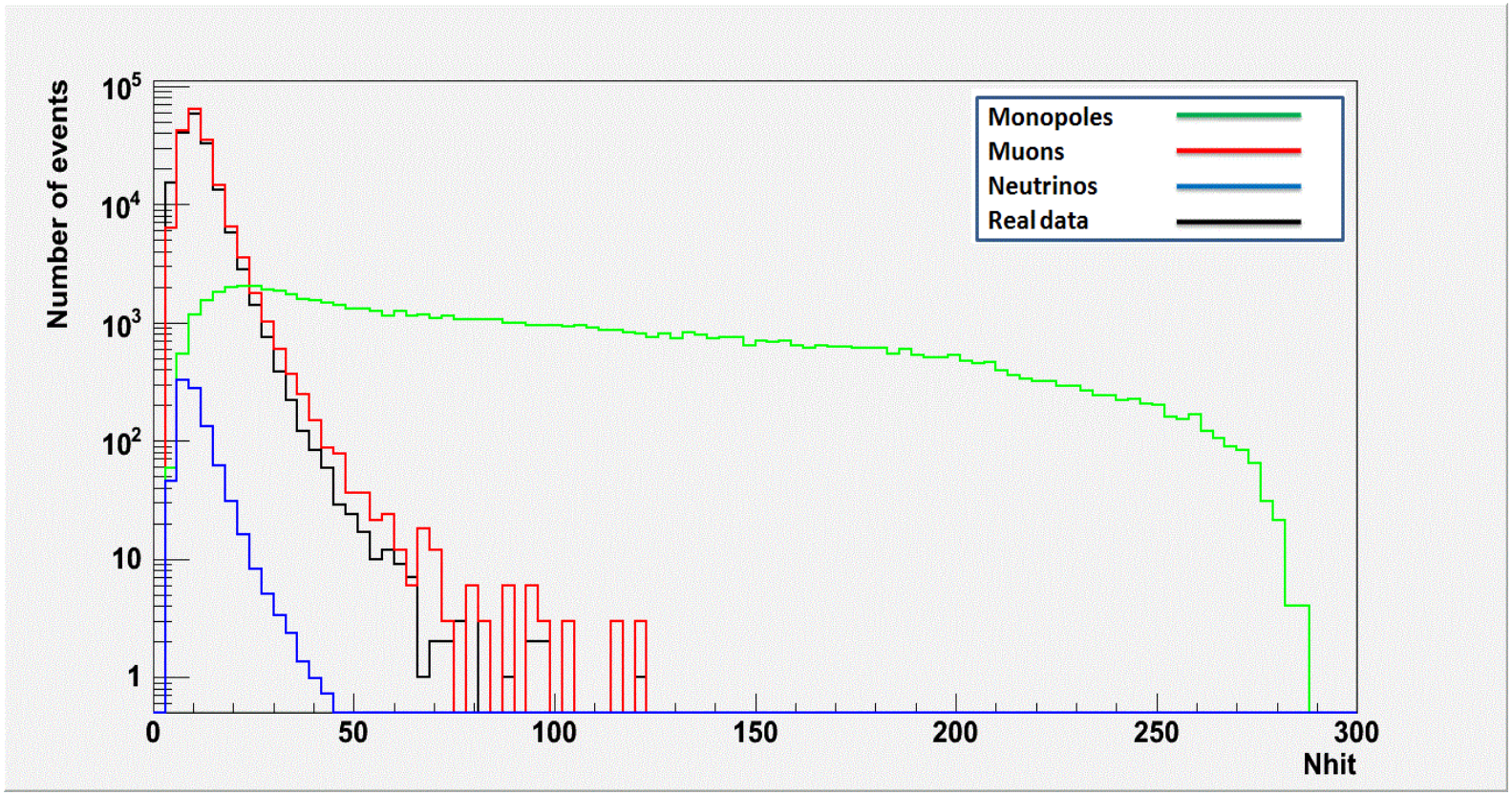
Analysis

1. Reducing the maximum of background



An efficient operation to do is to cut over the zenithal angle to choose only the up-coming events (Zenith <= 90)

2. Isolating monopoles signal



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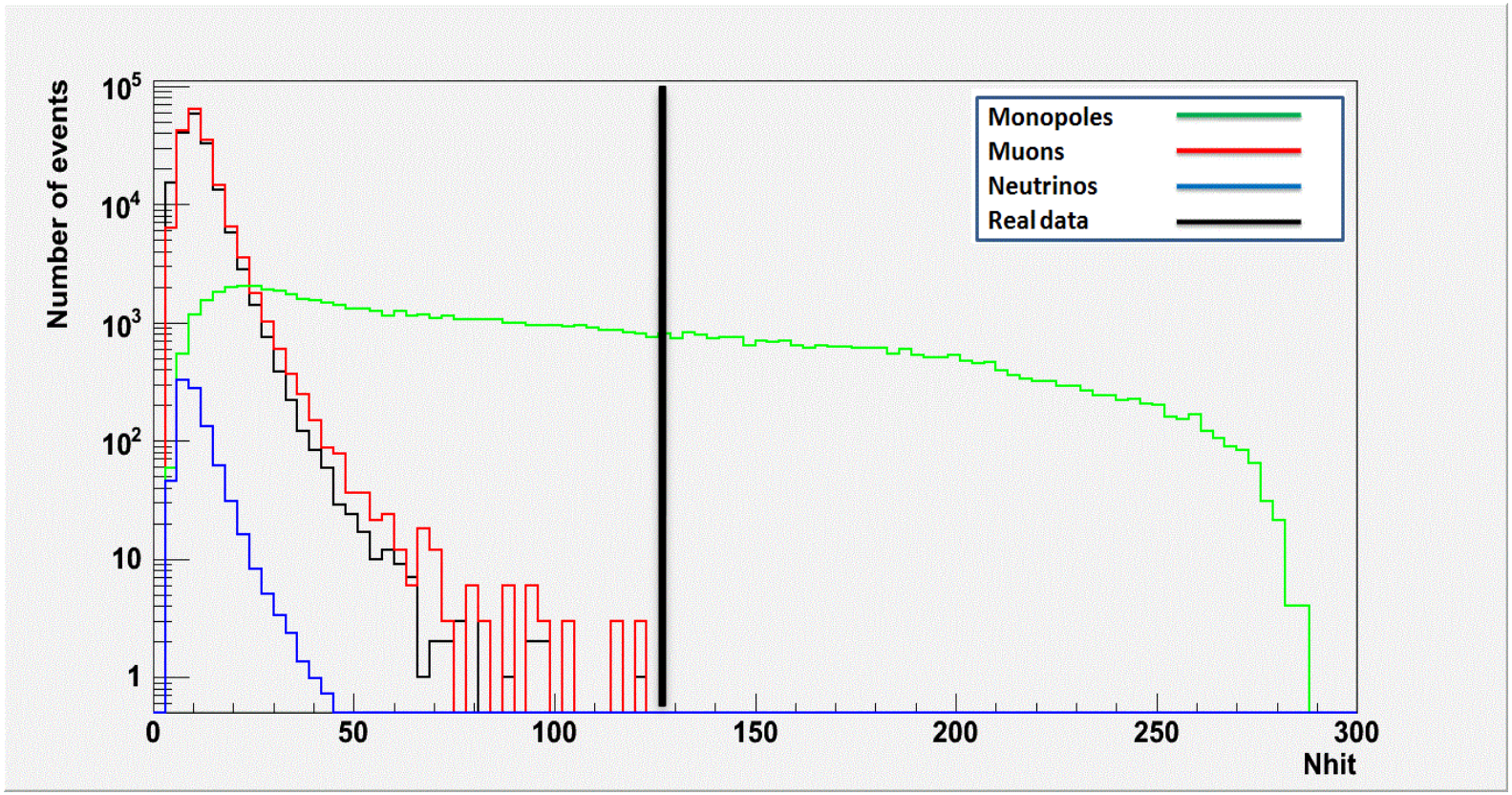


Monopoles with $\beta \geq 0.74$ can emit a large amount of light compared to that from muons ➔ high values of Nhit

3. Optimising the cuts

From the number of monopole and background events remaining after cuts, we can calculate the 90% C.L sensitivity using Feldman-Cousins approach

$$\bar{\mu}_{90}(n_b) = \sum_{n_{obs}=1}^{\infty} \mu_{90}(n_{obs}, n_b) \frac{n_b^{n_{obs}}}{n_{obs}!} e^{-n_b}$$

The Feldman-Cousins sensitivity depending on the number of backgound remaining after cuts

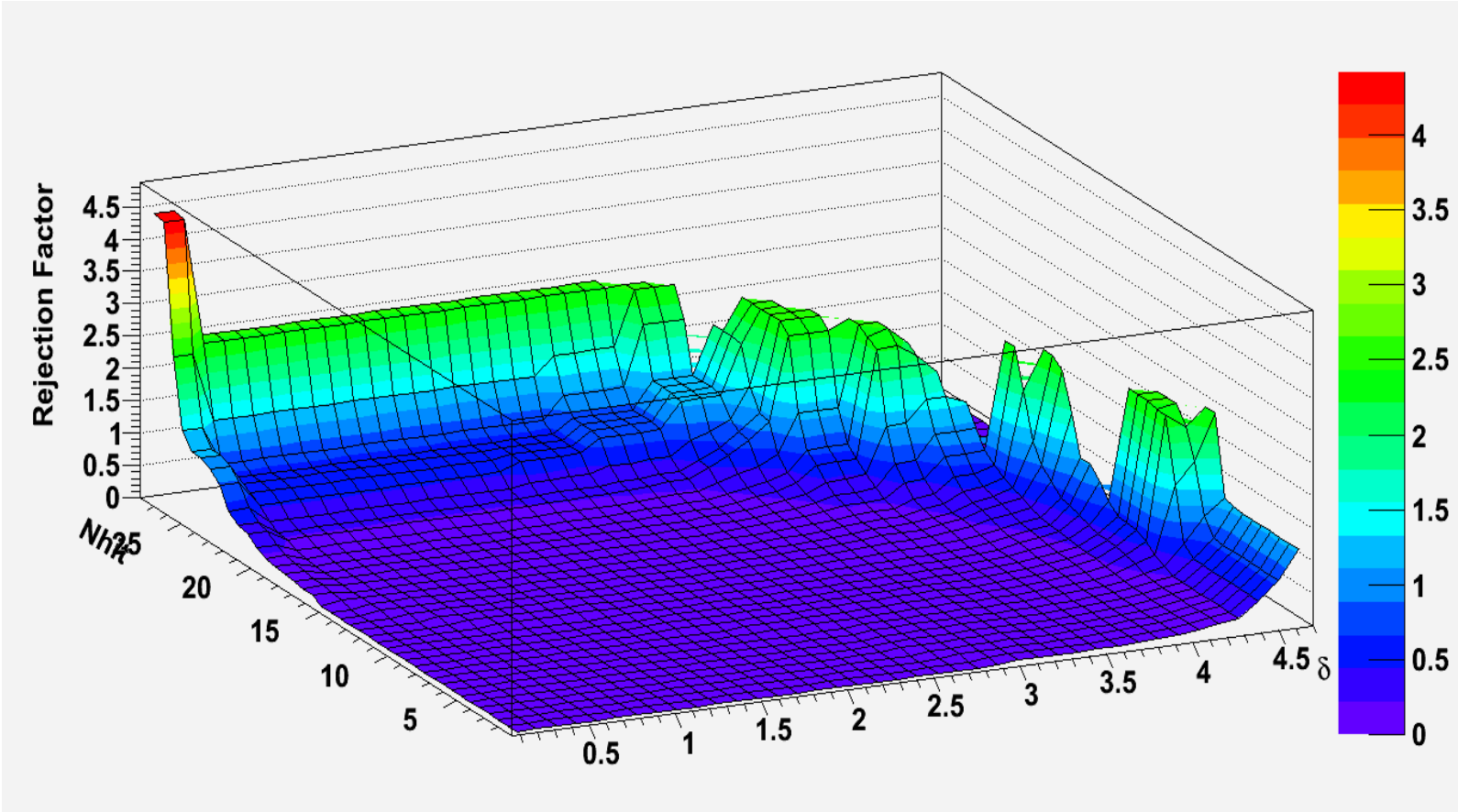
The Feldman-Cousins upper limit depending on the number of backgound and the number of real events remaining after cuts

We look for the cut giving the minimum of rejection factor:

$$RF = \frac{\bar{\mu}_{90}}{n_{MM}}$$

The number of monopole events remaining after cuts

3. Optimising the cuts



Remark:

- ***It is not always easy to find a parameter from which the signal can be isolated ➔ in the case of lower velocities new parameters have to be defined such as Delta.***

4. Calculating the sensitivity

The 90% C.L sensitivity is :

$$S_{90\%}\left(cm^{-2}.s^{-1}.sr^{-1}\right) = \frac{\bar{\mu}_{90}(n_b)}{S_{eff}(cm^2.sr) \times T(s)}$$

The duration of detecting data

The effective surface of monopoles

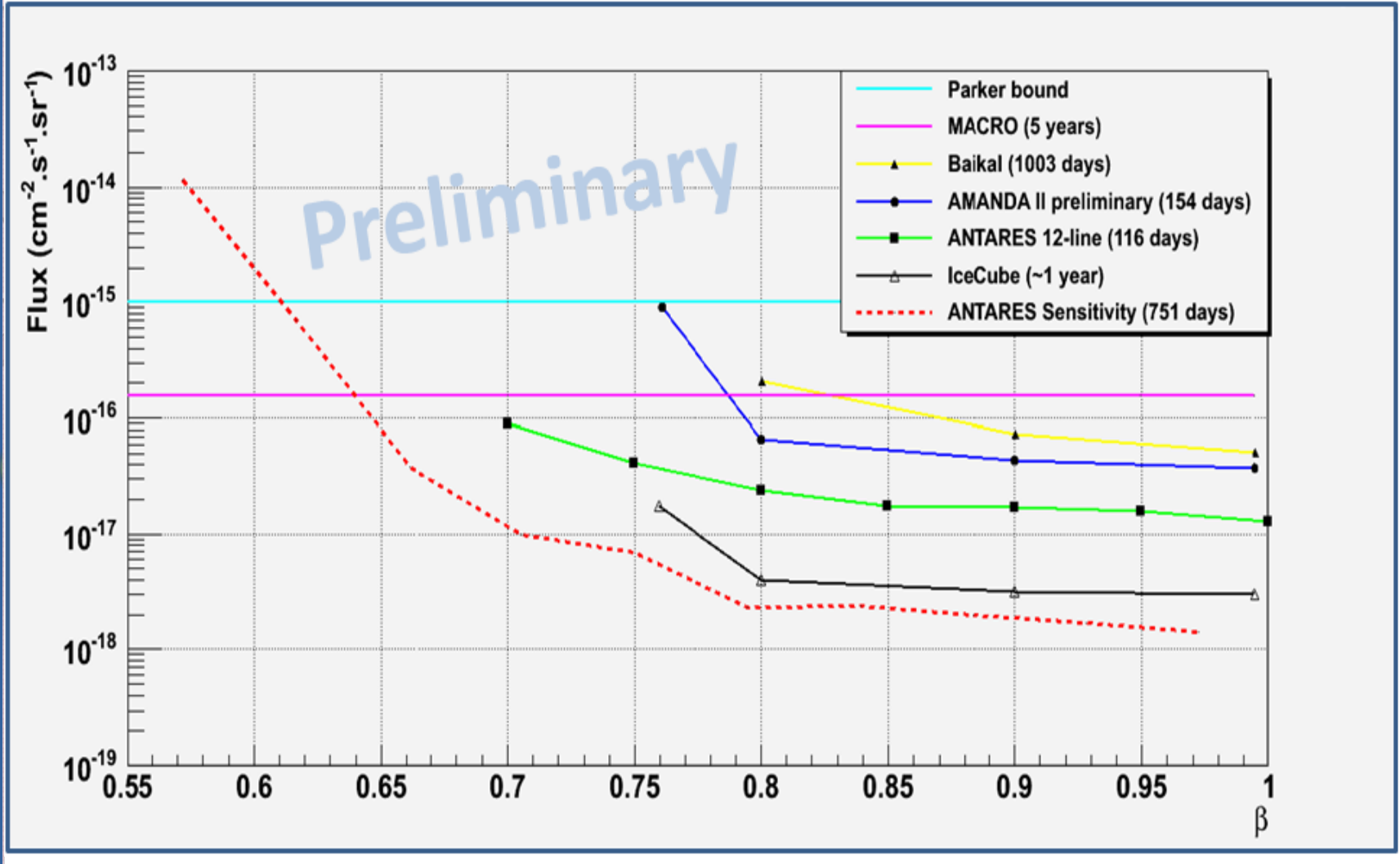
$$S_{eff} = \frac{n_{MM}}{\Phi_{MM}}$$

Monopoles flux generated into the CAN

Remark:

- ***The previous 4 steps have to be done for each interval of monopoles velocity range.***

Result



Publication :

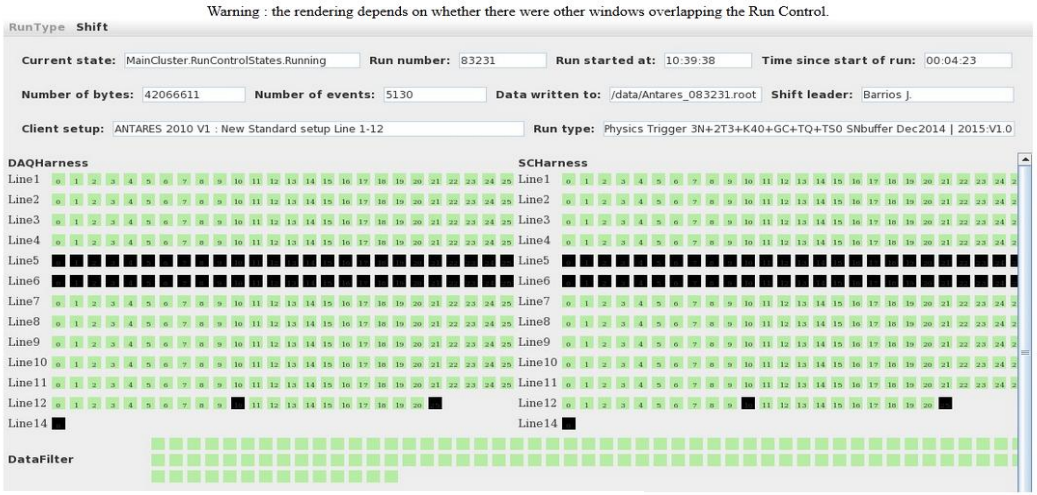
I. El Bojaddaini, Y. Tayalati, A. Moussa, J. Brunner, « Search for magnetic monopoles with the ANTARES neutrino telescope ». International Cosmic Rays Conference 2015, The Hague, Netherlands.

Conclusion

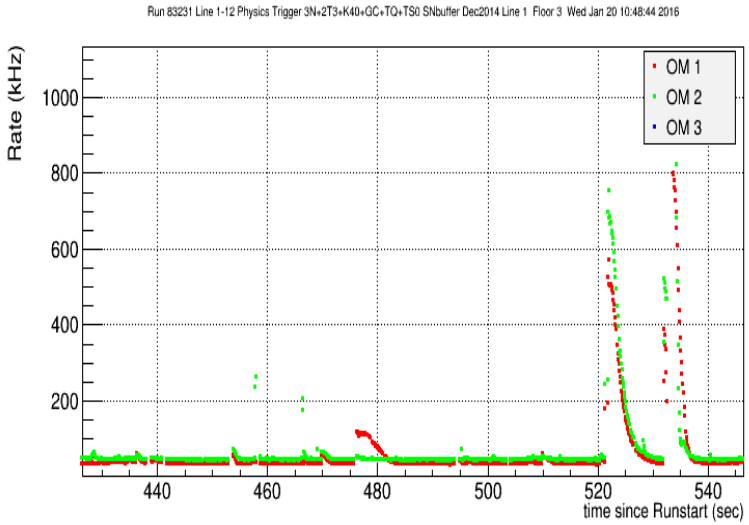
- ***We've got the collaboration's approval to use all the data collected from 2008 to 2013 (Unblinding policy)***
- ***A limit on monopoles flux will be published very soon…***

Our groupe is participating in the shift weeks attributed by ANTARES to control the operation of the detector

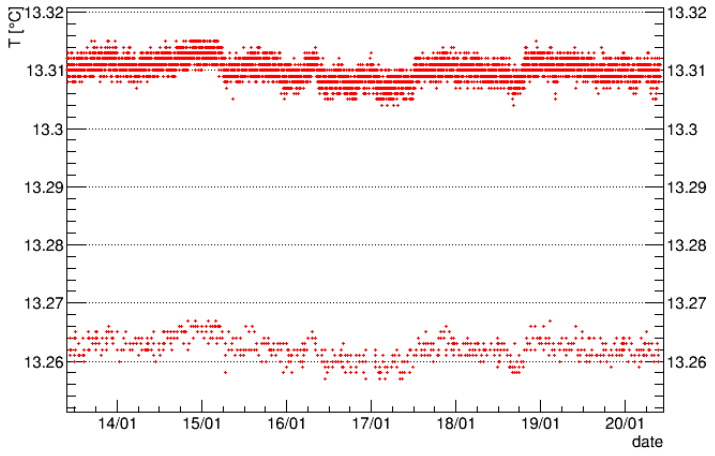
Main Run Control



L1F3



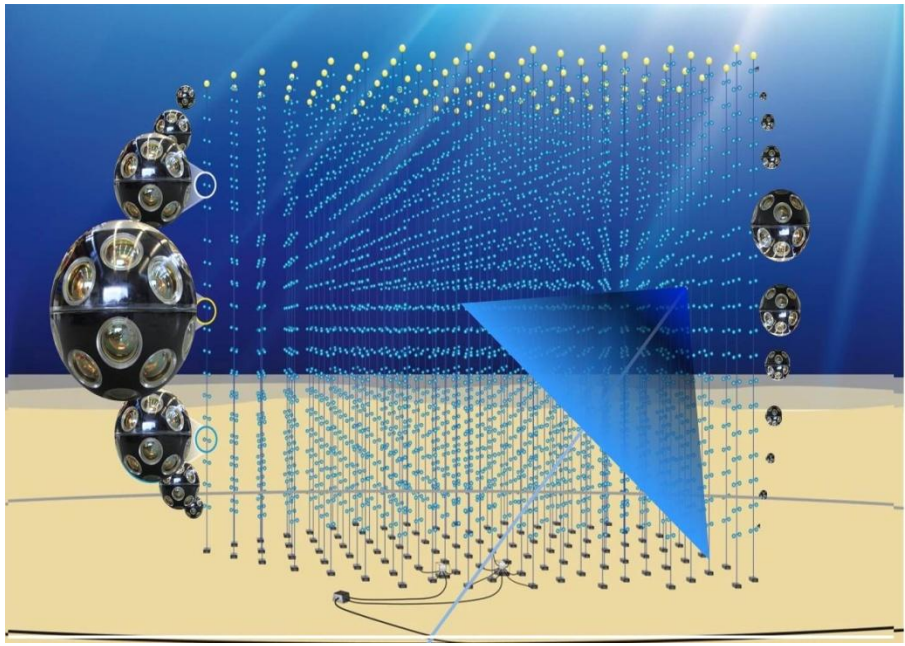
Sea water temperature



NB : "Ghost values", below 13.28 °C, are known artifacts.

- ***Multi-Km3 telescope***
- ***First line completed***
- ***Data acquisition started***

KM3NeT



Thank you very much for your attention!!