ApPEC/ASPERA Roadmap for Astroparticle Physics

S. Katsanevas
IN2P3/CNRS and ApPEC/ASPERA

25 November 2011

Visit
www.aspera-eu.org
For the complete statement of the agencies

http://www.aspera-eu.org

From ApPEC to ASPERA and beyond

- ✓ ApPEC (Astroparticle Physics European Consortium) 10 years 12 countries
- ✓ ASPERA(Astroparticle Physics European Research Area network) 5 years 19 countries
  - ✓ ASPERA (FP6) (July 2006-July 2009)
    - ✓ Roadmap of 2008 ➔ Definition of the field
    - ✓ Common R&D calls, census, linking, portal, newsletter , …
  - ✓ ASPERA-2 (FP7) (July 2009-July 2012)
    - ✓ Roadmap update 2011
    - ✓ Accompanying actions ➔ see slides at the end
- ✓ Sustainable structure of ApPEC based on the ASPERA experience
  - ✓ Letter of Intent ministerial level, under signature
  - ✓ MoU defining the bodies (General Assembly, SAC, Office)
- ✓ Astroparticle International Forum (APIF) reporting to OECD
- ✓

The questions of Astroparticle Physics
(OECD Global Science Forum definition)

What is the role of high energy phenomena in the Universe ?

- High Energy messengers (γ, ν , p/N)
- Gravitational waves

➔ Astronomy with new messengers

What is the Universe made of ?

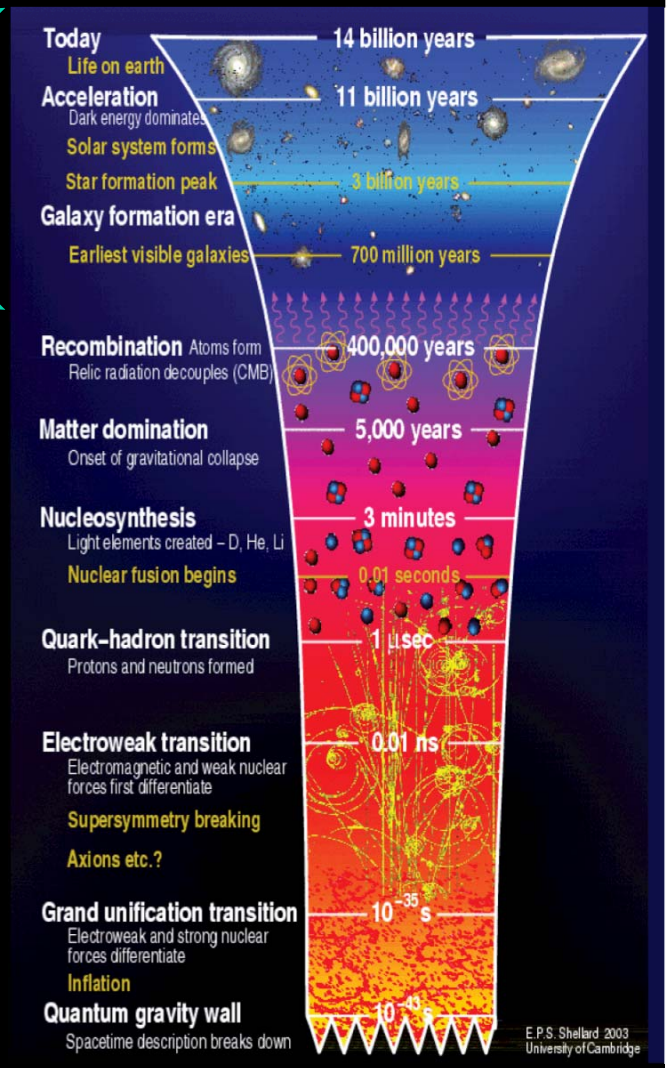
- Dark Matter
- Dark Energy

➔ New fields and particles

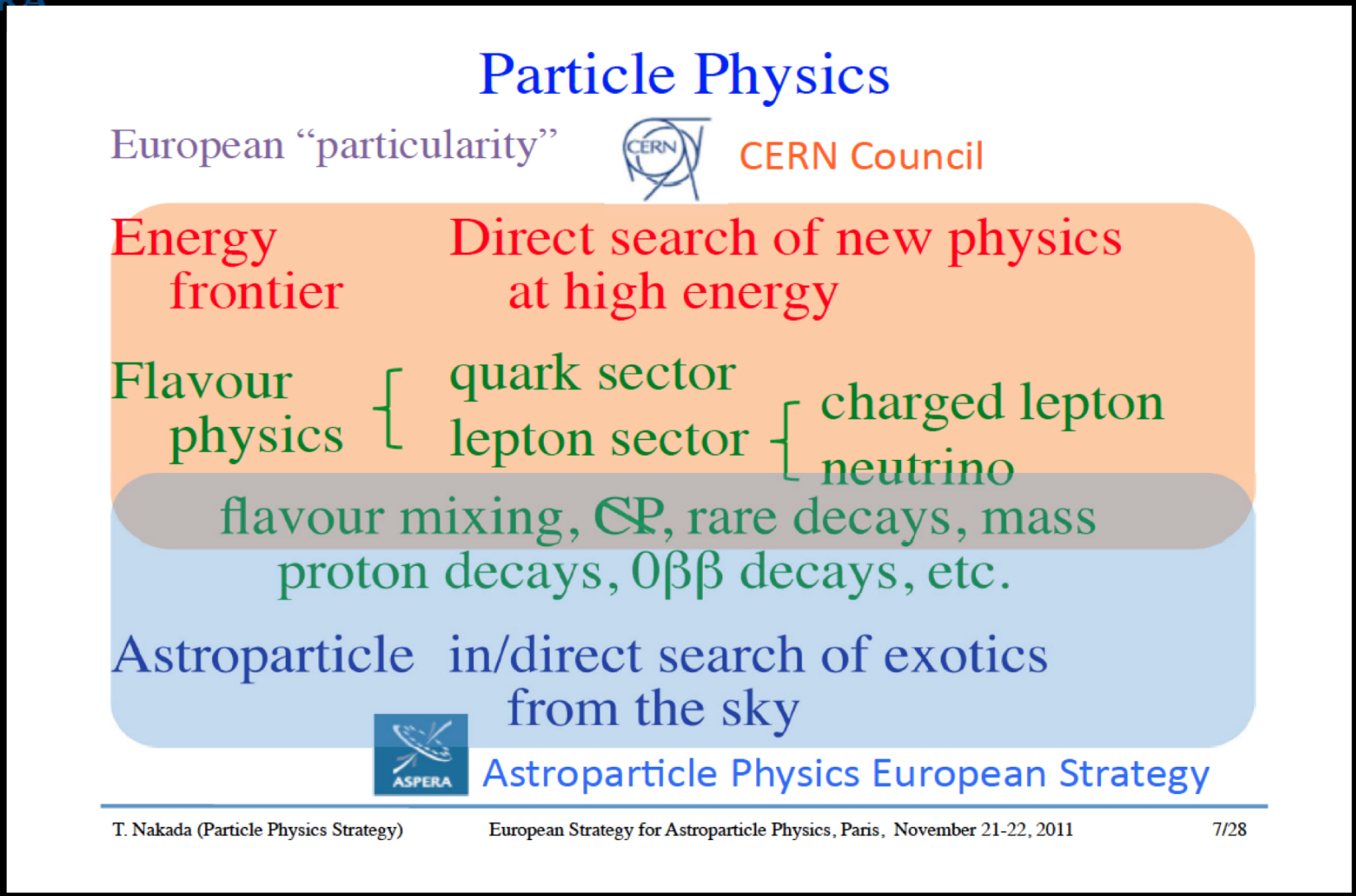
What is the nature of matter and interaction at the highest energies ?

- Neutrino Mass
- Proton decay and Neutrino Properties

➔ High energies through rare decays

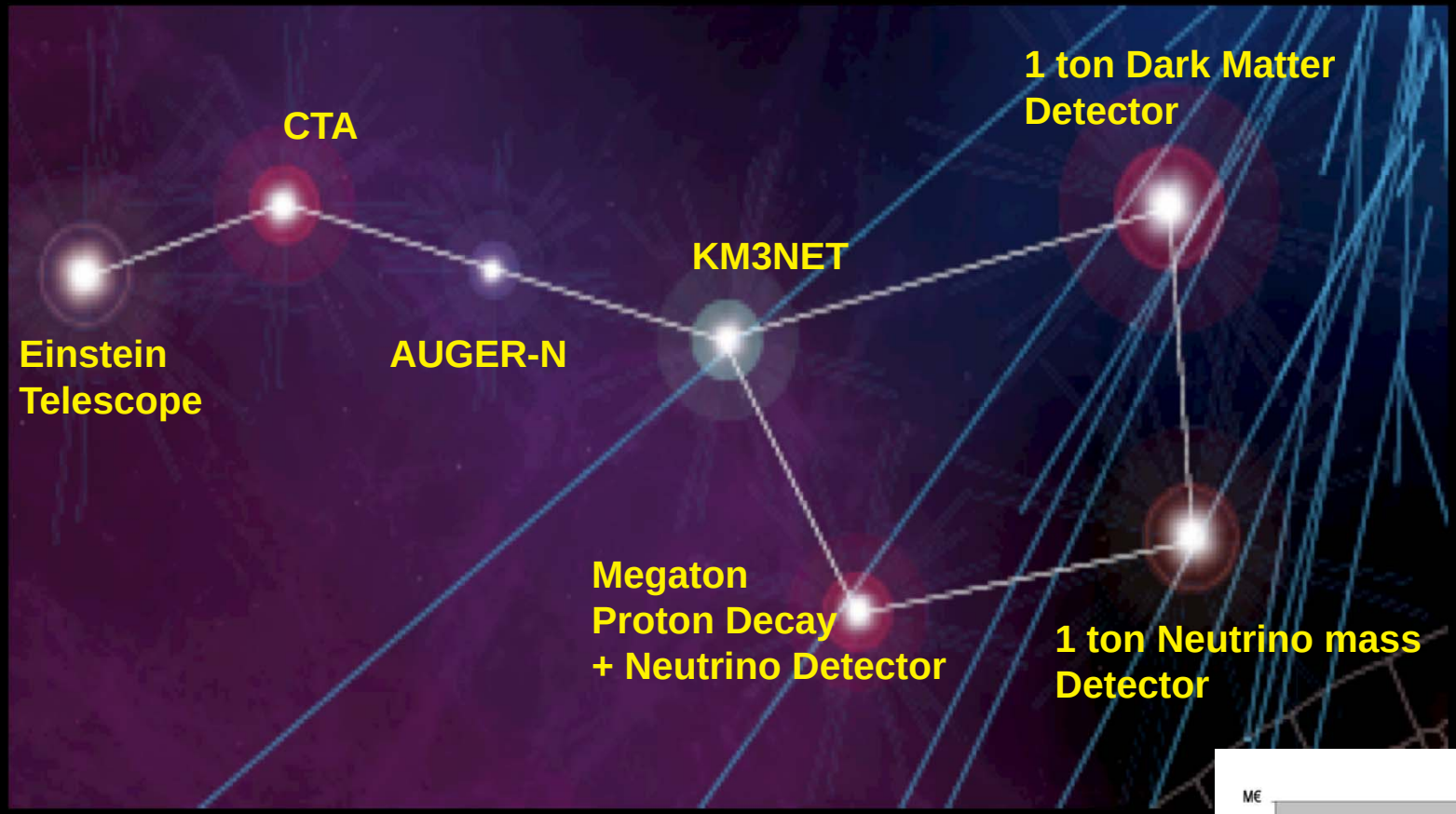


The frontiers seen from a Particle Physics frame of reference

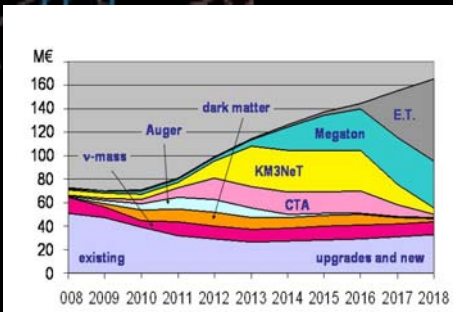


Physics is of course independent from frames of reference. For the time being…

The 2008 Roadmap: the « 7 magnificent » a definition of the field



The full program would need a 50% increase (integrated) of investment budgets traditionally available for astroparticle in the next 10 years



Why a new roadmap ?

The Roadmap Update

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

➔

- No budget timeline but movement towards a differential phasing of the projects consistent with their maturity

3 categories

- Medium scale, ongoing/extension
- Large scale, mid of decade
- Very large scale*, end of decade

* This category includes projects where the leaderships is in non-ASPERA agencies (e.g. US, ESA)

Medium scale

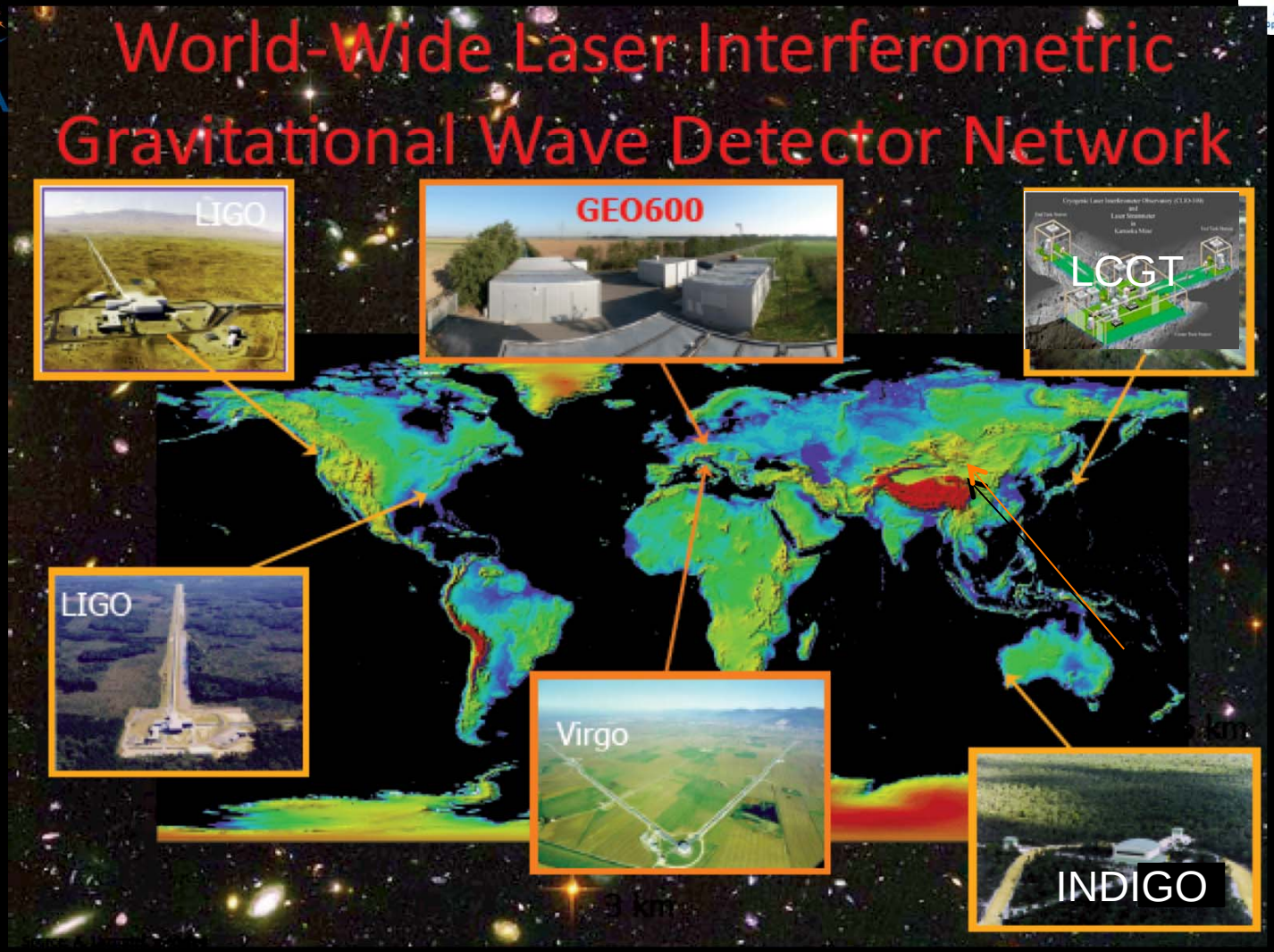
There are a few projects which need immediate and substantial funding,

- 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.

Medium scale

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

http://www.aspera-eu.org



Gravitational wave advanced detectors, where a discovery in the next five years becomes highly probable and would open an entirely new window to the Universe (advVIRGO, advLIGO, GEO-HF)

A few to several tens of sources per year

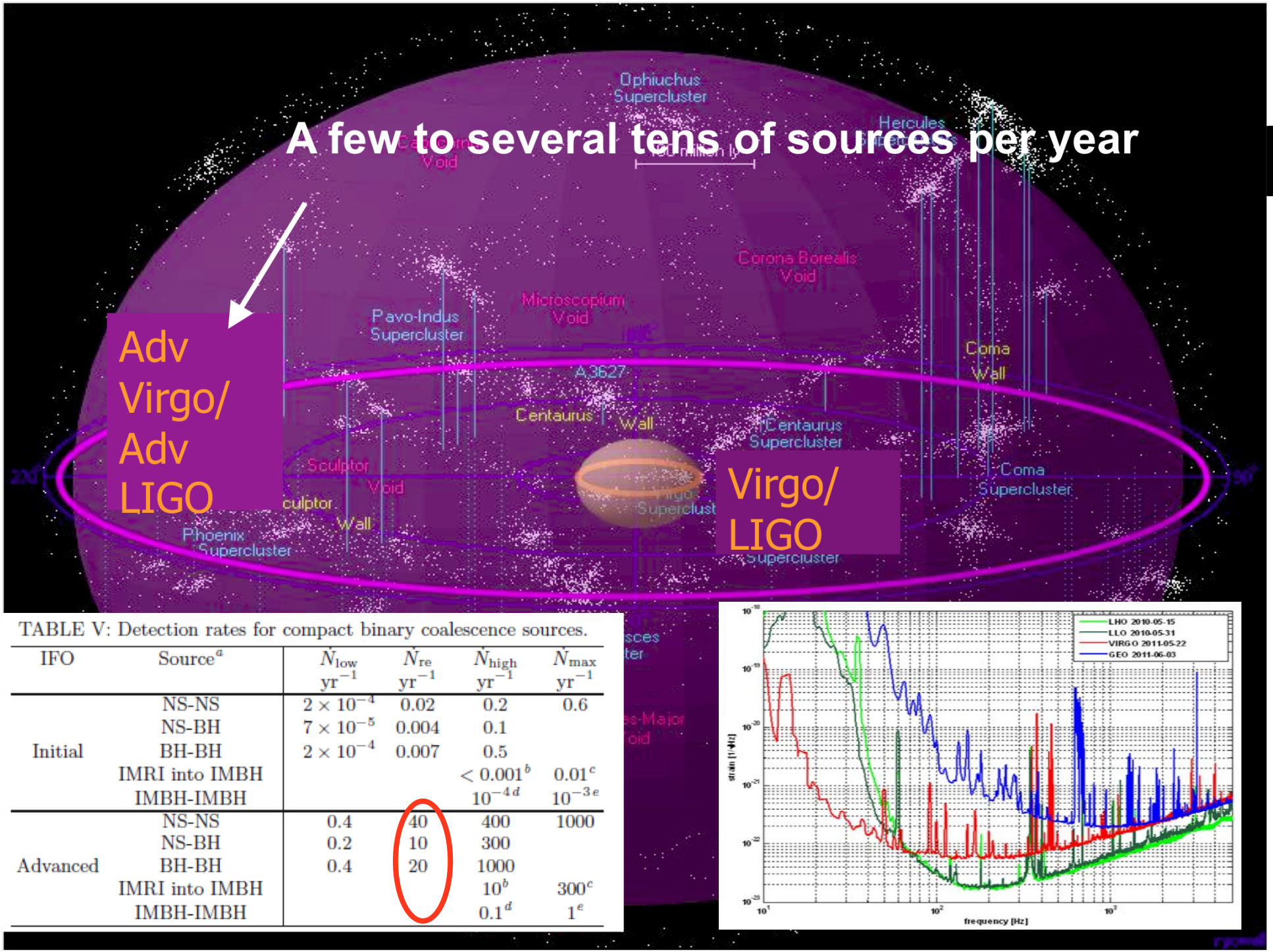
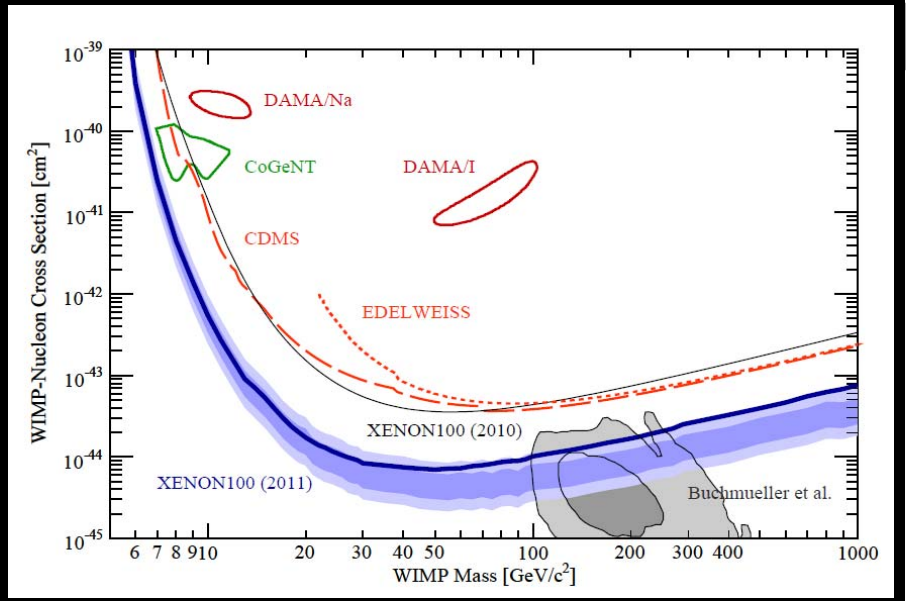


TABLE V: Detection rates for compact binary coalescence sources.

IFO	Source[a]	$\dot{N}_{\rm low}$ yr^{-1}	$\dot{N}_{\rm re}$ yr^{-1}	$\dot{N}_{\rm high}$ yr^{-1}	$\dot{N}_{\rm max}$ yr^{-1}
Initial	NS-NS	2×10^{-4}	0.02	0.2	0.6
	NS-BH	7×10^{-5}	0.004	0.1	
	BH-BH	2×10^{-4}	0.007	0.5	
	IMRI into IMBH			$< 0.001^{b}$	0.01^{c}
	IMBH-IMBH			$10^{-4\,d}$	$10^{-3\,e}$
Advanced	NS-NS	0.4	40	400	1000
	NS-BH	0.2	10	300	
	BH-BH	0.4	20	1000	
	IMRI into IMBH			10^{b}	300^{c}
	IMBH-IMBH			0.1^{d}	1^{e}

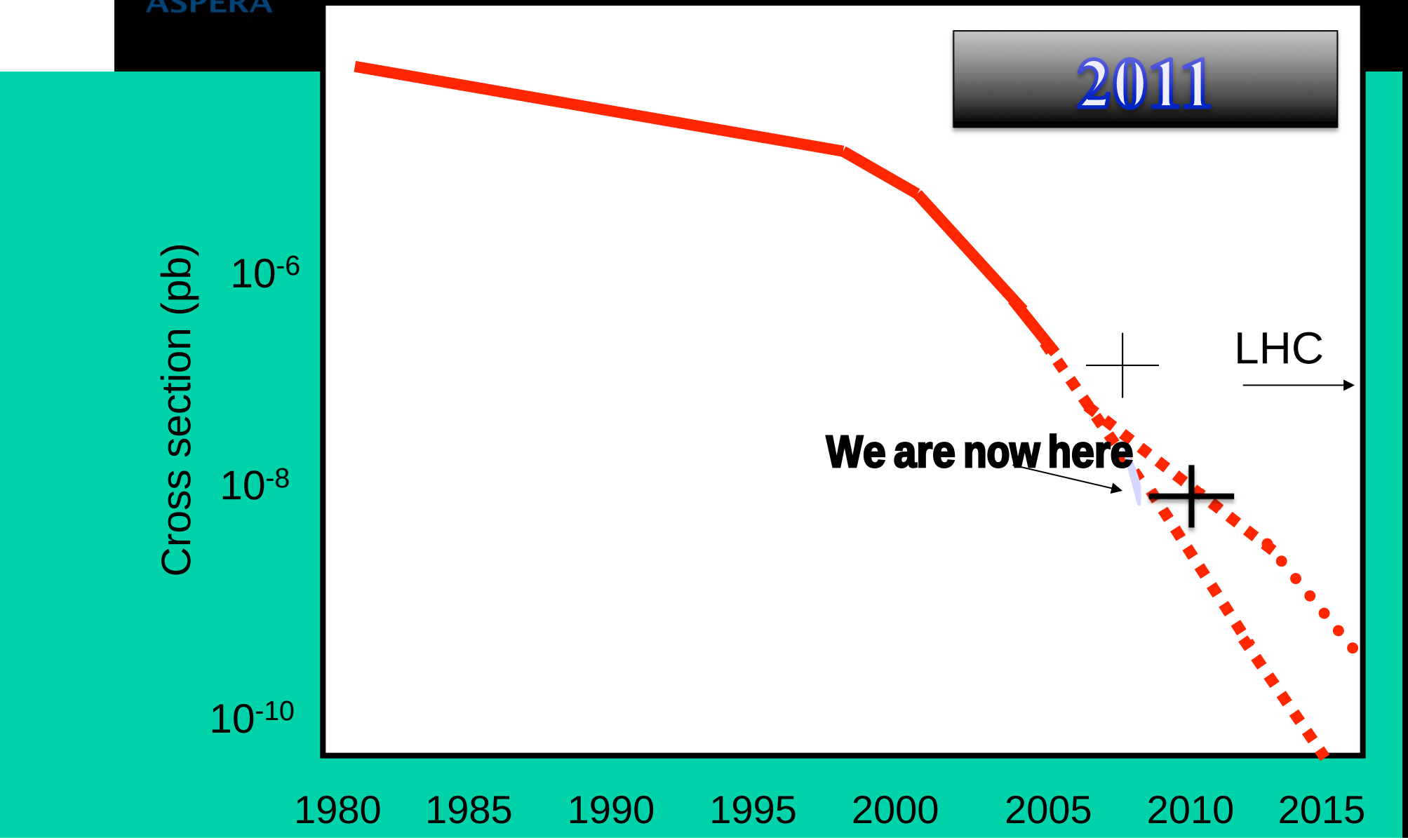
Dark Matter Highlights 2011

- Annual Modulations:
  - DAMA/LIBRA new results
  - CoGenT
- ZEPLIN-III final results
- CRESST excess (?)
- Edelweiss now close to CDMS
- Combined analysis Edelweiss-CDMS
- XENON100 achieves record limit
- XENON1t installation has started
- Spin-dependent: SIMPLE, COUPP, SK, IceCube



Recommendations of the Roadmap 2008 in progress !!!!

Dark matter: back in the projection of increase of sensibility



ASPERA

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

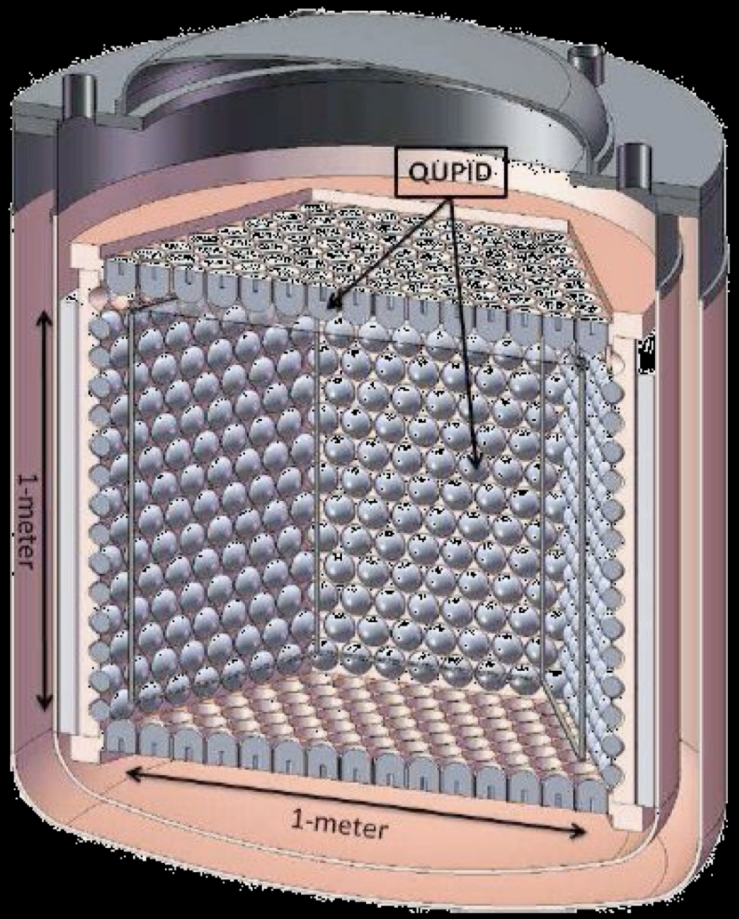
XENON

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

ASPERA

Germany, France, UK,

Spain, Russia, Ukraine

combines all European cryogenic DM efforts:

R&D cooperation with CDMS/GeoDM

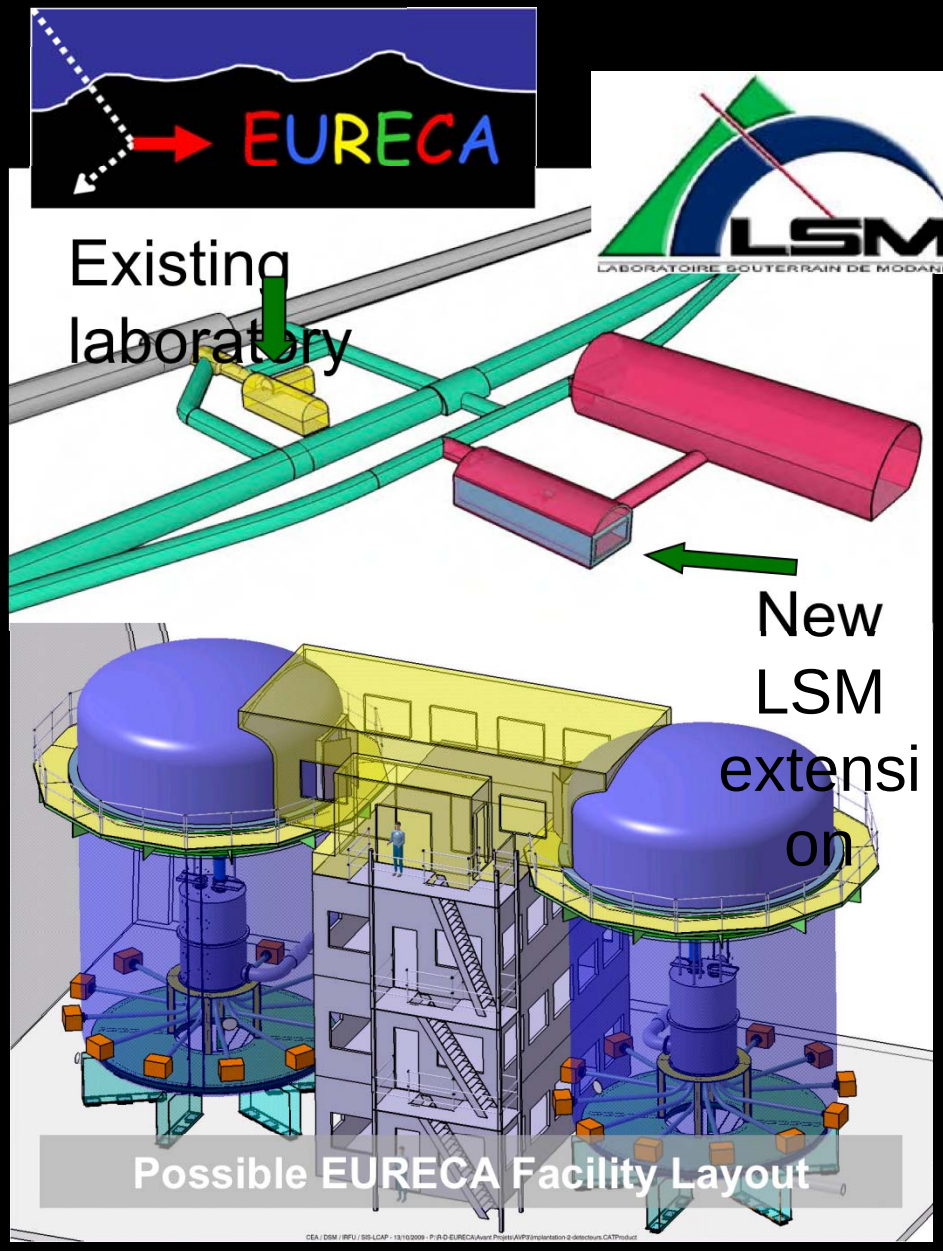
2009/11: design study → TDR

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

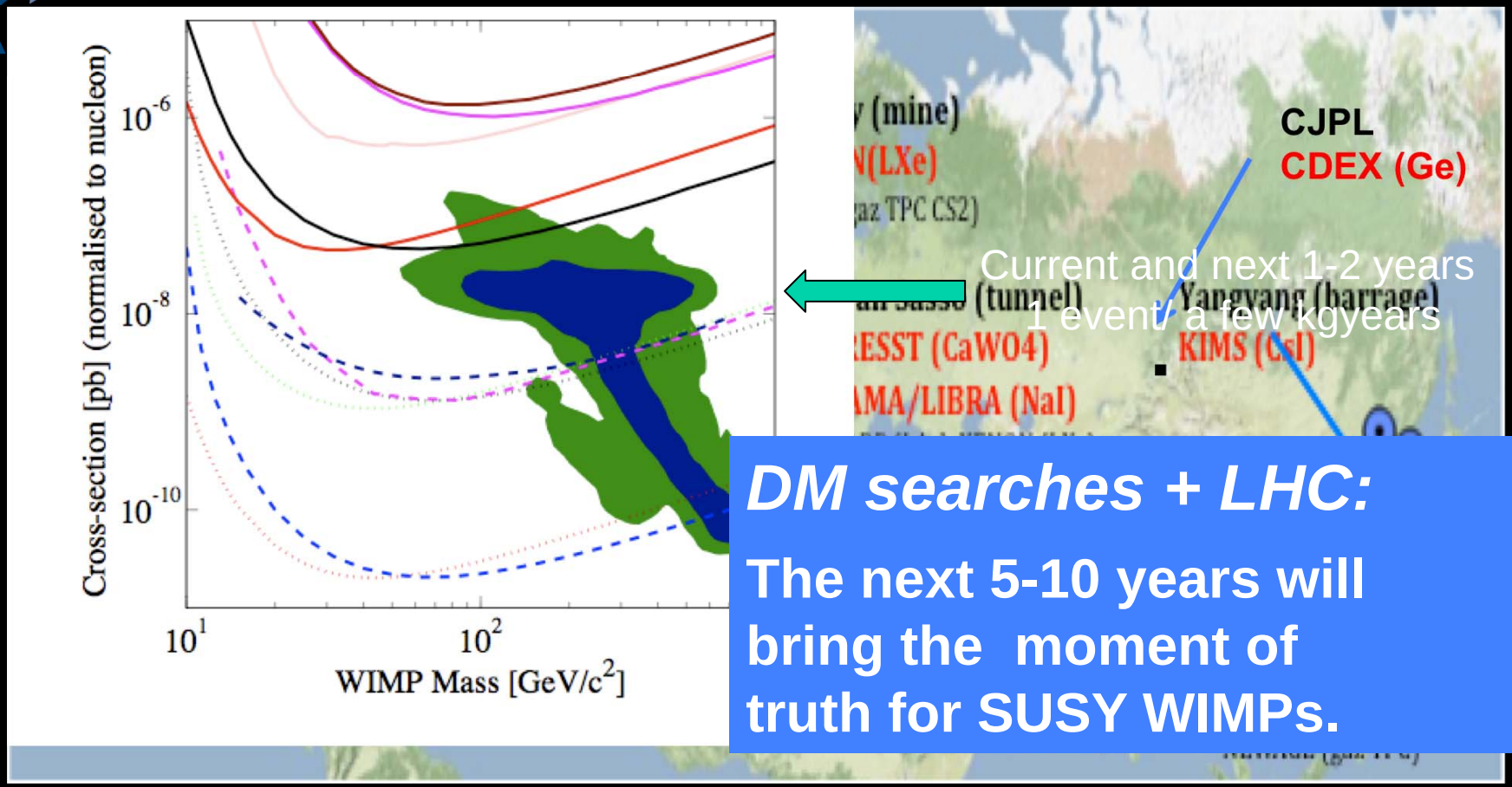
2013/14: construction at LSM

2015: begin data taking at LSM

2015 – 2018:
• continuous upgrade to 1t target
• ~ 10^{-46} cm^2



Dark matter

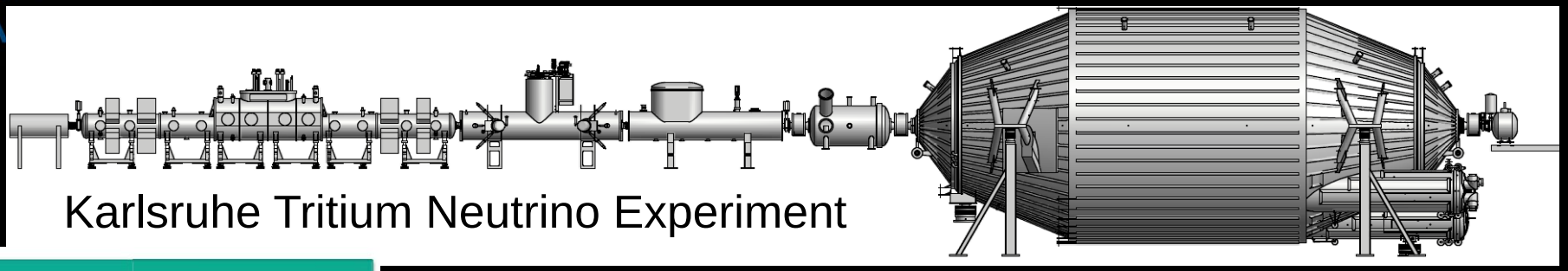


DM searches + LHC:

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

Dark matter searches, where the WIMP dark matter hypothesis will be proven or disproven within the next 10 years. The dramatic progress of the noble liquid technology and the steady progress of bolometric techniques over the past 2-3 years demonstrate a high momentum which must be maintained. Ton scale experiments using xenon and lower total mass low-temperature crystals will start taking data by the middle of the decade. A program extending the target mass of noble liquids to several tons is envisaged.

Neutrino mass KATRIN & beyond

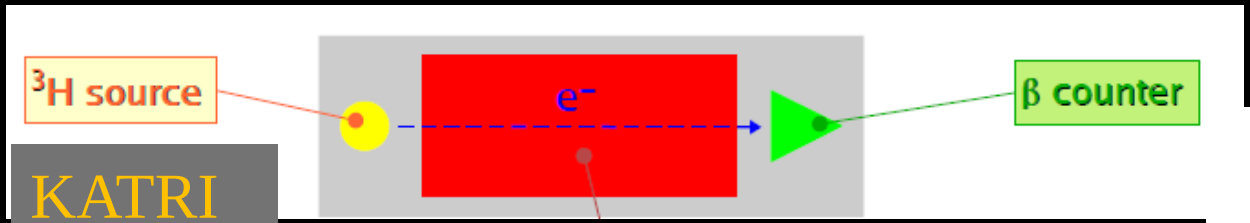


Karlsruhe Tritium Neutrino Experiment

sensitivity (90% CL)
m(ν) < 200 meV

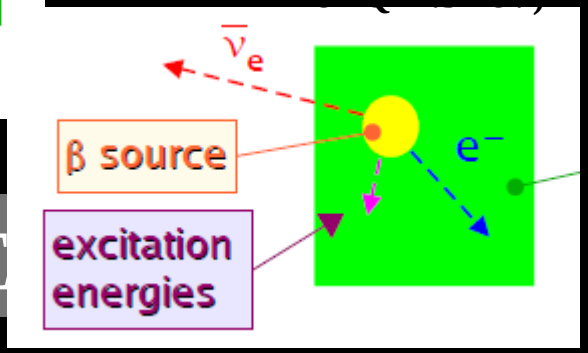
discovery potential
m(ν) = 350 meV (5σ)

- 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

MARE

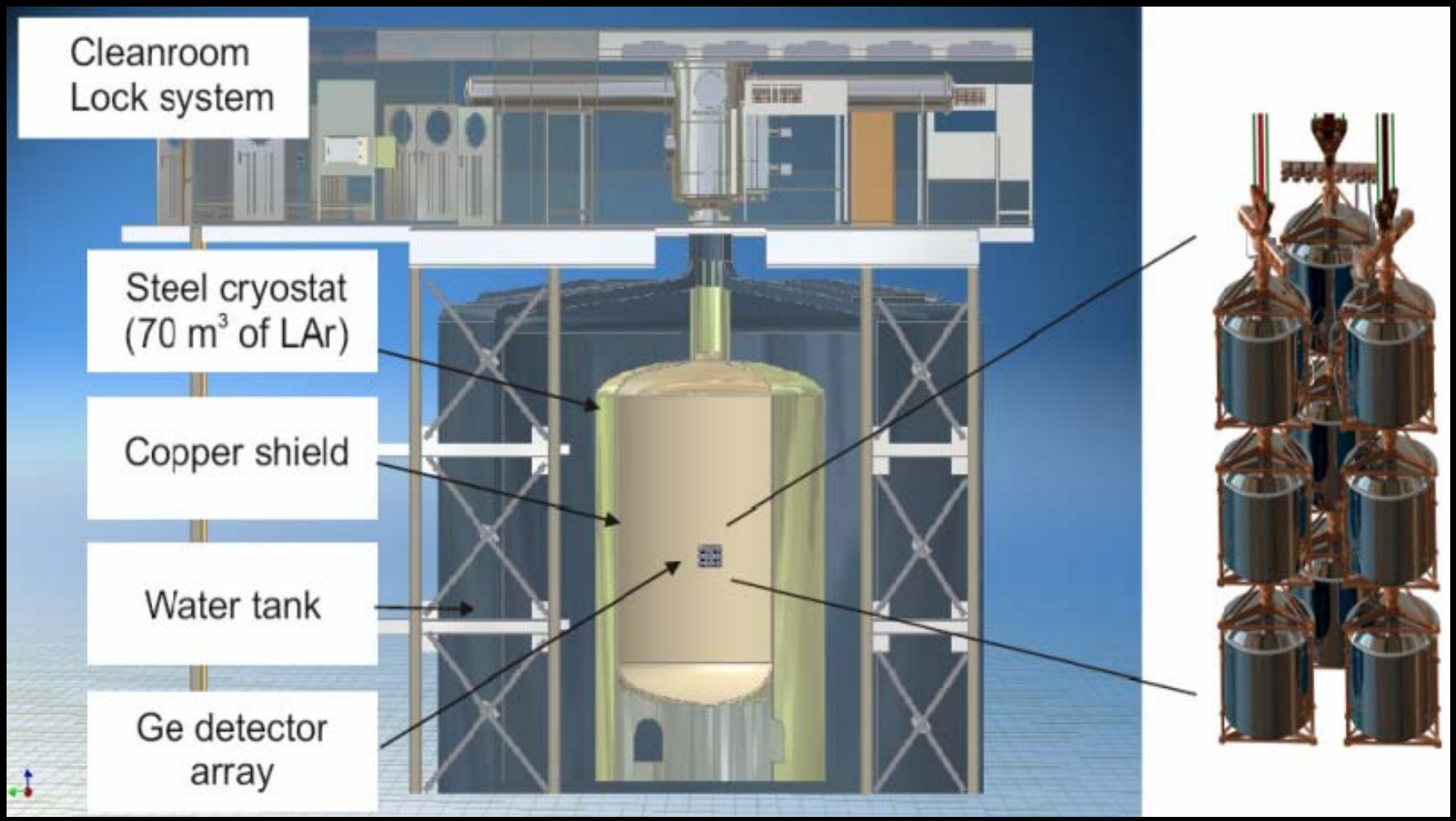


GERDA – phase 1

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



Start of first physics run at Nov 1, 2011

CUORE

Technique: natural TeO_2 bolometers at 10 mK

Location: **LNGS**

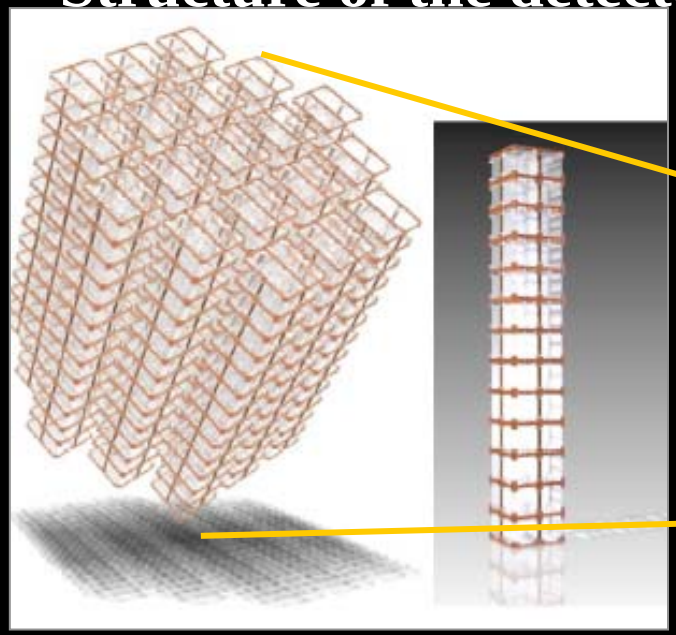
Sensitivity: 35 – 82 meV (with target background ~ 10^{-2} counts/(keV kg y))

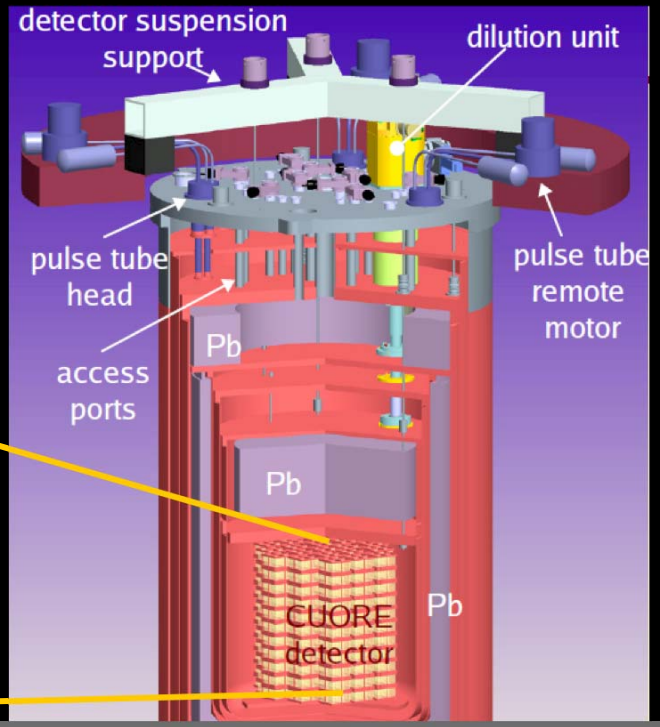
Timeline: first CUORE tower in 2011 – data taking with full apparatus in 2014

↓

CUORE-0 close to commissioning

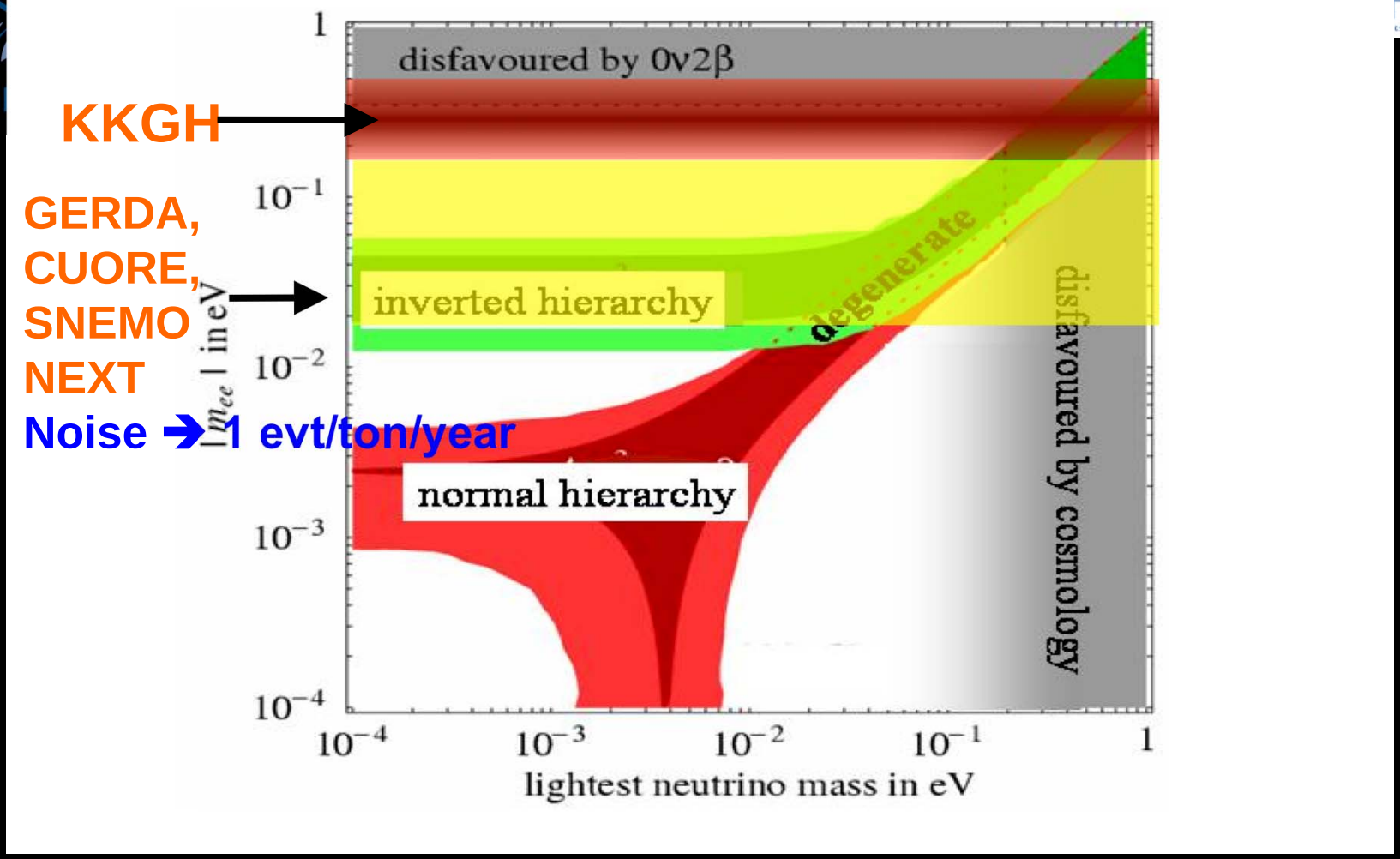
Structure of the detector





Detector in the custom fridge

Probing the neutrino mass



Neutrino property measurements, where several experiments in Europe are either in the commissioning phase or in the final years of construction to search for neutrino-less double beta decay, and to measure the neutrino mass via single beta decay. The further road towards double beta experiments covering full mass range characteristic for the inverted mass hierarchy depends on the results of the present generation experiments.

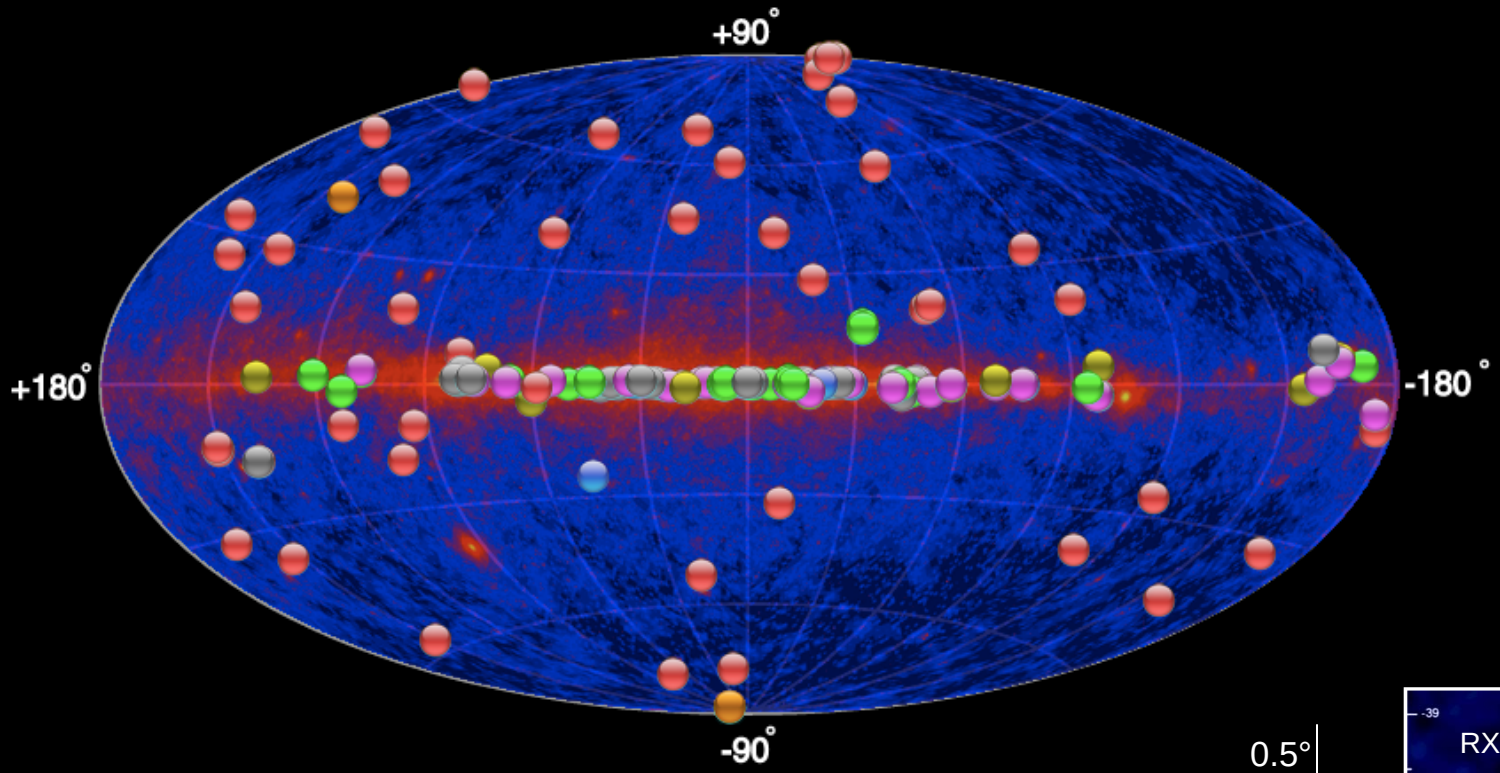
Large scale, mid of decade:

- 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

The VHE gamma ray sky

© TeVcat (14/May/2011)



Source Types

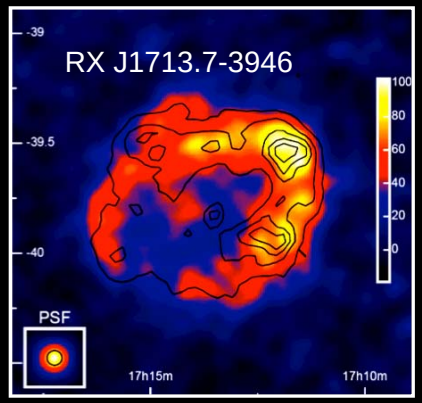
- PWN
- XRB PSR Gamma BIN
- HBL IBL FRI FSRQ LBL AGN (unknown type)
- Shell SNR/Molec. Cloud
- Starburst
- DARK UNID Other
- uQuasar Star Forming Region Cat. Var. Massive Star Cluster BIN WR

143 sources

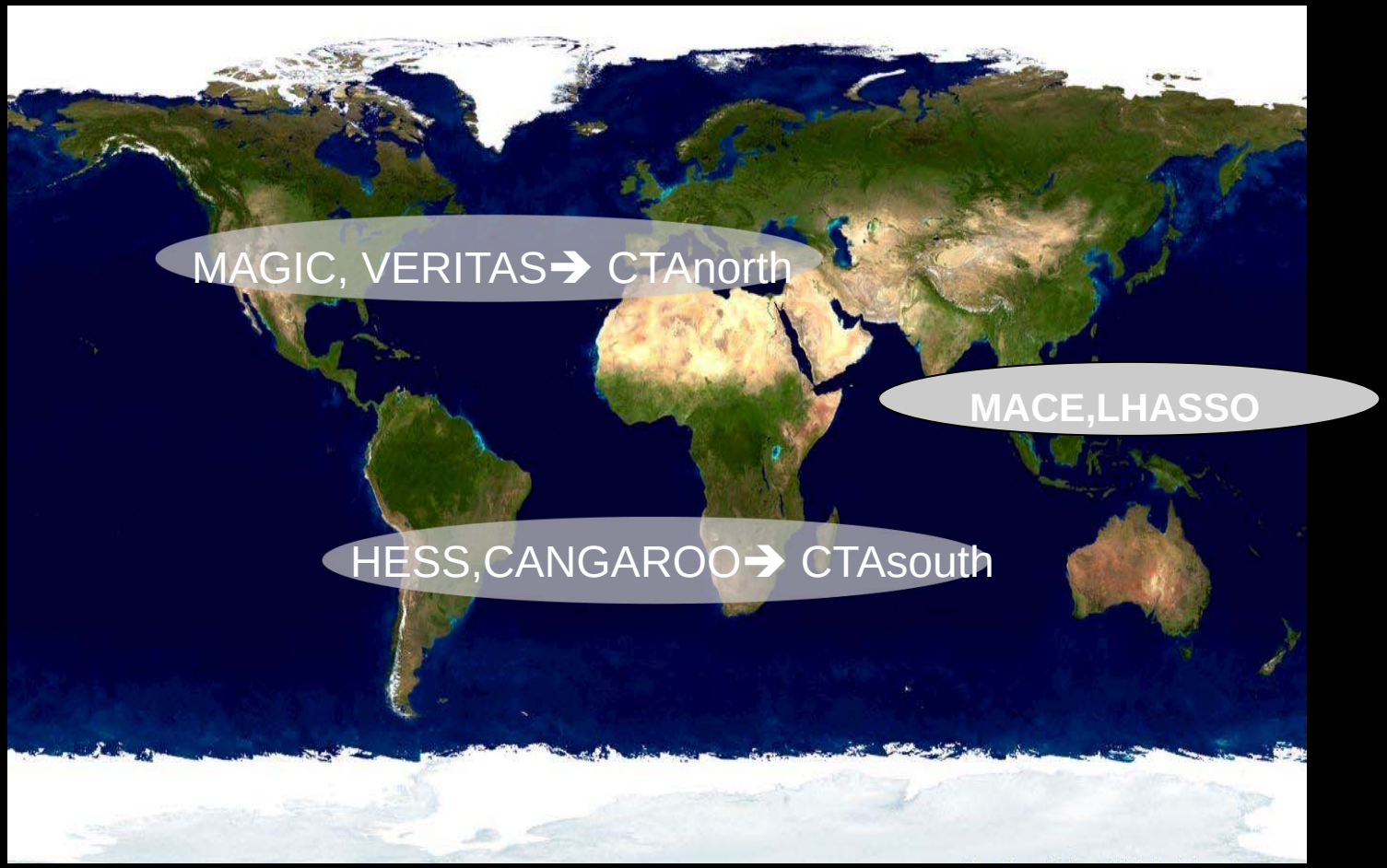
48 Extragalactic

Morphology

Timing



High energy gamma ray telescopes



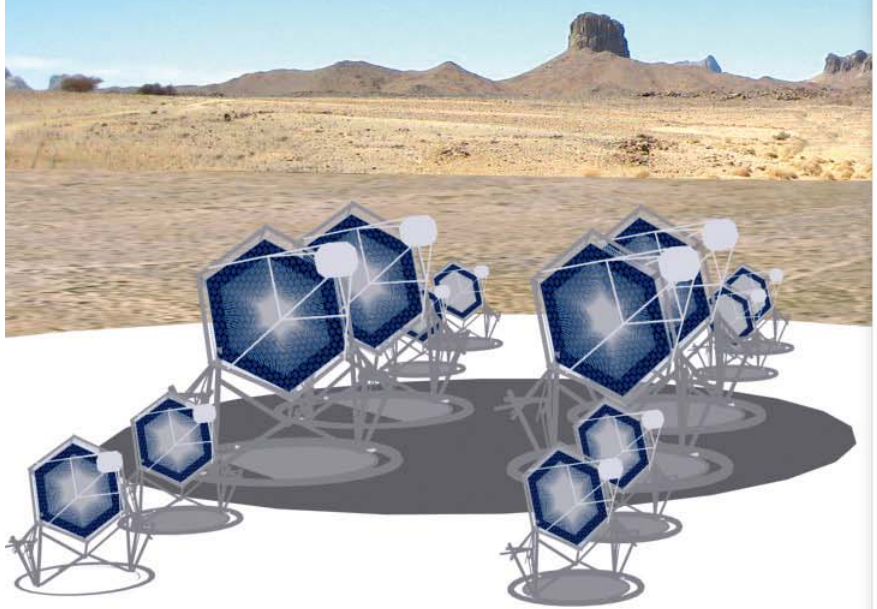
In the domain of TeV gamma-ray astrophysics the **Cherenkov Telescope Array** (**CTA)** is the worldwide priority project. It combines proven technological feasibility with a guaranteed scientific perspective. Its mode of operation and the wealth of data are similar to a large astronomy project. The ambitious time schedule for technical design and prototype development of CTA, as well as the selection of the site(s), is aiming at a start of construction before the middle of the decade.

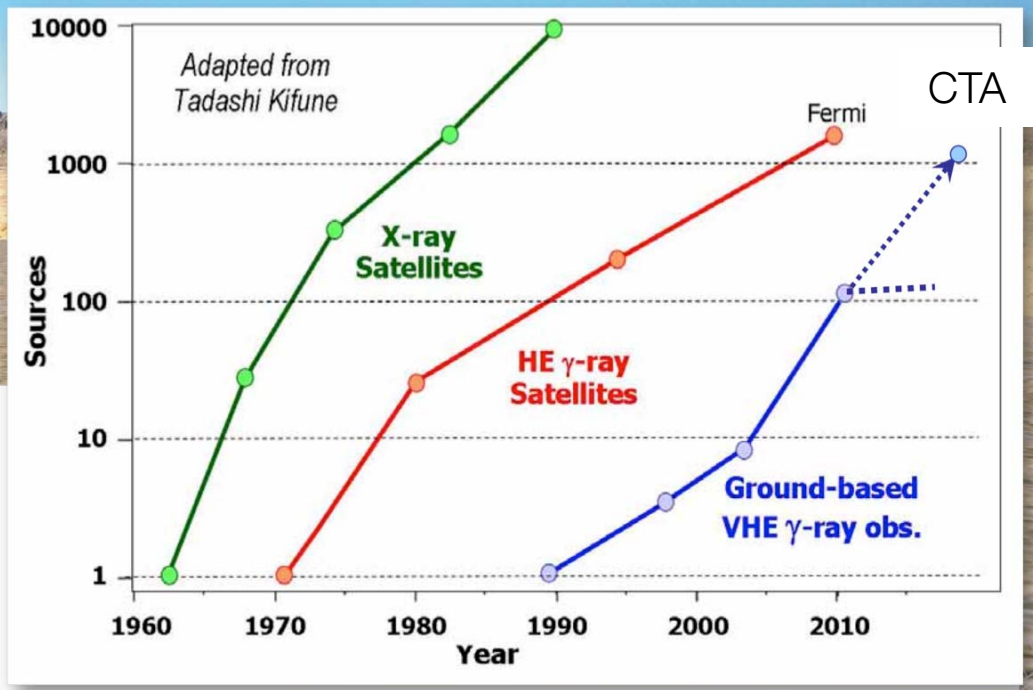
10 fold sensitivity of current instruments
10 fold energy range
improved angular resolution
~1000 sources expected
two sites (North / South)
operated as observatory

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

The future in VHE gamma ray astronomy:

cta
cherenkov telescope array





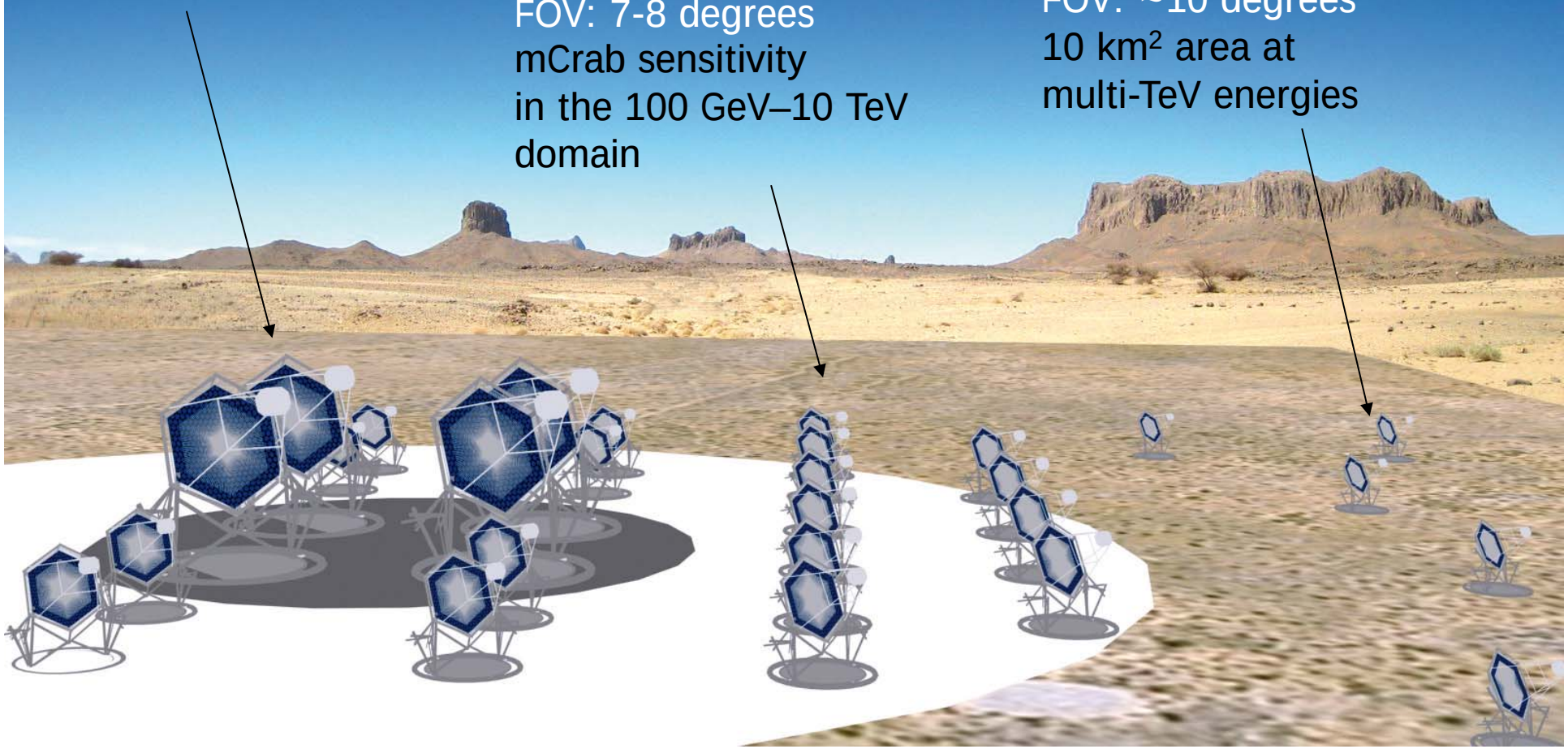
(one) possible configuration

100 M€ (2006 costs)

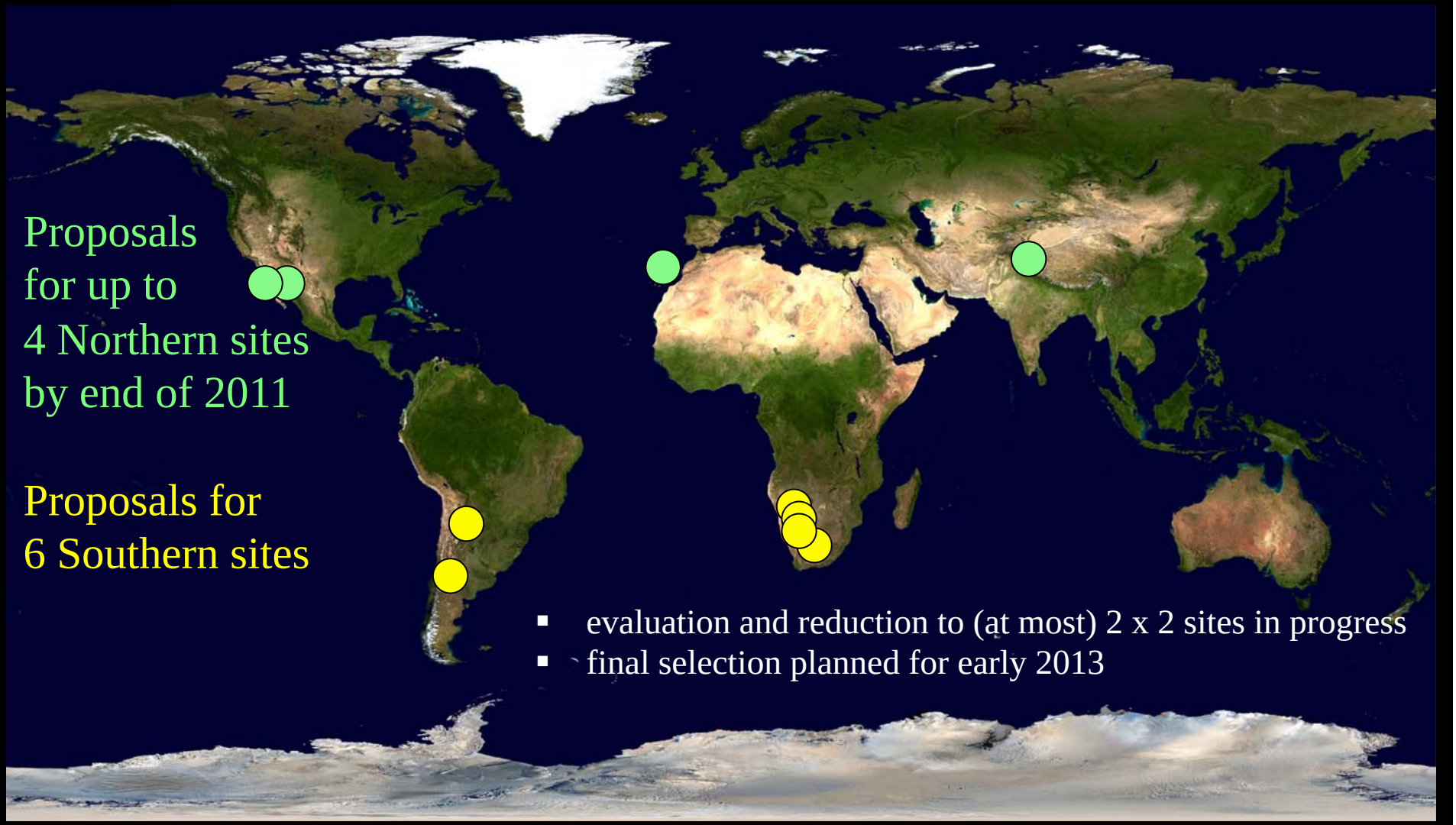
Low-energy section:
4 x 23 m tel.
Parabolic reflector
FOV: 4-5 degrees
energy threshold
of some 10 GeV

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

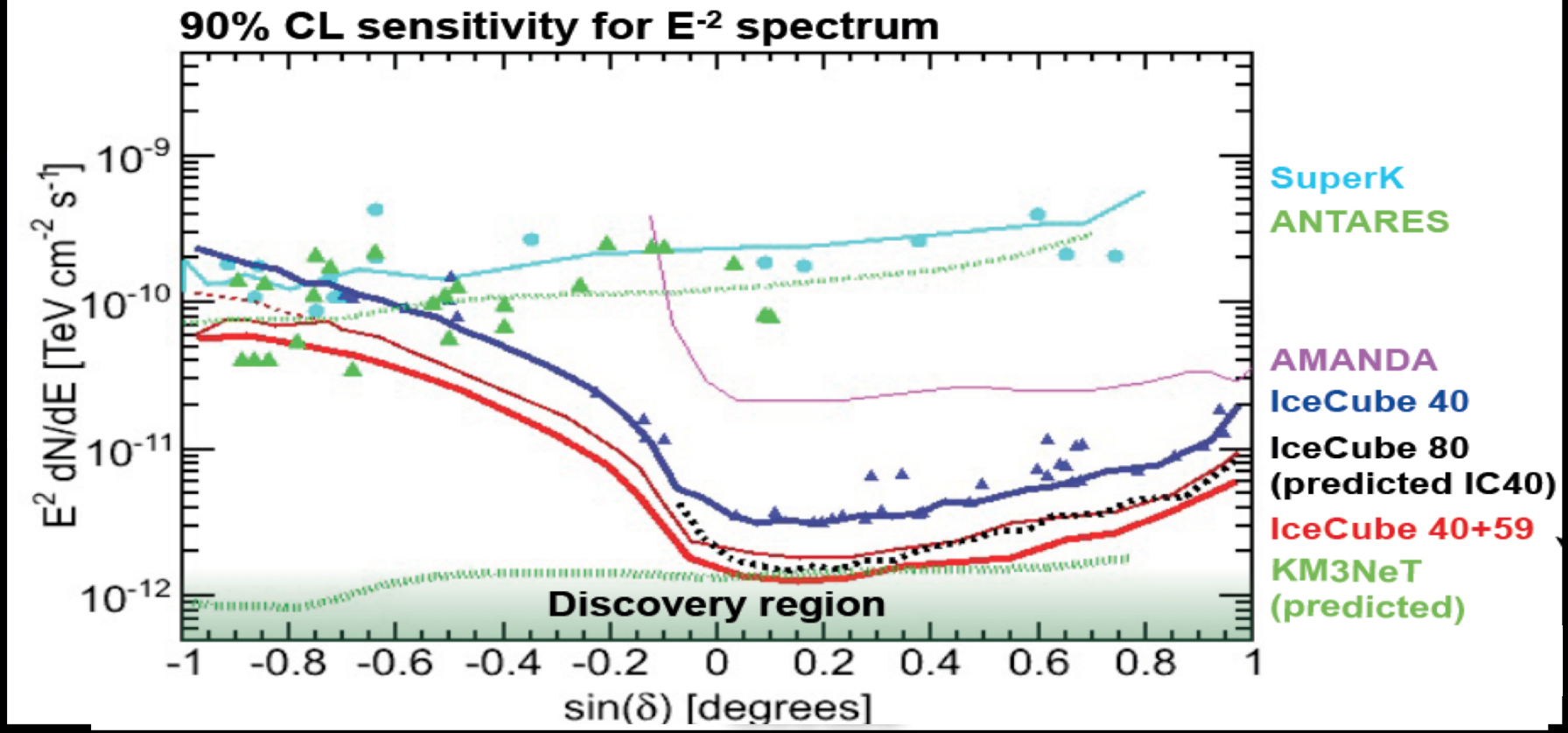


Site selection



High Energy Neutrino Telescope *KM3net*

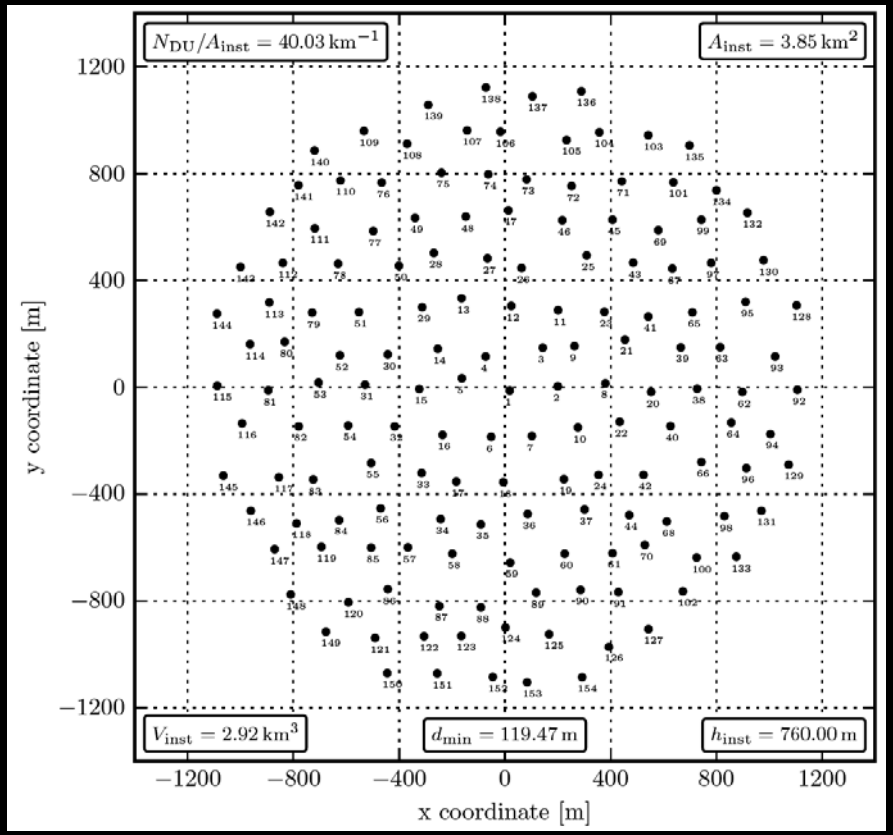
Sensitivities to point sources

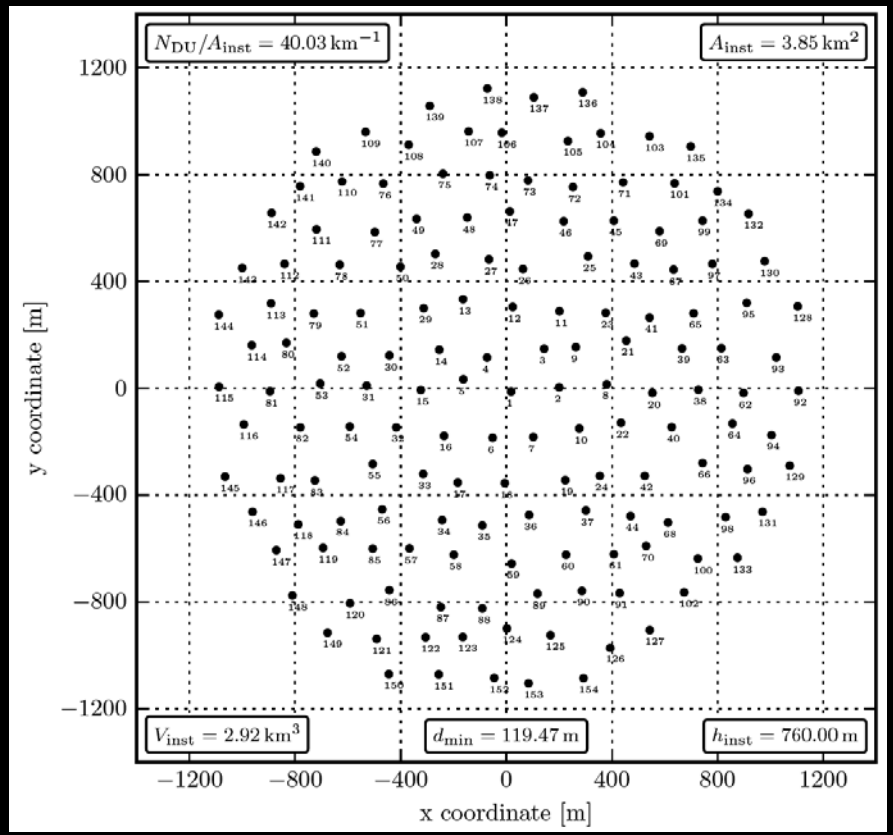


The next generation **high-energy neutrino telescope** in the Mediterranean Sea (**KM3NeT**), an ESFRI project, must have sensitivity substantially larger than that of IceCube, the neutrino telescope operating in Antarctica. The KM3NeT collaboration produced a corresponding technical design report, funded by the EU Preparatory Phase program. The technology definition is in its final stages with prototype deployment within the next 2 years, and eventual access to deep-sea research.

KM3NeT

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





Technology Convergence

1) DOM with 31 PMT

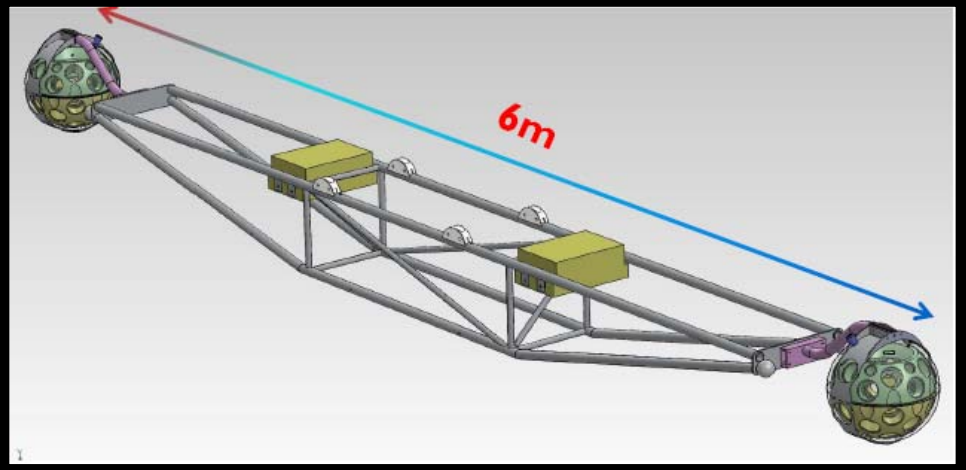
Still needs long-term in-situ test!
Backup 13´´ PMT

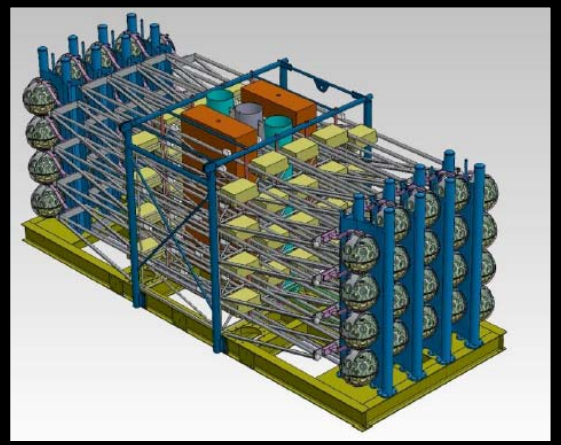
3) „All data to shore“ concept

cutting-edge fibre technology

2) Towers with 2-DOM floors

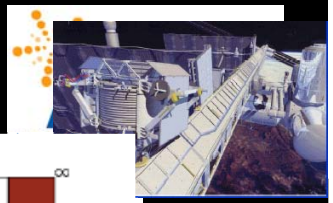
, Backup single string





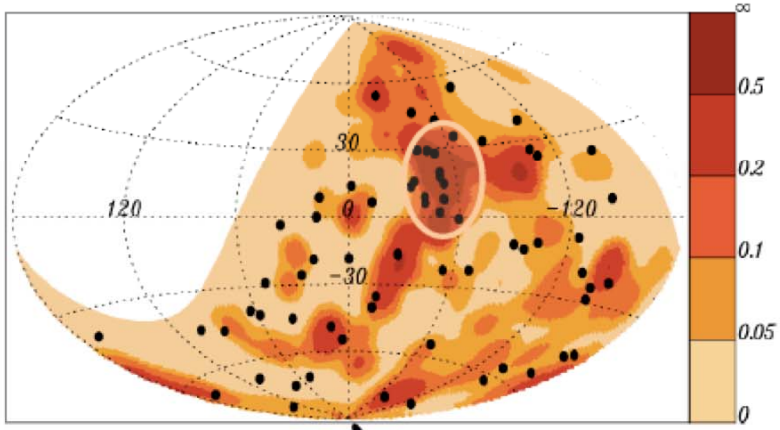
High energy cosmic ray observatories

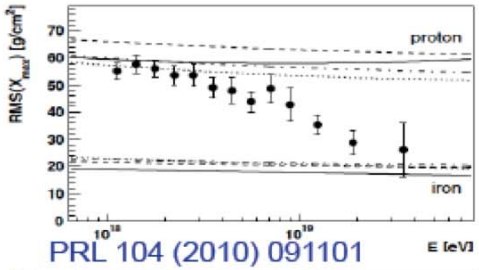
PAMELA
ATIC
CREAM



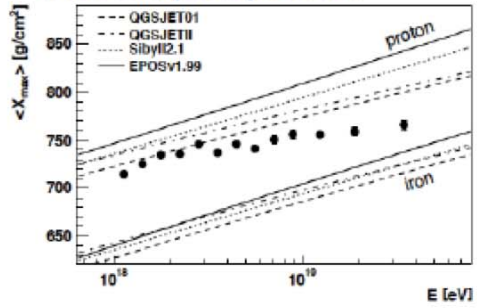
AMS
JEM-
EUSO

- sky distribution of events
E > 5.5 10^{18} eV: Anisotropic!
Large Scale Structure? **Protons?**
OR Cen A first observed source?





PRL 104 (2010) 091101



Tension between these 2 results

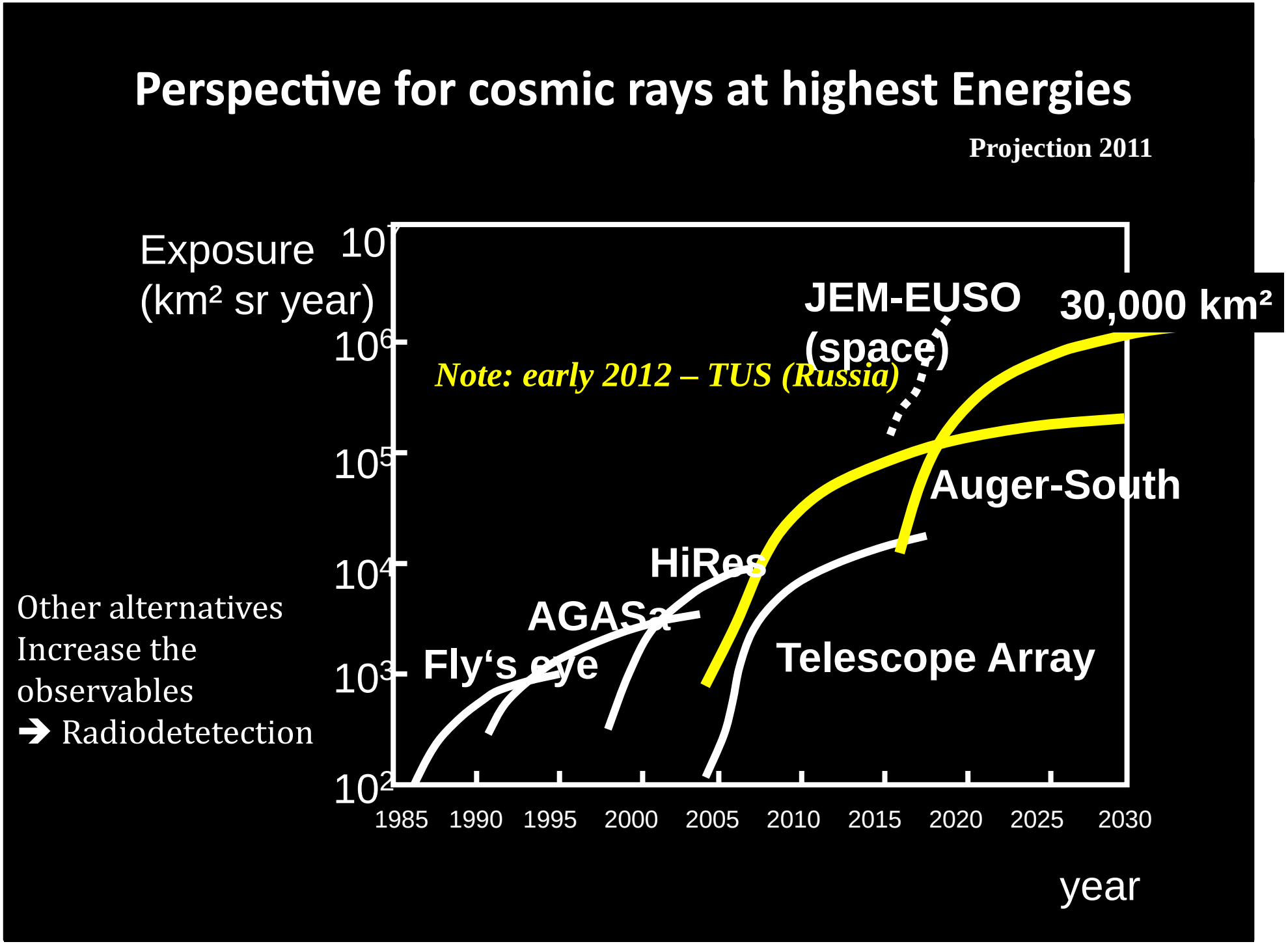
Science 318, 938 (2007)- Astropart Phys 34 (2010) 314

- **shower properties:** From **Protons to Iron?**
OR Change in Cross Section ~ 100 TeV c.m.

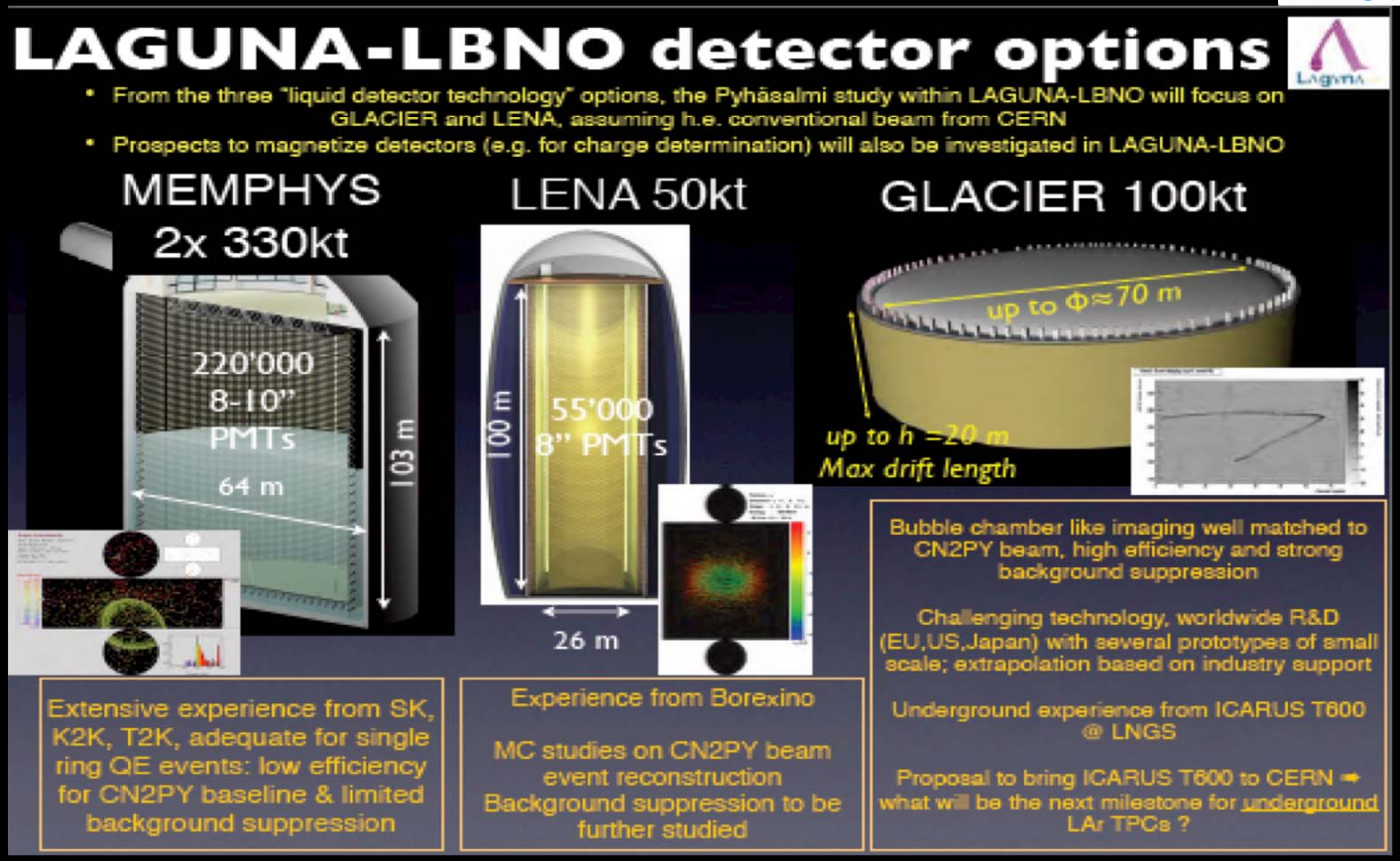
14

Following the footsteps of the Pierre Auger Observatory in Argentina a global **next-generation ground-based observatory** is envisaged with a substantial contribution from Europe**.** The preparations include the development of new detection technologies, the search for appropriate sites, and the attraction of new partners.

Perspective for cosmic rays at highest Energies

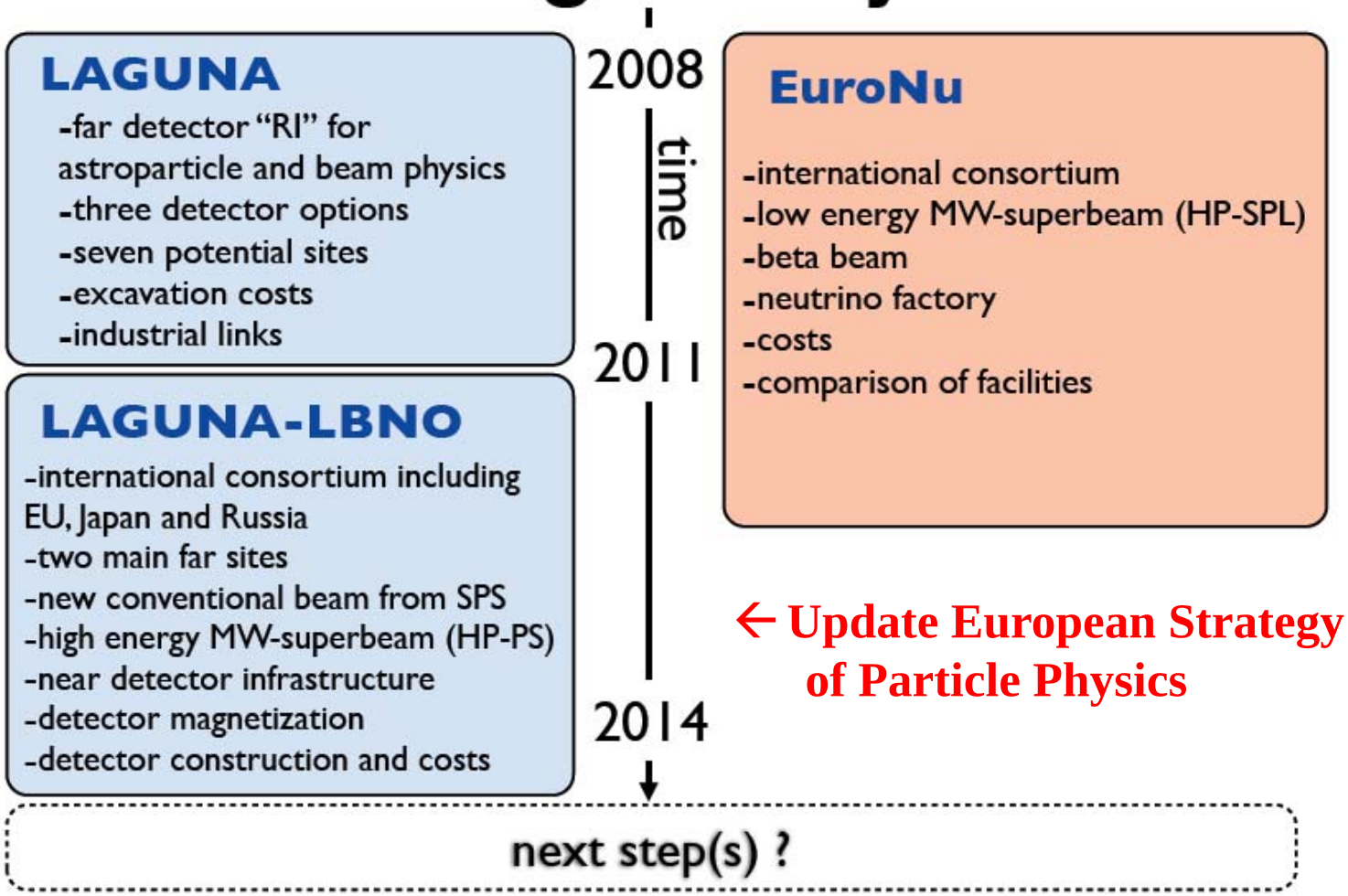


Megaton scale projects for proton decay and neutrino p

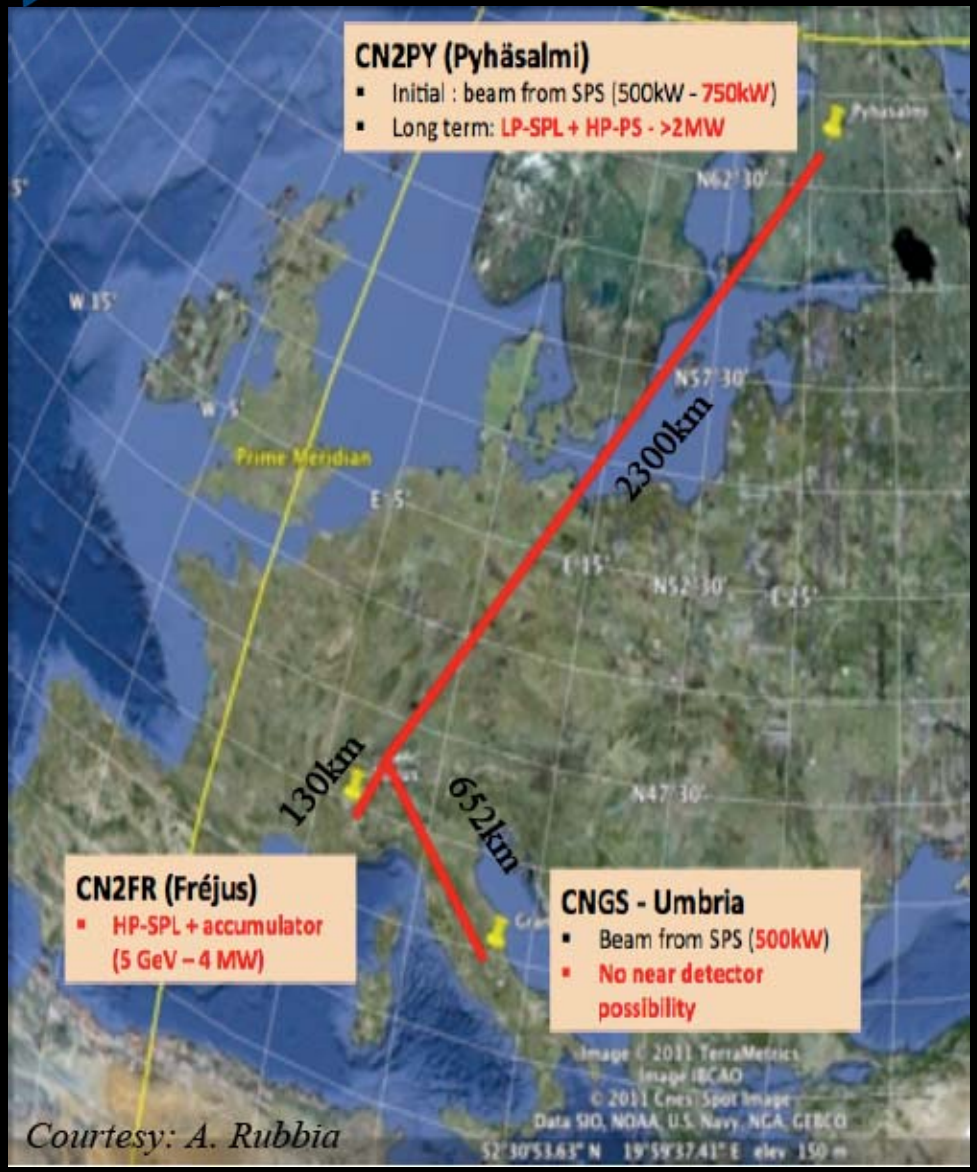


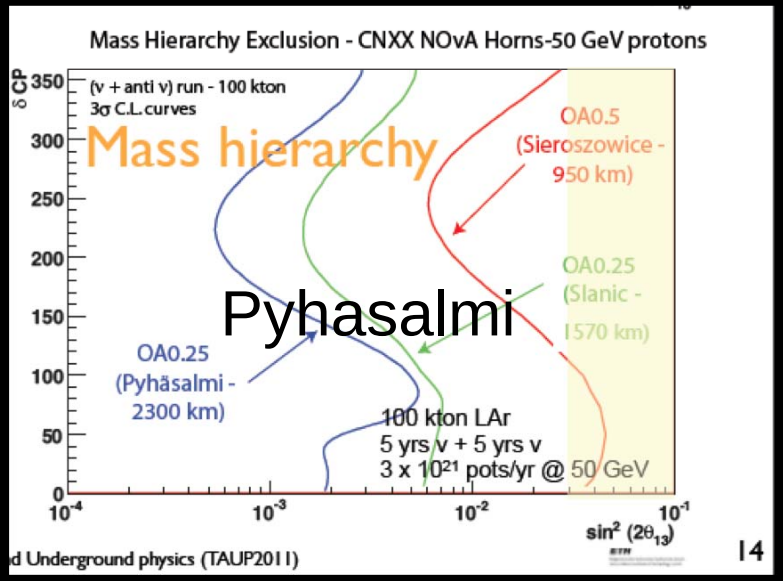
The goals of a megaton-scale detector as addressed by the design studies **LAGUNA** range from **low-energy neutrino astrophysics** (e.g. supernova, solar, geo- and atmospheric neutrinos) to fundamental searches without accelerators (e.g. search for **proton decay**) and accelerator driven physics (e.g. **observation of CP-violation**). Due to its high cost, the program can be developed only in a global context; furthermore the timing of its realization depends strongly on whether the indications for the mixing parameter defined as θ_{13} were to be confirmed within the next one or two years, permitting a series of very exciting measurements for neutrino mass hierarchy and CP violation using CERN beams. LAGUNA is therefore clearly at the interface with the CERN European Strategy Update to be delivered early 2013, where it represents a high-priority astroparticle project.

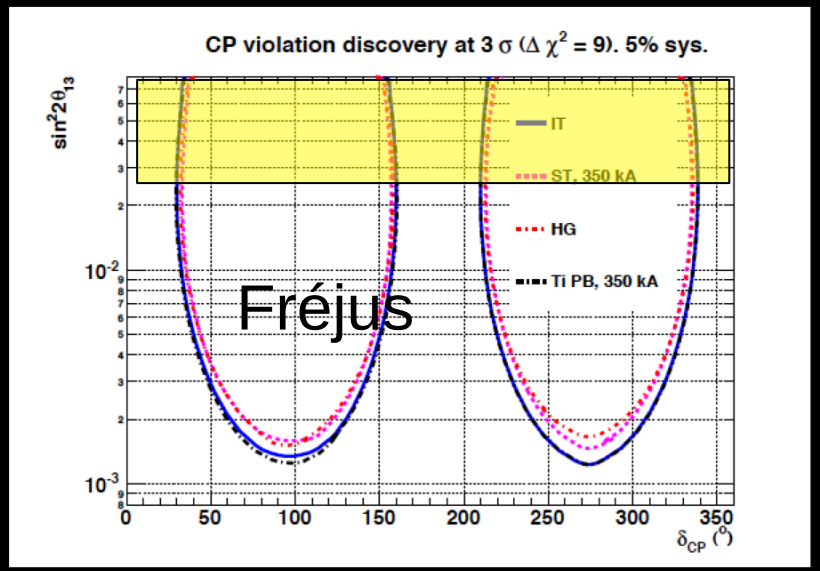
The EU design study "menu"



LAGUNA Case Studies for CERN Strategy
medium vs longer term?







Status of the Large 4

- CTA worldwide priority and large subscription
  - ASPERA Design Study, EDFRI Preparatory Phase
  - Collaboration and project formed
  - RB, SAC and Site selction committee in formation
  - TDR by end of 2013
- KM3Net
  - EU Funded DS and EFRI PP
  - Still a consortium
  - RB, SAC formed, Site ?
  - Large and recent regional funding (Italy, France, Greece) + Netherlands, Romania
- AUGER
  - Existing design Study of Auger-N
  - R&D for extensions/infill
  - Discussins for a worldwide collaboration
- LAGUNA
  - 3 EU funded Design Studies LAGUNA LBNO started 2010)
  - European Strategy issue

http://www.aspera-eu.org

Very Large scale, end of decade:

- **Gravitational Waves:**

ET and LISA

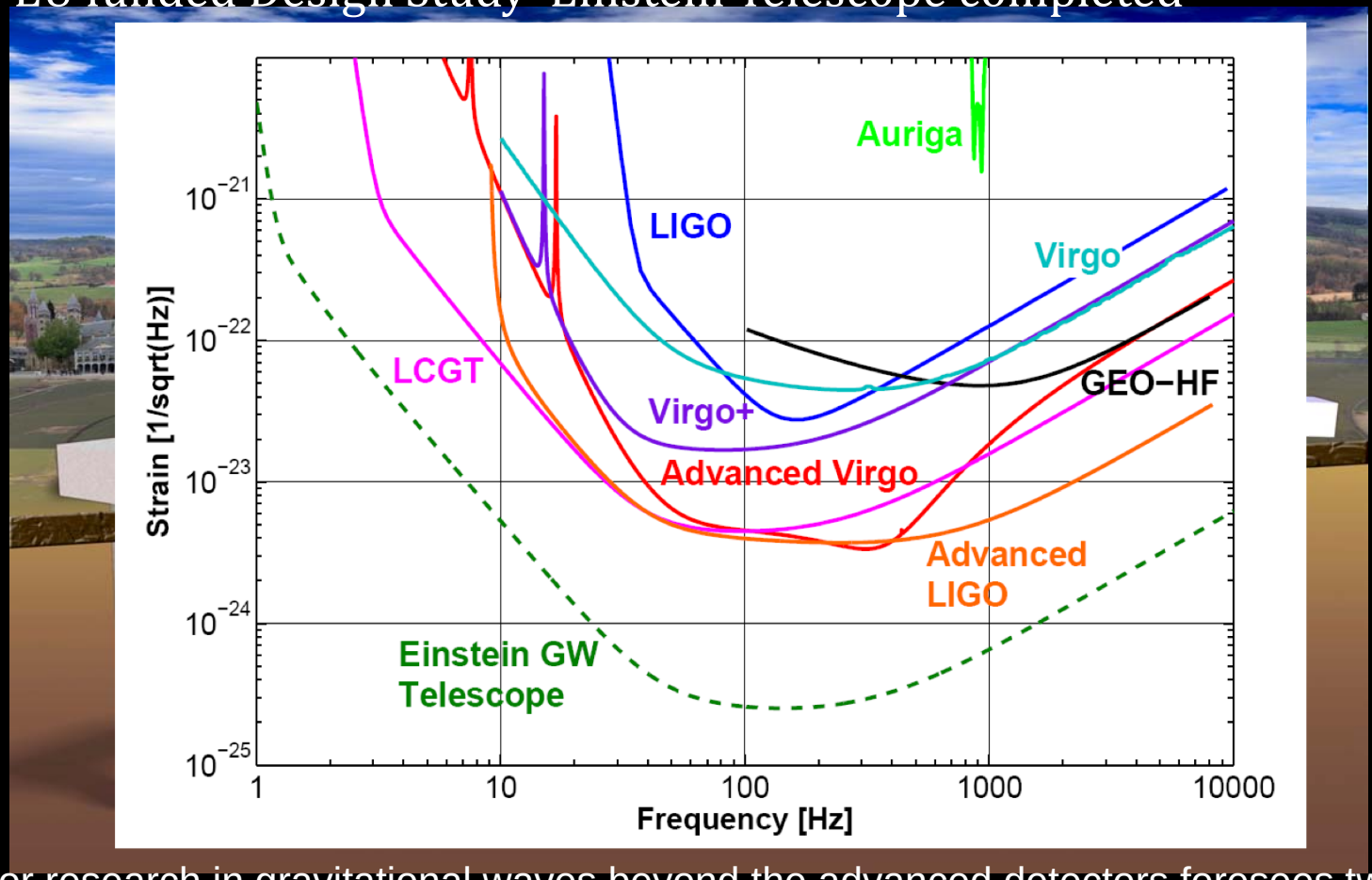
- **Dark Energy:**

LSST and EUCLID

http://www.aspera-eu.org

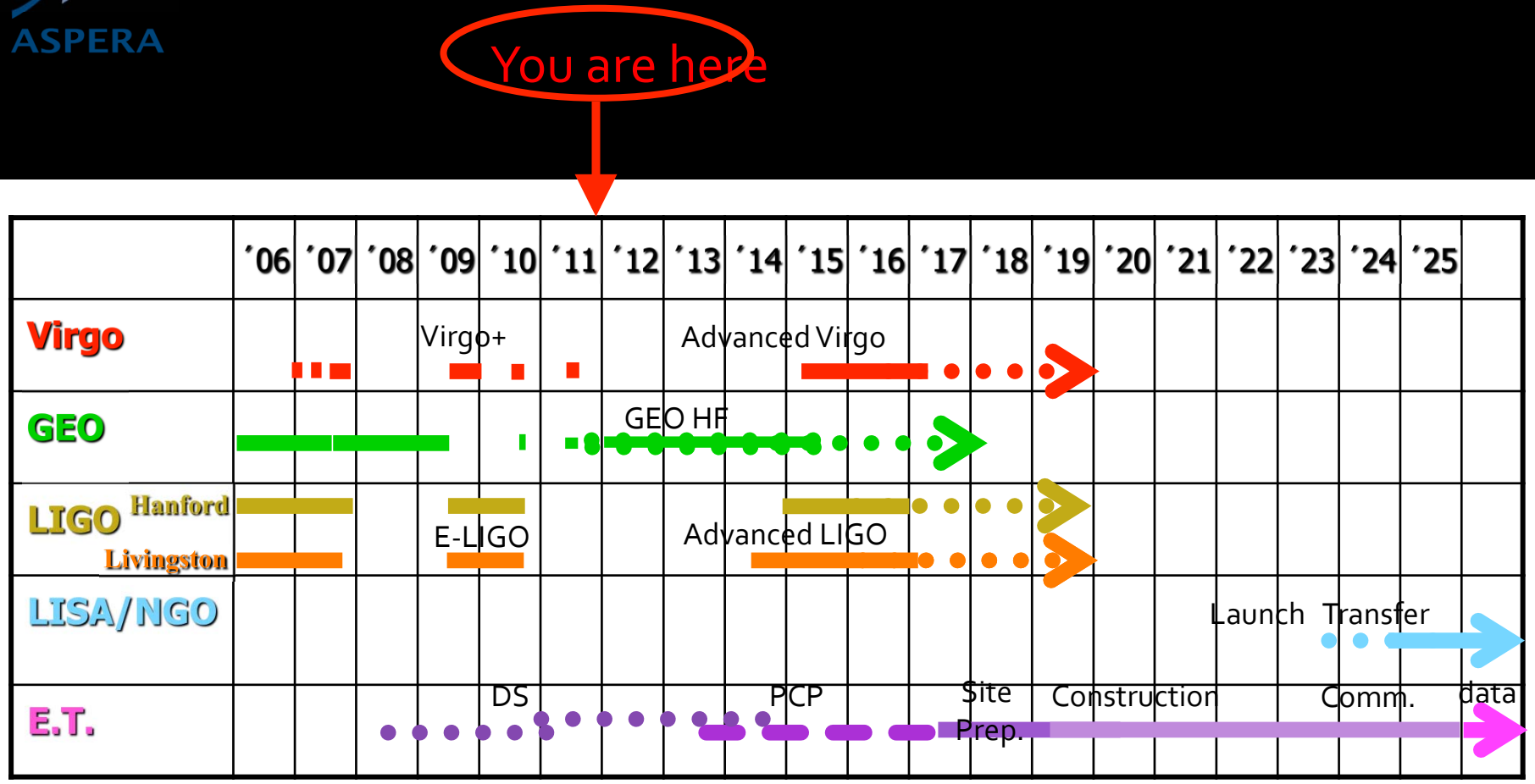
Gravitational waves: Einstein Telescope (ET)

EU funded Design Study Einstein Telescope completed



The path for research in gravitational waves beyond the advanced detectors foresees two projects of a very large scale: the Earth-bound **Einstein Telescope (ET)** and the space-bound **LISA** project. ET construction would start at the end of this decade, after the first detection of gravitational waves with the advanced detectors and following successful R&D. The LISA project, for which preparatory work in on-going, would eventually rely on the success of the technological mission LISA-Pathfinder

GW Timelines

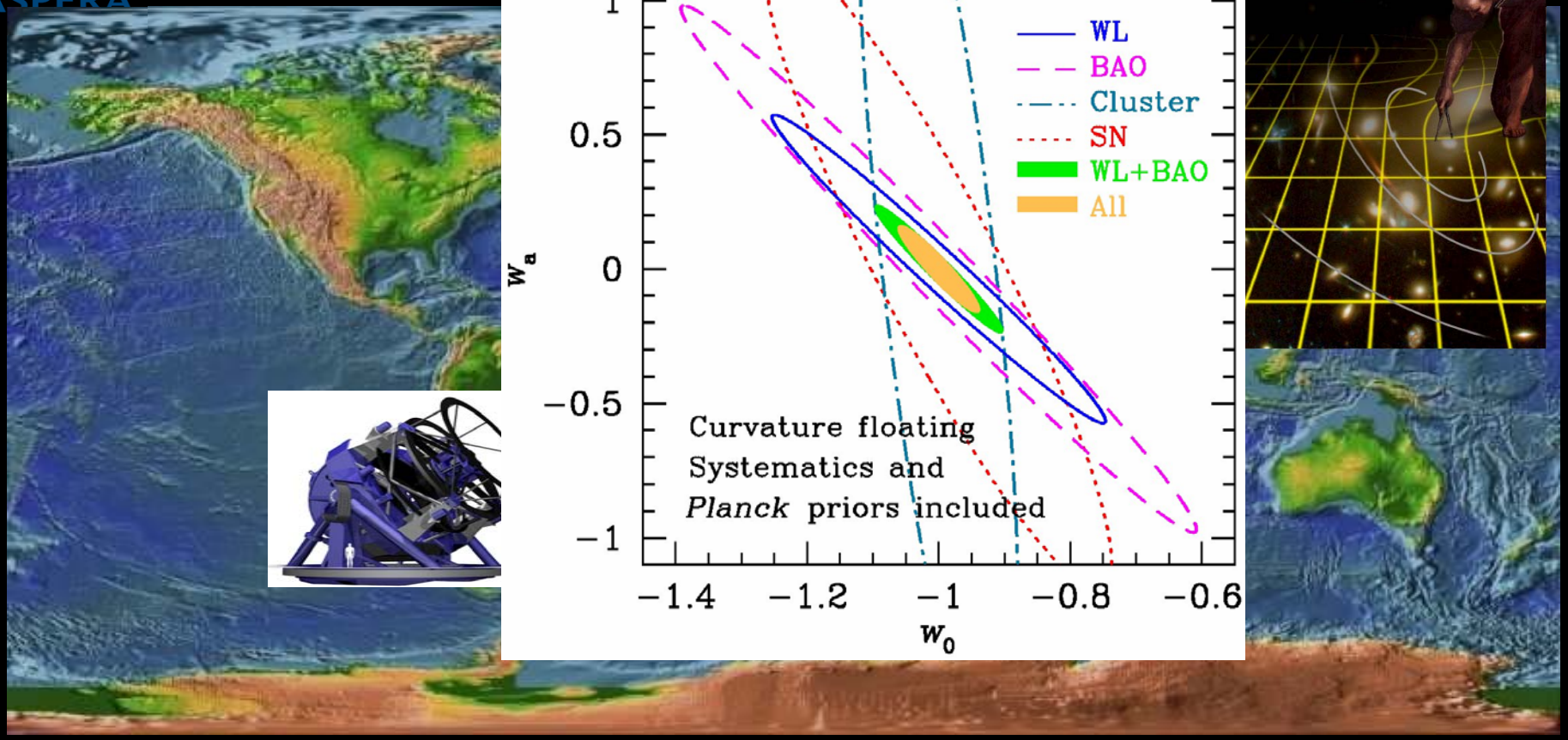


1st Generation

2nd Generation

3rd Generation

Dark energy large astronomical surveys



Astroparticle physicists play a major role in many international **Dark Energy programs,** such as the recently chosen Cosmic Vision ESA satellite **EUCLID** (2019) or the dominantly US-funded **LSST** observatory (2019), which would play a complementary role to EUCLID.

ASPERA

PEC
Physics European Coordination

A Worldwide Vision
ion of APIF

FROM THE GEOSPHERE
TO THE COSMOS

AST

OECD Global Science Forum

Report of the Working Group on Astroparticle Physics

MARCH 2011

OECD

Conclusions 1

(From the ASPERA/ApPEC event in Paris 21-22 November)
ASPERA chairman M. Bourquin

> ApPEC and ASPERA welcome the priorities defined by the scientific communities.

> They accept the recommendations addressed to the governmental funding agencies with best endeavours to implement them.

> Co-operation is the only way to achieve the critical mass for the ambitious projects.

Conclusions 2

> The Roadmap is also a timely input into the update of the European Strategy for Particle Physics launched by CERN Council.

> ApPEC looks forward for a fruitful cooperation with global international partners, thanks to APIF.

> The ApPEC Steering Committee members are very grateful to the SAC members for their work.