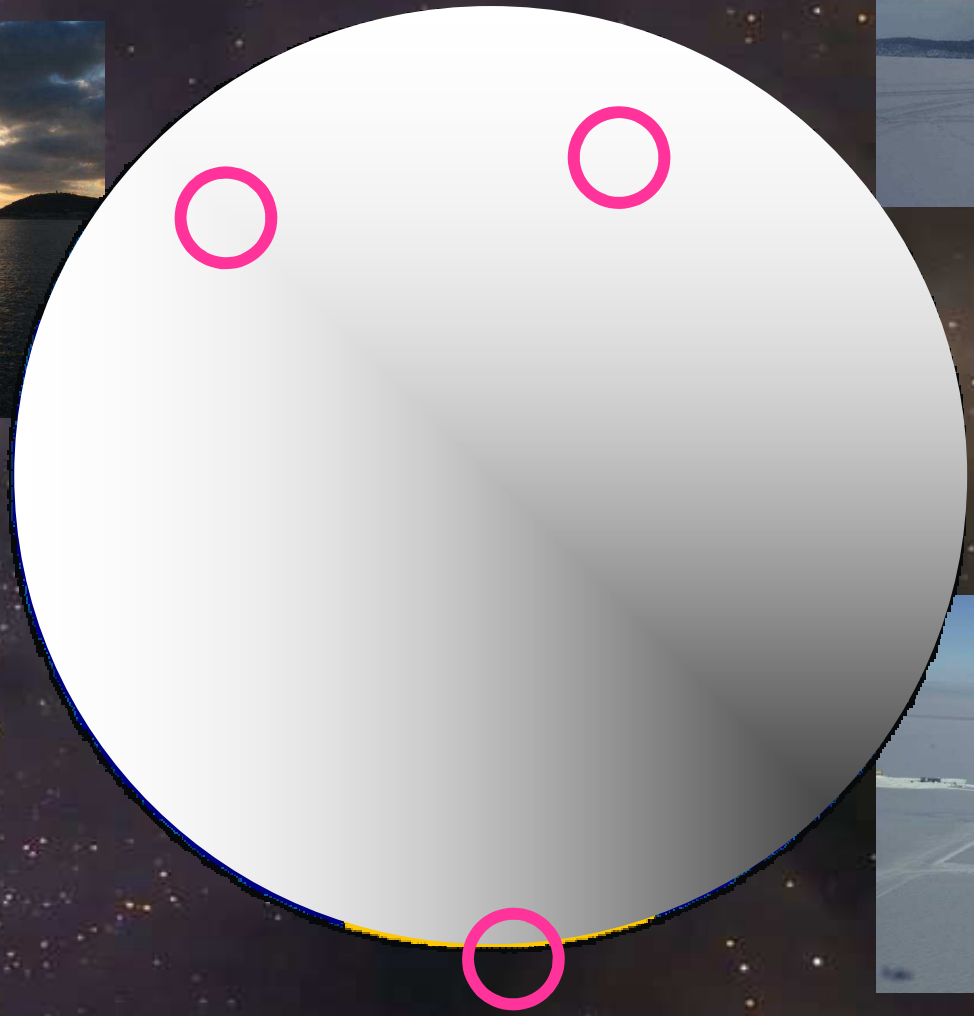
ν astronomy in the Northern hemisphere

- Baikal
- Antares
- KM3NeT

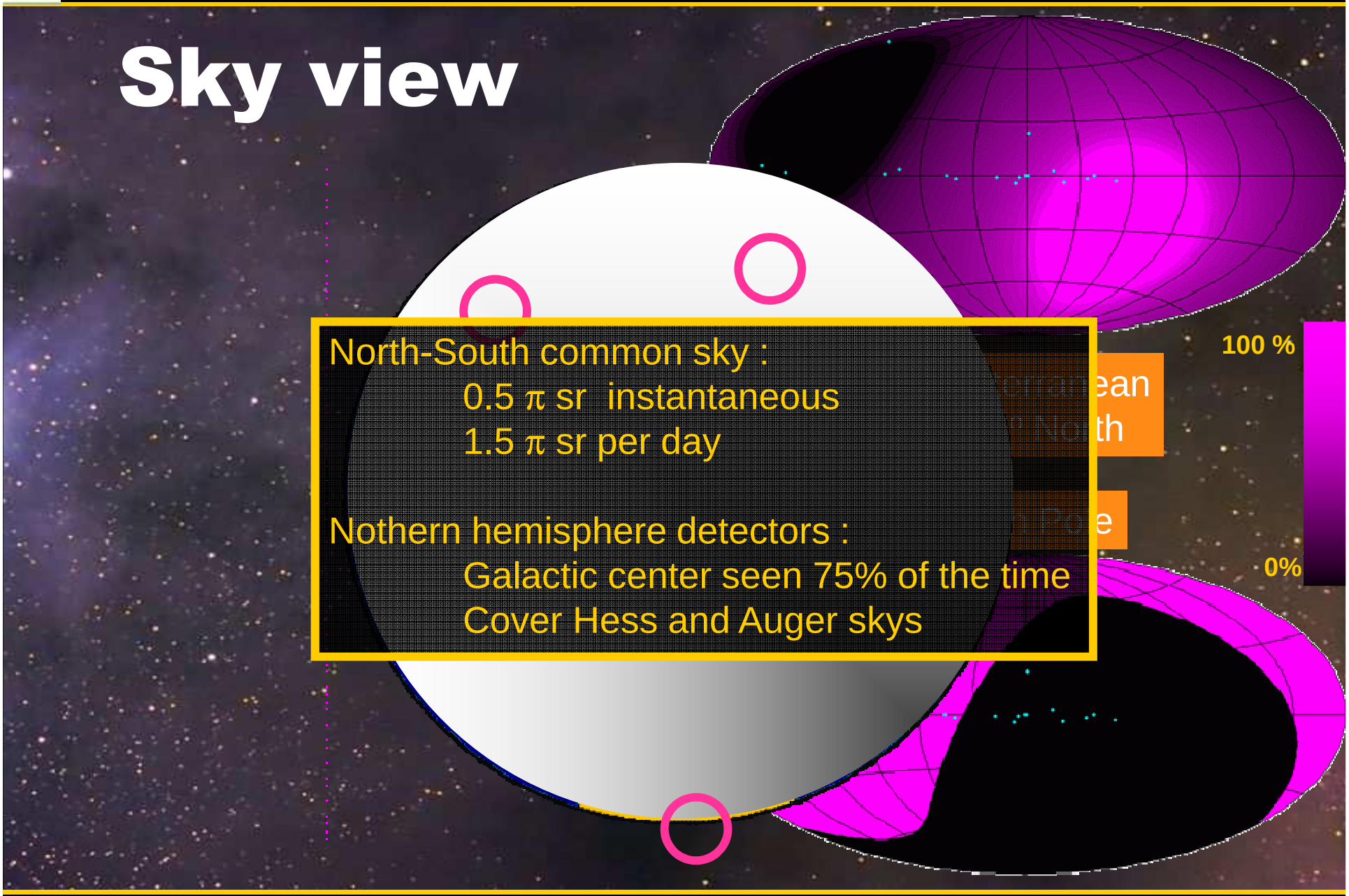
Th. Stolarczyk

CEA Saclay - IRFU / SPP

HE ν telescopes



Sky view

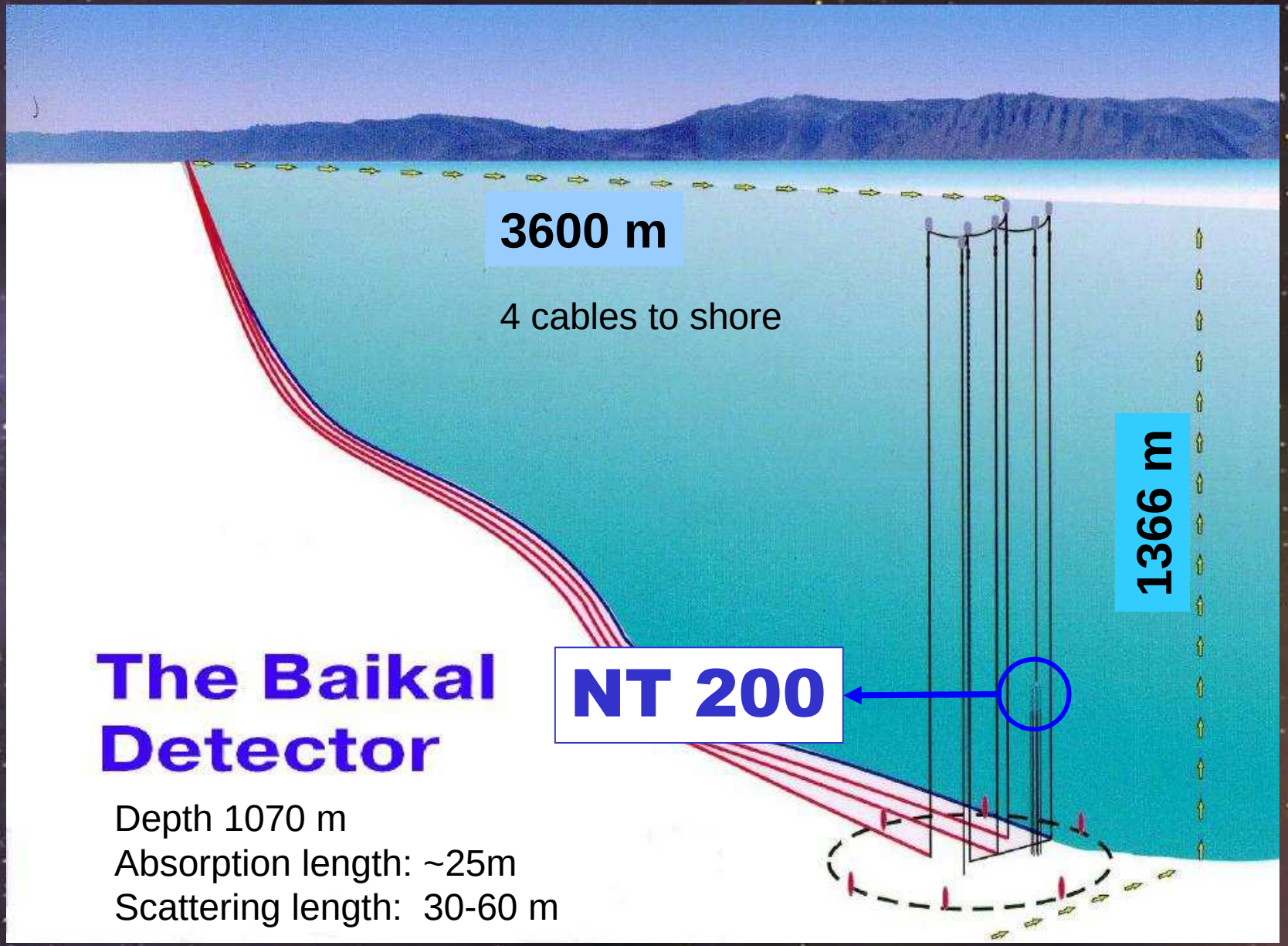


North-South common sky :
- 0.5 π sr instantaneous
- 1.5 π sr per day

Nothern hemisphere detectors :
- Galactic center seen 75% of the time
- Cover Hess and Auger skys

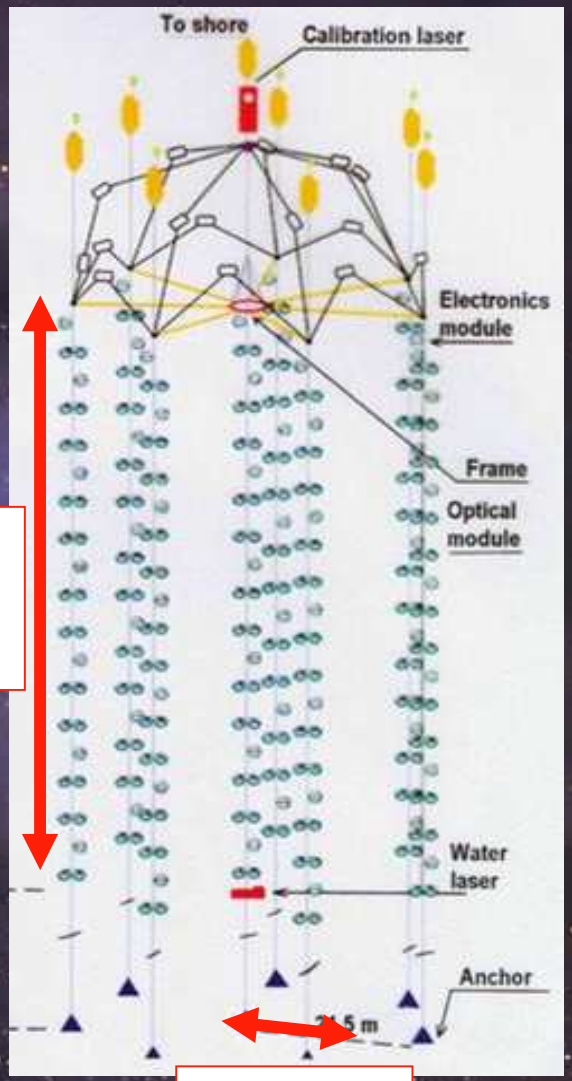
Baikal

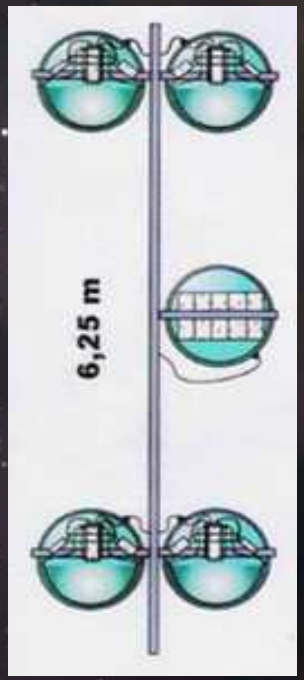
- **Collaboration**
  - **7 Russian institutes**
  - **Desy-Zeuthen, Germany**
  - **50 physicists**
- **1993 : 1st prototype**
- **Frozen surface in winter → Deployment and maintenance**


3600 m
4 cables to shore
1366 m
NT 200
The Baikal Detector
Depth 1070 m
Absorption length: ~25m
Scattering length: 30-60 m

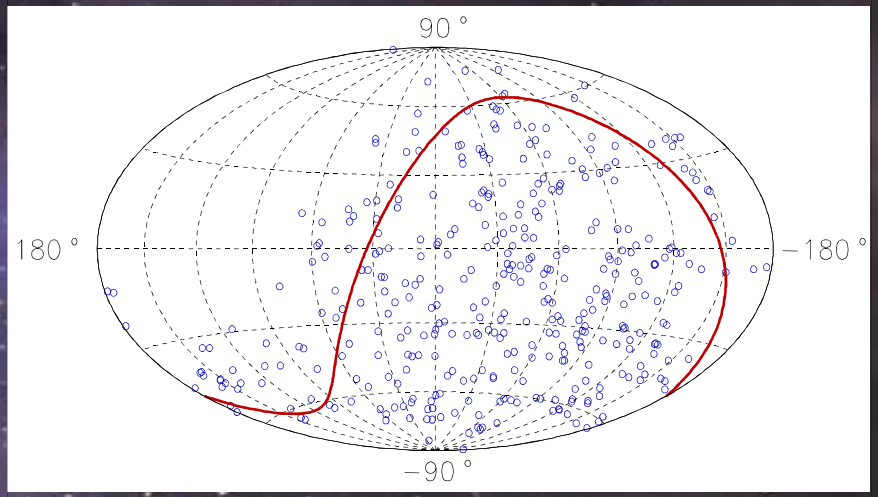
NT 200

- Since 1998
- 8 strings
- 192 optical modules
- Instrum. volume : 100 kTon (10^{-4} km^3)
- μ-effective area ≈ 2000 m^2 (E > 1 TeV)

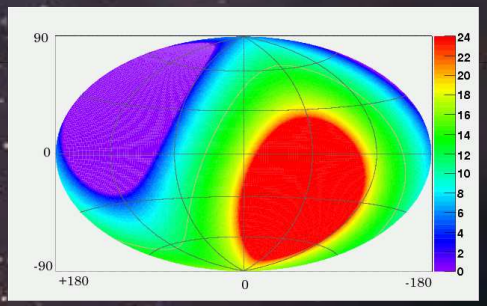




$\nu_\mu \rightarrow \mu$ in NT 200 (1998-2003)

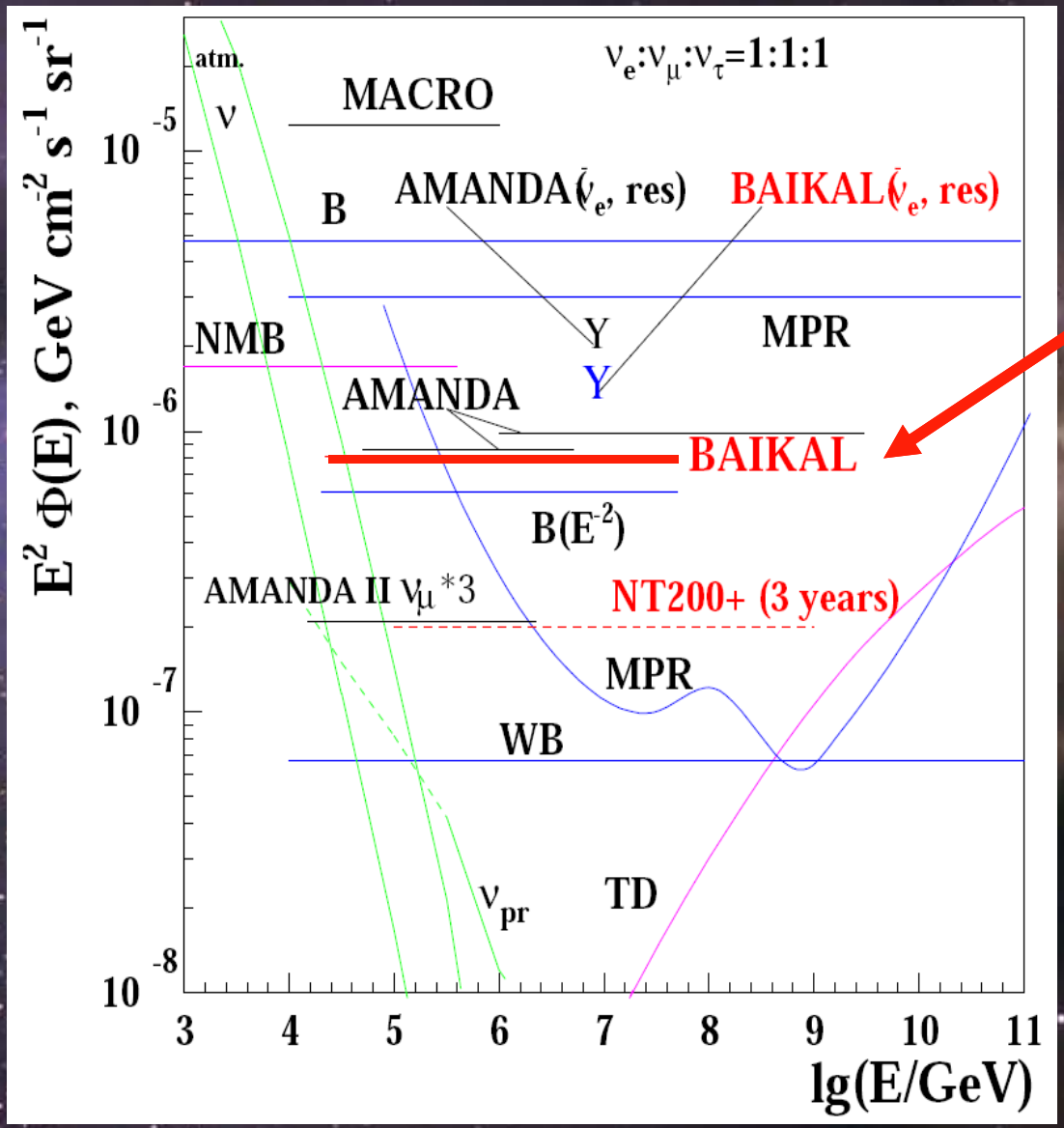


Sky coverage



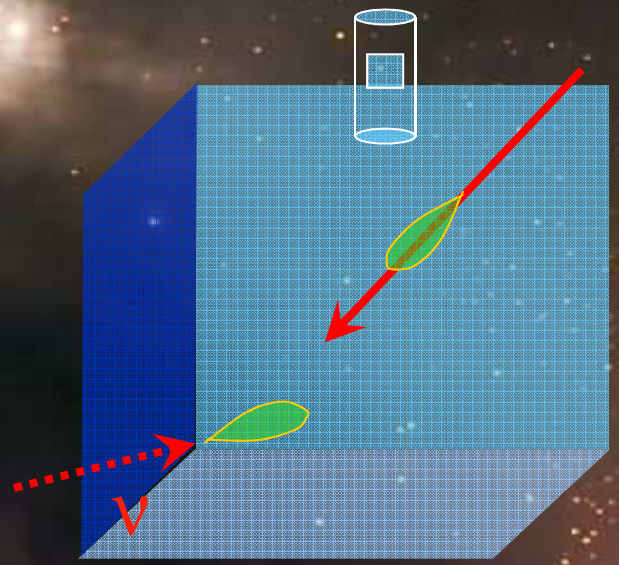
- **Angular resolution (1 TeV) ~ 4°**
- **No excess found**
  - **372 μ in 1038 d.**
  - **385 expected (E > 15-20 GeV)**

Diffuse ν fluxes

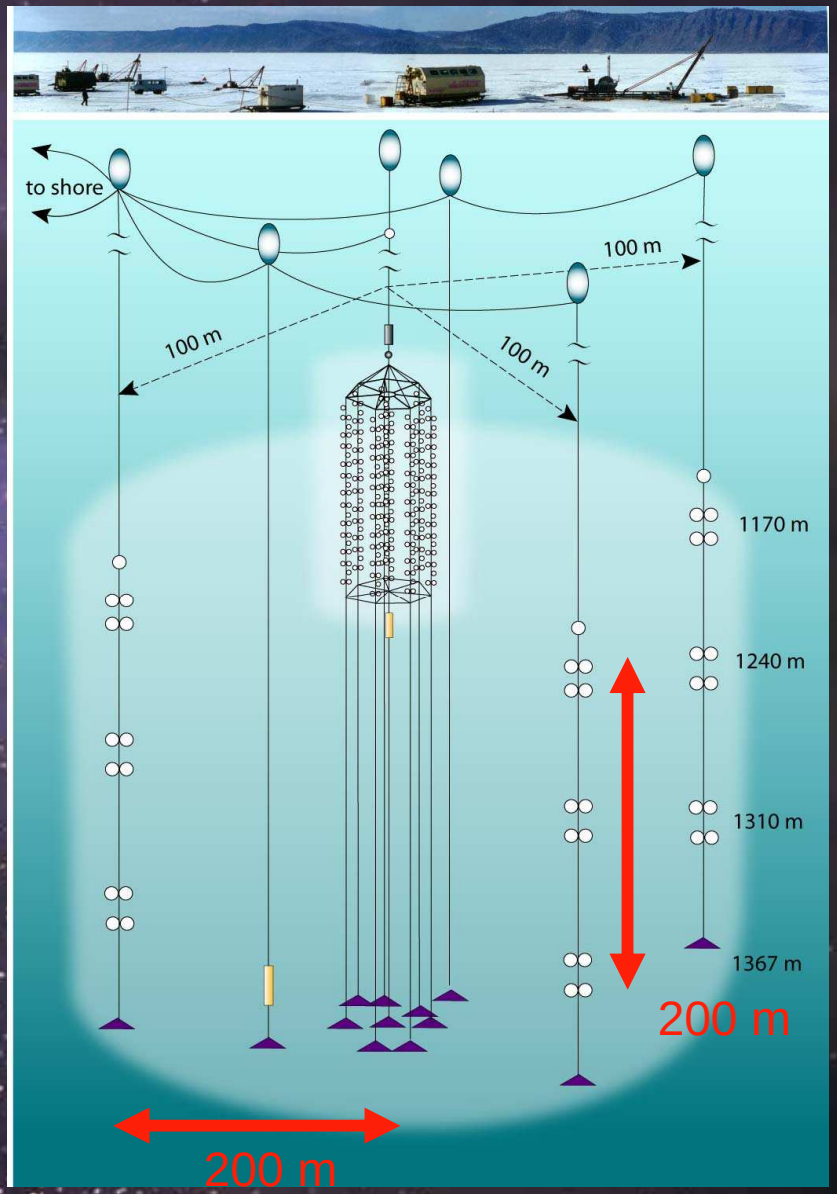


$8.1 \cdot 10^{-7}$ GeV $\cdot$cm^{-2} $\cdot$s^{-1} $\cdot$sr^{-1}

- **90% C.L.**
- **20 TeV < E_ν <50 PeV**
- **All flavors ($\nu_e+\nu_\mu+\nu_\tau$)**



Eff. Volume : 1 MTon
E> 10PeV

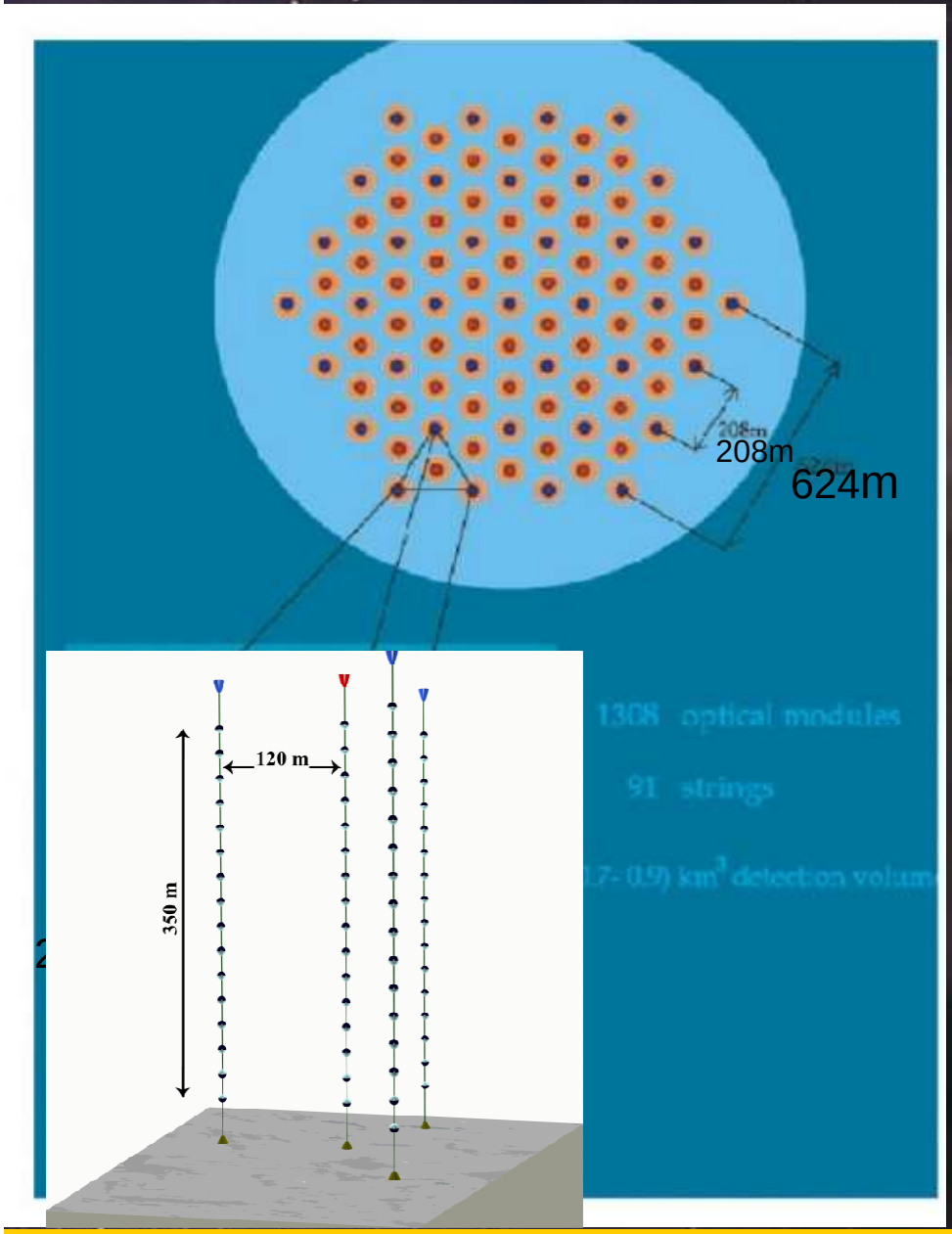


NT200 +

- **Since April 2005**
  - **+ 3 outer strings**
  - **12 PMT each**
- **Instrum. Volume**

  100 kTon → ~ 4 Mton
- **Shower eff. Volume E> 10PeV**

  1 MTon → 10 Mton
- **Still running…**

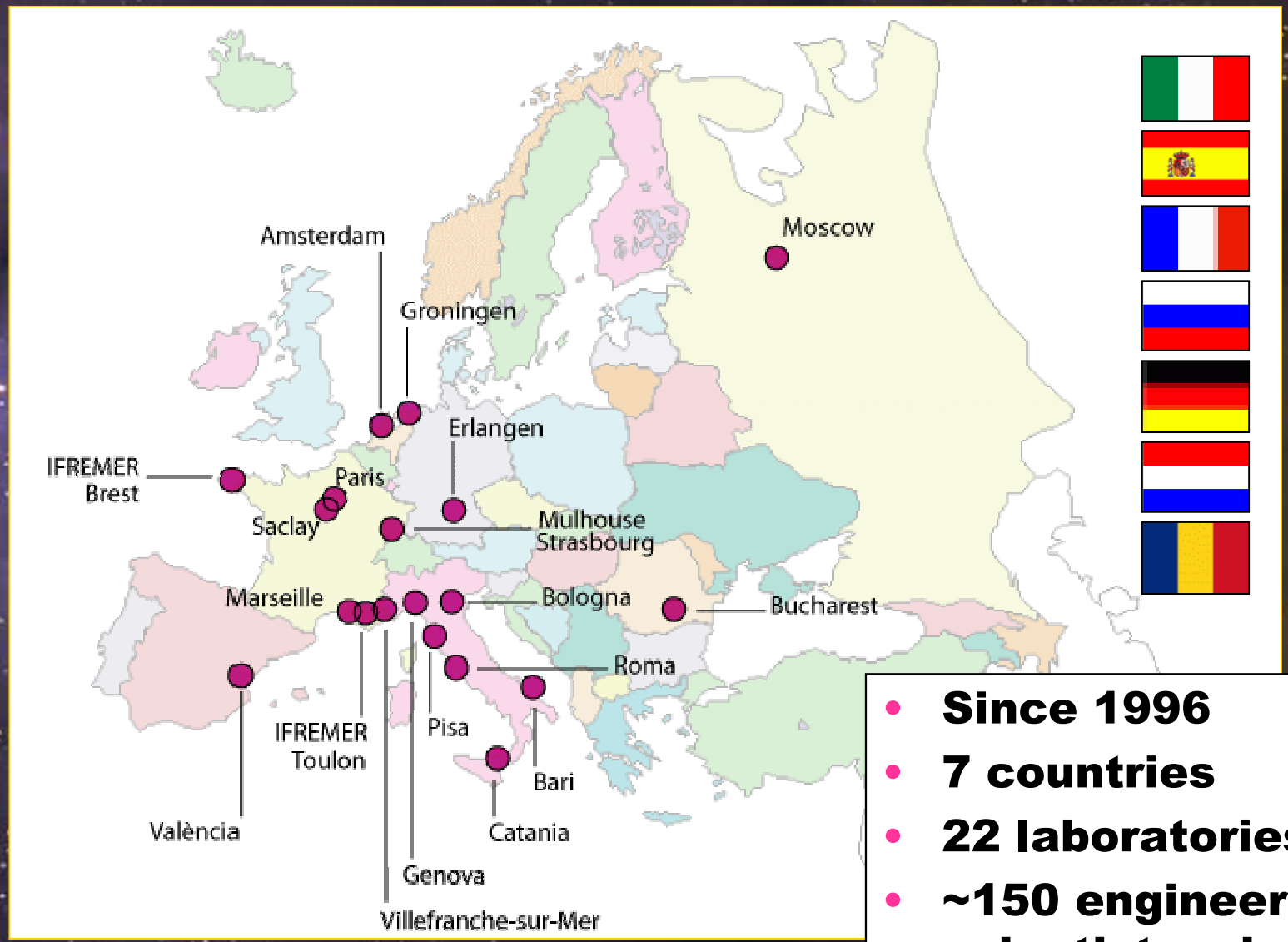


A km³ detector

- **Sparse instrumentation :**
  - **91 strings X 12/16 OM = 1300-1700 OMs**
- **Shower eff. Volume E> 100 TeV**

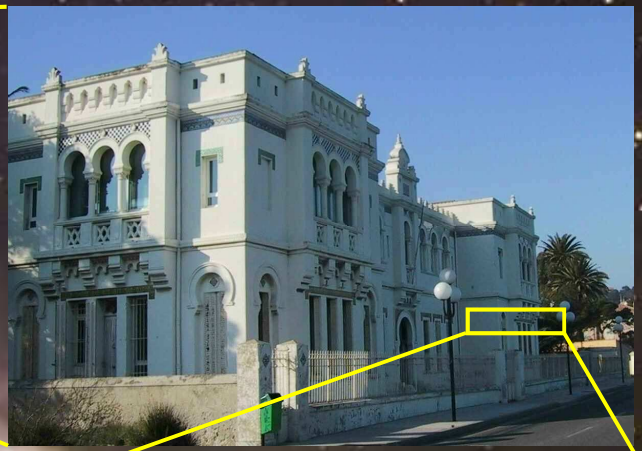
  ~ 4 MTon → 1 Gton
- **Muon detection :**
  - **E > 10-30 TeV**
  - **Angular resolution < 5°**
- **R&D +TDR : 2006-08 (Funded)**
  - **Prototype : April 2008**
- **Construction ≥ 2009**

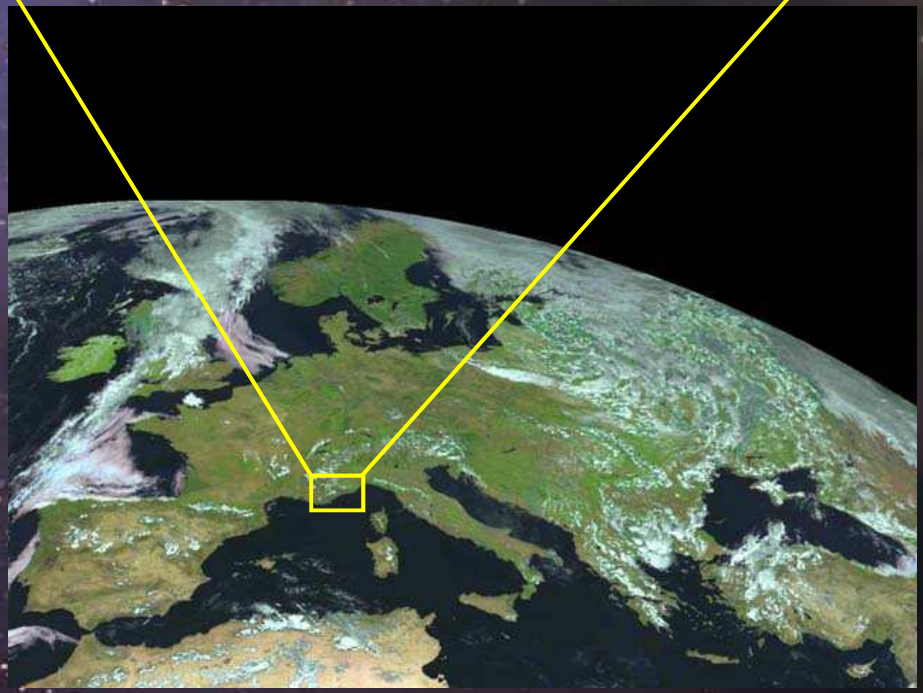
- Introduction
- Recent milestones
- Atmospheric μ
- Neutrinos

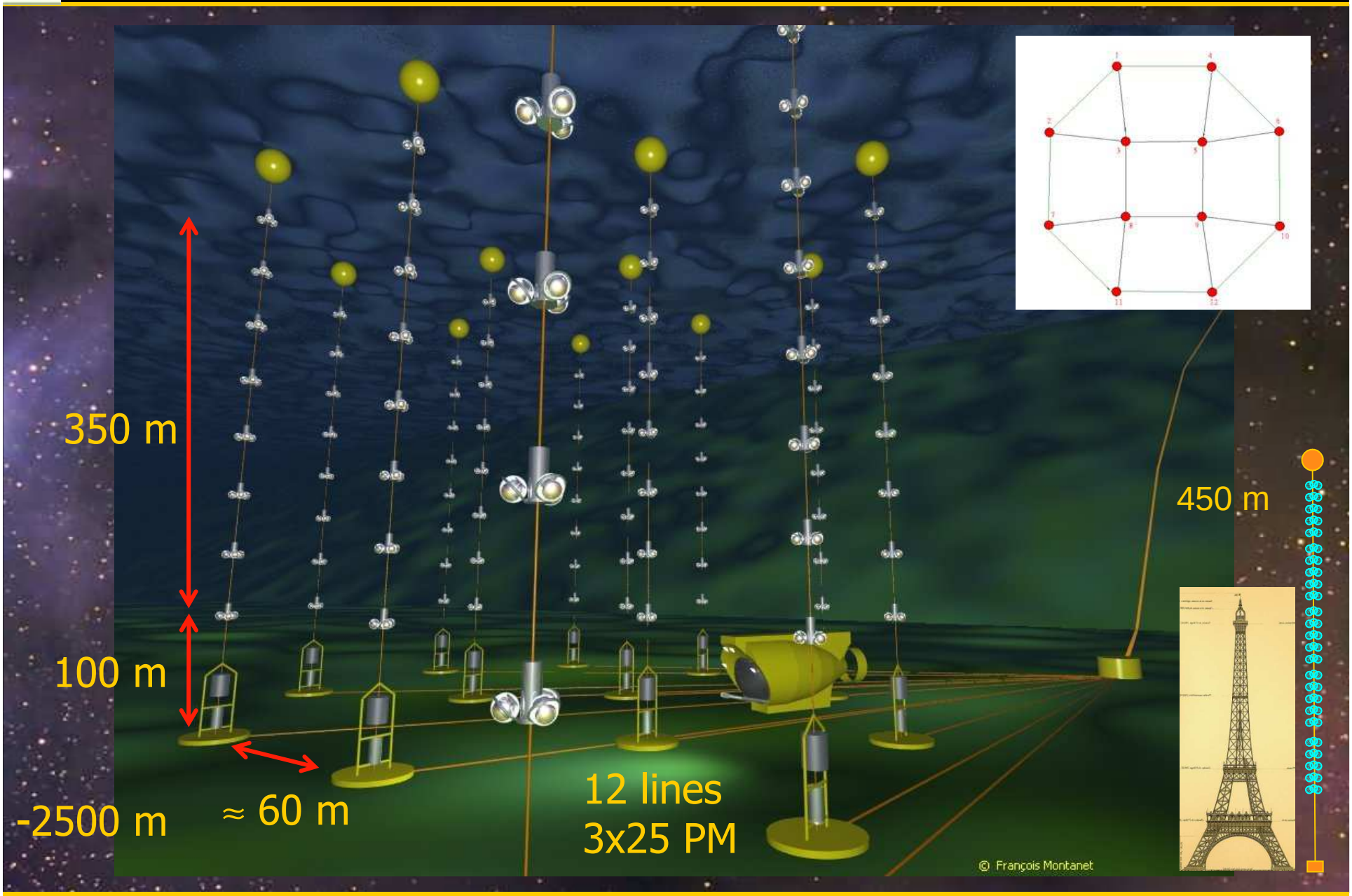


- **Since 1996**
- **7 countries**
- **22 laboratories**
- **~150 engineers, sea scientists, physicists.**


HYÈRES
LA SEYNE S-MER
ILES D'HYÈRES
Levant
Port-Cros
200 m
2200 m
ANTARES Site
2400 m

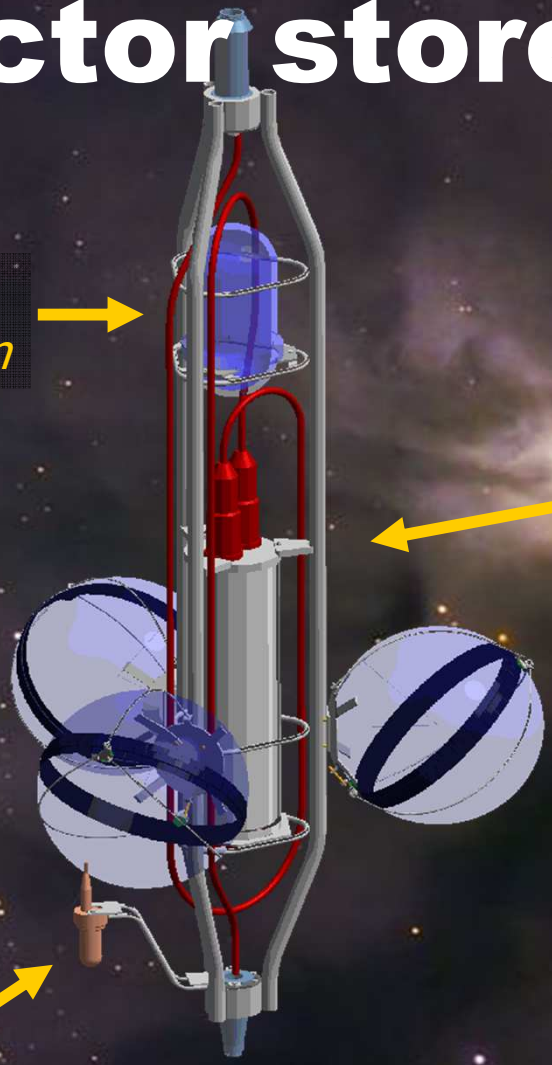


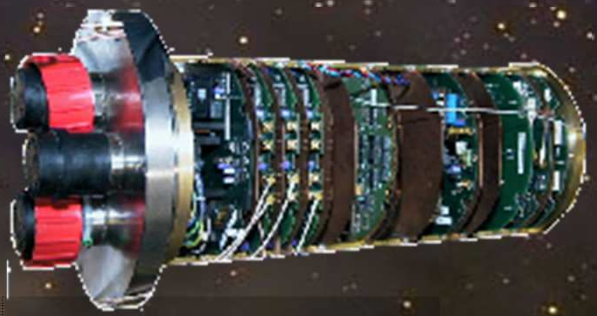



350 m
100 m
-2500 m
≈ 60 m
12 lines
3x25 PM
450 m
© François Montanet

A detector storey

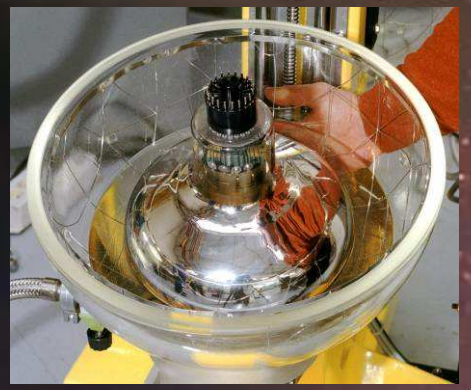
Optical Beacon:
Timing calibration





DAQ
Slow Control
Compass Cards

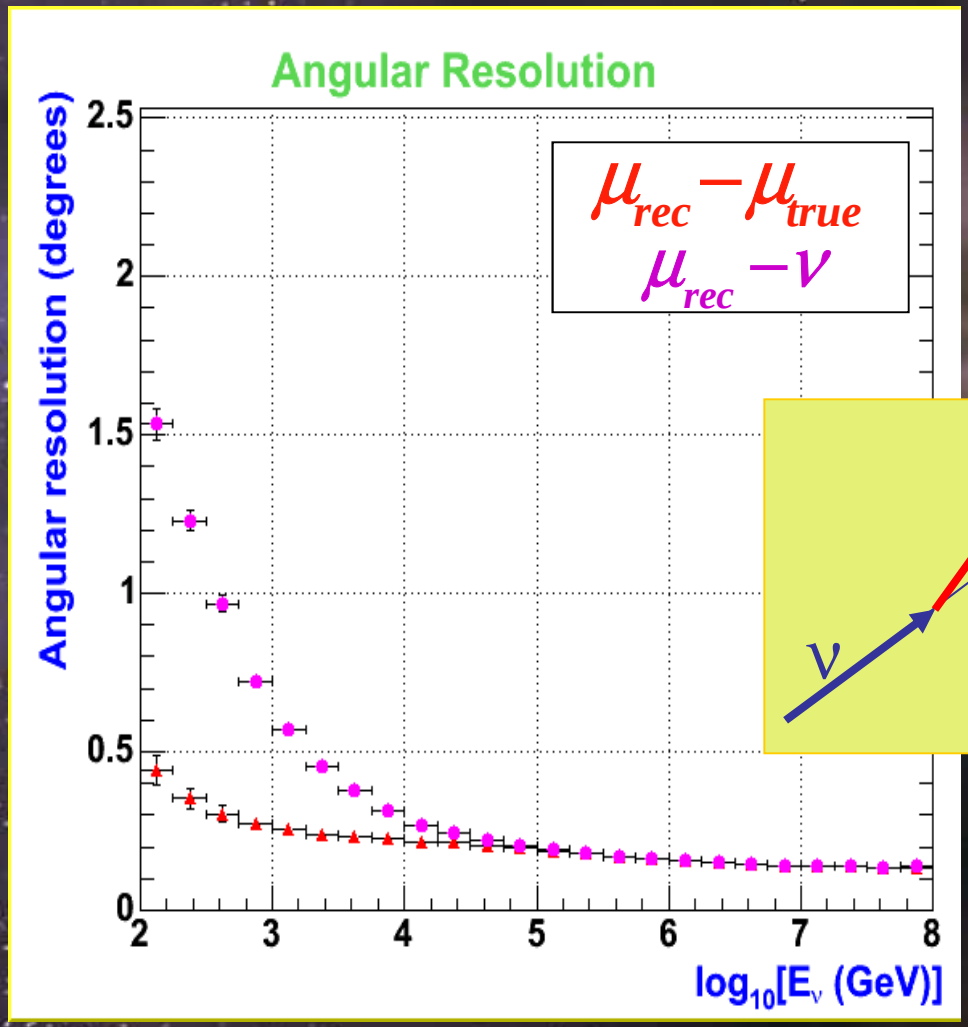
10″ PMT
17″ glass sphere



Hydrophone
Acoustic positioning

Titanium frame

Expected angular resolution



Measured :

- Δt < 1 ns
- Δr ~ 10 cm

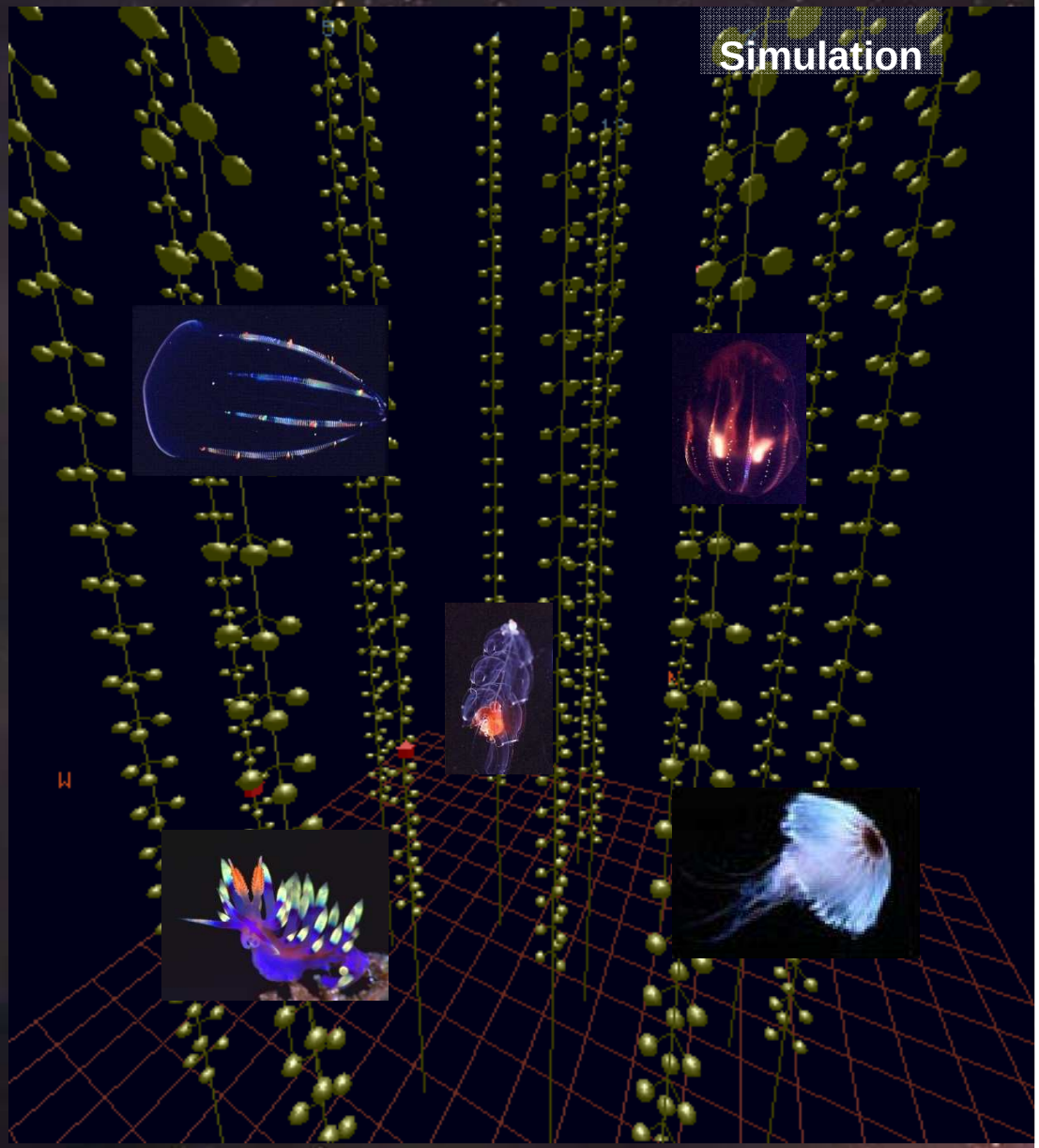
... as expected

- **Instrum. Vol. : 20 MTon (1/50 km³)**
- **μ-Effective area ≈ 20000 m² (E > 1 TeV)**

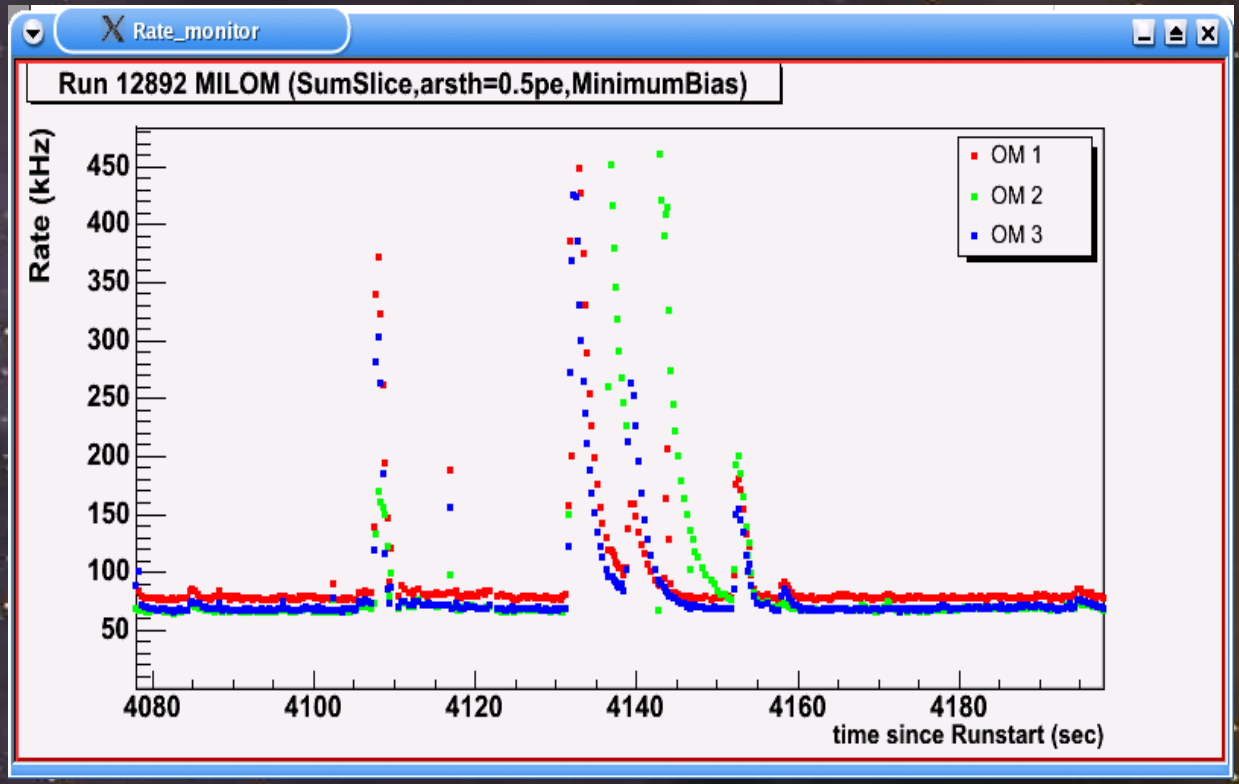
Signal

- **Muon**
  - 2 μs signal
  - Fires ~ 100 modules
- **^{40}K decay**
  - ~ 30 kHz* continuum
- **Bioluminescence**
  - Continuum ~ 30 kHz*
  - Bursts
    - > MHz
- **All data sent to shore**
  - Several software triggers implemented

*PM 10 ", 0.3 p.e. threshold



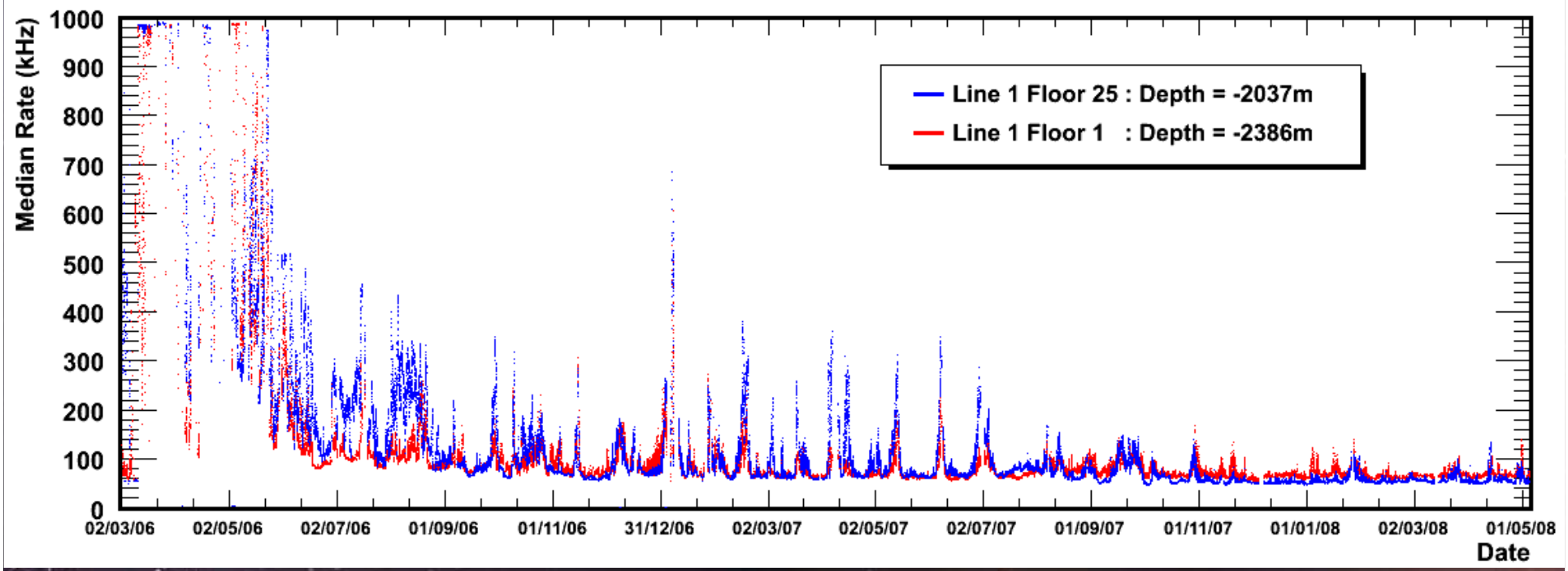
Bioluminescence

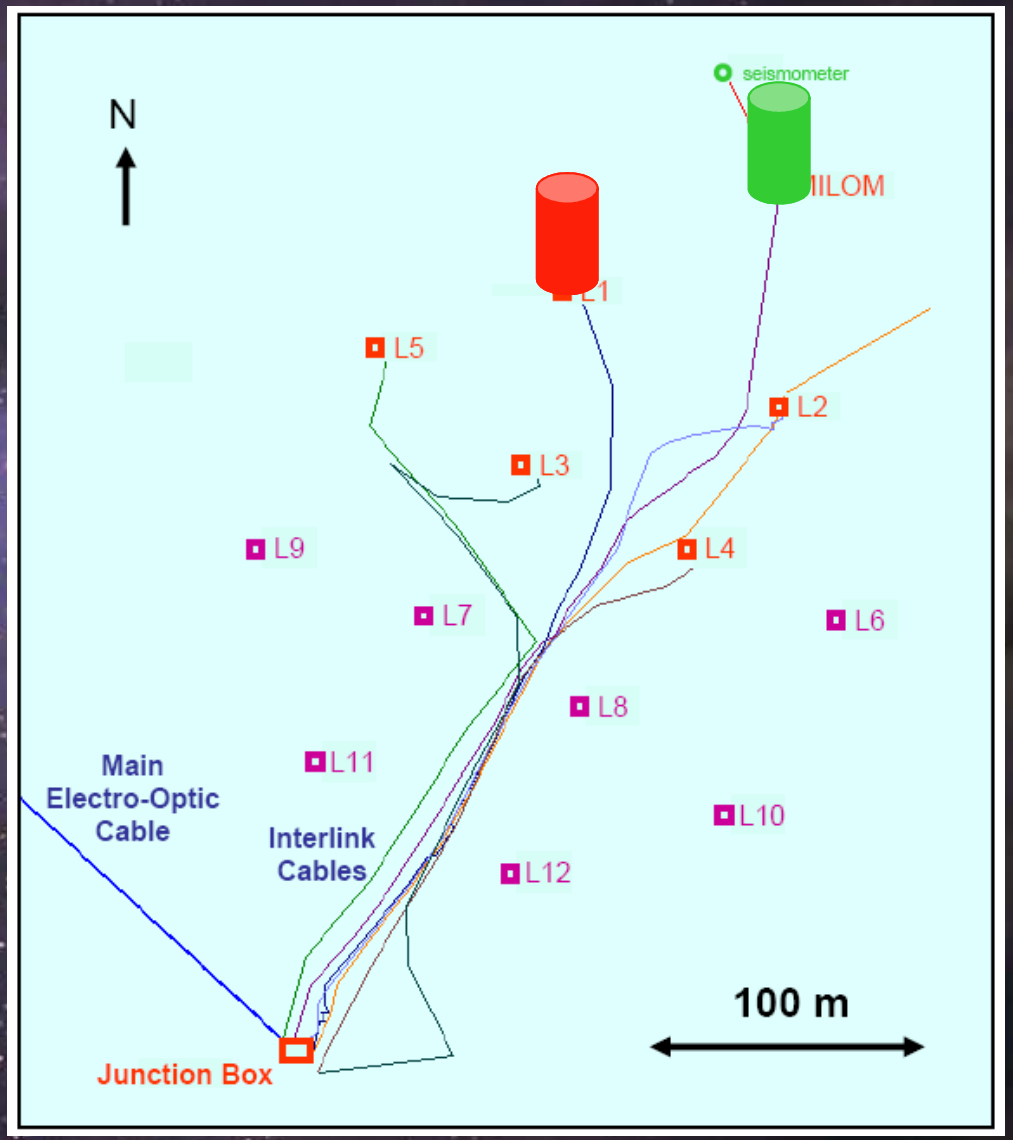


2 min

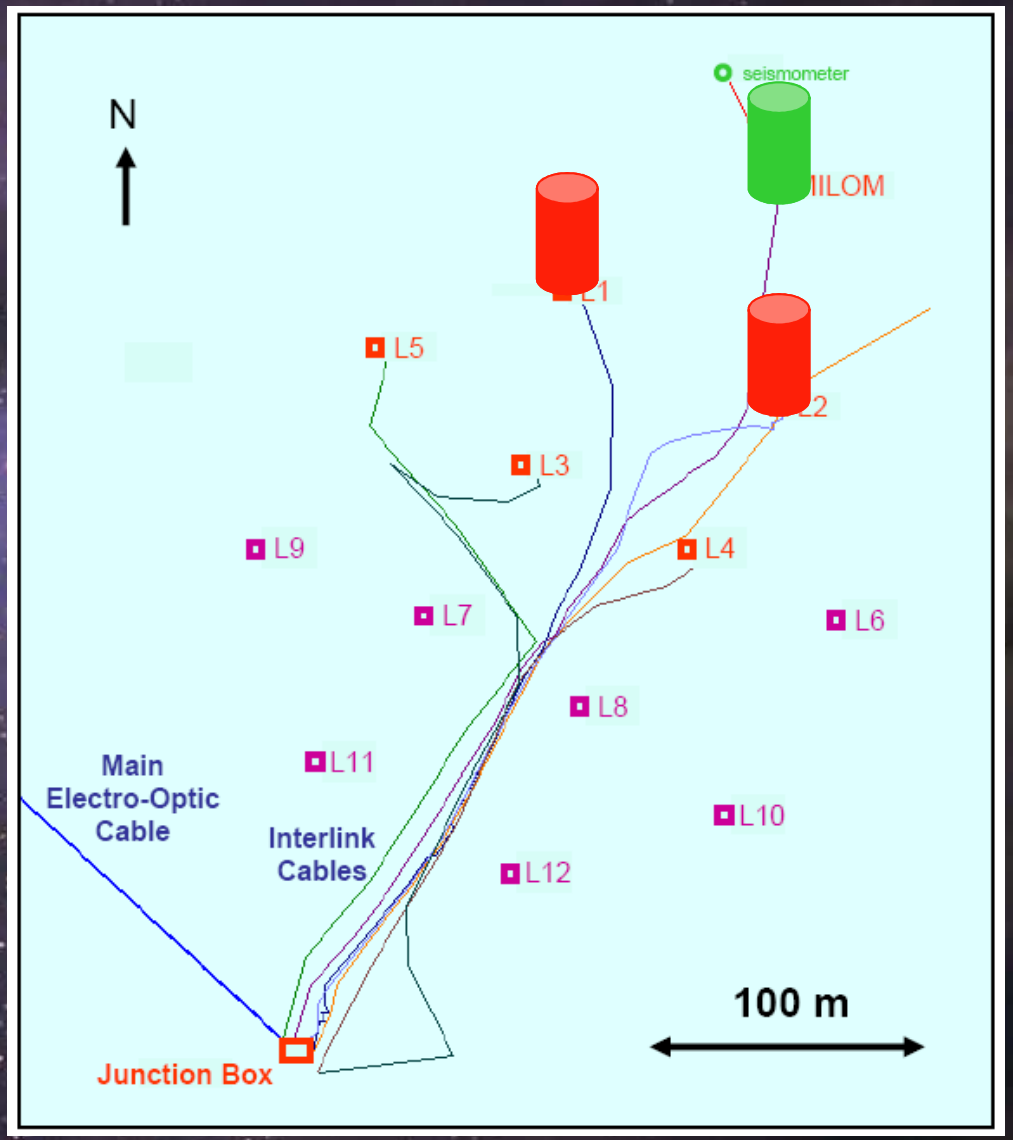
Mean rate on line 1

- **Line 1**
  - **Floor 1 (bottom, ~2400 m)**
  - **Floor 25 (top, ~2040 m)**
  - **March 2006 – May 2008 (more than 2 years!)**

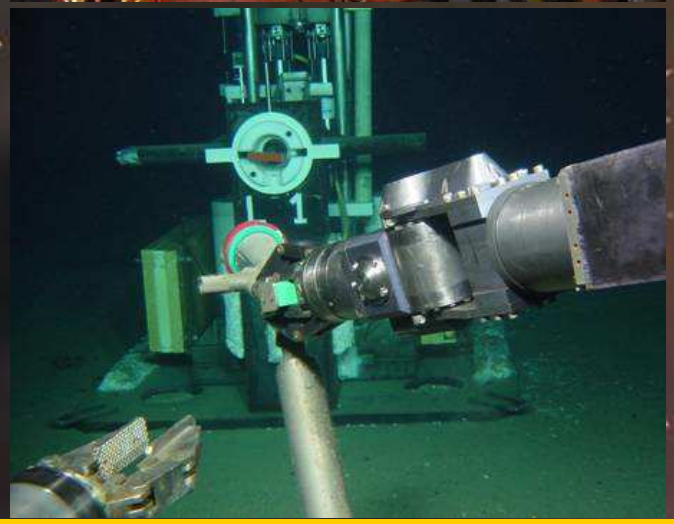


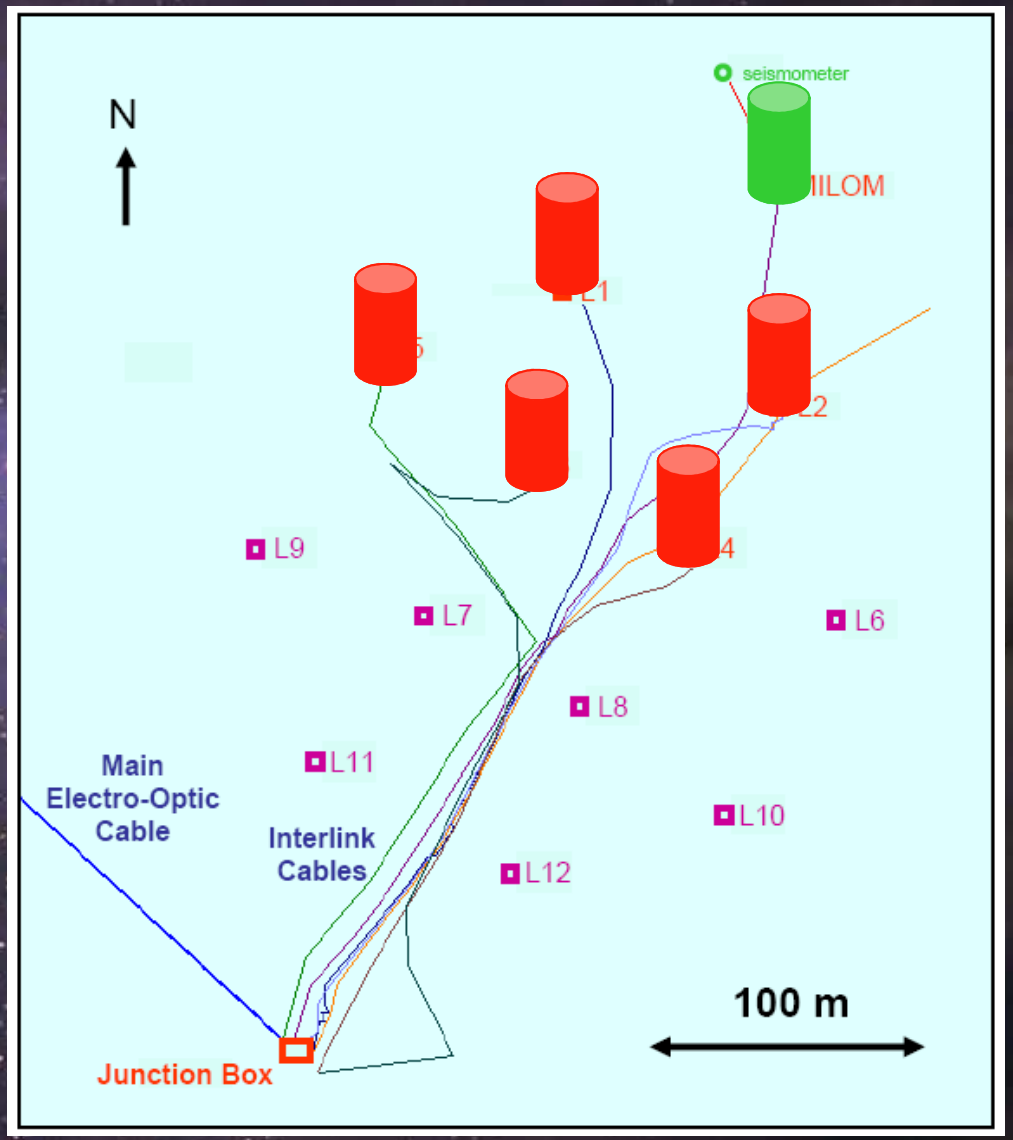


- **March 2006**
  - **First line**

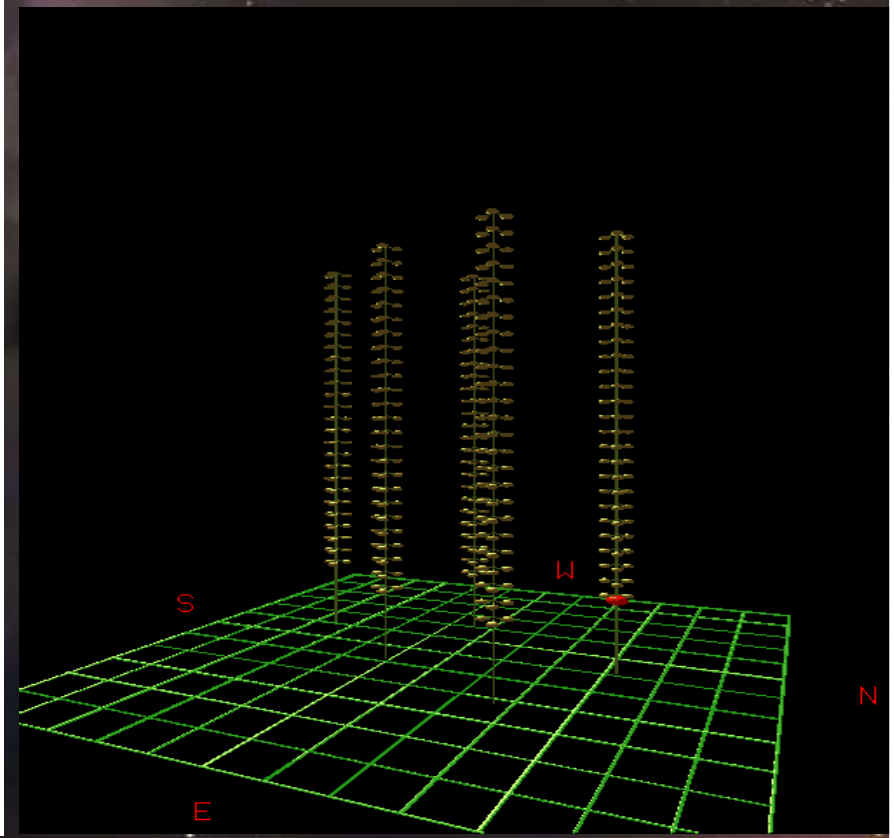


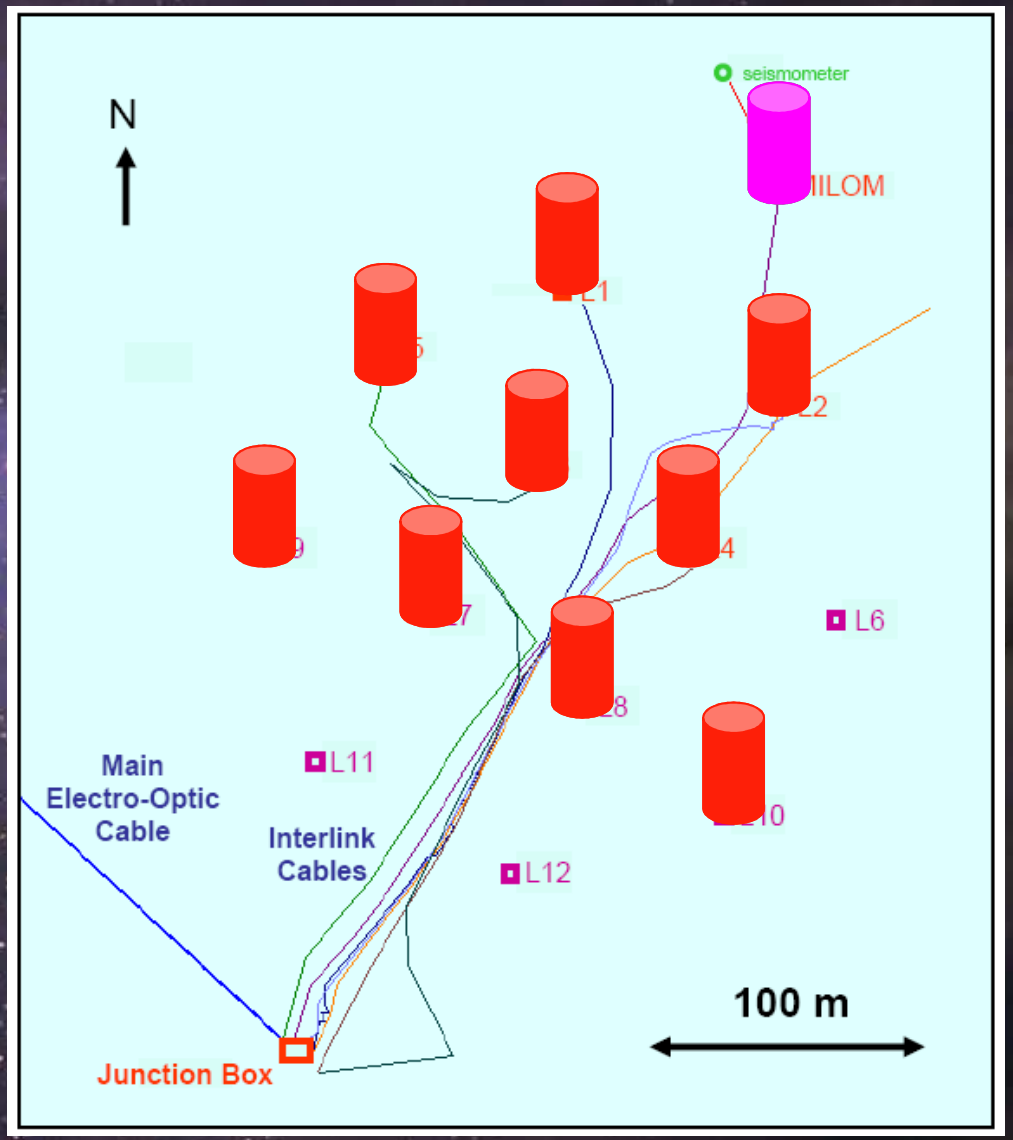
- **September 2006**
  - **Line 2**



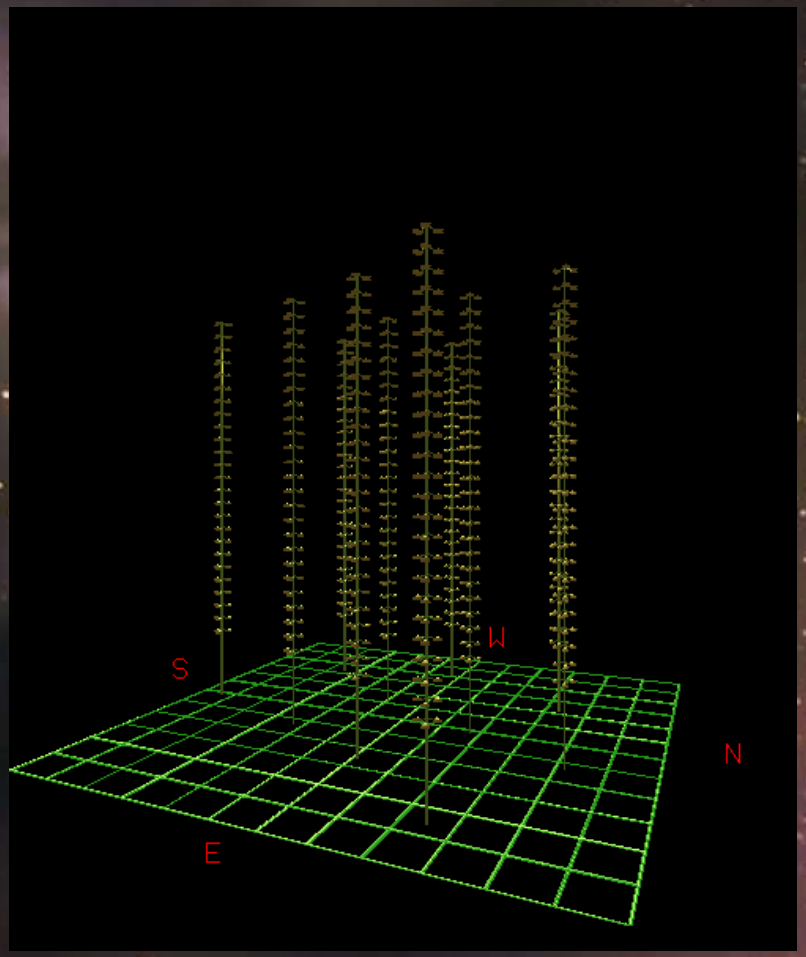


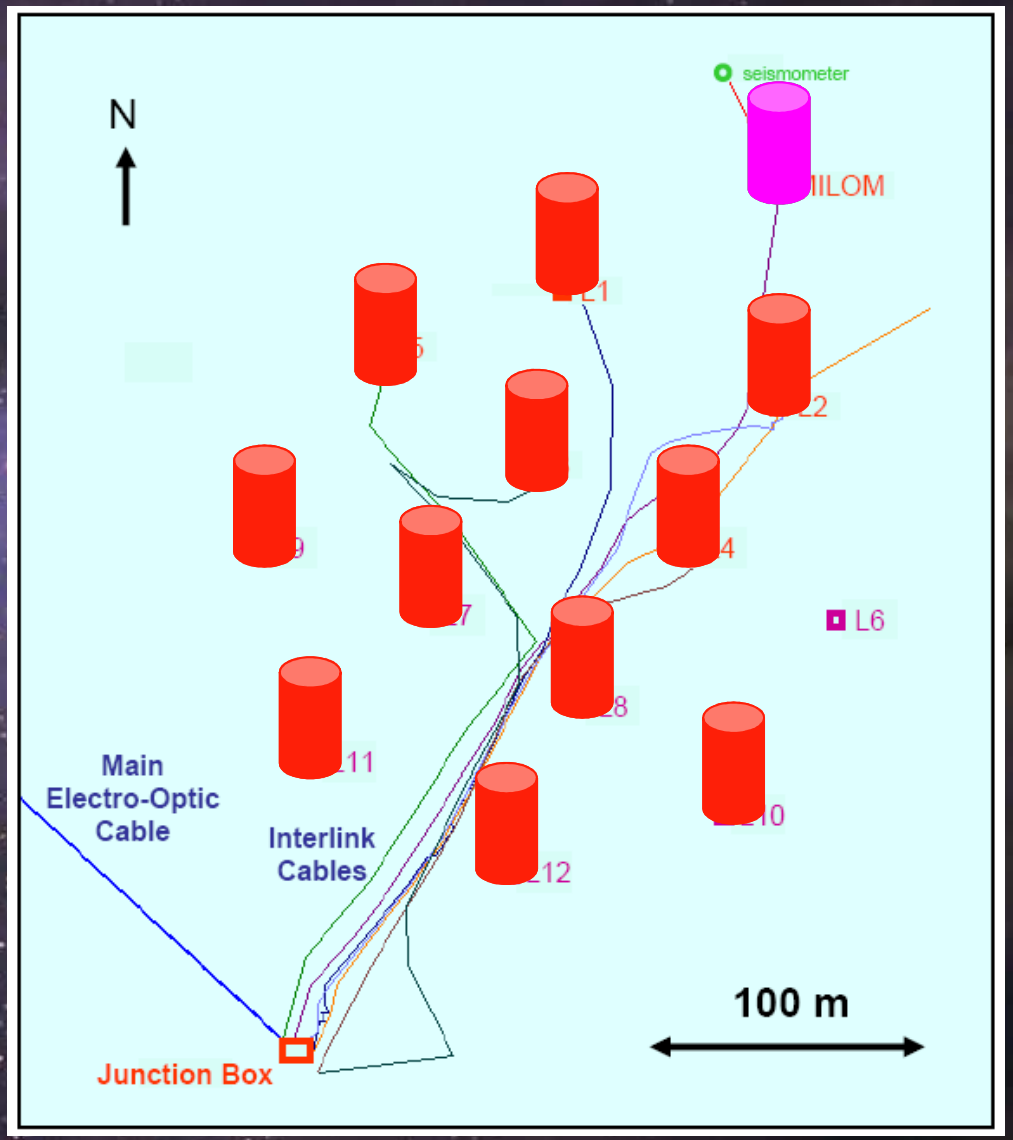
- **January 2007**
  - **5 lines**





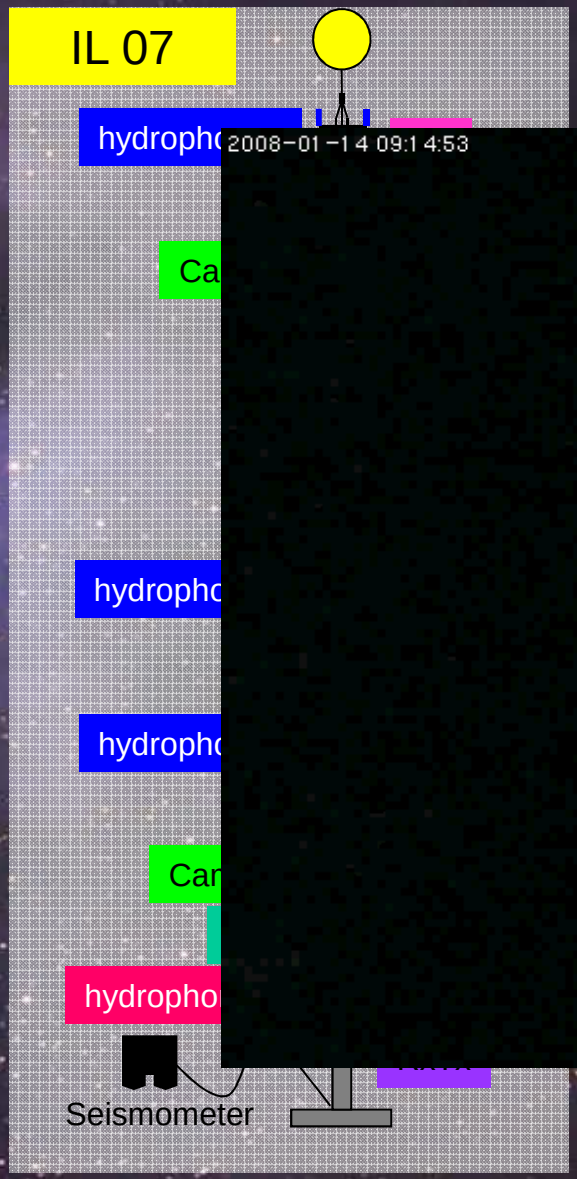
- **December 2007**
  - **10 lines**

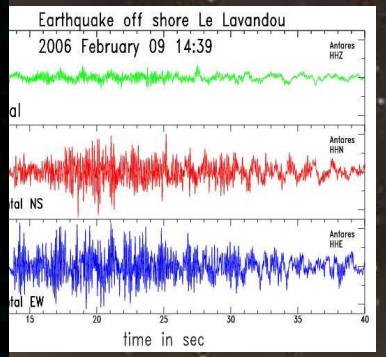




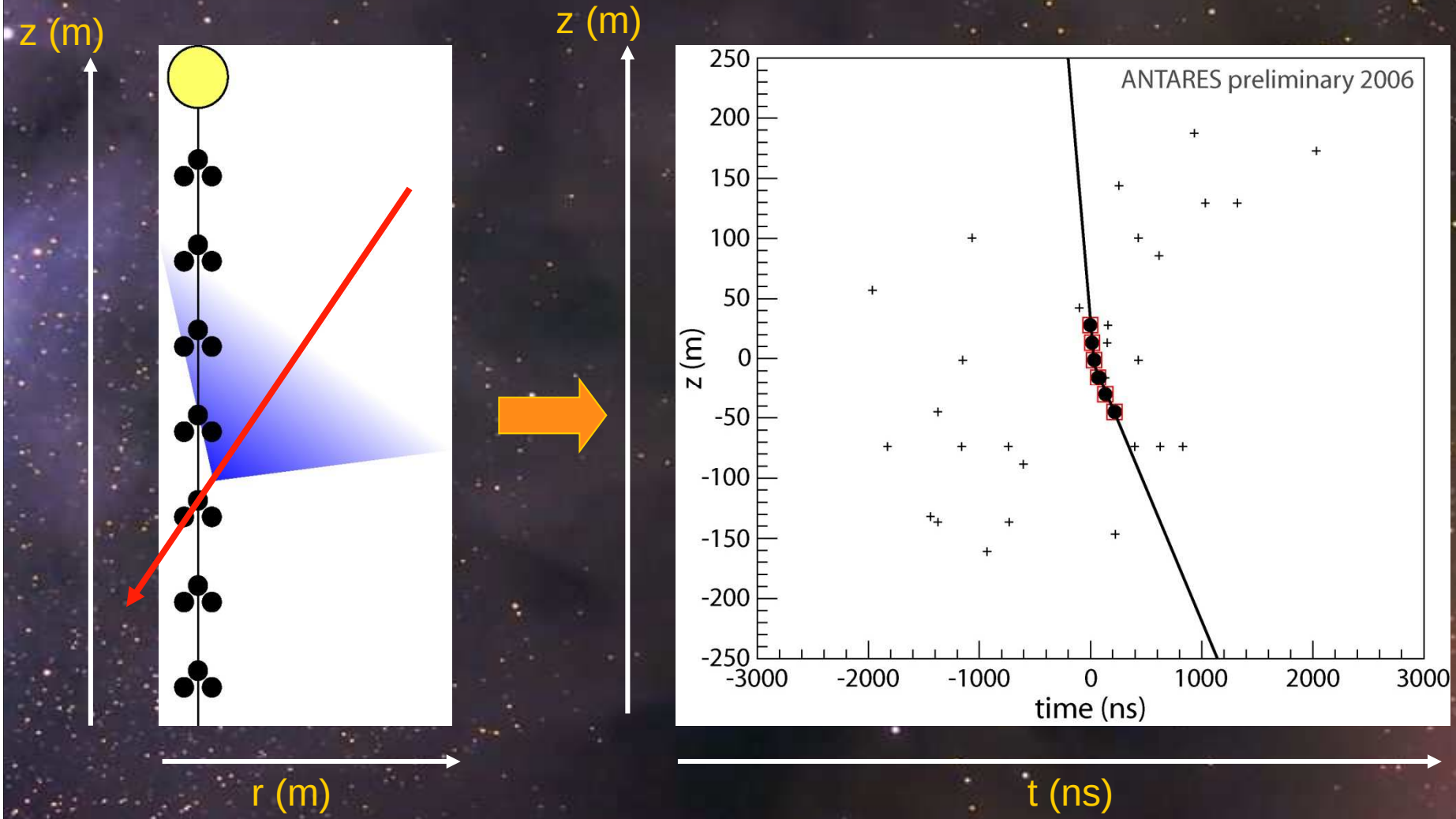
- **May 2008**
  - **12 lines**
- **Connexions are imminent !**

Other sciences

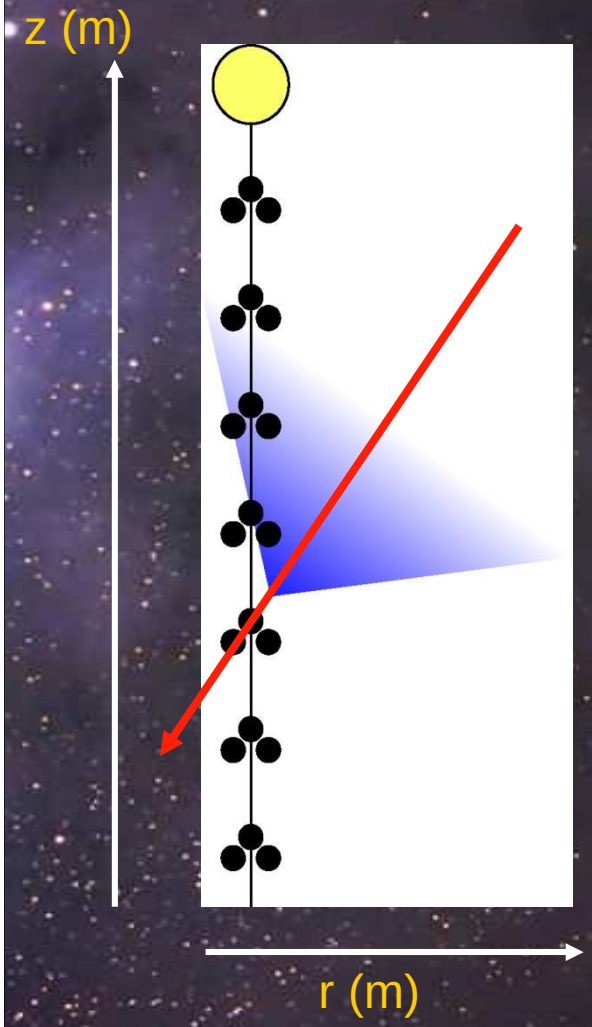


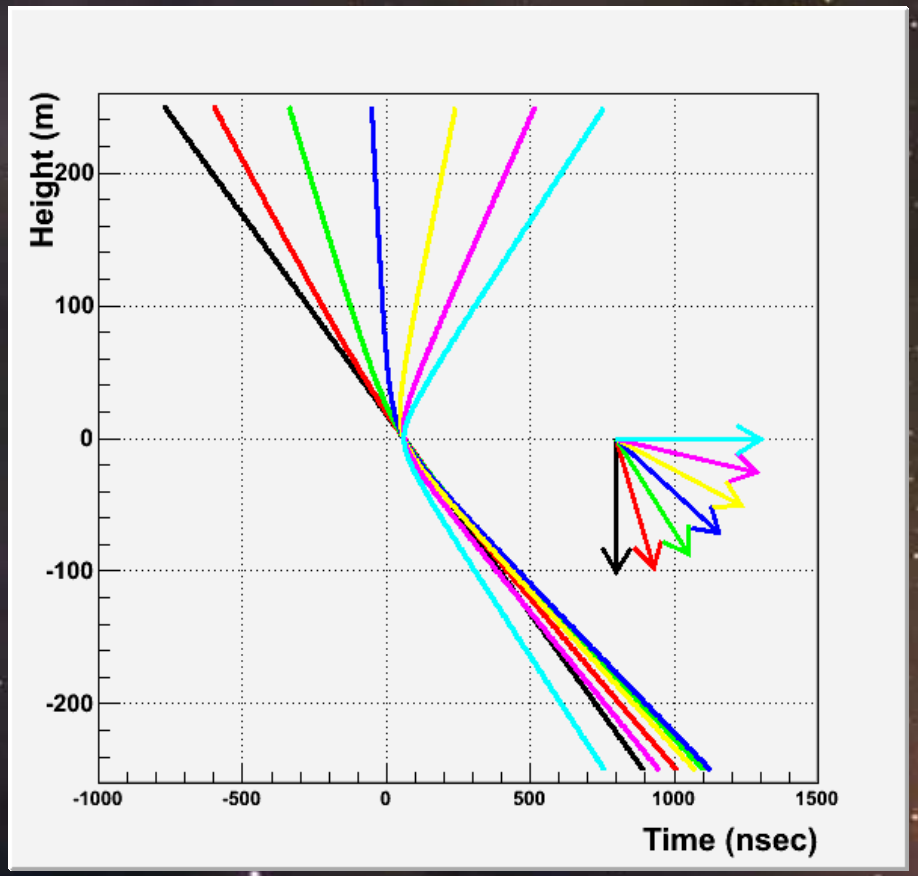


Atmospheric muons

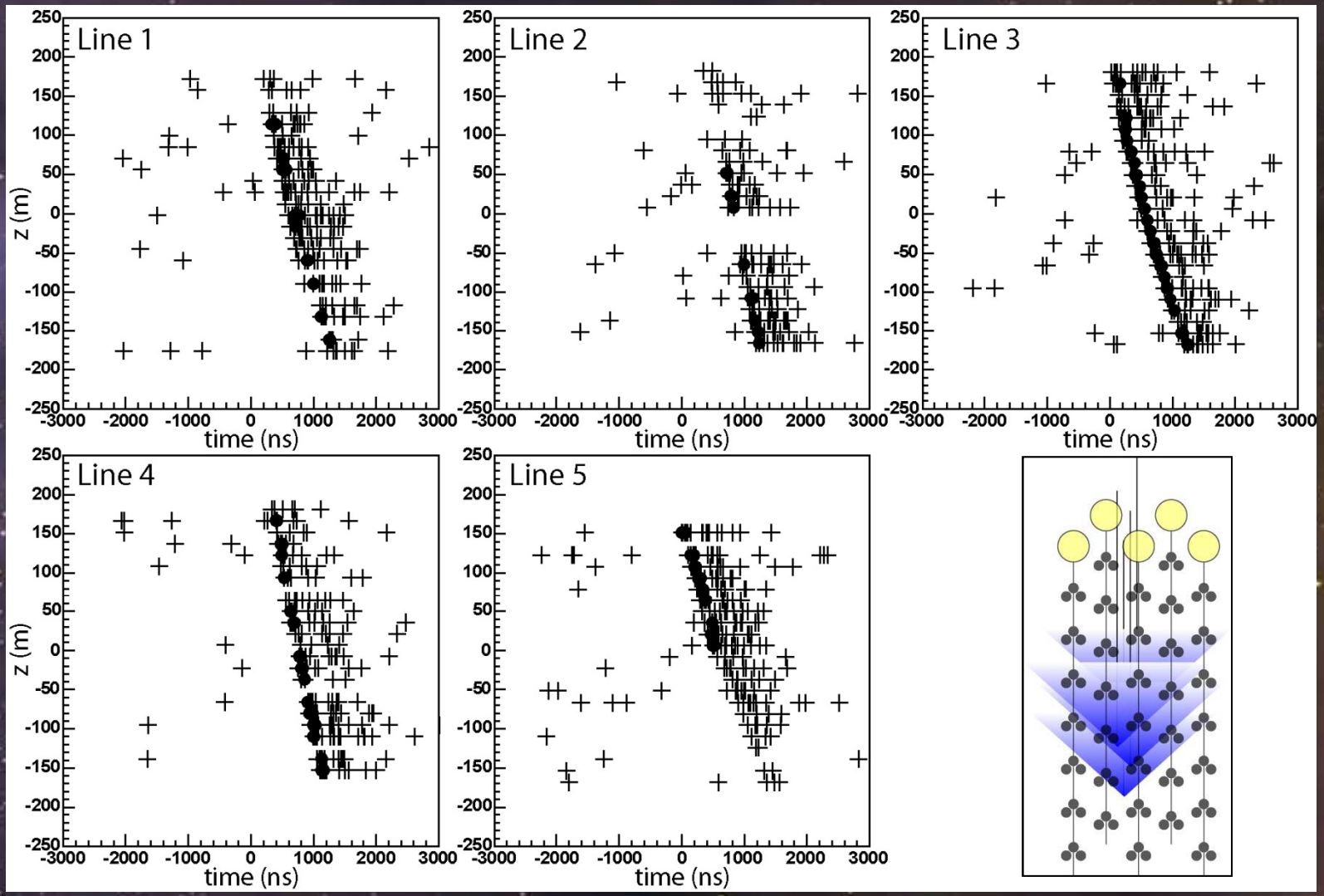


Atmospheric muons



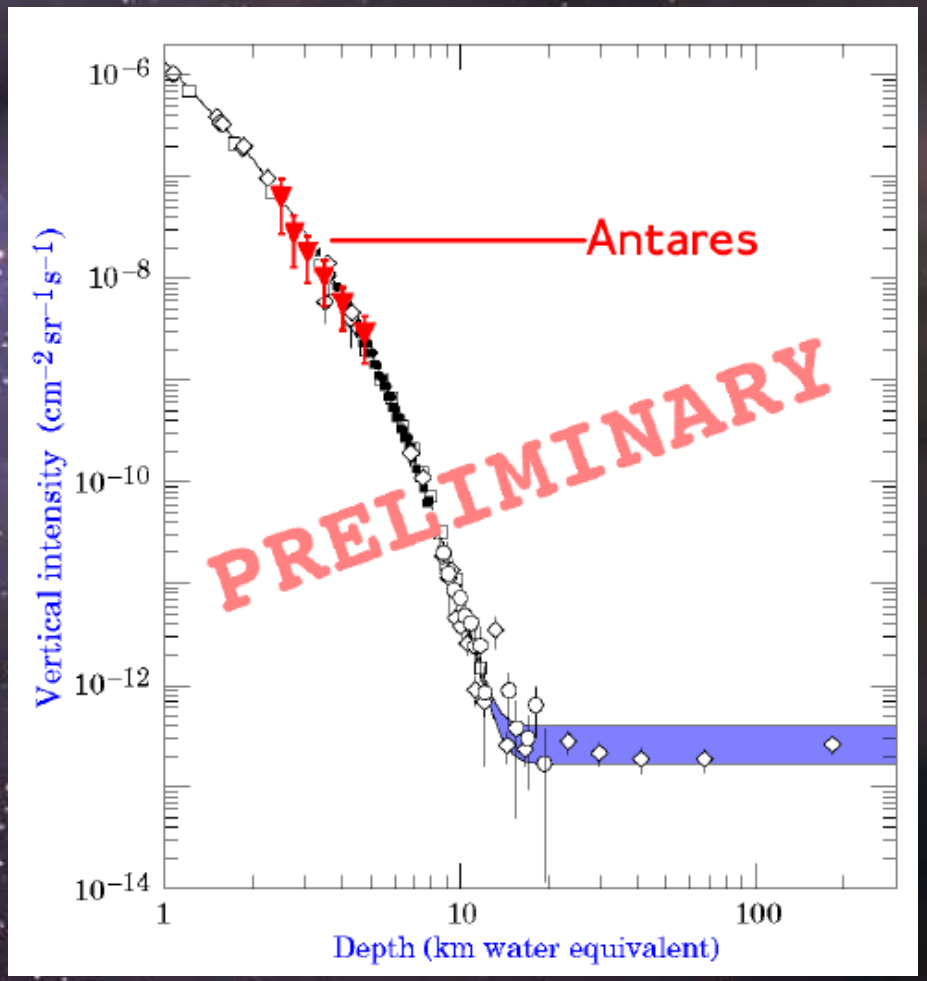


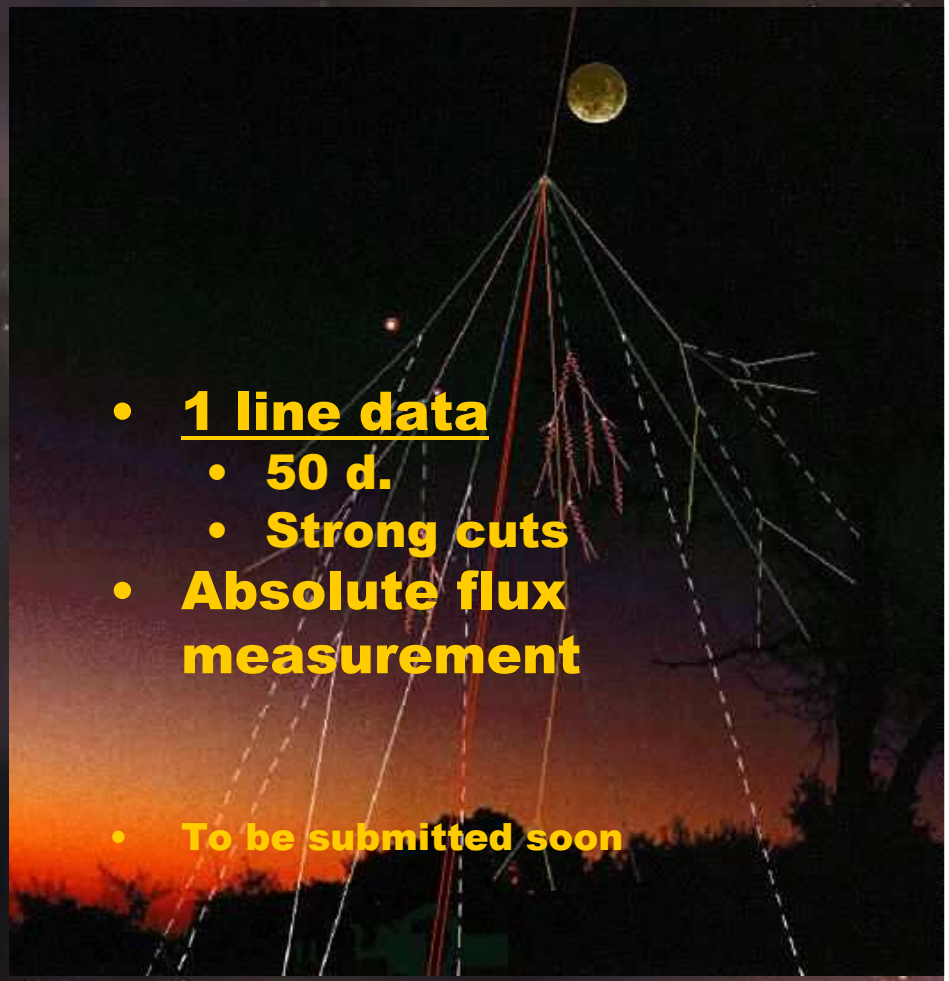
Atm. μ bundles



Atmospheric muons

Depth-intensity relation





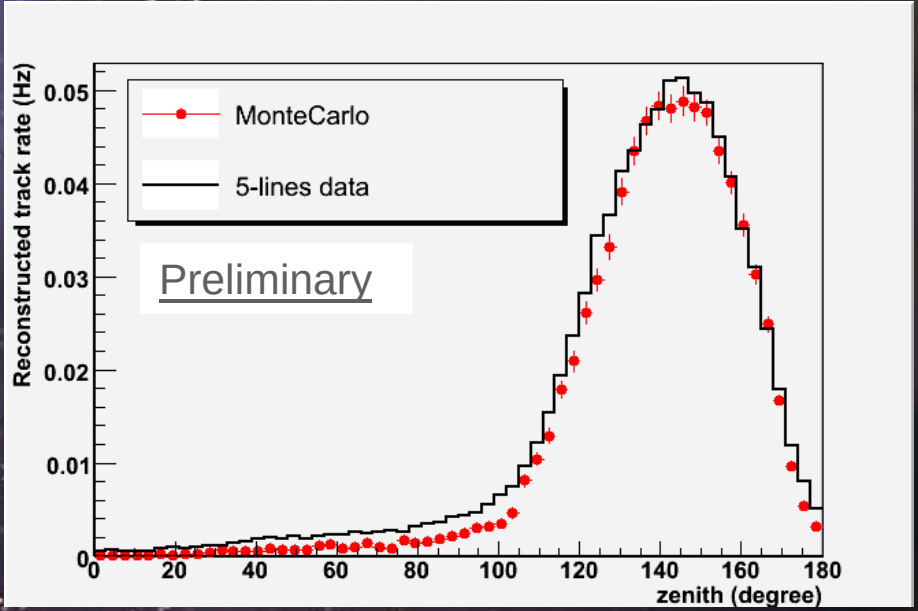
- **1 line data**
  - **50 d.**
  - **Strong cuts**
- **Absolute flux measurement**
- **To be submitted soon**

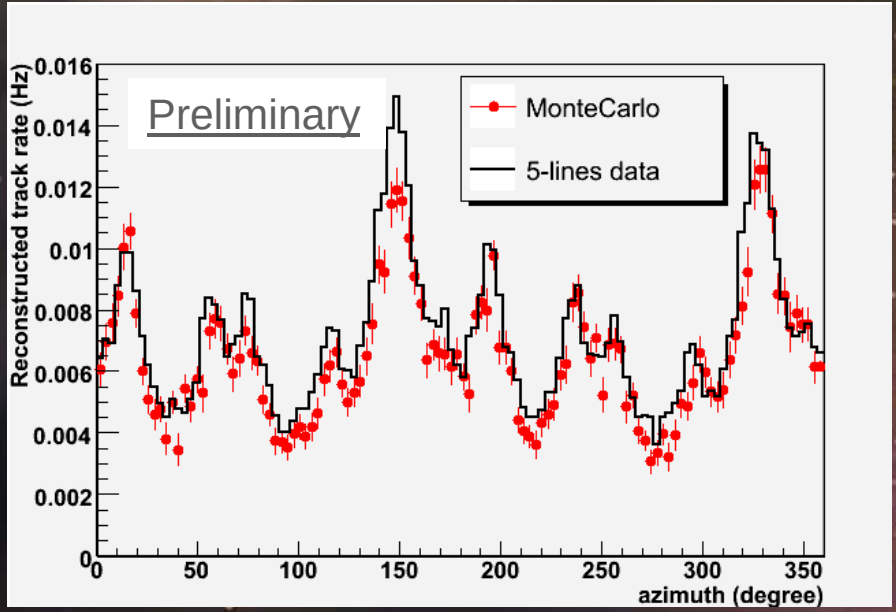
Atmospheric muons

5 line data

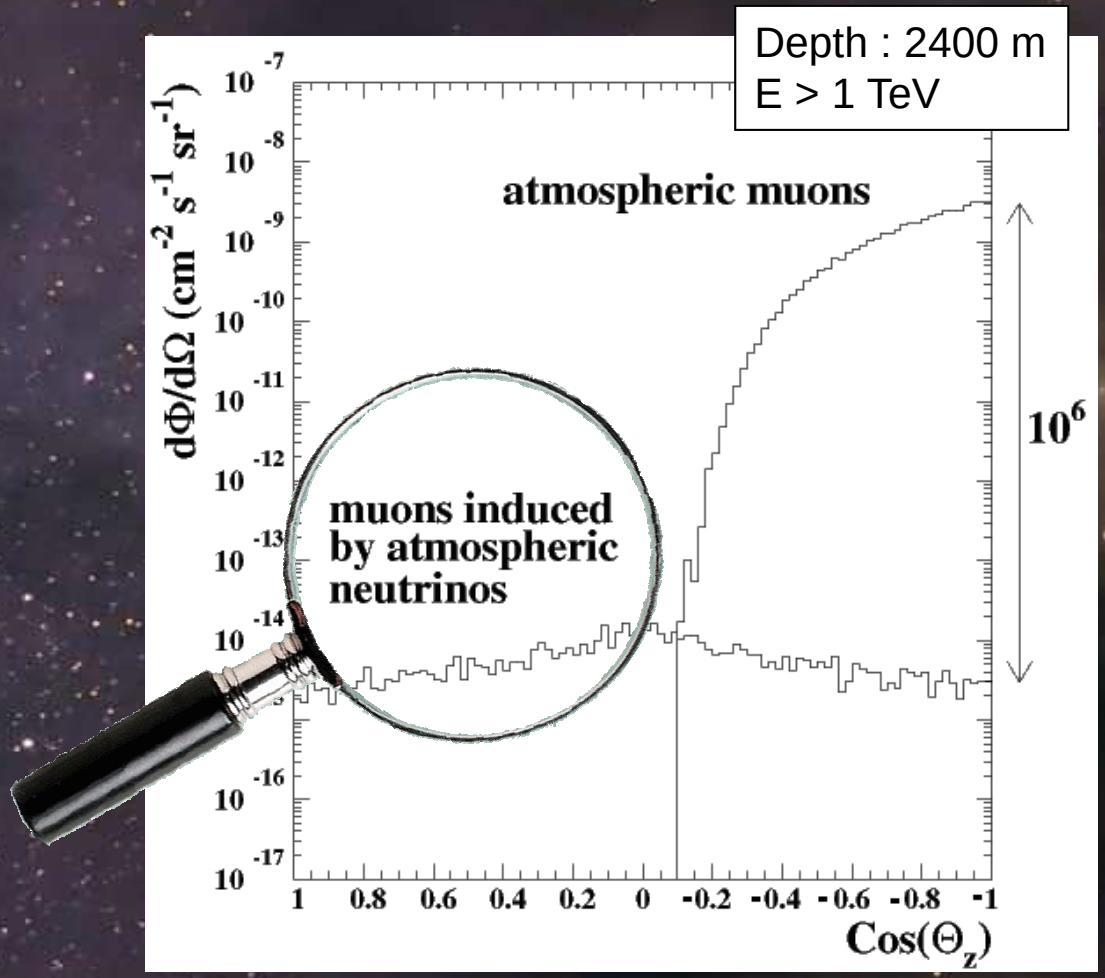
10 runs in February 2007

- All reconstructed events
  - No quality cut
- Data/simulation agreement ~10%
  - Too good ? Theoretical uncertainties > 20%





The search for neutrinos



Atmospheric ν
5 line data

- **Preliminary study**

- **Code initially used for online reconstruction**
- **Resolution and efficiency not optimal…**
  - **Simple χ^2 fit (no pdf)**
  - **Default calibration**

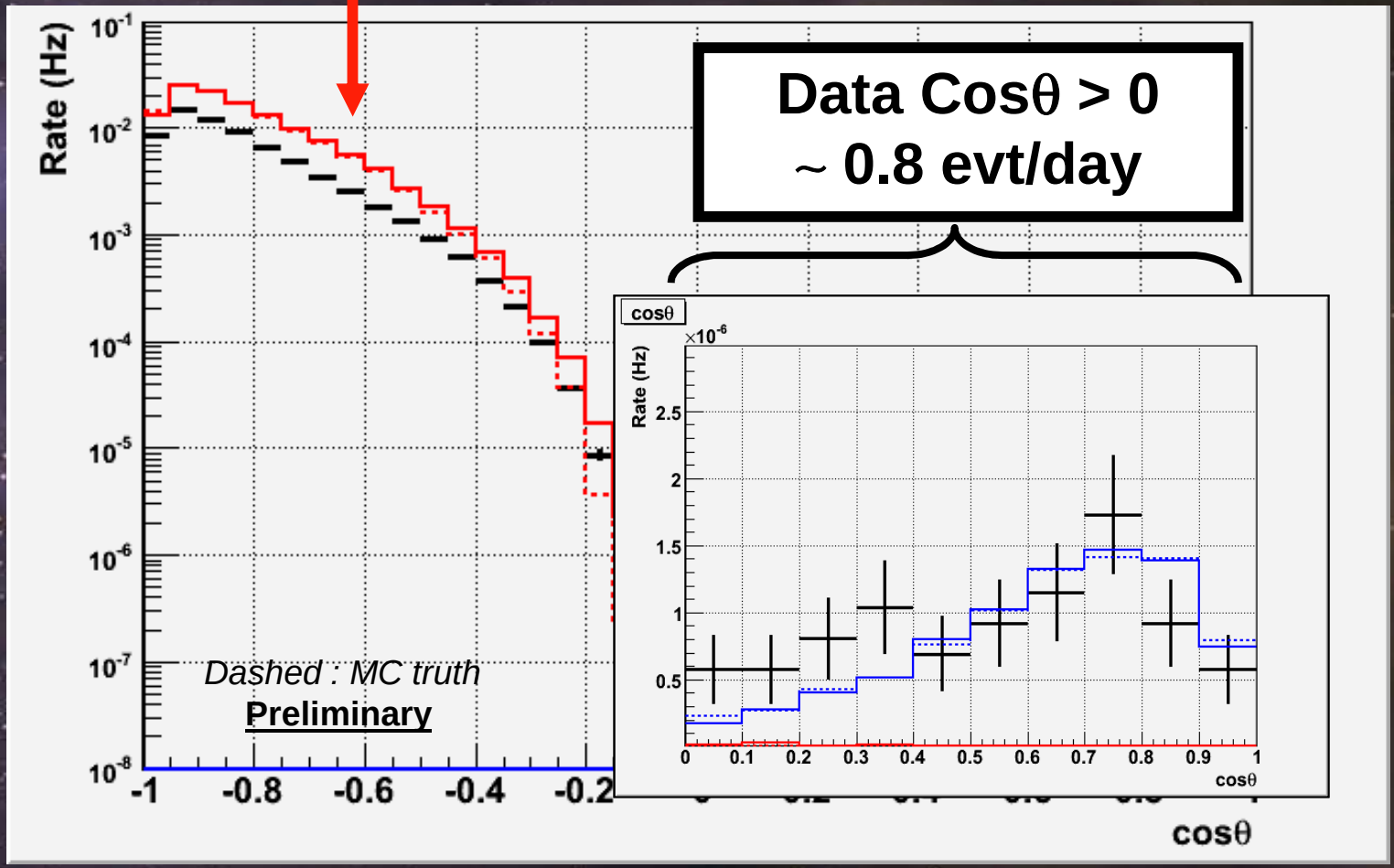
- **Simulation**
  - **Atmospheric μ : Korsika (QGset) + "Hoerandel"**
  - **Atmospheric ν : Bartol model**

- **χ^2 cut applied + at least 2 lines fired**

- **More sophisticated analysis under study…**

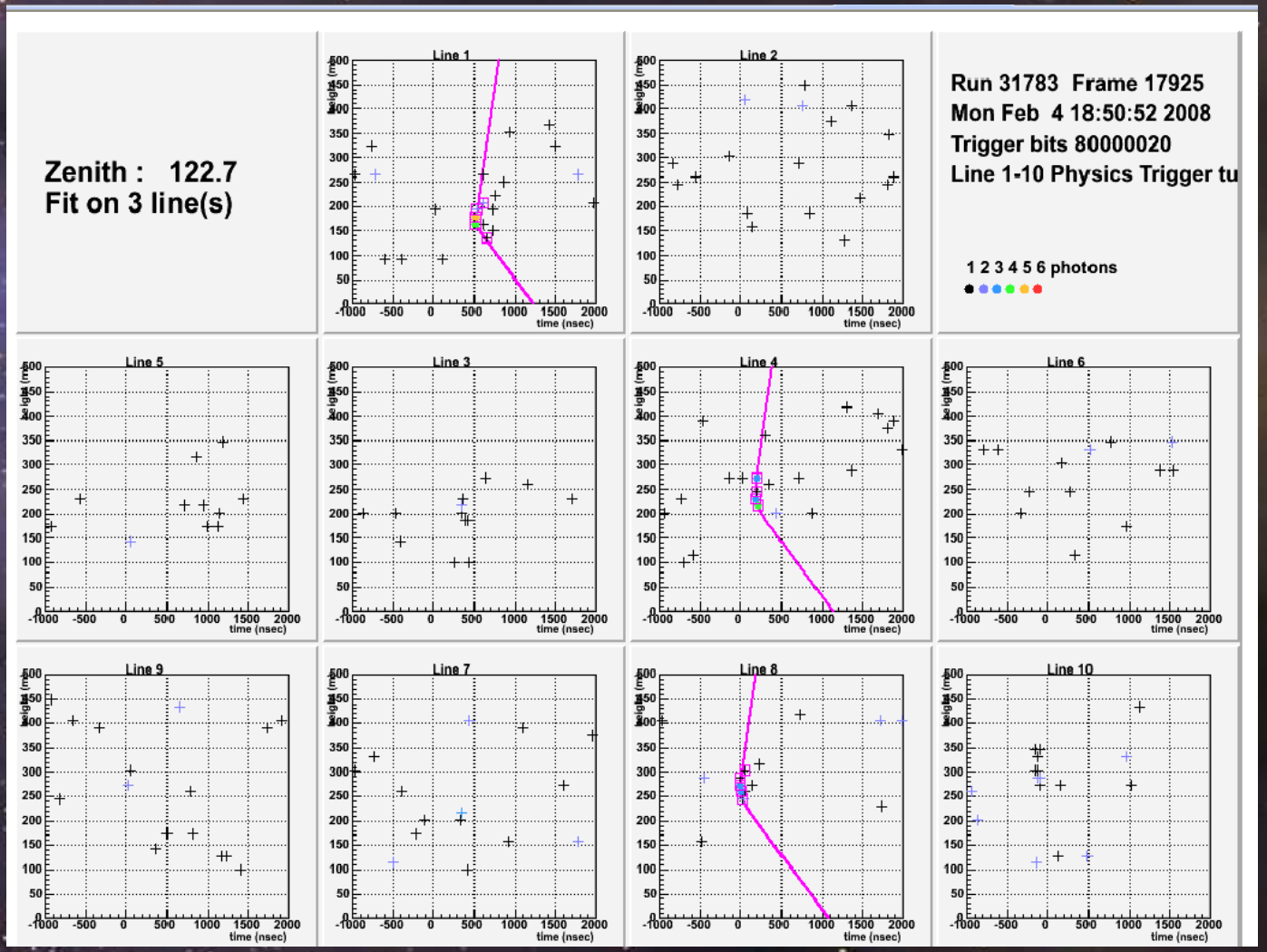
- 5 line data subsample
- ~ 12×10^6 triggers (May. – Dec. 2007)
- 100 days of active time

Atmospheric μ

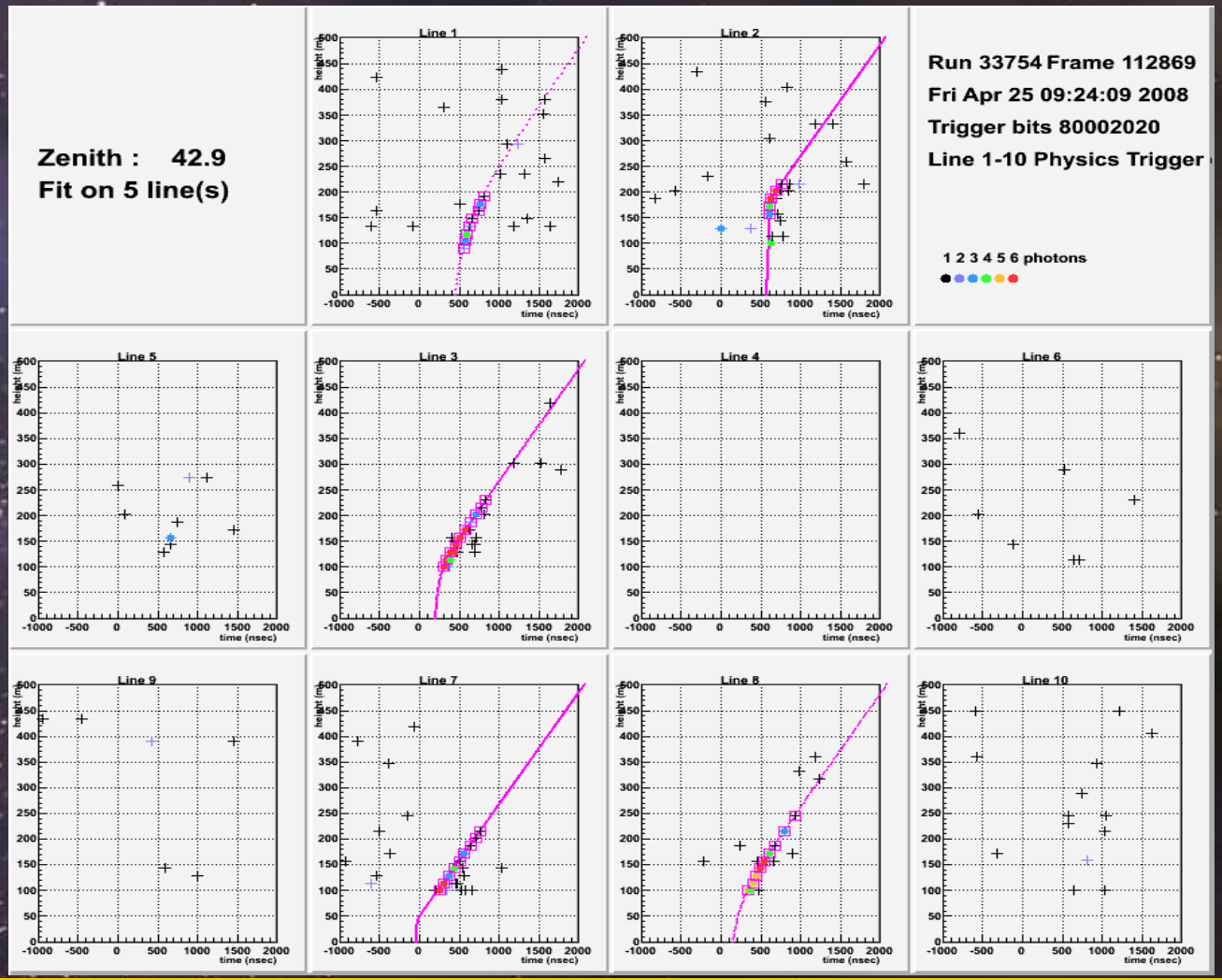


Atmospheric ν
10 line data

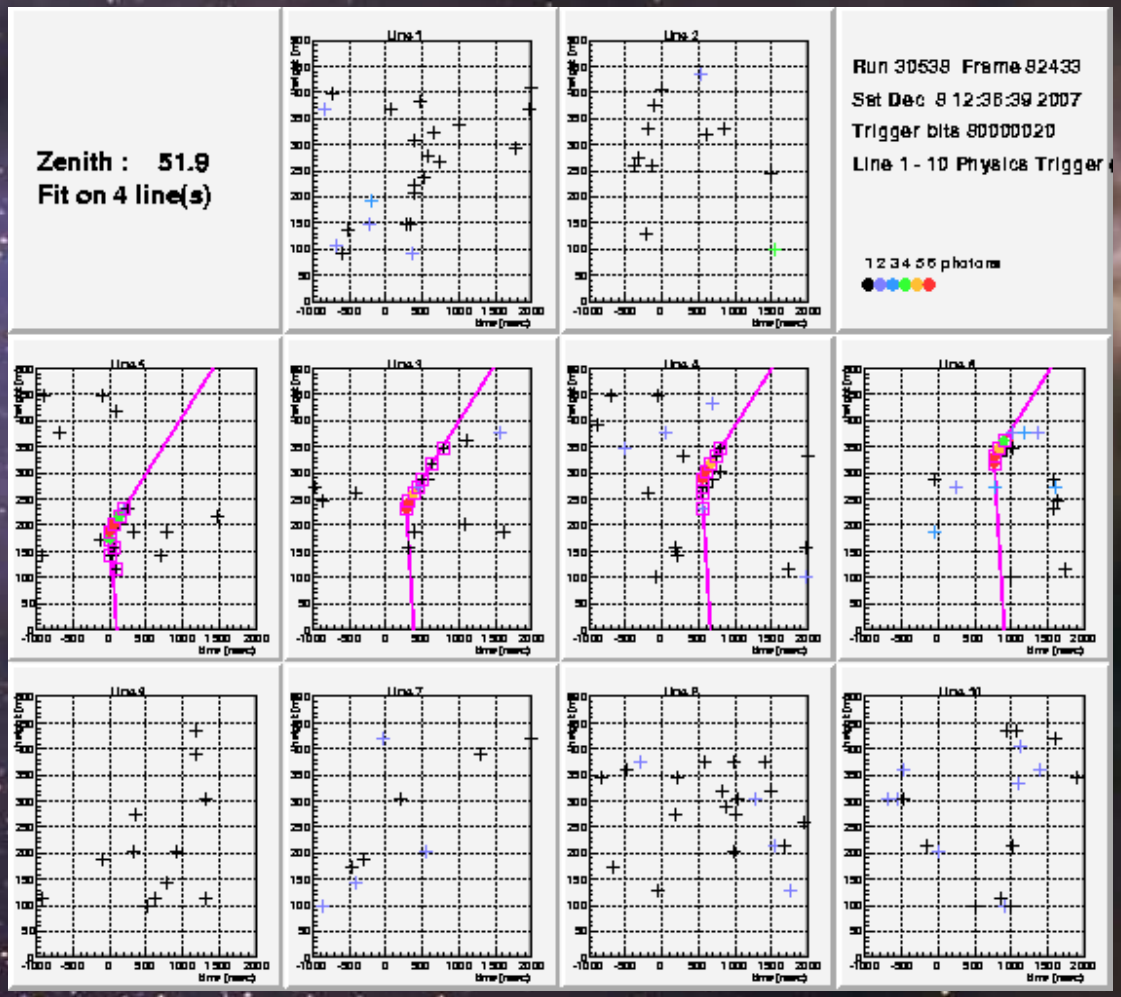
A neutrino candidate

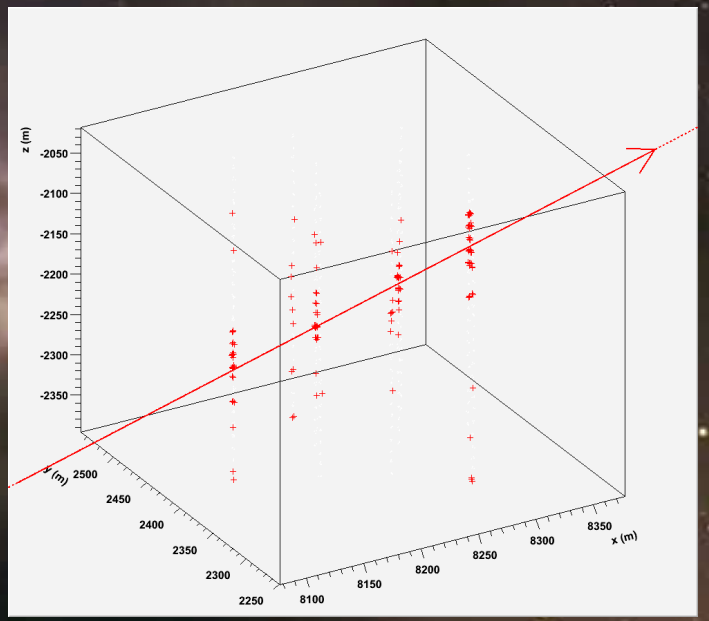


Atmospheric ν
10 line data



Atmospheric ν
10 line data

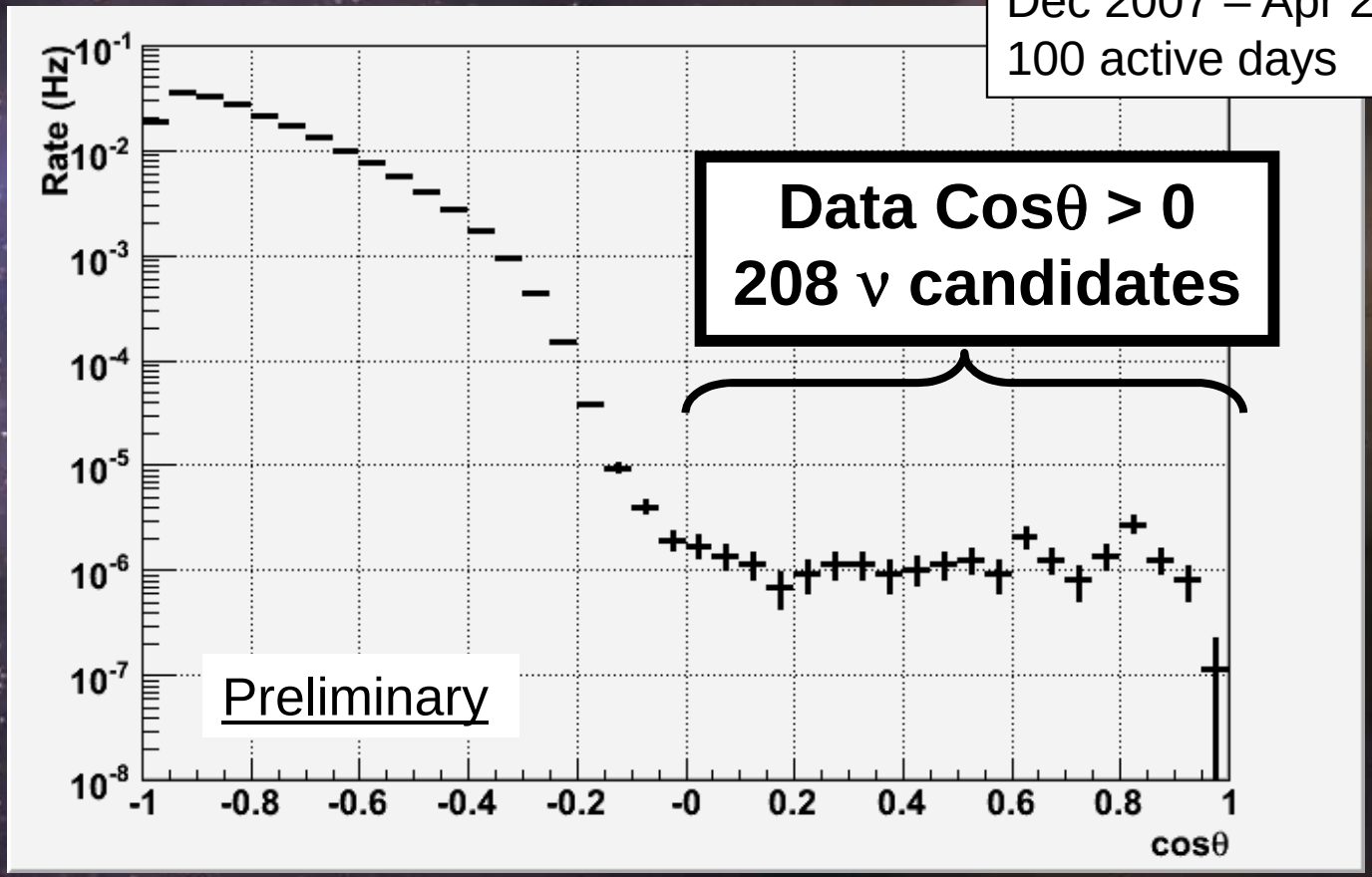




A neutrino candidate

Atmospheric ν
10 line data – a first look

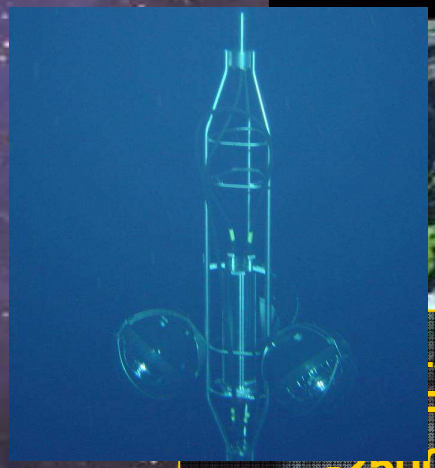
Dec 2007 – Apr 2008
100 active days

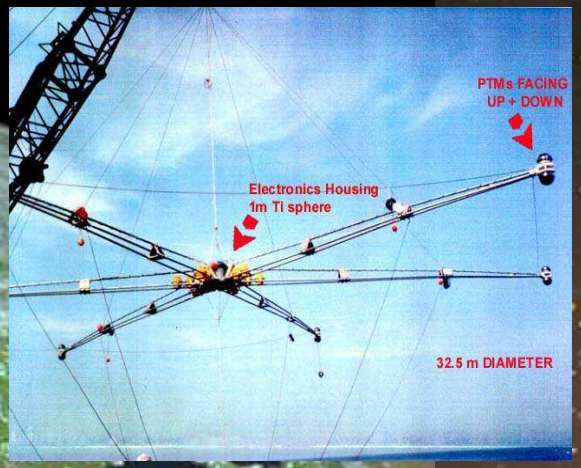


Antares status

- 1 line data – 2006 → Depth intensity relation
- 5 line data – Feb-Dec 2007
  - 15 millions of triggers on disk
  - 170 days of data analysed
  - Good agreement with atmospheric μ
  - Neutrinos reconstructed
- 10 line data – Dec-April 2007
  - 100 days of data, > 300 neutrinos identified
- Analysis in progress, systematics under study
- 12 + 1 lines deployed, May 2008
- Detector completion imminent
- Ready for source search !

KM3NeT





-2500m

Since 1996
Data taking
~150 members

Since 2000
R&D
80 members

Nemo
Capo Passero, Italy
-3350m

Since 1990
R&D
~ 50 members

Nestor
Pylos, Greece
-4000m

The KM3NeT consortium

8 countries, >30 institutes

Since sept. 2006 on ESFRI roadmap

FP6 - 2006-2009

- **Design study**
  - Get the best of the 3 pionneering experiments
  - CDR published (April 2008)
  - Toward the TDR

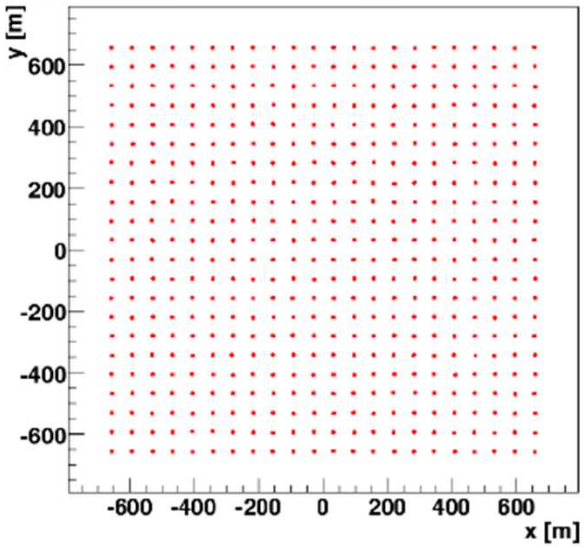
FP7 - 2008-2011

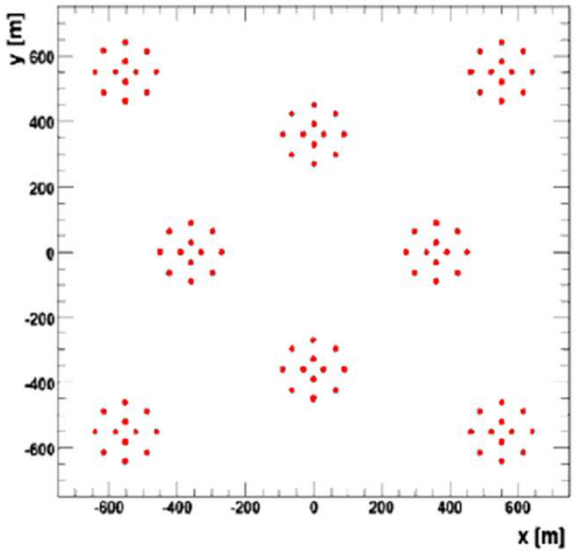
- **Preparatory phase**
  - Prepare the future collaboration
  - Study funding scenarios
  - Define a production model

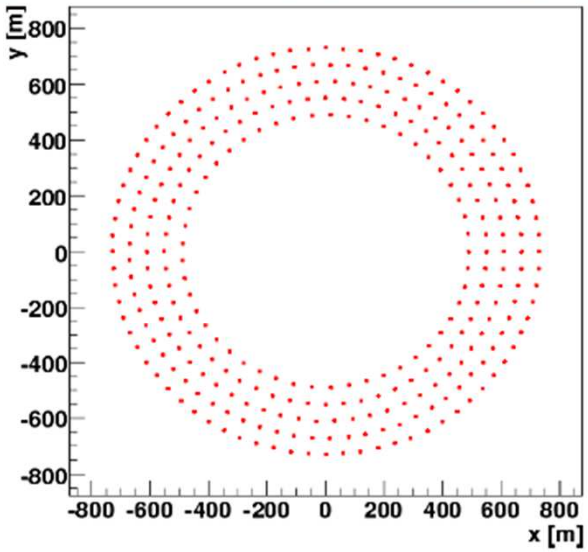
Strong links with ESONeT/EMSO

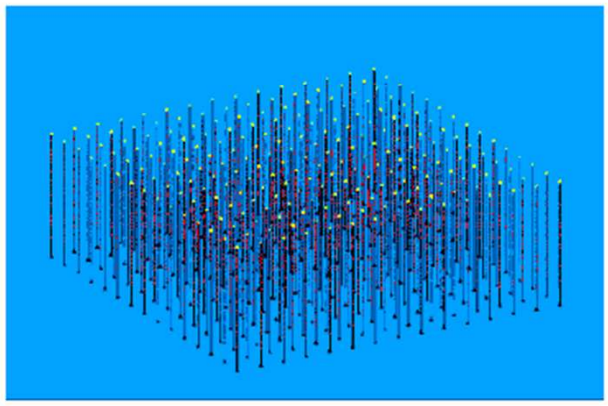
(ESFRI = European Strategy Forum on Research Infrastructures)

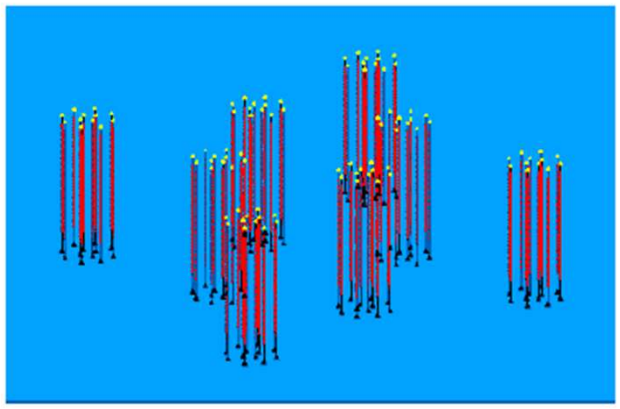
Configuration studies (CDR)

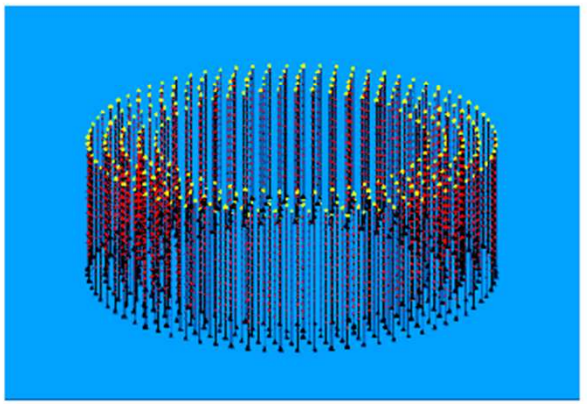






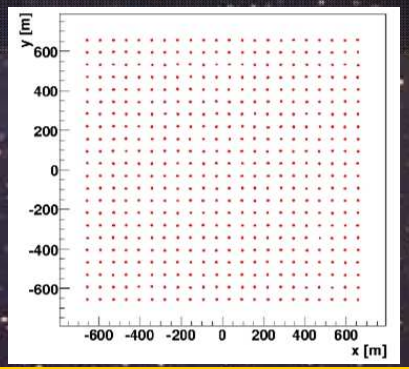


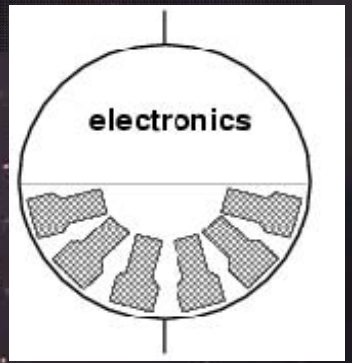


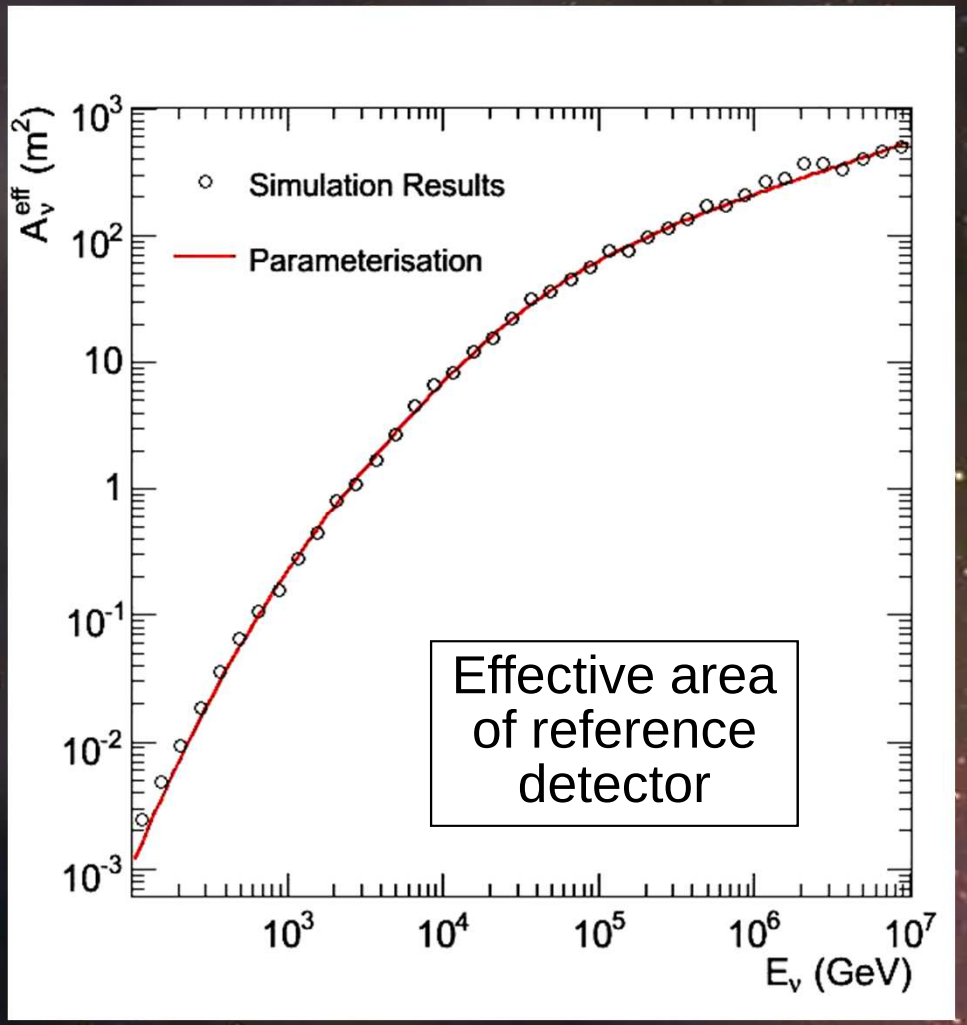


The CDR reference detector

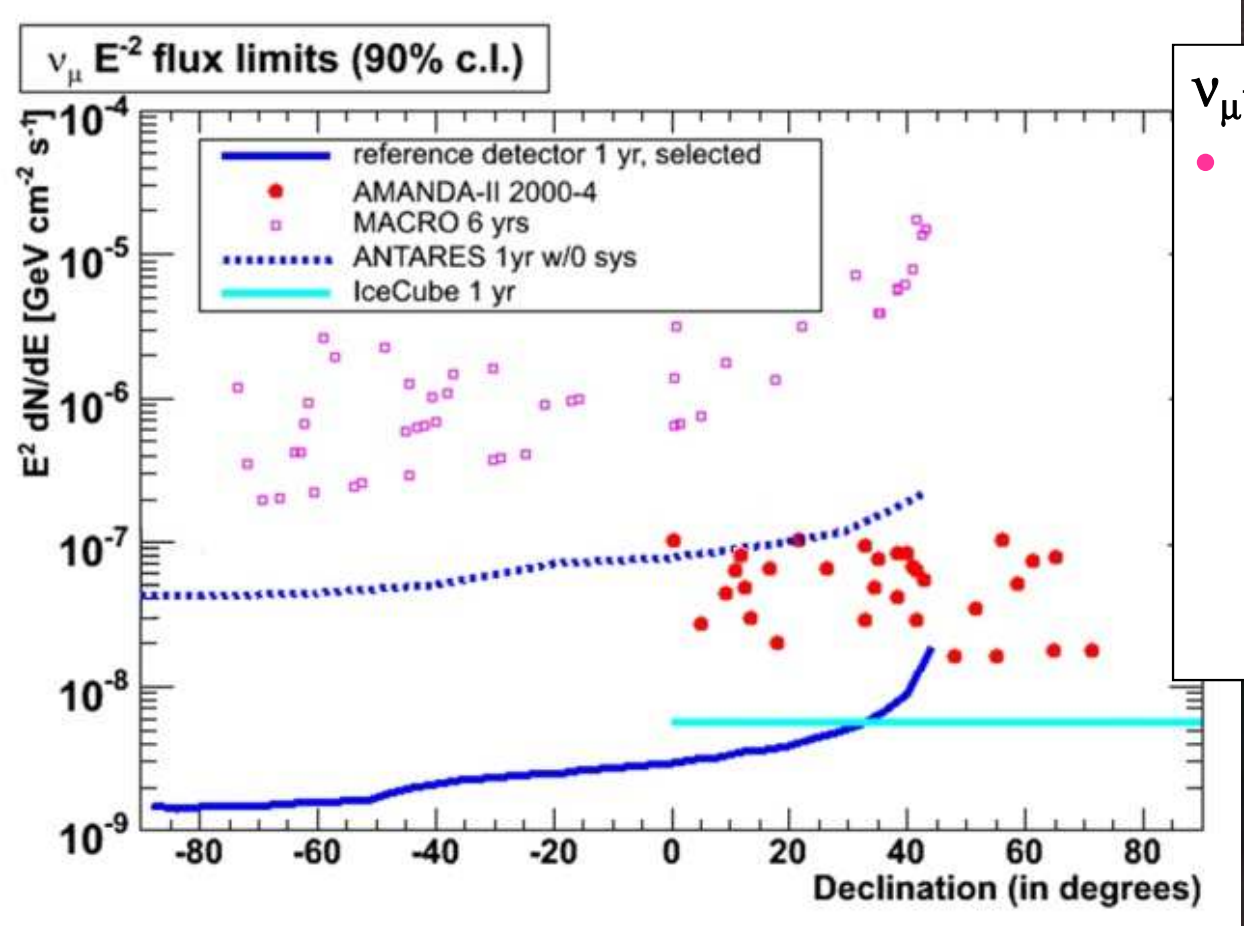
- **Not the final design**
- **15 x 15 "lines"**
- **Spacing 95 m**
- **Each "line"**
  - **37 optical module**
  - **Spacing 15.5 m**
- **Each OM : 21 x 3" PMTs**
- **Instrum. Vol. = 1 km³**







Point source sensitivity

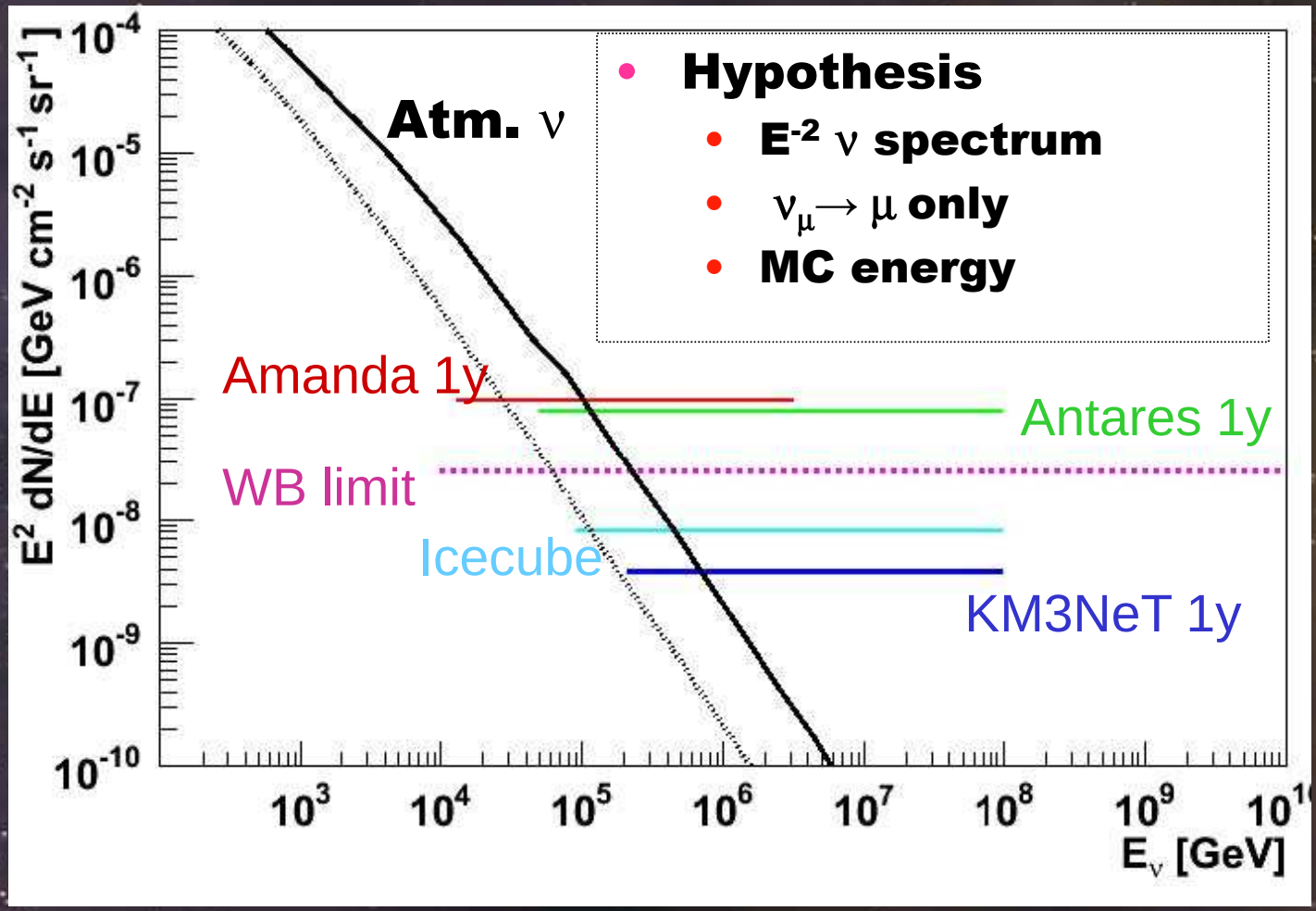


$\nu_\mu \rightarrow \mu$ **only**

- **Why better than Icecube ?**
  - **Larger photocathode area**
  - **Better angular resolution**

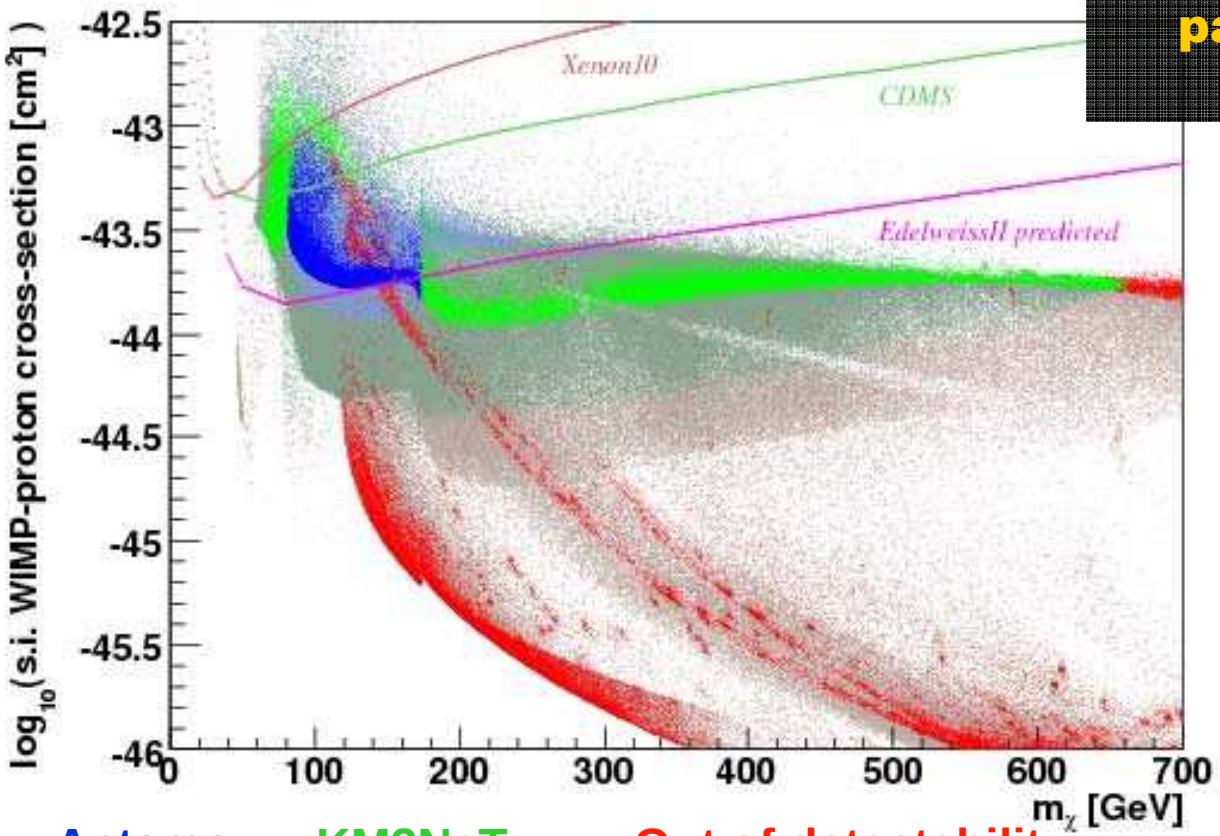
Preliminary

Diffuse fluxes

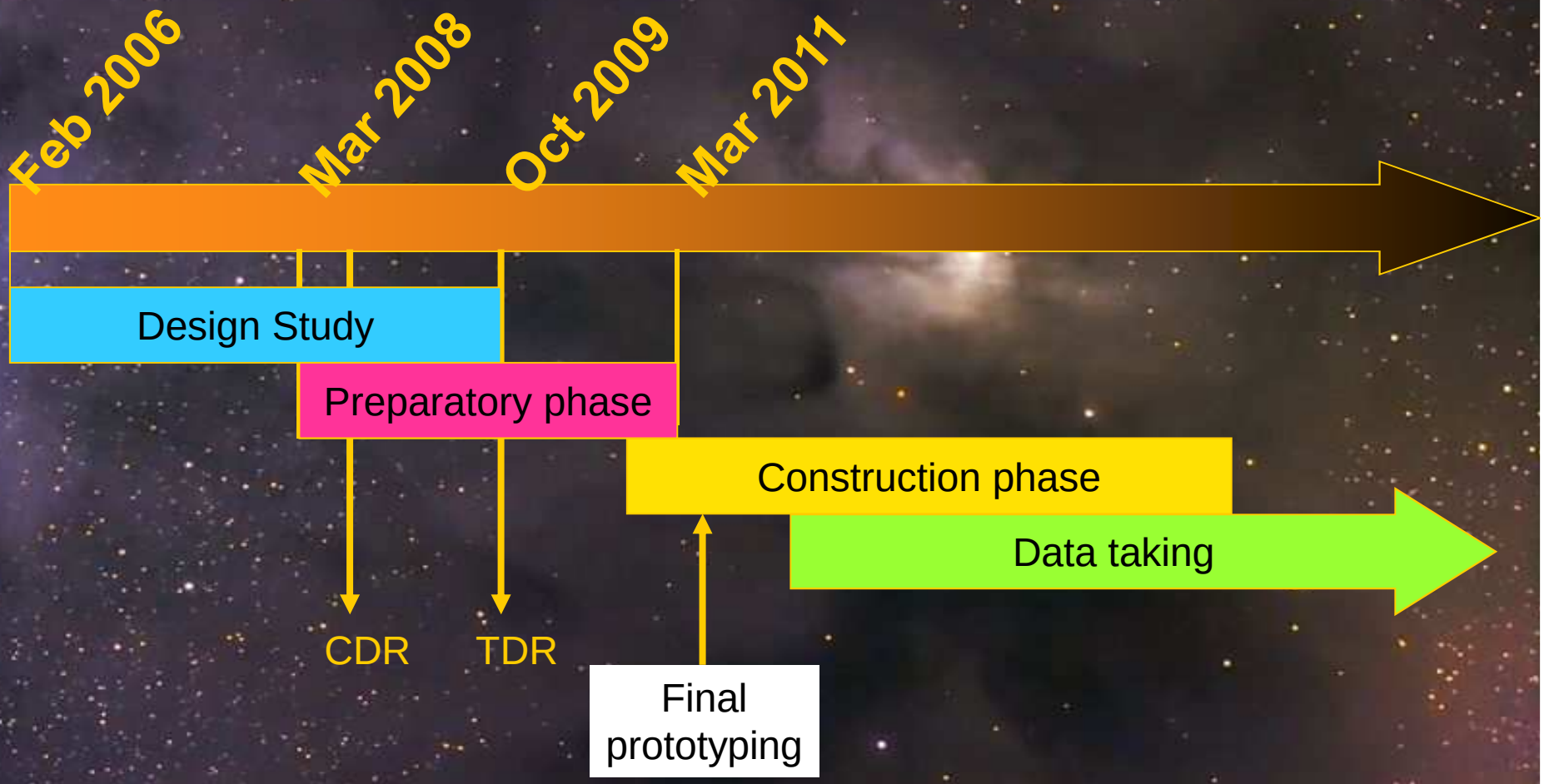


Dark Matter Sensitivity

- χ° annihilation in Sun
- Scan of mSUGRA parameter space



Timeline towards construction



Note: "Construction" includes the final prototyping stage

ν astronomy opens a new window on the Universe...

... the window has never been so wide open !