European Strategy for Astroparticle Physics

30 November 2007

S.Katsanevas

IN2P3/CNRS

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.

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>Themes

- European coordination since 2001
- The Roadmap process phases I and II
- Emerging priorities in :
  - Observatories of the High Energy Universe
  - Underground Science
- *Space: ESA cosmic vision*
- The Roadmap process phase III and possibilities of interregional coordination

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> ApPEC: AstroParticle Physics European Coordination

- 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
  1. Promote and facilitate co-operation within the European Particle Astrophysics (PA) community
  2. Develop and promulgate long term strategies for European PA, offering advice to national funding agencies and EU
  3. Assist in improving links and co-ordination between European PA and the scientific programmes of organisations such as CERN, ESA, and ESO
  4. Express their collective views on PA in appropriate international fora, such as OECD, UNESCO etc.

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> ApPEC Operation

- **ApPEC operates**
  - **Strategically through its Steering Committee,**
  - **Operationally through its Peer Review Committee**
- **Steering Committee (SC)**

France: M.Spiro, S.Katsanevas, J. Zinn-Zustin, Germany: T. Berghöfer, R.Köpke, H. Bluemer, Netherlands: F. Linde, UK: A. Coates, R. Wade , Italy: R. Petronzio B. Dettore, Spain: D. Espriu, A.Ferrer, Switzerland: M. Bourquin, Belgium: D. Bertrand, C. DeClerq, Portugal K. Gaspar Greece: D. Nanopoulos Poland S. Pokorski , CERN: D. Schlatter

- **Succesive Chairmen (2 year term): JJ. Aubert, J. Engelen (a few months), R. Petronzio, currently R. Wade, starting 2008 M. Spiro**
- **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

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> ApPEC achievements

- **Since 2001** ApPEC has been able to raise the profile of Astroparticle Physics in Europe as witnessed by the increasing numbers of national funding agencies which have joined
- **Since 2003** the PRC reviewed and issued recommendations on all major fields of PA creating a climate of convergence among competing projects.
- **Since 2004** obtained EU funds (7,5 M€) for networking and joint activities in the context of **ILIAS (Integrating Large Infrastructures for Astroparticle Physics)**
  - **In 2005** The succesful **KM3net** Design Study funded by EU (9 M€) came out of this process
- **In 2005,** the PRC under the chairmanship of C. Spiering was charged to draft a **roadmap** proposition to the community and the agencies
  - Links to the CERN European Strategy document
- **In 2006** obtained EU funds for the ERANET program **ASPERA**: EU funds for further inter-agency coordination

Astroparticle Physics for Europe

> AStroParticle European Reasearch Area Network (ASPERA)

AStroparticle Physics European Coordination ERAnet

'per aspera ad astra'

> ASPERA is a European network of national government agencies responsible for coordinating and funding research in astroparticle physics.

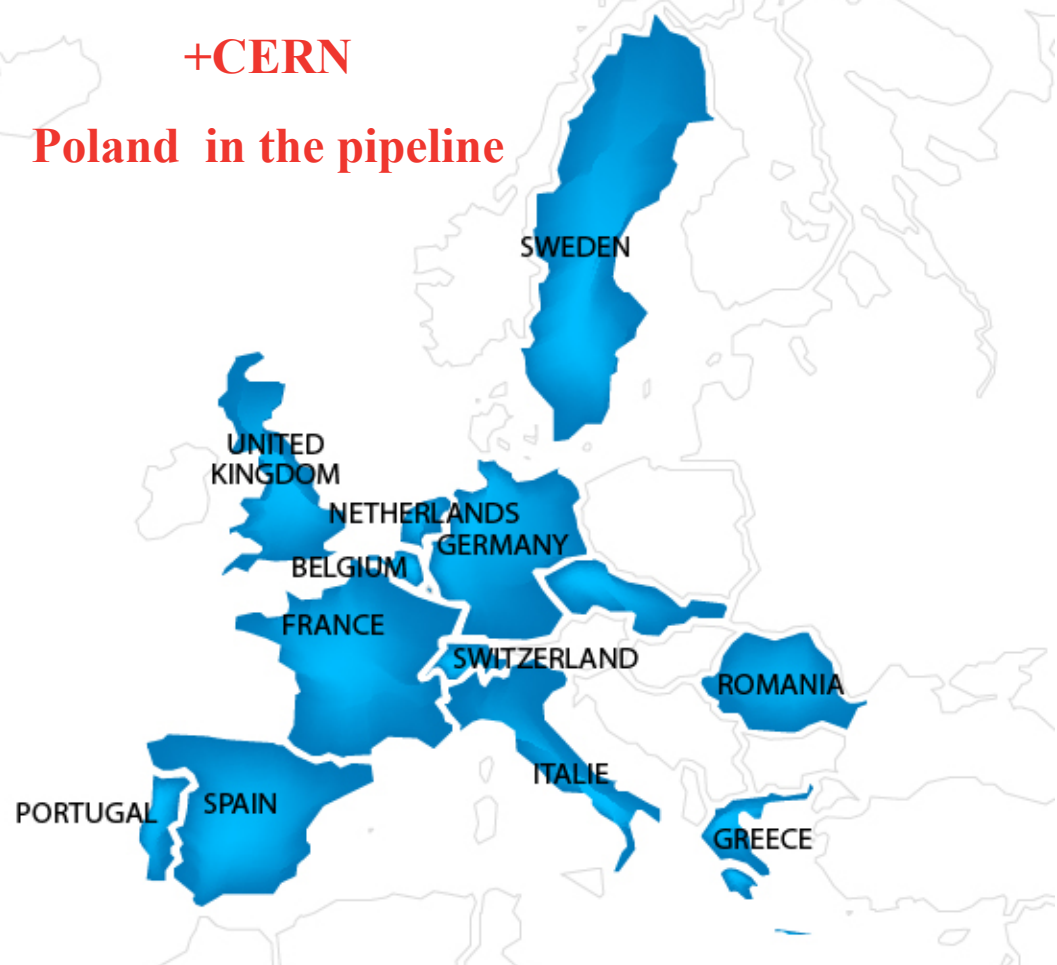
> ASPERA is funded by the European Commission at the level of 2.5 Million € over a three years period. It started in July 2006.

> ASPERA arises from the existence of ApPEC (Astroparticle Physics European Coordination).

13 countries

+CERN

Poland in the pipeline



> ASPERA objectives

- Study funding and evaluation of Astroparticle Physics in Europe
  - Study each others system (informal ”visiting commitees”)
- **Identify formal and legal barriers to inter-european coordination**

- *Define a roadmap* ***on infrastructures and R&D.***

- Explore further linking of existing astroparticle infrastructures and examine relations to existing labs (eg. CERN, particle physics labs)

- Launch common actions (e.g. common fund for design studies)

- Implement new European-wide, synchronised, procedures **of common funding of large infrastructures**

- Install a common information and outreach system.

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> ASPERA organization

AStroparticle Physics European Coordination ERAnet

Chart Title

Governing Board

T. Baez, D. Bertrand, M. Bourquin, C. De Clercq, D. Espriu, P. O. Hulth, R. Koeple, F. Linde, I. Ridky, J. Seed, M. Spiro, R. Petronzio, M. Pimenta, D. Schlatter, I. Siotis, J. Zinn Zustin

Peer Review Comitee

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

Coordinator, co-cordinator

S. Katsanevas, T. Berghoefer

Joint Secretariat

T. Berghoeger, C. Cavata, A. Coates, B. Dettore, A. Ferrer, J. Gillies, N. Olivier, D. Van Der Steenhoven

WP1
Status in Research Funding
G. Van Der Steenhoven

WP2
Roadmap
A, Coates

WP3
European Wide Procedures
B. Dettore

WP4
Electronic Infrastructure, Outreach, Extension
T. Berghoefer

- The Governing Board (GB) responsible for all management decisions of the network and for approval of all documents
  - (overlap with ApPEC SC)

> The Joint Secretariat (JS) assures the day-to-day follow up of the program.

- The Peer Review Committee (PRC) responsible for the evaluation of the network's activities
  - (the same as the ApPEC PRC)

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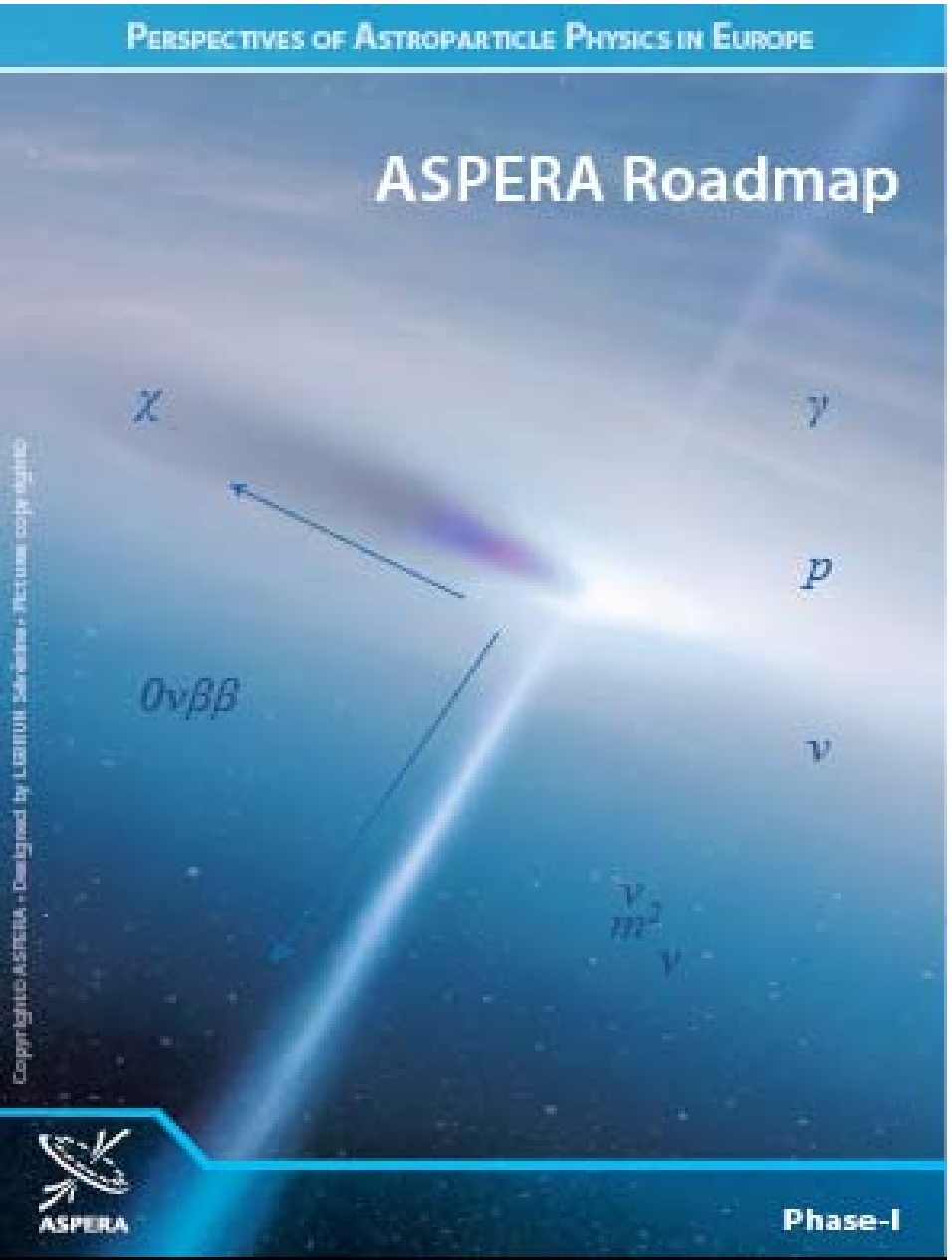
Roadmap process, Phase I

Astroparticle Physics for Europe

> Roadmap phase I the Opportunities (2005-2007)



- **Draft prepared by PRC, presented in Valencia Workshop November 2006**
- **Discussed in 7 working groups finalised by PRC (heads nominated by agencies, members from the community, sort of SDT)**
  1. **High Energy gamma**
  2. **High Energy cosmic rays**
  3. **High energy neutrino**
  4. **Gravitational waves**
  5. **Dark matter**
  6. **Neutrino mass**
  7. **Low energy neutrino and proton decay**

Ø **Not included: space and dark energy (implicit rule prioritize only the themes where aspera agencies give the majority of funds) . We are changing this.**

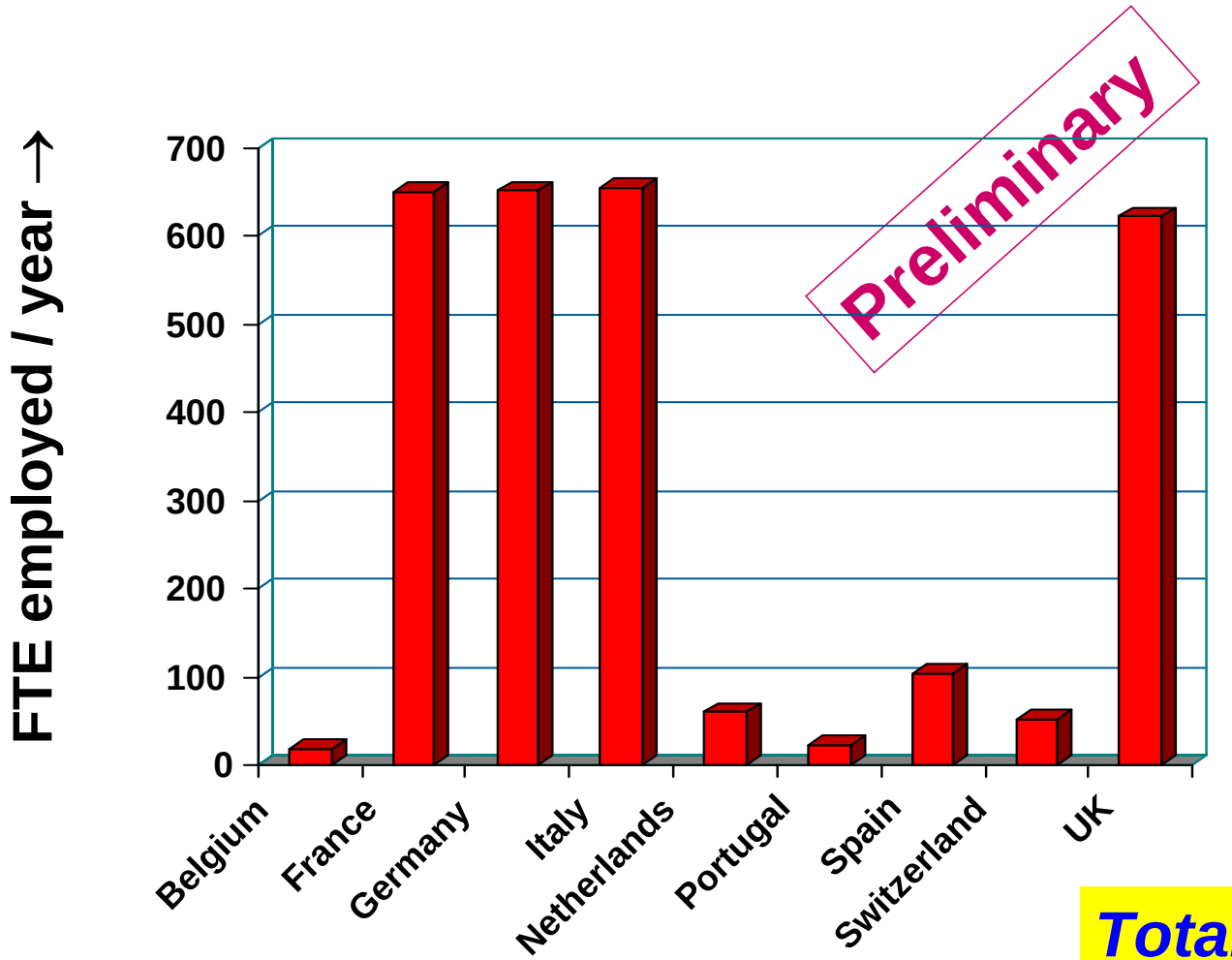
- **Phase I Roadmap Published May 2007**
  - **www.aspera-eu.org**

Roadmap process Phase II

> Roadmap phase II the Possibilities (2007-2008)

- The 7 working groups prepared timelines of 55 astroparticle projects detailing financial and human resources needed, milestones, enabling R&D, risks etc.
- In parallel a detailed comparison of resources available in each agency were evaluated
- First comparisons presented in a workshop in September 2007 in Amsterdam.
- The workshop was also the occasion to have a first comparison with non-European strategies (NSF, DOE, China)
- Currently the WG proposals are evaluated by the PRC for their science goals, and technical readiness
- Phase II will end with a workshop in Paris or Brussels in Autumn 2008
- Phase II document will be a 30 page detailed recommendation document

> General findings, personnel



70 M€/year are spent in investment for APP projects

600-650 FTE in 4 countries

Total #FTE's in '06: ~3000

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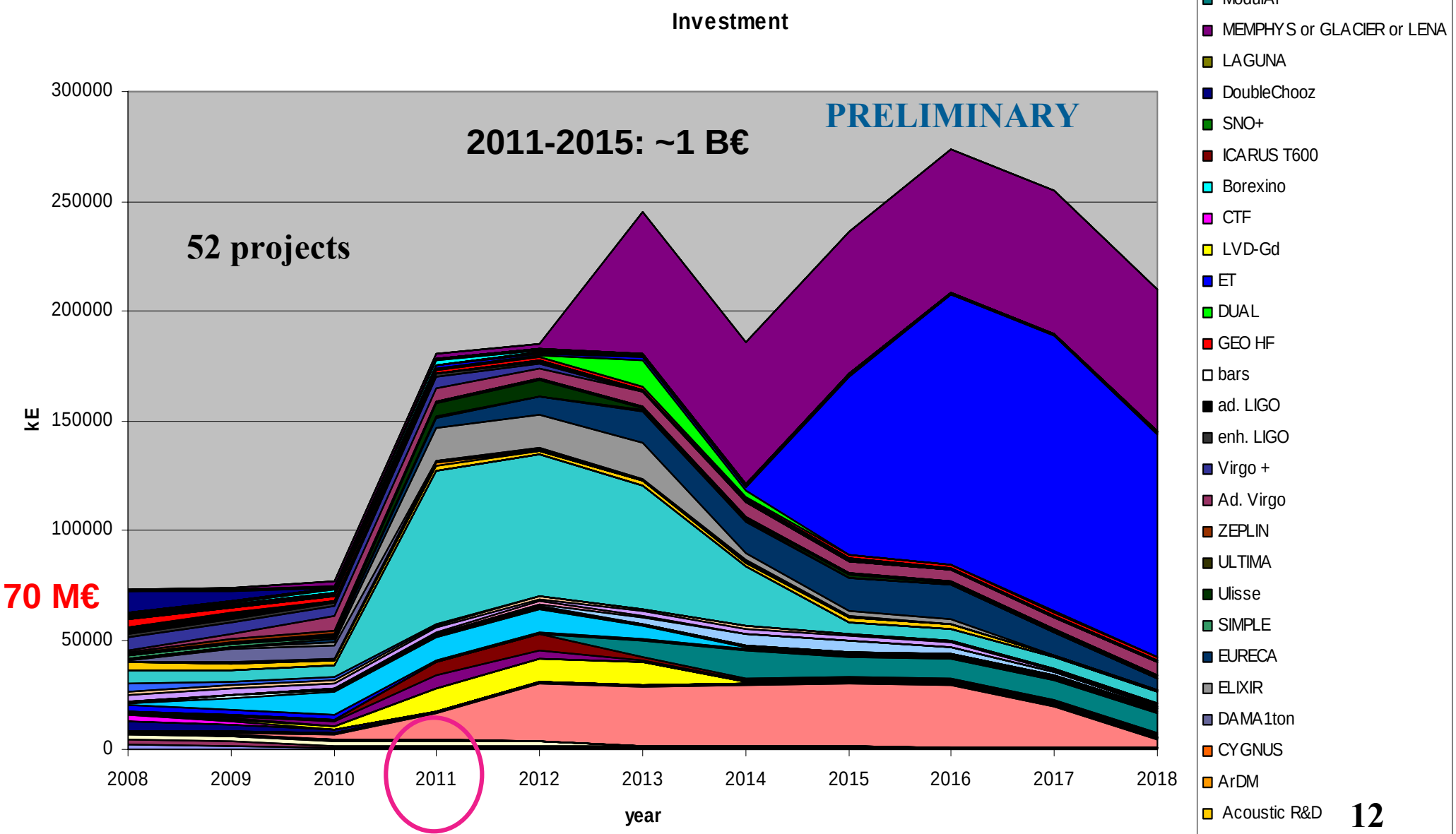
Roadmap process Phase II

Roadmap phase II, investment wish list 2 B€ in 10 years



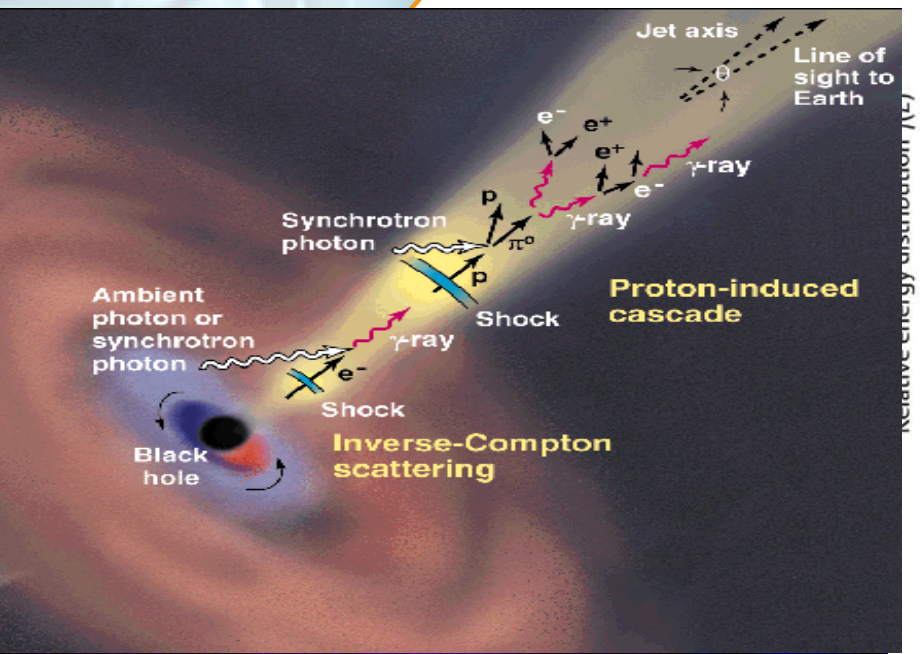
No other continents, no hard priorities

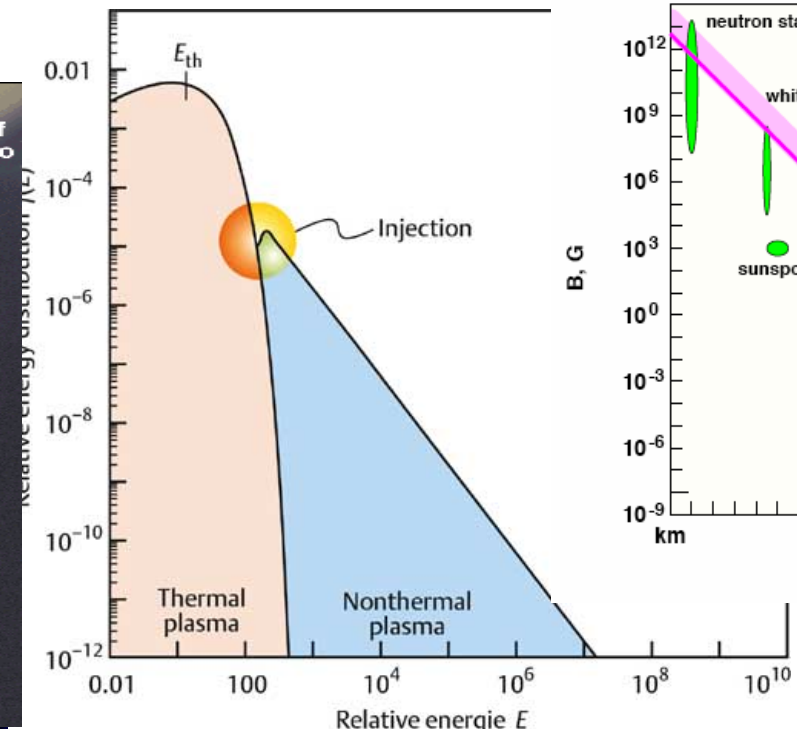
The High Energy Universe

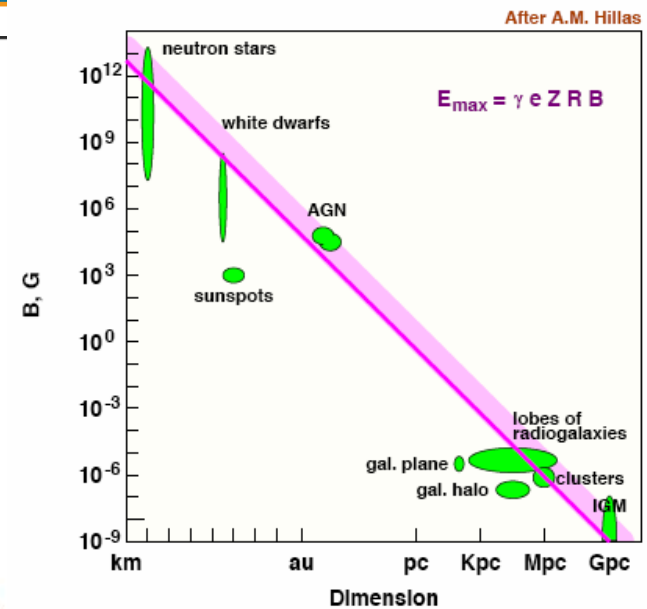
Light is not the only sidereal messenger

- We can study the non-thermal part of the Universe through:
  - High Energy gamma rays
  - High Energy cosmic rays
  - High Energy neutrinos
  - Gravitational waves
- They bring information on
  - The origin of cosmic rays
  - Sites of extreme phenomena testing the fundamental laws of physics
  - Sites that could become cosmological markers or probe the intergalactic space or even the spacetime fabric itself
  - Site of annihilation of dark matter
- It is a task for physicists to bring the new detection techniques to maturity opening new windows of astrophysical investigation

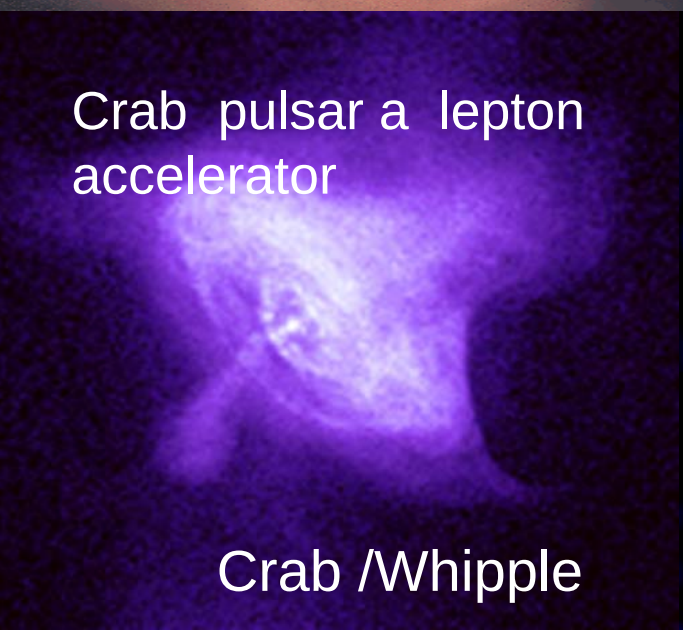
The High Energy Universe: sky accelerators





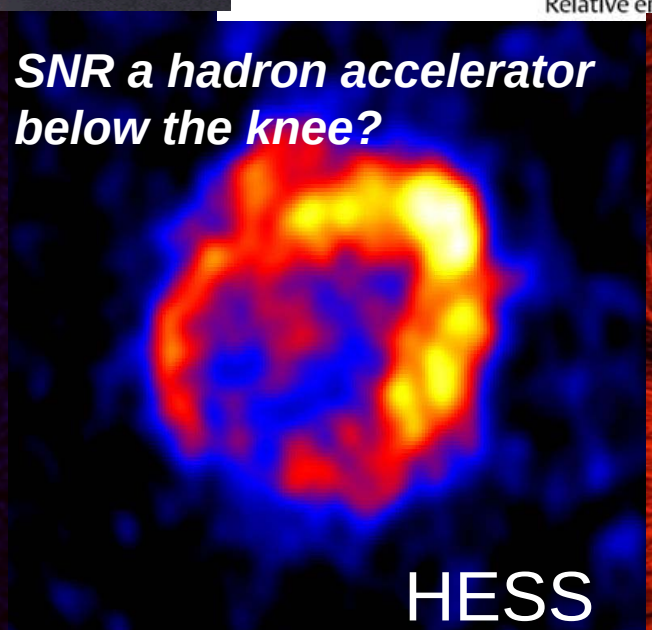


Crab pulsar a lepton accelerator



Crab /Whipple

SNR a hadron accelerator below the knee?

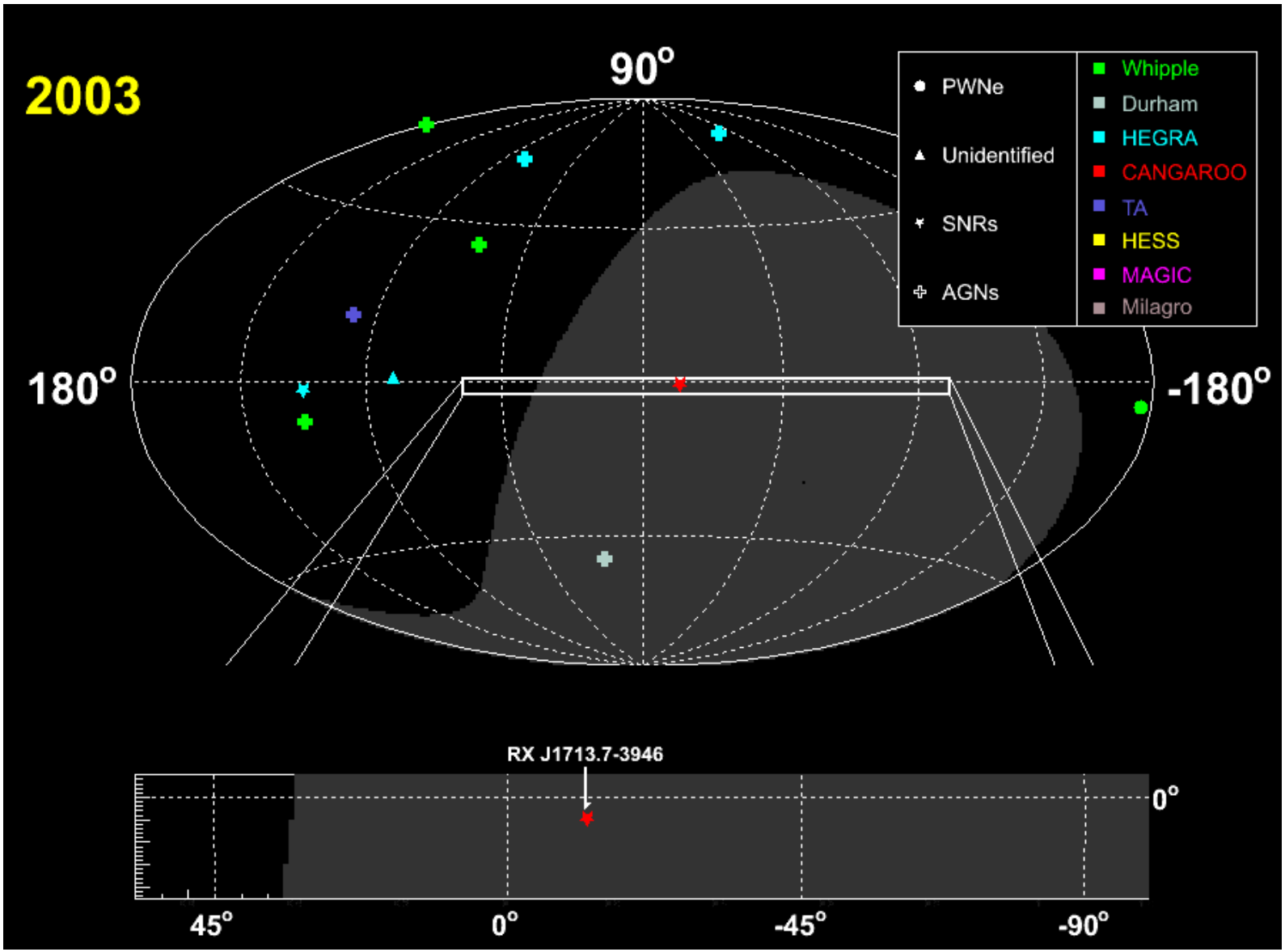


HESS

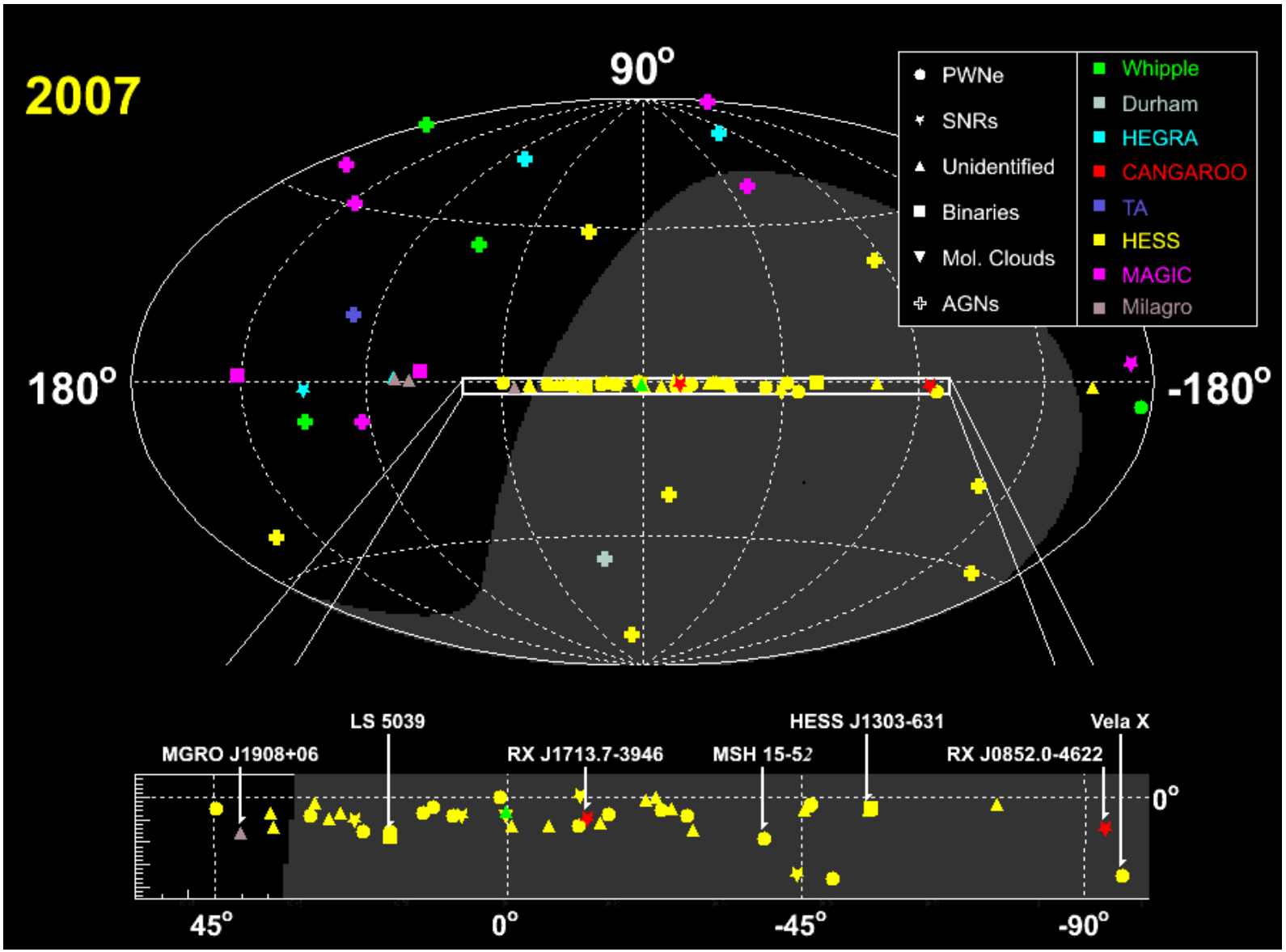
AGN a a very high energy hadron accelerator

AUGER

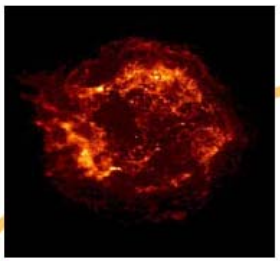
High Energy Gamma Rays



High Energy Gamma Rays

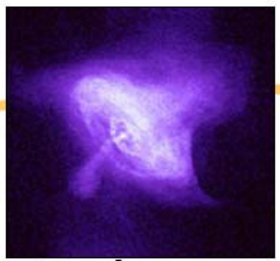


The VHE γ-ray Physics Program

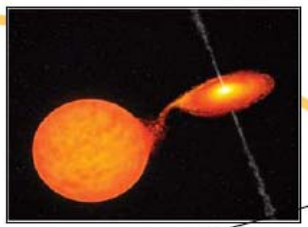


SNRs

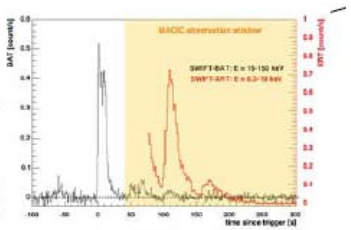
Origin of Cosmic Rays



Pulsars

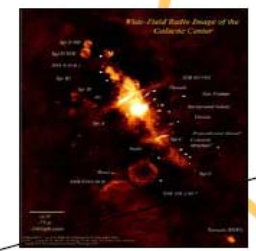


Binary systems



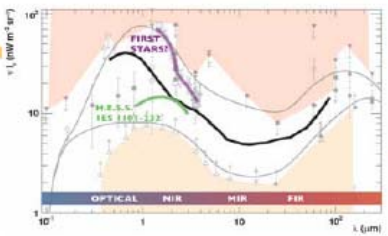
GRBs

Galactic

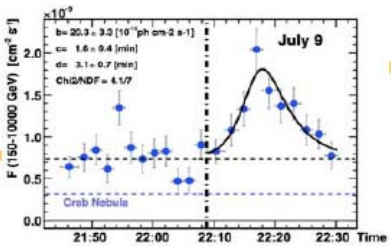


Cold Dark Matter

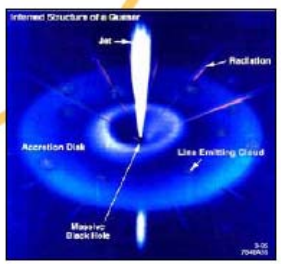
Extragalactic



Cosmological γ-Ray Horizon

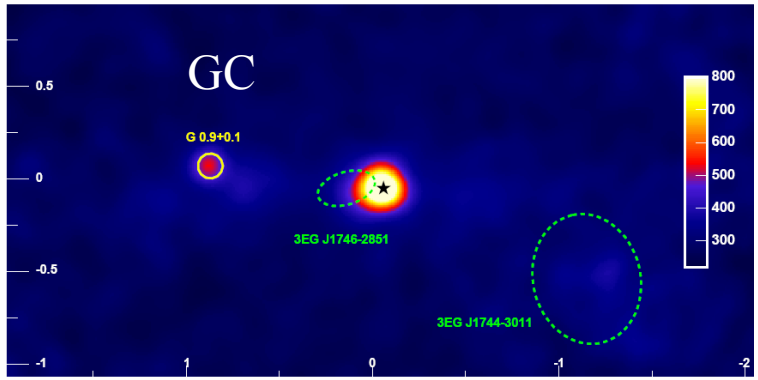


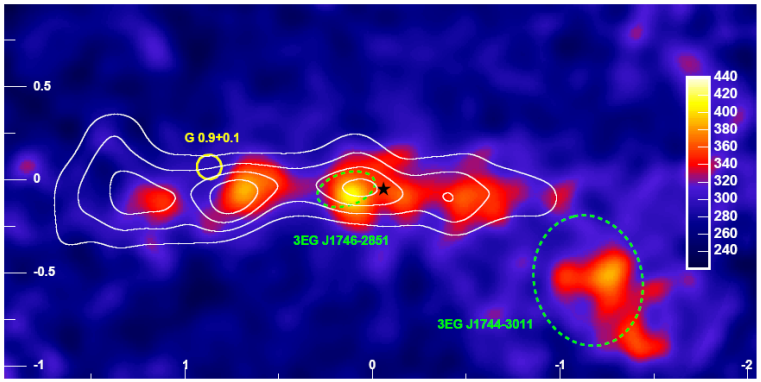
Test of the speed of light invariance

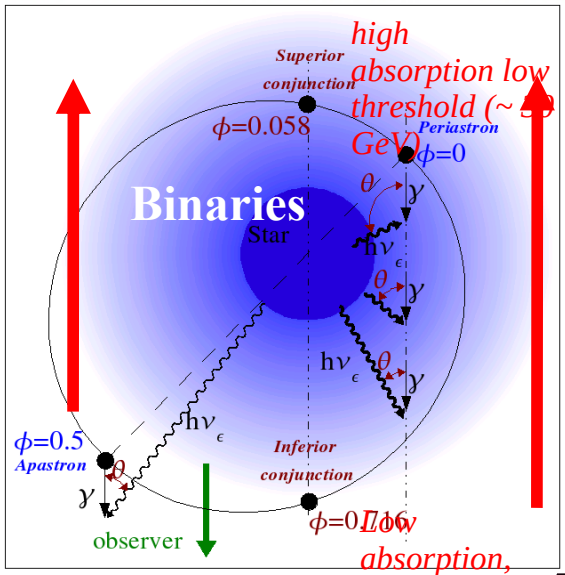


AGNs

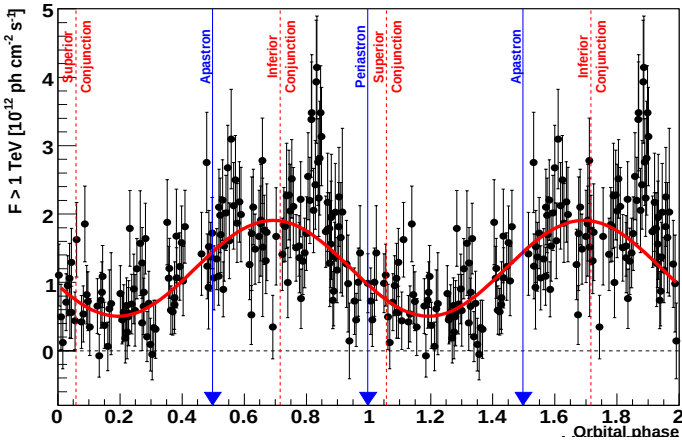
Highlights of recent discoveries



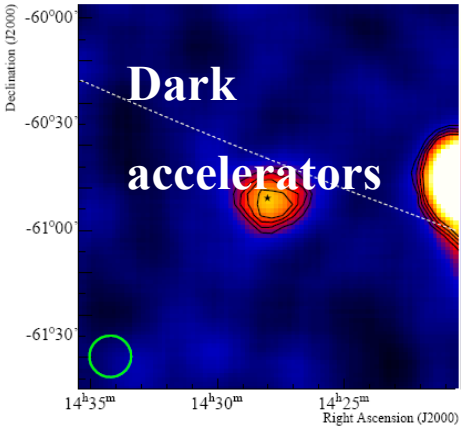


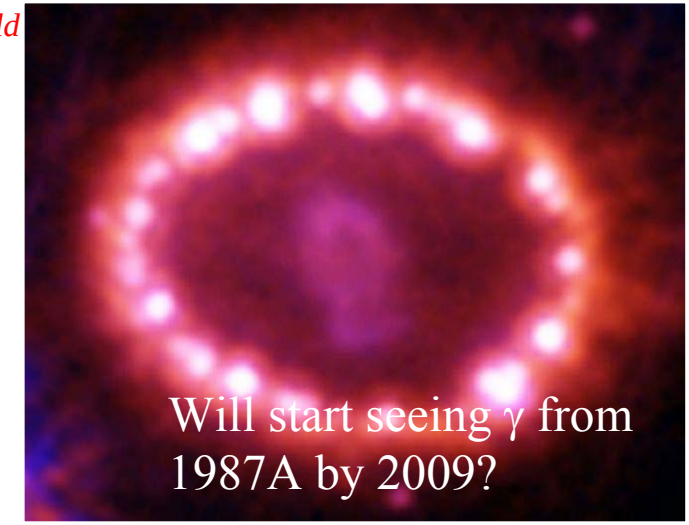


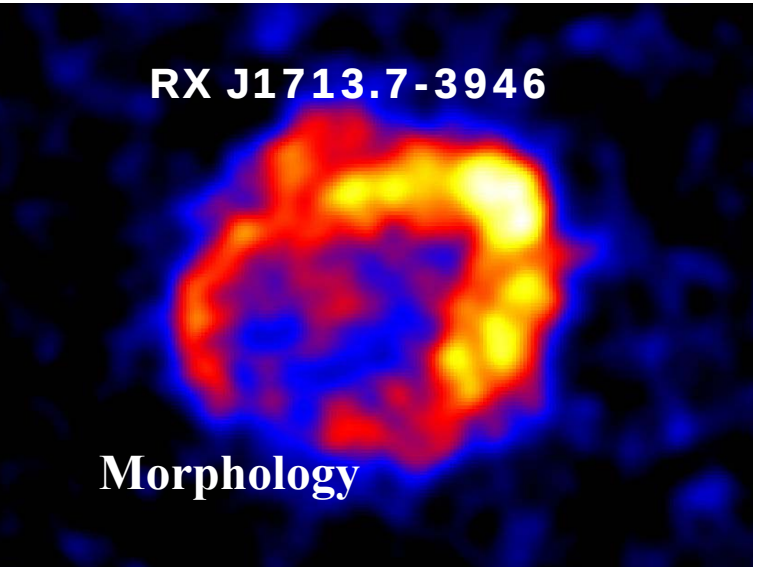
High Energy Gamma Rays



HESS J1427-608





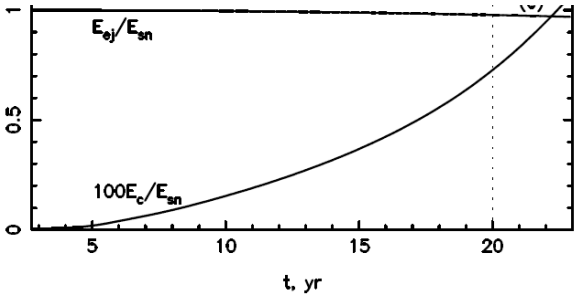


Strong Magnetic fields

Seen by eg CHANDRA in X

Make electron acceleration improbable?

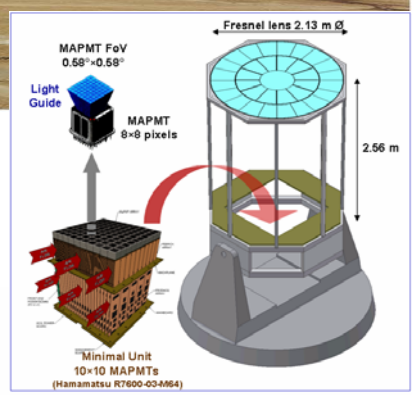
Origin of CR?



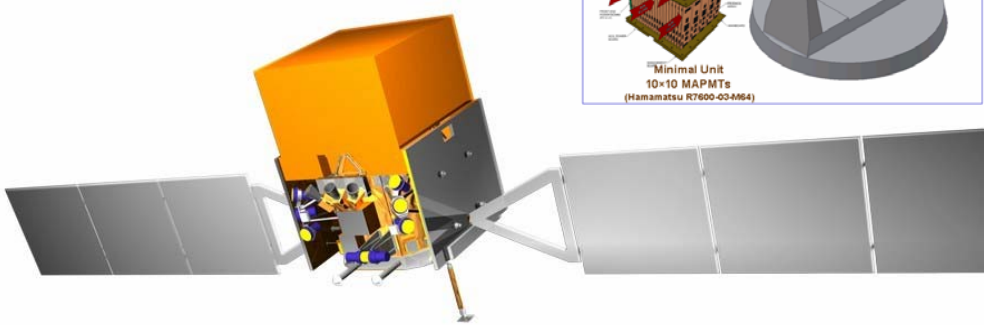
Infrastructure landscape

HESS I+II, MAGIC I+II,VERITAS

TIBET, ARGO-YBJ

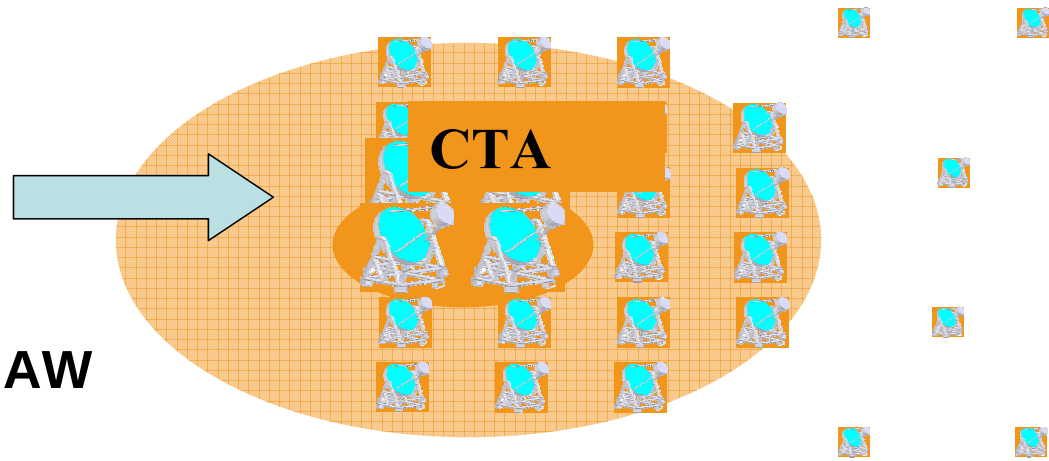


GAW



INTEGRAL, AMS, AGILE, GLAST

Cherenkov Telescope Array



2 sites, each x10 more sources

20 M€/year 200 FTE/year

for one site …

Sharing with US/Asia (AGIS)?

A centennial old task: understand the CR spectrum:

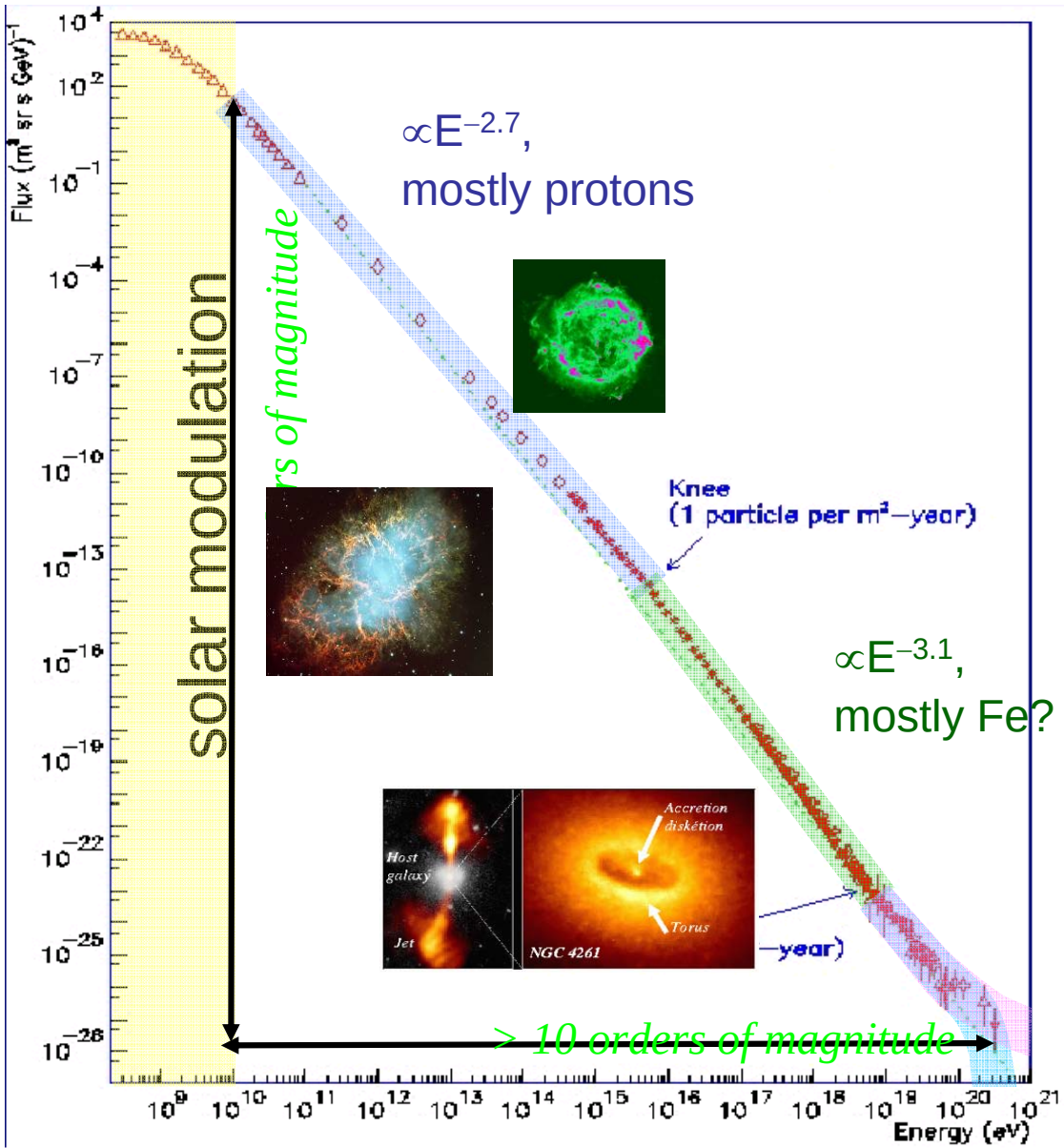
Open questions in GeV-TeV range

- Details on production, acceleration and propagation of cosmic rays
- Antimatter in cosmic rays
- Dark matter signals

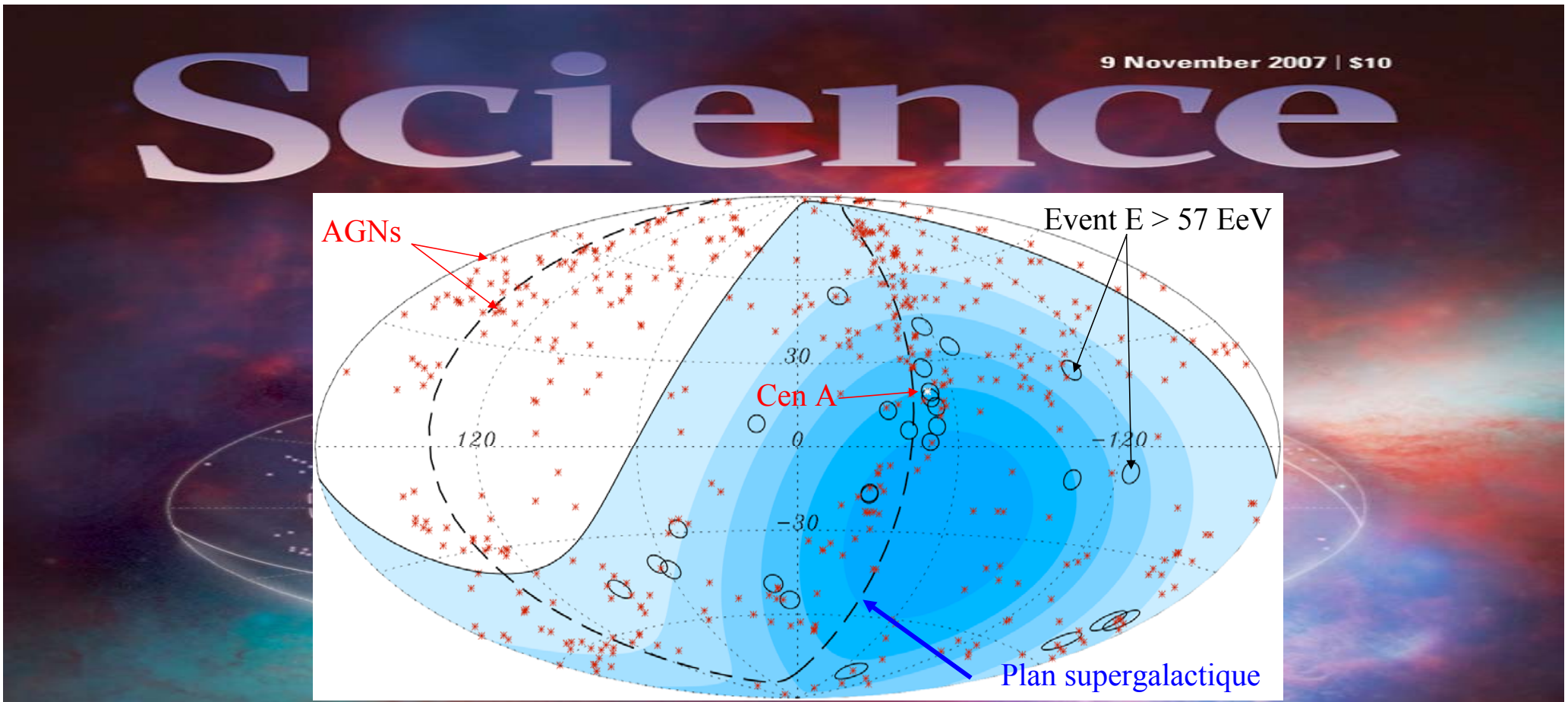
Open questions in PeV- EeV range

- Knee position(s);
- CR anisotropy in time and space (propagation in Galaxy, nearby source?);
- Where does the spectrum end? Is there a GZK cutoff ?
- Composition? Nuclei ? Protons ? Gamma rays ? Neutrinos ? X?
- Point sources?

High Energy Cosmic Rays



A first model of world wide collaboration AUGER observatory

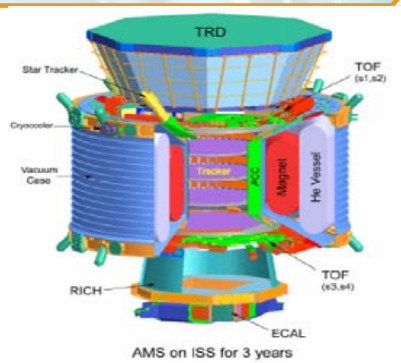


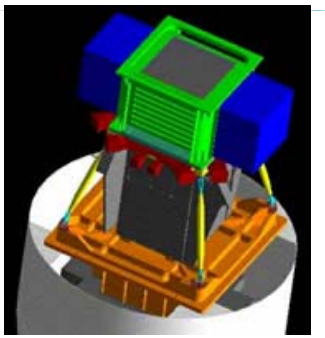
- 81 events > 40 EeV, θ < 60°
- Correlation with supergalactic plane ($P=10^{-5}$) (nearby AGN)

Astroparticle Physics for Europe

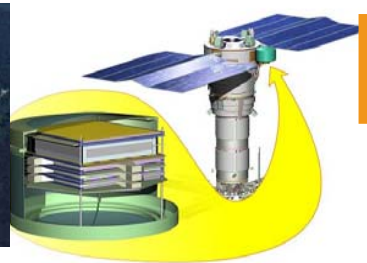
Infrastructures

High Energy Cosmic Rays

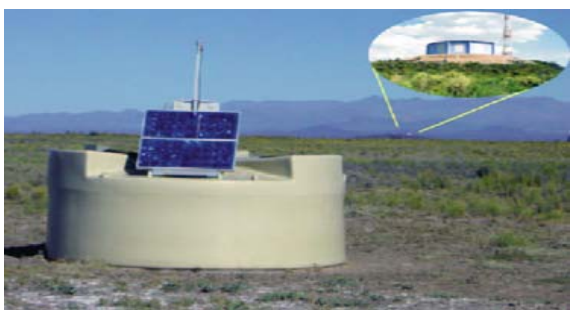




AMS-02, PAMELA,CREAM,…



KASCADE, LOFAR, Radiodetection, HEAT/AMIGA (Auger), NUCLEON,…



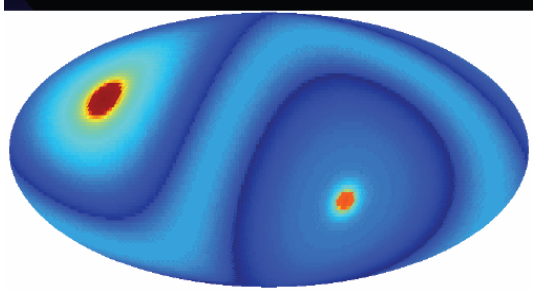
Northern Site: Colorado

4000 stations
10,370 km^2
Square mile grid

uthern Site: Mendoza

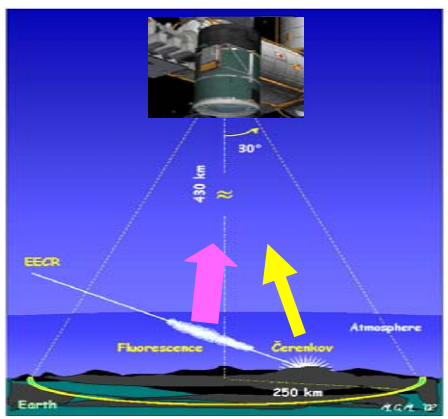
1600 stations
3000 km^2
1.5 km triangular grid

Sky Exposure
Auger North + South



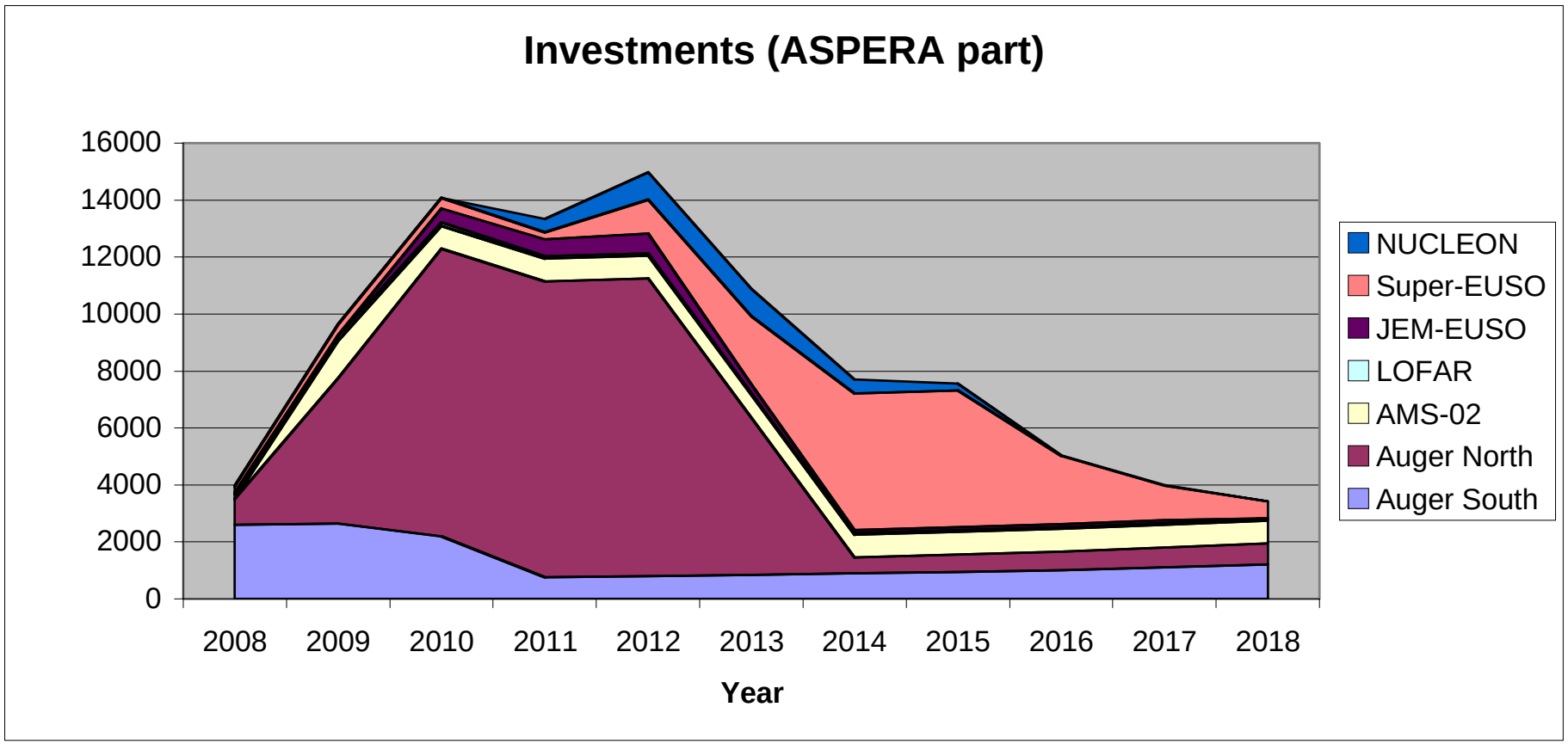
R&D New methods:

Radiodetection



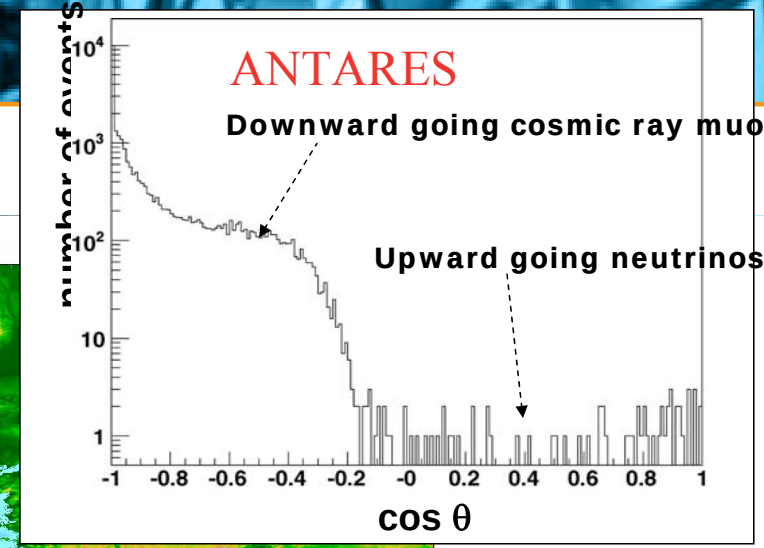
R&D on an EUSO concept well seen in ESA (beyond 2018)

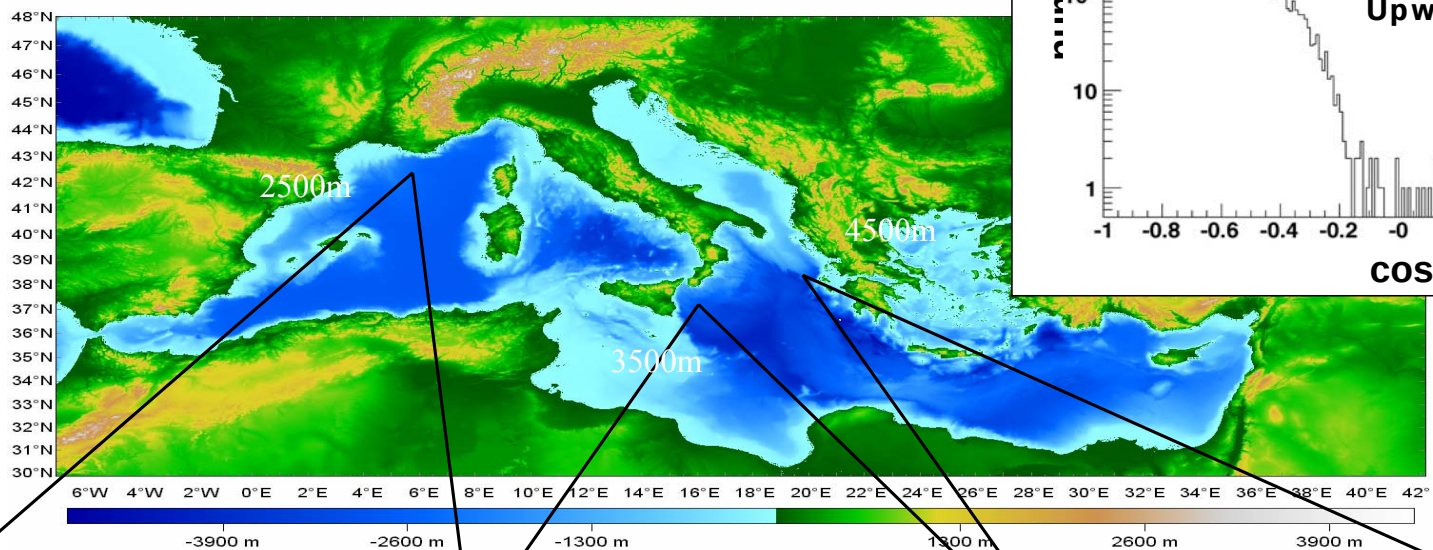
High Energy Cosmic rays

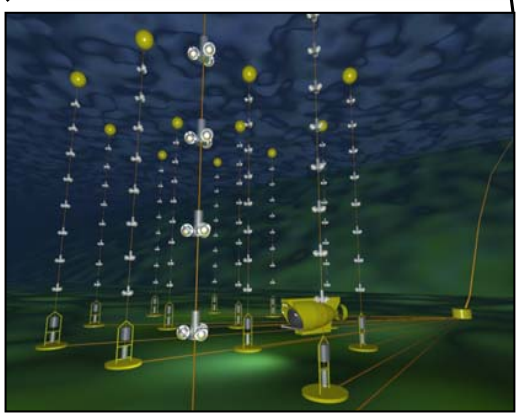


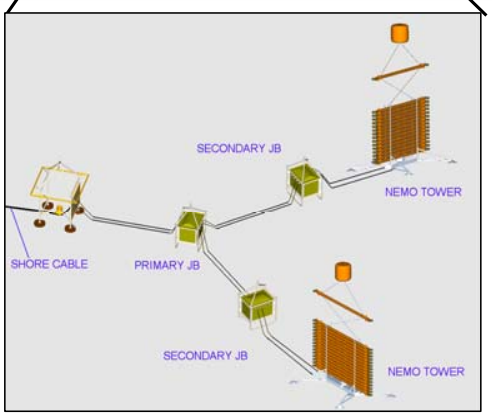
10 M€/year investment +150 FTE/year

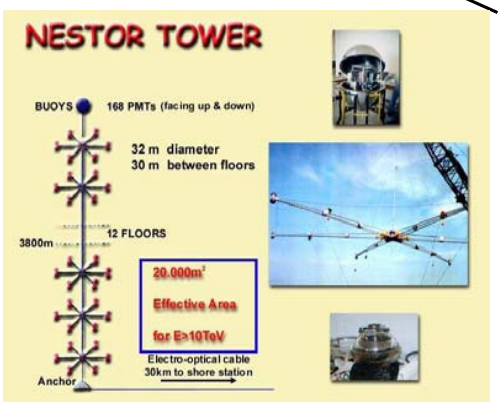
High Energy neutrinos











Location,

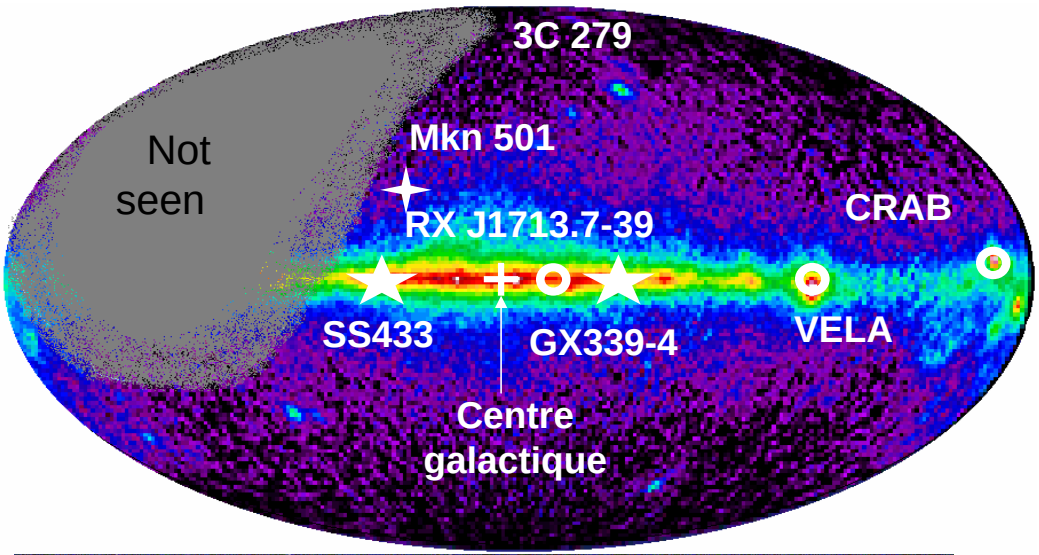
Location,

Location

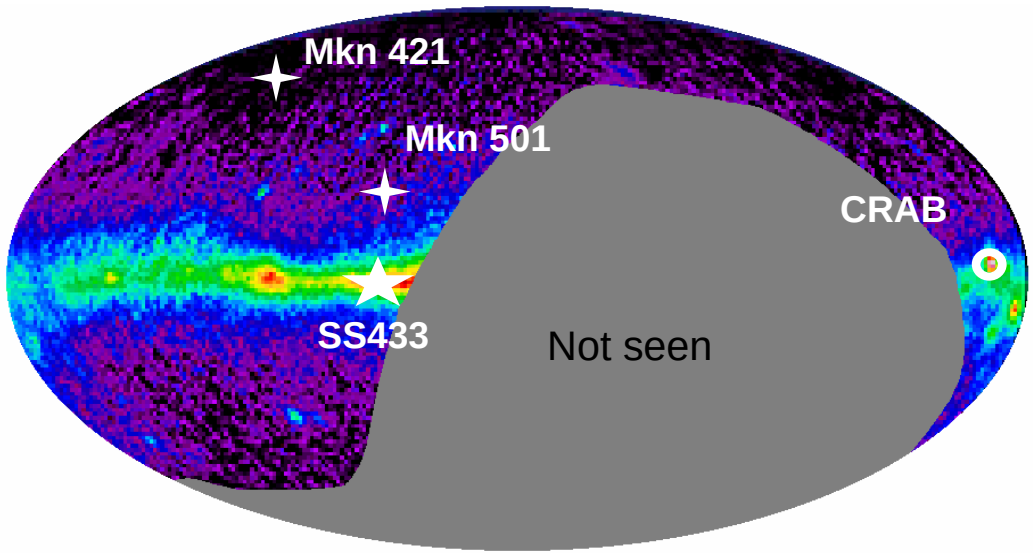
ANTARES Currently 5 lines, another 5 will be connected 3-7 Dec. 2007, All 12 lines early2008

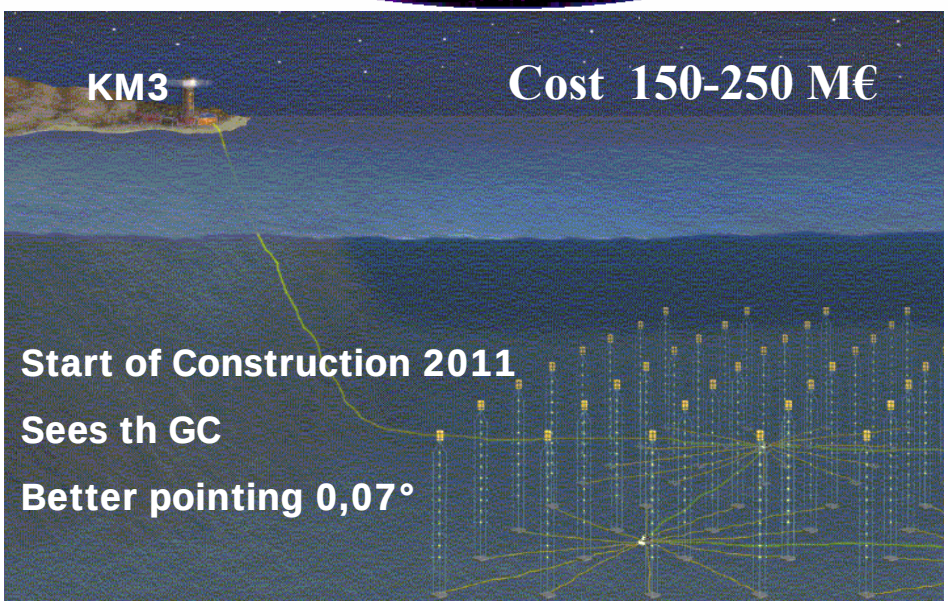
KM3NET/ICECUBE

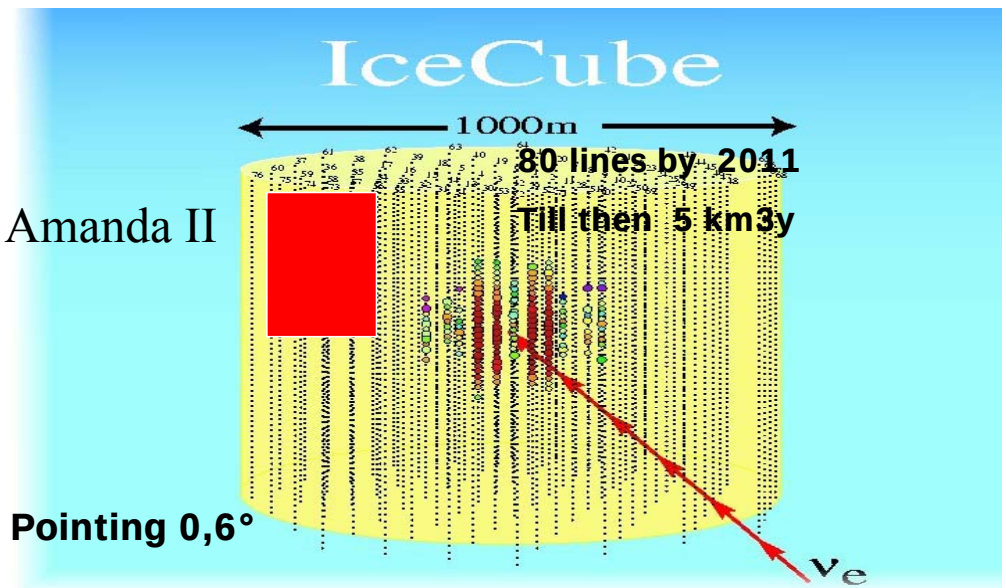
ANTARES (43° nord)



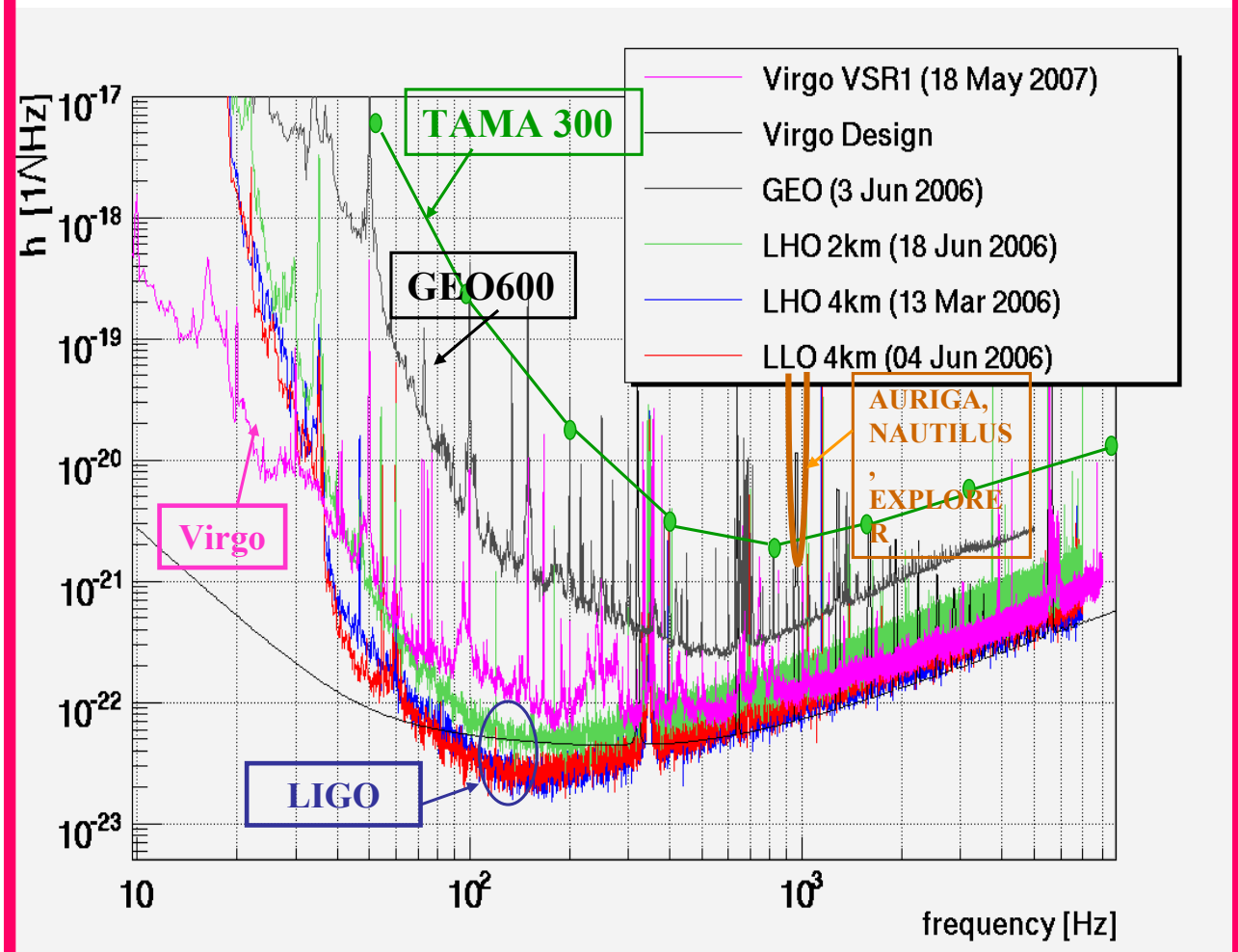
AMANDA (south pole)







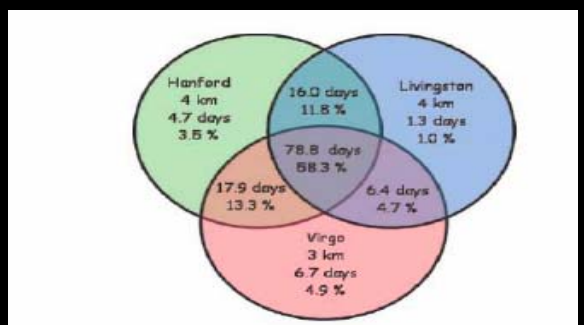
A second model of world collaboration: LIGO/VIRGO/GEO network for gravitational waves



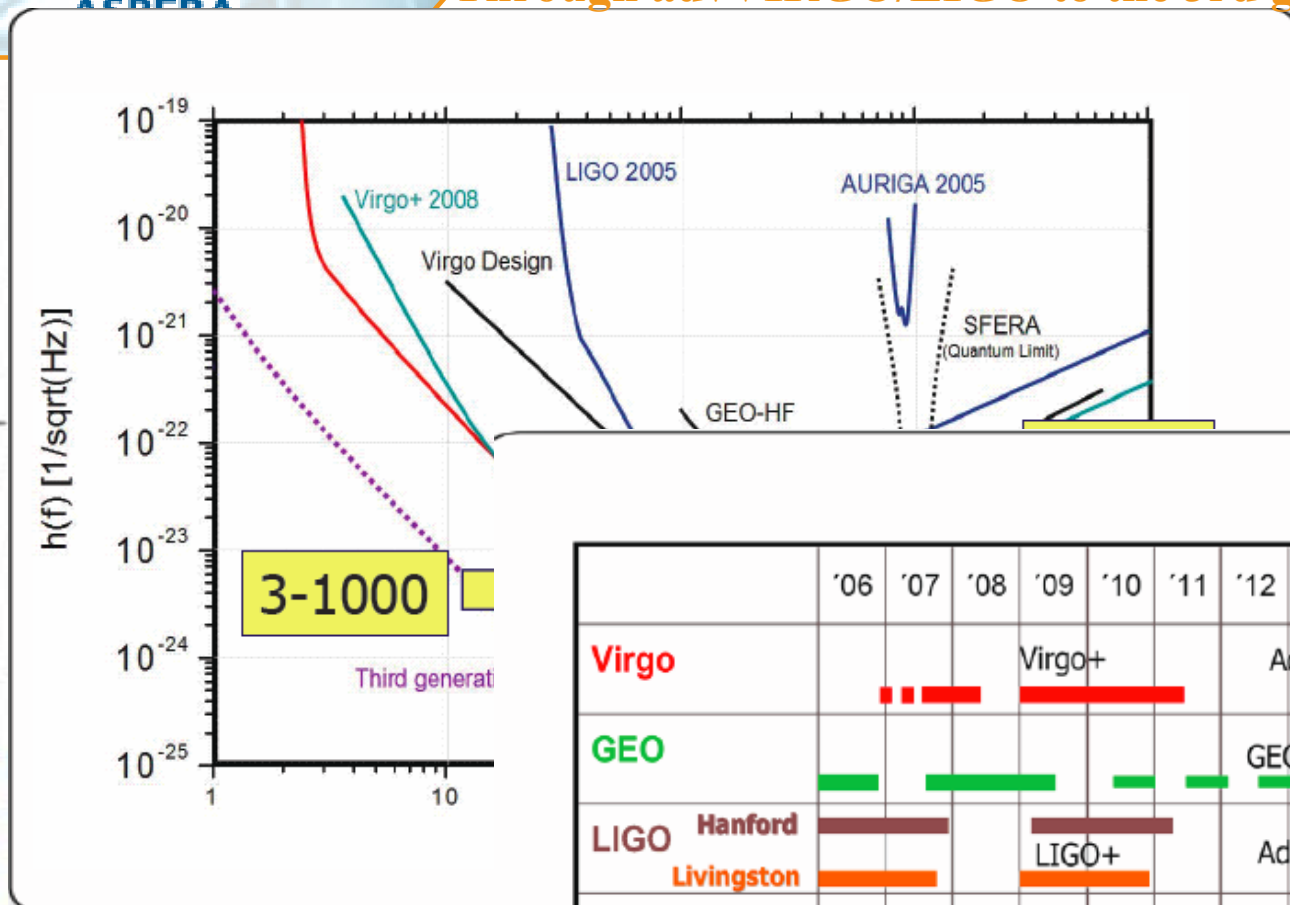
Coherent Analysis: why?

- Sensitivity increase
- Source direction determination from time of flight differences
- Polarizations measurement
- Test of GW Theory and GW Physical properties

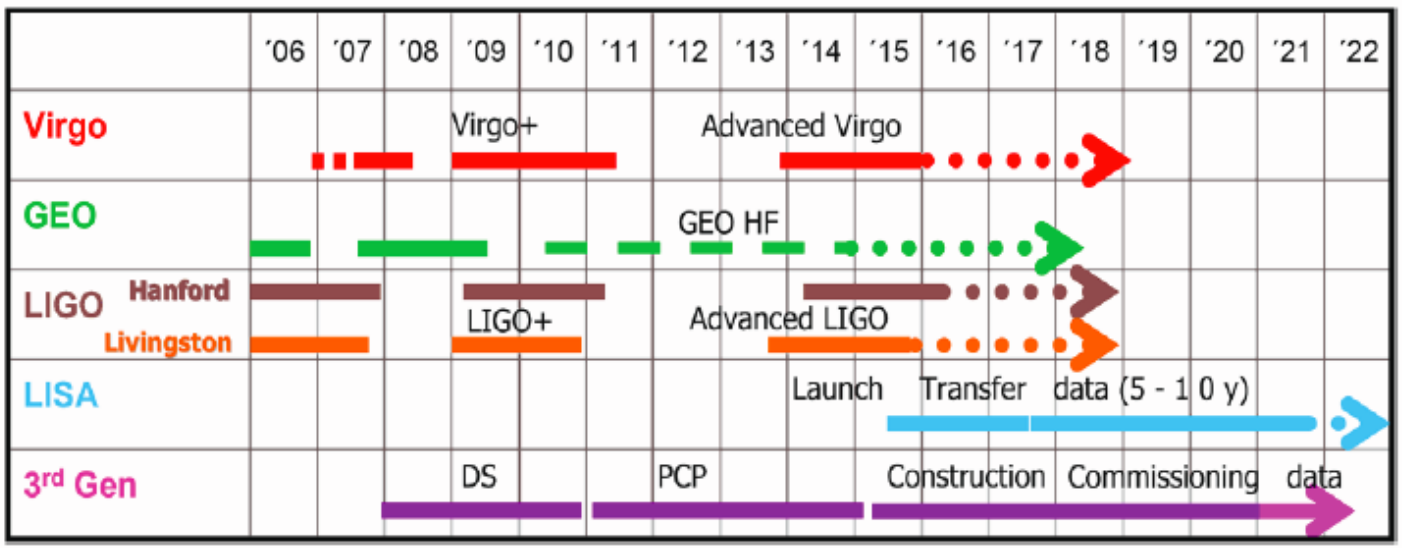
A LIGO/VIRGO/GEO 4 month common run

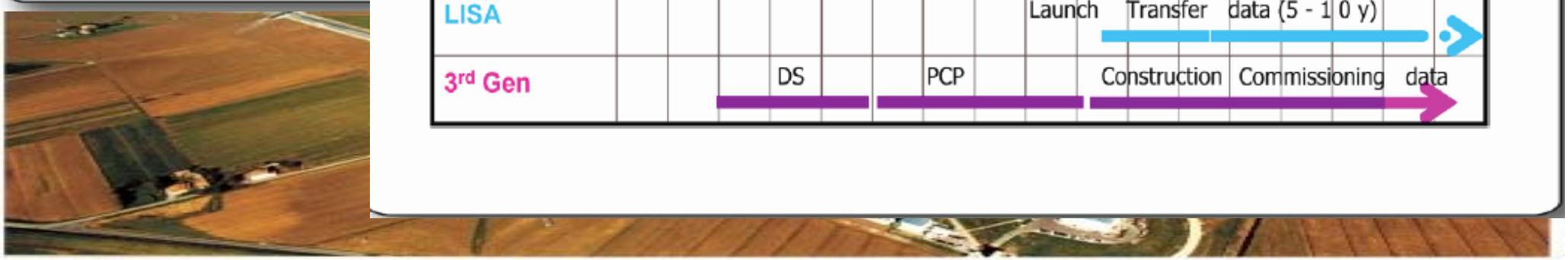


Through advVIRGO/LIGO to the 3rd generation GWA (Einstein Telescope)

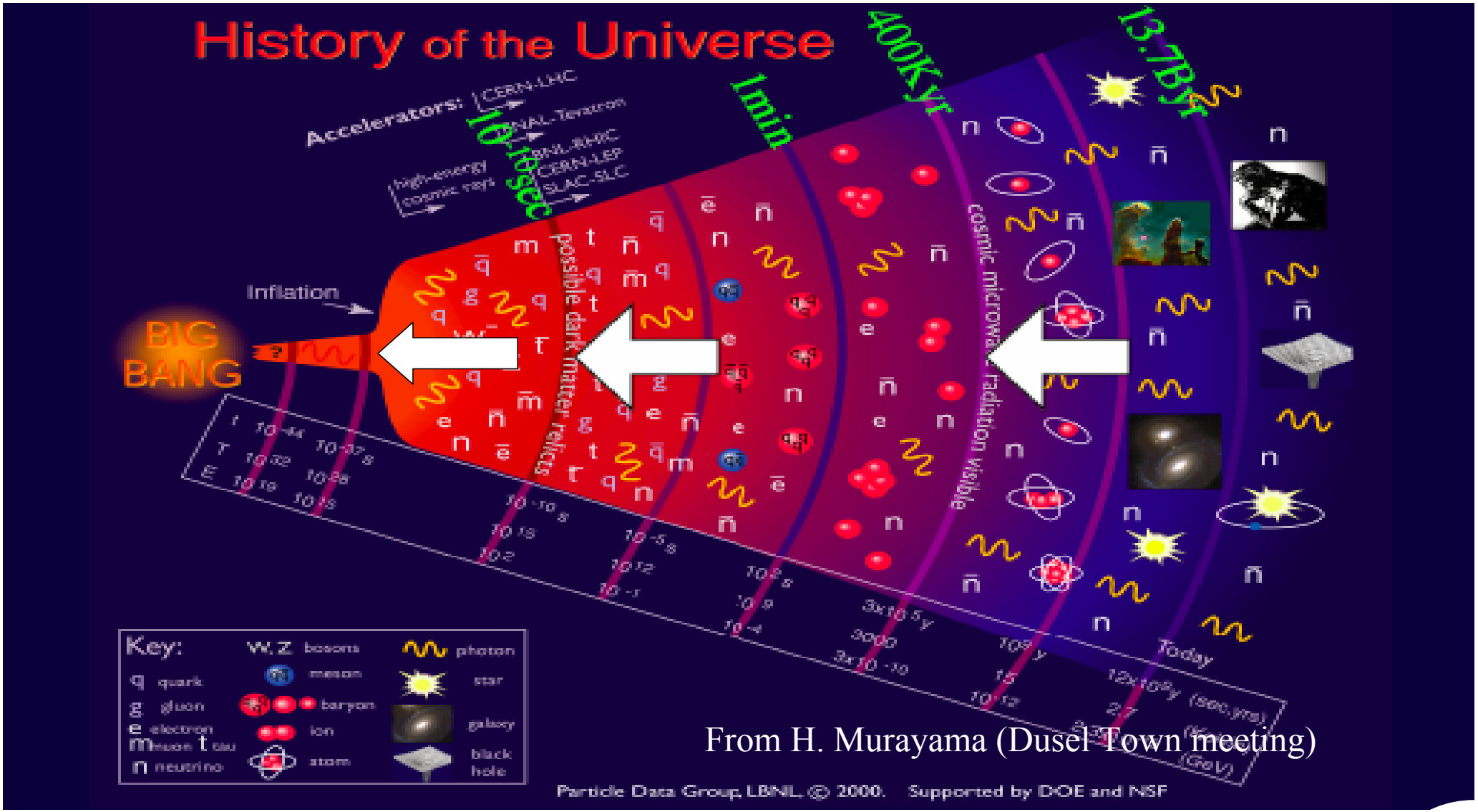


Design Study funded by EU





Underground science



From H. Murayama (Dusel Town meeting)

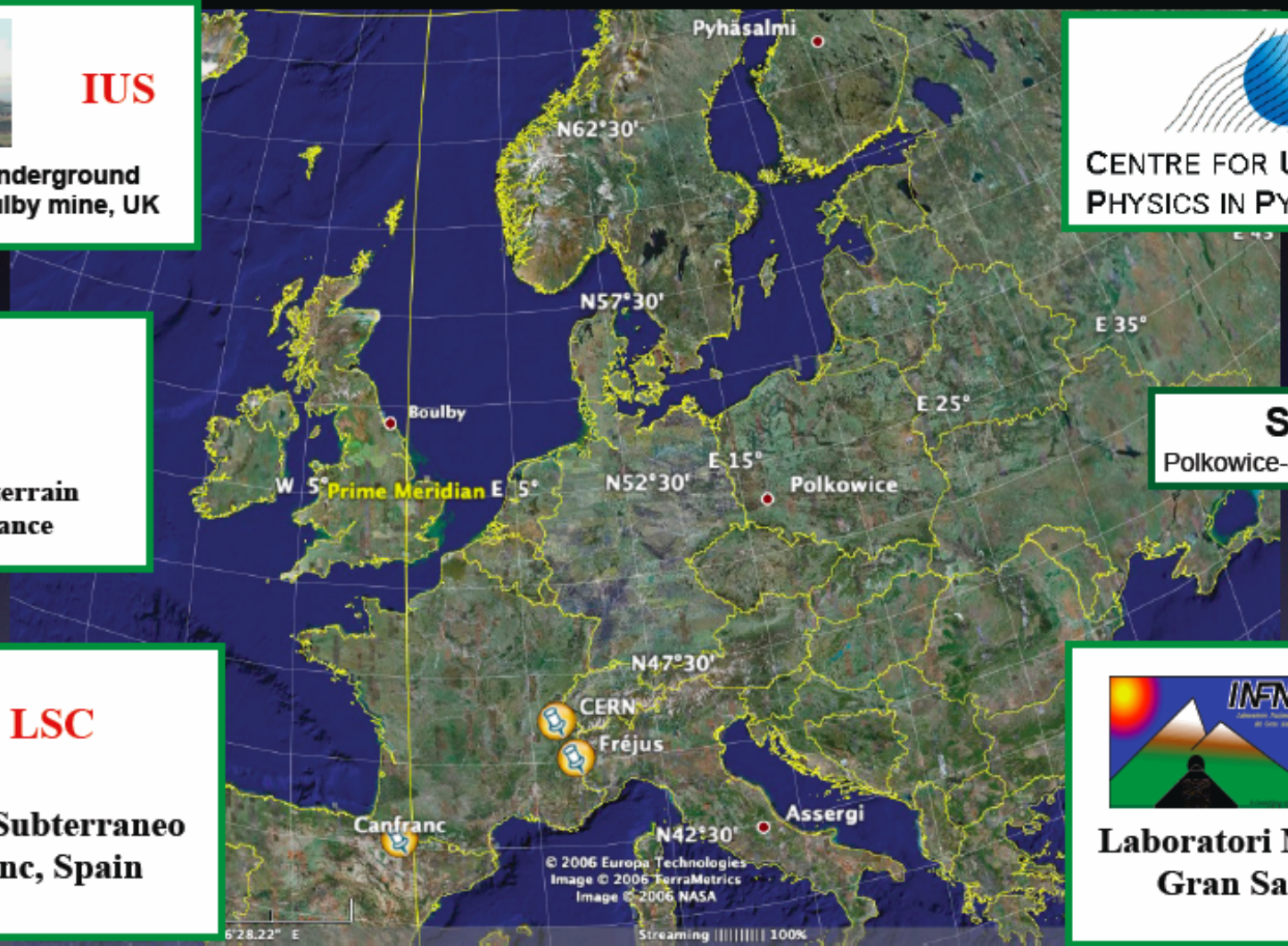
© AUGER

Six national underground science laboratories

IUS

Institute of Underground Science in Boulby mine, UK

CENTRE FOR UNDERGROUND PHYSICS IN PYHÄSALMI MINE



SUNLAB

Polkowice-Sieroszowice, Poland

LSM

Laboratoire Souterrain de Modane, France

LSC

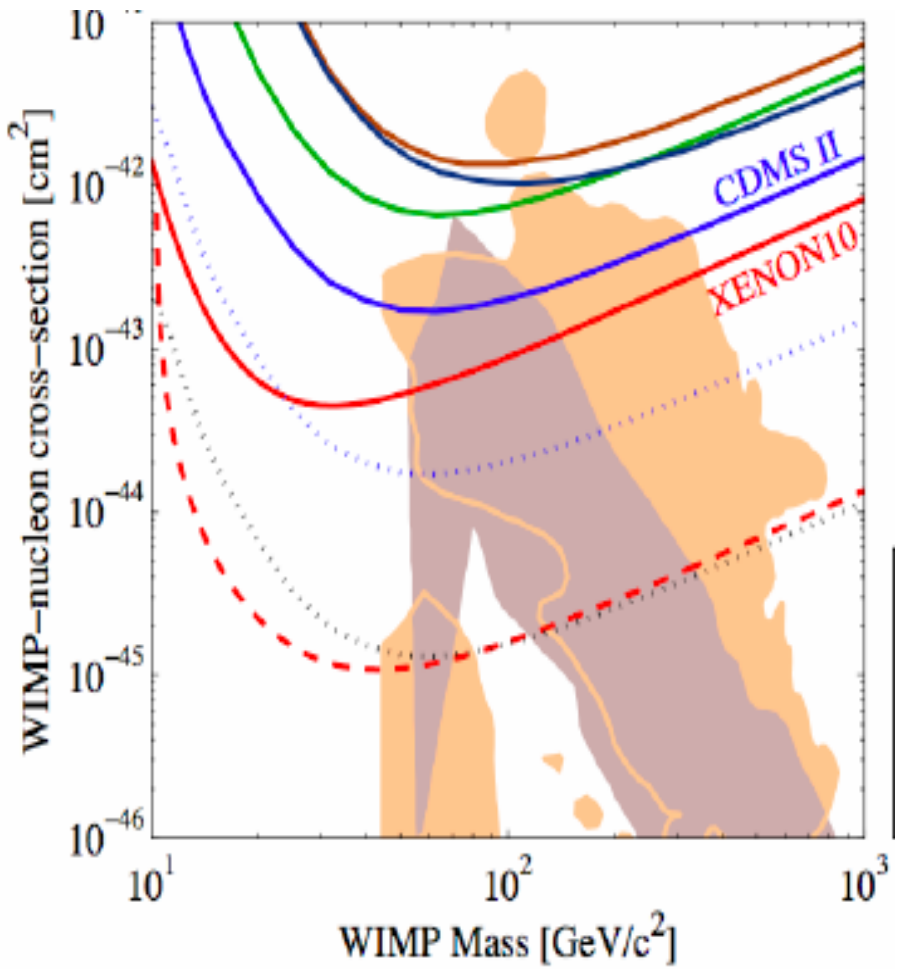
Laboratorio Subterraneo de Canfranc, Spain

LNGS

Laboratori Nazionali del Gran Sasso, Italy

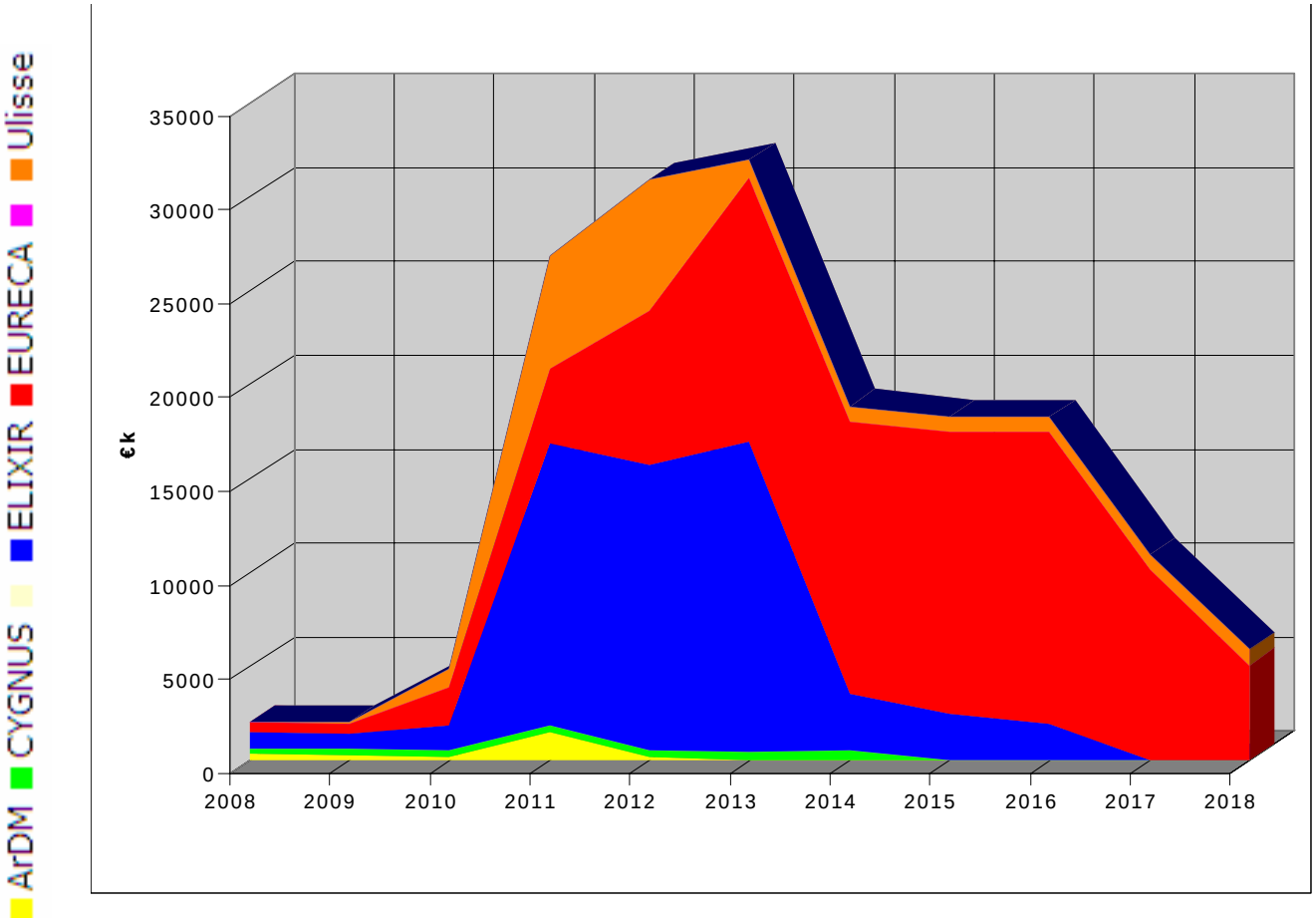
Dark matter experimental status and strategy

- Rapid evolution of sensitivity of discriminating experiments (**factor > 100 since 2000**)
- Cryogenic detector experiments (CDMS, CRESST, EDELWEISS) are progressing rapidly with their 10-kg stages
- Impressive progress has been realized over the last year by liquid target DM experiments (XENON, WARP, ZEPLIN-II)
- **The 10^{-8} pbarn " SUSY-rich " region should be reached within two years**
- But still more than 2 orders of magnitude progress in sensitivity still required compared to best present sensitivities
- Goal ≈ 10^{-10} pb @2018
- **PRC recommends to pursue in parallel 3 experimental lines: Ar, Xe, cryogenic detectors**



•In ≈ 2010, decision on 2 DM exp.

Dark matter timeline



20 M€/year and 70 FTE/year

(if 2 techniques are followed up)

My question: do we really need 5 experiments worldwide?

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
	Investment	Investment	Investment	Investment	Investment	Investment	Investment	Investment	Investment	Investment	Investment	
ArDM	360	260	210	1560	160	60	60	0	0	0	0	2670
CYGNUS	305	355	340	325	400	420	500	0	0	0	0	2645
ELIXIR	850	850	1350	15000	15200	16500	3000	2500	2000	0	0	57250
EURECA	500	500	2000	4000	8200	14000	14500	15000	15500	10200	5100	89500
Ulisse	50	50	1000	6000	7000	1000	800	800	800	800	800	19100

Neutrino mass: single beta decay

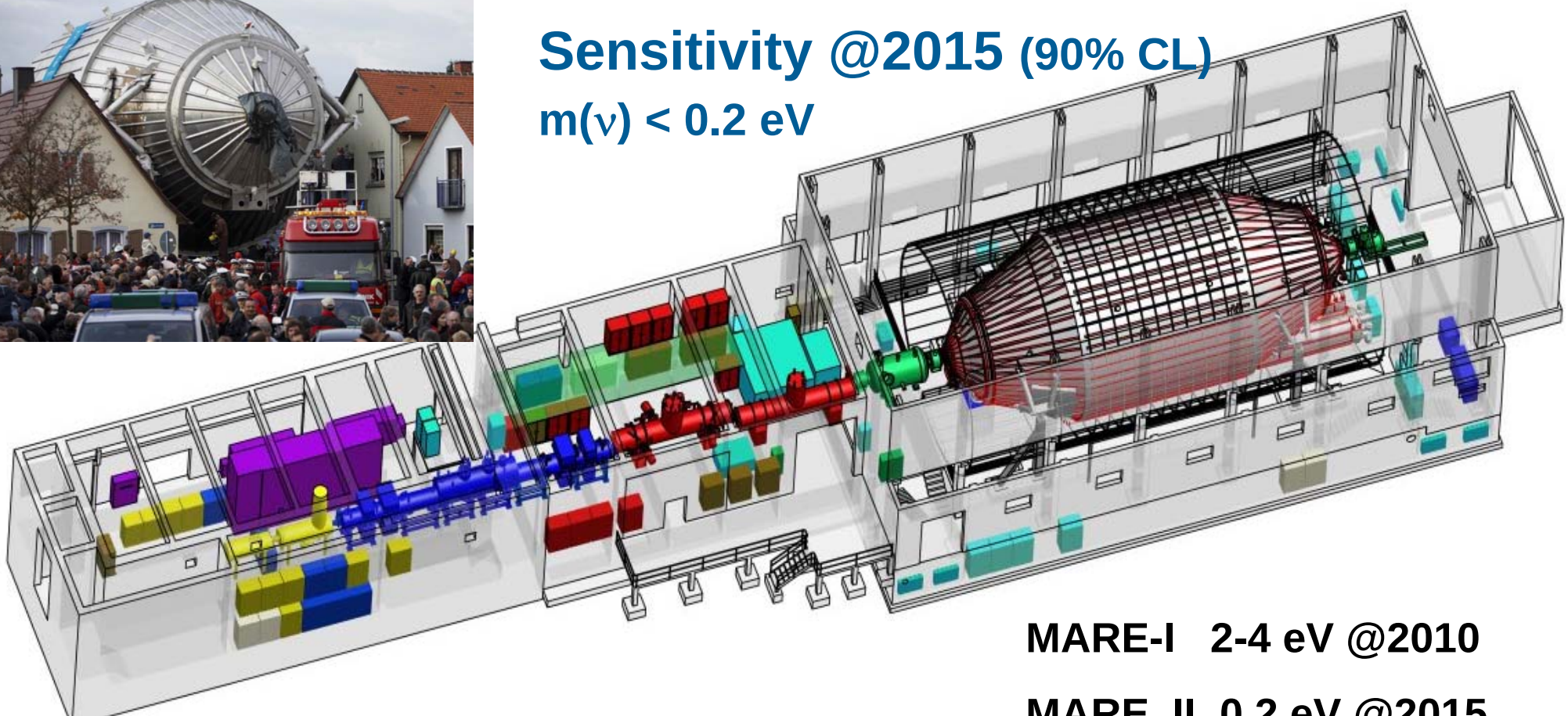
KATRIN

Czech Republic – Germany – Russian Federation – United Kingdom – United States

2007: 120 Collaborators from 16 institutions including 30 PhD and diploma

Sensitivity @2015 (90% CL)

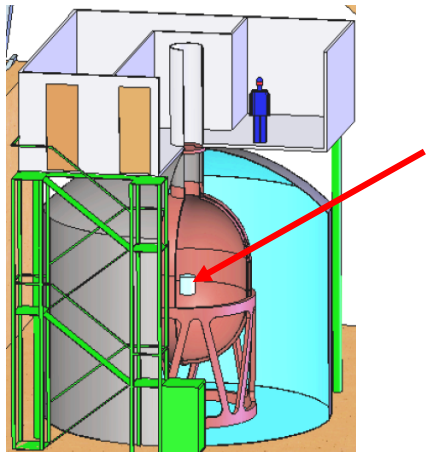
m(ν) < 0.2 eV



MARE-I 2-4 eV @2010

MARE_II 0,2 eV @2015

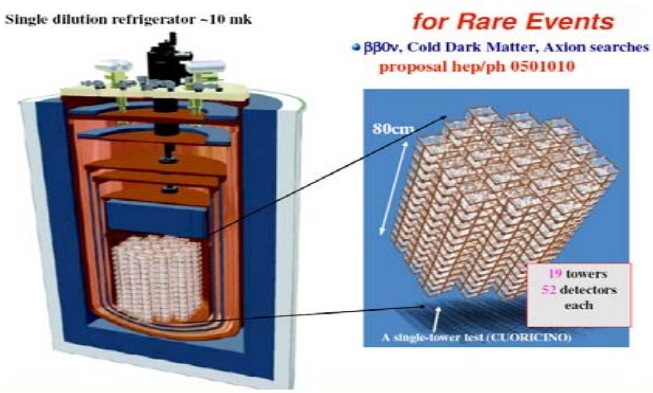
In operation CUORICINO, NEMO3 *Neutrino mass: double beta decay*



GERDA

Germany, Italy, Belgium, Russia (27 scientists in Europe)
Phase I and II funded

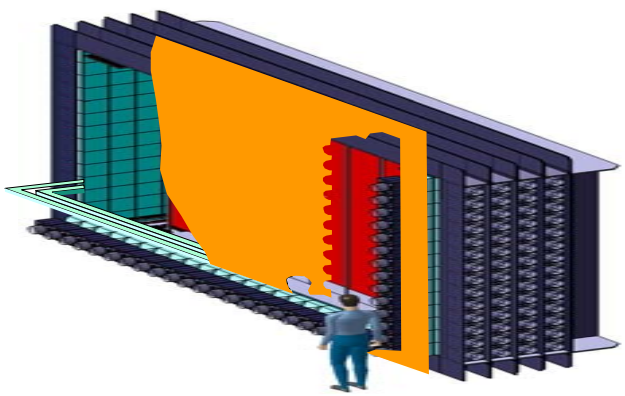
Ge diodes in liquid nitrogen
Background supression bu removing matter and active veto



CUORE

Italy, USA,Spain (12 scientists in Europe)

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



SuperNEMO

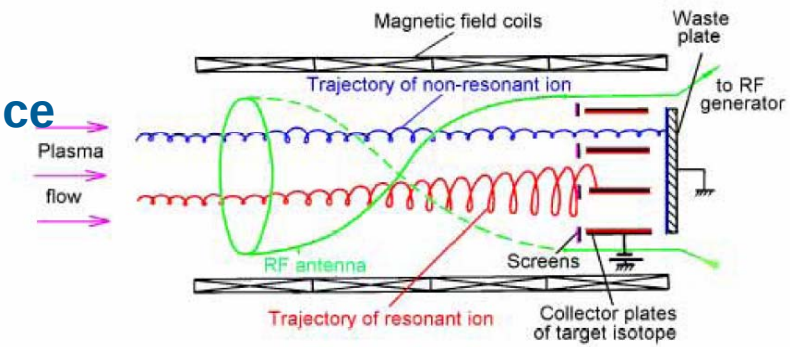
France, UK, Russia, Spain, USA, Japan, Czech Republic, Ukraine, Finland (30 scientists in Europe)

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

First modules in 2011

Neutrino mass Infrastructures

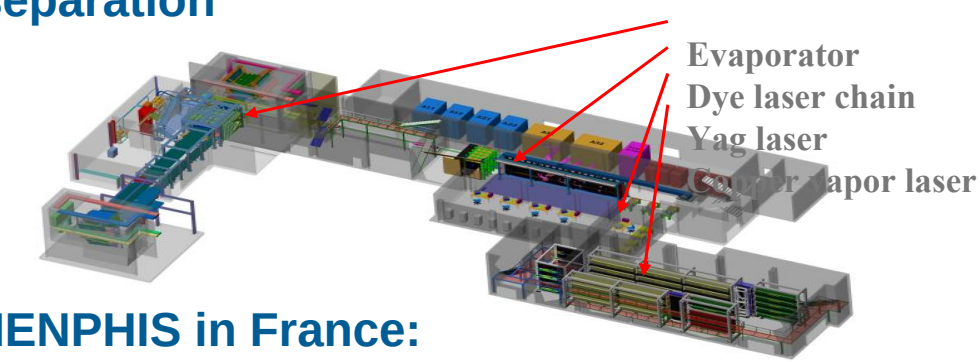
Isotope enrichment I: Ion Cyclotron Resonance



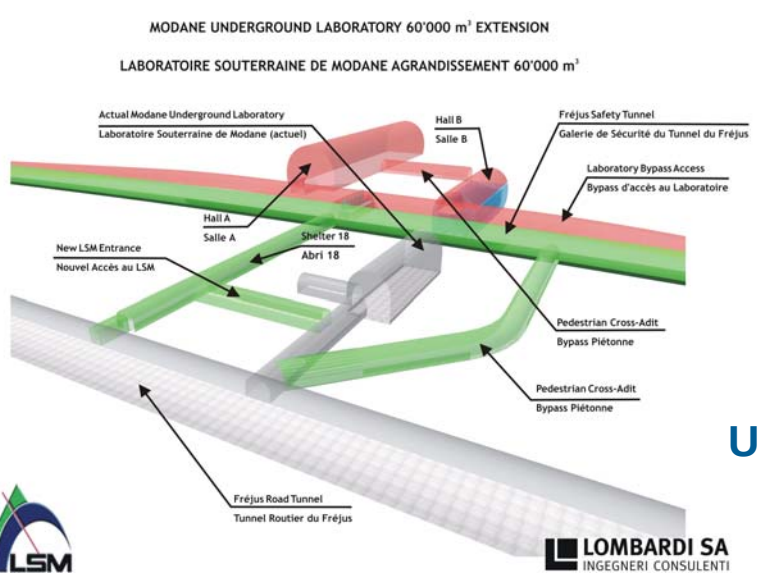
Allow production of ^{48}Ca, ^{76}Ge, ^{82}Se, ^{150}Nd, ^{100}Mo,…

Possible in principle to produce 10 – 100 kg

Isotope enrichment II: Laser isotopic separation



MENPHIS in France:
Could produce ^{150}Nd in large quantities

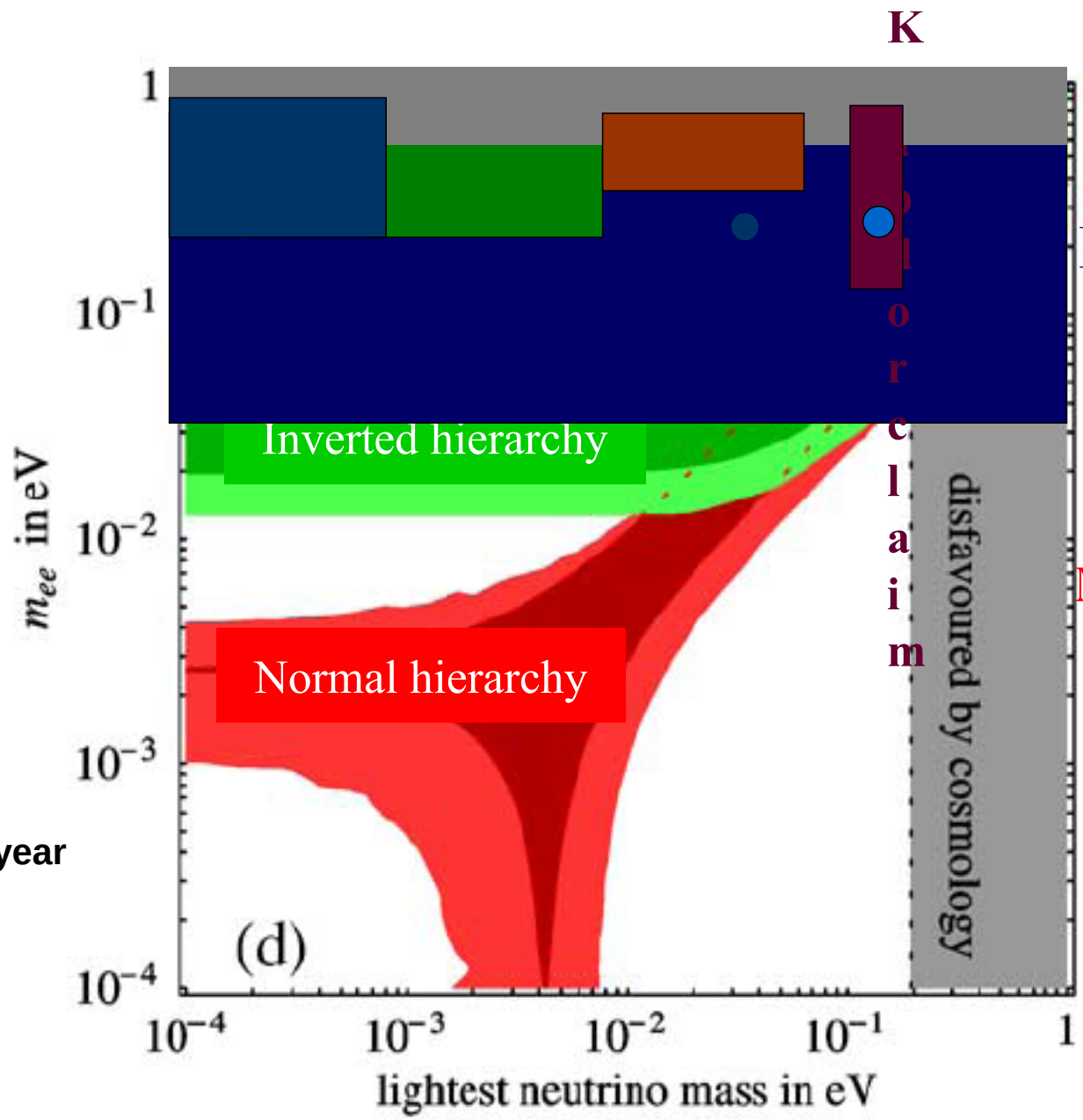


Underground Lab. extensions, e.g. Modane (2011-2013)

Neutrino mass

Limits in 2009

HM, NEMO3, Cuoricino Klapdor



Expected limits 2009 – 2015

CUORE,GERDA, SuperNEMO, Majorana,EXO,….

Results expected in 2013 - 2015

Need significant effort for R&D beyond this phase

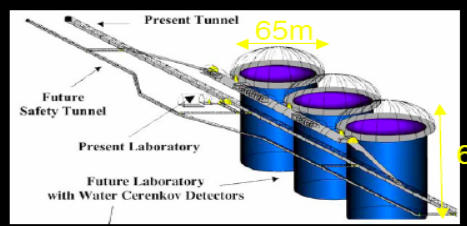
Future plans beyond 2015 will depends on the results of 100 kg phase

Investments 10 M€/year

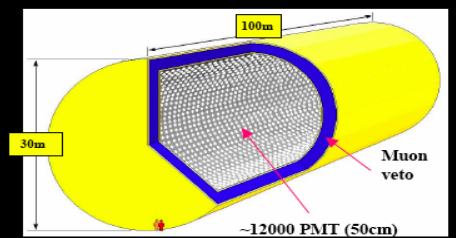
70 FTE/year

Large Underground detectors considered in LAGUNA

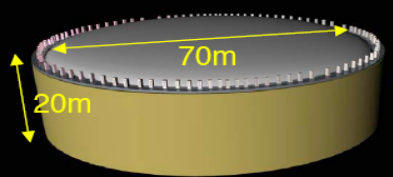
- Three types of large multi-purpose underground detectors with astrophysical program



Water Cherenkov (≈0.5 → 1 Mton)
MEMPHYS



Liquid Scintillator (→ 50 kton)
LENA



Liquid Argon (≈10→100 kton)
GLACIER

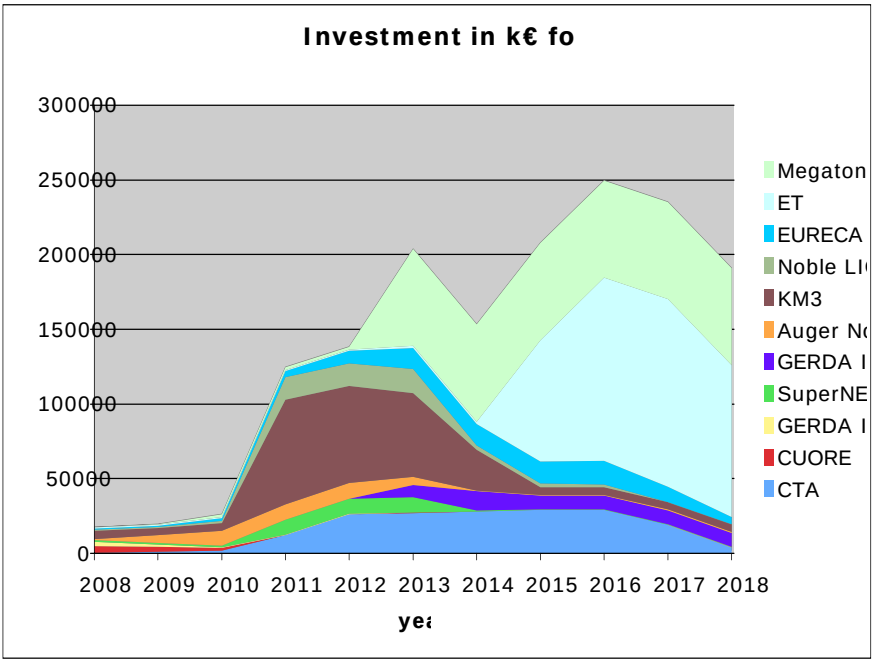
Table: Physics potential of the three types of detectors for proton decay and neutrino astrophysics

Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (400 kt)
proton decay, sensitivity $e^+\pi^0$ anti-ν K^+	 $0.5 \cdot 10^{35}$ $1.1 \cdot 10^{35}$	 - $0.4 \cdot 10^{35}$	 $1.0 \cdot 10^{35}$ $0.2 \cdot 10^{35}$
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) $3.0 \cdot 10^3$ $7.0 \cdot 10^3$ (p)	 $2.0 \cdot 10^5$ (anti-ν_e) - $1.0 \cdot 10^3$ (e)
Diffuse SN # Signal/Background events (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: $7.7 \cdot 10^4$ ^{8}B: $3.6 \cdot 10^2$	^{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	$1.7 \cdot 10^4$	Below threshold

- **LAGUNA a succesful EU Design Study**
- **World coordination:**
  - **since 2005 annual NNN conference**
  - **NNN05 Aussois, NNN06 Seattle,**
  - **NNN07 Hamamatsu, NNN08 Paris**

A summary ,from the phase I Roadmap

Astroparticle Physics for Europe



Field / Experiments	Cost scale per experiment (MŪ)	Desirable start of construction	Remarks
Observatories of the high energy universe:			
Gamma rays: Cherenkov Telescope Array CTA	100-150 MŪ	2011	Physics potential defined from present gamma experiments. Emerging ESFRI
Neutrinos: KM3NeT	150-250 MŪ	2011	FP6 Design Study. ESFRI, FP7 Preparatory Phas
Charged Cosmic Rays: Auger North	40-50 MŪ	2011	Worldwide sharing (shown 50% Europe is shown)
Underground Observatories:			
Dark Matter Search: Low background experiments ton-scale mass	50-100 MŪ	2013	2 different techniques (shown cost of one)
Properties of neutrinos: Double beta experiments ton-scale mass	50-150 MŪ	2013	2 experiments with different nuclei or different technique (shown cost of one)
Proton decay and low energy neutrino astronomy: Large infrastructure for p-decay and ν astronomy on the 100kt-1Mton scale	300-500 MŪ	Civil engineering: 2013-2015	3 technological options FP7 Design study (Worldwide, shown 30-50 % the European part)
Underground gravitational wave antenna: Third generation GW interferometer	300 MŪ	Civil engineering 2013-2015	FP7 Design Study

ESA cosmic vision

- ✓ 4 M type (<300 M€) missions for 2015-2016
  - ✓ CROSS-SCALE, MARCO-POLO, PLATO and DUNE/SPACE (dark energy)
  - ✓ ESA believes only MARCO-POLO within 300 M€
- ✓ 3 L type (B€) misions for 2018
  - ✓ TANDEM/LAPLACE, XEUS and LISA
  - ✓ LISA has priority but worries about state of preparation (LISAPATHFINDER)
- ✓ Calendar
  - ✓ DUNE/SPACE were asked to define a common mission in 2008 (also TANDEM/LAPLACE)
  - ✓ By Sept 2009: 2 M and 2 L
  - ✓ Select 1 M and 1 L by 2011. Their choice is correlated.
- ✓ LISA/Dark Energy are common priorities across the Atlantic. Sharing is optimal strategy.
- ✓ Also strong interest in some national agencies for the US Dark Energy program (eg. SNAP spectrograph studies funded by CNES)

>Roadmap phase III

Date: 26/09/2007
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Suppl.:
Rubrique:

Le Monde

PHYSIQUE SEPT PROJETS DE GRANDS INSTRUMENTS

L'Europe organise sa traque aux astroparticules

AMSTERDAM
ENVOYÉ SPÉCIAL

L'étoffe de l'Univers demeure un mystère : seuls 4 % de la matière qui le composent nous sont connus. Le reste ? De la matière sombre et de l'énergie noire, dont on ignore la nature exacte. La physique des astroparticules a l'ambition, par l'étude des neutrinos, des protons et autres rayons cosmiques, de résoudre cette énigme.

Mais cette jeune discipline est confrontée à un problème plus terre à terre, résumée par la définition qu'en donne le Petit Larousse 2008, où le terme « astroparticu-

Une stratégie affinée lors d'une réunion qui s'est achevée à Amsterdam le 21 septembre.

« *Actuellement, l'Europe des astroparticules compte 2 000 chercheurs, qui dispasent de 70 millions d'euros par an*, explique Stavros Katsanevas, coordinateur d'Aspera et chercheur à l'IN2P3 (CNRS). *Les projets que nous avons identifiés représentent un investissement de 1,4 milliard d'euros sur dix ans.* » Soit un doublement des crédits. Les instruments qui traquent les astroparticules sont en effet de plus en plus ambitieux.

Qu'il s'agisse de détecteurs sou-

couvrirait un volume d'un kilomètre cube en mer Méditerranée et dont les études de conception sont financées par la Commission européenne.

Aspera table sur la coopération internationale. « *Les astroparticules s'y prêtent*, convient Joseph Dehmer, directeur de la division Physique à la National Science Foundation américaine. *Les infrastructures restent de taille moyenne, et elles sont suffisamment nombreuses pour laisser place à la négociation. Quand il y a une seule machine au monde, comme l'accélérateur du CERN, c'est bien plus difficile.* »

- ApPEC/ASPERA will
  - Issue general priorities by autumn 2008
  - Form commun fund for Design studies
  - Form PAC in 2009-2010?
- Coordinate with CERN strategy group
- Discuss relationships of APP with CERN and other PP labs
- Coordinate with Astrophysics (ASTRONET)
  - Handle the delicate problem of eventually different priorities (KM3 vs CTA)
- Coordinate with other regions (OECD?, FALCtype? , PANAGIC?)
  - How can we coordinate ?
    - CTA/AGIS, DUSEL type physics (Megaton type, dark matter, neutrino mass)

Summary

- The european astroparticle physics roadmap process will define priorities
  - First constructions by 2011?
  - Some parallelism with US (and Asian?) …
- Emerging priorities (on ground or underground)
  - 3 large infrastructures for High Energy Universe (KM3, CTA, Auger-North)
  - Ton-scale detectors for dark matter and neutrino mass (How many decide by 2010)
  - Beyond 2013-2015
    - A large undergound detector for proton decay and/or neutrino oscillation and/or neutrino astrophysics
    - A 3rd generation gravitational wave antenna beyond
- Emerging priorities in space *(ESA cosmic vision)*
  - Convergence concerning astrophysics missions: Dark Energy and LISA?
- Interregional coordination of at least the roadmaps is perceived as a necessity by ApPEC/ASPERA
  - In what context? OECD? FALC-type? Other (e.g. PANAGIC)?

photo: BOREXINO calibration