Perspectives in Astroparticle Physics

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APPEC (Astroparticle Physics European Consortium)

Astroparticle Physics, a definition once more: Connecting scales

Two fundamental and interconnected themes:

The evolution of the Universe, from the Big Bang or the primordial inflation up to its present structure: Addressing the issues of inflation, dark matter and energy, as well as these of the neutrino sector and the possibilities of new physical energy scales and/or phase transitions between the electroweak and inflation scales or beyond.

The evolution – formation and destruction – of cosmic structures: How the particles of the Standard Model and possible new particles can influence the genesis, formation and destruction of cosmic structures? Topicality and urgency of multi-messenger studies of high energy photons, neutrinos, high-energy charged particles and gravitational waves.

The theme of the “dark sector” subtending visible structures associated with this of the “violent sector” providing regulation of structure formation through events mixing different distance scales, form the ultimate canvas (the “spider web weaved across the sky”) of our theoretical and experimental quest.

From the APPEC Scientific Advisory Committee (SAC)* Roadmap

If one attempts to chart the future discoveries and corresponding theories that will be tested, one could expect in the next decade or two:

1. The understanding of the neutrino sector and its cosmological role, in particular their number, type and masses.

2. Large theoretical and experimental progress in the understanding of inflation, in the dark matter quest, reaching close to the parameter limits of current theories and the precise study of the parameters of the equation of state of dark energy.

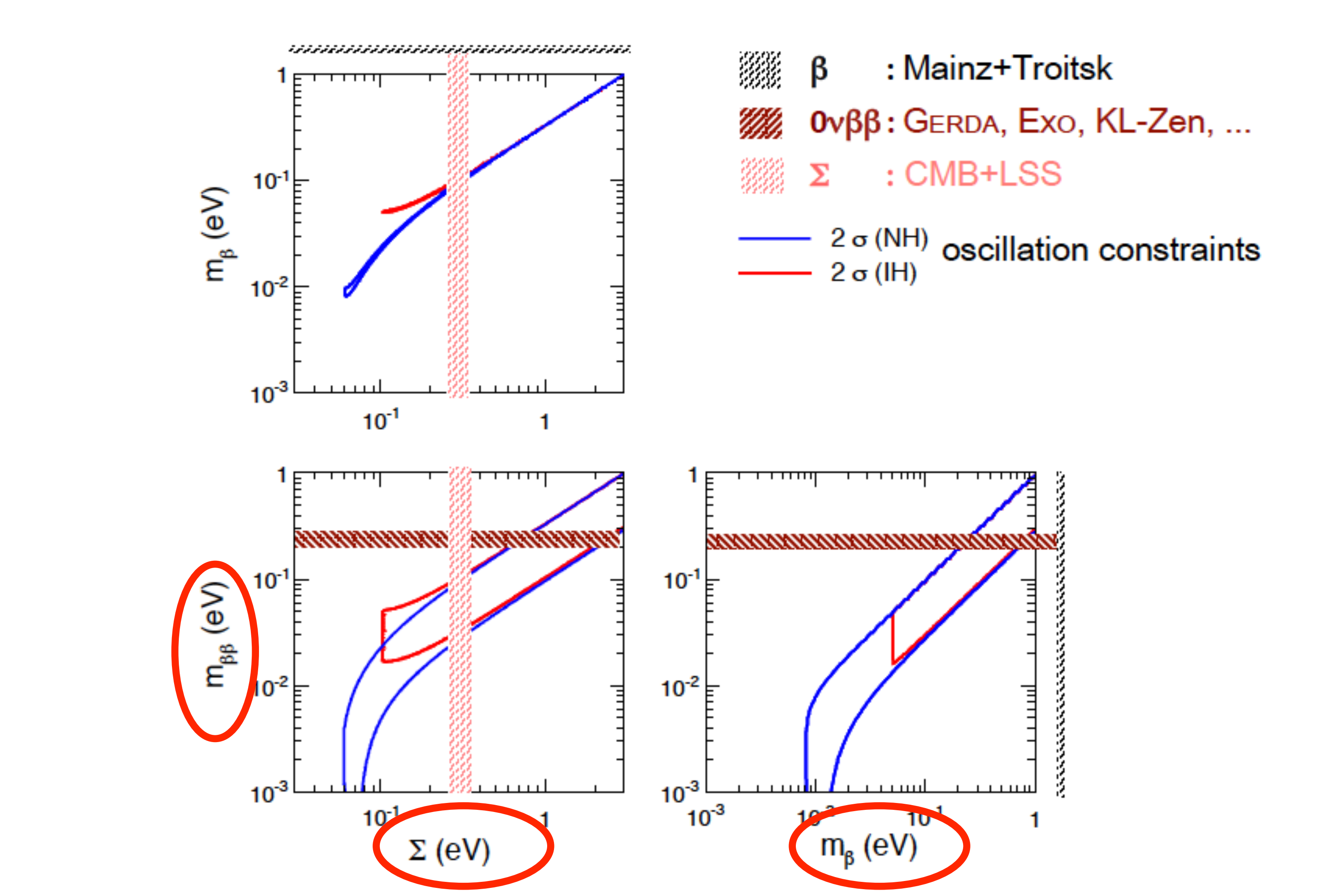
3. The consolidation of the recently opened high energy gamma ray astronomy and the opening of the new astronomies: neutrinos, gravitational waves and high energy cosmic rays

* A. Masiero (chair), Michal Ostrowski, Mauro Mezzetto, Gisela Anton, Laura Baudis, Jocelyn Monroe, Petr Tiniakov, Jo van den Brand, Patrick Sutton, Ramon Miquel, Zito Marco, Andrea Giuliani, Felix Aharonian, Pierre Binétruy, Ignatios Antoniadis, Yifang Wang, Francis Halzen, Hank Sobel, S.Katsanevas (APPEC)

From the APPEC
Scientific Advisory Committee (SAC)* Roadmap

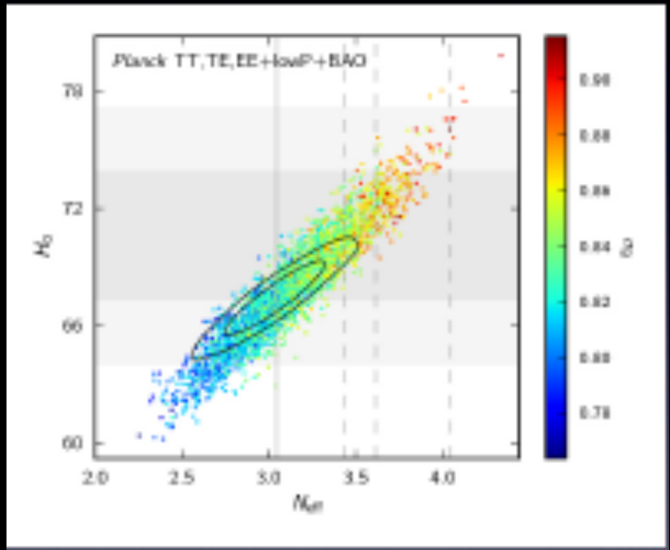
A. Understanding of the neutrino sector and its cosmological role
(mass, Majorana-Dirac, CPviol, Sterile?)

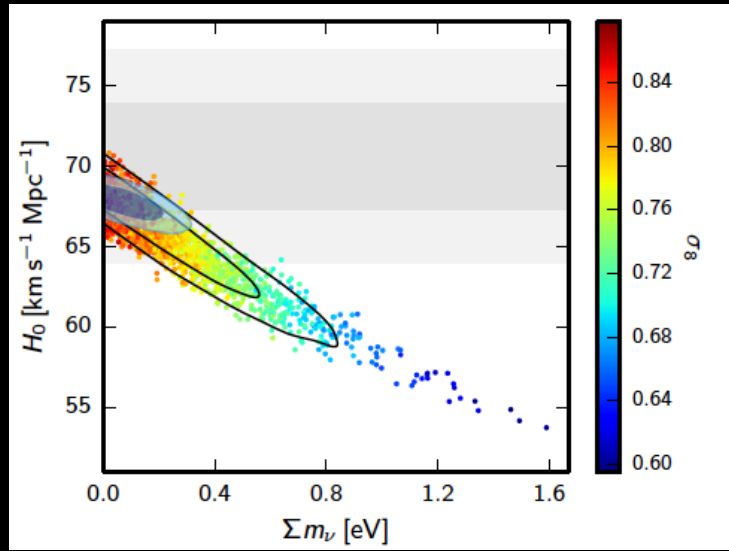
Neutrino mass parameter interconnected searches



From Fogli, Lisi,Marrone, Montanino, Palazzo, Rotunno 2013

Σm_ν from Cosmology

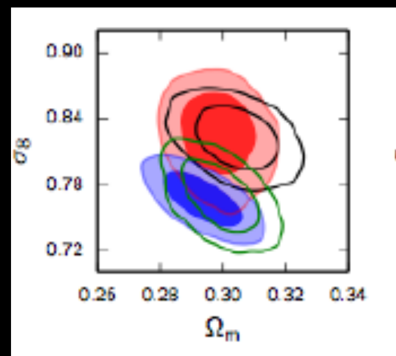




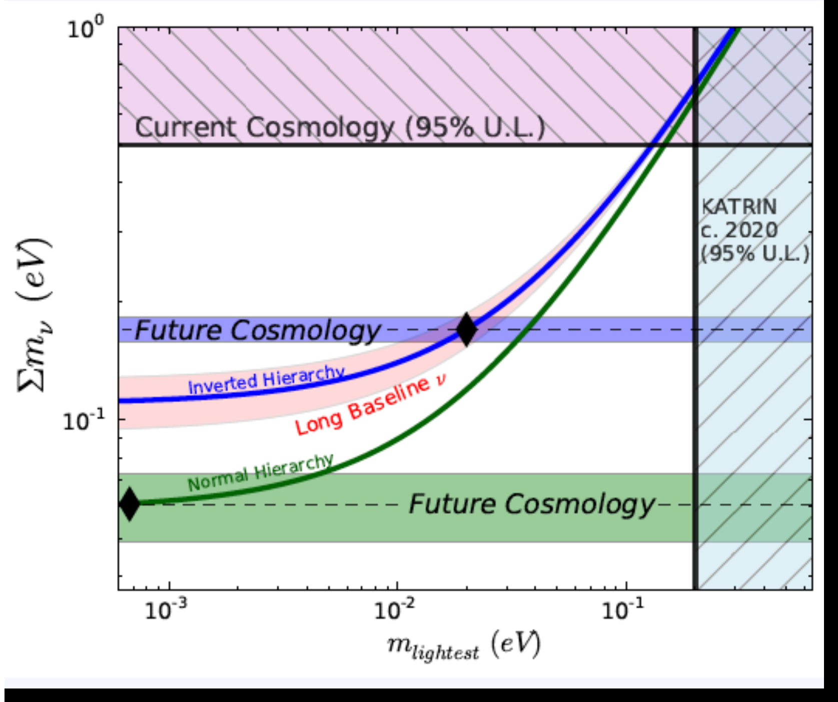
$$\sum m_\nu < 0.21 \qquad N_{eff} = 3.15 \pm 0.23 \quad \text{Planck TT} \qquad \text{+lowP+BAO}$$

$$\sum m_\nu < 0.17 \qquad N_{eff} = 3.04 \pm 0.118 \quad \text{Planck TT,TE,EE} \quad \text{+lowP+BAO}$$

Tension with Large Scale Structure (Planck SZ, X-ray) , in the σ_8-Ω_m plane could be alleviated with sterile neutrinos since sterile neutrinos are degenerate with σ_8. In general « recent » variables (H_0, σ_8) below values measured at recombination. An active topic of research, astrophysics uncertainties. Not yet at the maturity of the previous measurements of masses and $N_{eff.}$ (see Verde, Viel, Matarrese this conference)



Future Σm_ν measurements (2025-2030)



Forecast Sensitivities

	$\sigma(\Sigma m_\nu)$	$\sigma(N_{\rm eff})$
Galaxy Clustering (current CMB):		
Planck + BOSS BAO	100	0.18
Planck + BOSS galaxy clustering	46/68	0.14/0.17
Planck + eBOSS BAO	97	0.18
Planck + eBOSS galaxy clustering	36/52	0.13/0.16
Planck + DESI BAO	91	0.18
Planck + DESI galaxy clustering	**17/24**	0.08/0.12
CMB Lensing (current galaxy clustering):		
Stage-IV CMB	45	**0.021**
Stage-IV CMB + BOSS BAO	**25**	0.021
CMB Lensing + Galaxy clustering:		
Stage-IV CMB + eBOSS BAO	23	0.021
Stage-IV CMB + DESI BAO	**16**	0.020
Stage-IV CMB no lensing + DESI galaxy clustering	15/20	0.022/0.024
Galaxy Weak Lensing:		
Planck + LSST	23	0.07
Planck + Euclid	25	NA†

CF5 Neutrino Paper

- **What if we do not detect the minimal model?**
  If the minimal neutrino sector, with $\Sigma m_\nu = 58$ meV and $N_{eff} = 3.046$, is ***not*** *robustly detected, it would imply something is "broken" in another aspect or aspects of cosmology, including possibly:* non-constant dark energy, a non-power-law primordial perturbation spectrum, extra particle or radiation species, non-zero curvature, as well as other possibilities, e.g., a nonthermal cosmological neutrino background.

$\sigma(\Sigma m_\nu)$ = 16 meV & $\sigma(N_{\rm eff})$ = 0.020

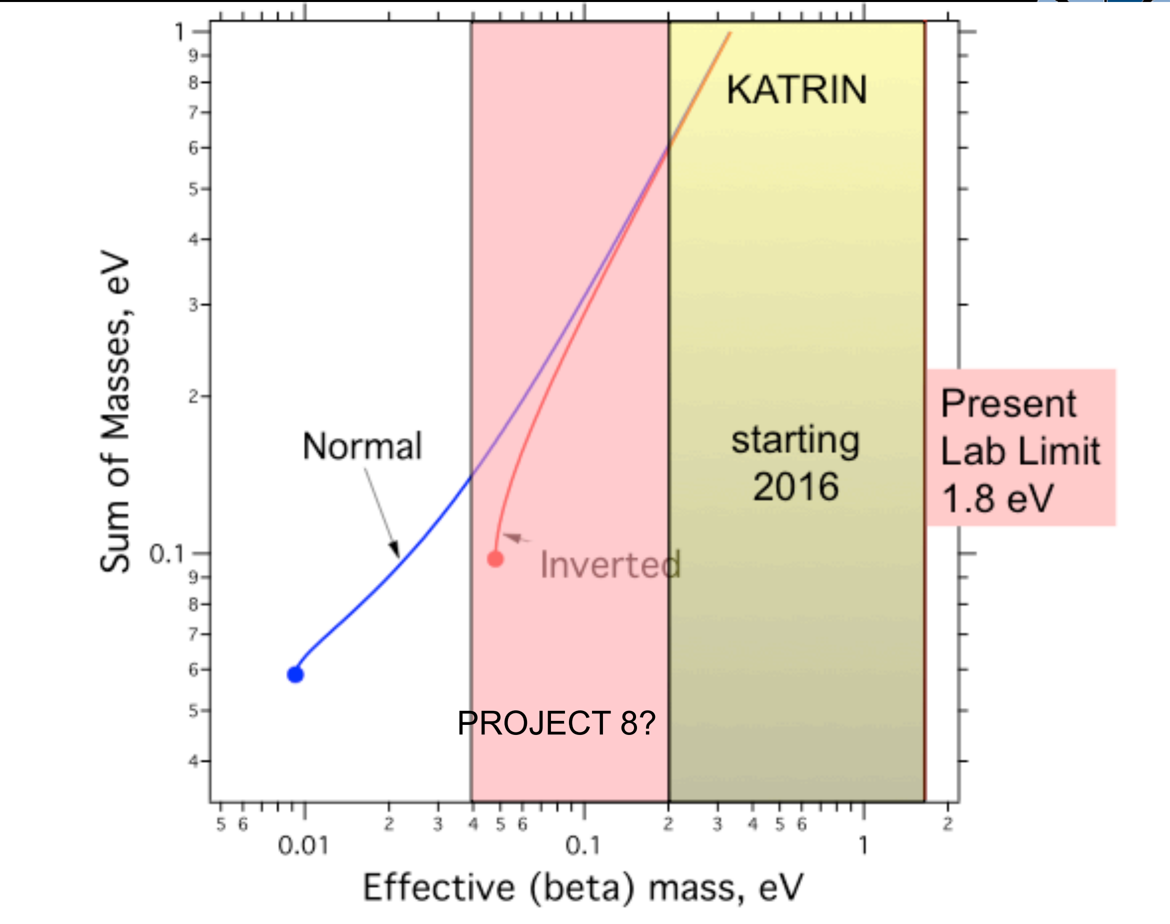
An order of magnitude improvement

m_β : KATRIN and PROJECT 8

Katrin 200 meV (2019)
Project 8 40 meV (202?)

Gatti, Ranitzsch, Oblath,

Also low T μ-calorimeters: source embedded inside the detector (ECHo, US-Ho, HOLMES)

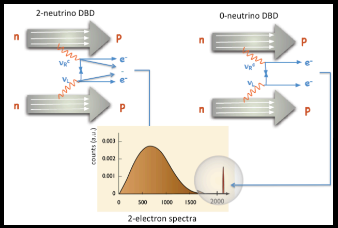


Project 8 Successful R&D

Phase: Timeline	I 2010-2014	II 2014-2016	III 2016-2017	IV 2018+
Science Goals	Proof of Principle; Kr Spectrum	T-He Mass Difference	$m_\nu < 2$ eV	$m_\nu < 0.2$ eV
Source	^{83m}Kr	Molecular ^{3}H	Molecular ^{3}H	Atomic ^{3}H
R & D Milestones	Single electron detection	Tritium spectrum; calibration and systematic error studies	High rate sensitivity	

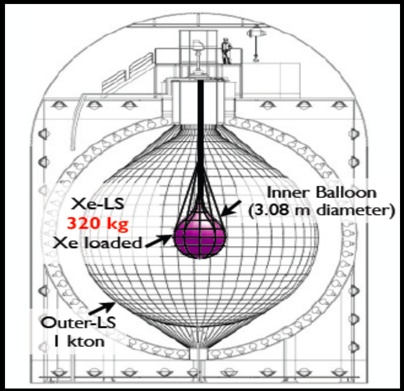
Cyclotron radiation from trium beta decay

$m_{\beta\beta}$ (2β0ν) detection technologies

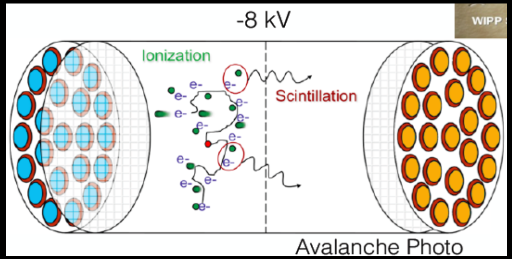


4 ways: 3 calorimetric + 1 tracking calorimeter

Xe



Xe and Te loaded LS
Kamlamd-Zen, SNO+

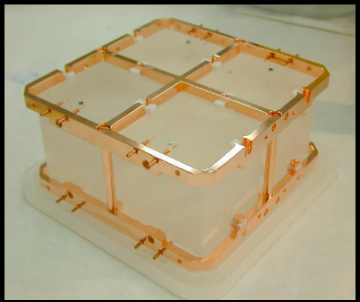


Liq and Gaz Xe
nEXO, NEXT

Ge

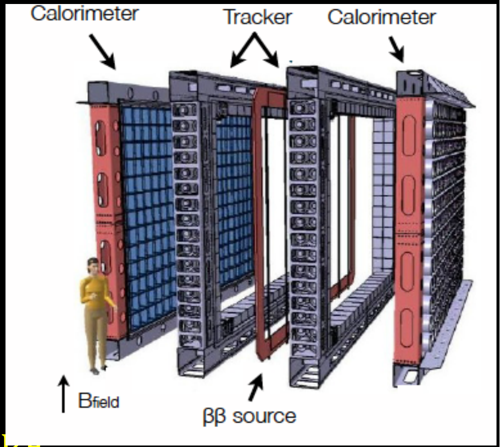
Ge Bolometers
GERDA, MAJORANA
MoU for 1t

Bolometer



Te, Se, Mo Bolometers
Cuore,
LUMINEU, LUCIFER, AMORE

Tracking-calo

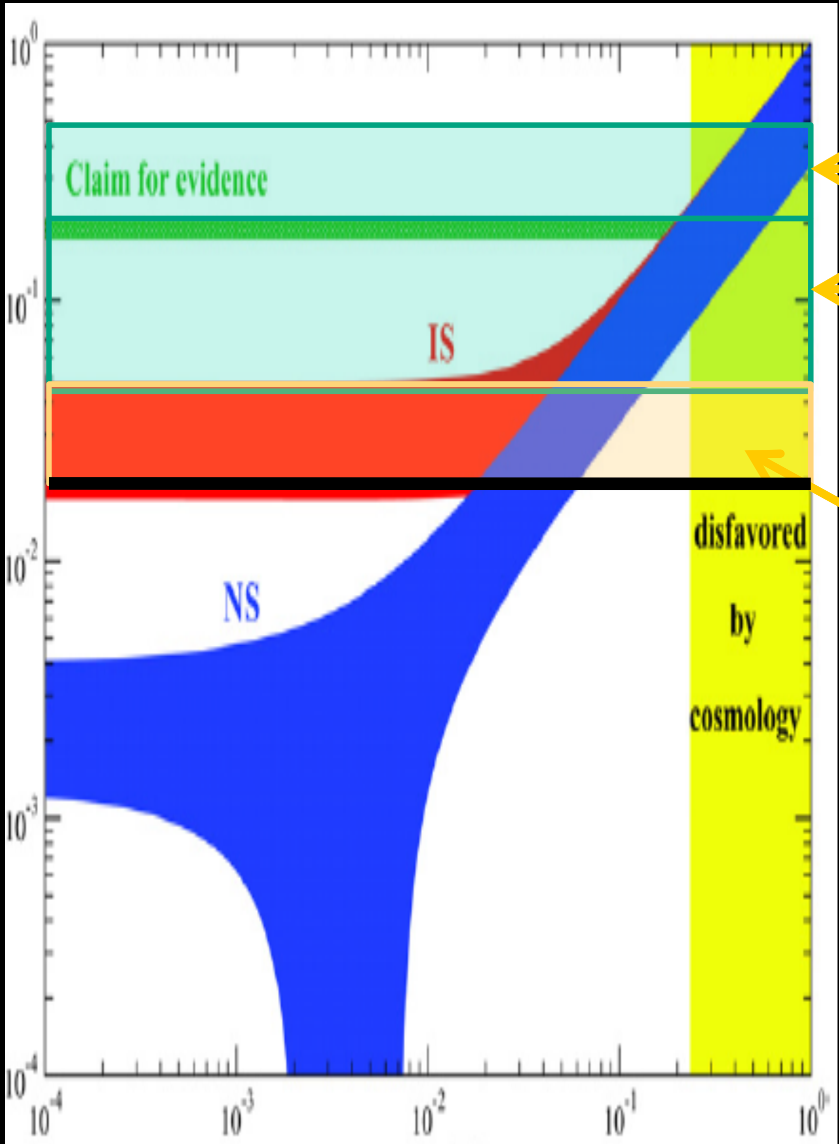


Many elements
SuperNemo
(eg Nd)

- 2nd generation for the inverse hierarchy region
- In US ➔ NSAC roadmap
- In Europe ➔ APPEC roadmap. Towards a decision in 2018.
  Global collaborations ? See 2nd ICMLNI 20-21 April 2015

Shimizu, Pocar, Macolino, Pavan, Remoto

0νββ approaching/exploring the inverted hierarchy the next decade



GERDA-1/KAMLAND/EXO-200 (140-300 meV, 10^{25}y) today

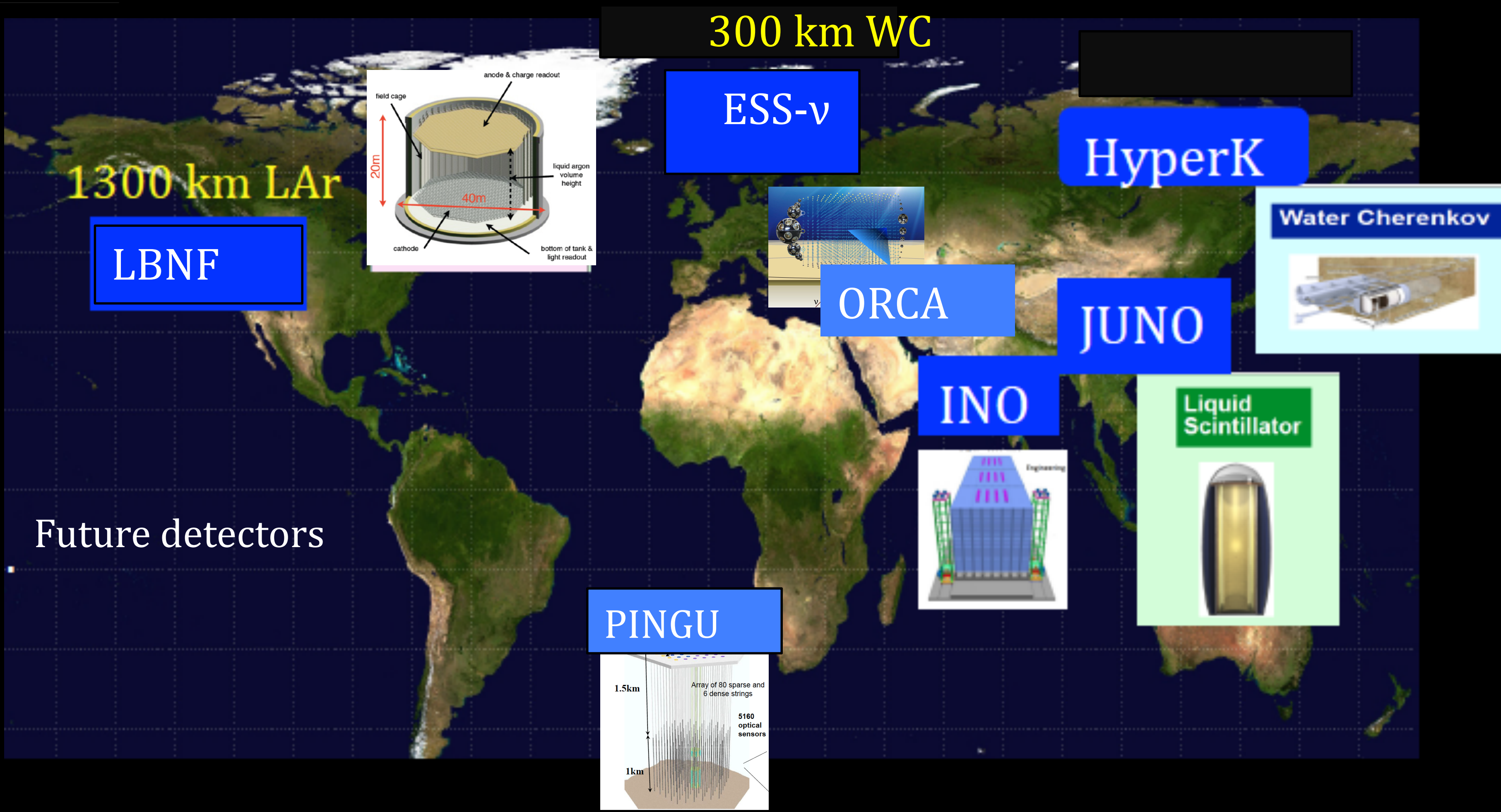
GERDA-2 (75 - 129 meV, 10^{26}y)
CUORE (51 – 133 meV)
NEXT, SuperNEMO (100Kg)
In 5-6 years, by 2020

20 mEV
0.5-5 evts/y/ton

Scintillating bolometers (350 kg, 5 y) (13 – 36 meV)
Initial nEXO (5 tons,10 y) (10 – 30 meV)
Similar sensitivites from GERDA-3/ Majorana and upgrade of KamLAND-Zen
Lower limit of IH by 2025 ?

Show stopper g_A quenching ? See Iachello this conference

Δm>0 OR Δm<0 Mass hierarchy



How soon ?

How many sigmas will be convincing proof ?

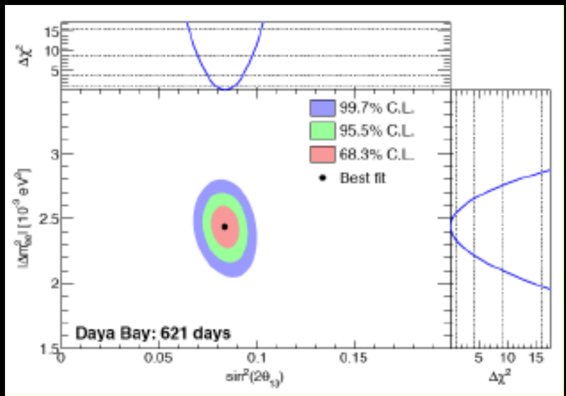
Knowledge early 2015 (T2K, DayaBay)

APPEC

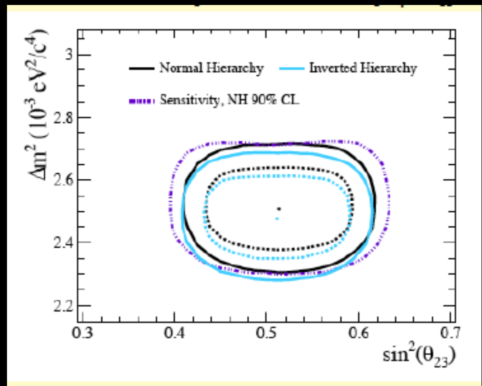
- Neutrino oscillations described by the PMNS matrix
  - 3 mixing angles, 2 mass differences, 1 complex CPV phase

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix}=\begin{pmatrix}\cos\theta_{12} & \sin\theta_{12} & 0\\ -\sin\theta_{12} & \cos\theta_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -\sin\theta_{13}e^{-i\delta} & 0 & \cos\theta_{13}\end{pmatrix}\begin{pmatrix}1 & 0 & 0\\ 0 & \cos\theta_{23} & \sin\theta_{23}\\ 0 & -\sin\theta_{23} & \cos\theta_{23}\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

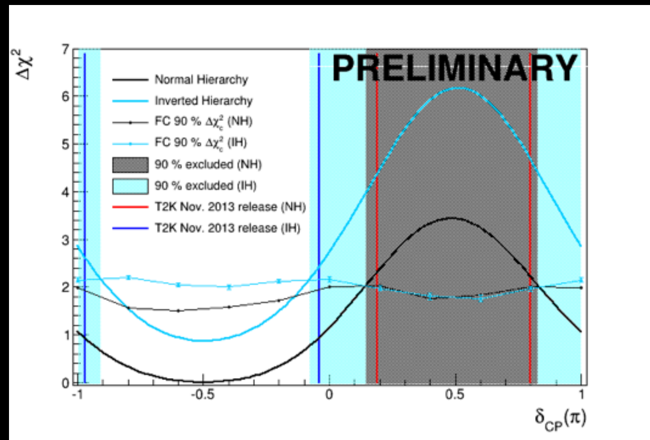
Solar and reactor	Interference	Atmospheric and accelerator
$\theta_{12} \sim 34°$	$\theta_{13} \sim 9°$	$\theta_{23} \sim 45°$
$\Delta m_{21}^2 \sim 7.6\text{x}10^{-5}$ eV^2	δ_{CP} = ??	$\Delta m_{32}^2 \sim 2.4\text{x}10^{-3}$ eV^2



$\sin^2(2\theta_{13}) = 0.084 \pm 0.005$



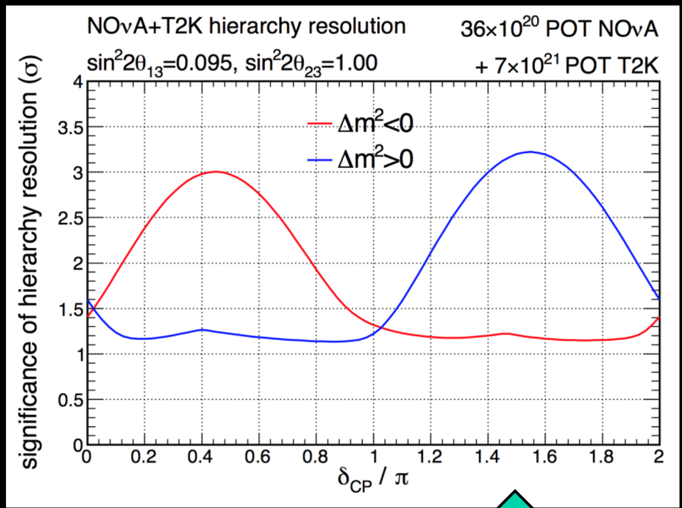
$\sin^2(2\theta_{23}) \approx 0.5 \pm 0.05$

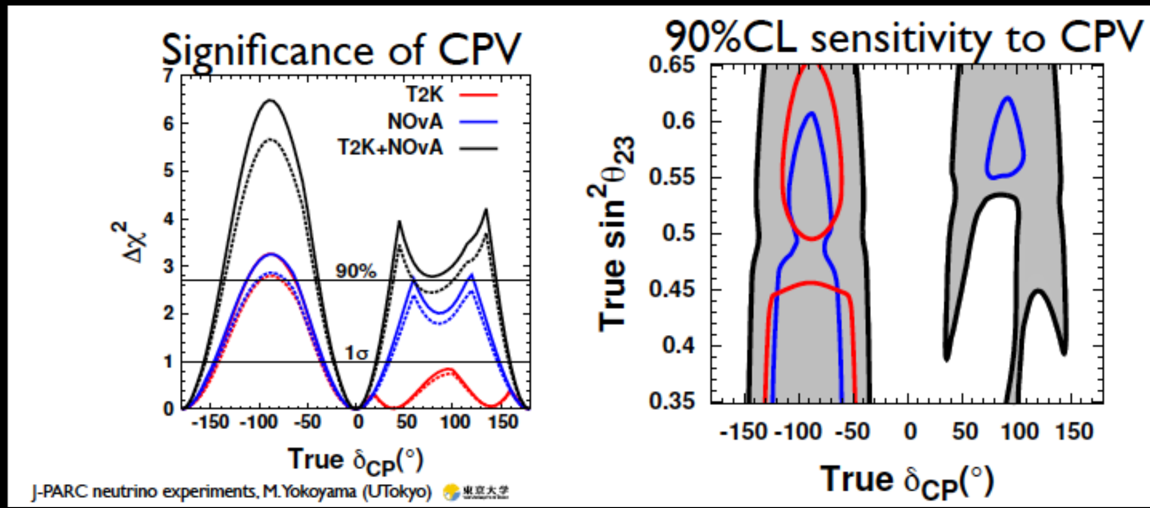


Start excluding 0<δ<π

Fogli, Nakahata, Paoloni, Buck, Seo, Zhan, Parke

T2K and NOVA expectations f or mass hierarchy CP violation in the next 5 years



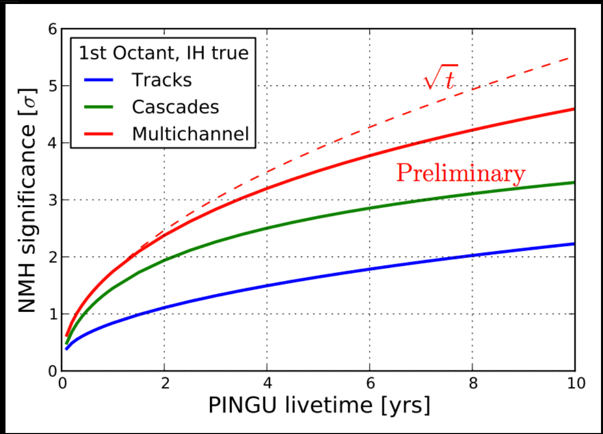


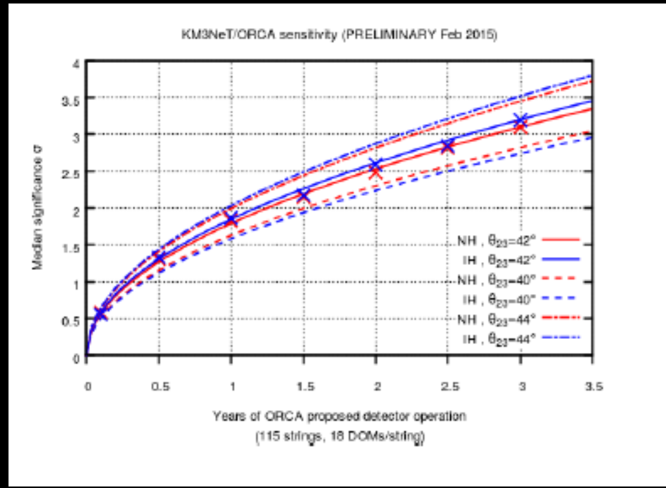
Current 1σ preferred value

- *Expect 2-3 σ effects on mass hierarchy with 50% probability*
- *Expect up to 2 σ effects on CP violation*

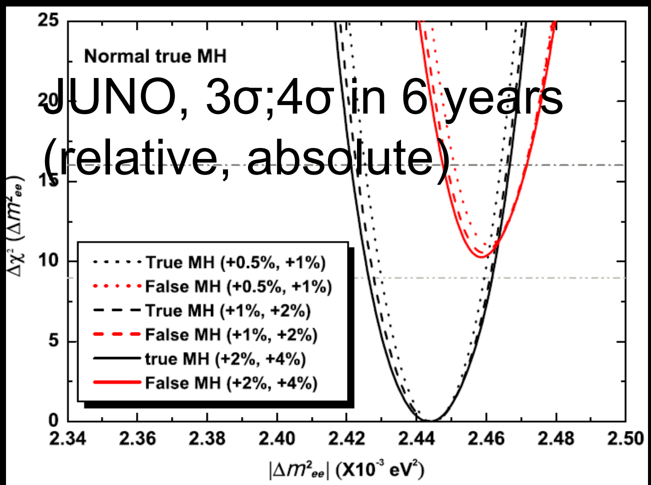
Yokoyama, Pawlosky

Mass hierarchy with atmospheric and reactor neutrinos

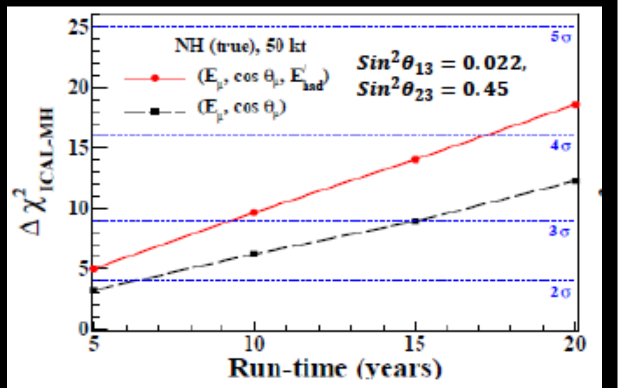


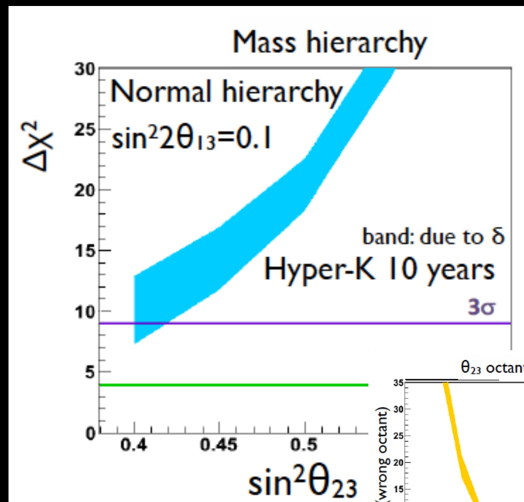


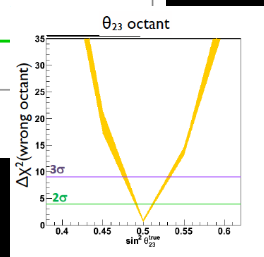
1. ORCA/PINGU 3σ in 3 years, (early 20's) 5σ in 10 years (end 2020's)
2. JUNO 3-4 σ in 6 years (ca 2025)
3. HK , INO 3-5σ ca 2035



JUNO, 3σ;4σ in 6 years (relative, absolute)

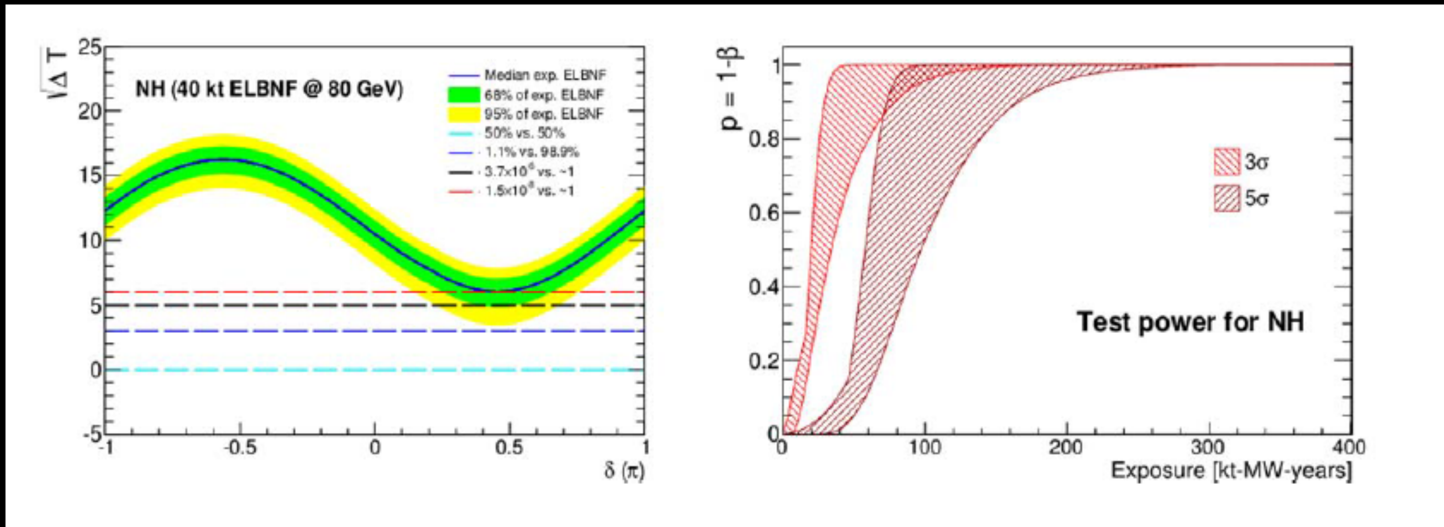






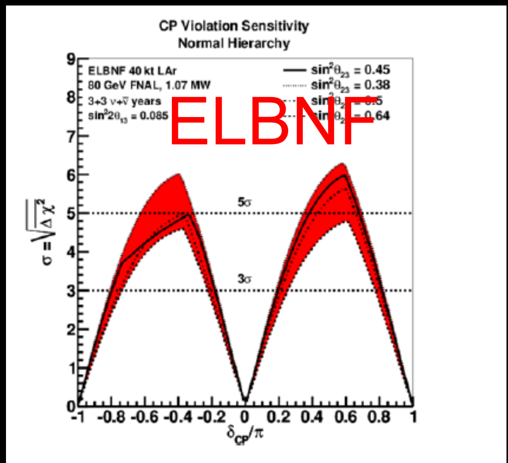
Cao, Majumder, Boser, Eberl

Mass hierarchy and CPviolation with a neutrino beam (ELBNF, HK, ESS)

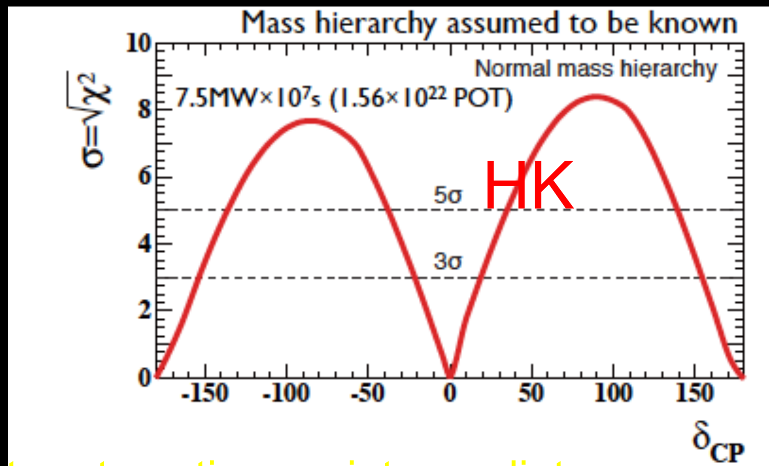


ELBNF
ca 2030

Hagedorn,
Pascoli,
Strait
Dracos,
Shiozawa



Similar perfrormances with ESS



Beware of cross section and other nuclear effect systematics, an intermediate program needed (Martini, McFarland)

Neutrino sterile “portal”

M_M	Motivation	ν-oscillations	laboratory searches	indirect signals	BBN	DM	Leptogenesis
$\lesssim$eV	ν-oscillations anomalies, dark radiation	masses by seesaw,[a] explain anomalies[b]	oscillation anomalies, β-decays	CMB: explain $N_{eff} > 3^b$ LFV, $0\nu\beta\beta^g$	may explain $N_{eff} > 3^b$	no	no
keV	DM	no if DM[c]	direct searches?[d], β-decays	if DM:nuclear decays?[d], pulsar kicks, supernovae if not DM also LFV, $0\nu\beta\beta^g$	effect on N_{eff} too small if DM	good candidate	no
MeV	testability, why not?	masses by seesaw	intensity frontier	$0\nu\beta\beta$	constrains $M_I \gtrsim 100$ MeV	no[e]	possible (fine tuning)
GeV	testability, minimality	masses by seesaw	intensity frontier	EW precision data, LFV $0\nu\beta\beta$, lepton universality	unaffected	no[e]	possible
TeV	minimality, testability	masses by seesaw	LHC, FCC	EW precision data, $0\nu\beta\beta$, LFV[f] lepton universality	unaffected	no[e]	possible
$\gg$ TeV	grand unification, “naturally” small ν-masses	masses by seesaw	too heavy to be found	$0\nu\beta\beta$, LFV[f]	unaffected	no[e]	works naturally

Colour code: green = can affect, red = does not affect

Dewes

Sterile neutrinos at all scales:

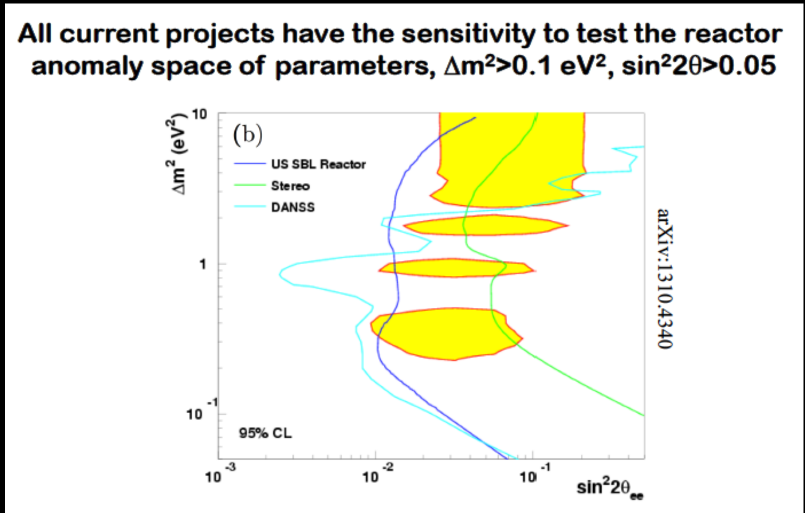
- <eV ν-oscillation anomalies $\nu_e, \bar{\nu}_e$ disappearance $\bar{\nu}_\mu \to \bar{\nu}_e$ appearance
  - Experimental program in development
- keV to TeV theoretical needs (e.g. Higgs as the inflaton with N1(KeV) DM and N2,N2 (GeV)) or indirect « hints »
  - New experiments, analyses proposed
  - Also indirect effects e.g. double-beta decay

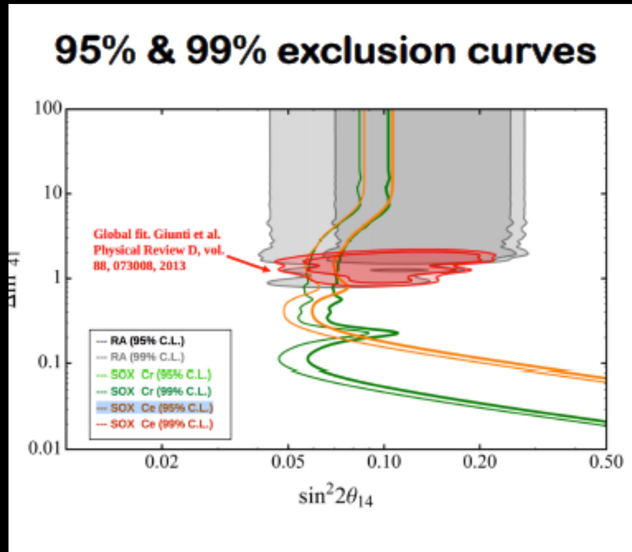
Smirnov, Giunti,

- >> TeV Good-old unification and leptogenesis
- Tensions with cosmology, unless new mechanisms…
- It is up to neutrino physicists to clear the situation.

Test sterile neutrino experimental anomalies. A medium-scale medium-term program in development

Kirby, Shaevitz, Lasserre, Dwyer,

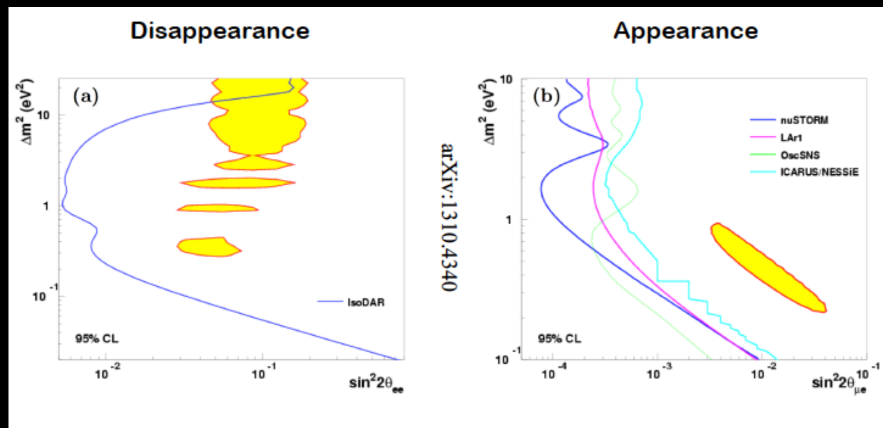




Test disappearance: Reactors: SOLID, STEREO, Prospect, Hanaro, CARR, DANSS, …

Test disappearance: Sources: CeSOX, CeLand, CeDayaBay LENS

Test disappearance, appearance: Short baseline program at LBNF (Lar1/Icarus/Nessie), MINOS +, Deadalus, ISODAR, JPARC, …
Synergies with new ν sources? CERN muon collider R&D, Nustorm, ESS ? (Rubbia, Long, Dracos)



Steps towards global coordination in the neutrino sector (APPEC)

APPEC

- P5 report released, 22 May
- CERN Council approved Medium term plan 18 June
- 1st International Meeting on Large Neutrino Infrastructures, Paris, 23-24 June (APPEC)
  - Common press release:
    - CERN Neutrino platform, LBNF,HK
- ELBNF collaboration formation procedures (see talk by J. Strait)
- 1st ELBNF meeting, MoU KEK/IPNS -ICRR January 2015

- 2nd International Meeting on Large Neutrino Infrastructures, Fermilab, 20-21 April 2015 (Fermilab/APPEC) After ELBNF collab.. Meeting. Also ICFA and APPIC.
  - https://indico.cern.ch/event/356320/overview
    - Gauge progress
    - Steps towards international decisions
    - Fund common R&D
    - Examine also Double-beta decay program

Nessi,
Strait

- LBNF/ELBNF CD-1 by mid-2015

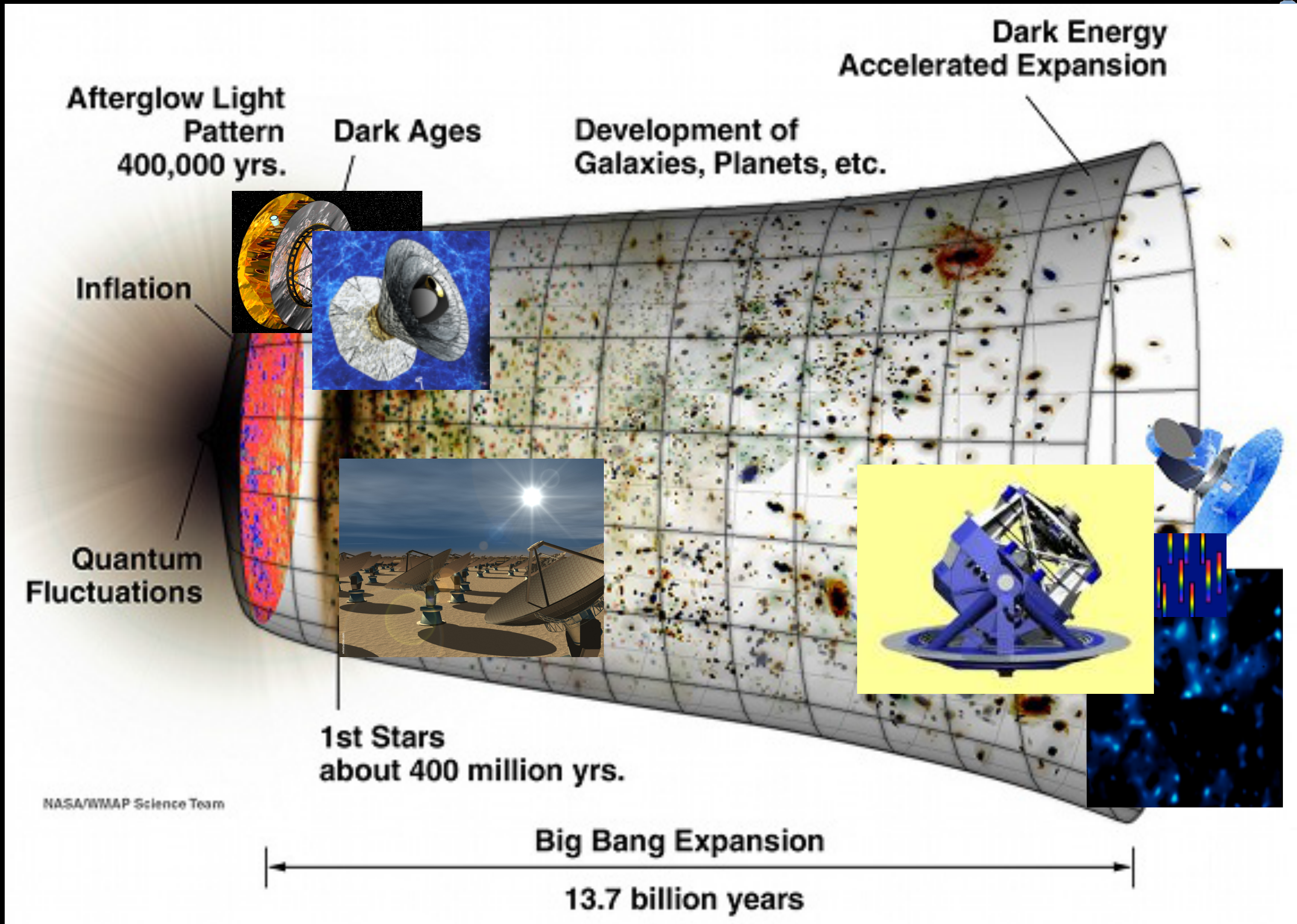
- ➔ Towards A 3rd meeting in Japan 2016.

From the APPEC
Scientific Advisory Committee (SAC)* Roadmap

B. Large theoretical and experimental progress in the understanding of inflation and large scale structure, in the dark matter quest, reaching close to the parameter limits of current theories and the precise study of the parameters of the equation of state of dark energy.

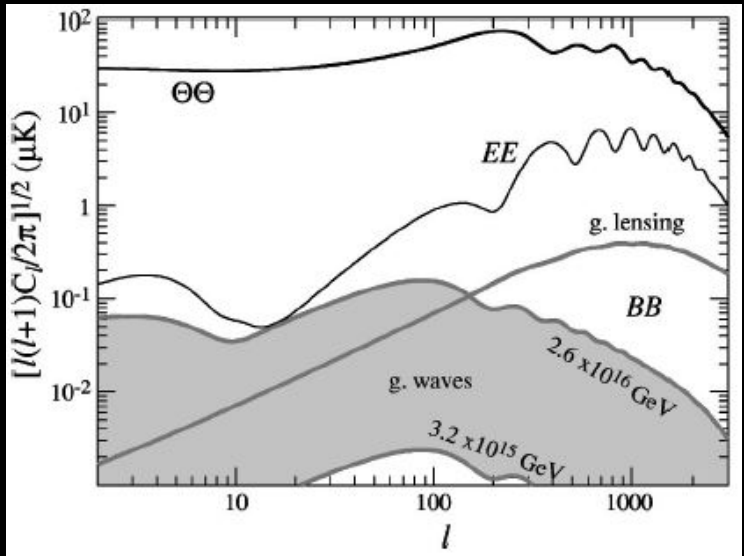
Cosmology: probing all the ages of the Universe

Matarrese



- Large Dark energy surveys (eBOSS, DESI, EUCLID, LSST, probing the « recent (z<1,5) Universe
- SKA and radio surveys probe the reionisation era (z = 7-10)
- PLANCK and ground based polarisation obseratories recombination and beyond

CMB in B-mode PLANCK/BICEP2



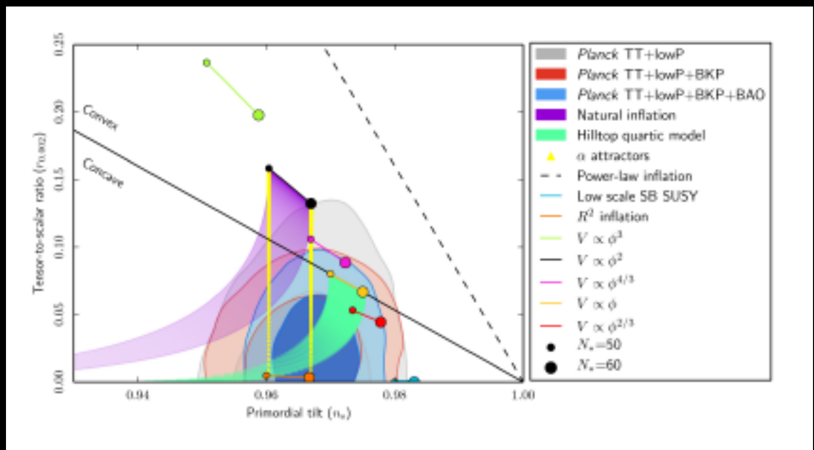
$$r = \frac{P_t(k_0)}{P_s(k_0)}$$

r=ratio of scalar to tensor modes (induced by inflation)

Small angles l>200 lensing giving access to neutrino mass

Large angles l<100 primordial spectrum In the simplest models *r* related to the GUT scale and proton decay (r<0.02 within HK sensitivities)

$$\tau(p \rightarrow \pi^0 + e^+) \approx 6 \times 10^{34} \times \left(\frac{r_{CMB}}{0,01}\right) \text{ years}$$



(Planck/BICEP2 r<0.09)

The 3 techniquesof large scale detectors give complementary information for proton decay

Outstanding physics goals

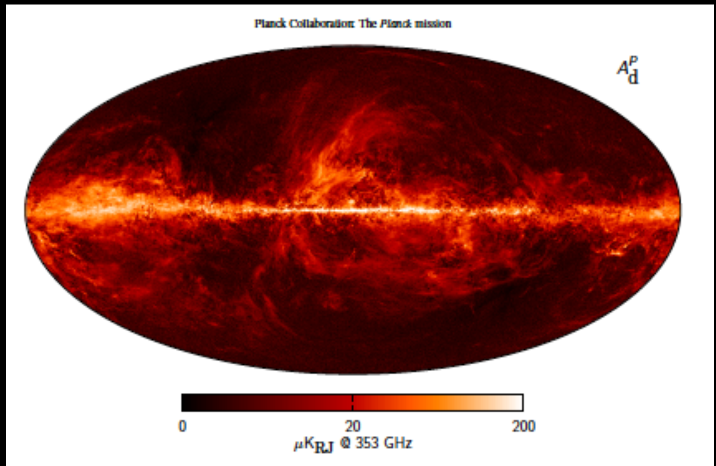
	ELBNFx2,5	JUNO x 2,5	HK
Total mass	100 Kton	50 kton	500 Kton
p -> $e\pi^0$ in 10 y	0.5 x 10^{35} y ε = 45%, ~1 BG event	?	1.2 x 10^{35} y ε = 17%, ~1 BG event
p -> ν K in 10 y	1.1 x 10^{35} y ε = 97%, ~1 BG event	0.4 x 10^{35} y ε = 65%, <1 BG event	0.15 x 10^{35} y ε = 8.6%, ~30 BG events
SN cool off at 10 Kpc	38·500 (all flavors) (64·000 if NH-L mixing)	20·000 (all flavors)	194·000 (mostly $\nu_e p \rightarrow e^+ n$)
Sn in Andromeda	7 - (12 if NH-L mixing)	4 events	40 events
SN burst at 10 Kpc	380 ν_e CC (flavor sensitive)	~ 30 events	~ 250 ν-e elastic scattering
DSN	50	20-40	250 (2500 with Gd)
Atm. neutirnos	~1·100 events/y	5600/y	56·000 events/y
Solar neutrinos	324·000 events/y	?	91·250·000/y
Geo-neutirnos	0	~ 3·000 events/y	0

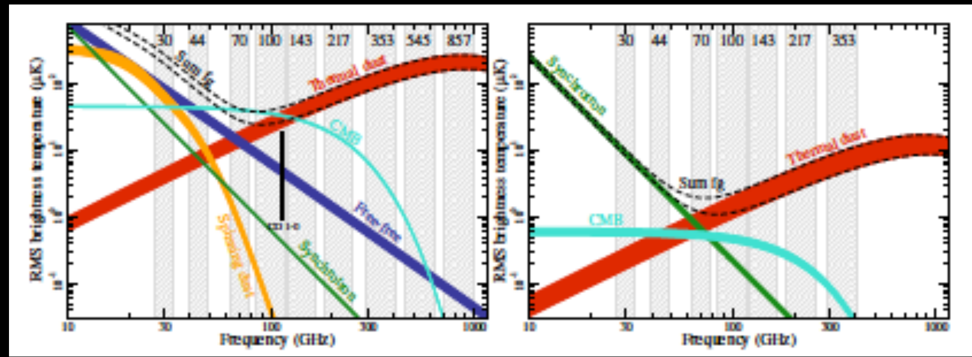
T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany

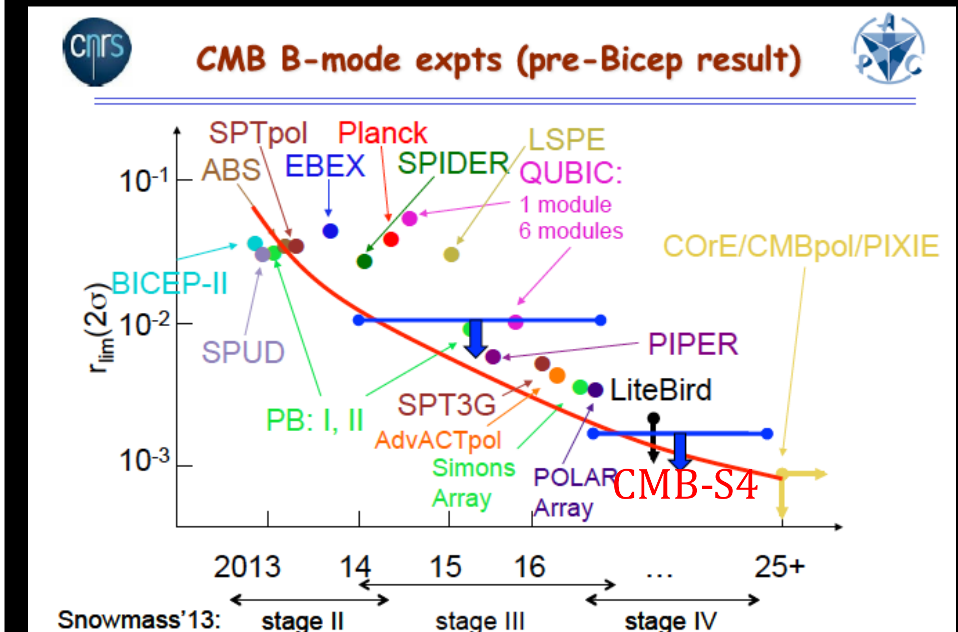
Mass, pattern recognition,flavour discimination, threshold

The future in CMB in B-mode

Beware of dust

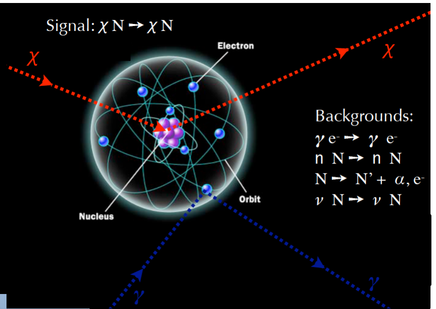




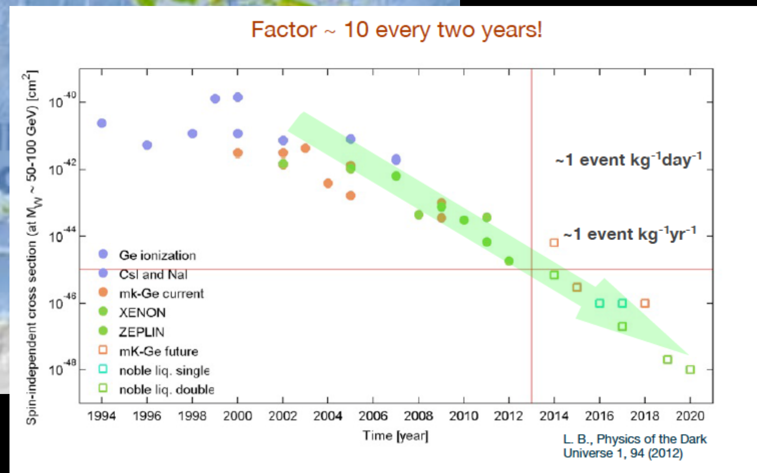


- On ground/balloon US leadership: ACT/ Polarbear/BICEP/SPT/SPIDER:ABS/CLASS/EBEX/ PIPER
  - P5 ➔ CMB-S4 (r=0,001)
- Japan: Groundbird, Litebird
- Europe Qubic, LSPE, QUIJOTE
- ESA-M4 CORE+ proposal rejected…
- APPEC organises a workshop on European policy on CMB B-pol 31 August/1 Sep, Florence
- Important detector R&D: TES, KIDS
- Further in the future precision measurements of the blackbody spectrum (SunyaeV, imprints of nuclei formation, DM annihilation, …)

Direct dark matter detection



Roncadelll,
Aprile,
Cirelli,
Ringwald
Galbiati



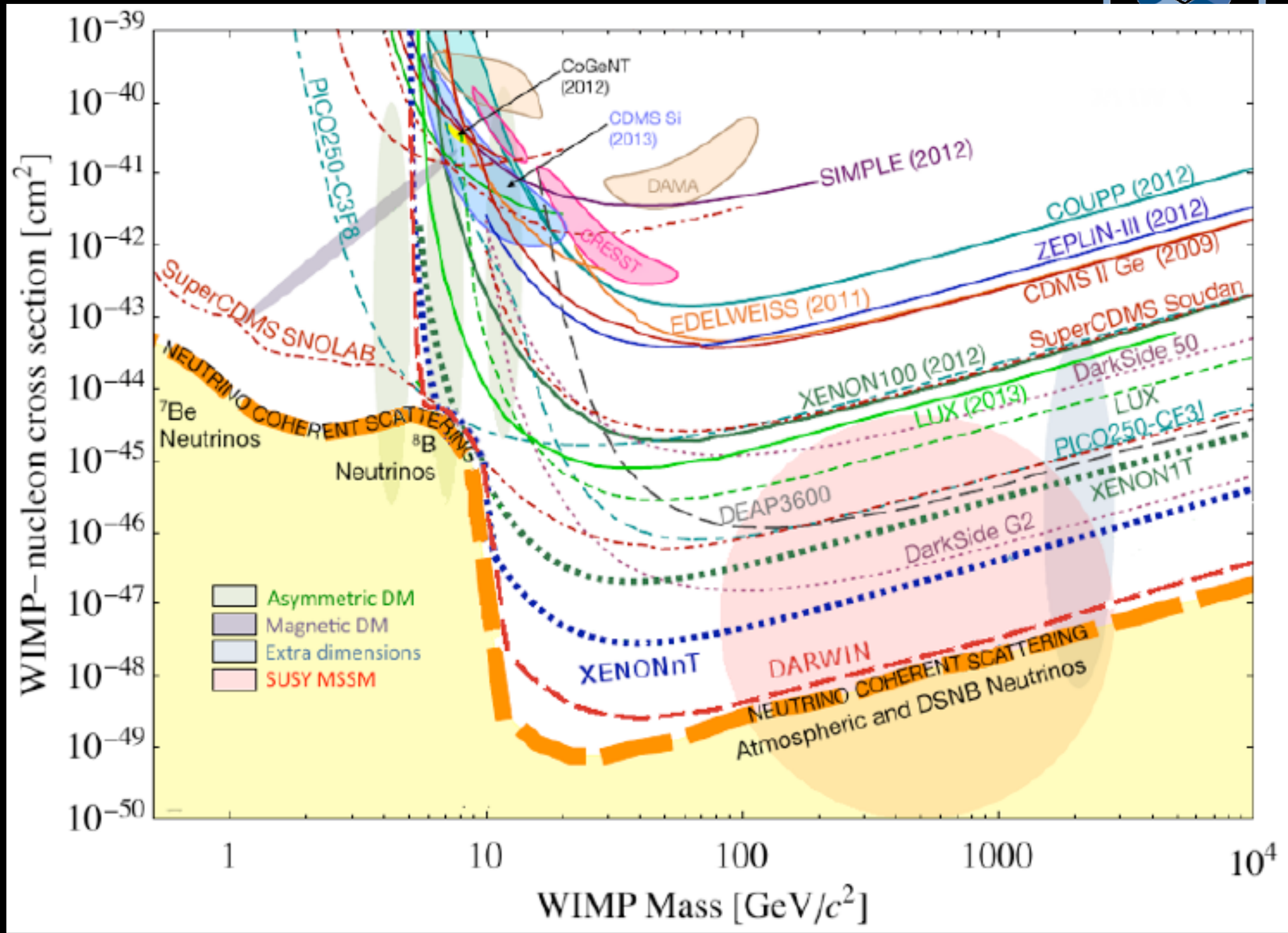
- WIMPs will be put in a severe, if not conclusive, test during the next 10 years. In case of discovery both accelerator and non-accelerator experiments will be needed to determine the physical properties of WIMPS.
- Great progress in axion searches also.

Direct Dark Matter direct detection

APPEC

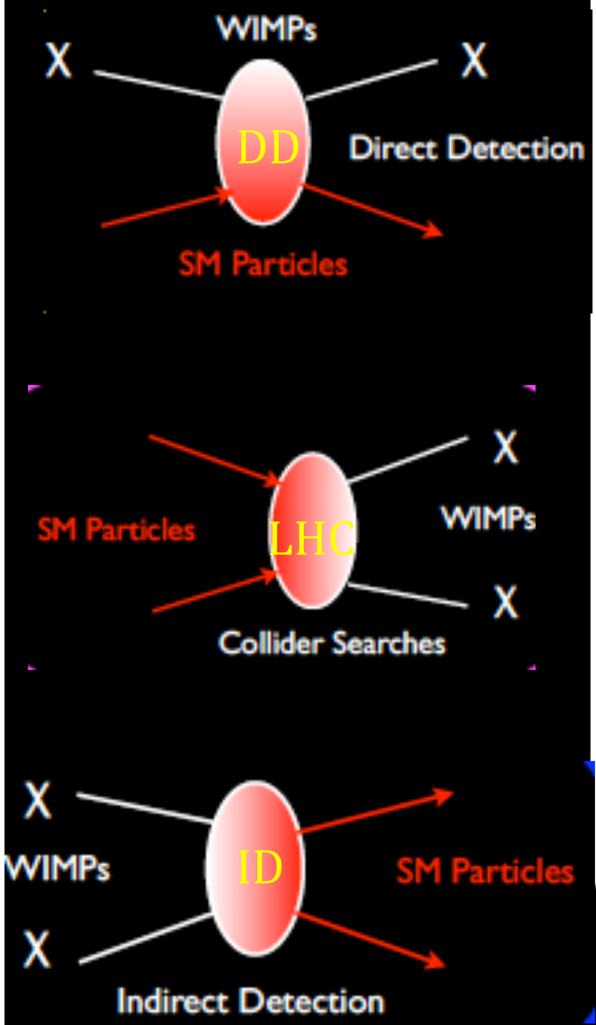
✓XENON100, LUX leading
✓XENON 1t start data taking 2015 and multi-ton follows
✓DarkSide-50 demonstrated zero background rejection, next step 5t and O(100t) ca 2020

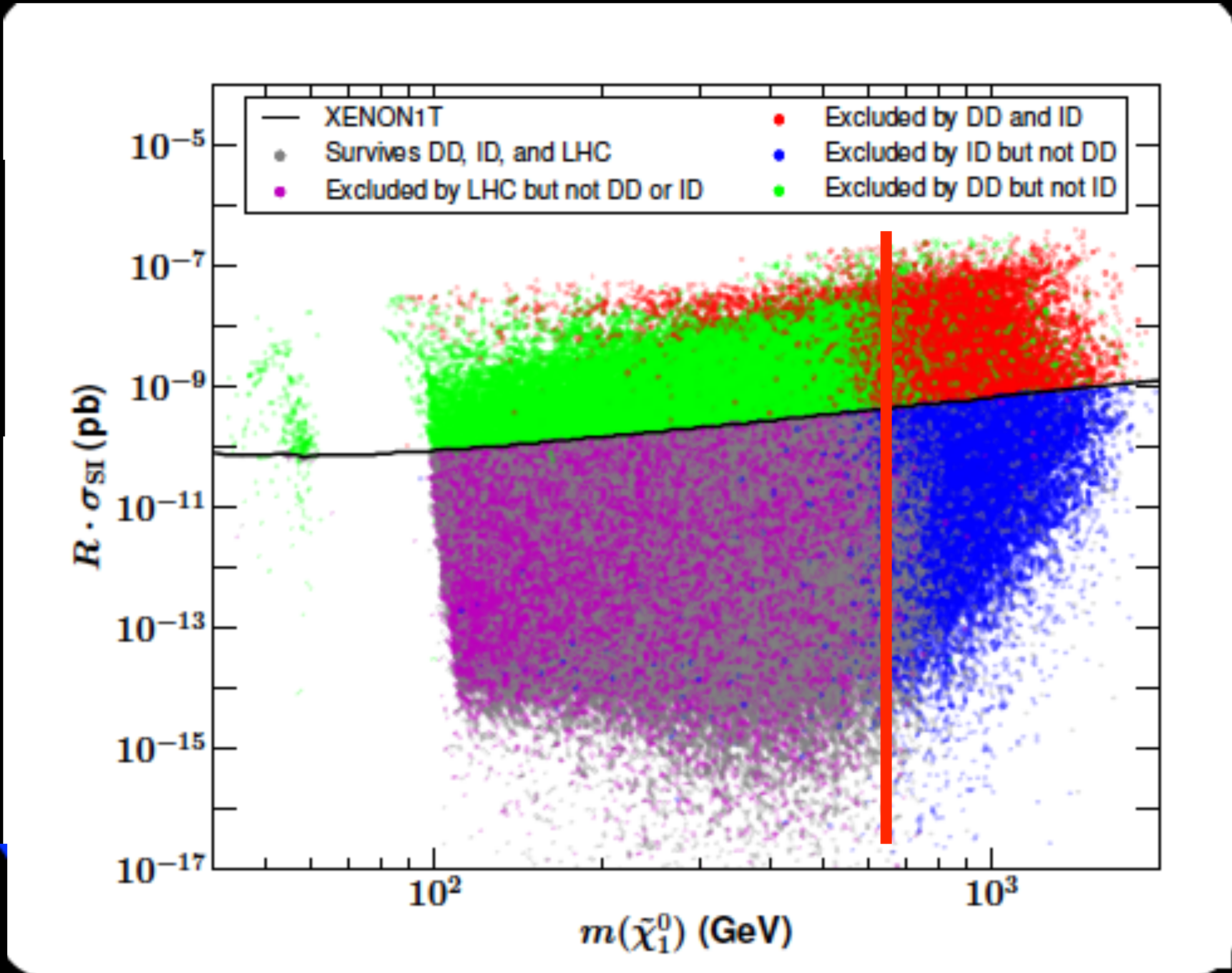
1. *10 GeV – 10 TeV multi-ton (Xenon, LZ, DARWIN, DarkSide)*
2. *<10 GeV European Bolometers (CRESST, EDELWEISS) in EURECA discussions of cooperation with SCDMS, also SSD*



✓ *Complementarity: Low masses ➔ bolometers /SSD, High masses ➔ Noble liquids*
✓ *P5 ➔ G2 projects : SCDMS and LZ*
✓ *APPEC SAC ➔ Decide ca 2018 the G3 multi-ton experiment.*
✓ *Beyond the neutrino background wall (ca 100-150t) ➔ directional R&D*

Complementarity Direct Detection, Indirect Detection, LHC



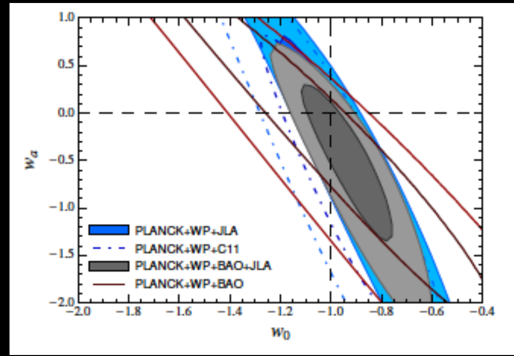


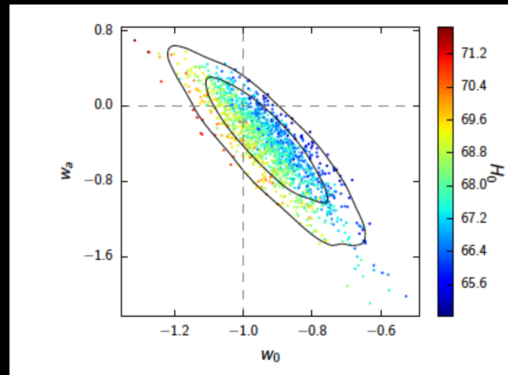
Complementarity with LHC, also in case of high WIMP masses rationale for next collider

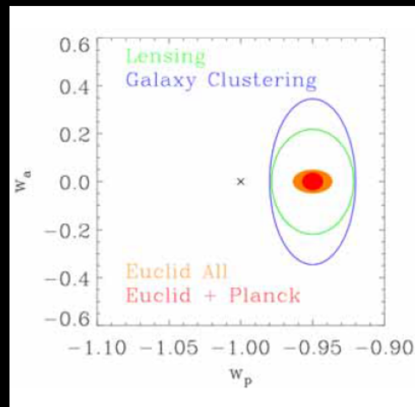
Dark energy from the Legacy Survey to EBOSS/DESI and EUCLID and LSST

- SNLS and PLANCK have been a key elements in the determination of dark energy parameters.

- Large dark energy surveys will study the large scale structure (WL, BAO, clusters) and associate it with knowledge obtained at recombination will give crucial information for neutrino mass (see above) and also dark energy equation of state.
- A very active front of cosmology
- EUCLID is an ESA M2 mission (NASA participation) a 1.2 m telescope at L2 with visible and NIR imaging, NIR slitless spectroscopy. Launch 2020
- LSST Complementary in systematics to Euclid superior spectroscopy (LSST) vs absence of atmospheric distortion (EUCLID). First light 2020
- APPEC recommended since 2011 the participation to both LSST and EUCLID.





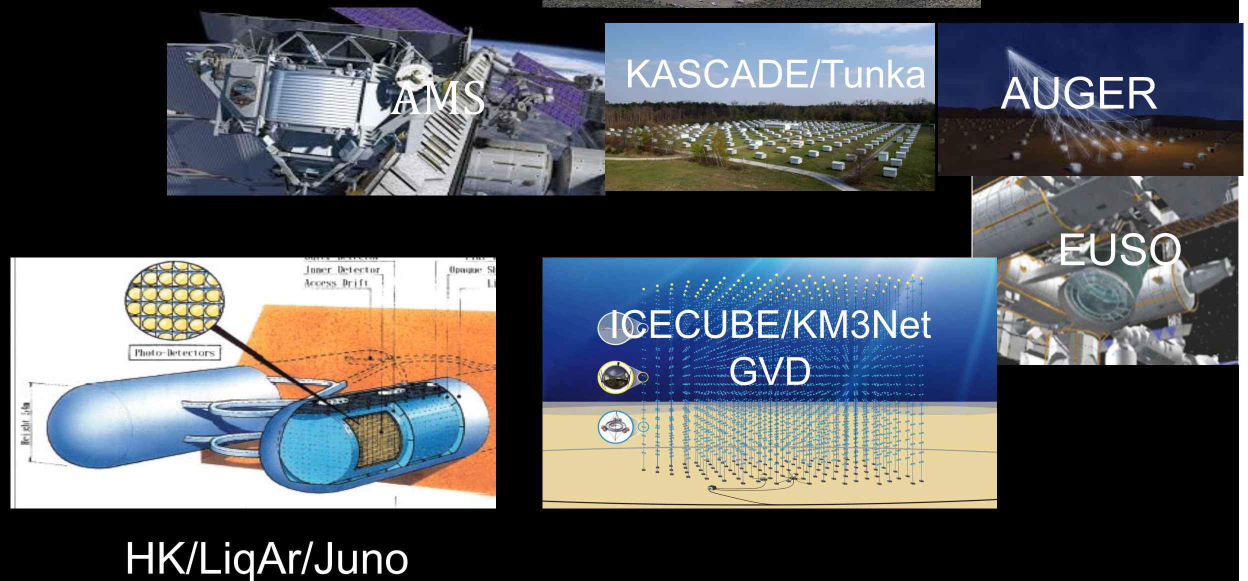


APPECC

From the APPEC
Scientific Advisory Committee (SAC)* Roadmap

C. Consolidation of the recently opened high energy gamma ray astronomy and the opening of the new astronomies: neutrinos, high energy cosmic rays and gravitational waves

High Energy photon, neutrino and CR observatories*
Finally reaching multi-messenger sensitivities ?

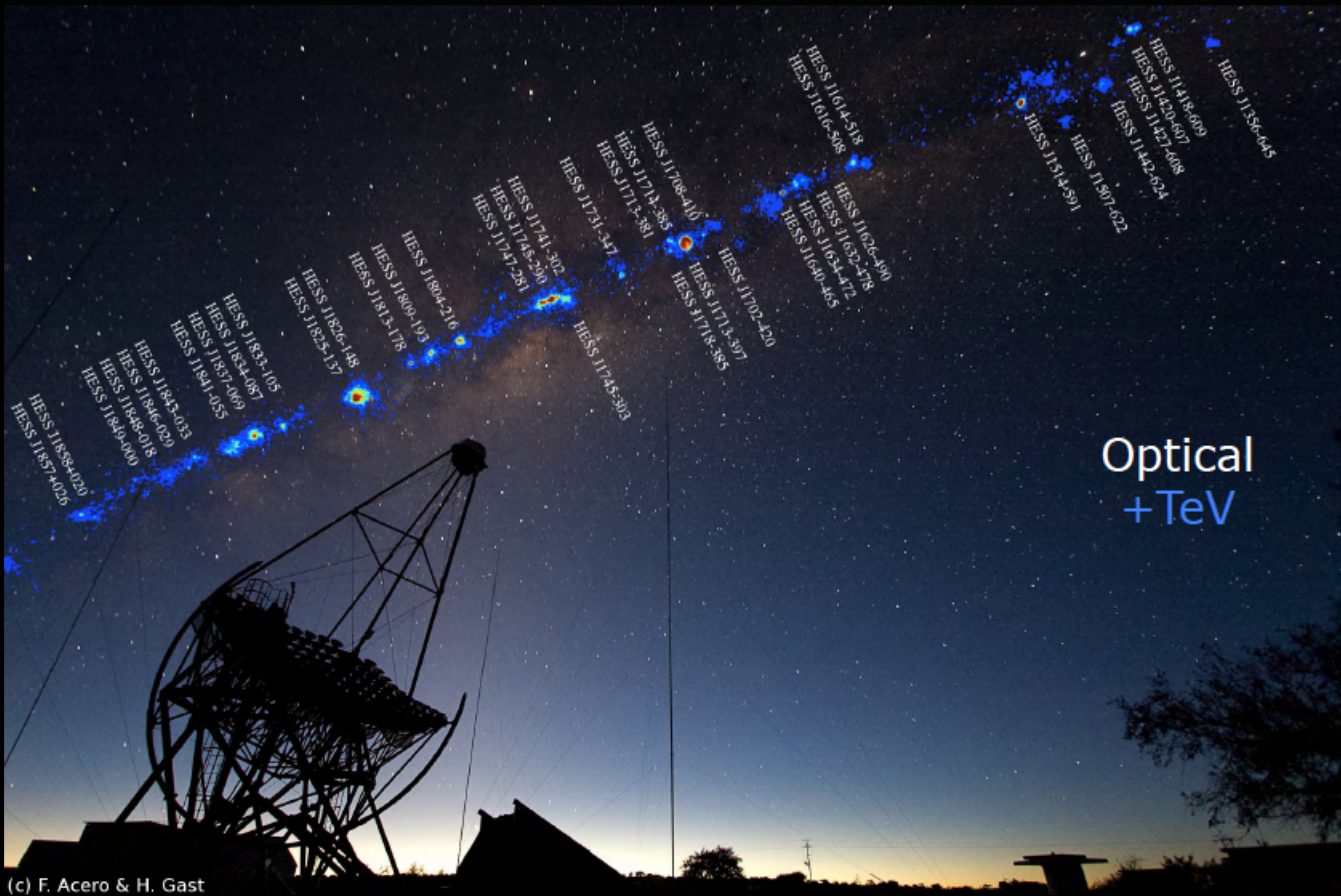


Space program (low energy) well defined.

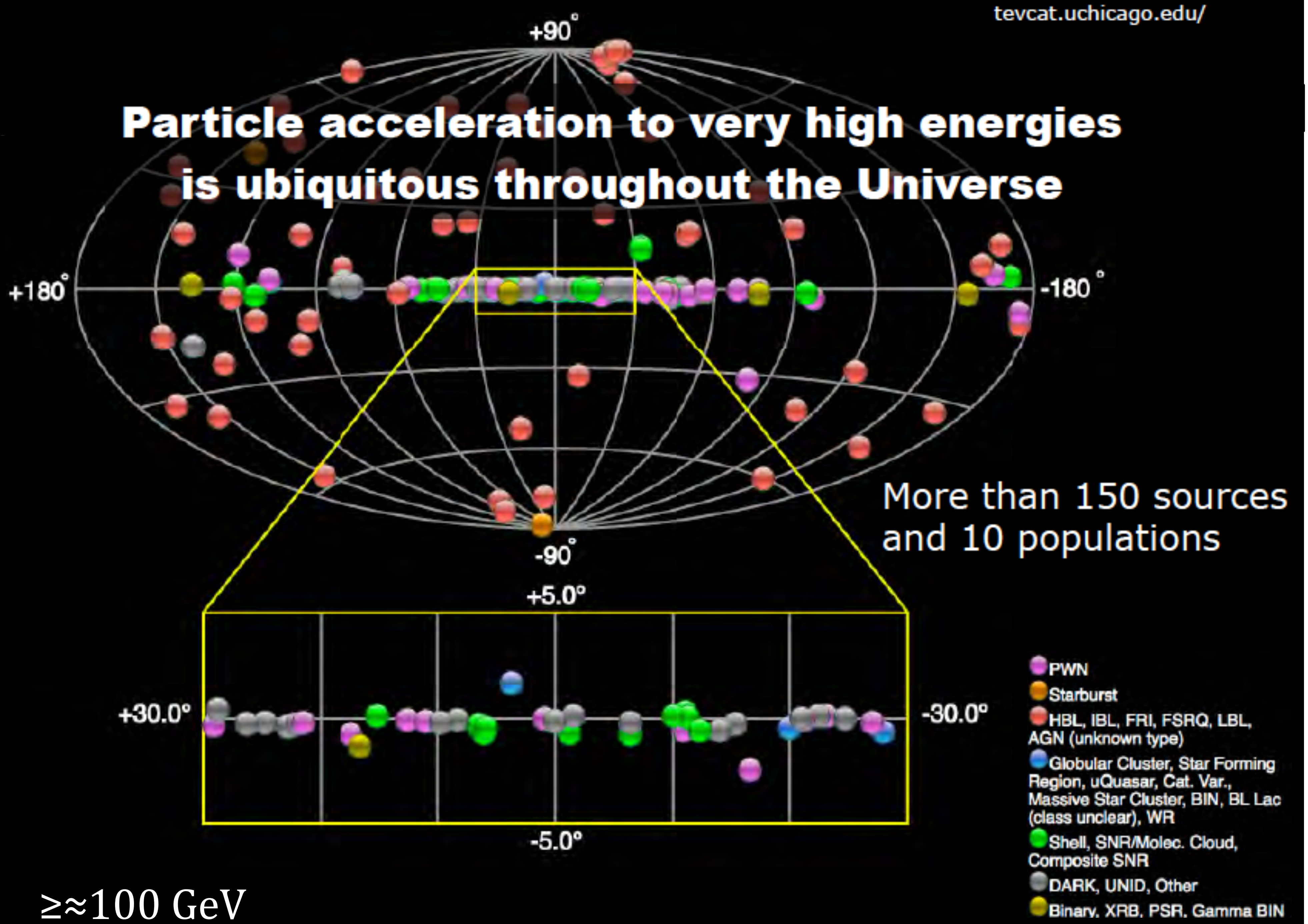
All programmatic uncertainty comes from medium and high energy observatories

*Also GW antennas

The H.E.S.S/Magic/Veritas legacy of 10 last years



Particle acceleration to very high energies is ubiquitous throughout the Universe

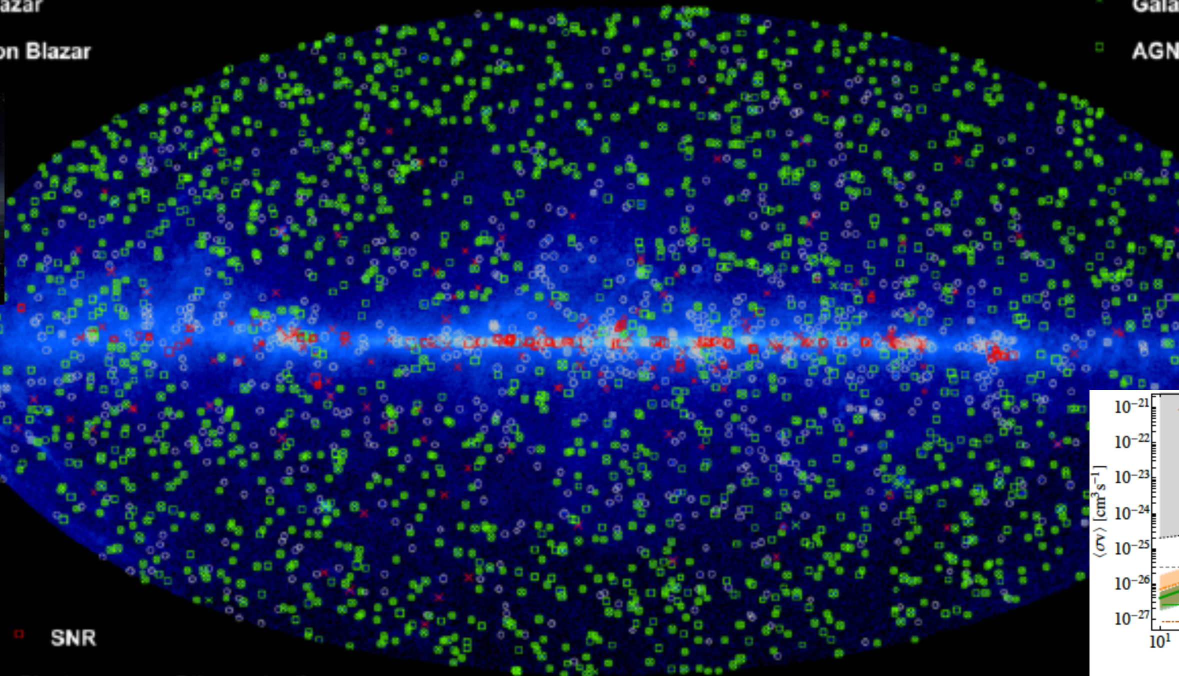


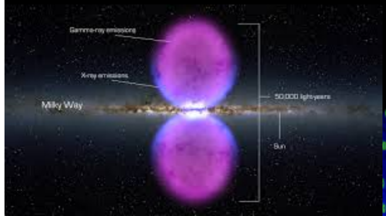
More than 150 sources and 10 populations

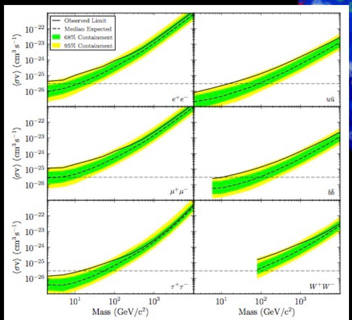
≥≈100 GeV

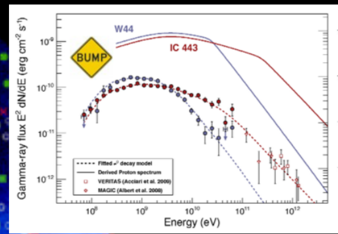
The legacy of Fermi of past 6 years

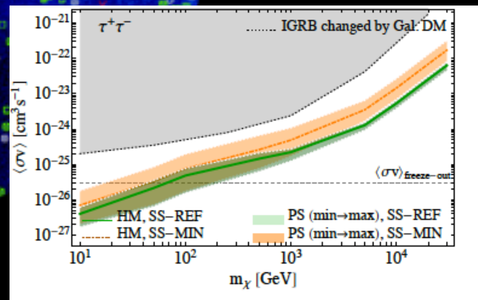
Fermi Large Area Telescope 3FGL catalog







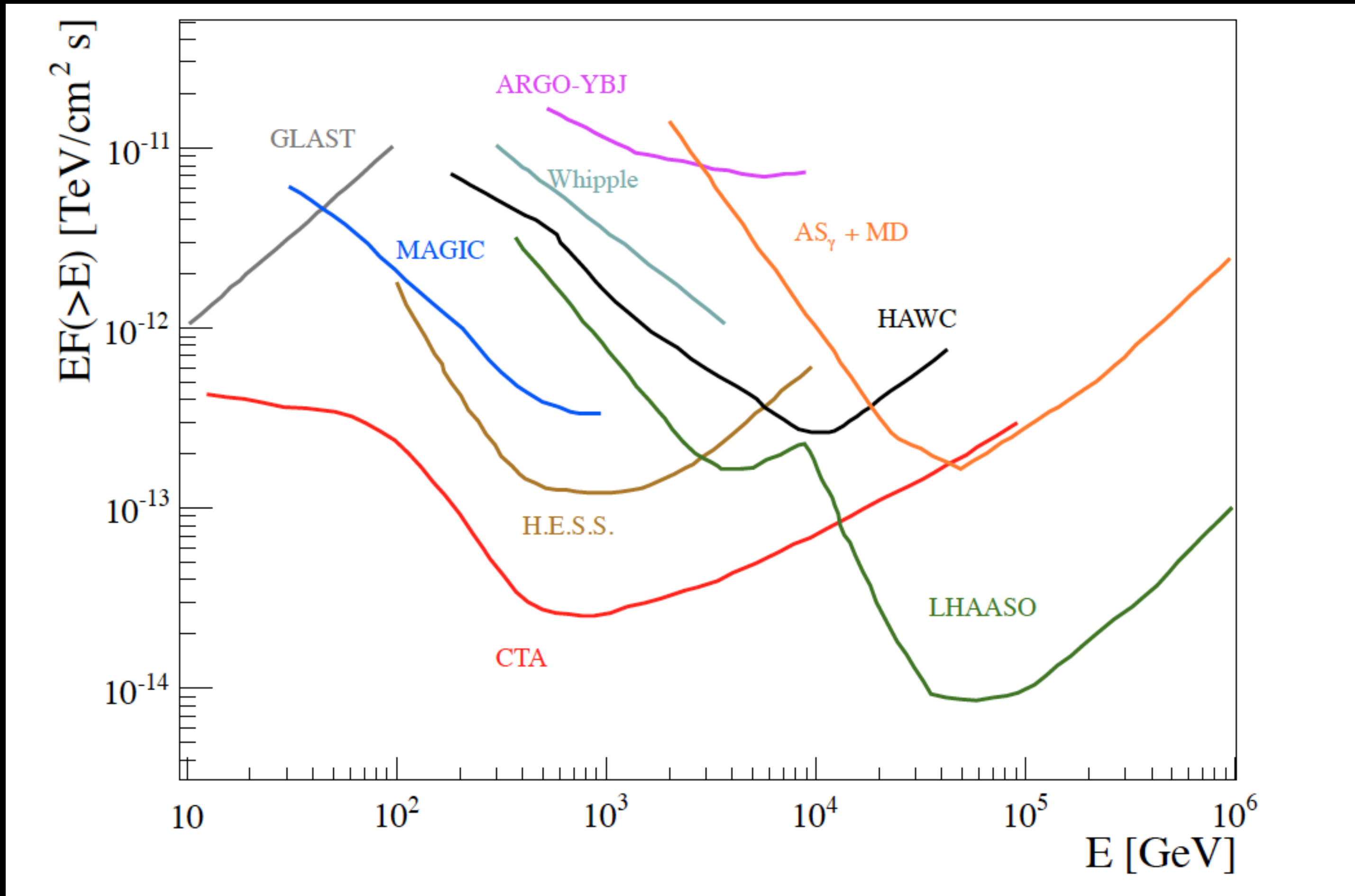




3033 sources (992 unassociated , 1755 AGN, PSR 137, SNR 23…)

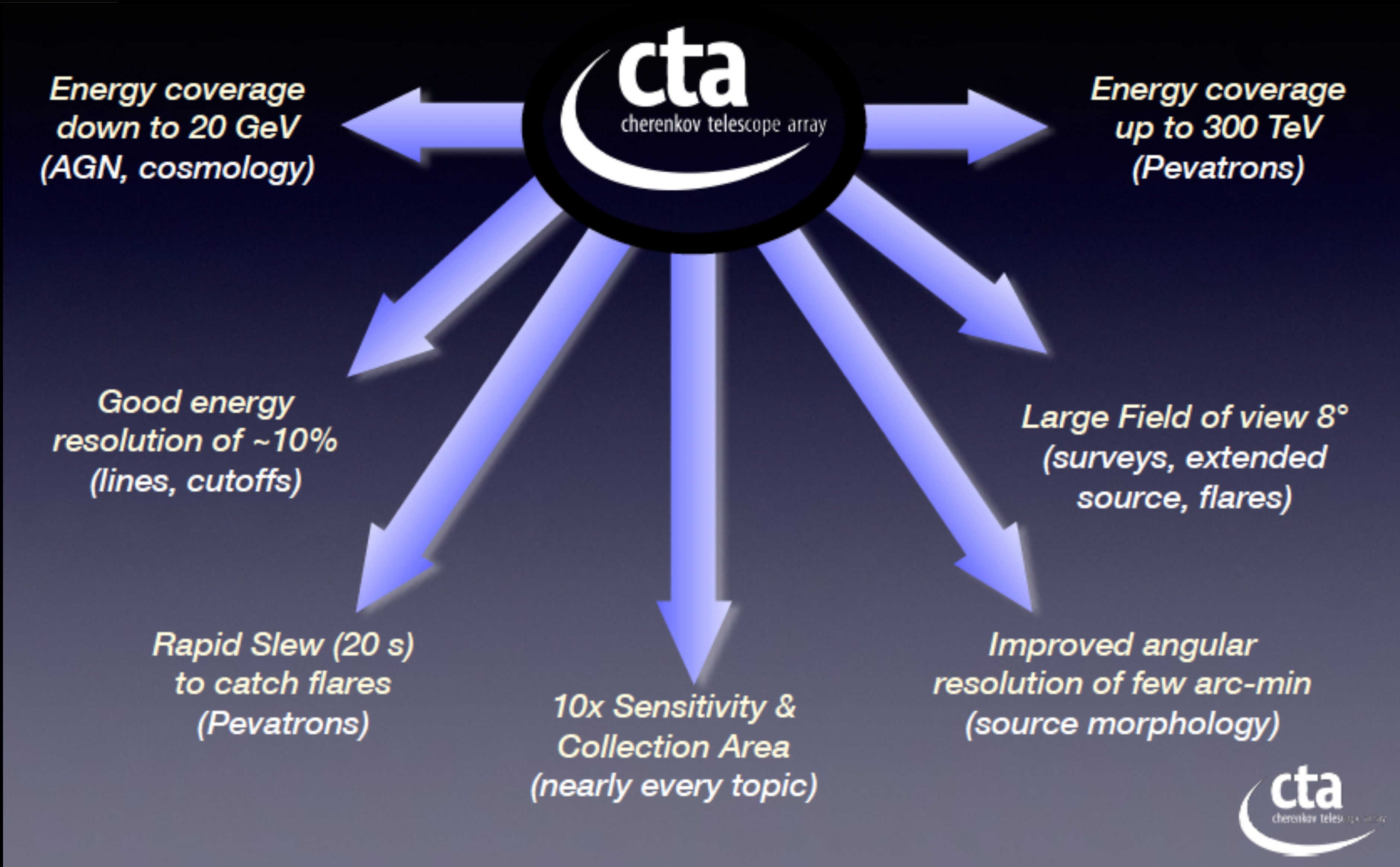
514 > 10 GeV
320 > 50 GeV

Future high energy γ sensitivities



In TeV domain the **Cherenkov Telescope Array (CTA)** is a worldwide priority
Complemented by PeV scale wide field observatories:
HAWC (constructed) and LHASSO under construction (2020)

CTA requirements and drivers

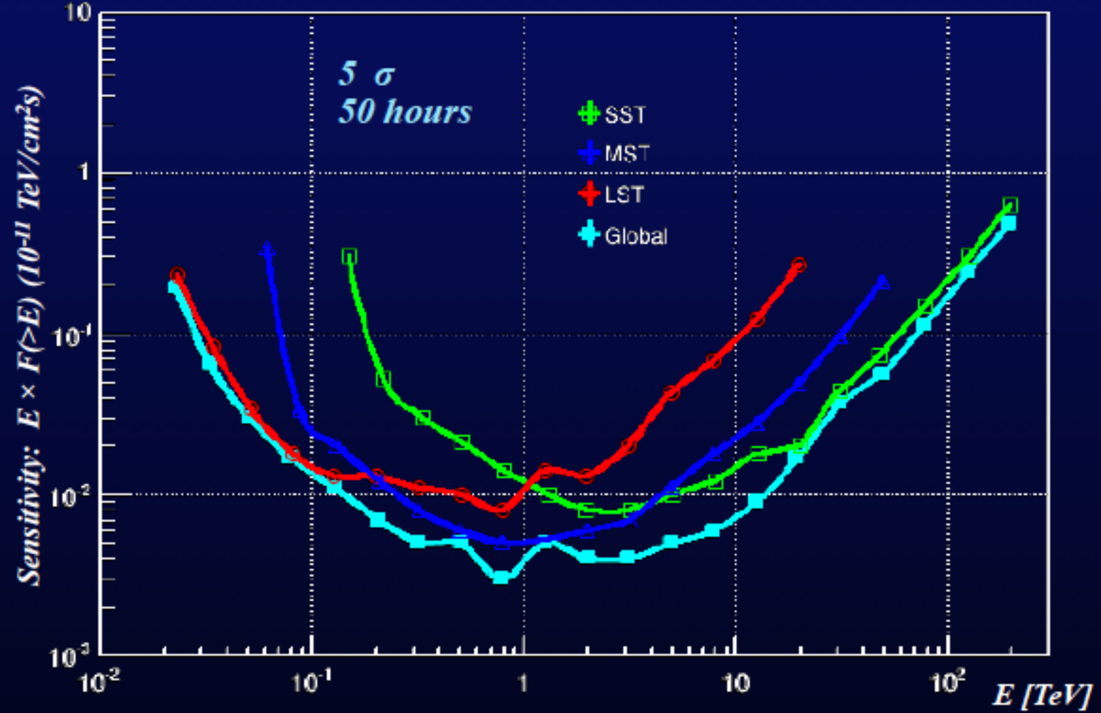


CTA site selection

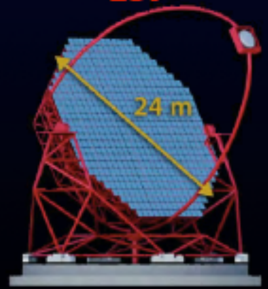
CTA Sites: Candidates

+additional lower priority candidates

CTA deployment elements

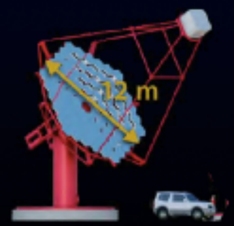


LST



4 South
4 North

MST

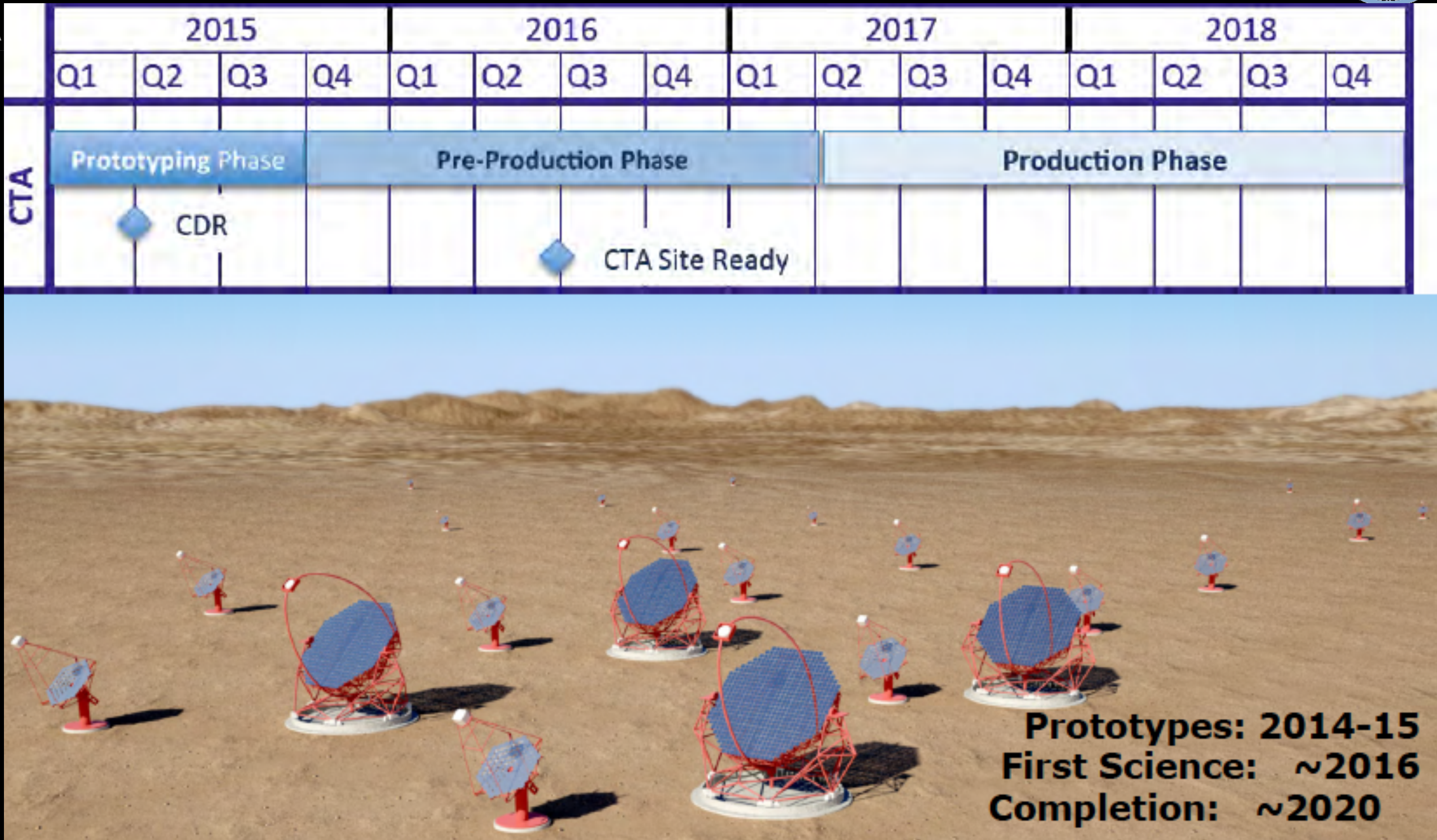


25 South
14 North
24 SCT South

SST

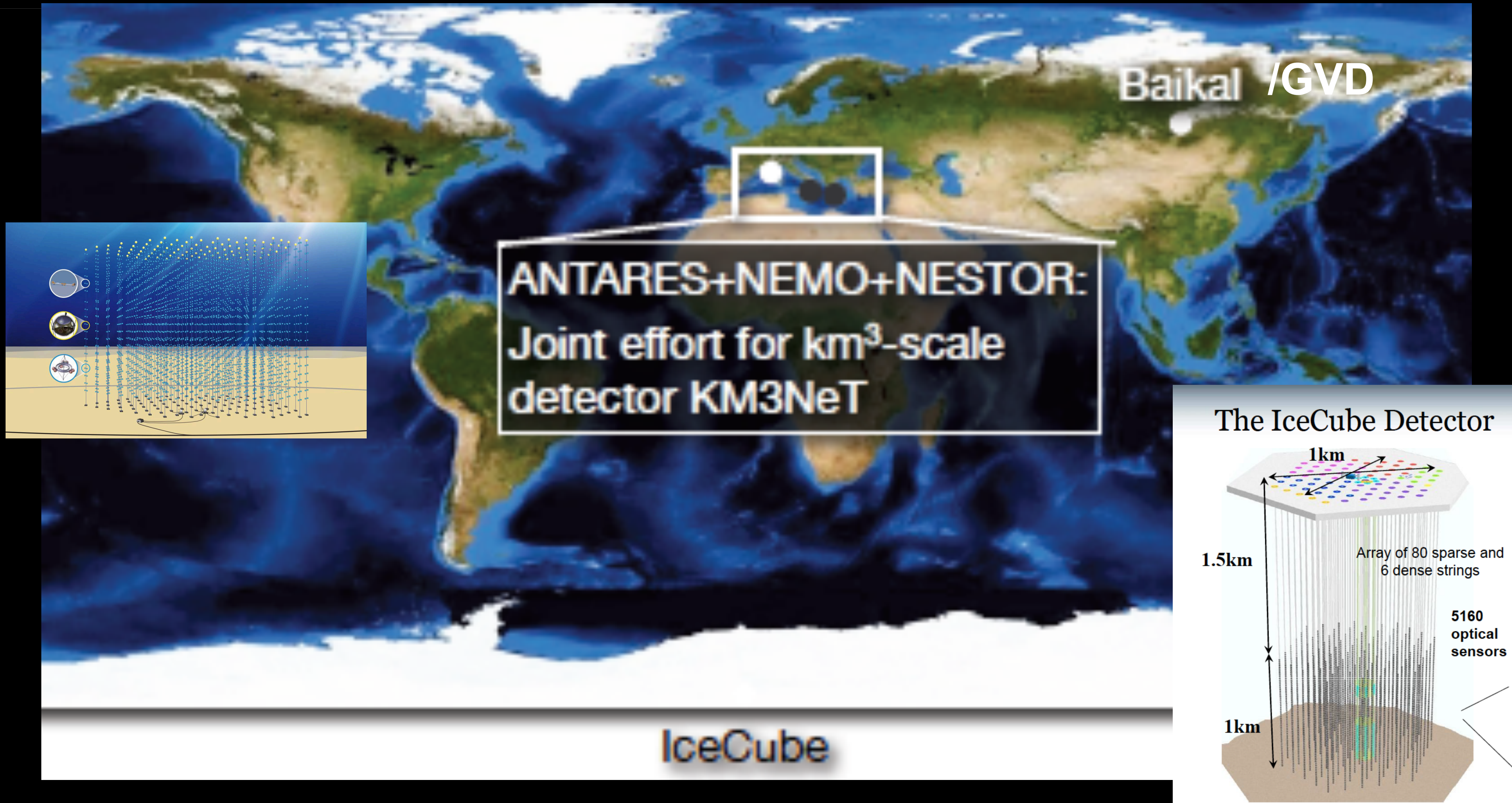
70 South

CTA: an aggressive schedule



Estimate 3-5 years of construction, investment 200 ME

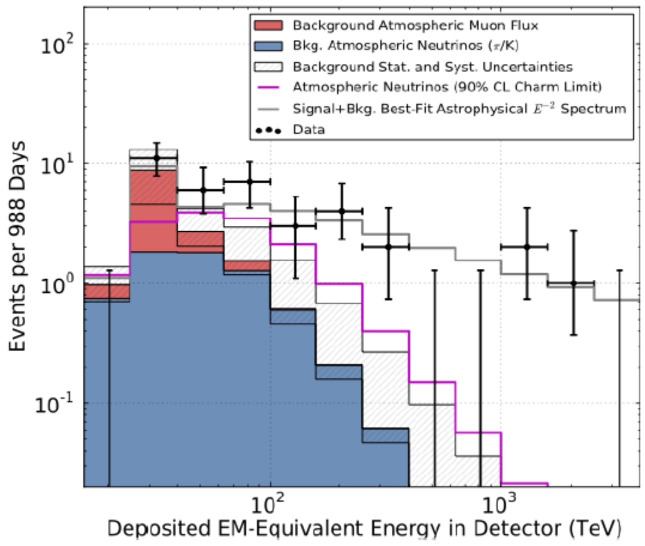
High Energy Neutrino telescopes



Nothern Hemisphere projects and IceCube move through coordination towards a future Global Neutrino Observatory.

The Dawn of Neutrino Astronomy

- 36(+1) events total
  - 8.4 ± 4.2 atm. muons
  - $6.6^{+5.9}_{-1.6}$ atm. neutrinos
- 5.7σ rejection of only atmospheric neutrino flux
- Consistent with 1:1:1 flavor ratio



Ahlers,
Hultqvist,
Spurio,
Dejong
Hallgren

- At what precision is it isotropic ?
- Break of the spectrum?
- Flavour ratio consistent with standard expectations ?
- What are the sources ?
  - Galactic (Gal Center et Fermi-bubble,SNR, PWN)?
  - Extragalactic (GRB,AGN,…) ?
  - A mixture ?
  - What sensitivity will permit to disentangle them ?
- What is the relationship with UHECR?
- Are there hints of new physics (e.g. dark matter?)

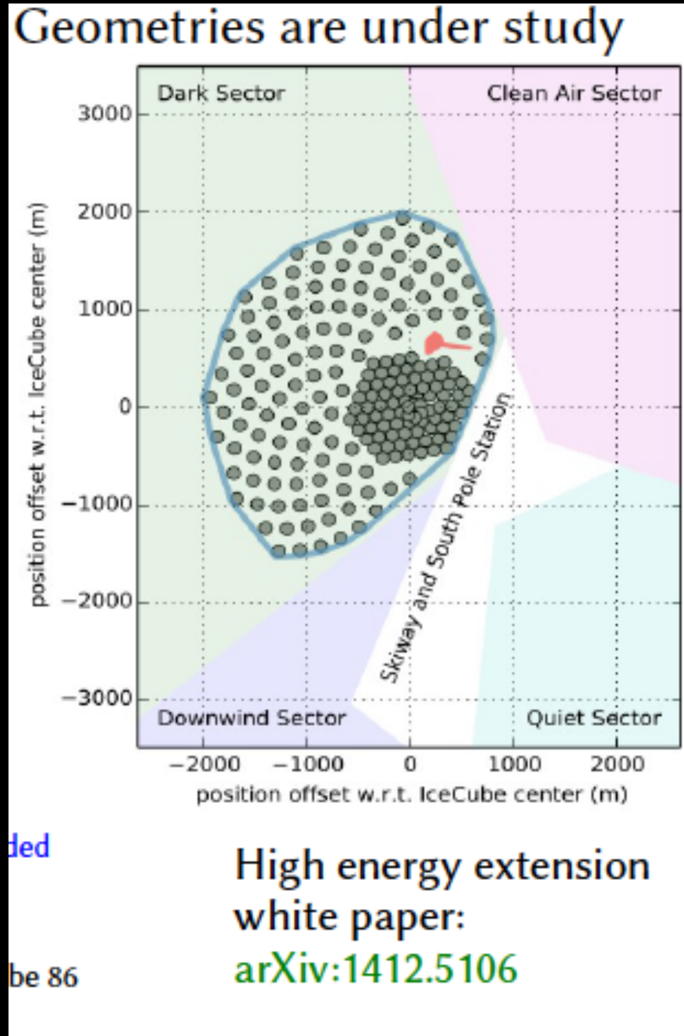
Solution of the puzzles comes through:

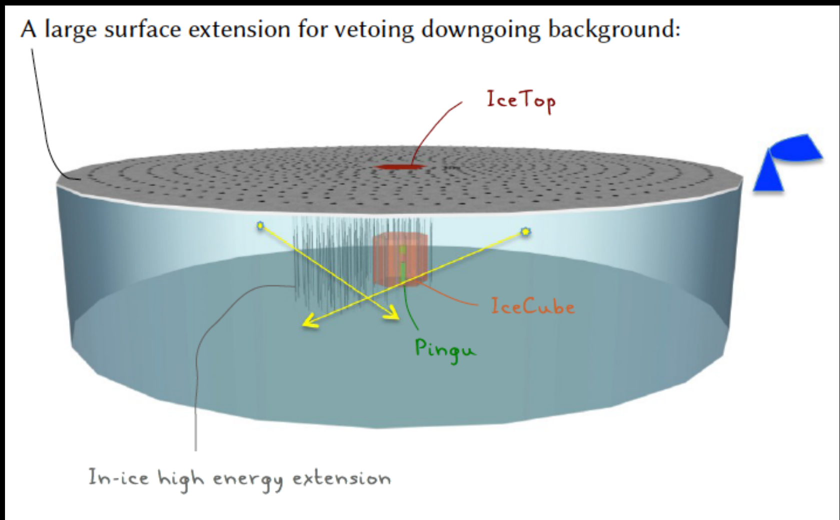
- Extension of sensitivity
- Complete coverage of the sky
- Multimessenger studies
  - DECACUBE, KM3Net
  - CTA, HAWC, LHAASO
  - NUSTAR/ASTRO-H
  - AUGER p vs Fe

An expanding litterature: will need special session for NEUTEL 2017 ?

ICECUBE → High Energy Extension 5-10 km^2

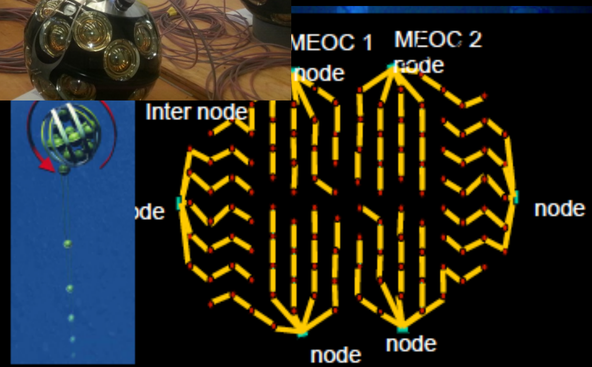
- Start 2018/2019 complete 2027?
- ICECUbe Gen 2 more veto
- Cost equivalent to ICECUBE 1 km^2
- Including Pingu for the first 3 of the 8 seasons



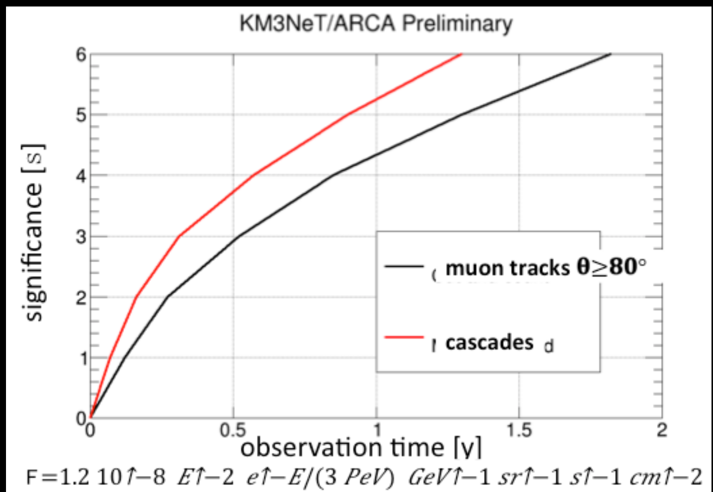


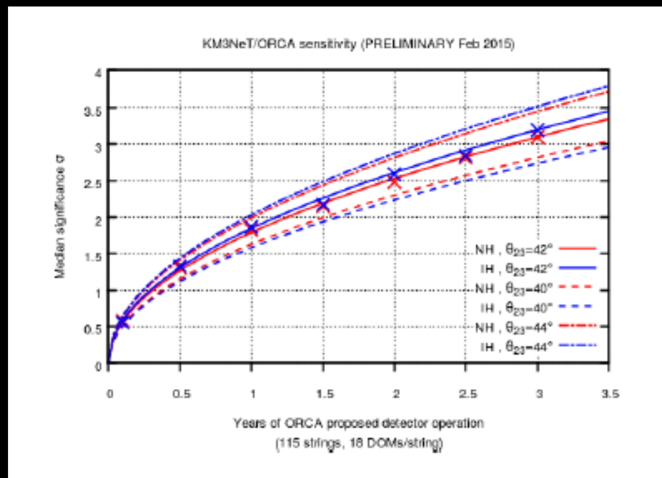
Antares ➔ KM3Net (ARCA and ORCA)

- Phase 1 (35 ME, funded in construction)
  - 24 lines KM3Net-Italy (➔ ARCA)
  - 6 lines KM3Net-France (➔ ORCA)
  - First full line deployment April 2015
  - Completion 2016
- Phase 2 (to be decided before end of 2016)
  - ARCA 2 x 115 lines, cost 55 ME
  - ORCA 1 x 115 lines (20m spacing) cost 40 ME
  - Structural funds.
  - Window of opportunity for ORCA ?
- Phase 3 6 blocks

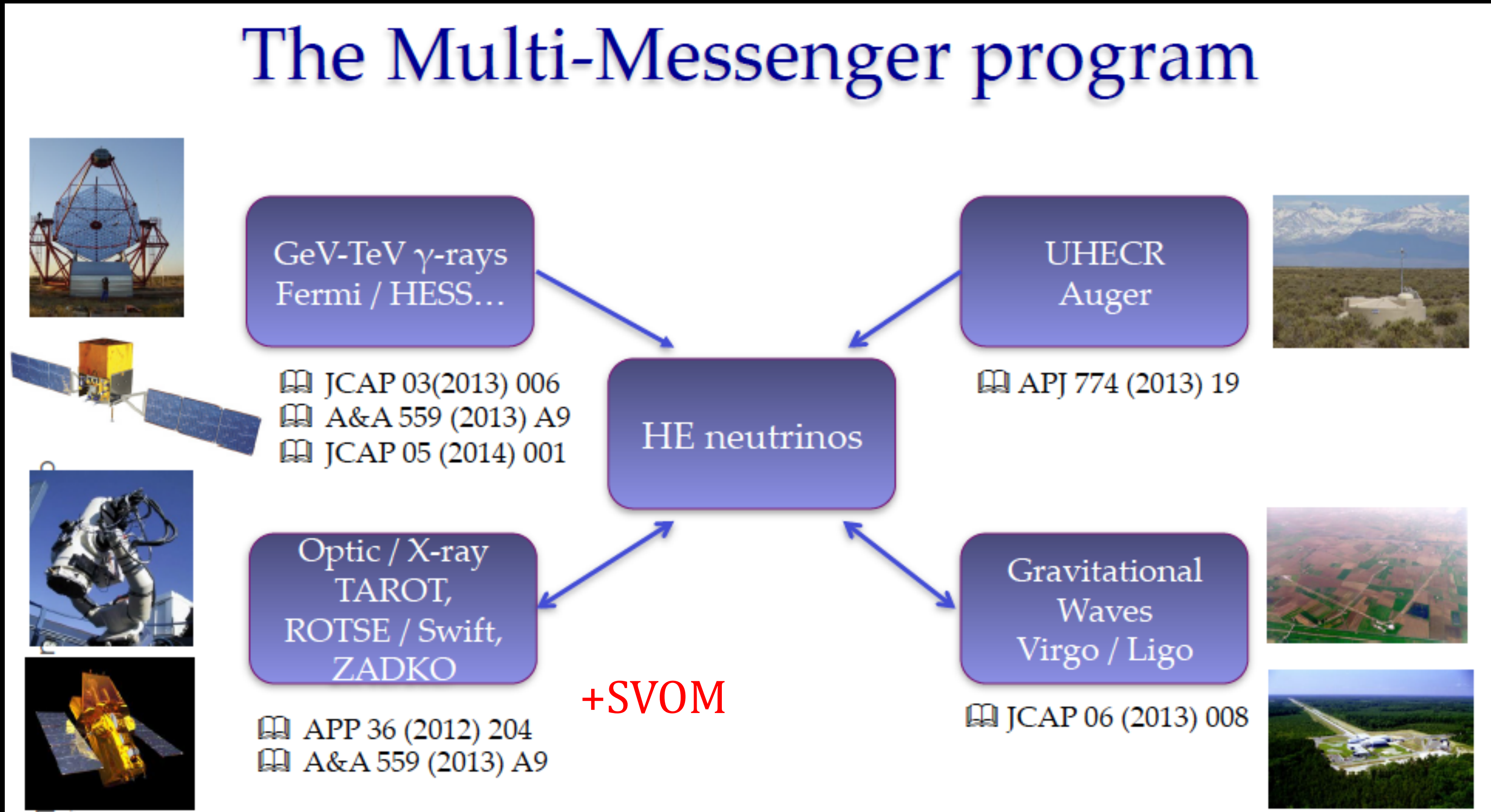


Current optimisation: 0.6 KM3 Blocks of 115 strings, 90m apart, 18 DOM/String, spacing between DOM's 36 m





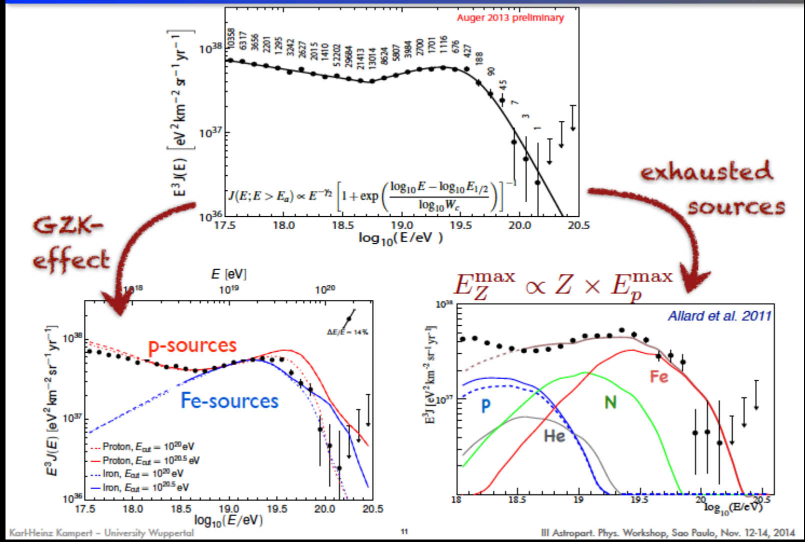
Did we reach finally the sensitivities necessary for multimessenger studies ?



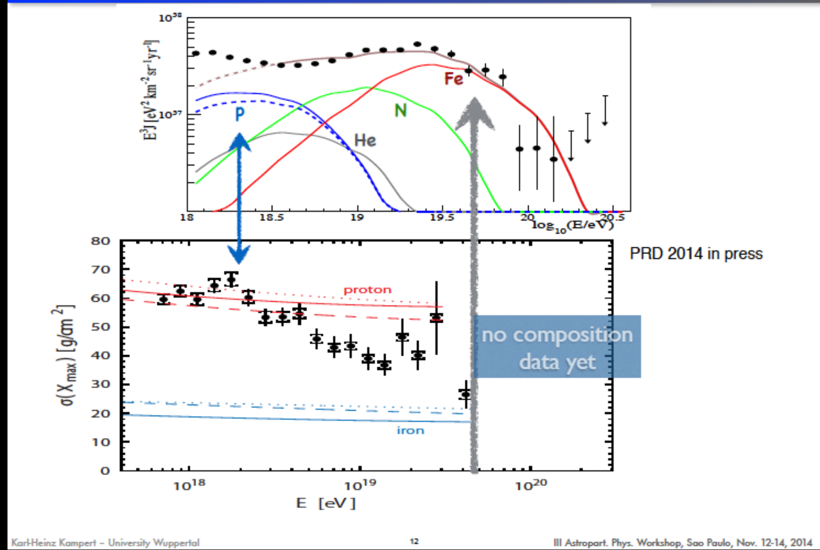
Spurio

UHECR observatories on the ground
AUGER and TA

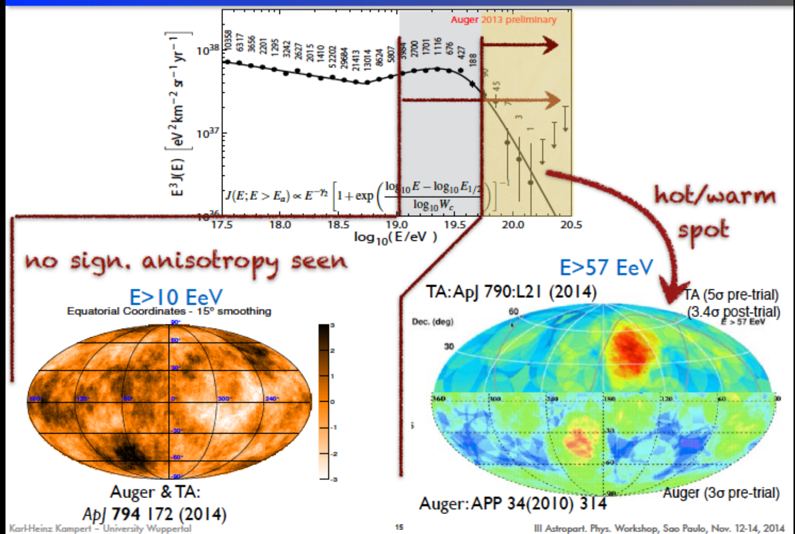
GZK-Effect or Exhausted Sources?



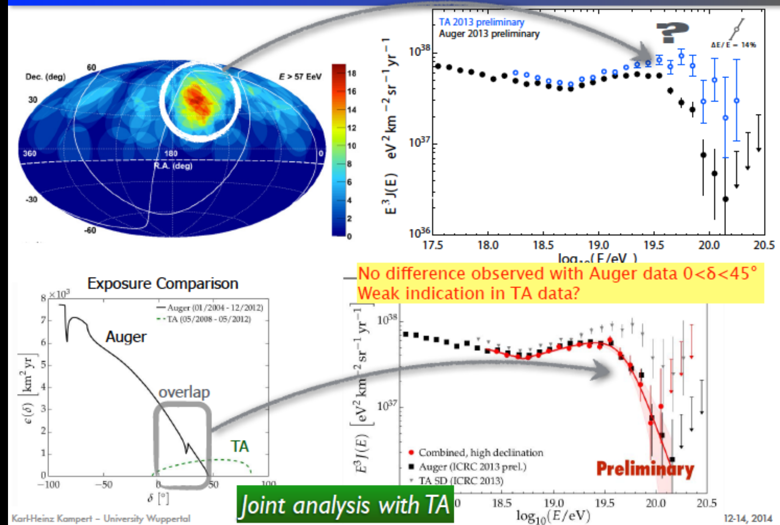
E_{max}-model supported by RMS(X_{max})…



UHECR Sky highly isotropic

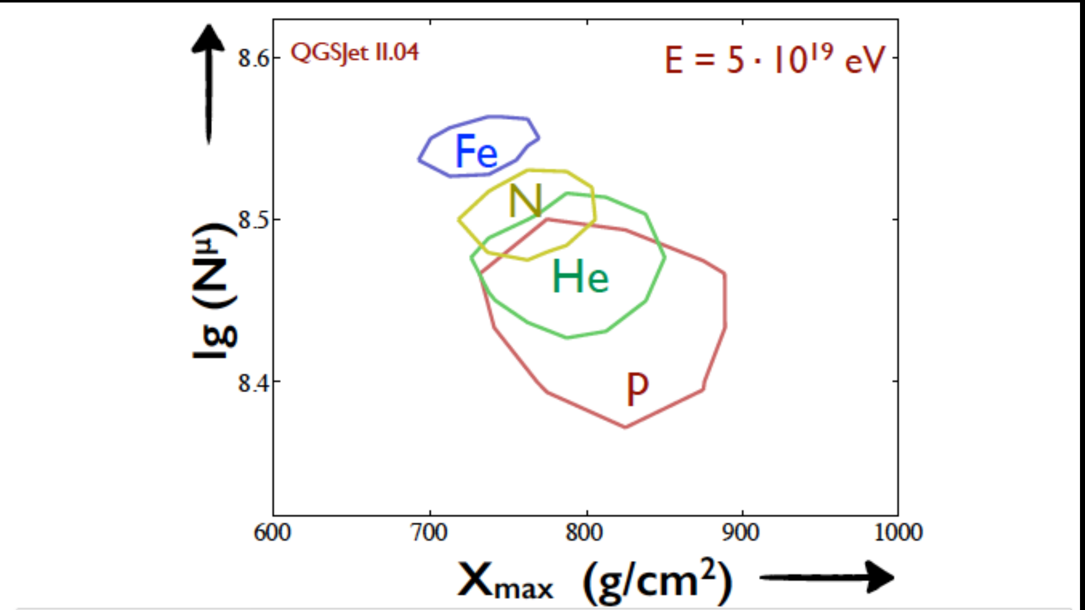


Are the Two Skies Different ?



Science goals of Auger upgrade

- Elucidate the origin of the flux suppression (GZK vs maximum energy)
- Separate protons from other nuclei
- Study extensive air showers and hadronic multi-production above 70 TeV
- ➔ Need to study composition event by event. Key ingredient for the above program measure the muonic component of the showers

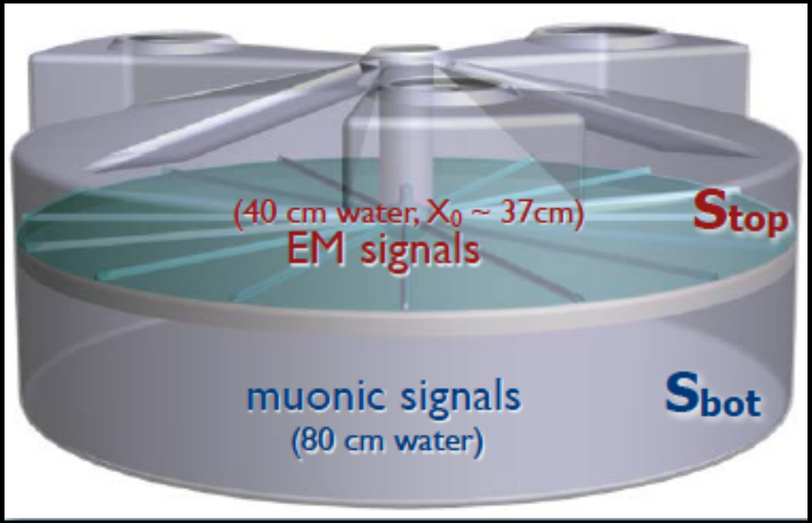


Muons may even outperform X_{max} at highest energies !

Auger upgrade (2015-2017, cost 10-12 ME)

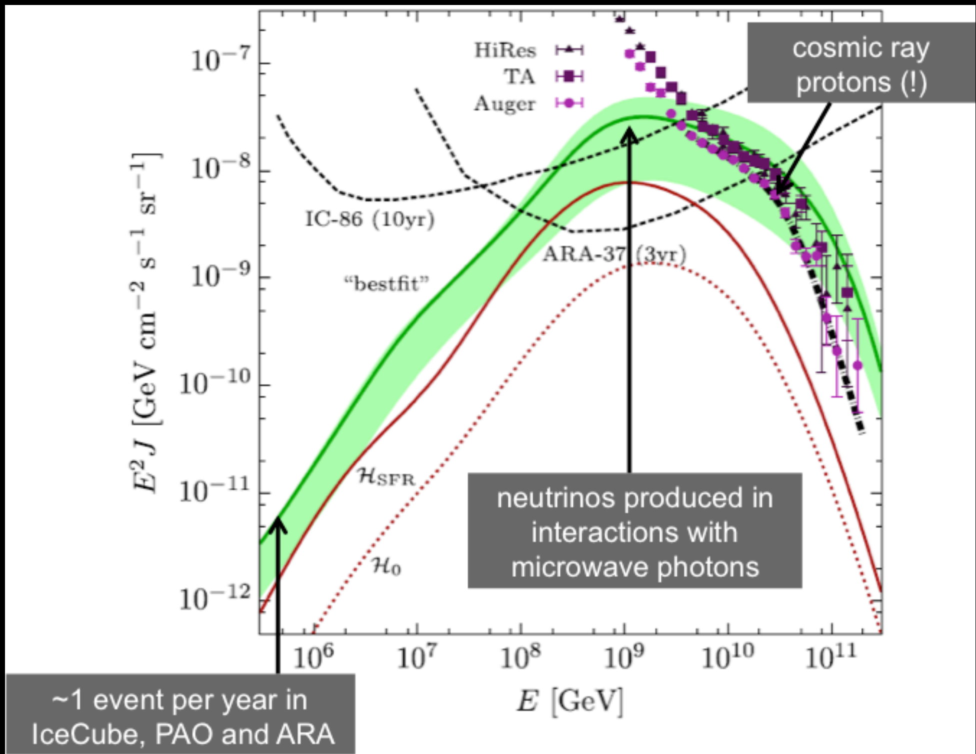
1) Enhanced muon counting ASCII

Also considered for high precision complementary array (near the knee) Longitudinally Segmented Detectors (LSD)



2) Faster electronics
3) Extended operation of FD-telescpes
4) High precision complementary array (burried scintillators)

Ultra High Energy sensitivities also start to be comparable (CR and ν)



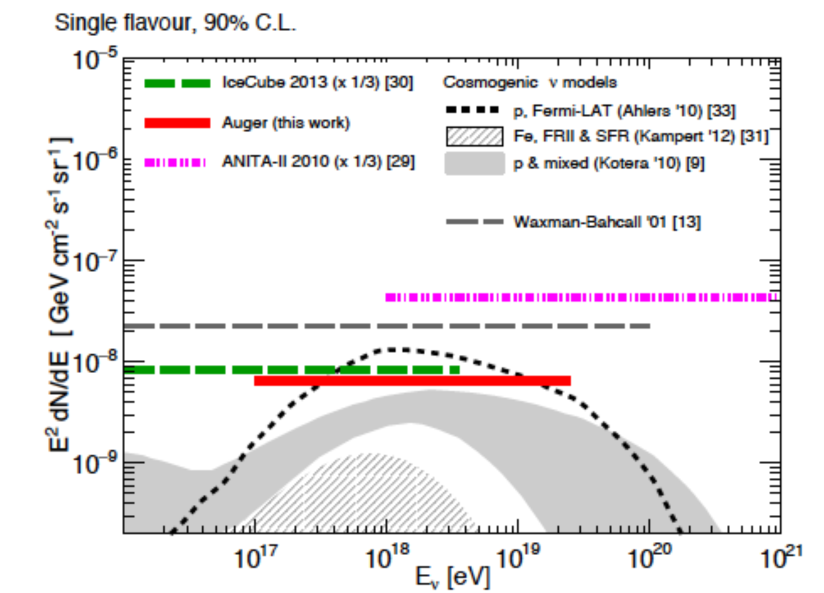
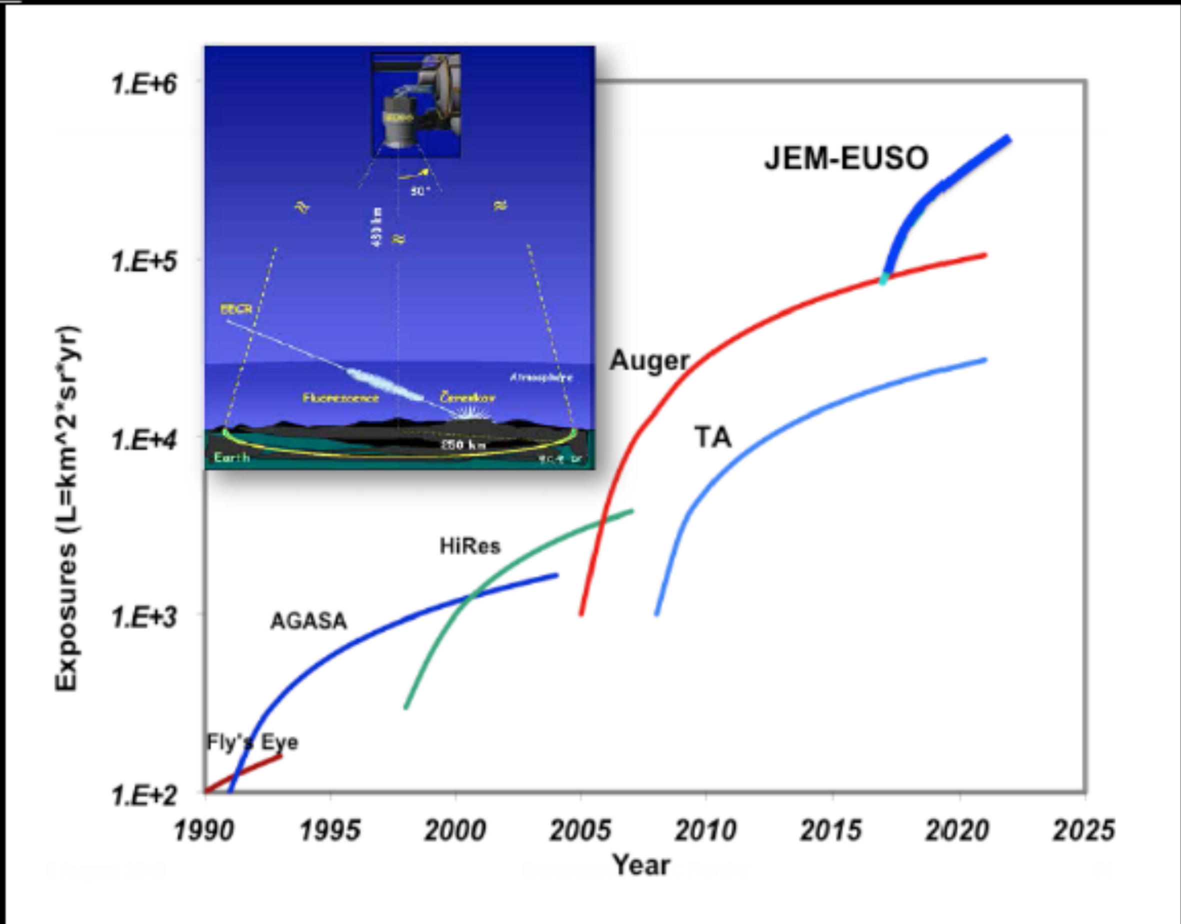


Figure 4. Integrated upper limit (at 90% C.L.) from the Pierre Auger Observatory for a diffuse flux of UHE neutrinos. We also show the integrated limits from ANITAII [29] and IceCube [30] experiments, along with expected fluxes for several cosmogenic neutrino models [9, 31, 33] as well as the Waxman-Bahcall bound [13]. All limits and fluxes converted to single-flavour. We used $N_{up} = 2.39$ in Eq. (2) to obtain the limit (see text for details).

High energy cosmic ray observatories
EUSO



JEM-EUSO
~200 events > 60 EeV/ yr

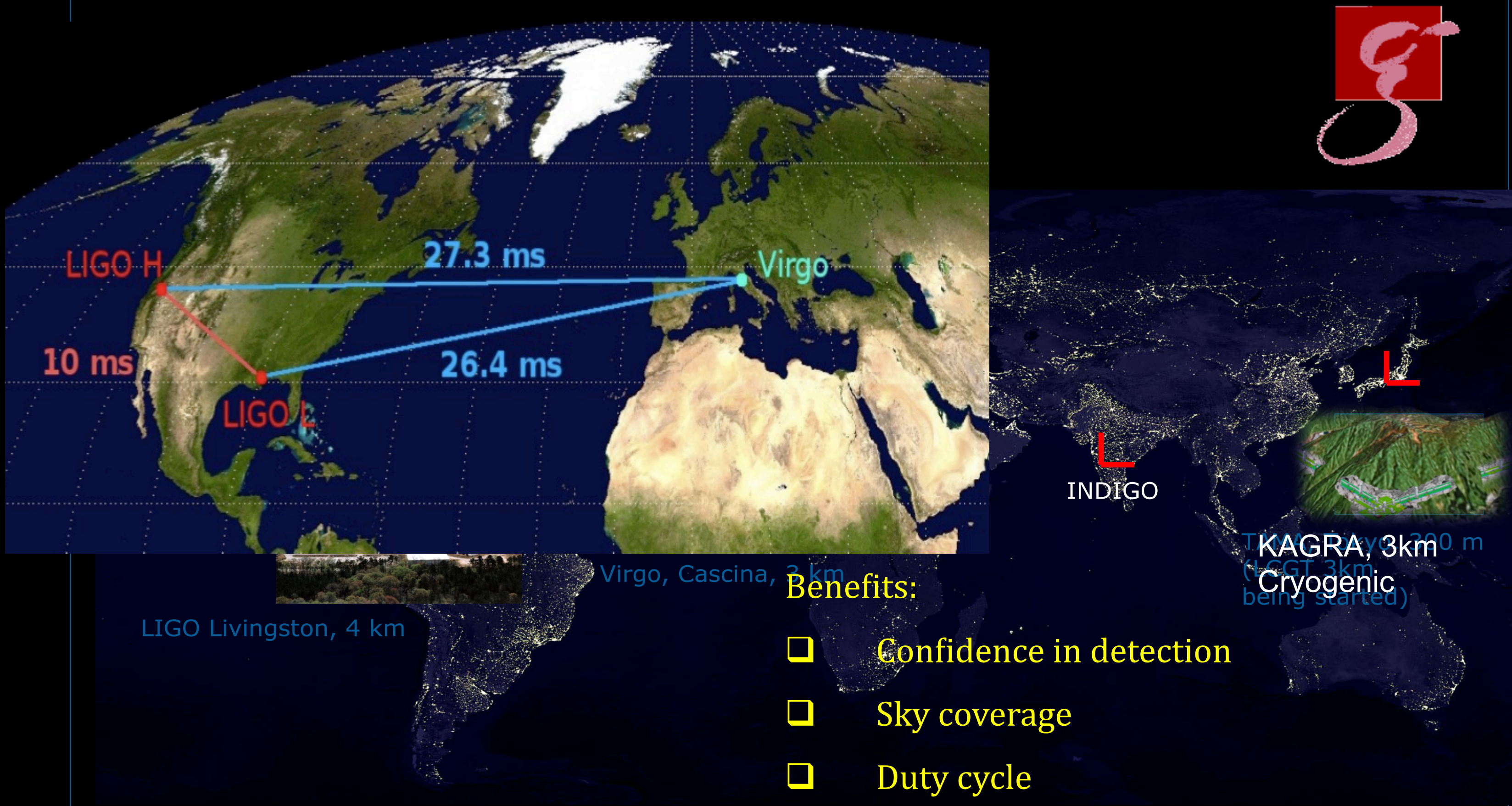
EUSO-Ballon,
Aug 2014

In the next 2years:

- EUSO at ISS (mini-EUSO)
- Long duration balloon flight

- Large international collaboration
- But also large programmatic uncertainty: Who and how will launch.
- Multipurpose cosmic ray observatory at the ISS?

Gravitational waves I
A worldwide antenna network



Benefits:

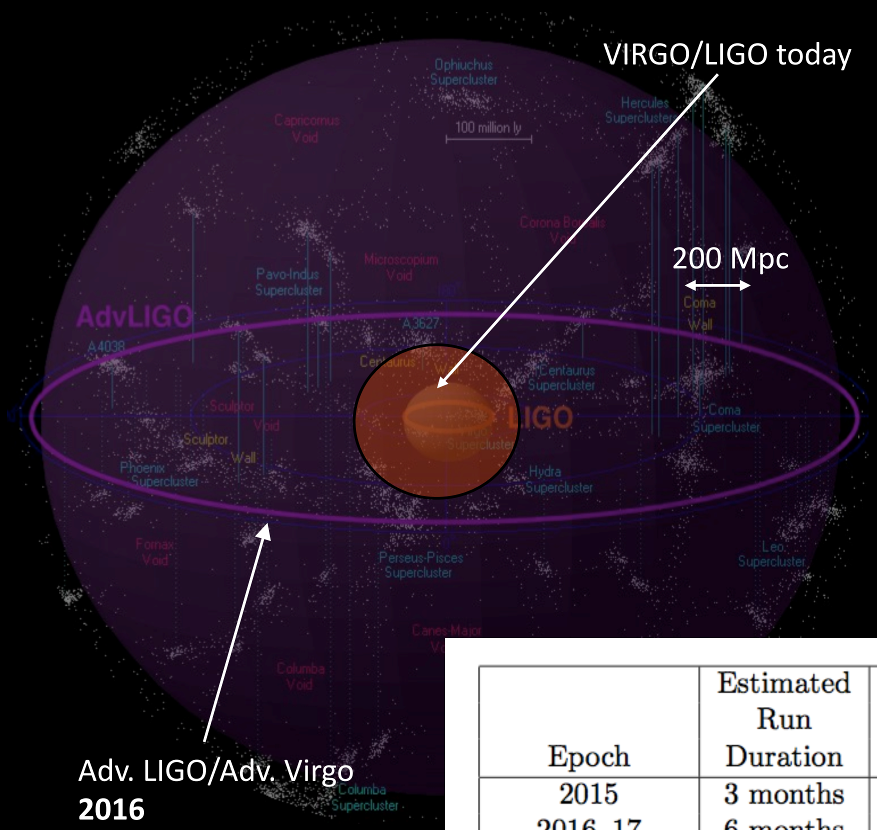
- Confidence in detection
- Sky coverage
- Duty cycle
- Sky position localization

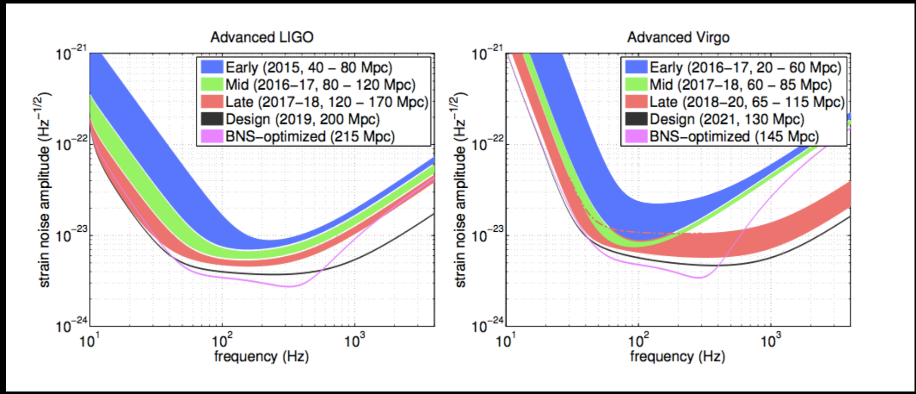
The GWIC community pioneered a network between the gravitational wave antennas in Europe and in the United States (advVIRGO, advLIGO, advGEO, MoU Since 2007) , with sharing of information and techniques, scie nce run coordinationand joint publication of results. Other antennae are expected to come on-line (KAGRA in Japan, INDIGO in India)

Gravitational waves II

✓ Towards a first detection in the next 5 years

- Advanced LIGO locked . Sensitivity achieved (Livingston site) ~ 60 Mpc (~ x 3 of initial LIGO)
- Advanced Virgo under integration. First lock expected end of 2015

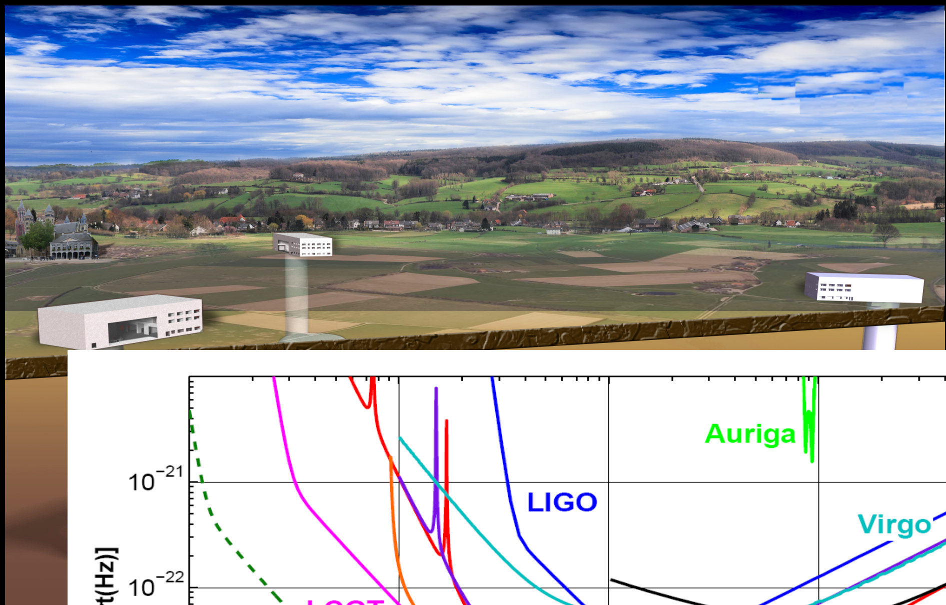


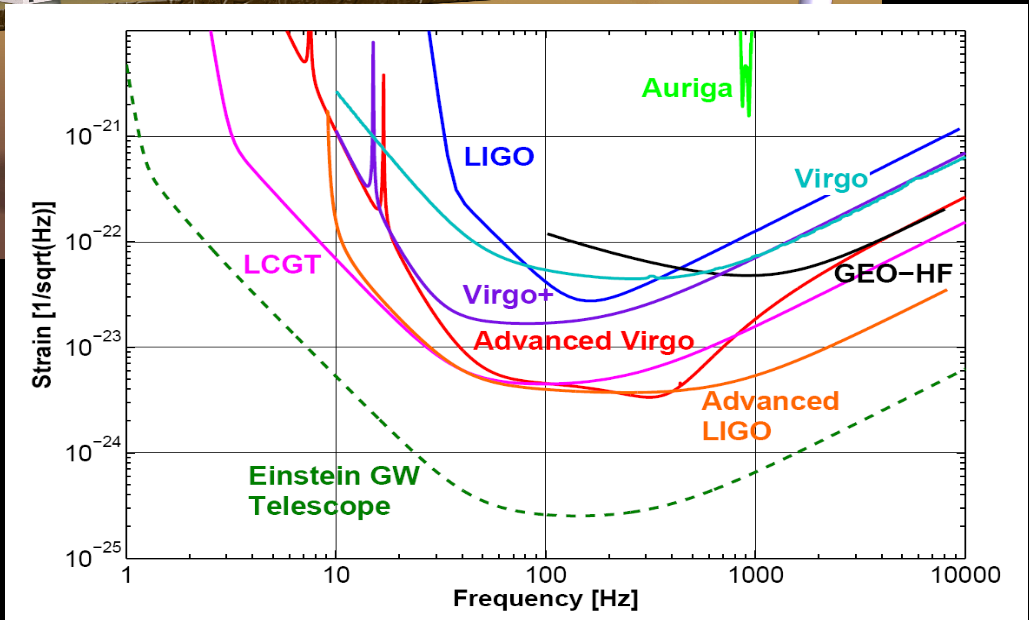


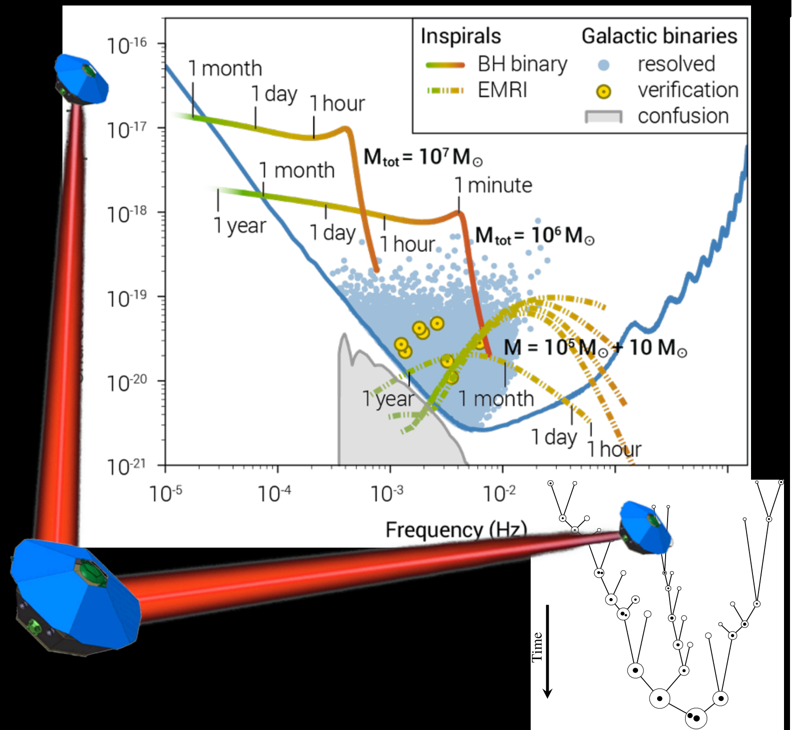
Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_{\odot} c^2$ Burst Range (Mpc) LIGO	Virgo	BNS Range (Mpc) LIGO	Virgo	Number of BNS Detections	% BNS Localized within 5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Gravitational wave III

Einstein Telescope (ET) and eLISA





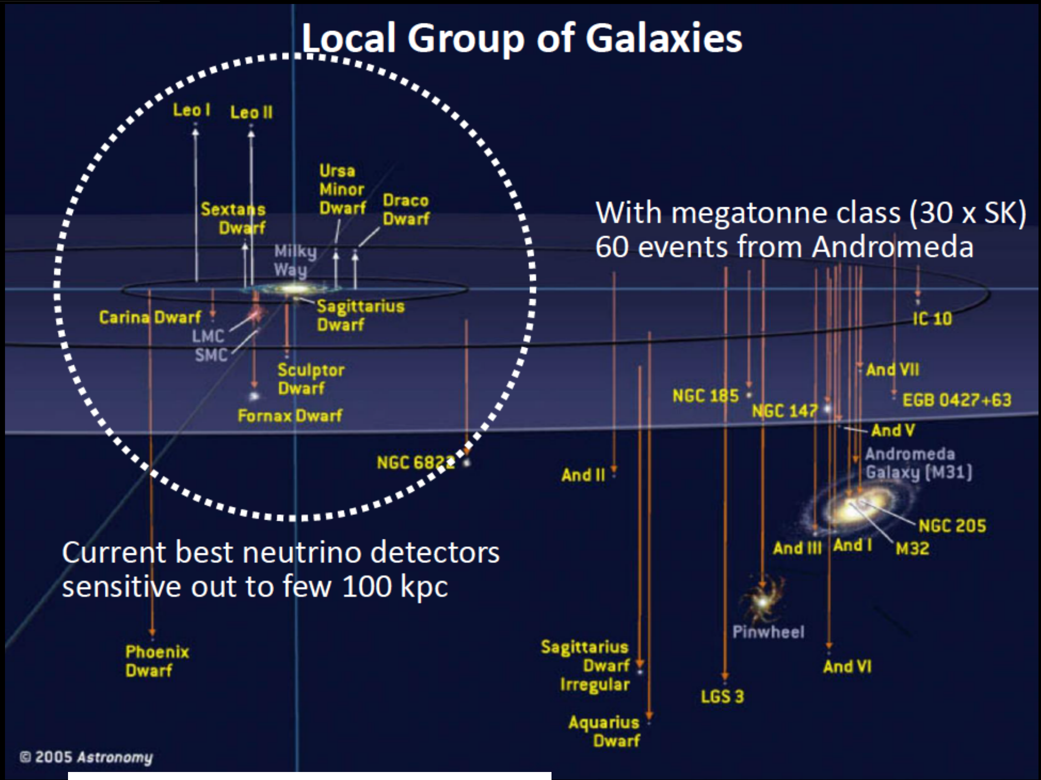


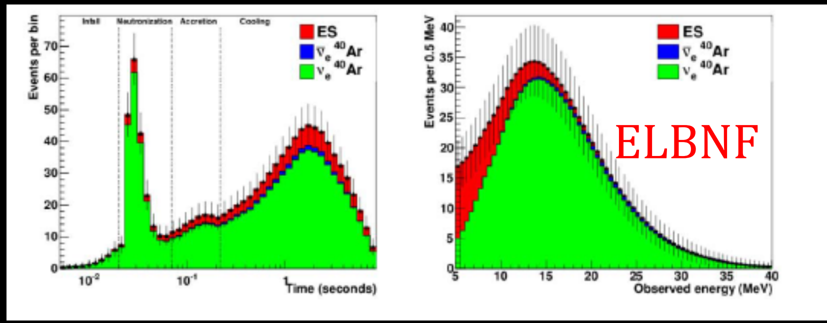
eLISA (2034)

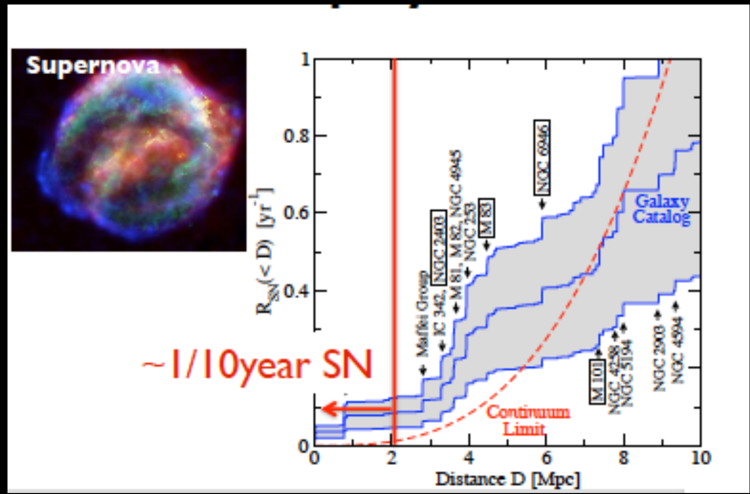
- 0.1-100 mHz ⟹ 1-1000 TeV (LHC)
- Phase transitions,
- Topological defects…
- Higgs self-couplings and potential
- Supersymmetry
- Extra dimensions
- Strings

✓ ET: if detection move to third generation (ca 2020) . ASPERA/ApPEC funding for R&D

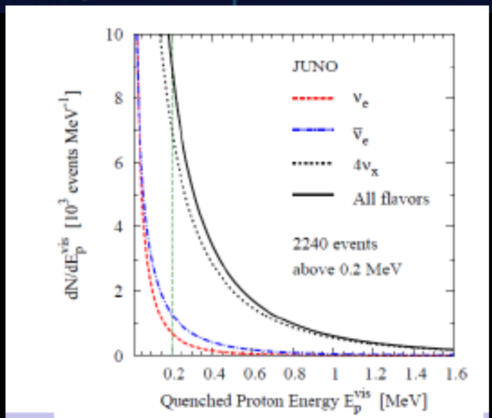
Last but not least: the first Neutrino Telescope Workshop happened in 1988 one year after 1987A, the next galactic supernova is expected by 2003±15….







Vissani



Also Diffuse Supernova Neutrinos for all techniques

Again, the 3 techniques give complementary information

Outstanding physics goals

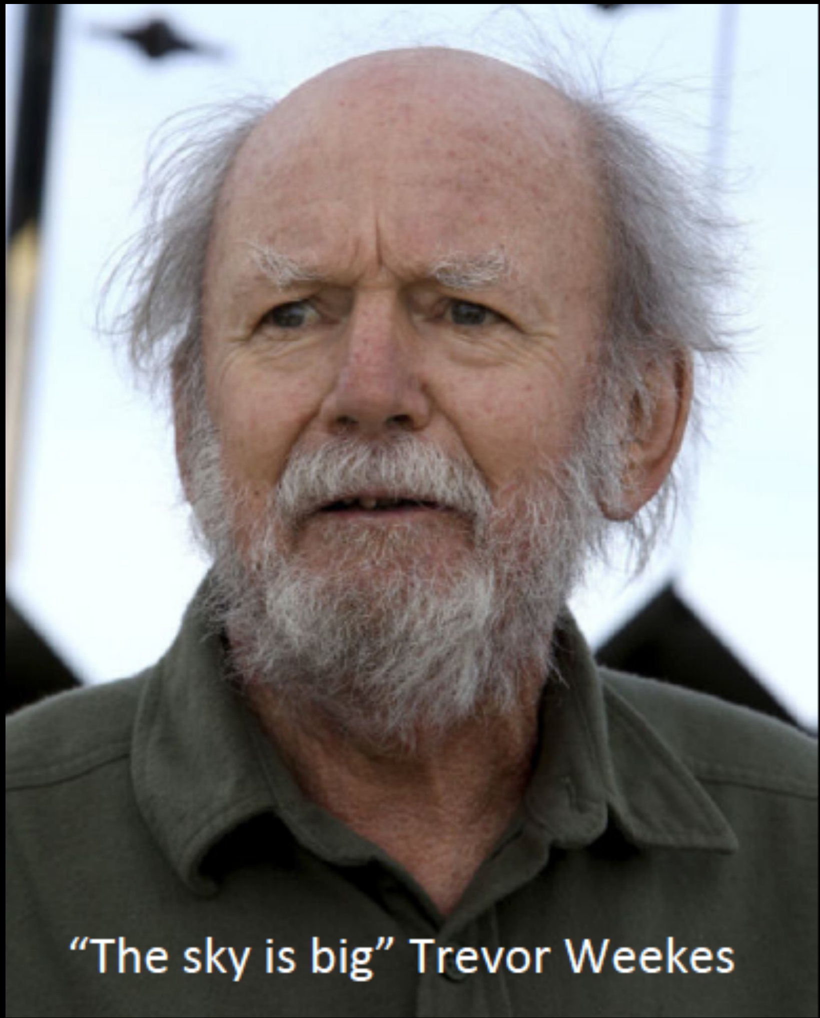
	ELBNF x 2,5	JUNO x 2,5	HK
Total mass	100 Kton	50 kton	500 Kton
p -> eπ^0 in 10 y	0.5 x 10^{35} y ε = 45%, ~1 BG event	?	1.2 x 10^{35} y ε = 17%, ~1 BG event
p -> ν K in 10 y	1.1 x 10^{35} y ε = 97%, ~1 BG event	0.4 x 10^{35} y ε = 65%, <1 BG event	0.15 x 10^{35} y ε = 8.6%, ~30 BG events
SN cool off at 10 Kpc	38·500 (all flavors) (64·000 if NH-L mixing)	20·000 (all flavors)	194·000 (mostly ν_ep->e$^+$n)
Sn in Andromeda	7 - (12 if NH-L mixing)	4 events	40 events
SN burst at 10 Kpc	380 ν_e CC (flavor sensitive)	~ 30 events	~ 250 ν-e elastic scattering
DSN	50	20-40	250 (2500 with Gd)
Atm. neutirnos	~1·100 events/y	5600/y	56·000 events/y
Solar neutrinos	324·000 events/y	?	91·250·000/y
Geo-neutirnos	0	~ 3·000 events/y	0

T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany

Ricci

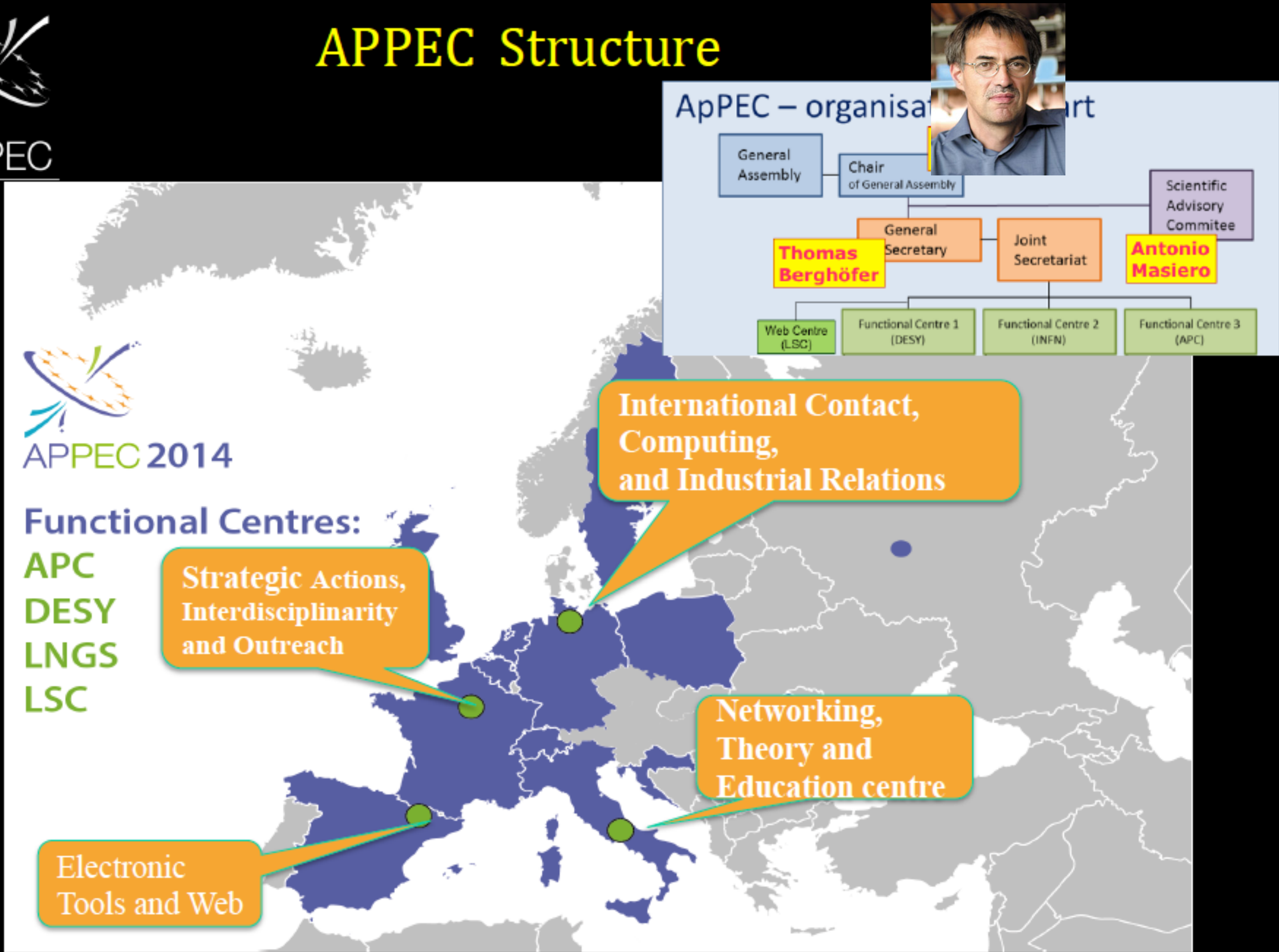
Mass, pattern recognition,flavour discimination, threshold

Remember Francis' quote of Trevor Weeks in the beginning of this conference :



But the agencies answer : « Yes but the budget is small… »

APPEC Structure



Since 9 January 2015 New chair Frank Linde

Decisions ahead in a European and global context in view of the APPEC Roadmap to be published by the end of 2015 after community consultation

We will need to take decisions in the next 2-3 years (in sync with CERN strategy) on:

1. the construction of the phase 2 of of KM3Net and the extension of ICECUBE including PINGU/ORCA
2. a major contribution to a long baseline program in US or Japan (active support to SBL also)
3. a European-led dark matter multi-ton experiment and a ton-scale neutrino mass detector (double beta decay technique) in a global context
4. A major contribution on ground and/or space to the cosmology program probing the parameters of inflation.

In parallel continue the support to 2nd generation gravitational wave commissioning , neutrino platform at CERN, CTA and large dark energy surveys on ground and space.

Attention to the many complementary aspects to the space program in development by ESA (EUCLID, ATHENA, eLISA, ?a space cosmology mission?)

Conclusions

- Since the start of these conferences 27 years ago, we have seen the first detection of a high energy source, the Crab in high energy photons by Weekes et al. (1989) and then at least 3 major paradigm-changing discoveries in the 90's
  - the CMB fluctuations
  - the confirmation of neutrino oscillation and mass
  - dark energy
- The precisions obtained in the past 10-15 years in all 4 domains is impressive
- What can we reasonably expect in the coming 10-20 years ?
  - A determination of the neutrino masses, number and CP violation and the understanding of their interplay with cosmology
  - the development of neutrino astronomy in a multi-messenger context
  - the first detection of gravitational waves,
  - dark matter sensitivities close to the parameter limits of our current theories, and ultimate precisions measurements in inflation and dark energy,
  - another supernova ?

SO PLEASE MAURO, PINA AND COLLEAGUES CONTINUE ORGANISING THIS MAGNIFICENT CONFERENCE