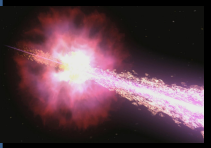
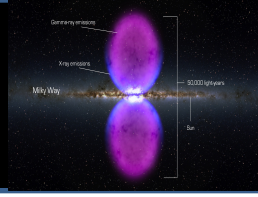




Gravitational Waves and Neutrinos Joint Searches In the Mediterranean

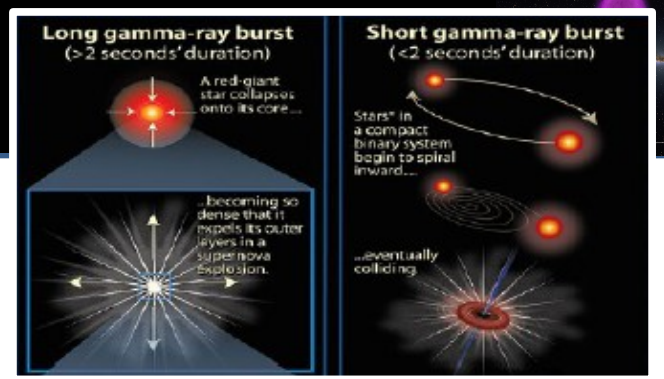
VLVnT 2018

JINJR – 04 Oct. 2018

Bruny Baret
For ANTARES & KM3NeT Coll.

Main coll.: A. Coleiro, T. Pradier, A. Kouchner (Ant/KM3NeT), C. Finley (I3), E. Chassande-Mottin (Virgo),I. Bartos (LSC, I3 gen2)+...

What kind of sources?



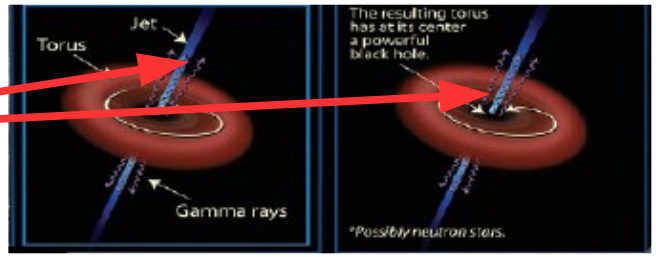
GW emission:

Collapse or binary mergers

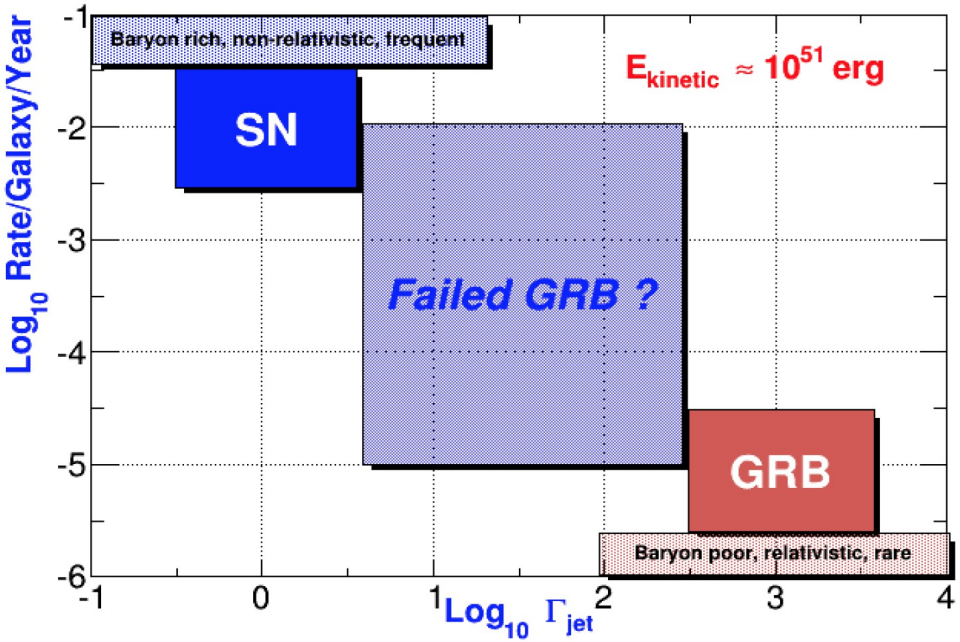
HEN emission:

Acceleration of protons, followed by pp and pγ interactions

$$p,\gamma \rightarrow \pi^{\pm} \rightarrow \mu^{\pm}, \nu_{\mu} \rightarrow e^{\pm}, \nu_{e}, \nu_{\mu}$$



From SN to GRBs (Ando, 2009)

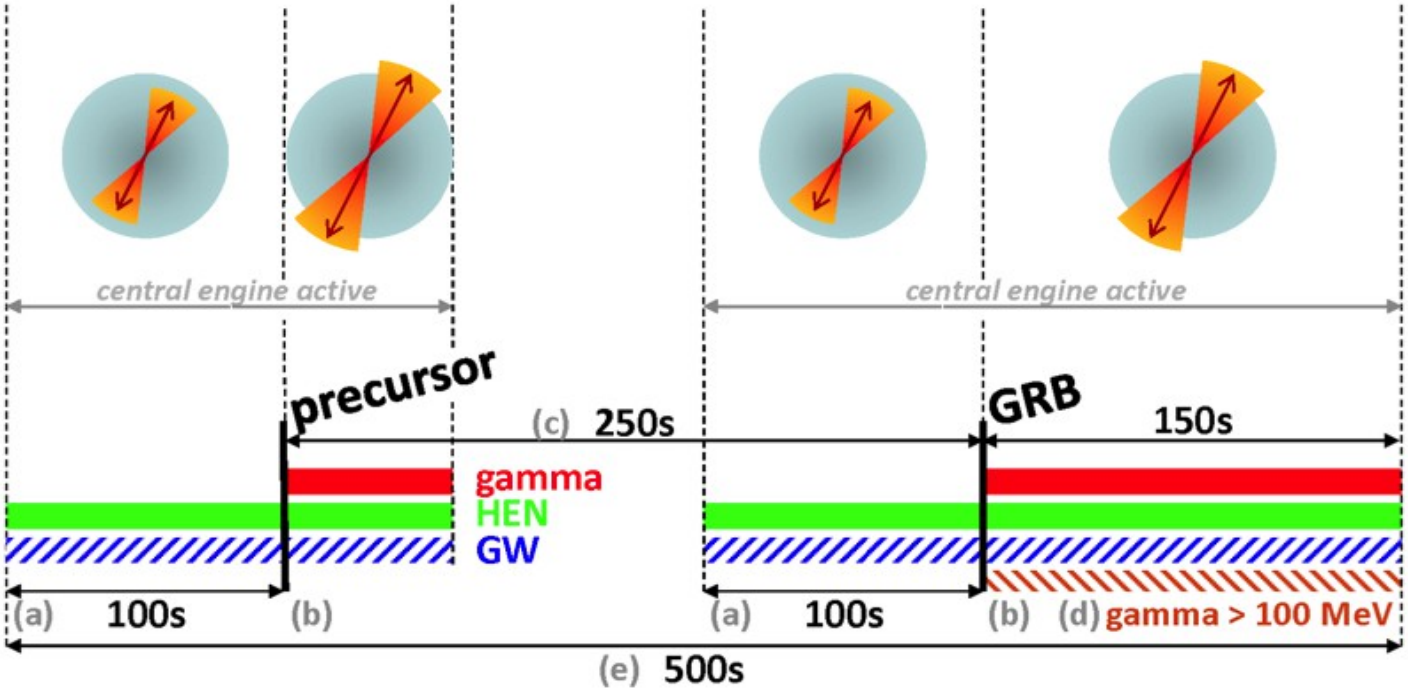


"Failed" GRB:

- Optically thick media: no or weak γ-ray emission
- Possibly detectable by GW+HEN

What kind of time window?

B. Baret et al., Astroparticle Physics 35 (2011) 1-7
T = ±500s [arXiv:1101.4669]



What kind of searches?

LSC Alerts

LSC low significance events

Low Latency (<1d):
"online" sample
- Raw calibrations
- up-going tracks
- Hard Cut: "best" evts

Yes/No
GCN notice

Refined Search (O(wk)):
"offline" sample:
- Refined calibrations
- Upward/Downward*
- Tracks/Showers**
- FAR based cut

Fluence Upper Limits
Skymaps

Subthreshold Search (O(yr)):
"offline" sample:
- Fine calibrations
- Upward
- Tracks/Showers

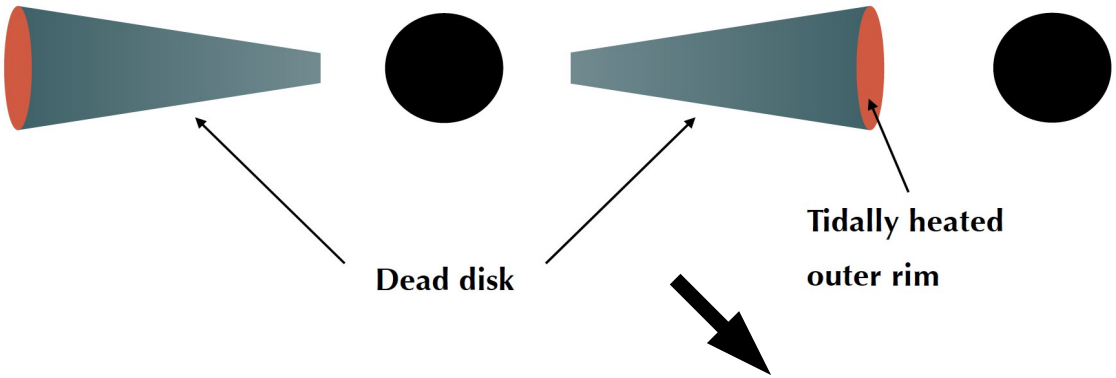
FAR based / Max horizon cut

Population constraints

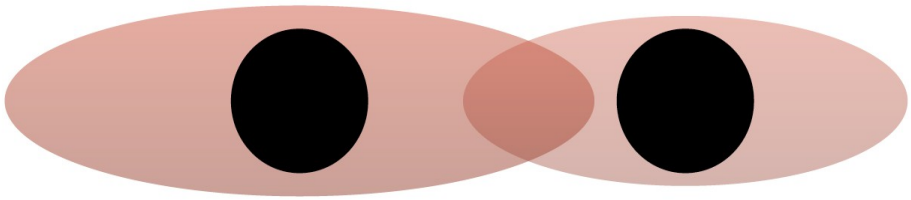
Data selection complexity (-> sensitivity gain)

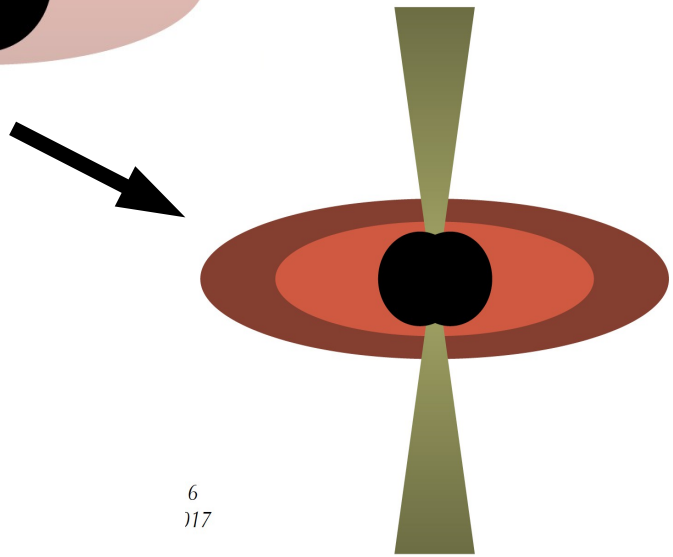
* From GW170104 on
**From GW170817 on

Why follow BH-BH mergers?



Perna et al., 2016
Kotera & Silk, 2017
et al., …

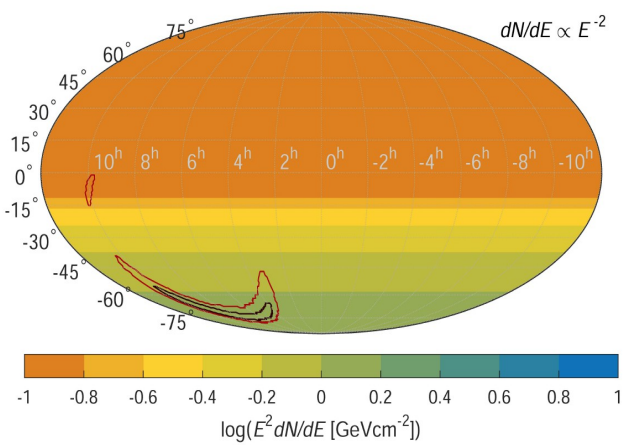


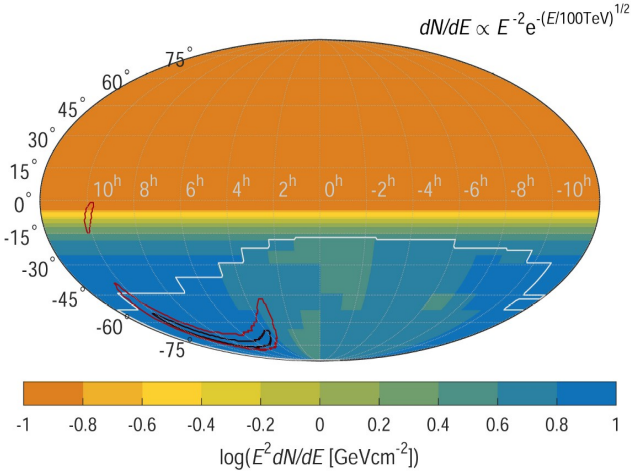


Or BHs in dense environment (near Galactic Nuclei)

Follow-ups I

GW150914





$$E^{ul}_{\nu,tot} = 5.4 \times 10^{51} - 1.3 \times 10^{54}\ \mathrm{erg}$$

$$E^{ul(cutoff)}_{\nu,tot} = 7.9 \times 10^{51} - 4.5 \times 10^{54}\ \mathrm{erg}$$

"ONLINE" cuts

	limit [GeV cm^{-2}]
100 GeV – 1 TeV	151.9
1 TeV – 10 TeV	17.5
10 TeV – 100 TeV	5.1
100 TeV – 1 PeV	5.5
1 PeV – 10 PeV	2.8
10 PeV – 100 PeV	6.5
100 PeV – 1 EeV	27.6

ANTARES

IceCube

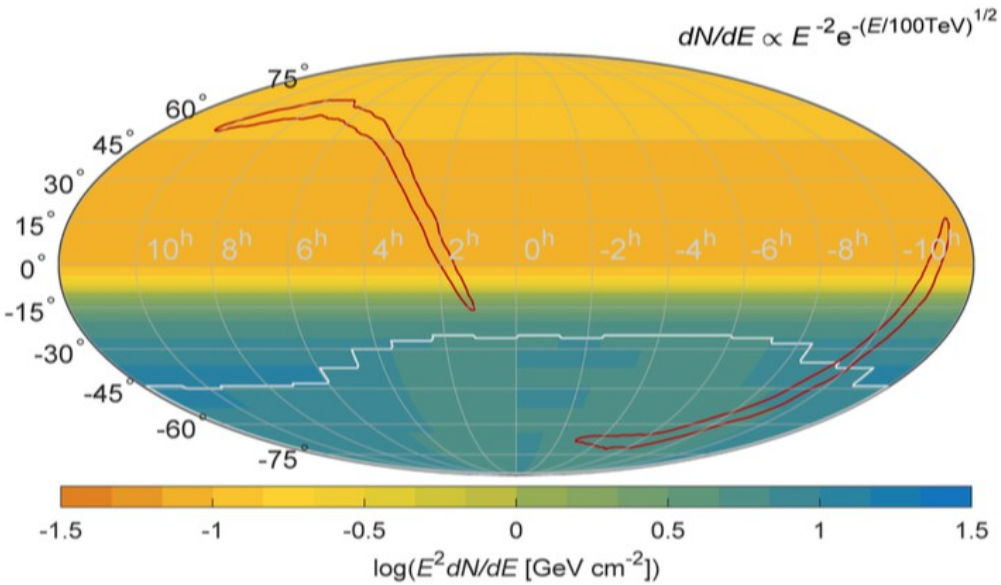
Phys. Rev. D 93, 122010 (2016)
Antares+IceCube+ Ligo+ Virgo Coll.

Follow-ups II

GW150914 (& LVT151012)

PRD 96, 2, 2017, Antares+IceCube+ Ligo+ Virgo Coll.

→ sensitivity~x1/2 by quality cut optimization (probability of a bgd evt=2.7e3 in 1000s)

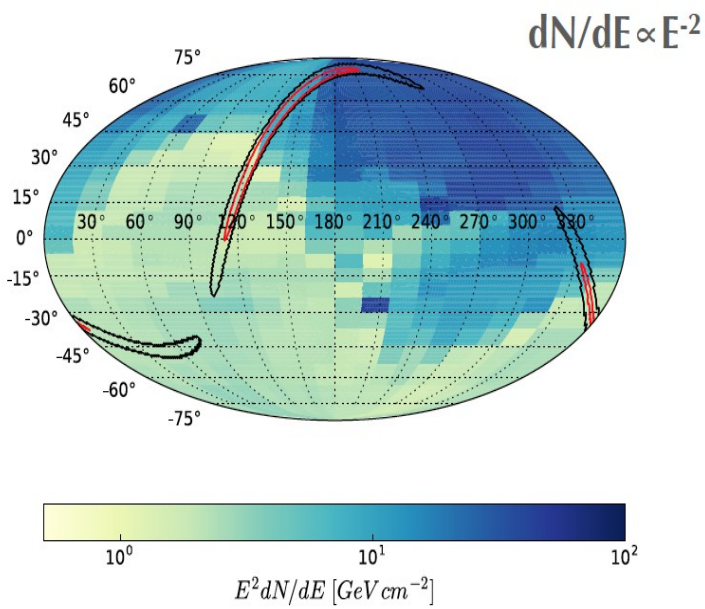


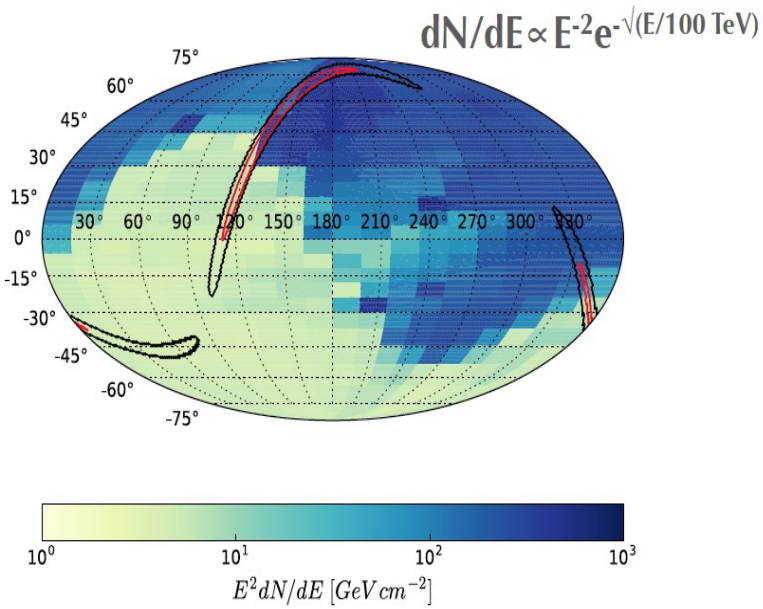
Follow-ups III

GW170104

EPJC 93, 77, 2017 , Antares Coll.

→ full sky(tracks) + systematic uncertainties

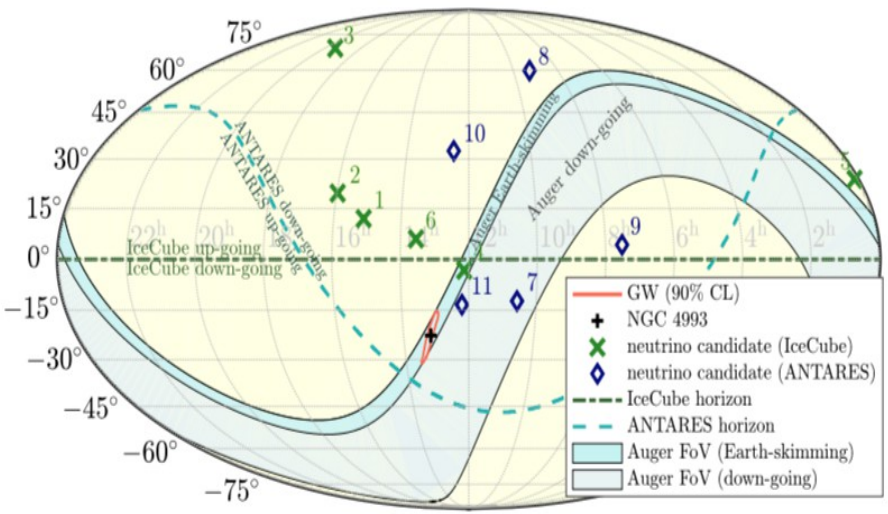


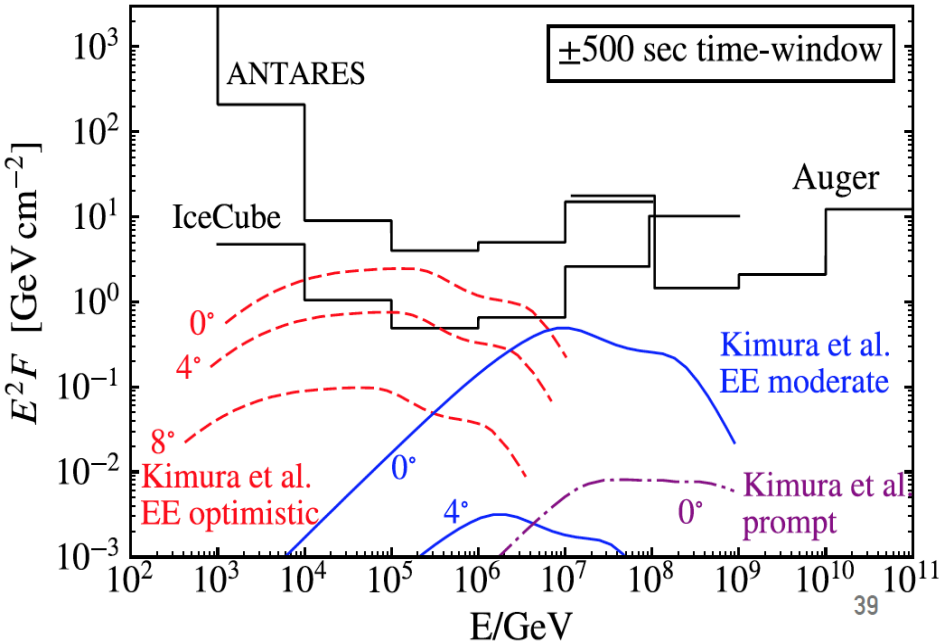


Follow-ups IV

GW170817

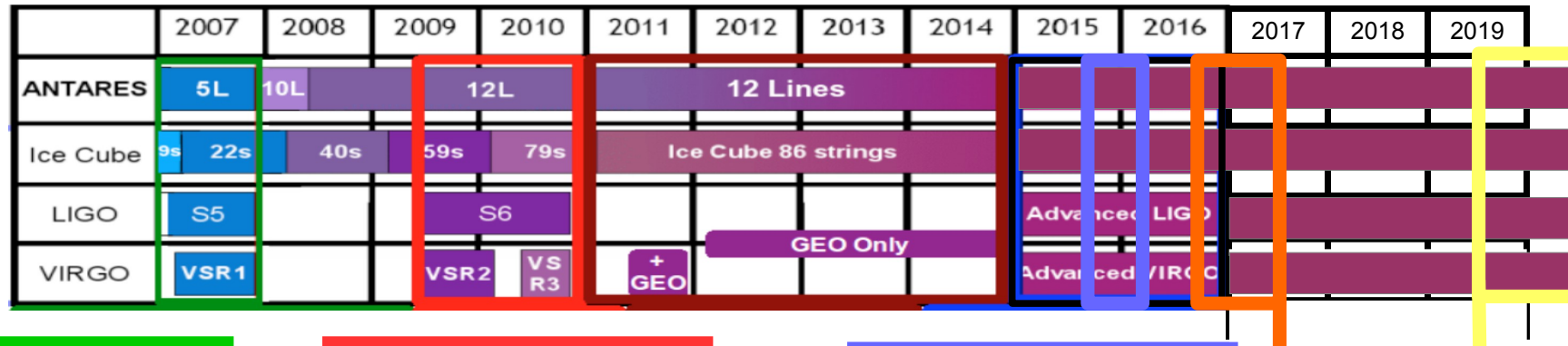
ApJL, 850, 2 (2017) , Antares+IceCube+LSC+AUGER





Antares: all-sky, all flavors (tracks+showers)

Subthreshold Searches



ANTARES+iLigo+iVirgo
JCAP 06 (2013) 008

IceCube+eLigo+eVirgo
PRD 90 102002 (2014)

Antares+Ice3+aLigo O1
To be submitted soon.

O2

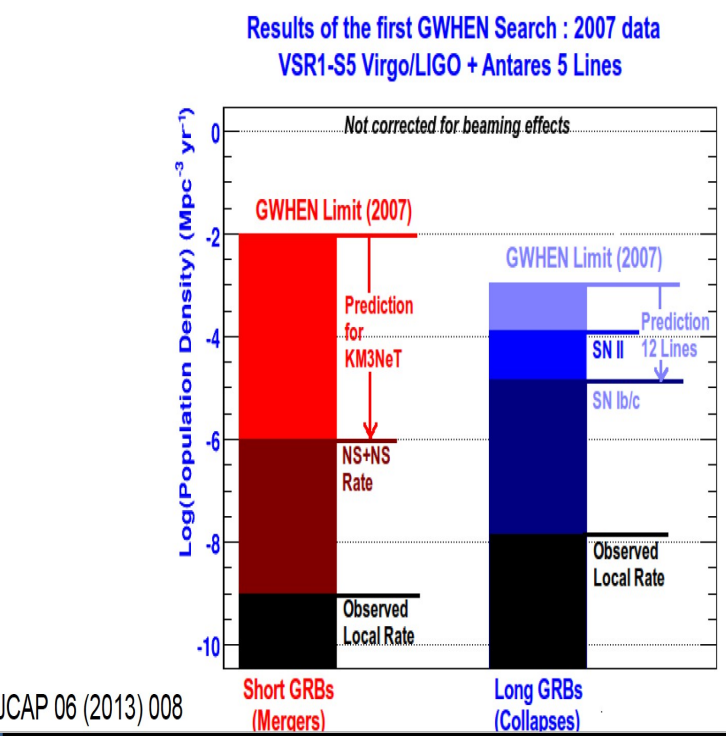
O3

Population constrains

2007: i-Ligo, Antares 7L.
Point Source cuts events -> search for GW

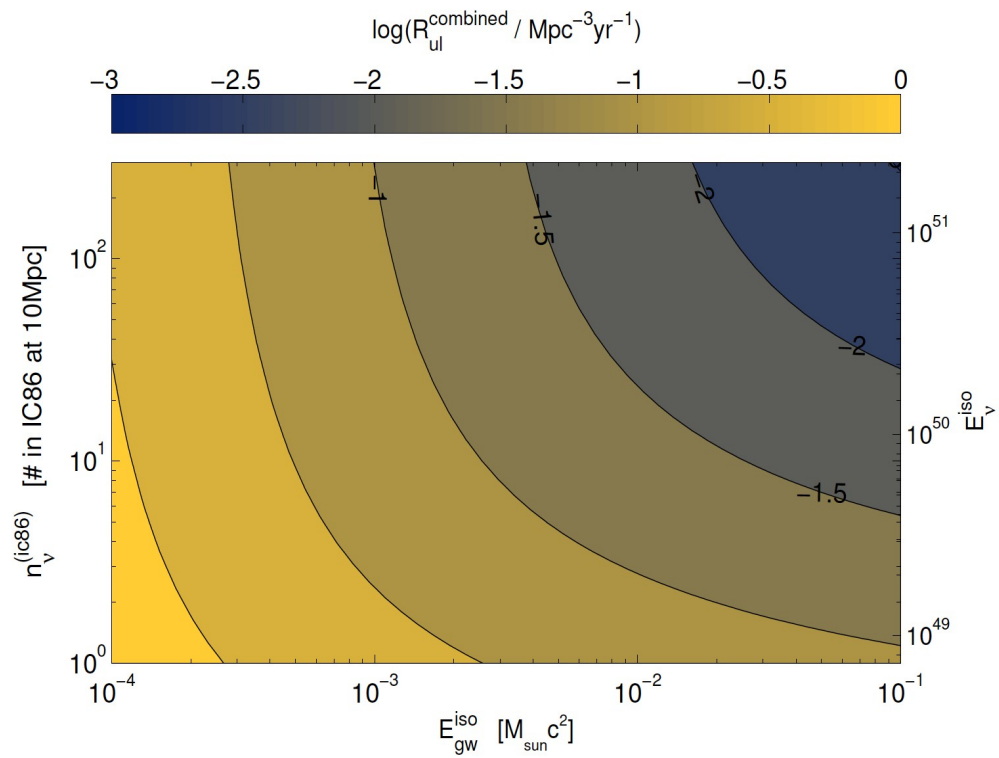
$$R_{UL} = \frac{2.3}{V_{GWHEN}\, T_{obs}} \leftarrow N_{GWHEN} = R_{GWHEN} \times V_{GWHEN} \times T_{obs}$$

GWHEN horizon limited by HEN typically 1-10Mpc



JCAP 06 (2013) 008

2009-2010: LigoVirgo S6 run, IC3 59-79
Point Source cuts, symmetrical search
Aartsen M. G. et al. Phys. Rev. D 90 102002 (2014)

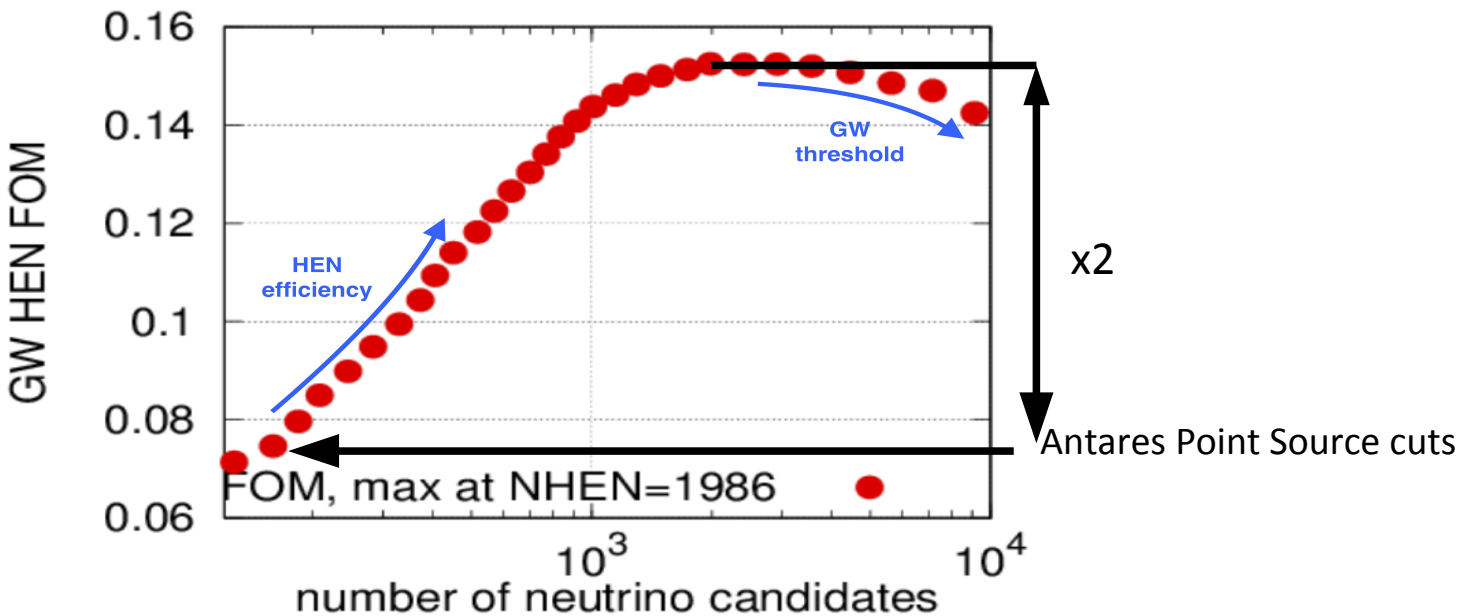


Horizon equalisation optimisation

Maximise the Figure Of Merit (FOM):

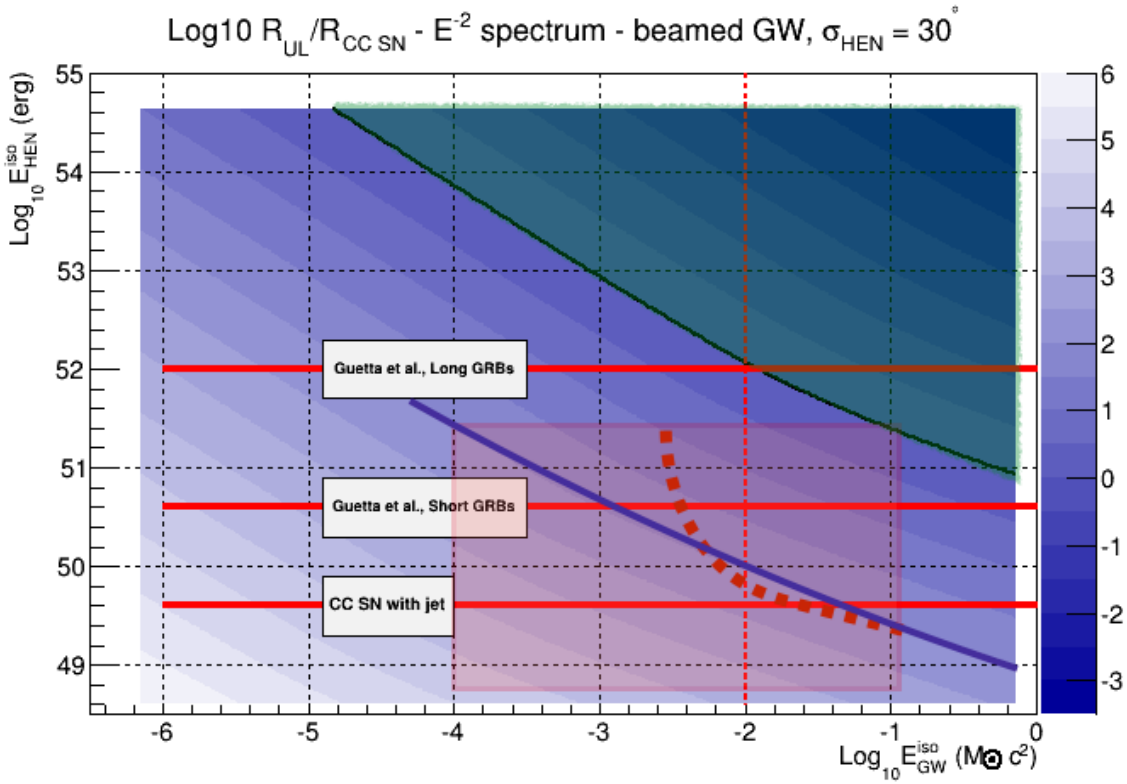
$$\mathcal{N}_{\mathrm{GWHEN}}(\mathrm{cuts}) = \int dt d^3\Omega \mathcal{R}(r,t)\varepsilon_\nu(\mathrm{cuts})\varepsilon_{GW}(\mathrm{cuts}; E_{GW}, r)$$

While keeping False Alarm Probability constant (2.7e-3)



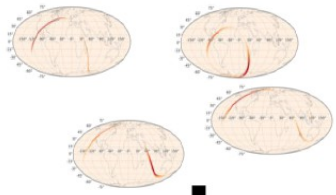
Population constrains – Effect of optimisation

Estimation of Antares sensitivity
with all sky GW efficiencies from Phys. Rev. D 85, 122007 (2012) → conservative

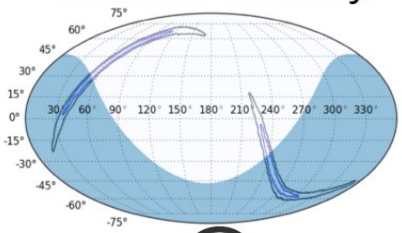


O1 – False Alarm Rate optimisation

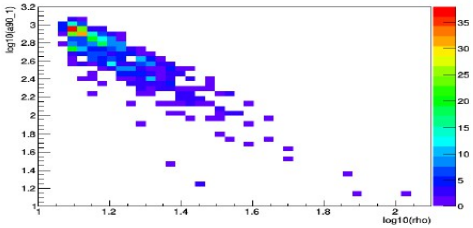
GW signal simulations :



Antares visibility

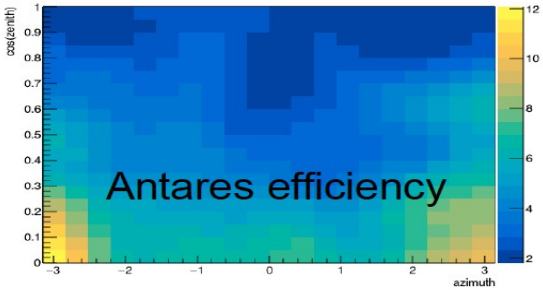


Area V.S. SNR

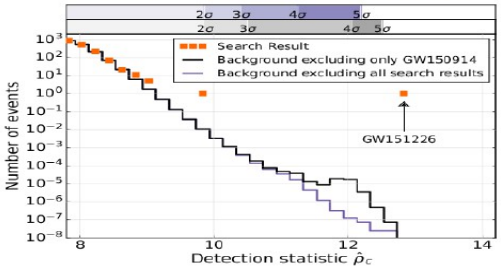


X

X



SNR Bgd distribution



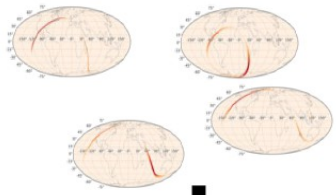
Cut on track quality so that probability to get >=1 event in a 1000s window in the mean banana is <2.7e-3

Nu Candidates list to be fed to the IC3-LigoVirgo S6 (2009-2010) analysis pipeline

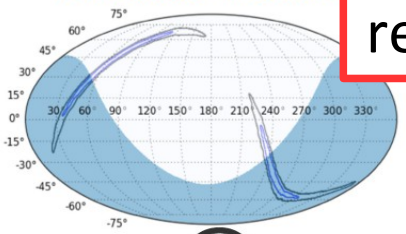
ANTARES data [09/15 ;01/16]

O1 – False Alarm Rate optimisation

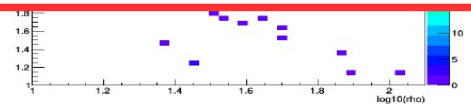
GW signal simulations :



Antares visibilit

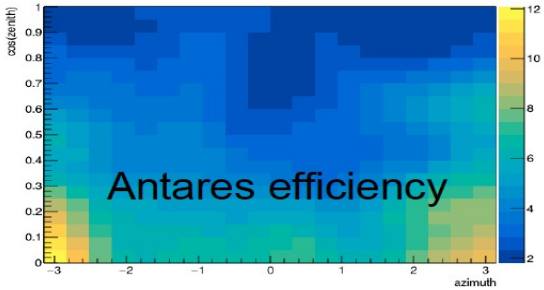


Antares + IceCube +LSC
results & publication coming very soon

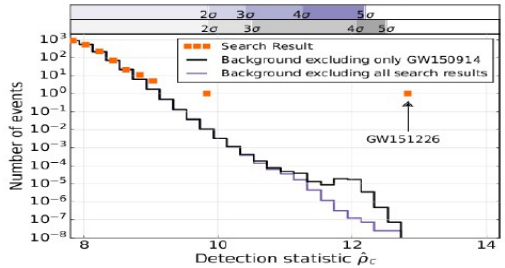


X

X



SNR Bgd distribution

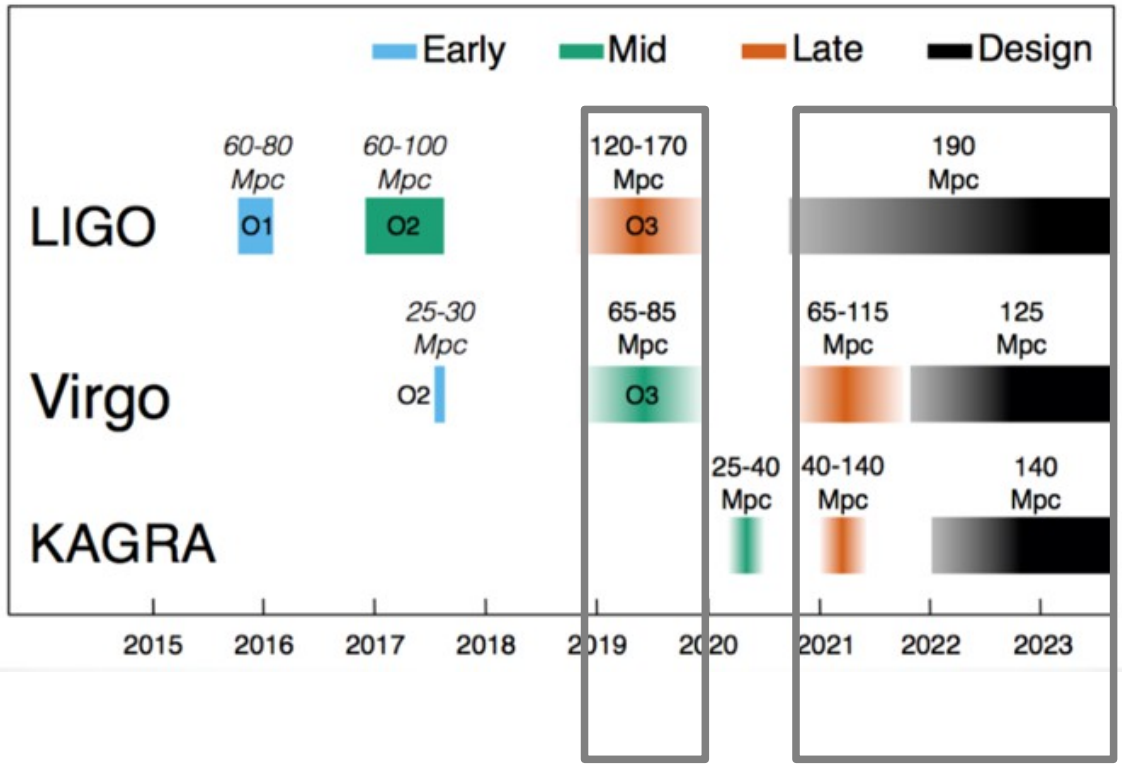


Nu Candidates list to be fed to the IC3-LigoVirgo S6 (2009-2010) analysis pipeline

Cut on track quality so that probability to get >=1 event in a 1000s window in the mean banana is <2.7e-3

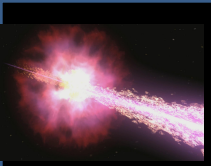
ANTARES data [09/15 ;01/16]

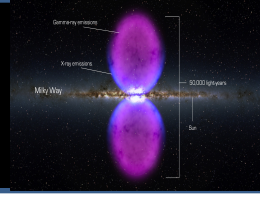
Future?

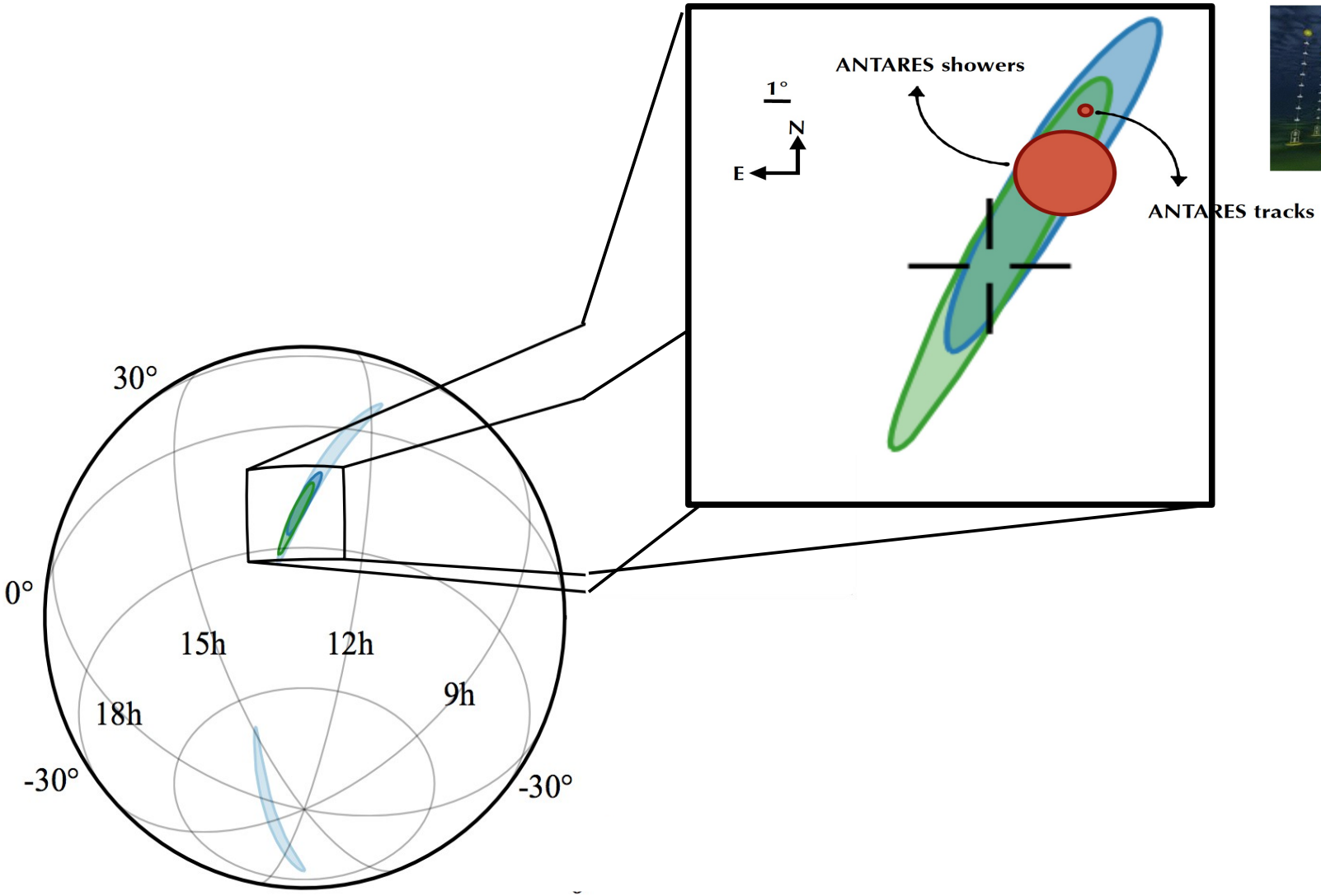


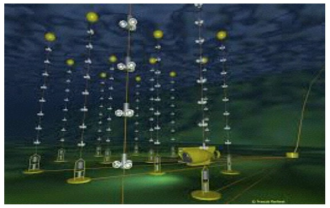
Antares KM3NeT

Future follow up – O3







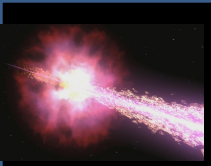


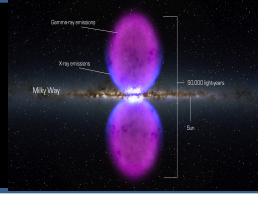
angular resolution:
<deg (tracks) /
~deg (showers)

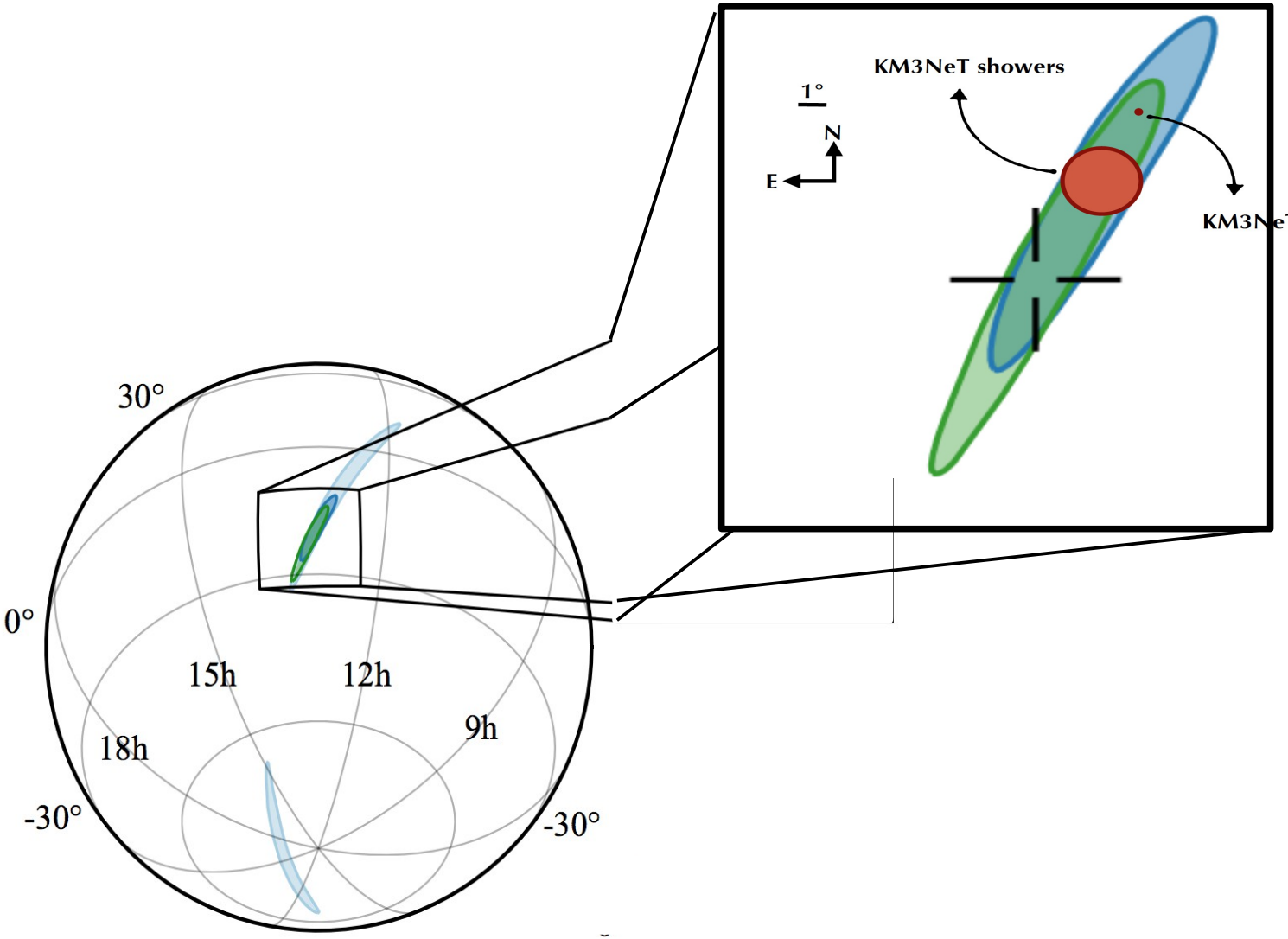
field-of-view:
> 2π sr

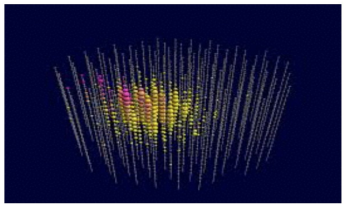
13

Future follow up – beyond O3







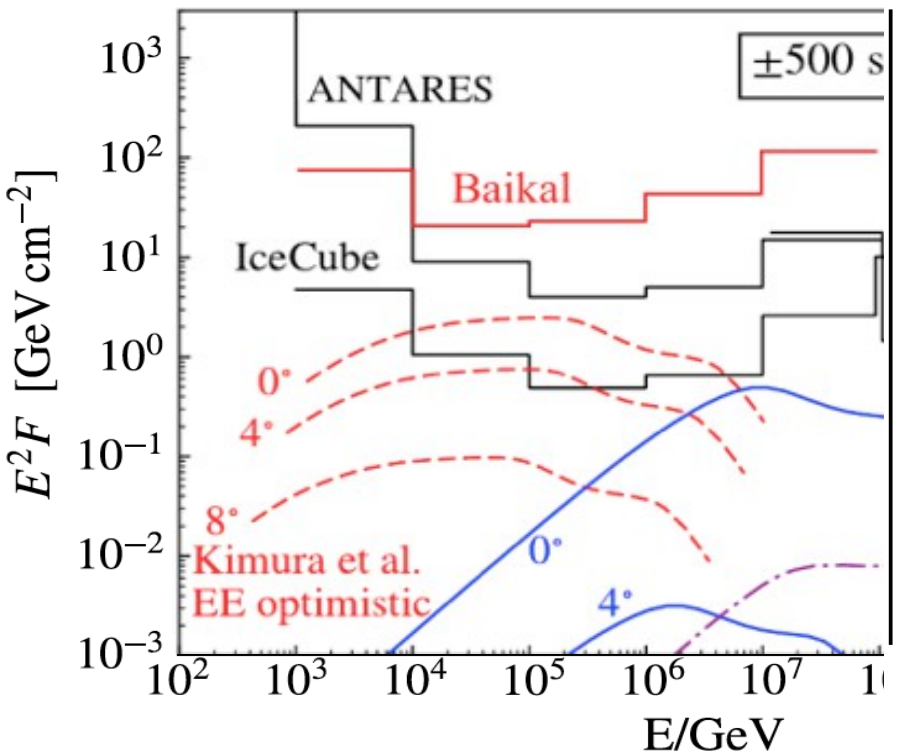


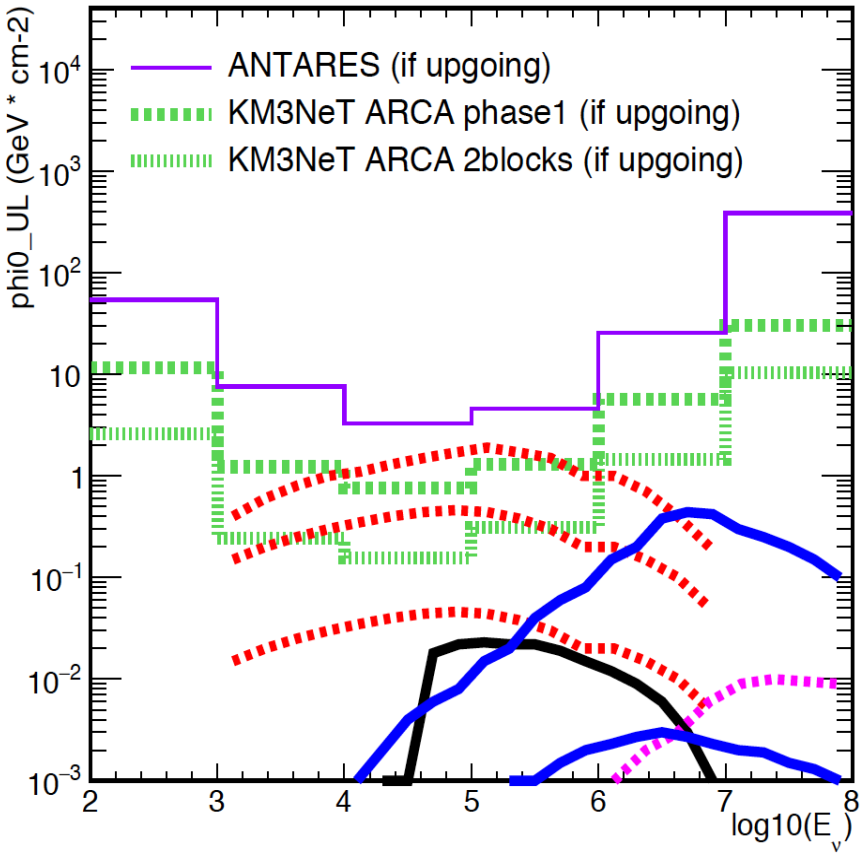
angular resolution:
<deg (tracks) /
~deg (showers)

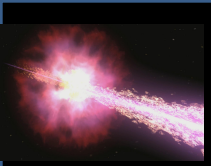
field-of-view:
> 2π sr

14

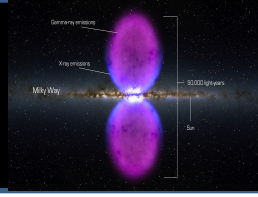
Future follow up - Limits







Take Home Message



- Detectors sensitive enough to touch the interesting region (CCSN)

--> Relevant constrains on populations

- Subthreshold searches:
  - Optimisation (joint or HEN only) can bring 1.5-2 factor in sensitivity
  - O2 still to be scrutinised including cascades

- Follow-up:
  - O3 coming -> ANTARES
  - Design Sensitivty run ->KM3NeT

+ Possible searches at low energies O(10) MeV SN & O(GeV) GRBs

Exciting times ahead!