European Roadmap for Astroparticle Physics

ApPEC

- Coordination
- Cooperation
- Competition
- Convergence

ILIAS

Integrated Large Infrastructures for Astroparticle Science

~1200 scientists, budget ~10 M€

Networking Activities

(N2) Deep Underground science laboratories
(N3) Direct dark matter detection
(N4) Search on double beta decay
(N5) Gravitational wave research
(N6) Theoretical astroparticle physics

gravitational waves,
dark matter
double beta decay

Joint Research Activities (R&D Projects)

(JRA1) Low background techniques underground
(JRA2) Double beta decay European observatory
(JRA3) Study of noise in gravitational wave detectors

Transnational Access Activities

(TA1) Access to the EU Deep Laboratories

www.ilias.in2p3/fr

European Underground Labs

IUS

Institute of Underground Science in Boulby mine,

Pyhäsalmi Mine

(plans...)

LSM

Laboratoire Souterrain de Modane, France

INFN

LNGS

Laboratori Nazionali del Gran Sasso, Italy

LSC

Laboratorio Subterraneo de Canfranc, Spain

Baksan

HEAPnet

Ground and space experiments

130 laboratories, about 800 scientists , 8.9 M€

- Networking activities
- Joint Research Activities
  - Photodetectors
  - Radiodetection
  - Spacedetectors
  - Atmospheric monitoring
- Transnational Access
  - Gamma observatories
  - Deep-Sea Platform for other scientists

What is AppEC ?

- Committee for Coordination of Astroparticle Physics in Europe
  - *Steering Committee*
  - *Peer Review Committee*
- Formed by large *funding agencies* for APP in Belgium, Germany France, Greece, UK, Italy, Netherlands, Switzerland and Spain
- Further countries joined or are going to join: Finland, Ireland, Poland, Portugal, Slovenia, Tchechia, Sweden, ...

"ASPERA"

- ERA-Net „Implementation of European Coordination in Astroparticle Physics“
- 2.8 M€, among others for:
  - Communication Structure
  - ApPEC secretariat
  - ApPEC web page
  - AppEC roadmap
  - Meetings
  - Support of bottom-up activities (like ILIAS)
  - Framework to direct part of the national rescources of the agencies to transnational reserach programs

Has just been approved !

Peer Review Committee

- Review and assess research proposals in the field of Astroparticle Physics at the request of the ApPEC Steering Committee
- Advise and make recommendations through the ApPEC steering committee to the national funding agencies involved in ApPEC on research proposals submitted to it.
- Keep under review current and proposed programmes in Astroparticle Physics of interest to ApPEC. Contribute to a medium and long-term plan of the future of APP in Europe.

Reviewed in 2002-2005:

Chair: Riccardo Barbieri

- Double Beta Decay
- Direct Dark Matter Search
- High Energy Gamma Telescopes
- High Energy Neutrino Telescopes
- Gravitational Waves
- High Energy Cosmic Rays

Astroparticle Roadmap

- Steering Committee has charged PRC to write a roadmap on Astroparticle Physics in Europe over the next 10 years, with a focus to the next 5 years
- Promote astroparticle physics
- Stimulate coordination and cooperation within the European APP community
- Prepare future decisions on National and European level

Astroparticle Roadmap

- Addressees of the roadmap:
  - national funding agencies
  - European institutions
  - general physics community
  - our own community (shaping and rationalize our view on goals and priorities)
- ApPEC roadmap will take note of existing national roadmaps. For national roadmaps being written → exchange of views and plans.
- Input to ESFRI and FP7
- Close connection to ILIAS, HEAPNET, …

What is the intention of the roadmap, and what not

- The roadmap intends to
  - Sell the field to the outside world
  - Promote coordination and cooperation
  - Promote the development of infrastructures
  - Identify critical points for decisions
- The roadmap will not
  - Declare decisions w. r. t. experiments and techniques which have to be taken by the cooperating/competing expert groups working in the field

Roadmap Committee

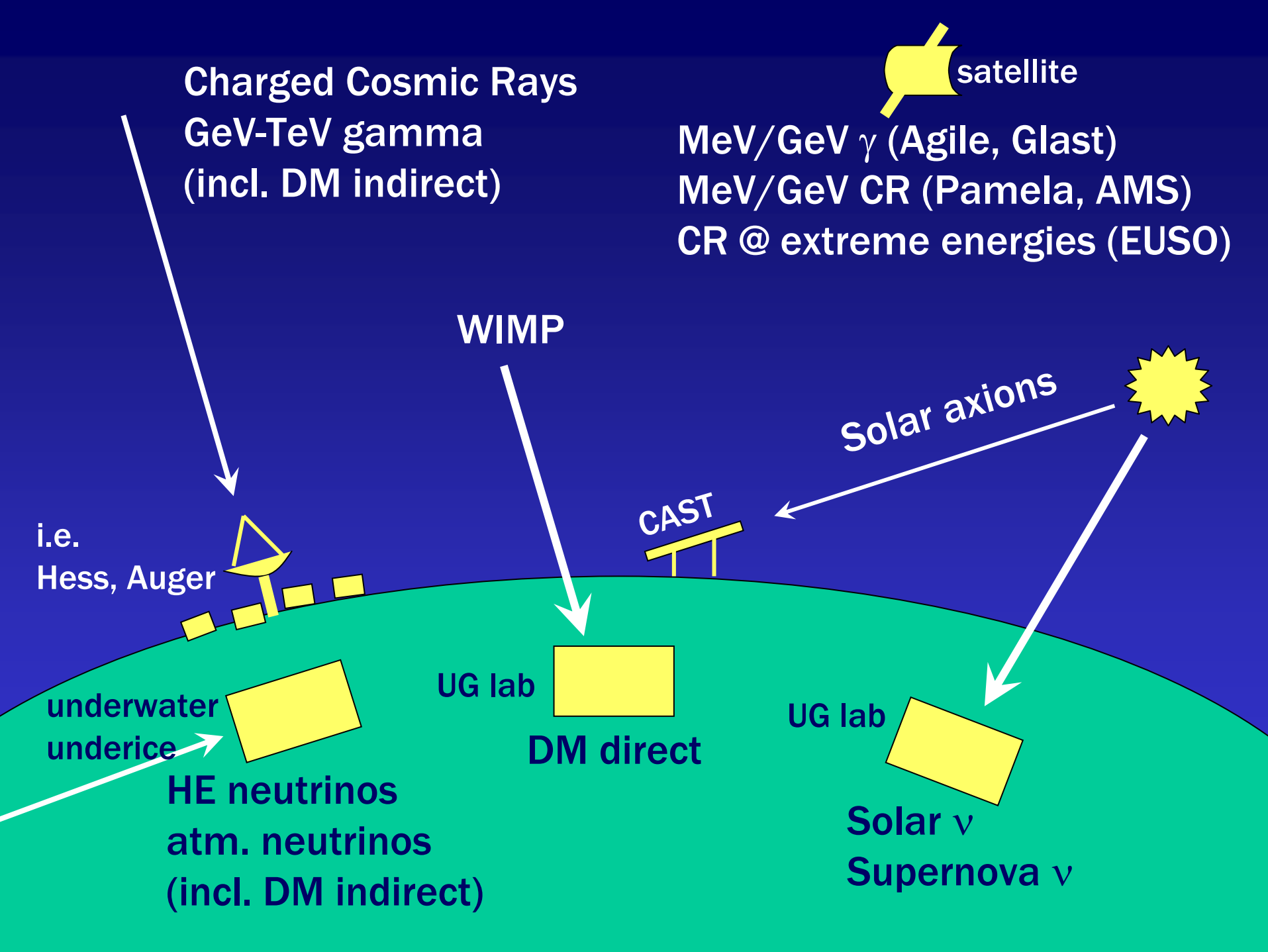
- Frank Avignone
- Jose Bernabeu
- Thomas Berghoefer
- Leonid Bezrukov
- Pierre Binetruy
- Hans Bluemer
- Karsten Danzmann
- Franz v. Feilitzsch
- Enrique Fernandez
- Werner Hofmann
- John Iliopoulos
- Uli Katz
- Paolo Lipari
- Manel Martinez
- Antonio Masiero
- Benoit Mours
- Francesco Ronga
- Andre Rubbia
- Subir Sarkar
- Guenther Sigl
- Gerard Smadja
- Nigel Smith
- Christian Spiering
- Alan Watson

What will be included ?

Don’t confuse this with the question

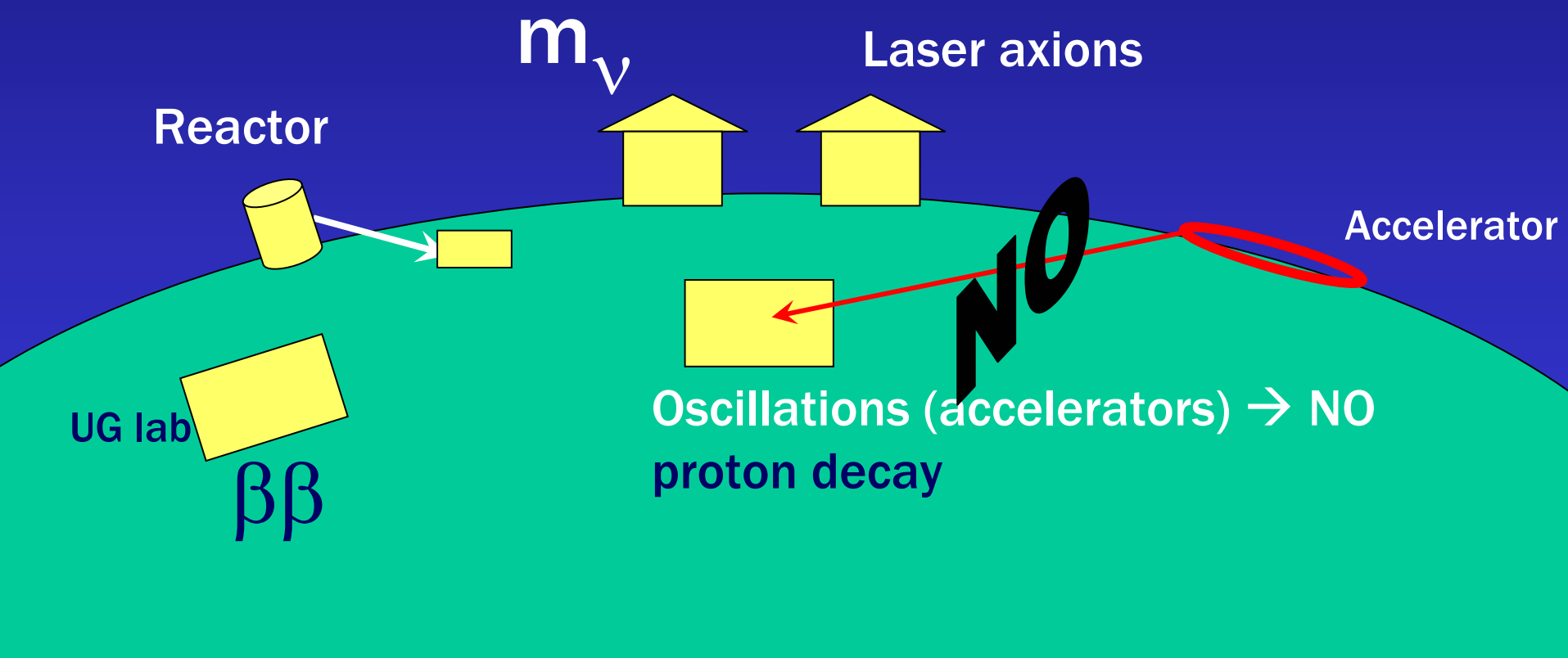
“What belongs to Astroparticle Physics?”

There is no unique answer to this question.

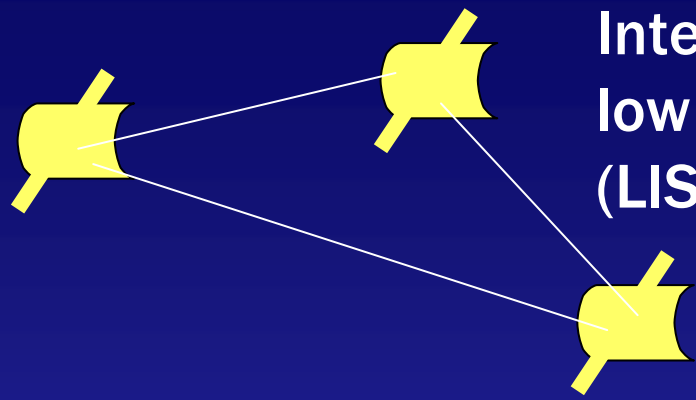

Charged Cosmic Rays
GeV-TeV gamma
(incl. DM indirect)
satellite
MeV/GeV γ (Agile, Glast)
MeV/GeV CR (Pamela, AMS)
CR @ extreme energies (EUSO)
WIMP
Solar axions
CAST
i.e.
Hess, Auger
underwater
underice
HE neutrinos
atm. neutrinos
(incl. DM indirect)
UG lab
DM direct
UG lab
Solar ν
Supernova ν

No particles from heaven but:

- same infrastructure ($\beta\beta$)
- closely related question (tritium decay)



Gravitational Waves



Interferometer
low frequency
(LISA)

Interferometers
(Geo-600, VIRGO)

Resonance Antennas

Not included, but closely linked :

- Nuclear astrophysics
  - Covered in nuclear physics programmes
  - In some countries listed under APP as well
- Dark Energy Missions
  - Necessary to set the stage for APP missions
  - Fully covered by astronomy community
  - Not our charge
  - In some countries under one roof with APP missions
- Others
  - Varying fundamental constants
  - Gravity at short distances (may be included)

Steps

1) Compile the facts

- collect questionnaires from all experiments with European participation

  76 spokespersons addressed
- Return rate 97% (only 2 missing)
- Second loop for corrections finished.
- 130 page document → will be available to the community

2) Start communication with the community

   TAUP, German Astroparticle Workshop,
   Munich Town Meeting Nov 2005, ...

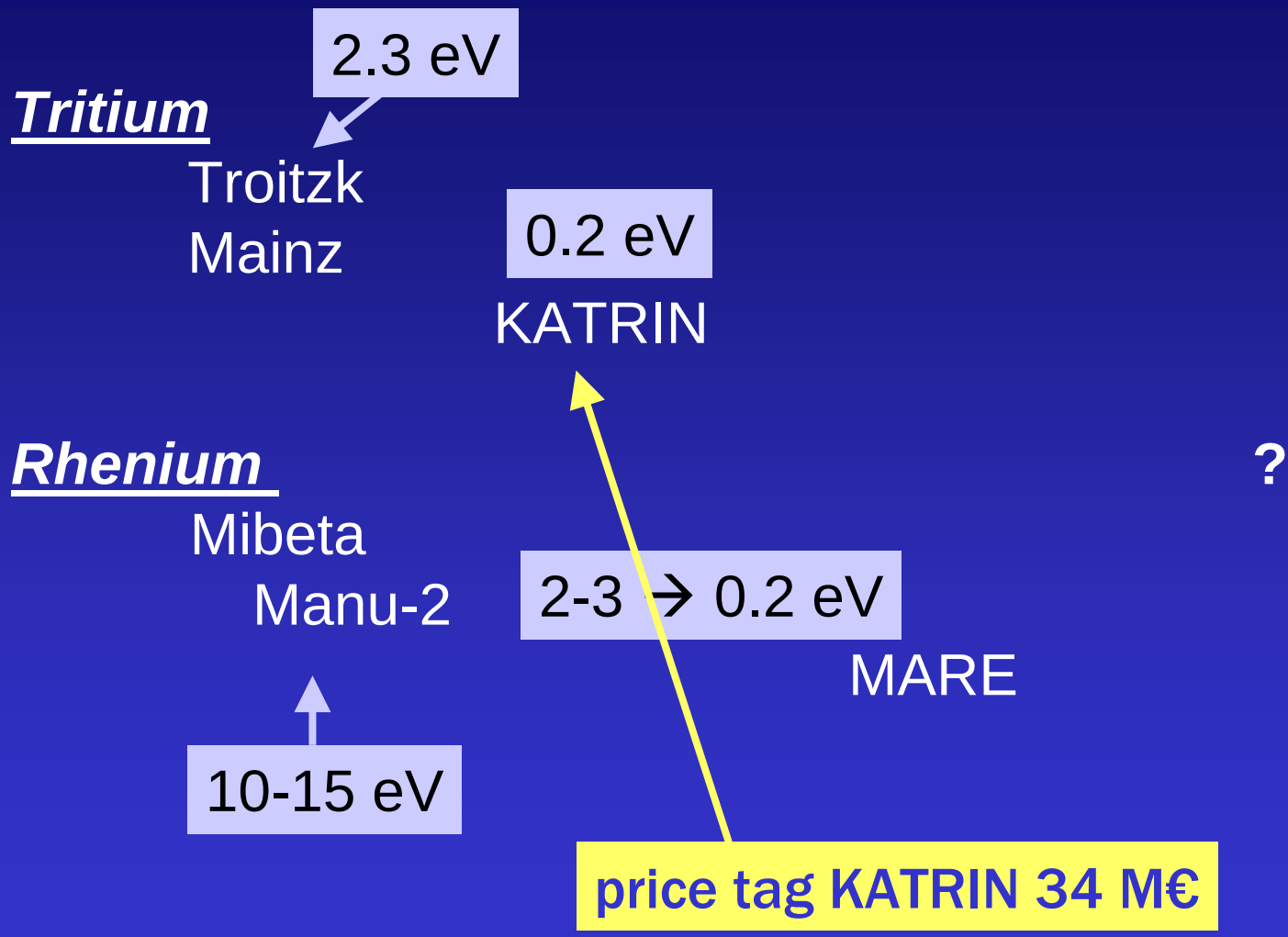
Steps

3) Contact CERN strategy group (Dec.12) and national roadmap committees
4) Finalize draft at a PRC meeting in Berlin at Jan. 16/17, 2006 (← will just arrive with a first draft and recommendations)
5) Submit draft to SC Meeting at Jan 23/24
6) After discussion with SC and modifications: place the draft on the web for everybody (mid February).
7) Start communication with ESFRI (ApPEC SC)
8) Feedback from the community
9) Open Meeting in Spring 2006
10) Finalize Roadmap Paper
11) Submit to SC (May/June 2006)

Sections of the Roadmap

- Cosmology and early Universe (including dark matter)
- Properties of particles:
  → neutrino mass (direct and double beta),
  → exotic particles (WIMPs, axions, Q-Balls, magnetic monopoles)
  → proton decay
- Thermal Universe: Low energy neutrinos
- Non-thermal Universe (gamma, neutrinos, cosmic rays)
- Properties of the gravitational force (interferometers and resonant detectors)

Neutrino Mass: single beta



Recommendtions Double Beta Experiments

June 2002

- Relevant neutrino mass parameter m_{ee} > 1 meV is likely
- Experiments are sensitive to (m_{ee} × nuclear matrix element), the matrix el. are highly uncertain (at diff. level for diff. nuclei)

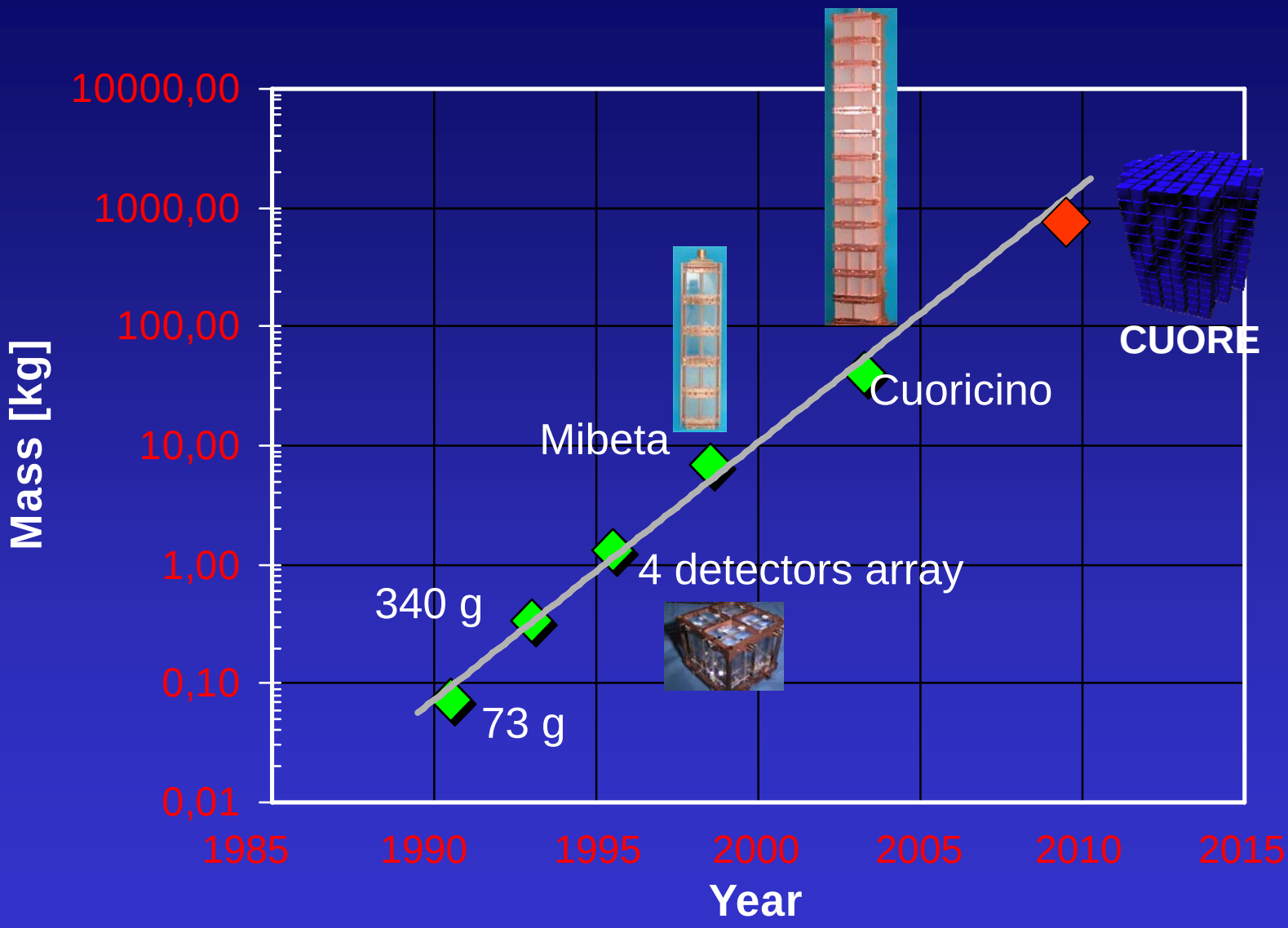
→ Form collaboration of adequate size and expertise aiming at a sensitivity down to or below 10 meV.

→ Some redundancy in the choice of nuclei (at least worldwide)

→ Vigorous program to reduce uncertainty of nuclear matrix elements, at least for a few key nuclei

„International Statement on neutrinoless Double-Beta Decay“

Sept. 2002


10000,00
1000,00
100,00
10,00
1,00
0,10
0,01
Mass [kg]
1985
1990
1995
2000
2005
2010
2015
Year
CUORE
Cuoricino
Mibeta
4 detectors array
340 g
73 g

Neutrino Mass: Double Beta

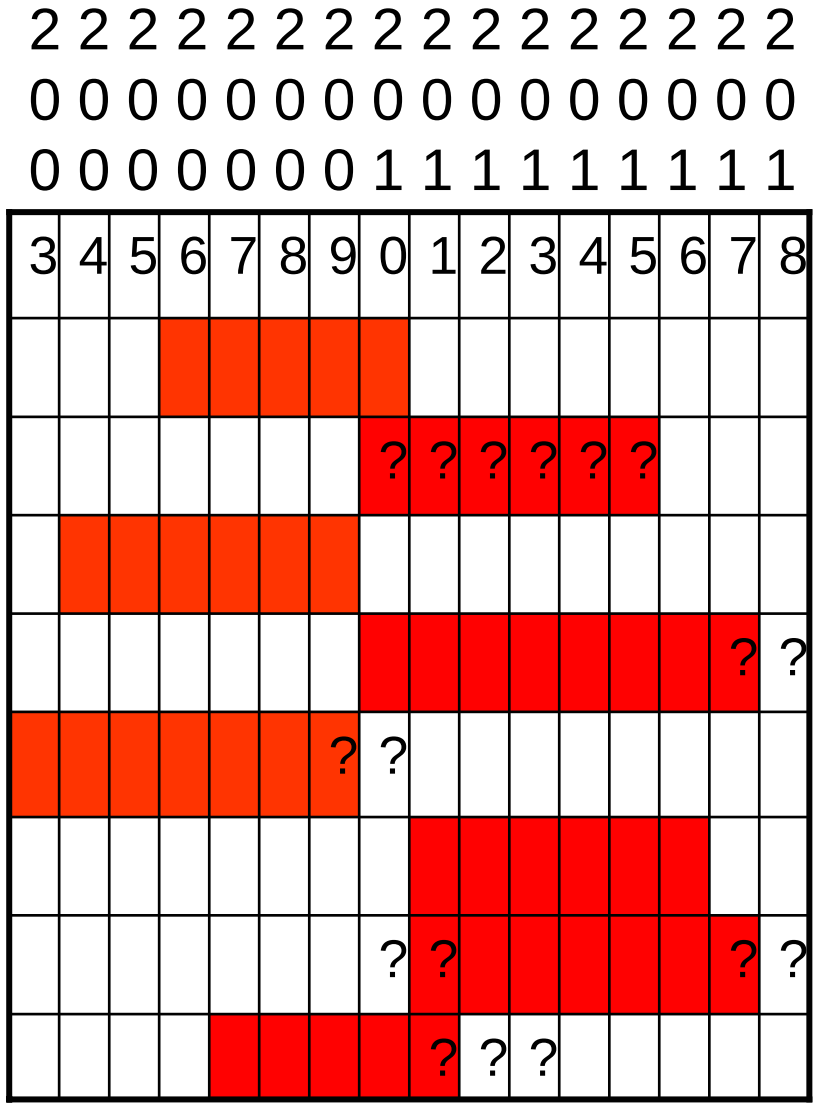
past	*present*	*next 5 years*	*next 10 years*	*?*
HDMS			price tag 30-60 M€	
		GERDA	Gerda+Majorana	
	Cuoricino			10 ton ?
		Cuore	Cuore enrich.	
	NEMO			
		Super-NEMO		
		EXO-200 *	EXO 1-10 ton*	

COBRA → ….
TGV → ….

price tag 10-20 M€

* USA with Swiss participation

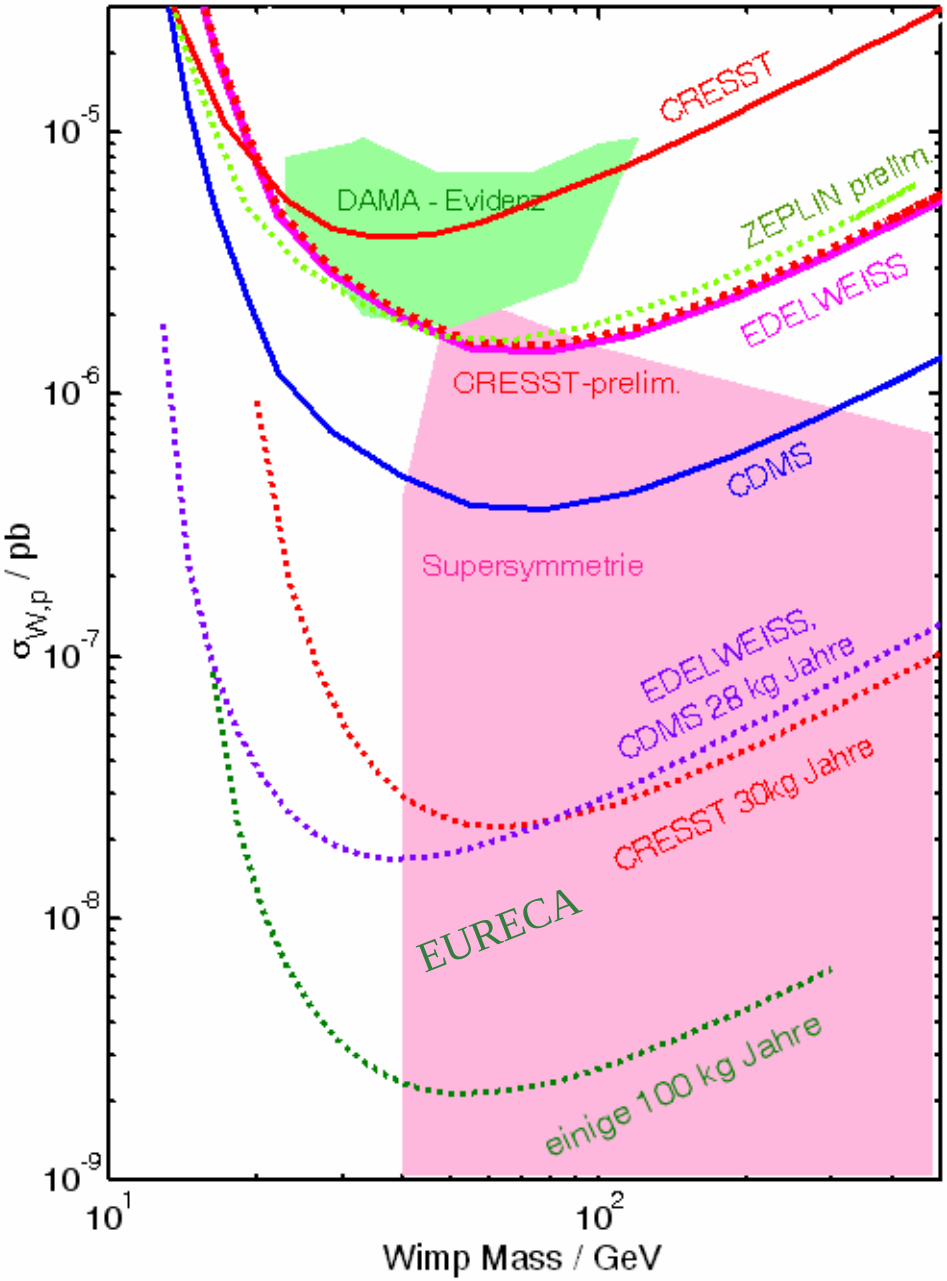
Experiment	Cost	Nuclei
GERDA	10	Enr. Ge 30 kg
GERDA+Maj.	**50?**	Enr.Ge>200 kg
Cuoricino	1	Te130, 41 kg
Cuore	**14**	Te130, 760 kg
NEMO	2.5	Various, 10kg
SuperNEMO	**20**	Various, 100kg
COBRA	**50**	CdTe, 400 kg
EXO-200	8	Xe136, 200kg



Recommendtions Dark Matter Experiments

Jan 2003

- Search for WIMPs by direct detection methods is a most valuable mean to solve the Dark Matter problem.
- At present several projects in Europe, US, Japan aim at a sensitivity for the spin-independent WIMP-nucleon cross section of 10^{-8} pb.
- Further increase by two orders of magnitude (10^{-10} pb) is conceivable and desirable.
- Requires detector on the ton scale.


CRESST
DAMA - Evidenz
ZEPLIN prelim.
EDELWEISS
CRESST-prelim.
CDMS
Supersymmetrie
EDELWEISS,
CDMS 28 kg Jahre
CRESST 30kg Jahre
EURECA
einige 100 kg Jahre
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
$\sigma_{W,p}$ / pb
10^{1}
10^{2}
Wimp Mass / GeV

→ Assessment of current activity in 2 years in order to determine the most promising technique.
(at that time a clear demonstration of an effective sensitivity in the 10^{-8} range should be available).

→ Common activity across Europe on
- nuclear recoil energy calibration
- properties of neutron background
- impact of nuclear form factors or halo parameters on sensitivity

→ Means of validating a possible signal.
Work on electron and gamma rejection techniques

Direct Dark Matter Search (1)

Ultimate price tag
20-100 M€

NaI

DAMA/LIBRA

DAMA-1ton ?

ANAIS

Bolometers

CRESST
Edelweiss

EURECA

ROSEBUD R&D

10^{-10} pb

Ge

IGEX-DM
HDMS
Genius-TF

Direct Dark Matter Search (2)

Noble Gases

Zeplin-1 → Zeplin-3

Xenon*
- WARP
- ArDM 1ton

Ultimate price tag
20-100 M€

Zeplin-4

10^{-10} pb

ArDM 10 ton

10^{-10} pb

Directional

Drift I, II → Drift III

Drift 1 ton

10^{-10} pb

particularly interesting if DM has been seen

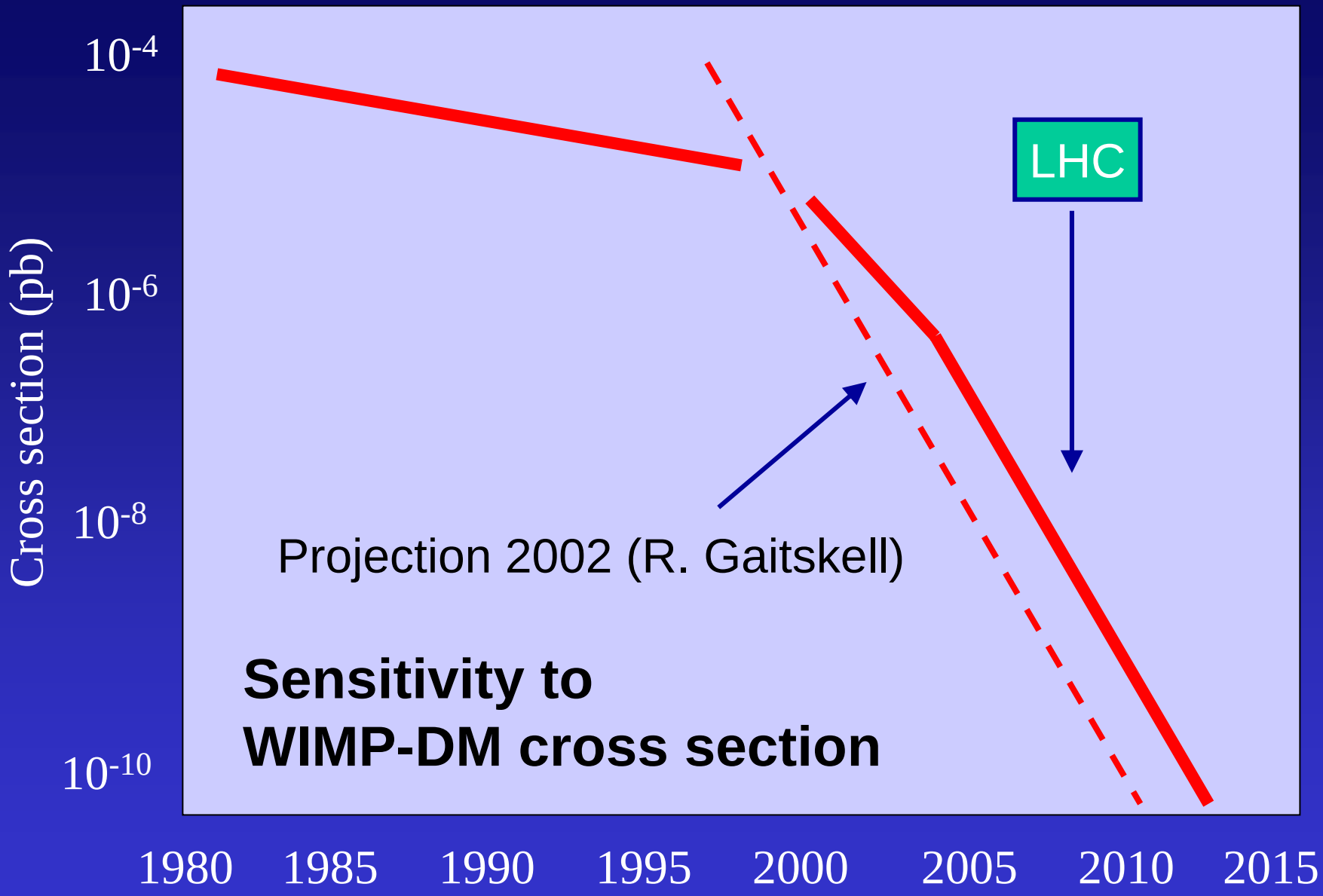
Direct Dark Matter Search (3)

Superheated grains (R&D)

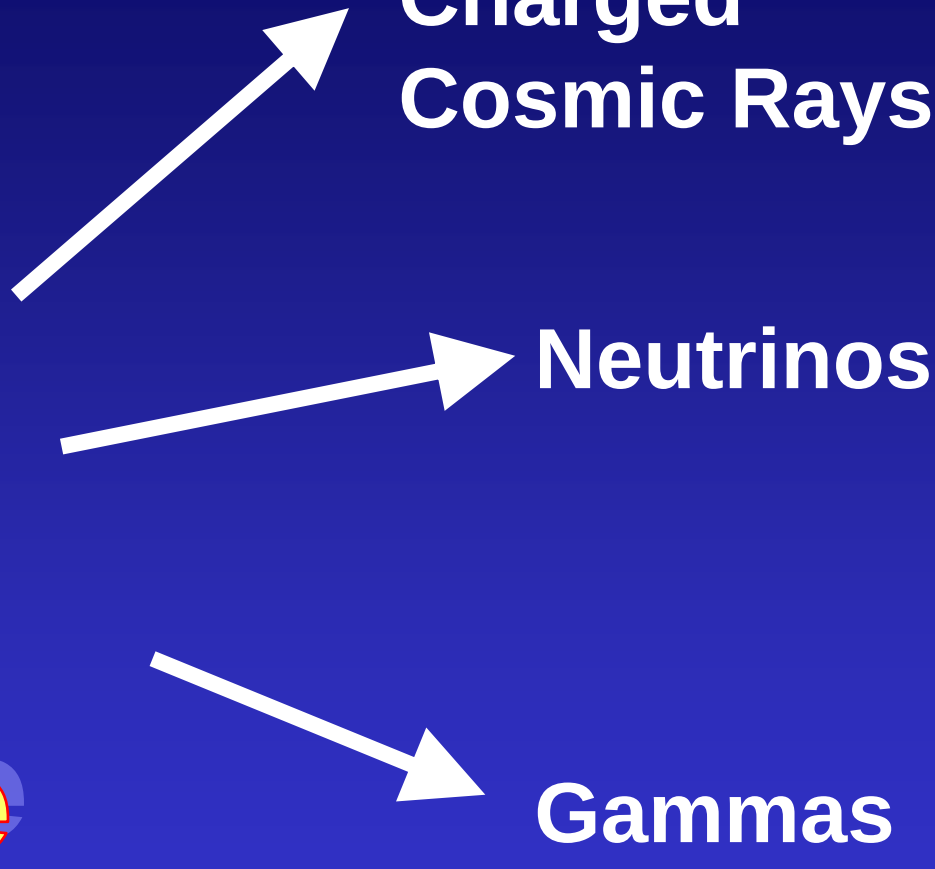
SIMPLE (Lisbon)
PICASSO (Montreal)

Axion Searches

CAST
PVLAS
HERA/LHC magnets?


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

The High Energy Universe



TeV Energy Gamma Telescopes

VERITAS

MILAGRO

MAGIC

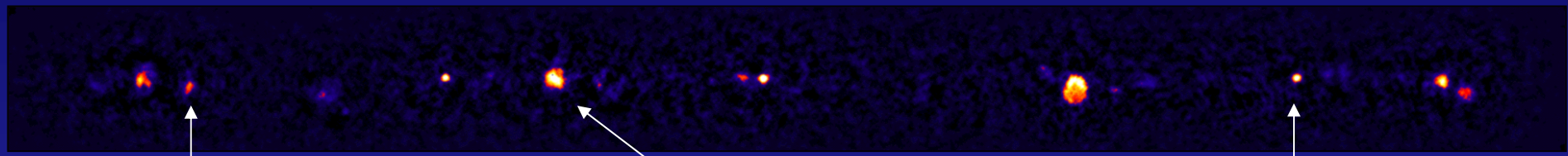
TIBET III

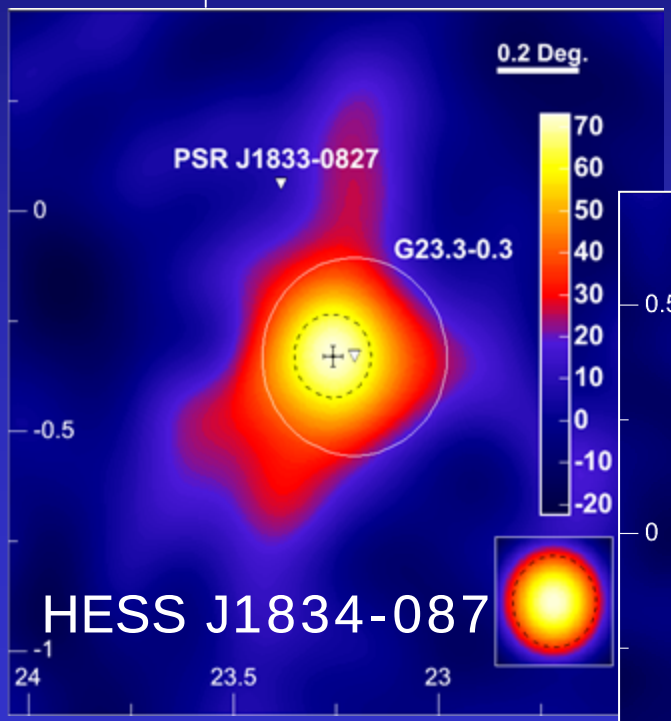
ARGO

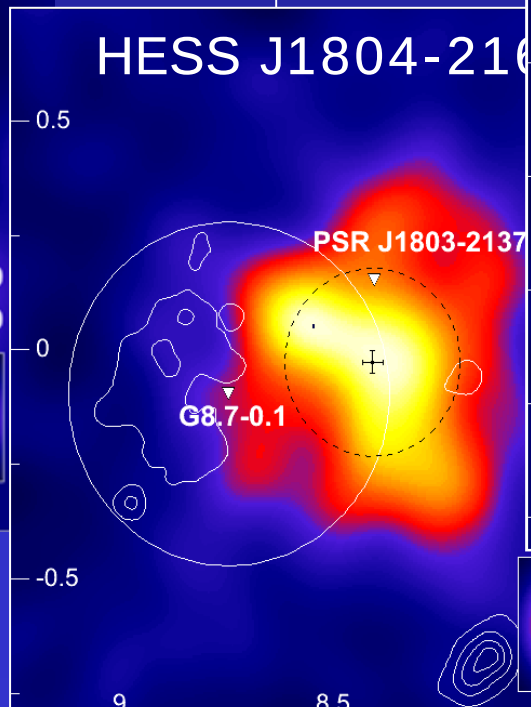
HESS

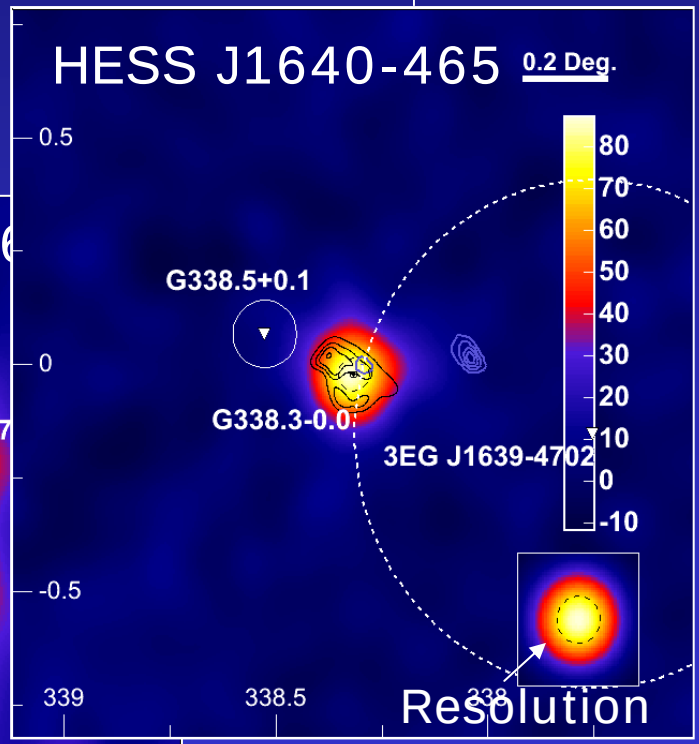
Cangaroo III

2005: H.E.S.S. Scan of Inner Galactic Plane !!



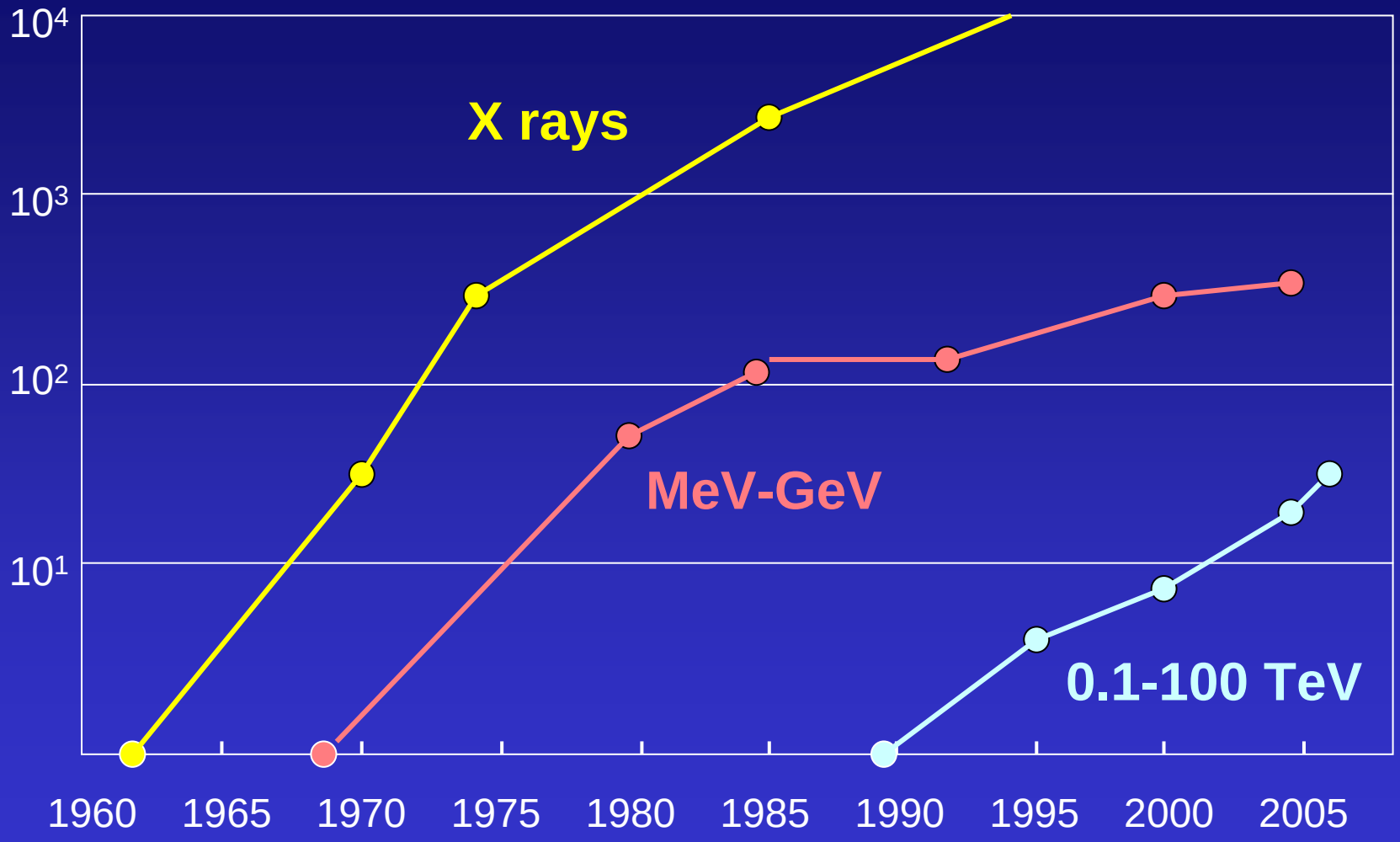






Resolution

High Energy Photon Sky: Source Count vs. Year



(modified from M. De Naurois, astro-ph/0409361)

Gamma Telescopes

operating *soon* *after 2010*

HESS HESS-2

MAGIC Magic-2

Whipple | Veritas

ARGO/YBJ

Large Array(s)

Č

price tag 5-12 M€

Ultimate price tag
2 x 100 M€

Satellite: AGILE
Satellite: GLAST
Satellite: GILDA

Recommendtions Neutrino Telescopes

July 2003

→ With the aim of constructing a detector of km3 scale in the Northern hemisphere, both in view of size and competition with IceCube: form a single coherent collaboration collecting *all* the efforts underway

→ Prepare report to ApPEC PRC with following informations:

- optical properties of water, incl. seasonal variations and using the same devices
- optical background and sedimentation
- comparative simulations about impact of depth and water properties to some benchmark km3 detectors (focussing to the central goals of Nu Telescopes)

→ Single design study in the European FP6 framework

→ New review in one year (summer 2004)

High Energy Neutrino Telescopes

* European contributions 15-20%

Baikal-NT200

→ NT200+

Baikal GVD (~2015) at this point no ApPEC members involved

Amanda

IceCube (2010)* HyperCube ? (radio+acoust)

Antares (2007)

Nestor

Nemo

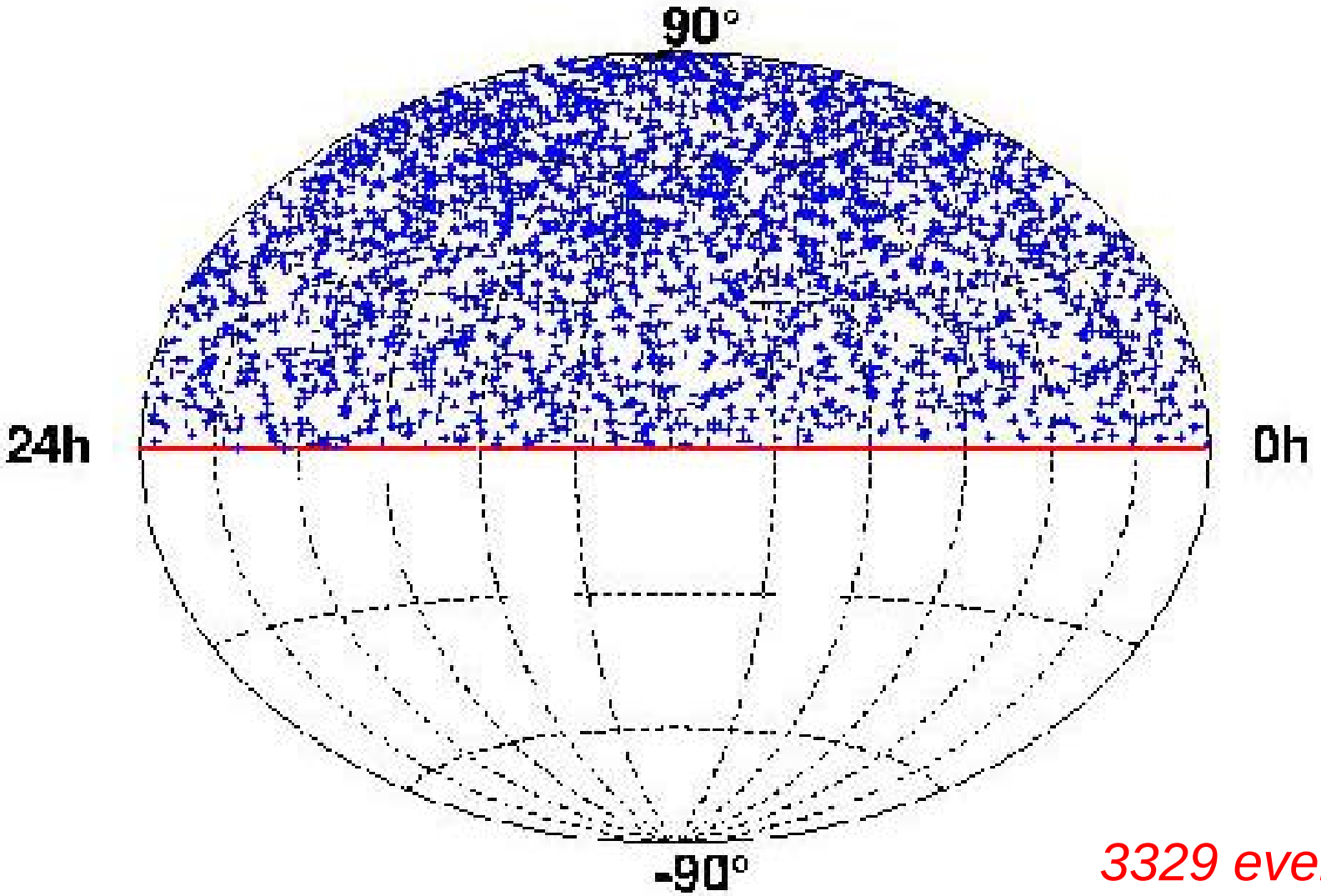
price tag 150-200 M€

KM3 (2013-14)

→ Integration of radio and acoustic detection into optical telescopes

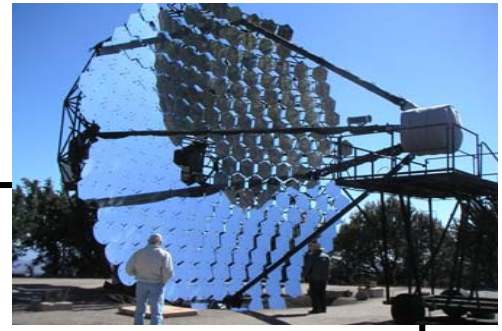
→ Neutrino interactions in atmosphere (Auger,EUSO), in the moon (radio antennas), ...

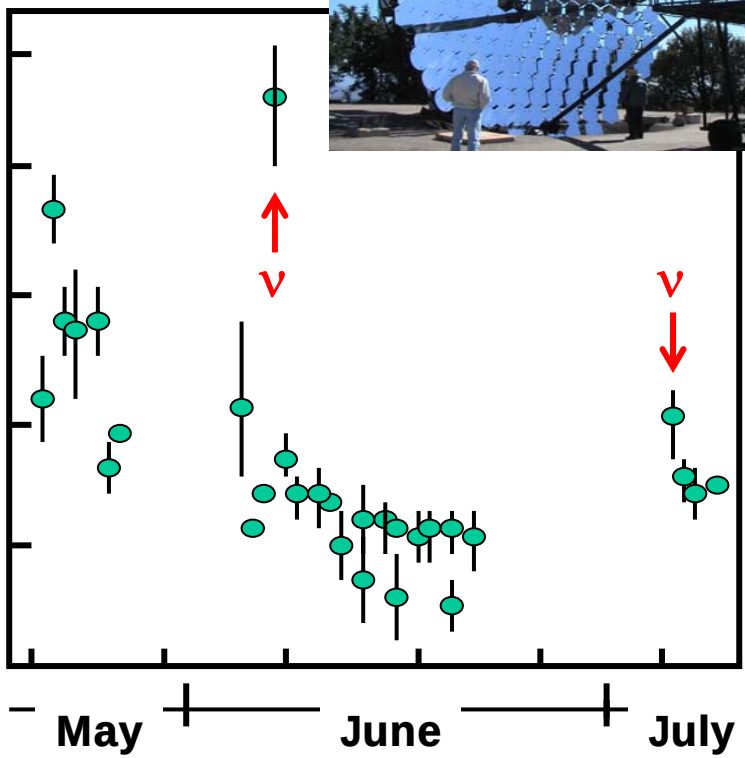
AMANDA skyplot 2000-2003



3329 events

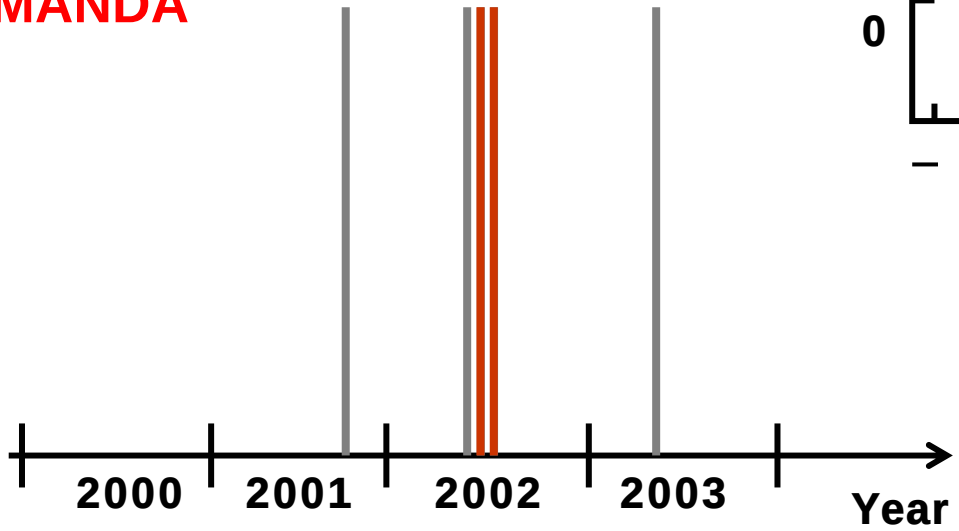
A tantalizing coincidence

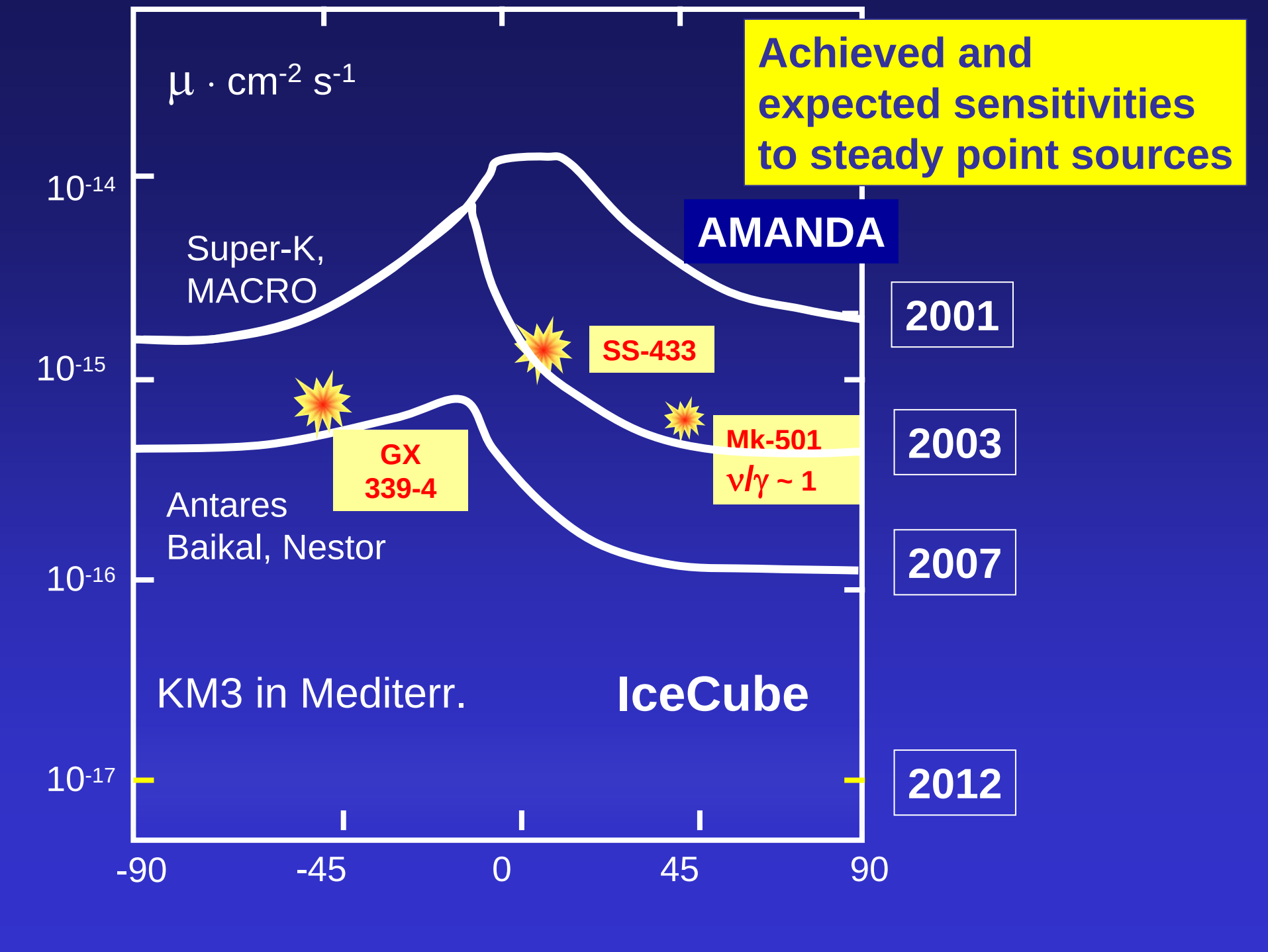




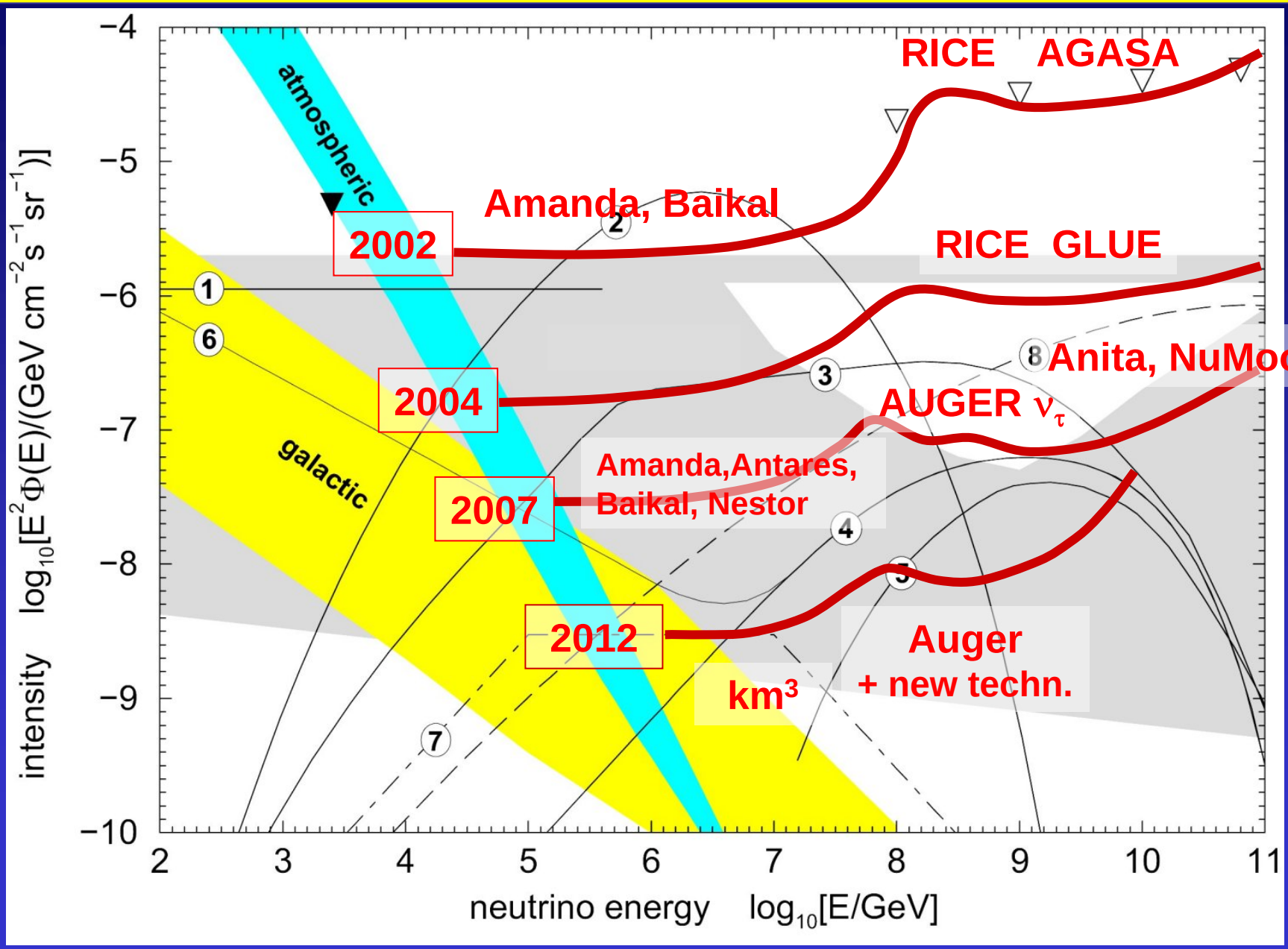
Gamma-rays detected by a TeV gamma telescope

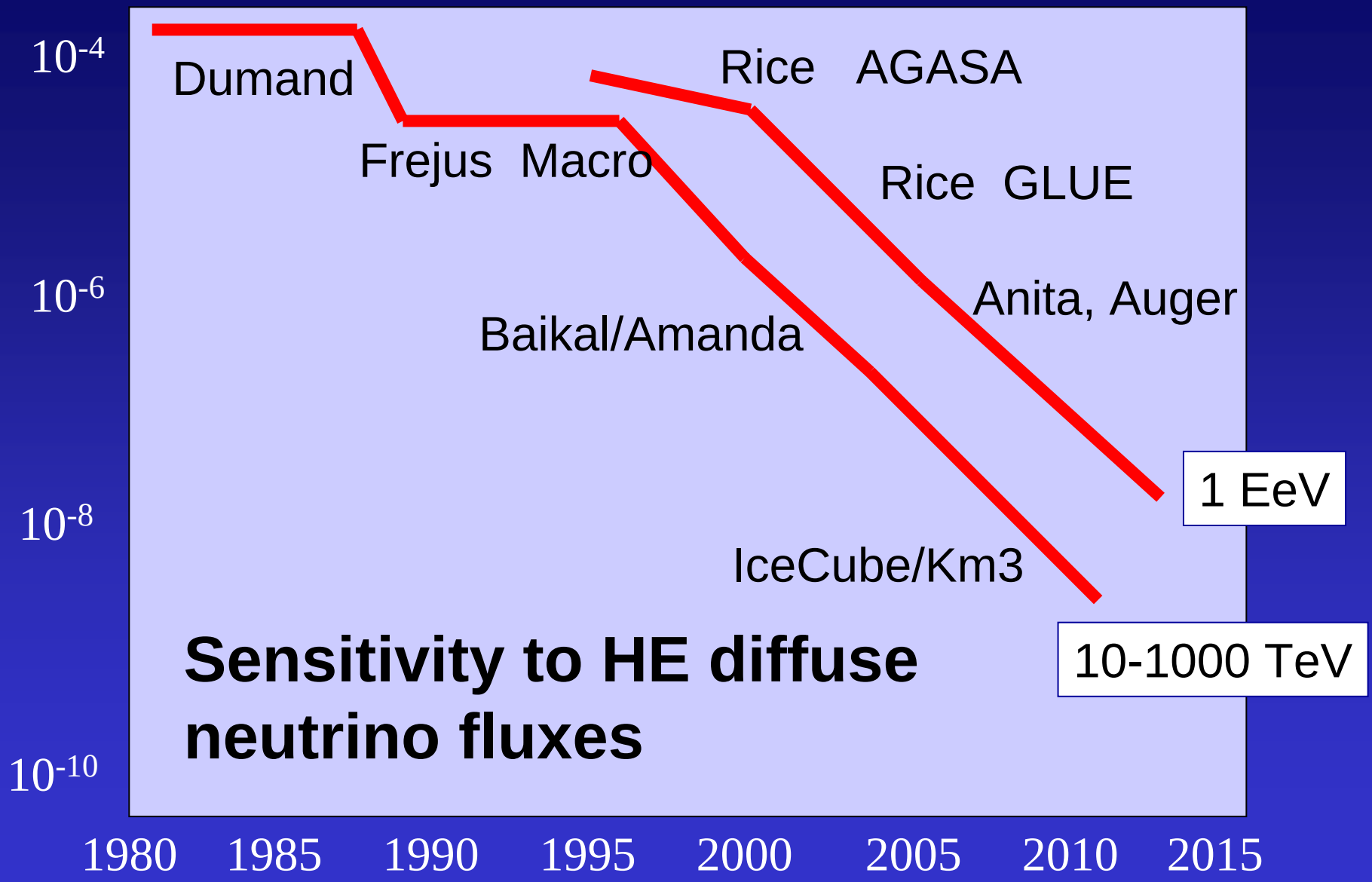
Arrival time of the neutrinos from the direction of ES1959+650 detected by AMANDA




Achieved and expected sensitivities to steady point sources
μ · cm-2 s-1
10-14
10-15
10-16
10-17
Super-K, MACRO
AMANDA
2001
SS-433
GX 339-4
Mk-501
ν/γ ~ 1
2003
Antares Baikal, Nestor
2007
KM3 in Mediterr.
IceCube
2012
-90
-45
0
45
90

Achieved and expected sensitivities to diffuse fluxes




Flux * E² (GeV/ cm² sec sr)
10-4
10-6
10-8
10-10
Dumand
Frejus
Macro
Rice
AGASA
Rice GLUE
Anita, Auger
Baikal/Amanda
IceCube/Km3
1 EeV
10-1000 TeV
Sensitivity to HE diffuse neutrino fluxes
1980
1985
1990
1995
2000
2005
2010
2015

Cosmic Ray Experiments

a) Low energy

TRACER
CREAM
ATIC
} balloons

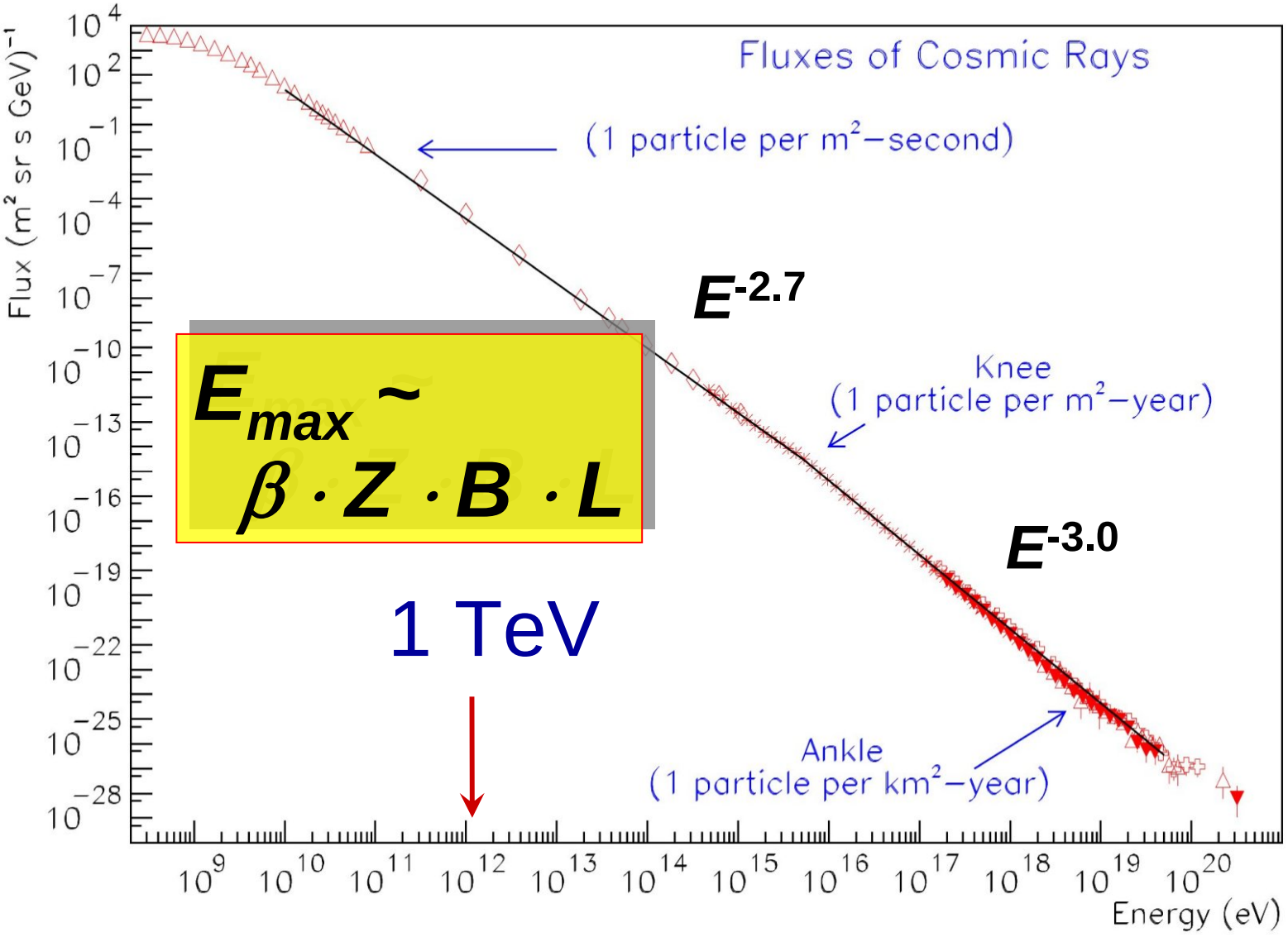
PAMELA

AMS

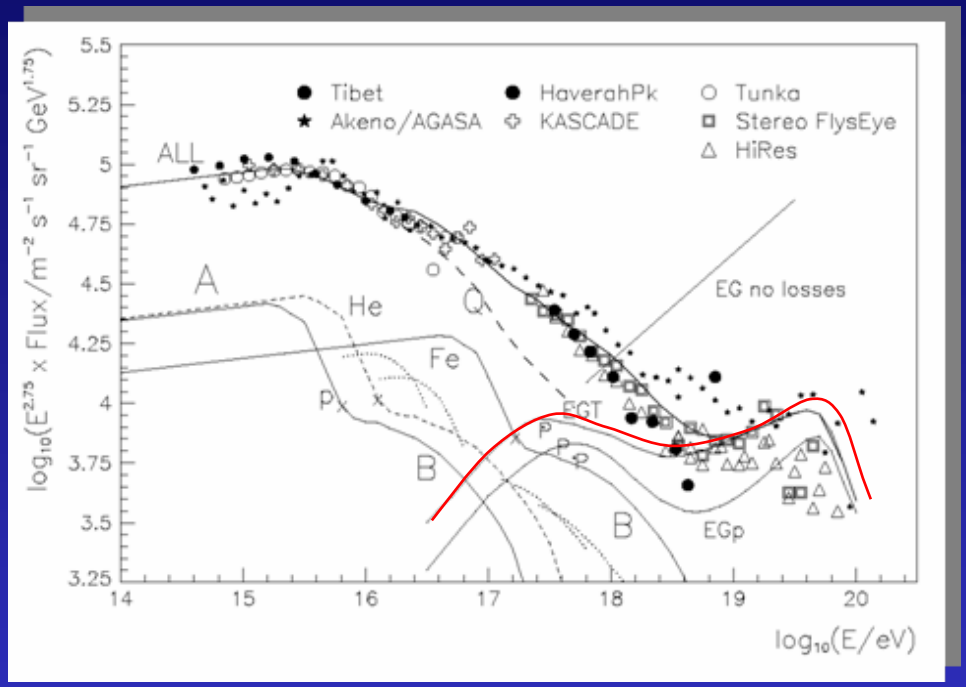
price tag:
~20 M€, 200 M€

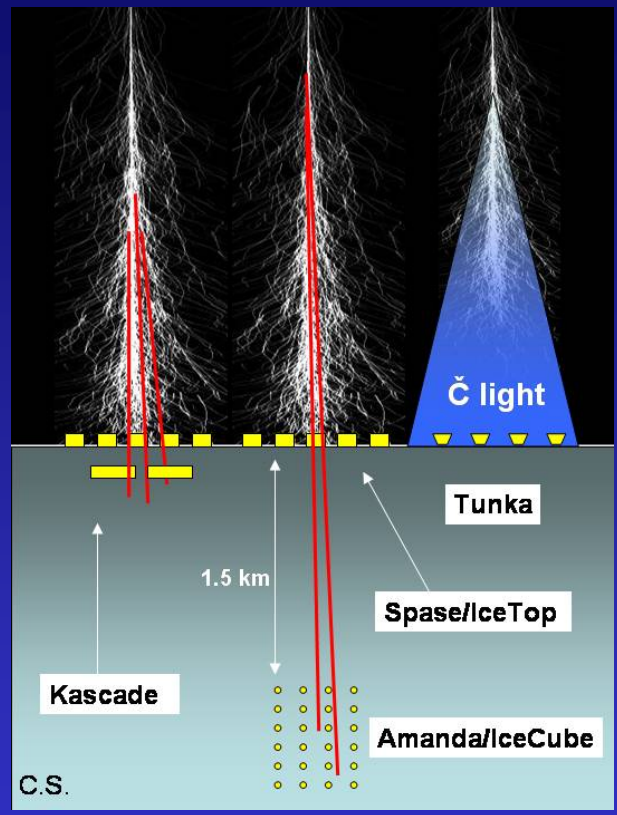
b) Towards the end of the galactic spectrum

Kascade-Grande |2008
2008..2010| IceTop/IceCube
2006..2008| Tunka


Fluxes of Cosmic Rays
(1 particle per m²–second)
E-2.7
Knee
(1 particle per m²–year)
E-3.0
Ankle
(1 particle per km²–year)
Emax ~ β · Z · B · L
1 TeV
Flux (m² sr s GeV)⁻¹
Energy (eV)

Nearly for free: Towards the end of the galactic spectrum ..



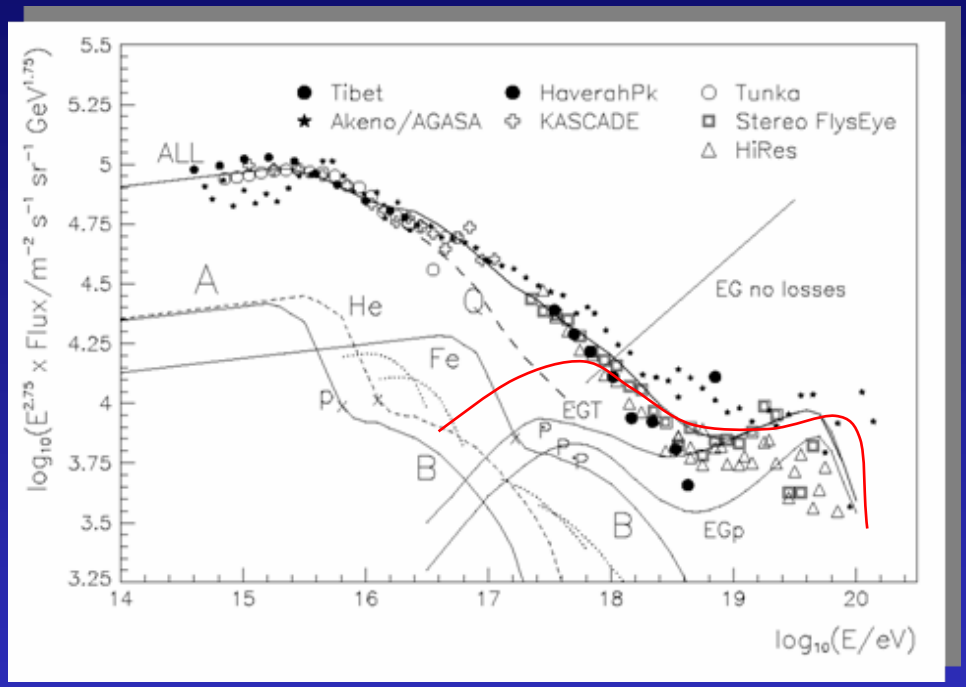


- Iron knee ?
- Second „component B“ ?
- where does extragalactic component starts to dominate ?

Three 1 km² arrays with Complementary approach.

- KASCADE-Grande
- IceTop/IceCube
- Tunka-133

Nearly for free: Towards the end of the galactic spectrum ..



- Iron knee ?
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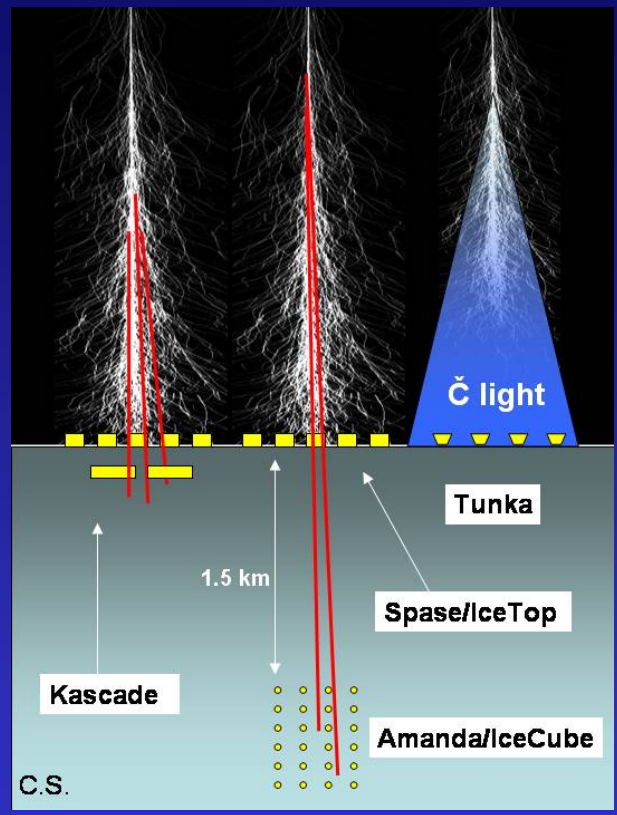


Three 1 km² arrays with Complementary approach.

- KASCADE-Grande
- IceTop/IceCube
- Tunka-133

Cosmic Ray Experiments

c) High and Ultra-high energies: Beyond the Galaxy

Auger South
Auger North

} price tag ~ 50 M€ per site

EUSO (> 2015)

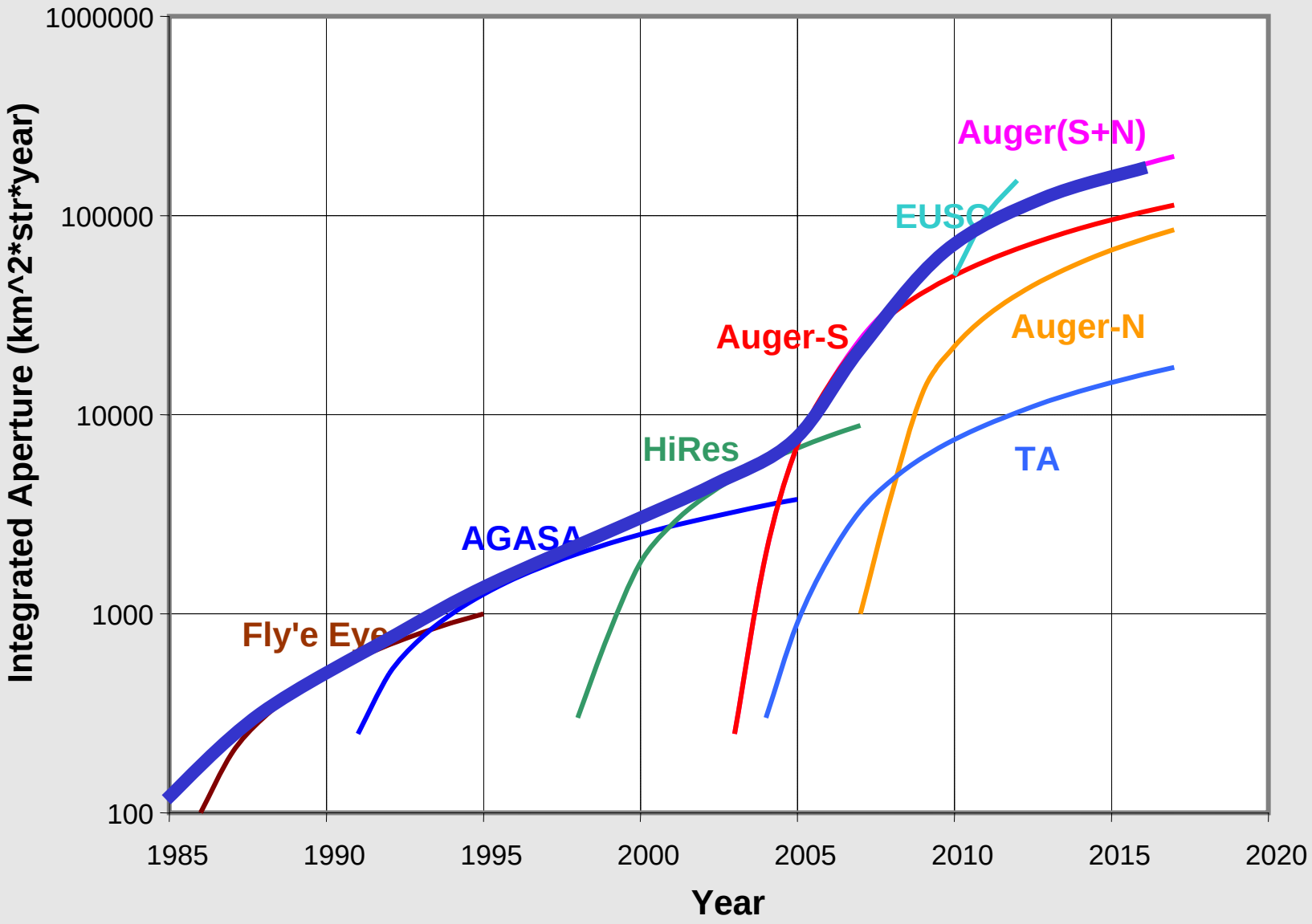
NuMoon/LOFAR

d) New methods

price tag 125 M€

LOPES, Codalema
LOFAR

Integrated Aperture



Gravitational Waves

a) Bar detectors

AURIGA
Mini-Grail
DUAL R&D
SFERA
ROG (Nautilus + Explorer)

b) Interferometers

Geo-600
VIRGO
LIGO
LISA Pathfinder/LISA
Large Underground Interferometer ?

Price tag
LIGO: 260 M€ (US costing)
only US
Adv.Ligo: +210 M€ (dito)
30 M$ Germ. + UK
VIRGO: 85 M€ (cap.invest)
LISA: 200 M€ (ESA costing)
US + Europe
L.U.I.: 200 M€ (?)

Low Energy Neutrinos, Proton Decay

LVD
CTF
Borexino
SNO

GLACIER (100 kton LAr)
LENA (50 kt scintillator)
MEMPHYS (Water Megatonne)

Ultimate price tag
500-800 M€

Decision~ 2010

Summary

- Strong process of cooperation and concentration is ongoing.
- European community has a lead position in many fields !
- From infancy to maturity: the past 1-2 decades have born the instruments & methods for doing science with high discovery potential.
- Accelerated increase in sensitivity in nearly all fields.
- → **We live in an exciting period !**
- The roadmap will reflect this process, make the physics case to funding agencies and the outside world.

Sorry for not including **Theory**: see the talk of Stefan Pokorski