Seven years of Astroparticle Roadmapping

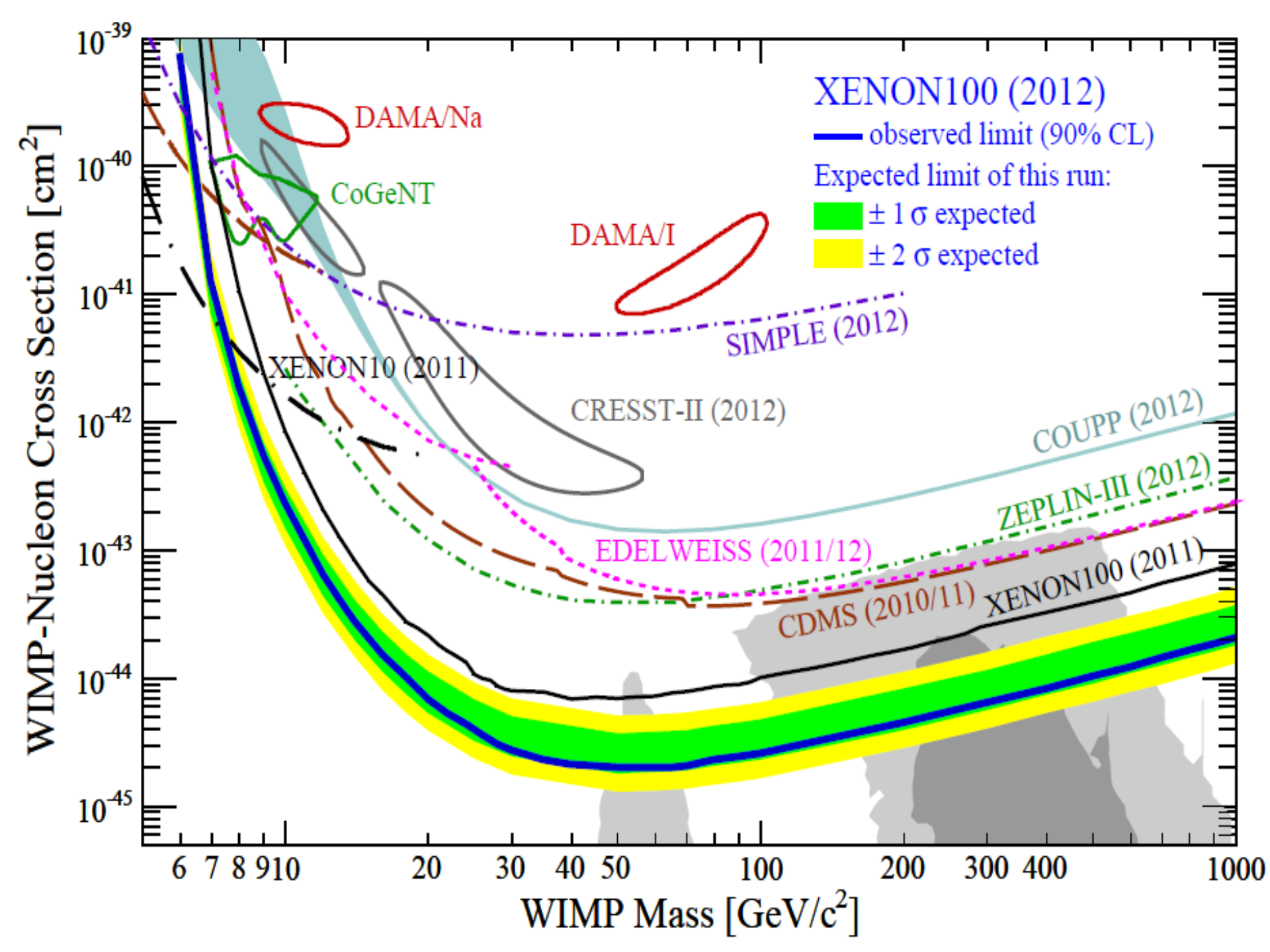
Progress, Reality Check, Lessons

Christian Spiering

The last 18 months:

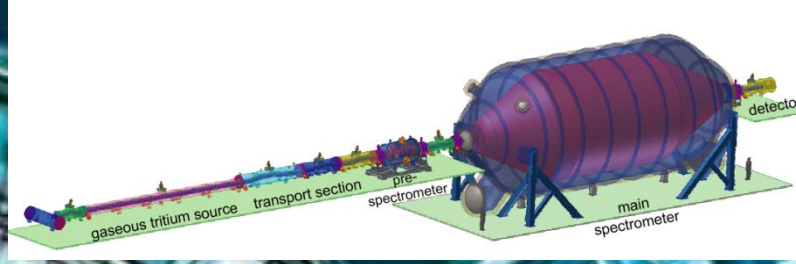
STEADY PROGESS

13


XENON100 (2012)
observed limit (90% CL)
Expected limit of this run:
± 1 σ expected
± 2 σ expected
DAMA/Na
CoGeNT
DAMA/I
SIMPLE (2012)
XENON10 (2011)
CRESST-II (2012)
COUPP (2012)
ZEPLIN-III (2012)
EDELWEISS (2011/12)
CDMS (2010/11)
XENON100 (2011)
WIMP-Nucleon Cross Section [cm^2]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
6 7 8 9 10 20 30 40 50 100 200 300 400 1000

KATRIN Main Spectrometer

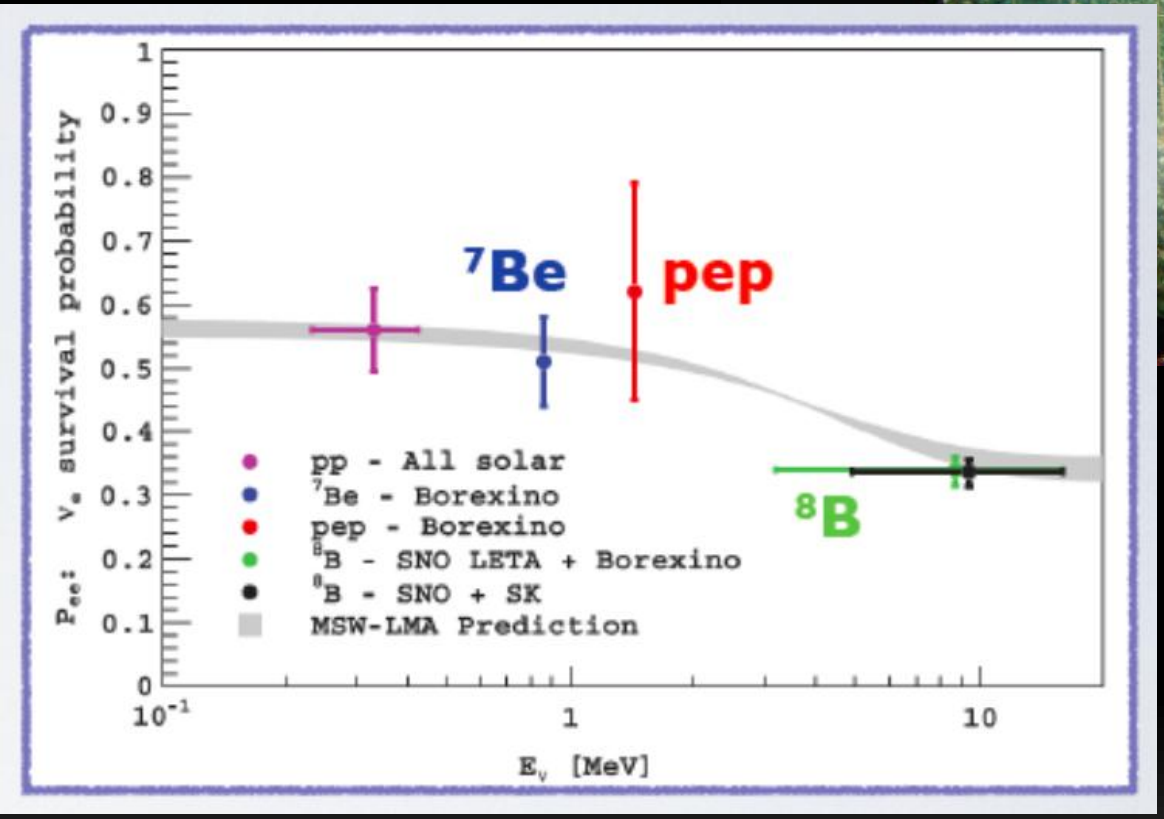
electrode sytem installed (Jan 2012)



GERDA: taking data

Unblinding: Spring 2013

Borexino



Solar nu: ^{7}Be, pep

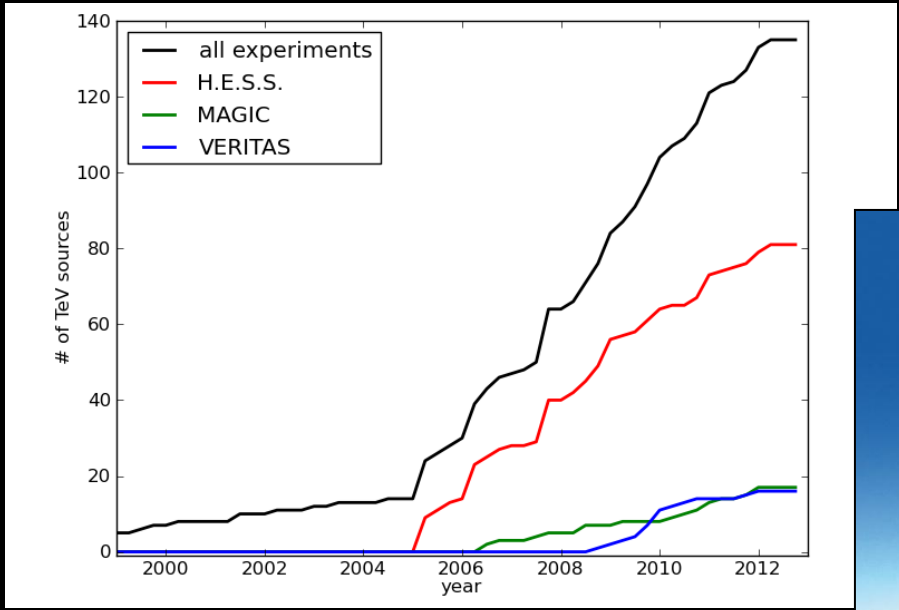
geo-neutrinos

Gamma Rays

H.E.S.S., MAGIC, VERITAS

Fermi, Agile

+ new technologies: FACT, HiSCORE



G-APD, La Palma

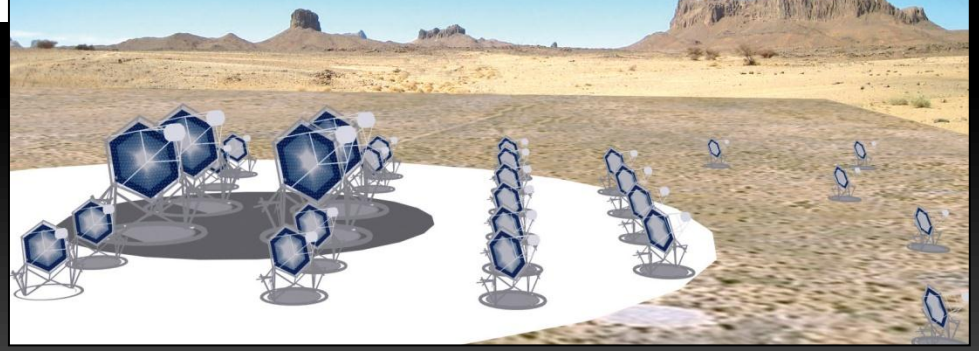
Timing Array, Siberia

10 fold sensitivity of current instruments
10 fold energy range

~1000 sources and
new phenomena expected

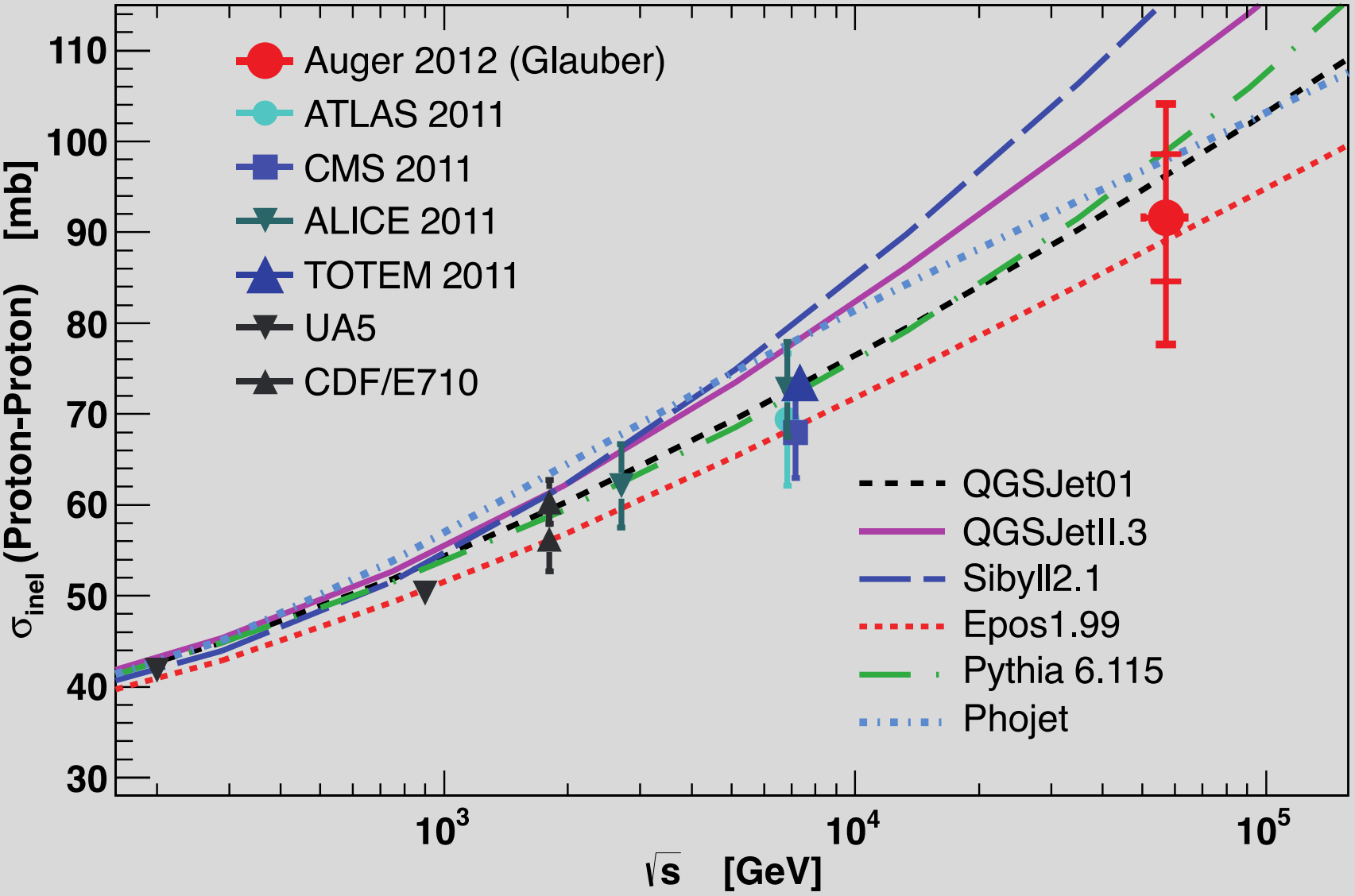
cta
cherenkov telescope array

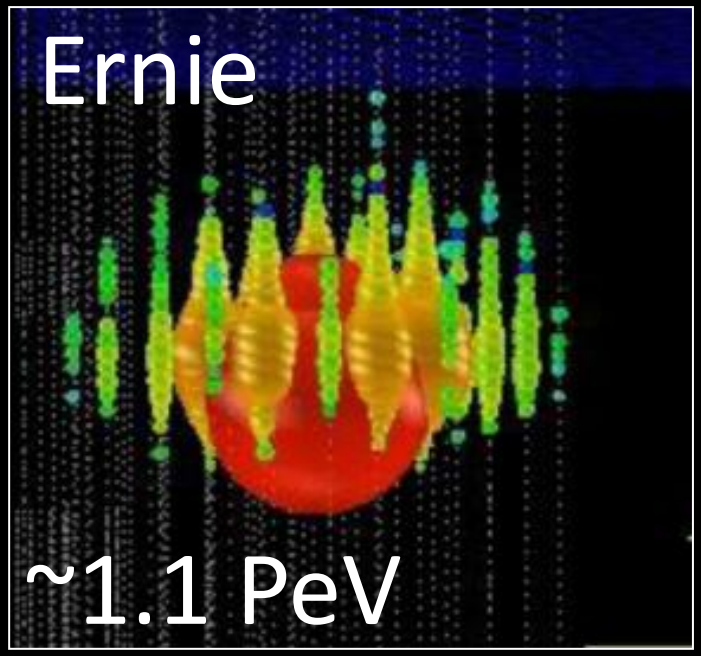
25 countries, 132 institutes,800 scientists

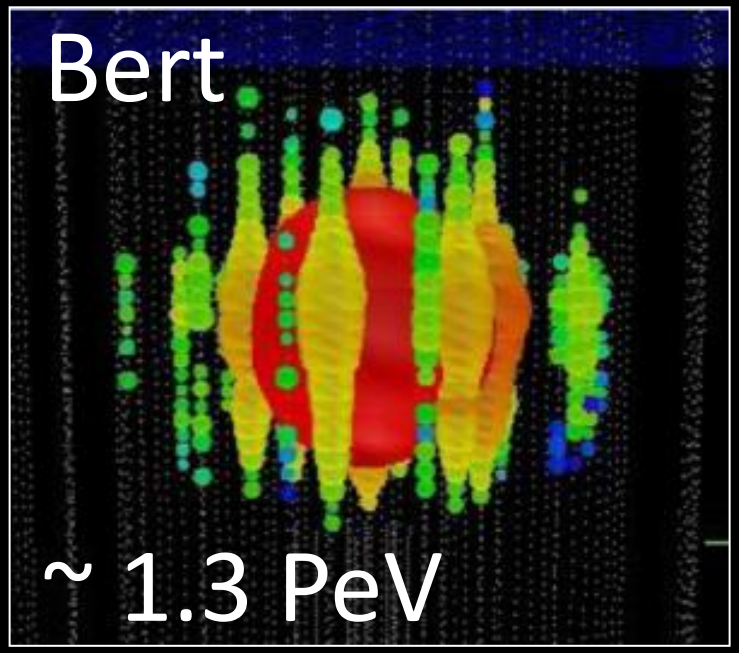



Prototype of Mid-Size Telescope CTA, Berlin
(photoshop version)

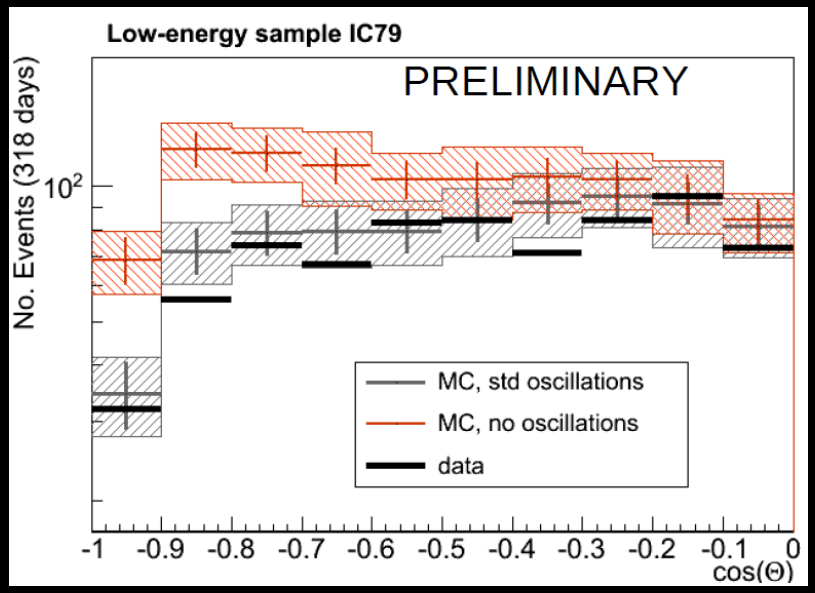
AUGER ↔ LHC


Auger 2012 (Glauber)
ATLAS 2011
CMS 2011
ALICE 2011
TOTEM 2011
UA5
CDF/E710
QGSJet01
QGSJetII.3
Sibyll2.1
Epos1.99
Pythia 6.115
Phojet
σ_{inel} (Proton-Proton) [mb]
$\sqrt{s}$ [GeV]
110
100
90
80
70
60
50
40
30
10^3
10^4
10^5





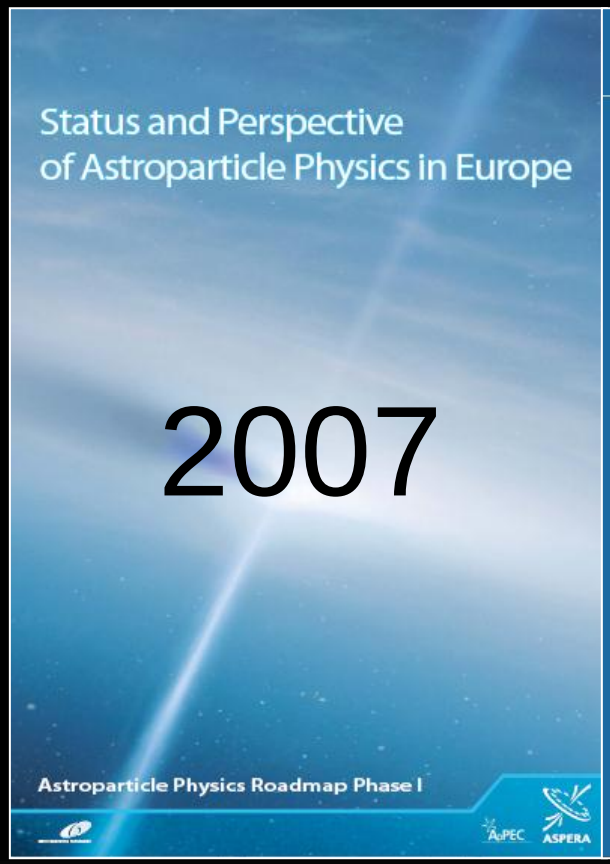
Excess at high energies?

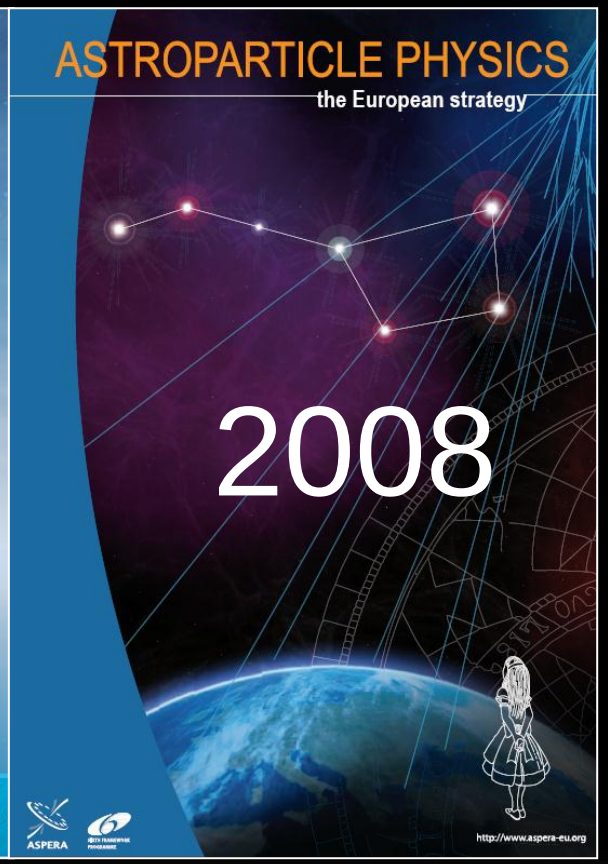


Neutrino Oscillation in DeepCore and Antares

→ PINGU/ORCA & mass hierarchy?

2 (+2) ROADMAPS

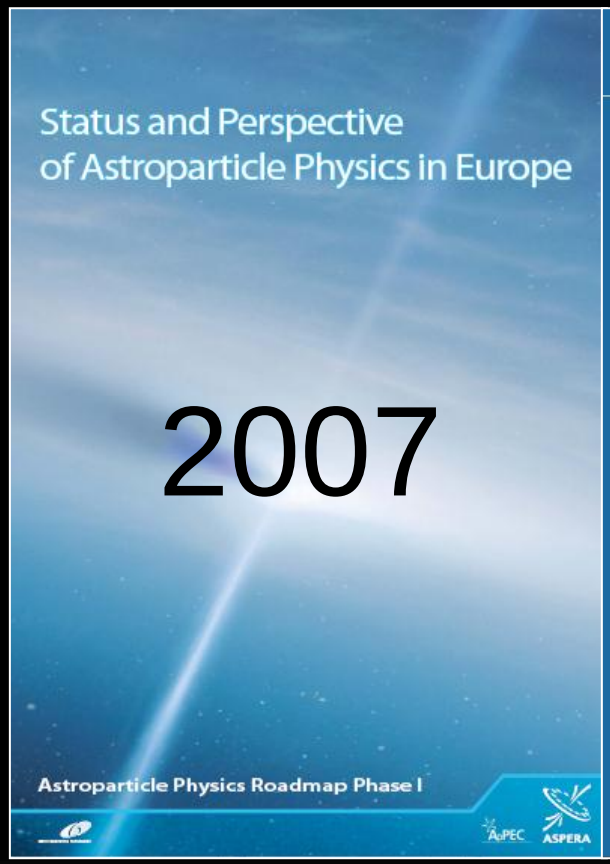

Status and Perspective
of Astroparticle Physics in Europe
2007
Astroparticle Physics Roadmap Phase I
ASPERA

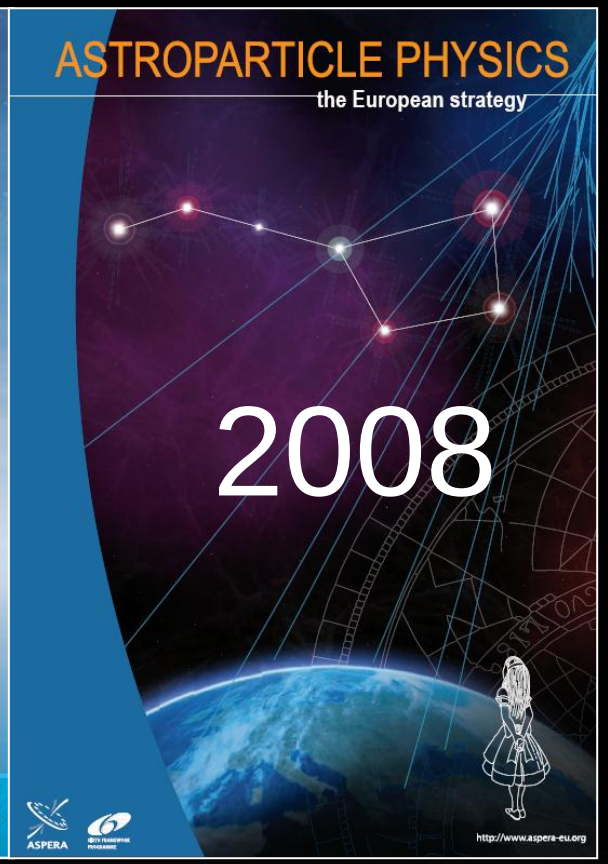

ASTROPARTICLE PHYSICS
the European strategy
2008
ASPERA
http://www.aspera-eu.org


Astroparticle physics
The European Roadmap
2011
ASPERA

S.K. coins „The Magnificent Seven“
(and notes that in the classic movie only 3 of them survive)

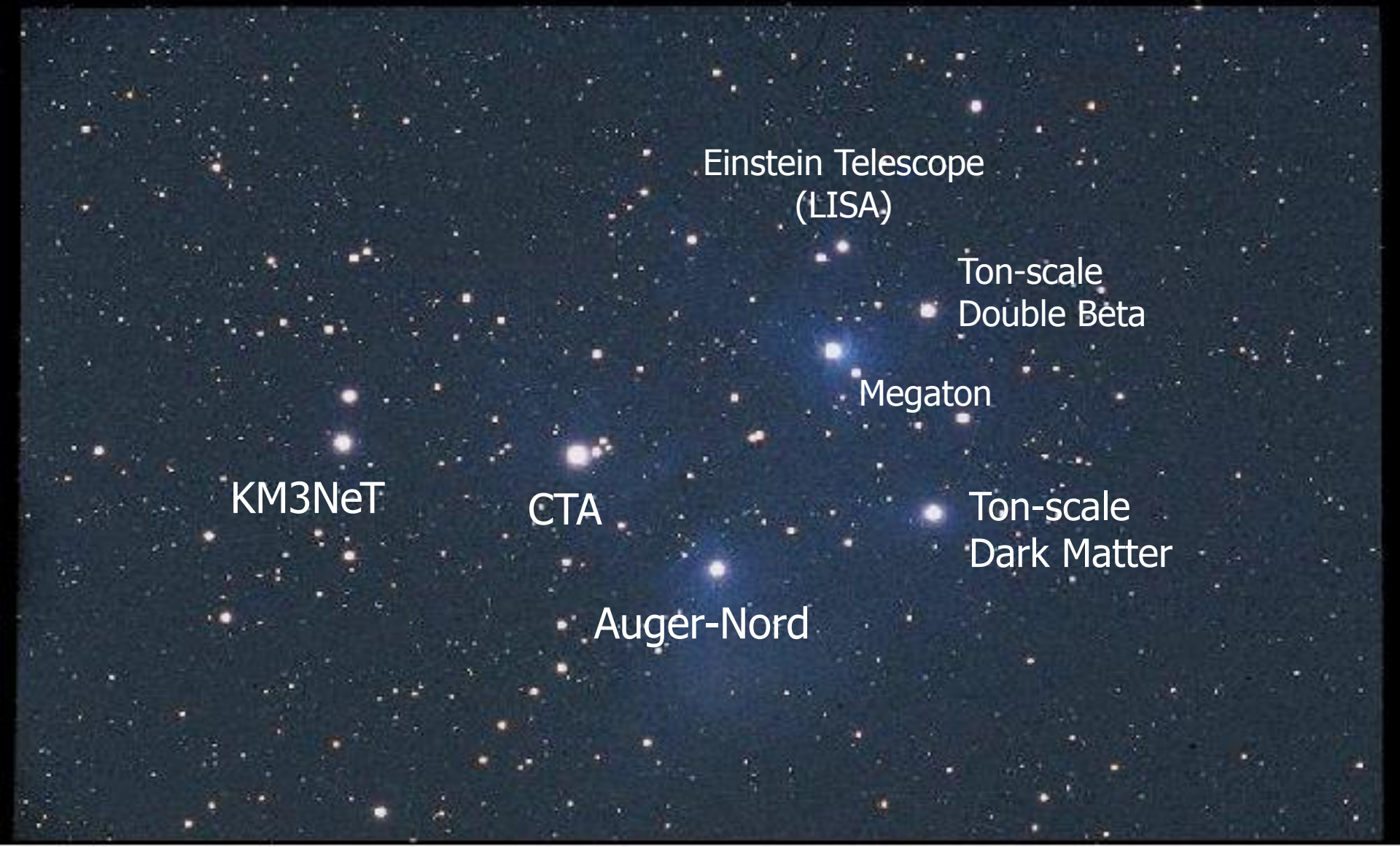
A.M. realizes the the Big Dipper looks better than the Pleiades

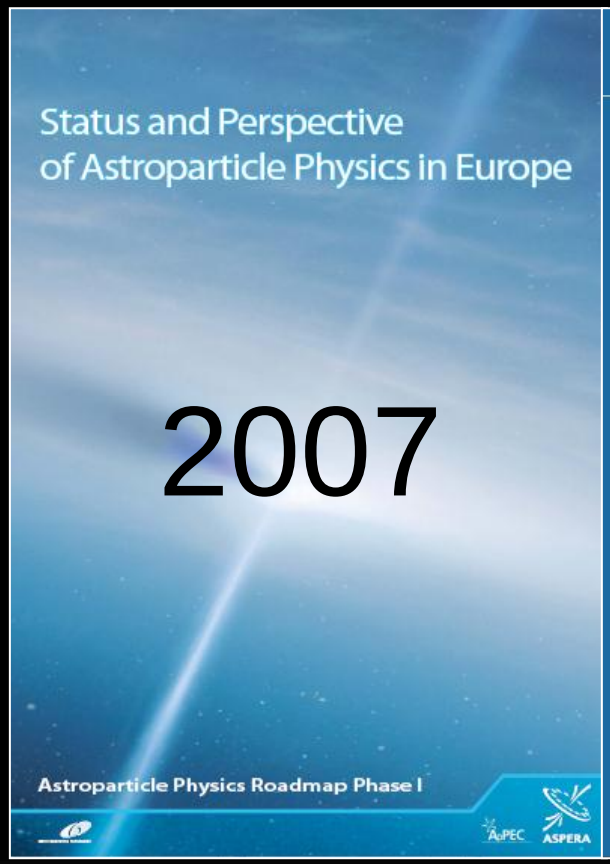




C.S. invents Alice, looking to the
Wonderland of Astroparticle Physics

AppEC's Plejades (Siebengestirn)




Status and Perspective
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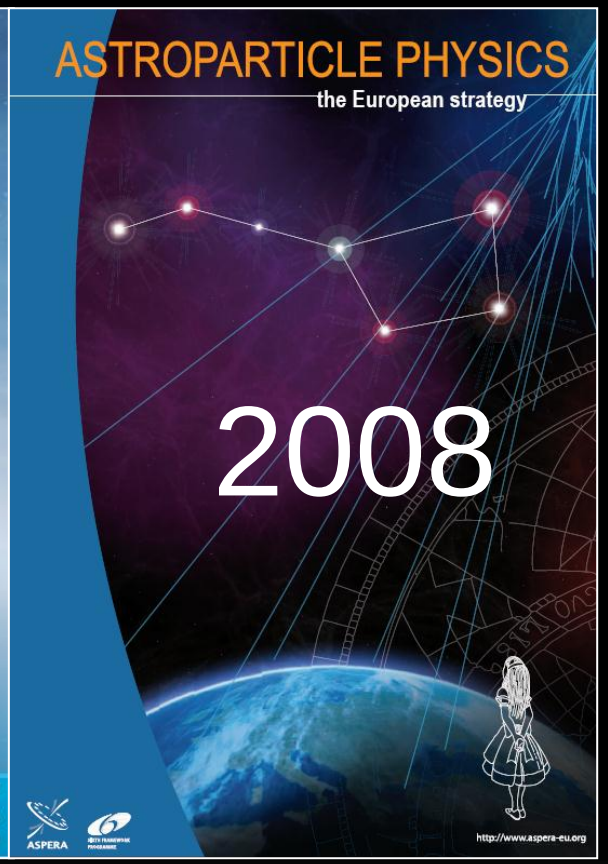
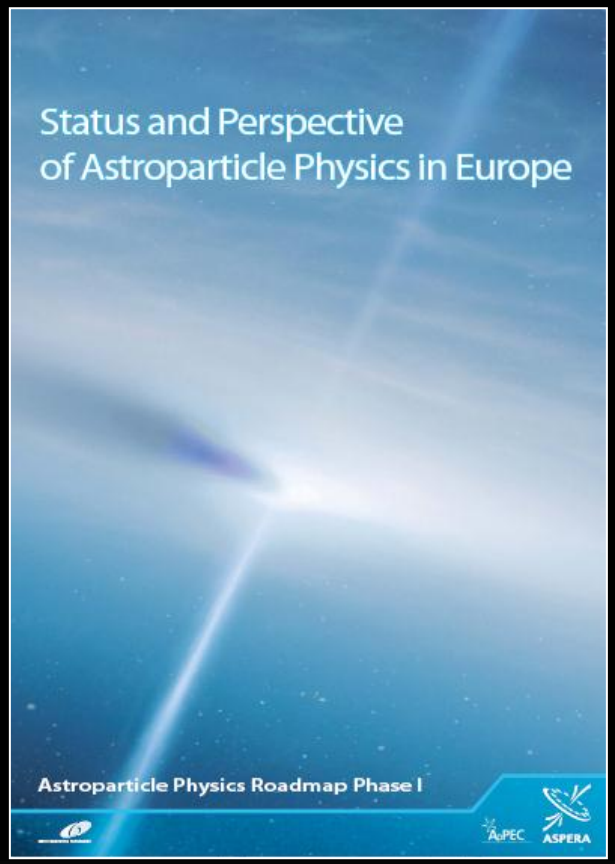

ASTROPARTICLE PHYSICS
the European strategy
2008
ASPERA
http://www.aspera-eu.org

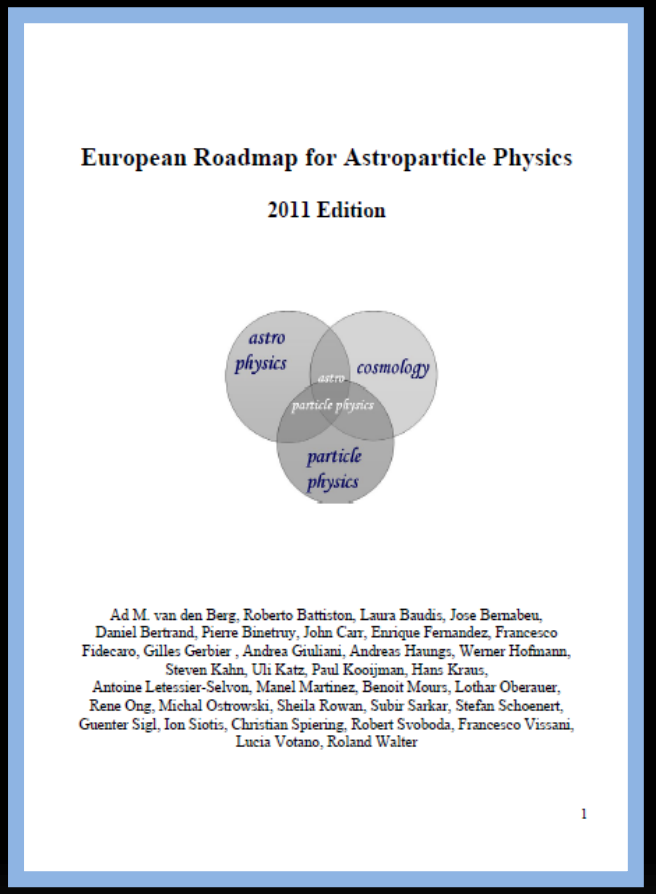

Astroparticle physics
The European Roadmap
2011
ASPERA

2007



142-page document

2011


European Roadmap for Astroparticle Physics

2011 Edition

astro physics
cosmology
astro particle physics
particle physics

Ad M. van den Berg, Roberto Battiston, Laura Baudis, Jose Bernabeu, Daniel Bertrand, Pierre Binetruy, John Carr, Enrique Fernandez, Francesco Fidecaro, Gilles Gerbier , Andrea Giuliani, Andreas Haungs, Werner Hofmann, Steven Kahn, Uli Katz, Paul Kooijman, Hans Kraus, Antoine Letessier-Selvon, Manel Martinez, Benoit Mours, Lothar Oberauer, Rene Ong, Michal Ostrowski, Sheila Rowan, Subir Sarkar, Stefan Schoenert, Guenter Sigl, Ion Siotis, Christian Spiering, Robert Svoboda, Francesco Vissani, Lucia Votano, Roland Walter

1

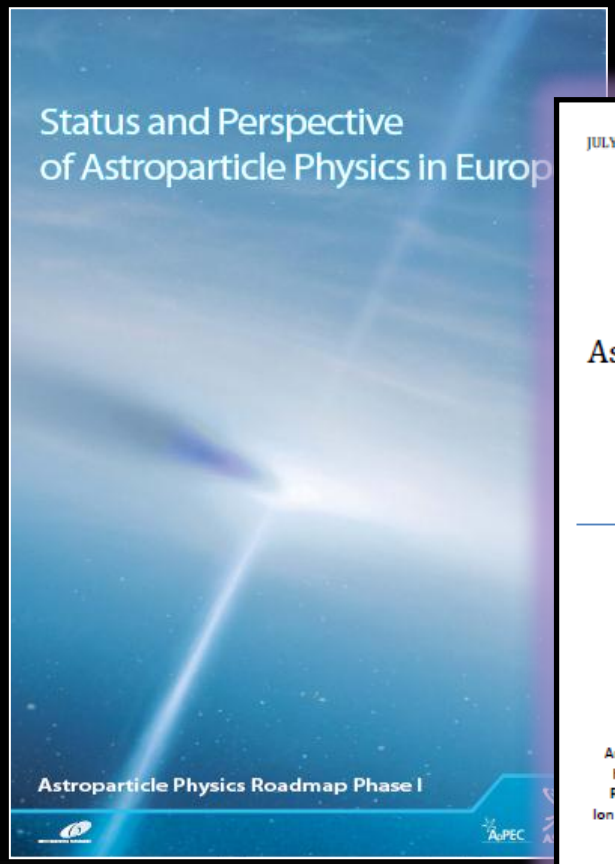
87-page document

2007

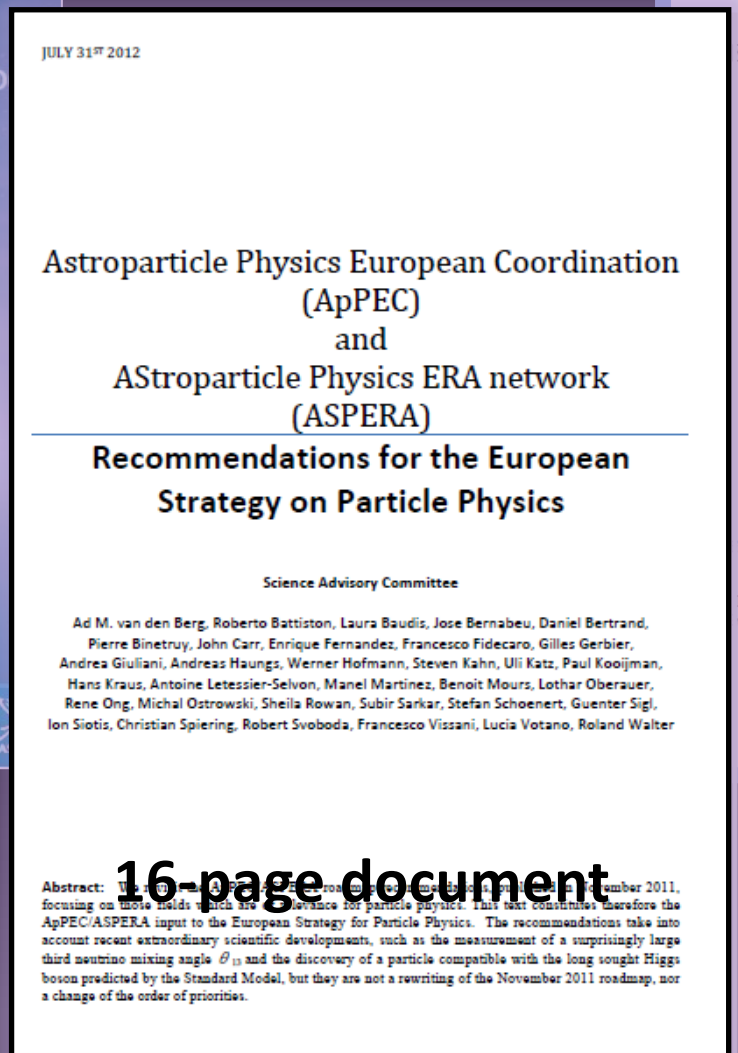
Input to the European Strategy

July 2012

2011



142-page document


JULY 31ST 2012

Astroparticle Physics European Coordination
(ApPEC)
and
AStroparticle Physics ERA network
(ASPERA)

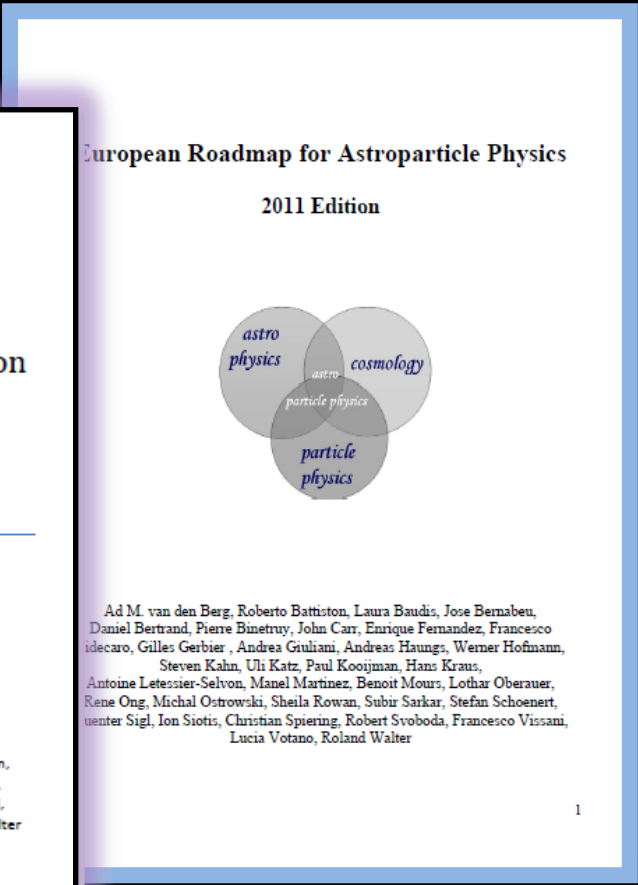
Recommendations for the European Strategy on Particle Physics

Science Advisory Committee

Ad M. van den Berg, Roberto Battiston, Laura Baudis, Jose Bernabeu, Daniel Bertrand, Pierre Binetruy, John Carr, Enrique Fernandez, Francesco Fidecaro, Gilles Gerbier, Andrea Giuliani, Andreas Haungs, Werner Hofmann, Steven Kahn, Uli Katz, Paul Kooijman, Hans Kraus, Antoine Letessier-Selvon, Manel Martinez, Benoit Mours, Lothar Oberauer, Rene Ong, Michal Ostrowski, Sheila Rowan, Subir Sarkar, Stefan Schoenert, Guenter Sigl, Ion Siotis, Christian Spiering, Robert Svoboda, Francesco Vissani, Lucia Votano, Roland Walter

Abstract: [illegible] November 2011, focusing on those fields which are relevance for particle physics. This text constitutes therefore the ApPEC/ASPERA input to the European Strategy for Particle Physics. The recommendations take into account recent extraordinary scientific developments, such as the measurement of a surprisingly large third neutrino mixing angle θ_{13} and the discovery of a particle compatible with the long sought Higgs boson predicted by the Standard Model, but they are not a rewriting of the November 2011 roadmap, nor a change of the order of priorities.

16-page document


European Roadmap for Astroparticle Physics

2011 Edition

Ad M. van den Berg, Roberto Battiston, Laura Baudis, Jose Bernabeu, Daniel Bertrand, Pierre Binetruy, John Carr, Enrique Fernandez, Francesco idecaro, Gilles Gerbier , Andrea Giuliani, Andreas Haungs, Werner Hofmann, Steven Kahn, Uli Katz, Paul Kooijman, Hans Kraus, Antoine Letessier-Selvon, Manel Martinez, Benoit Mours, Lothar Oberauer, Rene Ong, Michal Ostrowski, Sheila Rowan, Subir Sarkar, Stefan Schoenert, uenter Sigl, Ion Siotis, Christian Spiering, Robert Svoboda, Francesco Vissani, Lucia Votano, Roland Walter

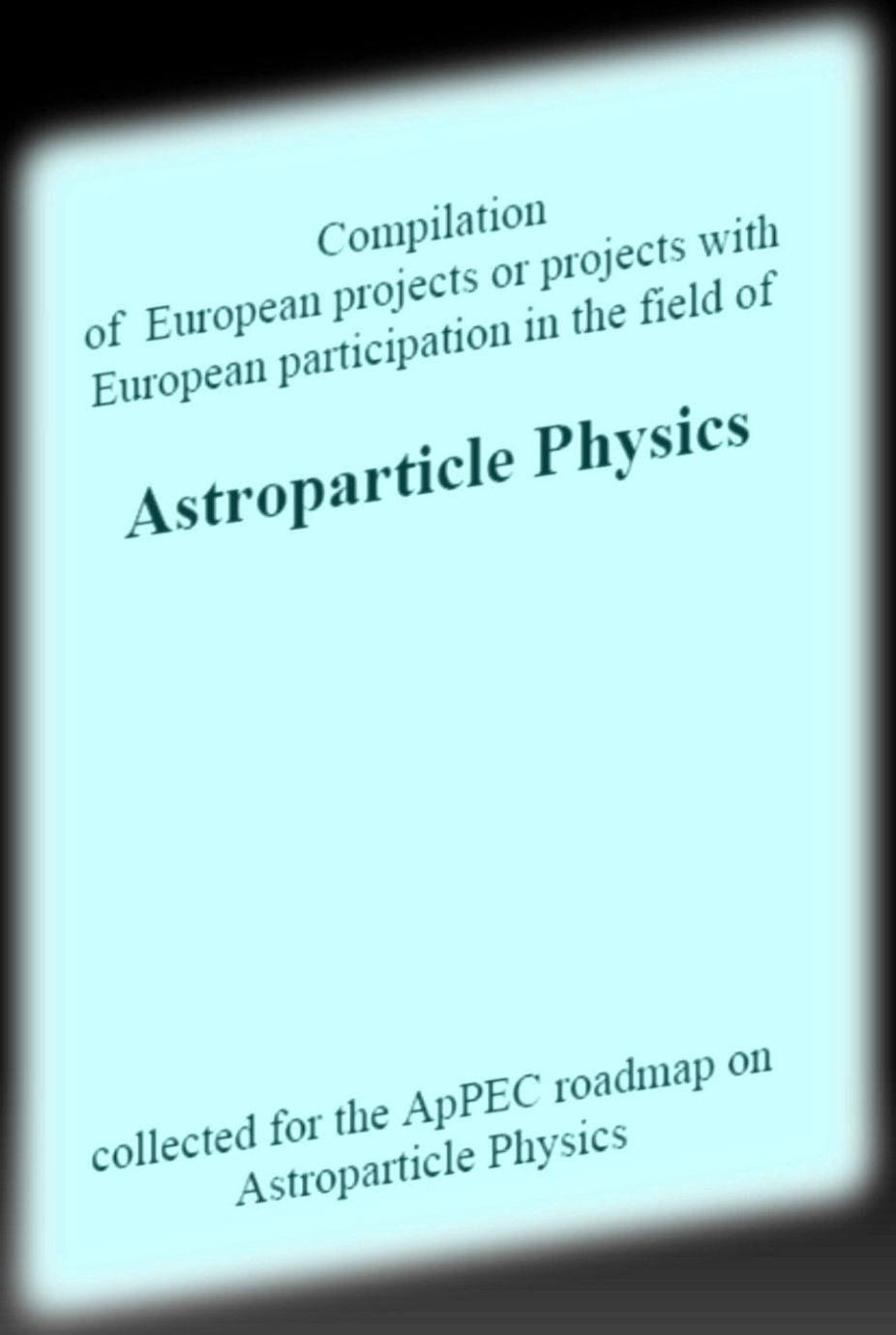
1

87-page document

2005-6

STARTING THE PROCESS

- Early 2005: ApPEC SC decides to order a roadmap
- June 23/24 2005: ApPEC PRC sketches length (50-60 pages) and content of the Roadmap
- First step: Questionnaire
- First drafts from the WG scheduled for Nov. 2005



Dec. 2005: Compilation of all activities

Double Beta Decay and Neutrino Mass

GERDA	Stefan Schoenert (Heidelberg)	Stefan.Schoenert@mpi-hd.mpg.de
Cuoricino	Ettore Fiorini (Milano)	ettore.fiorini@mib.infn.it
Cuore	Ettore Fiorini (Milano)	ettore.fiorini@mib.infn.it
EXO	Jean-Luc Vuilleumier (Neuchâtel) for Europe G.Gratta (SLAC)	jean-luc.vuilleumier@unine.ch gratta@stanford.edu
NEMO-3	Serge Jullian (LAL Orsay)	jullian@lal.in2p3.fr
SuperNEMO	Serge Jullian LAL Orsay Fabrice Piquemal (CEN Bordeaux)	jullian@lal.in2p3.fr piquemal@cenbg.in2p3.fr
COBRA	Kai Zuber (Oxford)	kai.zuber@physics.ox.ac.uk
KATRIN	Guido Drexlin (Karlsruhe) Christian Weinheimer (Münster)	drexlin@ik.fzk.de weinheimer@uni-muenster.de
MANU2	Flavio Gatti (Genoa)	flavio.gatti@ge.infn.it
MI-Beta	Andrea Giuliani (Milano)	andrea.giuliani@mib.infn.it
MARE	Flavio Gatti (Genoa) Andrea Giuliani (Milano)	flavio.gatti@ge.infn.it andrea.giuliani@mib.infn.it

GERDA

Name of experiment/device	GERDA: The Germanium Detector Array for the search of neutrinoless ββ decays of ^{76}Ge at LNGS
Present Spokesperson (location, email)	Stefan Schoenert (MPI Heidelberg, stefan.schoenert@mpi-hd.mpg.de)
Collaborating Institutions [2]	12 (MPI Heidelberg, MPI Munich, Univ. Tuebingen, Univ. Cologne, INR Moscow, ITEP Moscow, Kurchatov Moscow, JINR Dubna, Milano, Padova, LNGS, Cracow, Geel)
Collaborating countries	Germany, Italy, Russia, Belgium, Poland
Number of authors [3]	~ 70
Number of PhD students [3]	~ 6 (growing)
Location/Infrastructure	LNGS, Itlay
Funding agencies	MPG, BMBF, INFN
Scientific goals	Search for neutrinoless double beta decay
Design	Operation of 15 kg (phase I) / 30 kg (phase II) bare germanium detectors enriched in ^{76}Ge in liquid nitrogen/argon; background: 10^{-2} kg/keV/year (phase I) / 10^{-3} kg/keV/year (phase II)
Cost [4]	~ 10 Mio Euro (capital investment, incl. 2.6 Mio Euro in kind contributions from Russia)
Present status (R&D, construction, data taking, closed)	Construction work of detector infrastructures at LNGS 2005/6; enrichment of new Ge-76 completed
Most relevant results	Operation of bare Ge detectors in liquid nitrogen/argon, purification of liquid nitrogen/argon to <0.3 μBq/m^3
Perspective: - total cost, status of funding [5] - merging with other projects? [6] - close R&D relations to other projects ? [7] - coming relevant reviews ? [8] - branch points [9]	~10 Mio Euro, ~85% approved; GERDA and Majorana (USA) towards a next generation '10 meV experiment'; GERDA to Majorana
Which relevant results are expected, and when ? [10]	Scrutinze claim for 0νββ evidence in 2007/8; sensitivity for majorana mass <~90 meV in 2010
Most actual information - web page - recent transparencies available on the web - recent results in journals or on preprint server.	LoI, Proposal, Technical Proposal, Progress Reports, presentations at http://www.mpi-hd.mpg.de/GERDA

Compiled by: Stefan Schoenert Date: September, 7, 2005

CUORE

Name of experiment/device	CUORE (for Cryogenic Underground Observatory for Rare Events)
Present Spokesperson (location, email)	Ettore Fiorini (Milano-Bicocca, ettore.fiorini@mib.infn.it)
Collaborating Institutions [2]	Milano-Bicocca University , Milano-Politecnico, Laboratori Nazionali del Gran Sasso e di Legnaro, Lawrence Berkeley and Livermore National Laboratories, Zaragoza and Leiden Universities , Berkeley University, Firenze, Genova and Roma1 Universities
Collaborating countries	Italy, Netherlands, Spain, USA
Number of authors [3]	62
Number of PhD students [3]	18
Location/Infrastructure	Laboratori Nazionali del Gran Sasso
Funding agencies	Mainly INFN (Istituto Nazionale di Fisica Nucleare), CEE (TMR and ILIAS), DOE , NSF, Italian Ministry for Research, funds from the various Universities
Scientific goals	Search for neutrinoless double beta decay of Te-130, and likely of other nuclei, with a sensitivity of a few tens of meV at the level suggested by neutrino oscillation in the inverse hierarchy hypothesis , WIMPS, solar axions and rare nuclear events
Design	CUORE will be an array of 988 bolometers with absorbers made by cubic crystals of tellurite of 5 cm side with a total mass of ~ 760 kg
Cost [4]	About 14 M euro. Running costs will be ~ 300 keuro per year
Present status (R&D, construction, data taking, closed)	A pilot experiment, CUORICINO, is presently running in the Gran Sasso Laboratory. It is substantially identical to one of the 19 towers of CUORE. It is and will be essential for the evaluation and reduction of the background in CUORE. An intense R&D activity is going on in Hall C in Gran Sasso with a second powerful dilution refrigerator, while searches to reduce surface activity are carried out by all groups and in particular by the Laboratorio Nazionale di Legnaro. The building to house CUORE in Hall A of Gran Sasso has been designed. Data taking is expected to start at the beginning of 2010
Most relevant results	CUORICINO which is essential for R&D for CUORE is already successfully running and shows the perfect feasibility of CUORE which consists of 19 almost identical towers. Preliminary results show that the surface activity can be reduced by at least an order of magnitude
Perspective: - total cost, status of funding [5]	The tender for the CUORE dilution refrigerator has been published and the various offers are being
- merging with other projects? [6] - close R&D relations to other projects ? [7] - coming relevant reviews ? [8] - branch points [9]	analysed. Construction to house CUORE in hall A will start in 2006. Funds for the Italian part of the CUORE (6.5 Meuros) have been approved and 1.5 Meuros have been already allocated. A request for the remaining funds (7.5 Meuros) have been submitted by the American groups to DOE and are been considered by NuSAG. For R&D and especially for the reduction of the background, CUORE is in close contact with the running experiment NEMO III and with other major double beta decay experiments of second generation, in particular with GERDA and Majorana. Recently a review on CUORE has been presented by the USA groups (prof.Eric Norman) to NuSAG an a national review will be presented in October to INFN Reviews to the Gran Sasso Scientific Committee and to the funding authorities are presented twice per year
Which relevant results are expected, and when ? [10]	In a few years of running CUORE could prove or disprove the claimed evidence for neutrinoless double beta decay by Klapdor et al and (more important) will reach a sensitivity of a few tens of meV on the neutrino mass as indicated by the inverse hierachy in the neutrino oscillation resutls.
Most actual information - web page - recent transparencies available on the web - recent results in journals or on preprint server.	http://crio.mib.infn.it/wig/Cuorepage/CUORE.php 1. E. Fiorini: Double Beta Decay: the Future, Nucl.Phys.B (Proc.Suppl.) 91 (2001) 262 2. E.Fiorini: : Double beta decay and neutrino mass, Nucl.Phys.B(Proc.Suppl.) 110(2002)226 3. A. Alessandrello et al: A criogenic Underground Observatory for Rare Events : CUORE, an update, arXiv:hep-ex/0201038 v1 24 Jan 2002 4. C. Arnaboldi et al: CUORE: a Cryogenic Underground Observatory for Rare events Nucl.Instrum. and Meth.A 518 (2004) 775 5. C.Arnaboldi et al (CUORE Collaboration) Physics potential and prospects for the CUORICINO and CUORE experiments, Astroparticle Physics 20 issue 2 (2003) 91-110 . 6. E. Fiorini: Results from CUORICINO and perspectives for CUORE, Nucl.Phys.B (Proc.Suppl.) 143 (2005) 225

Compiled by: Ettore Fiorini Date August 20, 2005

First fragment of ApPEC Roadmaqp 16.10.2005

This report provides a European roadmap for astroparticle physics. It describes status and perspective of this field in Europe and links it to the activities in other parts of the world. It aims to promote astroparticle physics in the member states of ApPEC, to stimulate coordination and cooperation within the European astroparticle community and to prepare future decisions on National and European level. **The roadmap will cover the next ten years, with a focus to the next five.**

The document has been worked out by the ApPEC roadmap committee (RC) on request of the ApPEC Steering Committee (SC). The roadmap committee consists of the ApPEC Peer Review Committee (PRC), extended by additional experts from ApPEC member states, USA and Russia.

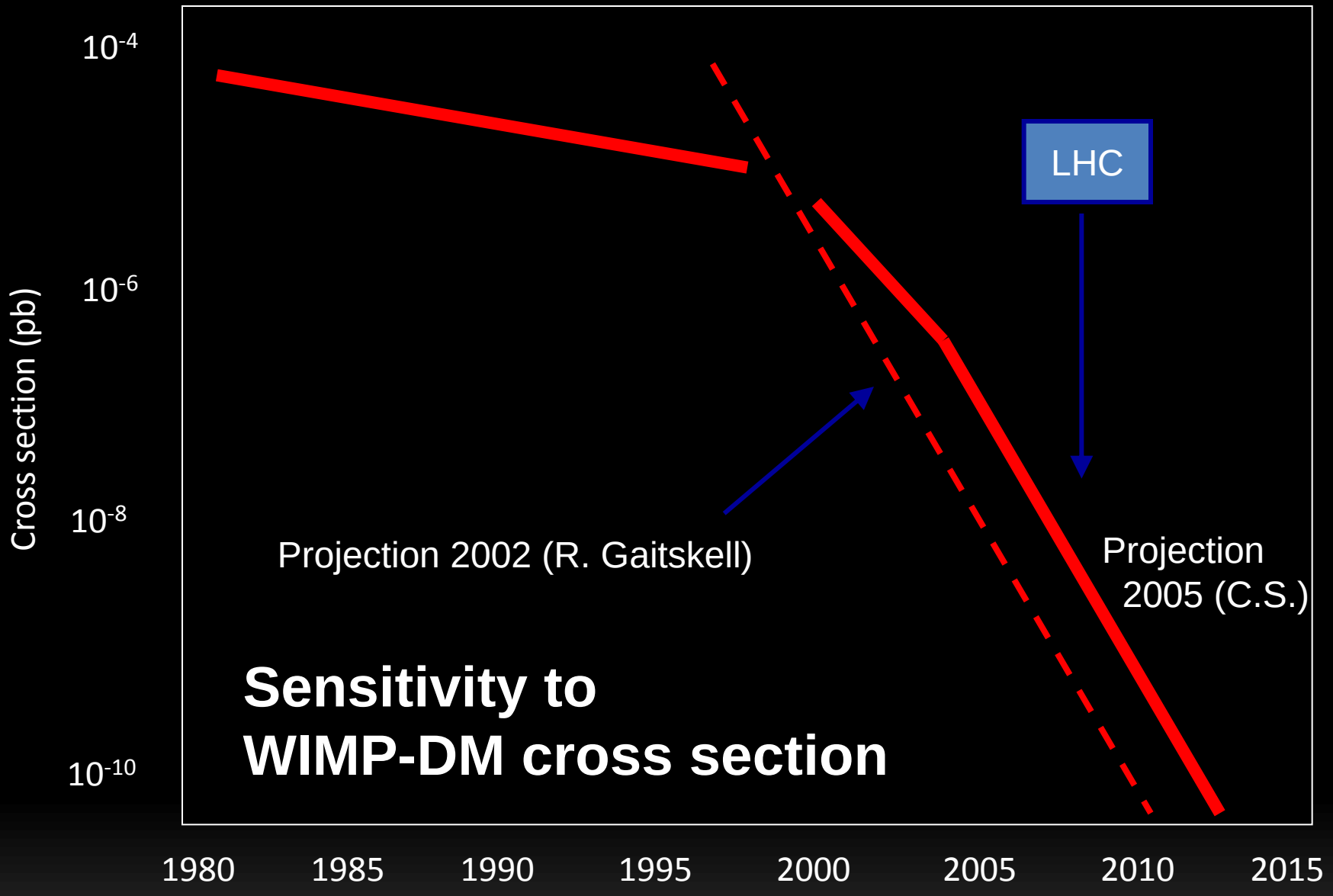
Six Questions

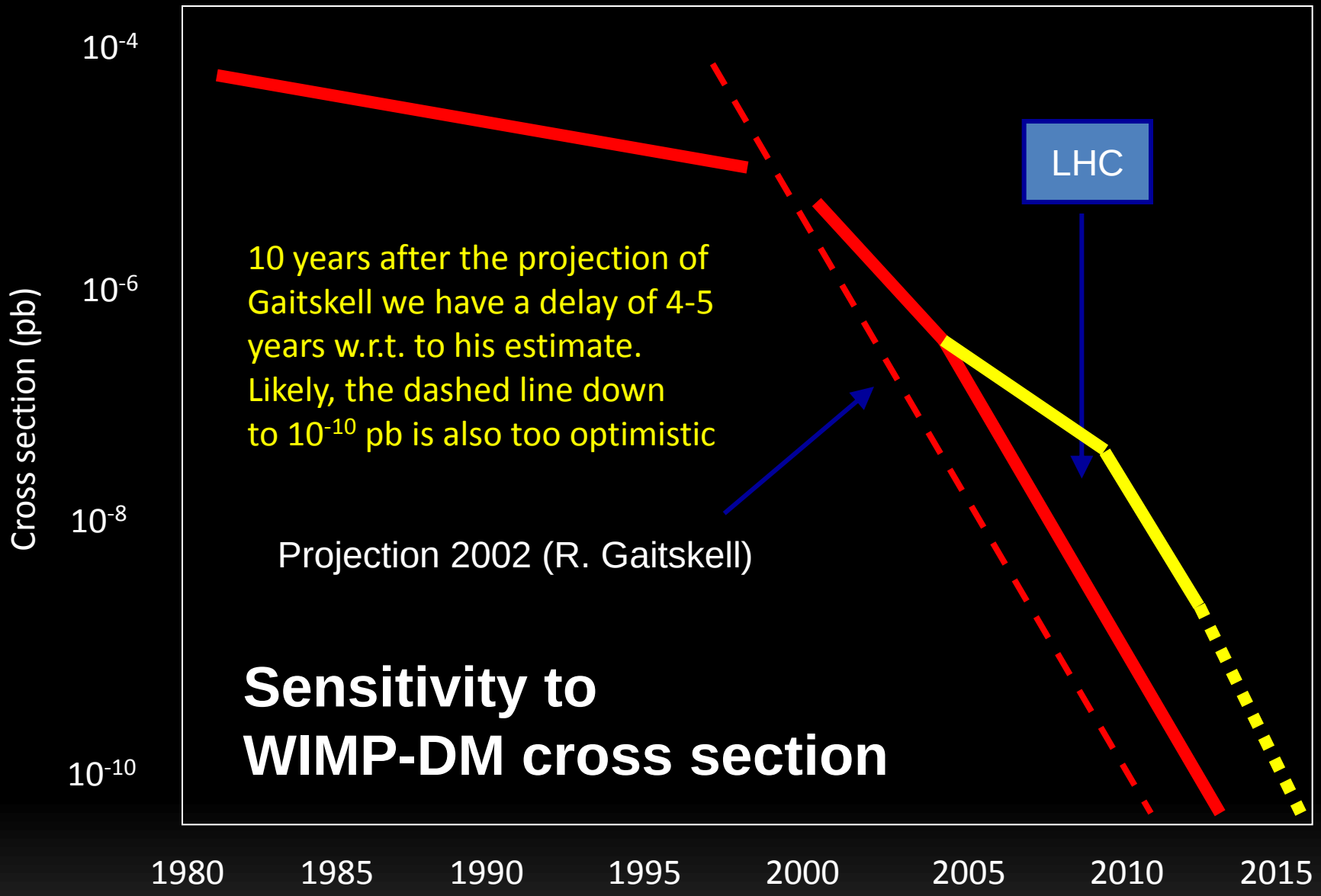
- What are the constituents of the Universe?
  In particular: What is dark matter?
- Do protons have a finite life time?
- What are the properties of neutrinos?
  What is their role in cosmic evolution?
- What do neutrinos tell us about the interior of the Sun and the Earth, and about Supernova explosions?
- What is the origin of cosmic rays ?
  What is the view of the sky at extreme energies ?
- What will gravitational waves they tell us about violent cosmic processes and about the nature of gravity?

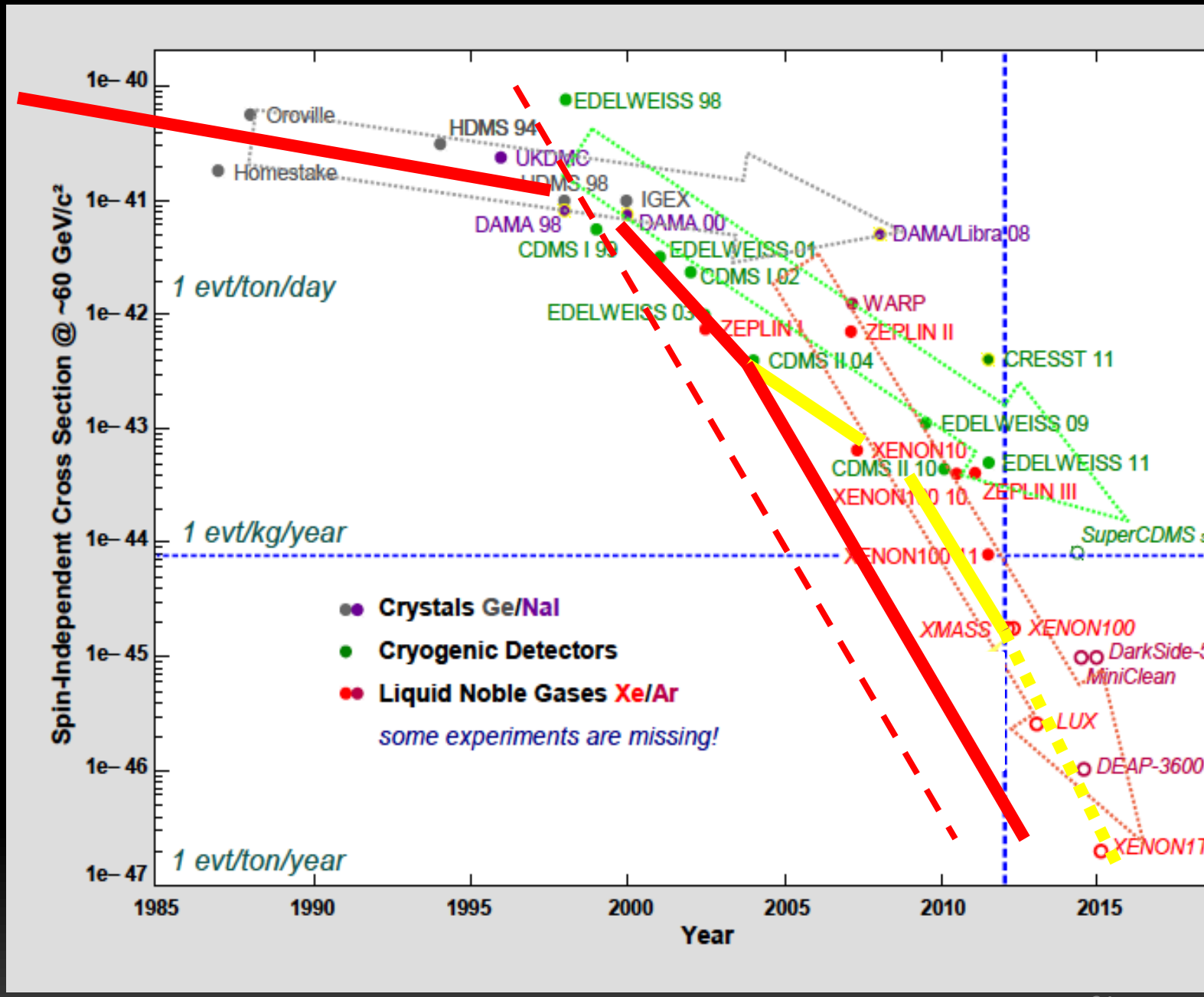
2005-2012

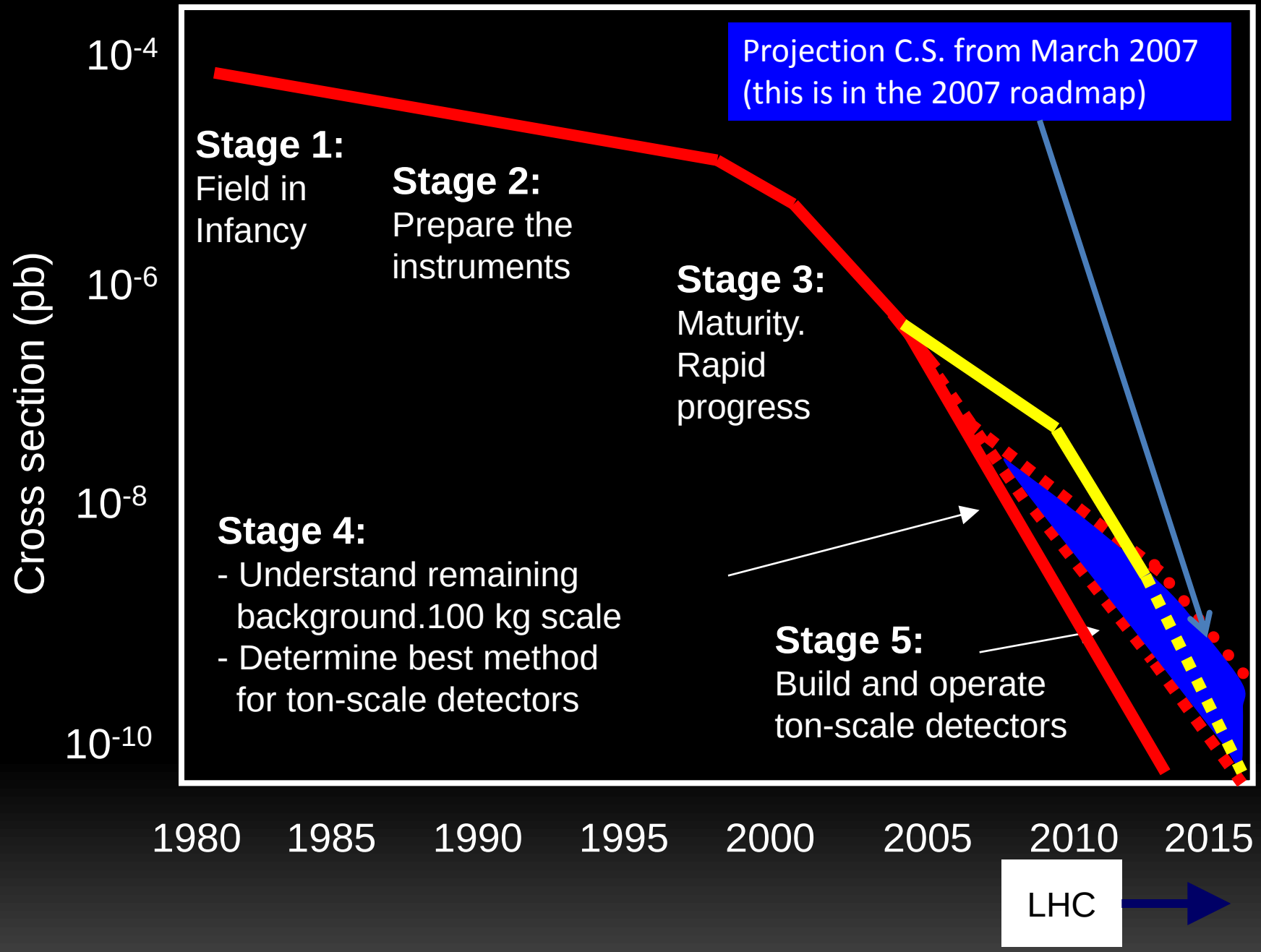
PROJECTIONS VS. REALITY

DARK MATTER

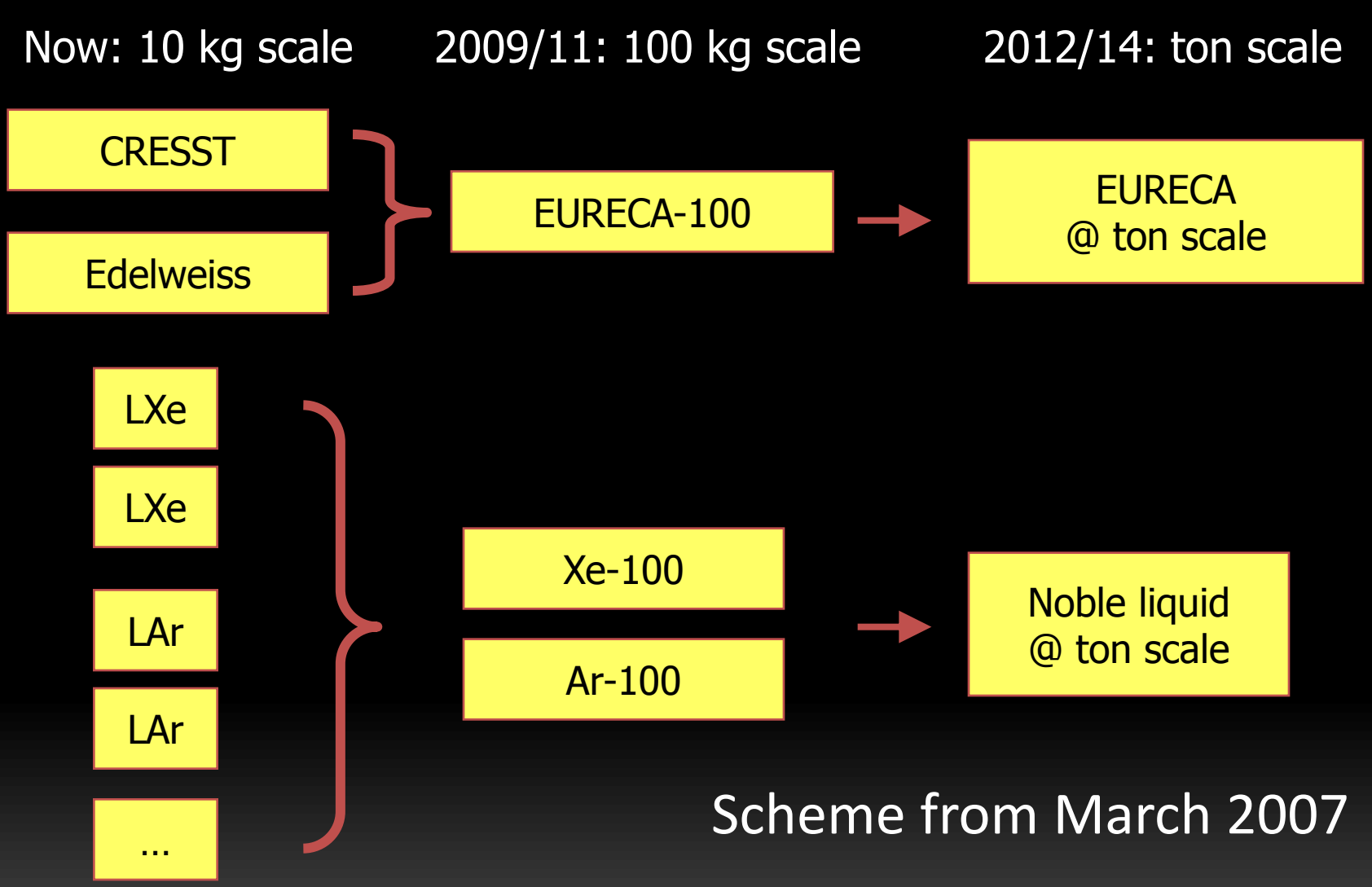

Cross section (pb)
10-4
10-6
10-8
10-10
1980
1985
1990
1995
2000
2005
2010
2015
LHC
Projection 2002 (R. Gaitskell)
Projection
2005 (C.S.)
Sensitivity to
WIMP-DM cross section


Cross section (pb)
10^{-4}
10^{-6}
10^{-8}
10^{-10}
1980
1985
1990
1995
2000
2005
2010
2015
LHC
10 years after the projection of Gaitskell we have a delay of 4-5 years w.r.t. to his estimate.
Likely, the dashed line down to 10^{-10} pb is also too optimistic
Projection 2002 (R. Gaitskell)
Sensitivity to WIMP-DM cross section


Spin-Independent Cross Section @ ~60 GeV/c²
1e– 40
1e– 41
1e– 42
1e– 43
1e– 44
1e– 45
1e– 46
1e– 47
1985
1990
1995
2000
2005
2010
2015
Year
1 evt/ton/day
1 evt/kg/year
1 evt/ton/year
Oroville
Homestake
HDMS 94
EDELWEISS 98
UKDMC
HDMS 98
IGEX
DAMA 98
DAMA 00
CDMS I 99
EDELWEISS 01
CDMS I 02
DAMA/Libra 08
EDELWEISS 03
ZEPLIN I
WARP
ZEPLIN II
CDMS II 04
CRESST 11
EDELWEISS 09
XENON10
CDMS II 10
EDELWEISS 11
ZEPLIN III
SuperCDMS
XMASS
XENON100
DarkSide-
MiniClean
LUX
DEAP-3600
Crystals Ge/NaI
Cryogenic Detectors
Liquid Noble Gases Xe/Ar
some experiments are missing!


Projection C.S. from March 2007
(this is in the 2007 roadmap)
Stage 1:
Field in
Infancy
Stage 2:
Prepare the
instruments
Stage 3:
Maturity.
Rapid
progress
Stage 4:
- Understand remaining
background.100 kg scale
- Determine best method
for ton-scale detectors
Stage 5:
Build and operate
ton-scale detectors
Cross section (pb)
10-4
10-6
10-8
10-10
1980
1985
1990
1995
2000
2005
2010
2015
LHC

Towards 2 large "zero-background" detectors



Scheme from March 2007

Towards 2 large "zero-background" detectors

Now: 10 kg scale | 2009/11: 100 kg scale | 2012/14: ton scale

CRESST

Edelweiss

EURECA-100

PLUS > 3 YEARS

EURECA
@ ton scale

LXe

LXe

LAr

LAr

...

~ IN TIME

Xe-100

Ar-100

DARKSIDE-50?
PLUS ~ 3 years

PLUS ~ 2-3 YEARS

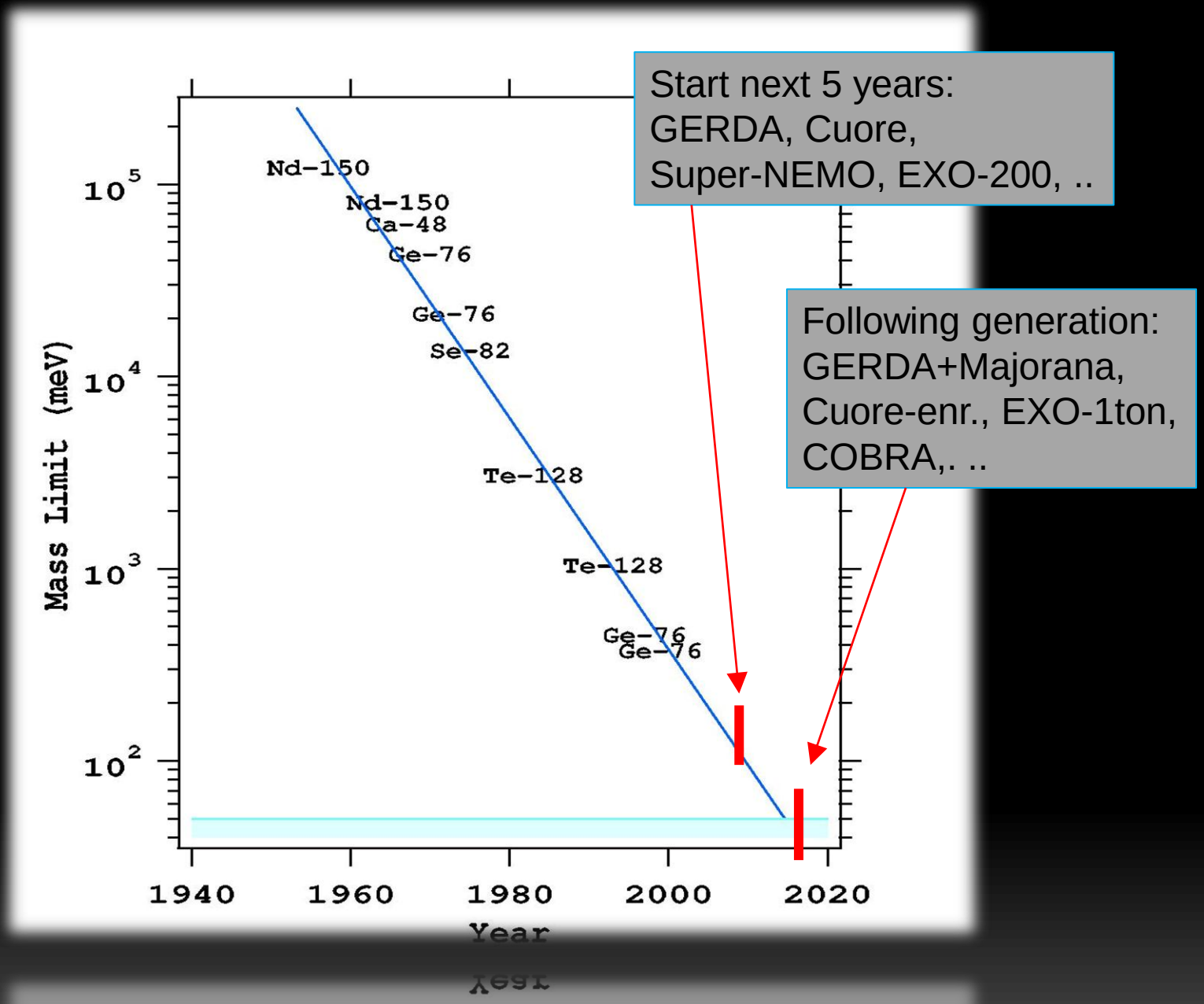
Noble liquid
@ ton scale

Résumé Dark Matter

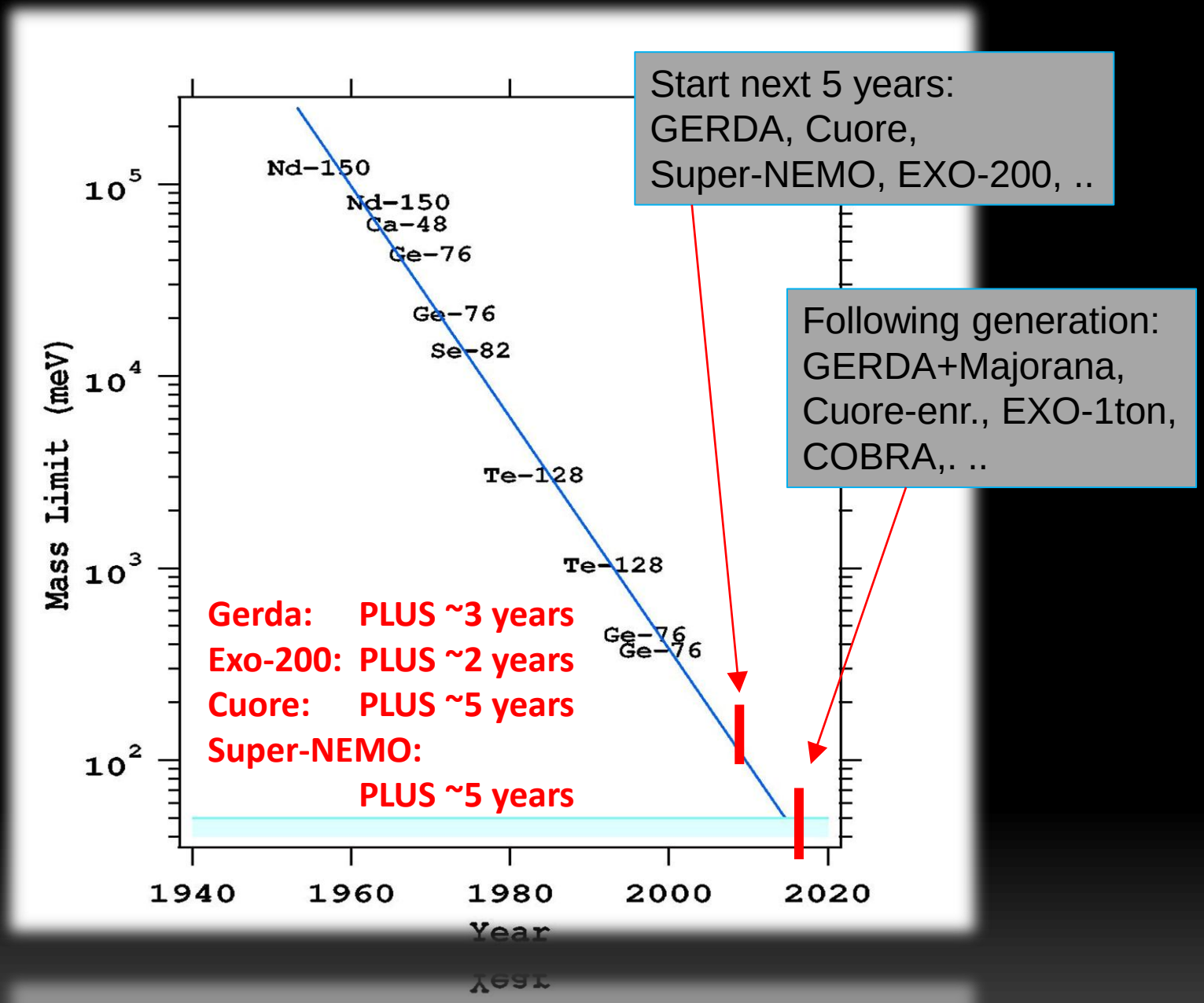
- Expectations have been too optimistic; we are now 5 years behind the projections from ten years ago.
- In 2005, bolometric detectors were clearly favored; this changed only with XENON.
- There is much less convergence than we hoped; worldwide, but even in Europe (and even in some countries!)

DOUBLE BETA

From the 2007 roadmap (picture already somewhat older)



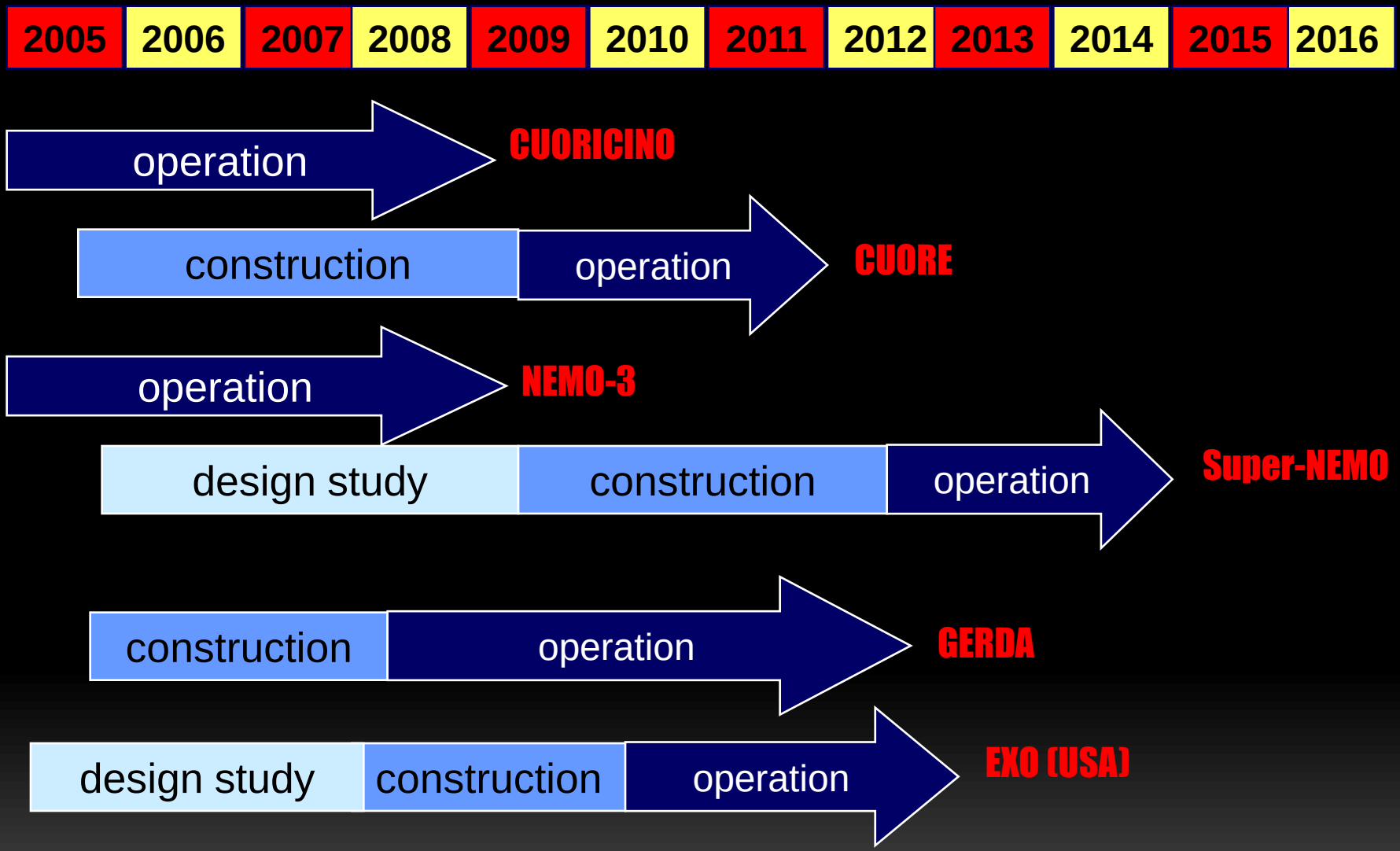
From the 2007 roadmap (picture already somewhat older)



DBD projects 0.1 eV scale

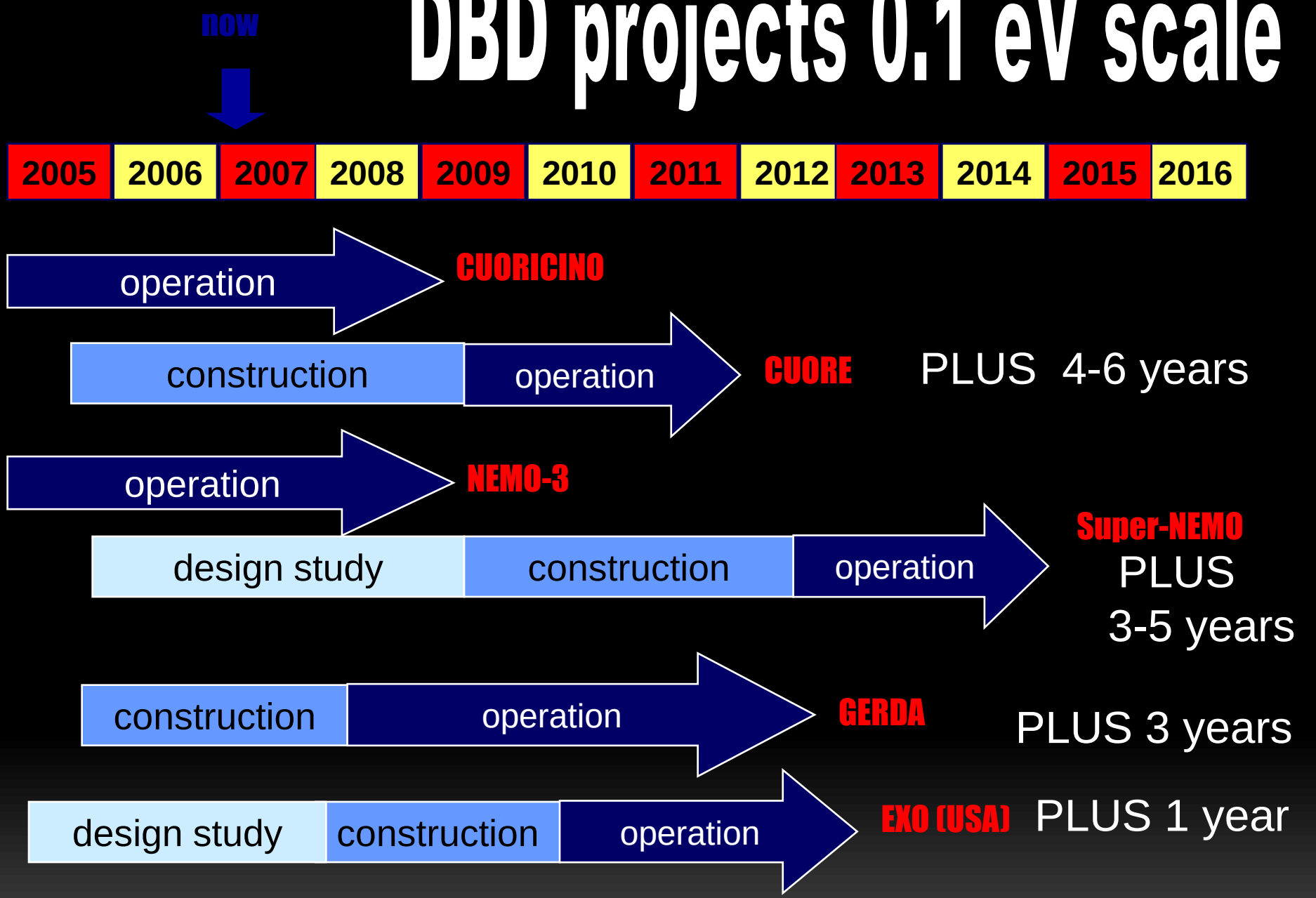
March 2007

now



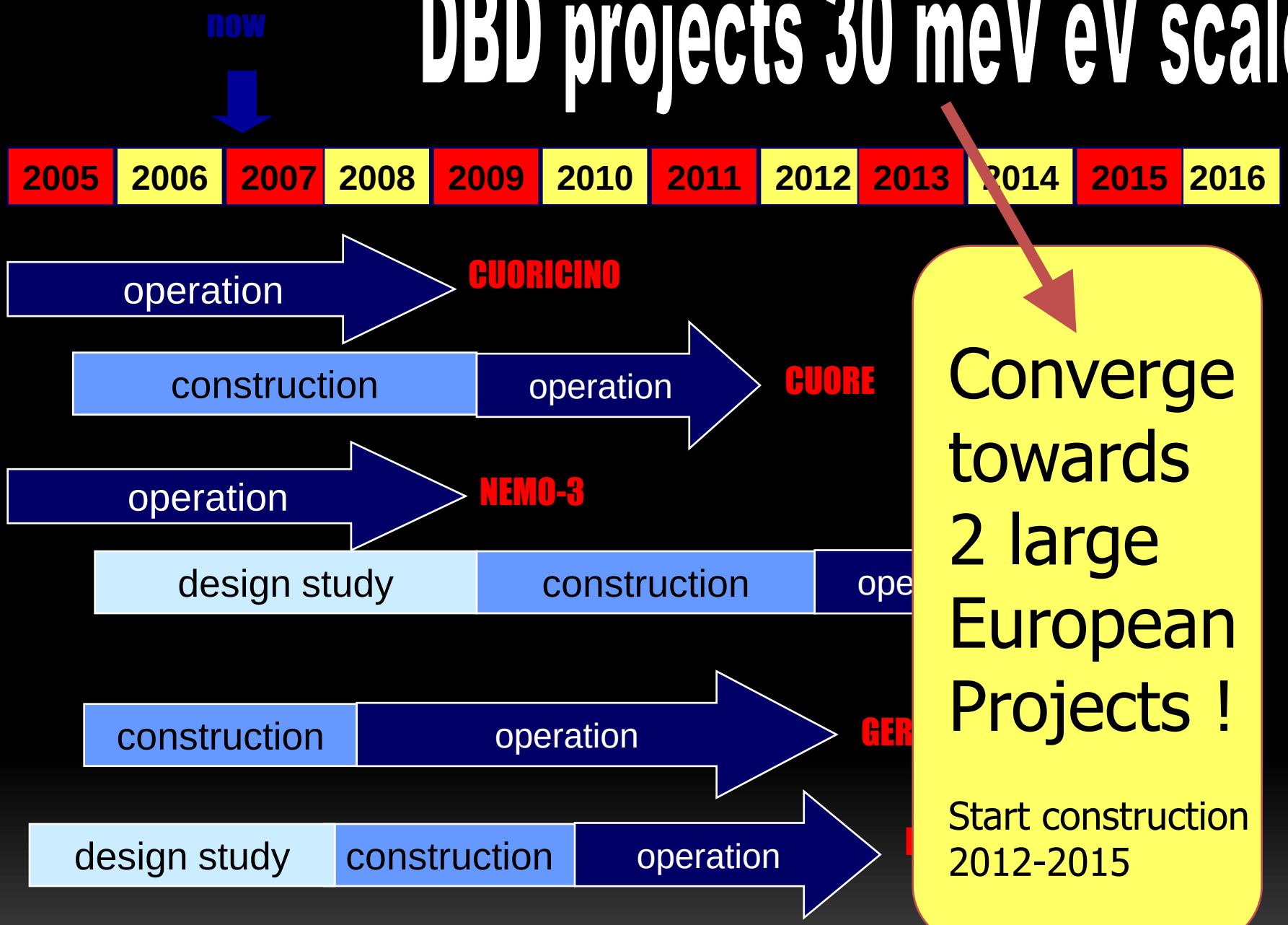
(Projects running, under construction or with substantial R&D funding)

DBD projects 0.1 eV scale



(Projects running, under construction or with substantial R&D funding)

DBD projects 30 meV eV scale



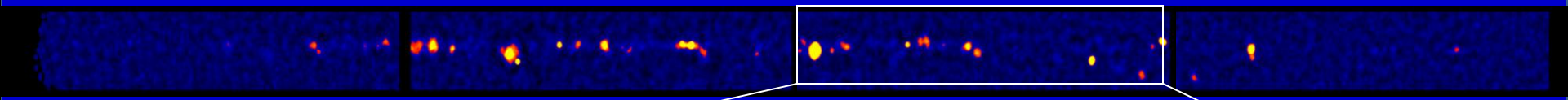
Résumé Neutrino Mass

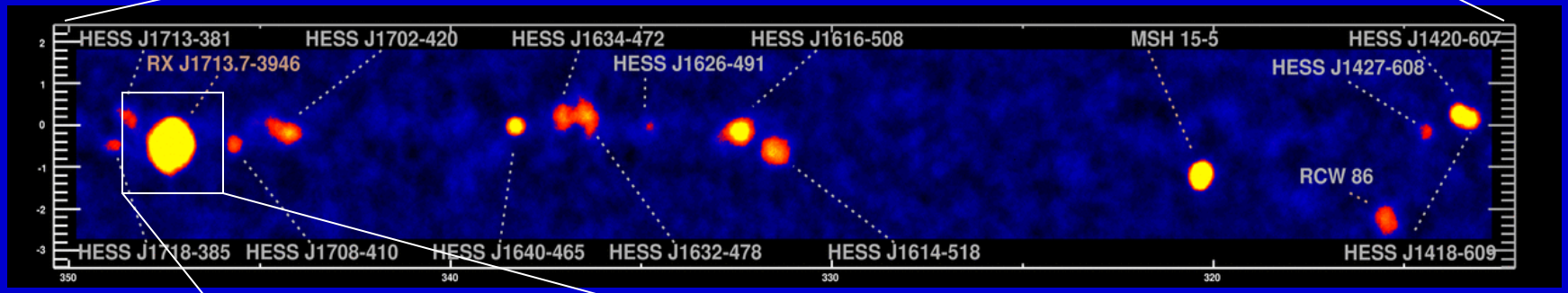
- Expectations for DBD have been too optimistic; we are now 4-6 years behind the projections from ten years ago.
- New DBD players with much drive appeared on stage, e.g. KamlandZen, NEXT, SNO+, ...
- Some DBD projects are since 2005 in R&D phase. Stamina or agony?
- Not enough convergence (Gerda/Majorana has at least the right spirit)

- **KATRIN: also delayed by 4-6 years. Cost over-run.**

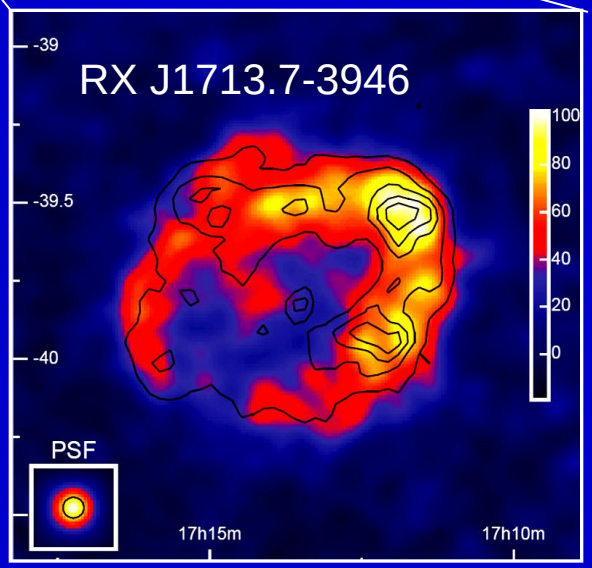
H.E. UNIVERSE

The Sky at TeV-Energies



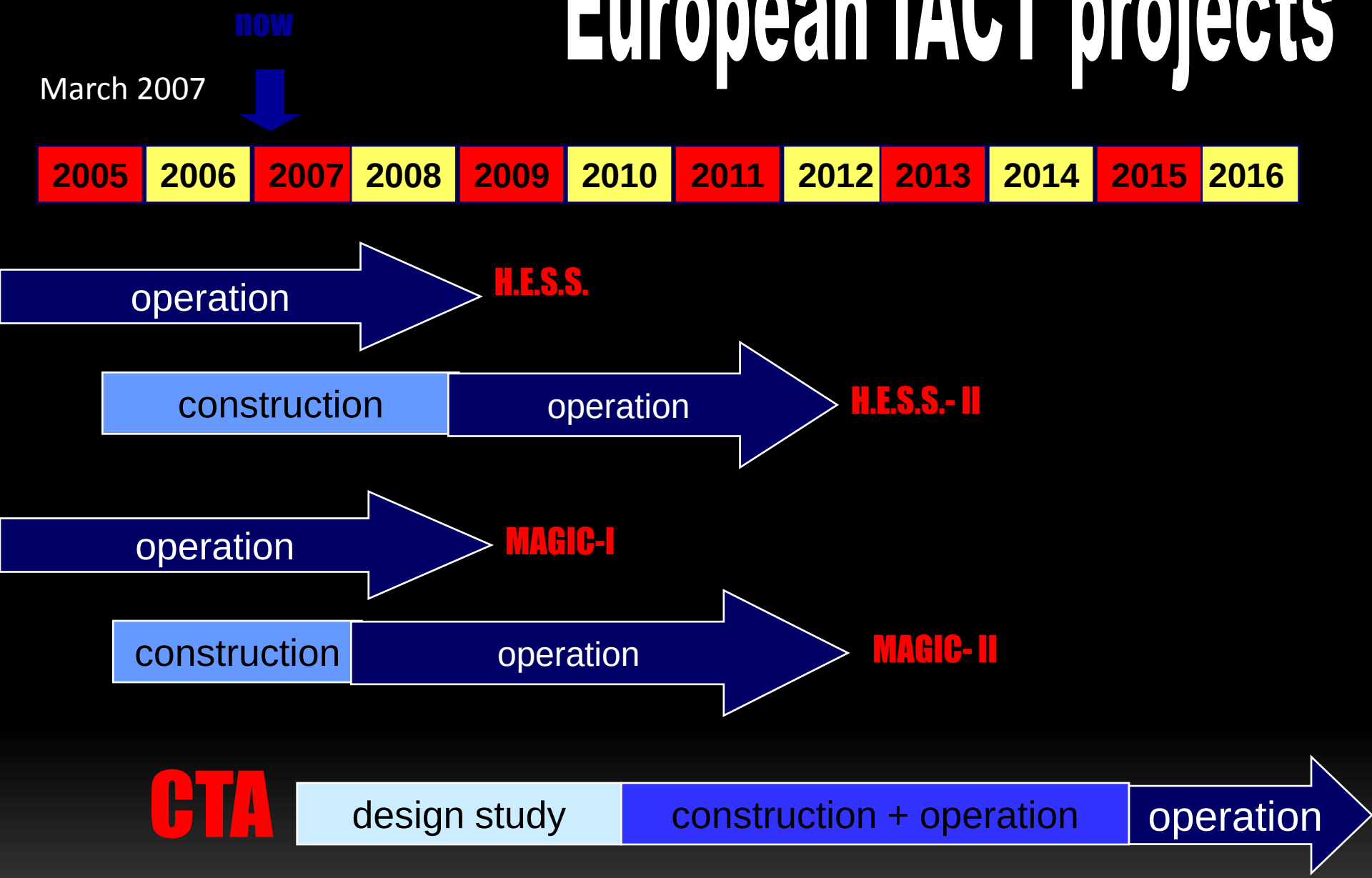


H.E.S.S.-Scan of the galactic plane

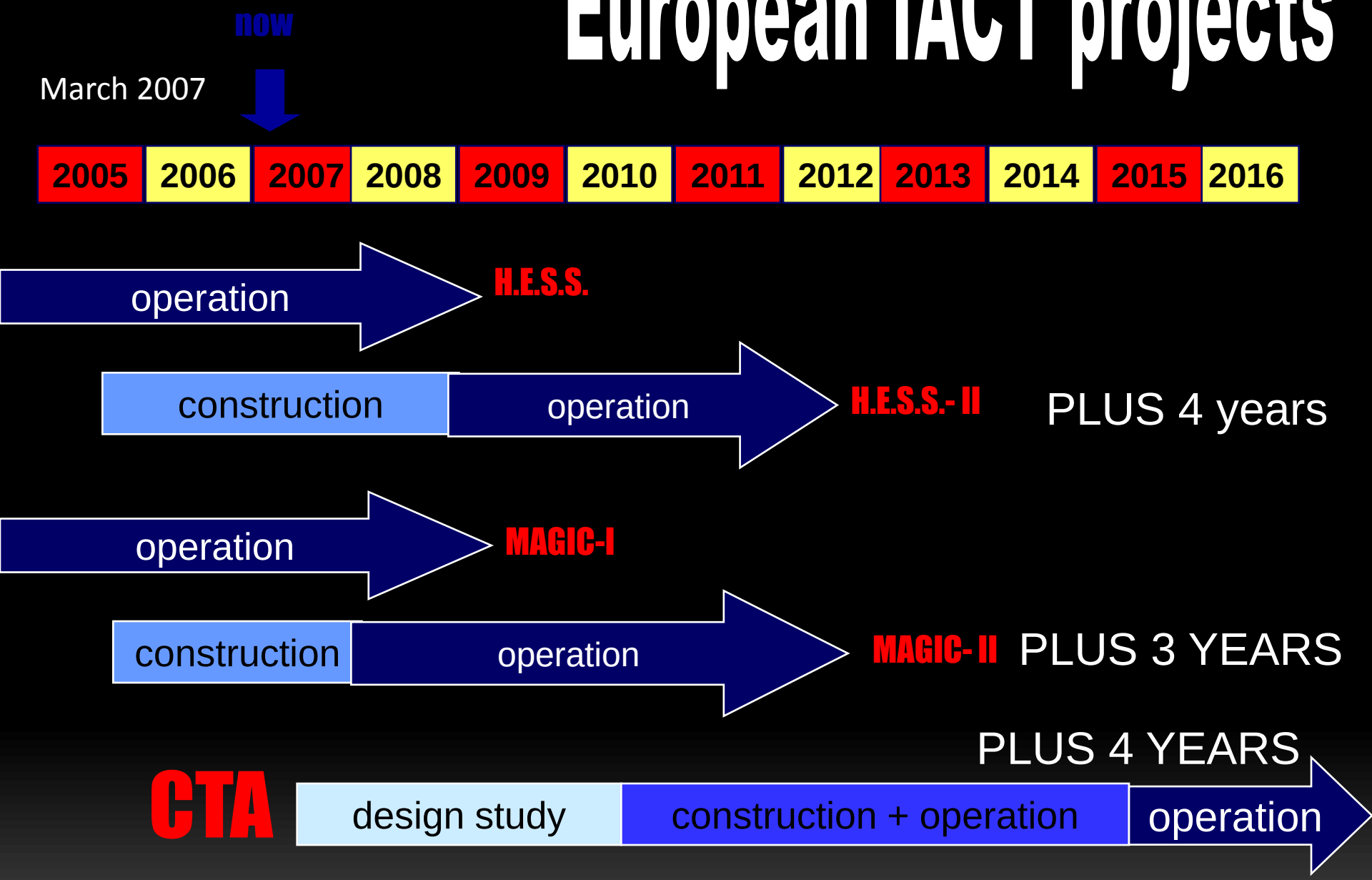


1989:	1 Source
1996:	3 Sources
2005:	80 Sources
2012:	150 Sources

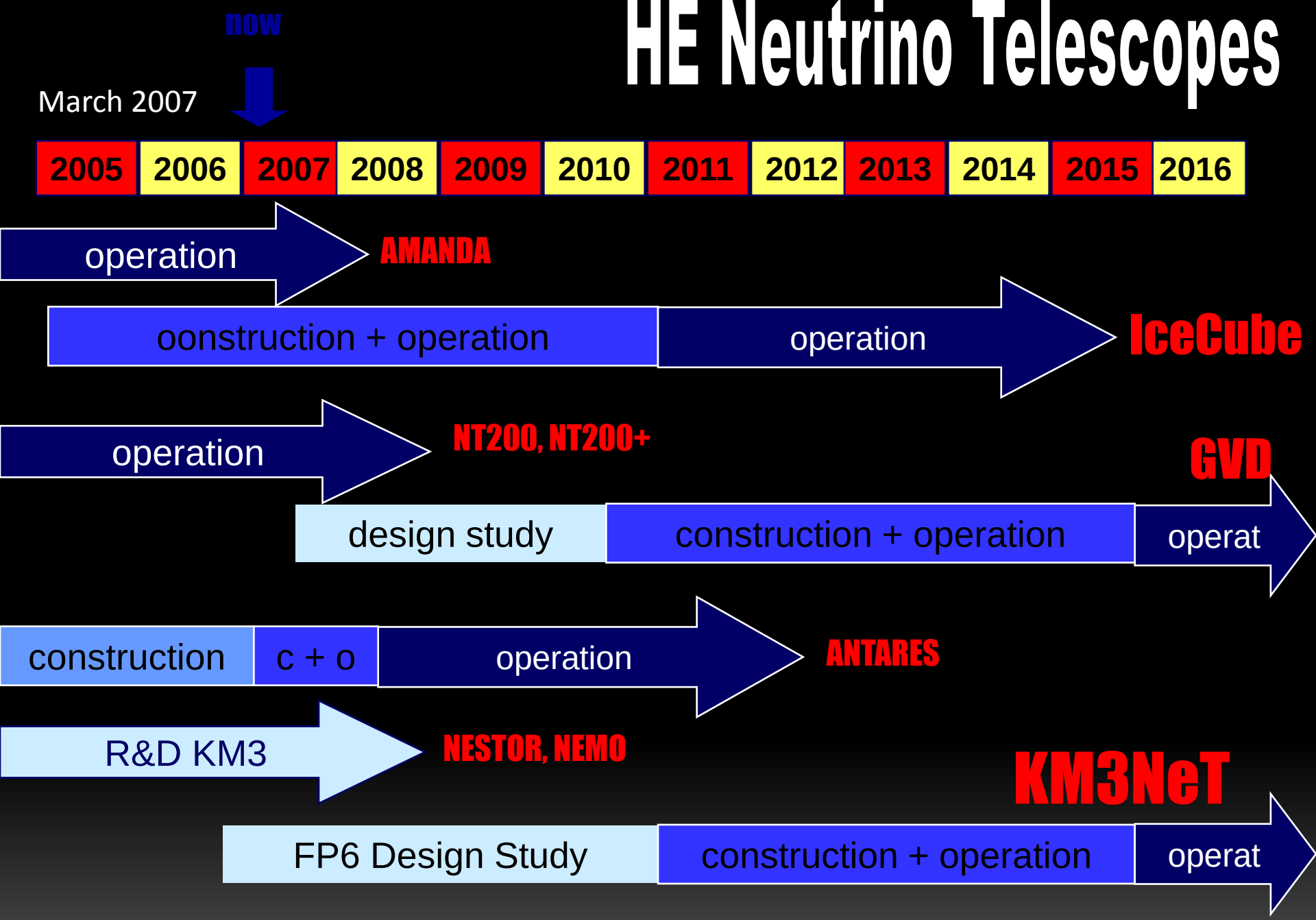
European IACT projects



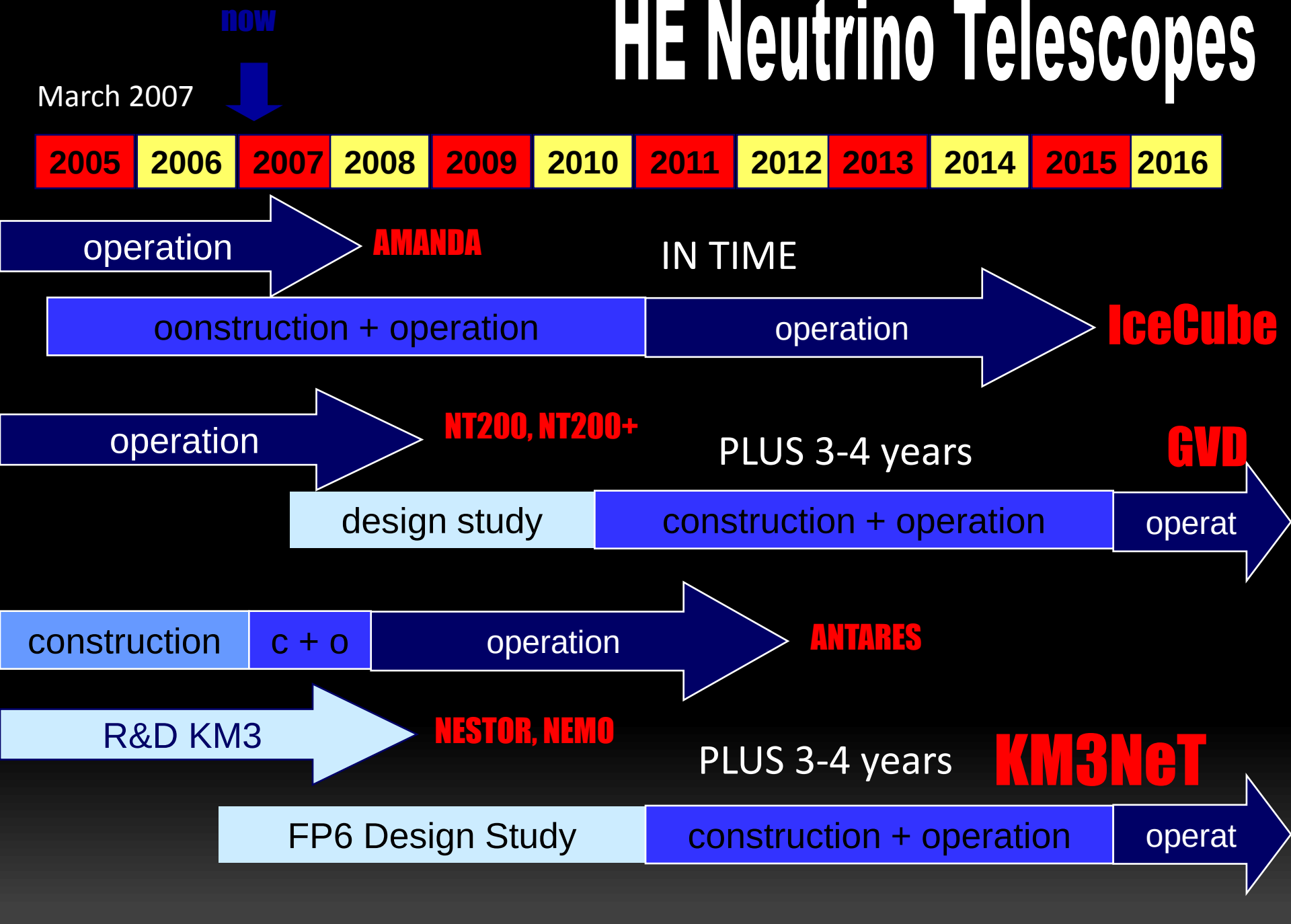
European IACT projects



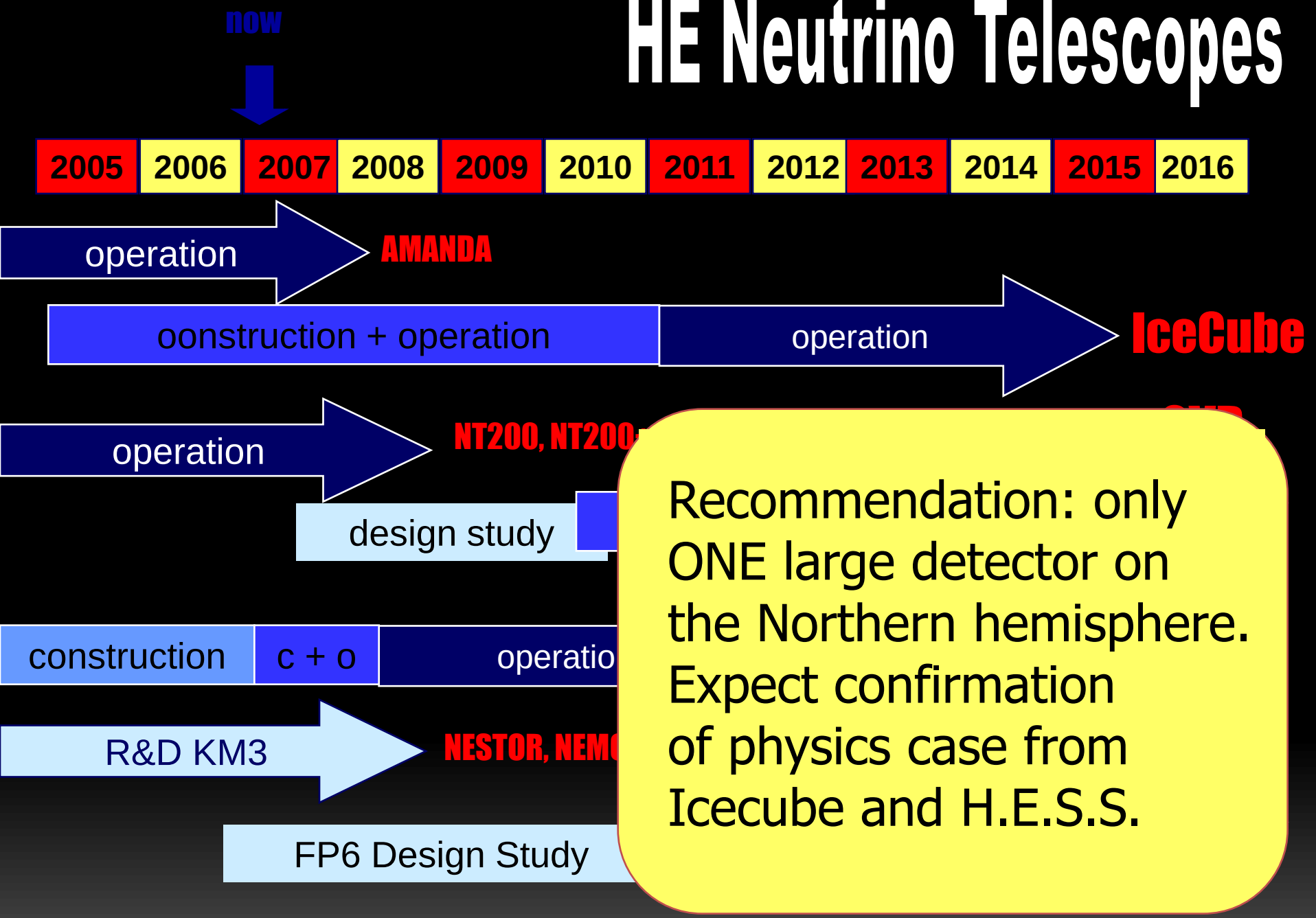
HE Neutrino Telescopes



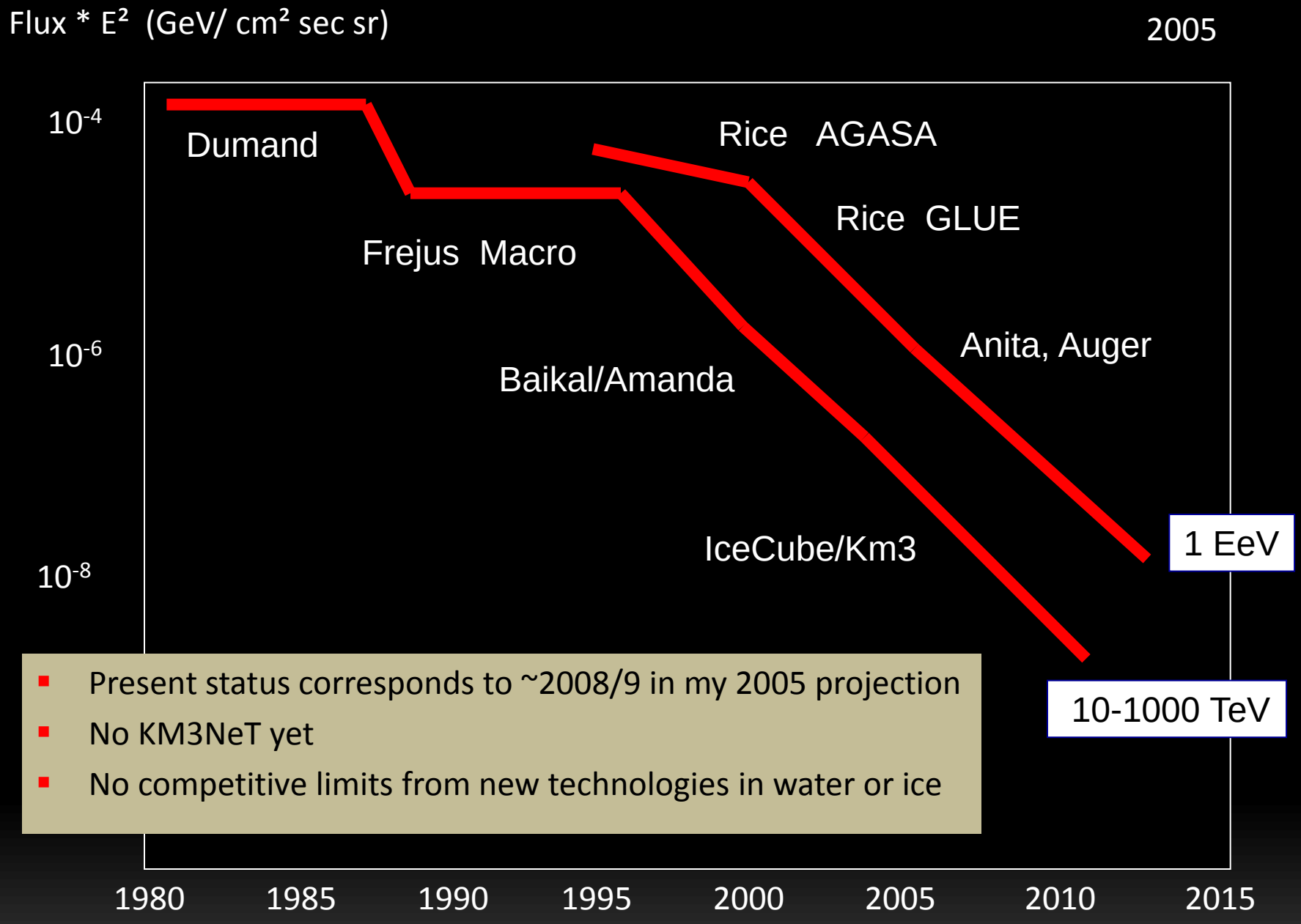
HE Neutrino Telescopes



HE Neutrino Telescopes



Recommendation: only ONE large detector on the Northern hemisphere. Expect confirmation of physics case from Icecube and H.E.S.S.

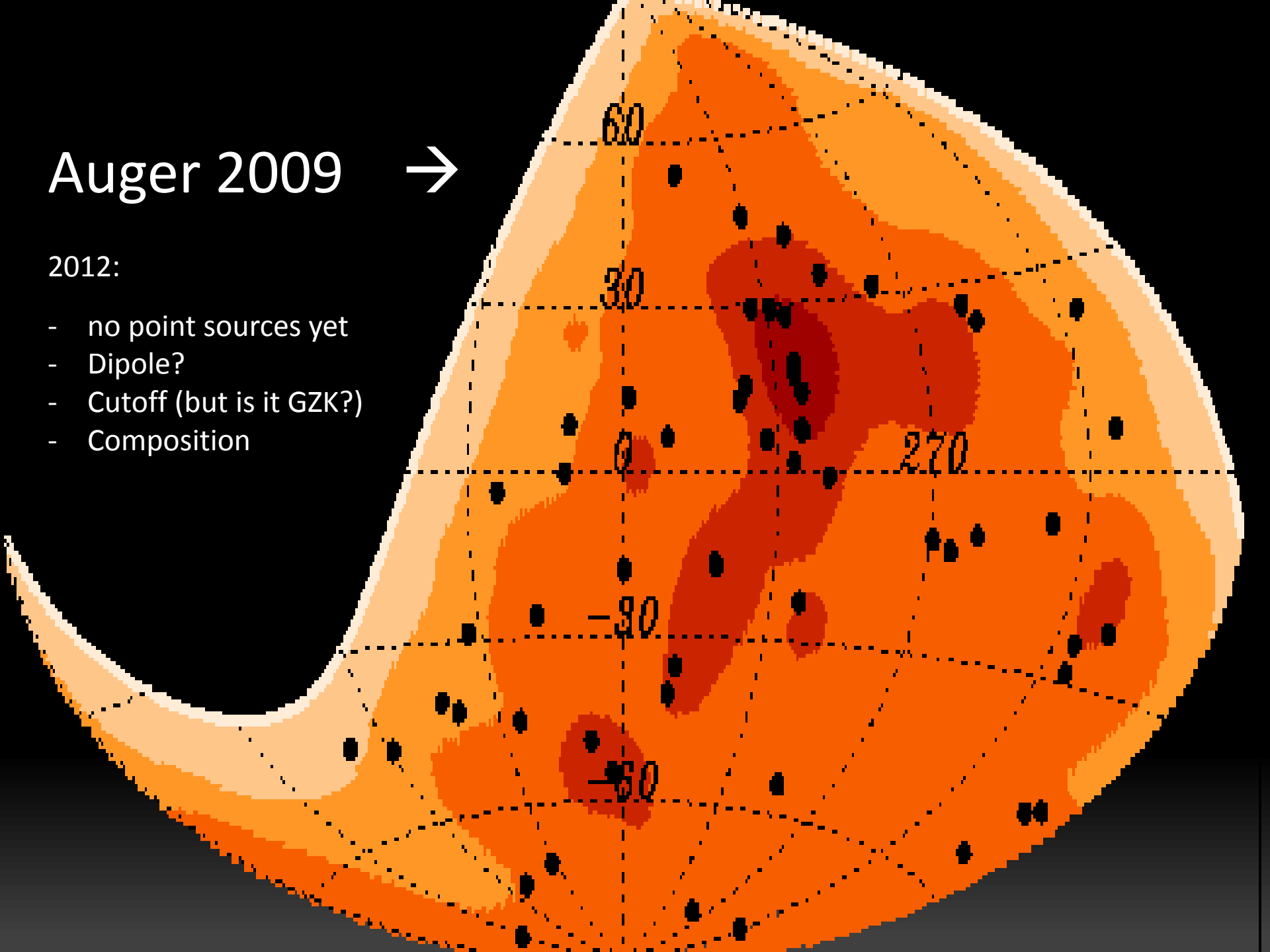


- Present status corresponds to ~2008/9 in my 2005 projection
- No KM3NeT yet
- No competitive limits from new technologies in water or ice

Auger 2009 →

2012:

- no point sources yet
- Dipole?
- Cutoff (but is it GZK?)
- Composition

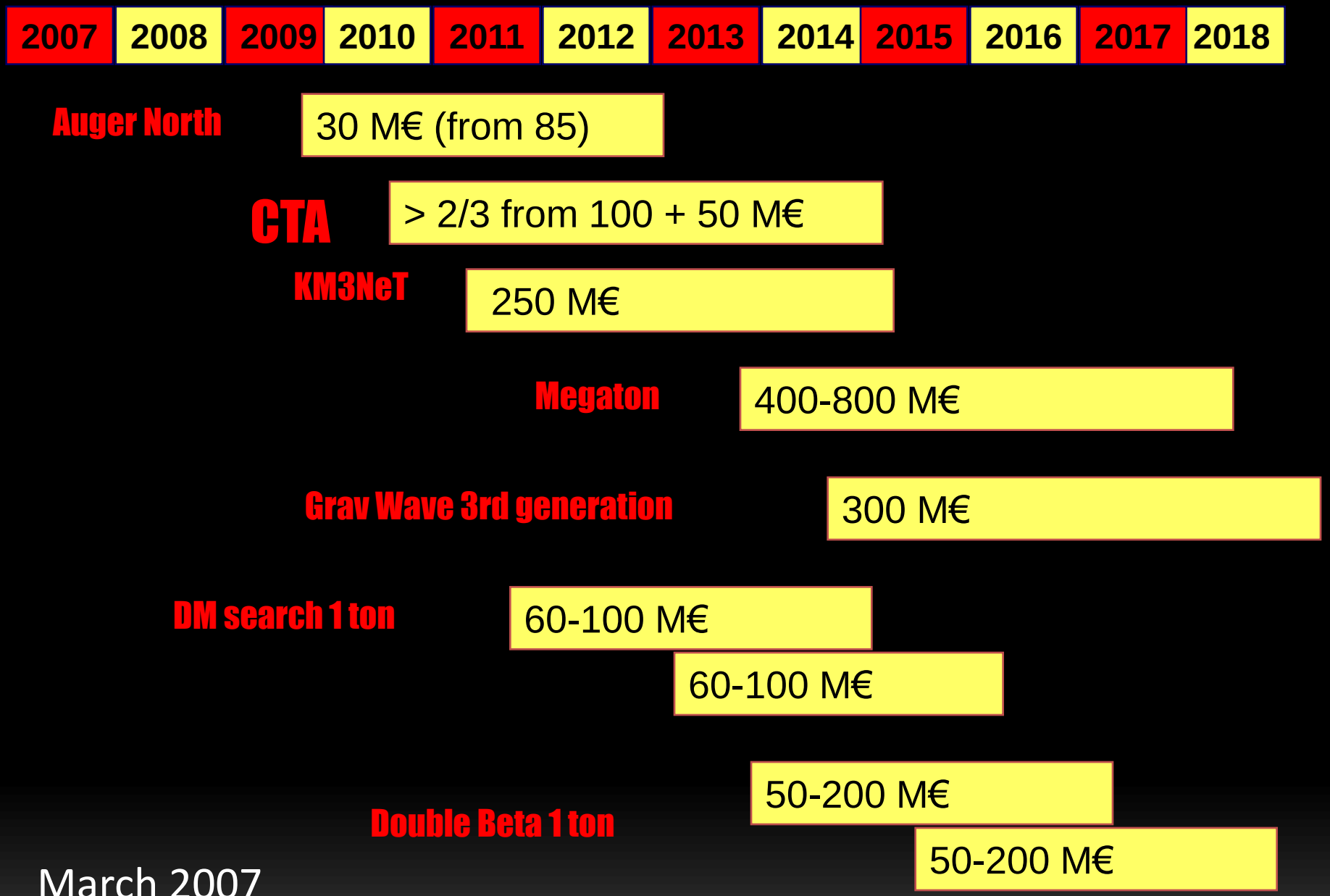


Résumé H.E. Universe

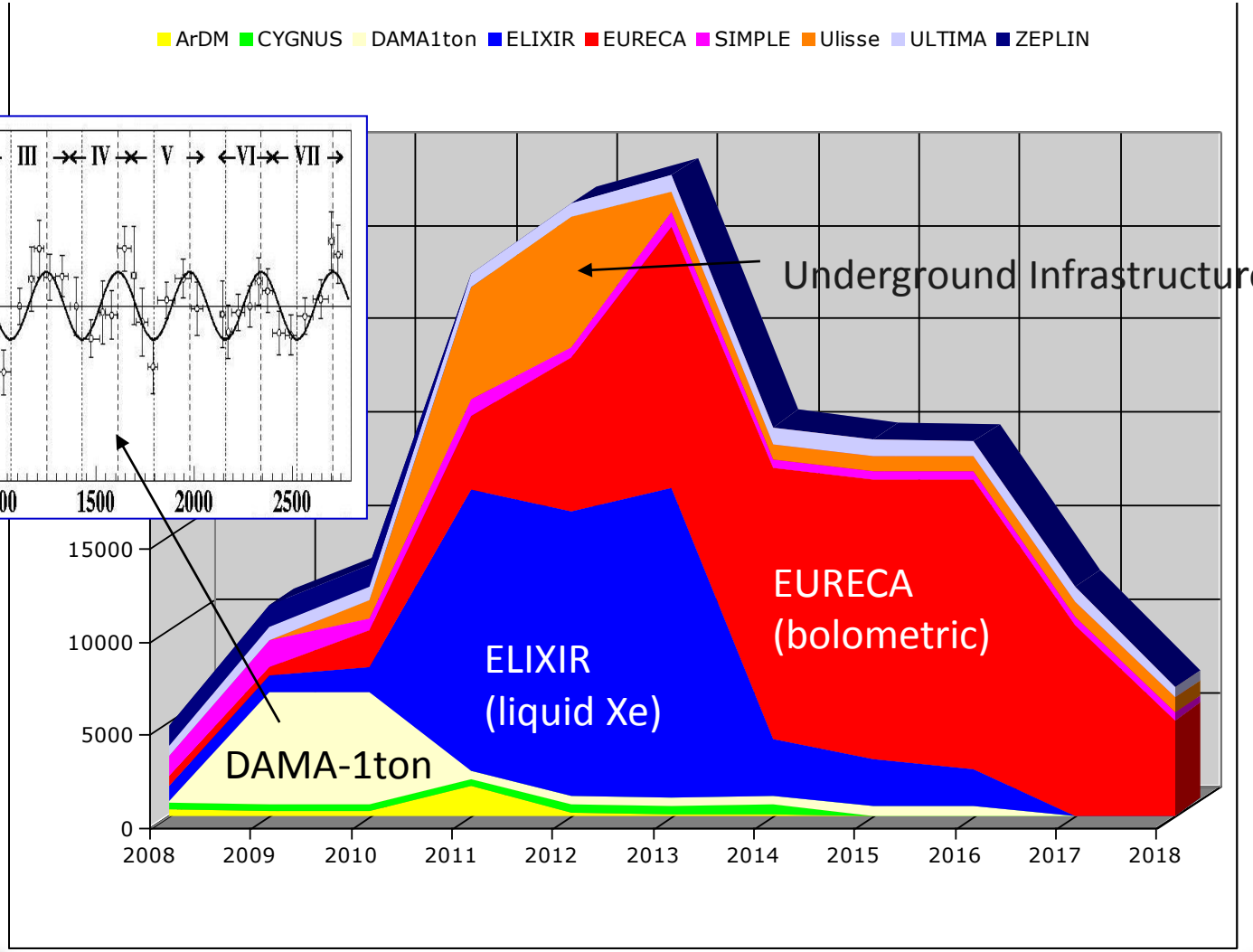
- Gamma Rays
  - Fermi fantastic success
  - IACTs fantastic scientific harvest : ~ 150 sources
  - MAGIC-2, HESS-II , CTA delayed by 3-4 years
- Neutrinos
  - IceCube within time and cost schedule, works excellently
  - KM3NeT delayed by 3-4 years. Troublesome convergence process. From single site to multi-site.
  - Sensitivity improvement neutrinos ~ 3 years behind expectations.
  - No point sources yet; tantalizing hints for H.E. diffuse excesses
- Cosmic Rays
  - Auger works excellently. Continuous succesfull upgrading.
  - Composition, Cut-off – but no point sources (yet). CEN-A?
  - Auger-North was not approved. New plans expected ~ 2015
  - JEM-EUSO gained more interest
  - New interest in Galactic CR (anisotropies, composition): IceTop, Tunka, LHHASO, ...

COST PROJECTIONS

All but the first figures from the preparation of the 2008 „Glossy Paper“

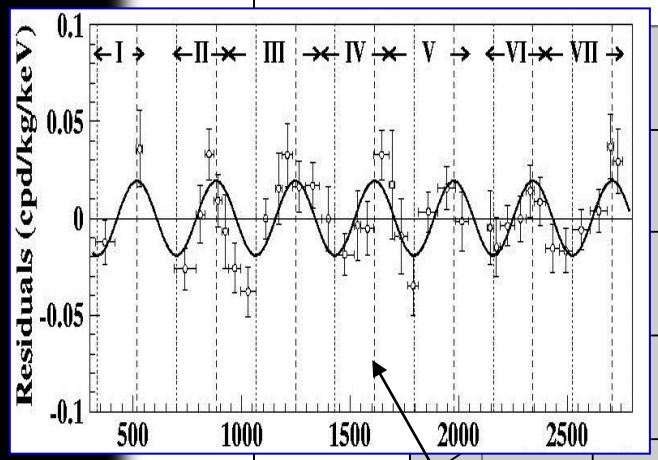

2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Auger North
30 M€ (from 85)
CTA
> 2/3 from 100 + 50 M€
KM3NeT
250 M€
Megaton
400-800 M€
Grav Wave 3rd generation
300 M€
DM search 1 ton
60-100 M€
60-100 M€
Double Beta 1 ton
50-200 M€
50-200 M€
March 2007

2007 Aspera WG requests European Dark Matter projects



2007 Aspera WG requests European Dark Matter projects

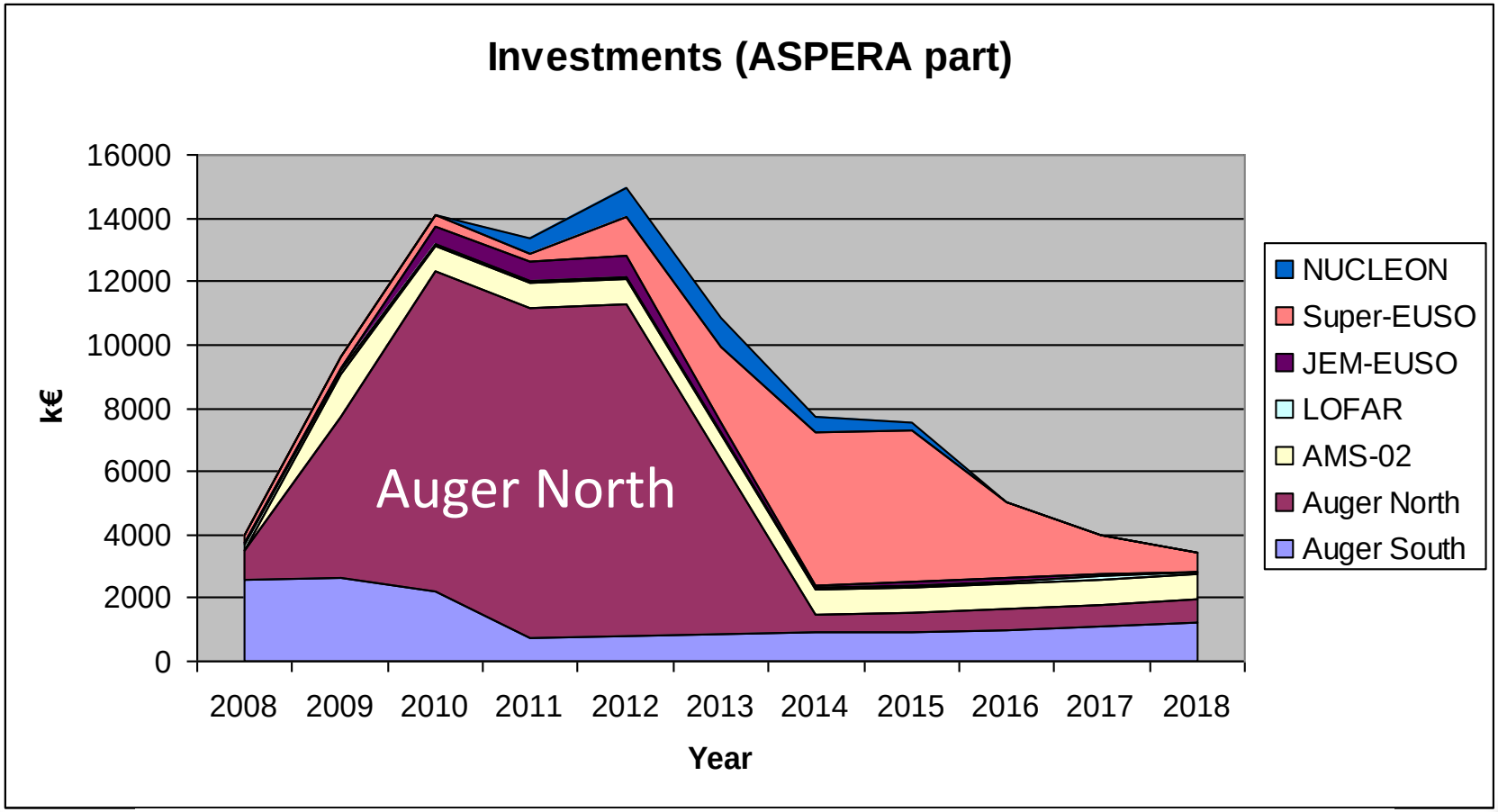
convergence within noble liquid community still poor



High Energy Cosmic Rays

Summary: ASPERA sum 2008-2018

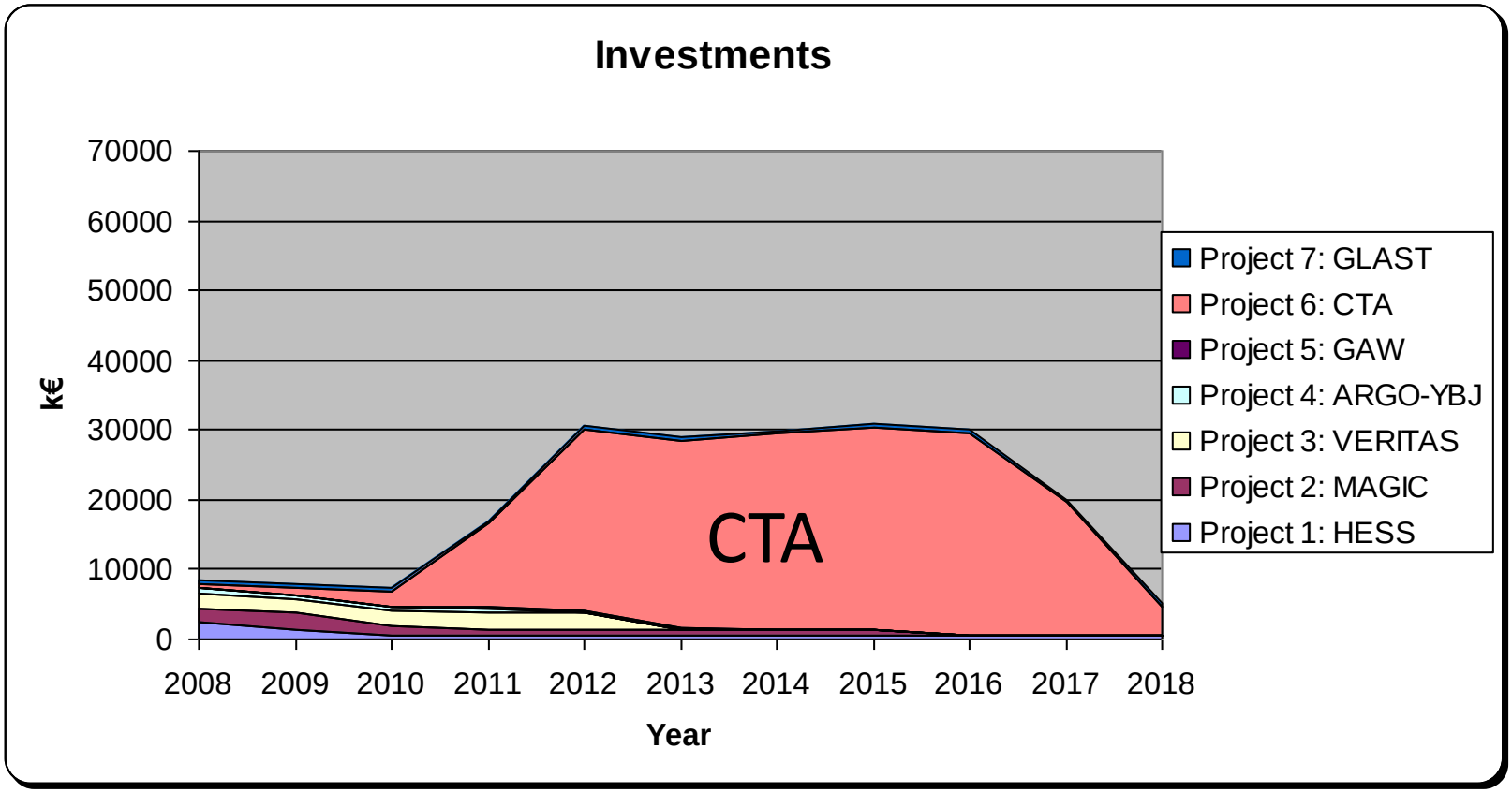
Clear priority: Auger North



Auger North planning at this point shifted by ~1 year compared to the figure

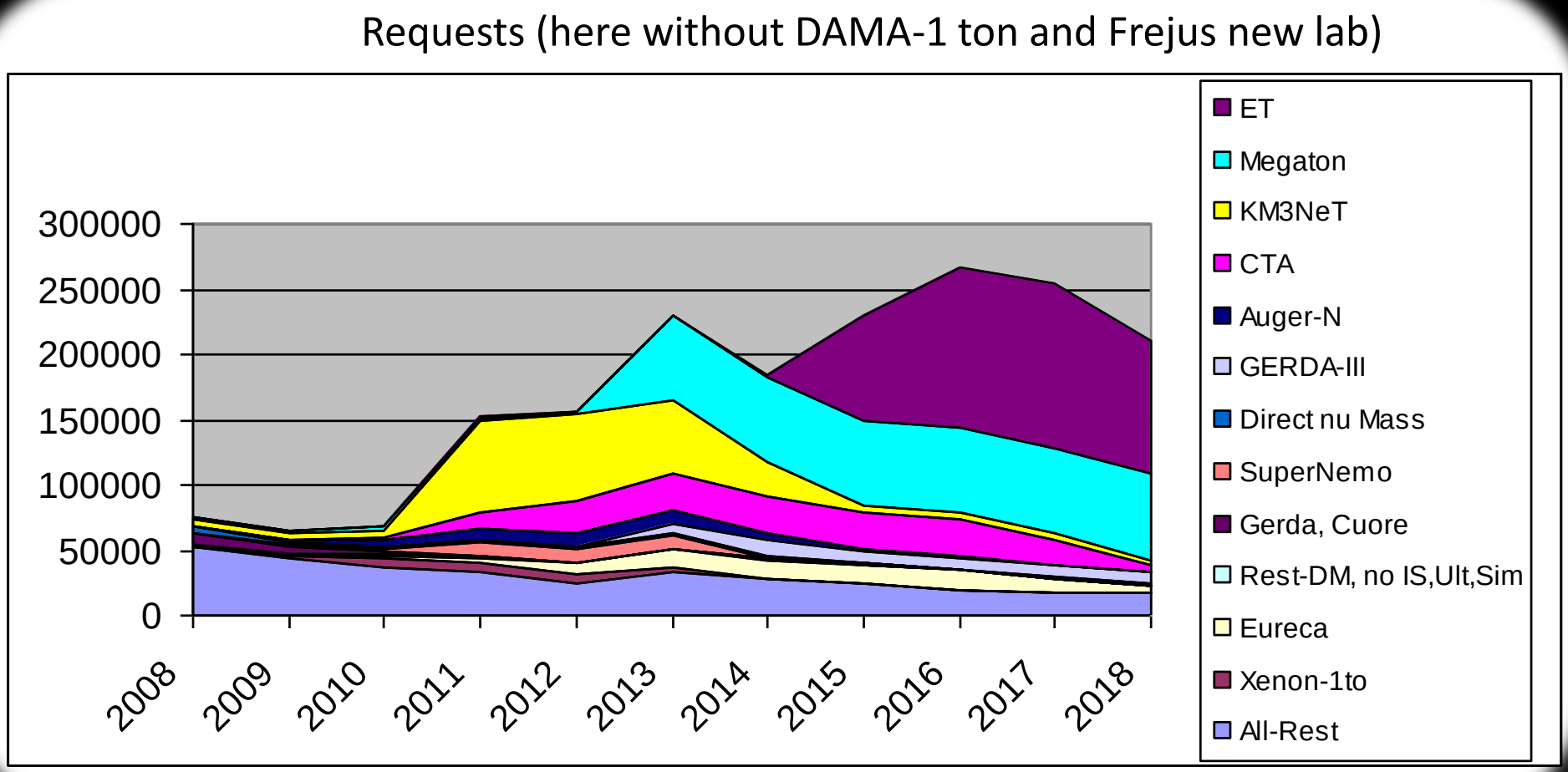
High Energy Gamma Telescopes

Clear priority: CTA



CTA planning at this point shifted by ~1 year compared to the figure

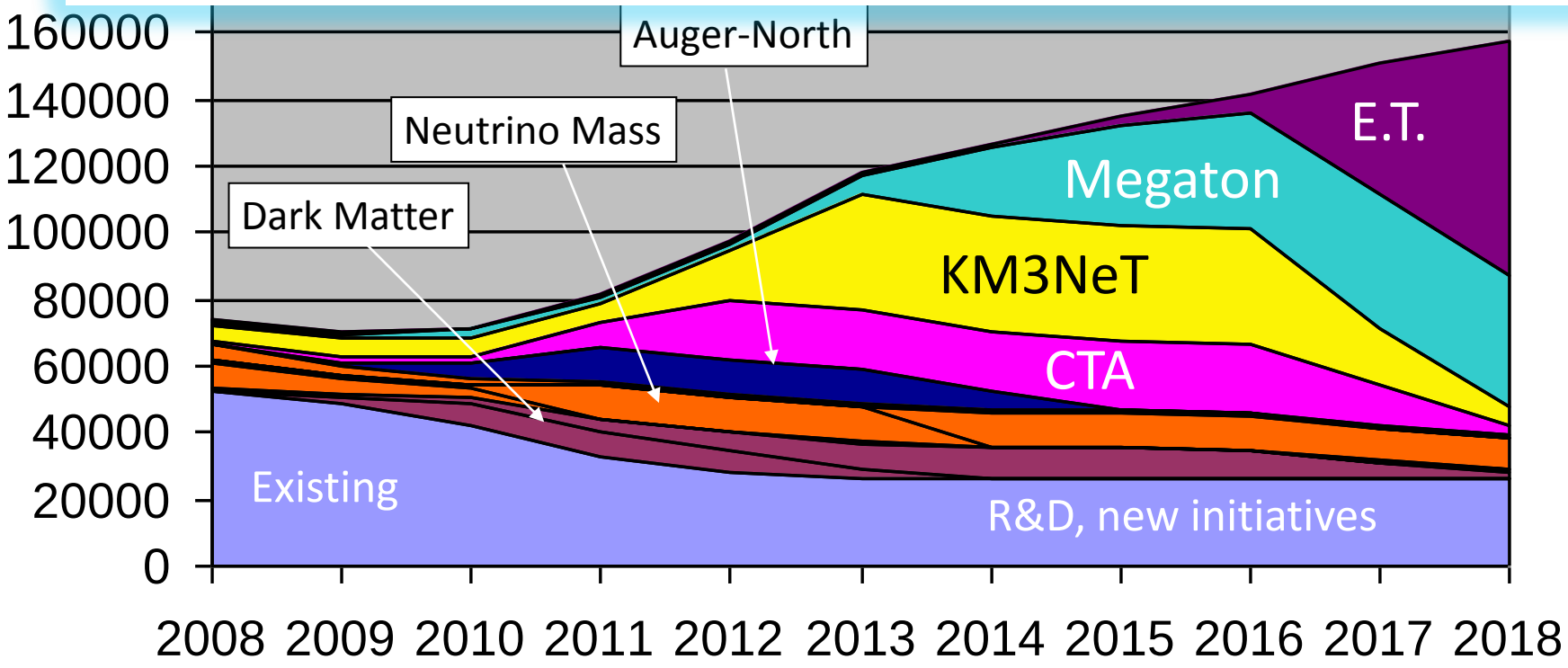
All Projects



All Projects

- without DAMA and new Frejus lab
- all projects shifted according to realistic estimates
- CTA: 1/3 from non-Europe
- KM3NeT: 200 M€
- Megaton: Europe only 200-300 M€
- DM and DBD shared with US

- can do it within a factor ~2 smooth increase over 8-10 years (investment)
- personnel will increase by less




We should create a factor-of-two pressure !


GREAT !

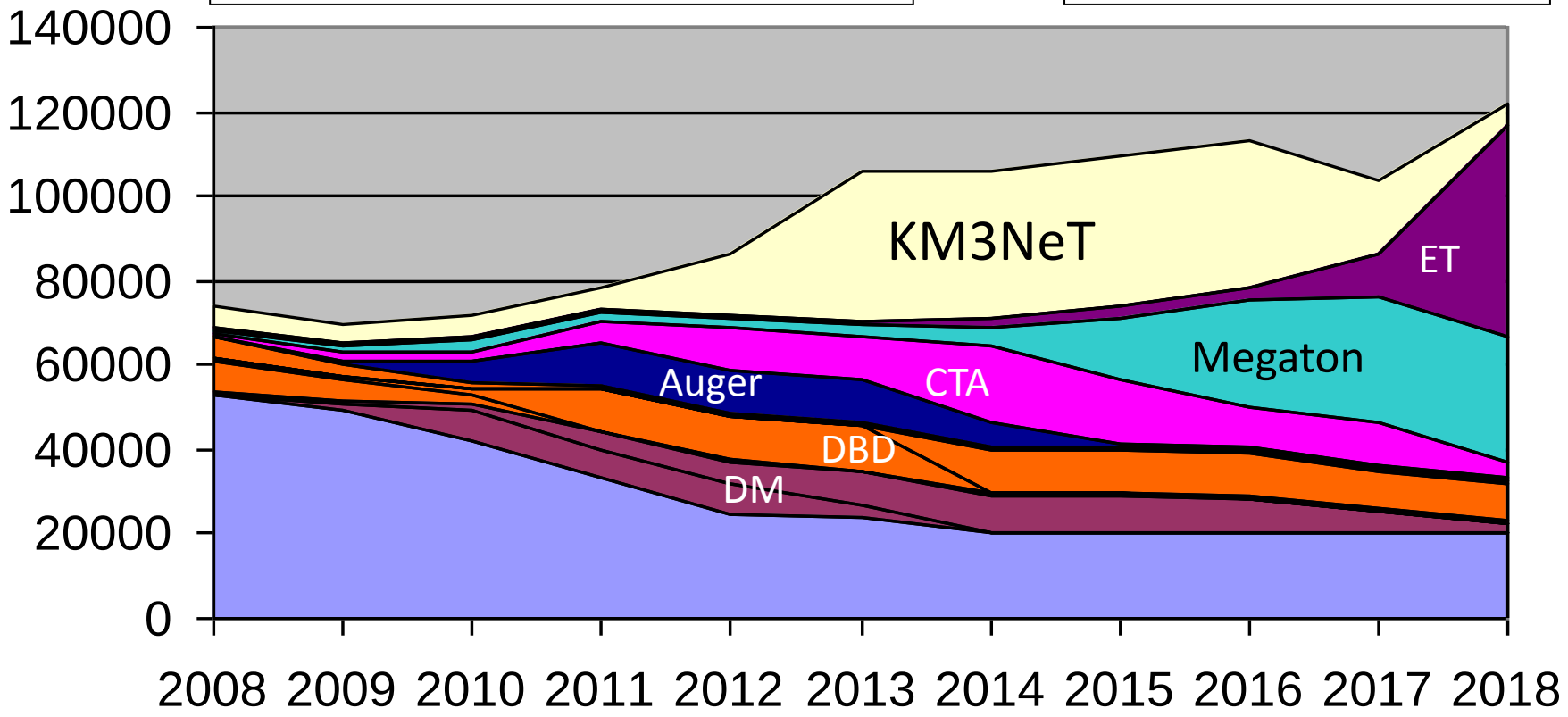

Hmm...

AUTUMN 2008:
THE ECONOMIC CRISIS

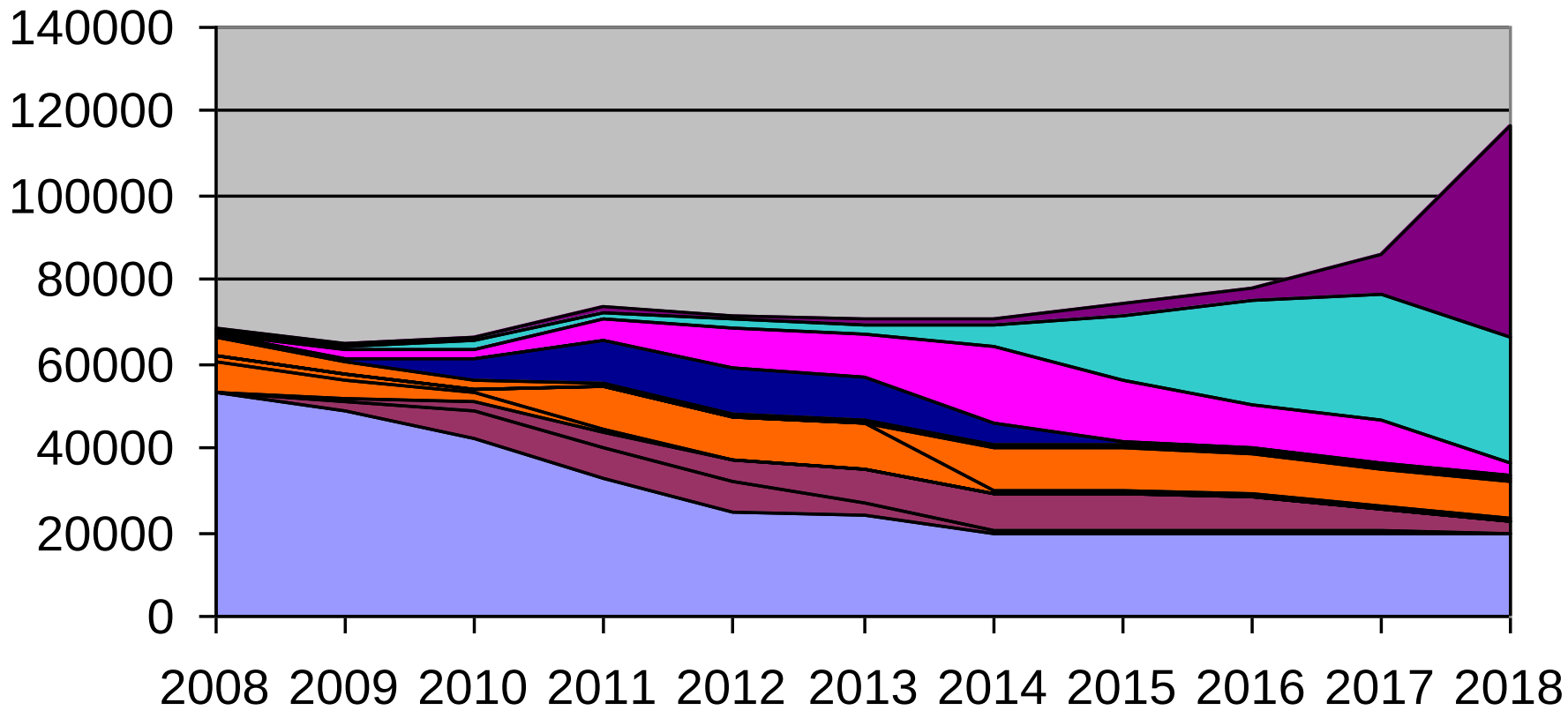
What about a flat funding scenario?

- further reduce CTA
- further shift and reduce Megaton
- further shift E.T.
- somewhat reduce new initiatives

Must not reduce Auger and KM3NeT. Either you build it huge or you do not build it at all !



What about a flat funding scenario?



ASPERA COMMON CALLS

- First call 2008
  - CTA F, DE, PL, ES, HE 2.7 M€
  - DARWIN IT, F, NL, HE 0.6 M€
  - EURECA FR, ES 0.6 M€

- Second call 2009 (10?)
  - AugerNEXT DE, NL, PL, F, PT, ES, IT, RO 1.8 M€
  - ISOTTA F, IT, PL 0.5 M€
  - SILENT IT, PL, HE 0.6 M€

- Third call 2012
  - Low-energy neutrinos (PINGU/ORCA, LENA, r.a. source)
  - Gravitational waves
    (community with a compelling worldwide coordination – GWIC!)

- The ASPERA Calls have been (and are) very important for community building
- The calls promote convergence tendencies
- The convergence is in some conflict with the competition principle (which one has, e.g., in EU design studies)

- Future:
  - Keep convergence character but add some competition?
  - Support should correlate with the number of groups behind the project (also within the individual countries)

… AND, AT THE VERY END:

LOW-ENERGY NEUTRINOS AND PROTON DECAY

- Gained enormous momentum after measurement of θ_{13} due to the interest of the accelerator community (Fermilab, CERN, Japan)

- Liquid Argon is prioritized by most of this community due to its (principally) superior features w.r.t. oscillation physics.

- Europe: LAGUNA-LBNO
  - GLACIER (LAr) LENA (LSc) MEMPHYS (water)
- USA: LBNE (LAr)
- Japan:
  - Hyper-K (water) Okinoshima-Project (LAr)

Science on the Megaton scale

- **Proton decay:** improve sensitivity by > factor 10
  and test a new class of Supersymmetry models
- **Galactic Supernova:** 10^4- 10^5 events
  Incredibly detailed information on the early SN phase
- **Diffuse flux from past SN:** probe cosmological star formation rate
- **Solar neutrinos:** details of the Standard Solar Model determined with percent accuracy. CNO cycle. Time variations.
- **Atmospheric neutrinos:** high statistics would improve knowledge neutrino mixing and provide information on the neutrino mass hierarchy
- **Geo-neutrinos:** improve understanding of the Earth interior
- **Indirect WIMP search**
- **Neutrinos from accelerators:** neutrino properties !

Physics potential of the 3 types of detectors for proton decay and neutrino astrophysics *

Topics	**GLACIER** (50 kt)	**LENA** (50 kt)	**MEMPHYS** (500 kt)
proton decay, sensitivity(10 years)			
$e^+ \pi^0$	2.5×10^{34}	-	15×10^{34}
anti-ν K^+ (**)	5×10^{34}	4×10^{34}	2.5×10^{34}
SN at 10 kpc, # events	~ 19,500	~16,000	~250,000
CC	0.8×10^4 (ν_e)	1.3×10^4 (anti-ν_e)	2.5×10^5 (anti-ν_e)
NC	1.1×10^4	1.0×10^3	-
ES	0.4×10^3 (e)	6.2×10^2 (e)	1.3×10^3 (e)
Elastic scatt. P	-	2.6×10^3 (p)	-
Diffuse SN #Signal/Background events (10 years)	~50/30	~60/10	~120/100 (1 module with Gd)
Solar neutrinos # events, 1 year	^{8}B ES : 1.5×10^4 Abs: 0.5×10^5 (dependent on the achievable threshold)	^{7}Be: 3.6×10^6 pep: 1.0×10^5 ^{8}B: 2.9×10^4 CNO: 7×10^4	^{8}B ES: 1.2×10^5
Atmospheric ν # events, 1 year	5×10^3	5×10^3	5×10^4
Geo-neutrinos # events, 1 year	Below threshold	1.5×10^3	Below threshold

* some numbers strongly depend on model assumptions and give a qualitative rather than an exact quantitative comparison.
** this channel is particularly prominent in SUSY theories. Indications for SUSY at the LHC would boost its importance.

Physics potential of the 3 types of detectors for proton decay and neutrino astrophysics *

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CC	0.8×10^4 (ν_e)	~16,000	~250,000
NC	1.1×10^4	1.3×10^4 (anti-ν_e)	2.5×10^4 (anti-ν_e)
ES	0.4×10^3 (e)	1.0×10^3	-
Elastic scatt. P	-	6.2×10^2 (e)	1.3×10^3 (e)
		2.6×10^3 (p)	-
Diffuse SN #Signal/Background events (10 years)	~50/30	~60/10	~120/100 (1 module with Gd)
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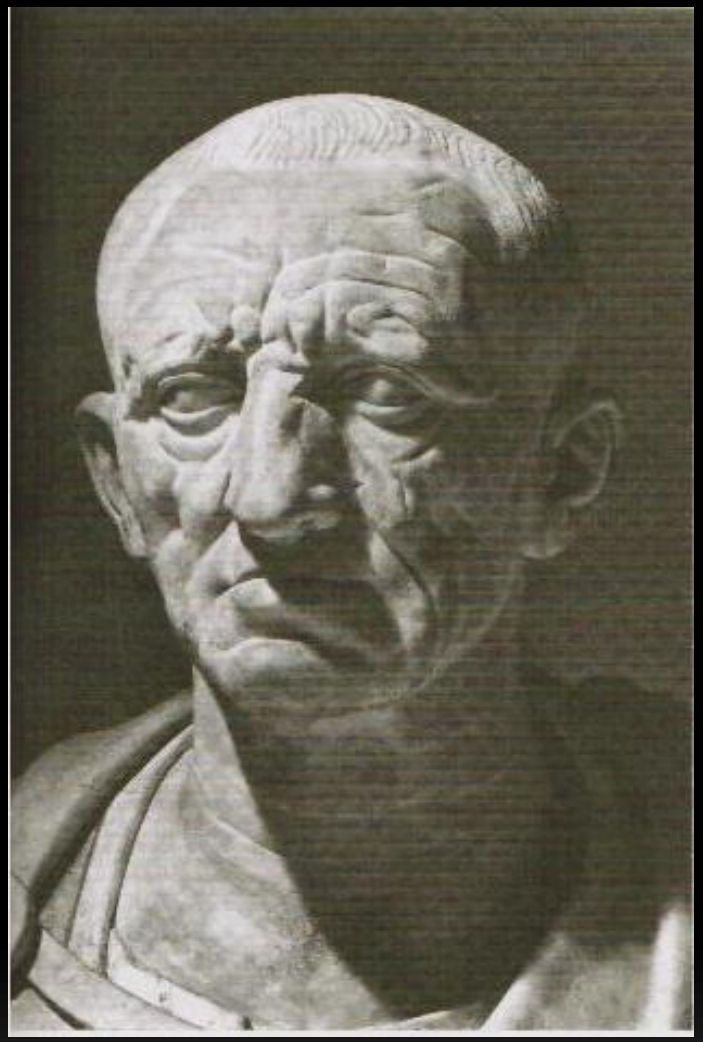
Atmospheric ν # events, 1 year	5×10^3	5×10^3	5×10^4
Geo-neutrinos # events, 1 year	Below threshold	1.5×10^3	Below threshold

Low energy!

* some numbers strongly depend on model assumptions and give a qualitative rather than an exact quantitative comparison.
** this channel is particularly prominent in SUSY theories. Indications for SUSY at the LHC would boost its importance.

Cato the elder:

„Ceterum censeo: Carthaginem delendam esse.”



C.S.:

„Ceterum censeo:
We need a large scintillation neutrino detector.“

Résumé on low-energy neutrino detectors (1)

- **Exciting symbiosis of**
  - ***tackling fundamental questions in particle physics,***
  - ***accessing new cosmic landscapes,***
  - ***high-precision measurement of known cosmic phenomena .***
- **Common program on**
  - ***accelerator based neutrino physics***
  - ***astroparticle physics***

  that will have more impact than the sum of its parts.
- **Impact of PINGU?**
- **Needs coherent international strategy**

Résumé on low-energy neutrino detectors (2)

- LAr vs LSc:
  Geo-neutrinos and high-statistics solar neutrinos
  only with LSc

Résumé on low-energy neutrino detectors (2)

- LAr vs LSc:
  Geo-neutrinos and high-statistics solar neutrinos
  only with LSc

- Its OUR star !
- Its OUR planet !

- Its more than getting errors down by a factor 2 or 20.

- Need both: LAr and LSc

Lessons

http://www.aspera-eu.org

Problems

- Experimenters must have visions & be optimistic – but with a reasonable sense for reality ...

- The reality check shows that nearly all projects were and are substantially delayed compared to the collaboration plans.
- They are even delayed to the schedule after „massaging“ the collaboration plans in the roadmap process.
- Reasons:
  - Technology and background rejection
  - Not enough convergence
  - Not enough money
  - Political conflicts (formal status, site decisions)

Lessons

- Fold the experience of our roadmapping into future projections
- Force more convergence
- Promote a mixture of high-risk explorations and projects with guaranteed (lathough in detail unknown) harvest
- Follow physics and not necessarily the road of the largest crowd
- More independent committees? Swarm intelligence?
- Avoid strategies relying on the „who dies first“ principle

Scientific Successes

- **Break-throughs:**
  - neutrinos from Sun and Supernova
  - neutrino oscillations
  - gamma-ray astronomy

- **Many fields approaching sensitivity with high discovery potential for fundamental questions:**
  - gravitational waves
  - dark matter
  - neutrino mass & double beta decay

- **Tantalizing hints:**
  - UHE cosmic rays
  - high energy neutrinos
  - sterile neutrinos ???

ApPEC has got a lot of work to do !

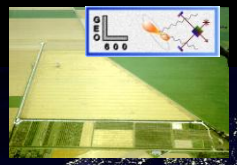
The best is yet to come !

http://www.aspera-eu.org

The current GW Network

LIGO Hanford, 4 km:
2 ITF on the same site!

GEO, Hannover, 600 m

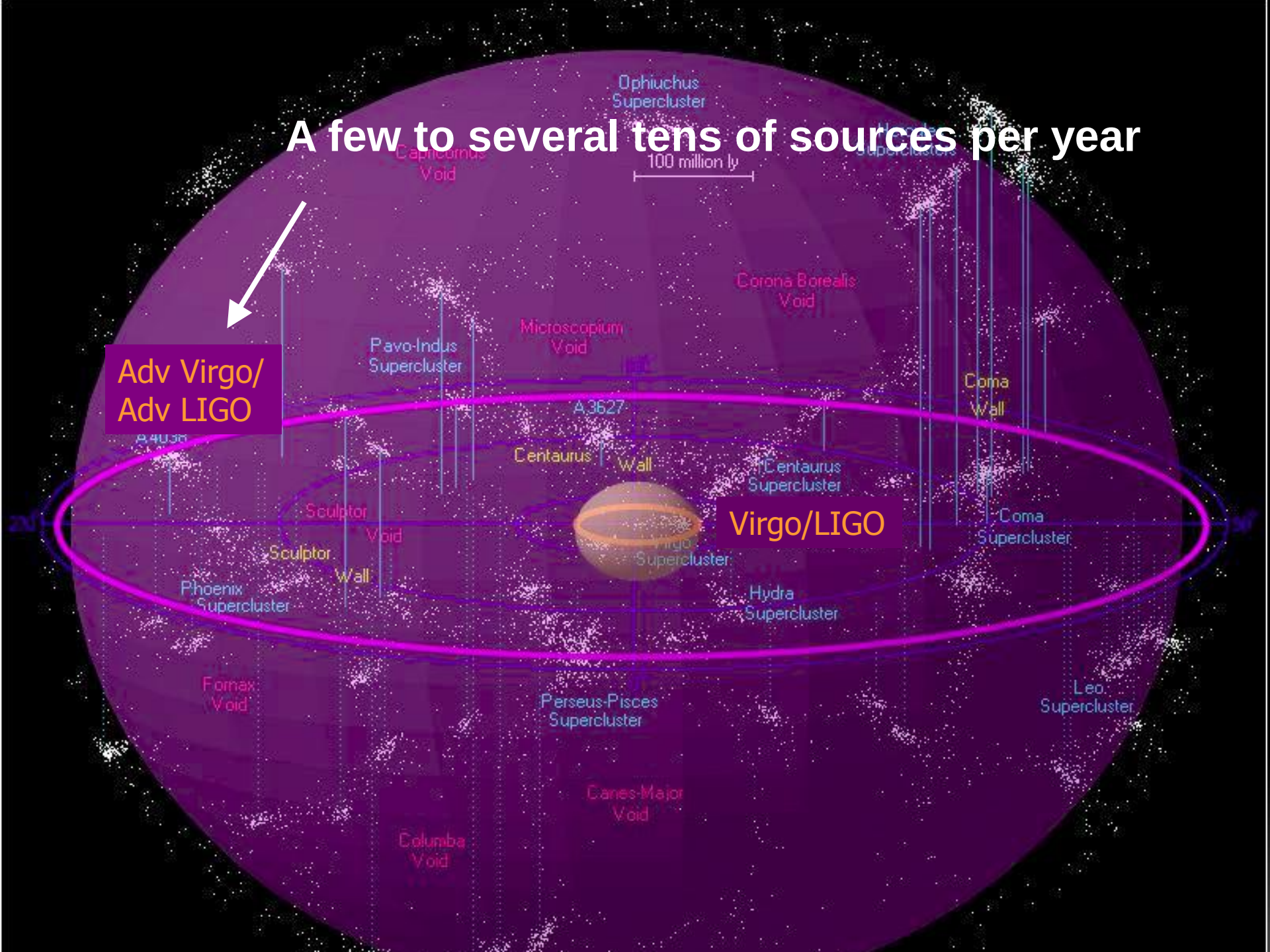


Virgo, Cascina, 3 km

LIGO Livingston, 4 km

INDIGO

TAMA, Tokyo, 300 m
(+CLIO, 3km
being started)


A few to several tens of sources per year
Adv Virgo/
Adv LIGO
Virgo/LIGO
Ophiuchus
Supercluster
100 million ly
Corona Borealis
Void
Microscopium
Void
Pavo-Indus
Supercluster
A3627
Coma
Wall
Centaurus
Wall
Centaurus
Supercluster
Sculptor
Void
Sculptor
Wall
Phoenix
Supercluster
Coma
Supercluster
Hydra
Supercluster
Fornax
Void
Perseus-Pisces
Supercluster
Leo
Supercluster
Canes Major
Void
Columba
Void