Astroparticle Physics

The 2011 ASPERA Roadmap

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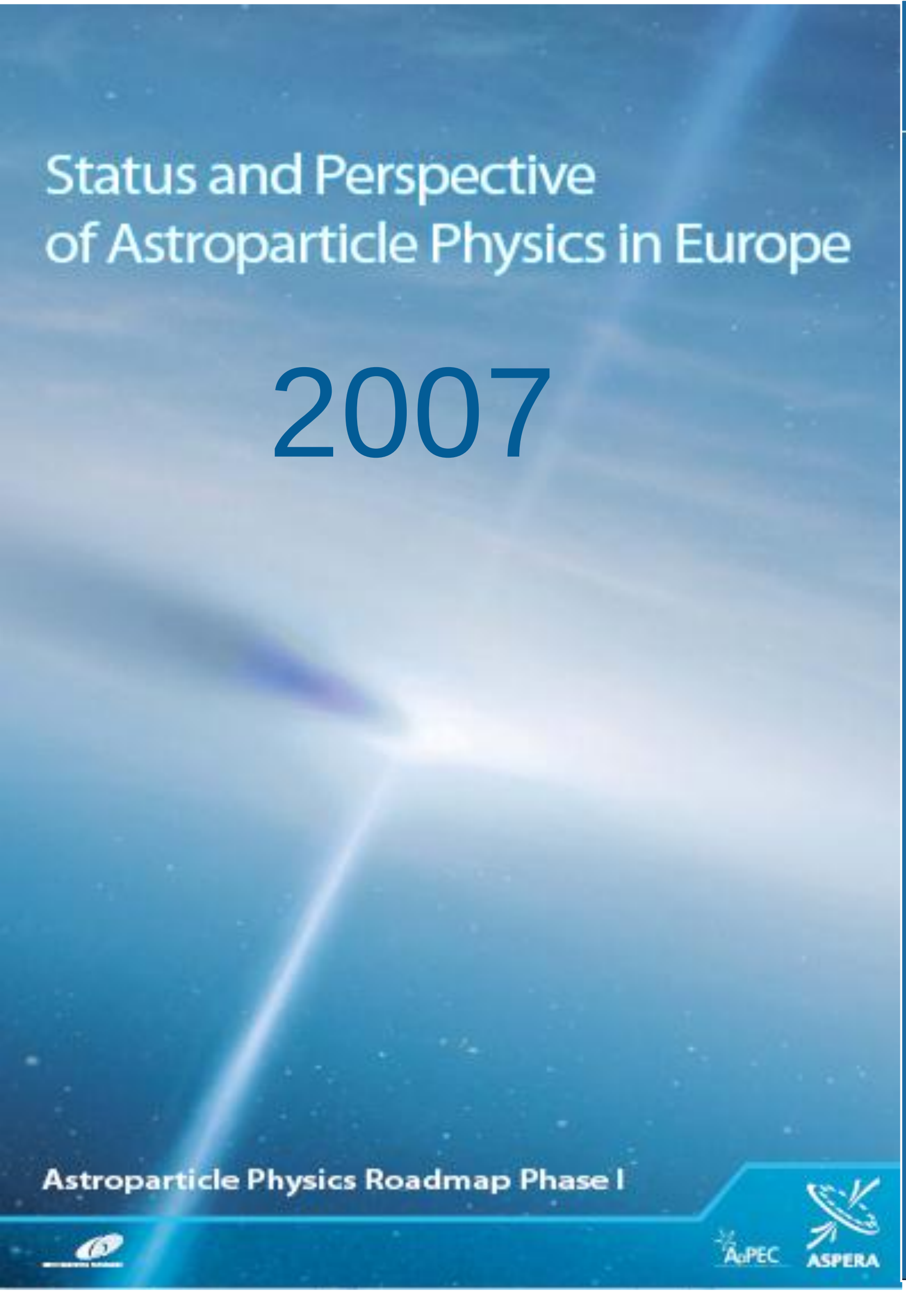
VLVNT-2011, Erlangen, October 14, 2011

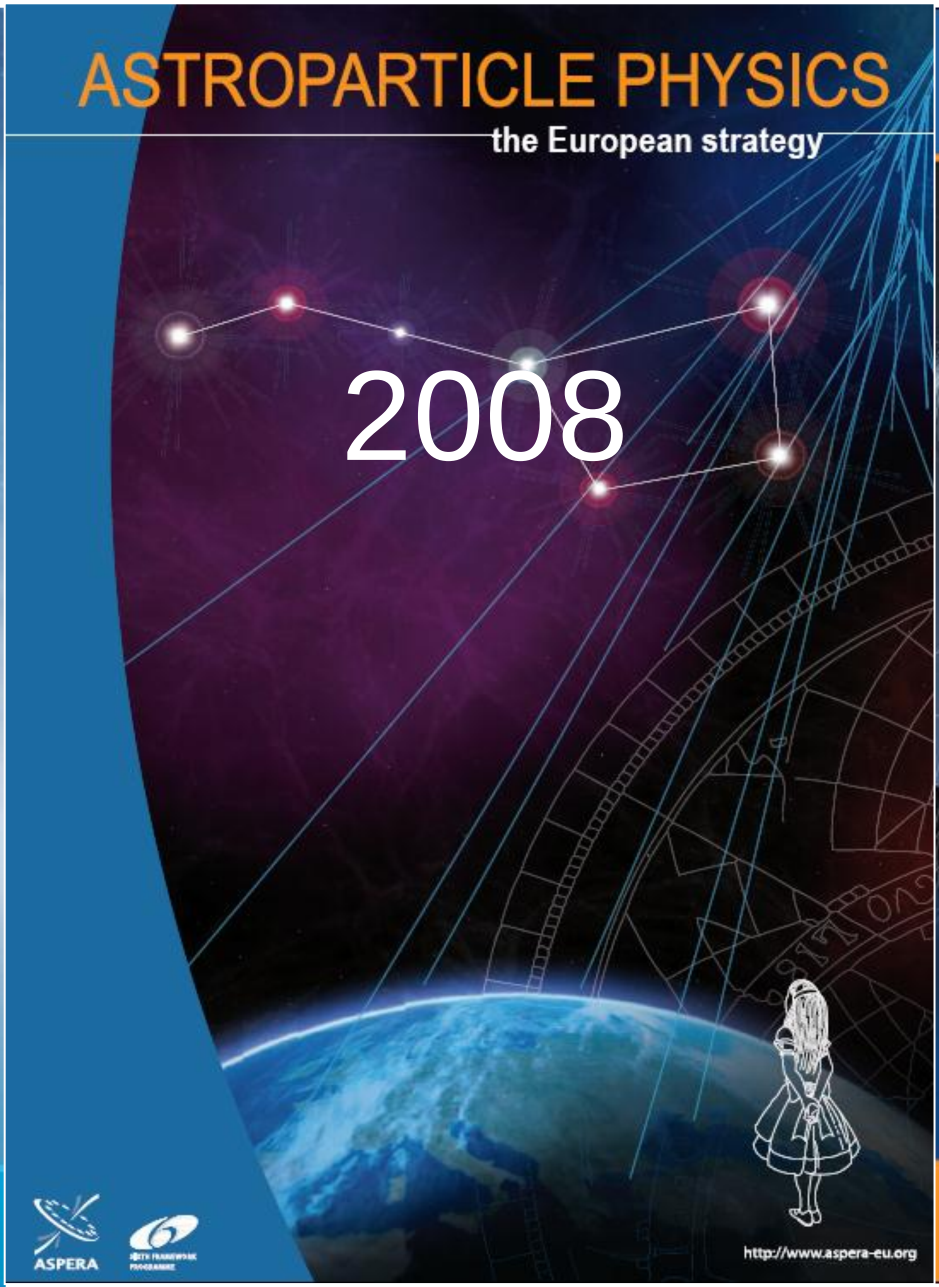
http://www.aspera-eu.org

ApPEC/ASPERA Roadmap process

Detailed Description of the Field



Glossy Paper „The Magnificent Seven“



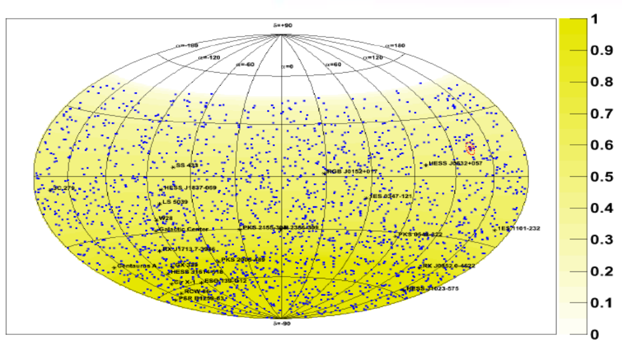
Actual Status & Extrapolation

Plans vs. Reality

- We were – and continue to be! – convinced that the prospects of astroparticle physics merit a factor-2 increase over the next decade. On the other hand we are aware that funding realities in most countries have become more challenging. An aggressive "factor-2 pressure" appears presently beyond realistic expectations. Instead, we propose to proceed with the most advanced projects as fast as possible and to exploit their discovery potential. The expected successes will then hopefully translate into additional momentum for the remaining priority projects.

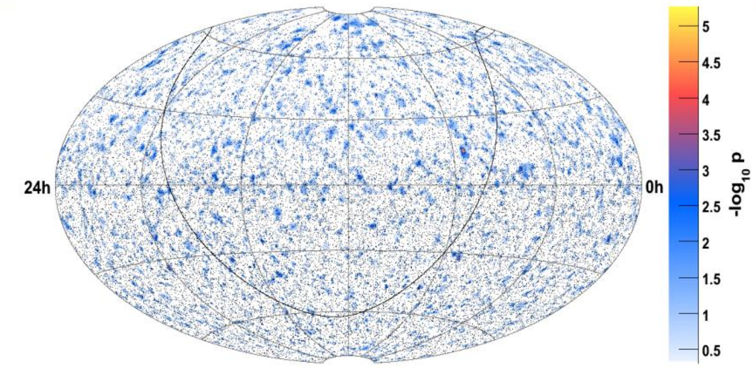
- The SAC is also aware, that research priorities will differ from country to country, depending, e.g., on their local infrastructures, or on their traditions and historically grown strengths in particular fields. The SAC ranks scientific arguments highest but at the same time keeps in mind that there are also historical and political aspects. We are careful not to define priorities in such a way that they might limit the phase space of national funding agencies for substantial, positive funding decisions, once such possibilities for a certain project may appear on a national level.

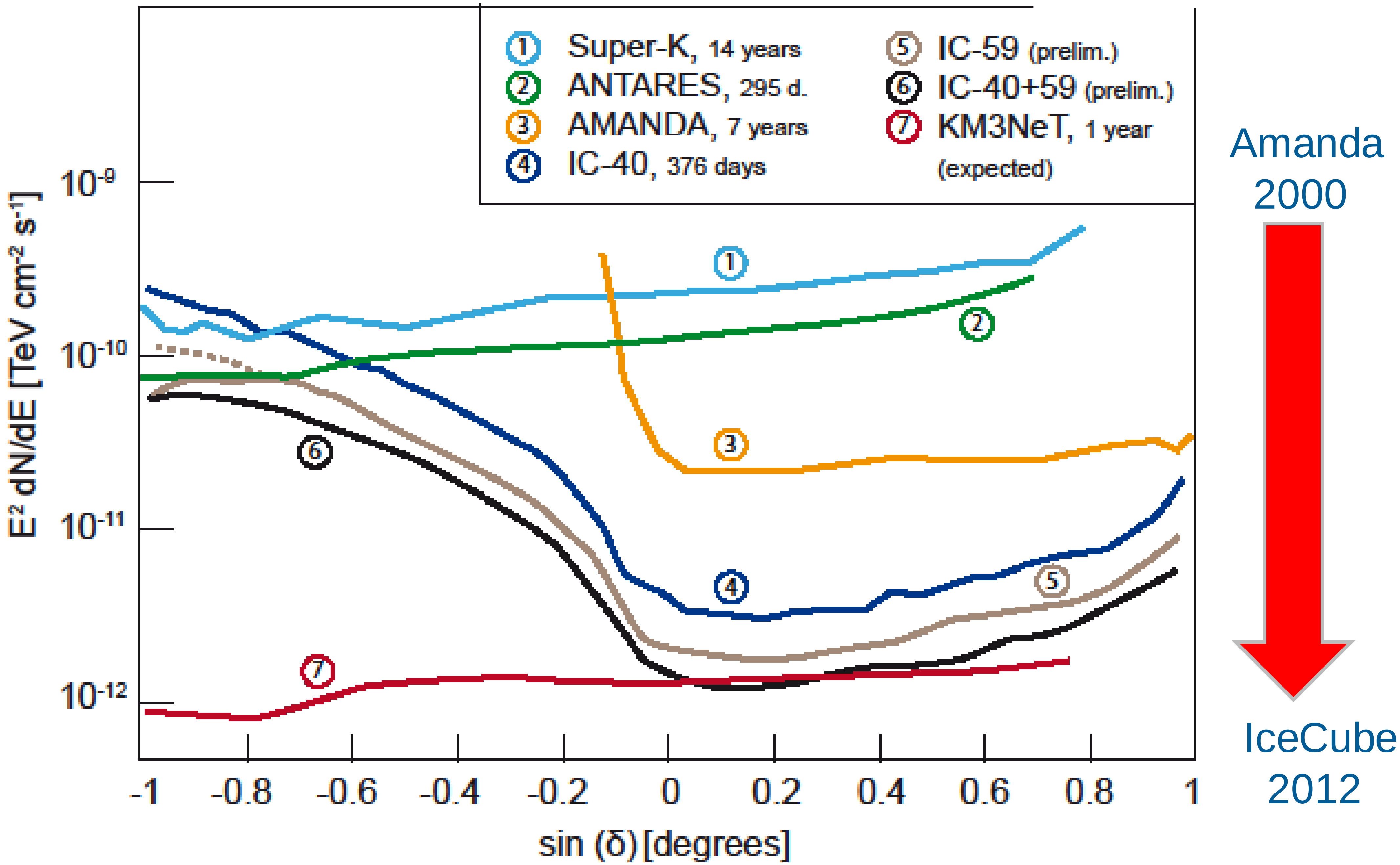
Examples for developments since 2008



New: ANTARES!

IceCube: factor 1000 !





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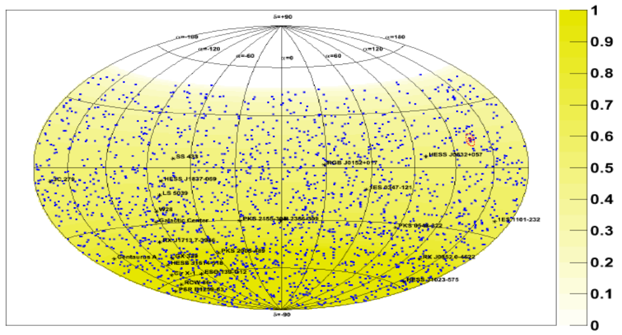

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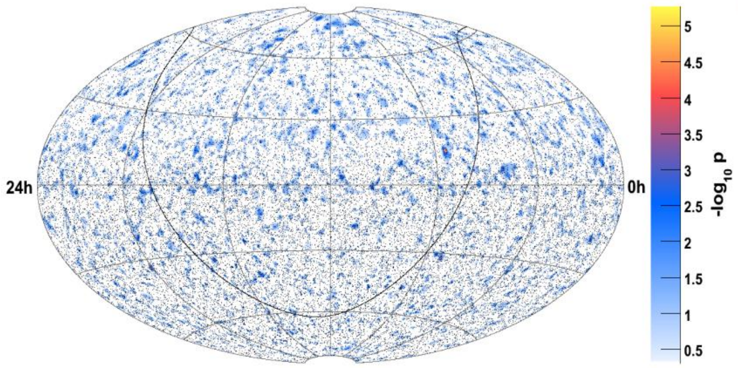
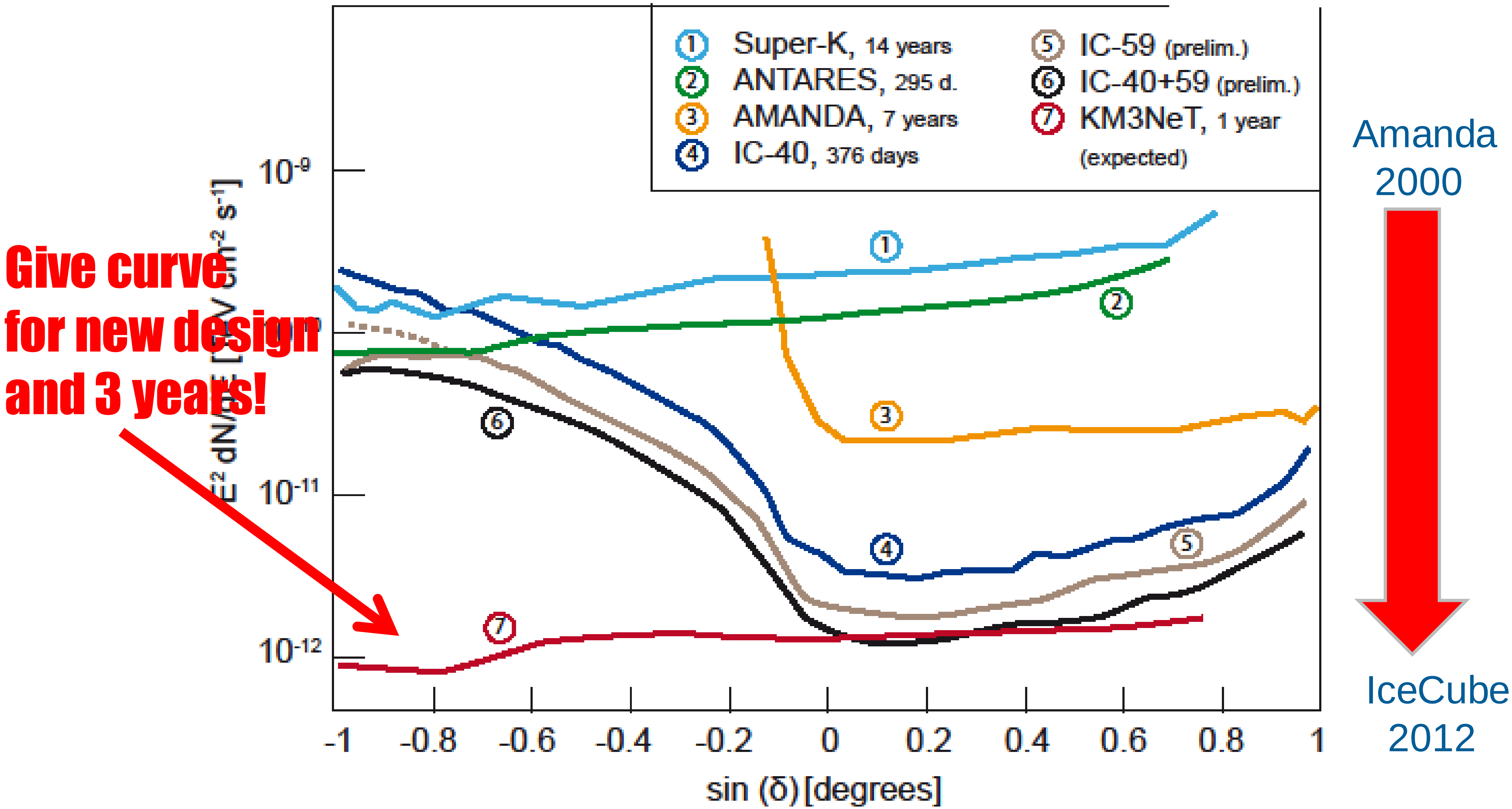
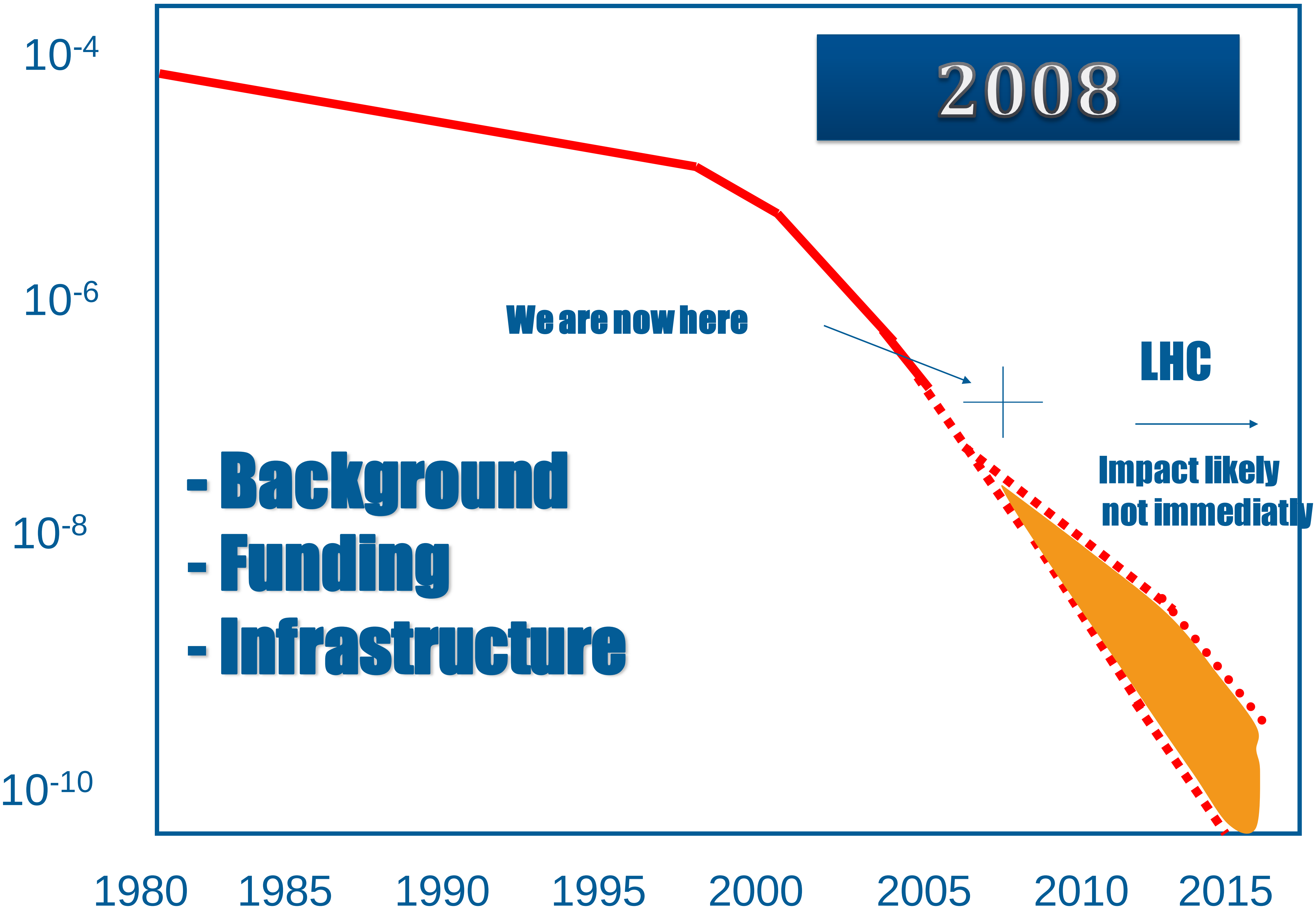




Examples for developments since 2008



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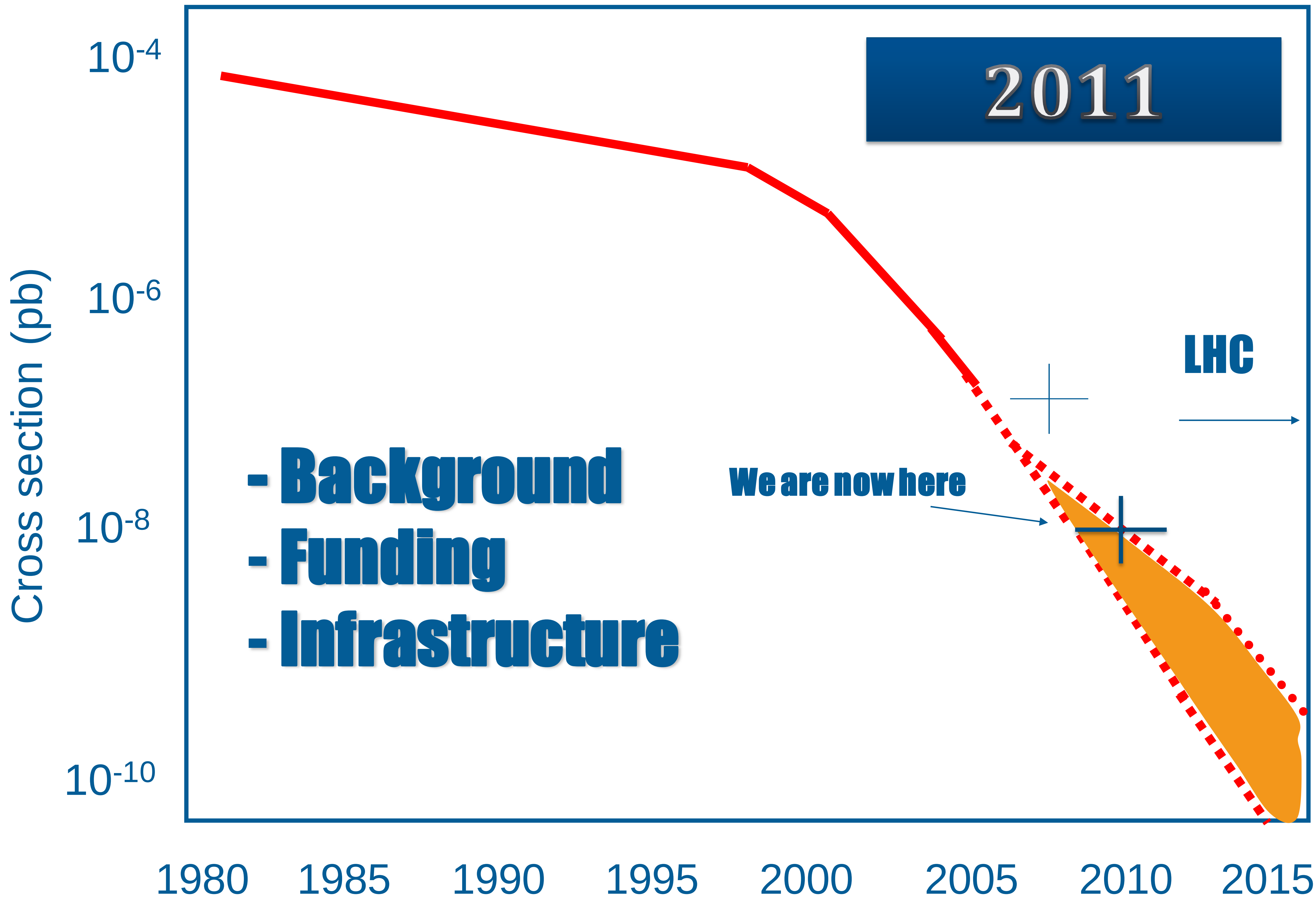


Examples for developments since 2008

Θ_{13}

- T2K results
- Autumn: DoubleCHOOZ
  - “To achieve full sensitivity and to be competitive with other experiments worldwide, **it is critical that the Double CHOOZ Near Detector be completed as soon as possible**”
- Summer 2012: further T2K results
- Relevant to CERN strategy!

Recommendations

From Executive Summary

Recommendations

- There are a few large 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 (5-50 M€ class):

Recommendations

- **Advanced detectors for gravitational waves:**
  - GW detection would be centennial discovery – a really new window to the Universe
  - With advanced VIRGO, advanced LIGO and GEO-HF, a discovery in 5 years is highly probable.
  - We urge the agencies to continue substantially supporting the advanced detectors.
- **Dark Matter:**
  - One of the most fundamental problems in physics and cosmology. Relations to LHC !
  - Dramatic progress of liquid Xe technology over the past 2-3 years demonstrates a high momentum, which must be maintained. **XENON1t** at Gran Sasso laboratory could start operation in 2014/15.
  - Bolometric experiments **CDMS** and **Edelweiss** have recently provided competitive upper limits 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.
- **Neutrino properties:**
  - Several highly important experiments in the commissioning phase or final years of construction:
  - ν-mass: GERDA, CUORE, SuperNEMO,NEXT (DBD), KATRIN (SBD).
  - θ_{13}: Double CHOOZ (imagine if T2K is not just a fluctuation !!!)
  - We renew our strong support for these experiments and look forward to first results. Beyond this, we recommend a 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

Four large-scale infrastructures whose construction should start towards middle of current decade include 3 high-energy projects and one on low-energy ν astrophysics (100-500 M€ scale)

Recommendations

- **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 end of 2013.**

- **High energy neutrinos:**
  - In the high-energy neutrino domain, the requirements on the necessary sensitivity have tightened, **but the scientific case for a large neutrino detector in the Northern hemisphere remains high**. The KM3NeT collaboration is working towards a technical proposal for a neutrino telescope with a substantially larger sensitivity than IceCube. The expected cost scale is **250 M€** and, based on pioneering technical work by the European astroparticle community, also provides access to deep-sea research.

- **High energy cosmic rays:**
  - In the cosmic-ray domain the community is working towards a next-generation ground-based observatory including the development of new detection technologies, the search for appropriate sites, and the possibility to attract new partners. **We reiterate the definition of a substantially enlarged ground-based observatory as the priority project of high-energy cosmic ray physics**. The cost scale is **100-150 M€,** with a substantial contribution from Europe.

Recommendations

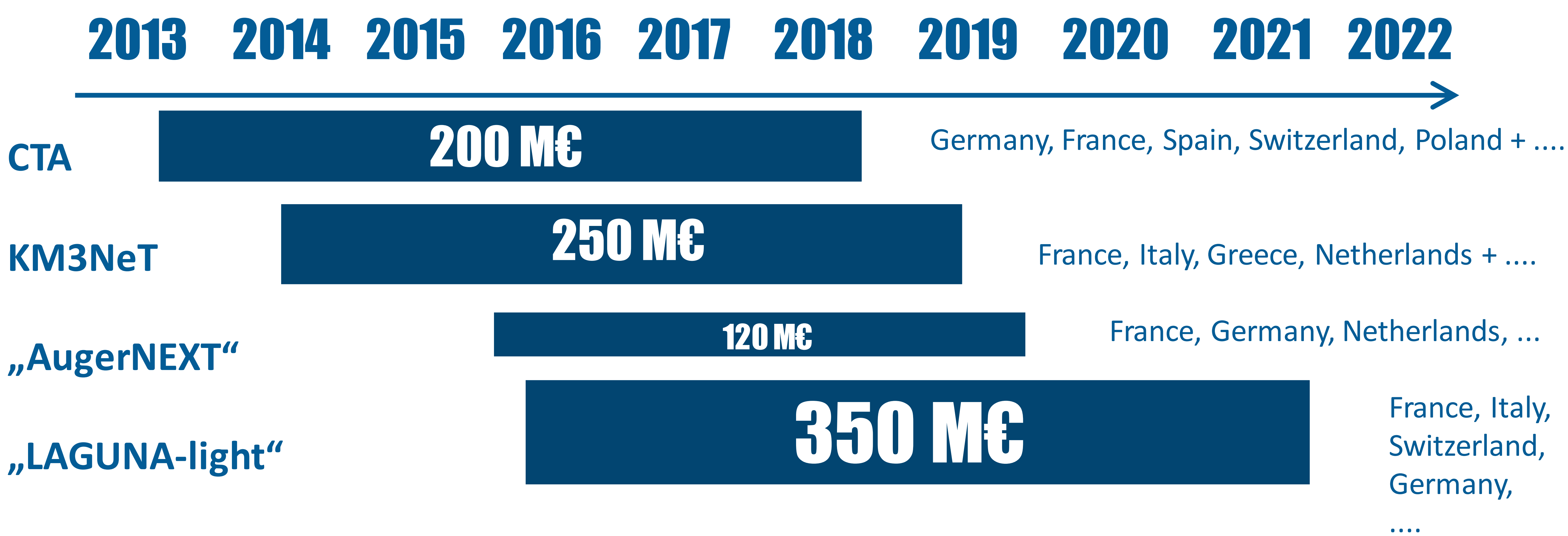
- **Low-energy neutrino astrophysics and proton decay:**
  - A megaton-scale **low-energy neutrino astrophysics and proton-decay** detector for astroparticle and accelerator-based neutrino measurements is addressed by the **LAGUNA** design study.
  - The scientific goals combine **high-risk research 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 θ_{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.**

Recommendations

- 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."**

Recommendations



(Don‘t take the time lines too serious!)

Recommendations

- **E.T. and LISA:**
  - **Acknowledge the progress of the E.T. Design Study.**
  - Propose an ASPERA call for related R&D. From today's perspective E.T. construction would start at the end of the decade.
  - Look forward to the results of LISA-Pathfinder and **renew strong support for LISA**.
- **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 ca 2016) or the ESA satellite **EUCLID** (launch ca. 2018). **The committee recommends a strong support for these participations.**

- **Transversal aspects:**
  - **Theoretical research:**. Similar to experimental activities, theoretical studies will strongly benefit from a strengthened and more coordinated support. In turn, this will also help to maximally exploit the impact of astroparticle physics experiments.
  - **Smaller projects and innovative R&D activities** are essential for the progress of our field and profit from international cooperation. ASPERA addressed this by a series of calls for R&D activities.
  - Most astroparticle observatories, whether they are located underwater/ice (neutrino telescopes) or underground (underground laboratories) or on the ground (air-shower detectors), have developed strong **synergies with geo-science and environmental studies.** They provide state-of-the-art technologies and attractive infrastructures to the corresponding communities, which in turn will increase the support of these infrastructures.

And now on high energy neutrinos, next generation:

KM3NeT: scientific impact

- KM3NeT increases the discovery potential for neutrino sources and potentially allows for looking deeper into black hole environments and, at energies beyond 100 TeV, further out into the Universe than possible with gamma-rays. Together with gamma-ray and cosmic ray observations (and with IceCube), it could pave the way to real multi-messenger astronomy.
- However, in absence of established cosmic high-energy neutrino sources, it is difficult to assess the sensitivity necessary to achieve these goals. Until now neither IceCube nor ANTARES have seen any cosmic neutrino sources.
- Should this picture pertain for the first few years of full-scale IceCube operation, KM3NeT in its currently planned configuration, being about five times more sensitive than IceCube, may provide only a limited additional discovery window for extragalactic sources. The abundance and characteristics of such sources should not differ much between the Northern and Southern skies, but firm flux predictions are absent.
- Predictions for Galactic sources are much more firm if we assume dominantly hadronic emission. In contrast to extra-Galactic sources, we seem to be close to the discovery region, therefore here a factor five, but with a telescope observing the Southern hemisphere, indeed counts. With the central part of the Galaxy in its field of view, KM3NeT therefore may provide a significant step beyond IceCube.

KM3NeT: scientific impact

- The gain from KM3NeT for indirect Dark-Matter searches, exotic phenomena such as magnetic monopoles or Q-balls, or oscillation studies with atmospheric neutrinos is restricted because the phenomena are not expected to depend on the hemisphere.
- If, however, IceCube would see an exotic effect, the confirmation by KM3NeT would be essential.
- Given recent constraints from Fermi-LAT measurements of the diffuse gamma radiation in the energy range below about 100 GeV, the sensitivity of KM3NeT in its current configuration to cosmogenic neutrinos is expected to be limited, but might be increased to a significant level by implementing (part of) the detector in a sparse array of several tens of km^3.

- The KM3NeT infrastructure will also provide access to continuous, real-time deep-sea measurements over long periods. This is of high interest to various science communities, e.g. marine biologists, oceanographers, geologists and geophysicists, environmental scientists, etc. It is foreseen that KM3NeT will be one node of a global deep-sea observatory system.

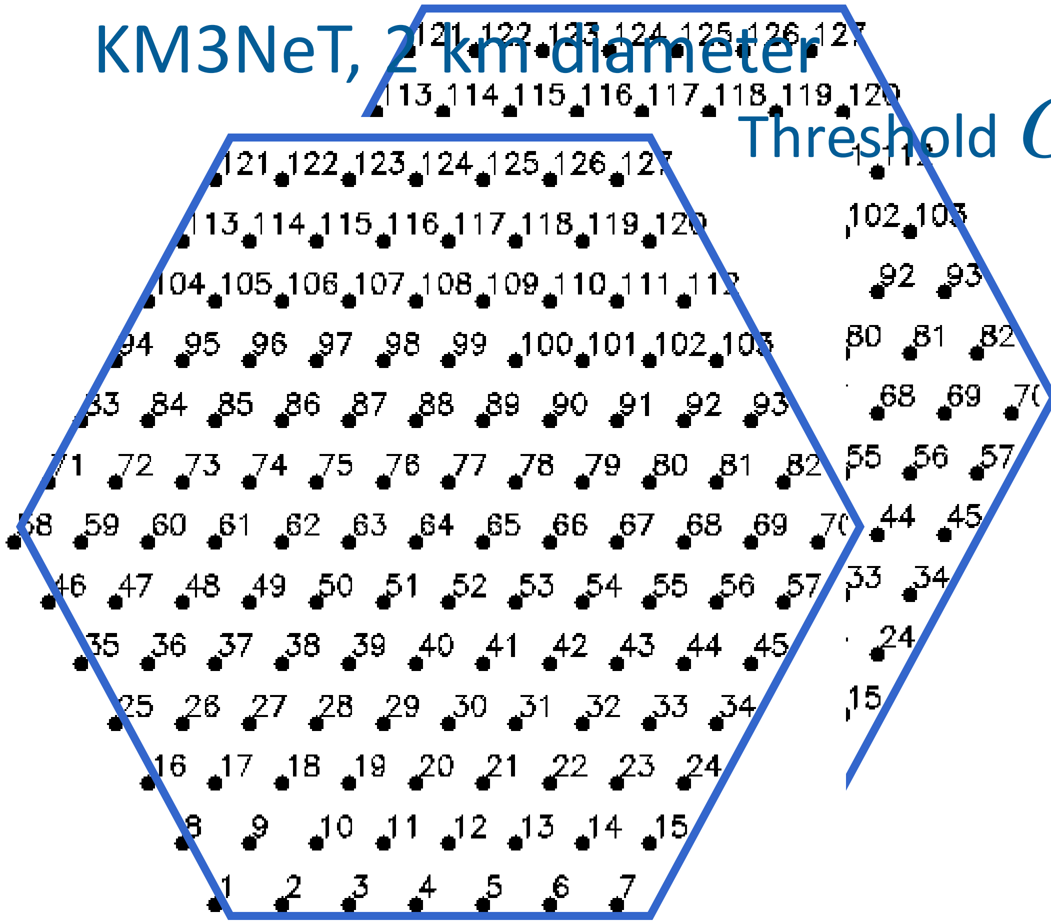
KM3NeT: Uniqueness/Complementarity

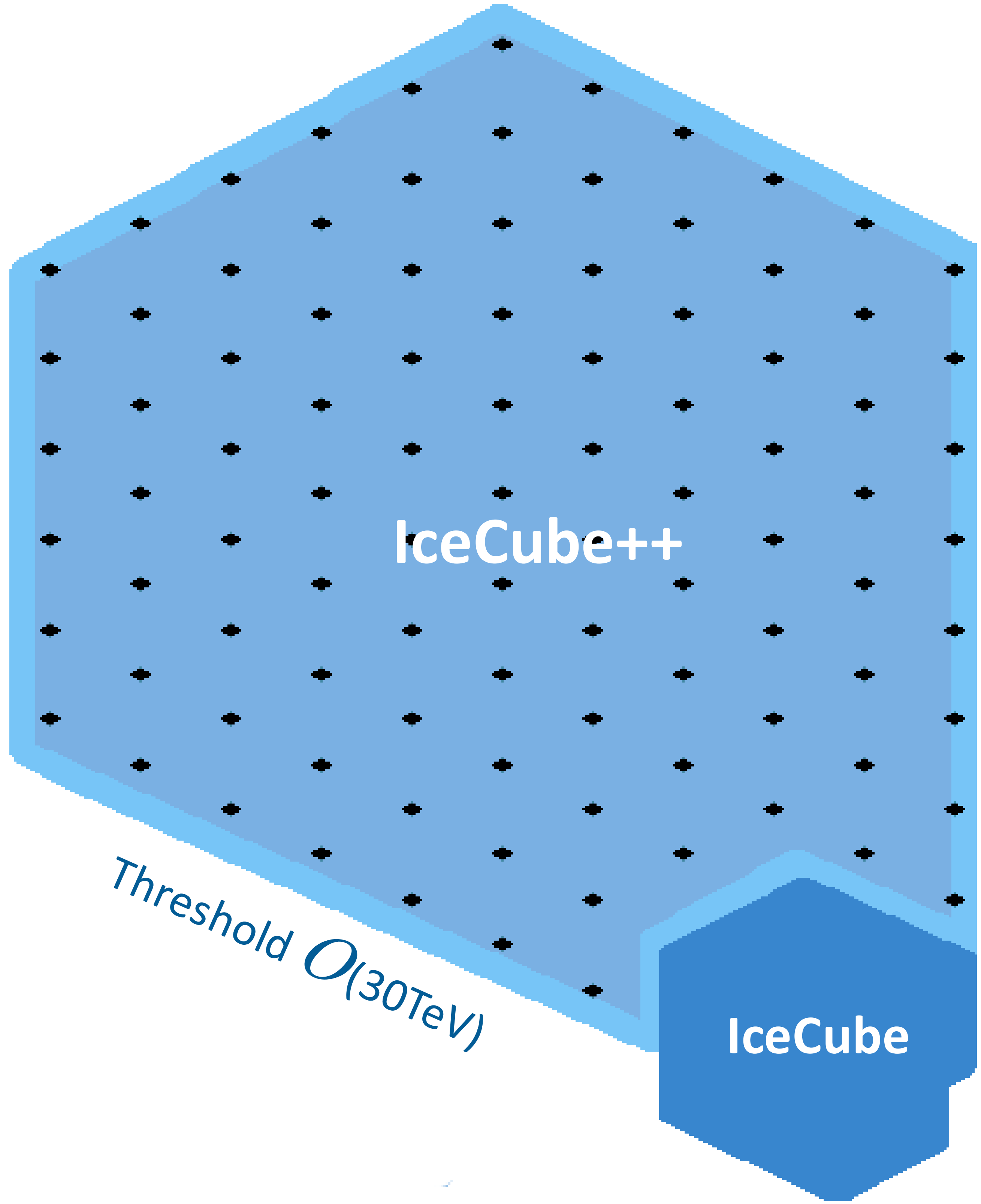
- **KM3NeT vs. IceCube vs. Lake Baikal GVD:**
  KM3NeT will have the highest sensitivity to neutrino point sources of all three telescopes. It will be the only detector with > 1 km^3 volume to observe the Southern sky (and with it the central region of the Galaxy) in the neutrino energy range 10^{12}-10^{15}eV. Together with IceCube, KM3NeT will provide full-sky coverage over the full energy range up to energies of cosmogenic neutrino fluxes. It seems obvious that the early observation or non-observation of sources by IceCube will impact the actual size and configuration of KM3NeT. KM3NeT will be about one order of magnitude more sensitive than GVD in Lake Baikal. GVD could be part of a distributed northern infrastructure and add statistics with a detector with different systematics.

KM3NeT, GVD, IceCube++

KM3NeT, 2 km diameter

Threshold $\mathcal{O}$(1TeV)





Threshold $\mathcal{O}$(30TeV)

Threshold $\mathcal{O}$(10TeV)

Roadmapping Process in Russia

- Recently, INR Moscow, JINR Dubna and Kurchatov Institute Moscow agreed to prepare a Russian roadmap on Astroparticle Physics.
- Time scale: mid 2012
- Chair: Y.P Velichov (Kurchatov), V.A.Matveev (JINR)
- Scientific Chair: V.A.Rubakov (INR)

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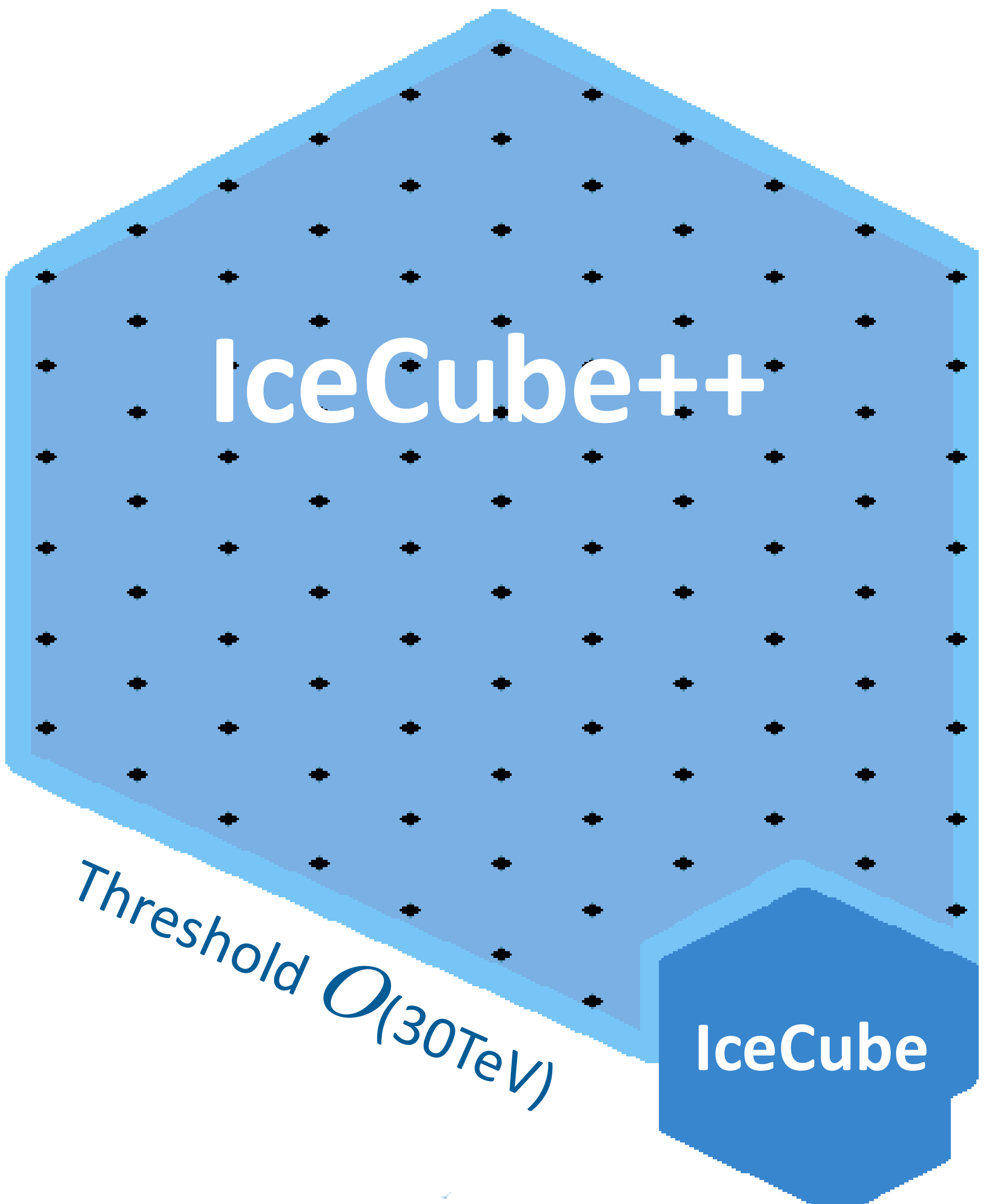
- **KM3NeT vs. CTA and Auger:**
  Even though KM3NeT, in contrast to CTA, might likely just scratch the sensitivity region of interest, it would/could open a truly new window, with the occasional surprises related to new territories. It also represents the one hitherto missing frontier of a multi-messenger approach. Even a low-statistics measurement of cosmic neutrino signals would provide highly relevant complementary scientific information to that of CTA and Auger. Thus this is a question of complementarity rather than of competition.
- **KM3NeT vs. "new detection methods":**
  The new detection methods (acoustics, radio …) are typically applicable at energies of 10^{17}-10^{18}eV and beyond; they are therefore complementary to the "traditional" neutrino-telescope technique. Rather than the physics of cosmic acceleration, their main focus is the detection of neutrinos from cosmic-ray interactions with the 2.7 K radiation and from possible exotic relics.

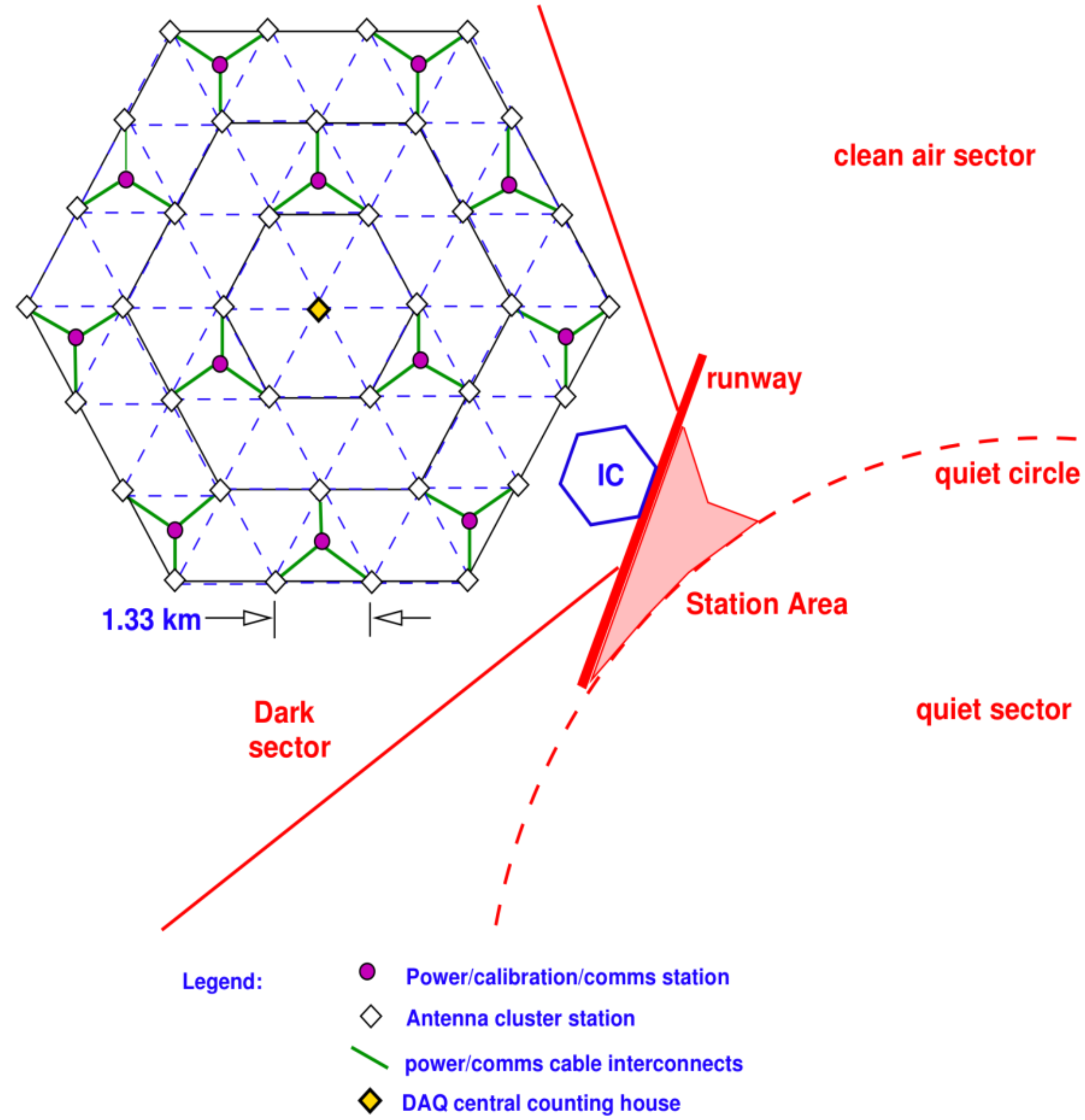
TeV-PeV vs. PeV-EeV vs. GeV

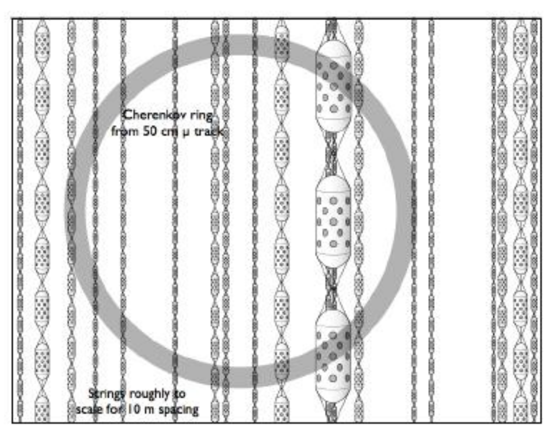


30 TeV – 30 PeV
continuation of
IceCube core program

ARA

> 30 PeV:
Cosmogenic
neutrinos





PINGU

< 10 GeV: neutrino oscillations
SN collapses beyond our Galaxy
proton decay (??).

KM3NeT: other criteria

- **Timeliness and schedule/milestones**: …. A Technical Proposal will be presented in 2012, and construction could commence in 2013/14 if the project is endorsed. It is expected that construction will take about 4-5 years, although also a staged implementation over a longer period might also be possible.

- **Scientific groups involved and transnational cooperation (Strength of Community): ….**
- **Project Management: ….**
- **Cost:** … lies in the range of 250 M€, with a projected spending profile peaking ~2014-17.

- **Technical readiness, challenges and risks:** The feasibility of a deep-sea neutrino telescope has been demonstrated by ANTARES. The KM3NeT technical design represents a major development beyond ANTARES, in particular concerning cost-effectiveness, reliability and deployment of state-of-the-art technology. KM3NeT is expected to be ready for construction by the end of 2012. The major challenge, besides securing funding and reaching political agreement, is to keep the consortium together and active in the phase before project endorsement. ~~The largest~~ A certain risk is that delays beyond the current schedule may lead to a drain of key experts and/or to the implementation of alternative, “specialised” projects of regional character that fail to match the scientific objectives of KM3NeT but tie up available resources.

- **Industrial involvement: …**

Recommendations for IceCube and KM3NeT

- 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, however, 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.

- DeepCore: 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 ongoing Monte-Carlo studies and related photo-sensor developments.

- The IceCube, ANTARES and KM3NeT collaborations are encouraged to strengthen cooperation, with the goal to form a future Global Neutrino Observatory, possibly also including GVD.