THEORY GROUP

INFN CSN 4

Institutions:

GSSI+AQ UNIVERSITY+LNGS

Giulia Pagliaroli

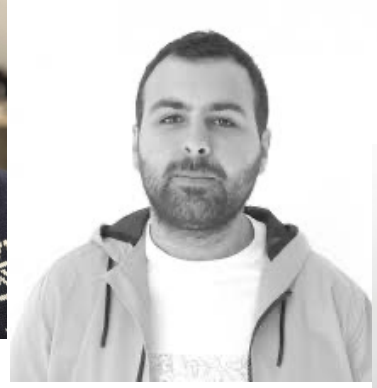
giulia.pagliaroli@lngs.infn.it

People: 25 members (8 PhD students)

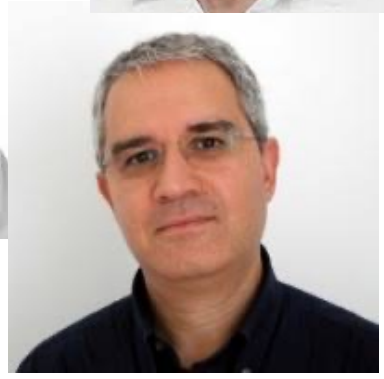









CSN4
Theoretical
physics

Physics TOPICS

- TEONGRAV: Theory of Gravitational Wave Sources
- NEUMATT: NEUtron star MATTer
- INDARK: Inflation, Dark Matter and the Large-Scale Structure of the Universe
- TAsP: Theoretical Astroparticle Physics

LOCAL COORDINATORS

- NEUMATT: Massimo Mannarelli
- INDARK: Luigi Pilo
- TEONGRAV: Andrea Maselli
- TAsP: Zurab Berezhiani




LOCAL COORDINATORS

- NEUMATT: Massimo Mannarelli ….see GSSI GW FAIR
- INDARK: Luigi Pilo …see also GSSI GW FAIR
- TEONGRAV: Andrea Maselli … see GSSI GW FAIR
- TAsP: Zurab Berezhiani. …see also GSSI HE FAIR

Zurab Berezhiani

Andrea Maselli

Massimo Mannarelli

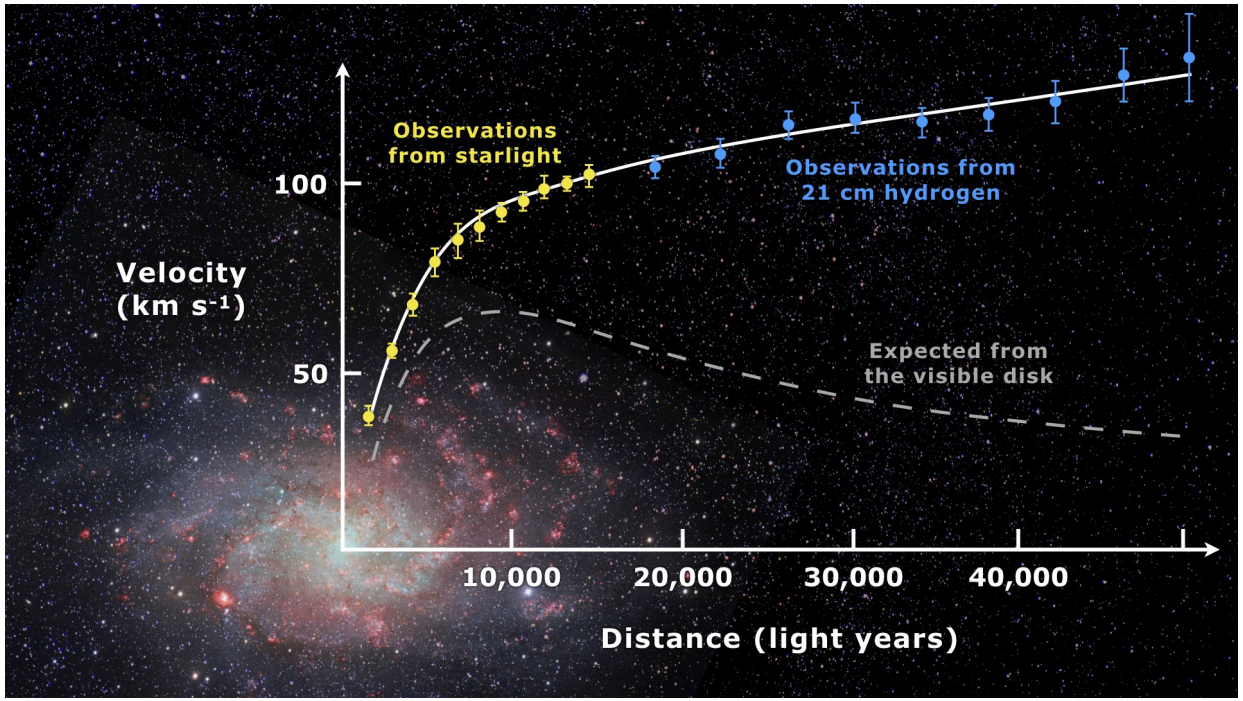
Luigi Pilo

THE LOW_ENERGY SECTOR

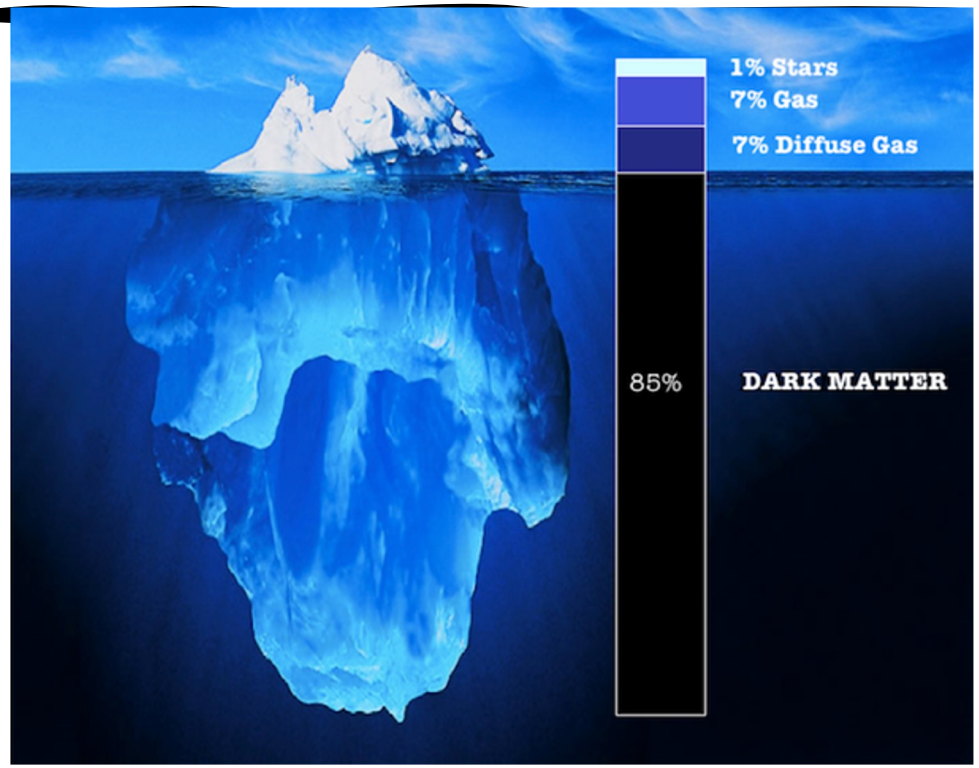
DARK MATTER

NEUTRINO PHYSICS AND ASTROPHYSICS

DARK MATTER

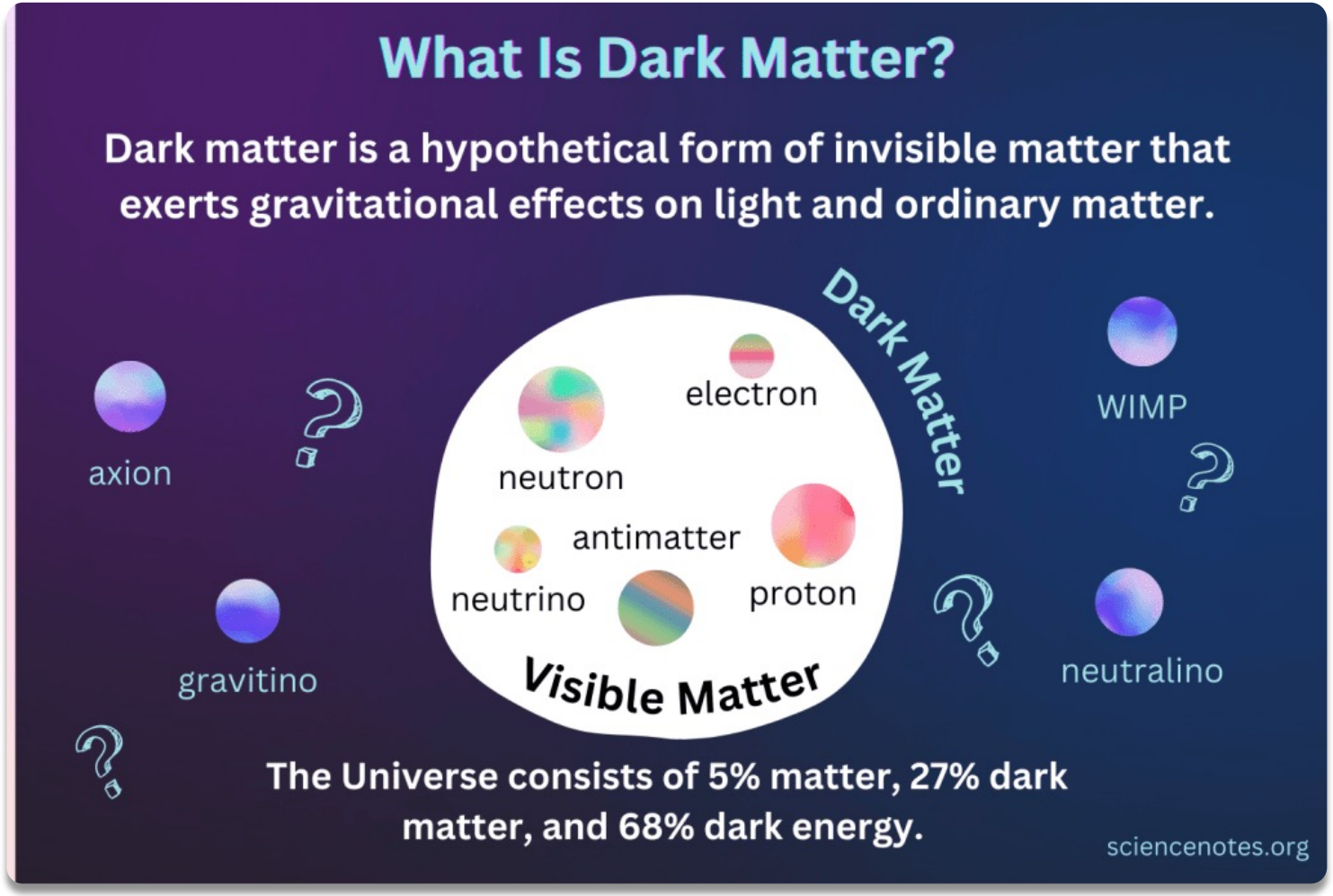


M33: the profile of the stellar disk contribution is in disagreement with the profile of circular velocity



A new Massive particle with a very small, but not necessarily zero,self-interactions or interactions with the SM particles

DARK MATTER and BSM



- Extension of Standard Model to predict new particles (DM candidates, Axions, Mirror Matter)
- Study of observative constraints on these candidates and how to preform experiments to look for
- Dark energy
- Study of Galaxies rotation curve

Berezhiani, Villante, Capozzi, Pilo, Nesti, Grilli Di Crotona

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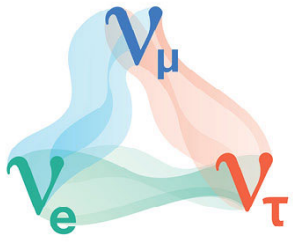
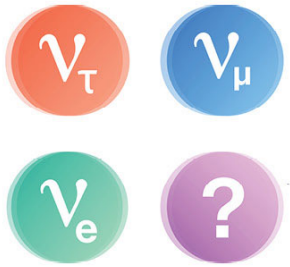
giovanni.grillidicrortona@lngs.infn.it

NEUTRINO PHYSICS

- Neutrino properties
- Non standard neutrino interactions
- Neutrino oscillations
- Sterile neutrinos
- Cross section estimation
- Neutrino mass ordering



OSCILLATING



MYSTERIOUS

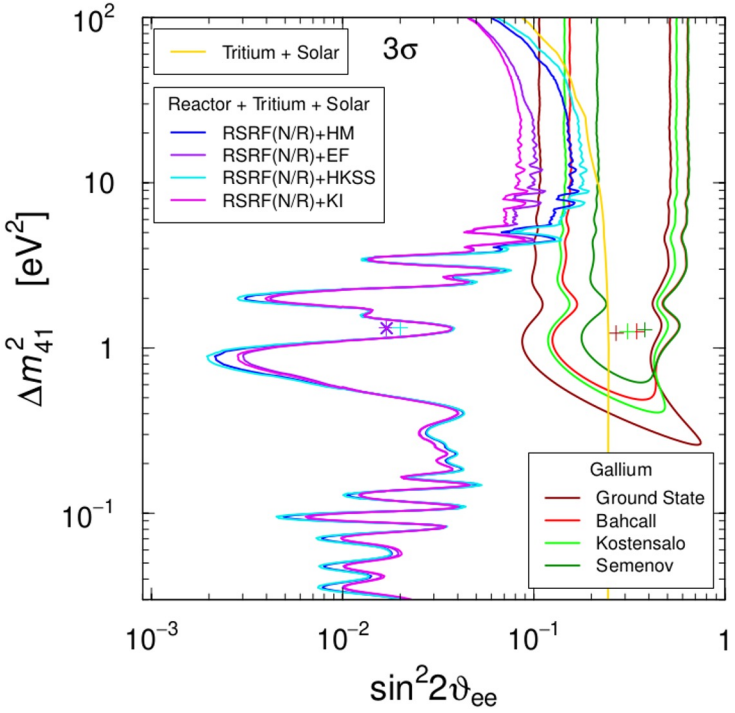
VERY MYSTERIOUS

Berezhiani, Vissani, Capozzi, Villante, Pagliaroli, Ternes

Research topics: Christoph Ternes

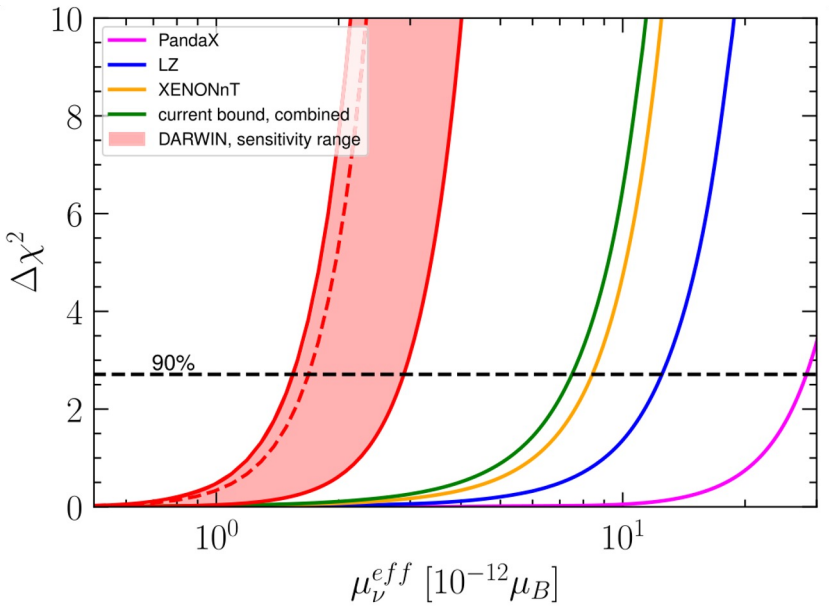
christoph.ternes@lngs.infn.it

- Investigation of neutrino anomalies
- E.g.: tension among Gallium and reactor experiments



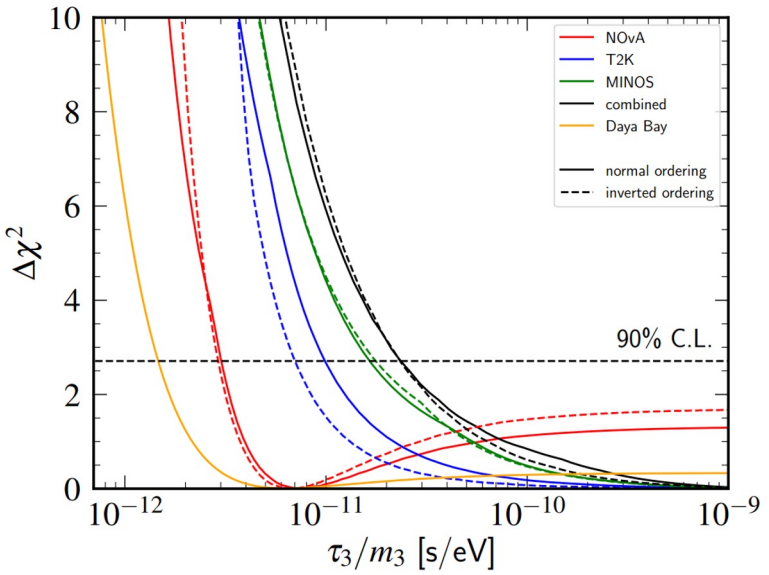
2209.00916, JHEP 2022

- New physics searches using neutrino interactions
- E.g.: Bounding neutrino electromagnetic properties with direct detection data



2309.17380, PRD 2023

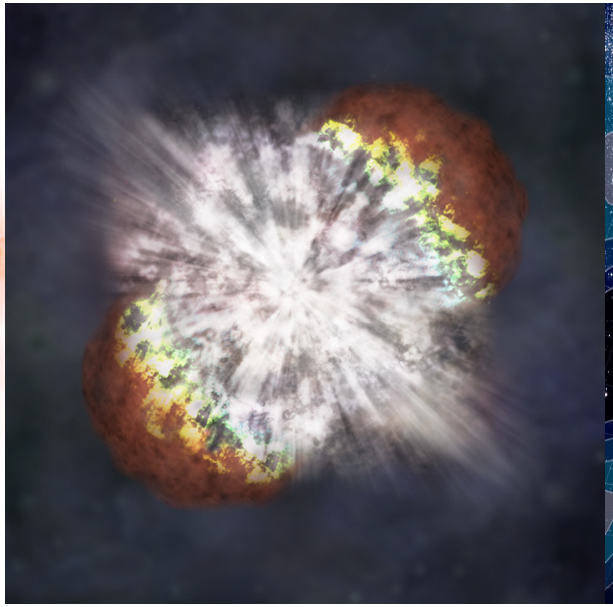
- Neutrino oscillation phenomenology
- E.g.: Invisible neutrino decay at accelerator experiments



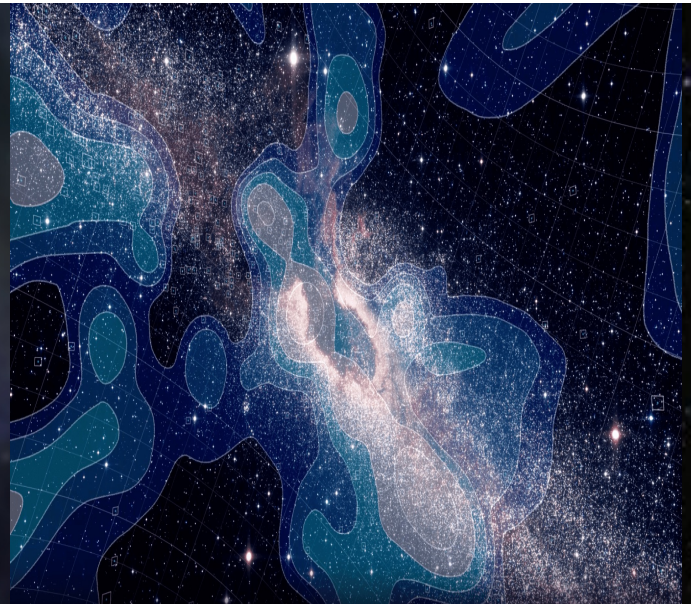
2401.14316, submitted to PRD

Astrophysical Neutrinos

Sun



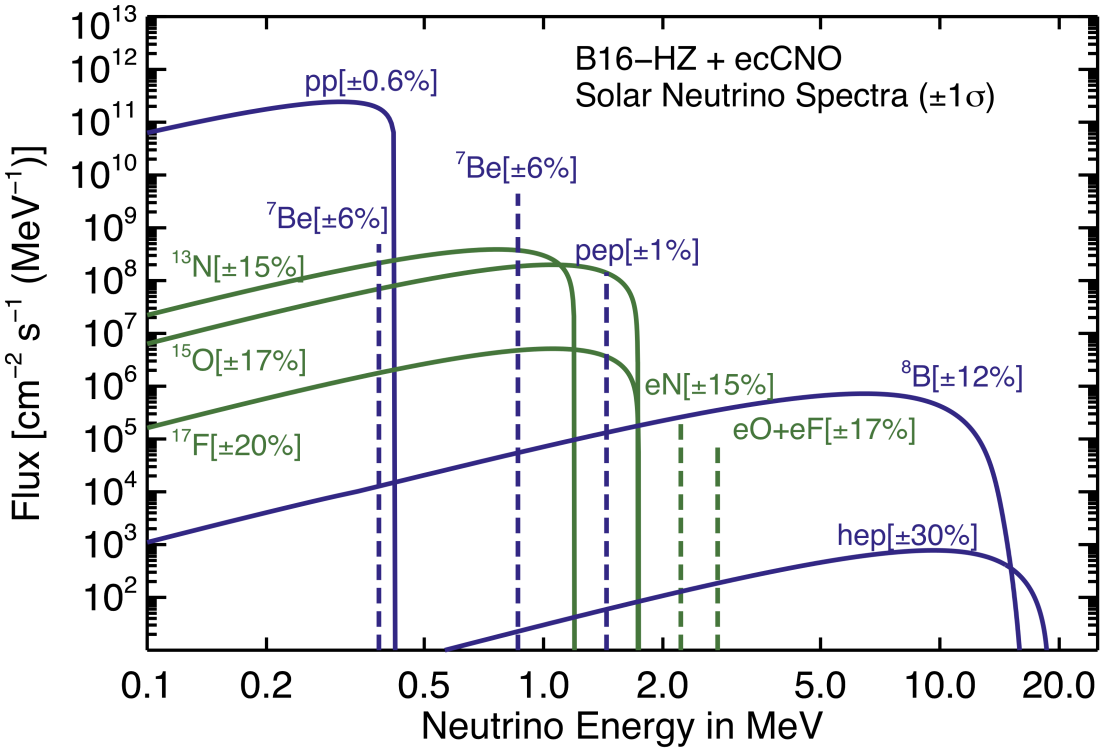
Supernovae

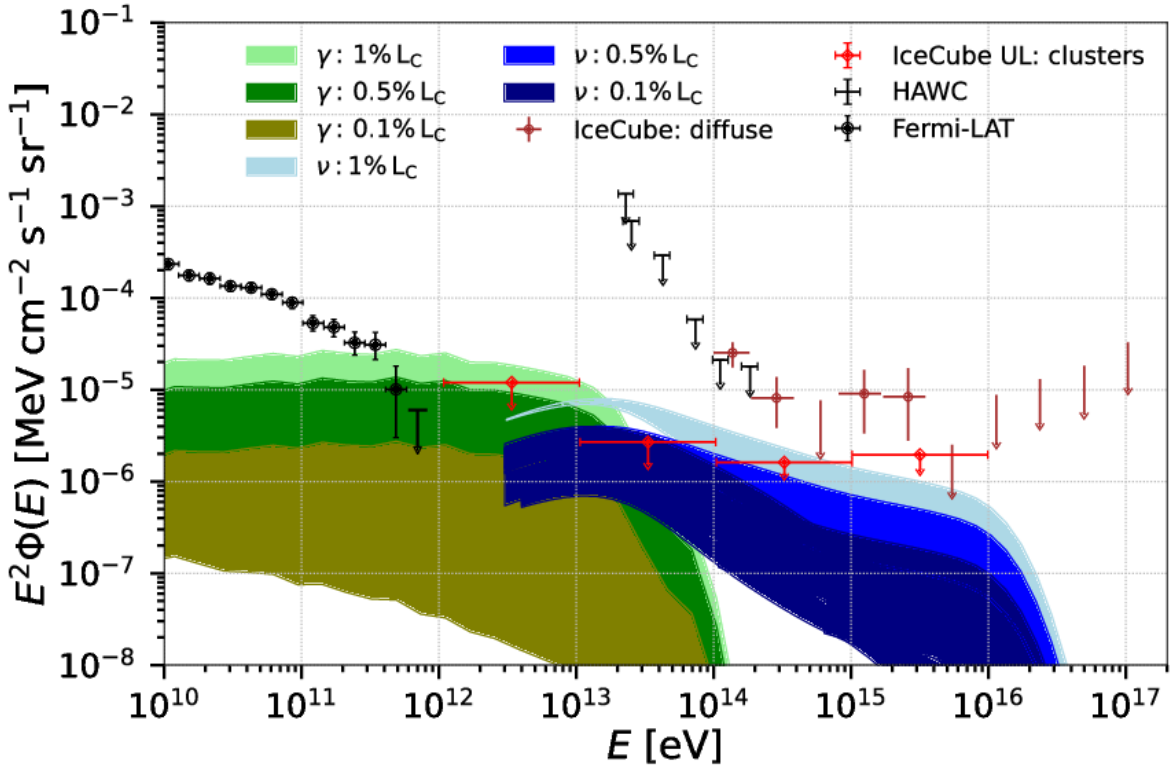


Cosmic-Ray interactions with Galactic ISM

Clusters of Galaxies

Astrophysical Neutrinos



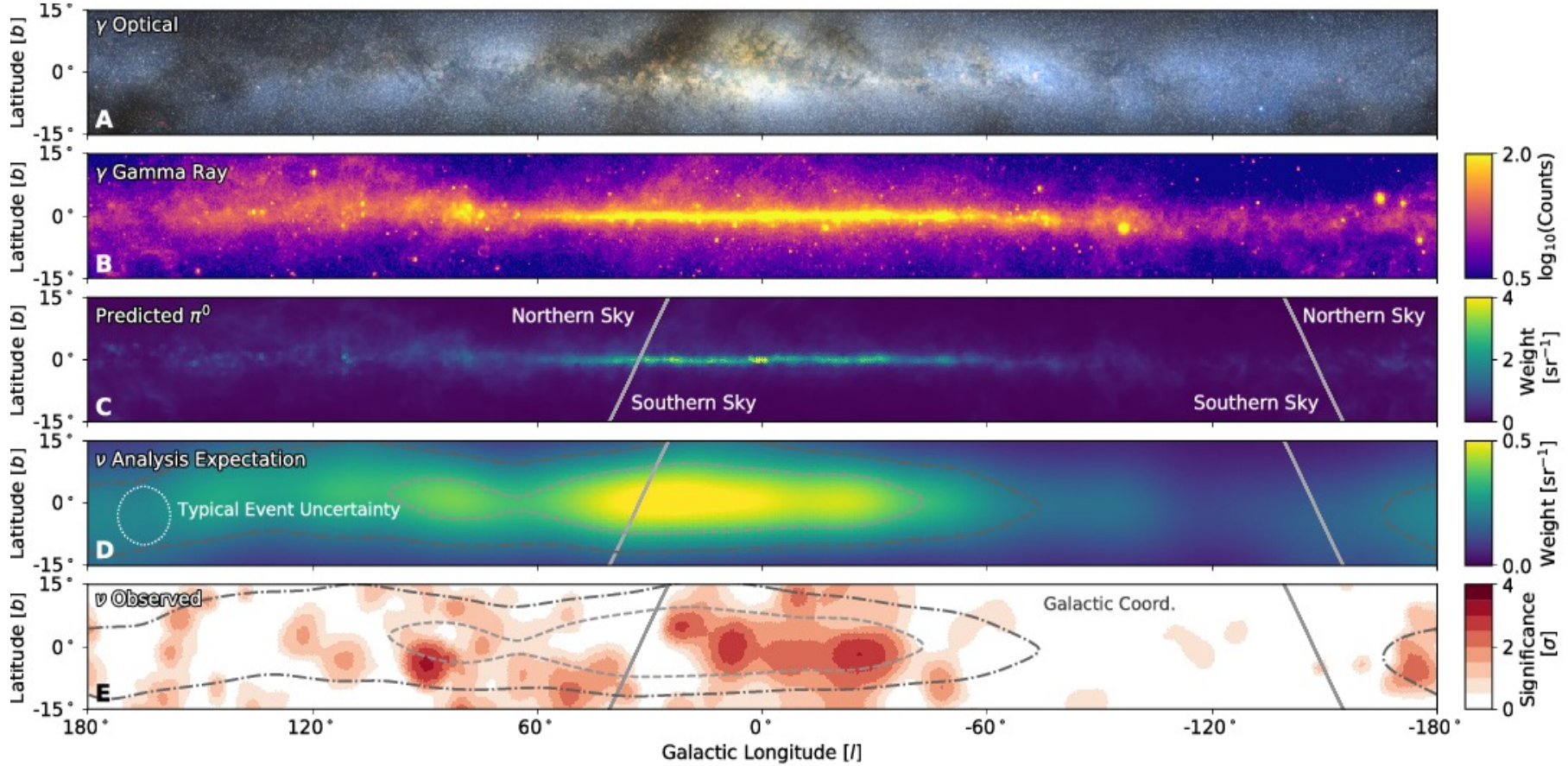


Solar models and solar neutrinos ask francescolorenzo.villante@univaq.it

Hussain et al. Astrophys.J. 960 (2024) 2, 124

Clusters of galaxies ask saqib.hussain@gssi.it

Neutrinos from the Galactic plane



$\varphi_{\nu,\mathrm{tot}}^{IceCube}$ ⇒ Measurement of the Galactic diffuse neutrino emission (4.5σ)

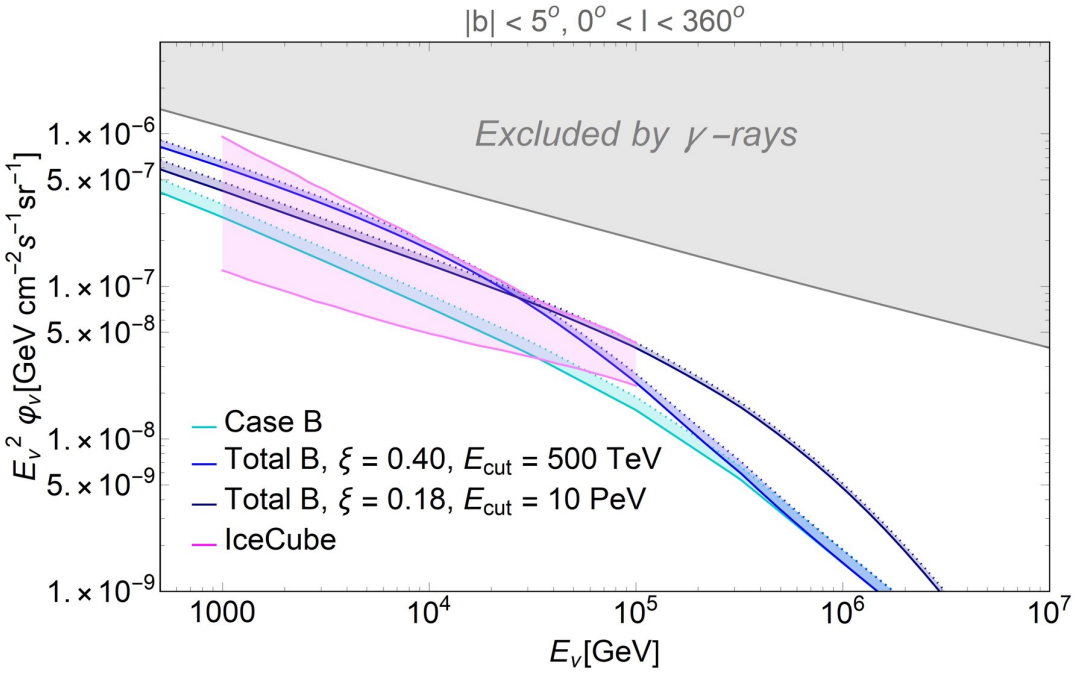
Abbasi, R, et al. 2023, Science, 380, 1338

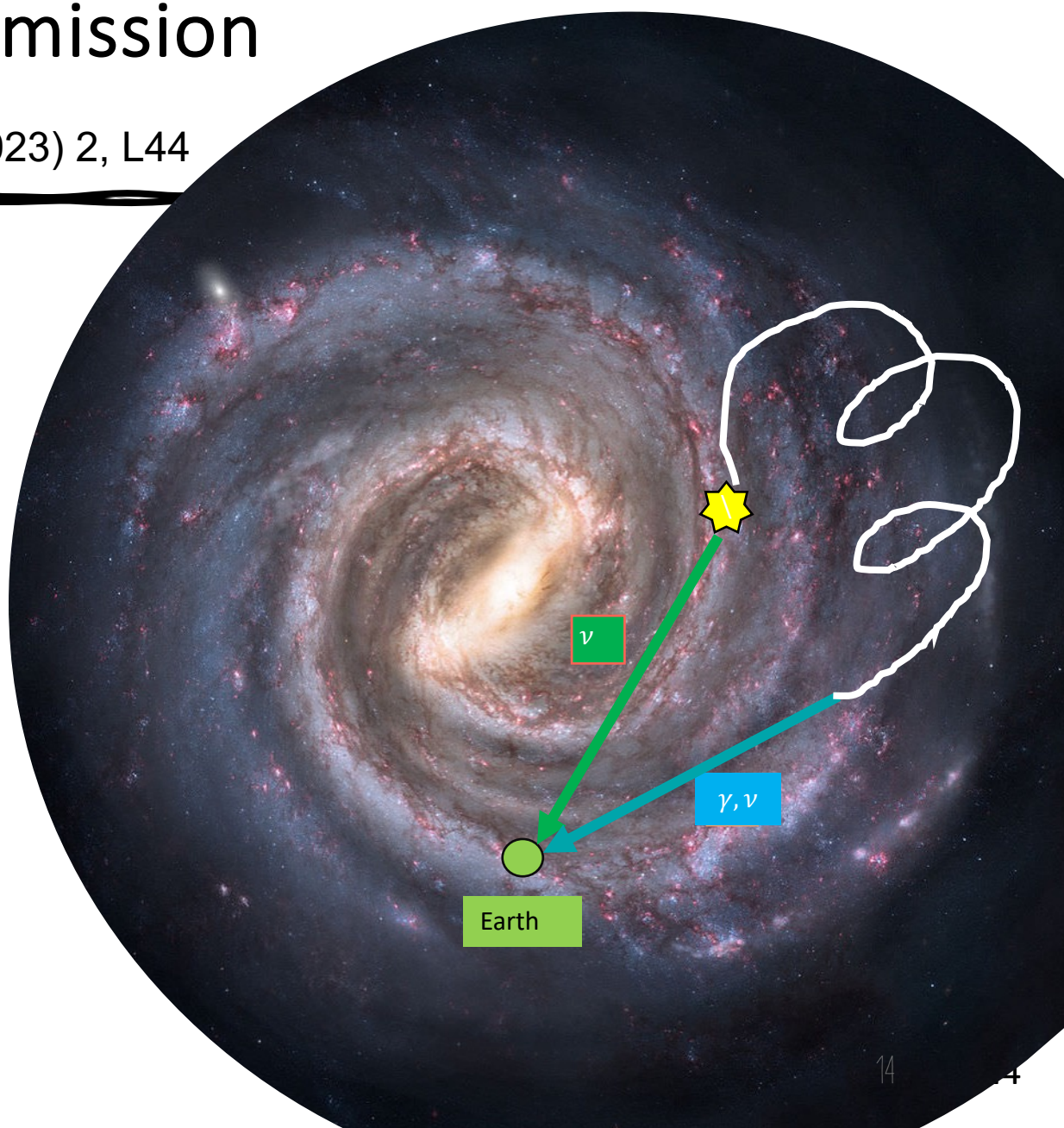
Large-scale neutrino diffuse emission

Vecchiotti, Villante and Pagliaroli, Astrophys.J.Lett. 956 (2023) 2, L44

The observed neutrino signal can be interpreted as:

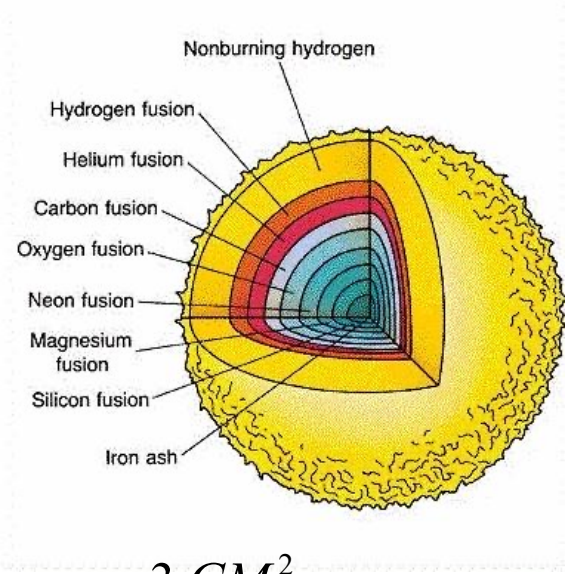
$$\varphi_{\nu,tot} = \varphi_{\nu,diff} + \varphi_{\nu,S}$$





Neutrinos from Supernovae

Core-Collapse Supernovae



$$\varepsilon_{NS}^{b} \cong \frac{3}{5}\frac{GM^2}{R} = (1-5)\cdot 10^{53}\, erg$$

Neutrinos => 99% of the energy

$$F_{\nu_x} \cong \frac{\varepsilon_B}{6\langle E_{\nu_x}\rangle}\frac{1}{4\pi D^2} \approx 5\cdot 10^{10}\left(\frac{20\ \mathrm{kpc}}{D}\right)^2 \frac{10\mathrm{MeV}}{\langle E_{\nu_x}\rangle}\frac{\nu_x}{cm^2}$$

$$\Delta t = 10\,\mathrm{sec}$$

Vissani, Capozzi, Pagliaroli

- Analysis of SN1987A data
- Study of the neutrino emission from different progenitors
- Study of the impact of neutrino-neutrino interactions inside the SN
- Study of the expected rate of CCSN
- Study of the expected detections and how to use data to infer SN physics
- Study of the best way to combine signals from different detectors
- Multi-messenger analysis with GW

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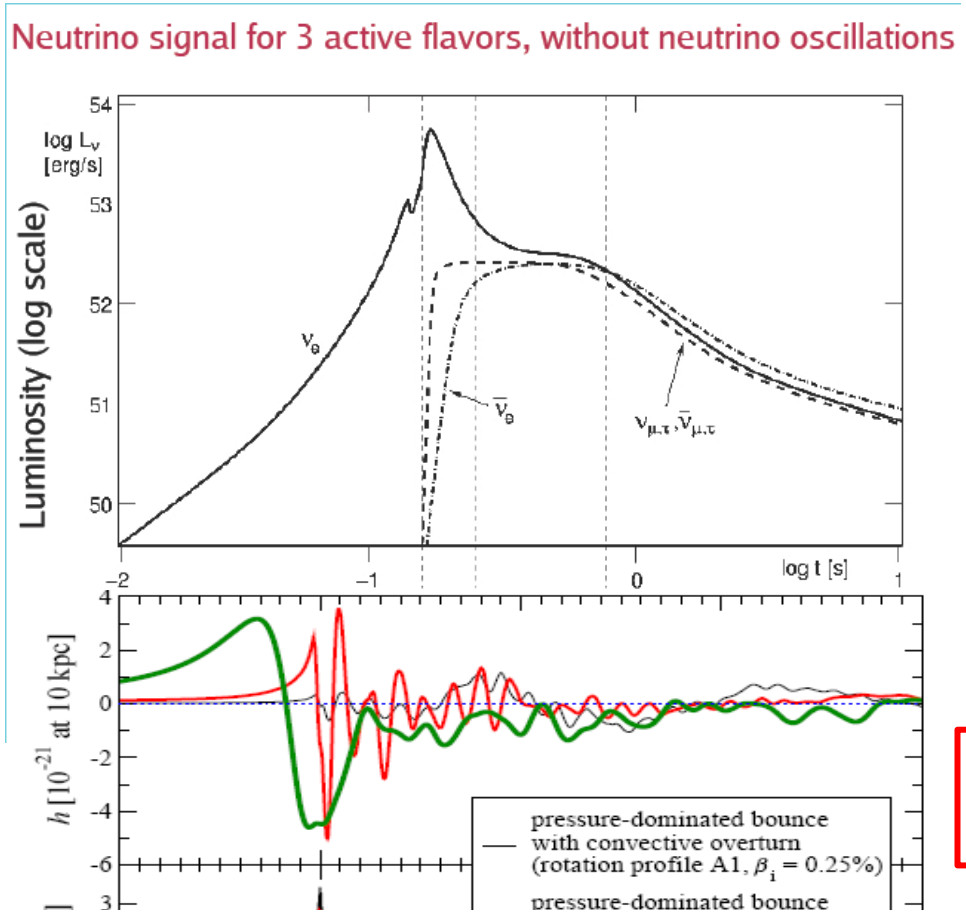
Multi-messenger analysis ν and GW



The starting times of both signal at the source are concident!!

SN1987A-LEN signal model @60kpc injections, KamLAND and LVD
Dimmelmeier2-GW model @60kpc injections, LIGO-H, LIGO-L, Virgo

Network & Type of Injections	Recovered $FAR_{GW} < 864/d$	η_{1param} $[> 5\sigma]$	η_{2param} $[> 5\sigma]$
HLV-KAM (Dim2-SN1987A)	784/2346= 33.4%	554/784= **70.7%**	650/784= **82.9%**
HLV-KAM-LVD (Dim2-SN1987A)	784/2346= 33.4%	776/784= **99.0%**	784/784= **100%**

Combining the 2 neutrinos detectors with the GW interferometers the detection efficiency grows from 0% to ~33%

Halim *et al. JCAP* 11 (2021) 021

GW signal is stocastic and very similar to noise

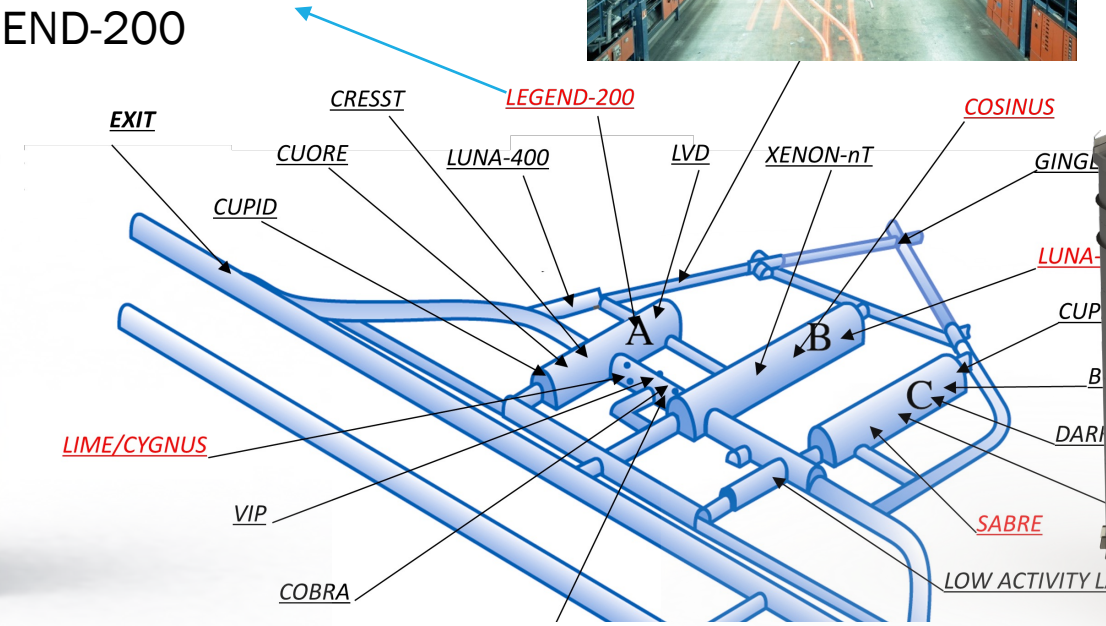
PRELIMINARY

SN@LNGS

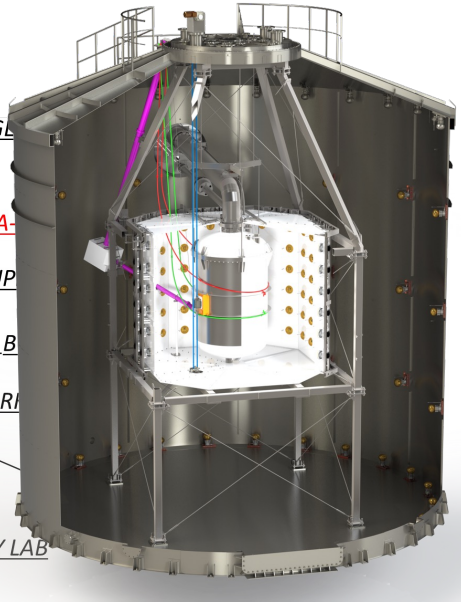
LVD (220 events)

SN@10 kpc -→H20 IBD and NO
XENONnT (700 ton) = 120
LEGEND 200 (590 ton) = 100
COSINUS (270 ton) = 50

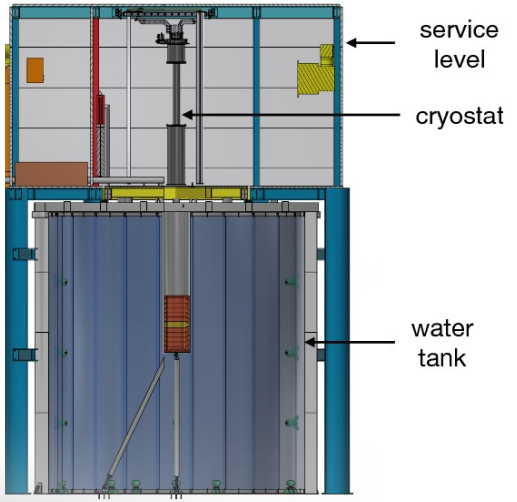
LEGEND-200



XENONnT



COSINUS



An infrastructure with several detectors sensitive to SN neutrinos: an interesting network of different detectors located in the same place. Combined Horizon: LMC. Very high duty cycle and fast coincidences in time (ms).

The Agreement with the Experiments is ongoing.