CSN2 review

CSN2
Fisica delle
Astroparticelle

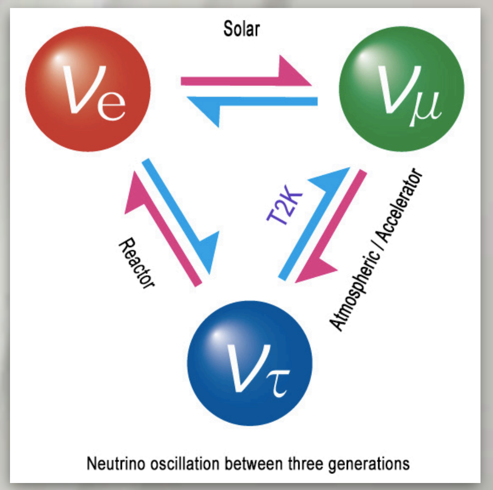
G. Mazzitelli - 2nd INFN Early Career Researchers meeting
LNF-INFN, 30 September 2024

CSN2: astro particle

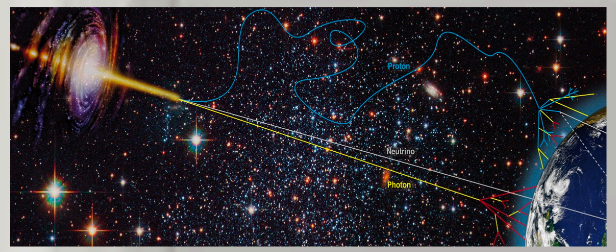
what: the studies of elementary particles and their relation to astrophysics and cosmology

a rich variety of primary interest scientific items
strong multidisciplinary
many ideas and a large number of proposals

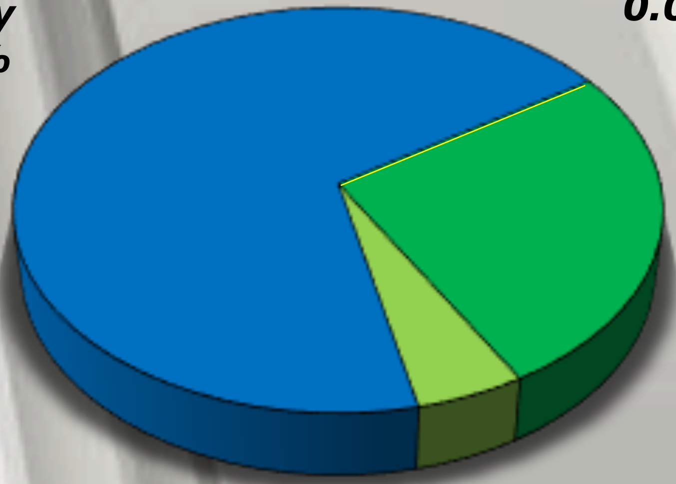
neutrino physics



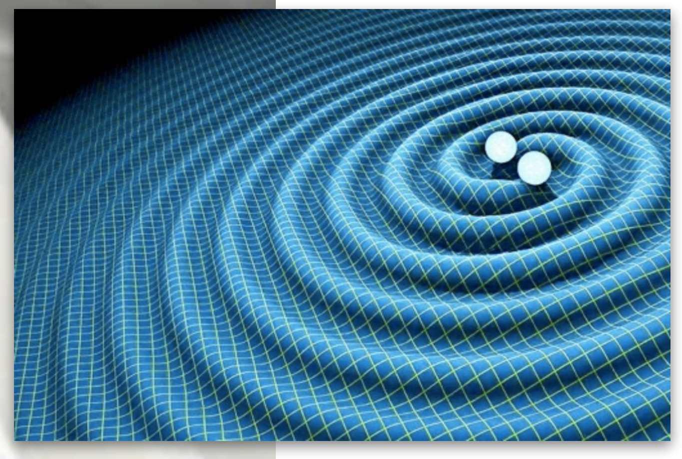
radiation from universe



the dark universe



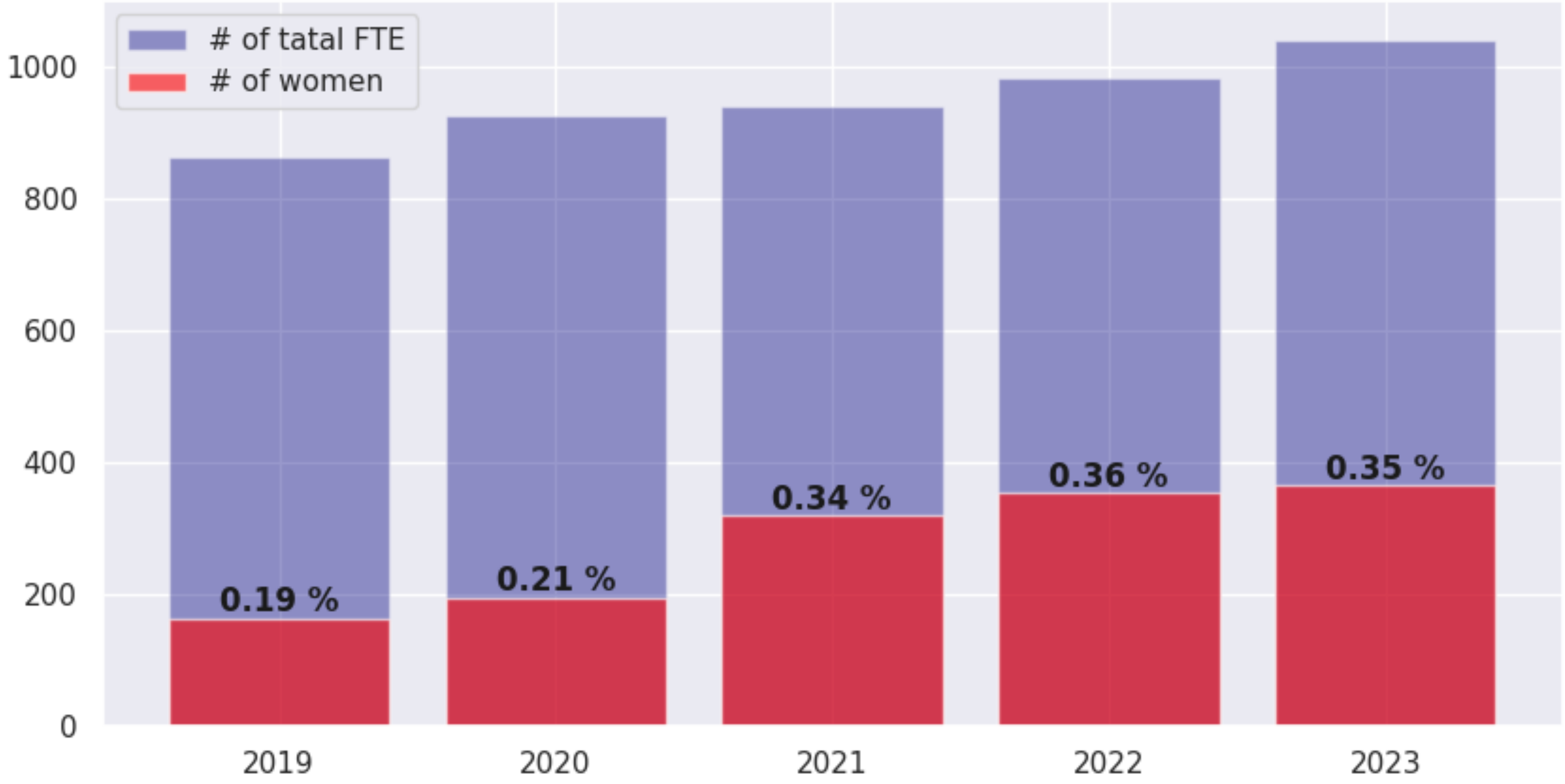
Gravitational Wave, general and quantum physics



CSN2: astro particle

who

label/yar	2023	2022	2021
# of FTE	1040	982	940
% of women	0.35	0.36	0.34
Budget/y (M€)	13.7	13.7	13.7
Number of projects	44	48	49
Milestones % achieved	65	53	78
# publications		566	502
# conference talks	603	576	493
# PhD thesis	41	26	31



international collaborations leadership roles

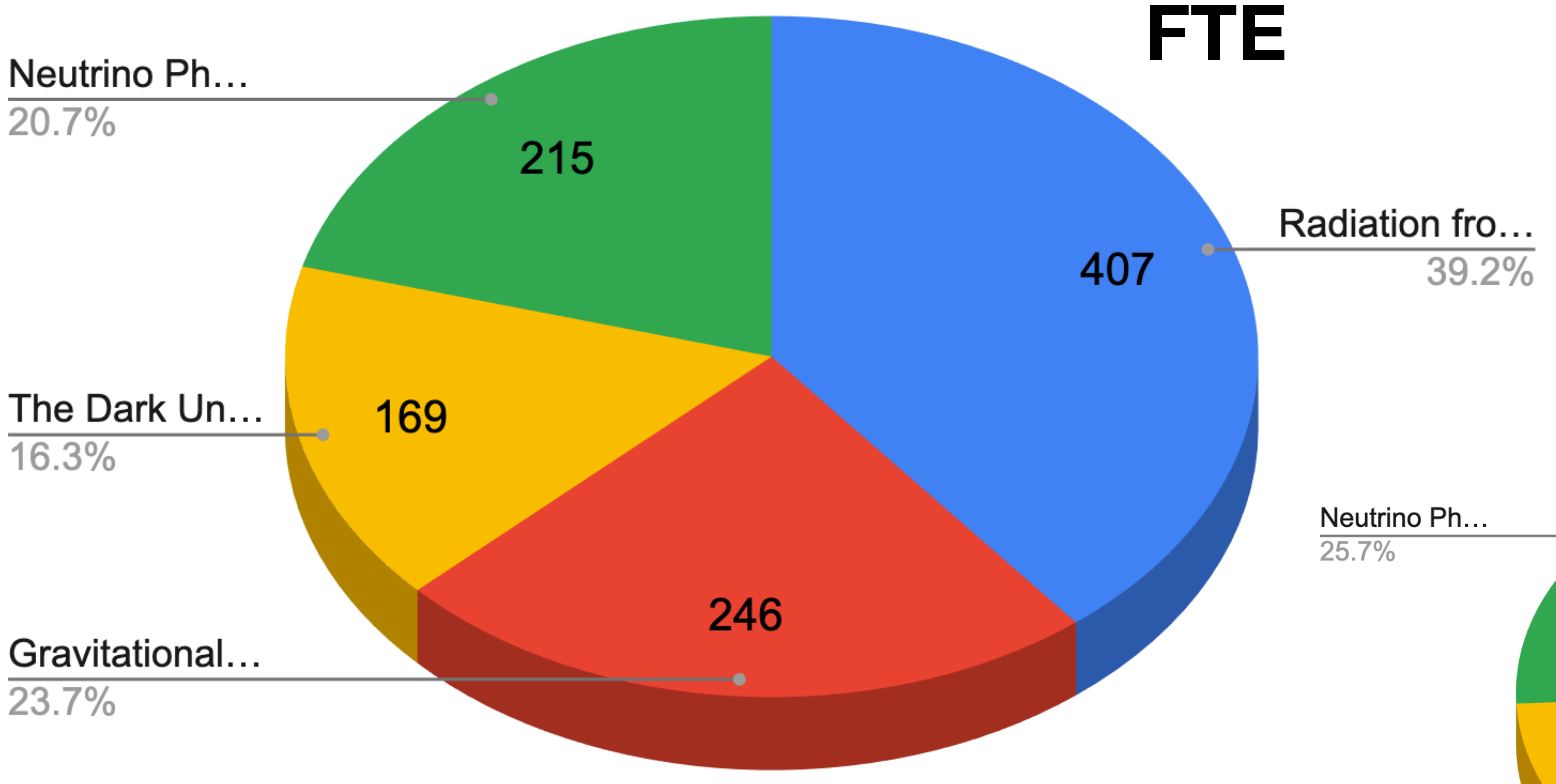
	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of INFN leadership roles.	51	71	88	160	163	215	248	147	200
INFN %		35	39	34	27	40	40	37	39
Female %	35	18	23	20	20	20	20	18	19

CSN2: astro particle

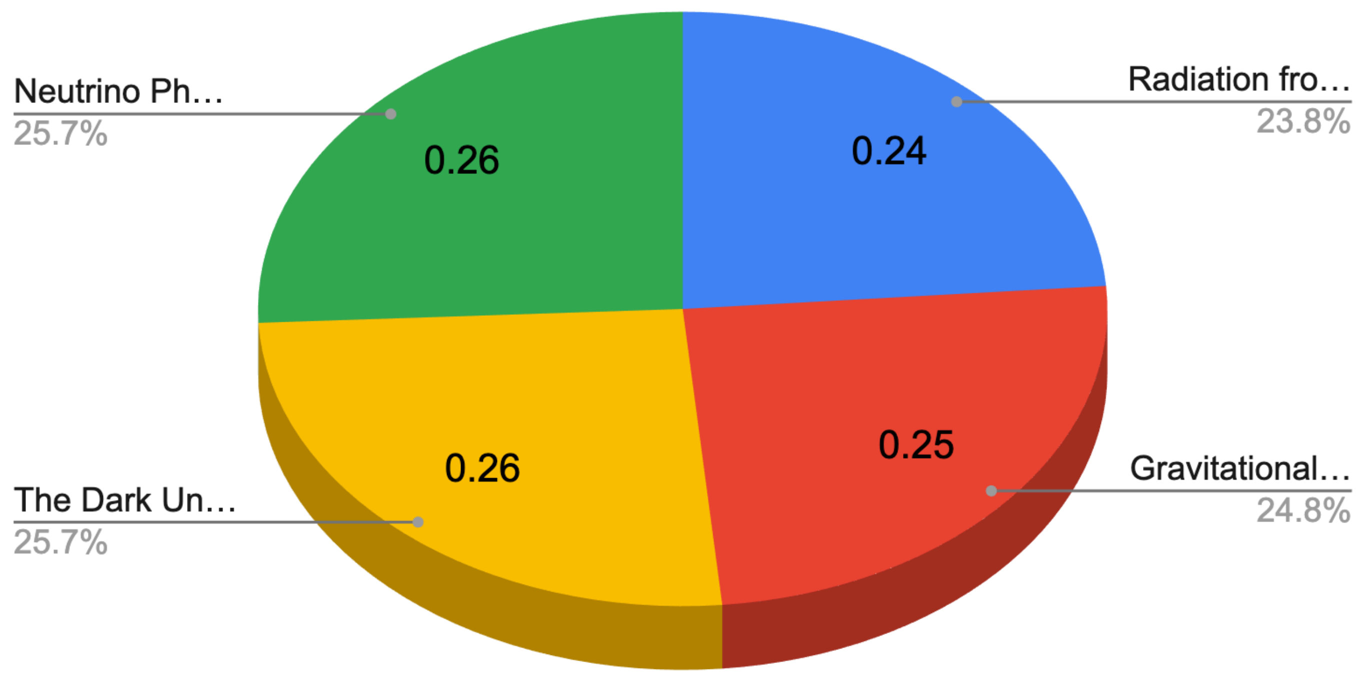
who 2023

label	Radiation from the Universe	Gravitational waves	The Dark Universe	Neutrino Physics
# of FTE	407	246	169	215
% of women	0.24	0.25	0.26	0.26
Budget/y (M€)	4.19	1.57	1.65	6.62
Number of projects	14	10	10	10
Milestones % achieved	69.4	74.2	90.7	65.6
# publications	260	69	79	79
# conference talks	310	47	101	109
# PhD thesis	11	15	6	9

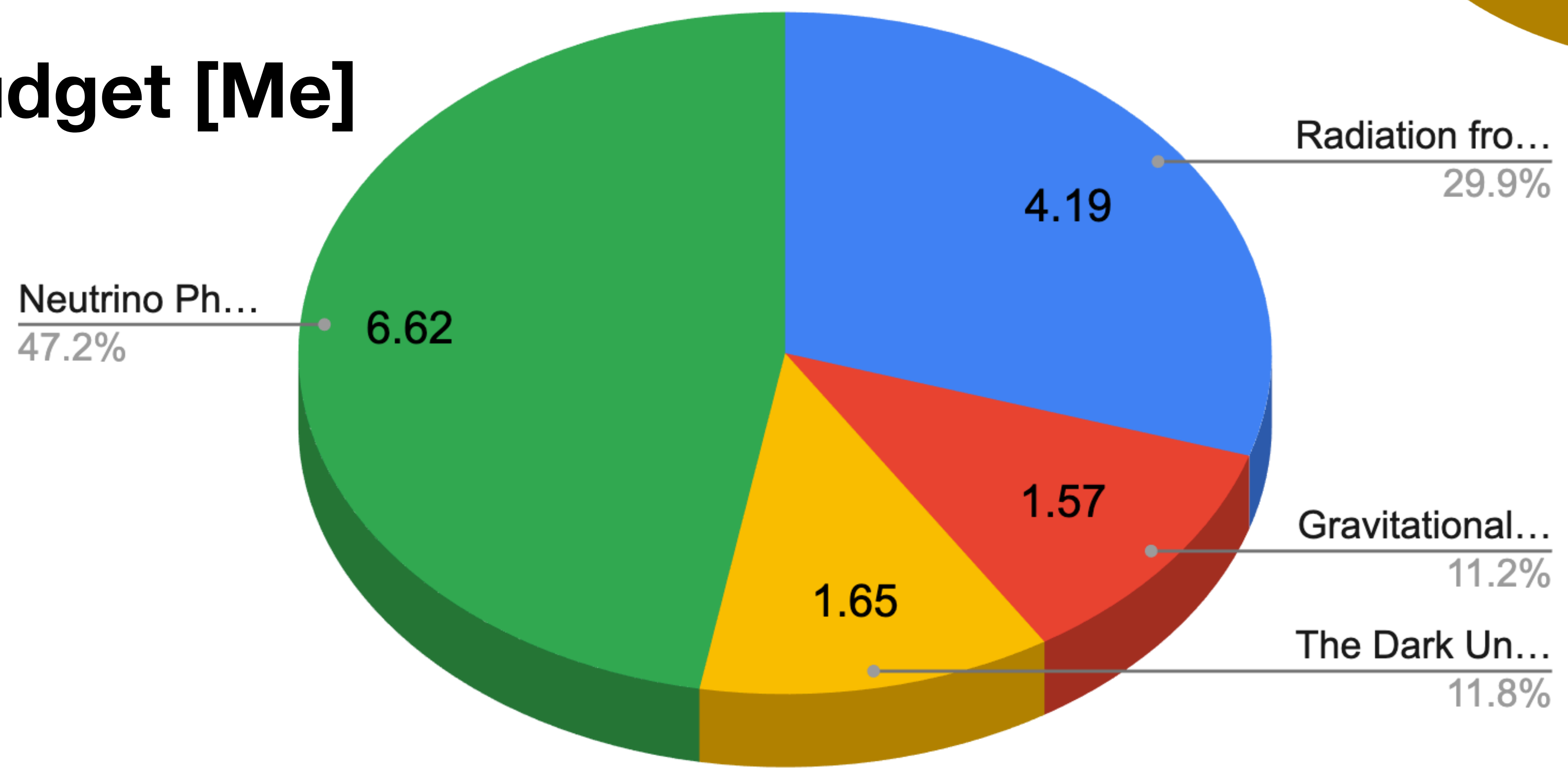
FTE



women



Budget [Me]

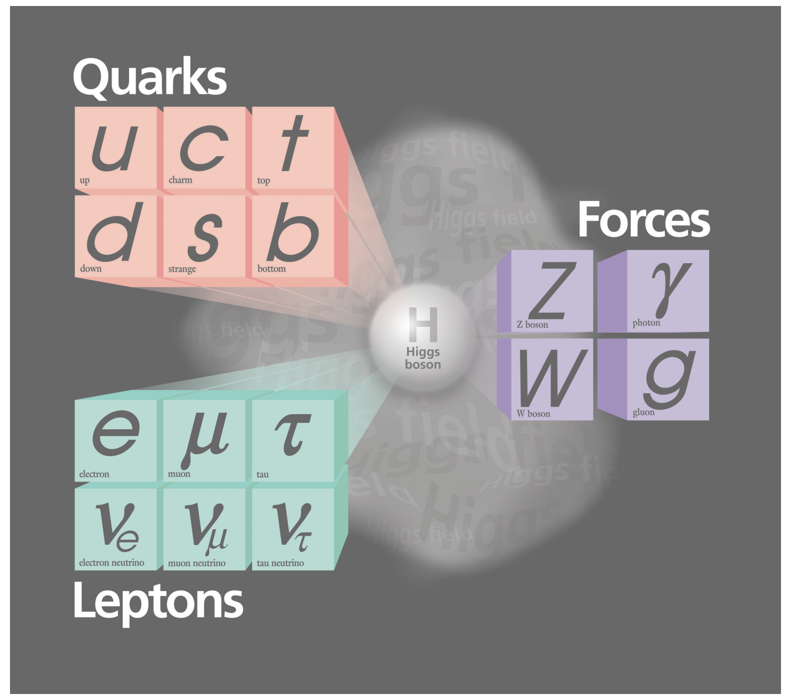


13.7 Me/year

Quarks
u c t
d s b
Forces
Z γ
W g
H
Higgs boson
e μ τ
ν_e ν_μ ν_τ
Leptons
SM
Λ-CDM
GR
$R_{\mu\nu} - \frac{1}{2} R \, g_{\mu\nu} + \Lambda \, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$

standard model (SM)/general relativity (GR)

- divergence - renormalization;
- gravity;
- dark matter;
- dark energy;
- neutrino masses;
- matter–antimatter asymmetry;
- the theory is composed of a mess of terms, stuck together.



$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- quantisation of the space-time;
- dark energy …;
- dark matter …;
- the black hole/singularity
- the theory is elegant and with profound meaning as never probably happened in physics

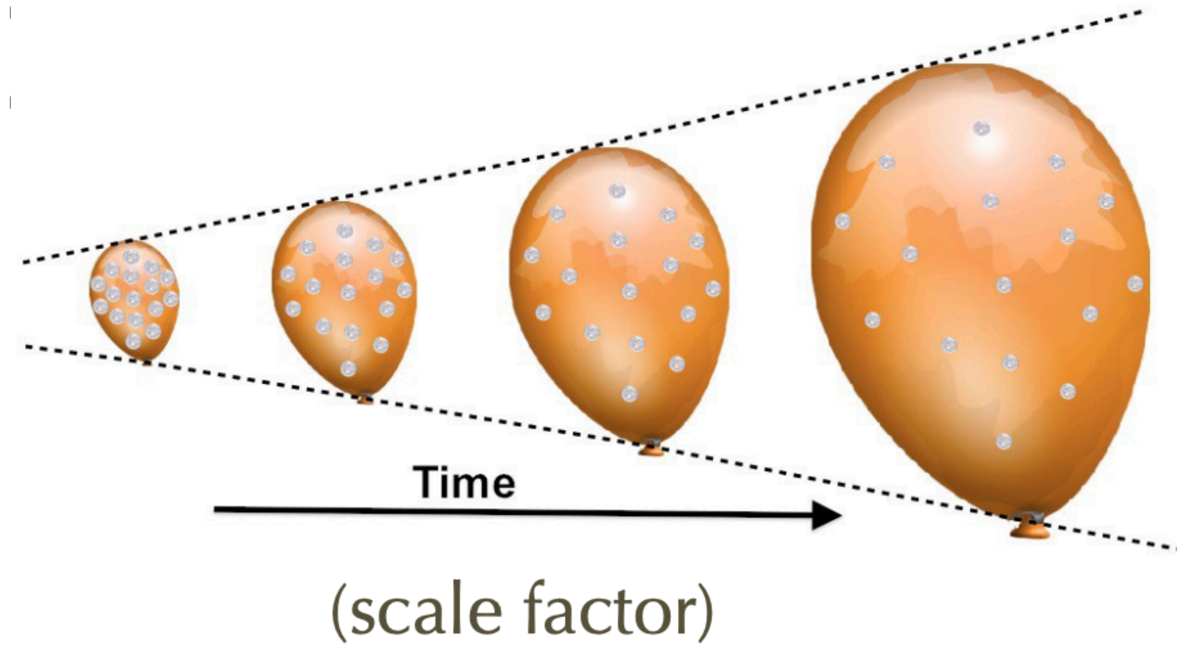
expansion vs gravitational collapse

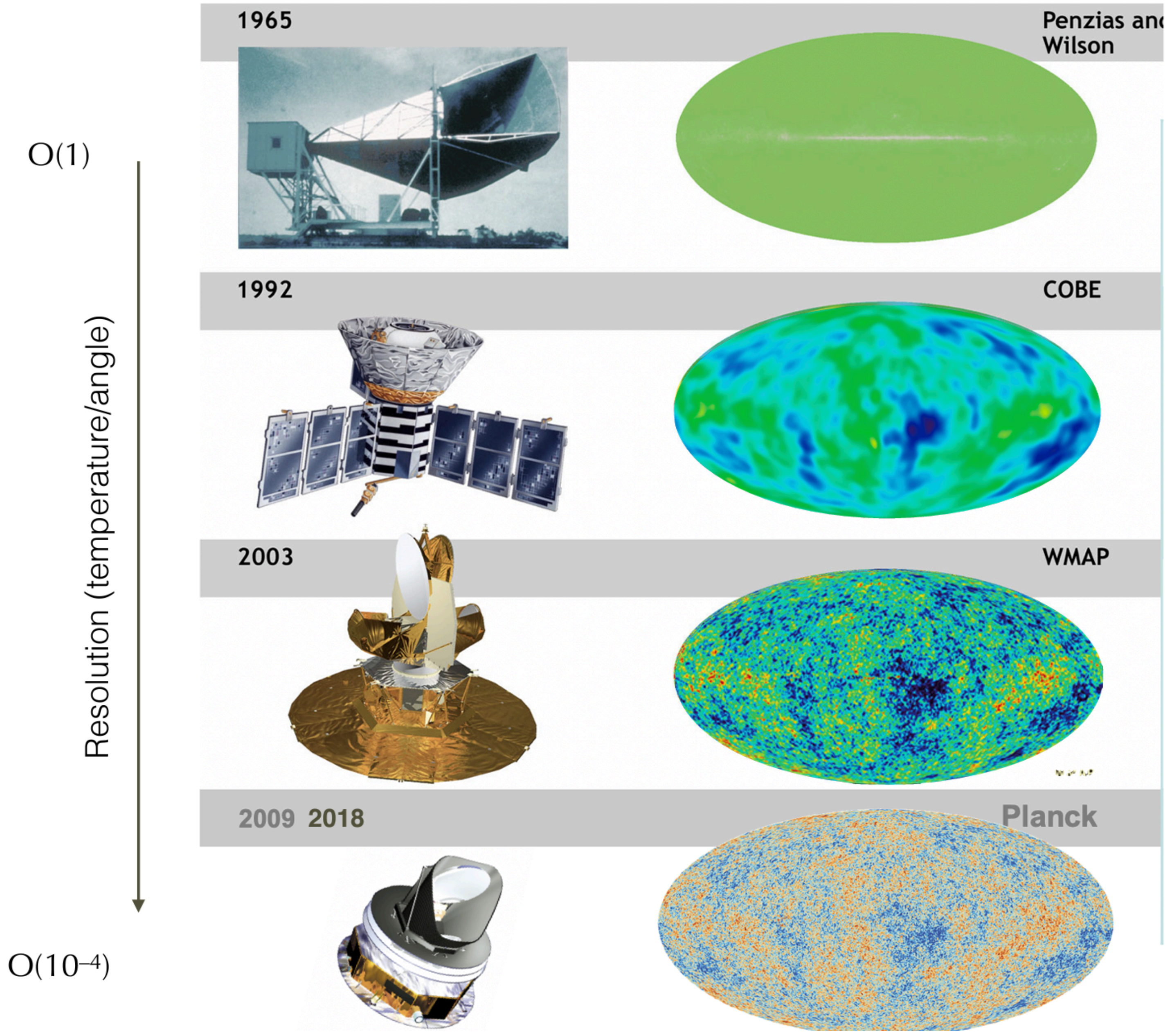
space-time

matter

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

space-time
in expiation





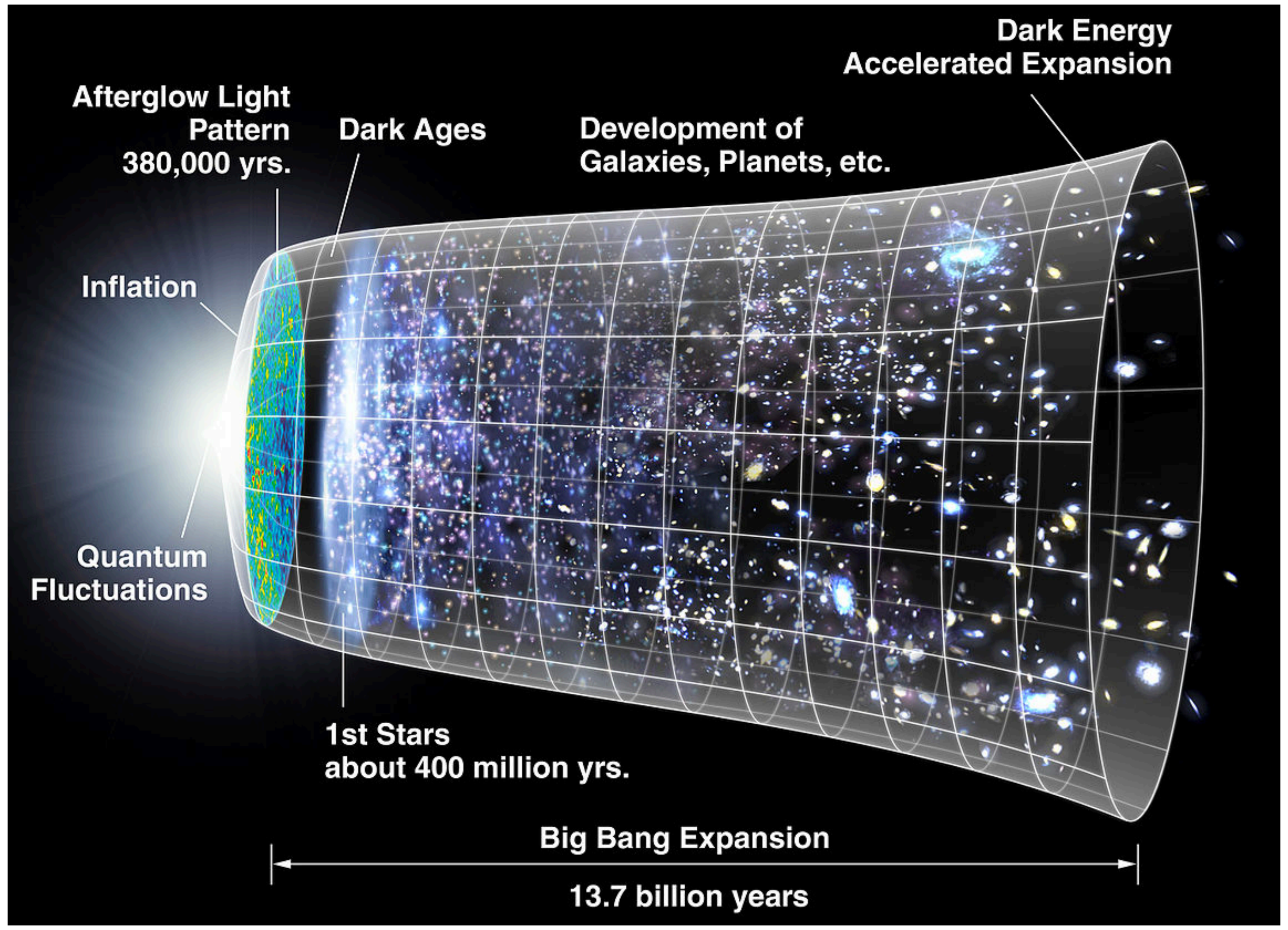
- **vacuum energy** coming from SM, E_{vacum} ~ 10^{120} times the needed one (Λ)
- **quintessence** just the fifth forces …
- **MOND** (Modified Newtonian dynamics), a modified theory of Gravity

cosmology (Λ-CDM)

origin and evolution of the universe, from the Big Bang to today and on into the future

time

- **The Planck epoch** - Time < 10^{-43} s - four fundamental forces were combined into a single, **unified force.**
- The universe **expands** - Time 10^{-43} - 10^{-36} s - **inflation** (exponential expiation) explaining why universe was so flat and uniform, **primordial black holes** could start to be formed
- The **elementary particles** are born - Time ~10^{-36} s - quarks were combined, forming **protons** and **neutrons**; **neutrinos** were able to escape this plasma of charged particles and began traveling freely through space, while photons continued to be trapped by the plasma. It could be that **dark matter** (WIMPs) was part of this plasma
- The first **nuclei** emerge - Time ~1 s to 3 min - **nucleosynthesis**: universe cooled enough for violent collisions to subside, **protons and neutrons clumped together into nuclei** of the light elements—hydrogen, helium and lithium
- The **cosmic microwave background** (CMB) becomes visible - Time 380,000 y - the particle soup had cooled enough for electrons to **bind to nuclei to form neutral atoms**; **photons** became free to traverse the universe
- The earliest **stars** - Time: ~100 million years
- Our **Sun** is born - Time: 9.2 billion years
- Today - Time: **13.8 billion years** - The universe is expanding at an increasing rate —> **dark energy**



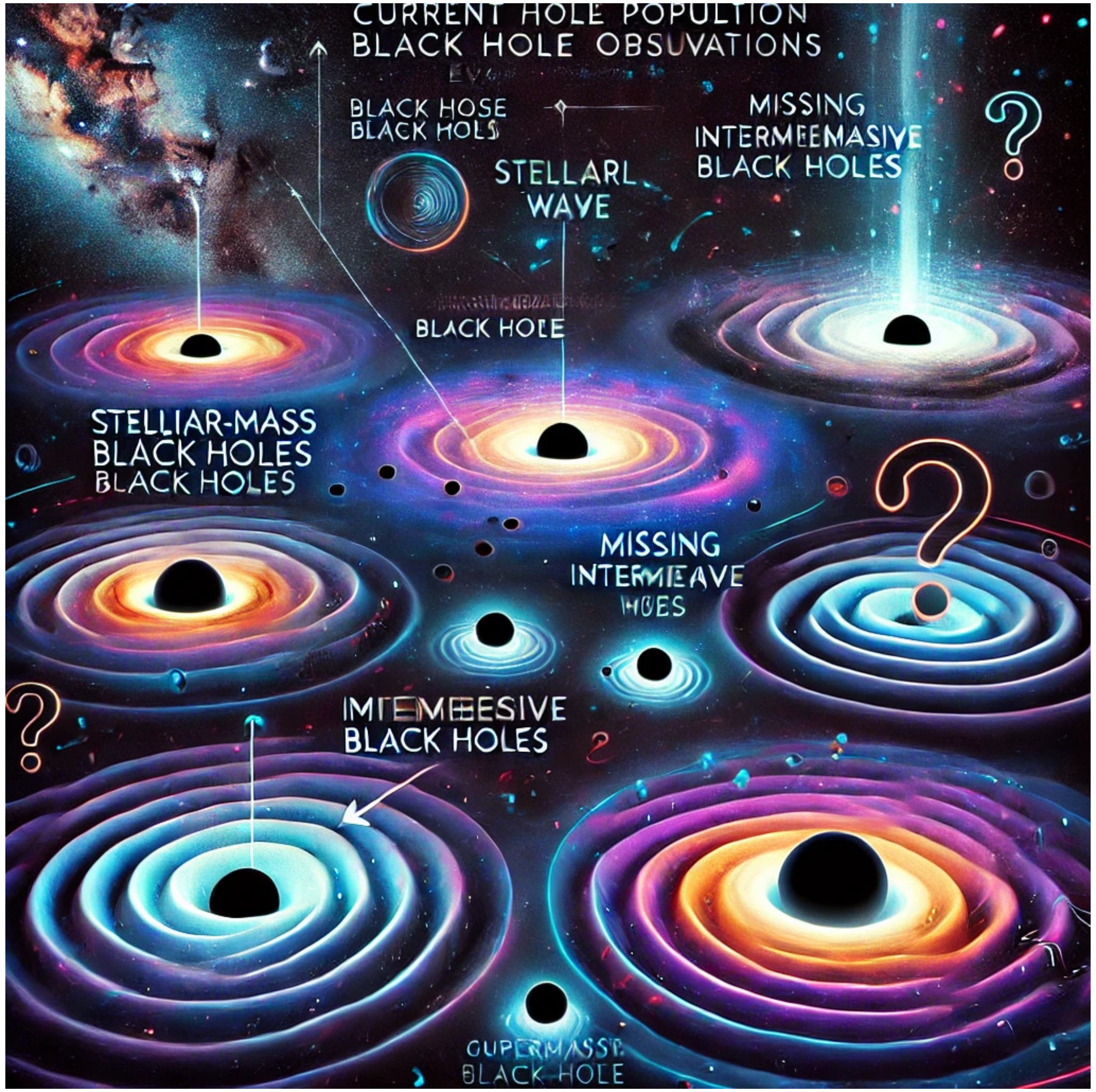
fixing the amount of "components" (eg. density/rates/distance) observable in the universe today

prediction vs observation

example of unexpected:

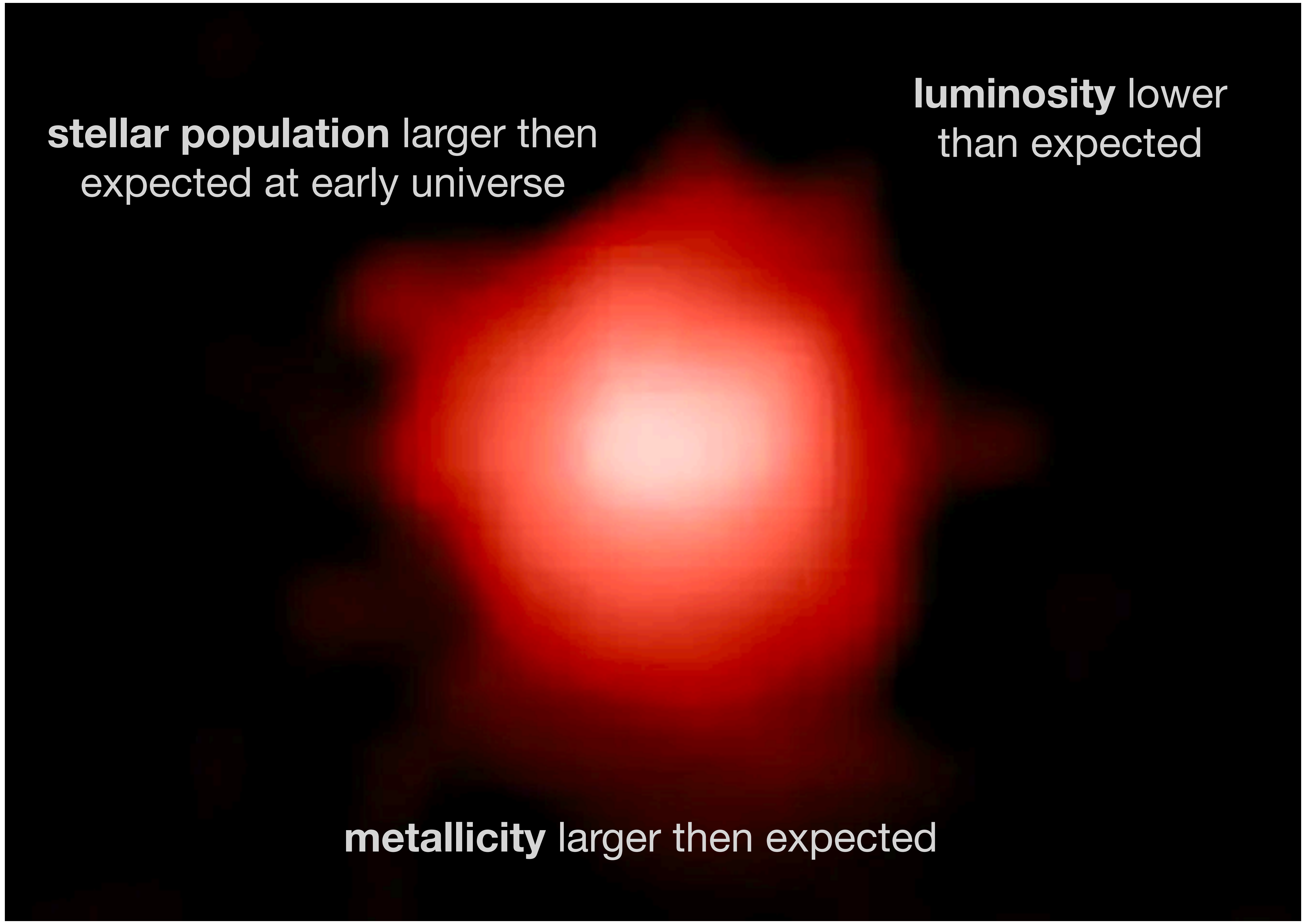
- the **distribution** of black hole **masses** in LIGO/ Virgo detected compared to that predicted by stellar evolution theories.
- the observed **rate of black hole mergers** compared to the expected rate.
- the **growth of supermassive black holes** versus time in the early universe.

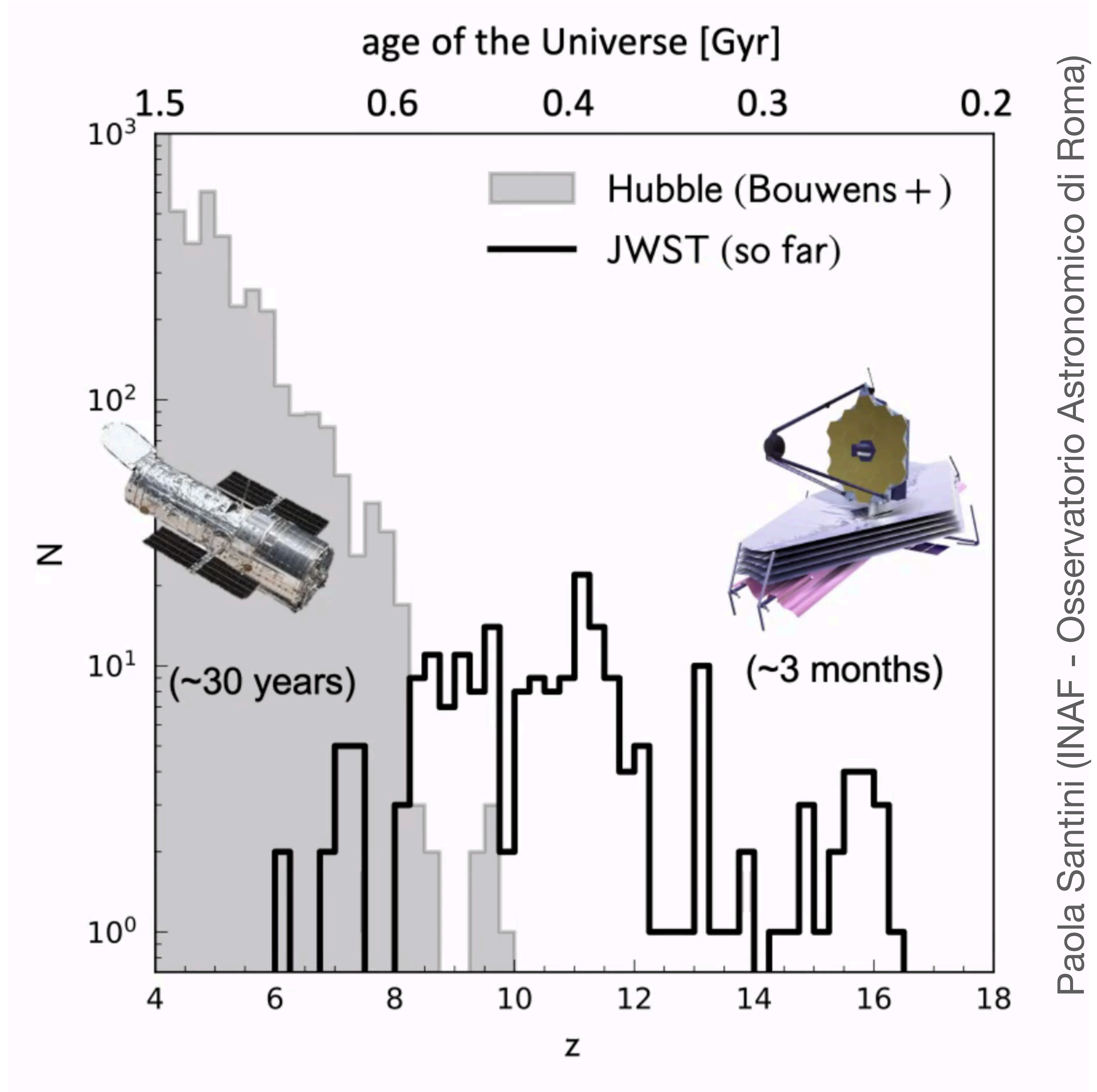
In general, the **higher the redshift, the greater the tension vs formation models**, especially in the case of **supermassive black holes that appear to grow too rapidly in the early universe.**



prediction vs observation

the JWST might have spotted a galaxy from 13.5 billion years ago, just 300 million years after the Big Bang





Paola Santini (INAF - Osservatorio Astronomico di Roma)
https://indico.gssi.it/event/529/

astro particle

the studies of elementary particles and their relation to astrophysics and cosmology

neutrino physics
BOREX
CUORE/CUPID
ENUBET
GERDA
HOLMES
ICARUS
JUNO
KATRIN_TRISTAN
NUCLEUS
DUNE
T2K (SK & HK)

radiation from universe
AMS
AUGER
CTA
FERMI
GAPS
HERD
KM3
LIMADOU
LITEBIRD
LSPE
QUBIC
SPB2
SWGO
XRO

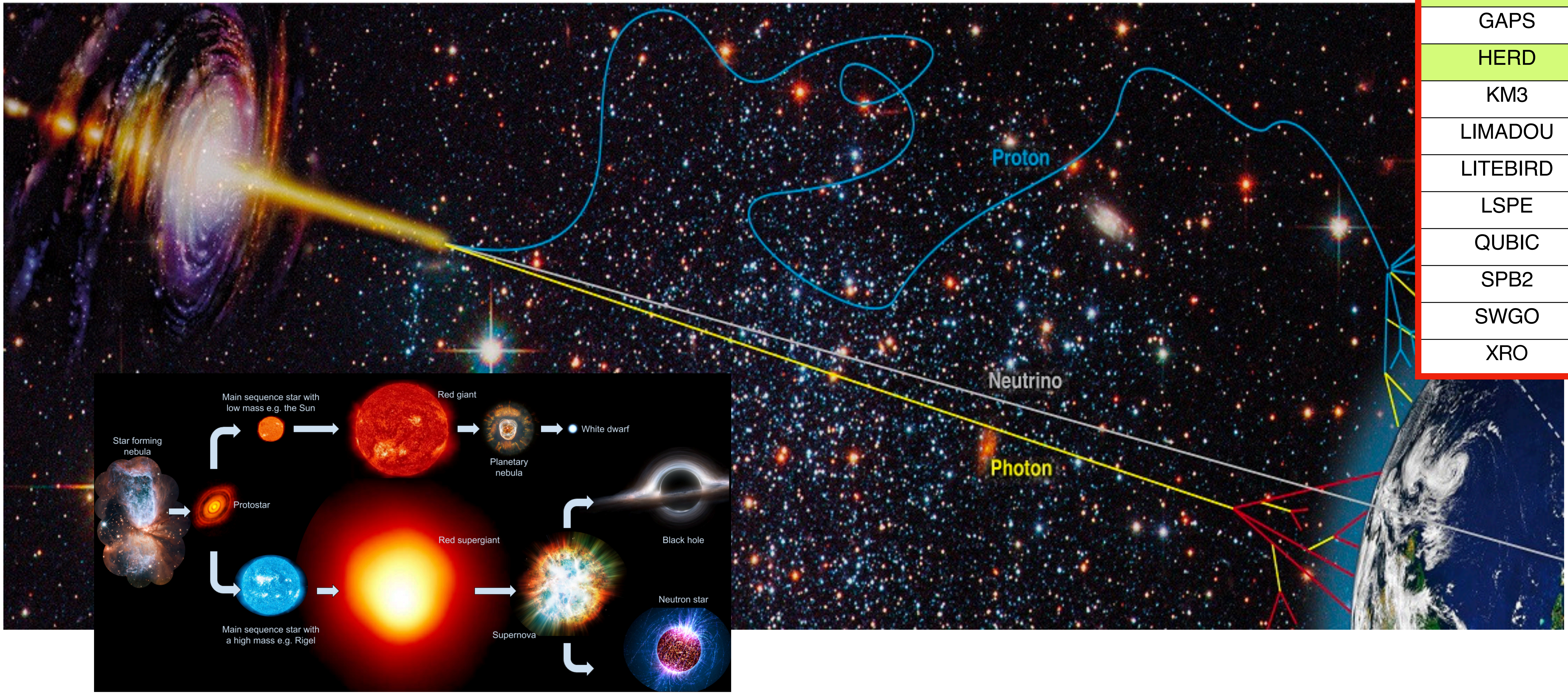
the dark universe
COSINUS
CRESST
CYGNO
DAMA
DARKSIDE
EUCLID
NEWS
QUAX
SABRE
XENON

Gravitational Wave, general and quantum physics
ARCHIMEDES
EINSTAN TELESCOPE
GINGER
GRAFIQO
LISA
MEGANTE
MOONLIGHT
SATOR_G
SUPREMO
VIRGO
VMBCERN

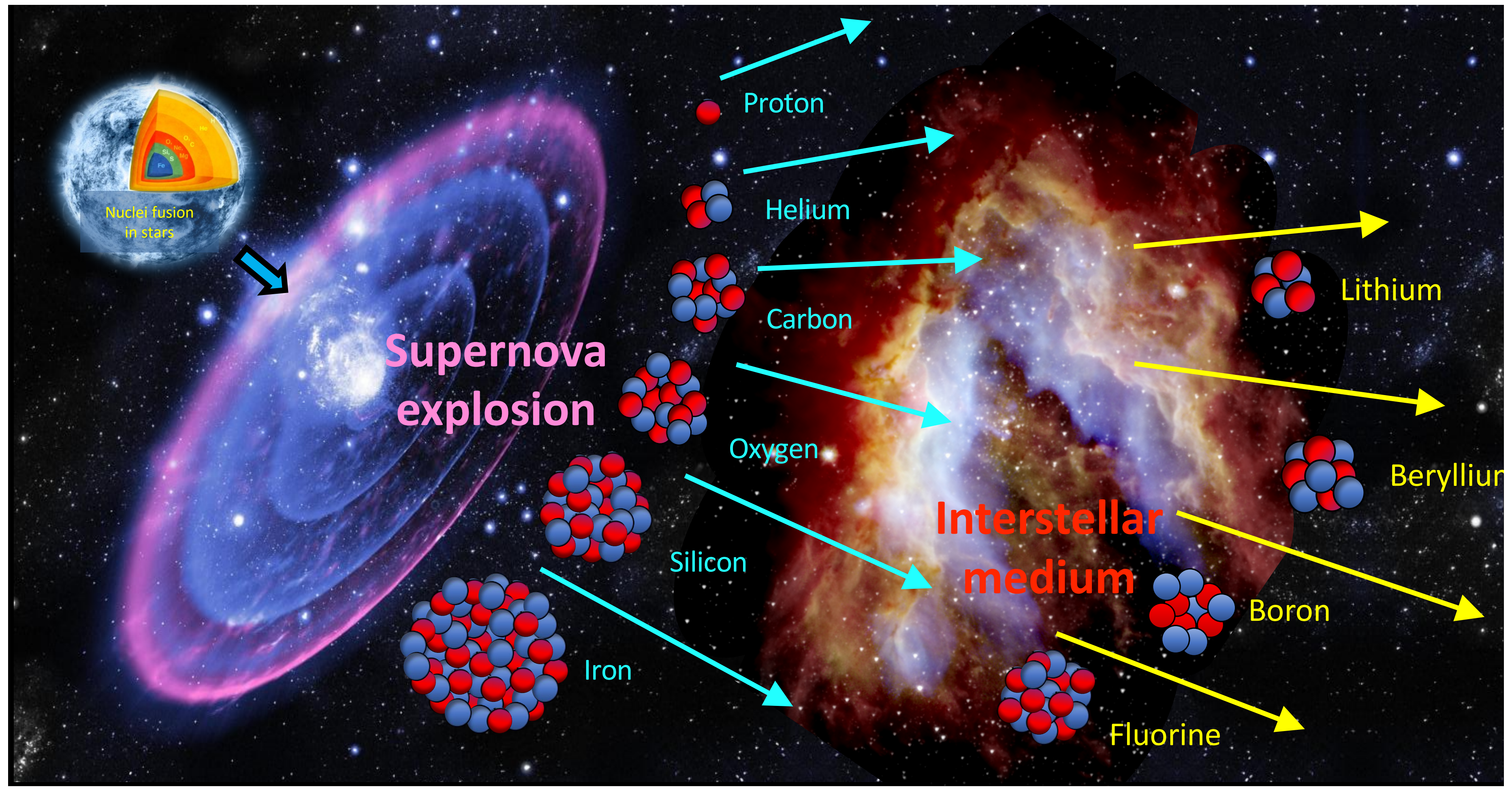
probing the universe

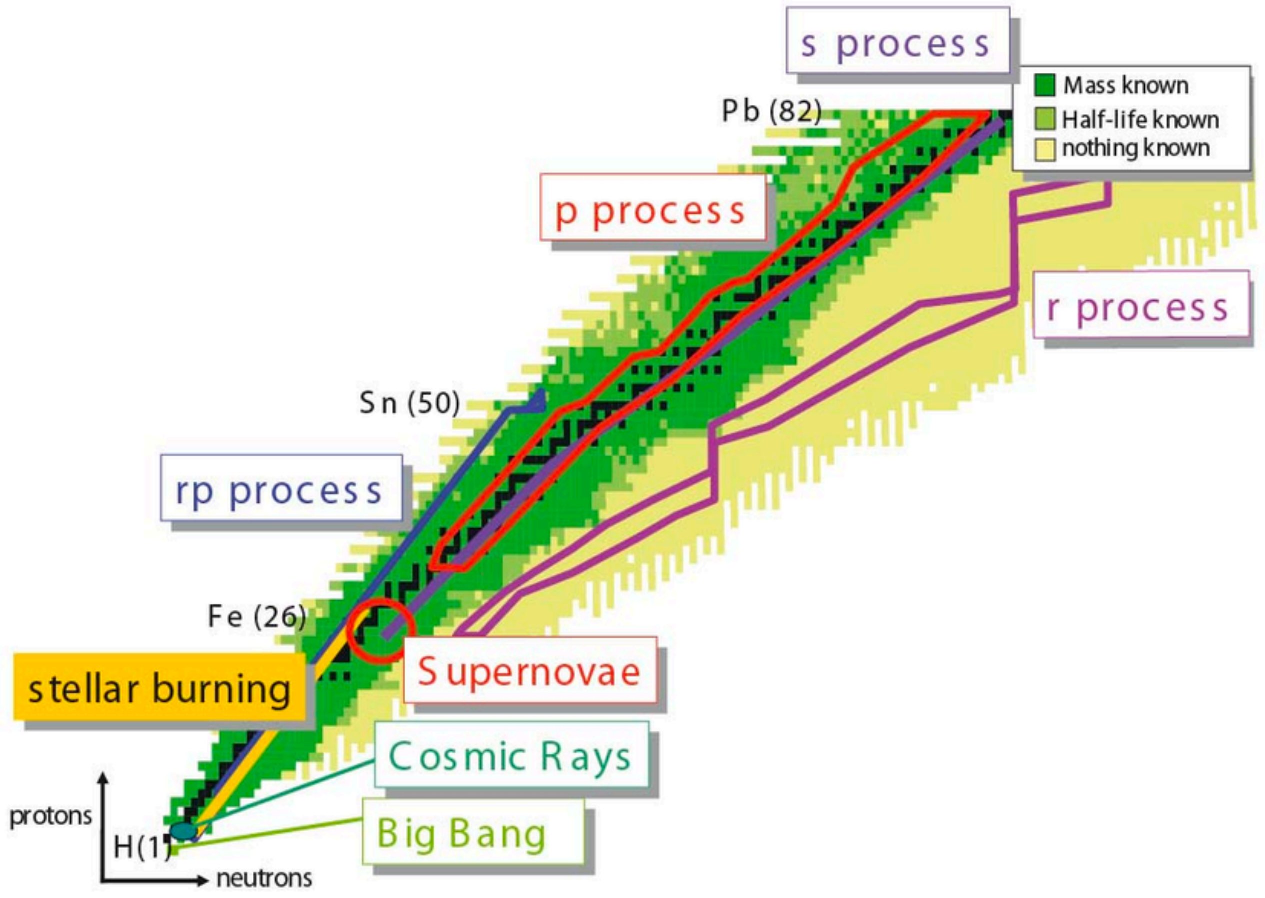
exploiting what we “see” from the cosmos

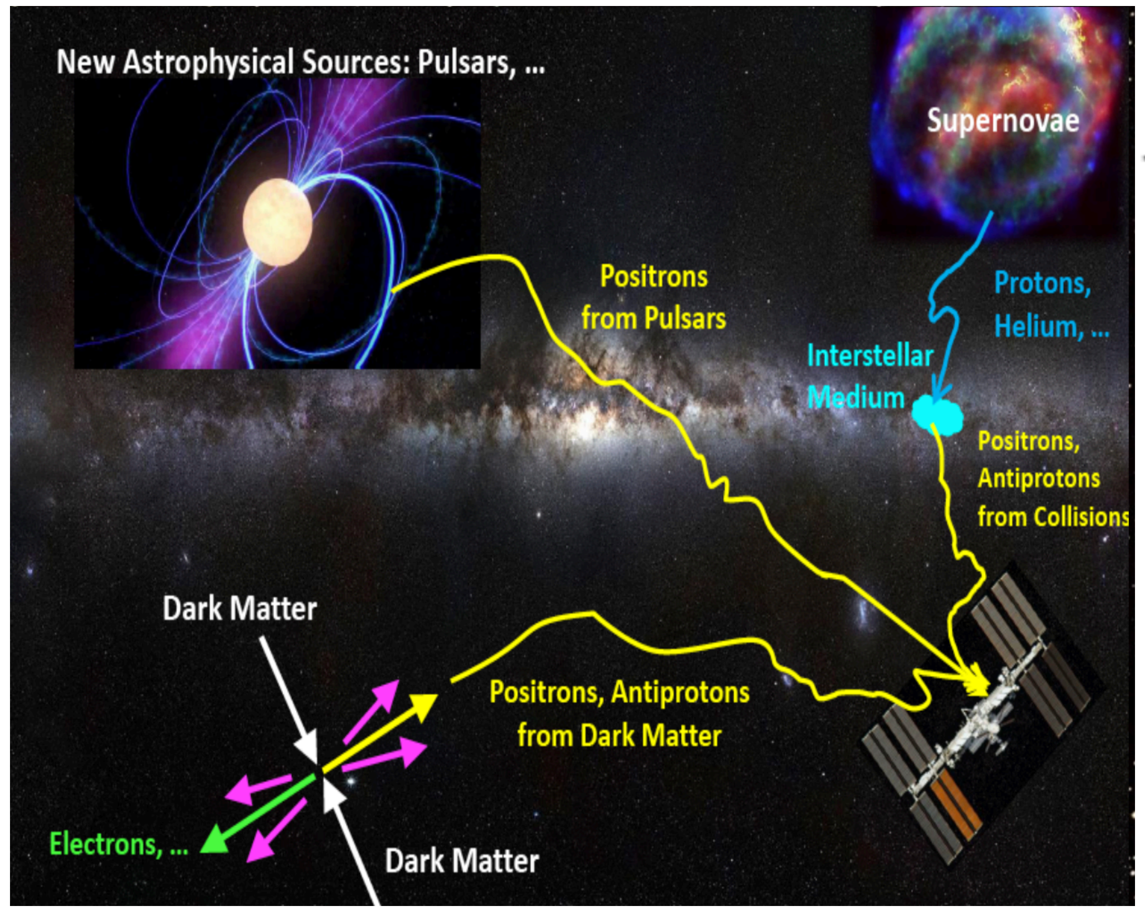
- AMS
- AUGER
- CTA
- FERMI
- GAPS
- HERD
- KM3
- LIMADOU
- LITEBIRD
- LSPE
- QUBIC
- SPB2
- SWGO
- XRO

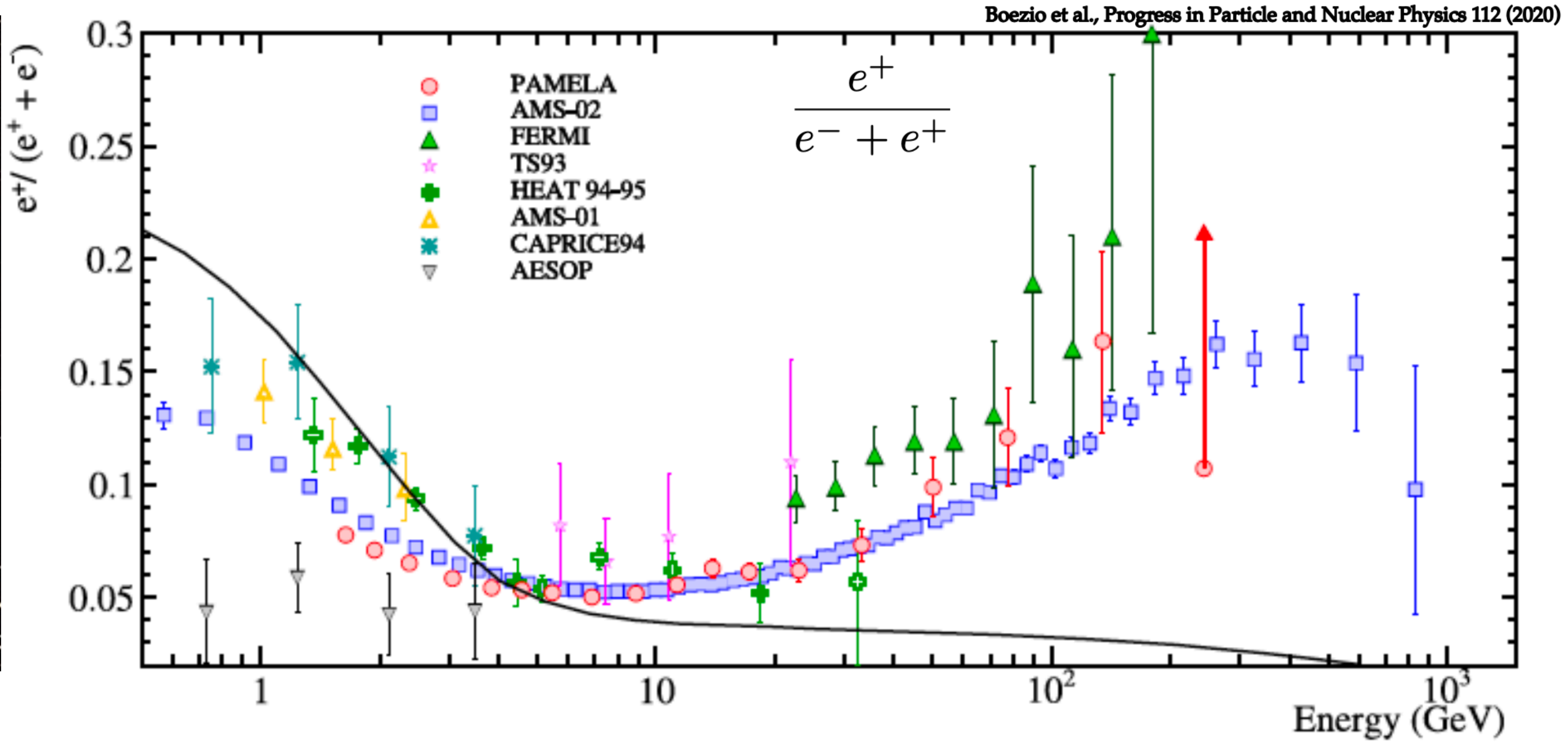


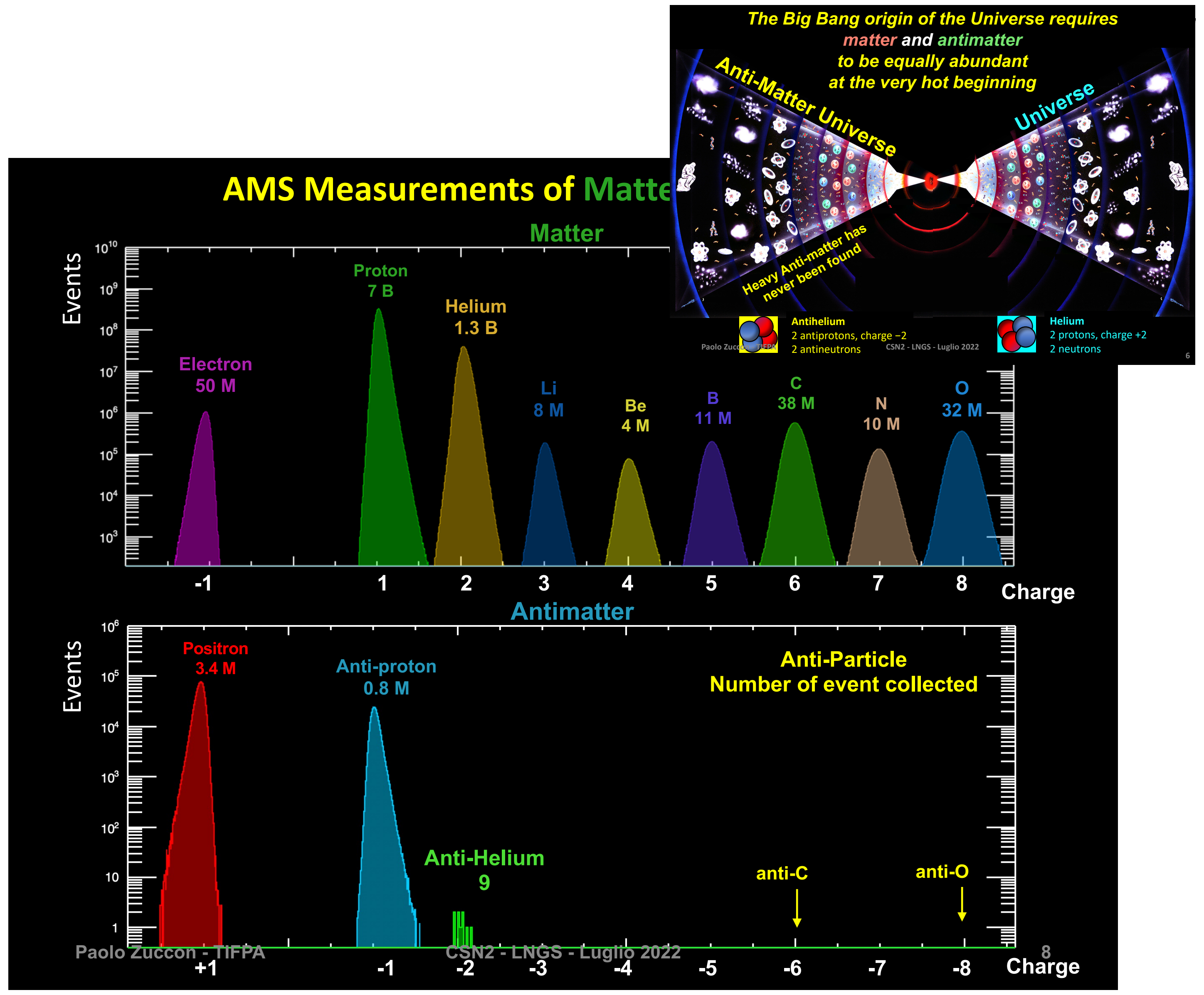
new physics/dark matter







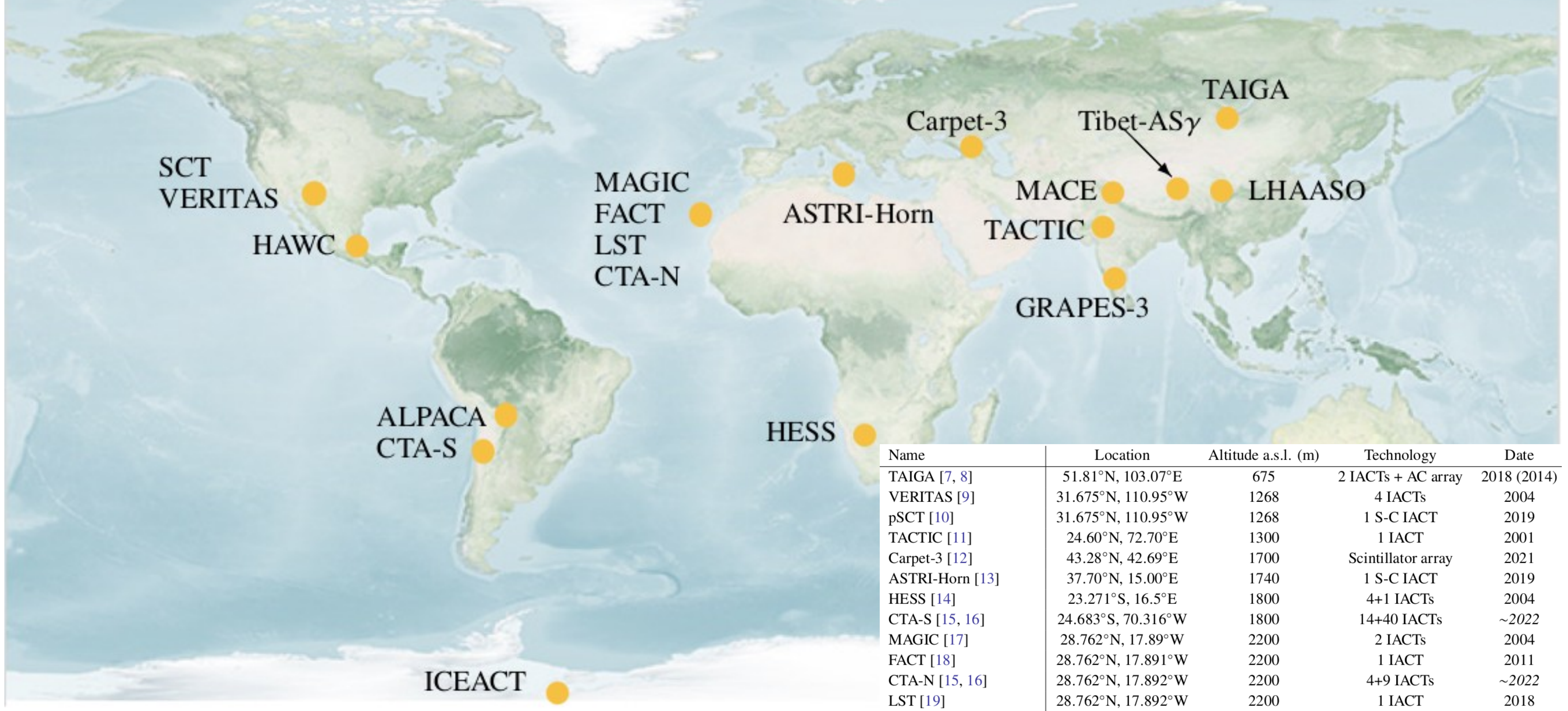




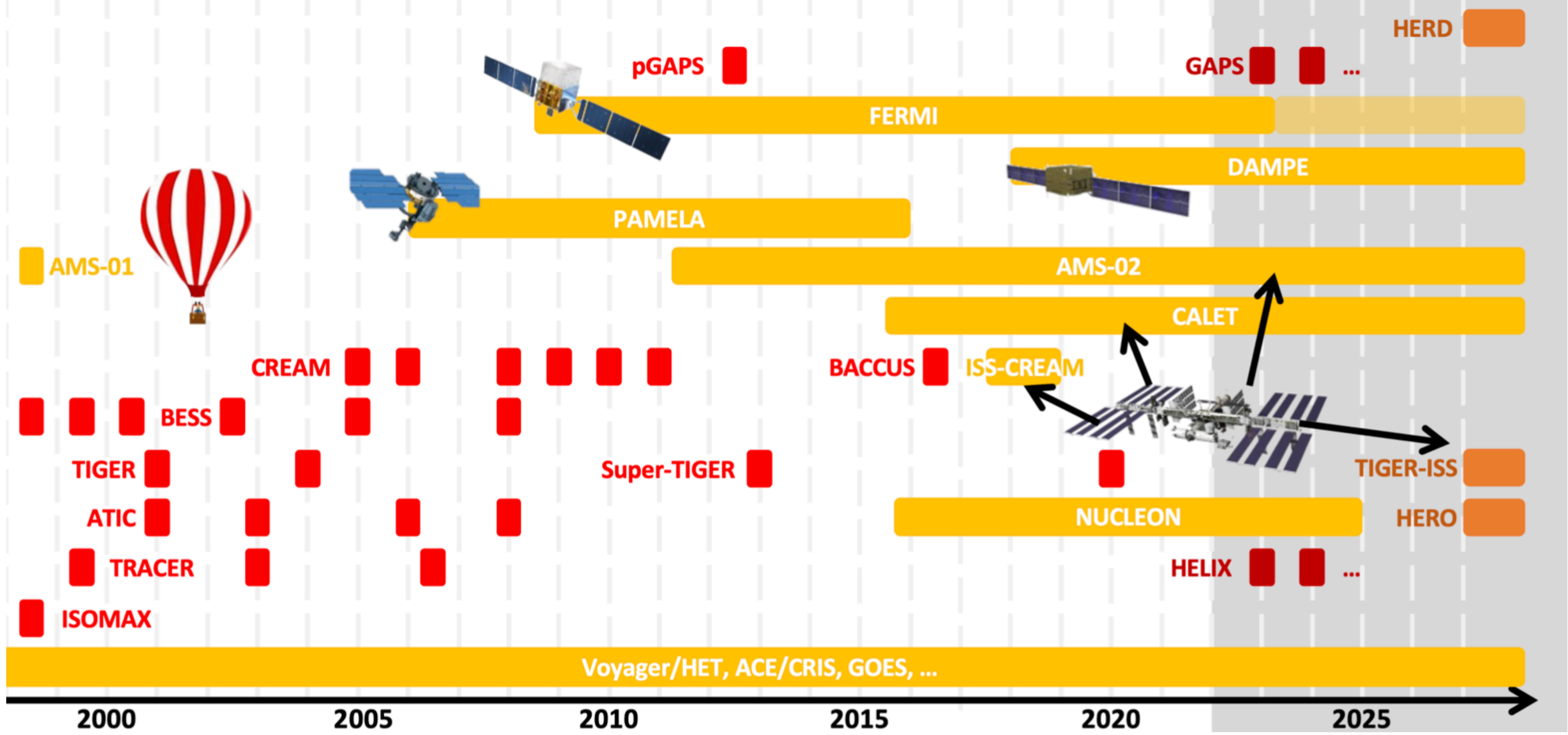
the cosmic rays

why and where…

- what is the origin of galactic cosmic ray?
- how do the cosmic ray acceleration work?
- cosmic ray propagation in the galaxy?
- are there any signature of new/dark matter physics?



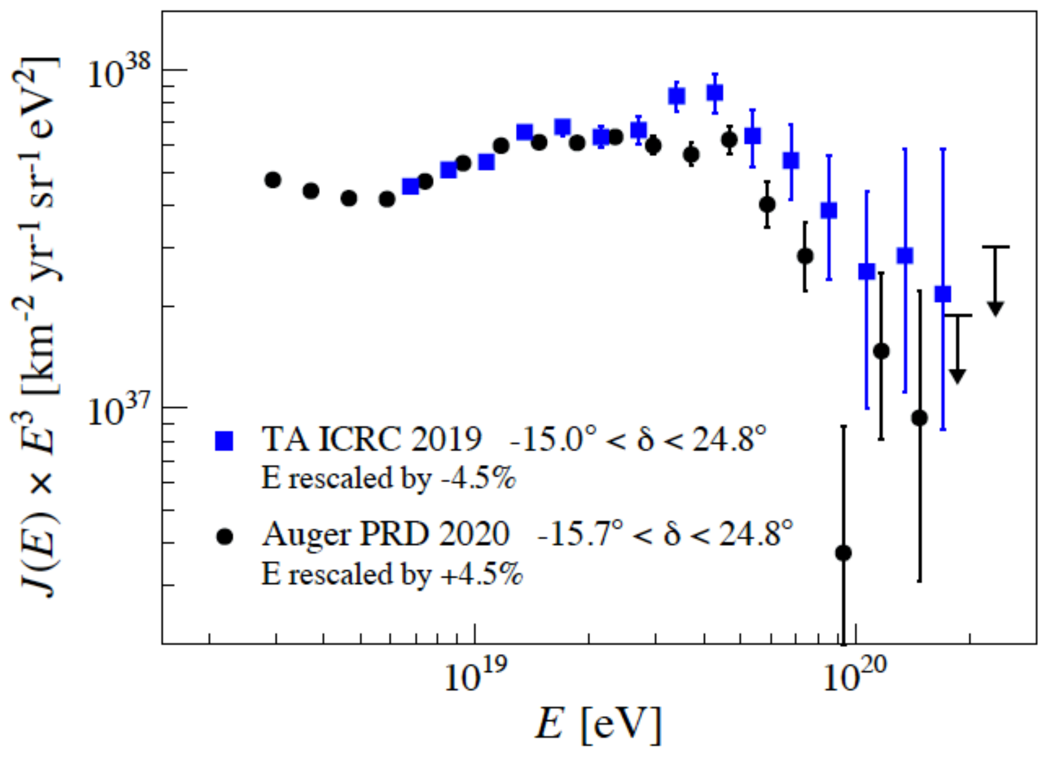
Name	Location	Altitude a.s.l. (m)	Technology	Date
TAIGA [7, 8]	51.81°N, 103.07°E	675	2 IACTs + AC array	2018 (2014)
VERITAS [9]	31.675°N, 110.95°W	1268	4 IACTs	2004
pSCT [10]	31.675°N, 110.95°W	1268	1 S-C IACT	2019
TACTIC [11]	24.60°N, 72.70°E	1300	1 IACT	2001
Carpet-3 [12]	43.28°N, 42.69°E	1700	Scintillator array	2021
ASTRI-Horn [13]	37.70°N, 15.00°E	1740	1 S-C IACT	2019
HESS [14]	23.271°S, 16.5°E	1800	4+1 IACTs	2004
CTA-S [15, 16]	24.683°S, 70.316°W	1800	14+40 IACTs	*~2022*
MAGIC [17]	28.762°N, 17.89°W	2200	2 IACTs	2004
FACT [18]	28.762°N, 17.891°W	2200	1 IACT	2011
CTA-N [15, 16]	28.762°N, 17.892°W	2200	4+9 IACTs	*~2022*
LST [19]	28.762°N, 17.892°W	2200	1 IACT	2018
GRAPES-3 [20]	11.39°N, 76.66°E	2200	Scintillator array	2000
IceACT [21]	89.99°S, 63.453°W	2840	2 ACT	2019
HAWC [22]	18.995°N, 97.309°W	4100	300+345 WCDs	2013
MACE [23]	32.78°N, 78.96°E	4270	1 IACT	2020
Tibet-ASγ [24]	30.11°N, 90.53°E	4300	Scintillators+WCDs	2014†
LHAASO [25]	29.359°N, 100.138°E	4410	Scintillators+WCDs	2018
ALPACA [26]	16.383°S, 68.133°W	4740	Scintillator array	2017*
ASTRI [27]	28.30°N, 16.51°W	2390	9 S-C IACTs	*~2022*
SWGO [28]	TBD	> 4500	WCDs	
ALTO/CoMET [29, 30]	TBD	> 5000	Scintillators+CLiC	
STACEX [31]	TBD	TBD	RPC	

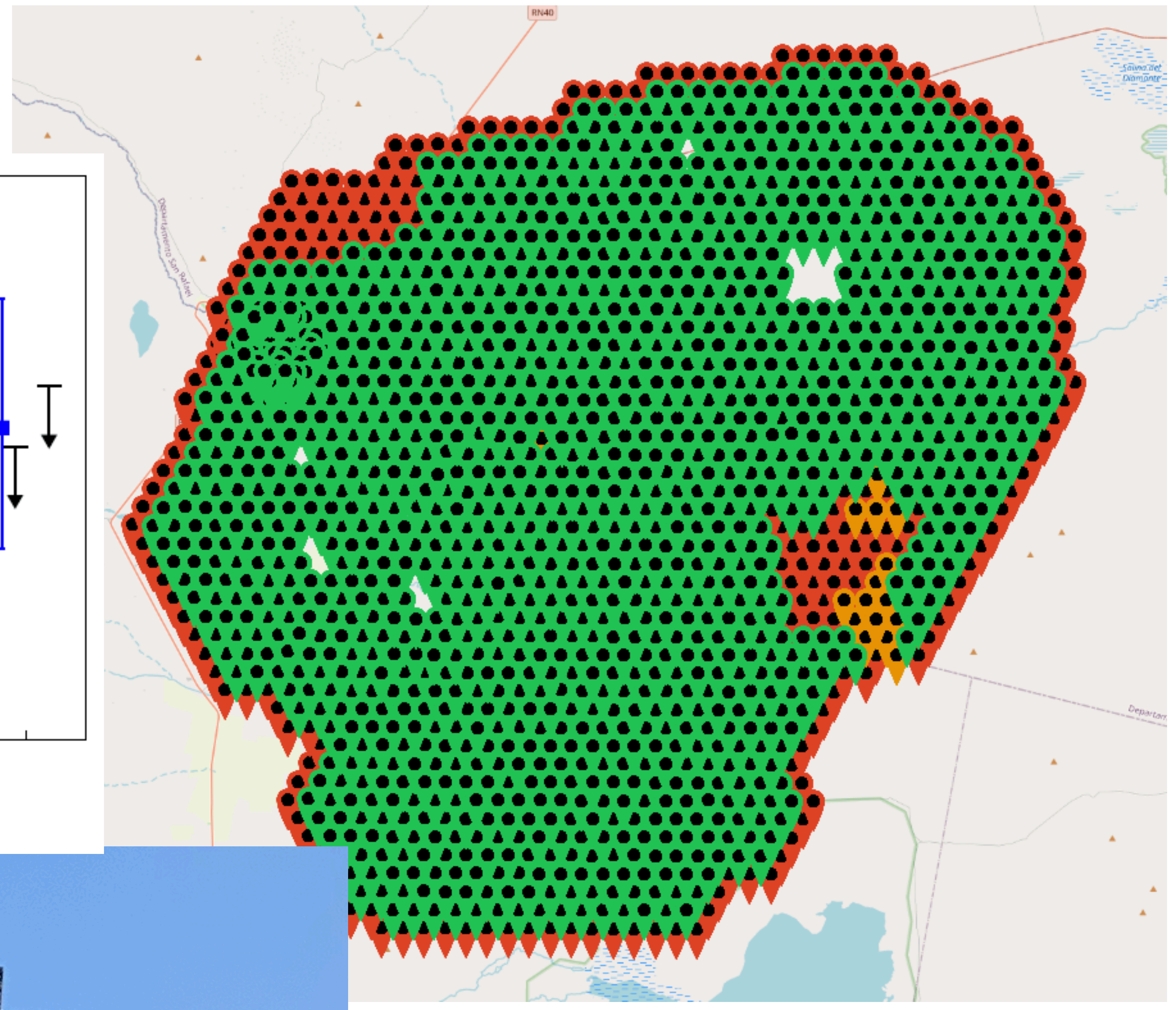


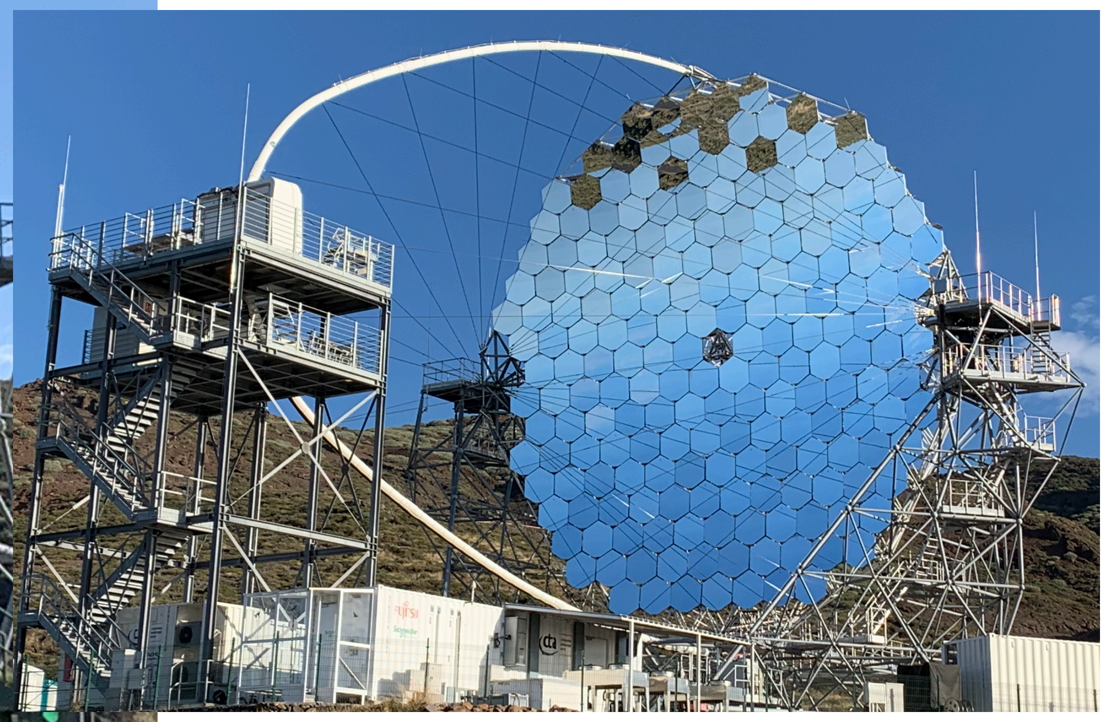
observation from the ground

- **AUGER** (taking data since many years, excellent production on HECR and GZK region, good visibility of italian groups); **AugerPrime**: UPGRADE for flux composition

- **CTA** (contribution to LST's ropes and caliboxes and pSCT); **MAGIC** (taking data since many years, rich scientific production and invaluable experience, presently operating jointly to LST1)

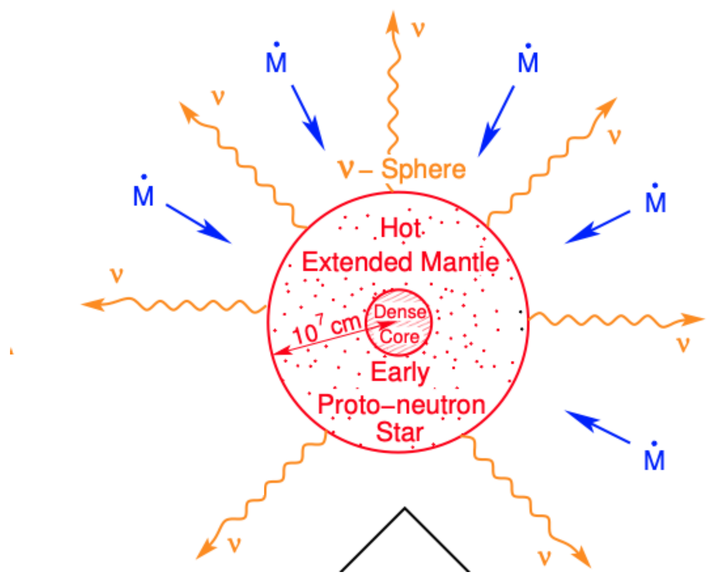


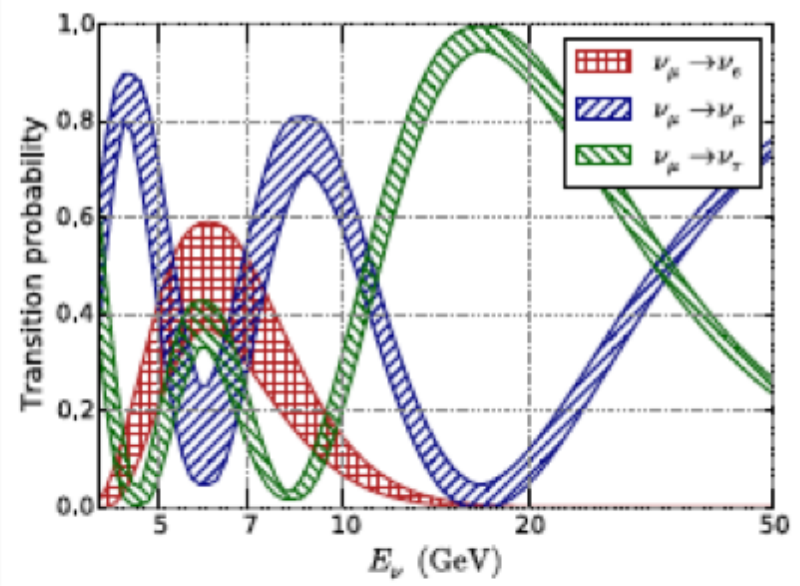


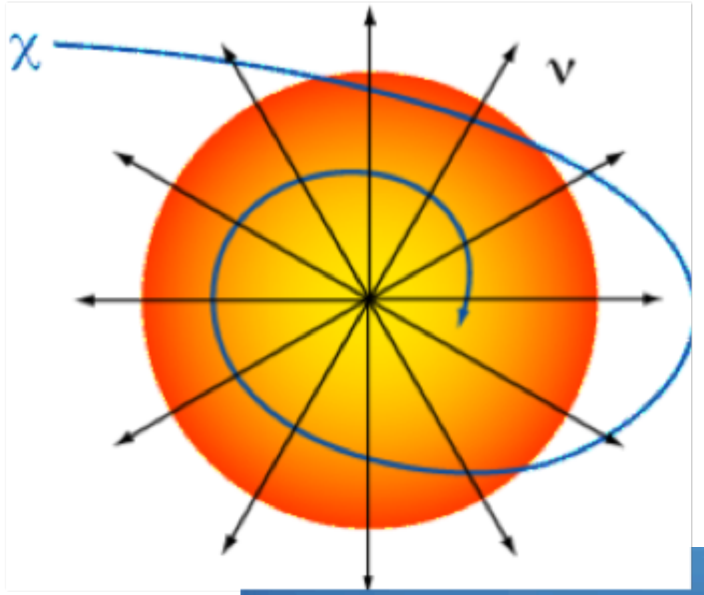


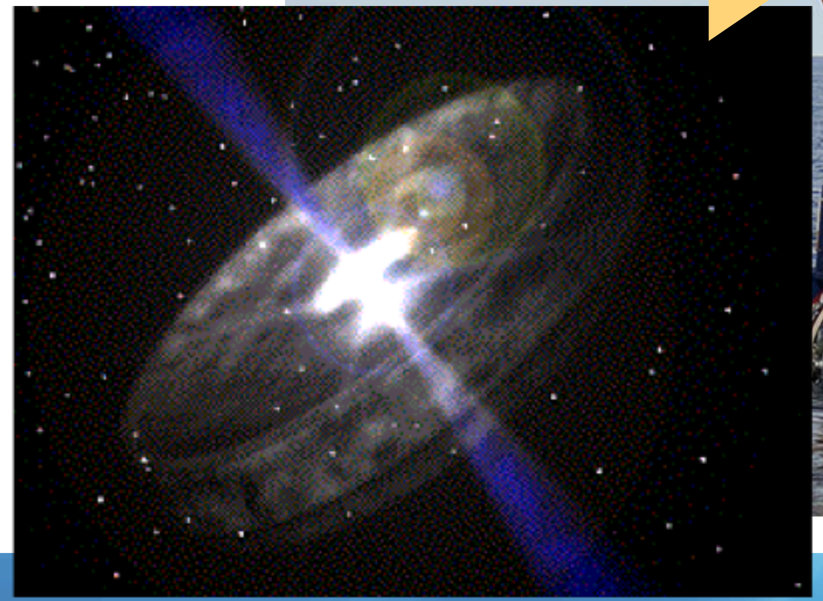
KM3 NeT

Neutrino Energy from MeV to PeV







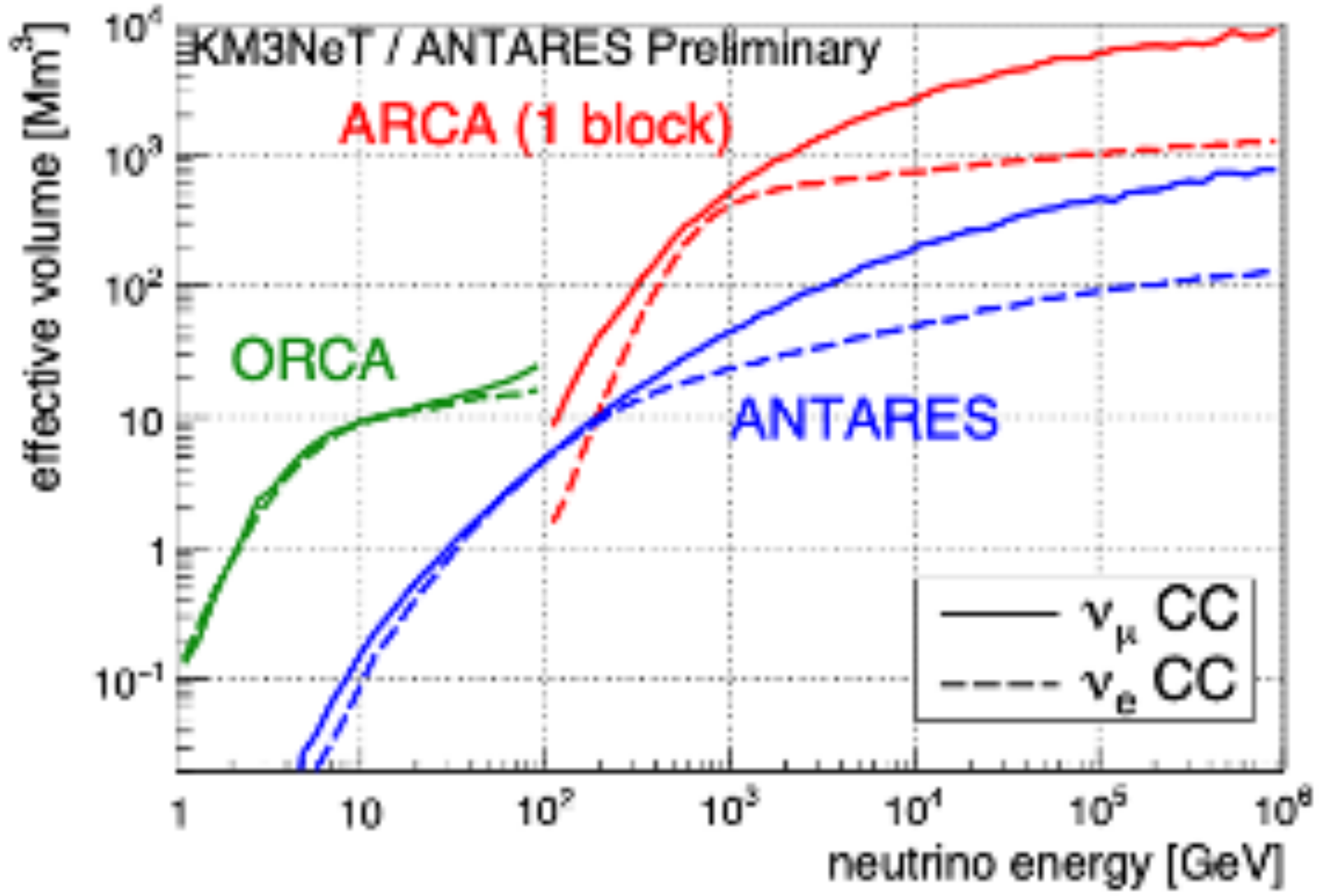


Super Novae explosion MeV	Neutrino oscillation GeV	Dark Matter TeV	HE neutrinos Multi-messenger program PeV

ARCA + ORCA

ORCA

ARCA



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NEWS | 21 June 2024

‘Fantastic’ particle could be most energetic neutrino ever detected

The ultra-high-energy neutrino was spotted by deep-sea detectors and could point to a massive cosmic event.

By Davide Castelvecchi

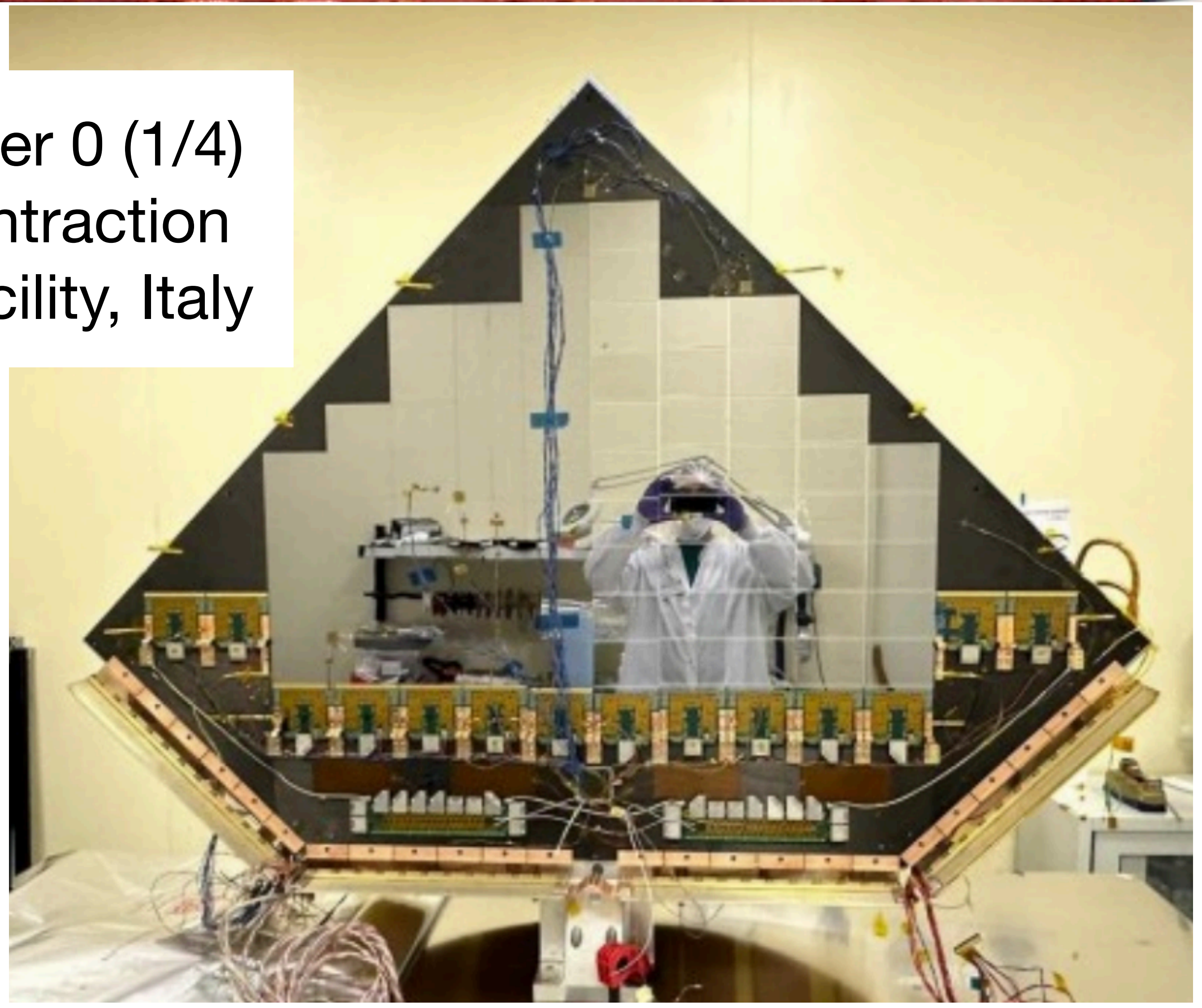
An observatory still under construction at the bottom of the Mediterranean Sea has spotted what could be the most energetic neutrino ever detected. Such ultra-high-energy neutrinos – tiny subatomic particles that travel at nearly the speed of light – have been known to exist for only a decade or so, and are thought to be messengers from some of the Universe's most cataclysmic events, such as growth spurts of supermassive black holes in distant galaxies.

observation from the space

international missions in orbit since many years:

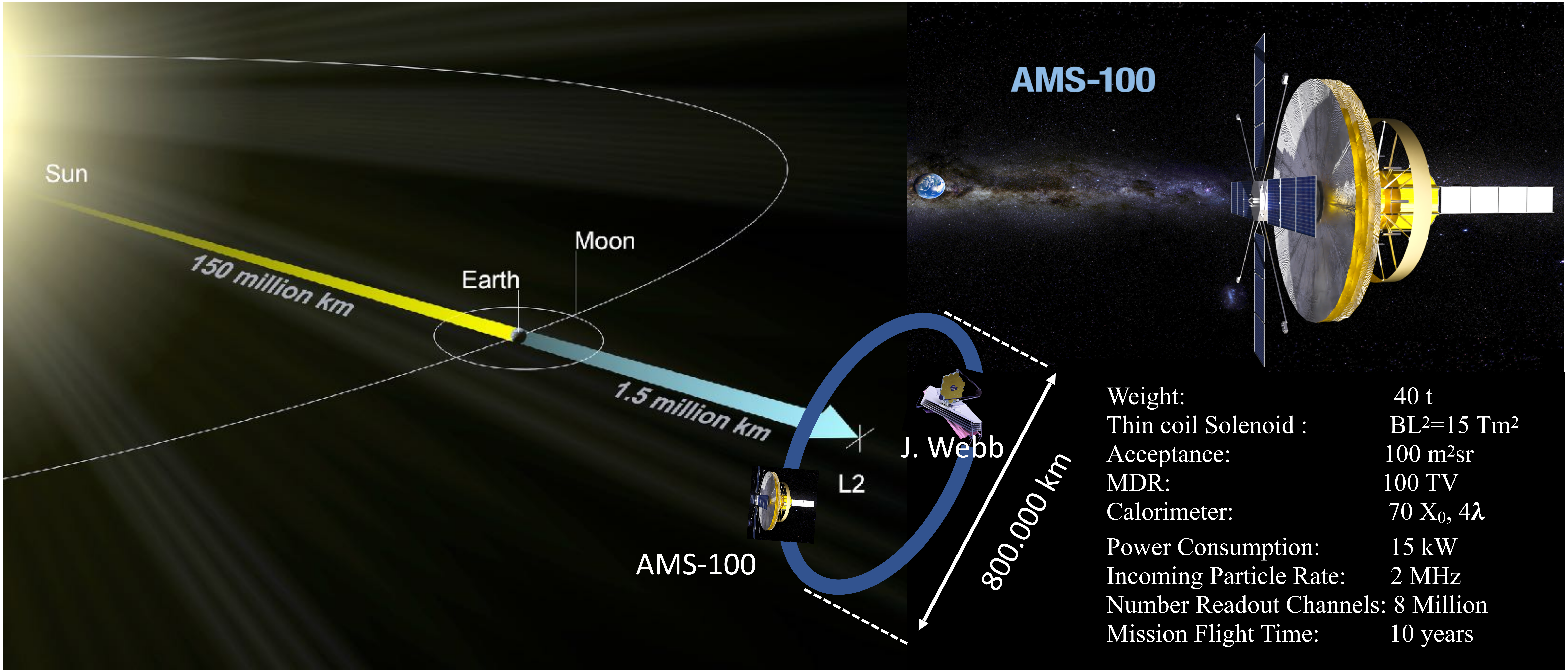
- **FERMI** (NASA 2008), **AMS** (NASA 2011), **DAMPE** (CAS 2015), **LIMADOU** (CNSA 2018), **IXPE** (ESA Dec. 2021) —> high scientific production, reliable, big community
- **EUCLID** (ESA) - commissioning completed, fits data are camping (INFN responsible for Near Infrared Spectrometer and Photometer instruments)
- **AMS UPGRADE** (LAYER0) ongoing, installation foreseen in 2026
- **GAPS** (NASA balloon) - launch expected Dec 24.

AMS Layer 0 (1/4)
under contraction
@ Terni facility, Italy



AMS 100 et all.

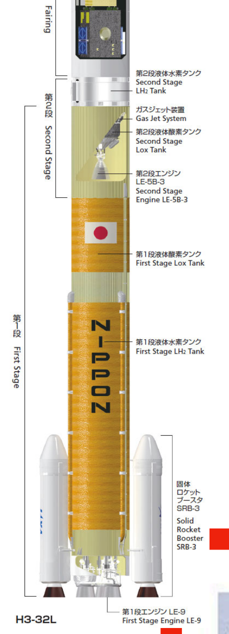
astroparticle 2035-2040…

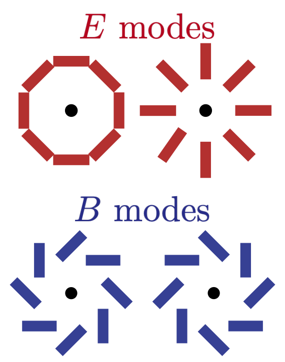


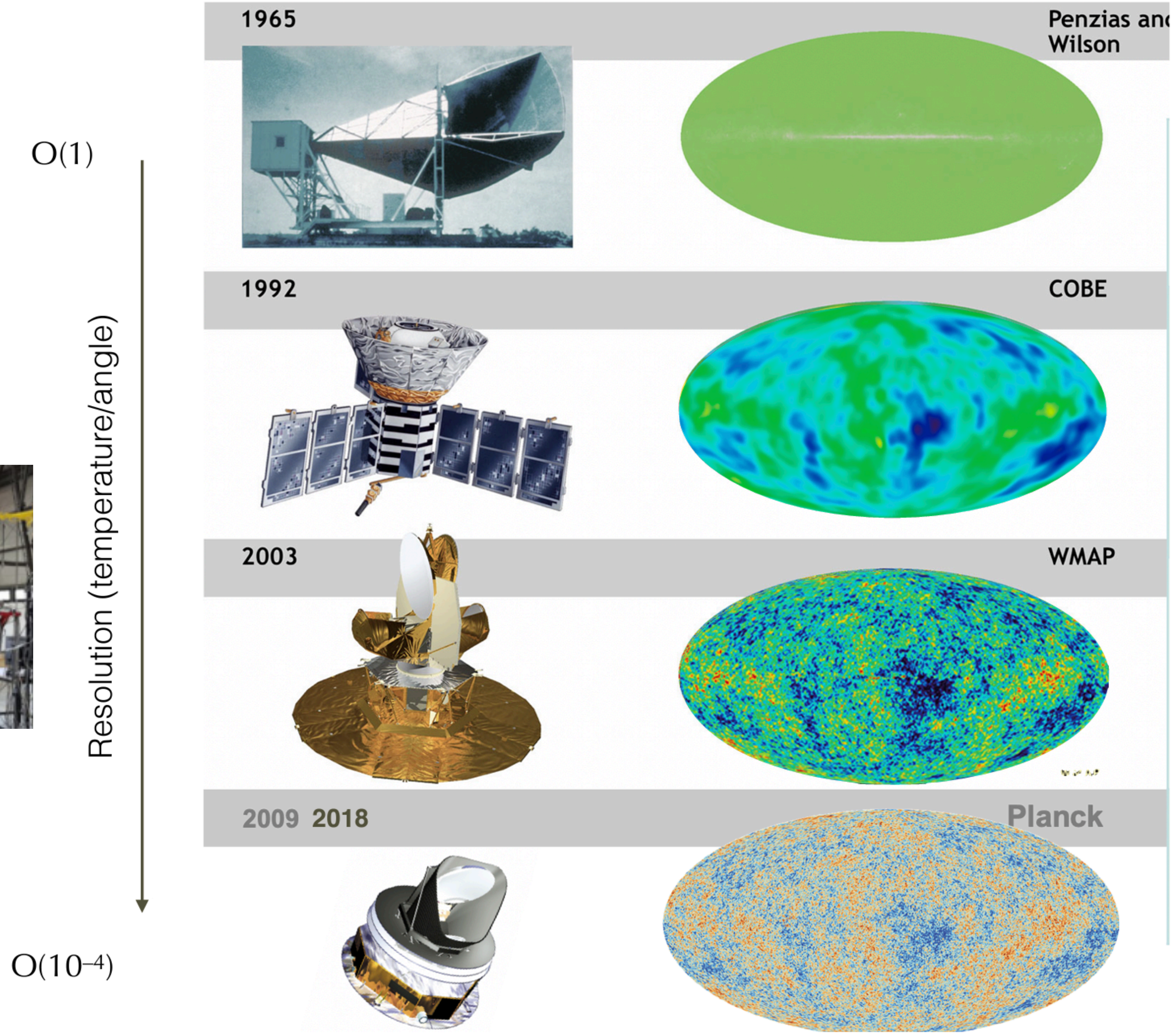
CMB

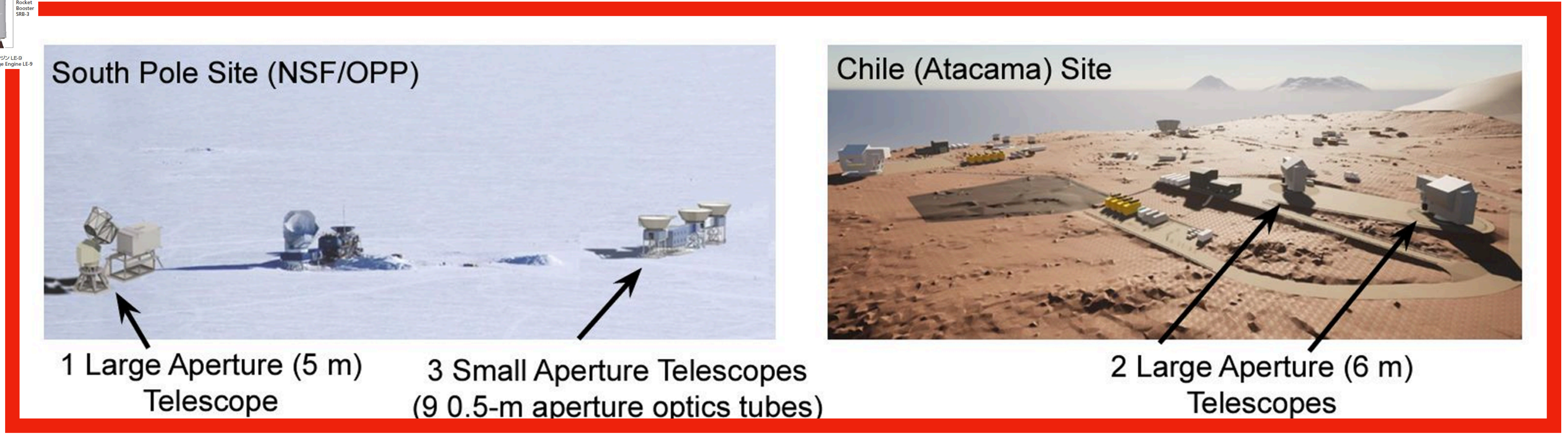
CMB polarization: B-modes

- **LSPE** launch: 1 day 2026 (NASA: Fort Summer)
- **QUBIC** installed (fall 2022) in Argentina
- **LITEBIRD** (JAXA): CMB B modes reference future experiment launch further delayed: **2033**
- **CMB-S4** (flagship experiment in the US program, large Italian community interested)



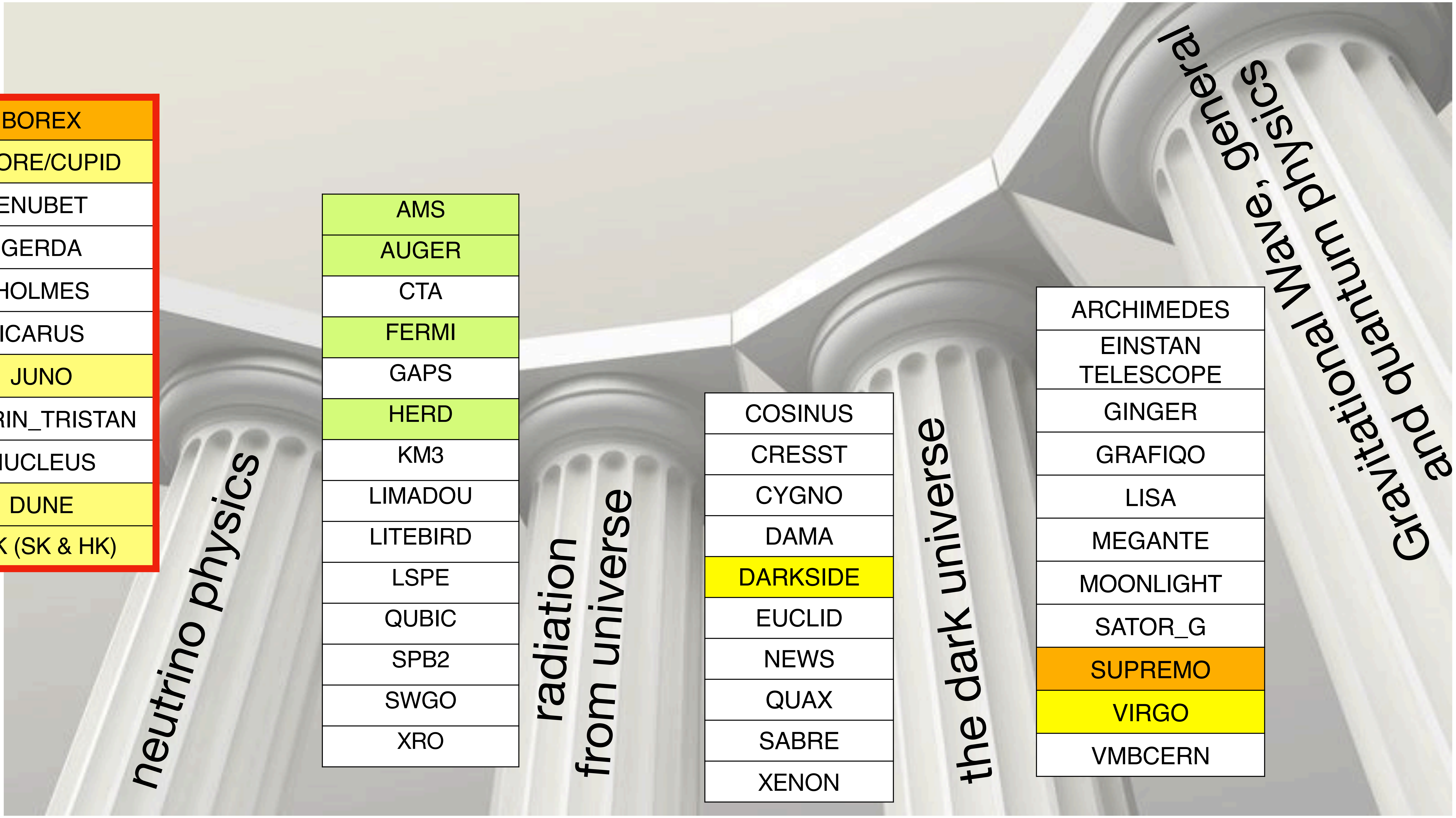






astro particle

the studies of elementary particles and their relation to astrophysics and cosmology



neutrino physics
BOREX
CUORE/CUPID
ENUBET
GERDA
HOLMES
ICARUS
JUNO
KATRIN_TRISTAN
NUCLEUS
DUNE
T2K (SK & HK)

radiation from universe
AMS
AUGER
CTA
FERMI
GAPS
HERD
KM3
LIMADOU
LITEBIRD
LSPE
QUBIC
SPB2
SWGO
XRO

the dark universe
COSINUS
CRESST
CYGNO
DAMA
DARKSIDE
EUCLID
NEWS
QUAX
SABRE
XENON

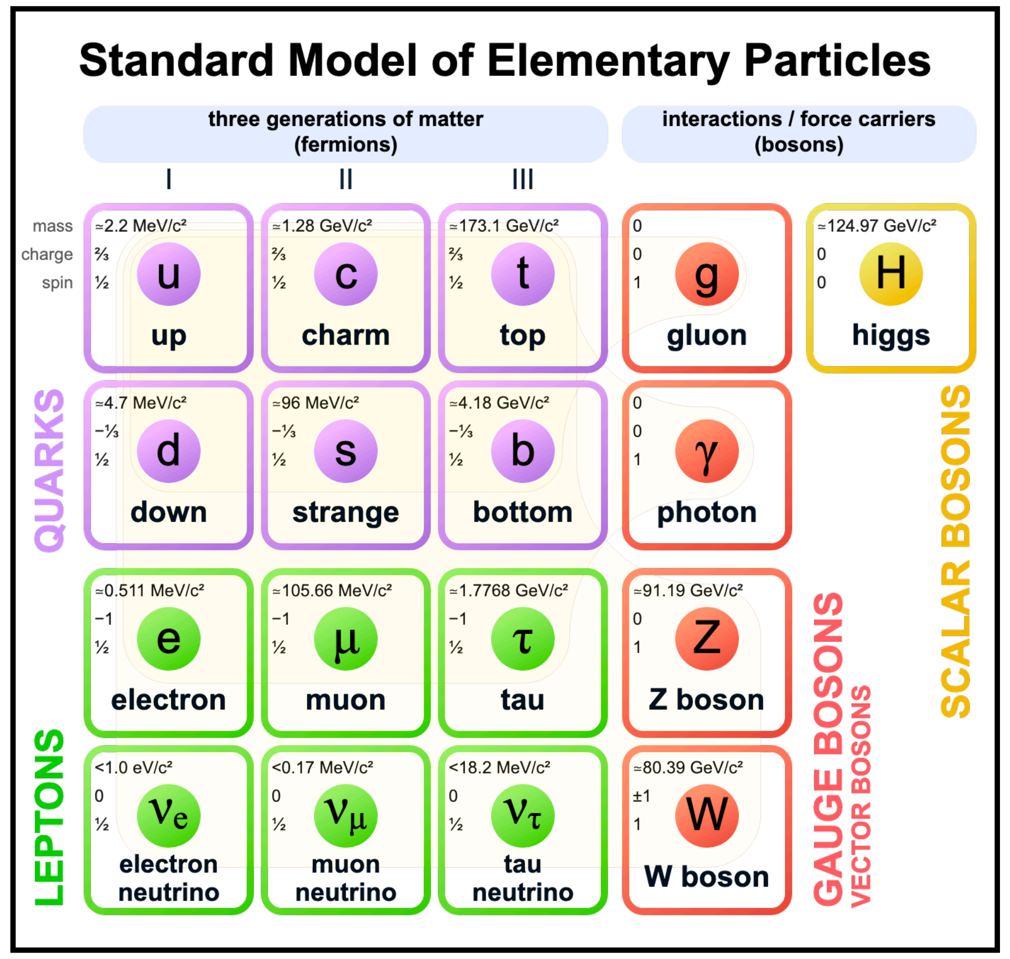
Gravitational Wave, general and quantum physics
ARCHIMEDES
EINSTAN TELESCOPE
GINGER
GRAFIQO
LISA
MEGANTE
MOONLIGHT
SATOR_G
SUPREMO
VIRGO
VMBCERN

neutrino physics

NEUTRINO PUZZLE

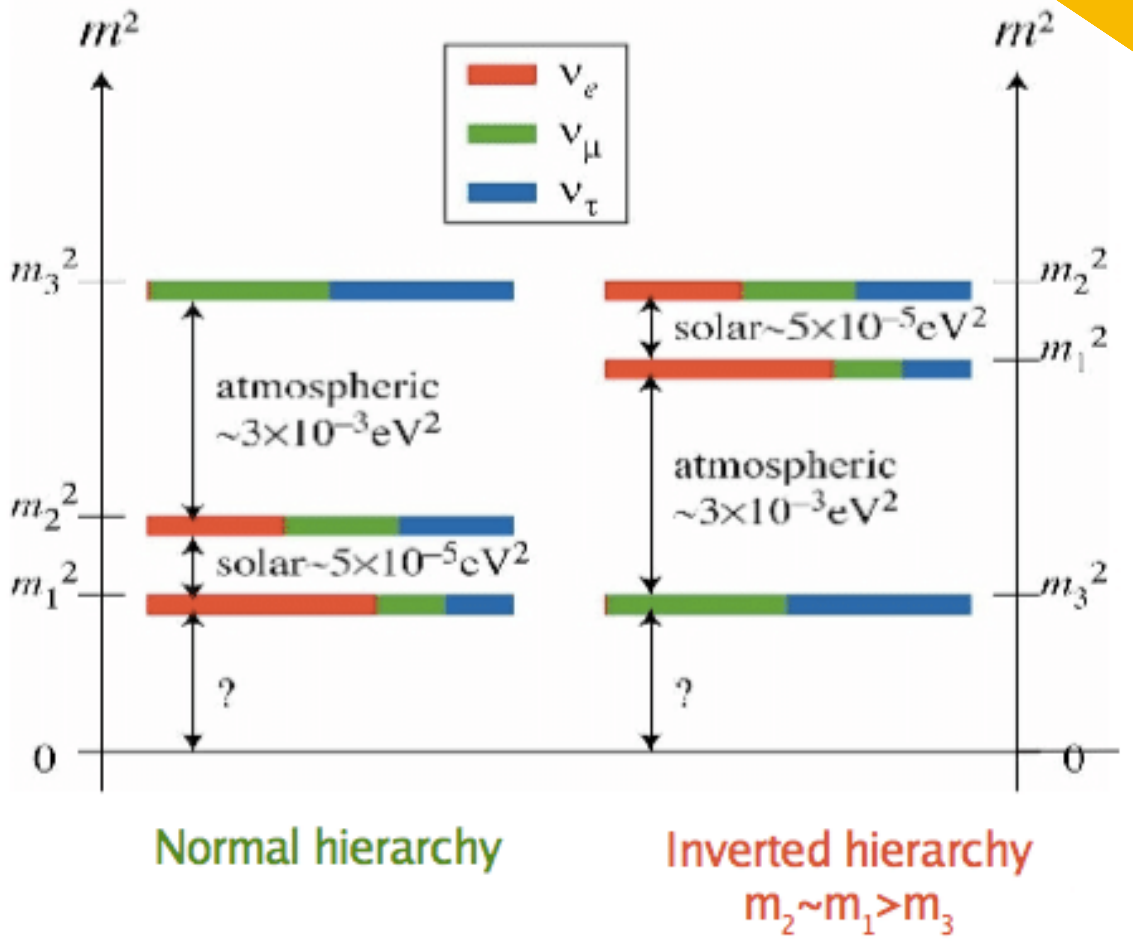
BOREX
CUORE/CUPID
ENUBET
GERDA
HOLMES
ICARUS
JUNO
KATRIN_TRISTAN
NUCLEUS
DUNE
T2K (SK & HK)

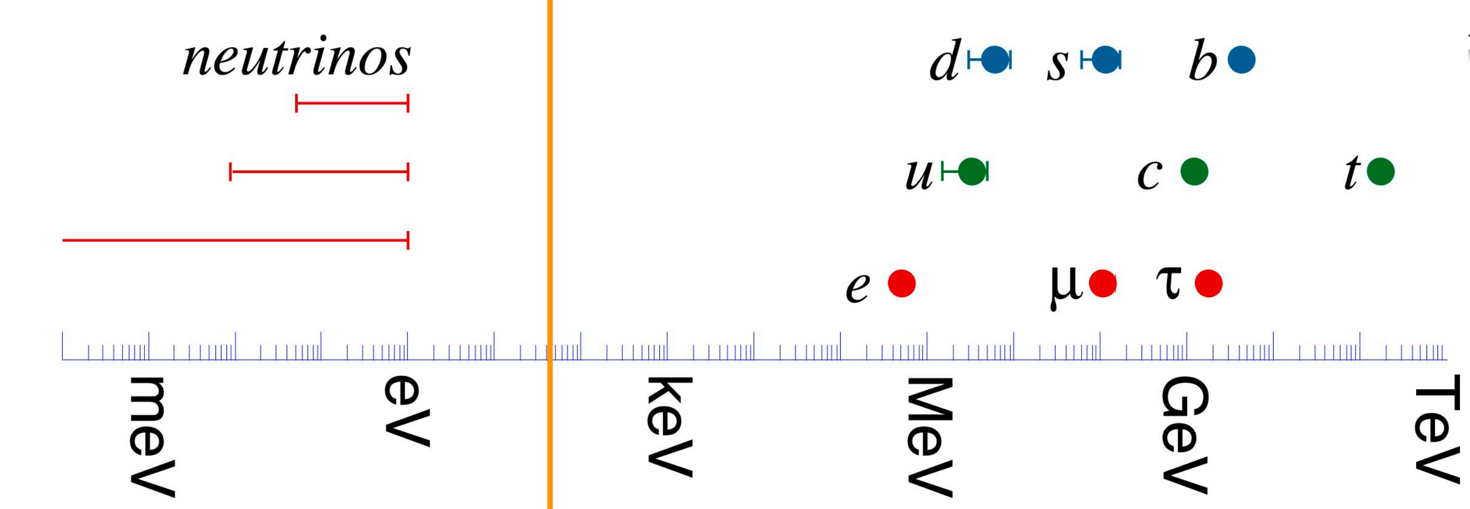
- SM and symmetry
- oscillation
- mass
- hierarchy
- number of neutrinos
- sterile neutrino



no mass and SM!?

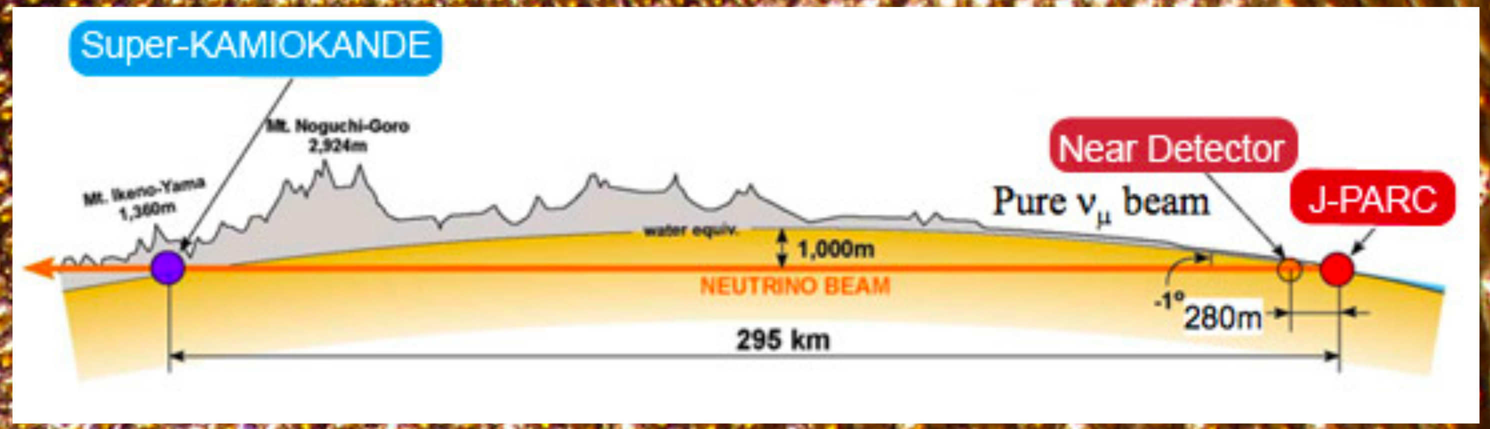
who have lower mass?



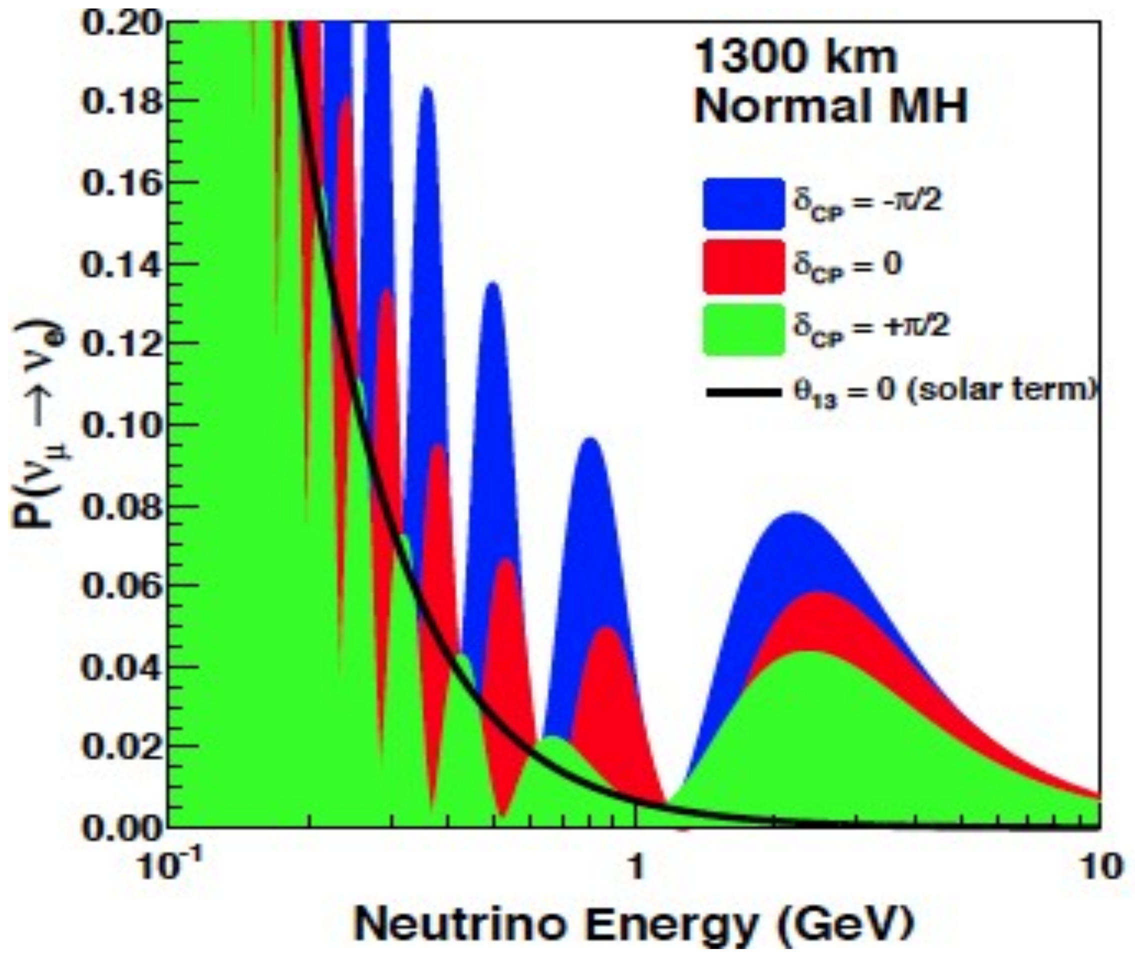


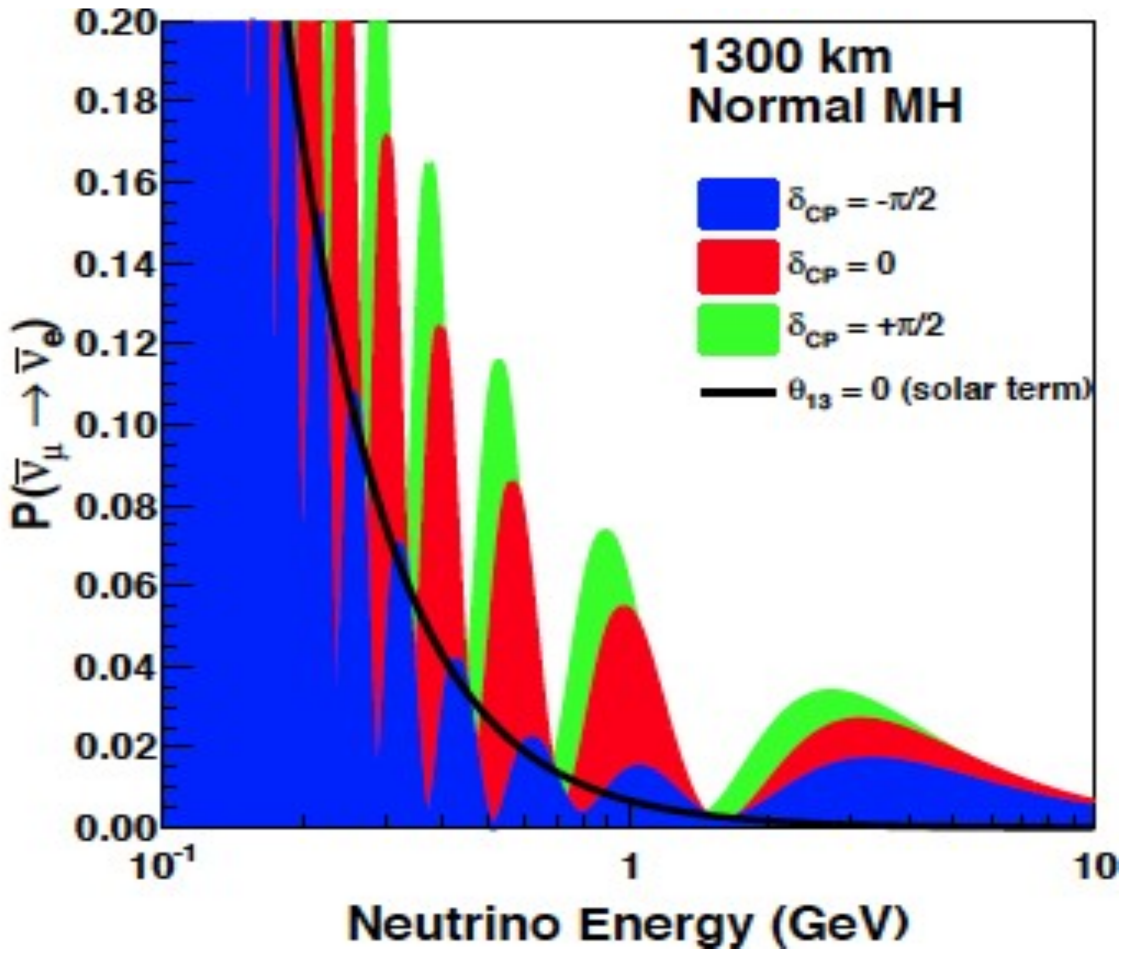
way so small mass!?

- HK: main goal mass hierarchy and δ_{CP} . . . but
  - extensive physics program (p-decay, cosmic ’s, DM, . . .)

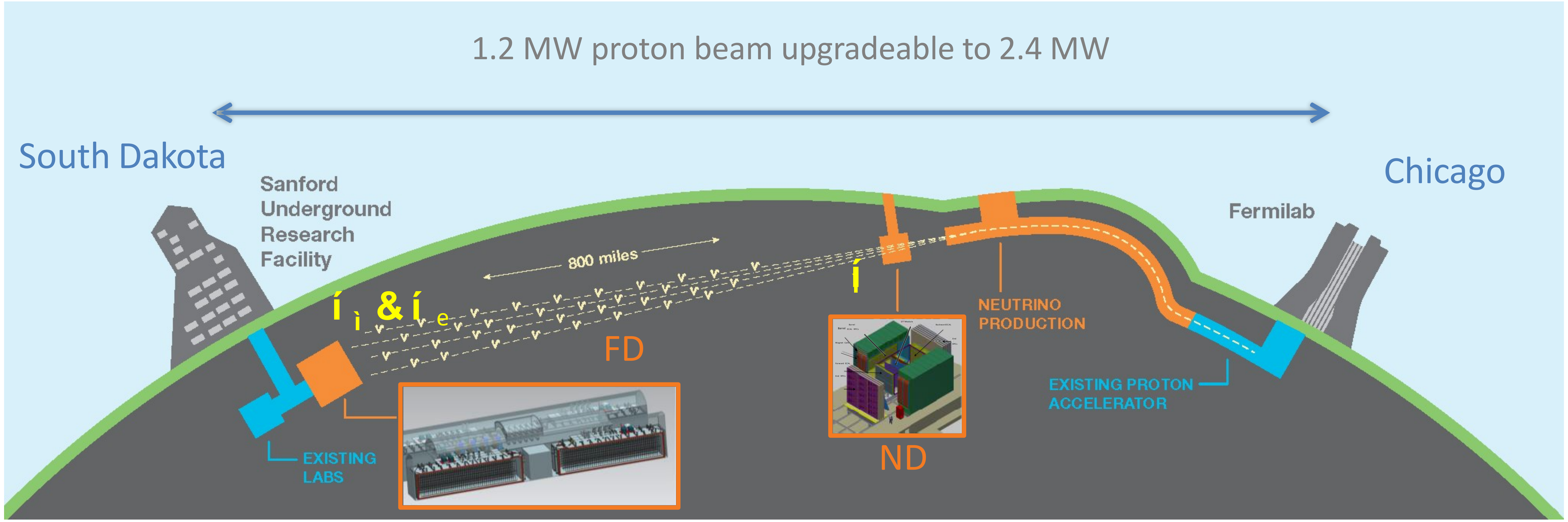


DUNE





- Measure neutrino spectra at 1300 km in a wide-band beam (ν_μ e anti ν_μ)
- ν_e appearance probability depends on θ_{13}, θ_{23}, δ_{CP}, and matter effects. All four can be measured in a single experiment.
- wide-band beam and long baseline break the degeneracy between CP violation and matter effects



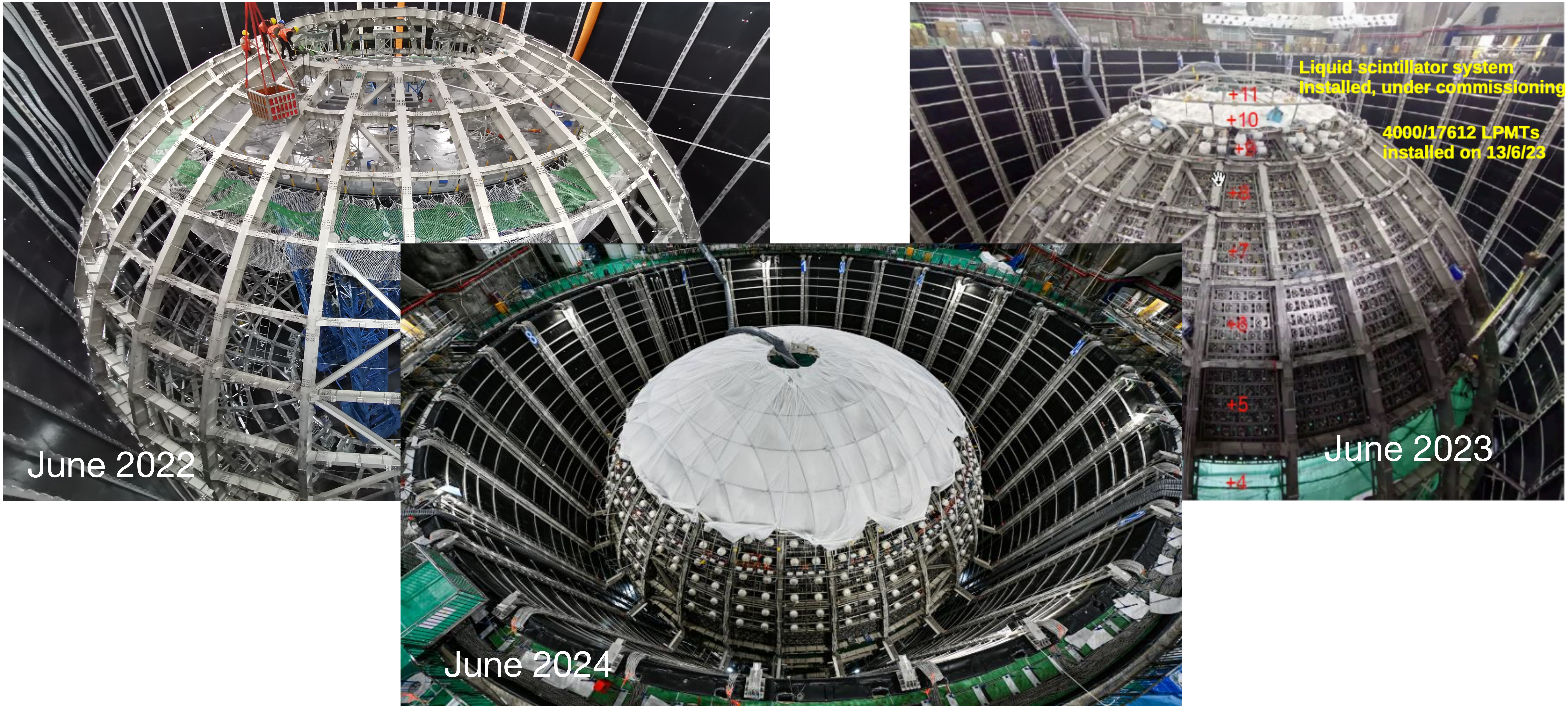
4x17 kt LAr TPC fiducial mass of > 40 kton

ICARUS installed at FANAL
legacy of experience at LNGS
and base tech. of the DUNE far detector

…legacy of BOREXINO experience

JUNO

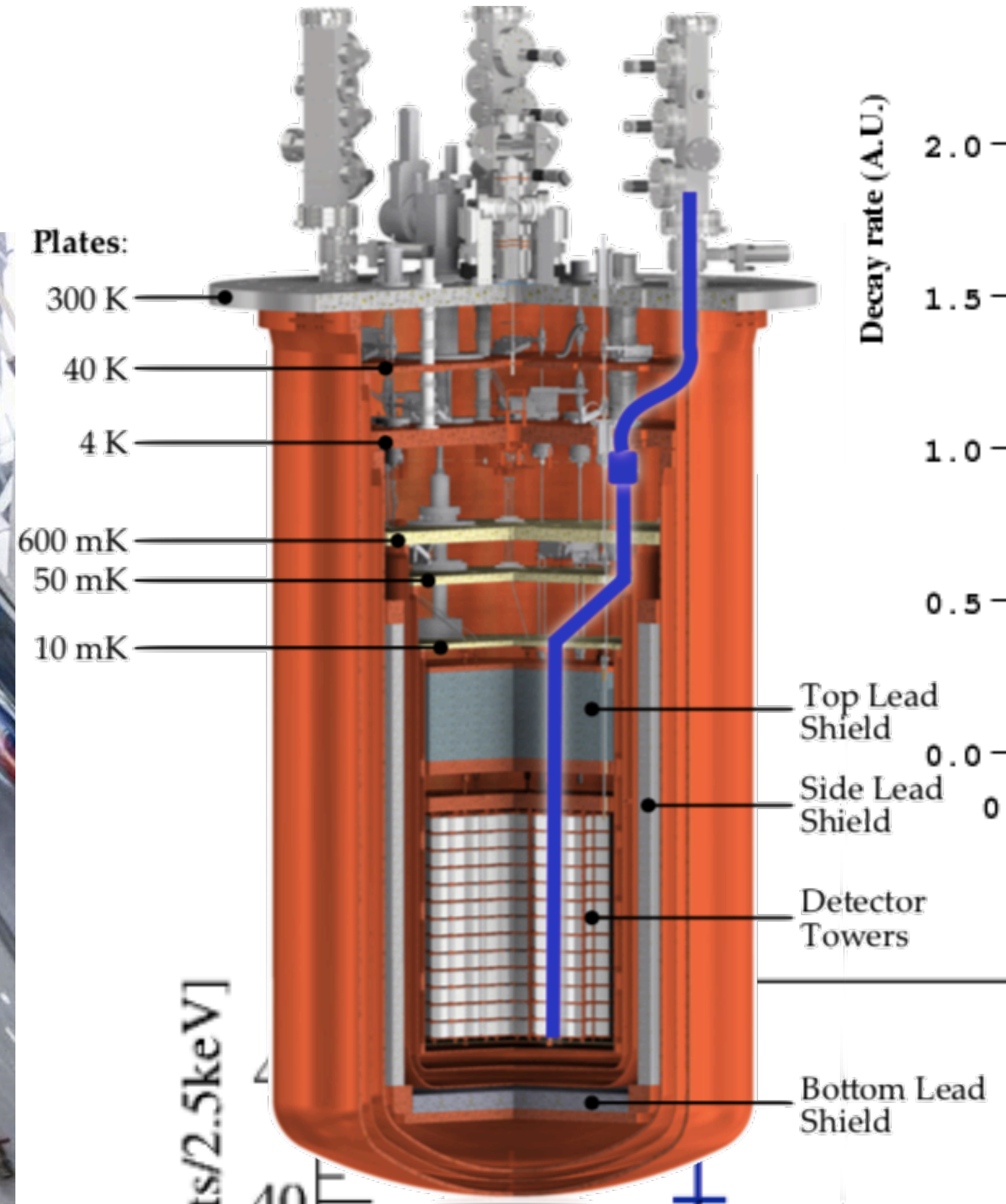
JUNO: main goal mass hierarchy and extensive astroparticle physics program

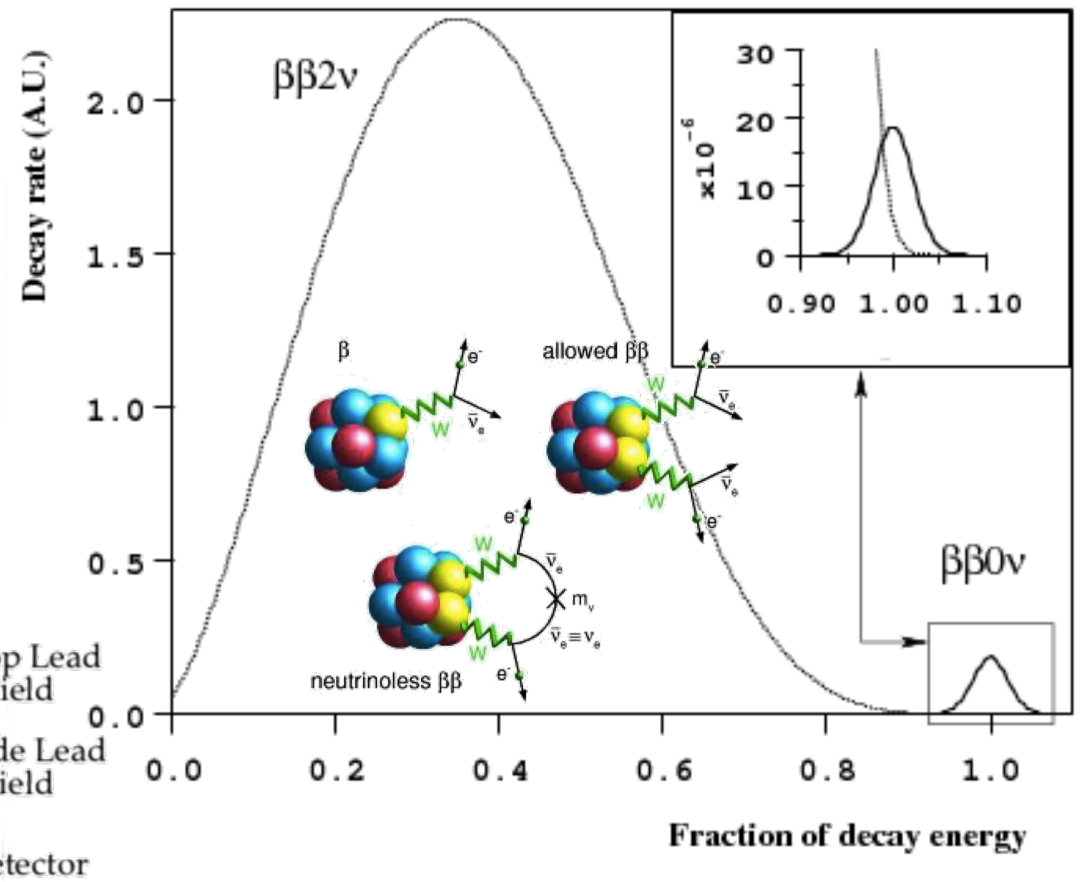


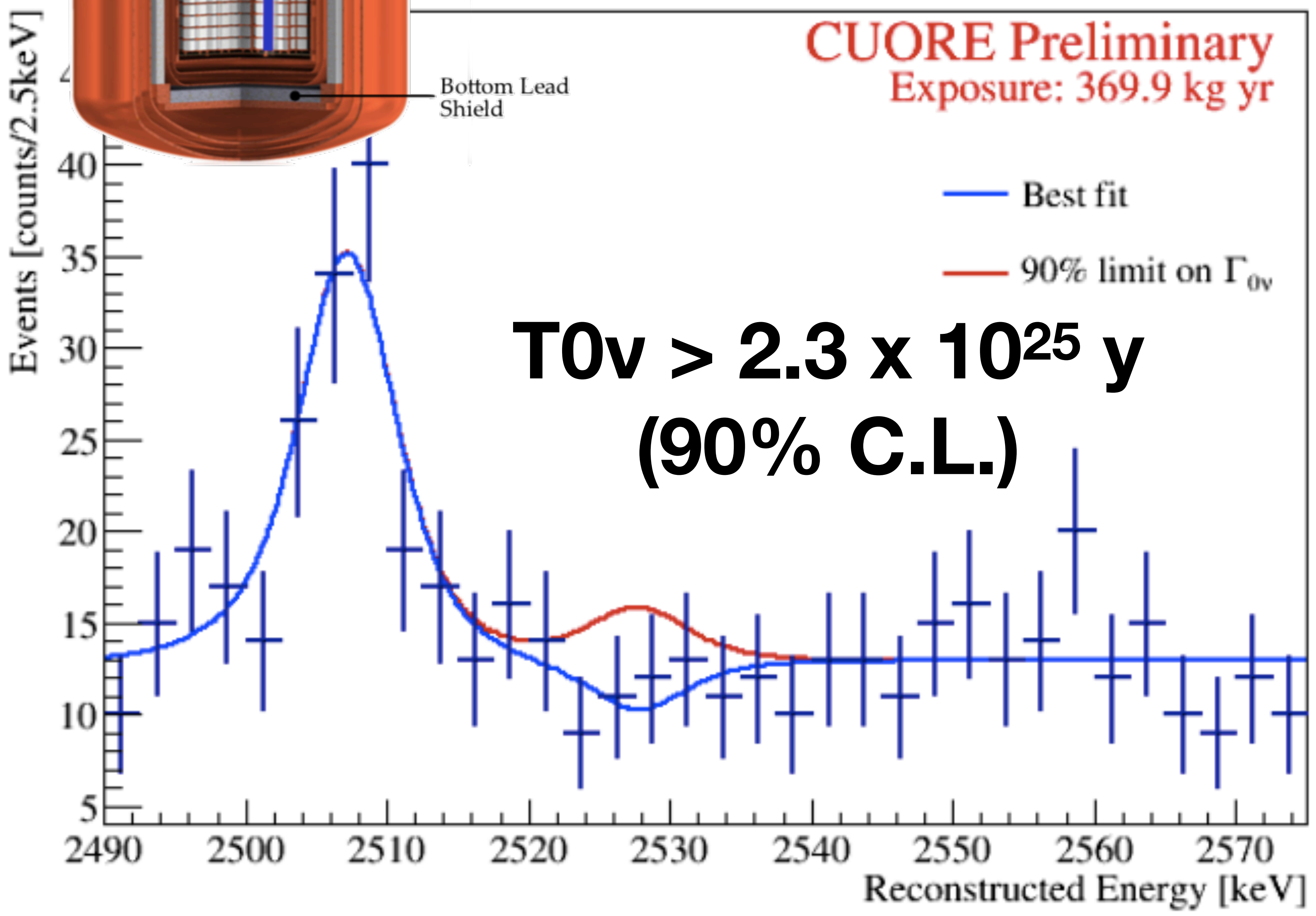
CUORE - Cryogenic Underground Observatory for Rare Events

Majorana' neutrino

Majorana' neutrino: if E >> m and the neutrino do not have any quantum number (leptonic, barionc, charge, ecc) the (LH) and (RH) are states of the same particle-antiparticle

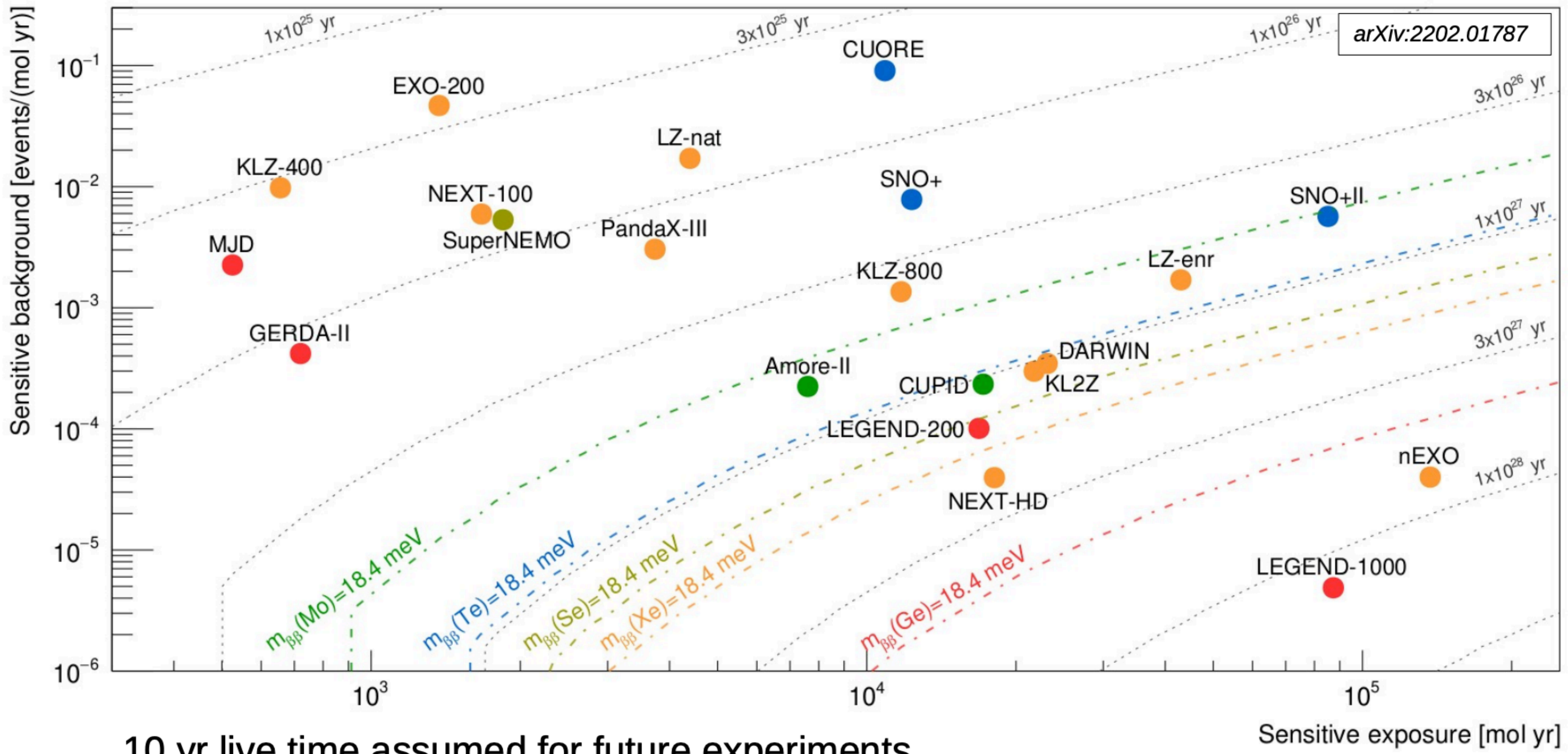






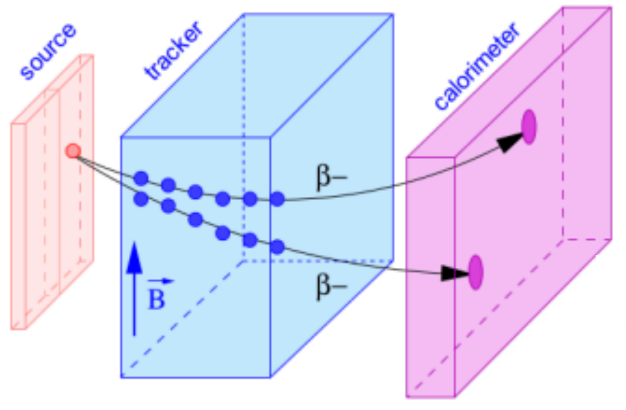
T0v > 2.3 x 10^{25} y (90% C.L.)

double beta decay

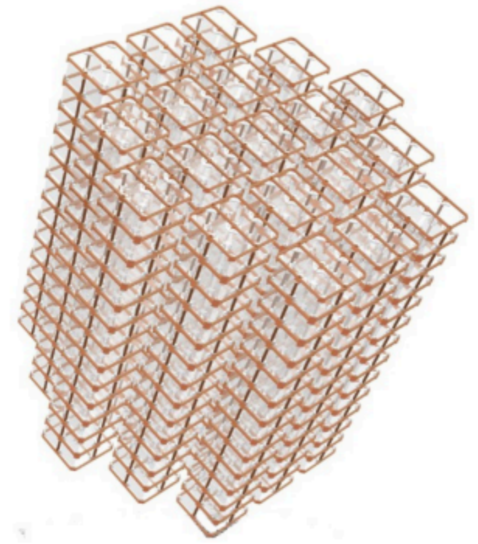


10 yr live time assumed for future experiments

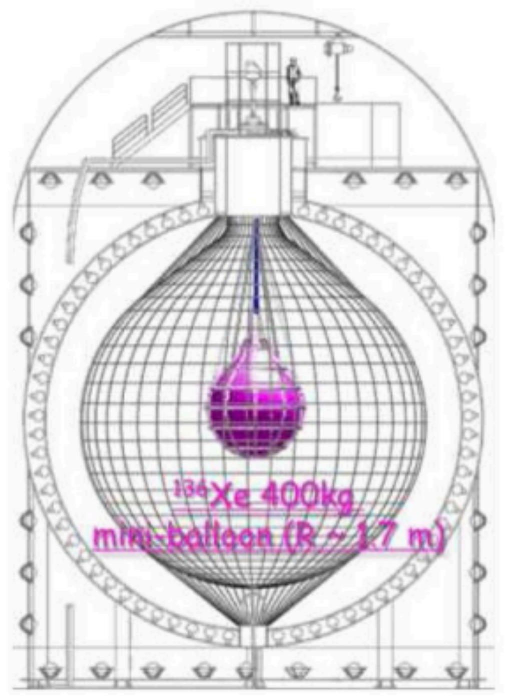
Tracking



Cryogenic calorimeters



Loaded liquid scintillators

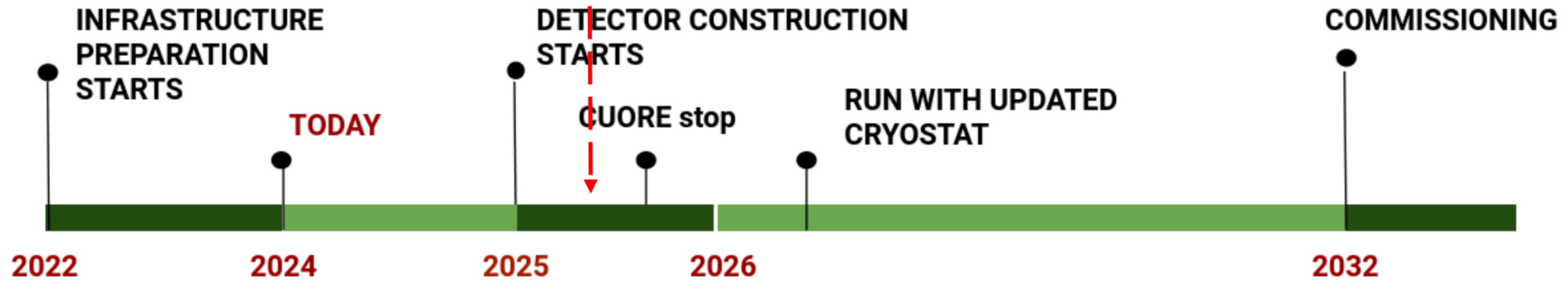


Exp.	kg ^{100}Mo	Enr.[%]	BI [ckky]	$T_{1/2}$ 90%CL[y]
CUPID-bsl.	240	>95	10^{-4}	1.4×10^{27}
CUPID-reach	240	>95	2×10^{-5}	2.2×10^{27}
CUPID-1t	1000	>95	5×10^{-6}	9.1×10^{27}

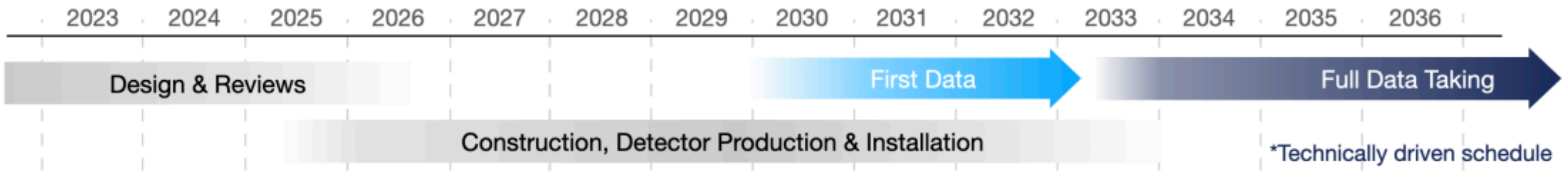
Exp.	kg ^{76}Ge	Enr.[%]	BI [ckky]	$T_{1/2}$ 90%CL[y]
Gerda-II	39	87	$5{,}2 \times 10^{-4}$ *	$1{,}8 \times 10^{26}$ *
LEGEND-200	200	90	2×10^{-4}	10^{27}
LEGEND-1000	1000	92	1×10^{-5}	1.4×10^{28}

CUPID-1t

contract with SICCAS **signed**, shifts in this date will affect the schedule (unless we negotiate a faster production rate)



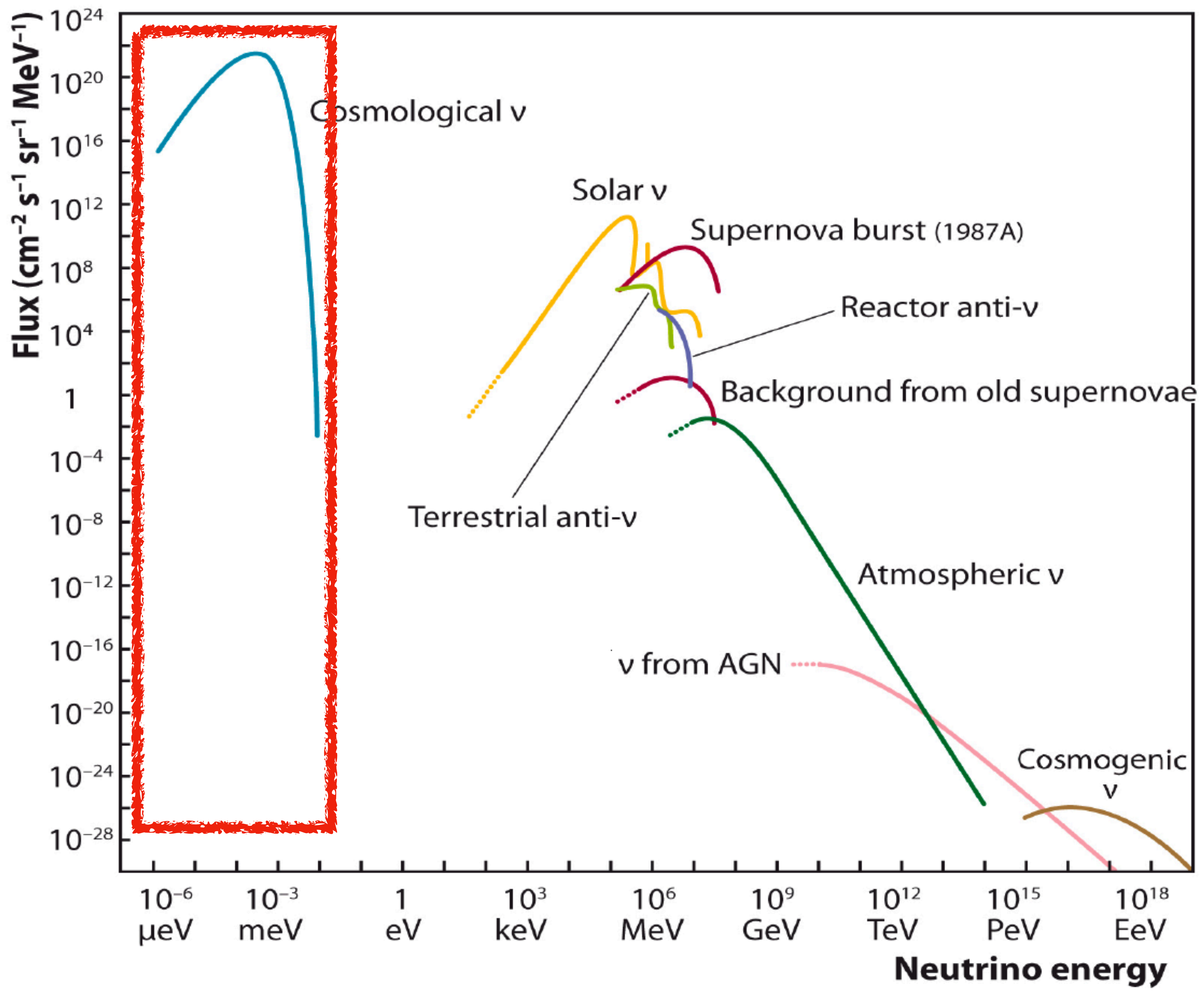
LEGEND1000

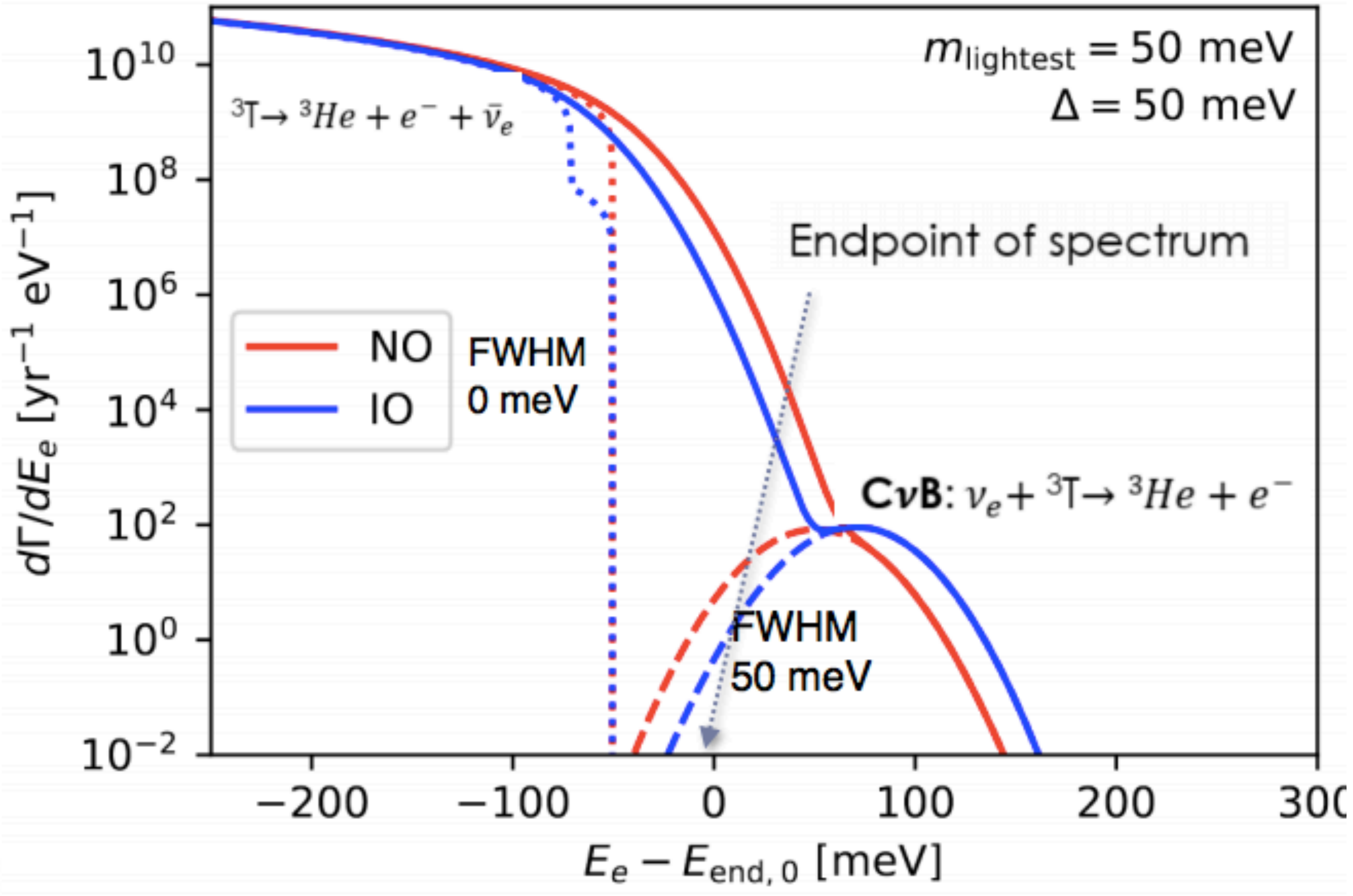


*Technically driven schedule

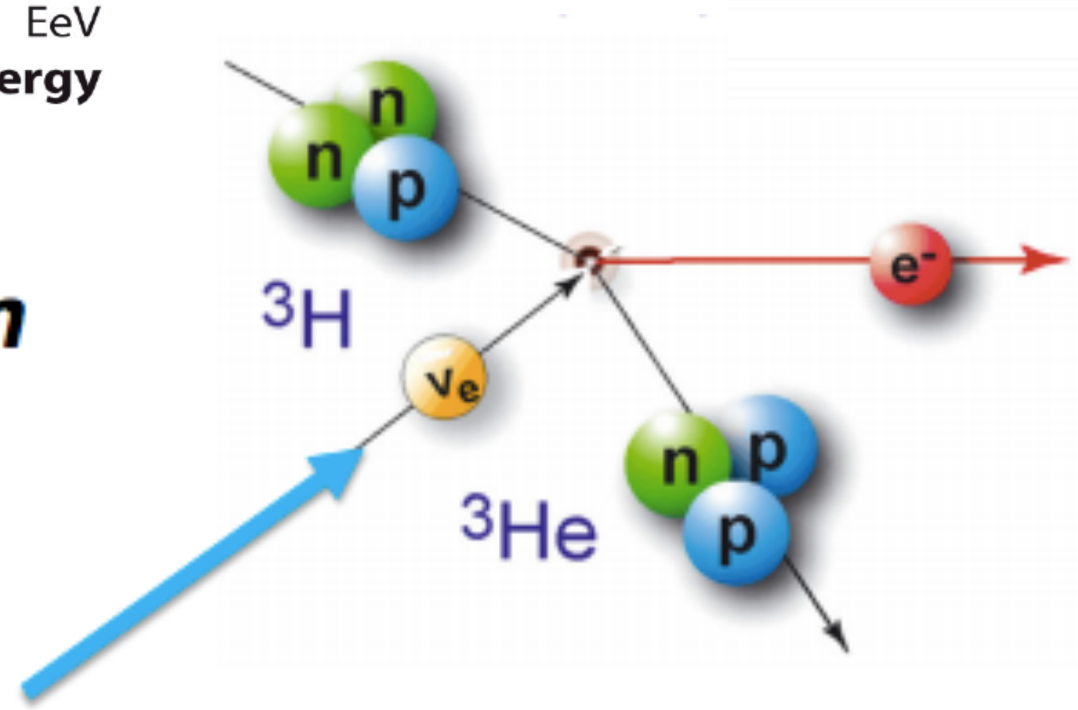
cosmological neutrinos

PTOLEMY

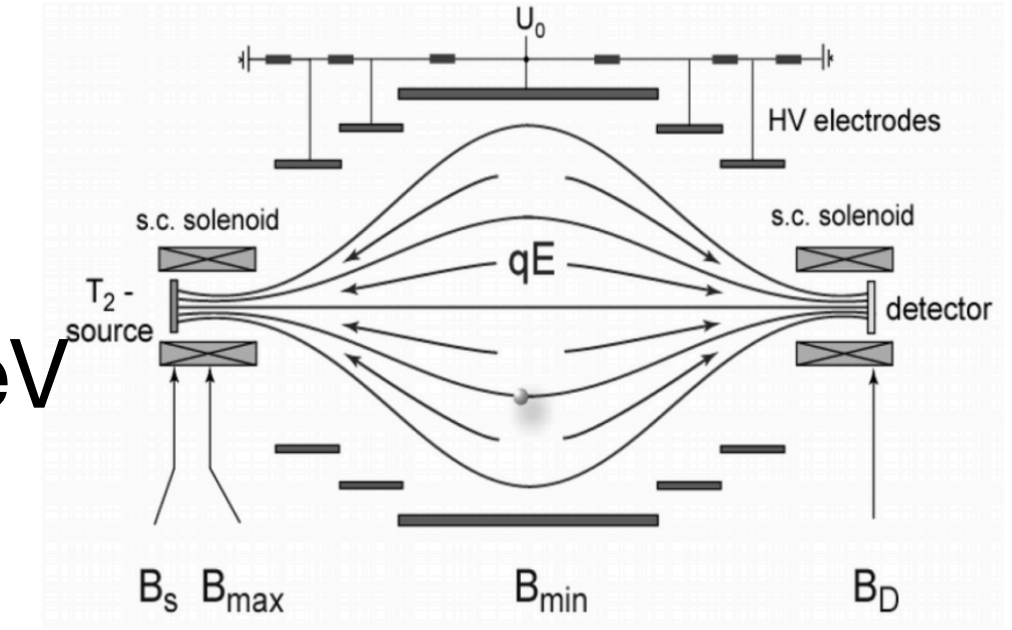




Neutrino capture on tritium



1% energy resolution @ meV



astro particle

the studies of elementary particles and their relation to astrophysics and cosmology

neutrino physics

- BOREX
- CUORE/CUPID
- ENUBET
- GERDA
- HOLMES
- ICARUS
- JUNO
- KATRIN_TRISTAN
- NUCLEUS
- DUNE
- T2K (SK & HK)

radiation from universe

- AMS
- AUGER
- CTA
- FERMI
- GAPS
- HERD
- KM3
- LIMADOU
- LITEBIRD
- LSPE
- QUBIC
- SPB2
- SWGO
- XRO

the dark universe

- COSINUS
- CRESST
- CYGNO
- DAMA
- DARKSIDE
- EUCLID
- NEWS
- QUAX
- SABRE
- XENON

Gravitational Wave, general and quantum physics

- ARCHIMEDES
- EINSTAN TELESCOPE
- GINGER
- GRAFIQO
- LISA
- MEGANTE
- MOONLIGHT
- SATOR_G
- SUPREMO
- VIRGO
- VMBCERN

gravitational wave, general and quantum physics

ARCHIMEDES
EINSTAN TELESCOPE
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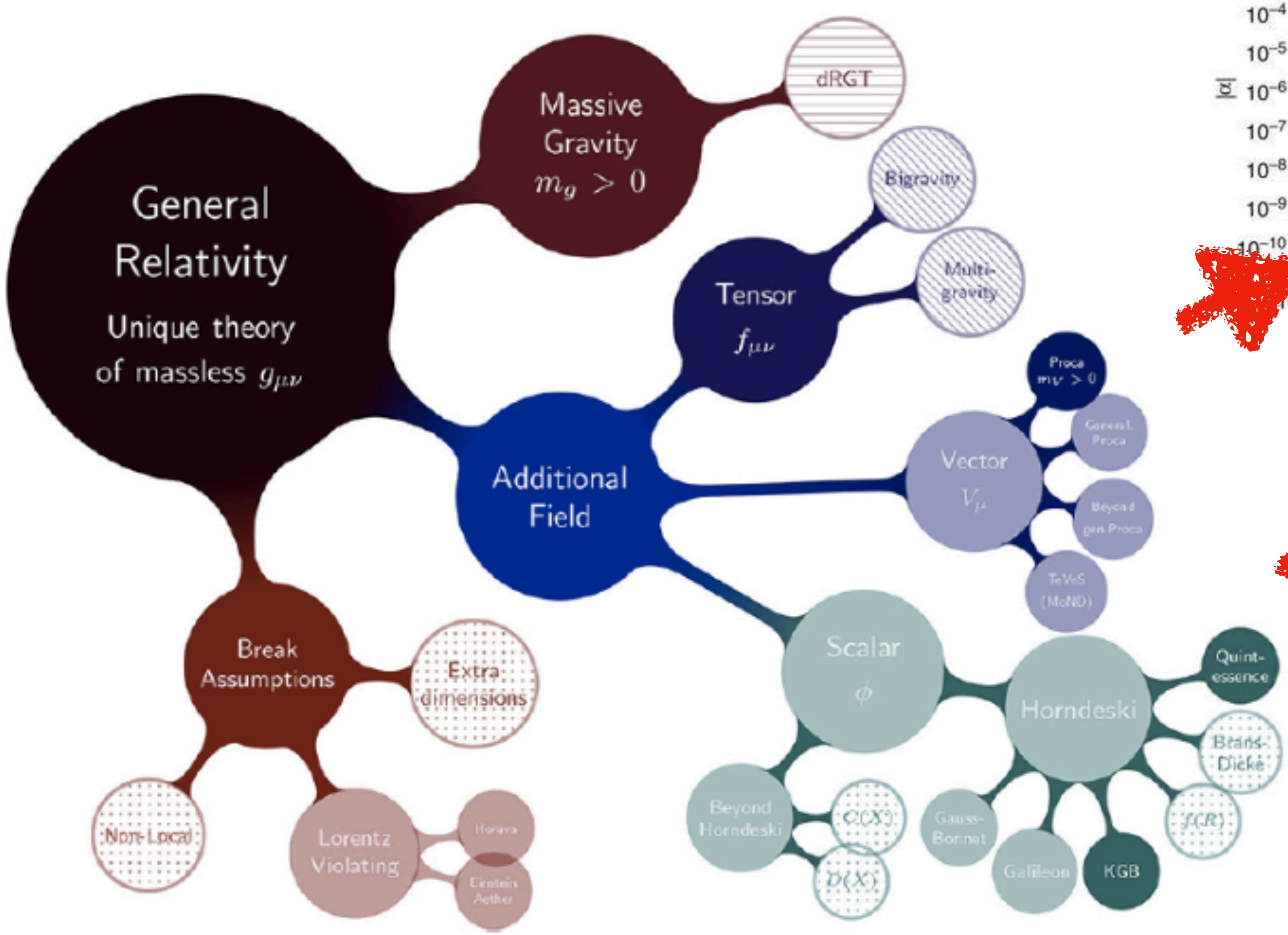
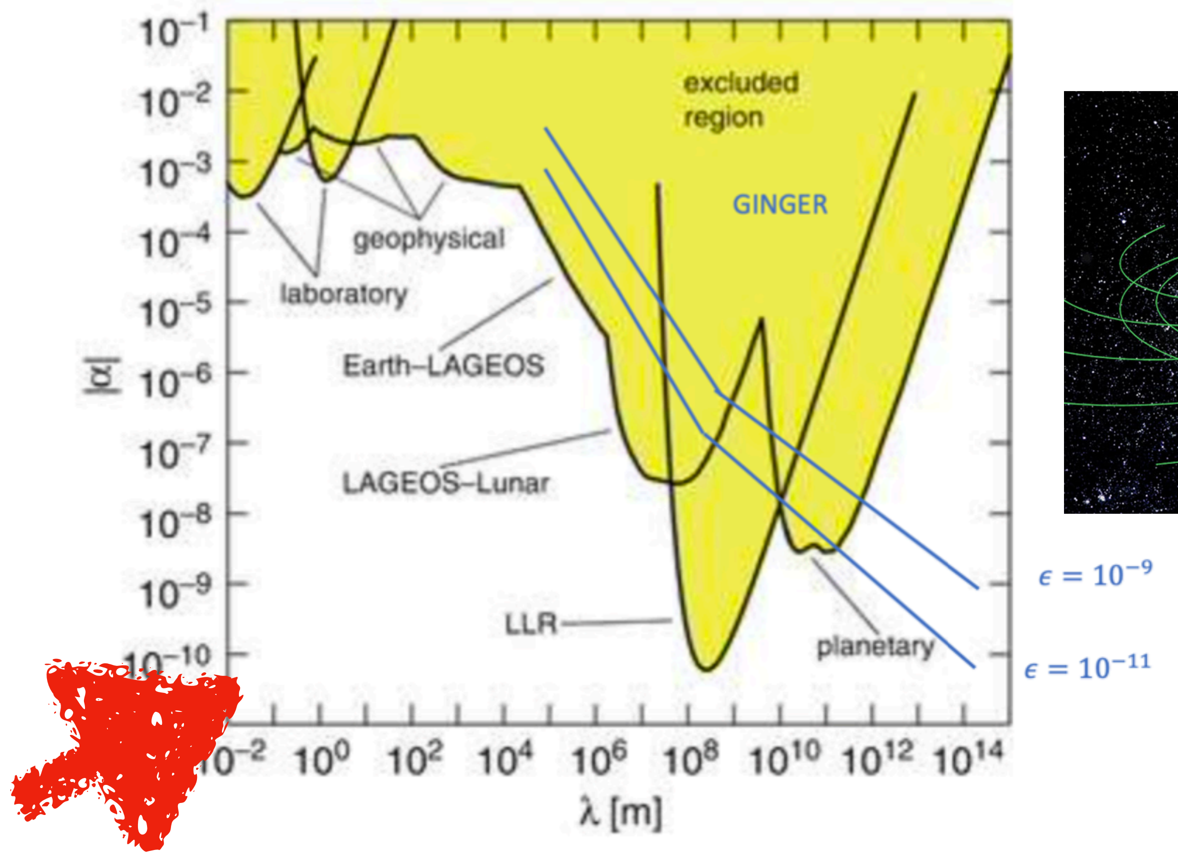
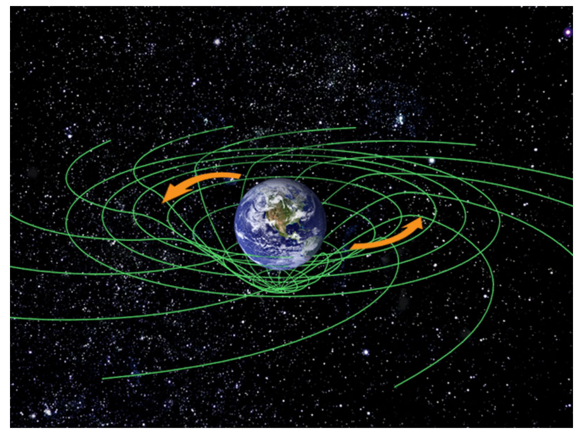
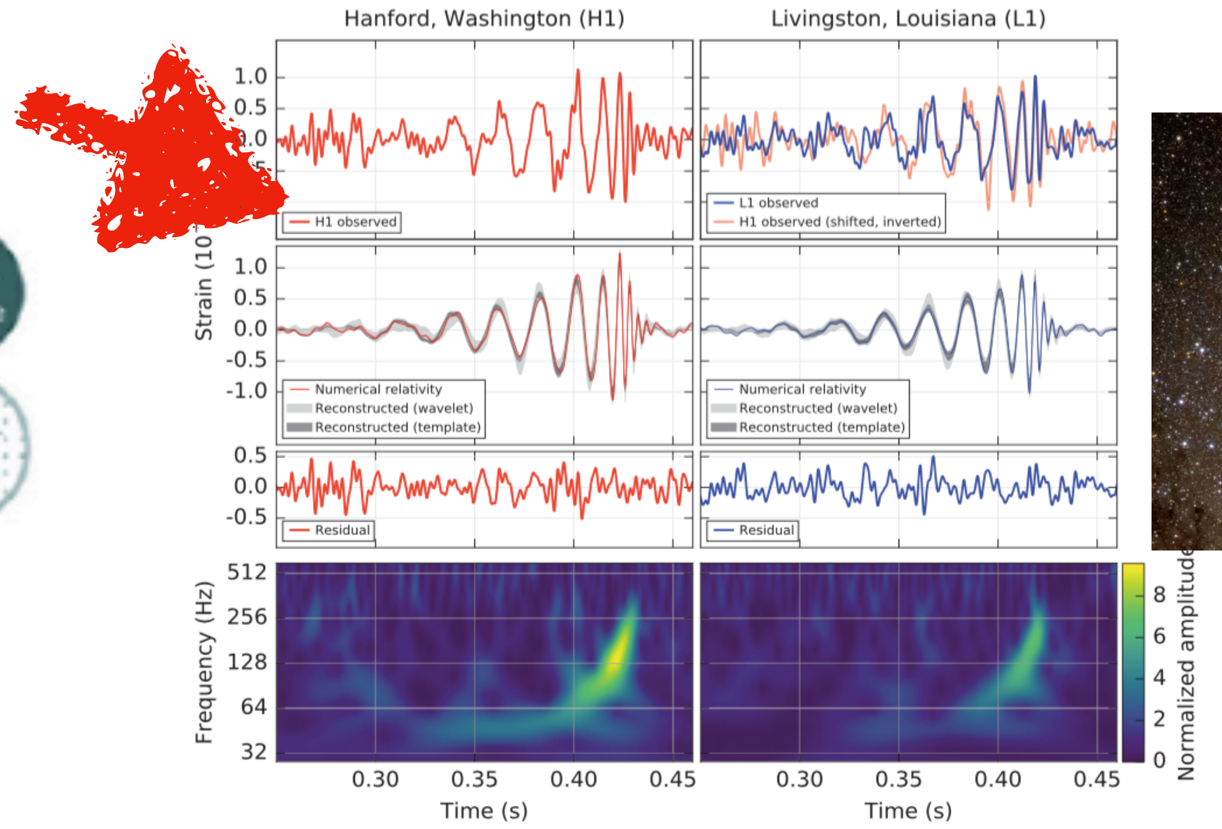
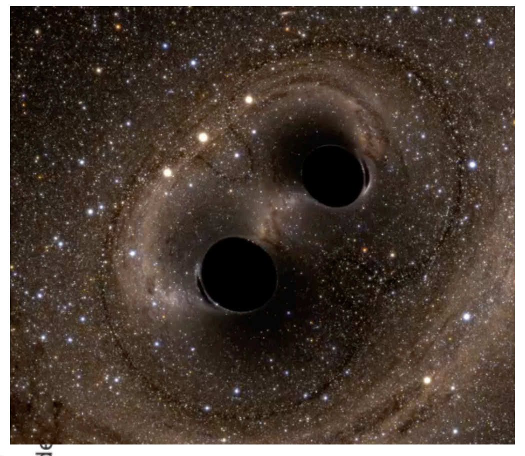


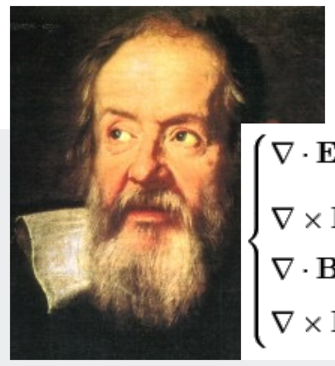




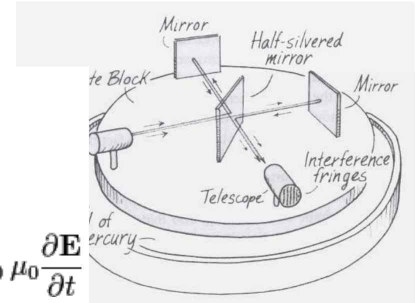




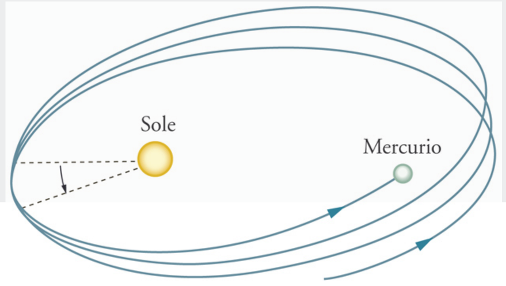
gravitational waves



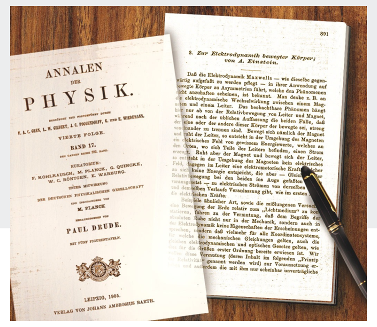
$$\nabla \cdot \mathbf{E} = \frac{\rho_c}{\varepsilon_0}$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \varepsilon_0 \mu_0 \frac{\partial \mathbf{E}}{\partial t}$$

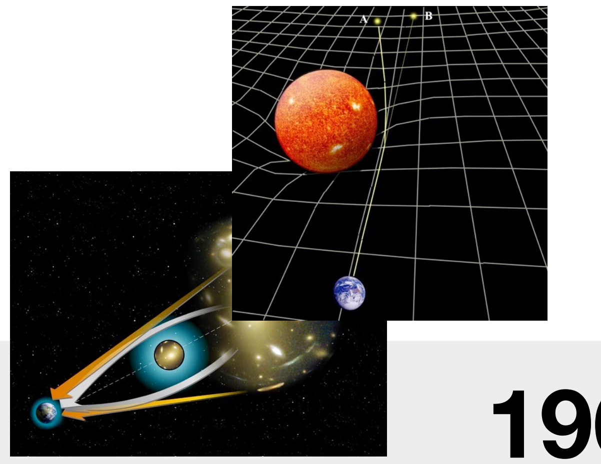


1600-1900



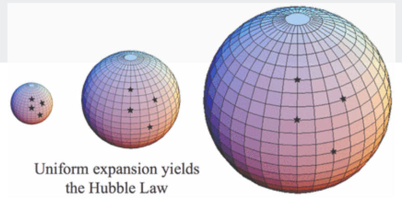
1915

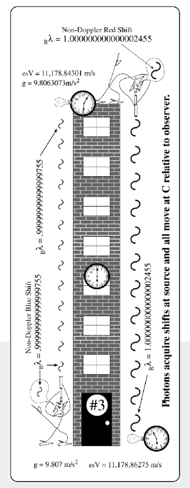




1919

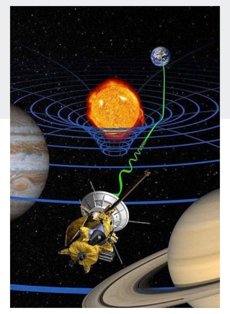
1930
Legge di Hubble

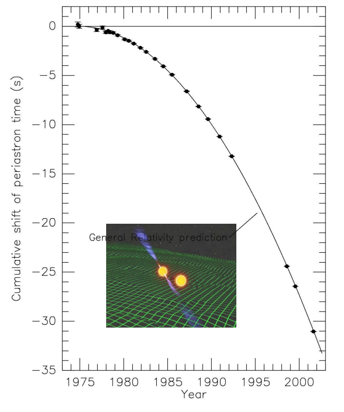




1960
Pound-Rebka

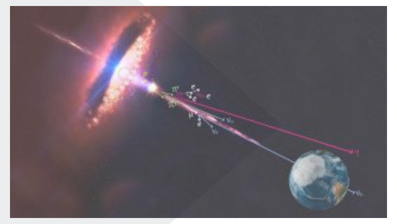
1971
Terra-Venere;
Viking



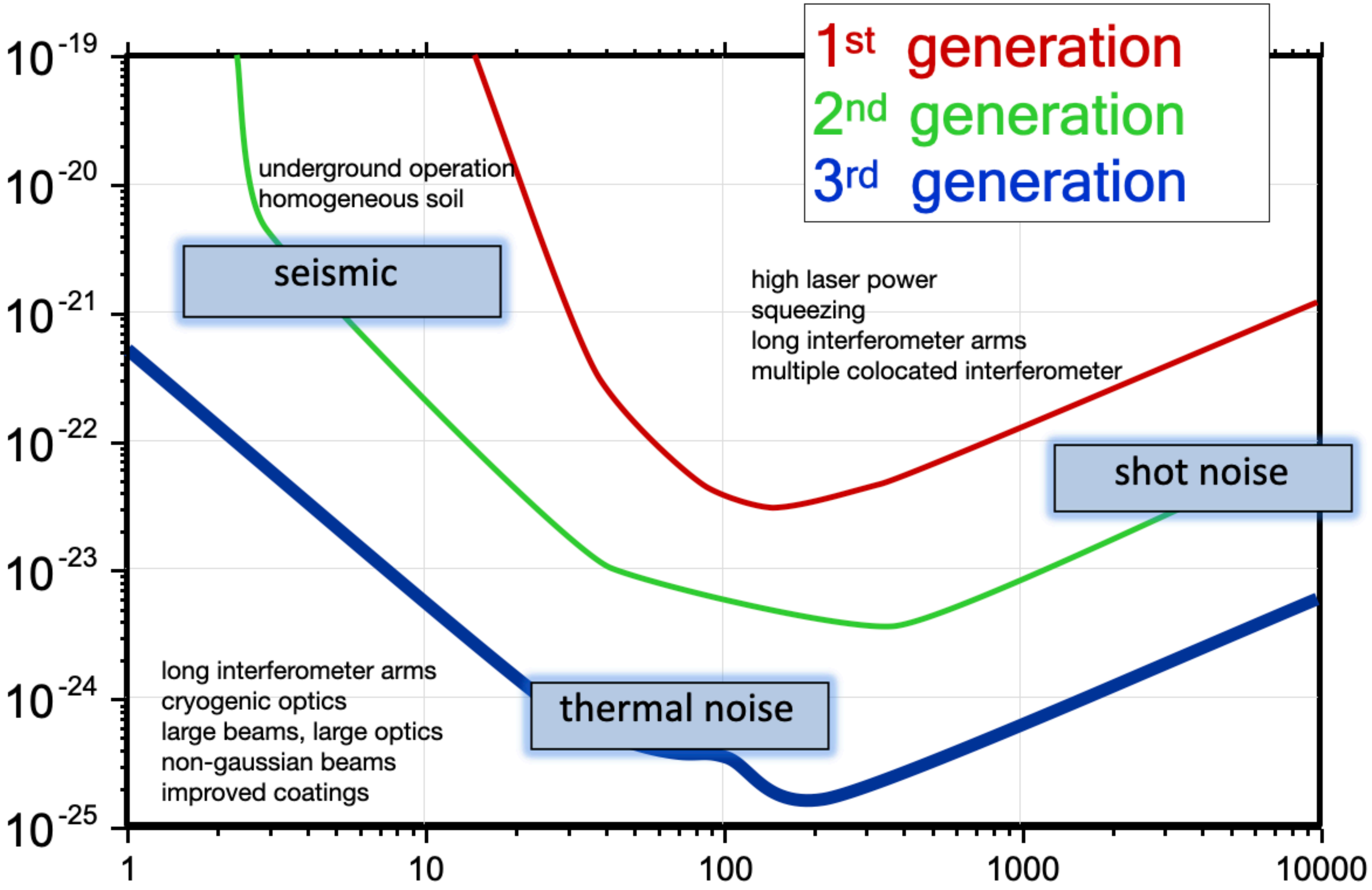


1974
Hulse-Taylor

2016

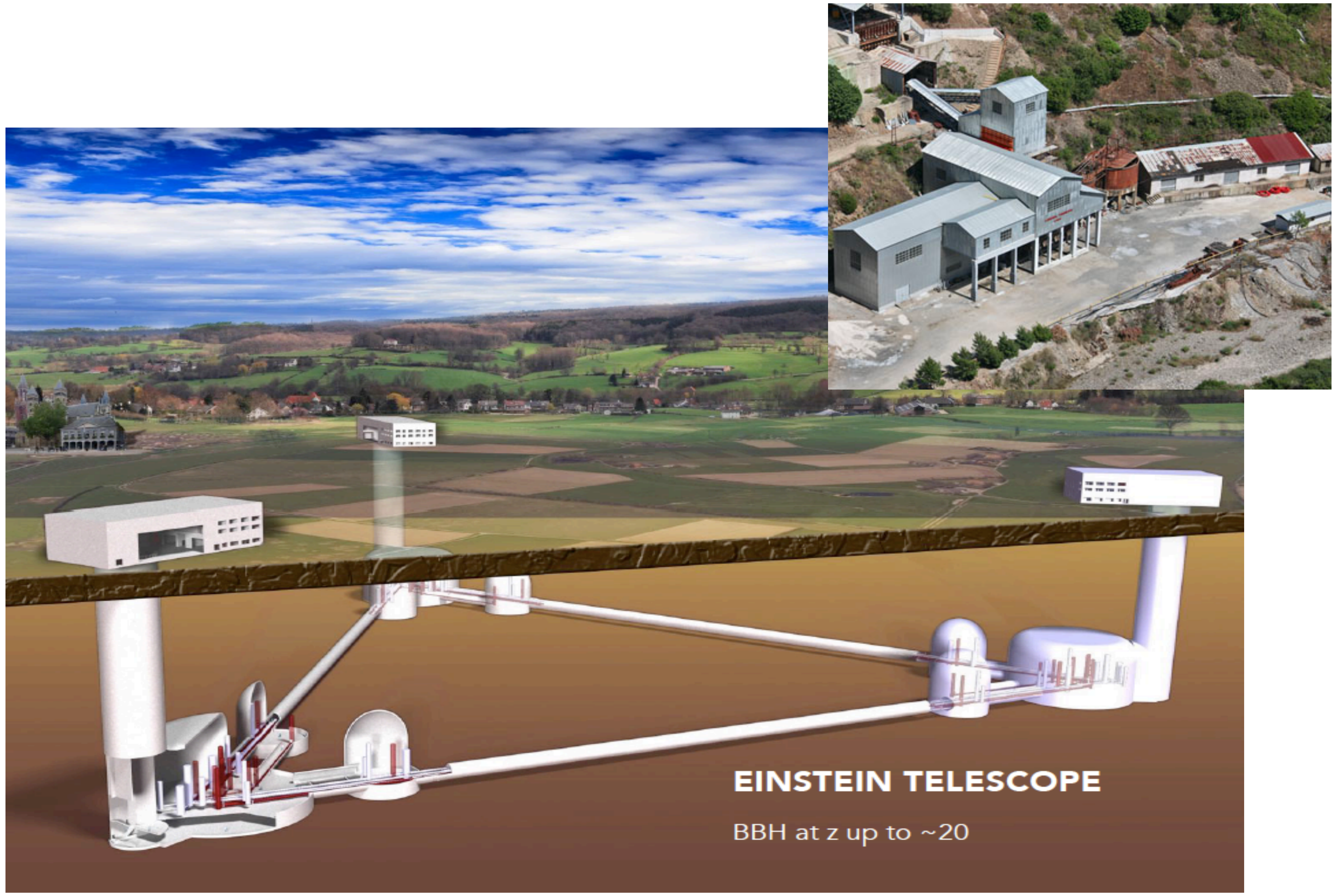


gravitational wave observatory

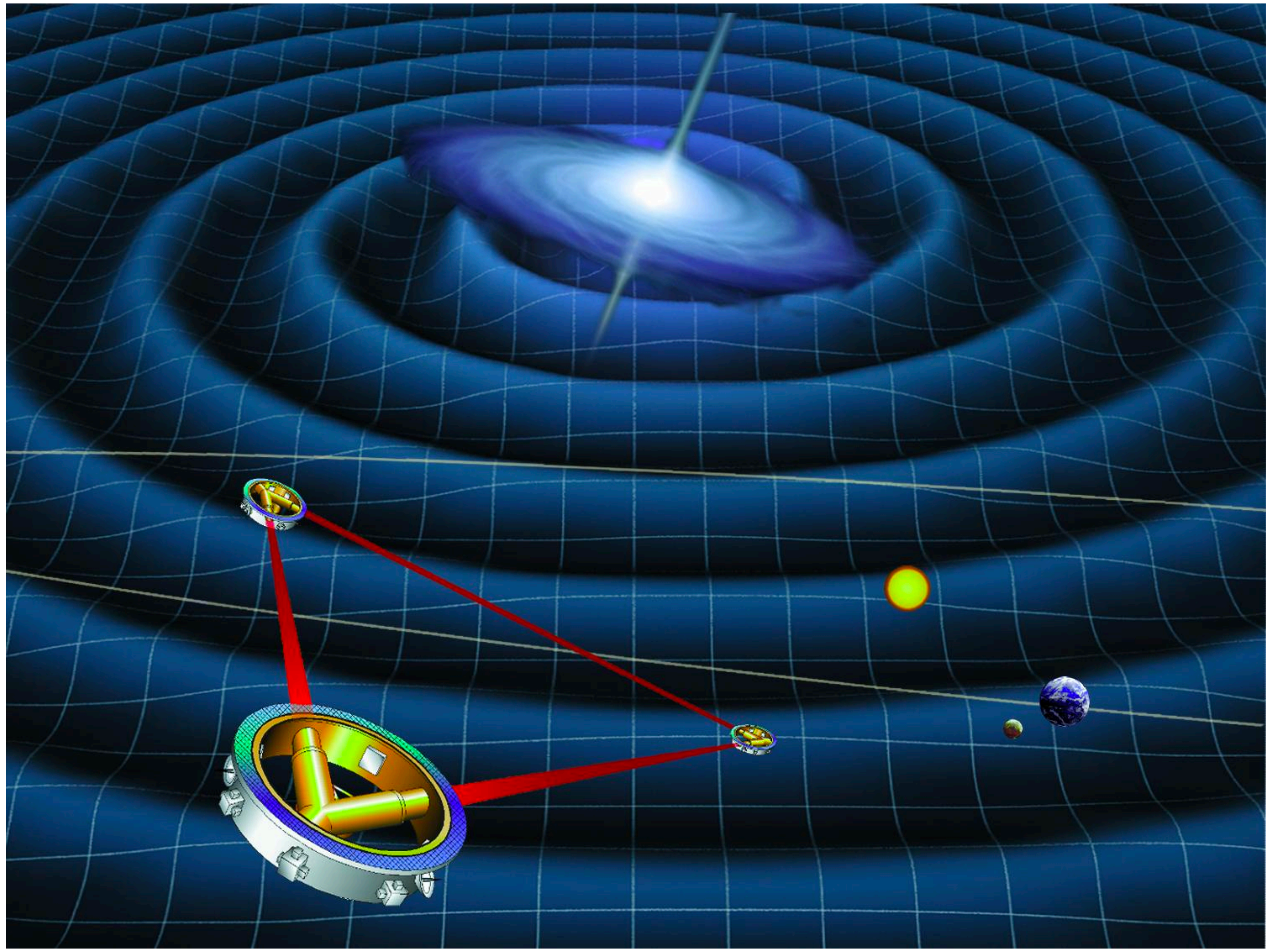


“ballistic” future

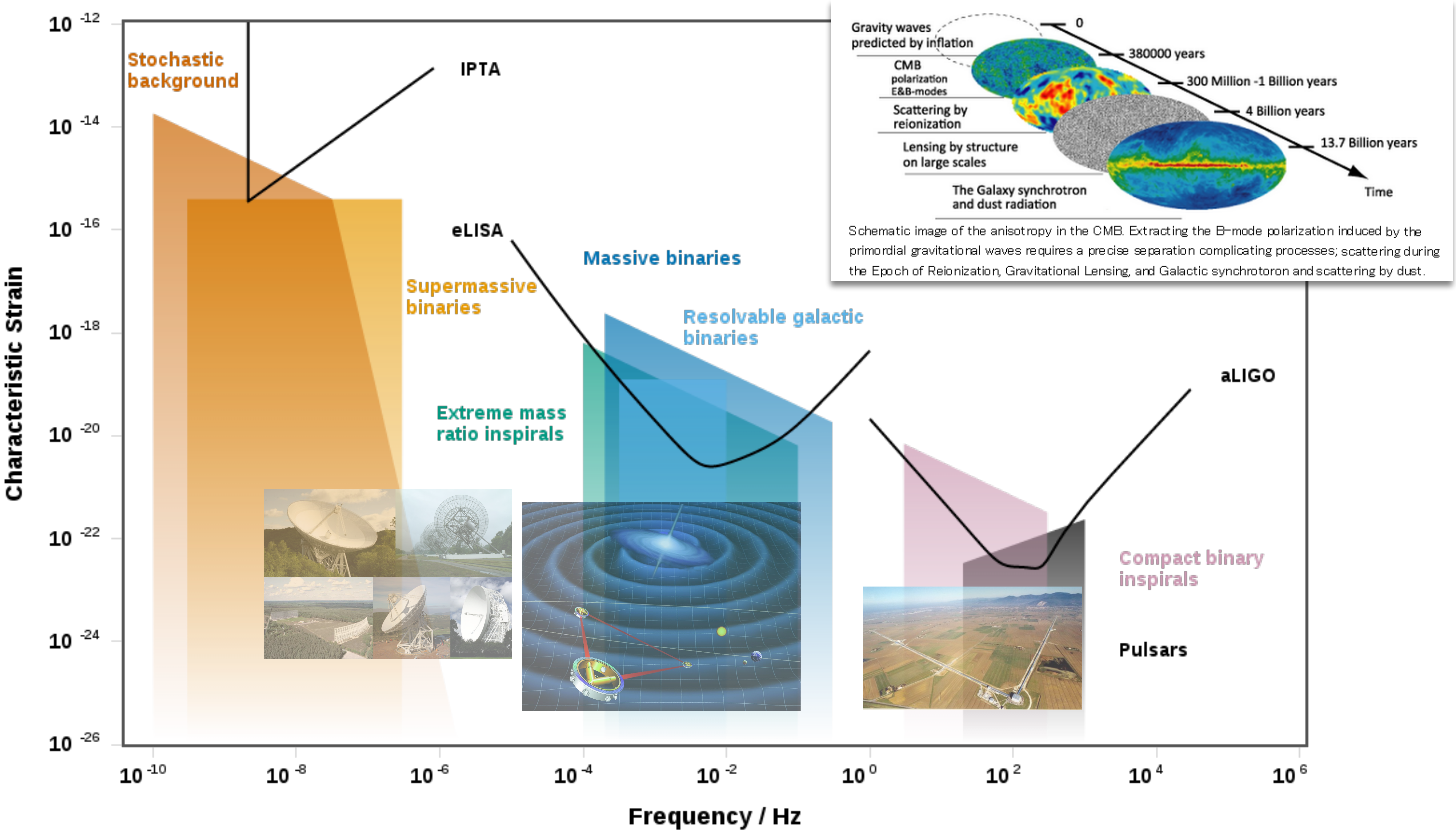
SOS ENATTOS, Lula, Italy



Einstein Telescope (ET)



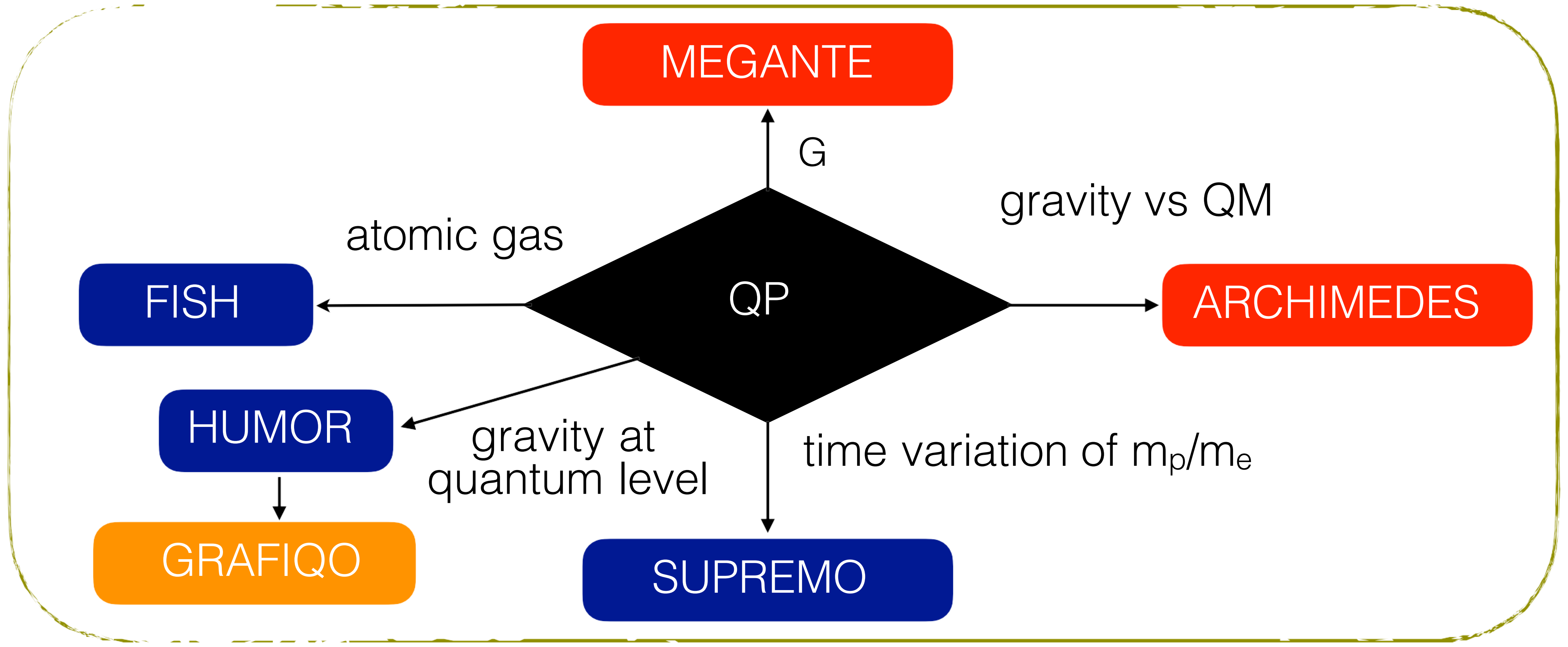
LISA - Laser Interferometer Space Antenna

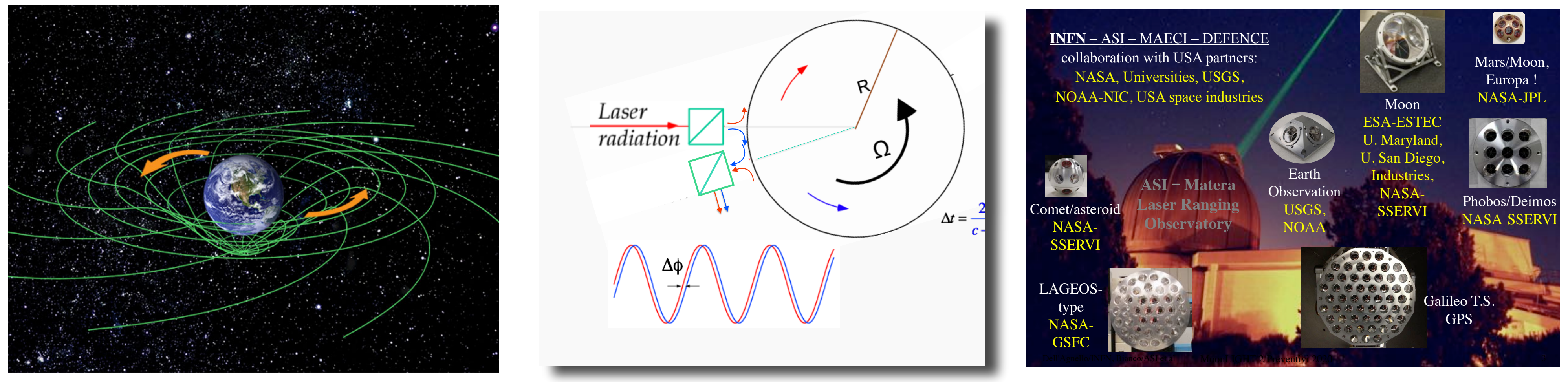


Schematic image of the anisotropy in the CMB. Extracting the B-mode polarization induced by the primordial gravitational waves requires a precise separation complicating processes; scattering during the Epoch of Reionization, Gravitational Lensing, and Galactic synchrotoron and scattering by dust.

future and very challenging future….

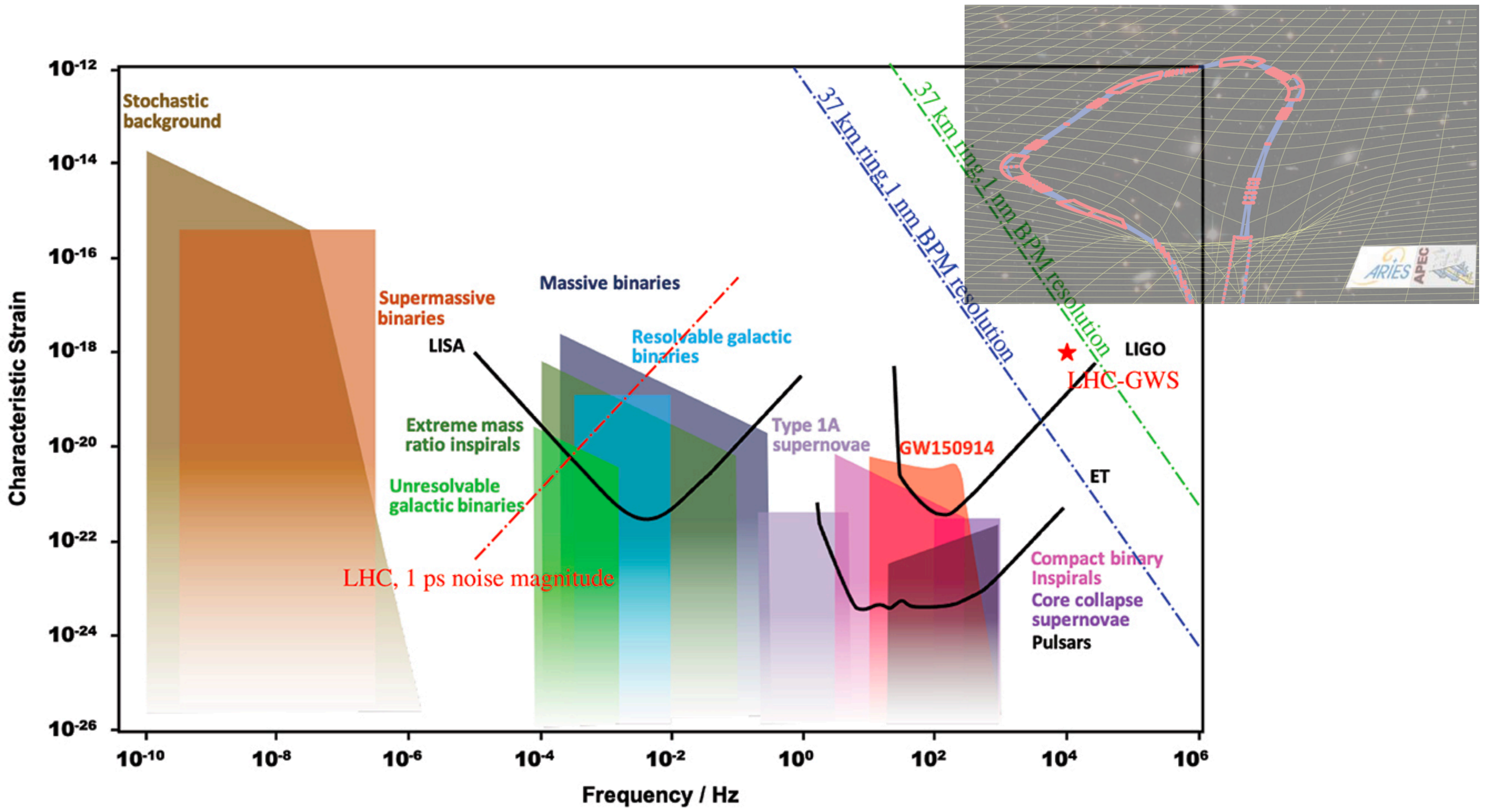
+ quantum experiments





general relativity test in weak filed (**GINGER**, **MOONLIGHT** etc)

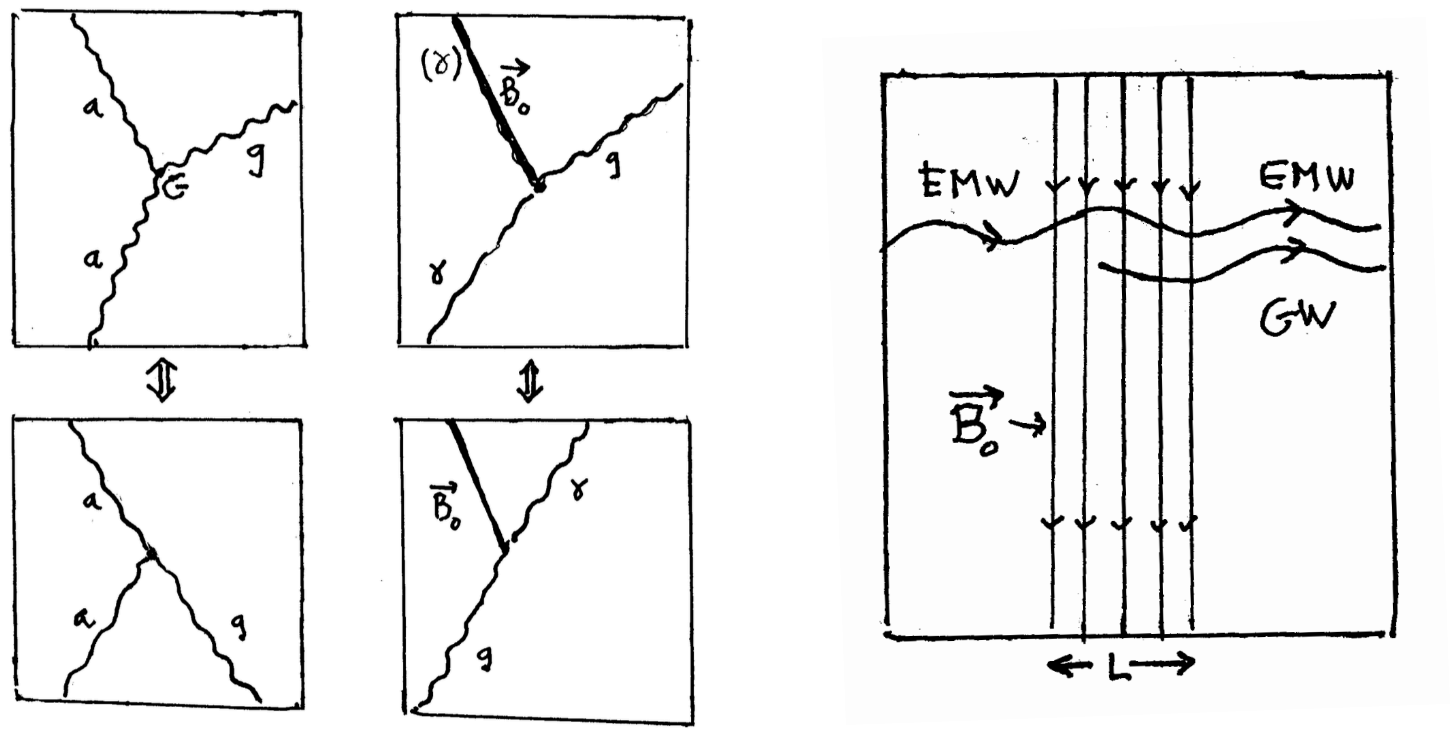
Storage Rings and Gravitational Waves "SRGW2021"
https://indico.cern.ch/event/982987/



GW passing through regions where beams circulate in storage rings, they should cause charged-particle orbits to seem to contract

$$h_{\mu\nu} = \frac{2G}{Rc^4}\ddot{I}_{\mu\nu}$$

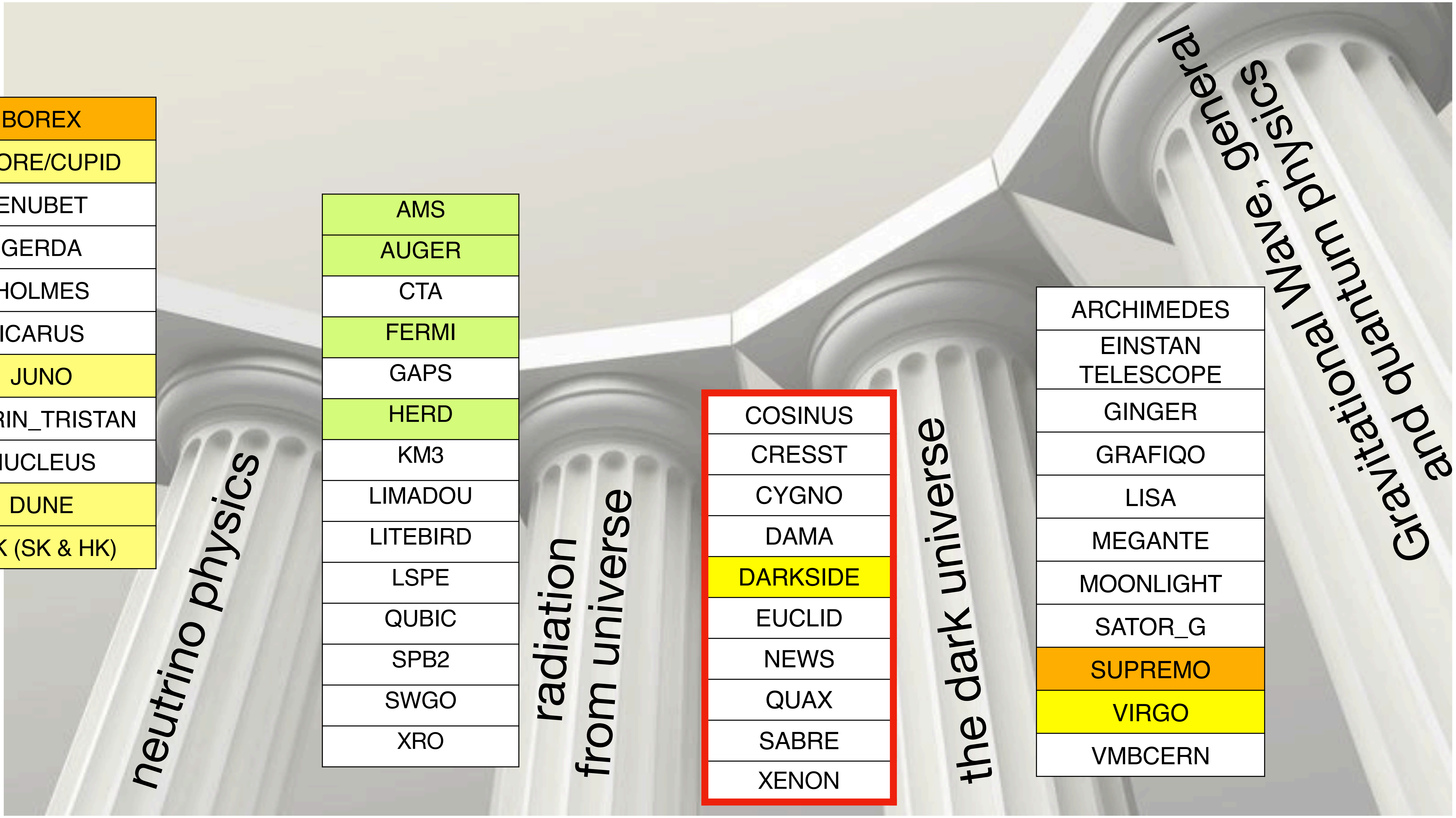
$2G/c^4 = 1.6\ 10^{-44}\ \mathrm{sec^2 kg^{-1} m^{-1}}$



today technology h ~ 9 10^{-39-35}

astro particle

the studies of elementary particles and their relation to astrophysics and cosmology



neutrino physics

- BOREX
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- ENUBET
- GERDA
- HOLMES
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- T2K (SK & HK)

radiation from universe

- AMS
- AUGER
- CTA
- FERMI
- GAPS
- HERD
- KM3
- LIMADOU
- LITEBIRD
- LSPE
- QUBIC
- SPB2
- SWGO
- XRO

the dark universe

- COSINUS
- CRESST
- CYGNO
- DAMA
- DARKSIDE
- EUCLID
- NEWS
- QUAX
- SABRE
- XENON

Gravitational Wave, general and quantum physics

- ARCHIMEDES
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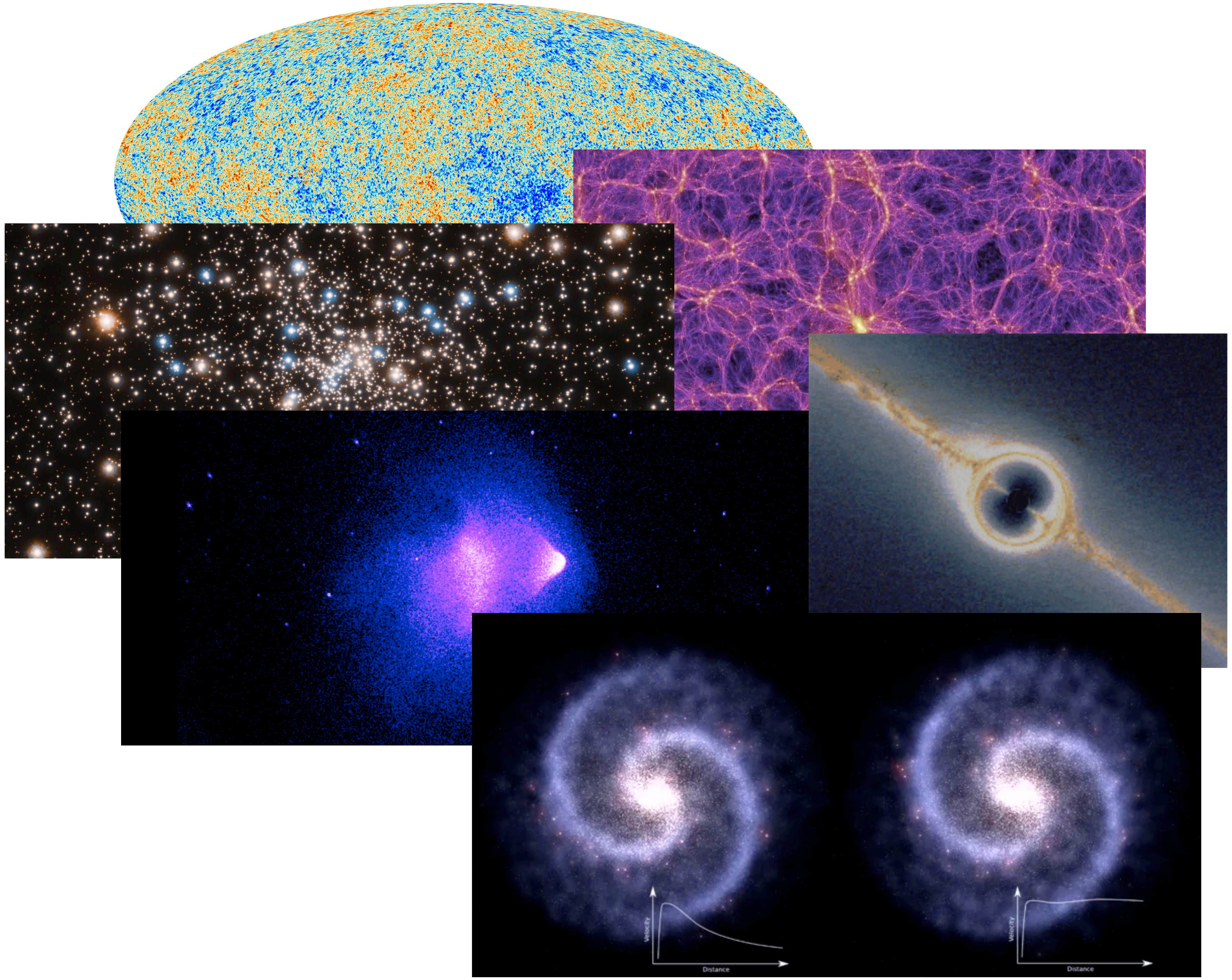
- GINGER
- GRAFIQO
- LISA
- MEGANTE
- MOONLIGHT
- SATOR_G
- SUPREMO
- VIRGO
- VMBCERN

dark matter footprint

dark matter: the ~85% of the matter in the universe that we can't "see"

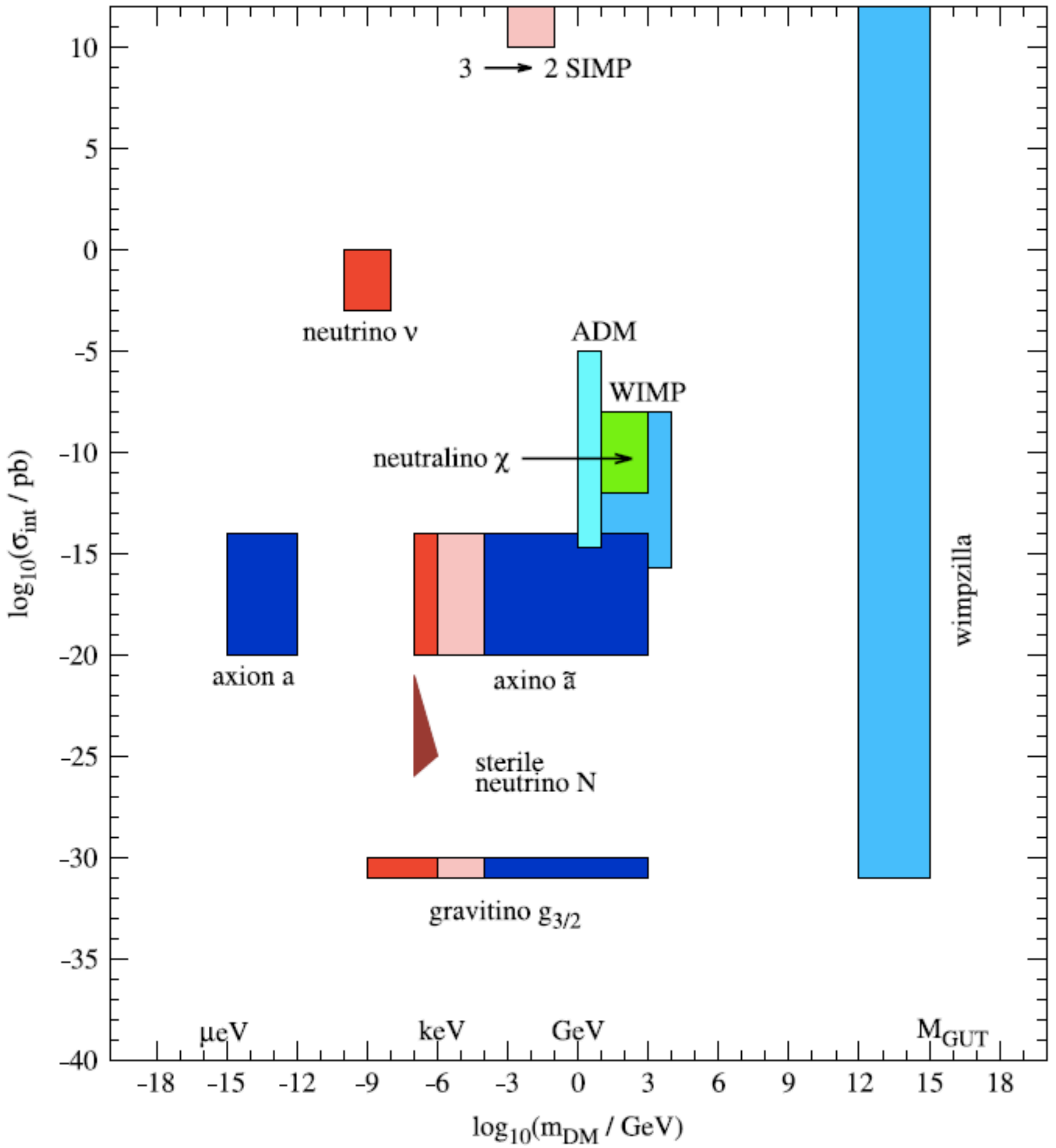
COSINUS
CRESST
CYGNO
DAMA
DARKSIDE
EUCLID
NEWS
QUAX
SABRE
XENON

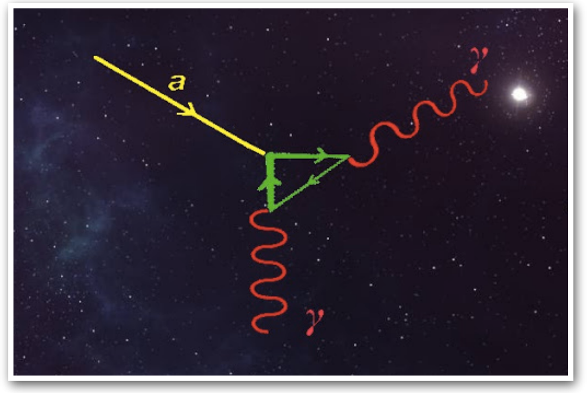
- Galaxy Rotation Curves
- Velocity Dispersions
- Galaxy Clusters
- Gravitational Lensing
- CMB - Cosmic Microwave Background
- Structure Formation
- Bullet Cluster
- Type Ia supernova distance measurements
- Sky surveys and baryon acoustic oscillations
- Redshift-space distortions
- Lyman-alpha forest

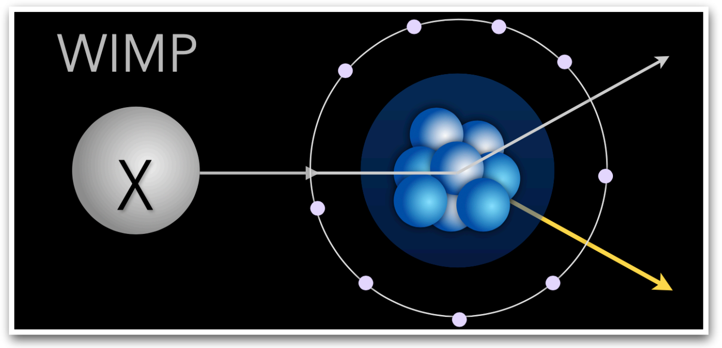


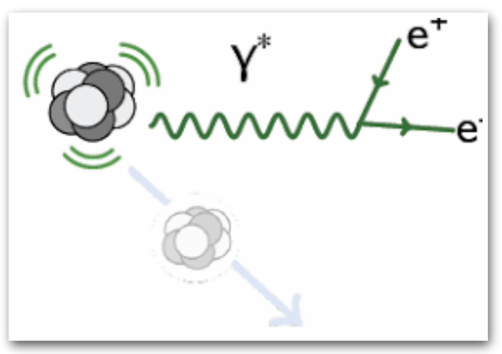
it’s another particle…

- it must have **mass** to interact with gravity
- it must be **stable** to explain today abundance (T>>10^{17} sec) and possibly relic from the early universe
- it must be **neutral** with no **electromagnetic** interaction
- it must be cold, not too warm (like neutrino) to not escape from mass cluster (p/m<<1 at CMB formation)
- it could be **axions**, particles with mass of 10^{-3}-10^{-5} eV, no charge, no spin, needed to solve the not observed CP violation in strong interaction.
- it could be **WIMPS**, particles with mass of 10^{9}-10^{12} eV, weakly interacting, motivated by SUSY and “**freeze out** miracle” that predict the relic abundance starting form the weak force cross section properties.
- it could be **gravitino**, **sterile neutrino** (~keV), **dark photons** (~ GeV)
- it could be **WIMPzillas** with mass of 10^{-21}-10^{-28} eV produced at the beginning of the universe due to the large energy available at that epoch





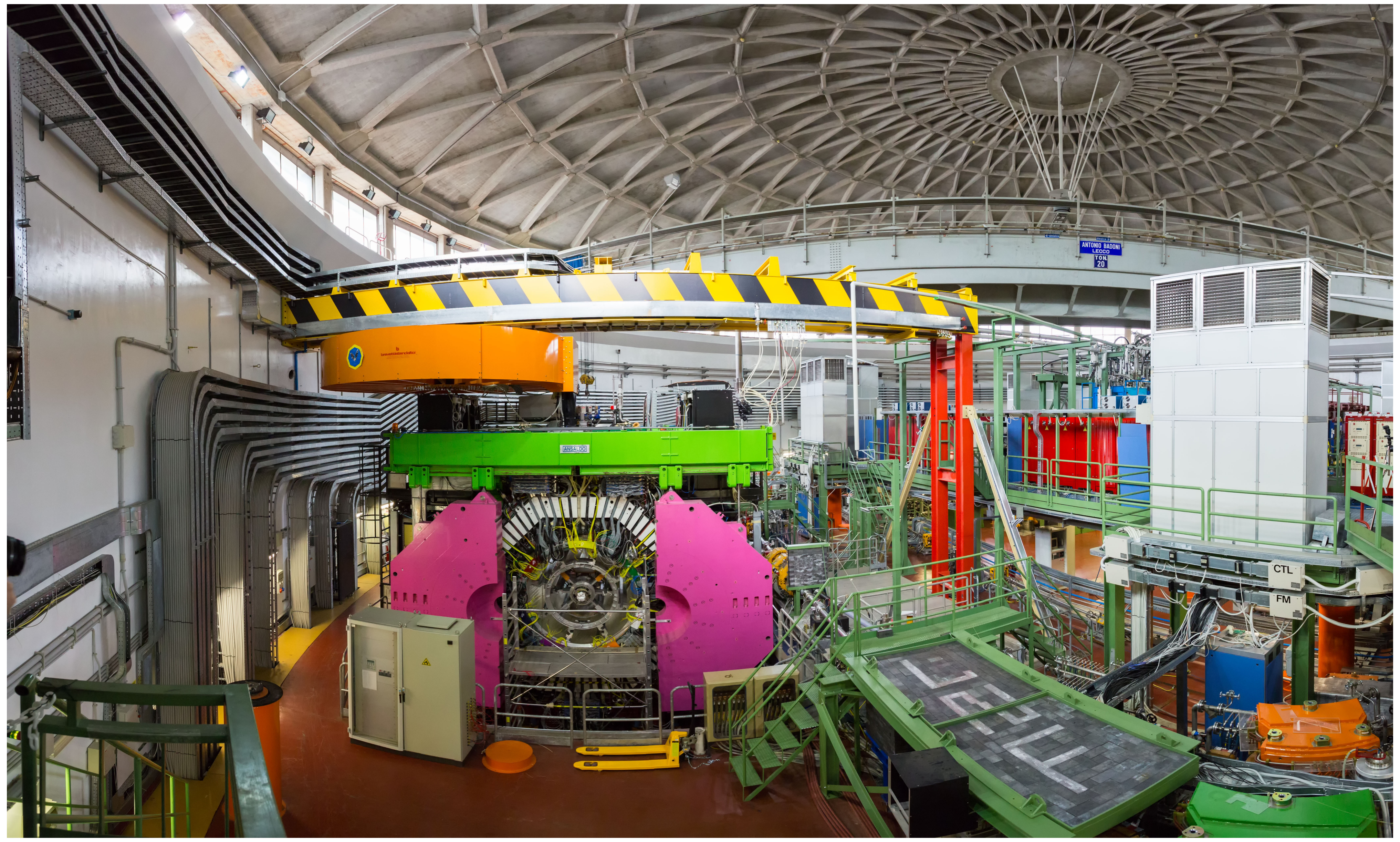




FLASH

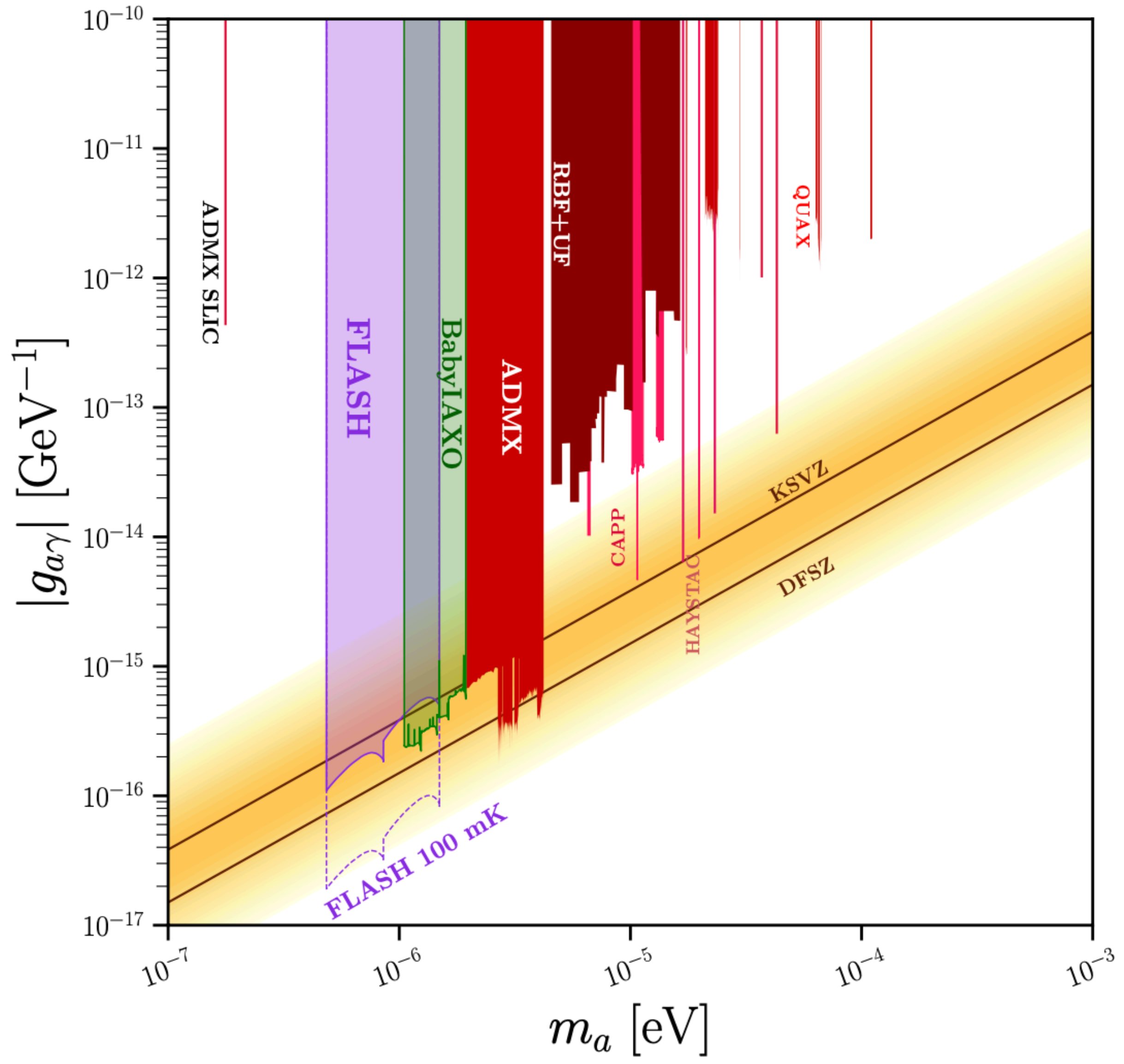
FINUDA Magnet for Light Axion SearcH at 100-300 MHz

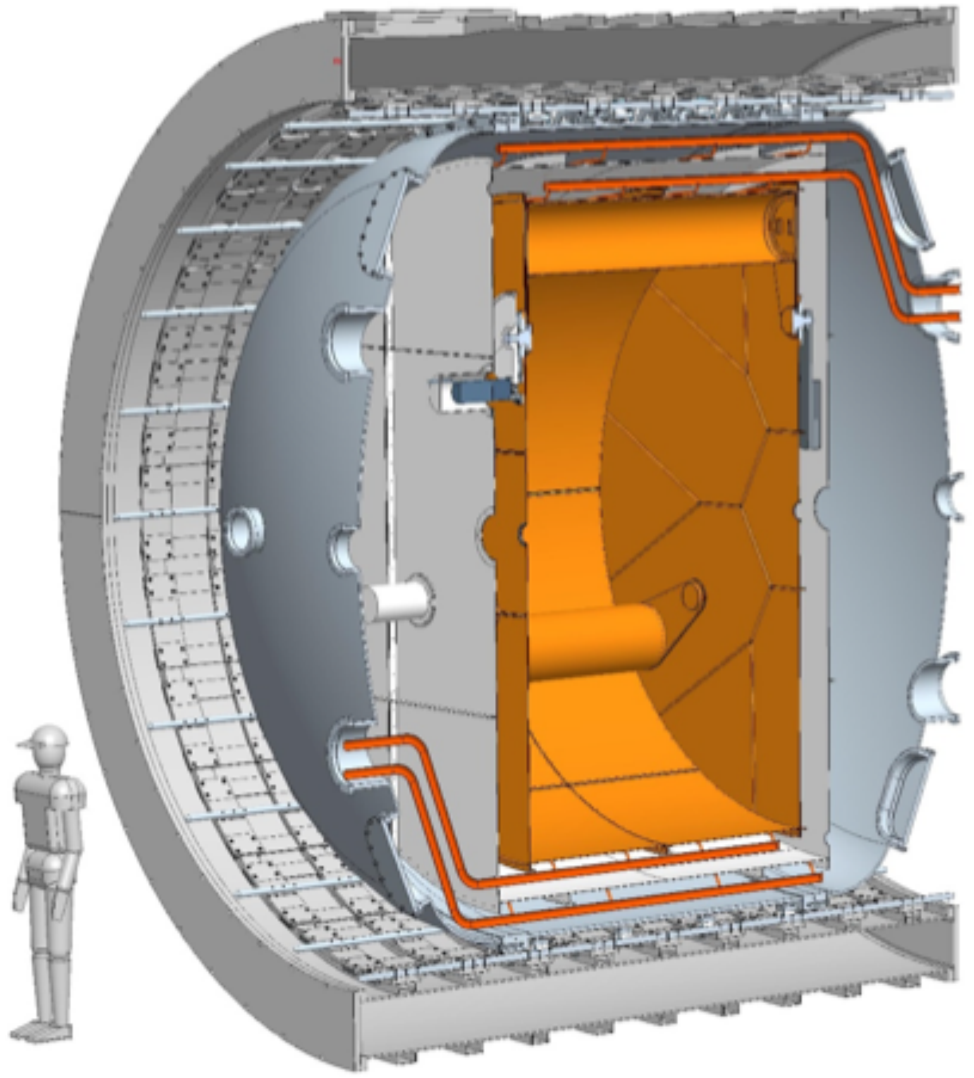
Recycling of the 1.1T, 3 m diameter, magnet of FINUDA experiment for a haloscope operating at 100 to 300 MHz



Magnet test foreseen in 2023

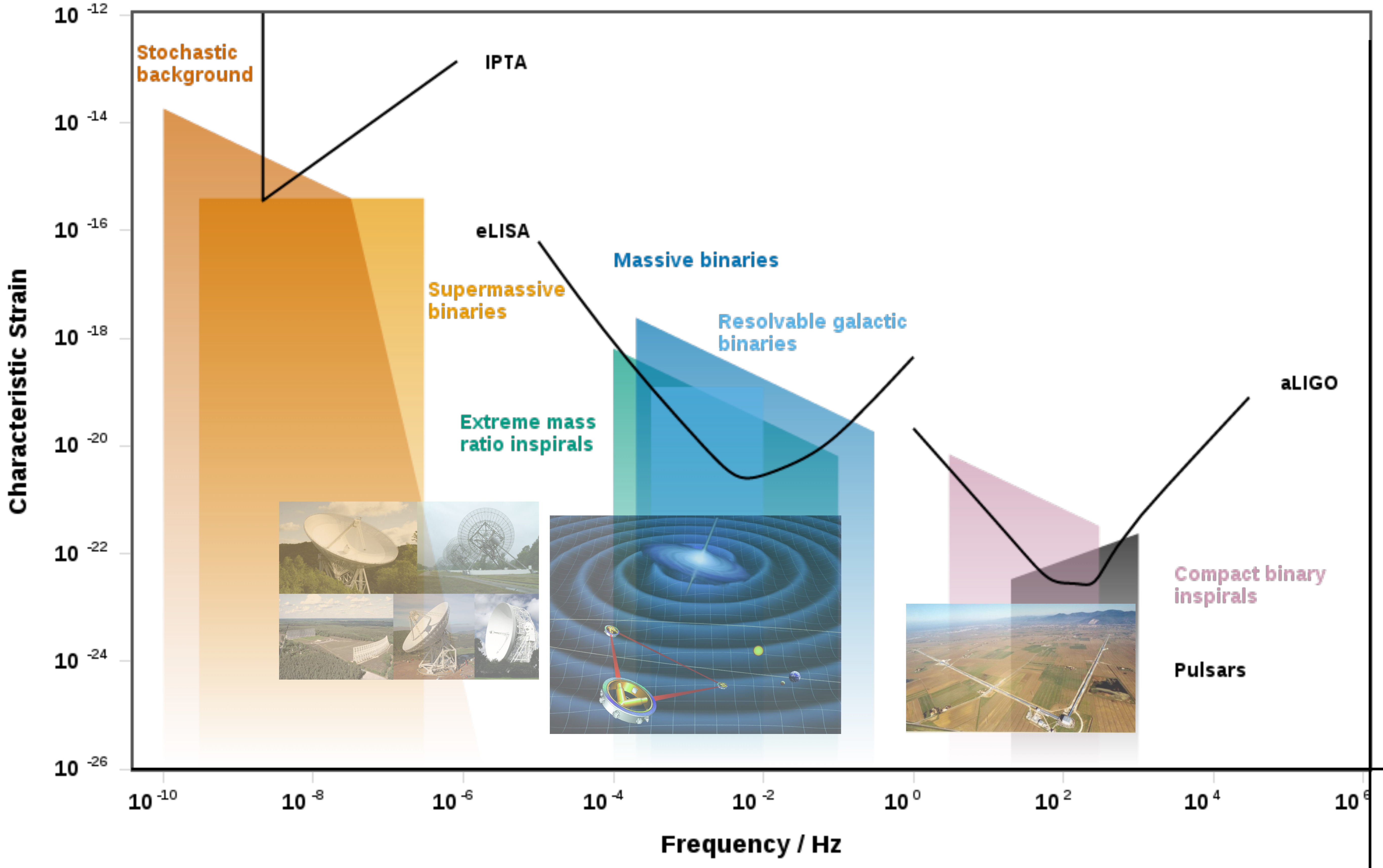
- Search of galactic axions in the mass range 0.5-1.5 μeV
- Large volume RF Cavity (4 m^3)
- Moderate magnetic field (1.1 T)
- Copper rf cavity Q~500,000
- T 4.5 K

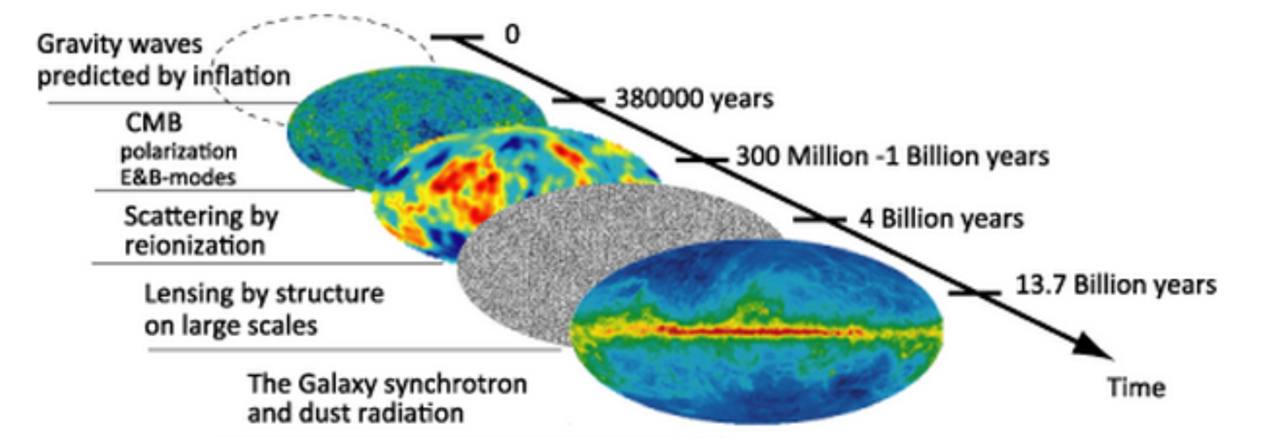




KLASH CDR arxiv:1911.02427

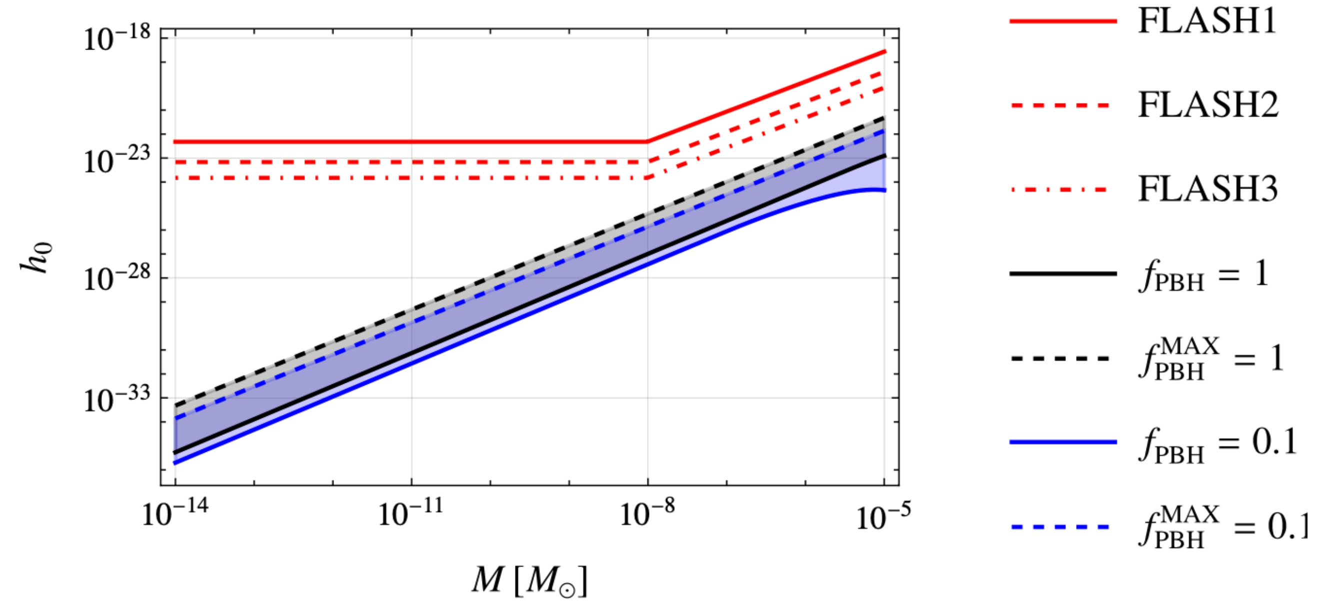
HFGW

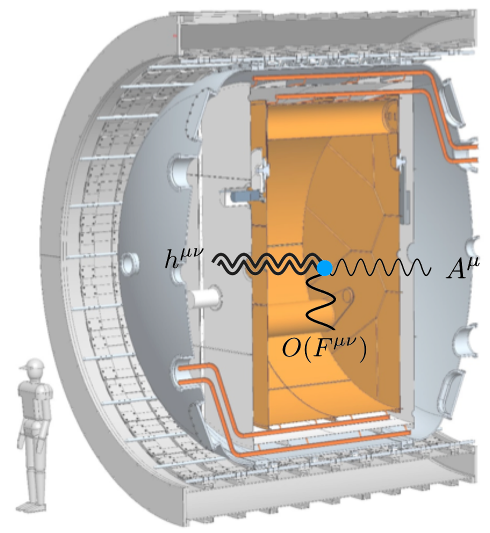




Schematic image of the anisotropy in the CMB. Extracting the B-mode polarization induced by the primordial gravitational waves requires a precise separation complicating processes; scattering during the Epoch of Reionization, Gravitational Lensing, and Galactic synchrotron and scattering by dust.

PBH - Primordial Black Hall





HFGW (10^5 - 10^{-8} Hz)
Haloscope,
FLASH, etc.

$< 10^{-35}$

Physics Opportunities at 100-500 MHz Haloscopes
https://indico.cern.ch/event/1115163/

the WIMPs production and detection

Early Universe “frese out” miracle

1) In the hot, early Universe DM WIMP is in thermal equilibrium with SM particles

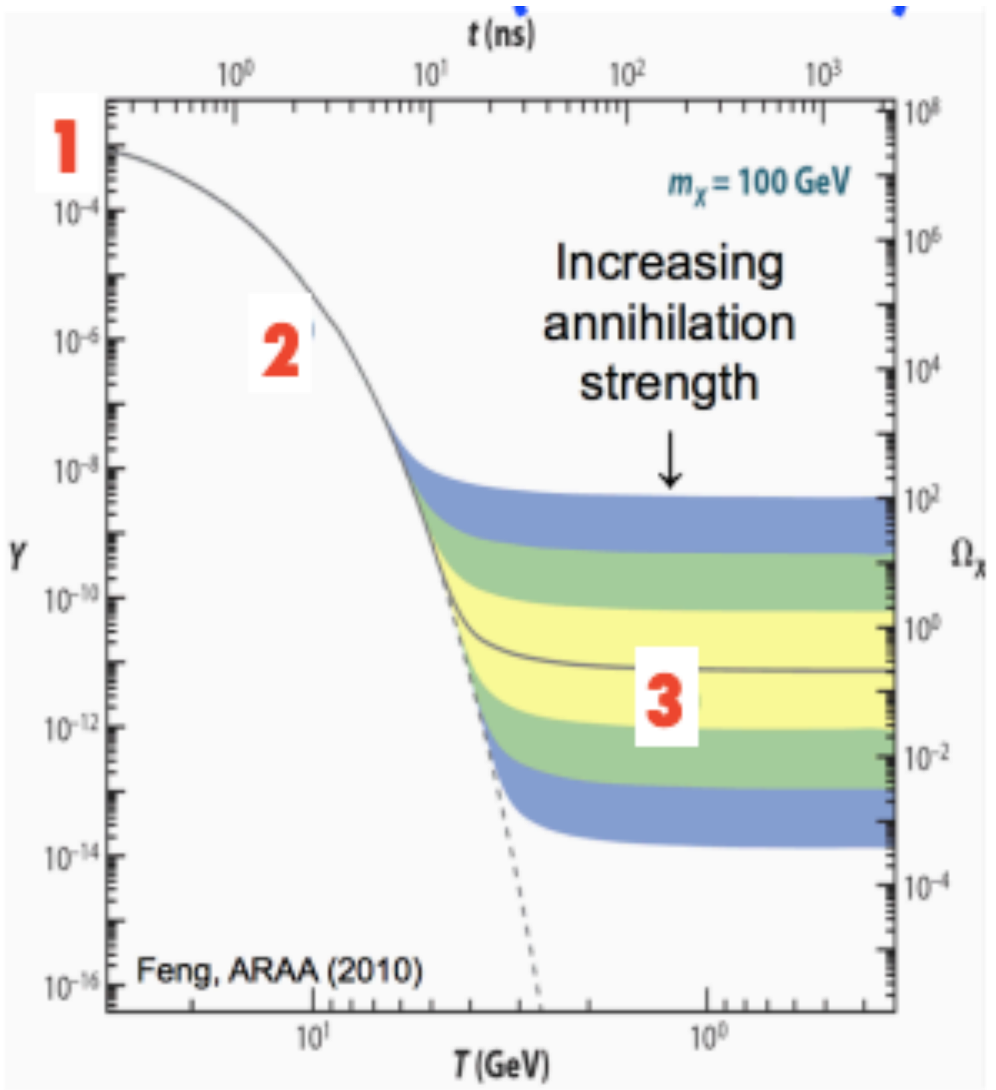
$$XX \leftrightarrow \bar{q}q$$

2) When the Universe starts to cool down, DM decouples from SM particles

$$XX \not\rightleftarrows \bar{q}q$$

3) When the Universe starts to expand, DM today relic density is determined

$$XX \not\rightleftarrows \bar{q}q$$

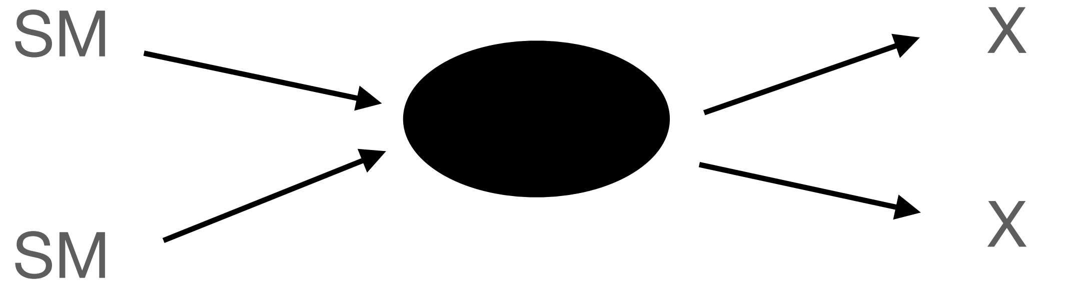


In order to reproduce the measured DM relic density, WIMP cross section and mass must be of the order of the weak scale

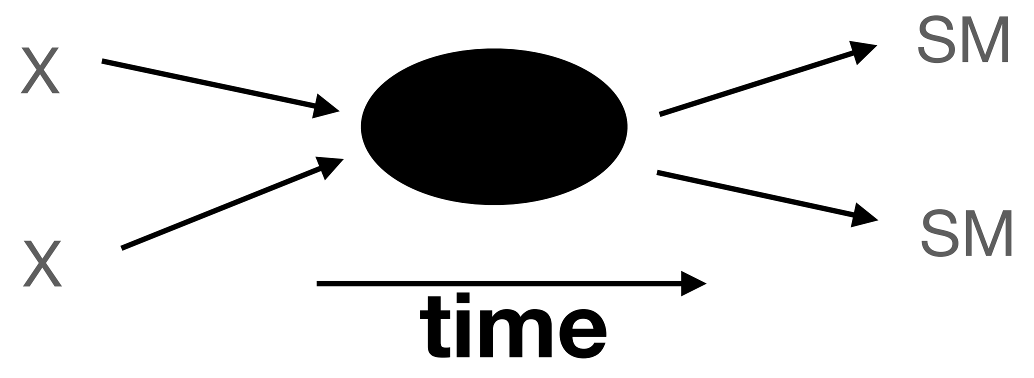
WIMP miracle

$$\Omega_X \propto \frac{1}{\langle \sigma v \rangle} \sim \frac{m_X^2}{g_X^4}$$

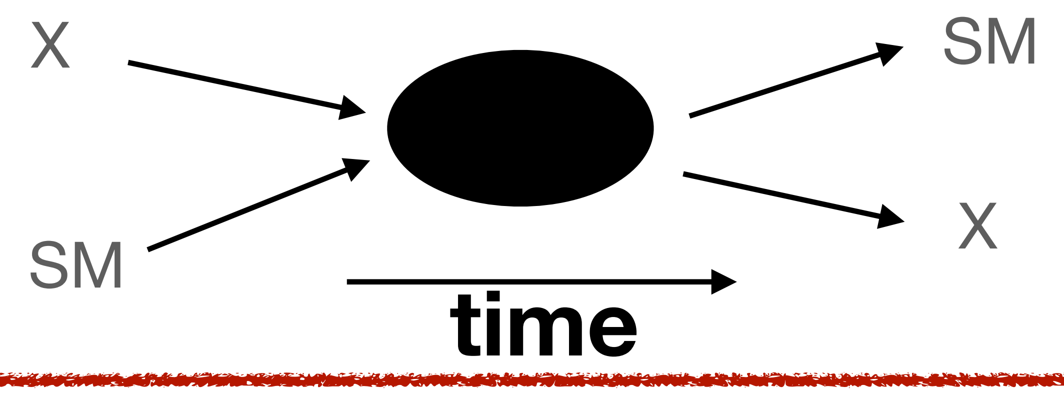
production



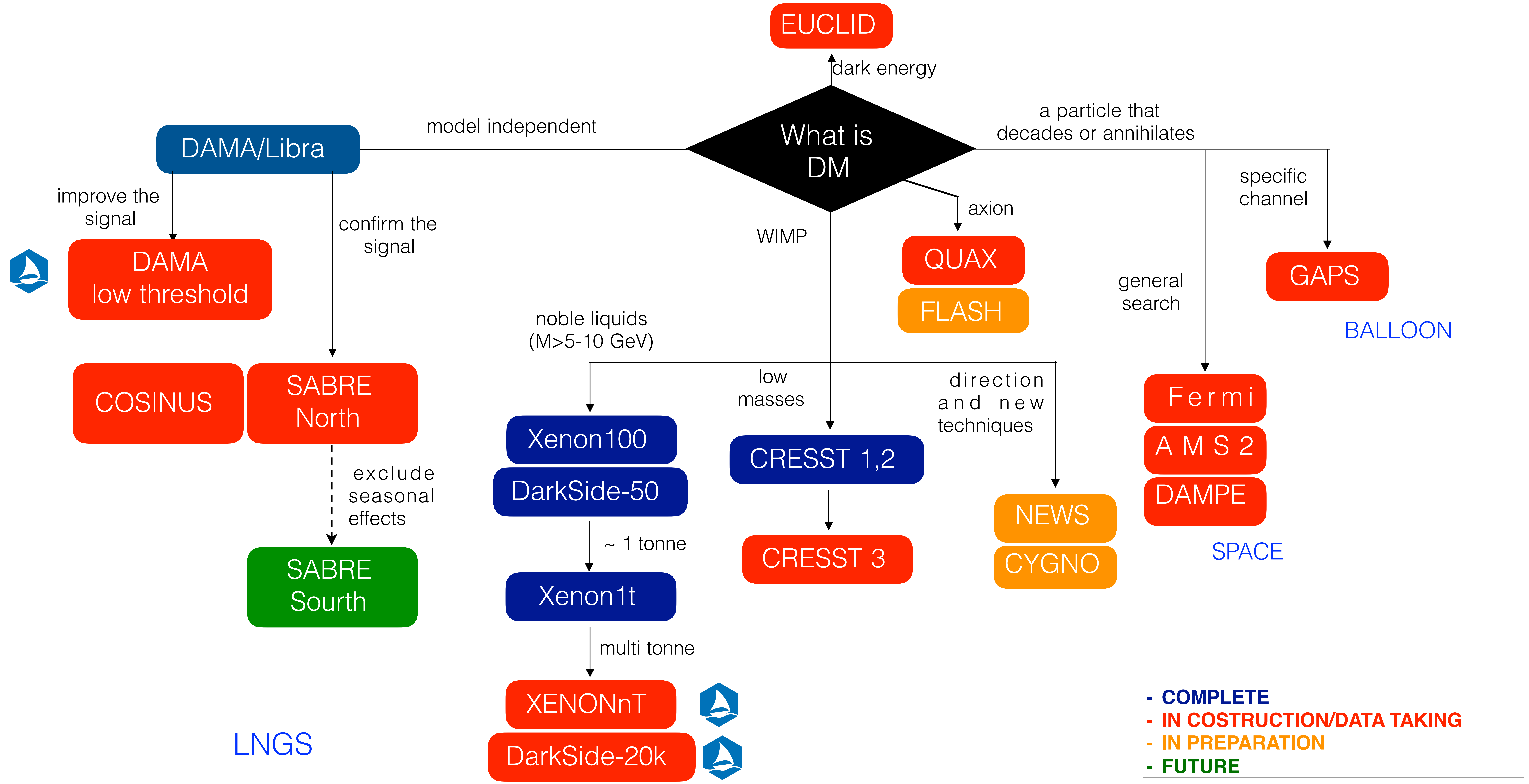
indirect detection



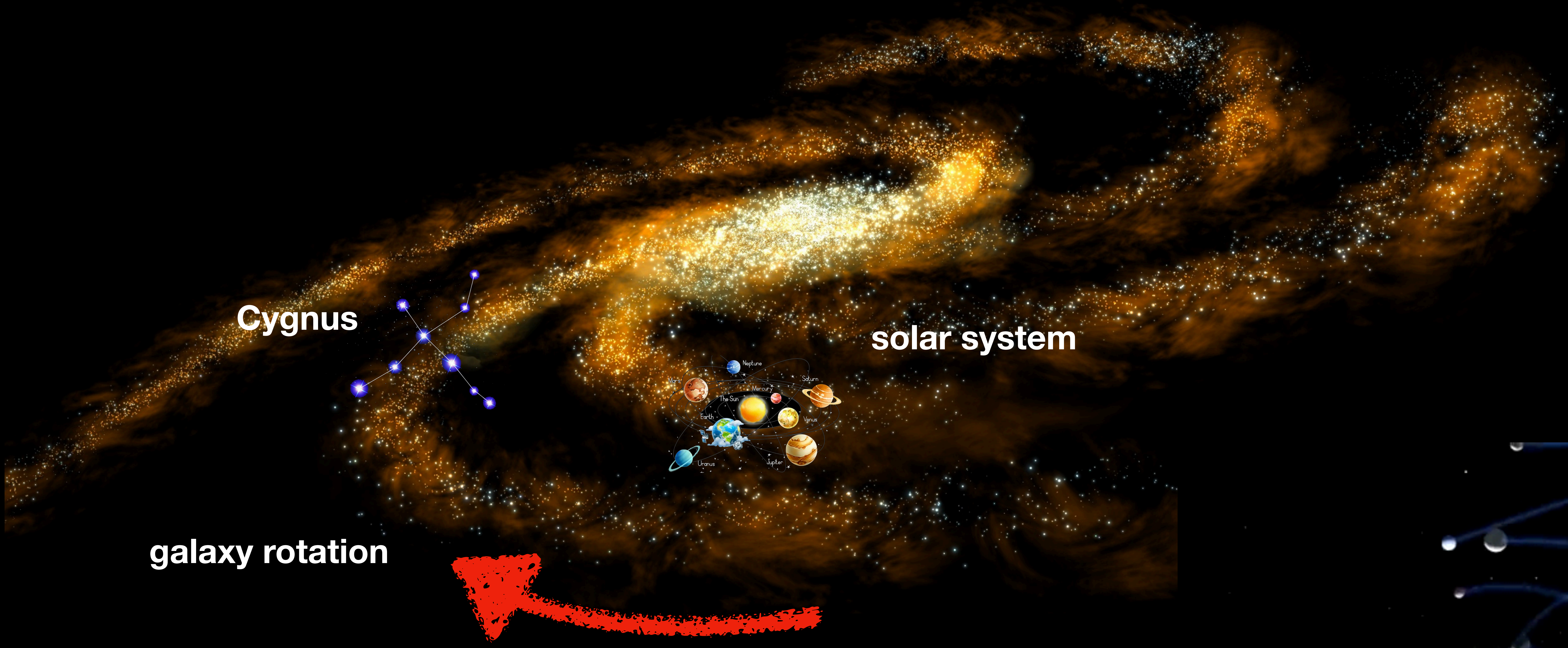
direct detection

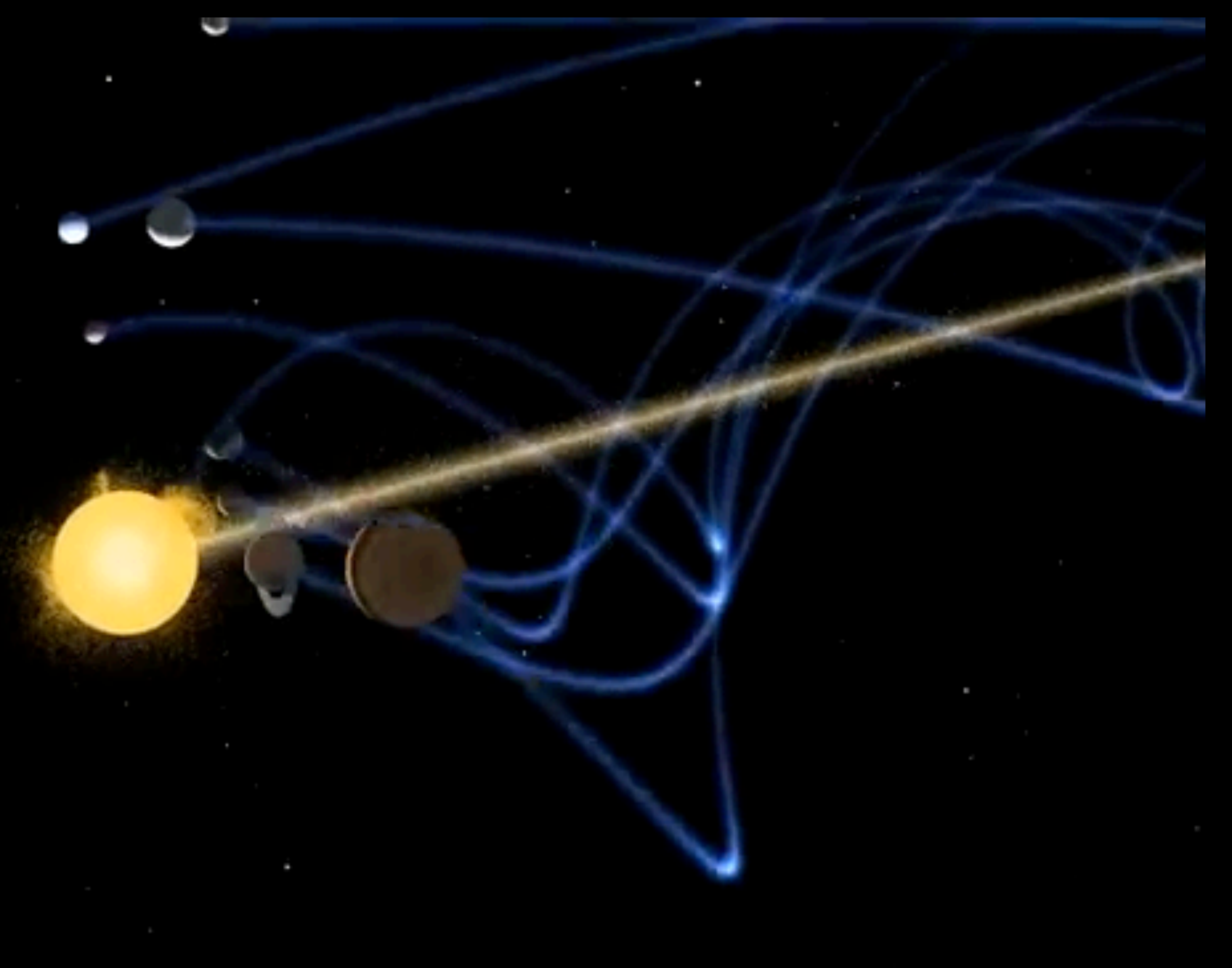


the dark universe



the dark matter when living on the earth

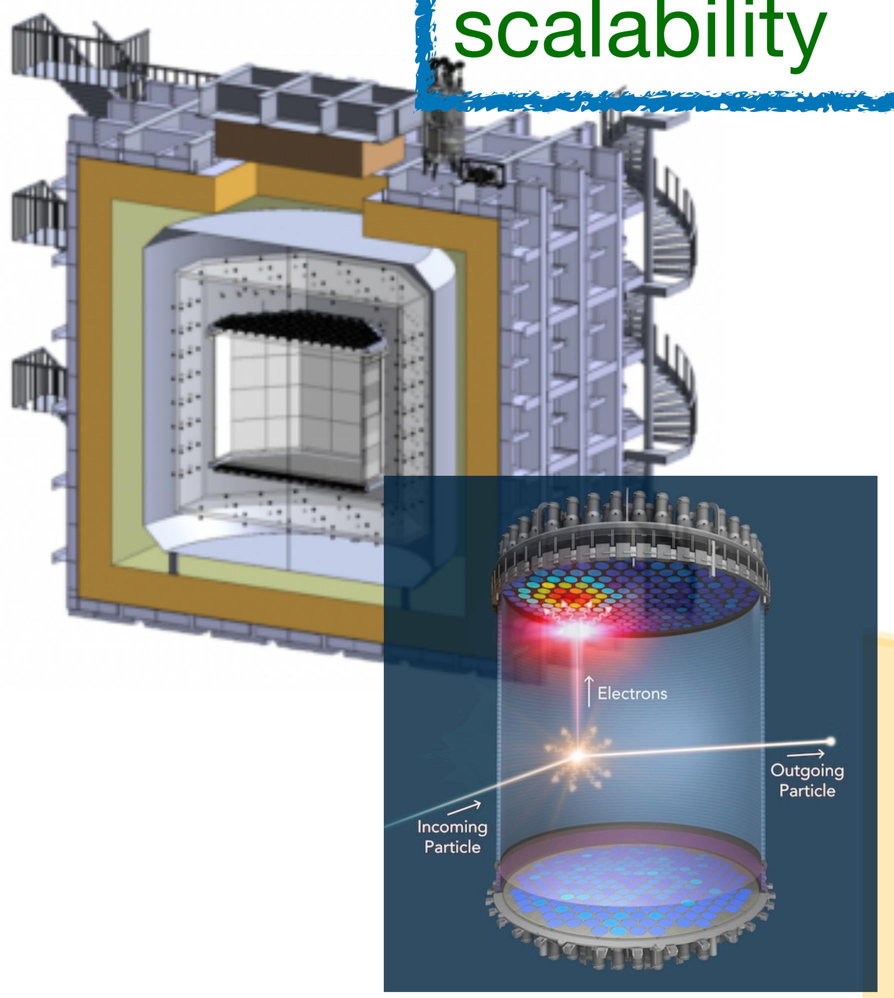




detector technology

gassous
low (O 100 eV) threshold
just some ideas to increase sensitivity and scalability

liquid, cryogenic
medium (O 1000 eV) threshold
high sensibility and scalability



Semiconductors:
Ge: CDEX, COGENT
Si: DAMIC, SENSEI

Noble Gas
CF4: DRIFT, DMTPC, MIMAC, Newage, NEWS-G

Superheated liquids:
C_3F_8, CF_3I: PICO

2-phase noble liquids:
- LXe: XENON 1t, LUX/LZ , Panda-X, DARWIN
- LAr: ArDM, Darkside, ARGO

Semiconducting calorimeters:
Ge, Si:
SuperCDMS, Edelweiss III

Ionization
~ 10 %

~1-5 %
fast signal
Scintillation

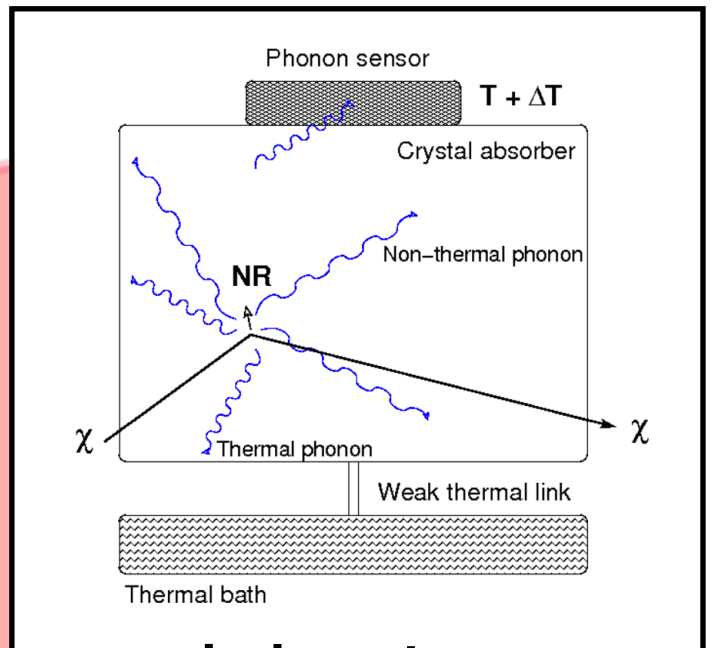
~100 %
slow signal
Phonons

Inorganic scintillators:
NaI: DAMA/LIBRA, ANAIS, COSINE, SABRE
CsI: KIMS

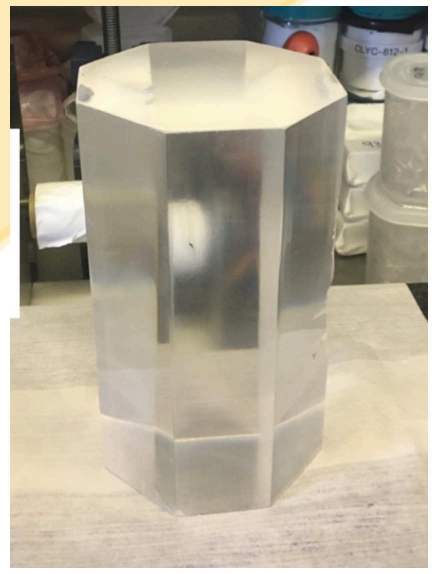
Single-phase noble liquids:
LAr: DEAP-3600
LXe: XMASS

21.03.19

Scintillating calorimeters
$CaWO_4$: CRESST III
NaI: COSINUS



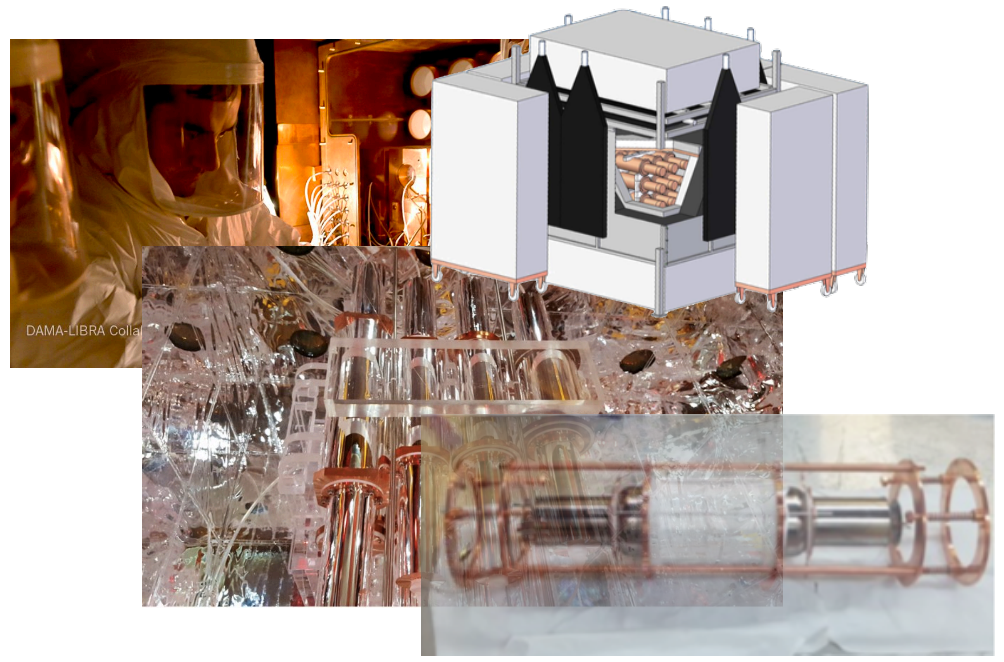
bolometers



solid, cryogenic
very low (O 10 eV) threshold
limited mass and scalability

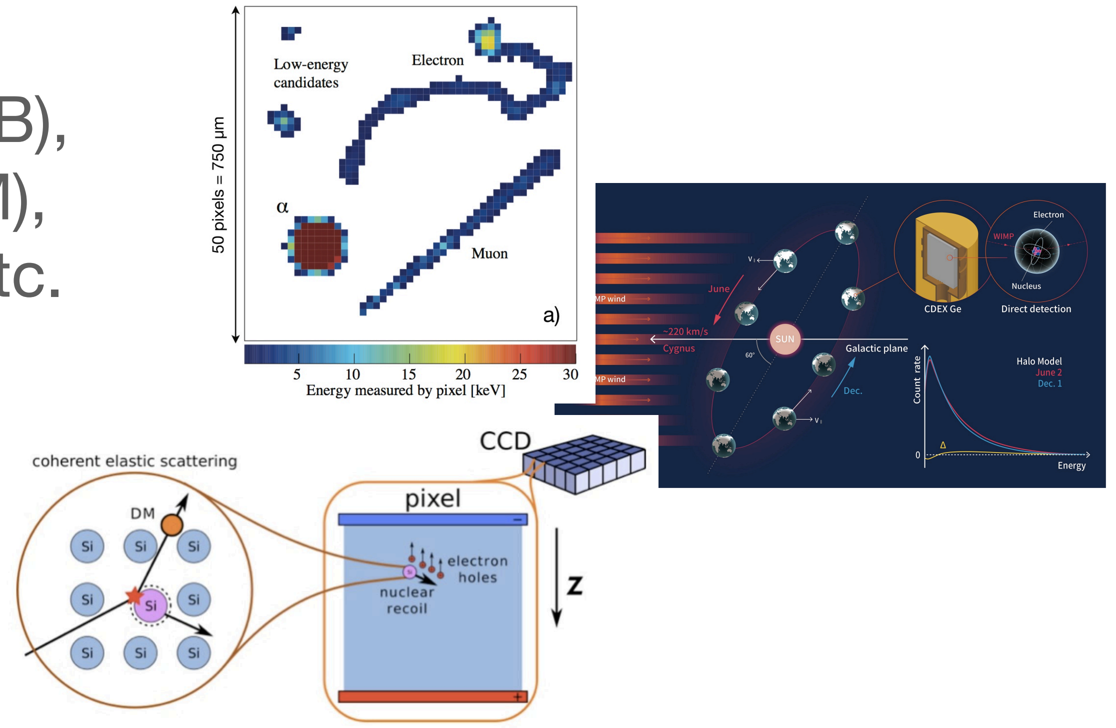
dark matter scenario

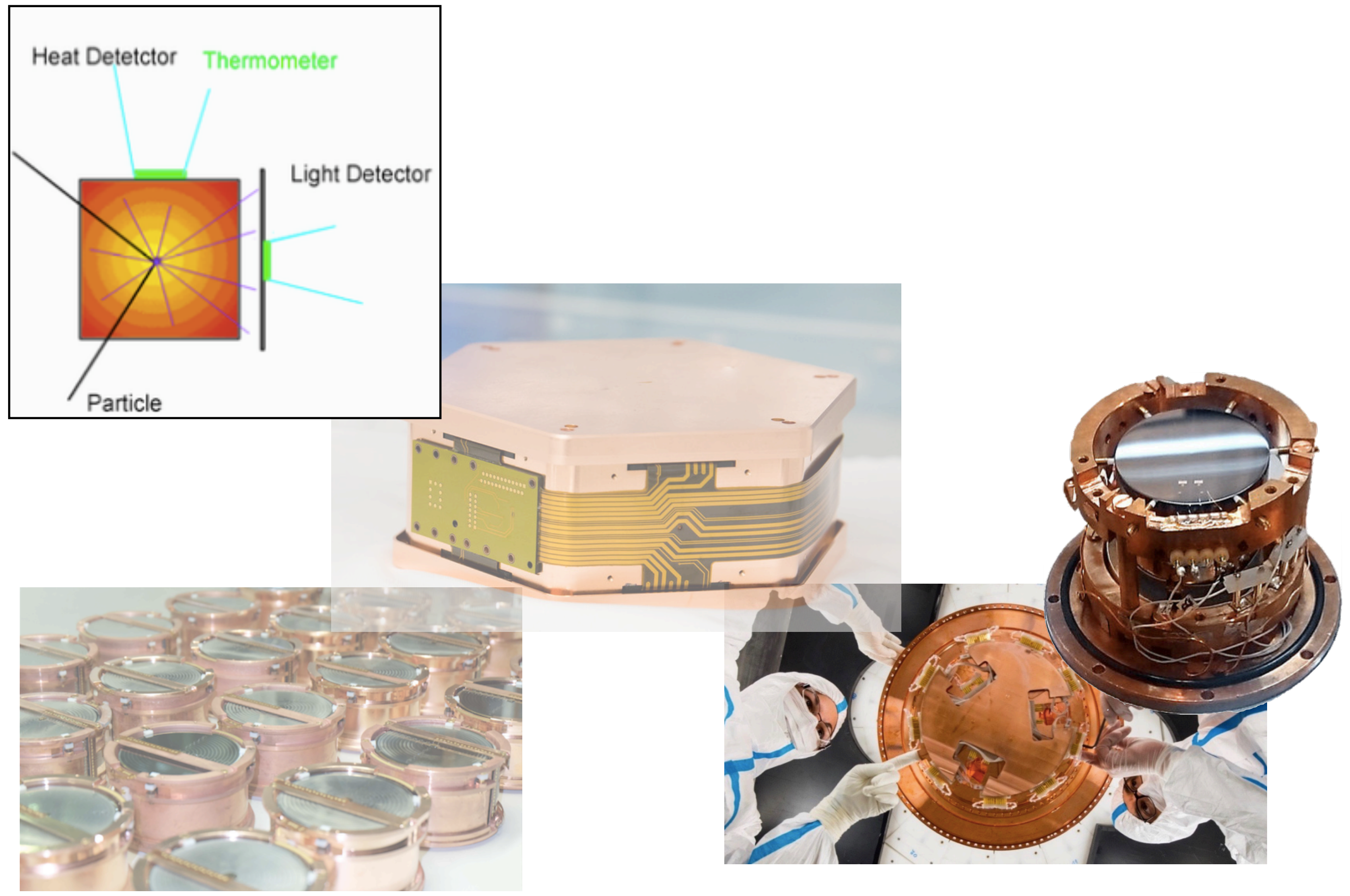
solid —> crystals —> gases —> liquid



DAMA (LNGS), **COSINE** (Korea),
SABRE (LNGS/LSC), ANAIS (LSM), etc

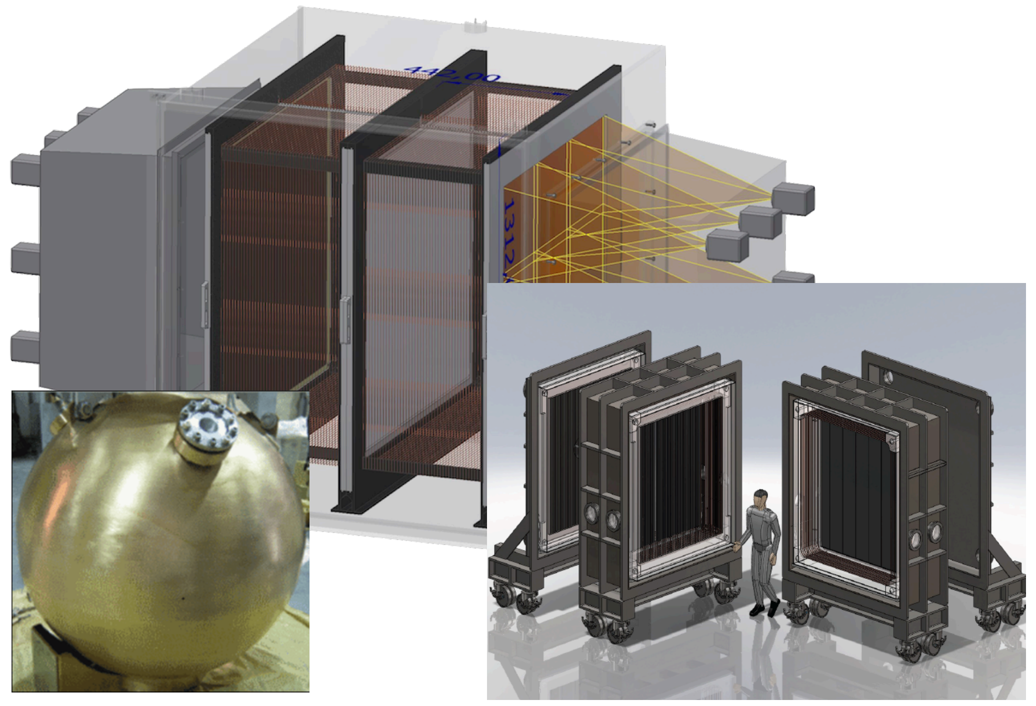
DAMIC (SNOLAB),
DAMIC-M (LSM),
CDEX (CJPL), etc.

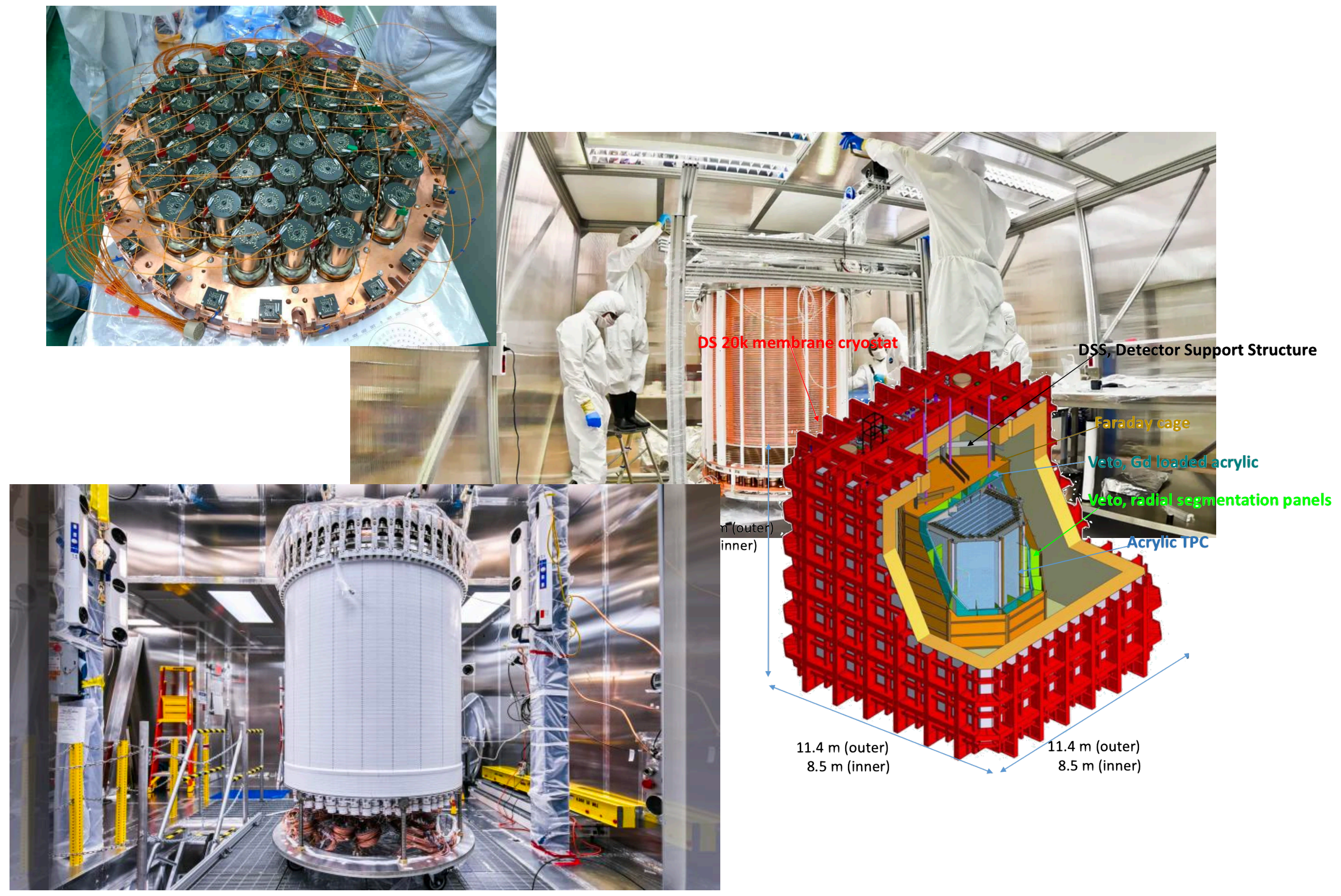




SuperCDMS (SNOLAB), EDELWEISS (LSM), **CREST**,
COSINUS (LNGS), etc

DRIFT (Bulby), **CYGNO** (LNGS),
TREX (LSC), NEWS-G (SNOLAB), etc



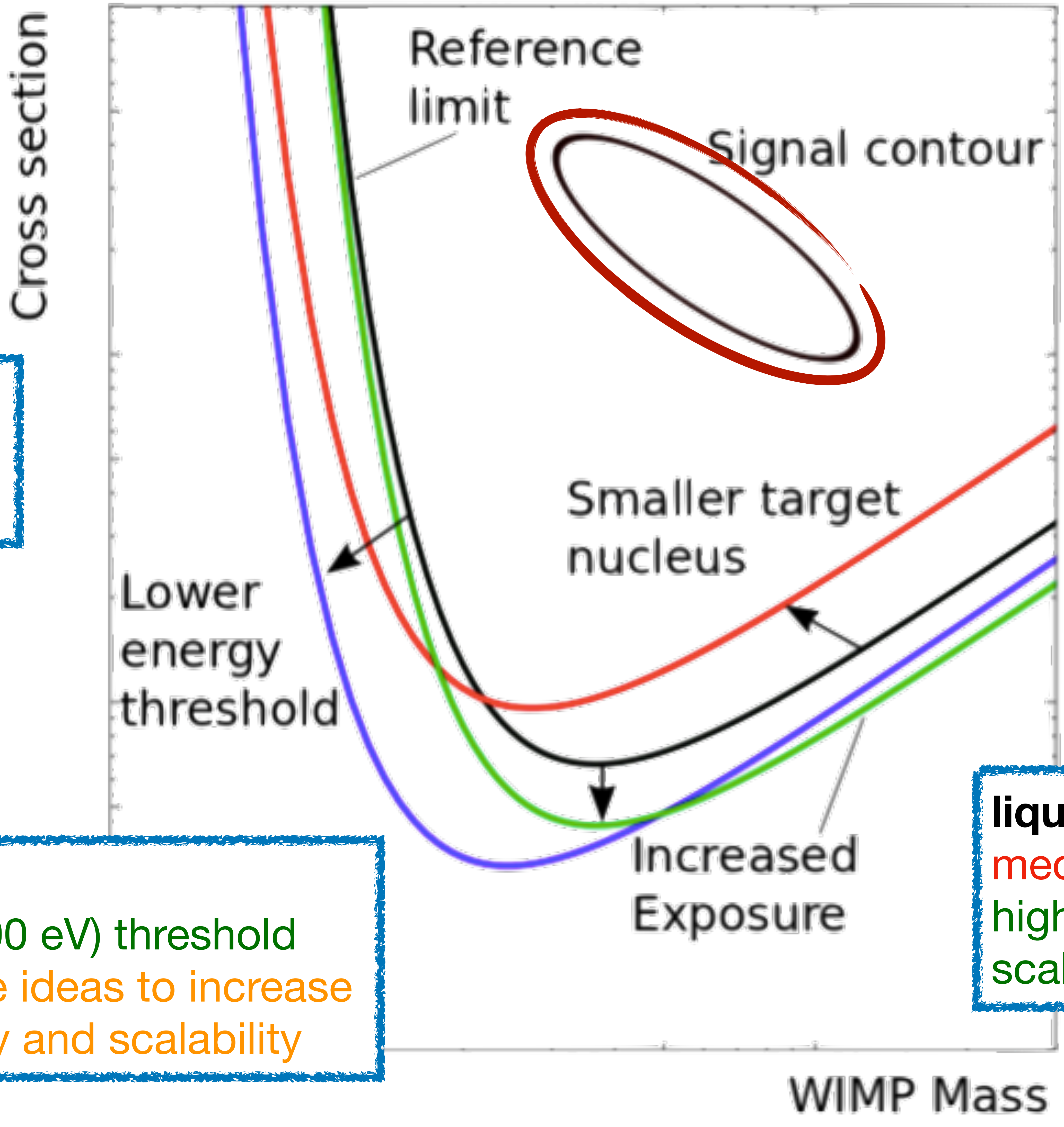


LUX (SNOLAB), **XENON** (LNGS),
DARKSIDE (LNGS), PANDAX (CJPL), etc.

0.1 | 1 | 10 **dark matter mass threshold (GeV)**

detector sensitivity characteristics

solid, cryogenic
very low (O 10 eV) threshold
limited mass and scalability



gassous
low (O 100 eV) threshold
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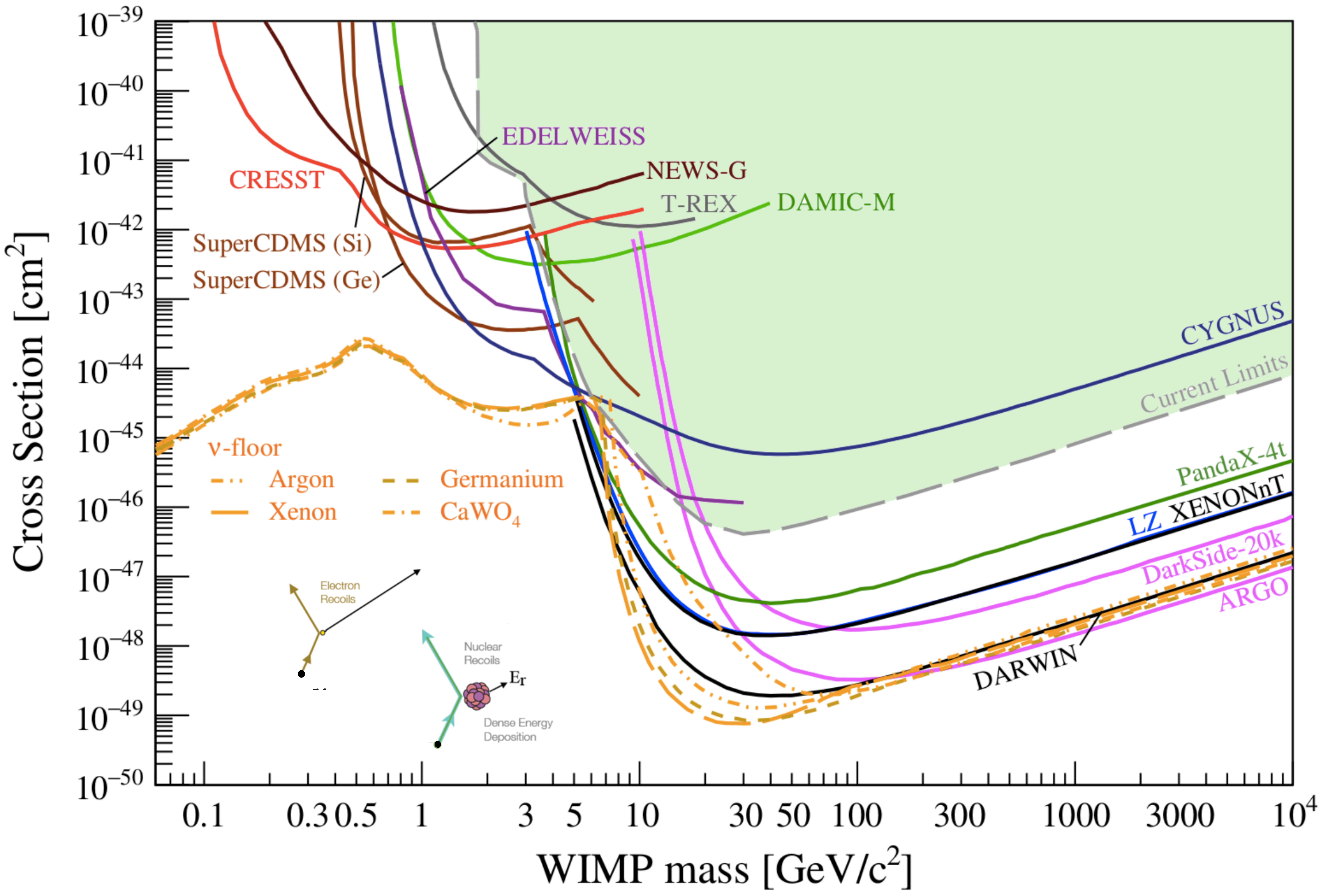
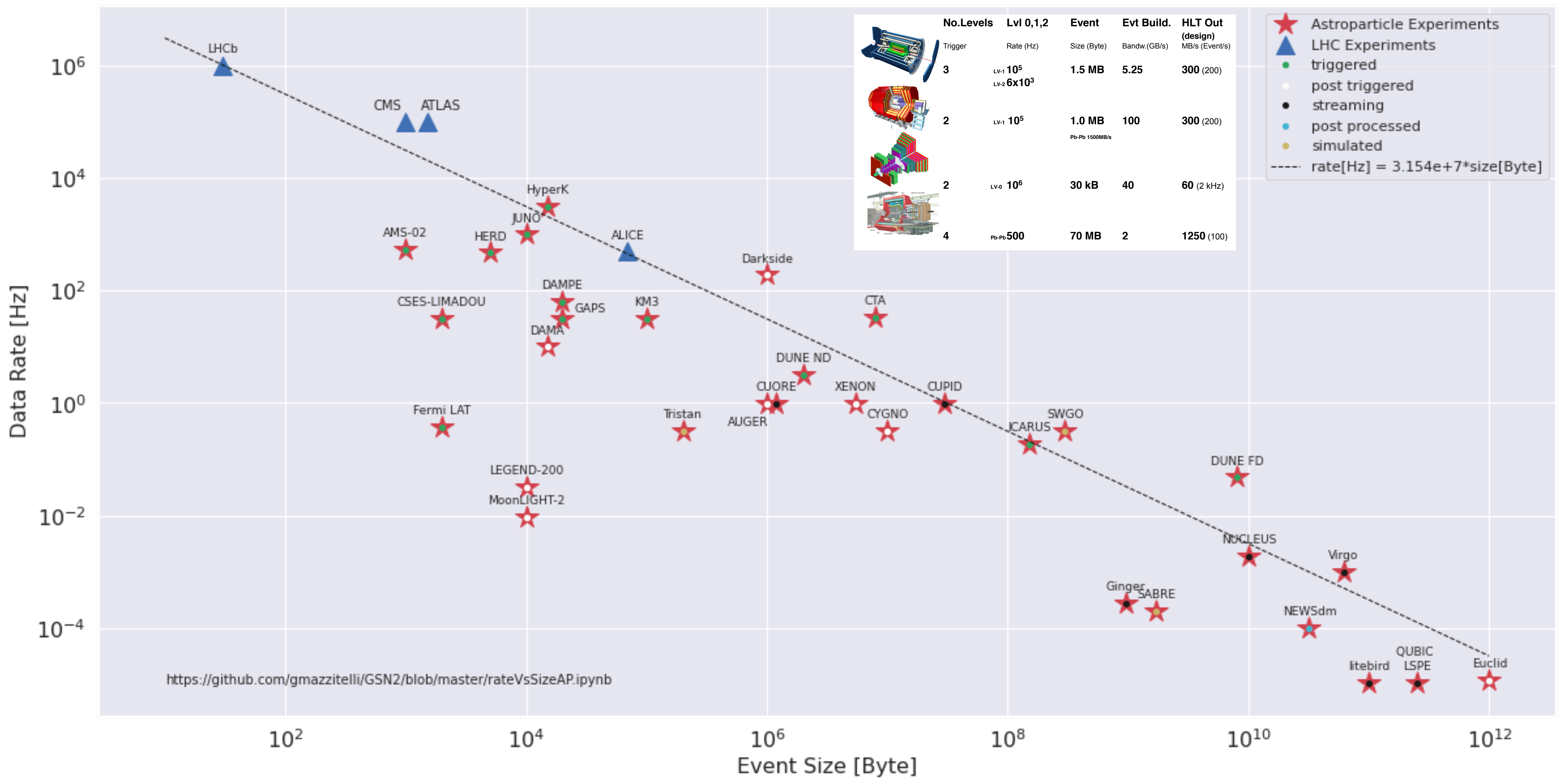
where we are going…

APPEC Dark Matter Report 2021 (to be published) submitted to APPEC for final approval



computing challenges

in astro-particle experiments



bigger rather then faster!
astroparticle experiments are characterised by having a **different throughput** respect to typical HEP experiments, anyhow following a scaling law that underline how are anyway demanding in the overall process.

astroparticle experiments features:

- **unique** and **unrepeatable** data (ex. ultra high cosmic events) constraint on uptime/dead-time
- data could be acquired in **difficult and extreme conditions** (ex. space, under water ice, etc) conditioning the possibility of interventions and changes in the setup
- **templates and montecarlo** are needed not only to evaluates systematic but also to identify "candidates" of events. (ex OG, cosmic ray shower, etc) with large request of computing resources
- for many experiment data need to often to be **re-calibrated and reconstructed many times** whit discontinuity and peak in the usage of computing resources

conclusions

what about CSN2: atro particle…

- **CSN2** is a very active **committee** managing an enthusiastic, continuously growing up
- **GW** observations and hints coming from **early universe** observations, are **changing the scenario** of the universe evolution
- **astro-particle messengers** studied by the experiments of the four of CSN2 pillars are playing leading role in understanding this new scenario:
    - we are working/leaders of to the most import **ground based cosmic rays** experiments and ideas for next futures as well as participating in many **space missions** that are continuing producing data beyond expectations whit strong effort in understanding **CMB and Dark Energy**
    - we are fundamental partner of the international community studying **gravitational wave** and playing a leading role in **future experiments** (ET, LISA), as well as **probing gravity** parameters and investigating **quantum technology**
    - although neutrino strategy brings part of neutrinos study outside Italy, and partially outside CSN2, **INFN is participating in most challenging international experiments** with leading roles and **LNGS** maintain a crucial role for **NLDBD** and **DM searches**