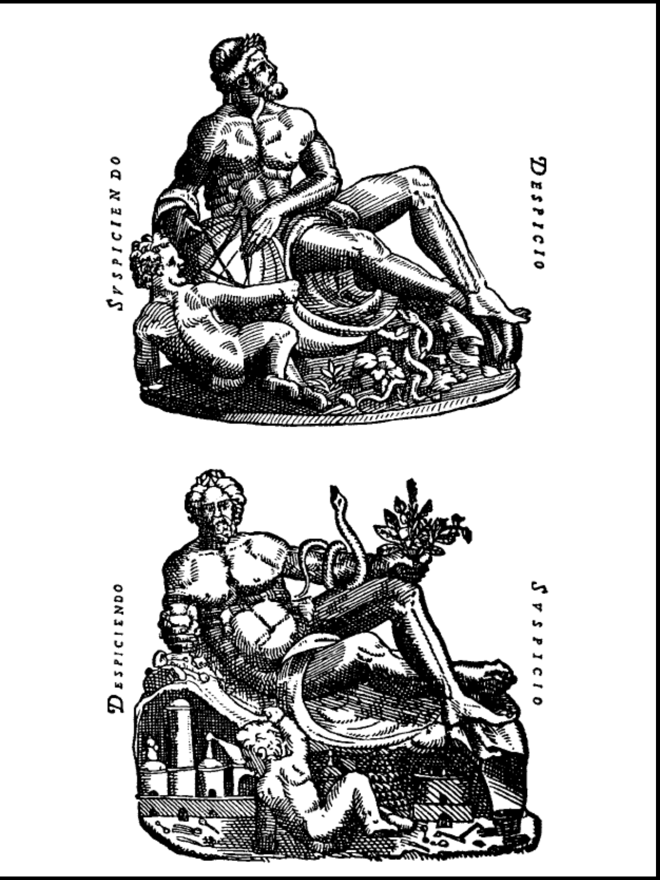
ASPERA

Astroparticle Physics,
Towards global coordination



S. Katsanevas
CNRS/IN2P3

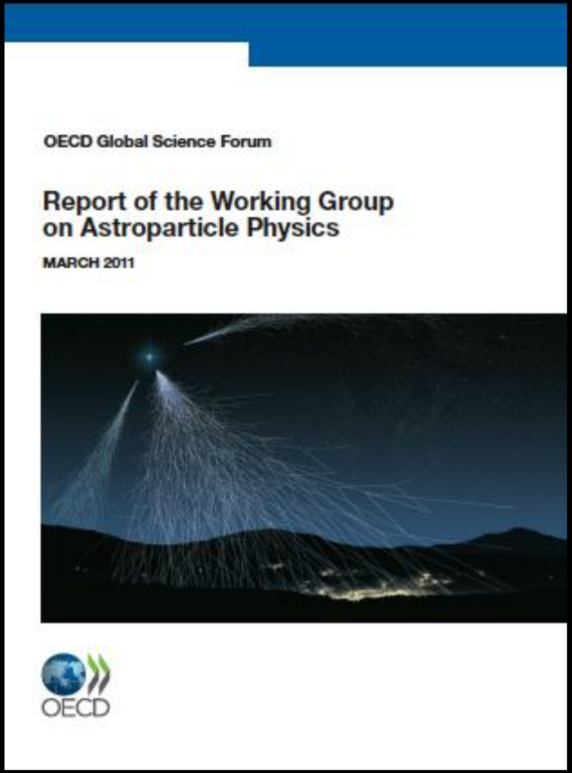
For the
Astroparticle Physics International Forum (APIF)*
(wishing fast recovery to its chairman Michael Turner)

Krakow, 11 Sept, 2012
Open Symposium European Strategy Preparatory Group meeting

* *Disclaimer: The statements that follow are my understanding of APIF discussions, plus input from agencies, no formal document issued yet.*

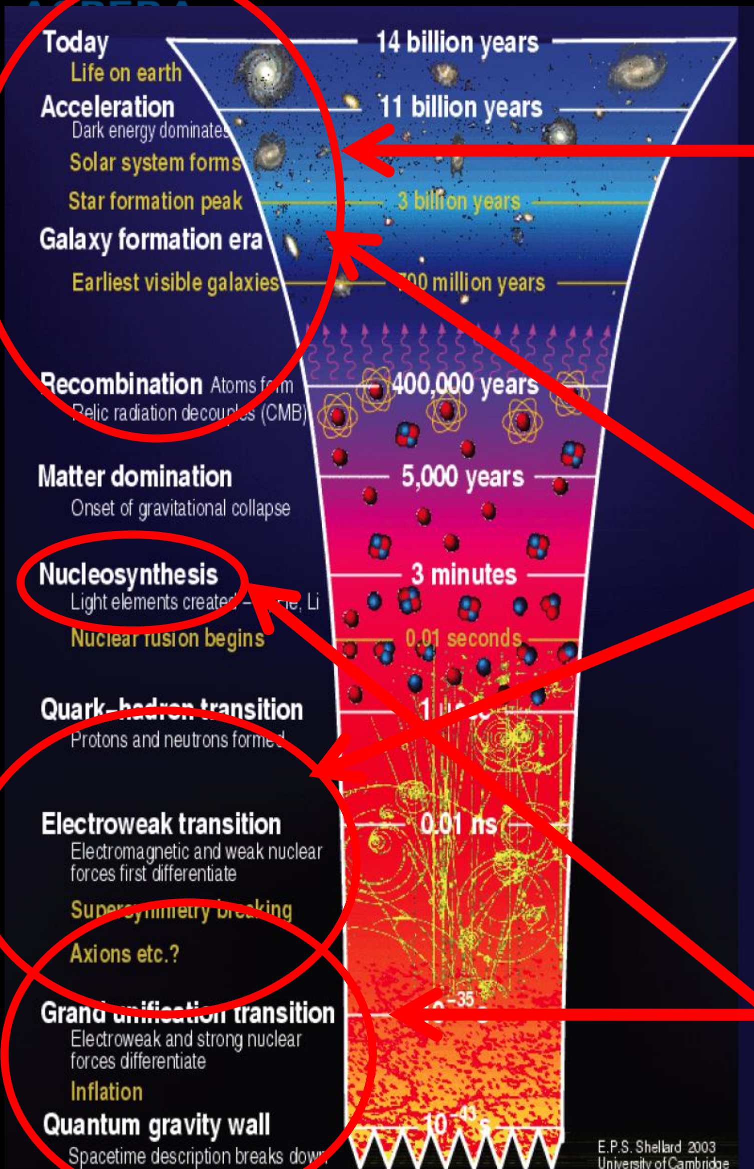
Global Roadmapping
From the OECD GSF Working Group on Astroparticle Physics (2009-2010) to the *Astroparticle Physics International Forum* (APIF, 2011-2013).

- Working Group on Astroparticle Physics: EU, US, Japan, China, India, Russia, Australia, Canada, Argentina worked for 2 years . Chair M. Spiro, Scientific Secretary S. Michalowski
    - Produced a strategic visions of the field
    - Prompted the creation of a committee reporting to OECD GSF called *Astroparticle Physics International Forum* (APIF). Chair M. Turner, Scientific Secretary S. Michalowski
- Previous meetings (Paris 2011, London 2012).
- Forthcoming Sudbury 2012
    - Exchange of agency programmatic information
    - Review of fields (e.g. of GWIC)
    - Discussion of coordination schemes
    - Synchronisation of project planning and implementation (phases, deliverables,…)
    - Interdisciplinary synergies
    - Data access, observation policies etc.

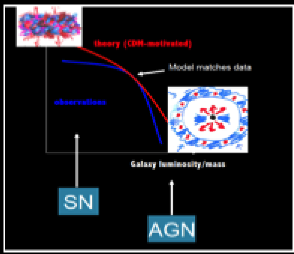


www.oecd.org/sti/gsf

The 3 themes (6 topics) of Astroparticle Physics
(APIF definition)



Understand cosmic accelerators and their role in the formation of cosmic structures. Probe for new particles (e.g. dark matter) or violations of fundamental laws



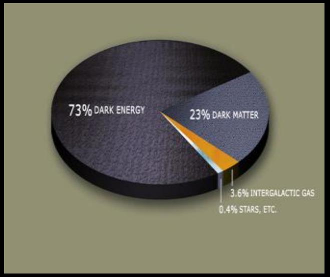
V. High energy cosmic messengers (γ, ν, CR)

VI. Gravitational waves

What is the Universe made of?

III. Nature of dark matter

IV. Nature of dark energy



Probe matter and interactions at the smallest scales or highest energies beyond these of accelerators, through rare decays.

I. Neutrino mass

II. Proton lifetime and neutrino properties

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \cdots$$

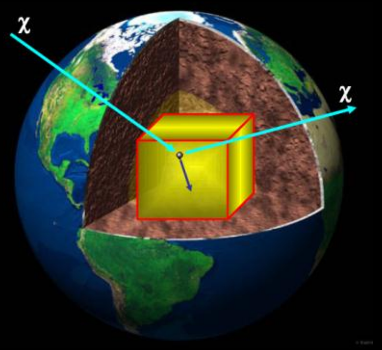
3 unities…

Dark Matter I, Direct detection
30 projects distributed worldwide

From Masaki Yamasita

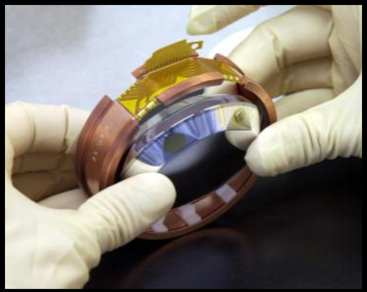
ASPERA

Dark Matter II, Methods of detection

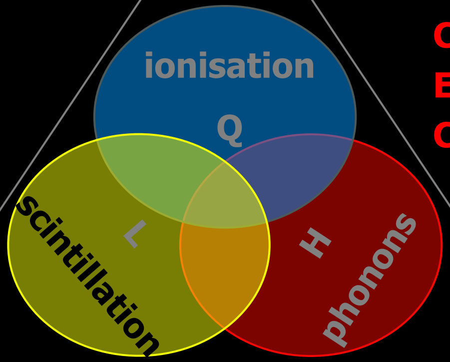


XENON, LUX,
ArDM, WARP
ZEPLIN III

PICASSO
SIMPLE
COUPP



CDMS
EDELWEISS
CoGENT



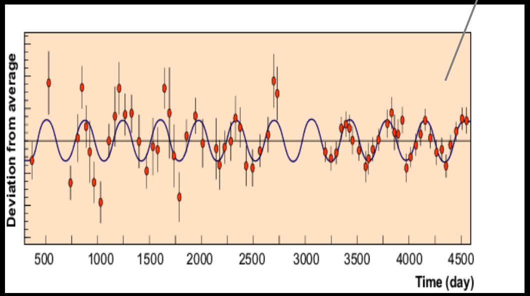
Strategies to detect Nuclear Recoil

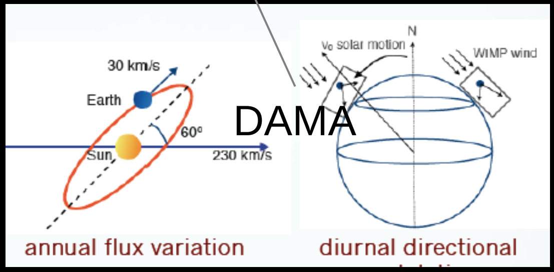
- Avoid electromagnetic recoils , neutrons, alphas (go deep, be radiopure)
- Use 2 signals self-shielding and/or pulse shape
- Use annual modulation, diurnal directional modulation

DAMA/LIBRA,
ZEPLIN I, ANAIS

CRESST
ROSEBUD

Originally
by T. Sumner





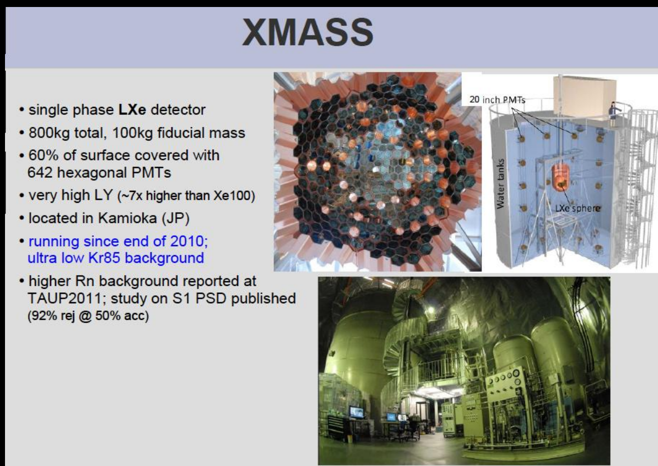
Dark Matter III, Distribution

Gran Sasso	DAMA LIBRA	CRESST GERDA		Xenon Darkside Warp			
Modane		EDELWEISS				SIMPLE(LBB)	MIMAC
Camfranc	NAIAD ANAIS			ArDM			
Boulby				ZEPLIN			DRIFT
SNOLab		SuperCDMS			DEAP CLEAN	PICASSO	
SOUDAN		CDMS	CoGENT				
DUSEL				LUX			
Fermilab						COUPP	
WIPP							DMTPC
KAMIOKA	KAM-NaI				XMASS		NEWAGE
JInPing(CJPL)			CDEX TEXONO	Panda-X			
YangYang	KIMS TEXONO						
South-pole	DM-ICE						
Future		EURECA/GEODM		Xenon1t/DARWIN MAX/LZ	CLEAN		

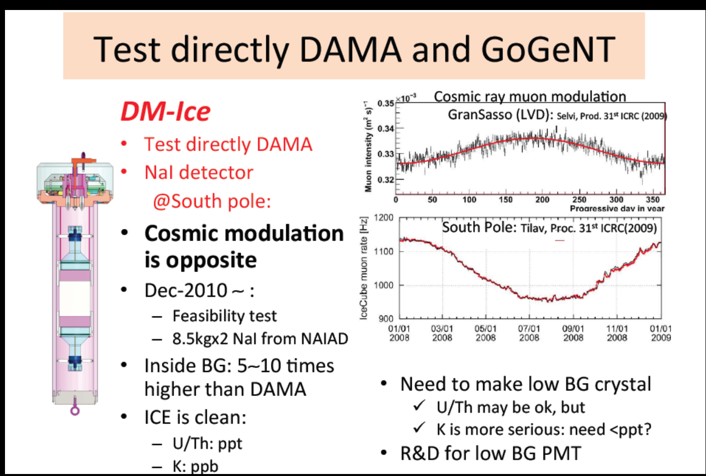
Although many projects are small to medium scale, APIF feels that some coordination in view of the ton-multiton realisations is in order (review in next meeting)

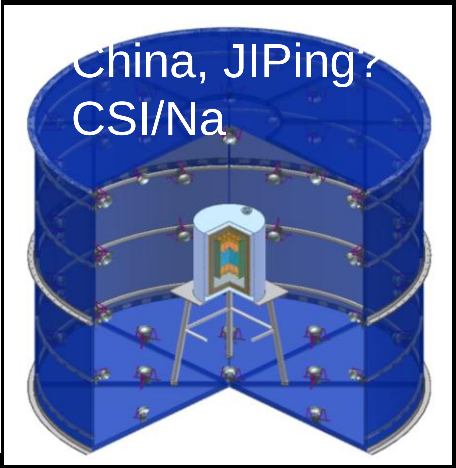
Dark Matter IV, Some examples (not covered by C.S)

ASPERA

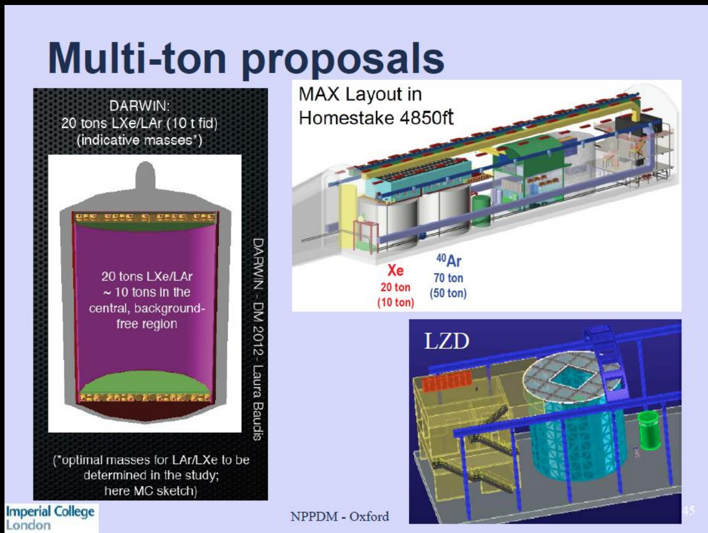


Self Shielding
Single Phase





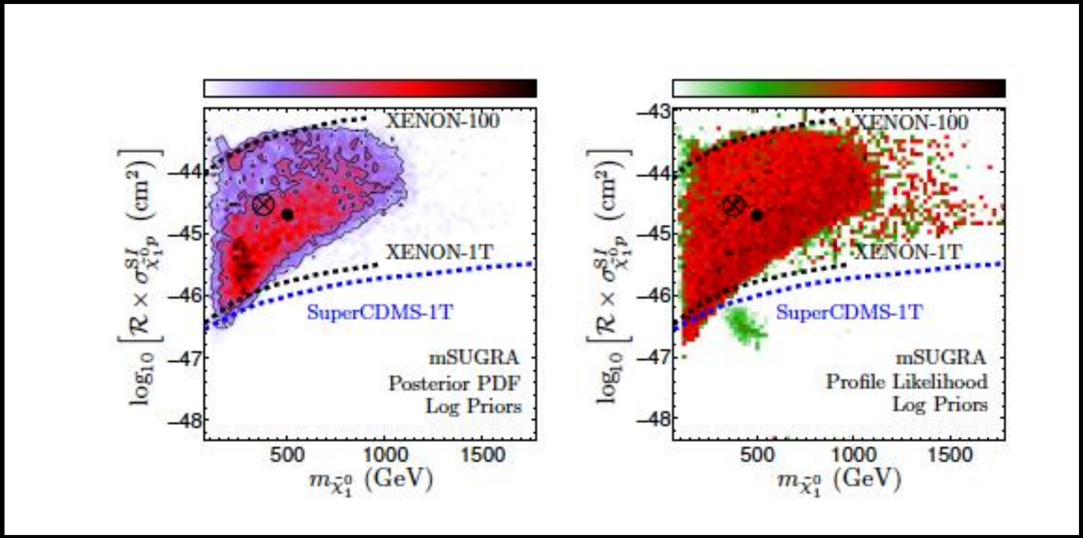
Pulse shape discrimination



Double phase multiton ➔

Dark Matter V, LHC-Direct detection complementarity (Work in Progress)

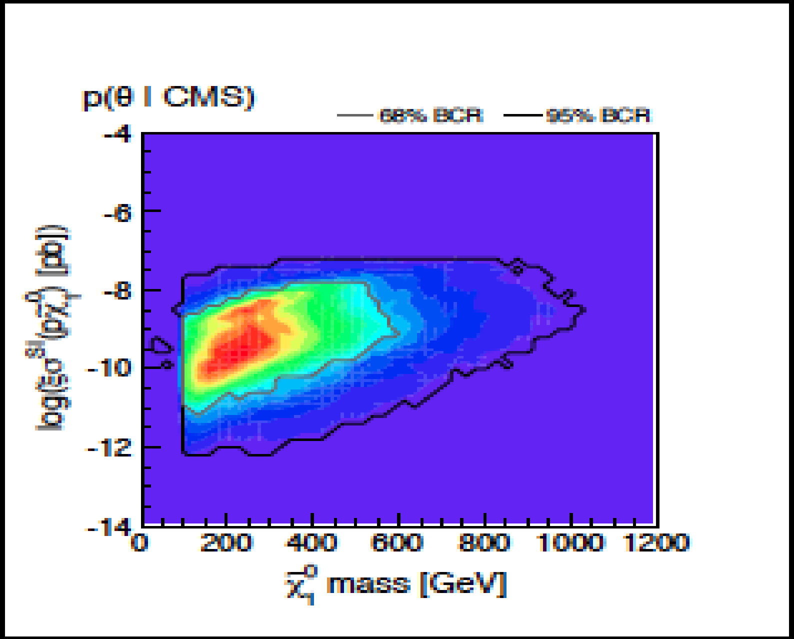
mSugRA+mH=125 GeV
Akula, Nath, Peim
Arxiv 1207. 1839



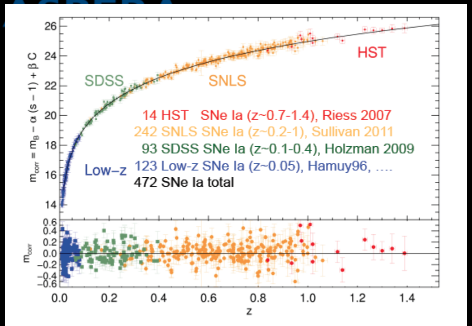
S. Kraml,
pMMSM (19 parameters)

Xenon100(2012) ≈ 10^{-9} pb
➔

10ton (10^{-12} pb) ➔



Dark Energy I

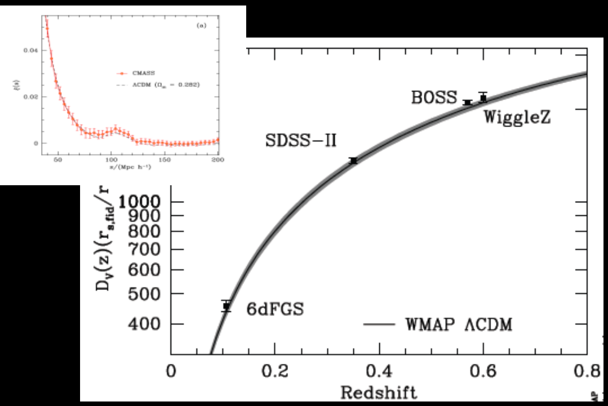


Guy et al, 2010 – Conley et al 2010, Sullivan et al, 2011

The accelerated expansion of the Universe due, presumably, to dark energy, was discovered through the study of very distant supernovae (SNae Ia= standard candle, Nobel 2011)

SNLS 2011 ➔ statistics(x10 since 1998) ≈ systematics 5,5 %

Another method that has reached maturity is the study of the imprint of primordial fluctuations on the distribution of visible matter. Baryon Acoustic Oscillations (B



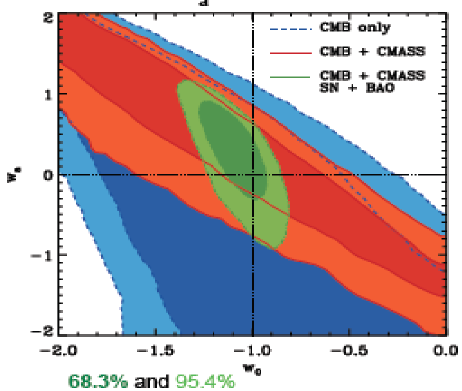
BOSS 2012 ➔ standard ruler

Sanchez *et al.* 2012

SN + BAO + CMB

w_0 =−1.08±0.11

w_a = 0.23±0.42



68.3% and 95.4% probability contour

(FoM = 1/area ellipse error)

Today : FoM ~ 33

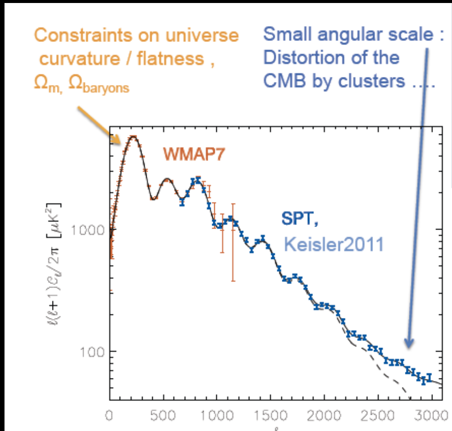
BAO and SN consistent with CMB on the equation of state ➔

Dark Energy Equation of state is a function of the universe scale factor « **a** » :

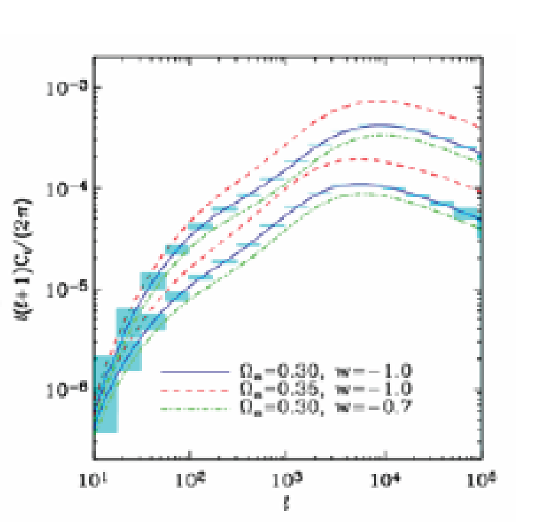
w(a) = w0 + wa(1 − a) = Pressure / density

Measuring this equation is the key to distinguish :
- a constant equation of state
(ex : Quantum vaccum /cosmological constant: wa=0, w0=-1)
- a Dark Energy field / “dynamic” (ex : quintessence: wa#0)

Dark Energy II



WMAP7 + South-Pole Telescope (2011), soon (2013) exquisite Planck data.



SNae and BAO probe the kinematics of the expansion (H(z))
Other observables as:

- Galaxy Clustering

  and

- Weak Lensing, where density fluctuations affect the path of light rays leading to correlations in the shape of neighbouring galaxies (see e.g. CFHLS data)

  probe the growth of structure (G(z)).

We need G(z) to adress properly the issue of modification of gravity

GC and WL are complementary to Snae, BAO and CMB

Dark Energy Survey (DES) starting this year and planning WL measurements will have a FoM > 200 (Also PAU in Spain)

Other programs between DES and the end of the decade:

• Japan: SuMIRe at the SUBARU telescope in construction
•US: an intermediate program is discussed in DOE (BigBOSS?)

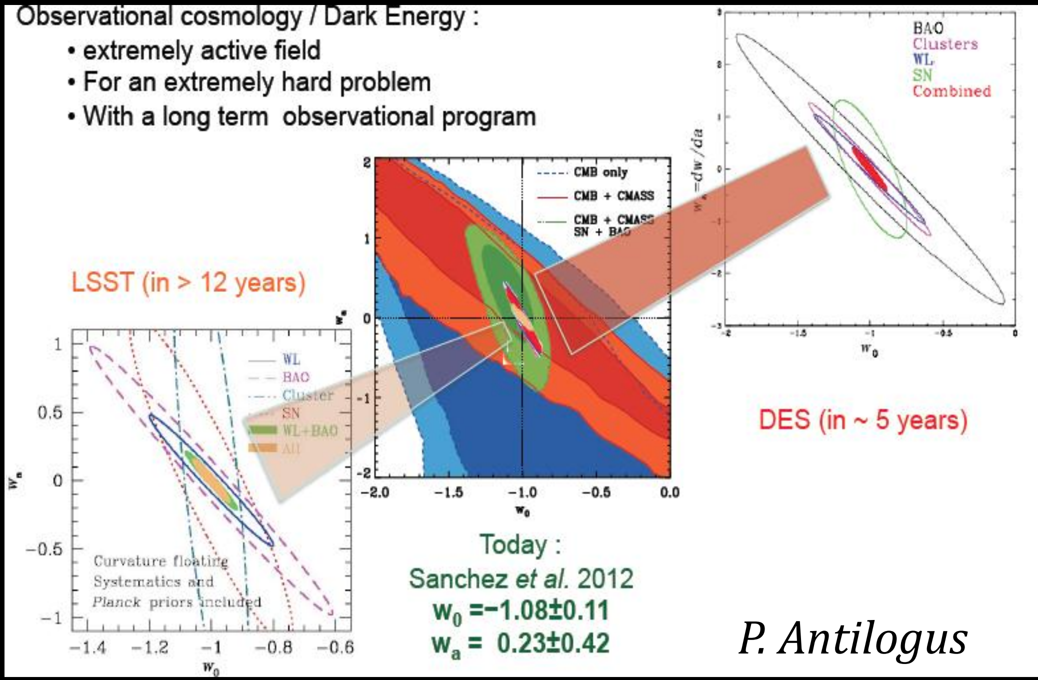
Dark Energy III

ASPERA

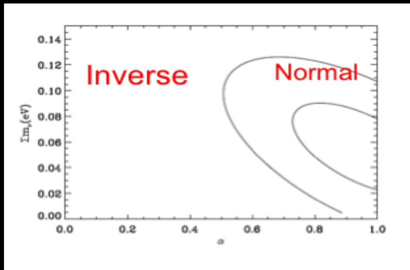
The communities and agencies have converged to large sky surveys (FoM > 800) with telescopes (first light 2020) :

•on ground **(LSST, NSF/DOE, 8.4m)**
and
• in space **(EUCLID, ESA, 1.2m)**

• LSST and EUCLID are complementary in systematics (superior spectroscopy vs absence of atmospheric distortion) they are both approved.



LSST/Euclid will be sensitive to the neutrino mass hierarchy (2022)



From the global coordination point of view:

- *The field has finally a clear long term program with complementary aspects*
- *The data management of e.g. the LSST is challenging and could be scaled in LHC units*
- *An interesting issue, under discussion is the issue of data-availability and exchange between LSST and EUCLID, and of course the rest of the world…*

DOE→ Cosmic Frontier – Program Planning & Future

See http://science.energy.gov/~/media/hep/hepap/pdf/20120827/Siegrist_HEPAP_aug_js_final.pdf

Emphasis on developing a staged, strong science program at the Cosmic Frontier.
- **Priorities: dark energy and dark matter**

Community input:
- Division of Particles and Fields (DPF) "Snowmass" science planning process in 2013
  http://www.snowmass2013.org/tiki-index.php?page=Cosmic+Frontier
- DOE dark energy science planning (August 2012)
  http://science.energy.gov/~/media/hep/hepap/pdf/20120827/Kolb_HEPAP_8_12_revised.pdf

Dark Matter:
Holding comparative review of direct detection dark matter generation 2 (DM-G2) proposals for FY2013 R&D funding. Further selection will lead to project(s) starting fabrication as early as FY2014.

Dark Energy:
- Developing a balanced, staged program from BOSS & DES → LSST camera (in FY2013 budget request for fabrication start)
- Now investigating possibilities for a mid-scale spectroscopic project to operate between DES and LSST.

Other areas: Consider other program areas in parallel with DPF process.
- DOE guidance to US CTA collaboration: We consider NSF to be the lead US agency; DOE has no funding identified for a contribution in the foreseeable future.

Operating Experiments:
Holding review of current operating experiments in September to plan the portfolio and budget for the coming years. → as operations budget decrease, funds for new projects will be available.

NSF Astroparticle Programs

Programs exist in both the Physics (PHY) and Astronomy (AST) Divisions at NSF

•We and DOE-HEP are working with the APS Division of Particles and Fields (DPF) "Snowmass" science planning process (Summer 2013)

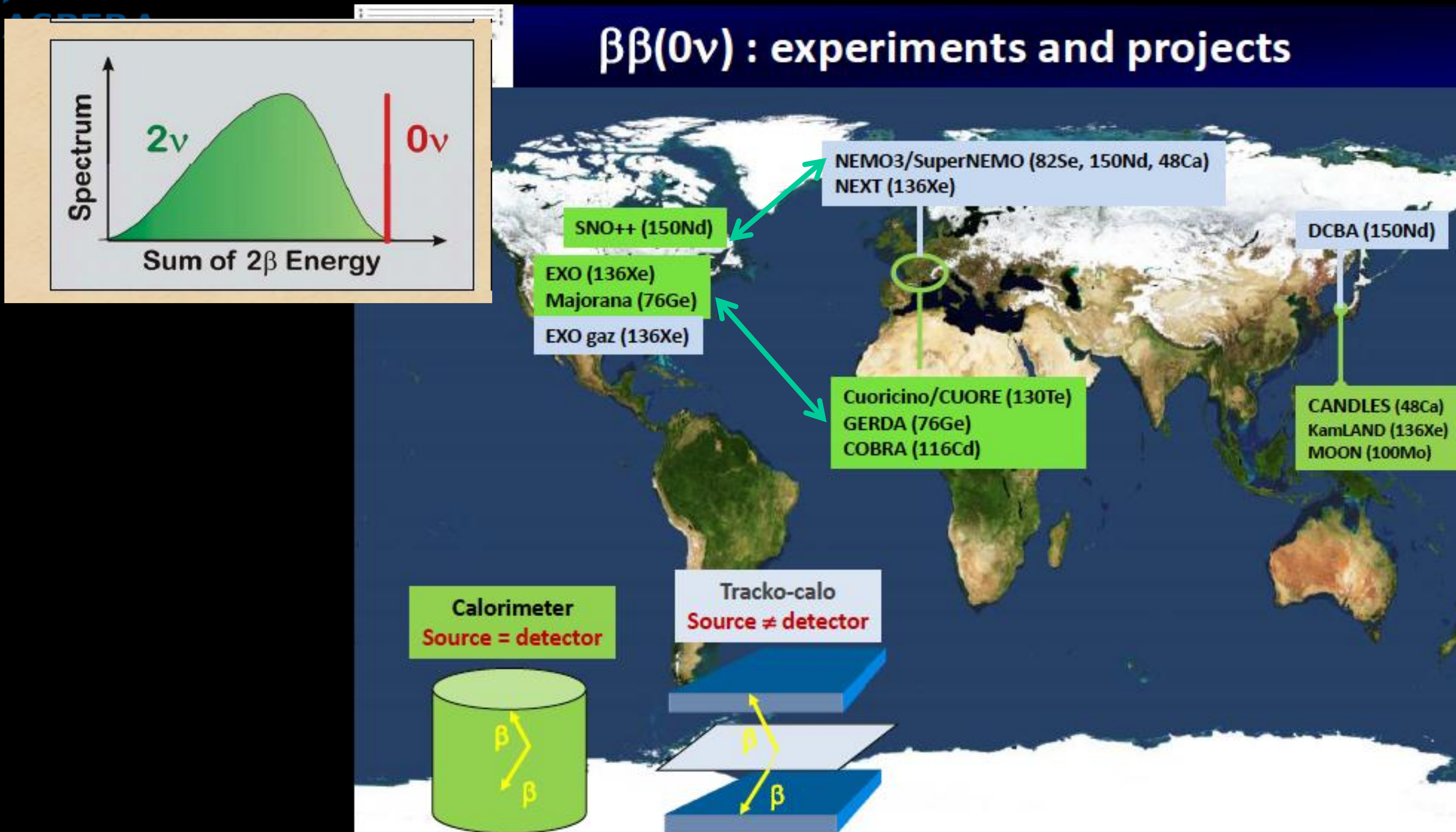
•We are working with DOE-HEP in providing R&D funds now and will coordinate funding for the next generation (G2) of Dark Matter experiments late in 2013.

•Concerning new projects (considering LIGO, ICeCUbe, etc funded):

Dark Energy
- Boss
  - Partnership NSF/AST with DOE
  - Underway, to end ~2015, One component of Sloan Digital Sky Survey III
- DES
  - Partnership NSF/AST with DOE for the camera, Operational late 2012 on telescope in Chile
- LSST
  - Partnership NSF/AST with DOE for the camera. Authorization to include in future NSF budget request for construction
  - Current schedule – operational ~2022

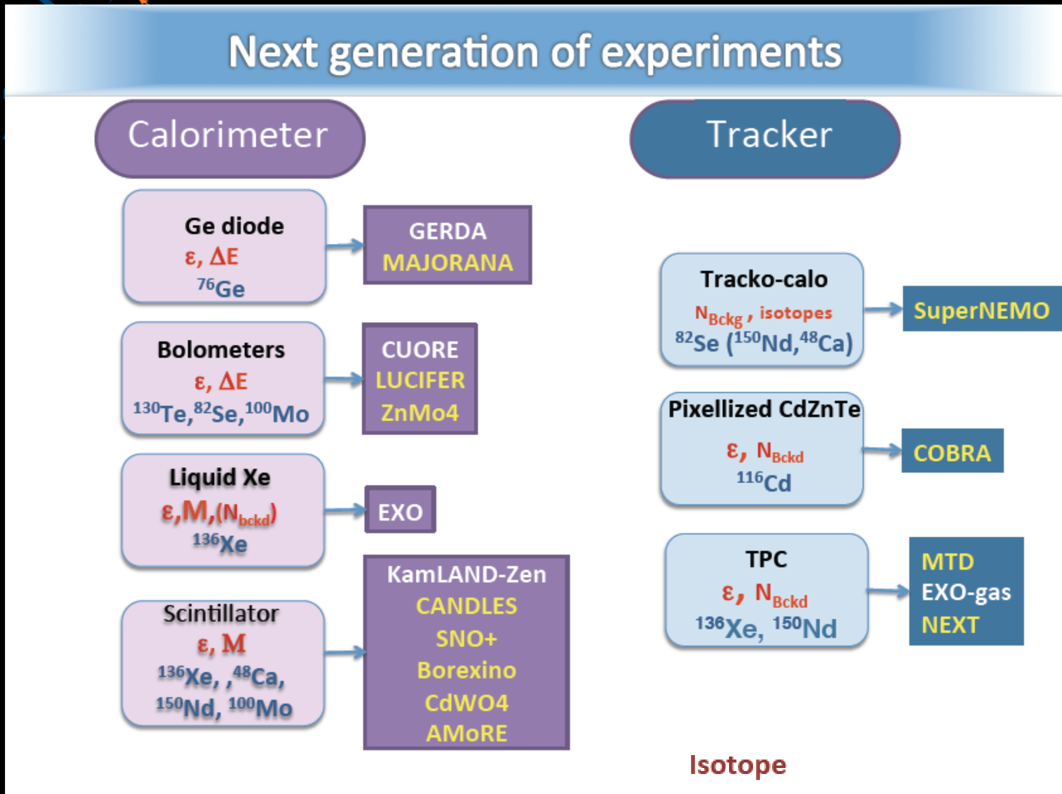
Other
- US CTA. No significant construction funding for CTA project for foreseeable future

Probing the neutrino mass I, Testing the Majorana nature of neutrinos through the detection neutrinoless double beta decays (which would also provide information about their masses).

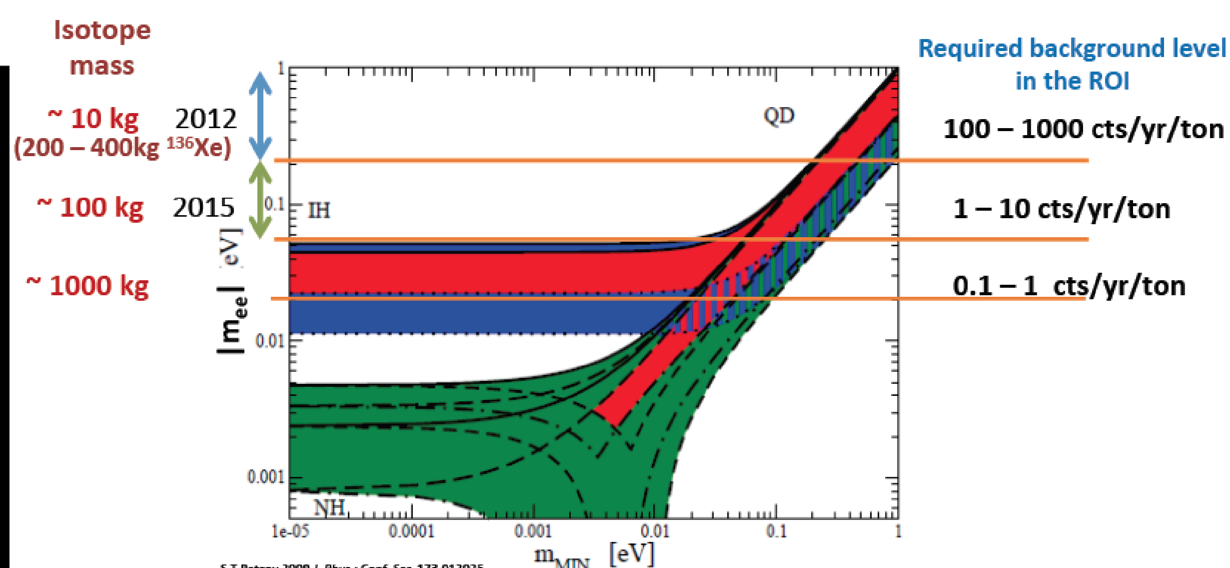


Healthy competition among projects is the rule in the investigation of neutrinoless double beta decay. However, global-scale coordination and avoidance of duplication would be beneficial, especially for the procurement of crystals and scarce enriched isotopes (Ge, Nd, Ca). A future generation experiments, using target masses of approximately one ton of isotope, will certainly need international coordination.

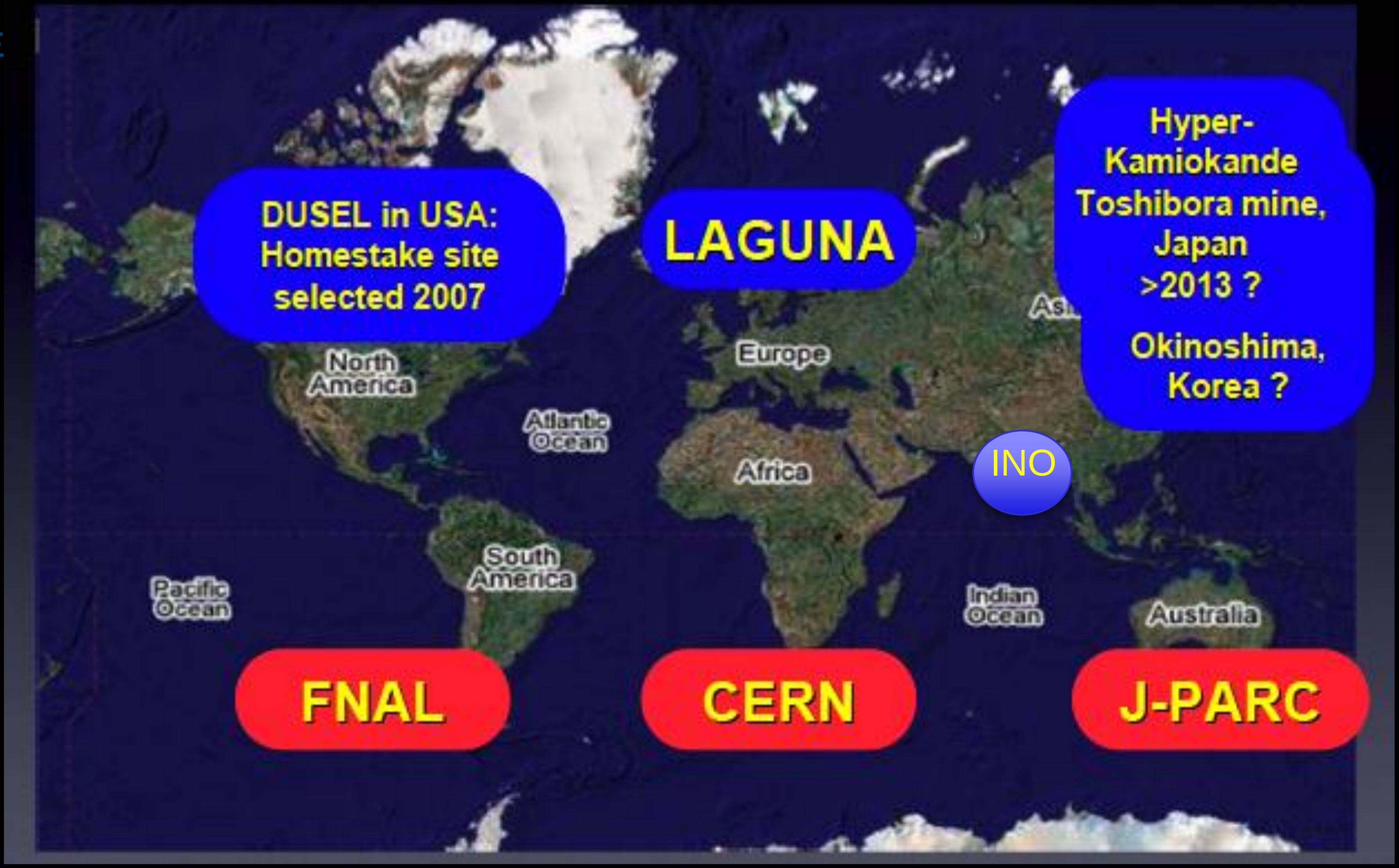
Probing the neutrino mass II, Toawards the ton



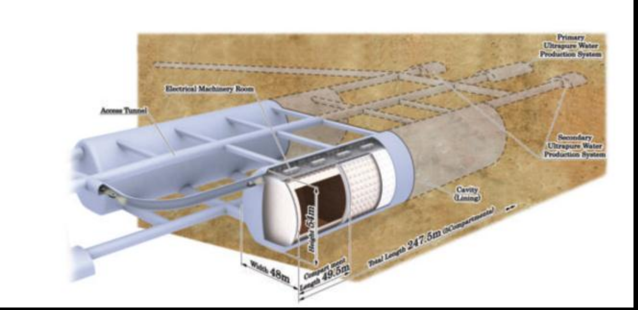
F. Piquemal
Kyoto 2012



Proton decay I,
"megaton" scale projects for proton decay and neutrino physics



The current surface option for LBNE (+15% to go underground) does not have an astroparticle physics program (see talk by K. Hagner). LAGUNA is covered by S. Spiering. Will not also cover INO and DayaBay II.



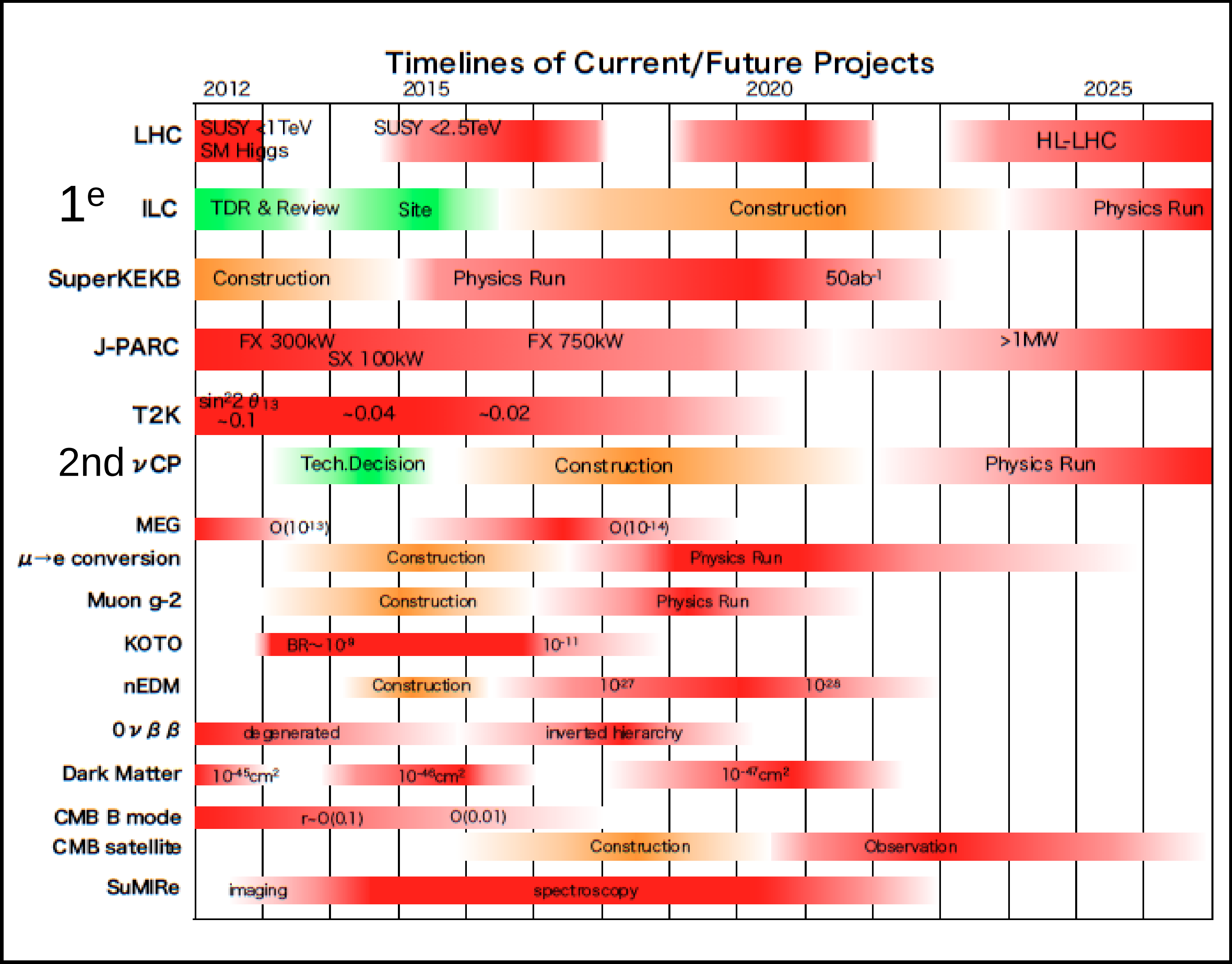
Proton decay II, HyperKamiokande
Recent open symposium at IPMU

0,56 Mt FV (1Mt total), 20% coverage,
1750 m we overburden

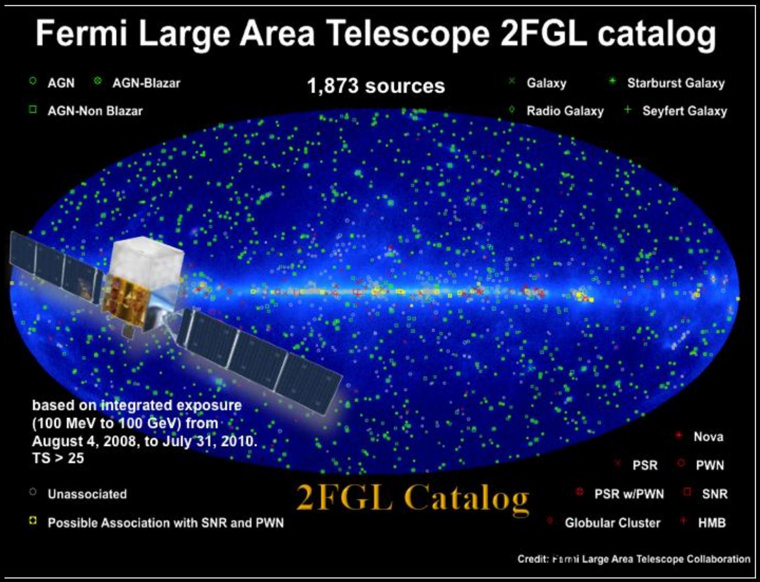
TABLE II: Physics targets and expected sensitivities of the Hyper-Kamiokande experiment. σ_{SD} is the WIMP-proton spin dependent cross section.

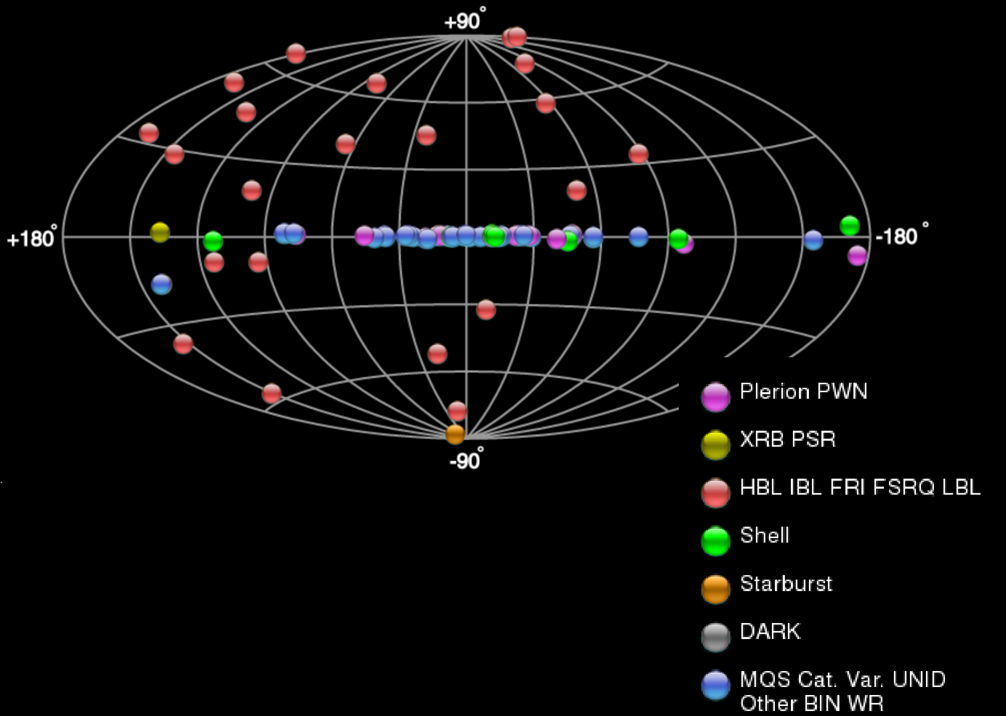
Physics Target	Sensitivity	Conditions
Neutrino study w/ J-PARC ν		750 kW $\times$ 10 years (1 year $\equiv 10^7$ sec)
– CP phase precision	$< 18°$	@ $s^2 2\theta_{13} (\equiv \sin^2 2\theta_{13}) > 0.03$ and
		mass hierarchy (MH) is known
– CPV 3σ discovery coverage	74% (55%)	@ $s^2 2\theta_{13} = 0.1$, MH known(unknown)
Atmospheric neutrino study		10 years observation
– MH determination	$> 3\sigma$ CL	@ $0.4 < s^2\theta_{23}$ and $0.04 < s^2 2\theta_{13}$
– θ_{23} octant determination	$> 90\%$ CL	@ $s^2 2\theta_{23} < 0.99$ and $0.04 < s^2 2\theta_{13}$
Nucleon Decay Searches		10 years data
– $p \to e^+ + \pi^0$	1.3×10^{35} yrs (90% CL)	
	5.7×10^{34} yrs (3σ CL)	
– $p \to \bar{\nu} + K^+$	2.5×10^{34} yrs (90% CL)	
	1.0×10^{34} yrs (3σ CL)	
Solar neutrinos		
– ^{8}B ν from Sun	200 ν's / day	7.0 MeV threshold (total energy) w/ osc.
– ^{8}B ν day/night accuracy	$< 1\%$	5 years, only stat. w/ SK-I BG $\times 20$
Astrophysical objects		
– Supernova burst ν	170,000~260,000 ν's	@ Galactic center (10 kpc)
	30~50 ν's	@ M31 (Andromeda galaxy)
– Supernova relic ν	830 ν's / 10 years	
– WIMP annihilation at Sun		5 years observation
	$\sigma_{SD} = 10^{-39}$cm^2	@ $M_{\mathrm{WIMP}} = 10$ GeV, $\chi\chi \to b\bar{b}$ dominant
	$\sigma_{SD} = 10^{-40}$cm^2	@ $M_{\mathrm{WIMP}} = 100$ GeV, $\chi\chi \to W^+W^-$ dominant

From the Japan Strategy Document

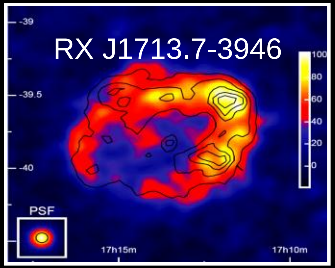


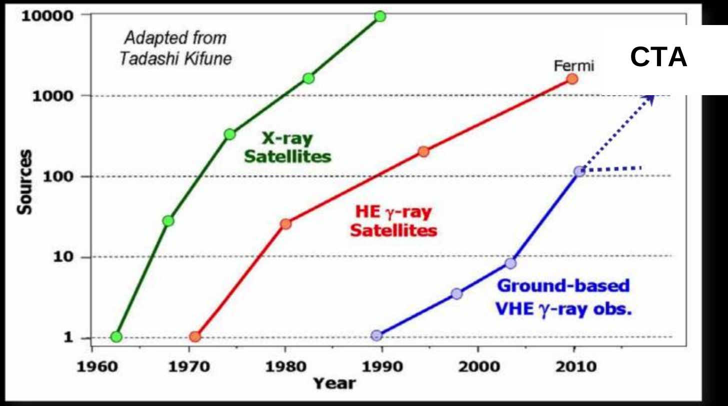
High Energy Universe I, Last 10 years have been the golden age of HE gamma ray astronomy (an order of magnitude more sources discovered at the GeV and TeV)





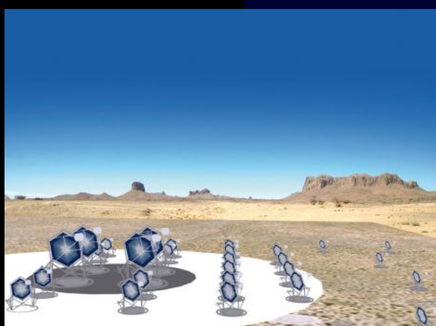
- 1873 GeV sources (FERMI)
- 136 TeV sources (HESS, MAGIC, VERITAS)
- Morphology, Timing





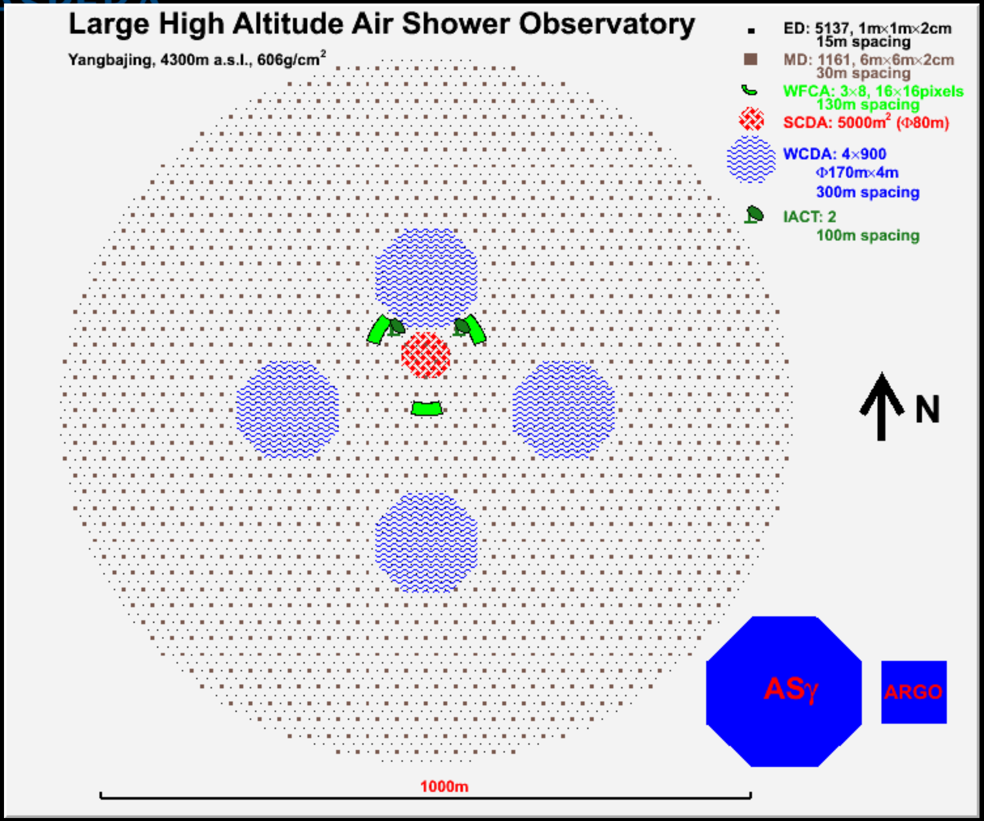
ASPERA

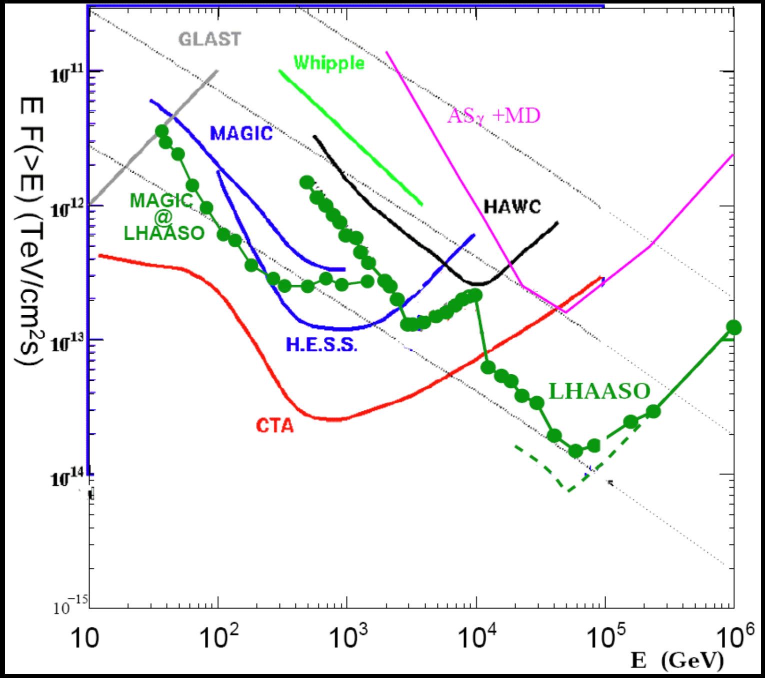
High Energy Universe II
High energy gamma ray telescopes



Good convergence. In the domain of TeV gamma-ray astrophysics the **Cherenkov Telescope Array (CTA)** is a worldwide priority 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 by the middle of the decade. LHASSO in Tibet will have a complementary coverage. Also MACE for lower energies in India?

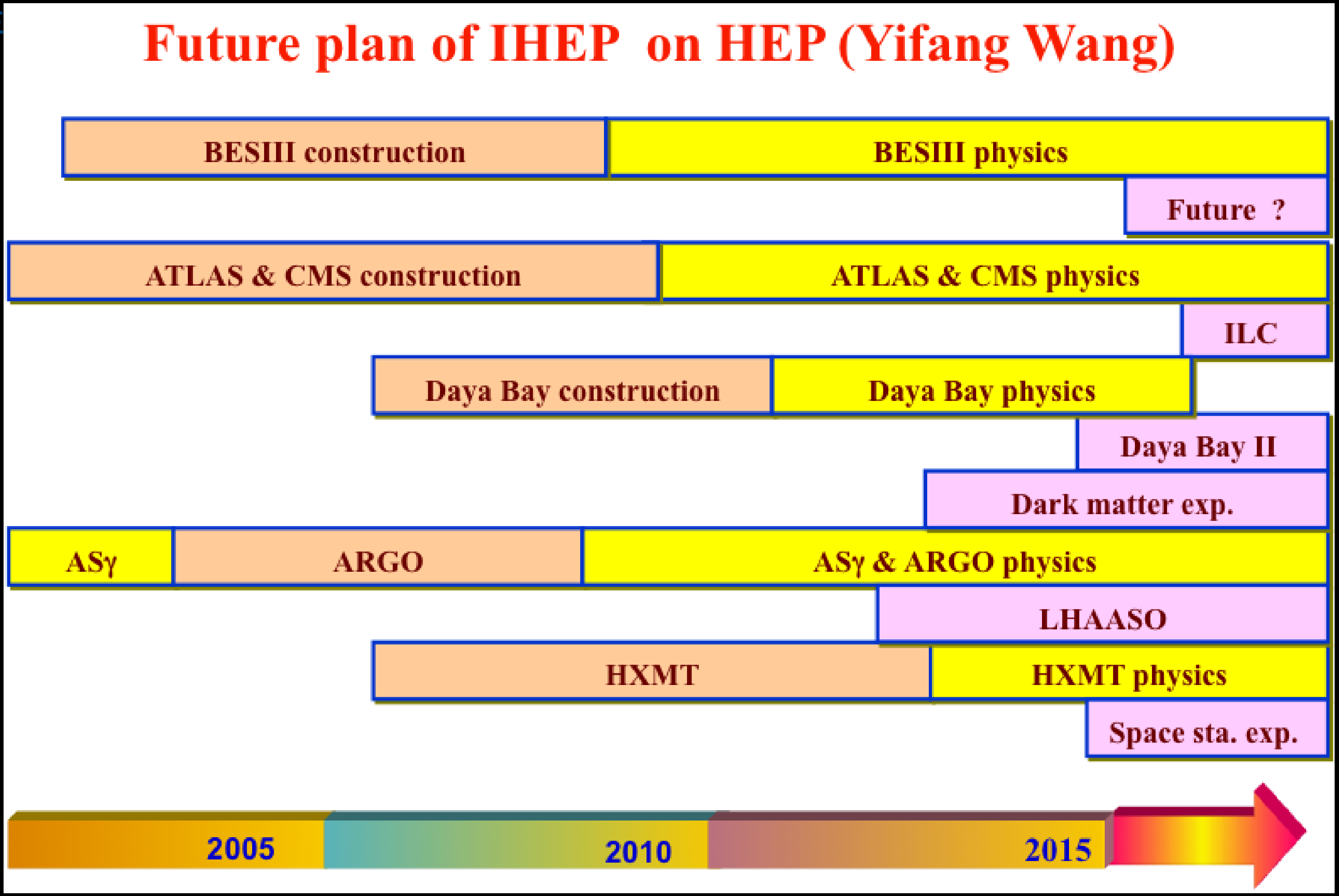
High Energy Universe III, LHAASO





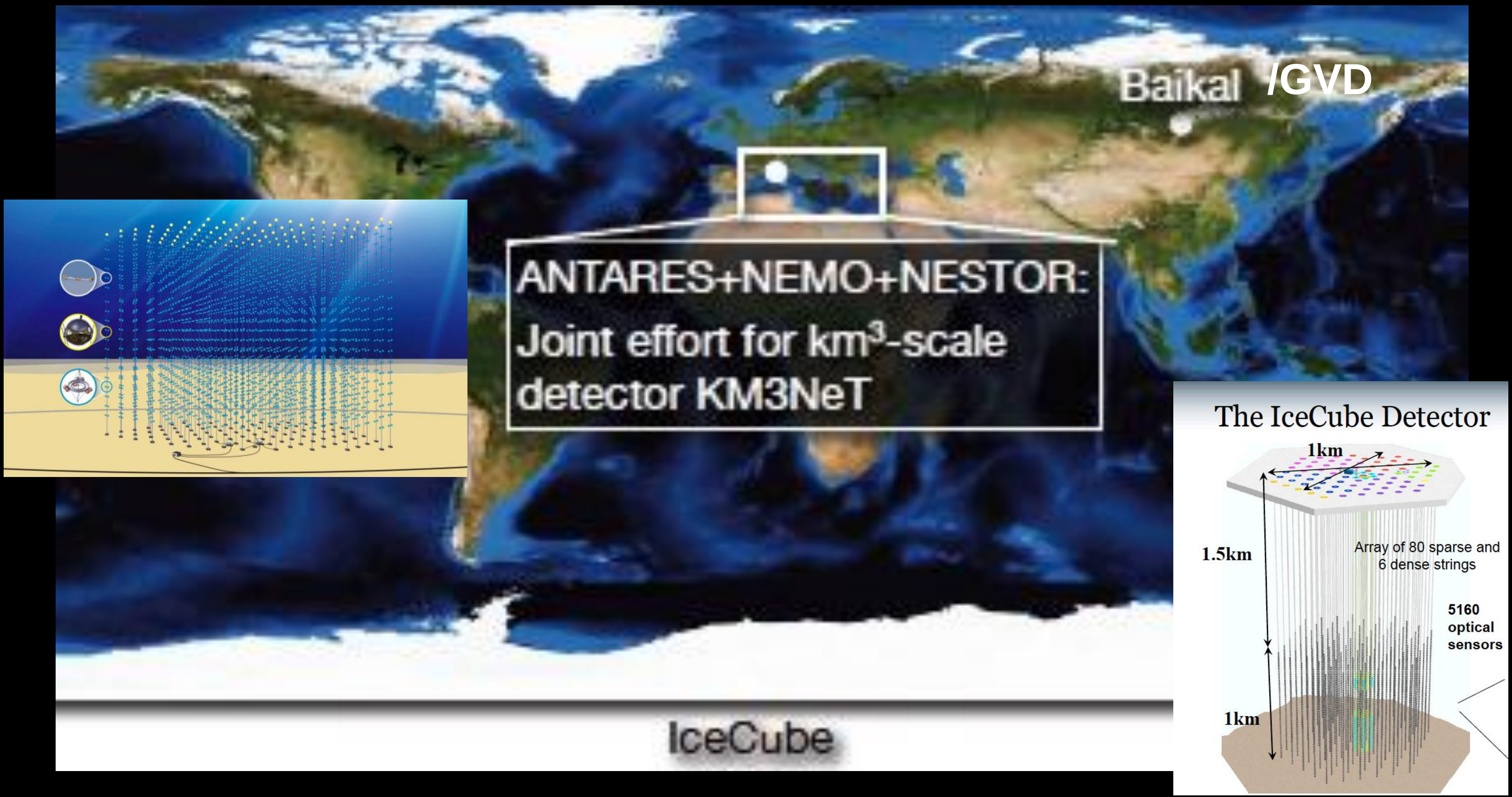
Cosmic-ray energy spectrum covering also “Knee” with absolute energy scale: understand acceleration mechanism

Planning from China



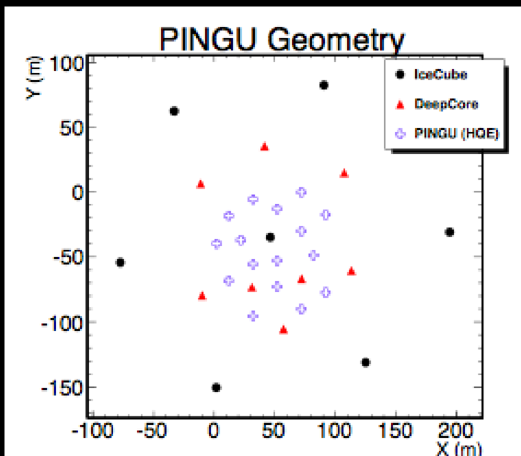
ASPERA

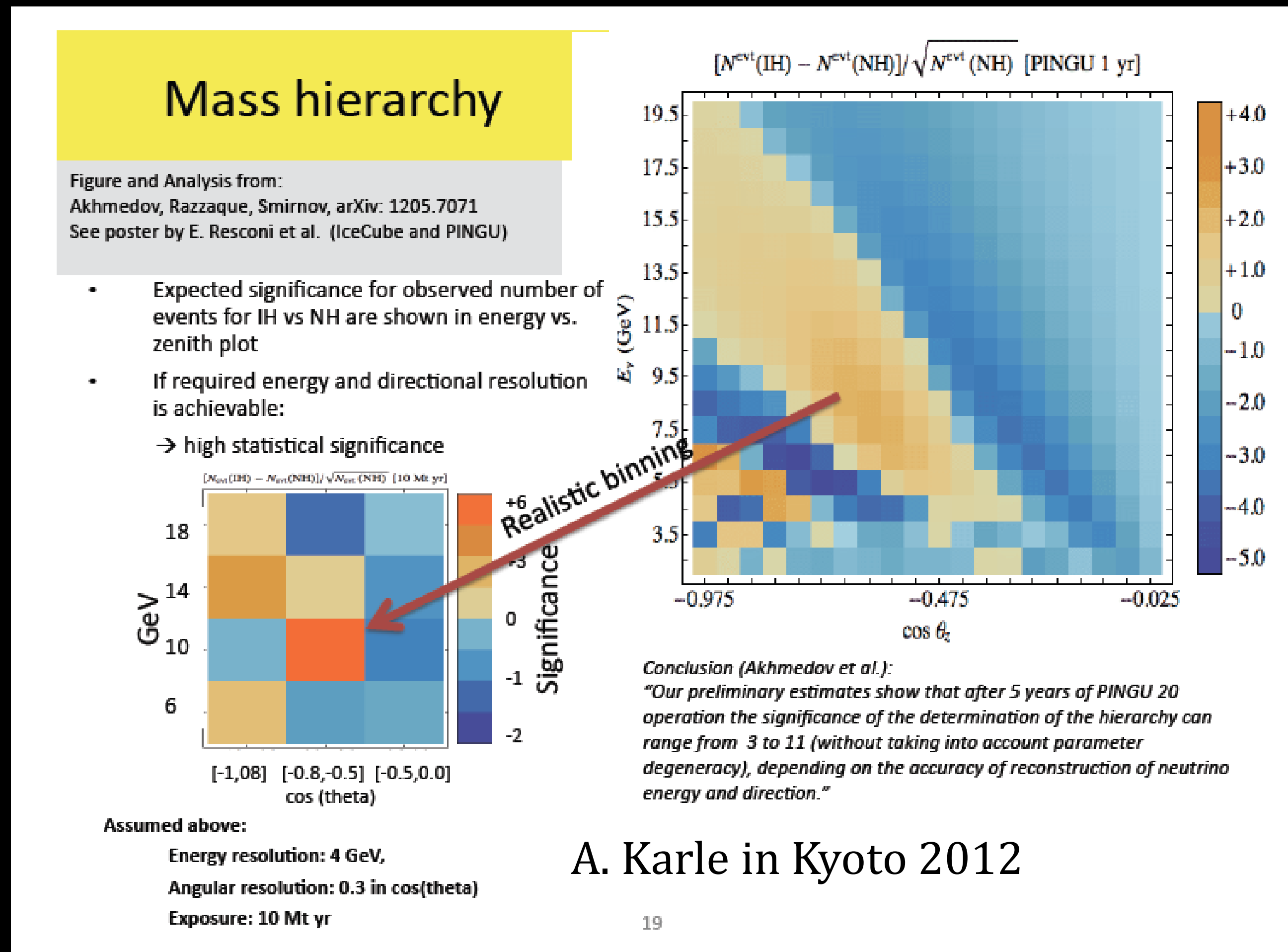
High energy Universe IV, HE Neutrino telescopes



See talk by C. Spiering. Nothern Hemisphere projects and IceCube move through coordination towards a future Global Neutrino Observatory
First exemple PINGU-ORCA

High energy Universe V, A compact version of Neutrino telescopes to study ν mass hierarchy +...





A feasibility study , common to PINGU and ORCA (the KM3Net equivalent) has been submitted to the European ASPERA R&D call.

High energy Universe VI

High energy cosmic ray observatories

PAMELA
ATIC
CREAM

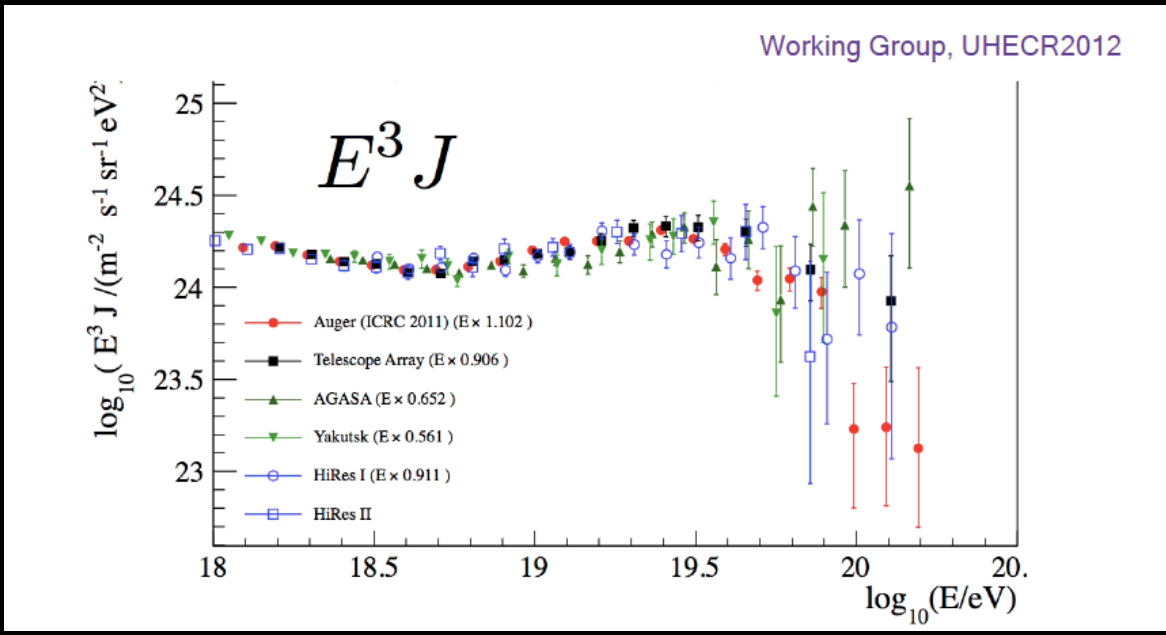
For direct synergies with LHC see talk by C.S

AMS
JEM-EUSO

Towards more area coverage or (e.g. JEM-EUSO, ideas on ground , TA2) or more
observables (separate e.m. component from Nμ) ?

ASPER

High energy Universe VII
Where do we stand in UHECR?

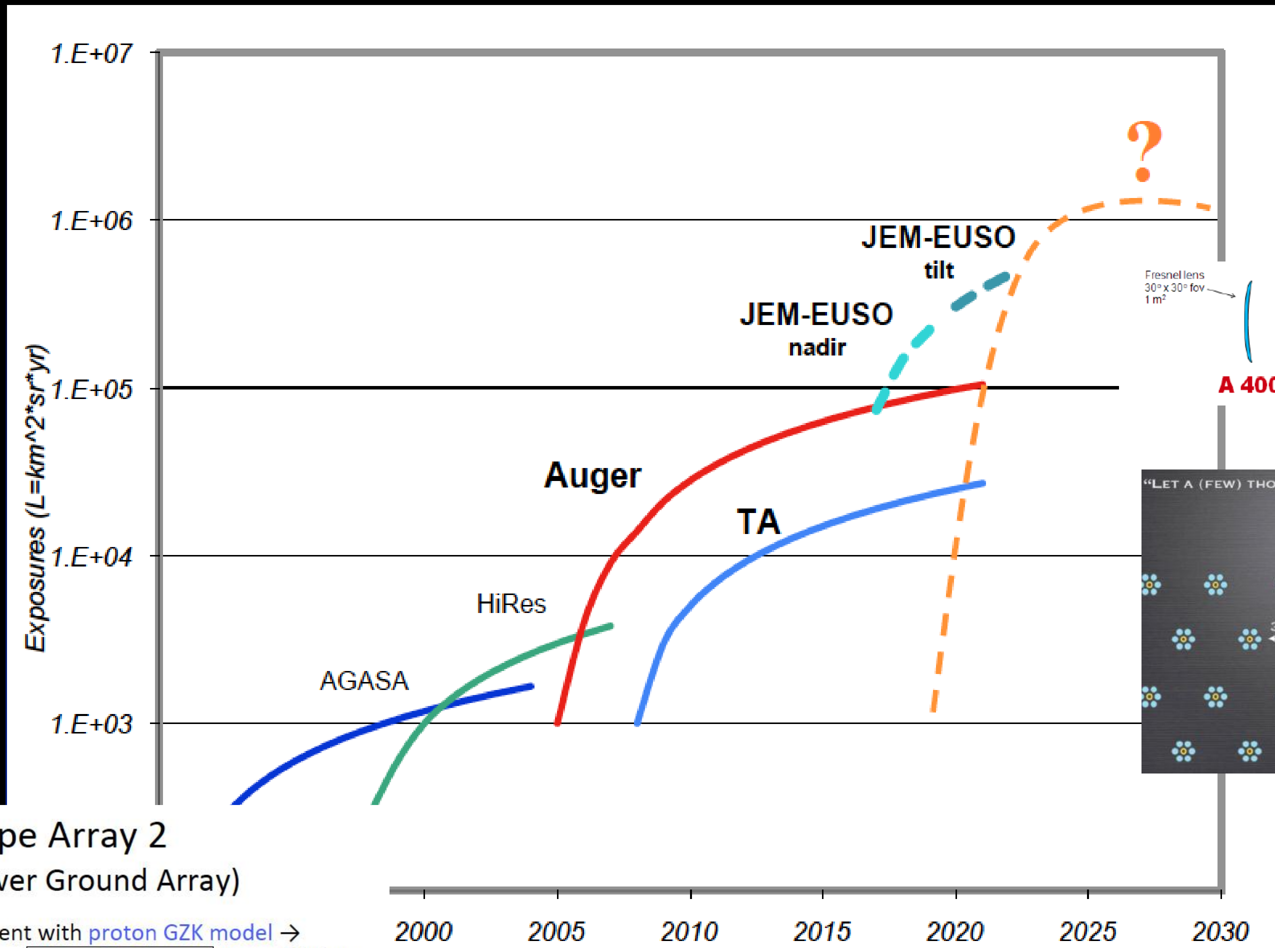


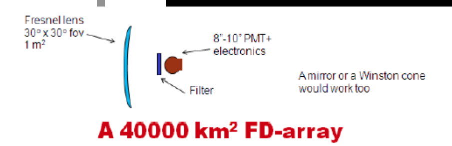
- Suppression of the UHECR spectrum
➔AUGER ≈ TA
- Energy calibration
➔ AUGER ≈ TA
- A trend towards heavier composition at highest energies
➔AUGER ≠ TA
- A weak correlation towards nearby matter distribution (14%)
➔ AUGER ≈ TA
- An excess of muons over models

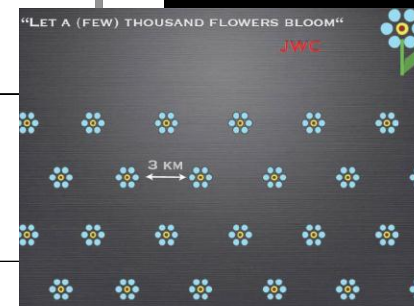
Q: Are we seeing the GZK or in large part the exhaustion of the acceleration mechanism ?

A: We need to identify the composition of cosmic rays on an event-by-event basis and to understand the characteristics of the hadronic interactions. Need more observables (e.g. Nμ in the events) to probe this.

High energy Universe VIII, more surface ?

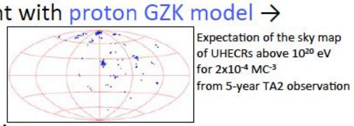




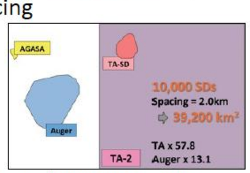


Telescope Array 2
(Huge Air Shower Ground Array)

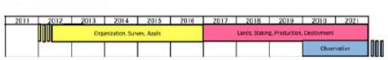
- The current TA result: consistent with proton GZK model → charged-particle astronomy

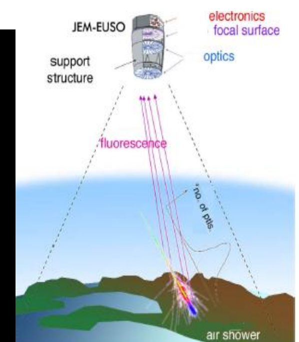


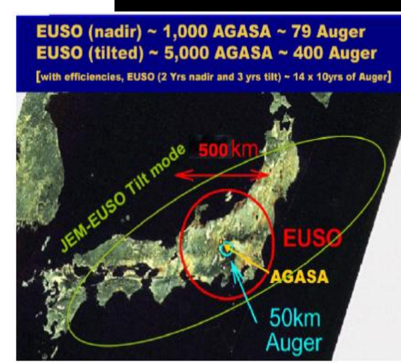
- TA2: 10,000 SDs with 2 km spacing
  - ~40,000 km² (~60xTA)
  - SDs with possibly techniques to identify mass composition
  - ~100M$ (~30M$ from Japan)



- Schedule
  - TA/Auger exchange (analysis/detector): JFY2012 – 2016
    - Resolve the discrepancies between TA and Auger
  - TALE: JFY2013 - 2017
  - TA2: production in JFY2017



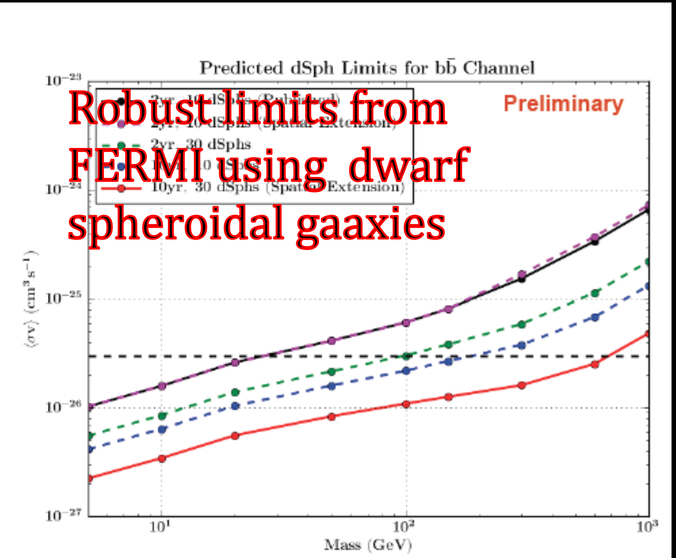


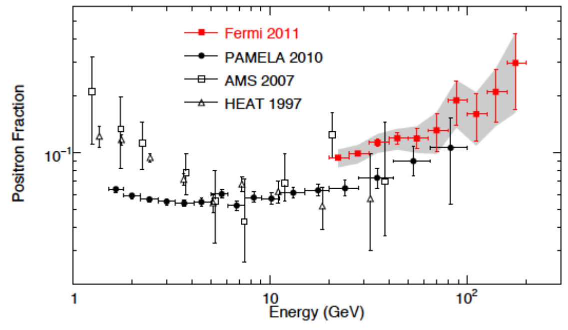


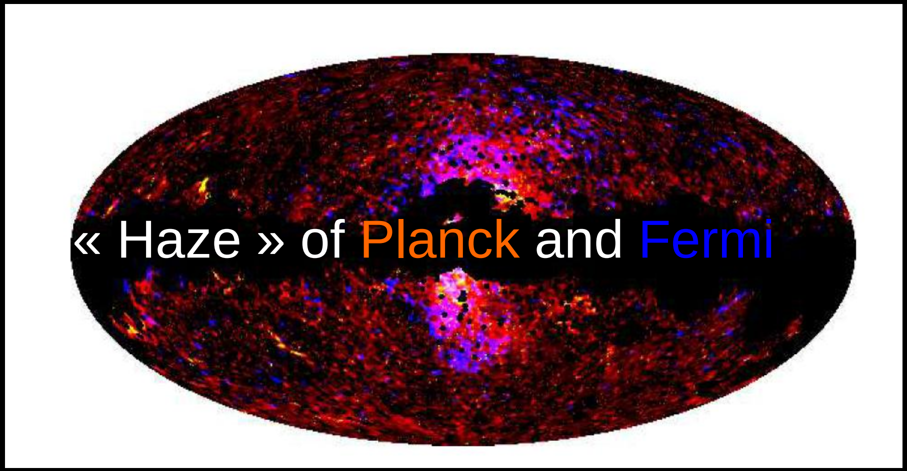
High energy Universe IX,
Indirect detection of dark matter

Detect co-annihilation products (γ, ν, antiparticles) in some cosmic body or region

1. Avoid confusion with astrophysical sources
2. Be independent from DM density distribution (add sources)
3. Sharp pics in spectra (e.g. photons)



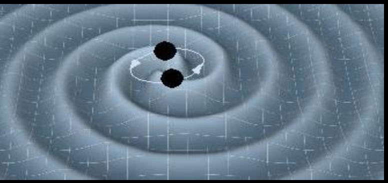


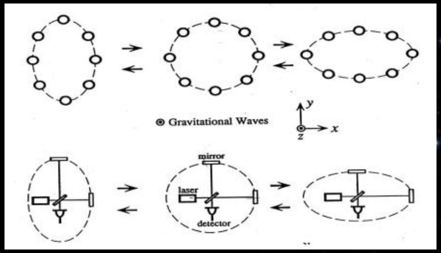


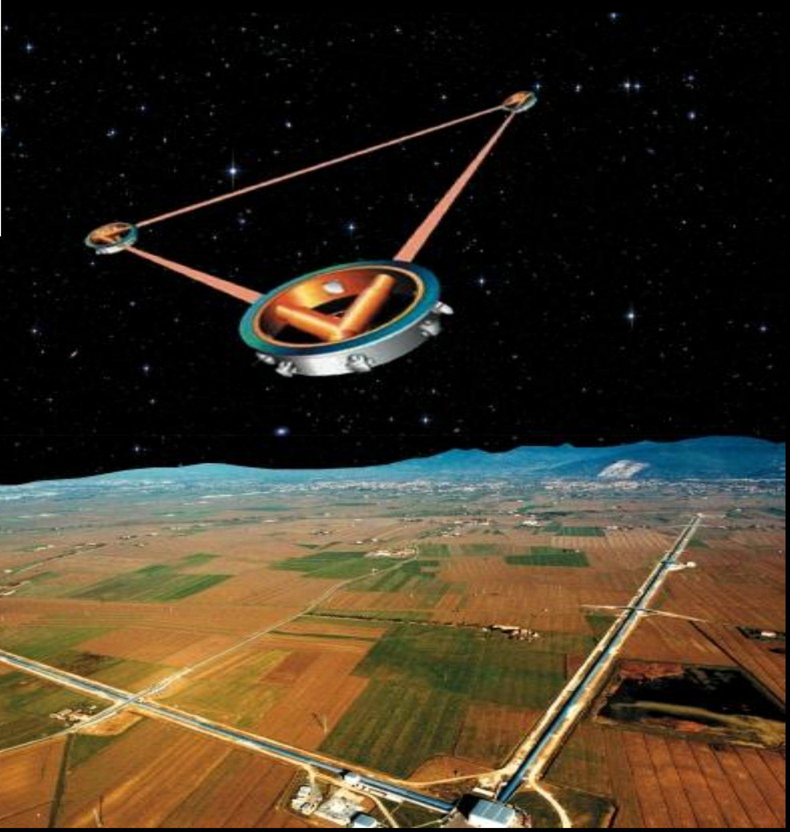
Positron excess :
waiting for AMS data

High energy Universe X, Gravitational waves

✓Today, there is a strong expectation that success will finally be achieved during the next ten years, using a network of second-generation (or "advanced") laser interferometers in the United States, Europe, Japan and India

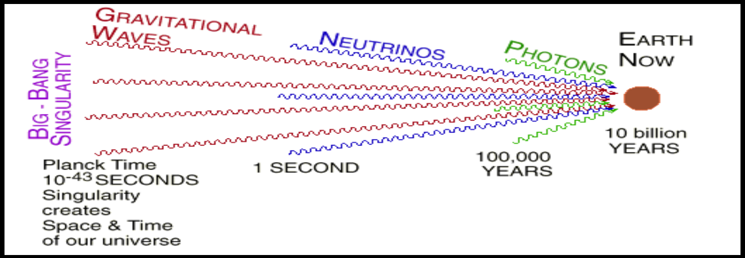






GW Sources

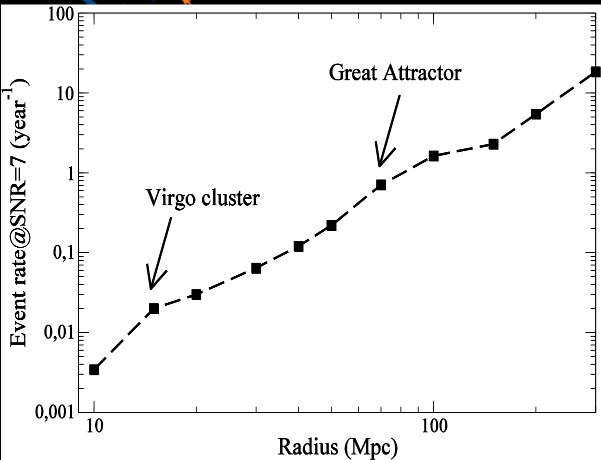
- ✓ **Binary fusion (NS-NS,BH-BH)**
- ✓ **Supernovae / GRBs: *"bursts"***
- ✓ **Pulsars : *"periodic"***
- ✓ **Cosmology *"stochastic background***



High energy Universe XI,
A worldwide GW antenna network

The GWIC community pioneered a network between the gravitational wave antennas in Europe and in the United States, with sharing of information and techniques, coordinated data-taking and joint publication of results. Other antennae are expected to come on-line (KAGRA in Japan, INDIGO in India) and join the network.

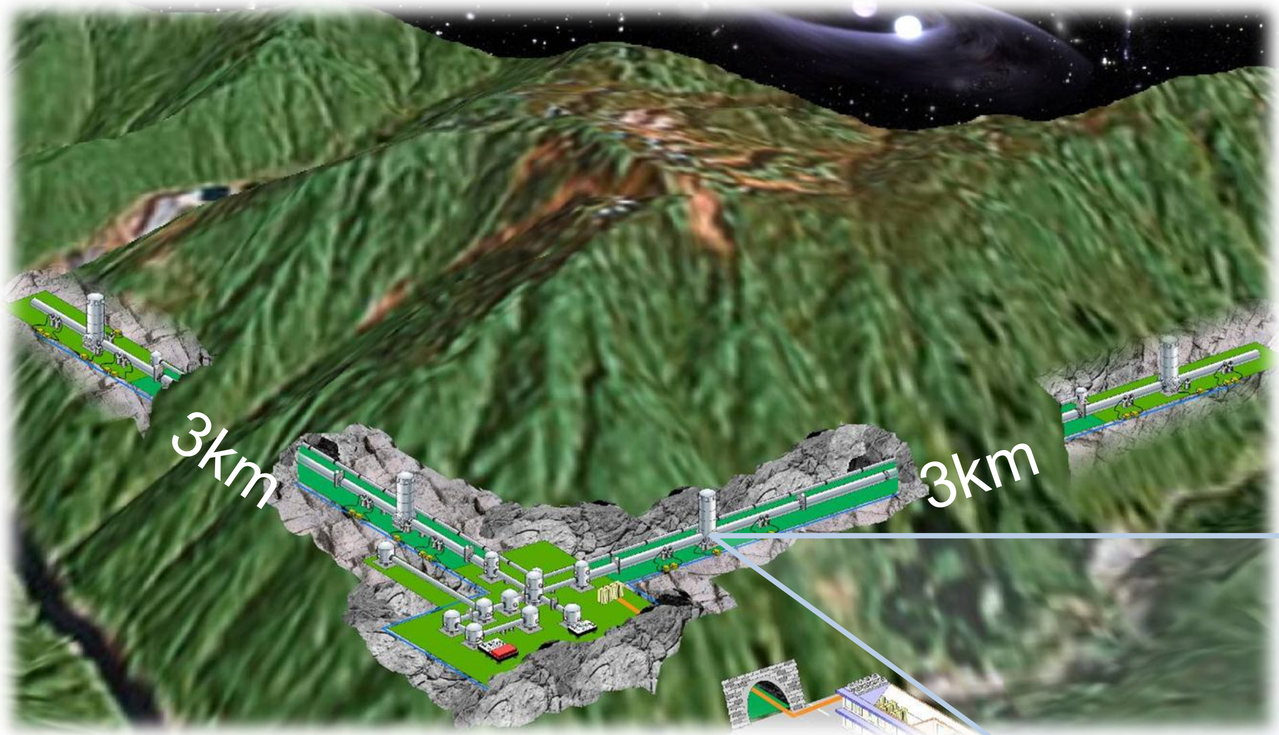
High Energy Universe XII, GW: a first detection by 2017-18?

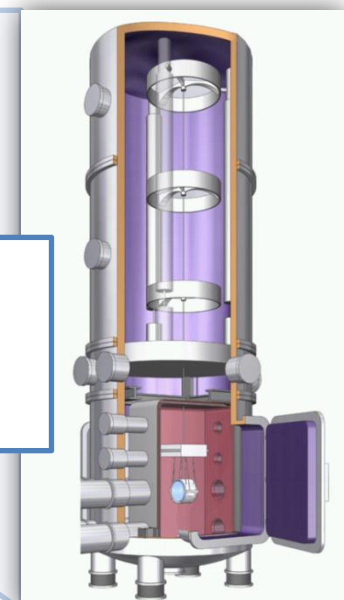


An inspiring example: World network of gravitational wave antennas:

- ✓ **Sensitivity increase**
- ✓ **Source direction determination**
- ✓ **Polarizations measurement**

Overview of the KAGRA project: Key features





The detector will be constructed underground Kamioka.
➔ Reduction of seismic noise (by approximately 10^{-2} @0.5-50Hz).

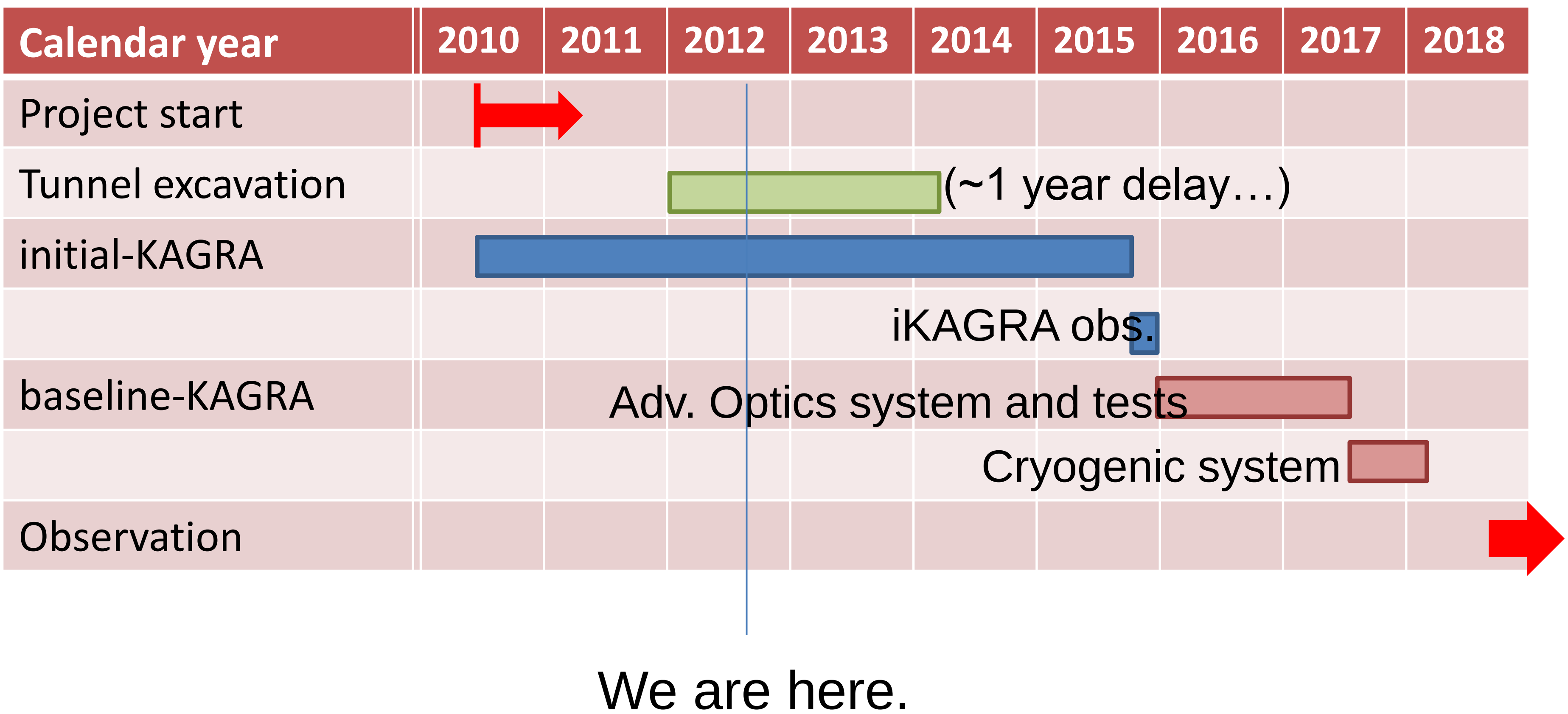
Cryogenic mirrors will be used to reduce the thermal noise.

Hoping to reach very high sensitivity.
(NS-NS merger within >200MPc to be observed.

Revised schedule

bottom-up schedule

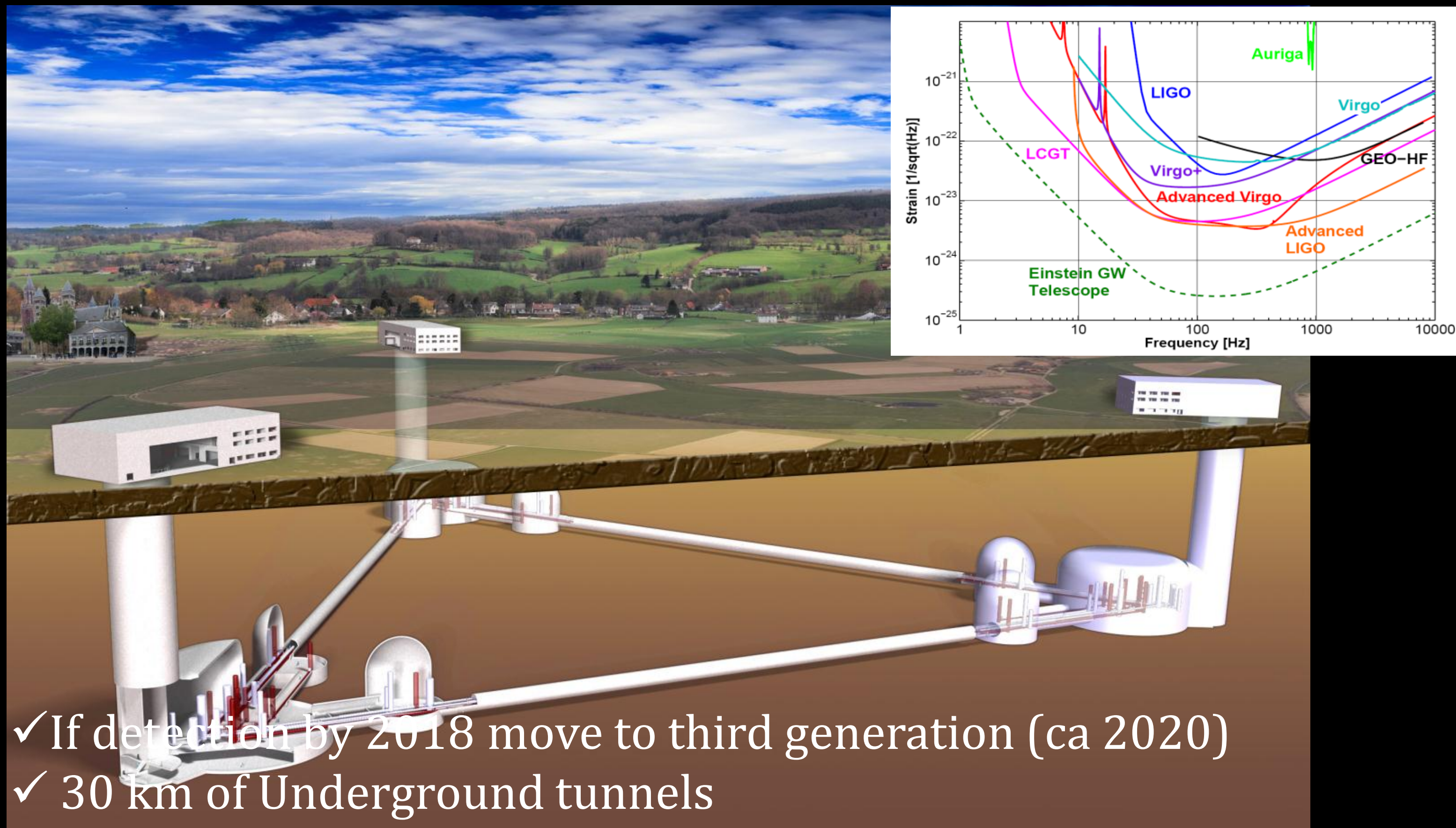
Feb.



ASPERA

High Energy Universe XIII, *Einstein Telescope (ET)*

EU funded Design Study Einstein Telescope completed

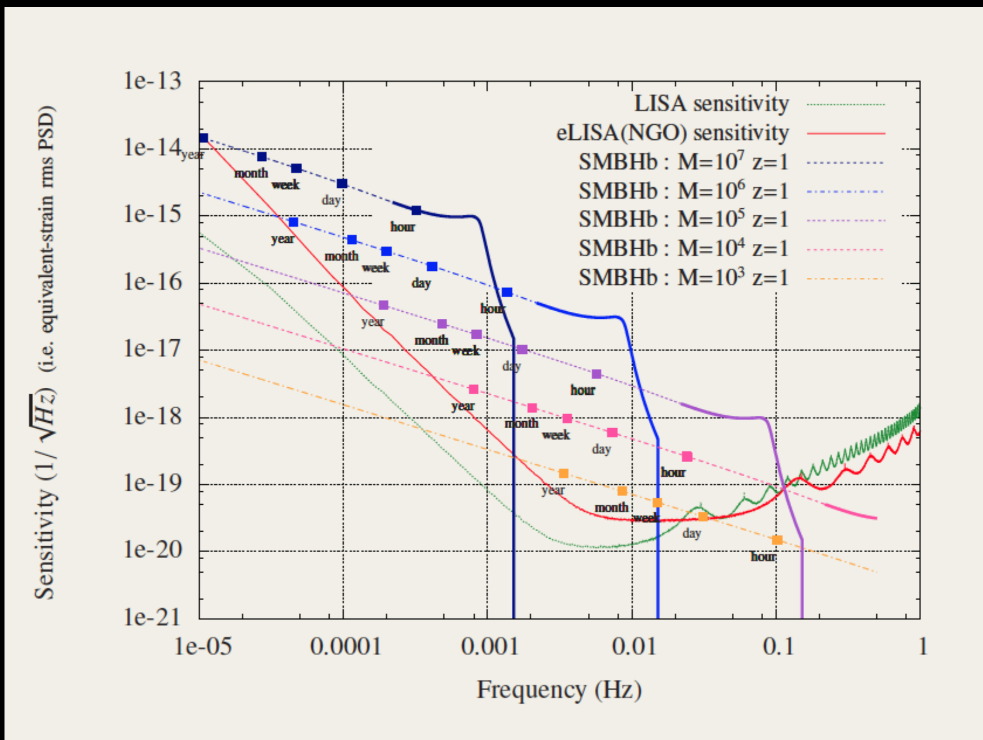


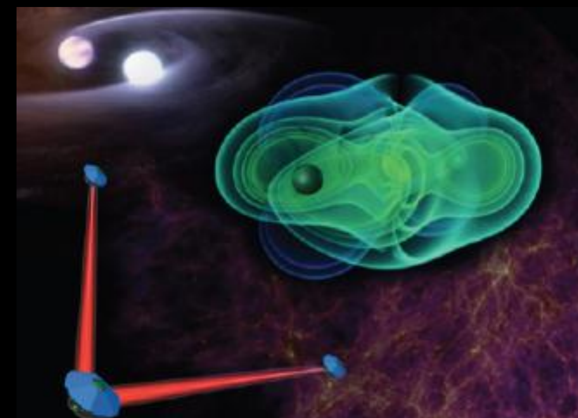
✓If detection by 2018 move to third generation (ca 2020)

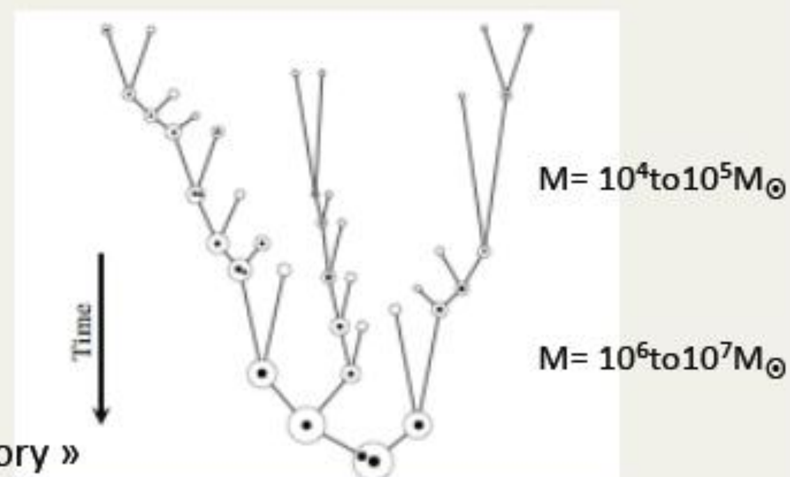
✓ 30 km of Underground tunnels

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 e**LISA/NGO** 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

High energy Universe XIV, eLISA/NGO







« merger tree history »

Conclusions

• Since 2008, roadmapping exercises, exchange of experts, information meetings for scientists and agencies although did not result in spectacular conversions eventually led to a clarification of the issues and/or the concentration to a small set of large infrastructures or closely knit networks in the domains of

- Dark Energy, Gravitational wave antennas and High Energy Universe observatories
- *We can then reasonably expect by 2020-2025 a % knowledge of the DE equation of state, a few GW detections and a better understanding of the violent phenomena in the Universe*

• In other domains, healthy competition is still the rule as in the case of :

- Direct dark matter detection , Double beta-decay experiments
- Here in order to obtain the necessary improvement of sensitivity by 2 orders of magnitude by moving to the ton or multiton scale detectors , more regional and interregional coordination (or avoidance of duplication) has to be implemented progressively (CDMS-EDELWEISS, MAJORANA-GERDA lead the way ?)

• Last but not least, and the closest to the ESG planning is the case of a large neutrino detector to measure the neutrino mass hierarchy and CP phase, where the synergy with a proton decay and astroparticle type of physics is largest and where the scale of the project demands interregional coordination for at least avoidance of duplication.

- This is where global coordination can accompany the necessarily agency/laboratory driven decision process.

Backup Slides

ASPERA

Budget and Personnel for Astroparticle Physics in Participating Countries

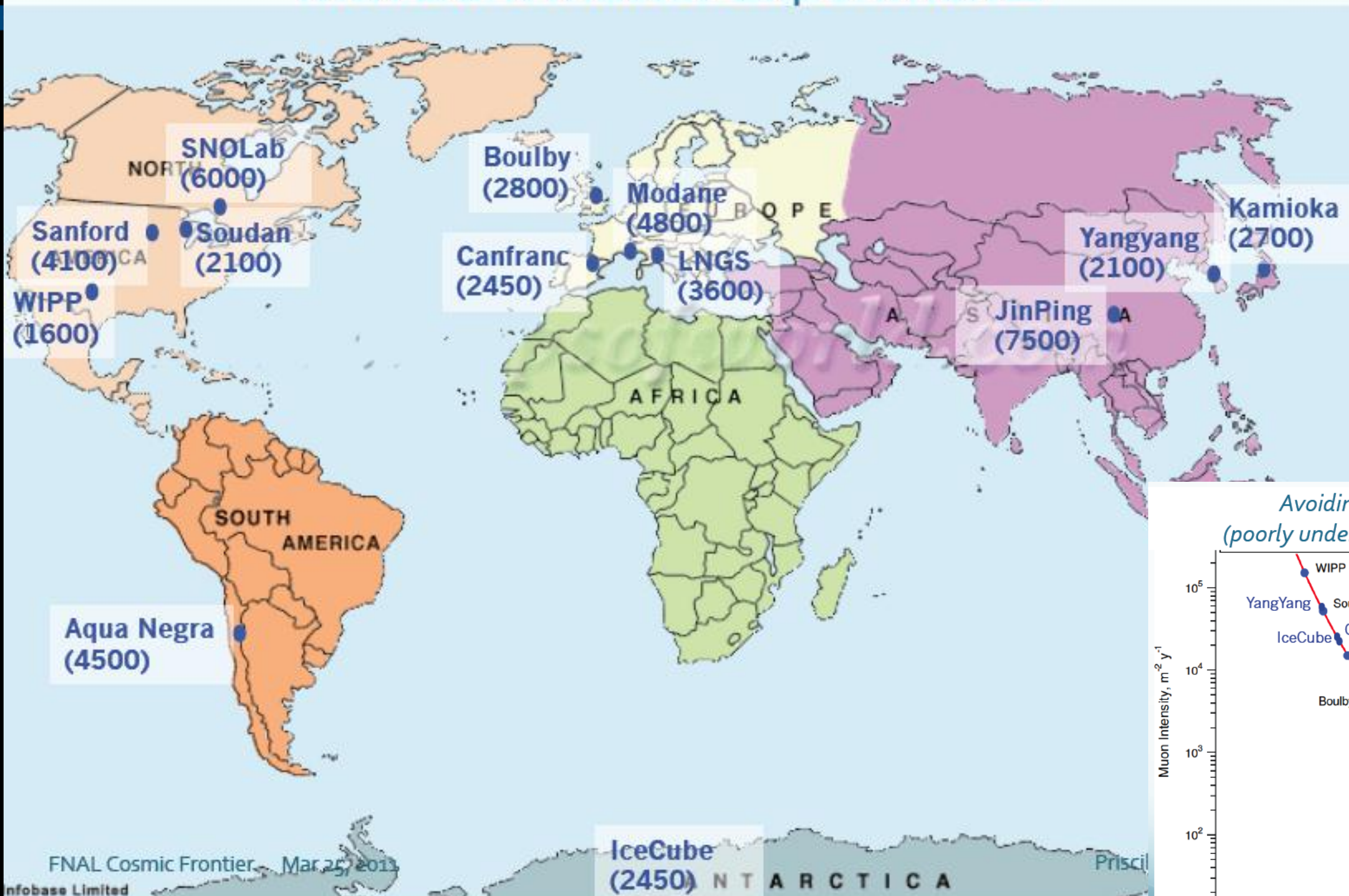
Annual Funding*	Lab Operation	Investment	Salaries	Other	Total
Europe	26	50.6	90.35	10	176.95
US	9.9	34.9	56.3	2.1	119.2
Canada	5	6	3	1.0	15
South America	0,95	1,42		0,2	2,57
Russia	3.5	2.5	6.0	0.5	12.5
India	1.5	2.0	1.0	0.5	5
China	3.5	5.6	4.6	0.5	14.2
Japan	14.0	13.2	24.4	0.4	52.0
Australia	0.3	0.3	1.4	0	2.0
TOTAL	64,35	116,2	187,05	15,2	399,42

*In Million Euros, Dollars or Okuyen, where an exchange rate of 1:1 was applied

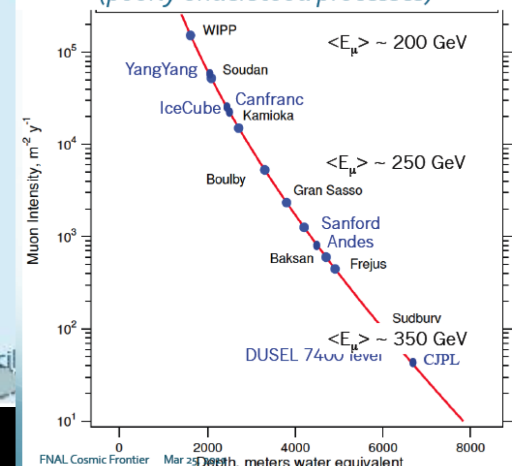
PERSONNEL (FTE)	Permanent*	Postdocs	Graduate Students	Other	TOTAL
Europe	1021	269	439	197	1926
U.S.	269	135	220	68	692
Canada	46	35	63	55	199
South America	61	22	40	23	146
Russia	500	60	50	100	710
India	45	5	20	0	70
China	100	20	90	35	245
Japan	150	48	98	29	325
Australia	6	4	20	0	30
TOTAL	2192	598	1040	505	4343

* Scientists and Engineers

Avoiding Neutrons: Worldwide Underground Labs with Dark Matter Experiments



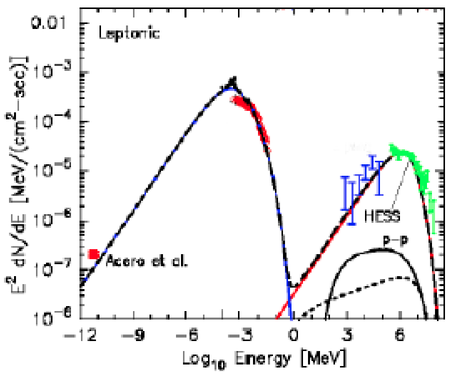
Avoiding Neutrons
(poorly understood processes)



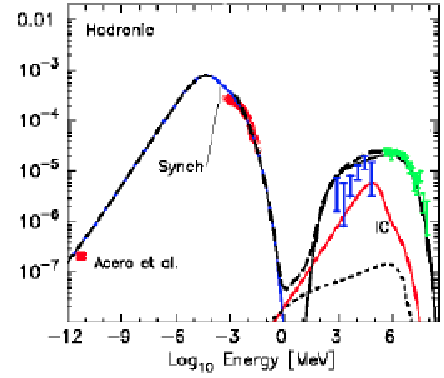
Searching for the origin of CR

Ex: SNR RXJ1713.7-3946

«Leptonic» model best fits



«Hadronic» model best fits



📖 D. C. Ellison et al. ApJ, 712, 287 (2010)

Observations from FERMI now favour ICS production of γ

📖 Abdo et al. ApJ, 734, 28, 2011