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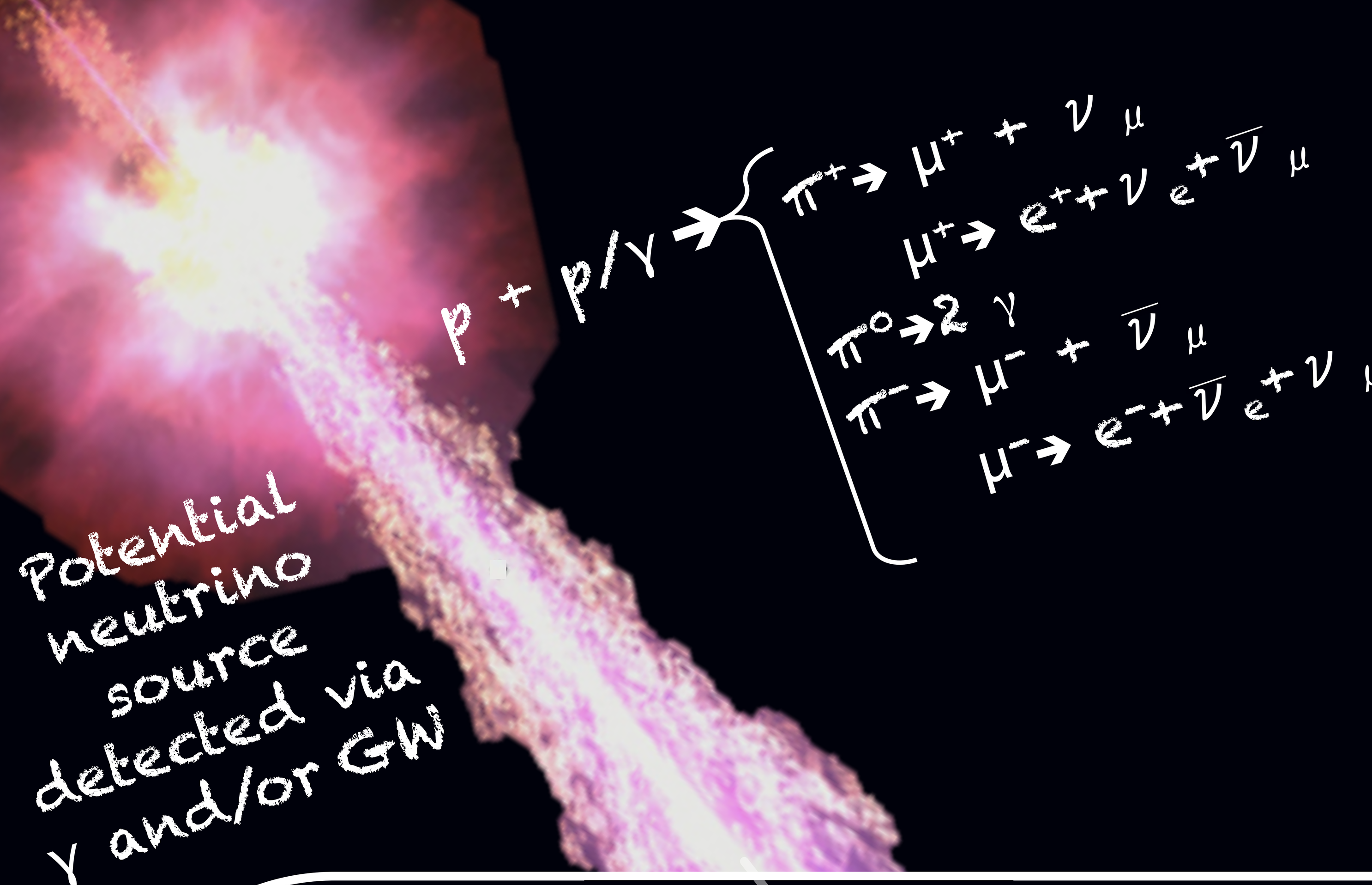

Sensitivity for astrophysical neutrino searches with KM3NeT/ORCA

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1. Motivation

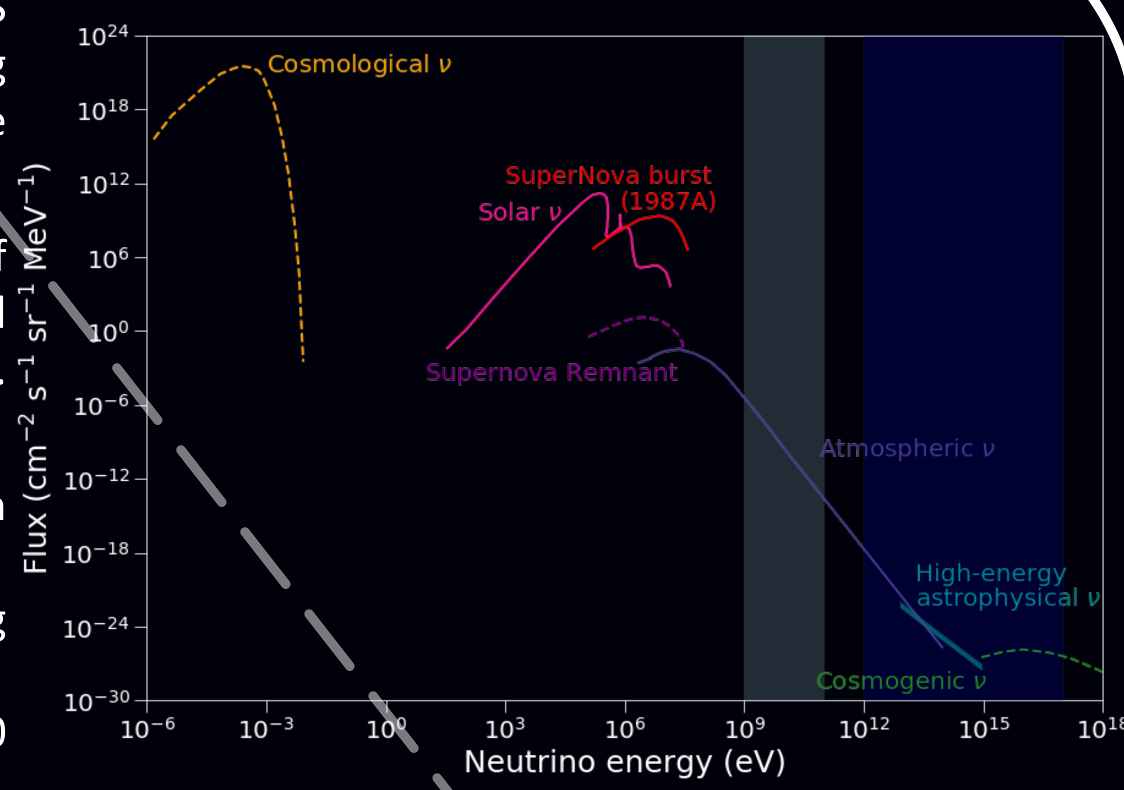
Low-energy astrophysical neutrino searches

Large neutrino telescopes, such as ANTARES and IceCube, have so far focused on detecting astrophysical neutrinos in the TeV-PeV range (blue band).

In this poster, we assess the capability of KM3NeT-ORCA to carry out astrophysical neutrino searches in the 1-100 GeV range. (light grey band).

Are current neutrino telescopes sensitive in this energy range?

- Super-Kamiokande with upward going muons between 1.6 GeV and 100 PeV
- IceCube with all-flavour search between 500 MeV and 5 GeV



Example: Gamma-ray Bursts

- TeV neutrino emission ➔ could be produced by the internal shock in the prompt emission phase
- GeV neutrinos ➔ could be produced by:
  - collisions of neutrons and protons following their decoupling during the acceleration phase
  - or by interactions of the accelerated proton flux with a dense environment surrounding the source

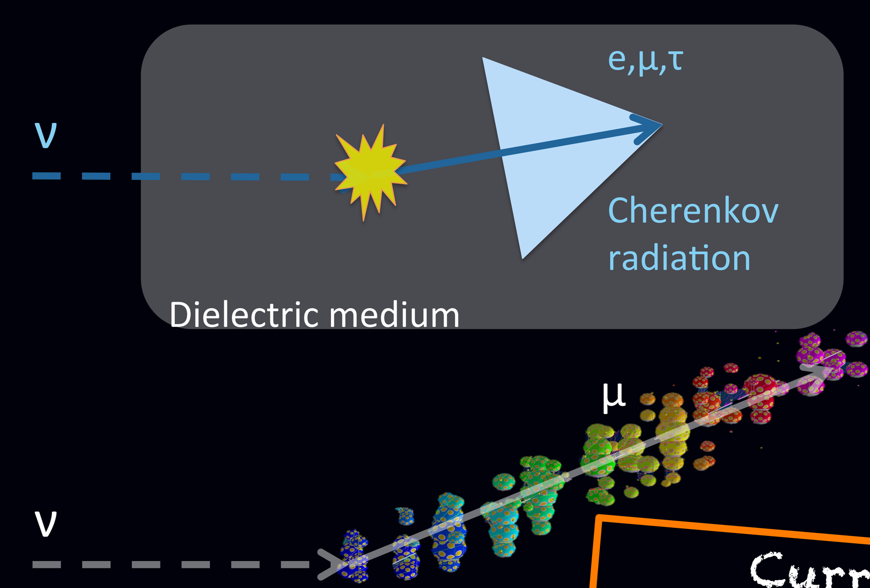
GeV neutrino searches could therefore lead to the evidence of hadronic acceleration mechanisms but also constitute a probe of the amount of matter surrounding the astrophysical object.

2. KM3NeT/ORCA

How to detect neutrinos with ORCA

ORCA (*Oscillation Research with Cosmics in the Abyss*) is the low-energy branch of the KM3NeT project.

It will consist of a multi-Mt deep-sea detector optimized for the detection of neutrinos in the 1-100GeV range and mainly targets fundamental neutrino physics, in particular the measurement of the neutrino mass ordering (NMO) with atmospheric neutrinos



Currently 4 ORCA DUs are taking data!

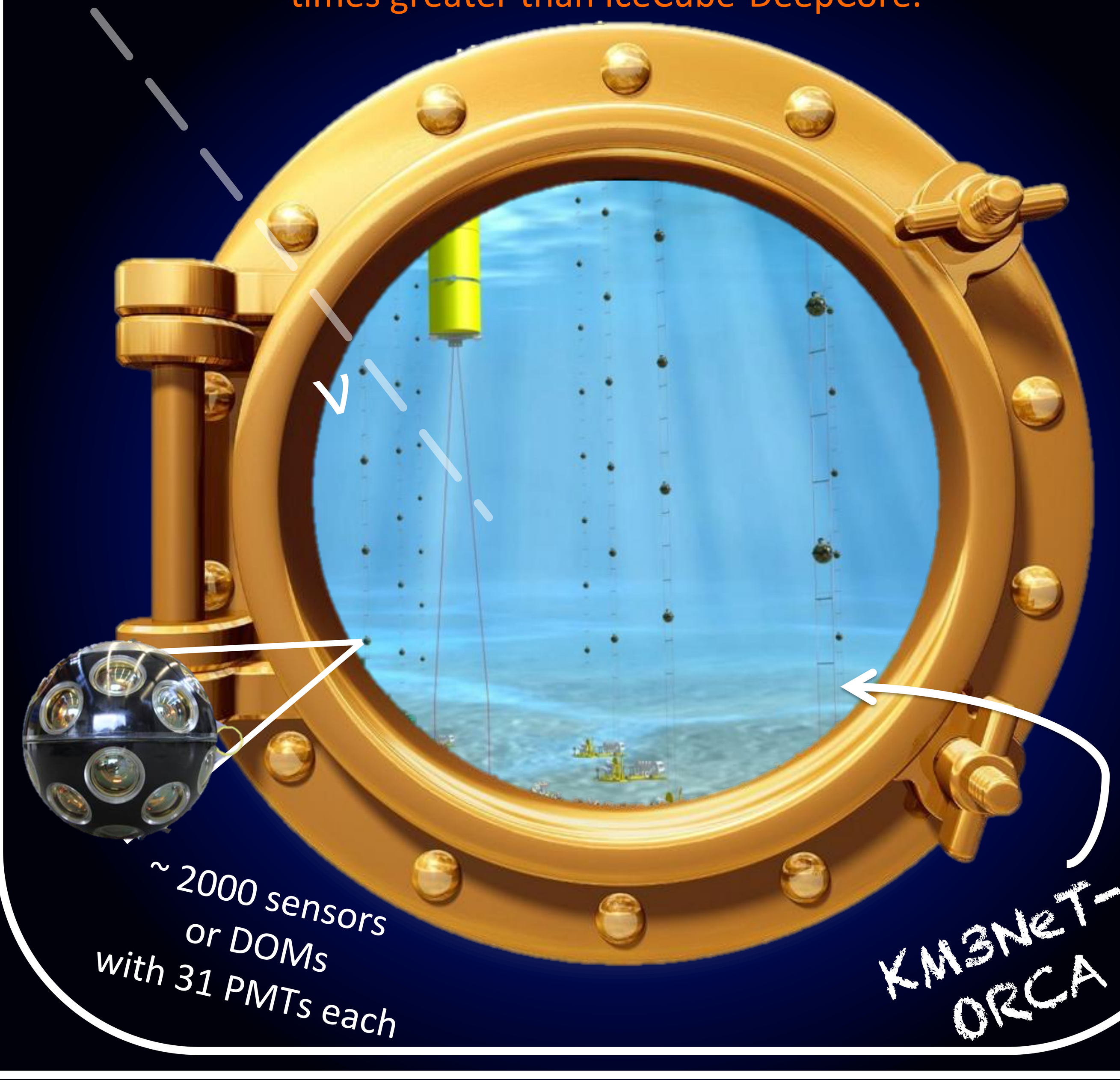
The ORCA digital optical modules (DOMs) rely on the innovative KM3NeT design featuring 31 small (3-inch) photosensors in one glass sphere. Such DOMs provide increased performance in photon counting, directionality and background rejection, leading to better selection and reconstruction capabilities for neutrino events.

ORCA detection units (DU):

- are flexible lines about 200 m high
- have a typical spacing of 20 m on average
- support 18 DOMs equally spaced by 9 m
- are installed off the shore of Toulon (France)

ORCA will become a 6 Mt detector with 115 DUs

ORCA will thus soon have an instrumented volume 100 times bigger than Super-Kamiokande and a density of photosensors about 30 times greater than IceCube-DeepCore.



3. Event selection

A. The NMO selection

We start from the event pre-selection optimized for the *NMO* analysis.

Requirements for an event to be selected:

(a) pass a pre-selection based on reconstruction quality
(b) have a reconstructed vertex contained inside or close to the instrumented volume
(c) be reconstructed as upward going in the detector

ensure good reconstruction performance

suppress part of the dominant background (atm. muons + pure noise)

Good to know:

- Pure noise = radioactive decays of ^{40}K + bioluminescence
- Median angular resolution after selection: < 20 degrees at low energies, < 5 degrees at 100 GeV

-> We can do astrophysical searches!

- Use of a Random Forest Classifier with 3 different scores ([0, 1])
  - A track-score: track-like (>0.6) vs shower-like events (<0.6)
  - A muon-score: 0 = probably not an atm. muon, 1 = probably an atm. muon
  - A noise-score: 0 = probably not noise, 1 = probably noise

B. Optimization for astrophysical searches

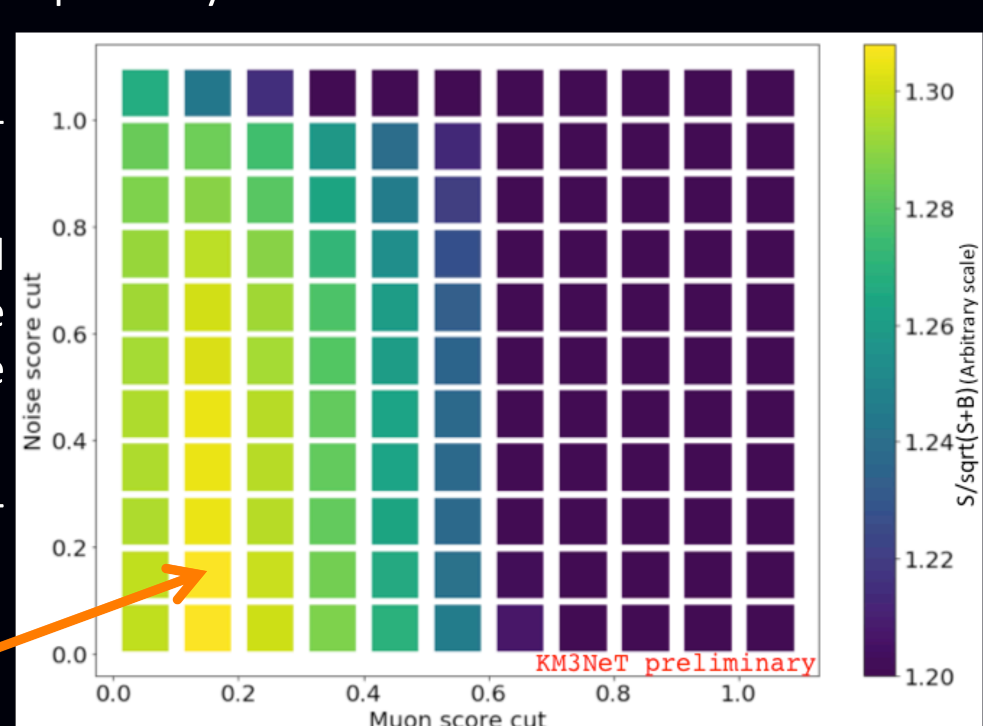
We can optimize the muon-score and noise-score for maximizing the signal-to-noise ratio.

- Signal (S) = neutrino events with a spectral index of -2 between 1 and 100 GeV. The normalization is such that 3 signal events can be detected in KM3NeT.

- Background (B) = atmospheric neutrinos + atmospheric muons + pure noise events.

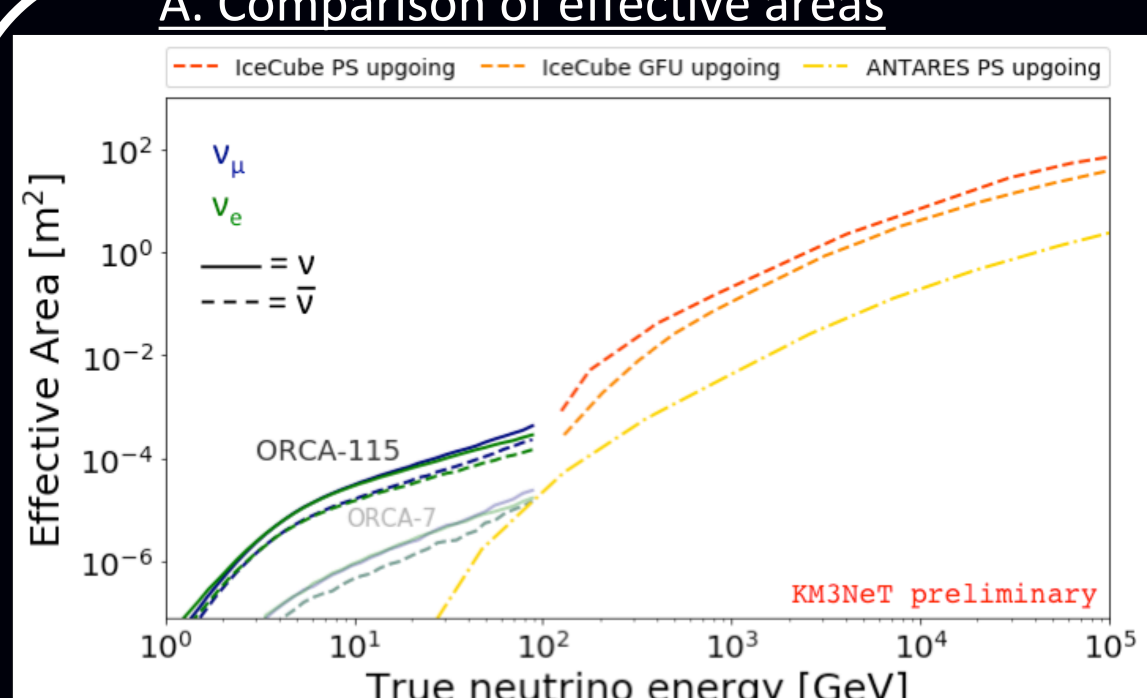
Maximization of S/sqrt(S+B):

- muon-score ≤ 0.15
- noise-score ≤ 0.15



4. Sensitivity

A. Comparison of effective areas



- Upgoing neutrino effective area
- Conservative estimate for ORCA capabilities. A detailed optimization for transients will be done in the near future.
- ORCA 7 DUs already competitive with existing analyses

B. Example of application:

Search for a neutrino counterpart to compact binary mergers detected by the LIGO and Virgo.

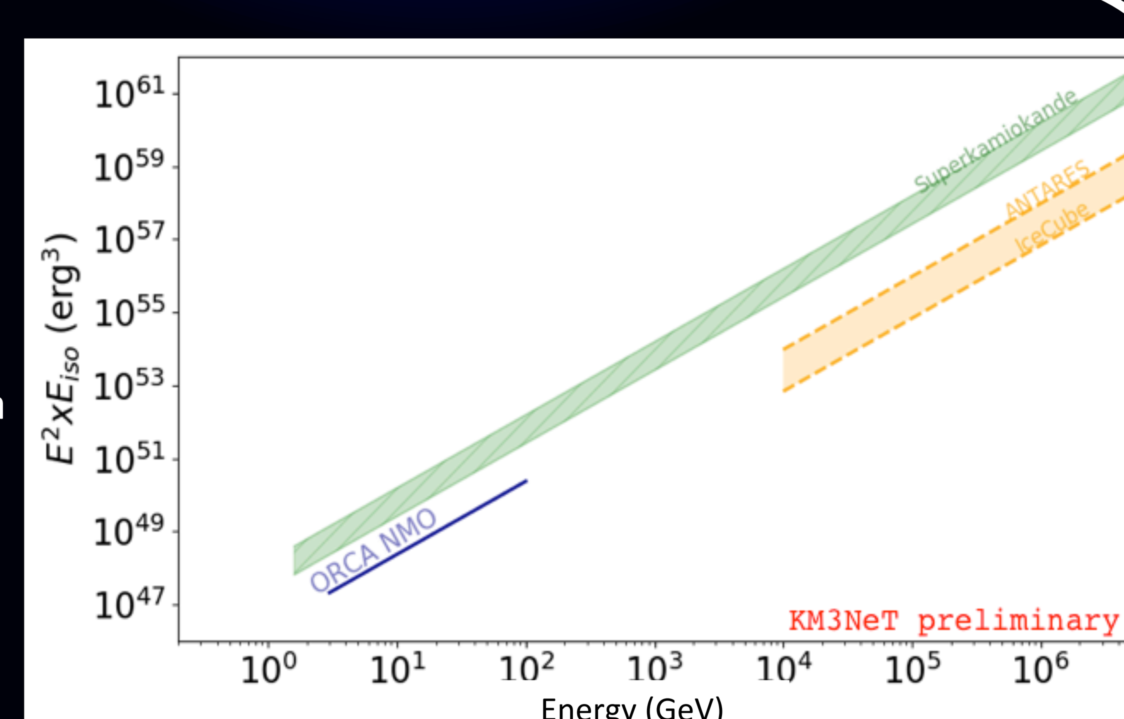
When: Conservative time window of [t_0-500s,t_0+500s]

How: Counting experiment in this time window.

We estimate the 90% sensitivity level by searching for a significant deviation from the Poissonian background.: 3 signal events needed to reach the sensitivity level.

-> Sensitivity on the neutrino fluence

$= 3 \times 10^5$ GeV m^{-2}



We can convert the fluence into a limit on the isotropic-equivalent energy E_{iso} released by the astrophysical event. This variable allows for comparison with constraints set using other messengers such as gamma-rays or gravitational waves. -> KM3NeT/ORCA will be able to produce competitive constraints compared to existing neutrino searches, in an energy range that has been poorly studied so far

ACAV+ · îledeFrance · European Commission · Horizon 2020 European Union funding for Research & Innovation · KM3NeT