

Cosmic particles, jets and accelerator science



Subir Sarkar
University of Oxford

KEK Theory Center Cosmophysics Workshop on High Energy Astrophysics, 10-12 Nov 2009

	10 (Tue) Nov.	11 (Wed) Nov.	12 (Thu) Nov.
9:00		9:00–10:00 [50+10] Mueller (Duke) [Hadron] via EVO–Polycorn	
9:30	9:30–10:15 Registration		9:30–10:30 [50+10] Moskalenko (Stanford) [Cosmic-Ray] via EVO–Polycorn
10:00		10:00–10:45 [40+5] Hirano (Tokyo) [Hadron]	
10:30	Opening		
11:00	10:30–11:30 [50+10] Uchiyama (SLAC) [Fermi]	10:45–11:30 [40+5] Itow (Nagoya) [LHCf]	10:30–11:30 [50+10] Sarkar (Oxford) [Astro-particle]
11:30			
12:00	Lunch	Lunch	Lunch
12:30			
13:00	12:45–13:30 [40+5] Asano (TITech) [GRB]	12:45–13:30 [40+5] Shimizu (KEK) [EUSO]	12:45–13:30 [40+5] Torii (Waseda) [CALET]
13:30	13:30–14:15 [40+5] Totani (Kyoto) [Gamma]	13:30–14:30 [50+10] Kappes (Erlangen) [Neutrino]	13:30–14:00 [25+5] Osone (N/A)
14:00			14:00–14:30 [25+5] Kawanaka (KEK)
14:30	14:15–15:00 [40+5] Inoue (Kyoto) [Gamma]	14:30–15:00 [25+5] Takami (IPMU)	14:30–15:00 [25+5] Yamada (KEK)
15:00	15:00–15:30 [25+5] Murase (Kyoto)	Break	Break
15:30	Break		
16:00		15:30–16:30 [50+10] Ballmer (NAOJ/Caltech) [GW]	15:30–16:30 [50+10] Fox (FNAL) [Particle]
16:30	16:00–17:00 [50+10] Teshima (MPI) [CTA, Gamma]	16:30–17:00 [25+5] Ando (Kyoto)	16:30–17:15 [40+5] Takahashi (IPMU) [Particle]
17:00		17:00–17:30 [25+5] Suwa (Tokyo)	
17:30	17:00–17:45 [40+5] Tsuboi (JAXA) [ASTRO-G]	Short Break	17:15–18:00 [40+5] Kohri (Tohoku) [Astro-particle]
18:00	17:45–18:30 [40+5] Nakamura (NiPR) [Radar]	17:45–18:45 [50+10] Casolino (Roma2, INFN) [PAMELA]	Closing
18:30			

Topics:

- First results from Fermi (Uchiyama, Asano, ...)
- PAMELA update (Casolino)
- Review of ANTARES/Baikal/IceCube + KMNeT (Kappes)
- Quark-gluon plasma (Hirano, Mueller)
- LHCf (Itow)

- Theory – cosmic rays (Kawanaka, Moskalenko,
Sarkar, Takami)
- Theory – dark matter (Fox, Kohri, Yamada, Takahashi)
- Theory – cosmic gamma rays (Inoue, Murase, Totani)

- CTA (Teshima)
- JEM-EUSO (Shimizu)
- Proposals for new experiments (Nakamura, Osone, Torii,
Tsuboi)
- Gravitational waves (Ando, Ballmer, Suwa)

Astroparticle Physics European Coordination (ApPEC)

- **Roadmaps:** BMBF, IN2P3/CEA, INFN, NIKHEF, STFC, ...
- **ESFRI** list of opportunities
 - Autumn 2006, call Spring 2007, participation EU (<10%)
 - At present: ELT, SKA, KM3, CTA ...
- **ApPEC** prepared a first draft through its *Peer Review Committee* with recommendations to **ESFRI** concerning:
 - Dark matter
 - Neutrino mass (β decay, $\beta\beta$ decay)
 - Large Underground Detectors
 - High energy cosmic rays
 - High energy gamma rays
 - High Energy neutrinos
 - Gravitational waves
- Based on this **ASPERA** has made a strategic plan, through the involvement of the community and related fields (**ASTRONET**)
- R&D/design studies funded for selected projects on dark matter and HE γ -rays



F. Avignone, J. Bernabeu, P. Binetruy, H. Blümer, K. Danzmann,
F.v. Feilitzsch, E. Fernandez, J. Iliopoulos, U. Katz, P. Lipari,
M. Martinez, A. Masiero, B. Mours, F. Ronga, A. Rubbia, S. Sarkar,
G. Sigl, G. Smadja, N. Smith, C. Spiering (Chair), A. Watson

Key questions:

What is the universe made of?

Do protons last for ever?

What are the properties of neutrinos ... and their role in cosmic evolution?

What can neutrinos tell us about the interior of the Sun and Earth, and about
supernova explosions?

What is the origin of cosmic rays? How does the sky look at extreme energies?

What is the nature of gravity? Can we detect gravitational waves? What can
they tell us about violent cosmic processes?



Panel A: Do we understand the extremes of the universe?

John Peacock chair Royal Observatory Edinburgh UK

Claes Fransson co-chair Stockholm Observatory Sweden

Juan Garcia-Bellido Universidad Aut´onoma de Madrid Spain

Francois Bouchet Institute d’Astrophysique de Paris France

Andrew Fabian Cambridge UK

Bruno Leibundgut ESO Germany

Subir Sarkar Oxford University UK

Peter Schneider Universit¨at Bonn Germany

Ralph Wijers Sterrenkundig Instituut Anton Pannekoek Netherlands

Bernard Schutz MPI-G Potsdam Germany

*** How did the Universe begin?**

*** What is dark matter and dark energy?**

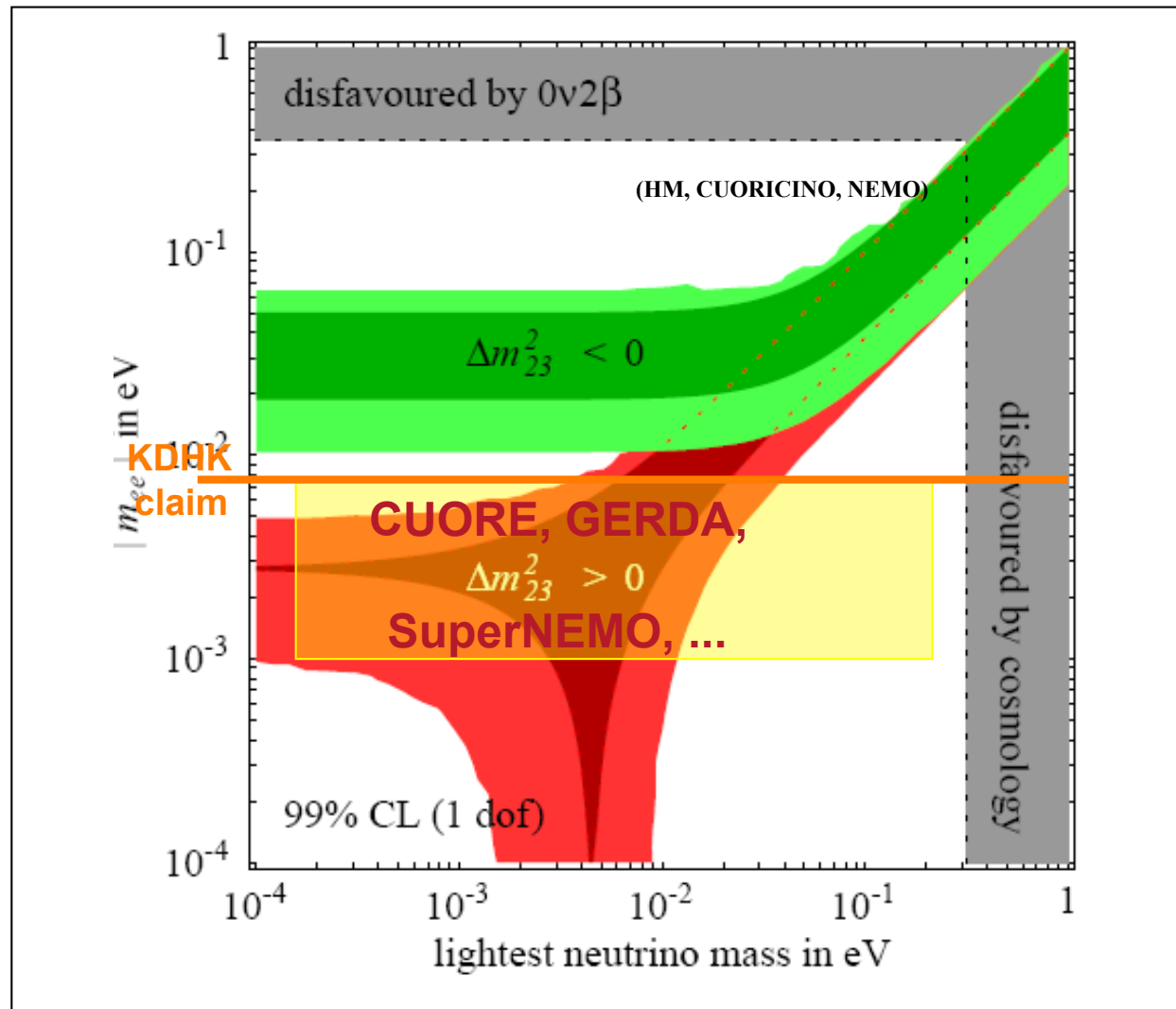
*** Can we observe strong gravity in action?**

*** How do supernovae and gamma-ray bursts work?**

*** How do black hole accretion, jets and outflows operate?**

*** What do we learn about the Universe from energetic radiation and particles?**

Neutrino mass scale: sensitivity from $0\nu\text{-}\beta\beta$ decay

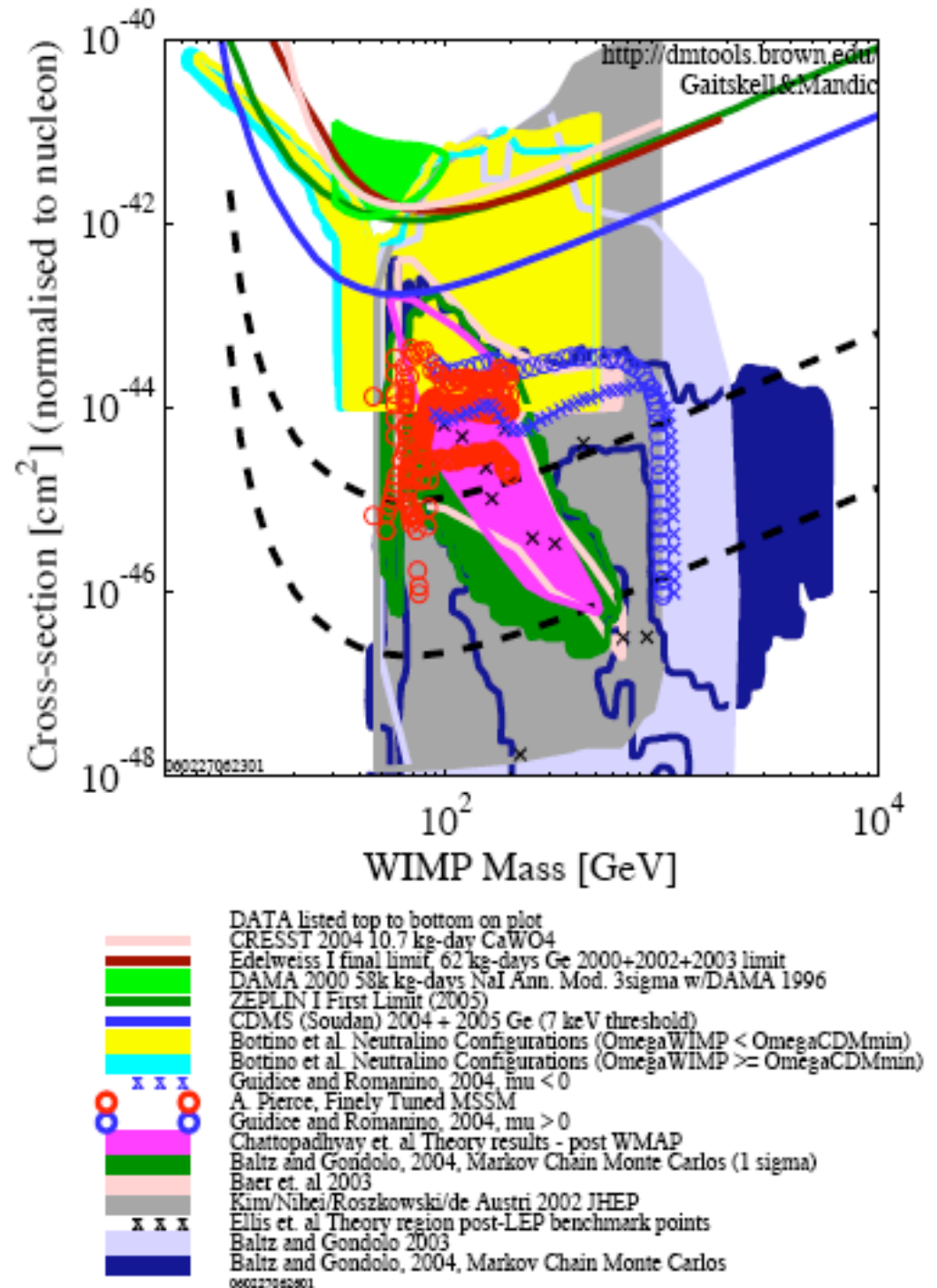


Several experiments will probe down to 10^{-3} eV Majorana mass

... also KATRIN will measure Dirac mass down to ~ 0.2 eV in 2012+

Dark matter searches:

- **Today:** 10^{-6} pb era
 - Starting to test SUSY
- **Next step:** 10^{-8} pb
 - Increased detector mass
 - Further reduce background rejection
 - Lower energy threshold
 - Improve event-by-event discrimination
- **Goal:** 10^{-10} pb within 10 yr
 - Probe most of the allowed SUSY parameter space
 - 1 ton scale cryogenic:
SuperCDMS, EURECA
 - Double phase noble gas
DARWIN, LUX



(Courtesy: Stavros Katsanevas)

World Map of Direct Dark Matter Searches

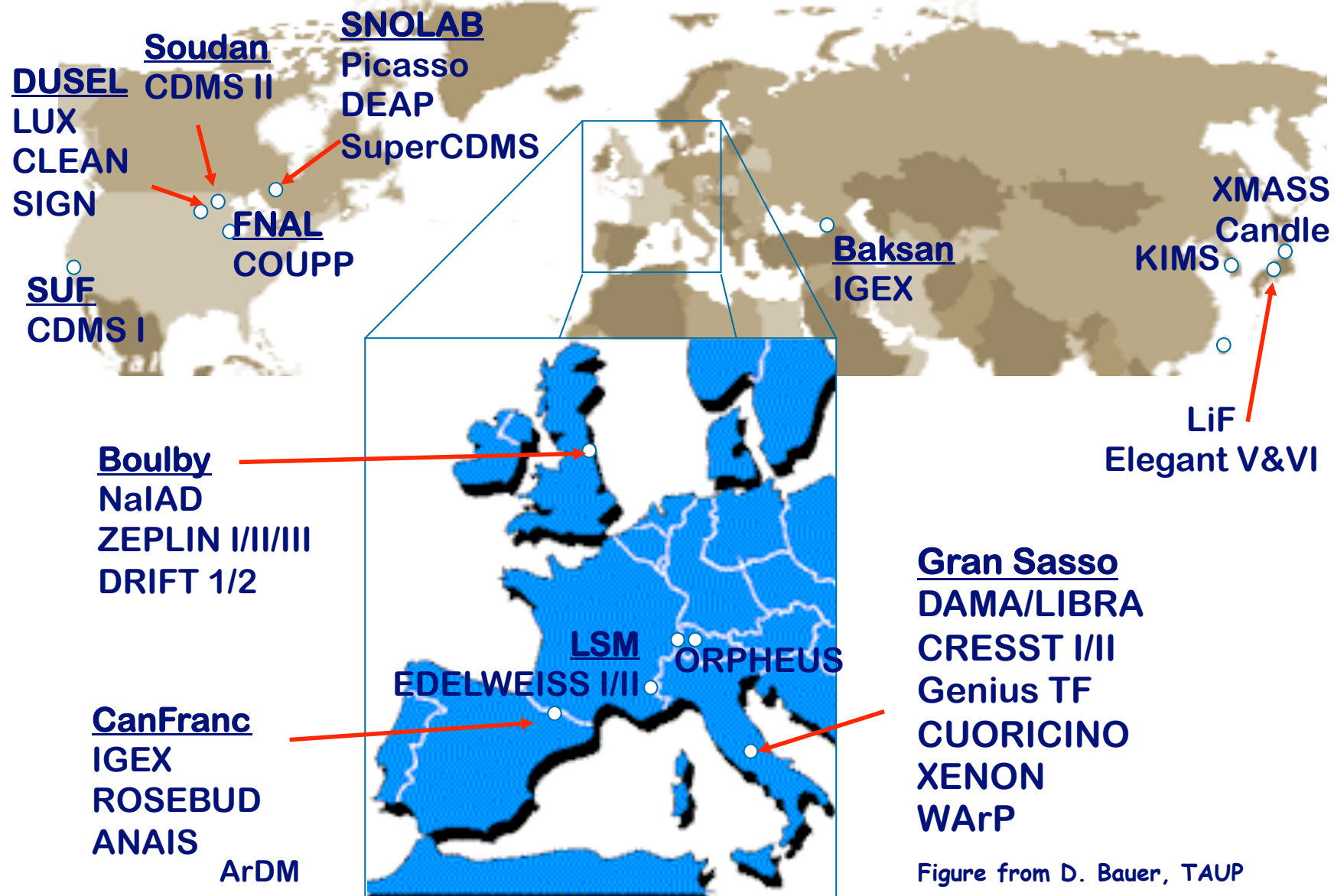
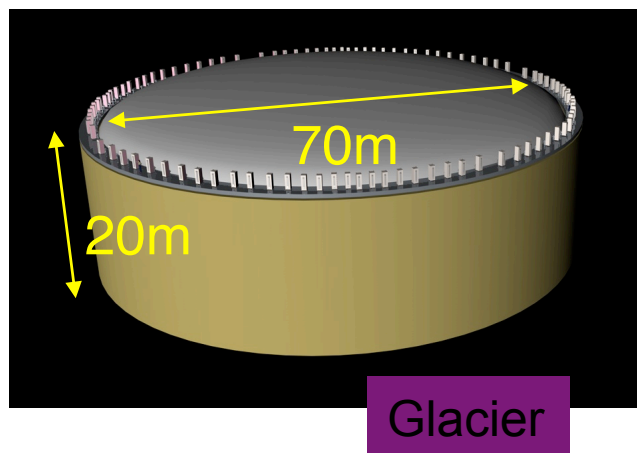
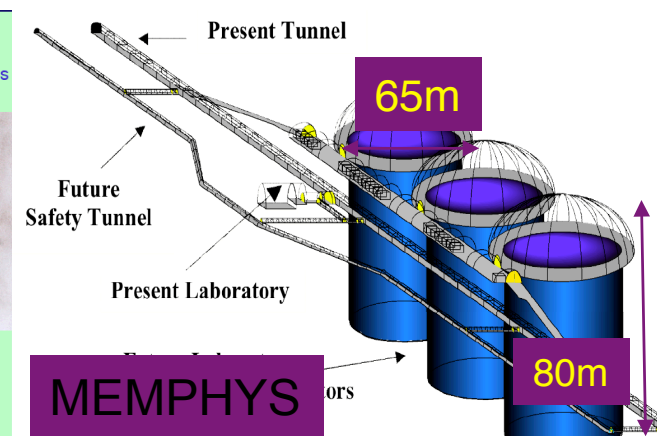
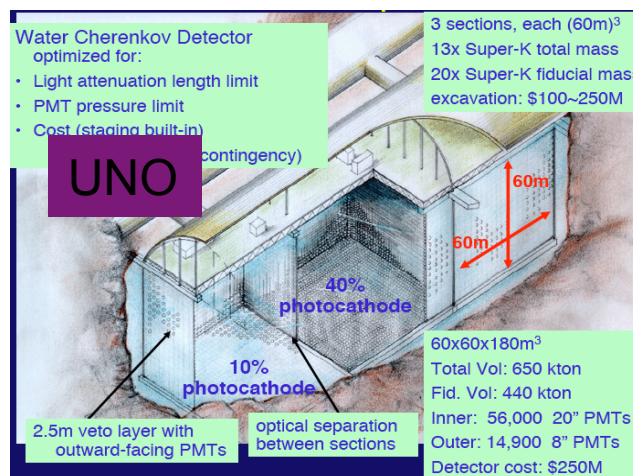
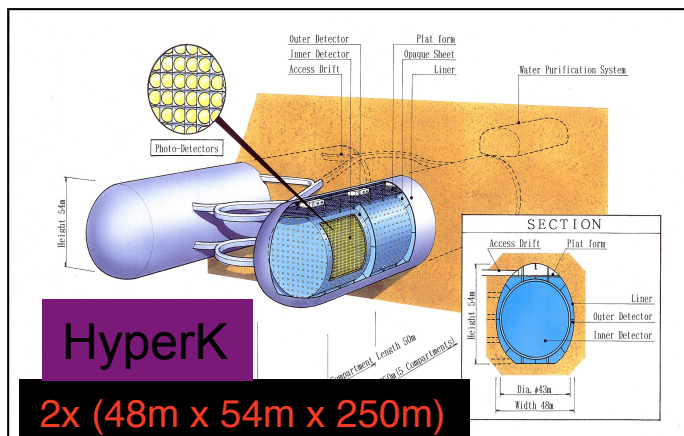


Figure from D. Bauer, TAUP

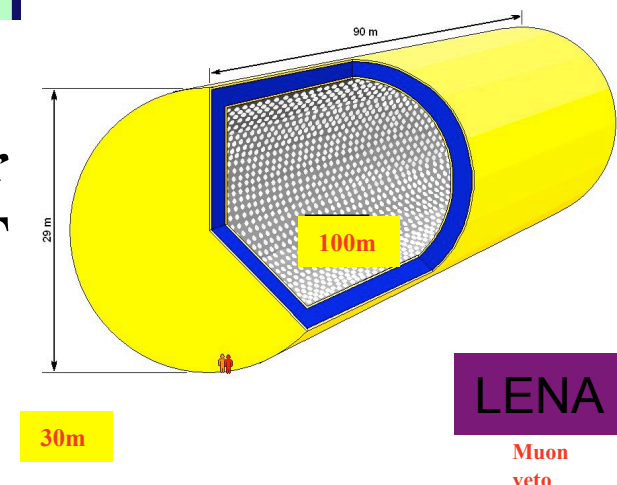
Large Underground Detectors

Water Cherenkov: 500 kT → 1 MT



Liquid Scintillator
→ 50kT

Liquid Argon
→ 100kT



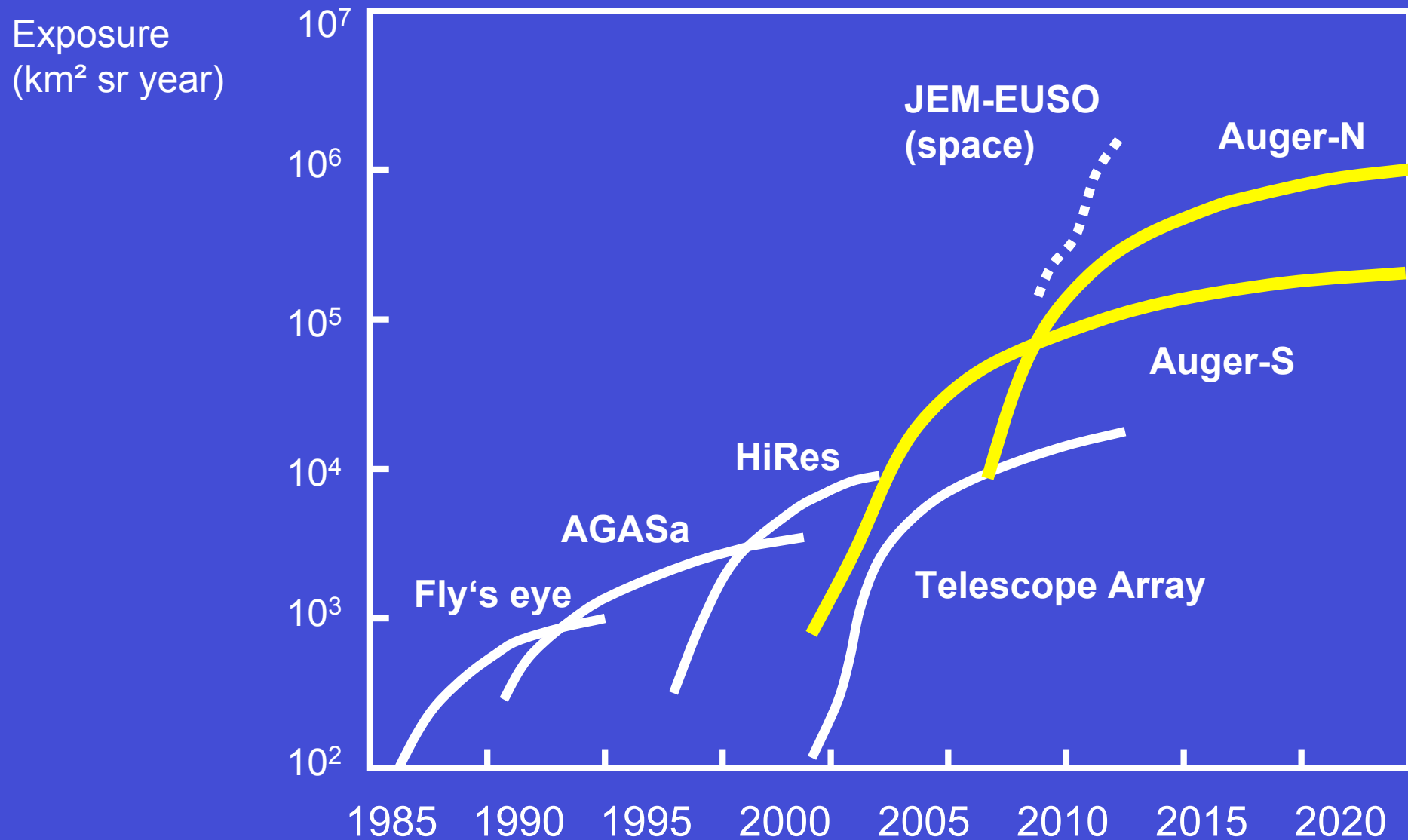
GLACIER, LENA, MEMPHYS - for proton decay and supernova neutrinos

Common issues (photodetection, large caverns, ...) + Complementarity in physics

→ Common design study **LAGUNA**

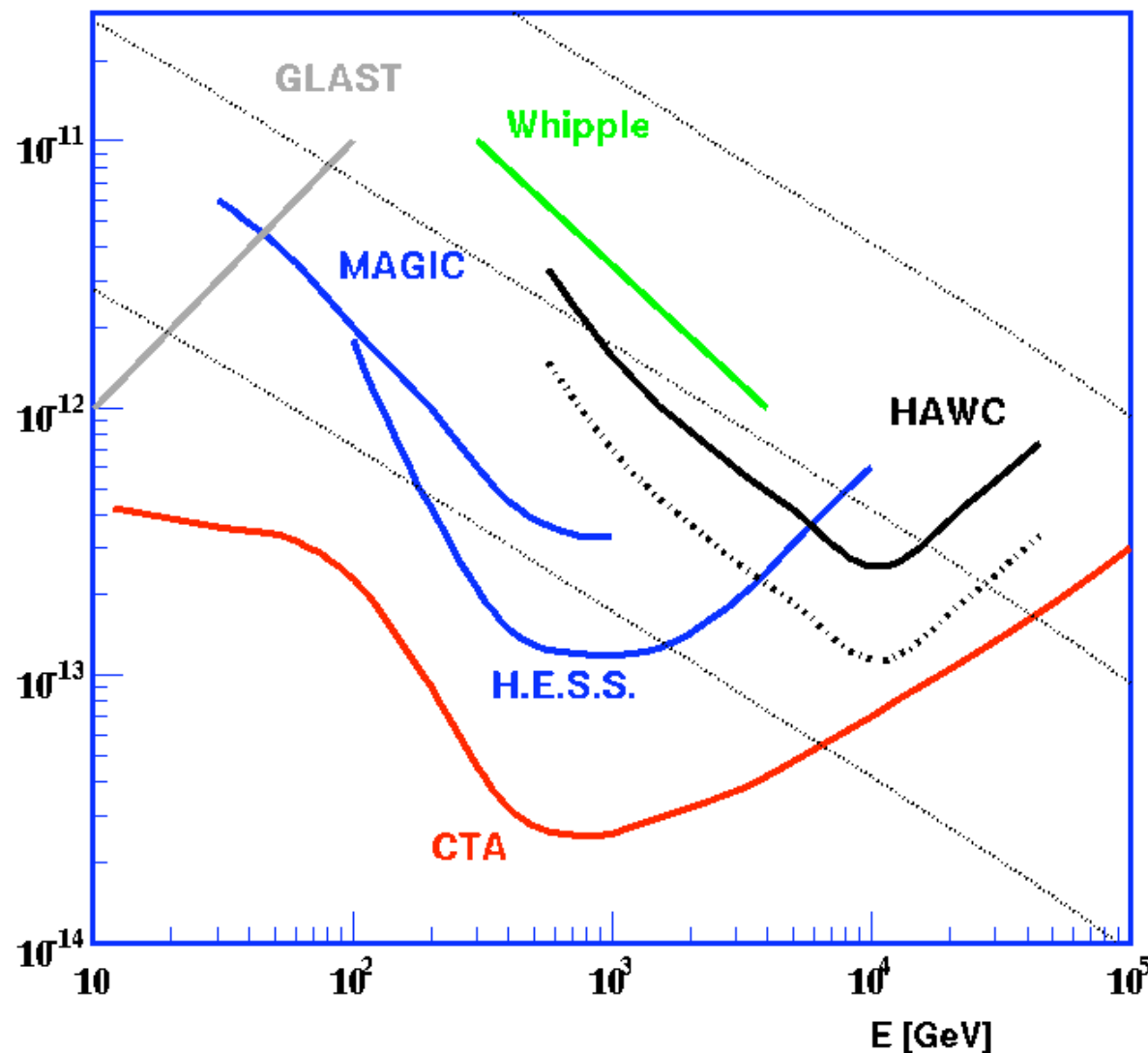
(Courtesy: Stavros Katsanevas)

Ultrahigh energy cosmic rays



(Courtesy: Christian Spiering)

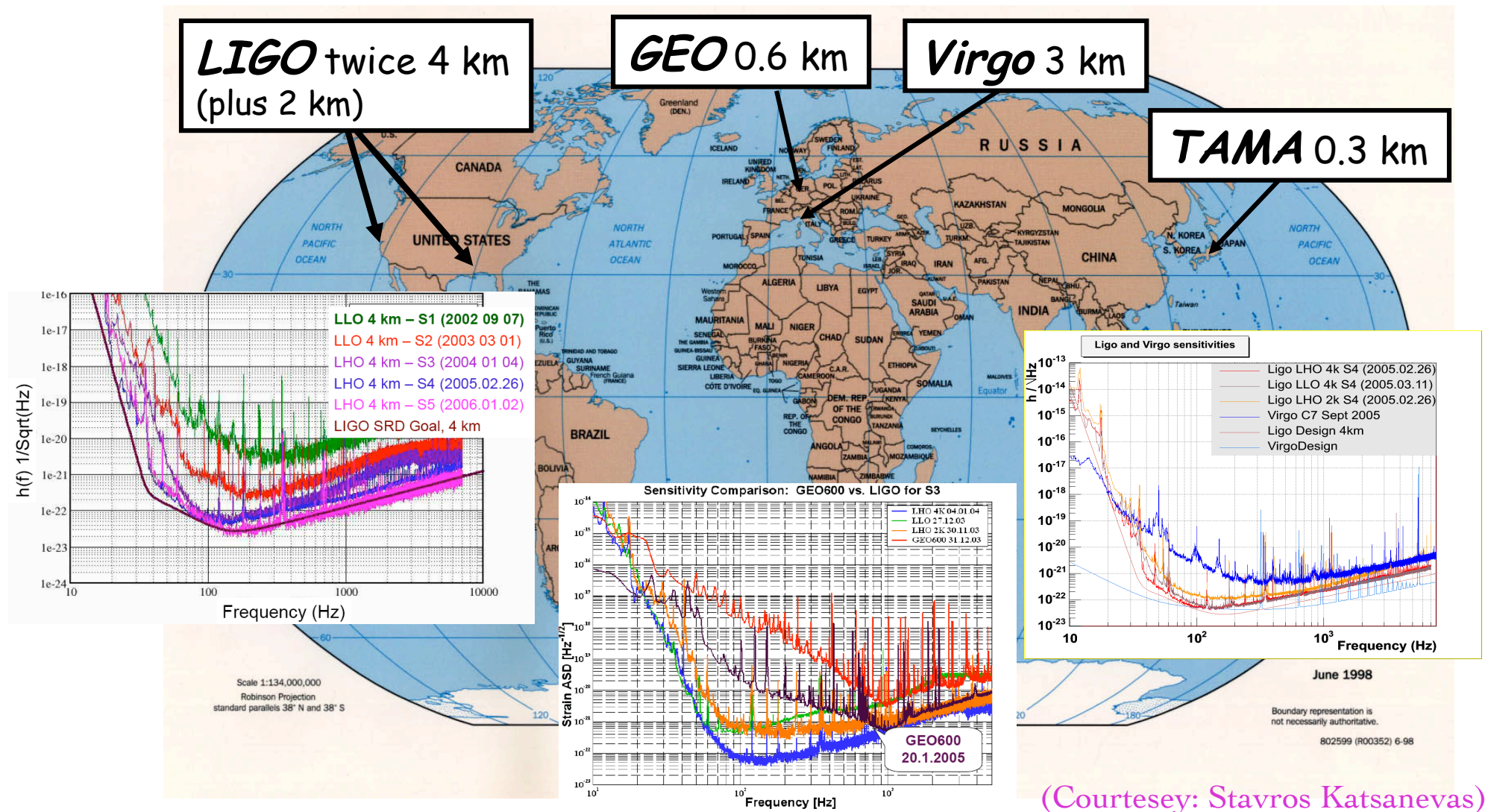
High Energy Gamma Rays



- **HESS/VERITAS, MAGIC, Whipple, CTA** sensitivity in 50 hours, (~ 0.2 sr/yr)
- **GLAST** sensitivity in 1 year (4π sr)
- **HAWC** sensitivity in 1(5) years shown as solid (dashed) line (2π sr)

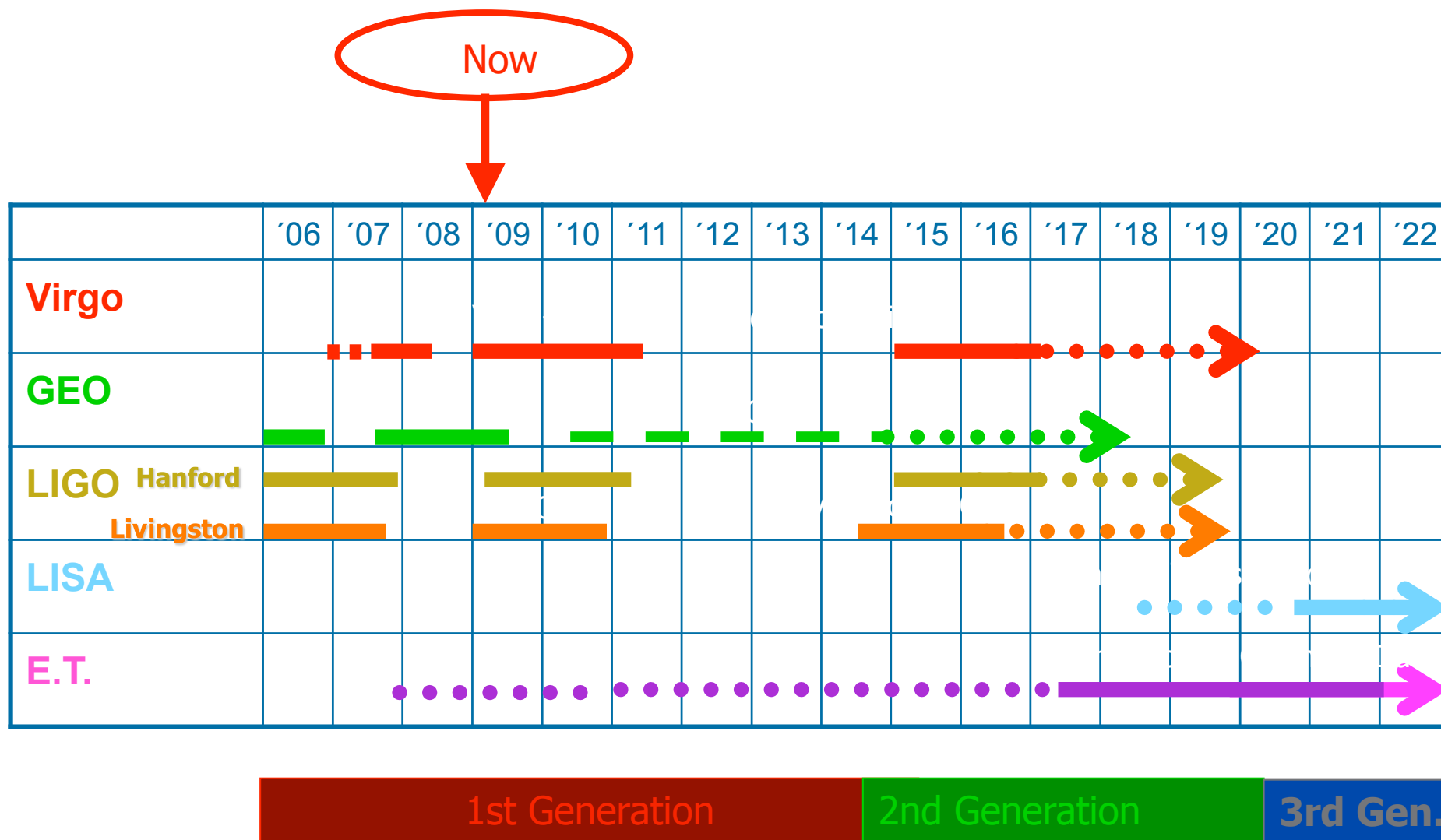
Towards a “distributed” Gravitational Interferometer Network

... in future: Einstein Telescope



(Courtesy: Stavros Katsanevas)

Gravitational Waves



Six large infrastructures

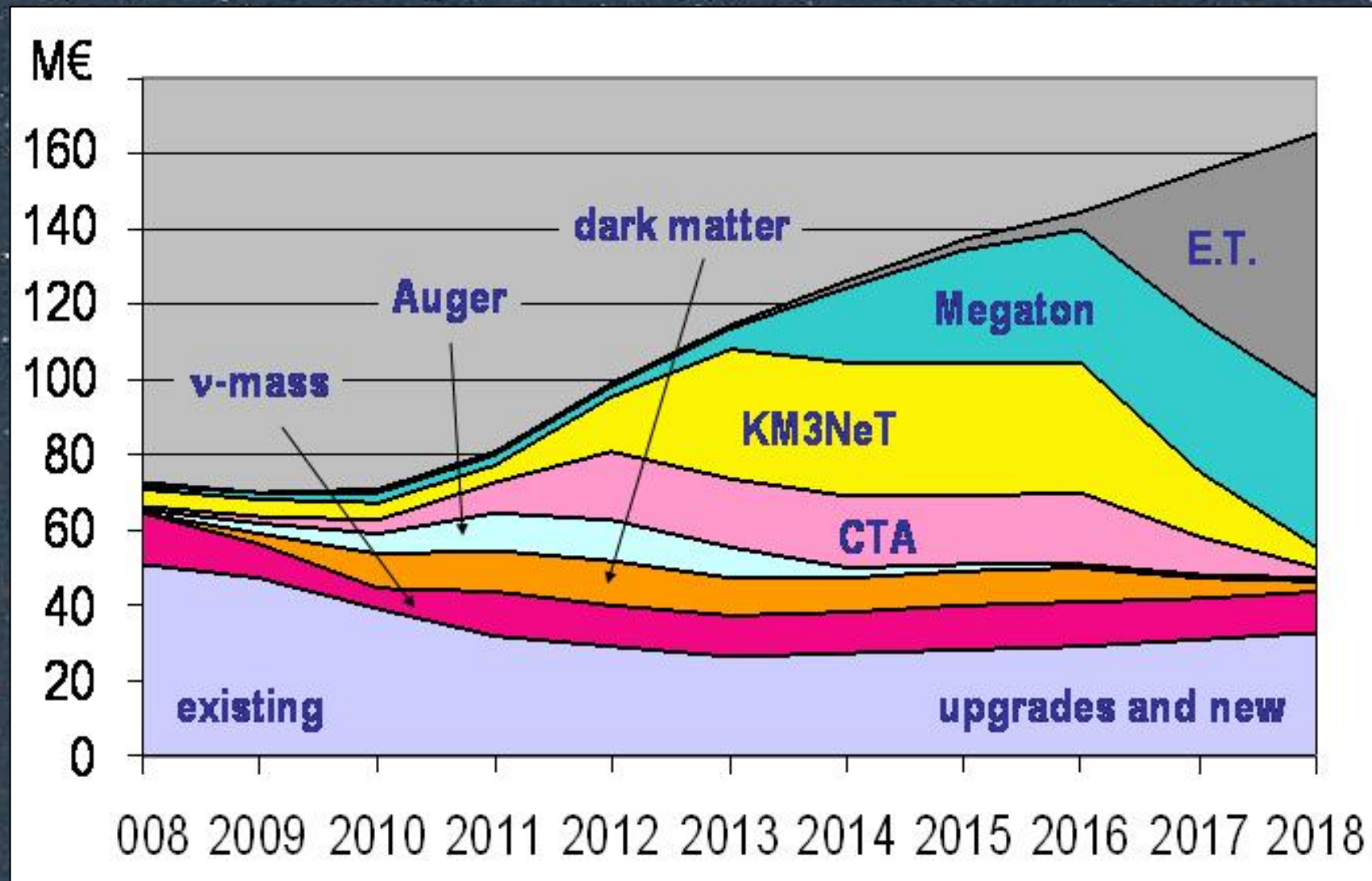
Type	Name	Site	Cost (M€)	Construction	World
High energy gamma rays		Namibia /Canaries	~150-200	2010	HAWC, AGIS
Neutrino telescopes		Europe	~200	2010	IceCube
Dark matter	 DARWIN	Europe	~20-50	2010	SuperCDMS, LUX
Double beta decay	GERDA, Cuore, SuperNEMO ...	Europe	~20-50	2010	MAJORANA, EXO, ...
Gravitational Waves		Europe	~150-300	2013-15	
Proton decay, Supernova neutrinos	MEMPHYS, GLACIER, LENA ...	Europe	~300-600	2013-15	UNO, H2K, ...
Total			>1000 M€	10 years	

Currently 350M€ over next 5 years (>2000 physicists)

(Courtesy: Christian Spiering)

The Magnificent Seven

Investment, only *Europe*





10. Coordination of astroparticle theory



Theoretical research is an invaluable source of new concepts, of inspiration for experimenters and a necessary tool to interpret experimental results. Theorists are spearheads in combining particle physics, cosmology and astrophysics. Like experiment, theory needs reliable support and coordination.

Theory often motivates experimental projects, links distinct sub-fields of astroparticle physics, and is indispensable for the interpretation of experimental results. In parallel with the ambitious plans for the next-generation astroparticle experiments in Europe, the associated theoretical activities – apart from project-specific analysis and computing activities – need stronger support and coordination. As examples for the need for coherent actions we mention the assessment and reduction of the uncertainty of nuclear matrix elements for double beta decay experiments, the interpretation of cosmological data and their relevance to dark matter and dark energy, and the modelling of high energy processes in violent environments.

<u>RE1</u>	(AMS) Alpha Magnetic Spectrometer (AMS) for Extraterrestrial Study of Antimatter, Matter and Missing Matter on the International Space Station
<u>RE3</u>	(AUGER PROJECT) The Pierre Auger Observatory Project
<u>RE5</u>	(EXPLORER) The Gravitational Wave Detector EXPLORER
<u>RE6</u>	(ANTARES) ANTARES: An Undersea Neutrino telescope
<u>RE7</u>	(GLAST) GLAST
<u>RE8</u>	(LISA) LISA
<u>RE9</u>	(NESTOR) NESTOR-Neutrino Extended Submarine Telescope with Oceanographic Research
<u>RE10</u>	(ICECUBE) IceCube
<u>RE11</u>	(MICE) Muon Ionization Cooling Experiment
<u>RE12</u>	(MEG) MEG: search for the $\mu \rightarrow e$ decay at PSI
<u>RE13</u>	(T2K) Neutrino Oscillation Experiment at JHF
<u>RE14</u>	(KATRIN) Tritium beta-decay experiment for direct measurement of the electron neutrino mass
<u>RE15</u>	(WARP) Search for cold dark matter using a cryogenic noble liquid detector
<u>RE16</u>	(HESS) High Energy Stereoscopic System
<u>RE17</u>	(MAGIC) MAGIC Major Atmospheric Gamma Imaging Cherenkov Telescope
<u>RE18</u>	(ArDM) ArDM: Search for Dark Matter in the Universe with Liquid Argon
<u>RE2B</u>	(PAMELA) Search for Antimatter in Space

This status is translated to reality on different levels:

- „essentially symbolic“
- using CERN for meetings
- using CERN as executive financial institution (e.g. Auger, Antares)
- input from CERN experiments (e.g. NA-61 → Auger)
- assembly and testing of detectors (e.g. AMS, ArDM)

Increasing intensity and impact
↓

- Recognized experiment (RE)
- Structural support with limited resources (reviewing and advisory role)
- Structural support with moderate resources (consolidating role in technology and site choices, project organisation etc., member of consortium)
- Involvement with significant resources (contribution to preparation and construction, leading member of consortium)

Summary

Astroparticle physics is exciting, inter-disciplinary science, bridging astronomy and particle physics

... the scale and scope of experiments is set to grow substantially over the coming decade

Japan has substantial expertise in many key areas – both in theory and in experiment

Should KEK consider supporting the engagement with these developments (at the international level)?

Sensible funding decisions require an **expert advisory body** and should reflect the community's interests!

*We are grateful for the very efficient
and thoughtful organisation by the:*

LOC

Kodama, Hideo

Ioka, Kunihiro

Kawanaka, Norita

Suwa, Yudai

Secretary: Shishido, Tamao

どうも有り難うございました

Doumo arigatou gozaimashita!

KEK Theory Center Cosmophysics Group Workshop on High Energy Astrophysics 2009

- Cosmic Particles, Jets and Accelerator Science -

10 (Tue) - 12 (Thu) Nov. 2009

[Seminar Hall 1F Building 4 \(Yon-Go-Kan Bldg.\), KEK, Tsukuba, Japan](#)

