ML based PID (astroparticles) and GW signal detection

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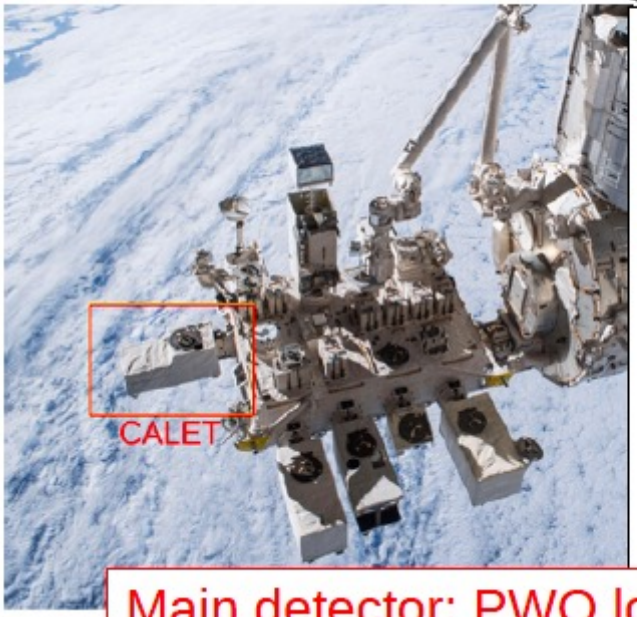
Personpower UNIFI

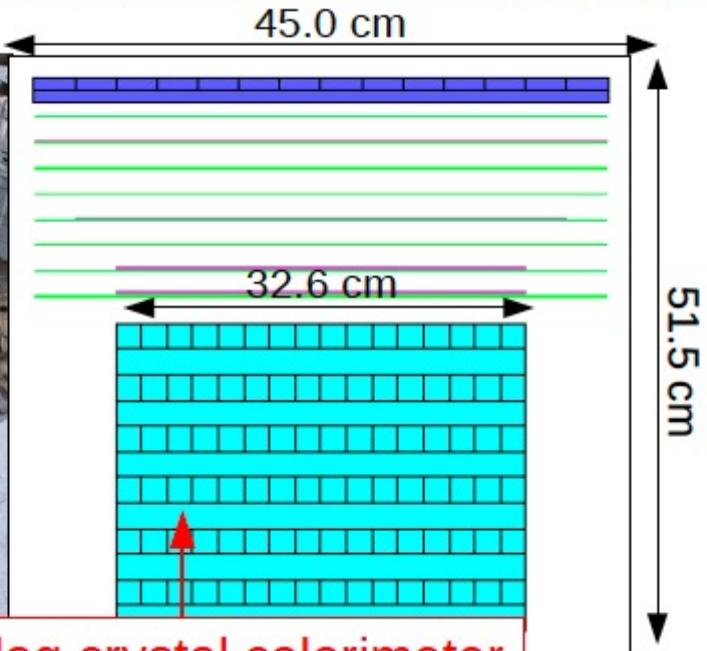
- Astroparticles (CALET and HERD): Adriani, Berti, Bongi (+ INFN staff)
- Gravitational Waves (Virgo and ET): Lenti (+ INFN staff) + Urbino group (Guidi) via possible Open Call
- New RTDa to be hired very soon
- Some thorists on GW also (partially) involved: Cotrone, Colferai, Panico

CALET: The experiment

The **CALorimetric Electron Telescope** (CALET) is an experiment operating aboard the International Space Station since 2015

Main observation channels	Main scientific goals
e^-+e^+ flux up to a few TeV	Search for local high energy sources Indirect search of dark matter
p, nuclei fluxes up to tens of TeV	Study of acceleration/propagation

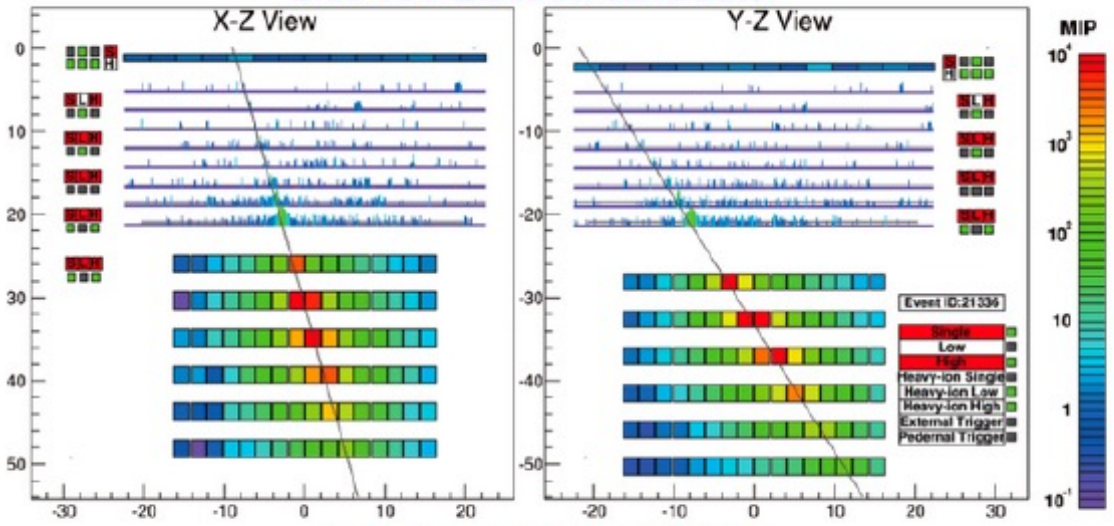




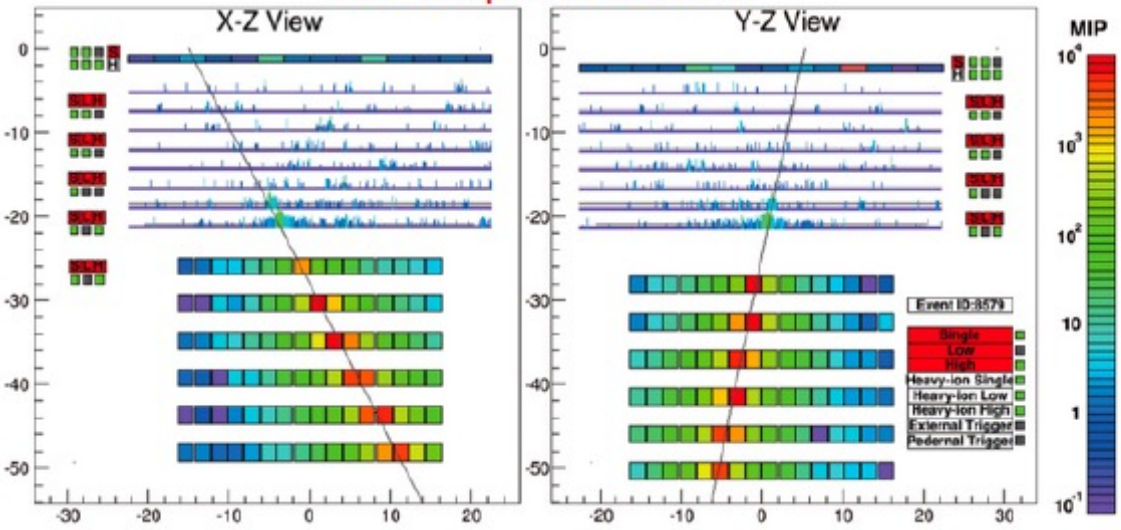
Main detector: PWO log crystal calorimeter

CALET: Foreseen activities

2.89 TeV Electron candidate



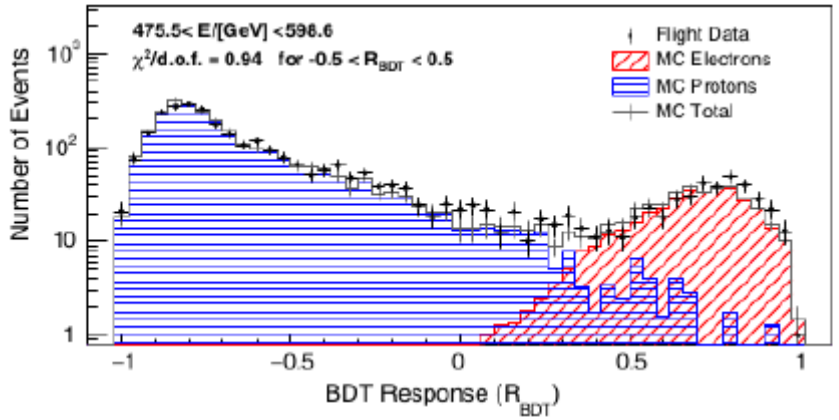
2.89 TeV proton candidate

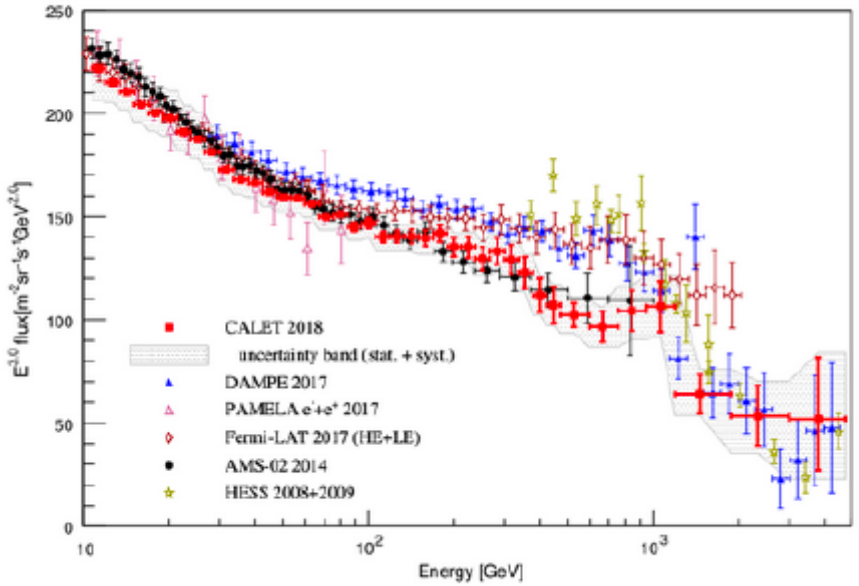


The major challenge in the measurement of the e^-+e^+ flux is the *proton background*: in cosmic rays p/e ratio is 100-1000, getting larger at higher energies, where the statistics is also very limited

<u>Need of powerful e-p separation techniques</u> based on the differences between electromagnetic and hadronic showers

CALET: Foreseen activities





Proton rejection is currently performed using Boosted Decision Tree (BDT) implemented in ROOT::TMVA package, with an electron selection efficiency of 80% and a proton contamination below 20%

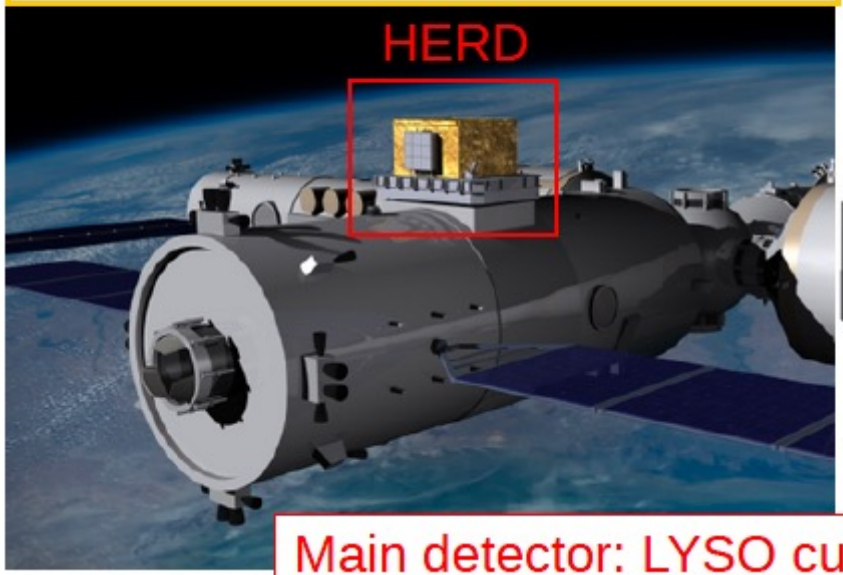
The CALET experiment has measured the e^-+e^+ flux up to 4.8 TeV: it has the potentiality to extend it up to 10 TeV, but requires a better e-p separation to coop with the limited statistics at high energy.

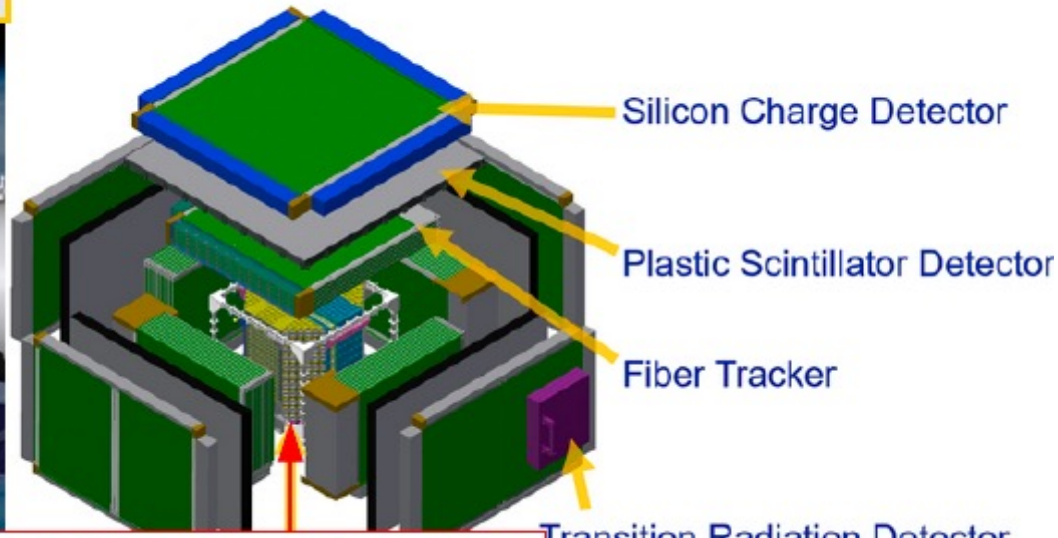
<u>Need of more powerful and more resource-consuming machine learning techniques</u> to extend the measurement to even higher energies

HERD: The experiment

The **High Energy cosmic-Radiation Detection** (HERD) facility will be installed aboard the China's Space Station around 2027

Main observation channels	Main scientific goals
p, nuclei fluxes up to few PeV	First direct detection of *knee* structure
e^-+e^+ flux up to tens of TeV	Search for local high energy sources
Gamma-ray above 100 MeV	Indirect search of dark matter





Main detector: LYSO cubic crystal calorimeter

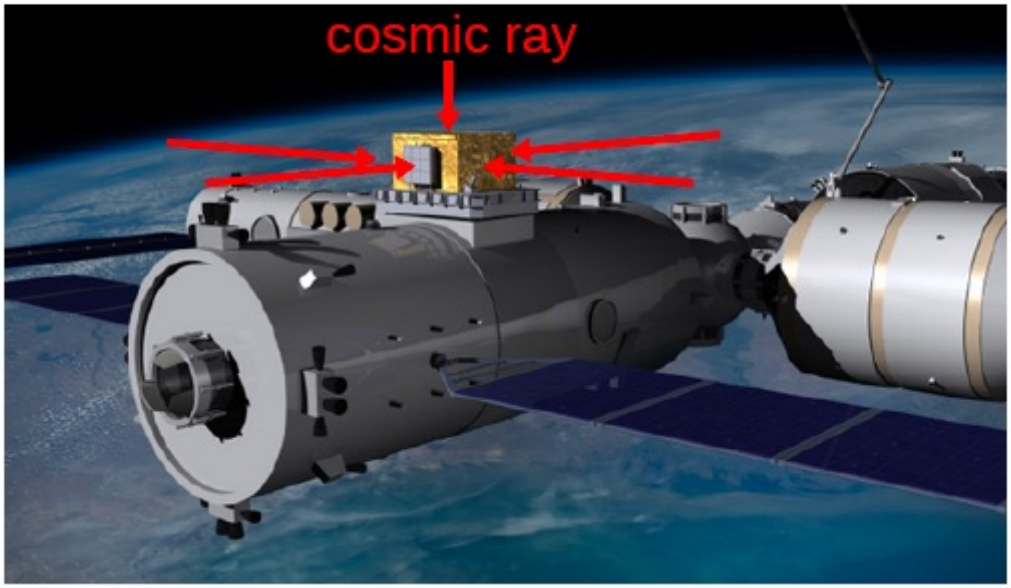
HERD: Foreseen activities

With a **3D design** increasing acceptance by a factor 10 with respect to CALET, the HERD experiment will extend direct measurements to higher energies

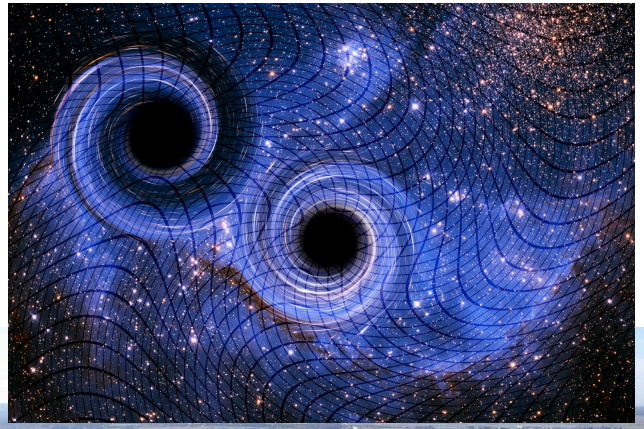
The measurement of the e^-+e^+ flux will benefit from the same development based on machine learning techniques described for CALET

Differently from CALET, the HERD experiment will detect particles entering not only from the top surface but also from the lateral ones

Need of complex 3D reconstruction algorithms to optimize the detector performances over the whole instrument acceptance

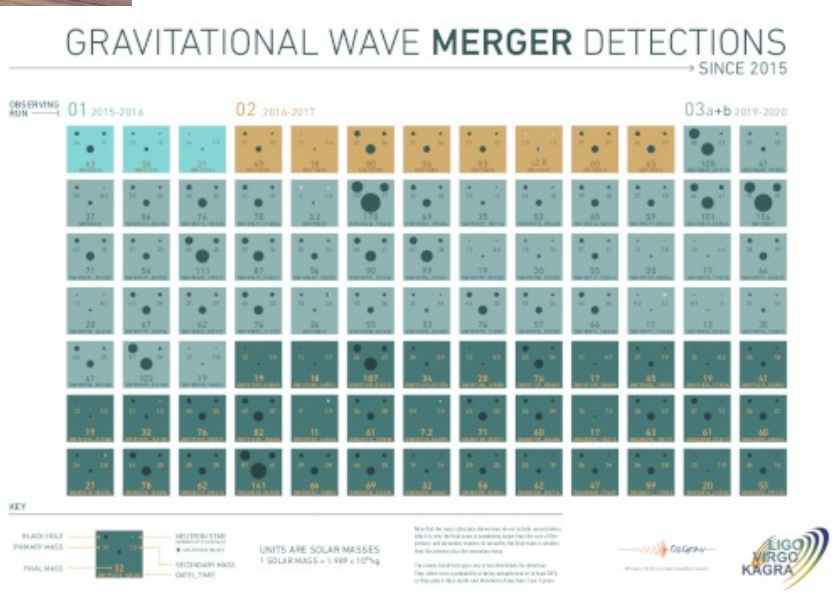


VIRGO



2G Gravitational Interferometer

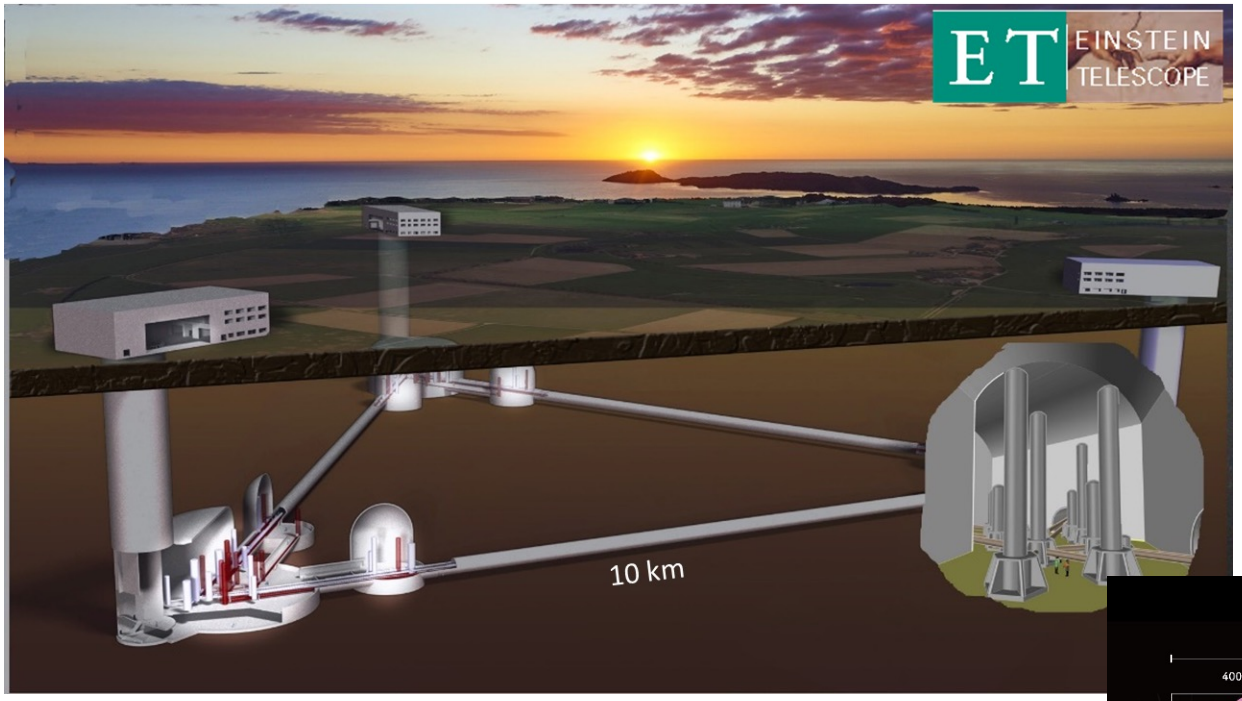
O4 observing run starting spring 2023



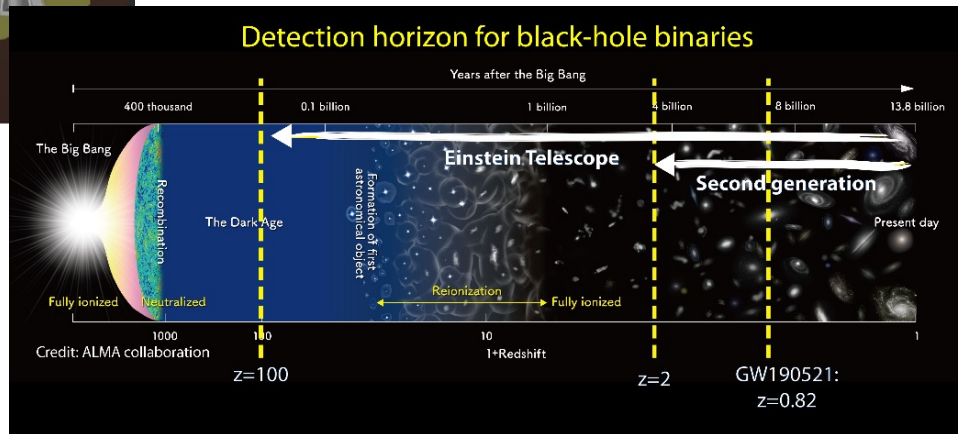
VIRGO: activities

- Esperience with MBTA (Multi Band Template Analysis) pipeline
- Searches by source type: CBC, bursts, stochastic, CW
- ML and DL for
  - Waveform simulation
  - Signal Detection
  - Parameter Estimation
- Many activities on ML already present within the Virgo collaboration
- Multimessengers opportunities
- Computing Infrastructure: European Open Science Cloud,use of GPU, Common data analysis platform with othe observatories (KM3net, CTA, …), quantum computing algorithms…

Einstein Telescope



3G Gravitational Observatory



Einstein Telescope: activities

- From 2G detectors to 3G

➢ Algorithms based on matched filtering, template banks,….

  - ➢ scalability
  - ➢ parallelizability

➢ Overlapping signals

➢ Long duration waveforms for CBCs: huge number of templates