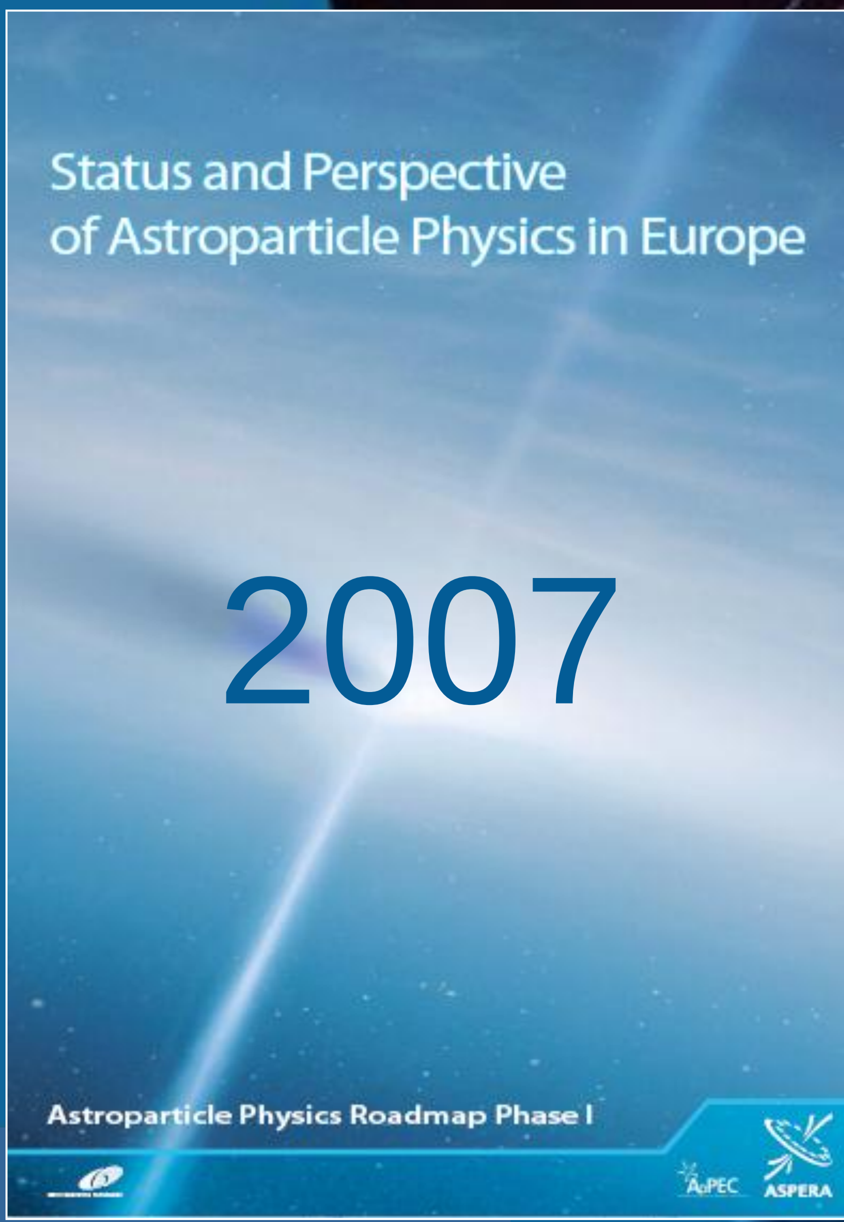
# Astroparticle Physics

## The 2011 ASPERA Roadmap

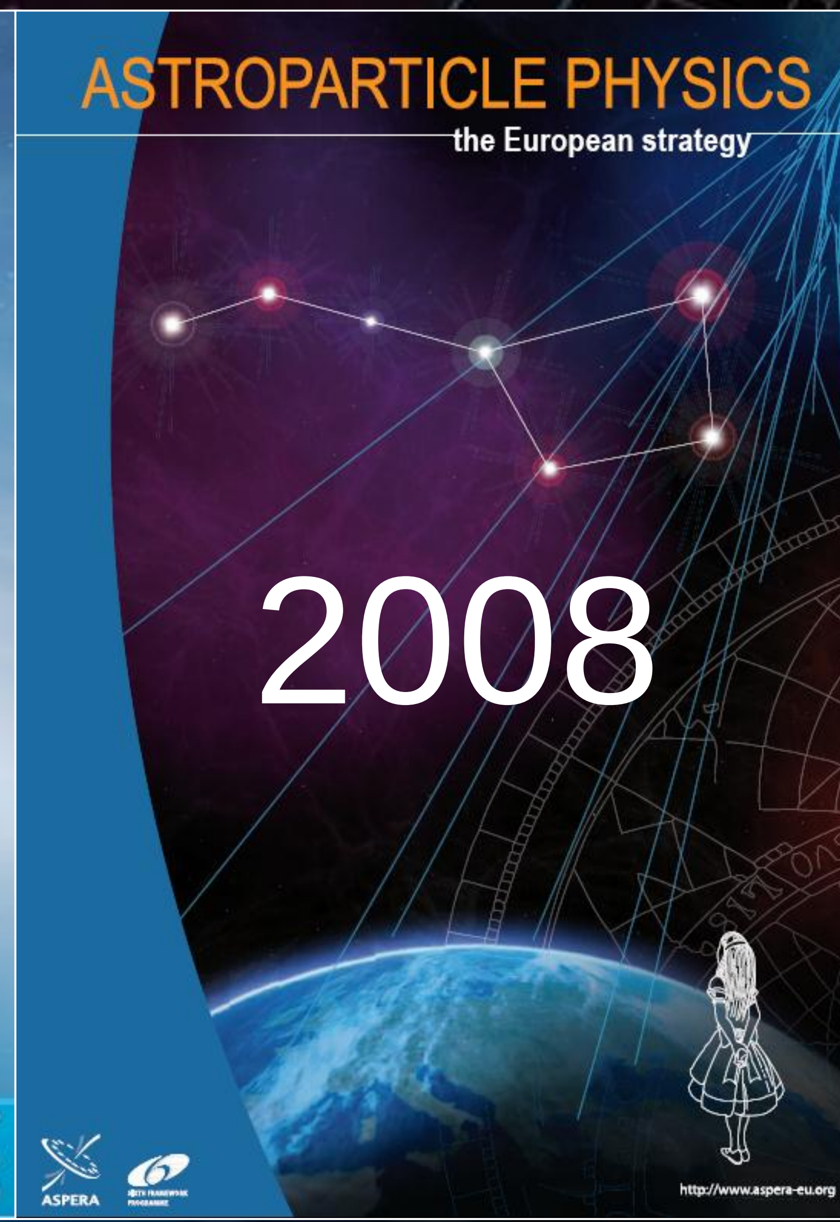
Christian Spiering, DESY

Paris, Nov. 21, 2011

http://www.aspera-eu.org




2007




2008


2011

http://www.aspera-eu.org

# Why a new Roadmap?

- Dynamics of the field!
- European Strategy for Particle Physics 2013
- Financial constraints
- Broadening of Community

# in 2008 ...

# …the Magnificent Seven

# in 2011 ...

- Medium scale, ongoing/extension
- Large scale (few hundred M€), mid of decade
- Very large scale (several hundred M€ to G€), end of decade

# Medium scale

There are a few projects which need immediate and substantial funding,

- be it that they have an impressing momentum which needs to be maintained;
- that they enter a region with high discovery potential; that they go hand in hand with LHC physics;
- that they are technologically ready and have a worldwide community behind them;
- or, finally, that a delay of decision and funding could jeopardize or even definitely kill the project.

**In this spirit, we prioritize the following projects for immediate funding, and urge the agencies to join their forces for an effective, substantial support:**

# Medium scale

- Advanced detectors for gravitational waves
- Dark Matter
- Neutrino properties
- Extension of the  Modane Underground Laboratory (LSM)

http://www.aspera-eu.org

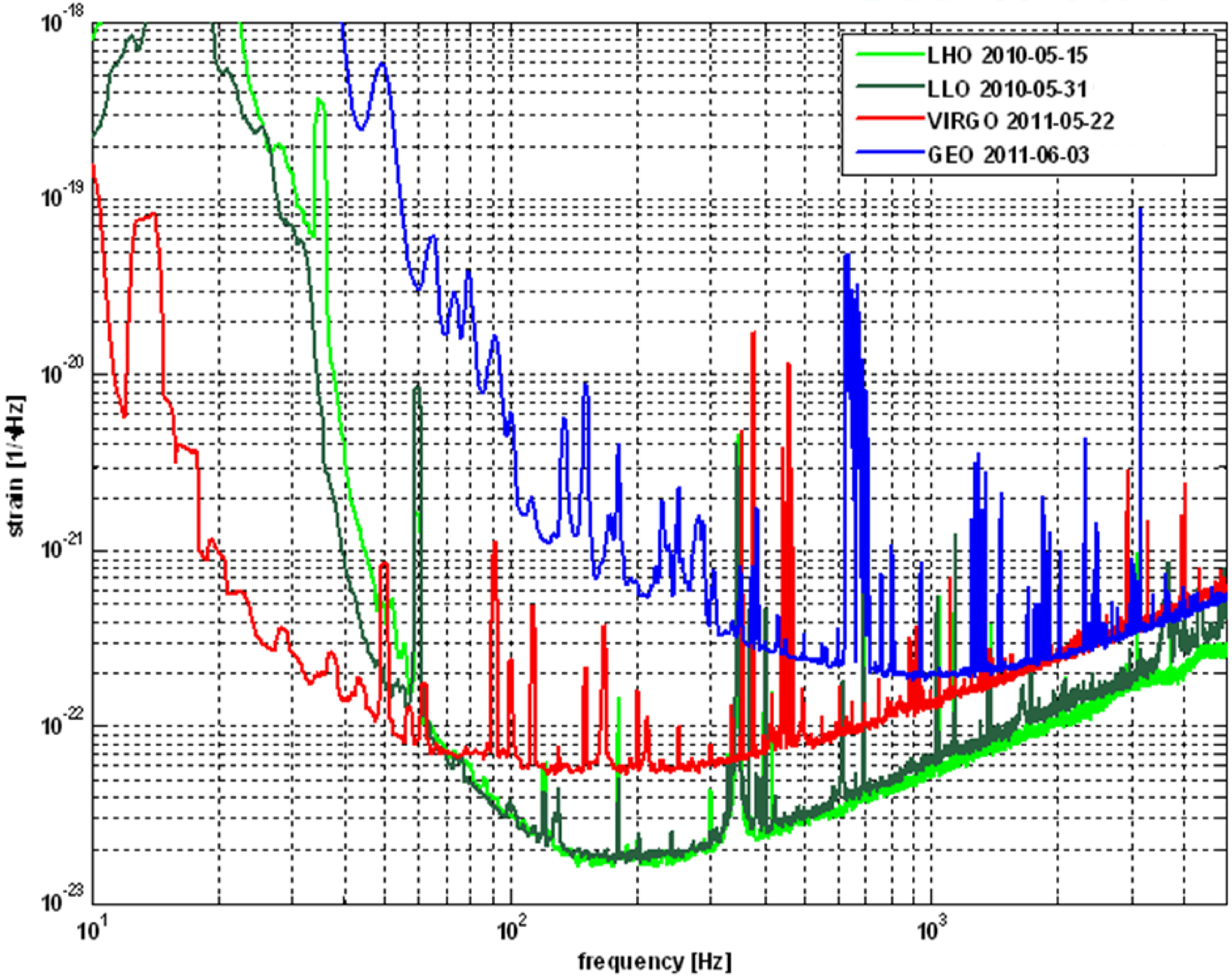
# Medium scale

- **Advanced detectors for gravitational waves**
- Dark Matter
- Neutrino properties
- Extension of the  Modane  Underground Laboratory (LSM)

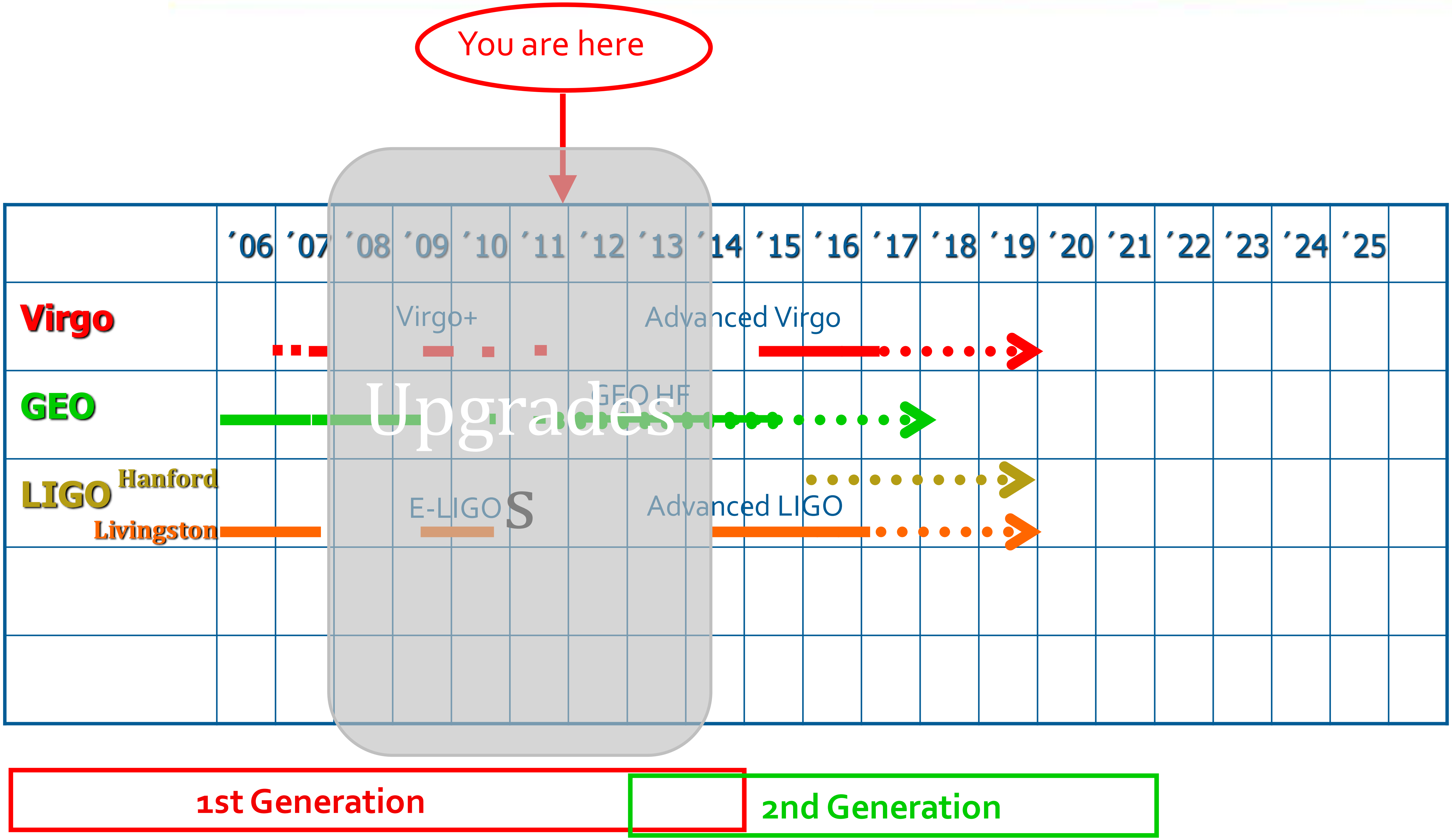
# The current GW Network

# Sensitivites achieved

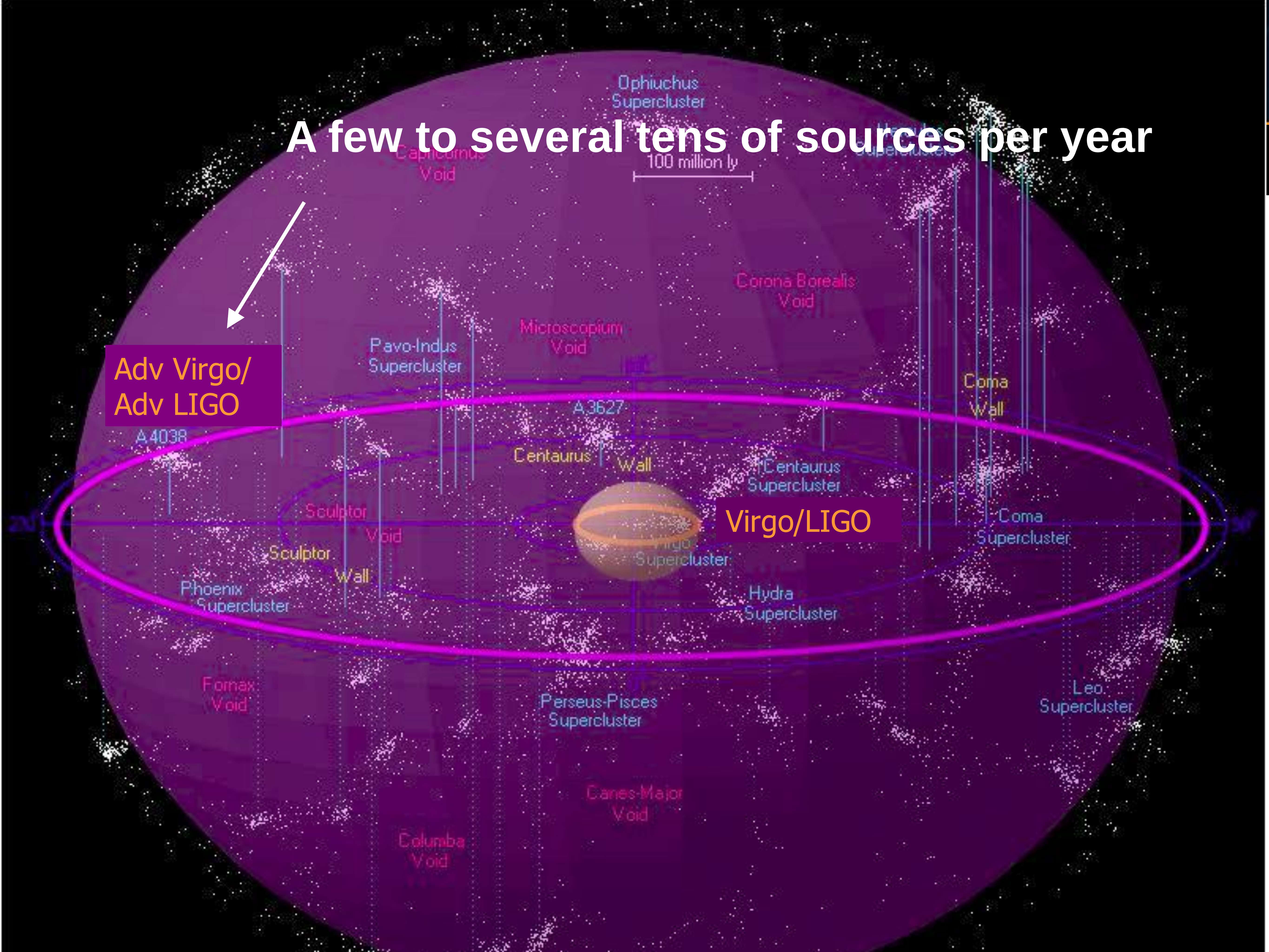
LSC LIGO Scientific Collaboration
VIRGO



# GW Timelines



# A few to several tens of sources per year



# Recommendations Gravitational Waves
## Advanced Detectors

With advanced VIRGO, advanced LIGO and GEO-HF, a discovery in the next five years becomes highly probable. This would open an entirely new window to the Universe.

**We urge the agencies to continue substantially supporting the on-going and planned upgrades to advanced detectors.**

# Medium scale

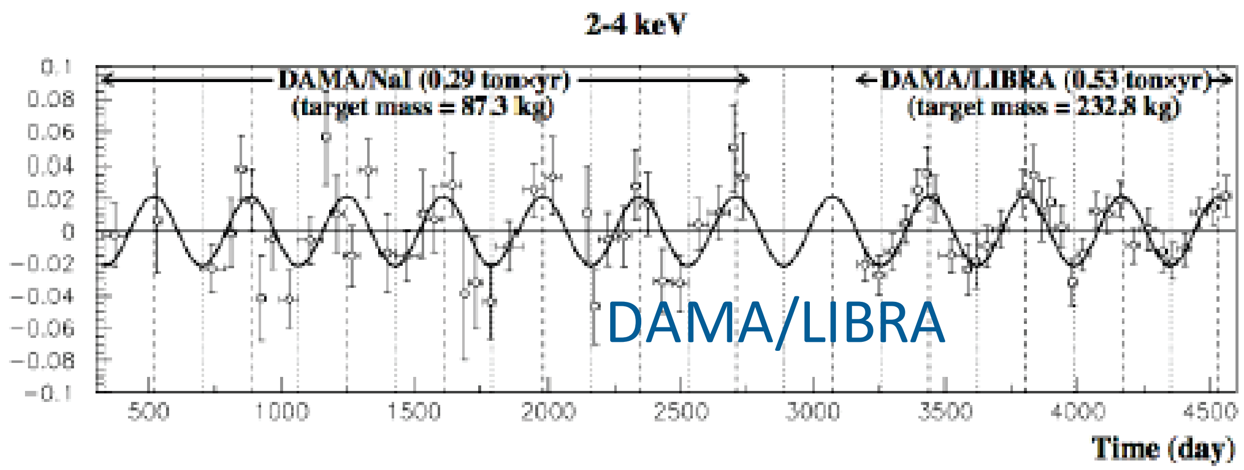
- Advanced detectors for gravitational waves
- **Dark Matter**
- Neutrino properties
- Extension of the Modane Underground Laboratory (LSM)

http://www.aspera-eu.org

# Dark Matter Highlights 2011

ASPERA Astroparticle Physics for Europe

- Annual Modulations:
  - DAMA/LIBRA new results
  - CoGenT

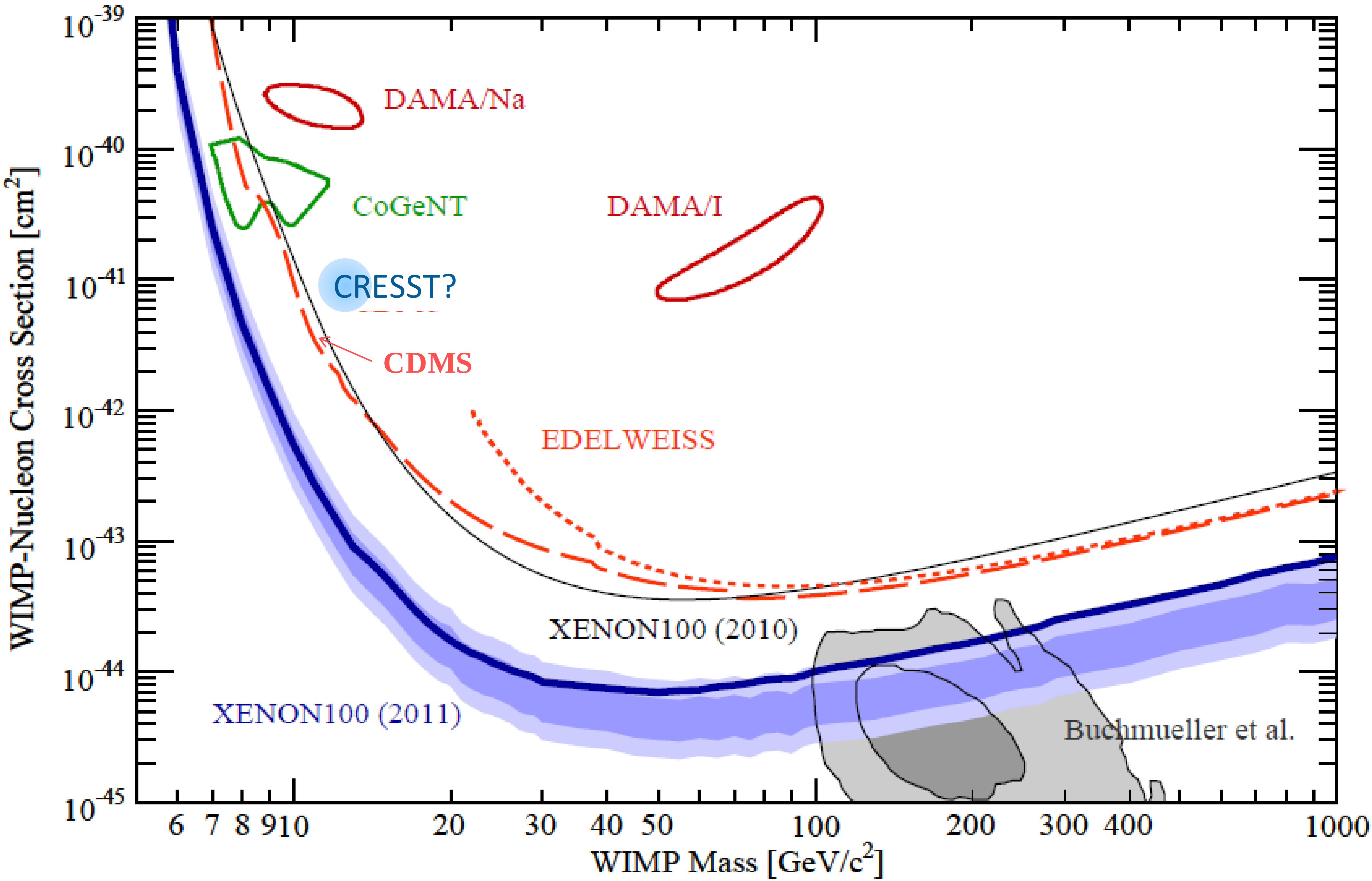


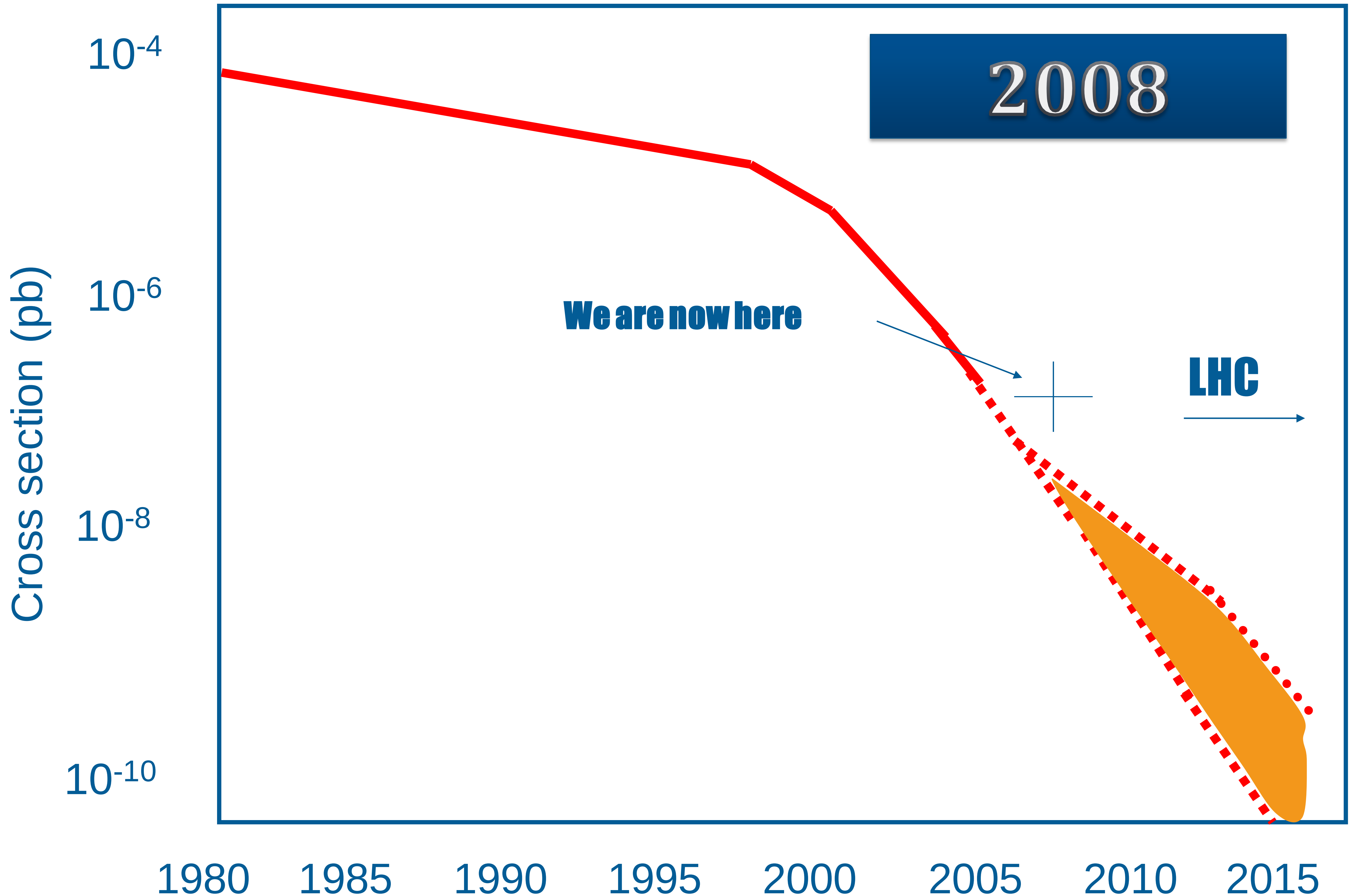

- ZEPLIN-III final results
- CRESST excess (?)
- Edelweiss now close to CDMS
- Combined analysis Edelweiss-CDMS

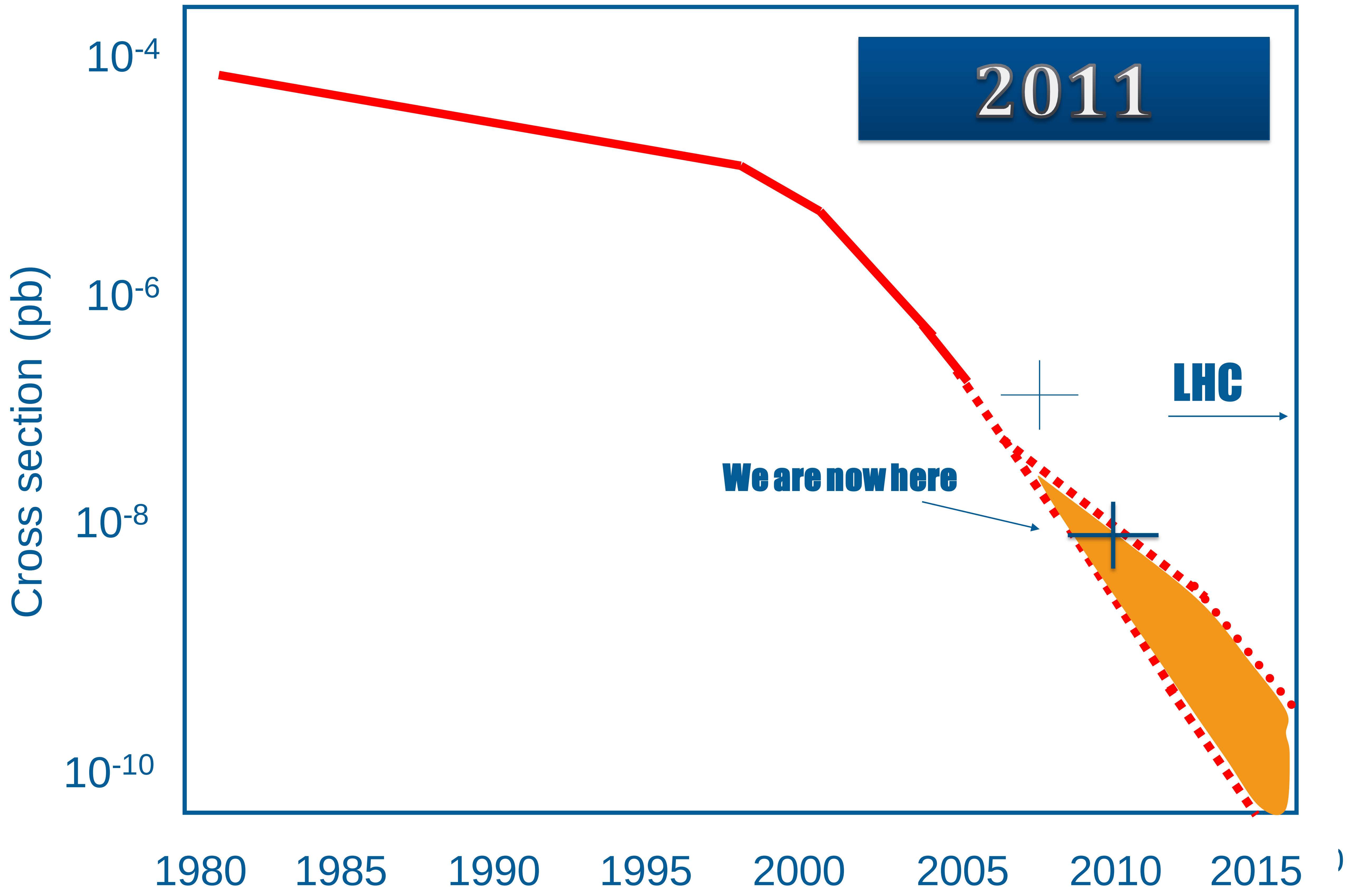
Edelweiss-II

- XENON100 achieves record limit (will be soon even better!)
- XENON1t installation has started
- Spin-dependent: SIMPLE, COUPP, SK, IceCube

# Dark Matter Highlights 2011




2008
We are now here
LHC
Cross section (pb)
10-4
10-6
10-8
10-10
1980
1985
1990
1995
2000
2005
2010
2015


2011
Cross section (pb)
$10^{-4}$
$10^{-6}$
$10^{-8}$
$10^{-10}$
LHC
We are now here
1980
1985
1990
1995
2000
2005
2010
2015

# XENON

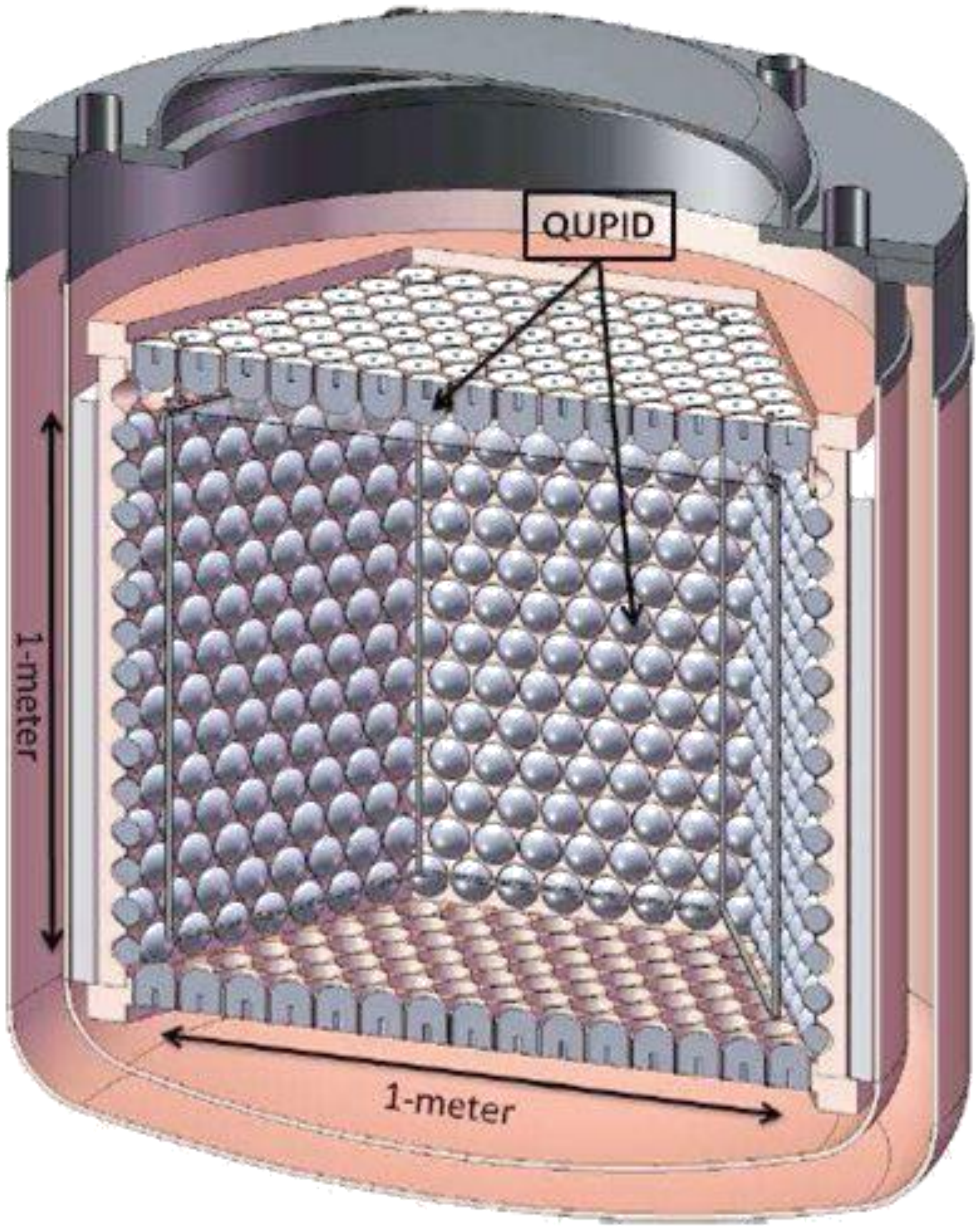
***USA, Switzerland, Italy, Portugal, Germany, France, Japan, China***

## XENON 100

- at Gran Sasso
- 50 kg fiducial / 170 kg total
- starting end of 2009
- achieved 2011: ~ 7 x $10^{-45}$ $cm^2$
- projected 2012: ~ 2 x $10^{-45}$ $cm^2$

## XENON 1t

- projected 2013:
- 1000 kg target < $10^{-47}$ $cm^2$



# EURECA

***Germany, France, UK,***
***Spain, Russia, Ukraine***

combines all European cryogenic DM efforts:

*R&D cooperation with CDMS/GeoDM*

**2009/11: design study → TDR**

2011/12: LSM excavation
2012/13: construction components
~ 100 kg fiducal target at present sites,
~ $10^{-45}$ cm$^2$

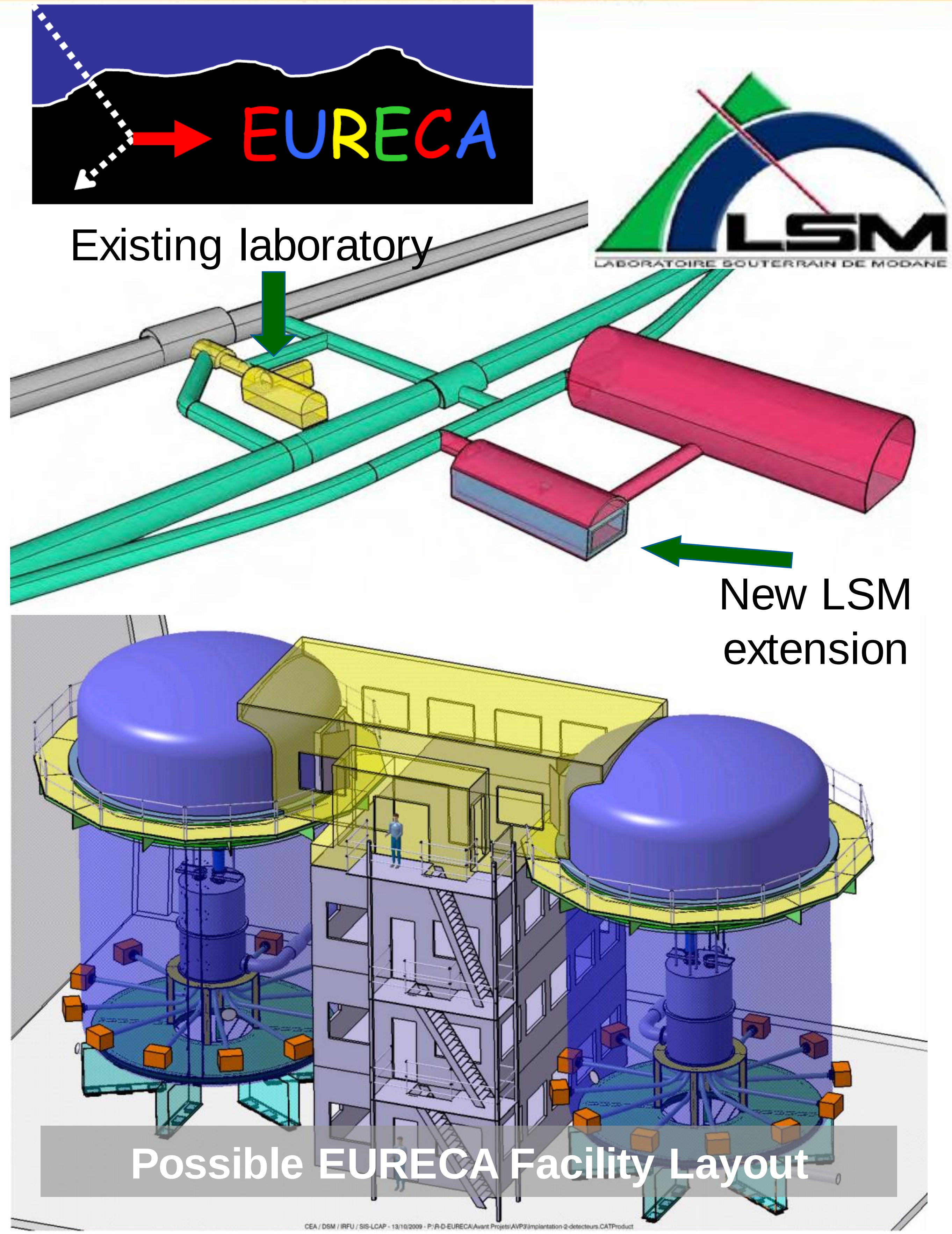
**2013/14: construction at LSM**

**2015: begin data taking at LSM**

**2015 – 2018:**

- continuous upgrade to 1t target
- ~ $10^{-46}$ cm$^2$

**+ GeoDM (SuperCDMS)**



# Other DM activities

- NAI
  - DAMA/LIBRA @ Gran Sasso
  - ANAIS @ Canfranc
  - IceDM @ South Pole?

The committee strongly supports improving the DAMA/LIBRA experiment in terms of a lower detection threshold and a lower background, in order to better understand the modulation signal. A fully independent experiment based on the same or on a similar technology would be crucial to cross-check the DAMA/LIBRA effect.

- LAr
  - WARP @ Gran Sasso
  - ArDM @ Canfranc
  - Darkside @ Gran Sasso

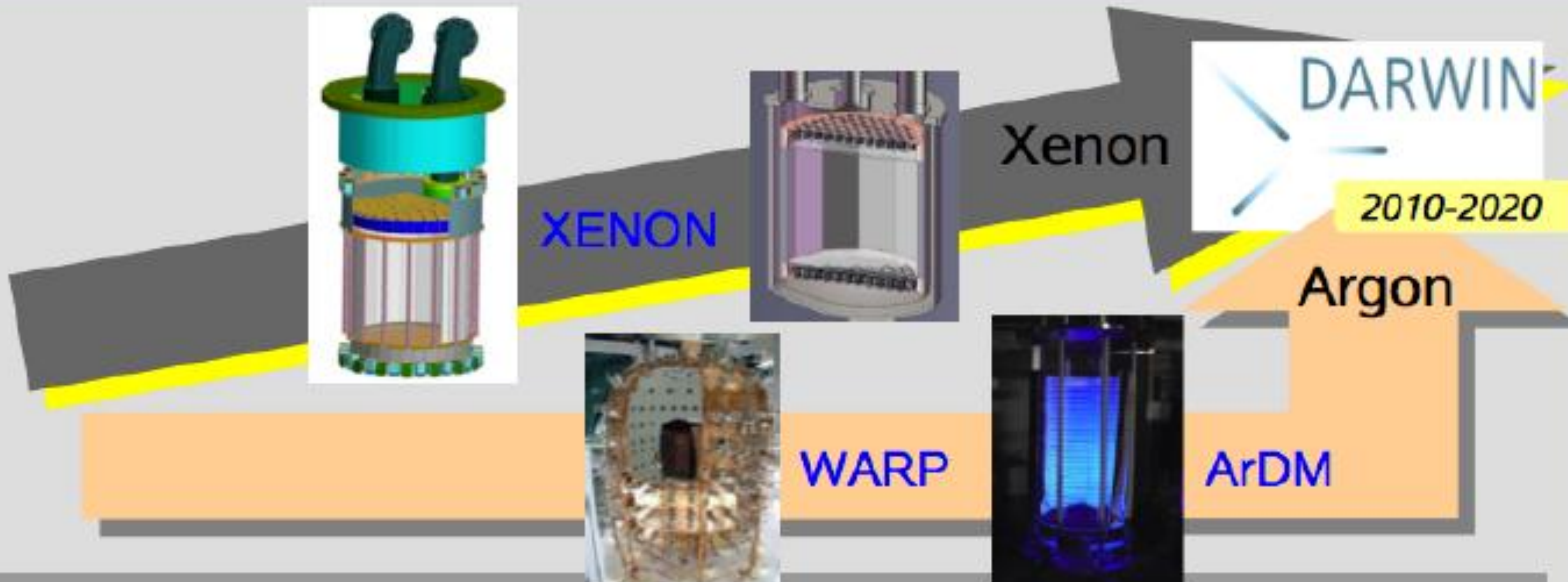
The committee endorses an expansion of the experiment SIMPLE with a lower background level in order to further increase its sensitivity to spin-dependent interactions. This search can be done in synergy with the possibilities provided by xenon (about 50% nuclei have half integer spin) and by the bolometric approach which offers the chance to study different odd-A target nuclei.

- SIMPLE (superheated droplets @ Rustrel)
- ROSEBUD (R&D for bolom. @ Canfranc)
- Directional detectors
  - DRIFT (prototype @ Boulby)
  - MIMAC, DM-TPC, NEWAGE

The committee recommends supporting the R&D activities related to the directional detection of WIMPs, in particular aiming at a substantial background reduction, as this may become essential to confirm the Galactic dark matter origin of the signal in case of a positive signal from the high-density target detectors.

# Beyond a ton with noble liquids

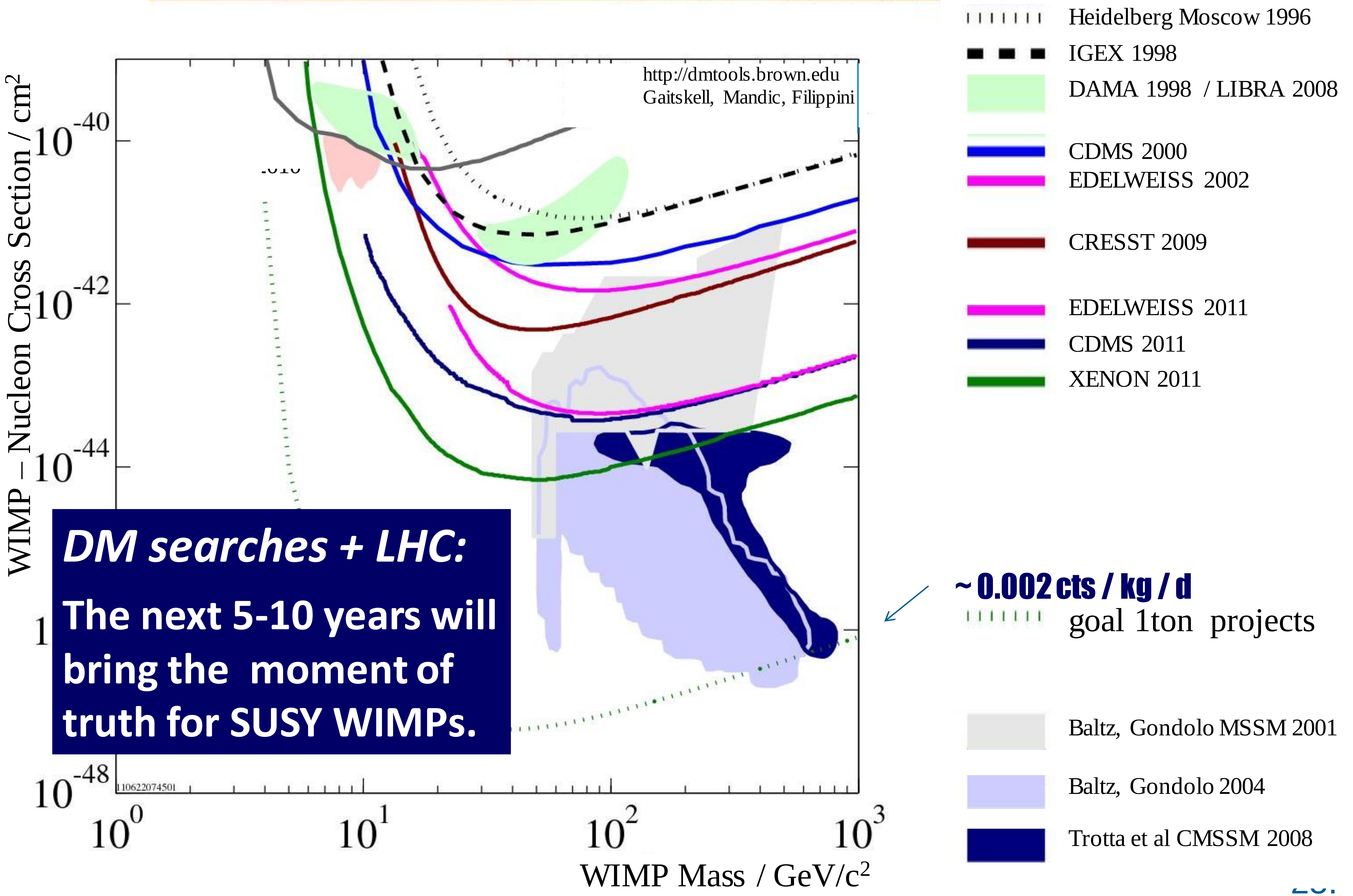
## DARWIN - Overview




**DARWIN – Dark Matter WIMP Search with Noble Liquids**

- *R&D and Design Study* for a next generation noble liquid facility in Europe. Approved by ASPERA in late 2009
- Coordinate existing European activities in LXe and LAr towards a multi-ton Dark Matter facility
- Physics goal: probe WIMP cross sections well below $10^{-47}$ cm²

# Towards the ton scale




***DM searches + LHC:***

**The next 5-10 years will bring the moment of truth for SUSY WIMPs.**

# Recommendations Dark Matter

- With the advent of the LHC and thanks to a new generation of astroparticle experiments using direct and indirect detection methods, the well-motivated SUSY - WIMP dark matter hypothesis will be proven or disproven within the next 5-10 years.
- The highly significant annual modulation signal observed by **DAMA/LIBRA**, and its interpretation in terms of dark matter interactions, will also be scrutinized in the next years**.**
- The dramatic progress of the liquid-xenon technology over the past 2-3 years demonstrates a high momentum, which must be maintained. The recently approved **XENON1T** at Gran Sasso laboratory is expected to start operation in 2014/15.
- The bolometric experiments **CDMS** and **Edelweiss** have recently provided upper limits close to those of XENON100 and move towards a closer US-Europe coordination. We recommend supporting the development of **EURECA**, which envisages one ton of sensitive mass, eventually in a common US-Europe framework.
- Looking beyond the scale of one ton, we strongly recommend that **DARWIN,** a program to extend the target mass of noble liquids to several tons, is pursued and supported.

# Indirect searches, axions

- **Indirect WIMP searches** do not require dedicated experiments. They **come "for free"** since X-ray and gamma-ray-missions, as well as neutrino telescopes, are mainly driven by astrophysical questions; also cosmic-ray missions on satellites address a variety of other fundamental questions.

- A **CAST follow-up** to search for axions from the Sun is discussed as part of CERN's physics landscape. It requires new magnets with increased field and aperture, as well as improved cryogenic and X-ray detection devices.
- Even if not all approaches to search for axion-like particles are strictly related to dark matter, there is a potential for revealing new physics. **Therefore we support the continuation of the corresponding programs.**

# Medium scale

- Advanced detectors for gravitational waves
- Dark Matter

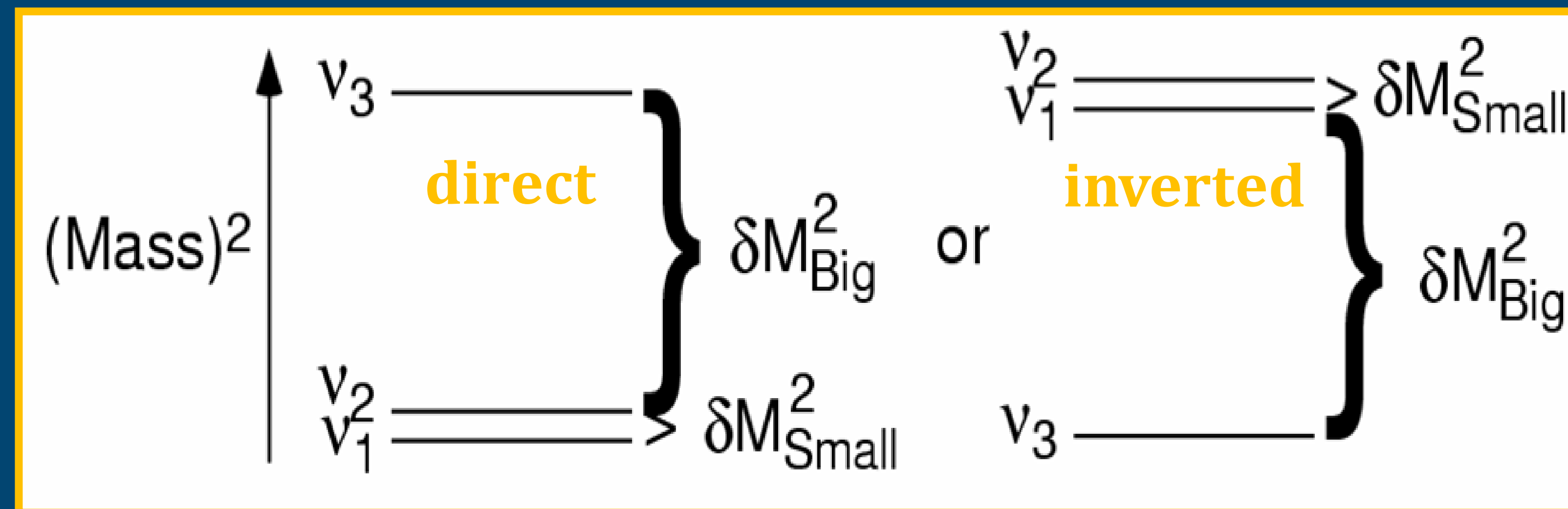
- **Neutrino properties**

- Extension of the Modane Underground Laboratory (LSM)

http://www.aspera-eu.org

# We do not yet know:

- Absolute neutrino mass scale
- Mass hierarchy




- Nature: Dirac or Majorana

$\nu \neq \bar{\nu}$ $\qquad$ $\nu \equiv \bar{\nu}$

- $\Theta_{13}$ (seems we are just going to know!)
- CP violating phase

$$\Sigma \equiv \sum_{i=1}^{3} M_i$$

cosmology

$$\langle M_\beta \rangle \equiv \left( \sum_{i=1}^{3} M_i^2 |U_{ei}|^2 \right)^{1/2}$$

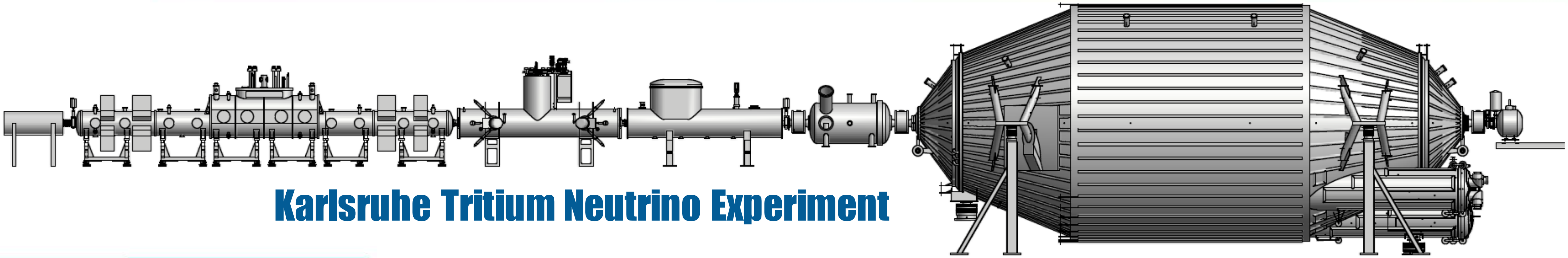
β decay

$$\langle M_{\beta\beta} \rangle \equiv \left| \sum_{i=1}^{3} M_i |U_{ei}|^2 e^{i\alpha} \right|$$

double β decay

Must have Majorana nature!

# KATRIN & beyond



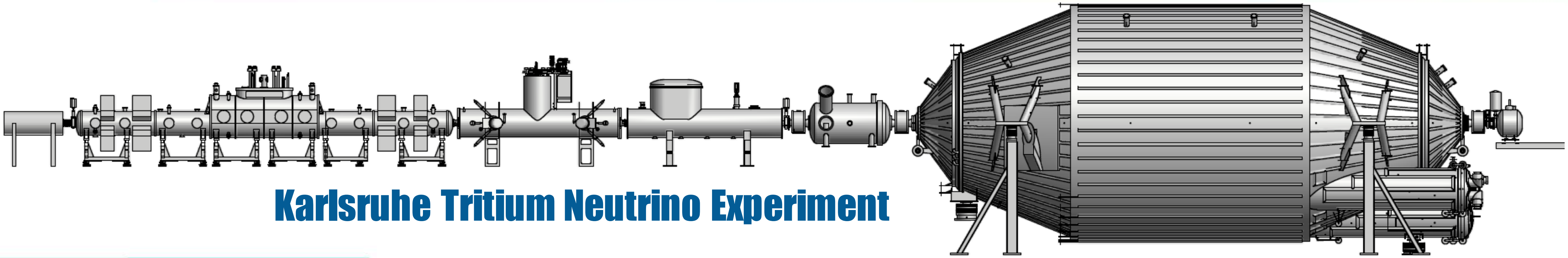
Karlsruhe Tritium Neutrino Experiment

sensitivity (90% CL)
m(ν) < 200 meV

discovery potential
m(ν) = 350 meV (5σ)

- start of commissioning: early 2012 (spectrometer)
- start of full data taking: mid-2014
- 90% CL sensitivity 300 meV: mid-2015
- 90% CL sensitivity 200 meV: 2018

# KATRIN & beyond



Karlsruhe Tritium Neutrino Experiment

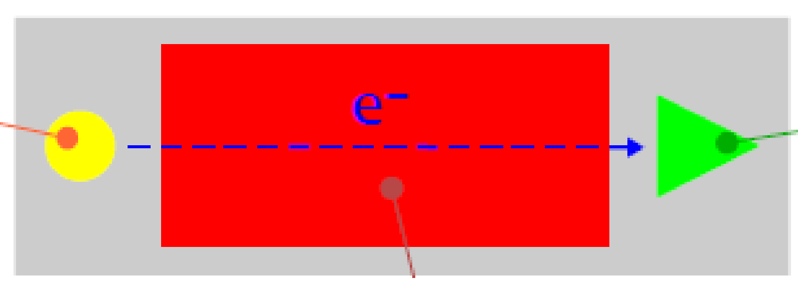
sensitivity (90% CL)
m(ν) < 200 meV

discovery potential
m(ν) = 350 meV (5σ)

| | |
|---|---|
| - start of commissioning: | early 2012 (spectrometer) |
| - start of full data taking: | mid-2014 |
| - 90% CL sensitivity 300 meV: | mid-2015 |
| - 90% CL sensitivity 200 meV: | 2018 |

$^3$H source

KATRIN



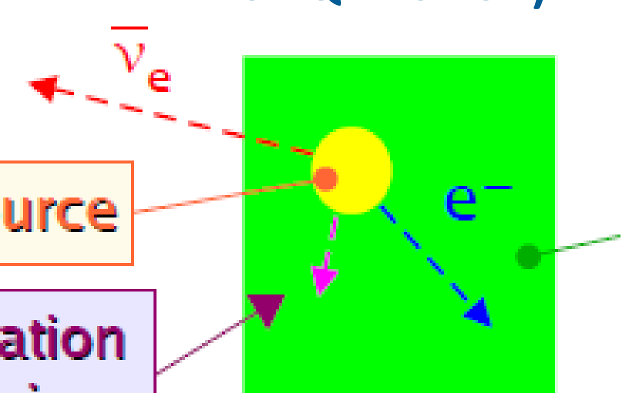

β counter

## The future?

MARE

Milano,.Genoa

$^{187}$Re - Q=2.5 keV)



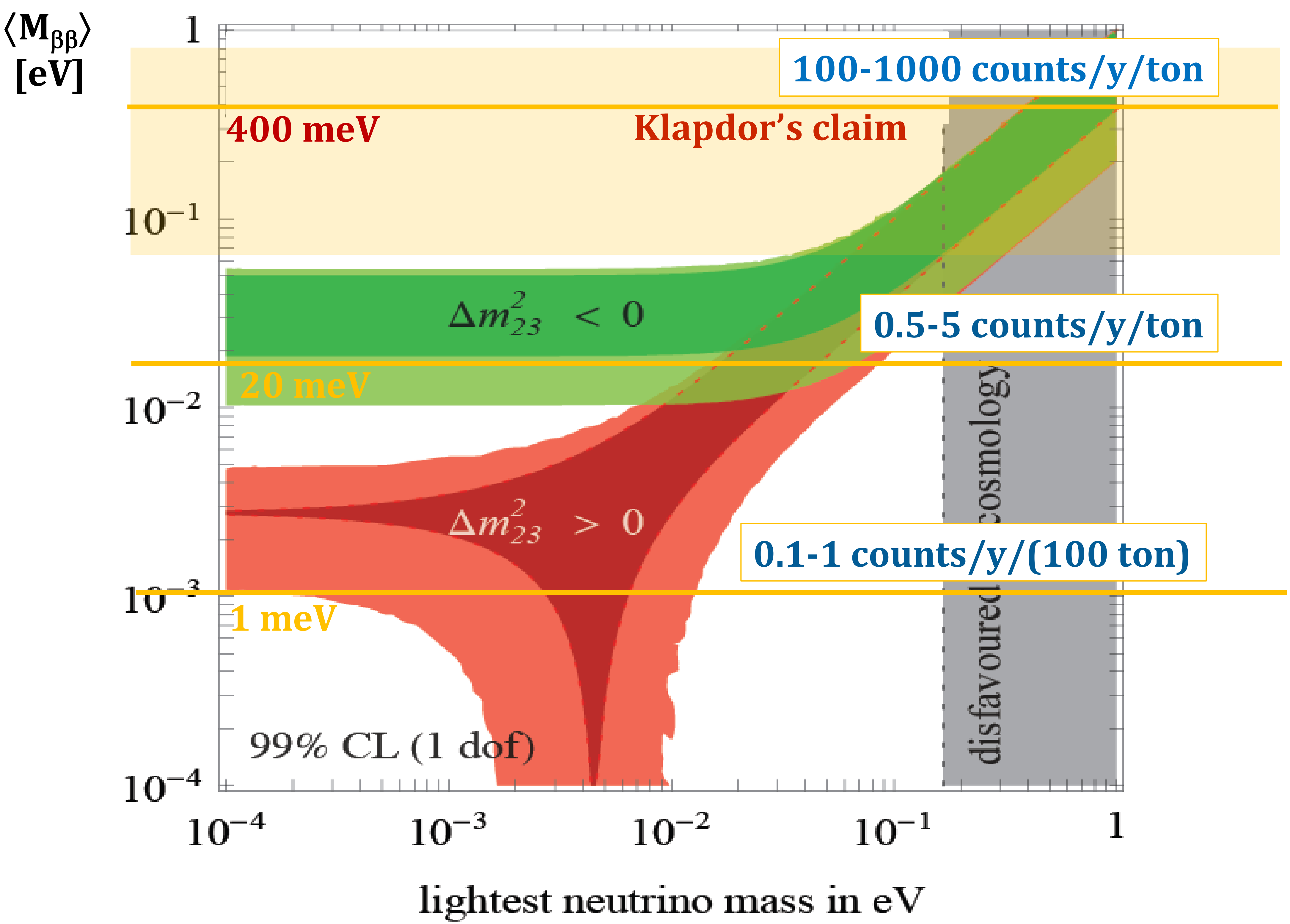

β source

excitation energies

Cryo-microcolorimeters

ASPERA Astroparticle Physics for Europe

# Neutrino-less double beta decay

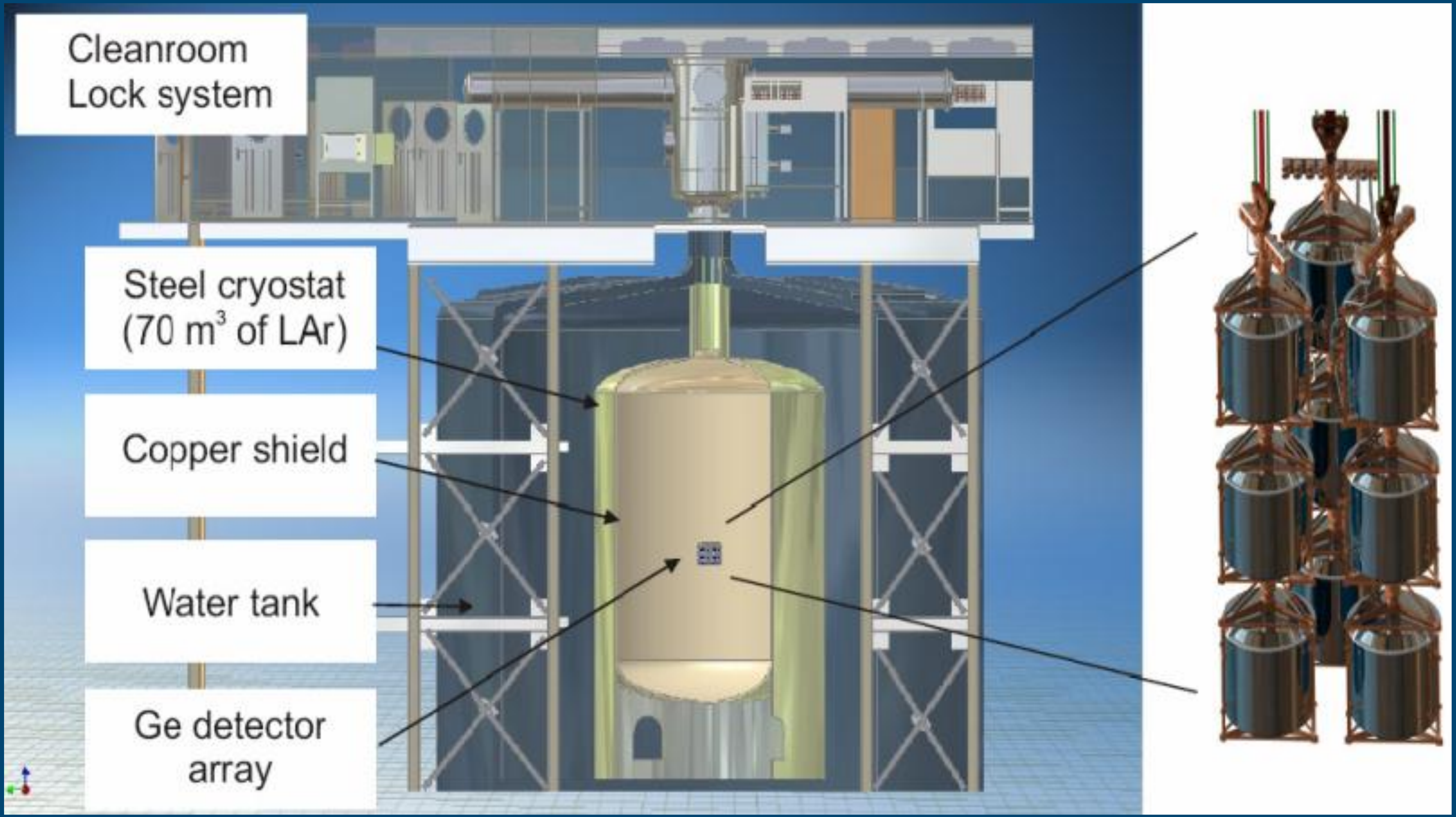


# GERDA – phase 1

**Technique:** Bare enriched Ge diodes (17.6 kg Ge ) in liquid argon

**Location:** LNGS

**Sensitivity**: designed to scrutinize Klapdor's claim in ~1 year data taking



ASPERA Astroparticle Physics for Europe

# GERDA – phase 1

**GERDA Phase 2: 70 – 130 meV**

**GERDA Phase 3 (together with Majorana): 20- 40 meV**

**GERDA Inauguration Nov 2010**

**Commissioning finished**

**Start of first physics run at Nov 1, 2011**

# CUORE

**Technique:** natural $TeO_2$ bolometers at 10 mK

**Location: LNGS**

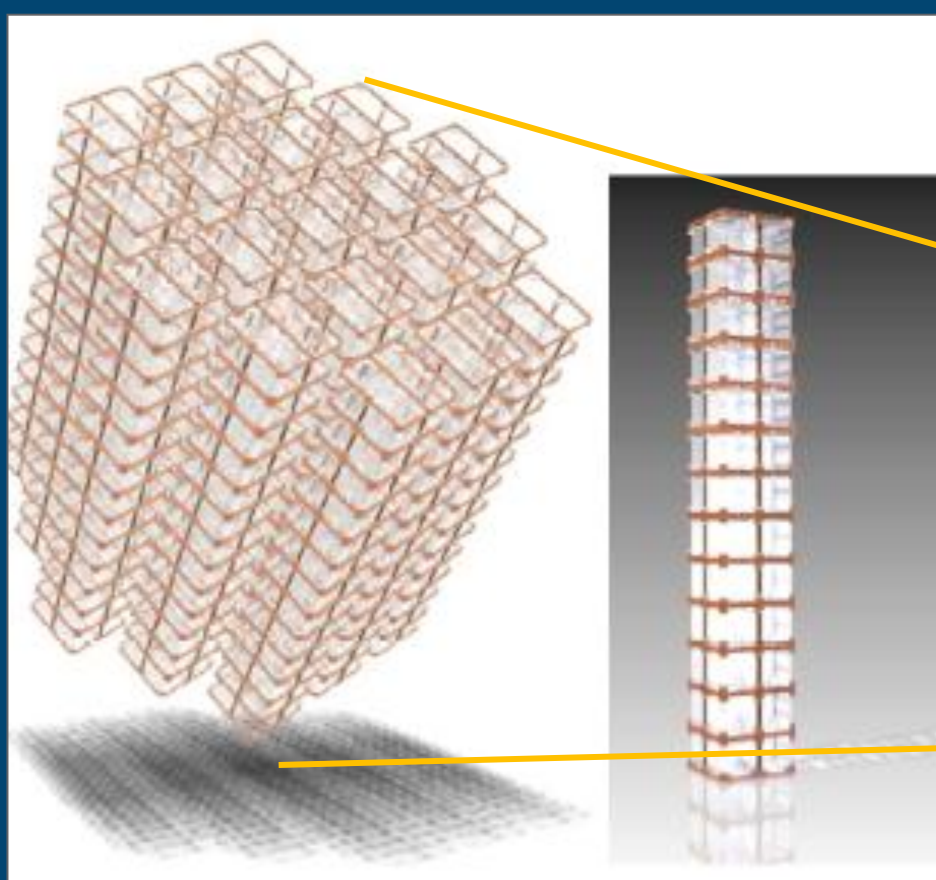
**Sensitivity**: 35 – 82 meV (with target background ~ $10^{-2}$ counts/(keV kg y) )

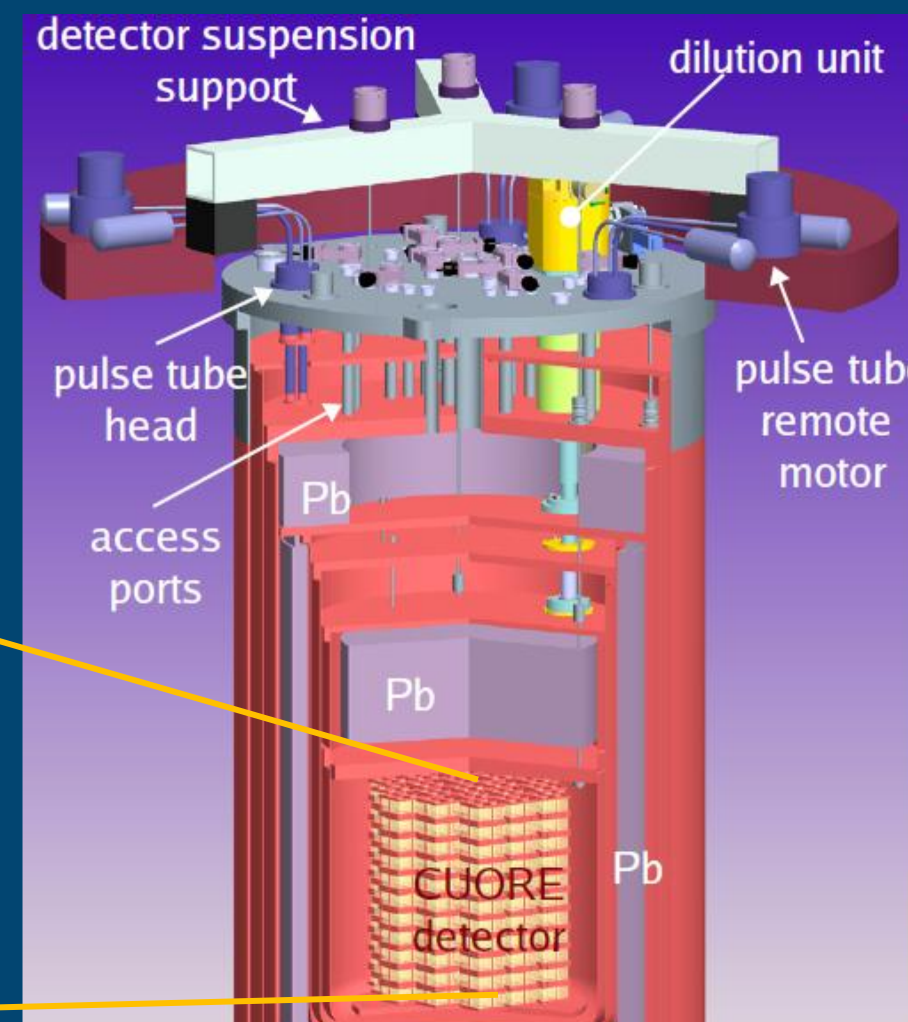
**Timeline**: first CUORE tower in 2011 – data taking with full apparatus in 2014

↓

CUORE-0 close to commissioning

**Structure of the detector**






**Detector in the custom fridge**

# Super-NEMO

**Technique:**
tracking Geiger cells+ plastic scintillator

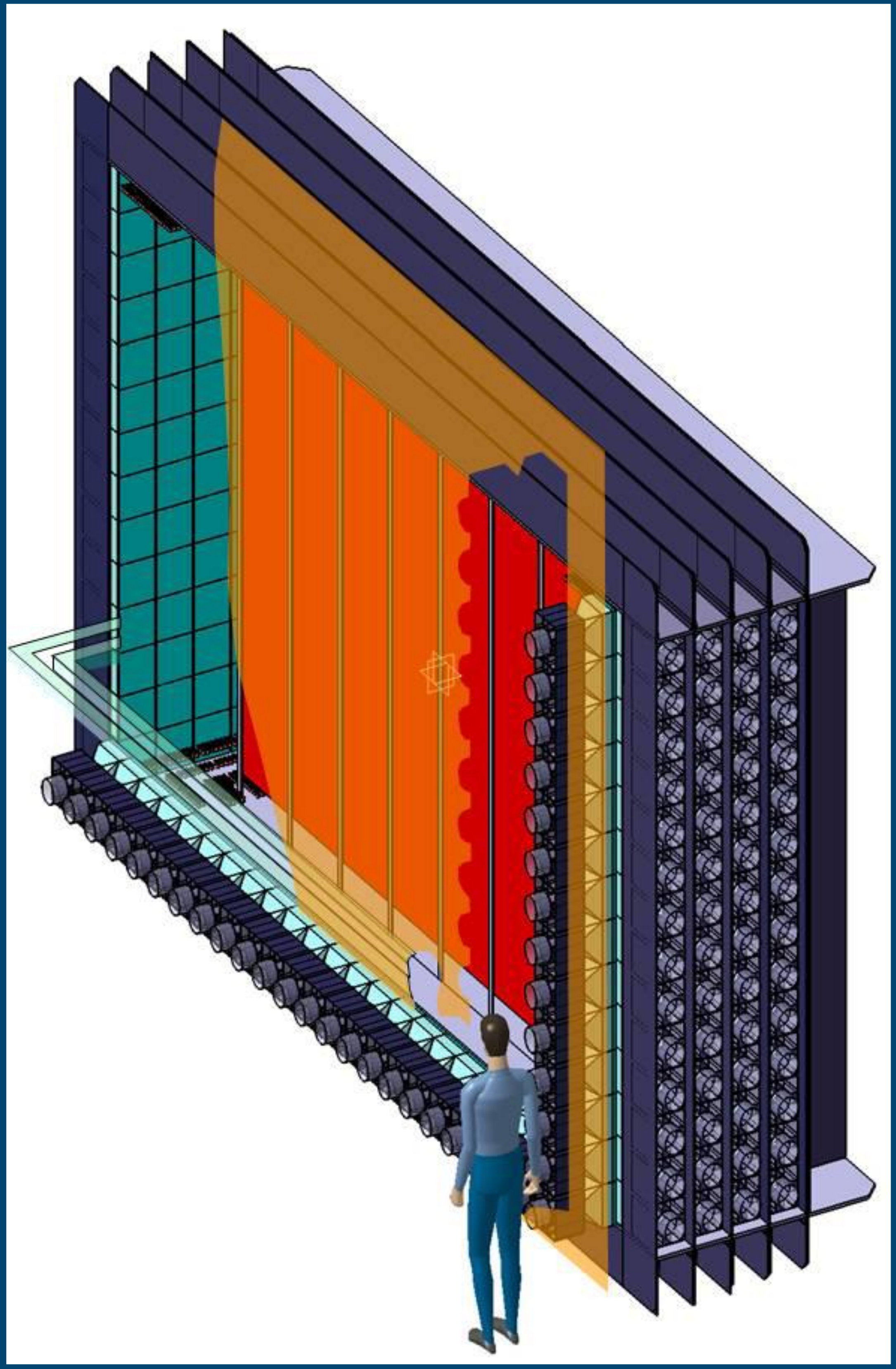
**Location:** LSM

**Source**: choice flexibility ($^{82}$Se, $^{150}$Nd, $^{48}$Ca)

**Sensitivity**: 53 – 145 meV (for $^{82}$Se)

**Status/Timeline**:
demonstrator module in 2014 (~7 kg)

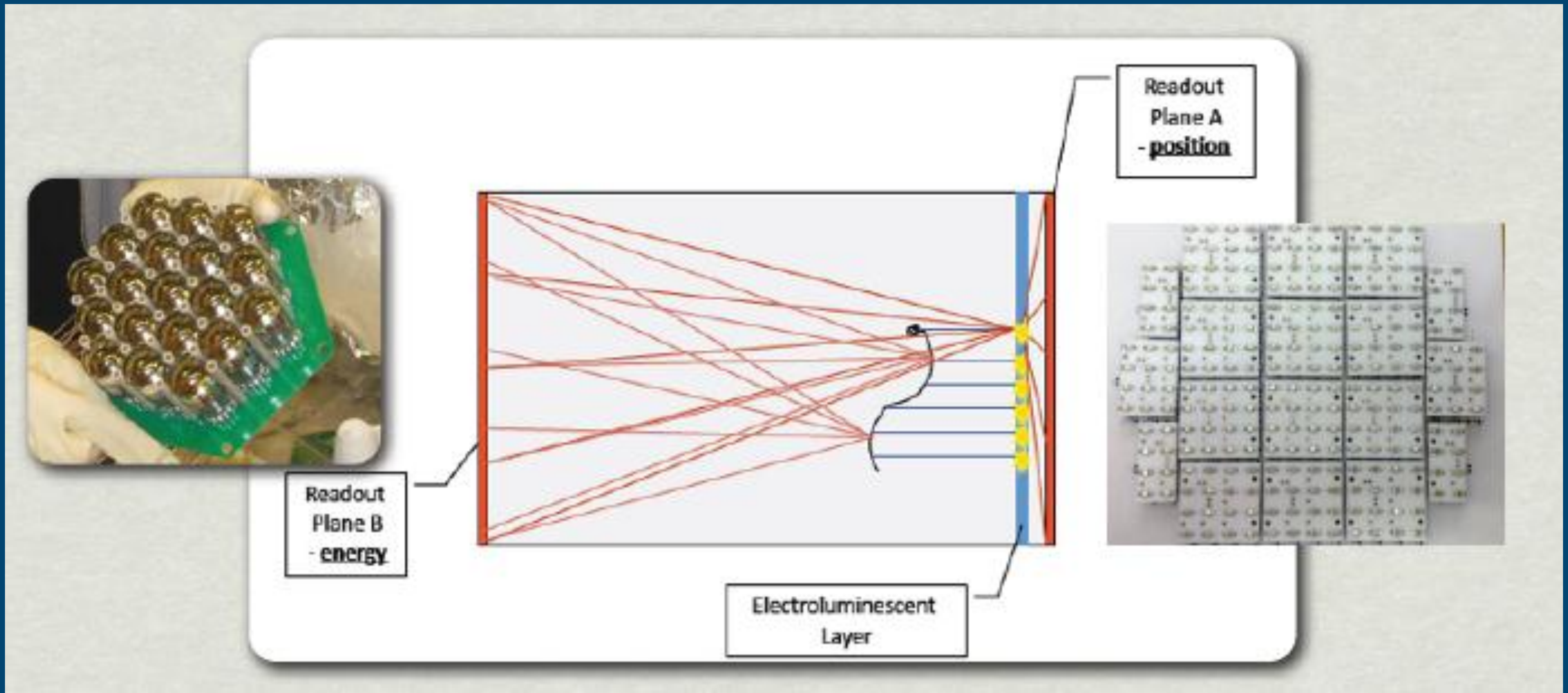
after that, construction of 20 modules estimated in 2 years



# NEXT

**Technique:** High pressure gaseous Xe TPC ($^{136}Xe$ - 100 kg enriched Xe)
**Location:** LSC/Spain
**Timeline**: prototyping with NEXT1 prototypes in 2011 (2x Spain, 1x US)
start construction larger systems in 2012 – complete construction final detector in 2013 – depleted Xenon run in 2014

Cathode: energy measurement with PMTs




Anode: position measurement with SiPMs

# Other DBD experiments

## EXO-200:
- Xenon
- Swiss participation in US experiment
- Commissioning

## SNO+:
- UK, German Participation in Canada experiment
- Construction

## COBRA:
- High CdZnTe crystals operated as semiconductor detectors
- LNGS
- Advanced prototyping

## LUCIFER:
- scintillating bolometers (**$^{82}$Se, $^{100}$Mo, $^{116}$Cd)**
- LNGS, LSM ?
- Prototyping

# Recommendations Neutrino Properties

- Several highly important experiments in Europe are either in the commissioning phase or in the final years of construction: **GERDA**, **CUORE** and the demonstrator for **SuperNEMO** will search for neutrino-less double beta decay, **KATRIN** for neutrino mass via single beta decay. **Double CHOOZ**, a nuclear reactor experiment, is studying neutrino oscillations. The mentioned experiments build on a long experience and validation with precursors. They have recently joined by **NEXT,** a new approach to the search for double beta decay.

- We renew our strong support for these experiments and look forward to first results.

- Beyond this, we recommend phased experimental approach in neutrino-less double beta decay with a sensitivity (ton scale masses) exploring fully the mass range predicted by oscillation experiments for the inverted mass hierarchy.

# Medium scale

- Advanced detectors for gravitational waves
- Dark Matter
- Neutrino properties

- Extension of the Modane Underground Laboratory (LSM)

There is a unique opportunity to extend the present underground laboratory of Modane -LSM- by taking advantage of the excavation of the safety tunnel of the Frejus road tunnel, now started a year ago. This new laboratory of 60,000 $m^3$ would be able to host recommended projects. LSM has the greatest depth of the present underground laboratories in Europe. The committee therefore strongly recommends the timely support for this infrastructure. Such a laboratory - of the size of one Gran Sasso hall with 6 times lower muon flux, in operation by 2014 - would enhance the complementarity of the European Deep Underground laboratories.

# Large scale, mid of decade:

- TeV gamma-ray astrophysics: CTA
- High energy neutrinos: KM3NeT
- High energy cosmic rays: 30,000 $km^2$ ground based array
- Low energy neutrinos & p-decay: LAGUNA

http://www.aspera-eu.org

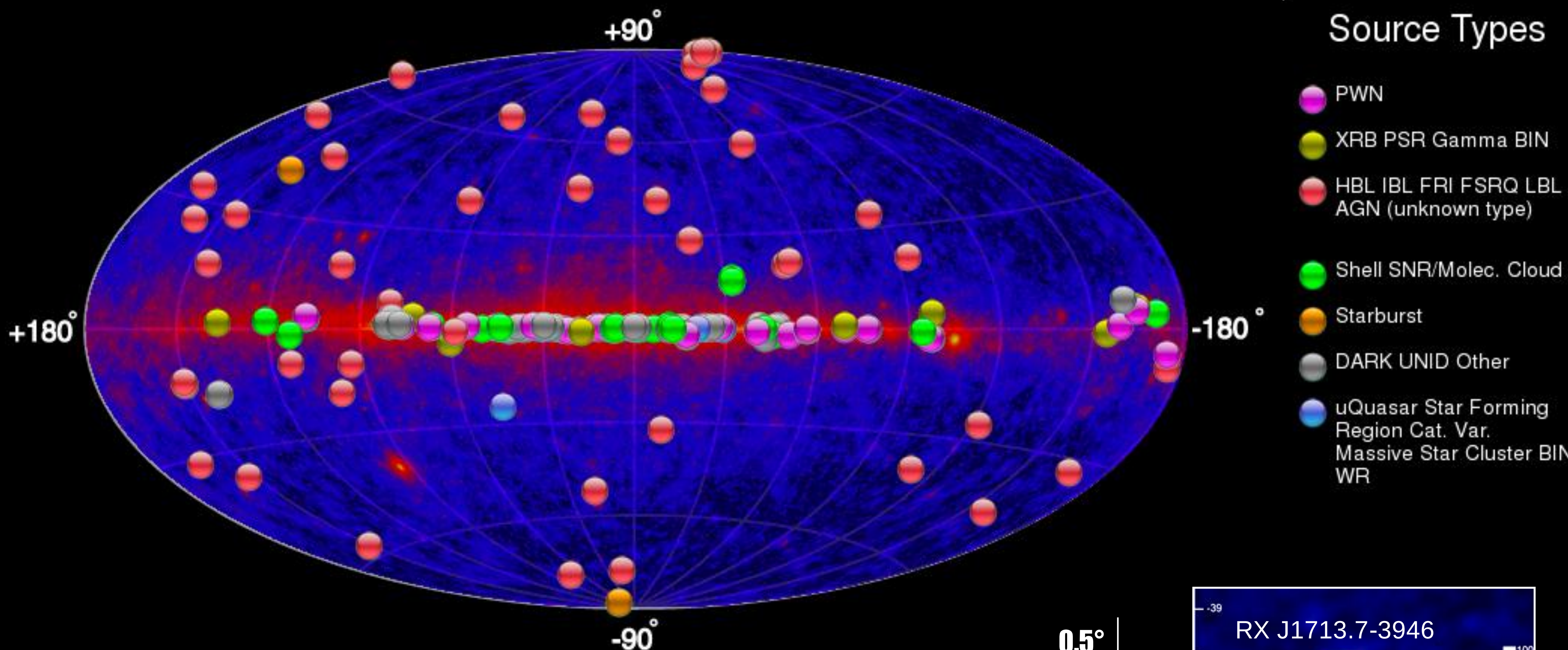
# Large scale, mid of decade:

- **TeV gamma-ray astrophysics**
  - High energy neutrinos: KM3NeT
  - High energy cosmic rays: 30,000 km² ground based array
  - Low energy neutrinos & p-decay: LAGUNA

ASPERA Astroparticle Physics for Europe

# The VHE gamma ray sky

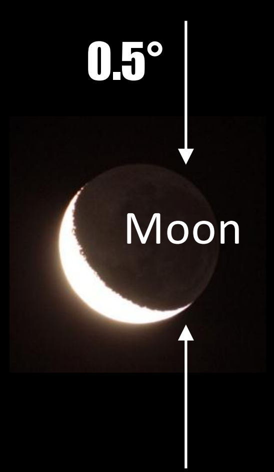
© TeVcat (14/May/2011)

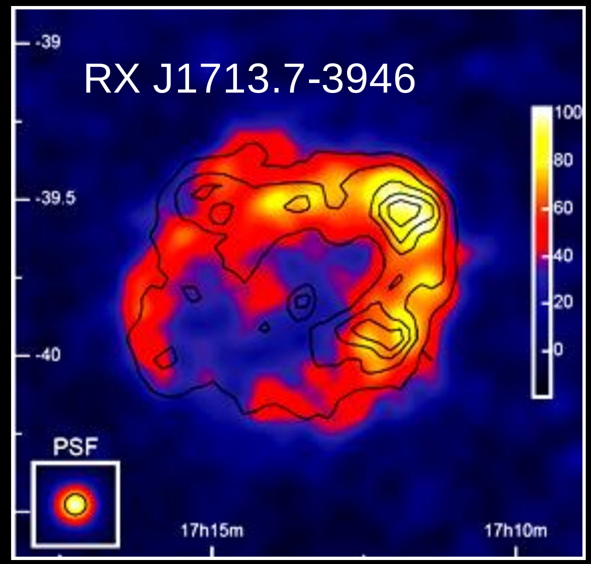



143 sources

48 Extragalactic

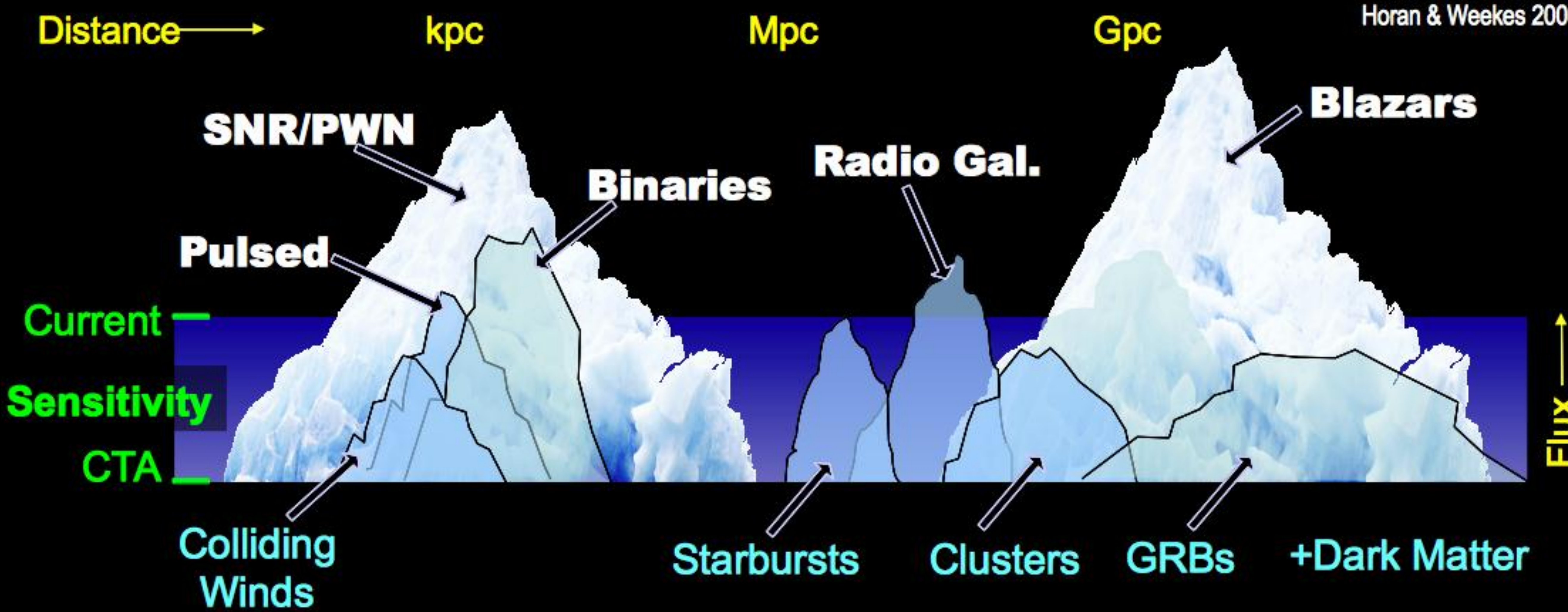
Morphology



# Science Potential

adapted by Hinton from Horan & Weekes 2003



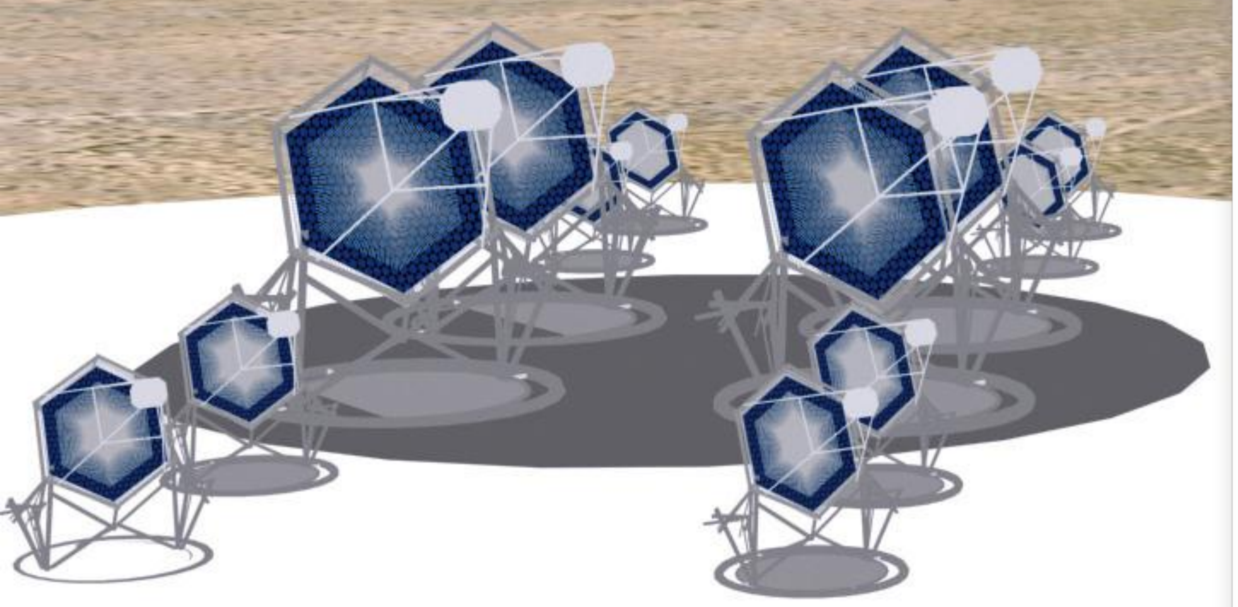

- Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, but this is clearly only the tip of the iceberg
- What big science questions remain ?

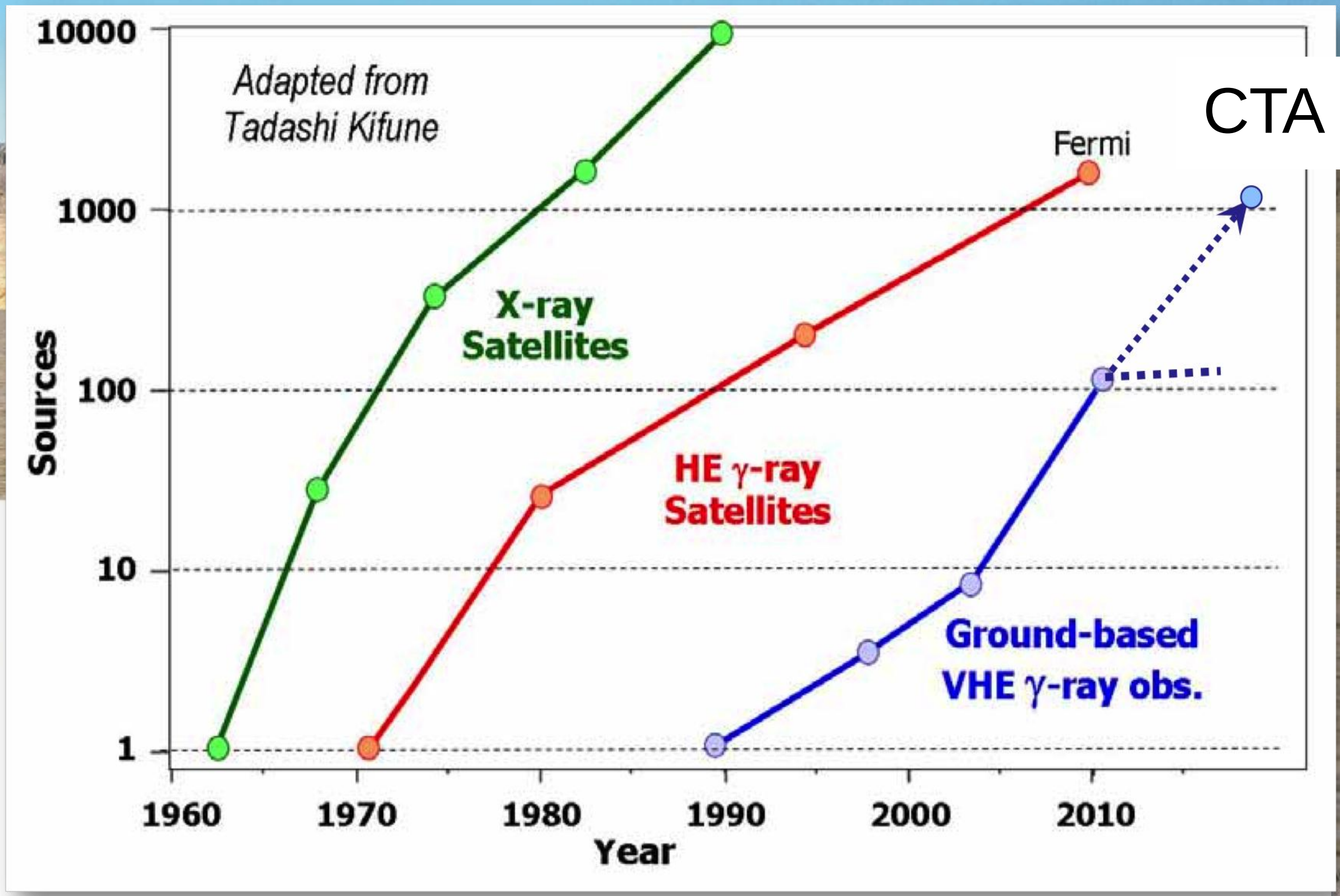
10 fold sensitivity of current instruments
10 fold energy range
improved angular resolution
~1000 sources expected
two sites (North / South)
operated as observatory

World-wide cooperation
25 countries, 132 institutes,800 scientists

**The future in VHE gamma ray astronomy:**

cta
cherenkov telescope array





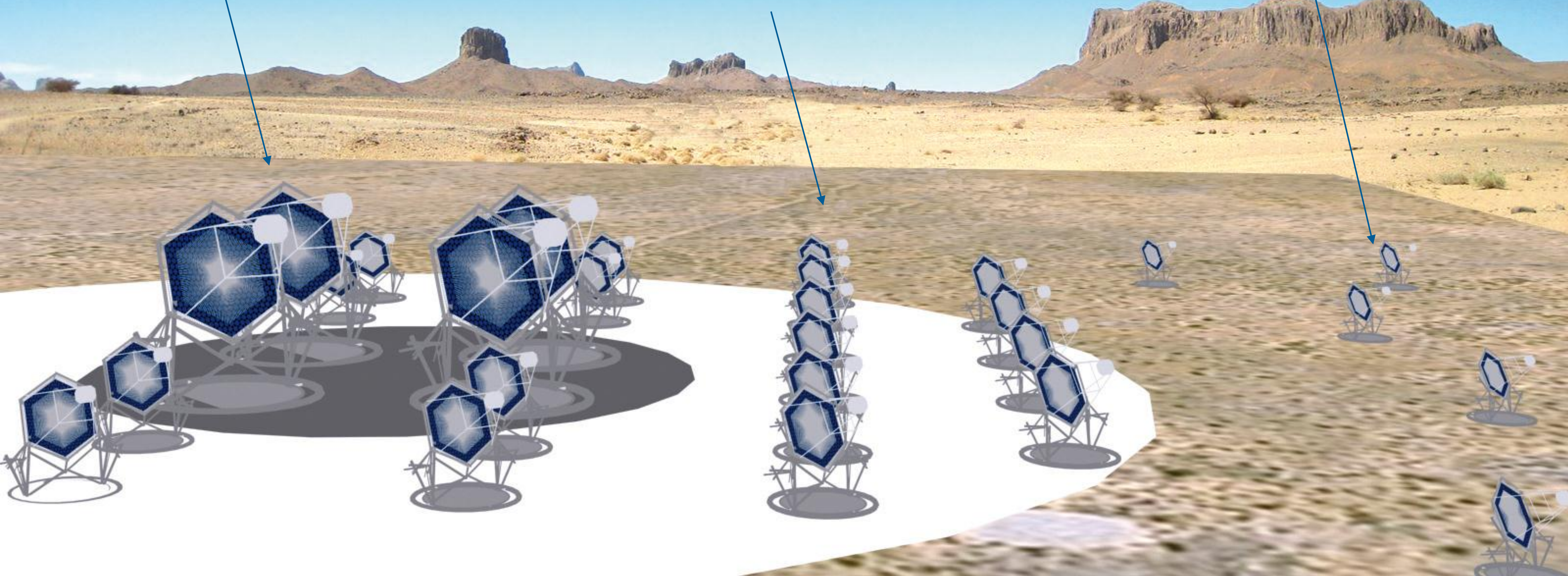
# (one) possible configuration

100 M€ (2006 costs)

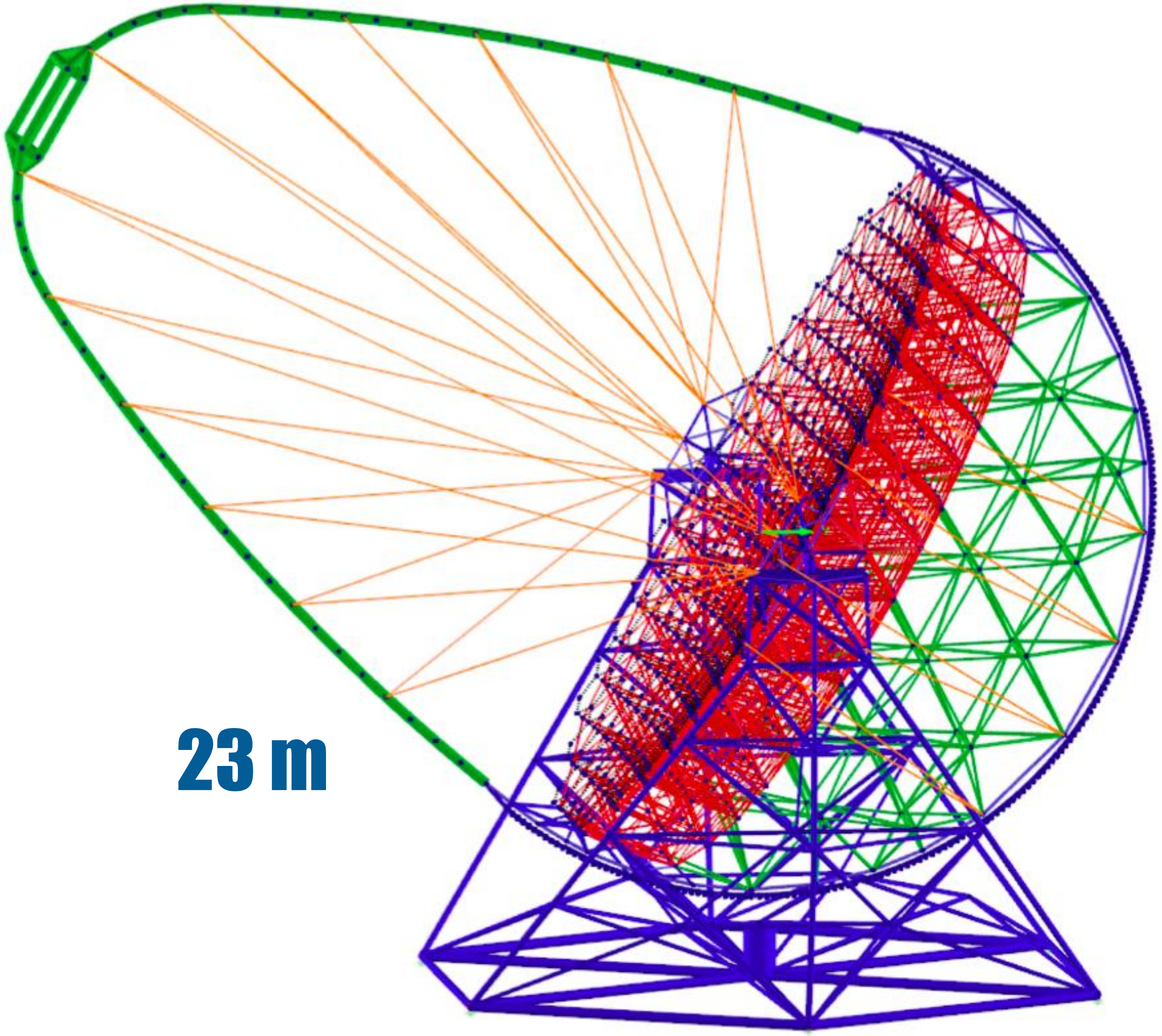
**Low-energy section:**
4 x 23 m tel.
Parabolic reflector
FOV: 4-5 degrees
energy threshold
of some 10 GeV

**Core-energy array:**
23 x 12 m tel.
Davies-Cotton reflector
FOV: 7-8 degrees
mCrab sensitivity
in the 100 GeV–10 TeV
domain

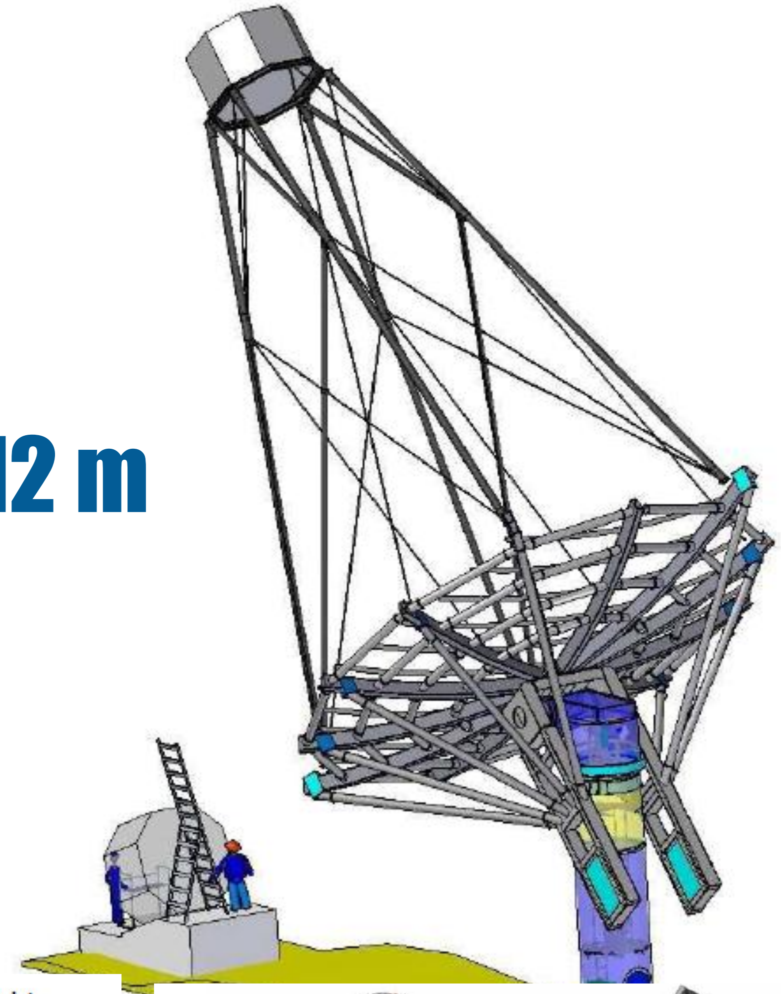
**High-energy section:**
32 x 5-6 m tel.
Davies-Cotton reflector
(or Schwarzschild-Couder)
FOV: ~10 degrees
10 km$^2$ area at
multi-TeV energies



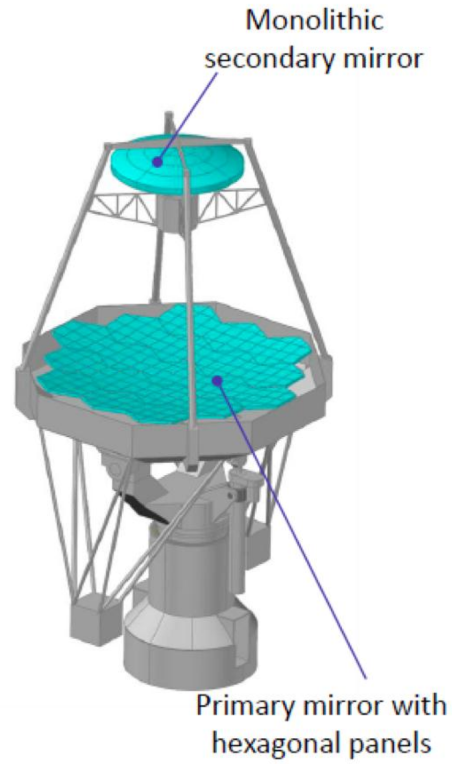
# Design: From small to Large



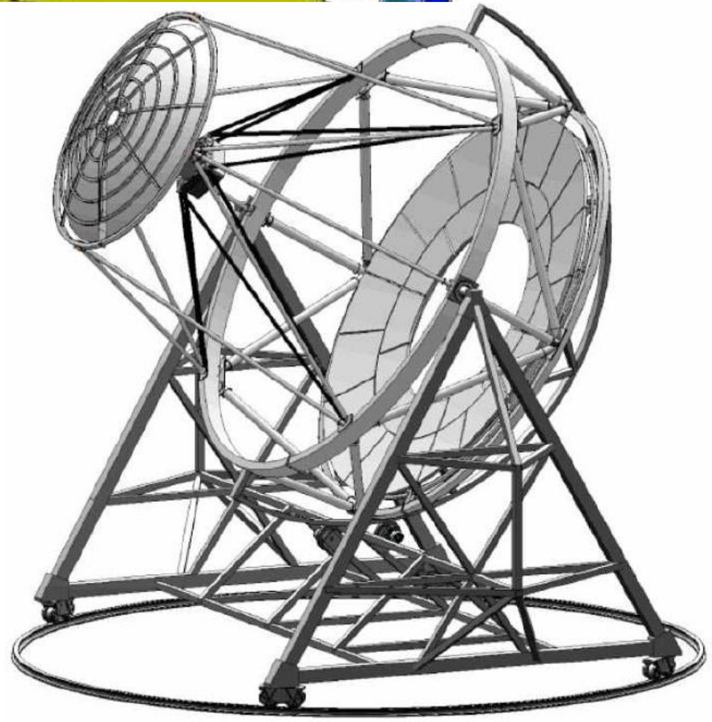
23 m



12 m




5-6 m



USA: Schwarzschild-Tel.

# Status and plans

## Design study phase concluded in Fall 2010

- Design Concepts for the Cherenkov Telescope Array (arXiv:1008.3703)

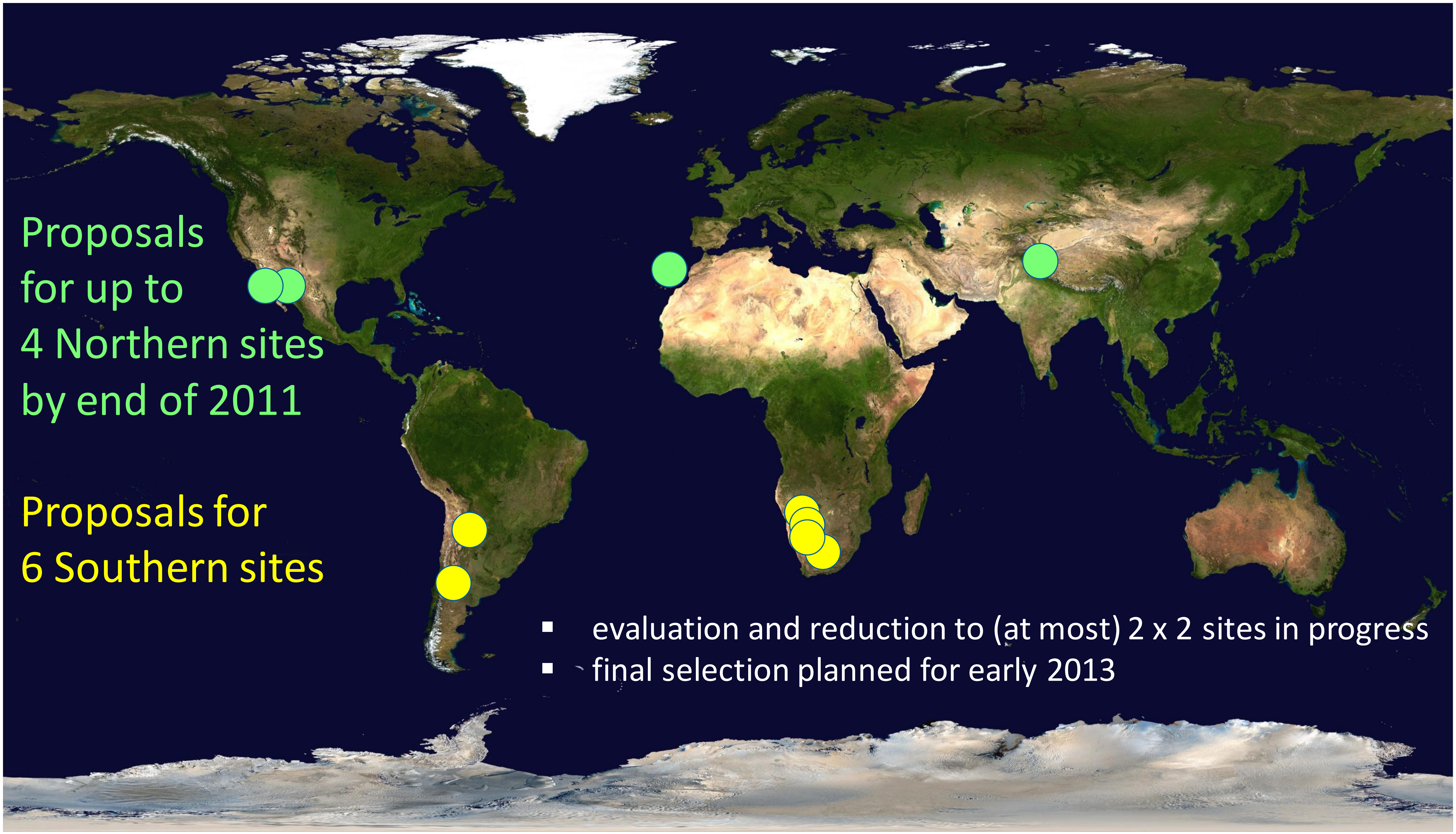
## FP7-supported Preparatory Phase: Fall 2010 – Fall 2013

- Technical design, sites, construction and operation cost
- Legal, governance and finance schemes
- Small + medium-sized telescope prototypes

## Aim for

- start of deployment in early 2014
- first data in 2016/17
- base arrays complete in late 2018
- expanded mid-energy array driven by US

# Site selection



# Summary CTA

- Now one year into Prep Phase
- Project Office established & active
- Agency “Resource Board” established & active, working towards “Declaration of Intent” for CTA

- CTA established on many national roadmaps
- CTA keeps growing; requests from new groups and new countries to join

- Technical design well underway, with regular design reviews
- South site candidates under evaluation, using archival information, locally deployed equipment, remote sensing, expert consultants (Namibia, Argentina)
- Study of legal & organizational options progressing in interaction with agencies

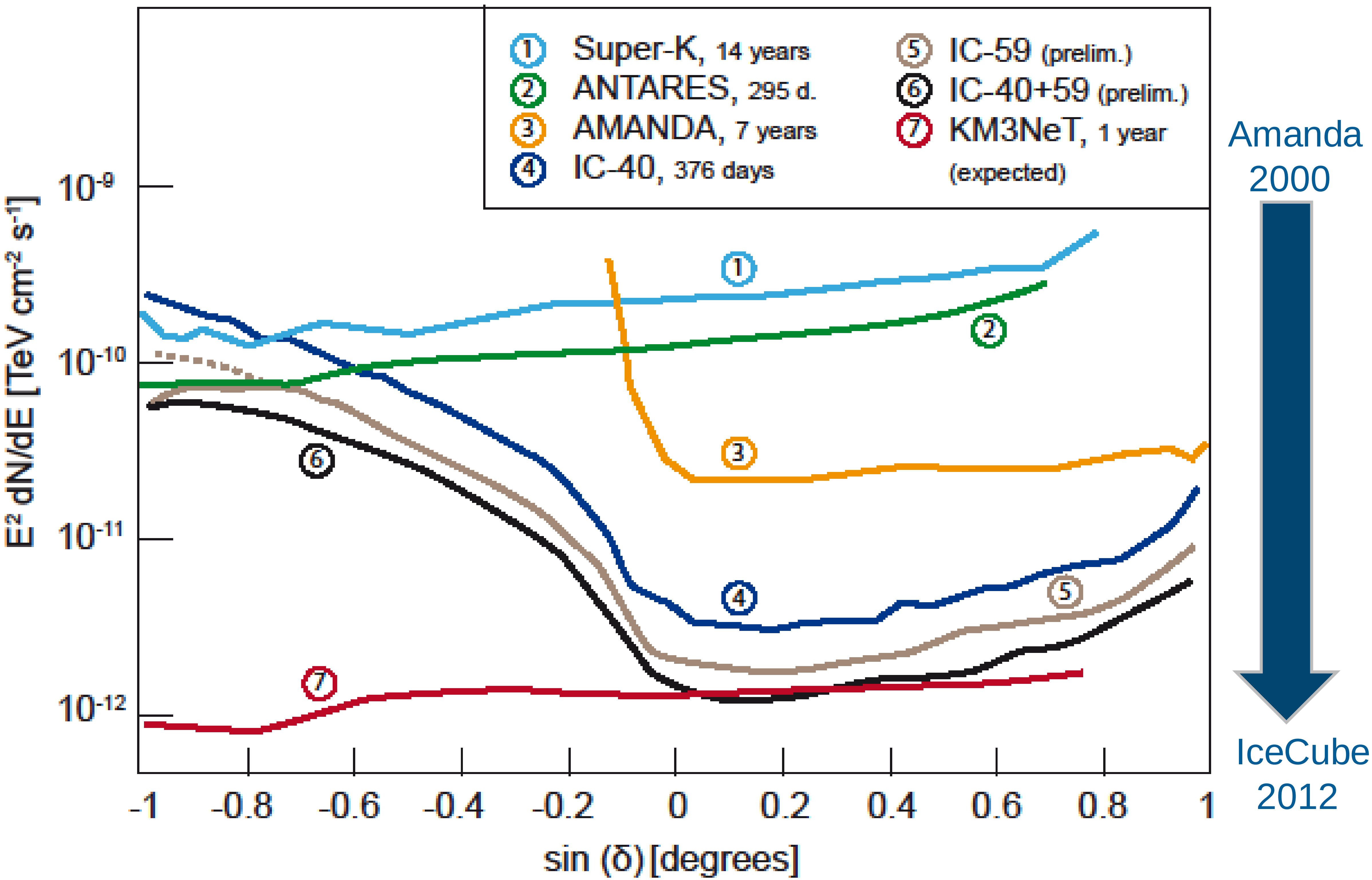
# TeV gamma-ray astrophysics:

- The Cherenkov Telescope Array (CTA) is the worldwide priority project of this field. It combines proven technological feasibility with a high speed towards prototyping, with a guaranteed scientific perspective and a mode of operation and wealth of data similar to mainstream astronomy.
- The cost scale of CTA is 200 M€.
- **We recommend to design and to prototype CTA, to select the site(s), and to proceed vigorously towards start of construction in 2014.**

# Large scale, mid of decade:

- TeV gamma-ray astrophysics: CTA
- **High energy neutrinos**
- High energy cosmic rays: 30,000 $km^2$ ground based array
- Low energy neutrinos & p-decay: LAGUNA

# Last 12 years: a factor of 1000 !



# KM3NeT

- on ESFRI list
- 2011: TDR
- Early 2012: end of preparatory phase
- Late 2012: Technical proposal
- **Physics: Focus to galactic sources !**
  → configuration
- Fresh funding for engineering arrays in France and Italy, also Romania. Netherlands since years
- Greece 50M€ promised

# Technology Convergence

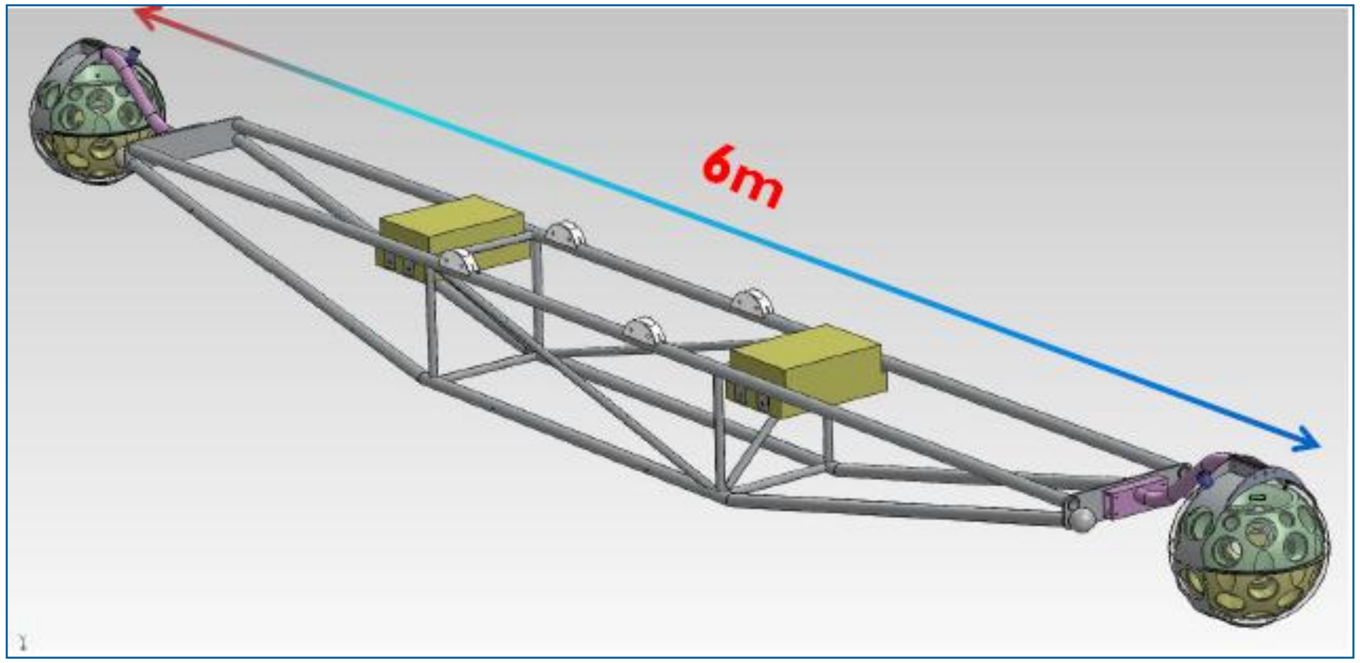
1) DOM with 31 PMT

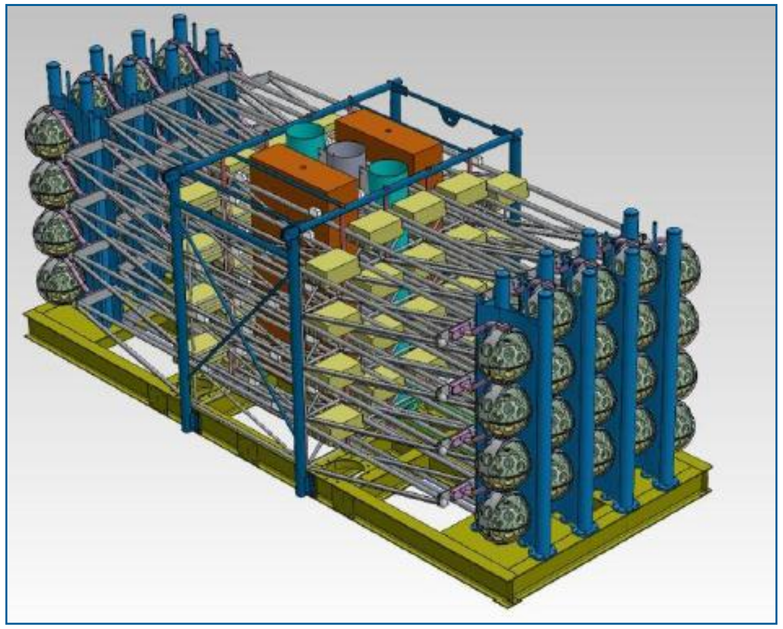
Still needs long-term in-situ test!

Backup 13´´ PMT

2) Towers with 2-DOM floors

Backup single string

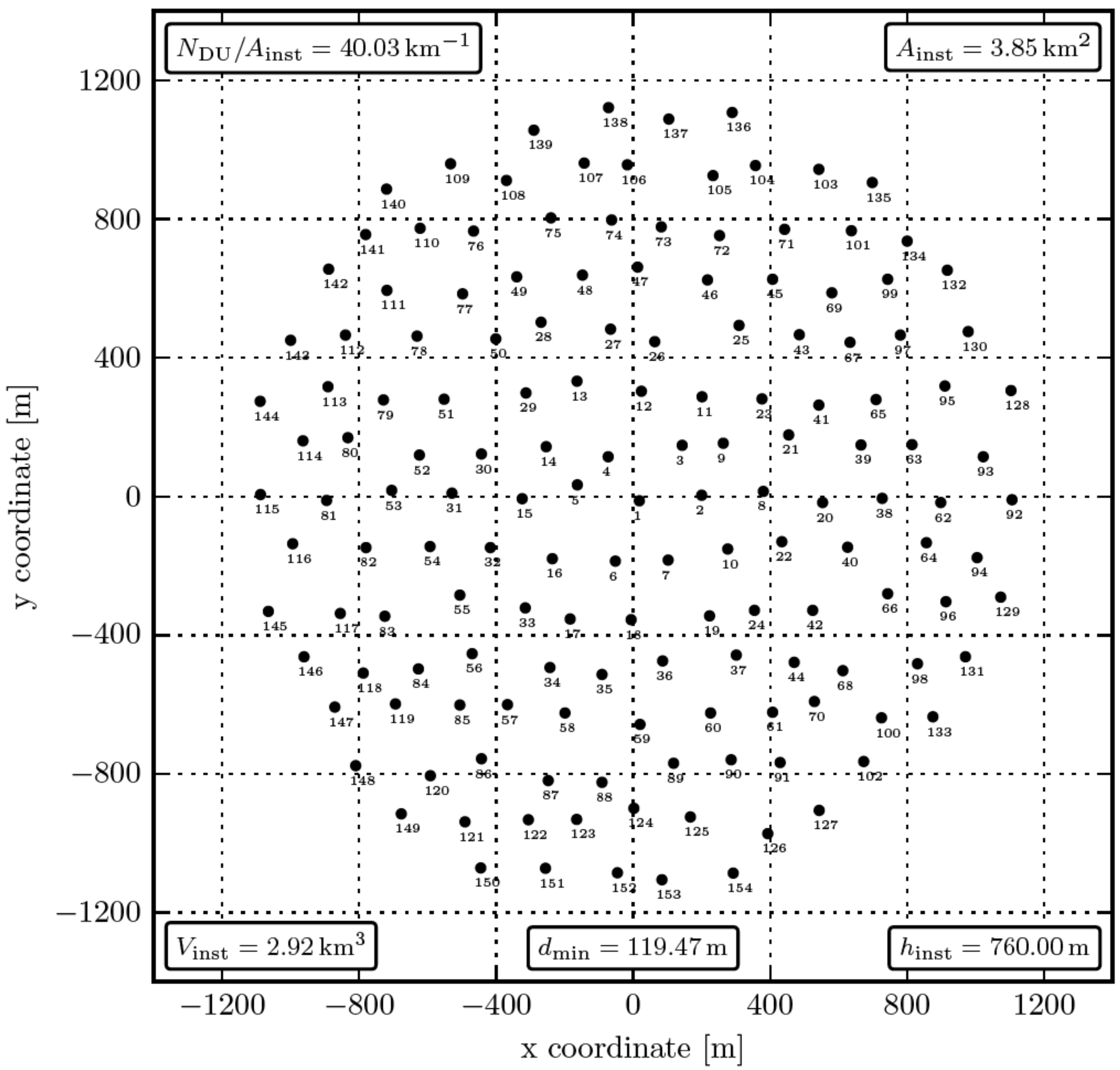


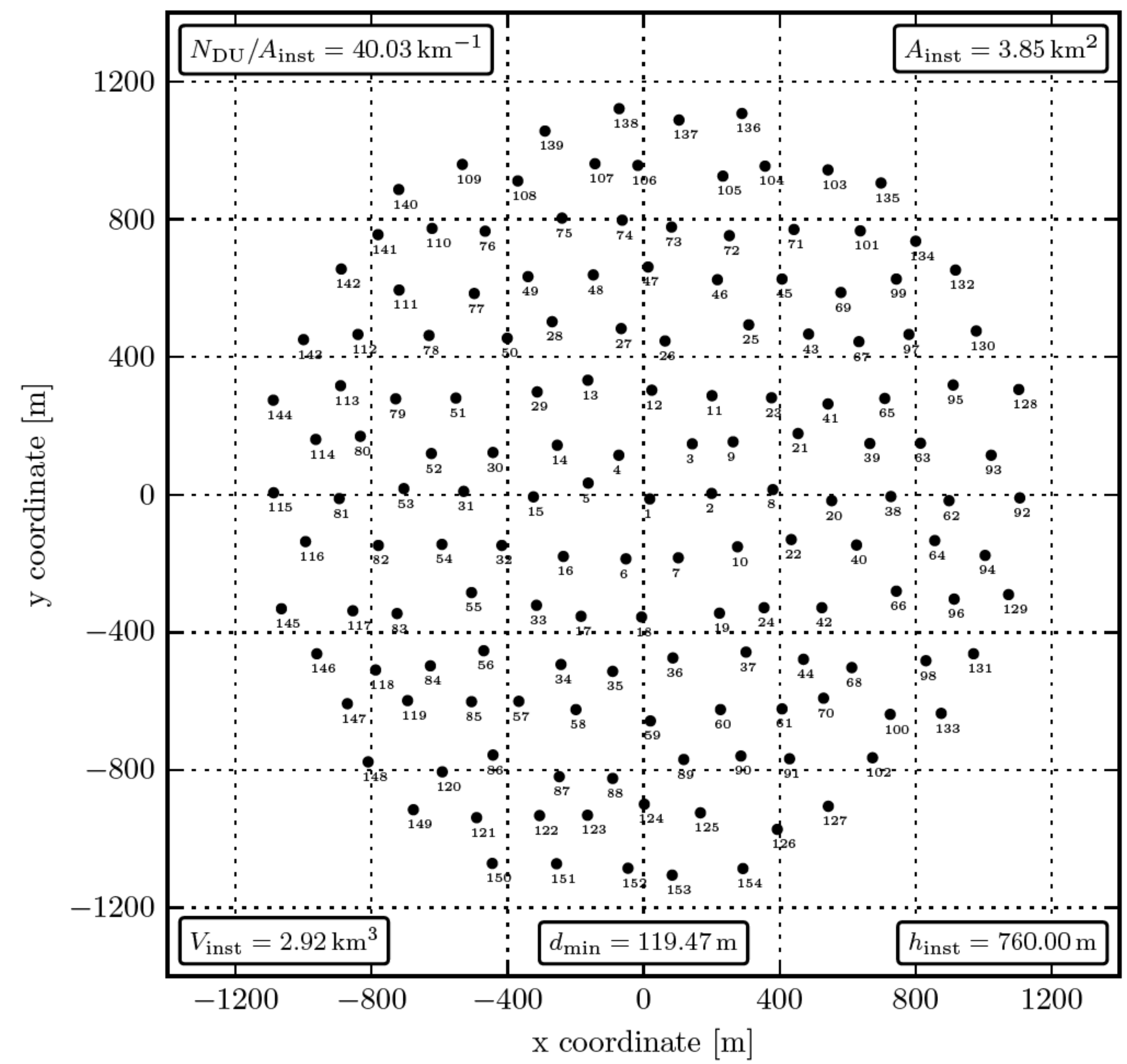



3) „All data to shore“ concept

cutting-edge fibre technology

- Site question still open. 1, 2 or even 3 sites?
- In any case: need to deploy in „blocks“
- Here: 2 blocks each à 3 km³
- **Cost ~ 250 M€**



# High-energy neutrinos

- IceCube is now providing data with unprecedented quality and statistics. **The European partners should be supported in order to ensure the appropriate scientific return**.
- There is a strong scientific case for a neutrino detector in the Northern hemisphere, with a substantially larger sensitivity than IceCube. **Resources for a Mediterranean detector should be pooled in a single optimized design for a large research infrastructure. The KM3NeT collaboration is encouraged to present a technical proposal matching these requirements and in particular take final site and design decisions that would enable start of construction in 2014.**
- The IceCube, ANTARES and KM3NeT collaborations are encouraged to strengthen cooperation, with the vision to form a **future Global Neutrino Observatory**, including also other projects like GVD-Baikal.
- **Ultra-high energy cosmic neutrinos:** Given the recent indirect constraints from Fermi on the cosmogenic neutrino flux at $10^9$-$10^{11}$ GeV, it seems clear that detectors of many tens of cubic kilometers will be necessary to record more than a handful of neutrinos from GZK interactions. **We encourage R&D efforts towards this goal.**

# Large scale, mid of decade:

- TeV gamma-ray astrophysics: CTA
- High energy neutrinos: KM3NeT
- **Cosmic rays**
- Low energy neutrinos & p-decay: LAGUNA

http://www.aspera-eu.org

# Galactic cosmic rays

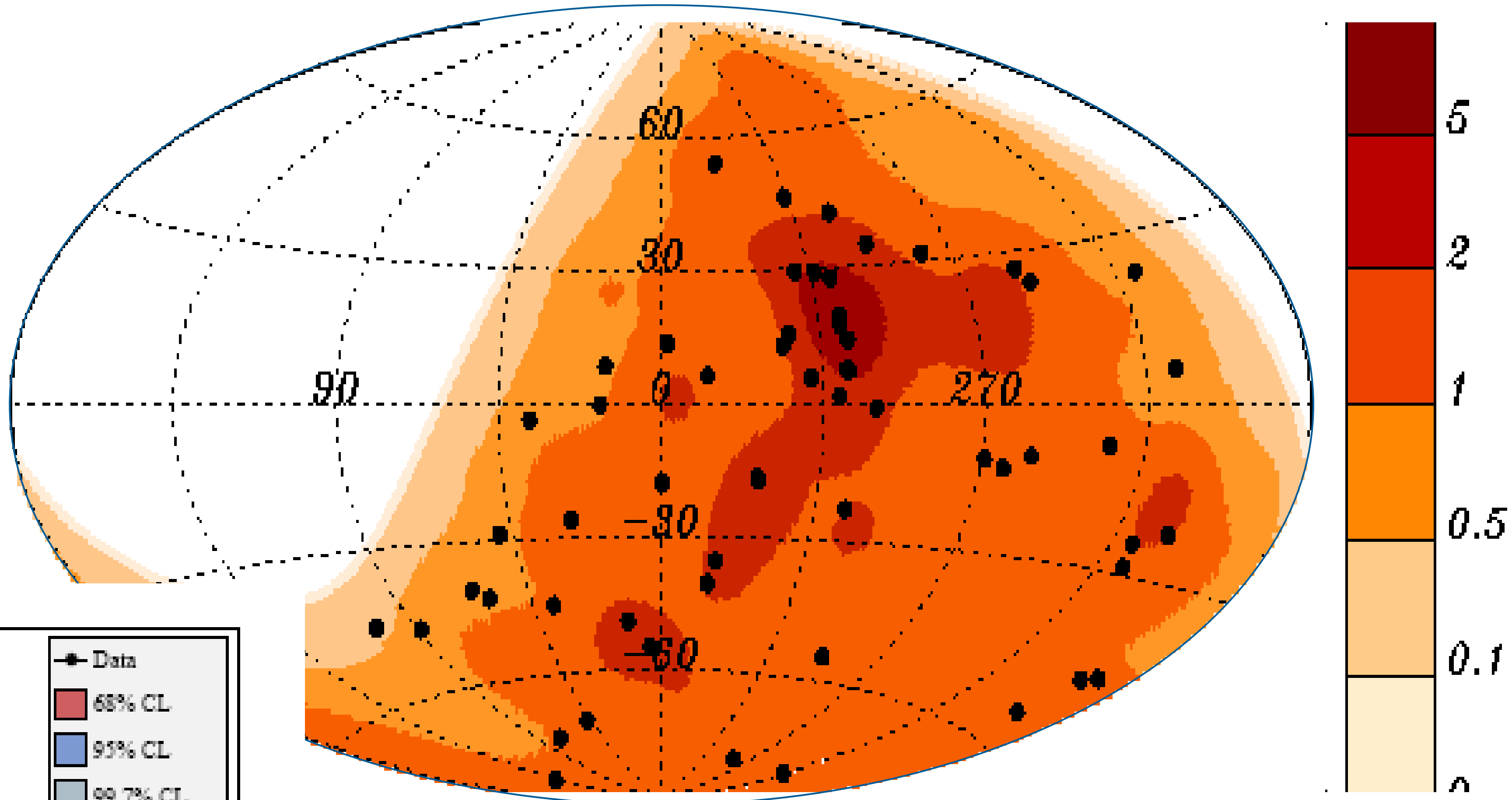
- Low energies: AMS – successful launch 2011
- We reiterate the suggestion of the 2007 roadmap, that efforts be directed to achieve an overlap between present direct and air-shower detection methods in order to get a better understanding on the mass composition and spectral features of cosmic rays. This goal may be pursued with large-aperture, long duration flight missions above the atmosphere (balloons/satellites) and/or by ground-based detectors with adequate particle identification placed at the highest altitudes.
- The existing experiments IceCube, TUNKA-133 and the low-energy extensions of the Pierre Auger Observatory (AMIGA/HEAT) should be exploited. We encourage the further development of MHz radio wave detection of air showers, e.g. at the large facilities Auger (AERA) and LOFAR, as well as at the South Pole and the Tunka site. There should be close cooperation with the particle-physics community, in particular with respect to LHC results. An array at the highest possible altitude is desirable to determine the chemical composition in the energy range overlapping with balloon experiments (10 TeV – PeV). At present, the planned LHAASO experiment in China seems to come closest to this requirement.

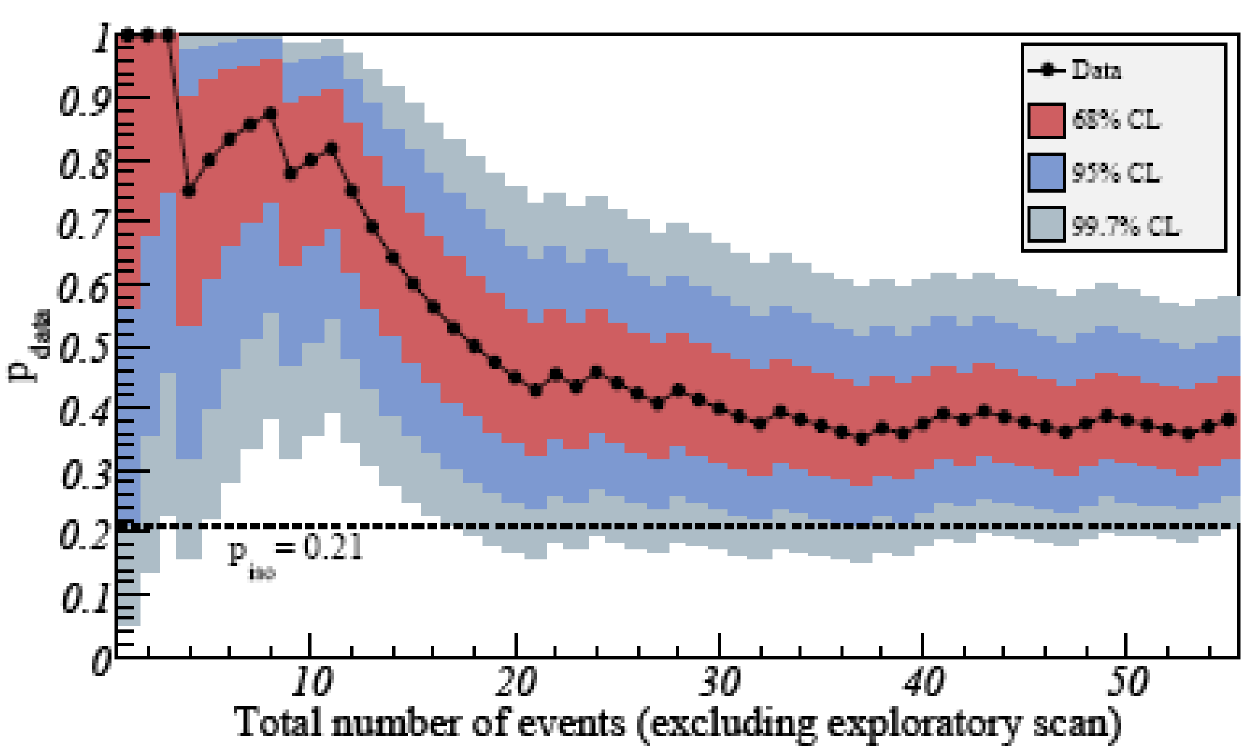
# Intriguing Auger Results

Spectral depression at highest energies (GZK cut-off ??)

Heavier masses at highest energies?

Skymap of 69 Auger-Events with E > 55 EeV compared to density distribution of AGN

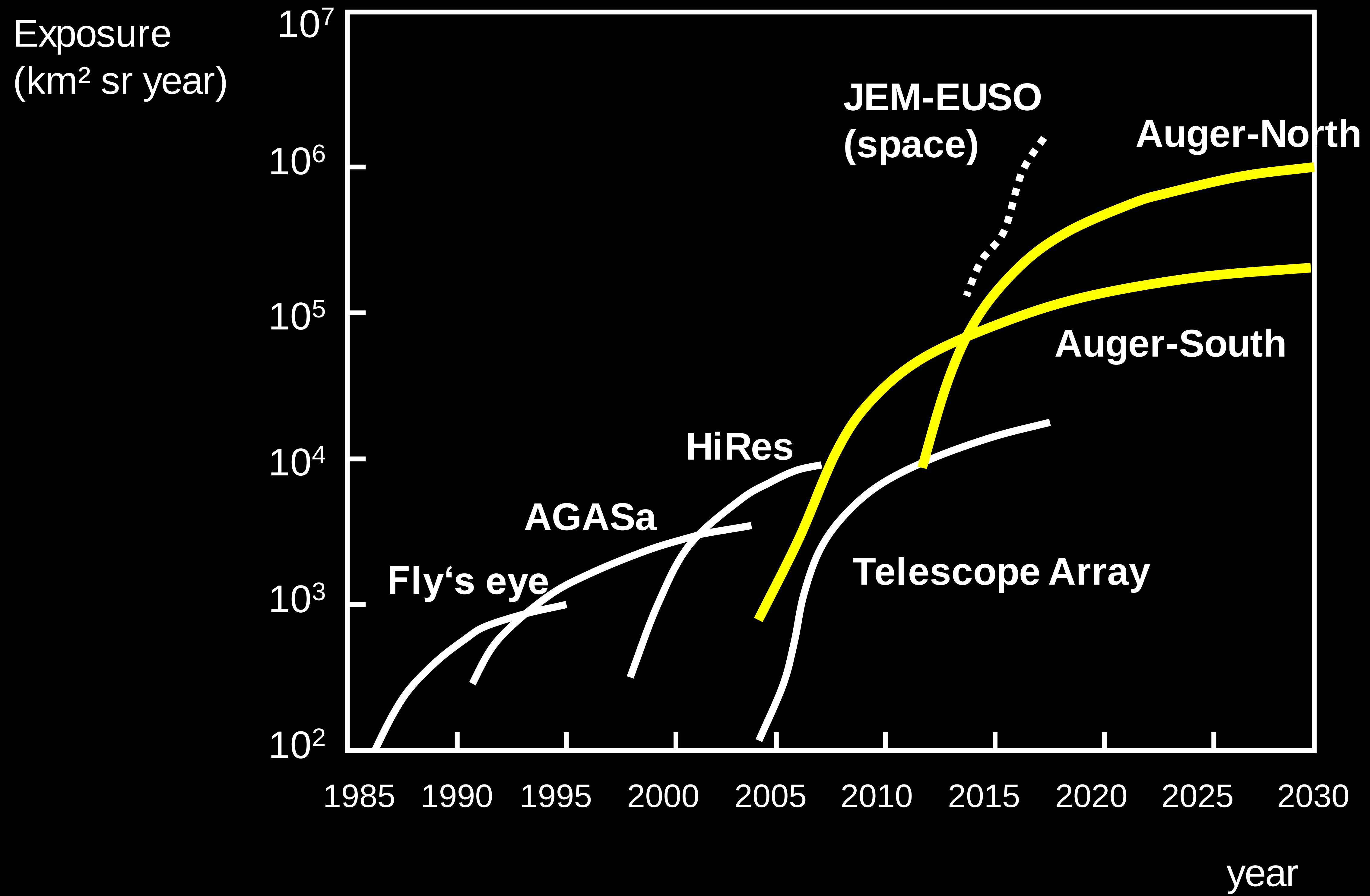



Correlation with AGN decreased
Significance nearly unchanged.

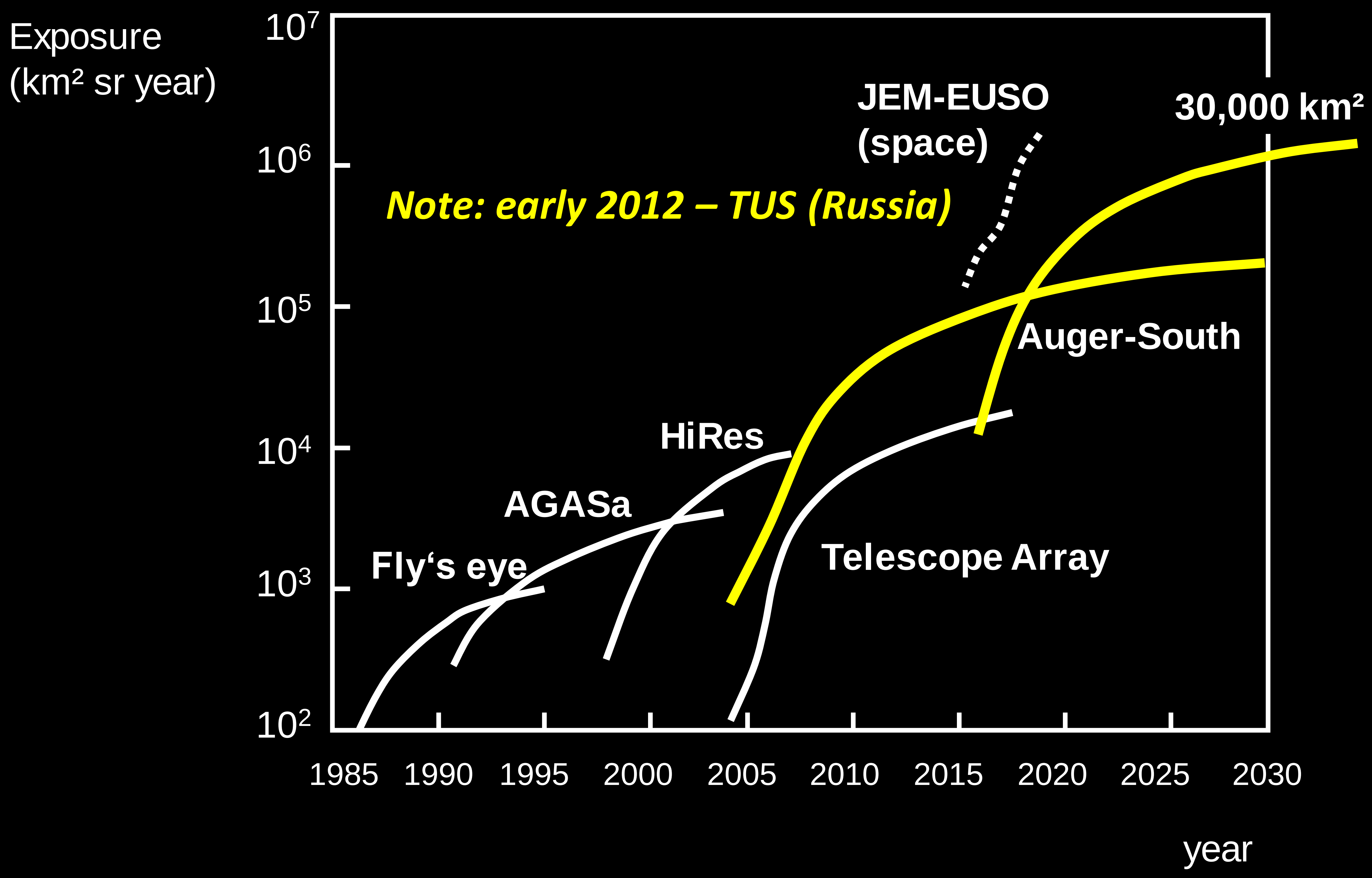
# Perspective for cosmic rays at highest Energies

**Projection 2008**



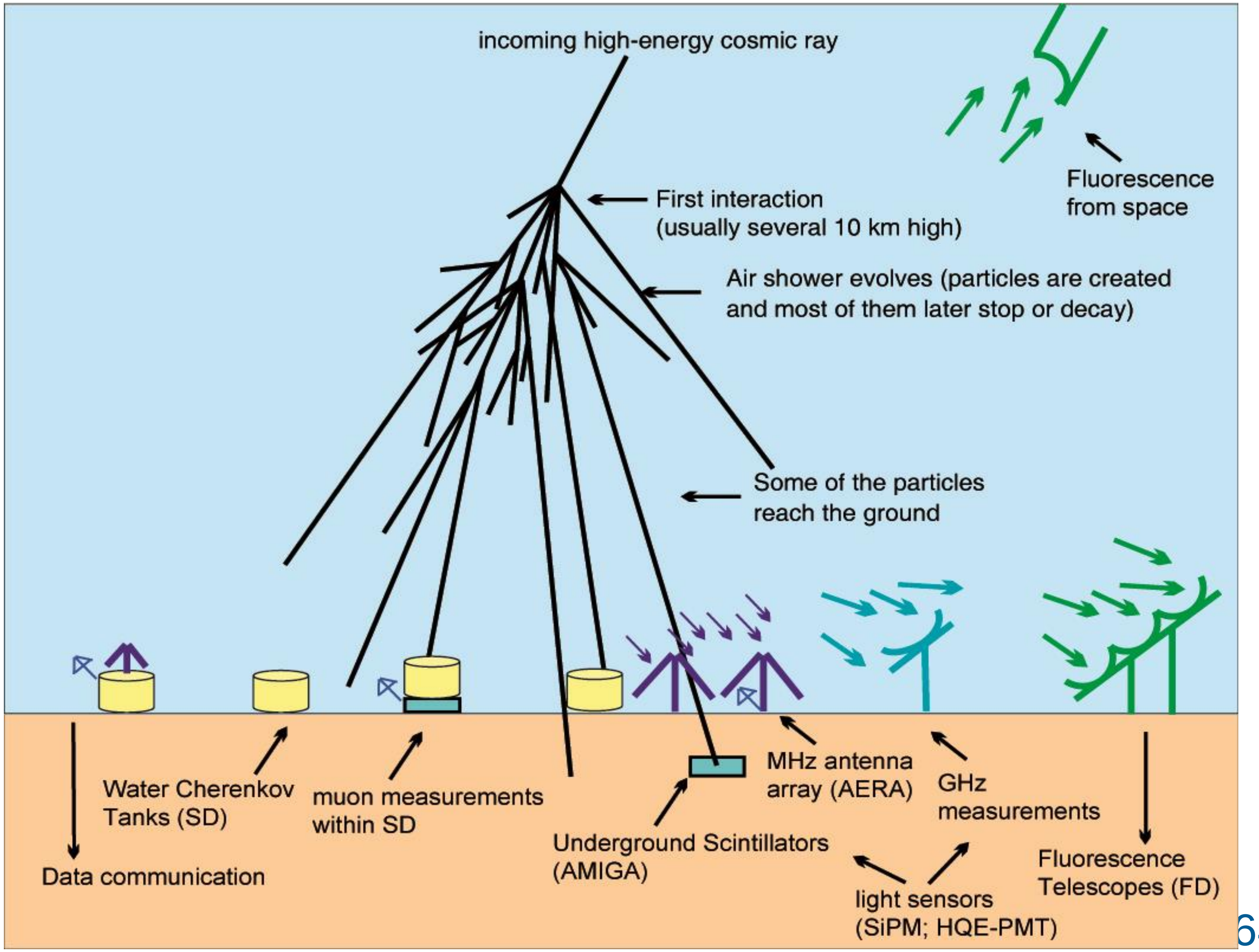
# Perspective for cosmic rays at highest Energies

**Projection 2011**



# The next 3-4 years

- Improve existing technologies
- Develop new technologies (radio MHz, GHz)
- Hybrid !



# High energy cosmic rays

- We reiterate the definition of a **substantially enlarged ground-based cosmic-ray observatory as the priority project of high energy cosmic-ray physics** – wherever it will be deployed.
- Cost scale 100-150 M€
- We encourage the community to work towards a global common path for such a substantially enlarged observatory including the **development of new detection technologies**. We recommend that **European groups** play a significant role in preparing a proposal for the next generation experiment, and, after its approval, make a **significant contribution to construction and operation**.
- We also support European participation in **JEM-EUSO** with its novel technology. We encourage cross coordination between these two approaches.

# Large scale, mid of decade:

- TeV gamma-ray astrophysics: <u>CTA</u>
- High energy neutrinos: <u>KM3NeT</u>
- High energy cosmic rays: 30,000 km² ground based array

- **Low energy neutrinos & p-decay**

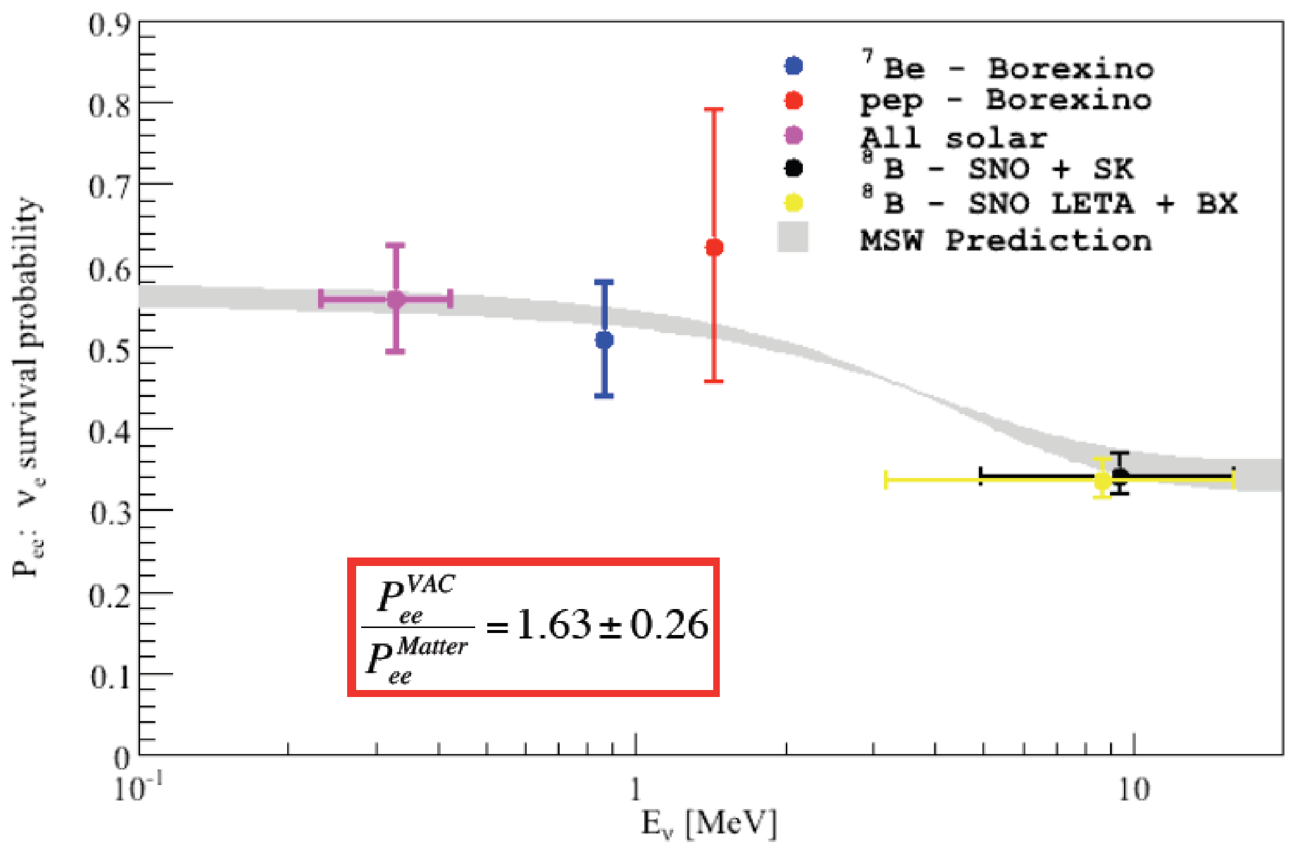
# Neutrino (astro-)physics & proton decay

- precise $^7$Be
- first time pep
- better $^8$B

- CNO neutrinos at 30% level in ~2 years.
- The committee strongly endorses further support the BOREXINO program, which is now unique in the world.

## 1) BOREXINO 2011

**solar neutrinos are not boring!**




## 2) 2011 hints to large $\theta_{13}$

Double CHOOZ: To achieve full sensitivity and to stay competitive with other experiments worldwide, it is critical that the Near Detector be completed as soon as possible.

# Science on the Megaton scale

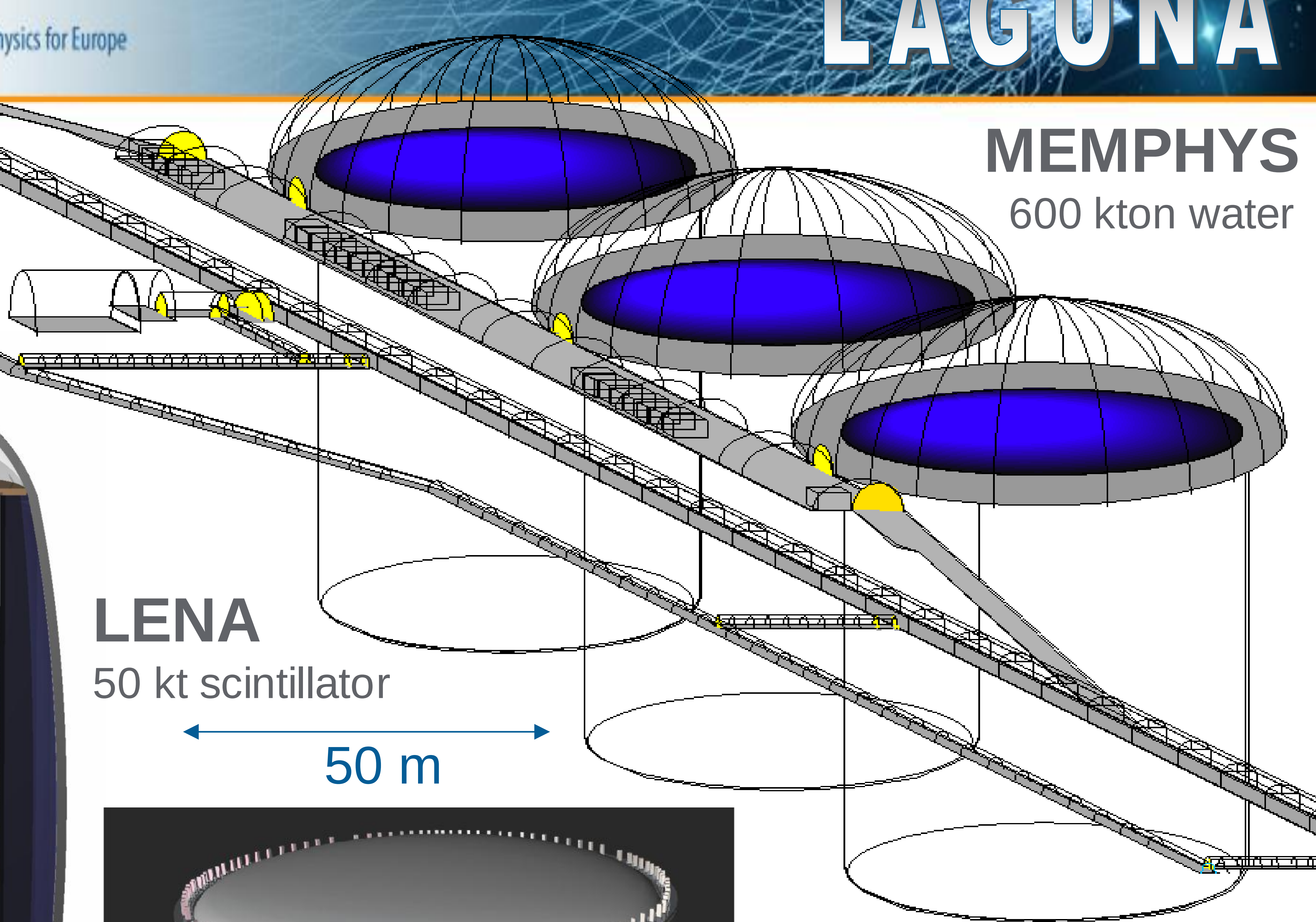
- **Proton decay:** improve sensitivity by > factor 10 and test a new class of Supersymmetry models
- **Galactic Supernova:** $10^4$- $10^5$ events Incredibly detailed information on the early SN phase
- **Diffuse flux from past SN:** probe cosmological star formation rate
- **Solar neutrinos:** details of the Standard Solar Model determined with percent accuracy
- **Atmospheric neutrinos:** high statistics would improve knowledge neutrino mixing and provide unique information on the neutrino mass hierarchy
- **Geo-neutrinos:** improve understanding of the Earth interior
- **Indirect WIMP search**
- **Neutrinos from accelerators** over a long baseline (also with dedicated smaller detectors): neutrino properties !

# Projects on the Megaton scale

**Europe:** LAGUNA

**Japan:** Hyper-K

**USA:** LBNE



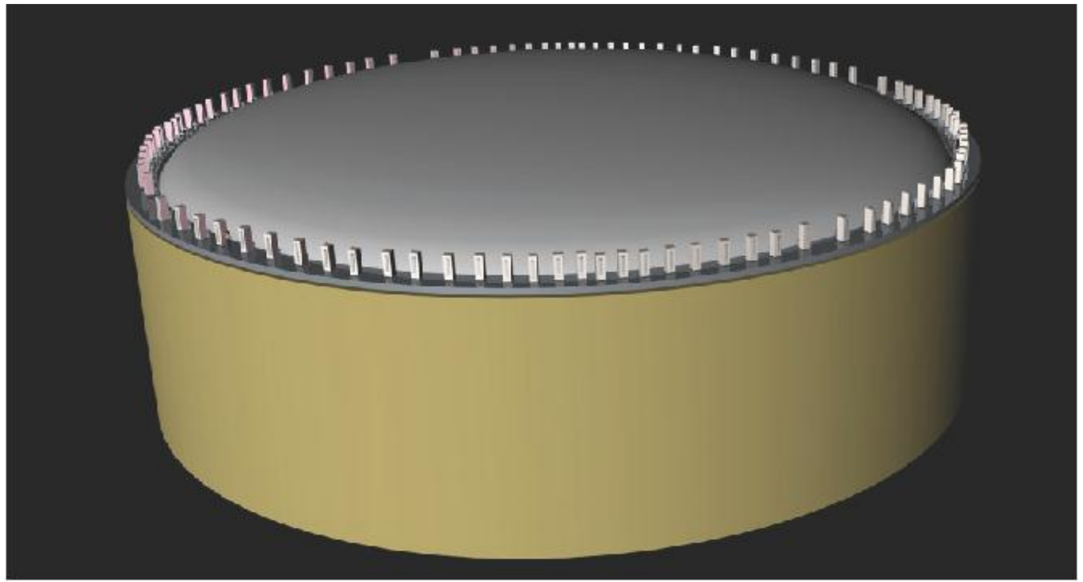
## MEMPHYS

600 kton water

## LENA

50 kt scintillator

50 m



## GLACIER

100 kton liquid argon

# Neutrino (astro-)physics & proton decay

- A megaton-scale low-energy neutrino astrophysics and proton-decay detector for astroparticle and accelerator-based neutrino measurements is addressed by the **LAGUNA** design study.
- The scientific goals combine high-risk research addressing several fundamental questions of physics (proton decay, CP violation) with exciting neutrino astrophysics (e.g. supernova, solar, geo- and atmospheric neutrinos).
- **The committee recommends that the study be pursued within the LAGUNA-LBNO program, including options with and without a new neutrino beam. Due to the high cost (350-700 M€, depending on site and type of detector) and the long development time, the committee recommends that this program be pursued in a global context.**
- Given the close relation to beam-related neutrino oscillation projects, the urgency of its realization depends strongly on the output of the current accelerator and reactor programs and in particular on whether the missing neutrino-mixing parameters are in the range that would permit a series of very exciting new measurements (neutrino mass hierarchy, CP violation etc). If the current indications for a large mixing angle $\theta_{13}$ were to be confirmed within one or two years, attractive scenarios for the medium-term CERN strategy open up, LAGUNA is therefore clearly at the interface with the CERN European Strategy Update to be delivered by the end of 2012. **As such the LAGUNA project constitutes a high astroparticle physics priority to be discussed within the CERN strategy update process.**

# The EU design study "menu"

## LAGUNA

-far detector "RI" for astroparticle and beam physics
-three detector options
-seven potential sites
-excavation costs
-industrial links

2008

time

2011

## LAGUNA-LBNO

-international consortium including EU, Japan and Russia
-two main far sites
-new conventional beam from SPS
-high energy MW-superbeam (HP-PS)
-near detector infrastructure
-detector magnetization
-detector construction and costs

2014

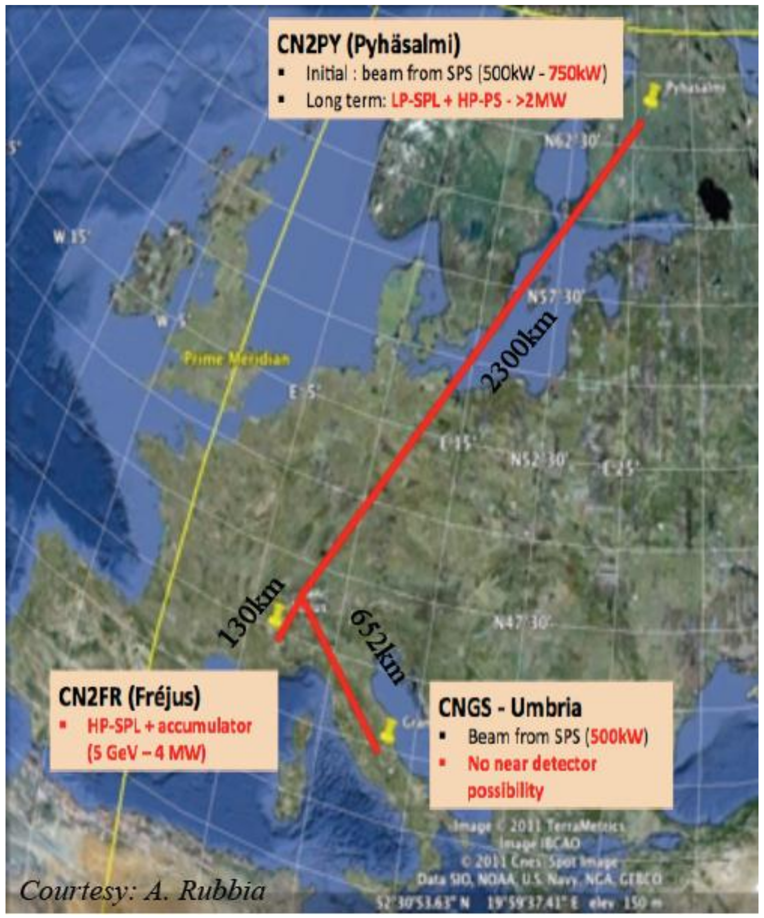
## EuroNu

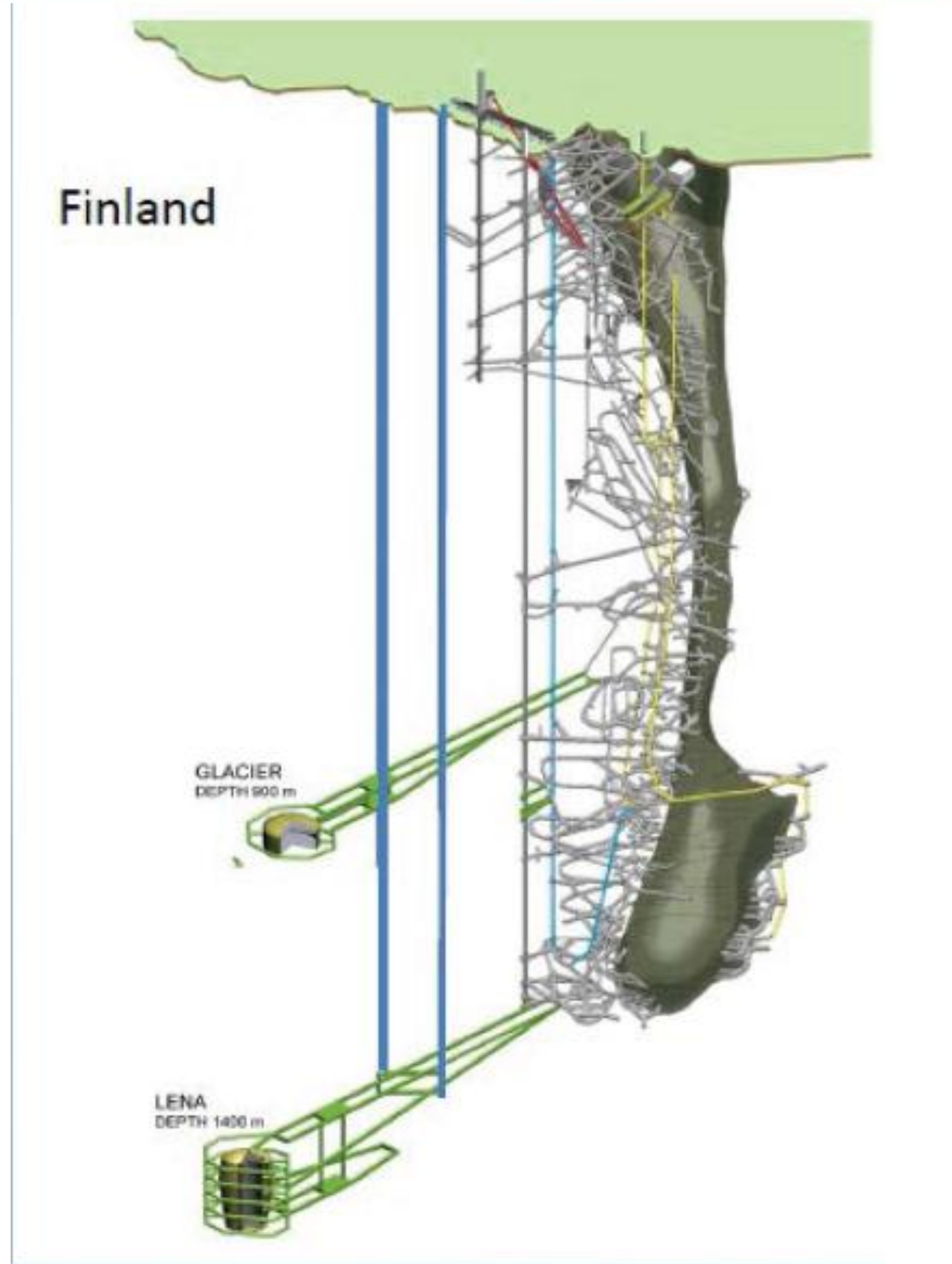
-international consortium
-low energy MW-superbeam (HP-SPL)
-beta beam
-neutrino factory
-costs
-comparison of facilities

← Update European Strategy of Particle Physics

next step(s) ?

# LAGUNA Case Study




**Case study for European Strategy Process:**

**- CERN-Pyhäsalmi**

**- LSc + LAr**

**(Studies also incremental approach)**

# Large scale, mid of decade: All Four ?

- The presently conceived start of construction of KM3NeT, "AugerNEXT" and LAGUNA is between 2014 and 2016.
- It seems likely that this does not fit into a realistic funding scheme!
    - **We would support a strategy to search for funding opportunities for these projects – both in Europe and worldwide – and promote any one of these projects as soon as a corresponding window appears.**

http://www.aspera-eu.org

# Very Large scale, end of decade:

- Gravitational Waves:

**ET** and **LISA**

- Dark Energy:

**LSST** and **EUCLID**

http://www.aspera-eu.org

# Very Large scale, end of decade:

- **Gravitational Waves:**

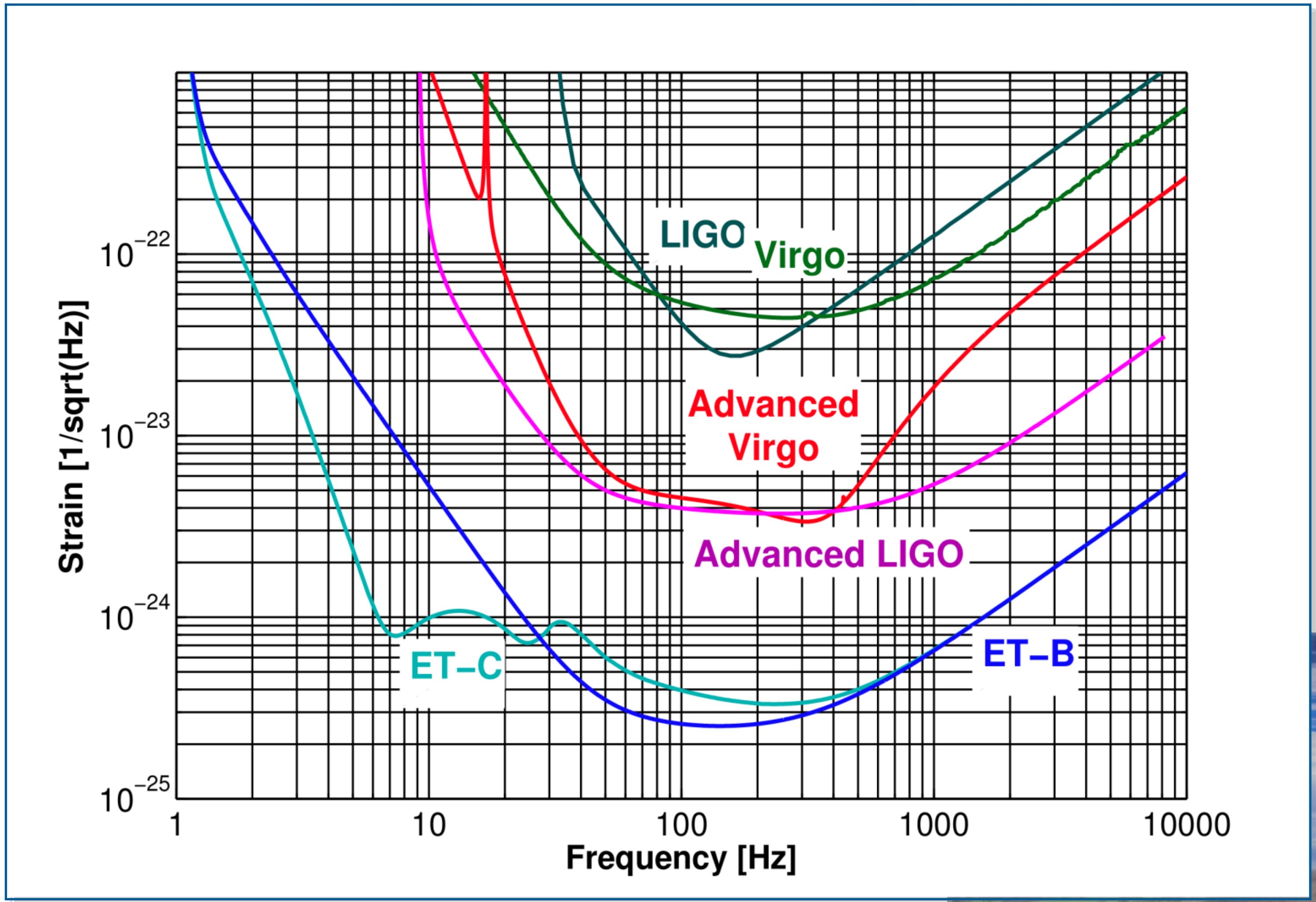
**<u>ET</u> and <u>LISA</u>**

- Dark Energy: <u>LSST</u> and <u>EUCLID</u>

http://www.aspera-eu.org

ASPERA Astroparticle Physics for Europe

# The Einstein Telescope

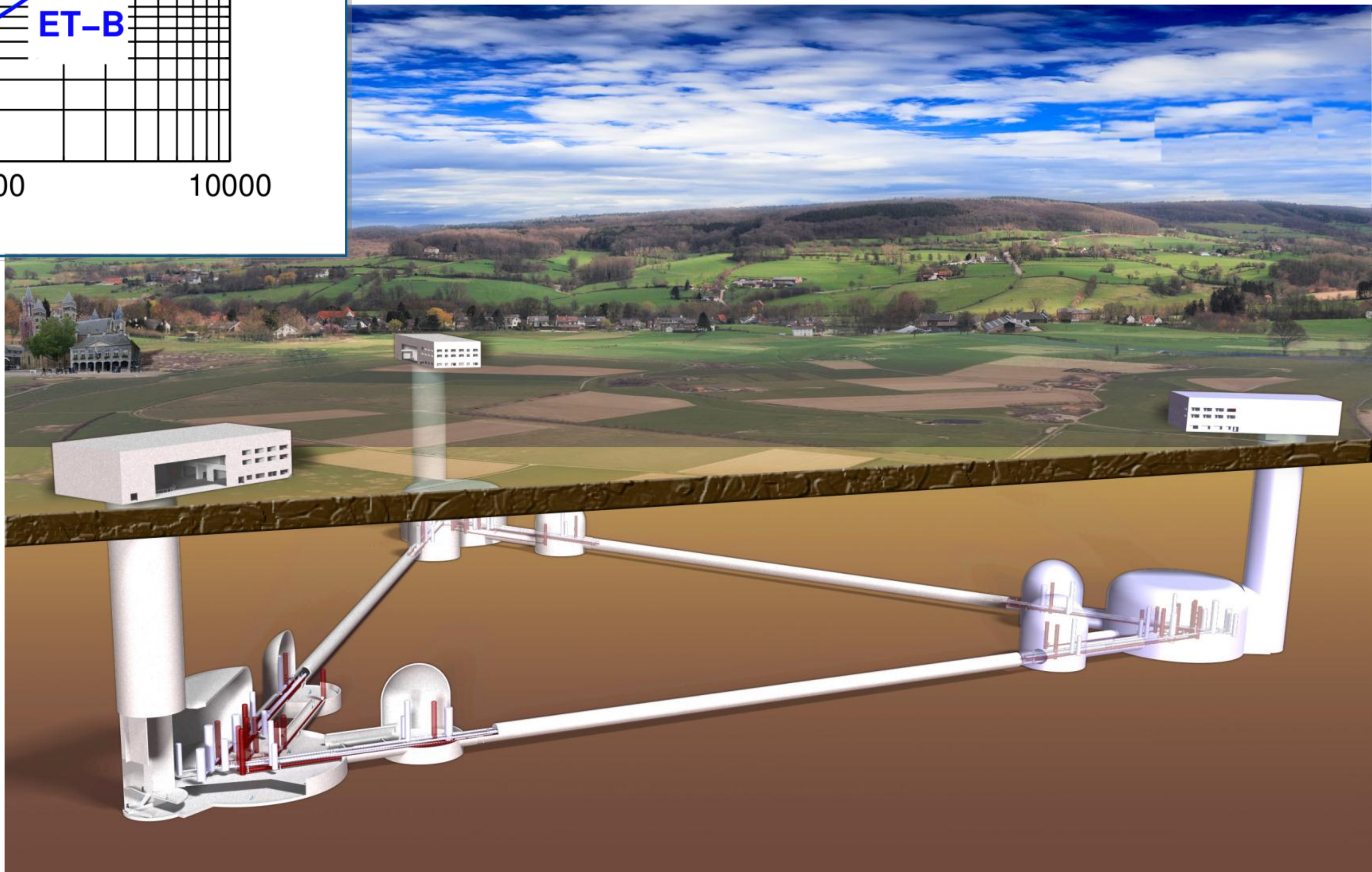


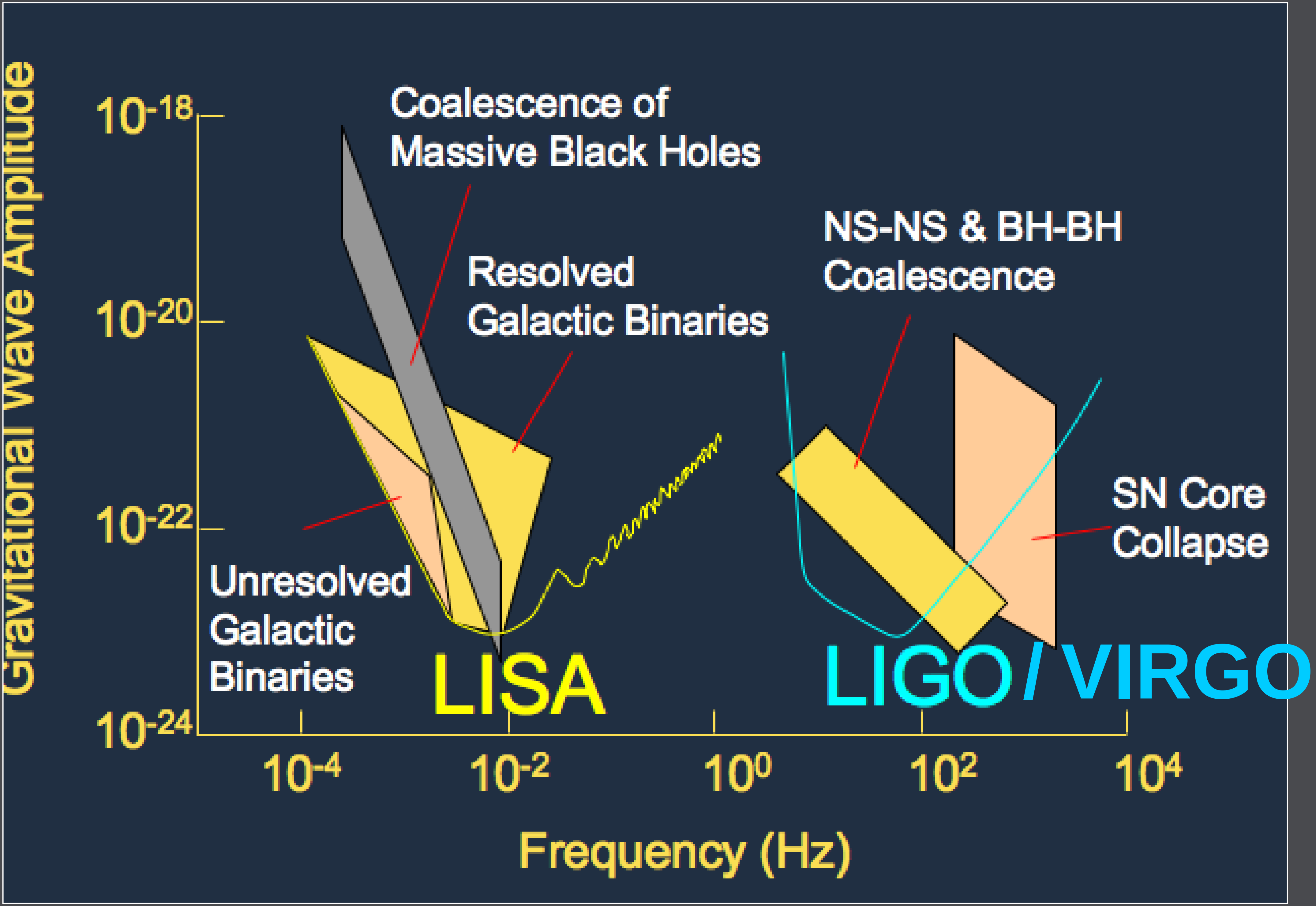

ET EINSTEIN TELESCOPE

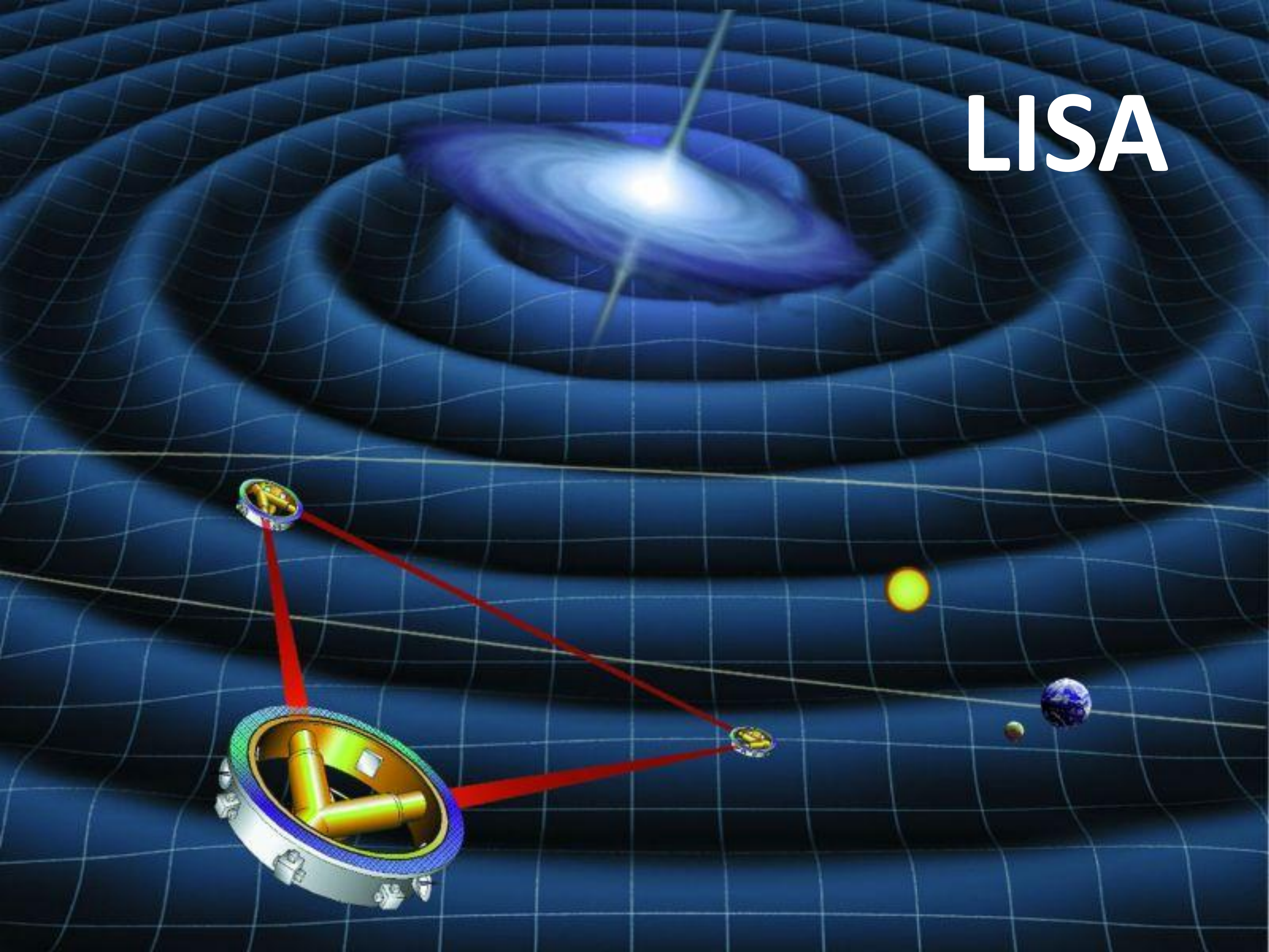
EU funded **conceptual design study** concluded May 2011

R&D ongoing

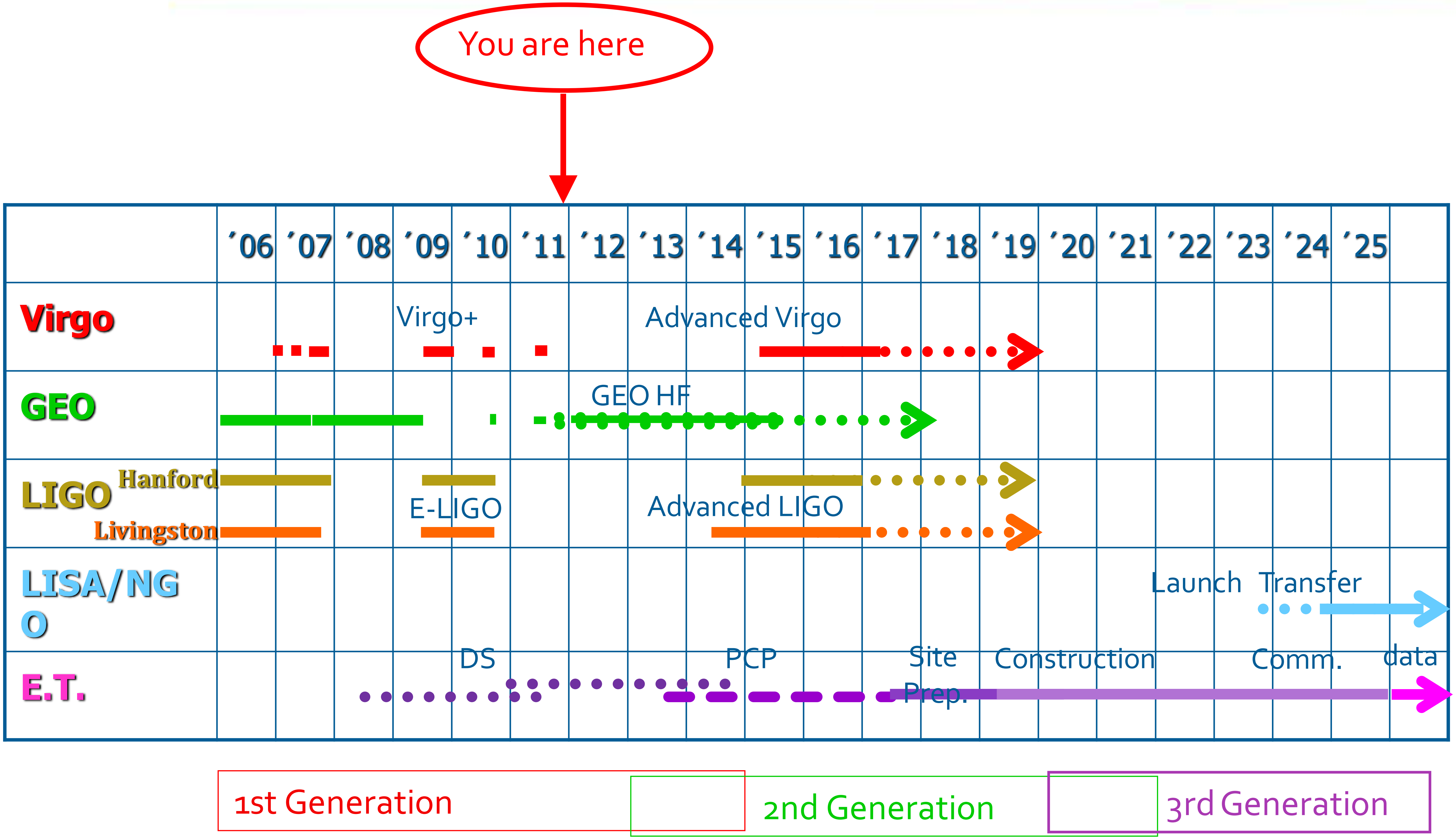
- 3rd generation GW detector
- 10x better than „advanced detectors“
- Expanded to low frequencies
- 1000x event rate
- Routine GW astronomy out to high red shifts




Gravitational Wave Amplitude
10-18
10-20
10-22
10-24
Coalescence of
Massive Black Holes
Resolved
Galactic Binaries
NS-NS & BH-BH
Coalescence
SN Core
Collapse
Unresolved
Galactic
Binaries
LISA
LIGO / VIRGO
10-4
10-2
100
102
104
Frequency (Hz)


LISA

# GW Timelines



# Gravitational Waves

- The path for research in gravitational waves beyond the advanced detectors foresees two huge-scale projects (costs on the billion Euro scale):
  - **the Earth-bound Einstein Telescope (ET)**
  - **the space-bound LISA project.**

- From today's perspective ET construction would start at the end of the decade and after the first detection of gravitational waves with the advanced detectors.

- We also look forward to the results of LISA-Pathfinder. We renew our strong support of the LISA mission and preparatory work on E.T. (propose ASPERA Call)

-

# Very Large scale, end of decade:

- Gravitational Waves: ET and LISA

- **Dark Energy:**

## LSST and EUCLID

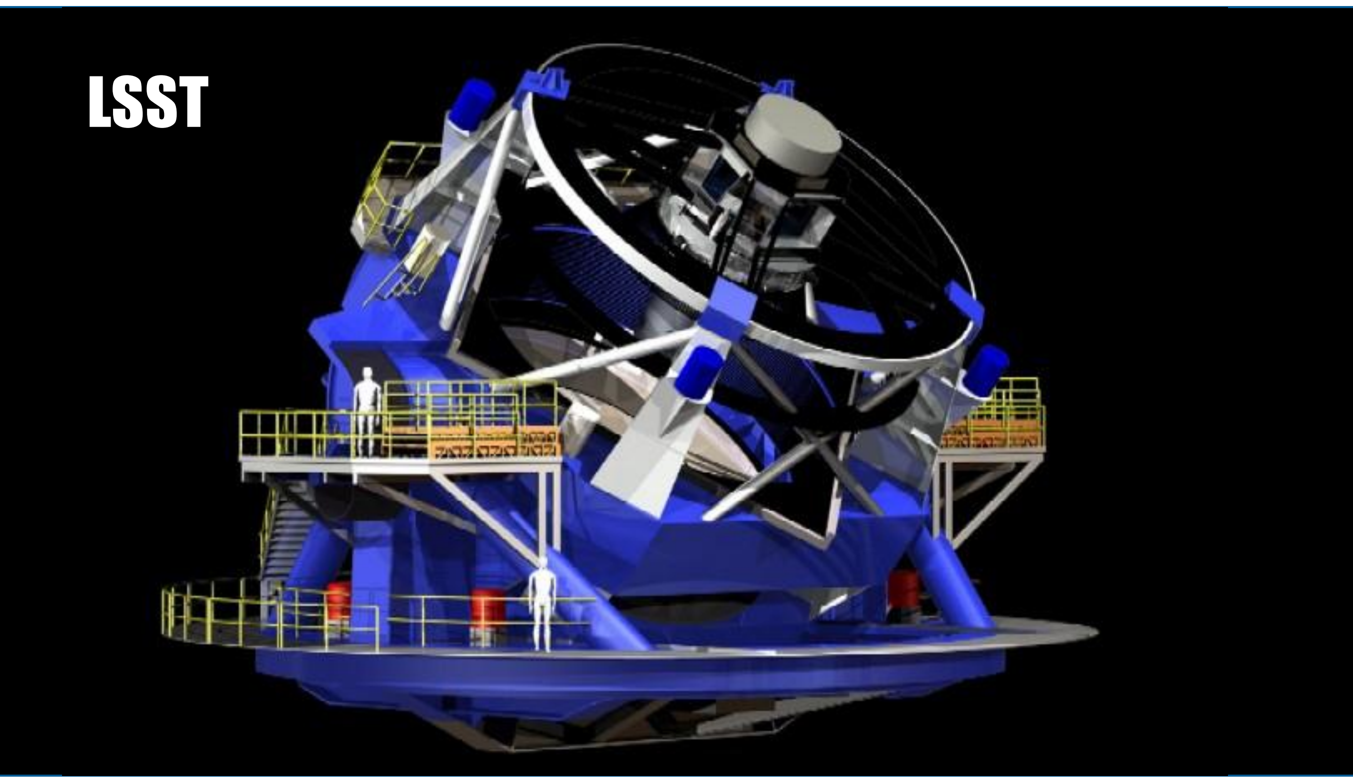

**Nobel Prize 2011**

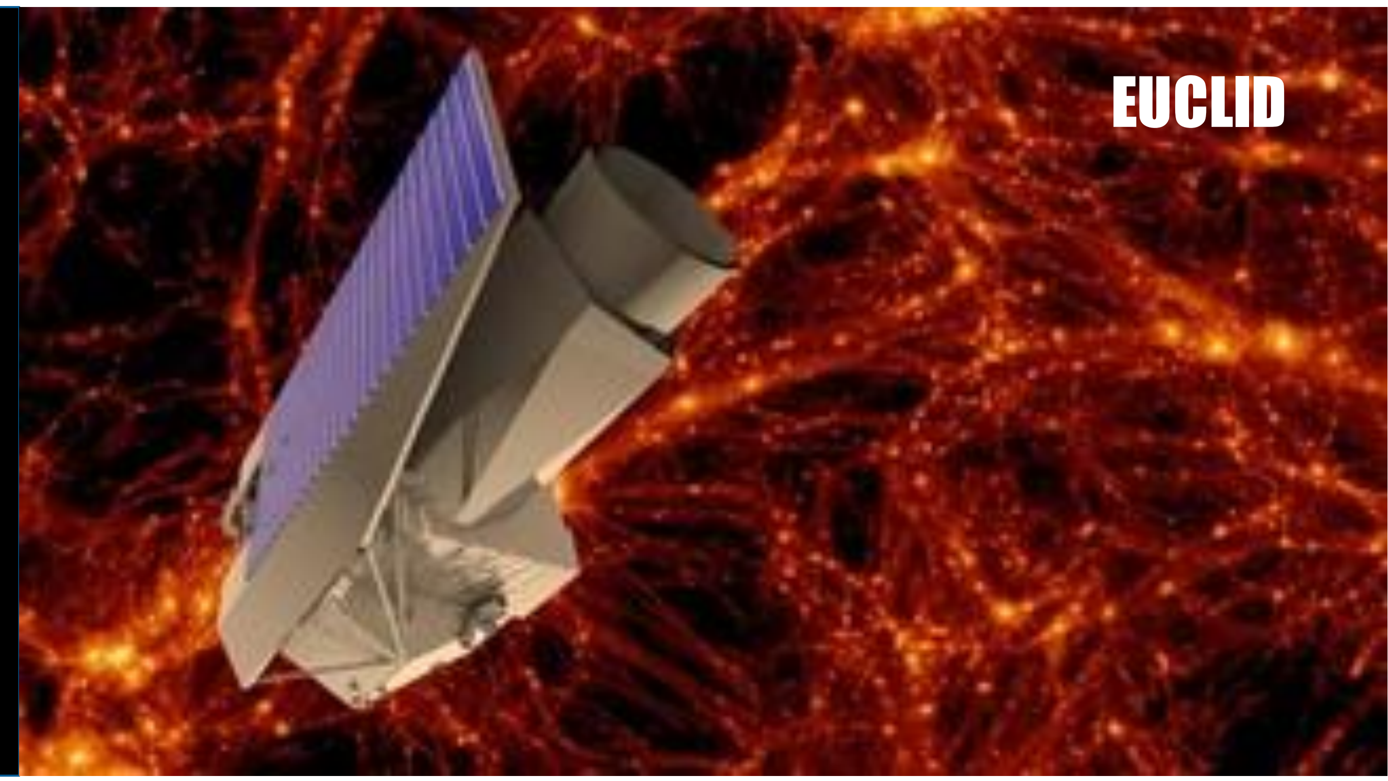
http://www.aspera-eu.org

ASPERA Astroparticle Physics for Europe

# Dark Energy

Astroparticle physicists play a major role in many international **dark energy programs,** as e.g. the dominantly US-funded **LSST** observatory (first light 2019) or the ESA satellite **EUCLID** (launch 2019).




We welcome the participation of the European astroparticle physics community in experiments in this field. This community should make sure that it can participate in the harvest of results from the presently planned ground projects and should, on the other hand, take the unique chance for leadership in space with the ESA-led Euclid mission.

**The committee recommends a strong support for these participations.**

# Transversal Aspects

- Theory
- R&D
- Environmental and Applied Physics
- Outreach

# Summary

- Astroparticle physics is a rapidly growing, dynamical field
- In full blossom: gamma-ray astrophysics → **CTA**
- Many fundamental topics have progressed to levels of sensitivity with high discovery potential (gravitational waves, dark matter, ...) → **maintain momentum !**
- Close relation to CERN strategy → **LAGUNA**

  - Relations to other sciences (particle, astro, environmental) → **broaden community!**
  - Europe is a leading player in astroparticle physics
  - Embedded in a worldwide landscape: **think global !**

http://www.aspera-eu.org