Session Alerts & Brokers neutrinos
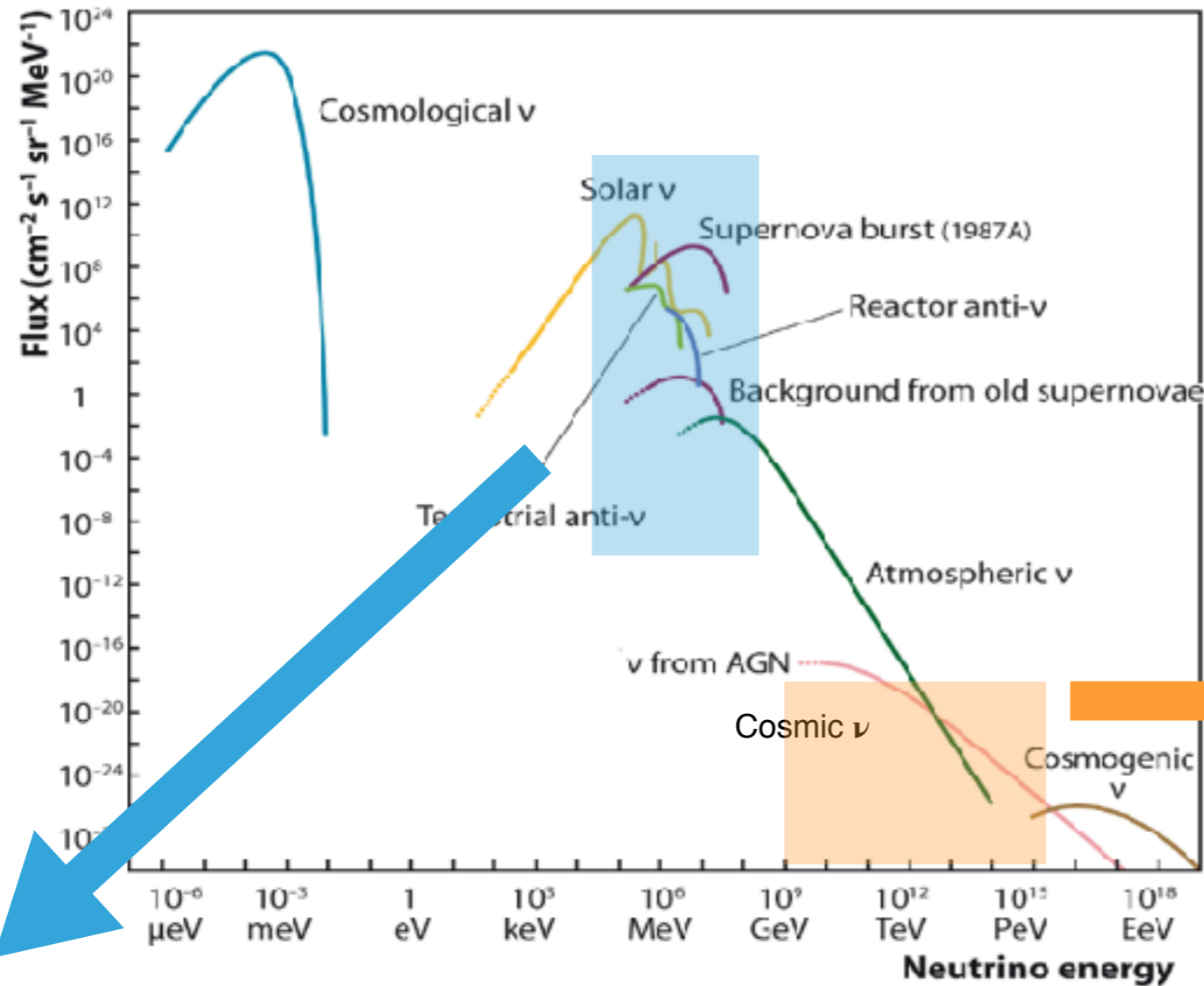
D. Dornic (CPPM)
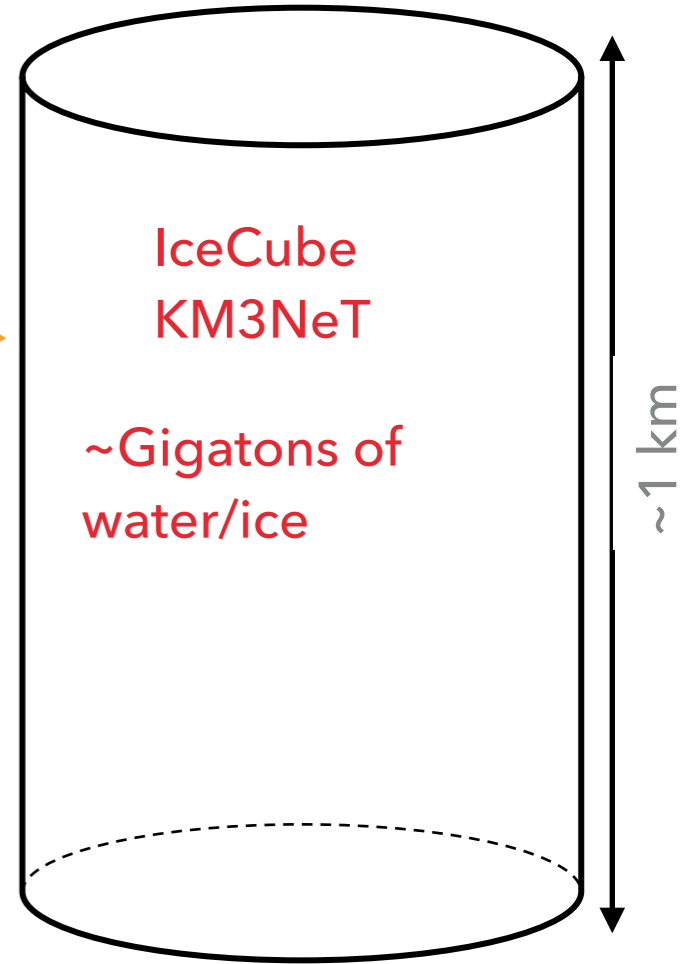
Neutrinos from MeV to PeV

Neutrino astronomy needs km³ scale detectors

IceCube
KM3NeT
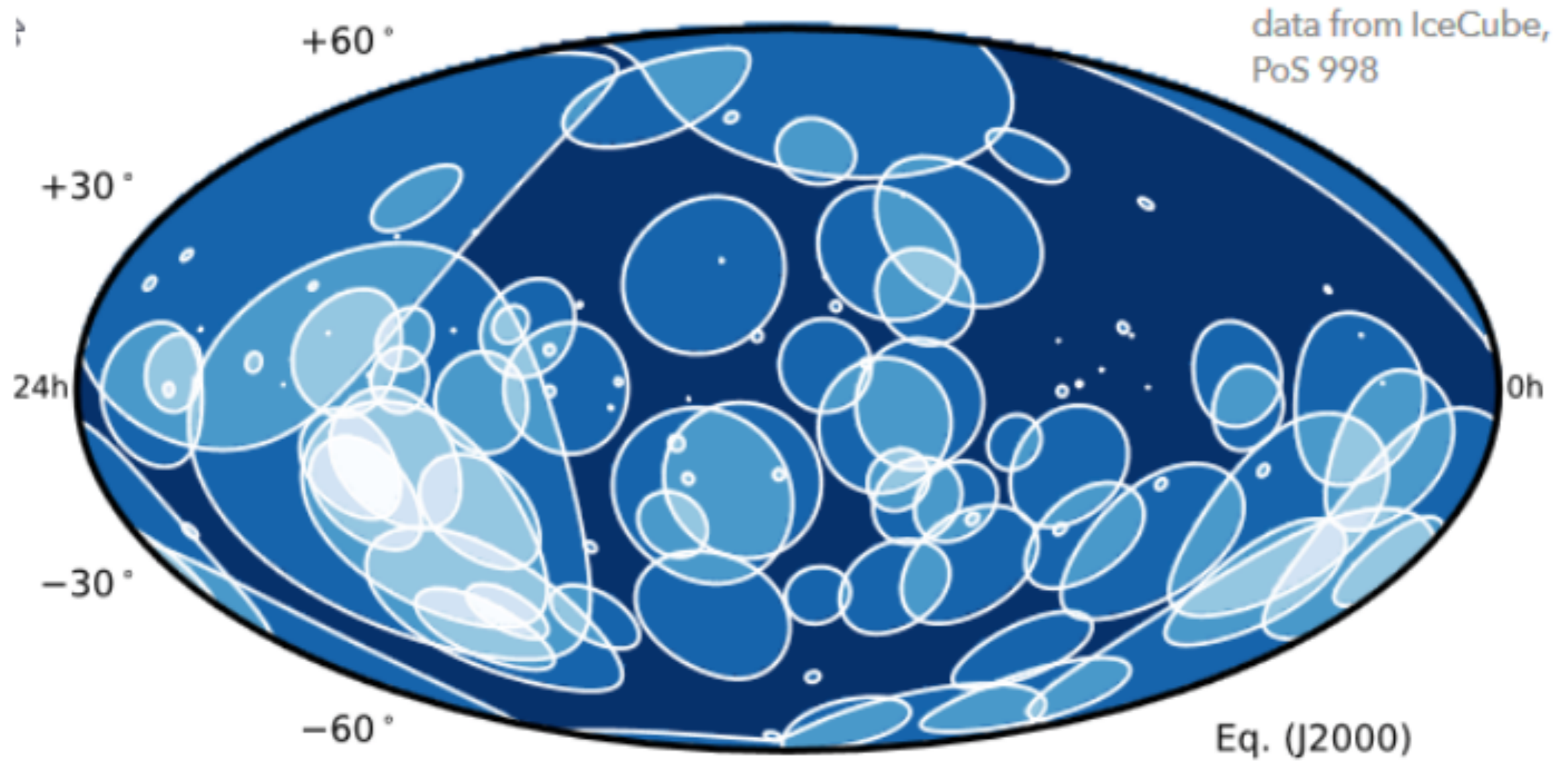
~Gigatons of water/ice

~1 km

~400 m

(AMANDA)
ANTARES

Super Kamiokande
~50 kilotons of water

~40 m
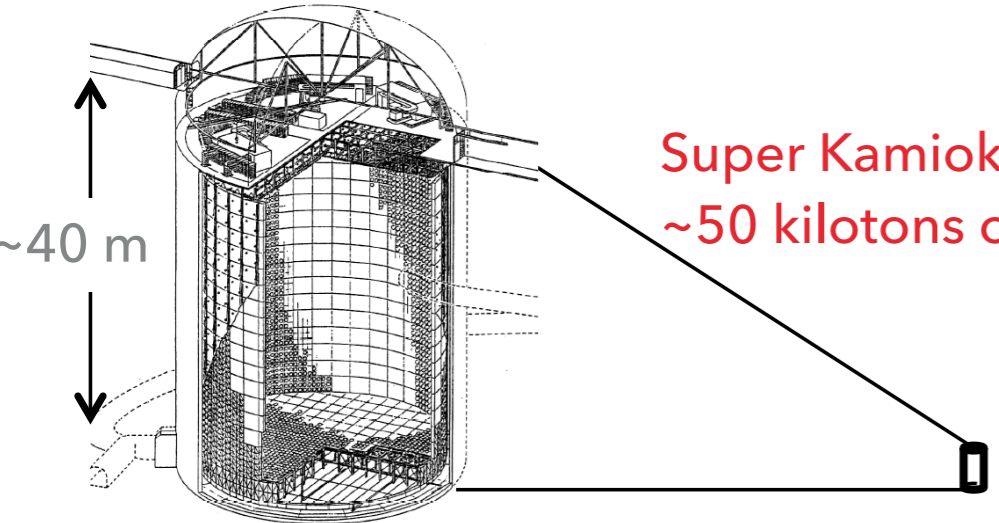
ν are weakly interacting + low cosmic flux → requires large instrumented volumes under sea/ice to reduce the muon background

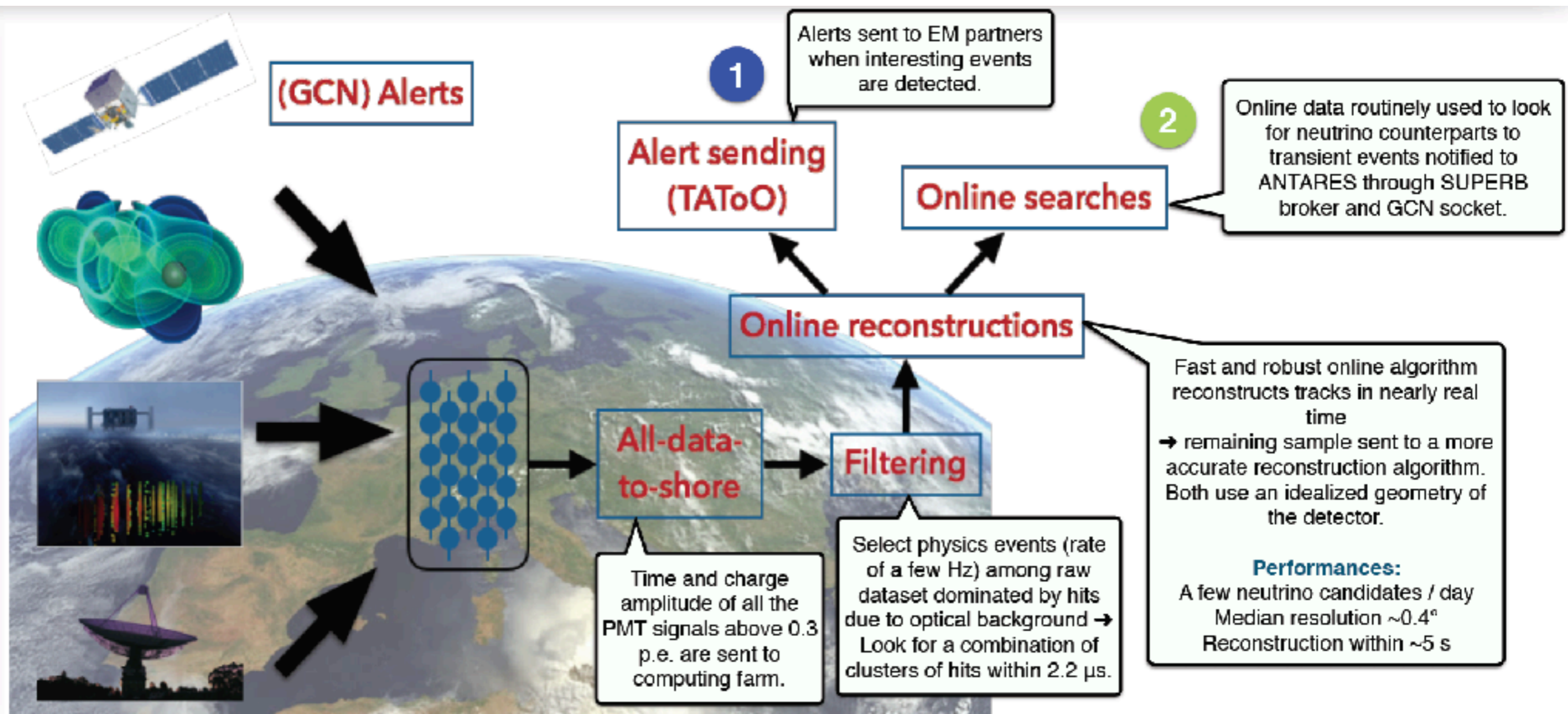# HE neutrino sky

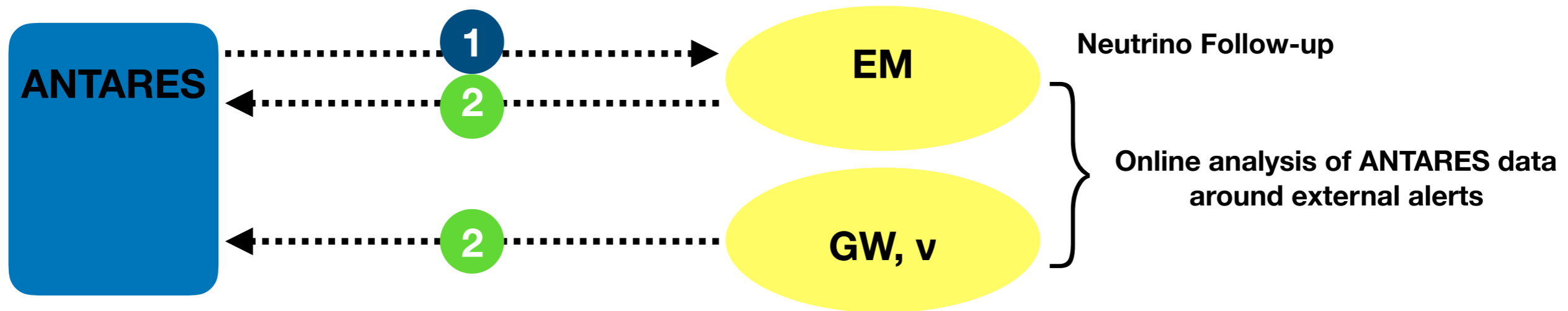

data from IceCube, PoS 998

Eq. (J2000)

Resolution for ν_e
ANTARES ○
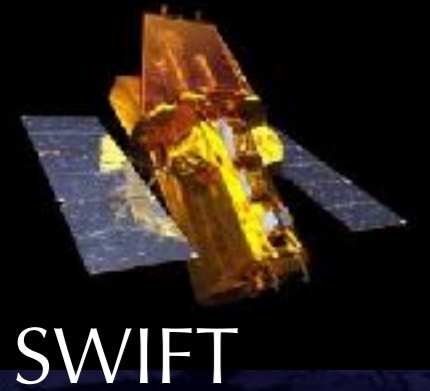KM3NeT ∘

3

ANTARES online system

Multi-λ observatories linked to ANTARES for the real-time analysis

SWIFT

INTEGRAL

MASTER
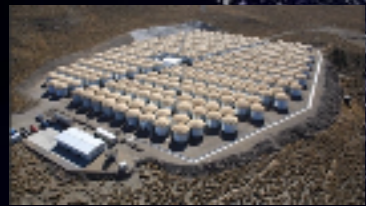
SVOM
GWAC

ANTARES

HAWC

TAROT

HESS

MWA

ZADKO

ROTSE

+ **GW alerts from LIGO/VIRGO**
+ **UHECR/UHEν with Auger/TA**
+ **Neutrino alerts from IceCube**
+ **AMON**

(Update 01/2018)

ANTARES alerts

Efficiency of prompt observations vs location on the Earth

ANTARES online system

Monitoring EM partner connections

2 independent event recos

Neutrino alert infos

Monitoring stability data-taking

External alert infos

ANTARES online system

Alert broker:
   * GCN socket: TAROT, ZADKO, MASTER, INTEGRAL
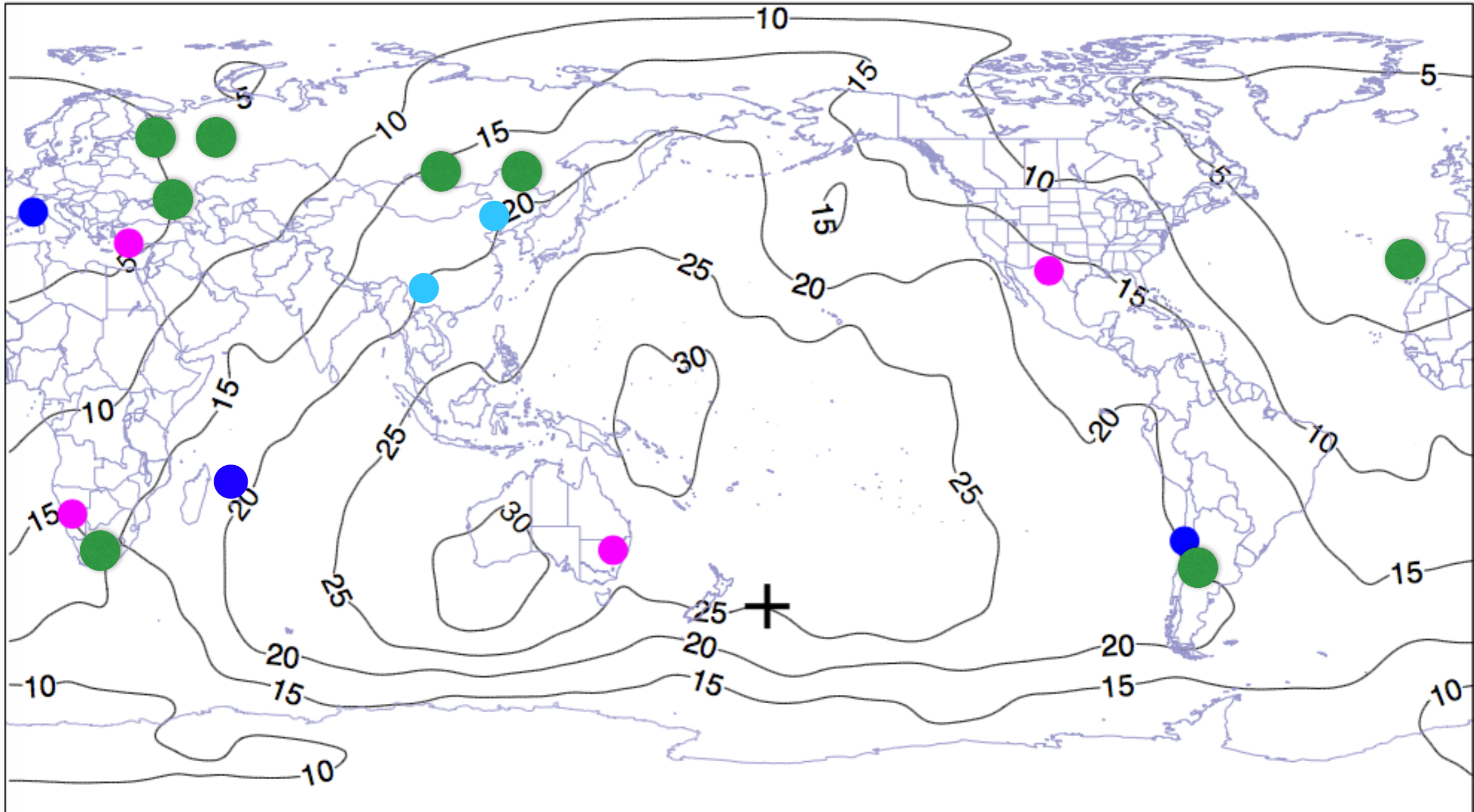   * VO Event: MWA, HESS, SVOM, AMON
   * Mail: Swift

For ANTARES, all neutrino information are private. Need MoU with external partners.

Alert Message:
   * ID
   * Time,
   * RA, DEC, error 50%
   * Energy proxy
   * Reconstruction quality
   * probability neutrino
   * Mutliplicity, type of trigger

     Only one real-time message

ANTARES neutrino alerts

Performances:
  * Time to send an alert: ~3-5 s
  * First image of the follow-up: < 20 s
(with TAROT/MASTER few alerts in 17 s)
  * Median angular resolution: $0.3-0.4^o$
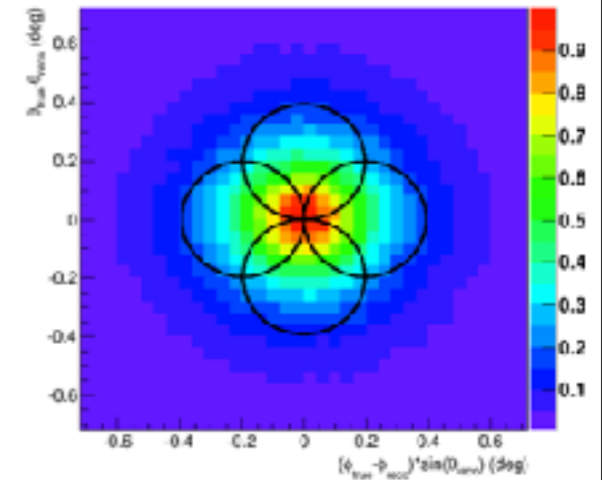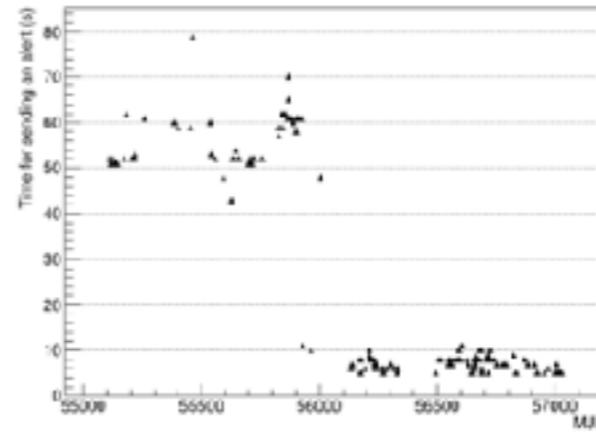
Triggers:
  * Doublet of neutrinos: ~0.04 events / yr.
  * Single neutrino with direction close to local galaxies: ~1 TeV, ~10 events / yr.
  * Single HE neutrinos: ~7 TeV, ~15 events / yr
        => Sub-sample HE neutrinos: ~5 TeV, 20 events / yr
        => Sub-sample VHE neutrinos: ~30 TeV, ~3-4 events / yr.

At the EM partner sites:
  * Number of alerts followed decided at the start of the project + annual revision
  * Observing strategies decided in advance for each type of alerts [early + long-term follow-ups]
  * Reporting of the results to the PI of the project
  * Reporting via GCN or Atels

ANTARES alerts
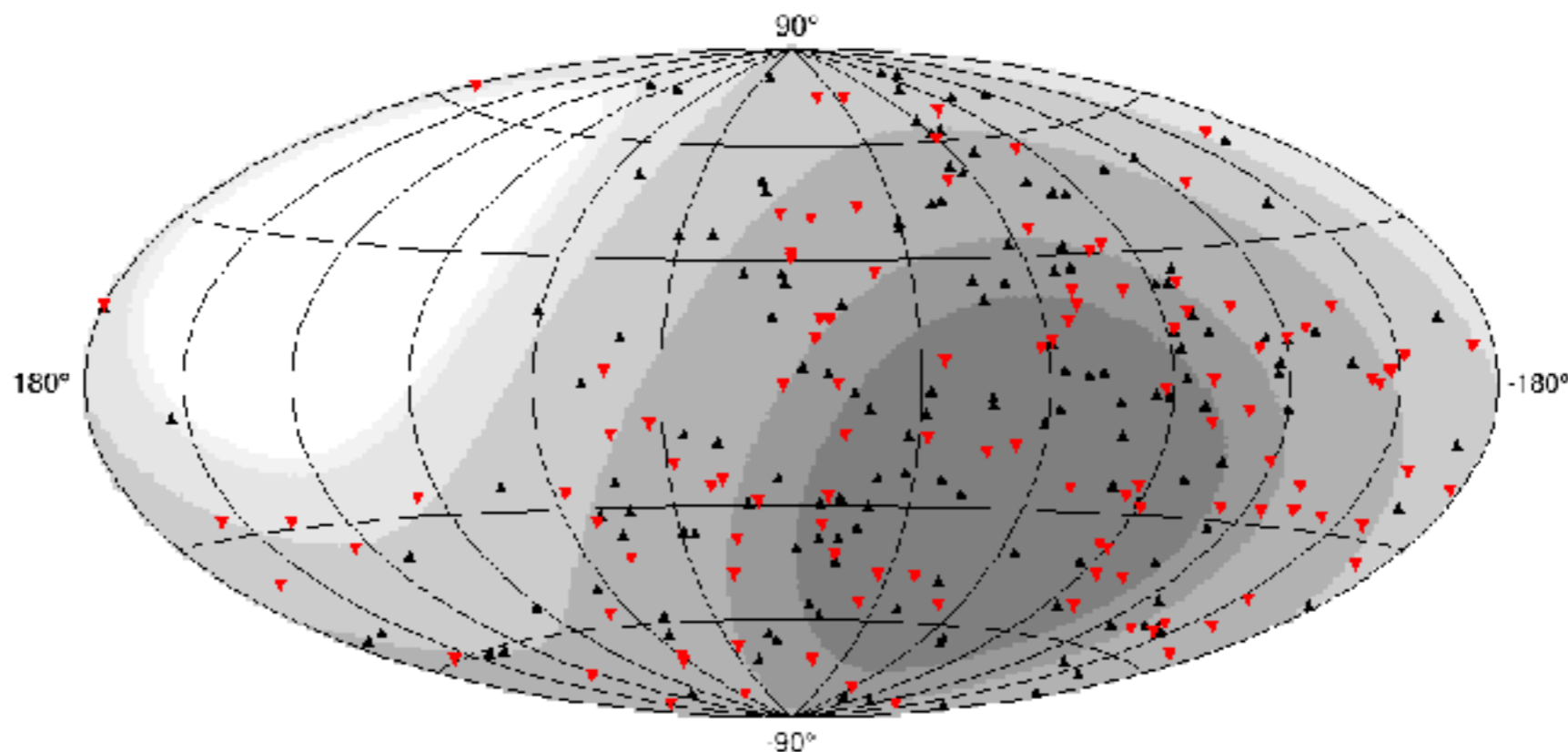
277 alerts sent to robotic telescopes TAROT/ROTSE/MASTER (07/2009-05/2018)
=> **~63%** early follow-up (<1 day)
=> **~71%** rather good long-term follow-up (min 2(3) nights up to 1(2) months)

For the most interesting events (highest energies), more complete follow-up:
15 to Swift since mid 2013 + **8** to INTEGRAL since 2018
+ **20** to M.W.A since 2016 + **2** to HESS in the last years

TAToO Follow-ups

Early follow-up:
Visible: 161 alerts analyzed 01/2010-07/2017 from TAROT, ROTSE, MASTER =>24 alerts with delay <1min

X-ray: 14 alerts analyzed 06/2013-08/2017 => average delay ~5-6h

=> no transient candidate associated to neutrinos

Adrían-Martínez et al, JCAP 02(2016) 062
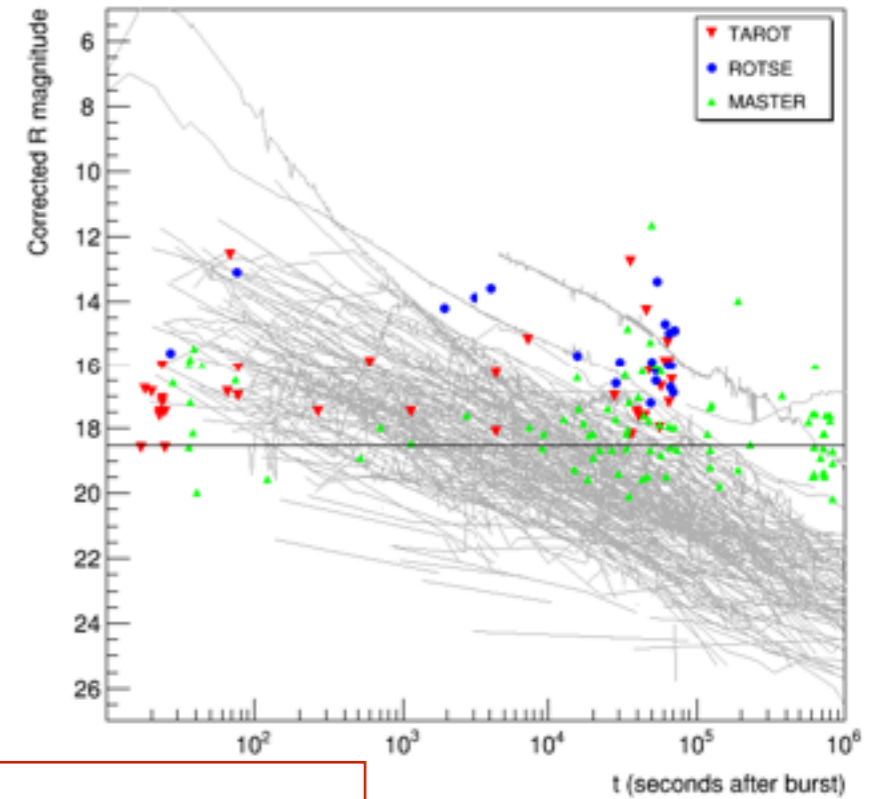
Long-term follow-up:
177 alerts with a "rather good" long-term follow-up (01/2010-07/2017)
- ➡ No SN (and no interesting transient) associated with the neutrinos
- ➡ N_{exp}(SN) = 0.3-0.4 for the full follow-up [SN rate=2.4 10^{-4} $yr^{-1}Mpc^{-3}$]

Adrían-Martínez et al, JCAP in preparation

Radio follow-up:
2 alerts followed over a year with M.W.A. (2013-14)
- ➡ No interesting transient associated with the neutrinos

Croft et al, Astrophys. J. 820 (2016) 24.

Other alerts followed in real-time with M.W.A. (2015-17)
- ➡ Analysis on-going

H.E.S.S. follow-up:
2 alerts followed with very small delay (2015-2017)
- ➡ ANT150901(+2.5d), ANT170130 (+32s): No VHE candidates associated with the neutrinos

Schüssler et al, arXiv: 1705.08258
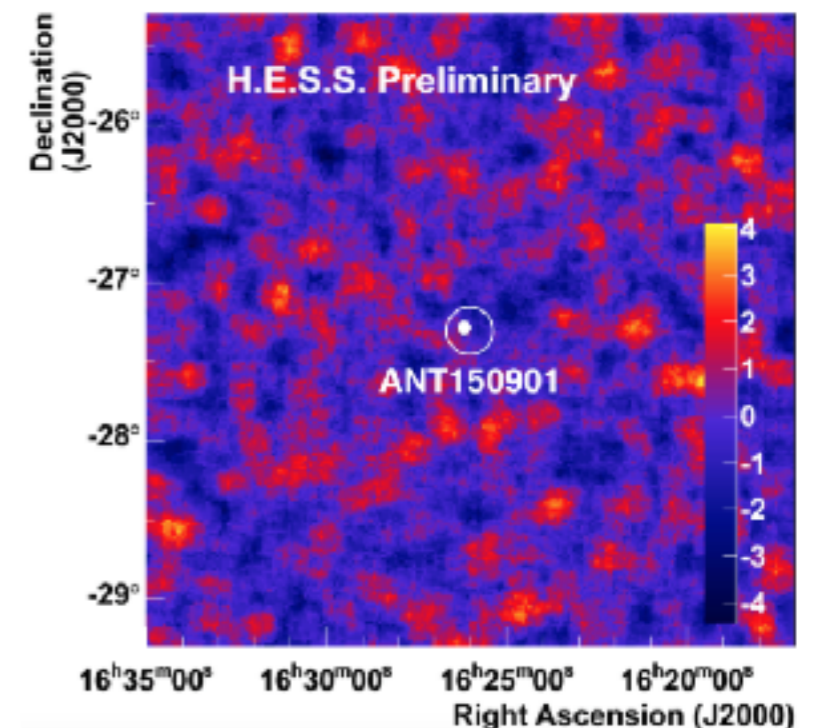
IceCube alert system
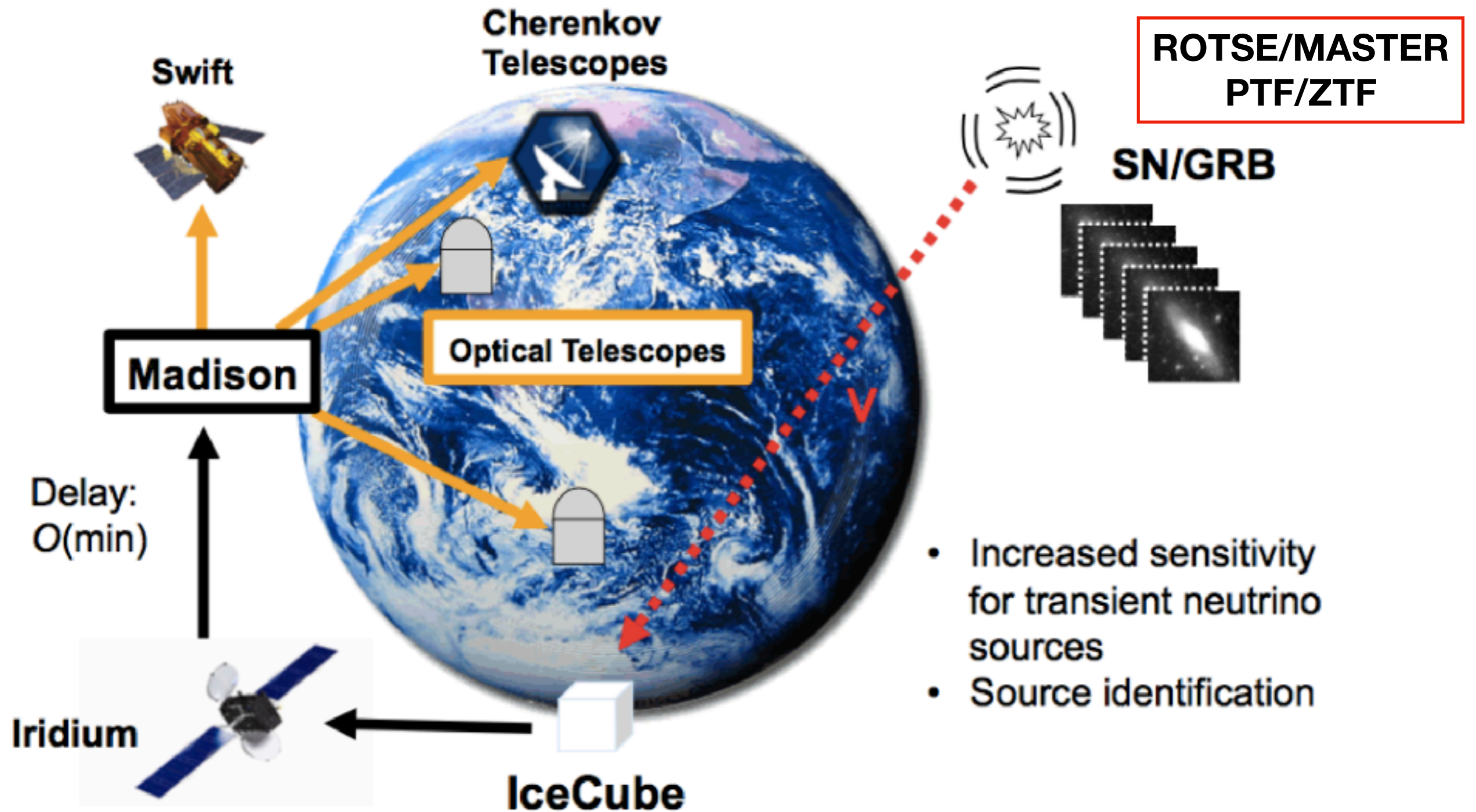
Anna Franckowiak

Limited computing resources at the South Pole + Limited connectivity (Iridium connection: low latency but low bandwidth; TDRSS connection: high latency but high bandwidth)

Event selection at South Pole ➜ Basic event info sent North ➜ analyses & alert generation in the North

EHE + HESE events sent via GCN notices by the AMON broker

```
                POS_ERROR       TIME SINCE
TYPE            [radius]        TRIGGER         COMMENTS
==================  =========   ===========     ====================================================
AMON_ICECUBE_HESE   2-9deg      0.5-3 min       Direction of a single hi-energy neutrino            ACTIVE
AMON_ICECUBE_EHE    0.2-0.8deg  0.5-3 min       Direction of a single extremely hi-energy neutrino  ACTIVE
AMON_ICECUBE_COINC  1-3deg      0.5-3 min       Temporal/spatial coinc between IceCube neutrinos    NOT YET PUBLIC
==================  =========   ===========     ====================================================
```

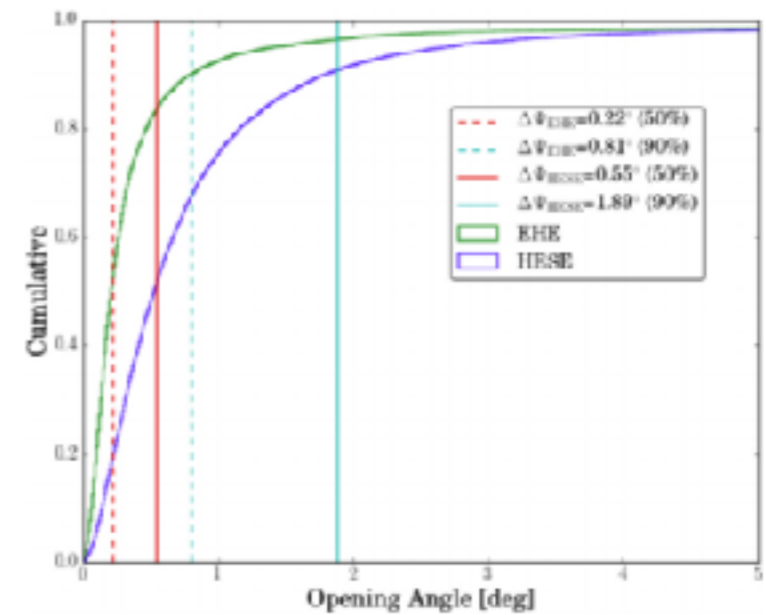| EVENT			OBSERVATION							
EventNum_RunNum	Date	Time UT	NoticeType	RA	Dec	Error	False_Pos	Pvalue	Charge	SignalTr
71165249_130949	18/04/23	02:28:40.98	HESE	294.8820	+71.9530	534.00	0.0000e+00	0.0000e+00	13631.57	0.34
34032434_130171	17/10/28	08:28:14.81	HESE	275.0760	+34.5011	534.00	0.0000e+00	0.0000e+00	6317.82	0.30
56068624_130126	17/10/15	01:34:30.06	HESE	162.5790	-15.8611	73.79	0.0000e+00	0.0000e+00	13906.14	0.51
32674593_129474	17/05/06	12:36:55.80	HESE	221.6750	-26.0359	73.79	0.0000e+00	0.0000e+00	8685.07	0.35
65274589_129281	17/03/12	13:49:39.83	HESE	304.7300	-26.2380	73.79	0.0000e+00	0.0000e+00	8858.64	0.78
38561326_128672	16/11/03	09:07:31.12	HESE	40.8252	+12.5592	66.00	0.0000e+00	0.0000e+00	7546.05	0.30
38561326_128672	16/11/03	09:07:31.12	HESE	40.8740	+12.6159	73.79	0.0000e+00	0.0000e+00	7546.05	0.30
58537957_128340	16/08/14	21:45:54.00	HESE	199.3100	-32.0165	89.39	n/a	n/a	10431.02	0.12
6888376_128290	16/07/31	01:55:04.00	HESE	215.1090	-0.4581	73.79	n/a	n/a	15814.74	0.91
6888376_128290	16/07/31	01:55:04.00	HESE	214.5440	-0.3347	45.00	n/a	n/a	15814.74	0.91
67093193_127853	16/04/27	05:52:32.00	HESE	240.5683	+9.3417	35.99	n/a	n/a	18883.62	0.92
67093193_127853	16/04/27	05:52:32.00	HESE	239.6639	+6.8528	534.00	n/a	n/a	18883.62	0.92
67093193_127853	16/04/27	05:52:32.00	HESE	239.6639	+6.8528	534.00	n/a	n/a	18883.62	-1.00
67093193_127853	16/04/27	05:52:32.00	HESE	239.6639	+6.8528	534.00	n/a	n/a	18883.62	-1.00

EVENT			OBSERVATION				
EventNum_RunNum	Date	Time UT	NoticeType	RA	Dec	Error	Signalness
17569642_130214	17/11/06	18:39:39.21	EHE	340.2500	+7.3140	14.99	7.4593e-01
50579430_130033	17/09/22	20:54:30.43	EHE	77.2853	+5.7517	14.99	5.6507e-01
80305071_129307	17/03/21	07:32:20.60	EHE	98.3268	-14.4861	19.48	2.8016e-01
80127519_128906	16/12/10	20:06:40.31	EHE	46.5799	+14.9800	60.00	4.9023e-01
80127519_128906	16/12/10	20:06:40.31	EHE	45.8549	+15.7851	14.99	4.9023e-01
26552458_128311	16/08/06	12:21:33.00	EHE	122.7980	-0.7331	6.67	2.8016e-01
6888376_128290	16/07/31	01:55:04.00	EHE	214.5440	-0.3347	20.99	8.4879e-01
6888376_128290	16/07/31	01:55:04.00	EHE	215.0929	-0.4191	10.31	8.4879e-01

13
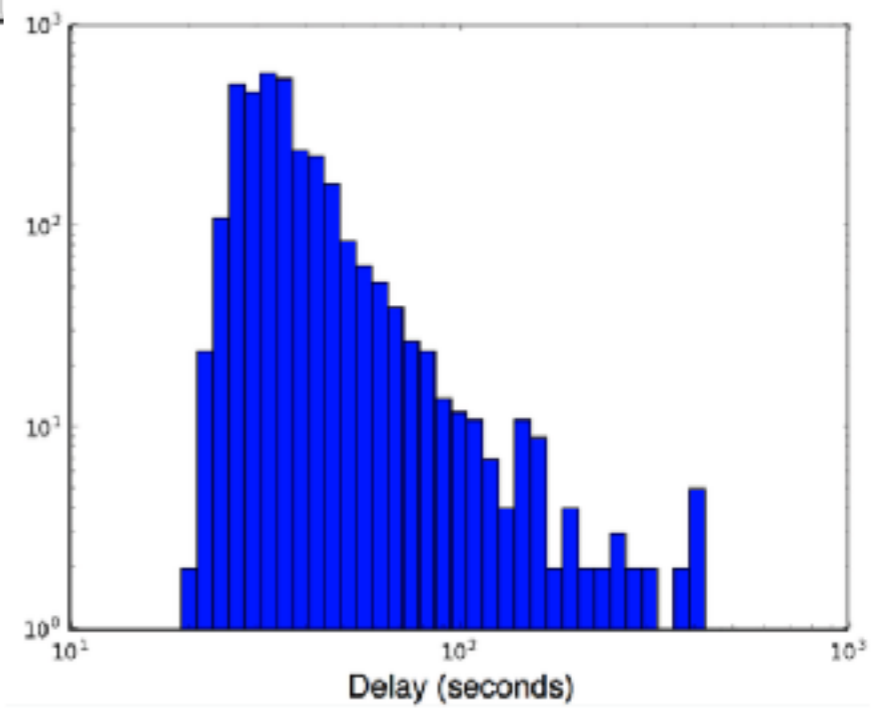
IC170922 (EHE alert) + TXS 0506+056

Lots of questions remain… (when multi-wavelength astronomy comes into play)

➤ 22nd Sept. 2017 at 20:54:30 UTC

➤ First notice: 22nd Sept. 2017 at 20:55:13 (43s later)

➤ Deposited energy ~120 TeV

➤ Angular error: ~15'
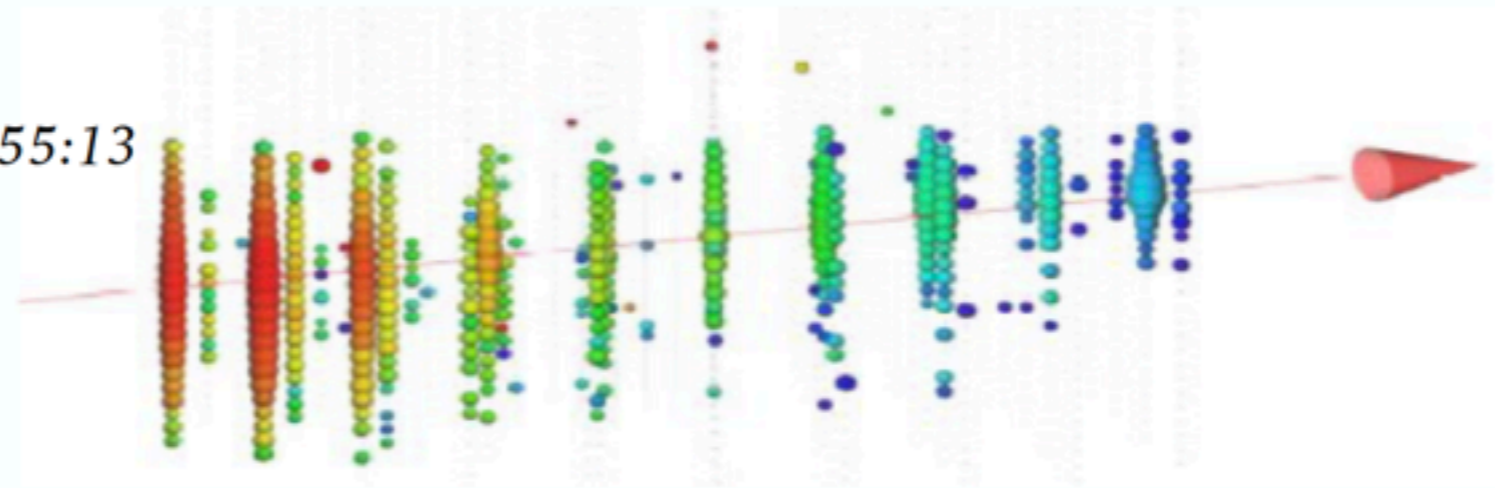
Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.
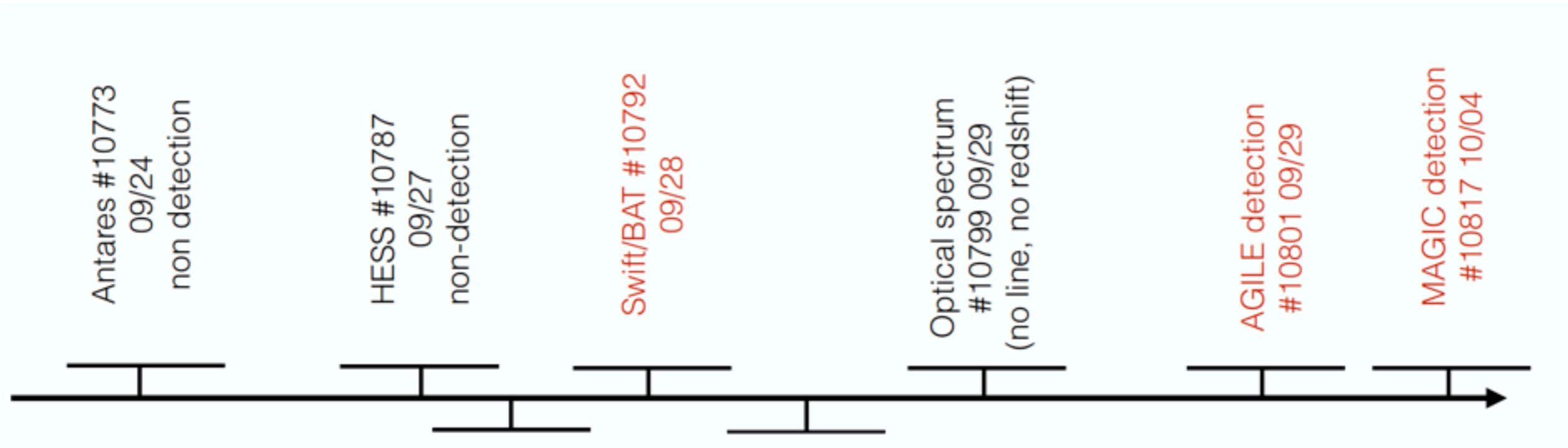
ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration on 28 Sep 2017; 10:10 UT*
Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)

➤ *Significance of the coincidence:*

rate of neutrinos x blazar density x duty cycle ➜ ~4σ

First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A
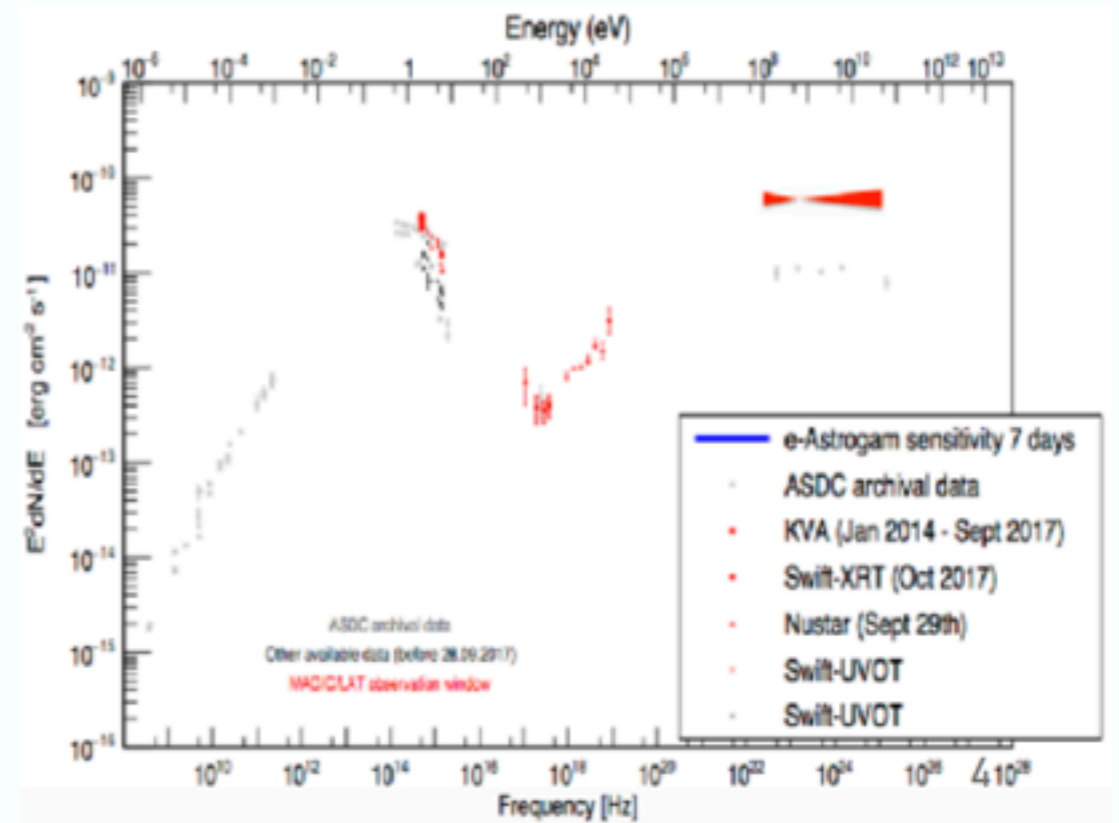
ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration on 4 Oct 2017; 17:17 UT*
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

IC170922 (EHE alert) + TXS 0506+056

Antares #10773
09/24
non detection

HESS #10787
09/27
non-detection

Swift/BAT #10792
09/28

Optical spectrum
#10799 09/29
(no line, no redshift)

AGILE detection
#10801 09/29

MAGIC detection
#10817 10/04

Fermi/LAT #10791
09/28

ASAS-SN 09/28
optical lightcurve
#10794

... and observations and reports by many more telescopes:
*AGILE, ASAS-SN, Kapteyn, Kanata, Liverpool, Subaru,*
*VERITAS, VLA, X-Shooter, GTC, ...*

Mediterranean neutrino telescopes

➡ **ANTARES**: 2006-, very complete scientific programs, especially very wide multi-messenger analysis. Probable dismantlement: 2020.

➡ **KM3NeT**: 2nd generation neutrino telescope in the Mediterranean Sea.

➡ **KM3NeT-ORCA**: off-shoreToulon (France) for the low energy (5 GeV - 1 TeV). Measurement of the intrinsic neutrino properties in particular the mass hierarchy

➡ **KM3NeT-ARCA**: off-shore Capo Passero (Italy) for the high energy (1 TeV - 10 PeV). Discovery and characterization of the high-energy neutrino sources in the Universe

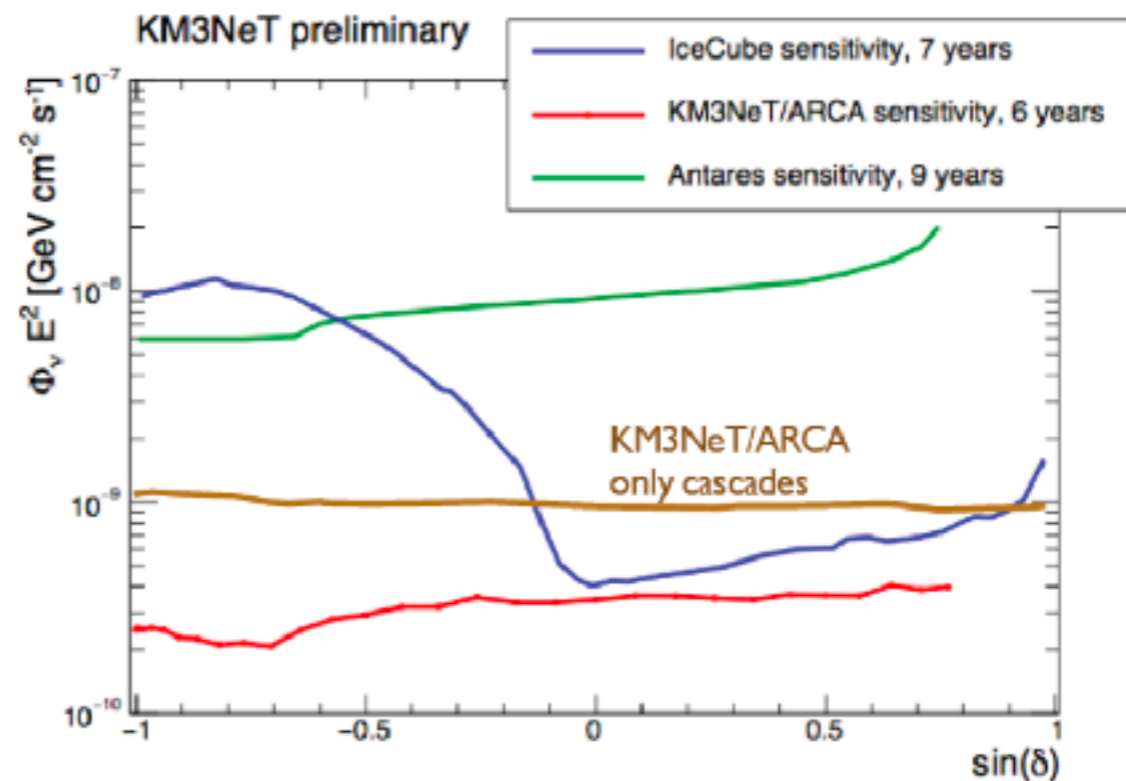➡ **Construction on-going in both sites in parallel**
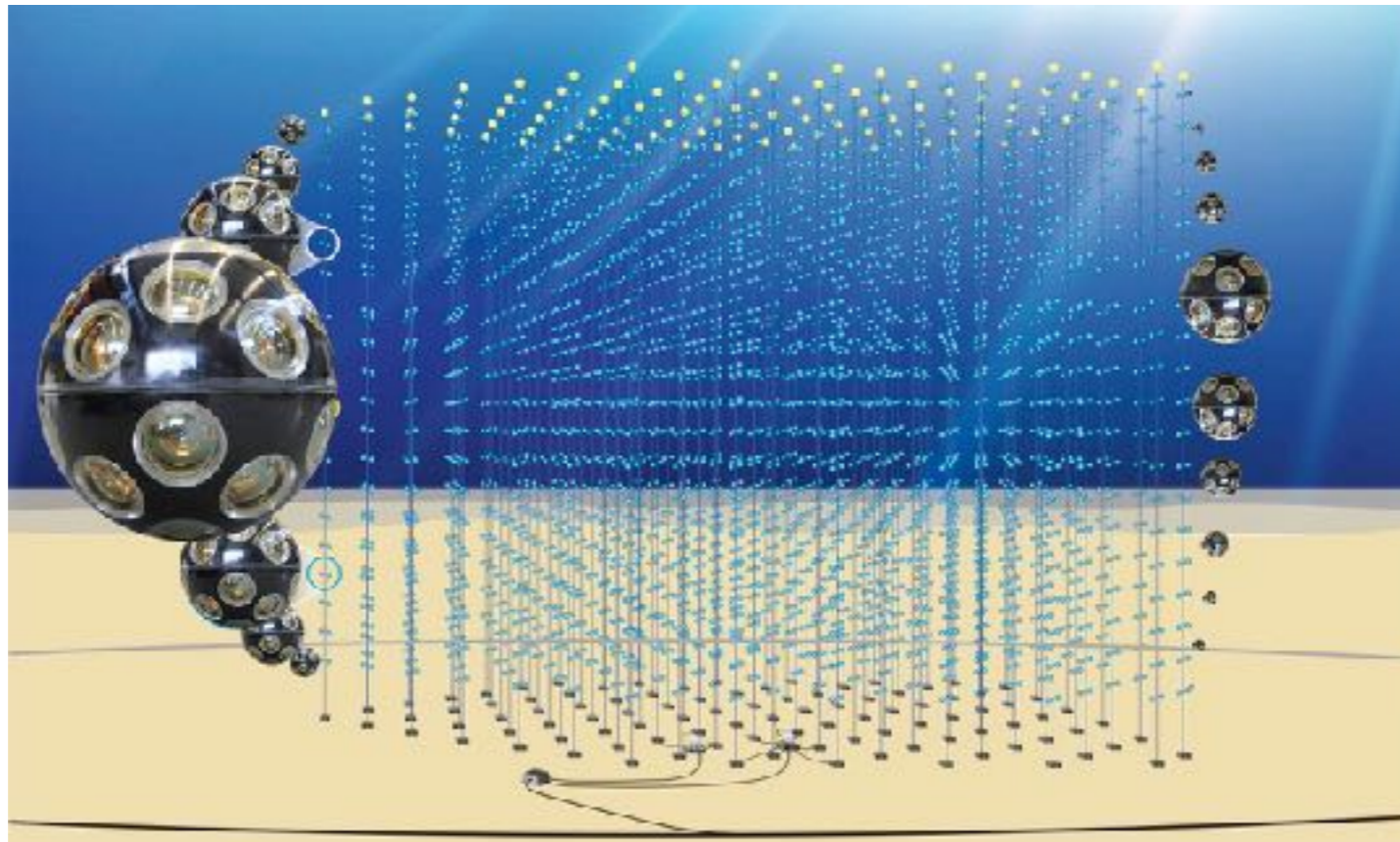
Performances HE neutrinos
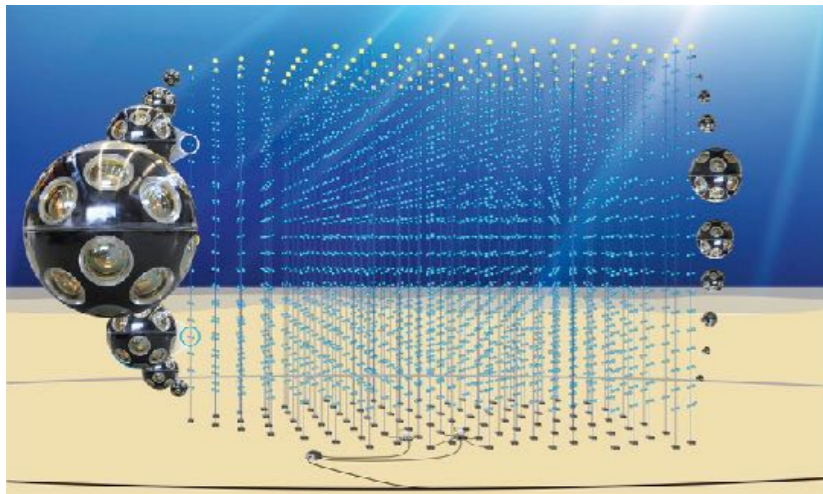
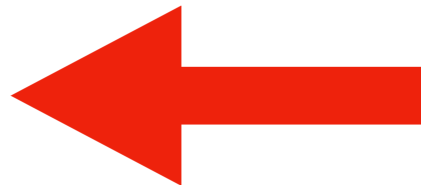**Angular resolution KM3NeT vs IceCube**
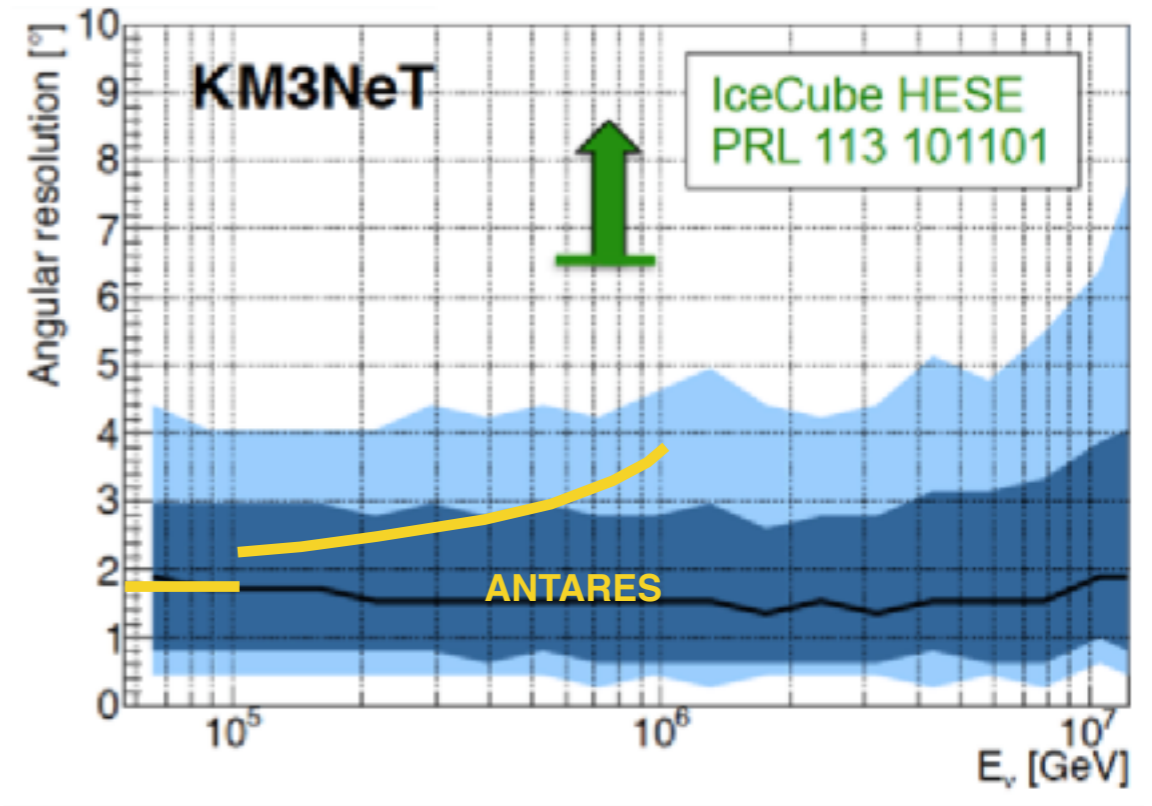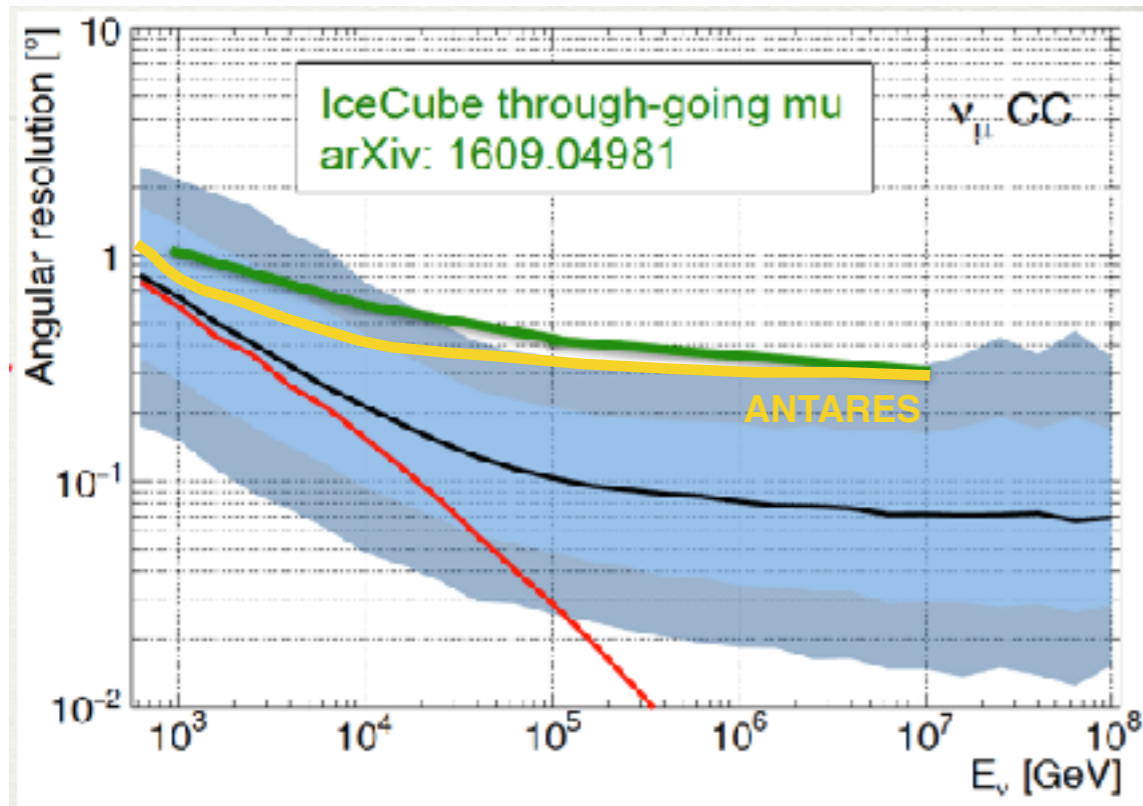
Point-source discovery potential

KM3NeT multi-messenger program

- **Follow-up of neutrino alerts**
- **Joint sub-threshold analysis**

KM3NeT
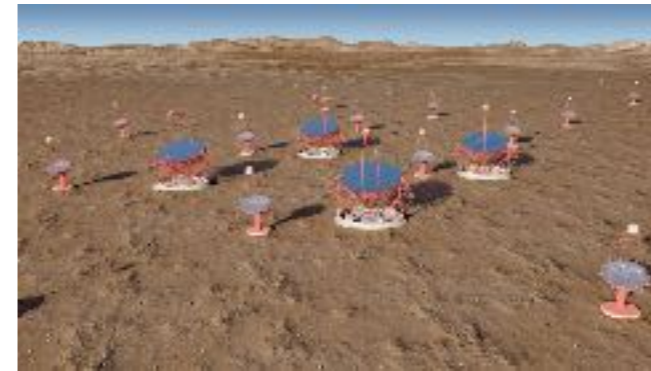
CTA

LSST

SVOM

HAWC

LIGO/VIRGO

SKA

ELT

Add cascade events in real-time
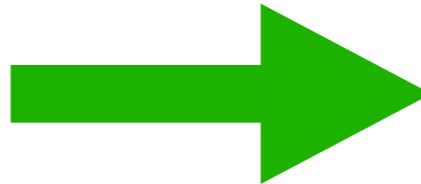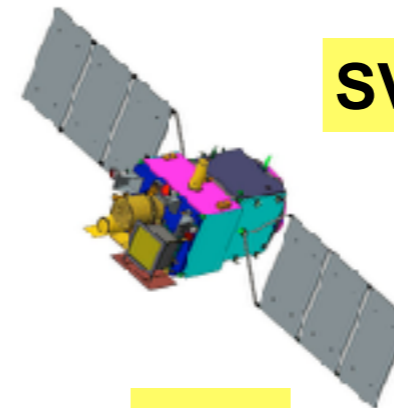
- **Follow-up of EM/GW alerts**
- **Offline time/space correlation search with catalogues (GRB, AGN, XRB, SN, FRB…)**

18

SNEWS - Supernova alert

The detection of even a single neutrino in association with a nearby supernova would reduce the uncertainty on the start time from ~ 1 day to ~ 10 seconds, which would help for GW searches for instance.

+ trigger of EM observations

http://snews.bnl.gov

- Neutrinos arrive several hours before photons
- Can alert astronomers several hours in advance

Super-K

IceCube

LVD

Borexino

Coincidence Server @ BNL
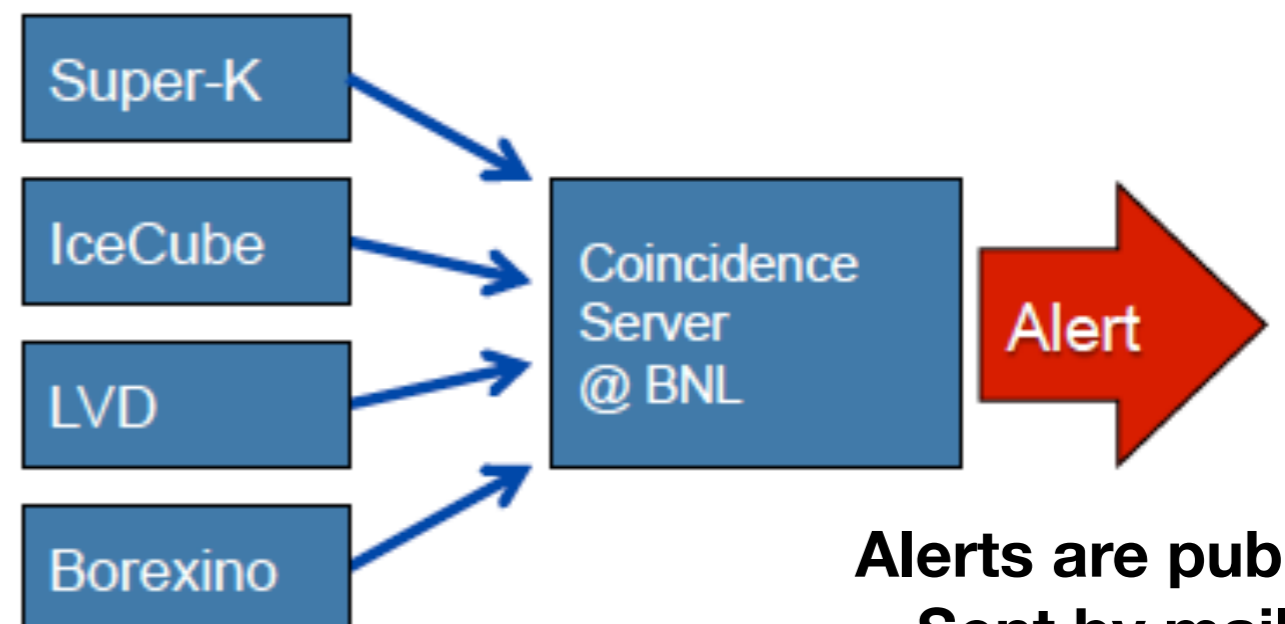
Alert

Alerts are public
Sent by mail

+ KM3NeT

KM3NeT data policies

➡ **KM3NeT neutrino data are proprietary but become public after a latency of 2 years after the data taking.**

➡ However, **significant events might trigger alerts** that will be distributed **publicly** to the astro community using standard **VO event** format within **~10s** after the neutrino detection. We will implement after a commissioning phase, an Open Public Alert distribution.

➡ **Sub-threshold alerts** and **multiplets** will be distributed though **private channel** to observing teams upon **MoU agreements.**

KM3NeT/IceCube Gen2 time-scale

Phase 1: 24 lines @ARCA + 7 lines @ORCA
Phase 2: fund on-going (more than1/2 ok)
(currently under deployment)

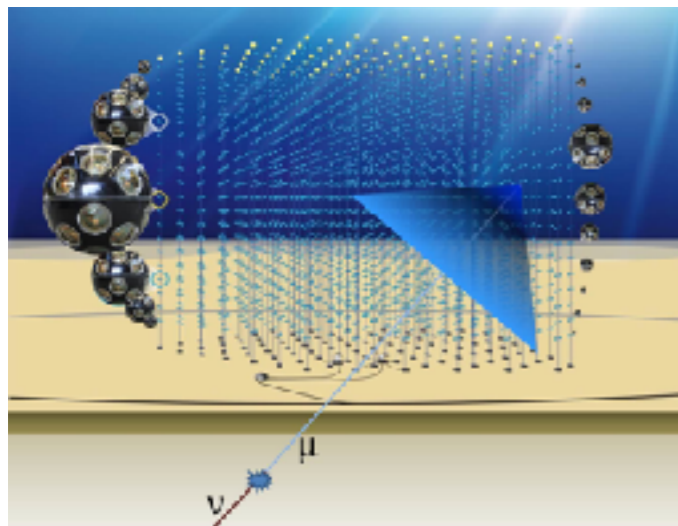**IceCube Gen-2 phase 1**
NSF proposal (7 lines)

2017
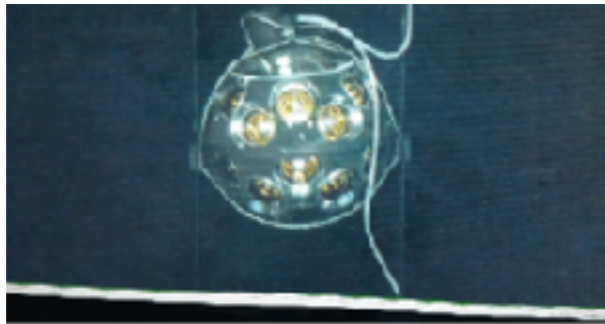
2025

2023

KM3NeT deployment

IceCube Gen-2 deployment

200 m   240 m   300 m

5 km²   7 km²   10 km²
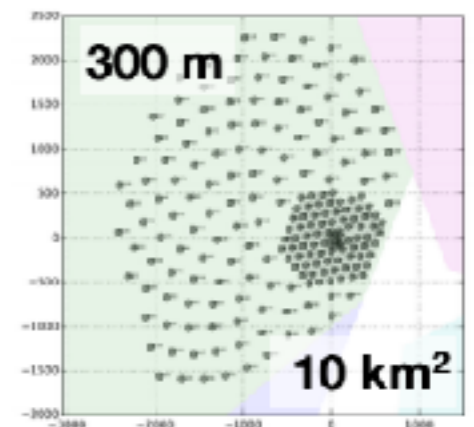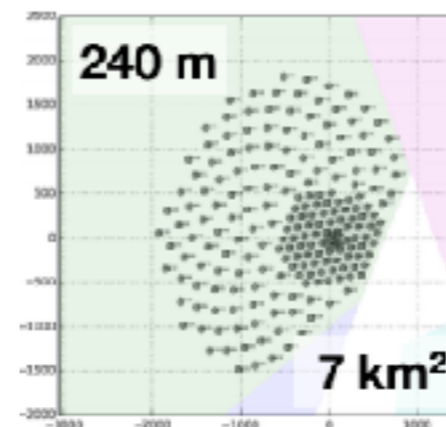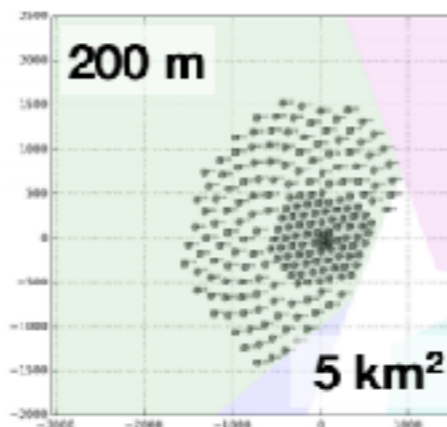
2x115 lines in Sicily (ARCA)
115 lines in France (ORCA)

~120 new lines
Perf. increased by 1 order of mag.