Lowering the HAWC threshold to search for GRB Signals

Giuseppe Di Sciascio (INFN Roma Tor Vergata, Italy) & Sabrina Casanova (IFJ PAN, Krakow, Poland)

HAWC Observatory

The High-Altitude Water Cherenkov (HAWC), which continuously surveys 2/3 of the sky every day, is among the most sensitive γ-ray survey instruments in the world (HAWC). Its large field of view (FoV) and continuous operation make it a powerful detector to search for GRBs and observe their prompt phase thanks to the lack of observational delays. The HAWC Observatory consists of two arrays of water Cherenkov detector (WCD) stations: a primary array of 300 densely packed large-volume WCDs located at the centre ("primary detector") surrounded by a sparse outer array of 345 small-volume WCDs ("outriggers").The introduction of novel custom particle recognition (gamma/hadron discrimination) and reconstruction algorithms, included in Pass5 release of HAWC analysis pipeline, have increased the low energy effective area by a factor of 5, and the detection energy range was extended to several hundred GeV [1,2,3].

HAWC WCDs + RPCs

The primary goal of our project is to test the possibility of lowering the threshold of the photomultipliers tubes (PMTs) in the HAWC WCDs by equipping the WCDs with a carpet of Resistive Plate Counters (RPCs), proved to be optimal detectors at 100 GeV energies by the ARGO-YBJ collaboration (ARGO_YBJ) [10].

RPCs allow us to exploit a high granularity read-out crucial for a flexible trigger logic at very low energy. As an example we mention 2 possible triggers tested with the ARGO-YBJ experiment [11, 12].

Low Multiplicity Trigger (LM): puts in coincidence and sums up the highest multiplicity asserted by each pad, a value in the range from 0 to 6. The logic generates a signal when the total sum evaluated on the entire ARGO-YBJ carpet exceeds a programmed threshold into 400 ns.

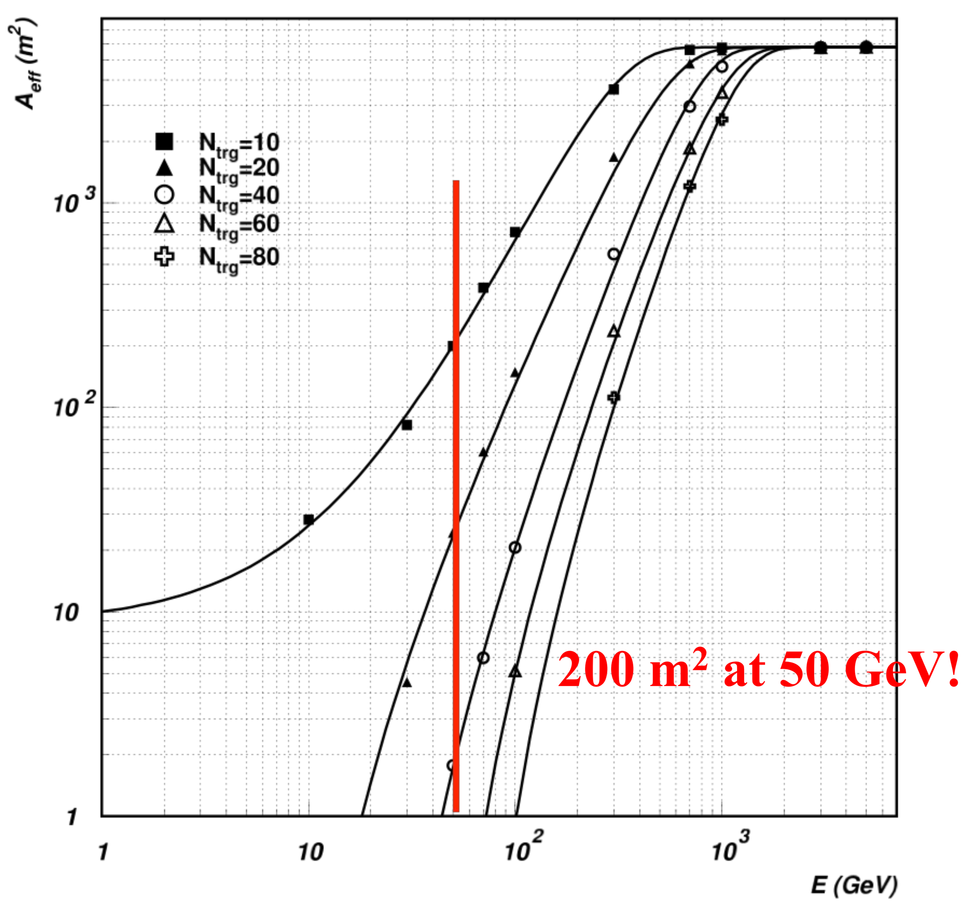
FAST Trigger: the logic generates a signal when the total sum evaluated on a Super-Cluster (4 Clusters) exceeds a programmed threshold into 150 ns.

If testing of the hybrid detector is promising and the HAWC collaboration agrees we will equip the whole HAWC detector with RPCs.

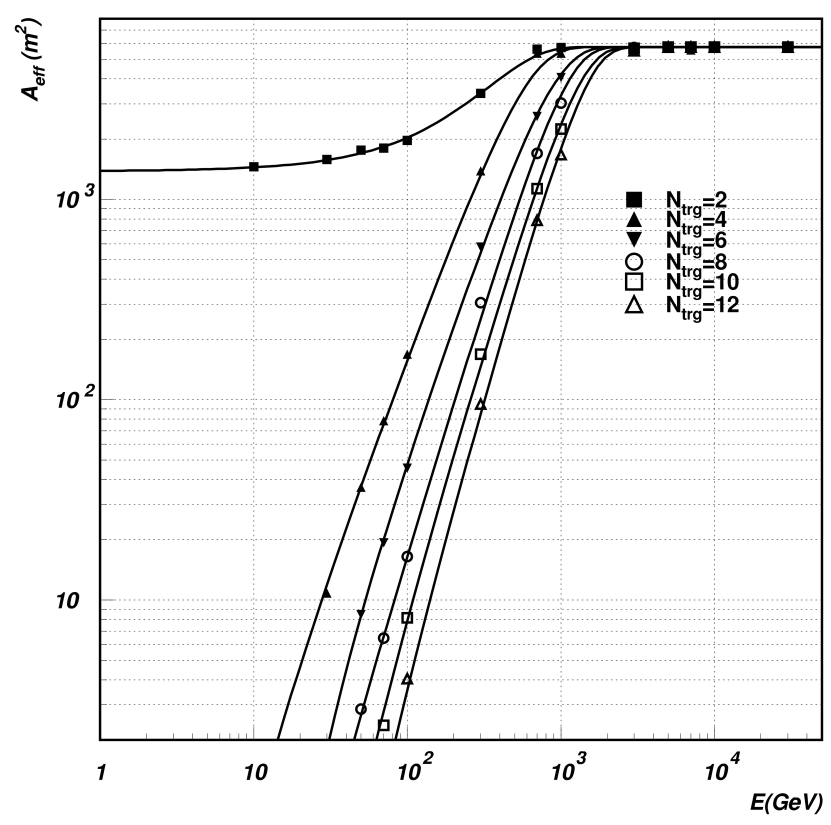
SubTeV to TeV emission from GRBs

Gamma-Ray Bursts (GRBs) are some of the most extraordinary events observed in the Universe [4,5]. Due to pair production with ultraviolet, optical and infrared extragalactic background light (EBL), energetic γ-rays are dramatically attenuated during their travel from these extragalactic sources to the Earth. The last energy band of the electromagnetic spectrum to be detectable from GRBs before the onset of the γ-ray horizon is the band between 100 GeV and several TeV.

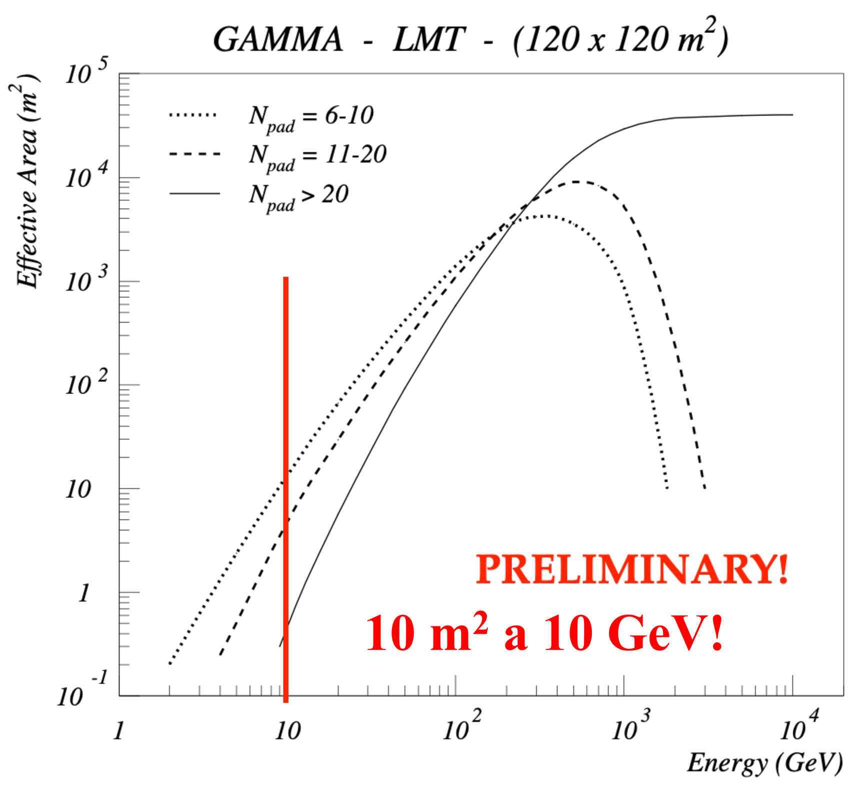
GRBs are thought to arise in dissipation processes in which the energy of relativistic jets is converted into non-thermal radiation. Several mechanisms have been suggested for this dissipation, such as internal shock or magnetic reconnection if the outflow is highly magnetized. Electron synchrotron has been suggested as a mechanism to explain the observed emission for most of the 200 bursts in the sub-MeV to GeV band. Inverse Compton (IC) up-scattering of the synchrotron photons by the same electrons accelerated in the shock is likely the mechanism responsible for the GRBs in the tens of GeV range. At higher energies the radiation from GRBs recently discovered with H.E.S.S. and with MAGIC can be generally included in the IC scenario [6,7,8,9]. However, the sub-TeV emission from GRB180720B, detected for a long time during the afterglow phase, challenges current IC emission scenarios [8] and motivates systematic searches for GRBs at sub-TeV to TeV energies.



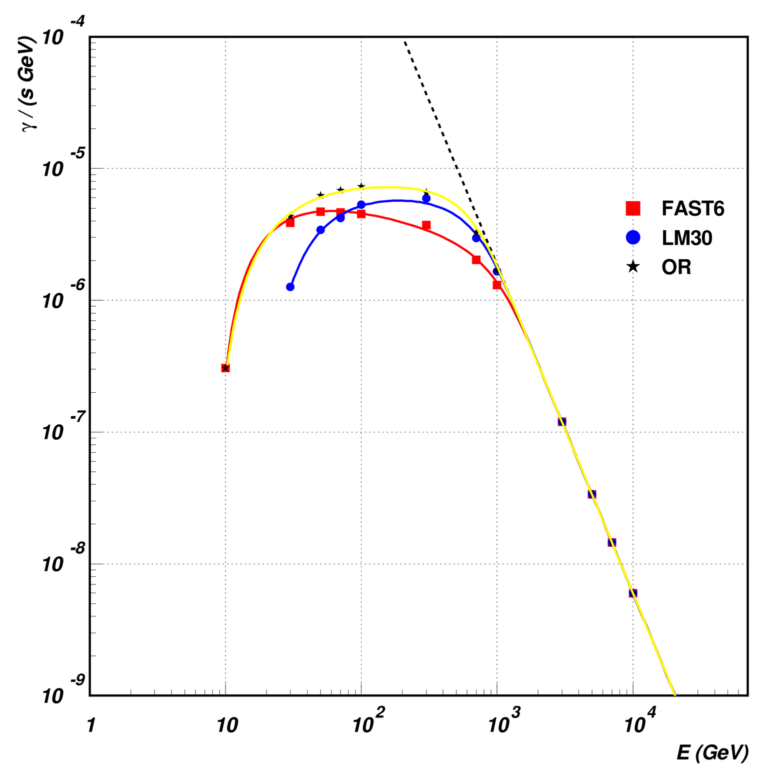
Effective areas for different LM trigger thresholds for vertical gamma-induced showers on the ARGO-YBJ carpet at 4300 m asl.



Effective areas for different FAST trigger thresholds for vertical gamma-induced showers.



Effective areas for a LM Trigger on a RPC carpet with a 120 X 120 m² area



Comparison between LM30 and FAST6 triggers and their OR. The Crab spectrum is assumed

Bibliography

[1] A. U. Abeysekara *et al* 2017 *ApJ* **843** 39
[2] A. U. Abeysekara *et al 2023 Nuclear Inst. and Methods in Physics Research, A* 168253
[3] A. Albert *et al 2024* eprint arXiv:2405.06050
[4] Ray W. Klebesadel, Ian B. Strong, and Roy A. Olson. 1973 *Astrophys. J.*, 182:L85–L88
[5] P. Kumar and B. Zhang, 2015 *Physics Reports*, 561,
[6] Acciari, V.A. *et al*,2019 *Nature* 575, 455 , 2006.07249
[7] Abdalla, H. *et al*. 2019 *Nature* 575, 464 , 1911.08961
[8] Abdalla, H. *et al* 2021 *Science* 372, Issue 6546, pp. 1081-1085
[9] Cao, Z. *et al* 2023 *Science*, 380, 6652 1390-1396
[10] Di Sciascio G, 2014 *International Journal of Modern Physics* D Vol. 23, No. 9, 1430019
[11] Aloisio A. *et al*., IEEE 2004, 51 1835-1839
[12] Mastroianni S. *et al., 2005 29th International Cosmic Ray Conference* Pune 5, 311–314