Astroparticle Physics

The 2011 ASPERA Roadmap

Christian Spiering, DESY

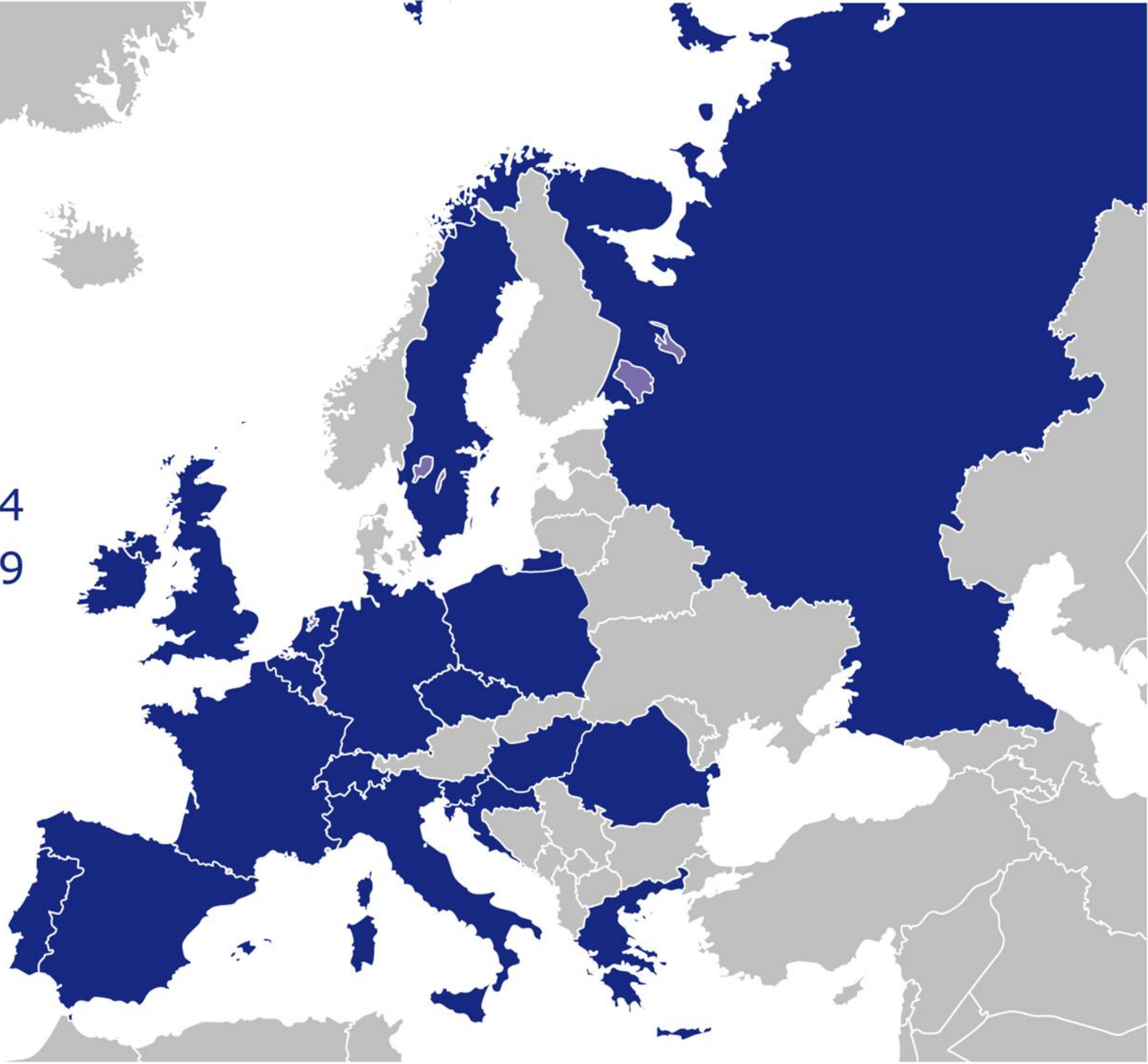
CERN, May 15, 2012

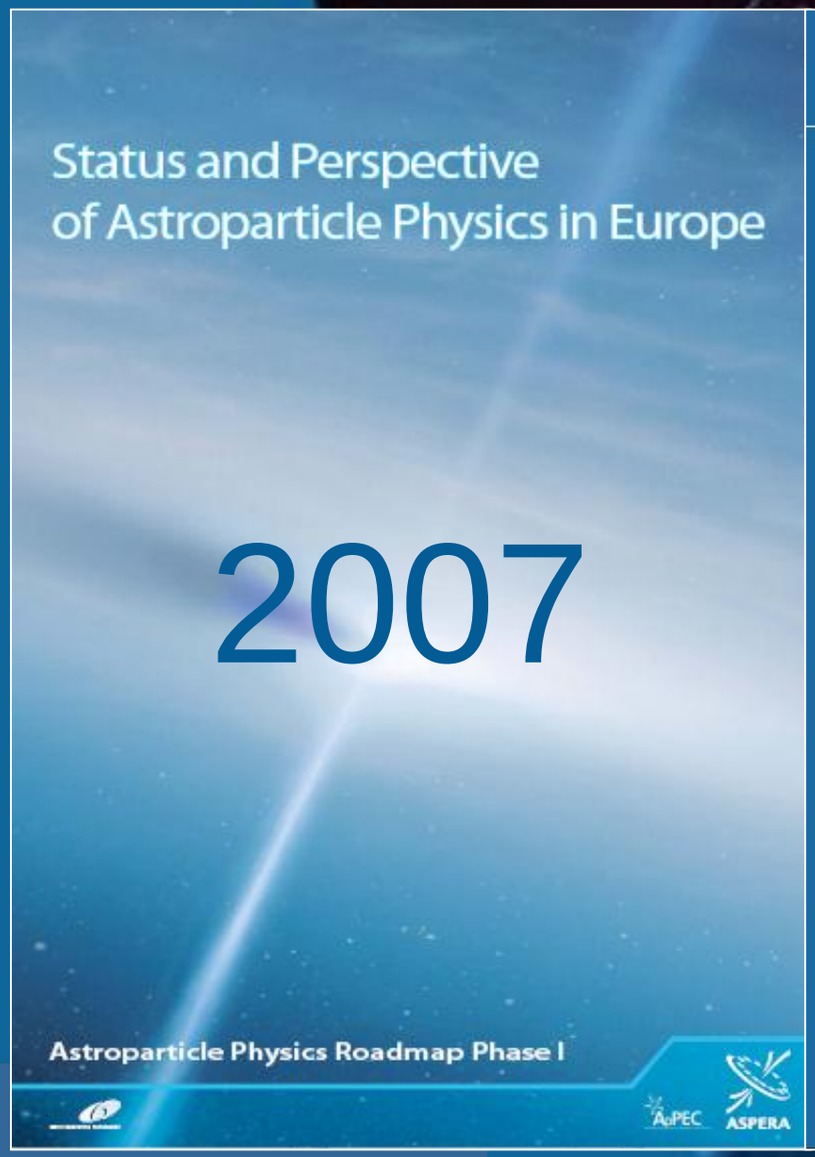
http://www.aspera-eu.org

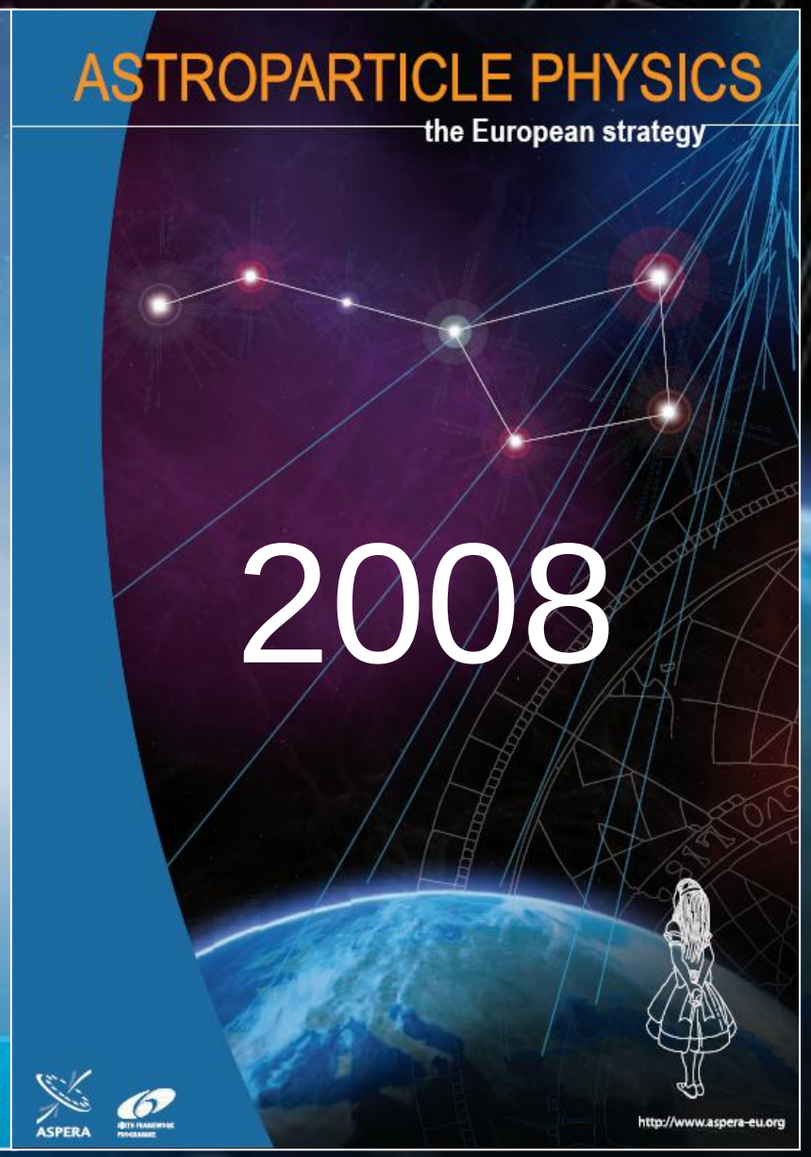
ASPERA

partners: 24

countries: 19







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- 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

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

"We prioritize these projects for immediate funding, and urge agencies to join their forces for an effective, substantial support"

- impressing momentum which needs to be maintained;
- enter a region with high discovery potential;
- hand in hand with LHC physics;
- technologically ready and worldwide community

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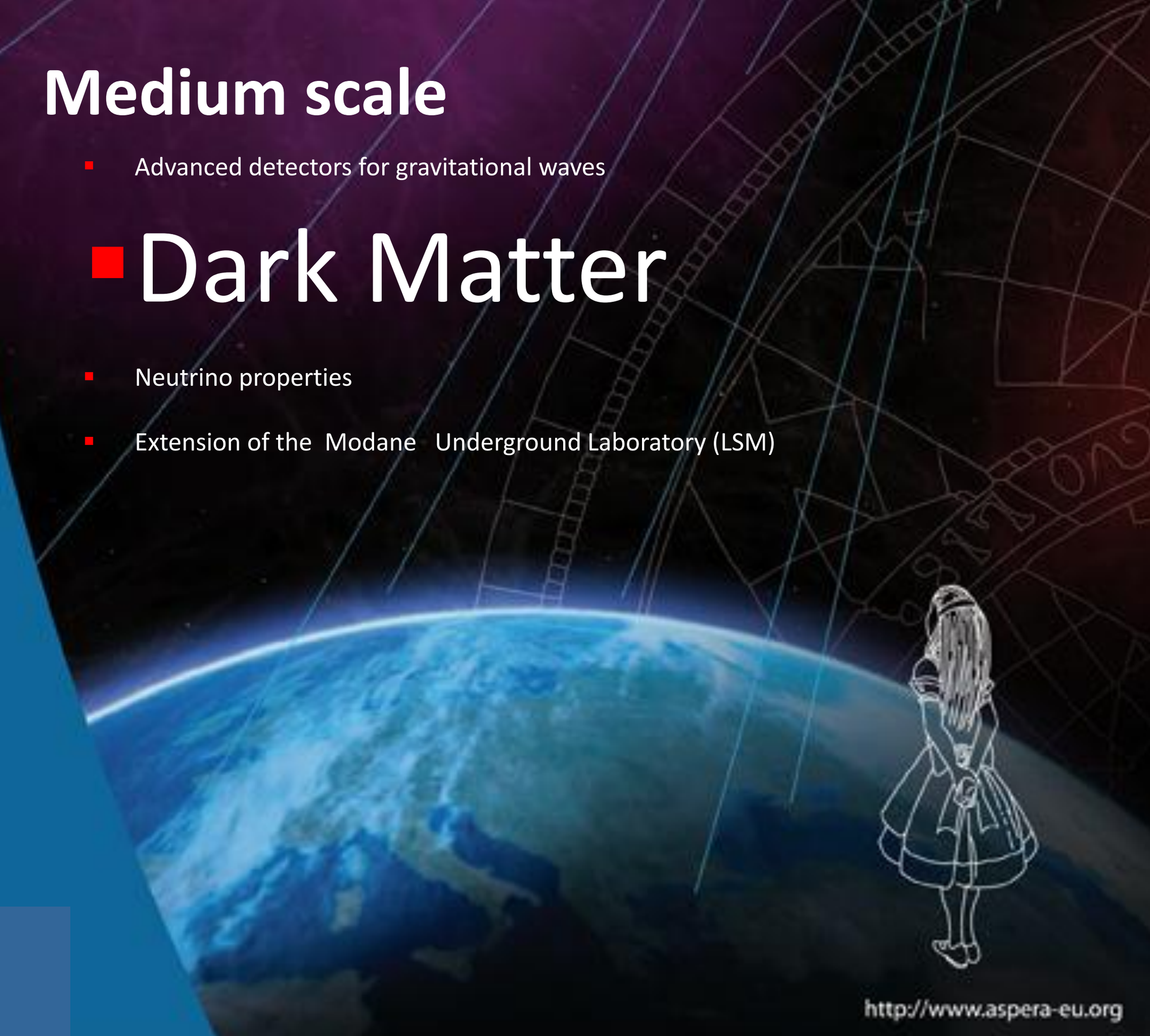

Recommendations Dark Matter

- 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.

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Liquid argon: WARP, ..., ArDM, Darkside

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- Dark Matter
- **Neutrino properties**
- Extension of the Modane Underground Laboratory (LSM)

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.

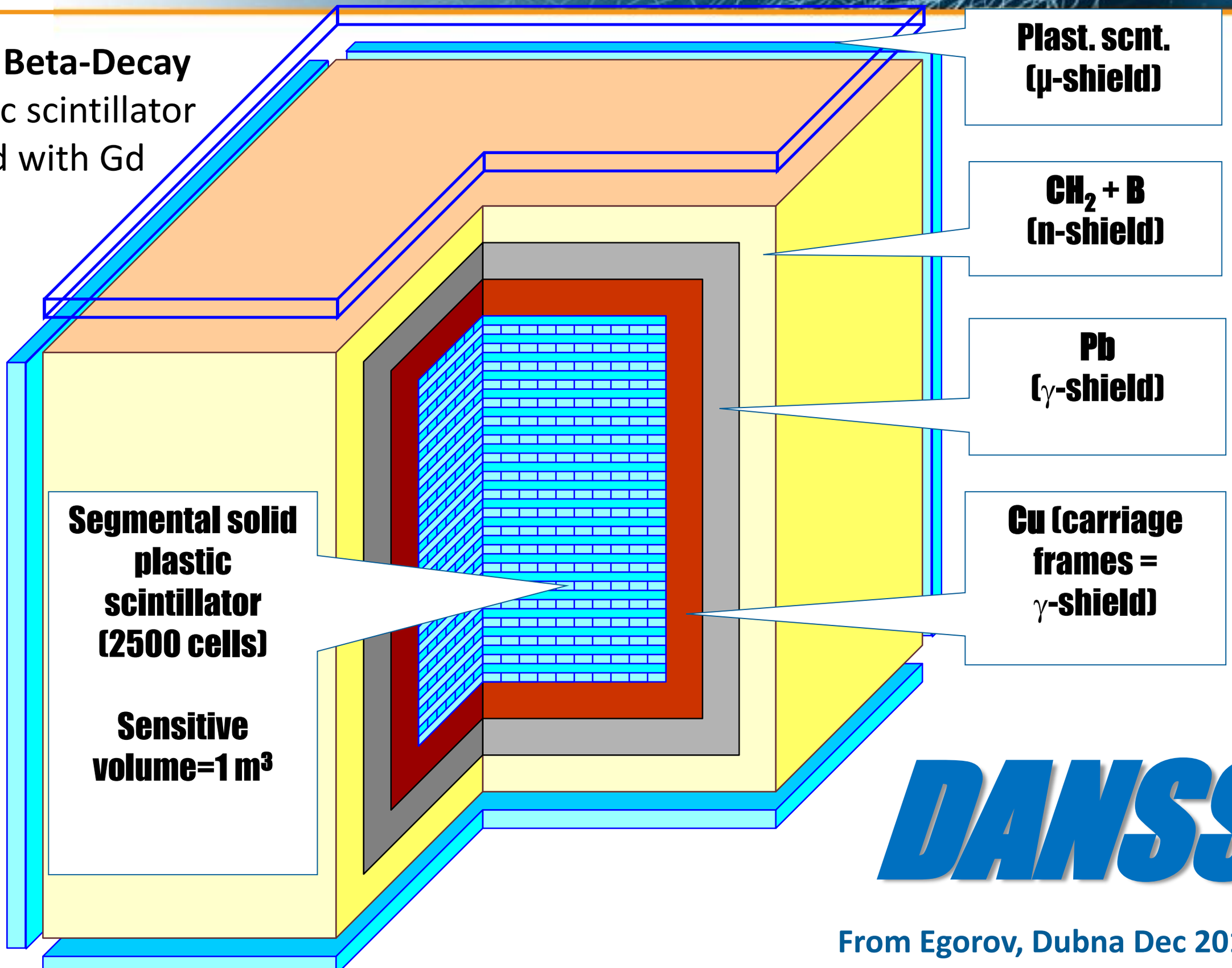
Side step:

- **Two interesting projects on sterile neutrinos in Russia**
- **ASPERA Roadmap:** Several anomalies in the neutrino sector and in cosmology have triggered increased interest in sterile neutrinos as a possible explanation. This makes new experimental campaigns necessary, with the goal to either falsify the anomalies or indeed discover physics beyond the Standard Model.

(see also the talk of Thierry Lasserre)

Sterile neutrinos in at the Kalinin Reactor

Inverse Beta-Decay
in plastic scintillator
interlaid with Gd



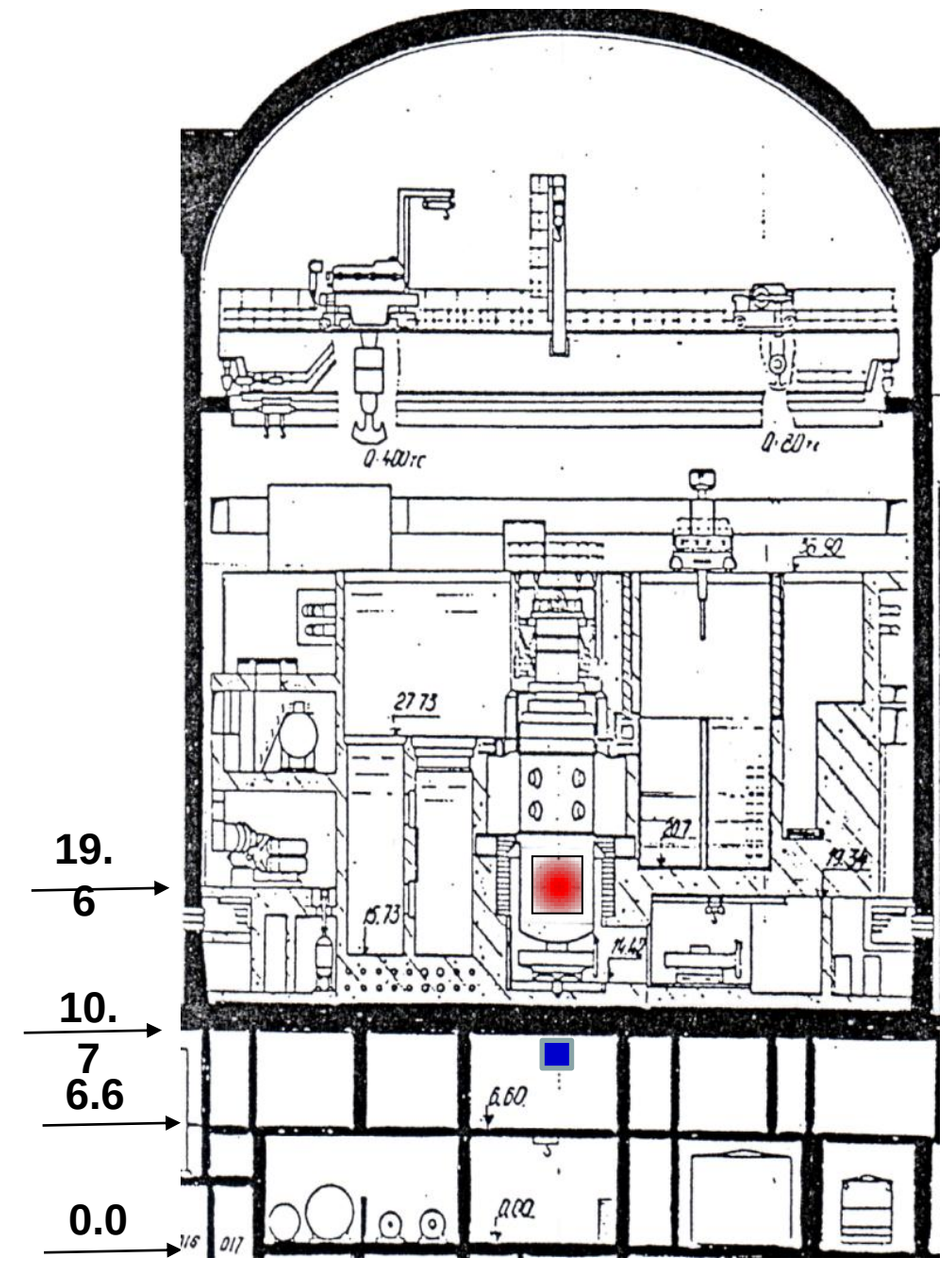
DANSS

From Egorov, Dubna Dec 2012

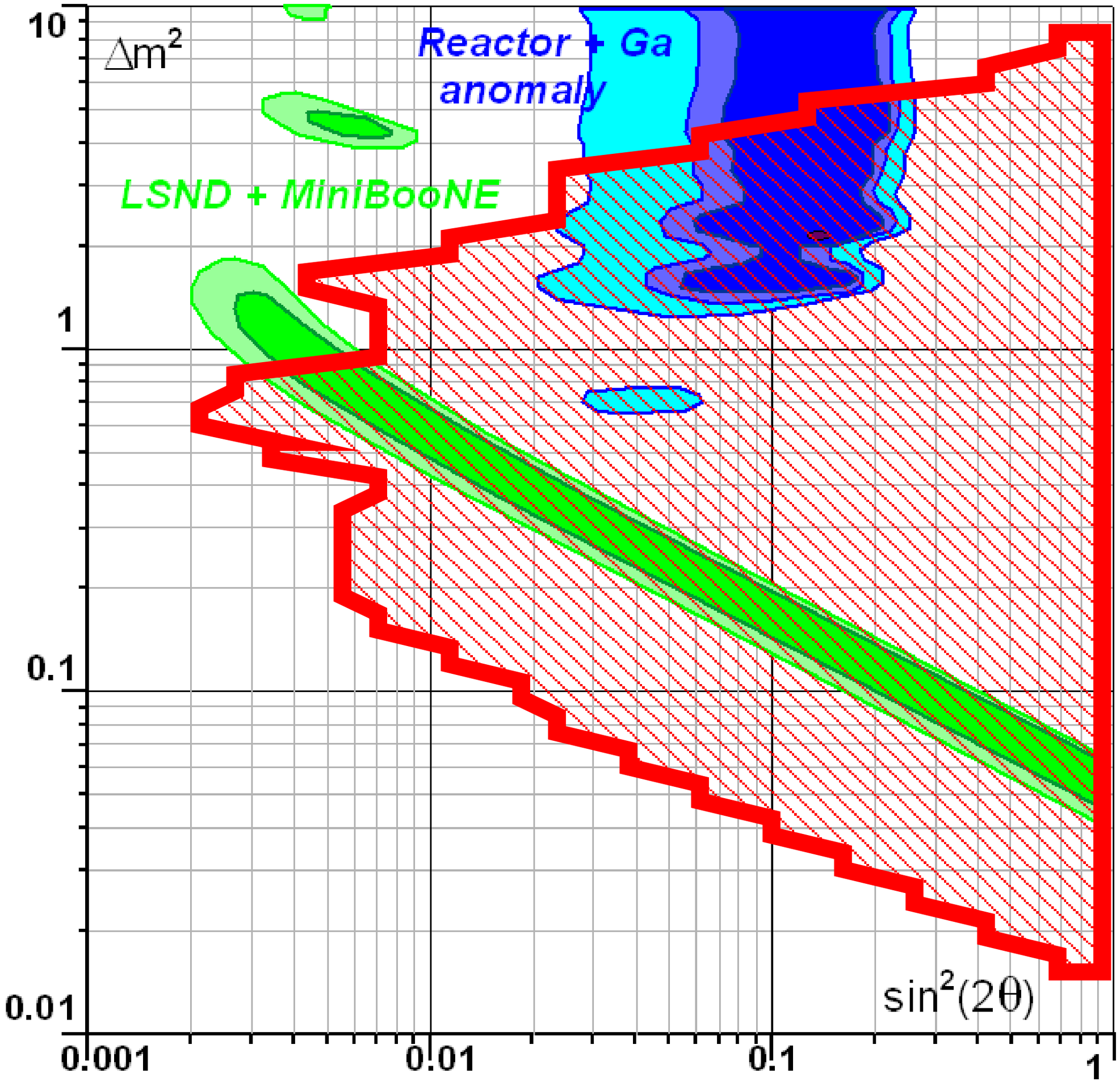
Sterile neutrinos in at the Kalinin Reactor

Count rate: **~10^4 IBD-events/day @11 m**

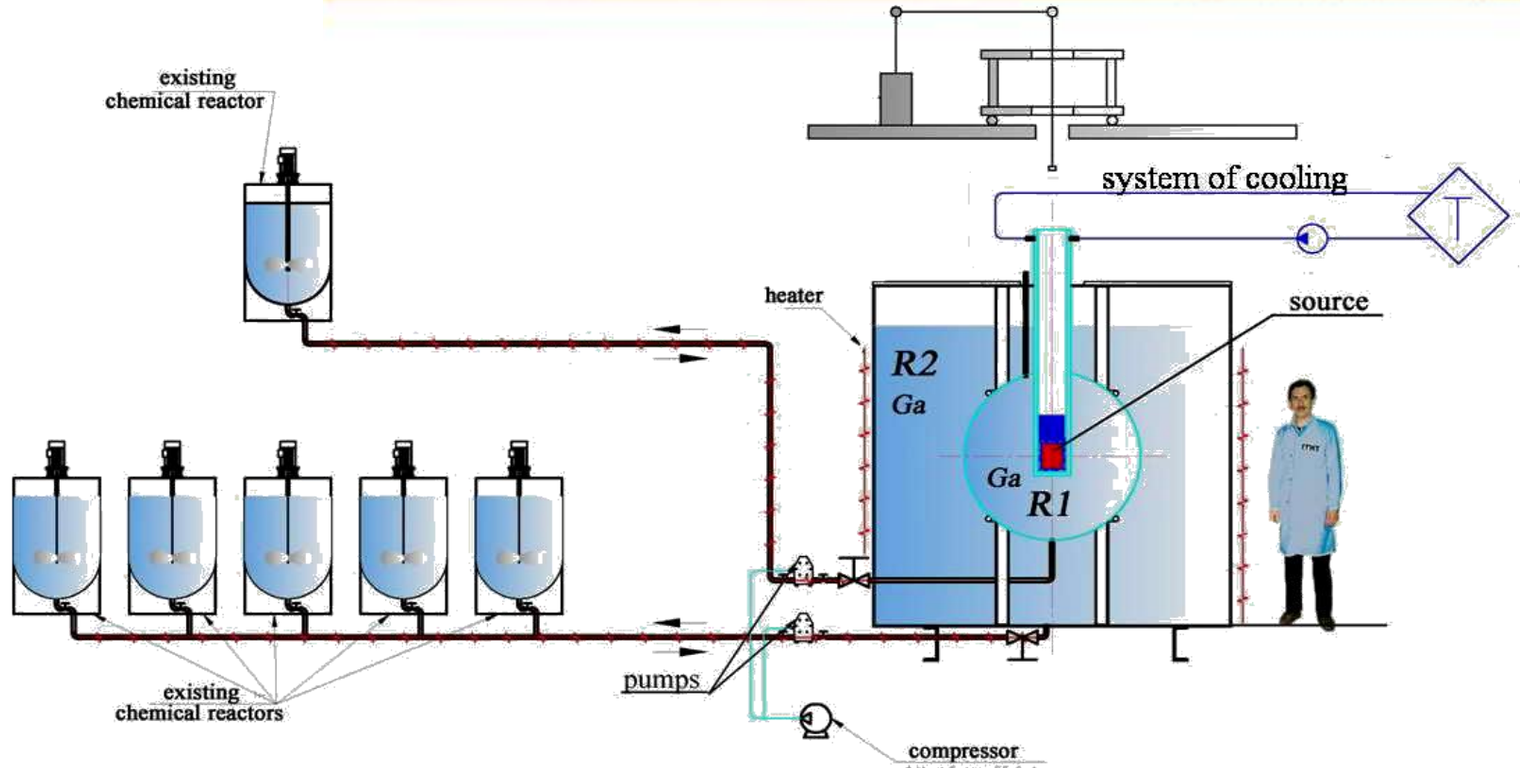
- <u>In principle</u> possible to move DANSS by ~2.5 m (from 9.7 to 12.2) <u>on-line</u>
- Or by longer distance (up to 18.8 m), but with partial dismounting ☹



From Egorov, Dubna Dec 2012


10
1
0.1
0.01
Δm^2
Reactor + Ga
anomaly
LSND + MiniBooNE
$\sin^2(2\theta)$
0.001
0.01
0.1
1

Sterile neutrinos in SAGE ?



Target: 50 t metallic Ga

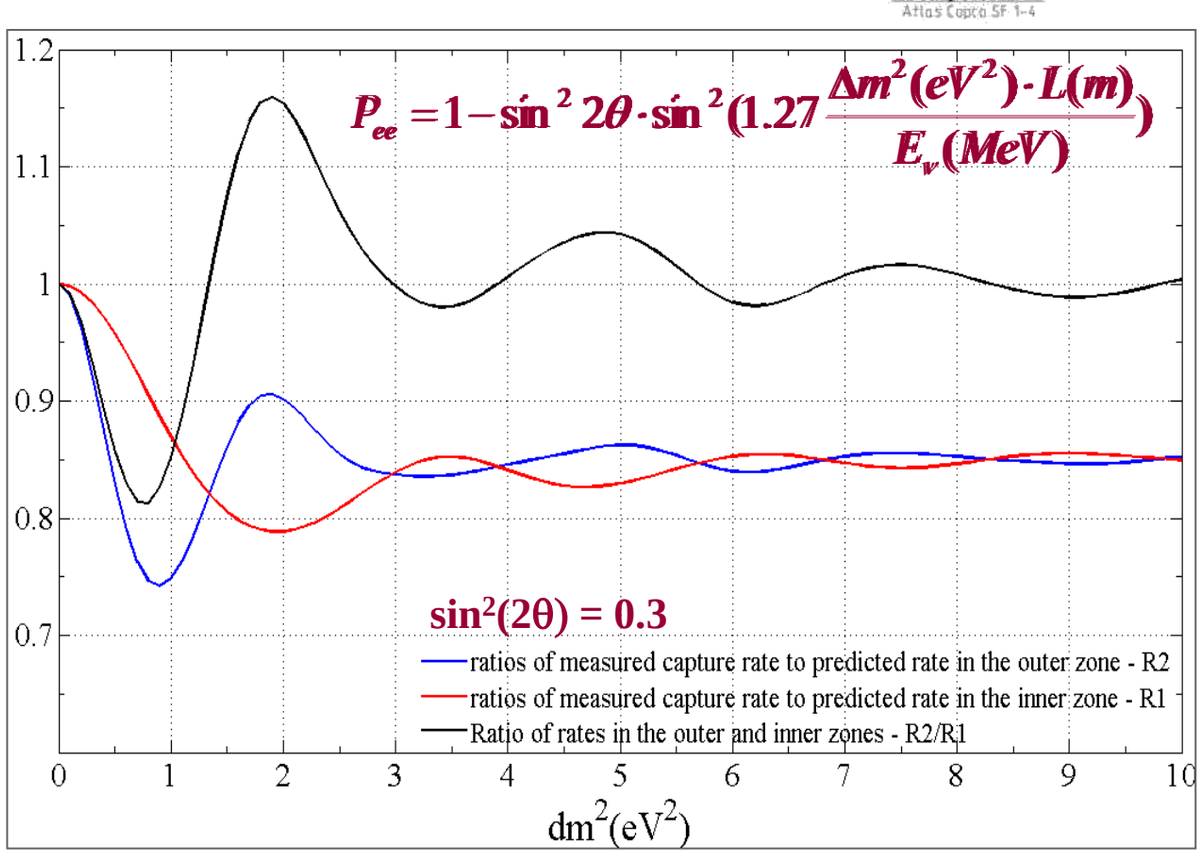
Masses of the zones: 8 t and 42 t

Path length in each zone: <L> = 55 cm

Source: ^{51}Cr, 3 Mega-Curie (~15 M€)

 # Measurements: 10 à 9 days

 # Events: 1650/870 in zone 1/2



Signature of nonstandard neutrino properties:

- significant difference between the capture rates in the two zones
- average rate in both zones below expected rate

From V. Gavrin, INR Moscow

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: <u>LAGUNA</u>

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Large scale, mid of decade:

- **TeV gamma-ray astrophysics**
  - High energy neutrinos: KM3NeT
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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.**

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- **High energy neutrinos**
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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**.

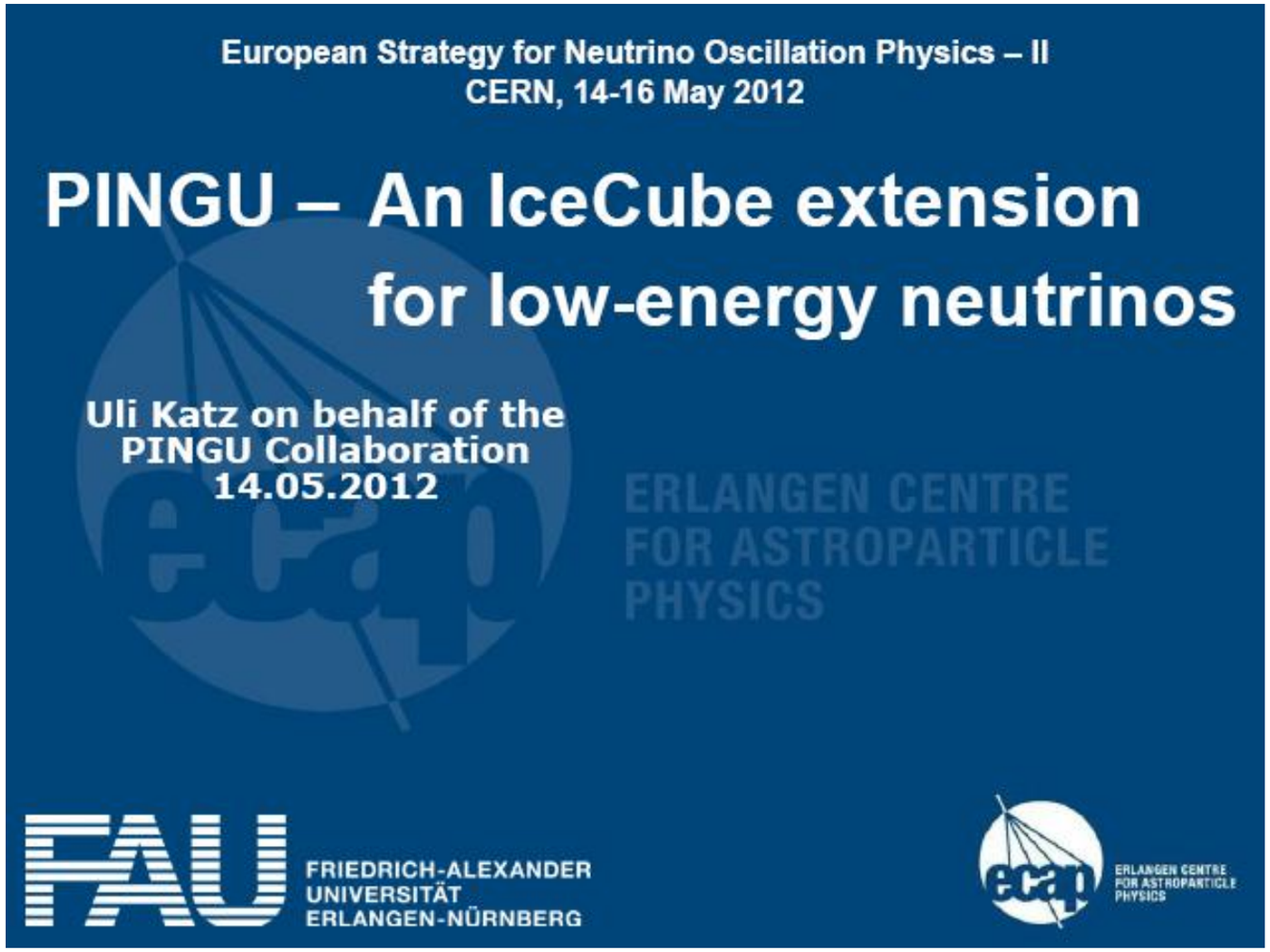
- There is a strong scientific case for a neutrino detector in the Northern hemisphere, with a substantially larger sensitivity than IceCube. **Resources for a Mediterranean detector should be pooled in a single optimized design for a large research infrastructure. The KM3NeT collaboration is encouraged 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**.

PINGU

ASPERA Roadmap: A moderate infill of 15-20 strings would results in a threshold of ~1 GeV and might allow to measure matter oscillation effects which are sensitive to the neutrino mass hierarchy. A massive infill of 50-100 strings might lead to a 20 Megaton detector sensitive to supernova bursts from much beyond our own galaxy and possibly even to proton decay. **The committee encourages the on-going Monte-Carlo studies and related photo-sensor developments.**

SEE THE TALK OF ULI KATZ



Large scale, mid of decade:

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

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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: CTA
- High energy neutrinos: KM3NeT
- High energy cosmic rays: 30,000 km² ground based array

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

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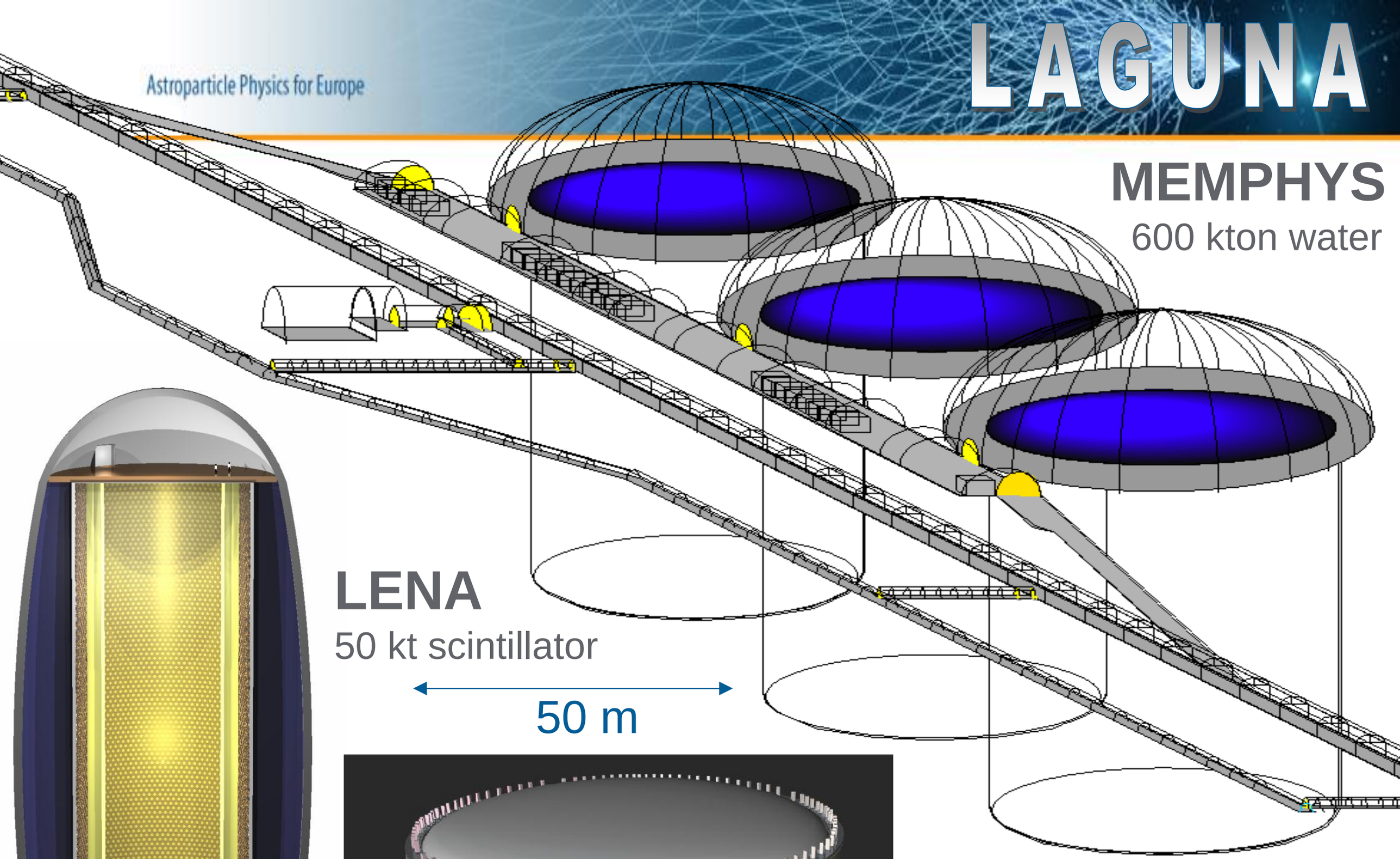
Astroparticle Physics for Europe

LAGUNA



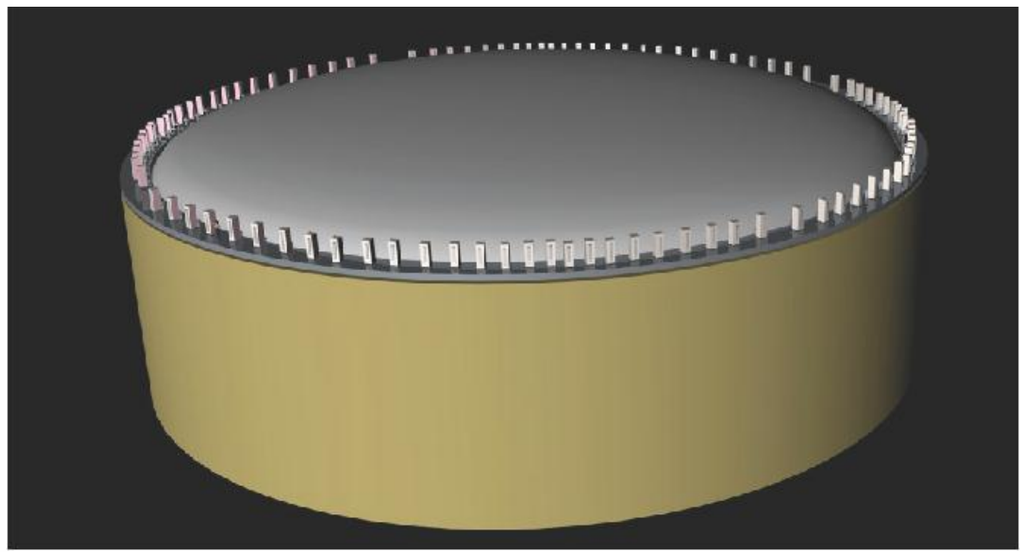
MEMPHYS

600 kton water

LENA

50 kt scintillator

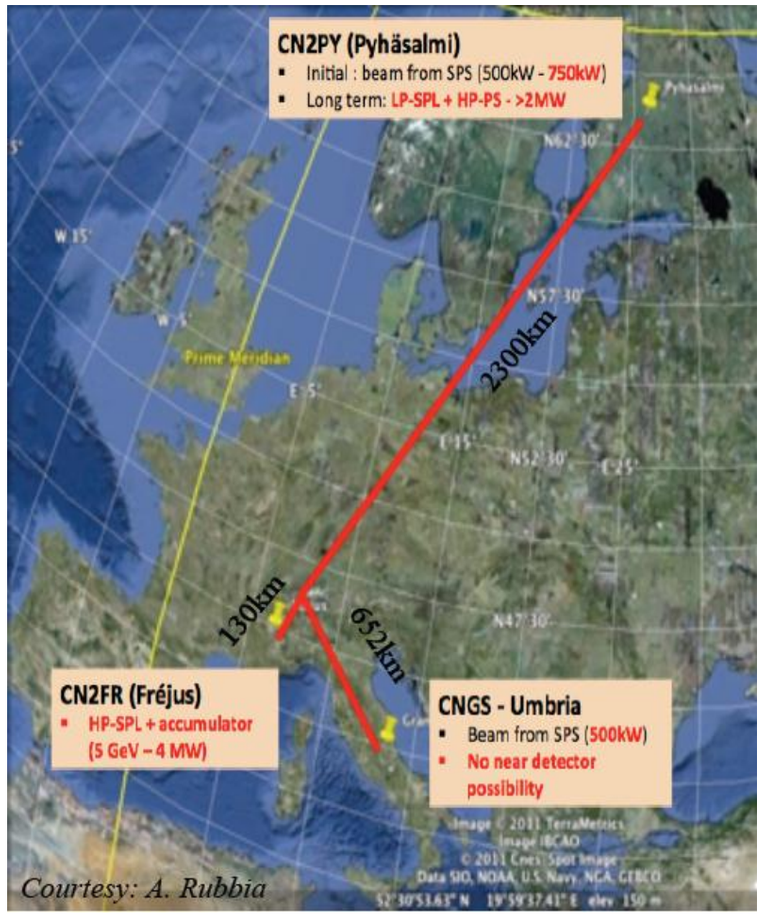
50 m



GLACIER

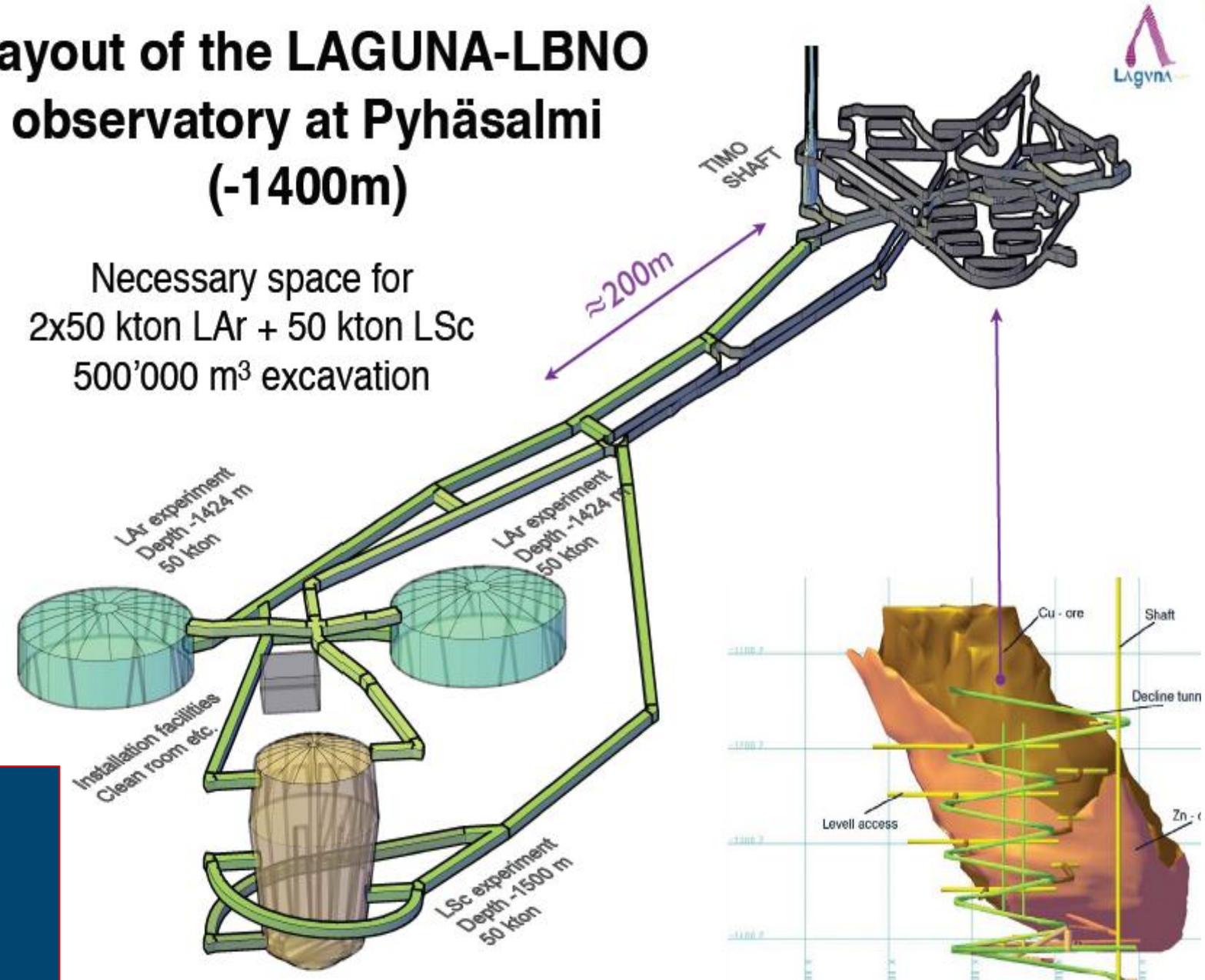
100 kton liquid argon

LAGUNA Case Study



Layout of the LAGUNA-LBNO observatory at Pyhäsalmi (-1400m)

Necessary space for
2x50 kton LAr + 50 kton LSc
500'000 m³ excavation



Case study for European Strategy Process:
- CERN-Pyhäsalmi
- LSc + LAr

(Studies also incremental approach)

Physics potential of the 3 types of detectors for proton decay and neutrino astrophysics *

Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (500 kt)
proton decay, sensitivity(10 years) $e^+\pi^0$ anti-ν K^+ (**)	5		
	11×10^{34}	4×10^{34}	2.5×10^{34}
SN at 10 kpc, # events CC NC ES Elastic scatt. p	~ 38,500	~16,000	~250,000
	-	2.6×10^3 (p)	-
Diffuse SN #Signal/Background events (5 years)	~		(1 module with Gd)
Solar neutrinos # events, 1 year	^{8}B ES : 3.0×10^4	^{7}Be: 3.6×10^6	^{8}B ES: 1.2×10^5
		B: 2.9×10	
Atmospheric ν # events, 1 year	1		
Geo-neutrinos # events, 1 year	B		

test a new class of Supersymmetry models

Bonanza for particle physics and astrophysics !
Incredibly detailed information on the early SN phase

probe cosmological star formation rate

details of the Standard Solar Model with percent accuracy

oscillation physics, indirect Dark Matter search

improve understanding of the Earth interior

* some numbers strongly depend on model assumptions and give a qualitative rather than an exact quantitative comparison.
** this channel is particularly prominent in SUSY theories. Indications for SUSY at the LHC would boost its importance.

Physics potential of the 3 types of detectors for proton decay and neutrino astrophysics *

Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (500 kt)
proton decay, sensitivity(10 years) $e^+ \pi^0$ anti-ν K^+ (**)	5×10^{34} 11×10^{34}	- 4×10^{34}	15×10^{34} 2.5×10^{34}
SN at 10 kpc, # events CC NC ES Elastic scatt. p	~ 38,500 1.6×10^4 (ν_e) 2.2×10^4 0.8×10^3 (e) -	~16,000 1.3×10^4 (anti-ν_e) 1.0×10^3 6.2×10^2 (e) 2.6×10^3 (p)	~250,000 2.5×10^5 (anti-ν_e) - 1.3×10^3 (e) -
Diffuse SN #Signal/Background events (5 years)	~50/30	~30/5	~60/50 (1 module with Gd)
Solar neutrinos # events, 1 year	^{8}B ES : 3.0×10^4 Abs: 1.0×10^5	^{7}Be: 3.6×10^6 pep: 1.0×10^5 ^{8}B: 2.9×10^4	^{8}B ES: 1.2×10^5
Atmospheric ν # events, 1 year	11×10^3	5×10^3	5×10^4
Geo-neutrinos # events, 1 year	Below threshold	1.5×10^3	Below threshold
beam LBL 2300 km	on model assumptions and give a qualitative rather than an exact quantitative comparison. minent in SUSY theories. Indications for SUSY at the LHC would boost its importance.		

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).
- **We recommend 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, we recommends that this program is pursued in a global context.**
- If the current indications for a large mixing angle θ_{13} were to be confirmed within one or two years, attractive scenarios for the medium-term CERN strategy open up.
- **As such the LAGUNA project constitutes a high astroparticle physics priority to be discussed within the CERN strategy update process.**

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.**

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 !**