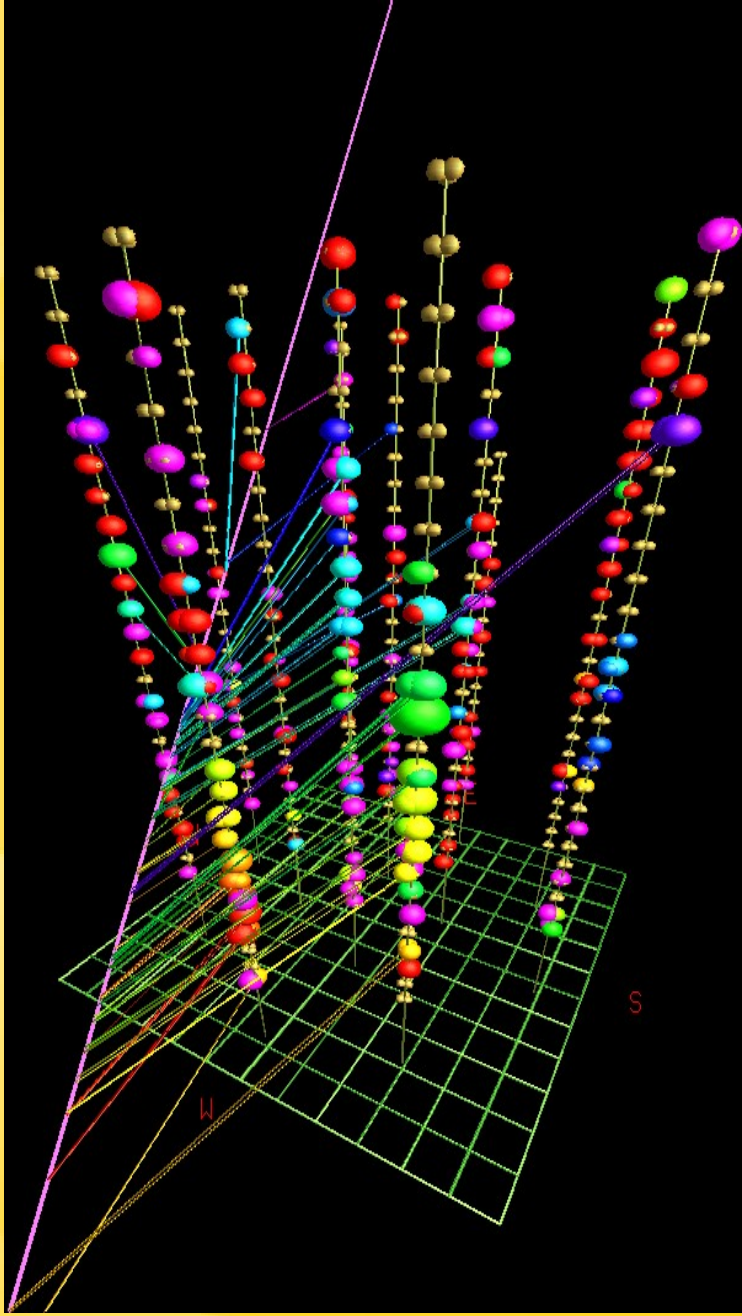
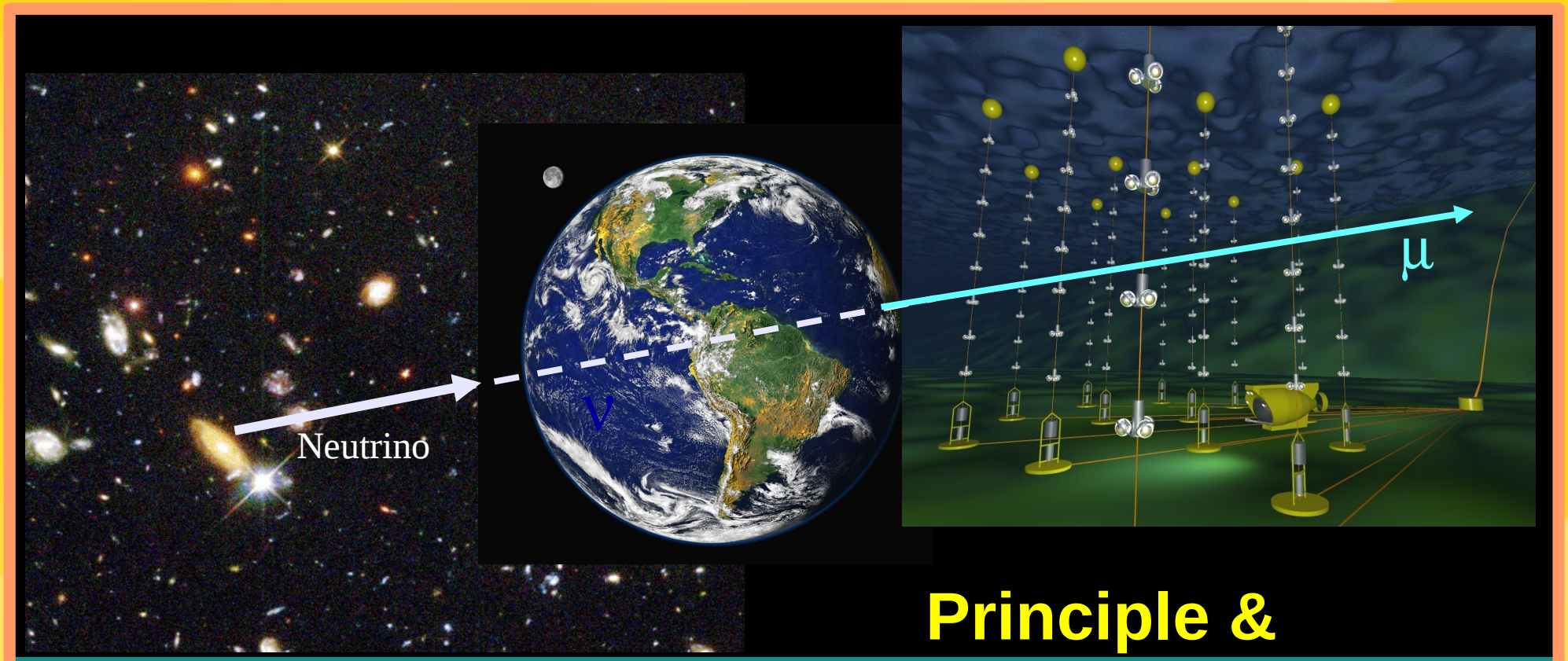
The ANTARES deep-sea neutrino telescope



JP Ernenwein, for the ANTARES collaboration
Univ Aix-Marseille
CPPM

TeVPA 2010
Paris
20/07/2010



Principle & Physics

Supernovae

Oscillations

Dark Matter

Astrophysical neutrinos

GZK, topological defects

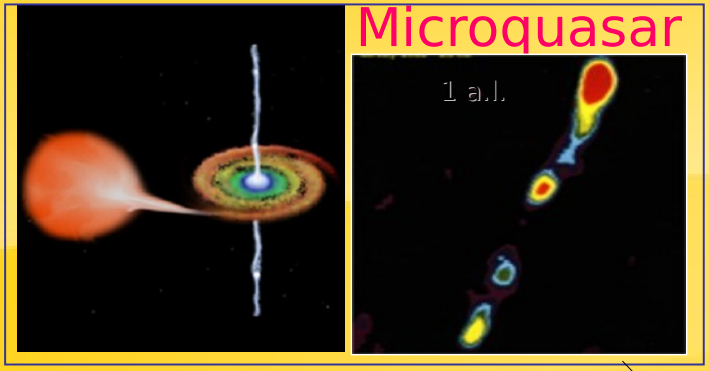
short muon path
weak light
^{40}K

MeV GeV TeV PeV EeV

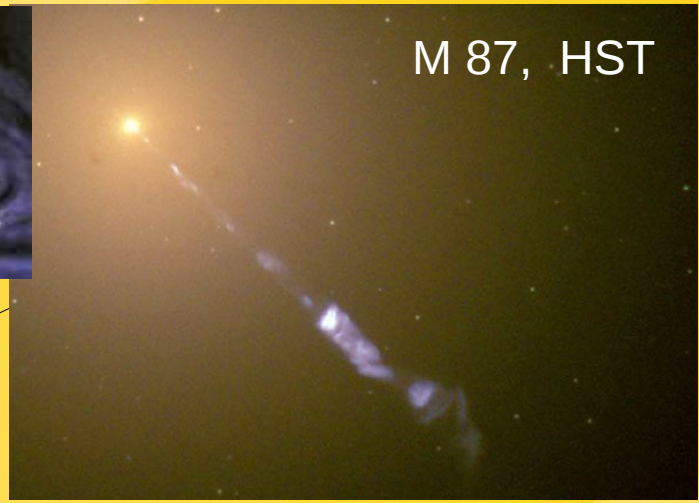
Fast decrease of fluxes E^{-2}, E^{-3}

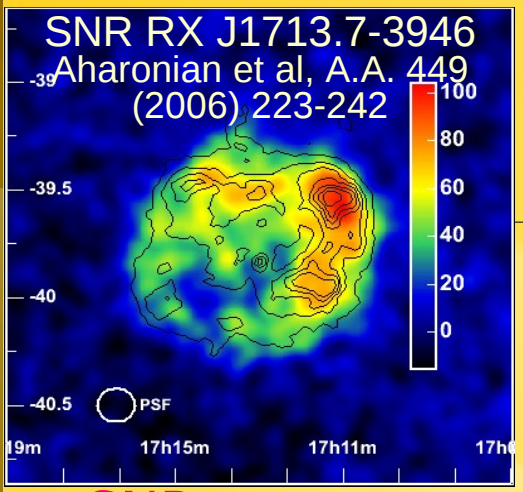
Potential sources of neutrinos

Microquasar

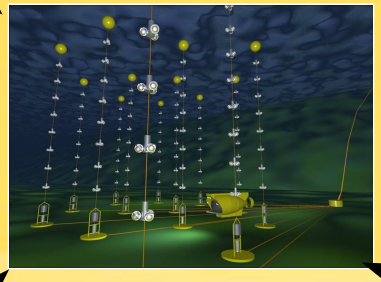


Active Galactic Nuclei

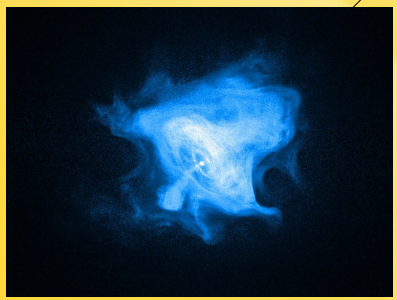




SNR

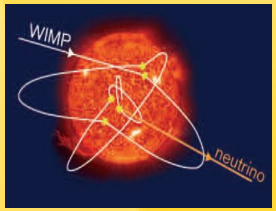


Gamma Ray Bursts



Pulsars

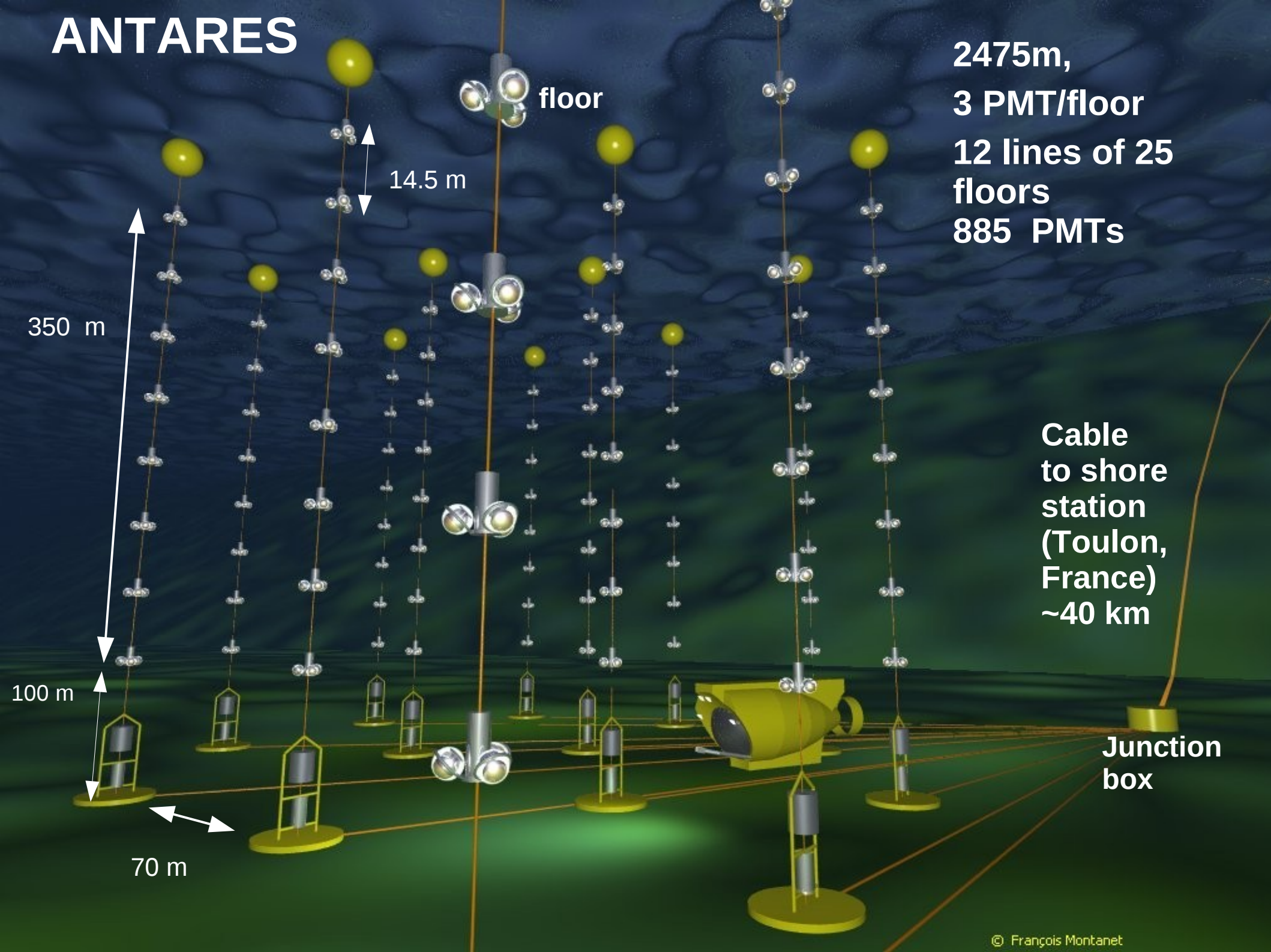
Dark Matter



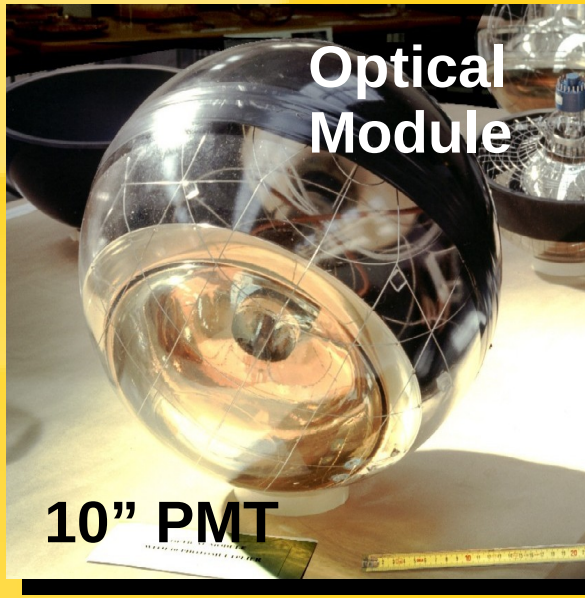
Exotic physics

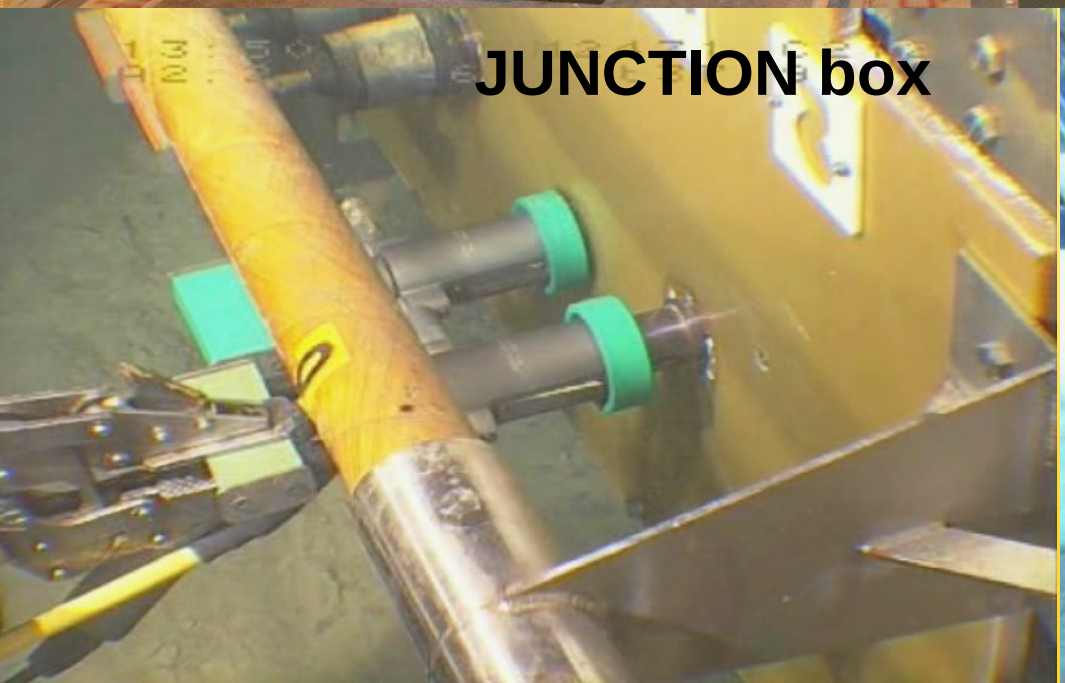
Magnetic Monopoles

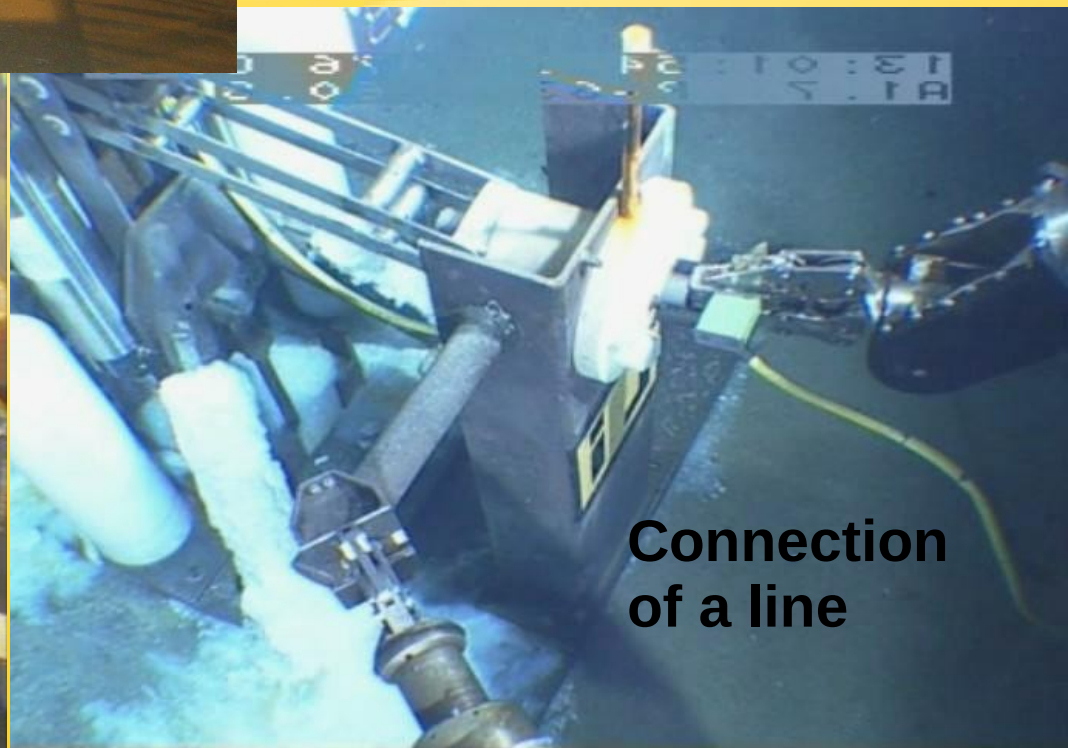
Nuclearites


ANTARES
floor
14.5 m
350 m
100 m
70 m
2475m,
3 PMT/floor
12 lines of 25 floors
885 PMTs
Cable to shore station (Toulon, France) ~40 km
Junction box
© François Montanet


floor


Optical
Module
10” PMT


JUNCTION box


Connection
of a line

2005 | 2006 | 2007 | 2008

Mar: MILOM

Mar: L1

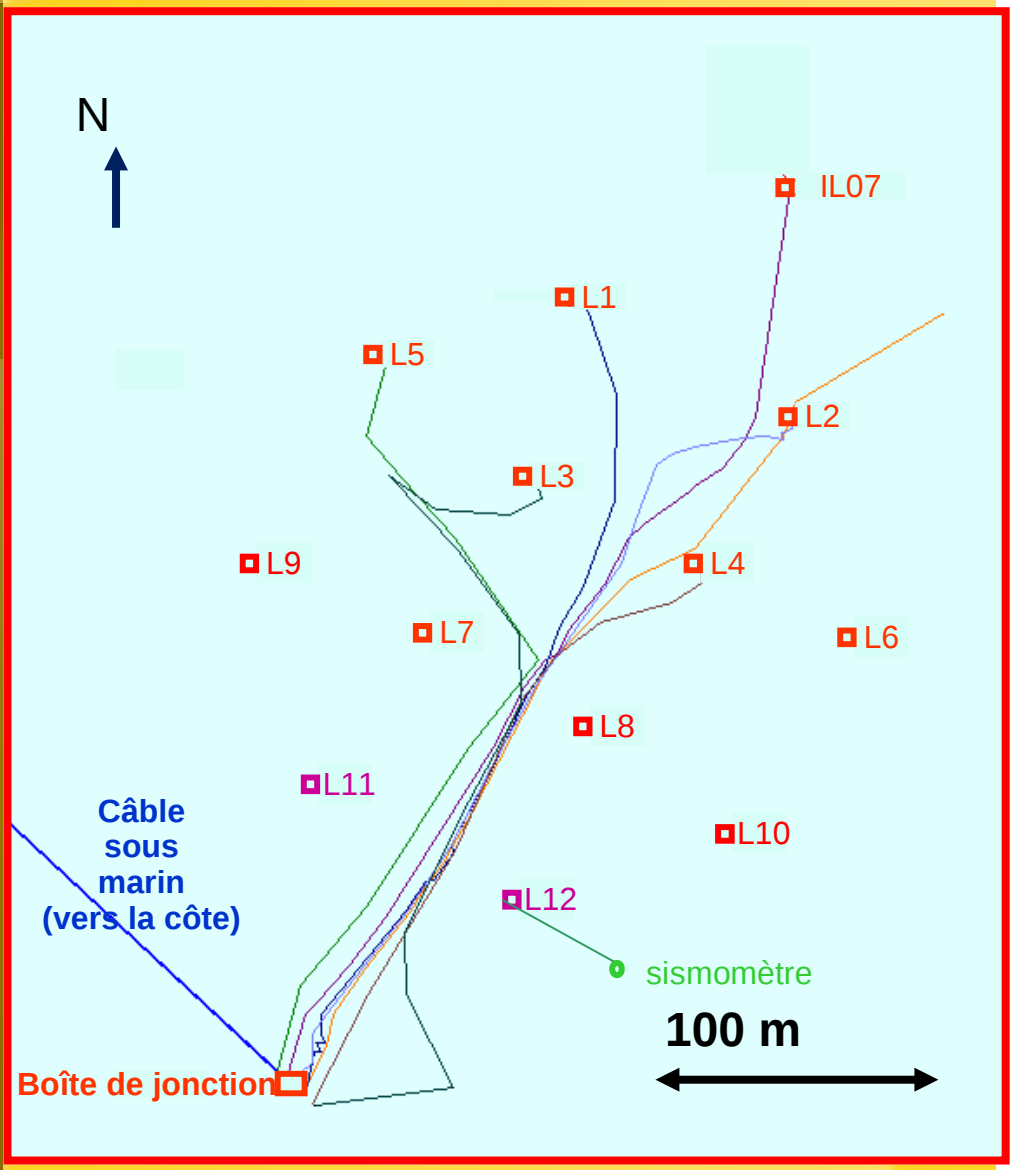
Sep: L2

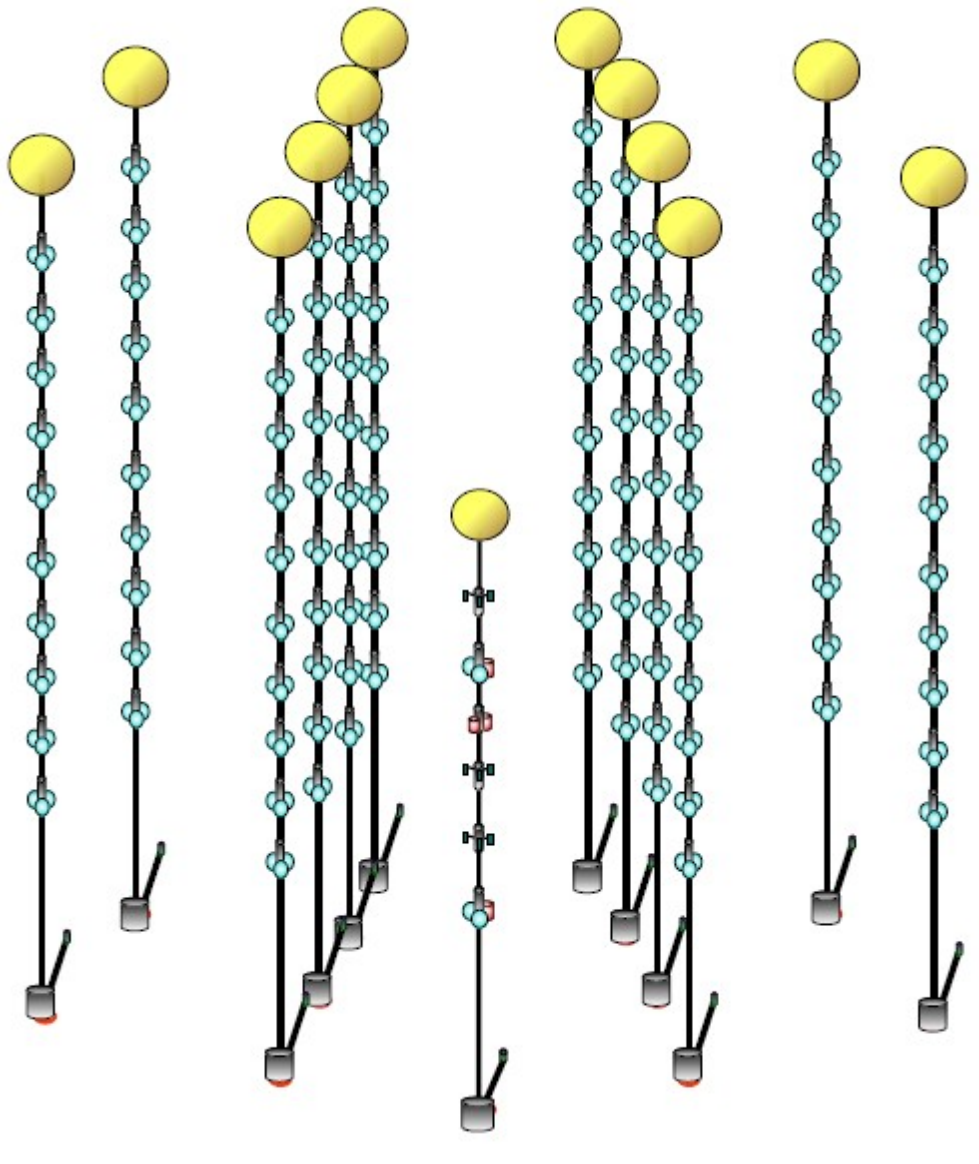
Jan : L3-5 MILOM recovery

Dec: L6-10 IL07

Jun: L11,12

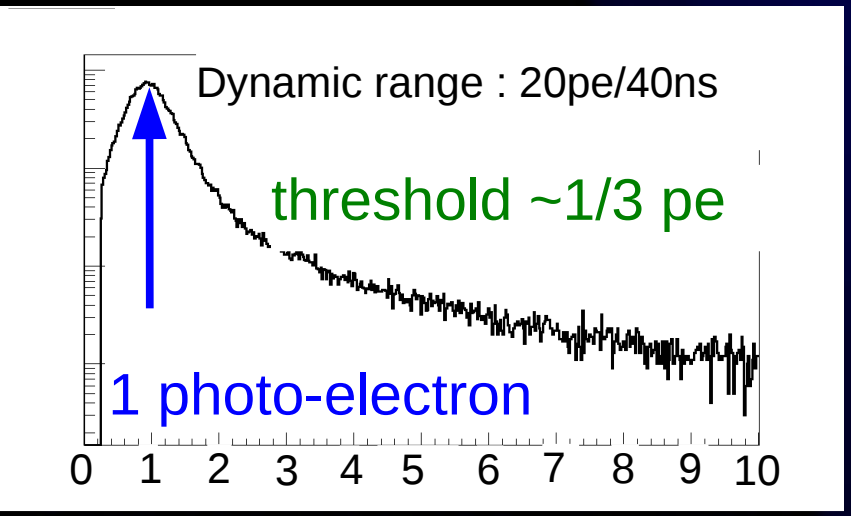
Connection of lines





Detection principle

3D matrix



Cherenkov light (μ)

$\gamma_{\check{c}}$

required sensitivity: photo-electron

shower

good energy resolution (O(30%)), poor angular resolution (O(10°))

ν_e

42°

2475 m

© François Montanet

Charged current interaction (W)

μ

track:

Good angular resolution (~0.3 degrees @ E>10 TeV), Poor energy resolution (factor 2-3)

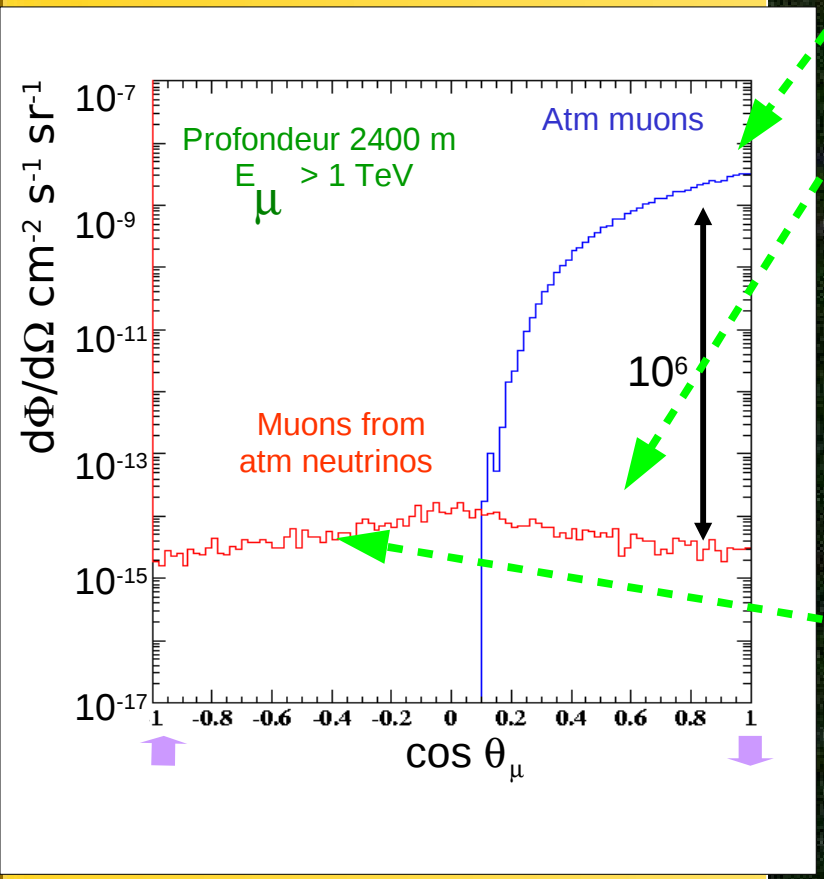
ν_μ

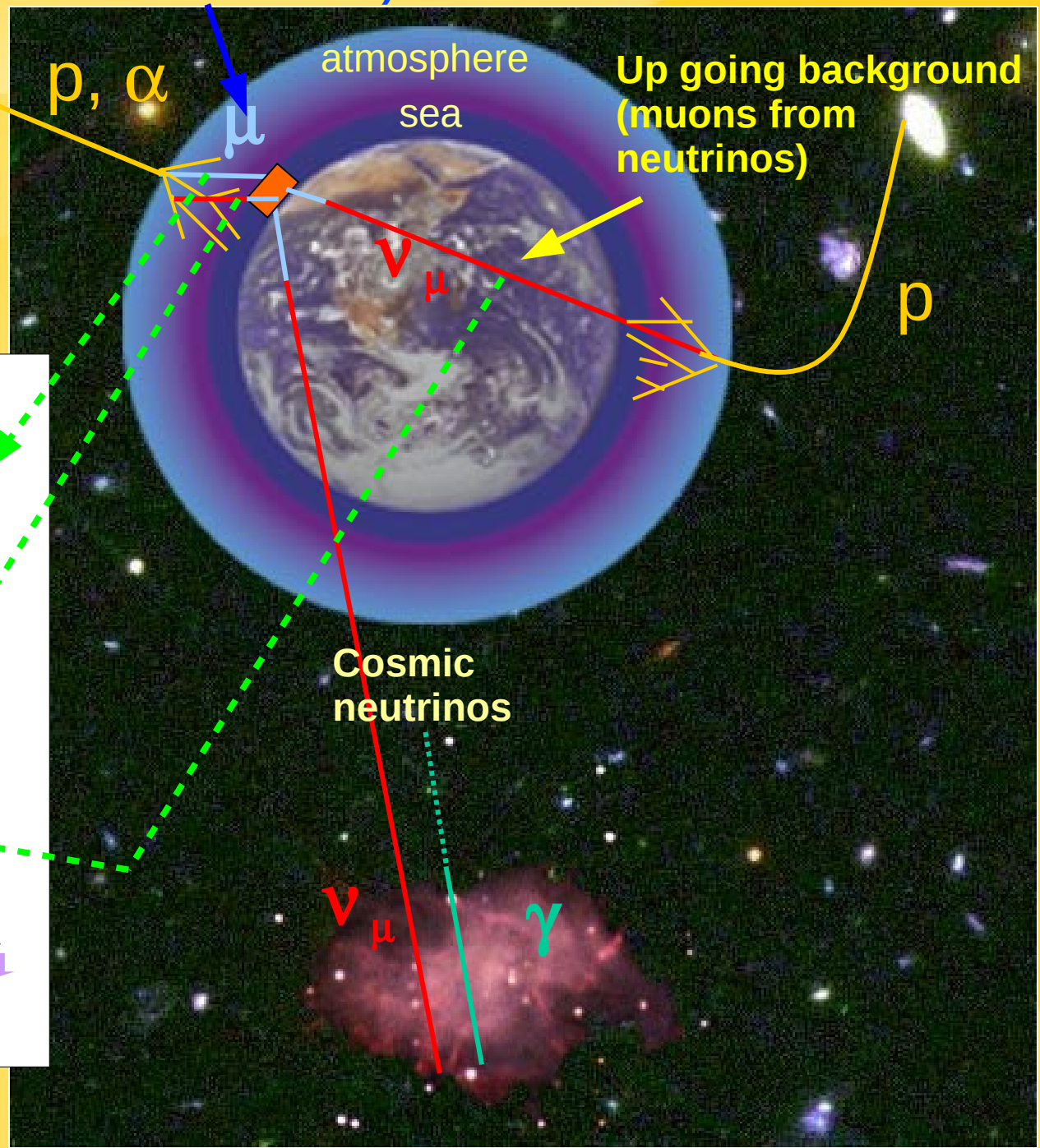
Measurements time (O(ns)), amplitude (30%) & hit position(O(10 cm))

Muon track or shower measurement

Signal & background

Down going background events (atm muons and muons from neutrinos)

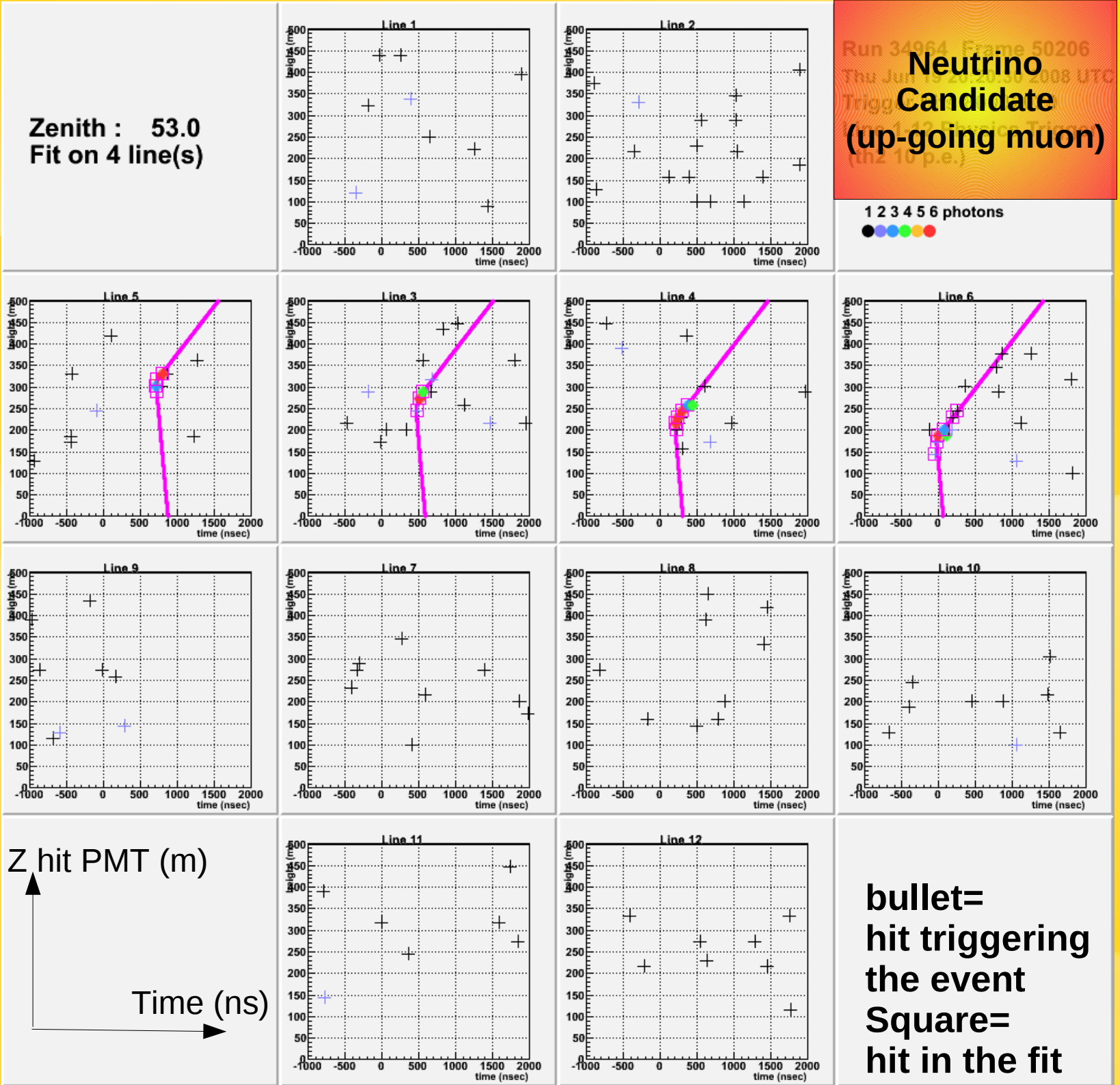




Atmospheric muons & neutrinos

χ^2 method (no alignment)

Zenith : 53.0
Fit on 4 line(s)



Neutrino Candidate (up-going muon)

1 2 3 4 5 6 photons

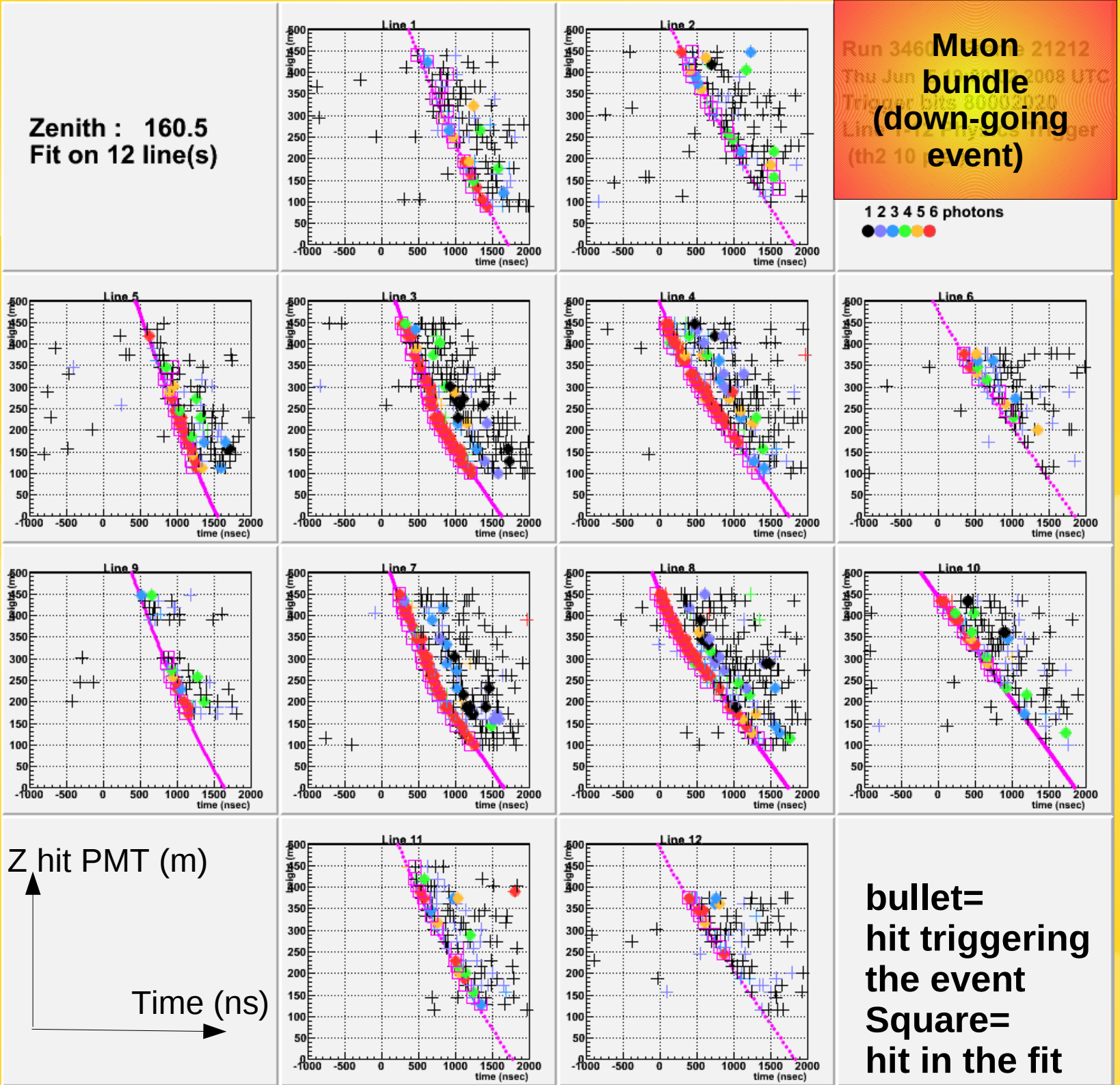
Z hit PMT (m)

Time (ns)

bullet= hit triggering the event
Square= hit in the fit

χ^2 method (no alignment)

Zenith : 160.5
Fit on 12 line(s)



Muon bundle (down-going event)

1 2 3 4 5 6 photons

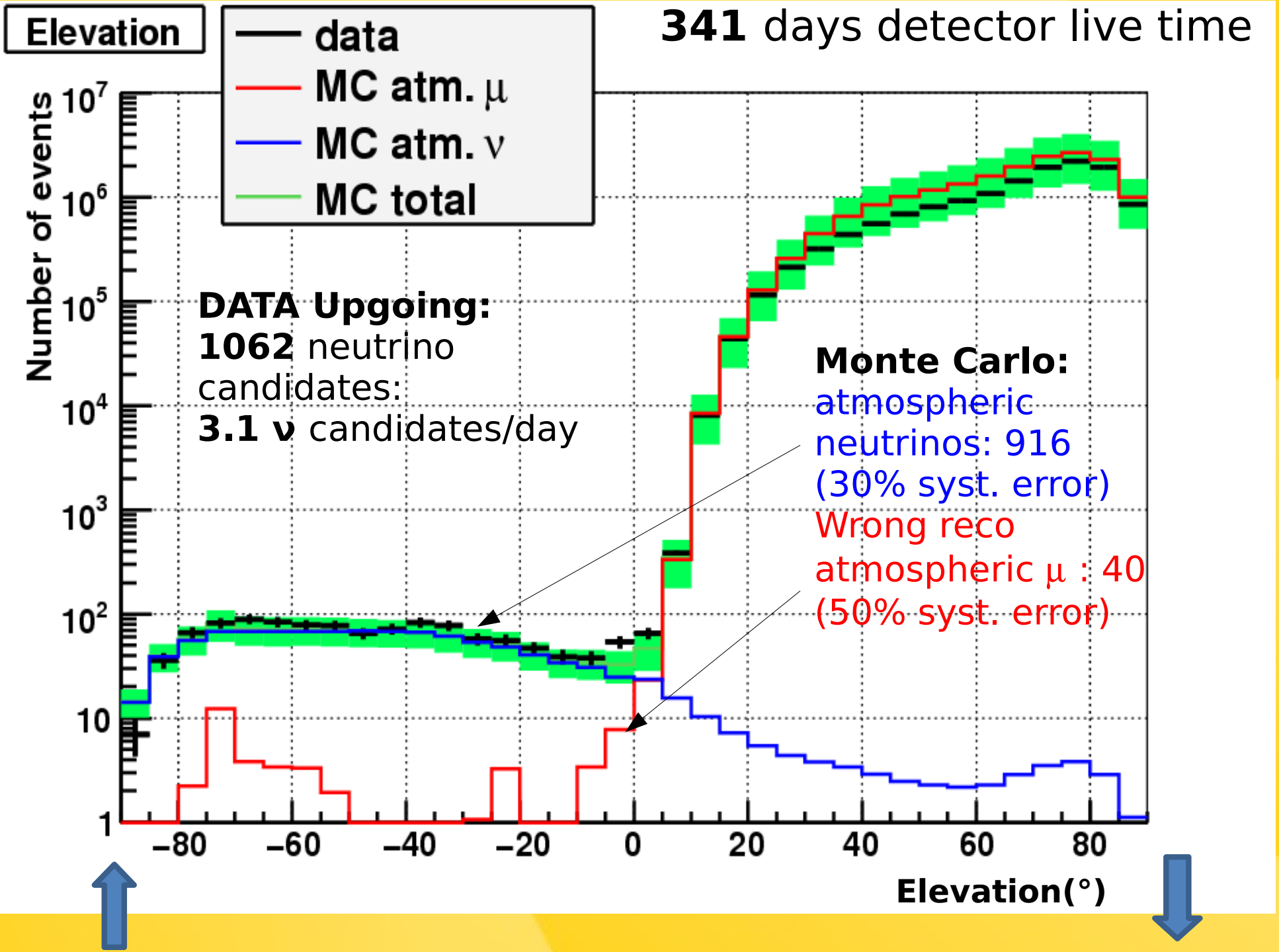
Z hit PMT (m)

Time (ns)

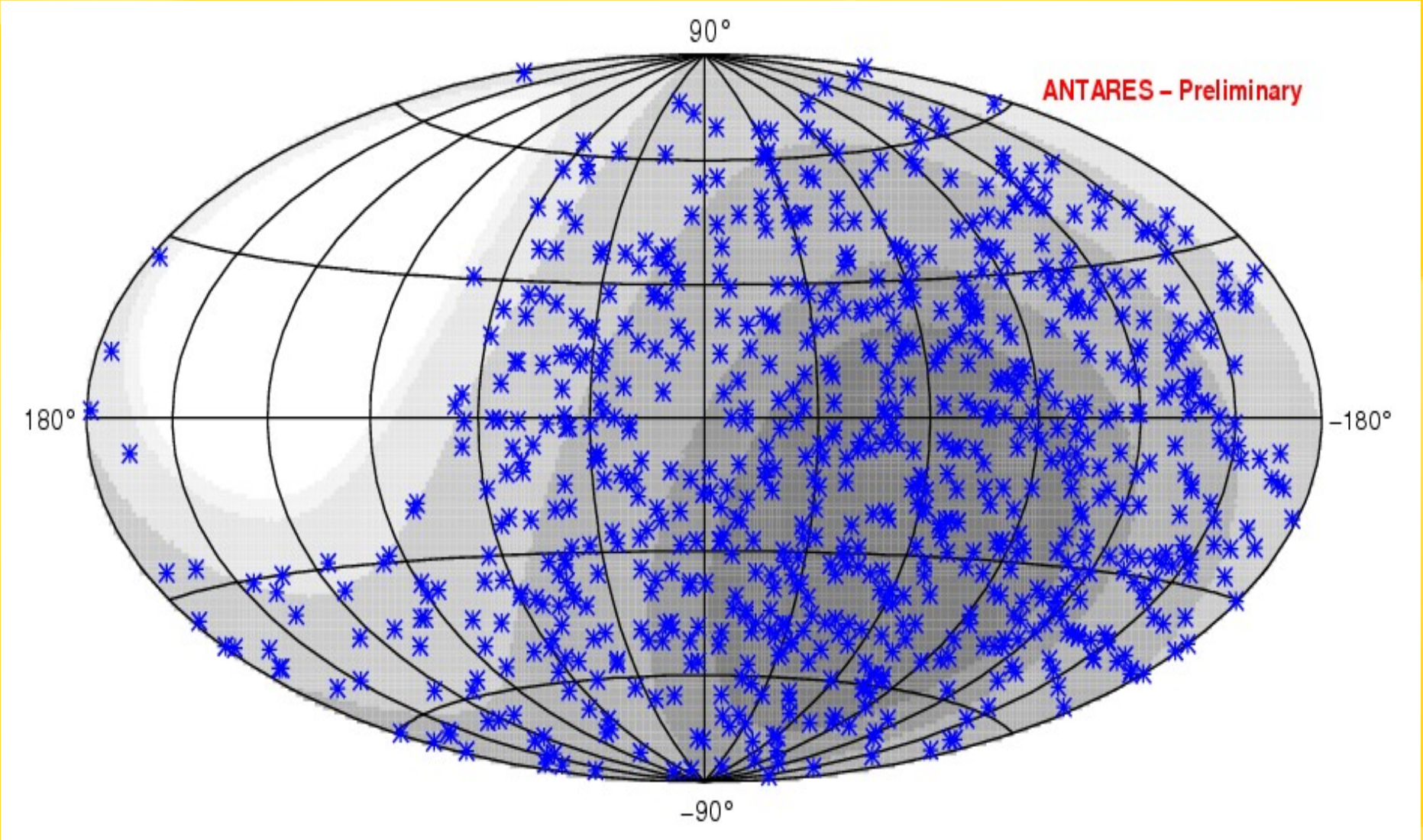
bullet= hit triggering the event
Square= hit in the fit

5-line data (May-Dec. 2007) + 9-12 line data (2008)=

341 days detector live time

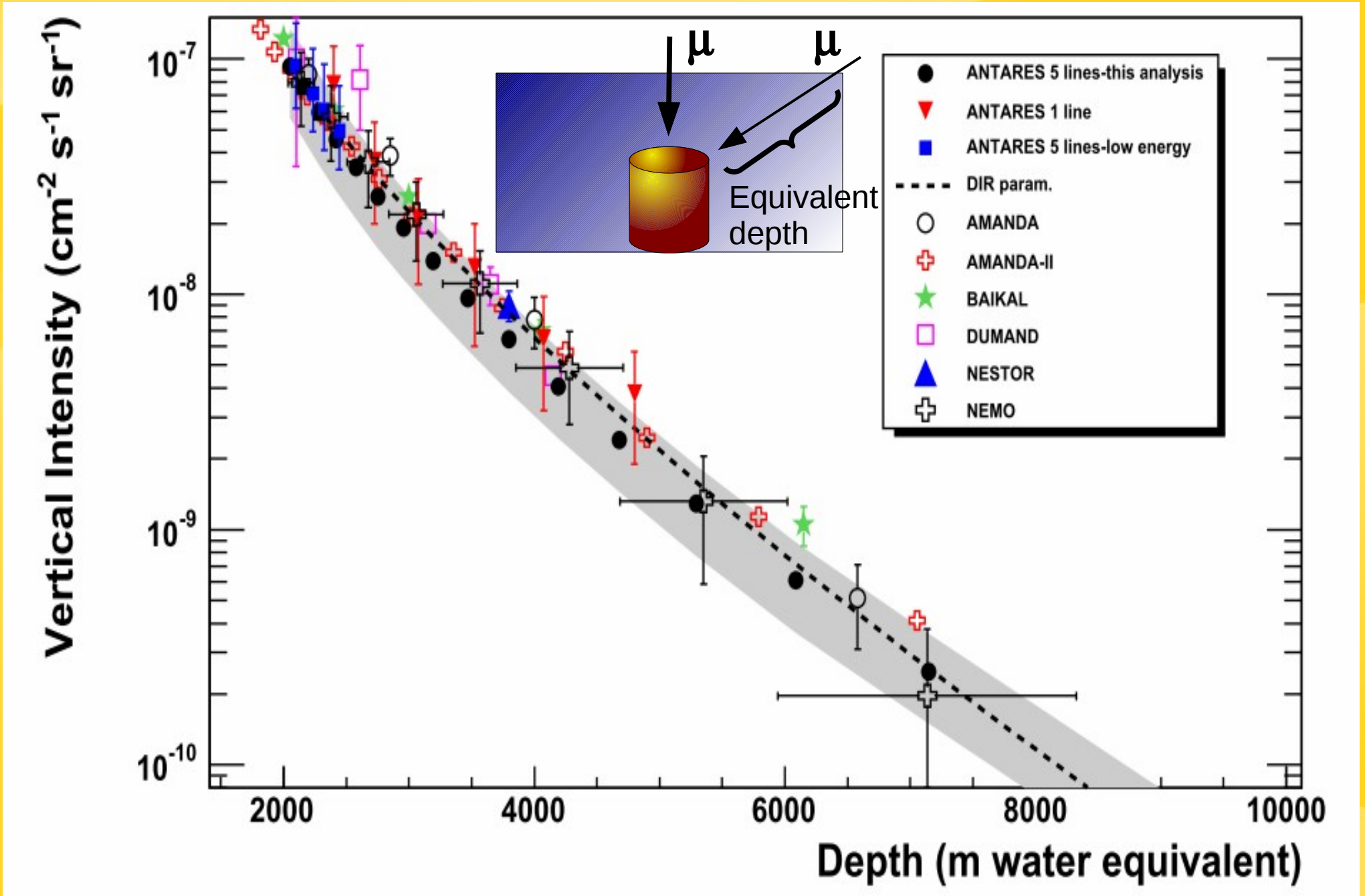


Scrambled ANTARES Sky map of 1000 ν

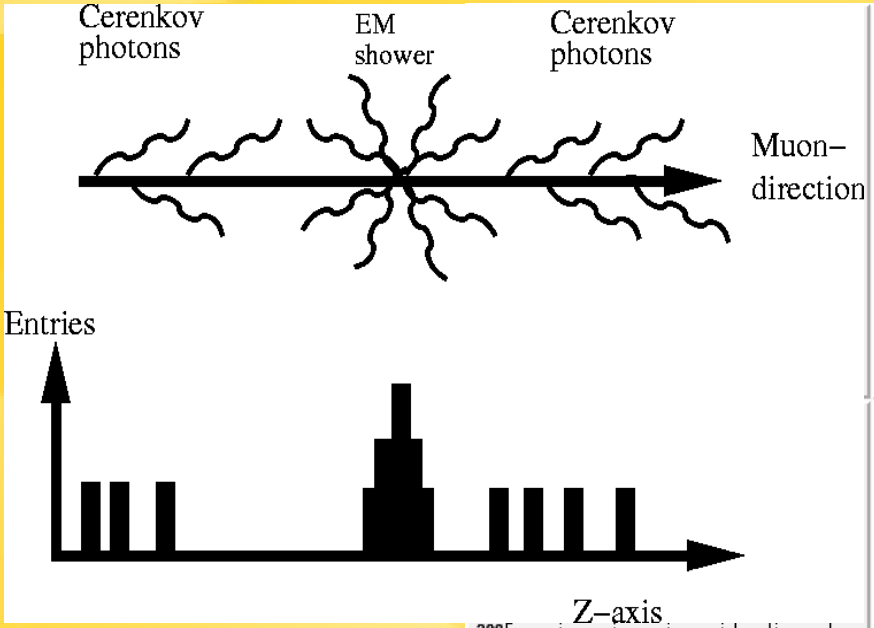


Galactic Coordinates

Muon depth-intensity relation

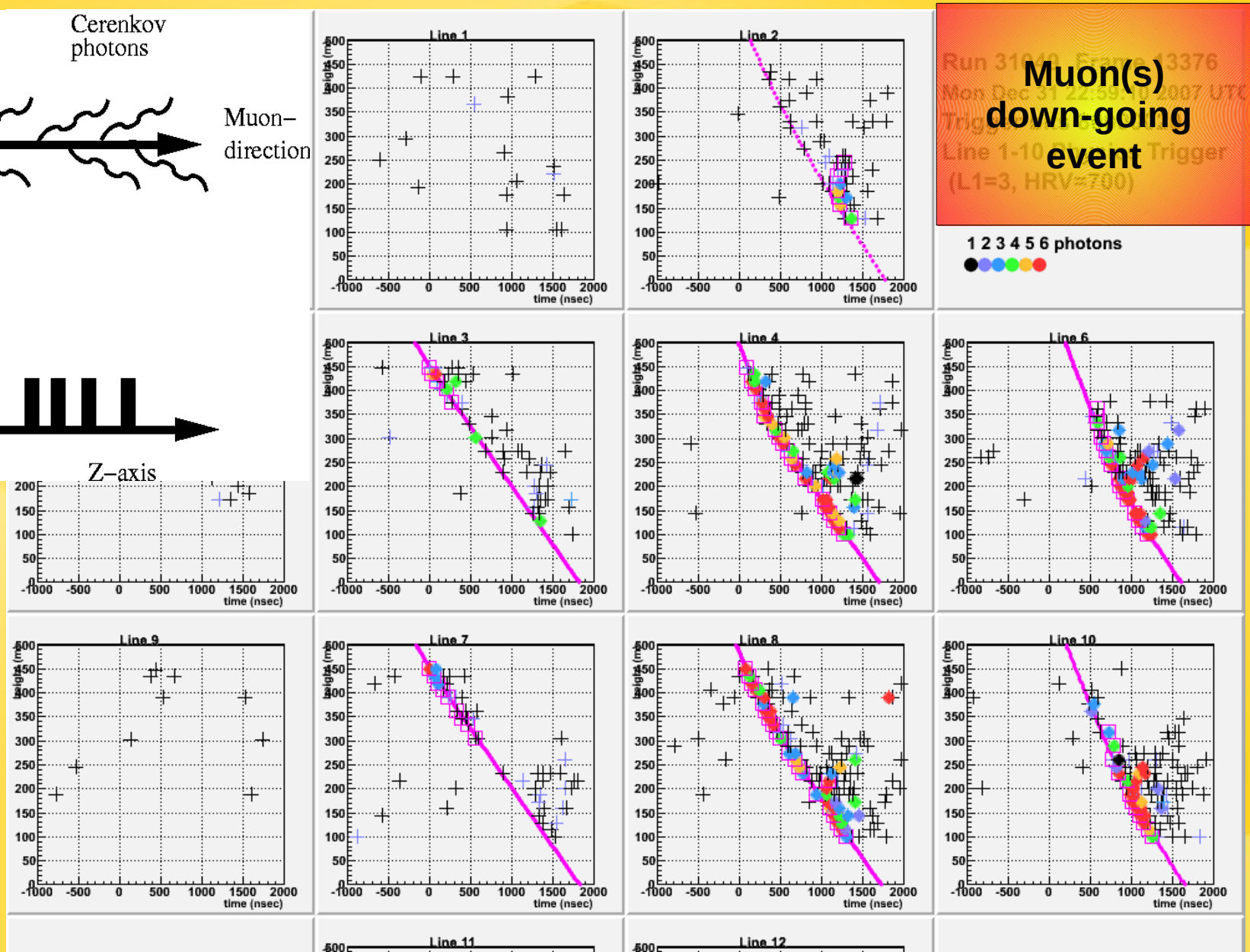


Electromagnetic showers induced by atmospheric muons



Muon(s) down-going event

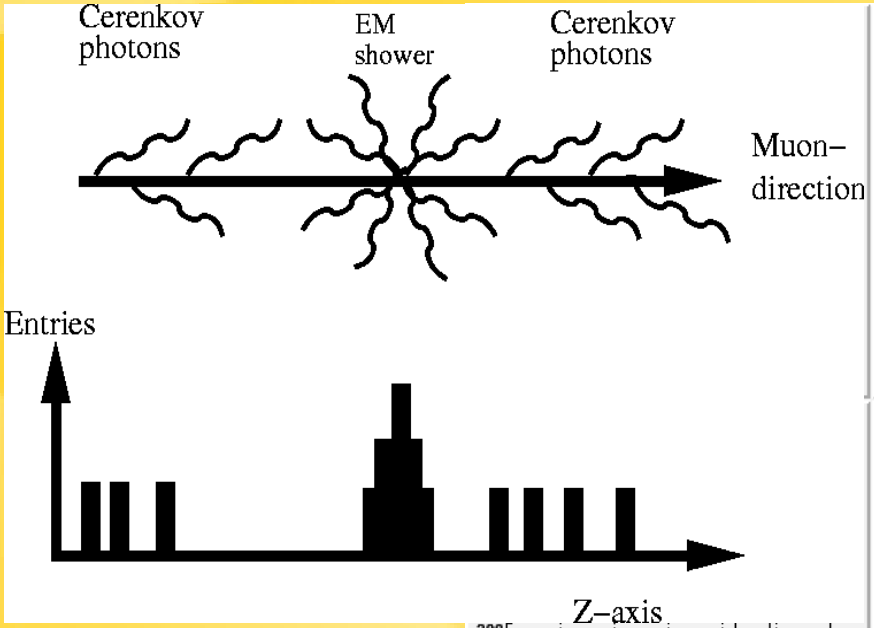
1 2 3 4 5 6 photons

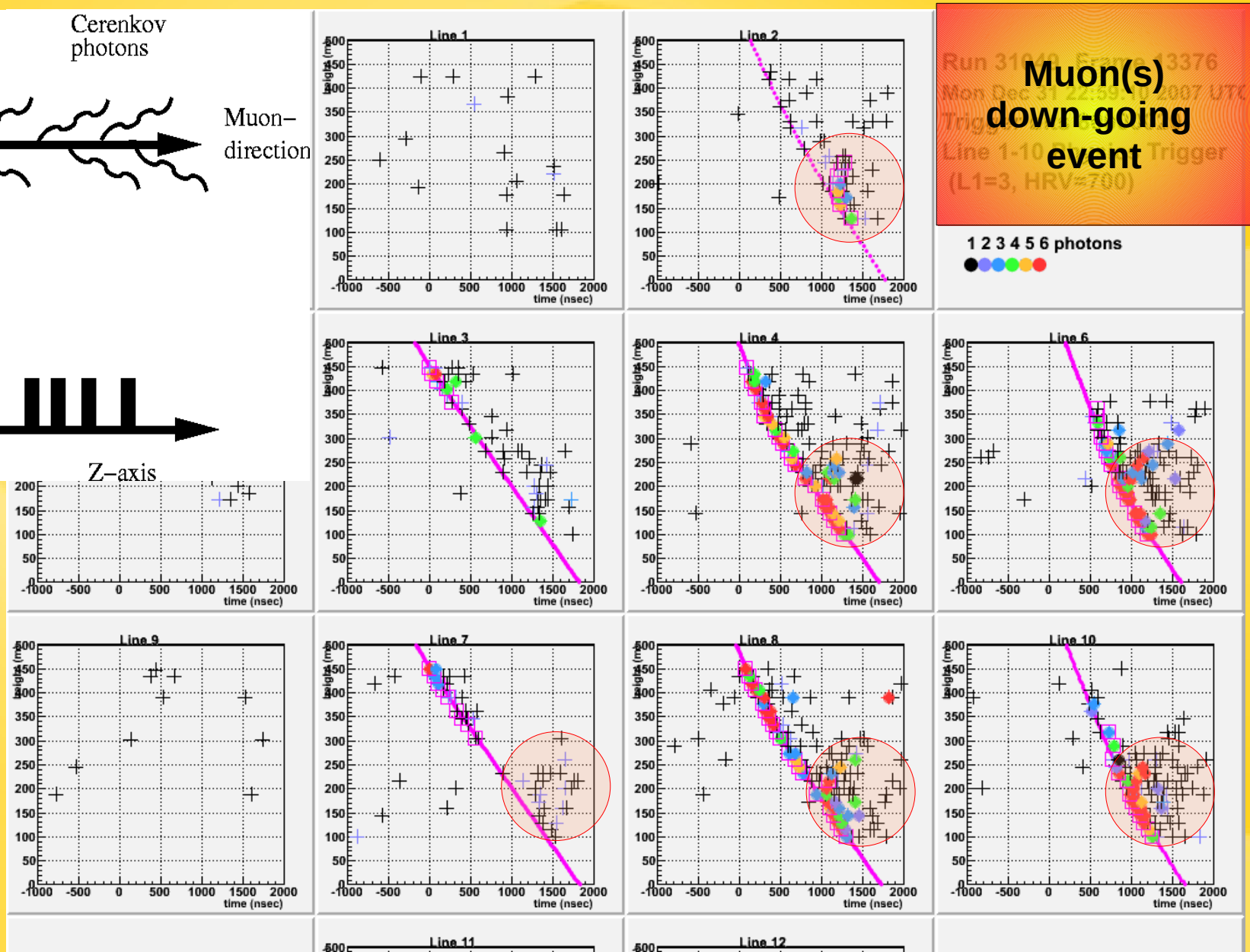


Z hit PMT (m)

Time (ns)

Electromagnetic showers induced by atmospheric muons



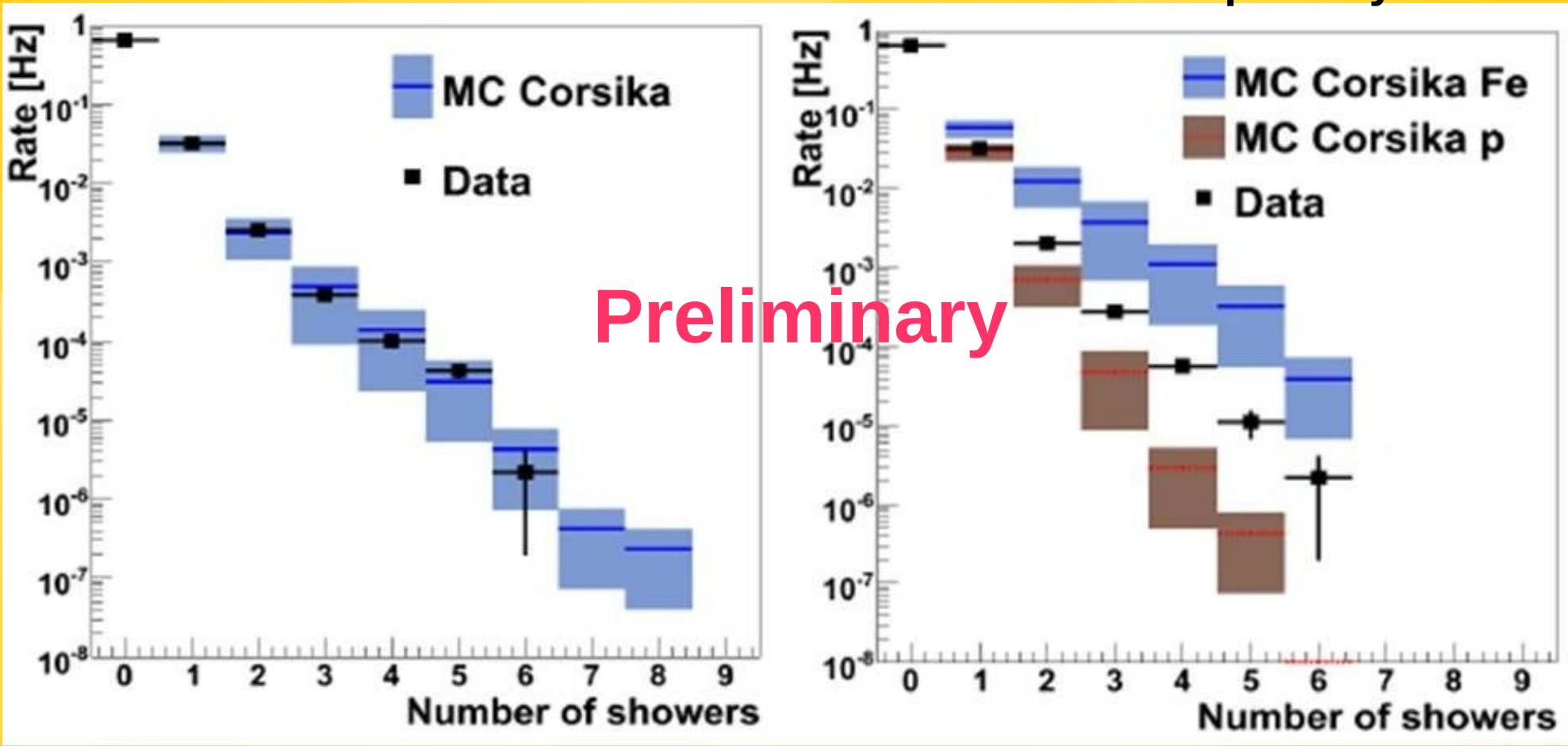


Muon(s) down-going event

1 2 3 4 5 6 photons

Electromagnetic showers induced by atmospheric muons

Sensitive to primary



Ongoing combined searches

- Receive GRB alerts from Satellites

search for coincident neutrinos within time window (~100 s)

- Send neutrino cluster alert for optical follow-up

Trigger: multiple or ”HE single” neutrino event; Reconstruction “on-line” (<10ms). Alert message to Tarot Telescope in La Silla and to the ROTSE system (4 telescopes)

- Correlation with AUGER source distribution

investigate directional correlation of neutrinos and UHE particles

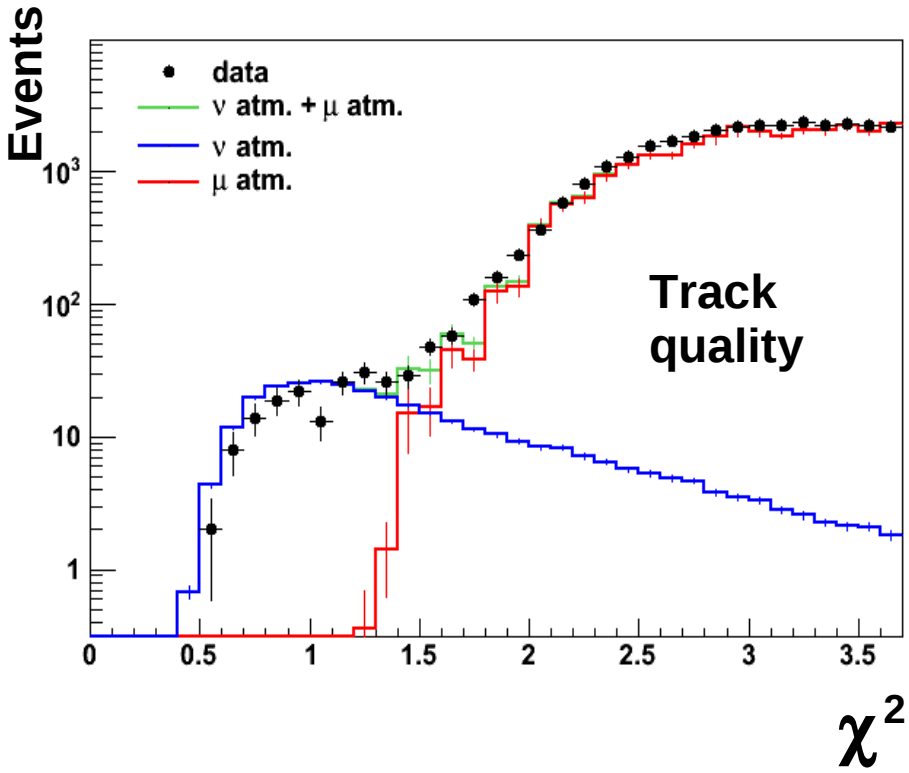
- Correlation with VIRGO-LIGO signals

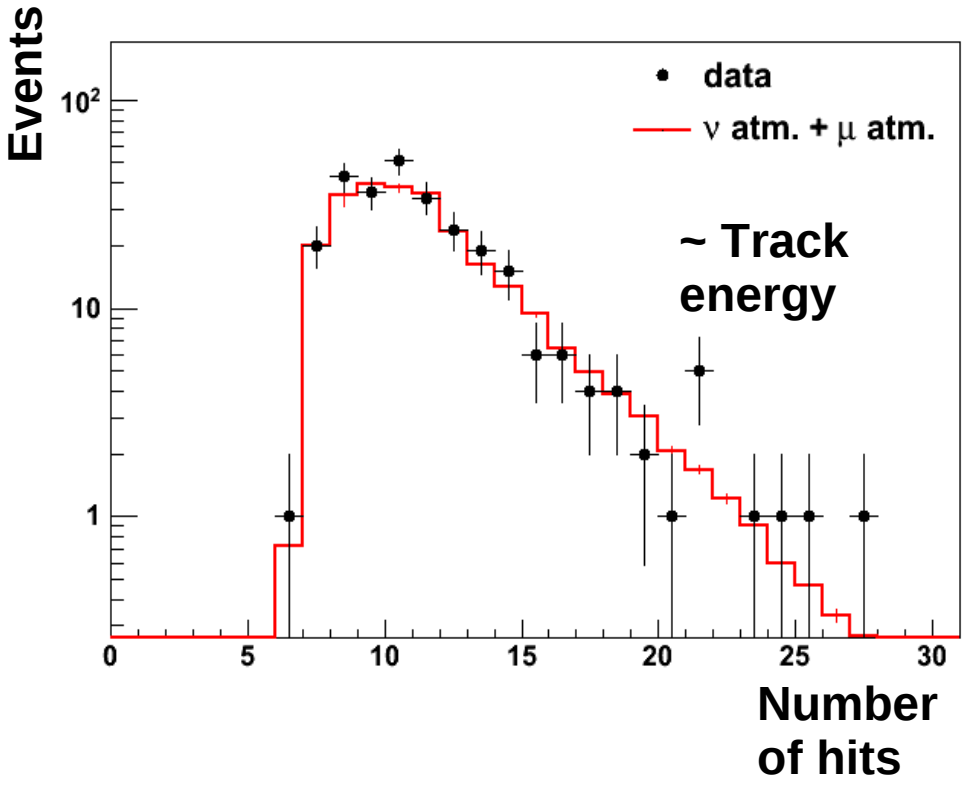
investigate correlation of neutrinos and gravitational waves

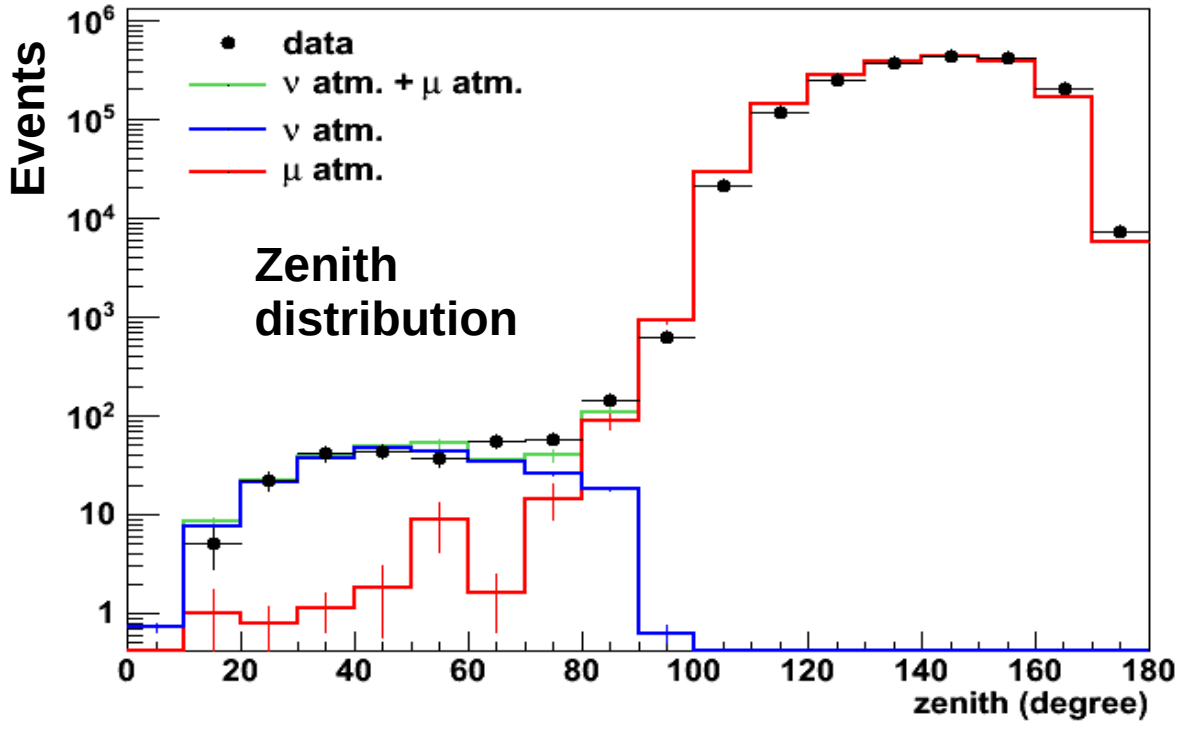
Point source search

DATA on 5 lines (2007)
140 days equivalent

Event reconstruction and selection



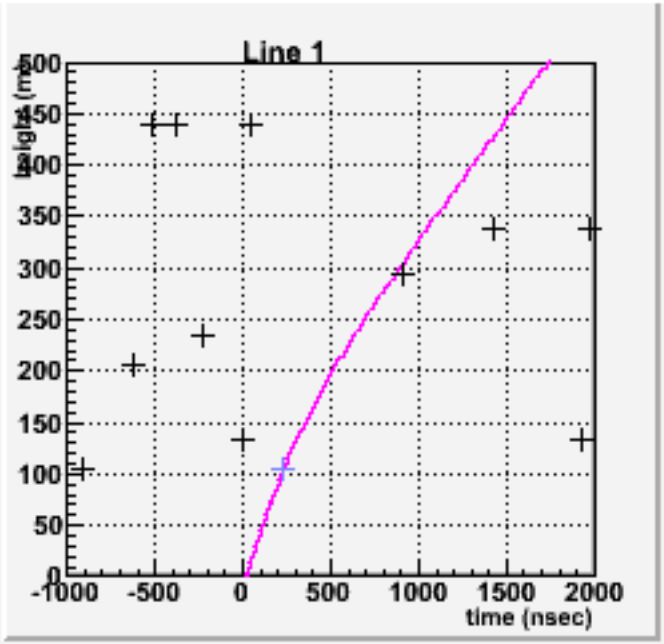


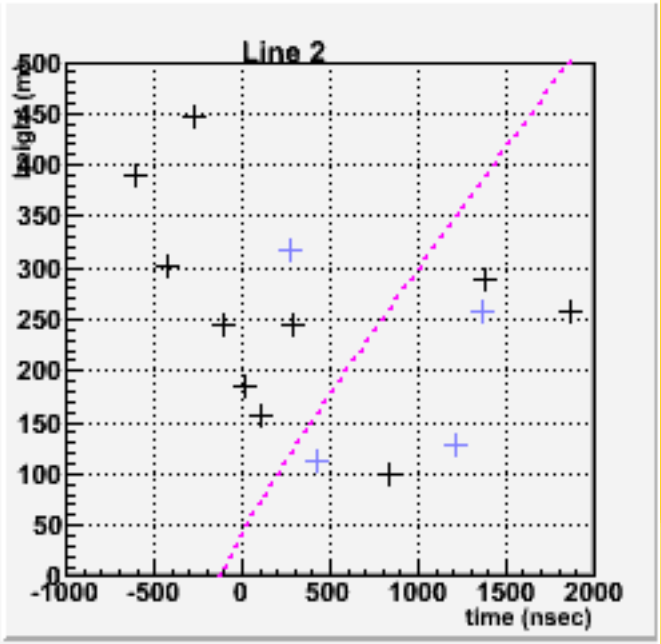


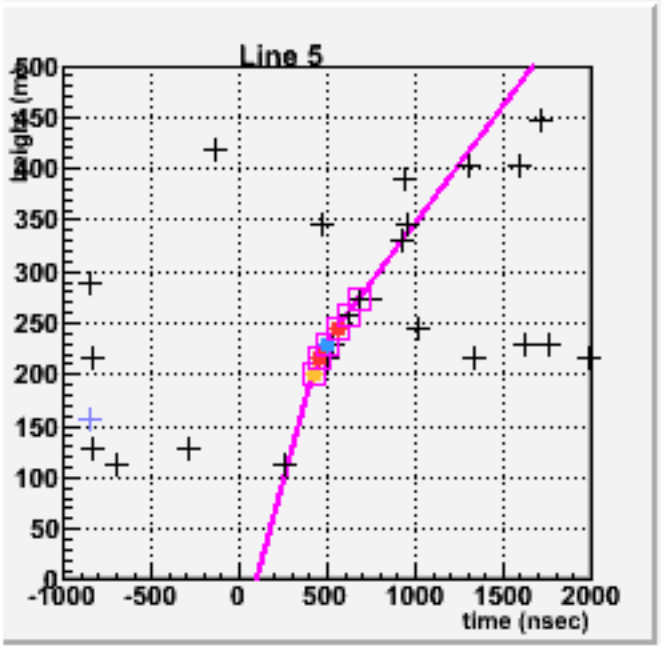
Selected neutrino Candidate (up-going muon)

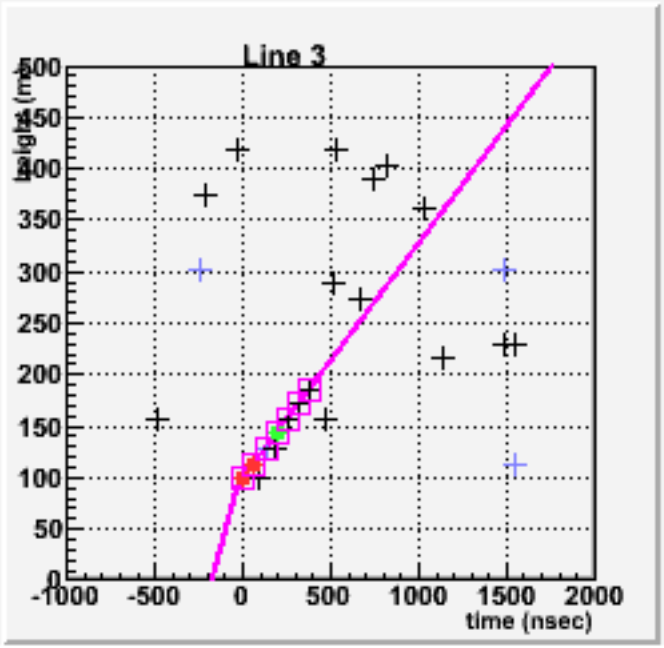
Zenith : 26.3
Fit on 2 line(s)

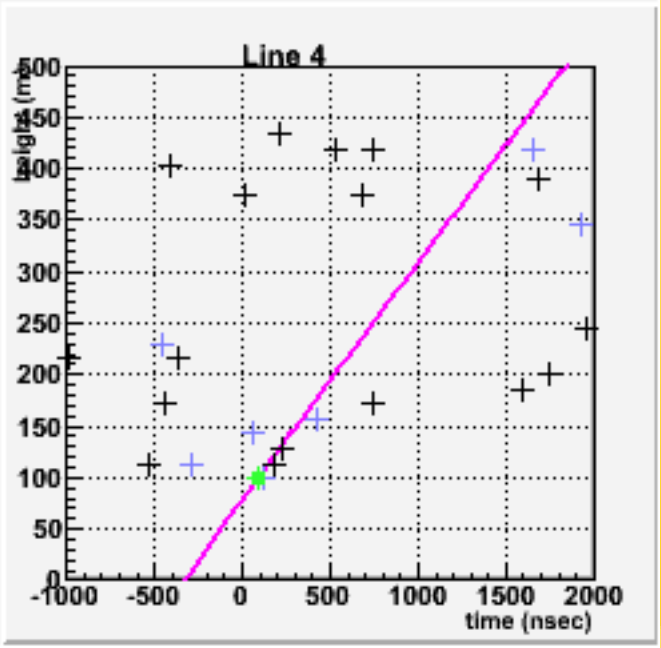
1 2 3 4 5 6 photons



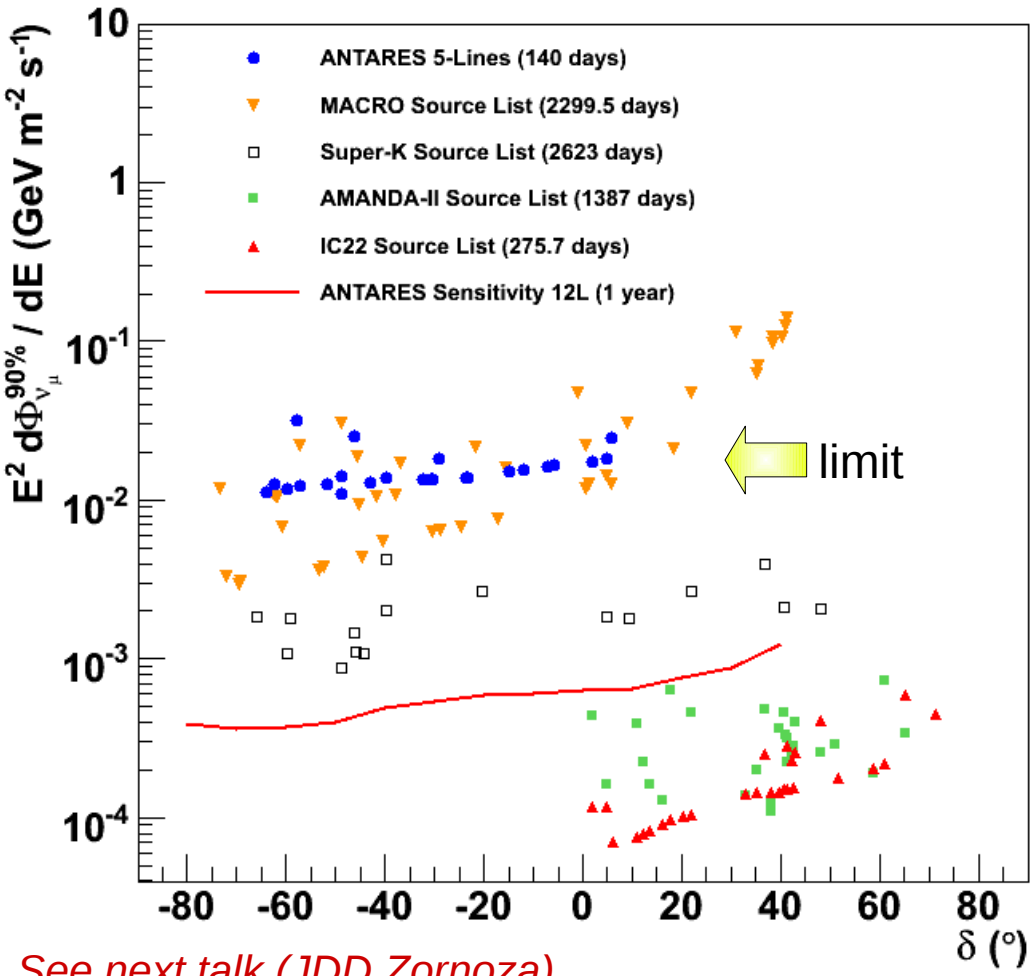






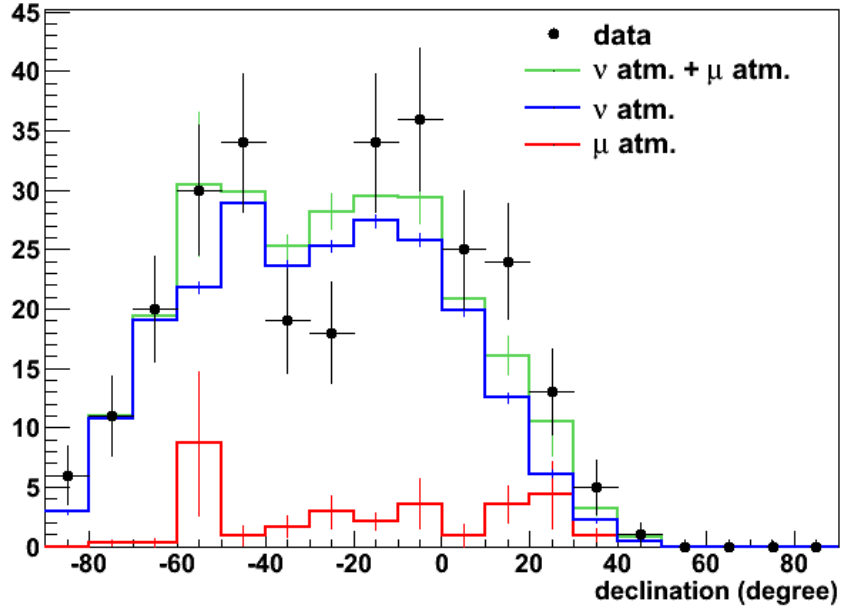


Selected events

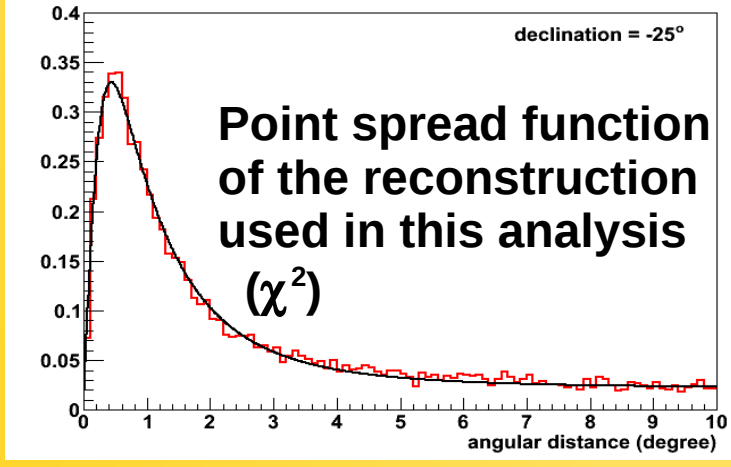


See next talk (JDD Zornoza)

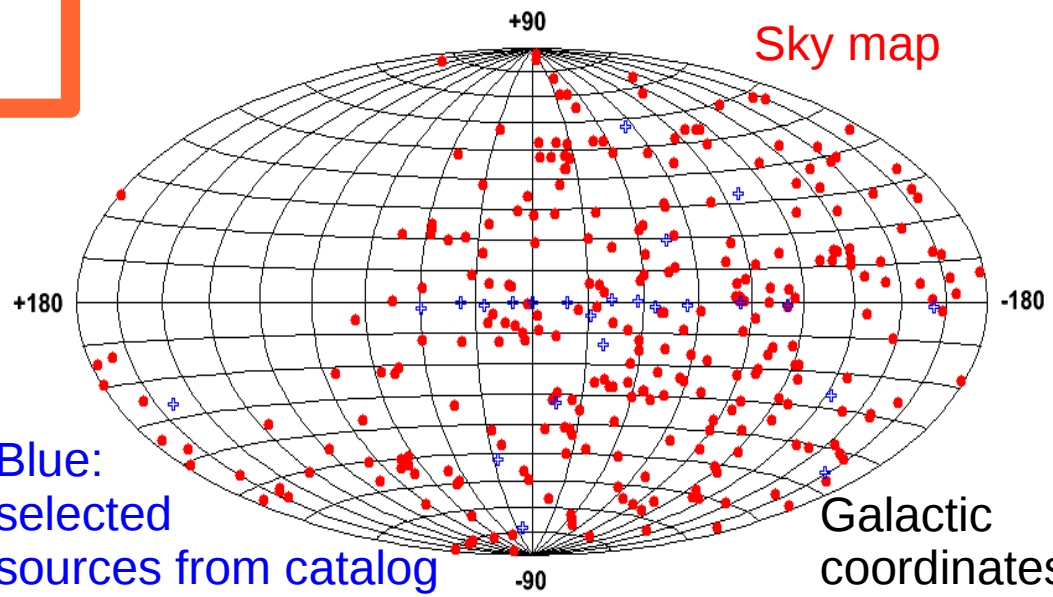
Declination distribution



No significant excess neither in all-sky search nor in selected source directions.



Sky map



Blue: selected sources from catalog

Galactic coordinates

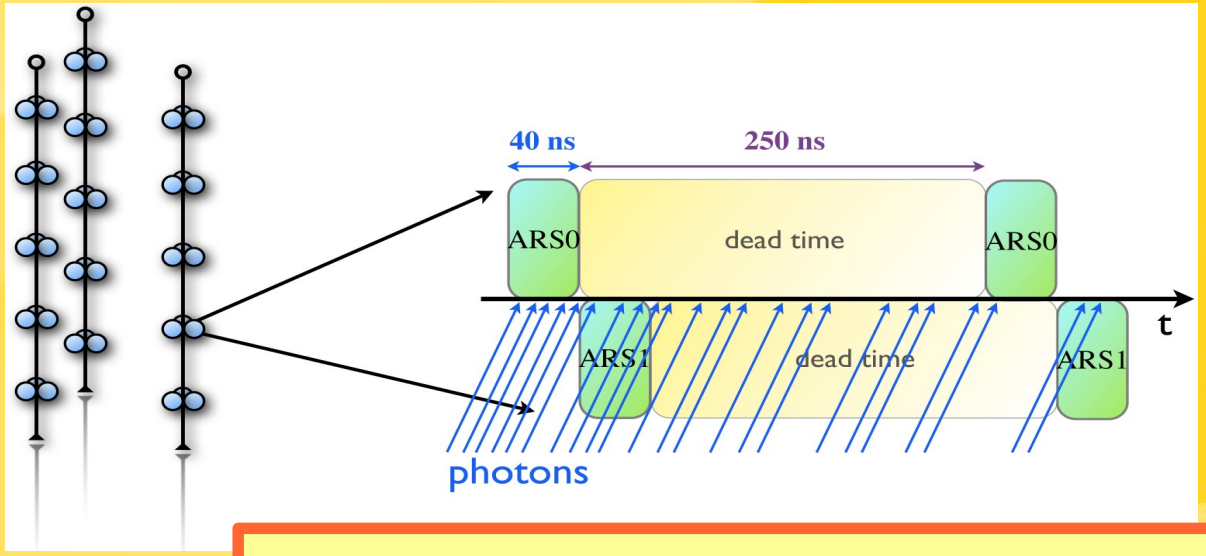
Diffuse flux of muon neutrinos

DATA on 9-10-12 lines (Dec. 2007, 2008, 2009)
334 days equivalent

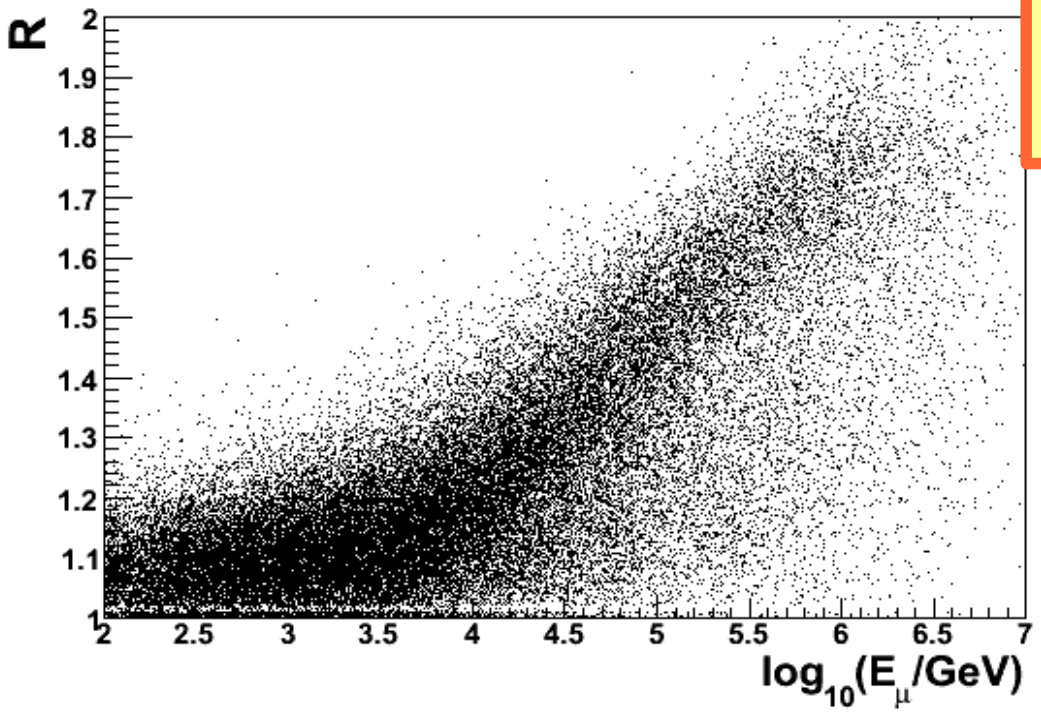
Energy estimator

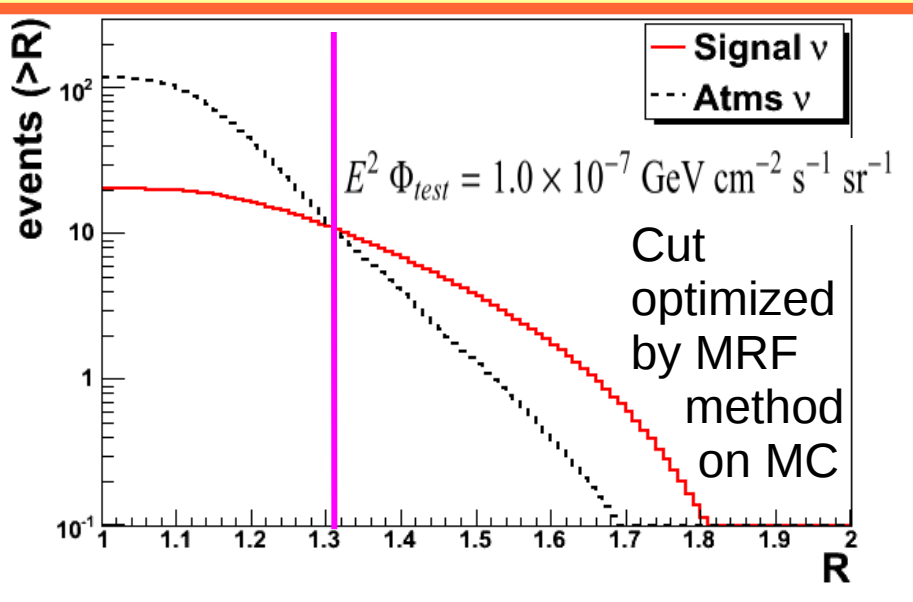
$$dE_\mu/dx = \alpha(E_\mu) + \beta(E_\mu) \cdot E_\mu$$

μ direct photons +
μ scattered photons
+
light from EM showers

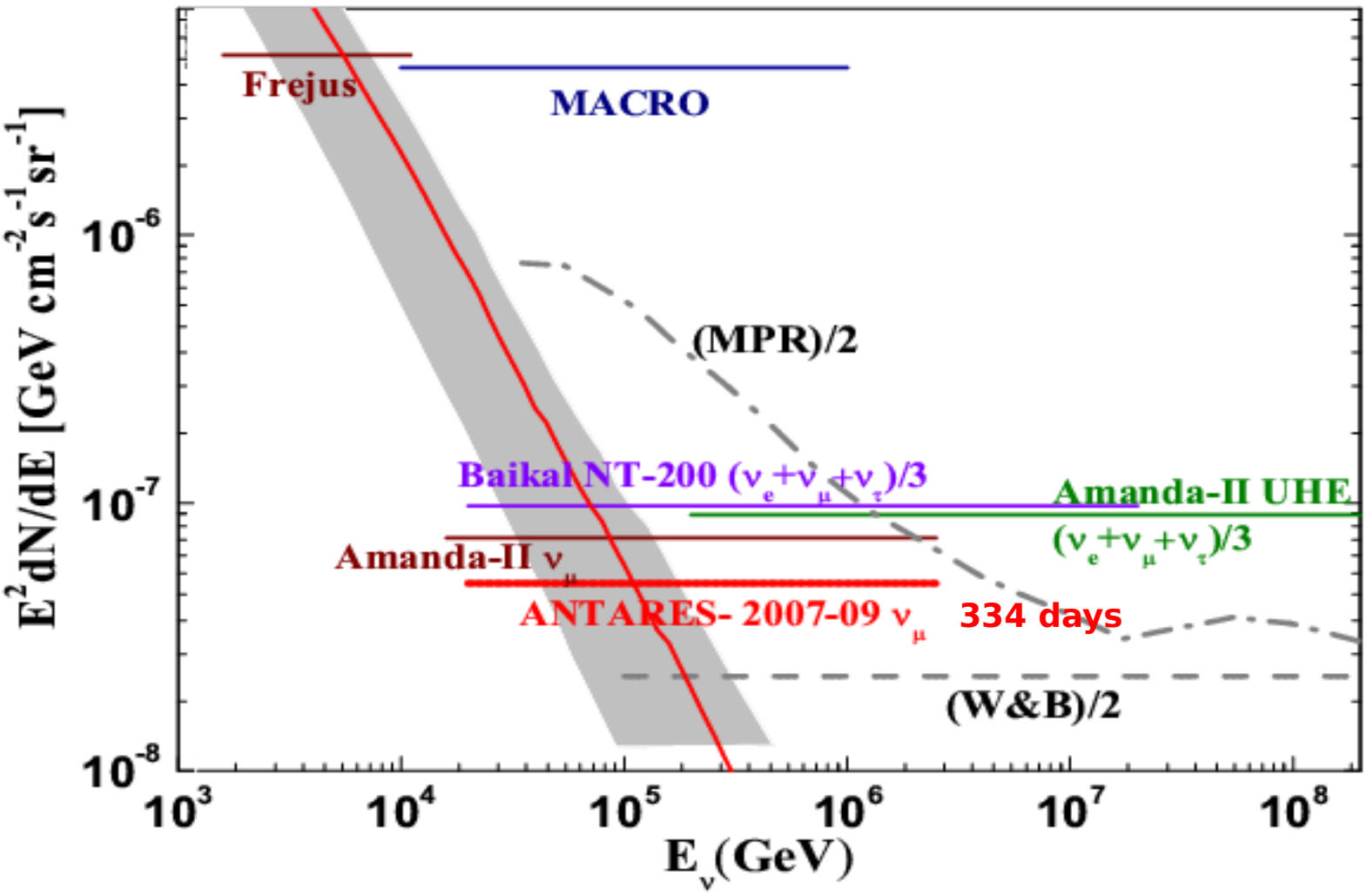


Energy estimator=
Repetition (R) of integration gate on the same Optical Module





Diffuse ν_μ flux – Upper limits (E^{-2})



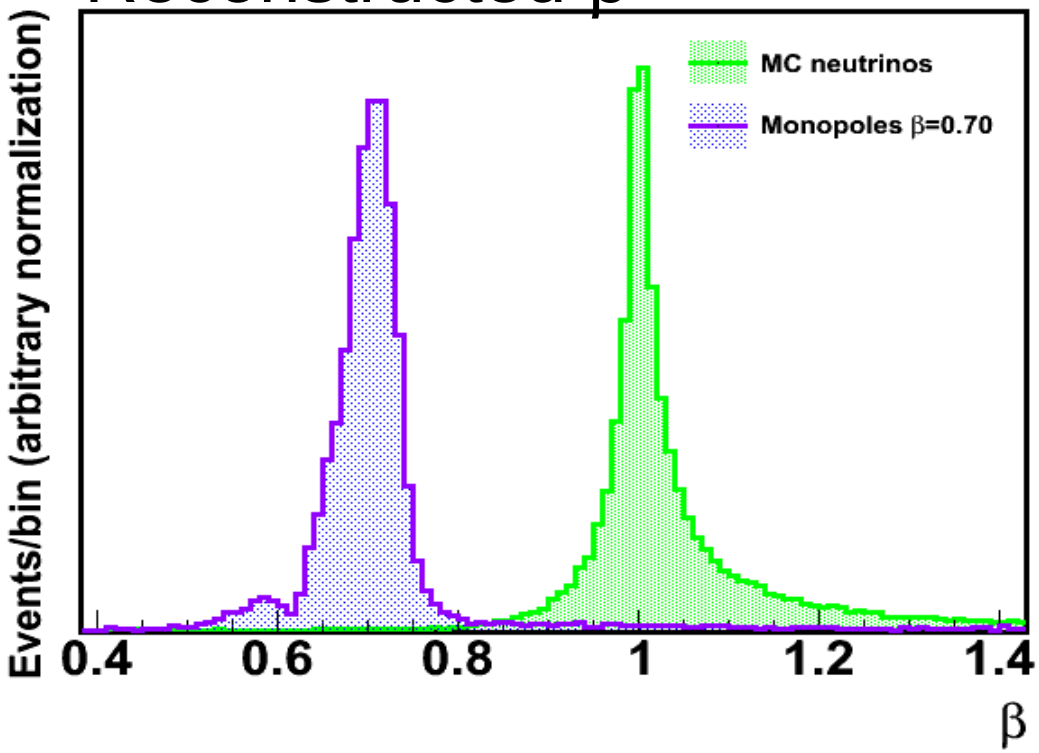
9 observed events for 10.5±2 expected background

$E^2\Phi(E)_{90\%} = 4.8\times10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1} 20 TeV<E<2.5 PeV

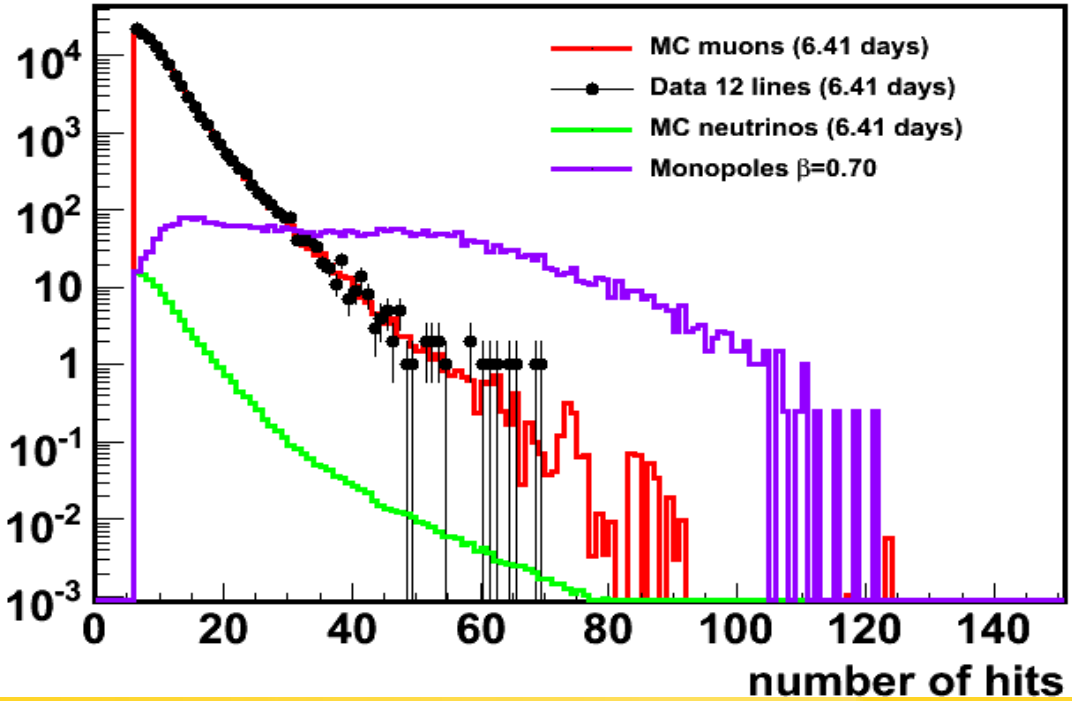
Magnetic Monopole search

DATA on 9-10-12 lines (Dec.2007-2008)
116 days equivalent

Reconstructed β



DATA/MC comparison before unblinding (small sample)



Reconstruction:

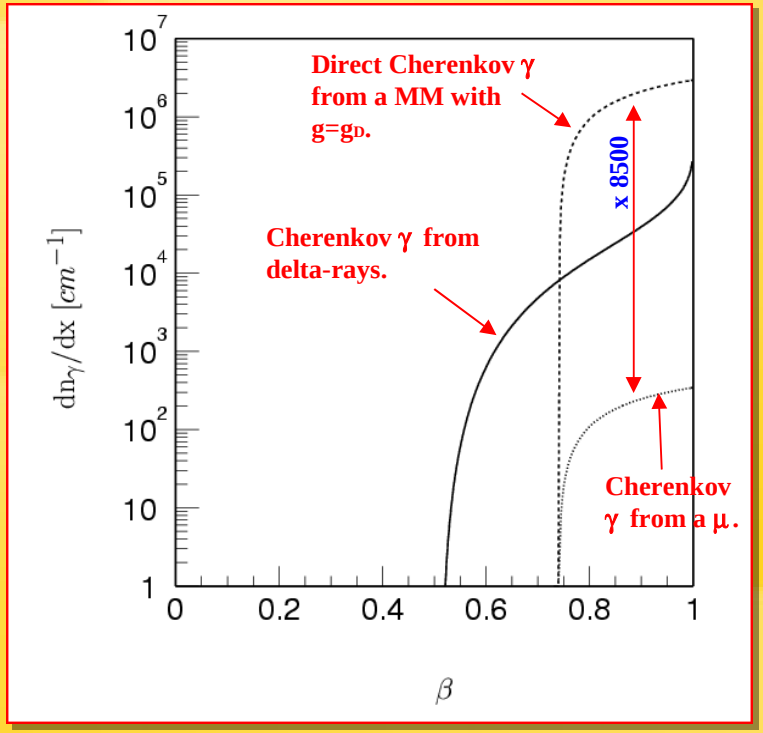
Same as for muon studies but velocity β is a free parameter.

Reconstruction of **trajectory + velocity**.

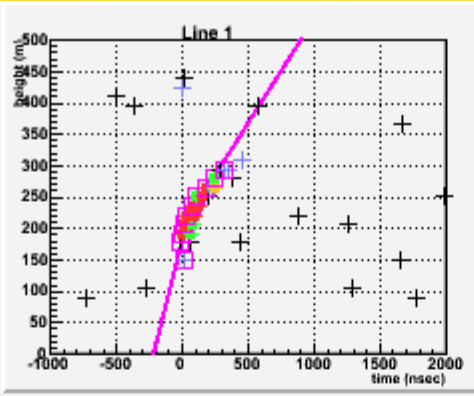
Selection of high energy up-going events:

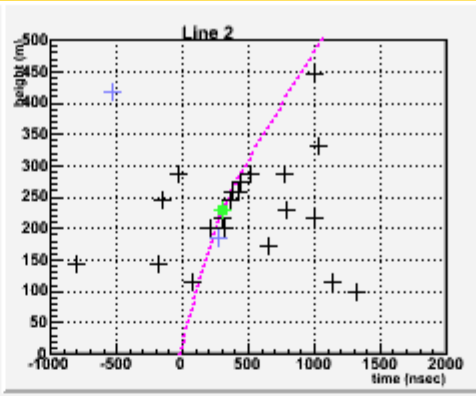
Above Cherenkov threshold: large amount of light (~8500 more photons than for a muon)

Below Cherenkov threshold: Delta rays (from β~0.55)



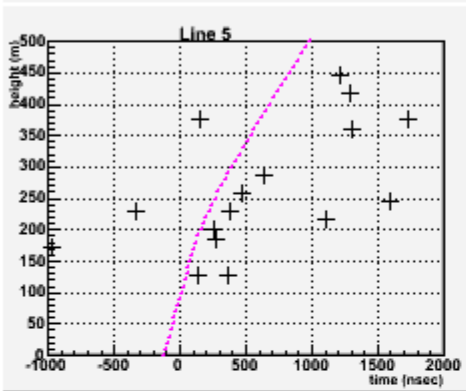
Beta : 0.692746
Fit on 6 line(s)

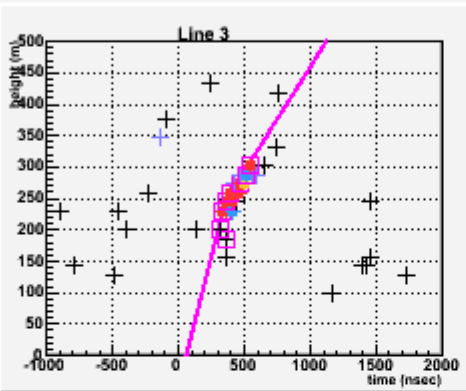


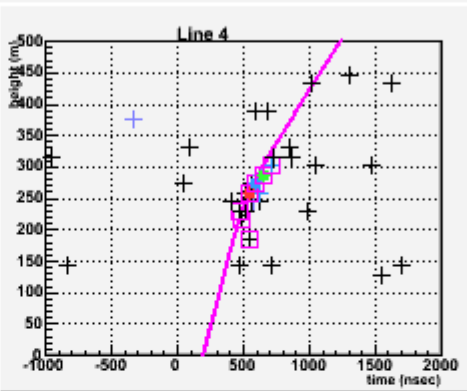


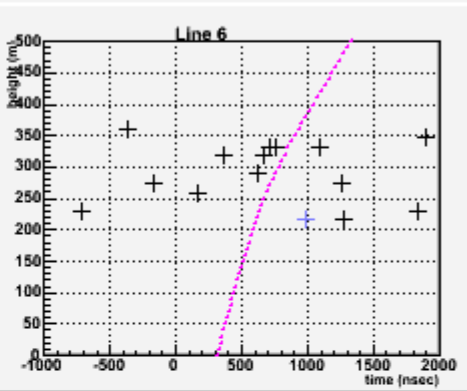
Simulated MM (beta=0.7)

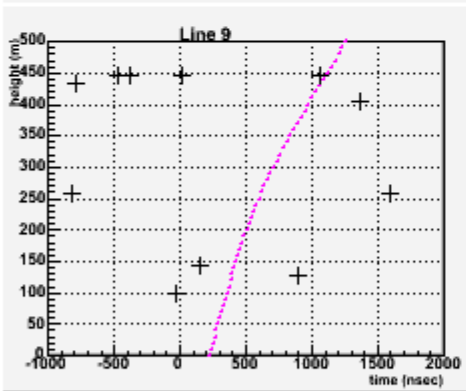
1 2 3 4 5 6 photons

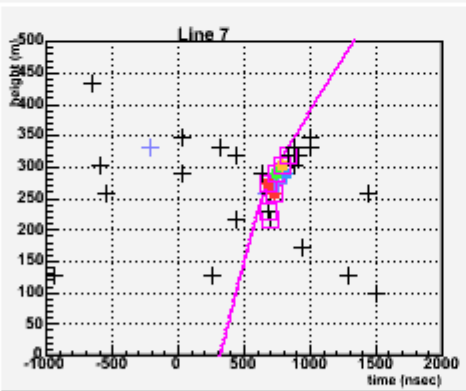


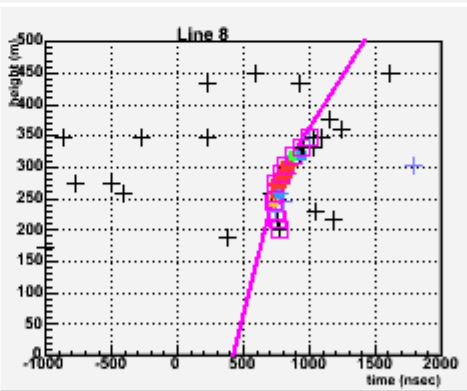


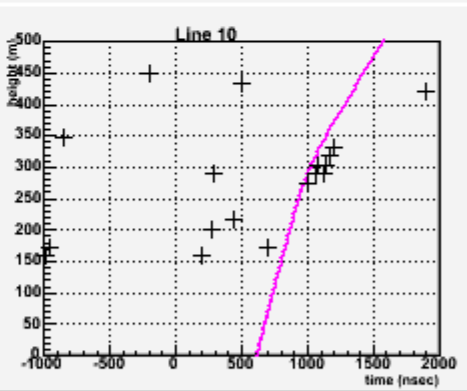






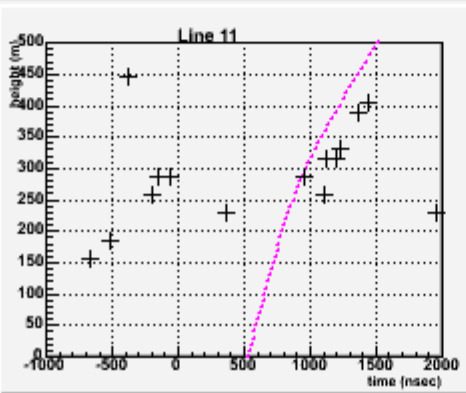


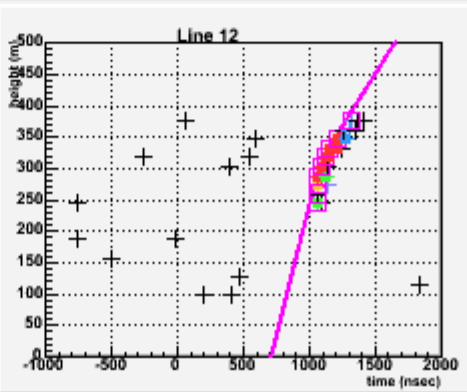




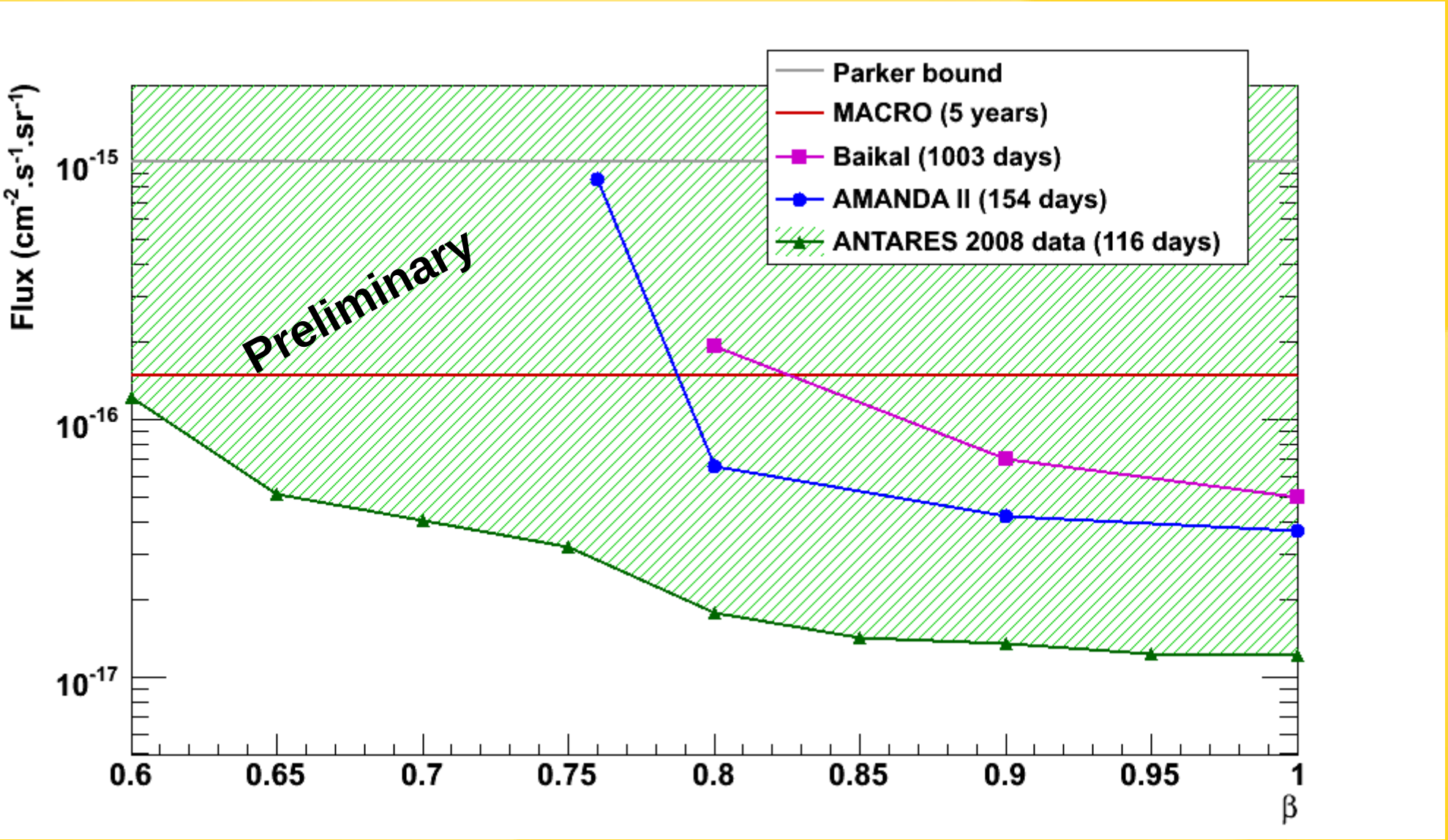
Z hit PMT (m)

Time (ns)



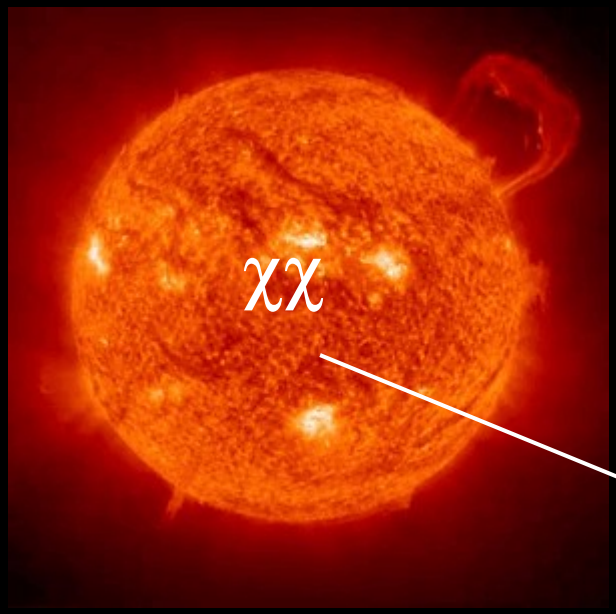


Expected sensitivity for 116 days (90% C.L.)



unblinding in progress

Dark Matter search



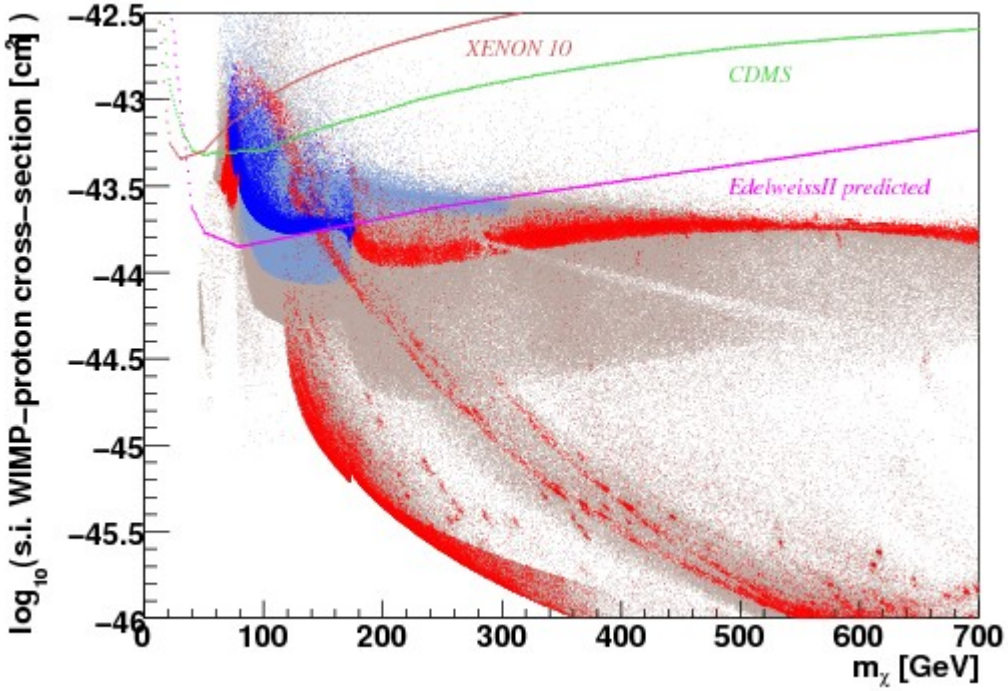
ν

3° half aperture cone
Background:
~7 events/3 yrs

Atm. ν bkg

μ

Atm. μ bkg
misreconstucted
(10% of ν)



3 years, 12 lines

mSugra models favoured by WMAP
- 90% CL excludable by ANTARES
- not excludable

mSugra models disfavoured by WMAP
- 90% CL excludable by ANTARES
- not excludable

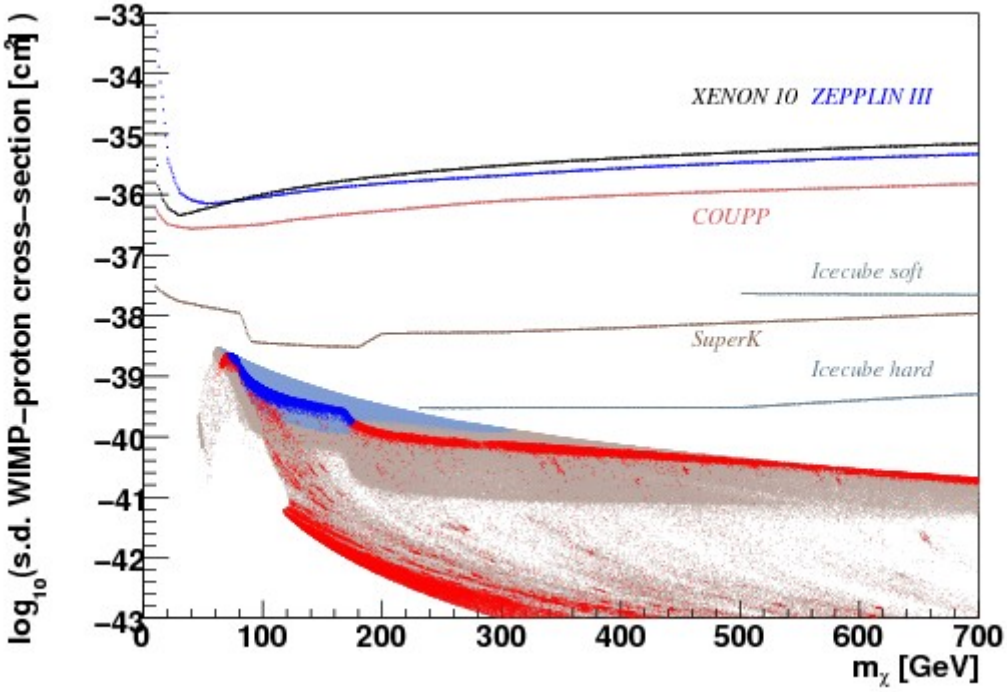
mSugra parameters

$0 < m_{1/2} < 2000$ GeV

$0 < m_0 < 8000$ GeV

$0 < \tan\beta < 60$

$-3\, m_0 < A_0 < 3\, m_0$



Summary, outlook

- Antares is taking data since 2007 in its different configurations (5, 9, 10, 12 lines)
- The detector and its environment are now well understood: good agreement DATA/MC
- First physics results are now available after unblinding: Point sources for the 5-line stage, Diffuse Fluxes
- For other topics the unblinding is in progress (Magnetic Monopoles) or the studies are on-going (Point sources with more than 5 lines, showers)