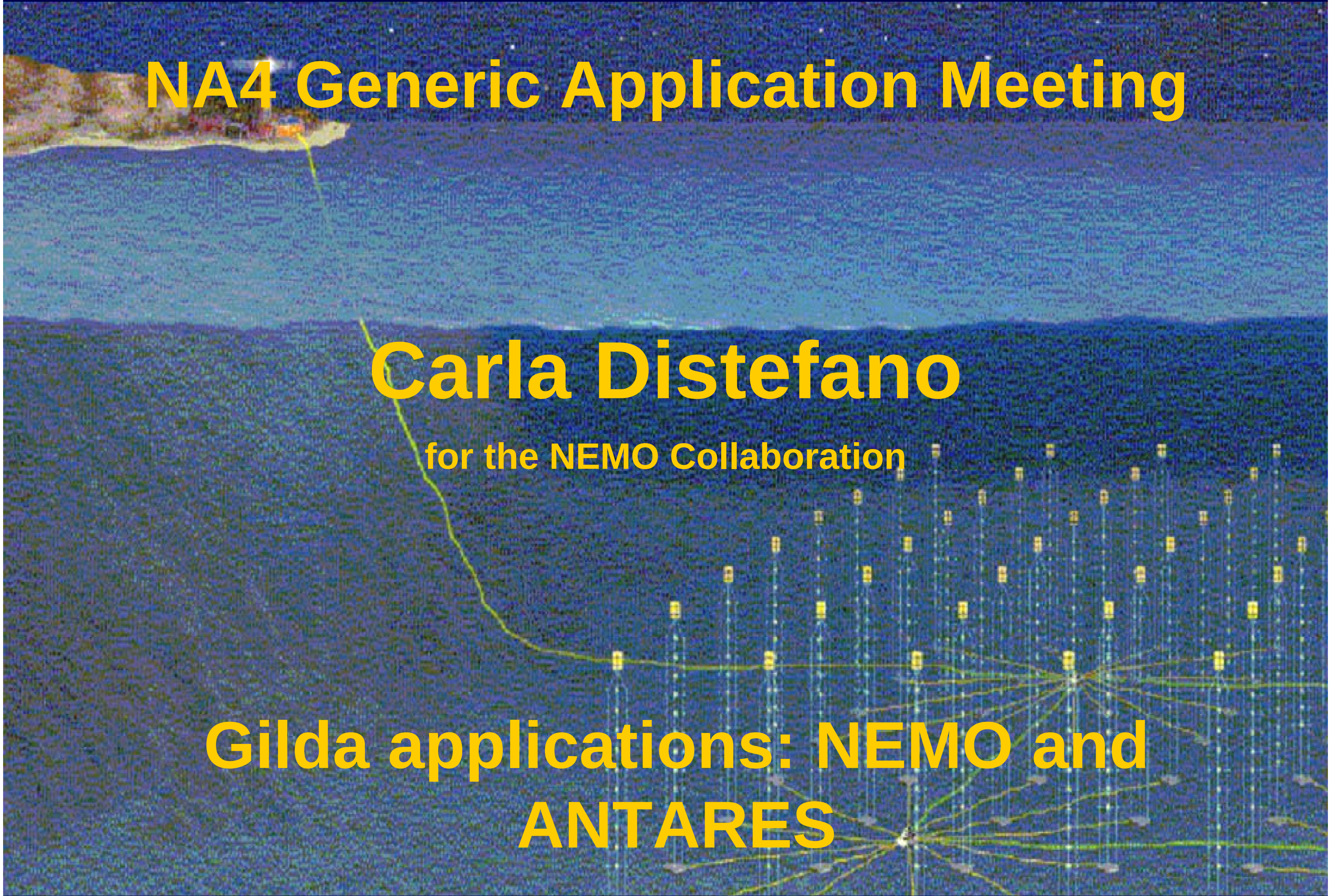


NA4 Generic Application Meeting

Carla Distefano

for the NEMO Collaboration

Gilda applications: NEMO and ANTARES

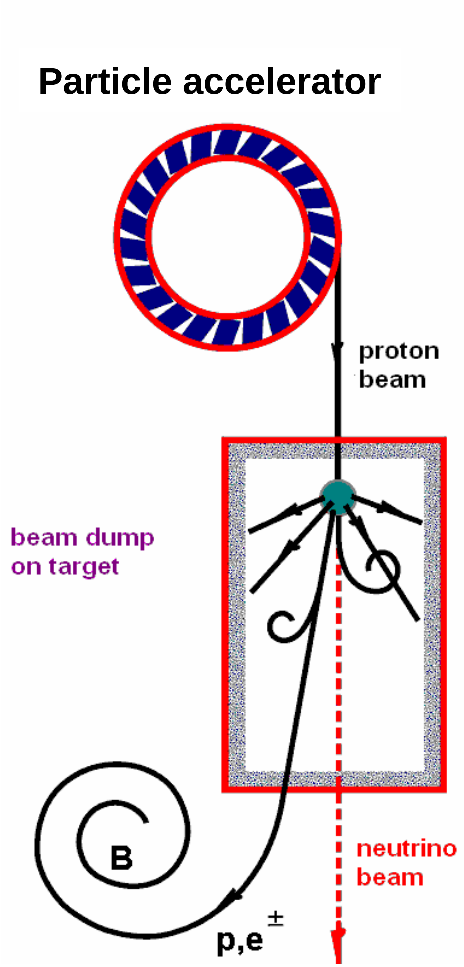
Why neutrino astronomy?

The detection of high energy cosmic rays (up to 10^{20} eV) are milestones in modern astrophysics but there are still several open questions:

- **Particle acceleration mechanism in astrophysical sources**
- **Identification of high energy CR sources**
- **Solution of UHECR puzzle**

- **Neutrinos traverse space without being deflected or attenuated**
  - **They point back to their sources**
  - **They allow to view into dense environments**
- **Neutrinos are produced in high energy hadronic processes**
  - **They can allow distinction between hadronic and leptonic acceleration mechanisms**

Halzen



Proton acceleration

- Fermi mechanism

proton spectrum $dN_p/dE \sim E^{-2}$

Neutrino production

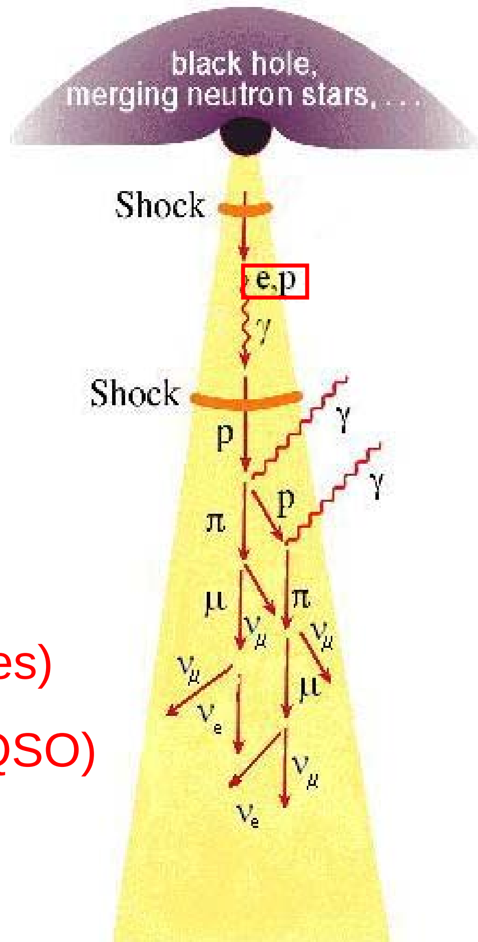
- Proton interactions

p → p (SNR,X-Ray Binaries)

p → γ (AGN, GRB, microQSO)

- decay of pions and muons

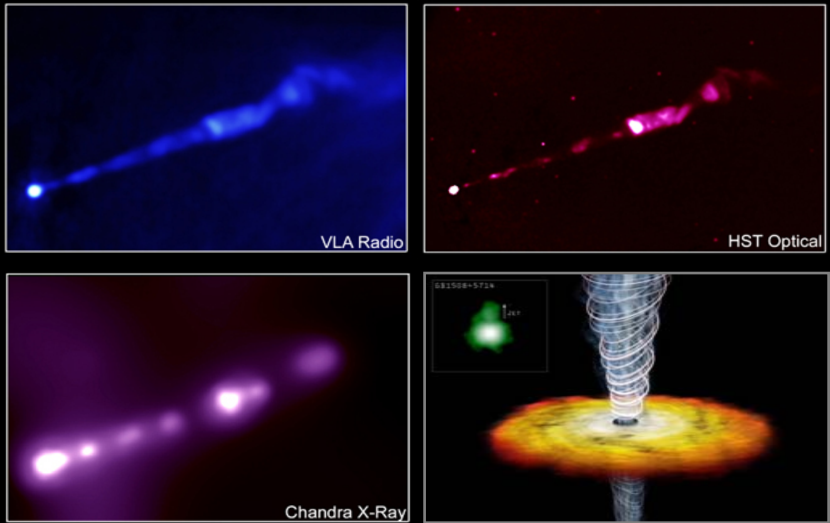
Astrophysical jet



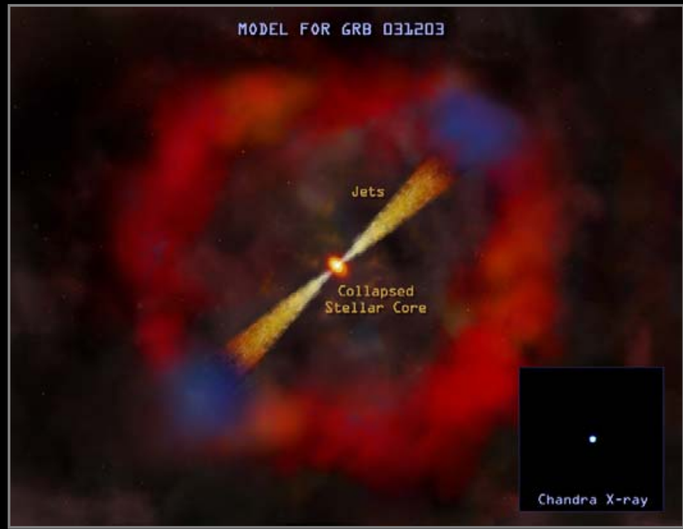
Electrons are responsible for lower energy gamma fluxes (synchrotron, IC)

Candidate sources of UHE (> TeV) neutrinos

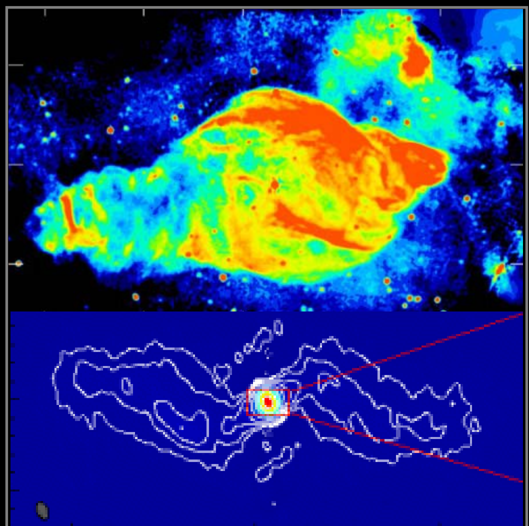
Jets and cores of Active Galactic Nuclei



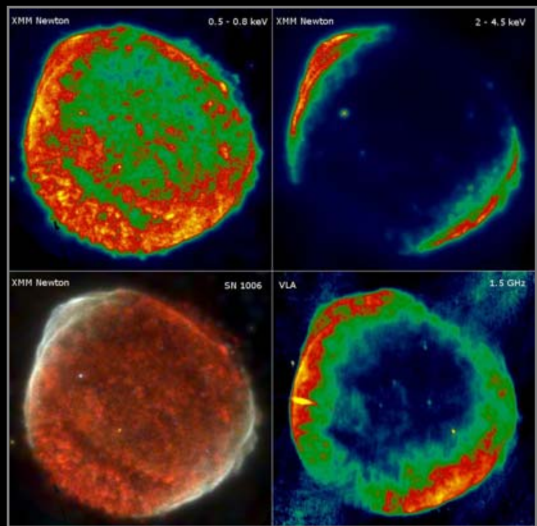
Gamma Ray Bursts



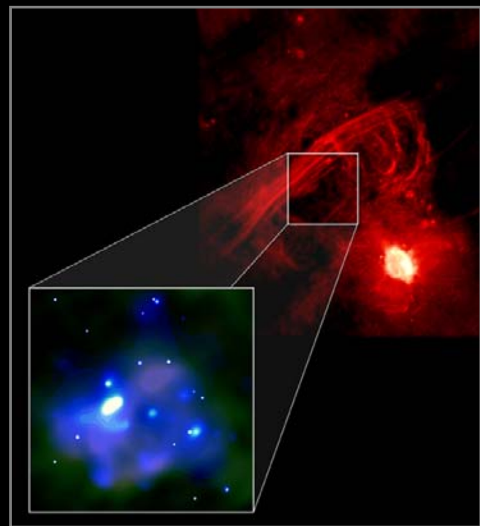
Galactic Microquasars



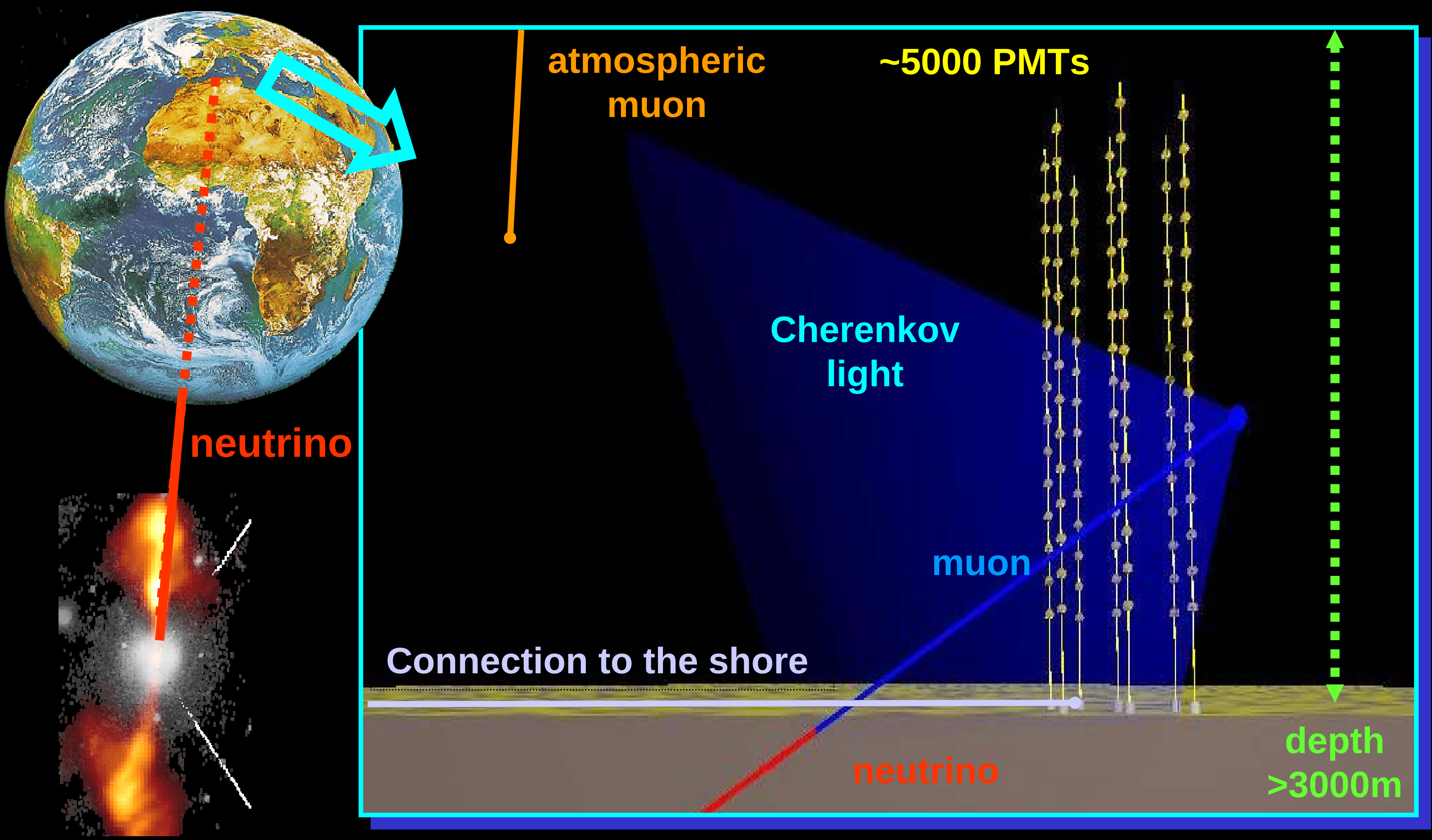
Galactic SuperNova Remnants



Galactic Centre



The observation of TeV neutrino fluxes require km³ scale detectors



Neutrino telescopes brief history

80’s: DUMAND R&D

90’s: BAIKAL, AMANDA, NESTOR

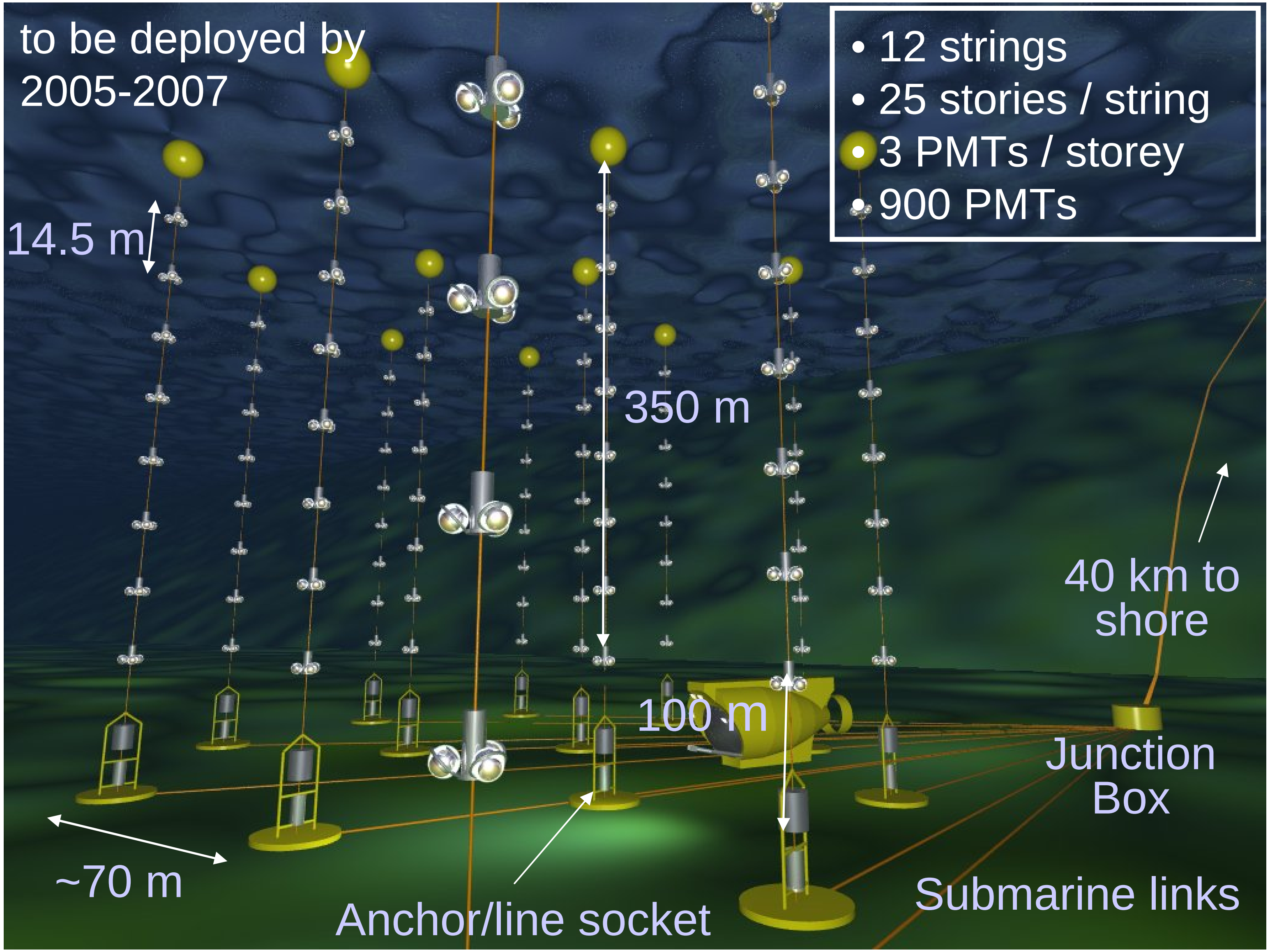
2k’s: ANTARES, NEMO R&D

2010: IceCube

Mediterranean KM3 ...

ANTARES

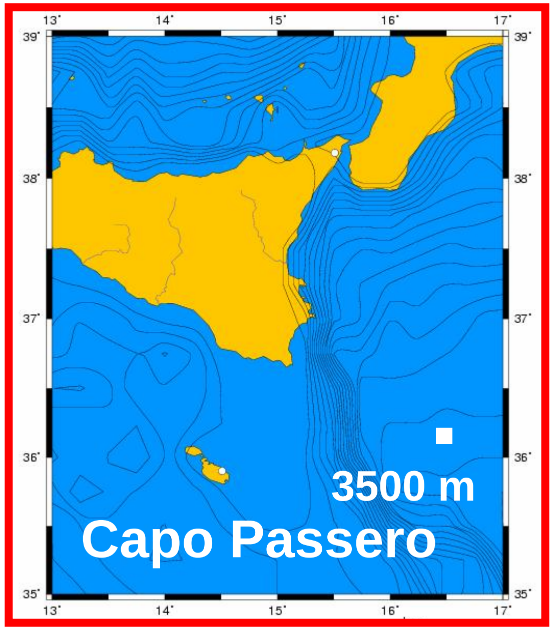
ANTARES is installing a 0.1 km² demonstrator detector close to Toulon at D=2400 m.

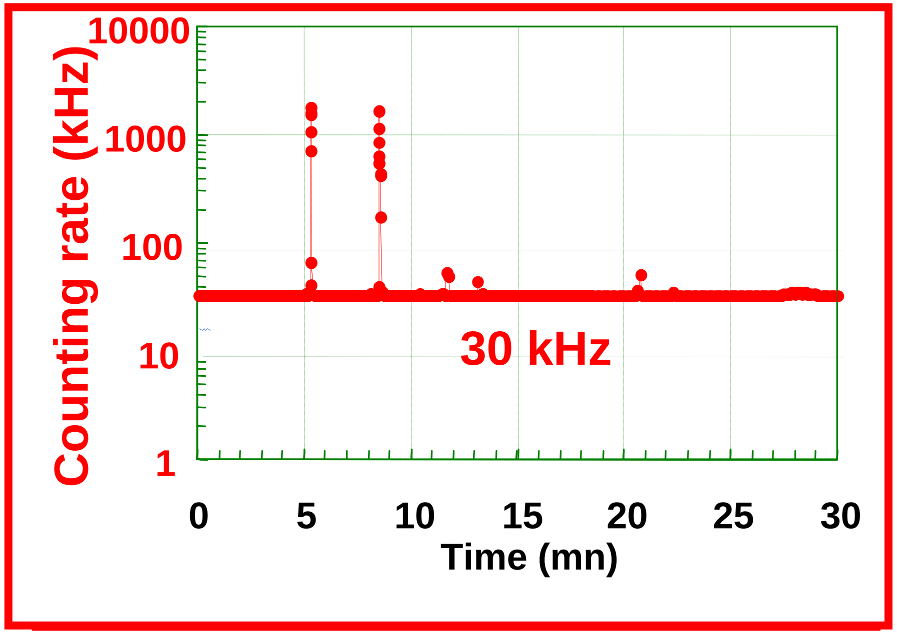


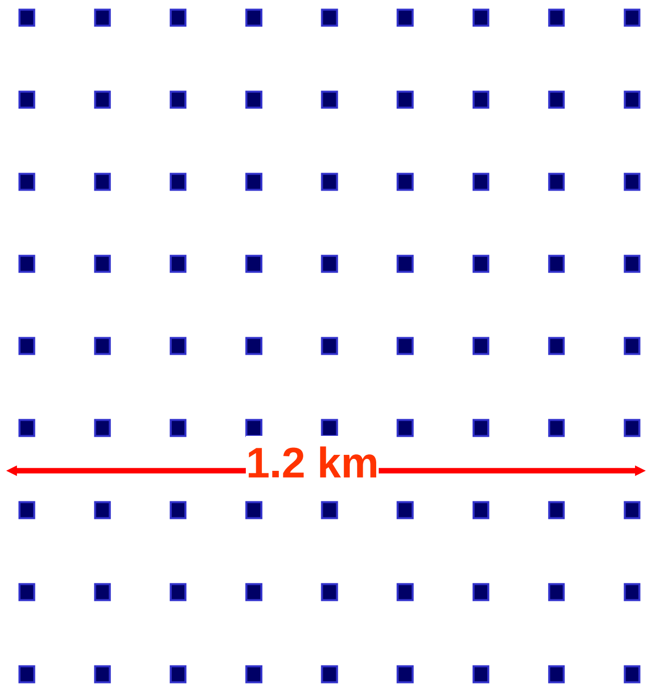
ANTARES deployed Line0 and Milom, underwater connection Apr. 2005.

The NEMO Collaboration is dedicating special efforts to:

- **search, characterization and monitoring of a deep sea site adequate for the installation of the Mediterranean km^3.**
- **development of technologies for the km^3 (technical solutions chosen by small scale demostrators are not directly scalable to a km^3)**





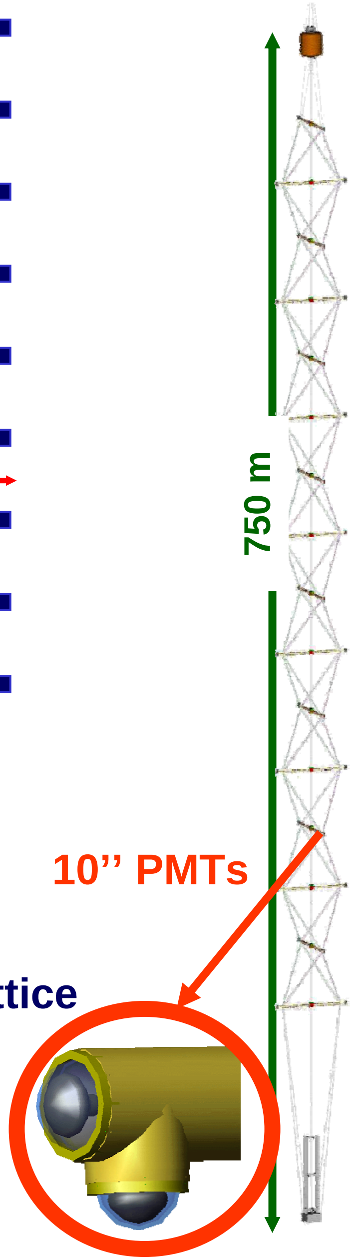


Proposed NEMO detector :

5000: 6000 PMTs

80:100 towers arranged in a lattice

~140 m between towers



The NEMO km3 architecture is based on the NEMO-tower module.

The tower is a semi-rigid 3D structure designed to allow easy deployment and recovery.

High local PMT density is designed to perform local trigger.

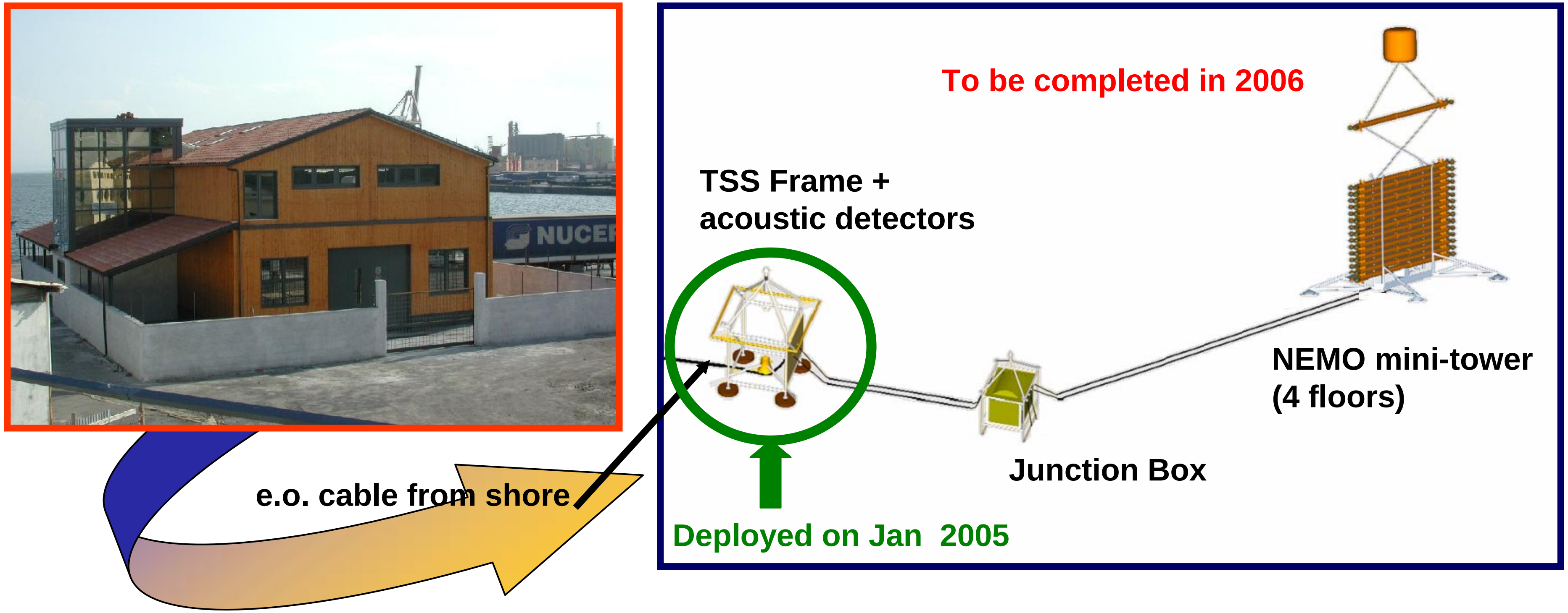
Height:	
compacted	15:20 m
total	750 m
instrumented	600 m
n. beams	16 to 20
n. PMT	64 to 80
Beams:	
length	20m
spacing	40 m

The NEMO test site in Catania: phase 1

The NEMO Collaboration is undergoing the Phase 1 of the project, installing a fully equipped Deep-Sea facility to test prototypes and develop new technologies for the detector.

Shore laboratory port of Catania

Underwater test site: 25 km E offshore Catania at 2000 m depth



An electro-optical cable (10 fibres, 4 conductors) was deployed on 2001. It connects the shore laboratory, in the Port of Catania, with the underwater test site

Present goals of Monte Carlo simulations

ANTARES:

Study detector response to neutrino fluxes

Optimization of analysis procedures (noise rejection,…)

NEMO:

Find the most efficient displacement of PMTs

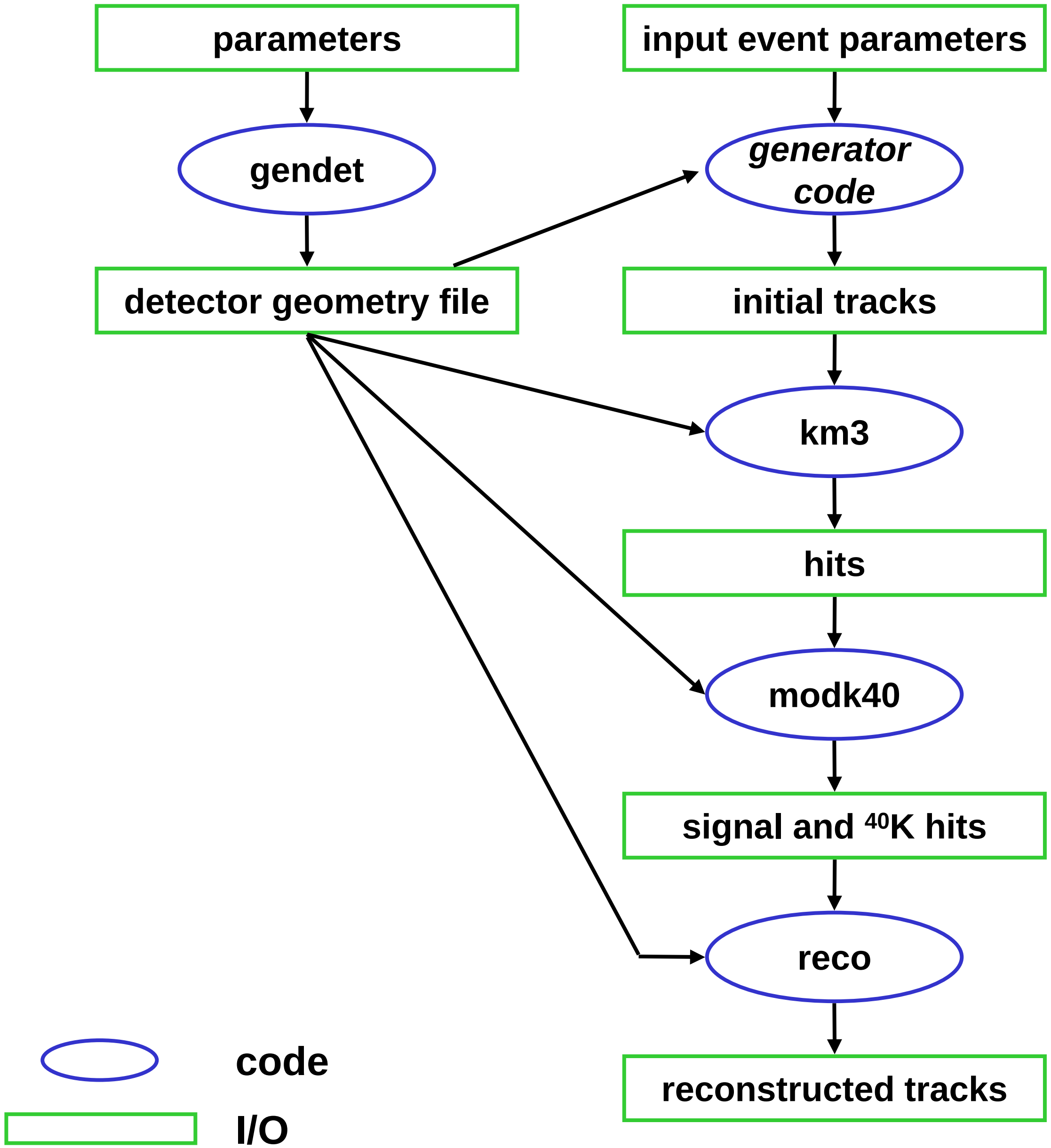
(effective area > 1 km^2 and angular resolution ~0.1°)

taking into account technological constraints

(mechanics, deployment, electronics)

... and budget !

ANTARES Monte Carlo Simulation Tools



event generator:

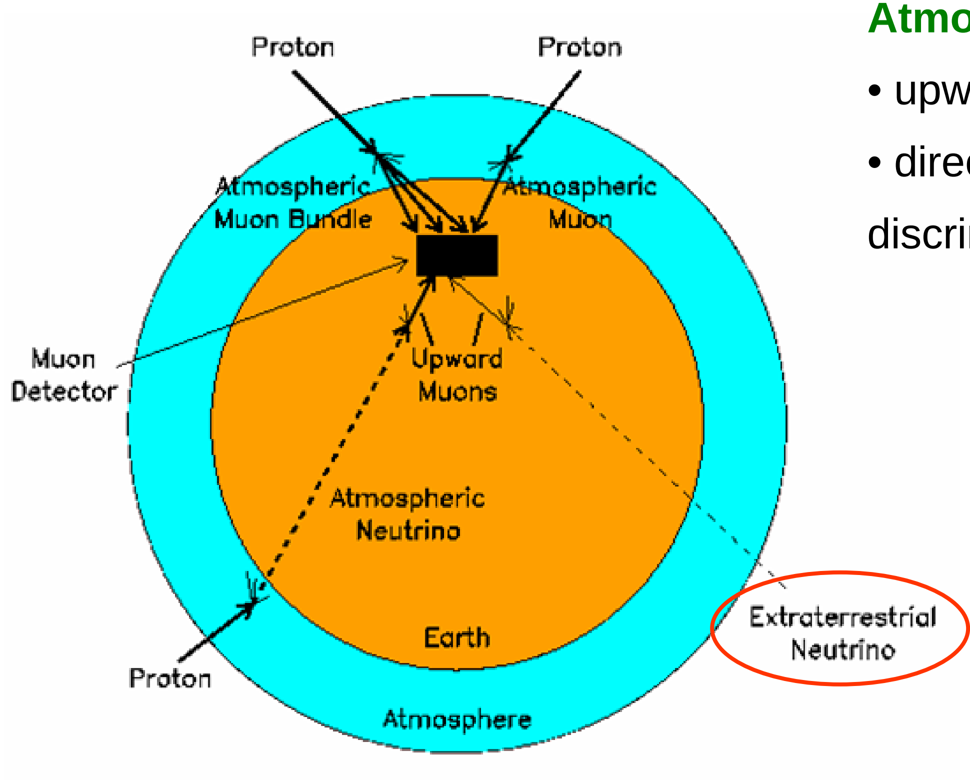
astrophysical signal

atmospheric bkg

muon propagation and light simulation

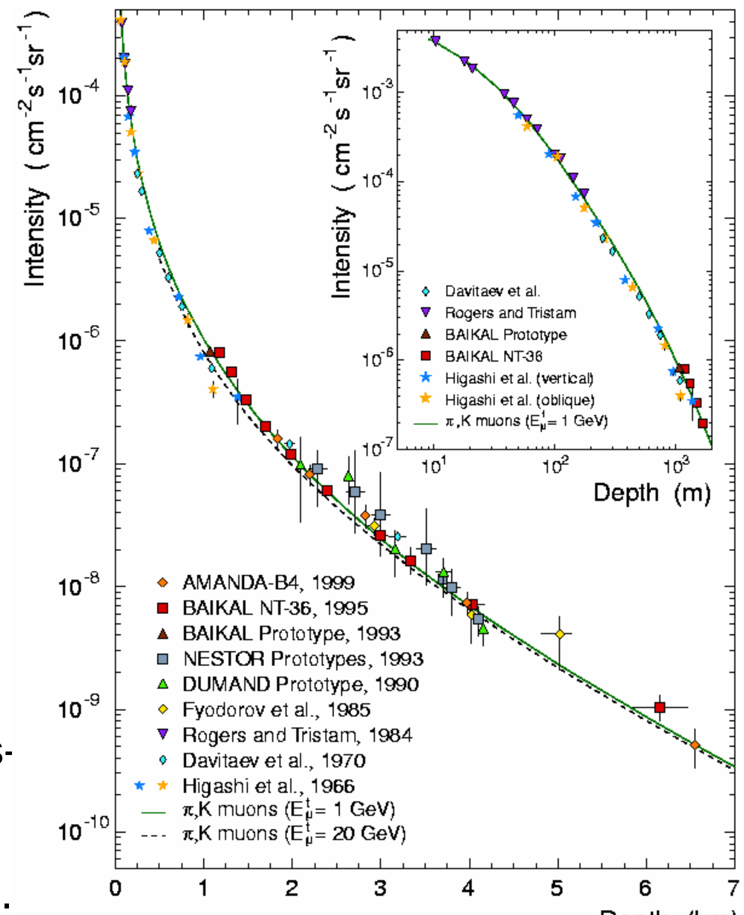
noise and electronics simulation

track reconstruction



Atmospheric neutrinos:

- upward tracks are good neutrino candidates;
- direction and energy criteria can be used to discriminate background from astrophysical signals.



Bugaev, E.V., 1998, Phys. ReV., D58, 054001.

Atmospheric muons:

- installation at Depth > 3000 m
- ***downward looking telescope*** but background due to mis-reconstructed muons;
- rejection of atmospheric muons background: ***quality cuts***.

Simulation of muon background

- **Background due to atmospheric muon flux is several orders of magnitude larger than the expected signal.**

- **We need to optimize reconstruction algorithms in order to minimize the number of mis-reconstructed tracks (up-going tracks).**

- **These algorithms have to be tested and applied on a muon sample as large as the expected one in 1 year (mass production), simulation of multi muon events with complete simultation are also mandatory.**

- **The NEMO and ANTARES Collaborations have chosen to use the CORSIKA and MUSIC codes to simulate the muon background reaching the detector.**

Official CORSIKA page http:://www-ik.fzk.de/corsika/
MUSIC: Antonioli et al, 1997, Astrop. Phys. 7, 375.

Mass production of atmospheric muons with *CORSIKA*

CORSIKA **is a program for detailed simulation of extensive air showers initiated by high energy cosmic ray particles:**

- **the particles are tracked through the atmosphere until they undergo reactions with the air nuclei or decay;**
- **atmospheric muons reaching the sea level are written in the output file.**

Mass production of Corsika events is conducted jointly by NEMO and ANTARES

Muons are then propagated in sea water up to the detectors (MUSIC):

the number of muons reaching the detectors depends on their geometrical surfaces and on site depth (muon energy loss in sea water)

ANTARES

A_{geom}~0.1 km^2

D=2400 m

NEMO

A_{geom}~ km^2

D=3500 m

Hardware tools for mass production

Atmospheric muons mass production requires intensive use of CPU and storage.

→ NEMO Collaboration decided to use GRID

First Step: GILDA-CT

GILDA is an excellent tutorial for GRID.
Easy access to the CPU resources (and less burocracy!)
Close interaction with GILDA team

Second Step: GRID

Mass Production requires a larger number of CPUs with fast processors

Open Problems

- Monte Carlo simulations with a sufficient number of events (10^6 primaries) require large CPU Time → job CPU time limit 48 h in GRID. CPU time limits depend on CPU speed. We need to require the attribute:

  GlueHostProcessorClockSpeed>1800

  This attribute is not published in some CEs.

- The migration to VOMS led problems due to the short (default 12 h) duration of the VOMS credential: see talk of E. Giorgio.

- A crash error is often

  LRC endpoint not found
  RMC endpoint not found

  The Local Replica Catalog end point not published by the CE
  The Replica Metadata Catalog end point not published by the CE

- Job crash: sometimes it is not clear or understood → poor diagnostics (at least for us!)

Running CORSIKA in the GRID:

- ***CORSIKA* compiled and linked in "USER INTERFACE" on GRID-CT**
- **Produce a script for launching the code**
- **Produce the jdl file for a specific run**

The Corsika JDL script: corsika_0.jdl

```
Type = "Job";
JobType = "Normal";

Executable = "run-corsika.sh" ;

StdOutput  = "std.out";
StdError   = "std.err";

Requirements = (other.GlueCEPolicyMaxCPUTime>2800)&&(other.GlueHostProcessorClockSpeed>1800);
RetryCount = 2;

MyProxyServer = "grid014.ct.infn.it";

InputSandbox = {"run-corsika.sh", "corsika.exe", "EGSDAT4_.05", "EGSDAT4_.15",
                "EGSDAT4_.4", "EGSDAT4_1.", "EGSDAT4_3.", EGSDAT4_.25", "NUCNUCCS",
                "SECTNU", "QGSDAT01", "inputs_h2_0"};

OutputSandbox = {"std.out","std.err","corsika_p_h2_0.log"};

OutputData = {
        [
                OutputFile = "corsika_p_h2_0.evt.gz";
                LogicalFileName = "lfn:p_h2_0.out";
                StorageElement = "grid005.ct.infn.it";
        ]
};
```

Running CORSIKA in the GRID:

- *CORSIKA* compiled and linked in "USER INTERFACE" on GRID-CT
- Produce a script for launching the code
- Produce the jdl file for a specific run
- Submit the jdl file using VO GRIDIT (edg-job-submit)

```
edg-job-submit --config CT.conf --config-vo CT-vo.conf -o job_run.name corsika.jdl
```

- Status inquire (edg-job-status)
- Job retrieving (edg-job-get-output)
- Download the output file from SE (~200 MB zipped file)

```
lcg-cp  --vo gridit lfn:p_h2_0.out file:corsika_p_h2_0.evt.gz
```

Used CPU times on GRID

- Tutorial on GILDA (October 2004)
- Mass production on INFN-GRID (since March 2005)

GRID Italia

CPU time for the statistics already collected in Catania:

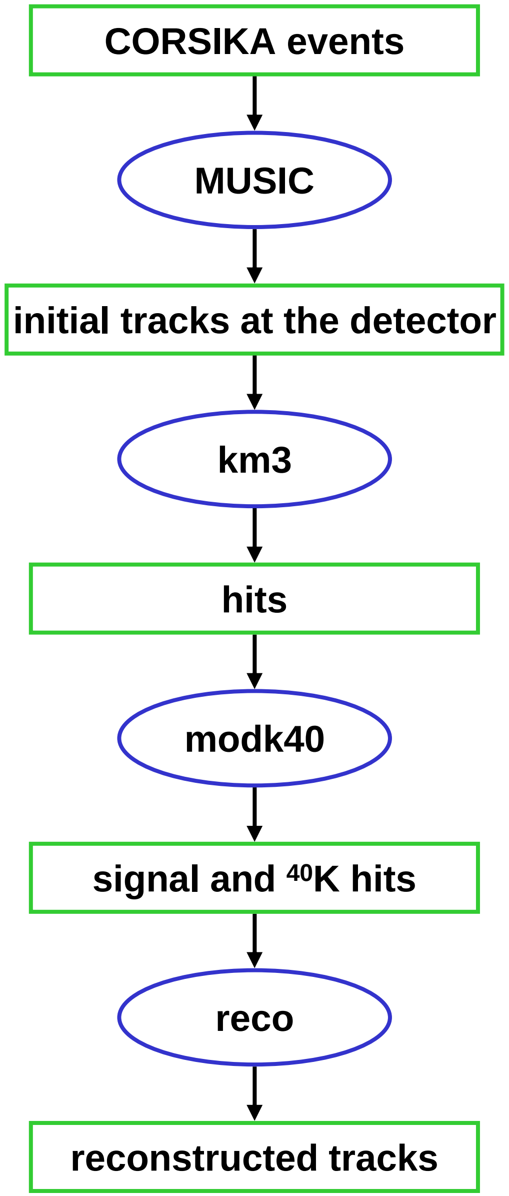
~ 6 years

Disk space for the statistics already collected in Catania:

~ 220 GB (zipped files)

Future applications on the GRID

- We would like to run the whole simulation chain on the GRID.
- Many codes linked with several libraries and that handle big I/O files (~ 1 GB).
- Codes are already compiled and a trial job was successful run.



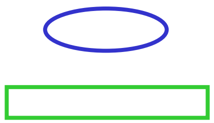
atm. muon events at the sealevel

muon propagation up to the detector

muon propagation and light simulation

noise and electronics simulation

track reconstruction



code

I/O

Summary and Outlook

- Simulation of neutrino telescope response requires a mass production of atmospheric muon background events;

- ANTARES and NEMO are jointly conducting a mass production of Corsika events → since March 2005, the NEMO Collaboration uses GRID for mass production;

- The next step is to implement the whole simulation chain in GRID → many different programs linked with several libraries and with big file to handle. The first attempt has been successful;

- At the LNS in Catania, a new GRID CE and SE will be soon available.

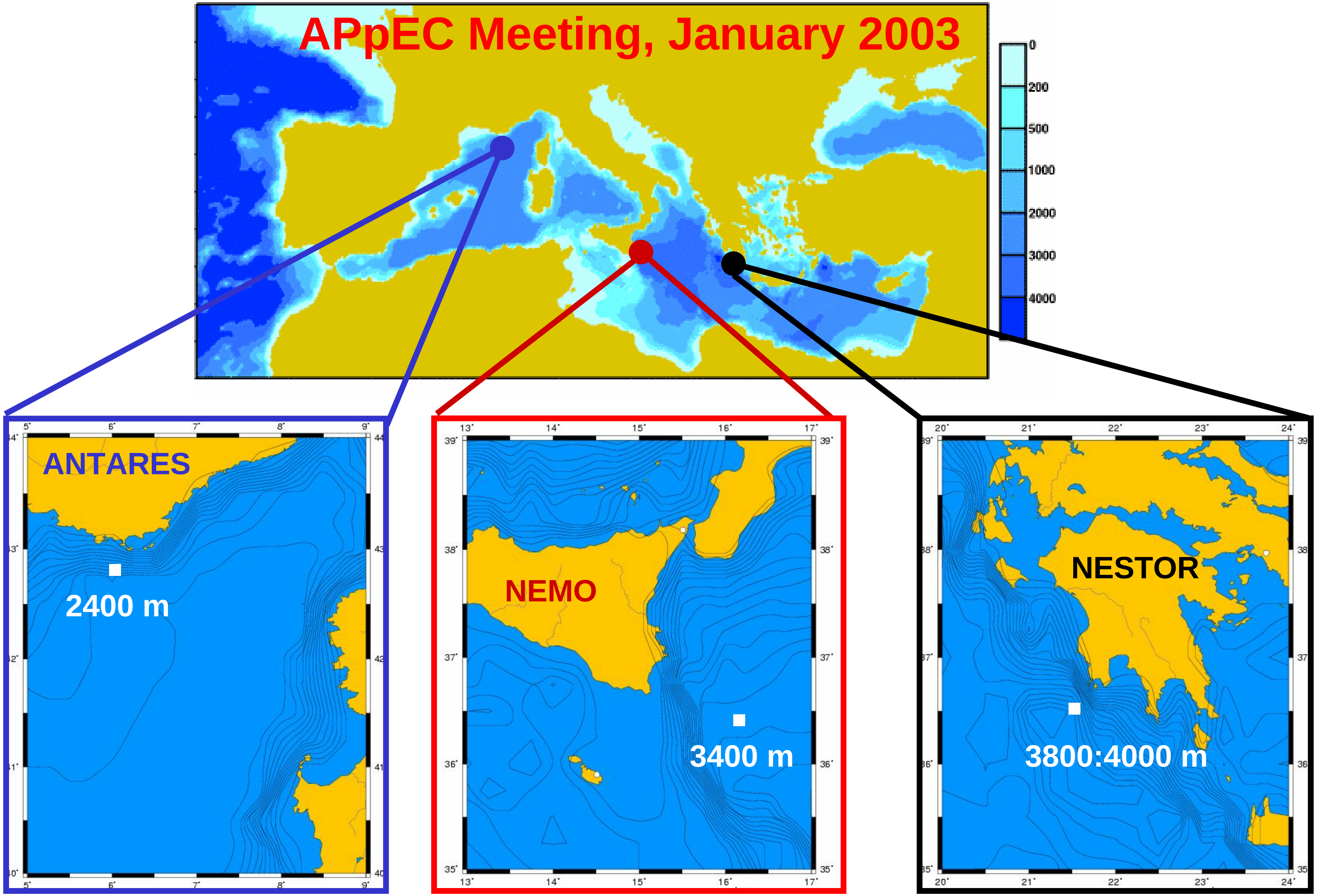
Generation of atmospheric muons with CORSIKA

Corsika is a program for detailed simulation of extensive air showers initiated by high energy cosmic ray particles:

- **the particles are tracked through the atmosphere until they undergo reactions with the air nuclei or decay;**
- **atmospheric muons reaching the sea level are written in the output file.**

Simulation inputs:

- Primary ions -> p, He, N, Mg, Fe
- Primary energy -> 10-10^5 TeV/nucleone
- Primary zenith angles -> 0°÷ 85°
- Energy threshold for muons at sea level -> 0.5 TeV for ions between 0° and 60° and 1 TeV for ions between 60° and 85°
- Slope primary spectrum $\propto E^{-2}$


APpEC Meeting, January 2003
0
200
500
1000
2000
3000
4000
ANTARES
2400 m
NEMO
3400 m
NESTOR
3800:4000 m

CT-vo.conf

```
#
# This file /opt/edg/etc/alice/edg_wl_ui.conf is managed by LCFG. Do not modify!
#

[
VirtualOrganisation = "gridit";
NSAddresses = "grid014.ct.infn.it:7772";
LBAddresses = "grid014.ct.infn.it:9000";
]
```

CT.conf

```
#
# Autogenerated  by LCFG cliconfig component. Do not modify!
#

[
rank = - other.GlueCEStateEstimatedResponseTime;
requirements = other.GlueCEStateStatus == "Production";
RetryCount = 3;
ErrorStorage = "/tmp";
OutputStorage = "/tmp/jobOutput";
ListenerPort = 44000;
ListenerStorage = "/tmp";
LoggingTimeout = 30;
LoggingSyncTimeout = 30;
LoggingDestination = "grid014.ct.infn.it:9002";
# Default NS logger level is set to 0 (null)
# max value is 6 (very ugly)
NSLoggerLevel = 0;
DefaultLogInfoLevel = 0;
DefaultStatusLevel = 0;
DefaultVo = "atlas";
]
```

run-corsika_0.sh

```
#!/bin/bash

export ION=p
export range=h2

nrun=0

ln -s inputs_${range}_${nrun} inputs

chmod +x corsika.exe

time ./corsika.exe > corsika_${ION}_${range}_${nrun}.log

gzip corsika_${ION}_${range}_${nrun}.evt
```

submit-job.sh

```
#!/bin/bash

nrun=1
NLIMIT=10

export range=h2

while [ $nrun -le "$NLIMIT" ]
do

sed "s/160/16${nrun}/g" inputs_${range}_0 > temp1
sed "s/170/17${nrun}/g" temp1 > temp2
sed "s/180/18${nrun}/g" temp2 > temp3
sed "s/aaaa/${nrun}/g" temp3 > inputs_${range}_${nrun}


sed "s/nrun=0/nrun=${nrun}/g" run-corsika_0.sh > run-corsika.sh

sed "s/${range}_0/${range}_${nrun}/g" corsika_0.jdl > corsika.jdl

edg-job-submit --config CT.conf --config-vo CT-vo.conf -o job_run.name corsika.jdl


nrun=$(($nrun+1))
done
```

Results: present event statistics

INFN LNS

Primary	ϑ = 0°-60°			ϑ = 60°- 85°		
	1 - 10 TeV/nucleon **V1**	10 -100 TeV/nucleon **V2***	100-10^5 TeV/nucleon **V3****	1 - 10 TeV/nucleon **h1**	10 -100 TeV/nucleon **h2***	100-10^5 TeV/nucleon **h3****
p	10^8	10^9 (10^8)	10^8	10^8	10^9 (10^8)	10^8 (10^7)
He	10^8	10^8 (10^8) Done	10^8	10^8	10^8 (10^8) Done	10^8 (10^7)
N	10^8	10^8 (10^8) Done	5.10^6	10^8	10^8 (10^8) Done	5.10^6 (10^6)
Mg	10^8	10^8 (10^8) Done	3.10^6	10^8	10^8 (10^8) Done	3.10^6 (10^6)
Fe	10^8	$3\ 10^7$ (3.10^7) Done	10^6	10^8	$3\ 10^7$ (3.10^7) Done	10^6 (10^6)

* NEMO in charge for production

** ANTARES in charge for production

Running CORSIKA in the GRID:

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```

- **Status inquire (edg-job-status)**

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```