Status of the ASPERA Roadmap

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LAGUNA Meeting,

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Content of Roadmap

~ 100 page document

- **Introduction**
- **The High Energy Universe**
  - Introduction
  - Charged cosmic rays
  - Gamma ray astrophysics
  - High Energy Neutrinos
- **Dark Matter, Neutrino Mass, Low Energy Neutrino-Astronomy and Proton Decay**
  - Introduction
  - Dark matter
  - Direct measurement of neutrino mass
  - Neutrino-less double beta decay
  - A large detector for proton decay, low energy neutrino astrophysics and long baseline experiments
- **Dark Energy and Gravitational Waves**
  - Dark Energy
  - Gravitational Waves
- **Summary and general recommendations**
- **Appendices**
- A.1 Overview information about experiment
- A.2 Spending profile as supplied by the large experiments

Why a new ASPERA roadmap?

- Rapidly growing, highly dynamical field, landscape has changed from 2008 to now.
- New global developments, OECD roadmap, LBNE, …
- 2012 ppdate of the *European Strategy for Particle Physics* which is worked out by the CERN Council Strategy Group. The present Roadmap should provide a qualified input to the updated document
- 2008 roadmap proposals met a funding scenario with a smooth factor-2 increase over the next 8-10 years. **We were – and are! – convinced that the prospects of astroparticle physics merit this increase.** On the other hand we have to face that funding realities in most countries have became more challenging, and astroparticle physics is among the victims of the economic crisis. Need a revision of the 2008 recommendations and a critical reality check.

New developments (1)

- **Cosmic rays:**
  - The AMS detector to be launched with the last shuttle start in April 2011.
  - Several successors of KASCADE-Grande have been completed in 2010 (Tunka-133, IceTop) or are being installed as low-energy extensions of the Pierre Auger Observatory.
  - Statistical significance of Auger AGN correl. decreased, Auger North delayed by 3-5 y
  - A small but significant anisotropy of TeV cosmic rays on large and medium angular scales, reported earlier by the American MILAGRO experiment, was confirmed by ARGO/YBJ in 2008 and by IceCube in 2009.

- **Gamma rays:**
  - Fermi !!
  - A huge number of new sources have been detected by H.E.S.S., MAGIC and VERITAS.
  - MAGIC-II started stereoscopic operation.
  - The CTA collaboration has formed and meanwhile includes all relevant players in the world. The project made it to the ESFRI list, and the construction of prototype telescopes has started.
  - Construction of the wide angle detector HAWC in Mexico (USA/Mexico) has started.
  - China is planning a new high altitude air shower array (LHAASO).

New developments (2)

- **High energy neutrinos:**
  - IceCube with its low-energy extension was completed in December 2010 and shows excellent performance. No sources yet !
  - The KM3NeT technical proposal has been finalized.
- **Dark Matter:**
  - The experiments XENON100, EDELWEISS and CDMS have improved the sensitivity of dark matter searches with a gradient which eventually appears to be as steep as optimistic extrapolations ten years ago suggested.
  - Construction of a 1ton XENON detector is under preparation.
- **Neutrino-less Double Beta Decay:**
  - The first detector of the new generation double beta experiments, GERDA, is in its commissioning phase.
- **Low energy neutrino astronomy:**
  - BOREXINO in the Gran Sasso Laboratory LNGS shows excellent performance and has detected not only solar neutrinos but also geo-neutrinos, with a much smaller background from reactor neutrinos than KamLAND (Japan).
  - The ICARUS detector in LNGS eventually started full operation and proves the feasibility of operating large liquid argon detectors underground.
  - The E7 design study LAGUNA is close to completion.
- **Gravitational Waves:** GWIC roadmap

Recommendations (1)

- ***Galactic Cosmic Rays:*** **We reiterate the suggestion of the 2006 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 hardening of cosmic rays. This goal may be pursued with large-aperture, long duration flight missions above the atmosphere (balloons/satellites) and by ground detectors with adequate particle identification at the highest altitudes (100 TeV-PeV).** The existing experiments IceTop, TUNKA-133 and the low energy Auger extensions (AMIGA/HEAT/AERA) should be exploited. This includes close cooperation with the particle physics community, in particular with respect to LHC results.

- ***Cosmic rays at highest energies:*** **We reiterate the definition of a substantially enlarged Auger as the priority project of high energy cosmic ray physics – wherever it will be deployed. We encourage the collaboration to work towards a common path for such an "Auger-Next" including the development of new detection technologies. We recommend that European groups play a significant role in preparing a proposal for Auger-Next, and, after its approval, make a significant contribution to construction and operation. We also support European participation in JEM-EUSO as pathfinder for a novel technology. We encourage cross coordination between the two collaborations.**

Recommendations (2)

- ***Space based gamma astronomy:*** The committee recognizes the scientific importance of a mission to cover the energy range of 1-30 MeV.
- ***Earth bound gamma astronomy*****: The Cherenkov Telescope Array, CTA, is the clear worldwide priority project of VHE gamma-ray astrophysics. We recommend to design and to prototype CTA, to select site(s), and to proceed vigorously towards start of deployment in 2013. We strongly recommend that the various funding agencies work together to secure the required funds for the construction and operation of CTA. The current IACTs should continue to take data until CTA has superior sensitivity and sky coverage.**
- ***High energy neutrino astronomy:*** 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, with a start of construction in 2014. The KM3NeT collaboration is encouraged to present a technical proposal matching these requirements and in particular take final site and design decisions. The IceCube and KM3NeT collaborations are encouraged to strengthen cooperation, with the vision to form a future Global Neutrino Observatory.**

Recommendations (3)

- ***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 kilometres will be necessary to record more than a handful of neutrinos from GZK interactions. **We encourage R&D efforts towards this goal.**

- ***Extension of the Modane Underground Laboratory:*** **There is a unique opportunity to extend the present underground laboratory LSM** by taking advantage of the excavation of the safety tunnel of the Frejus road tunnel, now started since 1 year. This **new laboratory of 60000 m3** would be able to host recommended projects, such as EURECA and DARWIN for Dark Matter and SuperNEMO for bb decay. The large depth of this laboratory is particularly suited to new generation experiments. Conversely, these projects - and possibly new medium size ones - could not be fitted in the available space of existing underground labs 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 in 2014 - would enhance the complementary character of the European Deep Underground laboratories.**

Recommendations (4)

Dark matter search:

- **The committee strongly supports improving the DAMA/LIBRA experiment in terms of a lower threshold and a lower background, with the goal to better understand the observed modulation signal.**

- The last two-three years saw a dramatic progress of the liquid-xenon based technology for the direct detection of WIMPs. The 100 kg scale has been realised with a very low background level and the 1-ton scale is currently being planned. **On this basis, the committee recommends that DARWIN, a program to further extend the target mass of noble liquids to several tons, is pursued and supported. The choice in favour of a double-target option should be taken after a clear experimental confirmation that a liquid argon target is competitive with liquid xenon in terms of rejection efficiency, background and operation reliability.**

- The bolometric techniques have remained competitive with the noble liquid approach in terms of sensitivity to WIMP interactions. The results of the EDELWEISS collaboration showed a clear technological advancement regarding the rejection of surface beta background, which was the main limitation in the “ionisation+heat” option. **The committee recommends therefore supporting the development of EURECA, an apparatus capable of housing 1 ton of bolometric sensitive mass. This facility is complementary to the solution provided by noble liquids, and is versatile enough to provide a multi-target approach (including low Z targets tailored to test the low-mass WIMP region) and to possibly house other rare event searches based on the bolometric technology.**

- **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.

Recommendations (5)

Direct measurement of the neutrino mass:

- The KATRIN beta spectrometer is expected to provide unique results on the direct measurement of the neutrino mass starting from 2012, testing the degenerate mass region at the 0.2 eV level. At the moment, no other technology seems to be really in competition. Since with KATRIN a maximum size of feasibility seems to be reached, no larger electrostatic spectrometer is currently being planned. On the other hand, the bolometric approach followed in MARE is modular and can in principle be extended arbitrarily. **Therefore, we recommend the continuation of R&D activities on the bolometric approach, regarding both ^{187}Re (beta decay) and ^{163}Ho (electron capture) sources.**

Neutrino-less double beta decay:

- **The European detectors GERDA and CUORE will explore in the next years the degenerate region of the neutrino mass pattern. CUORE will probe also part of the mass range predicted by neutrino oscillation experiments for the case of the inverted mass hierarchy. In case of discovery at the degenerate mass level, there is a clear path for "precision measurements", with possible evidence in three different nuclei and with the unique opportunity provided by SuperNEMO to investigate the leading DBD mechanism. The committee recommends therefore a prompt realization of the SuperNEMO demonstrator.**
- The community is working to improve the sensitivity with the aim to f**ully cover the inverted hierarchy region**, a crucial element for the determination of the neutrino mass hierarchy in synergy with the next stages of the neutrino oscillation program. The general requirement for this task is 1 ton of isotope and a background at the level or below 1 count/(y ton-isotope) in the region of interest. This challenging objective can be accomplished either by the technologies of the experiments running or in construction (this option would provide the advantage of a phased approach) or by new promising technologies which are currently under study (LUCIFER, NEXT, COBRA pixel detectors, pulse shape discrimination in bolometer experiments, argon instrumentation in GERDA, Cherenkov light in TeO2).**The committee recommends that these options are pursued at the R&D level in view of a final assessment of the most effective approaches for the 1 ton scale. As the required financial resources are substantial for ton scale experiments, the committee endorses their realisation in the framework of worldwide collaborations. This would allow the investigation of more than one double beta isotope, which is essential to provide an unambiguous signature of neutrino-less double beta decay and to determine the effective Majorana mass.**
- The committee acknowledges progresses in the calculation of the nuclear matrix elements for 0nbb, with clear signs of convergence and with a validation of the traditional methods through a new approach (the so-called IBM2). **The committee confirms therefore the necessity to continue this fruitful program, which is based on both theoretical and experimental investigations.**

Recommendations (6)

Present experiments on reactor and low energy natural neutrinos

- The BOREXINO collaboration is to be congratulated for measuring solar an geo-neutrinos. **The committee strongly endorses further support this scientific program, which is now unique in the world.**

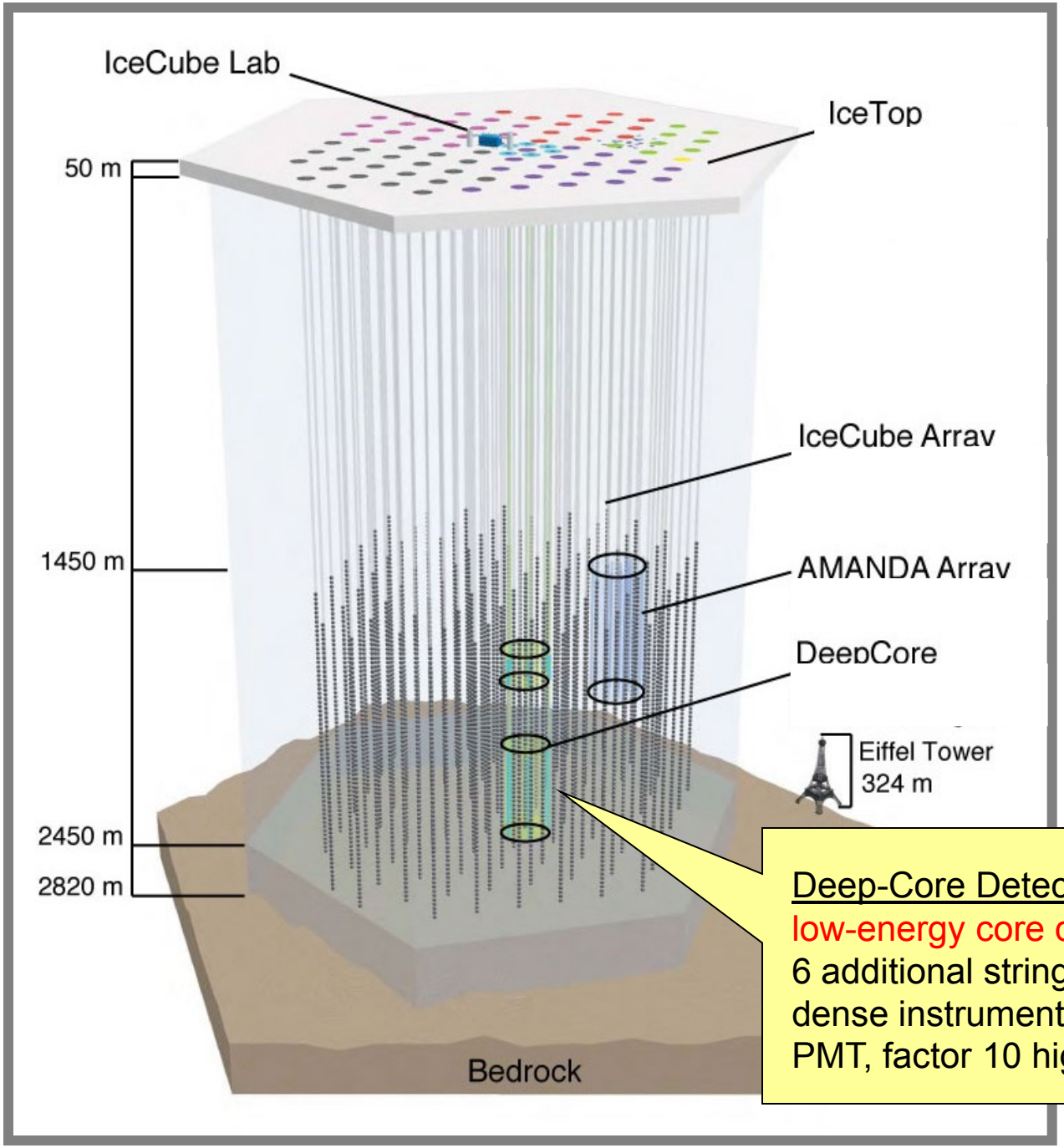
- The Double Chooz Far Detector has recently started operation and will measure electron neutrino disappearance with provide data on θ_{13} vastly improved from the original CHOOZ experiment. **To achieve full sensitivity and to be competitive with other experiments worldwide, it is critical that the Near Detector be completed as soon as possible.** Knowledge of θ_{13} is important to define the path to the discovery of CP violation in the leptonic sector. It will shed light on the expected flavor composition of neutrinos emitted by supernova core collapses.

Recommendations (7)

Towards a detector for neutrino astrophysics and proton decay search on the Megaton-scale:

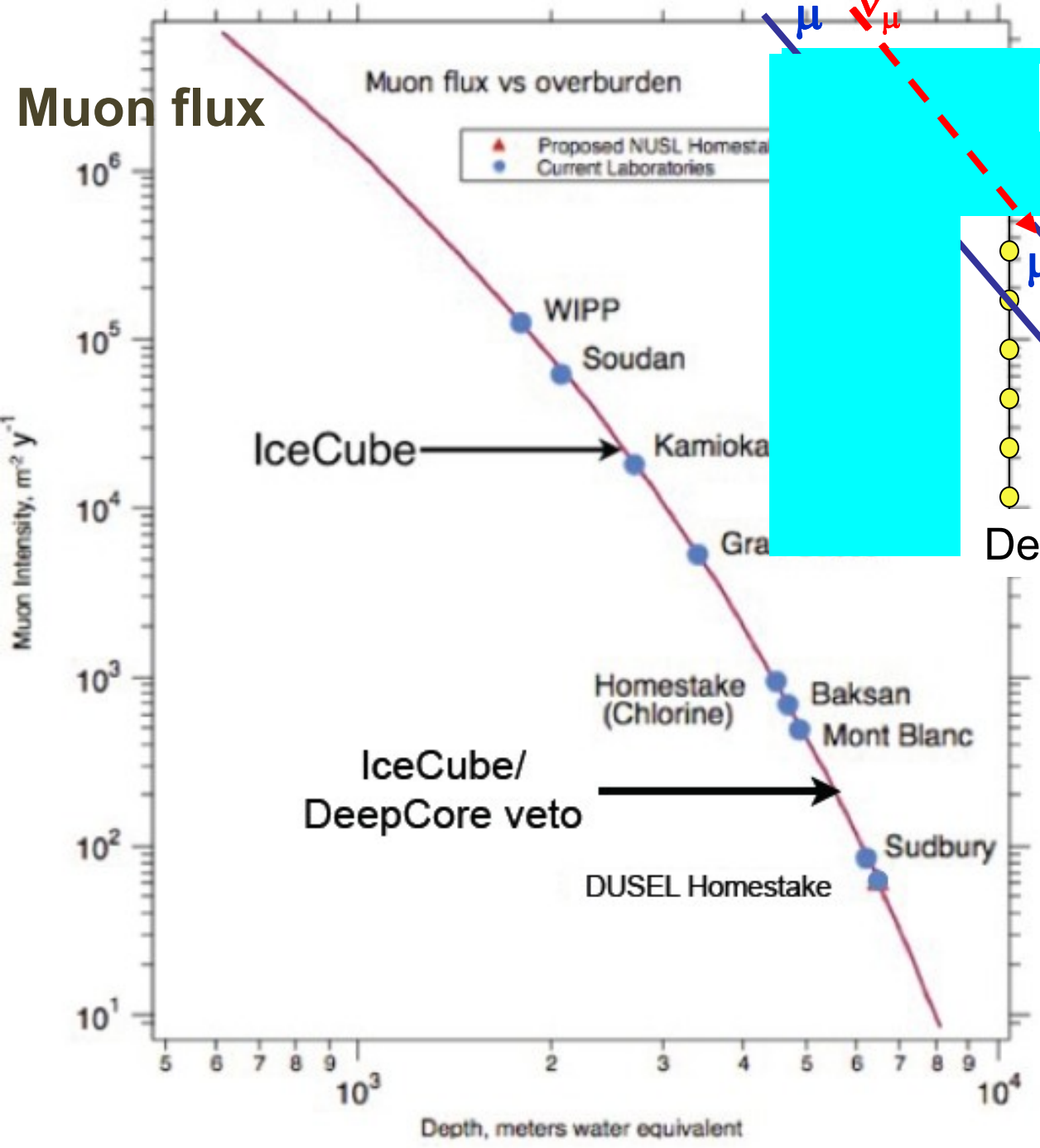
- **LAGUNA is the European effort to develop megaton neutrino detectors both for accelerator-based and astroparticle neutrino measurements.** The scientific goals are both broad and ambitious. The LAGUNA site study is almost completed, showing that there are possible sites in Europe that could host such experiments. **The committee recommends that the study be pursued with LAGUNA-LBNO focusing on detector designs to lead to a better understanding of the costs of the various detector technology options and on the prospects for a new long baseline neutrino beam from CERN. In addition, due to the high cost and long development time necessary to realize this program, the committee recommends that it be pursued in a global context. In addition, it is recommended that programs with and without a new neutrino beam are considered, in order to preserve possible science opportunities.**
- In this context we also recommend supporting programs to measure nuclear cross sections of astrophysical interest using underground nuclear accelerators.
- We also encourage studies to investigate to which extend parts of the LAGUNA program (supernova neutrinos, oscillation physics, proton decay) can be addressed by an IceCube low energy extension.

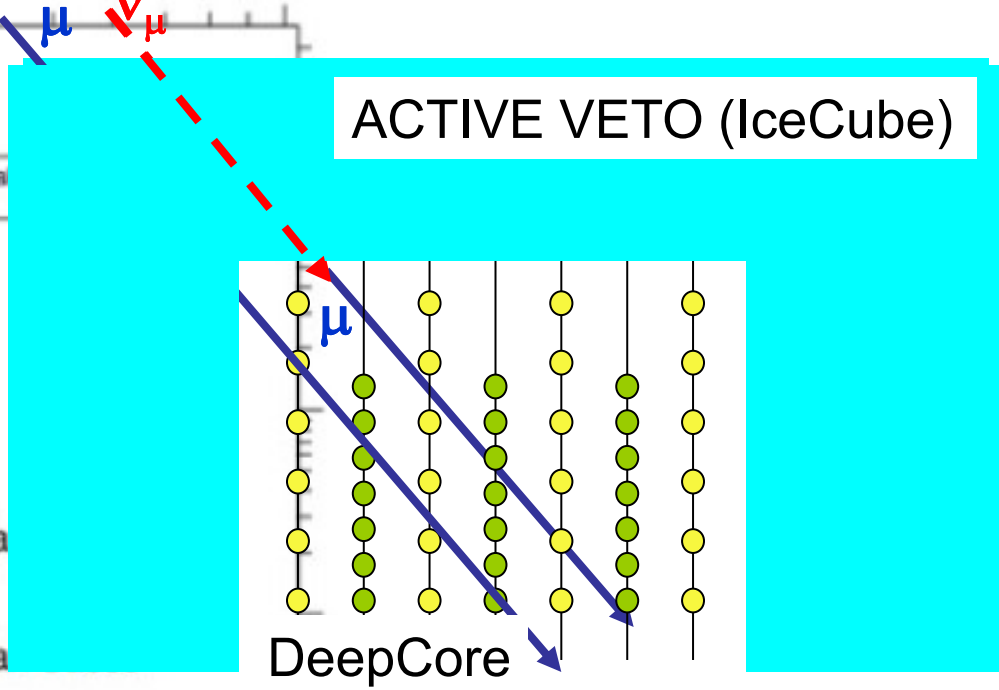
IceCube with DeepCore



Deep-Core Detector:
low-energy core detector: 10GeV-1TeV
6 additional strings, 70m distant
dense instrumentation (7m) high QE
PMT, factor 10 higher photon detection

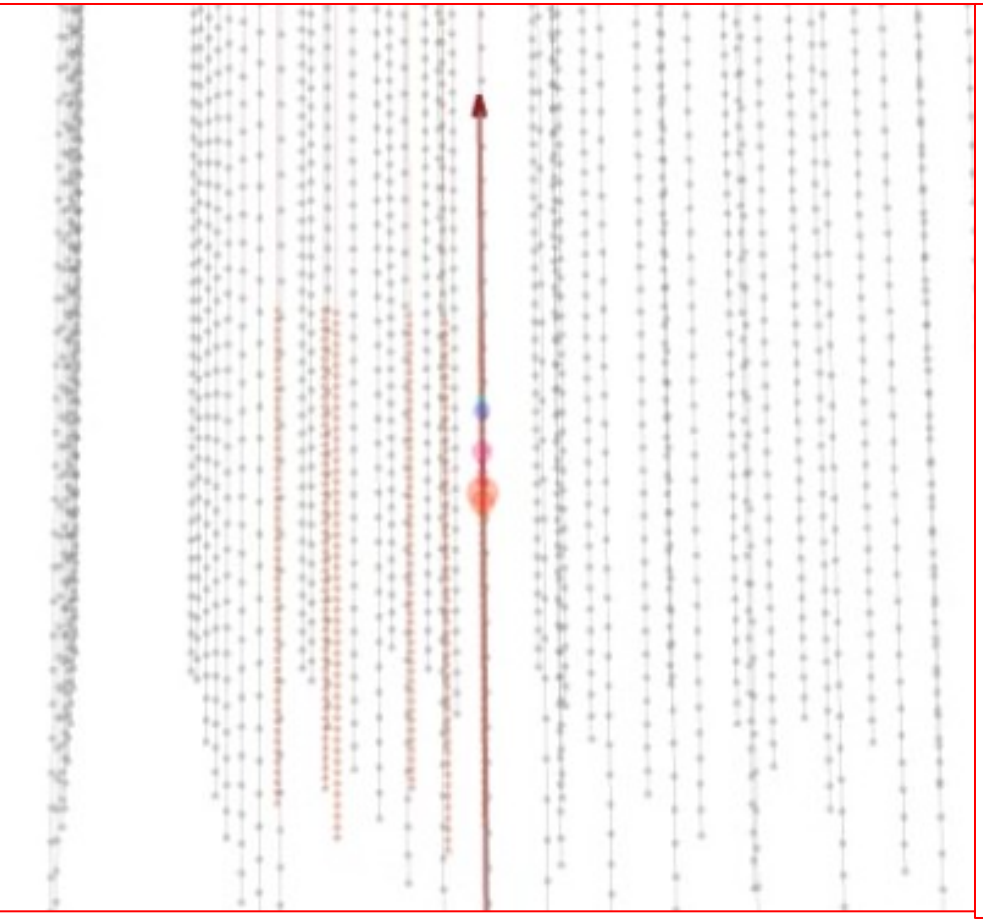
Muon flux

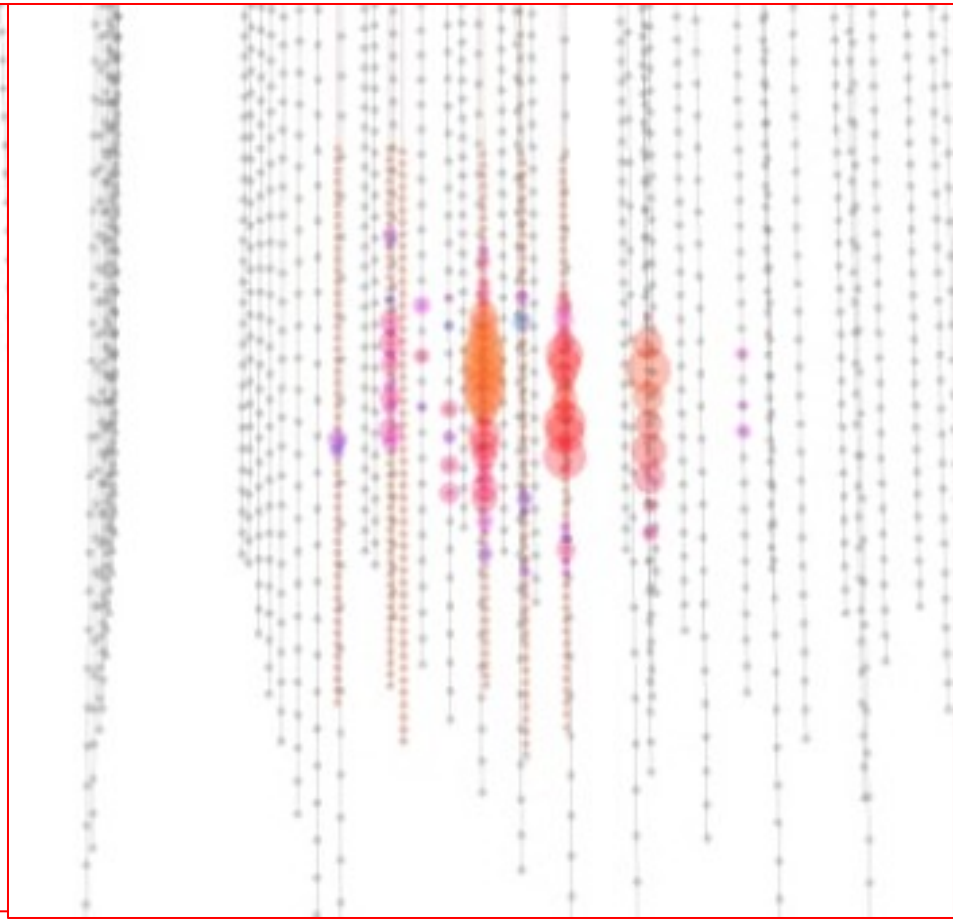


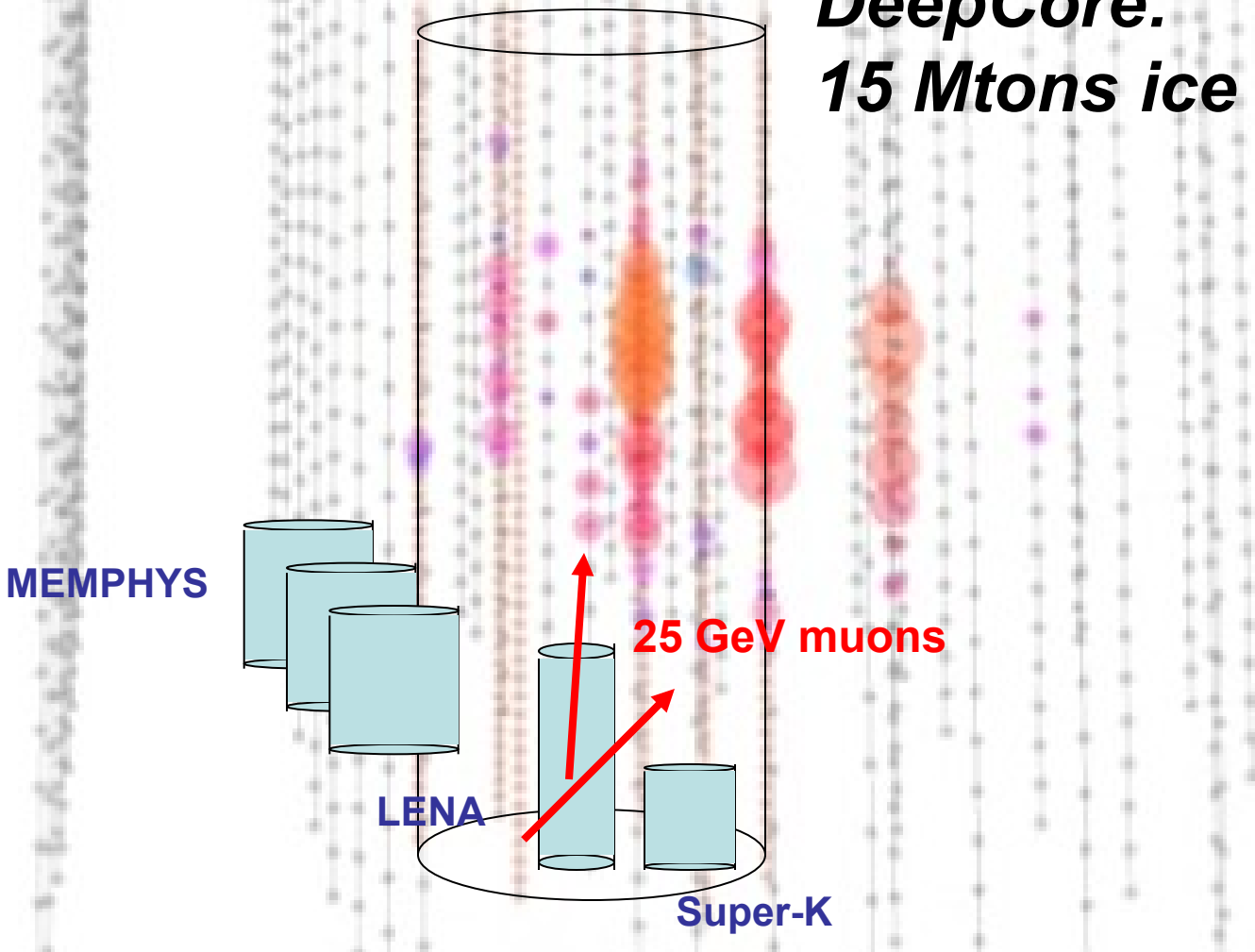


Shielded by IceCube, DeepCore has an „effective depth“ of ~6 km.w.e.

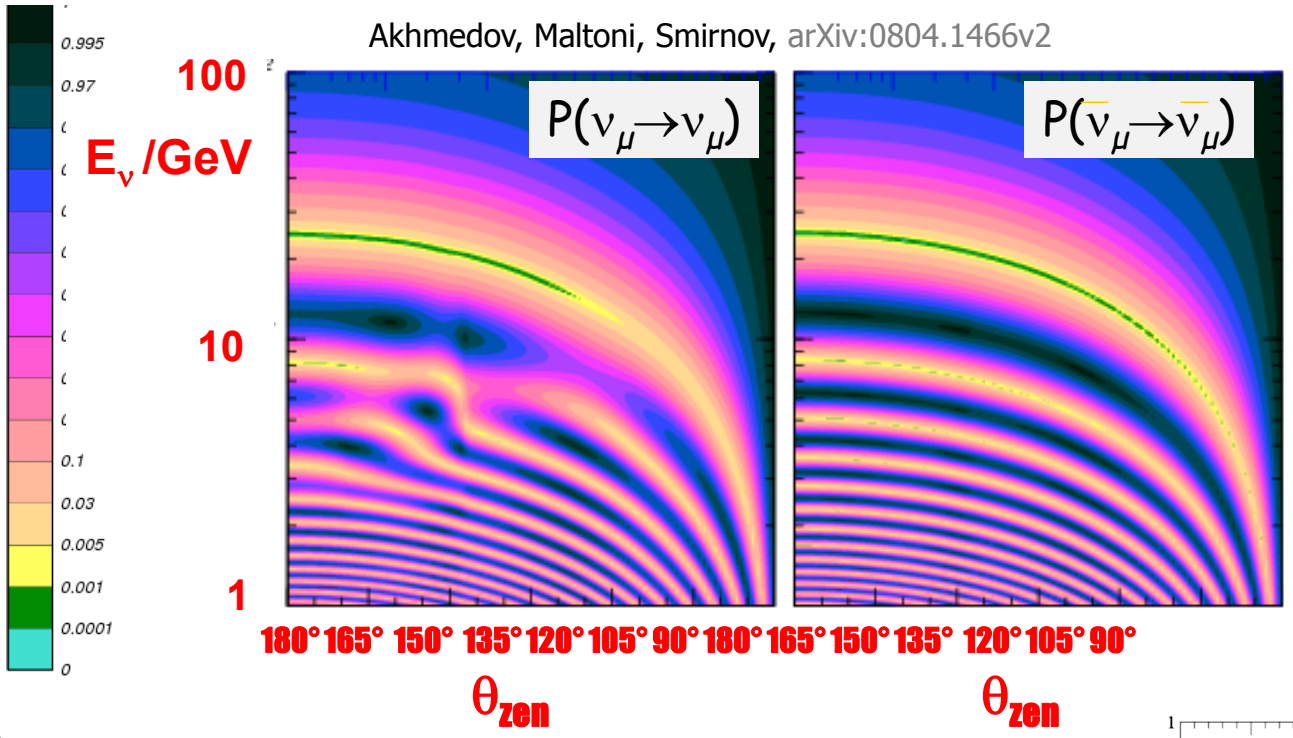
2 of the first DeepCore events

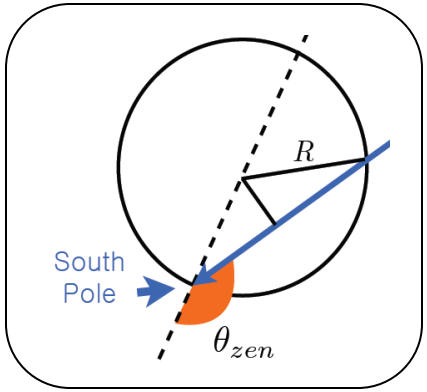





DeepCore:
15 Mtons ice
MEMPHYS
25 GeV muons
LENA
Super-K

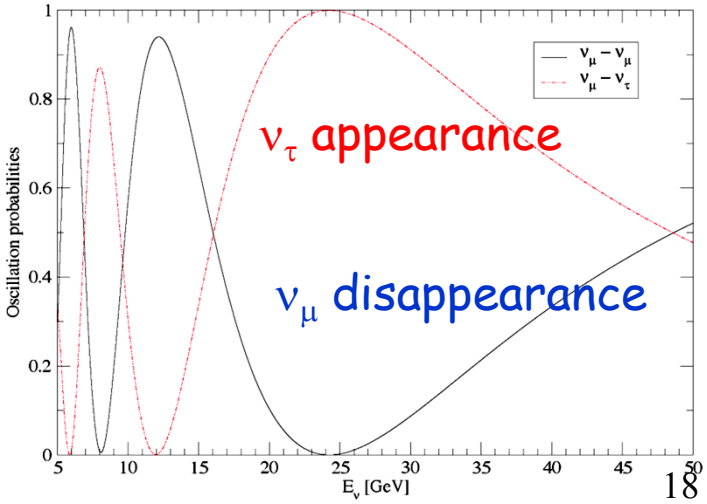
Oscillations with DeepCore





Oscillations between 10-100 GeV not well measured by underground experiments.

- 1st oscillation minimum ~25 GeV
  - ν_μ disappearance
  - ν_τ appearance
- matter effects only for <10 GeV



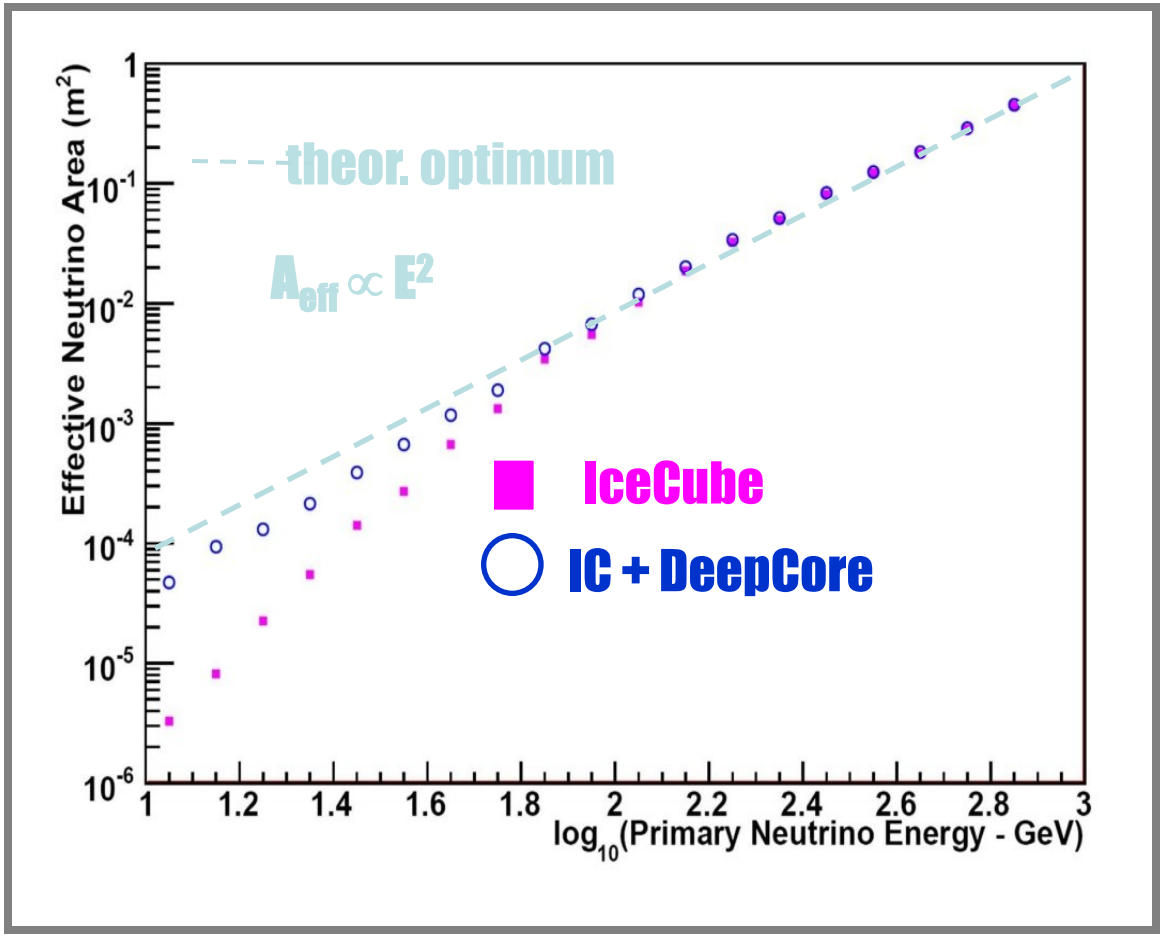
IceCube with DeepCore

- **Small spacing**
  → Low threshold

- **IceCube works as veto for DeepCore**

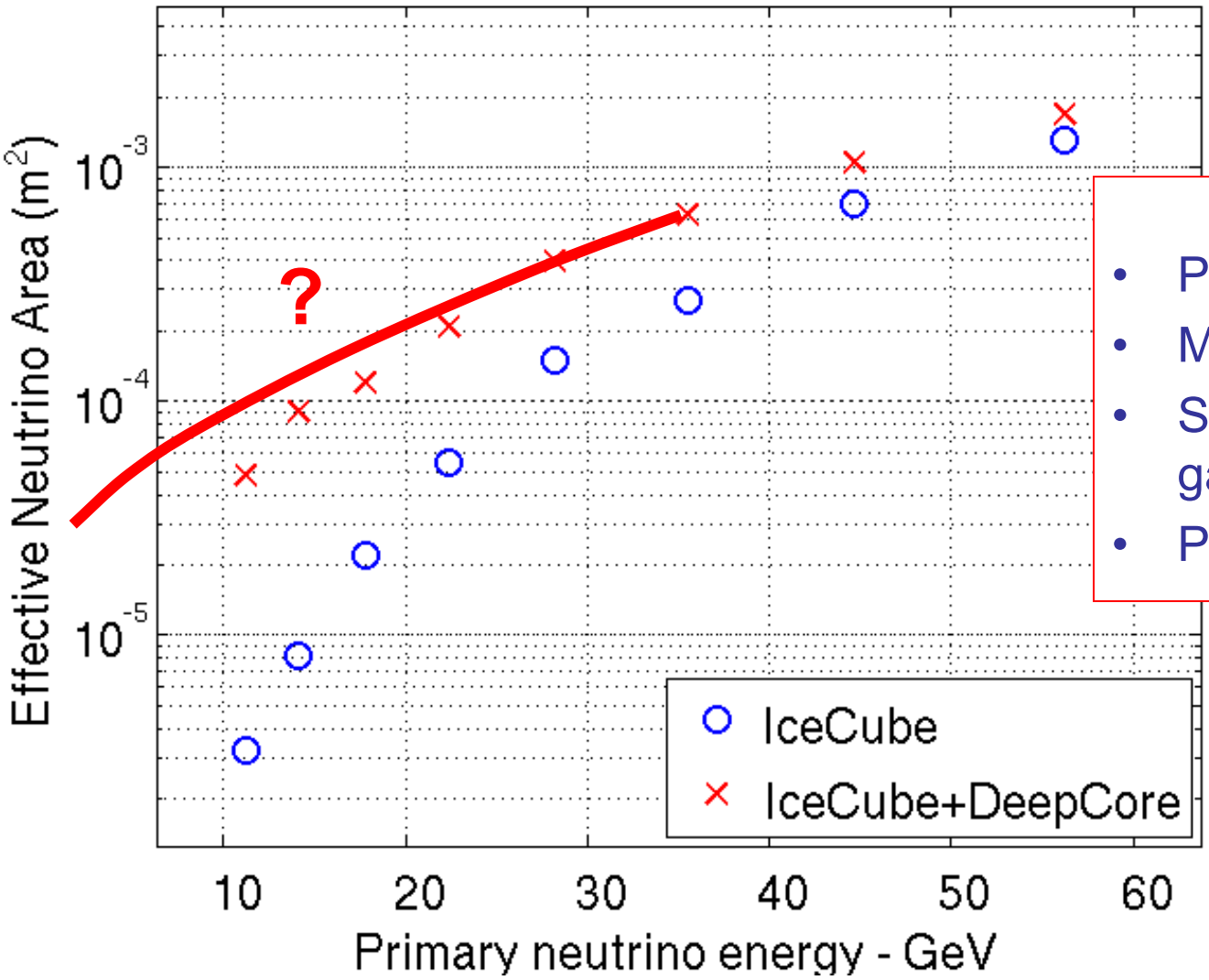
  → look upwards

  → even lower threshold



Beyond DeepCore?

Meeting in Amsterdam, March 19/20

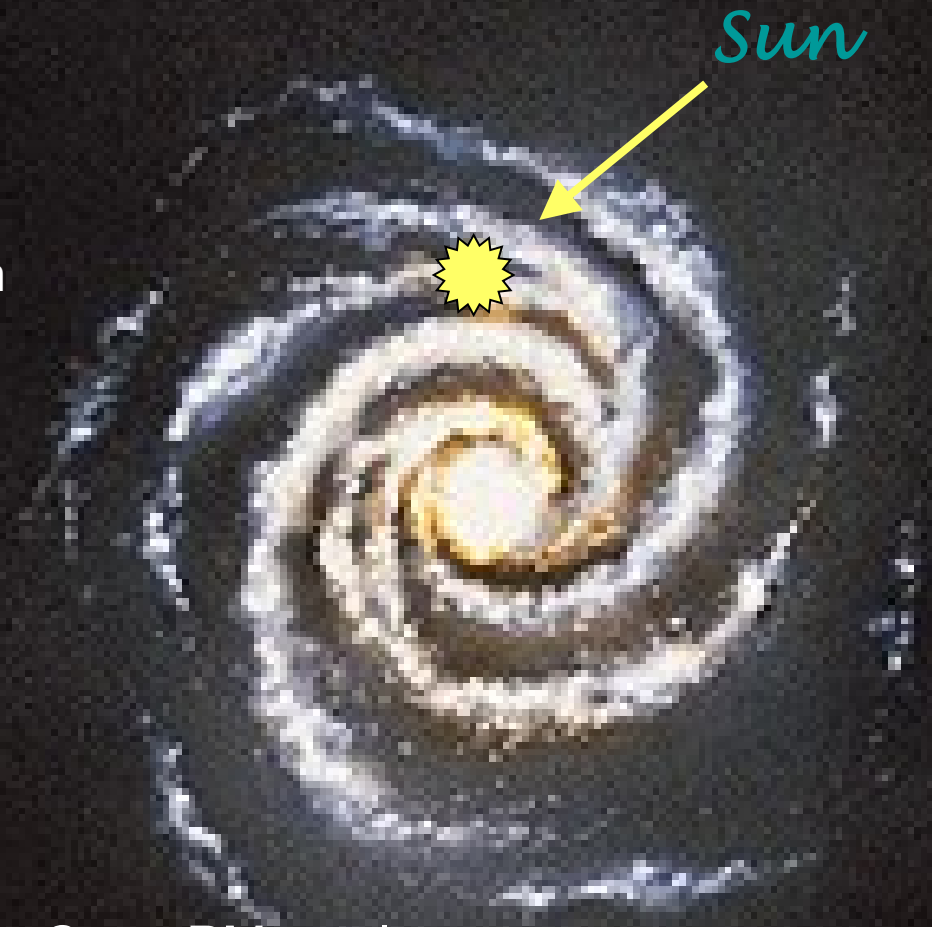


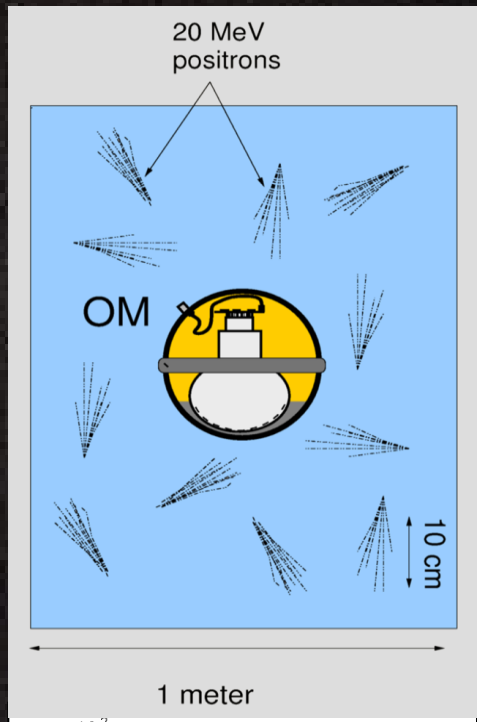
- PLUS 20-50 strings
- Matter oscillations
- SN beyond our own galaxy ?
- Proton decay ???

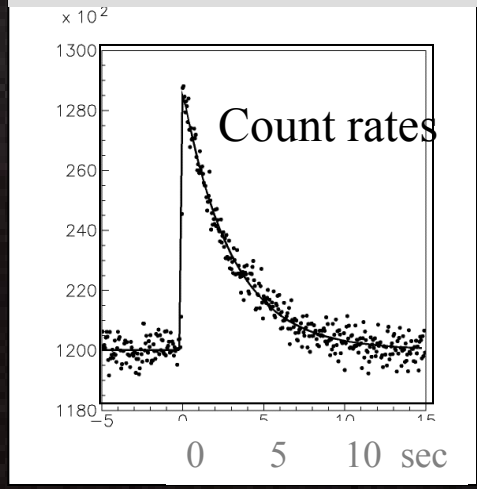
Supernova in IceCube

Detection via increased noise rates

Dark noise (1PE) in IceCube Photomultipliers only ~ 320 Hz !







Idea for BeyondDeepCore: PM so close that SN neutrinos give >2-fold coincidences → BG negligible
→ see small conicdent rate enhancement from SN in far galaxies. Every 3-5 years a SN?

Signal for SN in GC: 10^6 counts

Recommendations (8)

Dark Energy projects:

- **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.**

Gravitational waves:

- **We commend the move of the international gravitational wave community towards a single worldwide network of ground interferometers which will allow better coverage and better pointing capabilities. This also goes in the direction of increasing the community worldwide.**
- **At a time of down selection of the large mission of the ESA Cosmic Vision program, the community renews its strong support of the LISA mission which will open the scientifically challenging domain of low frequency (10^{-4}Hz,10^{-1}Hz) gravitational wave astronomy, as well as advance our knowledge of fundamental physics.**
- **We acknowledge the progress of the Einstein Telescope Design Study, support the new proposal «Coordination actions for research infrastructures» and urge ASPERA/ApPEC to actively contribute to the inclusion of E.T. into the ESFRI list.**
- **We support an enhancement of the R&D effort in order to accompany the development of the second generation network and to prepare for the third generation (E.T.). For this purpose, we propose an ASPERA call for R&D.**

Further Plans

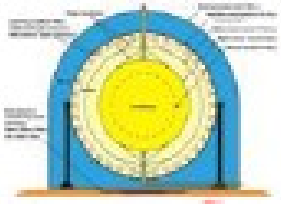
- Now: 88 of ~100 pages, including appendices
- Still missing: „synopsis“
- Mid-end of March: full text to Steering Committee (ApPEC) and Gov. Board (Aspera)
- Modifications
- May 2011: send roadmap to community
- Modifications
- Approval of the full text plus a 3 pages version as input to the European Strategy (CERN) on town meeting in Paris just after TAUP (September)

Supernova Neutrino-Detektoren weltweit

(laufend und zukünftig)

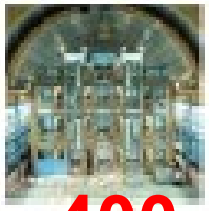
in rot: Ereignisse für SN bei 10 kpc

Borexino



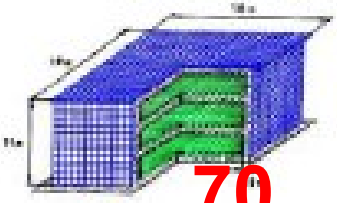
100

LVD



400

Baksan

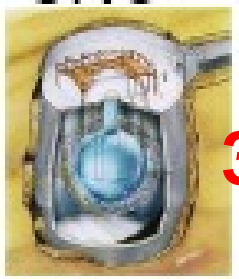


70

Super-K

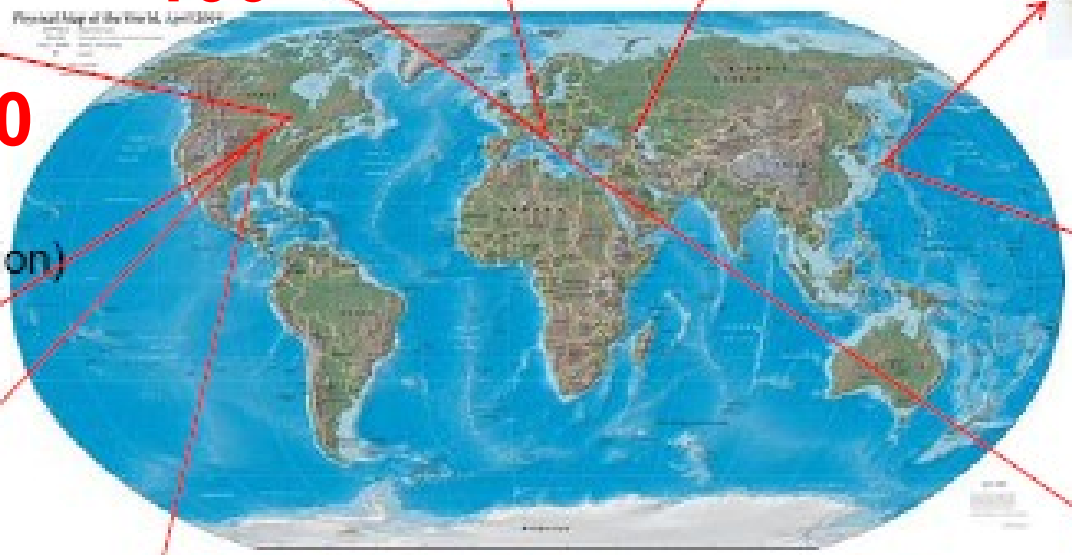
8500

SNO+



300

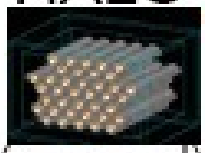
(beginning construction)



KamLAND

330

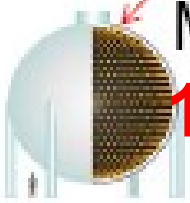
HALO



(proposed)

(in construction)

Mini-BOONE

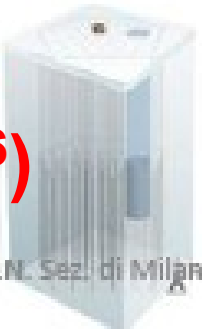


190

NOvA

einige 100

(construction started)

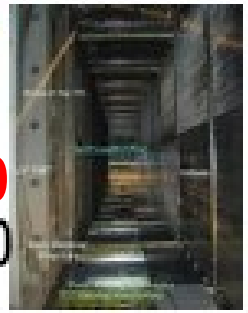


(10^6)

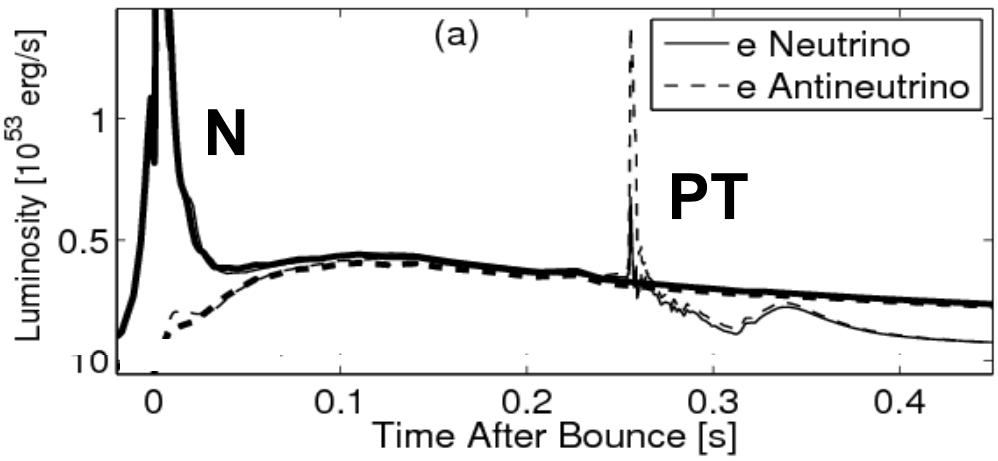
IceCube

einige 100

Icarus 600



Neutronization Peak and QCD Phase transition peak?



*Dasgupta, Fischer, Horiuchi, Liebendoerfer, **Mirizzi**, 2009*