



Neutrino-Multimessenger Searches In the Mediterranean

VLVnT 2018

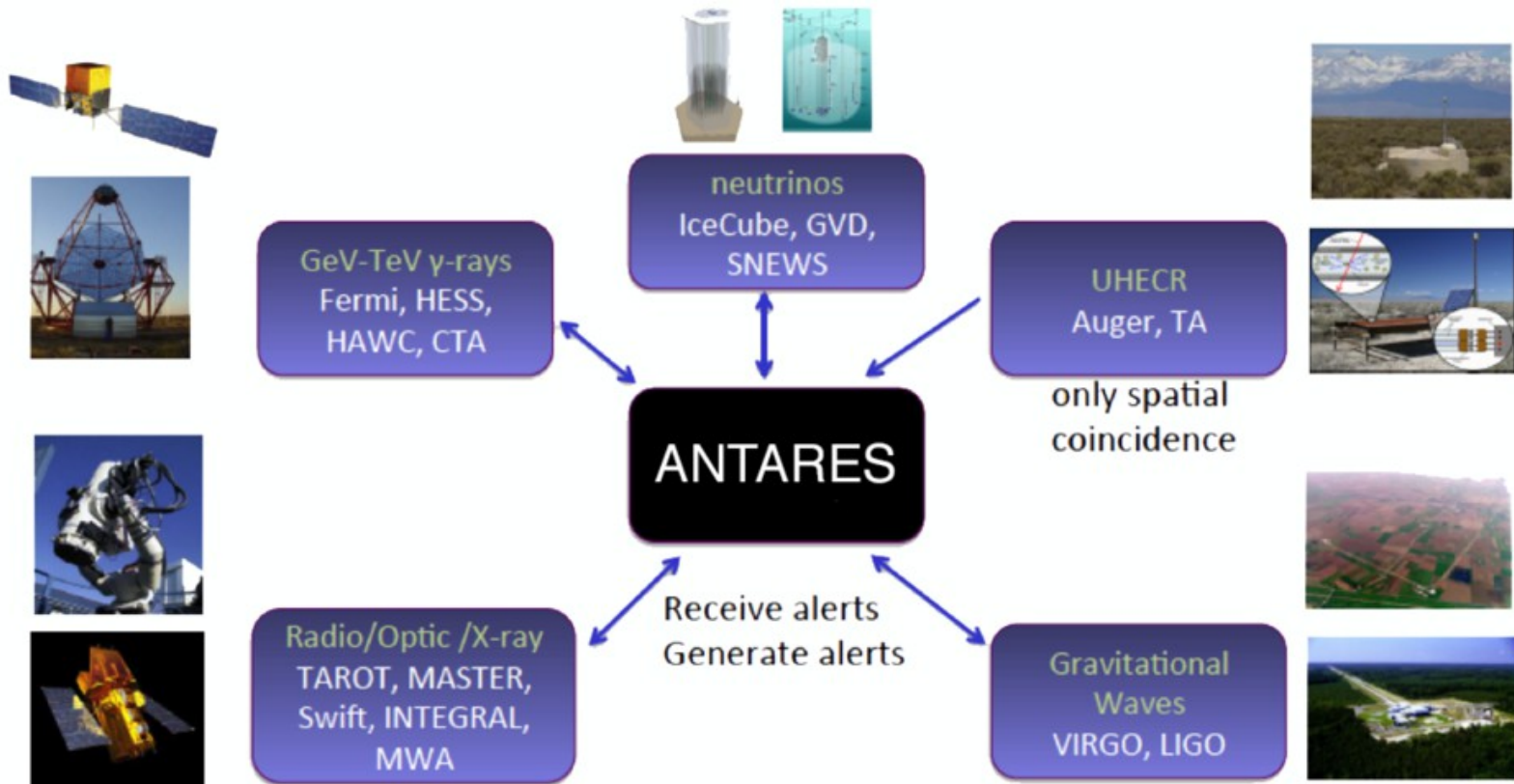


JINJR – 03 Oct. 2018

Bruny Baret, A. Coleiro, D. Dornic
For ANTARES & KM3NeT Coll.

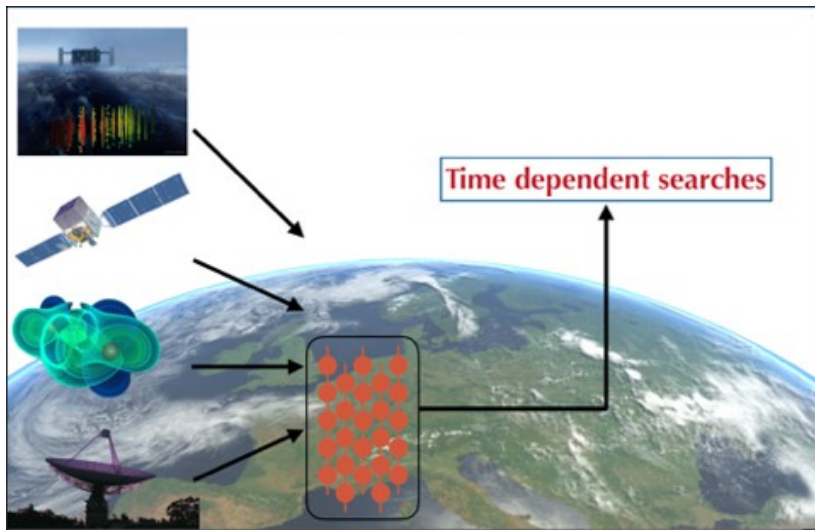


Multimessenger network

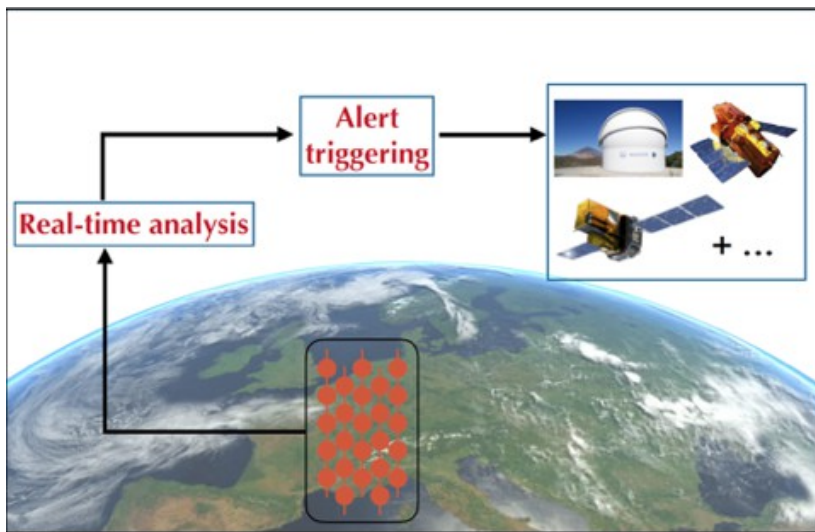




Two approaches



IceCube nus*, GW from LVC**, PARKES/UTMOST/ASKAP fast radio bursts, Swift/Fermi gamma-ray bursts, Fermi/IACT/Hawc blazars...



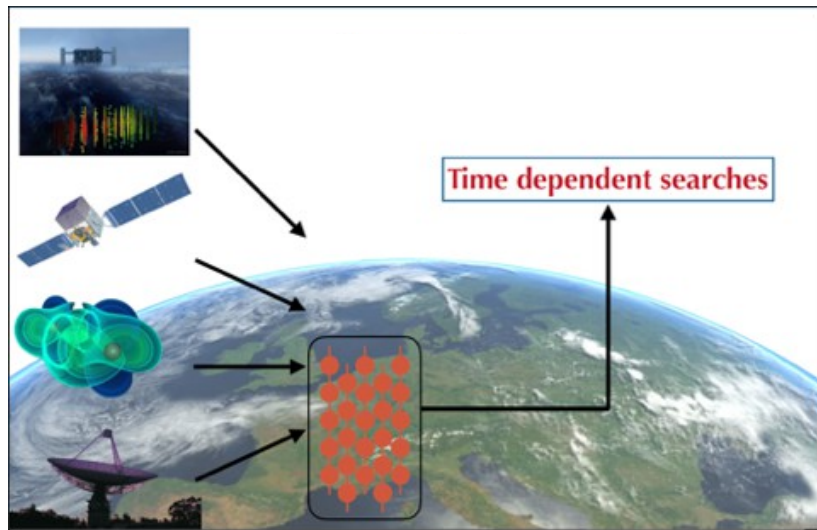
Fast neutrinos online reconstruction
Selection: HE, FAR, direction
Alerts sent to EM partners

* For TXS, see G. Illuminati HE1

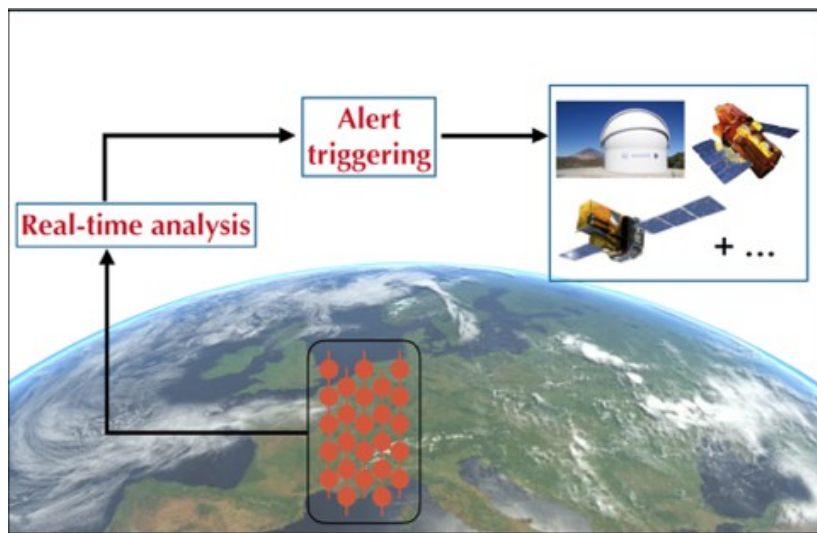
**B. Baret MM2



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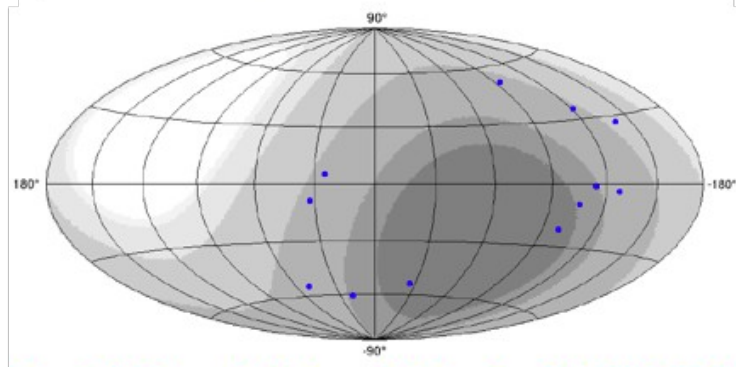
**B. Baret MM2



Fast Radio Bursts

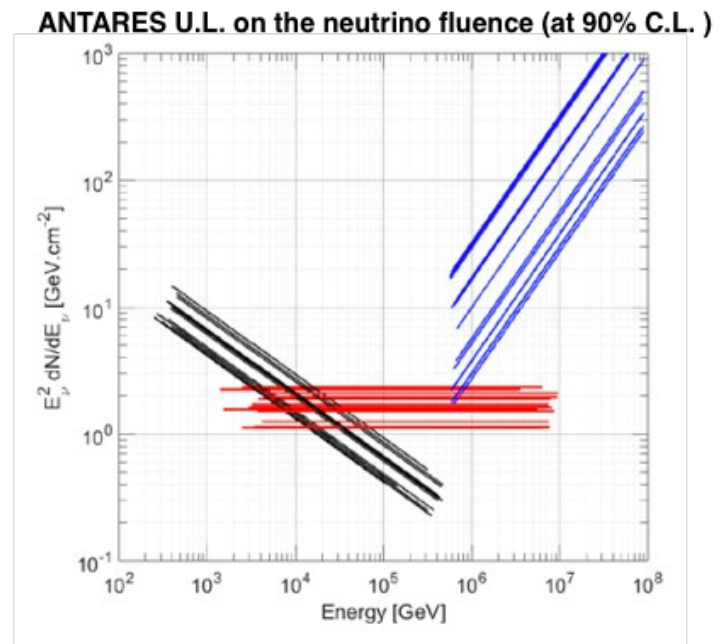
- Search for time/space correlations with fast radio bursts detected by Parkes, UTMOST and ASKAP between 2013 and 2017.

FRB	z_{DM}	T_0 (UTC)	RA ($^{\circ}$)	dec ($^{\circ}$)	radio telescope
131104	0.59	18:04:11.20	101.04	-51.28	Parkes
140514	0.44	17:14:11.06	338.52	-12.31	Parkes
150215	0.55	20:41:41.71	274.36	-4.90	Parkes
150418	0.49	04:29:06.66	109.15	-19.01	Parkes
150807	0.59	17:53:55.83	340.10	-55.27	Parkes
151206	1.385	06:17:52.78	290.36	-4.13	Parkes
151230	0.76	16:15:46.53	145.21	-3.45	Parkes
160102	2.13	08:28:39.37	339.71	-30.18	Parkes
160317	0.70	09:00:36.53	118.45	-29.61	UTMOST
160410	0.18	08:33:39.68	130.35	6.08	UTMOST
160608	0.37	03:53:01.09	114.17	-40.78	UTMOST
170107	0.48	20:05:45.14	170.79	-5.02	ASKAP



Since 2017, analysis in real-time for SUPERB FRBs.

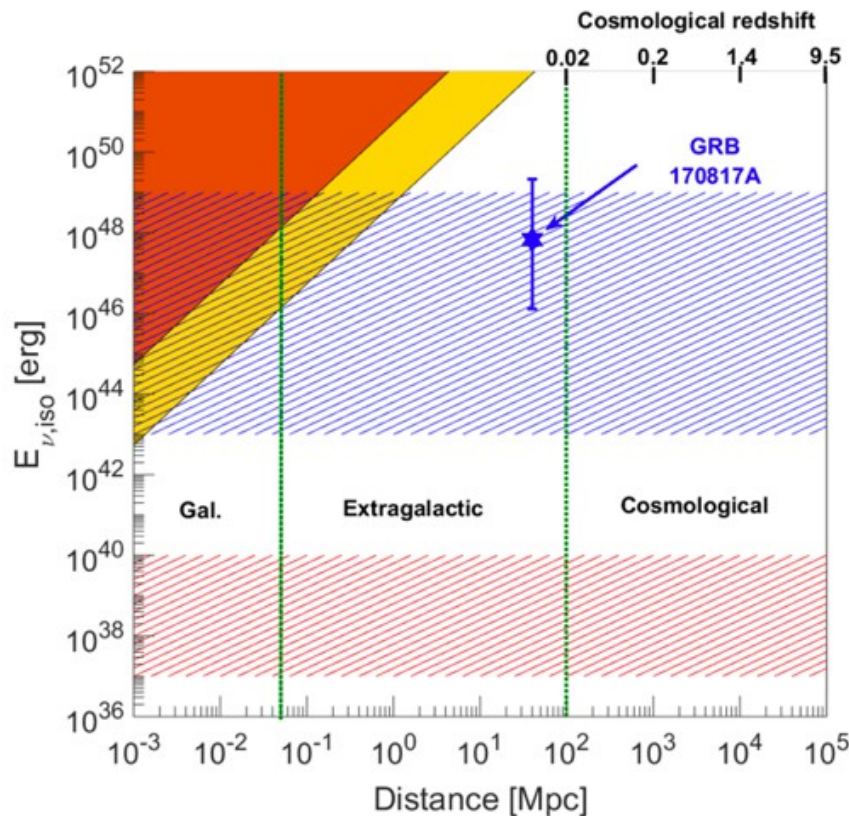
- No significant correlation
- Limits on the neutrino fluence assuming different energy spectrum.



Albert et al., arXiv:1807.04045



Fast Radio Bursts



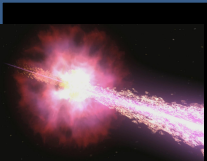
- ▶ Constraints on the TeV-PeV neutrino energy released by FRBs
- ▶ Comparison with short GRB and magnetar giant flares / soft gamma-ray repeaters models

$$E_{\nu,iso} = \frac{4\pi D(z)^2}{1+z} \cdot F_{\nu}$$

FRB: no distance measured [because no optical follow-up]. Only upper-limit with DM.

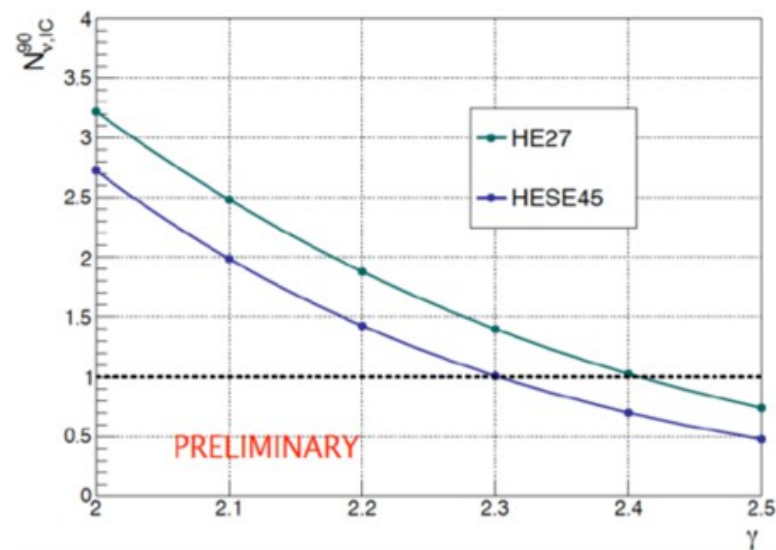
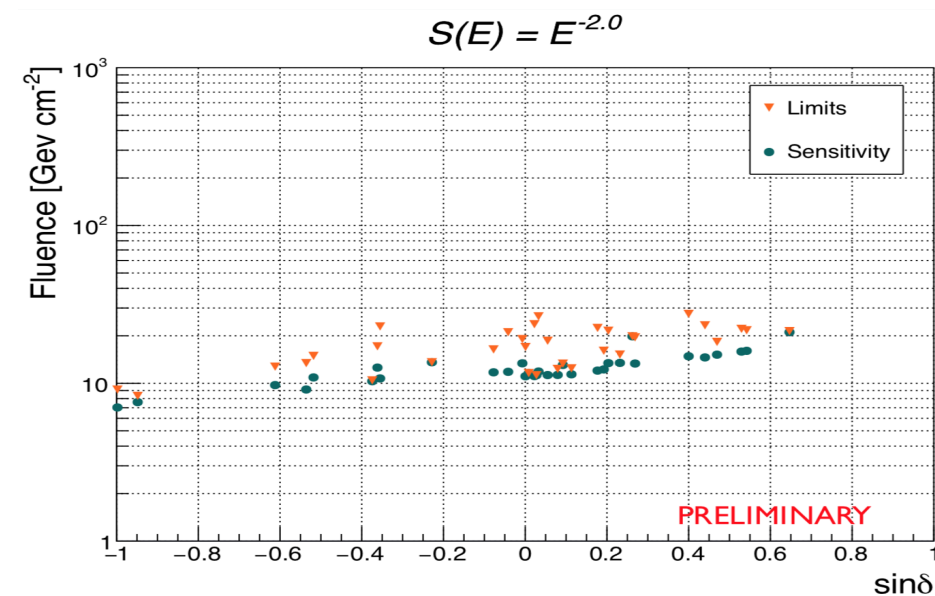
Using $R_{FRB} = 1.7 \cdot 10^3$ /day \Rightarrow upper limits on the quasi diffuse flux (normalised to $E_0 = 100$ TeV), $E^2\Phi^{90\%} < 0.9, 2.0, 0.7 \cdot 10^{-4}$ GeV cm⁻² s⁻¹ sr⁻¹ for E^{-1.0}, E^{-2.0} and E^{-2.5}

- **A polarized fast radio burst at low Galactic latitude** E. Petroff et al., MNRAS (2017) 469 (4): 4465-448
- **The SURvey for Pulsars and Extragalactic Radio Bursts II: New FRB discoveries and their follow-up** S. Bhandari et al., MNRAS 475, 1427–1446 (2018)
- **Search for high-energy neutrinos from the fast radio bursts with ANTARES** A. Albert et al., submitted MNRAS.

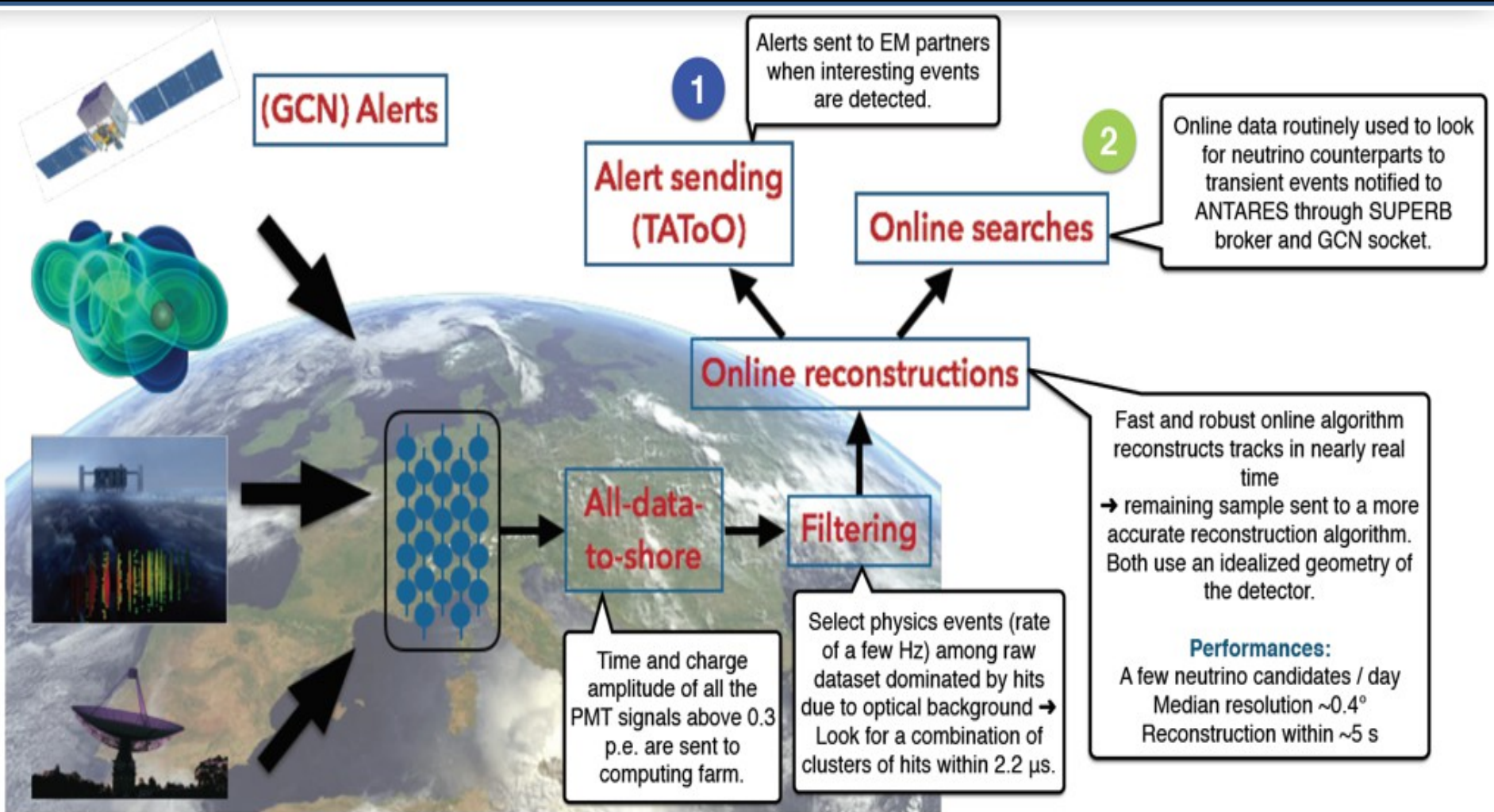


Time Correlation with IceCube events

- Search for track+cascade time correlations [0.1; 120 days] with IceCube HESE (x 20) and high-energy ν_μ tracks (x 34) in the ANTARES field of view between 2010 and 2016.
⇒ Test transient origin of IceCube events
- No significant correlation (largest excess: 89% p-value post-trial)
- Limits on the fluence w.r.t. flare duration
- Constraint on the spectral index of the neutrino spectrum (assuming ~sec. transient emission)



Antares Online System

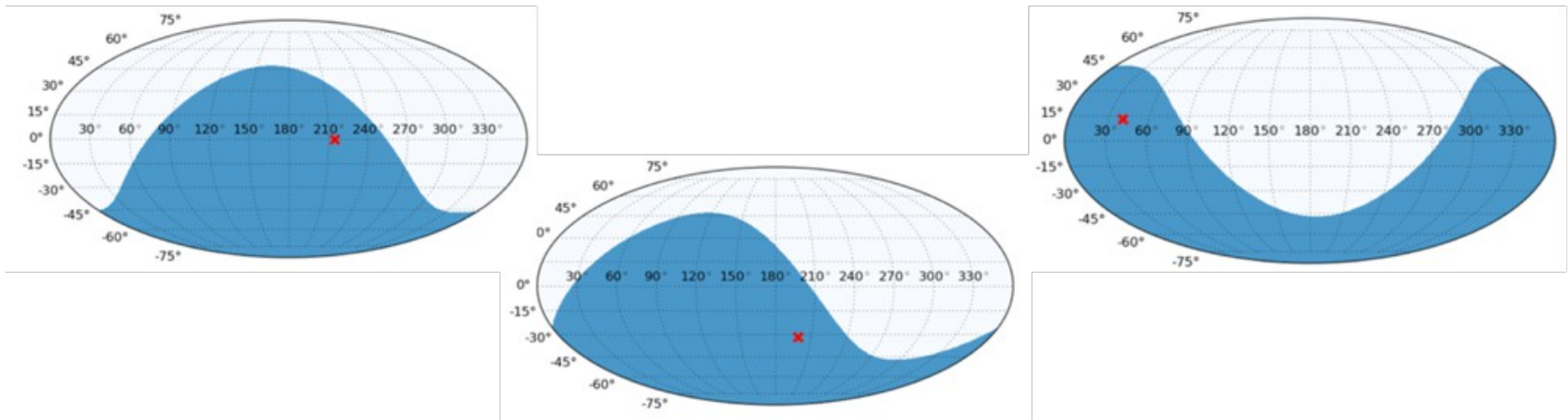


All-data-to-shore transfer, triggering, reconstruction in ~ 5 s.



Follow-up of IceCube Events

- Search in real-time for neutrino counterparts of IC HESE and EHE ($> 1\text{PeV}$) alerts sent through AMON to the public community (GCN network)
 - ⇒ 14 alerts sent so far: 6 analyzed, +4 retracted by IC, 4 not visible at T_0 as upgoing.



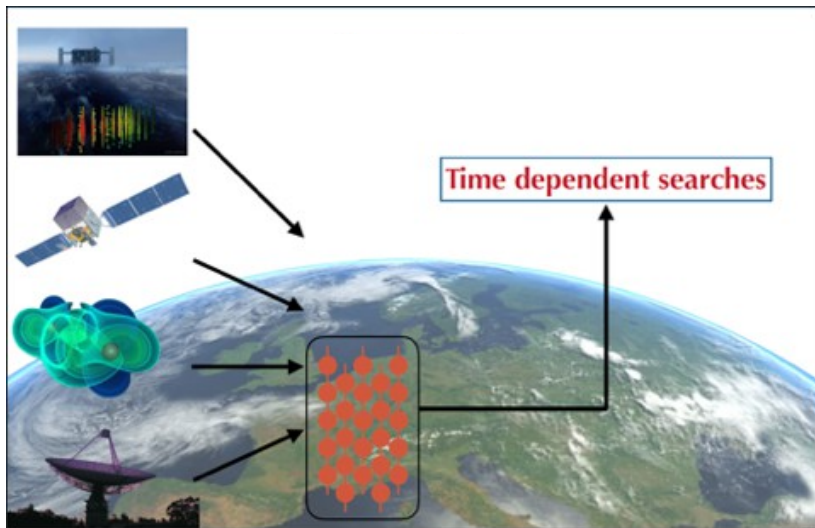
No ANTARES event found in coincidence (ROI= 2° , $\pm 500\text{s}$; $\pm 1\text{h}$)
⇒ U.L. on the radiant neutrino fluence for E^{-2} and $E^{-2.5}$ spectra:

$\sim 15 \text{ GeV/cm}^2$ in $[2.8 \text{ TeV}, 3.3 \text{ PeV}]$ for E^{-2}
 $\sim 30 \text{ GeV/cm}^2$ in $[0.4 \text{ TeV}, 280 \text{ TeV}]$ for $E^{-2.5}$

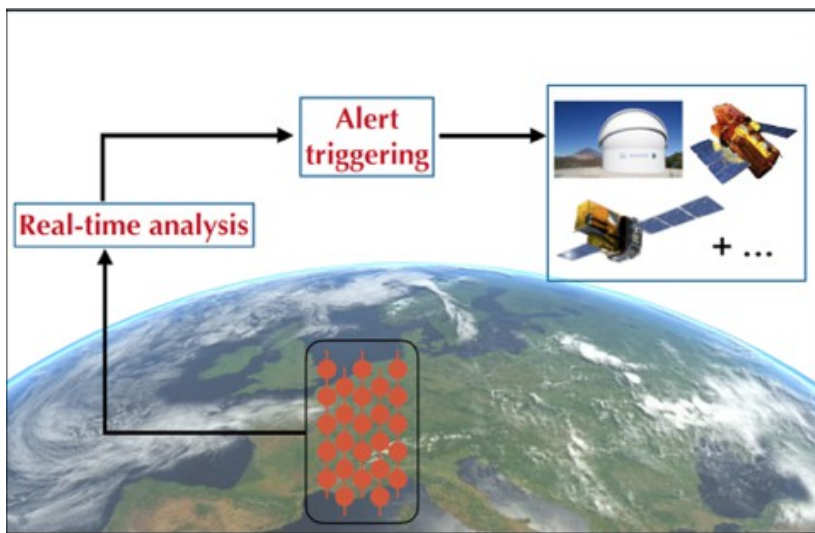
- IC171015: GCN #22019 / Atel #10584
- IC161103: GCN #20134 / Atel #9715
- IC170922: GCN #21923 / Atel #10773
- IC160814: GCN #19885 / Atel #9440
- IC170321: GCN #20926 / Atel #10189
- IC160731: / Atel #9324



Two approaches



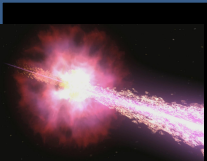
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Who's following Antares Alerts?

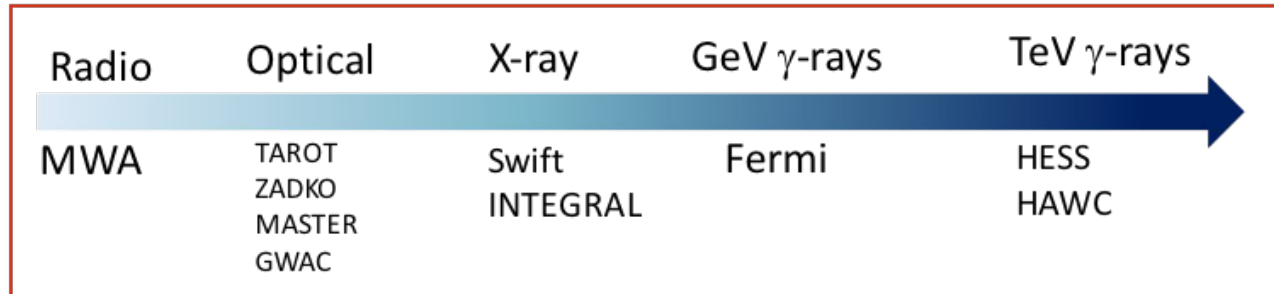




What kind of alerts?

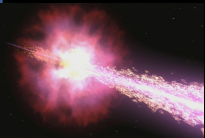
→ **ANTARES real time alerts:**

- Doublet of neutrinos: ~ 0.04 events/yr
- Single neutrino with direction close to local galaxies: ~ 1 TeV, ~ 10 events/ yr
- Single HE neutrinos: ~ 5 TeV, 20 ev/ yr
- Single VHE neutrinos: ~ 30 TeV, $\sim 3-4$ ev/yr



→ **Statistics of the sent neutrino alerts (07/2009-07/2018)**

- 281 alerts sent to robotic telescopes [79 DIR + 202 HE]
- 15 sent to Swift
- 15 sent to Integral (4 followed)
- >20 to MWA (3 followed)
- 2 to HESS



ANT150901A

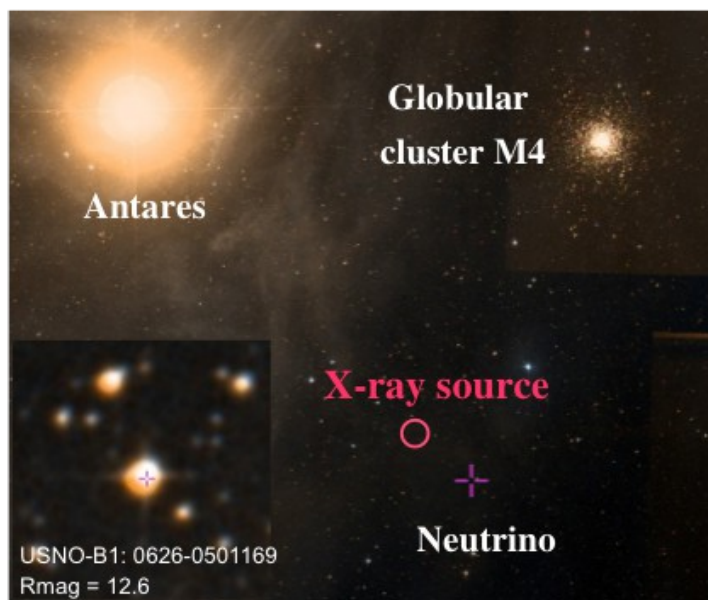
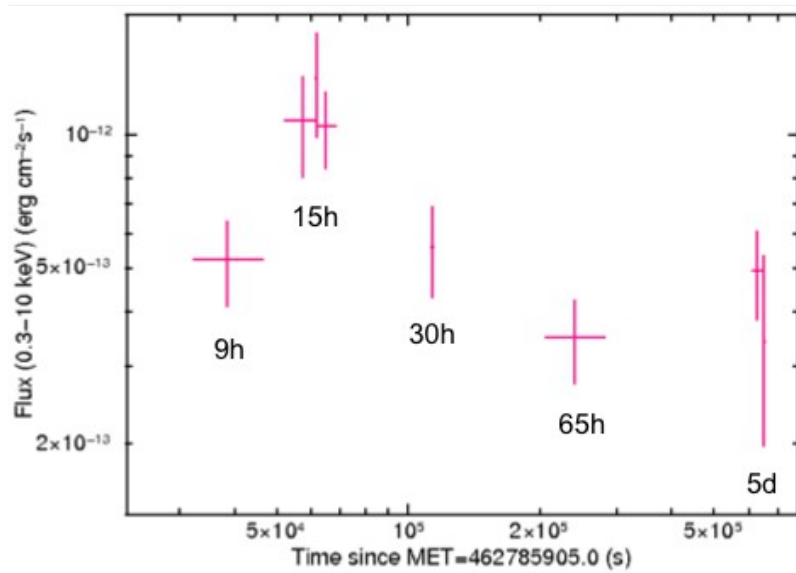
Alert VHE (Sept. 1, 2015)

(Nhit, Amp) = (127, 356), $E \sim 50$ TeV
RA=246.306°; dec=-27.468°

Sent after 10 s to MASTER, Swift-XRT

➔ Follow-up with Swift-XRT after 9h

➔ Follow-up with MASTER after 10h



➔ Emission of a GCN notice (#18231) and an ATEL (#7987) after ~24h to require more follow-up to identify the X-ray flare



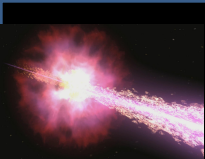
ANT150901A

Great interest from the community: 15 ATels + 6 GCNs + few non-reported

- ➔ Neutrino
IceCube: ATel 8097
- ➔ Optical
Pan-STARRS: ATel 7992, 8027
SALT: ATel 7993
NOT: ATel 7994, GCN 18236
WiFes: ATel 7996
CAHA: ATel 7998, GCN 18241
MASTER: ATel 8000, GCN 18240
LSGT: ATel 8002
NIC: ATel 8006
ANU: GCN 18242
GCM: GCN 18239
VLT/X-Shooter: private
- ➔ X-ray
Integral: ATel 7995
MAXI: ATel 8003
Swift: ATel 8124, GCN 18231
- ➔ Radio
Jansky VLA: ATel 7999, 8034
- ➔ Gamma-ray
MAGIC: ATel 8203
Fermi/GBM: GCN 18352
HESS: private
HAWC: private

⇒ USNO-B1.0 0626-0501169: **young accreting G-K star, or a binary system of chromospheric active stars (RS CVn) undergoing a flaring episode that produced the X-ray emission.**

Albert et al., MNRAS in preparation



Follow-up results

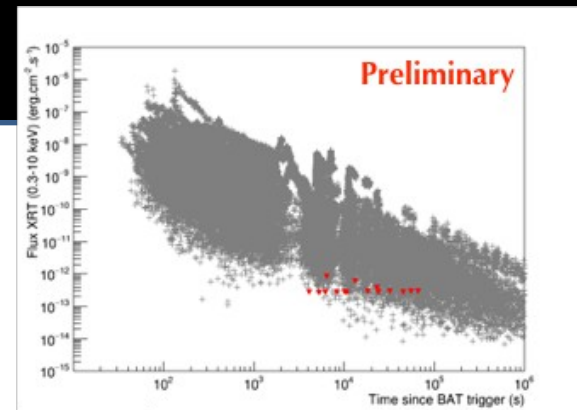
Early follow-up:

Visible: 189 alerts analyzed 01/2010-07/2018 from TAROT, ROTSE, MASTER => 27 alerts with delay <1min

X-ray: 16 alerts analyzed 06/2013-07/2018 => average delay ~5-6h

=> no transient candidate associated to neutrinos

Adrián-Martínez et al., JCAP 02(2016) 062

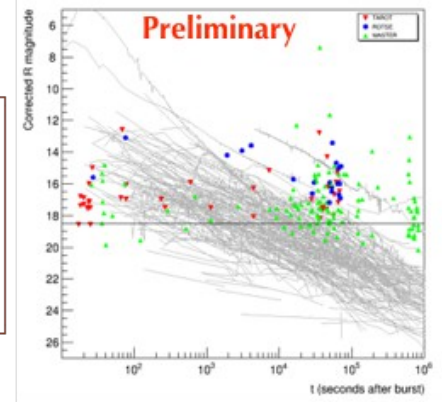


Long-term follow-up:

186 alerts with a “rather good” long-term follow-up (01/2010-07/2018)

- ➔ No SN (and no interesting transient) associated with the neutrinos
- ➔ $N_{\text{exp}}(\text{SN}) = 0.3-0.4$ for the full follow-up [SN rate = $2.4 \cdot 10^{-4} \text{ yr}^{-1} \text{ Mpc}^{-3}$]

Adrián-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)

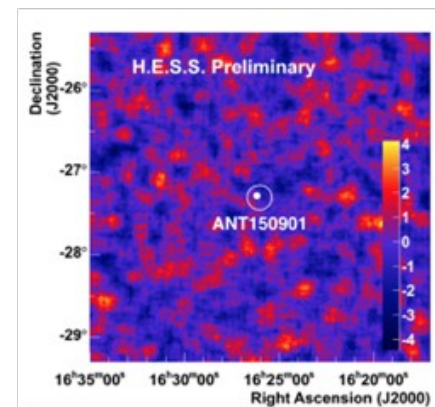
- ➔ Analysis on-going

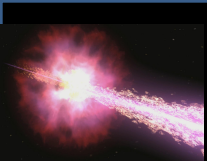
H.E.S.S. follow-up:

2 alerts followed with very small delay (2015-2017)

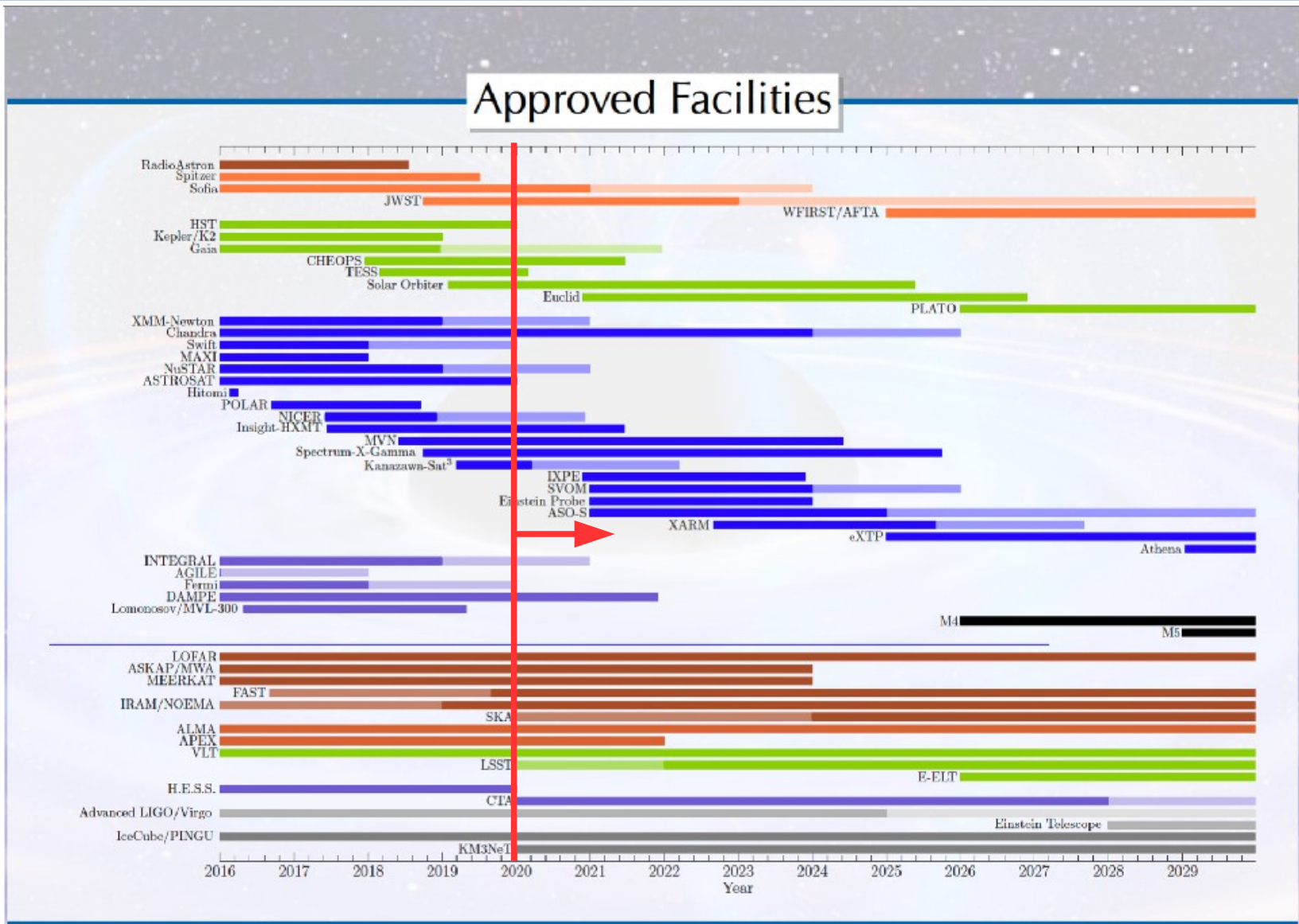
- ➔ ANT150901(+2.5d), ANT170130 (+32s): No VHE candidates associated with the neutrinos

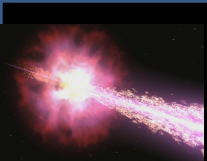
Schüssler et al., arXiv: 1705.08258





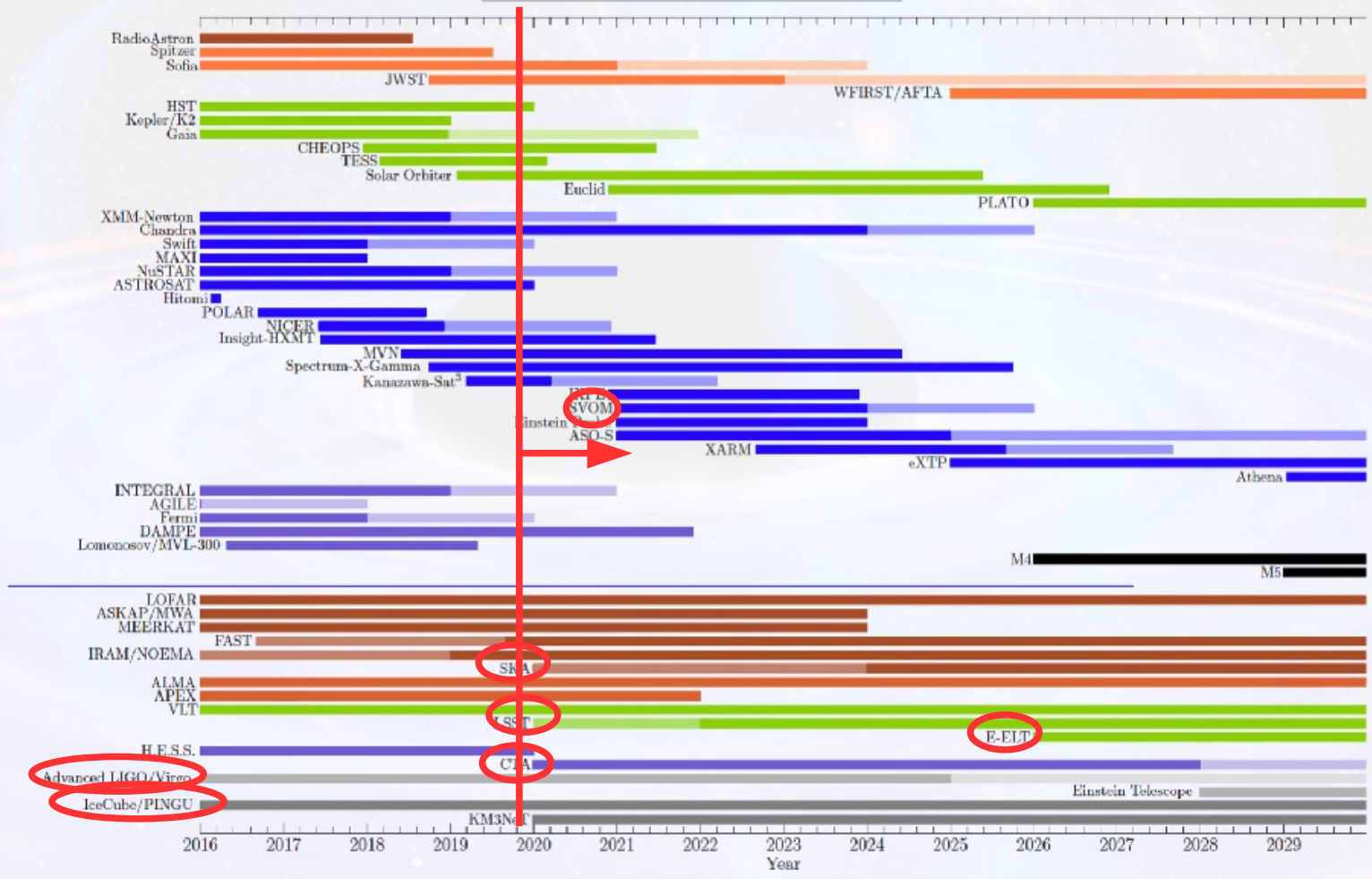
KM3NeT - Plans





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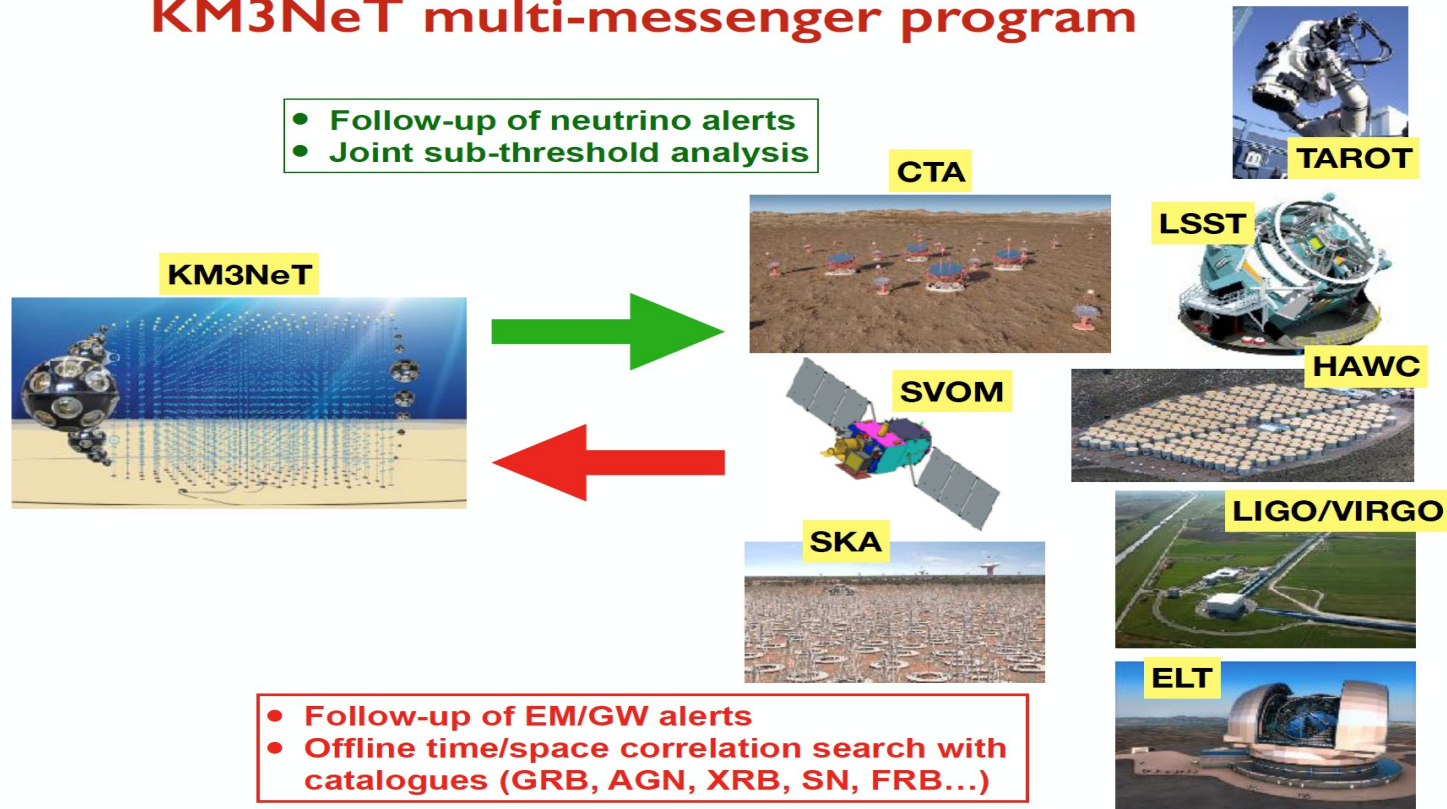
Approved Facilities





KM3NeT - Plans

KM3NeT multi-messenger program

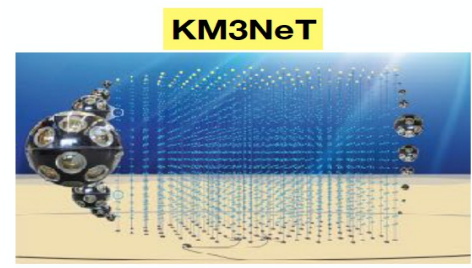




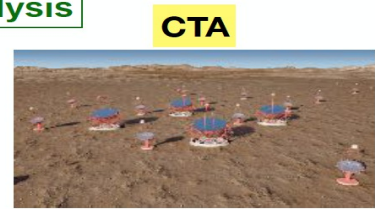
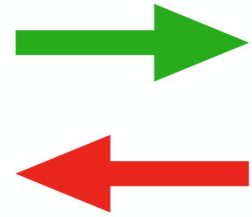
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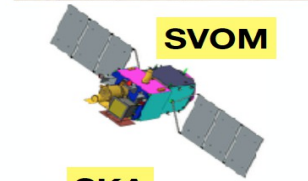
- Follow-up of neutrino alerts
- Joint sub-threshold analysis



KM3NeT



CTA



SVOM



SKA



TAROT



LSST



HAWC



LIGO/VIRGO



ELT

- Follow-up of EM/GW alerts
- Offline time/space correlation search with catalogues (GRB, AGN, XRB, SN, FRB...)

+
(NEW w.r.t Antares*!)



<http://snews.bnl.gov>

- Super-K
- IceCube
- LVD
- Borexino

+ KM3NeT



Alerts are public
Sent by mail

*M. Colomer HE3



What else?

Nothing to add, multimessenger is the way...