Searching for neutrino and ultra-high-energy gamma ray counterparts of gamma-ray bursts and neutrinos on the GCN/TAN

Unatlokov I.B.

Institute for Nuclear Research RAS

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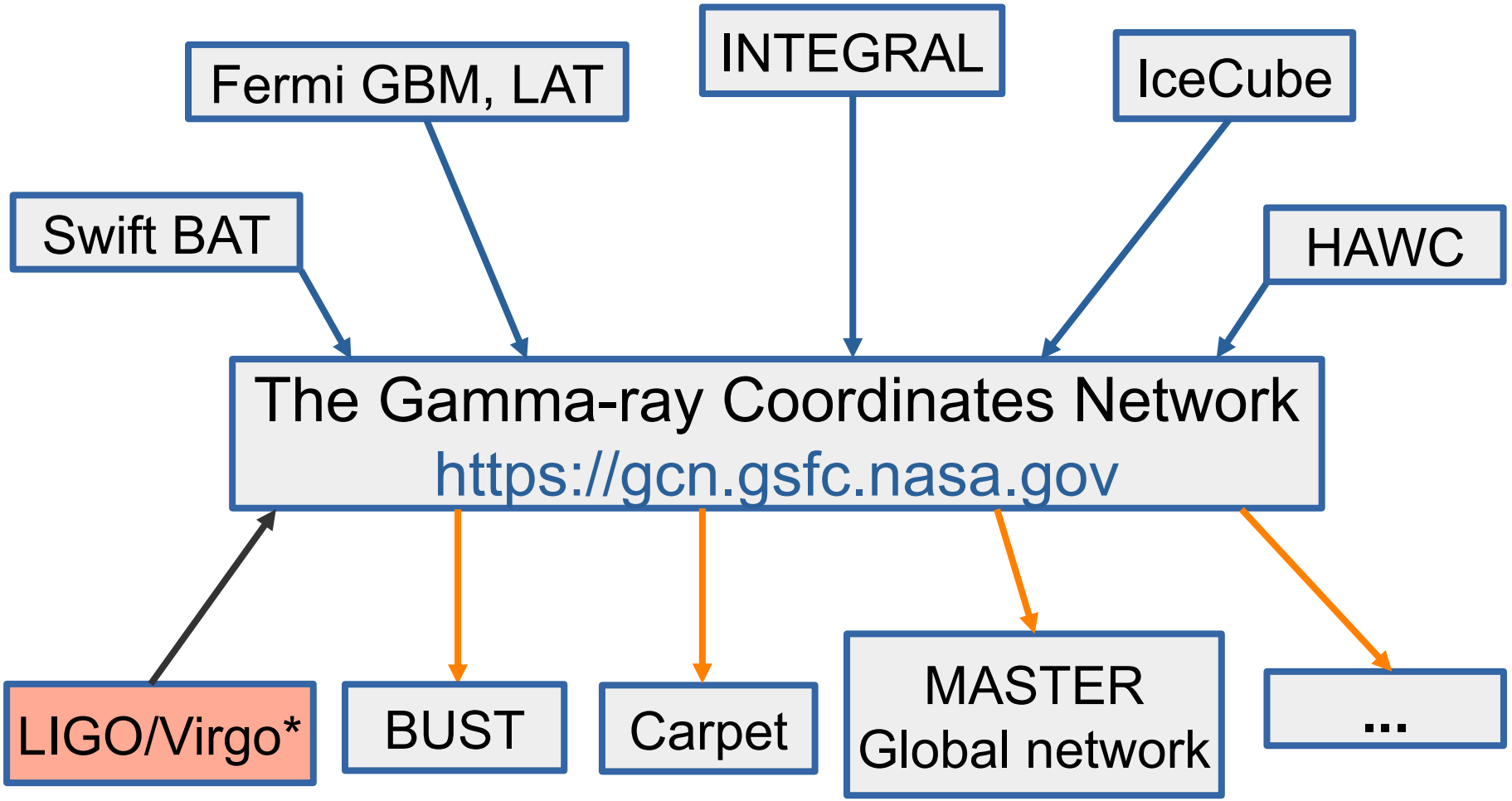
GCN alerts

The Gamma-ray Coordinates Network (GCN) — a system that distributes information about gamma-ray bursts, transients.



*«It is not yet possible to give a definitive start date for O4»
https://www.ligo.org/scientists/GWEMalerts.php (04.06.21)

Types of Alerts

- GCN Notices (machine-readable) — short text messages with information about the event, distributed through socket. They can be formed both in real time and by people.
- GCN Circulars (human-readable) — messages formed by people. Distributed through email.

Alert contents

- Socket packets contain 40 fields
- Necessary information:

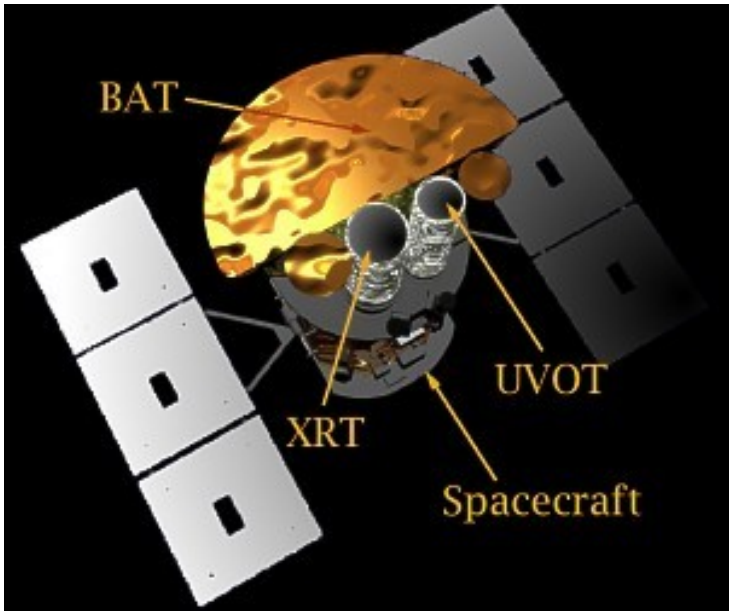
  1) Packet type (which setup/spacecraft is the origin)
  2) Date TJD
  3) Time UTC, SOD
  4) Coordinates RA, Dec, Error

General information

Type of alert	№ of packet	Epoch	Time delay	Location accuracy
SWIFT_BAT_GRB_POSITION	61	J2000	13-30 sec	1-3 arcmin
INTEGRAL_WAKEUP	53	Current	~1 min	<4 arcmin
INTEGRAL_REFINED	54	Current	1-2 min	<4 arcmin
INTEGRAL_OFFLINE	55	Current	1-3 hr	<4 arcmin
FERMI_GBM_FLT_POS	111	J2000	~10 sec	~20 deg
FERMI_GBM_GND_POS	112	J2000	20-300 sec	1-10 deg
FERMI_GBM_FIN_POS	115	J2000	~2 hr	1-3 deg
FERMI_LAT_GRB_POS_UPD	121	J2000	2-32 sec	60-120 arcmin
FERMI_LAT_GND	127	J2000	4-8 hr	10-60 arcmin
FERMI_LAT_OFFLINE	128	J2000	4-8 hr	10-60 arcmin
HAWC_BURST_MONITOR	171	J2000	0.5-1 min	0.4-0.8 deg
ICECUBE_ASTROTRACK_GOLD	173	J2000	0.5-1 min	0.2-0.75 deg
ICECUBE_ASTROTRACK_BRONZE	174	J2000	0.5-1 min	0.2-0.75 deg

SWIFT_BAT_GRB_POSITION

BAT_Position alerts are issued once per burst. This notice type does also contain detections of hard x-ray transients. There is both flight- and ground-software in place to correctly identify bursts from transients.
If, after ground-processing with humans-in-the-loop, the initial "burst" identification is determined to be incorrect, then a Retraction notice will be issued. The combination of the flight s/w identification code and the ground-processing identification code is 98% accurate (i.e. only 2% false positives: said it was a real GRB when it was not).



SWIFT spacecraft, www.swift.psu.edu

Energy range 15-150 keV

INTEGRAL_WAKEUP/REFINED/OFFLINE

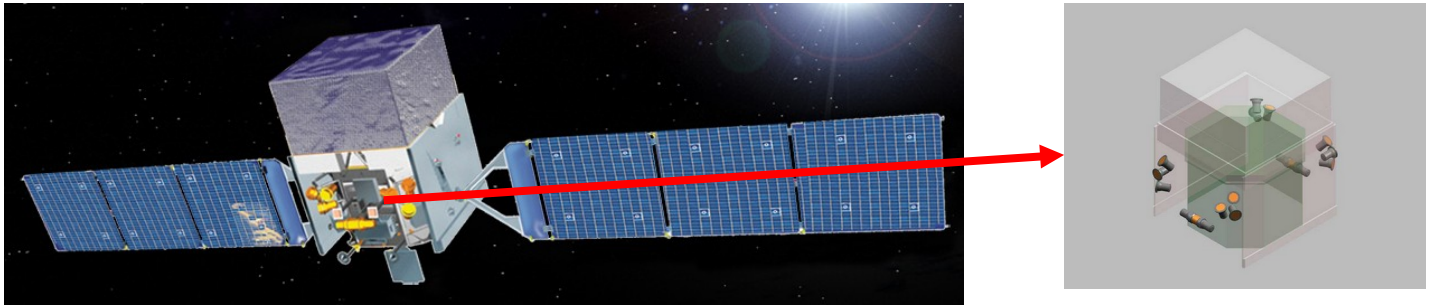
- WAKEUP packets are issued only once per burst, but may not be present for all bursts. This type of Notice comes first in the sequence of Notices on the burst. Since it is based on the least amount of data in the processing, it has the lowest significant in the localization and lowest confidence in the burst-vs-nonburst identification. These WAKEUP Notices come from automated ground processing.
- REFINED packets are issued only if there is more data with an increased significance that improves the detection and localization of the burst. There can be 0 to N of these Notces for each burst. These REFINED Notices come from automated ground processing.
- OFFLINE packets are generated manually by ground personnel. The OFFLINE Notice represents the final confirmation (or rejection) of a GRB and contains the most accurate GRB properties.

INTEGRAL spacecraft, www.cosmos.esa.int/web/integral/mission-overview

Energy range 15 keV-10 MeV

FERMI_GBM_FLT_POS/GND_POS/FIN_POS

- GBM_Flight_Position - positions are calculated by the on-board Flight software in real time. They are issued 1 to 5 times per burst. It contains detections of both GRBs and hard x-ray transients. There is both flight- and ground-software in place to correctly identify bursts from transients.
- GBM_Ground_Position - positions are calculated by automated ground software as soon as they are received on the ground in real time. More sophisticated algorithms can be applied to the data to improve the location accuracy. There can be 0, 1, or more instances of this Notice Type per trigger.
- GBM_Final_Position Notice - humans are involved in the analysis. They will be issued for the 10-20% brightest of the GRBs.

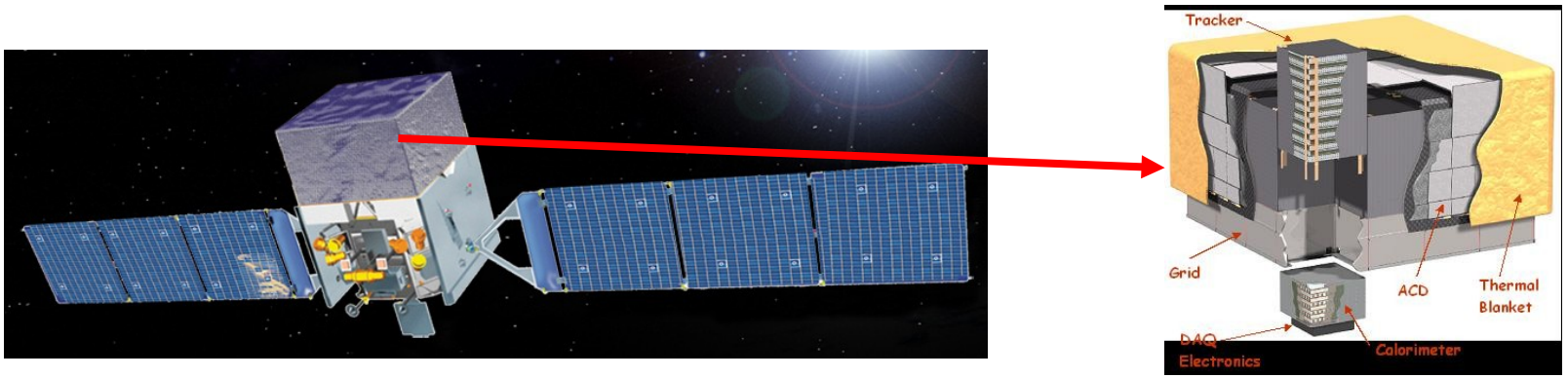


Energy range
10 keV-25 MeV

Placement of the GBM on Fermi.
https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Introduction/GBM_overview.html

FERMI_LAT_GRB_POS_UPD/GND/OFFLINE

- LAT_Position_Update - positions come from the LAT flight software in real time.
- LAT_Position_Ground - (delayed) positions come from the LAT ground processing where more sophisticated algorithms and data are used. This automated processing refines the position for on-board triggered events, and scans the total stream of LAT events applying trigger criteria looking for bursts that did not trigger on-board.
- LAT_Position_Offline - (delayed) positions come from the LAT ground-processing software plus human inspection/refinement of the results. They are issued only once (rarely twice) per ground-detected burst.



Placement of the GBM on Fermi.
https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Introduction/LAT_overview.html

Energy range 20 MeV-300 GeV

HAWC_BURST_MONITOR

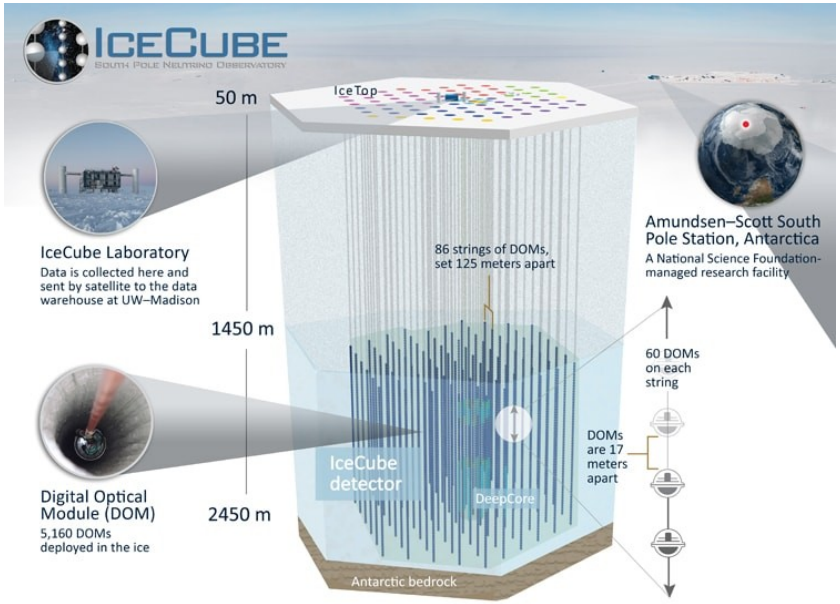
HAWC_BURST_MONITOR contains alerts from short time-scale searches looking for GRBs. The search is done using fixed-width sliding time windows in all points in the sky within 50 degrees from HAWC's zenith angle.

HAWC observatory, www.hawc-observatory.org

Energy range 300 GeV-100 TeV

ICECUBE_ASTROTRACK_GOLD/BRONZE

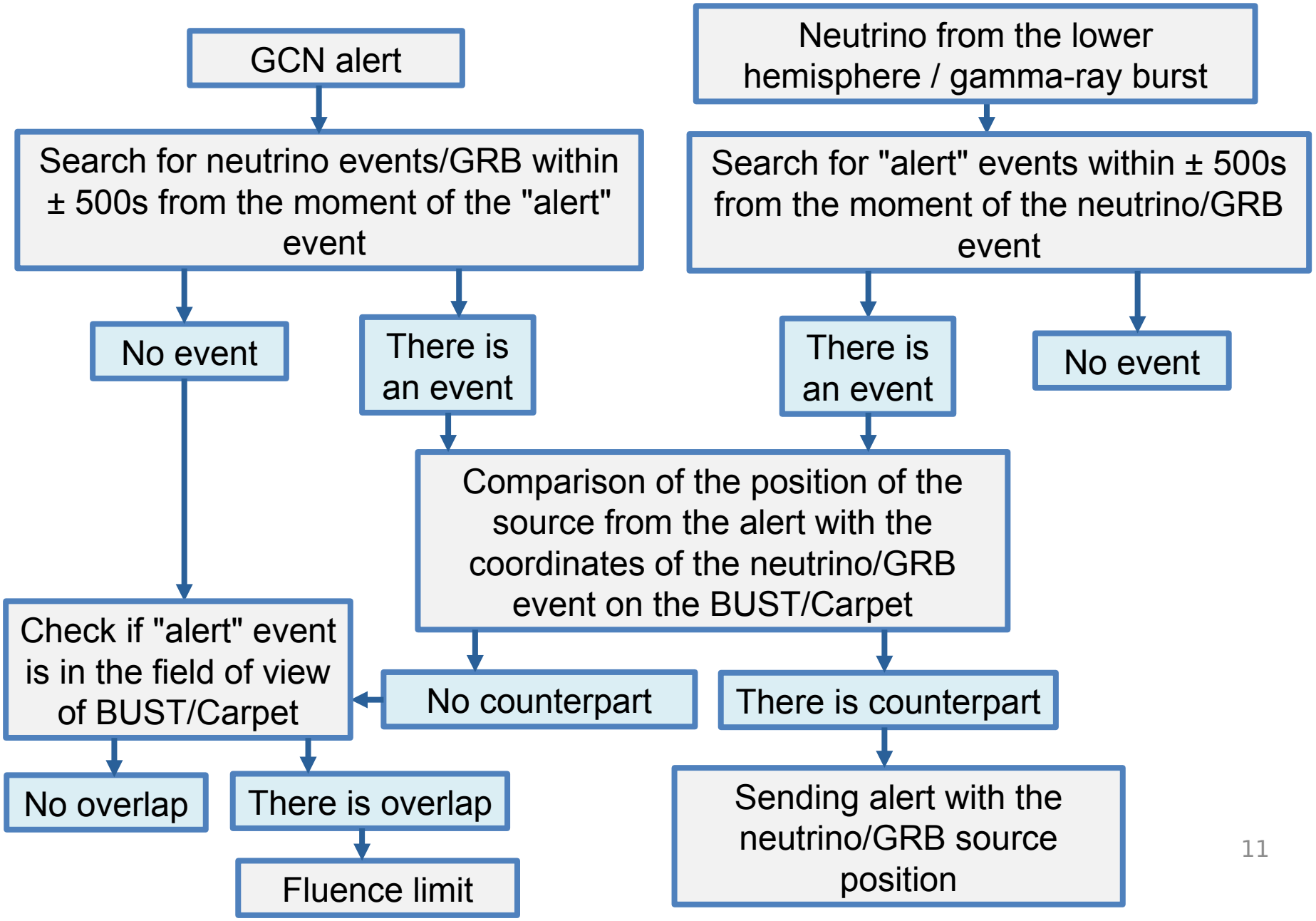
ICECUBE_ASTROTRACK_GOLD/BRONZE contain a single high-energy IceCube track neutrino event directions.
For the ICECUBE_ASTROTRACK GOLD notice type; the occurence rate is about 12/yr; >50% are astrophysical.
For the ICECUBE_ASTROTRACK BRONZE notice type; the occurence rate is about 16/yr; >30% are astrophysical.



Energy range 100 GeV-10^9 GeV

IceCube observatory, https://icecube.wisc.edu/science/icecube/

Real-time data analysis



Alert processing

Fluence limit

$$S_{eff}(E_\nu,\theta,\phi)=\sigma_{\nu N}(E_\nu)\cdot N_N$$

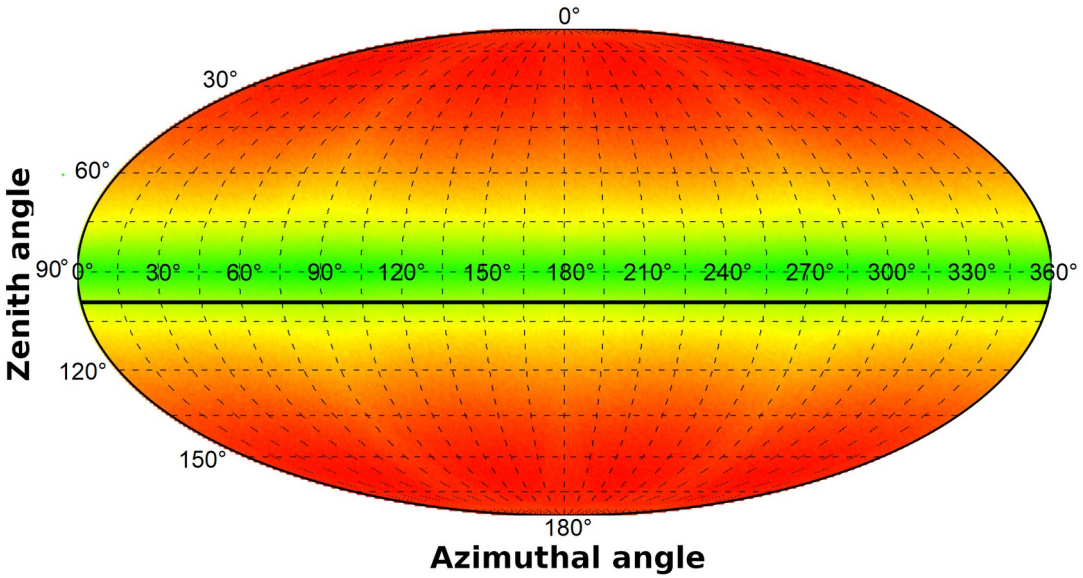
$$I(E_\nu,\theta,\phi)=\frac{n_{90}}{\varepsilon\cdot S_{eff}(E_\nu,\theta,\phi)}$$

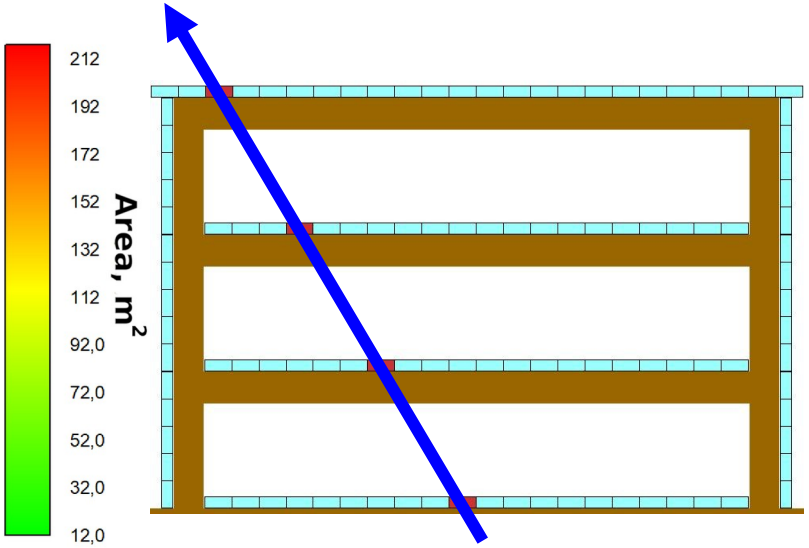
$n_{90} = 2.3$, $\varepsilon = 0.84$

$$I_{lim}=\frac{n_{90}}{\int_{E_{min}}^{E_{max}} I(E_\nu)\,\varepsilon\cdot S_{eff}(E_\nu)\,dE_\nu}$$

$$F_{lim}=\frac{n_{90}\int_{E_2}^{E_1} I(E_\nu)\,E_\nu\,dE_\nu}{\int_{E_{min}}^{E_{max}} I(E_\nu)\,\varepsilon\cdot S_{eff}(E_\nu)\,dE_\nu}$$

Telescope area in different zenith, azimuth angles (muon crosses 3 or more planes)





S_{Tmin} = 72 m²

S_{Tmax} = 217 m²

Alert processing

Fermi-GBM 21/06/06, 03:56:02 UT, $I_{\nu\mu}$ = 57 cm^{-2}, $I_{\bar{\nu}\mu}$ = 112.2 cm^{-2}

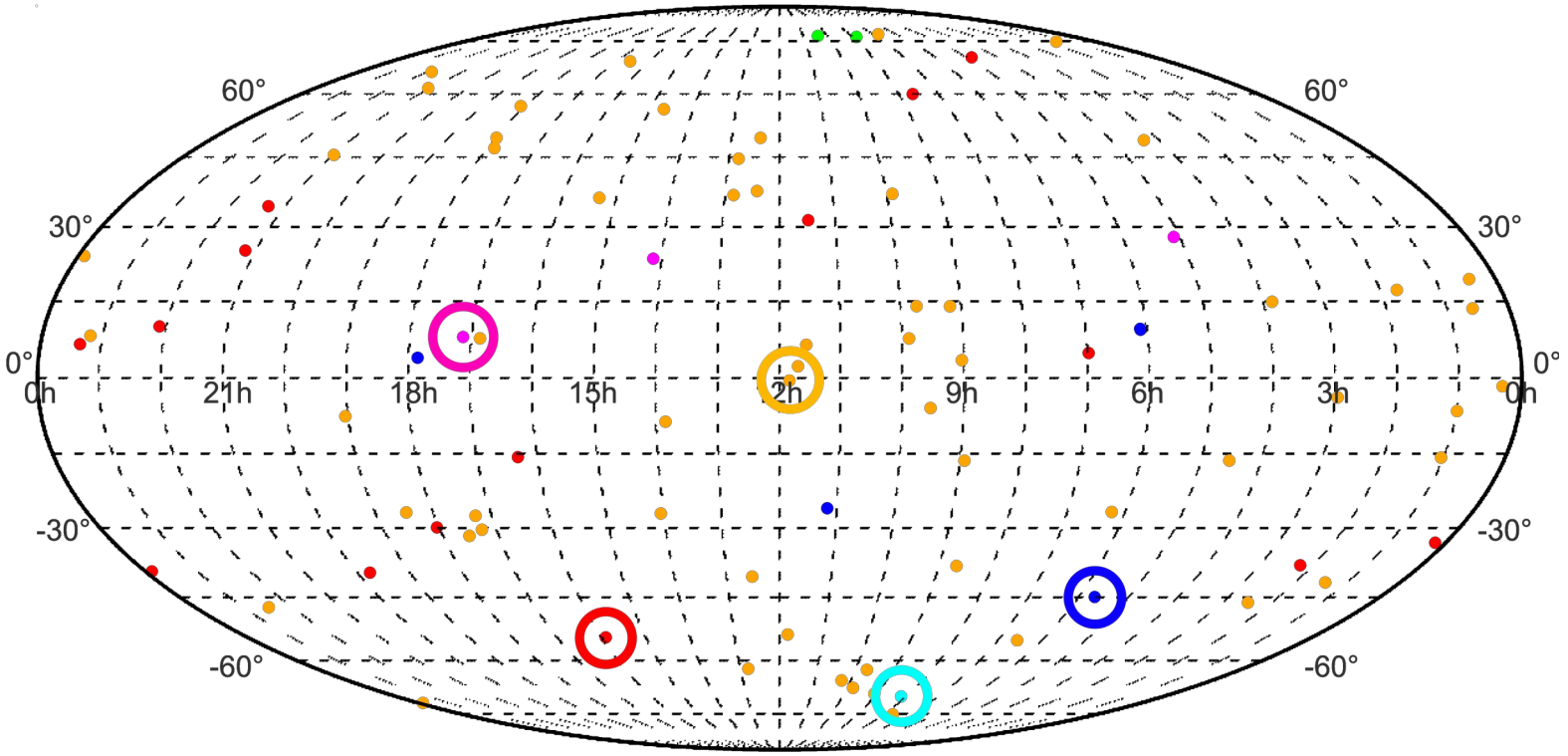
Fermi-LAT 21/05/20, 19:07:02 UT, $I_{\nu\mu}$ = 62.1 cm^{-2}, $I_{\bar{\nu}\mu}$ = 122.2 cm^{-2}

Swift-BAT 21/06/03, 09:45:46 UT, $I_{\nu\mu}$ = 53.1 cm^{-2}, $I_{\bar{\nu}\mu}$ = 104.5 cm^{-2}

IceCube 21/03/22, 02:34:09 UT, $I_{\nu\mu}$ = 56 cm^{-2}, $I_{\bar{\nu}\mu}$ = 110.2 cm^{-2}

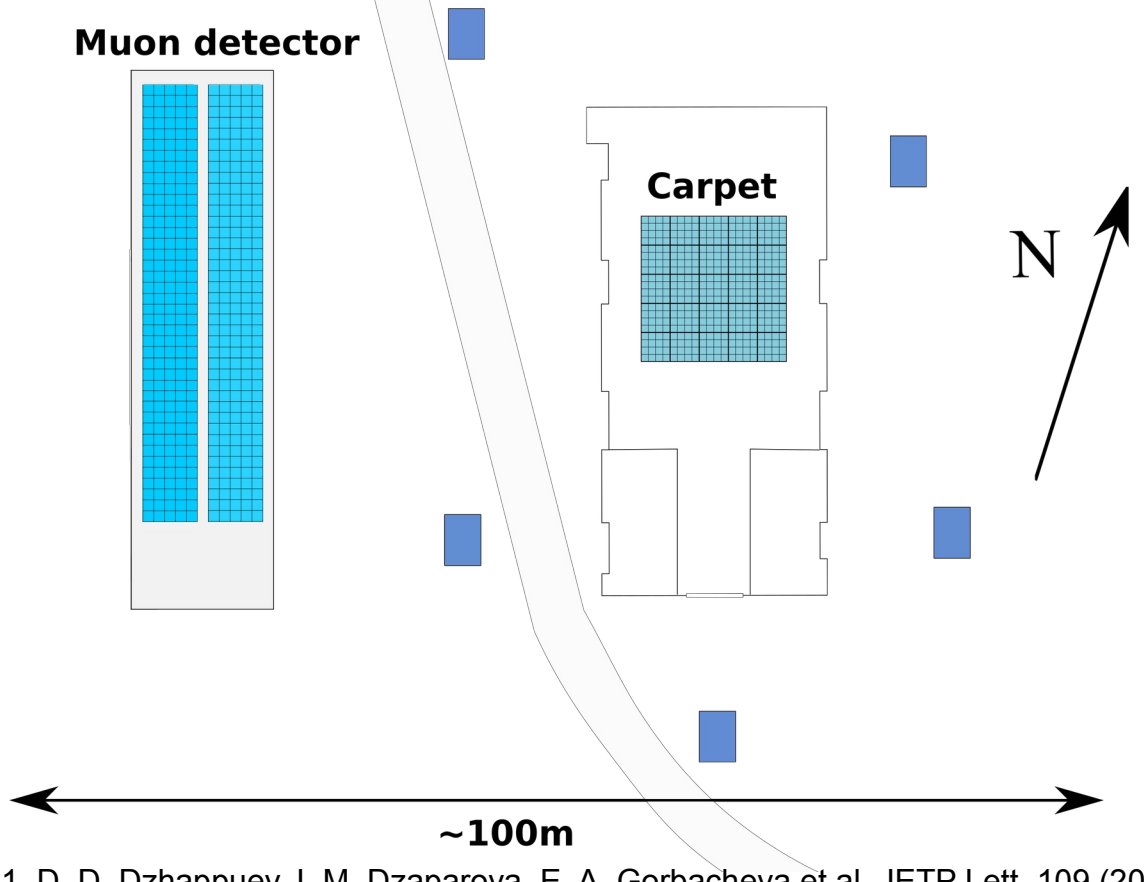
HAWC 21/05/07, 10:38:22 UT, $I_{\nu\mu}$ = 63.7 cm^{-2}, $I_{\bar{\nu}\mu}$ = 125.5 cm^{-2}

INTEGRAL *No events in the field of view*



Carpet-2

Carpet-2 includes a 200 m^2 continuous central scintillator detector (Carpet); five outer detector stations with 9 m^2 of scintillator in each of them; and a 175 m^2 shielded muon detector. The muon detector is used to select candidate gamma-ray showers which are muon-poor *[1,2,3]*. Carpet's field of view is within zenith angle <40°.



In the near future Carpet will be connected to the GCN. GRB candidate events will be shared and used for counterpart search. Thus real time alert analysis will be fully operating.

1. D. D. Dzhappuev, I. M. Dzaparova, E. A. Gorbacheva et al. JETP Lett. 109 (2019) 226 [arXiv:1812.02662 [astroph.HE]]
2. D. D. Dzhappuev, I. M. Dzaparova, E. A. Gorbacheva et al. PoS ICRC2019 (2020), 808 [arXiv:1907.10893 [astro-ph.HE]]
3. D. D. Dzhappuev, I. M. Dzaparova, E. A. Gorbacheva, I. S. Karpikov, M. M. Khadzhiev, N. F. Klimenko, A. U. Kudzhaev, A. N. Kurenya, A. S. Lidvansky and O. I. Mikhailova, et al. EPJ Web Conf. 207 (2019), 03004 [arXiv:1812.02663 [astro-ph.HE]]

Thanks for your attention!