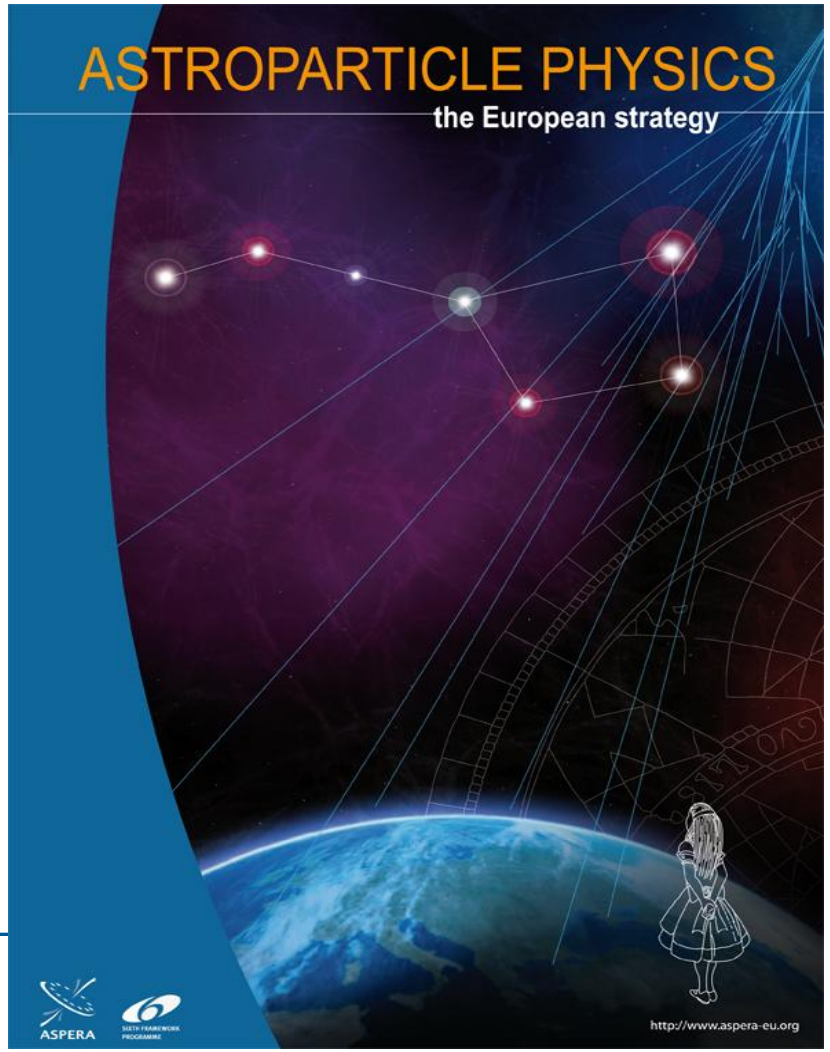
Roadmap to the Stars The European priorities for Astroparticle Physics

S. Katsanevas

IN2P3/CNRS and IPMU

ASPERA Coordinator



LE PETIT LAROUSSE ILLUSTRÉ 2008

LES MOTS NOUVEAUX

À l'écoute d'une langue en perpétuel mouvement, forte de ses diversités régionales, le *Petit Larousse* s'enrichit cette année encore d'une centaine de mots, sens, locutions et expressions.

Mots nouveaux

ANTENNE-RELAIS ou **ANTENNE RELAIS** n.f. (pl. *antennes[-]relais*). Émetteur-récepteur d'ondes hertziennes servant à l'acheminement des communications dans un réseau de téléphonie mobile.

ASTROPARTICULE n.f. 1. Domaine de recherche situé à l'interface de l'astrophysique et de la physique des particules. 2. (Génér. au pl.) Particule élémentaire constituant un objet d'étude en astrophysique.

GNV ou **G.N.V.** n.m. (sigle de *gaz naturel [pour] véhicules*). Gaz naturel comprimé, utilisé comme carburant automobile. (Il offre un grand intérêt écologique mais son emploi est réservé à des véhicules adaptés.)

INTERMODALITÉ n.f. Utilisation de plusieurs modes de transport au cours d'un même trajet, pour les marchandises ou les voyageurs.

IST ou **I.S.T.** n.f. (sigle). Infection sexuellement transmissible.

A QUESTION OF DEFINITIONS

What is Astroparticle Physics ?

✓**What is the Universe made of ?**

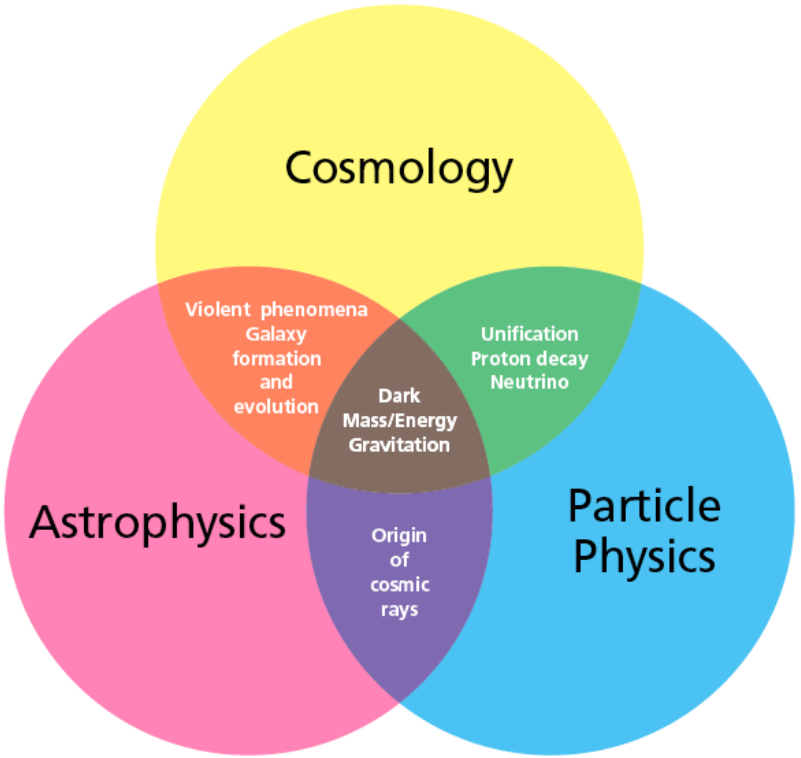
✓**Do protons have a finite lifetime ?**

✓**What are the properties of neutrinos ? What is their role in cosmic evolution ?**

✓**What do neutrinos tell us about the interior of the Sun and the Earth, and about Supernova explosions ?**

✓**What is the origin of cosmic rays? What is the view of the sky at extreme energies ?**

✓**What will gravitational waves tell us about violent cosmic processes and about the nature of gravity ?**



$10^{-30\text{-}33}$ cm
ν mass, proton decay, inflation

10^{28} cm event horizon (5 Gpc)
Cosmology, Dark Energy/matter, GRB,cosmological markers

10^{26} cm GZK horizon (100 Mpc) CR, HE γ, ν, GW

$10^{-24\text{-}27}$ cm
UHECR, HE ν, DM

10^{22} cm Galaxy (10 kpc)
(supernova, CR, HE γ, ν μquasars)

10^{-21} cm LHC,DM

Another definition the 2 ∞

10^{15} cm solar system (solar neutrinos)

$10^{-15\text{-}18}$ cm
Nucleosynthesis
Primordial/Star

10^{10} cm

10^{-5} cm

Asrparticle infrastructures help study ocean floor biodiversity

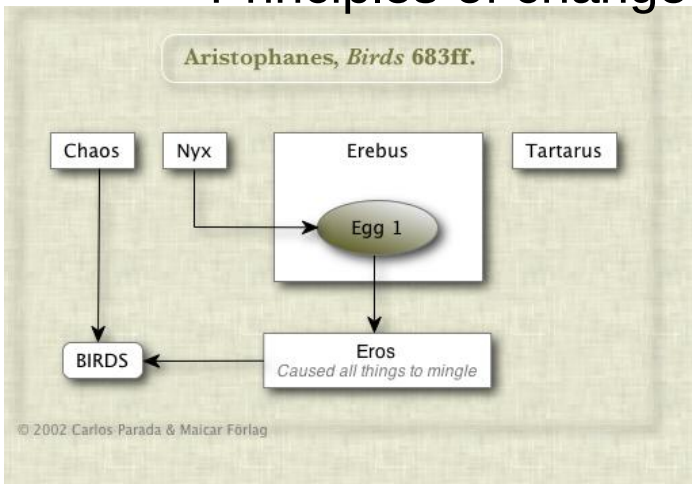
10^{5} cm

Astroparticle uses the geosphere as detecting medium

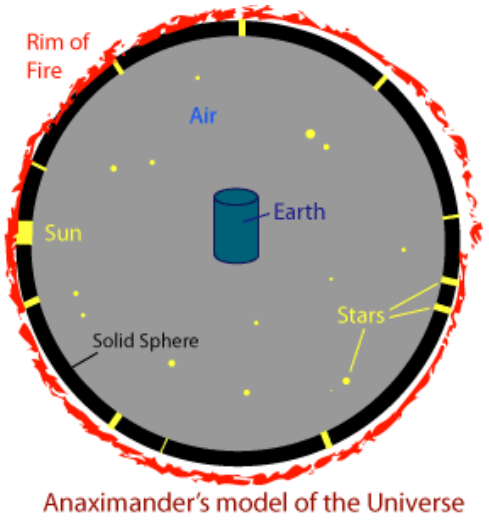
Astroparticle heps us understand our origins

Astroparticle an ancient endeavour

- ✓*From a cosmogonic narrative to a cosmological topology*
  - ✓Ancient cosmogonies deduce the universe from the fragmentation of a god, a cosmic egg, a divine mating a ritual diving or emergence
  - ✓The Presocratics pose
    - ✓A primordial element (water, air, infinity)
    - ✓A cosmological topology
    - ✓Principles of change of phase/movement
    - ✓PLATO: it is all math.



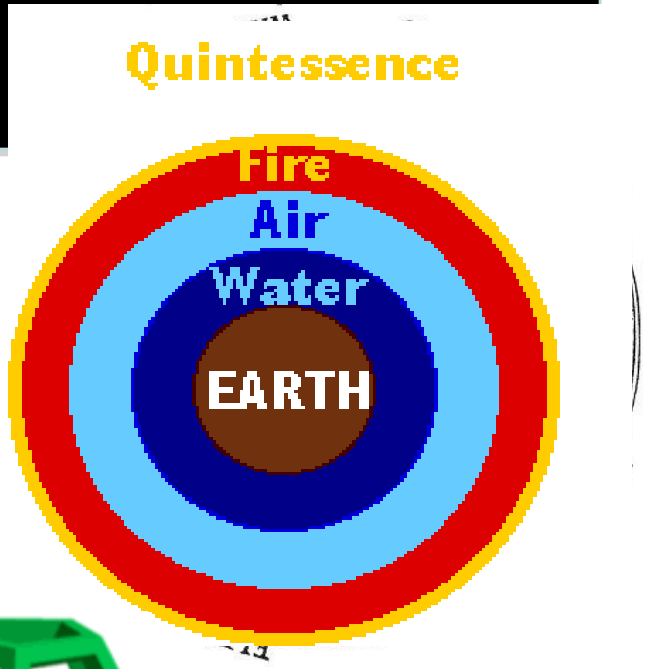
Night and children of night , orphic cosmogony



Anaximander's model of the Universe

Anaximander: an infinity of worlds (cosmos) emerge from the infinite and after some time return there

Cosmologies of Timaeus and De Caelo



Moon separates the world in 2 parts with different physics

- **Sublunar: generation and corruption, geocentric movement, physics of 4 elements**

- **Surlunar: 5 elements, quintessence, eternal and incorruptible, circular mouvement**

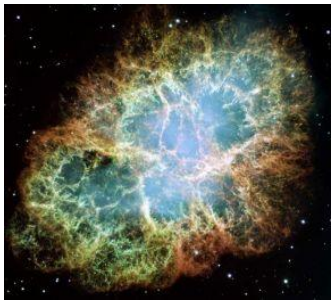
terre eau air feu quintessence

Platonic theory of the elements
(see IPMU news, Kyoji Saito)

Can we lough at it ? What then of QM/GR difference of approach? , dark energy, quintessence, non isotropic universe?

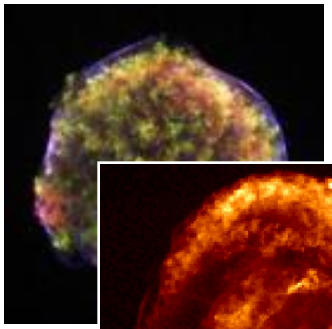
Pythagoras, first cosmology: harmony of the spheres….

Dissonance in celestial music the role of « Dark and Violent » Universe

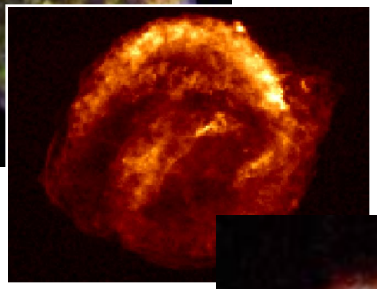


Crab 1054

Not seen in west but seen by the Chinese imperial astronomer: ” following the order of the Emperor, I respectfully predict that if the guest star does not infringe upon Aldebaran, this indicates that the country will attain great power.”



Tycho 1572



Kepler 1604

Supernovae 1572/1604 challenge the indestructibility of heavens. Transient phenomena are possible. Galileo points the telescope to the moon (1609)

1987A Birth event of Astroparticle Physics Koshiba Nobe Prize

Pleasures and miseries of interdisciplinarity

An interdisciplinary enterprise must assume for some time a lesser precision than this claimed by canonical branches of learning. Among the particularities of these canonical branches is the fact that they are comforted in their self-sufficiency by claiming always a larger precision than what is reasonable to expect and anyway they have obtained this precision by isolating and diminishing the size of the object under study without any theoretical counterpart. Since it does not accept the well defined delimitation of its object, interdisciplinarity starts by giving a slight impression of deception.

Hans Blumenberg

The defintion comes always at the end….. *E. Kant*

THE EUROPEAN INSTITUTIONAL ENVIRONMENT

What is ApPEC?

- **ApPEC created in 2001 by the national funding agencies of France, Germany, Italy, the Netherlands and UK.**
  - **Since then Spain, Belgium, Portugal, Greece, Switzerland and Poland have joined**
- **ApPEC aims to**
  - **Promote and facilitate co-operation within the European Particle Astrophysics (PA) community**
  - **Develop and promulgate long term strategies for European PA, offering advice to national funding agencies and EU**
  - **Assist in improving links and co-ordination between European PA and the scientific programmes of organisations such as CERN, ESA, and ESO**
  - **Express their collective views on PA in appropriate international forums, such as OECD, UNESCO etc.**

Operation

- **ApPEC operates**
  - **Strategically through its Steering Committee,**
  - **Operationally through its Peer Review Committee**
- **Steering Committee (SC):**
  - **France: *M.Spiro,* P.Chomaz, S.Katsanevas Germany: T. Berghöfer, R.Köpke, H. Bluemer, Netherlands: F. Linde, UK: D. Miller, J. Womerseley , Italy: R. Petronzio B. Dettore, Spain: J. Fuster, A.Ferrer, Switzerland: M. Bourquin, Belgium: D. Bertrand, C. DeClerq, Portugal K. Gaspar Greece: D. Nanopoulos Poland S. Pokorski , Romania NV. Zamfir, CERN: D. Schlatter**
- **Peer Review Committee (PRC)**
  - **Elena Aprile, Laura Baudis, Jose Bernabeu, Pierre Binetruy,*Christian Spiering,* Franz v. Feilitzsch, Enrique Fernandez,Andrea Giuliani, Werner Hofmann, Uli Katz, Paul Kooijman, Paolo Lipari, Manel Martinez, Antonio Masiero,Benoit Mours, Francesco Ronga, Sheila Rowan, Andre Rubbia, Subir Sarkar, Guenther Sigl, Gerard Smadja, Nigel Smith, Lucia Votano**

The ASPERA program

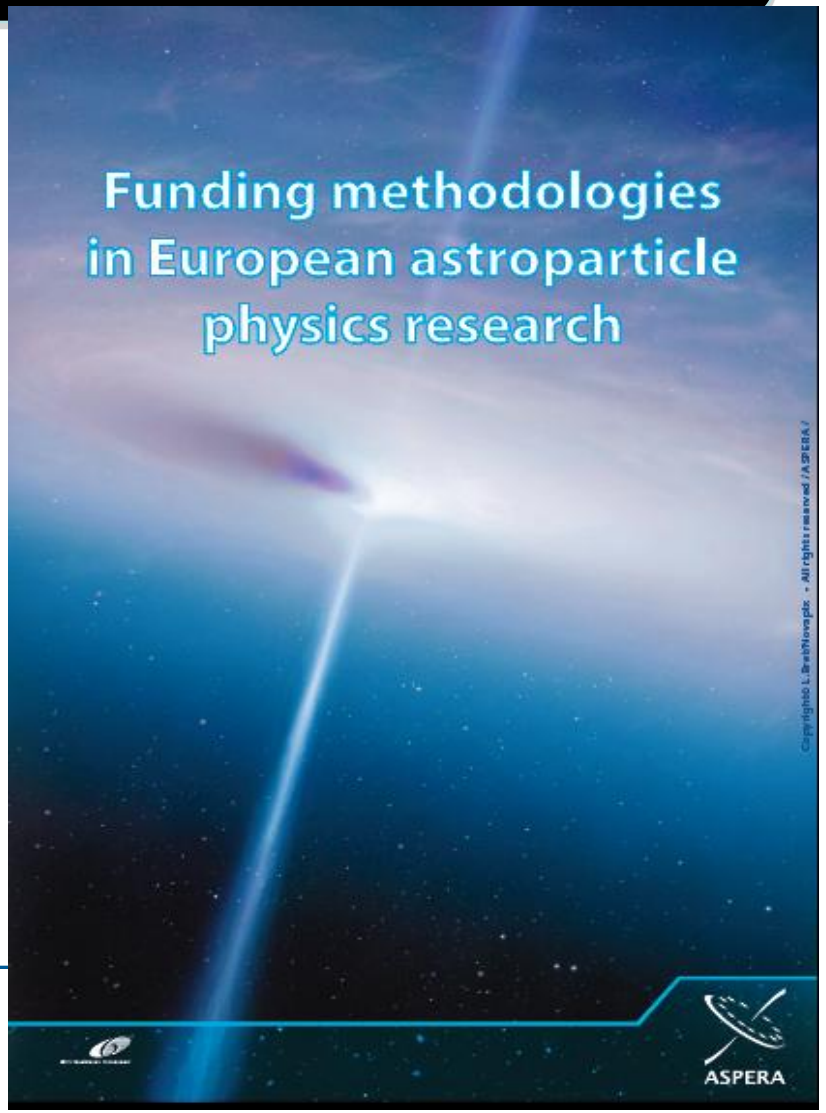
- **ASPERA, 14 countries (ApPEC+ Czech republic +Sweden + CERN) funded by EU in 2006 for 3 years for coordination actions**
  - Coordinator S. Katsanevas IN2P3/CNRS, France
- **EU funds its continuation for another 3 years 2009-2012**
  - Coordinator T. Berghoefer BMBF, Germany
- **Actions of ASPERA-1:**
  - **Status of astroparticle funding in Europe:**
    - 2500 Full time researchers + 70 M€/year investment or 190 M€ total
  - **Linking of existing large infrastructures**
    - Linking of underground labs in progress
  - **Roadmap of infrastructures**
    - PRC, working groups and 3 workshops (… Amsterdam 2007, Brussels 2008)
  - **Launch a common call for support of design studies of the priority projects**
    - A 3,5 M€ grant on CTA and Dark Matter starting this March

Study of funding mechanisms I

2 methods: Questionnaires (statics),
National days (dynamics)
National days: an ASPERA succes story:
Organisation of 11 « national days »
Comparison of funding systems.
Bi-monthly contacts of science managers

Diversity in European funding schemes:

- ✧Operators of research vs funding agencies.
- ✧Universities.
- ✧Large laboratories.
- ✧Regions.
- ✧Private foundations.
- ✧Funding of large infrastructures.
- ✧Funding of interdiciplinarity.
- ✧Knowledge transfer and outreach



Study of funding mechanisms II

Investment 70 M€/year

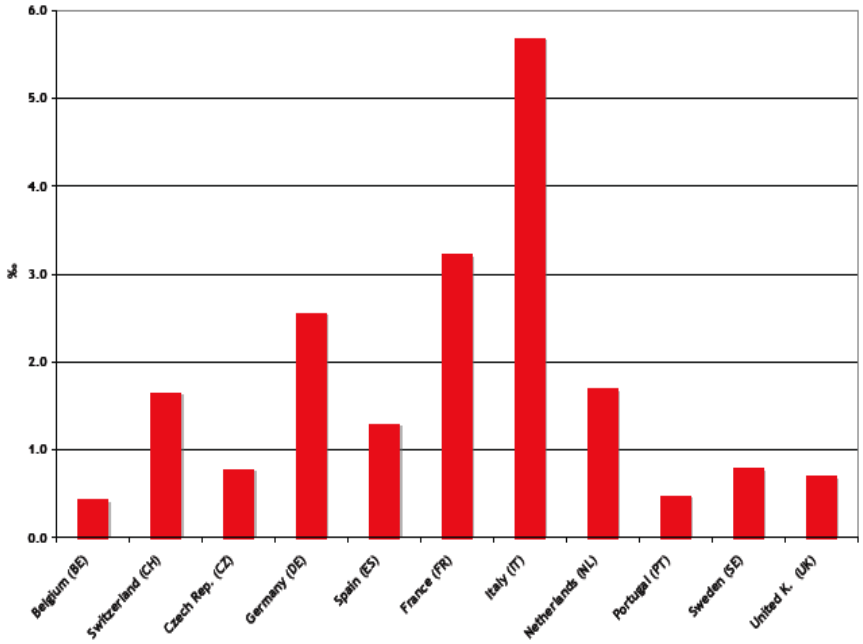


Figure 8: ratio of ApP budget to the government budget for R&D in the ASPERA countries

2300 FTE

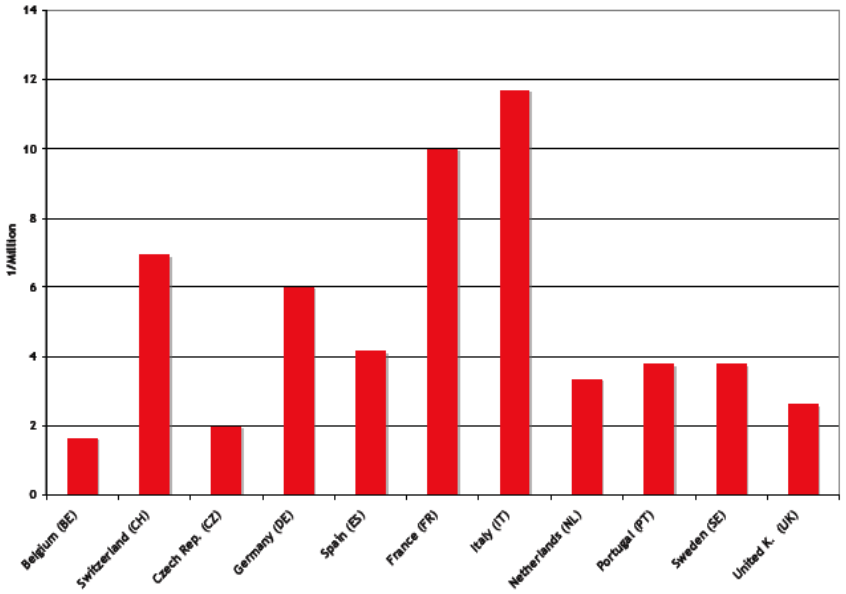


Figure 9: ratio of number of active ApP researchers to the total population of each country

◆**Overall budget 186 M€/year**

Does Europe need an astroparticle equivalent of CERN-ESO?

- ✓ **CERN**
  - ✓ A representative of the ApPEC SC attends in the European Strategy sessions of the CERN Council.
  - ✓ A representative of the ApPEC PRC is a member of the scientific secretariat for the European Strategy sessions of the CERN Council.
  - ✓ The “Working Group on the scientific and geographical enlargement of CERN” includes by right an ApPEC representative
  - ✓ CERN asks ApPEC when Astroparticle Physics experiments ask the “recognised experiment” status from CERN.
- ✓ **Discussions for an autonomous European entity in relationship with CERN and ESO , located et CERN to start with ?**

THE SCIENTIFIC PROGRAM
(THE MAGNIFICENT SEVEN)

The seven Samurai

Underground Science

Fundamental laws

Frontier to Particle Physics

Cosmology

Cosmic ray and Grav Waves

Origin of CR, HE Universe

Frontier to Astrophysics

Megaton	Ton	Ton	Gravitational	HE ν	HE γ	UHECR
p decay and ν	Dark Matter	νmass	Waves ET	KM3	CTA	AUGER Nc

$10^{-30\text{-}33}$ cm
ν mass, proton decay, inflation

10^{28} cm event horizon (5 Gpc)
Cosmology, Dark Energy/matter, GRB,cosmological markers

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10^{22} cm Galaxy (10 kpc) (supernova, CR, HE γ, ν μquasars)

10^{-21} cm LHC,DM

10^{15} cm solar system (solar neutrinos)

$10^{-15\text{-}18}$ cm
Nucleosynthesis
Primordial/Star

10^{10} cm

10^{-5} cm

Asrparticle infrastructures help study ocean floor biodiversity

10^{5} cm

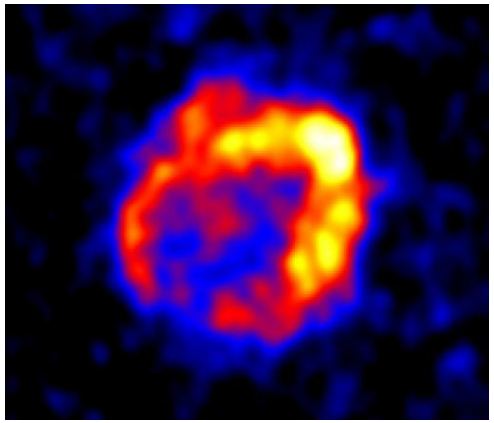
Astroparticle uses the geosphere as detecting medium

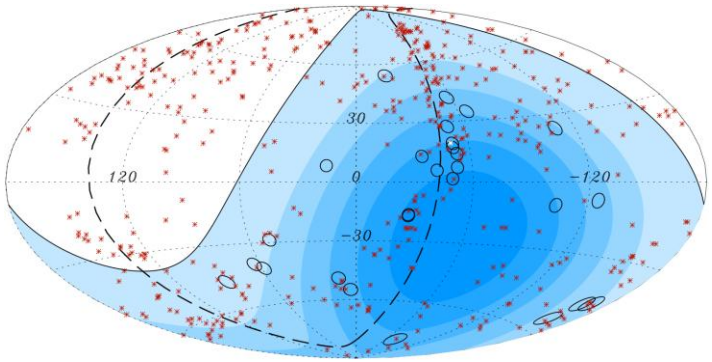
Astroparticle heps us understand our origins

High Energy Universe

Study

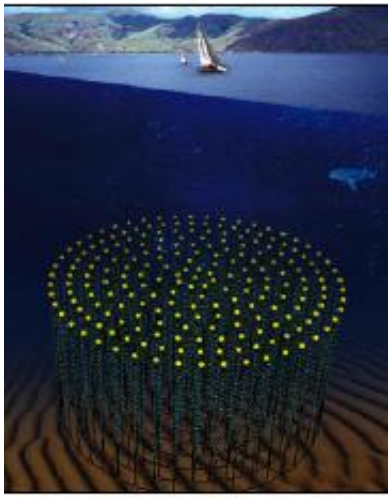
- The origin of cosmic rays and in general non-thermal processes
- Access to energies beyond LHC
- Indirect search of dark matter annihilation
- Extreme phenomena serving as cosmological markers
- Probe the intergalactic space and/or the space-time fabric itself

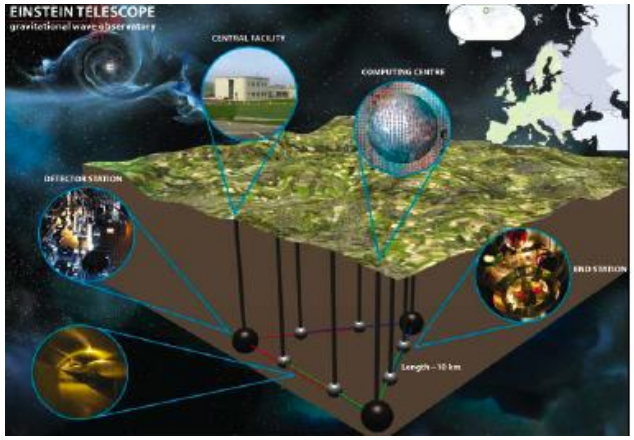




High Energy Universe Infrastructures

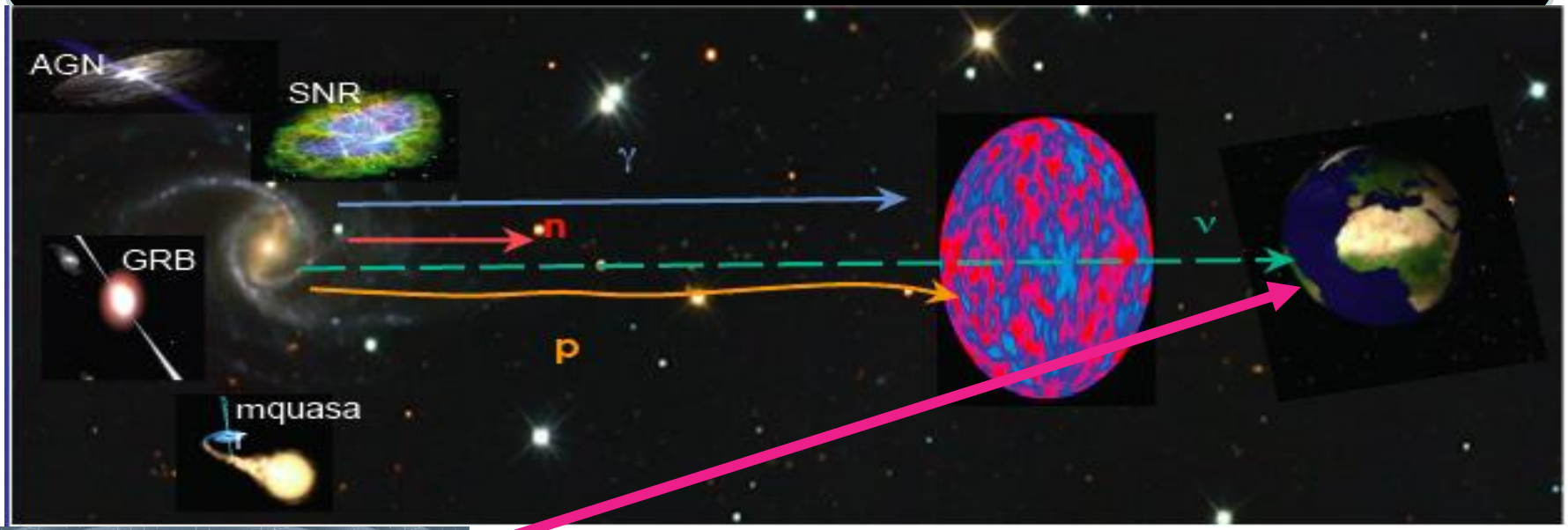
- Beyond the Auger South Observatory (Auger-North)
- High Energy Gamma Ray Cherenkov Telescope Array (CTA)
- Neutrino telescope in the Mediterranean (KM3Net)
- Einstein Telescope for gravitational wave detection (ET)
  - Complementary to a space program (JEM-EUSO, FERMI, LISA)

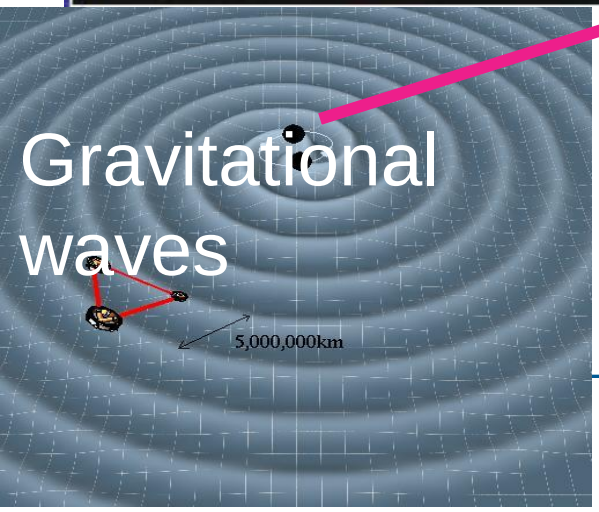




Possible designs

New messengers



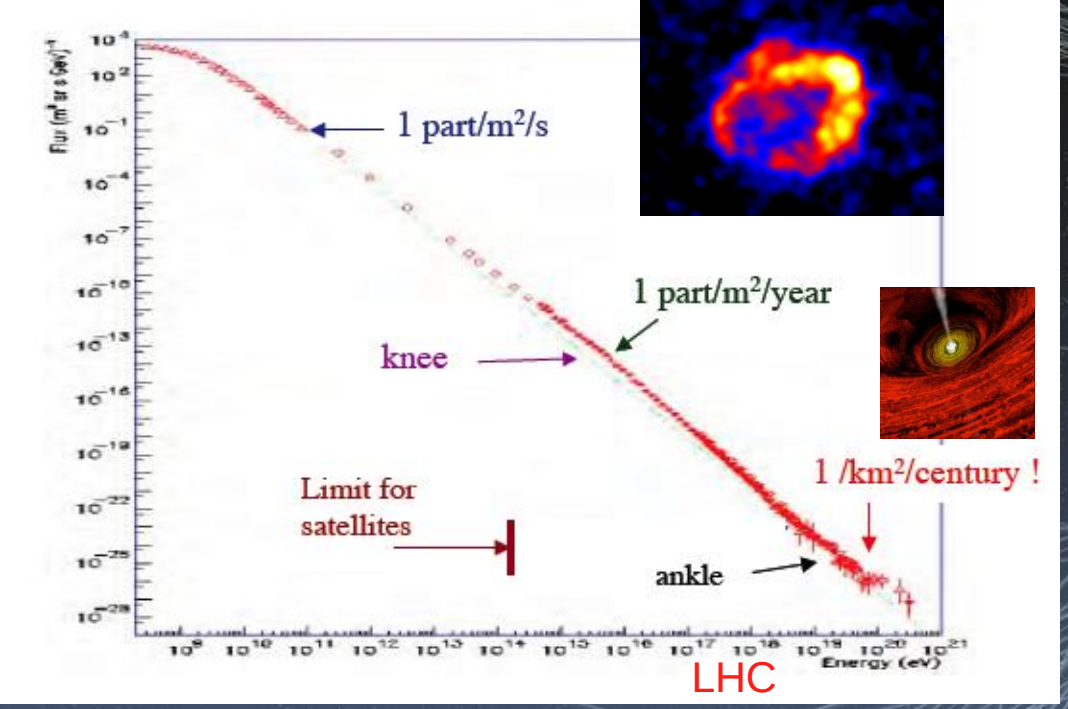


Correlations for

- **Visible strophysical sources**
- **Dark matter sources**

COSMIC RAYS

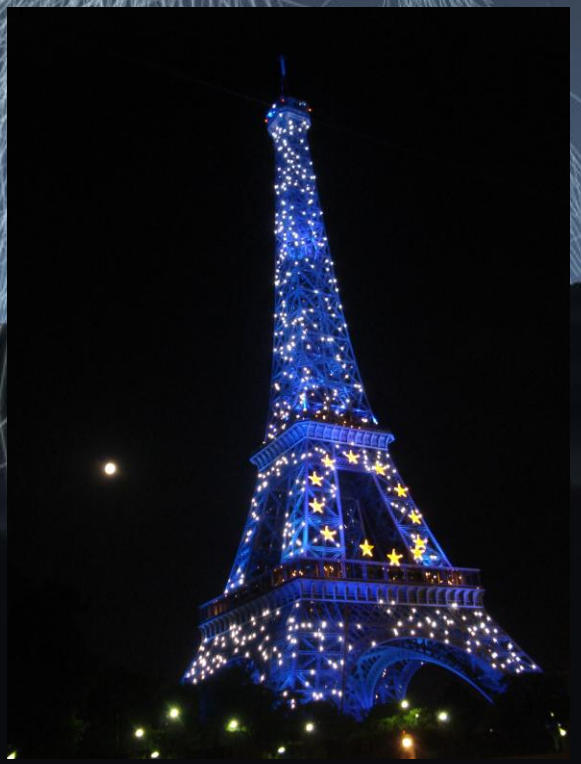
a centennial problem



LHC

Origin ?

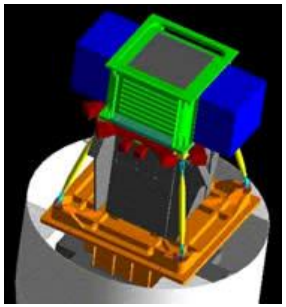
Composition ?



WULF Eiffel tour 1909, Balloons HESS 1911

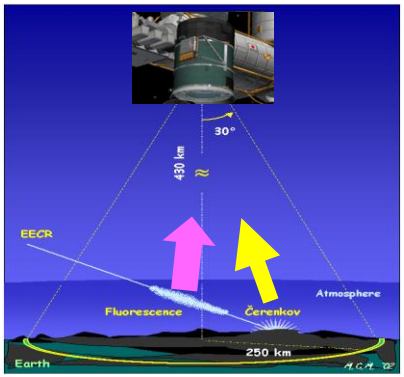
400 years of Astronomy, 100 yers of CR physics

High Energy Cosmic Rays

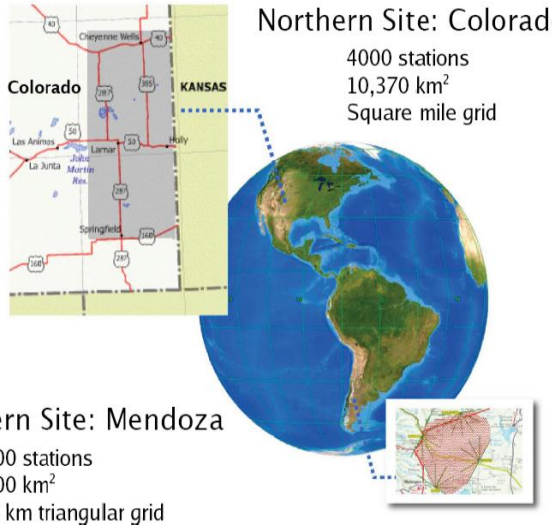


PAMELA,CREAM, ATIC,…

AMS on ISS for 3 years

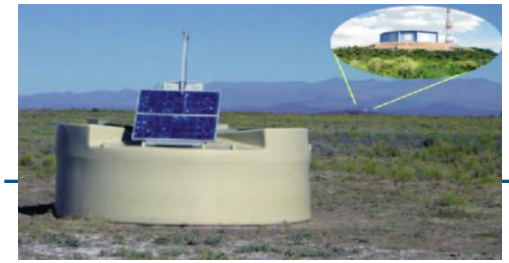


KASCADE, HEAT/AMIGA (Auger),,…



Northern Site: Colorado
4000 stations
10,370 km²
Square mile grid

uthern Site: Mendoza
1600 stations
3000 km²
1.5 km triangular grid

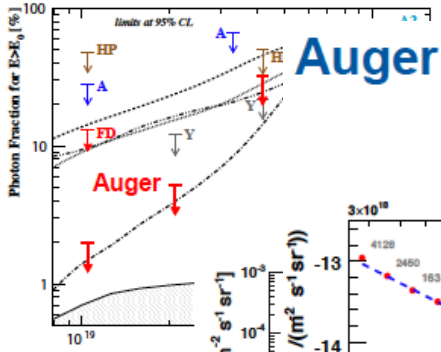


AUGER South

R&D Radiodetection

Auger Highlights

Auger Highlights – Composition

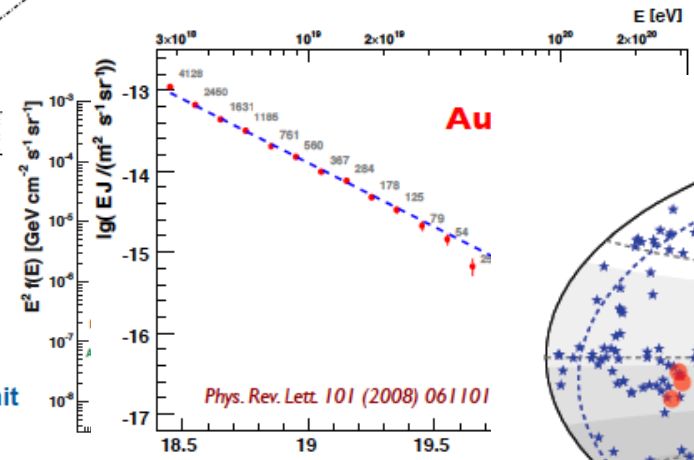


Photon limit

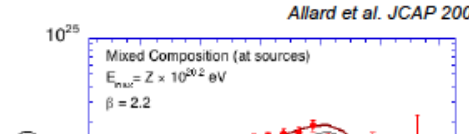
Neutrino limit

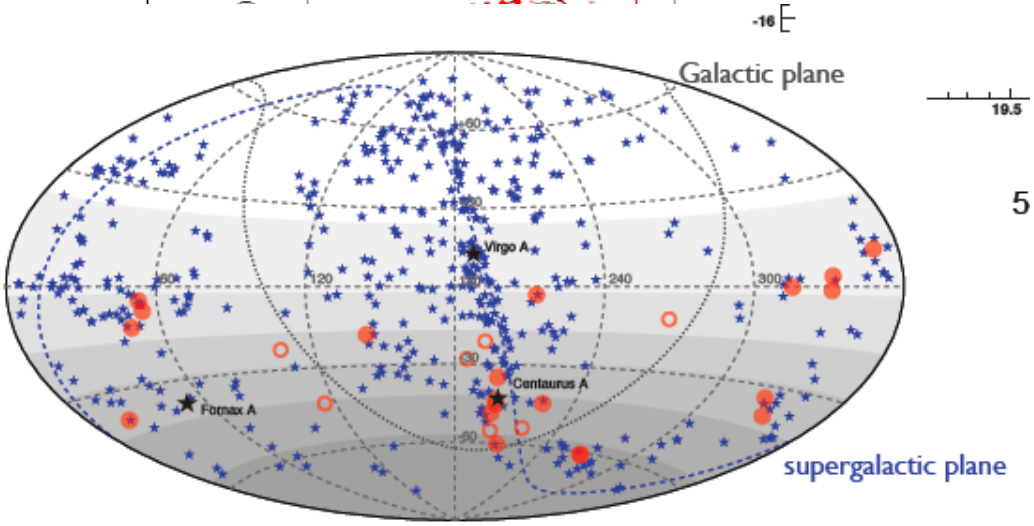
Phys. Rev. Lett. 100 (2008) 021101

Auger Highlights – Flux Suppression



Model-independent mea





Auger: 27 events above 5.7x10¹⁹ eV, 20 correlated within 3.1°

Transparencies of R. Engel

Auger North

Science with Auger-North

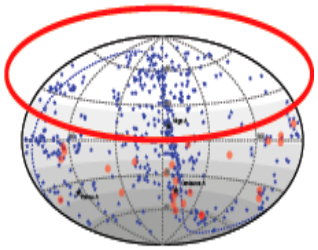
The sources of UHECR
- Anisotropy ⇉ correlations ⇉ source classes
- Study individual sources with spectra and composition on the whole sky

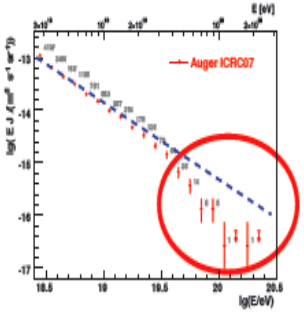
The acceleration mechanism
- Composition evolves from source to here
- Proton beam !? calibration !
- E>>10^{20} eV still difficult; E_{max} ?

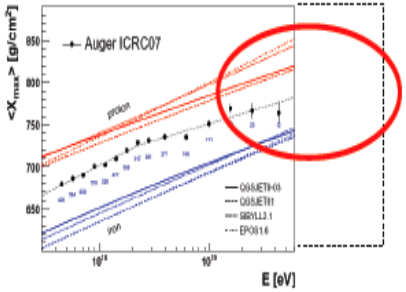
Propagation and cosmic structure
- Map galactic B-field
- Matter within 100 Mpc
- Extragalactic B-field small ?

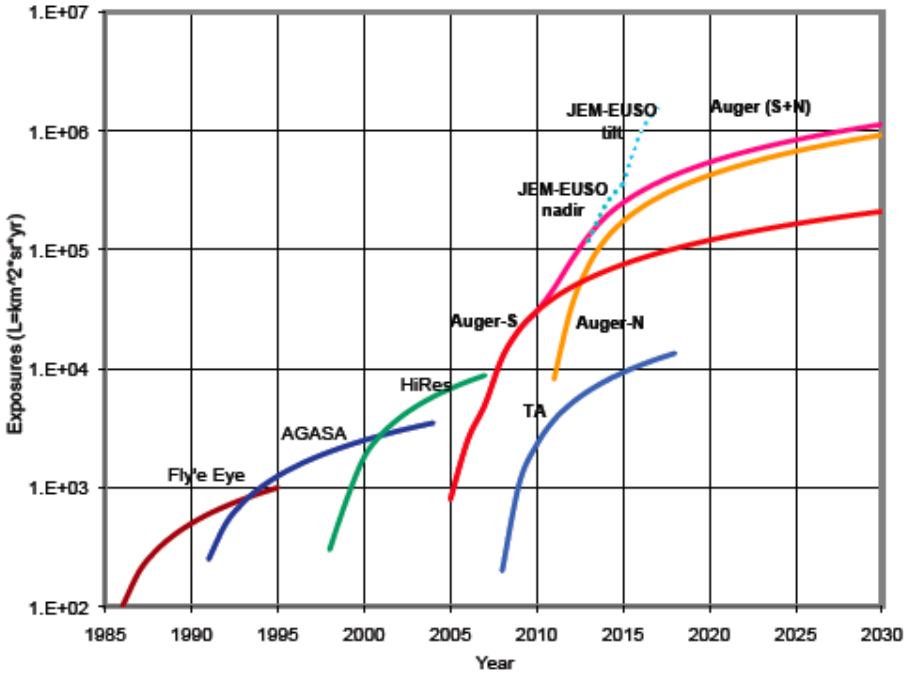
Particle physics at 350 TeV
- Mass and X_{max}
- Had. interactions, cross sections ?
- New physics, Lorentz invariance

Multi-messenger astrophysics
- Combine the data from photons, neutrinos and charged particles !
- Sources within field of view of IceCube

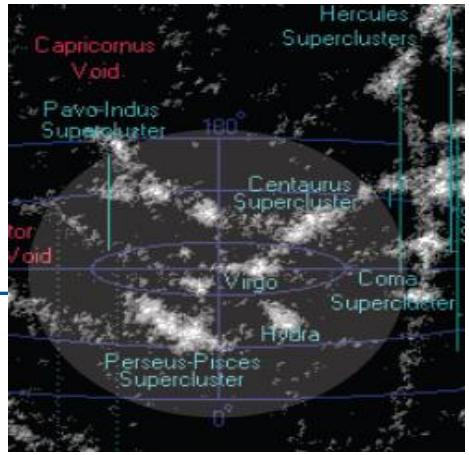








GSZ horizon



AUGER-South/ Antares/KM3

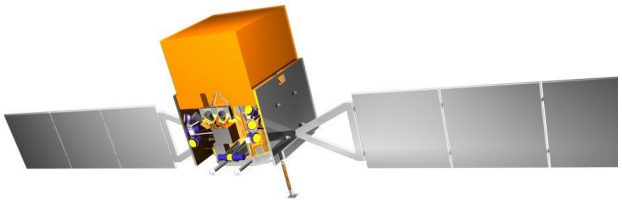
Thanks to R. Engel

IPMU

Infrastructure

High Energy Gamma Rays

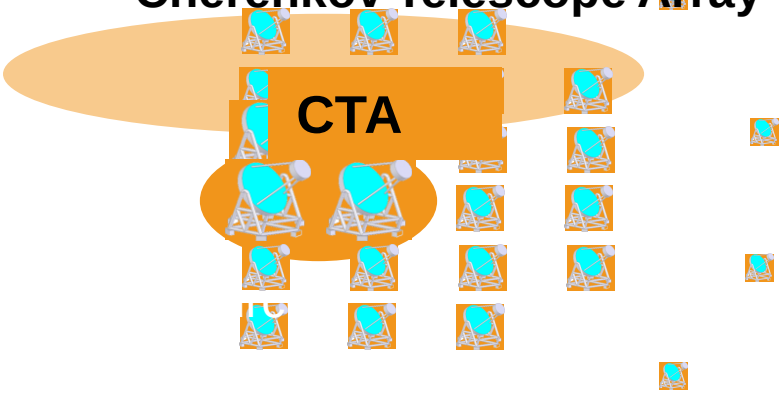
HESS I+II, MAGIC I+II,VERITAS

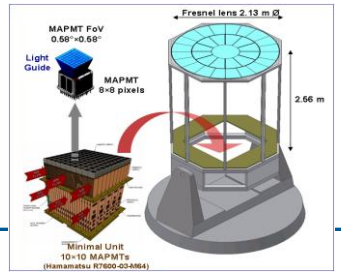


GLAST

TIBET, ARGO-YBJ

Cherenkov Telescope Array



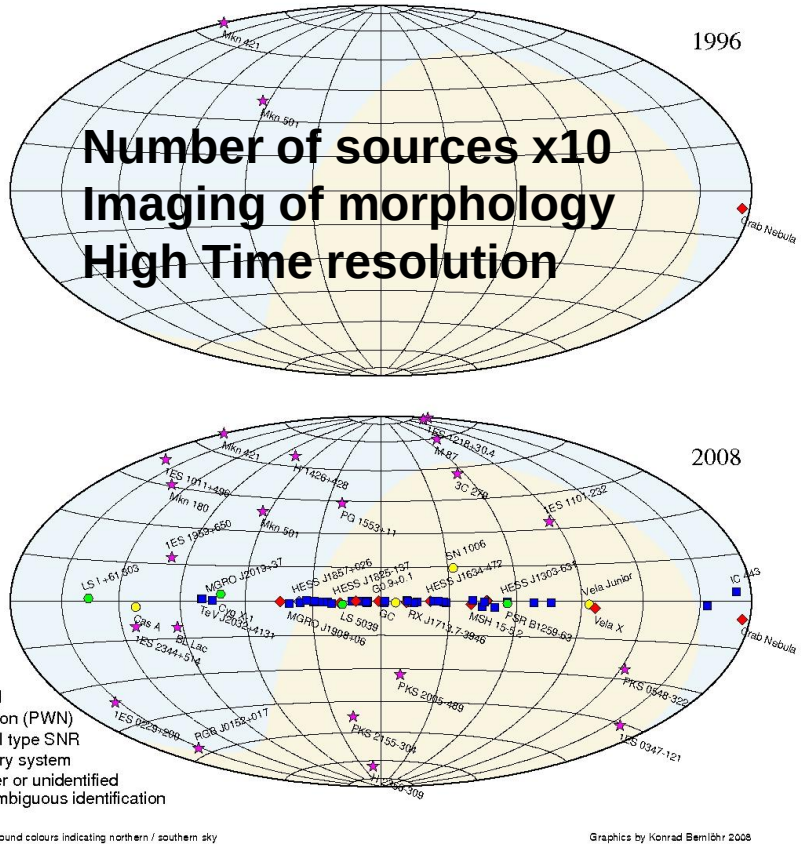


GAW R&D

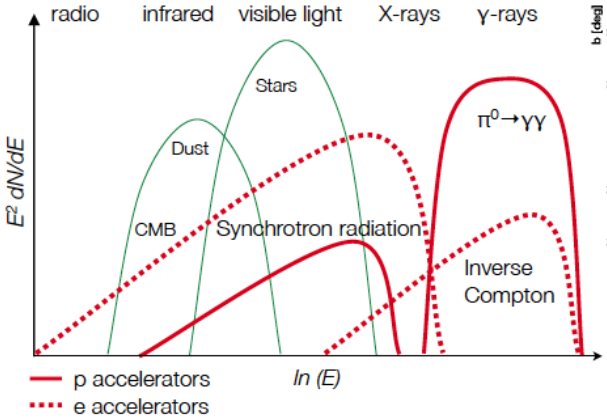
Space INTEGRAL, AGILE, GLAST

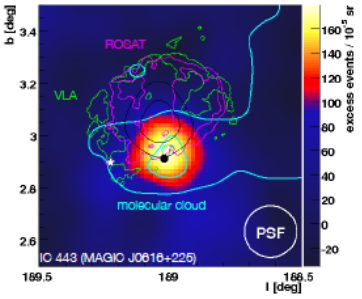
Relationship with AGIS?

High Energy Gamma Rays Highlights

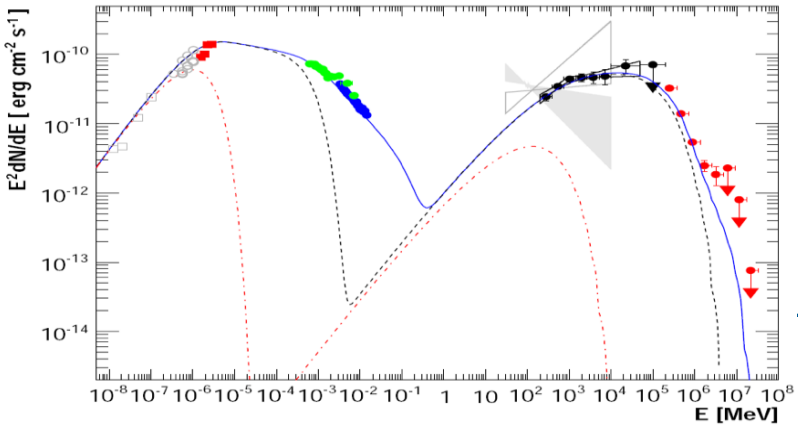


Multi-Wavelength Astronomy





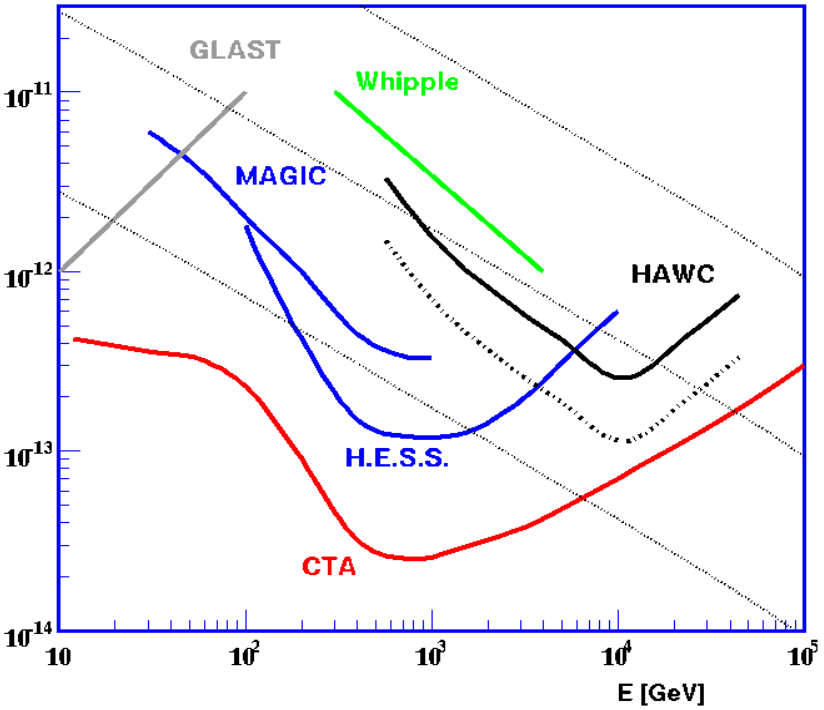
Origin of CR: HE γ hadronic or EM?

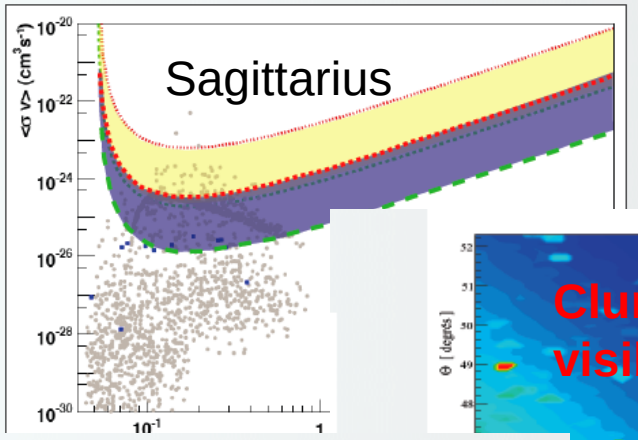


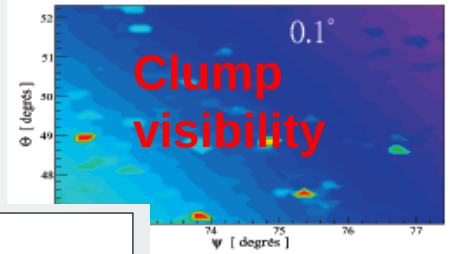
GLAST+HESS

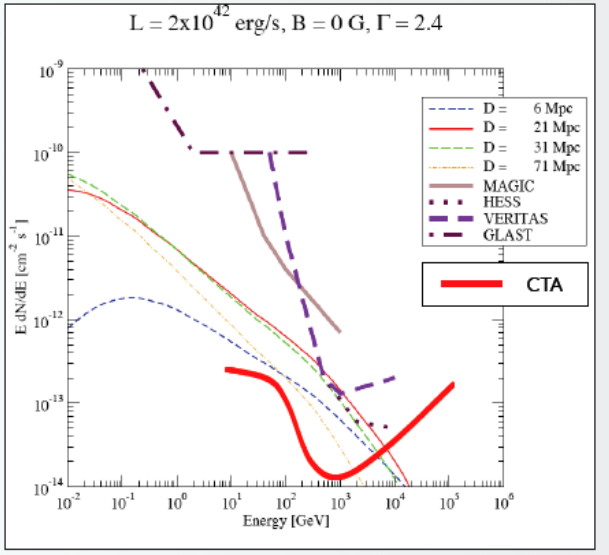
Variability in HE emission
Molecular cloud association
Extragalactic Background light

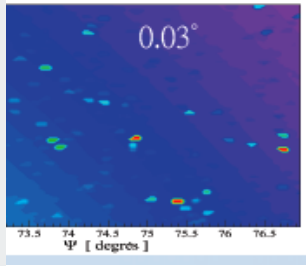
High Energy Gamma Rays
CTA











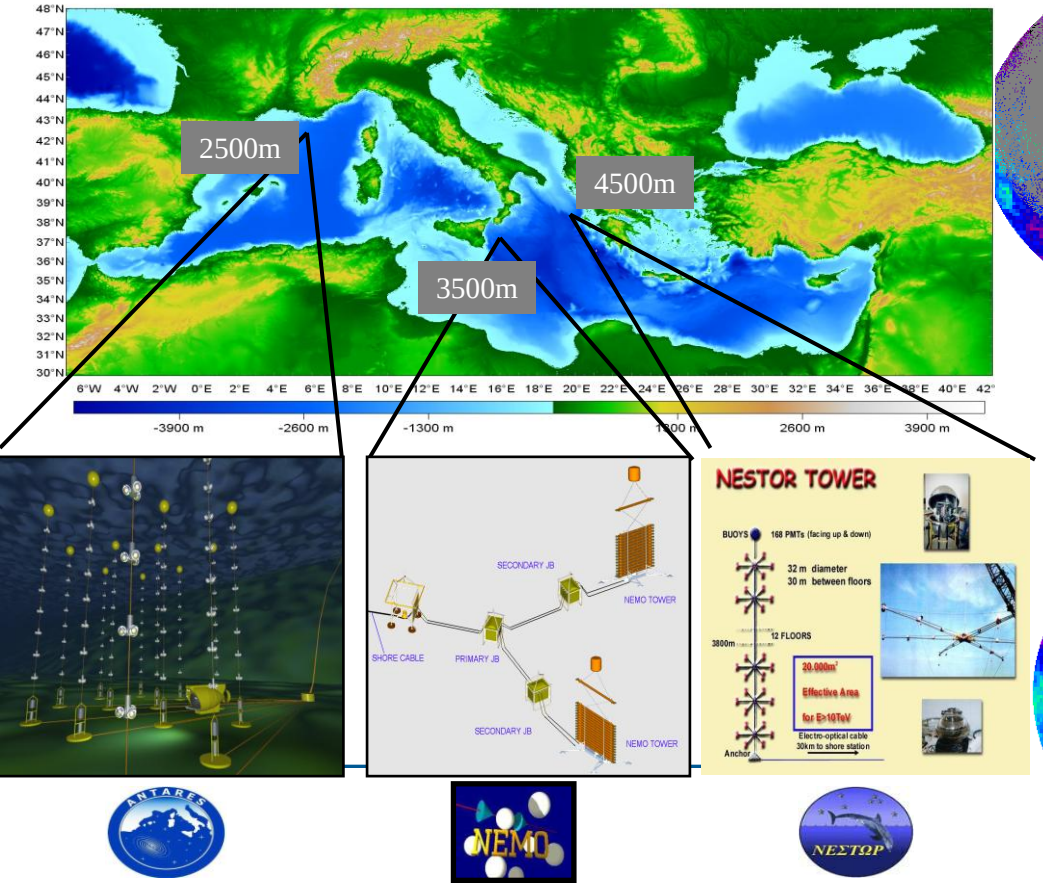
- **sensitivity x10 => x10 sources**
- **angular resolution x3**
- **field of view x2-3**

AUGER association

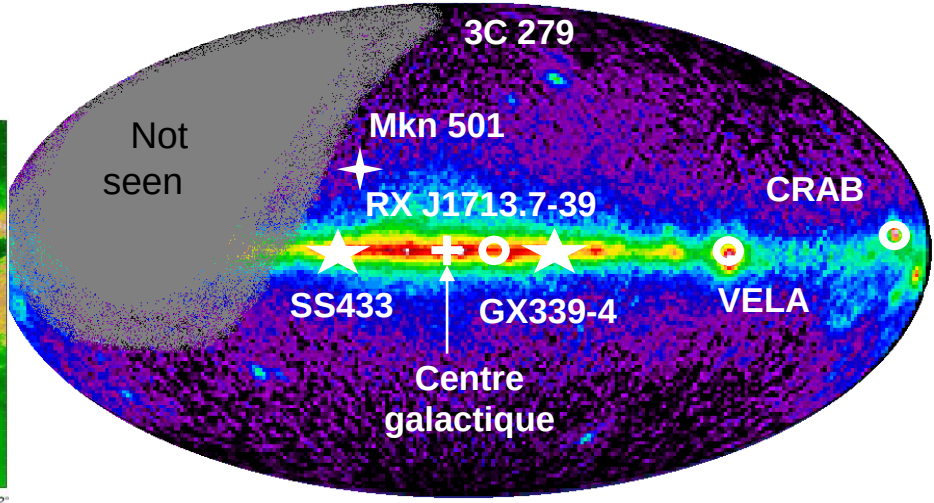
High Energy neutrinos

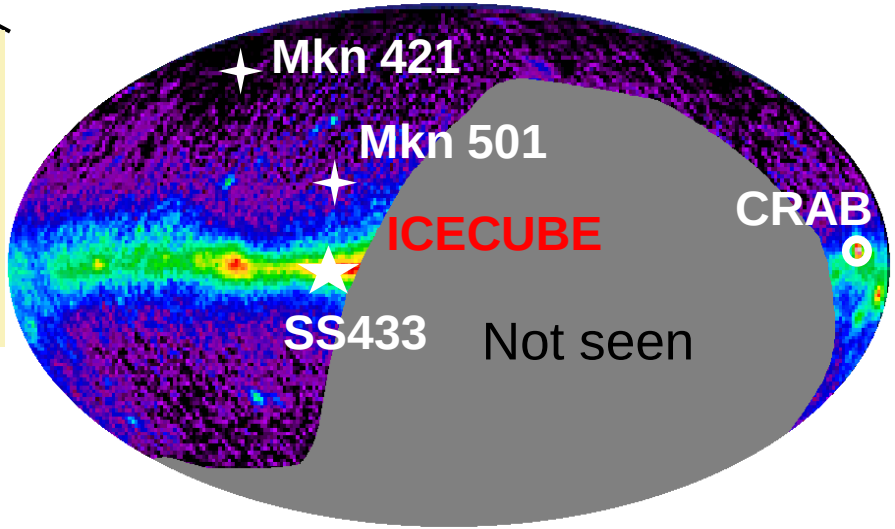
From ANTARES, NEMO,NESTOR ➔ KM3

In US AMAND/ICECUBE



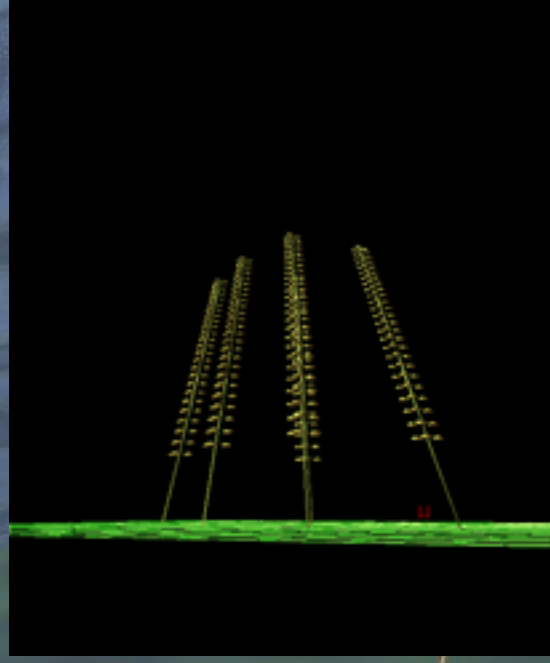
Need ν for origin of CR

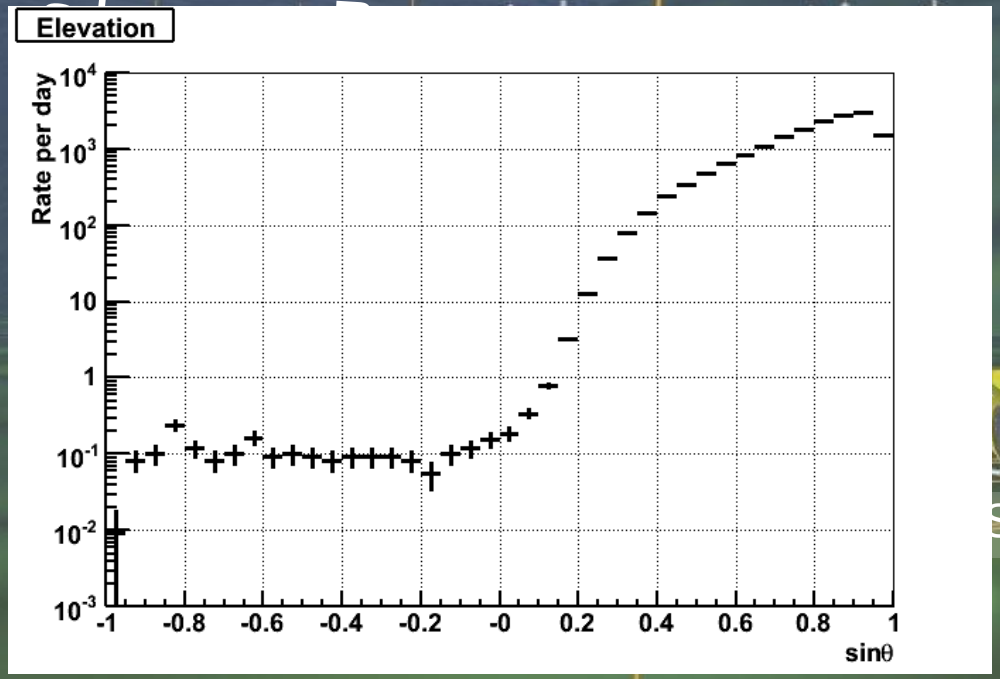




The ANTARES Detector

Buoy





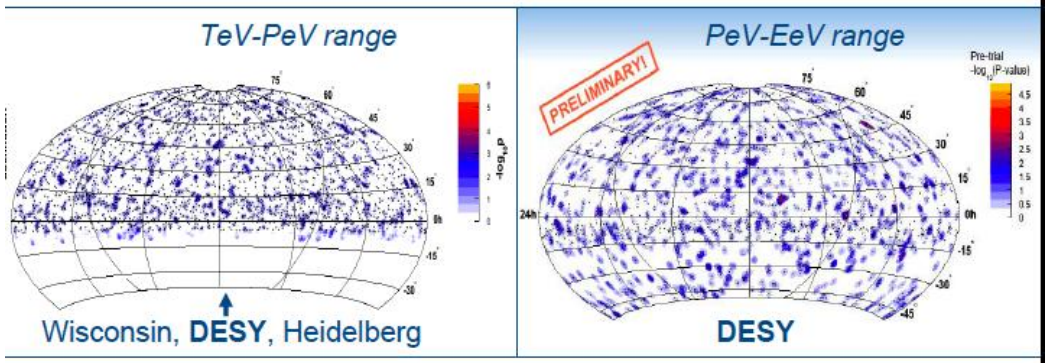
Cable to Shore station

Junction Box

Submersible

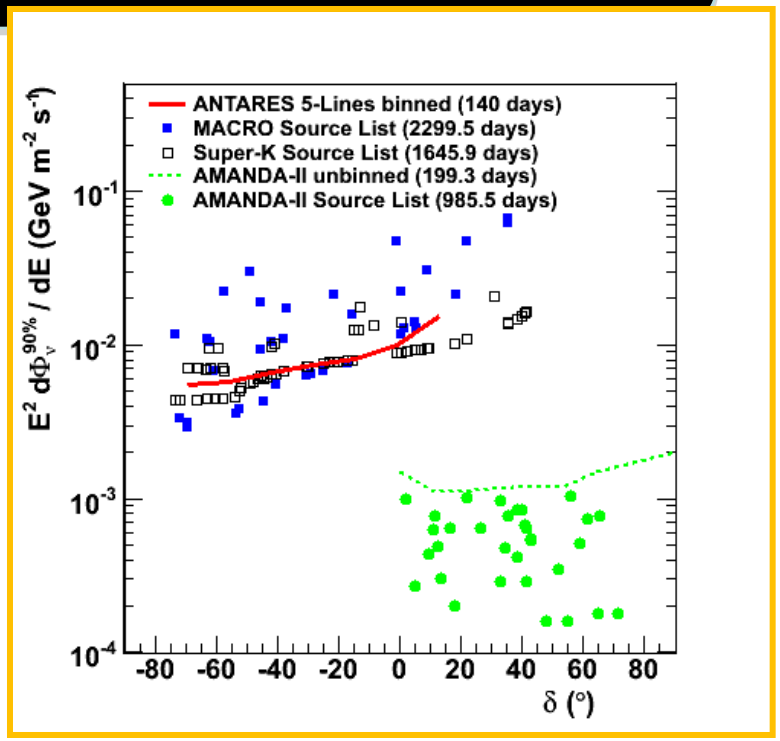
High Energy Neutrinos I

Point Sources



First skymaps, 22 strings, 2007 Ultra-High Energies

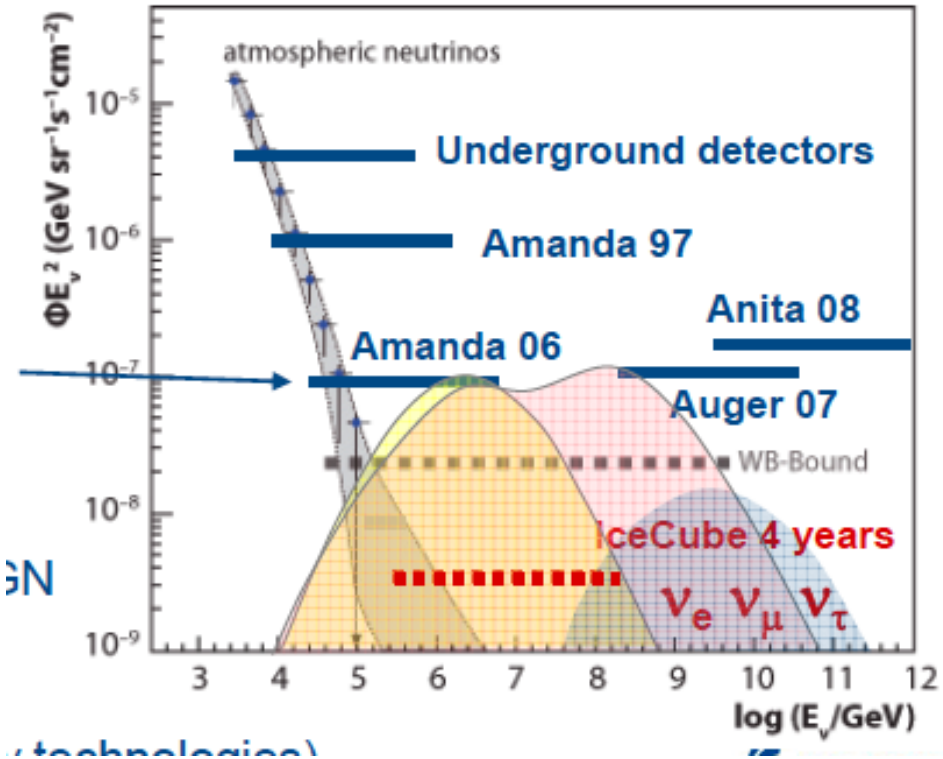
ICECUBE 75% deployed
By 2012 x20 times of 7 AMANDA years

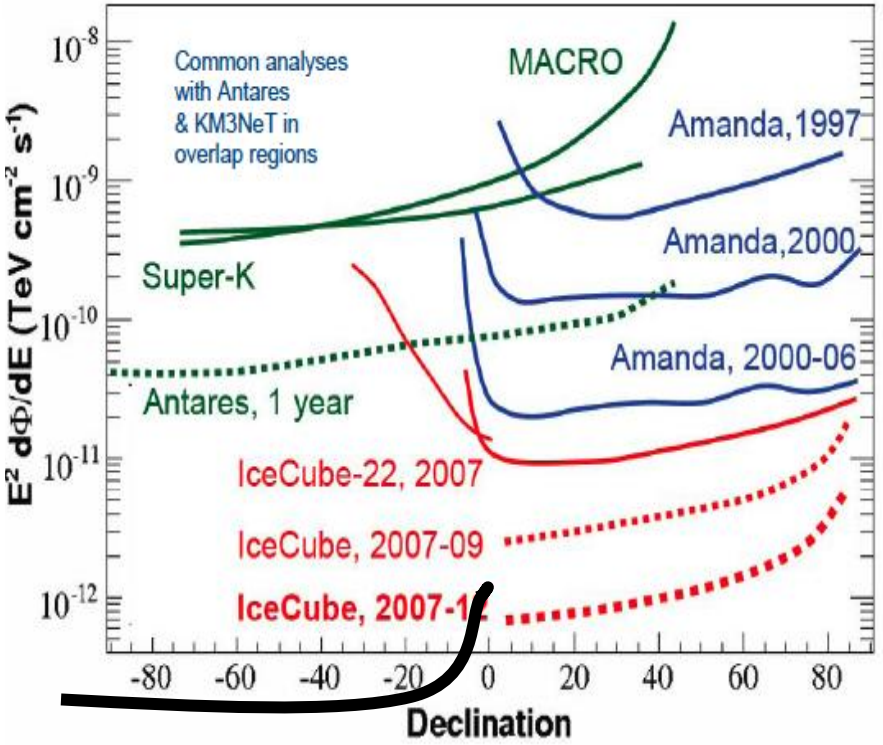


ANTARES complete and taking data

High Energy Neutrinos II

100fold progress in sensitivity in 15 years

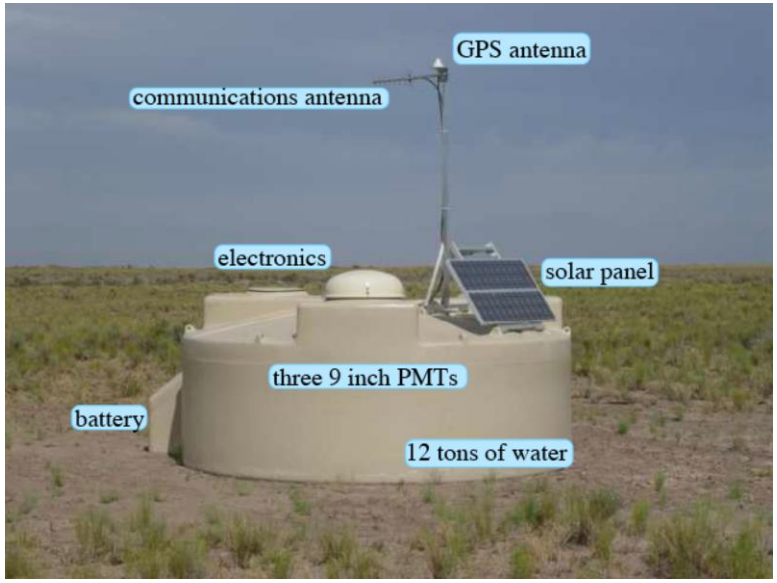




KM3net 3 years

KM3 sees galactic center, excellent resolution
0,7˚

Parenthesis: the interdisciplinary potential of astroparticle for the geosciences

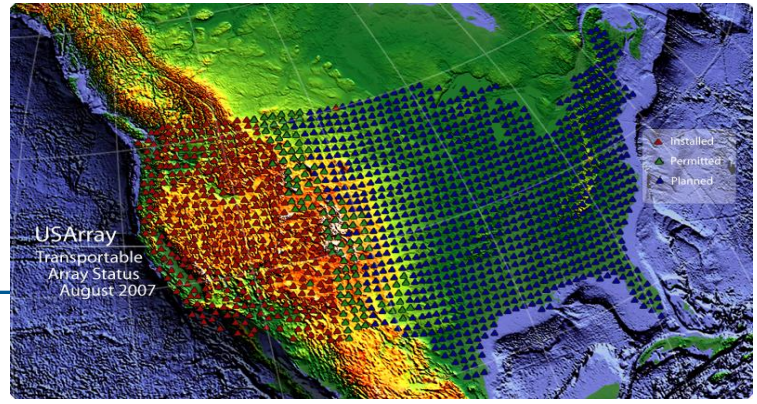


Astroparticle physics networks exhibit a natural synergy with climate and risk monitoring studies or geoscience observation networks.

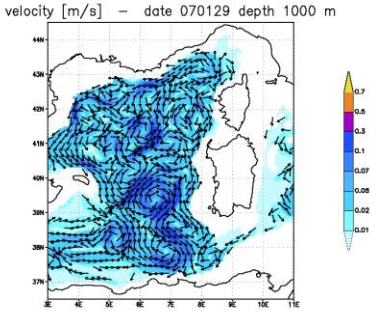
1)The atmosphere, the ocean and earth are both the target and detecting medium

2)They need to deploy large variable geometry networks of autonomous "smart" sensors in sometimes hostile environments

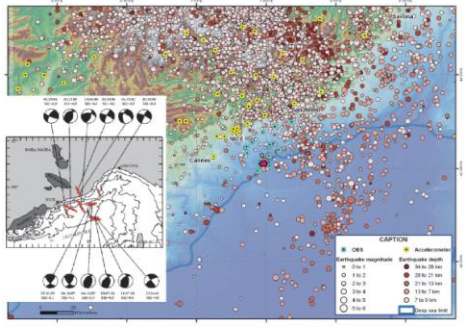
Compare e.g. the AUGER array of 1600 measuring stations covering 3000 km2 in the argentinian pampa with US geoscience networks EARTHSCOPE, US array, EPOS in Europe etc.



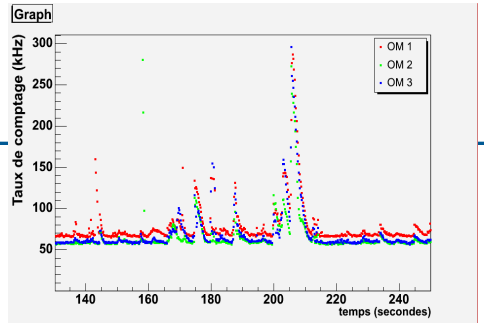
Neutrino telescopes provide for the first time a continuous high bandwidth link to the deep ocean floor useful for a multitude of environmental studies.



OCEANOGRAPHY: Continuous oceanographic measurements (currents, temperature variations) to be compared with modelling



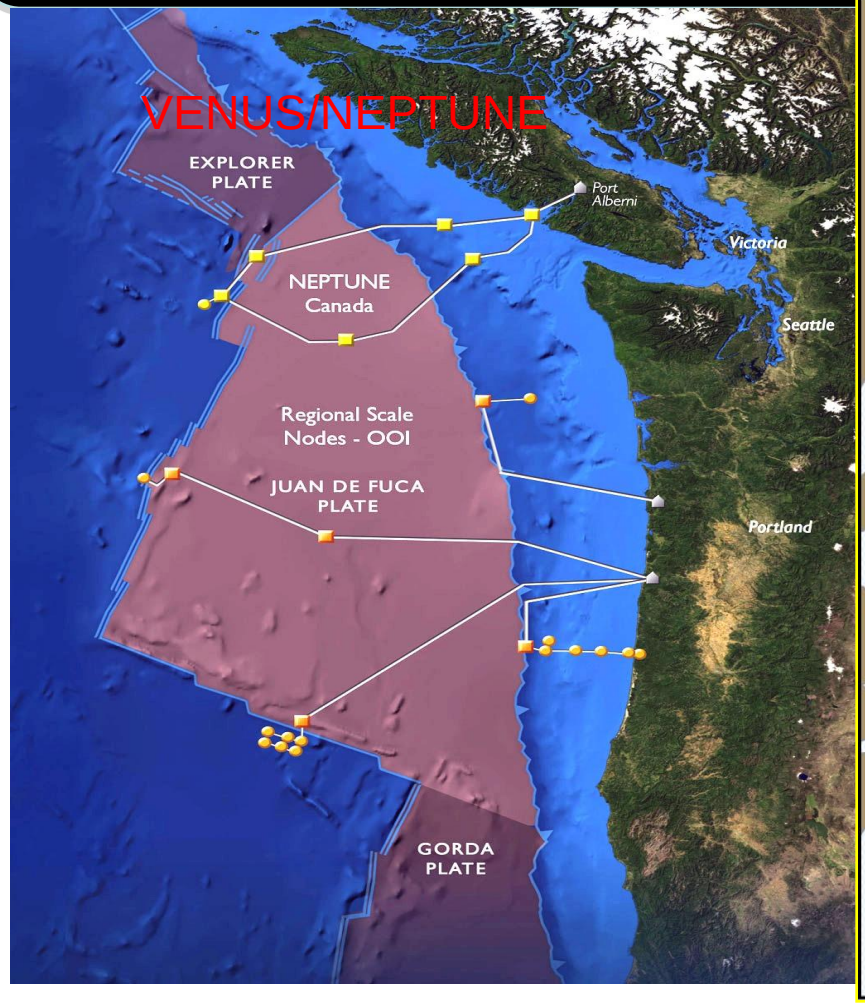
GEOSCIENCE: Seismometric networks and geomagnetic measurements

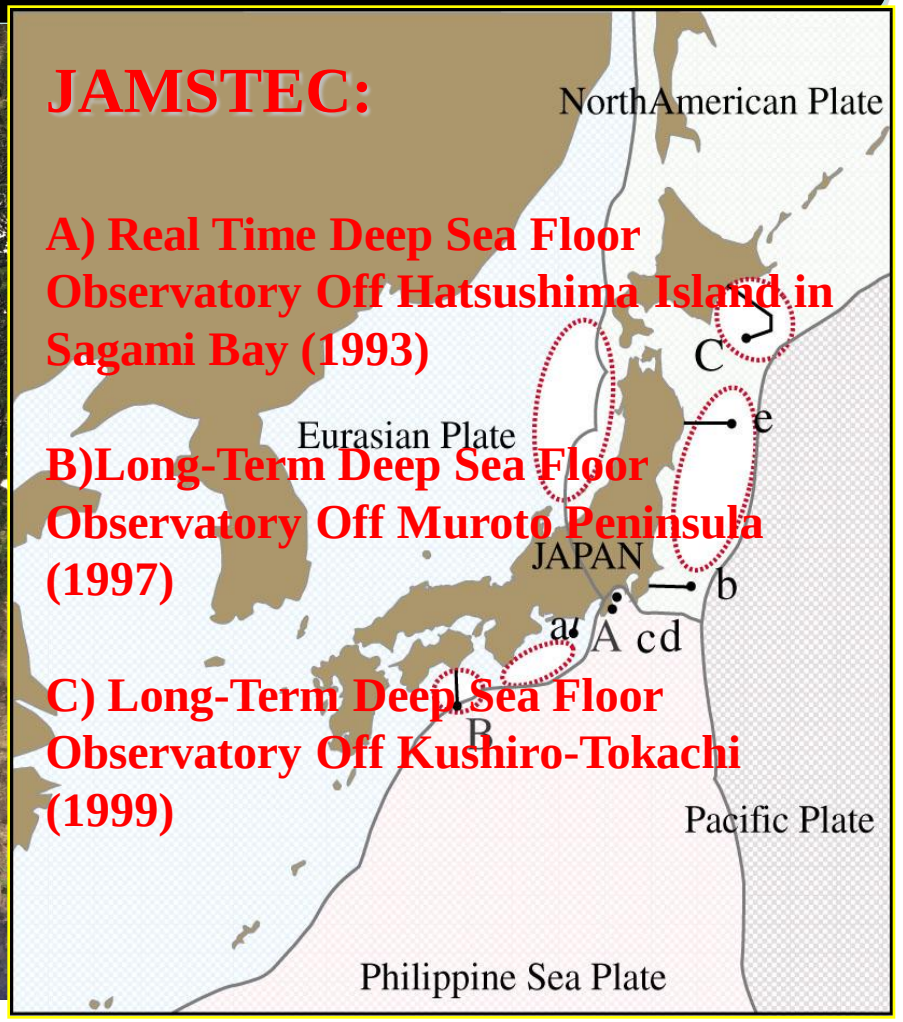


BIODIVERSITY: bioluminescence studies, whale counting through acoustic detection

(These signals form the background to neutrino detection)

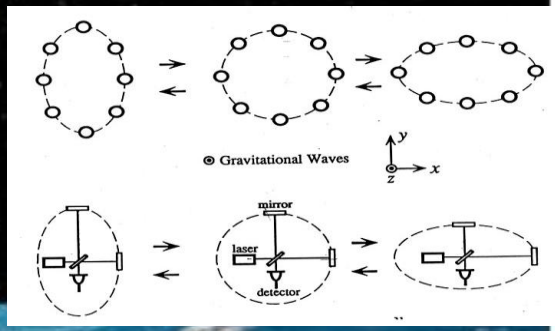
Promoting ocean floor technology:
VENUS/NEPTUNE (US) EMSO(EU), JAMSTEC(Japan)

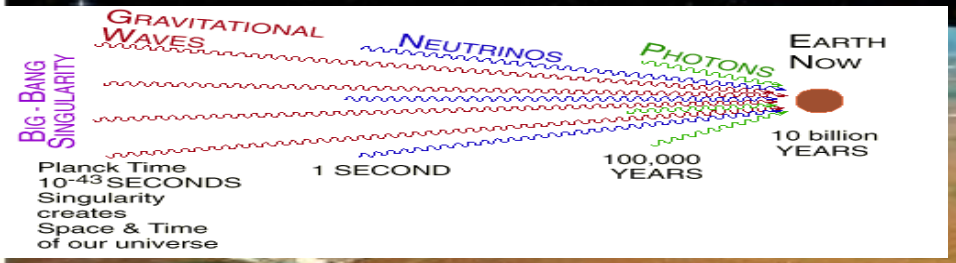




Gravitational waves VIRGO/LIGO and LISA

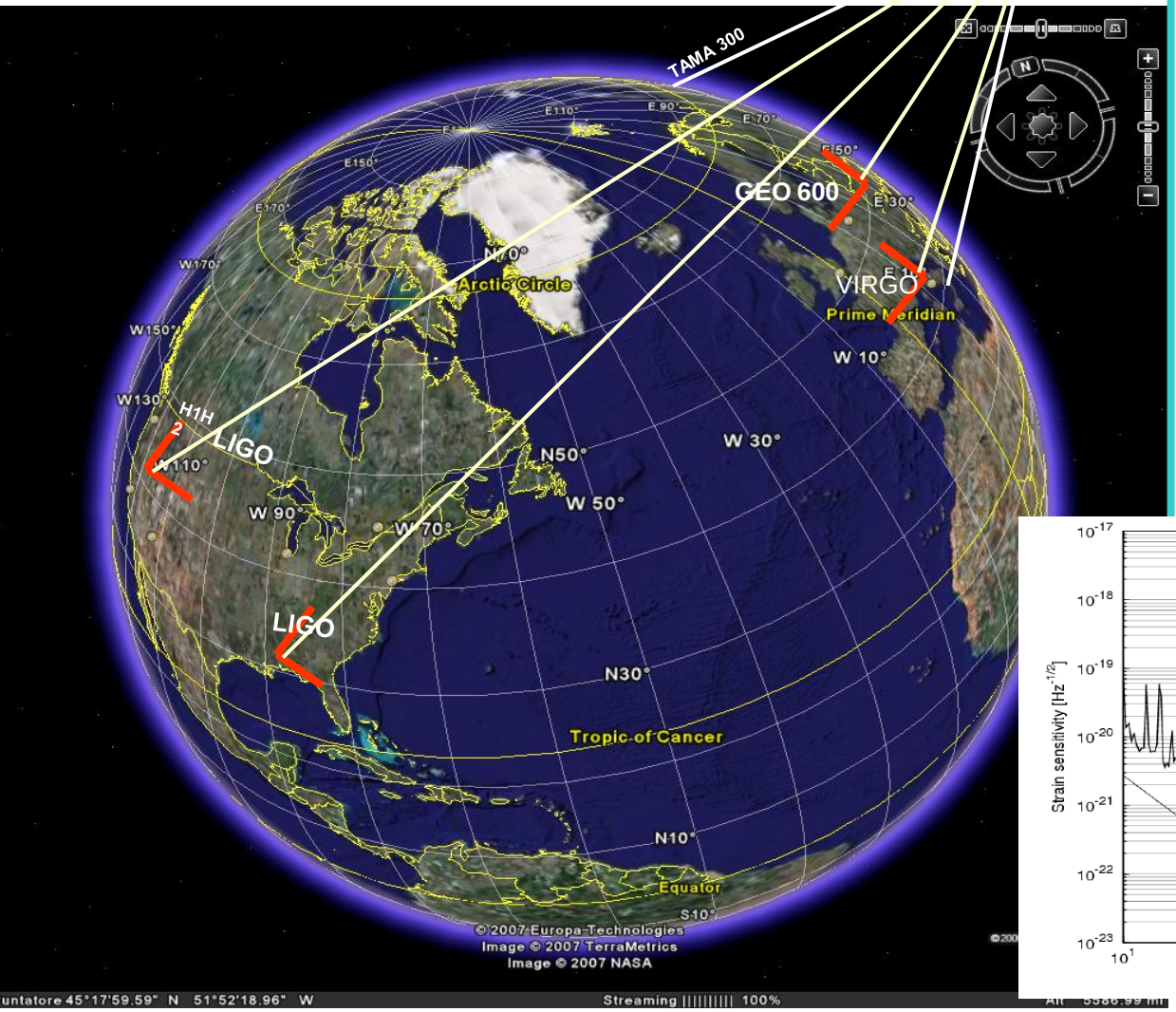
Binary fusion
(NS-NS,BH-BH)
Supernovae / GRBs:
"bursts"
Pulsars :
"periodic"
Cosmology
"stochastic background"





Gravitational antennas, a wordwide network

T

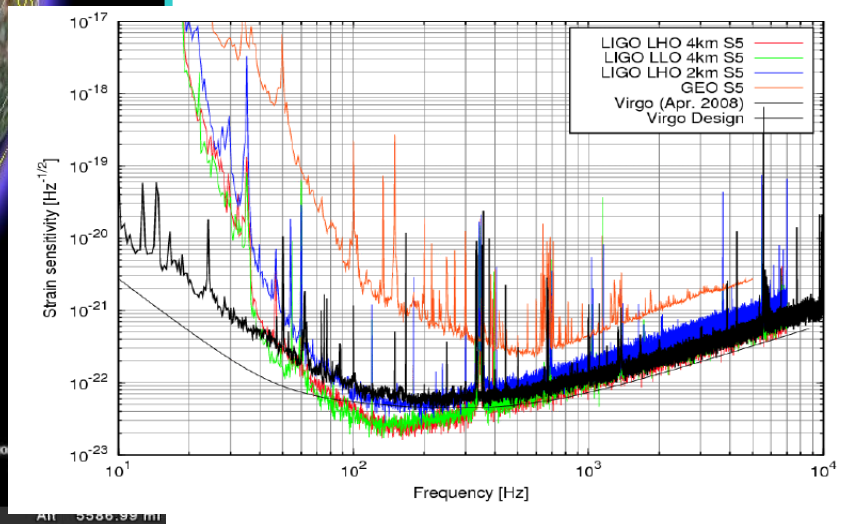


Towards GW detection

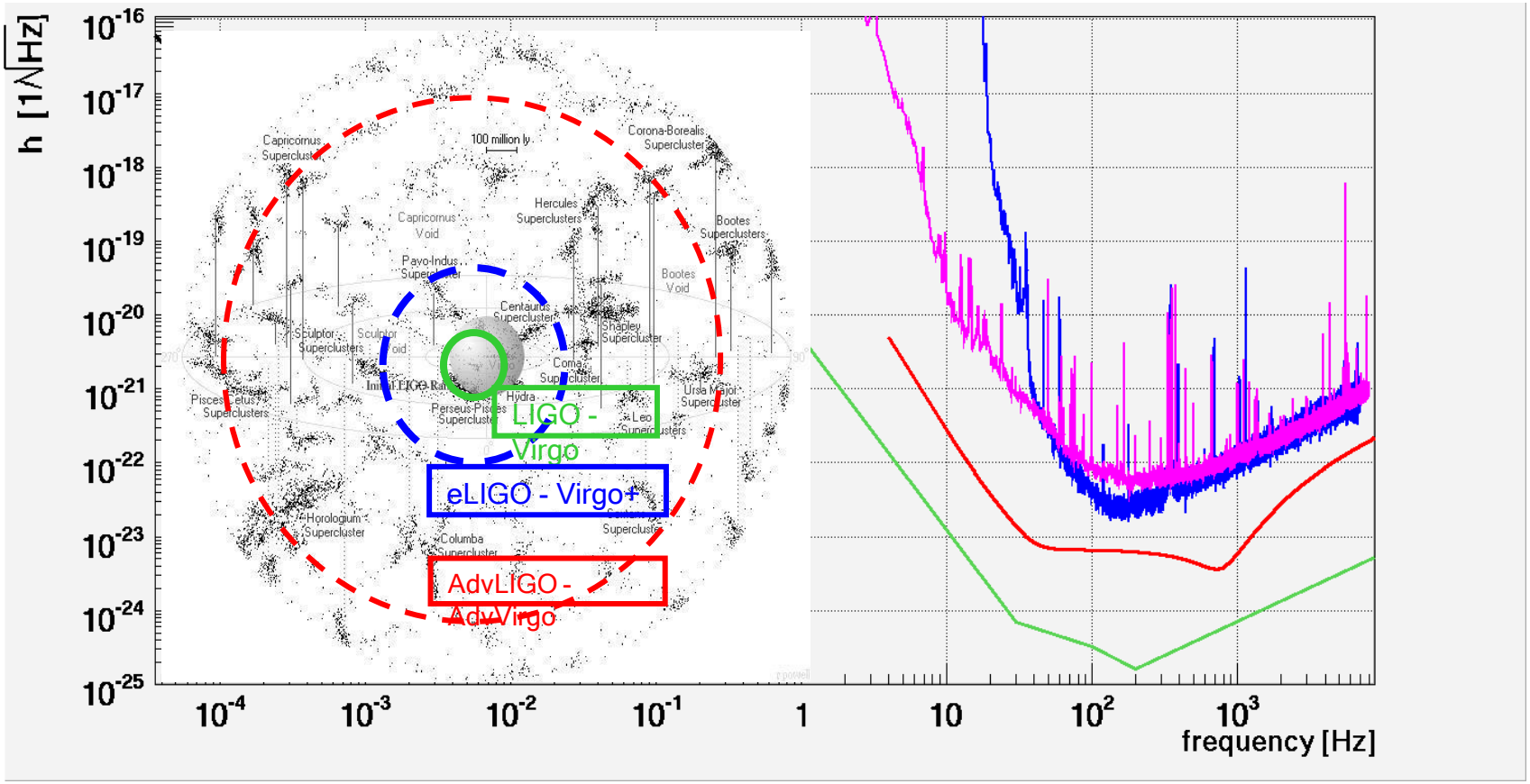
✓ **In 2008 LIGO/VIRGO/GEO performed a 4 month common run (comparable sensitivities)**

✓**They currently cosign publications and coordinate the upgrades towards advVIRGO and advLIGO**

✓**advVIRGO/LIGO sensitivity reaches 150 Mpc, expecting typically 40 NS-NS mergers per year**



Gravitational Wave Atennas



$10^{-30\text{-}33}$ cm
ν mass, proton decay, inflation

10^{28} cm event horizon (5 Gpc)
Cosmology, Dark Energy/matter, GRB,cosmological markers

10^{26} cm GZK horizon (100 Mpc) CR, HE γ, ν, GW

$10^{-24\text{-}27}$ cm
UHECR, HE ν,
DM

10^{22} cm Galaxy (10 kpc)
(supernova, CR, HE γ, ν μquasars)

10^{-21} cm LHC,DM

Another definition the 2 ∞

10^{15} cm solar system (solar neutrinos)

$10^{-15\text{-}18}$ cm
Nucleosynthesis
Primordial/Star

10^{10} cm

10^{-5} cm

Asrparticle infrastructures help study ocean floor biodiversity

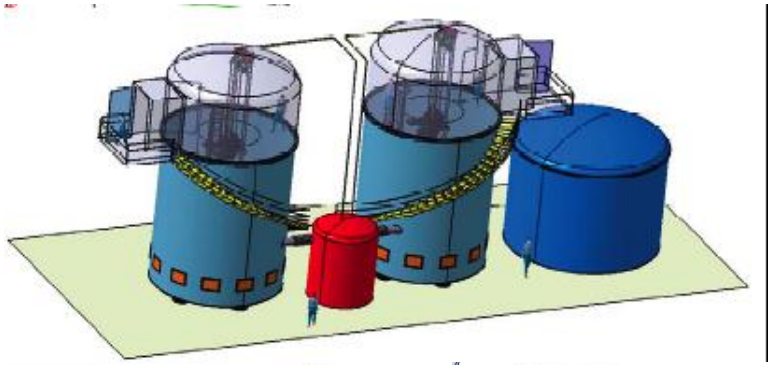
10^{5} cm

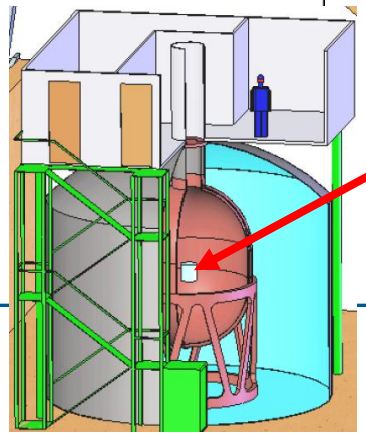
Astroparticle uses the geosphere as detecting medium

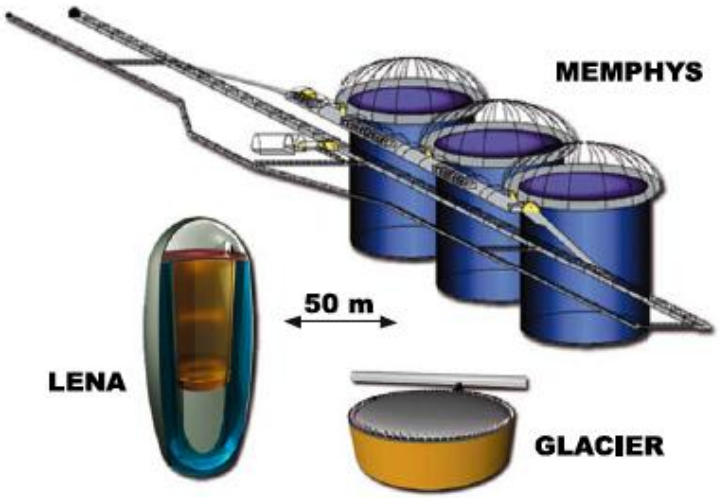
Astroparticle heps us understand our origins

Underground Science large infrastructures

- Dark matter detectors towards the ton
- Neutrino mass detectors towards the ton
- Proton decay and neutrino (astro)physics towards the megaton

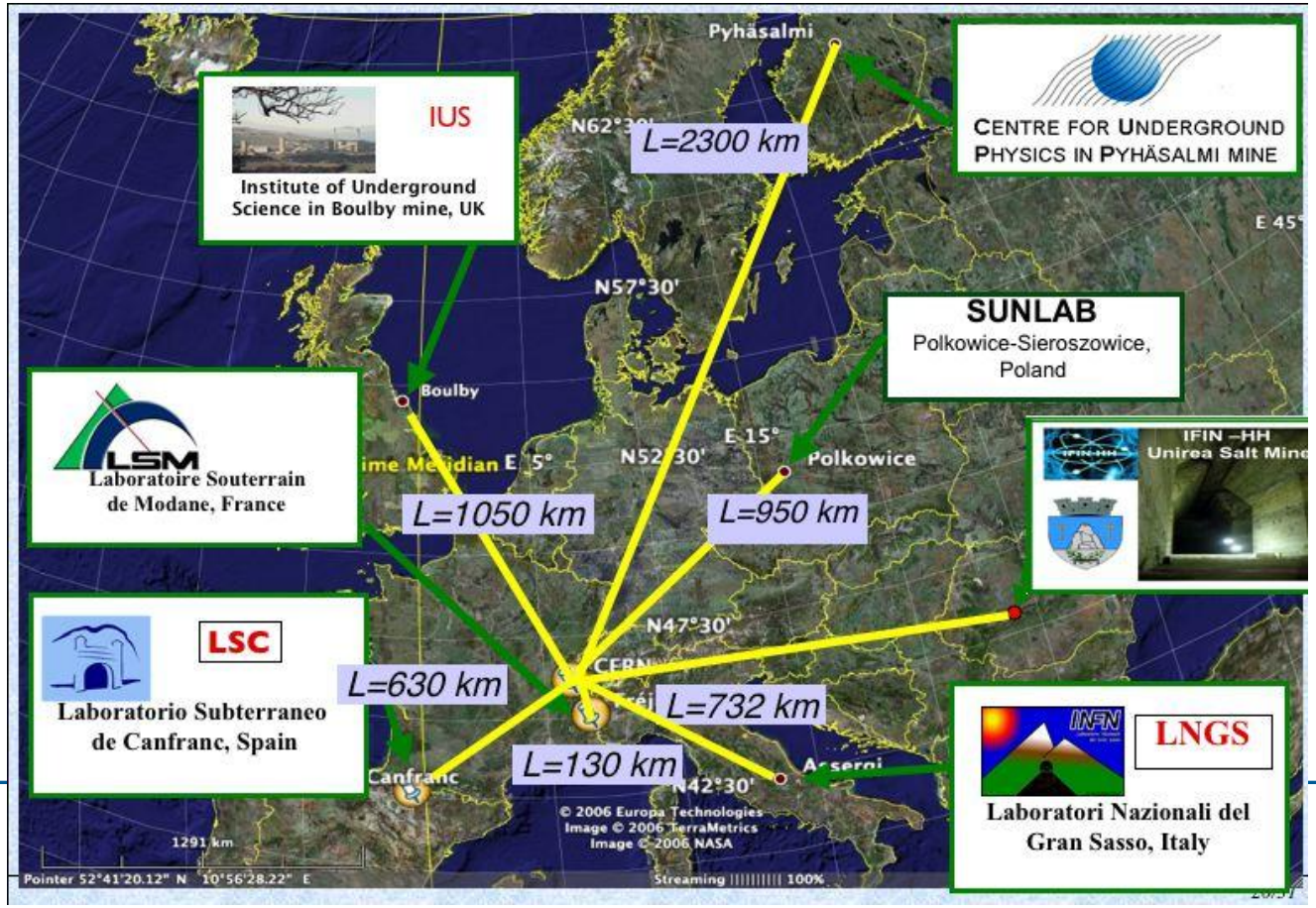




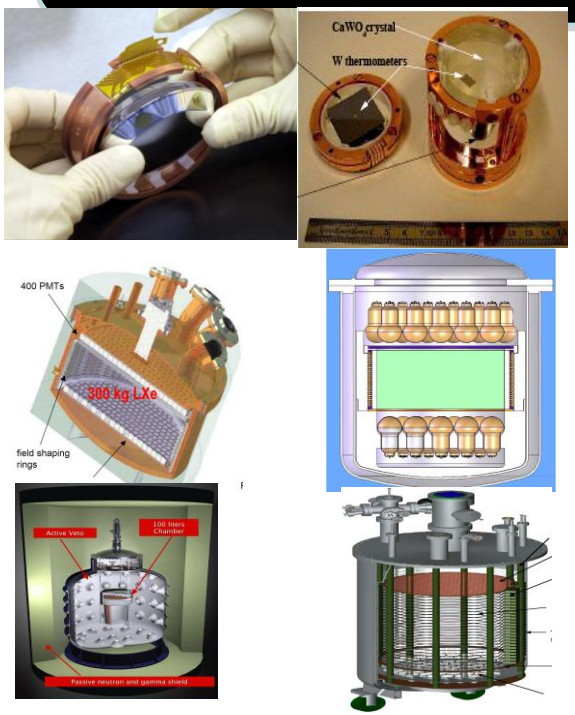


Underground laboratories

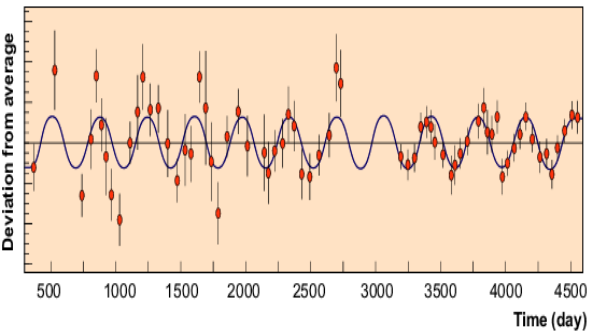
- **4 large laboratories + 3 smaller ones. Large effort of coordination towards sharing of management.**



Dark Matter Searches



DAMA annual modulation



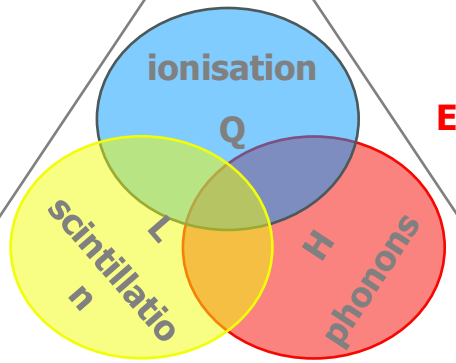
WIMP elastic nuclear recoils deposit < 50keV of energy at a rate 10^{-5} to 1 event/day/kg

PICASSO/SIMPLE
DRIFT I, II
GENIUS,

phonons, photons and charge whose relative proportions and /or characteristics depend on dE/dx ⇒ particle type

ArDM, WARP,
XENON, ZEPLINIII,LUX,

EDELWEISS, EURECA



DAMA/LIBRA, ZEPLIN I

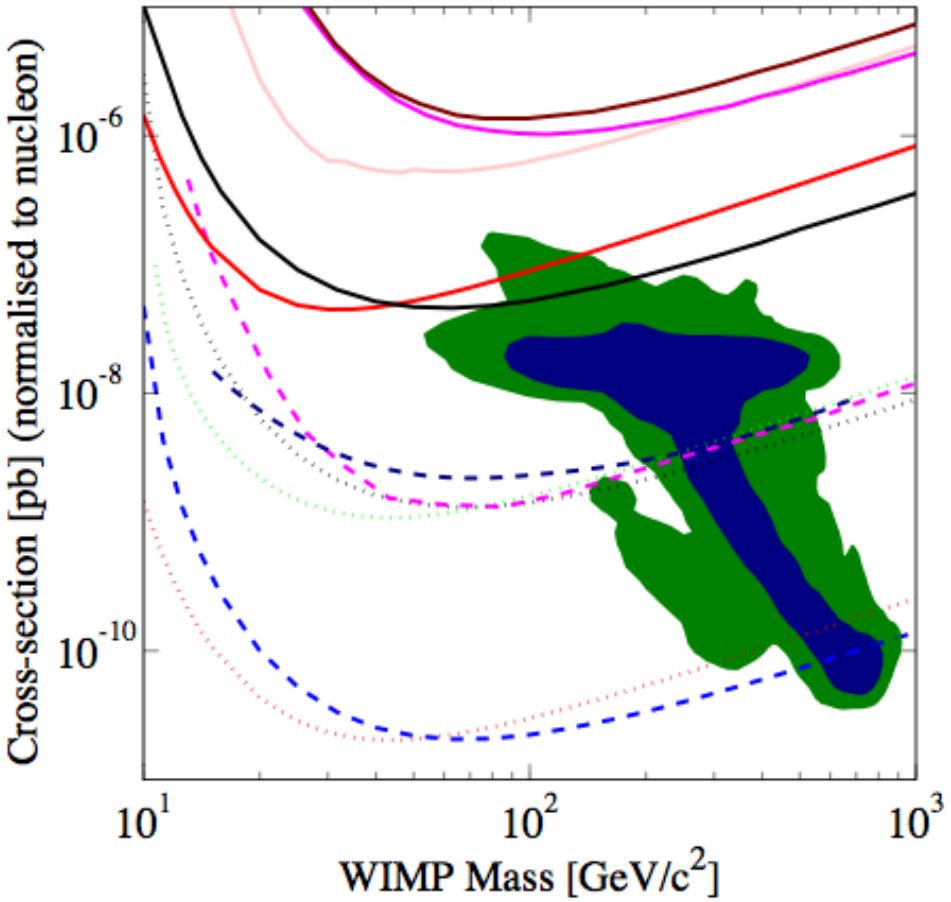
CRESST II,
ROSEBUD,
EURECA

High efficiency particle identification requires compound information and/or large self-shielding mass

Originally by T. Sumner

European or european participation projects only

Dark Matter Searches



EDELWEISS, CRESST, WARP
2003

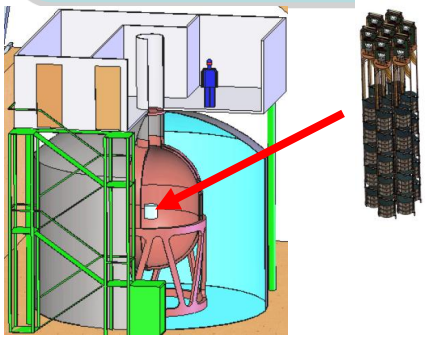
CDMS/XENON10
2007-2008

XENON100/WARP140EDELWEISSII/CDMS
2010-2011

1 ton Bolometer/Noble Liquide
2015-2016?

1 order of magnitude every 5 years ?

Neutrino mass searches

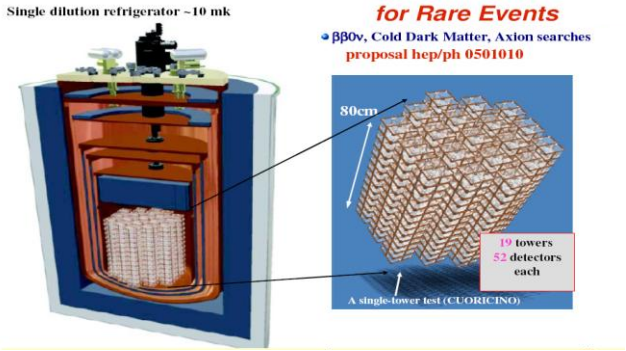


$0\nu\beta\beta$ decay: in operation CUORICINO, NEMO3

GERDA

Ge diodes in liquid nitrogen
Implemented in phases

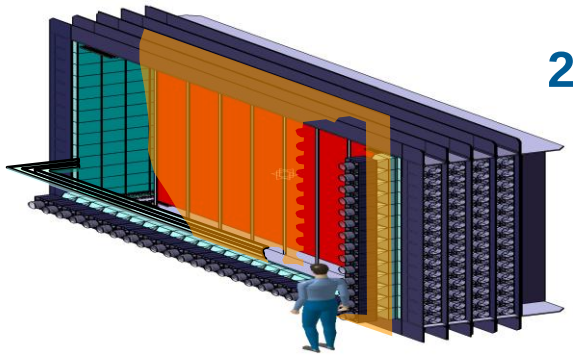
KATRIN β decay
Sensitivity 200 meV



CUORE

Bolometer of TeO_2
(^{130}Te 203 kg)
Operation 2011

SuperNEMO

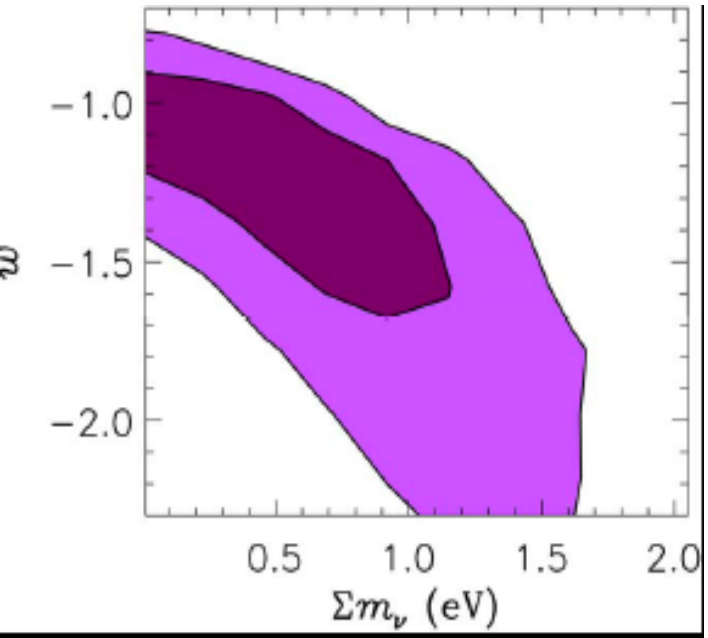


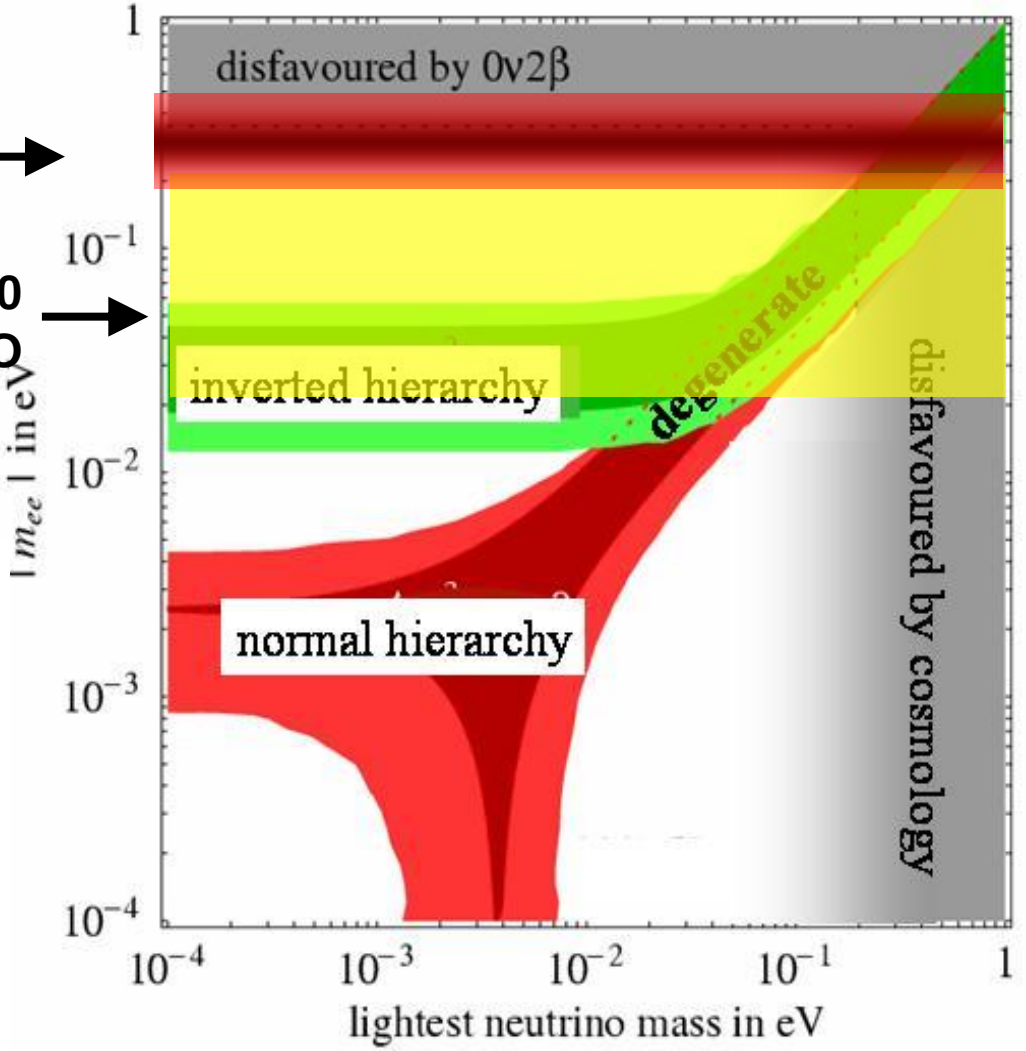
20 modules of a tracko-calo, 100 kg of ^{82}Se or ^{150}Nd
First modules in 2011

Neutrino mass searches

KKGH claim →

GERDA, EXO200
CUORE, SuperNEMO →

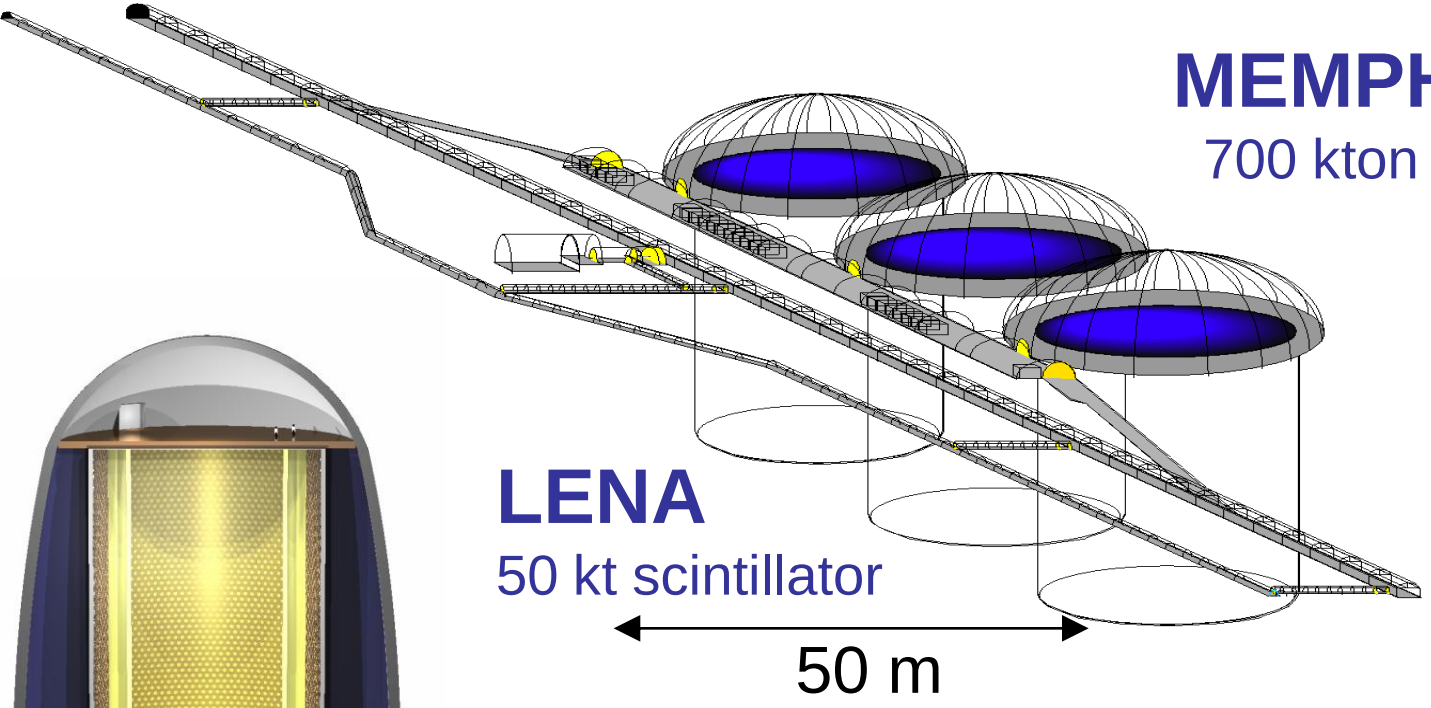




IPMU

Proton decay and neutrino (astro)physics

LAGUNA



MEMPHYS

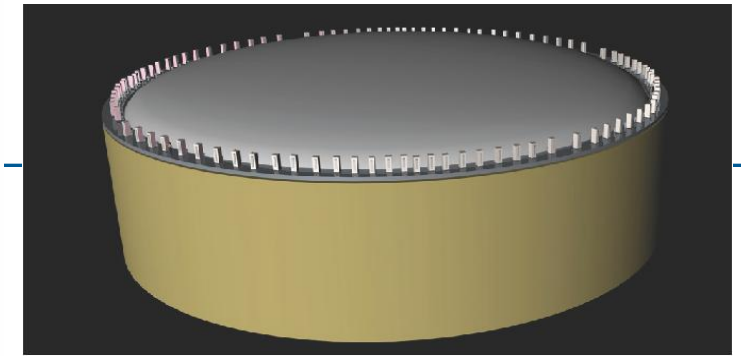
700 kton water

LENA

50 kt scintillator

50 m

European Consortium
Funded by EU
- **Study sites,**
- **Common issues**
- **Complementarity**



GLACIER

100 kton liquid argon

Complementarity of the aproaches

Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (400 kt)
proton decay, sensitivity (years) decay mode $e^+\pi^0$ decay mode anti-ν K^+	$0.5 \cdot 10^{35}$ $1.1 \cdot 10^{35}$	TBD $0.4 \cdot 10^{35}$	$1.0 \cdot 10^{35}$ $0.2 \cdot 10^{35}$
SN at 10 kpc, # events CC NC ES	$2.5 \cdot 10^4$ (ν_e) $3.0 \cdot 10^4$ $1.0 \cdot 10^3$ (e)	$9.0 \cdot 10^3$ (anti-ν_e) $3.0 \cdot 10^3$ $5.0 \cdot 10^3$ (p) $6.0 \cdot 10^2$ (p)	$2.0 \cdot 10^5$ (anti-ν_e) $1.0 \cdot 10^3$ (e)
Diffuse SN # Signal/Background events (after 5 years)	60/30	(10-115)/4	(40-110)/50 (with Gadolinium)
Solar neutrinos # events, 1 year	^{8}B ES : $4.5 \cdot 10^4$ Abs: $1.6 \cdot 10^5$	^{7}Be: $2.0 \cdot 10^6$ pep: $7.7 \cdot 10^4$ CNO: $7.6 \cdot 10^4$ ^{8}B(CC): $3.6 \cdot 10^2$ ^{8}B(NC): $5 \cdot 10^3$	^{8}B ES: $1.1 \cdot 10^5$
Atmospheric ν # events, 1 year	$1.1 \cdot 10^4$	TBD	$4.0 \cdot 10^4$
Geo-neutrinos # events, 1 year	Below threshold	$1.5 \cdot 10^3$	Below threshold

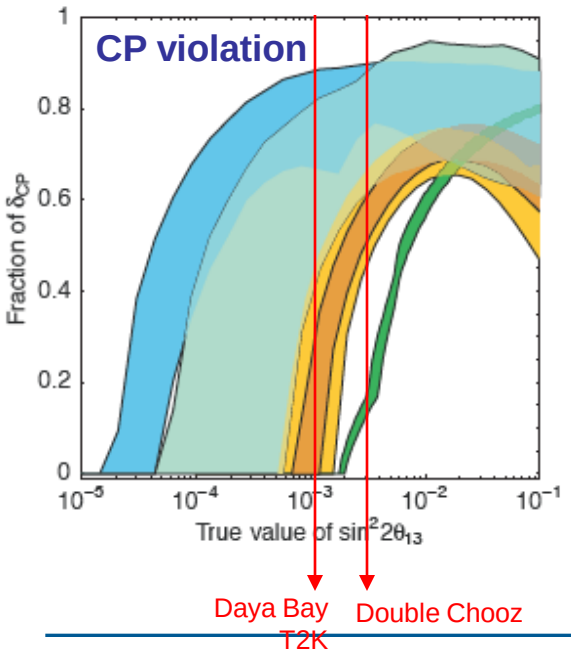
On bets in physics

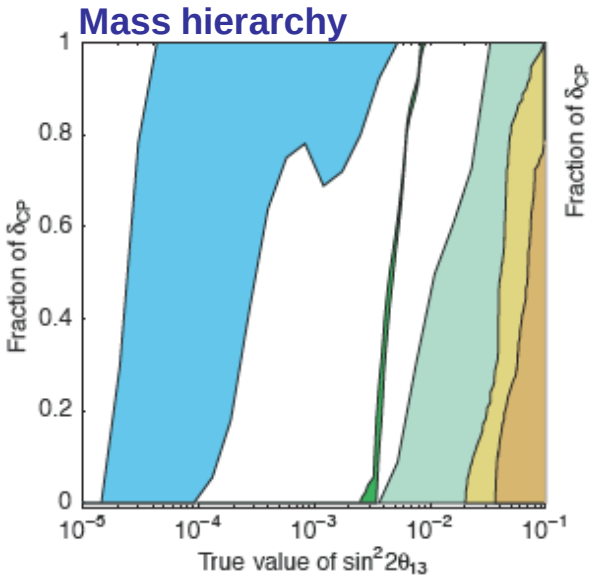
- Lev Okun in June 1988
  - **To predict the year of explosion of a supernova is not harder than to predict the year of fundingis fundinga big accelerator or a big detector. I expect that the date of the next supernova is 2003 ±±15 years**
- Lev Okun again on SLAC bet book (date unknown)
  - **I bet supersymmetry will be discivered before SSC enters in operation**
  - **Did he win? NO since Sid Drell wrote down the counterbet**

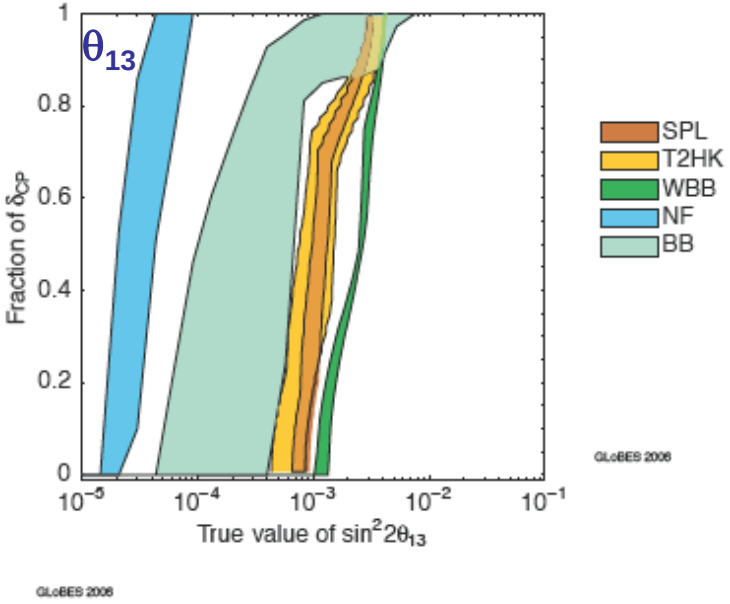
I bet supersymmetry will be FORGOTTEN before SSC enters into operation

Neutrino beam related physics

- Comparison of facilities from ISS:
  - If $\sin^2 2\theta_{13} > 10^{-2}$ super-beam and beta-beam facility compatible with neutrino factory to explore CP violation but accuracy might be issue
  - If $\sin^2 2\theta_{13} < 10^{-2}$, a neutrino factory with two detectors at ~7500 km and ~4000 km gives optimal CP violation coverage





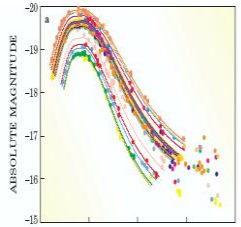


Water Cherenkov/ Liquid Argon results,
also Scintillator emerging concept (see J. Learned)

Dark Energy Methods

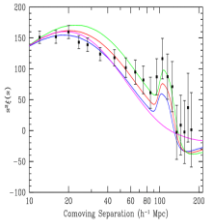
SNe **Standard candle**

Luminosity distance



Baryon Acoustic Oscillations **Standard ruler**

Angular diameter distance



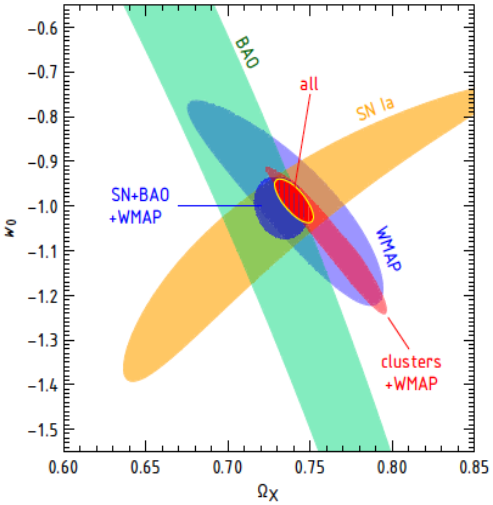
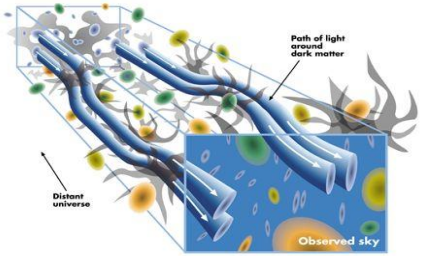


FIG. 10.— Dark energy constraints in flat universe from combination of all cosmological datasets. We find $w_0 = -0.991 \pm 0.045$ (± 0.04 systematic) and $\Omega_X = 0.740 \pm 0.012$, see Table 2 and § 8.3.

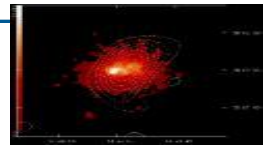
Cosmic Shear

Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure



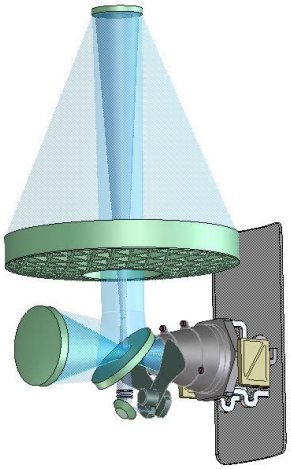
Cluster counts

Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure

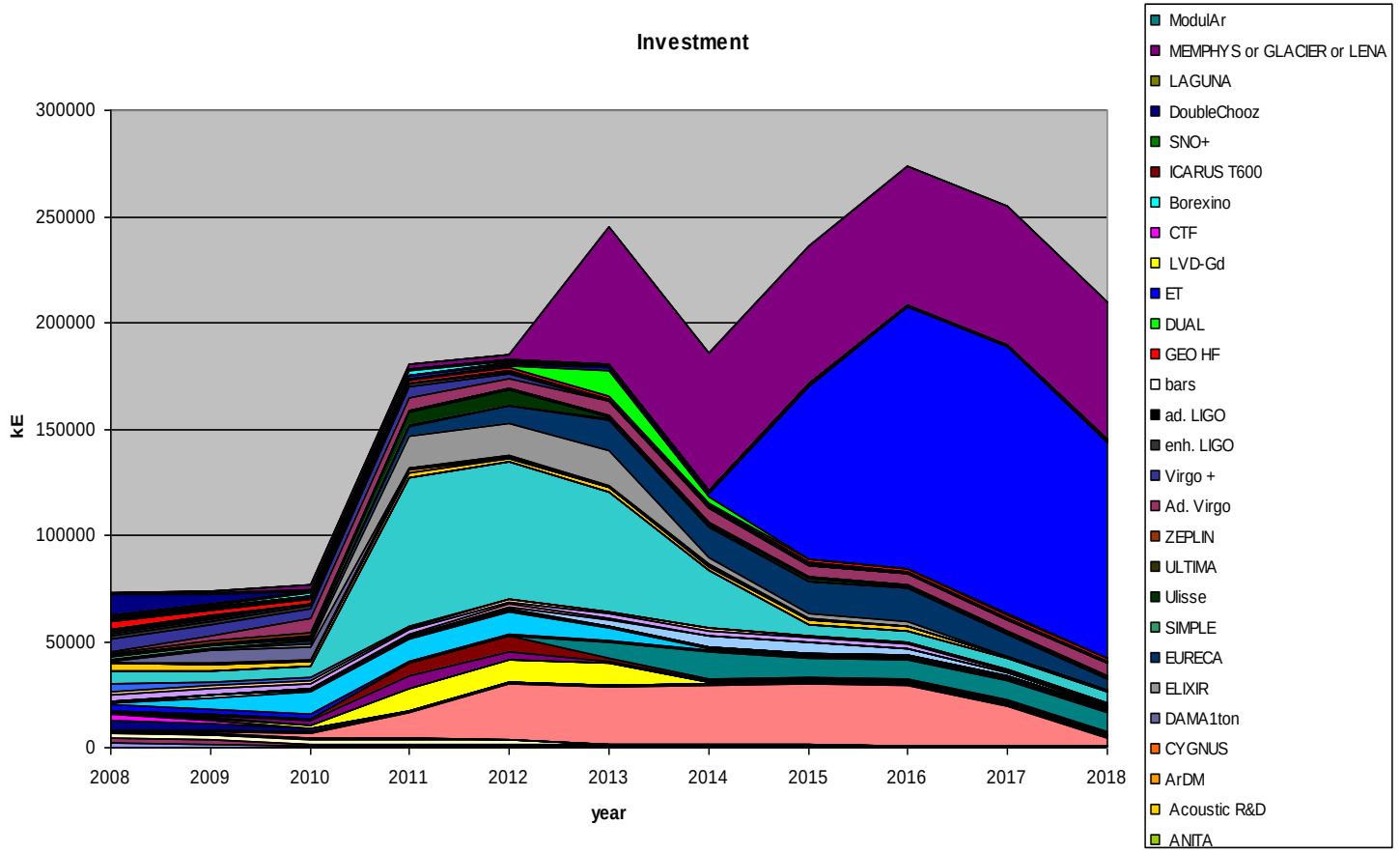


Dark Energy

- Not prioritised in the roadmap since DE depends also on other non-ApPEC agencies: (astrophysics, space) but important contributions of the astroparticle physics community to existing SNae program (SCP, SNFS, SNLS)
- The APPEC/ASPERA roadmap supports participation to existing and future US programs:
  - On ground: DES, LSST
  - Support for a common US-EU dark energy mission (If sufficiently large and sufficiently complete with all 3 methods)

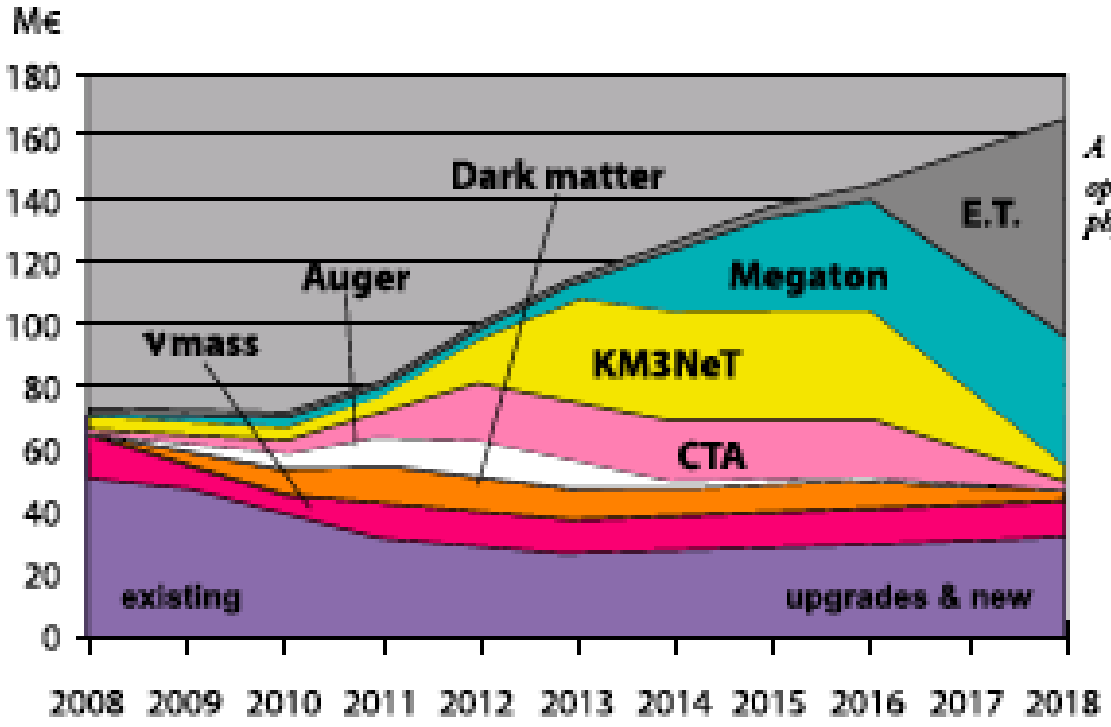


Projected budget before priorities



Close to 2 BEuros

Projected budget after priorities



A scenario for investment and operation cost of astroparticle physics in the ASPERA countries.

The full program demands a 50% increase in the next 10 years (integrated)

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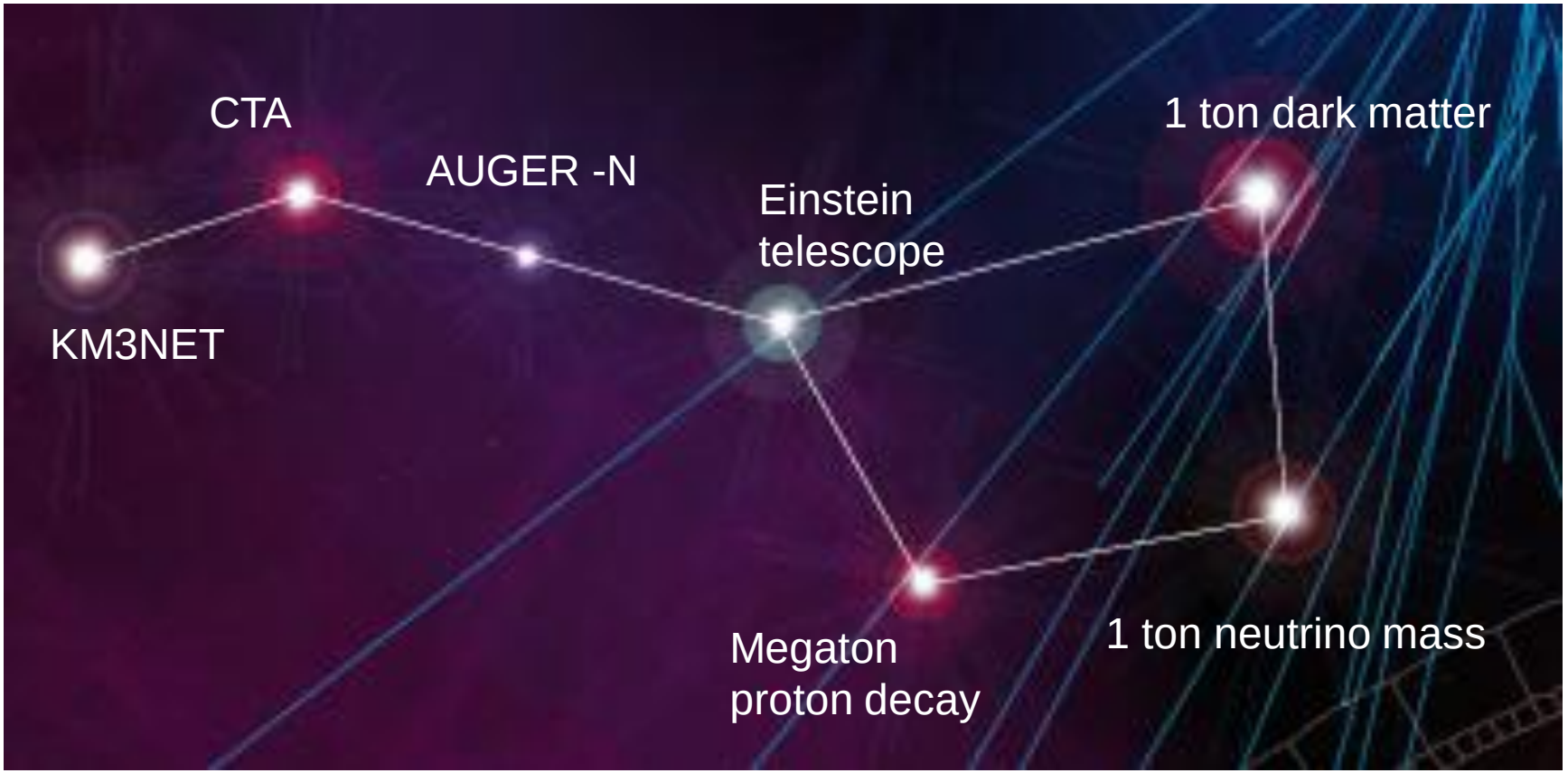
Projected calendar

- **CTA and KM3**
  - High priority also in Astrophysics Roadmap
  - Both in European project ESFRI roadmap
  - KM3 advanced Design Study and Preparatory Phase work in progress
  - Both could start construction by 2012
- **Auger North**
  - Start of construction depends on US evaluation processes
- **Dark matter and neutrino mass**
  - Continue with a few techniques at the 10-100 Kg scale
  - By 2011-2012 decide on the technology(ies) of the ton scale detector(e)
- **Megaton scale for proton decay**
  - EU Design Study in progress (essentially cavern feasibility and costing)
  - Decisions in 3-4 years for a start by mid-decade
- **Einstein Telescope**
  - Decisions by 2016 and after advVRGO/LIGO detections

NB. Most projects would profit from coordination either of a distributed type (e.g. the VIRGO/LIGO network) or the creation of a global scale single infrastructure (e.g. Auger-South)

Summary: The magnificent 7



TOWARDS A GLOBAL ASTROPARTICLE PROGRAM

World-wide complementarities

- ***Network (type I) or global infrastructure (type II)?***
  - ***Gravitational waves (type I)***
  - ***High energy neutrino (KM3/ICECUBE) Type I***
  - ***High energy CR (AUGER) type II)***
  - ? ***High energy gamma (CTA/AGIS) (Type I or Type II?)***
  - ? ***Dark matter (many efforts , type I)***
  - ? ***Dark Energy (towards type II)***
  - ? ***Neutrino mass (towards type I)***
  - ? ***Proton decay (HK/DUSEL and EU efforts, most probably type II, and in the future type I)***

Conclusions, future actions

- European Astroparticle Physics after a long but fruitful process of coordination has prepared a phased priority roadmap that enjoys large acceptance by the agencies and the community.
- Furthermore the discussion has started in Europe for the drafting of a more sustainable coordinating structure that would manage the realisation of the above program. Its eventual relationships to the existing pan European structures (CERN, ESO) are examined.
- Complementarities and budget demand the generalisation of this process of coordination to other regions. This process that has started in the context of the OECD Global Science Forum (1st meeting in Paris 12-13 February 2009) and could continue in other bodies (e.g. FALC).
  - **OECD GSF phase 1 (2009) perimeter, statistics and census of the field**
  - **OECD GSF phase 2 (2010) priority coordination ?**
    - (in synchronism with US decadal survey)