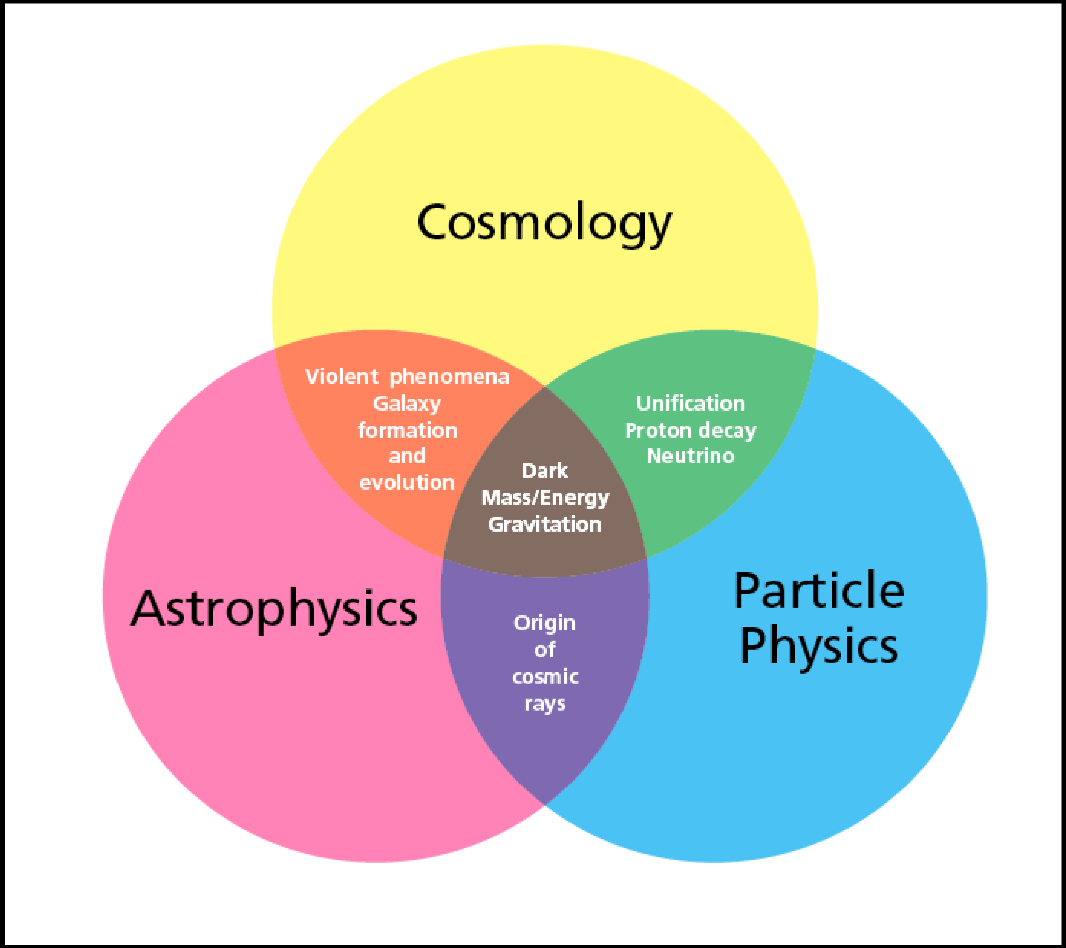
European Strategy for Astroparticle Physics

S. Katsanevas (IN2P3/CNRS)

AMS Workshop 9 March 2010

(from a presentation to the APS 2010)

How does one promote interdisciplinary science?



In Europe ApPEC since 2001 and ASPERA since 2006

What is the Astroparticle European Coordination (ApPEC)?

- **ApPEC is a consortium of 12 European agencies, created in 2001**
- **ApPEC aims to**
  - Promote and facilitate co-operation within the European Particle Astrophysics (PA) community
  - Develop long term strategies
  - 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 in international for a (e.g. OECD)

- ApPEC operates
  - Strategically through its Steering Committee (chairman M. Bourquin)
  - Operationally through its Science Advisory Committee (chairman C. Spiering)
    - ASPERA started as an ApPEC initiative
  - APPEC is in search of a sustainable structure
    - Association, CERN/ESF/ESO strategic board?

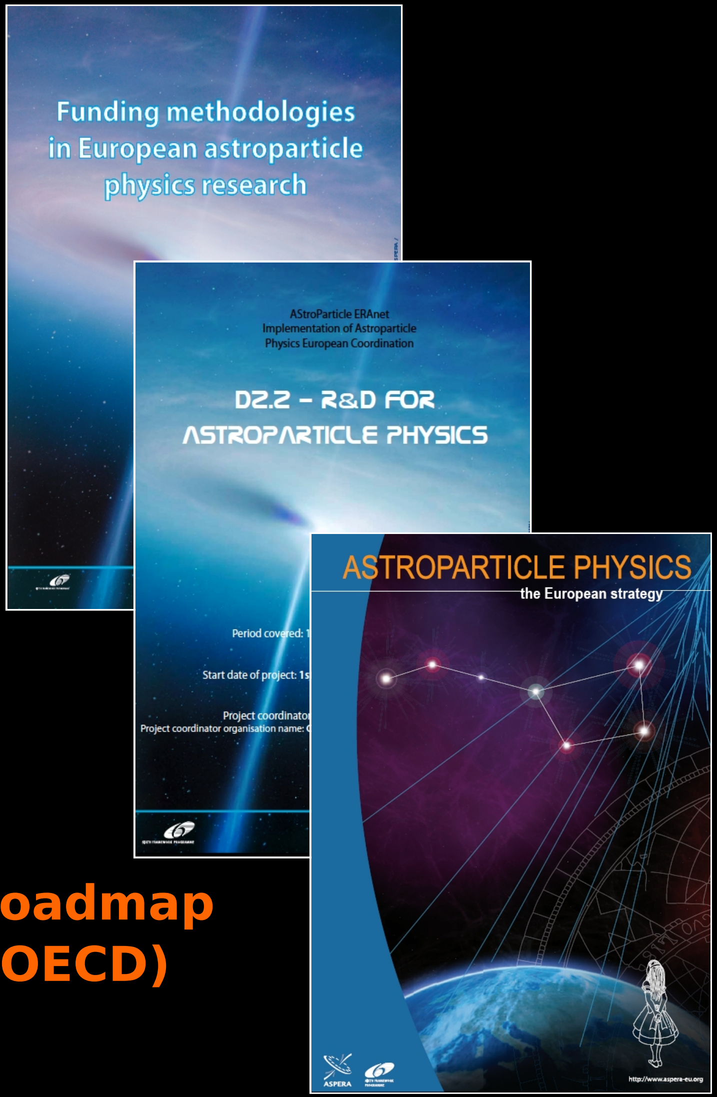
What is ASPERA ?

“per aspera ad astra”

www.aspera-eu.org

16 countries + CERN

- **ASPERA-I EU program FP6 (2006-2009)**
  - coordinator S. Katsanevas (CNRS)
  - Study APP personnel and funding in Europe
    - 2500 researchers and 70 M€/year
    - Organized 14 national days
  - Priority Roadmap for Infrastructures
    - and R&D
  - Linking of existing infrastructures
    - Underground laboratories
  - **Issue a common call for R&D/Design studies**
    - **CTA and Dark Matter**
  - **Common outreach, databases, portal, …**
- **ASPERA-II EU program FP7 (2009-2012)**
  - Coordinator T. Berghoefer (BMBF)
  - **Accompany the realization of the roadmap**
  - **Coordinate with other continents (OECD)**
  - **Knowledge transfer : industry, neighboring fields**
  - **Include the remaining European**



What is Astroparticle Physics ?

ASPERA

- What is the Universe made of?
  - Nature of dark matter and energy

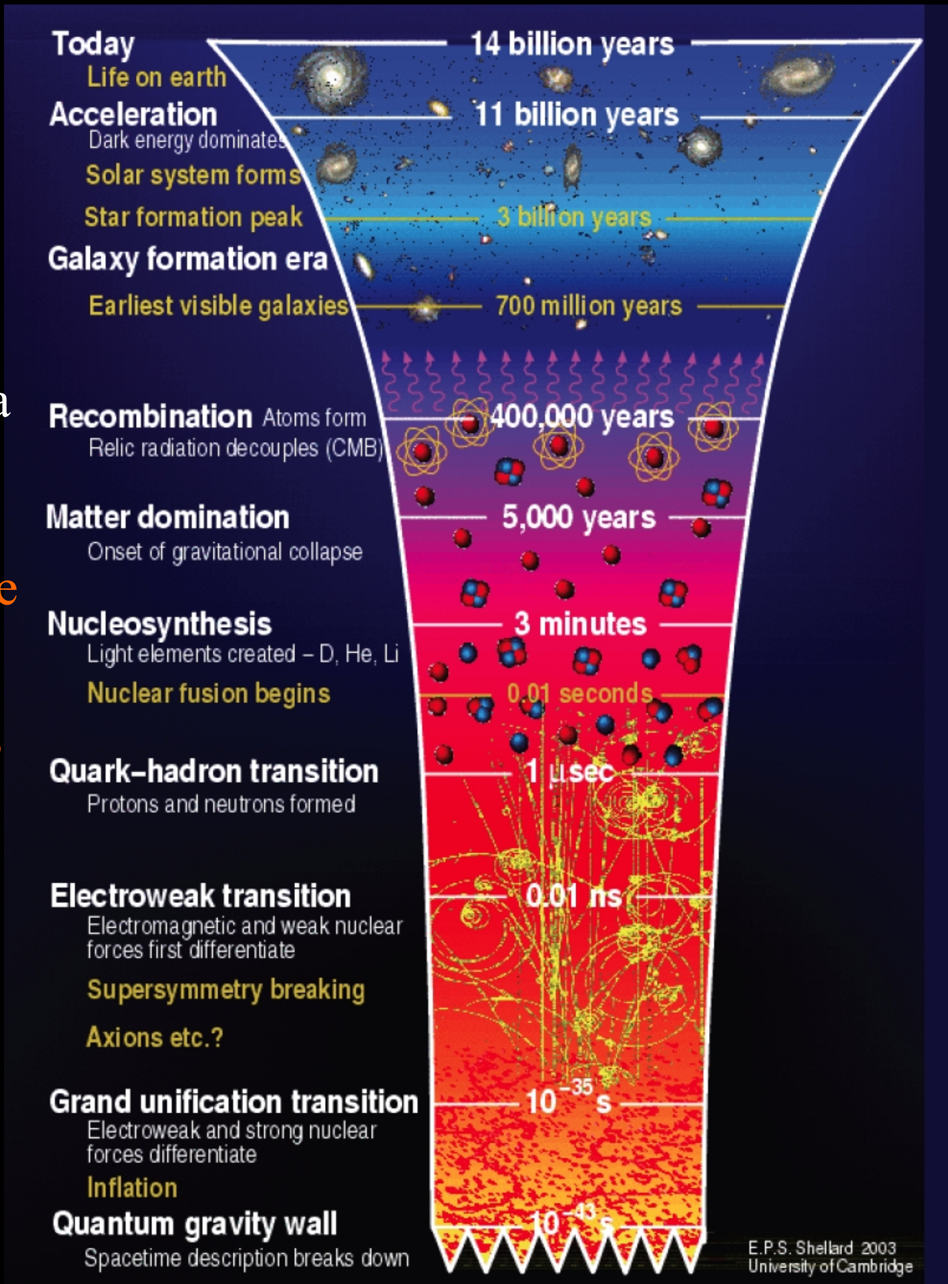
Probe EW scale, Gravitation

- What is the role of high energy phenomena in the formation of cosmic structures?
  - Multi-messenger (γ,CR,ν, GW) studies
  - Do high energy phenomena regulate the formation of cosmic structures?
  - Can we understand galaxy dynamics enough to detect indirectly dark matter?

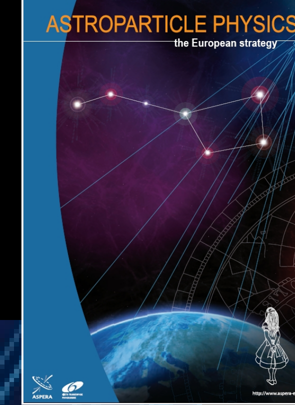
Probe limits of fundamental laws

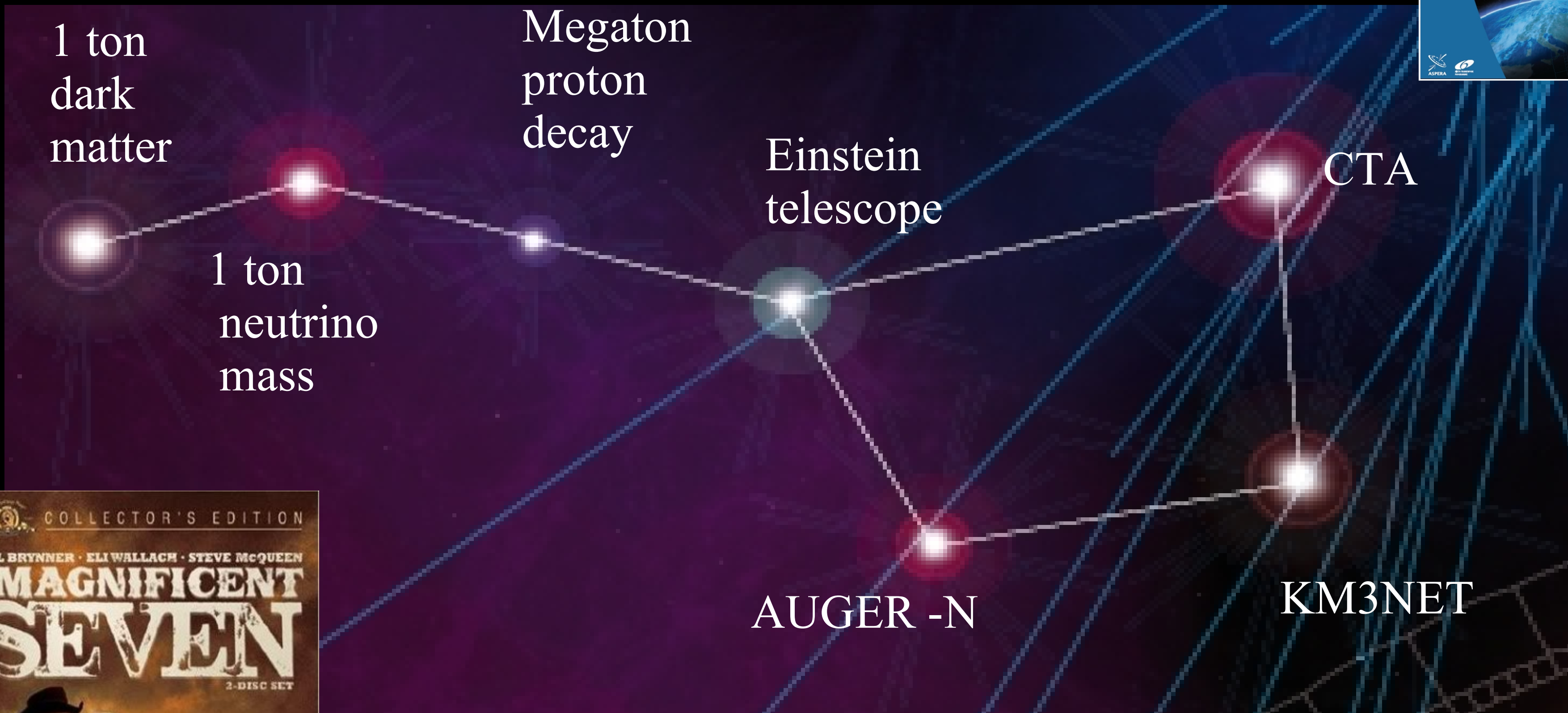
- What is the form of matter and interactions at the smallest scales ?
  - Rare decays (proton lifetime, neutrino mass)

Access GUT scales



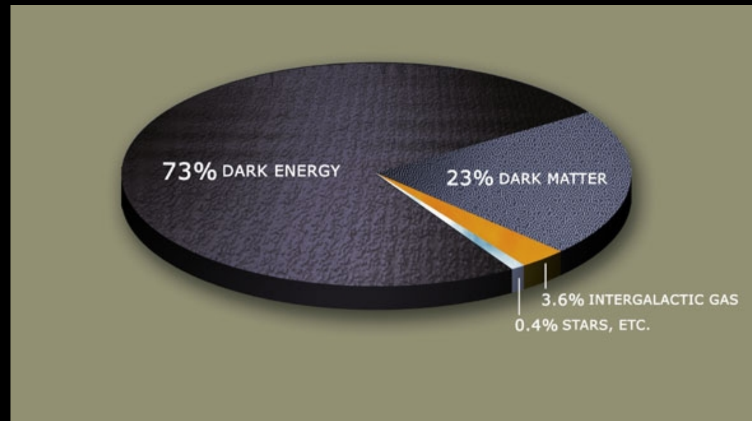
The European Roadmap priorities

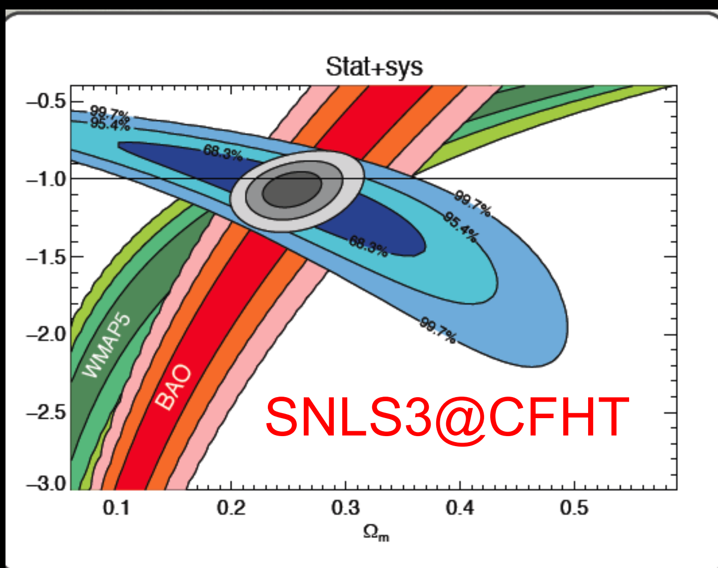




Did not cover in depth dark energy or space programs, since it concentrated in programs where the agencies participating were the major stakeholders. This will change in the update.

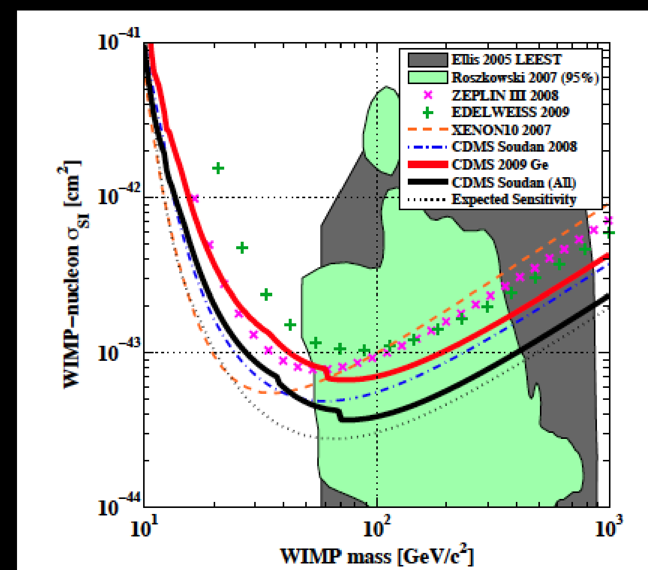
What is the Universe made of? Dark matter and energy





$w = P/\rho$

$$w = -1.06 \pm 0.07\,(\mathrm{stat} + \mathrm{sys})$$



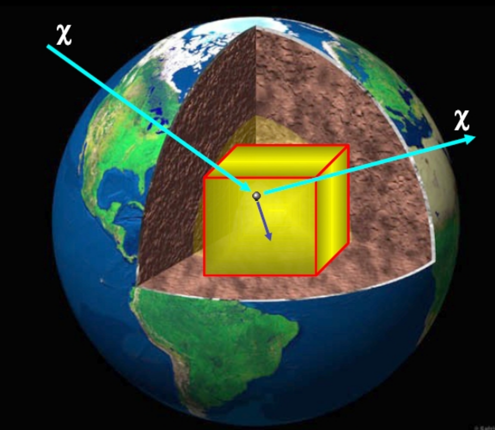
CDMS-II but check also EDELWEISS-II/XENON/…

Also WMAP7 (2010) PLANCK1 (2010-11)

Direct Dark Matter searches (with strong european component)

ASPERA

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

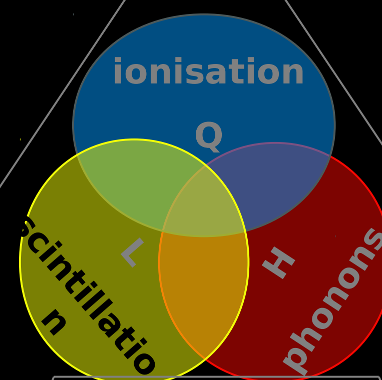


phonons, photons and charge whose relative proportions and /or characteristics depend on dE/dx particle type

PICASSO
SIMPLE

XENON, ArDM, WARP

EDELWEISS



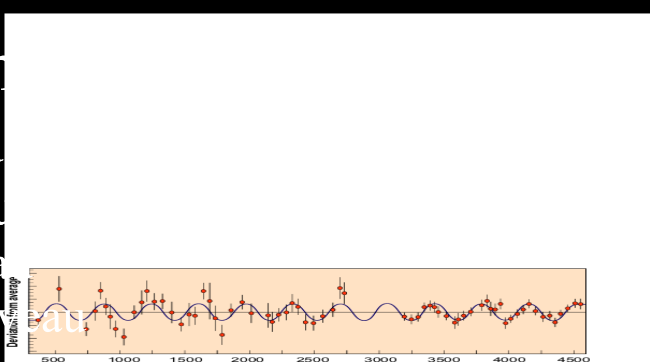
High efficiency particle identification requires compound information and/or large self-shielding mass

DAMA/LIBRA, ZEPLIN I
ANAIS

CRESST
ROSEBUD

Originally by T. Sumner

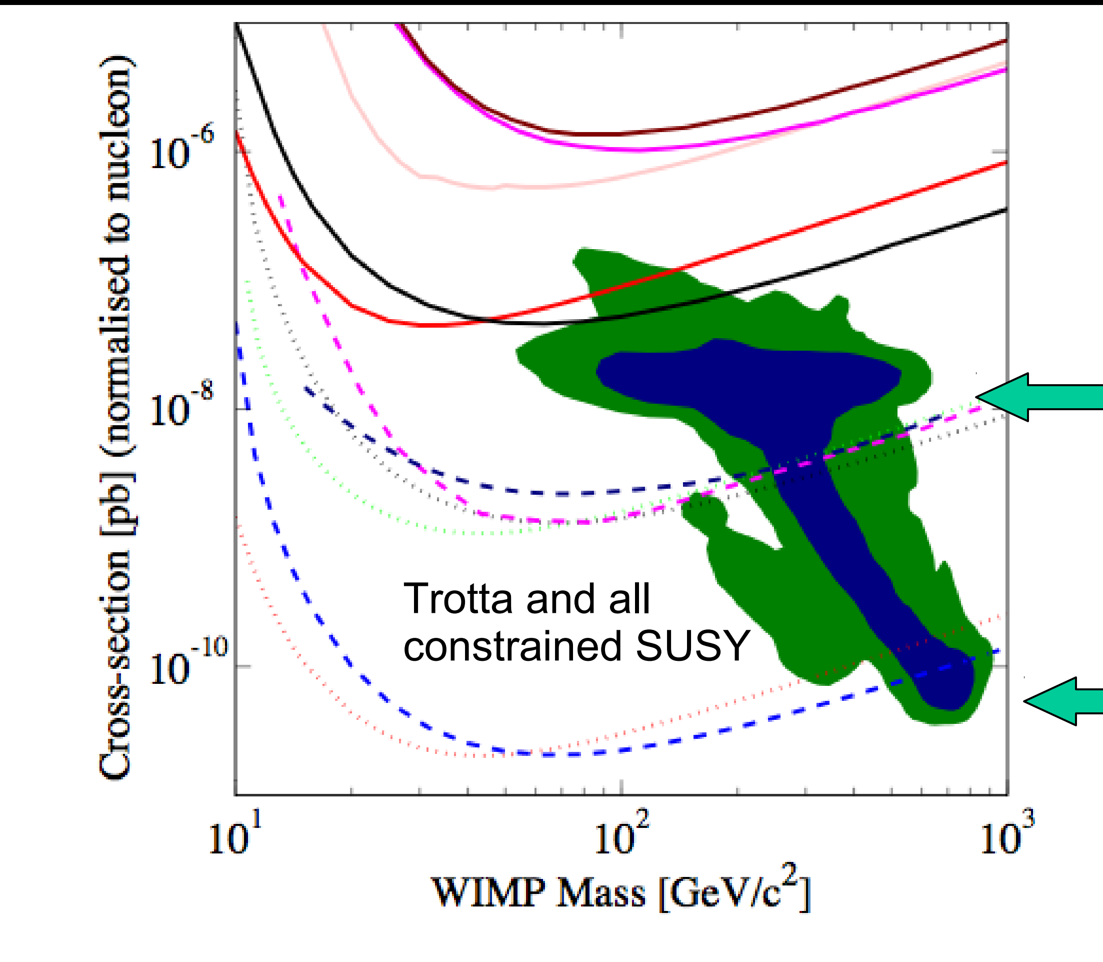
DAMA annual modulation



exte du masque

Towards 2 large consortia

- ***EDELWEISS, CRESST =>EURECA***
- ***XENON, ArDM => DARWIN***
- ***Design studies financed by ASPERA***



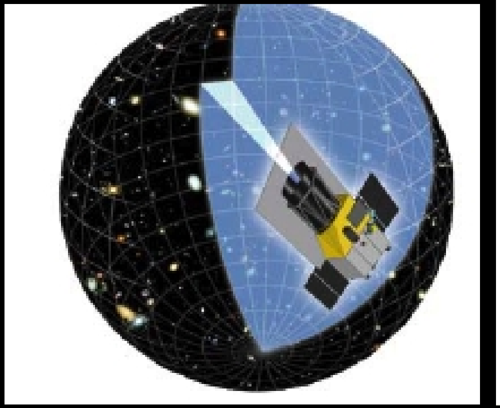
Present
1 event/ 100 kgdays

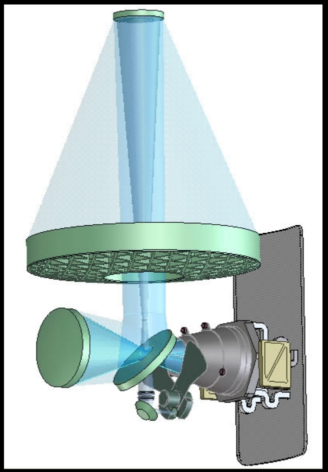
Next 3 years (2010-2012)
1 event/103-4 kgdays
XENON100/WARP140/
EDELWEISS-II/CDMS-II

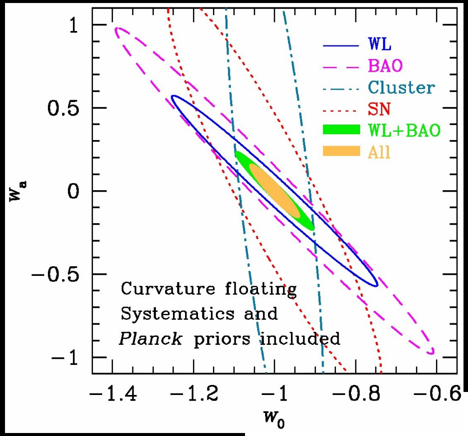
2013-2015
1 ton detector material
1-10 events/tonyear

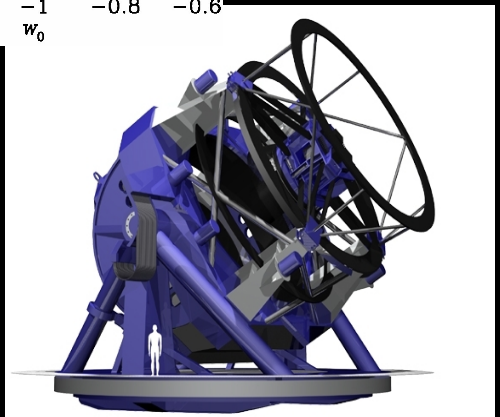
Dark Energy

- Not prioritised in depth in the roadmap since Dark Energy depends also on other non-ApPEC agencies: (astrophysics, space)
- Nevertheless there are very visible contributions of the European astroparticle physics community to existing SNae program (SNFS, SNLS)
- For ground projects it supports participation to existing or future programs: (DES, BOSS, Subaru,..) but the emphasis is on LSST
- Space: Support for a common or complementary (EUCLIDE/JDEM) US-EU dark energy mission (all methods)
- The ESA mission EUCLIDE in 2 M missions enters phase A/B1 for a final selection in 2012 (launch 2018-2020).



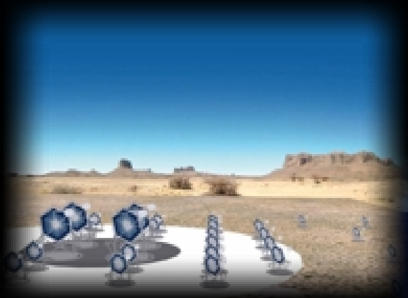


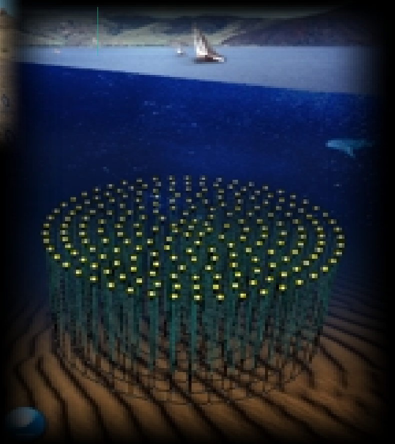




High Energy Universe infrastructures

European context (DS,PP)
(ASPERA,ASTRONET, ESFRI)





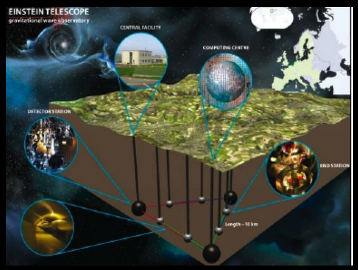
I. **Cherenkov Telescope Array (CTA)**
high energy γ

II. **Neutrino telescope (KM3)**
high energy ν

International context
(PASAG, US Decadal Survey, GWIC)

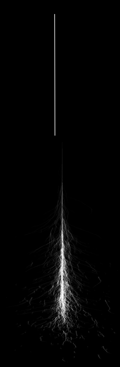
III. **Beyond the Auger South Observatory**
ultra-high energy CR

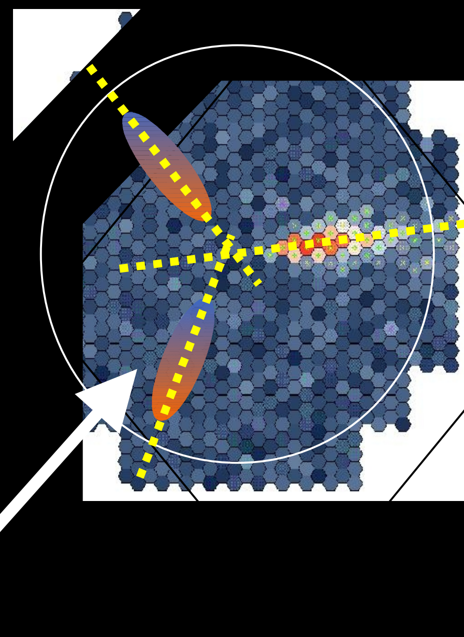
IV. **Einstein Telescope (ET, DS)**
gravitational waves

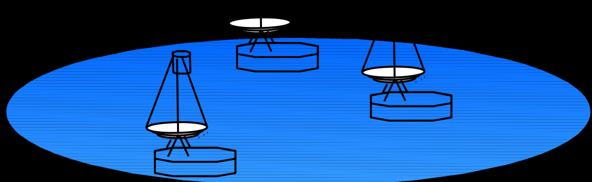


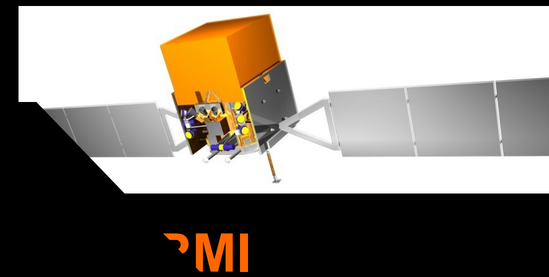
High Energy Gamma Rays

(Existing programs with strong European participation)



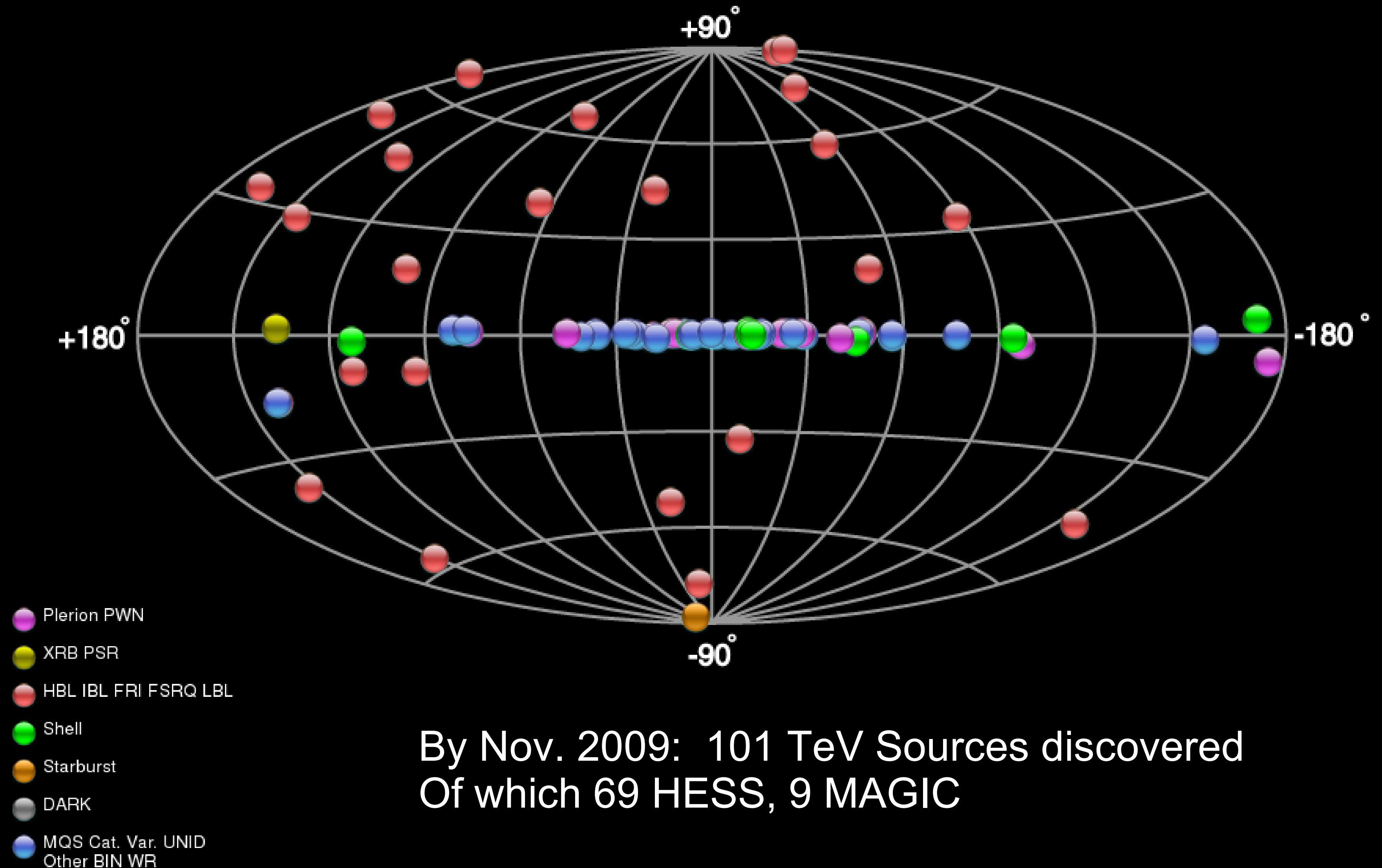






Also, TIBET, ARGO-YBJ , Italy-China

In the last 6 years an order of magnitude more sources discovered in the TeV sky



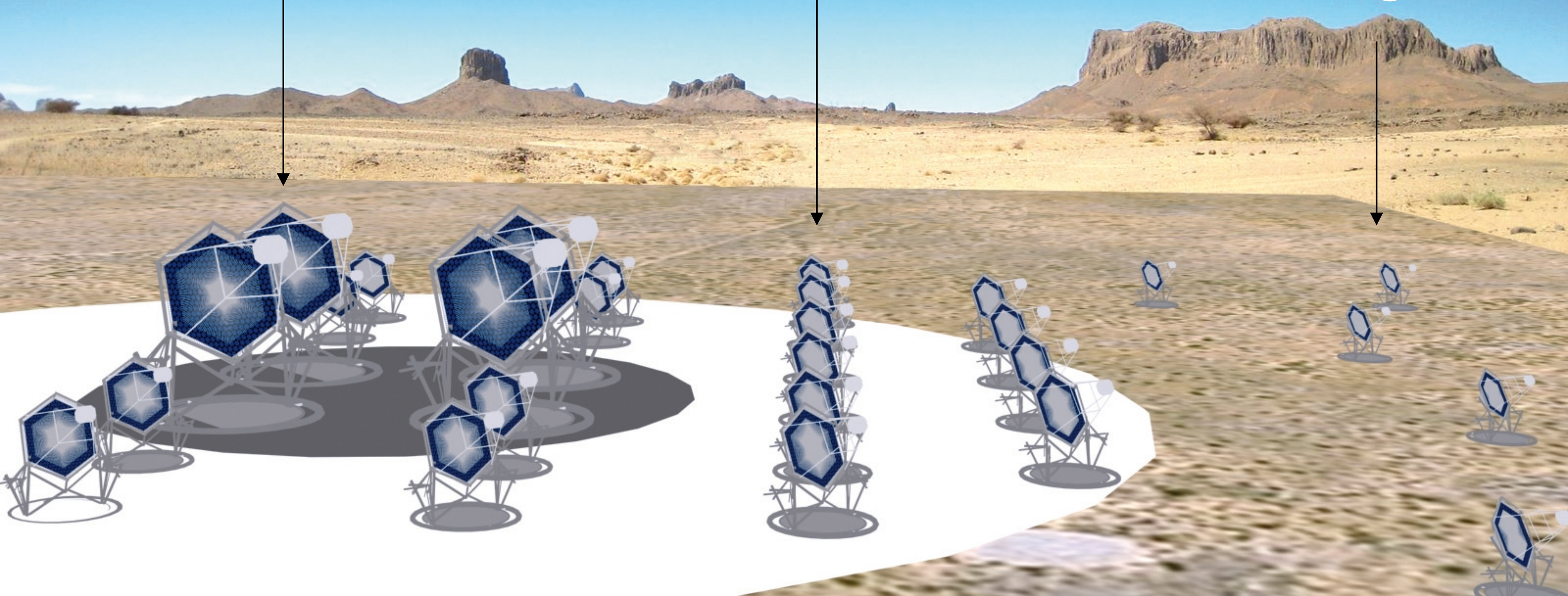
By Nov. 2009: 101 TeV Sources discovered
Of which 69 HESS, 9 MAGIC

The next step :CTA

Low-energy section:
energy threshold
of some 10 GeV

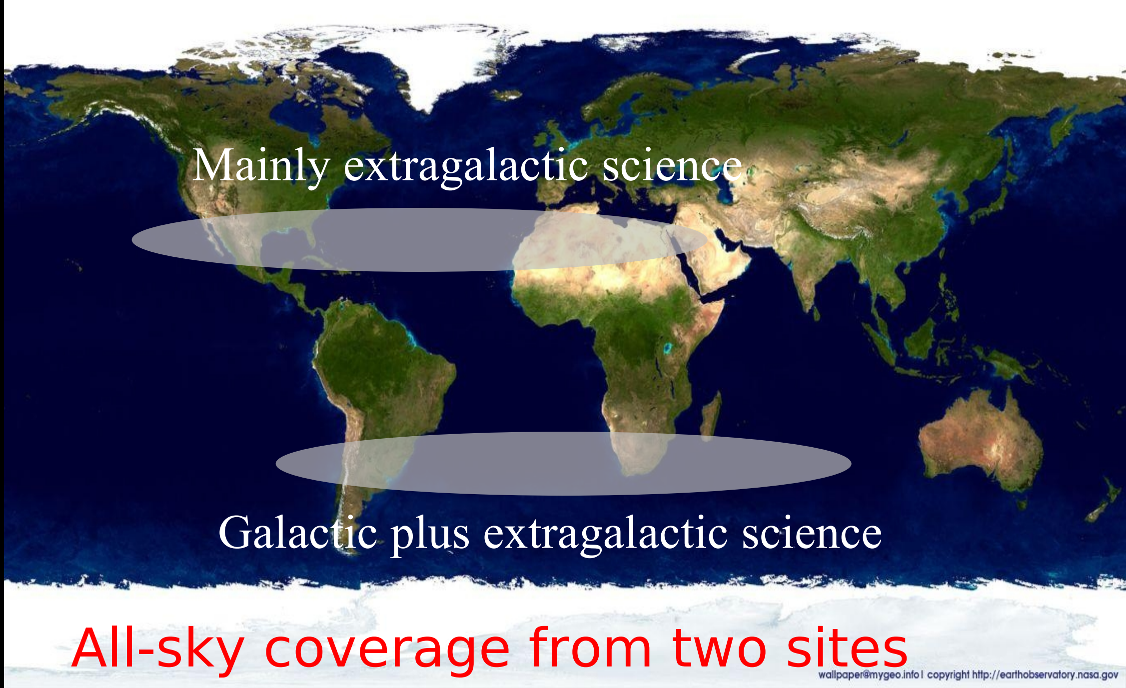
Core array:
mCrab sensitivity
in the 100 GeV–10 TeV
domain

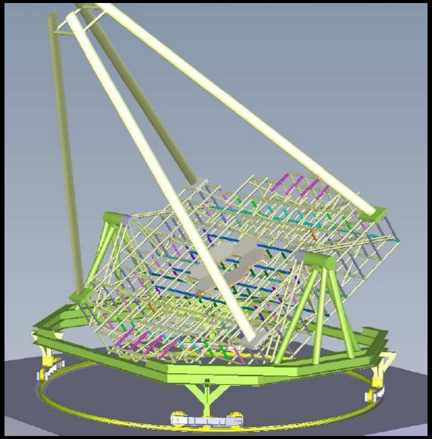
High-energy section
10 km2 area at
multi-TeV energies

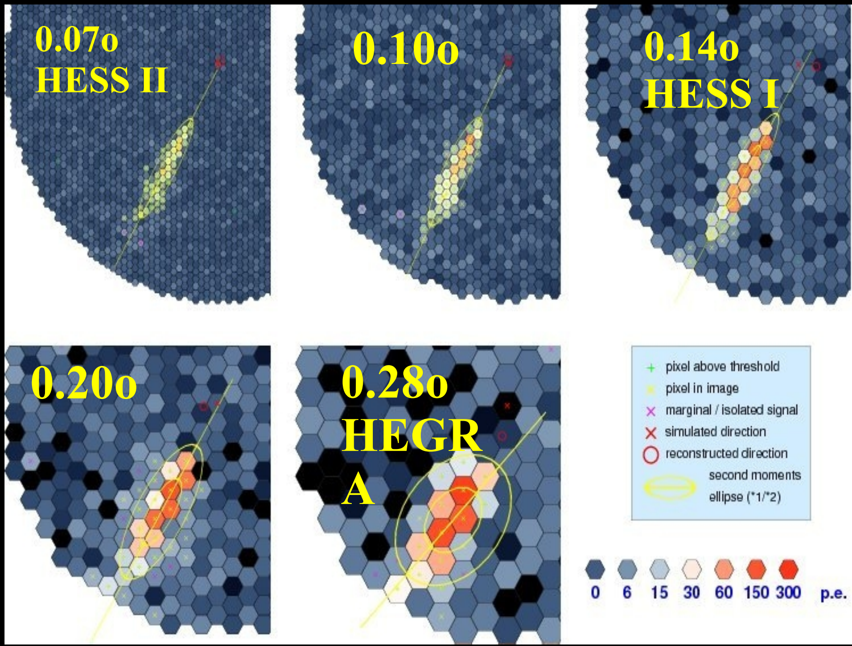


Design Options

- *Sites,*
- *PM et pixel size,*
- *Topologies*
- *Telescope technologies*







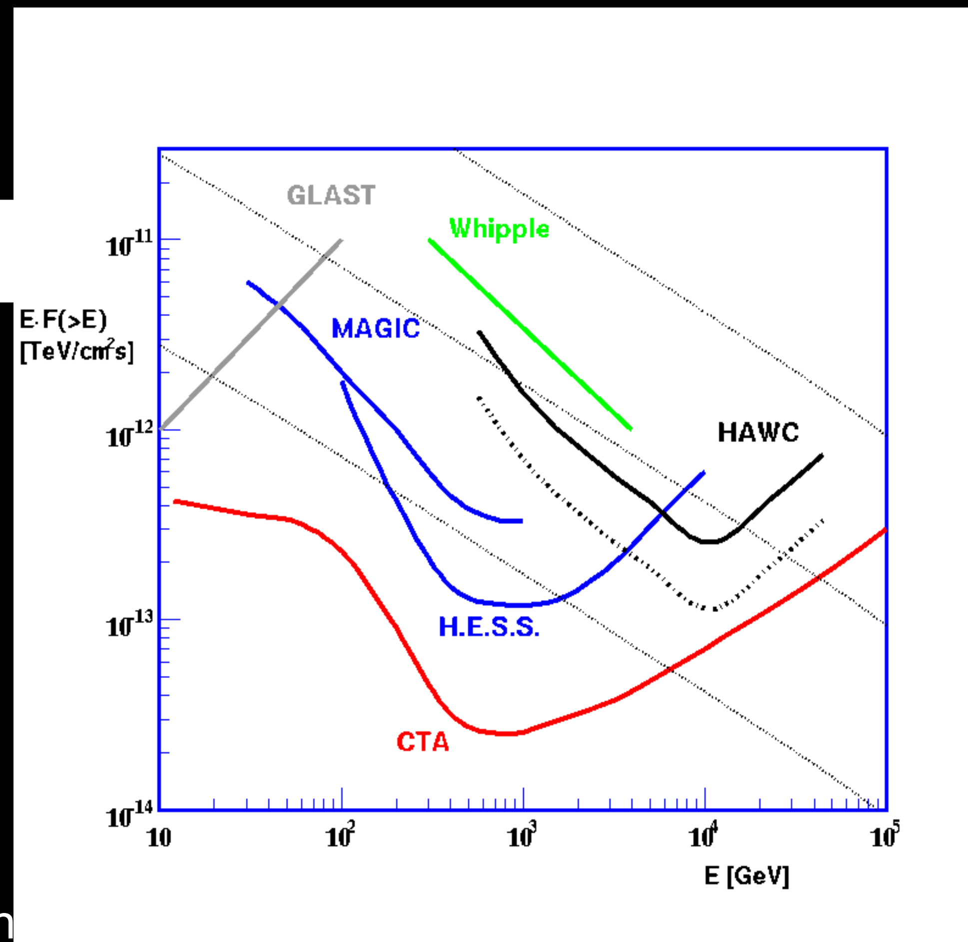
CTA specifications and timeline

- **sensitivity x10**
- **angular resolution x2-3**
- **Field of view 2-3**

- Collaboration: many European countries, plus other continents,
- Merger with AGIS?

- Design study 2009-2012
  - (financed by APPEC/ASPERA)
- Prep Phase 2010-2013
- Start construction 2013
- End construction 2018
- Superior to existing instruments 2015/16

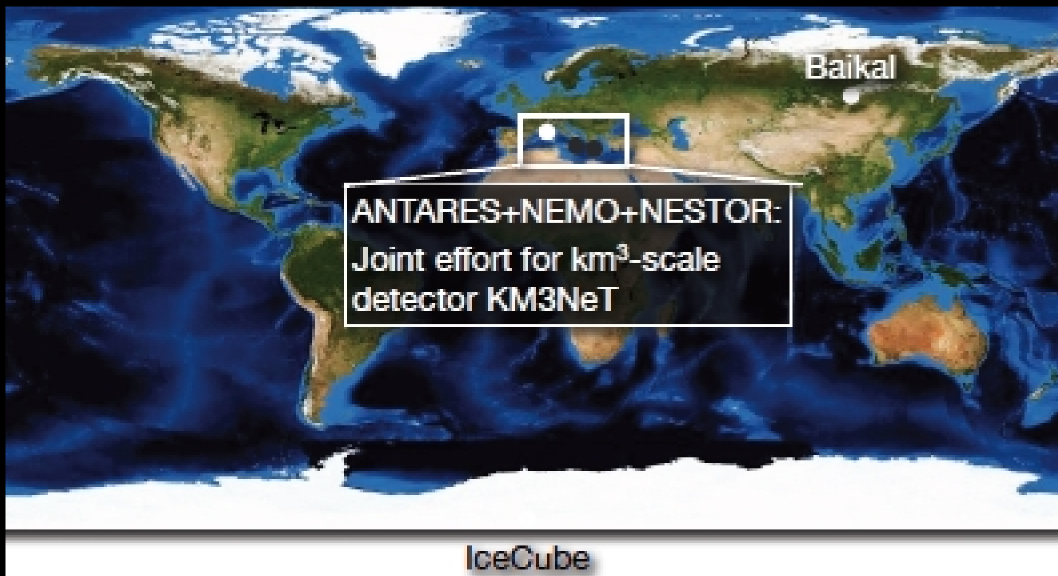
- Cost 150 M€ (2/3 south, 1/3 north

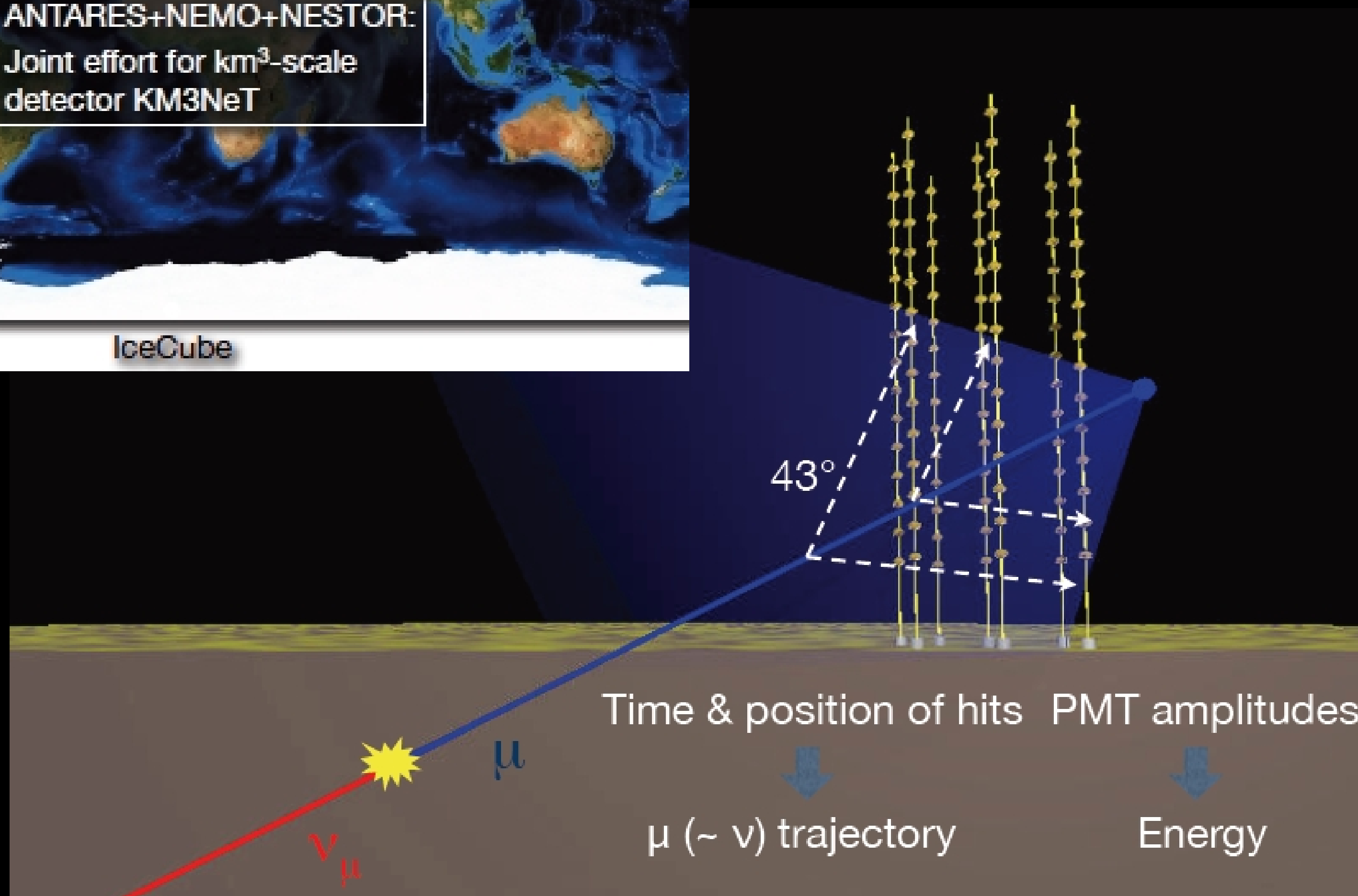



Veritas
Milagro
MAGIC
Argo/YBJ
Tactic
HESS
Cangaroo
now

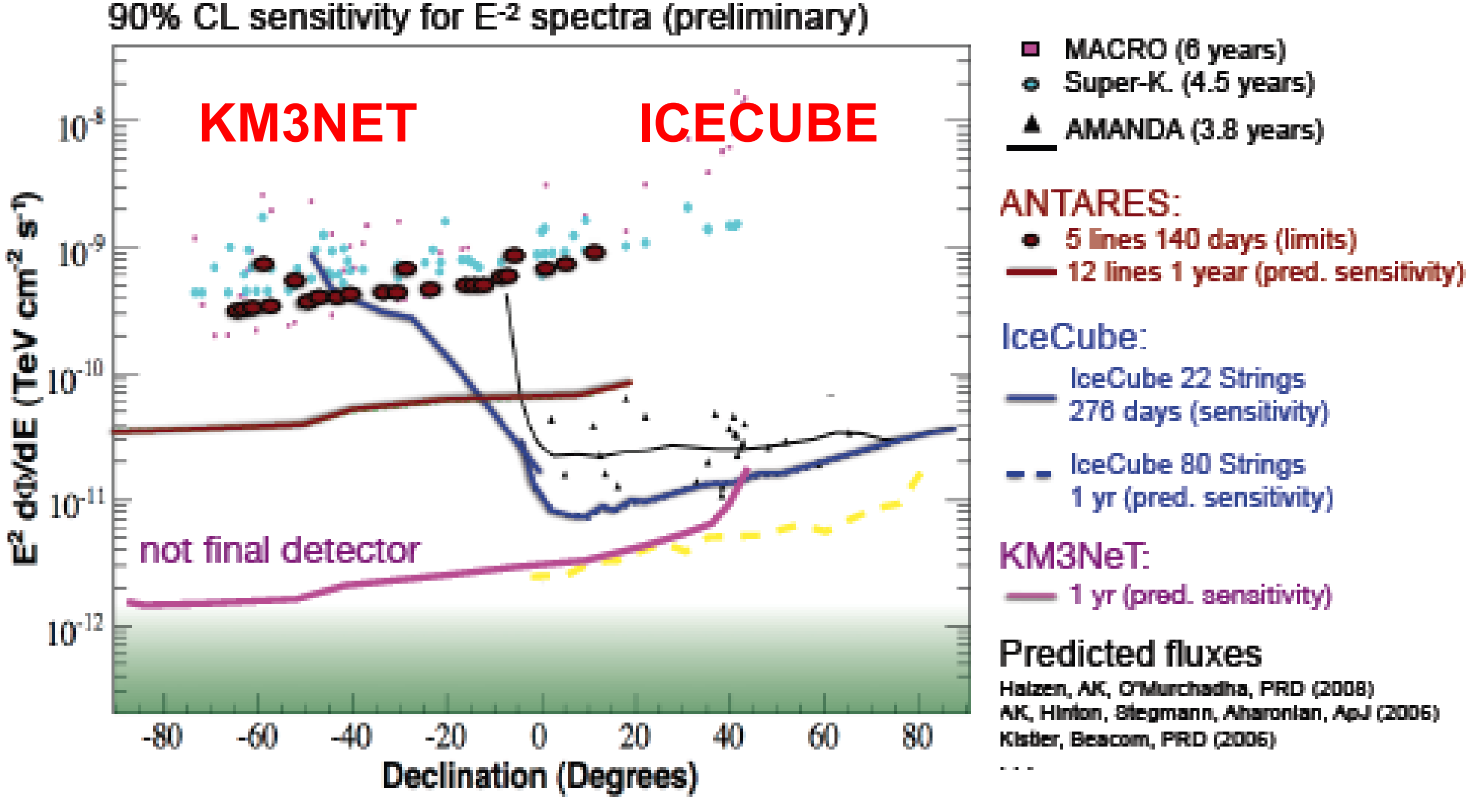
CTAgis North?
CTAgis North?
Yanbajing (High energy)
Mace (Low energy)
HAWC
CTAgis South?
CTAgis South?
in seven years
(world-wide complementarity)

High Energy Neutrinos KM3NeT

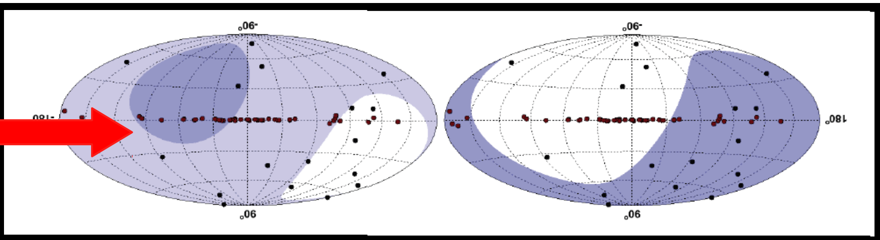




KM3NeT point source sensitivity



Attention the sky map is upside down

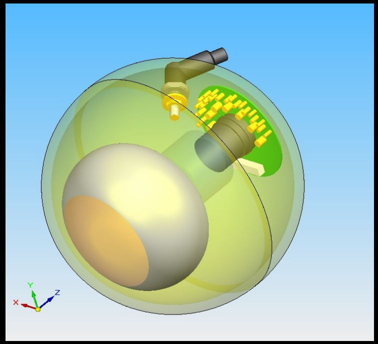


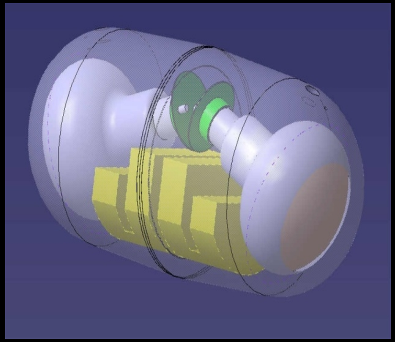
- Points @ Galactic Center
- Better pointing than ICECUBE
- Is a KM3 sufficient?

From A.Kappes HEP09

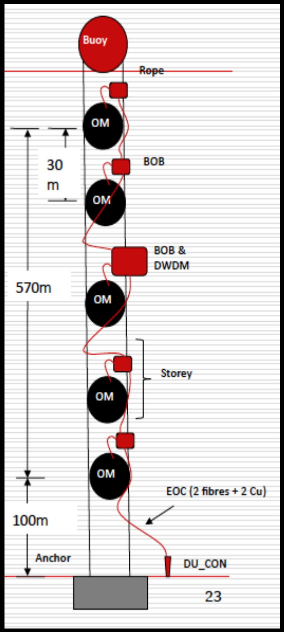
Design options studied in TDR (spring 2010)

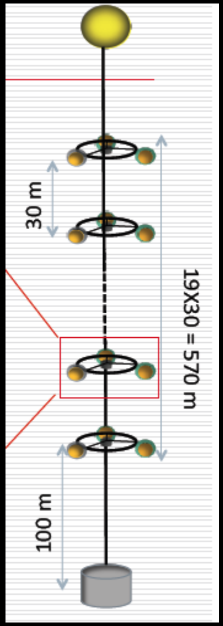
Optical modules





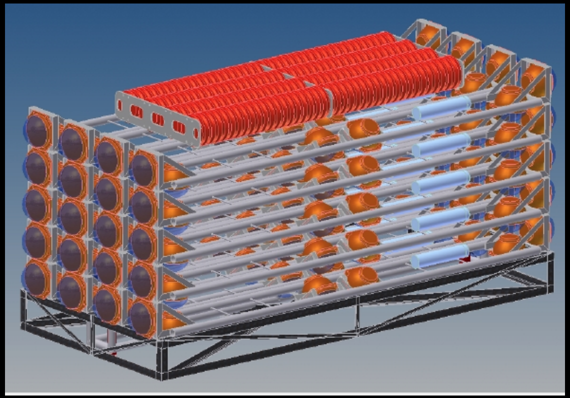
Unit topologies
(strings,bars, triangles)

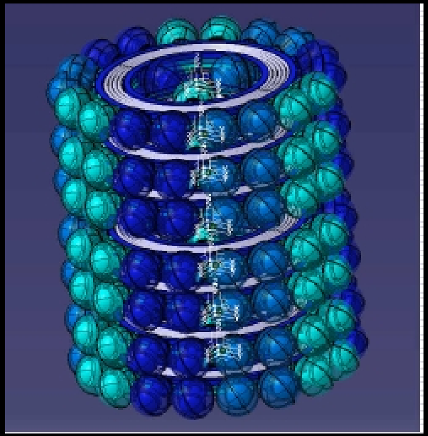


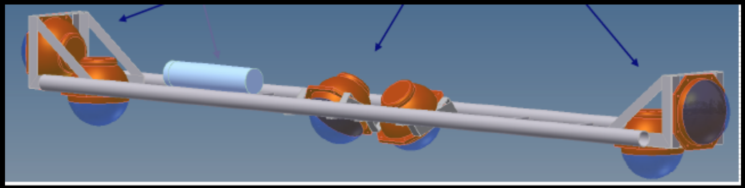


Deployment strategies….

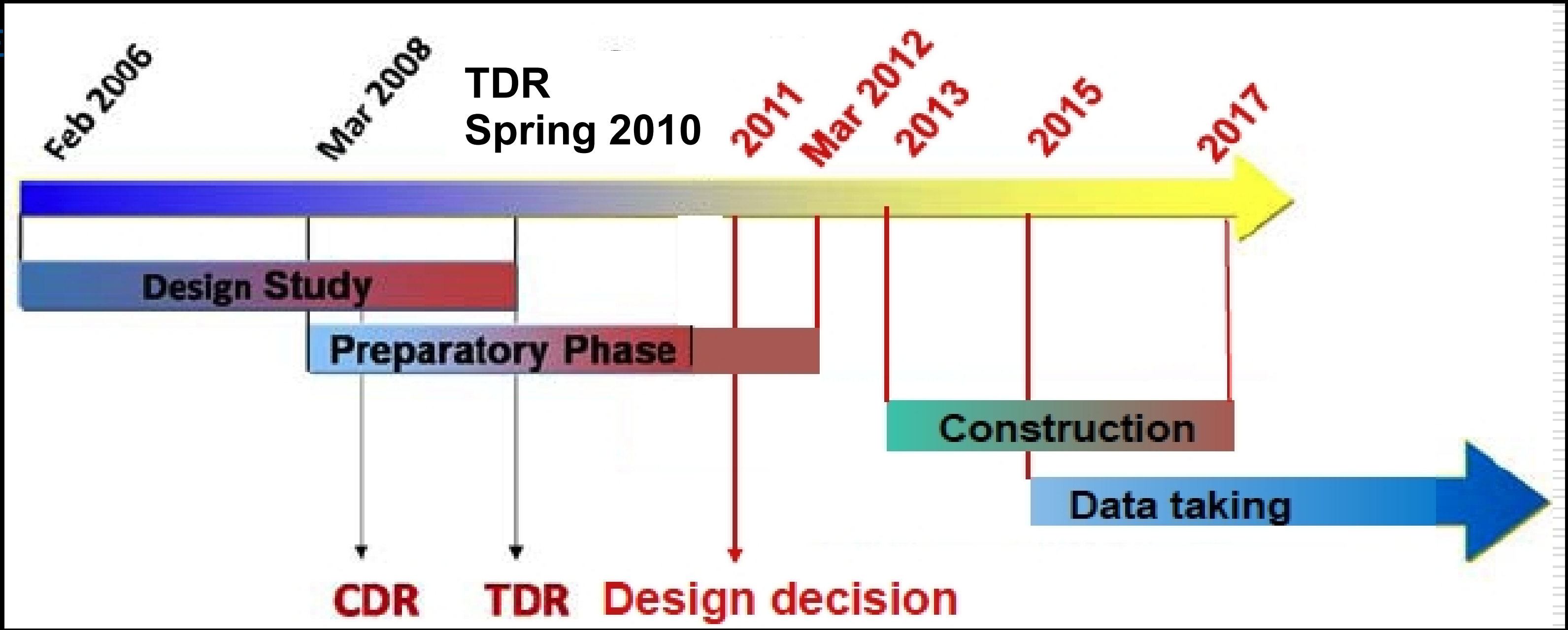
From simulation no clear winner, in situ testing and real costs will tell (2 years)







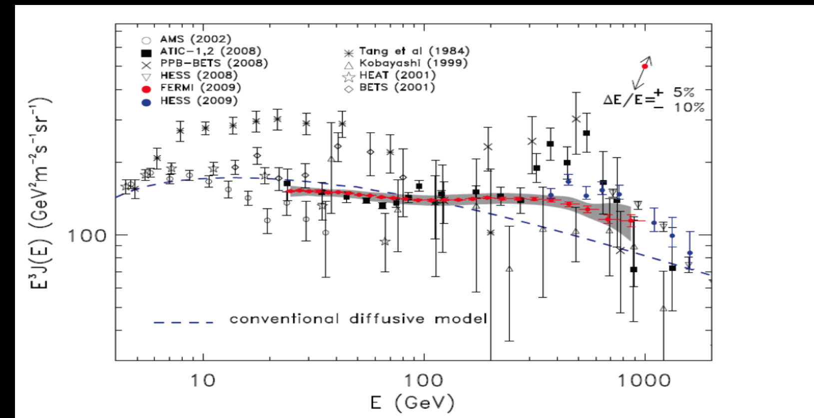
Timeline and cost



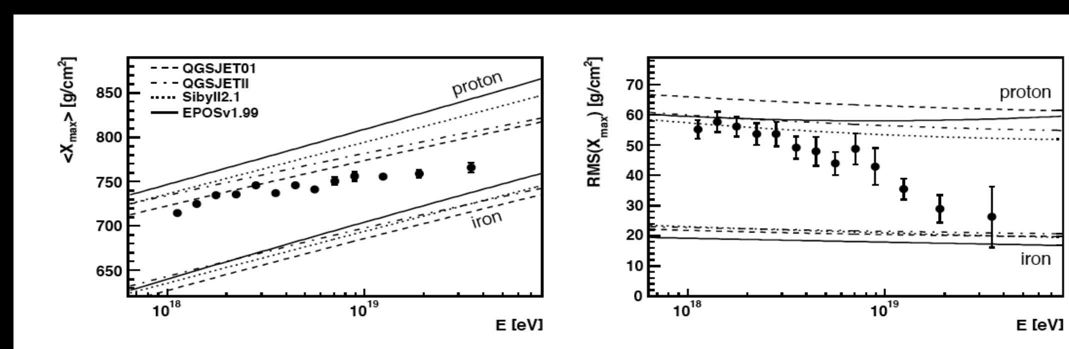
Concept	DU Cost	No. of DUs	Total DU Cost	Seafloor Infrastr.	Deploy-ment	TOTAL COST
Flexible towers	535	127	67 945	8 460	10 962	87 193
Slender strings	254	300	76 200	12 971	13 515	102 686
Triangles	657	127	83 439	8 470	6 867	98 776

Cosmic rays in the last years : a rich harvest but still many uncertainties…

- Lower energies (PAMELA , ATTIC,FERMI, CREAM): Pulsars or dark matter ?
  - è We must understand the galaxy to detect indirectly dark matter (remember the solar problem)
  - è ***AMS***



- Intermediate range (knee, KASCADE, future China, Russia)
  - Do we understand the galactic CR composition?
- UHECR , AUGER findings and ?
  - The GZK cutoff is there
  - No γ/ν (no top-down)
  - UHECR anisotropies, low statistics
  - Protons or Iron?

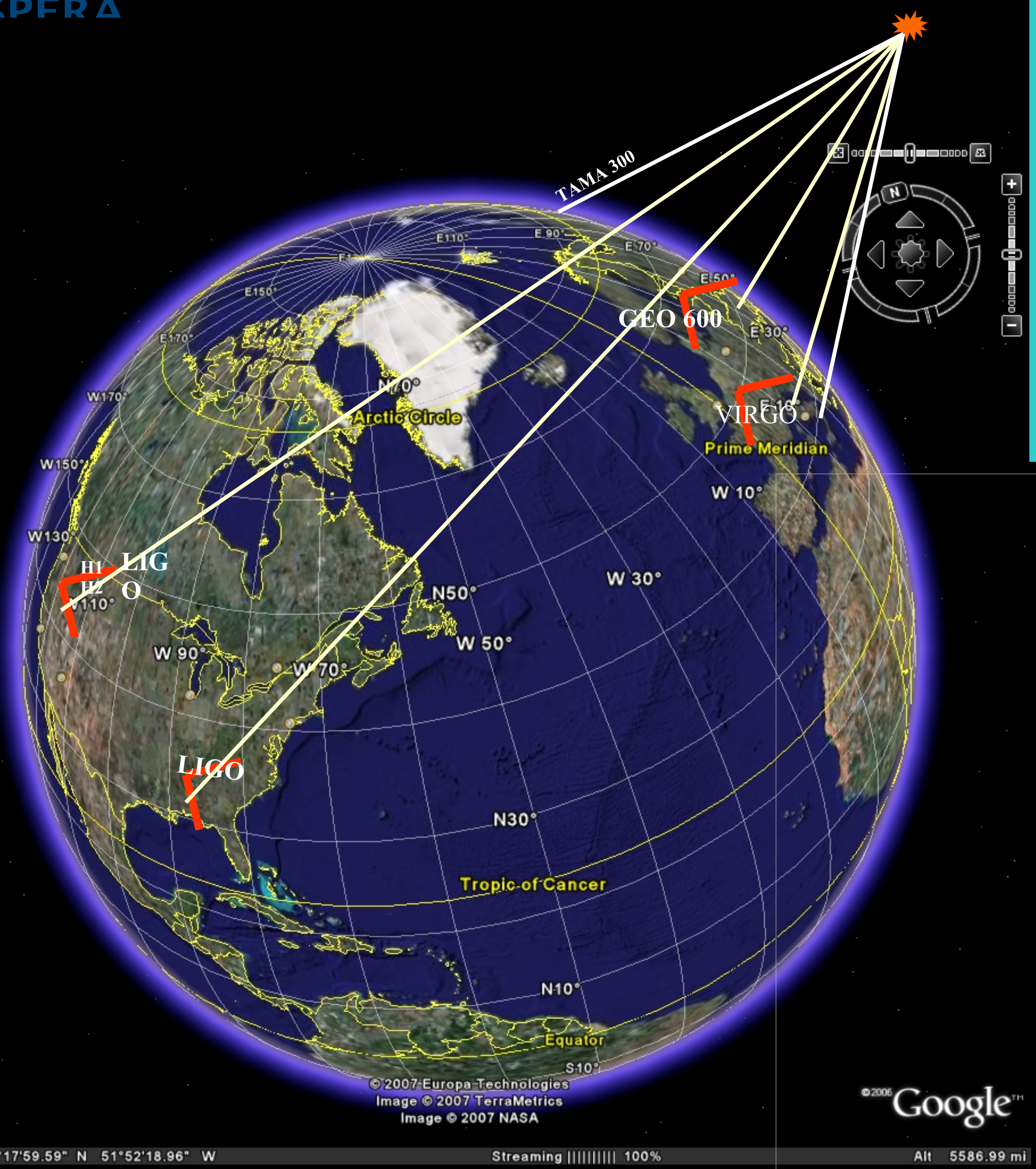


Auger North x7 statistics @ GZK horizon

AUGER is an inspiring example of Astroparticle world-wide collaboration

Also intensive R&D in radiodetection

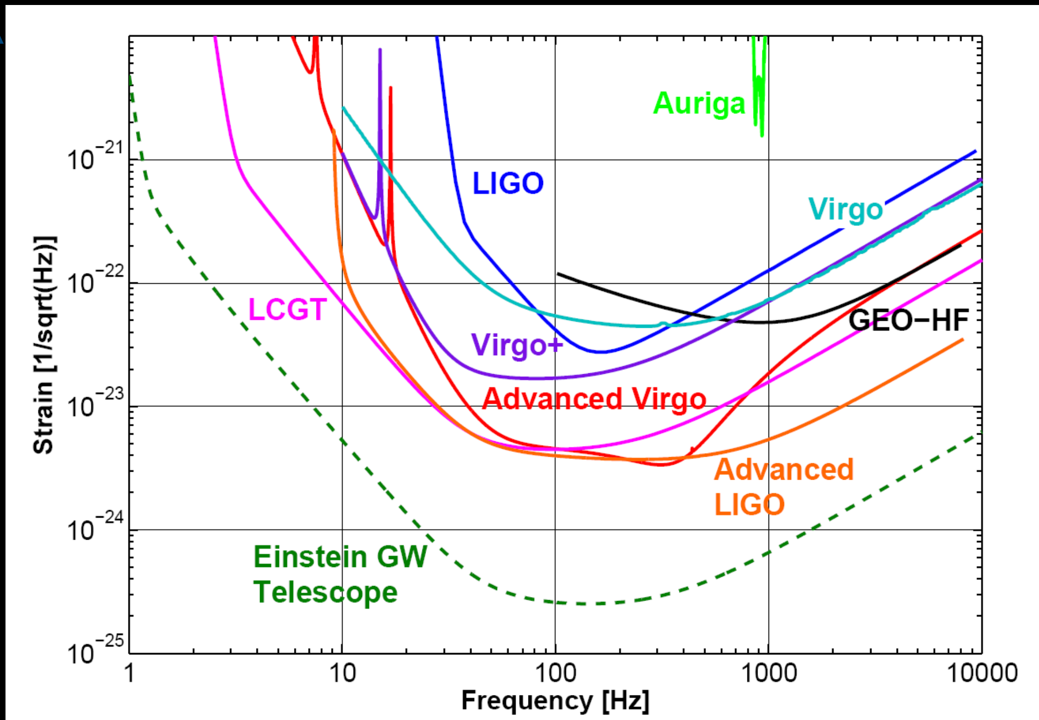
Gravitational waves: AdvLIGO-advVIRGO common runs

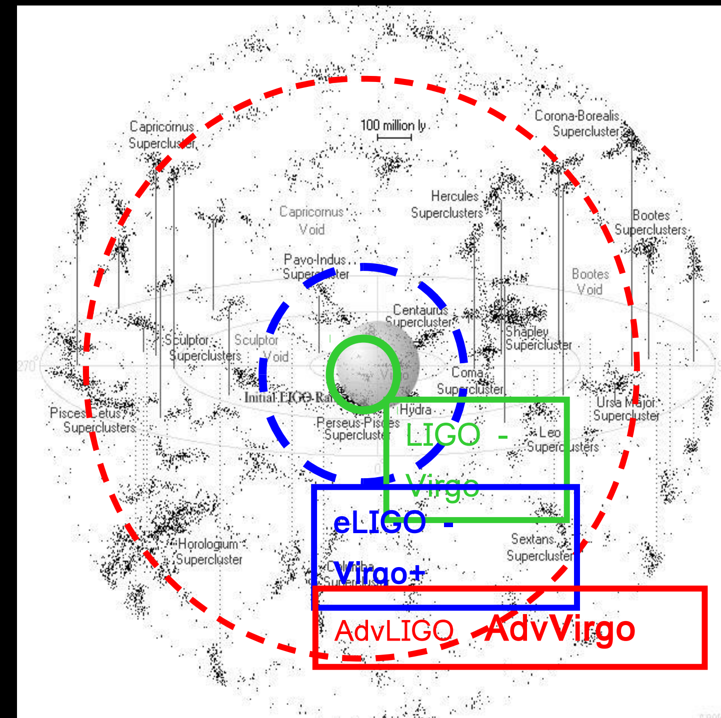


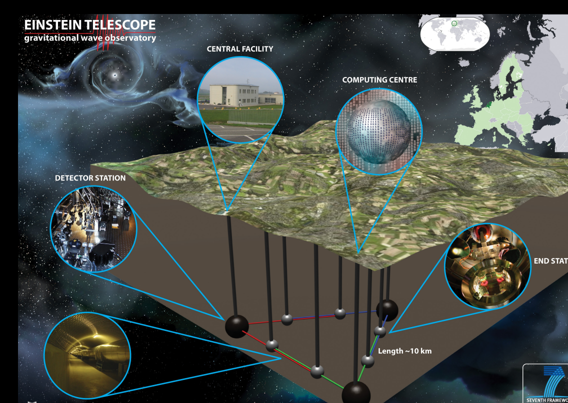
Another inspiring example: World network of gravitational wave antennas:

- **Sensitivity increase**
- **Source direction determination**
- **Polarizations measurement**

And beyond: 2nd Generation (Advanced) and Third (Einstein Telescope)

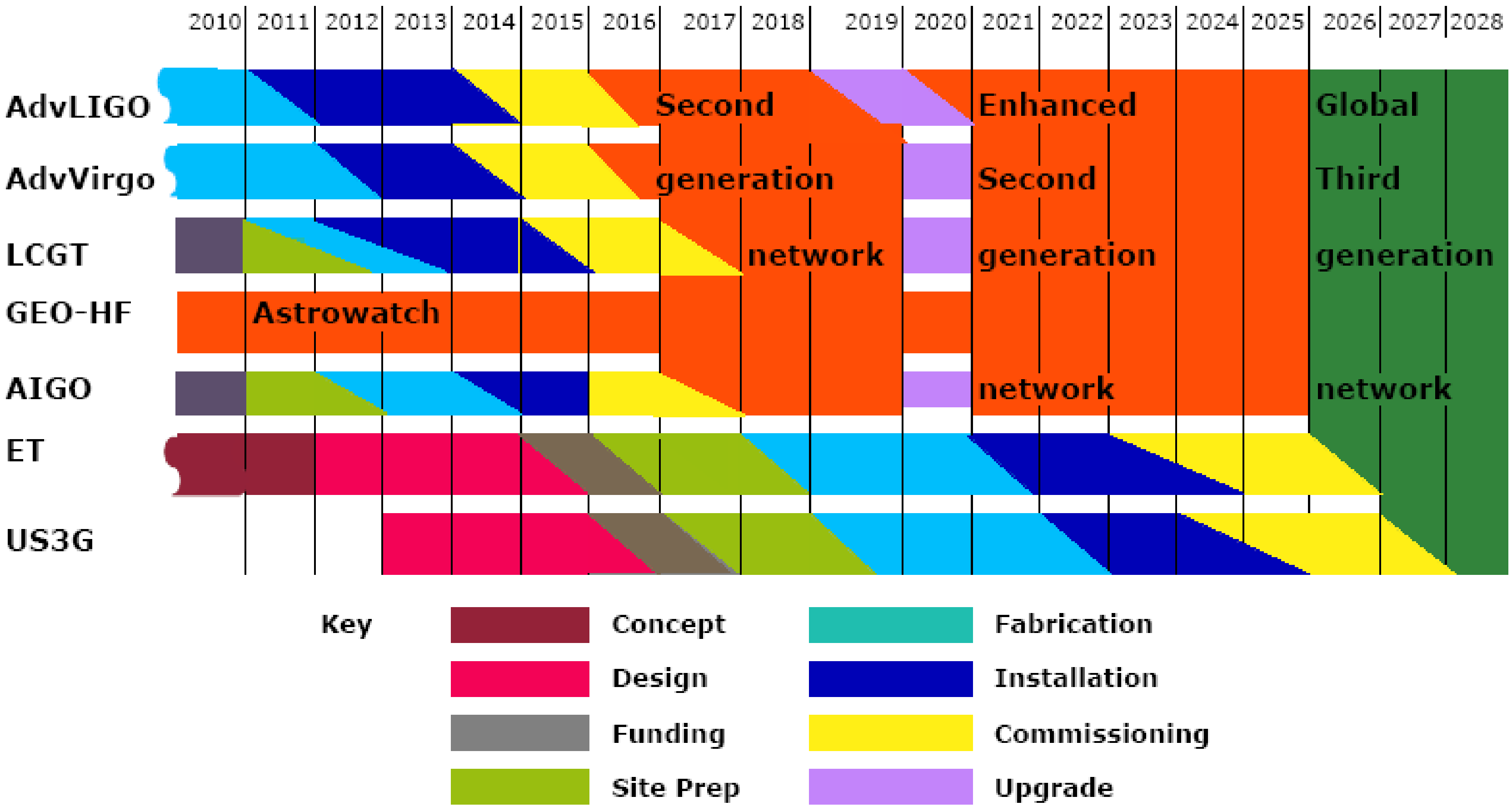






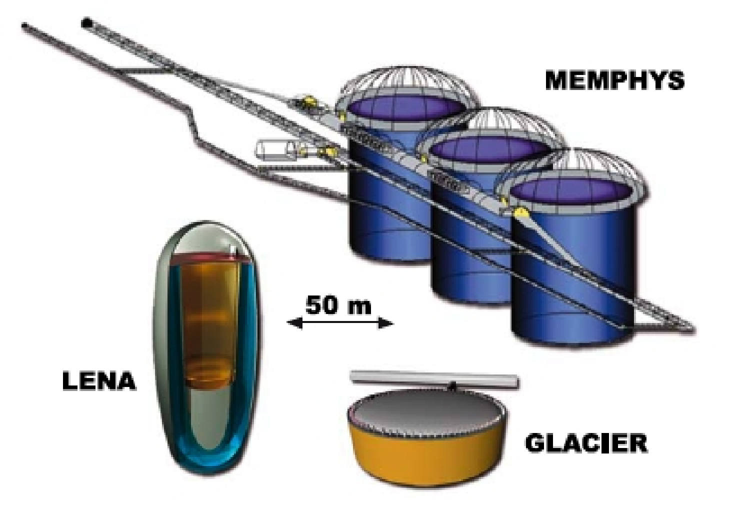
üAdv-Virgo approuved same timeline as adv-LIGO,
üBoth aim at advanced scientififc run by 2015
üExpected 1-10 events/year
üIf detection move to third generation
üIn Europe a Design Study in progress funded by the EU: Einstein Telescope ET)
üStong European support for LISA

A global roadmap: the GWIC roadmap for ground antennas



What is the form of matter and interactions at the smallest scales or equivalently the highest energies?

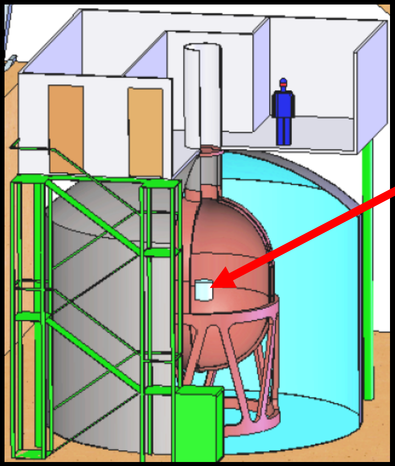
Rare decays

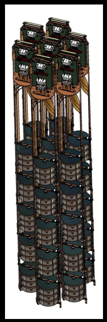


GUT predict finite timelife for the proton

I. Proton decay and neutrino detectors (LAGUNA, EU DS)

Neutrino masses through See-Saw probe GUT scales. The Majorana nature of the neutrino supports scenarii of matter-antimatter asymmetry

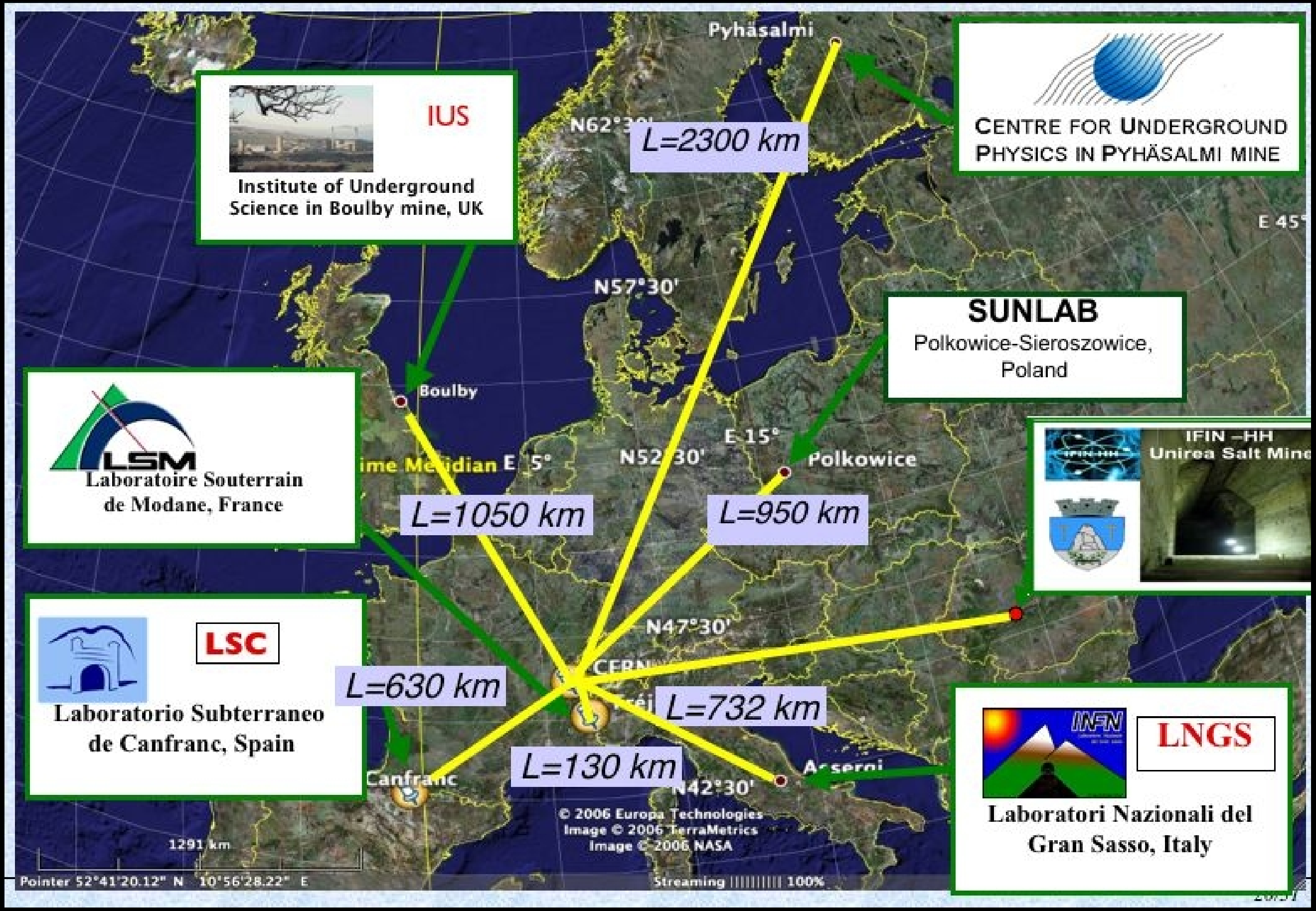




II. Ton scale neutrino mass detectors

Underground laboratories

- 4 large laboratories + 3 smaller ones. Effort of coordination towards a distributed platform (Eulabs) More global coordination (OECD) ?



A common design Study for extensions (LAGUNA)

LAGUNA Design Study

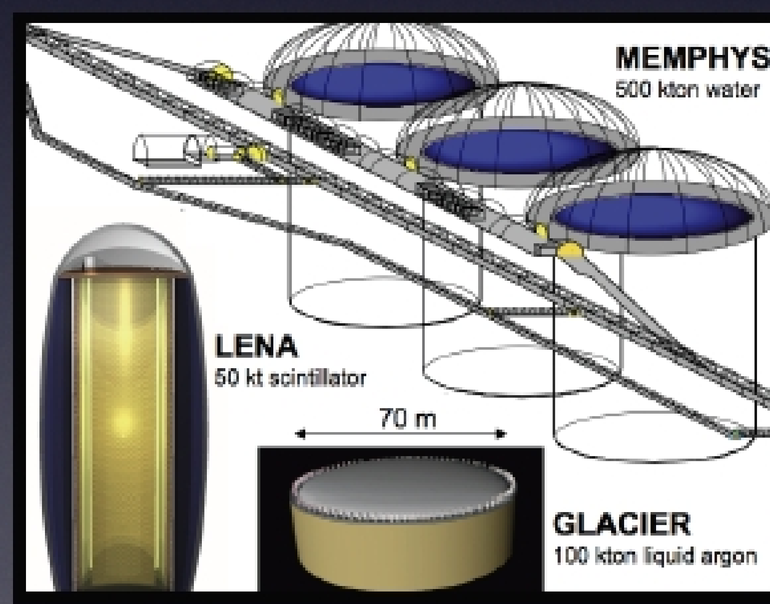
Large **A**pparatus for **G**rand **U**nification and **N**eutrino **A**strophysics

- Objective: assess feasibility of a new far detector at a new site
  7 preselected sites and 3 detector concepts
- Participation (open): very interdisciplinary - most European physicists interested in massive detectors; geo-technical experts, geo-physicists; structural engineers; tank and mining engineers
- EU Funding and beneficiaries: €1.7M - 9 (+4) HE institutes; 8 research organizations; 4 companies

WP2: Underground Infrastructure and Engineering ↔

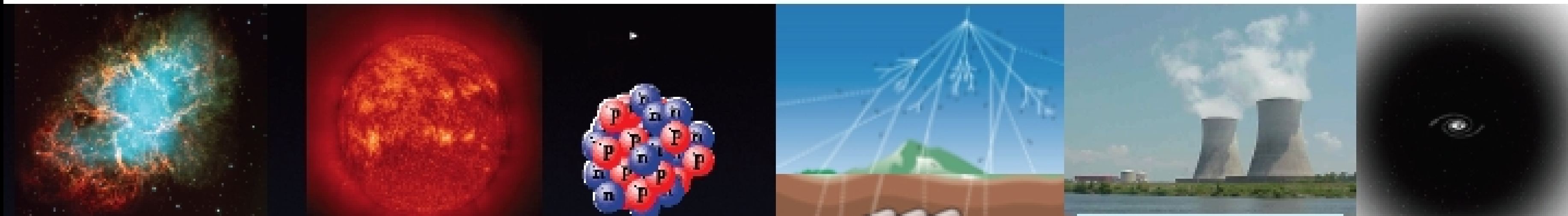
WP3: Safety, Environmental and Socio-Economic ↔

WP4: Science Impact and Outreach ↔



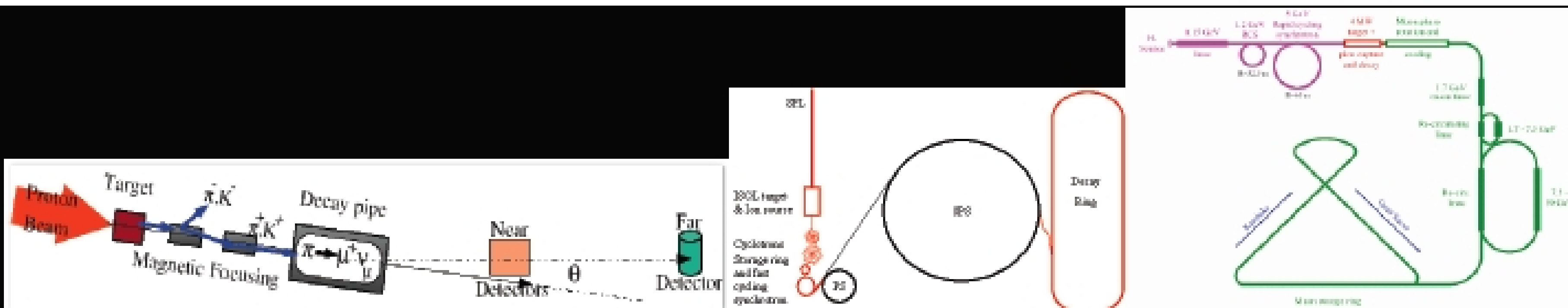
Science of LAGUNA

Particle Physics and Particle Astrophysics



Supernova neutrinos | Solar neutrinos | Proton decay | Atmospheric neutrinos | Reactor neutrinos | Dark matter

Neutrino Physics with accelerators



Superbeams | Betabeams | Neutrino factor

Science of LAGUNA

	Water Cerenkov	Liquid Argon TPC	Liquid Scintillator
Total mass	500 kton	100 kton	50 kton
$p \to e\,\pi^0$ in 10 years	1.2×10^{35} years $\varepsilon = 17\%$, ≈ 1 BG event	0.5×10^{35} years $\varepsilon = 45\%$, <1 BG event	?
$p \to \nu\, K$ in 10 years	0.15×10^{35} years $\varepsilon = 8.6\%$, ≈ 30 BG events	1.1×10^{35} years $\varepsilon = 97\%$, <1 BG event	0.4×10^{35} years $\varepsilon = 65\%$, <1 BG event
SN cool off @ 10 kpc	194000 (mostly $\bar{\nu}_e p \to e^+ n$)	38500 (all flavors) (64000 if NH-L mixing)	20000 (all flavors)
SN in Andromeda	40 events	7 (12 if NH-L mixing)	4 events
SN burst @ 10 kpc	$\approx$250 ν-e elastic scattering	380 ν_e CC (flavor sensitive)	$\approx$30 events
SN relic	250(2500 when Gd-loaded)	50	20-40
Atmospheric neutrinos	56000 events/year	$\approx$11000 events/year	5600/year
Solar neutrinos	91250000/year	324000 events/year	?
Geoneutrinos	0	0	$\approx$3000 events/year

Clear complementarity between techniques !

Superbeams Betabeams Neutrino factor

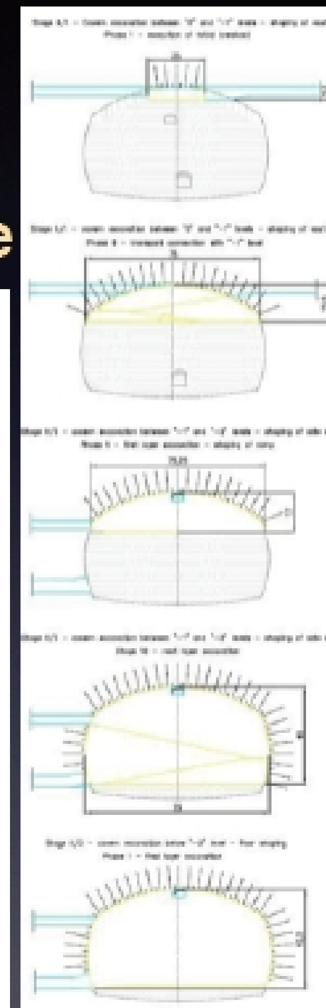
(5) Construction Sequences

Details of construction sequence also studied at all sites

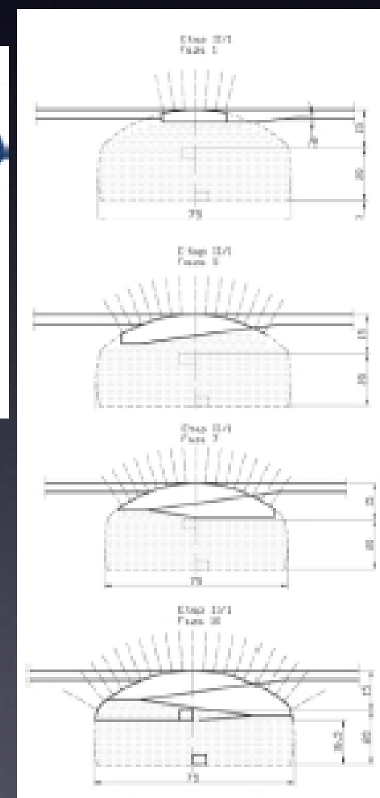
- Geotechnical stability and safety at each stage of excavation
- Requirements for rock removal and rock bolting
- Egress routes and evacuation safety

Umbria

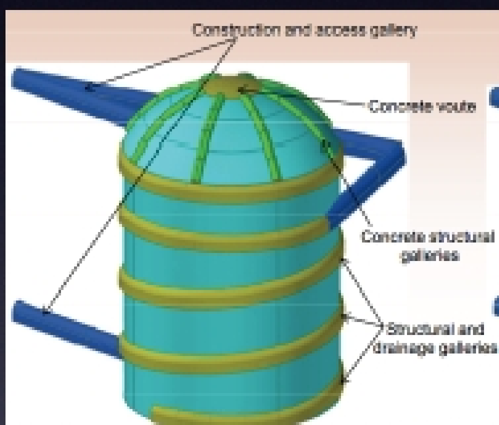
EXAMPLES



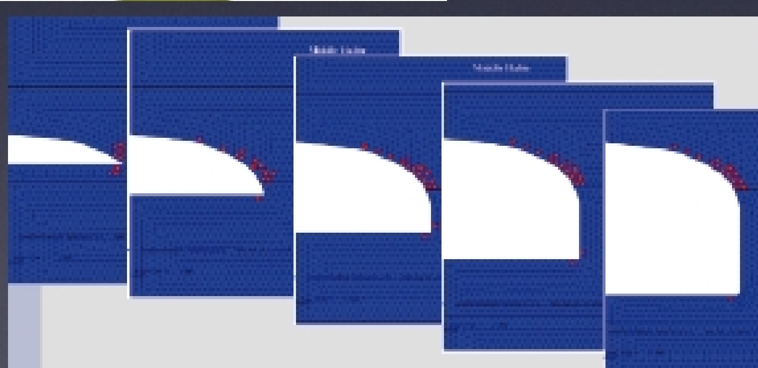
Sieroszowice



Frejus



Boulby



LAGUNA [redacted] Timeline

Paper Design Study (EU funded): 2008-2010

Prioritize the sites and down-select: July 2010

Prioritize detectors and down-select LAGUNA-NEXT: 2011-2012

Detailed construction phase study: 2012-2015

LAGUNA construction >2015

well matched to new CERN neutrino beam in 10 years?

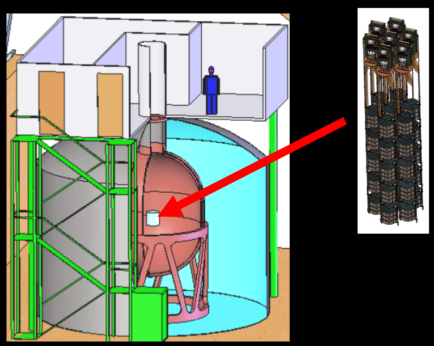
Boulby (UK)
Canfranc (Spain)
Frejus (France)
Phyasalmi (Finland)
Sieroszowice (Poland)
Slanic (Romania)
Umbria (Italy)

↔

Glacier (liquid argon)
Lena (liquid scintillator)
Memphys (liquid water)

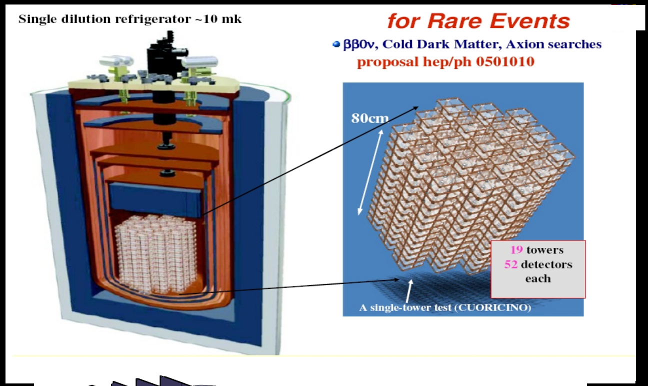
Megaton scale are Billion€ scale programs, need to have global coordination (OECD, FALC,…?)

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



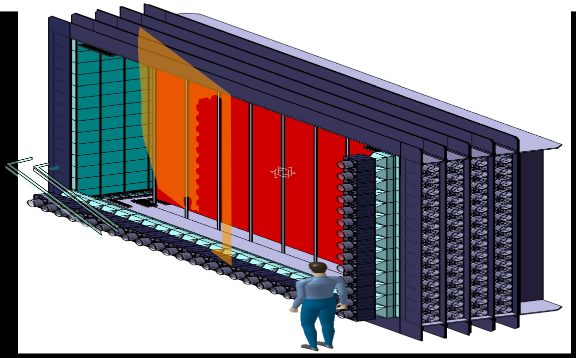
GERDA (I-II and III)

Ge diodes in liquid nitrogen
Implemented in phases (18,40,500 Kg)
Results phase I: 2011, phase II 2013



CUORE

Bolometer of TeO2 (130Te 203 kg)
Operation 2011, full detector in 2013



SuperNEMO

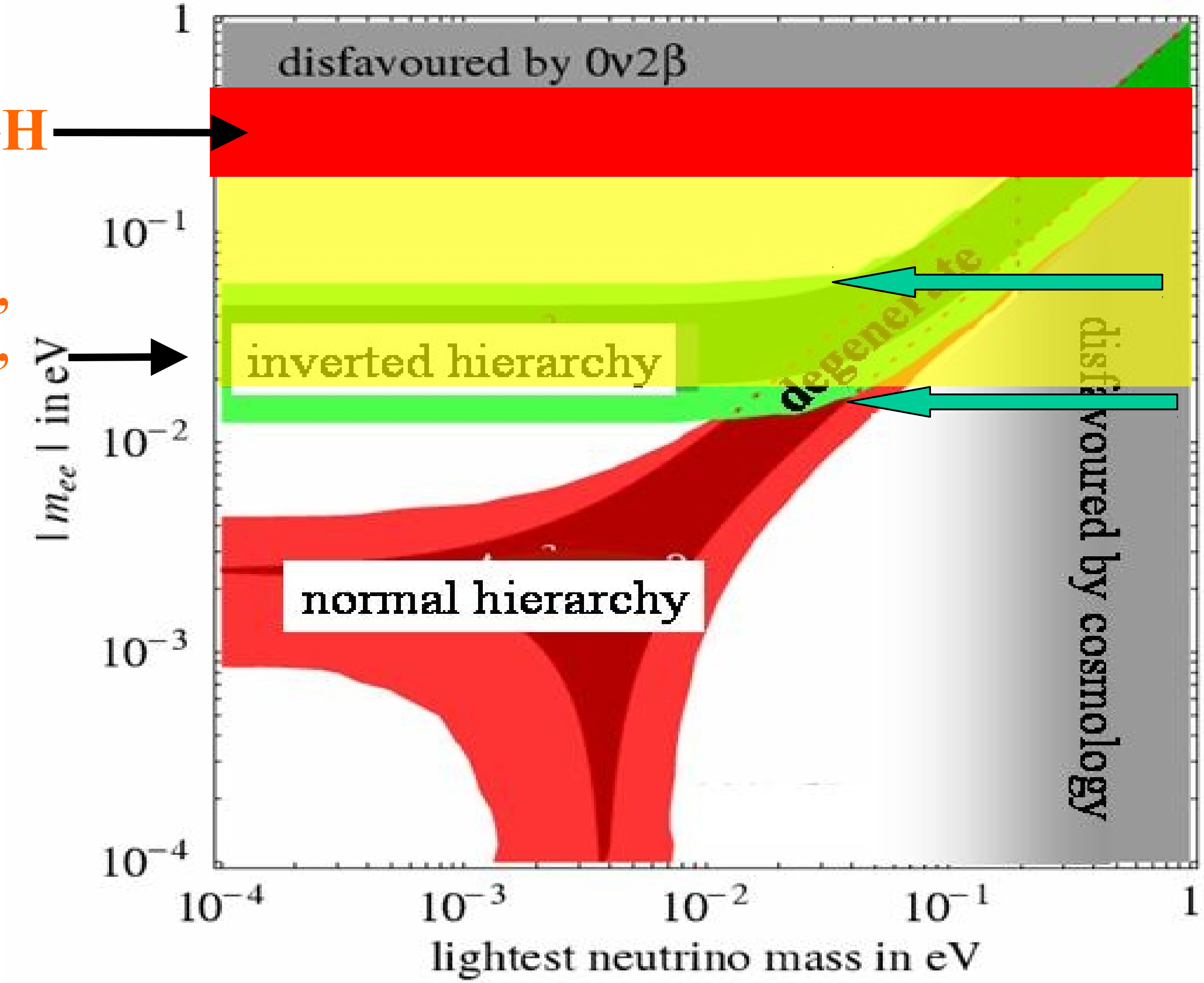
20 modules of a tracko-calo,
100 kg of 82Se or 150Nd

First module in 2012 (=GERDA I)

But also participation or R&D in EXO, Cobra, NEXT, Lucifer, …

KKGH

GERDA,
CUORE,
SNEMO
EXO200



1-10 counts/year*ton

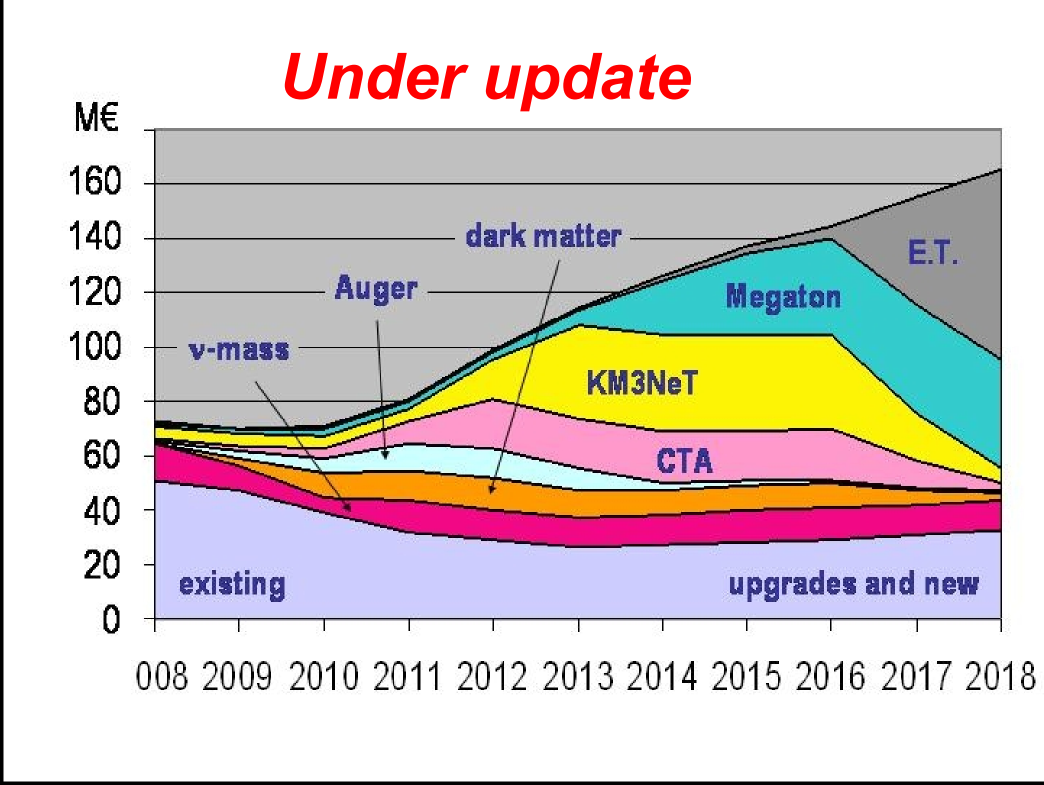
0,1-1 count/year*ton

Timeline and cost

Milestone 1 (2012) technology decisions for:
- ***Ton scale dark matter and***
- ***Ton scale neutrino mass***

Milestone 2 (2013) start the construction of :
- ***KM3net and CTA***
- ***Quid Auger North?***

Milestone 3 (> 2016) start the construction or participate in a worldwide collaboration for the construction of
- ***Megaton scale detector***
- ***Einstein Telescope***



- The 2008 roadmap presented a scenario with 50% increase over traditional astroparticle budget (could not go below, due to multpliicity of funding sources)
- Help from regions? International sharing ? Sharing with other disciplines?
- ASPERA2 :Update of the roadmap by mid-2011,setting up agency committees

The terms of reference of this Scientific Advisory Committee, which will work for a year (till spring 2011) will be:

- update the roadmap with new, more detailed information on the projects (essentially the Magnificent Seven)
- include considerations on dark energy, space projects and promising R&D
- address issues of critical R&D in view of the large projects of the roadmap and issues of procurement (from photomultipliers to rare isotopes)
- identify the major milestones and decision turning points with respect to the maturity of technologies and/or expected scientific results.
- discuss the site issues and the constraints they impose on the timescale
- take a critical look on budget and calendar claims concerning the large projects
- take into account international developments and
- represent the European scientific community opinion in the global coordination process happening in the context of the Global Science Forum working group of the OECD on Astroparticle Physics. In particular, address the issue of what is the minimal number of large projects of the same sub-domain that are scientifically justified on a global scale? Conversely, are there projects whose scale demands interregional/global coordination and/or cooperation and what actions should be taken in this context?

OECD Global Science Forum on Astroparticle Physics

ASPERA

EU, US (DOE,NSF, NASA), Japan, China, Australia, Canada, Corea, Russia, CERN

- **Timeline : 2 years (2009-2010)**

Started in Paris (spring 2009) , and will end at SLAC (Sep 2010)

Produced interim report (Oct 2009) well accepted by OECD GSF

The perimeter of the field was defined (8 themes: magnificent 7 +DE)

Four WG have been set and mapped the corresponding areas

- **"Cosmic rays" (CR, HE gamma and HE neutrino)**
- **"Beyond accelerator Particle Physics" (underground lab science: dark matter, neutrino mass, proton decay)**
- **Gravitational waves and Dark Energy**
-

From the report:

"The GSF Astroparticle Physics working group believes that the field has reached a high degree of autonomy, and that therefore an independent strategic vision for the field and its worldwide coordination should be developed"

Towards a Strategic Vision (issues under discussion)

Transversal issues

Needs for diversity, competition and coherence of the diverse approaches

Coordination on R&D/procurement (PM, rare isotopes, noble liquid)

Societal issues: environment (sea, ice, deserts, geosciences..), science in emerging countries (develop national plans complementary to the global adventure, which allow training and growth)

Forms of collaborations

For future very large projects: unified governance ? (CTA/AGIS, Megaton),

Network collaboration: from common operation to exchange of data and software (Ground based GW detectors, Neutrino observatories or more generally Cosmic Ray observatories)

Global convergence, despite diversity (Dark matter, Double beta decay)

- Establish something visible at the level of Funding Agencies (FALC type)
- To follow up the work of the Working Group. Facilitate merging, networking, coordination and coherence. Interact constructively with the neighboring fields (accelerator labs, astrophysics observatories), space agencies. The community, the ministries.

OECD GSF census

Census of Japan, China, India, Corea, Canada, Brazil, Argentina, Mexico in progress…

Study in progress …

Annual Funding*	Lab Operation	Investment	Salaries	Other	Total
Europe	26	50.6	90.35	10	176.95
US (incl. DOE-HEP, DOE-NP, NASA and NSF-PHY)	9.9	34.9	56.3	2.1	119.2
Russia (in Million $)	3.5	2.5	6.0	0.5	12.5
Australia	0.3	0.3	1.4	0	2.0
TOTAL	39,4	88	154,05	12,6	310,65

*In Million Euros, Dollars or Okuyen, without exchange rate applied

PERSONNEL (FTE)	Permanent*	Postdocs	Graduate Students	Other	TOTAL
Europe	1021	269	439	197	1926
US US (incl. DOE-HEP, DOE-NP, NASA and NSF-PHY)	269	135	220	68	692
Russia	500	60	50	100	710
Australia	6	4	20	0	30
TOTAL	1790	468	729	365	3358

* Scientists and Engineers

One could extrapolate to near 150-200 M$/year investment for 4000 FTE…

Conclusions

- What has been achieved the last few years
  - A sense of community among the scientists around a set of goals despite the absence centralising infrastructure (e.g. accelerator, telescope)
  - A roadmap that makes explicit the European strategy and makes it enter in the strategic thinking of the other regions (US, Japan but also China, India,..)
  - Close collaboration of the European agencies on a permanent basis
- What remains to be achieved in the next few years
  - Update of the roadmap based on internal/international developments (e.g. (PASAG, decadal survey)
  - Make happen the roadmap infrastructures (agency committees, technical review committees, more common calls on R&D, …)
  - A sustainable institutional structure for ApPEC/ASPERA (European Association?, Strategic board of CERN and/or ESA?)
  - A more permanent forum of coordination with other regions (OECD outcome?)