*Mohamed I University, Faculty of Sciences, Oujda*

# *Results of the search for magnetic monopoles with ANTARES*

Réunion du Groupement de Recherche sur les Neutrinos, Paris
29-30/05/2017

***J. Brunner  I. El Bojaddaini  A. Moussa  Y. Tayalati***

***On behalf of the ANTARES collaboration***

## *Magnetic monopoles (MMs)*

- ***Particles with one magnetic pole : the magnetic counterparts of electric charges.***

- ***Symmetry in Maxwell's equations***

- ***Quantization of the electric charge (Dirac in 1931):***

$$g = k \cdot g_D = k \cdot \frac{e}{2 \cdot \alpha}$$

## *Magnetic monopoles (MMs)*

- ***GUT theories : MMs would be created after the Big Bang (during the phase transition of symmetry breaking).***

- ***The mass of monopoles could exceed*** $10^{14}\,TeV$ ***which is energitically impossible to be created when the Universe cooled down.***

- ***A motivation to the scenario of inflation***

- ***MMs would be accelerated by galactic magnetic fields if their mass :***

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

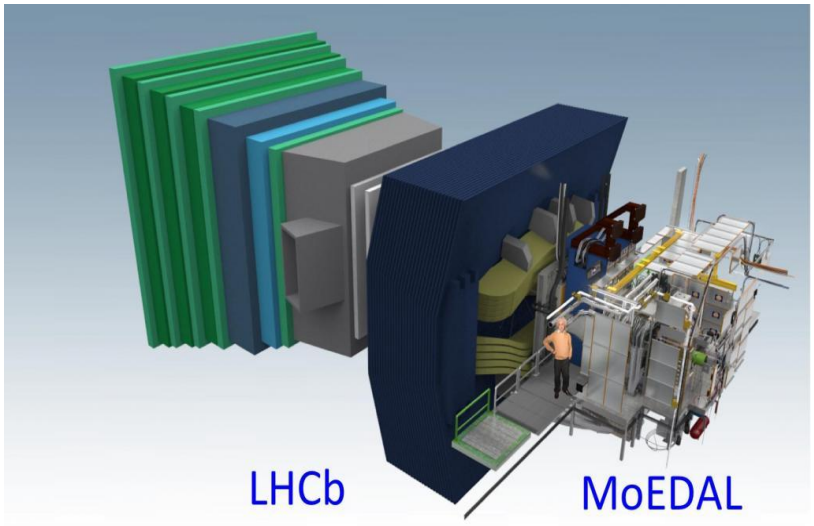
## *Synthetic monopoles at the lab !!*

Manipulation of a Rubidium gas in a non-magnetic state close to absolute 0 temperature !

Creation of a system behaving as a magnetic monopole in the quantum field describing the gas

M.W. Ray et al. Science: Vol. 348, Issue 6234, pp. 544-547

## *Search for MMs with MoEDAL experiment at LHC*



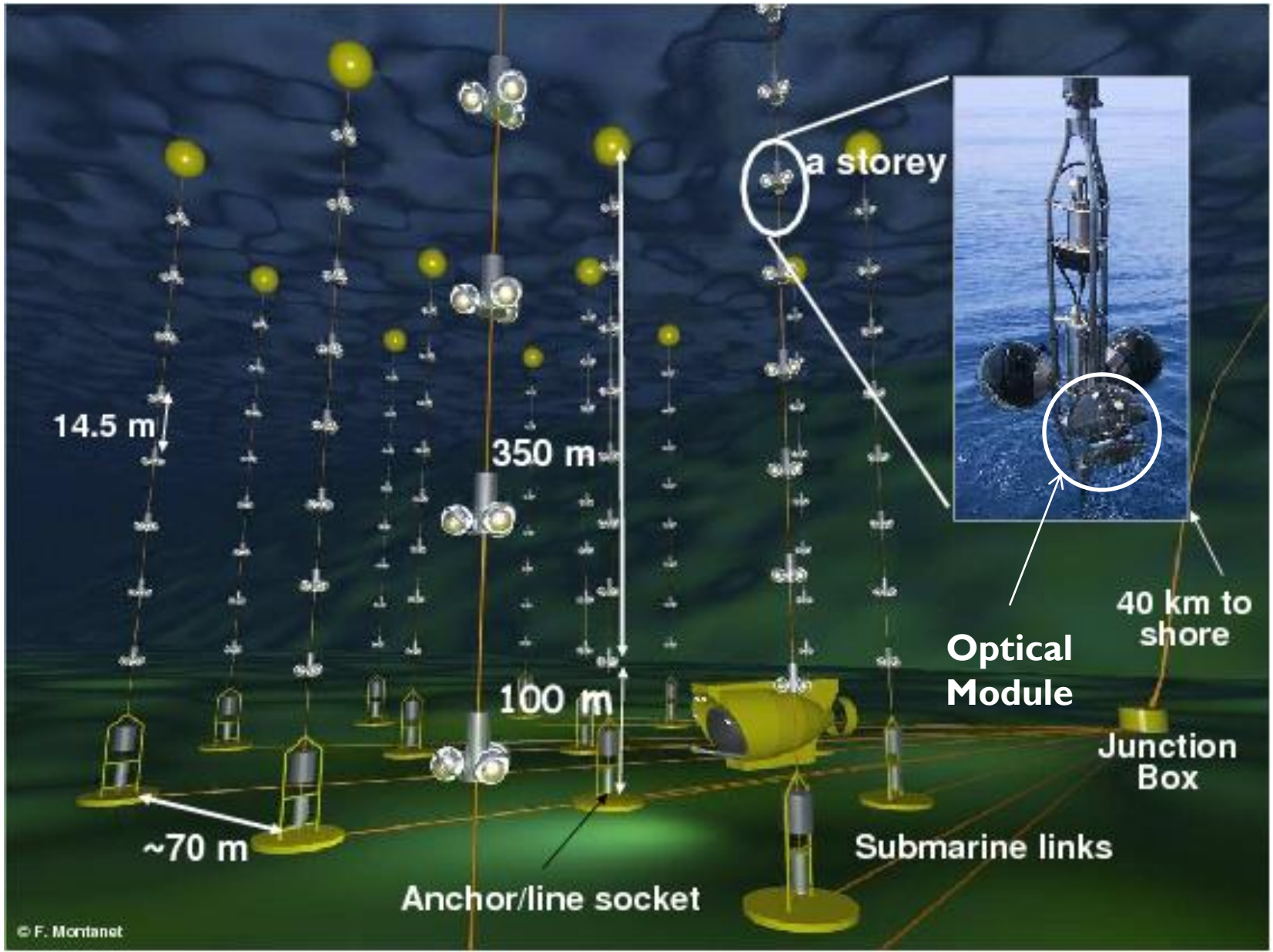
Electro-weak interactions ⟹ Magnetic monopoles with mass <10 TeV

No monopoles found ⟹ Upper limits on mass and cross section

B. Acharya et al. JHEP 08, 067 (2016).

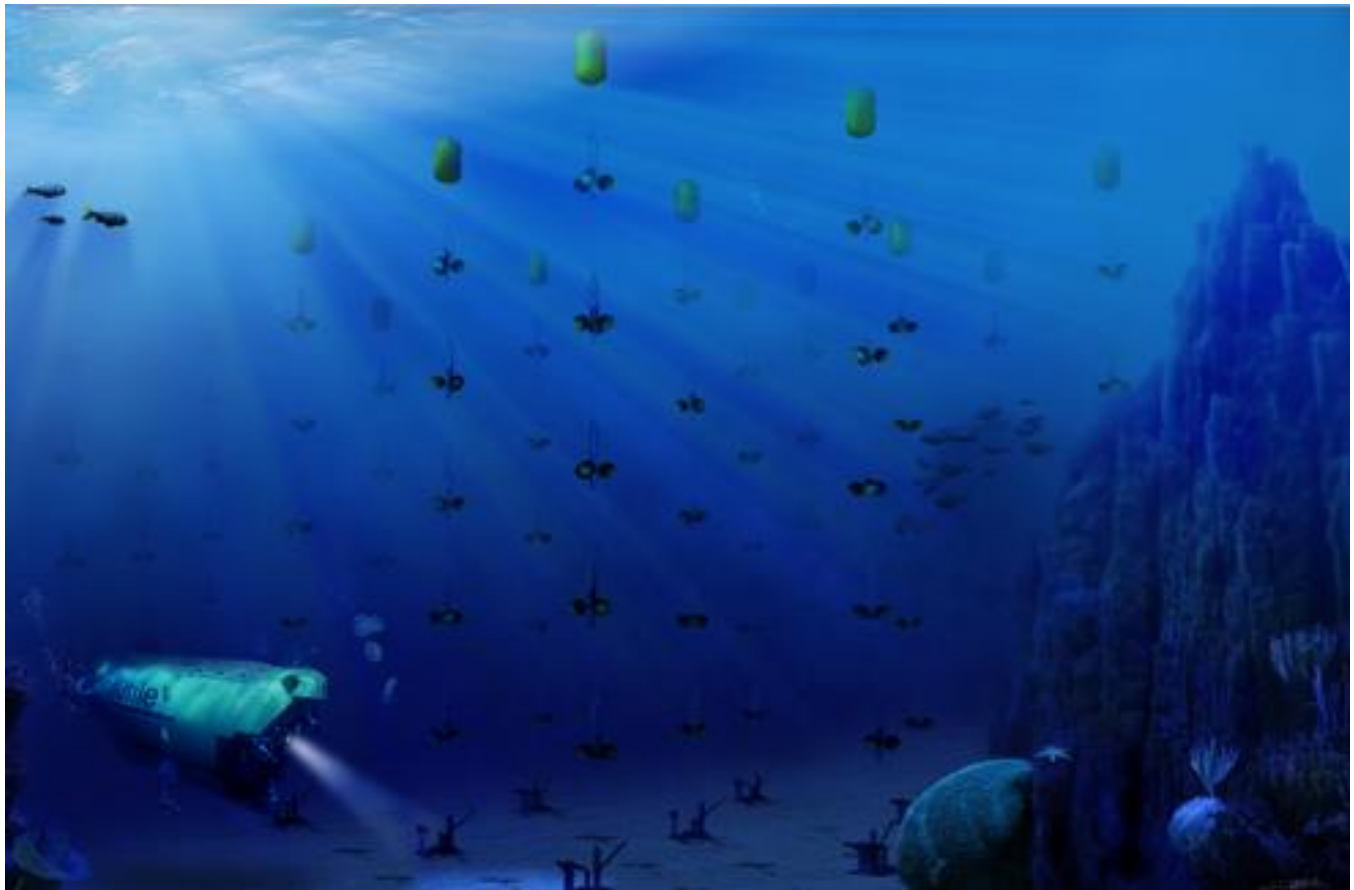
L. Patrizii, M. Spurio, Ann. Rev. Nucl. Part. Sci. 65 (2015) 279-302.

# *The ANTARES neutrino telescope*



## *Search for MMs with the ANTARES Neutrino Telescope*

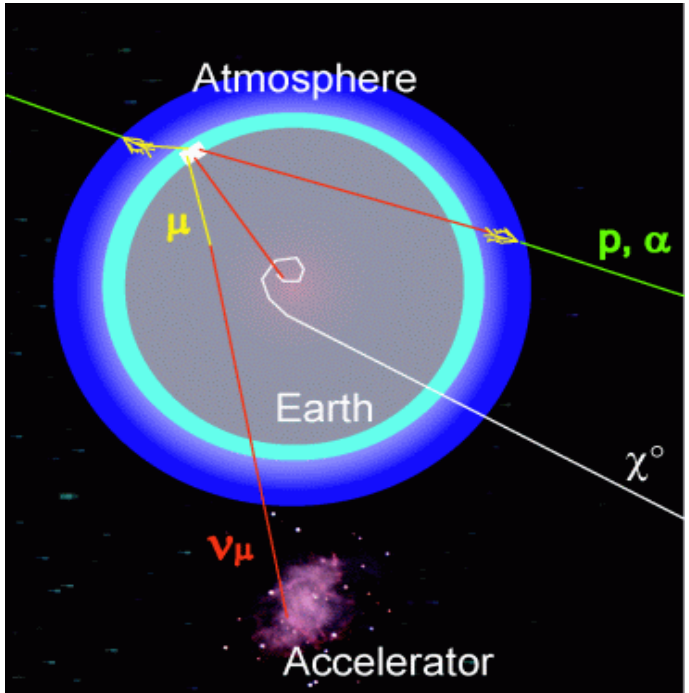
- A limit on flux found using 5 years of data (2008-2012)
- Total livetime : 1012 days
- ArXiv:1703.00424

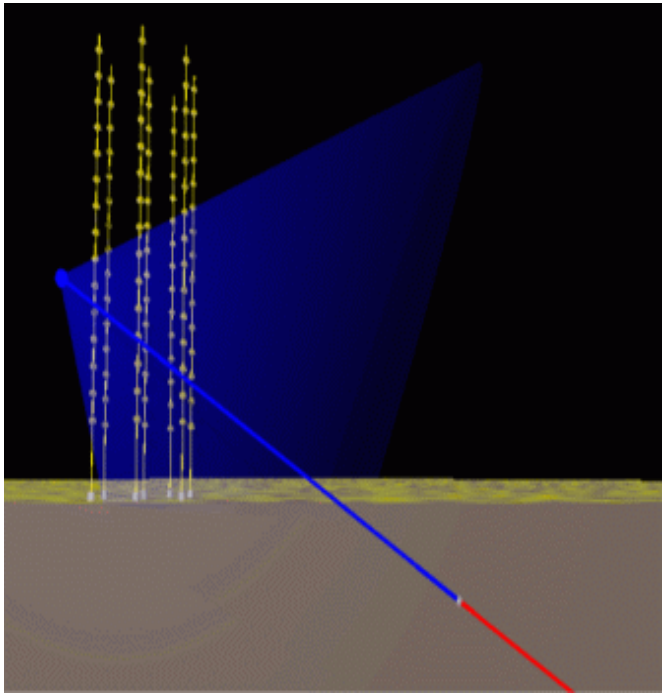


## *Detection principle*

- A neutrino telescope uses the detection of upward-going charged particles as a signature of neutrino interactions in the matter below the detector

- Charged particles emit light under a characteristic angle when passing through a medium if their velocity exceeds the speed of light in the medium



## *Magnetic monopole interaction when crossing the Earth*

- The ANTARES telescope is sensitive to up-going particles because of the large amount of background produced in the atmosphere.

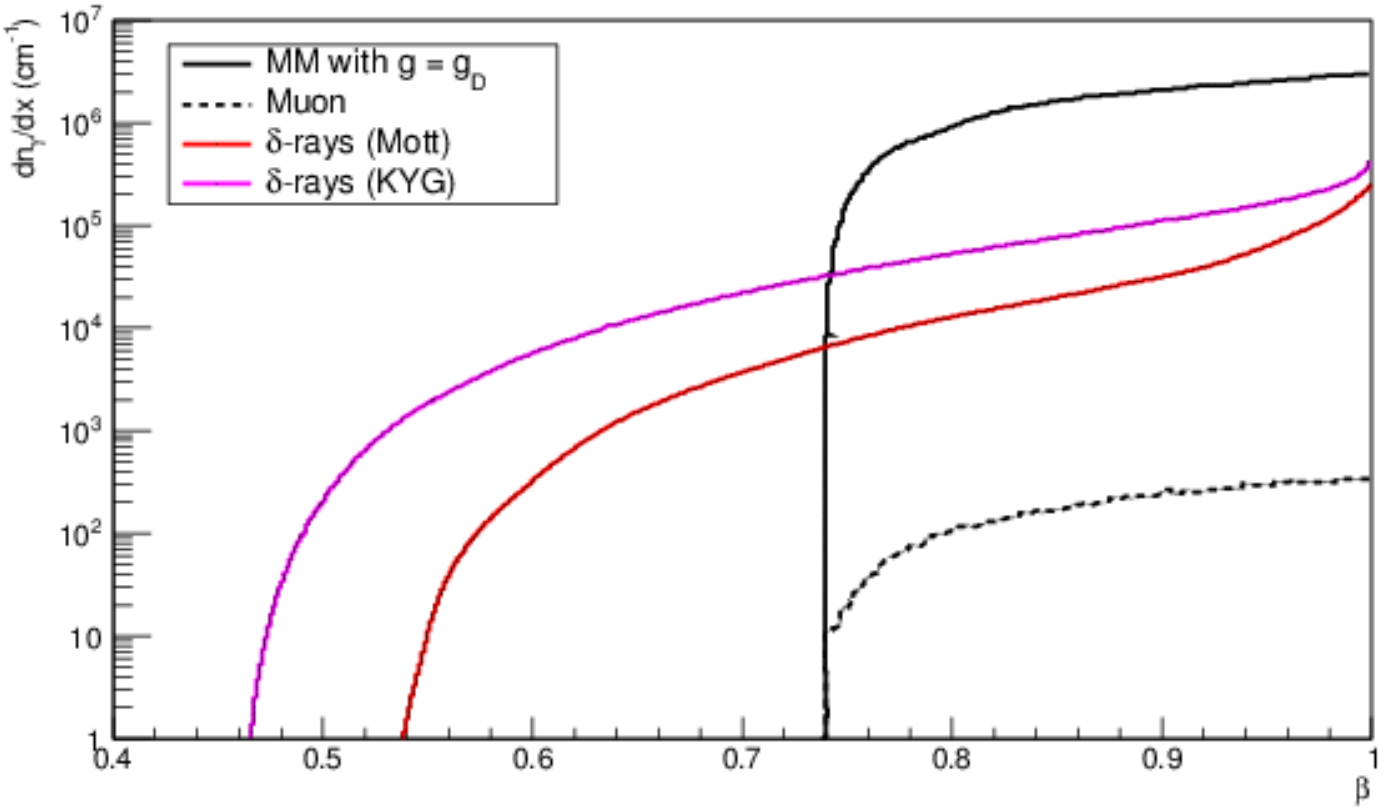
- The stopping-power defined by S. P. Ahlen has been used to estimate the energy loss of a monopole when crossing the Earth.

- Despite the high energy loss, magnetic monopoles would remain relativistic and detectable if $M \gtrsim 10^{10}\ \mathrm{GeV}/c^2$

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

## *The number of photons produced*

The total number of Cherenkov photons with wavelengths between 300 and 600 nm that are directly produced per cm length by a magnetic monopole, delta-rays with Mott and KYG cross section models and by a minimum ionizing muon, as a function of β

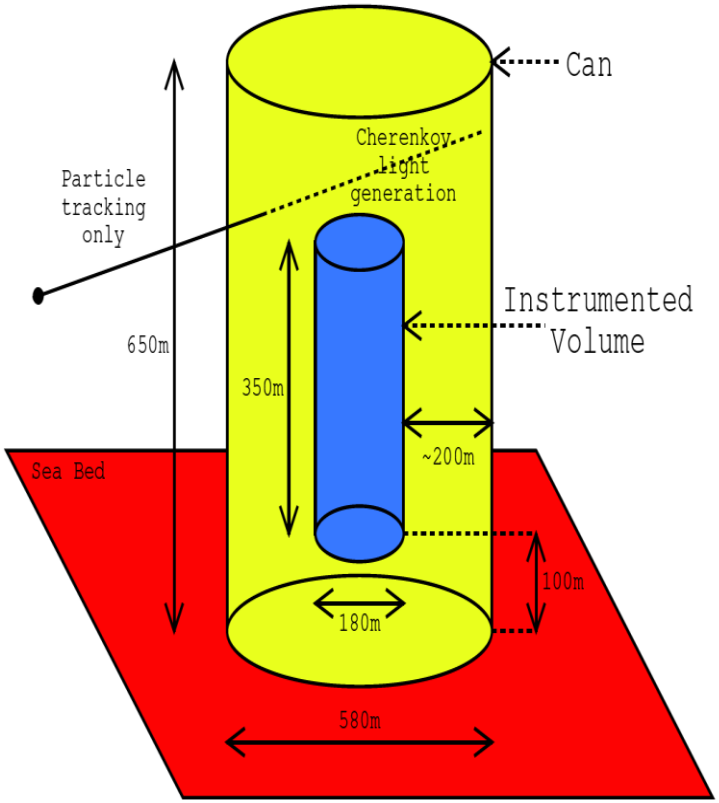


# *MC simulation & reconstruction*

- MMs are simulated with 9 equidistant ranges of velocity in the interval $\beta$ = [0.5945, 0.9950].

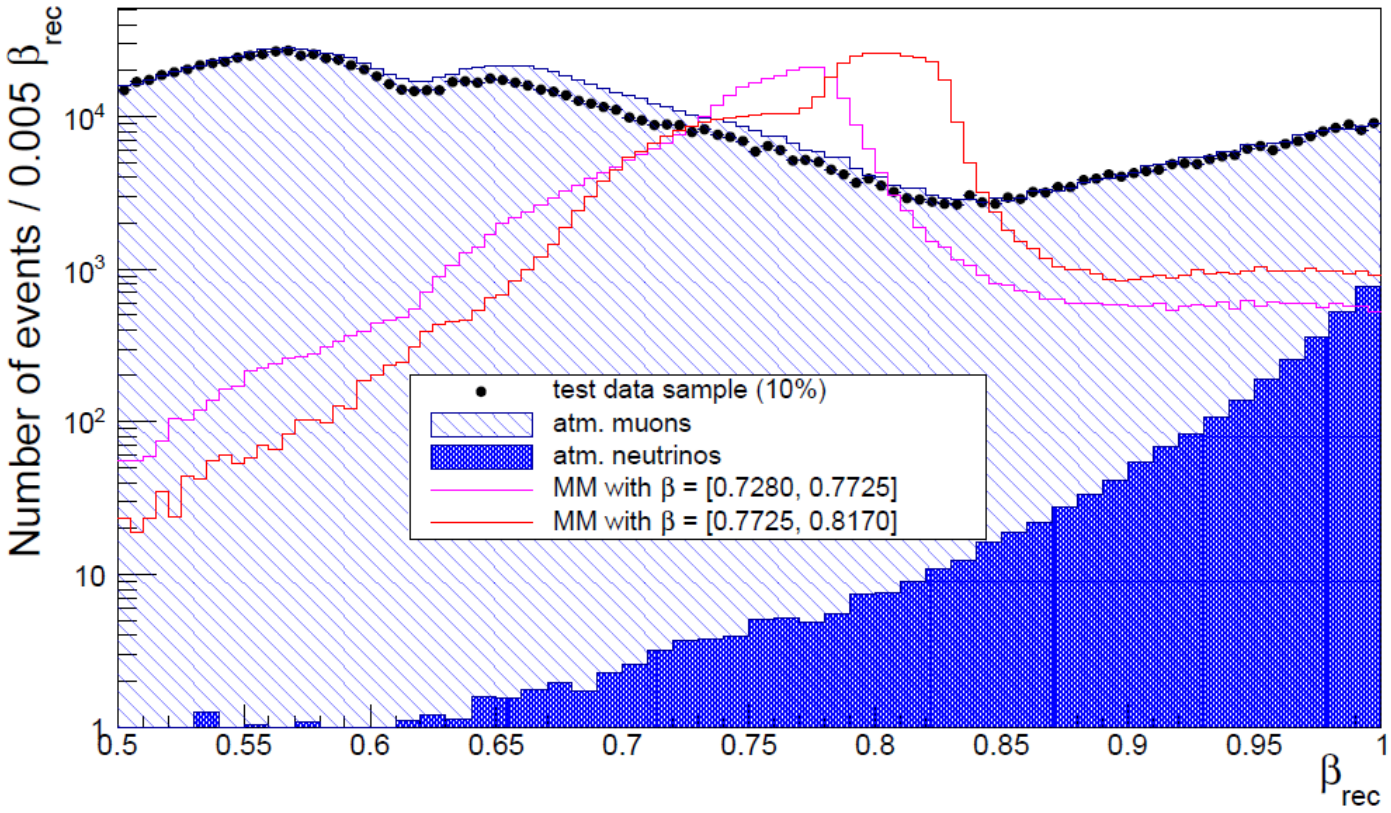
- The main source of background :
  1- Up-going muons induced by atmospheric neutrinos
  2- Down-going atmospheric muons wrongly reconstructed as up-going.

- The analysis is based on a run-by-run Monte Carlo simulation which takes into consideration the real data taking conditions of the detector.



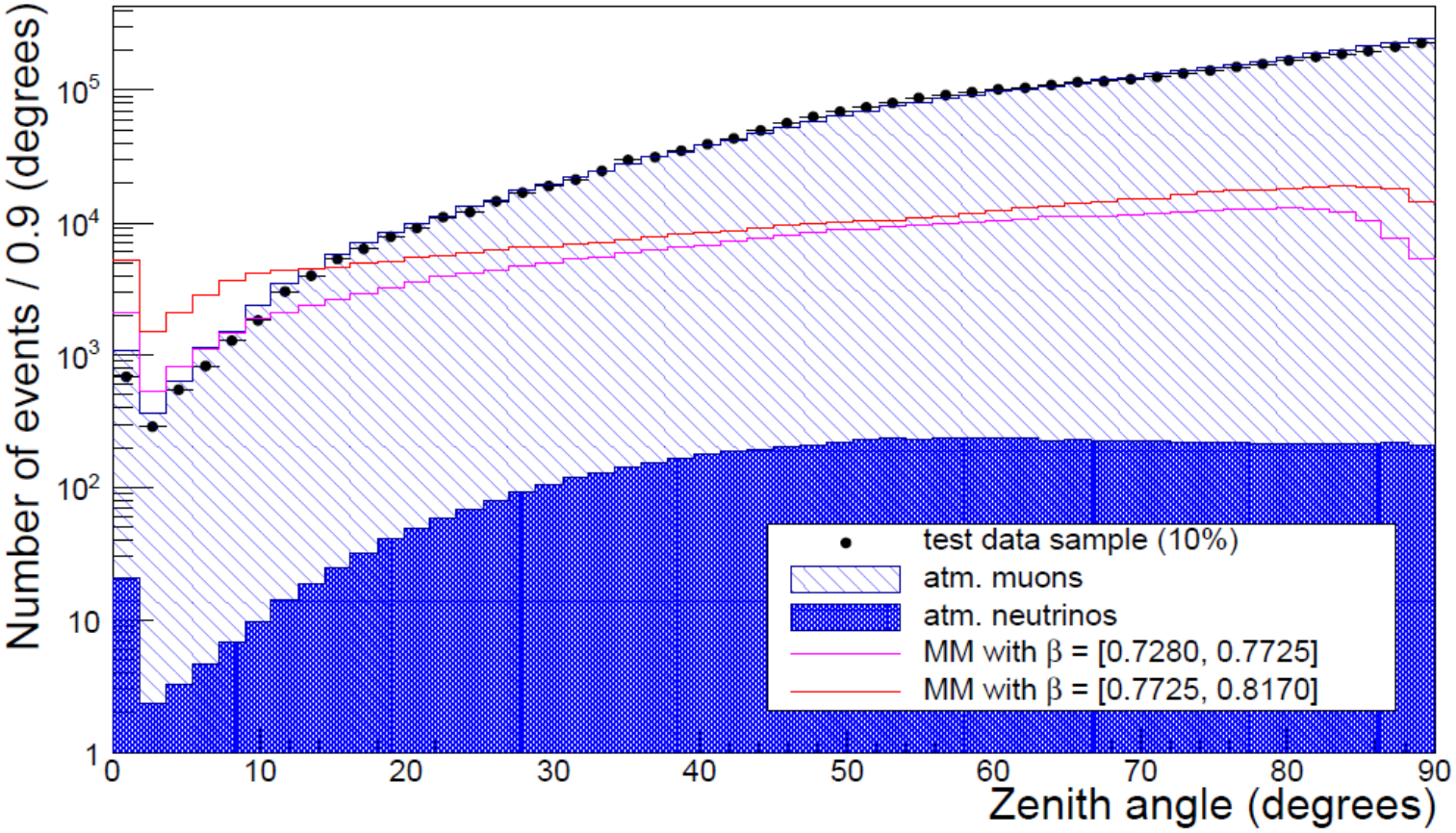
## *MC simulation & reconstruction*

- β is used to distinguish monopoles at low velocities.
- A sample of data (10%) is used for comparison.



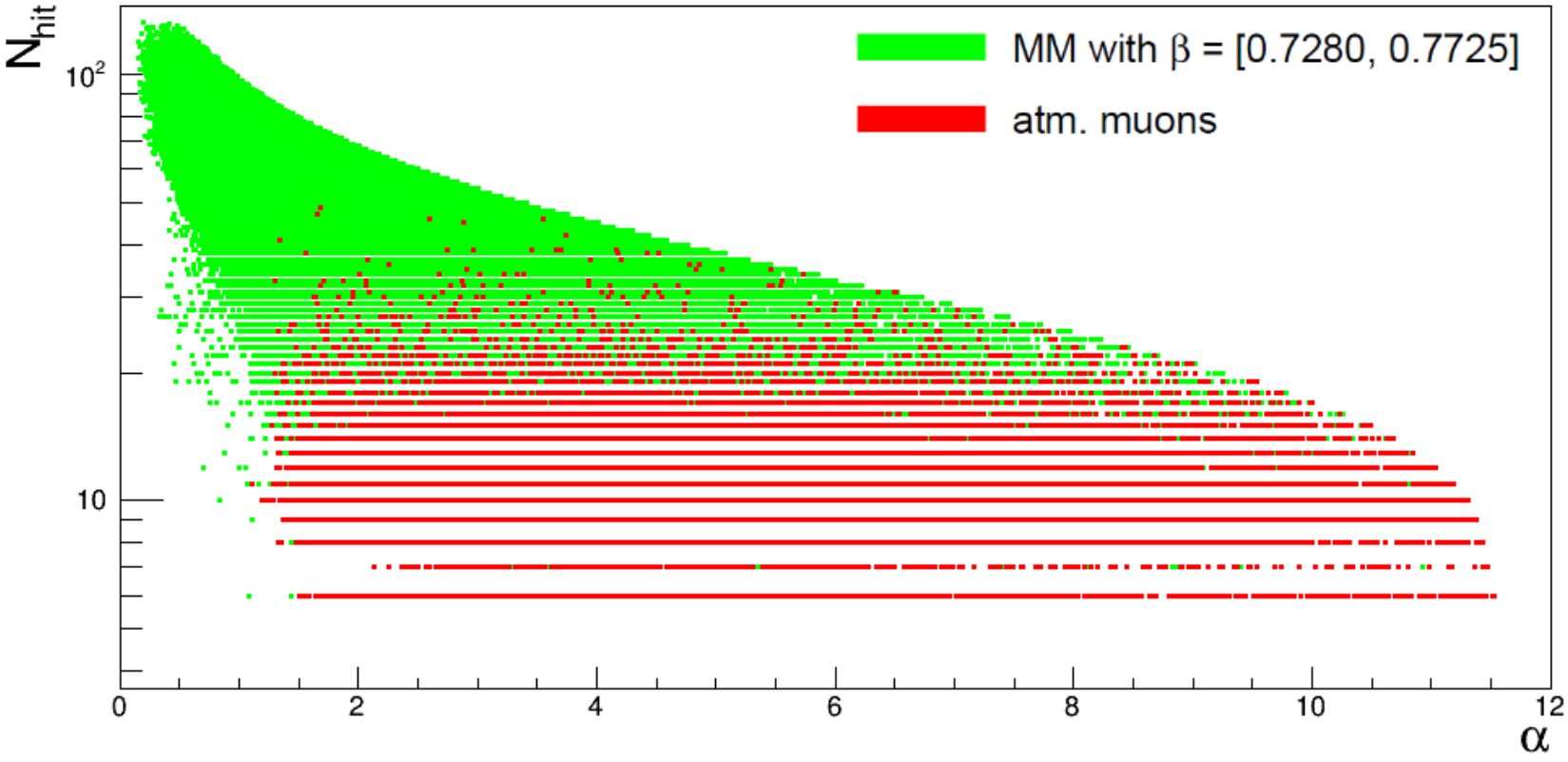
## *Event selection*

- Only up-going events with Zenith $\leq 90^{\circ}$ are selected
- Despite quality cuts, the selected event sample remains dominated by atm. muons for low beta



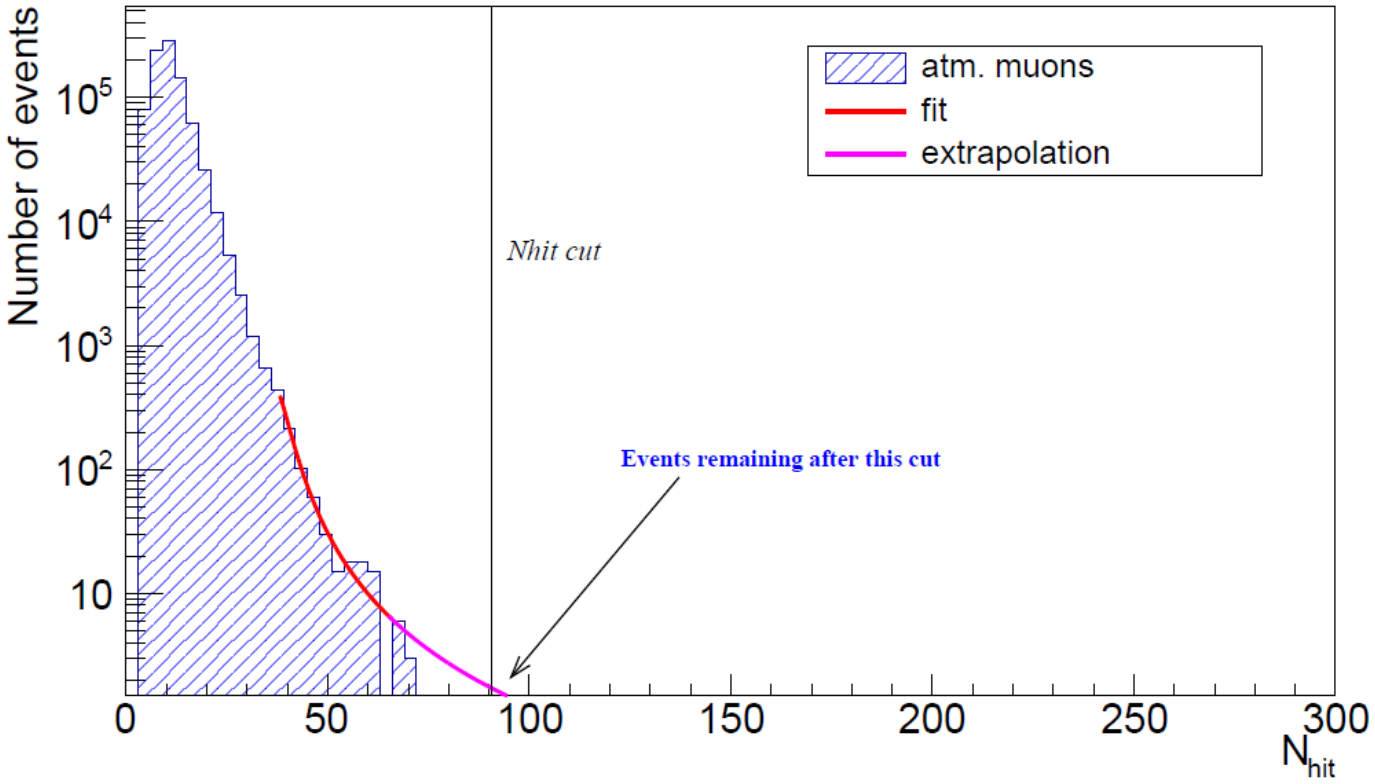
## *Optimization of cuts*

- Nhit : Number of storeys with a selected track hit.
- Alpha : Ratio of track fit quality parameter and Nhit.



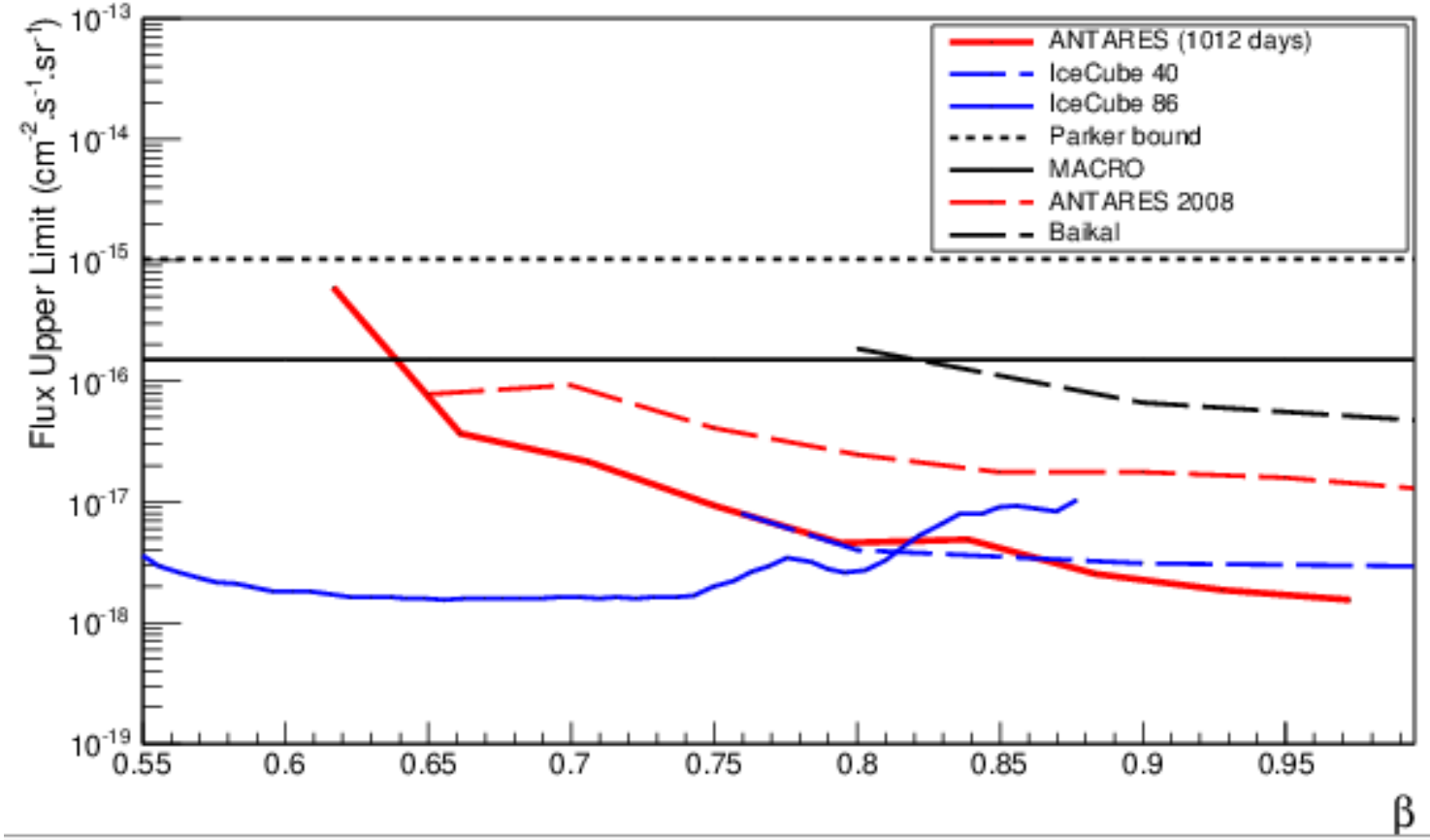
## *Atmospheric muon background*

To compensate the lack of statistics, an extrapolation of Nhit distribution is performed.



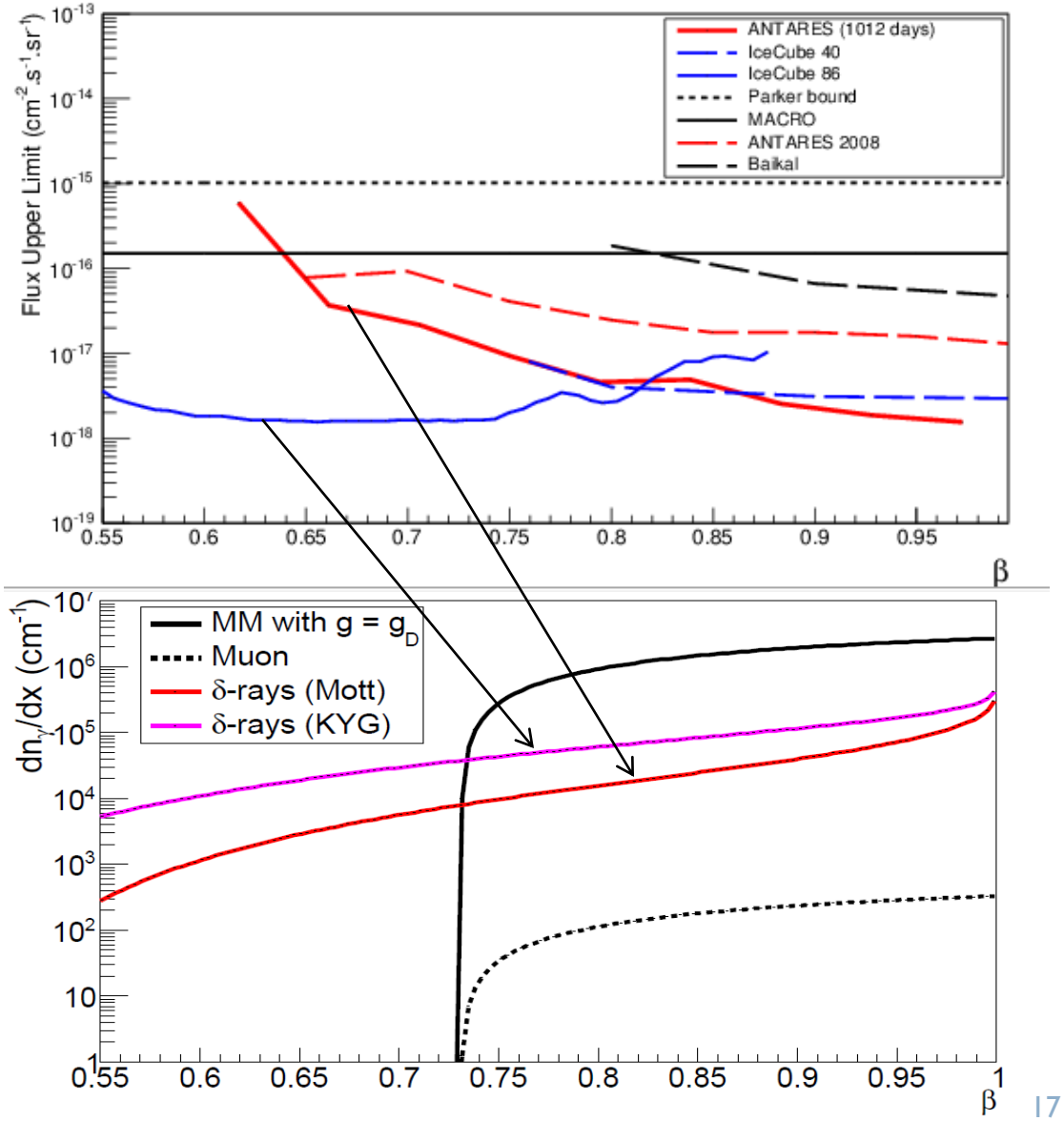
## *90 % C.L. upper limits on flux*

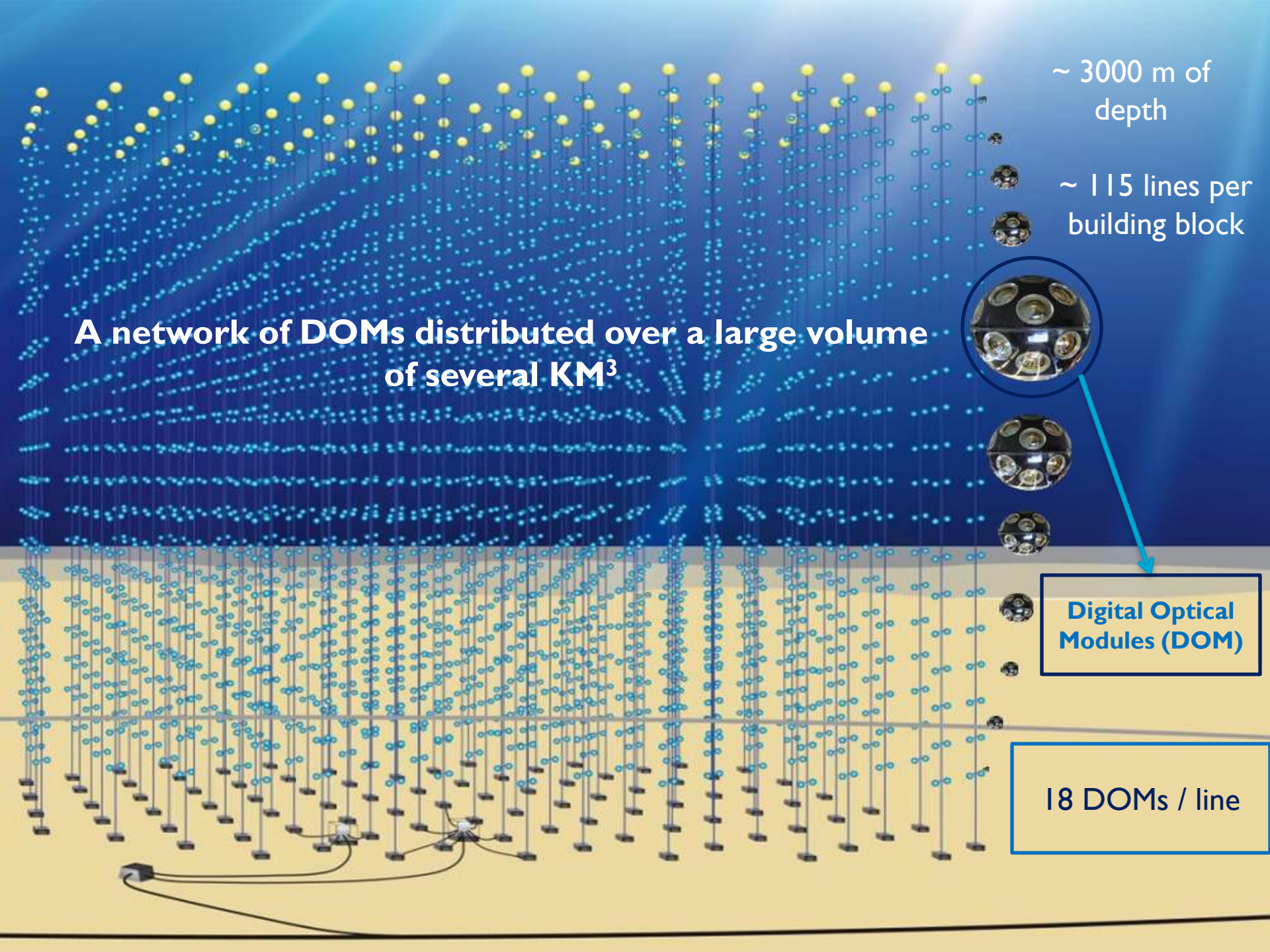
- The 90% confidence interval defined by the Feldman-Cousins approach is used.
- No events observed above the atmospheric background expected.
- Difficult comparison with IceCube: Use of a different model of cross section for the production of delta-rays.



# Conclusion

- Below the Cherenkov threshold β=0.74, the Mott mechanism is used for the production of delta-rays.
- Looking forward to use the KYG mechanism that provides more light for monopoles at low velocities.




~ 3000 m of depth
~ 115 lines per building block
A network of DOMs distributed over a large volume of several KM3
Digital Optical Modules (DOM)
18 DOMs / line

## *Perspectives*

***ARCA (Astroparticle Research with Cosmics in the Abyss)***

Site: Italy

**High energy neutrinos**

***ORCA (Oscillation Research with Cosmics in the Abyss)***

Site: France

**Low energy neutrinos**

***We are planning to start a new analysis of monopoles in the framework of KM3NeT !***

Merci pour

votre attention