Strategia Europea della Fisica delle Particelle

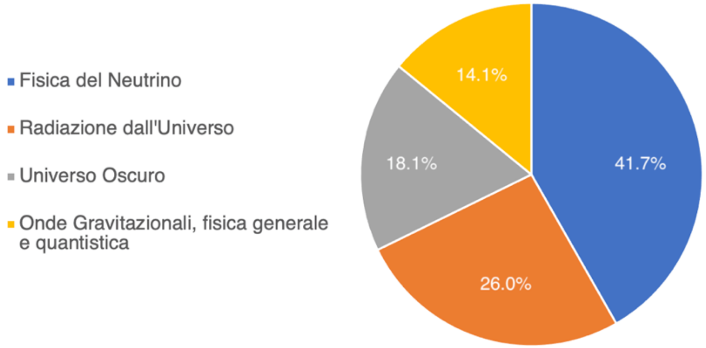
30 Oct 2024,

Emanuele Leonora
CSN 2 INFN-sezione di Catania

Linee scientifiche della CSN 2

Le ricerche e gli esperimenti di competenza della CSN2 riguardano la fisica astroparticellare

lo studio delle proprietà del neutrino,
(il suo valore, la sua natura di Dirac o di Majorana, i parametri di mix tra neutrini e la violazione della simmetria CP).



lo studio della radiazione cosmica,
la nuova astronomia multimessenger (lo studio correlato dei messaggeri cosmici, quali i fotoni, neutrini, raggi cosmici carichi, e le onde gravitazionali);

lo studio dell'universo oscuro,
(la natura della materia e della energia oscura)

la ricerca di onde gravitazionali e fisica generale e quantistica.

lo studio della radiazione di fondo cosmica (CMBR), incrocio tra cosmologia delle primissime fasi dell’Universo e unificazione delle interazioni fondamentali;

Infrastrutture della CSN 2 in Italia

In Italia sono presenti tre grandi infrastrutture di ricerca nella fisica astroparticellare:

il laboratorio INFN del Gran Sasso
(il più grande laboratorio sotterraneo al mondo per la fisica astroparticellare, 1400m di profondità)

l'osservatorio sottomarino KM3NeT al largo di Capo Passero
(il più grande laboratorio sottomarino al mondo per la fisica astroparticellare , 3000 m di profondita)

l'osservatorio europeo per le onde gravitazionali (EGO)
con l'interferometro Virgo a Cascina (Pisa)

Riflessione:
sono 3 importanti strutture che l'INFN ha costruito e su cui puntare per il presente e per il futuro

Linee scientifiche e Sigle di GR 2 a Catania

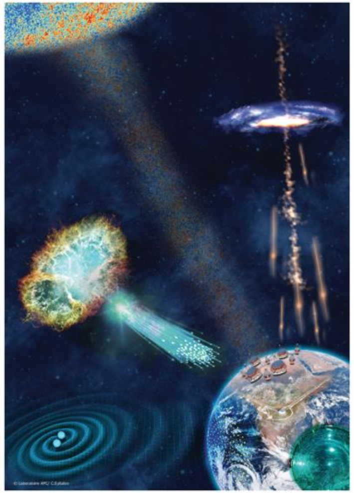
Neutrino Physics : **JUNO** *(G. Andronico)*

Gravitational waves, gravitation and quantum mechanics

Radiation from the Universe :
AUGER *(R. Caruso)*
SPB2 *(R. Caruso)*
CTA *(G. Marsella)*
KM3NeT *(N. Randazzo)*

Dark Universe: DarkSide *(S. Albergo)*

European Perspective



The Astroparticle Physics European Consortium (APPEC)
→ European Astroparticle physics strategy (2017-2026).

Astroparticle physics is the field of research at the intersection of astronomy, particle physics and cosmology.

Strategic objectives

- Provide a discussion forum for the coordination of European Astroparticle Physics and express collective views on astroparticle physics in international fora.
- Develop and update long term strategies (e.g. roadmap for European astroparticle physics) and participate in European scientific strategy such as the European Strategy Session of CERN Council and ESFRI.
- Develop closer relationships with organisations involved in Astroparticle Physics research such as CERN, ESA, ESO

Implementation objectives

- Facilitate and enhance the coordination between existing or developing national activities.
- Develop a common action plan for large astroparticle physics infrastructure based on the Roadmap for European Astroparticle Physics.
- Facilitate the convergence of future large scale projects and/or facilities.
- Provide organisational advice for the implementation of future large scale projects/facilities, for instance initiate and/or accompany the creation of resourcereview boards for international collaborative projects where the national funding
- agencies are involved.
- Initiate and guide activities funded by the European Commission (ERA-NET, IA, Prep-Phase).
- Launch common actions including common calls funded by a virtual common pot.

Riflessione:

il coordinamento e la collaborazione delle diverse azioni ed infrastrutture sembra essere la strada riconosciuta da qualunque strategia che guarda al futuro

KEY question

– The Extreme Universe:
What can we learn about the cataclysmic events in our Universe by combining all of the messengers high energy gamma rays, neutrinos, cosmic rays and gravitational waves that we have at our disposal?
– The Dark Universe:
What is the nature of Dark Matter and Dark Energy?
– Mysterious neutrinos:
What are their intricate properties and what can they tell us?
– The Early Universe:
What else can we learn about the Big Bang – for instance, from the cosmic microwave background (CMB)?

Today Astroparticle physics addresses fundamental questions: the physics of the primordial Universe, the nature of dark matter and dark energy; the eventual unification of fundamental interactions; the stability of protons; the properties of neutrinos and their role in cosmic evolution; the origin of cosmic rays; the nature of the Universe at extreme energies studied using multi-messenger probes including high-energy cosmic rays, photons, neutrinos and gravitational waves

Catania

Le sigle della sezione in gruppo 2

emanuele.leonora@ct.infn.it

AUGER

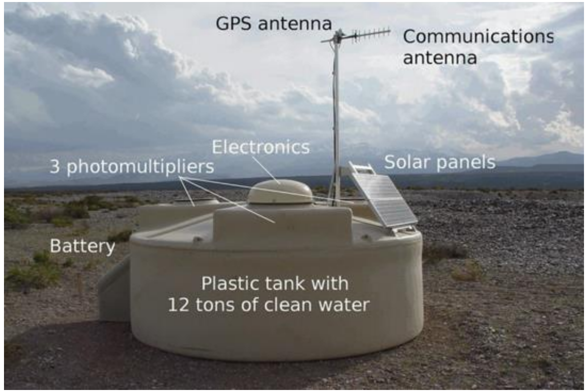
OBIETTIVO: rivelazione di EAS per lo studio di raggi cosmici di altissima energia (10^{17}eV - 10^{21}eV)
RIVELATORE: ibrido (3000 km^2) a 1400 s.l.m. nella Pampa nei pressi di Malargue (Mendoza-Argentina)
1600 + 71 rivelatori Cherenkov + 27 telescopi di fluorescenza + 185 radio sensori + upgrade AUGER prime

Auger Observatory: measures charged UHECRs

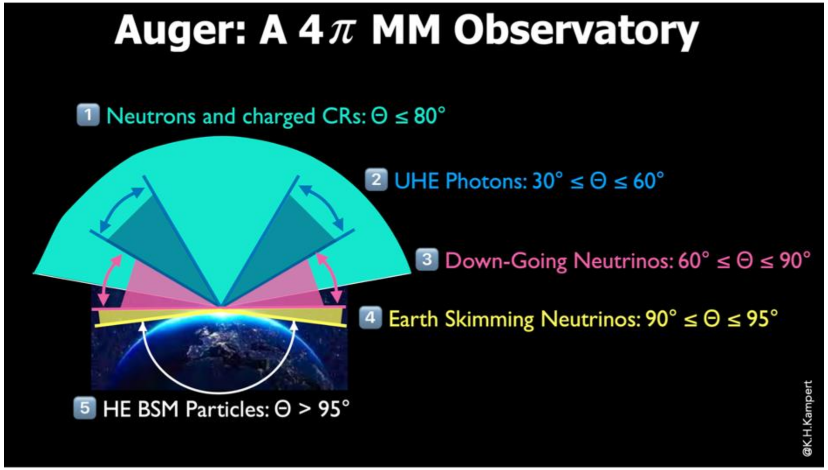
- Energy spectrum
- Nuclear composition
- Anisotropies
- information on UHE hadronic interactions

Auger Prime

Addition of plastic scintillators above each Surface Detector



Futuro dei grandi rivelatori: diversi canali di misura simultanei



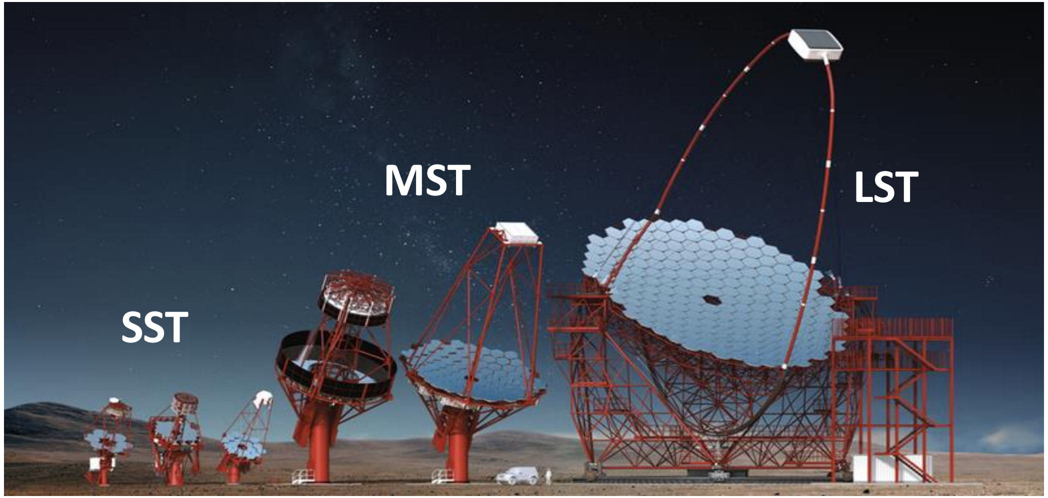
(see A. Castellina CRIS-MAC 2024)

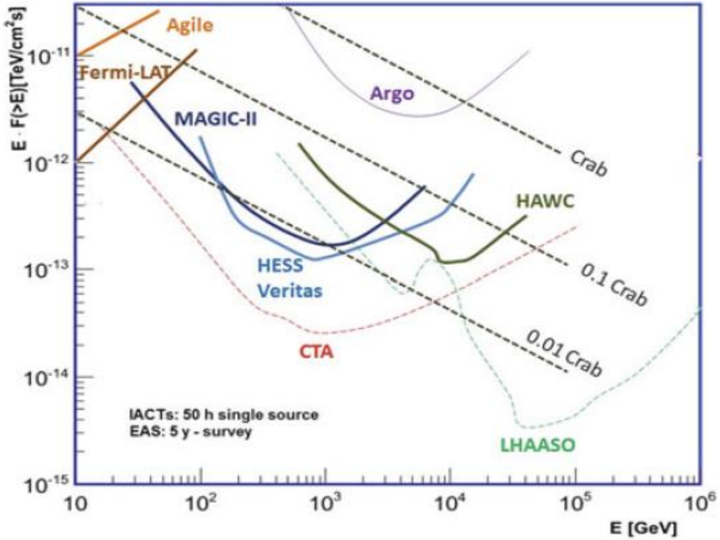
L' Upgrade AUGER PRIME sarà completato nel 2024. La presa dati dell'esperimento AUGER è stata estesa fino al 2030

The Cherenkov Telescope Array (CTA)

Il Cherenkov Telescope Array intende costruire due osservatori gamma, uno al NORD (CTA-N a la Palma Canarie) ed uno al sud (CTA-S Cile) con telescopi Cherenkov costruiti su tre modelli:

- **Large-Sized Telescopes** (LSTs - Φ 23m) (E < 100 GeV)
- **Medium-Sized Telescopes** (MSTs – Φ 12m) (100 GeV < E < 10 TeV)
- **Small-Sized Telescopes** (SSTs - Φ 4m) (E > 10 TeV)





Large energy range: from 10 GeV to beyond 10 TeV

Improvement in sensitivities in energy 0.1 – 10 TeV

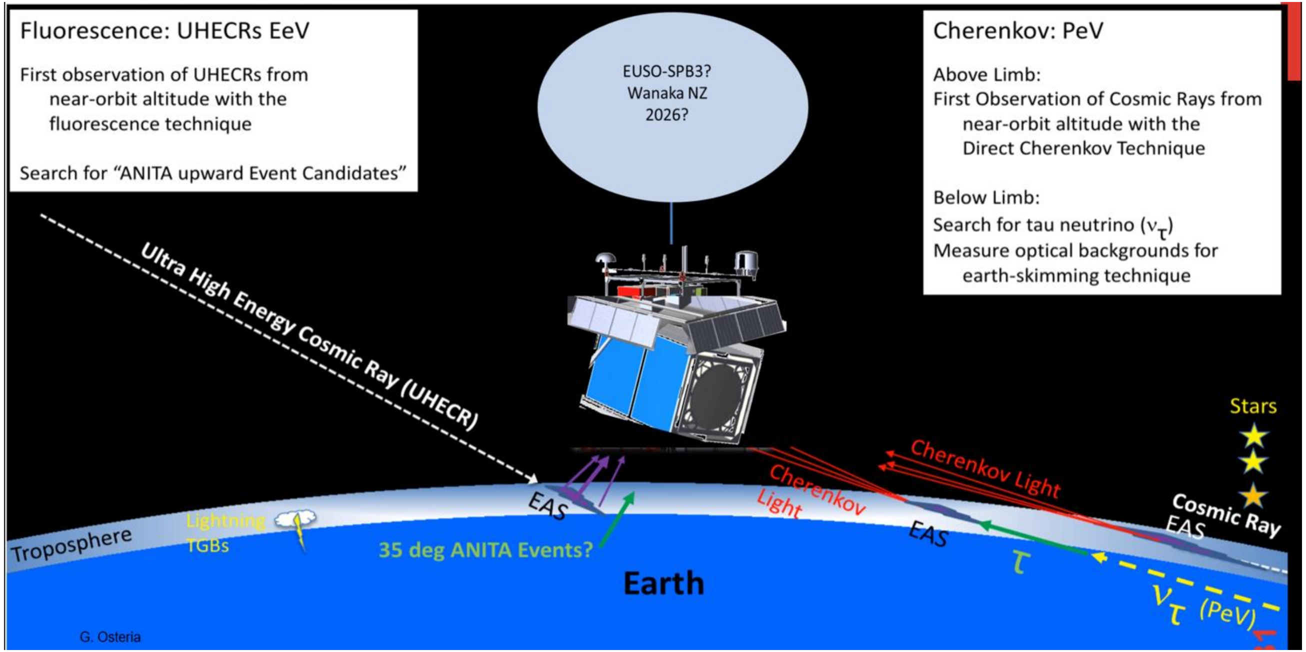
CTAO-North site: LST-1 taken data since Jan 2020
LST-2, LST-3, LST-4: under construction;

South site: Partially funded through PNRR (2 LST + 5 SST)

Super Pressure Baloon 2 (SPB2)

Scientific goals: study UHE cosmic rays (10^{20} eV) looking down and using the atmosphere as a detector

- Air-showers per mezzo di luce Cherenkov dall'alto (top dell'atmosfera). 10ns. PeV scale
- Air-shower orizzontali per mezzo della fluorescenza. 1 us . EeV scale



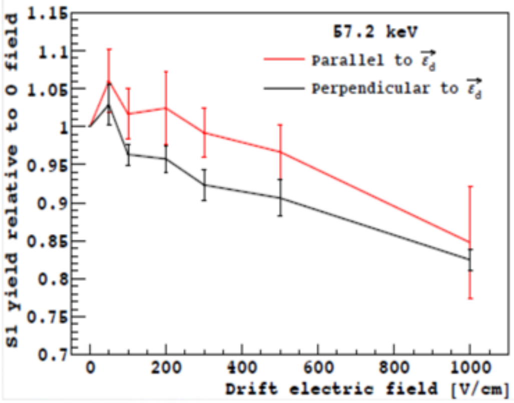
Esperimento a LNGS Liquid Argon TPC in dual phase per la ricerca diretta di materia oscura in WIMPS

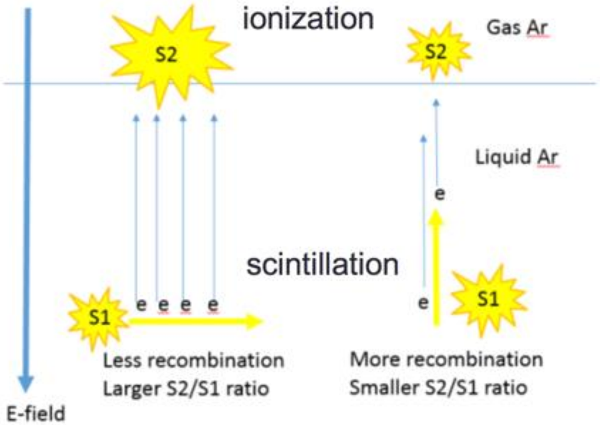
In INFN Catania le attività sono legate a RED (Catania-LNS INFN)

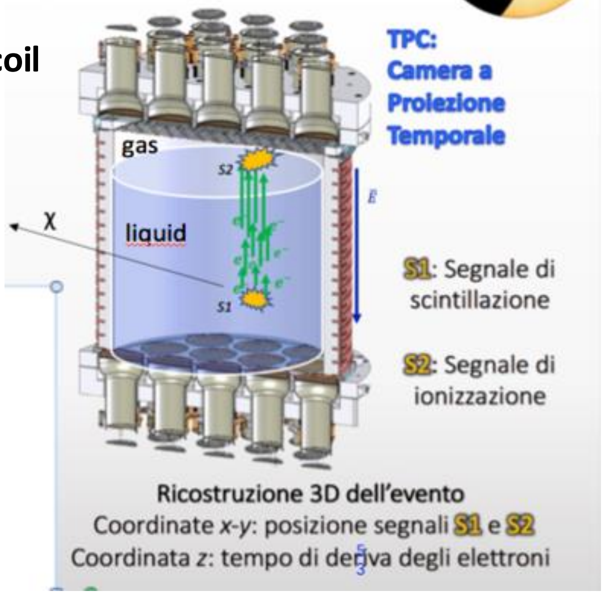
The ReD TPC is a miniaturized version of the DarkSide-20k TPC

Main ReD project goals:

- demonstrate that a dual phase LAr TPC has sensitivity to the direction of Ar recoil
- characterize the response of the LAr TPC to very low-energy recoils (< few keV)





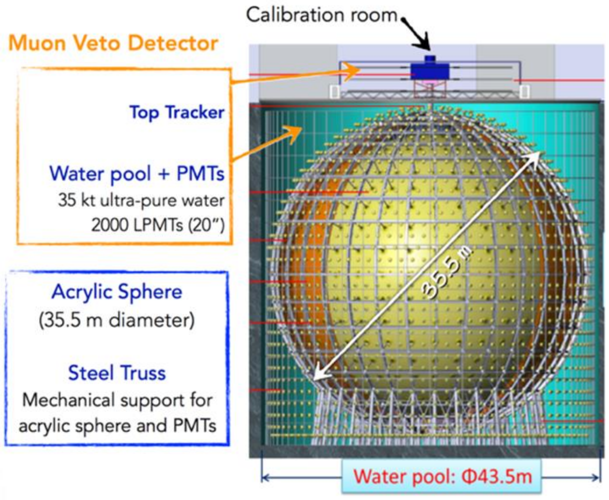


Jiangmen Underground Neutrino Observatory (JUNO)

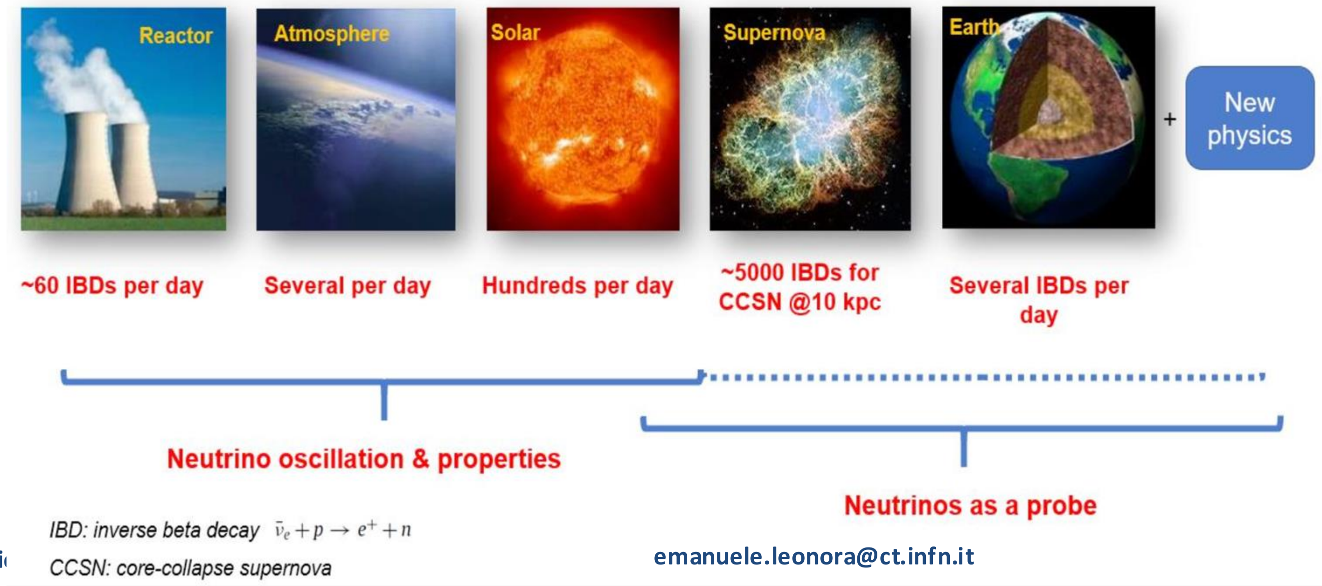
JUNO is a shallow 20kt liquid scintillator multipurpose neutrino experiment
Short-baseline experiment TAO provides JUNO the reference spectrum

Rich physics program (reactor and "no-reactor" neutrinos):

- Neutrino Mass Ordering (3% energy resolution)
- Neutrino oscillation, precision measurements (< 0,5% precision)
- Supernovae neutrinos, geo and solar neutrinos
- Future JUNO-0νββ



Central detector (CD)
Water pool (WP)
Top tracker (TT)
About 700 m underg.



Detector in RUN in 2025

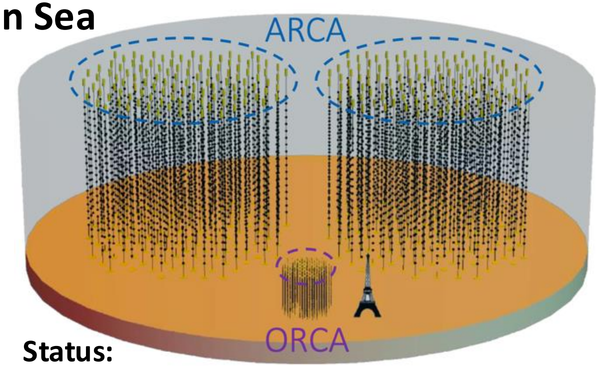
emanuele.leonora@ct.infn.it

KM3NeT: Km^3 Neutrino Telescope

Two neutrino detectors under construction in the Mediterranean Sea

ORCA (Oscillation Research with Cosmics in the Abyss, France)
Atmospheric neutrinos. Main goal: neutrino oscillations
(Eν ~ MeV–100 GeV) → GOAL: 7 Mton of instrumented water

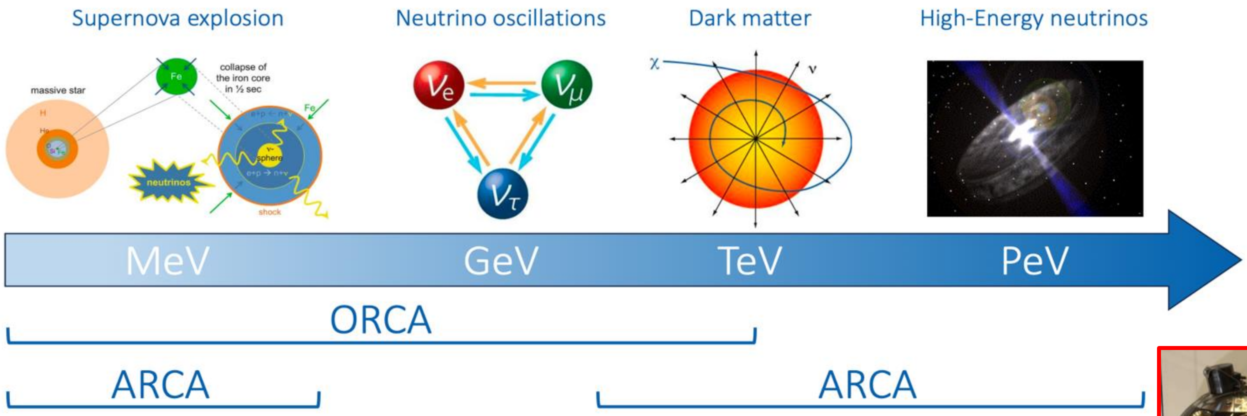
ARCA (Astroparticle Research with Cosmics in the Abyss, Italy)
Cosmic neutrinos. Main goal: neutrino astronomy
(Eν ~TeV-PeV) → GOAL: 1 km3 of instrumented water (1 Gton)



Status:
ORCA: 18DU (15%); ARCA: 28DU (12%)

Same technology for a multi-energy scale science program

	ARCA	ORCA
Location	Italy (Sicily)	France (Toulon)
Depth	3450 m	~2500m
Distance from shore	~100 km	40 km
Number of DUs	230 (115 x 2)	115
Instr. water volume	1 Gton	0.7 Mton
DU height	~750 m	~200 m
DU horizontal spacing	90 m	20 m
DU vertical spacing	36 m	9 m
DOMs/DU	18	18
PMTs/DOM	31	31



KM3NeT Multi-PMT layout → now a standard for next WC detectors