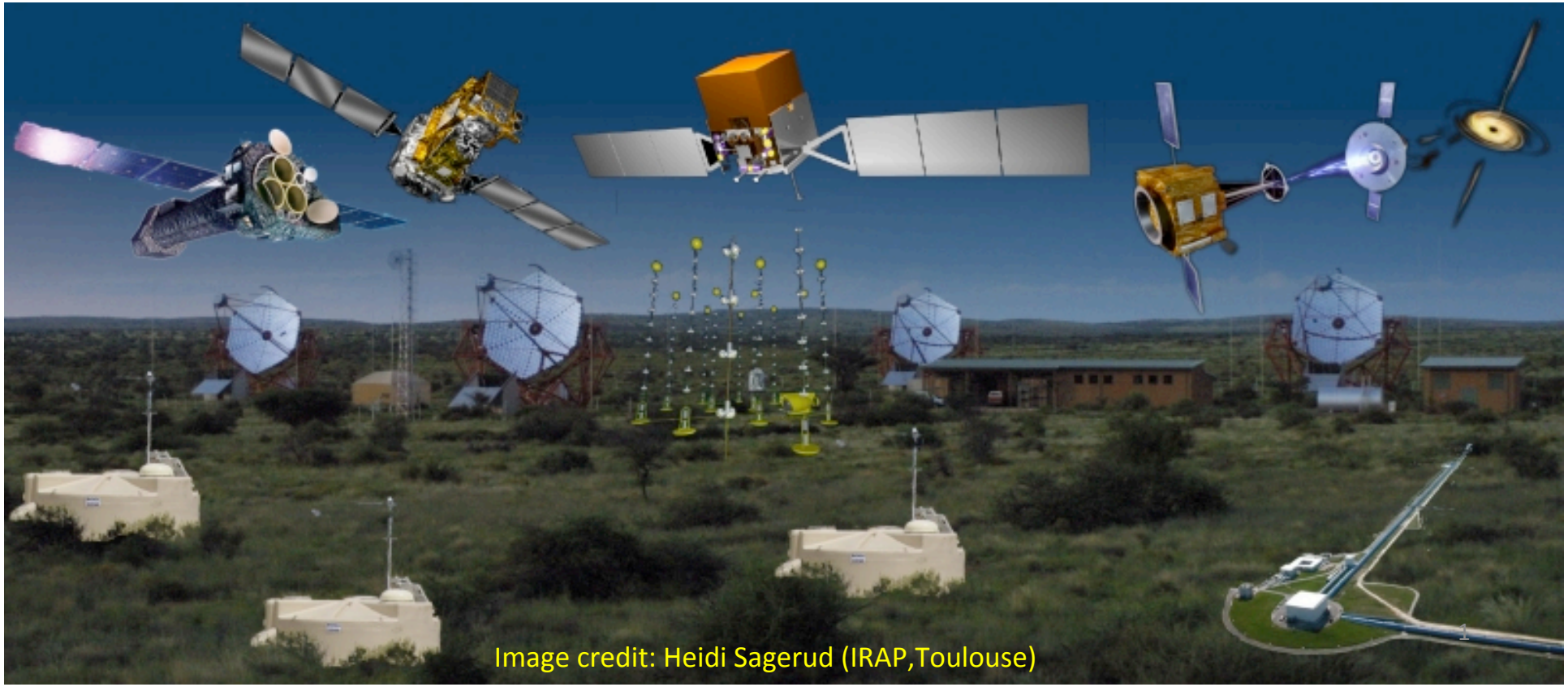
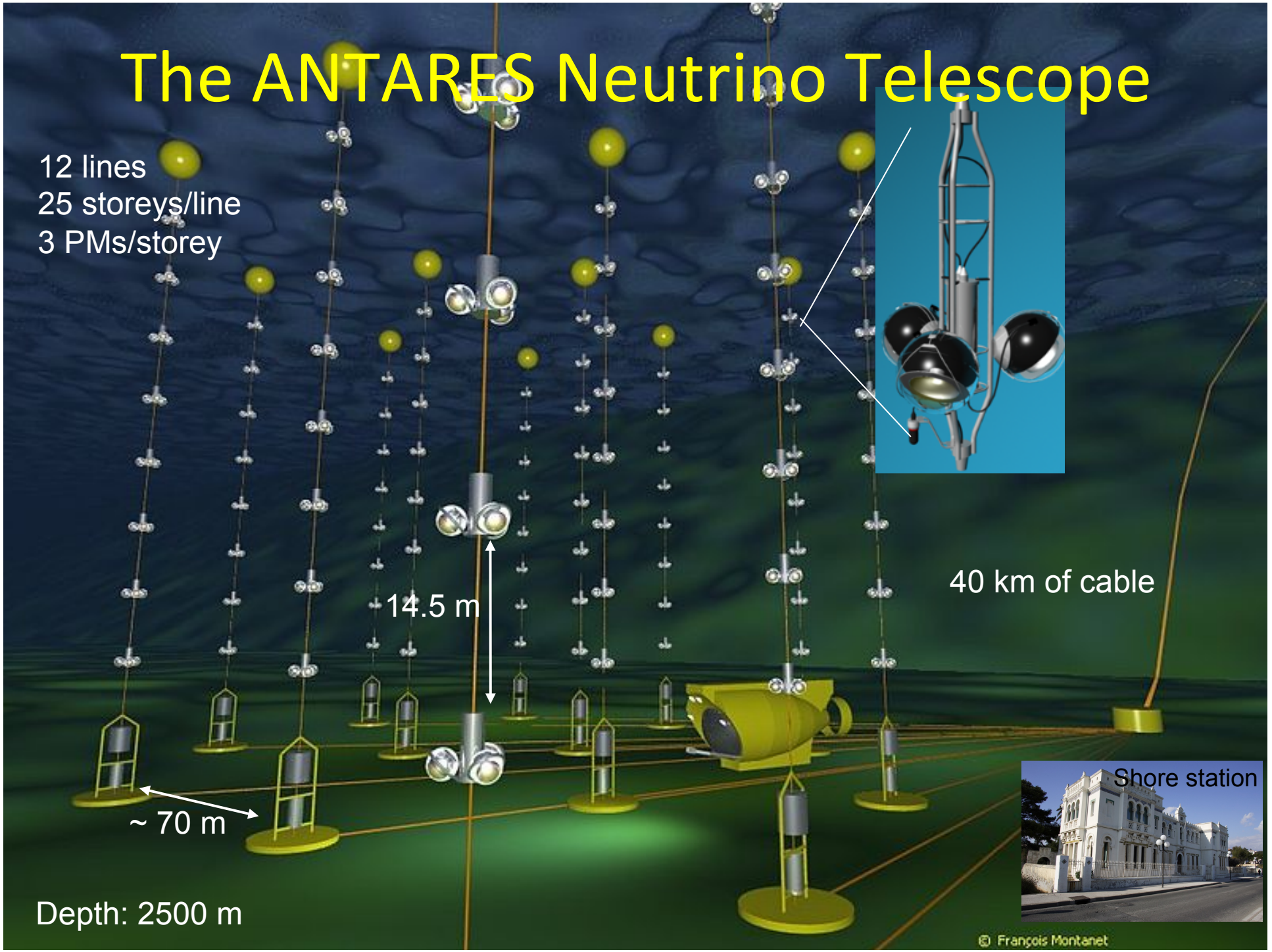
ANTARES/KM3Net
Neutrino Alert System

Jürgen Brunner

CPPM

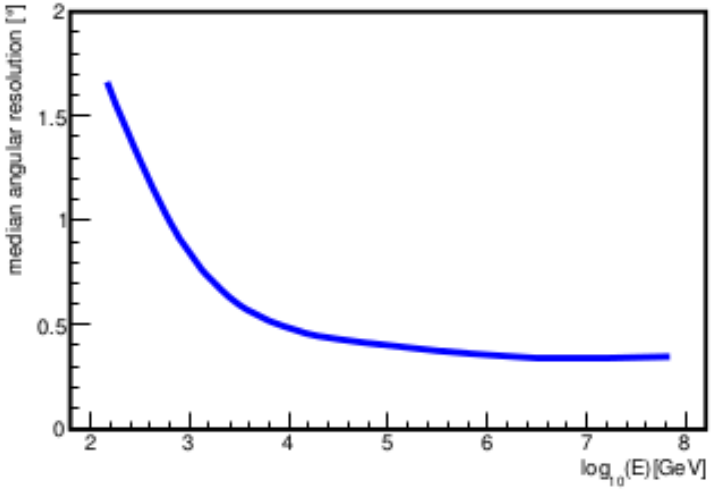


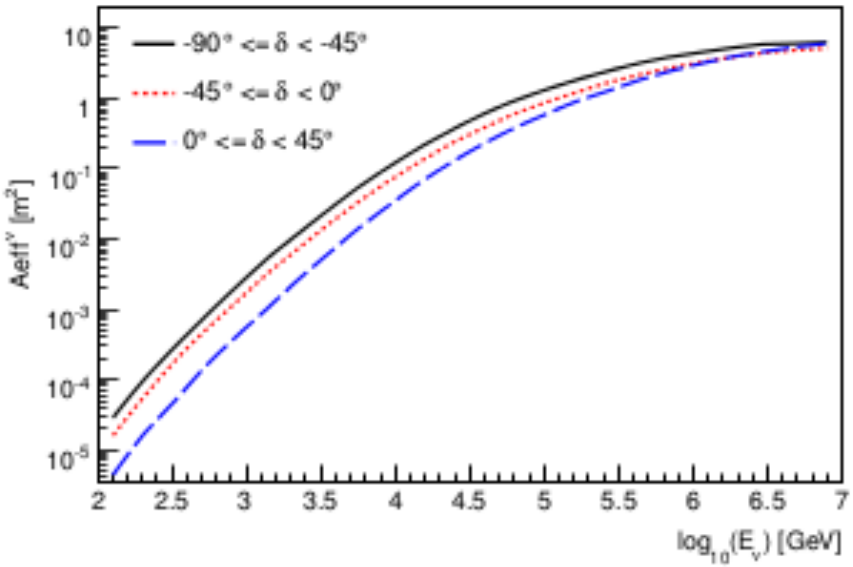
The ANTARES Neutrino Telescope

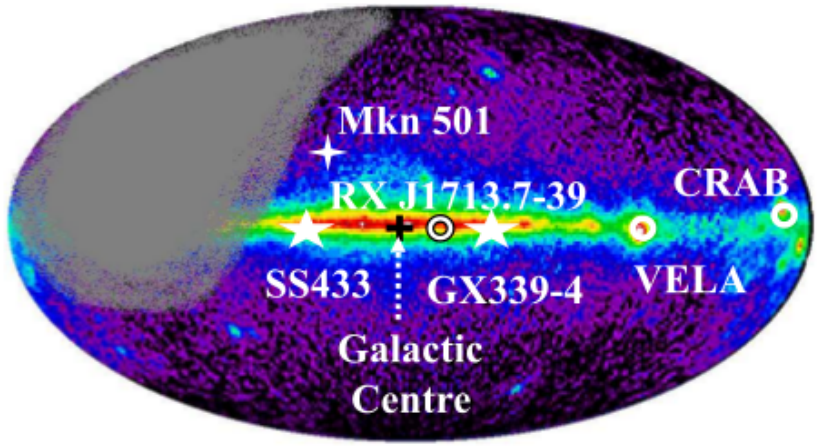


ANTARES performance

- 12-lines data taking since 2008
- ~ 10000 neutrinos
- Angular resolution: 0.3 – 0.4°
- Effective area: ~ 1m² (30 TeV)
- Visibility: ¾ of the sky, majority of the galactic plane
- Real-time data processing







KM3NeT

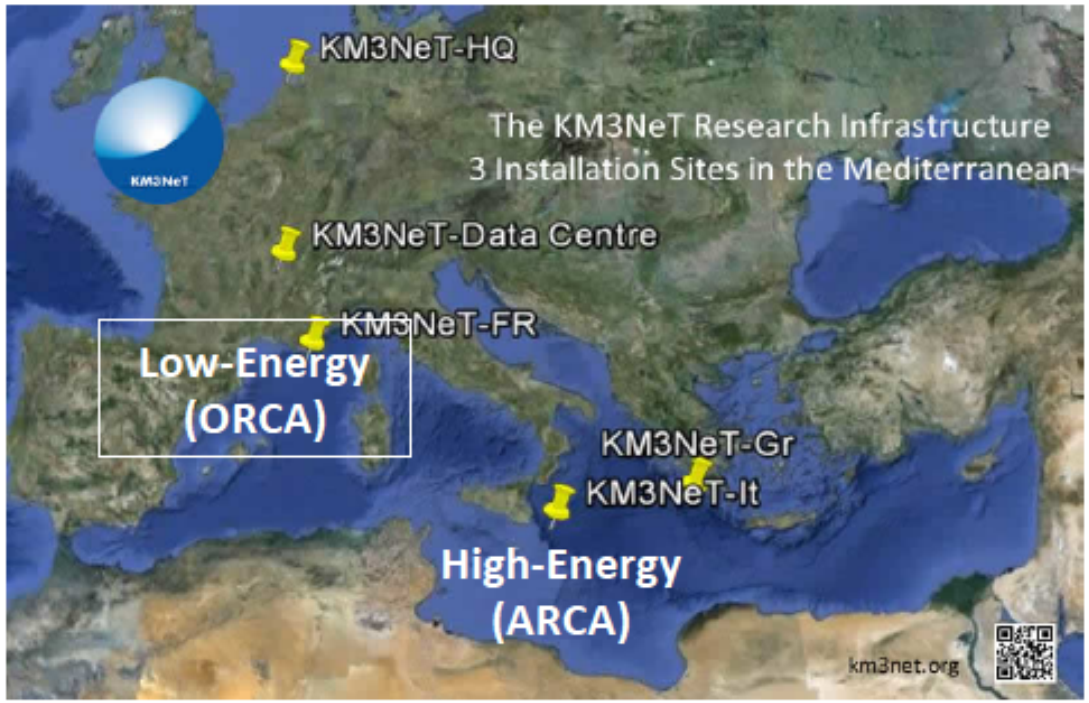
KM3NeT is a distributed research infrastructure with 3 main science topics:

- The origin of cosmic neutrinos (high energy)
- Measurement of fundamental neutrino properties (low energy)
- Deep Sea Observatory - Oceanography, bioacoustics, bioluminescence, seismology

Single Collaboration

Single Technology

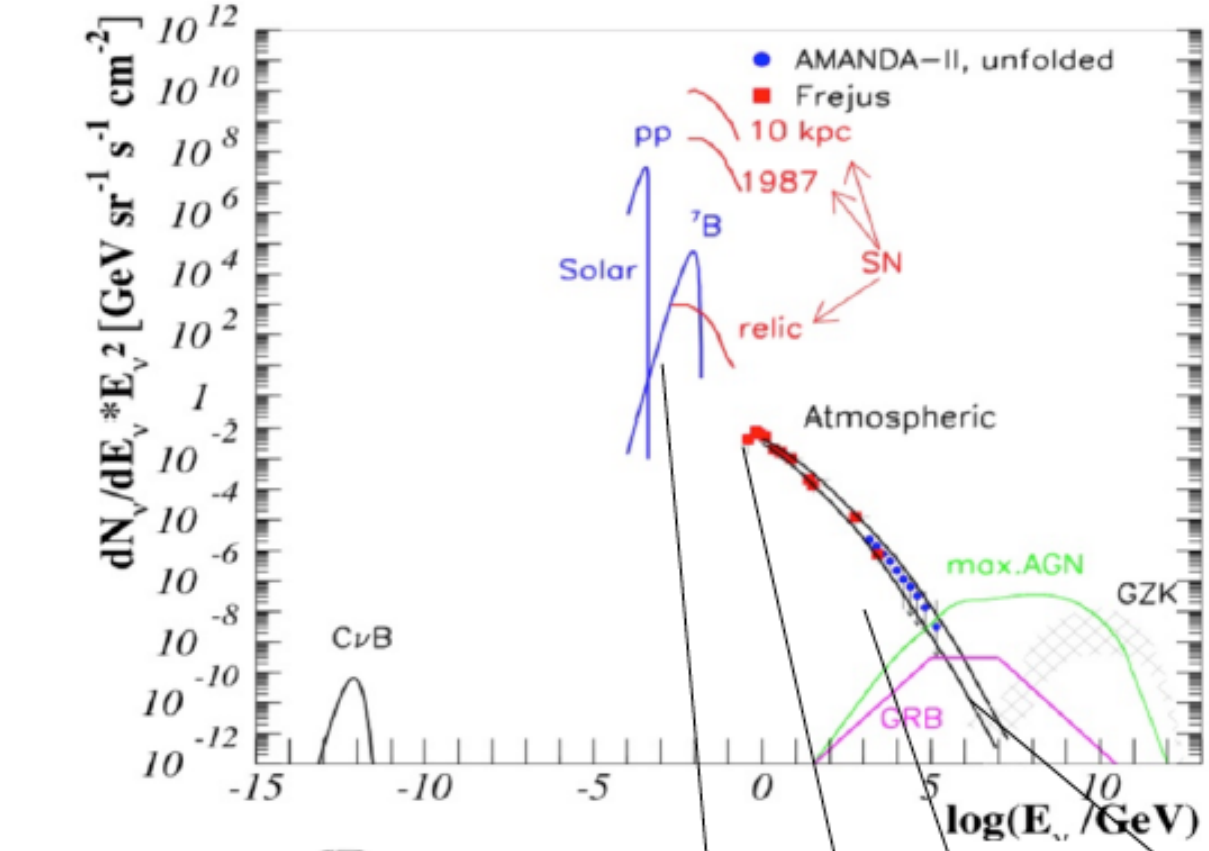
Single Management



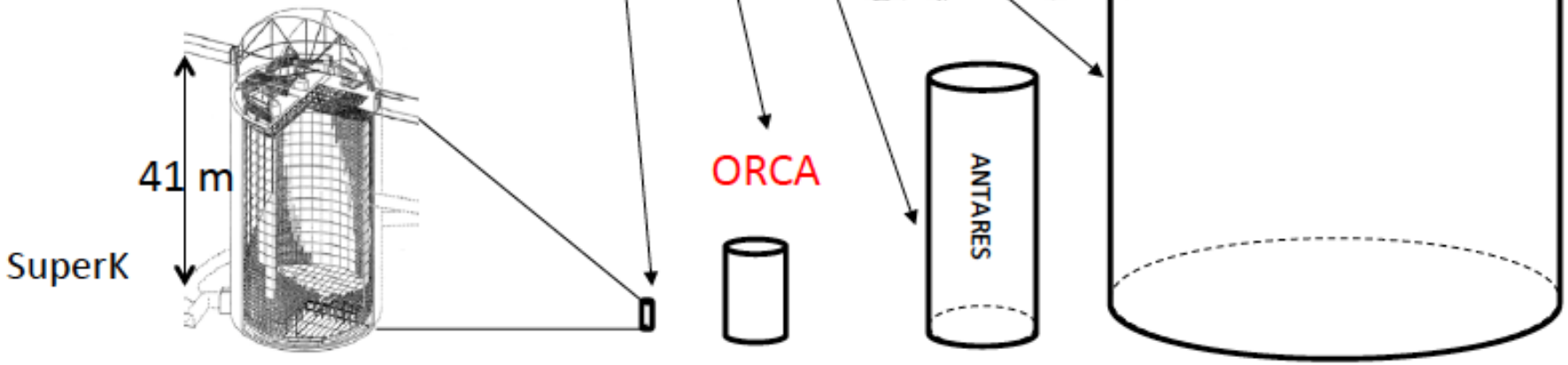
ARCA- Astroparticle Research with Cosmics in the Abyss

ORCA- Oscillation Research with Cosmics in the Abyss

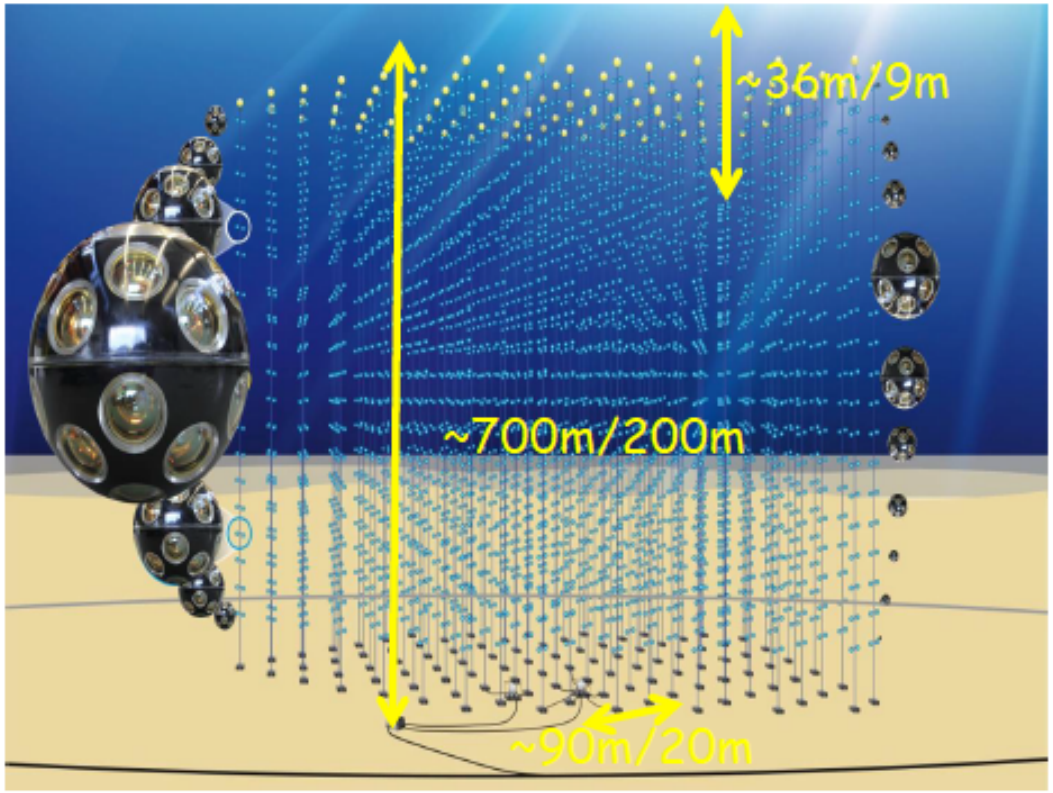
From MeV ν to PeV ν

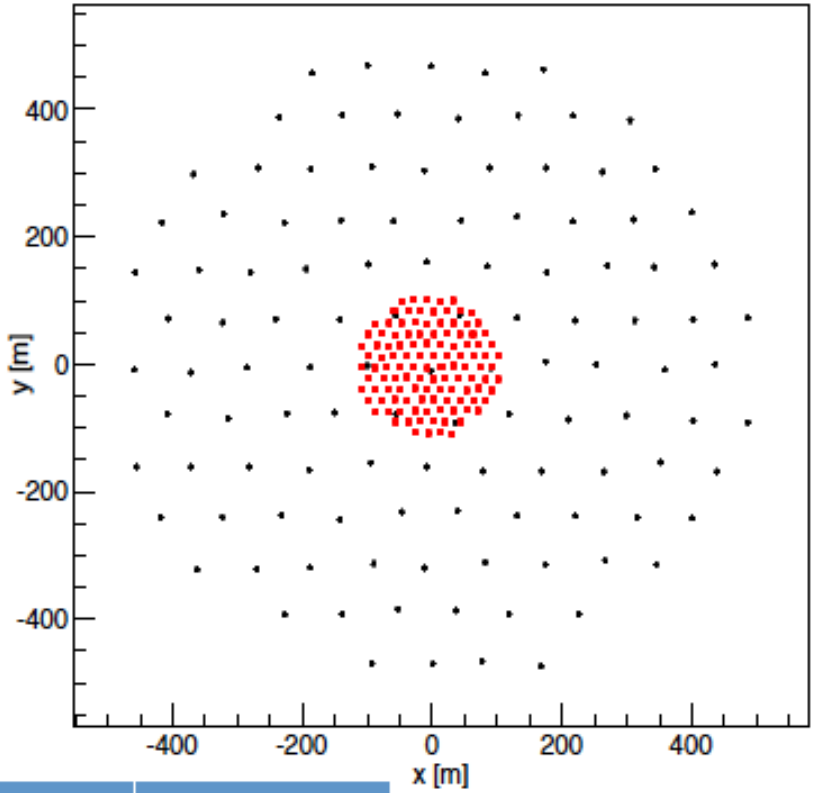


High energy neutrino:
Small cross-sections
Need large detectors
for wide energy range



KM3NeT Building Block (115 strings)





	ARCA	ORCA
Location	Italy	France
String distance (m)	90	20
DOM spacing (m)	36	9
Volume (MTon)	500	3.8

KM3NeT Timeline

KM3NeT Technical Design Report¶

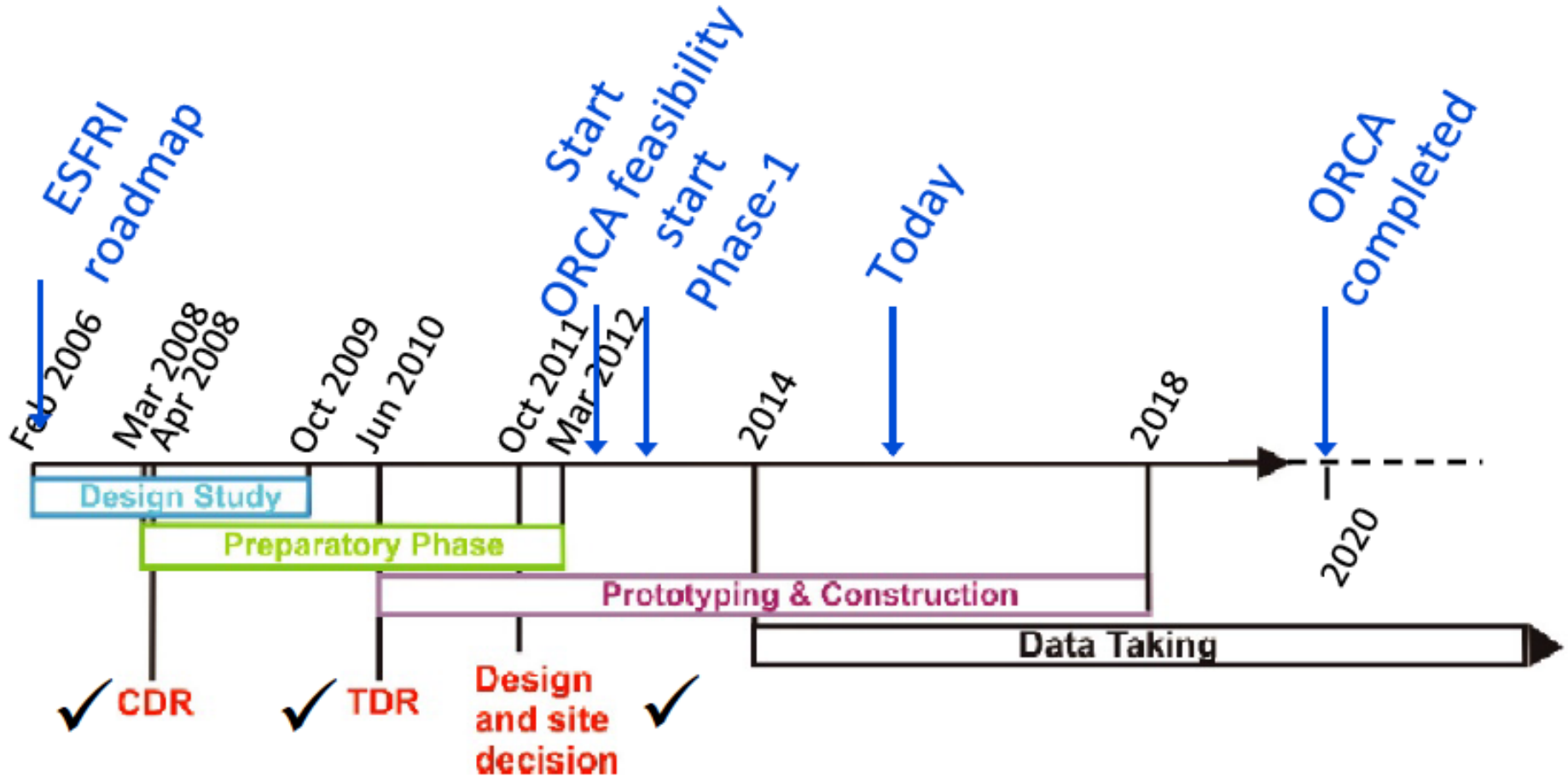
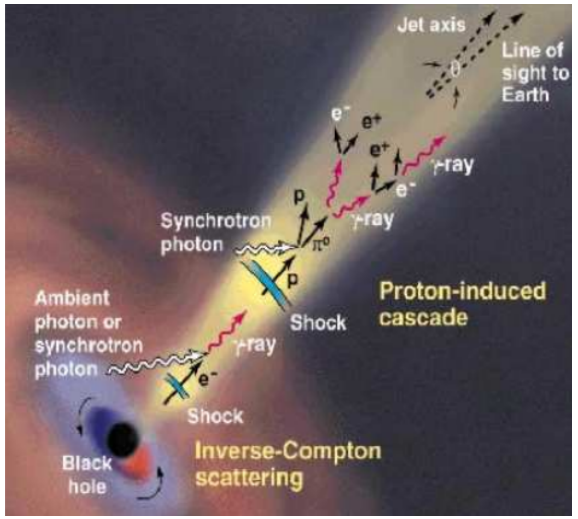


Figure 10-1: Overall time schedule of the KM3NeT project.

¶ Deliverable of EU-funded Design Study.

Why Neutrinos ?

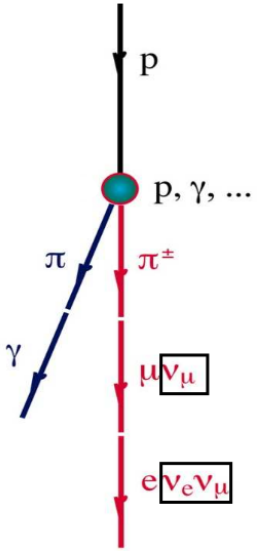
- Link between CR / γ / ν:
  - CRs and UHECRs origin?
  - Hadronic , leptonic or lepto-hadronic models?
  - Jet composition?



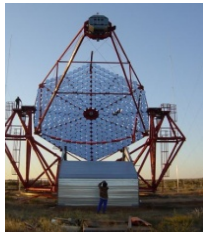
<u>Cosmic neutrinos</u>:

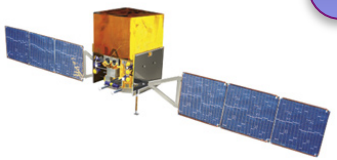
- Neutrinos possibly produced in the interaction of high energy nucleons with matter or radiation
- If **hadronic mechanisms**:

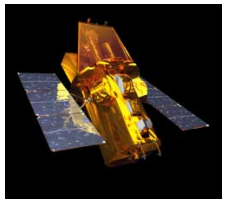
  Simultaneous emitters of neutrinos and photons
- Detection from a cosmic source would be a direct evidence of hadronic scenario



Multi-messenger programs online and offline







GeV-TeVγ-rays
Fermi / HESS…

UHECR
Auger

HE neutrinos

Optic / X-ray
TAROT,MASTER,
ROTSE / Swift,
ZADKO

Gravitational
Waves
Virgo / Ligo

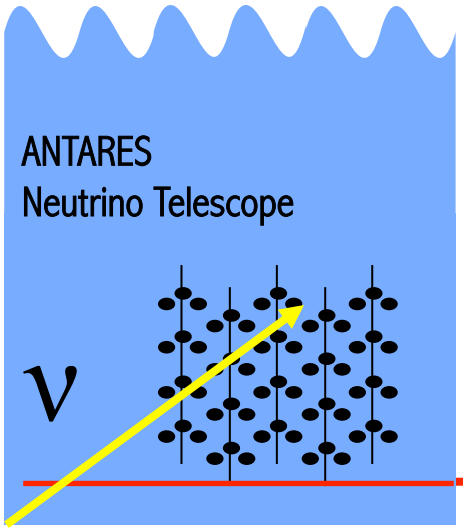
Real Time Alert Sending

Follow-up of the neutrino alerts
with optical telescopes
[TAROT, ZADKO, MASTER, PTF]
X-ray telescope
[Swift/XRT]
Gamma-Ray telescope
[HESS, VERITAS, MAGIC]

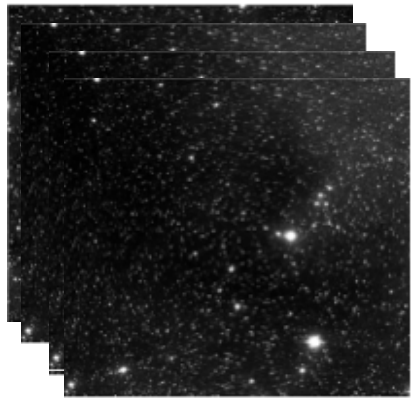
Antares Followup scheme

ANTARES Shore Station:
Trigger decision
On-line reconstruction
Alert message (GCN format)

4 types of triggers:
- doublet (0.04/yr)
- single HE (12/yr)
- single VHE (6/yr)
- single + loc galaxy directions (12/yr)



Real time



Optical images

FoV 1.9x1.9^0
Rmag < 18, 0.2m mirror
prompt observations

Astroparticle Physics 35 (2012) 530-536, arXiv:1103.4477

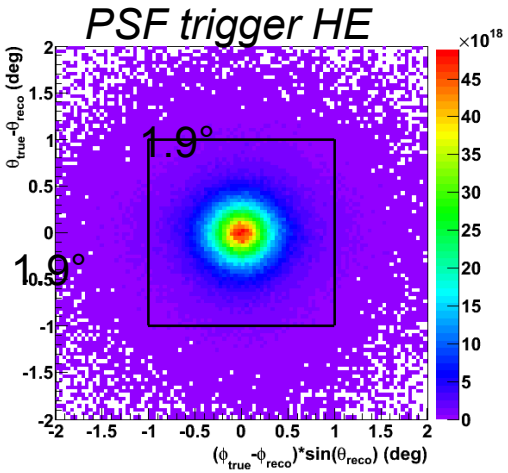
Alerts for Optical Followup

Online processing:

- Triggering & online reconstruction: ~3-5 s
- Alert transmission: ~1-10 s depending on the telescope response
- Telescope slewing: ~1-5 s

Minimum delay between the 1st image and the neutrino: ~20 s

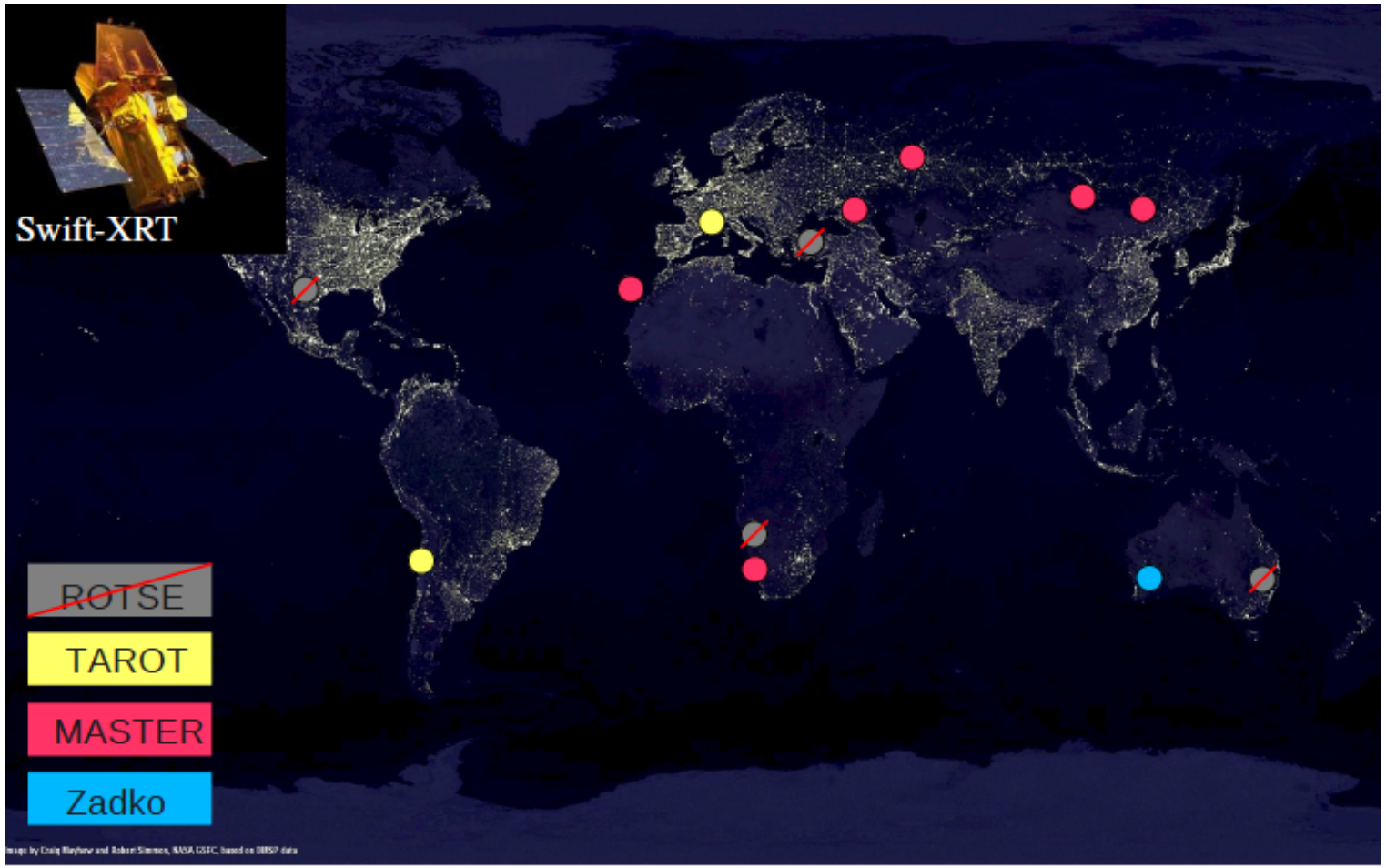
Angular performances:



Trigger	Angular resolution	Fraction events in fov	Muon contamination	Mean energy
HE	0.25-0.3°	96% (GRB) 68% (SN)	<0.1%	~7 TeV
Directional	0.3-0.4°	90% (GRB) 50% (SN)	~2%	~1 TeV

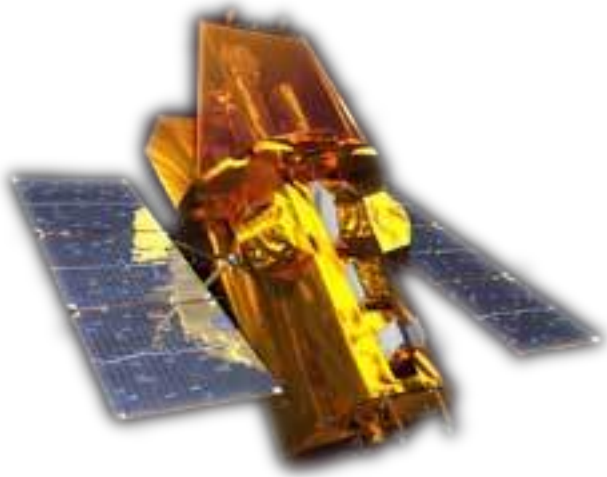
Average rate : 2 alerts per month

Followup Optical Telescopes

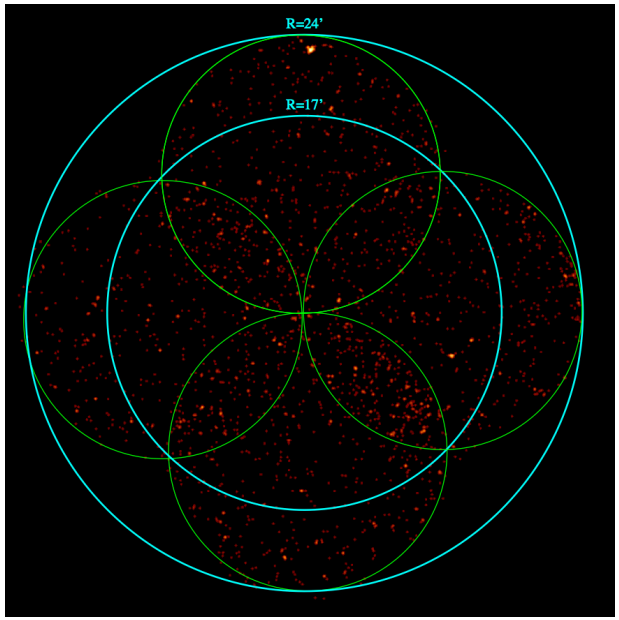


X-Ray Followup with Swift - ANTARES

- ✓ 6 alerts per year
- ✓ sub-sample of High Energy event
- ✓ Average Neutrino energy 50 TeV
- ✓ PSF : ~20 arcmin
- ✓ Delay of observation ~6h

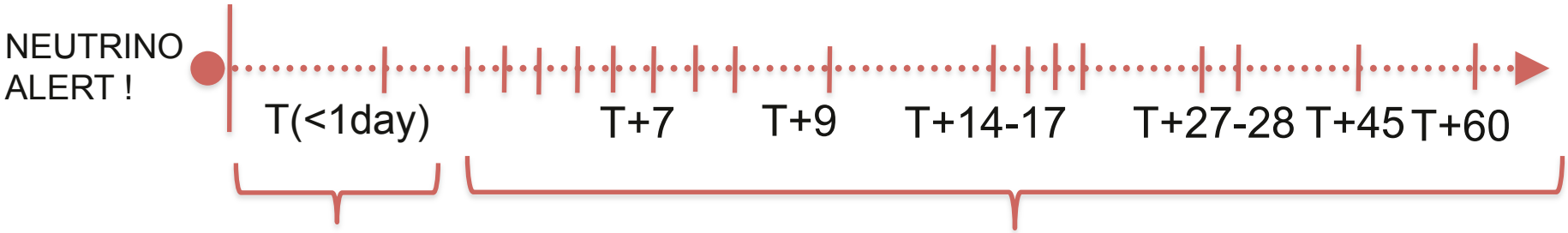


- ✓ Image: 2 x 2 tiles of 2ks exposure each
  - ⇒ Sensitivity: $2\ 10^{-13}$ erg/cm^2/s
  - ⇒ 4 tiles cover 48 arcmin fov

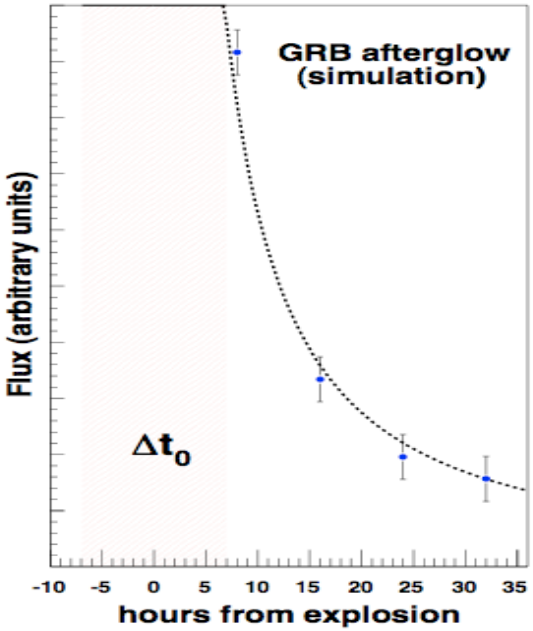


Further observation if variable object above ROSAT catalogue limit is found

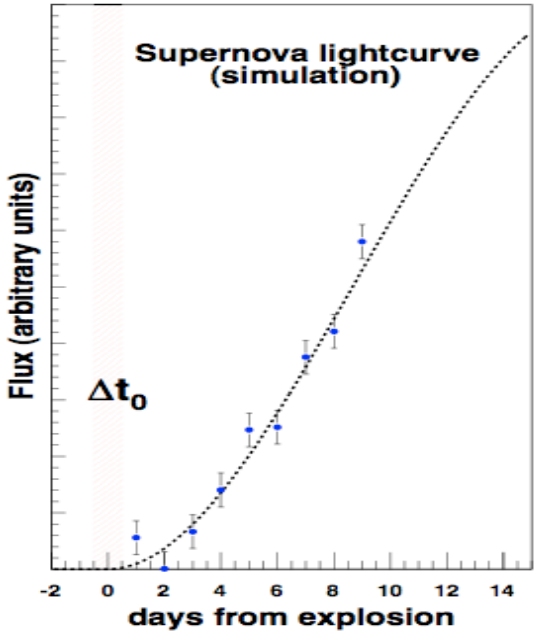
ANTARES-Tarot: observation strategy



Prompt observations



Follow-up observations

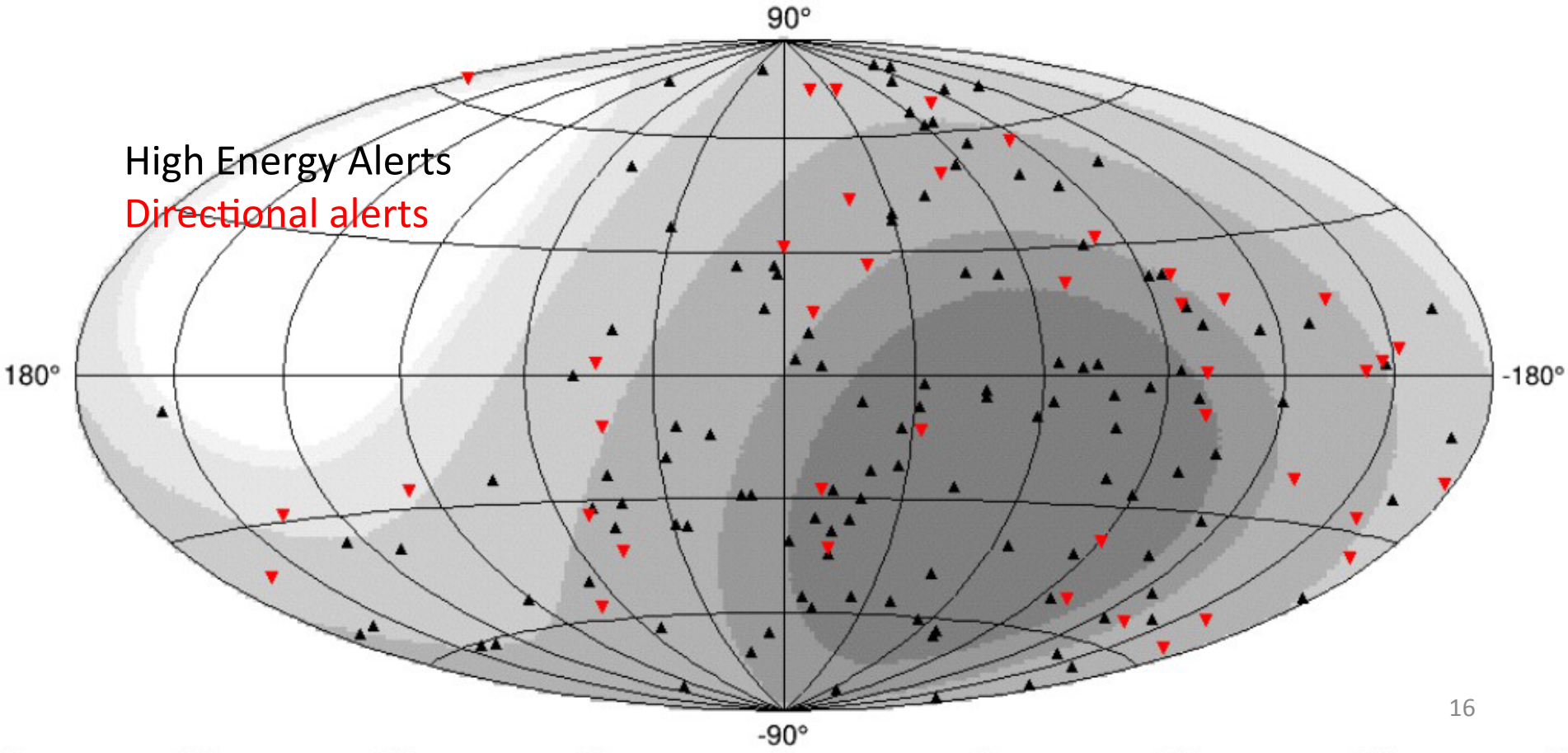


Alert summary

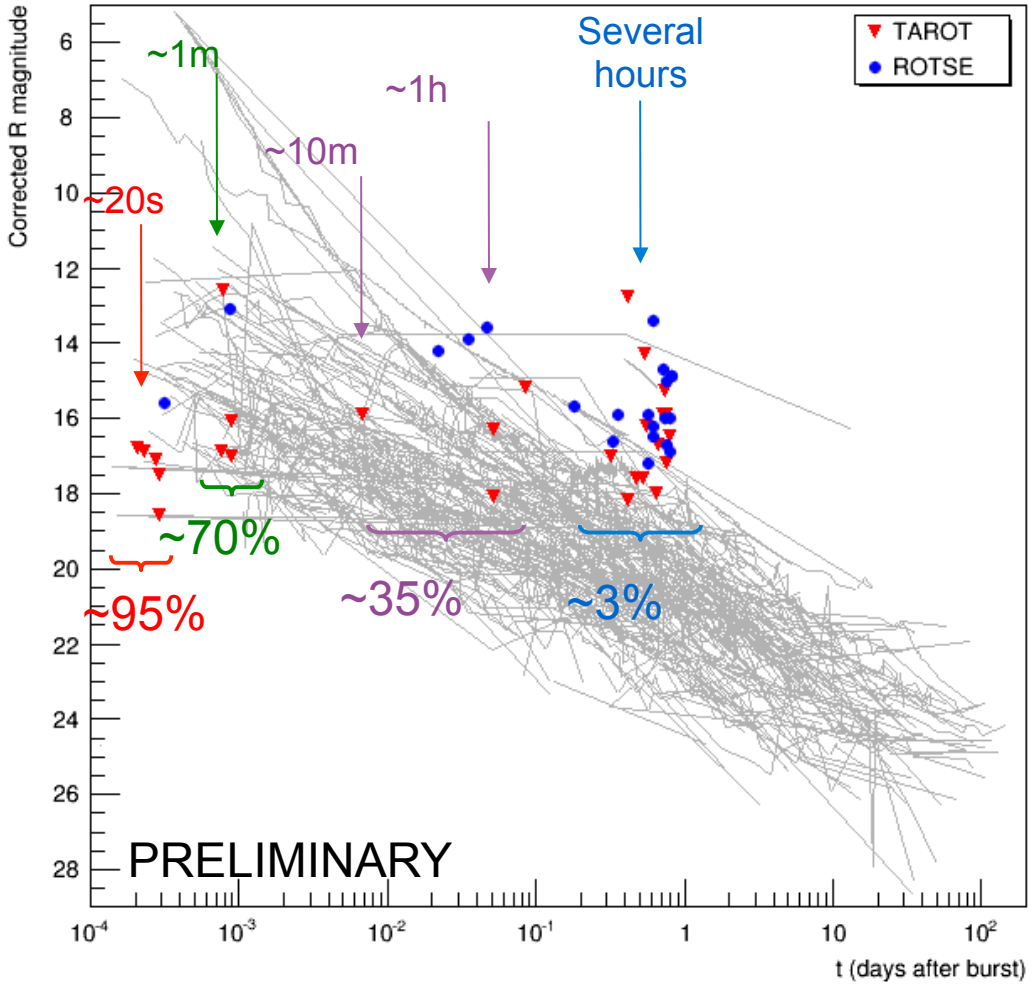
Antares since 2009

165 to optical telescopes

10 to Swift



ANTARES: GRB search results



→ Comparison with optical afterglow light curves

Grey:

158 optical afterglow lightcurves detected from 1997 to 2014 (Kann).

Fast followup:

GRB excluded

Slow followup:

no constraint

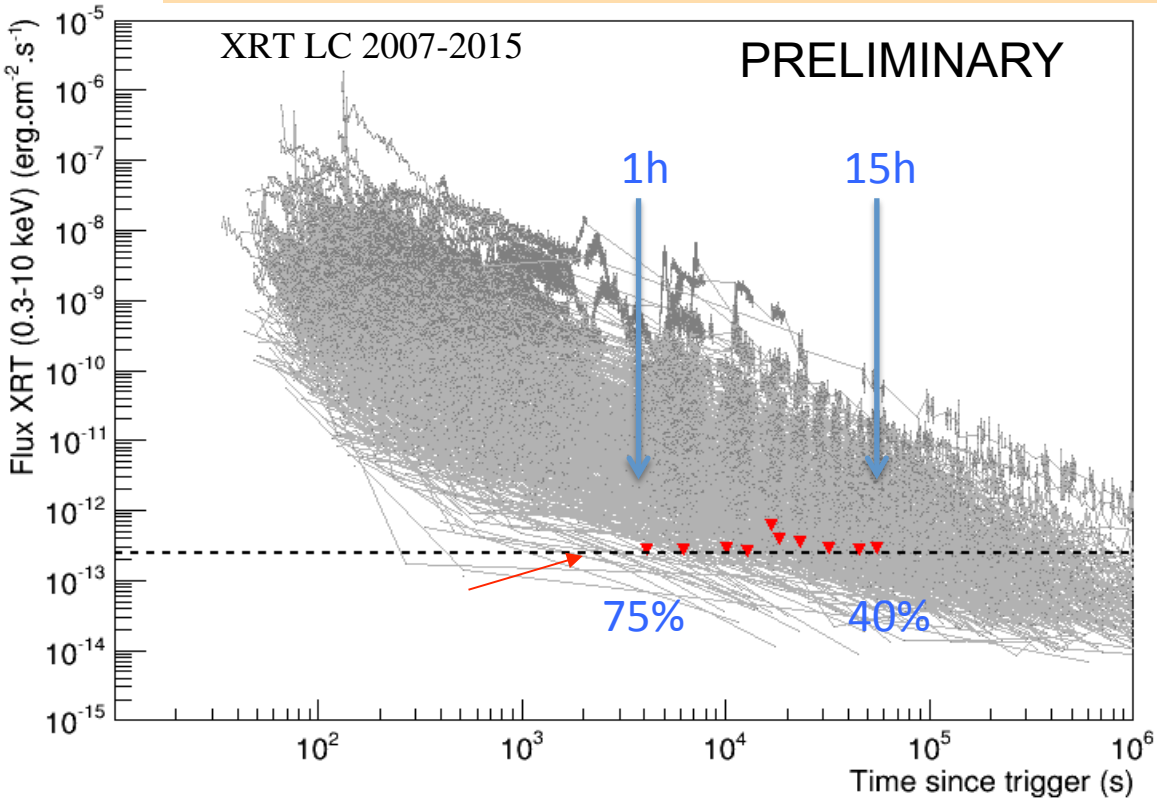
ANTARES: GRB search in X-Ray

→ 10 alerts sent to Swift

→ No X-ray counterpart associated to our neutrino alerts

→ Upper limits on transient sources magnitude

Time to send the alert: ~20 s
Time to process the alert by XRT: few hours



689 X-ray afterglow light curves detected by Swift/XRT from 2007 to 2015

Recent Alert ANTARES → Swift

- 01/09/2015 07:38
- High Energy event
  - By construction 1 of 6 highest energetic events of the year (defined by alert rate)
- Energy estimate: 50-100 TeV
- Sent to Swift & Master
- Observation after 9h Swift XRT, 10h MASTER

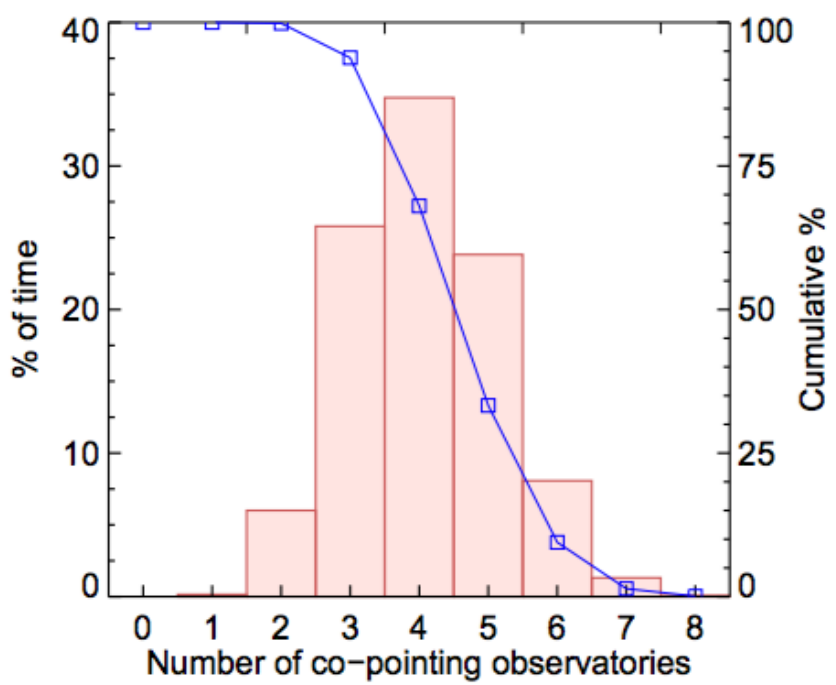
- Non catalogued X-Ray source found above ROSAT limit → ATel #7987 , GCN #18231
- X-Ray source coincides with star
  - USNO-B1 : 0626-0501169 (Rmag = 12.6)

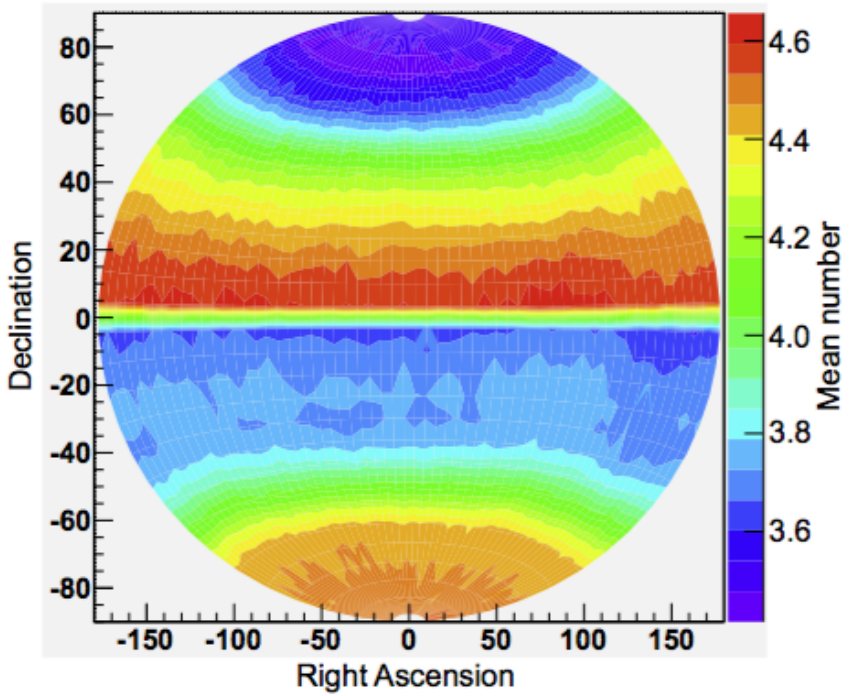
Multi Wavelength Observations

- 11 ATels & 5 GCN circulars within few days
- Optical
  - MASTER, Pan-STARRS
- Infrared/Optic (spectral analysis)
  - NOT, SALT, WiFES, CAHA, Kepler 2, CAHA, LSGT, Nishi-Harina NIR, VLT/X-Shooter
- X-Ray
  - GBM, MAXI, Integral
- Radio
  - Jansky VLA
- Gamma Ray
  - Contact with Fermi-LAT, HESS, HAWK

AMON

Astrophysical Multimessenger Observatory Network





Concept : Combine several sub-threshold (multi-messenger) observations into significant signal

AMON : Status of Participation

Observatories with AMON MoU	Stream content & format	TLS certificate	Test stream (fake data)	Test steam (real data scrambled)	Real data stream
IceCube Singlet	✔	✔	✔	✔	In progress
IceCube HESE	✔	✔	✔	✔	In progress
IceCube EHE	✔	✔	In progress		
ANTARES	✔	In progress	→		
Auger	✔	✔	In progress		
HAWC	In progress				
VERITAS	In progress				
MASTER	In progress				
FACT	In progress				
Swift BAT	✔	Not needed	Not needed	Not needed	In progress
Fermi	✔	Not needed	Not needed	Not needed	In progress

Informations provided

- Every neutrino defined by the following values
  - Sky position with its error ellipse
  - time
  - Energy with associated error
  - Topology (cascade/track)
  - Signal probability → false alarm rate
    - difficult to define, context-dependent
- Global data defining the experiment
  - position
  - Effective area = f(E,decl) or f(E,zenith)
  - Atmospheric neutrino rate =f(E,decl)

Possible data streams

- Real time
  - All neutrino candidates
  - High energy subset
  - Multiplets (none so far)
  - Matching with other catalogues (e.g. close galaxies)
- Archive (typical delay : several years)
  - Data set used for a given published analysis
    - Point source search
    - Diffuse flux search
    - Transient searches