The Baikal-GVD neutrino telescope:

search for high-energy cascades

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for the Baikal Collaboration
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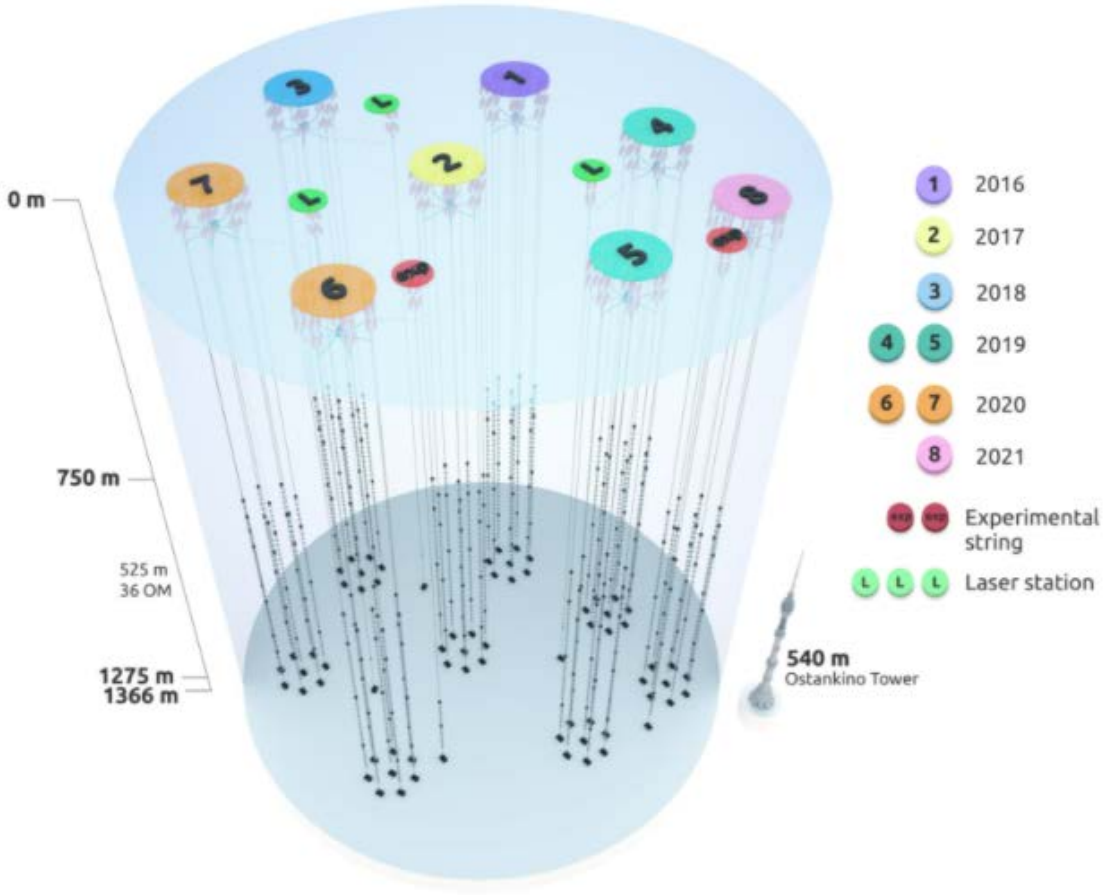
Baikal-GVD construction status and schedule

Status 2021: 8 clusters, 3 laser stations, experimental



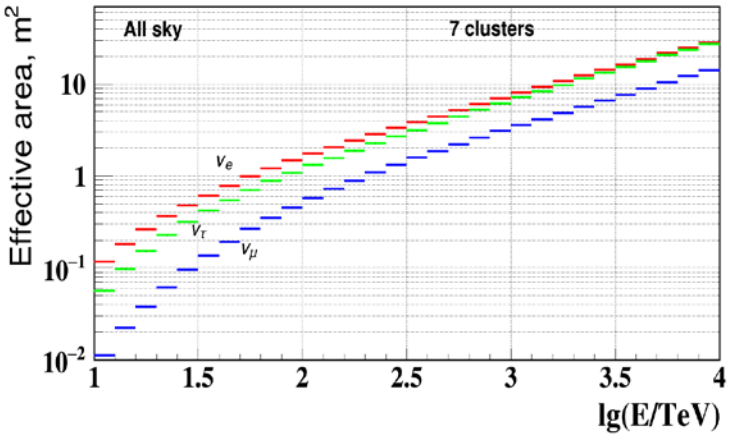
Deployment schedule

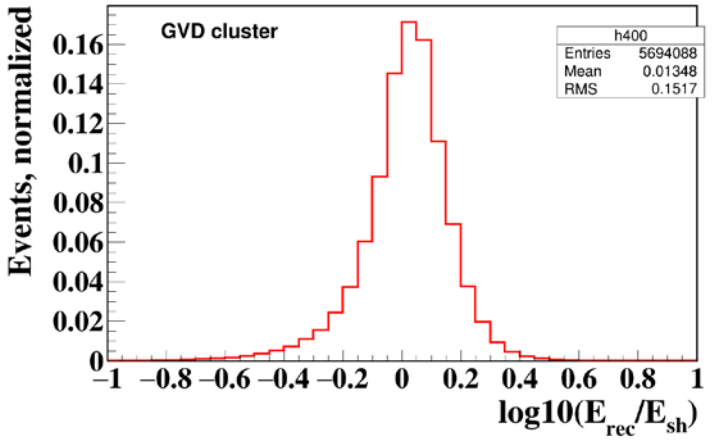
Year	Number of clusters	Number of OMs
2016	1	288
2017	2	576
2018	3	864
2019	5	1440
2020	7	2016
2021	8	2304
2022	10	2880
2023	12	3456
2024	14	4032

Effective volume 2021: 0.40 km^3 (cascade mode E>100 TeV)

Cascades detection with GVD Cluster

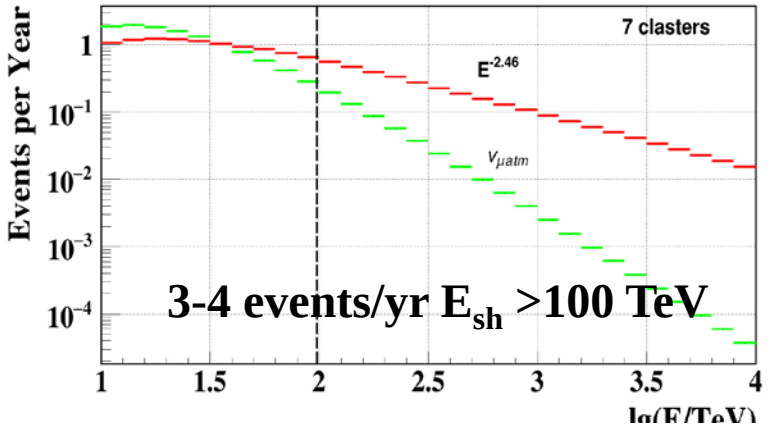
Neutrino Effective Area for 7 GVD Clusters

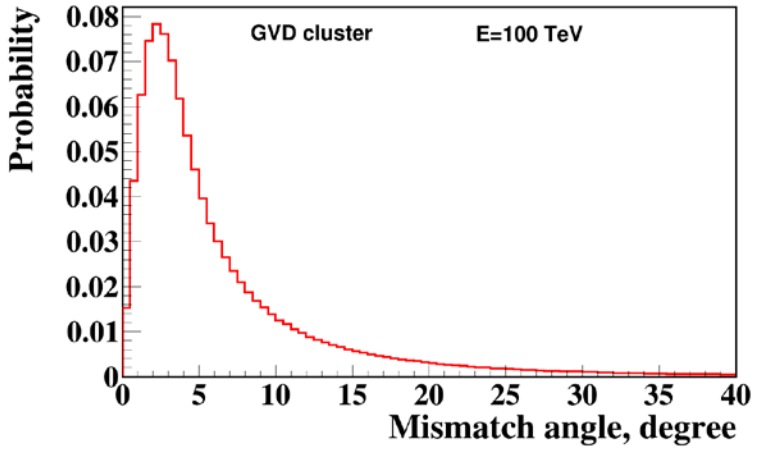




Energy resolution : δE/E ~ 10%-30%

Expected number of events in 7 GVD Clusters from astrophysical neutrinos for 1 yr.





Directional resolution for cascades:
2°- 4° - median value of mismatch angles

Preliminary!

High energy cascades (data and MC)

Data from 2019-2020 , **livetime: *2915* days** (in terms of one cluster)

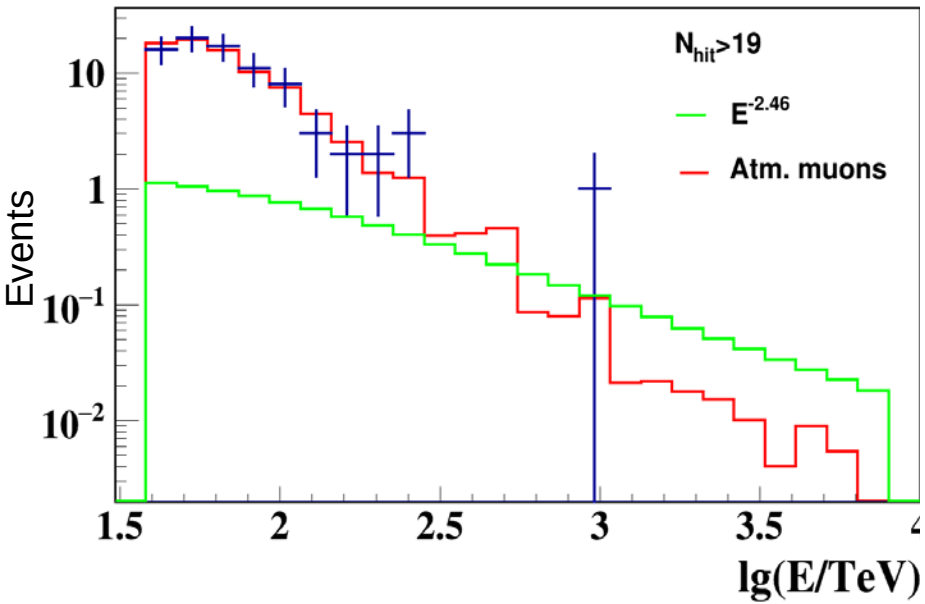
MC atmospheric muons - Corsika 7.74, Sybill 2.3c, protons, E_p>100 TeV

Thanks to Jakob van Santen for modification of DYNSTACK CORSIKA.

72 events with E > 40 TeV and N_{hit} > 19

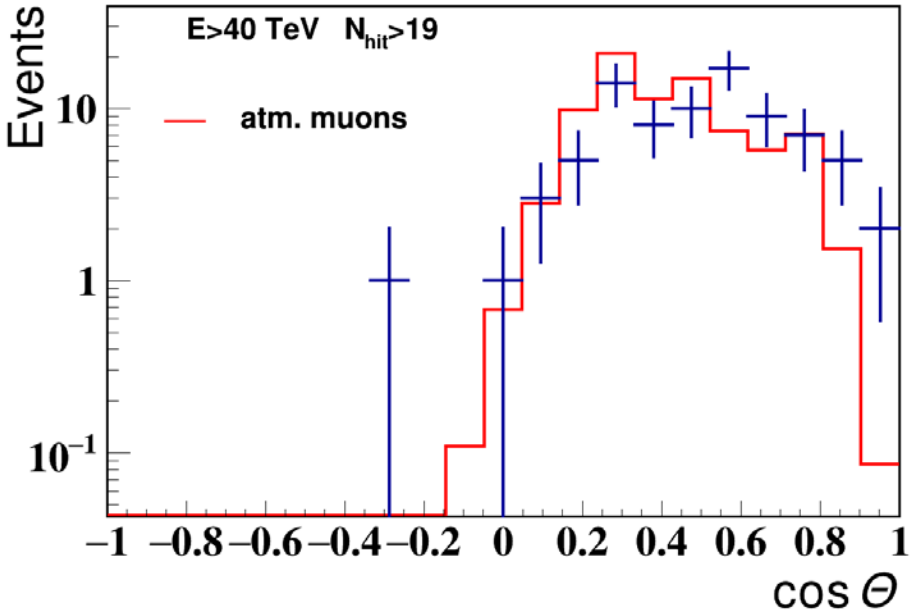
10 events with E > 100 TeV and N_{hit} >19:

Energy distribution



One upgoing cascade: E ≈ 91 TeV

Cosine of zenith angle



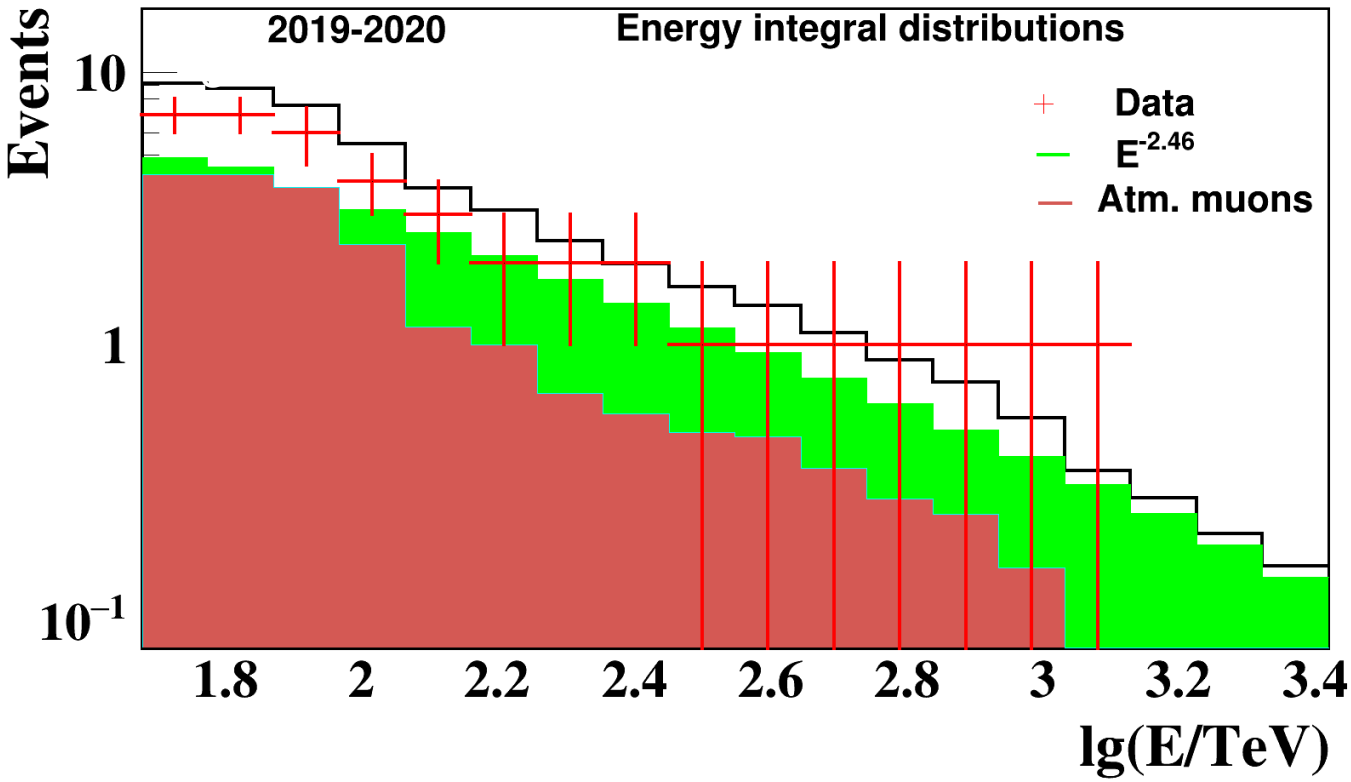
Final selection requirements:

Preliminary!

($N_{Type\_2} = 0$, $E_{rec} \geq 60$ TeV) or ($N_{Type\_2} = 1$, $E_{rec} \geq 100$ TeV)

7 data events have been selected.
4 events are expected from atm. muons
5 events are expected from $E^{-2.46}$ astrophys. flux with IC normalization

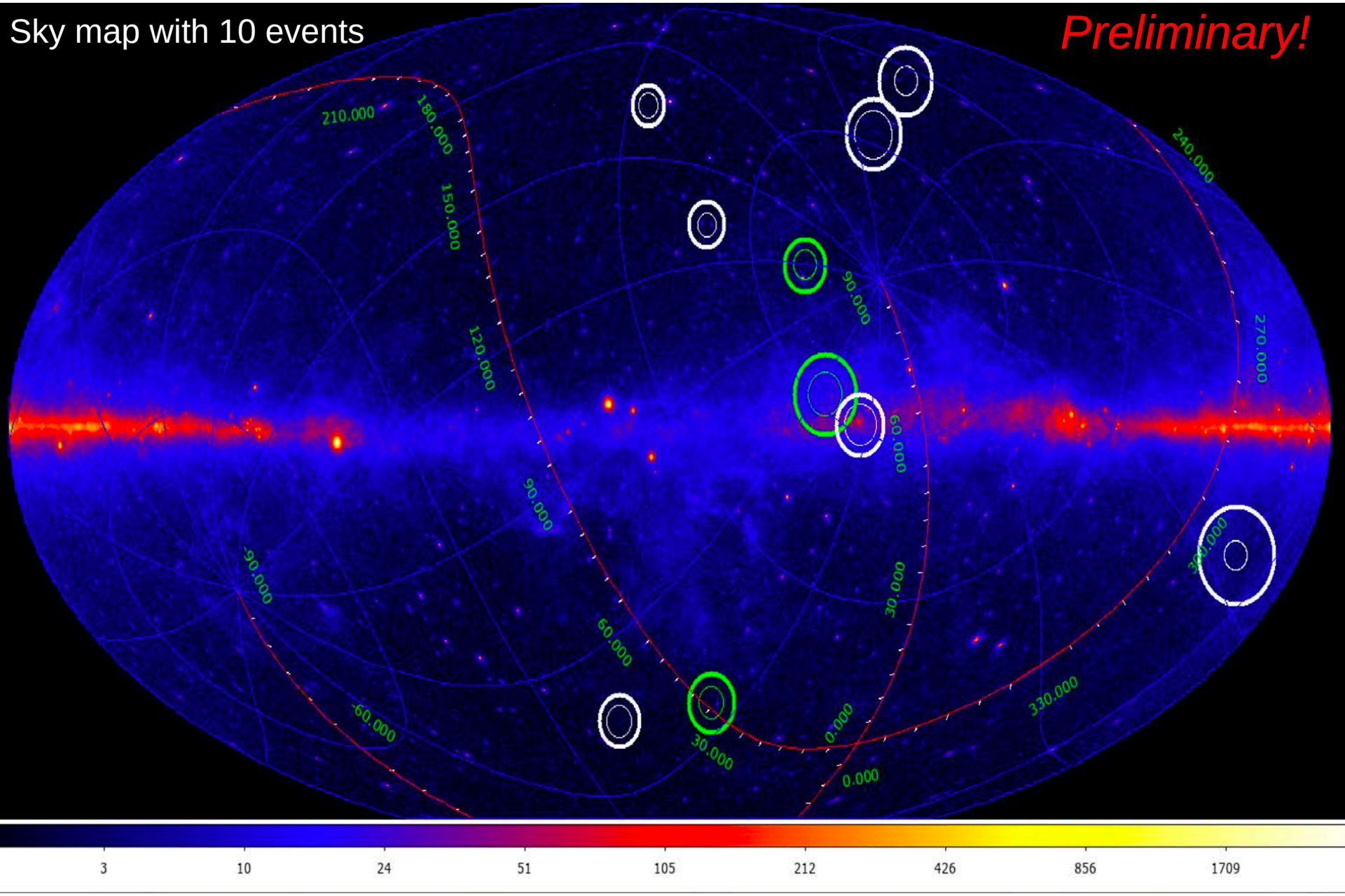
Cumulative distributions of data and events from atm. muons and astrophys. flux after final cuts



Preliminary!

Parameters of 10 selected events (2018-2020)

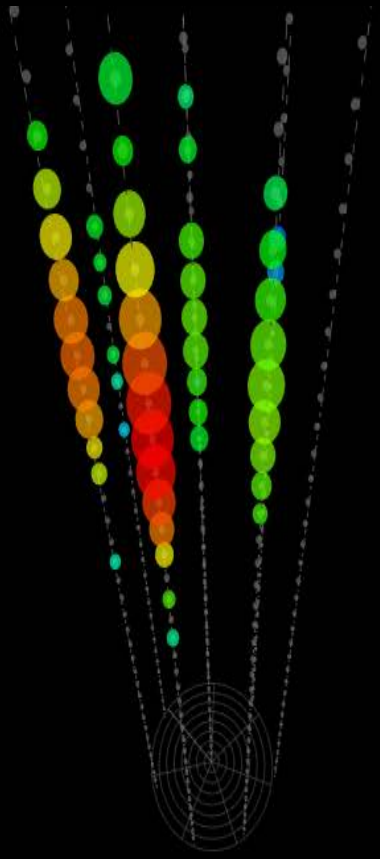
	E, TeV	θ_z, degree	φ, degree	R.A.	Dec
GVD2018_354_N	105	37	331	118.2	72.5
GVD2018_383_N	115	73	112	35.4	1.1
GVD2018_656_N	398	64	347	55.6	62.4
GVD2019_112_N	1200	61	329	217.7	57.6
GVD2019_114_N	91	109	92	45.1	-16.7
GVD2019_663_N	83	50	276	163.6	34.2
GVD2019_153_N	129	50	321	33.7	61.4
GVD2020_175_N	110	71	185	295.3	-18.9
GVD2020_332_N	74	92	9	223.0	35.4
GVD2020_399_N	246	57	49	131.9	50.2

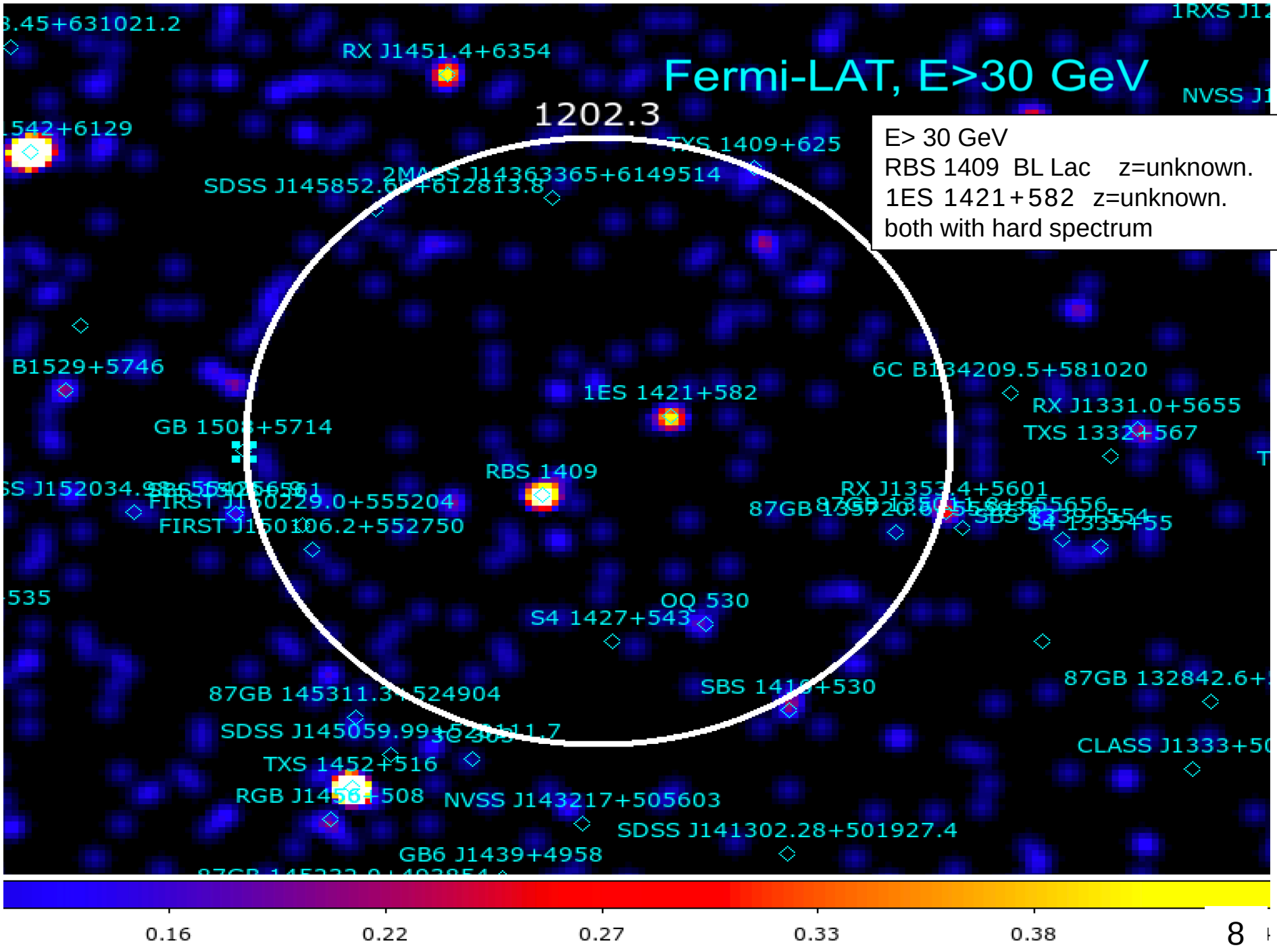

Sky map with 10 events
Preliminary!
210.000
180.000
150.000
120.000
90.000
60.000
30.000
0.000
-30.000
-60.000
-90.000
240.000
270.000
300.000
330.000
3
10
24
51
105
212
426
856
1709

GVD_2019_112_N

Preliminary

Energy E = 1200 TeV (±30%);
distance from central string r = 91 m;
Zenith angle = 61°

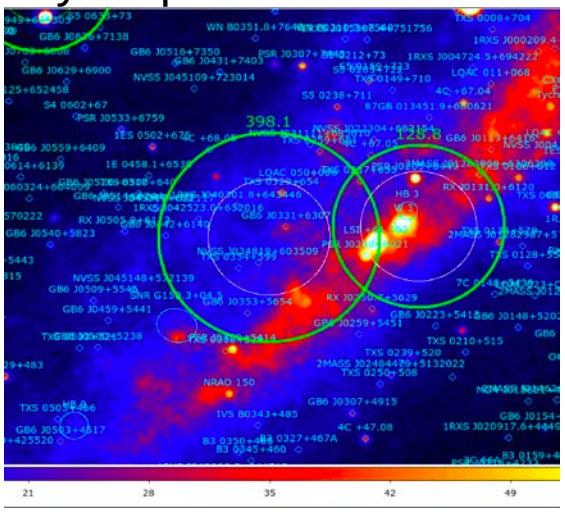



Fermi-LAT, E>30 GeV
1202.3
E> 30 GeV
RBS 1409 BL Lac z=unknown.
1ES 1421+582 z=unknown.
both with hard spectrum
RX J1451.4+6354
TXS 1409+625
1ES 1421+582
RBS 1409
B1529+5746
6C B134209.5+581020
RX J1331.0+5655
TXS 1332+567
OQ 530
S4 1427+543
SBS 1416+530
87GB 132842.6+
87GB 145311.3+524904
SDSS J145059.99+
TXS 1452+516
CLASS J1333+50
RGB J145
NVSS J143217+505603
SDSS J141302.28+501927.4
GB6 J1439+4958
0.16
0.22
0.27
0.33
0.38

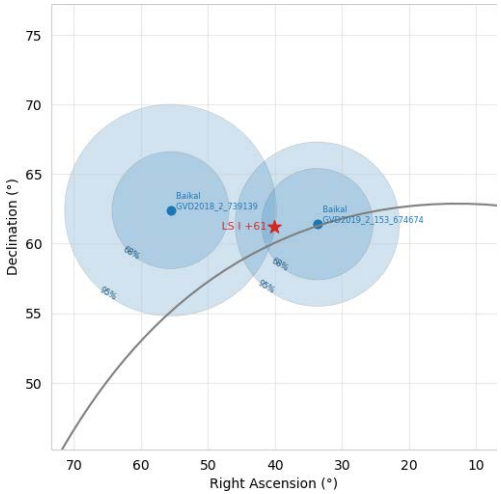
Preliminary!

Two close events at distance 10.3°: GVD_2018_656_N & GVD_2019_153_N

Sky map of Fermi sources



LSI +61 303 and two events



LSI +61 303 – at 3.1° and 7.4° from GVD_2019_153_N and GVD_2018_656_N

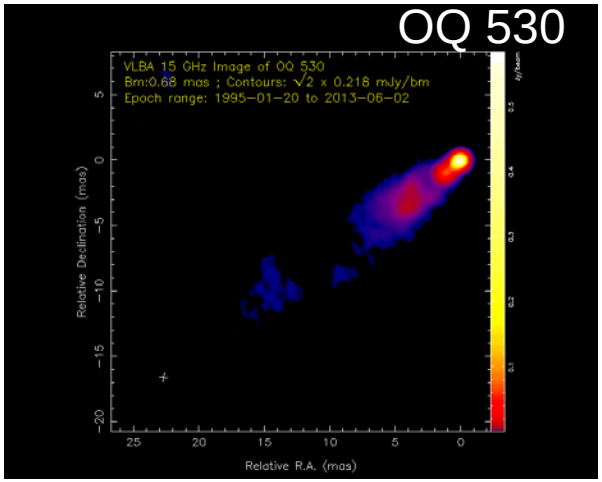
LSI +61 303 – γ-ray active microquasar

Using PSFs of all 10 events chance probability
to observe such configuration was estimated:

p-value = 0.007 or 2.7 σ ! (conservative, preliminary!!!)

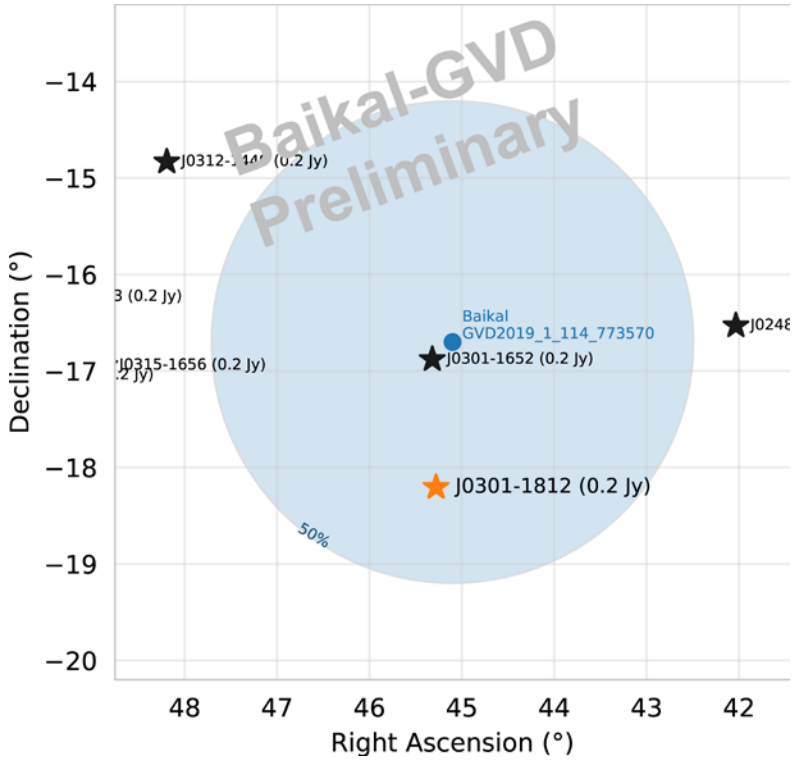
Radio-loud blazars – promising neutrino sources

A. Plavin et al., ApJ 894, 101 (2020)
A. Plavin et al., ApJ 908, 157 (2021)

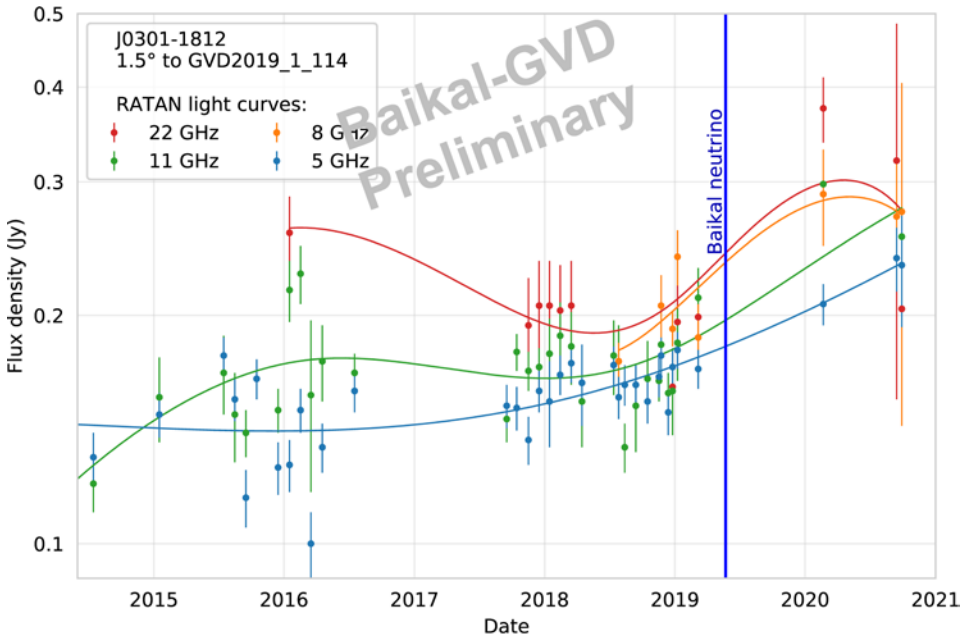


GVD2019_1_114_N
Radio blazar J0301-1812

Sky plot of radio-bright blazars nearby neutrino event

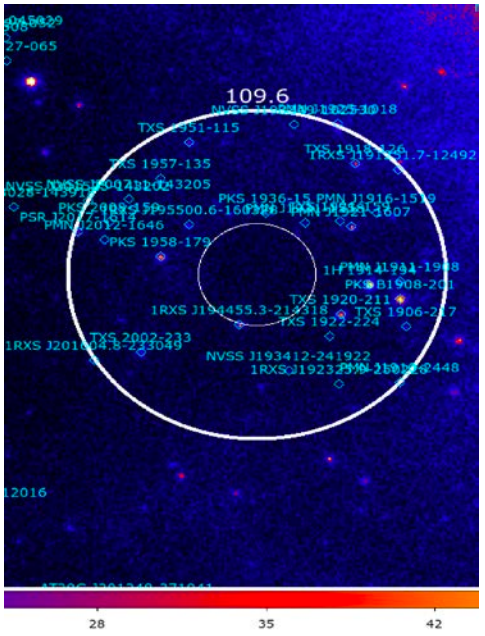


Light curves of J0301-1812 measured by RATAN-600

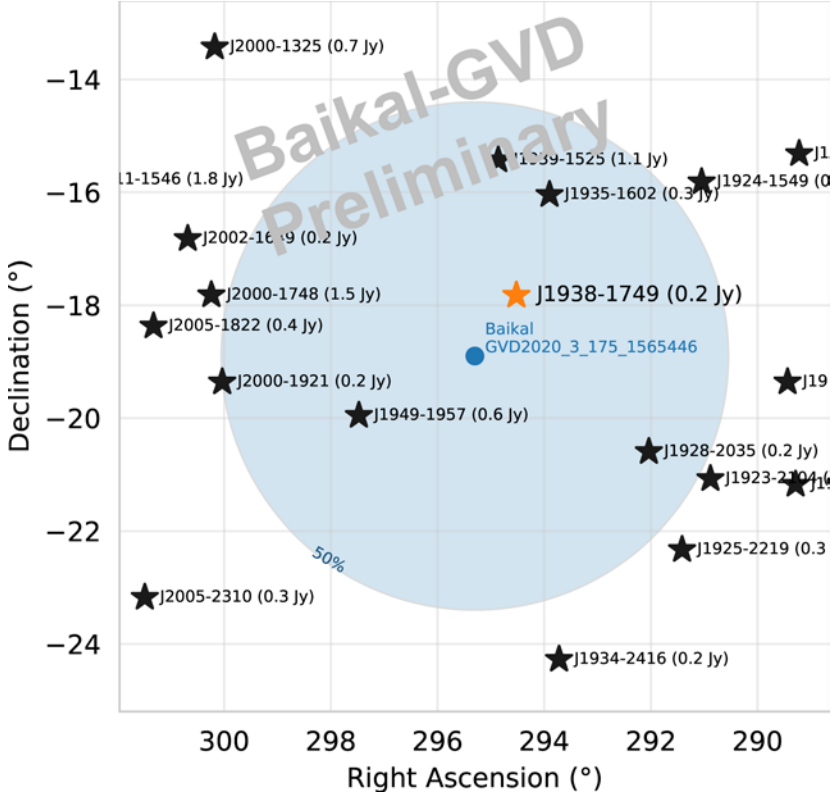


GVD2020_3_175_N

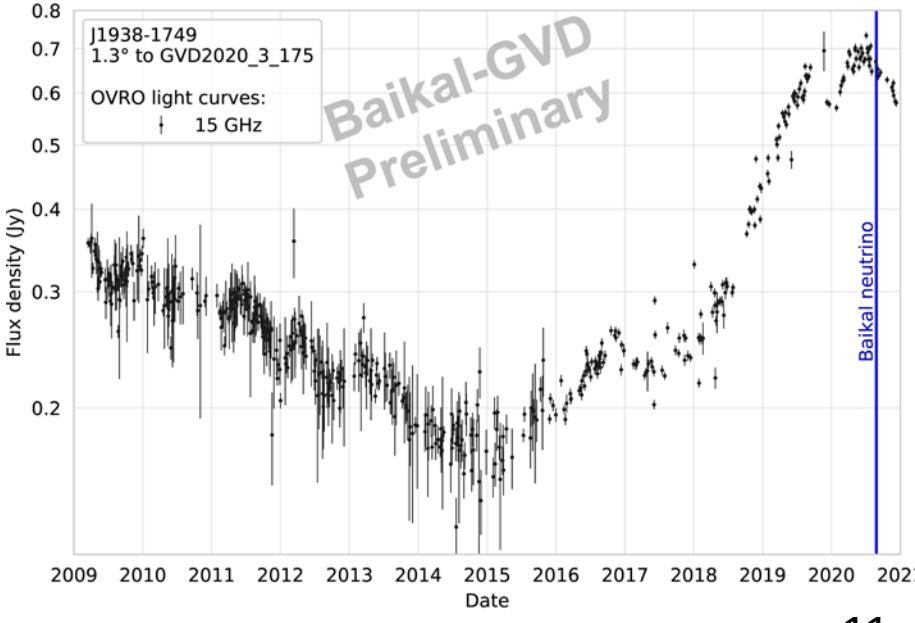
Radio blazar J1938-1749



Sky plot of radio-bright blazars nearby neutrino event



Light curves of J1938-1749 measured by OVRO



Conclusion

- Baikal-GVD is now the largest neutrino telescope in the Northern Hemisphere: 0.4 km^3 and growing

- Modular structure of GVD design allows a search for HE neutrinos and multimessenger studies at the early phases of array construction.

- Ten cascade-like events were selected from 2018-2020 data sample – first candidates for events from astrophysical neutrinos