Gravitational Waves with MAGIC and CTA

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The MAGIC Experiment

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

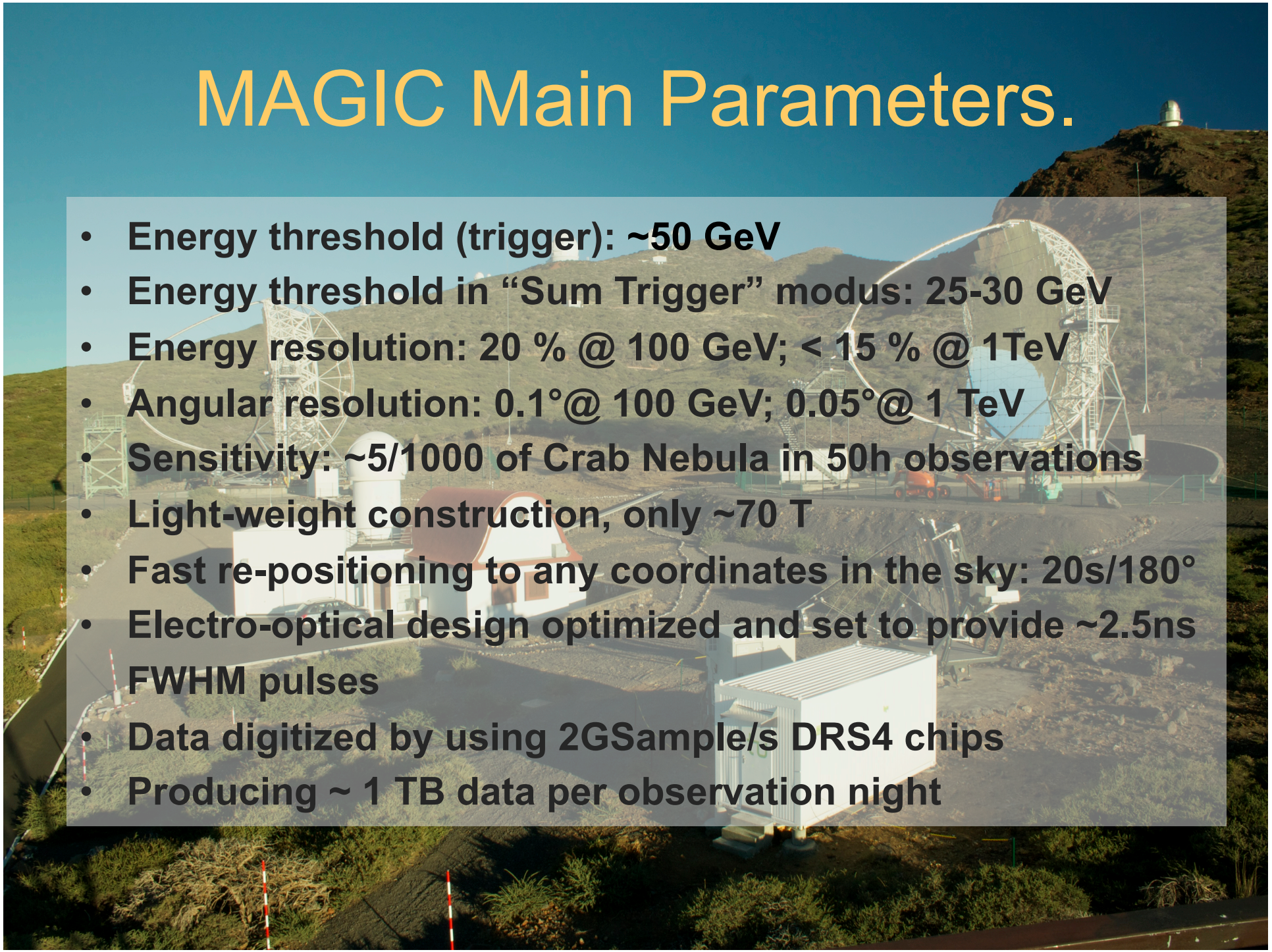
- Active from 2004
- In stereo configuration since 2009
- New MAGIC1 camera since 2012
- New mirrors for MAGIC 1 from august 2014
- At least 5 more years foreseen

New technologies to lower the threshold energy:

- 2x17m diameter (A=472 $m^{2)}$
- High resolution cameras (PSF ~0.06°, **FoV = 3.5°**)
- Hemispherical PMT with enhanced QE

Fast repointing capability: ~8 degree/s

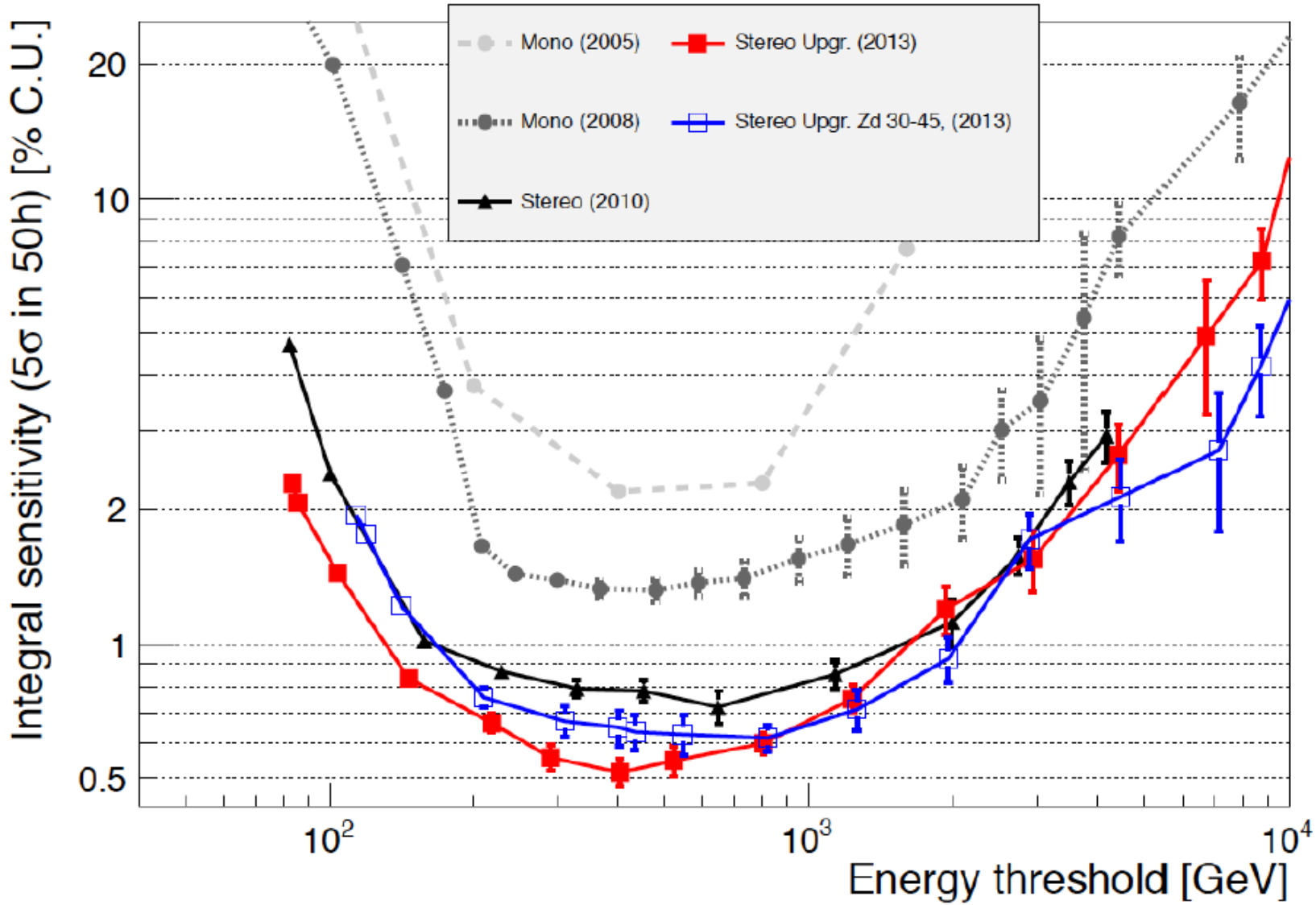
MAGIC Main Parameters.



- Energy threshold (trigger): **~50 GeV**
- Energy threshold in “Sum Trigger” modus: 25-30 GeV
- Energy resolution: 20 % @ 100 GeV; < 15 % @ 1TeV
- Angular resolution: 0.1°@ 100 GeV; 0.05°@ 1 TeV
- Sensitivity: ~5/1000 of Crab Nebula in 50h observations
- Light-weight construction, only ~70 T
- Fast re-positioning to any coordinates in the sky: 20s/180°
- Electro-optical design optimized and set to provide ~2.5ns FWHM pulses
- Data digitized by using 2GSample/s DRS4 chips
- Producing ~ 1 TB data per observation night

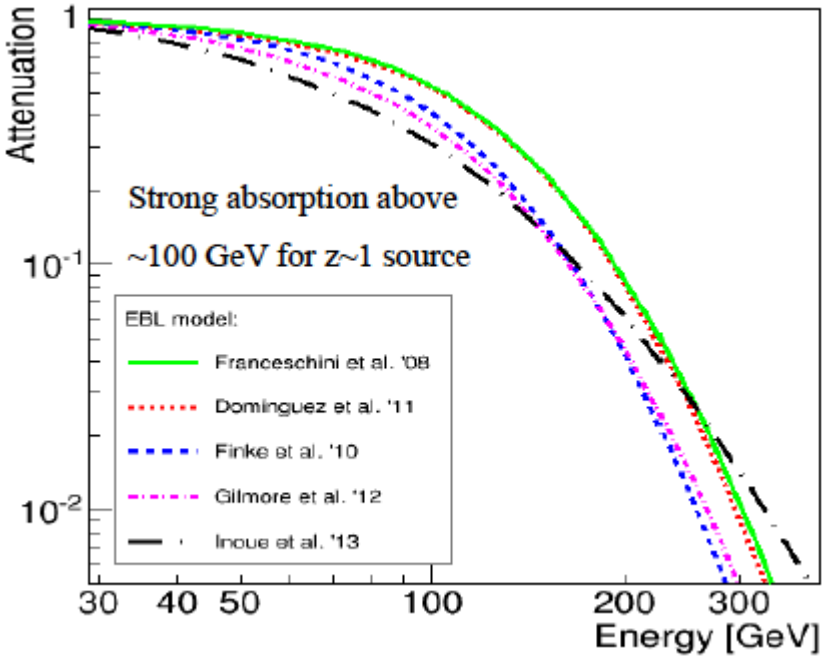
MAGIC sensitivity

Aleksić et al. (MAGIC) Astropart.Phys, 72, 2016



MAGIC Low-Energy Threshold

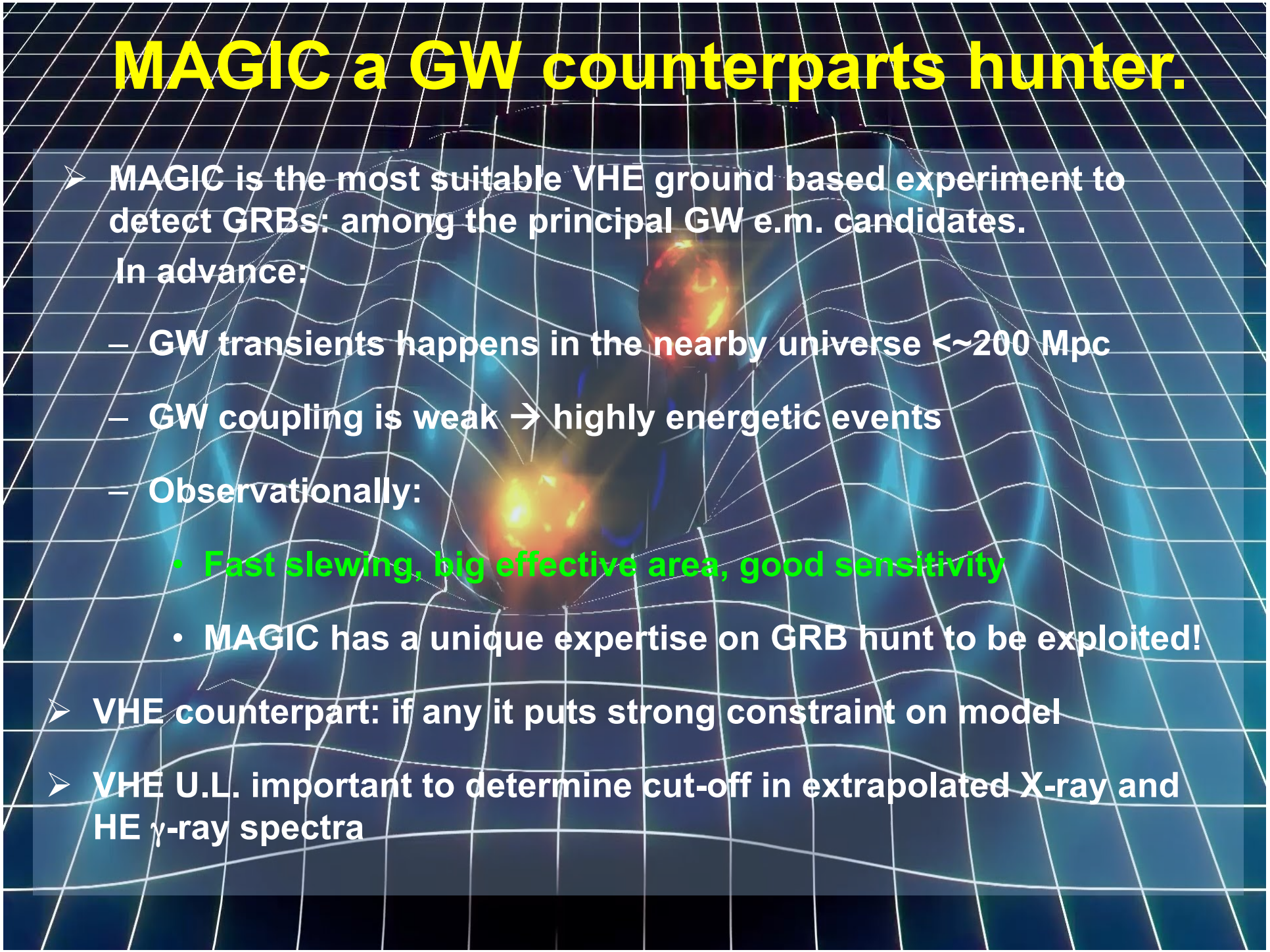
- The MAGIC Low-Energy Threshold allows to observe also objects at high redshift otherwise absorbed by Extragalactic Background Light.
- Farthest objects ever observed at VHE are FSRQ, most part of them has been discovered by MAGIC.
- At present the farthest FSRQ detected at VHE is at z=0.939.



FSRQ	*Redshift*	*First VHE detection by:*	*Year*
3C 279	0.536	**MAGIC**	2006
PKS 1510-089	0.361	HESS	2009
PKS 1222+216 (4C +21.35)	0.432	**MAGIC**	2010
B0218+35	**0.944**	**MAGIC**	**2014**
PKS 1441+25	**0.939**	**MAGIC**	**2015**
S4 0954+65*	0.368	**MAGIC**	**2015**

MAGIC Fast Repositioning

MAGIC a GW counterparts hunter.



- MAGIC is the most suitable VHE ground based experiment to detect GRBs: among the principal GW e.m. candidates.

  In advance:

  - GW transients happens in the nearby universe <~200 Mpc
  - GW coupling is weak → highly energetic events
  - Observationally:
    - Fast slewing, big effective area, good sensitivity
    - MAGIC has a unique expertise on GRB hunt to be exploited!
- VHE counterpart: if any it puts strong constraint on model
- VHE U.L. important to determine cut-off in extrapolated X-ray and HE γ-ray spectra

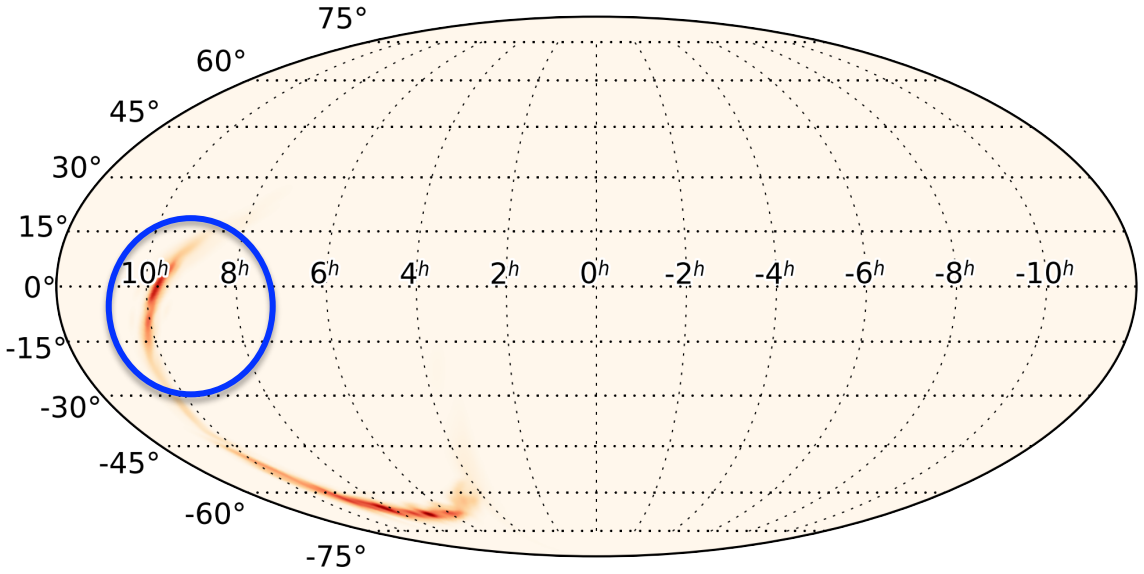
GW alerts received @ MAGIC

2015-09-14 09:50:45 UTC **G184098**

trigger identified by the online Burst analysis

- Probability skymap: median 50% credible region ~ 200 deg^2

- False Alarm Rate (FAR) passing threshold ~ 1/month



➢ LVC-GCN circular sent via internal mailing list; it happened during engineering run

GW alerts received @ MAGIC

2015-09-14 09:50:45 UTC **G184098**

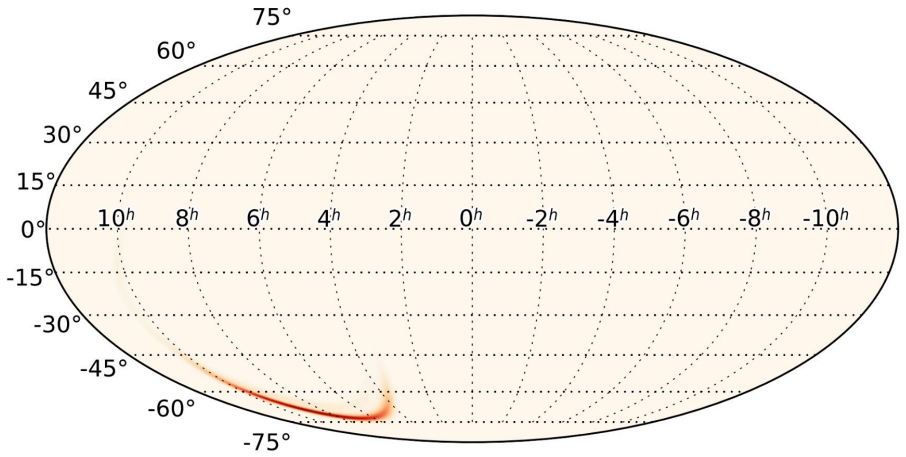
Updated
Bayestar map
Jan 2016

TITLE: GCN CIRCULAR
NUMBER: 18851
SUBJECT: LIGO/Virgo G184098: Updated FAR estimate
DATE: 16/01/11 10:20:22 GMT
FROM: Marica Branchesi at LSC <marica.branchesi@uniurb.it>

The LIGO Scientific Collaboration and Virgo report:

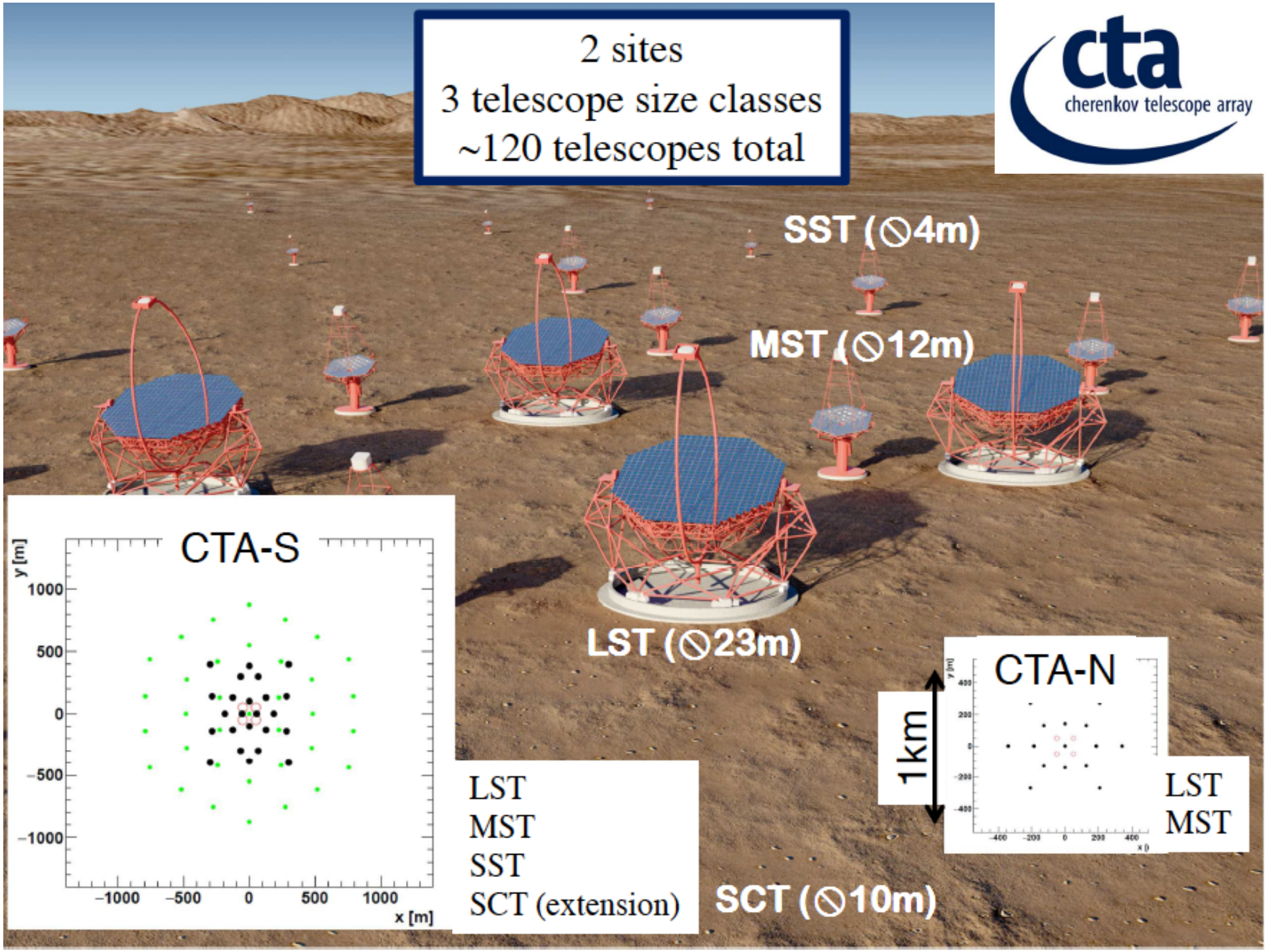
We have completed offline calibration and re-analysis of the segment of data containing the gravitational-wave trigger G184098, which was first recovered on 2015-09-14 (GCN 18330, GCN 18388).

We have calculated a revised false alarm rate based on four detection pipelines: the cWB (with and without BayesWave follow-up) and oLIB searches for un-modeled bursts plus the PyCBC and GSTLAL offline searches for compact binary coalescences of neutron stars and/or stellar-mass black holes. All four pipelines estimate that G184098 is more significant than one per hundred years.

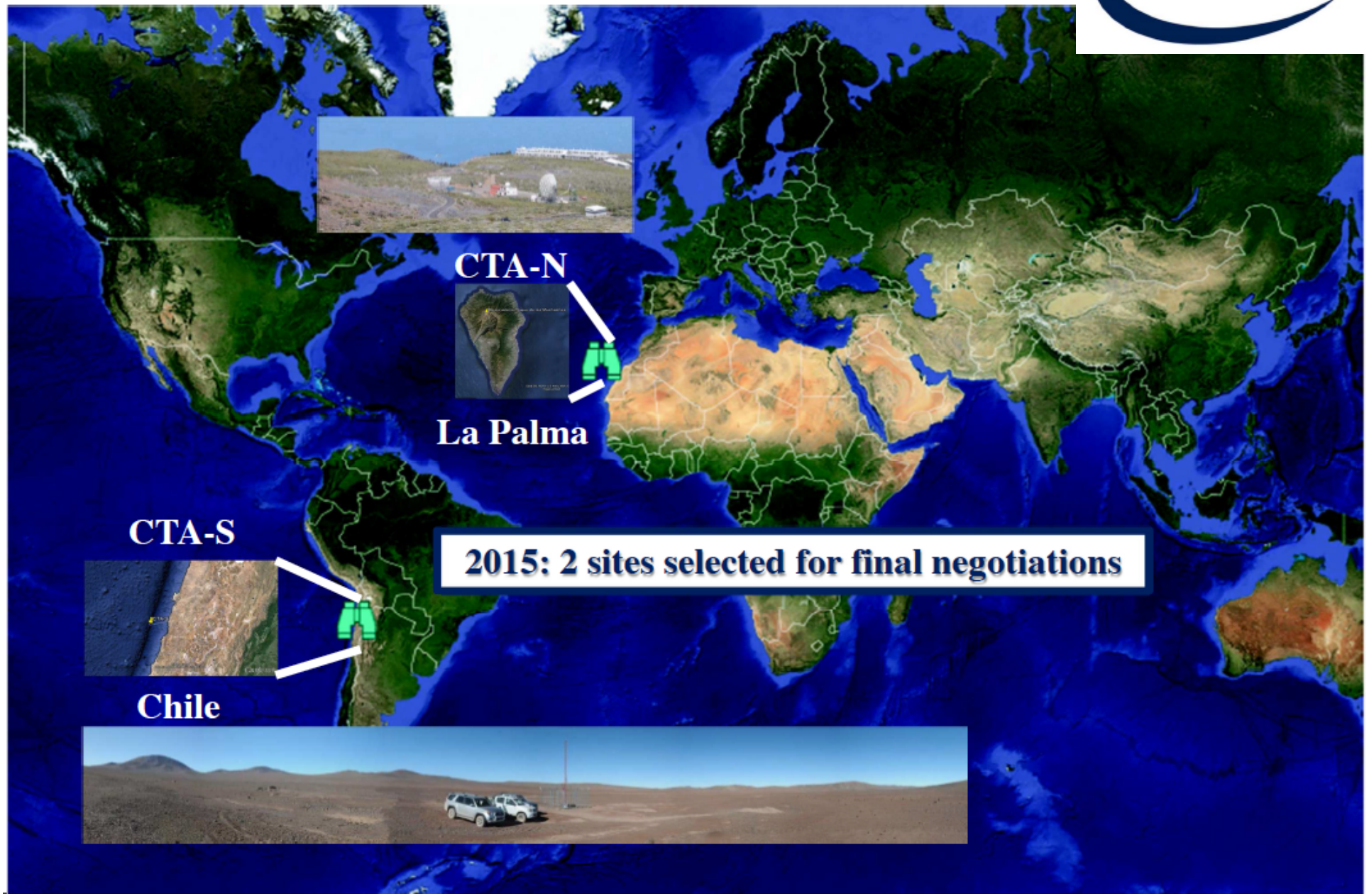


Possible hard-X counterpart from Fermi-GBM (GCN18339)

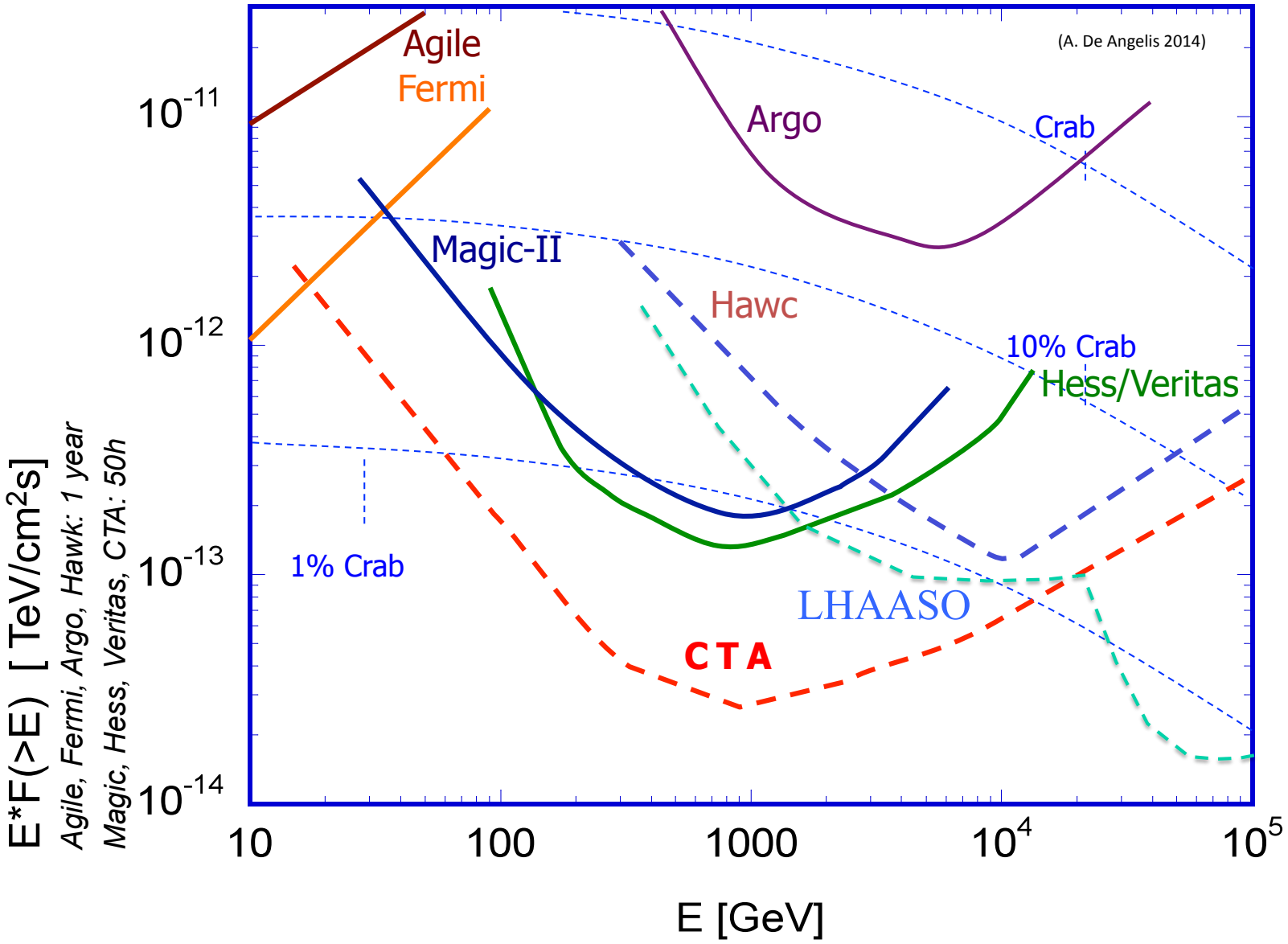

STAY TUNED!

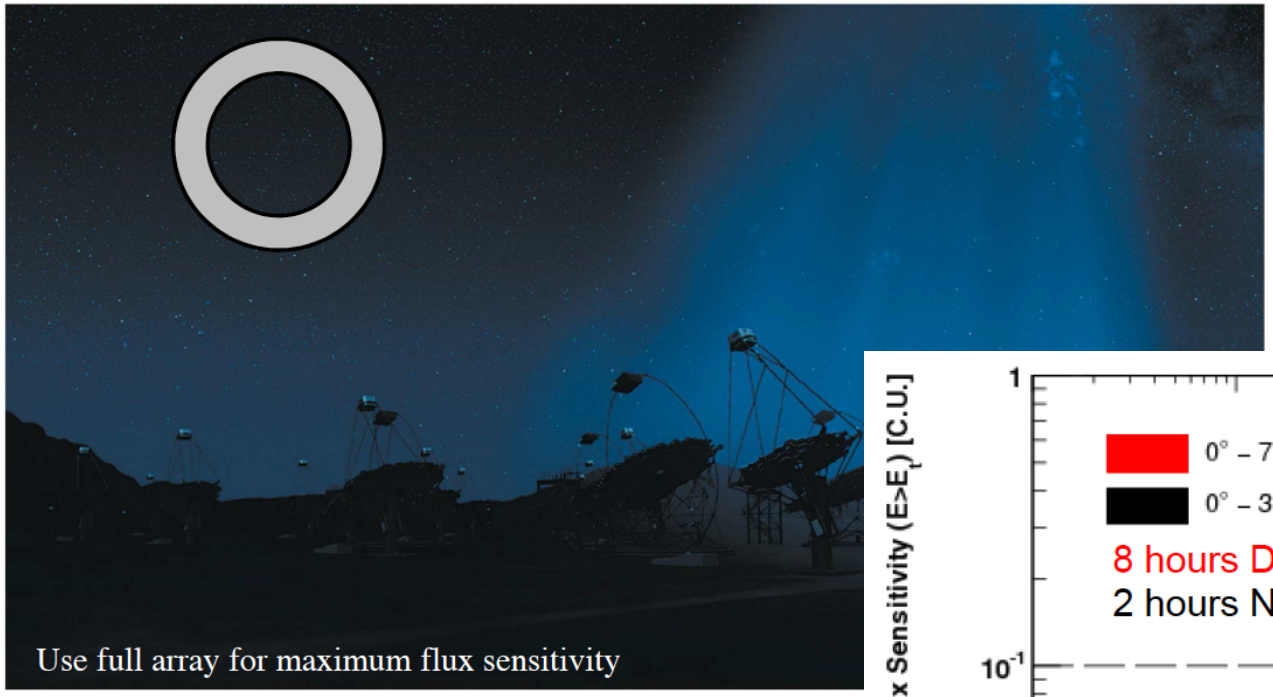

2 sites
3 telescope size classes
~120 telescopes total
cta
cherenkov telescope array
SST (⌀4m)
MST (⌀12m)
LST (⌀23m)
CTA-S
y [m]
1000
500
0
−500
−1000
−1000
−500
0
500
1000
x [m]
LST
MST
SST
SCT (extension)
SCT (⌀10m)
1km
CTA-N
LST
MST

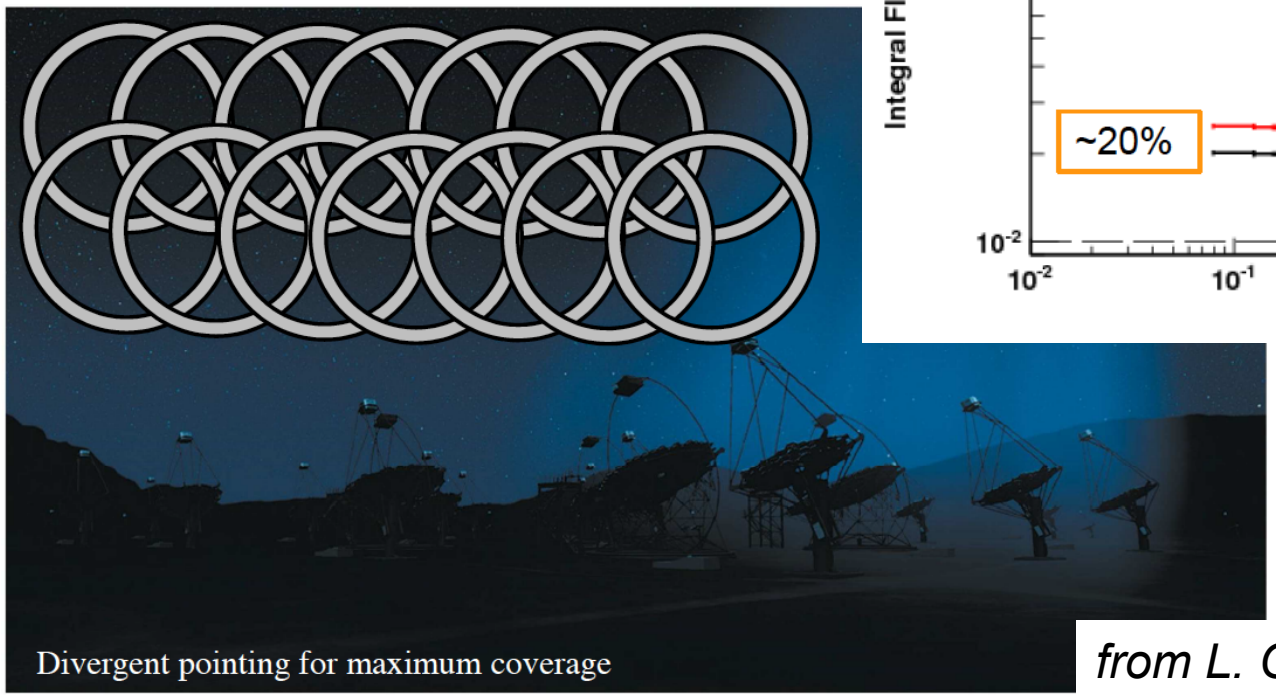
CTA SITES

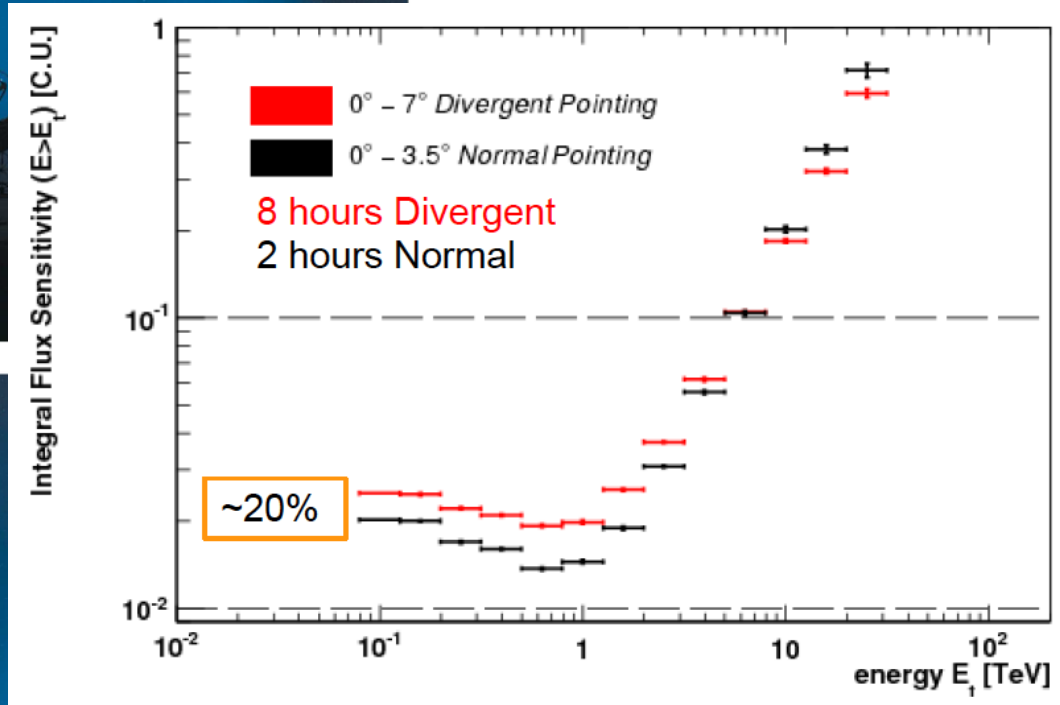

CTA-N
La Palma
CTA-S
Chile
2015: 2 sites selected for final negotiations

A summary (oversimplified…)







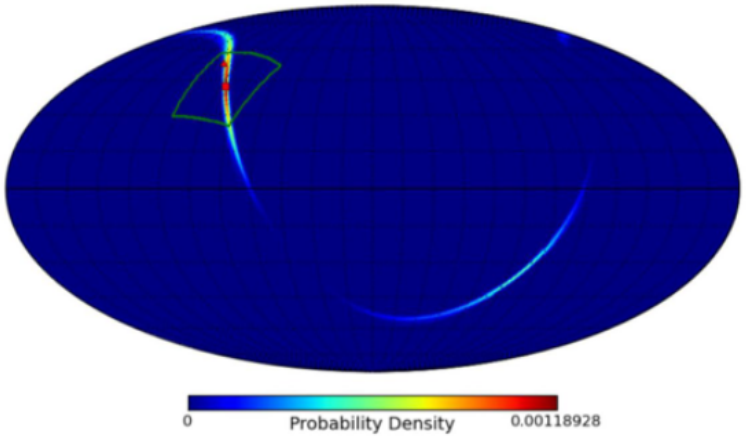


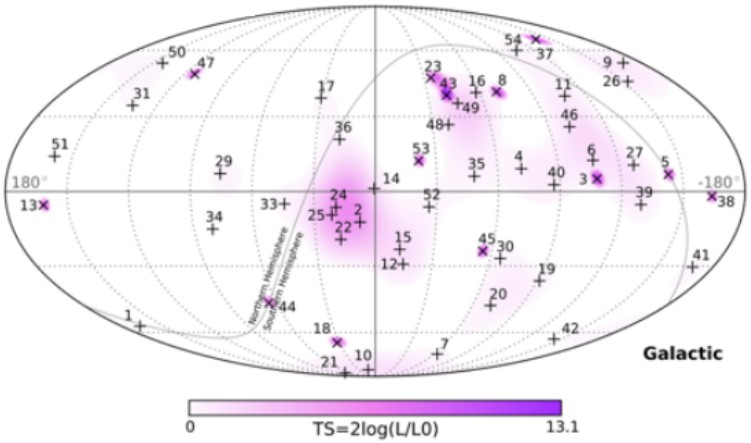
from L. Gerard, 2015, poster@ICRC

CTA and GW e.m. counterp.

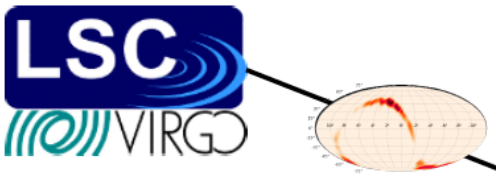
Overview + Introduction

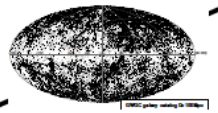
- Working group
  - Angelo Antonelli
  - Andrea Bulgarelli
  - Alessandro Carosi
  - Stefano Covino
  - Diego Götz
  - (Marcos Santander)
  - Antonio Stamerra
  - Fabian Schüssler
  - Paul O'Brien
  - Susanna Vergani
- Use Case templates:
  - Gravitational Waves
  - Neutrinos





Gravitational Waves: Observation Strategy

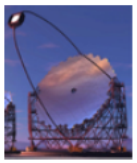




Additional input:
- Galaxy catalog(s)

GW-Scheduler pointings, priorities, etc.

Observation Mode #1



- at least 2 LSTs for 2h: **Observation mode #1**
- ToDO: divergent mode of LSTs/MSTs ?
- RTA searching for new source

End of GW follow-up

Observation modes

- #1: initial scanning of the GW error region
- #2a: full-array follow-up of a new source detected by the CTA-RTA during #1
- #2b: full-array follow-up of an EM counterpart detected during #1
- #3a: delayed, full-array follow-up of a new source detected by the CTA-RTA during #1
- #3b: delayed, full-array follow-up of an EM counterpart detected during #1
- #3c: delayed, full-array follow-up of a new source detected by the CTA-Level B analysis
- #3d: delayed, full-array follow-up of an EM counterpart


Thank you!